Poleward Shift of Southern Hemisphere Westerlies

Lisan Yu

Woods Hole Oceanographic Institution

Collaborator: Xiangze Jin (WHOI)

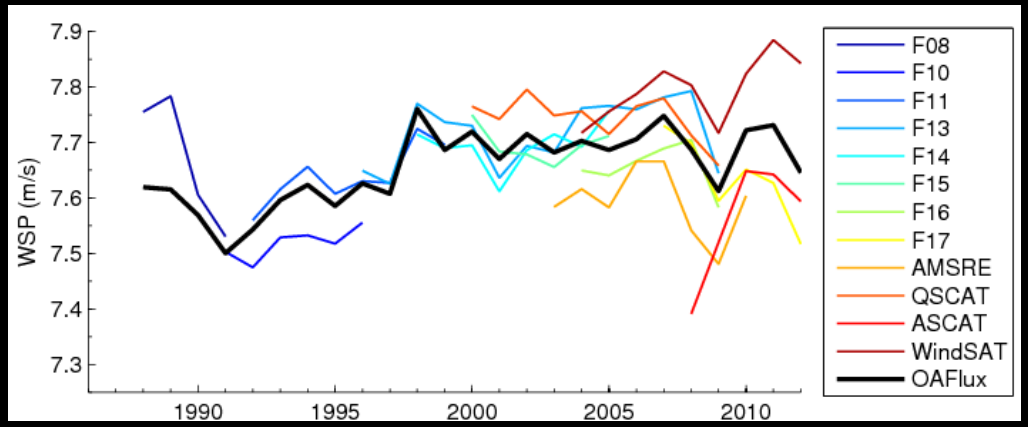
WHOI Summer Student Fellow: Samantha Whitmore
(Harvard University)

International Ocean Vector Wind Science Team Meeting
Kona, Hawaii, 6-8 May 2013

OAFlux High-Resolution Ocean Vector Wind Analysis

A 12-sensor synthesis, daily, 0.25°, 1987-present

Annual-mean time series of Wind Speed



Remote Sensing system. Version 7
- SSMI (F8, F10, F11, F13, F14, F15)
- SSMIS (F16, F17)
- AMSRE
- QuikSCAT, Version 4

KNMI, hosted at JPO. PODAAC
- ASCAT

Methodology and Strategy

OAFlux synthesis is in essence a least-square fitting in two dimensions.

(1) The synthesis is based on the Gauss-Markov theorem and a linear-squares estimator is formulated.

$$F = \sum_k \alpha_k (u_{ana} - u_{o,k})^2 + \sum_k \alpha_k (v_{ana} - v_{o,k})^2 + \sum_m \beta_m (\sqrt{u_{ana}^2 + v_{ana}^2} - w_{o,m})^2 + Dyn(vort, div)$$

(2) NWP wind directions used as initial guess if scatteometers are not available.

(3) Search the optimal solution through minimization.

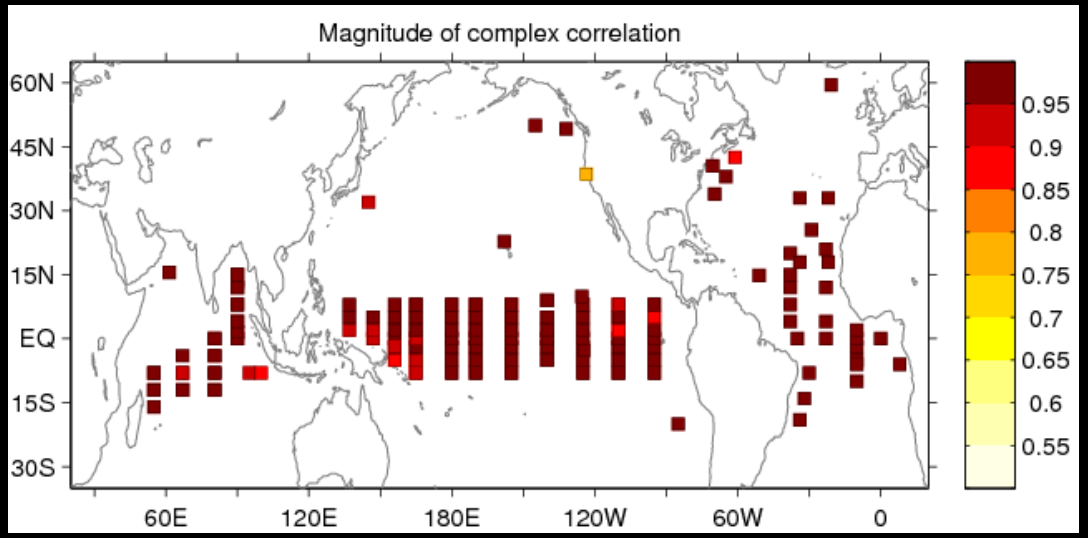
Yu, L. and X. Jin, 2013: Global Surface Flux Datasets from the Objectively Analyzed Air-sea Fluxes (OAFlux) Project: Satellite-based High-Resolution Analysis of Ocean Surface Vector Winds (1987 onwards). WHOI Technical Report. WHOI-OAFlux-2013-01, Woods Hole, MA.

Yu, L., and X. Jin, 2012: Buoy perspective of a high-resolution global ocean vector wind analysis using passive radiometers and active scatterometers (1987 – present). J. Geophys. Res, 117, C11013, doi:10.1029/2012JC008069.

OAFlux High-Resolution Ocean Vector Wind Analysis

A 12-sensor synthesis, daily, 0.25°, 1987-present

Vector correlation coefficients



Buoy evaluation

126 Buoy Locations

168,863 collocations

daily mean **1988-2011**

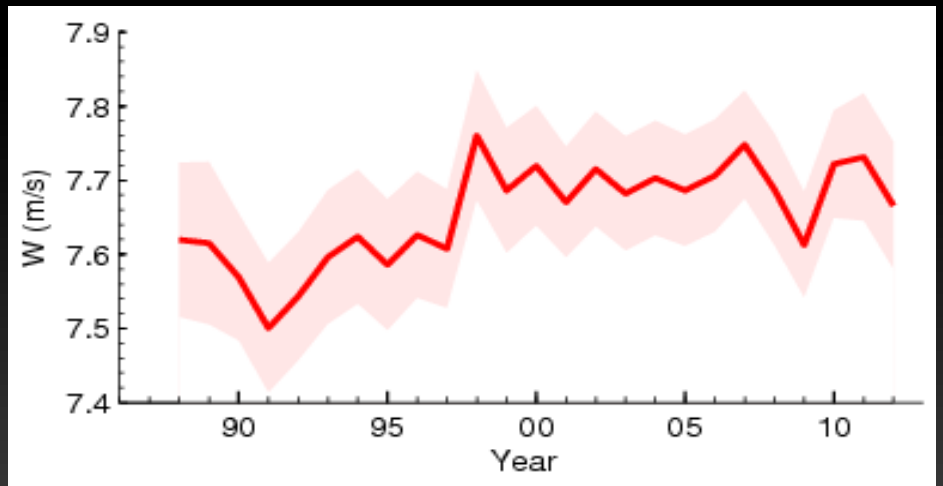
WSP: Mean Diff -0.13m/s

RMS error: 0.71 m/s

DIR: Mean DIFF -0.55°

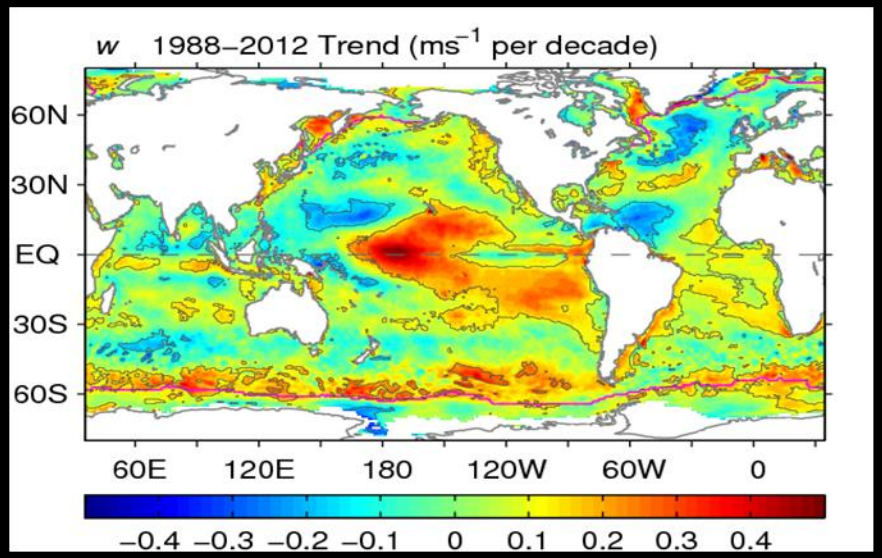
RMS error: 17°

Annual-mean time series of Wind Speed with error estimates

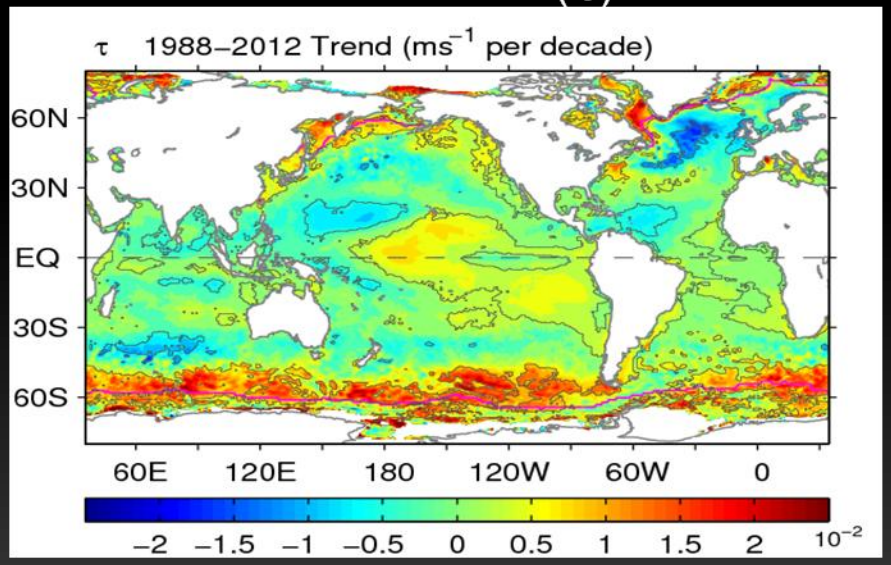


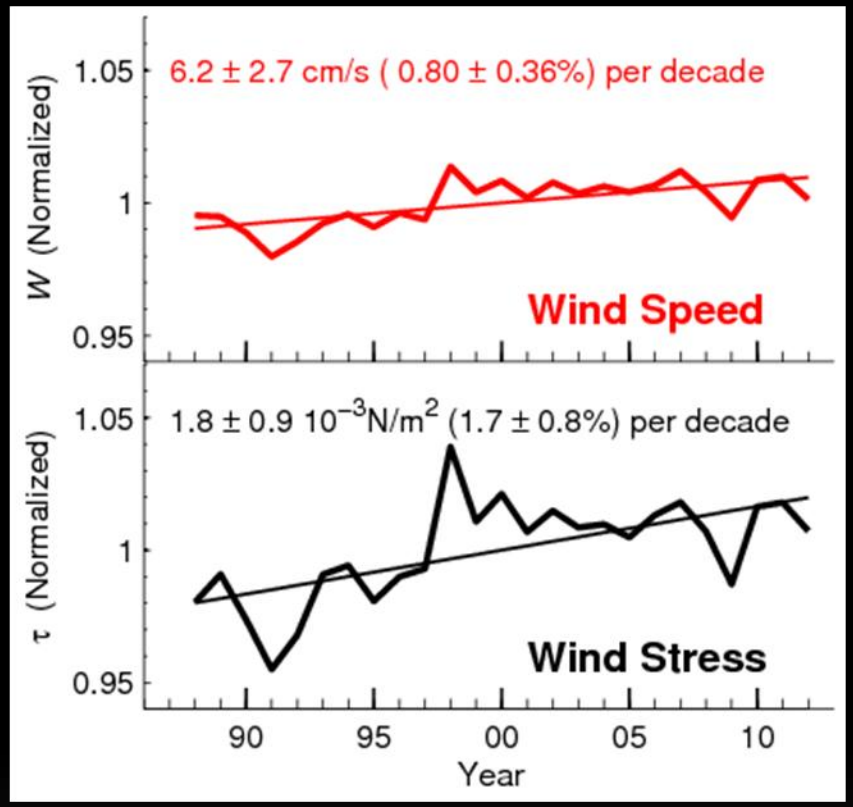
Decadal Change: Wind Speed versus Wind Stress

Wind Speed (W)



Wind Stress (τ)





$\tau \sim W^2$

Poleward shift of Southern Hemisphere Westerlies

(1) Originally detected in reanalyses

(e.g. Thompson and Solomon, 2002)

(2) Confirmed by station radiosonde data

(e.g. Marshall 2003; Hande et al. 2012),

(3) Evidenced in satellite altimetric wind speed and wave height retrievals

(e.g. Young et al. 2010)

This study uses the new 25-year vector wind analysis (1987 onwards):

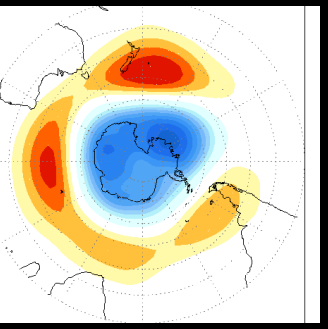
(1) to characterize the change in winds at the ocean surface,

(2) to connect the change of wind with ocean observations,

(3) to examine potential feedbacks between winds and the ACC (Antarctic Circumpolar Currents)

Leading modes of variability on Interannual and longer timescales

Mode 1
AAO (Antarctic Oscillation)



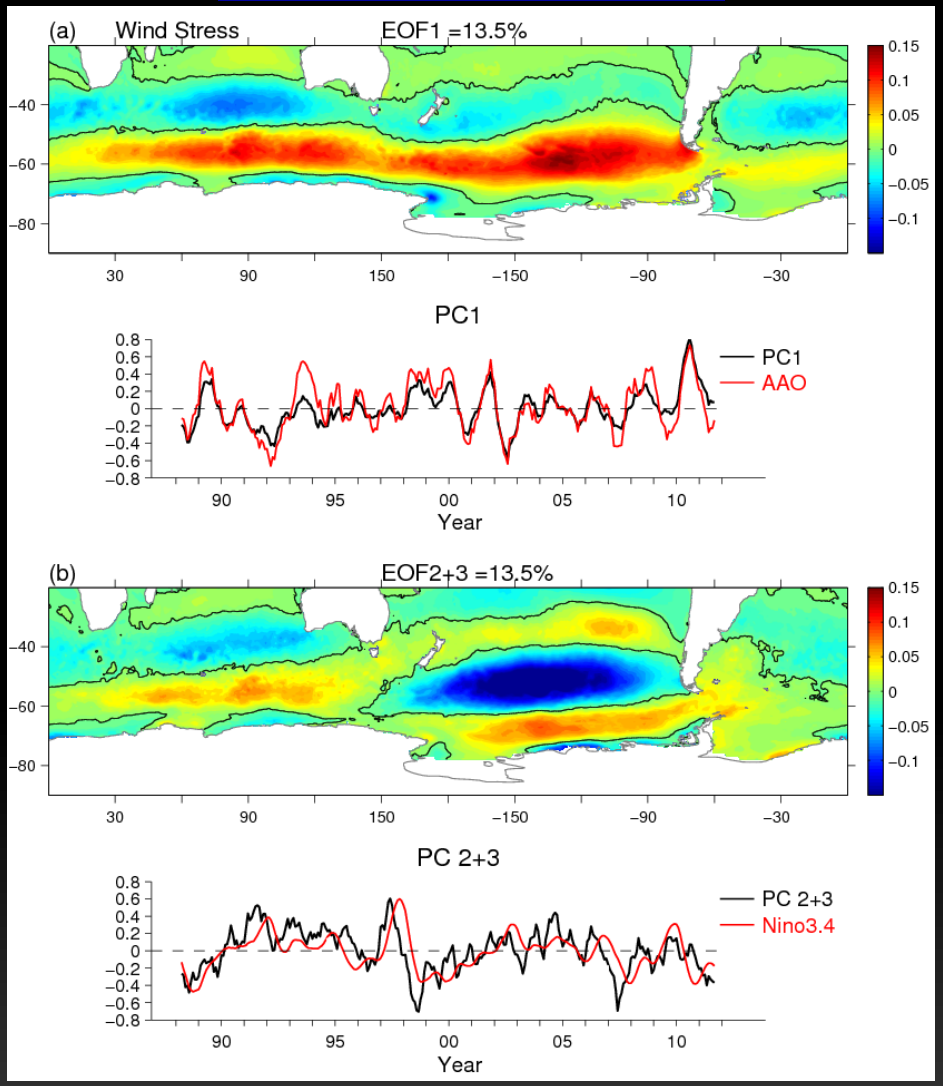
AAO: characterized by the difference of pressure anomalies between the Antarctic and 40-50S

Modes 2+3
ENSO (El Nino-Southern Oscillation)

Some low-frequency variances are related to ENSO.

ENSO influence is filtered out using a regression against Nino3.4.

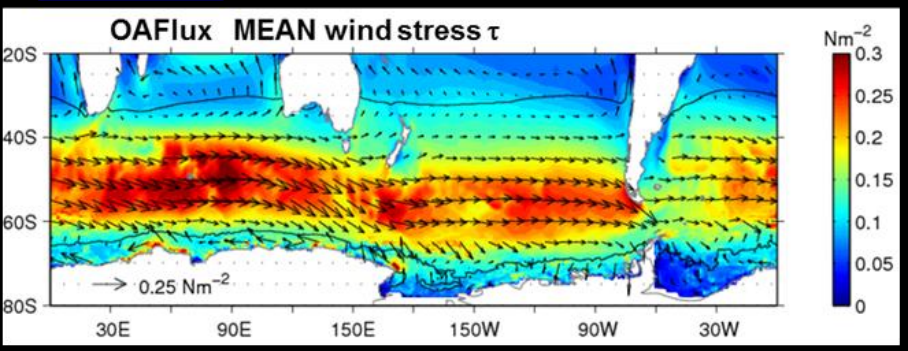
EOF modes



Decadal linear trends (1988-2012) ENSO signals are filtered out

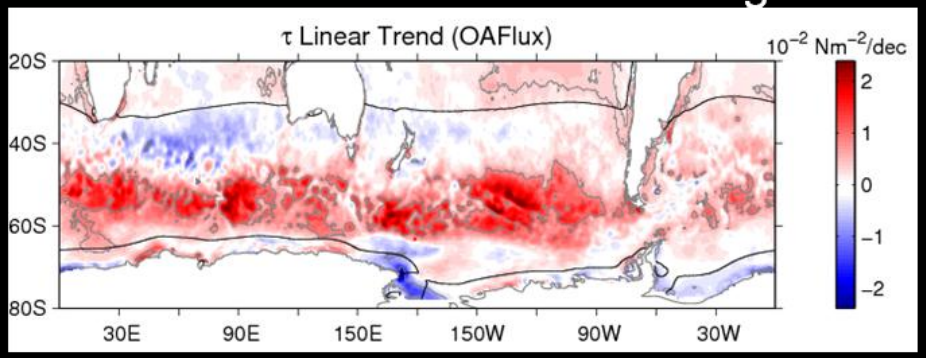
Mean

Stress Magnitude

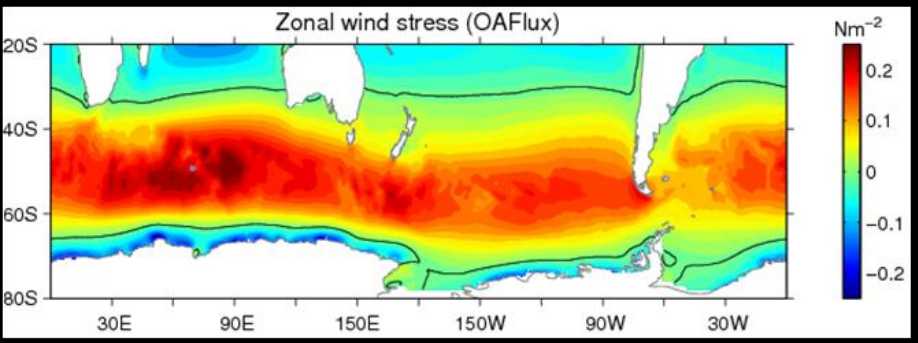


Linear Trends

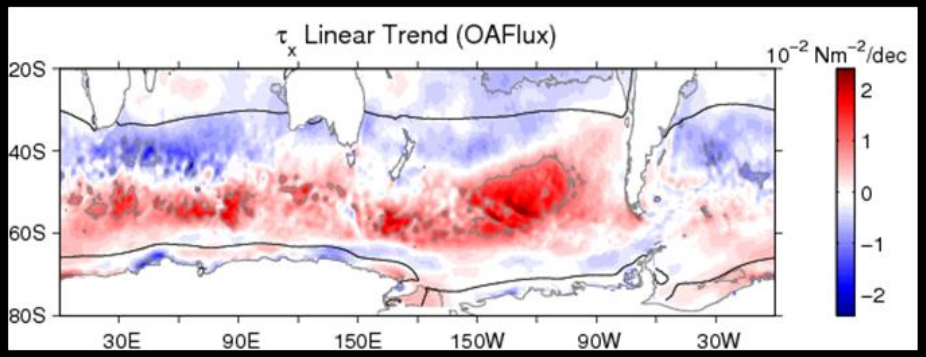
Stress Magnitude



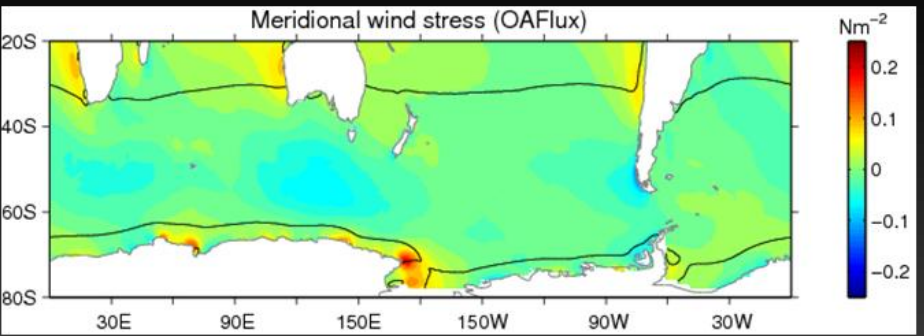
Zonal



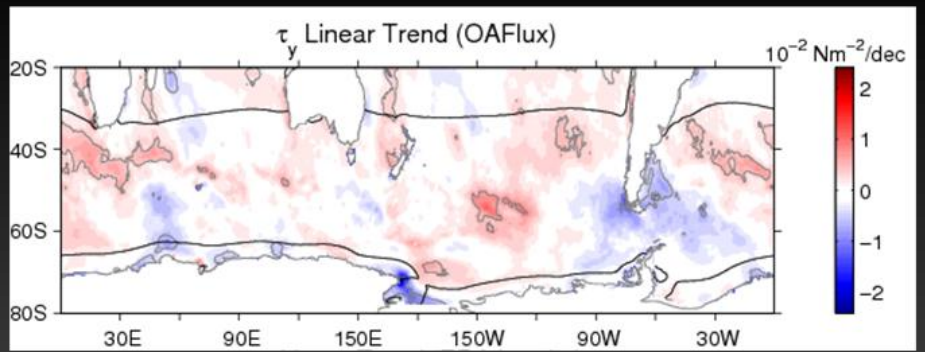
zonal



Meridional

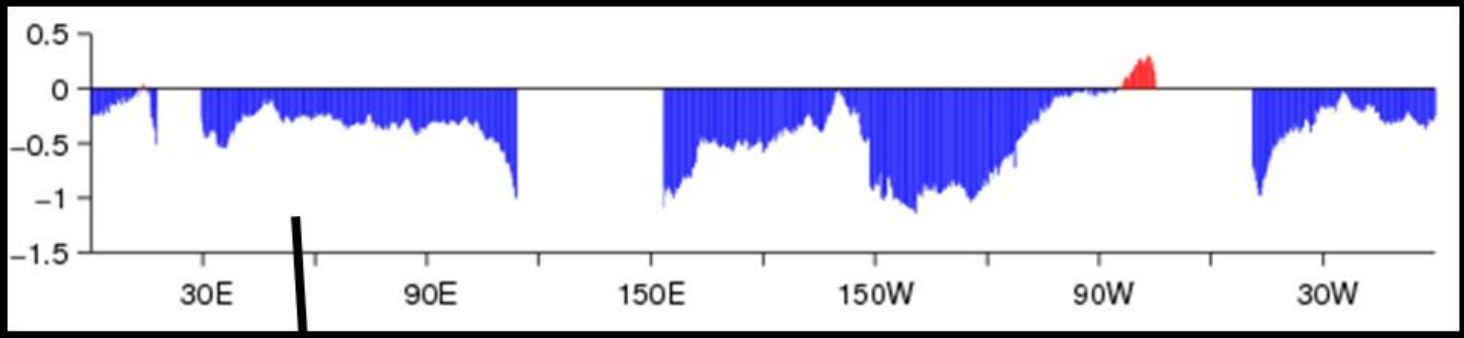


meridional

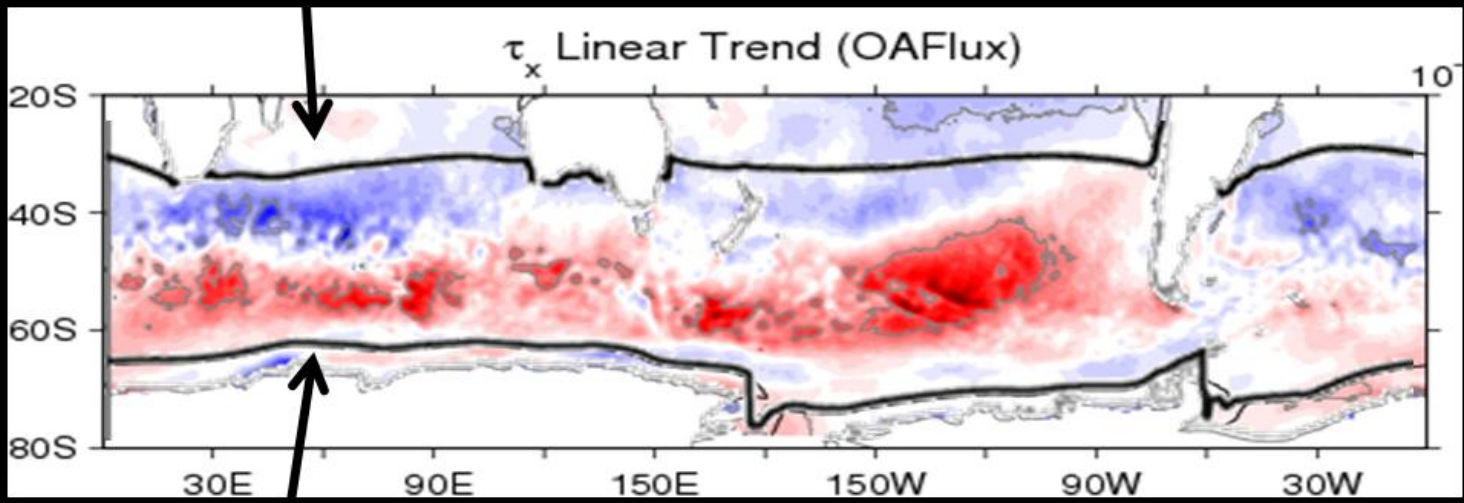


Shift in the westerly band

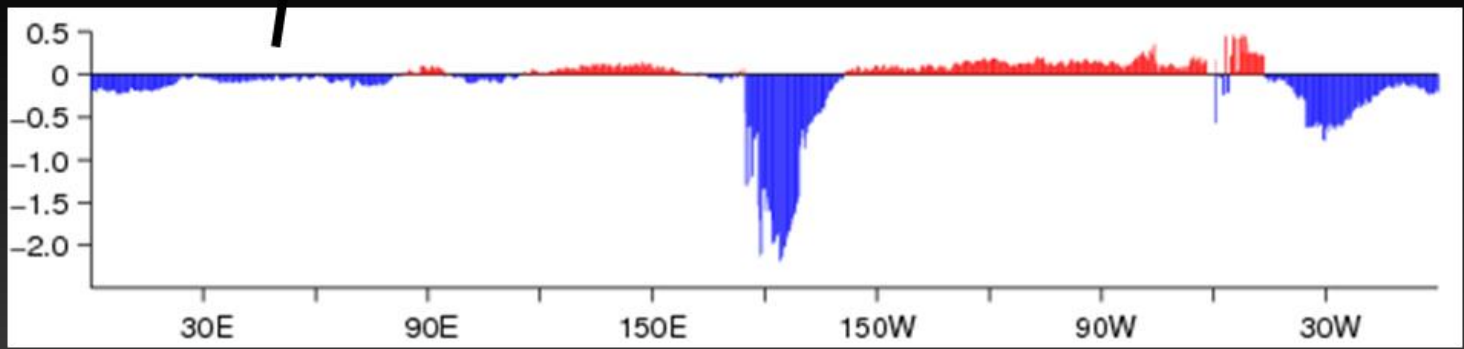
Trends in N. Lat(τ_x=0)
(°Latitude per 10 yrs)



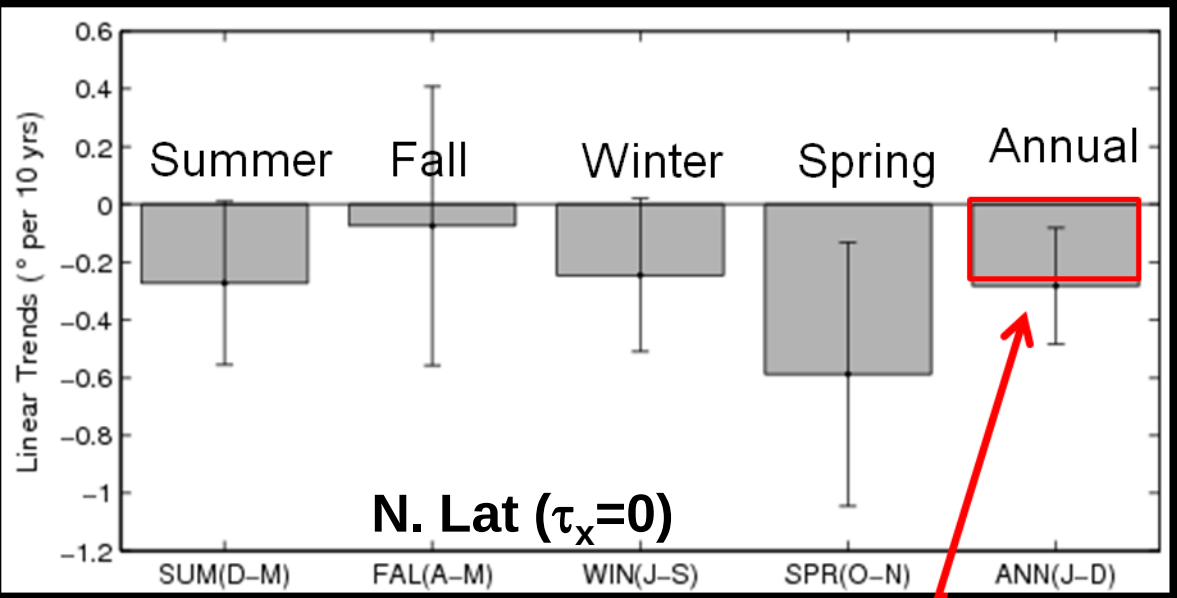
Linear trends in τ_x
(10^{-2} Nm^{-2} per 10 yrs)
(background colors)



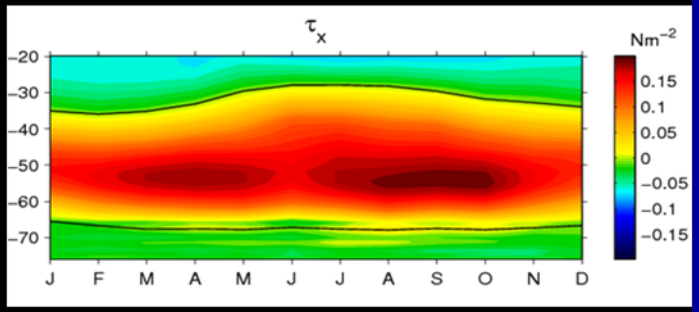
Trends in S. Lat(τ_x=0):
(°Latitude per 10 yrs)

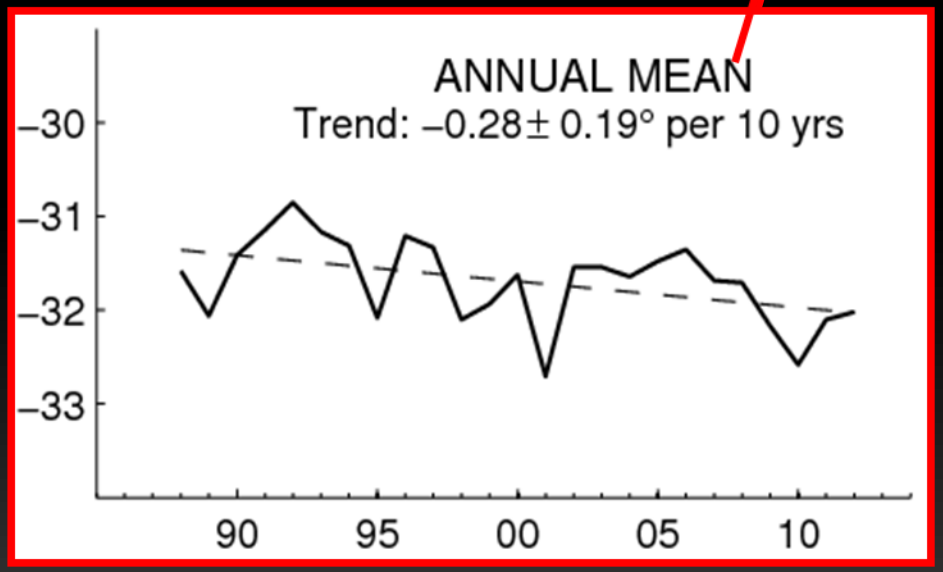


Seasonal dependence in the Shift



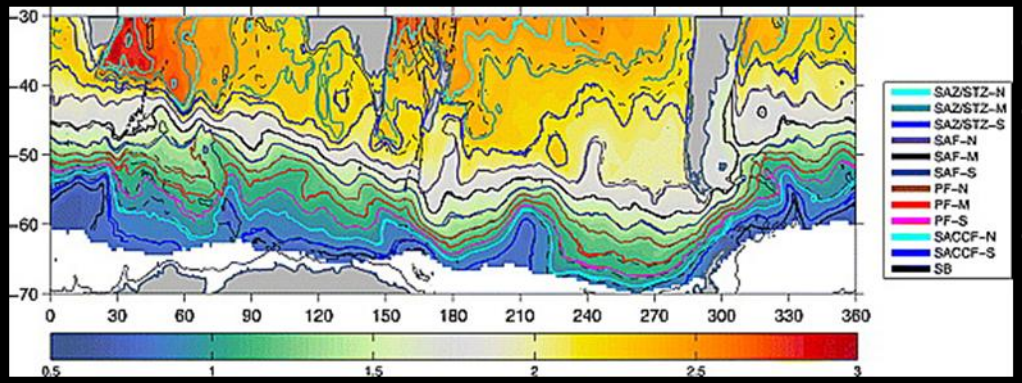
On seasonal timescales.
The westerly band contracts poleward during SPR and SUM





Poleward displacement of the ACC fronts from SSH

The ACC front positions



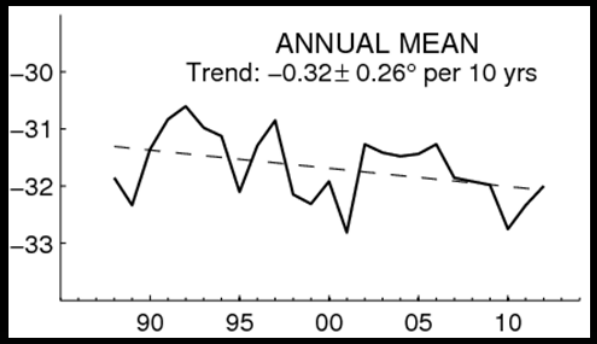
Sokolov & Rintoul (2009):

- Each of the ACC fronts has shifted to the south by about 60km, 1992-2007
- **Rate of change = 0.55°/16yrs**

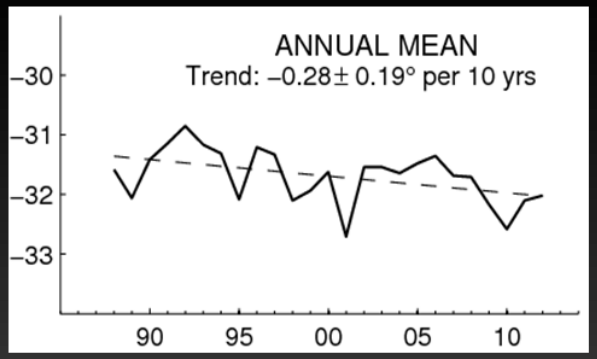
~ 0.34°/10 yrs

N. Lat (τ_x=0)

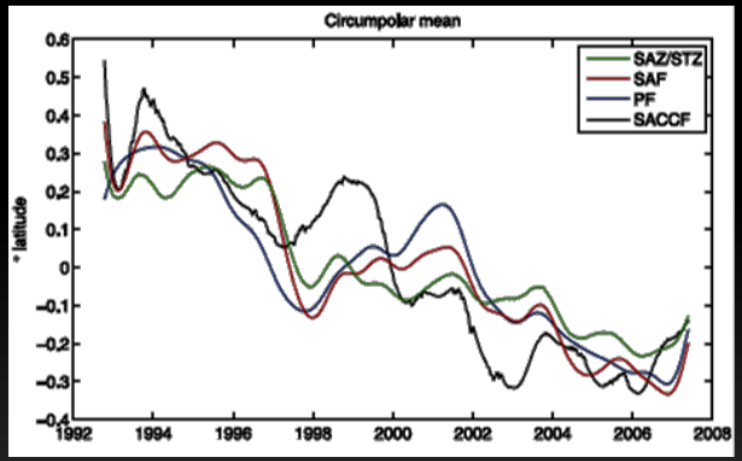
ENSO signals included



ENSO signals filtered out



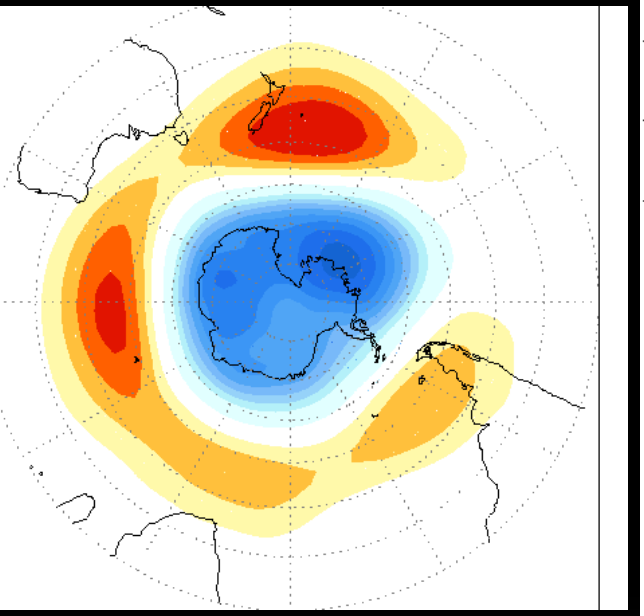
SSH front

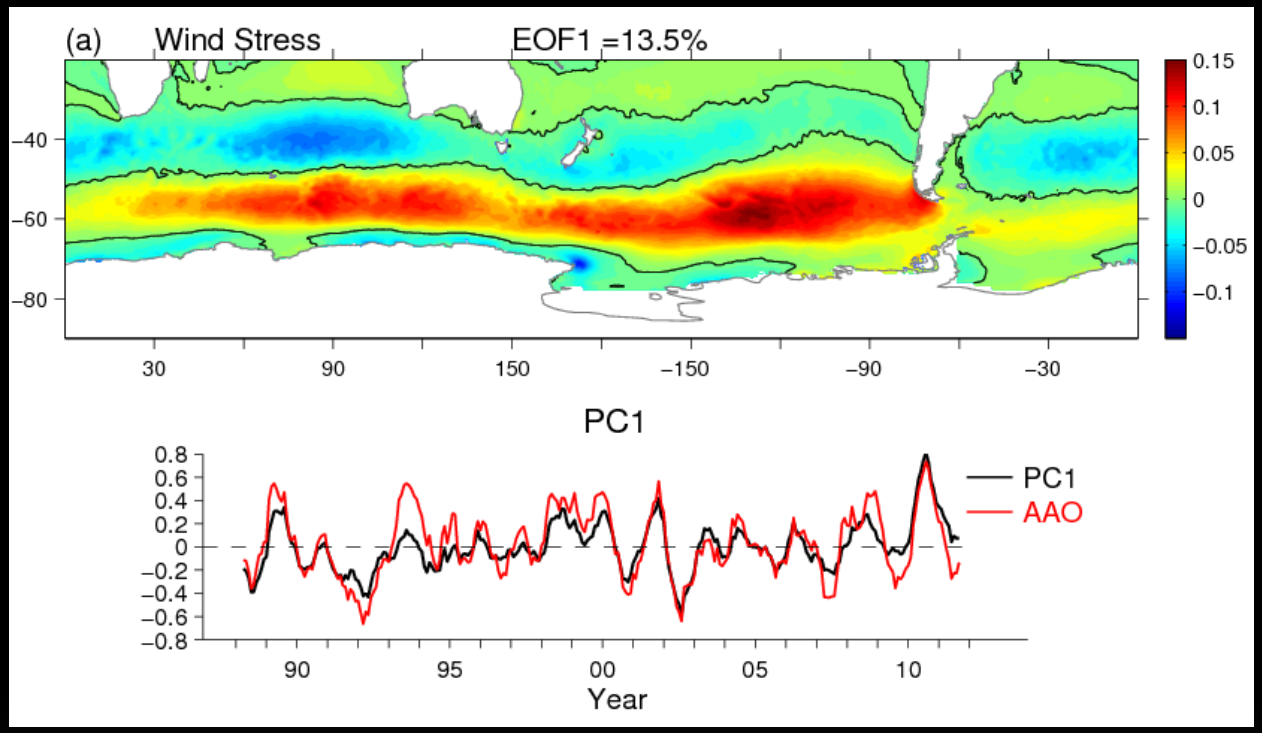


What governs the shift of SH westerlies?

EOF Mode 1
AAO (Antarctic Oscillation)

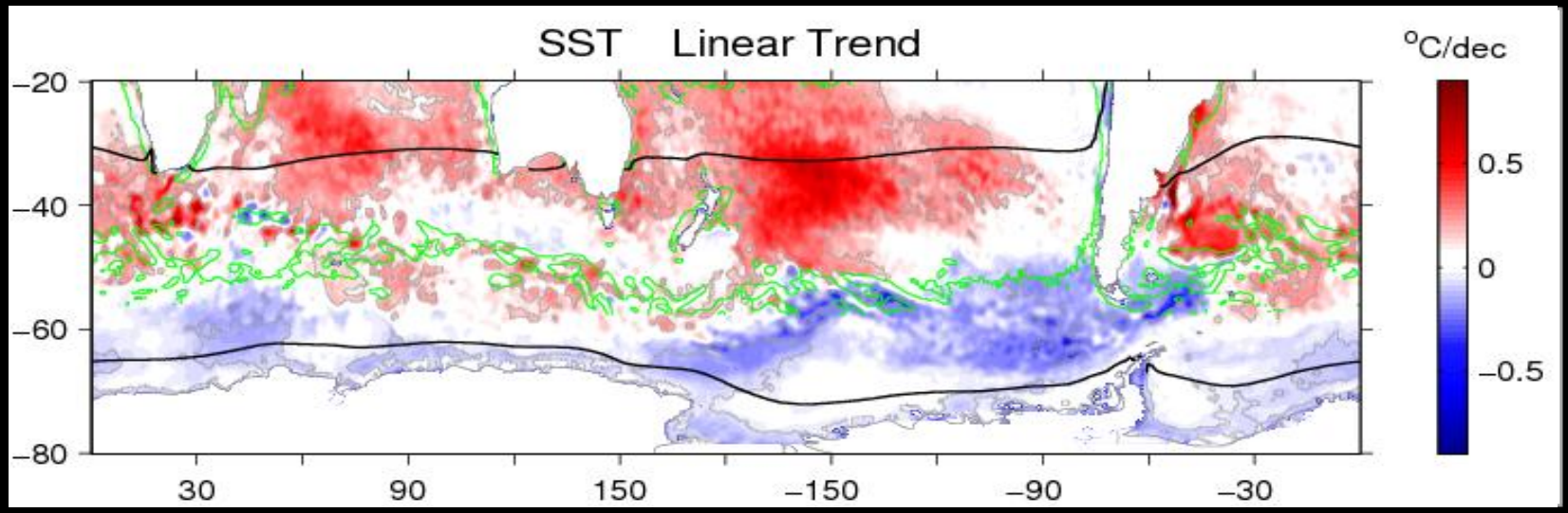
AAO
(Antarctic Oscillation)

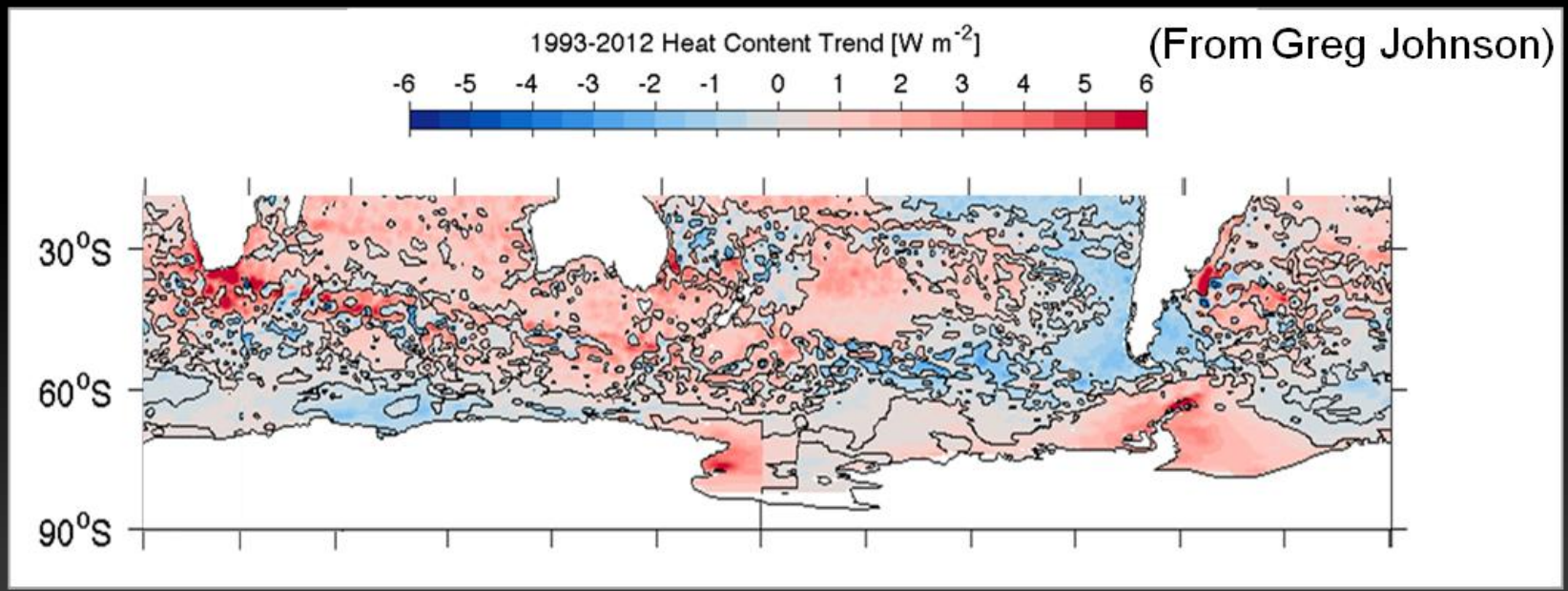




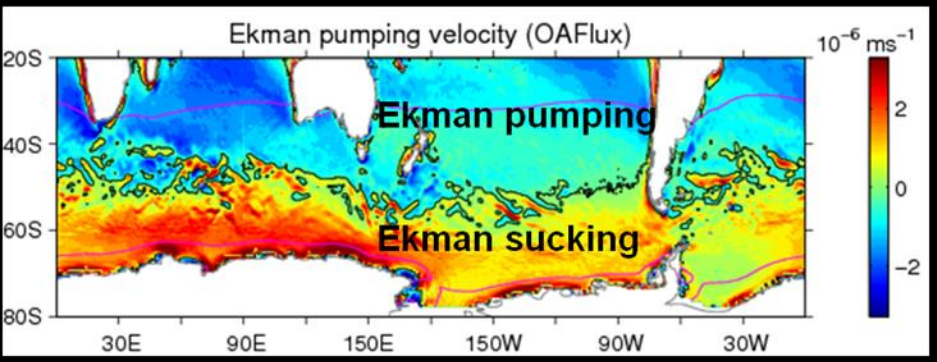
Are the ACCs just a slave of the change of AAO?

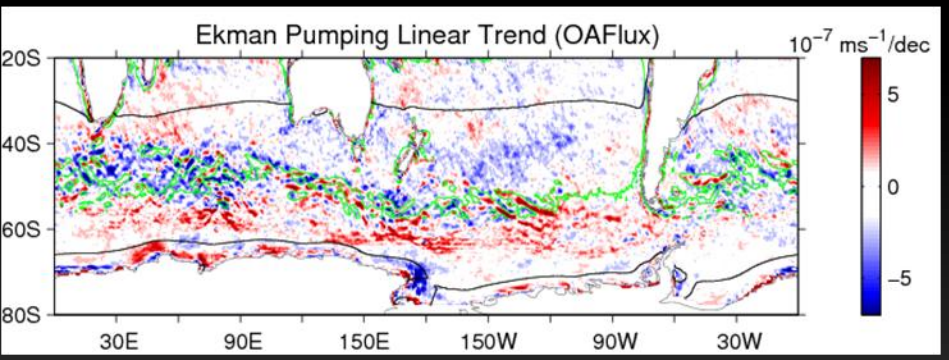
Both SST and Heat content show a cooling trend in the Antarctic Ocean



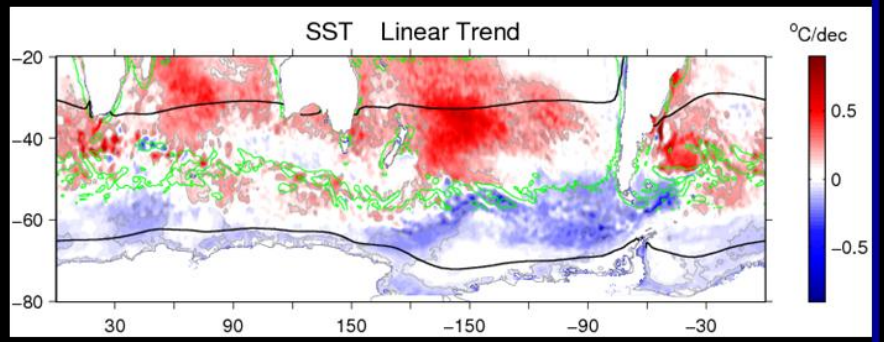


Ekman sucking/Pumping enhanced as a result of shifting westerlies



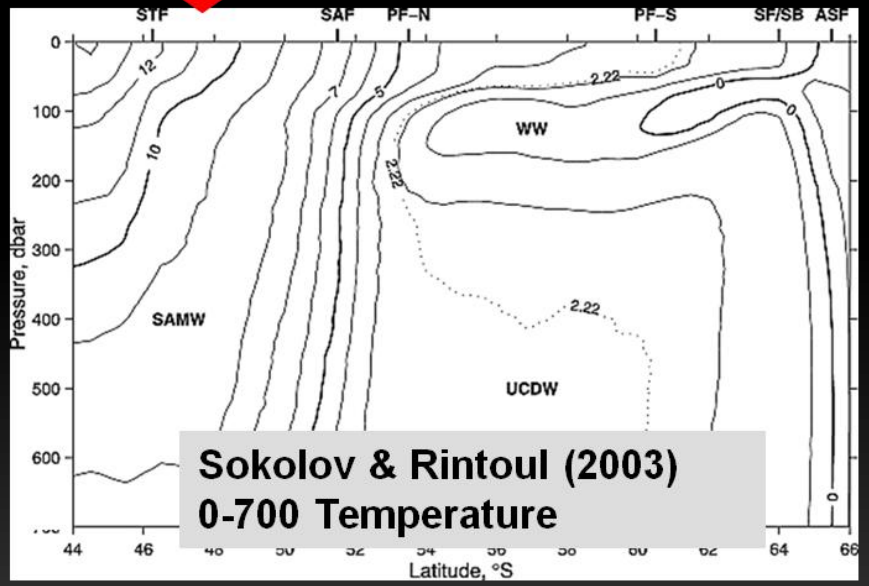


Effect of Ekman velocity on SST



Ekman convergence/ pumping pushes surface warmer water downward.

Ekman divergence/ sucking brings colder subsurface water to the surface.



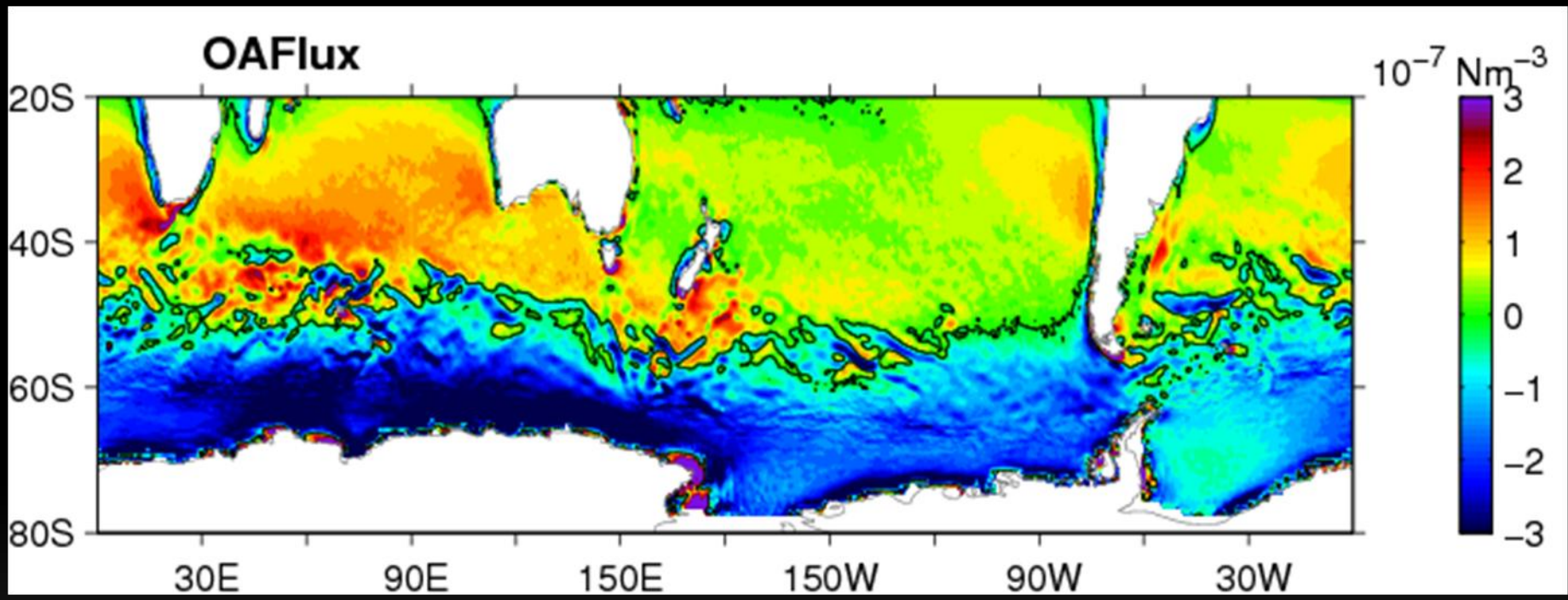
Sokolov & Rintoul (2003) 0-700 Temperature

Tasmania

Antarctic

Do the ACC fronts influence the winds?

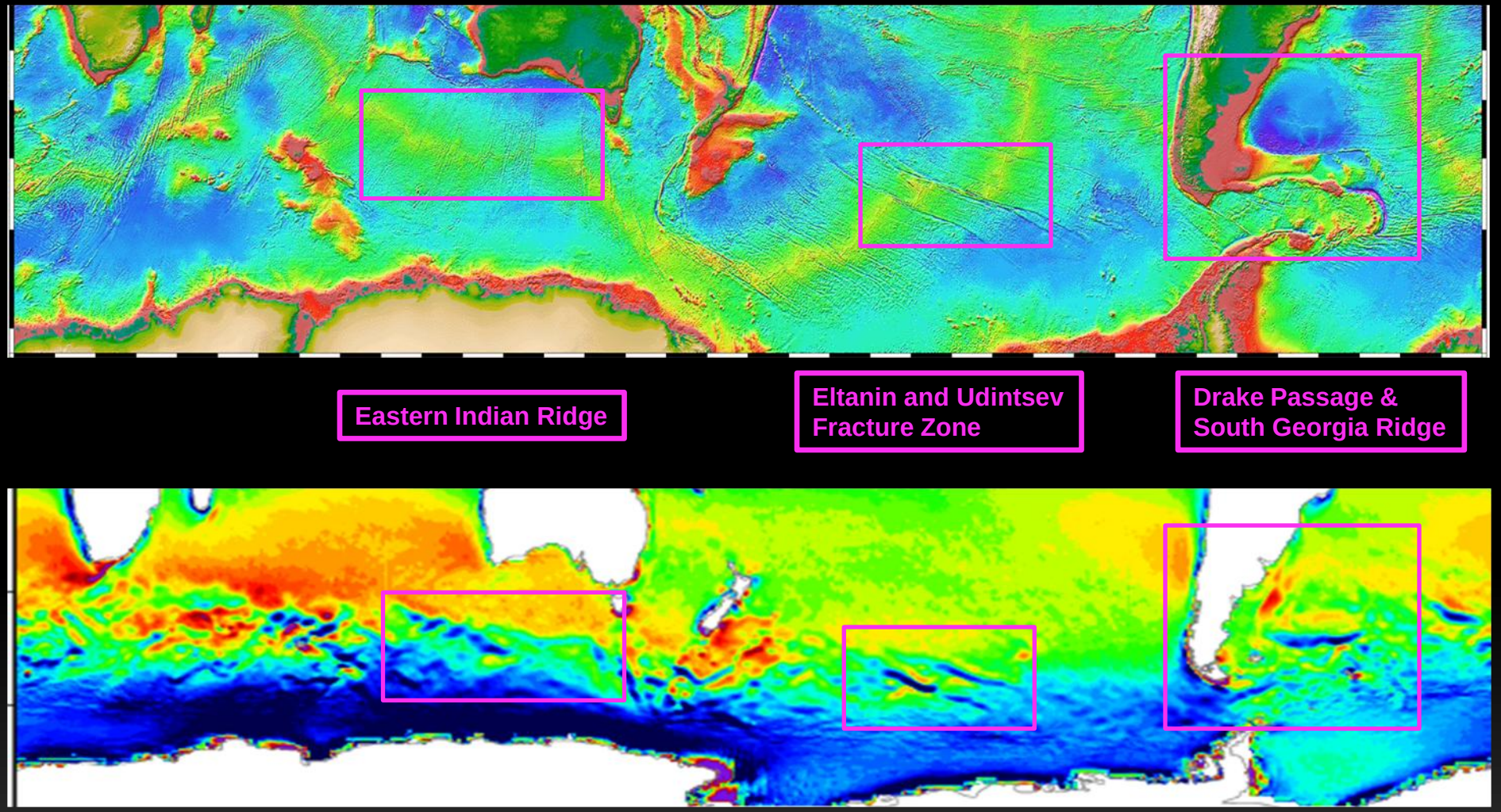
25-year Mean Wind Stress Curl (1988-2012) (positive: counterclockwise)



Average of ~ 9000 daily means

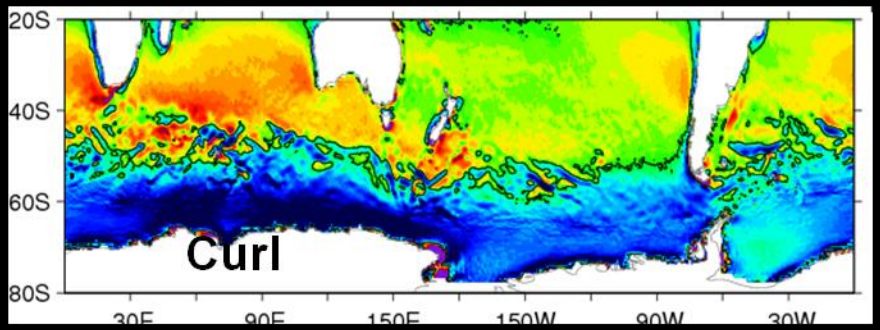
Wind stress curl sees the ocean bathymetry

(Smith and Sandwell, 1994)



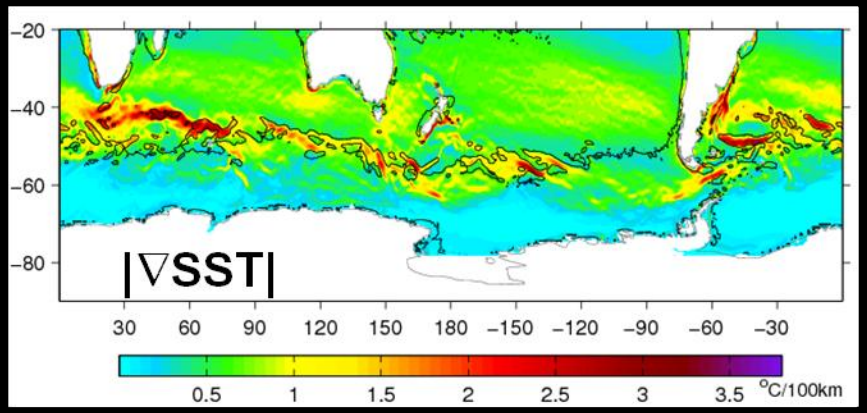
(curl negative: clockwise)

Coupling between wind stress, SST, and SSH



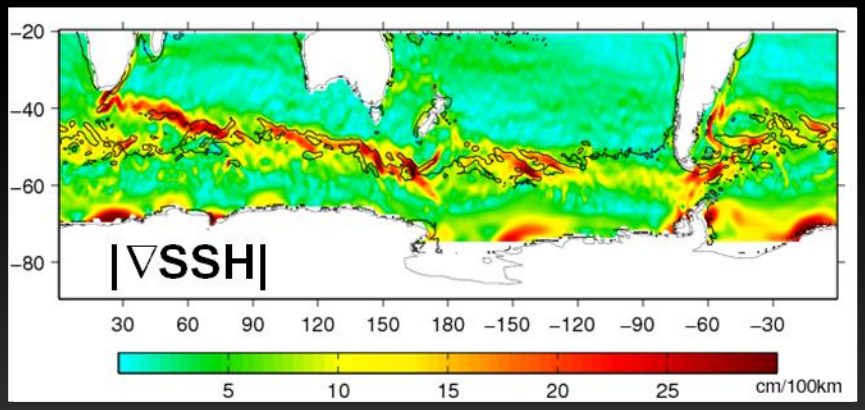
24-year average OAFlux

Mean Stress Curl (positive: counterclockwise)



24-year average AVHRR SST

Magnitude of Mean SST Gradient (**∇SST)**



Mean Ocean Dynamic Topography

Maximenko and Niiler (2005)

Magnitude of Mean SSH Gradient (**∇SSH)**

Summary and conclusions

(1) **Ocean general circulation responds to wind stress.**

Rate of increase:
Wind Stress: 1.7±0.8% per decade.
Wind Speed : 0.8±0.4% per decade

(2) **Wind stress curl sees ocean bathymetry**

A coupling between wind stress curl, SST, and SSH fronts along the ACC is evident.

(3) The surface westerly band has shifted poleward

Rate of change: - 0.28±0.20° per dec (~ 75 km in past 25 years)
(- 0.33±0.28° per dec if ENSO signals included).
The degree of shift is comparable to that of the ACC fronts derived from SSH.

(4) Ekman pumping and sucking are enhanced as a result of shifting westerlies, causing SST trends to change signs across the zero wind stress curl.