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Attributing Climate-Scale Variability in Atlantic Ocean Heat Storage

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The intense interest given to monitoring the Atlantic meridional overturning circulation (AMOC) is motivated in part by the notion that changes in the AMOC could affect Northern Hemisphere climate via a direct influence on Atlantic Ocean sea surface temperatures (SSTs). However, because the relative importance of overturning changes to ocean heat transport and storage is not presently understood, the precise nature of the AMOC-SST relationship remains opaque. The goal of this study was to elucidate the role of general circulation changes on ocean heat storage rates relative to the influence of air-sea heat fluxes in the low- and mid-latitude Atlantic Ocean. For these purposes an ocean state estimate produced by the ECCO ("Estimating the Circulation and Climate of the Ocean") consortium was used. The estimate is generated using a general circulation model with a $1^\circ \times 1^\circ$ horizontal grid resolution and 23 vertical levels and is optimized via ocean data assimilation. A unique characteristic of the solution is its retention of dynamical and kinematic consistency with the model's governing equations, which allows for the computation of property budgets that close exactly.

Ocean heat storage budgets were formulated for a set of control volumes covering the Atlantic Ocean from 32°S to 48°N. The focus was on large-scale regions (i.e. basin-wide zonal sections with meridional thicknesses of order $\sim$15°) and long time scales (mean seasonal cycles and interannual anomalies). Budget time series for the period 1993-2004 were integrated vertically to three depths to attribute heat storage in the near-surface ocean (i.e. the top 100 m), the upper ocean (top 1000 m), and the full water column. As expected, surface heat fluxes are generally important for seasonal heat storage, which is mainly confined to the near-surface layer outside the tropics. Within the tropics, near-surface processes explain only half the seasonal ocean heat storage variance, reflecting the important action of upper-ocean advective heat fluxes. At interannual time scales, heat storage rates can be attributed primarily to advection within the upper ocean and secondarily to surface heat fluxes, and hence heat storage anomalies are confined mainly to the upper ocean. Upper-ocean advective processes below 100 m are very important to the interannual heat balance.

In regions between 36°N to 30°S, seasonal and interannual changes in the advective heat transport divergence are generally attributable to vertical (meridional overturning plus Ekman) circulations rather than horizontal (gyre) circulations. At low latitudes the interannual upper-ocean heat storage can be ascribed almost entirely to changes associated with vertical circulations. Yet because near-surface heat storage rates appear quite distinct from the upper-ocean heat storage in these regions, any simple relationship between overturning-related ocean heat storage changes and near-surface temperature variability is thus precluded. Because advection by the horizontal component of the circulation becomes as relevant as the vertical component in regions poleward of 36°N, a direct relationship between vertical circulations and near-surface temperatures appears to be generally absent at high latitudes as well.