Transport of suspended sea spray droplets intensifying tropical cyclones

*Kosuke Ito[1]

1. University of the Ryukyus

A conventional bulk model for the surface layer assumes that the evaporation, in which liquid water turn into water vapor, depends on the local surface humidity and wind speed. In reality, sea spray droplets can stay for a few minutes to evaporate under the violent wind condition beneath tropical cyclones (TCs), and travel several kilometers toward the center of a TC. Although this transport has been neglected so far in numerical models, it can be one of the missing processes that intensify the vortex because the intensity of the TC relies on the inward accumulation of water vapor primarily. Here, a set of ensemble simulations with a simple atmosphere-ocean coupled model for intense TCs are conducted to verify this hypothesis with (i) no sea spray (NoSS), (ii) sea spray evaporating locally (SS_NoTrans), and (iii) sea spray having the duration of flight (SS_Trans). On average, steady-state TCs in SS_Trans are more intense than those in NoSS and SS_NoTrans. The difference between SS_NoTrans and SS_Trans is 25 hPa and 12 m/s and statistically significant. As expected, this intensification is consistent with the inward accumulation of water vapor that brings the inward transport of absolute angular momentum.

Keywords: Tropical cyclone, Sea spray droplets

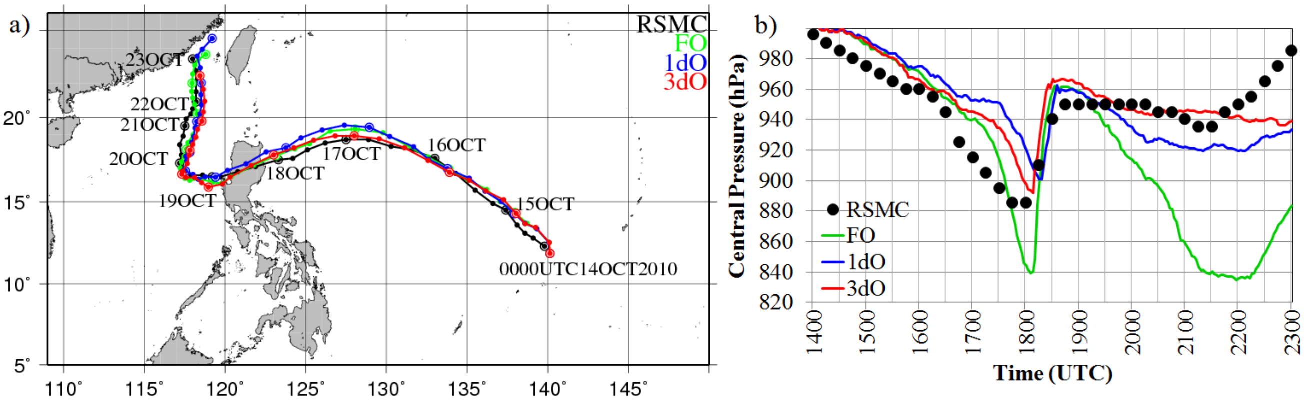
Atmosphere-Ocean Coupling Effect on Typhoon Megi (2010)

*Sachie Kanada[1], Satoki Tsujino[1], Hidenori AIKI[1,2], Mayumi K. Yoshioka[1], Yasumasa Miyazawa[2], Kazuhisa Tsuboki[1], Takayabu Izuru[3]

1. Institute for Space-Earth Environmental Research, Nagoya University, 2. Japan Agency for Marine-Earth Science and Technology, 3. Meteorological Research Institute/Japan Meteorological Agency

Typhoon Megi (2010) was one of the most intense tropical cyclones and the only typhoon that attained the minimum central pressure below 890 hPa in the decades after 1984. To investigate the ocean response to Typhoon Megi and the impact of sea surface temperature (SST) on Typhoon Megi, we used a high-resolution coupled atmosphere–ocean regional model, in which the atmospheric model is CReSS (Cloud Resolving Storm Simulator; Tsuboki and Sakakibara 2002) and the ocean model is NHOES (Non-Hydrostatic Ocean model for the Earth Simulator; Aiki et al. 2006, 2011), and the coupled model is referred to as CReSS–NHOES (Aiki et al. 2015). Three sensitivity experiments were conducted: two experiments using CReSS (hereafter FO and 1dO) and one experiment using CReSS-NHOES (hereafter 3dO). A time-fixed SST was used in the FO experiment. A simple vertical diffusion model for the ocean upper layer temperature (the so-called 1D-slab ocean model) was used in the 1dO experiment. The full three-dimensional structure of ocean was simulated in the 3dO experiment. The computational domain is 5°N –25.5°N and 109°E –150°E (Figure 1). The domain consists of 2048x1024 grid points, and the horizontal grid size of all models is 0.02° longitude by 0.02° latitude. All experiments started at 0000 UTC 14 October 2010. The integration time was 9 days.
Typhoon Megi was formed in 14 October and traveled westward in relatively large translation speed faster than 5 m s^{-1} as intensifying gradually (Figure 1a). Around 0000 UTC 17 October 2010, the storm started to intensify rapidly (hereafter, RI) and attained the minimum central pressure of 885 hPa at 1800 UTC 17 October 2010. Although all experiments represent the relatively accurate tracks over the Philippine Sea, the intensity of simulated storm differs significantly among the experiments; the minimum central pressure of the storms are 839, 901, and 892 hPa in the FO, 1dO and 3dO experiments, respectively (Figure 1b). Only the 3dO experiment represents reasonably the evolution and maximum intensity of Typhoon Megi. The simulated results reveal clear differences in the SST-cooling patterns in the vicinity of Typhoon Megi between the 1dO and 3dO experiments. In addition, the impacts of ocean responses to the storm are the most evident during the RI phase. Detailed analysis of the storm inner-core, defined by the region within a radius of 100 km, indicates that the convective activity around the storm center and onset of the RI phase could be modulated by the radial profiles of SST beneath the storm center.
Acknowledgments. This study was supported by the Ministry of Education, Culture, Sports, Science and Technology of Japan under the framework of the Sousei Program and by the Japan Society for the Promotion of Science, JSPS KAKENHI grant number 26400466.
Figure caption.
Figure 1. Six-hourly tracks (a) and central pressure (b) of Typhoon Megi from RSMC best-track dataset (black) and in the FO (green), 1dO (blue) and 3dO (red) simulations between 0000 UTC 14 October 2010 to 0000 UTC 23 October 2010. Large circles in (a) indicate the locations at 0000 UTC.

Keywords: Typhoon, Atmosphere-Ocean Coupling Model


a)
RSMC
FO
1dO
3dO
23OCT
22OCT
21OCT
20OCT
19OCT
18OCT
17OCT
16OCT
15OCT
0000UTC14OCT2010
b)
Central Pressure (hPa)
Time (UTC)
RSMC
FO
1dO
3dO

The Development of the Ensemble Based Typhoon Track Forecast Technique

Ling-Feng Hsiao[1], *CHIN-CHENG TSAI[1], Jia-Chyi Liou[1], Ming-En Hsieh[1], Der-Song Chen[2], Delia Yen-Chu Chen[1], Chou-Chun Chiang[1], Yu-Chun Chen[1], Tien-Chiang Yeh[2]

1. Taiwan Typhoon and Flood Research Institute, Taipei, Taiwan, 2. Central Weather Bureau, Taipei, Taiwan

The purpose of this study is effective in improving the ensemble technique for typhoon track forecasts using multi-model ensembles. The models from global (ECMWF, NCEP) and regional ensembles (CWB EPS, TTFRI EPS) were applied to develop the ensemble based technique. A selective ensemble technique is based on the 12-h typhoon track distance from the CWB (Taiwan’s Central Weather Bureau) best-track for 2014-2015. The results show that the superior performance of ensemble based technique to all ensemble means by reducing 12.1%, 6%, 4.1% track errors of 24-, 48- and 72-h forecast, respectively. We also applied this technique for tropical cyclones forecast over the Western North Pacific Ocean in 2016 . The detailed analyses on ensemble technique and individual ensemble models will be presented in the conference.

How much rainfall extremes associated with tropical cyclones can be attributable to anthropogenic influences?

*Cheng-Ta Chen[1], Shih-How Lo[1], Chung-Chieh Wang[1], Kazuhisa Tsuboki[2]

1. National Taiwan Normal University, 2. Nagoya University

The rainfall extremes and strong winds associated with tropical cyclones lead to significant damages and lost to where they make landfalling. Upward trend in term of financial lost was indicated for the past few decades from the report of major reinsurance firms. Whether the past anthropogenic warming played a significant role in such extreme event and their changes remained very controversial. On one hand, people argue it’ s nearly impossible to attribute an individual extreme event to global warming. On the other hand, the increase of heavy rainfall is consistent with the expected effects of climate change on tropical cyclone. To diagnose possible anthropogenic contributions to the odds of heavy rainfall associated with tropical cyclone, we adapt an existing event attribution framework of modeling a ‘world that was’ and comparing it to a modeled ‘world that might have been’ for that same time but for the absence of historical anthropogenic drivers of climate. The analysis was applied to Typhoon Morakot (2009) as an example. There was more than 2000 mm rainfall occurred over southern Taiwan when a category 1 Typhoon Morakot pass through Taiwan in early August 2009. Entire village and hundred of people were buried by massive mudslides induced by record-breaking precipitation. One limitation for applying such approach to high-impact weather system is that it will require models capable of capturing the essential processes lead to the studied extremes. Using a cloud system resolving model that can properly simulate the complicated interactions between tropical cyclone, large-scale background, topography, we first perform the ensemble ‘world that was’ simulations forced by the high resolution ECMWF YOTC analysis. We then re-simulate, having adjusted the analysis to ‘world that might have been conditions’ by removing the regional atmospheric and oceanic forcing due to human influences estimated from the CMIP5 model ensemble mean conditions between all forcing and natural forcing only historical runs. Thus our findings are highly conditional on the driving analysis and adjustments therein, but the setup allows us to elucidate possible contribution of anthropogenic forcing to changes in the likelihood of heavy rainfall associated tropical cyclone.

Keywords: Extreme Event Attribution, Climate Change

ENSO control on Arabian Sea tropical cyclones in a changing climate

*vineet kumar singh[1], roxy mathew Koll[1]

1. Indian Institute of Tropical meteorology

Tropical cyclones rarely occur in the Arabian Sea during the pre-monsoon month of May. However, our analysis reveals that there has been a significant increase in the number of cyclones in this region during the recent years. While the first half of the satellite era (1979-1996) saw a single cyclone, the second half (1997-2014) witnessed an increase of up to six cyclones. We investigate the mechanism and largescale conditions regulating the changes in cyclonic activity, and explore if this increase in the frequency of cyclones will continue into the future. Our analysis using observations and CMIP5 model simulations suggest an ENSO control on the pre-monsoon tropical cyclones in the Arabian Sea. We find that La Niña-like conditions during the recent years have resulted in an anomalous cyclonic circulation and reduced vertical wind shear in the Arabian Sea via a modification of the Walker circulation, thereby providing favorable conditions for cyclone genesis and development. This anomalous cyclonic circulation associated with the La Niña conditions are observed throughout the middle troposphere (700-400 hPa). Nevertheless, CMIP5 model projections suggest a 50% reduction in the number of tropical cyclones in the future (2051-2100), as compared to the recent decades (1951-2000). Our analysis shows that this decrease in cyclones is a response to the positive skewness towards El Niño like conditions in the future, which results in an anomalous anticyclonic circulation in the Arabian Sea along with increase in wind shear and decrease in relative humidity inhibiting the formation of cyclones in the region.

Keywords: Pre-monsoon cyclones, ENSO, climate change

Impacts of Boreal Summer Intraseasonal Oscillation on the Western North Pacific Typhoons and Rainfall in Taiwan

*Chih-wen Hung[1]

1. Department of Geography, National Taiwan Normal University

This study discusses the boreal summer intraseasonal oscillation (BSISO) impact on the western North Pacific (WNP) typhoons and the summer rainfall in Taiwan. The real time BSISO1 and BISISO2 indices are created using the first two and the third and fourth principal components of the multivariate empirical orthogonal function analysis, based on outgoing long-wave radiation and zonal wind at 850 hPa from Lee et al. (2013). The results show that heavy rainfall in Taiwan and the associated WNP typhoon frequency patterns are closely related to the 10 - 30 days BSISO2 phases during the typhoon season (July - October). Taiwan has larger rainfall during BSISO2 phases 3, 4, and 5 when the major BSISO2 convection moves northwestward from the Philippine Sea to the Taiwan area. During phases 3 and 4 the anomalous low-level cyclonic flow and the increased typhoon frequency directly result in larger rainfall in Taiwan. For the phase 5, enhanced low-level southwesterly flow which transports the moisture to Taiwan is responsible for more summer rainfall in Taiwan.

Keywords: Typhoon, BSISO, Taiwan

A Numerical Study of Outer Rainband Formation in a Sheared Tropical Cyclone

*Qingqing Li[1], Yuqing Wang[2], Yihong Duan[3]

1. Nanjing University of Information Science and Technology, 2. University of Hawaii at Manoa, 3. Chinese Academy of Meteorological Sciences

The dynamical process of outer rainband formation in a sheared tropical cyclone (TC) is examined in this study using the fully-compressible, nonhydrostatic TC model. After the easterly vertical wind shear of 10 m s^{-1} was imposed upon an intensifying strong TC, an outer rainband characterized by a wavenumber-1 structure formed as a typical principal rainband downshear. Further analysis indicates that the outer rainband formation was closely connected to the activity of the inner rainband previously formed downshear. Moving radially outward, the inner rainband tended to be filamented due to the strong radial gradient of angular velocity. As the inner rainband approached the outer boundary of the inner core, convection in its middle and upwind segments reinvigorated and nascent convective cells formed upwind of the rainband, caused mainly by the decreased filamentation and stabilization. Subsequently, the rainband reorganized into a typical outer rainband. Three different scenarios are found to be responsible for the outer rainband formation from downshear inner rainbands. The first is the outer rainband forming from an inner rainband downshear as a sheared vortex Rossby wave. The second is the outer rainband forming directly from a single deformation-induced inner rainband. The third is the outer rainband developing from an inner rainband downshear organized from a blend and merger of inner rainbands that were initiated from locally deformed convection upshear right.

Keywords: Tropical cyclone, Outer rainband, Vertical wind shear

High-Resolution Simulation of Super Typhoon Nepartak (2016)

*Hao Jin[1], Yi Jin[1], James D. Doyle[1]

1. Naval Research Laboratory

Typhoon Nepartak was the first category 5 tropical cyclone of 2016 and had significant social impacts. It formed as a tropical depression on July 2 near Guam in the western Pacific Ocean and strengthened to tropical storm the following day. It had a rapid intensification (RI) with the decrease in minimum sea-level pressure (MSLP) from 970 hPa at 00Z 5 July to 910 hPa at 06Z July 6, followed by a secondary eyewall formation (SEF), as shown from satellite observation before making landfall in Taiwan on July 8. The storm hammered Taiwan with 135 knots and a huge torrential rain, causing three deaths and 142 injuries as reported. It made second landfall in Fujian, China, on July 9 with a 65 knots wind speed, causing more than 188 deaths or missing and the most devastating flooding since 1998. The super typhoon Nepartak is a very interesting, while challenge case to study.

The high resolution simulations are conducted using the Coupled Ocean/Atmosphere Mesoscale Prediction System –Tropical Cyclone (COAMPS-TC) to understand the RI, SEF, eyewall replacement cycle (ERC) processes, and the associated heavy rainfall. The detailed diagnostics of the inner-core eyewall structures and the associated strong convection during RI and ERC will be performed to examine and understand the dynamics and physics. Detailed results will be presented at the conference.

Keywords: Tropical Cyclone, Typhoon, Rapid intensification

Global cloud-permitting simulations of Typhoon Fengshen (2008)

*Tomoe Nasuno[1], Hiroyuki Yamada[2], Masuo Nakano[1], Hisayuki Kubota[3], Masahiro Sawada[4], Ryuji Yoshida[5]

1. Japan Agency for Marine-Earth Science and Technology, 2. Faculty of Science, University of the Ryukyus, 3. Atmosphere and Ocean Research Institute, The University of Tokyo, 4. Meteorological Research Institute, 5. RIKEN, Advanced Institute for Computational Science

Large-scale fields and inner-core processes relevant to the formation and intensification of Typhoon Fengshen (2008) were examined by simulations using Nonhydrostatic Icosahedral Atmospheric Model (NICAM; Satoh et al. 2014) with a cloud-permitting (3.5-km mesh) resolution (Nasuno et al. 2016). Fengshen was formed in mid-June during the onset of the WNP monsoon and the active phase of a boreal summer intraseasonal oscillation (BSISO) event. The TC genesis was preceded by the formation of a lower tropospheric large-scale gyre associated with enhanced equatorial westerlies and a middle tropospheric wave trough intruding above the gyre.

To understand the impact of atmospheric conditions and the convective effects on the TC environment and precursor disturbance, five simulations were performed by varying the initial data (interpolated using ECMWF YOTC or NCEP FNL analysis) and cloud microphysics settings.

In three simulations initialized using the ECMWF YOTC, a middle tropospheric trough developed within a few days following a large-scale latent heat release, which enabled the successive occurrence of deep convective events within the 50-km radius of the incipient disturbance and subsequent TC formation. In the run with weaker latent heating in the lower troposphere, the trough was weak and TC formation was significantly delayed.

In the run initialized using the NCEP FNL, where the latent heat release averaged over the entre simulation was the same as its ECMWF YOTC counterpart, neither the trough nor a TC developed, lacking the collocation between the latent heat release and large-scale gyre in the early period. Under the vertical wind shear increasing poleward, it was critical for the incipient vortex to experience upward penetration before it moved farther northward.

These results indicate that the superposition of large-scale disturbances in the lower and middle troposphere and their linkage through convective enhancement played an important role in the genesis of Fengshen by preconditioning the establishment of a deep upright inner core. Another implication is that the modeled TC genesis is sensitive to difference in initial environment under a strong vertical shear like in this case.

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Keywords: Tropical cyclogenesis, global nonhydrostatic model, cloud-permitting simulation

Inner Core Structure of Hurricane Patricia Observed During TCI-2015

*Michael M Bell[1], Jonathan Martinez[1], James D Doyle[2], Robert F Rogers[3]

1. Colorado State University, 2. Naval Research Laboratory, 3. NOAA/AOML Hurricane Research Division

Hurricane Patricia (2015) rapidly intensified from a tropical storm to an estimated 185 kt intensity in 36 hours, making it the strongest tropical cyclone in the Western Hemisphere on record. Four high-altitude research flights with the NASA WB-57 aircraft were conducted into Patricia as part of the Office of Naval Research (ONR) sponsored Tropical Cyclone Intensity (TCI) field experiment from 20 to 23 October. The WB-57 was equipped with a new high-density sounding system (HDSS), enabling full-tropospheric profiling of temperature, humidity, and winds throughout Patricia's inner and outer core. A total of 257 dropsondes were released from the HDSS over the four day intensive observing period, spanning the development from a tropical depression to category 5 intensity. Doppler radar and dropsonde observations were obtained by the NOAA WP-3D aircraft reconnaissance from 21 to 23 October, allowing for complementary observations of the precipitation and kinematic structure during the rapid intensification period. Integrated kinematic and thermodynamic analyses of the full-tropospheric structure derived from dropsonde, radar, in situ, and satellite observations using a variational spline-based mesoscale analysis technique will be presented. The high-resolution observational analyses allow for calculation of axisymmetric potential vorticity (PV) during the extreme rapid intensification period. These new calculations reveal a compact inner core with an intensifying PV tower that breaks down just prior to landfall. The dynamics of Patricia’ s rapid intensification and weakening inferred from the observations will be discussed.

Keywords: Tropical Cyclone, Hurricane Patricia, Field Observations, TCI-15

Three-dimensional structure of Typhoon Mindulle (2016) observed by phased array radar

*Toru Adachi[1], Kusunoki Kenichi[1], Satoru Yoshida[1], Udai Shimada[2]

1. Meteorological Satellite and Observation System Research Department, Meteorological Research Institute, 2. Typhoon Research Department, Meteorological Research Institute

Since 2015, Meteorological Research Institute has been operating a phased array radar (PAR, hereafter) which is a modern technology that performs high-speed volumetric scan in 10–30 seconds. On 22 August 2016, Typhoon Mindulle made landfall near Tateyama, Chiba and moved north across the Kanto Plain. We therefore succeeded in observing a fine-scale three-dimensional structure of Mindulle as it passed close to the PAR observation site in Tsukuba, Ibaraki. The obtained data show that the inner region of Mindulle consisted of several spiral rainbands located around the center of circulating winds, in which many convection cells with 20-dBZ echo top altitudes of 5–8 km were embedded. We derived wind fields by carrying out a synthesis analysis of the Doppler velocity data obtained by PAR and a nearby operational radar. The low-level synthesis data show a strongly circulating wind region with a velocity of >25 ms^{-1} which originally existed at several tens of kilometers from the center. The radius of the strong winds then monotonically decreased to <10 km in 20–30 minutes, implying a contraction of circulating winds presumably caused by a surface frictional force. Meanwhile, the PAR reflectivity data exhibited rapidly developing convection cells in the innermost rainband, with 20-dBZ echo top altitude increasing from ~8 km to 14–16 km. This convection intensification was also detected by a meteorological satellite (Himawari-8) as a signature of brightness temperature lowering from 205 K to 199 K around the region in question. These results suggest a frictionally forced updraft occurring in the inner region of Mindulle during its decaying stage. It is apparent that PAR finely resolves three-dimensional structure of typhoon and detects signatures of underlying physical processes.

Keywords: typhoon, three-dimensional structure, phased array radar

Doppler radar analysis of intensity and inner-core structure of Typhoon Haiyan (2013) near landfall

*Udai Shimada[1], Hisayuki KUBOTA[2], Hiroyuki Yamada[3], Esperanza Cayanan[4], Flaviana Hilario[4]

1. Meteorological Research Institute, 2. Atmosphere and Ocean Research Institute, The University of Tokyo, 3. University of the Ryukyus, 4. Philippine Atmospheric, Geophysical and Astronomical Services Administration

Intensity and inner-core structure of the second most intense tropical cyclone in the world since 1979, Typhoon Haiyan (2013), were examined using ground-based Doppler radar data observed by the Guiuan radar over about 2.5 h immediately before landfall on Leyte Island in the Philippines. The wind fields of Haiyan from 2- to 6-km altitude were retrieved by the ground-based velocity track display (GBVTD) technique from the Doppler velocity data. The GBVTD-retrieved maximum wind speed reached up to 101 m s^{-1} at 4-km altitude on the right side of the track. A relatively fast moving speed of Haiyan, about 11 m s^{-1}, largely contributed to the increase in the maximum wind speed. Azimuthal mean tangential wind increased with height from 2- to 5-km and a local maximum lay at 5-km altitude with a value of 86 m s^{-1}. The central pressure was estimated at 908 hPa with uncertainty of ±5 hPa by using the GBVTD-retrieved tangential wind and by assuming the gradient wind balance. The radius of maximum radar reflectivity was located at about 23-km radius from the center, a few kilometers inside the radius of maximum wind. The reflectivity structure was highly asymmetric at 3-km altitude and above, and was almost axisymmetric below 3-km altitude in the presence of relatively weak vertical shear (~4 m s^{-1}). The axis of the eyewall ring tilted to the downshear direction. In addition, vortex precession with a period of about 75 min was analyzed.

Keywords: tropical cyclone, Doppler radar

Modeling of the Influence of Saharan Dust and Other Aerosols on Hurricane Nadine (2012) During the NASA Hurricane and Severe Storm Sentinel (HS3) Investigation

*Jainn J Shi[1,2], Scott A Braun[1], Zhining Tao[1], Toshihisa Matsui[1], Christa Peters-Lidard[1]

1. NASA Goddard Space Flight Center, 2. GESTAR/Morgan State University

The Hurricane and Severe Storm Sentinel (HS3) was a multiyear field campaign (2012-14) with the goal of improving understanding of hurricane formation and intensity change and determining the extent to which the Saharan air layer (SAL) impacts storm intensification. This talk will focus on simulations of the early stages of Hurricane Nadine (2012), which interacted with the SAL and never intensified beyond a minimal hurricane. Given the complexity of aerosol effects on cloud microphysics and radiation and their subsequent effects on deep convective clouds, there is a need to assess the combined aerosol effects of microphysics and radiation. We use the Goddard Space Flight Center version of the Weather Research and Forecasting model with interactive aerosol-cloud-radiation physics to study the influence of the SAL and other aerosols (sea salt and black/organic carbon) on Nadine via a series of model sensitivity runs. We also use three 30-member ensemble simulations of Nadine, one ensemble with aerosols of all types (dust, pollution, biomass burning, sea salt), one with dust only, and one without aerosol interactions. The role of the SAL is partly assessed through a correlation analysis relating relevant fields (temperature, humidity, winds) to the intensity of the simulated storms averaged over the final three days of simulation. The impacts of Saharan dust and other aerosols are evaluated by looking at the differences between the control (no aerosol) and either the all-aerosol or dust-only ensemble members.

Keywords: tropical cyclone, aerosol-cloud-radaition interaction, numerical modeling

Is the State of the Air-sea Interface a Factor in Rapid Intensification and Rapid Decline of Tropical Cyclones?

*Alexander Soloviev[1,3], Roger Lukas[2], Mark A Donelan[3], Brian K Haus[3], Isaac Ginis[4]

1. Nova Southeastern University, 2. University of Hawaii, 3. University of Miami, 4. University of Rhode Island

Some of tropical storms undergo spectacular rapid intensification and rapid decline. These processes have not yet been completely understood and still are a serious challenge in the tropical storm intensity prediction. Important physics of atmospheric, oceanic, and interfacial components are not yet well understood and implemented in tropical cyclone forecast models. Specific ambient environmental conditions including the ocean thermal and salinity structure and internal vortex dynamics (e.g., eyewall replacement cycle) have been considered by hurricane researchers among the factors favorable for rapid storm intensification. Here, we pursue the hypothesis that the state of the sea surface is another factor in rapid storm intensification and the rapid storm decline. In a laboratory experiment and coordinated numerical simulation, we have found that the air-water interface under hurricane force wind may develop Kelvin-Helmholtz shear instability. The resulting two-phase environment suppresses short waves and alters the aerodynamic properties of the sea surface (Soloviev et al. 2014). The unified wave-form and two-phase drag parameterization model shows the well-known increase of the drag coefficient (C_d) with wind speed, up to ~30 m/s. The negative slope of the Cd wind-speed dependence from approximately 40 m/s to 60 m/s favors rapid storm intensification.Around 60 m/s, one version of the new parameterization shows a local minimum ("sweet spot") of C_d. However, the positive slope of the C_d wind-speed dependence above approximately 60 m/s favors rapid storm decline. The storms that go above category 3 may have tendency to rapidly decline, when they enter areas of lower ocean heat content or less favorable atmospheric conditions.

Soloviev, A., R. Lukas, M. Donelan, B. Haus, and I. Ginis. The air-sea interface and surface stress under tropical cyclones. *Nature Scientific Reports* 4, 5306 (2014).

Keywords: Air-sea Interface, Tropical Cyclone, Rapid Intensification, Rapid Decline

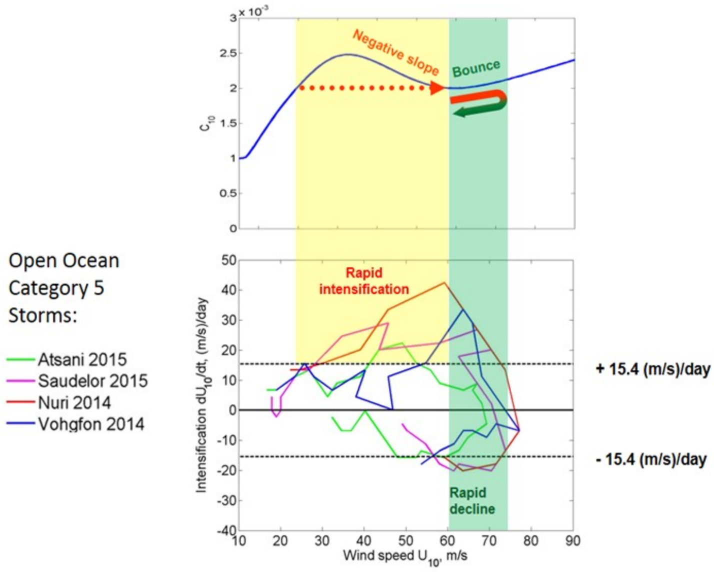

Figure. Rapid intensification and rapid decline of some 2014-2015 Category 5 Tropical Cyclones. Top: The air-sea drag coefficient as a function of wind speed; (bottom) the rate of wind speed change DU_{10}/Dt in (m/s)/day as a function of wind speed U_{10} in m/s. Rapid intensification is defined as a tropical cyclone intensity increase of at least 15.4 m/s in 24 hours; this level is shown by a dashed line U_{10} = 15.4 m/s. Rapid decay is defined as a tropical cyclone intensity decrease of at least 15.4 m/s in 24 hours; this level is shown by a dashed line U_{10} = -15.4 m/s.

Drag coefficient comparisons between observed and model simulated directional wave spectra under hurricane conditions

*Yalin Fan[1]

1. Naval Research Laboratory

Yalin Fan and Erick Rogers, U.S. Naval Research Laboratory, Stennis Space Center, MS 39529

In this study, Donelan et al. (2006) source function is used to calculate drag coefficients from both the scanning radar altimeter (SRA) measured two dimensional wave spectra obtained during hurricane Ivan in 2004 and the WAVEWATCH III simulated wave spectra. The drag coefficients disagree between the SRA and model spectra mainly in the right/left rear quadrant of the hurricane where the observed spectra appear to be bimodal while the model spectra are single peaked with more energy in the swell frequencies and less energy in the wind sea frequencies. These results suggest that WAVEWATCH III is currently not capable of providing sensible stress calculations in the rear quadrants of the hurricane.

Keywords: air-sea interaction, hurricane prediction, surface gravity waves

Tropical Cyclone-Ocean Interaction and Global Warming

*I-I Lin[1], Ping Huang[2], Chun-An Shi[1], Chun-Chi Lien[1]

1. Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan, 2. Center for Monsoon System Research, Chinese Academy of Sciences, Beijing, China

Tropical cyclones (TCs, i.e., hurricanes and typhoons) are among the most damaging natural disasters on earth. Its possible change under future global warming condition in the coming century is undoubtedly of critical importance to the humankind. There is much concern that global warming can lead to increase in TC intensity and thus its destructiveness, and this topic is one of the most active current research topics in the international community. In 2015, Huang, Lin et al. (Nature Commu.) discovered that if consider the contribution from subsurface ocean, there is a suppression effect to slow down the rapid TC intensity increase. Under global warming, though both ocean surface temperature (SST) and subsurface ocean warms, subsurface ocean warms slower than SST and increases upper ocean thermal gradient. As a result, the TC-ocean coupling effect is stronger under global warming and can contribute to suppression of TC intensity. This idea was soon confirmed by Emanuel (J. Climate 2015) and he reported that this sharpening can contribute to ~ 15% drop in category 4 and 5 TC occurrences and 13% drop in TC destructive potential (the power dissipation index, PDI), as compared to the projection without considering the ocean subsurface effect. This presentation will present latest development in this new field, including differences in this subsurface suppressive effect to future TC intensification over different regions.

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Intensification of landfalling typhoons over the northwest Pacific since the late 1970s

*Wei Mei[1,2], Shang-Ping Xie[2]

1. Department of Marine Sciences, University of North Carolina at Chapel Hill, 2. Scripps Institution of Oceanography, University of California at San Diego

Intensity changes in landfalling typhoons are of great concern to East and Southeast Asian countries. Regional changes in typhoon intensity, however, are poorly known owing to inconsistencies among different data sets. Here, we apply cluster analysis to bias-corrected data and show that, over the past 37 years, typhoons that strike East and Southeast Asia have intensified by 12–15%, with the proportion of storms of categories 4 and 5 having doubled or even tripled. In contrast, typhoons that stay over the open ocean have experienced only modest changes. These regional changes are consistent between operational data sets. To identify the physical mechanisms, we decompose intensity changes into contributions from intensification rate and intensification duration. We find that the increased intensity of landfalling typhoons is due to strengthened intensification rates, which in turn are tied to locally enhanced ocean surface warming on the rim of East and Southeast Asia. The projected ocean surface warming pattern under increasing greenhouse gas forcing suggests that typhoons striking eastern mainland China, Taiwan, Korea and Japan will intensify further. Given disproportionate damages by intense typhoons, this represents a heightened threat to people and properties in the region.

Keywords: Typhoons, Intensity change, Climate variability and change

Recovery of tropical cyclone activity in the western north Pacific in 1950

*Hisayuki Kubota[1]

1. The University of Tokyo

Tropical cyclone (TC) activity is influenced by the background atmosphere and ocean conditions; El Niño Southern Oscillation (ENSO), Madden-Julian Oscillation (MJO), Pacific-Japan pattern etc. Those have impacts to modulate the genesis numbers and locations, tracks and intensities of the TCs. In 2016, monsoon gyre was formed in the south of Japan in August. Seven TCs were generated in and around the monsoon gyre and four of them were landed mainland Japan.
Historical TC track data have been collected from various bulletins stored in US, Japan, Philippines, China and other countries back to late 19th century through the “data rescue” activity. The TC landfall numbers in mainland Japan were analyzed using historical TC track data and station data from 1900. TC is defined when it was generated south of Japan and measured less than 1000hPa near the cyclone. Landfall is defined when the minimum sea level pressure measured less than 1000 hPa near the landfall point and the right/left side station measured clockwise/anticlockwise wind direction change during the passage in Japan.
In 1950, ten TCs were landed Japan which was the maximum annual landfall numbers from 1900. Among ten, six of the TCs were landed in August. In this study, the background atmospheric condition and TC activities in August 1950 are recovered and discussed using the historical documents and data. Monsoon gyre was formed in the south of Japan in August 1950. Numbers of small TCs were formed in and around the monsoon gyre. On the other hand, the predecessor of Joint Typhoon Warning Center detected two TCs in August.

Keywords: tropical cyclone, data rescue, monsoon gyre

