Ekman transport in the South Atlantic Ocean

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Introduction

Ekman transport is an important component of ocean circulation. The wind driven circulation of the upper ocean has a mayor influence in mass and heat transport in the ocean. Even when its effects over the circulation are well known, the direct quantitative testing of this theroy seems to be very difficult. In this work we use the wind stress data from NCEP to estimate the Ekman transport and pumping on a basin scale to study Ekman's theory in the Atlantic Ocean. We also use wind data measured in the ship along the ship track between Cape Town and Rio de Janeiro.

Ekman theory

Wind blowing over the sea surfae for long time on a rotating earth, create a balance between wind drag and Coriolis [Ekman 1905].

$$\frac{1}{\rho}\frac{\partial \tau_x}{\partial z} = -fv$$

If this balance is integrated vertically, the result is a total transport perpendicular to wind blowing direction, known as Ekman tansport.

$$\frac{\tau_x}{\rho f} = -\int_{-D}^{0} v_{ageo}(z)\,\mathrm{d}z = M_y$$

$$M_y^{wind} = -\frac{\tau_x}{\rho f}$$

$$M_y^{vel} = \int_{-D}^{0} v_{ageo}(z)\,\mathrm{d}z$$

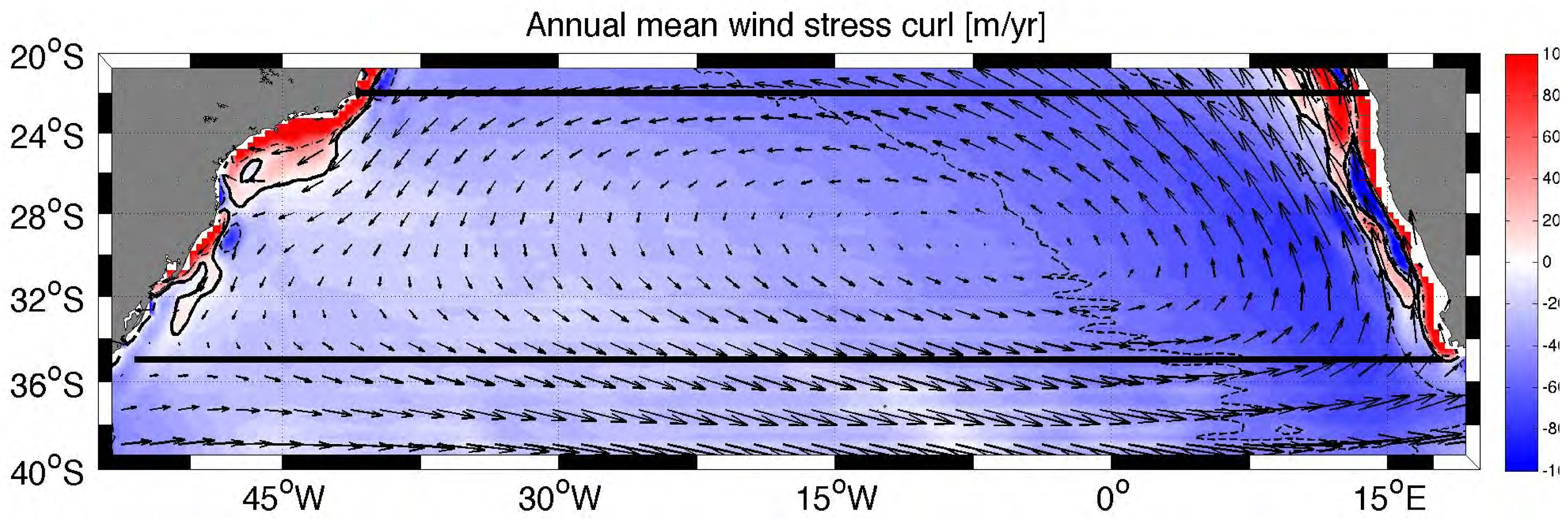


Figure: mean wind stress (vectors) and mean wind curl (color) calculated from NCEP monthly data. The black thick lines indicate the two latitudes where the Ekman transport was estimated (22°S Río de Janeiro and 35°S Cape Town). Ekman pumping can be easely estimated from wind curl. We can see here how water is mainly going down in the Southern ocean basin, with the exception of the upwellin coastal zones.

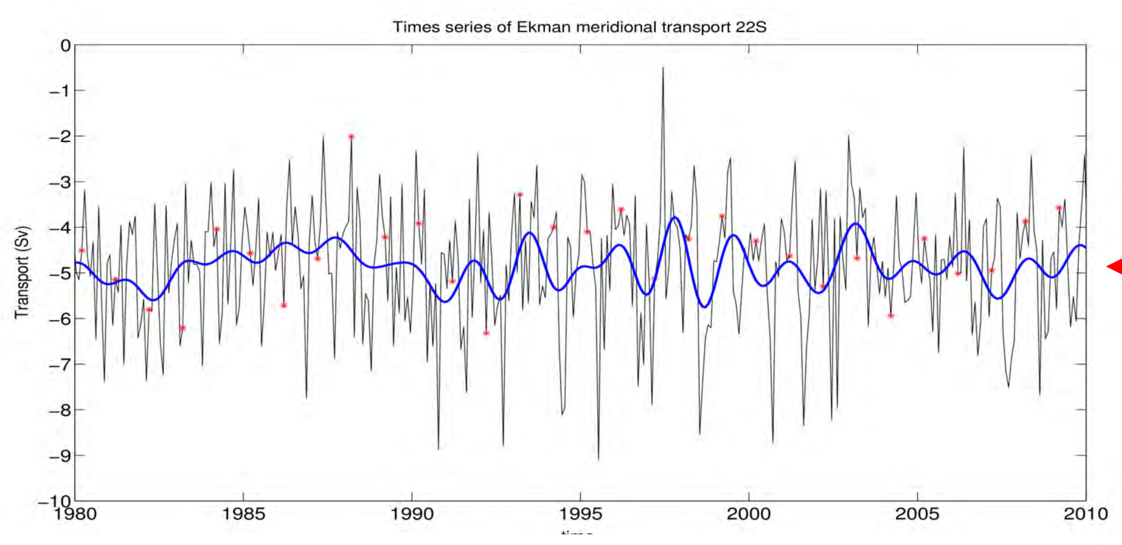
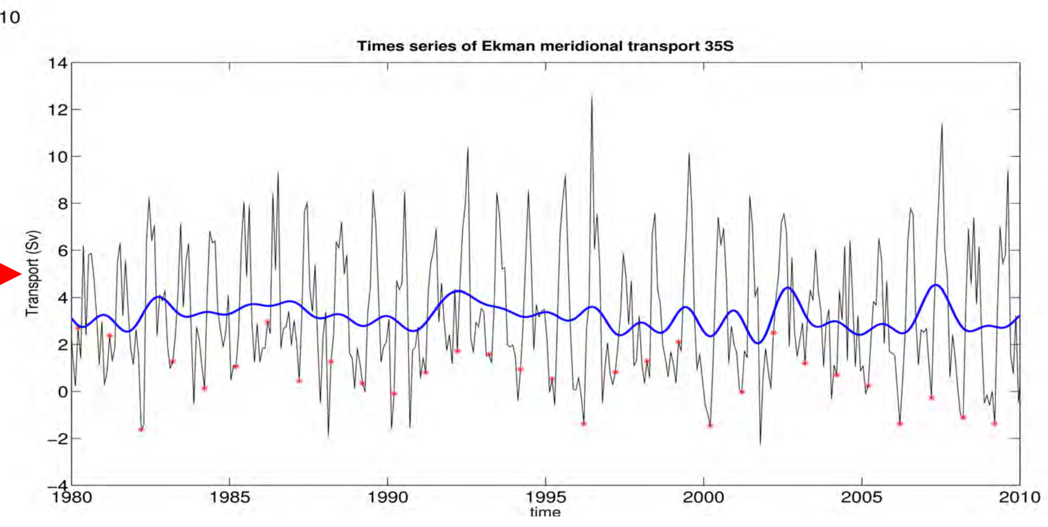


Figure: Monthly time serie (NCEP) of Ekman transport (black), filtered time series (blue) with 1.5yr low-pass filter. over 22°S. Red dots mark the morch month. At this latitude we can observe that Ekman transport is always southward

Figure: the same as the figure above, except for 35°S. Red dots mark the morch month. At this latitude we can observe that Ekman transpot is mainly to the north.



Data

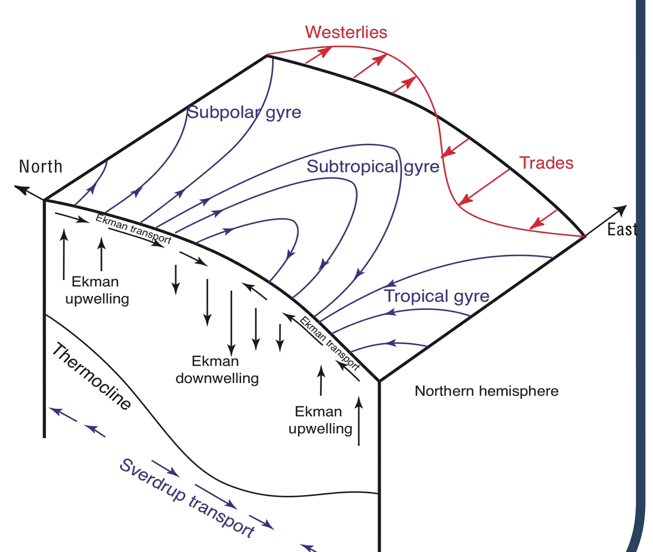
NCEP (1979 - 2010)
Monthly wind stress data over the south Atlantic Ocean was used to calculate the Ekman transport over 22°S (Cape Town) and 35°S (Rio de Janeiro). We also calculate wind curl and estimates ekman pumping on the basin.

Wind curl

Ekman pumping

$$\nabla_h \times \boldsymbol{\tau}$$

$$w_e = \frac{1}{\rho f}\nabla_h \times \boldsymbol{\tau}$$



Wind direction and velocity was recorded on the ship every 60 s, we calculate the hourly mean of both. UCTD data was obtain every hour on the ship and the mixed layer depth (MLD) is estimated from the UCTD data along the ship track.

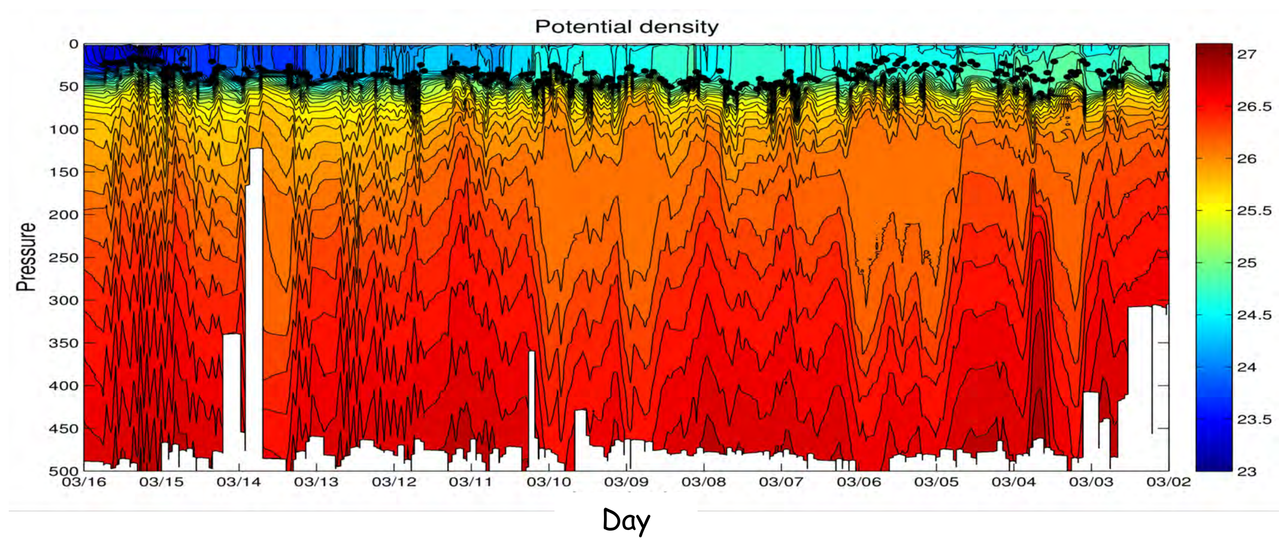


Figure: uCTD potential density field (color) and the black dots are the mixed layer depth, defined by the potential temperature threshold of 0.2°C. When the wind is more intense, mixed layer should be depper.

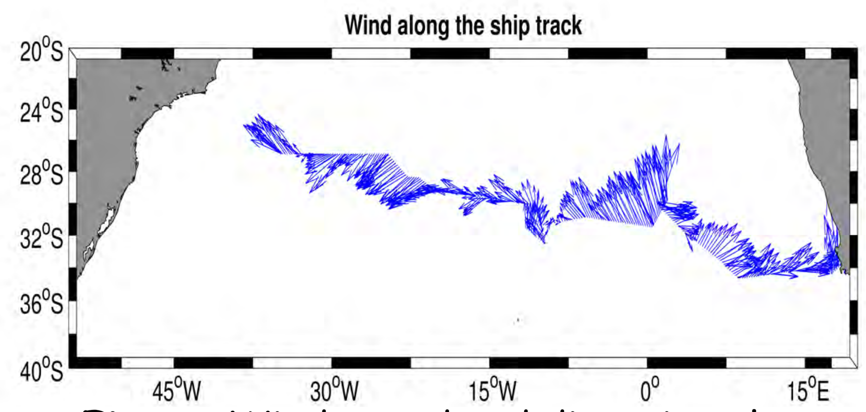


Figure: Wind speed and direction along the ship track.

Conclusion:

The transport of mass, heat and other properties by the ocean has major impact on climate as well as on human society. Surface winds has major influence in the upper ocean, but also on the deep circulation. This has been studied by Ekman and extended by Sverdrup. The mean wind stress over the ocean and the Coriolis force generates convergence and divergence zones that can be explained by the Ekman theory. In this work we could see the convergence of water mass over the Southern Ocean between 22°S and 35°S. This can be seen as a representative of the water mass transported from the equator to the south (22°S) and from the poles to the north (35°S), generating a convergence zone that should be balanced by the equatorward Sverdrup transport below the main thermocline.

Reference
Stewart, R. H. (2008), Introduction To Physical Oceanography.

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