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TROPICAL CYCLONE STRUCTURE (TCS08) FIELD EXPERIMENT IN THE WESTERN NORTH PACIFIC DURING 2008

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1. INTRODUCTION

The Office of Naval Research in conjunction with the Naval Research Laboratory and the U. S. Air Force is sponsoring a major field experiment called the Tropical Cyclone Structure (TCS08) during August and September 2008. The three scientific foci of the TCS08 field experiment are tropical cyclone formation, structure change including intensity changes, and the processes leading to recurvature. This TCS08 will then blend into the THORPEX-Pacific Asian Campaign (T-PARC) that focuses on targeting observations for predicting the recurvature, tropical cyclone structure and processes leading to extratropical transition, and the downstream impacts across the Pacific Ocean to North America and beyond (Parsons et al; Paper 7C.7). Whereas the primary sponsor of T-PARC is the National Science Foundation, many European and Asian nations are integral partners in the T-PARC because of the common interests in tropical cyclone recurvature, extratropical transition, and the downstream impacts. Since Taiwan and Australia are cooperating with TCS08, the combination of TCS08 and T-PARC is a large, multi-national field experiment that will address the entire life cycle of western North Pacific tropical cyclones from formation stage to extratropical transition and downstream impacts.

A summary view of the TCS08 and T-PARC field experiments for the “perfect storm” scenario is given in Fig. 1. The special, deployable observing systems that will be involved include: U. S. Air Force 53rd Weather Squadron C-130J reconnaissance aircraft; Naval Research Laboratory (NRL) P-3 with ELDORA radar and a Doppler wind lidar; the German DLR Falcon; the Taiwan DOTSTAR aircraft; and the Driftsonde. Special satellite observations, including some hourly 15-minute rapid scans for 20 hours by the Japan Meteorological Agency MTSAT-2, are an integral part of the field experiments. A key role of the WC-130 is to obtain large numbers of intensity and wind structure measurements that are necessary to evaluate satellite-based techniques that are essentially unvalidated in the western North Pacific since the discontinuation of aircraft reconnaissance in 1987.

Given the broad scope of the TCS08 and the many participants, it will not be possible to cover many aspects during the presentation, or even in this preprint. A summary of the observational platforms, aircraft flight hours, and U. S. sponsoring agencies for TCS08 is given in Elsberry et al. (2008) (www.ofcm.gov/homepage/text/spc_proj/ihc.html). Thus, the specific focus of this preprint is to give an overview of the presentations and posters at this conference that provide some of the scientific basis, some of the modeling and data assimilation, some preliminary analysis studies, and some of the new technology to be deployed in TCS08. It is recognized that because of the multiple sessions at the Conference a person can not attend all of the presentations. However, availability of recordings of these presentations at the AMS website will allow a person to view them retrospectively.

The combined TCS08 and T-PARC data sets represent a unique opportunity for the study of western North Pacific tropical cyclones. Since these data sets will be open to all researchers, the objective of this overview of the science as reflected in these conference presentations and posters is to encourage collaboration with other researchers. It will be possible for researchers anywhere in the world with a PC to view the mission planning meetings via Elluminate, and the NCAR EOL will provide a record of the mission planning and a catalogue. Thus, an opportunity for full participation in the TCS08 and T-PARC field experiment exists, and the goal of this preprint and presentation is to encourage and facilitate this participation.

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2. FORMATION COMPONENT OF TCS08

2.1 Validation of theory

The large-scale environmental conditions related to tropical cyclone formation are well-known. To move beyond these environmental conditions, a recognition of the contribution on the synoptic scale, mesoscale, and even the convective scale is required. The planning for TCS08 is based on theoretical studies on multiple scales.

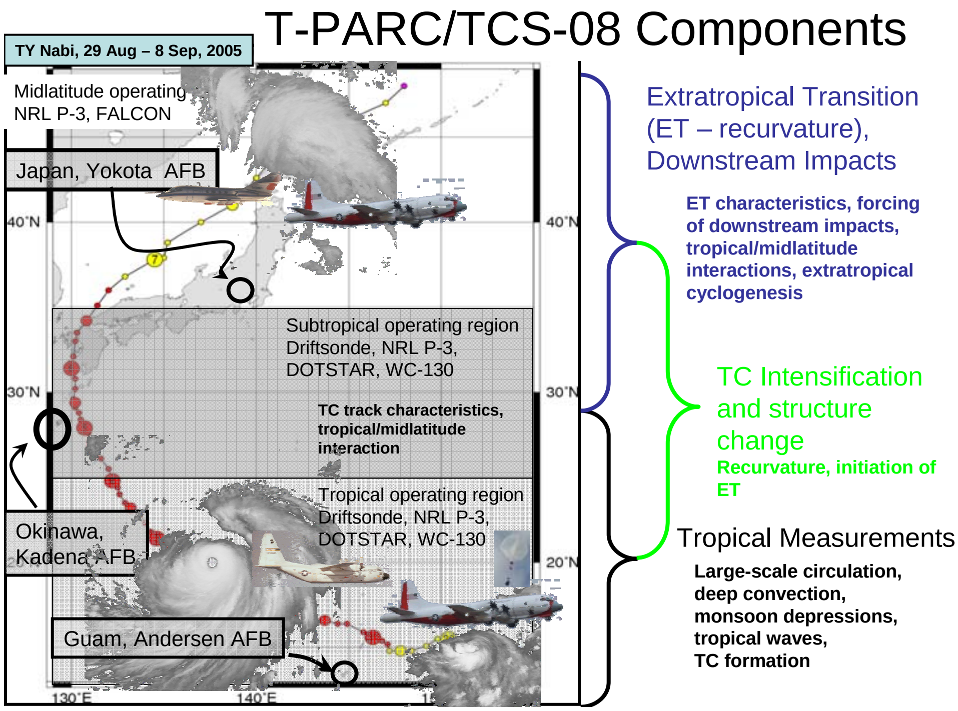

Fig. 1. Schematic of the combined TCS08 components during the formation, intensification, and structure change and T-PARC components of extratropical transition and downstream impacts for Typhoon Nabi during 29 August to 8 September 2005. Key operating areas for the aircraft are indicated.

The first three presentations in Table 1(a) by Wang et al. (Paper 7A.5), Dunkerton et al. (Paper 9A.3), and Dunkerton et al. (Poster P2F.9) are based on a recent comprehensive publication by Dunkerton et al. (2008). Although these papers primarily focus on the development of tropical depressions within tropical waves over the Atlantic, this group proposes that similar synoptic-scale considerations will be important in the TCS field experiment. The “marsupial paradigm” is that a closed circulation region exists along the tropical wave axis that provides: (i) a region of cyclonic vorticity and weak strain (characterized by large values of the Okubo-Weiss parameter) that serves to (ii) contain the inward moisture advection or moisture advected vertically by the convection and (iii) defines the region in which the mesoscale vortex will develop a (iv) “convective-type” heating profile with heating extending lower in the troposphere, and (v) generally maintain and enhance the parent wave until the developing vortex within this “sweet spot” becomes a self-sustaining entity. Whereas Dunkerton et al. (Paper 9A.3) describes the theory and Dunkerton et al. (Poster P2F.9) shows the application to 55 cases, Wang et al. (Paper 7A.5) have simulated the existence of such a confined weather region in a Weather Research and Forecast (WRF) model with idealized initial conditions. A convective-type heating profile is simulated that is consistent with the “bottom-up hypothesis” for tropical cyclone formation in which an upscale vorticity spinup from convective scale to mesoscale to synoptic scale occurs.

Tory and Montgomery (Paper 10A.1) continue this upscale concept from the individual convective ascent regions to the scale of the entire system via a nonlinear feedback between the concentration of the vorticity in the developing system and the future focusing of the convection. They address the inhibiting effects of downdrafts, and thus of dry air, on the vorticity concentration at low levels. They indicate that the processes of upward transport of moisture in the convective updraft and moistening of the environment by cloud water detrainment reduce the potential for downdrafts, and thereby increase the potential for stronger, deeper updrafts. The implication for the TCS08 field experiment is that updrafts and downdrafts in the convective areas of pre-tropical cyclone seedlings must be observed.

Hidalgo and Montgomery (Paper 10A.2) provide insight into this proposed "vortical hot tower" (VHT) route to tropical cyclone formation. They specifically address the sensitivity of MM5 simulations to a horizontal grid spacing of 1 km verses 3 km in the well-studied development of Hurricane Diana from a baroclinic system. Simulated vertical velocities in the 1 km simulation are larger (typically 15-20 m s^{-1} with maximum values of 35 m s^{-1}) and do lead to significant moistening by vertical transport of moisture. Another key aspect of the "bottom-up hypothesis" is that vortices merge, and Hidalgo and Montgomery conclude that vortex merger is a ubiquitous and important aspect of Hurricane Diana formation. Thus, the flight patterns for the TCS08 field experiment must be designed to observe the VHTs and their subsequent merger.

Table 1. Guide to *28^{th} Hurricane and Tropical Meteorology Conference* papers and posters relevant to the planning for the Tropical Cyclone Structure (TCS08) field experiment component related to the western North Pacific tropical cyclone formation.

PAPER	AUTHORS	TITLE
		(a) VALIDATION OF THEORY
7A.5	Wang, Montgomery, Dunkerton	Intermediate and high resolution simulations of the transition of a tropical wave critical layer to a tropical depression
9A.3	Dunkerton, Montgomery, Wang	Tropical cyclogenesis in a tropical wave critical layer: Easterly waves
P2F.9	Dunkerton, Montgomery, Wang, Tory	Spatial and statistical distribution of convective and stratiform clouds in the gyre-pouch of incipient tropical cyclones
10A.1	Tory, Montgomery	Tropical cyclone formation: A synopsis of internal dynamics
10A.2	Hidalgo, Montgomery	Vortical hot towers, their aggregate effects and their resolution dependence in the formation of Hurricane Diana (1984)
11B.6	Raymond, Cisneros, Sessions, Marin, Raga, Fuchs	Environmental influences on the spinup of tropical cyclones
		(b) NUMERICAL MODEL STUDIES AND TARGETED OBSERVATIONS
11A.2	Doyle, Amerault, Reynolds	Initial condition sensitivity for tropical cyclogenesis and intensification using a moist adjoint
11A.3	Penny, Ritchie	Tropical cyclogenesis: A modeling comparison between developing and non-developing cloud clusters
17D.3	Beattie, Elsberry	Western North Pacific monsoon depression formation and structure
P2C.9	Montgomery, Wang, Dunkerton	A first look at the genesis of Typhoon Man-yi (2007) during the TCS08 dry run
		(c) ANALYSES, COMPOSITES, CASE STUDIES
12A.7	Fu, Peng, Li	Developing versus non-developing disturbances for tropical cyclone formations. Part II: Western North Pacific
12D.7	Lussier, Montgomery, Harr	Analysis of the diurnal cycle of convection during the genesis stage of tropical cyclones in preparation for TCS08 in the western Pacific region
13B.2	Pineros	Using remotely-sensed observations to describe tropical cyclone formation and evolution
		(d) NEW TECHNOLOGY -- FORMATION
18B.1	Squires, Businger	Morphology of eyewall lightning outbreaks in two Category 5 hurricanes
18B.2	Leary, Ritchie	Using remotely sensed data to discriminate tropical cyclogenesis

Raymond et al. (Paper 11B.6; 2007 *Quart. J. Roy. Meteor. Soc.*) have developed a theory for the spinup of tropical cyclones based on the circulation theorem. This theory links the interplay between convection, mass convergence, and vorticity convergence that control the spinup. The production of rainfall by the convection is a function of the column relative humidity or saturation fraction of the environmental air. Thus, the key to cyclone development in this theory are the factors that affect the humidity in the cyclone core, e.g., surface moist entropy flux and vertical wind shear that can transport dry environmental air into the core. A specific requirement for testing this ventilation measure in the TCS08 field experiment is sufficient dropwindsondes from the C-130 around the periphery of the cyclone core and from a elevation that resolves most of the humidity in the column. Vertical transport of momentum through the top of the boundary layer from entrainment processes or to deep convection will be estimated from the P-3 ELDORA observations.

2.2 Numerical model studies and targeted observations (Table 1b)

Issues of the predictability of tropical cyclone formation and of targeted observations for the formation stage are addressed by Doyle et al. (Paper 11A.2). They have developed an exact adjoint to the explicit microphysics of the NRL Coupled Atmosphere/Ocean Mesoscale Prediction System (COAMPS), which is one of the key models for supporting TCS08. The adjoint-based sensitivity fields indicate where small differences in wind (1 m s^{-1}) and temperature (1 K) may lead to rapid growth in the near-surface horizontal velocity (~ 10 m s^{-1}) and deepening rate (~ 6 hPa) in only 24 h. This study is believed to be one of the first that offers guidance for targeted observations for formation (versus for track as in T-PARC), and has important implications for the predictability of formation, which is an important objective of the overall TCS08 program.

Just as Doyle et al. found considerable sensitivity to the microphysics representation in COAMPS, Penny and Ritchie (Paper 11A.3) are investigating the influence of the microphysics of the NCAR WRF model. The goal is to understand how the microphysical structure evolves in those cloud clusters that develop into tropical cyclones versus those clusters that do not develop. Although none of the aircraft in TCS08 have microphysical instrumentation, the model-detected differences may be explored with satellite-based instruments.

Beattie et al. (Paper 17D.3) are also exploring the sensitivity of the pre-formation forecasts to the physical process representations in three models: COAMPS, WRF, and MM5. They are testing these models to understand the sensitivity to the physical processes that influence the development and structure of western North Pacific monsoon depressions. The case study they are using is the monsoon depression that preceded the formation of Typhoon Man-yi that is the perfect storm in Fig. 1.

The poster P2C.9 by Montgomery et al. describes simulations of the formation stage given the pre-Man-yi monsoon depression as initial conditions in the WRF model. Their focus is on the superposition of the monsoon depression and a westward-propagating equatorial Rossby wave. Since the WRF simulation predicts the spin-up of a mesoscale vortex associated with multiple VHTs, this simulation is considered to be an example of bottom-up development, which is one of the scenarios to be observed in TCS08.

2.3 Analyses, composites, and case studies (Table 1c)

Large-scale environmental influences on tropical cyclone formation in the western North Pacific are being analyzed by Fu et al. (Paper 12A.7) using the Navy Operational Global Analysis and Prediction System (NOGAPS) analyses and TRMM microwave data. Compared to the Atlantic, they find large-scale, low-level convergence and horizontal wind shear have more impacts in whether a western North Pacific disturbance will develop into a tropical cyclone. Their study will contribute understanding of the multiple scales of circulations that are involved in the formations. The Driftsondes that are launched from Hawaii will provide *in situ* observations of the environment and westward-propagating waves during TCS08.

Because of the importance of convection in the tropical cyclone formation, the diurnal cycle of convection in the TCS08 operating region has been re-examined by Lussier et al. (Paper 12D.7). Halfhourly infrared brightness temperatures from MTSAT-1 were evaluated as a proxy for convective intensity. A diurnal maximum near sunrise existed during the August-September period corresponding to the TCS08 field period. This diurnal variability is an important consideration for planning the TCS08 aircraft operations.

Pineros (Paper 13B.2) is developing an objective technique to discriminate developing versus non-developing clouds system based on the degree of axisymmetry in the convection. A key task is to develop an objective technique to define the center of the system during the pre-formation stage so that the departure from symmetry in the convection about that center can be calculated. Whereas some early success has been achieved for the 2005 Atlantic season, the applicability in a monsoonal environment of the western North Pacific needs to be established to be useful for TCS08 mission planning.

2.4 New technology – formation (Table 1d)

Although Squires and Businger (Paper 18B.1) analyze lightning outbreaks in Atlantic Hurricanes Rita and Katrina, similar studies will be possible in the western North Pacific when a lightning network is established prior to the TCS08 field experiments. S. Businger is cooperating with Vaisala in finding sites for the instruments. Whereas the immediate objective is for analysis studies correlating high lightning strike rates with convection in developing versus non-developing systems during TCS08, later studies will incorporate the lightning observations in numerical models to study the impact on formation prediction.

Leary and Ritchie (Paper 18B.2) have carried out a feasibility demonstrating using the Long-range Lightning Detection Network applied to eastern North Pacific formations. They find distinct differences between developing tropical cyclones and non-developing cloud clusters, and that intensification and steady-state stages can be identified using the lightning data. This feasibility demonstration suggests similar results may be obtained from TCS08 since some eastern North Pacific form in a monsoonal environment similar to the western North Pacific.

2.5 TCS08 mission planning for formation

The primary TCS08 scientific hypotheses related to formation are:

Mesoscale processes determine the location and timing of tropical cyclone formation within the favorable environment

Top-down: Mesoscale Convective Vortex near center merges with monsoon depression circulation

Bottom-up: Low-level cyclonic vortices form from intense convection in “sweet spot”

Environmental processes lead to amplification of the secondary circulation that spin-up the tropical cyclone, but may inhibit via ventilation concept.

Given the multi-scale nature of formation, the focus on mesoscale contributions, and the large areas of the western North Pacific where formation can occur, mission planning is a challenge. The concept of operations includes localization of potential formation areas based on global models, which should be improved by the new Driftsonde observations and special satellite observations. Then mesoscale models centered on the likely formation area will provide additional information on mesoscale convective areas that will be useful for 24-h planning of missions when the system is within aircraft range of Guam. The adjoint sensitivity study by Doyle et al. (Paper 11A.2) may also provide a localization tool for targeted observations. However, continuous monitoring of the microwave imagery will be required prior to take-off and during the mission.

The second challenge is to design missions that will accomplish hypothesis testing and the satellite evaluation in combined C-130 and P-3 missions. For safety reasons, the P-3 will not fly in convective systems during darkness, and missions are generally limited to about 8 h due to limited alternate landing sites.

The combined T-PARC and TCS08 operations plan that will be available soon will contain the proposed flight plan.

3. STRUCTURE CHANGE COMPONENT OF TCS08

Here structure change includes intensity change, but TCS08 will have limited aircraft resources for measuring the physical processes that contribute to intensity change since the NRL P-3 can not penetrate through heavy convection near the center of a typhoon. However, the Air Force C-130 with the Stepped Frequency Microwave Radiometer (SFMR) will for the first time provide surface sustained wind profiles through western North Pacific tropical cyclones as well as intensity estimates.

The TCS08 focus on outer wind structure and structure change is to meet a Navy requirement to sortie ships from port and divert ships around regions of the tropical cyclone with gale-force winds and 12-foot seas. Hawkins and Helveston (2004) found that 80% of western North Pacific typhoons with intensities exceeding 50 m s^{-1} undergo secondary eyewall formation. Elsberry and Stenger (2008) and Stenger and Elsberry (Paper 13C.3) show that numerical model studies and observations indicate that large outer wind structure (as well as intensity) changes may accompany an eyewall replacement cycle. Thus, a scientific focus of the TCS08 structure change component will be secondary eyewall formation.

3.1 Validation of theory (Table 2a)

Montgomery et al. (Paper 1.4) have simulated in three dimensions intensification from initial conditions analogous to the many high-resolution axisymmetric models (e.g., no environmental vertical wind shear and on an *f*-plane). They find that the so-called vortical hot towers (VHTs) are the basic coherent structures during the intensification, and these VHTs undergo merger and axisymmetrization by the horizontal shear of the swirling flow. The chaotic nature of these convective-scale processes suggests a lack of predictability on that scale, but also for the inner-core wind changes. Rapid deployment of dropwindsondes as the C-130 passes through the eyewall region in western North Pacific typhoons will document the "over-shooting" boundary layer inflow process that is hypothesized to explain super-intensity (Montgomery et al. 2007).

Although the physical processes in the eyewall region will not be measured by the ELDORA radar, the Vortex Rossby Waves that are generated by these unbalanced motions in the eyewall region are hypothesized as one mechanism for initiating secondary eyewall formations (Terwey and Montgomery – Paper 18C.5). This hypothesis requires the existence of a region with moderate horizontal strain deformation and a sufficient low-level radial potential vorticity gradient associated with the swirling flow, moist convective potential and a wind-moisture feedback process. Most of these conditions will be observable with the ELDORA and Doppler wind lidar if the NRL P-3 can operate safely within the region of the secondary eyewall formation.

Kuo and Chang (Paper 18C.7) have focused on the formation of the "moat" region between the inner eyewall and the secondary eyewall. They devise a theoretical parameter that is the moat width implied in the rapid filamentation dynamics involving the strain flow and the horizontal wind shear as discussed by Rozoff and collaborators. This parameter can be estimated from the best track maximum wind speed and the satellite-estimated inner eyewall radius, and can explain 40% (19%) of the variance of the satellite-observed moat width for category 5 (4) typhoons. The *in situ* measurements from TCS08 will provide more accurate observations of these variables so that a better test of the theoretical parameter can be achieved.

Foster (Paper 3D.6) has developed a simple nonlinear boundary layer model for tropical cyclones that will be validated (at least in the near-inner core regions) with the Doppler wind lidar that is mounted on NRL P-3. Special flight patterns and operating sequences of the Doppler wind lidar have been planned to detect the presence and structural characteristics of coherent boundary layer structures that enhance the vertical fluxes of heat, moisture, and momentum through the boundary layer.

Table 2. Guide to *28th Hurricane and Tropical Meteorology Conference* papers and posters relevant to the planning for the Tropical Cyclone Structure (TCS08) field experiment component related to western North Pacific tropical cyclone structure change.

PAPER	AUTHORS	TITLE
		(a) VALIDATION OF THEORY
1.4	Montgomery, Smith, Nguyen	Revisiting the physics of tropical cyclone intensification in three dimensions
18C.7	Kuo, Chang	Western North Pacific typhoons with concentric eyewalls
3D.6	Foster	Simple nonlinear boundary layer model for tropical cyclones
13C.1	Ellis, Businger	Distribution of surface winds in Pacific typhoons
		(b) NUMERICAL MODEL STUDIES
3A.1	Zhao, Jin	Study of radar data assimilation for improving hurricane intensity and structure forecasts
7A.3	Li, Pu	Impact of cloud microphysical processes on the intensity forecast of tropical cyclones: High resolution numerical simulations and Doppler radar data assimilation
P2D.7	Jin, Doyle, Schmidt, Wang	Sensitivity of tropical cyclone intensity to the representation of ice microphysics
P2D.9	Reimer, Montgomery, Nicholls, Emanuel, Tang	Bottom-up route of tropical cyclone intensity change in vertical wind shear
		(c) ANALYSES, COMPOSITES, CASE STUDIES
13C.3	Stenger, Elsberry	Examining tropical cyclone structure using H*Wind analyses
14B.1	Hawkins, Helveston	Tropical cyclone multiple eyewall characteristics
		(d) NEW TECHNOLOGY – STRUCTURE CHANGE
7C.1	Lumpkin, Niiler, Black	Drifting buoy deployments into Hurricane Dean, 2007

A preliminary documentation of the existence and characteristics of boundary layer coherent rolls in western North Pacific tropical cyclones has been provided by Ellis and Businger (Paper 13C.1). This study utilized the Guam WSR-88D radar observations during the passage of Typhoons Dale and Keith. The updrafts and downdrafts in the coherent rolls in these observations are stronger than in Foster's theory. The tendency for convective areas (and topography) to deter roll formation is an important consideration for designing the NRL P-3 flight patterns during TCS08.

3.2 Numerical model studies (Table 2b)

Zhao and Jin (Paper 3A.1) have tested improvements to the COAMPS predictions of Hurricane Isabel intensity and structure from assimilating high-resolution, three-dimensional radar observations from land-based radars. Their variational data assimilation led to improved hurricane intensity and structure forecasts. The application of the data assimilation technique to the ELDORA radar data for the TCS08 cases is thus expected to lead to better analyses and predictions of intensity and structure for western North Pacific tropical cyclones.

Li and Pu (Paper 7A.3) have assimilated airborne Doppler radar reflectivity data into the WRF model to improve the initial specification of cloud microphysics properties in the inner core of Hurricane Dennis. Based on some high resolution numerical simulations, the intensity and inner-core dynamics and thermodynamics are impacted by assimilating the radar reflectivity to specify the microphysics. Because the forecasts of the structure and intensity of tropical cyclones are known to be sensitive to the microphysics in the model, a better representation of the initial conditions from the ELDORA reflectivity for the TCS08 cases offers hope for improved structure and intensity forecasts. Diagnosis of these forecast fields should then improve understanding of how cloud microphysics processes influence structure change.

Jin et al. (Poster P2D.7) perform high-resolution COAMPS simulations to evaluate the impact of different formulations of ice nuclei concentrations on tropical cyclone intensity. Different parameterizations of ice nuclei concentrations lead to an order of magnitude differences in the ice concentration at upper levels of the eyewall and anvil clouds, and to substantial differences in intensity (40 m s^{-1} or 32 hPa), thermodynamic structure, and turbulence distributions. In conjunction with the Zhao and Jin and the Li and Pu papers discussed above, it is clear that more modeling studies of ice microphysical processes will be an important part of the post-TCS08 field experiment activities.

Idealized modeling studies by Riemer et al. (Poster P2D.9) address the modulation of the tropical cyclone intensity by 850 – 500 hPa vertical wind shear values ranging from 5 to 15 m s^{-1}. Consistent with vortex resiliency theory, the downshear tilt of the vortex generates vortex Rossby waves, and a strong wavenumber one asymmetry develops in the boundary layer equivalent potential temperature. Since the modulation of the storm intensity in this model is strongly coupled to the boundary layer equivalent potential temperature, a proportionally larger intensity decrease occurs with stronger vertical shears. Because the upper-level warn core temperature decrease slightly lags the boundary layer response, the intensity decrease is considered to be a "bottom-up" effect. Clearly, estimates of the vertical wind shear and observations of the structure response are important objectives for TCS08 mission planning.

3.3 Analyses, composites, and case studies (Table 2c)

An extensive data base of H*Wind analyses that included SFMR estimates of the surface wind in Atlantic tropical cyclones has been produced by Mark Powell's group at the Hurricane Research Division. Stenger and Elsberry (Paper 13C.3) have studied the time evolution of the outer wind structure (radii of 34 kt, 50 kt, and 64 kt) based on these H*Wind analyses. A simple model that these wind radii will increase (decrease) when the intensity increases (decreases) is tested. A considerable percentage of R34 decreases are found during the intensification phase, and R34 increases during the decay phase. Corresponding studies will be possible for western North Pacific tropical cyclones from the SFMR observations on the C-130, and the NRL P-3 with the ELDORA and the Doppler lidar will be investigating the contribution of secondary eyewall formations to both outer wind structure and intensity changes.

Hawkins and Helveston (Paper 14B.1) have extended the global sample of multiple eyewalls. Certain preferred eyewall evolutions were documented: (i) Outer eyewall completely encircles the inner eyewall; (ii) Eyewall cycle repeats multiple times; (iii) Eyewall replacement cycle is interrupted and multiple eyewalls are maintained; (iv) An annular eyewall configuration evolves; and (v) An outer eyewall is created at large radii and remains for an extended time while the inner eye decays. A key result for TCS08 mission planning is that formation of secondary eyewalls typically occurs via asymmetric convection and the wrapping around of one dominant rainband. An objective for TCS08 is to determine the physical processes that lead (or not lead) to a wrap-around.

3.4 New technology – Structure change (Table 2d)

The lightning network discussed in section 2.4 will also provide data sets for structure/intensity change periods. Even though the Hidalgo and Montgomery simulations (Paper 10A.2) do not find a significant role for wind-dependent surface fluxes of latent and sensible heat, their possible contribution will be assessed in TCS08 via enhanced surface wind observations from the C-130 Stepped Frequency Microwave Radiometer (SFMR) and air-deployed bathythermographs. For western North Pacific tropical cyclones south of about 20° N the upper ocean layer is quite deep and proportionately smaller sea-surface temperature decreases are expected compared to the Atlantic hurricanes.

A successful Coupled Boundary Layer Air-Sea Transport (CBLAST) program of deploying drifting buoys to measure the ocean response will be utilized in TCS08. Lumpkin et al. (Paper 7C.1) describe a recent deployment in Hurricane Dean and the outlook for real-time transmittal to forecast centers and modeling centers for data ingest in coupled ocean-tropical cyclone models. These analyses and forecast experiments are the prototype for the TCS08 observations.

3.5 Implications for TCS08

One significant contribution in TCS08 will simply be obtaining in situ observations of tropical cyclone structure and intensity changes in western North Pacific first for validation of satellite techniques and for documenting how the structure changes. Although we will not have the capability to measure all of the physical factors in intensity change, the SFMR surface winds, dropwindsondes, and AXBTs will provide some surface flux information, and the drifting buoy deployment will document the response in the ocean. The special Doppler wind lidar missions are expected to increase understanding of where and how coherent boundary layer rolls contribute to the surface fluxes. Because a wide variety of outer wind structures from midget typhoons to monster typhoons exist in the western North pacific, we will only be able to sample some aspects of outer structure changes. The focus on secondary eyewall formation is expected to increase our understanding of some significant intensity changes and on outer wind structure changes that are important to forecasts and warnings.

Environmental dominance:
Outer wind structure evolves only slowly from the structure determined at the time of formation;
Internally determined:
Dynamic and thermodynamic imbalances in the inner region generate outward-and-upward propagating Rossby waves that modify the outer wind structure;
Super-intensity:
Frequent dropwindsonde releases through the eyewall of typhoons will detect structures leading to super-intensity.

Other than the long distances from Guam, and the need to also re-position the NRL P-3 to Okinawa for the T-PARC recurvature and extratropical transition missions, the biggest challenge for the NRL P-3 missions is the safety of flying in the region of deep convection during secondary eyewall formation. In the RAINEX missions, the NOAA P-3 with broader radar coverage was able to assist in the mission coordination. In the TCS08 missions, the NRL P-3 must work more independently. Although some guidance will be available from microwave satellite imagery, this information is not continuous in time.

4. Opportunities to participate and collaborate

In this new era of communication anywhere in the world, including to/from the NRL P-3 flying in the western North Pacific, the TCS08 operations center can be in Monterey, California. Two teams will be supporting the regular daily mission planning for TCS08 and T-PARC and supporting the aircraft missions in flight. The Elluminate technique allows a researcher with a personal computer to monitor the mission planning activities. As was done for the dry run during 2007, the NCAR EOL will provide a record of the mission planning and an online catalogue.

The objective of this preprint has been to document some of the science background for TCS08. However, the data set to be obtained will open opportunities for research on many aspects of tropical cyclones in a more monsoonal environment than in the Atlantic region, and thus has relevance to other tropical cyclone basins. Since the TCS08 data set will be freely available, other researchers are encouraged to learn more about the science and to work individually or collaborate with the ONR-funded and NRL researchers with the data set. Since these conference presentations are recorded and will be available on the AMS website, an opportunity exists to gain an understanding of the scientific background. The goal of this preprint and the presentation is to facilitate participation in the TCS08 field experiment and collaborate in the analysis of the data set.

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