5A.2 INTERHEMISPHERIC ATMOSPHERIC MASS EXCHANGE ASSOCIATED WITH THE ONSET OF AN ACTIVE PHASE OF THE AUSTRALIAN SUMMER MONSOON

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1. INTRODUCTION

The exchange of atmospheric mass between the northern hemisphere (NH) and southern hemisphere (SH) occurs with considerable regularity on intraseasonal time-scales. Observational evidence from previous studies indicates that anomalous and persistent regional atmospheric mass distributions may often be related to interhemispheric atmospheric mass exchange.

In this study we examine an event where the NH undergoes a loss of 1.80 hPa of hemispherically averaged dry air surface pressure over a 9 day period commencing on 3 March 1989. The value of 1.80 hPa represents greater than 60% of the mean annual cycle of NH dry atmospheric mass. Similar to a 25 case composite of NH cold season dry atmospheric mass fall events over a 30 year period from 1968 to 1997, this event is accompanied by a rapid buildup of the Siberian high and a subsequent pressure surge over Southeast Asia.

We will show a strong linkage between the pressure surge over Southeast Asia and the onset of an active phase of the Australian summer monsoon (ASM). Associated with this onset and the outbreak of deep convection is a redistribution of dry atmospheric mass in the upper-level divergent outflow into three prominent anticyclonic circulations in the extratropical SH.

2. DATA

In this study we use daily averaged data from the European Centre for Medium Range Weather Forecasts (ECMWF) reanalysis extending over the 15 year period 1979 to 1993. To document the enhancement of convective activity associated with the onset of the active phase of the ASM we use daily outgoing longwave radiation (OLR) data derived from NOAA satellites.

3. RESULTS

A variety of indices, based upon the zonal and meridional winds, have traditionally been used to characterize the principal components of the Asian-Australian monsoon region. We consider three geographical regions, the South China Sea (SCS) (5^oN-10^oN, 110^oE-115^oE), the Timor Sea region (TSR) (10^oS-15^oS, 125^oE-130^oE), and a region off the west coast of Australia (25^oS-30^oS, 105^oE-110^oE).

Figure 1a shows the time evolution of the surface meridional winds, area-averaged over the SCS (long dash) and off the west coast of Australia (short dash), and a time-series of the surface zonal winds averaged over the TSR (solid). The climatological lower tropospheric meridional winds over the SCS are northerly owing to the presence of the persistent Siberian high, while the climatological lower tropospheric winds off the west coast of Australia are southerly owing to the presence of the upstream anticyclone in the South Indian Ocean. One can clearly see, superimposed upon the climatological northerly flow, a strengthening of the northerly winds over the SCS beginning 4 March and peaking 9 March associated with the Southeast Asian pressure surge.

The westerly wind burst over the monsoon trough (TSR) is impressive (solid), with area-averaged surface zonal wind speeds increasing by approximately 7 m s^{-1} between 5 and 10 March. The peak coincides with the peak intensities of both the northerly (long dash) and southerly (short dash) surges from both the NH and SH. Bursts of lower tropospheric westerly winds to the south of the equator within the monsoon trough are known to accompany cold surges from Southeast Asia (Kiladis et al. 1994). The increase in the southerly component of the surface meridional wind off the west coast of Australia (short dash) is modest in comparison to the larger fluctuations seen over the 2 month period.

The vertical structure of the meridional and zonal winds, area-averaged, for the SCS and TSR are shown in Fig. 1b and c respectively. The strengthening of the lower tropospheric northerly flow over the SCS between 6 and 11 March is clearly evident (Fig. 1b). The zone of maximum northerlies is shallow, extending only up to approximately 800 hPa, consistent with the shallow nature of pressure surges in this region. Equally important is the strengthening of the upper-level southerly flow above the low-level northerly surge, indicative of an enhancement of the local Hadley cell. The vertical structure of the zonal winds for the TSR (Fig. 1c) depict a rapid transition from deep layer easterly to deep layer westerly winds occurring approximately 8 March. Transitions from break to active phases of the ASM can occur as rapidly as 1 day, and are characterized by the onset of a deep layer of westerly winds. From Fig. 1c the

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zonal winds extend from the surface to near 400 hPa, with strong easterlies above. Prior to 8 March, easterly winds are present throughout a deep layer, with westerly zonal winds above, characteristic of break phases of the ASM.

A comparison of Fig. 1b and c clearly reveals a strong temporal linkage between the northerly surge over the SCS and the subsequent onset of an active phase of the ASM.

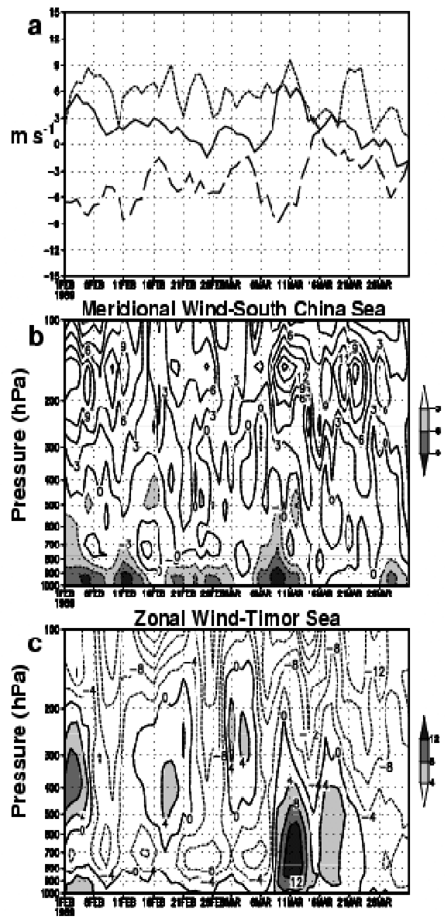

Figure 1. (a) Area-averaged surface meridional winds (m s^{-1}) for the SCS in long dash, and for the west coast of Australia (short dash). Area-averaged surface zonal winds (m s^{-1}) for the TSR in thick solid. Time-pressure plots of the area-averaged meridional winds (m s^{-1}) over the SCS, with negative values shaded, in (b), and the area-averaged zonal winds (m s^{-1}) over the TSR, with positive values shaded, in (c).

In Fig. 2 we show the intensification of the local Hadley circulation over Southeast Asia by means of lower (top panel) and upper (bottom panel) tropospheric dry atmospheric mass flux potentials for 10 March 1989. The upper troposphere is represented by the layer extending from 500 to 10 hPa, while the lower troposphere is given by the surface to 500 hPa layer. Also shown in Fig. 2 are the intraseasonal OLR anomalies.

Important features to note in Fig. 2 include the pronounced meridional overturning in the Asian-Australian sector, the southward displacement of the lower (upper) tropospheric convergent (divergent) center and associated convection over northern Australia, and the pronounced upper tropospheric dry atmospheric mass divergence extending both southeastward and southwestward from Australia into the extratropical SH.

Three prominent anticyclonic circulations intensify in the SH extratropics (not shown), stretching from the South Indian Ocean to the South Pacific, beneath regions of upper tropospheric dry atmospheric mass convergence, originating from the monsoon convection outflow. These anticyclonic circulations are largely responsible for the dry atmospheric mass increase in the SH.

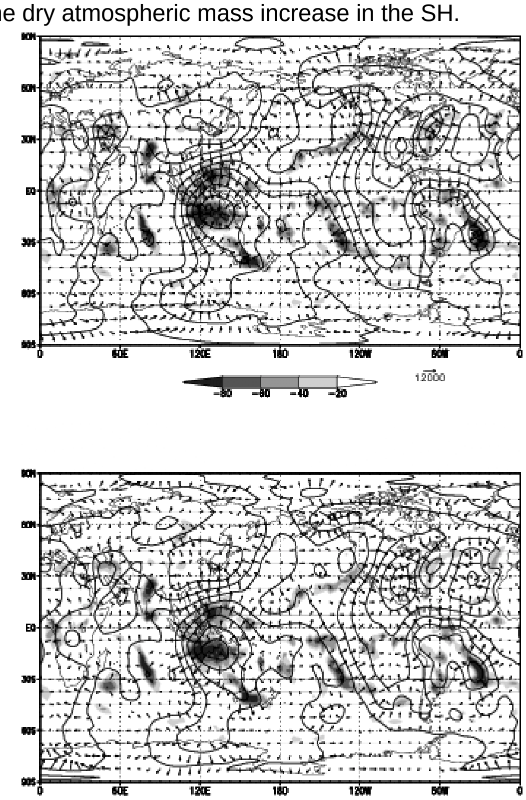

Figure 2. Dry atmospheric mass flux potential in units of $5x10^9$ kg s^{-1}, along with the zonal and meridional components of the dry atmospheric mass flux potential in units of kg (m s^{-1}) for 10 March 1989. A reference vector is provided. Top panel is from surface to 500 hPa, while the bottom panel is from 500 hPa to 10 hPa. The OLR anomalies (W m^{-2}) are shaded as indicated.

4. REFERENCES

Kiladis, G. N., G. A. Meehl, and K. M. Weickmann, 1994: Large-scale circulation associated with westerly wind bursts and deep convection over the western equatorial Pacific. *J. Geophys. Res.*, **99**, 18,527-18,544.