

The Northern Annular Mode in Atmosphere-Ocean Coupling

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Abstract: Strong western boundary currents in the midlatitude oceans transport heat from the warm tropical regions to the cool subpolar regions and are responsible for much of the ocean's share of the mean heat transport. Recent studies of the upper ocean heat budget point to the importance of interannual-to-decadal heat transport and heat storage fluctuations by these current systems and their link to air-sea heat fluxes. An observed coherence between the North Atlantic and North Pacific wind forcing, heat storage, and heat fluxes suggests an annular coupled mode.

Measurements of sea surface height (SSH) anomalies by the TOPEX/Poseidon radar altimeter have provided an unprecedented 10-year time series of variations in the western boundary currents. Currents derived from these SSH anomalies have been used in parallel studies of the upper ocean heat budget for the regions surrounding the Kuroshio Extension in the North Pacific and the Gulf Stream in the North Atlantic. The heat budgets reveal several important results: 1) these regions store a large amount of heat for periods of several years, 2) heat storage is controlled by the transport of heat into the region by the currents, rather than by air-sea fluxes, 3) the currents that transport most of the heat are part of the large-scale geostrophic circulation, rather than locally forced Ekman currents, and 4) the surface fluxes are controlled by the ocean's heat storage, rather than the other way around.

Surprisingly, a comparison of the 10-year heat budgets for the Pacific and the Atlantic show that the fluctuations in heat content and heat transport convergence are in phase, suggestive of repeat periods of about 6 years.

This connection must be provided by the in-phase component in atmospheric circulation, the Northern Annular Mode (or Arctic Oscillation). Assuming that the relationships between ocean currents, heat transport, and heat storage are consistent over time with those revealed by the ten-year altimeter record, we examine heat storage estimated from the relatively sparse oceanic subsurface temperature data with estimates of winds and surface fluxes from the NCEP Reanalysis. The dominant modes of variability of both heat content and surface heat fluxes north of 30N have their largest values in the western boundary current regions. The relationships are consistent with wind-forced heat flux convergence in the western boundary currents, and surface heat flux anomalies forced by these convergences. The large component of this response that is correlated between the North Atlantic and the North Pacific constitutes the oceanic part of the Northern Annular Mode.

These 10-year budgets used NCEP air-sea flux products. Recent analyses using scatterometer winds suggest that the air-sea coupling may be even greater than that which is estimated using numerical weather prediction (NWP) products, such as NCEP. NWP products neglect the effect of ocean currents on the relative wind speed needed for flux estimates; these currents have speeds up to 2 meters per second in these energetic ocean regions. In addition the commonly used SST products used by NWPs do not resolve the boundary currents well, so that the fluxes do not resolve the intense feedbacks possible in ocean frontal regions.

note: this is an invited paper