Poleward Shift of Southern Hemisphere Westerlies

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**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

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**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.

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

2. NWP wind directions used as initial guess if scatterometers are not available.

3. Search the optimal solution through minimization.

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OAFlux High-Resolution Ocean Vector Wind Analysis
A 12-sensor synthesis, daily, 0.25°, 1987-present

Vector correlation coefficients

Annual-mean time series of Wind Speed with error estimates

Buoy evaluation
126 Buoy Locations
168,863 collocations
daily mean 1988-2011
WSP: Mean Diff -0.13 m/s
RMS error: 0.71 m/s
DIR: Mean Diff -0.55°
RMS error: 17°
Decadal Change: Wind Speed versus Wind Stress

Wind Speed ($W$)

Wind Stress ($\tau$)

$\tau \sim W^2$
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.
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($\tau_x=0$)
($^\circ$Latitude per 10 yrs)

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

Trends in S. Lat($\tau_x=0$):
($^\circ$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 ($\tau_x=0$)

ENSO signals included

ENSO signals filtered out

ANNUAL MEAN
Trend: $-0.32 \pm 0.26$° per 10 yrs

ANNUAL MEAN
Trend: $-0.28 \pm 0.19$° per 10 yrs

SSH front

Circumpolar mean
What governs the shift of SH westerlies?

EOF Mode 1
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.

(From Greg Johnson)
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

(Eastern Indian Ridge) (Drake Passage & South Georgia Ridge) (Eltanin and Udintsev Fracture Zone)

(curl negative: clockwise)
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.**