Recent Science Highlights using Underway Observations in Drake Passage (AX22)

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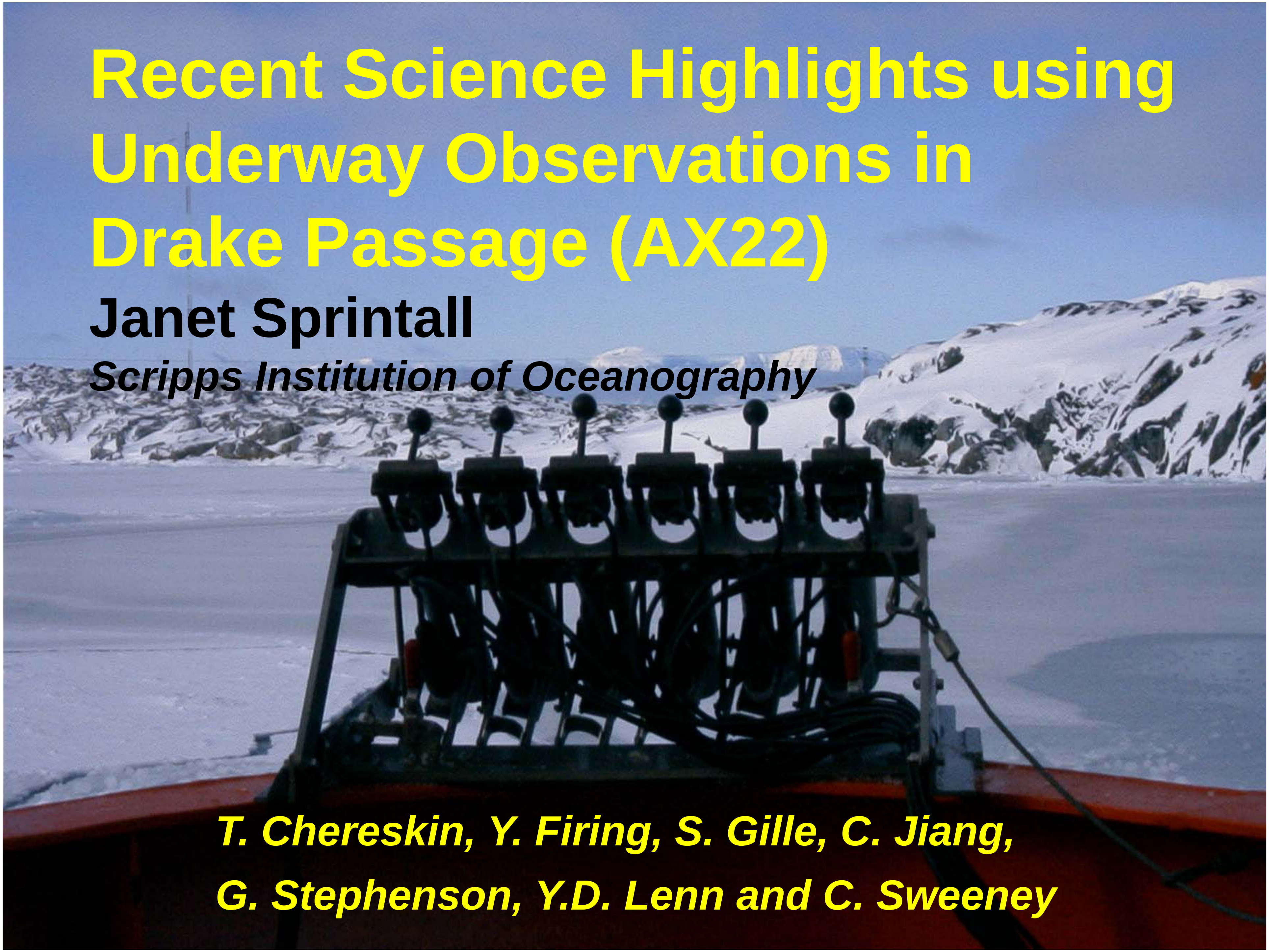
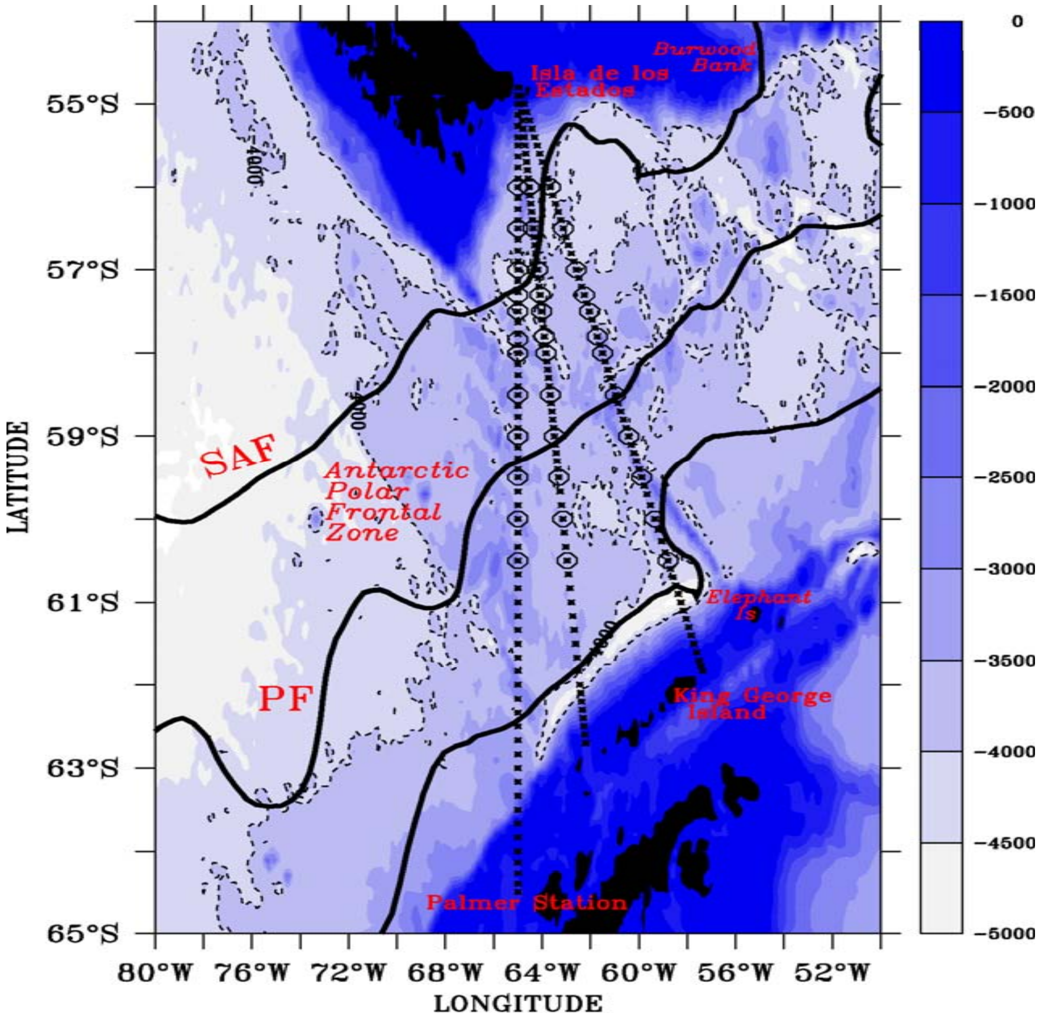


T. Chereskin, Y. Firing, S. Gille, C. Jiang,

G. Stephenson, Y.D. Lenn and C. Sweeney

AX22 Drake Passage Near-Surface Time Series



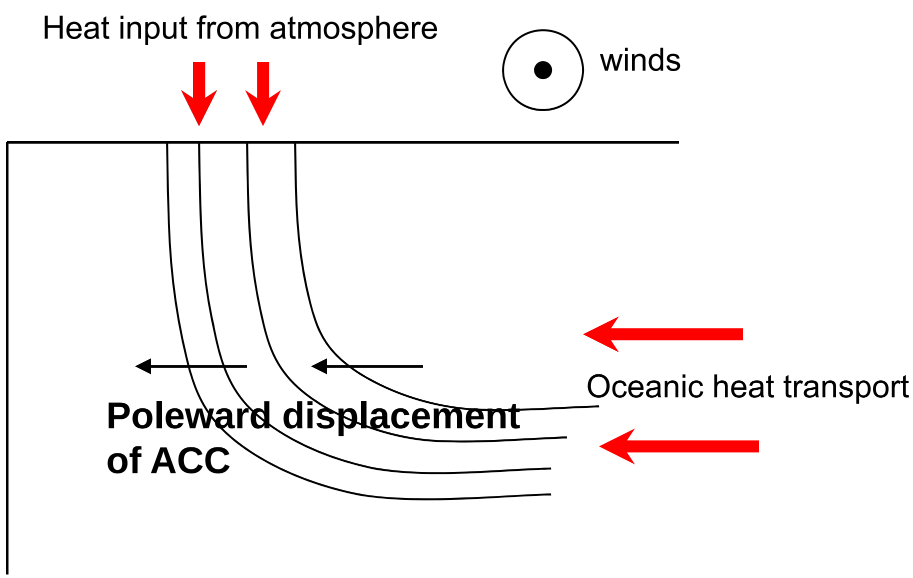
Year-round *R/V L.M. Gould* underway observations:-

- AX22 High-resolution XBT: 70 XBTs; 6-8 transects/year 96 T transects (1996 onward)
- XCTDs (2000 onward)
- ADCP: ~200 V transects (1999-2004 150 kHz; 2004 onward 38 kHz)
- pCO_2 & TCO_2: 326K obs (2002 onward)
- IMET (full suite) & TSG

Long-term time series of simultaneous measurements of V, T, S, air-sea heat and gas fluxes -> characterize spatial and temporal variability of near-surface processes in ACC.

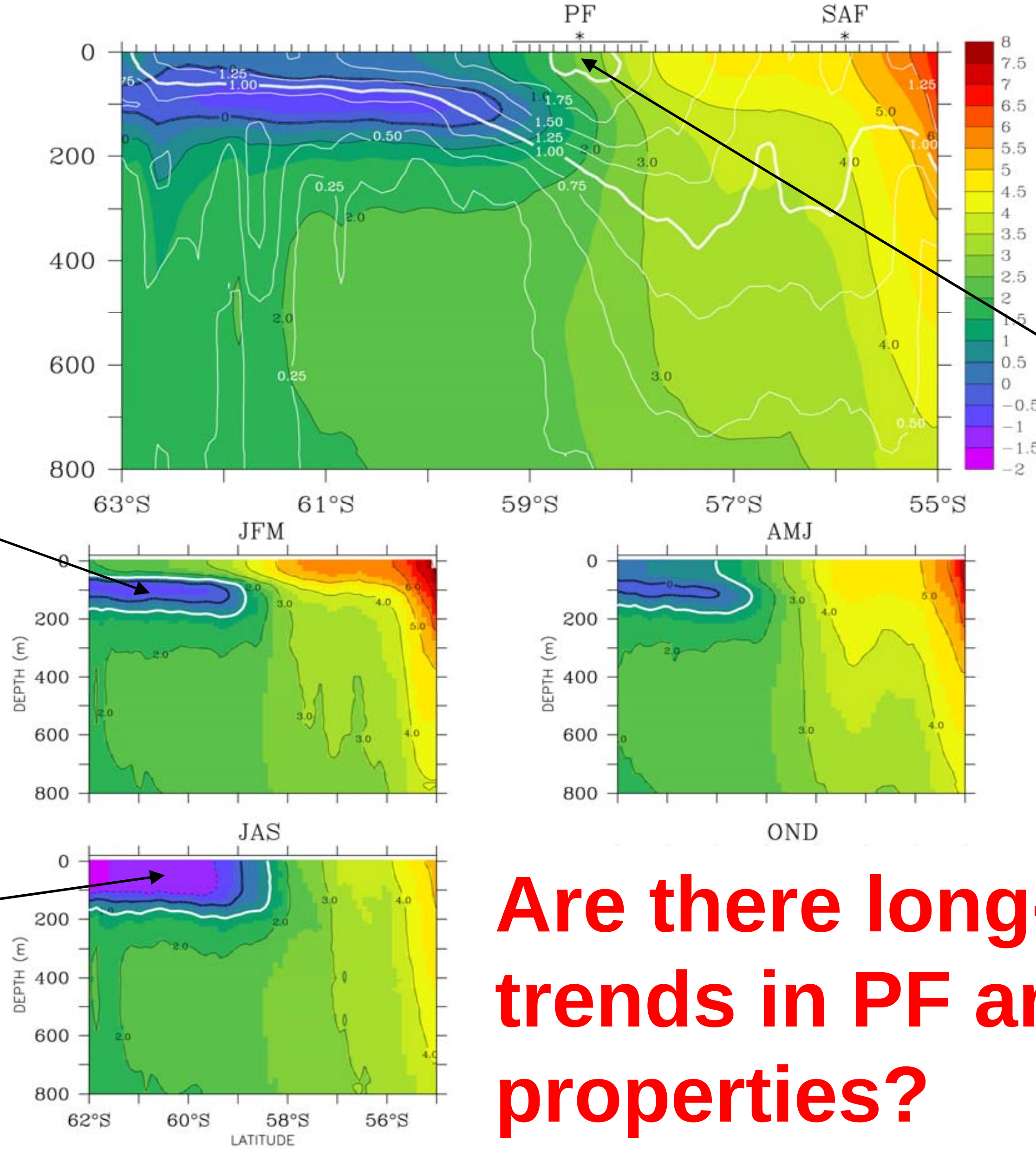
What Mechanisms Control Change in the Southern Ocean?

$$\overline{\frac{\partial T}{\partial t}} + \nabla.(\overline{u}\,\overline{T}) + \nabla.(\overline{u'T'}) = forcing$$



• mean advection:
- poleward shift in ACC fronts?
• eddy advection:
- changes in poleward eddy heat transport?
• Surface forcing:
-changes in upper air-sea heat exchange and heat input to the ocean?
- dependence on changes in winds, SST, Ta, humidity, etc.

AX22 Mean Temperature Transect: 15 years



High resolution of Polar Front (PF)

Winter Water (WW)

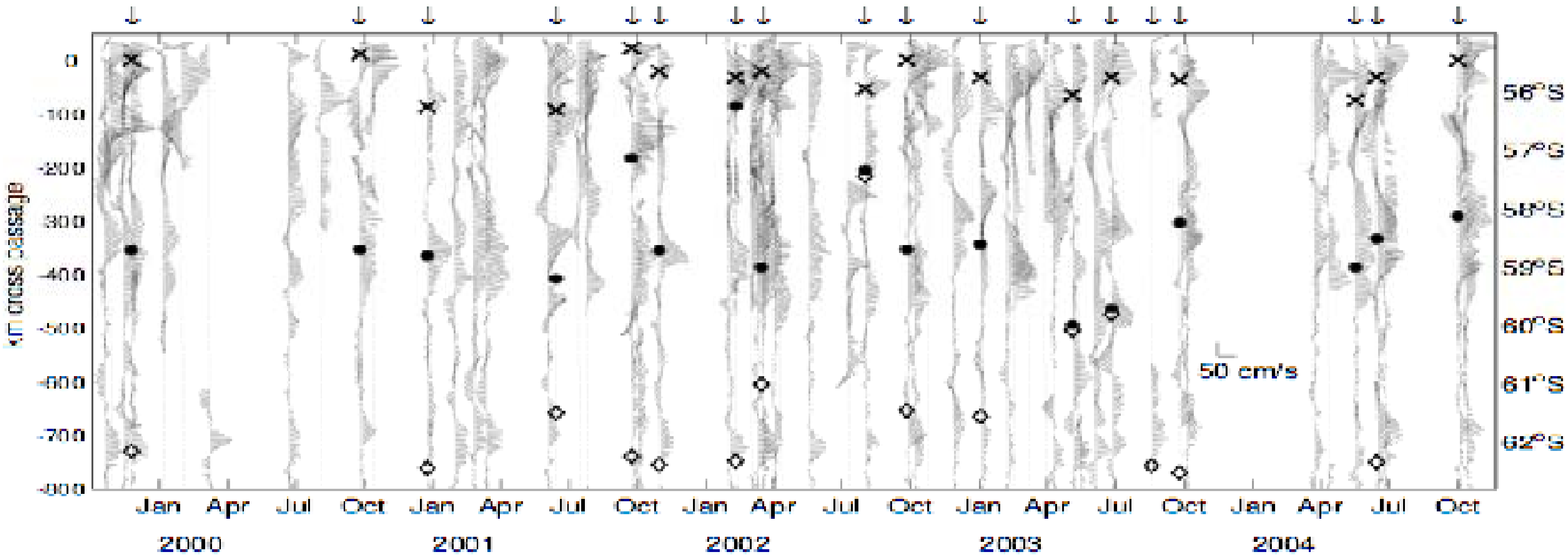
Antarctic Surface Water (AASW)

PF_{LAT} is northern extent of 2°C isotherm at 200 m depth

Are there long-term trends in PF and AASW properties?

Strong Velocity Jet at Polar Front

ADCP V_{150m}



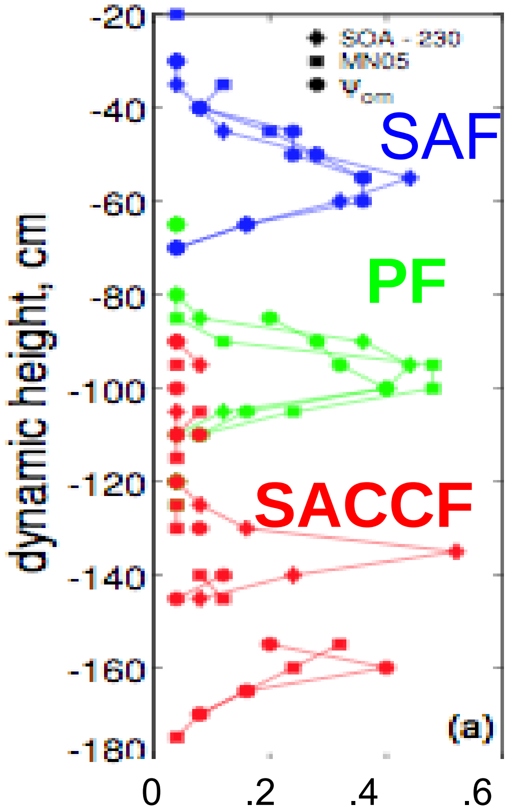
x XBT Subantarctic Front

• XBT Polar Front

◊ XBT Southern ACC Front

Lenn, Chereskin and Sprintall, *JMR*, 2007

Frontal Filaments Coalesce in Drake Passage



Multiple filaments of PF coalesce into single streamline in Drake Passage (strong f/h gradient)

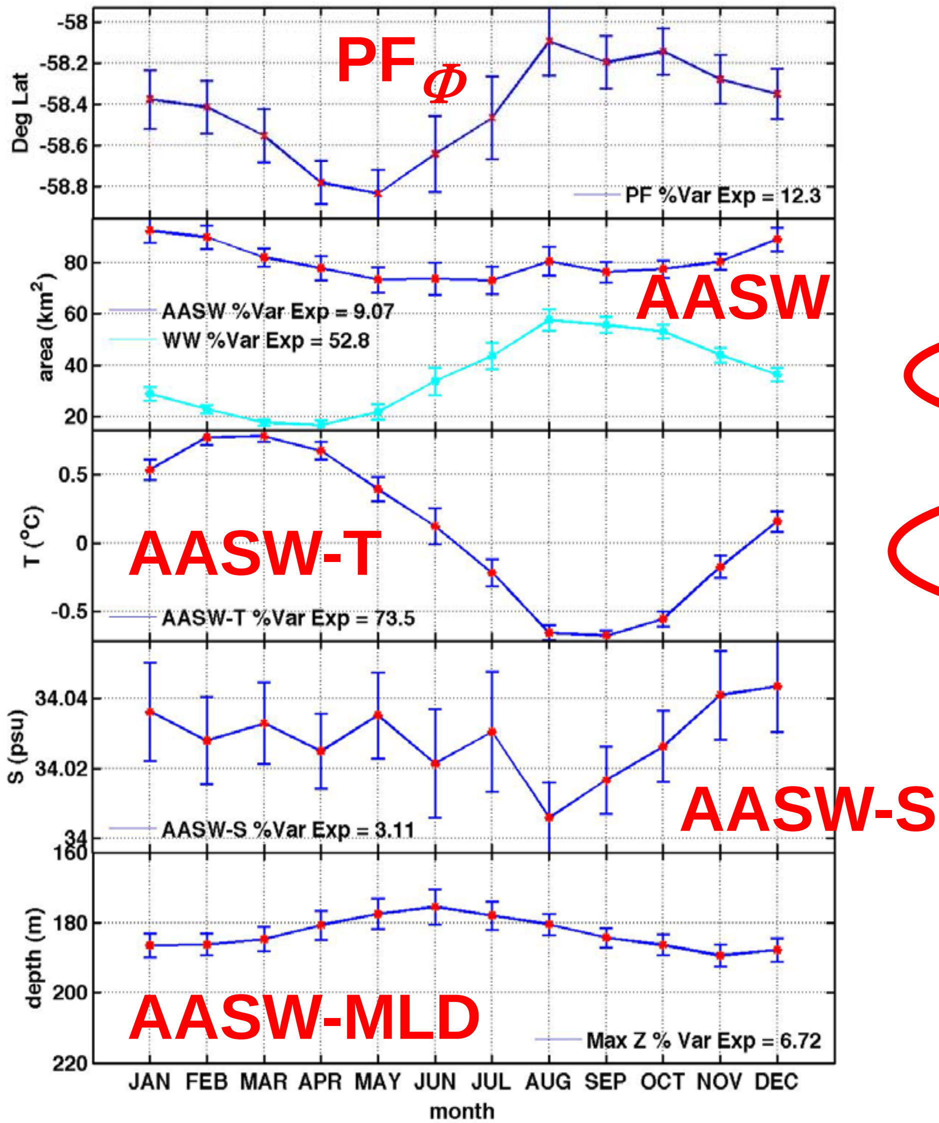
Mean and standard deviation of PF from AMSRE-E microwave SST
(Dong, Sprintall and Gille, JPO, 2006)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

PDF of instantaneous streamlines (SSH+mean streamfunction) at the XBT front positions in Drake Passage show narrow ranges in probability that XBT PF will fall within a dynamic height bin (5 cm)

Lenn, Y.D., T. Chereskin, and J. Sprintall, JPO, 2008

Anomalies: Removing the Seasonal Cycle

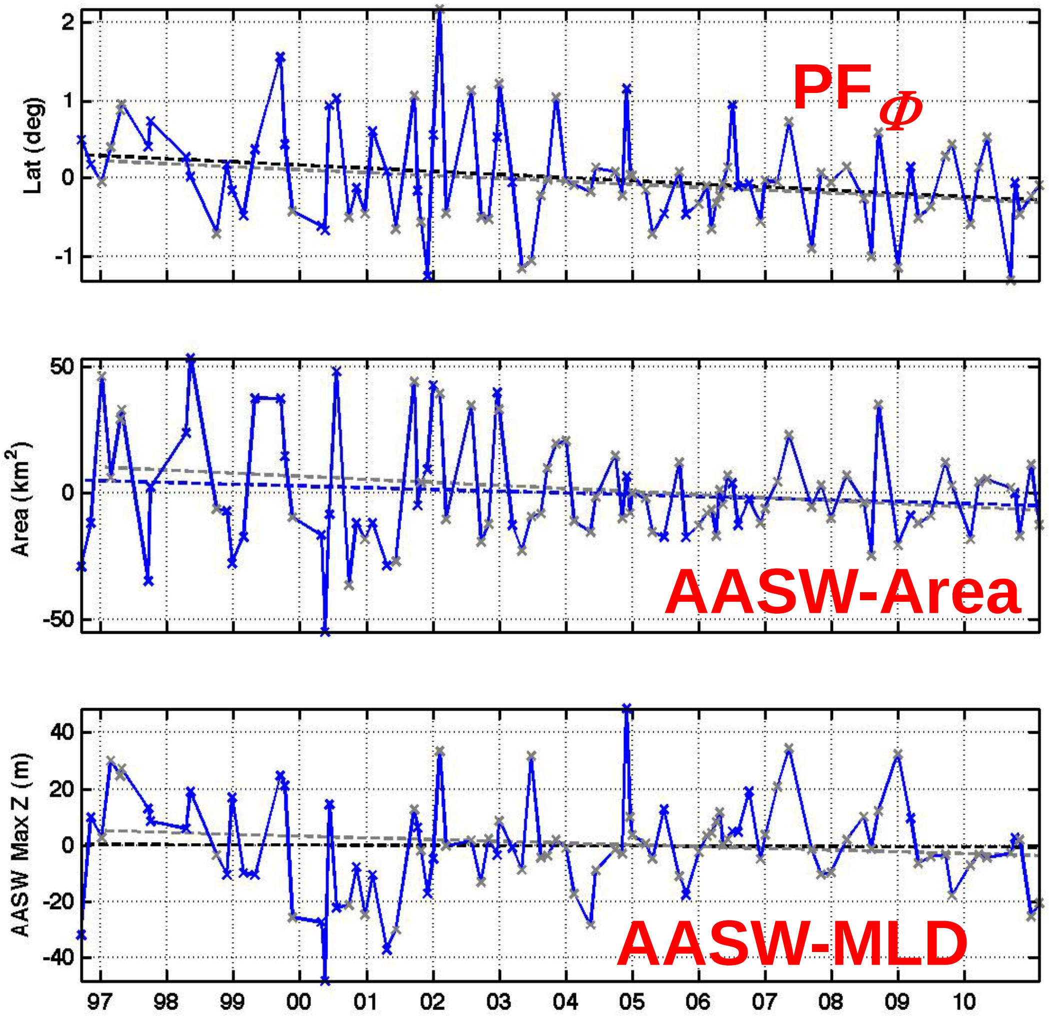


WW (53% var)

AASW-T (74% var)

PF and AASW Trends in Drake Passage

x Middle Transect



__Significant Trends:__

Poleward PF (~50 km)

Decreasing AASW (~20 km^2)

Shoaling AASW-MLD (~15 m)

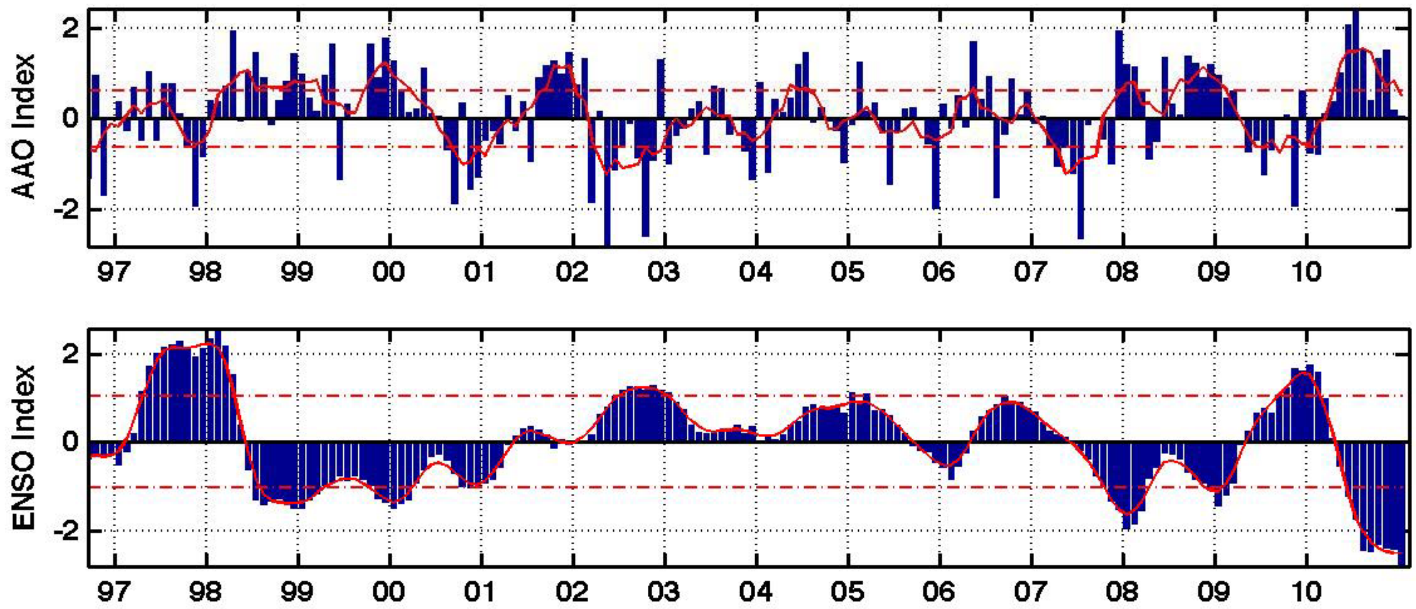
No significant trends:

AASW-temperature

AASW-salinity

How do SAM and ENSO phases impact the Polar Front and the Antarctic Surface Water properties in Drake Passage?

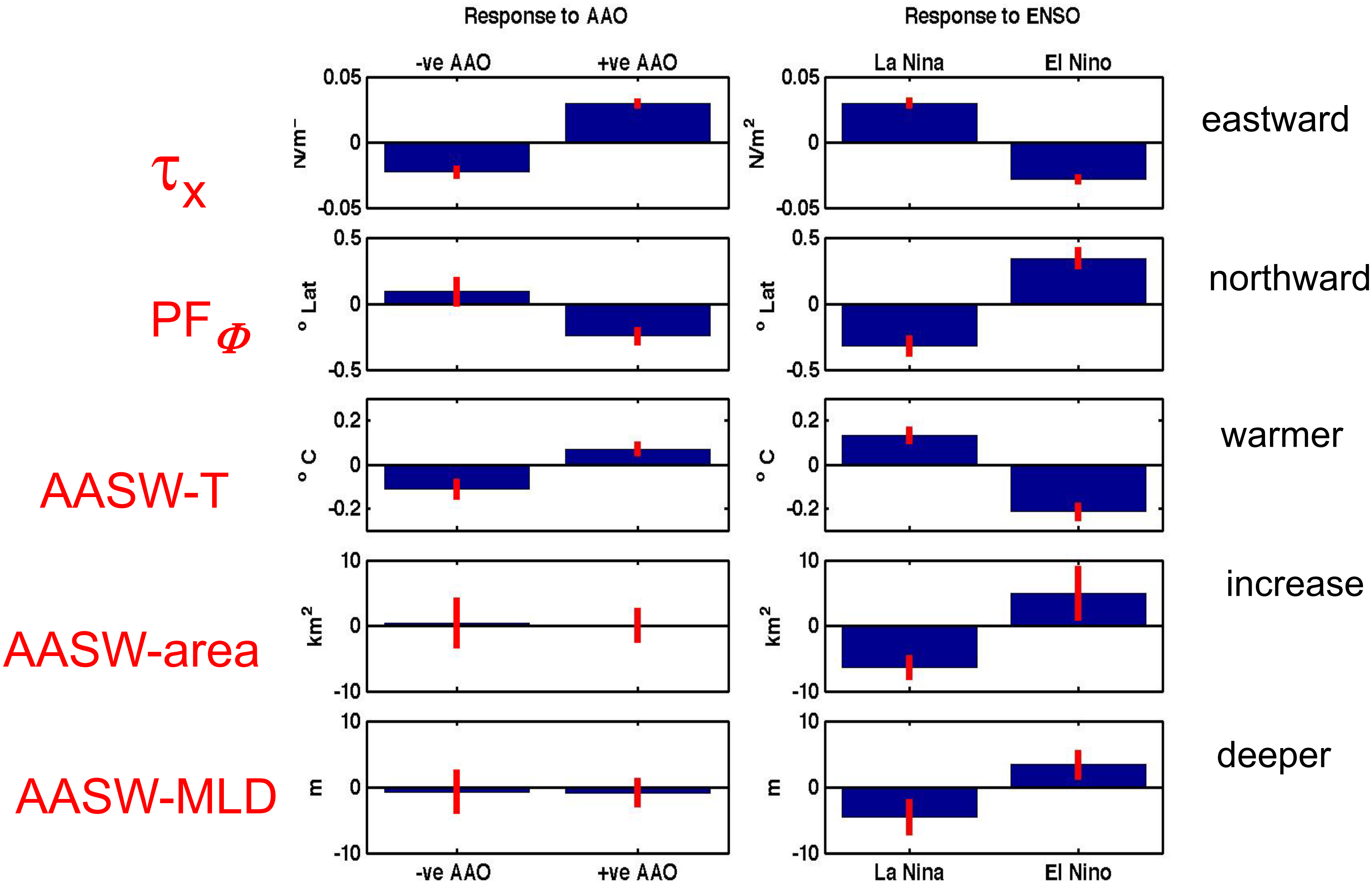
Forming Composites



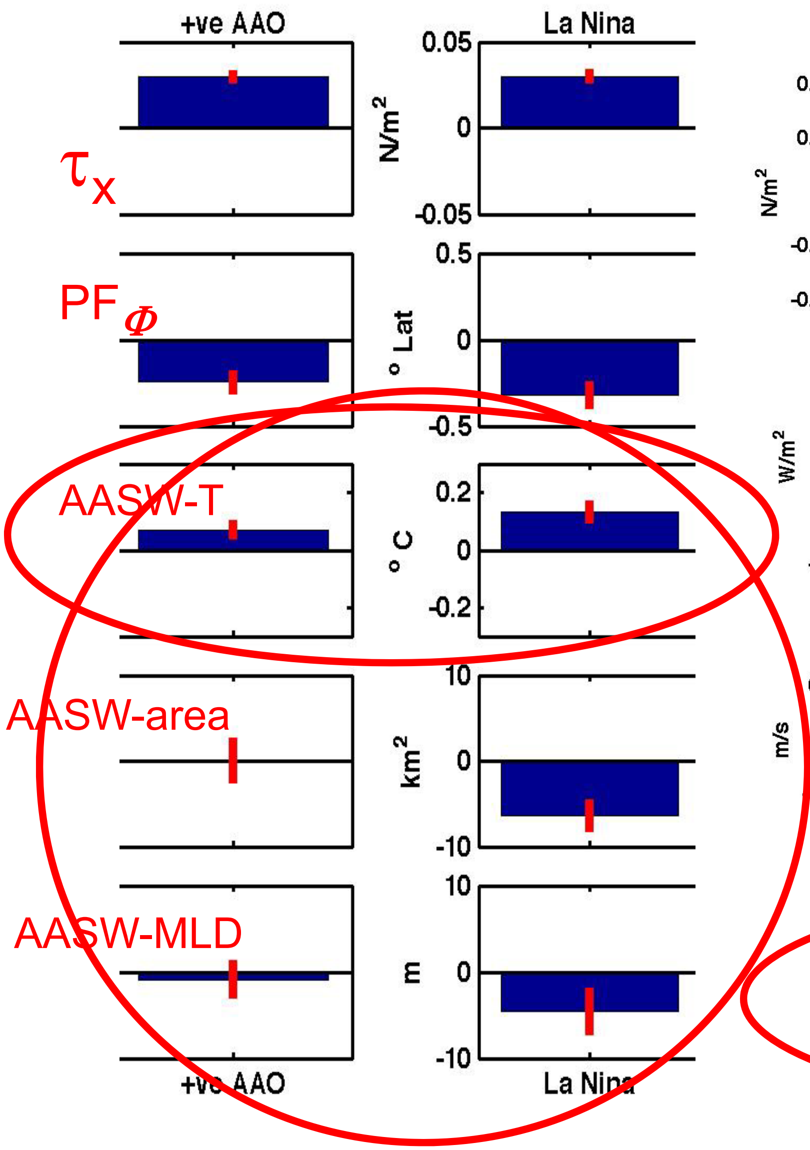
Form composites of PF and AASW properties (anomalies 3-month filtered) based on positive or negative values SAM and ENSO indices (>±1σ)

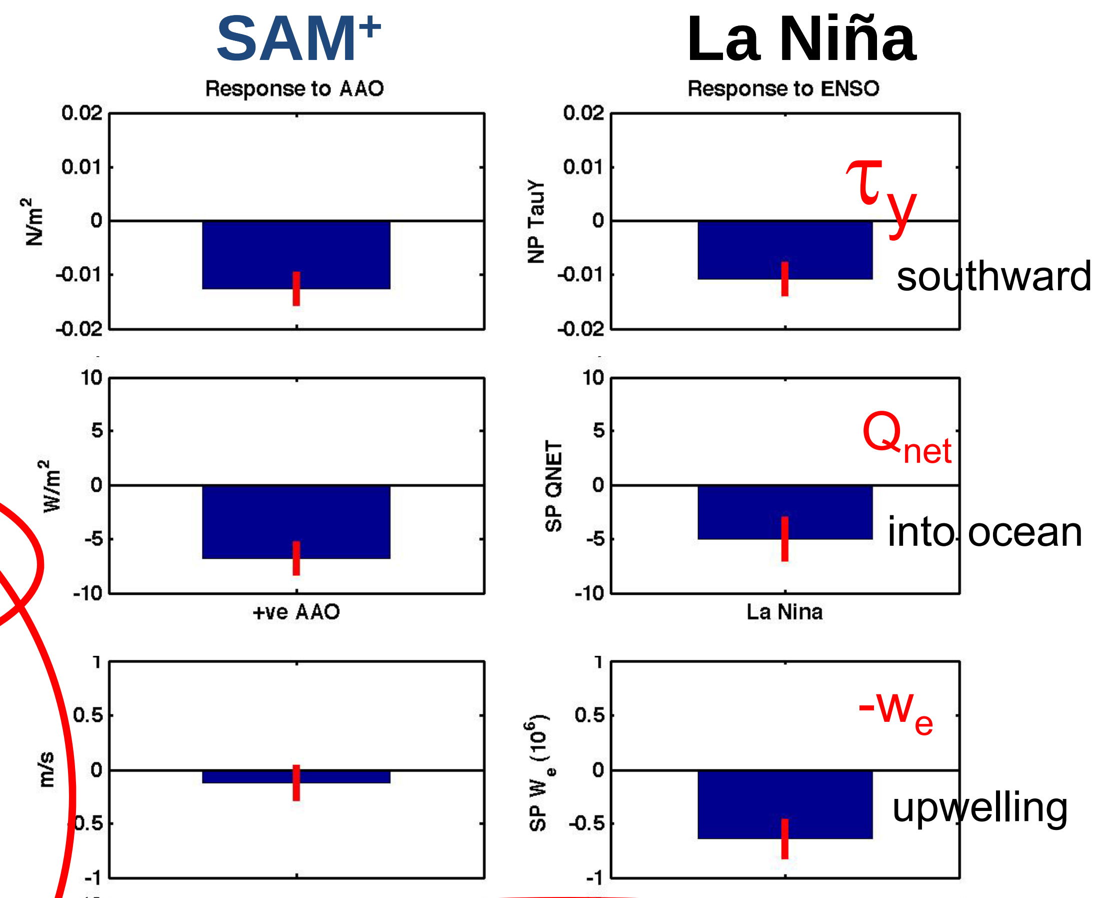
ENSO and SAM r = -0.45

Composite Relationships to ENSO and SAM



ENSO and SAM Forcing



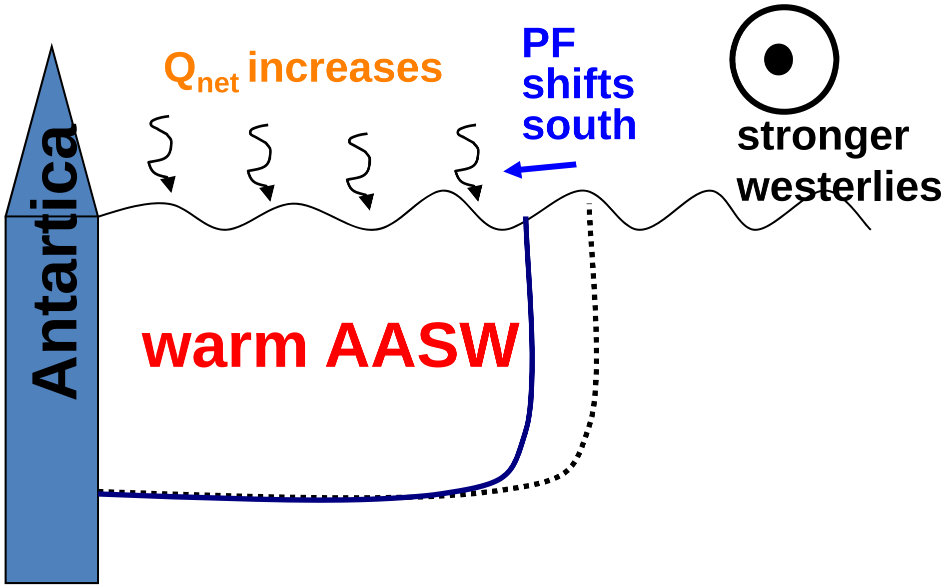


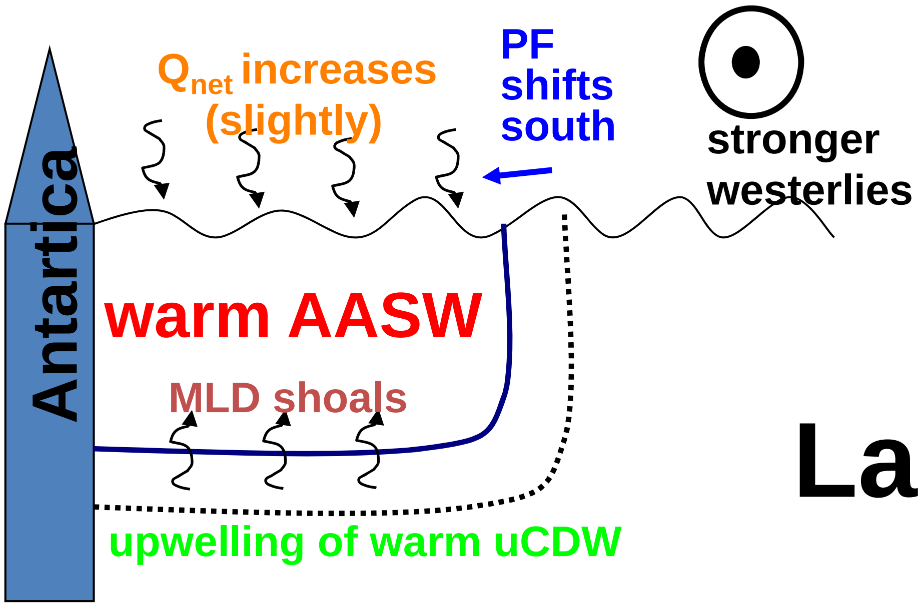
$$Q_{anom} = \rho_0 c_p h_{mld}\, \theta_{anom}\, \Delta t$$

$\sim$ *10 Wm^{-2} for* θ_{anom} of 0.1^{o}C

ENSO and SAM Forcing in Drake Passage

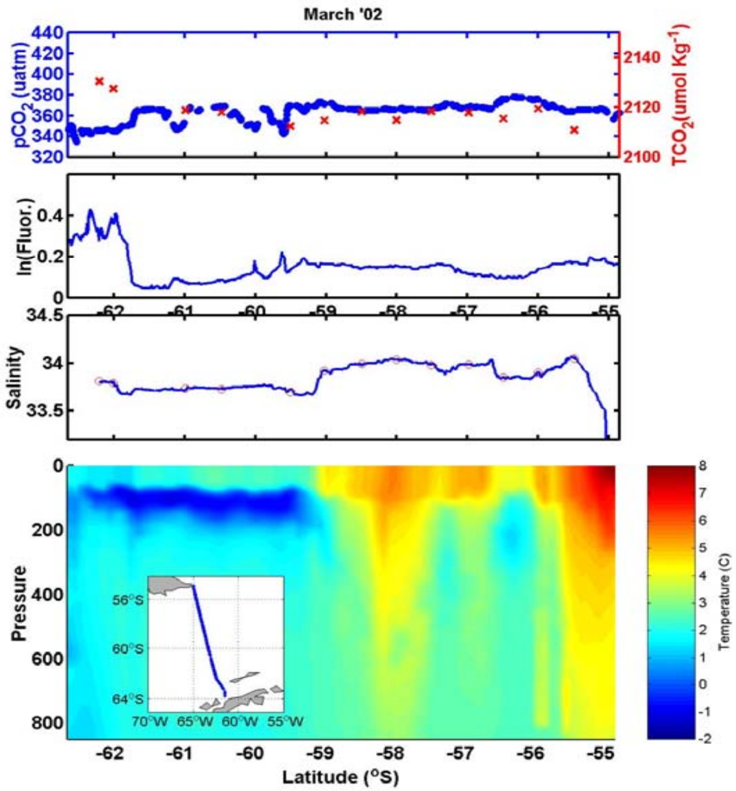
Positive SAM





La Niña

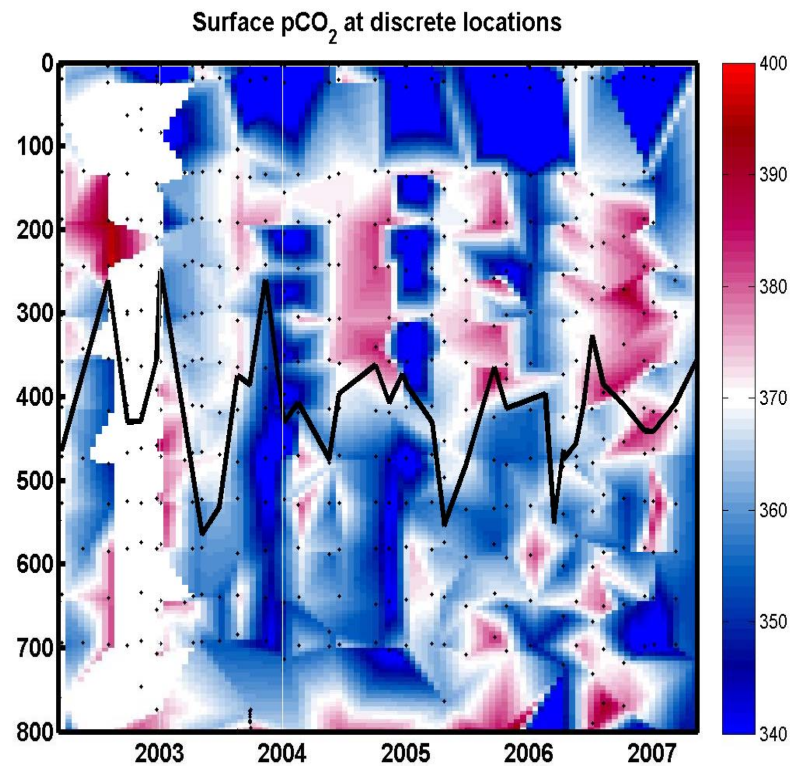
Climate Impact on S.O. Gas Uptake



<u>Surface pCO_2 Trends</u>

North of PF: high in winter -> cooler T

South of PF: vertical mixing and biological uptake more important



Increasing pCO2 trend from ⇑ winds?

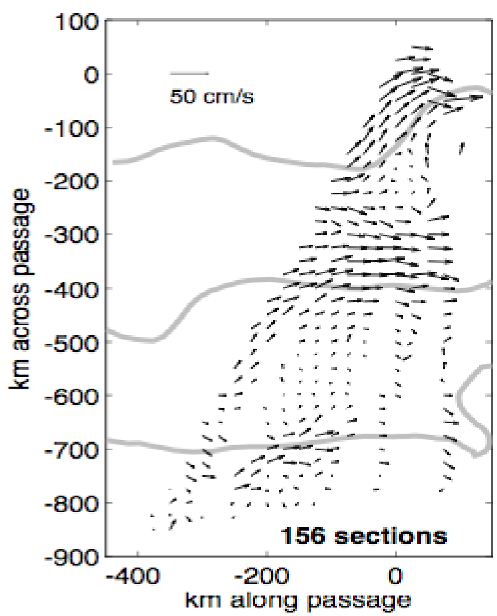
- increased upwelling south of PF?
- impact of a warming ocean?
- changes in upwelling area?

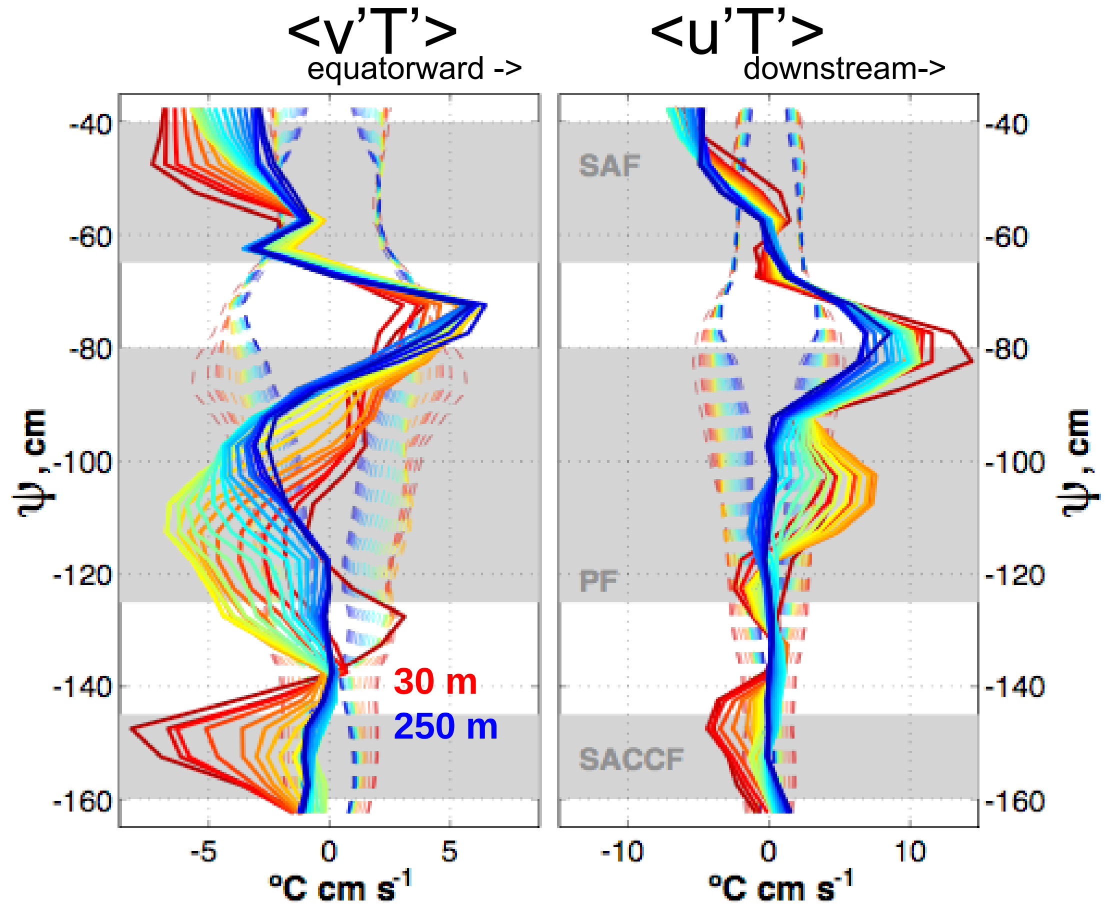
Evaluate the trends and mechanisms of pCO2 in IPCC AR5 Climate models

Colm Sweeny

Observed Eddy Heat Fluxes

- <v'T'> = <v(t)-<v>><T(t)-<T>> are small - need a good mean!
- mean ADCP V to map ACC streamlines; project V into stream coordinates and average fluxes along streamlines.
- 50 joint ADCP/XBT sections

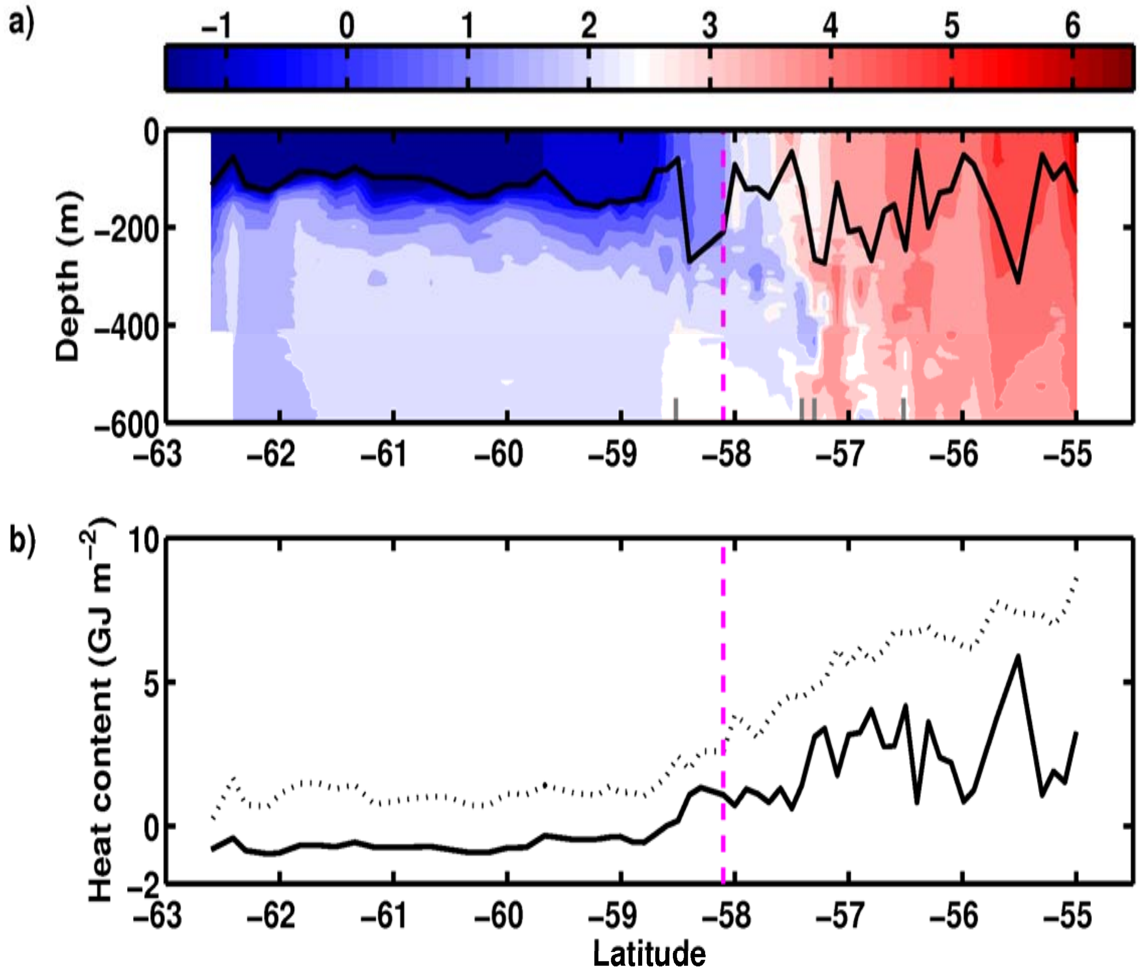




(Noisy!) eddy heat fluxes are polewards and downstream (where significant), typically near the mean front positions

Lenn, Chereskin, Sprintall, and McClean., *JPO,* 2011

MLD as proxy for upper ocean air-sea heat exchange?



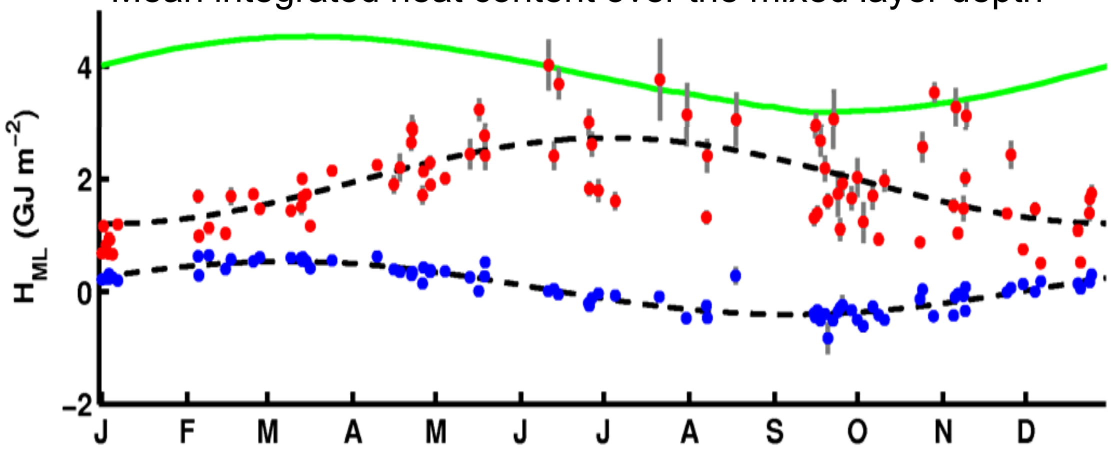
- MLD (solid) shows great cast-to-cast small-scale variability, particularly north of the **Polar Front**.

- Upper-ocean heat content (dashed) is a more robust measure

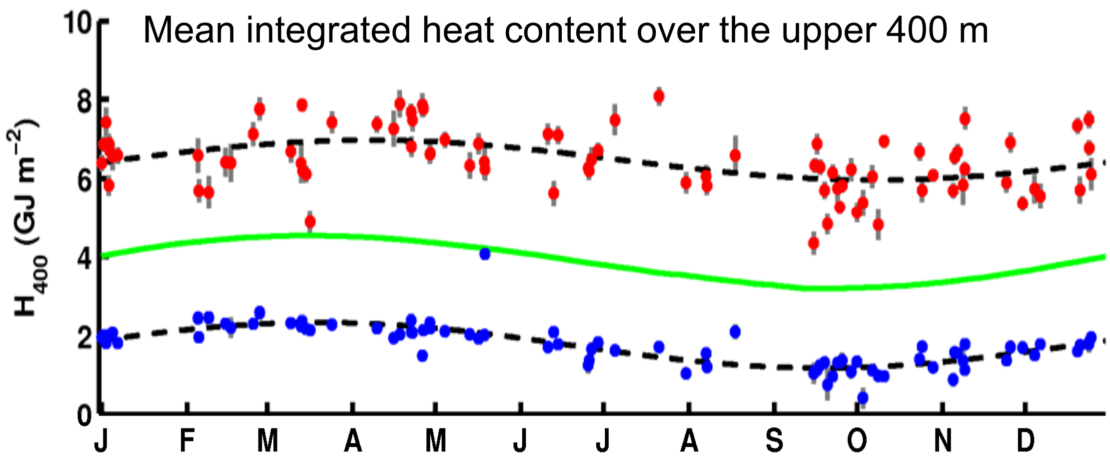
Stephenson, Gille and Sprintall, in prep., 2011

MLD as proxy for upper ocean air-sea heat exchange?

Mean integrated heat content over the mixed layer depth



Mean integrated heat content over the upper 400 m

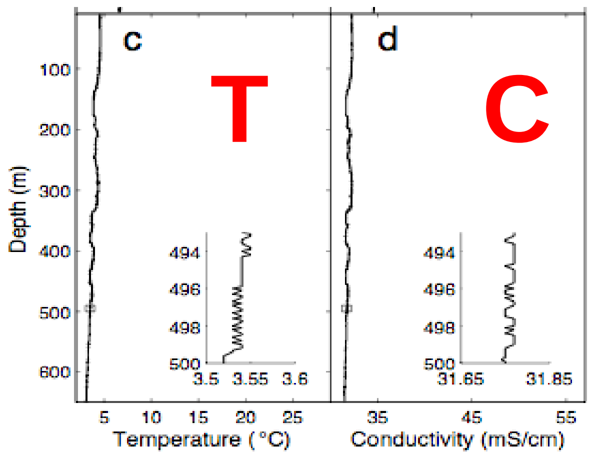


Mean integrated heat content **over the mixed layer depth** (top) and **upper 400 m** (bottom) for casts **north** and **south** of the **Polar Front.** (Least-squares fit to seasonal cycle)

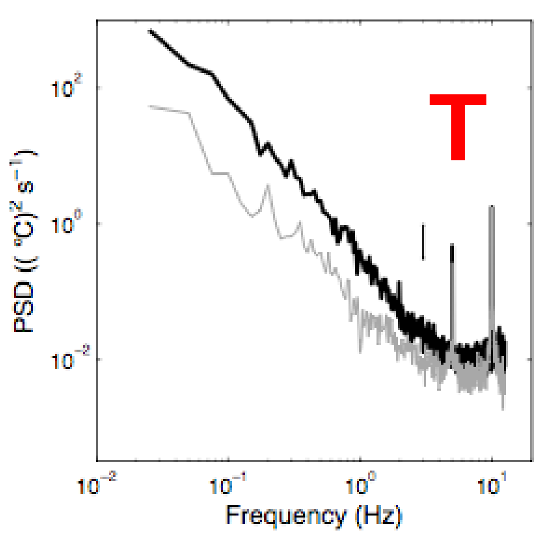
OAFlux Surface Heat Flux annual cycle (offset by 4 GJ m^{-2}) shows **better agreement with integrated heat content**.

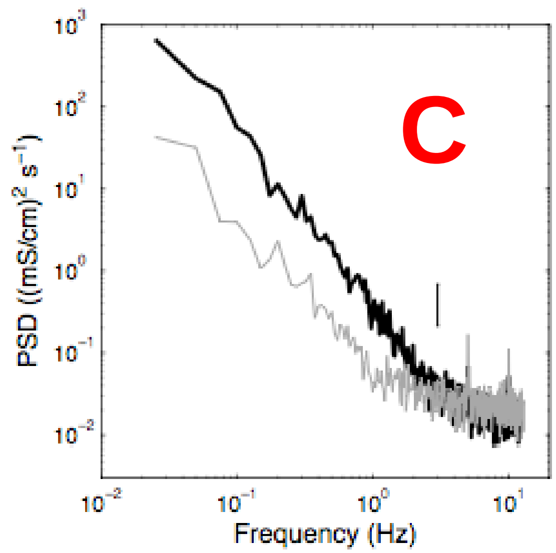
Stephenson, Gille and Sprintall, in prep., 2011

Quality Control for XCTD Profiles



•"Jitters" in T (~0.01°C) and conductivity (~0.015 mS cm^{-1}) of XCTD profiles (left) results in significant spikes in their spectra at 10 hZ and 5 hZ (below).
• Inherent to all XCTD probes (originate from digital noise cross-over to analog electronics) although most obvious in regions of low stratification.
• T and S still within manufacturer's specification
• Application of low-pass filter (Gille et al., 2009)





Gille, Lombrozo, Sprintall and Stephenson, JAOT, 2009

Patterns of Small Scale Mixing

XCTDs: diapycnal diffusivity

North: thermohaline intrusions, eddies, near-inertial internal waves

South: weakly stratified; double-diffusive convection

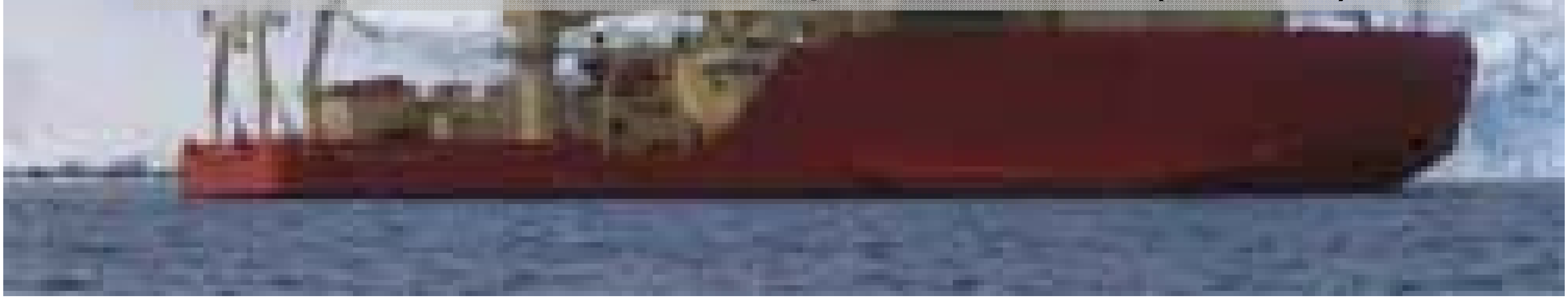
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Distinctly different patterns in winter and summer; and north and south of PF

Thompson, Gille, MacKinnon, Sprintall, JPO, 2007

Conclusions

- AX22 is a unique Southern Ocean time series: near-repeat transects; year-round
- Synergistic measurements (e.g. v'T'; pCO_2-T)
- Different variability patterns dependent on PF (e.g. κ_ρ, pCO_2 & TCO_2, MLD)
- 15-year time series to examine property changes in response to large scale climate modes (e.g. PF, AASW, pCO_2)
- 4 PhD theses and >20 publications (so far!)

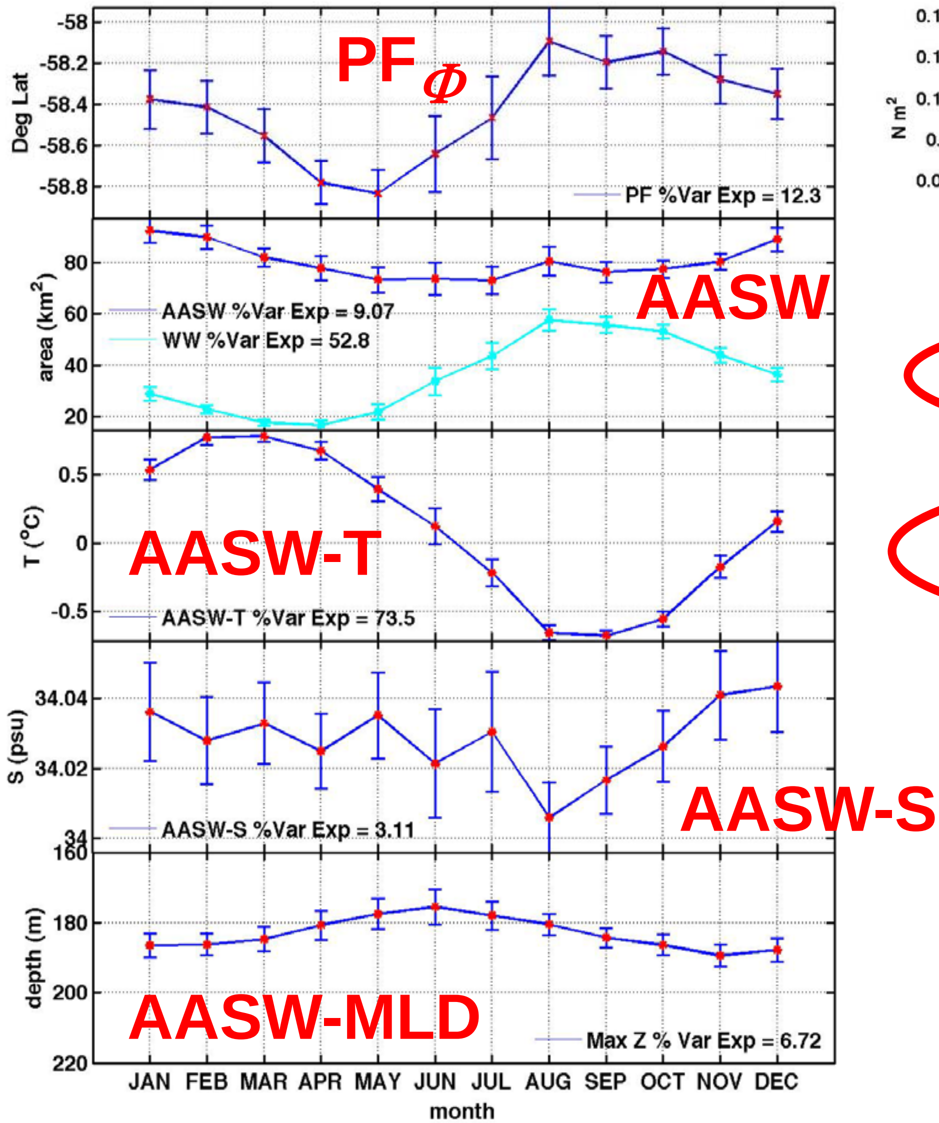


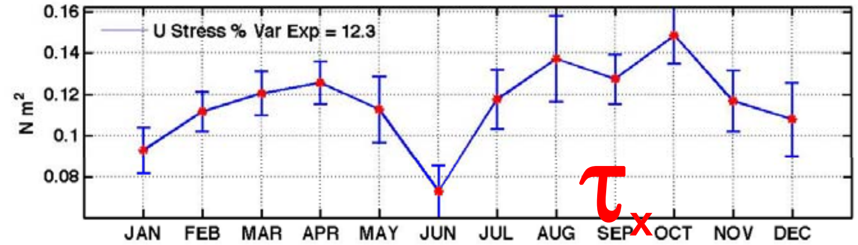
Conclusions

The HRX network’s unique contribution is in providing regularly repeating temperature, geostrophic velocity and transport estimates that span ocean basins from boundary to boundary

The HRX network increases the value of the combined observing system (Argo, air-sea fluxes, repeat hydrography, ADCP, pCO_2 etc.): complements these observing systems by supplying repeat, high resolution measurements in boundary currents, eddies and fronts

Anomalies: Removing the Seasonal Cycle

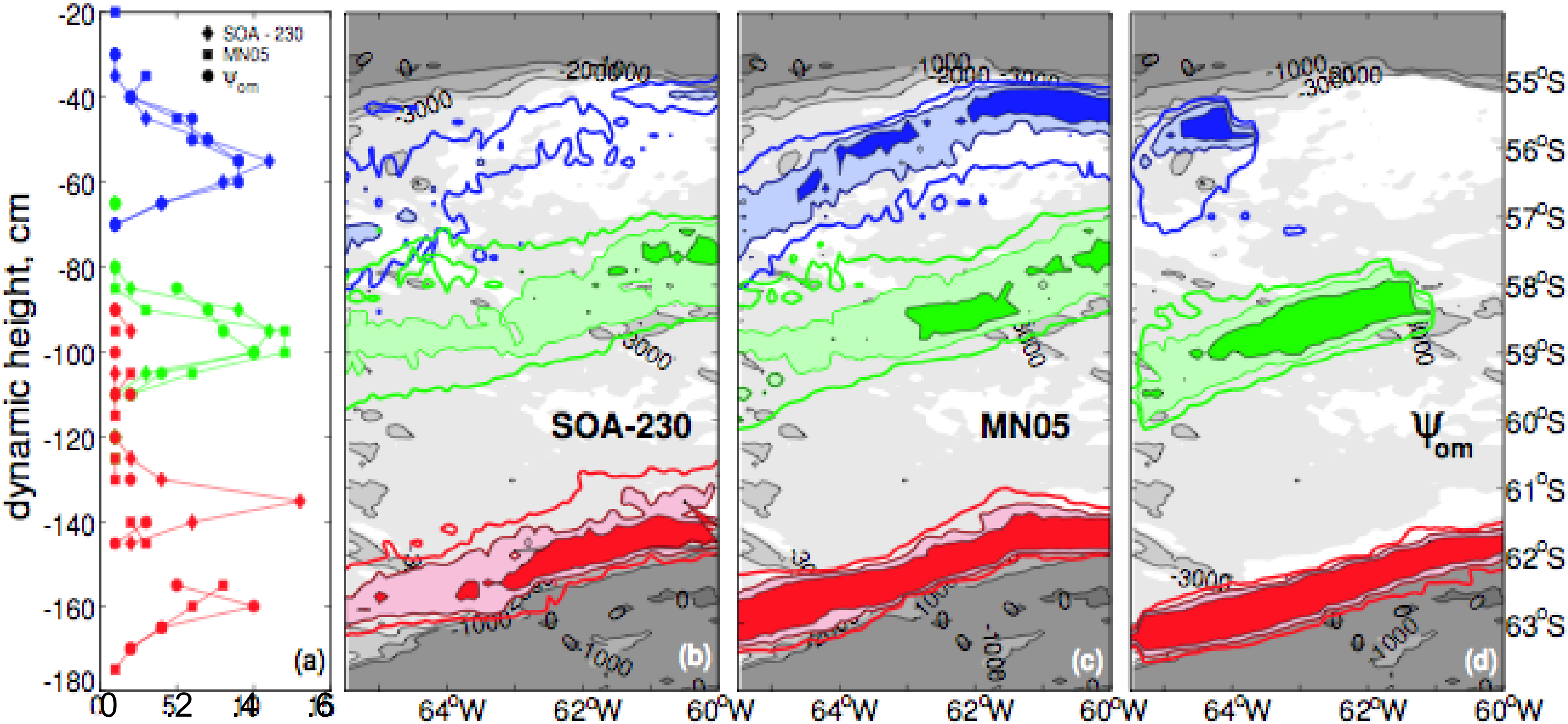




WW (53% var)

AASW-T (74% var)

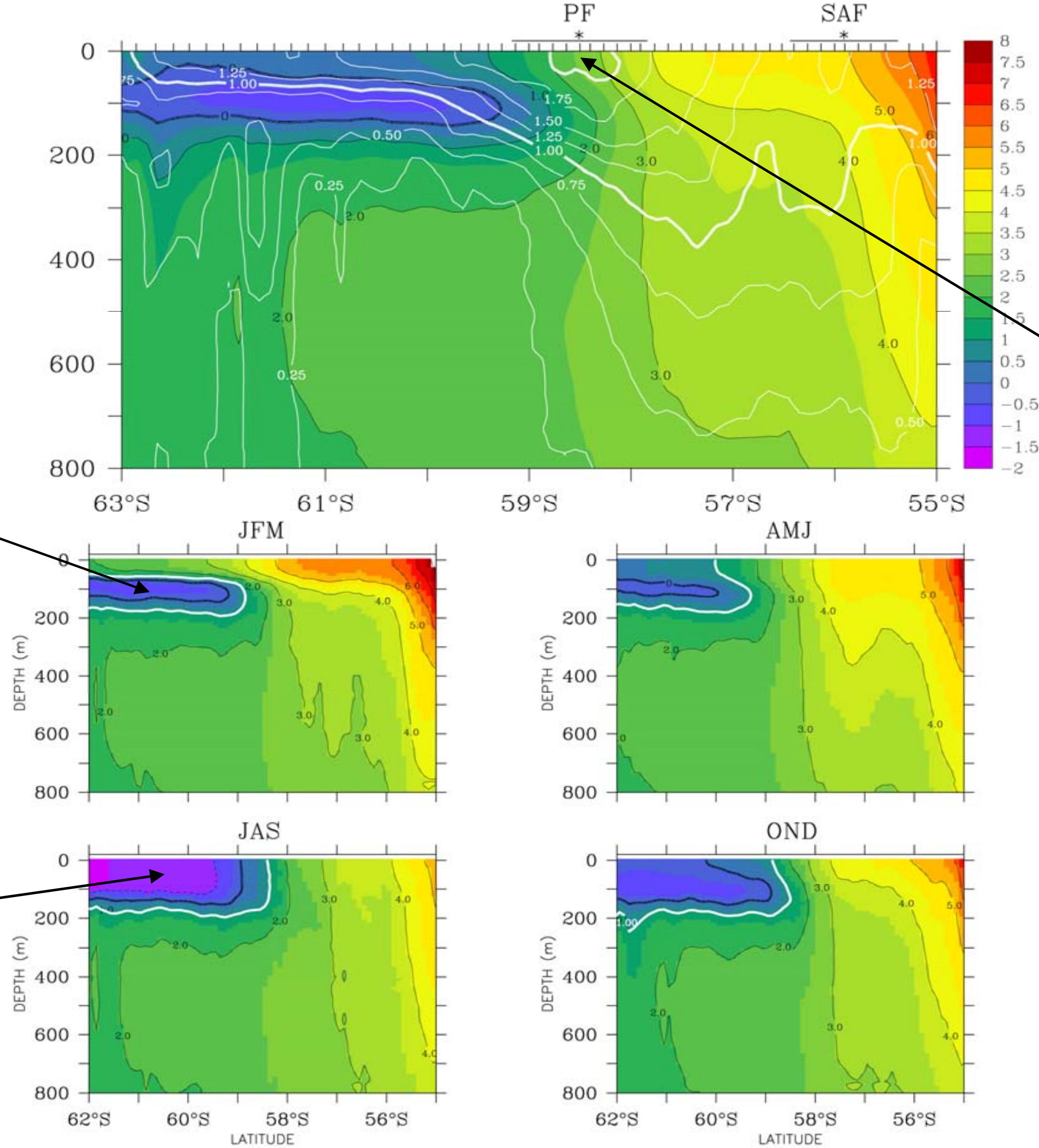
Frontal Variability from Streamlines



- PDF of instantaneous streamlines (SSH and various mean streamfunctions) at the XBT positions of the main fronts in Drake Passage
- narrow ranges
- Multiple filaments of PF (e.g. Sokolov and Rintoul, 2009) coalesce into single streamline in Drake Passage

Lenn, Y.D., T. Chereskin, and J. Sprintall, JPO, 2008

Mean Temperature Transect



High resolution of Polar Front (PF)

Winter Water (WW)

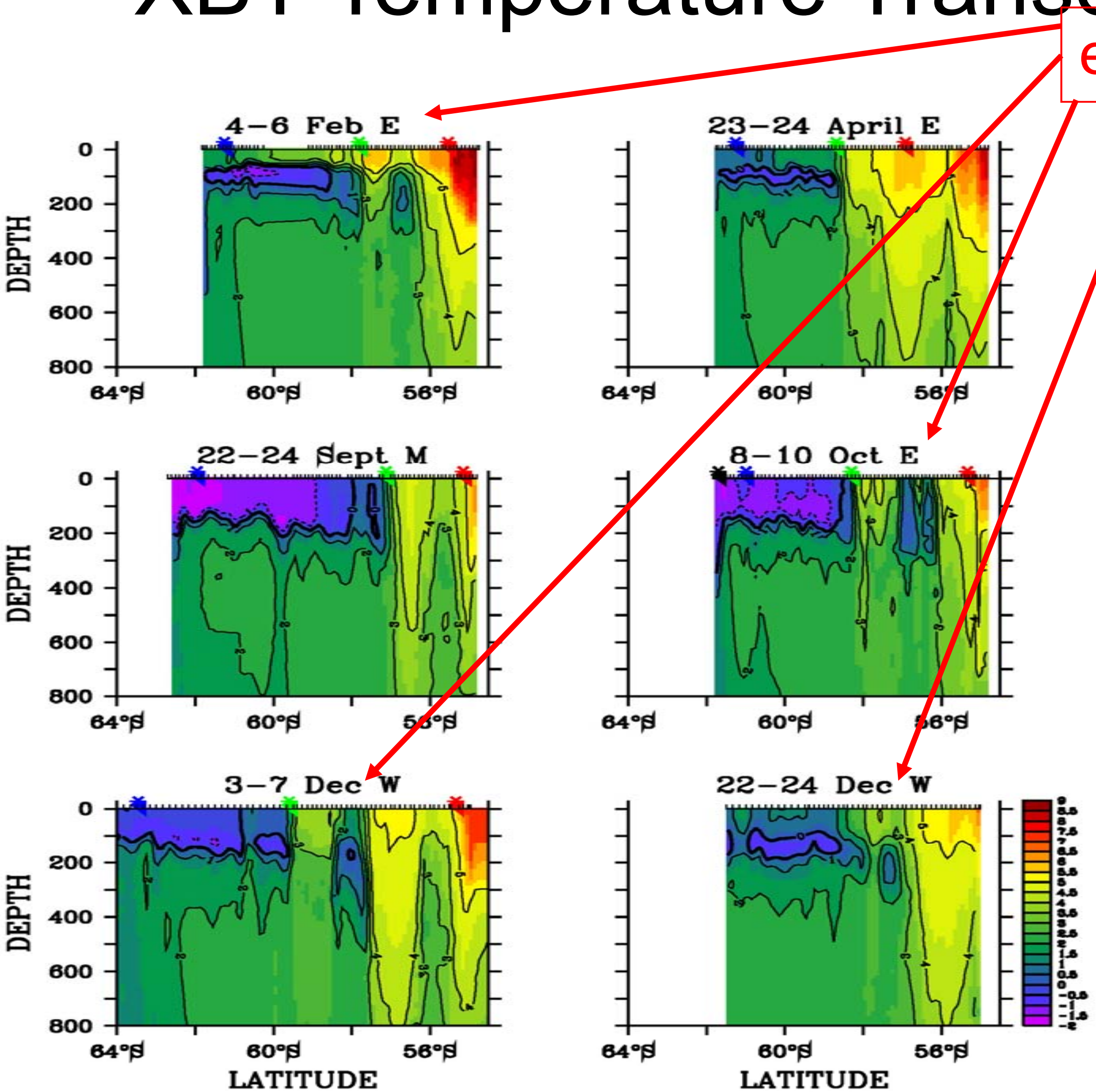
Antarctic Surface Water (AASW)

PF_{LAT} is northern extent of 2°C isotherm at 200 m depth

PF associated with velocity jet

(Lenn et al., 2007)

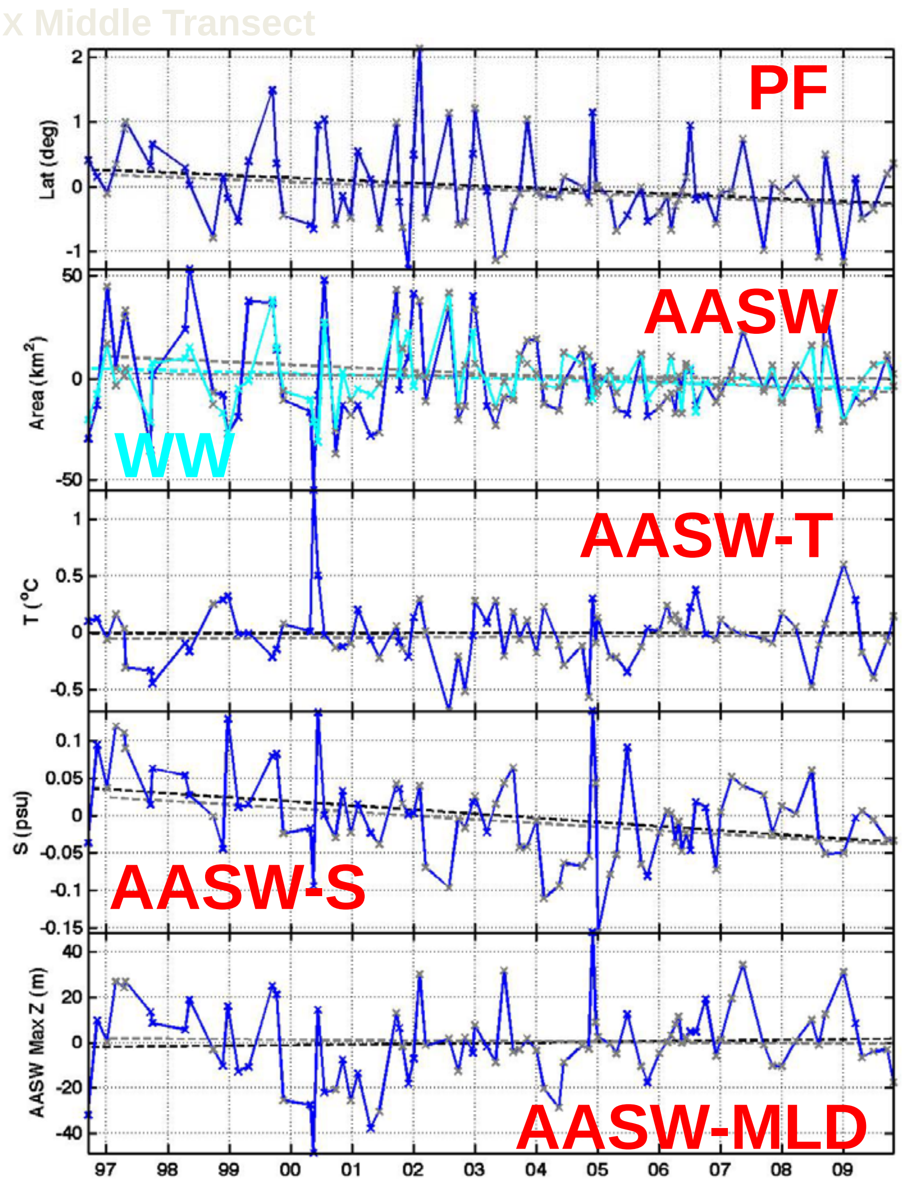
XBT Temperature Transects: 2001



High resolution of the Polar Front

Sprintall, *J. Mar. Res.*, *61*, 2003.

PF and AASW Trends in Drake Passage



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