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Typhoon Sinlaku During T-Parc: Sensitivity of the Re-Intensification and Downstream Development to the Track Following Recurvature

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9A.5 TYPHOON SINLAKU DURING T-PARC: SENSITIVITY OF THE RE-INTENSIFICATION AND DOWNSTREAM DEVELOPMENT TO THE TRACK FOLLOWING RECURVATURE

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1. INTRODUCTION

An accurate forecast of many tropical and extratropical factors associated with the extratropical transition (ET) of tropical cyclones remains a challenging problem and was a principal focus area for the THORPEX-Pacific Asian Regional Campaign (T-PARC). In September 2008, Typhoon Sinlaku became an intense tropical cyclone that recurved over Taiwan and moved poleward to pass just south of the primary islands of Japan. Typhoon Sinlaku presented an excellent opportunity to examine predictability issues associated with ET, as there was a large uncertainty in the track at recurvature and there was large variability in predicted downstream development following the ET. The ET of Typhoon Sinlaku was observed by multiple satellite and airborne reconnaissance platforms in support of the T-PARC field program, which provides for a unique opportunity to compare and contrast forecast, analyzed, and observed conditions associated with the character of ET and impacts on the midlatitude circulation into which the decaying tropical cyclone is moving.

Following recurvature over the northern tip of Taiwan (Fig. 1), deep convection in TY Sinlaku was severely reduced (Fig. 2) under the influence of strong vertical wind shear due to the midlatitude westerly winds. However, significant convection developed downshear of the low-level center of the decaying tropical cyclone. The resurgence of deep convection contributed to the re-intensification of TY Sinlaku such that it regained typhoon intensity south of Japan. The re-intensification altered the structure of the typhoon, enabled the onset of ET, and contributed to reduced predictability of the impact of the tropical cyclone on downstream midlatitude circulations.

The post-recurvature fluctuation in intensity and structure of TY Sinlaku prior to ET was not accurately forecast in any of the operational global models that were used during T-PARC (i.e., GFS, NOGAPS, UKMO, ECMWF, JMA), and we hypothesize that this error was directly related to the track and structure characteristics of the typhoon following recurvature. In all cases, the reduced predictability was in the sense of over development of significant downstream high-amplitude circulations that propagated to western North America. To more thoroughly understand the mechanism for the deepening, it is necessary to examine the relative role(s) of the typhoon track following recurvature and its relation to the re-intensification stage as the storm passed south of Japan. In several forecast sequences when overdevelopment of downstream development was severe, the forecast track was north of the analyzed track. This track shift influenced the interaction between the decaying typhoon and the midlatitude circulation into which it is

Figure 1. The track of TY Sinlaku. White boxes mark the locations and times of aircraft missions during T-PARC.

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moving. The northward shift in the forecast track is examined relative to the forecast storm structure and to factors related to downstream development.

2. EXTRATROPICAL TRANSITION OF TY SINLAKU

Although strong vertical wind shear from the west-northwest contributed to an exposed low-level center and a highly asymmetric distribution of convection (Fig. 2), TY Sinlaku rapidly re-organized and intensified to typhoon strength (Sanabia and Harr 2010). As Sinlaku approached southern Japan, a closed eye structure was observed in ground-based radar (Fig. 3).

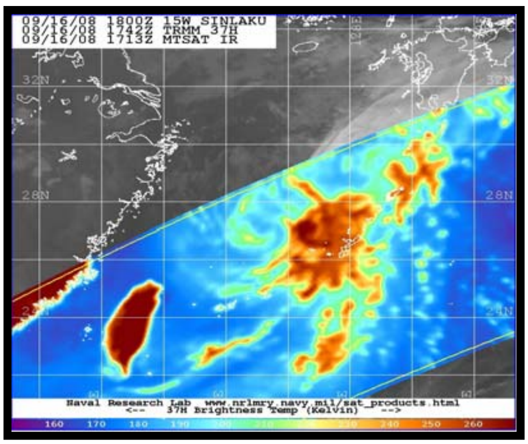

Figure 2. TY Sinlaku in the 1742 UTC 16 September 2008 37 GHz imagery from the TRMM satellite. (Image courtesy of http://www.mrlmry.navy.mil.sat_products.html)

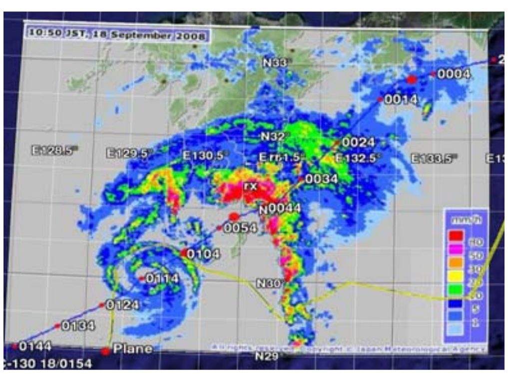

Figure. 3 Rain rate associated with TY Sinlaku derived from land-based radar at 0050 UTC 18 September 2008.

The re-intensification of TY Sinlaku led to an initiation of the transformation stage of extratropical transition (Klein et al. 2000) of Sinlaku as it moved past Japan toward the western North Pacific (Fig. 4).

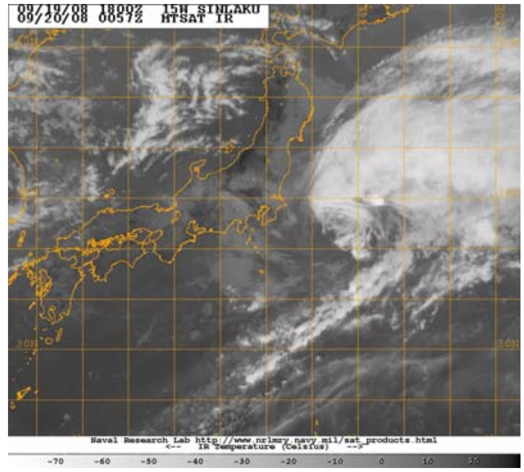

Figure. 4. Infra-red imagery from the MSTAT geostationary satellite at 0057 UTC 20 September 2008. (Image courtesy of http://www.mrlmry.navy.mil.sat_products.html)

3. DOWNSTREAM DEVELOPMENT

The process of downstream development (Orlanski and Sheldon 1995) has been found to often occur in association with the extratropical transition of tropical cyclones over the western North Pacific (Harr and Dea 2009). Furthermore, the occurrence of downstream development has been shown be related with periods of decreased predictability in forecasts from operational global numerical weather prediction models (Harr et al. 2008, Anwender et al. 2008). In these studies, decreased predictability was defined as an increase in spread in 500 hPa geopotential height among members of respective ensemble prediction systems.

As TY Sinlaku began to interact with the midlatitude circulation into which it was moving, forecasts from operational global models began to exhibit decreased predictability downstream over the central and eastern North Pacific (Fig. 5). In the regions where variability in 500 hPa heights among ensemble members increased, downstream development was analyzed based on the distribution of eddy kinetic energy (EKE) over the western, central, and eastern North Pacific. A characteristic pattern of EKE across the North Pacific that would be indicative of downstream development is a progressive downstream increase in EKE over time.

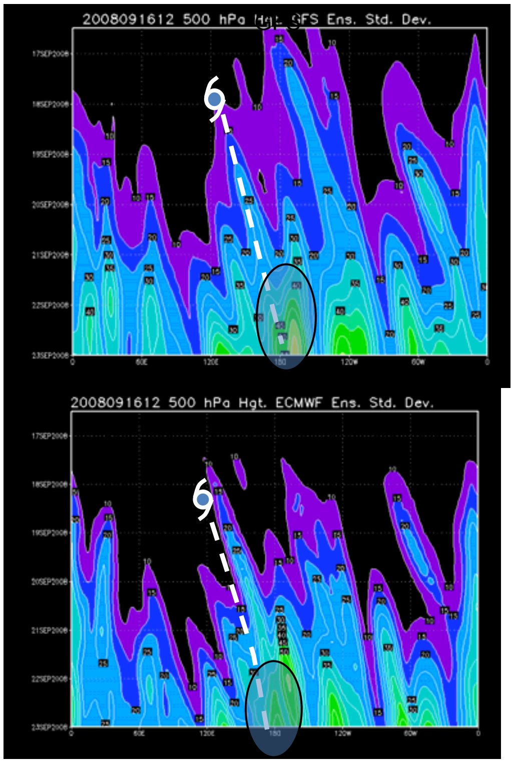

Figure 5. Time-longitude distribution averaged between 40°N-60°N of standard deviation in 500 hPa heights (m) among ensemble members from the (top) GFS and (bottom) ECMWF global model ensemble prediction systems. The oval in each panel marks the maximum standard deviation, which occurred over the central North Pacific.

For the GFS forecast initiated at 1200 16 September 2008 (Fig. 6), the distribution of EKE over the western North Pacific was quite accurate. However, for each successive downstream region, the forecast of EKE became increasingly too large. Therefore, for this forecast sequence, the prediction represented a false alarm case of significant downstream development. A similar false alarm pattern occurred in the ECMWF forecasts initiated at 1200 UTC 16 September 2008 (Fig. 7). Furthermore, for both models the large error in the distribution of EKE over the central North Pacific coincided with the increase in standard deviation of 500 hPa height among ensemble members from both model ensemble prediction systems (Fig. 5).

4. DISCUSSION

The pattern of over-forecasting downstream development following the

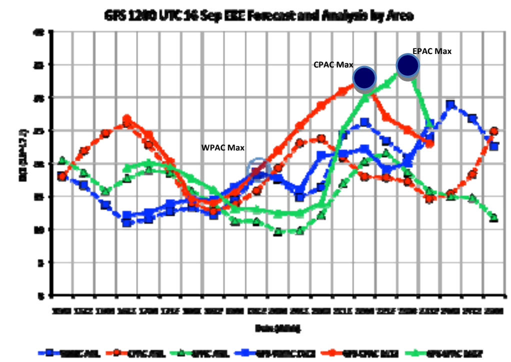

Figure 6. Volume integrated EKE (10^{18} J) over the western, central, and eastern North Pacific from GFS forecasts (solid lines) initiated at 1200 UTC 16 September 2008. Dashed lines define the distribution of EKE in each region as defined by the operational GFS analyses.

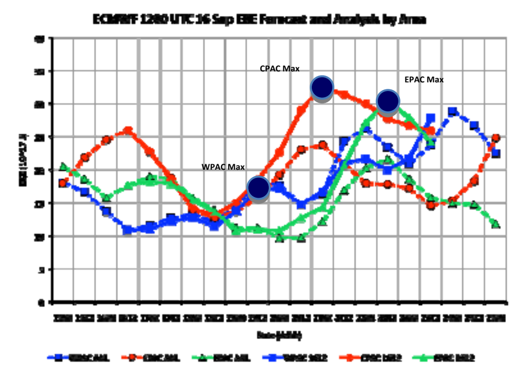

Figure 7. As in Fig. 6, except for ECMWF forecasts initiated at 1200 UTC 16 September 2008.

extratropical transition was common to all operational global forecast models that were examined during the T-PARC field program. However, there was quite a variety in the magnitude and timing of the distributions of EKE maxima across the North Pacific. As an example, the character of the sequence of downstream development forecasts from the ECMWF forecast system is examined (Fig. 8). It is clear that forecasts of the EKE distribution over the central North Pacific are quite accurate until 1200 UTC 18 September. After this time, the forecast distribution of central North Pacific EKE spreads considerably with the error increasing with increasing forecast range.

At 1200 UTC 18 September, TY Sinlaku had just completed the re-intensification back to a typhoon and was just moving past southern Japan. Therefore, forecasts of downstream development are sensitive to characteristics of either the tropical cyclone, the midlatitude circulation into which the tropical cyclone is moving, or the interaction between the tropical cyclone and midlatitude flow.

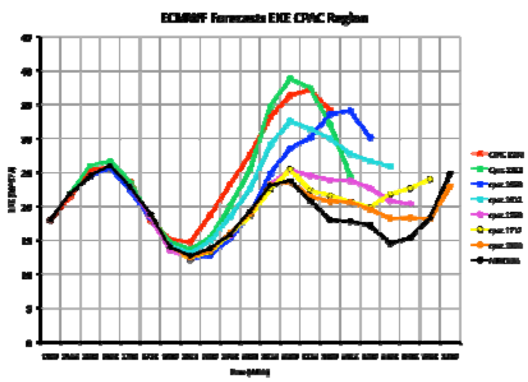

Figure 8. Analyzed (black line) and forecast (colored lines) EKE (10^{18} J) over the central North Pacific for ECMWF forecasts initiated between 0000 UTC 15 September and 0000 UTC 18 September.

In relation to the over-forecasting of the EKE over the central North Pacific, the track forecasts from the ECMWF deterministic forecast, control forecast, and ensemble forecasts (Fig. 9) were consistently poleward of the best-track position of Sinlaku. These factors are examined with respect to the synoptic patterns associated with downstream ridge amplification, jet streak modification. The distribution of EKE is also examined with respect to contributions from the generation of EKE associated with the movement of the tropical cyclone and outflow into the midlatitudes and the transport of EKE downstream by ageostrophic geopotential fluxes.

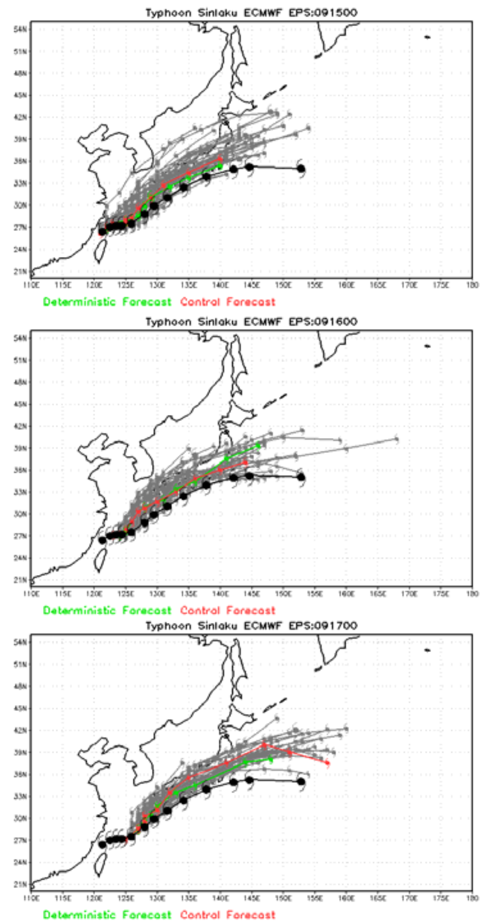

Figure 9. Track forecasts for Typhoon Sinlaku from the ECMWF deterministic (green) forecast, control (red) forecast, and ensemble members (gray) for forecasts initiated at 0000 UTC 16-17 September. Track positions were obtained from the THORPEX Interactive Grand Global Ensemble (TIGGE) data base.

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