Estimation of the Meridional Ekman Transport in the Tropical Atlantic

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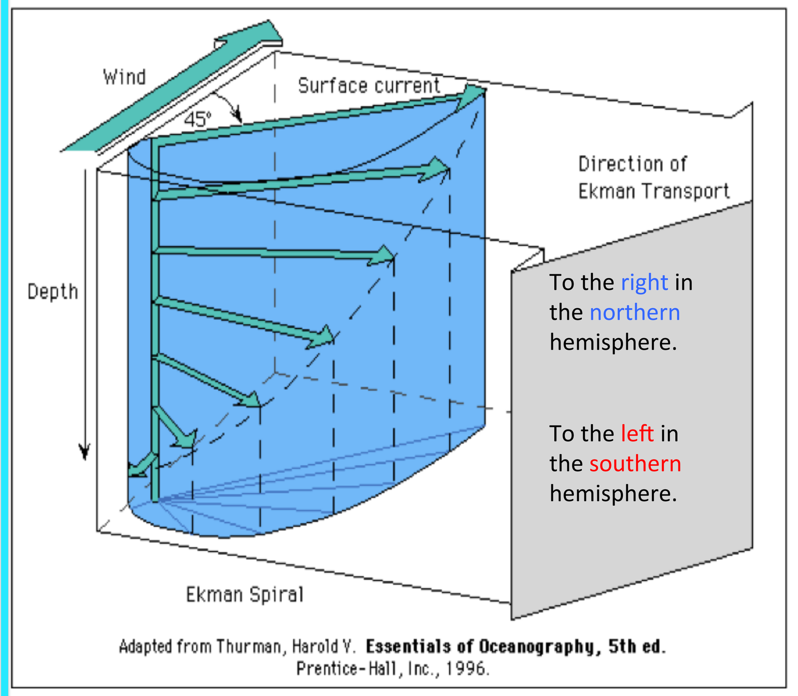
Introduction

In the tropical Atlantic Ocean, Ekman transport is an important upper layer component of the meridional overturning circulation. Wind induced Ekman divergence drives upwelling and poleward surface flow, forming the upper limb of the subtropical cell. Generally, in the absence of direct current measurement, Ekman transport and the associated heat and salt flux is derived from wind stress, SST and SSS based on the satellite observation. In this study, Ekman transport is calculated using direct velocity observation along two hydrographic sections and compared with the indirect approach.



Ekman Theory

Steady wind over a steady homogeneous ocean, the wind stress forcing is balanced by the effect of Earth's rotation.

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

The vertical integration result in a transport perpendicular to the wind blowing direction.

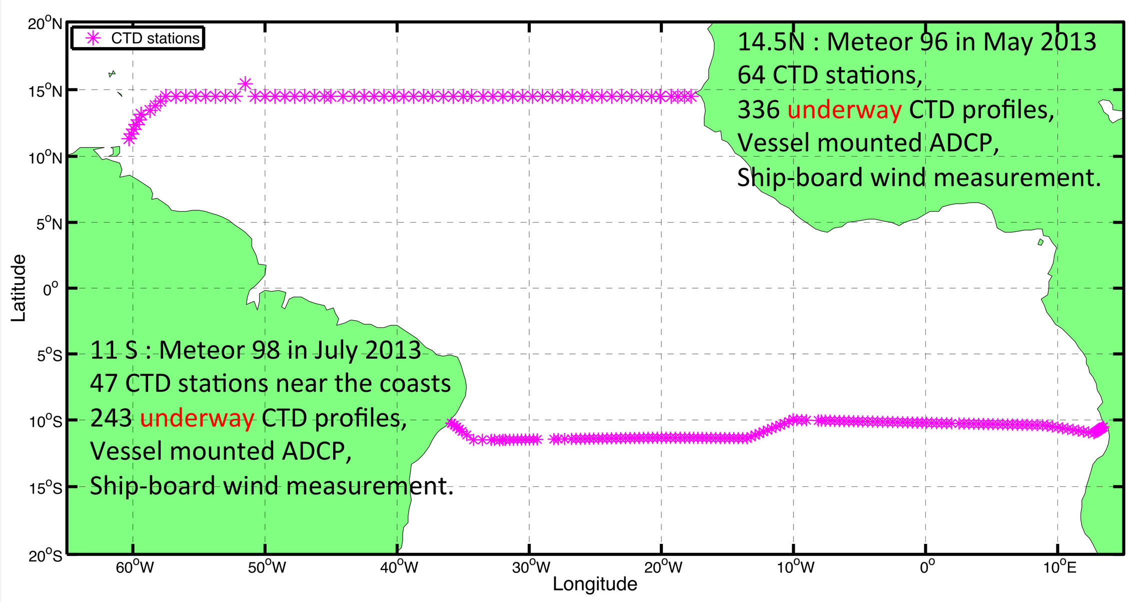
$$\frac{\tau_x}{\rho f} = -\int_{-D}^{0} v_{ageo}(z)\,\mathrm{d}z = M_y$$

Ekman transport can be calculated **separately** in two approaches:

Indirect: using **wind stress** $M_y^{wind} = -\frac{\tau_x}{\rho f}$

Direct: using **ageostrophic velocity** $M_y^{vel} = \int_{-D}^{0} v_{ageo}(z)\,\mathrm{d}z$

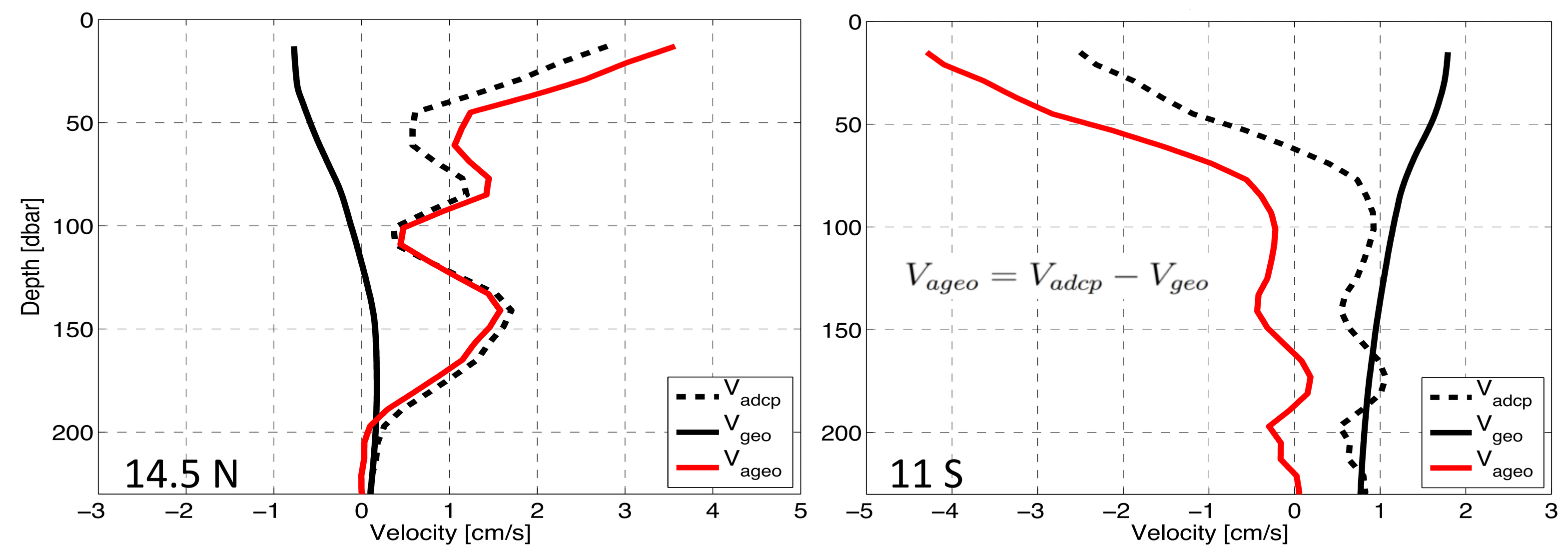
Data: Hydrographic Sections along 14.5 N and 11 S



Underway CTD (uCTD) data are applied to calculate the Ekman transport at both latitudes.

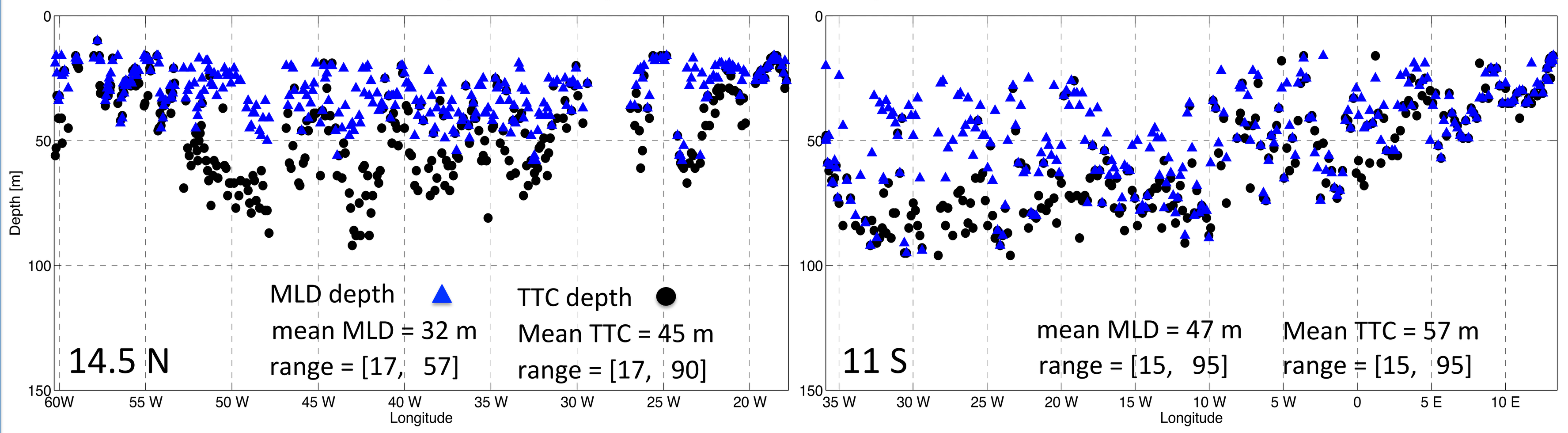
Satellite based wind, SST, SSS products are used as a comparison.

Direct Method: Ageostrophic Velocity



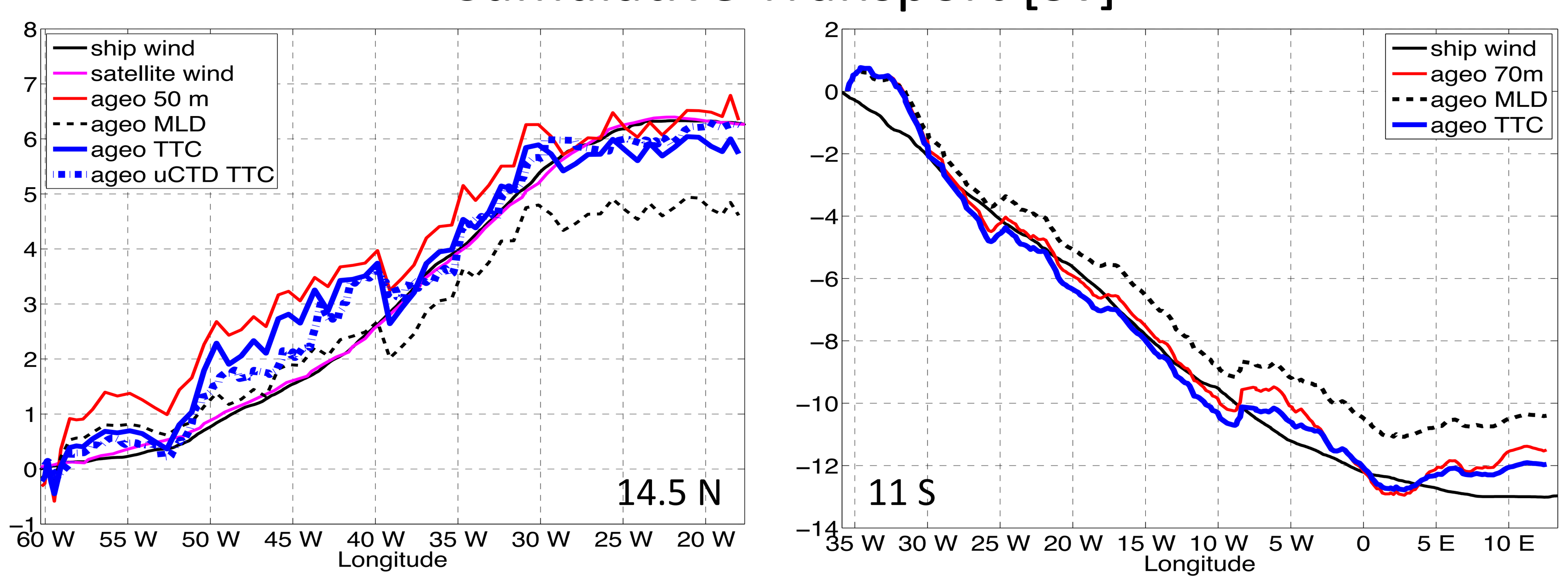
Geostrophic velocity was calculated from the density field measured by the CTD/uCTD, ageostrophic velocity is the difference between ADCP and geostrophic velocity. Assuming that in the upper layer, the ageostrophic flow is mainly due to the wind, Ekman transport can be calculated by integrating the ageostrophic velocity vertically and zonally.

Mixed Layer Depth and Top of the Thermocline



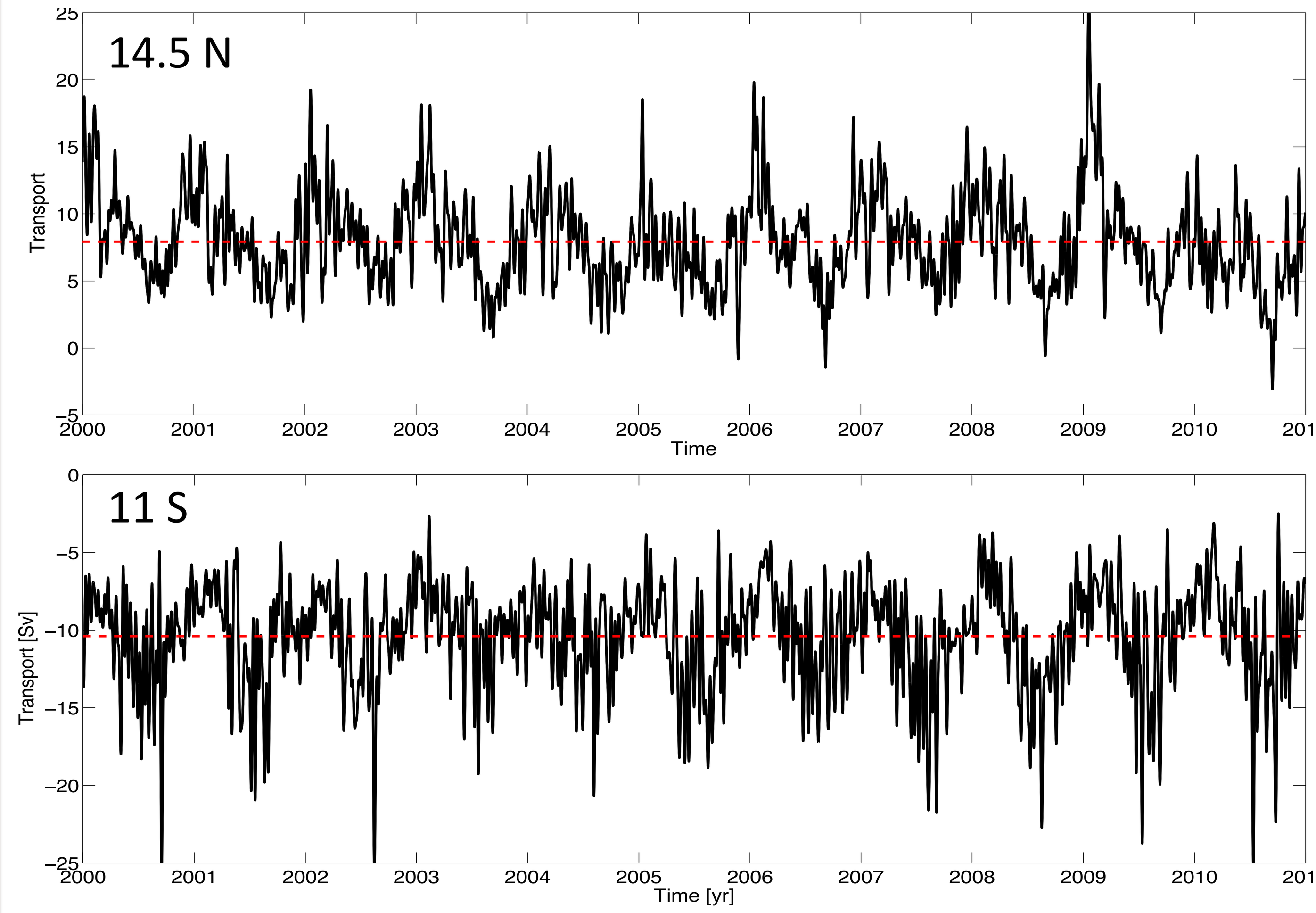
MLD is defined by a density threshold of 0.03 kg/m^3. TTC is defined by a density gradient threshold of 0.01 kg/m^4.

Cumulative Transport [Sv]



At 14.5 N, The calculation based on the uCTD data shows good consistency with the calculation based on the CTD data. The top of the thermocline appears to be a reasonable choice for integrating the ageostrophic velocity than either the MLD or a constant depth.

Long-term Variability of the Northward Ekman Transport



The wind stress data from NCEP CFSr. The seasonal cycle dominates the variability.

At 14.5 N, the mean Ekman Transport is 7.9 Sv with 3.5 Sv STD.

At 11 S, the mean is -10.4 Sv with 3.3 Sv STD.

Ekman Heat and Salinity Flux

		14,5 N					11 S				
		θ_E	s_E	M_E	H_E	S_E	θ_E	s_E	M_E	H_E	S_E
Direct	TTC	25,777	36,203	5,731	0,606	0,213	25,671	36,694	-11,959	-1,259	-0,449
	Const	25,618	36,171	6,342	0,666	0,235	26,051	36,836	-11,499	-1,228	-0,434
	Surface	25,907	36,207	5,731	0,609	0,213	25,672	36,668	-11,959	-1,259	-0,449
	Sat	25,893	36,266	5,731	0,608	0,213	25,768	36,390	-11,959	-1,263	0,446
Indirect	Surface	25,731	36,160	6,264	0,661	0,232	25,419	36,694	-12,971	-1,352	-0,488
	Sat	25,571	36,158	6,264	0,657	0,232	25,278	36,370	-12,996	-1,347	-0,484

θ_E : Transport weighted temperature [C]
s_E : Transport weighted salinity [psu]
M_E : Ekman volume transport [Sv]
H_e : Ekman heat flux [PW]
S_E : Ekman salinity transport [10^9 kg/s]

Summary and Outlook

The meridional Ekman transport along two transatlantic sections is estimated using direct and indirect method, respectively. The underway CTD data provide consistent results compared with the regular CTD data in estimating the Ekman transport. At both latitudes, the Ekman transport extended beyond the mixed layer. In the direct method, the Ekman flux is sensitive to the choice of integral depth, the top of the thermocline appears to be a reasonable choice for the integration of the ageostrophic velocity. Though in these two cases, the Ekman fluxes using the SST and SSS are not significantly different from using a layer of temperature and salinity.

In the next step, the observed Ekman transport and fluxes will be compared with GECCO/GECCO2 assimilation products. Eventually the study will be extended to the full water depth and different components related to the meridional overturning circulation will be estimated using observational data, and the variability of the MOC at 14.5 N will be analyzed with model data.

Reference

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