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ZONAL WIND VACILLATION AND ITS INTERACTION WITH THE OCEAN: IMPLICATIONS FOR INTERANNUAL VARIABILITY AND PREDICTABILITY

I. G. Watterson
CSIRO Atmospheric Research

1. **INTRODUCTION**

The vacillation of the southern midlatitude zonal mean zonal wind (u) is a significant driver of variability in the Southern Ocean, as simulated by the CSIRO coupled general circulation model (GCM). Watterson (2000) also detected a weak influence on the atmosphere by the resulting sea surface temperature (SST) anomalies. Extended simulations are examined here to provided a more accurate depiction. Given the recent interest in the potential for predictability based on the zonal wavenumber two SST pattern, the 'Antarctic Circumpolar Wave' (ACW, White, 2000), the interannual relationships between the present wave-0 anomalies are also examined.

2. **VACILLATION WIND INDEX**

Zonal and monthly mean anomalies about the mean annual cycle are considered here from three simulations: a 1000-year coupled model run 'C', and 500-y runs of a model with specified SSTs (S), and a model with a 50-m deep ocean mixed layer (M). For each run, an index W is defined using u at 500 hPa, from strongly anticorrelated latitudes: u(56°S)$-u$(37°S). For C, W has a standard deviation (SD) of 3.8 m s^{-1} and a (lag 1 month) autocorrelation (r_1) of 0.41, the values being only slightly greater than those for S and M. Regression coefficients for (lag 0) u with W are almost identical across the runs, at all latitudes. Values peak at 0.6 and –0.4 at the index latitudes. Winds at other pressure levels relate similarly to W, with amplitudes peaking near 340 hPa, consistent with a largely barotropic structure of the vacillation wind. These anomalies decline rapidly as they are lagged relative to W. At lag 4 months the winds have almost died away in S, as seen in Fig. 1a. However, wind anomalies remain in M and C. The differences between the runs relate to the differing surface temperature T_s anomalies (Fig. 1b) that persist in the runs with a responsive ocean (M and C). The influence on high latitude temperatures of ocean overturning, induced by surface stress from the vacillation wind, can be seen by comparing the dynamic ocean C result with that for M.

3. **OCEANIC SST INDEX**

We define an SST index, to be used for prediction, using the lag 1 month SST regression coefficient profile, T_1, for runs M and C. This is projected on the SST anomalies

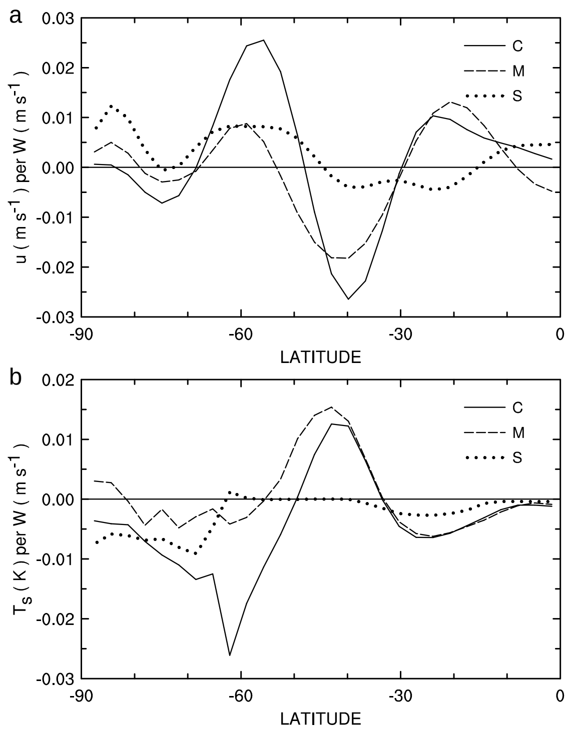

Figure 1: Regression coefficients for monthly mean anomalies at lag 4 months with the wind index W, for three GCM runs: (a) u at 500 hPa, and (b) T_s, lag 4 months.

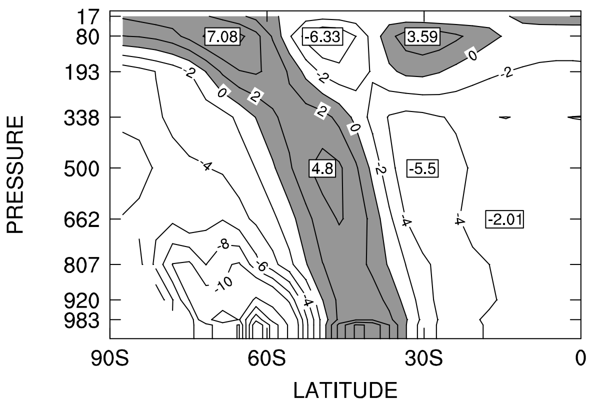

Figure 2: Regression coefficient (×1000) for monthly mean temperature anomalies (K) lagged 3 months, with the nondimensional SST index T for run C. T_s is shown as a bottom layer.

Corresponding author address: Ian G. Watterson, CSIRO Atmospheric Research, Private Bag 1, Aspendale 3195, Australia; e-mail igw@dar.csiro.au

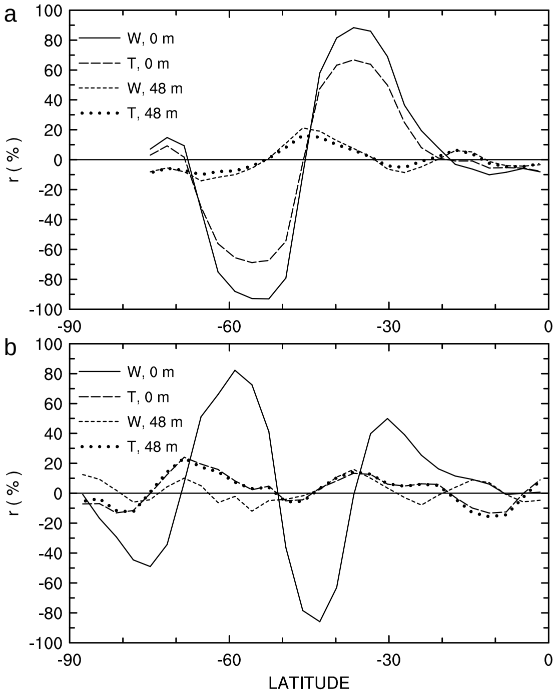

Figure 3: Correlation coefficients ($\times$100) for (a) v at 983 hPa, and (b) precipitation with the wind index (W) or the SST index (T), in run C; all quantities 48-month means, and at lags 0 and 48 months.

from each month over the ocean area A between latitudes 63°S and 19°S: $\int T_s T_1 dA / \int (T_1)^2 dA$. For C, this nondimensional index, T, has SD = 8.2 and r_1 = 0.87. Cross correlation indicates that T lags W by a month and then slowly declines. A similar result to Fig. 1b is thus seen from regression of T with (zonal mean) T_s lagged 3 months, as shown in Fig. 2. By this lag, the air temperature anomalies are largely forced by the SST anomalies, most strongly near the surface in a banded pattern, which then tilts poleward with altitude. Surface pressures are also perturbed, and consistent with geostrophic balance, there is a forced wind anomaly with a somewhat different structure to the original vacillation. In C, the perturbation largely augments the original wind at 500 hPa (Fig. 1a).

The lag of T relative to W is not evident at longer averaging periods, however, with the (lag 0) correlation between the series of 48-month averages of W and T being 0.80. Relationships between these series and other fields, including low-level meridional wind v and precipitation P, are strong at some latitudes, as seen in Fig. 3. For example, from Fig. 3b, W 'explains' 74% of the variance of these long-term, zonal mean P anomalies at 43°S.

Note that a simple model of the interaction between the two series, with W driven stochastically (Watterson, 2000) quite accurately reproduces the statistics and spectra of both series. An exception is a spectral peak at 20–25 y in T, and weakly seen in W, possibly a preferred time scale in the model ocean. This is absent in a run with a modified ocean mixing parameterization, however.

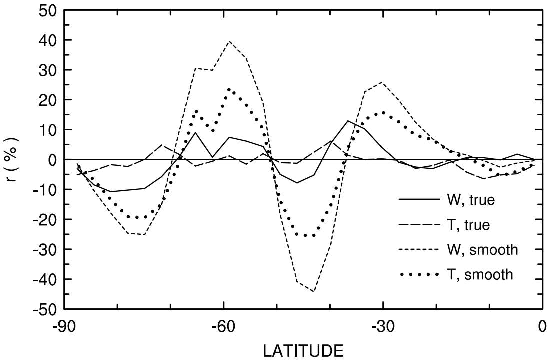

Figure 4: Correlation coefficients ($\times$100) for annual mean anomaly of precipitation, lagged 1 year, with an annual wind index (W) or SST index (T), either the (unfiltered) 'true' index or one based on 49-month running means ('smooth'), in run C.

4. INTERANNUAL PREDICTABILITY

While contemporaneous interannual relationships between T and other fields may be strong, it should not be inferred that this is due to a significant influence of the SST anomalies, or that T provides significant predictability (other than for the persisting SST anomalies). The results for fields lagged 48 months in Fig. 3 are much reduced over the lag 0 values, with peaks of only $r = 0.2$. These appear to be a better indication of SST influence. In the case of P, this has a different structure to the P directly associated with the vacillation.

Apparent predictability of ACW-related v and P at one-year lags using 3–6 y band-pass filtered data has been documented by White (2000). Comparable relationships are obtained here between annual means of these fields and 49-month running mean indices. There is some apparent predictability of P, shown in Fig. 4, from both W and T. However, if unsmoothed indices are used, the correlations are much reduced. The reason for the high values for smoothed data appears to lie in the direct influence of the wind during the lag 1 year, on both P and SST. This wind influences the smoothed W at the lag 0 time. However, as the wind appears largely unpredictable, the smoothed index cannot be calculated from data available at that time. The small 'true' values in Fig. 4 appear to be a better indication of realisable predictability in this wave-0 anomaly case. The results suggest that a further assessment of the practical predictability associated with the SST anomalies at similar latitudes of the ACW should be undertaken.

REFERENCES

Watterson, I. G., 2000: Southern midlatitude zonal wind vacillation and its interaction with the ocean in GCM simulations. *J. Climate*, **13**, 562–578.

White, W. B., 2000: Influence of the Antarctic circumpolar wave on Australian precipitation from 1958 to 1997. *J. Climate*, **13**, 2125–2141.