Coupling of Extratropical Mesoscale Eddies in the Ocean to Westerly Winds in the Atmospheric Boundary Layer

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Abstract

We find the sea surface temperature (SST) signature in mesoscale eddies in the western boundary current extensions around the globe and in the Antarctic circumpolar current (ACC) altering the surface stress associated with background westerly winds, producing mesoscale wind stress curl (WSC) residuals capable of modifying the eddy dynamics. This is revealed by examining satellite-derived sea level height (SLH) residuals from TOPEX/Poseidon and ERS-1/2 altimetry, SST residuals from multi-channel advanced very-high resolution radiometry, and neutrally-stable zonal wind residuals at 10 m height (ZSW) from the SeaWinds QuikSCAT project for 18 months from July 1999 through December 2000. In the presence of background westerly winds, warm mesoscale eddies reduce the stability of the marine atmospheric boundary layer, increasing the zonal air-sea momentum fluxes measured by QuikSCAT. Warm SST residuals of ~0.8°C are capable of producing westerly ZSW residuals of ~1.2 m s^{-1} on eddy space scales under background westerly winds of ~6 m s^{-1}. Alternatively, this means increasing the otherwise neutrally-stable drag coefficient by ~40%, consistent with in situ measurements by Friehe et al. (1991). The resulting feedback from atmosphere to ocean through corresponding mesoscale wind stress curl (WSC) residuals (e.g., ~5.0x10^{-7} N m^{-3}) produces residual Ekman pumping (e.g., ~1.6x10^{-8} m s^{-1}) on the same order as the residual SLH tendency in the eddy field. The RMS of this residual Ekman pumping ranges from 20% to 70% of that in the observed residual SLH tendency. Moreover, the spatial and temporal phasing of these mesoscale WSC residuals act, on average, to displace the mesoscale eddies equatorward with a phase speed of ~0.01 ms^{-1}, while suppressing their amplitude.

References

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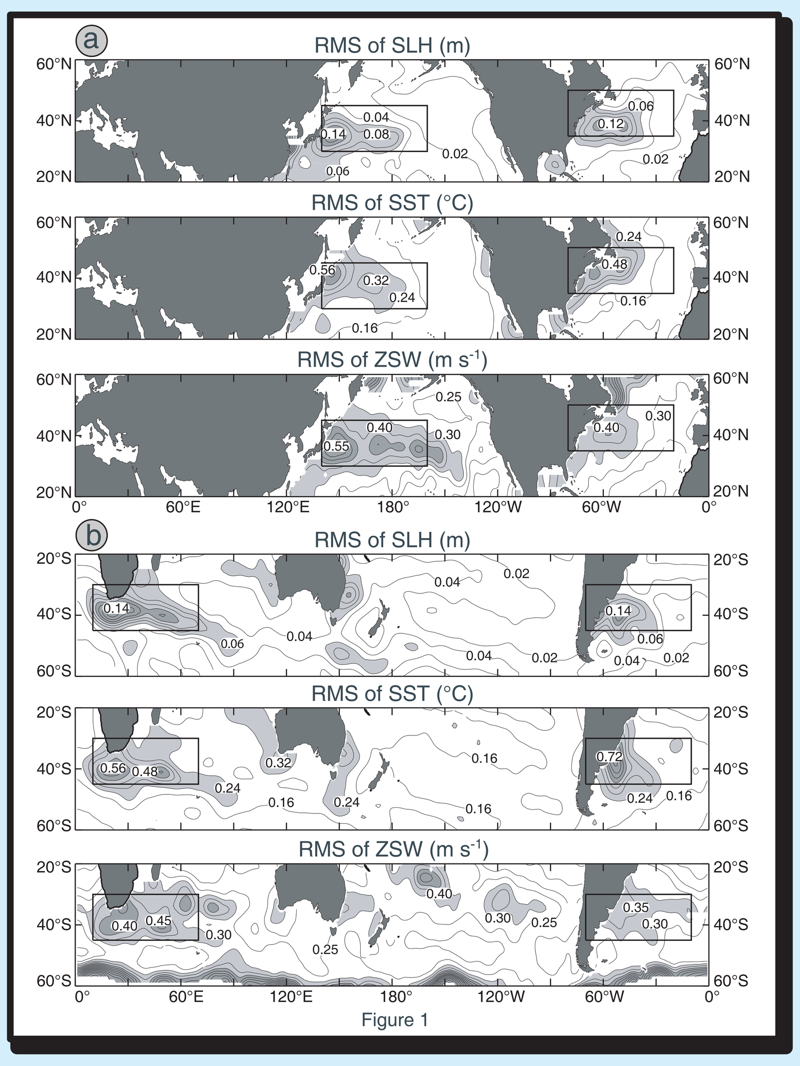


Figure 1

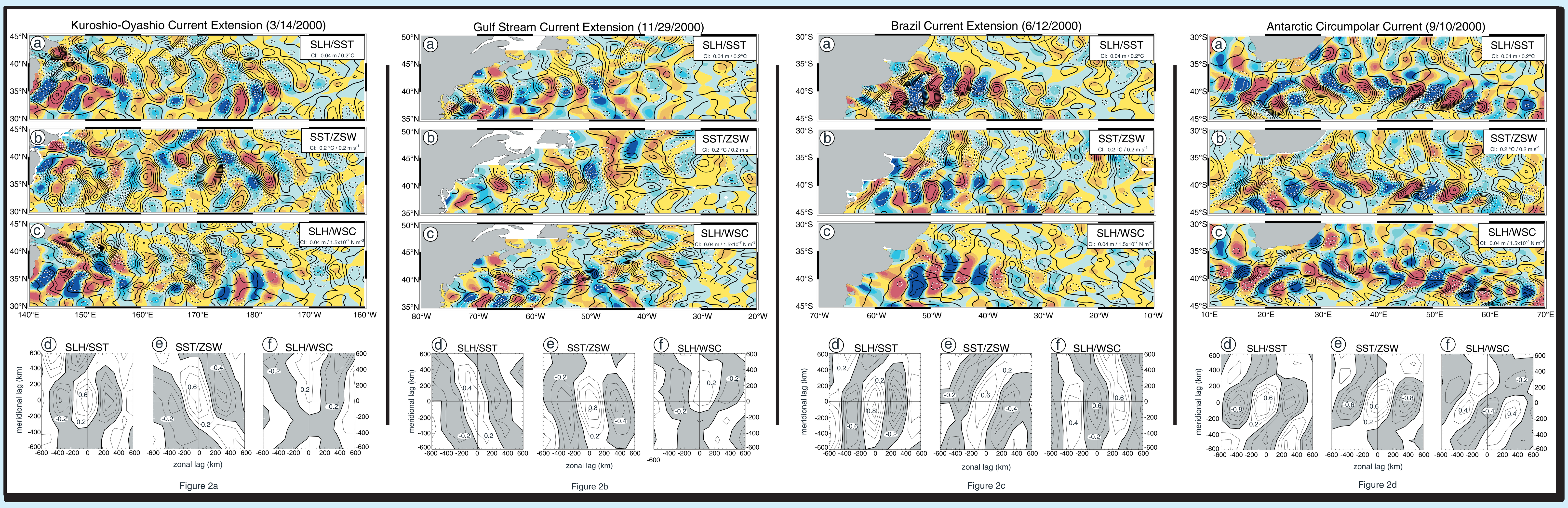


Figure 2a Figure 2b Figure 2c Figure 2d

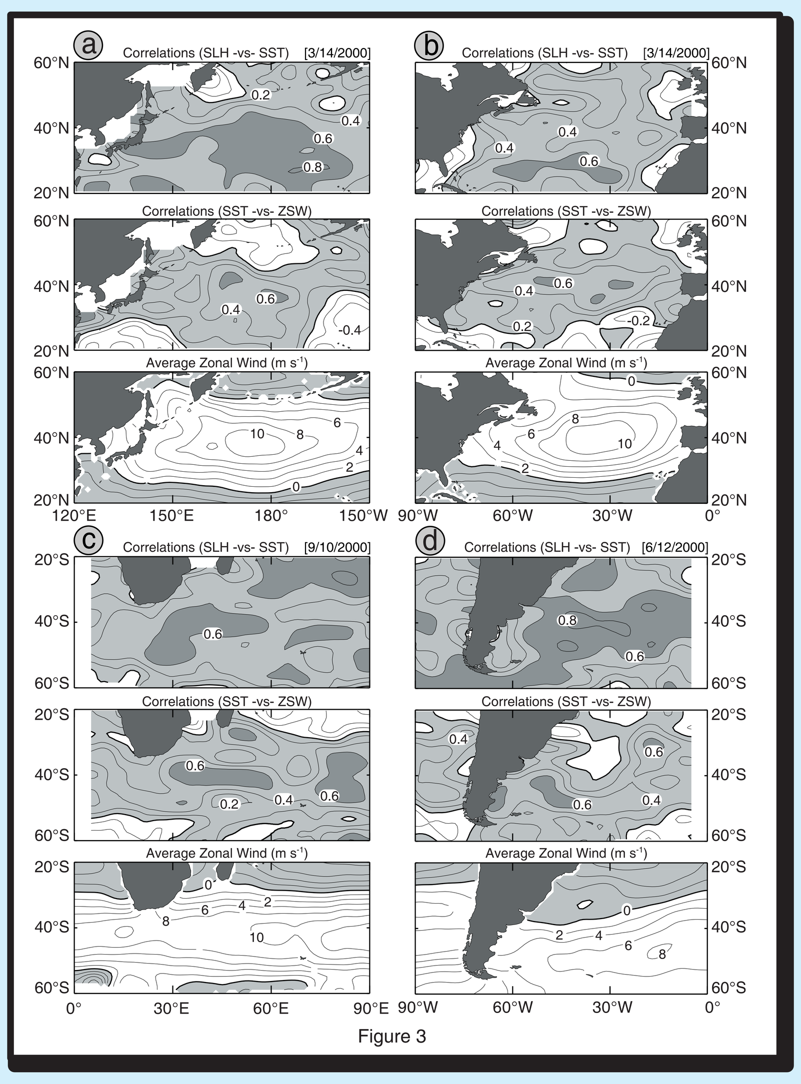


Figure 3

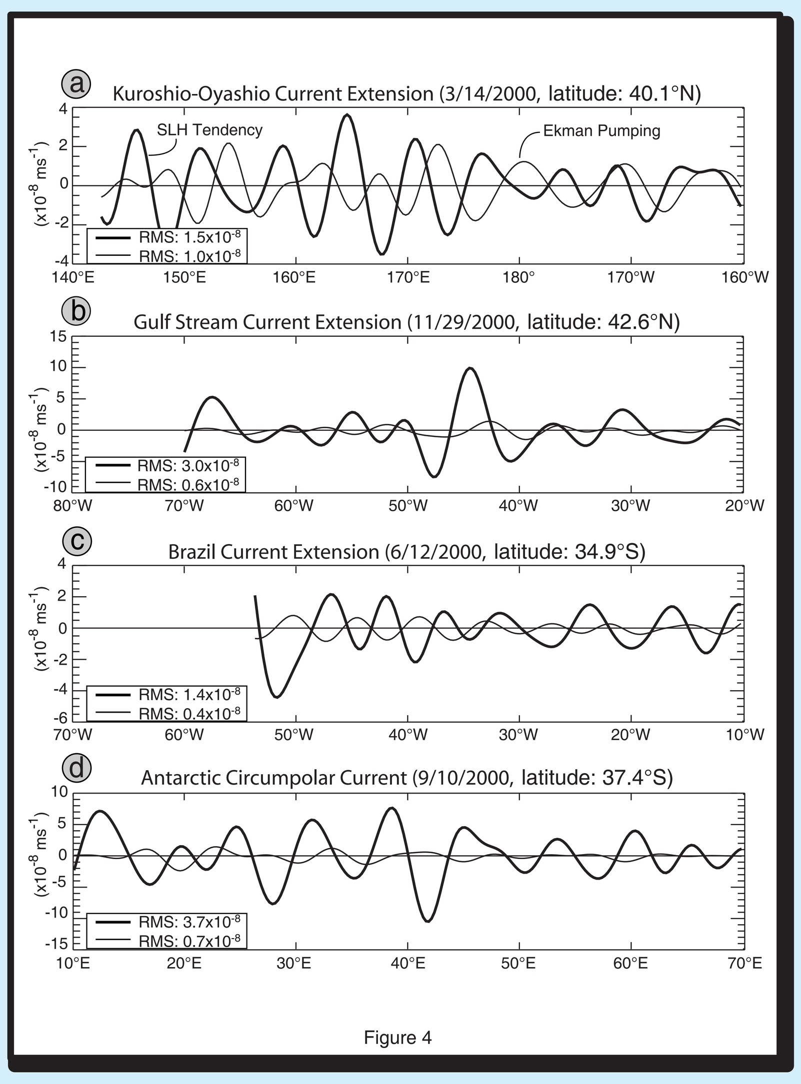
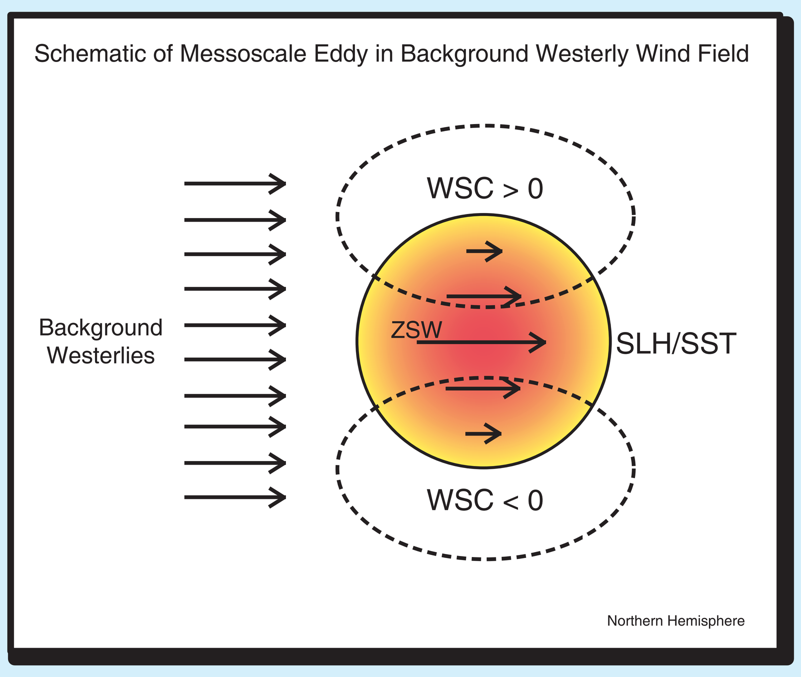


Figure 4



Discussion

Figure 1. Geographical distributions of the root-mean-square (RMS) of SLH, SST, and ZSW residuals in the extratropical mesoscale eddy field, filtered for zonal wavelengths of 400 to 1200 km and for periods >1 month, observed over the 18-month record from July 1999 through December 2000. Black boxes indicate regions where the eddy fields are examined in Figures 2 through 4. Note that the RMS of eddy ZSW residuals from QuikSCAT displays peak magnitude along western boundary extension currents and along the ACC.

Figures 2a, 2b, 2c, and 2d. The distribution of mesoscale eddies in the western boundary current extensions and in the ACC, revealed in SLH, SST, ZSW, and WSC residuals for selected 10-day periods. (a) The overlay of contours of mesoscale SST residuals on colors of mesoscale SLH residuals. (b) The overlay of contours of mesoscale ZSW residuals on colors of mesoscale SST residuals. (c) The overlay of contours of mesoscale WSC residuals on colors of mesoscale SLH residuals. Color levels for SLH residuals are 0.04 m; color levels and contour intervals for SST residuals are 0.2 °C; contour intervals for ZSW residuals are 0.2 m s^{-1}; and contour intervals for WSC residuals are 1.5x10^{-7} N m^{-3}. Positive contours are solid and negative contours are dashed. Zonal- and meridional-lag cross-correlation between mesoscale SST and SLH residuals, mesoscale SST and ZSW residuals, and mesoscale SLH and WSC residuals, are computed over each domain. Note that warm SST residuals and westerly ZSW residuals lie near the center of anticyclonic eddies. This yields cyclonic and anticyclonic mesoscale WSC residuals displaced poleward and equatorward, respectively, from the center of the anticyclonic eddies, tending to displace the eddies toward the equator through residual Ekman pumping at a phase speed of ~0.01 ms^{-1}.

Figure 3. The distributions of pattern correlations over the western boundary current extensions and in the ACC, between mesoscale SLH and SST residuals, and mesoscale SST and ZSW residuals, together with the average zonal wind for the selected 10-day period. Pattern correlations are computed over a 10° latitude/longitude box at each grid point. Positive correlations are shaded and negative correlations are unshaded, with positive correlations greater than 0.6 shaded darker. Note that maximum correlations are aligned with the background westerly wind field for the same 10-day period.

Figure 4. Zonal profiles of the residual SLH tendency (∂SLH/∂t) and residual Ekman Pumping [(ρ_o'/ρ_o)WSC/$(\rho_o f)$] in the eddy field at representative latitudes from each of the four regions depicted in Figures 2a, 2b, 2c, and 2d, each profile spanning the domain. The RMS of the residual Ekman pumping ranges from 20% to 70% of that in the residual SLH tendency.