NOTES AND CORRESPONDENCE

Comments on ''Northern Hemisphere Teleconnection Patterns during Extreme Phases of the Zonal-Mean Circulation''

J. M. WALLACE AND DAVID W. J. THOMPSON

Department of Atmospheric Sciences, University of Washington, Seattle, Washington

ZHIFANG FANG

Chengdu Institute of Meteorology, Chengdu, Sichuan, China

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In a recent article published in this journal, Ting et al. (1996) documented the three-dimensional structure of the stationary wave response to a distinctive mode of variability of the zonally averaged basic state: a meridional ''see-saw'' in zonal momentum represented by the algebraic difference between the zonal-mean, zonal (geostrophic) wind at 55° and 35°N. This particular choice of index was motivated by statistics derived from a suite of experiments with a linear baroclinic stationary wave model and prior analyses of observational data by Branstator (1984) and Kidson (1985). Here we relate the mode of variability that they examined to the ''Arctic Oscillation'' (AO; Thompson and Wallace 1998, hereafter denoted TW98) and reflect upon the broader implications of their findings.

In making this comparison we make use of monthly rather than seasonal mean fields because they capture more faithfully the structure of the AO and they afford a larger sample size. As in TW98, the AO is defined as the leading principal component of the (unstandardized) monthly sea level pressure anomaly field poleward of 20°N based on the sea level pressure analyses of Trenberth and Paolino (1981). The $5° \times 5°$ lat–long gridded data were weighted by the square root of cosine of latitude. Our analysis of monthly mean 500-hPa height and zonal wind fields is based on the National Centers for Environmental Prediction–National Center for Atmospheric Research reanalyses (Kalnay et al. 1996) for the 119 winter months (DJF) beginning with January 1958 and ending with February 1997, obtained from the National Oceanic and Atmospheric Administration Climate Diagnistics Center. The temporal correlation between the index of Ting et al. and the AO based on monthly data is 0.81. Figure 1 shows meridional profiles of zonal-mean 500-mb zonal wind amplitude associated with the two indices. They were obtained by regressing the zonal-mean 500-mb zonal geostrophic wind profile for each month upon the standardized time series of the two indices. The profile for the index of Ting et al. is inverted for ease of comparison. The two profiles are very similar, both with respect to amplitude and the placement of the maxima and minima.

Figure 2 shows the corresponding distributions for the stationary wave (total minus the zonal mean) component of the 500-mb height field (hereafter denoted Z^*), which were obtained in a manner analogous to the profiles in the previous figure. There is a one-to-one correspondence between all the major centers of action in the two maps. The only discernible difference is that the features over the Atlantic are slightly stronger in the AO pattern, whereas the features over the Pacific are stronger in the pattern derived from the index of Ting et al.

In order to determine whether the pattern identified by Ting et al. is optimal in the sense of explaining as much as possible of the variance of the Z^* field, we performed singular value decomposition (SVD) analysis upon the Z^* field paired with the meridional profile of zonal-mean zonal wind, both for the region poleward of 20°N and both weighted by the square root of cosine of latitude. Figure 3 shows the zonal wind profile regressed upon the standardized expansion coefficient of the Z^* field and the Z^* field regressed upon the standardized expansion coefficient of the zonal wind profile for the leading mode in this expansion, which accounts for 68% of the squared covariance (compared to 22% for the second mode). The expansion coefficient time series are correlated with one another at a level of 0.69.

Corresponding author's address: Dr. John M. Wallace, Department of Atmospheric Sciences, Box 351640, University of Washington, Seattle, WA 98195.
E-mail: wallace@atmos.washington.edu

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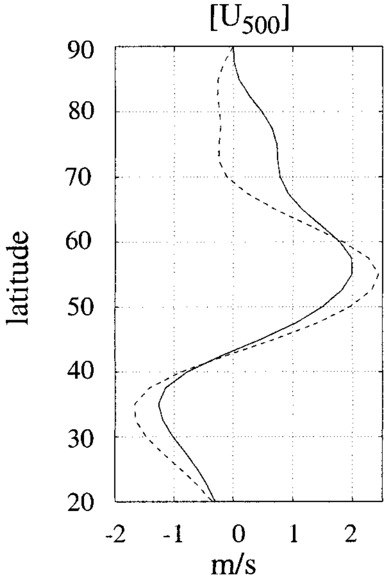
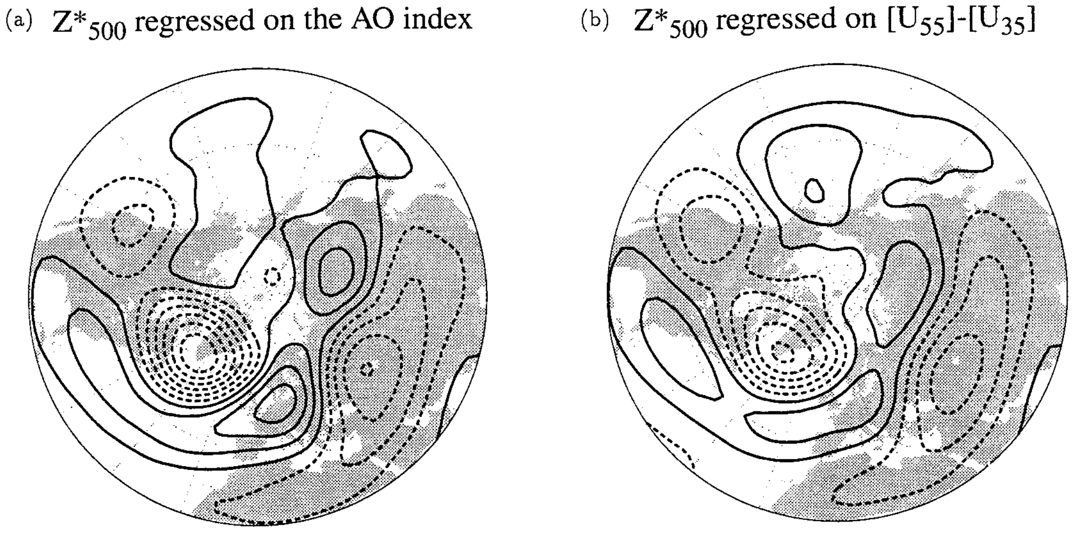


FIG. 1. Zonally averaged zonal wind at the 500-hPa level regressed upon Dec–Feb (DJF) monthly mean values of the AO index (solid line) and upon the inverted Ting et al. (1996) index (i.e., zonally averaged zonal wind at 55°N minus that at 35°N; dashed line).

Figure 3 is remarkably similar to the pattern of Ting et al. The AO signature is recognizable in it, but the relevant features in the zonal wind field are shifted southward by 3°–4° latitude and a pattern somewhat reminiscent of Pacific–North American (PNA) pattern (Wallace and Gutzler 1981) is evident in the Z^* field in that sector, with amplitude roughly comparable to that of the AO-related features.

The role of preferred modes of variability of the zonally averaged zonal flow as a source of planetary wave variability has been the subject of many studies in the general circulation literature, dating back to the studies of Rossby (1939) and Namias (1950). Interest in this topic waned during the 1980s when it was found that some of the more prominent patterns of planetary wave variability like the PNA pattern and blocking can be described and interpreted in terms of longitudinally localized forcing (Hoskins and Karoly 1981; Simmons 1982) and flow instabilities (Simmons et al. 1983). At one point the lead author went as far as to argue that "it is still possible that the observed low-frequency variations in the zonal [flow] may be nothing more than a collection of unrelated signals associated with regional phenomena such as blocking and two dimensional barotropic instability, whose signatures don't completely cancel in zonal averages" (Wallace and Hsu 1985). It is, in fact, quite likely that such regional phenomena contribute to the variability of the zonally symmetric flow and that some of them could even project quite strongly upon its leading modes of variability. But if regionally localized phenomena were the principal source of variability of the zonally symmetric flow, it would be difficult to explain why more than half of the squared covariance between the U and Z^* could be captured by a single SVD mode whose expression in the Z^* field does not correspond to any clearly recognizable regional phenomenon. It seems more plausible that the planetary wave structures reflected in this mode is determined not by processes intrinsic to the Z^* field but rather by the dynamics of the zonally symmetric flow.

These results support the contention of Ting et al. that dynamical processes intrinsic to the time varying zonal flow and its interaction with the (zonally averaged) eddies play a significant role in the variability of the general circulation, even in the presence of the strong zonal asymmetries observed in the Northern Hemisphere. Further evidence in support of this interpretation is offered


(a) Z^*_{500} regressed on the AO index

(b) Z^*_{500} regressed on $[U_{55}]$-$[U_{35}]$

FIG. 2. The eddy component of the 500-hPa height field at the 500-hPa level regressed upon (a) DJF monthly mean values of the AO index and (b) upon the inverted Ting et al. (1996) index. Contour interval 10 m (−5, 5, 15, . . .).

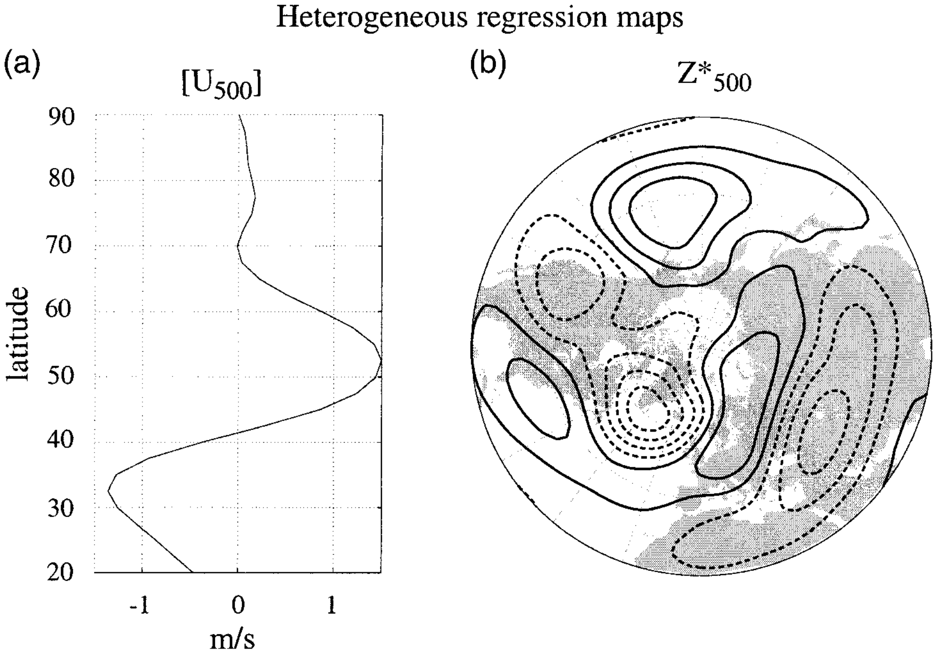


FIG. 3. Heterogeneous regression maps of the leading coupled mode in the zonally averged zonal wind field and the eddy component of the geopotential height field at the 500-hPa level as determined from SVD analysis. (a) Zonally averaged zonal wind regressed upon the standardized expansion coefficient of the eddy component of the height field. (b) The eddy component of the height field regressed upon the standardized expansion coefficient of zonally averaged zonal wind. Contour intervals as in Fig. 2.

in the companion paper (Thompson and Wallace 2000). But lest the importance of such ‘‘annular modes’’ be exaggerated, it should be emphasized that while the mode shown in Fig. 3 accounts for 68% of the squared covariance between the (zonal mean) zonal wind field and the Z^* field, it accounts for only 9% (13%) of the variance of the monthly (seasonal mean) 500-hPa height field.

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