COUPLED WAVES IN THE EXTRA-TROPICAL OCEAN-ATMOSPHERE SYSTEM

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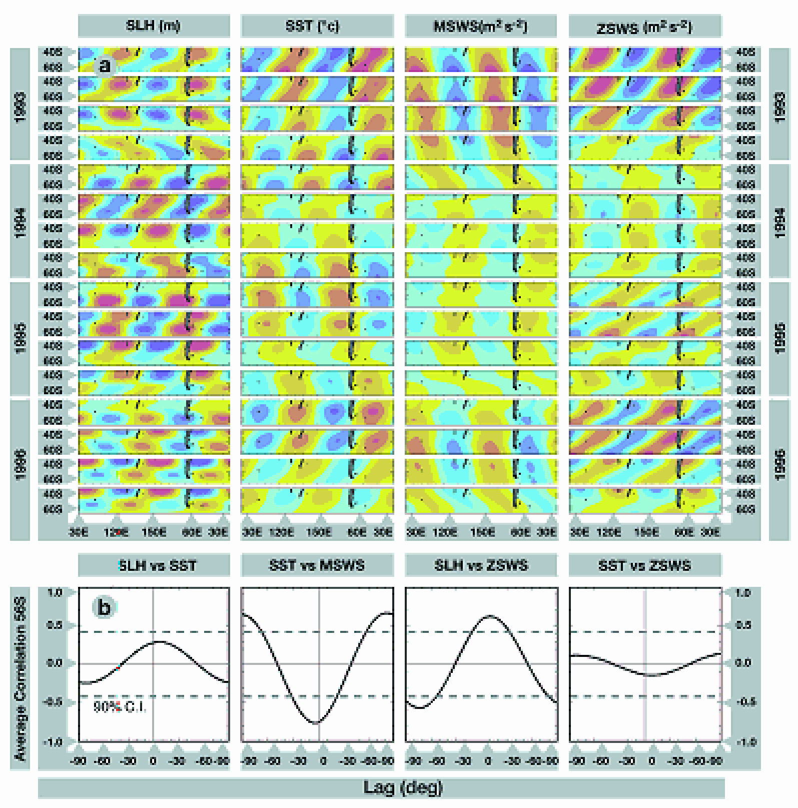
The advent of TOPEX/POSEIDON allows us to compare interannual variability in sea level height (SLH), AVHRR sea surface temperature (SST), SSM/I sea ice extent (SIE) around Antarctica, and in situ surface wind stress (SWS) from the National Centers for Environmental Prediction (NCEP) re-analysis [Kalnay et al., 1996]. These comparisons are beginning to reveal the coupled nature of interannual variability in the extra-tropical ocean, atmosphere, and cryosphere system on a variety of time and space scales.

The notion of extra-tropical coupling began with the discovery of the Antarctic Circumpolar Wave (ACW) by White and Peterson [1996] and Jacobs and Mitchell (1996). The ACW is a 4-year climate signal in the Southern Ocean, composed of 2 waves propagating eastward and taking 8 years to circle the globe, with high (low) SLH, warm (cool) SST , poleward (equatorward) SWS, and retracted (expanded) SIE anomalies occurring in fixed phase with each other. The apparent coupled nature of the ACW led White and Chen [1997] to analyze anomalous tropospheric heat and vorticity budgets over the Pacific basin on interannual timescales, finding SST-induced mid-level diabatic heating anomalies balanced by anomalous vertical heat advection, with anomalous vortex stretching in the lower troposphere balanced by anomalous planetary vorticity advection. This allowed them to construct a lower troposphere model for SST-induced SWS anomalies.

White, Chen, and Peterson [1998] applied this lower troposphere model to the ACW , exploring the different feedback mechanisms that SST-induced SWS anomalies have on the SST tendency. They developed a reduced coupled model that simulates ACW characteristics by relying on anomalous meridional Ekman heat advection to induce the SST tendency. This is a different feedback mechanism than the SST-induced Ekman pumping used to generate anomalous vertical and meridional heat advection by Jacobs and Mitchell [1996] and Qui and Jin [1997], respectively.

Recently, White and Peterson [1998] found 2 new species of ACW operating on biennial timescales, with covarying biennial SLH, SST , and MSW anomalies propagating eastward around the Southern Ocean, one taking 4 years for 2 waves to circle the globe (Figure 1) and the other taking 2 years for 1 wave to circle the globe. The shorter ACW in Figure 1 has characteristics similar to those on 4-year timescales, but with twice the propagation speed. These new species of ACW provide opportunities for revealing different extra-tropical coupling mechanisms operating on different time and space scales.



(159 Kb)

Figure 1

(a) Time sequences of maps of biennial- and spatial-filtered standardized anomalies for SLH, SST , meridional SWS, and zonal SWS for 4 years from 1992-1996, the period over which TOPEX/POSEIDON SLH is available. Each map extends around the globe from 40°S-60°S. The temporal band-pass filter isolates the 2-year timescale from annual and 4-year timescales. The spatial band-pass filter isolates global zonal wavelength 2 from global zonal wavelengths 1, 3, 4 and greater. In each time sequence, individual maps are 3 months apart, displaying the evolution of biennial variability over 2 cycles. The sense of propagation comes from following anomalies of similar sign from one map to the next in the time sequence.

(b) The zonal-lagged cross correlation between biennial- and spatial-filter anomalies at 56°S for SLH and SST , SST and meridional SWS, SLH and zonal SWS, and SST and zonal ZSW. The horizontal dashed line is the 90% confidence interval for 16 degrees of freedom (i.e., 4 in space and 4 in time over 4 years of record).

White, Chao, and Tai [1997, 1998] have examined 2 species of coupled Rossby wave in covarying SLH, SST , and SWS anomalies in the Pacific basin on biennial and 4-year timescales. They developed reduced coupled models that simulate observed wave characteristics by relying on SST-induced Ekman pumping of baroclinic Rossby waves to induce the SST tendency through meridional heat advection on biennial timescales and vertical heat advection on 4-year timescales. In the Pacific, this coupling decreases (increases) westward phase speeds of uncoupled Rossby waves equatorward (poleward) of 25° latitude on biennial timescales, and decreases them at all latitudes on 4-year timescales, as observed. In the future, these 2 species of coupled Rossby wave need to be verified over longer records, and placed within the context of extra-tropical coupled physics of similar timescales but global spacescales, presently observed only in the ACW .

References :

- Jacobs, G.A. and J.L. Mitchell, 1996: Ocean circulation variations associated with the Antarctic Circumpolar Wave. *Geophys. Res. Letters. 23*, 2947-2950.
- Kalnay et al., 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc., 77*, 437-471.
- Qiu, B. and F.-F. Jin, 1997. Antarctic Circumpolar Waves: an indication of ocean-atmosphere coupling in the extra-tropics. *Geophys. Res. Lett.* (in press).
- White, W.B. and R. Peterson, 1996: An Antarctic circumpolar wave in surface pressure, wind, temperature, and sea ice extent. *Nature, 380*, 699-702.
- White, W.B. and S.-C. Chen, 1997: Response of the extra-tropical troposphere to SST-induced mid-level diabatic heating anomalies on interannual timescales. *J. Climate* (in review).
- White, W.B., S.-C. Chen, and R. Peterson, 1997: The Antarctic Circumpolar Wave: A beta-effect in ocean-atmosphere coupling over the Southern Ocean. *J. Phys. Oceanogr.* (in review).
- White, W.B., Y. Chao, and C.-K. Tai, 1998: Coupling of biennial oceanic Rossby waves with the overlying atmosphere in the Pacific basin. *J. Phys. Oceanogr*., (in press).
- White, W.B. and R. Peterson, 1997: Biennial Antarctic circumpolar waves in sea level height, surface temperature and wind, and sea ice extent. *J. Geophys. Res.* (in review).
- White, W.B., Y. Chao, and C.-K. Tai, 1998: Coupling of quadrennial oceanic Rossby waves with the overlying atmosphere in the Pacific basin. *J. Phys. Oceanogr*., (in preparation).