Tightening of Hadley Ascent and Tropical High Cloud Region Key to Precipitation Change in a Warmer Climate

*Hui Su[1], Jonathan H. Jiang[1], J. David Neelin[2], T. Janice Shen[1], Chengxing Zhai[1], Qing Yue[1], Zhien Wang[3], Lei Huang[4], Yong-Sang Choi[5], Graeme Stephens[1], Yuk L. Yung[6]

1. Jet Propulsion Laboratory, California Institute of Technology, 2. University of California, Los Angeles, 3. University of Wyoming, 4. Joint Institute for Regional Earth System Science and Engineering, UCLA, 5. Ewha Womans University, 6. California Institute of Technology

The changes of global-mean precipitation under global warming and interannual variability are predominantly controlled by the changes of atmospheric longwave radiative cooling. Here we show that the tightening of the ascending branch of the Hadley Circulation is a key process coupled to the decrease of tropical-mean high cloud fraction when the surface warms. The magnitude of high cloud shrinkage is a primary contributor to the inter-model spread in the rates of tropical-mean outgoing longwave radiation (*OLR*) and global-mean precipitation change per unit surface warming (dP/dT_s) for both interannual variability and global warming. Compared to observations, most CMIP5 models underestimate the rates of interannual *OLR* and precipitation increase with surface temperature, consistent with the muted high cloud shrinkage. We find that the five models that agree with the observation-based interannual dP/dT_s all predict dP/dT_s under global warming higher than the ensemble mean dP/dT_s from the ~20 models analyzed in this study.

Keywords: hydrological sensitivity, high cloud shrinkage, tightening of Hadley ascent

Diagnostic relationships between precipitation and cloud types or regimes

*Lazaros Oreopoulos[1], Daeho Jin[2,1], Jackson Tan[3,1], Dongmin Lee[2,1], Nayeong Cho[2,1]

1. NASA Goddard Space Flight Center, 2. University Space Research Association, 3. Morgan State University

I will provide an overview of our group's recent work on obtaining diagnostics that expose the character of precipitation-cloud relationships mainly in tropical regions. The observational datasets on which our analysis is based are TMPA-3B42 precipitation rates and cloud types or regimes from ISCCP and MODIS. For comparisons with GCMs we use model cloud output from the CMIP5 archive that has been processed with the ISCCP simulator. Our investigation has focused on the following issues which I will address in my presentation: (1) Can we quantify the relationship between cloud types and precipitation events of particular strength and does the relationship change substantially between ocean and land? (2) Do Weather States or Cloud Regimes serve us well as a framework for distiguishing between different precipitation regimes? (3) Can we see evidence of aerosol effects on precipitation when the problem is decomposed by Cloud Regime? (4) Do models reproduce the observed dependence of tropical precipitation on Cloud Regime? The presentation will stress the value of spatiotemporally matched cloud and precipitation observations as a way forward for understanding their intricate connections.

Keywords: Cloud Types, Precipitation, Satellites, Cloud Regimes, Global Climate Models

The too fast, too frequent precipitation simulated in GCMs

*Xianwen Jing[1], Kentaroh Suzuki[1], Daisuke Goto[2], Tomo’ o Ogura[2], Tsuyoshi Koshiro[3], Huan Guo[4]

1. Atmosphere and Ocean Research Institute, University of Tokyo, 2. National Institute for Environmental Studies, Japan, 3. Meteorological Research Institute, Japan Meteorological Agency, Tsukuba, Japan, 4. UCAR CPAESS, NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ 08540, USA

The cloud-to-precipitation transition process simulated by some state-of-the-art global climate models (GCMs), including both traditional climate models and a global cloud-resolving model, is evaluated against A-Train satellites observations. The models and satellite observations are compared in the form of the statistics obtained from combined analysis of multiple satellite observables that probe signatures of the cloud-to-precipitation transition process. One common problem identified among these models is the too-fast triggering of precipitation, before clouds are developed to a stage when cloud particle sizes are large enough to collide into precipitating particles. Another common problem closely related to the too fast triggering of precipitation is the overestimated (underestimated) occurrence frequency of precipitation (non-precipitating clouds).
The cloud-to-precipitation transition process is represented in GCMs by bulk auto-conversion schemes. A sensitivity test with two widely used auto-conversion schemes in the global cloud-resolving model shows that a more realistic auto-conversion scheme significantly improved the model representation of cloud-to-precipitation transition process: the typical cloud radius where precipitation occurs is shifted close to the observations. However, precipitation occurrence frequency is still overestimated, implying that the parameterization of cloud particle size, besides the auto-conversion scheme, also contributes to the model bias of precipitation occurrence.
Results here demonstrate that both auto-conversion and the growth of non-precipitating cloud particles need to be better represented to achieve realistic precipitation rate and frequency.

Keywords: cloud, precipitation, auto-conversion, GCMs, Satellites

An Investigation of Microphysics and Sub-grid Scale Variability in Warm Rain Clouds using The A-Train Observations and A Multi-Scale Modeling Framework

*Hanii Takahashi[1,2], Matthew Lebsock[2], Kentaroh Suzuki[3], Graeme Stephens[2,4], Minghuai Wang[5,6]

1. Joint Institute for Regional Earth System Science and Engineering, University of California, Los Angeles, California, 2. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, 3. Atmosphere and Ocean Research Institute, The University of Tokyo, Chiba, Japan, 4. Department of Meteorology, University of Reading, UK, 5. Institute for Climate and Global Change Research, and School of Atmospheric Sciences, Nanjing University, Nanjing, Jiangsu Province, China, 6. Collaborative Innovation Center of Climate Change, Nanjing, Jiangsu Province, China

Particle-growth processes (e.g. the cloud-drizzle-rain process) in warm rain clouds play a significant role in controlling the energy budget and hydrological cycle. However, the cloud-to-precipitation process is generally not well represented by models. A common problem in climate models is that they are likely to produce rain at a faster rate than is observed and therefore produce too much light rain (e.g., drizzle). Interestingly, the Pacific Northwest National Laboratory (PNNL) multi-scale modeling framework (MMF) whose warm rain formation process is more realistic than other global models, has the opposite problem: the rain formation process in PNNL-MMF is less efficient than the real world. To better understand the microphysical processes in warm cloud, this study evaluates warm cloud properties, subgrid variability, and microphysics, using A-Train satellite observations to identify sources of model biases in PNNL-MMF. Like other models PNNL-MMF under-predicts the warm cloud fraction with compensating large optical depths. Associated with these compensating errors in cloudiness are compensating errors in the precipitation process. For a given liquid water path, clouds in the PNNL-MMF are less likely to produce rain than are real world clouds. However, when the model does produce rain it is able to produce stronger precipitation than reality. As a result, PNNL-MMF produces about the correct mean rain rate with an incorrect distribution of rates. The sub-grid variability in PNNL-MMF is also tested and results suggest that the possible sources of model biases are likely to be due to errors in its microphysics or dynamics rather than errors in the sub-grid scale variability produced by the embedded cloud resolving model.

Keywords: Warm rain clouds, Microphysical process, Sub-grid scale variability, A-Train observations, Multi-scale modeling framework

The Bias of South China Sea Summer Monsoon Precipitation Associated With Physical Processes in Global Climate Models: The Multi-year Hindcast Approach

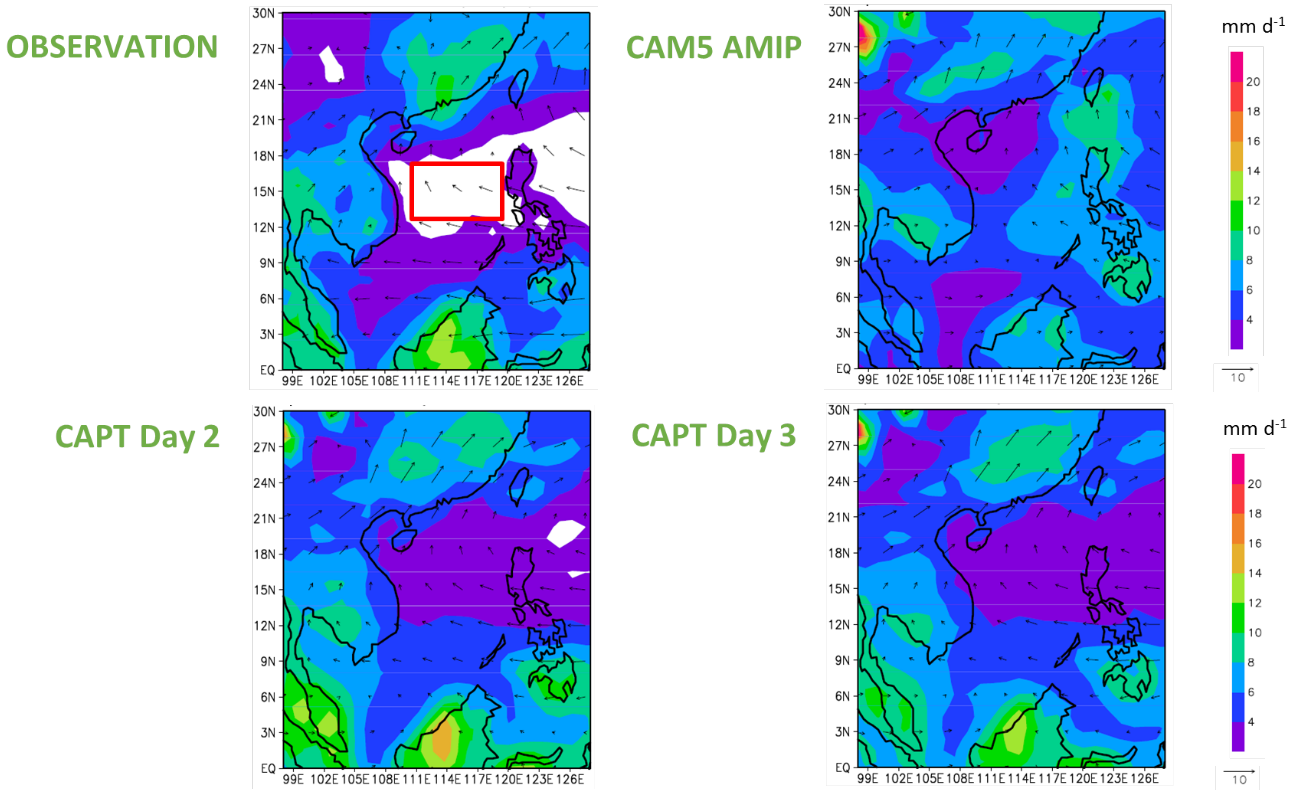
*Wei-Ting Chen[1], Chien-Ming Wu[1], Hsi-Yen Ma[2]

1. National Taiwan University, 2. Lawrence Livermore National Laboratory

The multi-year hindcasts, initialized from the ERA-Interim reanalysis, allow for evaluating the simulated monsoon system given a well-constrained large-scale state at the exact period surrounding the abrupt onset each year over the South China Sea (SCS), a key precursor of the overall East Asia summer monsoon onset. With this experiment, one can better attribute model biases to interactions among parameterizations of fast physical processes, such as the boundary layer turbulence, shallow and deep convective parameterizations. Compared with the observation data, Community Atmospheric Model v.5 simulates excess convective precipitation over SCS and the western Pacific during the pre-onset period, where the environment is mostly suppressed by subsidence of the subtropical high ridge but with high sea surface temperature. The moisture tendency budget analysis reveals the existence of a wet tendency bias in the lower troposphere caused by the interactions among the fast physical processes. We hypothesize that this moist bias enhances the convective instability and produces the precipitation bias, hence the early onset of SCS monsoon. In the future, idealized cloud resolving model simulations will be carried out using the pre-onset, suppressed conditions, and the statistics from cloud resolving model simulations can then be compared with outputs of physical parameterizations in the global climate model to identify potential areas for improvement.

Keywords: precipitation, monsoon, GCM, CRM

Pre-onset bias: Day2 → Day3 → AMIP



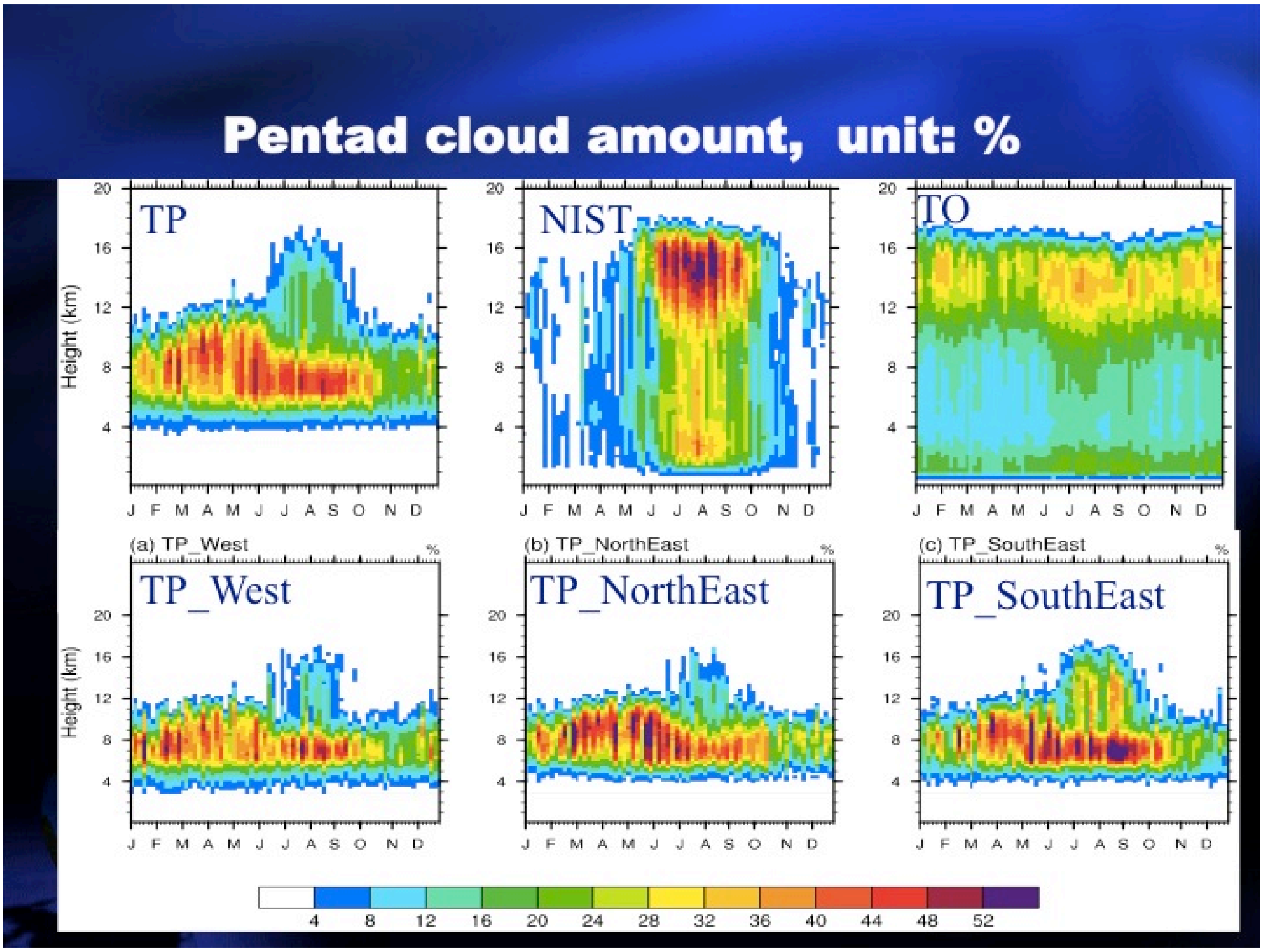
Cloud, Precipitation and Radiation over the Tibetan Plateau and its Neighboring Areas

*Yimin Liu[1], Yafei Yan, Jianhua Lu

1. Insititute of Atmospheric Physics, Chinese Academy of Sciences

By using CloudSat/CALIPSO and TRMM data, the characteristics of cloud vertical structure over the Tibetan Plateau (TP), its southern adjacent land (southern region) and the tropical region are comparatively analyzed. The cloud vertical structure over the TP and its southern region shows significant seasonal variation. In the TP, the cloud amount presents a single peak in January-April, while two peaks after mid-June, and resumes one peak after mid-August. In the southern region, the cloud occurs rarely from October to April, and the cloud amount is mostly below 4% ; while from May to September, the cloud is located at 10-17.5 km and the amount are more than 44%, which is the largest among the three regions. In the tropical region, the cloud is located stably through whole year. Due to the TP restrictions on moisture supply in lower level, there is a significant compression of cloud thickness, cloud layers, as well as cloud top height, so the possible precipitation intensity is smaller over the TP than the other two regions. The variation range of cloud thickness, cloud layers number and cloud top height corresponding to different precipitation intensity is significantly smaller over the TP than the other two regions. In summer, deep convection cloud, which can reach 12-16 km altitude, is significantly smaller over the TP than the other two regions, while the relatively shallow cloud, located in 5-8 km and corresponding to mixed phase cloud water content, appears much more than the other two regions. These significant differences of cloud microphysical characteristics over the TP and other regions may have impacts on the radiation and precipitation. Our results can be applied on the improvements of model simulation on the cloud characteristics and precipitation.

Keywords: Cloud, Precipitation, Radiation, the Tibetan Plateau


Pentad cloud amount, unit: %
TP
NIST
TO
Height (km)
(a) TP_West
(b) TP_NorthEast
(c) TP_SouthEast
TP_West
TP_NorthEast
TP_SouthEast
J F M A M J J A S O N D
4 8 12 16 20 24 28 32 36 40 44 48 52

Ensemble super-parameterization for subseasonal-to-seasonal prediction

*Aneesh C Subramanian[1]

1. University of Oxford

The sub-seasonal forecast timescale, which has long been known as the “predictability desert”, is receiving more interest from most weather forecasting centers in the recent decade. A major reason is due to improved representation of climate modes of variability that act as important potential sources of predictability at these timescales, such as the Madden-Julian Oscillation (MJO) and other tropical modes. Convection and cloud processes play a key role in the dynamics of the tropical atmosphere, especially in the MJO. Despite significant improvements in global modeling over the last three decade, our shortcomings in parameterising convection in global climate models (GCMs) are limiting our ability to simulate and understand the climate and weather of the planet. Recent innovative ideas on convection parameterisation such as super-parameterisation (embedding cloud resolving models within the GCM grid) or stochastic-parameterisation implemented in the ECMWF climate model has helped improve the model’s representation of the climate and weather systems. These two approaches in convection parameterisation have emerged as new paths forward and complement the conventional approaches rather than replace them. We study the impact of these two approaches and a combination of the two on forecasts from weather to sub-seasonal timescales with ensemble forecasts over a 20-year time period. Results from evaluation of forecast skill in the Tropics and for organized convective systems such as the MJO will be presented. We show that the combination of the two approaches helps improve reliability of forecasts of certain tropical phenomena, especially in regions that are mainly affected by deep convective systems. We will also present studies on how these new approaches impact the forecast of clouds and precipitation processes and their interaction with the dynamics. This has implications on improving conventional convection parameterisation using hybrid approaches for probabilistic earth system forecasting as we await the exascale computing systems of the future to resolve convective processes in climate models.

Keywords: convection, precipitation, weather forecasting

Improvements of the Eastward Propagation of the MJO in MIROC6

*Nagio Hirota[1], Tomoo Ogura[1], Hiroaki Tatebe[2], Hideo Shiogama[1], Masahiro Watanabe[3], Masahide Kimoto[3]

1. National Institute for Environmental Studies, 2. Japan Agency for Marine-Earth Science and Technology, 3. The University of Tokyo

A new version of the atmosphere–ocean general circulation model cooperatively produced by the Japanese research community, known as the Model for Interdisciplinary Research on Climate (MIROC6), has recently been developed. Many aspects of the Madden Julian Oscillation (MJO) simulations are improved compared with its previous version MIROC5. For example, MJO amplitudes underestimated in MIROC5 are enhanced; the MJO convective envelopes over the Indian Ocean, which often decays too early around the Maritime Continent in MIROC5, propagate farther to the Central Pacific; the vertical structure of the MJO related humidity shows more realistic stepwise moistening associated with the transition from shallow convection to deep convection. Our preliminary analyses indicate that these improvements are associated with a newly implemented shallow convection scheme. The shallow convection in MIROC6 transports the boundary layer moisture to the lower free troposphere, mitigating dry biases around 800hPa over the Western Pacific. MIROC6 also shows improvements in climatological mean precipitation and shallow cloud distribution.

Keywords: MJO, climate model MIROC6, convection

Impacts of entrainment model in cumulus parameterization on atmospheric general circulation

*Yuya Baba[1]

1. Japan Agency for Marine-Earth Science and Technology

Entrainment model is a key parameterization in cumulus parameterization since entrainment affects structure and formation of convective clouds, and thus has influences on atmospheric general circulation. In the past studies, several entrainment models have been proposed based on observation and results of cloud-resolving model simulations. However, there still coarse and inconsistent assumptions exist in those modeling. Considering drawbacks in the modeling procedures, long-range cloud-resolving model simulation was performed and detailed, statistical convective cloud structure was analyzed. Based on the analysis, entrainment model which can represent statistical structure of convective clouds and can be used with detrainment model in cumulus parameterization was proposed.
The new entrainment model was implemented into a spectral cumulus parameterization, and was compared with one of the recent entrainment models used in some cumulus parameterizations. The physical performance of the models was examined using AMIP experiment. The results indicated that the new model could simulate better climatology in terms of the annual mean states of atmospheric circulation. Significant difference in simulated results between two models appeared in vertical profiles of entrainment. Since existing model parameterized entrainment so that it is directly proportional to in-cloud buoyancy, the entrainment especially in low altitude was overestimated, resulting in too much low cloud amount. The new model suppresses the trend due to the consideration of detrainment effect into estimation of entrainment. Finally, further analysis revealed that the new formulation of currently proposed model also could contribute to the improvement of atmospheric variability.

Keywords: entrainment, cumulus parameterization, atmospheric general circulation

A study on Cloud Microphysics for Remote Sensing Data Assimilation

*Yasutaka Ikuta[1]

1. Japan Meteorological Agency

A new km-scale hybrid-4DVar data assimilation system is being developed to improve short-range precipitation forecasts at the Japan Meteorological Agency. One of the purposes of developing this system is to enable the assimilation of observations related to hydrometeors. For the assimilation of such observation, a new simplified 6-class 3-ice 1-moment bulk cloud microphysics scheme suitable for the tangent linearization has been developed. This cloud microphysics scheme is tuned to reduce the forecast bias of hydrometeors profile by updating the assumption of ice and snow particles. In this revision, the shape assumption of ice and snow is changed from spherical particle to non-spherical particle, and the particle size-distribution of snow is changed from negative-exponential distribution to negative-exponential and+ modified gamma distribution. The unbiased attribution of hydrometeors is very important for the appropriate assimilation of the observation as well as the improvement of precipitation forecast.
A traditional 4DVar uses climatological background error covariance. However, the errors of hydrometeors are correlated each other, and the error correlation depends strongly on meteorological situations. To consider such flow-dependency, the background error covariance of hydrometeors is constructed using ensemble perturbations in the new hybrid-4DVar data assimilation system. Using this km-scale hybrid-4DVar data assimilation system, the impact of space-borne radar and radiance data was investigated. The results of this investigation will be presented.

Convective cloud-top vertical velocity estimated from geostationary satellite rapid-scan measurements

*Atsushi Hamada[1], Yukari Takayabu[1]

1. Atmosphere and Ocean Research Institute University of Tokyo

We demonstrate that the development rate of cumulus clouds, as inferred from so-called geostationary satellite "rapid-scan" measurements, is a good proxy for convective cloud-top vertical velocity related to deep convective clouds. Convective cloud-top vertical velocity is estimated from the decreasing rate of infrared brightness temperature observed by the MTSAT-1R satellite over the ocean south of Japan during boreal summer. The frequency distribution of the estimated convective cloud-top vertical velocity at each height is shown to distribute lognormally and is consistent with the statistical characteristics of direct measurements of cumulus updrafts acquired in previous studies. We have commenced a follow-up study using data from a new Japanese geostationary satellite (Himawari-8), which is capable of routine full-disk observations with 10-minute interval and 2-km spatial resolution.

Keywords: cumulus, vertical velocity, geostationary satellite, rapid scan

Spatial variability of summer monsoon raindrop size distribution over Western Pacific Ocean.

*BALAJI KUMAR SEELA[1], JAYALAKSHMI JANAPATI[2], PAY-LIAM LIN[2], KRISHNA REDDY KRISHNAREDDYGARI[3], Ryuichi Shirooka[4]

1. Department of Atmospheric Science, National Central University & Taiwan International Graduate Program (TIGP), Academia Sinica, Taiwan, 2. Department of Atmospheric Science, College of Earth Science, National Central University, Taiwan., 3. Department of Physics, Yogi Vemana University, Kadapa, Andhra Pradesh, India, 4. Department of Coupled Ocean-Atmosphere-Land Processes Research, Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan

Raindrop size distribution (RSD) characteristics in summer monsoon (June to August) rainfall of two observational sites [Taiwan (24° 58’ N, 121° 10’ E), Palau (7° 20’ N, 134° 28’ E)] in Western Pacific region are studied by using four years of impact type disdrometer data. In addition to disdrometer data, TRMM, MODIS, ERA-Interim data sets are used to illustrate the dynamical and microphysical characteristics associated with summer monsoon rainfall of Taiwan and Palau. Significant differences between raindrop spectra of Taiwan and Palau rainfall are noticed. Palau rainfall is associated with higher concentration of small drops when compared to Taiwan rainfall. RSD of Taiwan and Palau rainfall are fitted to gamma distribution. RSD stratified on the basis of rain rate showed higher mass weighted mean diameter (D_m) and lower normalized intercept parameter ($\log_{10}N_w$) in Taiwan than Palau rainfall. Even after classifying the precipitation in stratiform and convective regimes, Taiwan rainfall showed higher D_m values than Palau rainfall. Furthermore, the mean value of D_m is higher in convective precipitation as compared to stratiform precipitation for both the locations. Radar reflectivity (Z) and rain rate (R) relations ($Z= A*R^b$) derived for Taiwan and Palau showed a clear variations in the coefficient with less variation in exponent values. Terrain influenced clouds extended to higher altitudes over Taiwan resulted with higher (lower) D_m ($\log_{10}N_w$) values in Taiwan rainfall as compared to Palau.

Keywords: Raindrop Size Distribution (RSD), mass weighted mean diameter, Normalized intercept parameter.

Characteristics and Environmental Properties of Warm-Season, Quasi-Stationary Mesoscale Convective Systems in Japan

*Tetsuya Takemi[1], Takashi Unuma[1]

1. Disaster Prevention Research Institute, Kyoto University

Mesoscale convective systems (MCSs) are one of the major mesoscale disturbances and sometimes spawn heavy rainfall/snowfall and high winds locally. MCSs occur over the various regions of the world in any season and take various forms such as a circular shape and a linear shape. Because of their potential impacts on the human society, diagnosing and predicting the development of MCSs are very important. For this purpose, it is required to obtain basic understandings on the characteristics and environmental properties of MCSs. We conducted statistical analyses by using operational radar and radiosonde data in order to reveal the characteristics and environmental properties of stationary or slow-moving MCSs during a warm season in Japan from a climatological point of view (Unuma and Takemi 2016a, 2016b). The analysis period was from May to October, referred to as the warm season here, during 8 years of 2005-2012. It was found that the MCSs in Japan have smaller spatial scales than those in midlatitude continental regions. We call such warm-season, stationary MCSs as quasi-stationary convective clusters (QSCCs). The environmental conditions for the development of QSCCs were described through a comparison with those for no-rain cases. With the use of an automated QSCC identification method by Shimizu and Uyeda (2012), 4133 QSCCs were extracted over the Japanese major islands. It was found that QSCCs are typically meso-β-scale phenomena. From the analyses of the shapes of QSCCs with the use of an automated shape-determining algorithm, it was shown that most of QSCCs have an elongated structure with the southwest—northeast orientation. The environmental analyses indicated that low-level moisture content controls the stability condition for the development of the QSCCs, and that the differences in the magnitude and directional shear of horizontal winds in the lower troposphere characterize the kinematic environments for QSCCs. An increased amount of the middle-level moisture was found for the QSCC environments, suggesting that atmospheric moistening is an important factor for the development of QSCCs. The vertical shear in the lower troposphere also controls the shape of QSCCs: circular mode versus elliptical mode. From the examination of the relationship between radar precipitation intensity and environmental conditions, it was found that the precipitation intensity has a higher correlation with the convective instability, whereas the precipitation area with the shear intensity. From the analyses, it was indicated that a stability condition plays a role in determining intensity of QSCCs while a shear condition tends to control the shape of QSCCs. This feature led us to conclude that a parameter combining shear and stability, i.e. bulk Richardson number, clearly distinguishes between the organization modes. It is suggested that the back-building process is one of the key factors in determining the organization mode. We have shown that the operational meteorological data are quite useful in studying the characteristics of MCSs. With the further advances of observation techniques and numerical modeling in accuracy and spatio-temporal resolution, the analyses on the characteristics and environmental conditions of MCSs and their precipitation characteristics are expected to be extended to MCSs for various regions of the world.

Keywords: convection, precipitation, environmental condition

Role of orography, diurnal cycle, and intraseasonal oscillation in summer monsoon rainfall over Western Ghats and Myanmar coast

*Shoichi Shige[1], Yuki Nakano[1], Munehisa K. Yamamoto[1]

1. Kyoto University

Rainfall over the coastal regions of western India (Western Ghats; WG) and Myanmar (Arakan Yoma; AY), two regions experiencing the heaviest rainfall during the Asian summer monsoon, is examined using a Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) dataset spanning 16 years. Rainfall maxima are identified on the windward slopes of the WG and the coastlines of AY, in contrast to the offshore locations observed in previous studies.

The rainfall in the WG and AY regions exhibits low diurnal variability, implying that the rainfall is not primarily driven by thermal convection, but by mechanical convection. Large rainfall amounts with small diurnal amplitudes are observed over the WG and AY under strong environmental flow perpendicular to the coastal mountains, and vice versa. Diurnal-driven mitigating systems are observed over the WG under weak environmental flow, but do not determine the seasonal distribution of summer monsoon rainfall, explaining why the rainfall maxima are not observed offshore.

Composite analysis of the boreal summer intraseasonal oscillation (BSISO) shows that the rain anomaly over the WG slopes lags behind the northward propagating major rain band. The cyclonic systems associated with the BSISO introduces south-west wind anomaly behind the major rain band, enhancing the orographic rainfall over the WG, and resulting in the phase lag. This lag is not observed in the AY region where more closed cyclonic circulations occur. Diurnal variations in rainfall over the WG regions are smallest (largest) during (preceding) the strongest BSISO rainfall anomaly phase.

Observational and Numerical Study on Terrain-induced Heavy Rainfall in Mt. Jiri, Korea

*Dong-In Lee[1], Dong-Kyun Kim[2], Yunhee Kang[1], Jisun Lee[1,3]

1. Division of Earth Environmental System Science, Pukyong National University, Korea, 2. Department of Environmental Atmospheric Sciences, Pukyong National University, Korea, 3. HM&Co, Ecole des Ponts ParisTech, Marne-la Vallée, France

During a summer monsoon season every every, severe weather phenomena caused by front, storm, mesoscale convective systems (MCSs), or typhoons influence the Korean Peninsula. Especially mountains that cover a large part of the Korean territory play an important role in controlling formation, amount, and distribution of rainfall. As convective systems move over mountains, they tend to intensify more and produce locally heavy rainfall. Observation data in mountainous areas is essential for studying terrain effects on the rapid development of rainfall.
In order to understand developing and decaying mechanisms of precipitation systems that pass over the mountain, we performed Orographic Rainfall Experiment (OREX) around Mt. Jiri (1950 m above sea level) during summertime on June and July 2015-2016 in the southern Korean Peninsula. Observation data from seven Parsivel disdrometers, three ultrasonic anemometers (measuring winds), and radiosondes were analyzed during periods of Typhoon Chanhom on July, 2015 and the heavy rain event on 1 July 2016. A dual-Doppler analysis was also conducted to retrieve three-dimensional wind fields in this mountain area. Vertical structure of radar reflectivity and winds (especially vertical velocity) within the precipitation systems moving over Mt. Jiri was examined. For comparing with retrieved vertical velocities, we developed a technique to derive vertical velocities from fall velocity and drop size spectra measured by the Parsivel disdrometers. From the comparison of vertical velocities between the Parsivel and anemometer, we found that upward motions were dominant in the windward side and the areas of upward motions were nearly coincident to those of a large amount of rainfall accumulation. During the periods of updrafts, rainfall rates and mean drop diameter were larger than those during the periods of downdrafts. We digitized these updraft periods as percentage, dividing them by the total rainfall period and these percentage values would be useful for inducing an area of updrafts around the mountain. Also, variances of Parsivel-measured fall velocities per each diameter bin, which are related to turbulent air intensity, were found to be larger when surface winds were stronger.
To find important atmospheric factors affecting the orographic rainfall enhancement we performed numerical study by assimilating observation data to a model. For validating model results with better accuracy, surface measurements as well as rainfall data from the field observations were used.

Acknowledgements
This work was funded by the Korea Meteorological Industry Promotion Agency under Grant KMIPA 2015-5060 and the BK21 plus Project of the Graduate School of Earth Environmental Hazard System.

Keywords: Orographic rainfall, Atmospheric factors

Observational and Numerical Study on Terrain-induced Heavy Rainfall in Mt. Jiri, Korea

Dong-In Lee[1*], Dong-Kyun Kim[2], Yunhee Kang[1], and Jisun Lee[1,3]

[1]Division of Earth Environmental System Science, Pukyong National University, Korea
[2]Department of Environmental Atmospheric Sciences, Pukyong National University, Korea
[3]HM&Co, Ecole des Ponts ParisTech, Marne-la Vallée, France.

Abstract

During a summer monsoon season each every, severe weather phenomena caused by front, storm, mesoscale convective systems (MCSs), or typhoons influence the Korean Peninsula. Especially mountains that cover a large part of the Korean territory play an important role in controlling formation, amount, and distribution of rainfall. As convective systems move over mountains, they tend to intensify more and produce locally heavy rainfall. Observation data in mountainous areas is essential for studying terrain effects on the rapid development of rainfall.

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Three-dimensional analyses of initial stage of convective precipitation using two X-band polarimetric radars

*Yura Kim[1], Masayuki Maki[2], Dong-In Lee[1]

1. Division of Earth Environmental System Science, Pukyong National University, Korea, 2. Department of Research and Education Center for Natural Hazards, Kagoshima University, Japan

Convective precipitation rapidly develops and often brings about localized torrential rain which cause flooding and landslides. The polarimetric radar is one of the key instruments for precipitation study, since it provides kinematic properties of precipitation developments as well as information on microphysical process in the precipitation. The present study uses two X-band polarimetric radars to understand the initiation process of convective precipitation. However, the volumetric data of X-band radar currently available is 5 min interval data which is not enough for studying initial stage of developing convective cell. In this study, to investigate three dimensional structure of convective cell in early stage, we developed an algorithm based on the interpolation method in both space and time. The algorithm produces three dimensional high spatio-temporal resolution CAPPI data using two X-band polarimetric radars (3D CAPPI). The mosaic of two radars has an advantage to construct whole images of precipitation compared to single radar analysis. The algorithm is applied a localized convective precipitation observed in Kanto area of Japan on 19 July 2012. The 3D CAPPI gives us detailed structure of rapidly developing convective cell and provides quantitative information on echo top height, maximum reflectivity, and first observation time of each cell. Using mosaic 3D CAPPI information, the present study clearly shows the back-building process at the initial stage of convective precipitation. In initial stage, the three dimensional analyses of convective precipitation could be helpful to detect the first core of cell and develop a short-term forecasting model.

Acknowledgment

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Keywords: localized convective precipitation, X-band polarimetric radar, high resolution, initial stage

Precipitation processes revealed from hydrometeor measurements by videosondes

*Kenji Suzuki[1]

1. Graduate School of Sciences and Technology for Innovation, Yamaguchi University

Videosonde is one of strong tools to measure hydrometeors in clouds directly. It is a balloon-borne radiosonde that acquires images of precipitation particles via a CCD camera. The system has a stroboscopic illumination that provides information on particle size and shape. Interruption of the infrared beam by particles triggers a flash lamp and particle images are then captured by the CCD camera. Precipitation particles are classified as raindrops, frozen (or partly melted) drops, graupel, ice crystals, or snowflakes on the basis of transparency and shape. One of the advantages for the videosonde is to capture images of precipitation particles as they are in the air because the videosonde can obtain particle images without contact.
Videosonde observations of Baiu monsoon clouds have been conducted from 2007 to 2016, as part of the in-situ campaign observation by a C-band polarimetric radar synchronized with videosonde, which were carried out at Okinawa Electromagnetic Technology Center of National Institute of Information and Communications Technology (26º29′N, 127º50′E). In the case of May 20, 2012, a Baiu stationary front was located over the Okinawa Island, and we experienced heavy rain of 71.1 mm from 09 JST to 13 JST. Six videosondes were launched into the different developing stages of the rainband. In the cases of the developing stage, frozen drops were observed from 0ºC to -15ºC. Graupel were also detected in the same altitude. On the other hand, in the mature stage, we observed them between 5ºC and 0ºC layer, and graupel were dominant in between 0ºC and -5ºC. It was supposed that freezing processes and graupel formation processes near the 0ºC was different in the different developing stages.
We also carried out the videosonde observation at Bengkulu (3.86ºS, 102.3ºE), Indonesia from November 24 to December 15, 2015 for the better understanding of microphysical precipitation processes of tropical convection, which were conducted as a part of Pre-YMC field campaign. In the case of November 30, 2015, we experienced a strong rain associated with diurnal variation with convection along the coastline of Sumatera Island. A videosonde was launched into this convective cloud with cloud top 9 km. It transmitted images of large raindrops up to 6 mm in diameter in the lower level, and nearly round frozen drops and graupel above the freezing level. This was a typical tropical convective cloud characterized by the warm rain and freezing process.

Keywords: precipitation process, cloud microphysics, videosonde

Thundercloud electric field fine structure and lightning initiation

*Dmitry Igorevich Iudin[1]

1. Institute of Applied Physics of the Russian Academy of Sciences

It is well known that the amplitude of the electric field measured in a thundercloud, is an order of magnitude less than the threshold value, which is necessary for the conventional electrical breakdown of air. This fact turns the lightning initiation question in one of the most intriguing problem of thunderstorm electricity. In this work, initiation of lightning in a thundercloud is regarded as a noise-induced kinetic transition. As a source of the noise we consider the collective stochastic electric field of charged hydrometeors. The intensity of the noise is equal to the product of hydrometeors concentration with the variance of their charge magnitude. Above-critical bursts of the stochastic field provide the appearance of elevated-conductivity areas and turn the cloud medium into a strongly inhomogeneous random mixture of highly conductive areas with poorly conducting, almost dielectric regions. Thus we reduce the consideration of lightning initiation to the dielectric breakdown problem in random conductor-insulator composites. The sensitivity of the dielectric breakdown field on the conductor fraction in the material is caused by the formation of conductive percolation clusters which act as equipotential for an applied quasi-static electric field. For a given applied field, a larger and larger local field is concentrated across the space between relatively large conductive clusters. The breakdown field is of order the inverse of the linear dimension of the largest of these percolation clusters. Since the size of the clusters diverges as the volume fraction of conductor tends to the percolation threshold value, the breakdown field tends to zero in this limit. In addition, the average breakdown electric field decreases logarithmically with the linear dimension of the system when the volume fraction of good conductor is below the percolation threshold. The proposed kinetic mechanism of the initiation of the lightning discharge provides both amplification of the local electric field in a thundercloud, and self-consistent support of the discharge process under the conditions when the free electrons attachment dominates over their production in ionization process.

Keywords: thundercloud, lightning initiation, charged hydrometeors

Algorithm Development for Discriminating Cloud and Precipitation Particle Type using CloudSat/CPR and CALIPSO/CALIOP Observation

*Maki Kikuchi[1], Hajime Okamoto[2], Kaori Sato[2], Yuichiro Hagihara[1]

1. Japan Aerospace Exploration Agency, 2. Kyushu University

Cloud and precipitation take key roles in the climate system. Information on the cloud phase, shape, rain and snow (hereafter, hydrometeor particle types) are among the major factors that determine the radiative properties of cloud and precipitation. The knowledge on the hydrometeor types is also necessary to retrieve their microphysical properties, such as liquid/ice/rain/snow water contents and effective radius. In this study, we developed an algorithm that discriminate the hydrometeor particle types using the cloud profiling radar (CPR) onboard CloudSat and Mie-scattering lidar, Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP), onboard Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO). The CloudSat and CALIPO satellites are in operation since June 2006 and they have accumulated vertical profiles of cloud and precipitation over the globe for ten years. The CALIOP is sensible to thin to moderately thick clouds and the CPR is sensible to moderately thick clouds to light precipitation. Therefore, the development of the synergetic algorithm that discriminate hydrometeor particle types for the CPR and CALIOP observation would not only derive the global picture of cloud-precipitation typing but also would offer opportunities to further study the cloud-precipitation process and to evaluate its representativeness in global and regional numerical models.

The CALIOP cloud particle type discrimination algorithm was based on the previous scheme originally developed by Yoshida et al. [2010] and modified by Hirakata et al. [2014]. The CPR algorithm consisted of three main steps: (1) initial type classification by radar reflectivity and European Center for Medium-range Weather Forecasting (ECMWF) temperature; (2) cloud-precipitation partitioning correction by attenuation corrected surface radar reflectivity; and (3) spatial continuity test. The initial type classification was conducted by selecting a type from a look-up-table of radar reflectivity and temperature. The look-up-table was constructed using the cloud particle type discrimination from CALIOP and the precipitation detection by Precipitation Radar (PR) onboard Tropical Rainfall Measuring Mission (TRMM). For each CloudSat bin, an initial type was selected from the look-up-table that corresponded to the observed radar reflectivity and ECMWF temperature. The second step was the cloud-precipitation partitioning correction where each profile was determined whether it was a precipitating profile or not by a simple threshold method of attenuation corrected surface radar reflectivity (Haynes et al. [2009]). If the profile was detected as precipitation but the initial classification had been registered as a cloud profile, the initial classification of the lowest hydrometeor classification was corrected to precipitation (and visa-versa). The last step of the CPR algorithm was the spatial continuity test to eliminate spike misclassification. The final CPR-CALIOP synergy scheme classified the hydrometer particles into 13 types: warm water, supercooled water, randomly oriented ice crystals (3D-ice), horizontally oriented plates (2D-plate), 3D-ice + 2D-plate, liquid drizzle, solid drizzle, rain, snow, mixed phase, water+liquid drizzle, water+rain and unknown. Taking the advantage of CPR's capability to penetrate cloud and light precipitation and CALIOP's capability to detect thin clouds, the synergy algorithm derived the global vertically resolved distribution of hydrometeor particle types from thin cirrus clouds to light precipitation.

The hydrometeor particle type algorithm is considered to be applied in upcoming Earth Clouds, Aerosols and Radiation Explorer (EarthCARE) Level 2 Standard Products that will be processed and released from JAXA to observe global and vertical distribution of the hydrometeor particle types.

Keywords: cloud radar, lidar, satellite, cloud observation, precipitation observation

A long term calibration of space-borne precipitation radar using natural target

*Kaya Kanemaru[1], Takuji Kubota[2], Toshio Iguchi[3], Yukari Takayabu[1], Riko Oki[2]

1. Atmosphere and Ocean Research Institute, The University of Tokyo, 2. Earth Observation Research Center, Japan Aerospace Exploration Agency, 3. National Institute of Information and Communications Technology

Precipitation observation by the Tropical Rainfall Measuring Mission’s (TRMM’s) Precipitation Radar (PR) has lasted for almost 17 years. On February 28, 2014, the core satellite of the Global Precipitation Measurement (GPM) mission was launched, and the GPM Dual-frequency Precipitation Radar (DPR) started providing precipitation data succeeding the TRMM PR observation. PR and DPR not only estimate precipitation accurately both over land and the oceans but also provide information to derive precipitation characteristics (e.g., rain top height and rain vertical profile). Homogeneity of long-term PR/DPR data will be essential to study the water cycle change related to the decadal climate variability. Then, a long-term stability of calibration accuracy for radars is an important factor to correctly obtain the nature variability. The radar algorithm for precipitation estimates converts from the observed radar reflectivity factor, Z, to the estimated rain rate, R, so that a Z bias of calibration error is a cause of absolute error of R. On the other hand, a temporal change of calibration bias causes an artificial trend of R. Therefore, the long term trend of calibration error (calibration drift) must be evaluated and compensated. In this study, we develop a method of calibration drift estimates. While the normalized radar cross section (NRCS or sigma-zero) over water surface is related with sea surface wind (SSW), sigma-zero at small incident angles is insensitive at moderate (8-10 m/s) wind speeds. Since a relationship between sigma-zero and SSW is invariant, a temporal change of sigma-zero filtered by moderate winds is obtained as the calibration drift of radars. In this study, calibration drift of the PR version 7 (V7) product is evaluated using SSW data by the TRMM microwave imager (TMI). The calibration drift of the PR is found for a 0.2 dB change during the entire TRMM mission. The long-term trend of unconditional rain by the PR V7 over the TRMM coverage is overall caused by the calibration drift. The calibration drift of the PR found in the current study will be compensated in future (version 8; V8) product.

Keywords: Precipitation radar, Calibration

Estimating vertical profile of water-cloud droplet effective radius from SWIR measurements of Himawari-8 via cloud profile statistics

*Takashi M. Nagao[1], Takashi Y. Nakajima[2]

1. Earth Observation Research Center, Japan Aerospace Exploration Agency, 2. Tokai University Research and Information

Remote sensing of clouds by geostationary meteorological satellites with multispectral visible-to-infrared imaging capabilities by improved spectral, spatial and temporal resolution (e.g. Himawari-8/AHI, GOES-R/ABI) have potential to advance scientific understanding of cloud and precipitation process, by quantifying spatio-temporal distributions and evolutions of cloud radiative and microphysical properties such as cloud optical thickness (COT), cloud droplet effective radius (CDER), and cloud top temperature (CTT) and height (CTH). However, limitation of passive remote sensing to provide vertically-resolved cloud information including in-cloud CDER vertical profile (CDER-VP), drizzling existence, cloud geometric thickness and base height is one of the barriers to advancing our understanding of cloud and precipitation process.
This study developed an algorithm to retrieve CDER-VP of water cloud from shortwave infrared (SWIR) measurements of Himawari-8/AHI via cloud statistical profiles derived from CloudSat/CPR observation towards continuous monitoring of temporal evolution of clouds by Himawari-8. Several similar algorithms in previous studies utilize a spectral radiance matching on the assumption of simultaneous observation of radar and visible-to-infrared imagery such as CloudSat/CPR and Aqua/MODIS. However, note that, since our aim is to apply the algorithm to Himawari-8/AHI measurements, the algorithm does not assume simultaneous observations with CloudSat/CPR.
First, in advance, a database (DB) of CDER-VP is prepared by the following procedure: Top-of-atmosphere (TOA) radiances at three spectral bands (0.65, 2.3, 11-μm) of AHI are simulated from CDER-VP contained in CloudSat Radar-Visible Optical Depth Cloud Water Content Product (2B-CWC-RVOD) and cloud optical depth vertical profile in contained in CloudSat 2B-TAU product. COT, CDER and CTT are retrieved from the simulated radiances using an algorithm in assuming plane-parallel cloud structure (Nakajima and Nakajima, 1995). A set of the COT, CDER and CTT retrievals and inputted CDER-VP is added to the DB.
Finally the algorithm retrieves CDER-VP from actual AHI measurement by the following procedure: COT, CDER and CTT are retrieved from the AHI radiances at 0.64, 2.3, 10.4-μm bands. Using the COT, CDER and CTT retrievals as key of the DB, multiple CDER-VPs are extracted from the DB. Using principal component (PC) analysis, up to three PC vectors of the CDER-VPs are extracted. Again, CDER-VP, COT, and CTT are retrieved from the AHI 0.64, 1.6, 2.3, 3.9 and 10.4-μm using the PC vectors of CDER-VPs with iterative radiative transfer calculation. Note that the sum of the contribution ratios of the three principal components vectors exceeds 95%.
This study evaluated the algorithm based on the simulation using the CloudSat 2B-CWC-RVOD and 2B-TAU products. The column mean CDERs calculated from the retrieved CDER-VPs are almost unbiased while the CDERs retrieved with the plane-parallel assumption have significant underestimation called so-called plane-parallel bias. The CDER-VP retrieval errors are almost smaller than 3-μm. The retrieval errors of the cloud base CDERs are almost larger than the others. The tendency can be explained by less sensitivity of SWIRs to CDER at cloud base.
Additionally, as a case study, this study will attempt to apply the algorithm to the AHI’s high-frequency observations, and to interpret the time series of the CDER-VP retrievals in terms of temporal evolution of water clouds.

Understanding sea surface temperature forcing of precipitation variability in the tropics

*Jie He[1]

1. Princeton University

The great dependence of human society and natural ecosystems on rainfall makes precipitation variability an essential aspect of the earth’s climate. In the tropics, it is well accepted that the ocean plays a crucial role in precipitation variability through variations in sea surface temperatures (SSTs). Above normal SSTs often increase the boundary-layer moist static energy and induce anomalous convection. An important yet unresolved question is: how strong is the SST forcing? Observational studies have long suggested an intense SST forcing for base SSTs around 27.5°C but little forcing for very high base SSTs. In this seminar, I will show that simultaneous SST-rainfall relationships in any coupled system, including observations, are inadequate for quantifying the SST forcing. This is largely due to the two-way interplay between the atmosphere and ocean. Results from uncoupled simulations show that the SST forcing in fact becomes larger for higher base SSTs. The relationship between the SST forcing and base SST can be parameterized with the moist static energy model. Future endeavors to quantify feedbacks between the SST and hydrological cycle will be presented with the aim of improving model simulations of tropical air-sea interaction.

Keywords: tropical precipitation variability, SST forcing, air-sea relationship

Intense thunderstorms and their large-scale environments over different regions

*Nana Liu[1]

1. Texas A&M University-Corpus Christi

During the past decades, the global precipitation systems has been extensively studied with ground based, ship based, airborne, and space borne radars. Especially with TRMM precipitation radar, Houze and his research group have examined convection over various selected regions, including the South Asian (Romatschke et al.2010; Medina et al. 2010), the South America (Rasmussen and Houze 2011), the Central Africa (Zuluga and Houze 2015), the indian and west Pacific oceans (Zuluaga and Houze 2013, Barnes et al. 2015), the Atlantic and east Pacific (Zuluaga and Houze 2015), as well as global (Houze et al. 2015). A general impression from these studies is that convection over various regions not only has their own special dynamic environment setups, but also shares some common features. For example, the most intense convection often occurs over basins downstream of mountains when dry warm air at mid troposphere is above a warm moist air continuously being replenished by a low level jet, which appears locally as a famous storm favoring "onion shape sounding". The question is whether we can/ how to utilize these common features to improve the numerical models, such as cumulus parameterization. To answer this question, first we examine the relationships between large-scale thermodynamic parameters and sub grid scale convective properties, such as intensity. Then we attempt to understand the importance of specific thermodynamic factors favoring intense convection over various regions. The properties of 16-year of TRMM Precipitation Features are analyzed along with the large-scale parameters from 0.75° ERA-Interim reanalysis. The environment variables, including CAPE, CIN, low level wind shear, lift condensation level, among many others, are individually as well as jointly correlated with fractional occurrence of strong convection with high lightning flash rates. Using these relationships, the global distribution of fractional occurrences of convection with high lightning rates are estimated from ERA-Interim variables and compared to the TRMM derived climatologies. Results suggest that regions favoring the intense convection may be partially explained by the combinations of several important thermodynamic environment factors. This work implies the potential of introducing the convective intensity into the cumulus parameterizations.

Keywords: intense thunderstorm, large-scale environment

Significance of cloud and precipitation in aerosol effect on climate

*Kentaroh Suzuki[1], Toshihiko Takemura[2], Daisuke Goto[3]

1. Atmosphere and Ocean Research Institute, University of Tokyo, 2. Research Institute for Applied Mechanics, Kyushu University, 3. National Institute for Environmental Studies

Aerosol impacts on Earth’s climate are still subject to large uncertainty. A major part of this uncertainty arises from atmospheric processes relevant to cloud and precipitation. This is fundamentally due to a dominant role of moist processes in Earth’s atmosphere. This study explores how aerosol’s impacts on climate are significantly modulated by the presence of cloud and precipitation. For this purpose, numerical experiments are performed with two global models, i.e. (i) MIROC and (ii) NICAM-Chem. The former is a traditional type of global climate model and the latter is a global non-hydrostatic atmospheric model, both of which are coupled to the SPRINTARS aerosol transport module. In the simulations, emissions of scattering (i.e. sulfate) and absorbing (i.e. black carbon) aerosols are separately perturbed with uniform factors multiplied to investigate the climate responses to perturbations of each aerosol type. The results are analyzed in the context of global energy budget to find that energy budget components respond differently to perturbations of scattering and absorbing aerosols due to different responses of cloud and precipitation. The cloud response to perturbations of absorbing aerosols is found to produce a negative radiative effect that significantly reduces the original positive radiative forcing of the aerosols whereas the cloud response to scattering aerosols tends to enhance the original cooling effect of the aerosols via aerosol-cloud interactions. The two types of aerosols also cause distinctly different responses of precipitation through different pathways of energy budget modulations occurring over different time scales. These results underscore a significance of cloud and precipitation processes in quantification of aerosol impacts on global climate and may help reduce a large inter-model spread in estimates of the hydrologic sensitivity in climate predictions.

Keywords: cloud, aerosol, energy budget, climate model

A statistical comparison of precipitation feature characteristics over land and oceans utilizing the GPM DPR data

*Marika Ono[1], Yukari Takayabu[1]

1. Atmosphere and Ocean Research Institute, the University of Tokyo

The relationship between tropical (30N-30S) and extratropical (30N-65N, 30S-65S) precipitation feature characteristics and the environment, such as an atmospheric moisture field, is analyzed focusing on a comparison over land and oceans using the GPM (Global Precipitation Measurement) DPR (Dual-frequency Precipitation Rader) data.
The difference between over land and the oceans is observed in terms of the relation between daily column relative humidity (CRH) derived from ERA-interim data and precipitation feature characteristics obtained from the GPM DPR. Over tropical oceans, volumetric precipitation and stratiform precipitation area of precipitation features rapidly increase with CRH, as reported in previous studies. Over tropical land, on the other hand, volumetric precipitation of precipitation feature has a peak at around CRH 0.7.
In terms of the relationship to CRH, we also analyzed tropical and extratropical precipitation feature characteristics. Over tropical oceans, a class of well-organized precipitation systems observed in the highly humid environment has the largest contribution to total precipitation. In contrast, highly convective precipitation systems observed in moderately humid conditions substantially contribute to total precipitation over land.
Over land, it is considered that the heated land surface during daytime is likely to prepare more unstable lower troposphere and thicker mixed layer compared to the case over ocean. Such unstable conditions can lead to the initiation of convective clouds. Therefore regional analysis about environment has been conducted from the perspective of a comparison in various CRH conditions and seasons. In the Amazon, for example, precipitation features observed in moderately humid conditions are dominant in the premonsoon season. In addition, lower troposphere is in most unstable condition in Amazonian premonsoon season. It is suggested that relatively lower humid conditions seasonally coexist with more unstable conditions. This result implies a possibility that the peak in volumetric precipitation of precipitation features at moderate CRH is associated with convective systems developed in such unstable conditions.
In mid-latitude regions, the different results between over land and over oceans are also observed. Over extratropical oceans, volumetric precipitation and stratiform precipitation area of precipitation features also increase with CRH as over tropical oceans. However, the relationship is relatively linear over extratropical oceans in contrast to an exponential growth observed over tropical oceans. It is possibly attributed to the difference in dominant precipitation mechanism between tropics and mid-latitude regions. Over extratropical land, volumetric precipitation of precipitation features has a peak at around CRH 0.55-0.65. This result over extratropical land is similar to that over tropical land. This agreement of results can be explained by the fact that highly convective systems greatly contribute to total precipitation over both land regions.

Keywords: Satellite Precipitation Measurements, GPM DPR, Precipitation Characteristics

Analysis of the Time Development on Release and Reconstruction of Barotropic Instability Field in the ITCZ in the Eastern Pacific Ocean

*Yuki Kawata[1], Yukari Takayabu[2], Atsushi Hamada[2]

1. Department of Earth and Planetary Science , School of Science , The University of Tokyo, 2. Atmosphere and Ocean Research Institute, The University of Tokyo

The intertropical convergence zone (ITCZ) in the Eastern Pacific Ocean is well known for occasional breakdowns of cloud bands that sometimes bear tropical cyclones. Previous studies show that these events have aspects of the barotropic instability with numerical simulations, but there are few quantitative observational studies to understand their processes. In this study, we performed a potential vorticity (PV) budget analysis by using observational data and tried to quantify the temporal evolution of the breakdown and reconstruction processes of the ITCZ instability.

We used the ECMWF reanalysis data, ERA-interim (ERA-I, every 6 hours), three-dimensional diabatic heating data (SLH ver.7) estimated from precipitation radar data of the Tropical Rainfall Measuring Mission (TRMM) satellite, and GSMaP surface precipitation data (every one hour). Horizontal resolutions of ERA-I, TRMM SLH, and GSMaP are 0.75 degrees in lat/lon, about 5 km, and 0.1 degrees in lat/lon, respectively.

Since the sampling of SLH data is limited in PR’ s narrow swath, we developed a look-up-table (LUT) method to estimate 3D diabatic heating. First, we divided the TRMM PR precipitation intensity into three classes according to its strength, and, for each class, created LUTs from SLH that give a vertical profile of diabatic heating for a specified vertical velocity at 500 hPa. Then, we utilized GSMaP precipitation, ERA-I vertical velocity at 500hPa, and the LUTs to obtain the diabatic heating in the ITCZ region. Finally, the PV budget analysis in the ITCZ region was carried out by quantifying the PV generations from estimated profiles of diabatic heating, together with the dynamic variables from the ERA-I.

First, we analyzed an event from July to August 1988, which is often cited as an example of the ITCZ breakdown, using ERA-I, separating the disturbance field from the basic field. It was confirmed that the initial state of the high PV band satisfied the necessary condition of the barotropic instability, and then, the instability was removed as disturbances developed after the breakdown.

Second, we analyzed events that occurred in August 2003. We observed a large amount of diabatic heating near the altitude of 2 km probably associated with congestus clouds in the ITCZ region. The heating reached the maximum in the early stage of the breakdown. We could also capture a stage in which as disturbances are detached from the ITCZ region and moved to higher latitude, the amount of heat calmed down and the field gradually recovered toward the initial stage.

Finally, the amount of the PV generation by the diabatic heating of the lower troposphere was quantitatively estimated, and the PV budget in the ITCZ region was investigated. As a result of the PV budget analysis on the 850hPa surface, it was found that the PV production due to the diabatic heating in the lower level was much larger, compared to either the inflow from the outside of the ITCZ region or the local PV tendency at 850 hPa. Since it was considered that the PV formed in the lower level was transported to the upper troposphere, a PV budget in the vertical direction was performed. We selected the 300 hPa surface and the 500 hPa surface to represent the upper level and the middle level, respectively. It was confirmed that the excessive PV generated in the lower level at the early stage of the breakdown event was transported to the upper levels. It is suggested that the PV generated in the lower troposphere helped strengthen the PV in the middle / upper levels. Such large vertical transport of PV could not be detected in the process of the field recovery, suggesting that ,at that stage, the PV generated in the lower level was used for the recovery on the spot.

In the future, we will also consider the uncertainty of the data used for the analysis of this research.

Keywords: Intertropical Convergence Zone, Barotropic Instability, Analysis of the satellite data, Diabatic Heating

Characteristics and regional differences of summer warm rain over the tropical and subtropical pacific ocean observed by TRMM

*Fang Qin[1]

1. University of Science and Technology of China

Based on the merged measurements from the TRMM Precipitation Radar and Visible and Infrared Scanner, refined characteristics (intensity, frequency, vertical structure and diurnal variation) and regional differences of the warm rain over the tropical and subtropical Pacific Ocean (40°S-40°N, 120°E-70°W) in boreal summer are investigated for the period 1998-2012. The results reveal that three warm rain types (phased, pure and mixed) exist over these regions. The phased warm rain, which occurs during the developing or declining stage of precipitation weather systems, is located over the central to western Intertropical Convergence Zone, South Pacific Convergence Zone, and Northwest Pacific. Its occurrence frequency peaks at midnight and minimizes during daytime with a 5.5-km maximum echo top. The frequency of this warm rain type is about 2.2%, and it contributes to 40% of the regional total rainfall. The pure warm rain is characterized by typical stable precipitation with an echo top lower than 4 km, and mostly occurs in Southeast Pacific. Although its frequency is less than 1.3%, this type of warm rain accounts for 95% of the regional total rainfall. Its occurrence peaks before dawn and it usually disappears in the afternoon. For the mixed warm rain, some may develop into deep convective precipitation, while most are similar to those of the pure type. The mixed warm rain is mainly located over the ocean east of Hawaii. Its frequency is 1.2%, but this type of warm rain could contribute to 80% of the regional total rainfall. The results also uncover that the mixed and pure types occur over the regions where SST ranges from 295 to 299 K, accompanied by relatively strong downdrafts at 500 hPa. Both the mixed and pure warm rains happen in a more unstable atmosphere, compared with the phased warm rain.

Keywords: warm rain, frequency, diurnal variation, radar reflective factor, trade wind

Multilayer Cloud Characteristics over the North Pacific Ocean Obtained from CloudSat/CALIPSO Combined Data

*Akira Yamauchi[1], Kazuaki Kawamoto[1], Hajime Okamoto[2]

1. Graduate School of Fisheries and Environmental Sciences, Nagasaki University, 2. Research Institute for Applied Mechanics, Kyushu University

Clouds have a large impact on the hydrological system and Earth’s energy budget. Many previous studies identified clouds as an important source of uncertainty when attempting to understand and predict global climate change (*e.g.*, *Stephens,* 2005; *Dufresne and Bony,* 2008). Cloud effects are strongly regulated by their microphysical (particle size, number concentration, and mass density of water or ice particulates) and macrophysical (temporal frequency, height, geometrical thickness, and rainfall intensity) structures. For example, *Kawamoto and Hayasaka* (2008) reported that surface radiative flux was dominated by cloud optical thickness and cloud cover. However, in the case of a structure where the upper cloud and the lower cloud vertically overlap, the influence of the upper cloud on the lower cloud is not known in detail.

In this study, we investigated the difference in the cloud geometrical thickness and maximum radar reflectivity between single and double layered-clouds. As a result, we found that lower cloud of the double layered-clouds were geometrically thinner than the single layer clouds, and those radar reflectivity decreased. Significant differences were observed when the upper clouds were geometrically thick. Altostratus clouds were dominated in the upper clouds over the northern part of the North Pacific Ocean, and upper clouds were geometrically and optically thicker than in other regions. Therefore, we concluded that growth suppression effect was strongly observed in this region.

Keywords: Multilayer Cloud, CloudSat/CALIPSO, North Pacific Ocean

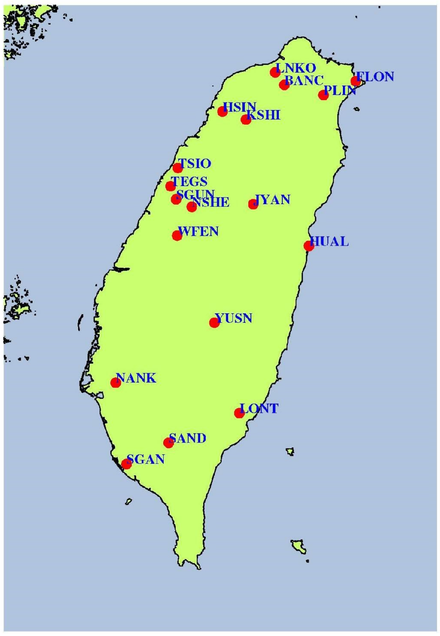
Feasibility Assessment of Heavy Rainfall Forecast Using GPS-Derived ZTDs

*LiChun Tseng[1], Shen Yu Hsiao[1], ChunMin Shih[1], LiPing Li[1], Chang Jung Chieh[1], FENG SHIH LIN[1]

1. National Chung Hsing University

This study focuses on the correlation between Zenith Total Delays (ZTDs) derived from global positioning system (GPS), and rainfalls. The feasibility assessment of heavy rain forecast by GPS-derived ZTDs during typhoon events are subsequently analyzed. The study period are selected during the strong typhoon events in recent years. We use the method of Point Precise Positioning (PPP) with the software "Bernese 5.2" to compute ZTDs in 129 GPS stations during study period. The ZTD results are both compared with those from University of the Atmospheric Research (UCAR), and the rainfall data from the rainfall stations of Central Weather Bureau, Taiwan. We currently have preliminarily analyzed the correlation between ZTDs and the rainfalls at 18 GPS-rainfall stations (See the attached Figure) during the period of Typhoon Soudelor, 2015. We conclude that heavy rain forecast by GPS-derived ZTD has great potential and it is worth doing further research for typhoon disaster prevention.

Keywords: GPS, ZTD, heavy rain forecast, typhoon disaster prevention



Remote Sensing of the Davao atmosphere using GNSS and radiosonde data for 2013-2015

Kristine Mae Rodriguez Carnicer[1], *Maria Cecilia Dandan Galvez[1], Rui M.S. Fernandes[2], Edgar Amemita Vallar[1]

1. Environment and RemoTe sensing ResearcH (EARTH) Laboratory, Physics Department, De La Salle University, Manila, 2. Space and Earth Geodetic Analysis Laboratory (SEGAL), University of Beira Interior, Portugal

One GNSS receiver installed at Davao University was utilized to obtain estimates of the atmospheric water vapor content in Davao City for the years 2013-2015. The datasets from the local radiosonde station was used to verify the measured GNSS-derived precipitable water vapor (PWV) and a significantly strong correlation (R=0.871) was calculated. The parameter water vapor weighted mean temperature, Tm is a significant factor in deriving PWV values from GNSS satellite data. A local Tm model utilizing the datasets from the Davao City radiosonde station was derived and validated by comparison to the global and regional models. Time series plots were made out of the calculated GNSS PWV values for the years 2013, 2014 and 2015 to test for any annual, seasonal and monthly variations. Results from analysis of variance (ANOVA) with post-hoc tests showed that significant differences were measured in the PWV means for the three years tested. There were also significant differences in the PWV averages for the dry and wet season as well as between the cool dry, hot dry and wet seasons. The results for the monthly variations agree well with the wet and dry seasons with the month of February (2013-2015) getting the lowest average monthly value of GNSS PWV and the months of May (2013, 2015) and June (2014) the highest. The temporal behavior of GNSS PWV was also evaluated for moderate to torrential rain events. It was shown that while moderate rain follows small variations in PWV, heavy torrential rains usually follow a peak in the PWV value with a time lag ranging from 2 –8 hours.

Keywords: GNSS, Atmospheric Water vapor, rain events

The analysis of Taiwan dry-season precipitation patterns and frontal system variations

*Shih-Hao Su[1], Bing-Kui Chiou[1], Jung-Lien Chu[2], Lee-Yaw Lin[2]

1. Chinese Culture University, 2. National Science and Technology Center for Disaster Reduction

Generally, there is relative less precipitation during the months between winter to next spring, December to April, in Taiwan. Therefore, we usually define these months as dry-season. . The historical drought events show that most events are occurred between February to April and lead to a huge economic loss in agriculture. The major synoptic weather events which affect Taiwan during this period is the frontal system. Therefore, understanding the correlation between the spatial-temporal variations of frontal systems and the seasonal rainfall amount and frequency is important.
In this study, the surface weather maps were used as the subjective analysis of synoptic scale frontal systems, which affected Taiwan, from 1980 to 2015. We also used the hourly data of precipitation from21 meteorological stations in Taiwan which operated by the Central Weather Bureau (CWB). Those stations are equally distributed over the island which including 5 mountain stations. The rainfall distribution of 21 stations is approximate match with detailed rain gauge observations and only may underestimated over the CMR southern slope.
The preliminary results show that the frontal systems have strong inter-annual variations in spatial and temporal characteristics for both front numbers and affecting days and there was a decreasing trend in past 36 years. We also noticed that the frontal properties have different varies between the seasons which may related to the temporal and spatial shifting of the large-scale circulations. Generally, 25% of days per year were affected by the frontal system. Moreover, 40% to 50% days during the Spring and Mei-Yu season were also affected by frontal system. The average affecting duration of each front was 12-24hrs of the Mei-Yu season and about 5hrs for other seasons.
The spatial and temporal variations of frontal systems were correlated to the seasonal precipitation. The seasonal total rainfall amount in the dry-season has significant correlation with the frontal numbers and frontal days (0.56/0.55). As speculation, the frontal extreme rainfall events are also highly related to the frontal numbers and days during the dry-season. Furthermore, we observed that there are two different types of precipitation patterns associated with frontal system. The extreme rainfall events are highly associated with frontal-terrain which is induced deep convections and the light/moderate rainfall are related with the stratiform components.
We also noticed that there are some large-scale patterns which may also play important roles to influence the spatial and temporal variations of frontal systems in Taiwan. The preliminary results show that large-scale patterns are different between seasons. For example, there is a low-level of anticyclonic circulation anomaly at northwest pacific region during the winter time for more fronts year, but it will change to the cyclonic circulation anomaly for more fronts year in spring time. The south-west flow also show an obvious feature for more fronts year in spring time.

Keywords: Dry-season precipitation, Subjective front analysis, Precipitation patterns, Extreme rainfall events

Statistical analysis of regional rainfall distributions around isolated Island by low-level winds during the winter season

*Gyeong-Tae Ryu[1], Dong-In Lee[1], Keun-Ok Lee[3], Dong-Kyun Kim[2], Cheol-Hwan You[4]

1. Division of Earth Environmental System Science Pukyong National University, Busan, Korea, 2. Department of Environmental Atmospheric Sciences, Pukyong National University, Korea, 3. LATMOS/IPSL, UPMC Univ. Paris 06, Sorbonne Universités, UVSQ, CNRS, Paris, France, 4. National Research Center for Disaster-free and Safe Ocean City, Dong-A University, Busan, Korea

In Korea, rainfall systems passing over an isolated mountain tend to develop by orographic effects. We statistically analyzed regional rainfall distributions according to wind characteristics at low levels (925–850 hPa) during winter seasons in 2009-2016 around Jeju Island which is elliptically shaped and oriented from the west-southeast to east-northeast direction with a height of 2 km, width of 35 km, and length of 78 km. For this study, rain gauge data at 26 sites, two operational S-band Doppler radar data, and mesoscale analysis model data were used.

The accumulated rainfall was recorded by the 26 rain gauges during December–February from 2009 to 2016. The accumulated rainfall maximum larger than 40000 mm appeared on the mountain crest (altitude > 1.25 km). In contrast, the region of the accumulated rainfall less than 15000 mm appeared on the western coast of Jeju Island. This means that the rainfall distributions were affected by the mountainous region in Jeju Island. For radar data analyses, 3-Dimensional CAPPI radar data during precipitation periods were used. To determine a representative environmental wind on Jeju Island, the MSM-GPV (Mesoscale Model-Grid Point Value) data between 850 hPa and 925 hPa levels were used. By wind direction and wind speed, CAPPI radar data were classified into 32 wind categories. The 2 km-CAPPI radar reflectivities were time-averaged in each category.

In this study, characteristics of regional rainfall distributions classified into the 32 wind categories by wind direction and speed were investigated. The most of high rainfall frequencies occurred when the northwesterlies (51.6%) and northerly winds (16.0%) prevailed at low-levels. Rainfall frequencies at westerlies (8.6%) and southwesterlies (7.5%) were relatively low. At relatively strong northwesterlies (SPD > 10 m s^{-1}), rainfall systems that moved from the offshore region have developed on mountain slope. When the relatively weak southwesterlies (5 m s^{-1} < 10 m s^{-1}) and strong southwesterlies (SPD 20 m s^{-1}) were dominant, there were high rainfall distributions on the top of the mountain and the southern upslope, respectively. Similarly, when the relatively weak southerly winds (5 m s^{-1} < SPD 10 m s^{-1}) and strong southerly winds (SPD 20 m s^{-1}) prevailed, high rainfall frequencies were concentrated on the top of the mountain and the southern upslope, respectively. Therefore, the development of rainfall systems that pass over the mountain around the Jeju Island seems to be closely related to the characteristics of wind direction and wind speed at low-levels.

Acknowledgements

This work was funded by the Korea Meteorological Industry Promotion Agency under Grant KMIPA 2015-5060 and the BK21 plus Project of the Graduate School of Earth Environmental Hazard System.

Keywords: regional rainfall distribution, isolated elliptical terrain, low-level wind

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[1]*Division of Earth Environmental System Science Pukyong National University, Busan, Korea*

[2]*Department of Environmental Atmospheric Sciences, Pukyong National University, Korea*

[3]*LATMOS/IPSL, UPMC Univ. Paris 06, Sorbonne Universités, UVSQ, CNRS, Paris, France*

[4]*National Research Center for Disaster-free and Safe Ocean City, Dong-A University, Busan, Korea*

Abstract

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Keywords: regional rainfall distribution, isolated elliptical terrain, low-level wind

Topographic effects on spatiotemporal variations of short-duration rainfall events in warm season of central North China

*Weihua Yuan[1], Yu Rucong[2], Sun Wei[1], Chen Haoming[2]

1. LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences, 2. Chinese Academy of Meteorological Sciences

Statistical analyses of the hourly station rainfall observation over the recent 8 years show that rainfalls in the warm season (May-October) of the central North China are dominated by short-duration rainfall events (lasting less than or equal to 6 h) and the southeastward delayed diurnal phases of total rainfall revealed by previous studies are mainly contributed by the propagating short-duration rainfall rather than the long-duration rainfall as that along the Yangtze River Valley. The spatiotemporal features of rainfall events are highly correlated with elevation heights. The largest frequency of short-duration rainfall events locates in the southeastern inner periphery of Taihangshan and Yanshan mountains. Rainfall over the northwestern mountains often occurs in the afternoon. Some rainfall events propagate southeastward and influence the rainfall in the southeastern foothills and plain. The rainfall with short duration time mainly begins around the late evening in the southeastern plain, and even later in coastal regions. The understanding of topographic effects to rainfall events is discussed based on reanalysis and station data. Results indicate that the topography influences the diurnal varied surface or low-level temperature, moisture and wind fields, which benefit rainfall events occurring in the afternoon over the northwestern mountains firstly and the southeastward propagation afterward.

Keywords: Short-duration precipitation, Topographic effects, hourly precipitation data

Does the climate warming hiatus exist over the Tibetan Plateau?

*Anmin Duan[1]

1. Institute of Atmospheric Physics, Chinese Academy of Sciences

The surface air temperature change over the Tibetan Plateau has been determined based on historical observations from 1980 to 2013. In contrast to the cooling trend in the rest of China, and the global warming hiatus post-1990s, an accelerated warming trend has appeared over the Tibetan Plateau during 1998–2013 (0.25 °C decade^{-1}) compared with that during 1980–1997 (0.21 °C decade^{-1}). Further results indicate that such an accelerated warming trend might be attributed to the cloud-radiation feedback, to some degree. The increased nocturnal cloud over the northern Tibetan Plateau will warm the nighttime temperature by the enhancement of atmosphere counterradiation, while the decreased daytime cloud over the southern Tibetan Plateau will induce the daytime sunshine duration increased, resulting surface air temperature warming. Meanwhile, the in situ surface wind speed has recovered gradually since 1998, and the energy concentration cannot explain the accelerated warming trend. It is suggested that the cloud–radiation feedback may play an important role in modulating the accelerated warming trend over the Tibetan Plateau.

Keywords: Tibetan Plateau, warming amplification , cloud-radiation feedback

Sensitivity of the surface parameters in CReSS for weather simulations over the arid and semi-arid regions

*WoonSeon JUNG[1], Masataka MURAKAMI[1], Taro SHINODA[1]

1. Institute for Space-Earth Environmental Research, Nagoya University

To conduct forecast and/or hindcast simulations for rain enhancement research over the United Arab Emirates (UAE), we need an accurate and reliable numerical model to simulate clouds formation and precipitation development over the desert areas. The main purpose of this study is to check the performance of Cloud Resolving Storm Simulator (CReSS: Tsuboki and Sakakibara, 2007) model and validate and improve the numerical model for weather simulations over the UAE.
Land surface temperature plays an important role in reproducing clouds and precipitation, especially over the desert areas. In spite of importance of land surface temperature, CReSS had not been validated in terms of land surface temperature in detail and it recently turned out that CReSS experiments underestimate the land surface temperature during not only daytime but also nighttime.
To investigate the major parameters to influence the land surface temperature, sensitivity test was performed for the time duration from 0600 UTC 09th to 0600 UTC 12th September 2015 and compared with Aqua/Moderate Resolution Imaging Spectroradiometer (MODIS) data. The parameters related to land surface processes, which were investigated in this study, were thermal diffusivity, thermal capacity, evapotranspiration efficiency, roughness length, soil temperature in the deepest layer, emissivity on surface, number of soil and sea layers, and thickness of each soil layer.
The sensitivity experiments showed that the increase of land surface temperature in the daytime resulted from smaller thermal diffusivity, thermal capacity, evapotranspiration efficiency, roughness length, emissivity of land surface and larger soil temperature in the deepest layer, number of soil layers and thickness of soil layers. On the other hand, the increase of land surface temperature in the nighttime resulted from smaller evapotranspiration efficiency, emissivity of land surface and larger thermal diffusivity, thermal capacity, soil temperature in the deepest layer, number of soil layers, thickness of soil layers.
On the basis of sensitivity experiment, numerical experiments were performed to optimize the parameters in trial and error manner. To increase the land surface temperature during both daytime and nighttime, diverse parameters were tuned, including soil temperature at the deepest layer, evapotranspiration efficiency, and so on. The difference of domain-averaged land surface temperatures between Aqua/MODIS observation and CReSS simulation decreased from 13 K in the experiments with default values of the parameters (CTL) to 1 K in the experiment with optimized values of the parameters (OPT) in the daytime (1400 LST 10 September 2015). The difference in the nighttime (0200 LST 11 September 2015) also decrease from 3 K in CTL to 1 K in OPT experiments (see Figure. 1).
CReSS CTL experiments with 5 km horizontal resolution showed an improvement in reproducing the convective clouds over the desert areas to some extent, but still significantly underestimated such convective clouds. To examine a grid size dependency of the reproducibility of clouds and precipitation over the desert areas, CReSS OPT experiment with 1km horizontal resolution was performed. The model well reproduced convective precipitation over the mountain area and also over northwestern coastal and inland desert areas, which was not well reproduced by CReSS OPT with 5km horizontal resolution.

Keywords: Cloud Resolving Storm Simulator (CReSS), Land surface temperature, United Arab Emirates (UAE)

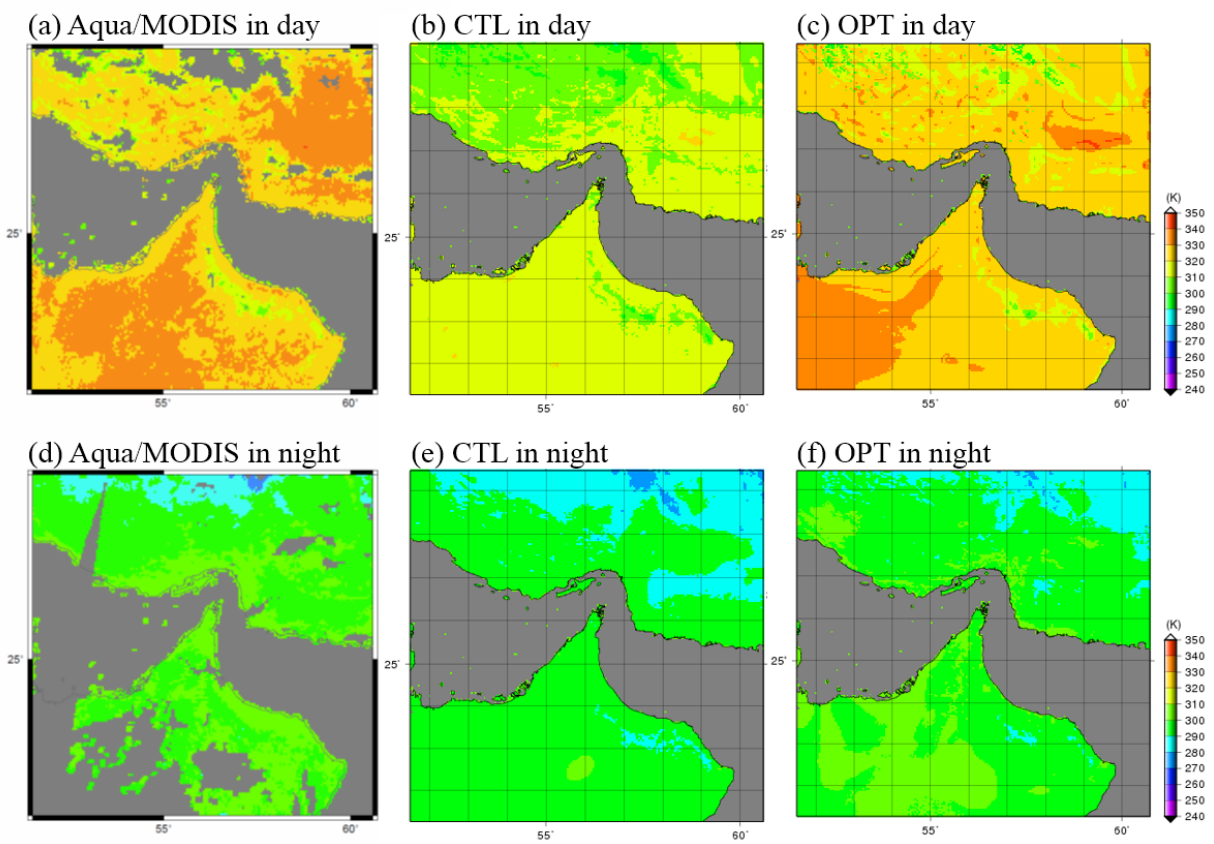

Figure 1. The distribution of land surface temperature by (a) Aqua/MODIS, (b) CReSS CTL, (c) CReSS OPT in 1400 LST 10 September 2015 and (d) Aqua/MODIS, (e) CReSS CTL, (f) CReSS OPT in 0200 LST 11 September 2015.

The role of soil moisture in convective rains in the central region of Mexico

*Edgar Dolores[1], Ernesto Caetano[1]

1. National Autonomous University of Mexico

Precipitation in the central region of Mexico during the summer occurs more frequently during the afternoons. Local surface heat and moisture fluxes represent a major source of convective rainfall in Mexico during the summer, driven by positive evaporation-precipitation feedback. The effects of soil moisture are directly reflected in the limitation of evapotranspiration, affecting the development of the planetary boundary layer and, therefore, the initiation and intensity of convective precipitation. This study presents preliminary analysis of the role of soil moisture in convective rains in central Mexico, for which a methodology for the detection of convective initiations similar to Taylor (2015) has been considered. The results show that the moisture fluxes from the surface influence the development of convection favored by mesoscale circulations at low levels. Initiations are more frequent in regions less humid than their surroundings with the very strong signal during the month of September.

Keywords: soil moisture, convective precipitation, mesoscale

Investigation of soil moisture - afternoon precipitation coupling in summer over the Tibetan Plateau using satellite observations

*xianhong Meng[1], Shihua Lyu[2], Tangtang Zhang[1], Lan Luan[1]

1. NIEER CAS, 2. It Univ.

Coupling between soil moisture and afternoon precipitation in summer over the Tibetan Plateau (TP) was investigated using a previously implemented convective triggering potential (CTP)–humidity index (HI) framework by combing satellite observations, including the Atmospheric Infrared Sounder (AIRS), the merged active and passive soil moisture products from the European Space Agency (ESA), and the U.S. Climate Prediction Center (CPC) merged satellite rainfall product (CMORPH). We found that a main atmosphere controlled region was mainly located in the south and the north edge of the TP, and a main negative feedback of soil moisture –afternoon precipitation was in the west of the TP, where the CTP over this region is relatively larger in most time. In the central and the northeast of the TP, both positive and negative feedbacks coexist, with the main positive feedback was shown in the central TP. In addition, the coupling between soil moisture and afternoon precipitation was affected by the statement of monsoon. With the water vapor transport of the monsoon, it is benefit for the co-existence of both positive and negative feedback converting to the positive feedback predominant.

Keywords: Tibetan Plateau, Soil moisture , afternoon precipitation, Satellite observations

Numerical studies of aerosol impact on warm rain using a cloud resolving model with the super droplet method

Kazuya Moriki[1], Sin-ichiro Shima[2], *Kazuhisa Tsuboki[1]

1. Institute for Space-Earth Environmental Research, Nagoya University, 2. Graduate school of Simulation Studies, University of Hyogo

It is well known aerosols affect formation and behavior of clouds. Albrecht (1989) showed that precipitation amount decreases and the cloud lifetime increases with high number concentration of aerosol while precipitation amount increases and cloud lifetime decreases with smaller number concentration of aerosol. To properly consider the interaction of aerosol and clouds, a detailed numerical simulation based on basic physical laws is necessary. In particular, impacts of aerosol on a very intense rainfall of about 100 mm from a warm rain should be studied using a detailed cloud model with resolving size distribution of particles (e.g. aerosol, cloud, and precipitation droplets). Takahashi et al. (1989) investigated precipitation process over the ocean near the Island of Hawaii using a numerical model with a bin method. They found that the process of drizzle is important for heavy rain formation. In the present study, we studied this type of heavy rain and an aerosol impact on the heavy rain.
We coupled the Super Droplet Method (SDM, Shima 2008; Shima et al., 2009) with the Cloud Resolving Storm Simulator (CReSS; Tsuboki and Sakakibara 2001; 2002) to calculate the detailed behavior of aerosol, cloud, and precipitation particles. The purpose of this study is to investigate the influence of change in aerosol number concentration on the heavy precipitation system. In the warm rain, water vapor deposition process and the collision and coalescence processes are important for the particle glows. These processes are considered precisely in the SDM. The sounding data of atmosphere used for the initial field was provided by Wyoming University.
Results of numerical experiments conducted with different aerosol number concentrations, time evolution of cloud and rain mixing ratio had changed drastically. In addition, particle size distributions and their temporal changes were obtained in the experiments. It showed that precipitation decreased while cloud increased with the increase of initial aerosol number concentration. When the initial number concentration decreased, precipitation amount increased. Particle growth was observed around a radius of 0.3 mm at the beginning of precipitation formation in the low aerosol concentration case. This indicates formation of drizzle particles and their growth. Particle growth was observed around 0.6 mm while the formation of drizzle was suppressed when the precipitation is in mature stage.
The effect of aerosol on cloud lifetime was suggested for warm clouds. When the initial aerosol number concentration is low [10.5], precipitation was remarkably increased (over 50 mm). On the other hand, no precipitation occurred when the aerosol concentration was 100 times as large as the low concentration case. In this case, evaporation of cloud droplets becomes dominant and the lifetime of cloud decreases.

Keywords: aerosol-cloud interaction, super droplet method, cloud-resolving model

REVIEW OF CHARACTERISTICS OF ELECTRIC FIELD PRIOR TO LIGHTNING

*SRICHITRA S[1], SEBIN SABU[1], NORA ELIZABETH JOBY[3,2], PREMLET B[3]

1. TKM COLLEGE OF ENGINEERING KOLLAM, 2. NATIONAL INSTITUTE OF TECHNOLOGY CALICUT, 3. MES KOLLAM

Abstract: A study on the atmospheric electric fields prior to lighting strike was conducted by means of literature survey and data analysis. Study of electric fields is an important tool of lightning research. Electric field mills are used to observe static atmospheric electric fields during fair weather and during storm conditions. Comparisons show significant changes in electric field due to an approaching storm or a thunderstorm. Attempts to comprehend the variations prior to and after a strike has been done by observatories all over and this paper focuses on identifying characteristic changes in atmospheric electric field prior to a lightning strike. The focus is on static electric field variations prior to strike and this points out to the significance of study of electric field varying from a fair weather scenario to generation of bipolar preliminary breakdown pulses which is defined as the dynamic electrical activity inside cloud before strike. It has been explained by means of BIL (Breakdown Intermediate Leader) model as proposed by Clarence and Malan. Simulation experiments done by Carlson and Liang are seen to reproduce the same characteristics as obtained from field data. This paper helps in identifying the characteristic change in atmospheric electric field prior to lightning strike can create a great advantage in lightning prediction.

Keywords: Lightning, Electric field , Prior to strike

AN ANALYSIS OF LIGHTNING RELATED PARAMETERS USING NASA GHRC DATASETS

*Nora Elizabeth Joby[1], Sebin Sabu[2], Sri Chithra S.[2], Abraham Mulamootil[2], Premlet B.[3]

1. National Institute of Technology Calicut, 2. TKM College of Engineering Kollam, 3. MES Kollam

The relationship between lightning occurrences and other weather parameters, especially the static and dynamic electric fields is explored based on weather datasets provided by NASA. The Global Hydrology Research Centre (GHRC) and the Kennedy Space Centre (KSC), NASA provides datasets of observed atmospheric parameters associated with natural disasters like lightning, hurricanes etc.
The lightning occurrence data is collected from LDAR (Lighting Detection and Ranging) datasets from GHRC and KSC and CGSLSS (Cloud-to-Ground Lightning Surveillance System) from KSC. Static electric field measurements are obtained with Electric Field Mills (EFM) from the AGBFM (Advanced Ground Based Field Mills) datasets. Dynamic Electric field measurements are also made using dipole and capacitive antennas, and data made available in the form of K-changes. This data, which is available along with timestamps and co-ordinates, are analysed for interrelationships and coincident occurrences. Changes in other weather parameters associated with lightning are also observed. Finally, the feasibility of using these parameters for lightning prediction and detection is examined.

Keywords: lightning, electric field, datasets, electric field mills, lightning detection and ranging

A study on effect of weather conditions on cellular signal strength

*Sebin Sabu[1]

1. TKM College of Engineering,Kollam,India

Cellphone density is growing at a very fast pace all over the globe.The high phone density among developing nations also posses it as a tool for a societal tool.India has a cellphone density of nearly billion and its fast growing too.In this study we are analyzing the effects of weather parameters on cellular signal strength, Rainfall and Temperature are considered in this study.Changing rainfall patterns are causing a heavy toll on India. we study the effects of rainfall and atmospheric temperature over a region on the cellular signal strength quality at the user endl. RSSI (Received Signal Strength Indicator) is a measurement of the power present in a received radio signal. Rainfall can cause natural interference over transmitting signals (radio waves) in microwave links. We use SignalStrength Android Application Programming Interface Keys popularly known as APIs to get real-time RSSI readings from smartphones. Rainfall intensity measurements are made by rain gauges and temperature measurements are made by weather station. It has been concluded from the analysis that there is an effect of weather parameters on cellular signal strength measured at the user end.This study raises the potential of using Signal Strength measurements as high-resolution weather analysis over a region.Growing concerns of climatic change can be addressed by improved weather analysis and prediction , this study can be the first step towards weather analysis using cellular signal strength measurement.

Keywords: Rainfall, ClimaticChange, Cellularsignalstrength

Bacterial communities in rainwater associated with different synoptic weather systems at a site in Kumamoto, southwestern Japan

*Wei Hu[1], Kotaro Murata[1], Daizhou Zhang[1]

1. Prefectural University of Kumamoto

Bacteria substantially exist in rainwater and can be disseminated by rain from the atmosphere to the earth's surfaces, on the one hand driving the development and evolution of ecosystems, but on the other hand causing great concern for their potential negative impacts on environments and public health. However, studies of bacterial communities in rainwater, especially those dependent on different synoptic weather systems, are largely lacking. In this study, rainwater samples were collected at a site (32.806°N, 130.766°E) in Kumamoto, southwestern Japan. Samples from four cases of each rain types of cyclone-, Meiyu (plum rain) front- and non-Meiyu stationary front-associated rains, and samples from three cases of typhoon-influenced rains were analyzed. The abundance of bacteria in these rainwater samples was 0.8–4.6×10^4 cells ml^{-1}, and the viability (the ratio of the abundance of bacteria with intact cell membranes to that of total bacteria) was 66–91%. Bacteria in the rainwater of cyclones, in accompany with the intrusion of continental air, were characterized by high abundance and low viability. In other cases of rain, when clouds were significantly affected by marine air, the concentration of bacteria was low and the viability was high. Bacterial communities in rainwater, identified by using 16S rRNA gene sequencing, were dominated by *Proteobacteria*, *Cyanobacteria*, *Bacteroidetes*, *Firmicutes* and *Actinobacteria* phyla. Diverse bacterial communities were appeared in four types of rainwater samples, and about half of the phyla (17 out of 35) were common in different types of rainwater. The presence of ice nucleation-active bacteria, such as the members of the genera *Pseudomonas*, *Xanthomonas* and *Erwinia*, indicate bacteria as nuclei in clouds were a potential source of bacteria in rainwater. Marine bacterial taxa, e.g., *Pseudoalteromonas*, *Synechococcus* and *Marinobacter*, were detected in rainwater samples, showing that marine bacteria were dispersed via cloud or rainwater.

Keywords: Bacteria, Community composition, 16S rRNA sequencing, Rainwater, Synoptic weather