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An Investigation into the Potential Effects of Recurving Western Pacific Tropical Cyclones on the Large-Scale Circulation.

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1. Introduction

Recurving tropical cyclones in the western Pacific Ocean are relatively frequent from late August to early November. The question can be raised: "What effect, if any, does the input of this energy into the baroclinic westerlies have on the general circulation of the atmosphere on a varying range of time and space scales?" Observations (e.g., Palmen, 1958; Erickson and Winston, 1972) and modeling studies (e.g., Ferreira and Schubert, 1999) show that there is often a significant acceleration of the midlatitude jet and downstream Rossby wave propagation subsequent to recurvature. To investigate the potential role the cyclones are playing in the forcing of these phenomenon, a composite analyses of various meteorological parameters and diagnostics for selected storms have been prepared.

2. Data Sources and Methods

Storm track data from 1988-1994 and 1996-1999 (weather.unisys.com) were examined to identify 35 recurving events for potential compositing. To identify the dynamic differences between events in terms of jet acceleration and wave development, composites of meteorological parameters and diagnostics for strong, moderate, and weak events were created (i.e., six sets of composites). A jet acceleration index used total windspeed increase at jet level downstream of recurvature to identify which events were placed in the strong, moderate, or weak acceleration composites. Meridional windspeed increase downstream of recurvature was the basis for a Rossby wave development index. This resulted in the strong, moderate, and weak acceleration composites containing seven, six, and five members respectively; the strong, moderate and weak wave composites had 12, 11, and 12 members respectively.

The composites were generated at 24 hour intervals from five days before recurvature to five days after recurvature (i.e. 11 time periods). A "pseudo-storm relative" coordinate system was used. This was done by shifting individual grids so composite members' recurvature locations were collocated. The time and location of recurvature was defined as the time and location at which the storm switches from westward motion to eastward motion. The majority of the data for the composites came from ECMWF uninitialized 1.125° grids. The exception was the outgoing longwave radiation dataset (Liebman and Smith 1996).

3. Results and Conclusions

The analyses' most significant result is concentrated diabatic heating associated with the cyclone on the warm side of the upper-level baroclinic zone plays an important role in forcing the strong acceleration of the jet(e.g., 20 m s^{-1} increase at the jet core (~200 hPa) in the 24 hours after recurvature) and the downstream propagation of Rossby wave energy. As the storm interacts with the baroclinic westerlies, diabatic heating in the region of the storm strengthens the thermal gradient driving the jet acceleration; it also rapidly builds a midlatitude ridge in that same area exciting downstream Rossby waves.

The presence of diabatic heating, the jet acceleration, and the wave development are seen when examining the strong jet acceleration and wave development composites for potential temperature (θ) on the dynamic tropopause (DT; 1.5 PVU) at t-24 hours through t+48 hours (Figs. 1-2). The strong acceleration composite at t-24 hours (Fig. 1a) shows a positively tilted large-scale trough located to the north and west of the recurvature location. Upper-level baroclinicity and a jet stream of 40 m s^{-1} are located approximately 15° north of the latitude of recurvature.

At t (Fig. 1b), the time of recurvature, warming is observed north of the recurvature location. Potential temperature in this region has increased by approximately 10 K in 24 hours. In response to this warming there is a tightening of the θ gradient and an increase in windspeed in the jet. Given the orientation of the flow relative to the θ gradient (i.e., wind vectors parallel to isentropes), diabatic heating is playing a significant role in this local temperature increase in comparison to thermal advection on the DT. The diabatic heating is also made evident by the erosion of the large-scale thermal trough as it progresses eastward.

The most dramatic effects, however, are seen in the composites for t+24 and t+48 hours (Figs. 1c and d). The diabatic warming on the warm side of the baroclinic zone is clearly seen as is the associated frontogenesis, jet acceleration ,and the building of the midlatitude ridge. There is little thermal advection on the DT and the erosion of the large-scale thermal trough continues. The area of θ greater than 360 K has expanded significantly northeast of the recurvature location. Wind speeds have increased to 60 m s^{-1}.

In contrast, results of the weak jet acceleration composites (not shown) indicate the midlatitude flow is initially too strong rapidly weakening the storms through shearing effects. This limits the aforementioned heating and frontogenesis. The weak acceleration composites do show, however, an increase in wind speed of approximately 10 m s^{-1} from t-24 to t+24 hours in the area of recurvature. Moderate acceleration composites were similar to the strong cases except the magnitude and scale of the windspeed increases were smaller.

The strong wave development composite of θ and winds on the DT shows similar effects to the strong jet acceleration composites discussed previously. Heating occurs on the warm side of the upper-level baroclinic zone as the storms interact with the westerlies. This builds the midlatitude ridge (Figs. 2a-c). Rossby waves are observed to propagate in response to this interaction (Figs. 2b-d). An important aspect of this propagation is the presence of a θ gradient on the DT that extends a sufficient distance downstream from the location of recurvature. This θ gradient reflects the potential vorticity (PV) gradient that serves as the waveguide for Rossby wave propagation. For the strong wave composites, a strong gradient extends from the western most edge of the domain to approximately 80° downstream (Figs. 2a-b). For moderate wave development (not shown) the θ gradient is weaker and of limited downstream extent. In the weak wave development composites a strong θ gradient is present in the region of recurvature but is limited in its downstream extent (~40°).

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5. References

Erickson, C.O. and J.S. Winston, 1972: Tropical Storms, midlatitude cloud band connections and the autumnal build-up of the planetary circulation. *J.Appl.Meteor.*,**11**, 23 -36.

Ferriera, R.N. and W.H. Schubert, 1999: The role of tropical cyclones in the formation of tropical upper-tropospheric troughs. *J.Atmos.Sci.*, 56, 2891-2907.

Hoskins, B.J., M.E. McIntyre, and A.W. Robertson, 1985: On the use and significance of isentropic potential vorticity maps. *Quart. J. Roy. Meteor. Soc.*, 111, 877-946.

Liebmann, B. and C.A. Smith, 1996: Description of a complete (interpolated) outgoing longwave radiation dataset. *Bull.Atmos.Meteo.Soc.*, **77**, 1275-1277.

Palmen, E., 1958: Vertical circulation and release of kinetic energy during the development of hurricane Hazel into an extratropical storm. *Tellus*, **10,** 1-23.

Figure Captions:

Figure 1. Potential temperature every 5K and winds (m s^{-1}; one pennant, barb, and half-barb denote 25, 5, and 2.5 m s^{-1}, respectively) on the DT for the strong jet acceleration composite at (a) t-24 hours, (b) t hours, (c) t +24 hours, and (d) t+48 hours where t is the time of recurvature. Latitude and longitude line are drawn every 10 degrees. The location of recurvature is indicated by an asterisk.

Figure 2. As in Fig. 1 except for the strong wave development composite.

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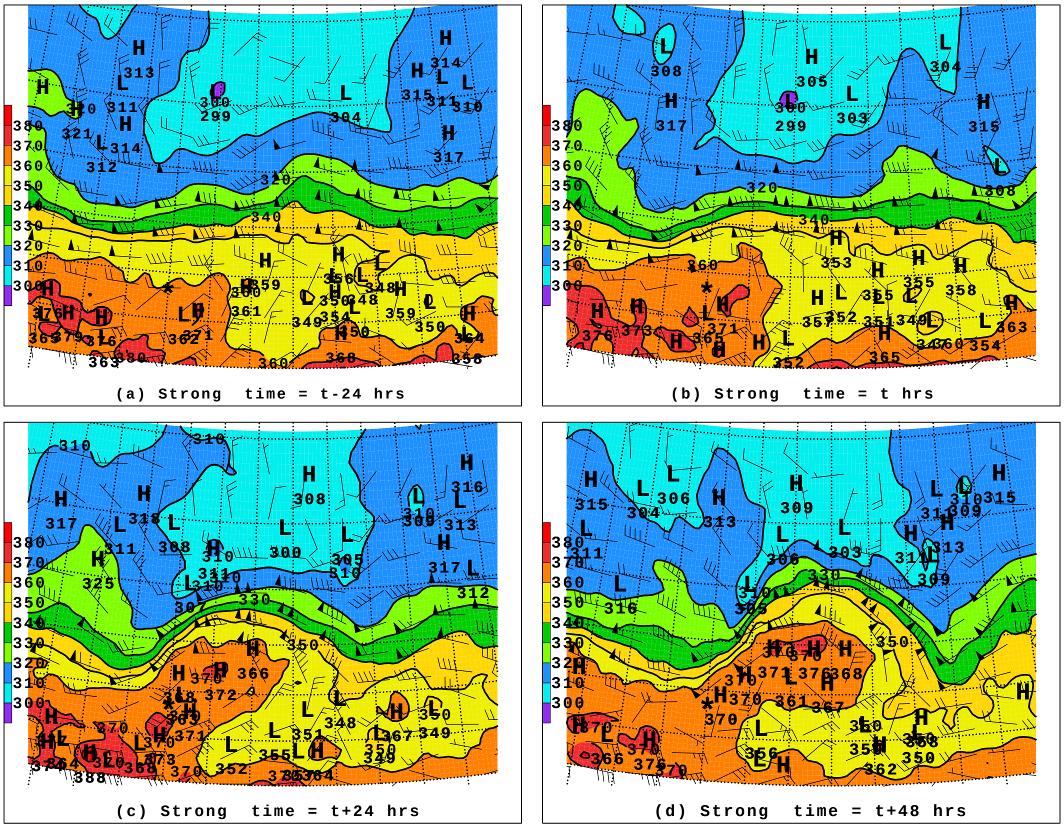


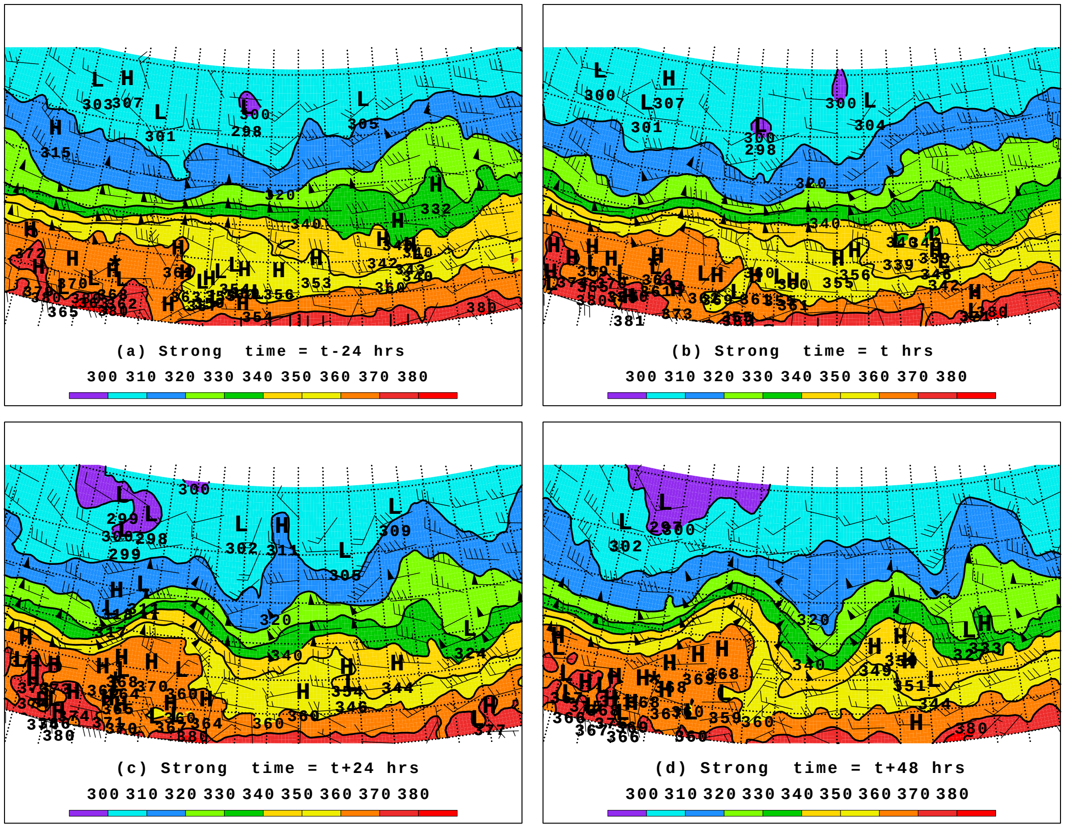
(a) Strong time = t-24 hrs

(b) Strong time = t hrs

(c) Strong time = t+24 hrs

(d) Strong time = t+48 hrs

Fig. 1



(a) Strong time = t-24 hrs

(b) Strong time = t hrs

(c) Strong time = t+24 hrs

(d) Strong time = t+48 hrs

Fig. 2