Satellite data versus in situ data in Drake Passage

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ABSTRACT:

The Southern Ocean, the only ocean that circles the globe without being blocked by land, is home to the largest of the world's ocean currents, the Antarctic Circumpolar Current (ACC). While the ACC is the major inter-ocean link, our understanding of the variability of the ACC and the impact of such variability on the climate system is rudimentary. Monitoring the ACC transport is essential for understanding the coupling of this major current with climate change. It is not an easy matter since the current is concentrated in highly variable narrow bands of swifts currents and since energetic eddies of all sizes are numerous. Our experimental set up is designed to use the complementarity between satellite and in situ observations. In January 2006, 10 currentmeter moorings were deployed in the Drake Passage below track 104 of the altimetric satellite JASON-1 and two high-resolution full depth hydrological sections were carried out along this track. We use satellite data (ocean color, sea surface temperature, altimetry) to describe the mesoscale activity during the cruise. Then, we place the cruise in the climatic context derived from analyzing years of satellite data. Finally, we carry out a Jason-1 data validation along track 104.

Drake Passage

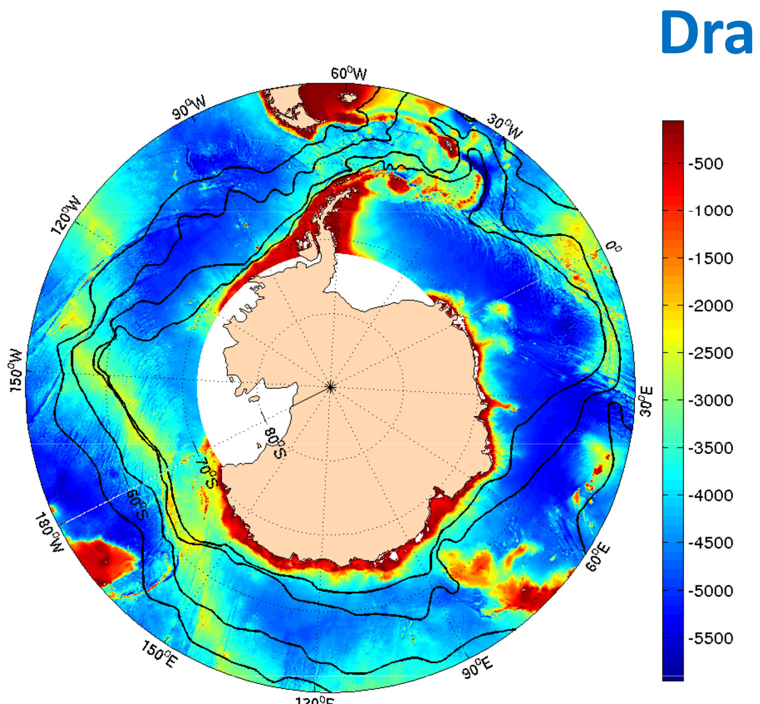

Fig. 1: Seafloor topography (in meters) around the Antarctica. Black lines represent the ACC fronts

The Antarctic Circumpolar Current (ACC) is the world's largest current in terms of volume and mass transport and is constricted to its narrowest extent (about 700 km) at Drake Passage (DP).

The ACC is closely associated with three deep-reaching oceanic frontal systems, from north to south:

- the **Subantarctic Front** (SAF),
- the **Polar Front** (PF),
- the **Southern ACC Front** (SACCF).

The **Southern Boundary** of the ACC (SBdy), farther south, separates ACC water from polar water.

The mean location of these deep-reaching fronts reflects the bottom topography.

- East of DP, the bathymetry is deep and flat (> 5000m).
- At DP, the seafloor rises (near 3700m) and is crisscrossed by a number of fracture zones and ridges that delimit small basins often textured with abyssal hills or depressions.
- West of DP, the South Sandwich Islands act as a barrier to the ACC, forcing it to deviate to the north and to proceed through narrow sills

Two major features in DP are:

- the West Scotia Ridge (WSR) oriented east–west at mid-distance between the tip of South America and the Antarctic Peninsula.
- the Shackleton Fracture Zone (SFZ), deflecting the SACCF northward

These ridges delimit the Yaghan Basin (YB) to the northeast and the Ona Basin (OB) to the southeast.

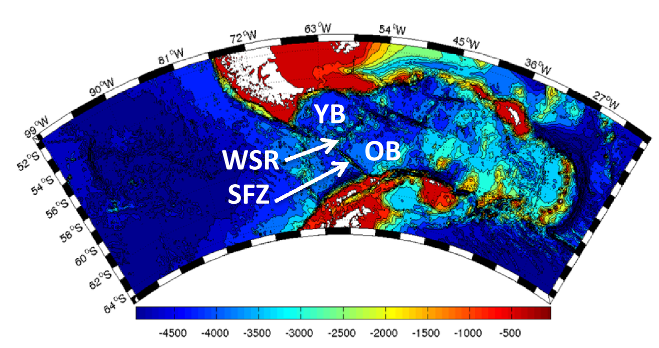

Fig. 2: Bathymetry in Drake Passage (in m)

Experimental program: DRAKE 2006-2009

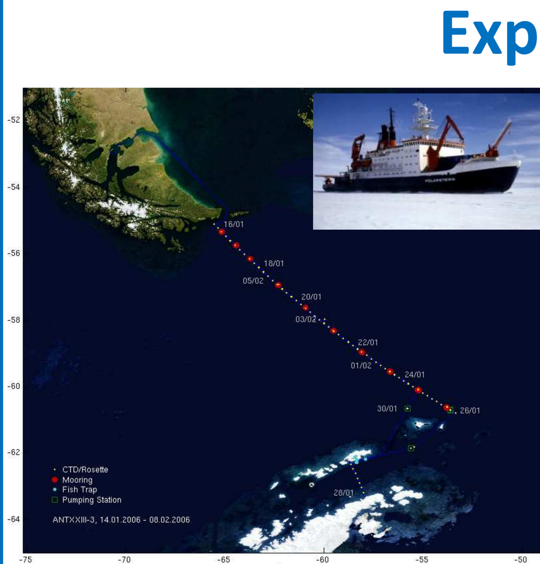

Fig. 3: Mooring locations and CTD stations

In January-February 2006, an expedition across Drake Passage (ANT-XXIII/3 cruise) took place on board the Polarstern.

A mooring array (red dots) was deployed below the track 104 of the altimetric satellite JASON-1 and two high-resolution sections of CTD/LADCP stations (white dots) were carried out on this track twice in three weeks (Fig. 3).

- Leg 1 of the cruise: 16 January to 26 January 2006 (way south)
- Leg 2 of the cruise: 31January to 6 February 2006 (way back)

The moorings, recovered and reinstalled in February 2008, will be brought up in March 2009.

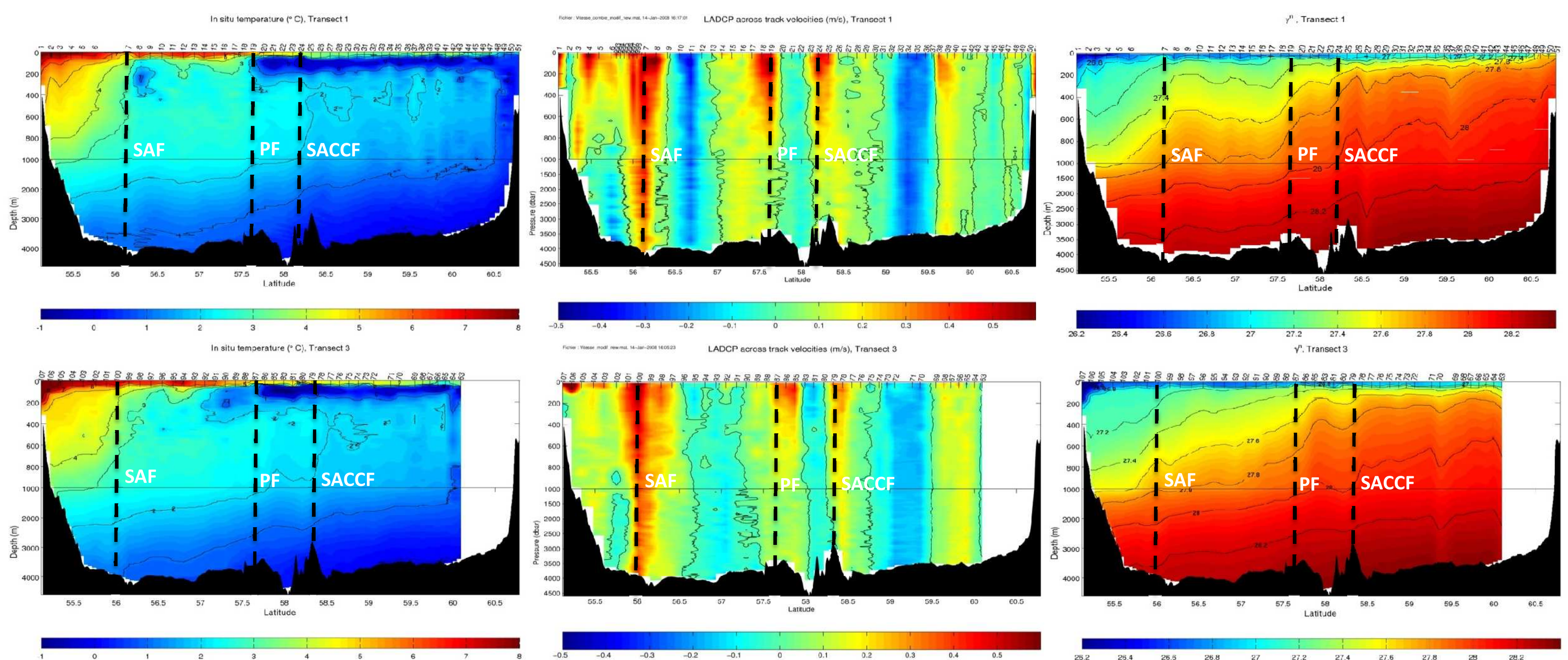

Fig. 4: Temperature, cross-track velocity and neutral density sections. leg1 at the top and leg 2 at the bottom.

SLA along JASON-1 track and dynamic height from CTD

SLA is highly variable showing differences (middle panel) as high as 40cm in only 10 days.

In the Antarctic Polar Frontal Zone (APFZ):

- high positive anomaly (~20cm) at 57.3°S corresponds to an anticyclonic eddy (visible the 15/01 only).
- the eddy disappears 10 days later and is replaced by a high negative anomaly (~30cm); some cold water from the south enters in the APFZ.

South to the PF:

- high positive anomaly (~20cm) at 59.5°S corresponds to an anticyclonic eddy along the SFZ (visible the 25/01 and 04/02).

In addition, in situ data show (bottom panel)

- high negative anomaly (~20cm) at 56.3°S corresponds to a cyclonic eddy in the APFZ during the leg2.
- the eddy in the APFZ is also documented and is moving southward.
- a branch of the PF meanders southward (~58.4°S)

In situ data was gathered over 21 days whereas satellite flew in a few seconds over the track three times (15 Jan, 25 Jan and 04 Feb.).

=> Comparing altimetry and in situ data illustrates the aliasing.

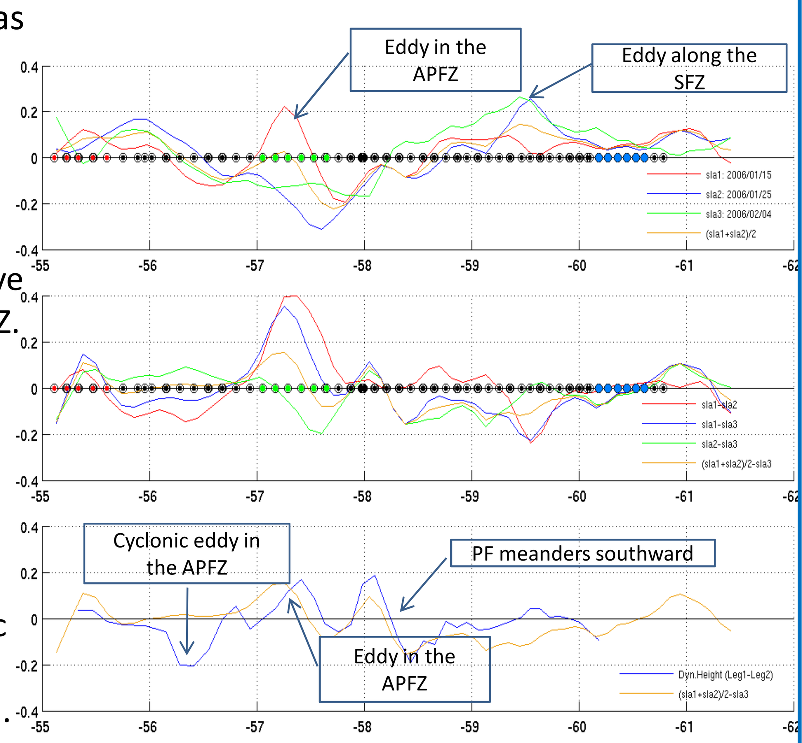

Fig. 5: the dots, which correspond to the location of the CTD station at the time of the satellite pass, are colored as SLA.
Top: SLA (in m) along the JASON-1 track in January-February 2006.
Middle: Difference between the three SLA
Bottom: Dynamic height (leg1-leg2 in blue) is equivalent to an anomaly and is compared to a composite of SLA (in orange)

Evaluation of the Mean Sea Rio05

The Mean Sea Rio05 is a combined product based on GRACE mission, altimetry and in situ data (hydrologic and drifters data) over 7 years (1993-1999) .

- The dynamic height is computed from the CTD data with two reference pressures: one at 2000db , the other at a depth of isopycnal 27.86 (neutral density).
- The surface height referenced to the depth of isopycnal 27.86 is close to the Mean Sea Rio05

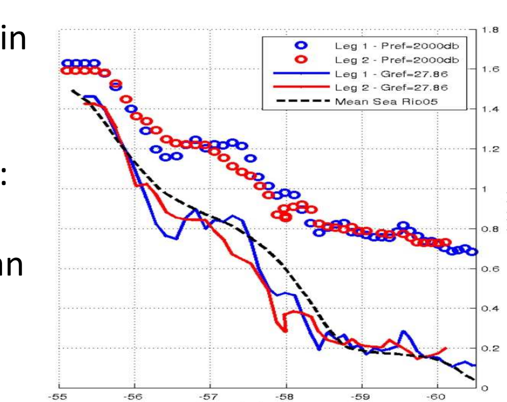

Fig. 6: Dynamic height at 2000db (blue and red dots) and at the isopycnal 27.86 (blue and red lines) and the Mean Sea Rio05 (dashed black line)

Geostrophic velocities referenced with the LADCP (fig. 4) and the geostrophic velocities set up with the reference pressure at isopycnal 27.86 are compared. Geostrophic velocities from the isopycnal 27.86 show:

- weaker intensity than the velocities referenced with the LADCP (fig. 4)
- reversal flow below the reference pressure
- very small transport

=> The Mean Sea Rio05 is not correct along the JASON-1 track #104

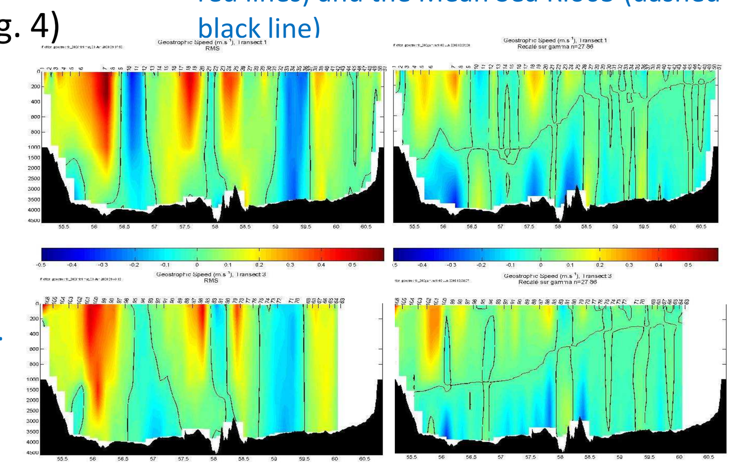

Fig. 7:
Top and bottom left: geostrophic velocities referenced with the LADCP (leg1 and leg2). The associated transport is equal to 137.33 Sv (leg1) and 120.45 Sv (leg2).
Top and bottom right : same as the left panels using a reference pressure at isopycnal 27.86. The associated transport is equal to 79.19 Sv (leg1) and 45.26 Sv (leg2).

Mesoscale Activity during the cruise 2006

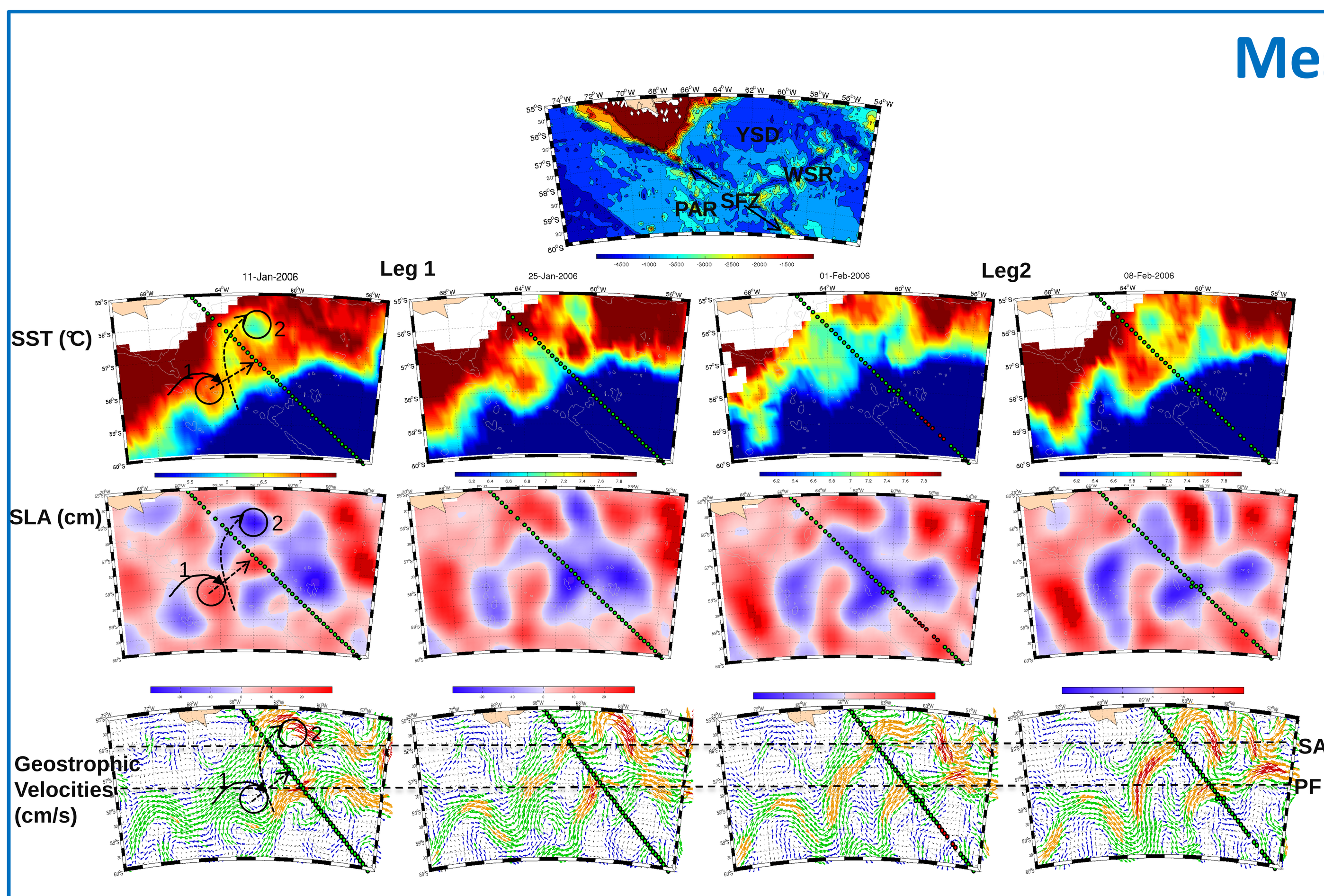

Fig. 8:
1st row: Elargement of the northern bathymetry in the Drake Passage.
PAR: Phoenix Antarctic Ridge; SFZ: Shackleton Fracture Zone; WSR: West Scotia Ridge; YSD: Yaghan Seafloor Depression

2nd row: Sea Surface Temperature (SST) in °C from AMSR-E (a microwave radiometer that gives cloud-free images)

3rd row: Sea Level Anomaly (SLA) measured by the satellite altimeters (in cm)

4th row: Geostrophic velocity field.
10<Vblue <20cm/s; 20<Vgreen <40cm/s; 40cm/s<Vorange<60cm/s; V red>60cm/s
Green dots are the CTD stations
Red dots are CTD stations which are concomitant with the satellite image.

(1) The SAF, mainly controlled by the bathymetry, meanders southward along the SFZ releasing an anticyclonic eddy (High positive SLA>20cm and T≈7.6°C). The eddy moves eastward.
(2) Deep penetrating cyclonic eddies from the south enters in the APFZ and are trapped over the YSD. (High negative SLA<20cm and T≈6°C).
These eddies are also clearly visible on the fig.5.

SAF:

- It is located at ~56°S
- It becomes more intense during the leg2 with stronger surface velocities (V1=45 cm/s. V2=55 cm/s).

PF :

- Strong surface-temperature signature (T=6°C)
- It becomes less intense with lower surface velocities (V1=45 cm/s, V2=35 cm/s)
- it seems to be shifted southward (~57.7°S to 57.8°S)
- Along the JASON-1 track, a branch of the PF meanders southward

SACCF:

- It has no clear signal in SST and in altimetry
- An outstanding bloom of Chl_a in Ona basin shows the turbulence of the SACCF after crossing the SFZ (Fig. 9)

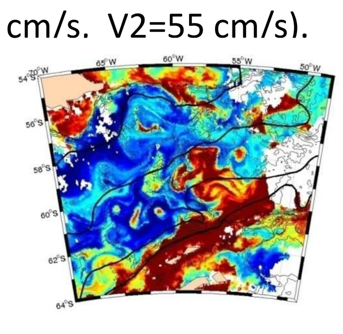

Fig. 9: Chlorophyll_a concentration (mg/m3)
MODIS Aqua, 4-km resolution, 8-Day composite image:17/01/06 => 24/01/06 to avoid the cloud cover.
Black lines are the front positions by Orsi, 1995.

Long term context

- The Southern Annular Mode (SAM) acts on different time scales which varies from the intraseasonal to the interannual variability (Thompson and Wallace, 2000).
- Previous studies have showed that SAM can influence the SST fields on different time and space scales (Lovenduski and Gruber, 2005).

=> Here, a negative SAM index is observed during the cruise period.

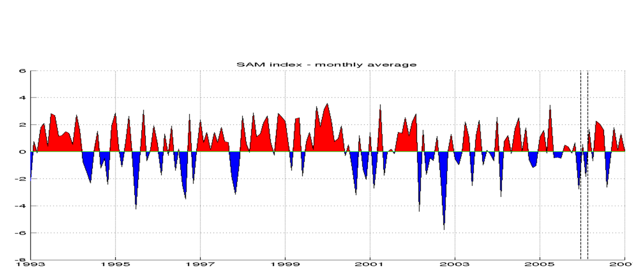

Fig. 10: Southern Annual Mode (SAM) index
Dashed lines represent the cruise period

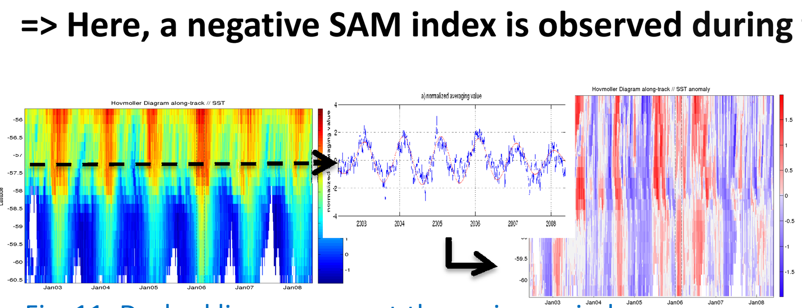

Fig. 11: Dashed lines represent the cruise period
Left: SST (in °C) along the JASON-1 track
Middle: SST signal (in blue) at the latitude 57.75°S with the ridge of the wavelet (in red)
right: SST anomaly (in °C) along-track.

- SST anomaly along JASON-1 track is computed since 2002.
- For each latitude, the annual cycle is removed by substracting the ridge of the wavelet to the SST.
- The ridge corresponds to the maxima of the power spectrum between 300 and 420 days.

=> Warm sst anomaly is observed during the cruise period.

Perspectives …

- A correction of the Mean Sea along the section must be carried out . It will give a more precise absolute dynamic topography and consequently, more accurate geostrophic velocities.
- Using the ADCP from the moorings, two years time series will be available in order to compute a fine validation the JASON-1 data along its track #104
- Estimation of the ACC surface transport along the JASON-1 track
- Mercator ocean model is composed of daily products on a 1/4 ° resolution grid. As it assimilates the altimetry, daily images of sea surface height are available. These images can be very useful to characterize the aliasing.
- Possible relationship between the SAM index, SST field and basin trapped modes (Barré et al., 2008) in Drake Passage.

References:

• Barré, N., C. Provost, N. Sennechael, and J.H. Lee (2008), Circulation in the Ona Basin, southern Drake Passage, J. Geophys. Res., 113, C04033, doi: 10.1029/2007JC004549
• Lovenduski, N.S., and N. Gruber, 2005: The impact of the Southern Annular Mode on Southern Ocean circulation and biology. Geophys. Res. Lett., 32, L11603, doi:10.1029/2005GL022727.
• Rio, M.-H., and F. Hernandez (2004), A mean dynamic topography computed over the world ocean from altimetry, in situ measurements, and a geoid model, J. Geophys. Res., 109, C12032, doi:10.1029/2003JC002226.
• Thompson, D. W. J., and J. M. Wallace, 2000: Annular modes in the extratropical circulation. Part I: Month-to-month variability. J. Climate, 13, 1000-1016.

4th ESA EO Summer School on Earth System Monitoring and Modelling (Frascati, 4-14 August 2008)