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INTERACTIONS OF MIDDLE LATITUDE TROUGHS AND TROPICAL DISTURBANCES ON 4-6 WEEK TIME SCALES

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1. INTRODUCTION:

A number of studies have examined the impact of upper tropospheric troughs reaching the subtropics and tropics during Northern Hemisphere winter. Webster and Holton (1982) noted that such propagation most likely occurs in the presence of upper tropospheric westerlies (the "westerly duct"), and is generally prevented by the presence of upper tropospheric easterlies. Kiladis (1998) examined troughs moving equatorward in the eastern Pacific. Only the upper tropospheric component of the trough reached the subtropics, effectively narrowing the vertical scale of the trough. Plots of "e vectors" (Hoskins and Ambrizzi 1993) showed that wave activity at 200 hPa penetrated to within 10 degrees of the equator in the upper troposphere. Kiladis (1998) showed that extensive convection broke out in response to the upper trough. Kiladis provided evidence that n = 1 equatorial Rossby (hereafter ER) waves formed in response, indicated by paired anomalies on either side of the equator. These waves propagated westward from the region of upper trough penetration.

In this work we are considering the same phenomenon in Northern Hemisphere summer in the western Pacific. Two major differences occur. The first is that westerly ducts are rarer and more transient, thus limiting the frequency of penetration of troughs into the tropics. Second, the resulting ER waves propagate into a climatologically convergent region that makes wave amplification more likely. Tropical cyclones frequently form in the presence of such amplifying ER waves (Frank and Roundy 2006; Molinari et al. 2006). This opens the possibility that such tropical cyclones will recurve into middle latitudes, amplify the middle latitude pattern, and produce additional trough penetrations downstream. A case study of this back-and-forth exchange of energy between midlatitudes and tropics is the subject of this study.

2. DATA AND METHODS:

Outgoing longwave radiation (OLR) will be used as a proxy for cloudiness. The OLR field was lowpass filtered with a 20-day cutoff. The filter is broad enough to encompass both persistent local forcing from middle latitudes and the ER wave response in the tropics. Similar filters with 10 and 15-day cutoffs produced only small changes.

3. EVOLUTION OF LOWPASS-FILTERED CLOUDINESS:

Figure 1 shows a sequence of maps of lowpass-filtered OLR once every 4 days. Figure 1a indicates the lowpass representation of the quasi-stationary frontal zone on 10 July, extending northeastward from 30ºN, 150ºE. Over the next 8 days (Figs. 1b,c), the convection extended equatorward along 150ºE and a separate convective maximum began to develop near 20ºN. Thereafter the separate convective maximum broke away from its midlatitude origins (Fig 1d), intensified and grew in area (Figure 1e), and moved westward along 20ºN (Figures 1e-1h). Throughout the time the convective maximum moved westward, it was accompanied by a large cyclonic gyre centered just to its north in the 850 hPa wind field (not shown). Two tropical cyclones formed on the northern edge of the convective maximum on 26 July and 5 August, respectively. One storm recurved into middle latitudes while the other struck mainland China.

4. DISCUSSION:

Mean 200 hPa flow during the month of July contained a narrow longitudinal region where easterlies nearly vanished at all latitudes north of the equator. This narrow westerly duct allowed four short waves crossing over an upstream ridge at 200 hPa to move equatorward in that region. These waves behaved like equatorward breaking waves (Thorncroft et al. 1993) and left behind the quasi-stationary front discussed earlier, which contained persistent convection near 20ºN, 150ºE. In response a large cyclonic gyre developed in the subtropics and moved westward. The westward propagation of an off-equatorial low suggests the involvement of ER wave dynamics.

This sequence of events resembles some aspects of the study by Molinari et al. (2006). In that study a midlatitude trough penetration excited a large cyclonic gyre in the subtropics. That gyre represented the first low pressure area in an extended ER wave packet that spawned 8 tropical cyclones over 2.5 months.

In the talk we will further investigate the cyclonic gyre that produced the convection in Figure 1, especially the means by which it formed, its relation to tropical cyclogenesis, and the subsequent impact on middle latitudes. Our overall interest lies in the sequence of events set off by the tropical penetration of upper tropospheric troughs during Northern Hemisphere summer.

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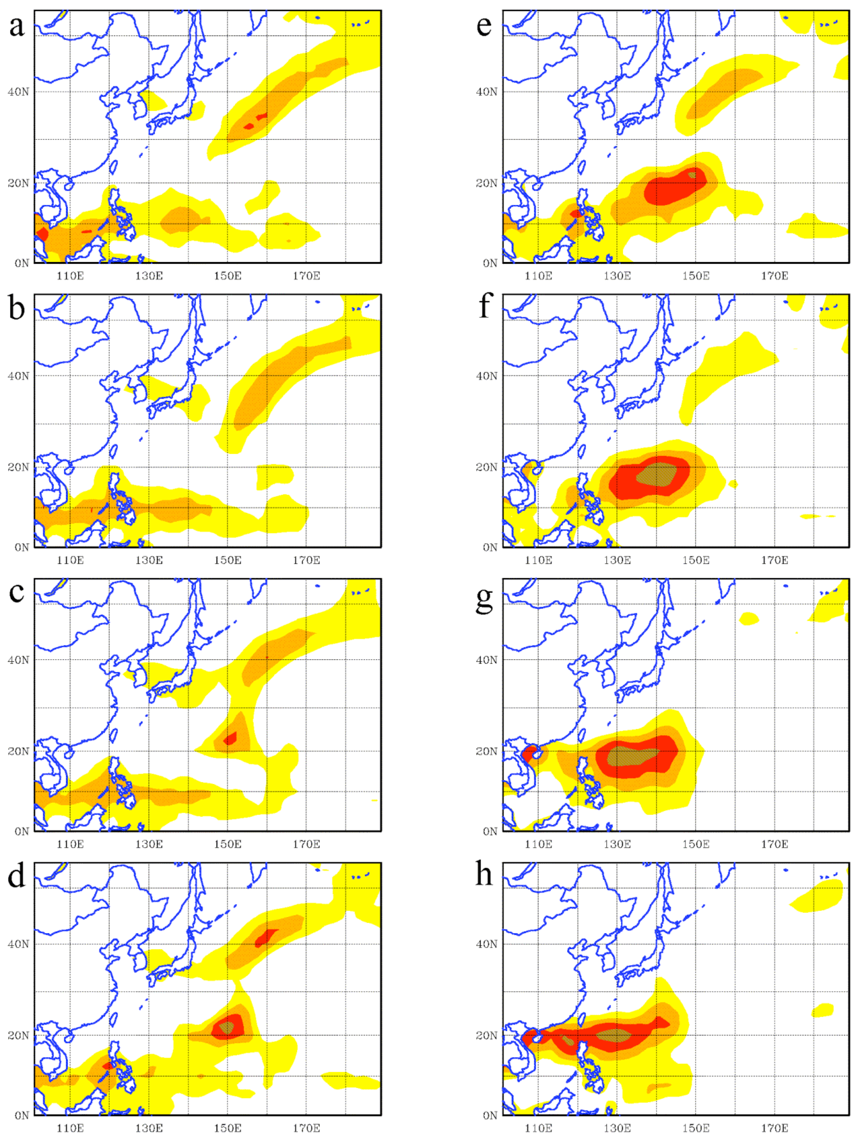

Figure 1: Evolution of lowpass-filtered OLR every four days from 10 July 1988 (panel a) to 7 August 1988 (panel h). Shading begins at 220 W m^{-2} in decreasing increments of 20 W m^{-2}.