Surface layer heat flux variability in the Southeastern Indian Ocean

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A major goal of climate studies is to understand the processes that control the heat content of the upper ocean. In particular, the heat content of mode water is of interest because the thermal anomalies in deep mixed layers tend to persist longer and might have a longer term effect on climate, through reappearance in winter or through subduction and interior mixing. Much effort is directed toward SST variability, but this does not necessarily represent substantial heat content, and studies of the mechanisms of heat transport and transport variability are needed.

Ekman advection and air-sea fluxes are thought to be dominant forcing contributions in the formation region of the Subantarctic Mode Water (SAMW), north of the Subantarctic Front in the Southern Ocean (Ribbe, 1999; Rintoul and England, 2002; Fig. 1). A recently submitted paper (Sallee et al, 2005) considers this matter by examining various terms in the upper ocean heat balance in the southern Indian Ocean. This article reports the air-sea and Ekman heat flux variability, since the interannual evolution of these two terms could reflect an interannual evolution of the SAMW characteristics.

We have estimated Ekman fluxes from satellite data and other sources (NCEP, COAPS winds, etc. – see Sallee et al., 2005). The derived Ekman fluxes from satellite data have shown substantial difference with those derived from the climatologies, but having made the calculations and with some understanding of the weaknesses of the climatologies we are now in a position to go back to the climatologies to infer long time scale variability, which is not possible with the short record from satellites. To illustrate the record, we plot the net air-sea heat flux, the Ekman heat transport, and their sum over the NCEP record 1948-2005 (Fig. 2). Before 1979 the analysis is considered to be less accurate because of the absence of satellite data (Hines et al., 2000; Marshall, 2003).

Post-1980, the variability is up to 20 W/m^2 in both the net air-sea heat flux and Ekman components, resulting in cooling ranging from near zero to -50 W/m^2. This is sufficient for temperature anomalies of up to 1 C or so in the mixed layer, consistent with the observed typical range of ± 0.5 C (Rintoul and England, 2002) south of Australia. There may be further agreement in the trend to cooler mode water over the period 1991 to 1995, when greater cooling occurred, but the trend is not consistent and the yearly differences in temperature are not quantitatively predicted. This situation is likely to be as much a mode-water sampling problem as a question of the accuracy of the fluxes or their averaging area and period.

Despite the uncertainties, the results do point to the influence of the net heat supply on mode water by the wind and air-sea exchange and its relevance as an indicator of climate variability. They also raise the question of the relationship between this variability and the major index of wind variability, the Southern Annular Mode (Thompson and Wallace, 2000). Ekman transport and air-sea flux depend directly on the surface wind, and would be expected to follow the variations of the Southern Annual Mode. Preliminary work (Fig. 3) suggests that while the SAM may explain some of the local variation, the connection between local Ekman heat flux forcing and the SAM is not entirely straightforward, partly because of longitudinal structure in both the atmospheric mode and SST fields, and propagation of SST in ocean currents.

References

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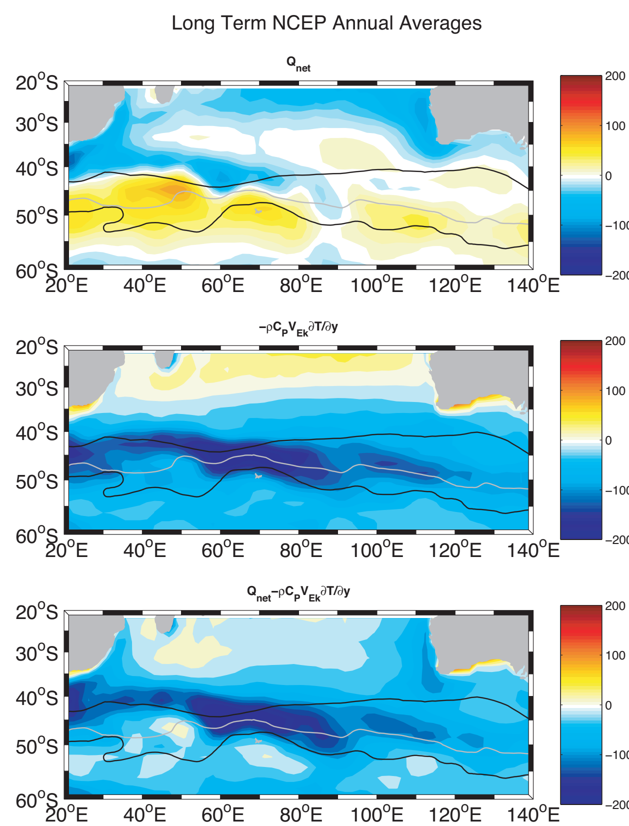

Fig. 1. Climatological average of net heat flux (upper), Ekman heat transport (middle), and their sum (lower), averaged over the entire NCEP record(1948-2005). Contours show the position of the STF, SAF (gray) and PF from Orsi et al. (1995).

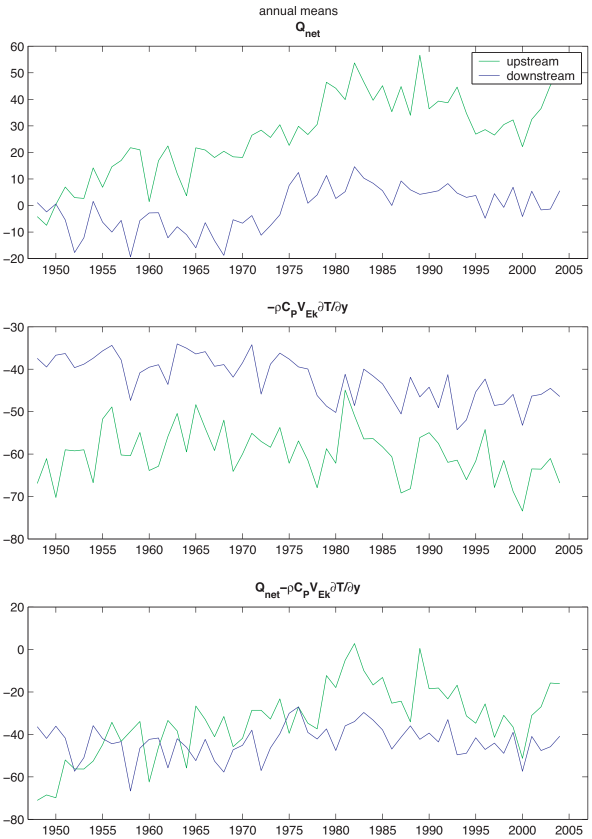

Fig 2. *Time series of annual mean net heat flux (upper), Ekman heat transport (middle), and their sum (lower) from NCEP data over the period 1948-2005 in the southern Indian Ocean (regions between SAF and STF: upstream 20 - 70 E, downstream 70 - 140 E).*

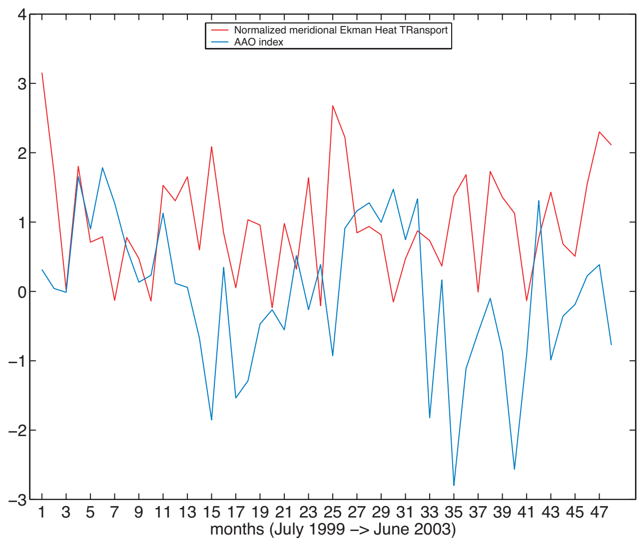

Fig. 3. Normalized meridional Ekman heat transport in the southern Indian Ocean between the Subantarctic Front and Subtropical Front for the period July 1999 to June 2003, and SAM or AAO index.

Feedbacks and uncertainties in a transient coupled simulation of the Weddell Sea

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We analyse the changes in the Weddell Sea region simulated by the Institut Pierre-Simon Laplace coupled climate circulation model (IPSL-CM2) in a transient global-warming scenario integration. Our aim is to describe possible mechanisms associated with abrupt swings in sea ice patterns and to discuss some related uncertainties, as a prelude to an improved understanding of the coupled climate system in this sector of the Antarctic periphery.

The IPSL-CM2 model is a state-of-the-art low-resolution coupled atmosphere-ocean-ice-carbon cycle model. After a 150 years spin up integration, two 241 years simulations (1860-2100) are performed without any flux corrections: a control simulation in which no CO_2 sources are considered and a climate change scenario simulation in which CO_2 emissions are prescribed following the IPCC SRES98 A2 scenario. The climatologies of both simulations can be examined at http://www.lmd.jussieu.fr/Climat/couplage/ipsl_ccm2/index.html. These simulations were extensively analysed to study the climate change and carbon cycle feedback (e.g. Dufresne et al, 2002). The control run displays no significant drift in the global mean surface temperature and atmospheric CO_2. The model is able to produce a stable multi-century control run as manifested by the time series of the large-scale heat and water balances. The drift of the zonal mean surface air temperature for the control simulation is about 0.5K at around 60°S since the year 100, and remains very small for the other latitudes of the Southern Hemisphere (SH).

The coarse resolution of the coupled model is potentially a serious shortcoming. Furthermore, there are processes that are not taken into account. As an example, the model neglects the wind-driven ice export because of the use of a thermodynamic sea ice model. Unfortunately, the precise impact of not using a dynamic sea ice model is difficult to estimate in the present framework. However, in a recent paper by Flato et al (2004) it was established that the errors in the ice climatology simulated by global models are not obviously related to the manner in which sea ice processes are represented. Overall, the area extent of SH sea ice and its seasonal variations are mostly well simulated by the IPSL-CM2 model. Sea ice extent is slightly overestimated in eastern Antarctica and underestimated in the western Weddell Sea (WWS) and in the Ross Sea. However, the simulated inner ice pack tends to be overestimated in the eastern Weddell Sea (EWS) and the Bellingshausen and Amundsen Seas.