7C.7 AN OVERVIEW OF THE THORPEX-PACIFIC ASIAN REGIONAL CAMPAIGN (T-PARC) DURING AUGUST-SEPTEMBER 2008

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1. INTRODUCTION

During August-September 2008, a major field program titled THe Observing systems Research and Predictability Experiment (THORPEX) Pacific Asian Regional Campaign (T-PARC) will be conducted. As a multi-national field campaign, T-PARC addresses the shorter-range dynamics and forecast skill related to tropical cyclones of one region (Eastern Asian and the western North Pacific) and their downstream impact on the medium-range dynamics and forecast skill of another region (in particular, the eastern North Pacific and North America). While T-PARC encompasses varying time and space scales, the primary objectives of each region are the same: To increase understanding of the mechanisms that will lead to improved predictive skill of high impact weather events.

A multi-scale approach of T-PARC is desirable as high impact weather events over these two regions have strong dynamical links. For example, high-impact weather events over the western North Pacific and East Asia, such as persistent deep tropical convection and tropical cyclones, can trigger downstream responses over the eastern North Pacific and North America via upper-tropospheric wave packets on the primary Asian wave guides. These wave packets can, in turn, be invigorated by subsequent cyclogenesis events that makes the impacts farther downstream fast-spreading, far-reaching, and associated with reduced predictability.

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A combination of observational platforms that includes multiple aircraft and collaborative experiments will be utilized to observe the structure and evolution of the primary Asian/North Pacific wave guides high impact events (i.e.,heavy rainfall, tropical cyclones and extratropical cyclogenesis) that take place over the western North Pacific and East Asian region. Such an ambitious measurement strategy can only be reasonably accomplished with the level of international collaboration envisioned in 2008. A tropical measurement strategy is designed to examine the large-scale variability in the circulation of the tropical western North Pacific as it relates to enhanced and reduced periods of wide-spread deep convection, tropical cyclone formation and the variations in intensity and track as the systems move to the northwest.

These observations will be used in concert with an unprecedented variety of numerical models, which includes research modeling and assimilation systems together with access to the members of the ensemble forecasts of all the major operational centers through the THORPEX Interactive Global Grand Ensemble (TIGGE). T-PARC will be able to readily include the deterministic and probabilistic nature of the forecast problem associated with tropical cyclone formation, intensification, structure change, extratropical transition, and downstream impacts. Observations and results gathered during this program expect to be applicable to all ocean basins that contain tropical cyclones, which is a reason for such wide-spread international participation in T-PARC.

2. PRIMARY HYPOTHESES

The primary science objectives of T-PARC are defined as the following:

1) Improved understanding of the dynamics and factors that limit the predictability of downstream high-impact weather events due to typhoons, extratropical transition events, and other intense cyclogenesis events originating in the North Pacific and adjacent land areas;

2) Understanding of forecast error growth and the role of scale interactions;

3) Developing, advancing, and evaluating data assimilation strategies in concert with superior utilization of satellite measurements with the goal of improving prediction of high-impact weather events both over the Pacific rim and downstream locations;

4) Testing the improvement in local and downstream forecast skill afforded by high-resolution, non-hydrostatic modeling of these high-impact weather events;

5) To quantitatively predict the reduction in forecast error variance due to supplemental/targeted observations and to test new strategies and observational systems for adaptive observing and modeling;

6) Improving the interpretation and utility of ensemble forecast systems; and

7) Understanding and improving society's response to weather disasters, including the appropriate use and evaluation of probabilistic information.

Many of these objectives will be addressed via study of the forcing of wave packets that propagate from eastern Asia and the western North Pacific in response to specific forcing events such as the extratropical transition (ET) of a tropical cyclone that has moved into the midlatitudes. The enhanced wave activity is responsible for downstream cyclone development or establishment of large-scale ridge-trough patterns that may trigger persistent weather patterns over North America (e.g., a blocking anticyclone that may trigger heat waves or "fire weather"). One such event of downstream wave activity related to the ET of Typhoon (TY) Tokage (Fig. 1) was an early-season, severe rain and snow event over central and southern California. In conjunction with the wave packet that originated over the western North Pacific, an unusually deep trough formed over the northwestern United States (Fig. 1) and moved southward toward central California by 20 October where heavy coastal rains occurred.

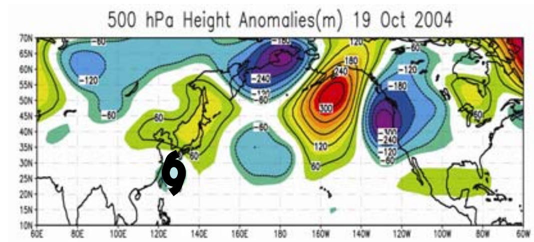

FIG. 1 Average 500 hPa height anomalies (m) for 0000 UTC 19 October and 1200 UTC 19 October 2004. The tropical cyclone symbol marks the location of TY Tokage.

The predictability of the wave train across the North Pacific downstream of TY Tokage was very low as defined by maxima in the standard deviation of 500 hPa heights (Fig. 2) from the ensemble prediction system (EPS) of the National Centers for Environmental Prediction (NCEP). Results from Harr et al. (2008) and Anwender et al. (2008) indicate that the increase in variability among ensemble members occurs during many ET events in the NCEP EPS and the EPS of the European Center for Medium-range Weather Forecasts (ECMWF). The decreased predictability associated with an ET event and downstream response may be associated with increased analysis errors and model uncertainties due to the complex physical and dynamical mechanisms that occur during ET. Although the poleward track of the tropical cyclone may be forecast accurately, the impacts of the ET are often not forecast correctly (Jones et al. 2003). Therefore, a primary objective during T-PARC is to obtain observations in an ET environment (Fig. 3) to define the roles of various physical mechanisms in defining the downstream impacts and associated predictability. All regions in Fig.3 likely play important roles in the transformation and re-intensification stages of ET. Furthermore, the relative structural changes in the stages of ET are hypothesized to be responsible for the type of variability in downstream development that is often associated with an ET event.

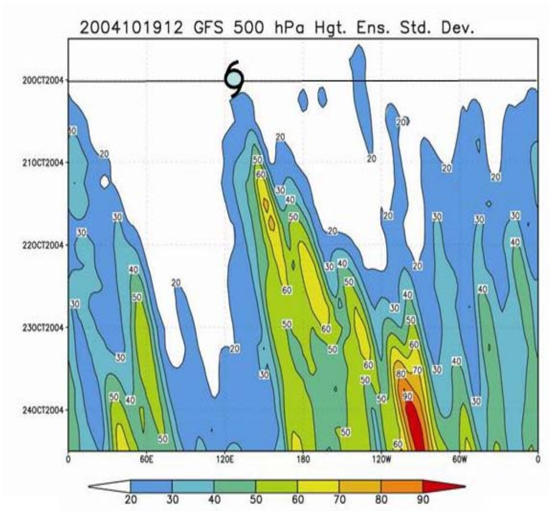

Fig 2 Time-longitude diagram of the standard deviation in ensemble members for 500 hPa heights for the forecasts initiated at 1200 UTC 19 October 2004 with the Global Forecast System model run at the National Centers for Environmental Prediction. The horizontal line at 0000 UTC 20 October marks the time of the ET of TY Tokage, which is located at the longitude marked by the tropical cyclone symbol

3. OBSERVATIONS: T-PARC FIELD PHASE

3.1 Aircraft

Observations will be based on a combination of aircraft and satellite sensors that will be coordinated under the T-PARC program. Understanding the ET process clearly requires tropical-to-extratropical measurement strategies as the predictability of an ET event depends on the intensity and structure of the tropical cyclone, where and when the tropical cyclone arrives in the middle latitude westerlies and the characteristics of the middle latitude wave guide that impact the ET cyclogenesis and the downstream propagation and evolution of the wave packets.

The measurement strategy for the ET and downstream impacts is based on the poleward movement of a decaying tropical

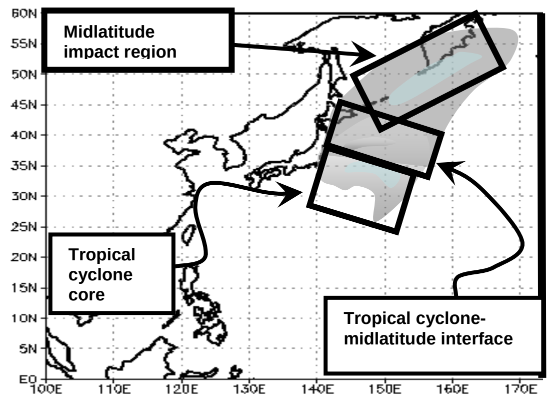

Fig. 3 Schematic of three regions associated with the ET of a decaying tropical cyclone over the western North Pacific. The light gray shaded region represents overall cloud patterns. Shaded regions within the light gray areas indicate regions of concentrated cloud amounts defined by convection in the tropical cyclone core region, large-scale precipitation in the tropical cyclone midlatitude interface region, and cirrus in the midlatitude impact region.

cyclone and the resulting cyclogenesis that often results from its interaction with the midlatitude circulation. A critical component to identification of the mechanisms responsible for forcing and variability of downstream responses to an ET event is the mapping of a comprehensive three-dimensional structure of the airflow and thermodynamic characteristics in the three regions of an ET event (Fig. 5). Observational facilities for this component of T-PARC involve Earth Observing Laboratory (EOL) facilities, which includes the NCAR ELDORA dual-Doppler radar system (Wakimoto et al. 1996) onboard the NRL P-3. The NRL P-3 will also deploy GPS dropwindsondes in the environment of an ET event. Also, a request has been made for mounting of the Twin Otter Doppler Wind Lidar (TOWDL, Emmitt et al. 2005) on the NRL P-3.

While the NRL P-3 with ELDORA and GPS dropwindsonde capabilities are able to provide detailed views of the physical characteristics associated with the decaying tropical cyclone core and tropical cyclone-midlatitude interface regions (Fig. 3) of an ET event, the interaction of the upper-level outflow and midlatitude jet will be observed by the Deutsches Zentrum fur Luft- und

Raumfahrt (DLR) Falcon aircraft that will be outfitted with an airborne Doppler wind lidar and a water vapor differential absorption lidar (DIAL). The 2 cm Doppler lidar was used in the Atlantic THORPEX Regional Campaign (A-TReC) in autumn 2003 (Weissman and Cardinali 2007). The wind lidar provides profiles between 0.5 and 12 km altitude with accuracy better than 1 m s^{-1} (Weissman et al. 2005). The horizontal resolution is up to 5 km and the vertical resolution is up to 100 m. The precursor to the DIAL system has participated in numerous international field programs to provide profiles of water vapor from 0.5 to 12 km altitude with 10% accuracy. The horizontal resolution varies between 2 km and 14 km and the vertical resolution varies between 0.2 km and 2 km depending on the boundary conditions. The DLR Falcon will also deploy GPS dropwindsondes.

3.2 SATELLITE

Remotely-observed observations from satellites will greatly enhance the T-PARC *in situ* measurements. The combination of infrared and microwave-based radiance data (i.e. MTSAT, TRMM, AMSU), high-resolution atmospheric motion vectors and surface winds from scatterometers will be utilized. Observations of the detailed structural aspects and changes of the core tropical cyclone as it undergoes ET are key to addressing the hypotheses in this program. The satellite observations and derived products will play an important role in this regard.

3.3 DRIFTSONDE

With respect to many weather events such as tropical cyclone formation, large-scale convection in the western North Pacific monsoon trough, ET events, intense oceanic midlatitude cyclogenesis, the western North Pacific is a data sparse region. A primary hypothesis in T-PARC is that a lack of proper initial conditions related to these types of events in numerical prediction models contributes to reduced forecast accuracy. Assimilation of dropwindsonde data from high-altitude aircraft has been shown to improved prediction of Atlantic hurricane tracks. However, logistics and costs prohibit deployment of aircraft with dropsonde capability for many important weather events that are expected to be sampled in T-PARC. Therefore, the Driftsonde systems will provide extensive spatial coverage of the vertical profile of atmospheric conditions to define the large-scale tropical and midlatitude environment in which an ET event, intense midlatitude cyclogenesis event, pre-monsoon depression, and tropical cyclone formation exist. These areas may be targeted regions in which numerical analysis indicates that vertical profiles of atmospheric parameters will improve the prediction of important weather events. Typically, these areas of sensitivity to initial conditions are over data-void regions with respect to operational radionsonde and aircraft coverage.

Fig. 4. Picture of a Driftsonde balloon with dropsonde gondola.

During the tropical component of T-PARC, dropsondes will be released from Driftsondes at a pressure level of 100 h Pa or less to provide vertical profiles of the large-scale tropical western North Pacific in which enhanced or reduced large-scale convection may be contributing to tropical and extratropical interactions. Dropsondes released from Driftsondes will also provide measurements of important atmospheric conditions that contribute to tropical cyclone motion, structure, and structure change.

4. Adaptive Sampling

A focus of T-PARC on adaptive measurements for typhoon prediction is prompted by successful dropwindsonde observations in the synoptic environment of typhoons (Wu et al. 2004) and hurricanes (Aberson 2003) to improve operational forecasts. Studies such as Aberson (2003) have shown that incorporation of dropwindsonde data around TCs approaching landfall has significantly improved the rate of increase in forecast skill. Although these aircraft-borne observations have been shown statistically to improve the accuracy of global model track forecasts (i.e., the average improvement typically ranges between 20 and 30%), the scientific premise of how observations influence forecasts of TC motion and structure remains unexplored. Another basic research topic to be explored is to increase the scientific understanding of the significant differences in the prediction of targeting locations by different targeting techniques. The techniques include sensitivity to conditions near the cyclone, but sometimes also include features within the middle latitudes. For the first time in a targeting experiment, there is an opportunity to oversample to better understand the impact of following different targeting experiments. Moreover, the benefits of assimilating additional observations from different platforms, including airborne and satellite remote sensing, on multiple spatial and temporal scales using novel data assimilation methods have not been studied. For example, studies will be provided to determine the relative contributions from in-situ adaptive measurements versus new satellite systems such as COSMIC or whether complementary approaches (in-situ winds only) should be developed.

Since research to date suggests that track forecasts of tropical system will improve through adaptive measurements, the question arises as to whether adaptive measurements taken to improve typhoon track prediction will improve the prediction of ET and downstream effects? Such an improvement is expected, since one would expect improvement in the prediction of where and when a TC enters the middle latitude westerlies. For this reason adaptive measurements will be taken during the recurvature of the TC. Alternate hypotheses are that the uncertainty lies with the middle latitude westerlies, a lack of resolution of the vortex moving into the westerlies or in the cyclogenesis process itself.

5. T-PARC Operations

The T-PARC field phase will be conducted during August-September 2008, which coincides with the climatological maximum in ET events over the western North Pacific (Jones et al. 2003). Based on climatology, approximately 5-10 ET events occur during this two-month period. The operations center will be at the Naval Postgraduate School (NPS) in Monterey, CA. Real-time satellite data are also available at NPS. As one of the primary forecast centers for tropical cyclones over the western North Pacific, the Joint Typhoon Warning Center (JTWC), Hawaii will also be part of the support for the field phase of T-PARC. Experienced tropical cyclone and midlatitude forecasters will be assigned to the T-PARC operations in support of daily activities.

Aircraft operations centers will be located on Guam and in Japan. The various aircraft will deploy to be best positioned to follow the entire life cycle of a tropical cyclone over the western North Pacific. The T-PARC operations plan will be complete in June 2008 and available on one of the T-PARC websites (i.e., http://www.eol.ucar.edu/deployment/field-deployments/field-projects/t-parc)

Acknowledgments

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