2.4 INTRASEASONAL DEVELOPMENT OF A WEST PACIFIC POLE TO POLE TELECONNECTION DURING LATE AUSTRAL WINTER

Keith M. Hines[1,*] and David H. Bromwich[1,2]

[1]Polar Meteorology Group, Byrd Polar Research Center,
The Ohio State University, Columbus, Ohio

[2]Atmospheric Science Program, Department of Geography
The Ohio State University, Columbus, Ohio

1. INTRODUCTION

The development on intraseasonal timescales is discussed for a climate linkage extending from Antarctica to the Arctic during late Austral winter. The teleconnection has previously been found in observations (Hines et al. 2001) and global climate model simulations (Bromwich et al. 1998). The latter suggest that the teleconnection can be forced from high southern latitudes. The observed teleconnection pattern includes three primary anomalies in Southern Hemisphere (SH) high latitudes, SH middle latitudes and the Northern Hemisphere (NH) subtropics. Figure 1 shows the structure in surface pressure of the teleconnection during August in the NCEP/NCAR Reanalysis obtained by taking the difference between 5-year ensemble means for opposite extreme phases. When the reanalysis surface pressure over southeast Australia and New Zealand during August is above average, the pressure will tend to be below average to the south over Wilkes Land, Antarctica and the Ross Sea. Thus, there is a resemblance to the SH high latitude mode/Antarctic Oscillation. At the same time the pressure will tend to be above average in a subtropical NH region centered near 25°N 130°E. This is linked to changes in monsoon precipitation over East Asia. In SH high and middle latitudes, most of the zonally asymmetric component is constrained within zonal wavenumber 1. Figure 1 also shows that the impact of the teleconnection extends northward to the Aleutian Islands and eastward to the Antarctic Peninsula.

2. THE DAILY TELECONNECTION INDEX

Monthly-mean fields suggest that the cross-equatorial teleconnection persists for about one month, inferring that the time scale is intraseasonal. Furthermore, the tropical wind field shows characteristics of the Madden-Julian Oscillation (Hines et al. 2001). To understand the development of the teleconnection, we need to look at finer timescales than available from monthly-mean fields. Therefore, daily fields from the NCEP/NCAR Reanalysis are used for the analysis. We first obtained daily values of mean sea level pressure for the months June to October during 1977-1999 from the NCEP/NCAR Reanalysis. A daily teleconnection index, based upon three primary anomalies in Fig. 1, is calculated with a weighted sum of sea level pressures, including a contribution from Southern Ocean grid point in high latitudes (**HL**) at 65°S, 140°E located slightly north of the observing station Dumont d'Urville. The daily teleconnection index also incorporates a grid point in the Australia-New Zealand sector of the SH mid-latitudes (**ML**) at 40°S, 150°E and a grid point offshore from China in the NH subtropics (**NHST**) at 25°N, 125°E,

$$\mathbf{INDEX = 0.462\ NHST + 0.302\ ML - 0.171\ HL - 604,}$$

where the input is in hPa, and the value 604 is subtracted to bring the mean toward zero. The index allows us to define "positive" and "negative" phases. The intensity of a particular phase of the teleconnection is proportional to the magnitude of the index.

The autocorrelation of the daily adjusted teleconnection index was evaluated from daily sea level pressures for each of the months June, July, August, September and October. It is found that the autocorrelation for August is clearly larger than for the other months over a broad range of lags. This finding indicates the persistence of the teleconnection pattern during the month of August, explaining the preference of the teleconnection to be seen during August in the monthly-mean fields.

3. INTRASEASONAL DEVELOPMENT OF THE TELECONNECTION

To evaluate the time evolution for the teleconnection anomalies, daily values of geopotential height and horizontal velocity on isobaric surfaces were also obtained from the NCEP/NCAR Reanalysis during 1977-1999 including 10 years with Augusts of extreme value (magnitude greater than 2 hPa) for a teleconnection index similar to that defined above. Additionally, daily outgoing longwave radiation (OLR) data from the National Oceanic and Atmospheric Administration (NOAA) for 1974-1997

* *Corresponding author address:* Keith M. Hines, Polar Meteorology Group, Byrd Polar Research Center, The Ohio State University, 1090 Carmack Road, Columbus, Ohio 43210-1002. email: hines.91@osu.edu

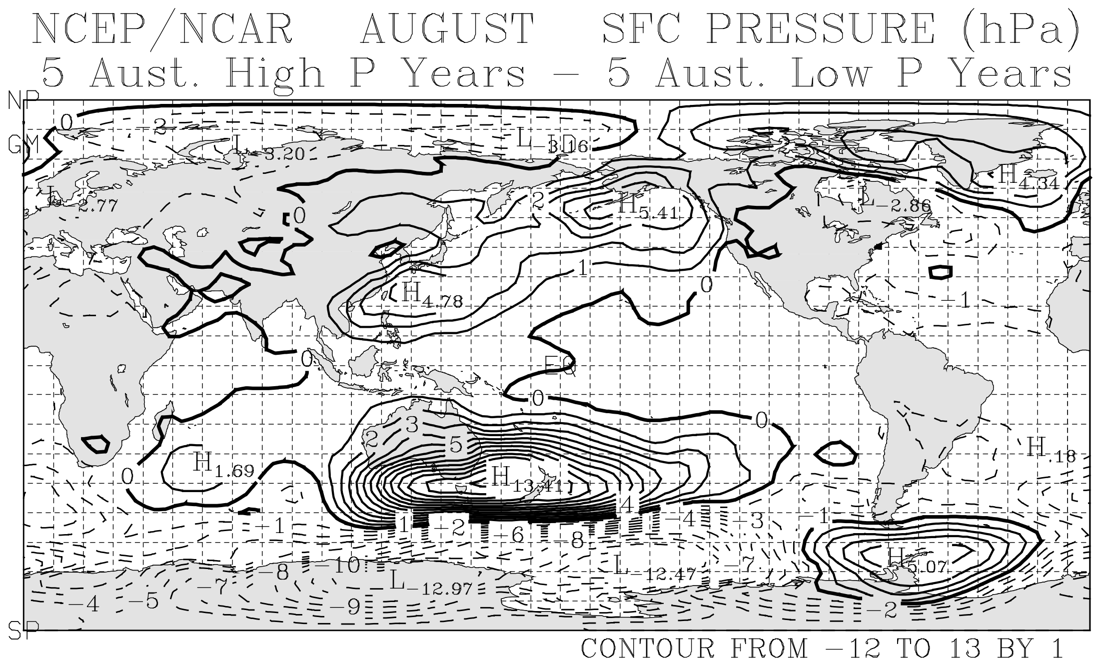

Figure 1. Map of difference in average surface pressure (hPa) of the NCEP/NCAR Reanalysis between 5 Augusts of above average pressure and 5 Augusts of below average surface pressure at 40°S, 145°E. Contour interval is 1 hPa.

were obtained on a 2.5° longitude by 2.5° latitude grid. The OLR is a good measure of tropical convection to which it is negatively correlated.

As it was believed that intraseasonal timescales are important for interactions between different components of the teleconnection, time filtering via Fourier series has been performed on the data. The data used covers the 151 days starting on June 2 and ending on October 30. Time series of the adjusted teleconnection index, OLR and the teleconnection sea level pressure anomalies suggest coordination on intraseasonal timescales between the individual teleconnection anomalies, and between the anomalies and OLR. The time series also suggest recurring seasonal development patterns for each of the positive and negative phases of the teleconnection. This suggests that we can study the development of the teleconnection by averaging similar events.

To verify the link between tropical convection and the pressure anomalies of the teleconnection index, we correlated the June-October OLR in the NH tropical sector 5°-20°N, 100°-115°E to the individual teleconnection pressure anomalies and to the adjusted teleconnection index. The fields were filtered to oscillations with periods of 25-75 days. A negative lag indicates that the filtered OLR anomaly leads the filtered pressure anomaly. Largest correlation magnitudes are found when the tropical sector OLR leads the teleconnection pressure anomalies. Extrema of the correlation between the adjusted teleconnection index and sector OLR include 0.565 for a lag of -11 days. Thus the maximum positive phase of the teleconnection, characterized by positive pressure anomalies for **NHST** and **ML** and a negative anomaly for **HL**, is frequently preceded by a positive OLR anomaly (reduced convection) for the tropical sector. There is also a tendency for a positive anomaly of the teleconnection index to be followed by a negative anomaly of OLR, though the lagged correlation is weaker in this case.

Compositing of similar phases of the teleconnection is now performed to understand the development of the positive and negative phases of the teleconnection. From the teleconnection index we identify Augusts of extreme positive and negative phase during 1977-1997. The extreme years are defined as years when the magnitude of the index exceeds 2 hPa. Figure 2 shows the development of the 850 hPa geopotential height field composite for 5 positive index years. The climatology for each day during 1977-1999 has been subtracted from the geopotential height fields that are then filtered to include variations with periods of 15 days or longer. Thus the annual cycle and synoptic scale variations are removed from the geopotential fields while intraseasonal variations are retained. Of the six stages shown in Fig. 2, the first panel displays the July 14 composite before the lower-tropospheric high is beginning to develop in the NH subtropics over the extreme western Pacific Ocean.

Figure 2 indicates that the region near 110°E is favorable for development of the two primary teleconnection anomalies in the SH. On July 14, there appears to be a chain of anomalies present in SH high and middle latitudes (Fig. 2a). A high is centered near 60°S, 125°E over the Indian Ocean with a low to the west centered at 55°S, 55°E. By July 22, the high seen in Fig.

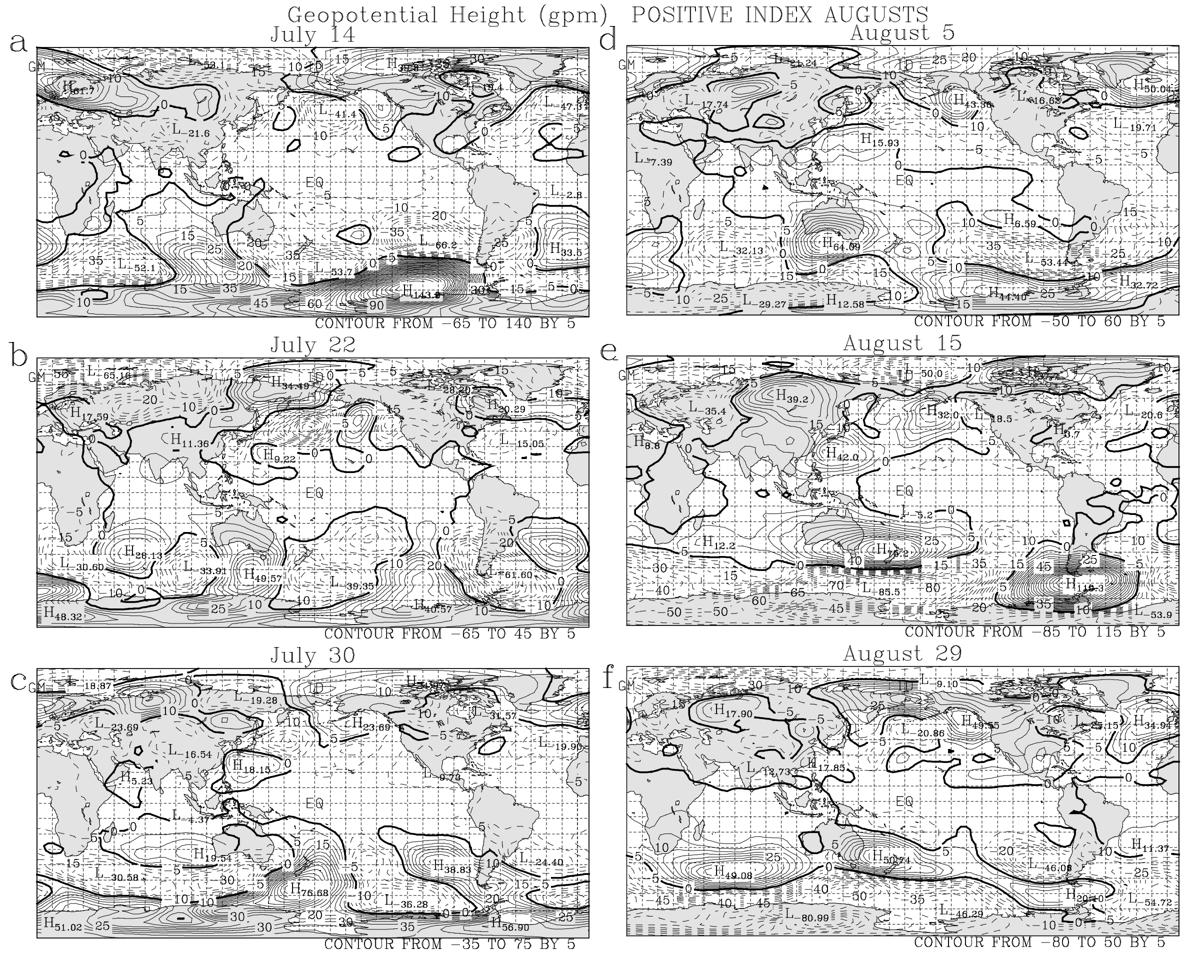

Figure 2. Daily composite difference in geopotential height (gpm) at 850 hPa between 5 positive phase teleconnection anomaly years and the 1977-99 mean filtered to periods of 15 days or longer. (a) July 14, (b) July 24, (c) July 30, (d) August 5, (e) August 15, and (f) August 29. Contour interval is 5 gpm.

2a has split into 2 components; one centered near 60°E, and one centered near 140°E (Fig 2b). On July 30, shortly before the period of rapid intensification of the teleconnection anomalies, the high-low-high pattern seen in Fig. 2b has translated eastward with the western high now weakened and centered near 105°E (Fig 2c). By August 5, the three cell teleconnection pattern across the equator is apparent, and the SH primary anomalies have rapidly intensified (Fig 2d). The western high has moved slightly east to near 130°E and has reached an intensity of 64.1 gpm. The low has moved south and has reached a center intensity of 56.1 gpm. The wavenumber 1 pattern for this time includes a mid-latitude ridge over Australia. The NH subtropical cell is centered offshore near 155°E and is weaker than the main SH anomalies as its amplitude is 15.9 gpm. August 15 is about the time of maximum intensity for the teleconnection anomalies (Fig. 2e). Notice the similarity between Figs. 1 and 2e. The teleconnection anomalies slowly weaken after mid-August. By August 29, the SH anomalies have weakened and stretched longitudinally (Fig 2f). The later panels show an example of the SH high latitude mode pattern with reduced pressure at high latitudes and increased pressure at middle latitudes. Furthermore, there appears to be a strong longitudinal preference for the rapid growth of the SH teleconnection anomalies, with development favored for high and mid-latitude anomalies moving into the region near 110°E. The development of the negative phase of the teleconnection is similar to that of the positive phase, except that the signs of the anomalies are reversed.

Figure 3 provides more insight on how the tropical circulation is linked to the SH anomalies of the teleconnection. The difference between composite August 7 velocities for phases of the teleconnection and the 1977-1999 daily mean has been diagnosed into its divergent component. The divergent wind is filtered to periods of 15-75 days. The arrows display this divergent component at 300 hPa, while the contours display the unfiltered wind speed at 300 hPa. The August 7 fields are representative of the growing stage of the teleconnection.

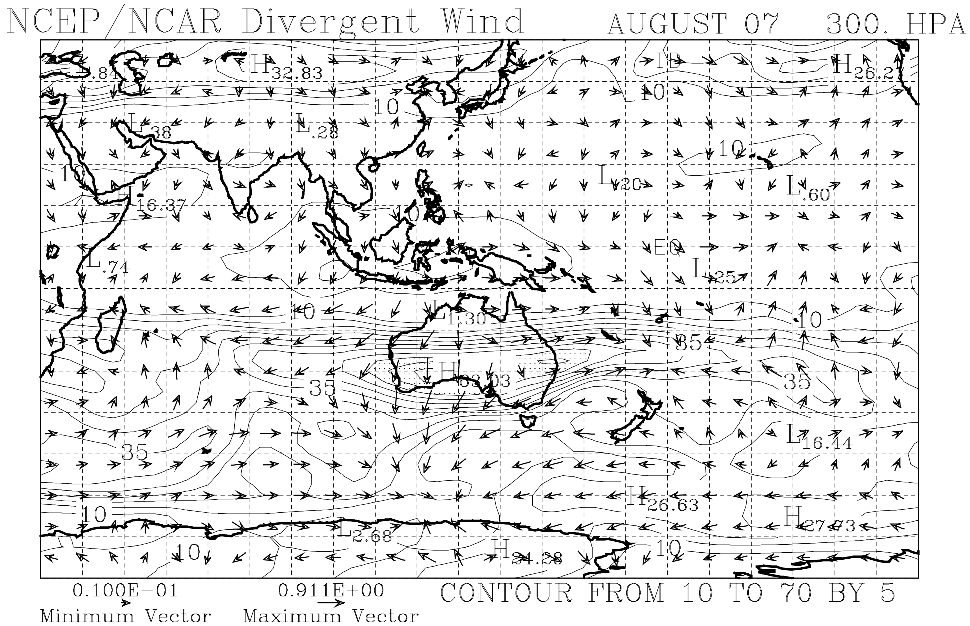

Figure 3. Divergent wind component (arrows m s^{-1}) filtered to periods of 15-75 days at 300 hPa for the August 7 composite of 5 negative phase events. The contours show the 300 hPa unfiltered wind speed. Contour interval is 5 m s^{-1}.

The wind speed in the SH subtropical jet stream beginning over the Indian Ocean and extending over Australia is enhanced (weakened) for the negative (positive) phase of the teleconnection. Figure 3 shows the enhanced subtropical jet stream for the negative phase. The divergent circulation is active in the region of the subtropical jets near northern Australia. In the upper troposphere, the SH anomalous divergent circulation is outward from tropical convection anomalies near Indonesia for the negative phase. The opposite is true for the positive phase. Tropical convection is known to interact with SH subtropical jet streams on intraseasonal time scales (e.g., Hurrell and Vincent 1991). The intraseasonal meridional circulation is seen to extend from the tropics to the latitude of the polar front jet near 50°S. The polar front jet is weakened (intensified) for the negative (positive) phase of the teleconnection. Thus, the teleconnection encompasses the anticorrelation between the SH subtropical and polar front jet streams, and the positive correlation between tropical convection and the SH subtropical jet stream.

4. SUMMARY AND CONCLUSIONS

An intriguing teleconnection extends from Antarctica to the Arctic during late Austral winter. The teleconnection was previously noted in observations and global climate model simulations. The pattern includes three primary anomalies in the SH high latitudes, SH middle latitudes and the NH subtropics. The teleconnection encompasses the SH high latitude mode/Antarctic Oscillation, and the anticorrelation between the SH subtropical and polar front jet streams. In SH high and middle latitudes, most of the zonally asymmetric component is constrained within zonal wavenumber 1. A filtered analysis on intraseasonal timescales indicates that intraseasonal tropical motions (the Madden Julian Oscillation) are closely linked to the teleconnection. An index from the composite of the three primary teleconnection anomalies is correlated to tropical outgoing longwave radiation. An analysis helps detail the linkage between the tropical and SH mid-latitude components. Variations, related to the teleconnection, of the subtropical jet stream near Australia are connected with convective inflow and outflow anomalies originating near Indonesia.

ACKNOWLEDGMENTS. This research is supported by NASA via grants NAG5-7750 and NAGW-2718 and by NSF via grant ATM-9820042.

5. REFERENCES

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