ICMCS-XIII

The 13th Conference on Mesoscale Convective Systems and High-Impact Weather in East Asia

6-8 March 2019
Naha, Okinawa, Japan

Okinawa Prefectural Museum and Art Museum

Hosted by

East Asia Weather Research Association

Sponsored by

University of the Ryukyus

Nagoya University

Preface

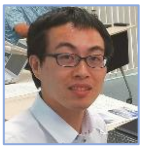
The Conference on Mesoscale Convective Systems and High-Impact Weather in East Asia (ICMCS) is a program initiated by the East Asia Weather Research Association, jointly organized by weather research scientists in East Asia and United States. The aim of this conference is to promote collaboration among researchers and forecasters related to mesoscale meteorology and high-impact weather in East Asia. The first meeting was held in Seoul in 2000, and subsequent meetings have been held in several regions including Taipei (in 2001, 2007, and 2017), Tokyo (in 2002), Beijing (in 2004 and 2013), Boulder, Colorado (in 2006 and 2014), Seoul (in 2009), Nagoya (in 2011), and Busan (in 2016). The thirteenth ICMCS is held at Okinawa, sponsored by the University of the Ryukyus and Nagoya University. This is the first opportunity for ICMCS to be held on a small island under the subtropical climate on the Pacific Ocean.

Heavy precipitation and high winds associated with mesoscale atmospheric phenomena are the primary cause of natural disasters for East Asia. They may cause great losses of civil economy and people's life and estate. Although understanding of the processes responsible for these phenomena continues to advance, there are still many challenges associated with prediction. Sharing knowledge from recent research activities at this conference is expected to contribute to both the progress of further research collaborations and the improvement of forecasts. Okinawa is the central island of the former Ryukyu Kingdom which played a central role in the maritime trade networks of medieval East and Southeast Asia. We believe that this island is a suitable place to hold such a meeting.

We take this opportunity to thank all the sponsored organizations and participants from various regions for their continuous and enthusiastic supports to make this program a successful one.

ICMCS-XIII International/Local Organizing Committee Chairs:

Dr. Hiroyuki Yamada
Associate Professor
University of the Ryukyus



Dr. Kosuke Ito
Associate Professor
University of the Ryukyus

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Ying-Hwa Bill Kuo
Roger Wakimoto
David Jorgensen
Richard Johnson
Wei-Kuo Tao

Program

March 6, 2019 (Wednesday)

	9:00	**Registration**
	9:45	**Opening Remarks**
Keynote Session		
	Chair	**SeonKi Park (Ewha Womans Univ.)** **Tetsuya Takemi (Kyoto Univ.)**
K101	**10:00**	**Overview of T-PARCII aircraft observations of typhoons in 2017 and 2018** **Kazuhisa Tsuboki (Nagoya Univ.)*, Taro Shinoda, Nobuhiro Takahashi, Hiroyuki Yamada, Kosuke Ito, Tadayasu Ohigashi, Munehiko Yamaguchi, Tetsuo Nakazawa, Hisayuki Kubota, Yukihiro Takahashi, Norio Nagahama, Kensaku, Shimizu**
K102	**10:20**	**ICE-POP 2018: Overview and preliminary results** **GyuWon Lee (Kyungpook National Univ.)*, Kwonil Kim**
K103	**10:40**	**Diagnosis of the Dynamic Efficiency of Latent Heat Release and the Rapid Intensification of Supertyphoon Haiyan (2013)** **Hung-Chi Kuo (National Taiwan Univ.)*, Satoki Tsujino, Chien-Chang Huang, Chung-Chieh Wang, Kazuhisa Tsuboki**
K104	**11:00**	**Warm-Sector Heavy Rainfall in Southern China and its WRF Forecast Evaluation: A Low-Level Jet Perspective** **Murong Zhang, Zhiyong Meng (Peking Univ.)***
K105	**11:20**	**Heating, Cooling, and Circulation in Tropical Cyclones** **Michael M. Bell (Colorado State Univ.)***
K106	**11:40**	**Big Data Assimilation: Past 5 Years and Perspectives for the Future** **Takemasa Miyoshi (RIKEN Center for Computational Science)*, Shigenori Otsuka, Takumi Honda, Guo-Yuan Lien, Yasumitsu Maejima, Yoshito Yoshizaki, Hiromu Seko, Hirofumi Tomita, Shinsuke Satoh, Tomoo Ushio, Tatiana V. Martsinkevich, Balazs Gerofi, Yutaka Ishikawa**
	12:00	**Group Photo**
	12:10	**Lunch**

	13:15	**Poster Presentation (Day 1)**
	14:45	**Break**
	Session 1	**Tropical Cyclone (I)**
		Chair Kazuhisa Tsuboki (Nagoya Univ.) **Michael M. Bell (Colorado State Univ.)**
A107-I	**15:00**	**Recent Observations in Tropical Cyclones Using small Unmanned Aircraft Systems** **Joseph J. Cione (NOAA)*, George Bryan**
A108-I	**15:15**	**Observations of the Intensification of a Weak Tropical Cyclone in Moderate Vertical Shear** **Robert Rogers (NOAA/AOML Hurricane Research Division)*, Jonathan Zawislak, Paul Reasor, Leon Nguyen**
A109-I	**15:30**	**Relationships among MJO, tropical cyclones, and high-pressure disturbances in the subtropical High seen in the NICAM aqua-planet experiment** **Shin-ichi Moriizumi, Masanori Yoshizaki (Rissho Univ.)*, Yuusuke Kobayashi**
A110-I	**15:45**	**SST Modulation of the Impacts of Tropospheric Stability on the Intensity and Structure of Tropical Cyclones** **Tetsuya Takemi (Kyoto Univ.)*, Shota Yamasaki**
A111	**16:00**	**Improved Tropical Cyclone Intensity Forecasts by Assimilating Coastal Surface Currents in an Idealized Study** **Ralf Toumi (Imperial College London)*, Yi Li**
A112	**16:15**	**The impacts of cold eddies on the intensity changes during the mature phase of Typhoon Trami (2018)** **Akiyoshi Wada (MRI/JMA)*, Yoshinori Oikawa**
A113	**16:30**	**Tropical Clouds and Precipitation Systems “Across Scales” in Convection-Permitting Aquaplanet Simulations** **Rosimar Rios-Berrios (NCAR)*, Brian Medeiros, George Bryan**
A114	**16:45**	**Development of upstream low-level humidification and selective ensemble methods for short-term precipitation prediction system** **Yasutaka Wakazuki (Ibaraki Univ.)*, Daichi Igarashi**
A115	**17:00**	**Detection of water-soluble ions in hailstones: An effective way to investigate aerosols in deep convection** **Xiaofei Li (Peking University)*, Qinghong Zhang, Tong Zhu, Zejun Li, Jipei Lin, Tian Zou**

A116 **17:15** **Important Factors for Development of Meso-beta Scale Vortex that Spawned Tornado-like Vortices**

Eigo Tochimoto (Univ. Tokyo)*, Sho Yokota, Hiroshi Niino, Wataru Yanase

17:30 **End**

18:30 **Welcome Dinner at Fine Dinning Kenny's Omoromachi**
1-1-2 Omoromachi, Naha, Okinawa, Tel. +81-98-861-3007

March 7, 2019 (Thursday)

	Session 2	**Mesoscale Convective Systems (I)**
		Chair Wen-Chau Lee (NCAR)
		GyuWon Lee (Kyungpook National Univ.)
A201-I	**9:30**	**Quasi-stationary band-shaped precipitation systems, named as “senjo-kousuitai”, causing localized heavy rainfall in Japan** **Teruyuki Kato (JMA)*, Hiroshige Tsuguti, Yasutaka Hirokawa**
A202-I	**9:45**	**Evolution of Microphysical Structure of a Subtropical Squall Line in Eastern China** **Kun Zhao (Nanjing Univ.)***
A203-I	**10:00**	**Sensitivity of hail precipitation to ensembles of uncertainties of representative initial environmental conditions** **Qinghong Zhang (Peking Univ.)*, Xiaofei Li, Fuqing Zhang, Matthew Robert Kumjian**
A204	**10:15**	**Banded Convective Activity Associated with Mesoscale Gravity Waves over Southern China** **Yu Du (Sun Yat-sen Univ.)*, Fuqing Zhang**
A205	**10:30**	**Convective cells embedded in widespread stratiform echoes observed by Kobe PAWR in July 2018** **Shinsuke Satoh (NICT)*, Tetsuya Sano, Hiroshi Hanado, Shigenori Otsuka, Takemasa Miyoshi**
A206	**10:45**	**Effect of the Sea Surface Temperature on Mesoscale Convective System-Produced Extreme Rainfall over Yellow Sea: 13 August 2012** **Yunhee Kang (Pukyong National Univ.)*, Dong-In Lee, Jong-Hoon Jeong**
A207	**11:00**	**Organizational Modes of Mesoscale Convective Systems associated with Warm-Sector Heavy Rainfalls in South China** **Sa Li (Peking Univ.)*, Zhiyong Meng**
	11:15	**Break**
	Session 3	**Observation Technique and Field Campaign**
		Chair Ming-Jen Yang (National Taiwan Univ.)
		Kun Zhao (Nanjing Univ.)
A208-I	**11:30**	**Airborne Phased Array Radar (APAR): The Next Generation of Airborne Polarimetric Doppler Weather Radar** **Wen-Chau Lee (NCAR)*, Louis Lussier, Vanda Grubišić**

A209	**11:45**	**Maritime Water Vapor Estimation using Ocean Platform GNSS Measurement** **Yoshinori Shoji (MRI)*, Teruyuki Kato, Yukihiro Terada, Toshitaka Tsuda, Masanori Yabuki**
A210	**12:00**	**Smartphone Pressure Observation from Chinese Moji users in 2016: Statistical Characteristics, Application and Bias Correction** **Rumeng Li (Peking Univ.)*, Qinghong Zhang**
A211	**12:15**	**Development of next-generation 1.3 GHz wind profiler radar** **Masayuki K. Yamamoto (NICT)*, Seiji Kawamura, Koji Nishimura, Kosei Yamaguchi, Eiichi Nakakita**
A212-I	**12:30**	**Multiscale Atmospheric Conditions in the Evolution of Convective Organization during MJO-1 of DYNAMO/CINDY/AMIE** **Jeffrey D. Thayer, Deanna A. Hence (Univ. Illinois Urbana-Champaign)*, Piyush Garg, Stephen W. Nesbitt**
A213-I	**12:45**	**Analysis and Forecast Using Dropsonde Data from the Inner-Core Region of Tropical Cyclone Lan (2017) Obtained during the First Aircraft Missions of T-PARCII** **Kosuke Ito (Univ. Ryukyus)*, Hiroyuki Yamada, Munehiko Yamaguchi, Tetsuo Nakazawa, Norio Nagahama, Kensaku Shimizu, Tadayasu Ohigashi, Taro Shinoda, Kazuhisa Tsuboki**
A214	**13:00**	**Field Campaigns in South China Sea Two Islands Monsoon Experiment (SCSTIMX) 2017-2018 and Its Extended Plan** **Po-Hsiung Lin (National Taiwan Univ.)*, Chung-Hsiung Sui, Wei-Ting Chen**
A215	**13:15**	**Airborne measurements for investigation of meteorological phenomena over Korea using the KMA/NIMS atmospheric research aircraft** **Chulkyu Lee (NIMS/KMA)*, Suengpil Jung, Ji Hyoung Kim, Hyojin Yang, Heejong Ko, Jongwhan Yun, Sangwon Joo**
	13:30	**Lunch**
	14:30	**Poster Presentation (Day 2)**
	16:00	**Break**

	Session 4	**Tropical Cyclone (II)**
		Chair Qinghong Zhang (Peking Univ.) **Deanna A. Hence (Univ. Illinois Urbana-Champaign)**
A216-I	**16:15**	**The Impacts of Vortical Hot Towers on the Inland Eyewall Reformation of Typhoon Fanapi (2010) over Taiwan** **Ming-Jen Yang (National Taiwan Univ.)*, Yao-Chu Wu, Yu-Cheing Liou**
A217-I	**16:30**	**Near-shore rapid changes in tropical cyclone intensity** **Johnny C L Chan (City Univ. Hong Kong)***
A218	**16:45**	**An observational study of the inner-core evolution of Typhoon Jebi (2018) at landfall** **Udai Shimada (MRI/JMA)*, Ryo Oyama, Shingo Shimizu**
A219	**17:00**	**Are outer tropical cyclone rainbands similar to squall lines?** **Che-Yu Lin (National Taiwan Univ.)*, Cheng-Ku Yu**
A220	**17:15**	**Characteristics of convective bursts in the rapidly intensified Typhoon Trami (1824)** **Ryo Oyama (MRI/JMA)***
	17:30	**End**
	18:30	**Bunquet at Pine Tree Bless Restaurant and Bar** 3rd floor, 4-1, Omoromachi, Naha, Okinawa, Tel. +81-98-941-3335

March 8, 2019 (Friday)

	Session 5	**Numerical Simulation and Data Assimilation**
		Chair Dong-In Lee (Pukyong National Univ.) **Zhiyong Meng (Peking Univ.)**
A301-I	**9:30**	**Improvements of two variational-based radar data assimilation systems and their applications in analyzing heavy rainfall processes** **Yu-Chieng Liou (National Central Univ.)*, Ying-Jhang Wu, Yung-lin Teng, Po-Chien Yang, I-An Chen, Shao-Fan Chang**
A302	**9:45**	**Consistent treatment of hydrometeors and cloudiness for convection and radiation processes in a numerical forecasting model** **Song-You Hong (KIAPS)*, Soo Ya Bae, Raeseol Park**
A303	**10:00**	**Data Assimilation Studies using Big Observation Data in the Projects of Post K and BDA** **Hiromu Seko (MRI/JMA, JAMSTEC)*, Masaru Kunii, Sho Yokota, Kosuke Ito, Kazuki Shimoji**
A304	**10:15**	**Predictability of the extreme precipitation event in Taiwan during 1-3 June 2017 based on the convective-scale ensemble data assimilation and prediction** **Shu-Chih Yang (National Central Univ.)*, Hsiang-Wen Cheng**
A305	**10:30**	**What is the source of chaos in MCS?** **Takuya Kawabata (MRI/JMA)*, Genta Ueno**
A306	**10:45**	**Application of the Multi-scale Blending Scheme on Continuous Cycling Radar Data Assimilation** **Jiang, Siou-Ying (National Taiwan Univ.)*, Ya-Ting Tsai, Jing-Shan Hong, Ben Jong-Dao Jou**
A307	**11:00**	**Assimilating Doppler radar observations with an ensemble Kalman filter for the convective development prediction in a heavy rainfall event over South China** **Xinghua Bao (CAMS)*, Yali Luo, Jiaxiang Sun, Zhiyong Meng, Jian Yue**
A308	**11:15**	**Simulation of Aviation Turbulence near the Cirrus Bands in East Asia** **Jung-Hoon Kim (Seoul National Univ.)***
	11:30	**Break**

	Session 6	**Monsoon Orographic Rainfall and Others**
		Chair Yu-Chieng Liou (National Central Univ.) **Cheol-Hwan You (Pukyong National Univ.)**
A309-I	**11:45**	**The analysis of lightning characteristics using LINET and weather radar in Korea** **Dong-In Lee (Pukyong National Univ.)*, Mi-Young Knag, Cheol-Hwan You**
A310	**12:00**	**Environments of High-Incidence Area for Warm-Season Tornadoes in China and a Comparison with Its Counterparts in US** **Ruilin Zhou (Peking Univ.)*, Zhiyong Meng**
A311	**12:15**	**Radar Observation of parent clouds of tornadoes in Tosa Bay** **Koji Sassa (Kochi Univ.)*, Akira Nishii**
A312	**12:30**	**Impacts of cyclogenesis and moisture transport by the marine boundary layer jet on heavy rainfall over southern Taiwan during SCSTIMX** **Yi-Leng Chen (Univ. Hawaii Manoa)*, Chuan-Kai Wang**
A313-I	**12:45**	**Characteristics of extreme convective systems in the East Asian monsoon as seen by TRMM** **Kristen L. Rasmussen (Colorado State Univ.)*, Warittha Panasawatwong, Michael Bell**
A314	**13:00**	**Characteristics of the Marine Boundary Layer Jet over the South China Sea during the Early Summer Rainy Season of Taiwan** **Chuan-Chi Tu (National Central Univ.)*, Yi-Leng Chen, Pay-Liam Lin, Yu Du**
	13:15	**Lunch**
	Session 7	**Tropical Cyclone (III)**
		Chair Hung-Chi Kuo (National Taiwan Univ.) **Anthony C. Didlake, Jr. (Pennsylvania State Univ.)**
A315-I	**14:15**	**TBD** **Nancy Hann (NOAA)***
A316-I	**14:30**	**The Influences of Sumatra Island and Synoptic Features on Tropical Cyclone Formation in the Indian Ocean: A Numerical Study** **Chung-Chieh Wang (National Taiwan Normal Univ.)*, Shin-Kai Ma, Richard H. Johnson**

A317	**14:45**	**Relationships between Shear-relative Lower-tropospheric Flow and the Intensity and Size Changes of Tropical Cyclones** **Buo-Fu Chen (National Taiwan Univ., NCAR)*, Christopher A. Davis, Ying-Hwa Kuo**
A318	**15:00**	**Asymmetric Intensification Processes of a Category 4 Super Typhoon Lan (2017) during High Vertical Wind Shear** **Sachie Kanada (Nagoya Univ.)*, Akiyoshi Wada, Kazuhisa Tsuboki**
A319	**15:15**	**Influence of Southwest Monsoon Flow and Typhoon Track on Taiwan Typhoon Rainfall during the Exit Phase** **Yu-Han Chen (National Taiwan Univ.)*, Hung-Chi Kuo, Chung-Chieh Wang, Yi-Ting Yang**
A320-I	**15:30**	**Impact of Dry Midlevel Air on the Tropical Cyclone Outer Circulation** **Shuai Wang (Univ. London, Imperial College London)*, Ralf Toumi**
A321	**15:45**	**Relationship between Typhoon Track Forecasts and Heavy Rainfall in Western Japan in July 2018** **Takeshi Enomoto (Kyoto Univ.)***
A322	**16:00**	**The lightning distribution of tropical cyclones over the western North Pacific** **Shu-Jeng Lin (.Chinese Culture Univ.)*, Kun-Hsuan Chou**
	16:15	**Break**
	Session 8	**Tropical Cyclone (IV) and QPE** **Chair Chung-Chieh Wang (National Taiwan Normal Univ.)** **Taro Shinoda (Nagoya Univ.)**
A323-I	**16:30**	**New observation strategies for typhoon intensity over the western North Pacific** **Hiroyuki Yamada (Univ. Ryukyus)*, Kazuhisa Tsuboki, Taro Shinoda, Hisayuki Kubota, Yukihiro Takahashi, Norio Nagahama, Kensaku Shimizu, Kosuke Ito, Tadayasu Ohigashi, Munehiko Yamaguchi, Tetsuo Nakazawa**
A324-I	**16:45**	**Asymmetric Aspects of Secondary Eyewall Formation in Tropical Cyclones** **Anthony C. Didlake, Jr. (Pennsylvania State Univ.)***
A325	**17:00**	**Tropical cyclones in global cloud-resolving simulations** **Falko Judt (NCAR)***

A326	**17:15**	**Evaluation of FAMIL2 in Simulating the Climatology and Seasonal-to-Interannual Variability of Tropical Cyclone Characteristics** **Qing Bao (LASG/IAP/CAS)*, Jinxiao Li, Yimin Liu, Guoxiong Wu**
A327-I	**17:30**	**A statistical approach on radar rainfall estimates using polarimetric variables in Korea** **Cheol-Hwan You (Pukyong National Univ.)*, Mi-Young Kang, Dong-In Lee**
A328	**17:45**	**Microphysical Characteristics of Different seasons and type of Precipitation over north Taiwan** **Pay-Liam Lin (National Central Univ.)*, Meng-Tze Lee, Wei-Yu Chang, Balaji Kumar Seela**
A329-I	**18:00**	**Variations of ZDR and KDP in Heavy Rain Storms in Taipei** **Ben Jong-Dao Jou (National Taiwan Univ.)*, Radiant Rong-Guang Hsiu, Ultimate Chi-June Jung**
A330-I	**18:15**	**What does a positive KDP-peak layer above the melting level indicate? ~ Statistics of KDP profiles obtained by a Ka-band polarimetric radar ~** **Taro Shinoda (Nagoya Univ.)*, Tadayasu Ohigashi, Hiroyuki Yamada, Yukiya Minami, Kazuhisa Tsuboki**
	18:30	**End**
	19:00	**Committee Meeting (Invitation only)**

Poster Presentation (Day 1)

P101 **Essential factors for formation and organization of afternoon thunderstorm in the Taipei basin: A case study on 30 Jun 2018**

Satoki Tsujino (National Taiwan Univ.)*, Hung-Chi Kuo, Kazuhisa Tsuboki

P102 **Characteristics of Quasi-2-Day Convective Disturbances over the Tropical Ocean**

Hungjui Yu (National Taiwan Univ.)*, Hung-Chi Kuo

P103 **The characteristics of eastward-propagating mesoscale convective systems and the diurnal evolution of long-lived mesoscale convective vortices east of the second-step terrain over the East China Plains**

Yuanchun Zhang (IAP/CAS)*, Fuqing Zhang, Christopher A. Davis, Jianhua Sun, Ruyi Yang

P104 **A Study on the Vertical Structure of the Jangma front in 2018 Using radiosonde Observation Data**

Jaekwan Shim (NIMS/KMA)*, Baek-Jo Kim

P105 **Lightning nowcasting with multisource data: A deep Learning approach**

Kanghui Zhou (NMC/CMA)*, Yongguang Zheng

P106 **The Triggering and Maintenance Mechanism of Guangzhou Extreme Precipitation on May 7,2017 - an Operational Perspective**

Fuyou Tian (NMC/CMA)*, Yongguang Zheng , Xiaoling Zhang, Tao Zhang, Yinjing Lin, Xiaowen Zhang, Wenjian Zhu

P107 **Thermal and Microphysical Effects of Ice Clouds on Torrential Rainfall over Northern China**

Xiaofan Li (Zhejiang Univ.)*

P108 **Mesoscale convective systems in the Asian monsoon region from Advanced Himawari Imager: Algorithms and preliminary results**

Dandan Chen (CAMS)*, Jianping Guo, Dan Yao

P109 **Sensitivity of quasi-stationary band-shaped precipitation system to orography for 28 August 2008 Okazaki heavy rainfall event**

Yoshinori Takasaki (Rissho Univ.)*, Masanori Yoshizaki, Asuka Parker Suzuki, Yasushi Watarai

P110 **Convective instability of slantwise convection in the Changma front**

Hyeon-Seok Do, Hosun Ryu, Joowan Kim (Kongju National Univ.)*

P111 **Evolution and Mechanism of a Rare Squall Line in Early Spring of 2018**

Jie Sheng (NMC/CMA)*

P112 **Analysis of generation and development process of an extraordinary rainstorm in Ili Valley**

Xin Huang (IAP/CAS, Univ. Chinese Academy of Sciences)*, Yushu Zhou, Lu Liu

P113 **Transition of convective system in Kochi Prefecture during the Heavy Rain Event of July 2018**

Akira Nishii (Kochi Univ.)*, Koji Sassa

P114 **A study on sensitivity of heavy rainfall simulation over the Korean Peninsula to cumulus convective parameterization schemes in WRF**

Haerin Park (Ulsan National Institute of Science and Technology)*, Hae-Rin Park, Dong-Hyun Cha, Ga-Young Kim

P115 **Role of internal gravity wave and lower convergence to initial convection: a case study of a heavy rain event on 17th January 2016 around Sakishima Islands**

Takashi Tanaka (Univ. Ryukyus)*, Hiroyuki Yamada, Kazuhisa Tsuboki

P116 **Structures of upper-tropospheric outflow-layer clouds of typhoons observed by a Ka-band cloud radar**

Tadayasu Ohigashi (NIED)*, Kazuhisa Tsuboki, Taro Shinoda, Haruya Minda, Moeto Kyushima, Hiroyuki Yamada, Hironori Iwai

P117 **Tropical cyclone structures as depicted by WWLLN data – Terrain-induced eyewall evolution**

Kun-Hsuan Chou (Chinese Culture Univ.)*, Shu-Jeng Lin

P118 **An Analysis of Typhoon Remote Rainfall in Taiwan**

Cheng-Shang Lee (National Taiwan Univ.)*, Yu-Chi Liu, Yu-Jing Guo, Ching-Wei Wang

P119 **The influence of urbanization on the rainfall of landfalling typhoons**

Yan Meng (Nanjing Univ.)*, Johnny C. L. Chan, Kun Zhao

P120 **Relabeling the images of the potentially violent typhoons generated by the DCGANs using the CNN**

Maiki Higa (Univ. Ryukyus)*, Shinya Tanahara, Kosuke Ito, Hiroyuki Yamada, Ryota Miyata

P121 **Impact of cloud microphysics schemes on typhoon forecast over the western North Pacific**

Jinyoung Park, Minkyu Lee, Dong-Hyun Cha (Ulsan National Institute of Science and Technology)*

P122 **Estimating Tropical Cyclone Intensity by Satellite Imagery Utilizing Convolutional Neural Networks**

Buo-Fu Chen (NCAR, National Taiwan Univ.)*, Boyo Chen, Hsuan-Tien Lin, Russell L. Elsberry

P123 **Characteristics and False Alarm Analysis of Tropical Cyclone Rapid Intensification Events**

Hsiao-Chung Tsai (Tamkang Univ.)*, Kuo-Chen Lu, Wei-Chia Chin, Chia–I She

P124 **Vertical Structure and Microphysical Characteristics of Typhoon Kong-rey (1825) during the passage near Jeju island**

SooHui Jeon (National Typhoon Center/KMA)*, JiHye Ryu, DaeJoon Kim, WonCheol Lee, Nam-Young Kang, Eun Jeong Cha

P125 **Typhoon KONG-REY's Rainfall over Eastern Coastal Region of Korea and Its Relation to Environmental Factors**

So-Ra In (NIMS/KMA)*, Baek-Jo Kim, Chag-Geun Park, Hae-Min Kim

P126 **A Vortex-Based Doppler Velocity Dealiasing Algorithm for Tropical Cyclones**

Pao-Liang Chang (CWB)*, Wei-Ting Fang, Pin-Fang Lin, Ming-Jen Yang

P127 **A Typhoon Disaster Assessment Method and its application over the South China**

Zhenzhen Wu (Sun Yat-sen Univ.)*, Donghai Wang, Kaifeng Zhang, Lebao Yao, Yu Zhang

P128 **Observational Study of Coastal Jet of Landfalling Typhoon in the Taiwan Area**

Yu-Chenga Kao (National, Taiwna Univ.)*, Ben Jong -Dao Jou

P129 **Comparison between global and regional model forecast skills for tropical cyclones over the western North Pacific**

Jihong Moon (Ulsan National Institute of Science and Technology)*, Woojin Cho, Dong-Hyun Cha

P130 **Structural and Microphysical Features of a Landfalling Rainband of Typhoon Maria (2018) Observed by a Polarimetric Doppler Radar**

Tsubaki Hosokawa (National Taiwan Univ., Univ. Ryukyus)*, Hiroyuki Yamada, Ben Jong-Dao Jou

P131 **Heavy Rainfall Associated with Double Low-level Jets over Southern China**

Yu Du (Sun Yat-sen Univ.)*, Guixing Chen

P132 **Interannual variation of spring precipitation over southern China**

XiaoJing Jia (ZheJiang Univ.)*, YuJia You

P133 **Observational Analysis and Mechanism Research in a Breaking-record Extreme Rainfall Event over Southern China on August 2018**

Yun Chen (NMC/CMA)*, Zhilin Zeng, Shengqi Li

P134 **Numerical Analyses of the Easterly-related Weather Systems in the Eastern Coastal Region of Korea using WRF: A Case Study of Heavy Rainfall in 5-6 August 2018**

Sojung Park (Ewha Womans Univ.)*, Seungyeon Lee, Seon Ki Park

P135 **The Research and Data Analysis of CVPR-FMCW Developed for Retrieving the Microphysics Parameters in Precipitation Cloud**

Ruan Zheng (CAMS)*, Feng Li, Zhaoyang Huo, Runsheng Ge

P136 **A Variational Approach for DSD Retrieval and Quantitative Precipitation Estimation Using Polarimetric Radar Data**

Hao Huang (Nanjing Univ.)*, Kun Zhao, Guifu Zhang

P137 **X-Net Based Radar Data Assimilation Study over Seoul Metropolitan Area**

Ki-Hong Min (Kyungpook National Univ.)*, Jiwon Lee, Gyuwon Lee

P138 **Near-real-time SCALE-LETKF forecasts of the record breaking rainfall in Japan in July 2018**

Takumi Honda (RIKEN Center for Computational Science)*, Guo-Yuan Lien, Takemasa Miyoshi

P139 **Sampling Error in the Ensemble-Based Radar Data Assimilation System and Its Impact on Convective-Scale Precipitation Prediction - A Case Study of IOP#8 during SoWMEX**

Pin-Ying Wu (Kyoto Univ.)*, Shu-Chih Yang, Chih-Chien Tsai

P140 **Blending of Regional Analyses and EAKF Forecasts with a Spatial Filter: Application to the Taiwan Ensemble Prediction System**

Chih-Hsin Li (CWB)*, Jing-Shan Hong

P141 **Improvement of GRAPES_3Dvar with A New Multi-Scale Filtering and Its Application in Heavy Rain Forecasting**

Zhifang Xu (NMC/CMA)*, Yang Wu, Ruichun Wang, Hua Zhang, Zhigang Cheng

P142 **A Thermodynamically and Dynamically Consistent Atmospheric Forcing Data over the South China**

Chunyan Zhang (Sun Yat-sen Univ.)*, Donghai Wang, Zihao Pang, Xiaoling Jiang

P143 **Evaluation the performance of very short-term forecast by dual-polarimetric radar observations: a case study of Squall Lines during 2008 SoWMEX-IOP8**

Cheng-Rong You (National Central Univ.)*, Kao─Shen Chung, Chih─Chien Tsai

P144 **A Case Study of Afternoon Thunderstorm in Taipei City: Characteristics of Rainfall Structure**

Ultimate Chi-June Jung (National Taiwan Univ.)*, Ben Jong-Dao Jou, Yu-Chieng Liou

P145 **On the Short-term Forecast of Rainfall Brought by Yagi to China in 2018**

Jun Xu (NMC/CMA)*, Fanghua Zhang, Kan Dai, Yun Chen

P146 **The Regional Meteorological Analysis and Prediction System and its near real-time forecasts in the South China**

Donghai Wang (Sun Yat-sen Univ.)*

P147 **Analysis of Using Different Microphysics Schemes for the Cloud-Resolving Ensemble forecasts**

Kao-Shen Chung (National Central Univ.)*, Chin-Hung Chen, Shu-Chih Yang

P148 **Study of the Mechanisms of Severe Thunderstorm in Tokyo Metropolitan Area using High Frequent Assimilation of Ground-based In-situ and Remote-sensing Observations**

Yoshinori Shoji (MRI/JMA)*, Tetsu Sakai, Ahoro Adachi, Satoru Yoshida, Tomohiro Nagai

P149 **Droplet Size Distrubutions of a Stratocumulus Cloud Undetected by a Ka-band Radar in the Okinawa Region**

Atsumi Murasaki (Nagoya Univ.)*, Taro Shinoda, Tadayasu Ohigashi, Kenji Suzuki, Kosei Yamaguchi, Hiroyuki Yamada, Seiji Kawamura, Kazuhisa Tsuboki, Eiichi Nakakita

P150 **Estimation of Extreme Wind Speeds over the Taiwan Offshore Region Related to Tropical Cyclones**

Ying Li (CAMS)*, Xue Lin

P151 **The effect of increased resolution of geostationary satellite imageries on predictability of tropical thunderstorms over Southeast Asia**

Kwonmin Lee (Ewha Womans Univ.)*, Hye-Sil Kim, Yong-Sang Choi

P152 **Building resilience to weather-related weather hazards through better preparedness---The World Weather Research Program High Impact Weather Project (HIWeather)**

Qinghong Zhang (Peking Univ., HIWeather International Coordination Office, CAMS)*, Liye Li, Brian Golding, David Johnston, Elizabeth Ebert, Brian Mills, Sally Potter, Shannon Panchuk, Michael Riemer, Jenny Sun, Paolo Ruti, Julia Keller

P153 **Large-Scale Environmental conditions associated with Heavy Precipitation in the Korean Peninsula**

Eunsil Jung (Kyungppok National Univ.)*

P154 **High-resolution regional climate model experiments with urban impact in the Tokyo metropolitan area in summer**

Ibuki Sugino (Ibaraki Univ.)*, Yasutaka Wakazuki

Poster Presentation (Day 2)

P201 **A study on future projections of precipitation characteristics around Japan in early summer combining GPM DPR observation and CMIP5 large-scale environments**

Chie Yokoyama (Univ. Tokyo)*, Yukari N. Takayabu, Osamu Arakawa, Tomoaki Ose

P202 **Environment and processes for heavy rainfall in the morning over the Korean peninsula during episodes of cloud clusters associated with mesoscale troughs**

Uju Shin (Yonsei Univ.)*, Tae-Young Lee, Sang-Hun Park

P203 **Changes of Extreme Hourly Precipitation and its Associated with Thunderstorm over Eastern China from 1969 to 2011---- Dominated by Synoptic Weather Systems**

Chanpang Ng (Peking Univ.)*, Qinghong Zhang

P204 **Impacts of convective activity over the Tibetan Plateau on plateau vortex, southwest vortex, and downstream precipitation**

Shenming Fu (IAP/CAS)*, Zi Mai, Jian-Hua Sun, Wan-Li Li, Ya-Qiang Wang

P205 **A Simulation of Mesoscale Convective System of Mei-Yu Front Affecting Taiwan on 2 June 2017**

Jyun-Yu Lin (National Defense Univ.)*, Jyun-Yu Lin, Horng-Syi Shen, Chia-Hung Huang

P206 **Microphysically Induced Bow Echo within a Squall Line after its Merging with a Convective Cell observed by Polarimetric Radar**

Ang Zhou (Nanjing Univ.)*, Kun Zhao

P207 **Ensemble Sensitivity Analysis of a Heavy Rainfall Event with Three MCSs Coexisting over Southern China**

Yian Shen (Sun Yat-sen Univ.)*, Yian Shen, Yu Du, Guixing Chen

P208 **Investigation of the vertical microphysical characteristics of heavy rainfall events during the SoWMEX/TiMREX using observational data**

Wei-Yu Chang (National Central Univ.)*, Ke-Xin Lu, Tai-Chi Chan Wang

P209 **A Case Study of the Northern Kyushu Heavy Rainfall Event during 5-6 July 2017**

Hiroshive Tsuguti (MRI/JMA)*

P210 **Contrastive Analysis of Lightning Characteristics Between Rainstorm Case and Hailstorm Case**

Tingbo Wang (China Meteorological Administration Training Centre)*

P211 **Analysis of a severe precipitation process in Aksu Area under the background of the Central Asian Vortex**

Nannan Guo (IAP/CAS, Univ. Chinese Academy of Science)*, Yushu Zhou, Guo Deng

P212 **Simulation of quasi-linear mesoscale convective systems in northern China: lightning activities and storm structure**

Wanli Li (China Meteorological Administration Training Center)*, Xiushu Qie, Shenming Fu, Debin Su, Yonghai Shen

P213 **Analysis of misocyclone structure of a storm generating waterspout on 15 May 2017 in Okinawa using a phased array weather radar**

Ryusho Imai (Nagoya Univ.)*, Nobuhiro Takahashi

P214 **The Effect of Ocean Waves on an Explosive Cyclone Development: Investigation with a Coupled Model**

Yuki Kita (Univ. Tokyo)*, Takuji Waseda

P215 **Essential Role of Synoptic Environment on Rainfall Distribution of Landfalling Tropical Cyclones Over China**

Shoujuan Shu (Zhejiang Univ.)*, Xibin Feng, Yuan Wang

P216 **Kinematic and Microphysical Properties of Secondary Rainbands of Soudelor (1513) Observed by Polarimetric Radar**

Shiou-Rong Chu (National Taiwan Univ.)*, Ben Jong-Dao Jou

P217 **A Dynamical Mechanism for Secondary Eyewall Formation in Tropical Cyclones**

Yoshiaki Miyamoto (Keio Univ., RIKEN)*, David S. Nolan, Norihiko Sugimoto

P218 **The influence of typhoon strength and size on Taiwan's wind and rainfall**

Sheng-Yu Wu, Kun-Hsuan Chou (Chinese Culture Univ.)*

P219 **Withdrawn**

P220 **Ensemble Synoptic Analysis on the Slowing Motion of Typhoon Morakot (2009) Crossing Taiwan Island**

Ying Li (CAMS)*, Yueting Gong

P221 **Improve TWRF Predictions by utilizing Himawari-8 AMV on Typhoon Track and Intensity Forecast**

Der-Song Chen (CWB)*, Jia-Hong Xie, Ling -Feng Hsiao, Tien-Chiang Yeh, Jing-Shan Hong

P222 **Precipitation efficiency and water budget of Typhoon Fitow (2013)**

Guoqing Zhai (Zhejiang Univ.)*, Xiaofan Li

P223 **On the Effects of Radiation on Tropical Cyclone Intensity Changes under Moderate Vertical Wind Shear**

Rosimar Rios-Berrios (NCAR)*

P224 **Development of Typhoon Jebi (2018) and Model Simulation**

Chia-Hung Huang (National Defense Univ.)*, Horng-Syi Shen, Jyun-Yu Lin, Chiao-An Chung, Song-Hao Guo, Yi-Chun Wu

P225 **Bias-Correction of the Extended-Range Tropical Cyclone Formation and Activity Forecasts by Using the 20-Year Reforecasts**

Hsiao-Chung Tsai (Tamkang Univ.)*, Tzu-Ting Lo, Meng-Shih Chen, Chia-I She

P226 **Direct Measurements of Momentum Flux and Dissipative Heating in the Surface Layer of Tropical Cyclones During Landfalls**

Jie Ming (Nanjing Univ.)*, Jun A. Zhang

P227 **Numerical Simulation of Typhoon Nepartak (2016) Using the MPAS-GSI system**

Shu-Ya Chen (National Central Univ.)*, Cheng-Peng Shih, Ching-Yuang Huang, Zhiquan Liu, Wen-Hsin Teng, Hsiu-Wen Li

P228 **Prediction of Typhoon Track over the Western North Pacific using Machine Learning**

Kyoungmin Kim (Ulsan National Institute of Science and Technology)*, Tae-ho Mun, Dong-Hyun Cha

P229 **Northward expansion of tropical cyclone tracks in the western North Pacific during the early fall**

Minkyu Lee (Ulsan National Institute of Science and Technology)*, Jihong Moon, Changyong Park, Gayoung Kim, Dong-Hyun Cha

P230 **The Global Characteristics and Mechanisms of Diurnal Offshore Propagation of Rainfall**

Junying Fang (Sun Yat-sen Univ.)*, Yu Du

P231 **Characteristics of vertical structure of snowfall over complex terrain during ICE-POP 2018**

Kwonil Kim (Kyungpook National Univ.)*, Wonbae Bang, Choeng-lyong Lee, DaeHyung Lee, Daejin Yeom, Kyuhee Shin, Eunbi Jeong, Kwang-Deuk Ahn, Walter A. Petersen, Wei-Yu Chang, GyuWon Lee

P232 **Characteristics of Coastal Low Level Jets in Bei-Bu Gulf during the warm summer**

Hoiio Kong (Peking Univ.)*, Qinghong. Zhang, Yu Du, Fan Zhang

P233 **Fidelity of the Observational/Reanalysis Datasets and Global Climate Models in Representation of Extreme Precipitation in East China**

Jing Yang (Beijing Normal Univ.)*, Sicheng He, Qing Bao, Lei Wang, Bin Wang

P234 **Synoptic Patterns Associated with Summer Heavy Rainfall near the South Coast of China**

Chenli Wang (Nanjing Univ.)*, Kun Zhao, Kefeng Zhu, Xiaona Rao

P235 **Development of a new balloon-borne sensor for the precipitation particle electric charge measurement**

Kenji Suzuki (Yamaguchi Univ.)*, Takuji Sugidachi, Kensaku Shimizu, Katsuhiro Nakagawa, Satoru Oishi, Yasuhiro Saito, Taro Shinoda, Masaki Katsumata, Shuichi Mori

P236 **The Impact of Vortex Initialization on Convection Development and TC Intensity: A Case Study of Typhoon Megi (2010)**

Yi-Pin Chang (National Central Univ.)*, Shu-Chih Yang, Kuan-Jen Lin, Chien-Ming Wu

P237 **Withdrawal**

P238 **The observation sensitivity and the forecast sensitivity to observations: theoretical development and an OSSE case study**

Yu Zhang (Sun Yat-Sen Univ.)*, Donghai Wang

P239 **Introduction to CWB's HRLDAS and evaluation of the impact of surface parameters on HRLDAS over Taiwan**

Po-Hsun Lin (CWB)*, Lin-Feng Hsiao, Jing-Shan Hong

P240 **Withdrawal**

P241 **Application of the model perturbation scheme in the convective-scale ensembles predict system**

Yi-Jui Su (CWB)*, Jing-Shan Hong

P242 **Three-Dimensional Cloud Initial Field Created and Applied in GRAPES Numerical Weather Prediction Nowcasting**

Lijuan Zhu (NMC/CMA)*, Jiandong Gong, Liping Huang, Dehui Chen, Yuan Jiang, Liantang Deng

P243 **Predictability of heat wave in the operational prediction system of KMA**

Donghyuck Yoon (Ulsan National Institute of Science and Technology)*, Gil Lee, Dong-Hyun Cha

P244 **Impact of FORMOSAT-7/COSMIC-2 Radio Occultation observation on tropical cyclone formation: OSSE based on Hurricane Helene in 2006**

Chih-Chien Chang (National Central Univ.)*, Shu-Chih Yang, Shu-Hua Chen

P245 **The Role of Initial Cloud Condensation Nuclei Concentration in Hail Using the WRF NSSL 2-moment Microphysics Scheme**

Xiaofei Li (Peking Univ.)*, Qinghong Zhang, Huiwen Xue

P246 **The short-term forecast model experiment near coastal urban areas**

Hyeon-Joon Kim (Pukyong National Univ.)*, Dong-In Lee

P247 **High-resolution simulation with a Large Domain of western Japan heavy rainfall in July 2018**

Tsutao Oizumi (JAMSTEC, MRI/JMA)*, Kazuo Saito, Le Duc, Junshi Ito

P248 **Thermodynamic characteristics associated with snowfall cloud using dropsonde data collected 2018 ICE-POP campaign**

Sueng-Pil Jung (NIMS/KMA)*, Chulkyu Lee, Hyojin Yang, Ji-Hyoung Kim, Jonghwan Yoon, HeeJong Ko

P249 **Observational study on the heavy snowfall by ground-based hydrometeor measurement and satellite/ground-radar remote sensing**

Rimpei Kamamoto (Yamaguchi Univ.)*, Kenji Suzuki, Hiroshi Hanado, Katsuhiro Nakagawa, Yuki Kaneko, Aritoshi Masuda

P250 **Development of blended Quantitative Precipitation Forecast Product**

HsiaoWei Lai (CWB)*, Jing-Shen Hong

P251 **Hot weather characteristics in China**

Tianyu Zhu, Qinglan Li (Shenzhen Institute of Advanced Technology, CAS)*, Pengcheng Xu

P252 **The analyisis on the Verification of National Severe Convective Weather Categorical Forecasts**

Wenyuan Tang (NMC/CMA)*, Qingliang Zhou, Xinhua Liu, Wenjian Zhu

P253 **Impact of cloud microphysical processes on the simulation of a hailstorm in east China**

Fan Ping (IAP/CAS)*, Lei Yin, Jiahua Mao

P254 **Synoptic climatological analyses on the Korea easterlies over the eastern coast of South Korea**

SeungYeon Lee (Ewha Womans Univ.)*, Sojung Park, Ebony Lee, SeonKi Park

Keynote Presentation
Day 1 10:00-12:00

Overview of T-PARCII aircraft observations of typhoons in 2017 and 2018

Kazuhisa Tsuboki[1*], Taro Shinoda[1], Nobuhiro Takahashi[1], Hiroyuki Yamada[2], Kosuke Ito[2], Tadayasu Ohigashi[3], Munehiko Yamaguchi[4], Tetsuo Nakazawa[4], Hisayuki Kubota[5], Yukihiro Takahashi[5], Norio Nagahama[6], and Kensaku, Shimizu[6]

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[3]National Research Institute for Earth Science and Disaster Resilience, Tsukuba

[4]Meteorological Research Institute, Japan Meteorological Agency, Tsukuba

[5]Hokkaido University, Sapporo, [6]Meisei Electric Co. Ltd., Isesaki

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Abstract

Just after the last ICMCS XII held in Taipei in 2017, the T-PARCII (Tropical cyclones-Pacific Asian Research Campaign for Improvement of Intensity estimations/forecasts) team performed an aircraft observation of Typhoon Lan in collaboration with Taiwan DOTSTAR, which was the most intense typhoon in 2017 and caused huge disaster over Japan when it made a landfall to the southwest of Tokyo. It was categorized as a supertyphoon by JTWC and as a very intense typhoon by JMA. Typhoon Lan moved northeastward to the east of the Okinawa main island at 23 N on 21 October and at 28 N on October 22. In these two days, we made dropsonde observations inside of the eye and in the surrounding area of the eyewall. The observation showed a significant double warm core structure and the maximum wind speed along the eyewall. The dropsonde data were used for forecast experiments. The result shows that a large discrepancy of the central sea level pressure and improvement of track prediction (Ito et al. 2018).

The T-PARCII team also made aircraft observations of Typhoon Trami (2018) during the period from 25 to 28 September 2018 in collaboration with the SATREPS group as well as DOTSTAR. Trami was almost stationary during the period to the south of the Okinawa main island. Then, it moved northward and finally made a landfall over the central part of Japan. This also caused a big disaster and electricity was shut down for several days in the central part of Japan. Typhoon Trami showed a drastic change of intensity from 25 to 26 September with a large change of eye size from about a diameter of 60 km to 200 km. Dropsonde observations showed the change of central pressure and maximum wind speed as well as the thermodynamic structure of the eye. This presentation will show an overview of these two observations of very intense typhoons.

Reference

Ito, K., H. Yamada, M. Yamaguchi, T. Nakazawa, N. Nagahama, K. Shimizu, T. Ohigashi, T. Shinoda, and K. Tsuboki, 2018: Analysis and forecast using dropsonde data from the inner-core region of Tropical Cyclone Lan (2017) obtained during the first aircraft missions of T-PARCII, *SOLA*, **14**, 105-110.

Key words: typhoon, aircraft observation, dropsonde, T-PARCII, SATREPS

ICE-POP 2018: Overview and preliminary results

GyuWon Lee[1*] and Kwonil Kim[1]

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Abstract

The understanding and predicting the winter precipitation over complex orography is quite challenging due to high temporal and spatial variability of snow. As a World Meteorological Organization (WMO)'s World Weather Research Program (WWRP), ICE-POP 2018 (International Collaborative Experiments for Pyeongchang 2018 Olympic and Paralympic winter games) was held in PyeongChang region during Nov. 2018 to April 2019 with contribution from 29 agencies from 12 countries. The scientific goal is to understand the winter precipitation over complex terrain with intensive observations and to improve the numerical model based on the understanding from the observation as well as direct utilization of these observational data.

During the field campaign, dense observational networks of upper air (2 wind profilers, 8 soundings, ship, and aircraft), surface stations (64 stations), remote sensing (3 S-Pol, 1 S-band, 2 C-band, 3 X-Pol, 1 Ku/Ka-Pol radars, and 3 Doppler lidars), microphysics (2DVD, PIP, Parsivel, MRR, POSS, MASC, Pluvio, and so on) were implemented. The network of the supersite was designed in direction parallel to the mountain range (9 sites) and across the range (14 sites) that is the same direction with the easterly or north-easterly.

One of the supersite, MHS (MayHills Supersite), is equipped with comprehensive microphysical observation. DFIR (Double Fence Intercomparison Reference) is also installed to minimize wind effect. DGW (DaeGwallyeong Weather office, ~2.1 km from MHS) is representative for remote sensing. Three-wavelength (X-band T-Rex radar, and Ku/Ka-band D3R radar) observation of cloud/precipitation is conducted. Observation of clear air condition is performed by two Doppler lidars at MHS and DGW and one at the near costal area.

Phase I (2015-2018) of the experiment is ended with intensive observation and Phase II (2019-2021) is initiated for quality control of data and detail analysis. We produce all different types of microphysical products including precipitation types and map, microphysical information, three dimensional structure of precipitation and winds, and model re-analysis and multi-model forecast by re-running them. We will further demonstrate overview of phenomena, some statistical results, and preliminary results.

Key words: ICE-POP 2018, Snow, complex terrain, PyeongChang Olympics, field experiment

Diagnosis of the Dynamic Efficiency of Latent Heat Release and the Rapid Intensification of Supertyphoon Haiyan (2013)

Hung-Chi Kuo[1], Satoki Tsujino[1], Chien-Chang Huang[1],
Chung-Chieh Wang[2], and Kazuhisa Tsuboki[3]
1 Department of Atmospheric Sciences, National Taiwan University, Taipei
2 Department of Earth Sciences, National Taiwan Normal University, Taipei
3 Institute for Space-Earth Environmental Research, Nagoya University, Nagoya

Abstract

Before landfall in the Philippines, Supertyphoon Haiyan in 2013 experienced a period of rapid intensification (RI) with the maximum wind speed increasing by 31 m s^{-1} in 24 h. A 2-km horizontal resolution full-physics cloud-resolving model is used to study the RI of Haiyan. To aid in the diagnosis of RI, we employ a dynamic efficiency factor (DEF), which is based on axisymmetric gradient wind vortex theory. The DEF measures the efficacy of convective heating at any point in generating kinetic energy. The DEF is large in the presence of strong baroclinicity near the eyewall. The simulated tropical cyclone (TC) becomes more symmetric and resembles the observations of Haiyan during the RI period. Our results highlight the nonlinear feedback process in which deep convection becomes co-located with the large DEF area near the eyewall. With the intensity increase and with large inertial stability in the eye, the eyewall convection results in significant subsidence warming at the edge of the eye rather than at the center of the eye. The overall eye warming enhances the baroclinicity near the eyewall and the system DEF in the eye-core region is increased by 33% before and after the RI onset. The vortex intensity increase during the RI period also leads to large unbalanced radial inflow in the boundary layer. The large radial inflow causes the deep convection to occur in the region of large inertial stability inside the radius of maximum wind. The deep convection further efficiently intensifies the TC. Our simulation emphasizes the importance of model resolution in simulating the internal nonlinear processes of RI.

Key words: rapid intensification, dynamic efficiency factor, cloud-resolving model

Warm-Sector Heavy Rainfall in Southern China and its WRF Forecast Evaluation: A Low-Level Jet Perspective

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Abstract

Warm-sector heavy rainfall in southern China refers to the heavy rainfall occurs within the warm sector hundreds of kilometers to the south of the front system or in southwesterly/southeasterly without a front during the presummer rainy season (April to June), characterized by poor predictability and close relationship with low-level jets (LLJs). Based on 45 warm-sector heavy rainfall episodes in 2013 and 2014 in Guangdong Province, this study examines their general characteristics and evaluates the convection-permitting WRF model performance from a LLJ perspective, aiming at further understanding the poor predictability of warm-sector heavy rainfall and its relationship with LLJs.

The results showed that 32 episodes (79%) were attributed to LLJ type and 13 episodes (21%) to no-LLJ type. Compared with no-LLJ type, LLJ type was characterized by more sufficient moisture, stronger coastal rainfall, and a significant rainfall peak in the early morning. Composite analyses showed that the 850-hPa LLJ was located to the southwest of Guangdong Province, while the 925-hPa LLJ was located at Beibu Gulf and South China Sea. In the LLJ type, there were 22 episodes where the LLJ existed on both 850 hPa and 925 hPa (coupled LLJ, CLLJ), 8 episodes where the LLJ only existed on 850 hPa (synoptic LLJ, SLLJ) and 2 episodes where the LLJ only existed on 925 hPa (boundary layer jet, BLJ). CLLJ type was most common and featured with prominent coastal rainfall, which could be attributed to the coastal convergence associated with the BLJ over SCS.

Convection-permitting WRF simulations (3-km) were performed for 45 warm-sector heavy rainfall episodes. WRF generally presented lower equitable threat scores (ETSs) of QPF in LLJ type than in no-LLJ type due to the severe underestimation of coastal rainfall. Evaluation of WRF forecasts on different weather variables showed that there was significant underestimation in 850-hPa u-component and overestimation in 925-hPa v-component and the moisture on both levels. The ETSs of LLJ type were significantly correlated with the forecast accuracy of LLJs, especially the accuracy of 925-hPa southerly over focused region. The 925-hPa southerly was overestimated due to the north bias of the 925-hPa LLJ over SCS, which significantly weakened the coastal convergence and eventually led to the underestimation in coastal rainfall.

Key words: Warm-Sector Heavy Rainfall，South China，WRF Forecast Evaluation,Low-Level Jet, presummer rainy season.

Heating, Cooling, and Circulation in Tropical Cyclones

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Abstract

Skillful forecasts of tropical cyclone (TC) formation, intensity change, and extreme precipitation remain a difficult challenge due to complex, multi-scale interactions between convection and dynamics. It is been known for some time that deep convective heating associated with strong precipitation is a critical component of genesis and subsequent intensification, but recent research has emphasized that the specific location of latent heat release plays a crucial role in determining the rate of intensification. The role of radiative and evaporative cooling in TC intensification has received less attention in the literature, but recent research indicates that the specific location of cooling is also important. This talk will focus on a synthesis of recent studies on the impacts of the location of heating and cooling on the TC primary and secondary circulations. Results from the National Science Foundation PRE-Depression Investigation of Cloud-systems in the Tropics (PREDICT, 2010), Office of Naval Research Tropical Cyclone Intensity (TCI, 2015), and ongoing NOAA Intensity Forecasting Experiment (IFEX) field experiments will be presented, along with complementary numerical modeling efforts, to explore recent progress in our understanding of the dynamics and thermodynamics of TC intensity change. The links with extreme precipitation and future joint international field experiments will be discussed.

Key words: tropical cyclone, field experiments, diabatic heating, precipitation, numerical modeling

Big Data Assimilation: Past 5 Years and Perspectives for the Future

Takemasa Miyoshi[1*], Shigenori Otsuka[1], Takumi Honda[1], Guo-Yuan Lien[2,1], Yasumitsu Maejima[1], Yoshito Yoshizaki[3], Hiromu Seko[4], Hirofumi Tomita[1], Shinsuke Satoh[5], Tomoo Ushio[6], Tatiana V. Martsinkevich[1], Balazs Gerofi[1], and Yutaka Ishikawa[1]

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Abstract

The Japan's Big Data Assimilation (BDA) project started in 2013 and is now ending its 5.5-year period. The BDA project aimed to fully take advantage of "big data" from advanced sensors such as the phased array weather radar (PAWR) and Himawari-8 geostationary satellite, which provide two orders of magnitude more data than the previous sensors. We have achieved successful case studies with newly-developed 30-second-update, 100-m-mesh numerical weather prediction (NWP) system based on RIKEN's SCALE model and local ensemble transform Kalman filter (LETKF) to assimilate PAWR in Osaka and Kobe. We achieved less than 20 seconds of the computer time using the Japan's "K" supercomputer for SCALE-LETKF at 250-m resolution, good for real-time 30-second forecast-analysis cycling. Also, we succeeded in assimilating Himawari-8 all-sky infrared radiances every 10 minutes effectively for strong typhoon and extreme-rain cases. This project also implemented a near-real-time SCALE-LETKF NWP system at 18-km resolution, producing 5-day forecasts every 4 times a day continuously. There was a record high precipitation event in early July 2018 over a broad area of western Japan, with more than 200 fatalities, the worst in the past 30 some years. The near-real-time prediction predicted well the extreme precipitation in this case. We will investigate how effective the high-resolution, high-frequency NWP systems developed in the BDA project are for this historic disaster case. In this presentation, we will summarize what we have achieved in the past 5.5 years and will discuss our future perspectives based on the achievements.

Key words: data assimilation, phased array weather radar, ensemble Kalman filter, big data, numerical weather prediction

Oral Presentation
Day 1 15:00-17:30

Recent Observations in Tropical Cyclones using small Unmanned Aircraft Systems

Joseph J. Cione[1*], George Bryan [2]

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Abstract

Scientists from NOAA's Hurricane Research Division of the Atlantic Oceanic and Atmospheric Laboratory recently collected valuable and highly unique data from six (6) Coyote small Unmanned Aircraft Systems (sUAS) deployed into Hurricane Maria (2017) and one (1) mission into Hurricane Michael (2018). Using NOAA's P-3 reconnaissance manned aircraft as a deployment vehicle, boundary layer observations of wind speed, wind direction, atmospheric pressure, temperature, moisture and sea surface temperature were recorded by the sUAS. In all cases, High Definition OBServations (HDOBS) collected by the Coyote were transmitted to NOAA's National Hurricane Center and made available to forecasters in near-real time. Analyses from these novel sUAS missions will be presented.

Key words: tropical cyclone, hurricane, UAS, UAV, boundary layer, air-sea interaction, turbulence

Observations of the Intensification of a Weak Tropical Cyclone in Moderate Vertical Shear

Robert F. Rogers[1*], Jonathan A. Zawislak[1,2], Paul D. Reasor[1], and Leon T. Nguyen[1,3]

[1]*NOAA/AOML Hurricane Research Division*

[2]*Cooperative Institute for Marine and Atmospheric Studies/University of Miami*

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Abstract

Observations of the development and intensification of a tropical depression in Hurricane Hermine (2016) in the Gulf of Mexico are presented. Hermine was a long-lived tropical depression that eventually intensified to a tropical storm and subsequently rapidly intensified to hurricane strength prior to landfall in the Florida panhandle in September 2016, all while encountering moderate westerly vertical wind shear. The structures associated with Hermine's intensification in shear are examined here using airborne Doppler radar observations from NOAA WP-3D missions as well as full-tropospheric dropsondes from NASA Global Hawk missions. In particular, the mechanisms underlying the development of a deep, aligned vortex are explored, as is the relative importance of the low-level vs. midlevel vortex, the role of deep convection, and how shear impacted this development. It is found that a low-level vortex develops underneath the midlevel vortex in the presence of deep convection after several days of repeated cycles of precipitation development downshear of the vortex. A notable transition of vertical mass flux underneath the midlevel vortex from a top-heavy to more of a bottom-heavy profile marked the development of the low-level vortex. This transition to a bottom-heavy profile appears to be related to a moistening in the middle troposphere, a stabilization in the lower troposphere, and more widespread moderate precipitation occurring in conjunction with the deep convection. It is speculated that moistening from evaporation from repeated cycles of precipitation preconditioned the downshear environment to allow for the transition of the mass flux to a bottom-heavy profile and associated spin-up of the low-level vortex.

Key words: tropical cyclone intensification, aircraft observation, moderate vertical shear

Relationships among MJO, tropical cyclones, and high-pressure disturbances in the subtropical High seen in the NICAM aqua-planet experiment

Moriizumi, S., M. Yoshizaki*, Y. Kobayashi, M. Sunohara, T. Suetugu, T. Watanabe,
M. Miyata, E. Sakai and K. Kadoi

Abstract

Analytical studies were conducted, using the 180 day NICAM aqua-planet experiment under the environment with the fixed SST distribution of Gaussian function in the latitudinal direction and wavenumber 1 and amplitude 4.5 degrees in the longitudinal direction. On the western part of high SST area over the equator, eastward-propagating MJO (Madden-Julian Oscillation)-like disturbances with a speed of 5-7 m s^{-1} repeatedly occur, following westerly bursts and, single, one pair, or two pairs of tropical cyclones. It is found that (1) the most intense westerly burst is formed due to one pair of tropical cyclones crossing the equator, not due to the MJO, and (2) various types of tropical cyclones are produced by the temporal and spatial differences between the high-pressure disturbances in the sub-tropical region and westerly bursts in the tropics. The latter indicates that disturbances between tropics and mid-latitude are interrelated each other.

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SST Modulation of the Impacts of Tropospheric Stability on the Intensity and Structure of Tropical Cyclones

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Abstract

The intensity and structure of tropical cyclones (TCs) is more or less controlled by their environmental conditions. How the environmental properties affect the intensity and structure of TCs is one of the major targets of the TC studies not only from a weather forecasting point of view but also from a climate projection viewpoint. For example, the influence of the changes in the environmental conditions under global warming is an important issue in order to understand the risks caused by extreme TCs. A recent study by the present authors has revealed, by conducting an ensemble of sensitivity experiments in which the tropospheric temperature lapse rate and the tropopause height are systematically changed, that the intensity of the simulated TCs changes more sharply with the increase in the temperature lapse rate than with the increase in the tropopause height.

In this study, we further conduct a number of numerical experiments in which not only the temperature lapse rate and the tropopause height are changed but also sea surface temperature (SST) is changed by using a non-hydrostatic, axisymmetric model, Cloud Model version 1 (CM1) developed by Bryan and Fritsch (2002). The environmental properties are examined with reference to the case of Typhoon Vera (1959) which Kanada et al. (2018) investigated. In the control set of the numerical experiments, SST was fixed at 303.5 K. If the SST value as well as the temperature at each level is uniformly increased by 3 K, the sensitivity of the TC intensity to the tropopause height becomes higher than that in the control set of the experiments. With the increased SST and temperature, the moisture content in the troposphere is increased, resulting in enhanced convection. However, even with the increased SST and temperature, the sensitivity to the tropopause height is still lower than that to the temperature lapse rate. It is emphasized here that with the increases in SST and temperature, like that found in a projected future climate under global warming, the importance of the tropopause height relative to the temperature lapse rate becomes significant.

Key words: tropical cyclone, environmental stability, sea surface temperature, numerical model

Improved Tropical Cyclone Intensity Forecasts by Assimilating Coastal Surface Currents in an Idealized Study

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Abstract

High-frequency (HF) radars can provide high-resolution and frequent ocean surface currents observations during tropical cyclone (TC) landfall. We describe the first assimilation of such potential observations using idealized twin experiments with and without these observations. The data assimilation system consists of the Ensemble Adjustment Kalman Filter and a coupled ocean-atmosphere model. In this system, synthetic HF radar-observed coastal currents are assimilated, and the 24-, 48- and 72-hr forecast performances are examined for TCs with various intensities, sizes, and translation speeds. Assimilating coastal surface currents improves the intensity forecast. The errors of the maximum wind speed reduce by 2.7 (33%) and 1.9 m/s (60%) in the 72-hr forecast and 2.8 (40%) and 1.4 m/s (62%) in the 48-hr forecast, for Category 4 and 2 cyclones, respectively. These improvements are similar to the current operational TC forecast errors, so that assimilating HF radar observations could be a substantial benefit.

Key words: tropical cyclone, HF radar, data assimialtion, numerical model

The impacts of cold eddies on the intensity changes during the mature phase of Typhoon Trami (2018)

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Abstract

Typhoon Trami (2018) is one of the typhoons that made landfall in Japan. According to the Regional Specialized Meteorological Center (RSMC) Tokyo best track analysis, the central pressure reached 915 hPa at 18 UTC on 24 September around 20˚N and then rapidly increased by 950 hPa in 18 hours. After the rapid decreases in the central pressure, intensity forecasts announced further intensification to 935 hPa, but the typhoon couldn't intensify again. Typhoon Intensity Forecast scheme based on the Statistical Hurricane Intensity Prediction Scheme also forecasted intensification again due to high ocean heat content represented by tropical cyclone heat potential exceeding 70 kcal/cm^2 in addition to the effect of vertical wind shear, while the National Oceanic and Atmospheric Administration (NOAA)/ Atlantic Oceanographic and Meteorological Laboratory (AOML) satellite analysis clearly indicated the existence of cold eddies around 20°N, 130°E and 21˚N, 125˚E. In order to clarify the impact of the cold eddies on typhoon intensity forecasts, we conducted numerical simulations with different oceanic initial conditions (daily data from 19 to 25 September were used) using a 2 km-mesh nonhydrostatic atmosphere model coupled with ocean surface wave and multilayer ocean models with the Japan Meteorological Agency (JMA) global objective analysis with horizontal resolution of 20 km and the JMA North Pacific Ocean analysis with horizontal resolution of 0.5°. The initial time and integration period are 00 UTC on 23 September and 180 hours with the time interval of 3 seconds.

The results of simulated tracks were reasonable compared with the RSMC best track analysis. The decreases in the simulated central pressures were reproduced only when the coupled model was used. However, the rapid decrease in the central pressure could not be simulated because the lowest simulated ocean heat content among numerical simulations was approximately 60 kcal/cm^2, which was relatively high compared with the estimated value of the NOAA/AOML ocean heat content (lower than 40 kcal/cm^2) . This suggests that the cold eddies around 20˚N at the initial time was not analyzed sufficiently in the present analysis system for forecasting the typhoon intensity.

Key words: tropical cyclone, atmosphere-wave-ocean coupled model, intensity forecast, cold eddy

Tropical Clouds and Precipitation Systems "Across Scales" in Convection-Permitting Aquaplanet Simulations

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Abstract

Tropical clouds and precipitation systems are important components of Earth's climate system, yet our knowledge about their coupling with dynamic systems across different spatiotemporal scales remains limited. Expanding such knowledge is a challenge in part due to the complex interplay between thermodynamic and kinematic structures of different scales that can result in intense rainfall over prolonged periods of time. This challenge is exacerbated by the convective nature of tropical precipitation, which is not necessarily captured by most existing global models. Limited-area models can leverage those issues at the expense of not directly solving synoptic-to-planetary-scale structures. Those issues motivate this study, which aims at examining tropical clouds and precipitation systems in global, convection-permitting idealized model simulations.

A set of aquaplanet experiments was produced with the Model for Prediction Across Scales (MPAS) largely following the experimental design from the AquaPlanet Experiment. A refined mesh allowed for convection-permitting resolution (3-km cell spacing) in the tropics with 15-km cell spacing elsewhere. This first-of-its-kind simulation captures a wide variety of phenomena ranging from tropical squall lines to tropical cyclones to planetary-scale convectively-coupled equatorial waves. A long integration period, following model spinup, was used to composite different phenomena in order to identify thermodynamic and kinematic structures resulting in extreme precipitation events, with special emphasis on tropical cyclones and convectively-coupled equatorial waves. Results from that analysis can guide the refinement of hypotheses, observation strategies, and modeling techniques to be employed during the joint PRECIP/TAHOPE/T-PARCII field experiments in 2020.

Key words: tropical rainfall, convectively-coupled equatorial waves, idealized numerical simulation

Development of upstream low-level humidification and selective ensemble methods for short-term precipitation prediction system

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Abstract

High-resolution Precipitation Nowcasts (HN) provided by JMA (Japan Meteorological Agency) is a state-of-the-art operational short-term precipitation prediction. However, schemes covering uncertainties of prediction are not sufficiently considered in the single prediction. In addition, modifications of predictions corresponding to the temporal change in prediction error are not sufficiently considered in the system. Thus, it is necessary to introduce ensemble prediction schemes. Moreover, correction schemes based on the systematic error of the prediction result are also expected. In this study, a precipitation prediction system named as the selective ensemble nowcast (SEN) is installed. In SEN, the most accurate prediction is selected by the evaluation using scores of previously predicted precipitation among multiple predictions basing on precipitation motion extrapolation with various schemes. We also introduced a scheme to correct predictions based on the error information in past. The system showed the comparable scores to HN. For the rain-band cases, the shapes and amounts of the maximum accumulated precipitation were more accurately predicted in the proposed system for the forecast time of 60 minutes. It showed high responsiveness to the occurrence of rainfall for cases with severe changes in precipitation.

In addition to the precipitation motion extrapolation nowcast, cloud-resolving non-hydrostatic atmospheric model simulations are also expected to be used for short-term precipitation predictions. For the initiation of the simulations, thermodynamic structures of cumulonimbus clouds must be expressed using radar observation information with lighter computational costs. A simplified data assimilation technique named as the upstream low-level humidification (ULH) scheme was introduced by Wakazuki (2015). In this study, the dynamical simulation predictions are also used as candidates of the SEN combining with precipitation motion extrapolation nowcasts. The dynamical simulations were effective and beneficial to the precipitation predictions after forecast time of 60 minutes. In the ULH scheme, information of intense precipitation is converted to the low-level moisture on the upstream side in about 20 minutes before. Intense precipitations were sufficiently induced by the low-level disturbances. In addition, several schemes to remove unexpected intense precipitations are introduced.

Key words: quantitative precipitation forecast, nowcast, cloud-resolving model

Detection of water-soluble ions in hailstones: An effective way to investigate aerosols in deep convection

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Abstract

Interactions between aerosols and hydrometeors in deep convection remain largely unknown, which is at least in part due to the lack of direct observations. Natural hailstone could provide useful information in deep convective storms. Ten water-soluble ions, consisting of four inorganic cations (Na^+, K^+, Mg^{2+}, and Ca^{2+}), four inorganic anions (Cl^-, NO_3^-, SO_4^{2-}, and NO_2^-), and two organic anions ($HCOO^-$ and CH_3COO^-), were measured in hailstone samples collected from 15 hailstorm events over China during 2016. The metallic element concentrations were determined by inductively coupled plasma–optical emission spectrometry, while the anion concentrations were determined by ion chromatography. The presence of these ions suggests that hailstones are likely to absorb ions from aerosols, based on the correlation of ion concentrations with aerosol optical depth (AOD) retrieved from the Moderate Resolution Imaging Spectroradiometer (MODIS). Pearson correlation analysis were also calculated with six pollutants, i.e., SO_2, NO_2, CO, O_3, PM_{10} (particulate matter with an aerodynamic diameter $\leqslant$ 10 μm), and $PM_{2.5}$ (particulate matter with an aerodynamic diameter $\leqslant$ 2.5 μm), which were measured at ground with air quality monitoring network. PM_{10} was found to have the most significant positive correlation with all ions in hailstones (except NO_3^-), which suggests that most of these chemicals in hailstones are likely originated from PM_{10}. This was a preliminary study designed to provide evidence of the presence of water-soluble ions and the possible resources in natural hailstones.

Keywords: hailstone, water-soluble ions, PM_{10}

Important Factors for Development of Meso-beta Scale Vortex that Spawned Tornado-like Vortices

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Abstract

On 1 September 2015, a sudden gusty wind caused 6 shipwrecks in the Tsushima Straight at the southwestern part of the Sea of Japan, resulting in 5 fatalities and a missing person. Near the location of the shipwrecks, a meso-beta-scale vortex (MBV) that formed in the northeast quadrant of an extratropical cyclone was observed by a C-band Doppler radar observation of JMA. Our previous study performed a triply nested high-resolution numerical simulation with horizontal resolution of 50 m and has suggested that tornado-like vortices that formed within MBV caused the shipwrecks. In the present study, ensemble forecasts with 100 members using ensemble Kalman filter analyses are performed to understand favorable atmospheric condition for the development of the MBV.

A composite analysis, which is performed to clarify the differences in structure and environment of the MBV between strongest 8 members (STRONG8) and weakest 10 members (WEAK10), shows that large cyclonic horizontal shear and strong convection are crucial to the development of the MBV. The near-surface cyclonic horizontal shear between southerly and southeasterly winds in the south region of the MBV, and northeasterly and easterly winds in the north region of the MBV for STRONG8 are stronger than those for WEAK10. In addition, low-level water vapor and its horizontal flux for STRONG8 is larger than those for WEAK10. The differences of near-surface horizontal shear are closely related to the structure of an extratropical cyclone. For STRONG8, cyclonic horizontal shear of winds in the northeast quadrant of the extratropical cyclone is larger than that for WEAK10, although the strength of extratropical cyclones is comparable to WEAK10. An ensemble-based sensitivity analysis also shows that strength of the MBV is sensitive to cyclone scale cyclonic horizontal shear of winds, low-level water vapor, and its horizontal flux around the MBV.

Key words: meso-beta scale vortex, ensemble experiment

Oral Presentation
Day 2 09:30-11:15
11:30-13:30
16:15-17:30

Quasi-stationary band-shaped precipitation systems, named as "senjo-kousuitai", causing localized heavy rainfall in Japan

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Abstract

In Japan localized heavy rainfall events with total precipitation amounts larger than 200 mm $(3h)^{-1}$ are often observed to cause severe landslides and floods. About two-thirds (three-fourths in the Baiu season) of the events are brought from quasi-stationary band-shaped precipitation systems, named as "senjo-kousuitai" in Japanese (Tsuguti and Kato 2014 in Japanese). Senjo-kousuitai is defined in Japan Meteorological Agency (JMA) as a band-shaped heavy rainfall area with the length of 50-300 km and the width of 20-50 km, produced by successively formed and developed convective cells, lining up to organize multi-cell clusters, and passing or stagnating at almost the same place for a few hours. The formation processes of senjo-kousuitai are divided mainly into two types of Bluestein and Jain (1985). One is the broken line type that convective cells simultaneously forms on a local front by the inflow of warm humid air, and the other is the back building type that new cells successively forming on the upstream side of winds linearly organize with pre-existed convective cells.

Favorite occurrence conditions for diagnostic forecast of senjo-kousuitai were statistically examined using atmospheric conditions in previous localized heavy rainfall events (Kato 2015, 2016 in Japanese). Two conditions of (1) water vapor flux amount (FLWV > 150 g m^{-2} s^{-1}) and (2) distance to level of free convection (dLFC < 1000 m) were chosen from the low-level water vapor field that is judged based on 500m height data, because they are representative height to examine the initiation of moist convection in East Asia (Kato 2018). Other four conditions are selected; (3) high relative humidity at midlevel (RH > 60 % at 500 hPa and 700 hPa), (4) large vertical shear judged by storm relative environmental helicity (SREH > 100 m^2 s^{-2}), (5) upward motion area for judgement of the synoptic-scale upward field (400 km mean field at 700 hPa), and (6) development of convection for exclusion of warm air advection frequently appearing at 700-850 hPa (equivalent level (EL) > 3000 m). These conditions are operationally used in JMA from 2016, and highly hit the occurrence of senjo-kousuitai, but at high false alarm rates. Further conditions need to improve diagnostic forecasts (i.e., θ_e values, low-level convergence).

Key words: localized heavy rainfall, diagnostic forecast

Evolution of Microphysical Structure of a Subtropical Squall Line in Eastern China

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Abstract

The evolution of the microphysical structures of a subtropical squall line observed during the Observation, Prediction and Analysis of Severe Convection of China (OPACC) field campaign in Eastern China is documented in this study. The data collected from a C-band, polarimetric Doppler radar and a disdrometer are used to investigate the variations of microphysical characteristics within the convective region during the formative, intensifying, and mature stages of the squall line. The microphysical characteristics of the squall line are noticeably different among these three stages. When the squall line develops from the formative stage to the mature stage, its radar derived drop-size distribution (DSD) in the convective region evolves from continental-like convection to more maritime-like convection. Contrary to previous studies, DSD characteristics of a convective line may not be simply locked to a geographical location but varied extensively throughout its life cycle. The polarimetric radar derived liquid water content below the freezing level in the convective region is three times higher than the ice water content above the freezing level. This, in conjunction with a low cloud base (~0.68 km) and a high freezing level (~5 km), indicates a deep warm cloud layer and the dominance of the warm rain process within this squall line.

This study also attempts to examine cloud microphysical parameterizations used in the squall line simulations. By comparing the observed polarimetric radar variables with those simulated by ARPS model using single-, double-, and three-moment bulk schemes. It is found that the three-moment scheme can produce the most accurate structure and evolution of the squall line. However, there is still a lot of room to improve for the microphysical research of the squall line in Eastern China.

Key words: Microphysics, Squall line, Polarimetric radar

Sensitivity of hail precipitation to ensembles of uncertainties of representative initial environmental conditions

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Abstract

Considerable progress has been made to improve the prediction of severe storms in recent years. However, the critical initial perturbations contributing to variance in hail precipitation as well as the intrinsic operational predictability of hail remains particularly challenging. This paper investigates the sensitivity of hail precipitation from an idealized hailstorm to realistic environmental uncertainties through ensembles of cloud-resolving simulations using the Weather Research and Forecasting (WRF) Model, with initial condition perturbations derived from the European Centre for Medium-Range Weather Forecasting (ECMWF) operational ensemble.

Ensemble sensitivity analyses revealed that hail precipitation was very sensitive to small initial environmental perturbations, particularly in thermodynamic variables. The hail precipitation rate was significantly positively correlated with an initial potential temperature below 750 hPa and with a water vapor mixing ratio above 750 hPa. These small initial perturbations led to substantial subsequent differences in updraft velocity, diabatic heating, and microphysical processes, all of which play a key role in hail growth. The larger sensitivity of hail precipitation to thermodynamic rather than kinematic environmental initial conditions persisted even when the magnitude of the initial perturbations was reduced to 10% of the realistic uncertainties derived from the ECMWF ensemble. In the ensemble with a reduced amplitude of initial perturbations, there was still a moderately strong positive correlation between hail precipitation rate and the initial perturbations of the thermodynamic variables. However, the sensitivity of hail to initial environmental perturbations was highly nonlinear, suggesting that the predictability of hail precipitation may be inherently limited, even when environmental uncertainties are reduced to 10% of the currently realistic magnitude of initial perturbations.

Real atmospheric conditions are much more complicated than the idealized hypothesis proposed here, particularly in deep convections. The uncertainty of hail precipitation might be case dependent, and therefore more cases need to be investigated to reach general conclusions.

Keywords: Hail precipitation; Ensemble sensitivity analyses; Cloud and precipitation processes

Banded Convective Activity Associated with Mesoscale Gravity Waves over Southern China

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Abstract

Banded convective activity that occurred near the south coast of China on 30 January 2018 was investigated through convection-allowing simulations using a nonhydrostatic mesoscale model. The simulations capture reasonably well the observed characteristics of this event. The convective bands are found to be closely related to an episode of mesoscale gravity waves propagating northeastward with a wave speed of around 12 m s^{-1} and a primary wavelength of about ~40-50 km. Further analyses and sensitivity experiments reveal that the environment provides a wave duct for these gravity waves, with a thick low-level stable layer below 850 hPa capped by a low-stability reflecting layer with a critical level. The strength and depth of the low-level stable layer determine the intrinsic phase speed and wavelength of the ducted gravity waves. In the sensitivity tests that the stable layer depth is reduced, the wave characteristics change according to what are predicted with the wave duct theory. The convective bands collocate and propagate in phase with the peak updraft regions of the gravity waves, suggesting strong interactions of convection and gravity waves, in which the ducted gravity waves can trigger and modulate convection, while latent heating from convection enhances the waves. In essence, both wave ducting and wave-convection interaction are jointly responsible for the banded convective activity.

Key words: convection, gravity wave, wave ducting, numerical simulation

Convective cells embedded in widespread stratiform echoes observed by Kobe PAWR in July 2018

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Abstract

The X-band phased array weather radar (PAWR) can measure three-dimensional dense precipitation data with about 100 elevation angles every 30 seconds. The PAWR installed at NICT Kobe covers the range of 60 km radius with range resolution of 100 m. In July 2018, recordable torrential rainfall with Baiu-front occurred in western Japan. In the PAWR observation area, heavy rainfall lasted more than 72 hours from July 04 to 07. The significant characteristics of the PAWR observation data is that strong echoes are embedded in widespread echoes. The widespread echoes with over 50% echo area in CAPPIs at 2 km height were observed for more than 60 hours. On the other hand, strong echoes over 40 dBZ were frequently observed within the widespread echoes. Most of the strong echoes had a cell-shape with a diameter of 5 to 10 km, but band-shape strong echo with a length of 30 km was also observed. Looking at the vertical sections, the widespread echoes are stratiform echoes with bright-band and the strong echoes have a convective structure. Although the over 40 dBZ echo region is also appeared at a developed bright-band and a streak line just below it, its structure is clearly different from the convective cells. The PAWR data observed every 30 seconds revealed that the band echo was formed by organizing multiple convective cells.

Key words: convective echo, stratiform echo, heavy rainfall, Baiu-front, phased array weather radar

Effect of the Sea Surface Temperature on Mesoscale Convective System-Produced Extreme Rainfall over Yellow Sea: 13 August 2012

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Abstract

An extreme rainfall-producing mesoscale convective systems (MCSs) occurred over Yellow Sea, Korea on 13 August 2012, recording 430 mm of rain in less than 12 hours. To better understand the factors of heavy rainfall-producing MCSs underlying this event, the formation and development mechanisms of MCSs causing the extreme rainfall were examined using observation and cloud resolving model simulation. Synoptic analyze showed that the MCS occurred in association with a stationary front. A southwesterly low-level jet (LLJ) transported warm and humid air and supplied the moisture toward the front. In the upper-level synoptic environment, the trough and upper-level jet promoted the development of convection. MCSs mode is Echo Training/back-building (BB) type, which the convective cells continue to pass over the same area while the convective system motion is stationary. This synoptic environment and MCSs mode are advantageous to make extreme rainfall over Yellow Sea. The extreme rainfall-producing MCSs are dependent not only at the atmosphere but also at sea. The sea surface temperature (SST) field of Yellow Sea in this event was 1.1℃ higher than 30-years mean, and existed local warm pool (>28.5℃). To investigate the impact of warmer SST field on MCSs than 30-years mean, the cloud resolving simulation result shows that simulated low-level convergence and latent heat flux on MCSs was enhanced in warm SST field. Sensitivity experiment showed less rainfall amount and weaker convective available potential energy. Therefore, warmer SST field than 30-years mean has an important role on the continuous development of convective cells over Yellow Sea.

Key words: Extreme Rainfall, Mesoscale Convective Systems, Sea Surface Temperature, Yellow Sea

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Organizational Modes of Mesoscale Convective Systems associated with Warm-Sector Heavy Rainfalls in South China

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Abstract

Warm-sector heavy rainfall has been a big challenge in pre-summer rainy season in south China, which may cause severe flooding some times. The organization of the associated mesoscale convective system (MCS) is a very important factor that affects the distribution of the rainfall they produce. This work examines the organizational modes of the MCSs associated with the warm-sector heavy rainfalls in south China based on composite reflectivity Doppler radar data during May-June of 2007-2014.

Results showed that the organizational modes of the MCSs associated with the warm-sector heavy rainfall in south China can be classified into eight modes including one nonlinear mode (NL) and seven linear modes: trailing stratiform precipitation (TS), no stratiform precipitation (NS), leading stratiform precipitation (LS), parallel stratiform precipitation (PS), embedded lines (EL), bow echoes (BE), and training lines (TL). NL mode accounted for 39% of the total and linear modes accounted for 61%. The most frequently observed organizational modes are NL, TS, NS. TS occurred the most frequently among the linear modes. On average, the lifespans of linear modes were longer than that of NL mode with the TS mode having the longest average lifespan.

The environmental characteristics of NL, TS, NS are examined. Among the three modes, TS mode had the strongest 0-1 km shear, largest MLCAPE (Mixed Layer Convective Available Potential Energy), the most precipitable water, while NS mode had the weakest low-level shear, the lowest MLCAPE, and the least precipitable water. NL mode generally occurred under the condition of intermediate MLCAPE and low-level shear. The CIN (convection inhibition) of these three modes was similarly small (absolute value not exceeding 50 J/kg).

Different formation features were found for these top three organization mode systems. About 70% of NL systems formed via broken areal mainly near the coastline of Guangdong and Guangxi provinces. About 67% of NS systems formed via broken line. About 50% of NS systems formed in west Guangxi. TS systems formed mainly via intersecting convective bands (50%) and broken areal (about 40%) in Guangdong Province.

Key words: organizational mode, warm-sector heavy rainfalls, mesoscale convective system

Airborne Phased Array Radar (APAR): The Next Generation of Airborne Polarimetric Doppler Weather Radar

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Abstract

This paper presents a configuration of a novel, airborne phased array radar motivated by major advances in cellular technology, component miniaturization, and radar antenna simulation software. This has paved the way for a next-generation radar being designed by NCAR/EOL to be installed on the NSF/NCAR C-130 aircraft. The APAR system will consist of four removable C-band active electronically scanned arrays (AESA) strategically placed on the fuselage of the aircraft. Each AESA measures approximately 1.5 x 1.5 m and is composed of 2368 active radiating elements arranged in a total of 37 line replaceable units (LRU). Each LRU is composed of 64 radiating elements that are the building block of the APAR system.

Polarimetric measurements are not available from current airborne tail Doppler radars. However, APAR, with dual-Doppler and dual polarization diversity at a lesser attenuating C-band wavelength, will further advance the understanding of the microphysical processes within a variety of precipitation systems. Such unprecedented observations, in conjunction with the advanced radar data assimilation schema, will be able to address the key science questions to improve understanding and predictability of significant weather.

The development now underway is expected to take ~5 years. It adopts a phased approach as an active risk assessment and mitigation strategy. At the present time, both the National Science Foundation and the National Oceanic and Atmospheric Administration are funding the APAR project for risk reduction activities. The APAR Team is actively seeking partners in industry and in the university community. An APAR science and engineering advisory panel has been organized. The authors will review the overall design and current progress of APAR and outline ambitious future development work needed to bring this exceptional tool into full operation.

Key words: phased array radar, aircraft observation, polarimetric radar

Maritime Water Vapor Estimation using Ocean Platform GNSS Measurement

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Abstract

Japan is an island country located in the easternmost of East Asia and influenced by the East Asian monsoon. Moist air inflow coming from ocean often causes heavy rainfall (Kato 2006, Tsuguchi and Kato 2014). With the increase of extreme precipitation events, water vapor monitoring over the ocean is one of the important issues in Japan. Shoji et al. 2009 showed improvement of a heavy rainfall prediction by assimilating precipitable water vapor (PWV) estimated at Global Positioning System (GPS) observation network in East Asia as well as Japan's nationwide dense GPS network. The result insists the importance of water vapor monitoring in upstream.

Unlike ground-based fixed GNSS stations, ocean-platform (ship and buoy) GNSS measurements face difficulties in analyzing the variable antenna position simultaneously with the atmospheric delay. However, recent advancement of kinematic precise point positioning technology is beginning to overcome these difficulties. Shoji et al (2017) installed two GNSS antennas on a research vessel, the RYOFU MARU of the Japan Meteorological Agency (JMA), and conducted experimental observations to assess the GNSS derived PWV from October 19, 2016, to August 6, 2017. The GNSS derived PWVs showed good agreement with the radiosonde observations on the vessel (1.7 mm root mean square difference, −0.7 mm bias, and 3.6% rejection rate).

Kato et al. (2018) introduced a GNSS buoy system for a synthetic geohazard monitoring. The buoy is located about 40 km south of Cape Ashizuri, west of Shikoku, Japan. We succeeded continuous PWV retrieval from June to September 2018. Retrieved PWVs vividly captured water vapor variations associated with north-south shifting of the "BAIU" seasonal rain front and passages of heavy rainfalls and typhoons. The GNSS buoy PWVs also suggest that, compared to over land, uncertainty of water vapor field in JMA's objective analysis is larger over the ocean.

In the year of 2018, we started a new research project to monitor PWV over the ocean west of Kyushu, Japan, getting supports from eight vessels (six regular line cargo vessels, one fisheries research vessel, and one JMA's research vessel).

Key words: Precipitable Water Vapor, Global Navigation Satellite System, Oceanplatform

Smartphone Pressure Observation from Chinese Moji users in 2016: Statistical Characteristics, Application and Bias Correction

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Abstract

More and more smartphones are equipped with pressure sensor, providing an auxiliary resource for global high-resolution pressure observation and making it possible to resolve convective-scale features. Previous studies have been conducted on calibration of smartphone pressure and its applicability in some region, but barely performed in China, and the statistical characteristics of this kind of dataset has not been fully discussed. Using smartphone pressure data in the whole year of 2016, obtained from Moji, a smartphone weather app, we carry out the spatial and temporal distribution of the dataset, application in severe weather cases and a bias correction method.

Quality control of observations is applied and the spatial and temporal characteristics of this dataset are investigated in a global view. Results demonstrate that the data is distributed in each continent around the world except Antarctica, and with high density in urban cities. The total amount and distribution of data reach maximum in July and minimum in December. The diurnal variation of data quantity also has two peaks, which is consistent with the rush hour in the morning and evening. Besides, several case studies show there is another peak of data when severe storms occur. The smartphone pressure data in severe storm day can provide more detailed information about cold pool comparing to the automatic weather station observation. Finally, a bias correction method using machine learning is evaluated. Through this approach, the mean absolute error decreases by 88%, below 1hPa.

Due to large population and globalization, smartphone users in China may contribute more surface observation in the world, and data assimilation using smartphone data may improve numerical weather prediction.

Key words: smartphone data, pressure observation, machine learning

Development of next-generation 1.3 GHz wind profiler radar

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Abstract

Wind profiler radar (WPR) is an instrument used for measuring height profiles of vertical and horizontal wind in the clear air. By producing perturbation of temperature and humidity of the air, turbulence generates irregularities of the radio refractive index. The irregularities of the radio refractive index with a scale half of the radar wavelength (i.e., Bragg scale) produce the clear-air echo. WPR measures vertical and horizontal wind by using the clear-air echo. WPR is used not only for atmospheric researches but also for weather condition monitoring and weather forecast.

Though WPR is a useful means for measuring wind profiles in the clear air, its measurement resolution and the quality of wind products have room to be improved. In order to attain the breakthrough in measurement capability of WPR, next-generation 1.3 GHz WPR has been developed. In the next-generation 1.3 GHz WPR, range imaging (RIM), which uses multiple frequencies and adaptive signal processing, is employed for enhancing vertical resolution. By using oversampling (OS), measurement accuracy of RIM is able to be gained. Adaptive clutter suppression (ACS), which controls the antenna side lobe by using subarrays and adaptive signal processing, is also employed for mitigating undesired echoes (i.e., clutter) contaminating in received signals. In order to implement RIM, OS, and ACS capabilities in existing WPRs, a unique digital receiver using software-defined radio technique has been developed. Currently, RIM, OS, and ACS capabilities are implemented in a 1.3 GHz WPR operated by NICT and a 1.3 GHz boundary layer radar operated by DPRI, Kyoto University. At the meeting, overview and development status of the next-generation 1.3 GHz WPR are presented.

Acknowledgment

Part of the development of next-generation 1.3 GHz WPR has been supported by KAKENHI Grant Number 26281008, 15H05765, and 16K12861 funded by the Japan Society for the Promotion of Science.

Key words: wind profiler radar, wind, turbulence, radar imaging, clutter mitigation

Multiscale Atmospheric Conditions in the Evolution of Convective Organization during MJO-1 of DYNAMO/CINDY/AMIE

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Abstract

Case study analysis of tropical oceanic convection during a Madden-Julian Oscillation (MJO) event in late-October 2011 of the DYNAMO field campaign characterizes the convection during this MJO and highlights the evolution of the mesoscale convective behavior and organization linked to multiscale atmospheric interactions in the tropical Indian Ocean. Statistical analysis of S-PolKa dual-polarization radar data stationed on Addu Atoll (0.7°S, 73°E) is combined with environmental conditions from nearby 3-hourly quality-controlled soundings and 6-hourly ERA-interim reanalysis data to examine changes in precipitation distribution, intensity, and microphysics during large-scale changes in the wind and moisture environment associated with the passage of the MJO.

The changes in precipitation areal coverage and vertical distributions of moisture and wind reveal two distinct convective periods at the beginning and end of the MJO passage over the radar. Shifts in reflectivity and dual-polarization hydrometeor characteristics of four precipitation types over these time periods showed a transition from a blend of widespread convective and stratiform precipitation during the deeply moist environment of the main convective envelope of the MJO active phase towards shorter bursts of more intense convective precipitation over a smaller portion of the radar domain as low-level dry air advection steadily increased during the westerly wind burst. Dry aggregates and ice crystals generally occurred at lower frequency and shallower depth as the MJO progressed, which corresponded to decreased longevity in stratiform precipitation late in the period.

The changes in the vertical distribution of ice particles indicate that graupel progressively occurred over a greater depth, associated with the overall increasing intensity of convective precipitation, while other ice particle types occurred over shallower depths with decreased reflectivity values. These intense but infrequent convective elements displayed a tendency towards squall line organization as the surrounding environment gradually became more strongly sheared with greater instability, but the presence of other convective types weakened overall. High-resolution sensitivity simulations reveal significant differences in how different cumulus and microphysics parameterization scheme combinations handle both convective organization tendencies and cold pool generation in this event.

Key words: tropical convection, mesoscale convection. Madden-Julian Oscillation, radar observations, ground-based observations, numerical model, DYNAMO

Analysis and Forecast Using Dropsonde Data from the Inner-Core Region of Tropical Cyclone Lan (2017) Obtained during the First Aircraft Missions of T-PARCII

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Abstract

The inner core of Tropical Cyclone Lan was observed on 21−22 October 2017 by GPS dropsondes during the first aircraft missions of the Tropical Cyclones-Pacific Asian Research Campaign for the Improvement of Intensity Estimations/Forecasts (T-PARCII). To evaluate the impact of dropsondes on forecast skill, 12 36-h forecasts were conducted using a Japan Meteorological Agency non-hydrostatic model (JMA-NHM) with a JMANHM-based mesoscale four-dimensional data assimilation (DA) system. Track forecast skill improved over all forecast times with the assimilation of the dropsonde data. The improvement rate was 8−16% for 27−36-h forecasts. Minimum sea level pressure (Pmin) forecasts were generally degenerated (improved) for relatively short-term (long-term) forecasts by adding the dropsonde data, and maximum wind speed (Vmax) forecasts were degenerated. Some of the changes in the track and Vmax forecasts were statistically significant at the 95% confidence level. It is notable that the dropsonde-derived estimate of Pmin was closer to the realtime analysis by the Regional Specialized Meteorological Center (RSMC) Tokyo than the RSMC Tokyo best track analysis. The degeneration in intensity forecast skill due to uncertainties in the best track data is discussed.

Key words: tropical cyclone, aircraft observation, numerical model, data assimilation, T-PARCII

Field Campaigns in South China Sea Two Islands Monsoon Experiment (SCSTIMX) 2017-2018 and Its Extended Plan

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Abstract

For supporting the integrated project "Interaction of convection over the Maritime Continent – South China Sea with large-scale flow" of MOST (Ministry of Scientific Technology, Taiwan) in coordination with the international project "Years of the Maritime Continent" (YMC), we have carried out several field campaigns in South China Sea Two-Island Monsoon Experiment (SCSTIMX). IOP-W (Dec. 2017) and IOP-S (May-June, 2018) are collected vertical atmospheric profiles over Taiping Island and Dongsha Island by surface weather station, wind profiler, radiometer, and upper-air balloon sounding. Two 12-day cruises by NTU R/V Ocean Research #1 collected the wintertime north-south section of marine atmospheric boundary layer between Taiwan and Taiping Island.

SCSTIMX aims to investigate two major themes. The first is the mid-latitude-tropical interactions driven by the vigorous tropical convection in the Maritime Continent region and mid-latitude baroclinic systems in East Asia, including the Siberian High, the East Asian jet stream, and the East Asian Major Trough. The second theme is the evolution of intra-seasonal oscillations (ISO) over the SCS-MC (South China Sea - Maritime Continent), and the associated processes. In order to give guideline for field campaign and revise the data impact to model simulations, we performed some study on the evolution processes for propagating intra-seasonal oscillations [the MJO in winter] with strong magnitude over Indian Ocean (IO) and Maritime Continent through a diagnosis of ECMWF Re-analysis in November-April, 1982-2011 (Hung and Sui 2018). Also, the extended weather and intra-seasonal oscillations of the 2018 Meiyu (summer monsoon) season is analyzed. The field observation data from these two islands and cruises could be shared for research cooperation. The upper air observation at these two remote islands in South China Sea will be extended and is welcome to join international programs.

Key words: SCSTIMX, South China Sea, Maritime Continent

Airborne measurements for investigation of meteorological phenomena over Korea using the KMA/NIMS atmospheric research aircraft

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Abstract

Airborne campaigns for the meteorological and environmental research have been conducted in regional and global scales. The aircraft is increasingly considered as one of the best platforms to get the atmospheric spatial information, especially over sea. National Institute of Meteorological Sciences (NIMS), Korea Meteorological Administration (KMA) has been utilizing an aircraft (King Air 350HW, Beechcraft) equipped with 25 scientific mission instruments since 2018, in order to fill in observational gaps and observe the upper level of troposphere at higher temporal/ spatial resolution and test advanced observational and experimental techniques, resulting in enhancing meteorological technologies and research capabilities. Our airborne observation plans are designed for the aircraft campaigns over the Korean Peninsula; severe weather (e.g., tropical cyclone, heavy rainfall and snowfall) monitoring, greenhouse gas monitoring, environmental meteorology monitoring (e.g., Asian dust), and cloud physics and cloud seeing experiments. Regarding severe weather monitoring mainly using dropsondes and stepped frequency microwave spectrometer, the airborne measurements focus on characterizing generation/migration of severe weather phenomena and investigating meteorological precursors sensitive to severe weather and variations in its thermo-dynamical structures, and then improving predictability of numerical models with the data assimilation. Here, we discuss here current status and future plan of our airborne measurement campaigns over the Korean Peninsula including specifications of the aircraft and scientific instruments, in particular severe weather monitoring with examples of data observed from the aircraft.

Key words: aircraft observation, tropical cyclone, greenhouse gases, Asian dust, cloud physics

The Impacts of Vortical Hot Towers on Inland Eyewall Reformation of Typhoon Fanapi (2010) over Taiwan

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Abstract

Numerical simulations of Typhoon Fanapi (2010) interacting with the terrain of Taiwan are conducted using the Advanced Research Weather Research and Forecasting model (ARW; version 3.3.1) on a triply-nested grid (with the finest grid size of 1 km and 55 vertical levels). Fanapi made landfall on eastern Taiwan at 0000 UTC 19 September and left Taiwan at 1200 UTC 19 September 2010, producing heavy rainfall and severe floods. After landfall, the Fanapi eyewall weakened and broke down over the Central Mountain Range. Vortical hot towers (VHTs) occurred along the Fanapi rainband, and the VHTs in land have weaker maximum updrafts (7.0–8.0 m s^{-1}), narrower diameter (7.0–11.5 km), and shallower depth (6.5–9.0 km), compared with oceanic VHTs over the Taiwan Strait. The VHTs over the Taiwan Strait remained organized along the rainband and propagated toward the southeast quadrant of the Fanapi circulation over land by the tangential flow. These organized VHTs in the southeast quadrant help transport cyclonic vorticity from lower into middle levels and then cooperate with the rich vorticity within the rainband by horizontal vorticity advection to rebuild the Fanapi eyewall upward from the bottom. The vorticity balance within the entire Fanapi circulation is largely dominated by its southeast quadrant with organized VHTs over Taiwan Island. In the simulation with no latent heat release, the VHTs quickly decay and radiate outward from the eyewall as gravity-wave perturbations.

Key words: eyewall reformation, vertical hot tower, Typhoon Fanapi (2010)

Near-shore rapid changes in tropical cyclone intensity

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Abstract

As a tropical cyclone (TC) is about to make landfall, predictions of its intensity change are as important as its track. In this paper, some statistics will first be presented on the rapid changes in intensity for TCs in the South China Sea and Gulf of Mexico. The results show preferred locations of rapid intensification, which suggests the possible contribution from the ocean. Some case studies will be presented to illustrate the importance of the ocean. The results are substantiated with a fully-coupled numerical model.

Key words: tropical cyclone, rapid intensification, air-sea interaction

An observational study of the inner-core evolution of Typhoon Jebi (2018) at landfall

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Abstract

Tropical cyclones (TCs) at landfall experience structural changes due to increased friction, topography, and reduced moisture supply. The evolution of the inner-core structure over a few hours just after landfall, however, has not been well documented observationally, in particular, from the perspective of interaction with vertical wind shear. Typhoon Jebi (2018) at landfall was examined to clarify dramatic changes in the inner-core structure due to landfall and vertical wind shear by using surface, radar, and satellite observations. The azimuthal-mean structure of Jebi shows that while the tangential wind at 1-km altitude decreased from 45 m/s to 30 m/s after landfall, the structure became more compact, with the radius of maximum wind (RMW) at 55-km radius and reflectivity maximized at 40-km radius. Because of increasing forward speed and active convection inside the RMW, maximum wind speed below 5-km altitude did not decrease significantly even after landfall. Inside the RMW, a mesovortex with a scale of 50 km and the associated active convection formed in the downshear-left quadrant. The formation of the mesovortex was likely attributed to dynamically forced updraft associated with the storm vortex tilted in the downshear-left direction and attributed to tilting of horizontal vorticity associated with convergence of strong frictional inflow inside the RMW. Observations suggest that remarkable changes in the structure of Jebi at landfall were caused by two key factors: (i) increase in frictional inflow; and (ii) effect of vertical wind shear.

Key words: landfalling tropical cyclones, radar analysis, mesovortices

Are outer tropical cyclone rainbands similar to squall lines?

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Abstract

Tropical cyclone rainbands (TCRs) are not only one of the most striking and persistent features of tropical cyclones (TCs) but also one of the major causes for extreme floods as TCs approach or encounter the land area. TCRs are conveniently classified into inner and outer rainbands based on the degree to which convection is influenced by the inner-core vortex circulation. In contrast to the inner TCRs, which has been recognized to be more probably related to near-core wave activities, the origin of the outer TCRs remains largely controversial. The increasing evidence from observational and modeling studies reveals the important effect of convectively generated cold pool, instead of wave forcings, on the triggering and maintenance of moist convection associated with outer TCRs. Limited recent studies also suggest the possibility for TCRs to develop squall-line-like characteristics in the outer region of TCs. However, whether this appealing similarity emerges as a common or exceptional case has not been identified nowadays because only very few outer TCRs have been thoroughly studied and reported in the literature. In this study, the degree of the prevalence for this similarity is explored by long-term radar and surface observations from a large set of 50 outer TCRs associated with 22 TCs as they approached Taiwan. The results indicate that around 58% of outer TCRs are similar to squall lines. These outer TCRs are generally characterized by convective precipitation, an obvious convergence zone between the band-relative rear-to-front flow and front-to-rear flow at low levels, either frontward or rearward tilting updrafts, and a surface cold pool signature. The frequent similarity between the outer TCRs and squall lines documented in this study provides important insights into the formation of organized, heavy precipitation associated with TCs.

Key words: tropical cyclone, tropical cyclone rainbands, squall lines

Characteristics of convective bursts in the rapidly intensified Typhoon Trami (1824)

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Abstract

Typhoon Trami (1824) is one of the tropical cyclones (TCs) which approached Japan and caused damage to the infrastructure due to the strong winds in 2018. Trami rapidly intensified with the intensification rate of 12.9 m s^{-1} day^{-1} under the environments of low vertical wind shear and warm ocean during 0600 UTC 23 September – 0000 UTC 24 September, and the maximum sustained wind (MSW) of Trami reached 54 m s^{-1} during the mature phase. The motivation of this study is to identify the characteristics of Trami's structural changes during the intensification in terms of the deep convection and wind field and to discuss the roles in the intensification. For these purposes, this study examined the deep convective clouds (DCC) within the TC inner core and changes in the wind field of Trami using observations by the IR and WV bands of Himawari-8 rapid scans. The preliminary investigations found that the DCC tended to correspond to high echo-top rainfall captured by GPM/DPR. The wind field near the cloud top within Trami was analyzed using atmospheric motion vectors (AMVs) which were derived by tracking clouds in the Himawari-8 consecutive images at intervals of 5–10 min.

The analysis revealed that the number of DCCs significantly increased near the TC center (radius < 150 km) before the intensification started. The convection deepening with the increase in DCCs enhanced the azimuthally averaged radial outflow near the cloud top, indicating that the TC secondary circulation intensified. Another noticeable feature was the expansion of the eyewall radius after the eyewall replacement during 26–27 September 2018. Trami did not develop and the number of DCCs significantly decreased within the inner core after the expansion of the eyewall radius though it was still moving over the warm ocean in the weak wind shear. It is possible that this stagnation of TC intensity could be explained by the outward shift of DCC locations from the TC center. In addition, the enlargement of the upper-tropospheric warm core during 26–28 September, which was revealed by the Advanced Microwave Sounding Unit -A (AMSU-A) of NOAA and MetOp satellites, might make the atmosphere more stable after the eyewall radius expanded.

Key words: typhoon, convective bursts, warm core, satellite observations

Oral Presentation
Day 3 09:30-11:30
11:45-13:15
14:15-16:15
16:30-18:30

Improvement of two variational-based radar data assimilation systems and their applications in analyzing heavy rainfall processes

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Abstract

WISSDOM (Wind Synthesis System using Doppler Measurements) is a 3DVar-based multiple-Doppler radar wind analysis system. It is able to recover the winds along/near radar baseline and over complex terrain. The retrieved wind from WISSDOM can be readily applied for vorticity budget analysis. In this study, WISSDOM is further improved so that it can optimally synergize the information obtained not only from Doppler radar, but also from mesoscale model outputs, satellite, profiler, radiosonde, and surface station. A thermodynamic retrieval is designed to utilize the WISSDOM-synthesized wind fields to construct the three-dimensional pressure and temperature fields over complex topography.

IBM_VDARS (Immersed Boundary Method__Variational Doppler Radar Analysis System) is a 4DVar-based radar data assimilation system with terrain-resolving capability. Further improvement is also conducted allowing this system to assimilate surface wind, temperature, and vapor observations.

Both WISSDOM and IBM_VDARS are applied to generate high spatiotemporal resolution of meteorological fields, which are utilized to analyze heavy rainfall processes, and identify key factors leading to the extreme precipitation.

Key words: radar, data assimilation, heavy rainfall, topography

Consistent treatment of hydrometeors and cloudiness for convection and radiation processes in a numerical forecasting model

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Abstract

Radiative fluxes are mainly affected by the cloud optical properties calculated with effective radius, water path of hydrometeors, and cloud fraction. The prognostic cloud fraction scheme of Park et al. computes the cloudiness from precipitating convection through the explicit treatment of hydrometeors. The RRTMG radiation scheme is modified to explicitly consider the cloud properties from convection processes and predicted cloudiness. The amount of hydrometeors from both the cumulus parameterization scheme (CPS) and microphysics schemes is explicitly taken into account in computing radiative fluxes. It is found that the information of hydrometeors from CPS tends to increase water path, which leads to larger cloud optical depth and cooling. Skill scores of the simulated precipitation in a medium-range forecast testbed confirm benefits of the consistent treatment of hydrometeors in both CPS and radiation processes.

Key words : convection, radiation, numerical model

Data Assimilation Studies using Big Observation Data in the Projects of Post K and BDA

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Abstract

In the projects of 'Advancement of meteorological and global environmental predictions utilizing observational Big Data' of 'The post K computer development plan of the FLAGSHIP2020 Project' and 'Innovating "Big Data Assimilation" Technology for Revolutionizing Very-short-range Severe Weather Prediction', the data assimilation techniques including the coupling with the ocean model have been developed to improve the prediction accuracy of heavy rainfalls, typhoons, tornadoes, and to obtain the longer leading time (the time from the prediction to the occurrences of severe phenomena). Most of these studies were conducted by using the super computer 'K' and Big Observation Data. In this presentation, we will present the impacts of rapid-scan atmospheric motion vector and sea surface temperature of Himawari-8 on the typhoon intensity and track predictions and on the rainfall predictions of heavy rainfalls, and the reproduction of rainfall system that caused tornadoes by the data of Polarization radar and dense surface observation network.

Key words: data assimilation, numerical model

Predictability of the extreme precipitation event in Taiwan during 1-3 June 2017 based on the convective-scale ensemble data assimilation and prediction

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Abstract

Quantitative precipitation forecast/nowcast (QPF/QPN) is one of the most challenging tasks in numerical weather prediction (NWP) models. In Taiwan, a lot of efforts have been put to improve QPFs for decision making and disaster prevention. Among the heavy rainfall events, it is even more challenging to predict the intensity and location of extreme rainfall episodes over northern Taiwan. Based on the extreme rainfall event during 1-3 June 2017, this study investigates the predictability of heavy rainfall, which had a rainfall intensity more than 100mm/hr in northern Taiwan. High-resolution ensemble data assimilation and prediction is conducted to investigate the uncertainty in convective scale.

In general, the rainfall system is strongly determined by the synoptic-scale weather system and most of the ensemble members well predict the heavy rainfall in central and southern Taiwan, even with 2-day leadtime. However, there is a large rainfall discrepancy in northern Taiwan, which leads to a large root mean square error (RMSE) in precipitation prediction. Results based on radar ensemble data assimilation system show that the movement and orientation of the front and the offshore convergence associated with the barrier jet can be better represented with assimilation of radar data. Nevertheless, the observation impact is limited within 3-h forecast. Sensitivity test shows that the location and intensity of the heavy rainfall in northern Taiwan are sensitive to the southerly wind and moisture transport in the upstream region, and the model physics. Improving the observation network related to these factors is expected to improve the precipitation prediction for such cases.

Key words: convective-scale data assimilation, heavy rainfall prediction, Ensemble Kalman Filter

What is the source of chaos in MCS?

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Abstract

Non-Gaussian probability densities in convection initiation (CI) and development are investigated using a particle filter with a numerical weather prediction model (NHM-PF). An observation system simulation experiment (OSSE) is conducted with a storm scale of 2-km grid spacing, 36 of observations and 1,000 of particles. The observations are created from a nature run, which simulates a well-developed cumulonimbus. For evaluation of non-Gaussianity, we propose to apply the Bayesian Information Criterion to compare the goodness of fit of three statistical models of Gaussian, two-Gaussian mixture and histogram. The PDFs become strongly non-Gaussian, when NHM-PF produces diverse particles over the CI period. This is led by non-Gaussian PDF of updraft at the beginning, and then the upper-bounded PDF of relative humidity, which creates non-Gaussian PDFs of QV and PT. The PDFs of cloud water and QR are quite far from Gaussian distributions throughout the experimental period. From these examination in addition to examinations on ensemble mean and spreads, it is concluded that the source of non-Gaussian in the CI is updraft.

Key words: data assimilation, non-Gaussianity, MCS

Application of the Multi-scale Blending Scheme on Continuous Cycling Radar Data Assimilation

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Abstract

The predictability of the short duration extreme rainfall system is very limited due to the fast evolution and strong nonlinearity nature. The assimilation of radar observation with rapid update cycle frequency and high resolution model is a key to level up the predictability of such systems. However, the spin-up problem becomes more serious in the frequent update continuous cycle. It could introduce significant model error and hurt the first guess in data assimilation (DA). Therefore, how to handle the model error well is one of the important issues to provide the reliable first guess in the frequent update continuous cycle.

In order to reduce the model error in the first guess, the multi-scale blending scheme using a low-pass spatial filter was applied to continuous hourly cycling radar DA system. The blending scheme combines the global model analysis and the convective scale model forecast which take the advantage from the two models. WRF 3DVAR based deterministic DA and LETKF (Local Ensemble Transform Kalman Filter) based ensemble DA experiments were conducted to evaluate the effect of the blending scheme to reduce the accumulated model error in an hourly full cycle strategy. The blending scheme is to reduce the accumulated model error in the deterministic first guess in 3DVAR and re-center the ensemble mean in LETKF.

Case studies show that the both 3DVAR and LETKF radar DA with blending scheme provide consistently better FSS scores in all rainfall thresholds. The blending scheme is workable to reduce the accumulated model error from the continuous hourly cyclic radar data assimilation. In addition, the results also show that the improvement from 3DVAR is more significant than that from LETKF.

Key words: model error, frequent, spin-up, blending scheme

Assimilating Doppler radar observations with an ensemble Kalman filter for the Heavy-Rain-Producing convective development prediction in a heavy rainfall event over South China

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Abstract

This study examines the effectiveness of an ensemble Kalman filter based on WRF model to assimilate Doppler-radar radial-velocity observations for convection-permitting prediction of convection evolution in a heavy-rainfall event over coastal areas of South China during the pre-summer rainy season. An ensemble of 40 deterministic forecast experiments (40 DADF) with data assimilation (DA) is conducted, in which the DA starts at the same time but lasts for different time spans (up to 2 h) and with different time intervals of 6, 12, 24, and 30 min. The reference experiment is conducted without DA (NODA). To show more clearly the impact of radar DA on mesoscale convective system (MCS) forecasts, two sets of 60-member ensemble experiments (NODA EF and exp37 EF) are performed using the same 60-member perturbed-ensemble initial fields but with the radar DA being conducted every 6 min in the exp37 EF experiments from 0200 to 0400 BST.

It is found that the DA experiments generally improve the convection prediction. The 40 DADF experiments can forecast a heavy-rain-producing MCS over land and an MCS over the ocean with high probability, despite slight displacement errors. The exp37 EF improves the probability forecast of inland and offshore MCSs more than does NODA EF. Compared with the experiments using the longer DA time intervals, assimilating the radial-velocity observations at 6-min intervals tends to produce better forecasts. The experiment with the longest DA time span and shortest time interval shows the best performance. However, a shorter DA time interval (e.g., 12 min) or a longer DA time span does not always help. The experiment with the shortest DA time interval and maximum DA window shows the best performance, as it corrects errors in the simulated convection evolution over both the inland and offshore areas.

Key words: Radial velocity, EnKF, heavy rainfall forecast, Pre-summer rainy season, South China

Simulation of Aviation Turbulence near the Cirrus Bands in East Asia

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Abstract

Aviation turbulence occurred in Upper Troposphere and Lower Stratosphere (UTLS) has been considered as one of dangerous weather hazards for cruising aircraft, because it sometimes happens without any precursors like on-board radar echoes and/or visible deep convections. Clear-Air Turbulence (CAT) or Near Convective Turbulence (NCT) near the radial cirrus bands are often located ten's or hundred's kilometers away from the main convective region. Those cirrus bands can be also found near the jet stream and/or mountain region due to the instability. In this study, severe turbulence events occurred near the cirrus bands in East Asia are investigated by using the high-resolution numerical simulations. In 9 Sep 2010, a commercial aircraft encountered sever turbulence at about z = 12 km in or just above the banded cirrus anvil cloud shield associated with the mid-latitude cyclone in the northwestern Pacific Ocean. The Weather Research and Forecasting (WRF) model with a finest horizontal grid spacing of 370 m reproduced the banded structures within the southern edge of the anvil cirrus, which is consistent with the characteristics of the cirrus bands observed in infrared satellite data. The estimated value of the cube root of Eddy Dissipation Rate (EDR) within the bands corresponds to the severe level of turbulence experienced by a large aircraft. Generation mechanism of the cirrus bands is similar to the horizontal convective roll in boundary layer. Difference here is that the convective instability is strongly driven by the radiative cooling at cloud top and warming at bottom of the layer within the cirrus anvil under the strong wind shear near anti-cyclonic upper-level ridge. Another severe turbulence event occurred at around z = 4 km near Tokyo, Japan is also investigated. Synoptic condition for this case showed that a strong westerly jet stream is dominant over Japan. And, cirrus clouds are developed at the lee side of the mountains and the east coast of Japan. More detailed mechanism on this case will be also discussed in the conference.

Key words: aviation turbulence, high-resolution numerical simulation, radial cirrus bands

The analysis of lightning characteristics using LINET and weather radar in Korea

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The Korea Meteorological Administration (KMA) monitors the lightning in real time with the LINET (A modern lightning location network in Germany named LINET) lightning detection system in 2015. Lightning observation data is very important as a complement to other observational data like weather radar and input data of numerical model in order to understand the severe weather. However, there is a lack of research on the characteristics of spatial and temporal lightning and on the mechanism of occurrence of the lightning in Korea. In specially, there is no research on the relation between lightning and the polarimetric radar which are recently operated in KMA.

In this study the general characteristics of LINET which started operation in 2015 are described, and lightning data quality was compared with radar rainfall data. The frequency, lightning intensity, and its location observed in LINET were analyzed for three years (2015~2017) and investigated the spatial and temporal characteristics of lightning events in the Korean peninsula. The statistical characteristics of lightning over the strong reflectivity region (more than 45dBZ or radar rainfall more than 10 mm/h) were accomplished over the inland and the ocean. And the microphysical properties of severe weather case using LINET data and polarimetric radar were examined. We investigated the characteristics of polarimetric variables with respect to the lightning/non-lightning precipitation system and analyzed the correlation between the lightning data and the dual polarized radar observation data.

Key word: Lightning intensity, Lightning frequency, Statistical characteristics, Polarimetric Radar

Acknowledgements
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Environments of High-Incidence Area for Warm-Season Tornadoes in China and a Comparison with Its Counterparts in US

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Abstract

There are 40-150 tornadoes reported in China per year, which is only about 5%-10% of the tornadoes in the U.S. Most tornadoes occur during warm-season (defined here as April-August) in both China and the U.S. This study examines the environmental features behind the tremendous distinctions in the frequency and temporal distribution of warm-season tornadoes in the high-incidence area of China and the U.S.

High-incidence areas are determined in this study as 4 °×4 °regions where high incidence of warm-season tornadoes during 2004-2016 are located. In China, the highest frequency of warm-season tornadoes, primarily located in Jiangsu Province, is labeled as JS. The three high-incidence areas selected in the U.S. are located respectively in central, southern, and southeastern US, which are labeled as U_C, U_S and U_SE. The numbers of tornado in JS, U_C, U_S and U_SE are 228, 945, 495 and 203, respectively. JS has the peak tornado occurrence in July and August, while U_C peaks in May, and U_S and U_SE peak in April.

NCEP reanalysis data was used to examine the tornado environments of the peak month for all the four areas. Results show that Significant Tornado Parameter (STP) is well correlated with the number of tornadoes. The STP in the peak month of U_C, U_S, JS and U_SE are 0.19, 0.11, 0.04, and 0.03 respectively, which is consistent with the decreasing tornado numbers in peak month from U_C (531), to U_S (345), JS (114) and U_SE (83). JS has much lower 0-1 km storm-relative helicity (SRH1) and 0-6km bulk shear (SHR6) throughout the warm season than the other three areas. The highest SRH1 and SHR6 and thus the highest STP in U_C may have helped to produce multiple tornadoes simultaneously, which significantly increases the total number of the tornadoes.

Interestingly, results suggest that the variables that determine the peak month of tornadoes is different in different areas. In JS, CAPE seems to be the dominate factor: the mixed-layer CAPE rises to the highest in the peak month, while the SRH1 shows no difference between the months and the SHR6 even decreases approaching to the peak months. In contrast, vertical wind shear seems to be the dominant factor that determines the peak month of tornadoes in the U_S and U_SE. Their SRH1 and SHR6 peak in April while CAPE in April is much less than other months. Meanwhile, the peak of U_C seems to be determined by an optimal combination of instability and shear.

Key words: tornadoes, environments, warm season, high-incidence area

Radar Observation of parent clouds of tornadoes in Tosa Bay

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Abstract

Tosa Bay is the hot spot of tornado occurrence. The probability of tornado identified in the shoreline from Kochi city to Aki city is 32 in the area of 100km times 100km per year. This value is 10 times larger than that of the Tornado array in United States. Therefore, we have constructed our own radar network composed of 6 compact X-band polarimetric radars. Since April 2014, we caught 2 tornadic mini supercell and 8 non-supercell tornadoes.

The present study aims to clarify the characteristics of parent clouds of tornadoes and the structure of tornado vortices by using radar data. The observation range and the beam width of Asakura radar is 80 km and 2 deg., respectively, and those of the other radars is 30 km and 2.7 deg., respectively. Asakura radar makes 3 PPI scans of low elevation angles every 1 minutes and full volume scan every 5 minutes. The other radars make 5 PPI scans every 1minutes. So, these radars can observe tornado vortical structure in more detail than the Doppler radar of Japan Meteorological Agency.

Even for small non-supercell tornadoes, hook echo can observed by our radars. Most of these parent clouds were relatively small, namely less than 5 km in width. Some tornado vortices were observed in the other larger vortices even in non-supercell tornadoes. Statistics of the diameter and tangential velocity of tornado vortices will be examined.

Key words: tornado, radar observation, vortex structure

Impacts of cyclogenesis and moisture transport by the marine boundary layer jet on heavy rainfall over southern Taiwan during SCSTIMX (2018)

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Abstract

During the 19–20 June 2018 South China Sea Two-Island Monsoon Experiment (SCSTIMX), heavy precipitation (> 600 mm) occurred over southwestern Taiwan. Prior to this heavy rainfall event, a series of mesoscale cyclones formed along the NE-SW orientated Mei-Yu front south of Taiwan between the strong (> 15 m s^{-1}) cold northeasterlies coming from the Taiwan Strait and the warm, moist prefrontal southwesterly flow. These mesoscale cyclones developed in the open ocean in the subtropics under baroclinic settings.

The dissipation of the Mei-Yu front south of Taiwan occurred after the last mesocyclone made landfall over the southern China coast around 0600 UTC 18 June, bringing SSW monsoon flow over the Taiwan area. The SSW monsoon flow strengthened and extended northeastward. During 19–20 June, the horizontal moisture fluxes associated with the strong (> 20 m s^{-1}) SSW monsoon flow occurred primarily within the marine boundary layer (MBL) with maximum TPW > 65 mm. The heavy rainfall over southwestern Taiwan during 19-20 June is mainly caused by the warm, moist marine boundary jet (MBLJ) impinging on southwestern Taiwan under favorable large scale settings including warm advection within the SSW monsoon flow and the passage of a 500-hPa trough to the north.

On 19 June, the maximum rainfall axis (> 300 mm) occurred on the windward slopes of the Central Mountain Range due to orographic blocking and lifting. On 20 June, with the development of cold pool (~ 25°C) over southwestern Taiwan, due to rain evaporative cooling, the rainfall maximum (> 300 mm) occurred along the southwestern coast. This heavy rainfall event over southern Taiwan ended in the late afternoon of 20 June after the weakening of the MBLJ due to the westward extension of the West Pacific Subtropical High.

Keywords: Localized heavy rainfall, marine boundary jet, moisture transport, orographic and local effects

Characteristics of extreme convective systems in the East Asian monsoon as seen by TRMM

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Abstract

Thunderstorms, mesoscale convective systems, frontal systems, and tropical cyclones are vital to both hydrologic and energy cycles on Earth. As the global climate changes, patterns of severe weather are likely to shift. In order to accurately represent all types of storms in numerical forecasts and general circulation models, it is becoming increasingly important to incorporate the effects of physical mechanisms and specific details involving clouds and mesoscale processes, storm life cycle, mesoscale organization, topographical and diurnal effects, latent heating, and precipitation from such storms. The East Asian monsoon is characterized by a variety of convective systems associated with the Mei-Yu front, organized mesoscale convective systems, and tropical cyclones that produce very heavy precipitation in the region. Many of the convective systems associated with the East Asian monsoon occur over oceanic regions off the coasts of China, the Philippines, Taiwan, Japan, and South Korea. The historical absence of detailed and long-term radar observations over oceanic regions near East Asia previously limited the study of convective systems and their kinematic and thermodynamic characteristics in the East Asian monsoon. However, the Tropical Rainfall Measuring Mission (TRMM) satellite's Precipitation Radar (PR) has provided an unprecedented dataset to investigate the three-dimensional nature of the oceanic convective systems that are major components of the East Asian monsoon system.

This study uses 17 years of TRMM PR observations over East Asia and the surrounding oceanic regions to fully characterize the sub-seasonal and diurnal characteristics of extreme convective systems associated with the East Asian monsoon. Using a similar algorithm to previous studies using TRMM PR data (Houze et al. 2007; Romatschke and Houze 2010; Rasmussen and Houze 2011, 2016; Rasmussen et al. 2013, 2014, 2015, 2016; Zuluaga and Houze 2015; Houze et al. 2015), three specific types of extreme storms with extreme horizontal and vertical dimensions have been identified and are used to characterize the frequency of occurrence, seasonal and diurnal variability, lightning activity, and latent heating characteristics of the most extreme storms in the East Asian monsoon. Information on how much precipitation the three extreme storm categories contribute to the total rain climatology will be presented to determine the overall importance of extreme storms to the very heavy precipitation during the East Asian monsoon. Time-lagged synoptic composites for each of the different types of extreme storms will indicate the relationship of the various categories of precipitating systems to the large-scale conditions and related monsoon circulations that have been well studied in the literature.

Characteristics of the Marine Boundary Layer Jet over the South China Sea during the Early Summer Rainy Season of Taiwan

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Abstract

The marine boundary layer jets (MBLJs) over the northern South China Sea during the early summer rainy season over Taiwan are analyzed using 5-yr (2008-2012) National Centers for Environmental Prediction Climate Forecast System Reanalysis data with a 6-h interval. The MBLJ is distinctly different from the low-level jets associated with the subsynoptic frontal systems. During this period, the MBLJ events over the northern South China Sea mainly occur during the second half of the monsoon rainy season over Taiwan (after 1 June) and have a wind speed maximum around the 925-hPa level.

The MBLJs are mainly related to the subsynoptic-scale pressure gradients related to a relatively deep Mei-Yu trough over southeastern China and a stronger than normal West Pacific Subtropical High. Within the MBL there is a three-way balance between pressure gradients, Coriolis force, and surface friction with cross-isobar ageostrophic winds pointing toward the Mei-Yu trough throughout the diurnal cycle. At the jet core, the vertical wind profile resembles an Ekman spiral with supergeostrophic winds > 12 m s^{-1} near the top of the MBL. The MBLJs are strongest at night and close to geostrophic flow in the late afternoon/early evening. This is because the friction velocity and ageostrophic wind decrease during daytime in response to mixing in the lowest levels. The MBLJs play an important role in horizontal moisture transport from the northern South China Sea to the Taiwan area. In the frontal zone, the moisture tongue extends vertically upward. The rainfall production is related to vertical motions in the frontal zone or localized lifting due to orographic effects.

Key words: Marine Boundary Layer Jet, moisture transport, orographic rainfall

The Influences of Sumatra Island and Synoptic Features on Tropical Cyclone Formation in the Indian Ocean: A Numerical Study

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Abstract

Sitting across the Equator with a northwest-southeast orientation and steep terrain, the Island of Sumatra can exert significant influences on low-level prevailing flow near the Maritime Continent. Under an easterly flow regime, in particular, lee vortex (or vortices) tends to form to the west of the island, and some of them may subsequently develop into a tropical cyclone (TC) in the Indian Ocean (OI). This study, therefore, investigate the roles of the Sumatra Island and other migratory tropical disturbances on the formation of TCs using a cloud resolving model.

A total of four cases in the northern IO during the Year of Tropical Convection (YOTC) period were selected for analysis and two of them (TCs Nisha and Ward) for simulation using the Cloud-Resolving Storm Simulator (CReSS) with a horizontal grid spacing of 4 km (i.e., the control experiments). Sensitivity tests with the Sumatra topography removed were also performed. The results indicate that when the pre-TC vortices remain stationary at the leeside of Sumatra at their early stage, they are indeed slightly stronger with a clearer circulation due to the blocking effect of Sumatra on the prevailing northeasterly flow. However, the island's terrain is not a deciding factor on TC formation in these events, as the vortices without the terrain also eventually reach TC status, just at a slightly later time. In addition, westerly wind burst at low latitudes along the equator and migratory disturbances, typically from tropical convection or the ranments of a TC that move westward from the South China Sea (SCS), are also common factors to provide enhance vorticity and moisture, and thus appear important. An examination on all TC cases in northern IO after monsoon in 2008 and 2009 suggests that all their pre-TC vortices evolve in a similar environment with positive horizontal wind shear and advection of vorticity and moisture from the SCS. During the period of TC Ward, another TC (Cleo) also formed in the southern IO, to the southwest of Sumatra, so that it is also examined. It is suggested that the deflection of equatorial westerly wind into a northwesterly flow by the Sumatra terrain (on the windward side) does contribute to the vortex circulation there and is thus also helpful in the formation of TC Cleo later.

Key words: tropical cyclone, lee vortex, Sumatra, topographic effect, cloud-resolving model, Indian Ocean

Relationships between Shear-relative Lower-tropospheric Flow and the Intensity and Size Changes of Tropical Cyclones

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Abstract

Although deep-layer (200−850 hPa) vertical wind shear (VWS) is generally an inhibiting factor for tropical cyclone (TC) intensification, there is still a considerable variability of TC intensification and structural evolution under similar VWS magnitudes. A hypothesis to address this variability is that the interaction between a vertically-sheared TC and the shear-relative low-level mean flow (LMF) modifies the convective structure and its azimuthal distribution, resulting in various pathways of TC structure evolution. This hypothesis was explored from three different perspectives: (1) a global, climatological statistical analysis of the correlations between the 24-hour intensity/size changes and the shear-relative LMF orientations, (2) examining the structural evolution of 180 western North Pacific TCs based on satellite composites, (3) a set of idealized numerical simulations produced with Weather Research and Forecasting (WRF) Model. Based on the best track data of 775 TCs from all basins during 2003−2016, statistical results suggest that a TC affected by an LMF orienting toward down-shear-left favors a relatively large intensification rate, while an LMF orienting toward up-shear-right is favorable for TC expansion. Also, in a storm-motion-relative and shear-relative framework, the analyses based on satellite observations and idealized WRF simulations reveal possible mesoscale processes in the boundary layer causing the distinct convective features associated with TCs affected by various shear-relative LMF

Key words: tropical cyclone, intensity, size, vertical wind shear

Asymmetric Intensification Processes of a Category 4 Super Typhoon Lan (2017) during High Vertical Wind Shear

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Abstract

On 21 October 2017, Typhoon Lan developed to a Category 4 super typhoon with the minimum central pressure (MCP) of 915 hPa at 25.6 degrees north latitude and maintained the peak intensity until the storm arrived at 29.9°N under a strong environmental vertical wind shear (VWS) of 14 m s^{-1}. To understand the intensification processes of an intense typhoon with such high VWS, numerical simulations on Typhoon Lan were conducted using a high-resolution three-dimensional atmosphere regional model, the Cloud Resolving Storm Simulator (CReSS; Tsuboki and Sakakibara, 2002). Two sensitivity experiments, 1dO and FO, were conducted with different SST representations. In the 1dO experiment, a simple thermal diffusion model was used to express temperature changes due to ocean vertical mixing. The FO experiment with a time-fixed SST did not consider the evolution of SST. Both experiments used the same initial and boundary conditions and model specifications for the atmosphere, started at 0000 UTC 18 October 2017, and had an integration time of 5 days. The computational domain was 2°N–37.8°N and 115°E–145°E. The number of horizontal grids in the computational domain was 752×896 with the horizontal grid size of 0.04 longitude by 0.04 latitude.

The typhoon simulated in the 1dO experiment successfully achieved the MCP of 910 hPa at 29.5°N, exhibiting strong asymmetric precipitation pattern as observed by the satellites. The intensification processes were accompanied by rapid developments of the strong winds and warm core in the low-levels. The strong northeast VWS forced to tilt the storm axis to downshear side (northeast) and, in the downshear quadrants, tall, intense and upstanding eyewall updrafts (CBs) formed from the low-level convergence of the storm travelling northeastward with a relatively fast translation speed of 10 m s^{-1}. Meanwhile, dry subsidence from the upper-levels intensified the low-level warm core in the upshear side of the eye. Despite the inner-core convection and precipitation exhibited strong asymmetric structures, the axisymmetricity of the storm circulation was maintained in the mid-to-low levels and abundant water vapor enclosed in the eye allowed to develop CBs around the radius of the maximum wind speeds. The similar asymmetric patterns in precipitation and convection were also found in the FO storm, implying the storm structures would be less sensitive to the SST-cooling effect due to the relatively fast translation speeds.

Key words: tropical cyclone, inner-core structures, numerical model

Influence of Southwest Monsoon Flow and Typhoon Track on Taiwan Typhoon Rainfall during the Exit Phase

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Abstract

We study the influence of southwest monsoon flow on rainfall after typhoon centers leave Taiwan. Exit phase is defined as the time interval when a typhoon center leaves the Taiwan coast to 100 km away from the nearest coastline. Typhoons move across Taiwan through its northern (track N), central (track C), or southern (track S) part are selected for a statistical study. Taiwan hourly rainfall data from the past 57 years are divided into two periods: 1960-1989 (P1) and 1987-2016 (P2). From P1 to P2, there are decadal increases of rainfall (~60%) and rainfall intensity (~30%, mm h^{-1}) in the exit phase. There is also a decadal increase of the track-C typhoons. The southwest monsoon water vapor flux (SWF) in a local region southwest of Taiwan is substantially larger in the track-C typhoons than that in the track-N typhoons. Our analysis indicates that the increase of SWF leads to the increase of rainfall intensity. Moreover, both the enhanced SWF and the prolonged duration time contribute to the increased rainfall in the exit phase. Typhoon Morakot (2009), a track-C typhoon with extremely slow speed in the exit phase, produced the record-breaking rainfall. Model experiments and potential vorticity tendency diagnosis are used to understand the dynamics of increased duration time. The slowdown of typhoon motion is due to the asymmetric convection in the Taiwan Strait, which is produced by the interaction between typhoon circulation and southwest monsoon flow. The enhanced SWF and the prolonged duration time may explain the observed fact that the decadal rainfall increase is much larger than that of rainfall intensity in the exit phase of typhoons. On the other hand, northward-moving typhoons across east of Taiwan on the Pacific Ocean may produce extreme rainfall in southern Taiwan. Typhoons may strengthen the western ridge of subtropical high, and the sustainable southwesterly moisture flux has the characteristic of atmospheric river. Without other strong synoptic-scale forcing near Taiwan, SWF is enhanced by the south side of norward-moving typhoon circulation and transports strong moisture into Taiwan. 10 (13) of 18 northward-moving typhoons produced extremely heavy (heavy) rainfall in southern Taiwan during 2000-2016. This important science issue needs more detailed investigations.

Key words: typhoon rainfall, decadal variation, southwest monsoon, diabatic heating

Impact of Dry Midlevel Air on the Tropical Cyclone Outer Circulation

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Abstract

The impact of dry midlevel air on the outer circulation of tropical cyclones is investigated in idealized simulations with and without a moist envelope protecting the inner core. It is found that a dry midlevel layer away from the cyclone center can broaden the outer primary circulation at both developing and mature stages. When the relative humidity of dry midlevel air outside a radius of 400 km from the cyclone center is reduced from a typical value to 40% at the developing stage, the sensitivity simulations show that the integrated power dissipation (a measure of destructive potential) more than doubles after three days.

The midlevel outer drying enhances the horizontal gradient of latent heating in the rainbands and drives the expansion of the outer circulation. The moist convection at large radius is suppressed rapidly after the midlevel air is dried in the outer rainbands. An enhanced horizontal gradient of latent heating initiates a radial-vertical overturning circulation anomaly in the rainbands. This anomalous overturning circulation accelerates the radial inflow of the main secondary circulation, increases the angular momentum import, and thus increases the cyclone size. The dry air, mixed into the boundary layer from the midtroposphere, is “recharged” by high enthalpy fluxes due to the increased thermodynamical disequilibrium above the sea surface. This “recharge” process protects the eyewall convection from the environmental dry air ventilation. Dry midlevel air intrusion can increase the total destructive potential of tropical cyclones for no changes or even moderate decreases in the core intensity.

Key words: tropical cyclone; outer circulation; size; dry air; latent heating; midtroposphere

Relationship between Typhoon Track Forecasts and Heavy Rainfall in Western Japan in July 2018

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Abstract

Forecast experiments were conducted to investigate the relationship between the track forecasts of Typhoon Prapiroon and heavy rainfall in western Japan in July 2018 using a community version of a global operational forecast model. In the forecast initialized earlier than 12 UTC 30 June, the typhoon deviates from the observed track with a large westward bias due to weak intensity. The forecast typhoon reproduces intensity in analysis and its tracks are converged to observation in the forecasts from 12 UTC 30 June and afterwards. The forecasts with small track error reproduce the overall precipitation distribution in western Japan, but those with large error do not. The forecast failure of precipitation seems to be related to the positional error of the typhoon. The typhoon acts to enhance the pressure gradient against the Pacific subtropical anticyclone to draw airmass with large equivalent potential temperature. In the unsuccessful forecasts, the typhoon does not migrate northeastward in the Sea of Japan to allow the erroneous northwestward extension of the subtropical anticyclone. As a result, the eastward migration of the warm and moist airmass and frontogenesis occurs over the Sea of Japan rather than over the Japanese Iles to bring precipitation with northward bias.

Key words: tropical cyclone, Baiu frontal zone, numerical weather prediction

The lightning distribution of tropical cyclones over the western North Pacific

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Abstract

This study examines the lightning activity under the directions of vertical wind shear (VWS) and movement of tropical cyclones (TCs) over the western North Pacific. The lightning data from the World Wide Lightning Location Network (WWLLN) for 230 TCs between 2005 and 2017 were analyzed. The spatial distribution of the analyses of lightning frequency and normalized lightning rate shows that the VWS dominates the appearance of the lightning. The flashes are active in the downshear-left side of the inner core, and that in the downshear-right side of the outer region. However, the asymmetric pattern is unobvious when sorting with the movement direction of TCs, only the flashes are slightly active in the front-left side of the inner core. Furthermore, the patterns of lightning distribution are almost the same between with and without considering the adjustment factor where improving the low detecting frequency of lightning rate in the early period of analyzed time.

In addition, this study investigates the differences of TC lightning distribution in the different strength of environmental VWS and TC intensity. For the 3 categories of VWS, with the increasing VWS, the flashes of lightning are more asymmetric and higher proportion in the outer region of the downshear side. In the 3 categories of TC intensity, by contrast, the same features occur with the decreasing TC intensity. Furthermore, the calculation of the average lightning rate (total flashes/total time period) for the categories of different strength of VWS and TC intensity indicate that lightning occurs most frequently in the strong VWS and rarely occurs in the weak VWS; on the other hand, the lightning appears more frequently in the weak TC than that in the moderate and strong TCs. Based on a series of composite analyses, when the stronger TC intensity and weaker VWS, the lightning distribution is the more compact, and if the weaker TC intensity and stronger VWS, the lightning distribution is more asymmetric. Besides, it is found that there is the largest average lightning rate in the type of weak TC and strong VWS.

Key words: lightning frequency, normalized lightning rate, lightning asymmetry

New Observation Strategies for Typhoon Intensity over the Western North Pacific

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Abstract

Recent activities on typhoon intensity observation/estimation using aircraft reconnaissance and ground-based Doppler radars in the western North Pacific are introduced. Since aircraft reconnaissance by the US military was ceased in 1987, new techniques of intensity estimation using microwave radiometer and a geostationary satellite are used in this basin without enough verification. The major obstacle of aircraft reconnaissance is the difficulty of having a specially-designed propeller aircraft that withstands strong turbulence. Since wind speed in a typhoon is stronger in the lower troposphere, it takes a great deal of labor and expense to measure the center position and the central pressure of a typhoon through low-altitude flight with slow speed. On the other hand, since the winds become weaker in the upper troposphere, it is possible to fly into the typhoon center if the risks of heavy icing and severe turbulence in a convective burst can be avoided by using an airborne weather radar. During T-PARCII (Tropical Cyclone-Pacific Asian Research Campaign for Improvement of Intensity Estimations / Forecasts), we succeeded in observing the central pressure of two intense typhoons, Lan (2017) and Trami (2018), by using a commercial jet aircraft (Gulfstream-II) with a newly-developed GPS dropsonde system. These flight missions were made in the upper troposphere (43,000ft, approximately 13.7 km) and were marked by very weak turbulence during eyewall penetration. These flights demonstrated a possibility of typhoon intensity observation using a civil aircraft. In the Pacific coast of Japan and Philippines, Doppler radars became available in this decade. The combination of aircraft reconnaissance off the coast with the ground-based velocity track display (GBVTD) analysis near the coast will provide accurate information on typhoon intensity.

Key words: aircraft reconnaissance, typhoon intensity, western North Pacific, Doppler radar

Asymmetric Aspects of Secondary Eyewall Formation in Tropical Cyclones

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Abstract

This study examines observations of asymmetric convection associated with the formation of secondary eyewalls in mature tropical cyclones. Most hypotheses for secondary eyewall formation (SEF) invoke axisymmetric dynamical reasoning without fully identifying the role of asymmetric features in the preceding hours. This investigation uses a combination of airborne Doppler radar and in situ observations to address this issue. Convection asymmetries captured by these datasets were analyzed relative to the deep-layer environmental wind shear vector.

Airborne Doppler radar captured the SEF process in Hurricane Earl (2010), mapping the precipitation and kinematic structures of the involved asymmetric features. Prior to SEF, Earl exhibited a predominantly stratiform rainband in the left-of-shear half of the storm. In the downshear-left (DL) quadrant appeared mesoscale descending inflow that began in the midlevels, attained negative buoyancy, descended into the boundary layer, and locally accelerated the tangential winds. This downdraft induced a persistent convective updraft just radially inward, suggesting that the precipitation regime transitioned from stratiform to convective in this rainband region. This updraft appeared to be nascent convection of the developing secondary eyewall. Eventually, this secondary eyewall exhibited a convective asymmetry with stronger updrafts and tangential winds in this same left-of-shear half.

Flight level observations were next analyzed in a composite study of several tropical cyclones undergoing SEF. Prior to SEF, the DL quadrant exhibited enhanced angular momentum. Leading up to SEF, the left-of-shear half exhibited a significant increase in tangential wind and vorticity. The left-of-shear occurrence of these enhanced kinematic features across many storms is consistent with the hypothesis that the mesoscale descending inflow in a collocated stratiform rainband plays a primary role in spinning up the secondary eyewall wind maximum. Understanding the evolution of these asymmetric structures will improve our ability to predict SEF and the resulting changes in tropical cyclone intensity and structure.

Key words: tropical cyclone, rainbands, aircraft obsevations

Tropical cyclones in global cloud-resolving simulations

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Abstract

Accurately predicting tropical cyclone (TC) activity is one of the most important aspects of numerical weather prediction and climate models. Traditionally, global models have been used for predicting TC track and regional models for predicting TC intensity because global models lacked the high resolution necessary to simulate TC inner core processes. However, this "two-pronged approach" is scientifically inelegant and often inconsistent because the forecast track in the regional model may diverge from the forecast track in the global model. One way to overcome this problem is to use global models with grid spacings high enough to resolve convective processes that drive TCs. To determine whether global cloud resolving models can, in principle, be used to predict TC track, intensity, and impacts in one instant, TCs were analyzed in several Model for Prediction Across Scales (MPAS) simulations run at cloud resolving resolution. Specifically, the simulations were produced on meshes with globally uniform grid spacings of 3.75 km and 4 km. The simulated TCs were evaluated with "best track" data as well as surface wind analyses and rainfall observations. Overall, the evaluation demonstrates that the global cloud resolving simulations are able to produce weak and strong TCs in all ocean basins where TCs occur. However, the model tends to spin up more TCs than observed. While capturing the intensity evolution of some real TCs especially in the western Pacific, the model generally over-intensified storms in the Indian Ocean and central Pacific. These biases indicate that MPAS needs to be improved before it can be a "one stop shop" for accurate TC track and intensity forecasts across the globe.

Key words: tropical cyclone, numerical model, global cloud resolving model

Evaluation of FAMIL2 in Simulating the Climatology and Seasonal-to-Interannual Variability of Tropical Cyclone Characteristics

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Abstract

We evaluate the ability of the latest generation atmospheric general circulation model (AGCM) from State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, Chinese Academy of Sciences (IAP-LASG) (namely, FAMIL2) in simulating some key characteristics (genesis location, track, number, intensity) of tropical cyclones (TC) in terms of their climatology and seasonal to interannual variability. A standard 1° × 1° AMIP experiment is carried out for the period 1979–2002, and the last 20 years of outputs are used for analysis. The same period from International Best Track Archive for Climate Stewardship (IBTrACS) is used as the observation for comparison purposes. The evaluations focus on TC activity at the global scale as well as in the three key regions of the northern Indian Ocean (NIO), western Pacific (WP) and northern Atlantic (NA). With respect to the simulated TC climatology, FAMIL2 shows notable ability in correctly reproducing the main characteristics of the genesis locations, tracks and numbers of TC, particularly over the key regions of TC activity in the Northern Hemisphere; whereas, it underestimates the intensities of TC, as is the case with many state-of-the-art climate models operating at a medium resolution. On seasonal-to-interannual timescales, meanwhile, FAMIL2 successfully reproduces the seasonal cycles of TC numbers over the NIO and WP regions, the former being characterized by double TC peaks (in May and October) and the latter by a maximum peak season in August. However, the model only captures these features approximately. For the simulated interannual variability of TC activity, the correlation coefficients of 20-year TC numbers between FAMIL2 and IBTrACS are 0.22, 0.51 (95% confidence interval) and 0.49 (95% confidence interval) for the NIO, WP and NA, respectively. We also examine the possible reasons behind the performance of FAMIL2 by investigating its subseasonal signs related to the Madden–Julian Oscillation (MJO) and convectively coupled equatorial waves (CCEWs). The TC Genesis Potential Index (GPI) is employed to investigate the possible impacts of the large-scale dynamic fields on the simulation of TC activity. Finally, the biases of simulated TC activity, as well as possible solutions for these biases, are discussed with respect to the horizontal resolution of the model. A TC forecasting case study is introduced as a first step in applying FAMIL2 to a TC forecasting system.

Key words: tropical cyclone, climate system model, S2S prediction

A statistical approach on radar rainfall estimates using polarimetric variables in Korea

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Abstract

To improve the accuracy of radar rainfall estimations, a plenty of rainfall relations composed of polarimetric variables calculated from DSDs measured by POSS disdrometer were examined and a new method was proposed using the four different rainfall events caused by Changma front, indirect effect of Typhoon, low pressure accompanied with front, and low pressure in Korea.

15 rainfall relations using all combination of polarimetric variables calculated from DSDs were analyzed. The analysis of correlation coefficients between polarimetric variables as an independent parameter showed that multi-collinearity would expect in case of reflectivity (Z) - specific differential phase (K_{DP}), Z - specific attenuation (A_H), and K_{DP} - A_H pairs. However, the statistical values of $R(Z,K_{DP})$ were only the relation which has not good enough to apply to the radar rainfall estimation among the three relations.

The RMSEs of $R(Z_{DR},K_{DP},A_H)$, $R(Z)$, $R(K_{DP},A_H)$, and $R(Z,Z_{DR},K_{DP},A_H)$ have the most accurate on 9 July in 2011, on 28 August in 2012, on 8 September in 2012, and on 25 August in 2014, respectively according to the analysis of each rainfall relation accuracy. It means that there were no one unique rainfall relation which has the best performance in all rainfall events. The ensemble mean using eight rainfall relation members such as $R(Z)$, $R(A_H)$, $R(Z,Z_{DR})$, $R(Z,A_H)$, $R(K_{DP},A_H)$, $R(Z,Z_{DR},A_H)$, $R(Z_{DR},K_{DP},A_H)$, and $R(Z,Z_{DR},K_{DP},A_H)$ which had the best performance of statistical values on each rainfall event showed relatively better statistical values in all rainfall events.

It is possible to obtain the ensemble mean due to the polarimetric radar which can measure more parameters than single polarization radar. The ensemble mean would obtain more robust rainfall estimation with deviation information for rain regions using polarimetric radar even further research is required for another climatological region.

Key words: polarimetric variables, drop size distribution, rainfall estimation

Acknowledgements

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Microphysical Characteristics of Different seasons and type of Precipitation over north Taiwan

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Enormous quantities of rainfall during the transition season often cause flooding and mudslides. Accurate rainfall prediction can help to alleviate the effects of such rainfall events. In the present work, long-term (10 years) raindrop size distribution (RSD) measurements from Joss-Waldvogel Disdrometer (JWD) installed at National Central University (NCU, 24°58'6"N 31 121°11'27"E), Taiwan and vertical profile of radar reflectivity were used to analyze the variations in gamma parameters of six seasons (winter, spring, mei-yu, summer, typhoon, and autumn) and types of precipitation. The normalized Gamma distribution of RSD revealed that the highest mean D m (Mass-Weighted Average Diameter) values were in summer, whereas the highest mean log10 N w (normalized intercept parameter) values were in winter. Vertical structures detected in radar reflectivity profiles dominate the results of seasonal RSD. Furthermore, most of the rainfall rate falling at less than 20 mm h-1 occurs in Northern Taiwan. In this study, we used radar reflectivity to differentiate between convective and stratiform systems. It was discovered that the mean D m value is higher in convective systems, whereas the mean log10 N w value is higher in stratiform systems. The structure of RSD in stratiform systems remains constant in all seasons; however, convection is similar to maritime type. Contoured Frequency by Altitude Diagrams (CFADs) revealed that vertical structures dominate RSD in various types of precipitation.

Variations of ZDR and KDP in Heavy Rain Storms in Taipei

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Abstract

Earlier researches find the microphysical process could be inferred by polarimetric observables. The Z_{DR} and K_{DP} columns represent the existence of liquid water content above the freezing level due to enhanced updrafts and the lightning and heavy rain occur after the appearance of the column signature. We follow the work of van Lier-Walqui et al. (2016) and calculate the area of differential reflectivty (Z_{DR}) larger than 1dB and specific differential phase (K_{DP}) larger than $0.75°km^{-1}$ and plot in a time-height section. The spatial-temporal variations of Zdr and Kdp columns in various types of severe convective storms are displayed for analysis.

Four heavy rain cases in Taipei area (north Taiwan) and one multicellular thunderstorm in Pingtung (South Taiwan) are analyzed, including two cases of mesoscale convective systems associated with the Mei-Yu front: 20th May 2015 and 2nd June 2017, two afternoon thunderstorm complex cases: 14th June 2015 and 8th September 2018, and a multicellular storm case on 20th June 2008 in Pingtung Plain.

What does a positive K_{DP}-peak layer above the melting level indicate? ~ Statistics of K_{DP} profiles obtained by a Ka-band polarimetric radar ~

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Abstract

A positive K_{DP}-peak layer above the melting level in a stratiform region associated with the Baiu front was observed by a Ka-band polarimetric radar of Nagoya University during the simultaneous particle sounding observation. Our previous study indicated that the layer would be attributed to the existence of large number of plate- and/or column-type ice crystals. In this study, we explore statistical properties (thickness, duration time, maximum value) of the positive K_{DP}-peak layer and indicate a hypothesis its formation mechanism.

The positive K_{DP}-peak layer is defined by a vertical profile of median of K_{DP} at each level obtained by every 10 min RHI observations. If it has greater than 1 deg. km^{-1} above the melting level, we evaluate that the K_{DP}-peak layer is detected. From May 15 to June 14, 2016, total 40 cases of the layer are detected and almost all cases locate near convective precipitation regions detected by a JMA radar. It has a deep thickness (7-12 km) and maximum K_{DP} reaches 5.7 deg. km^{-1} near the convective precipitation region. It is thinner (5.5-7.5 km) and maximum K_{DP} has smaller value when it locates in the stratiform region far from the convective one. Time-height section of the median of K_{DP} shows the duration time existing the layer is 1-2 hours and the descending of K_{DP}-peak for 2 km in 1 hour in several observed cases.

As a result, the observed positive K_{DP}-peak layer should be attributed to the existence of large number of ice crystals formed in the upper level (from -15 to -40 degree Celsius) in the convective region. This large concentration region of ice crystals advects to the stratiform region with descending. In the stratiform region, depositional heating in the layer should form weak updraft, thus it is expected to cancel the fall speed of growing ice crystals and the height of the layer is sustained. Using the Ka-band polarimetric radar, we can observe the existence of high density region of ice crystals and its advection in a mesoscale convective system. We will also confirm the characteristics of the positive K_{DP}-peak layer in the winter snow clouds observed in the Hokuriku District in our presentation.

Key words: Ka-band polarimetric radar, specific differential phase (K_{DP}), ice crystals

Poster Presentation
Day 1
Core time 13:15-14:45

Essential factors for formation and organization of afternoon thunderstorm in the Taipei basin: A case study on 30 Jun 2018

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Abstract

Afternoon thunderstorms in the Taipei basin often cause severe meteorological disasters in the metropolitan area. Full understanding of essential factors for formation and organization of the afternoon thunderstorms is important for accurate weather prediction using numerical models. In this study, numerical simulations in two realistic situations, which are thunderstorm (TS) and no-thunderstorm (no-TS) cases, are performed to clarify the essential factors using a non-hydrostatic atmosphere model with full physics. The simulation in TS succeeds to capture formation and development of the realistic precipitation clouds in the Taipei basin. The two simulations are verified by hourly atmospheric soundings in a field campaign, and reasonably capture thermal structure and evolution of sea-breeze circulation in the Taipei basin. In TS, the simulated moisture field is high in the troposphere, the environmental flow is weak, and sea-breeze layer is gradually developing in the afternoon. On the other hand, a thick and dry layer lies in 3-km to 10-km heights, there is clear southeasterly wind above 3-km height, and the sea-breeze layer is suppressed below 1-km height in no-TS.

To isolate the essential factors, two additional simulations are performed with vertical profiles of temperature and humidity based on actual soundings in the TS and no-TS cases under no environmental flows. Although the thermal structure in the TS case is significantly different from that in the no-TS case, amount and horizontal distribution of rainfall and evolution of the sea-breeze layer in the additional simulations qualitatively resemble the realistic simulation in TS. The four simulations clarify that (1) depth of afternoon sea-breeze circulation in the Taipei basin and (2) moisture and weak large-scale flow in the middle troposphere are essential factors for the formation and organization of the afternoon thunderstorm. In particular, the large-scale flow can play several important roles in suppression of the afternoon rainfalls due to ventilation in the middle troposphere and choking off the sea-breeze circulation.

Key words: meso-scale convective system, sea-breeze circulation, numerical model

Characteristics of Quasi-2-Day Convective Disturbances over the Tropical Ocean

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Abstract

The westward-propagating convective disturbances with quasi-2-day intervals of occurrence, as known as the quasi-2-day (q2d) convective disturbances, were identified over the central Indian Ocean (IO) from mid to late October 2011 during the Dynamics of the Madden–Julian Oscillation (DYNAMO) field campaign. Based on the intensive observations during DYNAMO, an interpretation is proposed for the mechanisms for the q2d disturbances, which combines concepts from prior studies of this phenomenon over the western Pacific (WPAC) and IO.

The interpretation of the q2d disturbances within the MJO convective envelope is that they are manifestations of westward-propagating, diurnal disturbances whose convective signal becomes modulated over the central IO on a q2d timescale. At the central IO, only every other diurnal disturbance is amplified, leading to a q2d convective signal. Composite analyses support the idea that this modulation is essentially due to the stabilization of the boundary layer and lengthy recovery from the stratiform stage in the event.

Further investigations show that while the diurnal convection prevails over land and the coastal regions due to topographical forcings, the q2d convective disturbances are more prominent over the open ocean regions in tropical IO and WPAC. In addition, the prominent q2d convective signals are corresponded to higher SST, hence associated with the variation of Indian Ocean Dipole on the seasonal time scale.

Keywords: quasi-2-day (q2d) convective disturbance, DYNAMO, Indian Ocean, diurnal, mesoscale convective system, stratiform, boundary layer, SST, Indian Ocean Dipole

The characteristics of eastward-propagating mesoscale convective systems and the diurnal evolution of long-lived mesoscale convective vortices east of the second-step terrain over the East China Plains

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Abstract

A total of 316 eastward-propagating mesoscale convective systems (MCSs) that form over the second-step terrain are detected during May to August 2000~2016 (except 2005) using an hourly black body temperature (TBB) dataset. These MCSs last from three to dozens of hours and moved along various trajectories. These detected MCSs are divided into four categories (i.e., C1, C2, C3, and C4) according to their key characteristics. Eastward-propagating mesoscale convective vortices (MCV) always evolve and develop with the long-lived C3 MCSs. The structure and diurnal evolution of long-lived, eastward-propagating mesoscale convective vortices (MCVs) east of the second-step terrain are investigated through composite analysis of a 30-day semi-idealized simulation. The simulation uses lateral boundary conditions that vary only diurnally in time using analyses of recurring MCV events during 1-10 July 2007. Assisted by the eastward extension of enhanced vorticity anomalies from the Sichuan Basin, the incipient MCV forms in the morning hours over the immediate lee (east) of the central China mountain ranges (Stage 1). From local afternoon to early evening, as the MCV moves over the plains, convection weakens in the daytime downward branch of the mountain-plains solenoid. This allows the upper-level and lower-level portions of the vortex to partially decouple, and for convection to shift to the east-southeast side of the surface vortex (Stage 2). Immediately after sunset, convection reinvigorates above the low-level MCV center due to moistening and destabilization from a combination of radiative forcing and an intensified low-level jet. This intensifies the MCV to maturity (Stage 3). The mature MCV eventually evolves into an occluding sub-synoptic cyclone with strong convection across all sectors of the low-level vorticity center during the subsequent-day morning hours along the East China coastal plains before it moves offshore (Stage 4).

Key words: mesoscale convective systems, mesoscale convective vortices, diurnal evolution

A Study on the Vertical Structure of the Jangma front in 2018 Using radiosonde Observation Data

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Abstract

The National Institute of meteorological Sciences conducted a special observation for the summer from July 2 to 17, 2018 for the purpose of understanding cloud and planetary boundary physical processes related to heavy rainfall and improving physical parameterization of numerical models.

The special observation was performed by using radiosonde at five locations in Jeolla Province of south Korea. In this study, the analysis was conducted focusing on the vertical structure of the jangma fornt and the precipitation caused by the jangma front. At the back of the jangma front, eastery wind was observed up to 850 hPa. As the front went north and passed through the observation point, the wind direction gradually changed to southery wind. As the front lines move northward, the variations of wind direction were able to confirmed the changing level gradually come downstairs. And it seems that the thickness of the front and front surfaces can be analyzed qualitativly.

Key words: Jangma front, structure, front surface

Lightning nowcasting with multisource data: A deep Learning approach

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Abstract: Based on multi-source observation data such as geostationary meteorological satellite (abbreviated as "satellite"), Doppler weather radar (abbreviated as "radar"), cloud-ground lightning (abbreviated as "lightning"), a lightning nowcasting model with the deep learning is proposed in this study. Considering the characteristics of geographical distribution and spatial resolution of radar and lightning observations in China, the mid-eastern region of China was selected as the experimental analysis area of this paper, with a spatial resolution of 0.05° longitude×0.05° latitude. Twelve bands (including visible, infrared, water vapor, etc.) from Himawari satellite and radar mosaic products (including basic reflectivity, vertically integrated liquid, etc.) were used as the predictors, and they are marked with lightning data to establish a training set with millions of samples. According to the characteristics of lightning development, a deep three-dimensional(3D) convolutional neural network including 3D convolutional layer, pooling layer, fully connected layer, softmax classifier, etc., was constructed and trained. The training results showed that the test set classification accuracy exceeded 94%. The performance of the trained model was evaluated. The results show that the Threat Score(TS), Probability of Detection(POD) and False Alarm Rate(FAR) of 0-1hour lightning nowcasting reach 0.51 ,0.60 and 0.23, respectively, in August 2017. Because the softmax classifier is used in the deep learning network and the forecast result is a probabilistic forecast product. The nowcasting results show that the regions with larger probability values usually correspond to the area with the intense lightning activities, which means the probability is a good indicator for thunderstorms. Since satellites have a capability of convection initiation(CI) observation, this model has a good performance in CI nowcasting before it is generated. The CNN3D-LPM implemented in this paper using the satellite, radar and lightning data could effectively improve the prediction performance of thunderstorms compared to that based on only a single-source data.

Keywords: deep learning, multisource data, convection initiation, nowcasting

The Triggering and Maintenance Mechanism of Guangzhou Extreme Precipitation on May 7, 2017- an Operational Perspective

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Abstract

An extreme precipitation event occurred on May 7, 2017 in Guangzhou with maximum hourly precipitation excess 180 mm and 3-hour rainfall accumulation excess 330 mm reported (shortly 5.7 extreme precipitation event). Severe economic damage was caused. Observation based on very density automatic rainfall detecting stations show that heavy rainfall produced in two or three hours. The maximum minute rainfall is high up to 5.0 mm. About 120 mm of the rain poured-out between 05:30 and 6:00 for the extreme hourly precipitation of 184.4 mm in Xintang town of Zengcheng. No severe flashes observed throughout the severe convection. Radar observations and satellite image show that the heavy rain producing convective cells can be characterized as small-scale, short lifetime, and rapid reconstruction. The radar observations show the convective are low-echo-centroid warm clouds. The strong updraft was the cause of inconsistency between radar maximum reflectivity and minimum TBB of satellite image. It is the topographic radiation cooling formed the surface cold center near Huadu. The terrain near Huadu area was of prime important for the initiation and maintenance of the convections over Huadu. The terrain combined with large-scale weak cold air blocked the north moving warm and moist stream, and maintained the mesoscale convective system (MCS) between 01 and 03 BST (Beijing Standard Time). The south moving large-scale weak cold air enhanced the cold pool, and pushed the MCS move southerly faster between 03 and 04 BJS. The combination of south moving MCS and local convection enhanced the convection over Zengcheng area. The cold pool driven theory can explain the long time maintenance and development of the MCS over Zengcheng area. Both weak environmental flow and southerly surface stream made the MCS slowly moving, and extreme precipitation happened over Huadu and Zengcheng of Guangzhou. The accurate forecasting of such events caused by low-echo-centroid warm cloud are still challenges for operational quantitative precipitation forecast (QPF).

Key words: extreme precipitation, triggering and maintenance mechanism, low-echo-centroid warm cloud precipitation, terrain effect

Thermal and Microphysical Effects of Ice Clouds on Torrential Rainfall over Northern China

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Abstract

Ice clouds are an important part of precipitation systems and their thermal (radiative and latent heat) and microphysical effects may impact rainfall. In this study, the thermal and microphysical effects of ice clouds on rainfall are investigated through the diagnostic analysis of rainfall and heat budgets of a torrential rainfall simulation in north China during July 2013. During evening, the maximum reduction in rainfall caused by the inclusion of the thermal effects of ice clouds is mainly associated with the inclusion of latent-heat effects of ice clouds, which suppresses instability and upward motions. During early morning, the maximum increase in rainfall caused by the inclusion of the thermal effects of ice clouds is mainly related to the inclusion of radiative effects of ice clouds, which enhances radiative cooling in the upper troposphere and suppresses radiative cooling in the lower troposphere and thus increases instability and upward motions. The inclusion of microphysical effects of ice clouds increases rainfall directly by the inclusion of deposition and indirectly by the increase in condensation.

Key words: WRF model simulation, thermal and microphysical effects of ice clouds, rainfall budget, heat budget.

Mesoscale convective systems in the Asian monsoon region from Advanced Himawari Imager: Algorithms and preliminary results

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Abstract

The knowledge of mesoscale convective system (MCS) in the Asian monsoon region remains still deficient due to the limited available data and less powerful algorithms. Here, using the data from Advanced Himawari Imager (AHI) onboard Himawari-8 (HW8), an improved algorithm combining the area overlapping (AOL) with the Kalman Filter (KF) is developed, which captures much smaller MCSs that are unavailable otherwise. Several influential factors like the overlapping rate and splitting/merging in the AOL method, and the initial state variable in the KF method, all of which were less appreciated, are handled explicitly. The occurrence frequency, and moving trajectory of two types of MCS, including the ordinary MCS and superconvective system (SCS), have been comprehensively examined in the Asian monsoon region for the warm season (April to September) of 2016. Comparison analyses with ground precipitation and radar measurements confirms the good performance of our algorithm. In particular, the moving direction of MCS strongly depends on latitudes, so does the horizontal velocity. Compared with over ocean, the frequency of MCSs dominate over land or along coasts in the tropics, where strong moisture flux convergence is frequently observed in the low troposphere. In addition, the MCSs detected in eastern China can roughly capture the meridional propagation over time, which corresponds well to the precipitation belts linked to Meiyu front systems. The SCSs dominate over the Bay of Bengal and South China Sea due to the large-scale circulation. Our findings provide new insights to spatio-temporal pat-terns of MCSs during warm season in the Asian monsoon region.

Key words: Himawari, tracking method, mesoscale convective system, superconvective system, meiyu front

Sensitivity of quasi-stationary band-shaped precipitation system to orography for 28 August 2008 Okazaki heavy rainfall event

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Abstract

The Okazaki heavy rainfall event, which occurred at midnight on 28 August 2008 around Okazaki city in Japan, was produced by a quasi-stationary band-shaped precipitation system. This precipitation system remained quasi-stationary for approximately 5 hours over Okazaki city and the surrounding area, and produced prolonged intense precipitation. This study presents sensitivity experiments to examine the impact of surrounding mountains on the quasi-stationarity of the precipitation system using the Weather Research and Forecasting (WRF) model with 500 m horizontal resolution. In an experiment without the mountains to the east of Okazaki city, the quasi-stationary precipitation system was not reproduced. On the other hand, experiments including eastside mountains produced a low-level convergence in south of Okazaki city, resulting in the quasi-stationary precipitation system as observed near Okazaki city. The convergence was formed by sustained easterlies together with northerly winds blowing in west of Okazaki city. The easterlies were maintained by westward shift of southeasterly inflow from the Pacific Ocean due to the enhanced pressure gradient on the upstream side of the eastside mountains in the low-level atmosphere with low Froude numbers ($Fr < 0.5$).

Convective instability of slantwise convection in the Changma front

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Abstract

Convective available potential energy (CAPE) is a widely used quantity measuring convective potential of the atmosphere. CAPE is well correlated to intensity of deep convection and associated precipitation over the central part of the United States. However, convective systems in the East Asian summer monsoon generally have small CAPE values while inducing a large amount of precipitation. Particularly during the summer monsoon, rainfall amount is affected by synoptic and large-scale circulation along the monsoon front, thus the convective potential is sensitive to both vertical and horizontal trajectories of air parcel.

This study examines convective instability of heavy precipitation events over the Korean peninsula based on the CAPE calculation along parcel trajectories. A series of trajectories are computed for the heavy rainfall cases using Weather Research and Forecast (WRF) simulations and backward trajectory model. CAPEs are computed along the trajectories and compared to the typical CAPE values. CAPEs computed along the trajectories show considerably large values compared to those from traditional CAPE calculation. This result suggests that a more comprehensive evaluation on slantwise convection is required to better understand convective potential in the monsoon front.

Key words: monsoon front, CAPE, Changma

Evolution and Mechanism of a Rare Squall Line in Early Spring of 2018

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Abstract

A large-scale strong convection weather occurred in South China and Jiangnan region during 4-5 Mar 2018. The process occurred in a wide range and early time. Severe convective weather such as thunderstorms, hail and short-term heavy precipitation occurred widely, especially the severe gale disasters caused by squall line in Jiangxi Province. Based on the characteristics of atmospheric circulation and radar echo evolution, the process can be divided into three stages: initial stage, development stage and weakening stage. In the initial stage, the low pressure trough caused by southwest jet before westerly trough provide large scale trigger conditions for severe convective. In the development stage, squall line occurred before the trough of warm zone, characterized by obvious strong winds. After the night, the cold front invaded the low pressure trough and the convection weakened. The diagnosis of environmental field and convective parameters shows that high low-level temperature and humidity, dry and cold middle-level air, and large temperature lapse rate, are conducive to the generation of extreme gale. The analysis of long time series of soundings at Nanchang Station shows that the climate state of temperature and humidity elements is abnormal. Compared with the same period in history, the bottom layer is obviously warmer and wetter, and the middle layer is drier. Combined with multi-source observations and radar data, the characteristics and causes of squall line winds in Jiangxi during the process include:(1)Under the combined action of steering current and forward propagation, squall line moves faster. (2) Surface pressure field presented strong thunderstorm high after squall front and the leading low cause strong density current, which is conducive to large-area straight wind at the stage of mature squall line. (3) Through the comparison of the squall line bow echo north-south structural differences show that precipitation particle fallen in middle dry rear inflow, intense cooling forming the strong sinking motion (downburst) is a major cause of extreme winds. The downdraft in squall line stratiform clouds makes the enhancement of wind through increased pressure.

Key words： large-scale thunderstorm gale, extreme weather, severe convection, squall line

Analysis of generation and development process of an extraordinary rainstorm in Ili Valley

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Abstract

The observation data and the high-resolution numerical simulation result are used to analyze the synoptic background and the generation and development process of the strong convective ascending motion that occurred in the Ili Valley, Xinjiang, China on June 26, 2015. The results show that the maintenance of the Central Asian vortexes and the upper jet provide a favorable circulation background for the rainstorm. The convective activity on the large-scale windward slope of the Tianshan Mountain, on the east side of the Ili Valley, releases a large amount of condensation latent heating at the upper level and generates the westward inertial gravity wave; at the same time, the vortex column near the west side of Gongliu County, the rainstorm center in the Ili Valley, is formed. Then the vortex column cooperates with the weak uplift caused by the upwind slope of the low terrain near Gongliu County to form a strong ascending motion, which makes the unstable energy release. Thereby the convective ascending movement is enhanced, the rainstorm begins to occur. The strong convection then moves eastward with the vorticity column and merges with the ascending motion caused by the gravity wave, so it is further enhanced. The mesoscale three-dimensional EP-flux shows that the gravity wave also contributes to the development of strong convection near Gongliu County by energy transport. The trend of the movement and development of the local rainstorm is consistent with that of the strong convection.

Key words: Ili Valley, rainstorm, terrain, convection, inertial gravity wave

Transition of convective system in Kochi Prefecture during the Heavy Rain Event of July 2018

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Abstract

The torrential rain from 28 June to 8 July in the west Japan killed more than 200 peoples and called as "the Heavy Rain Event of July 2018" by Japan Meteorological Agency (JMA). Cumulative rainfall in Kochi Prefecture was maximum in all over the west Japan. The present study aims to investigate the relationship between synoptic environment and transition of convective system. We employed for the analysis the synthetic radar data and rain gage data obtained by JMA, the data obtained from 13 rain gages and the data obtained from the compact X-band radar network of Kochi University.

We divided the synoptic environment into three stages; i.e.,flow along the edge of the Pacific high, typhoon Prapiroon and stationary front. In the first stage until 22 JST, 1 July, some quasi-linear convective system embedded in cloud cluster moving north-eastward yielded heavy rain of 54.5 mm/h in hourly rainfall in the middle area of Kochi Prefecture. In the second stage from 22 JST, 1 July to 09 JST, 4 July, the principal convective system was the slope streak type called by Sassa and Makigusa (2013), in which some quasi-linear rain bands align parallel to the slope of mountains. Though such system occurs when typhoon locates the west of Shikoku Island, it occurred from the early stage when the typhoon located near Okinawa Islands. This is because southerly wind was kept for long time between the typhoon and the Pacific anticyclone. Many quasi-linear rain bands occurred in the wide stratiform cloud area and cloud clusters in the final period from 09JST, 4 July to 00JST, 9 July. The trend of most of the linear rain bands was parallel to the south-westerly wind, but the last system formed near Sukumo city was almost northward. JMA issued the heavy rain emergency warning due to the last linear rainband.

Cumulative rainfall was large in mountainous region. Especially, cumulative rainfall exceeded 2000 mm in the region from central to eastern Kochi. Even in the plain region, cumulative rainfall increased 200 mm as it moves several kilometers inland. The rainfall in the third stage mostly contributed to total rainfall. Such trends were apparent in the east portion of Kochi Prefecture. On the other hands, the contribution of the first and second stages was relatively large in the west portion except Sukumo and Misaki.

Key words: precipitation system, heavy rain, radar observation

A study on sensitivity of heavy rainfall simulation over the Korean Peninsula to cumulus convective parameterization schemes in WRF

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Abstract

Numerical simulations using the Weather Research and Forecasting (WRF) model have different results depending on cumulus convection parameterization scheme (CPS). This study investigated sensitivity of the performance of the Weather Research and Forecasting (WRF v3.9.1) to the use of different CPSs for heavy rainfall simulation. The Betts-Miller-Jangic (BM), Kain-Fritsch (KF) and Multi-Scale Kain-Fritsch (MSKF) scheme were selected for the sensitivity tests. The date of the study was July 16, 2017, when a prominent moisture convergence zone was developed between the northwestern edge of the western North Pacific high and the synoptic trough over the Manchuria, resulting in heavy rainfall around the central region of South Korea, in particular daily accumulated precipitation 290 mm over the Chung-ju.

Three sensitivity tests to the CPSs tended to underestimate the precipitation amount and the rainband patterns differed from the observation data. In temporal and spatial distributions of precipitation were more reasonably simulated by the MSKF scheme than other schemes (i.e., BMJ and KF schemes). In the temporal distribution of precipitation, the BM and KF schemes simulated the peak time of the precipitation 6 hours and 20 hours later than the observation, respectively, while the peak time in the experiment with the MSKF scheme was just 3 hours later. In term of the spatial distribution, the MSKF scheme properly captured the narrow rainband zonally developed around the central region of South Korea. In contrast, the rainband was northward shifted by the BMJ and KF schemes. In the BM scheme, low pressure system inducing heavy rainfall was unrealistically affected by the mid-level blocking system developed over the Kamchatka peninsula, and upper-layer jet stream tended to be exaggerated by the KF scheme.

Key words: Weather Research and Forecasting (WRF) model, cumulus parameterization scheme, heavy rainfall

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Role of internal gravity wave and lower convergence to initial convection: a case study of a heavy rain event on 17th January 2016 around Sakishima Islands

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Abstract

A heavy rainfall occurred on 17th January 2016 around the Sakishima Islands before passing through a cold front. This event is marked by the rain rate of 79.5mm/h at Tarama Island and rainfall amount exceeding more than half of monthly mean, which was brought by a quasi-stationary line-shaped meso-scale convective system (MCS) in the warm sector of the front. The JMA Doppler Radar at Ishigaki Island have captured the initiation of convective echoes to the east of Taiwan, which subsequently developed into the MCS as approaching the front. Since the local meteorological bureau failed to predict this rain event due to poor representation of rainfall in an operational model, it is necessary to clarify factors causing the evolution of the MCS. Based on numerical simulations using Cloud-Resolving Strom Simulator (CReSS), we examined dynamical and thermodynamic processes leading to the initial convective development in the warm sector of the front. Simulated Initial convection was similar to the one observed by the radar and developed on lower convergence region that was formed by the airflow bypassing Taiwan topography. In addition, the simulation represented the arrival of internal gravity waves during the convective initiation. These gravity waves propagated eastward over the Taiwan topography and slowed down in the low-level convergence area. The initiation of convection was resulted from the vertical amplification of waves with the level of free convection (LFC) lowering over the convergence line. A sensitivity experiment with a half depth of Taiwan topography could not reproduce the initial convection due to weak convergence. These results show that the combination of low-level convergence and gravity waves played an important role for the development of MCS. These results can contribute to a better understanding of the organization of MCSs near the Sakishima Islands.

Key words: MSC, gravity wave

Structures of upper-tropospheric outflow-layer clouds of typhoons observed by a Ka-band cloud radar

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Abstract

Clouds in upper-tropospheric outflow layers of typhoons affect typhoon structure and motion through cloud microphysical and radiative processes. Observations of the outflow-layer clouds enable to validate numerical simulation and contribute to improvement of forecasting. The outflow-layer clouds of typhoons were observed by a Nagoya University Ka-band (35 GHz) polarimetric and Doppler cloud radar. Characteristics of microphysics and vertical air motions in the outflow-layer clouds were examined. Typhoon Chaba (2016) approached up to a distance of 135 km from the radar installed at Sesoko Island, Okinawa. The outflow-layer clouds ranged from 10 to 17 km. Upper half of the outflow-layer clouds showed considerably weak reflectivities below −10 dBZ. On the other hand, lower half showed relatively larger reflectivities between 0 and 10 dBZ. Vertical structure shown by range height indicator scans showed that the echo tops were flat without generating cells. Vertical Doppler velocities and reflectivities indicated that alternately upward and downward motions of −2 to 2 m s^{-1} were present. Differential reflectivities were 0-1 dB in larger reflectivity regions in lower layer and showed around 1 dB in lower reflectivities at echo tops. This differential reflectivities were relatively smaller, as compared with larger differential reflectivities occasionally in excess of 5 dB observed around −15˚C with smaller reflectivities. At the cloud bases, lobes of clouds with a horizontal scale of a few kilometers were observed for several hours. This characteristic clouds were associated with considerably dry air below and vertical wind shear. Vertical Doppler velocities of this cloud lobes in Typhoon Cimaron (2018) observed at Kobe indicated downdraft at a downward projected part and updraft at a hollow part with an amplitude of 2 m s^{-1}. A vertical extent of the lobe pattern estimated from a Doppler velocity variation was 1 km.

Key words: tropical cyclone, upper-tropospheric outflow-layer clouds, Ka-band cloud radar

Tropical cyclone structures as depicted by WWLLN data – Terrain-induced eyewall evolution

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Abstract

This study is the first attempt to use the global lightning dataset to investigate the eyewall evolution induced by the landfall process and terrain interaction for tropical cyclones (TCs) traversing the Philippines and Taiwan. The lightning signal is a proxy to represent the deep convection in the cloud, thus its distribution over the storm could be applied to determine the convective structure of TC. It is expected that the high temporal and spatial resolution lightning location information could provide another better data to demonstrate the terrain-induced eyewall evolution process. This process includes the eyewall expansion during landfall, followed by contractions in some cases after re-entrance to the warm ocean.

The global lightning location data from the World Wide Lightning Location Network (WWLLN) and the best track data from Joint Typhoon Warning Center (JTWC) are utilized. The study period is from 2005 to 2017 were mainly based on the availability of WWLLN dataset, and the TCs with intensity reached 65-kt prior landfall are selected for the studied cases. Fifty-five TCs meet the criteria in this study, with 22 and 33 storms passing Taiwan and the Philippines respectively. The radius-time Hovemöller diagram of the azimuthal mean lightning flashes is calculated for determining the eyewall expansion during storm's passage. Preliminary results show that for the cases passing the Philippines, most of the cases (23/33, 70%) reveal higher lightning frequency areas around the storm's inner-core before landfall, and those areas obviously vanish and expand outward after landfall. However, for cases crossing Taiwan, few of them (4/22, 18%) exhibit this scenario. Furthermore, it is found that the TC landfall intensity is a factor for distinguishing the eyewall expansion that determined by the lightning flashes. For both the storms passing Taiwan and the Philippines, the averaged landfall intensities appear stronger in eyewall expanding cases than eyewall non-expanding cases.

Key words: eyewall evolution, eyewall break down, eyewall expansion

An Analysis of Typhoon Remote Rainfall in Taiwan

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Abstract

Severe rainfall may occur in Taiwan when typhoon is located around Taiwan but with a certain distance. Purpose of this study is to analyze the important process leading to such typhoon remote rainfall in Taiwan. The role that the remote typhoon plays on this type of rainfall will be addressed. Objective criteria are used to select the typhoon remote rainfall cases in Taiwan. To be considered as a candidate case, the daily rainfall has to exceed 200 mm at 2 stations in one of the four areas in Taiwan when a typhoon is located at a certain distance from Taiwan. In addition, there should be no other major weather system that might cause severe rainfall in Taiwan.

Results show most of this type of typhoons are located to the northeast or southwest of Taiwan with a distance of about 400-1500 km from Taiwan. The analyses of two selected cases, Typhoon Halong (2014) and Typhoon Aere (2016), show that there are large scale cyclonic circulations located around the vicinity of Taiwan. Low level flow brings warm and moist air to Taiwan and causes convections on the windward side. Results of sensitivity experiments show that severe convections with similar rainfall amount still occur but with a shift in the rainfall location when typhoon is removed in the simulation. On the other hand, the intensity and spatial distribution of the rainfall change significantly when the altitude of Taiwan topography is changed.

Key words: typhoon, typhoon remote rainfall, heavy rainfall, Taiwan topography

The influence of urbanization on the rainfall of landfalling typhoons

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Abstract

Heavy rain associated with TC landfall is difficult to predict because of our relative poor understanding of the mechanisms for its development and the limited amount of data available. The rapid development of coastal cities in Asia has led to questions as to how these cities may have modified the air-land interaction that contribute to rainfall intensity and distributions.

The influence of urbanization on the rainfall of landfalling typhoons is investigated using rain gauge data in Guangdong province from 1981 to 2015,two-dimensional video disdrometers (2DVD) deployed in Guangzhou and coastal ground-based S-band Doppler radar(Guangzhou radar and Hongkong radar).With the development of urbanization, the precipitation characteristics of Guangdong province have changed significantly in the past 35 years we studied.We found that the annual precipitation shows an increasing trend in urban areas.The rainfall frequency shows a decreasing trend while the extreme rainfall frequency shows a increasing trend.Typhoons that made landfall in the Pearl River Delta from the east have been analyzed.Their rainfall intensity and distribution within 24 hours after landing appear to be different.So TC Hato is chosen for specific analysis to explore the relationship between urbanization and typhoon landfall precipitation. Numerical modelling experiments were conducted using the Weather Research and Forecasting Model Version 3.3.1.The simulated rainfall intensity and distributions after TC Hato landed show good agreement with the radar observation.

For further work,sensitivity experiments will be run from the perspective of urban anthropogenic heat and land properties including moisture availability, surface friction and topography of the landmass to figure out how urbanization will influence the rainfall of landfalling typhoons.

Key words: tropical cyclone, urbanization, numerical model,landfall,precipitation

Relabeling the images of the potentially violent typhoons generated by the DCGANs using the CNN

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Abstract

In our previous study, using deep convolutional generative adversarial networks (DCGANs), we generated fake images of the typhoons to be violent after 24 hours, which have been rarely observed. In this report, using the convolutional neural networks (CNNs) trained with the real satellite images of typhoons to predict their 24-h intensities, we verified whether the fake images generated by the DCGANs were properly judged as "potentially violent". As shown in Fig. 1, we found that some of the sophisticated images could deceive the well-trained CNN.

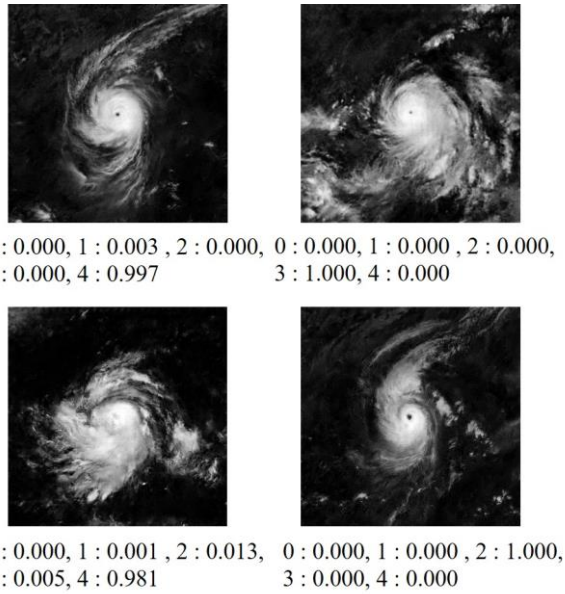

Fig1: The examples of the images generated by the DCGANs, which were predicted (left column) to be violent and (right column) not to be by the trained CNN. The 5 parenthetic numbers and decimals under each image show the 24-hour intensity classes predicted by the CNN (e.g., [4] represent "violent") and the prediction probabilities, respectively. The DCGANs were trained with the original satellite images of the potentially violent typhoons which intensities at the time of photographing were very strong and with those which intensities were strong or normal, separately. These images in the upper and lower rows were the results in the former and latter cases, respectively.

Key words: typhoon intensity prediction, DCGAN, CNN.

Impact of cloud microphysics schemes on typhoon forecast over the western North Pacific

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Abstract

In high-resolution numerical modeling, cloud microphysics parameterization schemes play an important role in typhoon forecasting by controlling the phase changes of the water. Simulated typhoon structure can be changed depending on how many hydrometeors are used in cloud microphysics schemes. In this study, thus, we investigate the sensitivity of track and intensity forecasts to cloud microphysics schemes in real-time typhoon forecast using a Weather Research and Forecasting (WRF) model. The WSM3, WSM6 (WRF-single-moment-microphysics classes 3, 6), and WDM6 (WRF-double-moment-microphysics classes 6) cloud microphysics schemes are selected for the sensitivity test. Also, 24 forecasts for 12 typhoons occurred from 2012 to 2017 are conducted using high-resolution (2 km for core region) model with moving nesting method. The model outputs are validated using the best track from the Joint Typhoon Warning Center (JTWC).

Both track and intensity errors are overall decreased in the experiments with 6 hydrometeors-based schemes (i.e., WSM6 and WDM6) compared in that with 3 hydrometeors-based scheme (i.e., WSM3), in particular for typhoons northward moving to the mid-latitude. In the experiments with the WSM3 scheme, typhoon intensity is prominently underestimated compared to the best track, and simulated typhoon track tends to be shifted eastward compared to the experiments with the WSM6 and WDM6 schemes. Typhoon motions are determined by the environmental wind (averaged 300-850 hPa wind) and β-effect which is associated with the typhoon structure. To elucidate the β-effect on typhoon movement, we conduct additional f-plain experiment with a constant Coriolis parameter. Because the WSM3 scheme simulates smaller and weaker typhoon compares with other schemes indicating reduced β-effect, simulated typhoon track tends to be shifted more eastward. However, the sensitivity of typhoon tracks to microphysics schemes is not relatively significant for typhoons moving westward. This indicates that numerical prediction for typhoons moving to the mid-latitude requires more sophisticated cloud microphysics schemes.

Key words: typhoon, cloud microphysics scheme, high-resolution model

Estimating Tropical Cyclone Intensity by Satellite Imagery Utilizing Convolutional Neural Networks

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Abstract

Accurately estimating tropical cyclone (TC) intensity is one of the most critical steps in TC forecasting and disaster warning/management. For over 40 years, the Dvorak technique (and several improved versions) has been applied for estimating TC intensity by forecasters worldwide. However, the operational Dvorak techniques primarily used in various agencies have several deficiencies, such as inherent subjectivity leading to inconsistent intensity estimates within various basins. This collaborative study between meteorologists and data scientists has developed a deep-learning model using satellite imagery to estimate TC intensity. The conventional convolutional neural network (CNN), which is a mature technology for object classification, requires several modifications when being used for directly estimating TC intensity (a regression task). Compared to the Dvorak technique, the CNN model proposed here is objective and consistent among various basins; it has been trained with satellite infrared brightness temperature and microwave rain rate data from 1097 TCs during 2003−2014 and validated with data from 282 TCs during 2015−2017. This paper also introduces a second version that is optimized by using additional TC information (i.e., basin, day of year, local time, and latitude) to estimate TC intensity throughout the globe. Independent sample verification indicates that 79% of the estimations have less than 10 kt differences from the best-track intensities. In a homogeneous comparison with several operational techniques, a smaller root-mean-square intensity difference (8.66 kt) is achieved relative to a dataset of best-track intensities analyzed with reconnaissance observations.

Key words: tropical cyclone intensity, convolutional neural network, deep learning

Characteristics and False Alarm Analysis of Tropical Cyclone Rapid Intensification Events

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Abstract

According to the National Hurricane Center, a Rapid Intensification (RI) event is defined as an increase in the maximum sustained wind speed by at least 30 kt within a 24-h period. If a tropical cyclone (TC) undergoes RI, the intensity forecast errors are significantly larger (Ito 2016). In addition, the wind and precipitation in local areas may have significant differences if a TC undergoes RI before making landfall.

The historical RI events in the western North Pacific are analyzed in this study. The SHIPS (Statistical Hurricane Intensity Prediction Scheme) Developmental Dataset is used to explore the characteristics of RI and non-RI events. In addition to the ocean thermal structure (i.e., ocean heat content), recent studies have shown that the RI events are also related to the salinity structure (i.e., barrier layer thickness; BLT). In this study, the ocean analysis dataset from the Hybrid Coordinate Ocean Model (HYCOM) and Navy Coupled Ocean Data Assimilation (NCODA) system is used to study the impact of the pre-existing ocean conditions on TC intensification. A probabilistic RI forecast model will be developed by using the Quantile Regression. Finally, the characteristics of the RI false alarm events will be discussed by using the cyclone phase diagram (Hart 2003).

Key words: Tropical Cyclone, Rapid Intensification, and Quantile Regression.

Vertical Structure and Microphysical Characteristics of Typhoon Kong-rey (1825) during the passage near Jeju island

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Abstract

The vertical structure and microphysics of typhoon Kong-rey (1825) that caused damage associated with strong winds and heavy rainfall over Jeju island on 4~6 October 2018 were examined primarily from the UHF wind profiler located at the National Typhoon Center. Five different periods that represent a stratiform, outer /inner rain band, eyewall, and near eye region during passage of Kong-rey were selected based on surface observation, bright band intensities and vertical profiles of backscatter and Doppler velocities. Kong-rey has been weakening with primarily stratiform clouds and the tiled eyewall. During the passage near Jeju island, The level of the melting layer increased with time, which suggests that Kong-rey had a warm-core structure. A strong bright band was present in the rain bands, which indicates more active aggregation right above the melting layer. The eyewall and near eye transformed to an almost stratiform structure showing a weaker bright band than other periods, in association with weakening updrafts. Except in stratiform region, the spectral widths above the freezing levels are nearly constant due to almost uniform sizes distributions of ice particles. Outward tilt of the eyewall increases more substantially as the tangential winds become weaker with height. In particular, the weak wind speed in near eye is possibly due to the eyewall tilt that is more outward at upper levels which results in vertical wind shear. We plan to add radar variables to the analysis in the future version of the current study.

Key words: Typhoon Kong-rey, vertical structure, microphysical characteristics.

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Typhoon KONG-REY's Rainfall over Eastern Coastal Region of Korea and Its Relation to Environmental Factors

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Abstract

In this study, the characteristics of rainfall associated with typhoon KONG-REY and its relation to environmental factors were examined using rawinsonde, wind profiler, and Automated Surface Observing System (ASOS) precipitation data at Uljin, which is located the eastern coastal region of Korea. The rawinsonde data were obtained from intensive observation from 1500 LST October 5 to 0000 LST October 7, 2018. The environmental factors such as Total Precipitable Water (TPW), Strom Relative Helicity (SRH) and change of wind direction were analyzed.

The TPW peak with 60.54 mm appeared at 1200 LST October 6, which is later by 6 hours than typhoon rainfall peak. It is considered as the effect of the continued supply of water vapor from the closest typhoon to Uljin at 1500 LST 6 October. Mean SRH which indicates a mechanical instability was 761 m^2s^{-2} during the period of typhoon rainfall occurrence. This environment provides a good condition for the development of super-cell storms. In addition, it is showed that there is the correlation coefficient of 0.8 between SRH and typhoon rainfall. The wind was veering (warm advection) and backing (clod advection) before and after the typhoon approached Uljin, respectively.

Key words: Typhoon, Rawinsonde, TPW, SRH

A Vortex-Based Doppler Velocity Dealiasing Algorithm for Tropical Cyclones

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Abstract

In this study, a vortex-based Doppler velocity dealiasing (VDVD) algorithm for tropical cyclones (TC) is proposed. The algorithm uses a Rankine combined vortex model as reference field for dealiasing. The parameters of the reference vortex are tuned in an iterative procedure that applies the ground-based velocity track display (GBVTD) technique. An idealized case based on the ground-based velocity track display (GBVTD) and GBVTD-simplex techniques shows reasonable results for recovering the aliasing of Doppler velocity and finding the proper TC center. For Typhoon Fitow (2013), which was observed by Wu-Fen-San radar, the proposed vortex-based Doppler velocity dealiasing algorithm recovers most of the aliased velocity observations with 99.4 % accuracy for all pixels, based on 472 data sweeps. In addition, it is found that the local circulations generated by terrain would conflict with the assumption of the Rankine combined vortex and result in inadequate dealiased Doppler velocities from the VDVD algorithm. Therefore, the radial-by-radial verification procedure is adopted and can adequately recover from the consequences of local circulations.

Generally, the VDVD algorithm can provide high-quality Doppler velocity for TCs. Using the velocity data dealiased from VDVD algorithm, a stable performance is observed for the temporal evolution of mean tangential winds based on the single radar wind retrievals (GBVTD algorithm). In addition, more reasonable and obvious circulation characteristics are retrieved in the typhoon inner core and outer rainband area based on dual Doppler wind retrievals using dealiased data from VDVD algorithm. It is suggested that the VDVD algorithm can improve the quality of downstream applications such as the Doppler wind retrievals and radar data assimilations of TCs and other storms, such as tornadoes and mesocyclones, with vortex signatures.

Key words: radar, Doppler velocity dealiasing, GBVTD, tropical cyclone

A Typhoon Disaster Assessment Method and its application over the South China

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Abstract

Typhoon has a major impact on the population and economy of the South China. There are currently few high-resolution typhoon disaster assessment methods for the South China. Using WRF model and GIS technology, this paper establishes a typhoon disaster assessment method with a spatial resolution of 800 meters, which is based on curve projection pursuit dynamic clustering algorithm by introducing S-curve as the projection. On the basis of the historical typhoon disaster data in the South China, the method combines real-time automatic weather stations observation data, numerical weather forecast products and static data such as terrain, population density and Gross Domestic Product (GDP) to form the real-time typhoon disaster assessment data, which uses five levels to indicate the intensity of the disaster. The typhoon disaster assessment method has been used for the real-time disaster prediction of super typhoon Mangkhut in September 2018. Compared with the actual disaster situation, the result shows that the method has a better effect on disaster prediction.

Key words: typhoon, disaster assessment method, WRF model, GIS technology

Observational Study of Coastal Jet of Landfalling Typhoon in the Taiwan Area

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Abstract

Coastal jet (CJ) along east coast of Taiwan is one of pronounced mesoscale phenomena induced by landfalling typhoon. CJ of typhoon Haitang (0505), Talim (0513) and Longwang (0519) which with similar tracks (from east to west and approached in the central part of the island) and intensity (classified as super typhoon by JTWC) are analyzed by using the coastal radar and surface observations. The similarities and differences of the CJs structure are described and possible causes are analyzed.

Two types CJ are observed and documented. The prevailing strong northeasterly wind associated with Haitang impinging on the steep coast led to CJ being parallel to the terrain, length ~140 km and width ~25 km, its core locates at low-level and persists for ~6 hours. The northern branch of the CJ exhibits stronger wind speeds (maximum wind speed 49-52 $m\ s^{-1}$) with a higher vertical extent (the core of jet is between 1.0-2.5 km height) and a more persistent jet signal. On the other hand, the southern branch of the CJ has a lower wind speed (maximum wind speed 43-46 $m\ s^{-1}$), lower vertical extent (jet core is between 1.0-2.0 km height) and is less persistent. After the eyewall region reached the coast, due to inherent significant curvature of the core-region circulation, the CJ started to change structure by shifting its southern branch offshore. Rather than Haitang, the CJ associated with Talim appears at mid-level (jet core located at 4.5 km height), exhibits a broad curve shape rather than terrain parallel, more than 150 km in length and ~30 km in width, persists for shorter period (~2.5 hours). No CJ signal along east coast is observed in Longwang.

These different flow characteristics along east coast in three STY cases might cause by different circulation and rainfall structure of three STYs. Mid-level and shorter duration of CJ associated with Talim is suggested relative to the passage of serval intense rainband, low-level and longer duration of CJ accompanied with Haitang is suggested relative to wider circulation and relative weaker rainfall distribution.

Key words: coastal jet, landfalling typhoon, radar observation

Comparison between global and regional model forecast skills for tropical cyclones over the western North Pacific

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Abstract

Regional model is widely used to predict specific phenomenon and region with an advantage of computational efficiency. Many tropical cyclone (TC) forecasts also have been conducted with the regional model since the dynamics of a TC are relatively well resolved by high-resolution regional models. Thus, TC intensity forecast is clearly improved with using regional model compared to the global model especially for strong intensity TCs. However, the effect of downscaling in track forecast is uncertain since large-scale environment which plays a significant role in driving TCs are likely to be more reasonably simulated by global model. To clarify the downscaling effect on TC track forecast, we compare the forecast skills between global and regional models for 5-day forecasts. Global Forecasting System (GFS) with 0.5 degree horizontal grid spacing and Weather Research and Forecast (WRF) model with 12 km resolution are used for the global model and the regional model, respectively. We conduct 51 WRF forecasts for 18 TCs activated on western North Pacific (WNP).

In 5-day track forecast, the global model has smaller track position error (TPE) than the regional model. During the forecast lead times less than 72 hr, the regional model predicts the TC tracks better than the global model. However, the TPE of the regional model rapidly increases after 72 hr compared to the global model, therefore TPE of the regional model is larger. It seems that the impact of artificial lateral boundary condition become significant at the late forecast lead times. To elucidate the locational characteristics of downscaling effect, we additionally divide the TCs according to the position of TC center into high-latitude TCs (above 20^{o}N) and low-latitude TCs (below 20^{o}N). The TPE of high-latitude TCs is smaller in the global model, because those are highly influenced by the WNP subtropical high, which is more reasonably simulated by global model. Otherwise, the TPE of low-latitude TCs is smaller in the regional model. A significant error of the global model often occurs in the cases whose TC intensity is underestimated.

Key words: tropical cyclone, global model, regional model, track forecast skill

Structural and Microphysical Features of a Landfalling Rainband of Typhoon Maria (2018) Observed by a Polarimetric Doppler Radar

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Abstract

Typhoon Maria (2018) brought heavy rain especially over northern Taiwan during its passage over the northern ocean of Taiwan on 10 July 2018. At surface station Anbu which located on the top of Yang-Ming-Shan, maximum value of about 40 mm per one hour of rainfall was observed around 10 July at 1900 UTC. Moreover, maximum accumulated rainfall over 24 hours were reached 244 (306) mm at Anbu (Zhuzihu).

A nar row band-shaped radar reflectivity exceeding 35 dBZ approaching from norther offshore of Taiwan was represented by radar composite images from 1600 UTC to 2000 UTC. The lowest-level PPI (0.5°) showed well-organized rainband and reflectivity increasing after its landfall, and the rainband seemed to be staying over the northern land of Taiwan for about an hour. As it approached Taiwan island, the rainband entered the coverage of two Doppler radars. The one is operational S-band (10-cm) Weather Surveillance Radar-1988 Doppler (WSR-88D) on Wu-Fen-San (RCWF), the other is the Civil Aeronautics Administration (CAA) operational C-band (5-cm) Doppler radar located at Taoyuan International Airport.

The aim of this study is to clarify the three-dimensional structure and the evolution of the rainband interacting with Taiwan topology by using observational radar data. From the polarimetric variables obtained by RCWF, we can estimate microphysical processes associated with the rainband. Additionally, it is possible to conduct dual-Doppler synthesis while the rainband was captured by both two Doppler radars so that we may identify three-dimensional flow pattern and kinematic structure of the rainband.

Keywords: Typhoon rainband, polarimetric radar, Doppler radar, terrain effect, microphysical structure, observational study

Heavy Rainfall Associated with Double Low-level Jets over Southern China.

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Abstract

Heavy rainfall occurred at both the inland frontal zone and coastal warm sector in southern China during 10–11May 2014, which is a typical pattern in the early-summer rainy season. To clarify the key factors controlling the rainfall, we conduct an ensemble-based analysis using the operational global ensemble forecasts from ECMWF. The forecasts of frontal (warm sector) rainfall have a relatively small (large) spread and a small (large) bias of ensemble-mean amount, suggesting an obvious difference in the predictability. It is shown that double low-level jets (LLJs) in the southwesterly moist flow play a significant role in the heavy rainfall over southern China. The inland frontal rainband is closely related to the synoptic-system-related low-level jet (SLLJ) with maximum wind speed at 850–700 hPa, especially for its meridional wind component. The more intense cold front is accompanied by the stronger southwesterly SLLJ on the adjacent south side, favoring more precipitation near the front. The warm-sector heavy rainfall, a few hundred kilometers away from the front, is associated with the boundary layer jet (BLJ) at 925 hPa. The southerly BLJ occurs over the northern region of the South China Sea and reaches its maximum wind speed in the early morning.

To clarify the role of the double low-level jets in convection initiation (CI), we perform convective-permitting simulations using a nonhydrostatic mesoscale model. The simulations reproduce the occurrence location and mesoscale evolution of new convective cells. The nighttime BLJ over the northern South China Sea strengthens the convergence at ~950 hPa near the coast where the BLJ's northern terminus reaches the coastal terrain. Meanwhile, the SLLJ to the south of the inland cold front provides divergence at ~700 hPa near the SLLJ's entrance region. Such low-level convergence and mid-level divergence collectively produce strong mesoscale lifting for CI at the coast. In addition to the enhanced mesoscale lifting, the double low-level jets also provide favorable conditions for the superimposed small-scale disturbances that can serve as effective moistening mechanisms of the lower troposphere during CI. In a sensitivity experiment with coastal terrain removed, CI still occurs near the coast but is delayed and weaker compared to the control run. This latter experiment suggests that double low-level jets and their coupling indeed exert key effects on CI, while the BLJ colliding with terrain may enhance coastal convergence for amplifying CI. These findings provide new insights into the occurrence of coastal heavy rainfall in the warm sector far ahead of the fronts.

Key words: low-level jet, heavy rainfall, CI

Interannual variations and of spring precipitation over southern China

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Abstract

The interannual variations and the prediction of the leading two empirical orthogonal function (EOF) modes of spring (April-May; AM) precipitation over China for the period from 1951 to 2014 are investigated using both observational data and the one-month-lead seasonal forecast made by six coupled climate models. The leading EOF mode of spring precipitation over China (EOF1-prec) features a mono-sign pattern, with the maximum loading located over southern China. The ENSO-related tropical Pacific SST anomalies in the previous season can serve as a precursor for EOF1-prec. The second EOF mode of spring precipitation (EOF2-prec) over China is characterized by a dipole structure, with one pole near the Yangtze River and the other one with opposite sign over the Pearl River Delta. An equivalent barotropic Rossby wave train-like circulation anomalies in northern mid- to high latitudes associated with EOF2-prec can be observed, originating from the Ural Mountains across the Eurasian continent and reaching the Japan Sea, causing anomalous moisture convergence over the Yangtze River alongside divergence conditions in southern China. A North Atlantic sea surface temperature (SST) anomaly dipole in the preceding March can contribute to the prec-EOF2 related wave train-like circulation changes. A physics-based empirical (P-E) model is then formulated according to the observational analysis. It has been demonstrated that, compared to the six coupled climate models, this P-E model can significantly improve the forecast skill of the time variations of the leading two EOF modes of the spring precipitation over China. Further experiment suggests that the forecast skill of the spring precipitation over southeast China, especially over the Yangtze River area, can be significantly improved by using a linear regression model based on the time series predicted by the P-E model.

Keywords spring precipitation · southern China· EOF ·interannual variation

Observational Analysis and Mechanism Research in a Breaking-record Extreme Rainfall Event over Southern China on August 2018

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Abstract

An extreme daily rainfall (maximum of 1056.7mm) produced by a long-lived mesoscale convective system (MCS) occurred over Gaotan town of Guangdong province during 30-31 August 2018, which broke the historical record in Guangdong province, caused severe flash flood and aroused social concern. Analysis of the extreme rainfall based on various observation data and NCEP/NCER_FNL reanalysis include property of the precipitation, environmental conditions, initiation and maintenance of the β-MCS. It is shown that the record-breaking rainfall is characteristic of high intensity and ultra-long duration with high-thermal, high-humidity and high-CAPE on background of monsoon depression. New convective cells (γ-MCSs) are continuously initiated from the meso-small scale valley, propagating and developing along the background wind field at low troposphere constantly, then merging and enhancing. These γ-MCSs line up to form a linear-shaped β-MCS, with characteristics that low-echo top, low-echo-centroid and train effect. The organization of β-MCS is closely related to near-surface wind field, which is affected by multi-scale systems that we qualitatively analyze using rotation rate equation of the direction of sea and land breezes. The southerly flow is able to sustain for a long period that is determined by the forcing of monsoon depression and local topography, and the southerly flow on the side of river valley over slope topography enhancement helps the warm-ridge development of temperature field, thus outflow from cold pool on the side of mountain over slope topography cannot pushes the boundary moving southeastward, leading to sharp temperature gradient over that region. Quantitative diagnosis using Boussiniesq equation shows the dynamic mechanism to sustain convection maintenance and β-MCS organization stems from local vertical wind shear at 0-3km, causing by the sharp temperature gradient.

Key words: Extreme rainfall, Linear-shaped β-MCS, Convection organization, Temperature gradient, Local vertical wind shear

Numerical Analyses of the Easterly-related Weather Systems in the Eastern Coastal Region of Korea using WRF: A Case Study of Heavy Rainfall in 5-6 August 2018

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Abstract

The eastern coastal region of South Korea has complex terrain with a narrow coastal area surrounded by the East Sea/Sea of Japan (ESJ) and a steep and long mountain range. The heavy snowfall and rainfall events occur frequently in this region, in association with intensification of instability, cold air damming, and barrier jets parallel to the mountain range, mostly due to the prevailing easterly winds. Sometimes intense orographic convective systems are developed, resulting in heavy rainfall and enormous damage. The Korea easterlies are defined as winds blowing from ESJ, which cause weather systems such as heavy rainfall/snowfall, fog and low temperature in the eastern coastal areas of South Korea. In this study, we perform high-resolution numerical simulations for a Korea easterly case that brought about heavy rainfall, using the Weather Research and Forecasting (WRF) model, and carry out the synoptic and mesoscale analyses. The first phase of rainfall occurred by a convective system which developed over the sea in the convergence areas near the coast and moved to the coastal areas. It has further developed through continuous advection of moisture and potential instability from ESJ by the easterlies. The second phase of rainfall is related to the orographic effect of the Taebaek Mountain Range. Moreover, the cold core at 500 hPa and positive vorticity at 700 hPa have induced instability and vertical convection. Therefore, the heavy rainfall event is complicatedly related to thermodynamical and dynamical mechanisms as well as the orographic effect. In this study, we investigated the occurrence and development mechanisms, structure characteristics, and the spatiotemporal features of the easterly-related heavy rainfall system.

Key words: easterly, heavy rainfall, orographic effect, WRF, the eastern coastal region of Korea

The Research and Data Analysis of CVPR-FMCW Developed for Retrieving the Microphysics Parameters in Precipitation Cloud

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Abstract

Air motion and precipitation result from the complex interaction of dynamics and microphysical processes occurring within cloud systems. The vertical structure and evolution in precipitation cloud are rapid and complex, the provided new, unique, and complementary observations not available from the permanent instruments stationed. Different wavelength ground-based vertically pointing radars (VPRs) and PARSIVEL disdrometer, observed continuously from 2016 in Longmen station, which is the rainstorm center of Guangdong province in south China. The work introduced includes three parts: 1.Introduced of C band Vertical Radar with the technology of Frequency Modulated Continuous Wave (CVPR-FMCW). 2. Using the PARSIVEL disdrometer and CVPR-FMCW data, the characteristics of DSDs of different types of precipitation clouds were analyzed. Based on the profiles of CVPR-FMCW, the four types of convection, stratiform, mixture and shallow precipitation are classified. The rain rate R, the mass-weighted mean diameter Dm, the radar reflectance Z, and the liquid water content LWC, are presented as the rule of convection > mixture > stratiform > shallow. The DSDs characteristics of four types of precipitation were studied, and the relationship between μ-Λ, Dm-Nw, Dm-R, Dm-Z and Z-R was obtained. 3. Retrieval techniques of raindrop distribution and air vertical motion in precipitation clouds with the Doppler spectral observed from dual-wavelength VPRs. In rain, the measurements from VPRs at C band offer a Rayleigh scattering and Ka band which subject to attenuation and Mie effects. The key technique include: a) the dual-wavelength VPRs observations calibration consistency and match in time and space. b.) Disentangling Mie and attenuation effects with C-Ka bands of VPRs. c). To disentangle quantities Mie attenuation effects hydrometeors and gas attenuation of Ka band from a C-Ka band pair Doppler spectral measurements.

Key words: CVPR-FMCW, raindrop size distributions, vertical structure classification of precipitating clouds, precipitation microphysical parameters.

A Variational Approach for DSD Retrieval and Quantitative Precipitation Estimation Using Polarimetric Radar Data

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Abstract

Attenuation correction for polarimetric radars is critically important for quantitative precipitation estimation (QPE) and raindrop size distribution (DSD) retrieval. The uncertainty of attenuation estimation caused by DSD variability may deteriorate the accuracy of rainfall and DSD estimates. To avoid the multi-step propagation of error, we propose a variational approach for optimized drop size distribution (DSD) retrieval and attenuation estimation from polarimetric radar measurements (horizontal reflectivity factor Z_H, differential reflectivity factor Z_{DR}, and differential phase shift Φ_{DP}). The liquid water content and mass-weighted mean diameter of raindrops are chosen as the state variable, which are then connected to DSD using a gamma distribution constrained by a statistical shape-slope relation. In the forward model of the variational approach, the attenuation in Z_H and differential attenuation in Z_{DR} are directly predicted from the DSDs. After the minimization of cost function, which is defined as the difference between the measured and the predicted polarimetric radar variables, the rainfall estimates can also be derived from the optimized DSDs. The approach is hereafter evaluated using the data obtained by a mobile C-band and an operational S-band polarimetric radar in China. And the rainfalls estimated from polarimetric radars using this proposed approach agree well with the gauge measurements.

Key words: Quantitative Precipitation Estimation, Optimization

X-Net Based Radar Data Assimilation Study over Seoul Metropolitan Area

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Abstract

The ability of high resolution Weather Research and Forecasting (WRF) model in simulating summer precipitation with dual polarized X-band radar network data (X-Net) over Seoul metropolitan area is studied. Numerical experiments of data assimilation (DA) with X-Net (S- and X-band Doppler radar) radial velocity and reflectivity data for two summer monsoon cases are conducted. The results show that radar DA improves quantitative precipitation forecasts (QPF) during the model spin-up time and can better capture precipitation approaching the west coast of the Korean Peninsula in the beginning hours. The WRF DA results are compared with surface AWS precipitation data and radar reflectivity data. The DA experiment improves the microphysical structure of clouds and the timing and intensity of precipitation events. The overall impact of additional AWS and X-band data are relatively small compared to S-band radar data but rainfall biases are reduced. The assimilation of X-Net radar and AWS have more positive impact on the forecast skill than the assimilation of either type of data only for the selected rainfall events. In cases of 3D-Variational (VAR) assimilation and 3D-VAR null-echo assimilation with climatological background error (BE), the precipitation areas are narrower to the north than the observations and precipitation error increased. The most improvement of rainfall accuracy comes from hybrid DA with flow dependent BE for simulation cases in Seoul metropolitan area when compared to other 3D-VAR methods.

Key words: convective precipitation, radar data assimilation, high-resolution modelling, quantitative precipitation forecast

Near-real-time SCALE-LETKF forecasts of the record breaking rainfall in Japan in July 2018

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Abstract

In July 2018, a stationary precipitation band associated with the Baiu front induced a record breaking rainfall and caused catastrophic destruction in Japan. This event was successfully captured by the near-real-time SCALE-LETKF system (Lien et al. 2017) consisting of the Scalable Computing for Advanced Library and Environment-Regional Model (SCALE-RM, Nishizawa et al. 2015; Sato et al. 2015) and the Local Ensemble Transform Kalman Filter (LETKF, Hunt et al. 2007; Miyoshi and Yamane 2007). This system has been continuously operated since 2015 with an 18-km mesh model domain and the ensemble size of 50. In this system, only conventional observations are assimilated every 6 hours. By conducting a series of 50-member ensemble forecasts from the 6-hourly SCALE-LETKF analyses, this study aims to investigate predictability of this torrential rainfall event and important factors that contributed to the heavy precipitation. In general, the SCALE-LETKF system provides skillful ensemble forecasts of the rainfall a few days in advance. Interestingly, the forecast skill exhibits sudden improvement due to assimilating conventional observations far from the peak accumulated rainfall location. Forecast differences suggest that an extratropical cyclone over the Sea of Japan and a low-level trough near Taiwan play important roles in determining the front location.

Key words: data assimilation, heavy rainfall

Sampling Error in the Ensemble-Based Radar Data Assimilation System and Its Impact on Convective-Scale Precipitation Prediction - A Case Study of IOP#8 during SoWMEX

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Abstract

Sampling errors in the ensemble-based data assimilation (EDA) can result in spurious background error correlations, leading to false analysis corrections. To investigate the sampling error in the convective-scale EDA and its impact on precipitation prediction, the WRF-LETKF radar data assimilation system (WLRDAS) with ensembles of 256 and 40 members are performed in this study. The comparison of the background error correlation revealed that the sampling error is generally more serious over the intense reflectivity area. In addition, at the observation points where the radar cannot observe the radial velocity (Vr), the sampling error between Vr and model variables may be more serious. On the other hand, the water vapor of the model suffers from the sampling error severely even over the weak reflectivity area. We found that this can result in under-estimating of the rainfall significantly from the results of the precipitation prediction, especially when the horizontal localization radius is larger. The experiments with different vertical localization setting also revealed that a larger vertical localization distance is helpful for capturing more reasonable vertical structure and further shows the positive effect on precipitation prediction.

Key words: sampling error, ensemble-based radar data assimilation, convective-scale precipitation prediction

Blending of Regional Analyses and EAKF Forecasts with a Spatial Filter: Application to the Taiwan Ensemble Prediction System

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Abstract

A Weather Research and Forecast model (WRF) based ensemble prediction system (WEPS) with 20-members was operated in Taiwan Central Weather Bureau (CWB). Initial conditions of the WEPS were obtained by adding the perturbations of the Ensemble Adjustment Kalman Filter (EAKF) 6-hr forecast on the analysis of the CWB deterministic reginal forecast system. However, the spin-up was occurred due to the imbalanced initial condition from simple arithmetic combination. A multi-scale blending scheme using a low-pass spatial filter (Hsiao et al. 2015) was applied to replace the simple arithmetic combination. The blending scheme combines the deterministic analysis and the EAKF ensemble forecast field according to the specific cut-off length obtains better balanced ensemble initial condition.

In this study, experiments were conducted to exam the sensitivity of the cut-off length scale. The control run used the simple arithmetic to combine EAKF perturbation and deterministic analysis. Sensitivity experiments were designed using the blending schemes with different cut-off length of 300 km, 1200 km, 1800 km, and 2400 km respectively. The performance shows that both the RMSE and the dispersion relations using the blending scheme were improved against the control run. The experiment with 1200 km cut-off length outperformances the other experiments.

Key words: ensemble forecast, blending scheme

Improvement of GRAPES_3Dvar with A New Multi-Scale Filtering and Its Application in Heavy Rain Forecasting

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Abstract

To improve the effect of the numerical simulation and forecasting of heavy rains, it is very important to introduce the meso- and small –scale information in the regional GRAPES 3DVAR system, climatic background error sample was used in this paper to estimate the level covariate correlation scale of variable error, and then statistical results fitting was performed with recursive filter of the feature scales of the three different levels, thus replacing the original single-scaled recursive filtering. The new scheme was used to assimilate and forecast the rainstorms in Jianghan Plain during the 1-2 Jun,2015, and the research results showed that power spectrum attenuation in the new scheme is slower. Through single point test and field analysis, we found that the new assimilation scheme introduces more meso-α scale information. In the report of the rainstorm, it was found that, with the adoption of the new scheme, the moisture field, divergence field and vorticity field are much closer to the observation values when measured in the analysis field and forecasting field. So the precipitation forecasting skill is improved obviously. By analyzing the energy spectrum, it was learned that the new scheme could reflect more meso-α scale information and the new scheme had positive effect on the forecasting of rainstorms in the Jiang Plain area. In meso-α scale, there are some favorable factors for rainfall, such as lower convergence, upper divergence and increased humidity. Base on individual cases of rainstorm, batch experiments of 16days were completed, and the result showed that the new scheme could improve precipitation forecasting skill which is consistent with the results of cases study.

Key words: GRAPES, multi-scale, recursive filters, heavy rain

A Thermodynamically and Dynamically Consistent Atmospheric Forcing Data over the South China

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Abstract

A thermodynamically and dynamically consistent atmospheric forcing data of Longmen region (the heavy rainfall center over the South China) has been produced. This data was derived from surface and sounding measurements from May to June 2016 by the constrained variational objective analysis method. With surface precipitation and flux data at the surface and the top of the atmosphere as constraints, the variational method satisfied the conservation of mass, moisture, static energy and momentum in the atmospheric column. Large-scale forcing variables were also calculated. In this case, vertical velocity and advective tendencies were utilized as the primary benchmark to examine the performance of the variational objective analysis. The results from the forcing data show that there was a fierce rainfall event arising from May 20 to 21, and the heat and moisture budgets were consistent with the precipitation variations.

Key words: forcing data, precipitation, vertical velocity, advective tendencies

Evaluation the performance of very short-term forecast by dual-polarimetric radar observations: a case study of Squall Lines during 2008 SoWMEX-IOP8.

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Abstract

To evaluate the performance of numerical weather prediction and identify the model errors at storm scale, observation operators for dual-polarimetric radar data have been applied in this study. First, the WRF-LETKF system is used to assimilate radar reflectivity and Doppler wind to obtain the optimal analysis on Jun 14th during the SoWMEX IOP8 in 2008. By using Polarimetric Radar Data Simulator (PRDS) which developed by Jung et al (2008), model outputs have been converted and compared to the NCAR S-Pol dual-Pol parameters.

The traditional forecast skill scores prove that the very short-term forecast is much better after radar data assimilation. By examining Contour Frequency Altitude Diagrams (CFADs) of Z_H, ZDR and KDP, results show that the improvements can be up to 3 hour forecast lead time. When differentiating the precipitation between convective and stratiform regions, results of reflectivity (Z_H) show both straitform and convective regions are improved. However, the improvement of Z_{DR} and K_{DP} could be limited without assimilating dual-polarimetric data.

Key words: polarimetric radar data, data assimilation, model verification

A Case Study of Afternoon Thunderstorm in Taipei City: Characteristics of Rainfall Structure

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Abstract

In this study, observational characteristic of an urban flash flood case in Taipei basin associated with afternoon thunderstorm (14 June 2015) is examined using radar network around Taipei, includes WSR-88D polarimetric radar, and Parsivel disdrometer. The urban flash flood associated with afternoon thunderstorm is characterized with extreme rainfall intensity with short duration (almost 200 mm in 3 hours) and is closely related to the merge of severe convective cells.

From the surface analysis, the convergence, which composing of sea breeze coming into basin and the down-sloping cold pool due to earlier precipitation, is favorable of cell merging. The updraft regions coordinate with the convergence of lower level and the upward motion increase after the cells merge together. Large region of ZDR (differential reflectivity) is in the edge of updraft core before and lately after the merging stage. The merge of convective cells produces enlarged precipitation area and strong echoes that can extend to a much higher altitude. The appearance of KDP (specific differential phase) increasing toward ground accompany with downdraft suggests occurrence of heavy rainfall. Column of positive ZDR extended 2 km above the melting layer accompanies with strong updraft. Large amounts of big raindrop contained in this storm were observed by disdrometer. Comparison between the ZDR on ground and at 1 km height shows the size sorting effect in the beginning of rainfall. During heavy rainfall period, the collision–coalescence processes near surface could be speculated also.

Key words: afternoon thunderstorm, severe rainfall, ZDR column

On the Short-term Forecast of Rainfall Brought by Yagi to China in 2018

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Abstract

Yagi, the No. 14 typhoon that made its landfall in Zhejiang province on August 12, 2018, brought severe rainstorms to northern China on August 13 and 14, with its maximum daily precipitation over 300mm and its maximum hourly precipitation over 120mm. This event, however, was not well forecasted. The 24-h rain-area forecast, made based on forecasts of ECWMF IFS and NCEP numerical weather prediction (NWP) models, were west to the observation by more than 100 kilometers. With an analysis on the circulation and precipitation fields, we found that this bias in heavy-rain region forecast was caused by both biases in typhoon track and precipitation pattern. The forecast of typhoon track was sensitive to initial fields. Our sensitivity analysis of ECWMF ensemble forecast revealed that subtropical high being north to the observation and a weaker-than-observation upper trough near Baikal in initial field will lead to a track forecast west to the observation. Without these two biases, only in Member 18 of ECWMF ensemble forecast, the forecast of heavy rainfall region was closer to the observation.

The bias in the precipitation pattern was related to the bias in simulating MCS. The rain bands developed in an environment characterized by high relative humidity, high freezing level, and moderate CAPE, favorable for high precipitation efficiency. Near the periphery of typhoon, the boundary layer was highly humid and warm. Easterly wind speed convergence within the boundary layer triggered and maintained MCS, which manifested a train effect, leading to heavy rainfall. However, global models such as ECWMF and NCEP did not describe MCS well and therefore predicted much more precipitation in the north and west of typhoon while underestimated the MCS precipitation near the east. This, in turn, led to biases in the low-level wind through excessive latent heat release and further led to a bias in the track forecast. In contrast, the 3-km grapes-meso model which depicted the meso-scale process better and had better initial fields gave a forecast that is closer to observation.

It was often found in short-term forecast operation that the largest bias occurred when typhoon moving northward interacted with mid-high latitude waves. In conclusion, in order to improve precipitation forecast, forecasters should give more attention to the initial fields, adjustment of circulations, as well as high resolution models.

Key words: landfall typhoon rainstorm, short-term forecast, MCS, bias analysis

The Regional Meteorological Analysis and Prediction System and its near real-time forecasts in the South China

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Abstract

A Regional Meteorological Analysis and Prediction System (*ReMAPS*), which is combined by the model prediction module, data assimilation module, ocean-wave-atmosphere coupled module and ensemble forecast module, is used to get the near real-time forecasts during the typhoon and heavy-rainfall seasons in the South China since 2017. Some results from the near real-time forecasts will be shown in this workshop: The typhoon track forecasts are close to the real observation; The wind and precipitation structures are revealed in the high resolution (800m) simulation for the Typhoon Hato; Some ocean forecast products such as the significant wave height/swell periods/tide are provided via the ocean-atmosphere coupled module; The high impact weather forecasts such as squall lines and the warm sector rainfall are reliable.

Key words: near real-time forecast, high resolution, Typhoon, heavy rainfall

Analysis of Using Different Microphysics Schemes for the Cloud-Resolving Ensemble forecasts

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Abstract

In this study, we aim to understand the ensemble characteristics of using four different microphysics schemes (including GCE, WSM, WDM, MOR) in the cloud-resolving ensemble forecasts. A case study of mesoscale convective systems during SoWMEX IOP#8 in 2008 is examined with the WRF model. By using 36-member of ensemble, we focus on the comparison of ensemble-based error structures and investigate the sensitivity of the initial conditions to microphysics schemes.

Results show that although double-moment schemes have more freedom in terms of the evolution of drop size distribution, they are not always possessed larger uncertainties in the ensemble forecasts. For instance, WDM (double-moment) can generate larger uncertainty than WSM (single-moment) in all the variables especially for the cloud water and rain water, but GCE (single-moment) has the largest uncertainties among four schemes. Therefore, the choice of multi-microphysics schemes in the ensemble forecasts cannot be randomly selected. Finally, the characteristics of the forecast errors also present the interaction between cloud dynamics and cloud physics.

Key words: ensemble forecasts, forecast uncertainties, microphysics schemes

Study of the Mechanisms of Severe Thunderstorm in Tokyo Metropolitan Area using High Frequent Assimilation of Ground-based In-situ and Remote-sensing Observations

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Abstract

Highly urbanized Tokyo metropolitan area is vulnerable to severe storms such as local torrential rainfall, thunder lightning and tornado. Recently, the number of days with thunderstorms has been increasing in Tokyo. Elucidation of the mechanism of extreme weather in Tokyo is urgent matter (Nakatani et al. 2013). To study the rolls of water vapor and wind for the rapid life-cycle (initiation, development and dissipation) of hazardous cumulus convection, we installed a mobile Raman-lidar (Sakai et al. 2018), a wind profiler, and five GNSS stations in and around Tokyo.

Using 3DVAR capability of WRF data assimilation system (WRFDA)(Barker et al. 2012) , three-dimensional atmospheric fields with 1 km horizontal resolution were produced at every 10min throughout the August 2017 and 2018. Background fields were produced by JMA nonhydrostatic model (NHM)(Saito et al. 2007). In addition to the observed data at these campaign observation instruments, Japan Meteorological Agency's operational surface meteorological stations, wind-profiler stations and GNSS PWV derived at dense GNSS network of Geospatial Information Authority of Japan are assimilated. We confirmed that the reproduced atmospheric fields (Temperature, humidity, and wind) showed better agreement with observations of radiosonde, lidar derived water vapor mixing ratio, and wind-profiler than background fields at altitudes lower than 2 km. Assimilation of surface meteorological observations (atmospheric pressure, temperature, humidity and wind) introduced better agreement mainly at altitude lower than 0.5 km. Inclusion of GNSS derived PWV resulted better agreement of humidity at altitude higher than 0.5 km and inclusion of wind field from wind-profiler led better agreement of wind field.

We have investigated roles of water vapor for several local heavy rainfall events occurred in Tokyo in August 2017 and 2018 and found that convergence of water vapor flux at 0.5 km altitude had intensified prior to the occurrence of torrential precipitation. Statistical and quantitative results will be discussed at the symposium.

This study is supported by JSPS KAKENHI Grants 17H00852.

Key words: water vapor, observation, assimilation

Droplet Size Distributions of a Stratocumulus Cloud Undetected by a Ka-band Radar in the Okinawa Region

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Abstract

A Ka-band radar can observe smaller cloud particles by shorter wavelength than microwave-band radars. However, a Ka-band radar cannot sometimes detect stratocumulus and shallow cumulus clouds visually observed. The purpose of this study is to confirm characteristics of droplet size distributions (DSDs) of a stratocumulus cloud undetected by a Ka-band radar by a simultaneous observation using two kinds of cloud particle soundings; Hydrometeor Videosonde (HYVIS) and Cloud Particle Sensor (CPS).

A Ka-band radar was installed at Sesoko Research Facility, University of the Ryukyus. Two balloon-borne soundings were launched from around the top of Mt. Yae into a stratocumulus cloud whose thickness was between 400 and 700 m at 1916 LST on June 10, 2017.

Analyses of the soundings show that volume average and maximum diameters of DSDs in the lower two third of the cloud are 16.5 and 30.6 μm, respectively. The number concentration of particles is approximately 110 cm^{-3}. The radar conducted RHI observations for the direction of the soundings at every 30 seconds. The radar cannot detect any echoes related to the stratocumulus cloud. Equivalent reflectivity estimated by DSDs obtained by the HYVIS at every 50 m is approximately -20 dBZ. Considering the attenuation of the atmosphere and cloud particles, the estimated reflectivity should be below the detection limit of the radar. Thus, the estimated equivalent reflectivity should correspond to the observed one. The Ka-band radar is not expected to detect cloud whose maximum particle diameter is smaller than 30 μm and concentration is 116 cm^{-3} at least.

Key words: stratocumulus cloud, cloud particle sounding, Ka-band radar,

Estimation of Extreme Wind Speeds over the Taiwan Offshore Region Related to Tropical Cyclones

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Abstract

The high wind distribution usually changes remarkable when a tropical cyclone approaches Taiwan Island. Estimation of extreme wind speed values induced by tropical cyclones (TCs) in the Taiwan area is essential for structure wind-resistant design and disaster risk reduction in this area. However, the insufficient gauge observations make it more difficult to estimate extreme winds in the offshore water. In this study, ERA-Interim global atmospheric reanalysis dataset ($0.5° \times 0.5°$) and the TC Best Track Dataset from the China Meteorological Administration during 1979 to 2014 are used to investigate the structure changes of TCs in different directions to Taiwan Island in order to lay a background for estimate. Results indicate that the wind distribution in the Taiwan area is asymmetric and varies with the TC relative positions to the island, which are highly related to the topography effects of Taiwan Island. With long-term continuous temporal and global spatial coverage, the reanalysis data can describe the TC circulation features well, providing background circulations to estimate extreme wind speed values in the regions without observations. Then, an error analysis is done by using global surface observation data in coastal region of China from 1980 to 2014, indicating that the extreme wind speeds related to TC are underestimated by reanalysis data. So a bias-corrected method is developed to correct the extreme wind values over Taiwan region at last. Results show that the estimated extreme wind speed is reasonable compared to the Best Track data records. Meanwhile, we deduce the possible positions and tracks of tropical cyclones according to the specific location of an extreme wind speed based on reanalysis dataset and Best Track dataset, which is favorable to avoid risk from tropical cyclones.

Key words: extreme wind speed, tropical cyclone, Taiwan offshore region, estimation

The effect of increased resolution of geostationary satellite imageries on predictability of tropical thunderstorms over Southeast Asia

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Abstract

Tropical thunderstorms cause heavy damage to property and lives, and there is a strong interest in advancing the predictability of thunderstorms with more precise satellite observations. Using high-resolution (2 km and 10 minutes) imageries from the geostationary satellite (Himawari-8) recently launched over Southeast Asia, we examine how early the thunderstorms can be predicted compared to the low-resolution (4 km and 30 minutes) imageries of the former satellite. We compare the lead times for eight thunderstorms that occurred in August 2017 between high and low resolution imageries. These thunderstorms are identified by pixels with a brightness temperature at 10.45 μm (BT11) gradually decreasing by more than 5 K per 10 minutes (15 K per 30 minutes) compared to the previous imagery. The lead time is then calculated as the time passed from the initial to the mature stage of the thunderstorm signal, based on the time series of a minimum BT11 of these pixels. The lead time is found to be 100-180 minutes for the high-resolution imagery, while it is only found to be 30 minutes if detectable at all for the low-resolution imagery. This result suggests that the high-resolution imagery is essential for substantial disaster mitigation because of its ability to note an alarm more than two hours ahead of a matured thunderstorm.

Key words: Thunderstorm alarm, Geostationary satellite, High resolution imagery, Southeast Asia, Predictability of thunderstorm

Building resilience to weather-related weather hazards through better preparedness---The World Weather Research Program High Impact Weather Project (HIWeather)

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Despite advances in forecasting and emergency preparedness, weather related disasters continue to cost many lives, to displace populations and to cause wide-spread damage. Therefore, The High Impact Weather Project (HIWeather), a 10-year research project was established in 2016 by WMO's World Weather Research Program. The mission of HIWeather Project is to promote cooperative international research to achieve a dramatic increase in resilience to high impact weather, worldwide, through improving forecasts for timescales of minutes to two weeks and enhancing their communication and utility in social, economic and environmental applications.

HIWeather research focuses on the entire value chain of the provision of weather forecasts and warnings on time-scales of minutes to two weeks. HIWeather project covers but not limited to the impacts related to urban flood, wildfire, localized extreme wind, disruptive winter weather, urban heat waves and air pollution. The research required to deliver enhanced resilience to these hazards will be carried out in five themes that cover areas traditionally separated into the physical and social sciences, which are 1) predictability and processes, 2) multi-scale forecasting of weather-related hazards, 3)impacts, vulnerability and risk, 4)communication, 5)user-oriented evaluation.

The complexity of research and of prediction systems demands multi-disciplinary expertise and international collaboration will be essential to achieving optimal progress. China Meteorological Administration is hosting the international coordination office (ICO) in Beijing to support HIWeather. We encourage scientists who are working in any of the above-mentioned research areas contact us. Please reach ICO (hiwico@cma.gov.cn) or follow us on website (www.hiweather.net) and WeChat.

Key words: High Impact Weather, International coordination office, CMA

Large-Scale Environmental conditions associated with Heavy Precipitation in the Korean Peninsula

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Abstract

If we can identify large-scale environmental variables associated with destructive phenomena such as heavy snowfall and rainfall, these environmental variables can be used to detect storm clouds and help improve the weather forecast.

In this study, we investigated the occurrences of summer heavy rainfall, typhoons, and heavy snowfall in the Korean Peninsula since 1970, examined the large-scale characteristics associated with these occurrences. The large-scale characteristics related to the east coast snowfall centered on Daegwanryeong and Sokcho in winter and snowfall occurring on the southwestern coast of Muan and Buyeo were distinctly different in SST anomalies. The large-scale characteristics of the heavy rainfall observed in the Seoul Gyeonggi area in summer and the heavy rainfall in the southern coast are also distinctly different. It is expected that these large-scale characteristics will be helpful to predict the heavy precipitation in the Korean Peninsula. It is expected that these large-scale characteristics can be helpful in pre-observation and prediction of the heavy precipitation in South Korea.

Key words: heavy snowfall, heavy rainfall, SST anomalies, observation, occurrence pattern.

High-resolution regional climate model experiments with urban impact in the Tokyo metropolitan area in summer

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Abstract

There are several reports that precipitation is a little enhanced in the urban area in the afternoon basing on the observation and cloud-resolving atmospheric model simulations. However, the significance of the signal and the mechanisms should be further examined by numerical simulations with various configurations. In this study, ten-year climate simulations with the target season of August have been performed with a 1-km grid size. In addition, three types of sensitive experiments have been performed. In Type-I, a single layer urban canopy model named as the square prism urban canopy (SPUC) scheme developed by Aoyagi and Seino (2011) has been used in the simulations of non-hydrostatic regional climate model (NHRCM) developed by Japan Meteorological Agency (JMA). In Type-II, the urban area is artificially modified into crop lands. In Type-III, only the roughness of the urban is considered for the crop lands modified from urban area.

The urban heat island phenomenon was clearly reproduced by a comparison between experiments of Type-I and -II. Increase of precipitation in the afternoon was reproduced but the significance was not so high. On the other hand, cloud amount was significantly enhanced around Tokyo in the afternoon. For the dynamical effect estimated by the difference between Type-II and Type-III, the urban roughness affected the remarkable weakening a sea breeze, the deepening of turbulent mixing layer and the generation of clouds in the earlier afternoon when the sea breeze showed the maximum. For thermal effect estimated by the difference between Type-I and Type-III, a turbulent mixing layer deepened and low-pressure perturbation and the related weak convergence were intensified on the inland side of Tokyo in the later afternoon. The water vapor supply seems to be enhanced by the urban effect because Tokyo is located the area facing sea, meanwhile the atmosphere in the urban area become a little dryer.

Key words: urban climate, regional climate model, urban heat island

Poster Presentation
Day 2
Core time 14:30-16:00

A study on future projections of precipitation characteristics around Japan in early summer combining GPM DPR observation and CMIP5 large-scale environments

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Abstract

Early-summer precipitation around Japan varies its characteristics from weak stratiform precipitation to heavy precipitation just before the Baiu withdrawal. It is important to know how precipitation characteristics will change at a given location in the future. However, current climate models, which can project large-scale environments to some extent, still have difficulties in projecting detailed precipitation characteristics. This study estimates future changes in early-summer precipitation characteristics around Japan with those in large-scale environments, combining Global Precipitation Measurement (GPM) Dual-frequency Precipitation Radar (DPR) observation and Coupled Models Intercomparison Project Phase 5 (CMIP5) climate model large-scale projections.

Satellite-observed rainfall events are first classified into “mid-latitude”, “organized”, and “small” types, and precipitation in the three types is related to large-scale environments. Two indices are chosen to determine large-scale conditions for precipitation: sea surface temperature and mid-level large-scale vertical velocity. The former is related to lower-tropospheric convective instability, while the latter affects precipitation through moistening/drying the mid-troposphere. Favorable conditions are found to differ among the three types of precipitation in terms of the two environmental fields.

Using these precipitation-environment relationships, we then reconstruct precipitation distributions for each type with reference to the two environmental indices of twenty-five climate models in the present and future climates. Future changes in reconstructed precipitation are found to vary widely among the three types in association with large-scale environments. More than 90% of models project that the region affected by organized-type precipitation will expand northward, leading to a substantial increase in this type of precipitation in the area of Japan along the Sea of Japan, and the northern and eastern Japan in the Pacific side, where its present amount is relatively small. This result suggests an elevated risk of heavy precipitation in those regions, since the maximum precipitation intensity is more intense in the organized type than the other two types.

Key words: Baiu, precipitation characteristics, future change, GPM DPR, CMIP5

Environment and processes for heavy rainfall in the morning over the Korean peninsula during episodes of cloud clusters associated with mesoscale troughs

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Abstract

An investigation has been carried out using observations, NCEP CFSR analysis and forecast data to explain the environment and processes that lead to heavy rainfall in the early morning over the Korean peninsula during episodes of cloud clusters associated with mesoscale troughs (CCMTs). For this study, nine episodes with maximum hourly rainfall amount in the early morning (i.e., 0300–0900 LST) are selected from seventeen heavy rainfall episodes associated with CCMTs during 2001–2011. Diurnal variation in rainfall amount for nine CCMT episodes show clear tendency to produce heavy rainfall in the early morning, and composite fields for 925-hPa wind show significant diurnal variation over the East China Sea.

Case study on the heavy rainfall episode during 13–14 July 2004 has revealed that, 1) a low-level trough develops over eastern China and its coastal area during the daytime; 2) the strong southwesterly band (SWB; and area with wind speeds > 12.5 m s^{-1}) at 925 hPa over the East China Sea, which is located southeast of the trough, strengthens and expands at nighttime toward the southwestern Korean peninsula; 3) the SWB supplies large amount of moisture and convective instability over the southwestern Korean peninsula with a convection trigger mechanism (i.e., strong horizontal convergence); and 4) heavy rainfall occurs in the early morning over the southwestern Korean peninsula, where exit region of the SWB is located. The growth of the SWB over the East China Sea is found to be the key process for heavy rainfall in the early morning over the southwestern Korean peninsula. The growth is achieved mainly through ageostrophic processes in an environment of changing height fields over the East China Sea.

Key words: diurnal variation in rainfall amount; heavy rainfall; cloud cluster; strong southwesterly band

Changes of Extreme Hourly Precipitation and its Associated with Thunderstorm over Eastern China from 1969 to 2011---- Dominated by Synoptic Weather Systems

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Abstract

Extreme hourly precipitation events (EHPEs) can cause human life and property losses in a short period of time. Extreme rain events associated with synoptic events are dominated by convective storms in the United States. However, little is known about the relationship in China. Based on the hourly precipitation and thunderstorm dataset of 573 ground observation stations during the warm season (May to September) from 1969 to 2011 over eastern China, we develop an original approach to investigate the contribution of the thunderstorm to EHPEs, which was defined as top 5th percentile precipitation. The contribution rate of thunderstorms to EHPEs increases with the intensification of rainfall intensity. More than 70% of EHPEs were associated with the thunderstorm when rainfall intensity reaches 20mm/hr in the past 43 years. In addition, the occurrence of EHPEs increased in central China and parts of the coastal area, and thunderstorms continued to decline nationwide, but the occurrence of thunderstorm decreased in weak precipitation and increased in heavy precipitation. The decline of thunderstorm number in northern (southern) China was found after (before) 1990. The occurrence of EHPEs shows obvious seasonal variation with three peaks, which are spring in southern China, early summer along Yangtze River, and summer in Jianghuai Basin and northern China. It seems the variation of EHPEs were associated with the movement of the summer monsoon. Further analysis did verify that the changes of EHPEs are mainly contributed by thunderstorm embedded in synoptic-scale circulation, rather than the local storm. Our study implies that initiation and development of thunderstorm in synoptic weather systems should be paid more attention in the future study of EHPEs.

Keywords: extreme hourly precipitation, thunderstorm, occurrence change

Impacts of convective activity over the Tibetan Plateau on plateau vortex, southwest vortex, and downstream precipitation

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Abstract

In summer, convective activities over the Tibetan Plateau (TP) are vigorous, with some of them moving eastward and vacating the plateau [they are defined as the eastward-moving type (EMT)]. Although the EMTs only occupy a minor proportion, they are closely related to heavy precipitation east of the TP. This study investigates the EMT's impacts based on composite semi-idealized simulations and piecewise potential vorticity (PV) inversion. Main findings are as follows: (i) An EMT begins to affect downstream precipitation before it vacates the TP. A weaker EMT tends to make the downstream main rainband reduce in intensity and move southward. (ii) The EMT contributes to formation of an eastward-moving plateau vortex (PLV) through enhancing the convergence-related horizontal shrinking. Over the TP, the PLV mainly enhances/maintains the EMT, whereas, during the vacating stage, the PLV dissipates (since convergence decreases rapidly when sensible heating from the TP reduces), which abates intensity of the EMT remarkably. (iii) After the PLV dissipation, a southwest vortex (SWV) forms around the Sichuan Basin mainly due to convergence-related horizontal shrinking, convection-related tilting, and background transport. Positive PV anomalies associated with the EMT can directly contribute to SWV formation via lowering geopotential height and enhancing cyclonic wind perturbation around the Sichuan Basin (even if they do not vacate the TP), while neither of them governs the SWV formation. Sensitivity runs show that the EMT is not necessary for the SWV formation, but it can modify the SWV's formation time and initiation location, as well as its displacement, which also affect downstream precipitation significantly.

Key words: Convective system, Tibetan Plateau, plateau vortex, southwest vortex, piecewise potential vorticity inversion

A Simulation of Mesoscale Convective System of Mei-Yu Front Affecting Taiwan on 2 June 2017

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Abstract

The first mei-yu front of 2017 was developed in South China on June 1. Accompanied with appropriate atmospheric conditions from both high and low level, the mei-yu front affected the northern part of Taiwan and then moved southward gradually. Under the effect of this mei-yu front and the southwestern flow, the accumulated rainfall over the central mountainous area was over 300 mm on June 2. Strong low level jet (LLJ) with wind speed over 15~ 25 ms^{-1} on the 850 hPa could be found. The airflow was split over Taiwan Strait, which indicated a divergence flow on 200 hPa. Indexes of Skew-T diagram on 0000 UTC and 1200 UTC of Magong on 2 June indicated extremely unstable atmospheric condition, causing heavy rainfall over the central and southern part of Taiwan. Furthermore, a mesoscale convective system was developed over South China at 0900 UTC on June 2 and moved gradually toward central part of Taiwan Strait. It made landfall over central Taiwan on 1200 UTC and began intensified. The data of pressure, temperature and wind speed recorded by the auto stations of the Central Weather Bureau meet the evidences of past studies, including pressure surge, temperature dropping and sudden change of wind speed.

WRF 3.7 was adopted in this case study. The initial date of simulation was 0000 UTC June 1 to 0000 UTC June 3. The simulated accumulated rainfall, 850 hPa, 200 hPa and Skew-T diagrams were close to observation. By analyzing simulated vertical profile, it would have more understandings of the mesoscale convective system for forecasters.

Key words: mesoscale convective system, low level jet

Microphysically Induced Bow Echo within a Squall Line after its Merging with a Convective Cell observed by Polarimetric Radar

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Abstract

The formation and evolution of a bow echo within a typical subtropical squall line was documented in this paper by Guang Zhou polarimetric radar in southeast China on 15 May 2016. Being different from previous studies that emphasized the mesoscale kinematical impact (e.g., rear-inflow jet) in the genesis of bow echoes, this case particularly detailed the storm-scale microphysical processes with the help of quantified estimations based on polarimetric radar observations. As the linear squall line propagated southeastly toward coastline, an isolated convective cell emerged in front of the squall line due to the boundaries collision between the gust front and a sea-breeze front. The merger between the squall line and this convective cell induced a chain of microphysical processes (icing, melting, evaporation, and loading), leading to the formation of a bow echo as a result.

Absolute wind field depicted the reduction of rear-inflow jet when the squall line approached the convective cell. As the two convective entities merged together, the bowing segment emerged on radar reflectivity, while the edge of the surface cold pool still held its line shape behind. The strengthened updraft resulting from merger therefore promoted the appearance of ice particles (e.g., hail and graupel) in the front of the leading convective line. The negative buoyancy of melting from ice and evaporation from rain locally cooled the air near surface via downdraft just in front of the cold pool. As a result, the cold pool moved forward in the merger region and caught up with the bowing reflectivity, leading to a more obvious bow echo eventually. This case suggested another hypothesis for the formation of a bow echo where storm-scale microphysical processes mattered within the leading convective line thermodynamically.

Key words: bow echo, polarimetric radar, cell merge, microphysical processes

Ensemble Sensitivity Analysis of a Heavy Rainfall Event with Three MCSs Coexisting over Southern China

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abstract

A heavy rainfall event over southern China was analyzed with ensemble-based sensitivity analysis to investigate its key factors and predictability. The heavy rainfall event was caused by three coexisting mesoscale convective systems (MCSs) that occurred over southwestern China (MCS-A), the south coast of China (MCS-B) and northern Taiwan (MCS-C). The three MCSs exhibited differences and similarities with respect to their forecast accuracy and key factors. Ensemble forecasts from ECMWF indicate that the forecast capability of MCS-A was better than that of MCS-B and MCS-C. Although the three MCSs were all related to low-level vortices and low-level jets, relevant behaviors of those factors influencing the MCSs were different. The strength and shape of a southwest vortex, a mesoscale vortex over southwestern China with a horizontal scale of 200–600 km, exerted a significant effect on MCS-A and MCS-B, whereas the location of a vortex near the east coast of China was crucial for MCS-C. In addition, the low-level jets and their associated moisture transports had a strong influence on the three MCSs via their location, strength, height and direction. The uncertainties of those key factors might further influence the predictability of the three MCSs.

Keywords: Heavy rainfall, vortex, low-level jet

Investigation of the vertical microphysical characteristics of heavy rainfall events during the SoWMEX/TiMREX using observational data

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Studying the microphysical processes of precipitation systems from the perspective of observations is important and challenging. During the 2008 Southwest Monsoon Experiment /Terrain-influenced Monsoon Rainfall Experiment (SoWMEX/TiMREX), huge amount of microphysical observation data was collected from S-band dual-polarimetric radar (NCAR S-POL) and disdrometers. The vertical profiles of dual-polarimetric measurements are used to investigate the microphysics characteristics of seven heavy rainfall events. Two distinct types of precipitating characteristics can be among these seven heavy events. The deep convection (26^{th} May and 13^{th} June) contained large rain drops, low liquid water content, high graupel water content and pronounced collision coalescence process. On the other hand, the well-organized convection (5^{th} June and 6^{th} June) had small rain drops, high liquid water content and less pronounced coalescence process. In addition, the dual-polarimetric measurements of Z_{DR}, K_{DP}, R_{HV} and L_{DR} of these two types precipitation systems also show diverse characteristics.

A Case Study of the Northern Kyushu Heavy Rainfall Event during 5-6 July 2017

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Abstract

During 5-6 July 2017, an extremely heavy rainfall occurred over Northern Kyushu region, western Japan, which brought rainfall amounts exceeding 500 mm. The heavy rainfall led to devastating floods and landslides that caused more than 40 fatalities. This event was officially named the "Northern Kyushu Heavy Rain Event of July 2017" by the Japan Meteorological Agency.

During the heavy rainfall event, line-shaped precipitation system, which was an almost stagnant rainband approximately 100 km long and 20-30 km wide, formed over Northern Kyushu area. To clarify the formation and maintenance mechanisms of the line-shaped precipitation system, they were examined using observation data, objective analysis data, and numerical simulations by Japan Meteorological Agency Nonhydrostatic Model (JMA-NHM). These investigations showed that the line-shaped precipitation system was regarded as one kind of mesoscale convective system (MCS), and it could be formed from a group of convective clouds organized quasi-stationary in a back-building process. Also, numerical sensitivity experiments for topography showed that the topography was not essential for the formation of the line-shaped precipitation system, but was important for the maintenance of it.

Key words: heavy rainfall, MCS, band-shaped precipitation system, numerical simulation

Contrastive Analysis of Lightning Characteristics Between Rainstorm Case and Hailstorm Case

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Abstract

Two kinds of classic convective systems in and around Beijing are picked to investigate the lightning activities (observed by SAFIR3000) and the relationship between lightning and precipitation (retrieved from radar) during different thunderstorms. Lightning activity characteristics of a rainstorm and a hailstorm are analyzed and compared. Due to different microphysics and dynamic processes, there are significant differences in the discharge process within clouds, resulting in significant differences in corresponding lightning activities. The hailstorm has larger ratio of CG (cloud-to-ground) lightning, and the ratio of positive CG lightning is 0.311, comparing to 0.191 of the rainstorm.During the rainstorm, the intensity of convective precipitation is decreasing sharply when the lightning frequency reaches the highest value. The lightning frequency in this region can provide about 5-15 min warning time for the maximum rainfall intensity. In the early stage of hailstorm, rainstorm with short duration occurs, and the frequency of lightning reaches the peak when the hailstorm occurs, and then it declines as the hailstorm maintains. The hailstorm has larger ratio of CG lightning than the rainstorm. The main discharge area in hailstorm is higher than that in rainstorm, the temperature layer corresponded to the main charge region in hailstorm is lower than that in rainstorm. The total lightning frequency between convective precipitation's linear correlation coefficient is better in rainstorm than that in hailstorm.

The linear correlation between lightning and precipitation in hailstorm is more complicated, because hailstorm has more complex dynamic and ice phase microphysics. These quantificational results can provide reference for applications of lightning data in severe weather warning and precipitation estimation.

However, it's not certain whether all hailstorms have the similar lightning and precipitation relationships (the highest precipitation in the early stage of the hailstorms, and the total flash to reach the maximum in the hail stage). These results can be improved through further analysis when there are more observation cases.

Key words: lightning, precipitation, rainstorm, hailstorm

Analysis of a severe precipitation process in Aksu Area under the background of the Central Asian Vortex

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Abstract

In order to strengthen the understanding of the mesoscale system development mechanism in torrential rain over Xinjiang province, this paper analyzes the rainstorm process occurred in the Aksu region that is near the west of Tianshan Mountains, during June 17 to 18, 2013 basing on a variety of observation data and WRF high-resolution numerical simulation result. The results show that the precipitation process occurs under the background of the circulation of the two ridges in a trough over the middle and high latitudes, and the Central Asian vortex provides favorable large-scale dynamic and water vapor conditions for this rainstorm. The convergence line is the important mesoscale system, which is formed by the superposition of the Central Asian vortex circulation and the flow stream around the special topography of the west Tianshan Mountains. Due to the difference of thermal properties between the mountain and desert, the slope wind drives convergence line to move and the strong convection developed along the convergence line triggers strong precipitation in the Aksu region. The WRF is able to well simulate not only the location and intensity of the heavy rain but also the evolution of wind field. Preliminary analysis combined with observations and simulation data shows that under the blockage of west Tianshan Mountains, the south wind accumulates and convergences near the valley. As a result, a local convergence line is formed. Meanwhile, with the adjustment of the large-scale circulation situation, especially after the Central Asian vortex moves to the vicinity of the Aksu area, one part of the westward flow that comes from the south of the vortex turns into northwest wind after crossing the west Tianshan Mountains, and the other part turns into the northeast wind after passing through the Yili Valley, these two flow aggravate the northerly airflow and enhance the intensity of convergence, thereby promote the formation of mesoscale convergence lines and strengthen it. The eastward airflow-induced water vapor accumulates in front of the southern foot of the Tianshan Mountains, and strengthens as the convergence line moves towards southeast with the enhancement of the valley wind at night. Accompanied with the convergence uplift, the accumulation of water vapor at the foot of the mountain promotes the release of unstable energy and brings heavy precipitation to the Aksu region.

Key words Rainstorm, Central Asian vortex, Terrain, Numerical simulation, Convergence line

Simulation of quasi-linear mesoscale convective systems in northern China: lightning activities and storm structure

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Abstract

Two intense quasi-linear mesoscale convective systems (QLMCSs) in northern China were successfully simulated using the Weather Research and Forecasting (WRF) model and the three-dimensional variational (3D-Var) analysis system of the Advanced Regional Prediction System (ARPS) model. A new method in which the lightning density is calculated using both the precipitation and non-precipitation ice mass was created to reveal the relationship between the lightning activities and QLMCS structures. Results indicate the lightning density calculated using the new method to be in good accordance with observations; and moreover, superior to results calculated using two other effective methods proposed by McCaul JR et al. (2009) and Yair et al. (2010), respectively. Based on the calculated lightning densities using the new method, it was found that most lightning activity is located on the right side and at the front of QLMCSs, where the surface wind field converges intensely; whereas, very few lightning flashes appear in the stratiform region. The location of intense convective available potential energy (CAPE) zones could reflect the direction of movement of QLMCSs, and their lightning events mainly occur in regions with a large gradient of CAPE. Comparisons between lightning and non-lightning regions indicated that lightning regions feature more intense ascending motion than non-lightning regions; the vertical ranges of maximum reflectivity between lightning and non-lightning regions are very different; and the mixing ratio of graupel in lightning regions is higher than in non-lightning regions. However, the distributions of the ice mixing ratio in lightning regions and non-lightning regions present no obvious differences.

Key words: MCS, WRF, ARPS

Analysis of misocyclone structure of a storm generating waterspout on 15 May 2017 in Okinawa using a phased array weather radar

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Abstract

On 15 May 2017 a waterspout was reported off the coast of Yomitan Village, Okinawa Prefecture. Misocyclones in the convective storm generating the waterspout were observed by a phased array weather radar (PAWR) located at National Institute of Information and Communications Technology in Onna Village and KIN radar owned by Nagoya University located at University of Ryukyus. In this study, we investigate the structure and lifecycle of the misocyclones by using radar data. The PAWR data were used for analysis of rapid development of misocyclones, because it takes only 30 seconds for a full volume scan whereas it takes 6 minutes for KIN radar. Radar reflectivity and Doppler velocity data were mainly used for the analysis. Assuming the Rankine's vortex, a misocyclone is identified by a pair of maximum and minimum values of Doppler velocity. Using PAWR and KIN radar, dual Doppler analysis are conducted to estimate the low-level wind field. A precipitation echo of the target convective storm was observed at 15:12 JST for the first time, which located at about 20 km southwest of PAWR and at about 20 km north-northwest of KIN radar. The echo moved to the east at about 4 m/s. The target precipitation echo had low-level horizontal wind shear with the direction from southwest to northeast; northerly wind prevailed the western part of the echo, southeast wind of the eastern part. Intense precipitation echo associated with two misocyclones were formed along the shear line. Relative positions of misocyclones in the precipitation echo had not changed over 21 minutes (15:26-15:47). The southwestern misocyclone was detected from 1.0 km to 1.5 km in height through its life time (15:29-15:36). The northeastern misocyclone was detected from 1.5 km to 2.5 km in height (15:26-15:28), and went down its top height to 1.7 km in height (15:28-15:35). Then lower boundary of the misocyclone suddenly went down to 0.7 km (15:36). At the same time, its diameter changed about 1 km to 0.5 km and maximum vorticity reached 2.8×10^{-2} /s.

Key words: waterspout, misocyclone, phased array weather radar

The Effect of Ocean Waves on an Explosive Cyclone Development: Investigation with a Coupled Model

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Abstract

An explosive cyclone is an intense type of extratropical cyclones which emerge in strong baroclinic zones like the Northwestern Pacific and the Northwestern Atlantic. Violent ocean waves are generated by the explosive cyclone. Since it is reported that ocean waves affect the development of tropical cyclones, the impacts of ocean waves on the development of explosive cyclones should be warranted. Ocean waves have several impacts on atmospheric surface layer: (i) surface friction, (ii) sea spray, and (iii) momentum flux. We have investigated how ocean waves affect atmosphere with an atmosphere-ocean-wave coupled model. The test case is the explosive cyclone emerged in early January 2018 over the Northwestern Atlantic. The atmospheric model is Weather Research and Forecasting Model (WRF), the ocean model is Coastal and Regional Ocean COmmunity model (CROCO), and the ocean wave model is WAVEWATCH III (WW3). We compared the numerical simulation results between the WRF-CROCO model and the WRF-CROCO-WW3 model. In the WRF-CROCO-WW3 coupled model considering ocean wave impacts just on (i) surface friction, it is found that the deepening of the explosive cyclone was intensified by about 2hPa in the central sea level pressure and the center track slightly shifted. In the fully coupled model, the temperature and specific humidity elevated, and the wind speeds declined in the southern low-troposphere of the cyclone center. The amplified moisture should intensify the development of the explosive cyclone. On the southern side of the cyclone center, ocean waves were almost mature; hence the surface roughness decreased. We assume that on the southern side of the cyclone center the ocean waves reduced the wind speeds and weakened the cold air inflow from the north. The increased temperature obtained more moisture, which intensified the development of the cyclone.

Key words: Explosive Cyclone, Ocean surface waves, Coupled model

Essential Role of Synoptic Environment on Rainfall Distribution of Landfalling Tropical Cyclones Over China

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Abstract

How the rainfall characteristics of landfalling tropical cyclones (TCs) over China change with the dry-air intrusion is explored through analyzing Tropical Rainfall Measuring Mission (TRMM) and environmental fields. It is found that the rainfall area of landfalling TC is positively correlated to the midlevel environmental relative humidity: the larger the surrounding relative humidity before TC landfall, especially in the southern quadrants of the TC, the larger the rainfall coverage at landfall. Even when situated in a dry environment, the TC may produce severe concentrated rainfall with stronger intensity than in a moist environment. Results show that interaction between synoptic environment and TC is essential for influencing rainfall distribution for landfalling TCs over China. As a TC moves with northward component under two subtropical highs and westerly trough, it is under the influence of significant dry-air intrusion, which results in limited rainfall area. The increasing northwesterly vertical wind shear that is nearly opposite to the TC movement, on the one hand enhances the upshear-side subsidence, which offsets the friction-induced ascent ahead of TC. On the other hand, it strengthens the downshear-side updraft with the corporation of increasing synoptic convergence and results in severe asymmetric rainfall there. When a TC moves under the influences of enhanced subtropical high and monsoonal southwesterlies, it is under the moist environment that causes a larger rainfall area. Influenced by the weaker vertical wind shear with a similar direction as the TC movement, the rainfall distributes relatively symmetrically with heavy rain over the downshear-friction convergence overlapping region at landfall.

Key words: landfalling tropical cyclone, rainfall, synoptic environment

Kinematic and Microphysical Properties of Secondary Rainbands of Soudelor (1513) Observed by Polarimetric Radar

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Abstract

Typhoon Soudelor (201513) made landfall and moved across the topography in northern Taiwan. The Convective-Stratiform Separation Algorithm was used to identify two secondary rainbands ("rainband N" and "rainband S") located in the right front quadrant during Soudelor's landfall. The evolution, kinematic and microphysical characteristics of two rainbands are examined in this study.

The reflectivity and dual-Doppler retrieved winds seem to suggest these two rainbands were in different developing stages when they were offshore: rainband S was intensifying while rainband N was dissipating. Consistent with the kinematic structures, the polarimetric vertical profiles of rainband S indicate more moisture content was transported through the intensifying updraft, which caused greater supersaturation for ice particles to grow above the melting layer. The polarimetric features below the melting layer suggest collision-coalescence process. Rainband N presents similar distributions but with smaller values, which might due to the dissipation. These characteristics might suggest both ice-phased and warm-rain process play important roles in the heavy rainfall within rainbands when they were offshore.

When two rainbands first made landfall, the polarimetric features exhibit the largest mean raindrop size and liquid water content, which relates closely to heavier rainfall within the rainbands due to the terrain lifting. However, as rainband oved further inland, the weakening updrafts and the less curved polarimetric profiles above the melting layer were observed in both rainbands, indicating the less moisture content transported for ice-phased processes. Therefore, the dominated process to the precipitation after two rainbands made landfall is mainly via warm-rain processes.

Key words: polarimetric radar, typhoon rainbands, kinematic structure, microphysics

A Dynamical Mechanism for Secondary Eyewall Formation of Tropical Cyclones

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This study proposes that secondary eyewall formation (SEF) of tropical cyclones (TCs) is attributed to an instability of flow in free atmosphere coupled with Ekman pumping velocity. Unstable solutions of a 1.5-layer shallow water system are obtained under fast wind speed conditions in free atmosphere. The condition to occur the instability in the liner model is derived, indicating the importance of a ratio of vorticity to angular velocity, and the condition is more likely satisfied when the ratio is large and its radial gradient is positive. In other words, fast angular velocity, low absolute vertical vorticity, small negative radial gradient of angular velocity, and large gradient of vertical vorticity are favorable. Eigenvalue analyses are performed by applying a vortex profile having a secondary jump with a very small magnitude for a wide range of parameters. The growth rate increases with vorticity outside the radius of maximum wind (RMW), radius of secondary vorticity jump, magnitude of jump, and Rossby number defined as the ratio of maximum tangential velocity to RMW multiplied by Coriolis parameter. Thus, stronger intensity, smaller RMW, lower Coriolis parameter, and faster wind speed outside the RMW are more favorable. Furthermore, the growth rate is positive only between 2 and 7 times the RMW, and it is negative nearby or far outside the RMW. These features are consistent with previous observational/modelling studies on SEF. A dimensionless quantity U obtained from the unstable condition in the linear theory is applied to SEF events simulated by two different full-physics numerical models. It is observed that U increases a couple of hours before secondary peak of tangential velocity forms, indicating that SEF can be attributed to the proposed theory.

The influence of typhoon strength and size on Taiwan's wind and rainfall

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Abstract

In 2015 and 2016, there were four typhoons with different intensities landed in Taiwan, including severe typhoon Dujuan (2015) and Nepartak (2016) and moderate typhoon Soudelor (2015) and Megi (2016). Although the first two were stronger typhoons, the associated wind and rainfall impacts on the island were much less than the latter two storms. This situation didn't in line with the traditional impression that the stronger landfalling typhoon which could lead to more damages over the island. Not only the tropical cyclone (TC) intensity, this study also investigates the relationship between the others TC parameters and associated wind and rainfall distributions during landfall.

The NCEP-GFS and CFSR model analysis data are utilized to calculate TC strength and size. It is found that there is a good correlation between strength and size, while the correlations between the intensity and size, as well as intensity and strength, are not obvious. In the past studies, the influence factors of TC on Taiwan's wind and rainfall were analyzed, including TC path, structure, speed, and environment. This study specially focuses on the relationship between the strength, size, speed, and Taiwan's wind and rainfall. According to the analysis of the overall wind and rainfall in Taiwan, it is found that the correlation between TC strength, size, speed and wind, rainfall indexes is better than TC intensity. According to the analysis of different types of path, it is found that the TC intensity, speed of the second type appears better correlations in wind and rainfall indexes. The correlation between the size, speed of the third type, and wind, rainfall indexes is better than intensity, especially the rainfall index is obvious. According to the analysis results of different stations under different paths, it is found that the wind and rainfall indexes of stations near the storm core area reveal a better correlation with the TC intensity, and the wind and rainfall indexes of stations over the outer-core area of storm appear a better relationship with the TC size.

Key words: typhoon strength, typhoon size, Taiwan's wind and rainfall

Ensemble Synoptic Analysis on the Slowing Motion of Typhoon Morakot (2009) Crossing Taiwan Island

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Abstract

Typhoon Morakot (2009) caused an extreme heavy rainfall amount beyond 1000 mm in 24 hours in 8 August 2009, resulting in severe flooding throughout southern Taiwan, which is closely related to its slow cross-island movement. However, it is difficult to make an accurate forecast on whether a typhoon moves across Taiwan island or not. The European Medium Range Weather Forecasts (ECMWF) ensemble dataset is used to investigate the uncertainties in Typhoon Morakot's track forecasting. A larger uncertainty is found in Morakot's track forecasting at various leading times, which some ensemble members move westward crossing Taiwan while some turn northward instead of westward landfall. In the early stage, the forecasting dispersion is mainly attributed to the different descriptions on western Pacific subtropical high activity and binary typhoon situation in ensemble simulations. The differences between large scale circulations may lead to various steering flow for Morakot motion. In the later period, Morakot's track forecasting is sensitive to the generation and development of the secondary low pressures induced by Taiwan topography effects. Success predictions have stronger induced-lows developing on west side of the island, which replace the original typhoon centers forming discontinuous tracks across Taiwan Island. In contrast, the induced-lows are weak and cannot replace the original typhoon centers in the eastern coast of the island in failed predictions. A set of sensitivity experiments with various Taiwan terrain heights are designed to explore the impacts of terrain on typhoon motion. Results show that Taiwan terrain may induce secondary low pressures in another side of the island forming westward track crossing the island. The typhoon would move rapidly if without remarkable induced-low generation when Taiwan terrain elevation is reduced by 50% or 100% of the original height. Besides, a strong induced-low can lead to asymmetric structure of typhoon, which will slow down a typhoon motion and accumulate its rainfall amount.

Key words: Typhoon Morakot, slow cross-island motion, ensemble synoptic analysis

Improve TWRF Predictions by utilizing Himawari-8 AMV on Typhoon Track and Intensity Forecast

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ABSTRACT

With violent wind and severe rainfall, the tropical cyclone is one of the most disastrous weather system over ocean and the coastal area. To provide accurate tropical cyclone track and intensity forecasts is one of the most important task of the national weather service of countries affected. Taiwan is one of the area frequently influenced by tropical cyclones. Improving the tropical cyclone forecast is the highest priority task of Taiwan's Central Weather Bureau (CWB).

Recent improvement of the tropical cyclone forecast is due to the improvement of the numerical weather prediction. A version of the Advanced Research Weather Research and Forecasting Model (ARW WRF), named TWRF (Typhoon WRF), was developed and implemented in CWB for operational tropical cyclones forecasting from 2011. During the years, partial update cycling, cyclone bogus scheme, relocation scheme, 3DVAR with outer loop, analysis blending scheme, new trigger Kain–Fritsch cumulus scheme, and so on have been studied and applied in TWRF (Hsiao et al. 2010, 2012, 2015) to improve the model. The averaged 24/48/72 hours cyclone track forecast errors of TWRF are 91/147/223, 84/133/197, 74/127/215 and 70/120/194 km in year 2014, 2015,2016 and 2017 respectively.

In this study, Four-dimensional data assimilation (FDDA) is adopted to reply the high-temporal frequency atmospheric motion vector (AMV) retrieved from Himawari-8 satellite images to generate a model balanced TC structure and thermodynamic state at the initial time. The specific goal is to improve the track, structure and intensity prediction of TCs and their associated rainfall distribution in Taiwan. The detail will be presented in the conference.

Keywords: Himawari-8 AMV, Four-dimensional data assimilation, typhoon prediction.

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Precipitation efficiency and water budget of Typhoon Fitow (2013)

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Abstract

In this study, the WRF model is used to simulate the torrential rainfall of typhoon Fitow (2013) over coastal areas of East China during its landfall. Data from the innermost model domain are used to trace trajectories of particles in three major 24-hour accumulated rainfall centers using the Lagrangian flexible particle dispersion model (FLEXPART). Surface rainfall budget and cloud microphysical budgets as well as precipitation efficiency are analyzed along the particles' trajectories. The rainfall centers with high precipitation efficiency are associated with water vapor convergence, condensation, accretion of cloud water by rain, and raindrop loss/convergence. The raindrop loss/convergence over rainfall center is supported by the raindrop gain/divergence over the areas adjacent to rainfall centers. Precipitation efficiency is mainly determined by hydrometeor loss/convergence. Hydrometeor loss/convergence corresponds to the hydrometeor flux convergence, which may be related to the increased vertical advection of hydrometeor in response to the upward motions and upward decrease of hydrometeors, whereas hydrometeor gain/divergence corresponds to the reduction in hydrometeor flux convergence, which may be associated with the decreased horizontal advection of hydrometeor in response to the zonal decrease in hydrometeor and easterly winds and the meridional increase in hydrometeor and southerly winds. The water vapor convergence and associated condensation do not show consistent relationships with orographic lifting all the time.

Key words: precipitation efficiency, water budget, Lagrangian flexible particle dispersion model, WRF model

On the Effects of Radiation on Tropical Cyclone Intensity Changes under Moderate Vertical Wind Shear

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Abstract

Tropical cyclone intensity remains one of the most challenging topics of atmospheric science and prediction. Many recent efforts to improve intensity forecasts have focused on understanding the complex interaction between tropical cyclones and vertically sheared environmental flow. At the same time, emerging research suggests that cloud-radiation feedbacks largely influence the track, intensity, and structure of tropical cyclones. Yet, the asymmetric nature of cloud-radiative feedbacks in sheared tropical cyclones and their impacts on intensity changes remain unexplored. This study addresses that issue by exploring the sensitivity of intensity changes in sheared environments through ensembles of idealized numerical simulations with and without radiation. Those simulations show that radiation largely influences the timing, likelihood, and variability of intensity changes within sheared environments. A comparison between simulations shows smaller tilt magnitudes and more symmetric precipitation with than without radiation. Consequently, the simulations with radiation allow for earlier intensification at stronger shear magnitudes than without radiation. An in-depth analysis of those idealized simulations will be presented to disentangle the role of cloud-radiative feedback on simulated tropical cyclone intensity changes in sheared environments.

Key words: tropical cyclones, radiation, vertical wind shear, idealized numerical simulations

Development of Typhoon Jebi (2018) and Model Simulation

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Abstract

Studies of typhoon and interactions with front were fewer. Typhoon Jebi (2018) was chosen in this case study. Heavy rainfall over Japan was induced due to the effect of severe typhoon and front. Causing flood and landslide in Shikoku and Kansai regions. Millions of people were evacuated and airport was shutdown. According to JMA, hourly rainfall in Aki, Kochi Prefecture was over 92 mm. Accumulated rainfall was 159 mm in the afternoon. Total rainfall was 328 mm. Extreme rainfall in a very short amount of time was the characteristic of typhoon Jebi.

The simulation was conducted by using WRF model and NCEP's FNL data. Typhoon Jebi moved north after approaching Taiwan, made landfall over Tokushima Prefecture and dissipated near Kyushu. The simulated rainfall over Shikoku regions (Kitashitara District, Aichi Prefecture; Aki, Kochi Prefecture and Nara Ken, Kinki Chihou) were 200- 300 mm, slightly less than observations. Pressure simulation on 0300 UTC 4 September was 955 hPa, very close to observation. In addition, WRF model captured the interaction between typhoon Jebi and front, which brought heavy rainfall and water vapor convergence over East Sea. The results indicated WRF model has sufficient credibility. By simulating the tracks of typhoon and structures of front precisely, it would be greatly helpful for forecasters to issue warnings and evaluate heavy rainfall in advance.

Key words: Typhoon rainfall, model simulation

Bias-Correction of the Extended-Range Tropical Cyclone Formation and Activity Forecasts by Using the 20-Year Reforecasts

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Abstract

The objective of this study is to improve the forecast skill of the two-week tropical cyclone (TC) activity forecasts from the NCEP Global Ensemble Forecast System (GEFS). An objective TC tracking method developed by Tsai et al.(2011) is used to detect the western North Pacific TCs in the 20-year GEFS reforecasts and also in the real-time GEFS forecasts during the 2017 season. The model settings for the operational forecasts in 2017 and the 20-year reforecasts are identical, except the ensemble size is reduced to 5 members in the reforecasts. Previous studies have shown that false alarms are an important issue in the extended-range ensemble forecast models (Tsai et al. 2013; Elsberry et al. 2014).

Preliminary results show that the false alarms can also be found in the GEFS reforecasts, especially when the forecast probabilities are higher. The relationships between the large-scale environmental factors (e.g., ENSO, MJO, etc.) and the reforecast skill are also being investigated. Better skill is found for these week-1 and week-2 forecasts in the western North Pacific that are initialized during the MJO Phases 5-7. The predictabilities before and after TC formations will also be presented. Finally, a simple bias correction scheme obtained from the reforecasts will be applied to the real-time forecasts during the 2017 season to investigate whether the TC activity forecasts provided by the raw GEFS forecasts can be improved if the model biases are considered.

Key words: Tropical Cyclone, Extended-Range Forecast, and Reforecast Dataset.

Direct Measurements of Momentum Flux and Dissipative Heating in the Surface Layer of Tropical Cyclones During Landfalls

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Abstract

This study analyzes high-frequency wind data collected by research towers in the surface layer of Typhoons Hagupit (2008) and Chanthu (2010) to investigate the characteristics of the momentum flux, turbulent kinetic energy (TKE), drag coefficient and dissipative heating (DH) during landfalls. It is found that the momentum flux, TKE and DH increase with the wind speed up to the maximum observed wind speed (~40 m s^{-1}), in agreement with previous studies that presented eddy-correlation flux data in a similar condition but with lower maximum observed wind speed. However, the momentum flux, TKE, drag coefficient and DH are found to be substantially larger in Typhoon Chanthu (2010) than those in Typhoon Hagupit (2008) at a given wind speed, likely due to much rougher surface conditions surrounding the tower deployed in Typhoon Chanthu (2010). Furthermore, the DH is calculated using two different methods: [1] based on surface-layer theory and [2] based on the standard turbulent spectra method. It is found that the first method tends to overestimate the value of DH compared to the second method, and the overestimation of the DH by the first method is much smaller over rougher underlying surface than over the smoother underlying surface. Our analysis shows that the magnitude of the DH over land is as large as the sensible heat flux (~100 W m^{-2}) previously observed over the ocean, which should not be neglected in numerical models simulating tropical cyclones during landfalls.

Key words: turbulent characteristics, dissipative heating, tropical cyclones, landfall

Numerical Simulation of Typhoon Nepartak (2016) Using the MPAS-GSI system

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Abstract

Typhoon Nepartak is the first cyclogenesis over the Northwestern Pacific Ocean in 2016, which generated in early July and rapidly developed. In early July, a 5-day track prediction from most of the operation weather centers showed a northwestward deflection and predicted no landfall in Taiwan. For a typhoon prediction, the Global Navigation Satellite System (GNSS) radio occultation (RO) data could provide useful information for the numerical weather prediction especially in a region of sparse observation. In this study, we use the Model for Prediction Across Scales (MPAS) and an initial condition comes from the global Gridpoint Statistical Interpolation (GSI) data assimilation. GNSS-RO data were assimilated by GSI in 3DVAR and hybrid algorithms for the Typhoon Nepartak. All the simulations show landfall tracks and smaller track errors when RO data are assimilated. The performances of assimilating different RO variables are compared as well.

Key words: Typhoon, GNSS-RO, MPAS, GSI

Prediction of Typhoon Track over the Western North Pacific using Machine Learning

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Abstract

Typhoon is kind of atmospheric systems with strong wind and heavy rainfall, which causes property damage and human casualty. To reduce such damages, it is important to improve the prediction skill of typhoon track. Many previous studies have attempted to predict the typhoon track accurately using a numerical or statistical model. Recently, machine learning technology is attracted as a new application field instead of previous models and can capture non-linearity and complex relation. In this study, we developed a model for predicting the track of typhoon after 24 hours from the current typhoon location using Random Forest which is kind of the machine learning algorithm and evaluated this model based on the root mean square error (RMSE). This model was trained for typhoon cases during 1976-2016, and Regional Specialized Meteorological Center (RSMC) Best Track and ERA-Interim Reanalysis were used as 80% training and 20% testing data separately. The predictors consist of the current typhoon information (current typhoon latitude, longitude, maximum wind speed, Julian Day), kinematic parameters (horizontal wind) and past typhoon information (latitude and longitude before 6 hours, 12 hours, 18 hours, 24 hours). Performance of Random Forest model by each predictor was compared by RMSE. Experiment using all predictors performs the best prediction result. In the case of the model using all predictors, the prediction error is more reduced when the data of tropical storm (more than 17.2 m/s maximum wind speed) is only included. It is noteworthy that forecast error before turning point (20°N) is less than after turning point. The model is also applied to predict typhoon location after 2 days and 3days. RMSEs for 2 days and 3 days forecast are 413.3 km and 618.0 km, respectively.

Key words: tropical cyclone, typhoon track prediction, machine learning, random forest

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Northward expansion of tropical cyclone tracks in the western North Pacific during the early fall

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Abstract

Tropical cyclone (TC) is the most destructive natural hazard in East Asia due to the associated storm surge, flood, and strong wind. It can lead to significant casualty and property damage in East Asian countries. About 25 to 30 TCs occur per year in the western North Pacific (WNP) basin, among them 5 to 8 TCs result in direct or indirect damages to Korea and Japan.

We analyzed recent changes in the tropical cyclone (TC) track over the western North Pacific (WNP) for the period between June to September for 36 years (1979-2014). The study area (30–45 °N, 120–145 °E) covered the regions that TCs mainly affect on Korea and Japan. In recent years, the northward migrations of TCs over the WNP to the mid-latitudes prominently increased in early fall. The increasing rates of TCs frequency and the Power Dissipation Index (PDI) within the study area were greatest in September because of favorable environmental conditions such as increasing sea surface temperature, decreasing vertical wind shear, shrunken subtropical high, and increasing relative vorticity. We also found that the negative phase of the Pacific Decadal Oscillation in recent years can be associated with the increasing migration of TCs to the mid-latitudes.

※ This work was funded by the Korea Meteorological Administration Research and Development Program under Grant KMI (KMI2018-01211)

Key words: tropical cyclone, interannual variability, Pacific decadal oscillation

The Global Characteristics and Mechanisms of Diurnal Offshore Propagation of Rainfall

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Abstract

The diurnal cycle of rainfall, a fundamental mode of precipitation variability, is a significant aspect of weather and regional climate. One of the most prominent features is diurnal offshore propagation near the coasts. In the present study, the global characteristics and mechanisms of diurnal offshore propagation of rainfall are investigated using satellite data (CMORPH) in order to provide a clear view of the diurnal offshore propagation features (e.g. occurrence, direction and phase speed) and their relevant physical factors.

A statistical analysis for global coasts indicates that offshore propagation of rainfall are generally observed near many coasts, and they are influenced by latitude, moisture and background wind. Lower latitudes, more moisture and the offshore wind facilitate offshore propagation. In the most of tropical coasts, the propagation is offshore, whereas the propagation is often onshore under the onshore wind in extratropical coasts. In the tropical coasts, offshore-propagating diurnal precipitation signals are broadly consistent with the inertia–gravity waves mechanism, in terms of speed and phase. Background wind plays a modulating role in the diurnal propagation through changing the pattern of the inertia–gravity waves. It is noted that sufficient moisture is also an important factor on diurnal propagation. In the extratropical coasts, land-sea breeze circulation is trapped and background wind thus plays a dominating role with the effect of advection. The offshore (onshore) background wind generates the offshore (onshore) propagation of rainfall.

Key words: diurnal cycle, offshore propagation, latitude, background wind, moisture

Characteristics of vertical structure of snowfall over complex terrain during ICE-POP 2018

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Abstract

During the ICE-POP 2018 (International Collaborative Experiments for Pyeongchang 2018 Olympic & Paralympic winter games) intensive observation period (IOP), it was able to observe the winter precipitation with dense observational network. Prior to 2017-2018 winter, we had a similar observation during 2016-2017 winter (so-called pre-ICE-POP 2018 period). The one of good observational networks of ICE-POP 2018 is the MRR-2 network. MRR-2 were deployed at 10 sites over PyeongChang region and 8 sites were placed almost in a straight line across the mountain range (4 sites in a straight line for 2016-2017). All MRR-2 had a identical height resolution of 150 meters. With this well-organized network, we could monitor and analysis the vertical precipitation development and modification as the precipitation system passed over the terrain.

The algorithm for MRR-2 proposed by Maahn and Kollias (2012) allows us to analyze winter precipitation. This not only improve the sensitivity to snow particles and reduce measurement noise but also de-alias Doppler velocity in Doppler spectra. This technique is applied to our dataset to study vertical structure of winter precipitation. When we interpolate CFAD value to common height grid from 0 m MSL and normalize CFAD value by the total number of observation times (Minder et al., 2015), a direct comparison between sites is possible.

We used dataset collected during ICE-POP 2018 period as well as 2016-2017 winter. It was found that bimodal distribution of reflectivity and Doppler velocity at mountain sites while GWU (coastal) site shows only one peak. The spectrum width due to vertical wind shear is more enhanced at 3 km height toward mountain range.

Key words: ICE-POP 2018, Snow, complex terrain, PyeongChang, Olympics, vertical structure

Characteristics of Coastal Low Level Jets in Bei-Bu Gulf during the warm summer

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Abstract

The coastal low level jets (CLLJs) over South China Sea during the warm summer are investigated by using 2006-2011 hourly model data from the Weather Research and Forecasting Model (WRF) with a 9-km horizontal resolution. We find that the occurrence of CLLJ over the South China Sea is relatively frequent in June in Bei-Bu Gulf. There are two high incidence areas of CLLJ in Bei-Bu Gulf: one is next to the Annamite Range and the shore of Vietnam while this CLLJ prevails after sunset; the other one is off the northwestern coast of Hainan Island while this CLLJ arrives its maximum at midnight.

The wind is weak over the upstream of the Annamite Range during the daytime due to relative strong turbulence mixing near surface, the wind becomes strong because of the suppression of turbulence in the mixed layer after sunset. The relative strong airflow can flow over the Annamite Range results in a hydraulic CLLJ next to the Annamite Range after sunset. Another high incidence area of CBLJ where is off the northwestern coast of Hainan Island is contributed by the topographic blocking effect. This CLLJ exists day and night while it is relative strong at midnight.

Further momentum budget analysis and sensitivity experiments verified the hydraulic jet next to the Annamite Range and the topographic blocking jet off the northwestern coast of Hainan Island. However, the advection term and the Coriolis force acting on the ageostrophic winds are the primary contribution to the CLLJ in the downstream of the Annamite Range.

This study gave the primary mechanism of CLLJ in Bei-Bu Gulf and may shed light to CLLJ in other coastal region over the world.

Key words: coastal low level Jet, South China Sea, numerical analysis/modeling

Fidelity of the Observational/Reanalysis Datasets and Global Climate Models in Representation of Extreme Precipitation in East China

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ABSTRACT

Realistic reproduction of historical extreme precipitation has been challenging for both reanalysis and global climate model (GCM) simulations. This work assessed the fidelities of the combined gridded observational datasets, reanalysis datasets, and GCMs [CMIP5 and the Chinese Academy of Sciences Flexible Global Ocean–Atmospheric Land System Model–Finite-Volume Atmospheric Model, version 2 (FGOALS-f2)] in representing extreme precipitation over East China. The assessment used 552 stations' rain gauge data as ground truth and focused on the probability distribution function of daily precipitation and spatial structure of extreme precipitation days. The TRMM observation displays similar rainfall intensity–frequency distributions as the stations. However, three combined gridded observa- tional datasets, four reanalysis datasets, and most of the CMIP5 models cannot capture extreme precipitation ex- ceeding 150 mm day^{21}, and all underestimate extreme precipitation frequency. The observed spatial distribution of extreme precipitation exhibits two maximum centers, located over the lower-middle reach of Yangtze River basin and the deep South China region, respectively. Combined gridded observations and JRA-55 capture these two centers, but ERA-Interim, MERRA, and CFSR and almost all CMIP5 models fail to capture them. The percentage of extreme rainfall in the total rainfall amount is generally underestimated by 25%–75% in all CMIP5 models. Higher-resolution models tend to have better performance, and physical parameterization may be crucial for simulating correct extreme precipitation. The performances are significantly improved in the newly released FGOALS-f2 as a result of increased resolution and a more realistic simulation of moisture and heating profiles. This work pinpoints the common biases in the combined gridded observational datasets and reanalysis datasets and helps to improve models' simulation of extreme precipitation, which is critically important for reliable projection of future changes in extreme precipitation.

Key words: extreme precipitation, CMIP5, reanalysis, High resolution

Synoptic Patterns Associated with Summer Heavy Rainfall near the South Coast of China

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Abstract

The synoptic patterns associated with summer heavy precipitation over coastal south China was investigated using objective T-mode principle component analysis. NCEP FNL data of summer 2008-2018 are collected and used. We define the heavy rainfall day as the top 10% days sorted by regional precipitation amount. The results show that the heavy rainfall occurs more frequently under two patterns: one is the presence of western vortex over southwestern China, while the other displays similar pattern but with westward subtropical high. The cooperation of western vortex and eastern subtropical high enhances the pressure gradient and onshore wind speed near the south coast of China, and the moisture transportation to the coastal region are greatly enhanced. The diurnal variation of heavy rainfall under two patterns are investigated. Both show bimodal structure with morning peak at 07 LST and afternoon peak at 14 LST. To further illustrate the role of vortex and also other factors such as orography, an extreme precipitation along the south China coast during 29-30 August 2018 was selected and explored. This case shows similar double peak structure as the 11-years mean and is well reproduced by 4-km WRF forecasts. The mechanism of diurnal peak is studied through sensitivity experiments.

Key words: heavy rainfall, T-mode principle component analysis, synoptic pattern, the mechanism of diurnal peak

Development of a new balloon-borne sensor for the precipitation particle electric charge measurement

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Abstract

A balloon-borne instrument "videosonde" was developed by Takahashi (1990) for the better understandings of the precipitation mechanisms and the electric charge distribution in clouds. The system has not only a stroboscopic illumination that provides information on particle size and shape but also an induction ring to measure the electric charge of the particles. In the previous studies, several hundred videosondes have been launched into clouds in climatologically different areas (Takahashi et al. 1999; Takahashi and Keenan 2004; Takahashi and Suzuki 2010; Takahashi et al. 2017, etc.) and provided valuable results to contribute to the lightning study. However, the electric charge measurement by the videosonde has some disadvantages. Because the videosonde could transmit only the video signal by a 1680 MHz carrier wave, the charge sign and magnitude of particles were displayed on a series of LEDs inside the field of view of the CCD camera. Therefore, it takes a lot of time for the analysis, far from the real-time monitoring. In addition, the videosonde was too big, heavy and expensive to use in the field experiment easily.

In-situ electric charge measurement, which is real-time and user-friendly monitoring system, is important for the understanding of electrification in clouds and the validation of the numerical models including the lightning processes. In this study, a new balloon-borne sensor for the measurement of the precipitation particle electric charge is being developed. The induction ring leaves the same performance which Takahashi (1990) developed, and the signal control unit is improved from the cloud particle sensor (CPS; Fujiwara et al. 2016), using a 400 MHz radiosonde (Meisei RS-11G). This new sensor is now in the experimental stages of development.

Key words: electric charge, precipitation particle, balloon-borne sensor, videosonde

The Impact of Vortex Initialization on Convection Development and TC Intensity: A Case Study of Typhoon Megi (2010)

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Abstract

Vortex initialization based on ensemble data assimilation (EDA) is conducted under a framework coupling Weather Research and Forecasting model with the TC Centered-Local Ensemble Transform Kalman Filter (WRF TCC-LETKF) in this study. The impacts from assimilating inner-core observations, including dropsonde data from the Impact of Typhoons on the Ocean in Pacific field campaign (DP experiment) and synthetic axisymmetric surface wind structure (VT experiment), on predicting rapid intensification (RI) are investigated based on a case study of Typhoon Megi (2010). EDA is performed for one day using nested domains with 18- and 6-km grid spacing, and an additional nested domain with 2-km grid spacing is used for the following forecast. Results show that the dropsondes can bring asymmetric information and help establish realistic TC structure in DP, while the axisymmetric surface wind structure more efficiently spins up the TC in VT. However, although the TC in DP forecast is weaker initially, its characteristics of convective burst (CB) development allow the TC to undergo RI for 36 hours. By contrast, the TC in VT forecast intensifies greatly in the first 6 hours but slows down thereafter because the excessive coverage of CBs at forecast initial time results in a too early high-level warm core. In addition, the assimilation of axisymmetric surface wind structure also contributes to the dry thermal condition and hinders RI. Assimilating both types of inner-core observations (BOTH experiment) gives the best result, which possesses the advantages of DP and VT, and the TC is also able to achieve RI.

Key words: data assimilation, EnKF, TC intensity prediction

The observation sensitivity and the forecast sensitivity to observations: theoretical development and an OSSE case study

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Abstract

The warm-sector heavy rainfall is the major high impact weather in south China. The forecasting for the warm-sector heavy rainfall is challenging. Our previous study shows that the forecast skill might be improved by deploying the adaptive observations in the hours or days ahead of the warm-sector heavy rainfall cases over the sensitive regions. However, these sensitive regions were estimated by the global ensemble forecasts with the Ensemble Transform Sensitivity (ETS) method. In this study, the ETS method are optimized to deal with the non-linear problem for the heavy rainfall cases. The impact of the synthetic observation data over the sensitive regions, which are estimated by the global and regional ensemble forecasts, are evaluated by the Observation System Simulation Experiments (OSSEs). The impact for the observations is given based on the Ensemble-based forecast sensitivity to observations method as well.

Key words: warm-sector heavy rainfall, sensitive regions, ensemble transform sensitivity, ensemble-based forecast sensitivity to observations

Introduction to CWB's HRLDAS and evaluation of the impact of surface parameters on HRLDAS over Taiwan

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Abstract

Land physical processes and land-atmosphere interaction are important factors for short-term weather forecasting and regional climate change (e.g. Chen et al. 2001). Complicated land-atmosphere interactions manifested as, for example, soil temperature and soil moisture, exchange energy and moisture with the atmosphere by using sensible heat, latent heat flux, or plant evapotranspiration; moreover, they influence the development of the atmospheric boundary layer and local circulation. Solar radiation, precipitation, surface temperature, moisture and wind etc. from atmospheric forcing influence the soil temperature and moisture by soil diffusion processes.

The High Resolution Land Data Assimilation System (HRLDAS, Chen et al. 2007) is operational at the Central Weather Bureau (CWB). In HRLDAS, the atmospheric surface forcing including hourly precipitation, near-surface air temperature, moisture, wind, and radiation from the model forecast, and radar Quantitative Precipitation Estimation (QPE) are ingested into the NOAH land surface model and spread the surface forcing to the deep soil layers. After a long spin up time, HRLDAS can reach an equilibrium state between atmospheric forcing and soil variables. HRLDAS can output many soil analysis fields including soil temperature and soil moisture. These soil analysis fields can then be used to provide the initial soil conditions of the operational model system.

Comparisons of the soil temperature and moisture analyses from HRLDAS and NCEP GFS, show that the higher-resolution HRLDAS soil temperature and soil moisture fields have more reasonable patterns than the NCEP GFS. We also find that the HRLDAS has a cold bias as compared to observations. In this study, the sensitivity of the surface parameters, such as emissivity, albedo, leaf area index etc. were examined to improve the bias of HRLDAS soil moisture and temperature.

Key words: Land data assimilation, soil moisture, soil temperature, surface parameters

Application of the model perturbation scheme in the convective-scale ensembles predict system

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Abstract

In order to better understand the high impact weather, such as the afternoon thunderstorm, the 2-km convective-scale ensembles predict system (CEPS) was designed. The CEPS in this study consist of 16 members with the initial condition perturbation from hourly updated LETKF. The surface and radar observation were assimilated in the LETKF which use stochastic kinetic energy backscatter (SKEB) to generate the model perturbation. The primary CEPS was under-dispersive. To improve the ensemble dispersion, the model-error schemes, included SKEB and multi-physics, was used to evaluate their impact on the ensemble spread.

In this study, experiments were conducted to exam the sensitivity of the parameter of SKEB, such as the decorrelation time and the amplitude of perturbations. The results show that the SKEB scheme has more effect on the model dispersion than the multi-physics scheme. In addition to, increasing the amplitude and decreasing decorrelation time can really enlarge the model dispersion.

Key words: ensemble forecast, LETKF, stochastic kinetic energy backscatter (SKEB)

Three-Dimensional Cloud Initial Field Created and Applied in GRAPES Numerical Weather Prediction Nowcasting

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Abstract

In order to get more accurate cloud initial fields in GRAPES_Meso model, the ARPS cloud analysis scheme is introduced. With some modifications or improvements basing on the rational law in cloud macro-characteristic and micro-characteristic, the cloud analysis scheme is used to set up a local cloud analysis scheme which suitable for domestic numerical weather prediction model and local synoptic observations. Based on the background field, it integrates data sources from Doppler weather radar three dimensional mosaic reflectivity data, geostationary meteorological satellite data, and surface observation. The cloud initial information is analyzed based on cloud physical laws of thermodynamics and dynamics and the observation experience relationship. After the cloud analysis, the analyzed three dimensional fields which include information of cloud hydrometeors are introduced by nudging technique for initialization of the GRAPES_Meso model. One-month (15 Jul 2014 – 14 Aug 2014) time serial of experiments in different horizontal resolution (0.03°×0.03°,0.1°×0.1°) are designed to verify the performance of the cloud analysis scheme. Case study shows that cloud micro-characteristic and cloud initial hydrometeors of synoptic system, such as typhoon, Squall line etc., could be represented better by using cloud analysis scheme. The satellite cloud simulation technology of university of Wisconsin is adopted to produce the satellite cloud simulation product, which is convenient to compare the cloud product of model output with FY-2 meteorological satellite cloud produce. The comparing result shows that the 1 hour now-casting cloud of GRAPES_Meso model with cloud information initialized is close to satellite measurement in cloud macro-characteristic and cloud spatial distribution, while the one without cloud information initialized is missing and the brightness temperature is higher than satellite measurement. Until 6 hours, the now-casting cloud of cloud analysis scheme is more similar to satellite measurement than the one without cloud analysis scheme, and there isn't the problem that the brightness temperature of simulation without cloud analysis scheme is still higher than the satellite measurement. As for performance of precipitation forecast, it is found that forecast with the cloud analysis has a significant positive impact on short range precipitation forecast. The 1h precipitation forecast with cloud analysis is closer to observation, and the positive effect can last for over twelve hours, which meets the demand for the short time nowcasting operational system. Furthermore, the spin-up time is also shortened. In long time experiments, the statistical variable of equitable threat score (ETS) of the precipitation forecast is calculated. At the first 6 h forecast in horizontal resolution of both 0.03°×0.03°and 0.1°×0.1°, the ETS of the precipitation forecast with cloud analysis is obviously increased compared with the one without cloud analysis. In the following three 6-hour forecast, the positive effects are decreased as forecast time increasing.

Key words: cloud initial field; GRAPES_Meso; nowcasting

Predictability of heat wave in the operational prediction system of KMA

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Abstract

Because of global warming and abnormal climate change, record-breaking heat wave events have been increasing over South Korea. In particular, the heat wave events for recent two years (i.e., 2016 and 2018) have been recorded as the longest and most damaging events ever. The average numbers of heat wave days (maximum surface air temperature) during JJA were 22.4 days (29.4℃) in 2016 and 31.5 days (30.3℃) in 2018. According to the Korea Centers for Disease Control and Prevention, the numbers of patients affected by the summer heat wave were 2,125 in 2016 and 4,519 in 2018. Therefore, accurate prediction of heat wave is necessary to reduce the related damages.

To examine the predictability of the Korea Meteorological Administration (KMA)'s operational prediction system, the simulated surface air temperature during 36 hours is evaluated for heat wave events among the two years. The bias between model and observation data has a diurnal variation; model tends to underestimate (overestimate) surface air temperature in the late afternoon (early morning). Regardless of the heat wave event, a negative bias of the maximum surface air temperature tends to be largest over the southeastern region of South Korea.

The results of KMA's operational local prediction system (LDAPS) are compared with those of global system (GDAPS) to investigate the cause of temperature bias. The cold bias over the northern region of South Korea in GDAPS is prominently decreased by LDAPS, whereas that over the southeastern region still exists. Also, the temperature bias of LDAPS was lager in 2016 than 2018. A numerical experiment using the WRF model is conducted to demonstrate the reason why predictability of LDAPS in 2016 is worse than that in 2018. The WRF model is evaluated for heat wave events in 2016 and 2018, and analyze the differences in the simulation performance for two years. As a result, the simulated western North Pacific subtropical high over South Korea is underestimated compared with that of reanalysis data in both 2016 and 2018. In contrast, a strong blocking high at 500 hPa around the Aleutian Islands in 2016 is underestimated. This could be a possible reason for larger error in 2016 than 2018.

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Key words: heat wave, numerical model, WRF

Impact of FORMOSAT-7/COSMIC-2 Radio Occultation observation on tropical cyclone formation: OSSE based on Hurricane Helene in 2006

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Abstract

Many studies have shown that the space-borne GPS (Global Positioning System) RO (Radio Occultation) observation provide positive impact on severe weather prediction, such as typhoon and the heavy precipitation caused by Mei-Yu front. With the benefits of having atmospheric moisture and temperature profiles in high vertical resolution, assimilating the GPS RO observation is able to improve the thermodynamical initial condition and thus improve prediction. Although the FORMOSAT-3/ COSMIC mission reached the end of its design life and the real-time observing ability has been degrading, the next-generation mission, the FORMOSAT-7/COSMIC-2, is designed to be the replacement with a focus on tropic to sub-tropics.

Given the higher horizontal observational density and better quality of FORMOSAT-7/COSMIC-2 data, we are motivated to understand to what extend this new generation GPS RO observation is capable to improve the accuracy of moisture analysis and to modify its transportation through the data assimilation. An Observing System Simulation Experiment (OSSE) was conducted with the WRF-LETKF data assimilation system for the period when Hurricanes Helene and Gordon (2006) developed on the Atlantic Ocean. The RO refractivity observations were generated from the nature run at the simulated FORMOSAT-7/COSMIC-2 observation locations. Preliminary results indicate that while assimilating FORMOSAT-3/COSMIC successfully depicts the development of Hurricane Helene, assimilating the FORMOSAT-7/COSMIC-2 observation has the advantage in capturing the genesis and development of Hurricane Gordon.

Key words: Data Assimilation, GPS Radio occultation, FORMOSAT-7/COSMIC-2

The Role of Initial Cloud Condensation Nuclei Concentration in Hail Using the WRF NSSL 2-moment Microphysics Scheme

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ABSTRACT

The effects of the initial cloud condensation nuclei (CCN) concentrations (100-3000 mg^{-1}) on hail properties were investigated in an idealized non-severe hail storm experiment using the Weather Research and Forecasting (WRF) model, with the National Severe Storms Laboratory 2-moment microphysics scheme. The initial CCN concentration (CCNC) had obvious non-monotonic effects on the mixing ratio, number concentrations, and radius of hail, both in clouds and at the surface, with a CCNC threshold between 300 and 500 mg^{-1}. An increasing CCNC is conducive (suppressive) to the amount of surface hail precipitation below (above) the CCNC threshold. The non-monotonic effects were due to both the thermodynamics and microphysics. Below the CCNC threshold, the mixing ratios of cloud droplets and ice crystals increased dramatically with the increasing CCNC, resulting in more latent heat released from condensation and frozen between 4 and 8 km and intensified updraft volume. The extent of the riming process, which is the primary process for hail production, increased dramatically. Above the CCNC threshold, the mixing ratio of cloud droplets and ice crystals increased continuously, but the maximum updraft volume was weakened because of reduced frozen latent heating at low level. The smaller ice crystals reduced the formation of hail and smaller clouds, with decreased rain water reducing riming efficiency so that graupel and hail also decreased with increasing CCNC, which is unfavorable for hail growth.

Key words: CCN, hail, microphysics, thermodynamics, threshold

The short-term forecast model experiment near coastal urban areas

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Abstract

The precipitation systems that inflow to the inland coastal urban area from the ocean are often increased due to oceanic characteristics with warm and moist environment, topography and urbanization. Natural disasters (floods, landslides, etc.) caused by heavy rain and strong winds are rapidly occurred in coastal urban area. In order to reduce the damage caused by the precipitation occurring in the coastal area, it is essential to study the characteristics of coastal precipitation and the prediction technique of precipitation considering the characteristics of the coastal area.

The short-term forecast model (STEPS; Short-term ensemble prediction system) was used to conduct a performance test for the precipitation cases passed over the coastal area. The short-term forecast model generates a predict rainrate fields with the temporal resolution every 10 minutes and the horizontal resolution of 1x1 km based on the ensemble member set by the user. The advection velocity of precipitation area is calculated by applying an optical flow algorithm to the initial fields. In this study, the PMEM (Probability matched ensemble mean (Ebert, 2001)) technique was applied to obtain representative results for several ensemble results. In addition, Radar-AWS rainrate (RAR) data and AWS rainfall amount data were used to verify qualitative and quantitative model results. Due to the PMEM method is dependent on the ensemble mean intensity distribution, the model predict result in the coastal area was underestimated when there was a strong intensity of ensemble mean distribution in the outside the coastal area. Especially, when the precipitation passed over the coastal area was rapidly developed, the degree of underestimation had increased. In order to overcome the limitations of the PMEM technique, the new designed PMEM technique was applied to each sub-domain by set a sub-domain in the entire predicted fields.

The detailed results of the short-term forecast model performance experiment near coastal urban areas will be introduced in conference.

Key words: the short-term forecast model, STEPS, ensemble mean, new designed PMEM technique, coastal urban area

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High-resolution simulation with a Large Domain of western Japan heavy rainfall in July 2018

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Abstract

Several landslides and floods caused by heavy rainfall in western Japan, on July 5th – 8th, 2018. To mitigate disasters damage and evacuate residents in a timely fashion, an accurate numerical weather prediction (NWP) system is vital. In the previous heavy rainfall events in Izu Ohsima in October 2013 and Hiroshima in August 2014, the authors showed importance of grid spacing, planetary boundary layer (PBL) schemes, terrain data and model domain size.

In this study, we conducted an ultra-high resolution numerical weather prediction (NWP) simulations with a very large domain area to this western Japan rainfall event in July 2018. Several important model factors (grid spacing, PBL scheme model domain size) influencing heavy rainfall forecasting in NWP models were investigated. An optimized version of JMA-NHM for the K computer was used to this study with the two different model domain sizes.

The result showed the 2-km resolution models showed better precipitation performance than 5-km resolution models. And the 500-m resolution models showed better precipitation performance than 2-km resolution models. The 2-km and 500-m resolution models with the large model domain shows better performance than those with the small domain. Overall, the results indicated that using a high-resolution model (500 m grid spacing) with the large model domain area provides an advantage for simulating heavy rain events.

Key words: heavy rainfall, high resolution simulation, JMA-NHM, K computer

Thermodynamic characteristics associated with snowfall cloud using dropsonde data collected 2018 ICE-POP campaign

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Abstract

The special observation using dropsonde of aircraft was performed to investigate thermodynamic characteristics and improve prediction accuracy of precipitation during 2018 winter Olympic and Paralympic. Dropsonde (Vaisala RS94) data at 06 UTC collected from 2 Feb to 16 Mar 2018 over the East Sea of Korea were used for this study. We analyzed the atmospheric conditions in low-level (under 8,000 m; dropped level) over the Ocean, and compared those differences with inland as coast and mountain. The snowfall cases showed following thermodynamic characteristics: 1) strong convective inhibition (~ CIN 500 J kg^{-1}) with reverse layer in 500 ~ 1,000 m, 2) moderate storm relative helicity (SRH ~ 100 m^2 s^{-2}) with vertical wind shear as easterly wind in surface to 3,000 m and westerly wind in the upper-air, 3) adequate moisture in winter season as sufficient total precipitable water (TPW ~ 15 mm). In addition, snowfall clouds detected by radar echo at less than 4,000 m and their signals were stronger inland than the Ocean. This means that moisture flow from the ocean (easterly wind) rises on ground-mountain, it was saturated and snowfall cloud formed.

Furthermore, this study introduces to aircraft observational campaigns such as International Collaborative Experiments for Pyeongchang 2018 Olympic & Paralympic winter games (ICE-POP 2018) and proactive observation for severe weather such as typhoon, heavy rain, and heavy snow.

Key words: winter snow, aircraft, dropsonde, thermodynamic

Observational study on the heavy snowfall by ground-based hydrometeor measurement and satellite/ground-radar remote sensing

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Abstract

We carried out the field observation along the coast line of the Japan Sea in 2017-2018 winter season, for the ground validation of Global Precipitation Measurement (GPM) Dual-Frequency Precipitation Radar (DPR) rain type classification algorithm (Awaka et al. 2014). Ground-based Particles Image and Mass Measurement System (G-PIMMS; Suzuki et al. 2016), which were installed at Ishikawa Prefectural University (36.509ºN, 135.599ºE) and Kanazawa University (36.544ºN, 136.705ºE), can capture the nondestructive image of particles without contact, and it provides information on particle size, shape and types. It measured not only particle images but also their weight by an electronic balance. Solid precipitation was classified into melting particles, graupel, and snow (including aggregate).

One of X-band polarimetric radars, which were deployed nationwide as eXtended RAdar Information Network (XRAIN), was installed at Noumi (36.459ºN, 136.523ºE) covering our observation sites. In recent years, hydrometeor classification techniques using X-band polarimetric radar were developed (Masuda and Nakakita 2014; Kouketsu et al. 2015), which can classify into rain, graupel, snow, ice crystal and so on.

During the intensive observation period, great disaster was brought by record-breaking heavy snowfall in the western part of the coast of the Japan Sea in February 2018. Much terrible traffic obstruction and huge damage amount by collapse of greenhouse occurred due to heavy snowfall. In this study, we examined this heavy snowfall event from 4 to 8 February 2018 using the data obtained from G-PIMMS, GPM DPR and XRAIN, focusing on the comparison of hydrometeor between radar remote sensing and direct observation.

Key words: Microphysics, Global Precipitation Measurement, X-band Polarimetric Radar

Development of blended Quantitative Precipitation Forecast Product

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Abstract

A mosaic quantitative precipitation forecast (so called blended-QPF, BQPF) products was developed in Taiwan Central Weather Bureau to meet the goal to provide the unified QPF product from the multi-QPF guidance.

The hourly BQPF product was updated every hour and extended to 72-hr forecasts. The various QPF guidance was collected in this study, including hourly updated nowcasting products, such as radar extrapolated QPF, integration on Taiwan Extended Ensemble Nowcasting (iTEEN), and short range QPF from radar data assimilation. In addition, the BQPF also included the synoptic QPF guidance from regional deterministic and ensemble prediction systems which are updated 4 times a day. Objective verification is performed to understand the forecast characteristics of individual guidance in order to draft a time-based stitching strategy.

In order to match the official subjective 6-h QPF, the BQPF was proportionally adjusted the first 24-hour hourly forecast to fit official QPF. However, BQPF exhibits discontinuous precipitation patterns when the different forecasting guidance are stitched, which makes the forecast performance fluctuate significantly. Therefore the further tuning is needed to make sure the robustness of the BQPF products.

Key words: multi-QPF guidance, verification, post-process

Hot weather characteristics in China

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Abstract

In this study, three indices, temperature, HUMIDEX and Heat index, are used to analyze the hot weather conditions at 15,000 weather stations from 2015 to 2017 in China. Furthermore, thirty-one capital cities of the mainland China which have different climate types are selected to show the different hot weather patterns, as well as the relationship between temperature, HUMIDEX, and Heat index. Specifically, three regions of Northeast China, East China, and Southeast China are compared in terms of the hot weather condition. The contribution of the temperature and the relative humidity to the heat stress conditions are discussed. Comparing to temperature which has been currently used as the criterion to issue hot weather warning in China, HUMIDEX and Heat index which have considered the influence of both temperature and humidity are more appropriate and reliable to evaluate the heat discomfort. It is concluded that a universal criterion based on HUMIDEX or Heat index to issue hot weather warnings in summer is applicable to the whole country. This study is valuable to provide reliable information that can help the government, civilian, industrial and public health agencies to identify heat stress conditions that are likely to be harmful to human health, and therefore they can implement appropriate health services and precaution.

Key words: hot weather, temperature, relative humidity, humidex, heat index

The analyisis on the Verification of National Severe Convective Weather Categorical Forecasts

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Abstract

The objective assessment of forecast is an important part in the whole weather forecasting cycle. By using of it the qualities of the different operational forecasts could be noted and thought, and then the level of forecast can be enhanced. In this paper the strict objective Threat Score (TS) is adopted which is 'point-to-area'. The verification of national severe convective weather categorical forecasts from April to September during 2010 -2015 is displayed in this paper. Analysis is carried out for different time interval forecasts of the annual mean verification index (mainly is from April to September of the year). Furthermore, the problems existing in the verification of severe convective weather categorical forecasts and its development in the future have been discussed.Over past six years, in addition to falling of thunderstorms forecast TS score during 2012-2013, there is rising trend for TS of severe convective weather forecasting. For 6-24 hour forecasting, the TS of thunderstorm lies between 0.22-0.34, the TS of the short duration heavy rain lies between 0.18-0.24, the TS of thunderstorm gale and hailstone lies between 0.01-0.07; for 48-72 hour forecasting, the TS of thunderstorm lies between 0.30-0.40, the TS of severe convective weather lies between 0.16-0.23. The TS of thunderstorm gale and hailstone is lower than that of other two kinds of severe convective weather. The False Alarm Rate (FAR) of thunderstorm is twice as large as Missing Alarm Rate (MAR) of thunderstorm; the FAR of short duration heavy rain is close to MAR of it, while the FAR and MAR of thunderstorm gale and hailstone are all larger than 0.8. Compared with the TSs of similar products in Storm Prediction Center of USA, the TSs of thunderstorm and short duration heavy rain are higher than that of SPC and the TS of thunderstorm gale and hailstone is lower than that of SPC. Verification of typical case forecasting shows that the TS of thunderstorm gale and hailstone which is systemic widespread is higher than that of other situations. The reason is that the predictability of thunderstorm gale and hailstone which is systemic widespread is higher than that of other situations.

Key words: **Forecasts Verification**, **Severe Convective**, **Threat Score**

Impact of cloud microphysical processes on the simulation of a hailstorm in east China

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Abstract

Two severe hailstorms that occurred during spring in east China were simulated by the Weather Research and Forecasting model, version 3.9, with four bulk microphysics schemes. Despite some general similarities in the simulation results, the microphysical schemes produced many differences in the radar structure, surface precipitation, wind field, and the mass of hydrometeors. In particular, the Morrison (MOR) scheme produced the best prediction of the radar structure, while the Milbrandt–Yau two-moment (MY2) scheme produced the worst. The mass of ice-phase particles differed greatly in different schemes. An accumulation zone of supercooled rainwater was found in the WDM6 scheme. Analysis of the mass and heat budgets of hydrometeors revealed that embryos of hail were mainly formed through the collection of ice and rain (MOR) or conversion from graupel (MY2), and developed by collecting cloud droplets (MOR) or rainwater (MY2). Microphysical processes generally cooled the air at lower levels while warming it in the mid-upper troposphere. Based on the 1-km resolution results simulated by MOR and MY2, the growth mechanism of hailstones was analyzed preliminarily. Hail embryos were first formed at the upper edge of the upright main updraft, which could be regarded as the “embryo curtain”, and developed through up–down cycling. To conclude, we present a conceptual model of the initial, developing, mature and dissipating stages of the two hailstorm cases.

Key words: hailstorm, numerical simulation, microphysical scheme, formation mechanism

Synoptic climatological analyses on the Korea easterlies over the eastern coast of South Korea

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Abstract

The Korea easterlies are defined as the winds from the East Sea/Sea of Japan (ESJ) that cause precipitation or lowers temperature on the eastern coastal areas in South Korea. Especially, the Yeongdong area has frequent development of heavy snowfall in winter due to the easterlies and the orographic effect. In this study, we performed synoptic climatological analyses on the Korea easterlies, especially for precipitation systems in the categories of heavy rainfall and snowfall and ordinary rainfall and snowfall, using synoptic weather charts, observation data from radar, satellite, and automatic weather stations, and the ERA5 reanalysis data of recent 10 years (2008~2017). Our results indicate that the precipitation systems are related to specific synoptic patterns, and the mean vertical soundings revealed a humid layer due to easterlies at the levels lower than 700 hPa. In terms of precipitation types, several upper-level (500 hPa) patterns are characterized, over the Korean Peninsula and ESJ, such as trough over Korea, trough over Korea and ridge over the Sea of Okhotsk, flat pattern over Korea, etc. Various synoptic climatological analyses are performed, including vertical sounding and horizontal distributions of wind, temperature, and moisture flux to identify the characteristics of the Korea easterlies.

Key words: Korea easterlies, heavy precipitation, wind, synoptic climatology

Okinawan "Katabui" (local heavy rainfall)
Photo by Hiroyuki Yamada