4B.3 EXTRATROPICAL-TROPICAL INTERACTION DURING ONSET OF THE AUSTRALIAN MONSOON

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1. INTRODUCTION

The tropical circulation over Australia is characterized by a summer-wet, winter-dry monsoon circulation. The transition from dry to wet is the monsoon onset and is often sudden with enhanced rainfall and strengthening low level westerly winds. Various mechanisms have been proposed that influence the onset. They include extratropical-tropical interaction, intra-tropical interactions, and the Madden-Julian Oscillation (MJO). Through an observational case study (one of many onsets we have studied), we provide evidence of an association between high latitude cyclogenesis over the southwest Indian Ocean (SWIO) and triggering of monsoon onset. We then show idealized simulations that suggest that the effects of high latitude cyclogenesis, in the presence of a subtropical jet (STJ), can influence the monsoon flow.

2. CASE STUDY OF THE MONSOON ONSET

Figure 1 shows a time-height section of zonal wind over the monsoon region (northern shaded region in Fig. 2). The first westerly burst near day 15 is associated with a midlatitude trough, and features upper tropospheric westerlies (not easterlies). Interestingly this is also preceded by high latitude cyclogenesis (see later discussion and Fig. 3). Onset has occured by day 36 when the flow is characterized by deep, low level westerlies and upper level easterlies. However, the onset process appears to have commenced much earlier. Examination of time sections of vertical motion and equivalent potential temperature (not shown) indicate that ascent commenced near day 28 and low level moistening near day 30 – the approximate start of the onset process.

Figure 2 shows the 200 hPa flow at day 31 and reveals the presence of a trough-ridge-trough-ridge structure extending from the SWIO to the Australian tropics. This follows major cyclogenesis over the SWIO. Evolving structures similar to this precede many onsets.

Figure 3 shows time series of sea level pressure averaged over a region representing the SWIO (southern shaded box in Fig. 2.), and an STJ index, given by the 200 hPa zonal wind averaged over a region of the sub-tropical Indian Ocean (central shaded box in Fig. 2). The major cyclogenesis over the SWIO preceding onset is clearly evident, commencing near day 25. The STJ index shows a trend to strengthening and then rapid decay of the jet just prior to onset. We propose that this is evidence of the northeastward propagating wave train evident in Fig. 2 as the evolving trough-ridge structures develop. The origin of these developments appears to be the major cyclogenesis event over the SWIO.

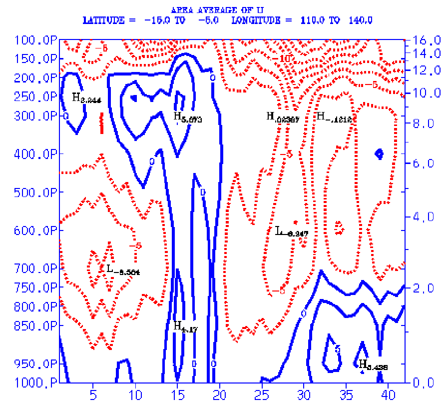

Figure 1: Time-height section of monsoon zonal wind (m/s) for period 19901120 to 19901231.

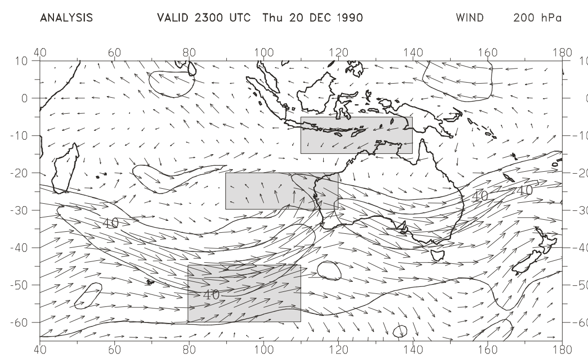

Figure 2: 200 hPa wind 19901220, 2300 UTC.

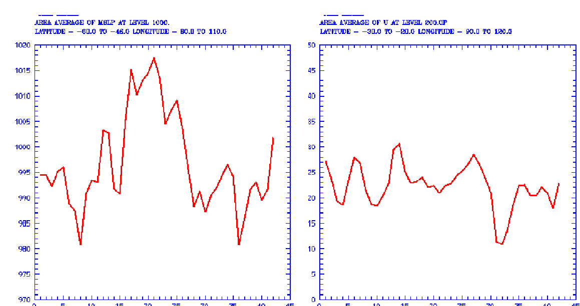
Figure 3: Time series MSLP SWIO, 200 hPa zonal wind STJ.

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3. SIMULATIONS

Simulations are based upon a *dry*, channel version of the model from the BMRC Limited Area Prediction System, LAPS. It is configured with cyclic boundary conditions, and initialized from a zonally-averaged, baroclinically-unstable polar front jet (PFJ). The model was developed by Tory (1997) to study high latitude cyclogenesis. We have extended this to optionally include (a) a monsoon trough (MT) at 12.5^0S, and (b) a STJ at 25^0S. Experiments have been made with all combinations of the PFJ, STJ, and MT. The zonally-averaged initial state is based upon a baroclinically-unstable PFJ, and *observed* cross-sections of the pre-onset STJ and MT, just prior to the observed high latitude cyclogenesis. The initial south-north cross-section of zonal wind is illustrated in Fig. 4. The initial thermal field (not shown) is in balance with this wind field.

Figure 5 shows from the (PFJ+STJ+MT) simulation, the difference between the initial and 168-hour simulated 200 hPa wind field; i.e. flow changes that developed during the simulation. (*We have included some topography for reference only.*) Because the strength of the wind changes over the tropics are not large (~ 5m/s) we have split the diagram into extratropical and tropical parts. Points to note are: (a) the high latitude cyclogenesis is influencing the large scale wind patterns over the tropics, with trough-ridge structures developing to low latitudes; (b) associated with these are large regions of changed zonal wind (and divergence) over the tropics; (c) similar to Fig. 2, there is evidence of the trough-ridge-trough-ridge structure extending from the high latitude cyclogenesis into the tropics. There is little evidence of strengthening low level monsoon westerly winds in these simulations (not shown), suggesting that convection is critical to this process. However, significant zonal and meridional variations in the location and strength of the MT develop during the simulation. Simulations with no STJ show a significantly reduced influence of the cyclogenesis on the tropical flow, consistent with the theoretical study of Webster and Holton (1982).

4. SUMMARY

NCEP/NCAR objective analyses have been used to re-assess onset of the Australian monsoon. Similar to previous findings, onset is characterized by a sudden strengthening and deepening in tropical westerly winds. However in all events considered, this is preceded by up to a 7-day period of enhanced vertical motion and moistening. Evidence suggests that the onset process may be associated with major cyclogenesis over the SWIO. The proposed mechanism is the eastward and equatorward development of troughs and ridges, and the eventual impact of this on the tropical flow.

Idealized, dry simulations initialized with a balanced, zonally-averaged, baroclinically-unstable polar front jet, a weak monsoon trough, and a subtropical jet, suggest that the developing trough-ridge structures may be associated with an energy dispersion mechanism, in which successive troughs and ridges develop northeastward from the high latitude cyclogenesis. This eventually results in the amplification of an equatorward-extending upper trough-ridge couplet over low latitudes, which can influence the development of the low level monsoon trough, and the divergence field over the tropics. Consistent with theoretical studies, the subtropical jet is critical to the process, and acts as a duct for propagation from high to low latitudes.

Finally, even though onset may occur during the passage of an active phase of the MJO, we suggest that triggering and modulation within this slow mode may be related to the extratropical–tropical interaction described here.

5. REFERENCES

Tory, K. J., 1997: The effect of the continental planetary boundary layer on the evolution of fronts. PhD thesis. Monash University, 294 pp.

Webster, P.J. and J. Holton, 1982: Cross-equatorial response to middle-latitude forcing in a zonally varying basic state. *J.Atmos.Sci.,* **39**, 722-733.

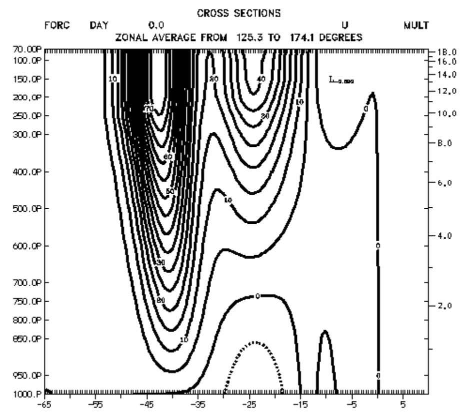

Figure 4: South-north cross-section of initial, zonal wind.

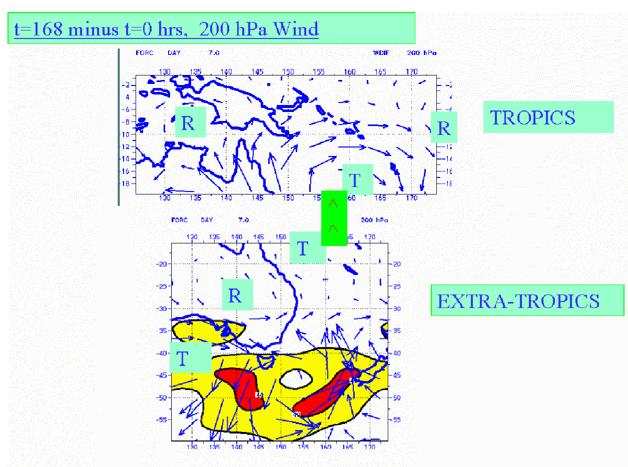

Figure 5: Simulated t=0 minus t=168 hour 200 hPa zonal wind for tropical and extratropical regions.