Understanding Climate Related Process in the Southwestern Atlantic Ocean

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- Mesoscale eddies in the SWA Ocean (CIMA, LOCEAN)
- Monitoring the cold route in the SWA Ocean (<u>LOCEAN</u>, SHN)
- Monitoring the ACC transport through Drake Passage (<u>LOCEAN</u>, SHN, CIMA)

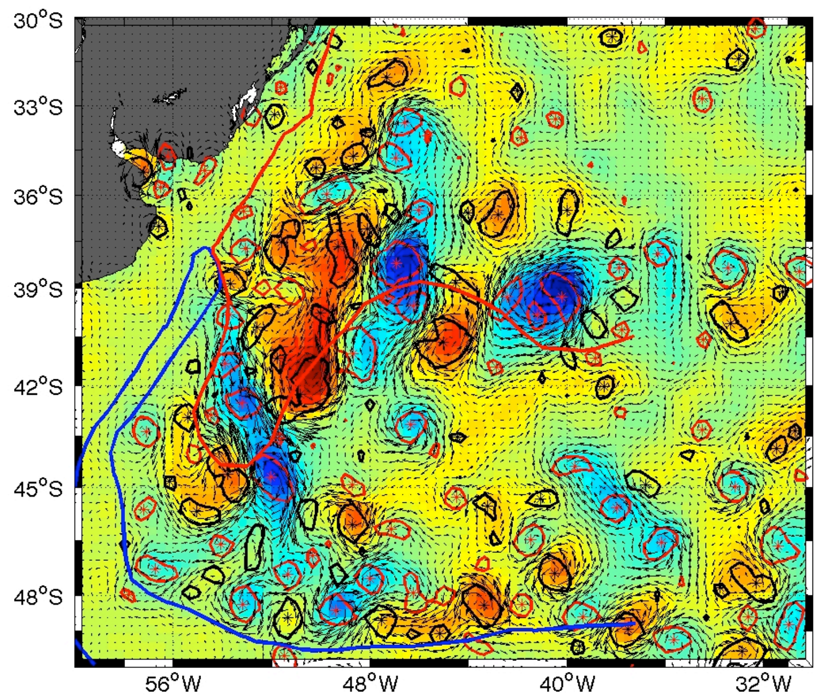
Mesoscale eddies in the Southwestern Atlantic Ocean

Martín Saraceno and Christine Provost

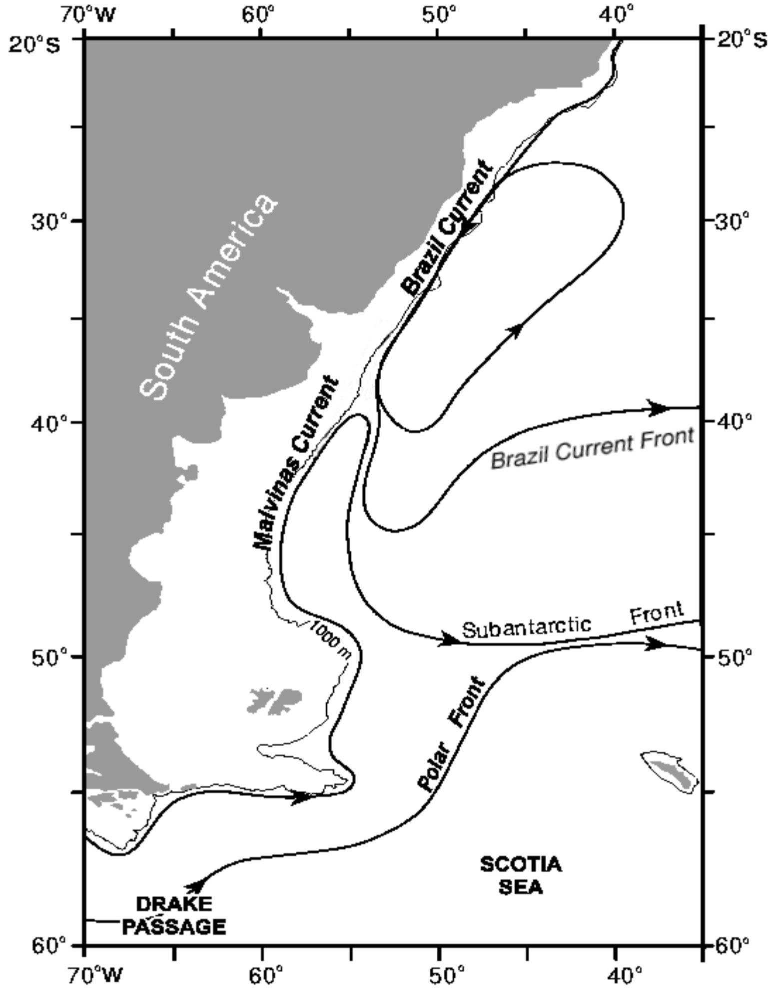
With contributions from N. Barré (LOCEAN, France) and
U. Zajaczkovski (UCSD, USA)

Objectives:

To study the relationship between eddies distribution and main flow in the Southwestern Atlantic

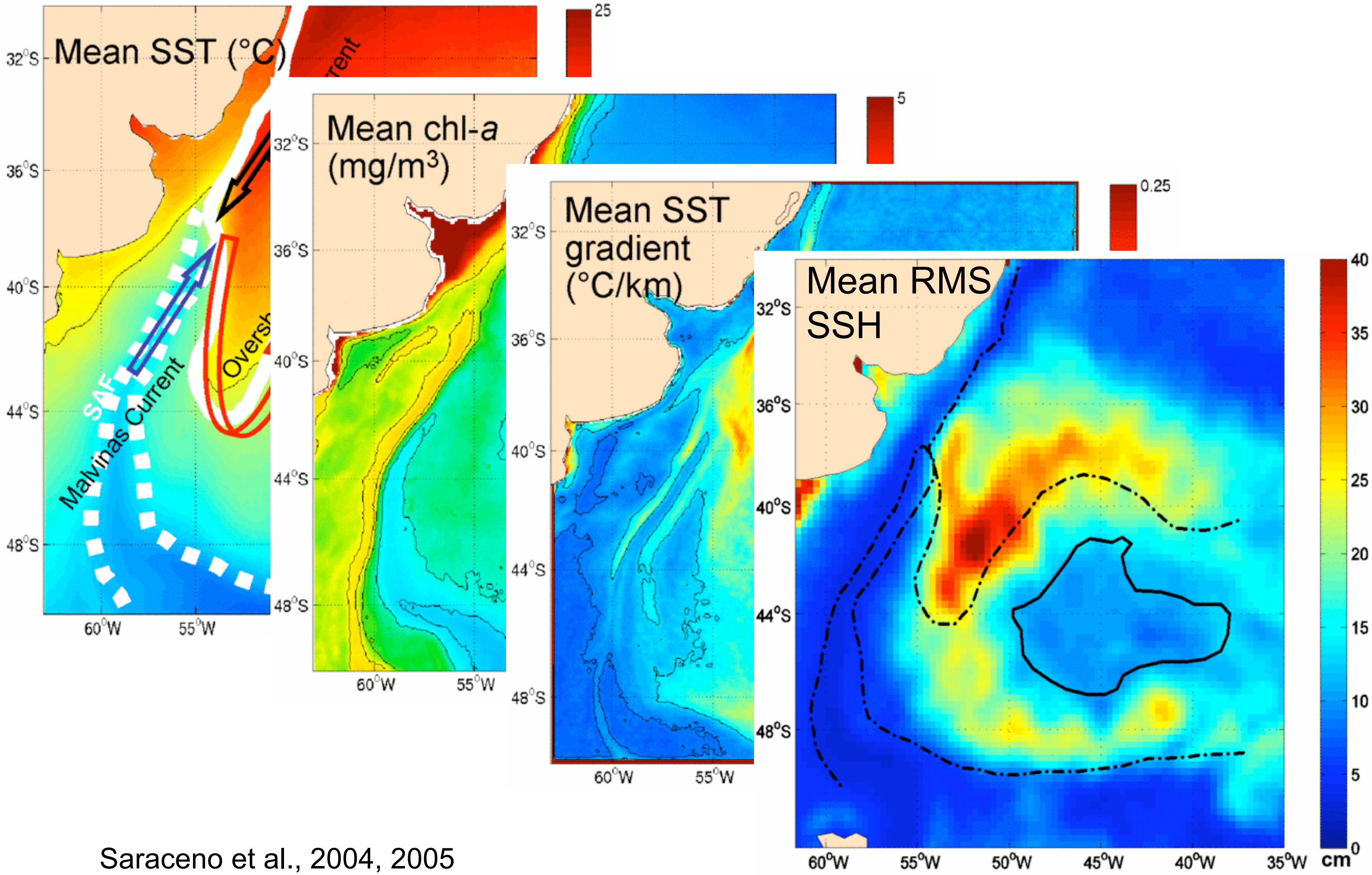


The Southwestern Atlantic region



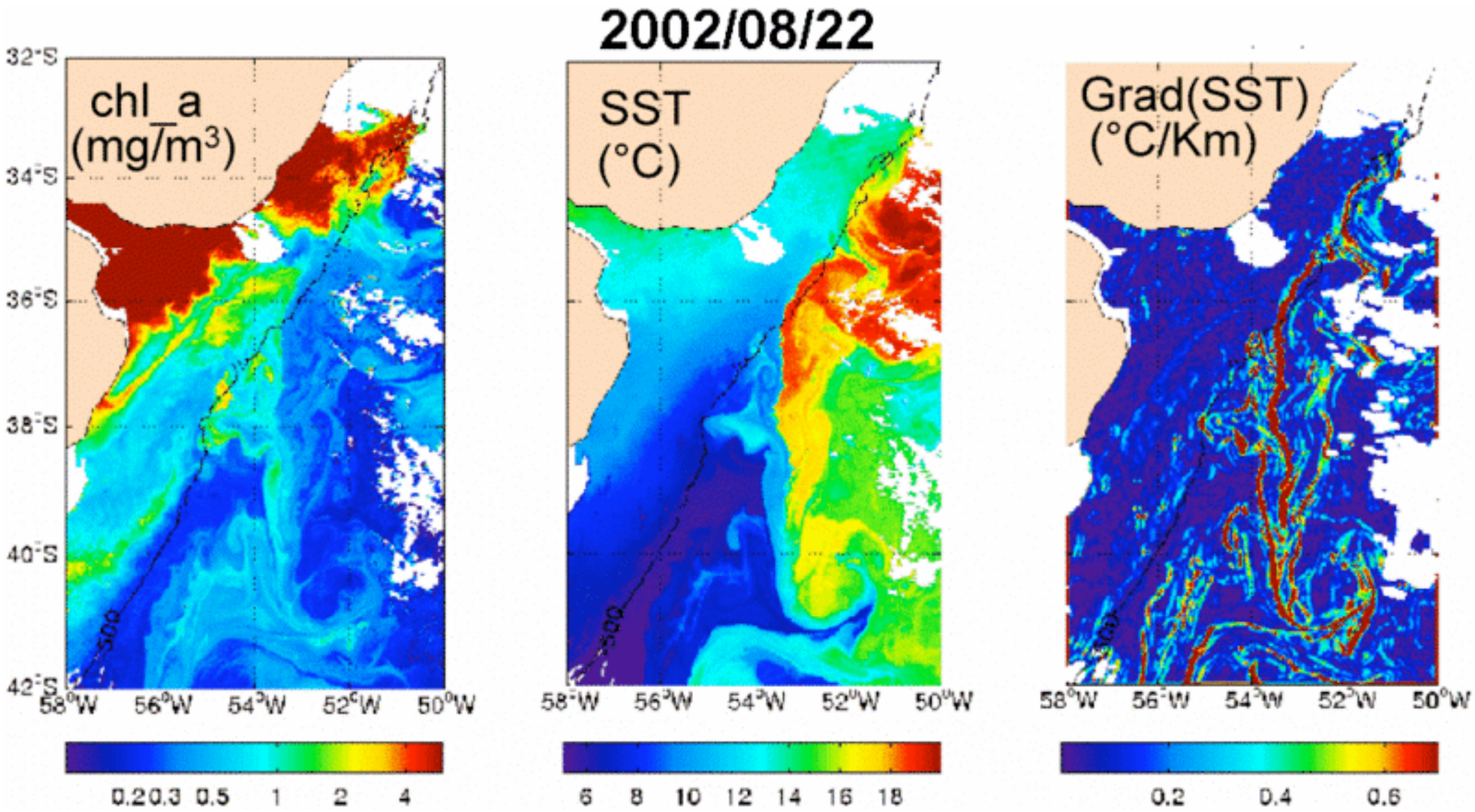
The cold and low-salinity waters transported poleward by the Malvinas Current encounter the warm and salty subtropical waters transported by the Brazil Current at about 38°S.

Mean fields of several variables reveal clear patterns in the SWA:

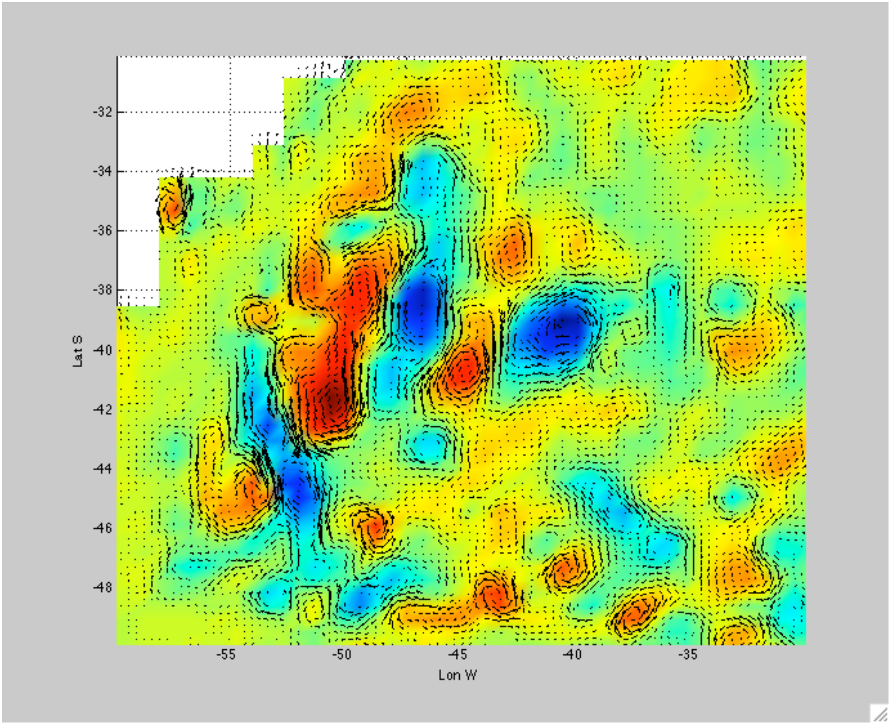


Saraceno et al., 2004, 2005

Mean fields are very different from instantaneous fields:

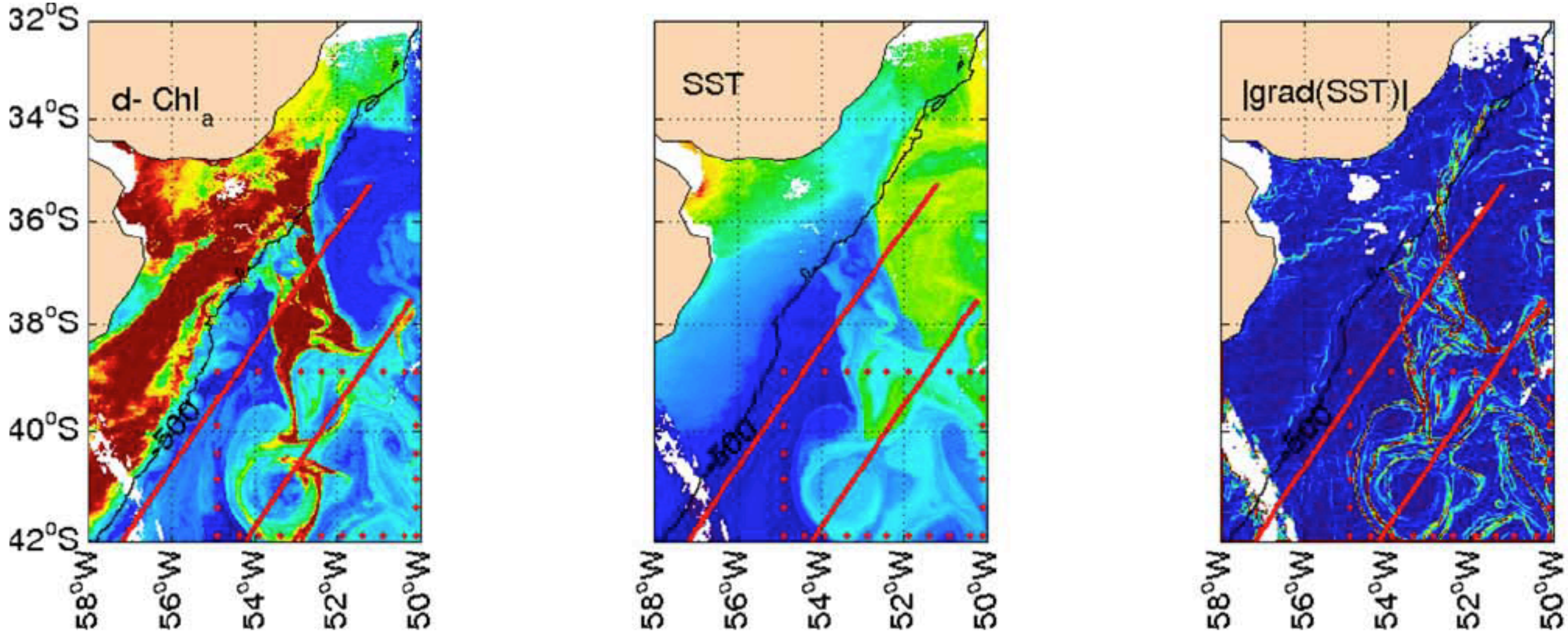


Satellite radar altimetry data do not provide instantaneous maps of SSH but do reveal mesoscale eddies – and without clouds



SSH map representative of a seven day period obtained from the interpolation in space and time of 4 different missions (Jason 1, ERS, GFO and T/P). Black vectors represent geostrophic velocities.

Eddies play a crucial role in the region:

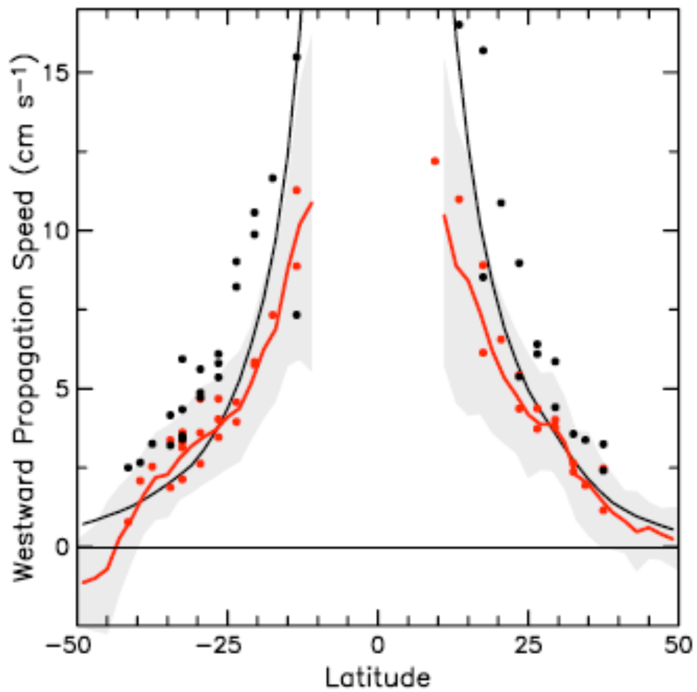


[Barré et al., 2006]

- Eddies can transport momentum, heat, potential vorticity but also nutrients, chlorophyll and zooplankton
- Eddies thus have a direct implication for the role of the oceans in the global heat balance.

Much of the mesoscale variability outside of the tropics consists of nonlinear eddies.

- Far from the equatorial band (+-20º), the largest portion of the mesoscale variability observed is due to nonlinear interaction of eddies, not to Rossby waves.



- nondispersive baroclinic Rossby waves

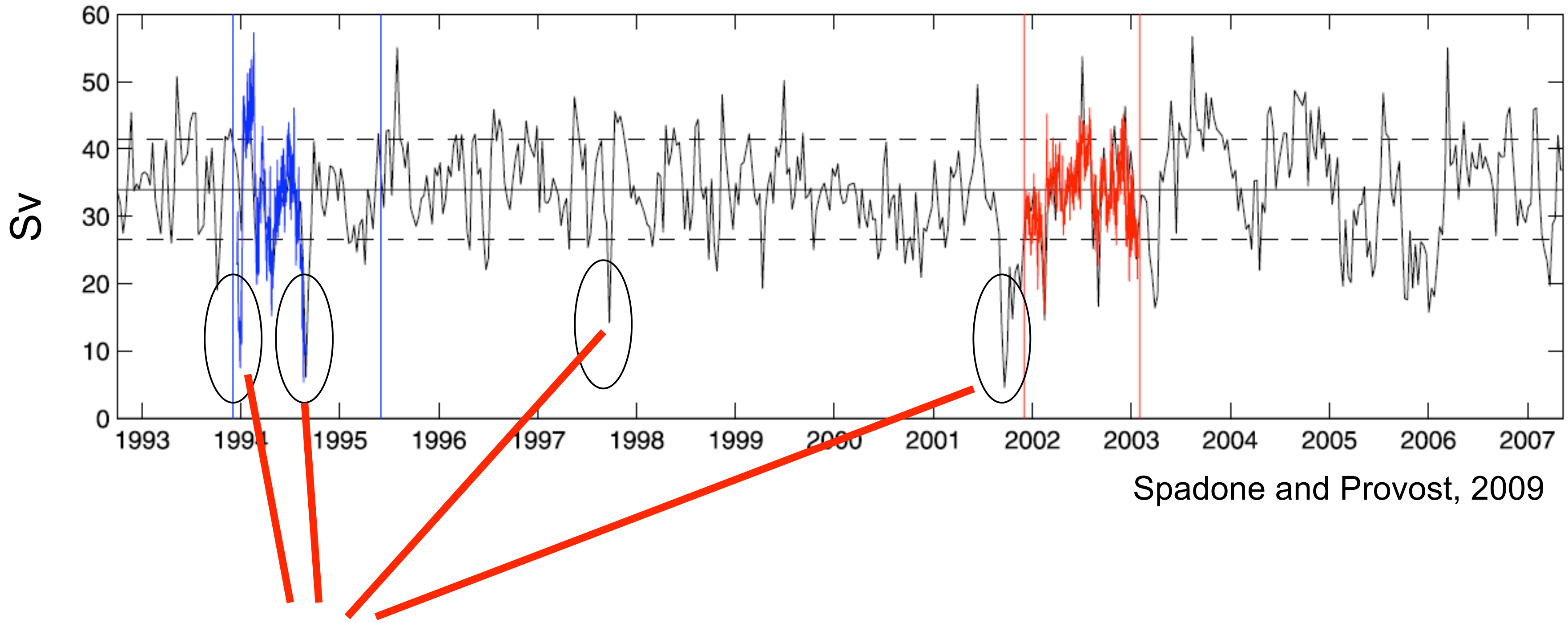
• large-scale, long-lived eddies

• short-scale, long-lived eddies

[Chelton et al., 2007]

Eddies interact with the Malvinas Current

Malvinas Current transport at 41°S from altimetry (black line) and in-situ data (red and blue):



Spadone and Provost, 2009

SSH clearly shows eddies blocking the MC (Spadone and Provost, 2009; Saraceno et al, 2008)

Methodology used: Okubo-Weiss algorithm

(i) Geostrophic velocities & derivatives:

$$U' = -\frac{g}{f}\frac{\partial(SLA)}{\partial y},$$
$$V' = \frac{g}{f}\frac{\partial(SLA)}{\partial x},$$

$$g_{11} = \frac{\partial U'}{\partial x}; \quad g_{12} = \frac{\partial U'}{\partial y}; \quad g_{21} = \frac{\partial V'}{\partial x}; \quad g_{22} = \frac{\partial V'}{\partial y}.$$

(ii) The following parameters are estimated

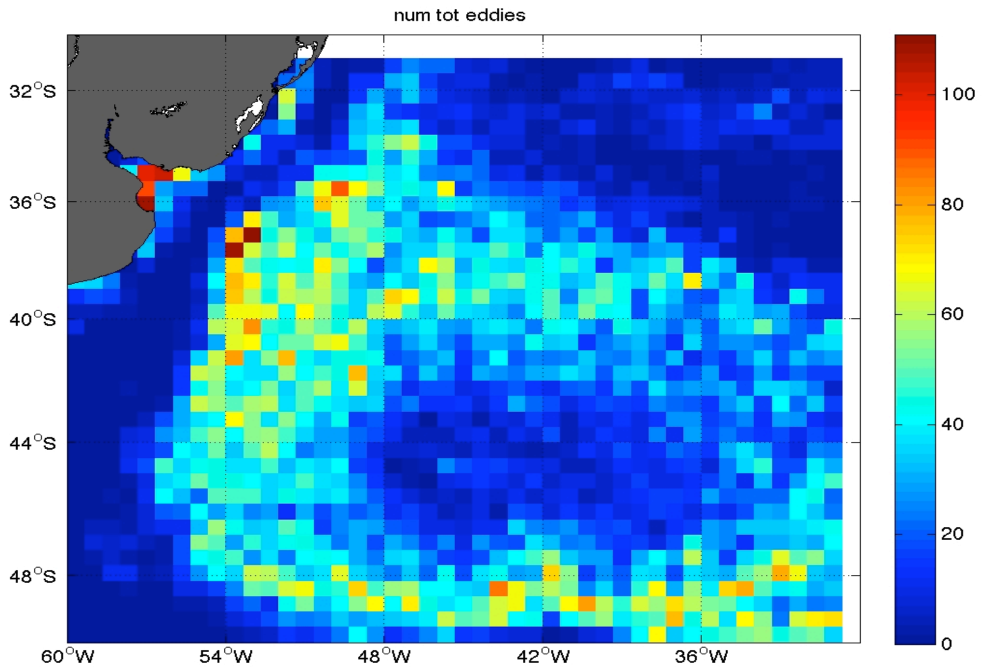
Shearing deformation rate: $s_s = g_{21} + g_{12},$

Stretching deformation rate $s_n = g_{11} - g_{22},$

Total deformation rate : $s = \sqrt{s_s^2 + s_n^2}$

Divergence: $\psi = g_{11} + g_{22}.$ Vorticity: $\omega = g_{21} - g_{12},$

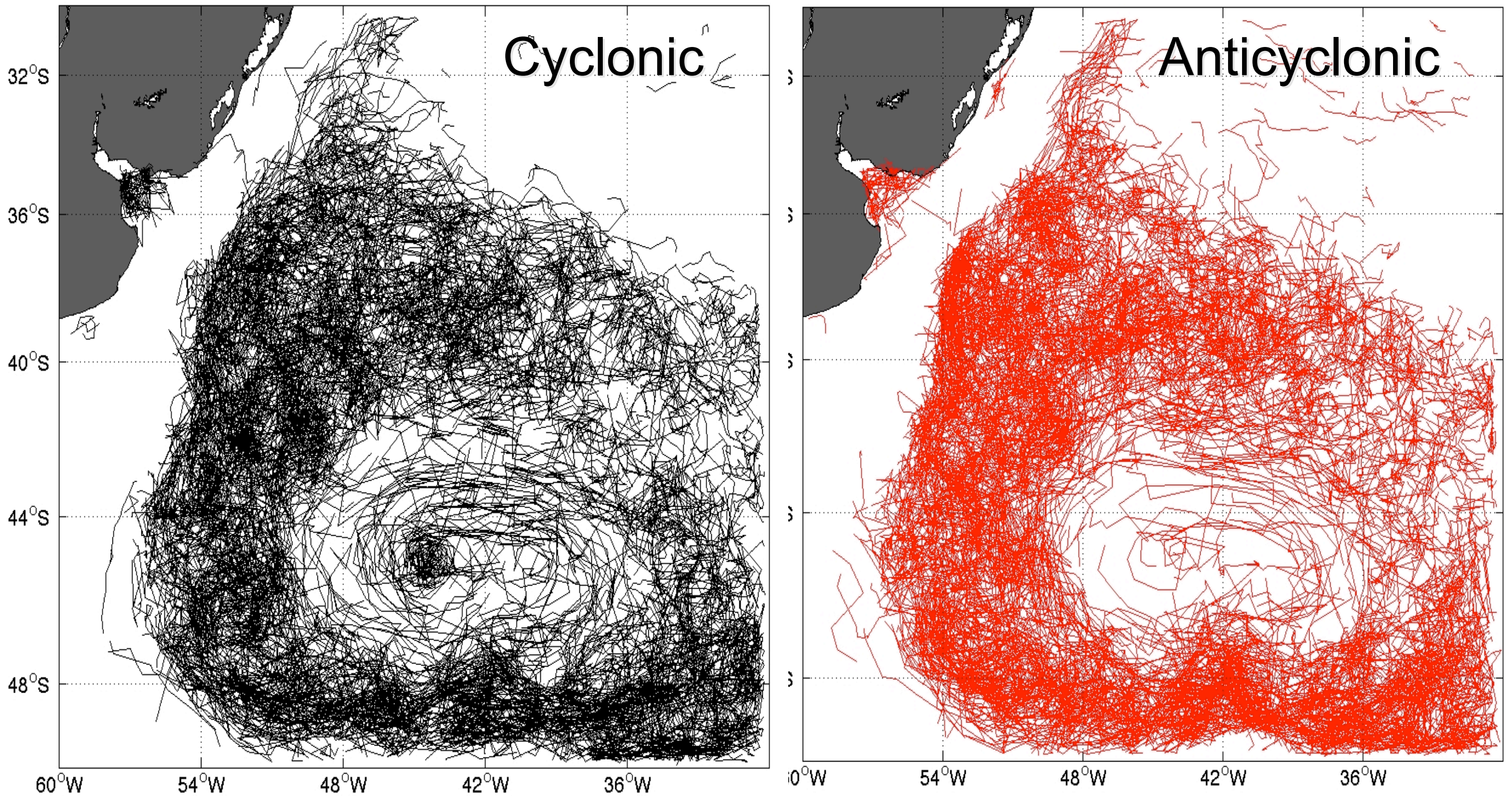
Spatial distribution of eddies



- Large number of eddies in the regions with high mesoscale activity: in the Brazil-Malvinas Confluence region and along the Subantarctic Front.

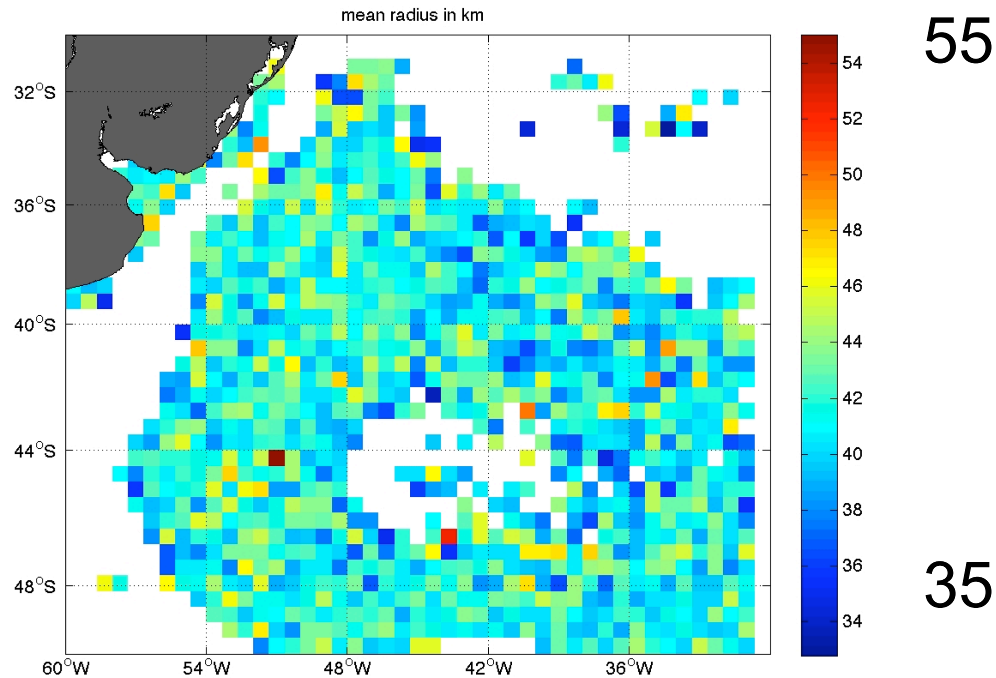
- Regions corresponding to the Zapiola Rise, the Malvinas Current and north of the Subtropical Front present a minimum number of eddies.

Trajectories of long-lived (> 6 weeks) eddies



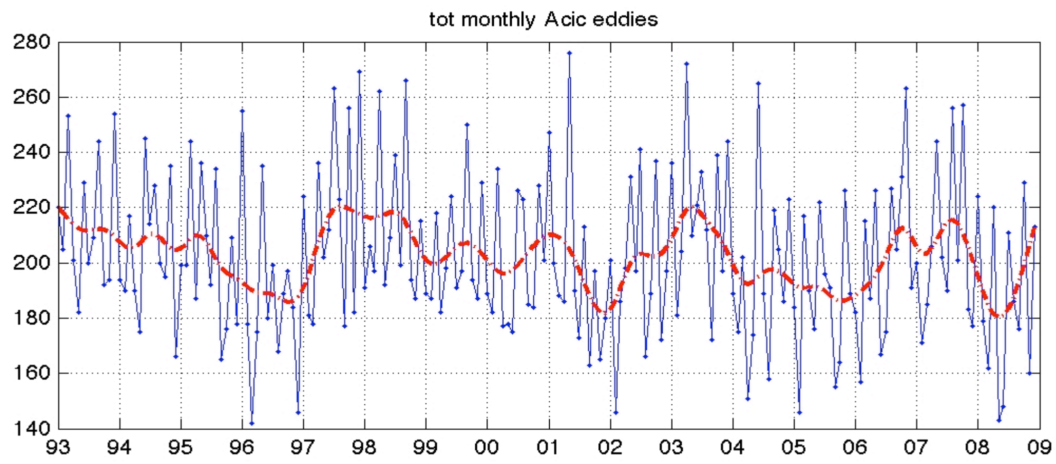
Trajectories of the long lived C & A eddies are similar.
Cyclonic eddies are found more often in the Zapiola Rise region compared with anticyclonic ones.

Radius (km)

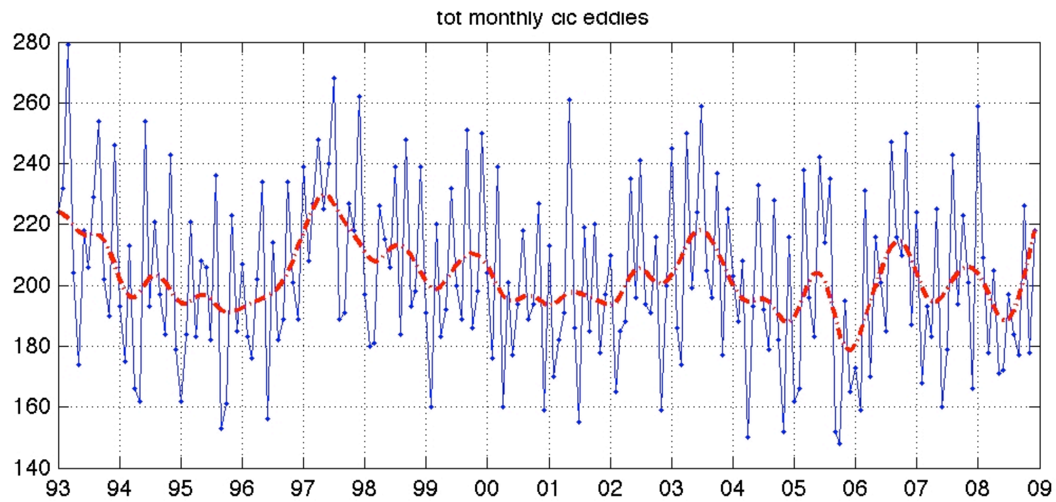


The spatial distribution of the mean radius of the eddies shows an homogeneous distribution pattern. The number, mean radius and spatial distribution of these variables does not varies significantly for the total cyclonic or anticyclonic eddies. Similar results are found in other regions of the ocean (Chaigneau at al, 2009)

Interannual variability in the SWA (whole region)



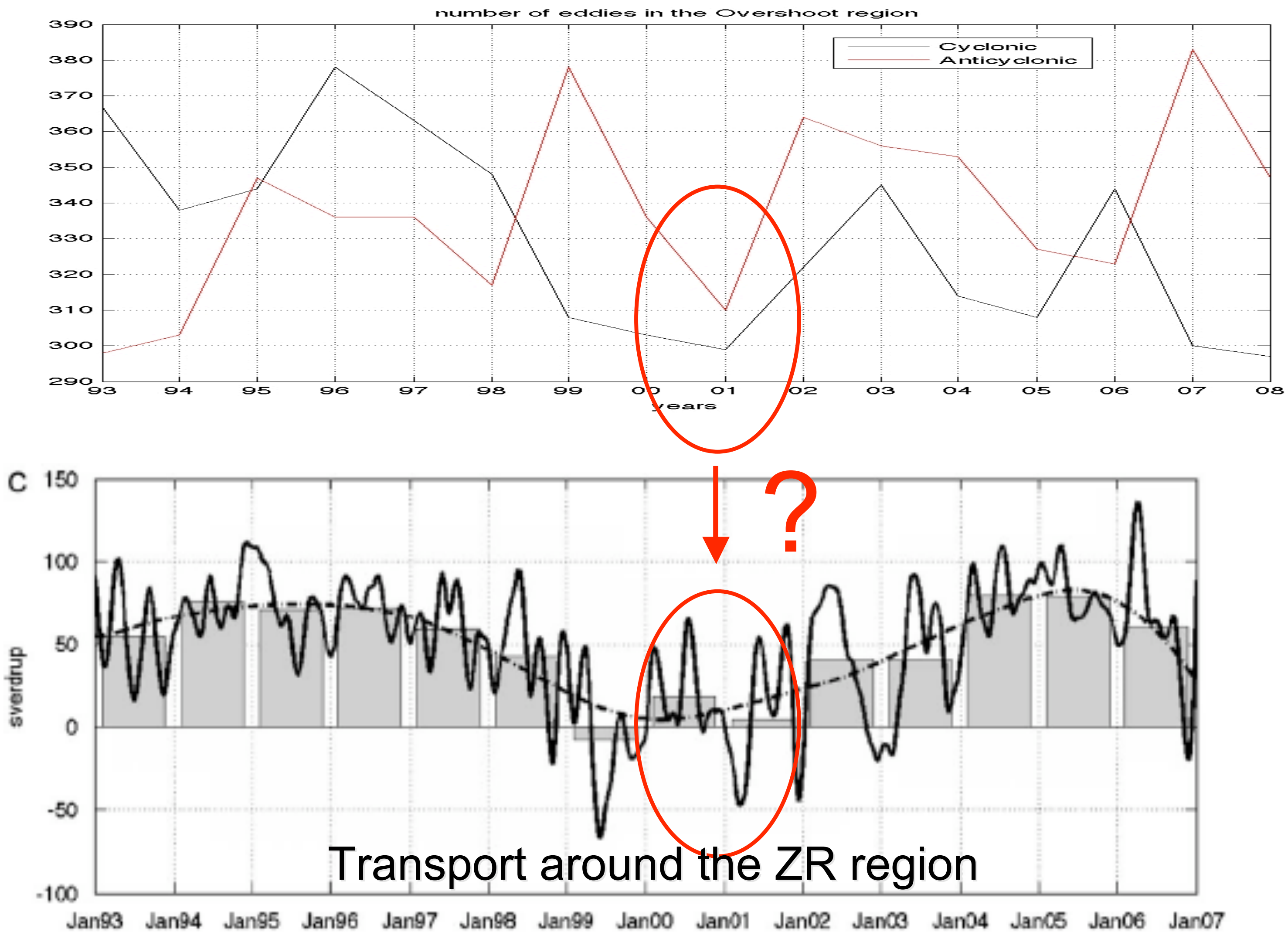
Anticyclonic



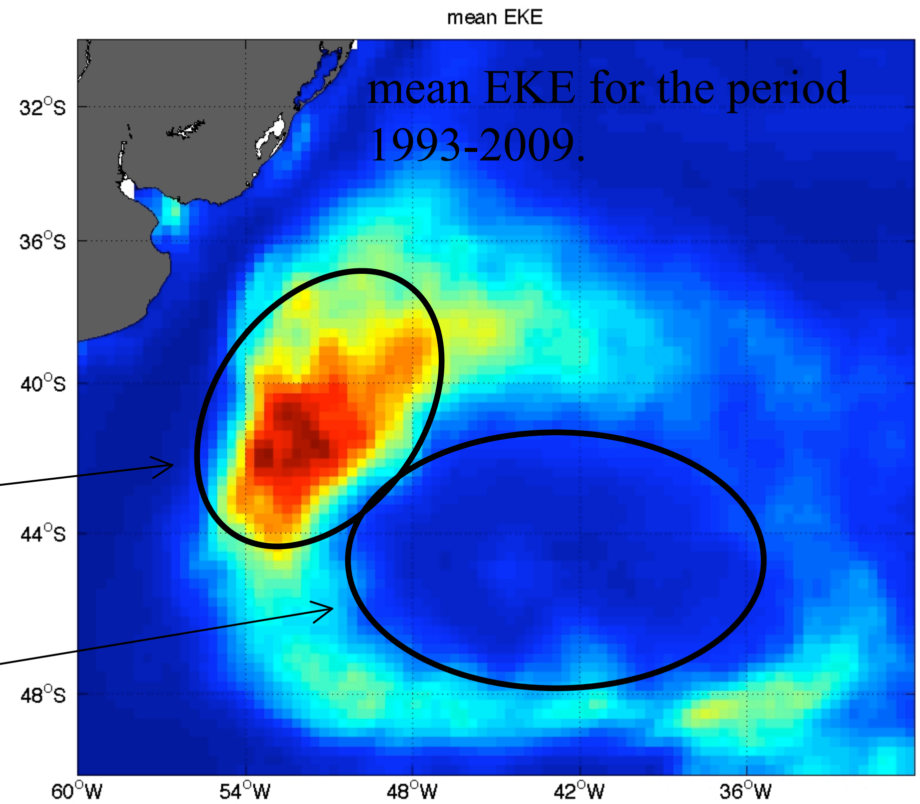
Cyclonic

Interannual variability in the Overshoot region

Interannual variability in the Overshoot region



Saraceno et al, 2009



Overshoot Region

Zapiola Rise Region

Are eddies in the Overshoot region the main forcing of the circulation around ZR?

Conclusions

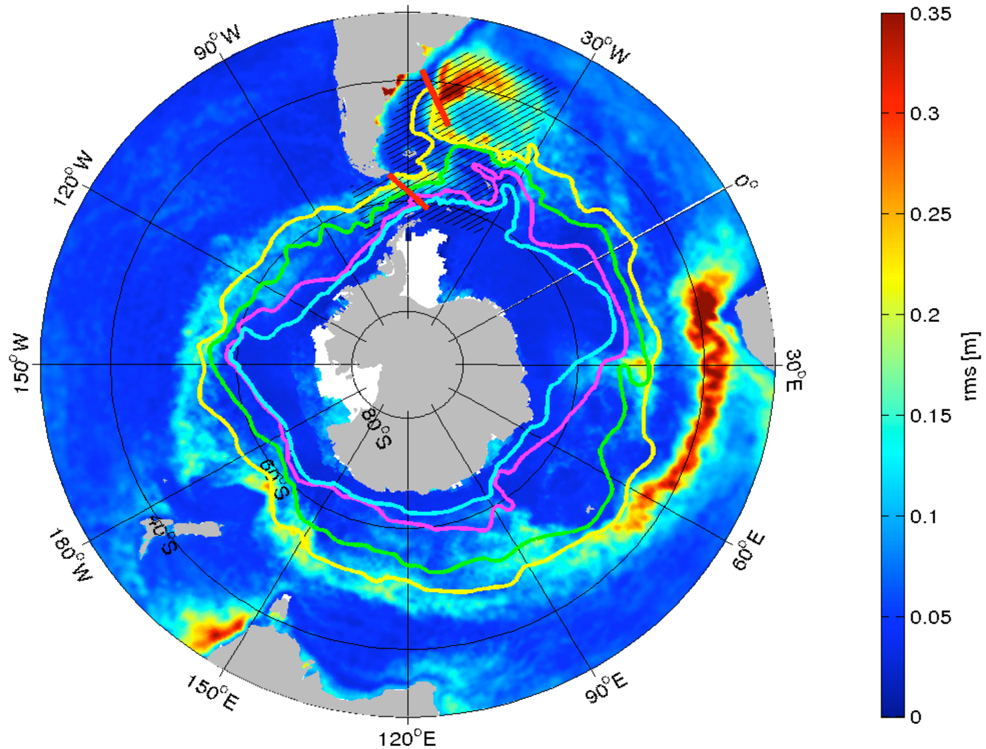
– Eddies detected with the Okubo-Weiss method in the SWA originate mainly in the Brazil-Malvinas Confluence region and along the Subantarctic Front, where the EKE is higher.

– Eddies circulate around and do not enter the Zapiola Rise (ZR) region. This observation is in agreement with the eddy-driven circulation theory [e.g. Dewar, 1998].

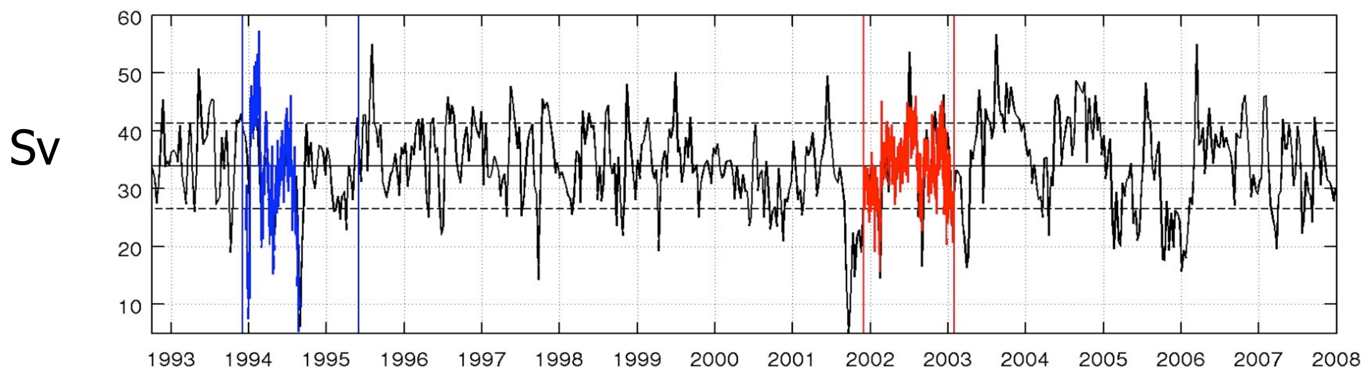
– It is suggested that the interannual variability of the transport associated to the ZR may be associated to the number of eddies in the Confluence region.

Monitoring the cold route in the SWA Ocean

1- monitoring transport of the Malvinas Current (Moorings + altimetry)
2- documenting water mass transformation processes in the Argentine Basin (Argo floats)
3- monitoring transport and water masses variability through Drake Passage (Hydrography, Moorings, altimetry)



Malvinas Current : 15 year transport time series

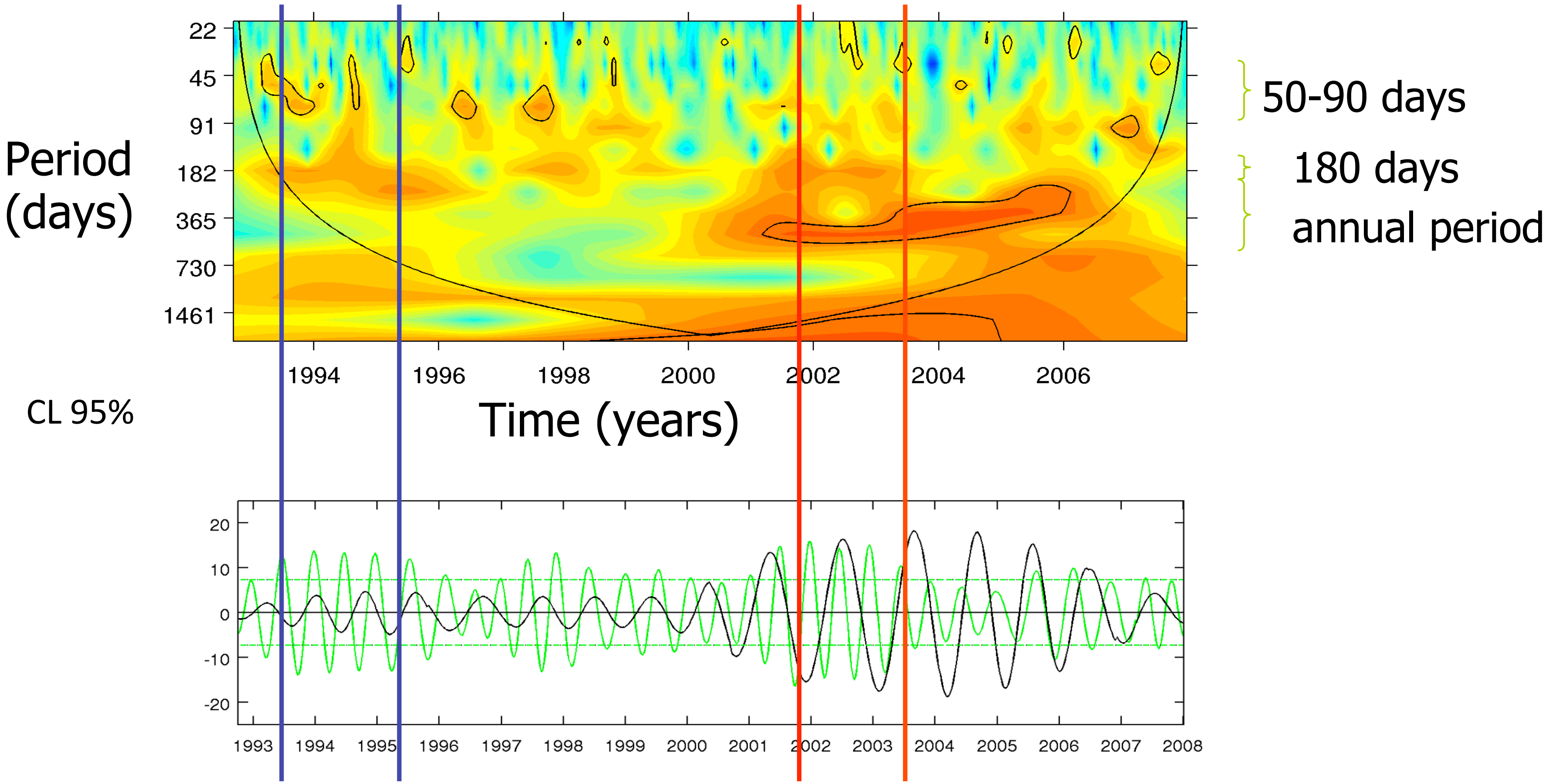


Mean 34.3 Sv, std 7.4 Sv

> good correlation (> 0.7 [95% CL=0.48] for each period) between transport computed from currentmeter data (alone) and transport time series from altimetry

Spadone and Provost, 2009. JGR-Oceans

Time evolution of the spectral content

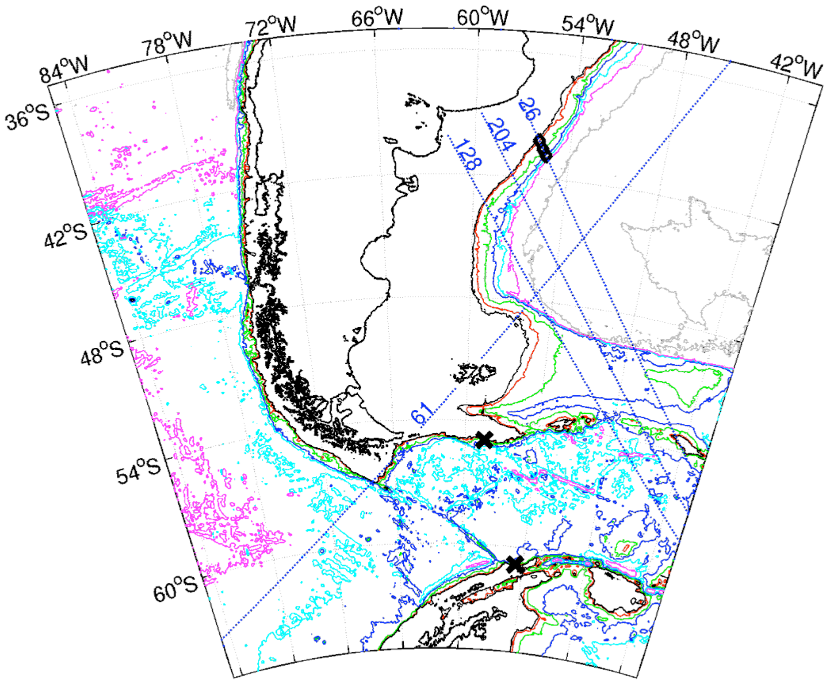


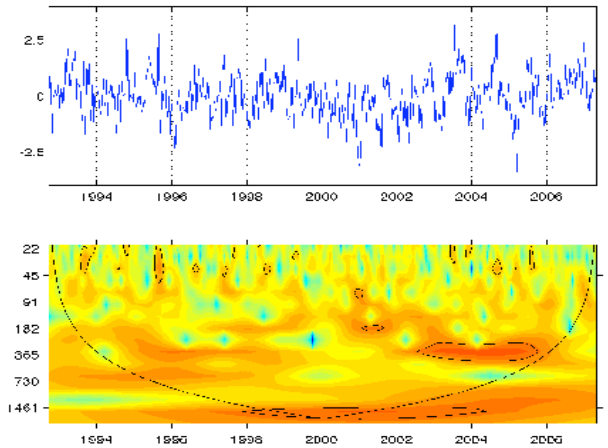
> modulations at all frequencies

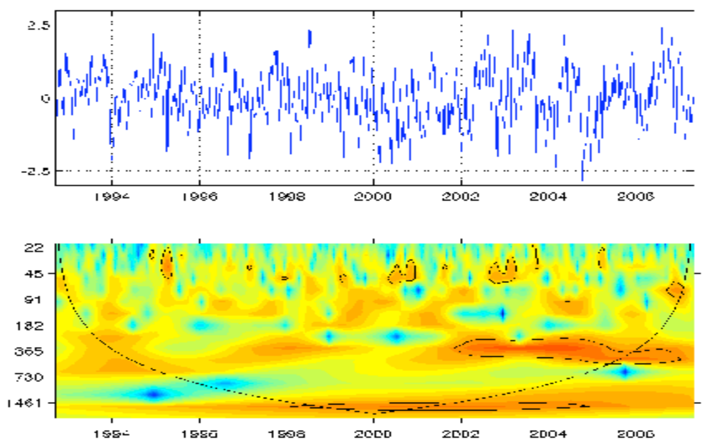
> apparition of a signal around the annual period after 2000 (maximum in 2001-2006 seems to be decreasing afterwards)

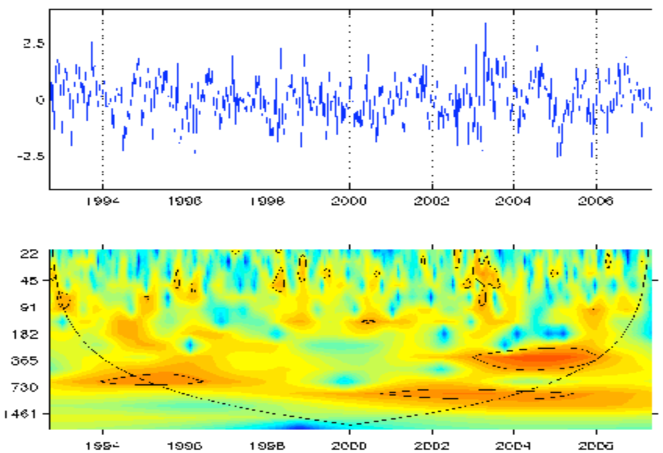
Variations : local or remote causes ?

Surface geostrophic velocity anomalies between 2 f/H contours corresponding to the core of the MC

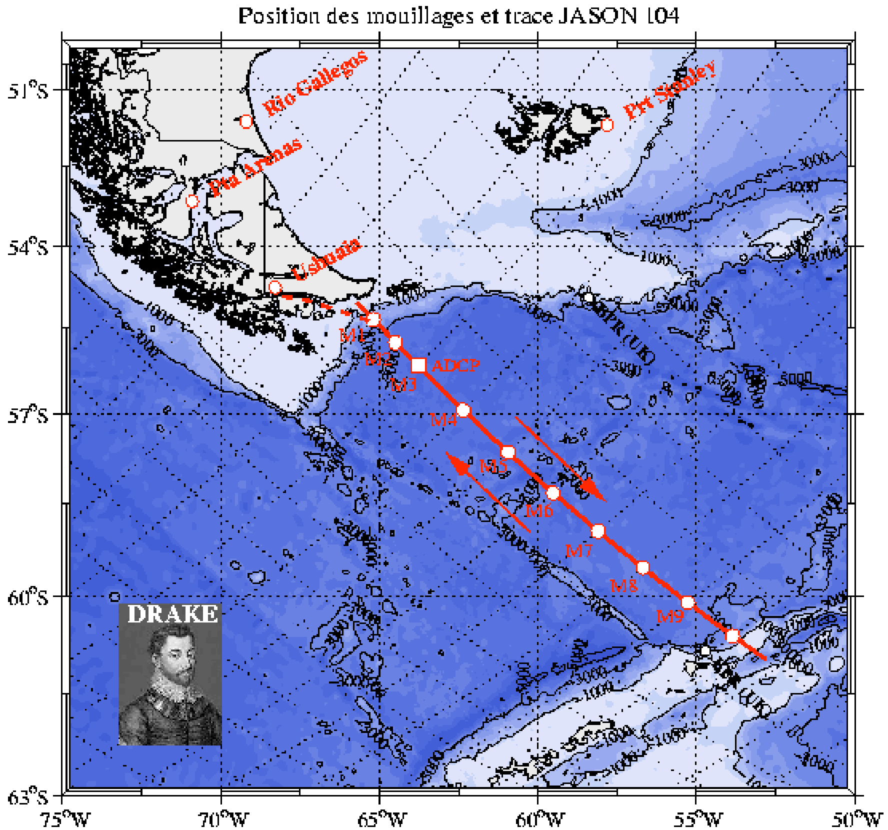








DRAKE Moorings



Jason track # 104
Eastern side of Shackleton Fracture Zone
West Scotia Ridge
Yaghan Basin - Ona Basin

- Feb 2006: M1 to M10 deployed below Jason track # 104 at crossover points.
  M2, better resolution in the North
- 8 moorings recovered in April 2008
  M2 and M8 lost
- 5 moorings M1-M5 redeployed in April 2008
- All 5 moorings recovered March-April 2009

Over 3 years in Yaghan Basin

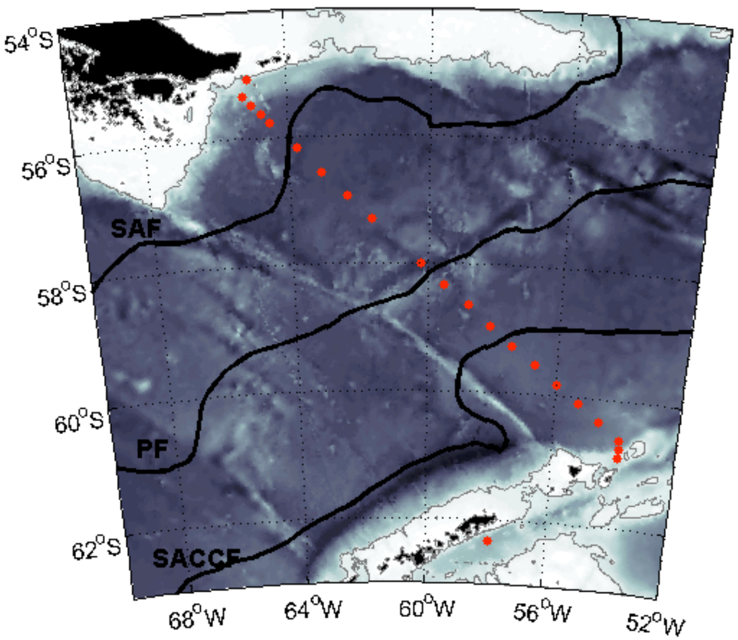
2 years in Ona Basin

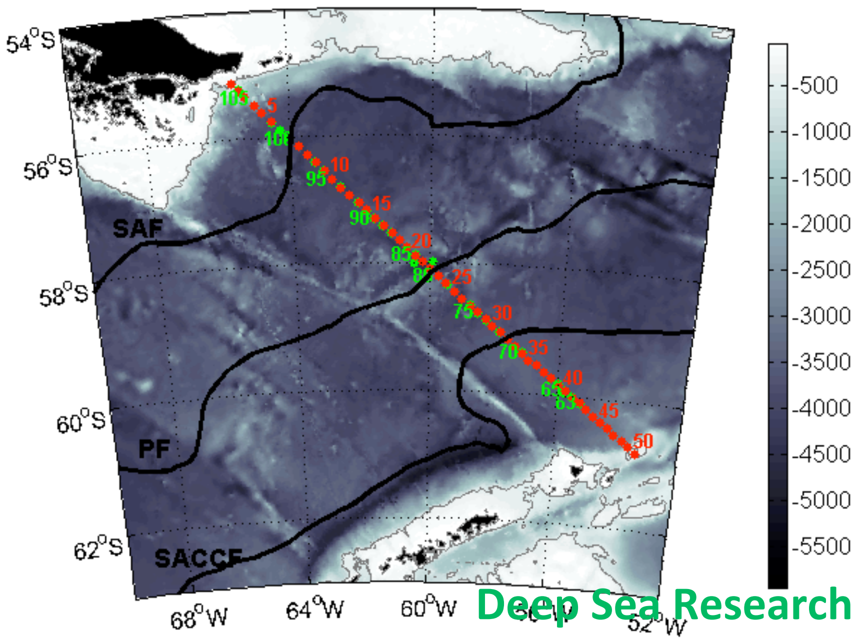
Data gathered during DRAKE Project

4 Hydrographic cruises from RV POLARSTERN

3 with tracers (V. Garçon, O. Huhn, H. de Baar) and LADCP

2005 April E. Fahrbach	2006 January-February
21 CTD stations	**2 sections along track 104**
no LADCP no tracers	51 CTD/LADCP/tracers stations southward
Precise bathymetry	43 CTD/LADCP/tracers stations northward





Deep Sea Research special issue. 4 papers

Data gathered during Drake Project

4 Hydrographic cruises from RV POLARSTERN

2008 - ZERO-DRAKE (IPY)

E. Fahrbach - Feb - April

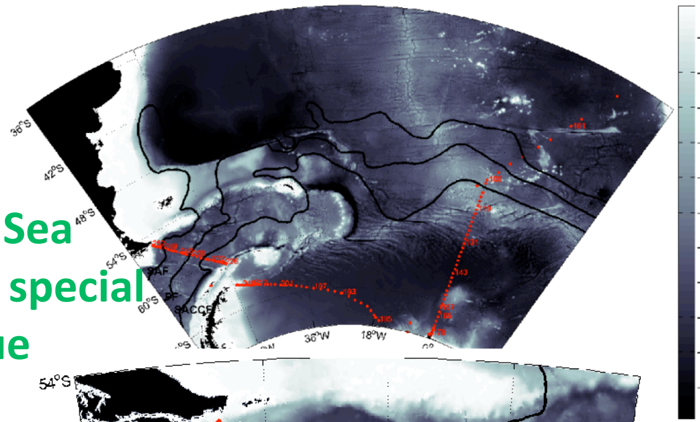
31 CTD/ 29 LADCP stations (#104)

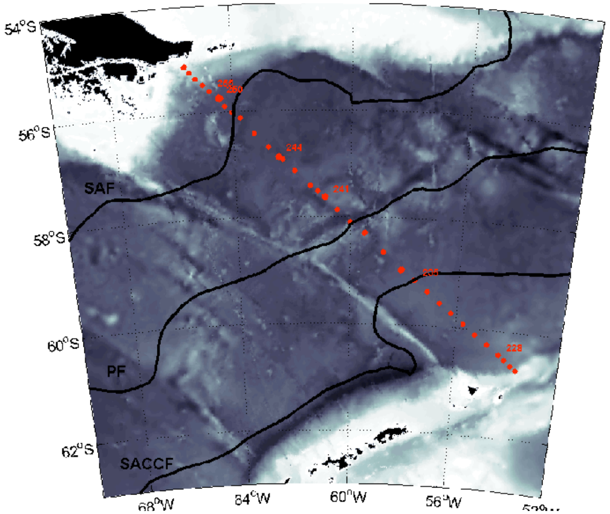
2009 March-April (poor weather)

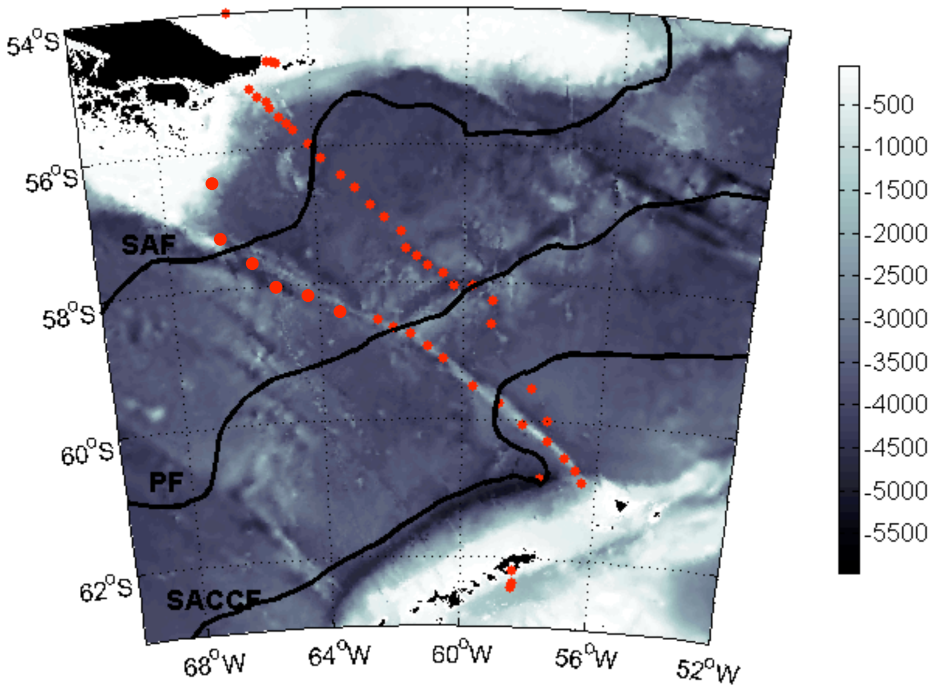
25 CTD/LADCP stations southward (#104)

17 CTD/LADCP stations northward on the SFZ (Jason track #28)

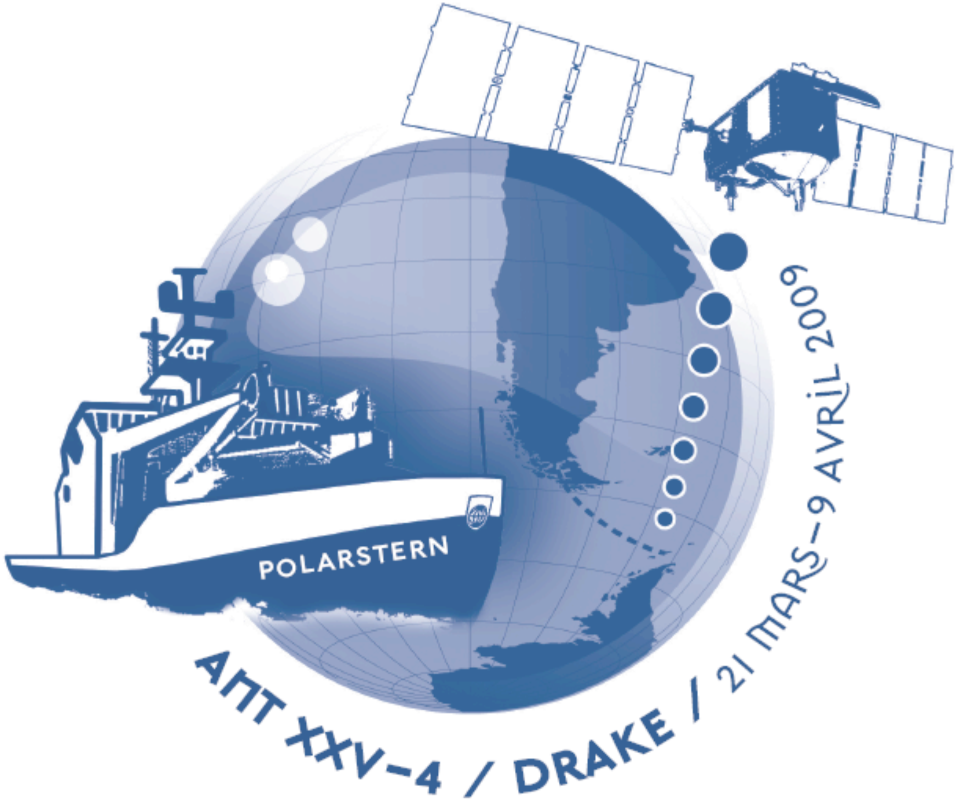
Deep Sea Research special issue





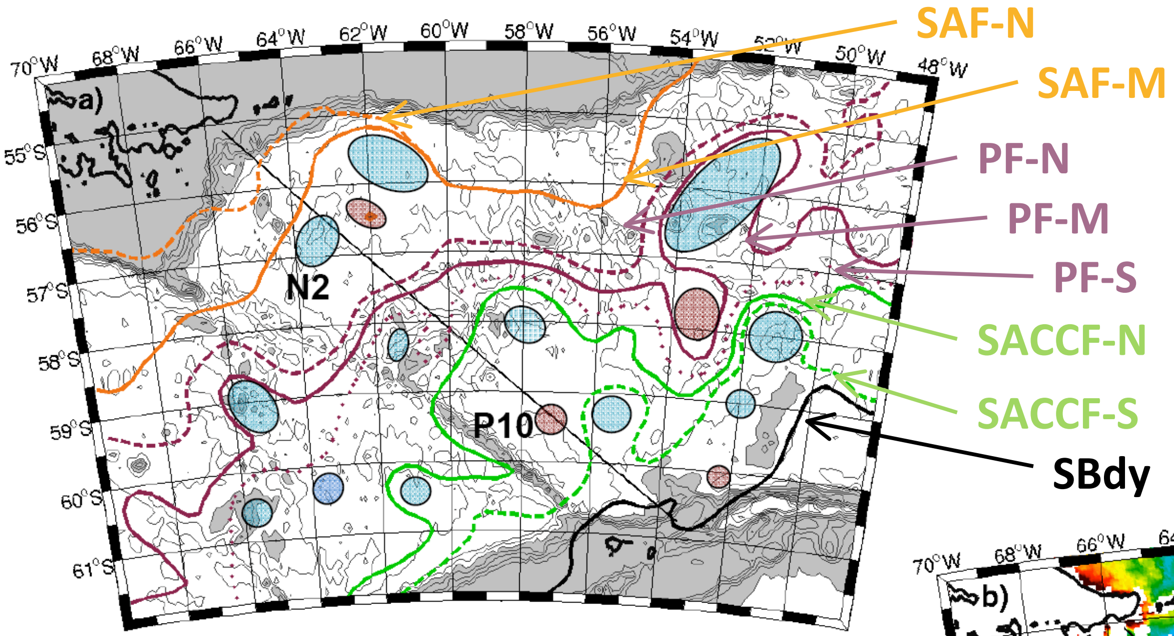


Two crossings of the Drake Passage in austral summer 2006



C. Provost, A. Renault, N. Barré, N. Sennéchael, V. Garçon, J. Sudre and O. Huhn

Spatial context: Jan-Feb 2006

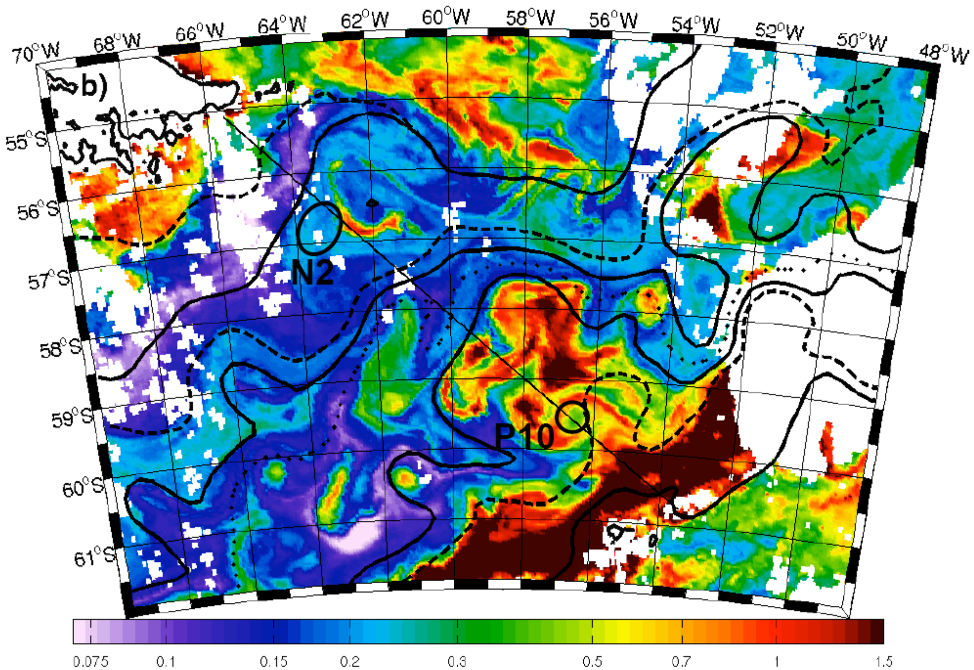


Fronts, 8 branches:

- 2 SAF,
- 3 PF,
- 2 SACCF

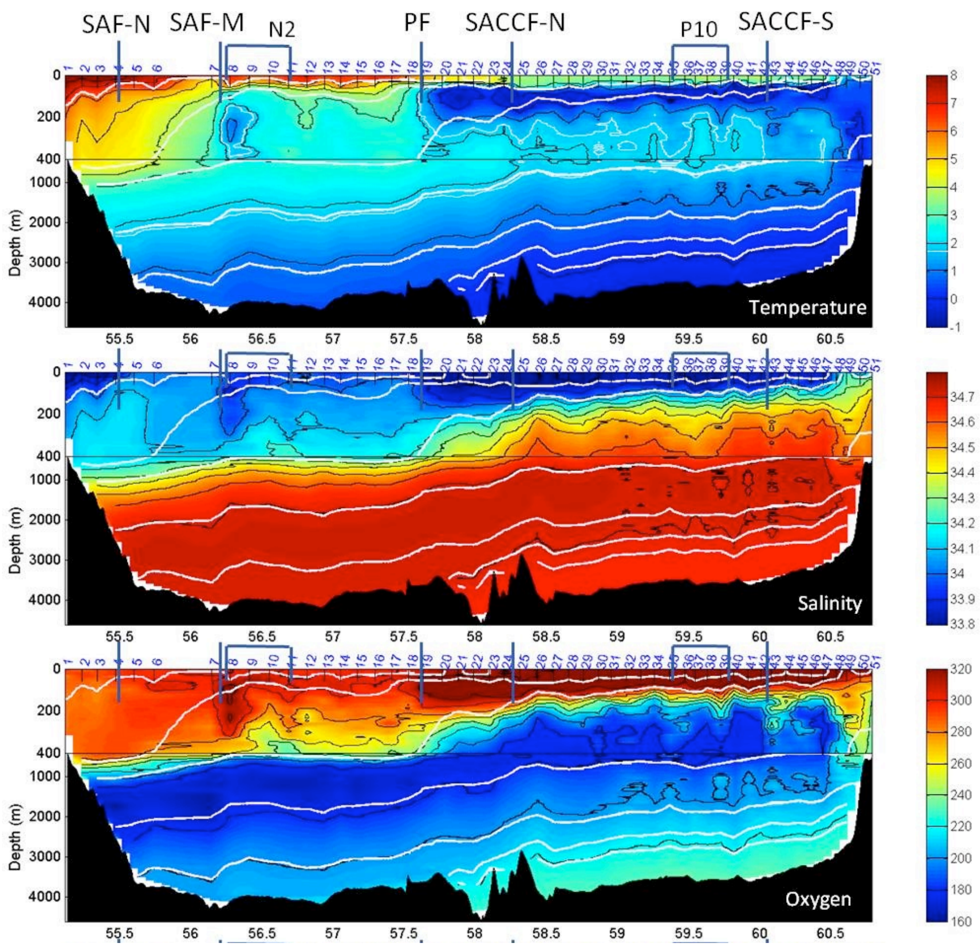
(cf SR 2009, Barré et al. 2011)

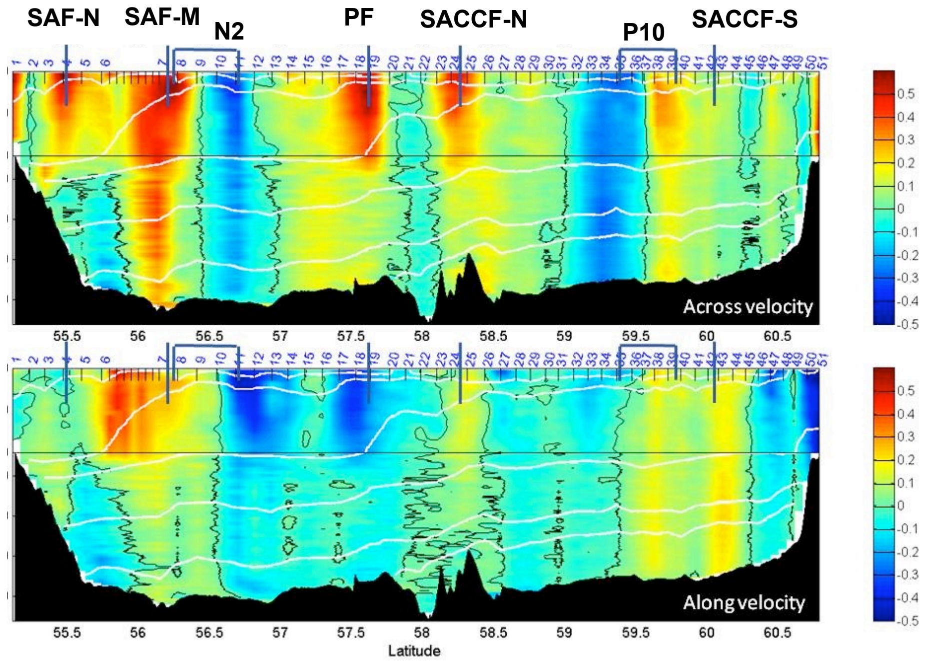
Major eddies



- Major features:
- SAF southward meander at the entrance of the DP
- PF northward meander to the north of WSR
- PF southward meander over the OSD (cf Barré et al., JGR 2008)
- PF meander/eddy at the exit of DP

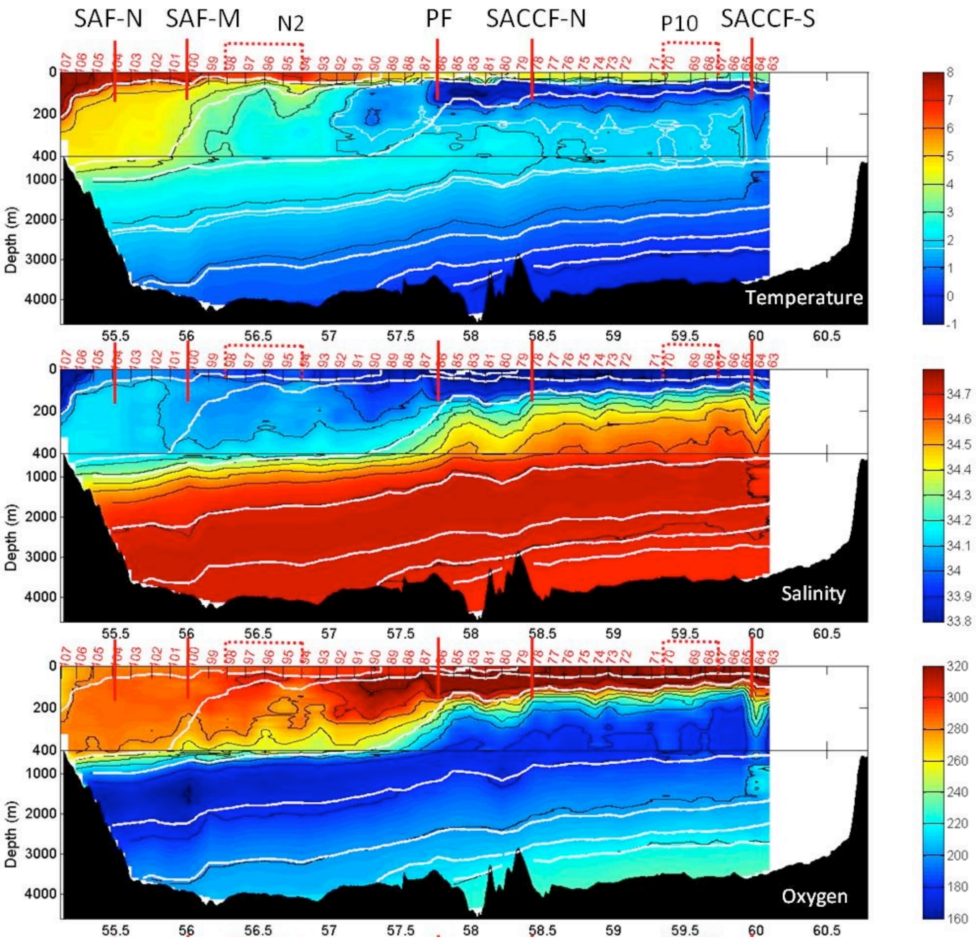
Southward Transect: 51 stations

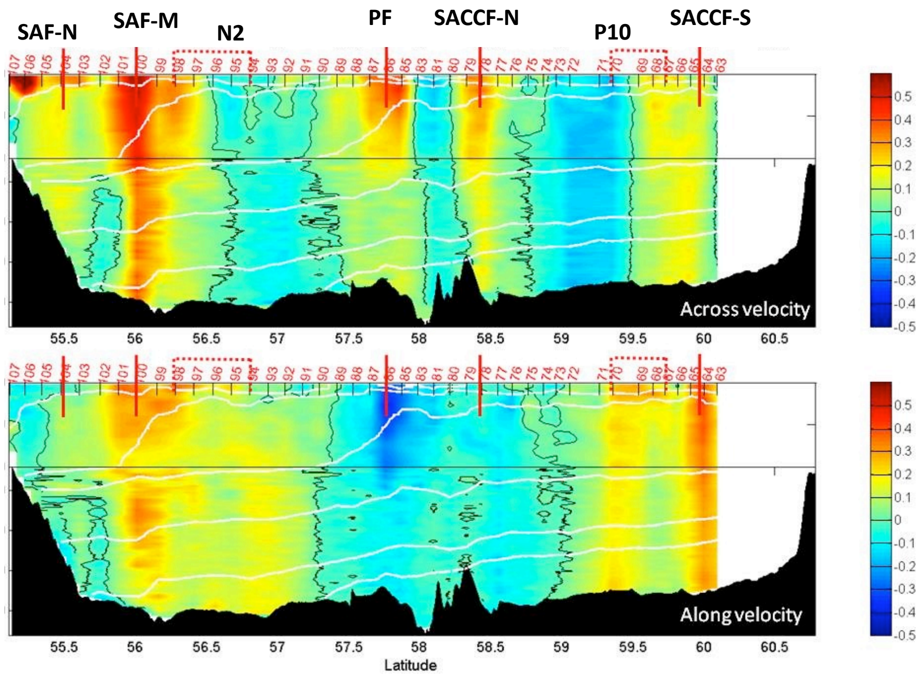




- Fronts- branches - eddies
- Signature in velocities, hydrography, altimetry

Northward Transect: 43 stations





- Time evolution between the 2 transects
- Fronts- branches - eddies
- Signature in velocities, hydrography, altimetry

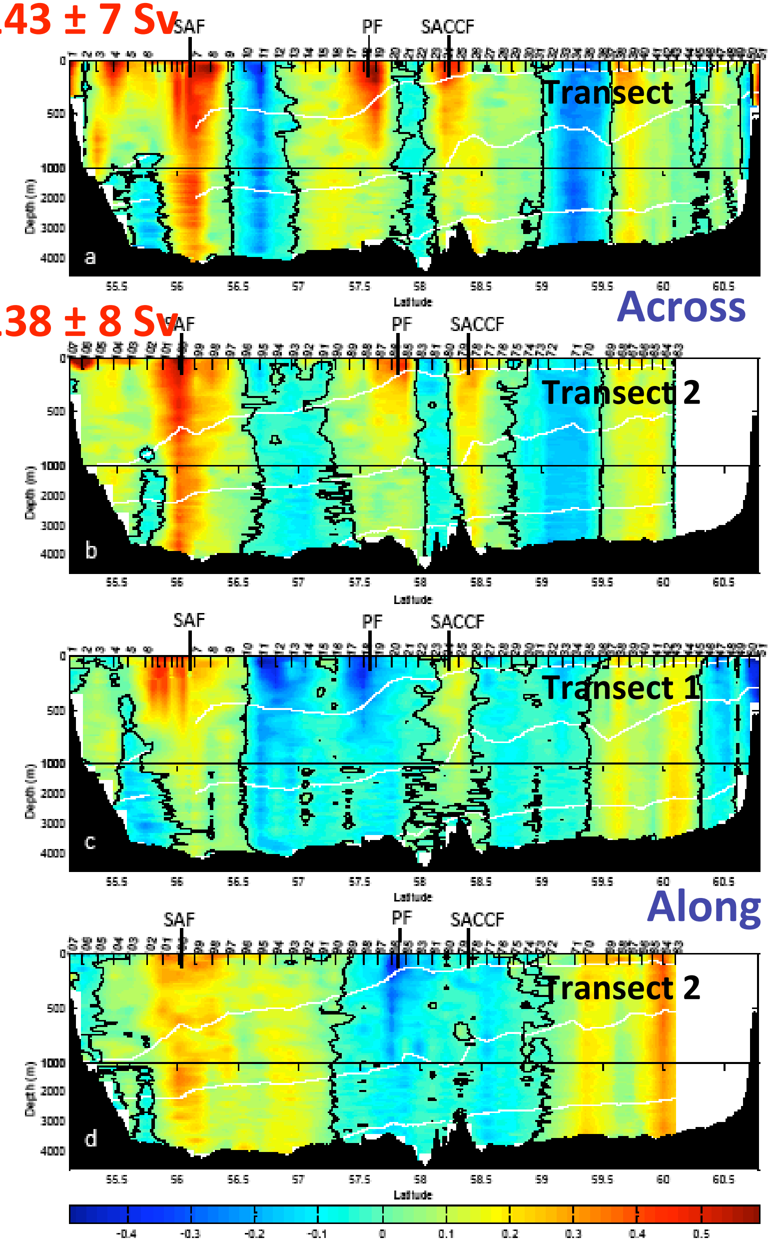
LADCP Data

143 ± 7 Sv

138 ± 8 Sv

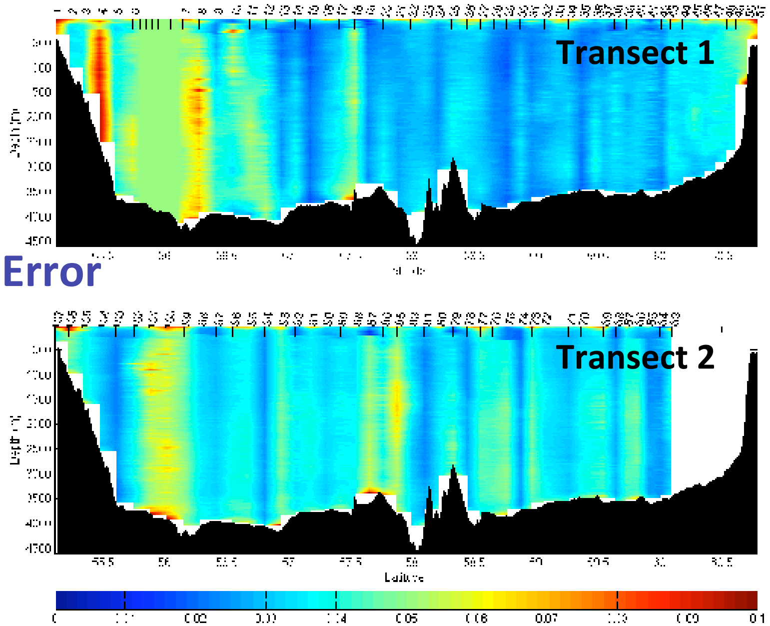
Across

Along



- ✓ The error bar is small over the entire section (less than 3 cm/s) with few exceptions
- ✓ Velocity structure in narrow bands
- ✓ The fronts are well defined in the across track velocities
- ✓ Several eddies are observed
- ✓ Evolution within three weeks
  - ▪Position and strength of the PF and SACCF are modified
  - ▪Smaller westward velocities

Error

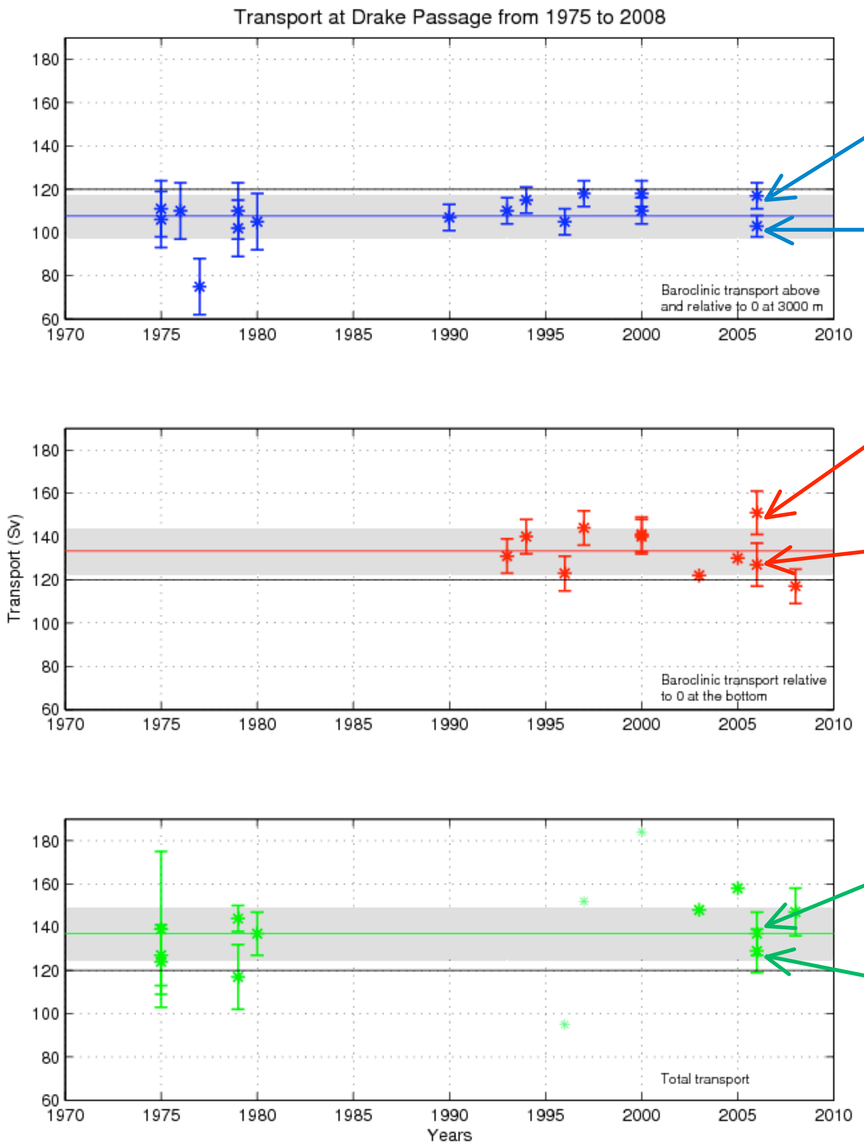


Transport estimates

Transport above and relative to 0 at 3000 m

Transport relative to 0 at the bottom

Total transport



Transect 1: 117 ± 6 Sv

Transect 2: 103 ± 5 Sv

Transect 1: 151 ± 6 Sv

Transect 2: 136 ± 6 Sv

Transect 1: 137 ± 7 Sv

Transect 2: 129 ± 7 Sv

Differences in properties

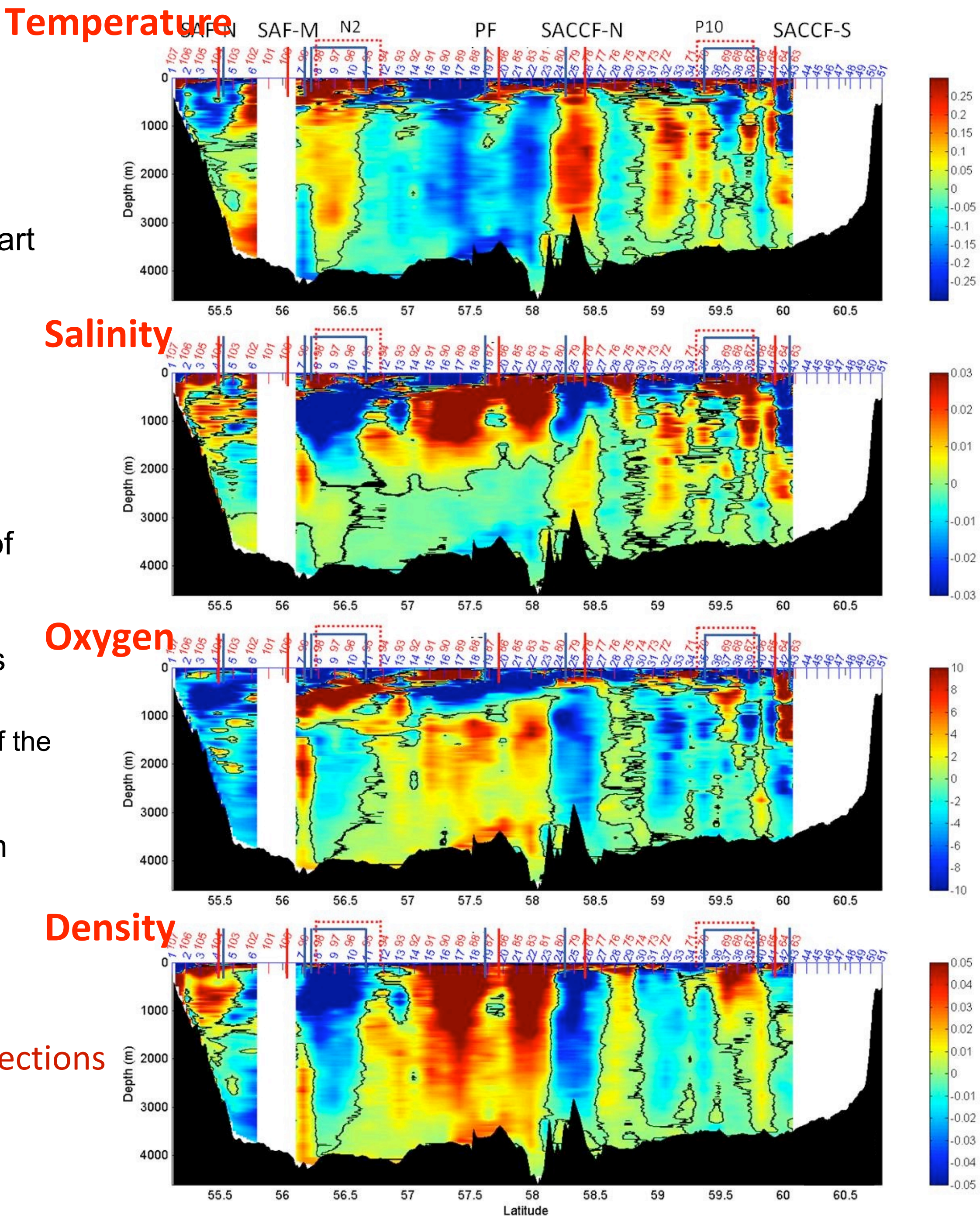
- High differences between the 10-day apart sections
  - Below 3000 m:
    - ΔT=0.2°C,
    - ΔS=0.01,
    - $\Delta \gamma^n$=0.03 kg/m^3,
    - ΔOxy=10 µmol/kg

- Only part attributable to displacements of fronts and eddies

- Spatial heterogeneity of water properties upstream
  - PF: heterogeneity upstream, funnelling of the flow due to topographic constraints

- Strong differences in water properties on short time scales

Caution when interpreting different sections in terms of **climatic signals**



Conclusions

- Fine horizontal resolution of the hydrographic data and high accuracy of the data
- 2 sections repeated within 3 weeks
  - Unique opportunity to document full depth variability at 10-day interval
- Contributions of fronts and eddies to total transport changed
  - No strong modification of the transport (about 10%)
- Strong differences in water properties
  - Frontal or eddy displacements
  - Spatial differences of properties upstream the section