Structure of the Antarctic Circumpolar Current in Drake Passage observed from satellite altimetry

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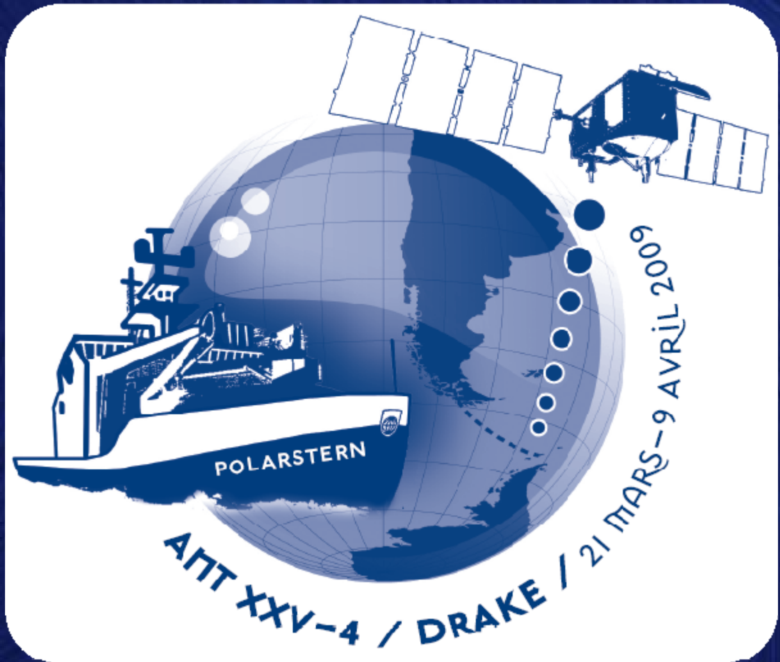
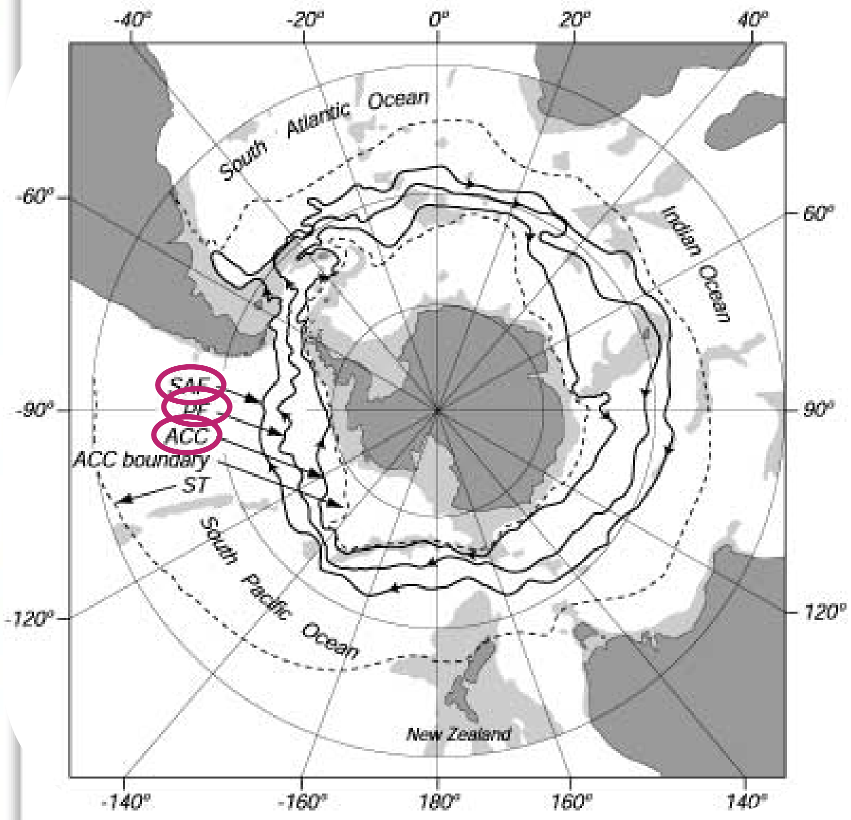
LOCEAN, CNES support



Altimetry for Oceans and Hydrology,
OST-ST meeting, 18 - 22 October 2010

Fronts of the Antarctic Circumpolar Current



Orsi et al. (1995)

Climatology:
3 deep reaching, intense eastward oceanic jets:

- Subantarctic front (SAF)
- Polar front (PF)
- Southern ACC front (SACCF)

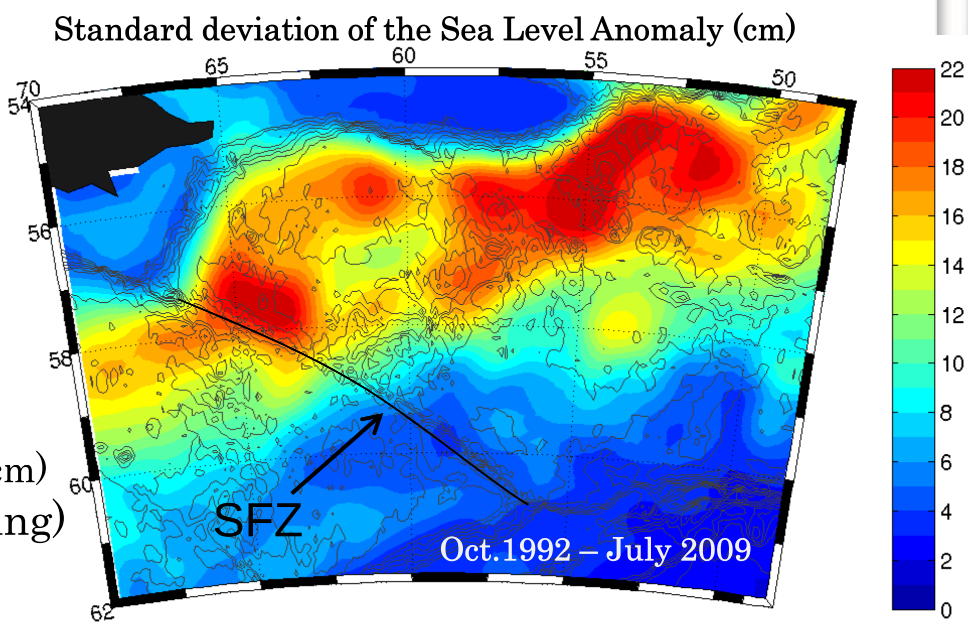
Recently, high resolution:

- Observations (e.g. Lenn et al., 2007)
- Models (e.g. Zhang and Klinck, 2008)
- Altimetry (Sallée et al., 2008, Sokolov and Rintoul 2007, 2009)

⇒ Structure of the ACC is more complex
Fronts divided into branches

Drake Passage:

- Complex bathymetry (in black)
  - Ridges (Shackleton Fracture Zone - SFZ)
  - Seafloor depressions
  - Seamounts
- Sea-level is highly variable (max ~22 cm)
  - Front movements (meanders, merging)
  - Eddy activity



In such complicated region …

… precise observation of the ACC frontal branches from altimetry?

✓ Structure and distribution of the branches and eddies
  - ➢ Maps of sea-surface height (SSH)

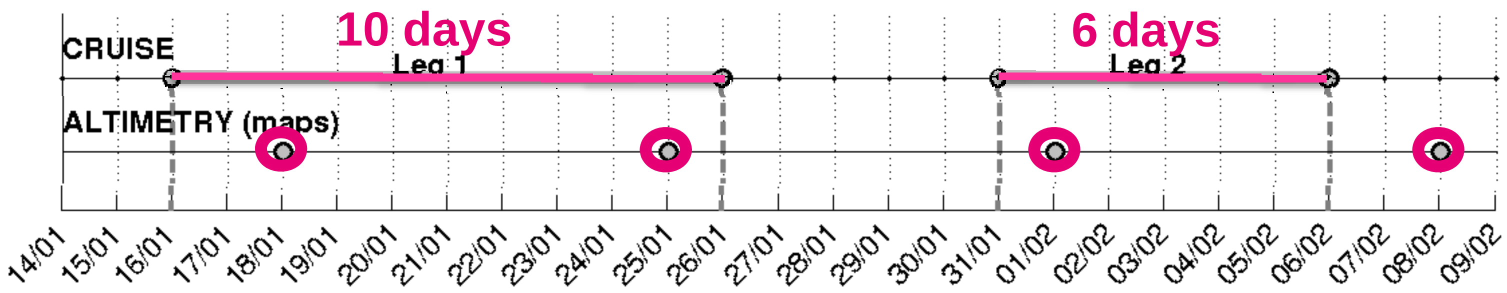
✓ Context of the DRAKE experiments:
  - ➢ 5 full depth hydro. sections (2005, 2006, 2008 and 2009) below Jason track
  - ➢ Barré et al., Deep Sea Res., IPY special issue

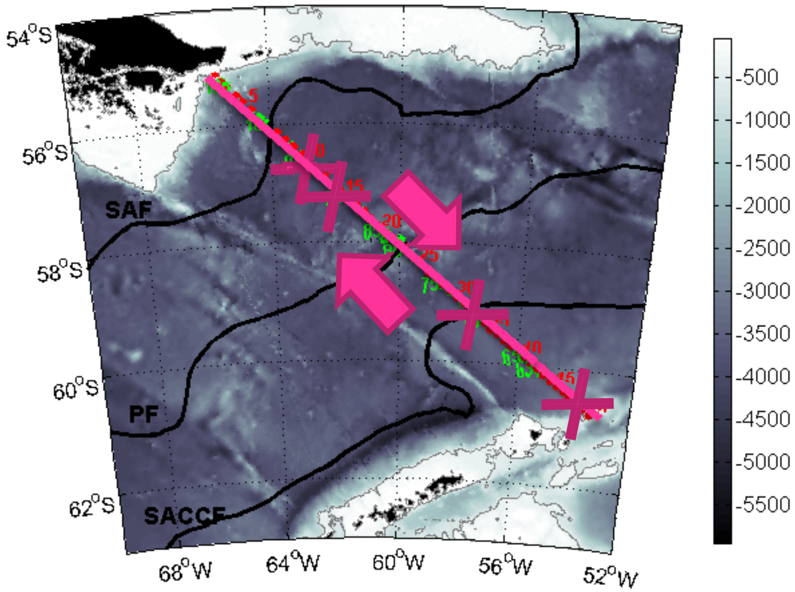
DRAKE 2006 = Unique !

Section repeated twice with high resolution in less than 3 weeks

+ Transects below Jason-1 ground track #104

⇒Excellent opportunity to compare altimetry and in situ data





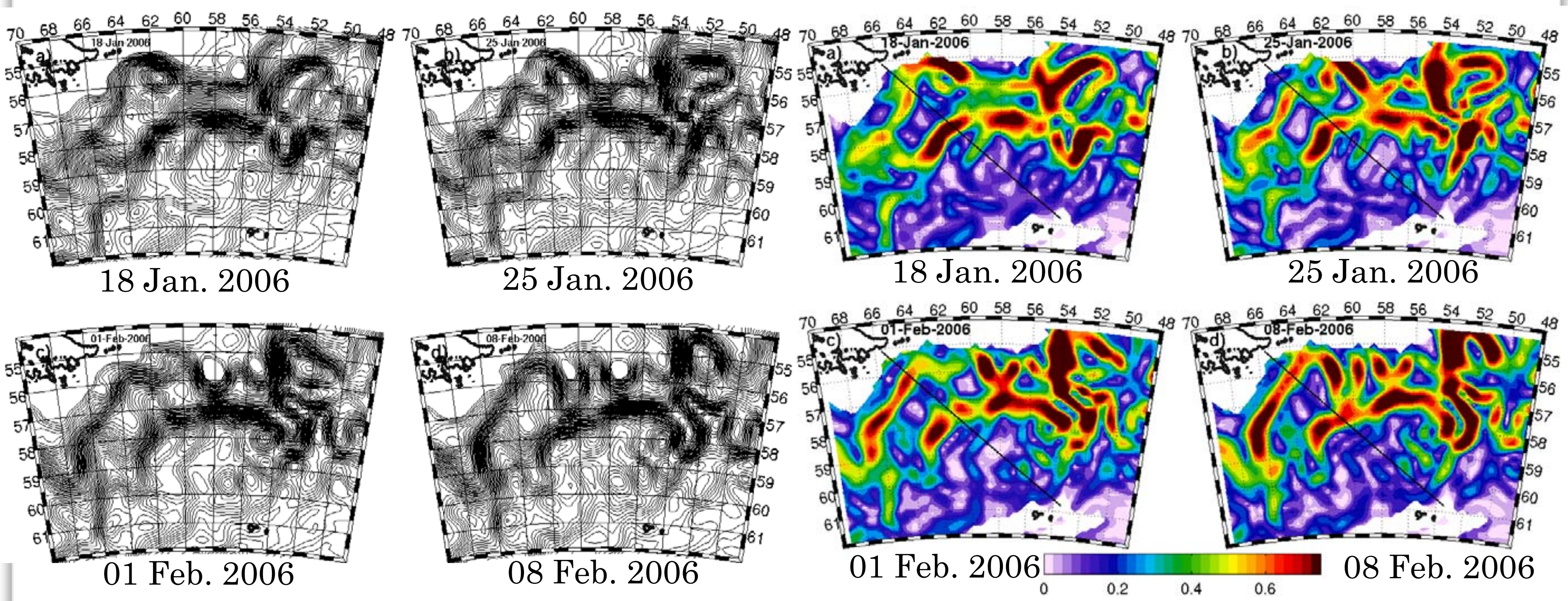
- 2006 oceanographic survey:
  - 51 CTD/LADCP stations (way south)
  - 43 CTD/LADCP stations (way north)
- Altimetry (Aviso):
  - Multi-satellite gridded products (1/3°)

Bathymetry (in m)

Black lines: ACC fronts from Orsi et al. (1995)

SSH (MDT CNES-CLS09)

SSH (isolines every 2 cm) SSH gradients (m/100km)

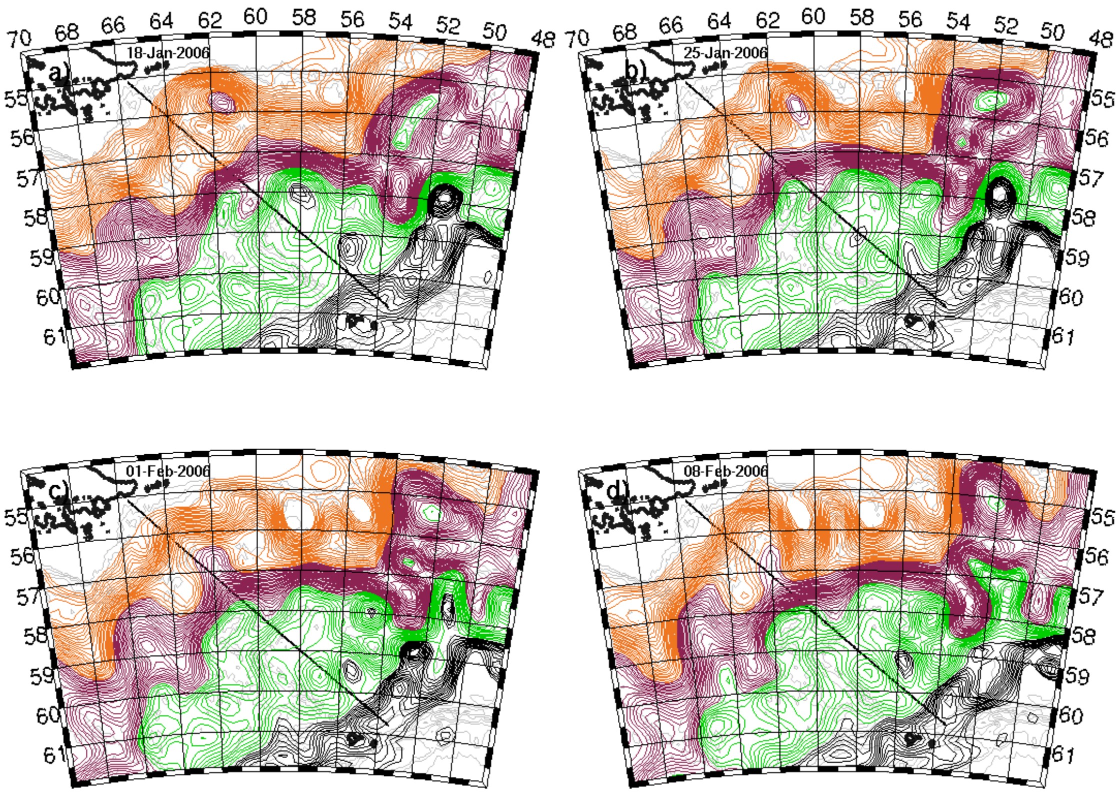


- Precise SSH isolines fit the gradient maxima = frontal branches
- Closed SSH isolines = eddies

ACC frontal branches in Drake Passage

Fitting the gradient maxima:

$\Rightarrow$ 8 SSH isolines, identical for the 4 maps



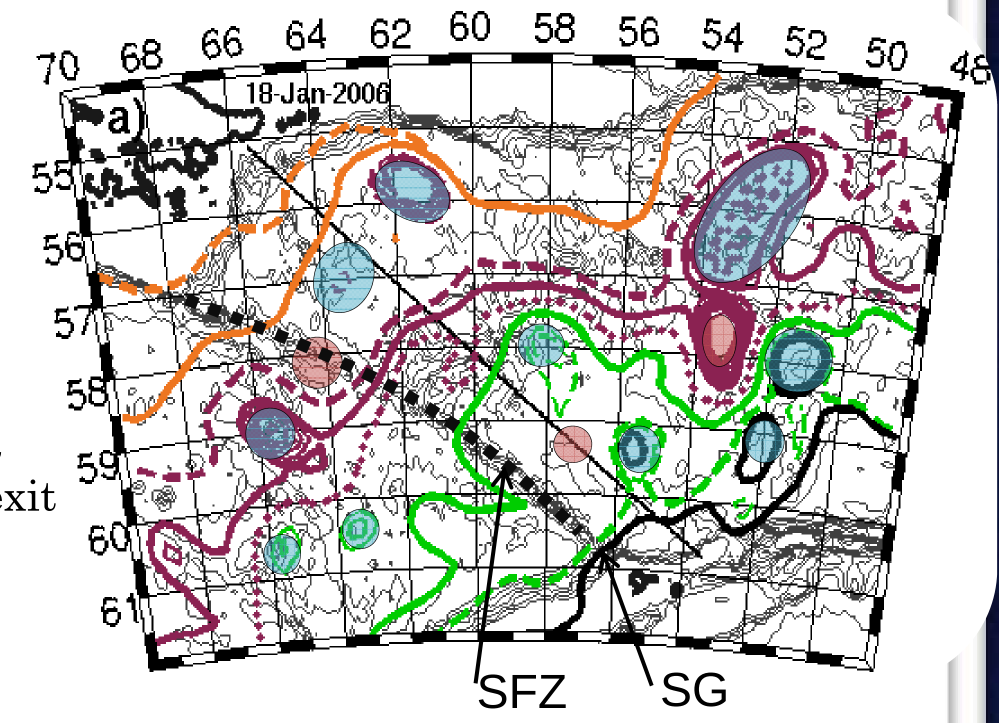
ACC fronts	SSH (cm)
SAF-N	23
SAF-M	-10
PF-N	-43
PF-M	-62
PF-S	-78
SACCF-N	-92
SACCF-S	-106

18 Jan. 2006

SAF:
- SAF-N follows continental slope
- SAF-M through a gap in SFZ
- joining at ~61°W before exiting

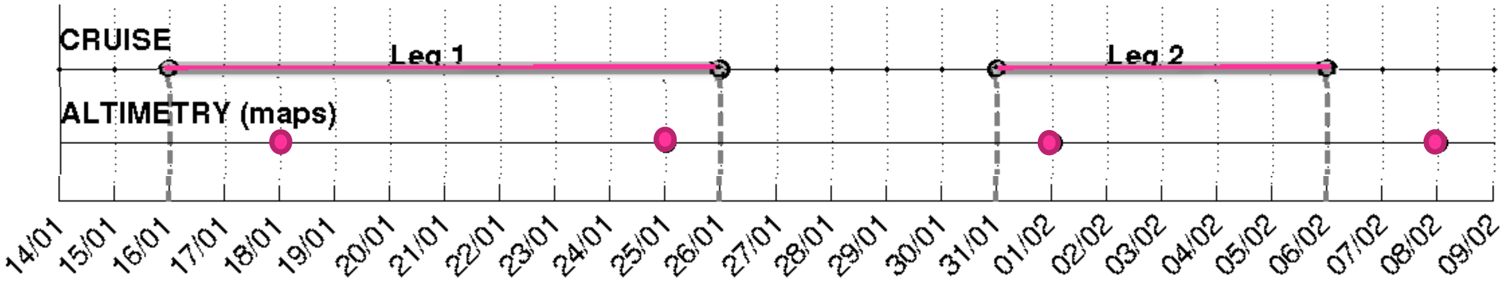
PF:
- 3 branches at the entrance
- go through a gap in SFZ
  ⇒PF-N & PF-M merge as a single front
- branches meander and separate at the exit

SACCF:
- SACCF-N, constrains by SFZ
  ⇒joins the PF-S + meanders
- SACCF-S, through SG + meanders



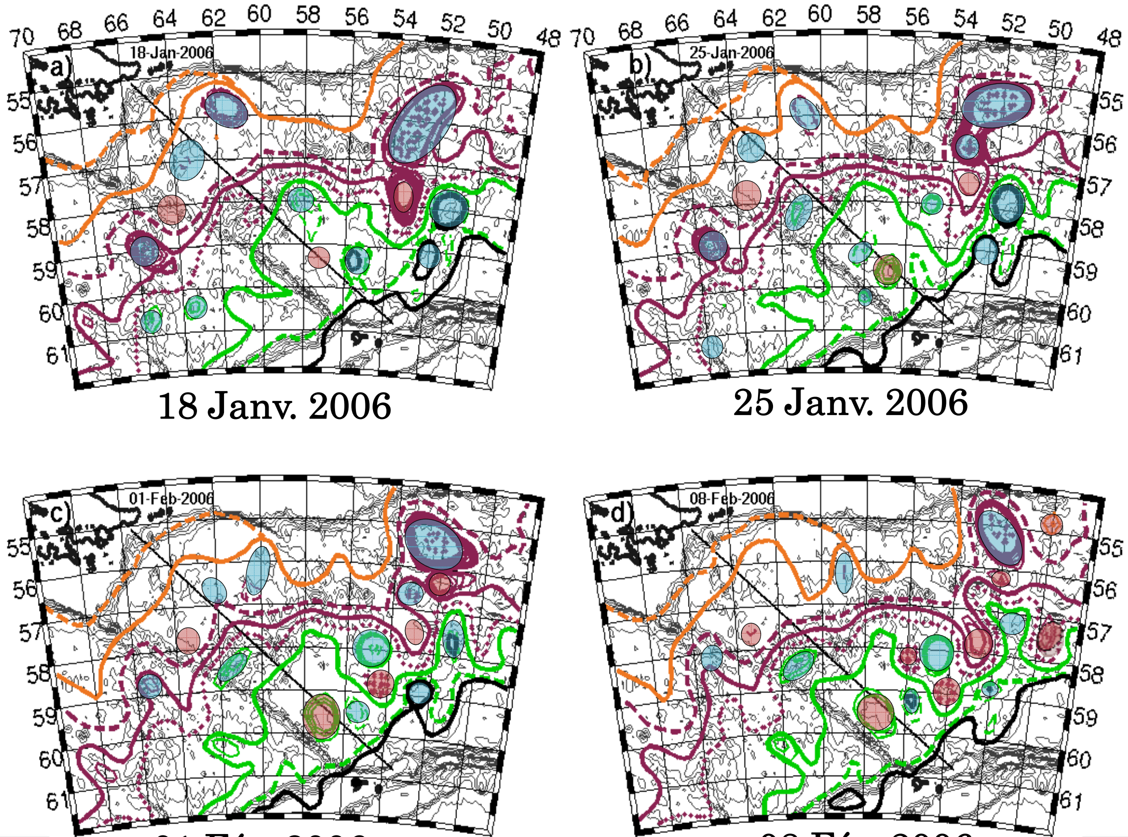
Closed SSH isolines = eddies:
Cylconic
Anticyclonic

4 maps during the cruise

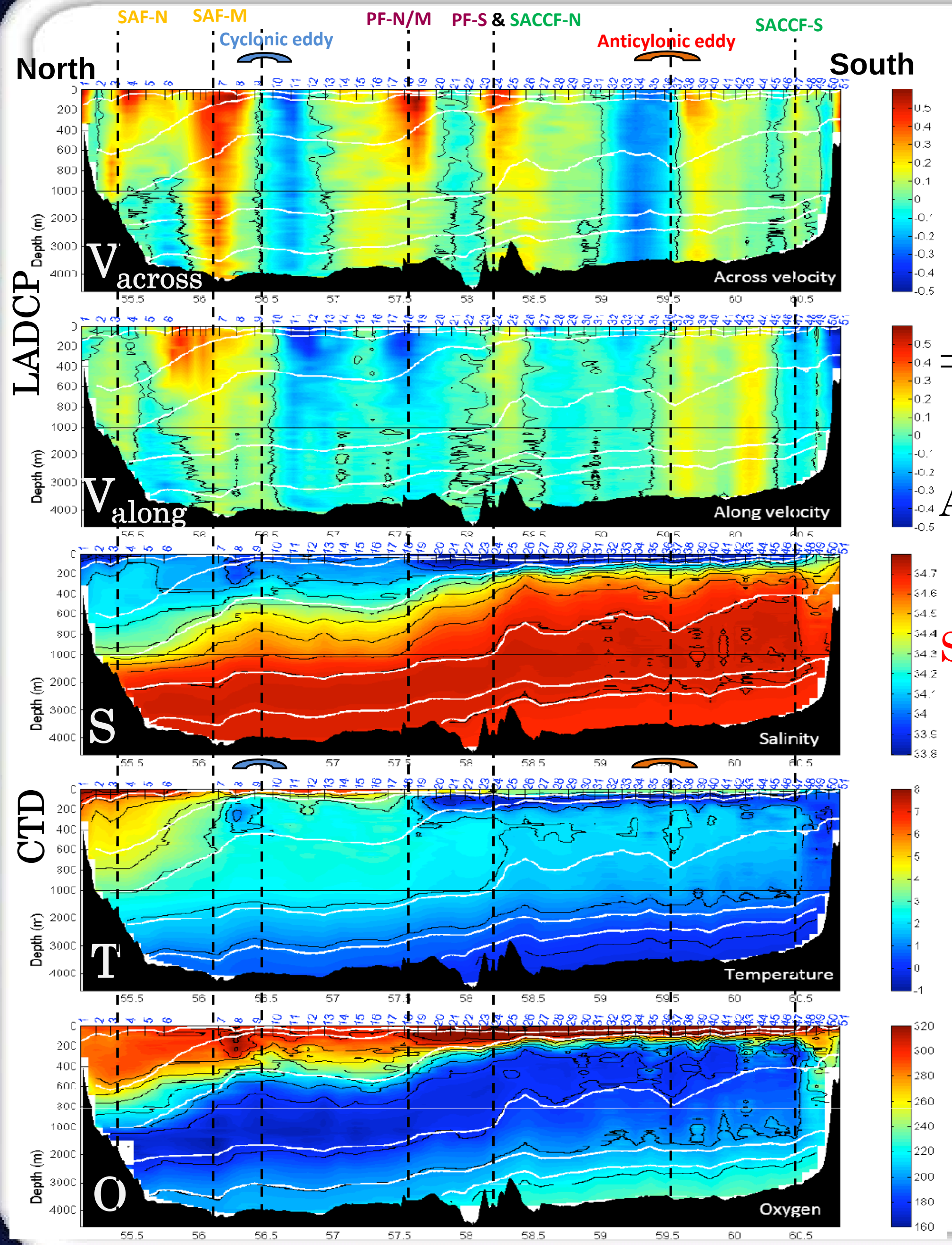


Position & evolution branches + eddies

⇒ Comparison with in situ data



18 Janv. 2006 — 25 Janv. 2006 — 01 Fév. 2006 — 08 Fév. 2006



Leg 1 (way south)

51 stations, full depth

⇒Branches (altimetry) coincide with:

- Maxima of the velocities
- Meridional gradients of T, S, O and γ^n

Agreement with traditional hydro. criteria

SSH isolines

= efficient to determine the position

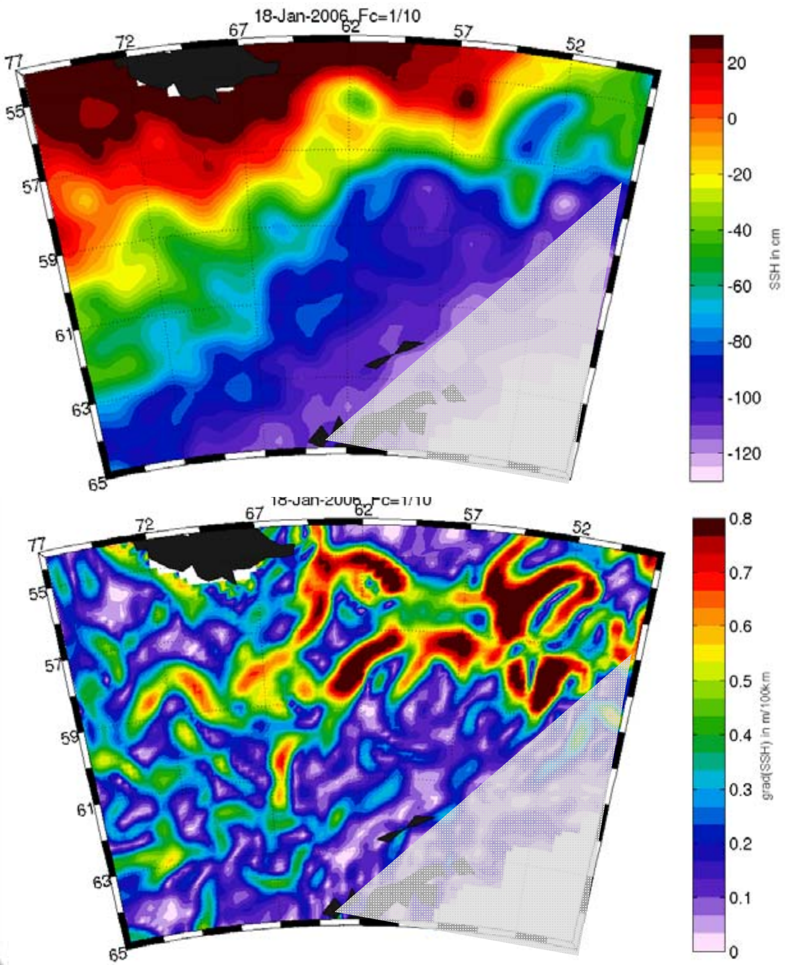
- branches of the ACC fronts
- eddies

⇒ Spatial and temporal context of the cruise

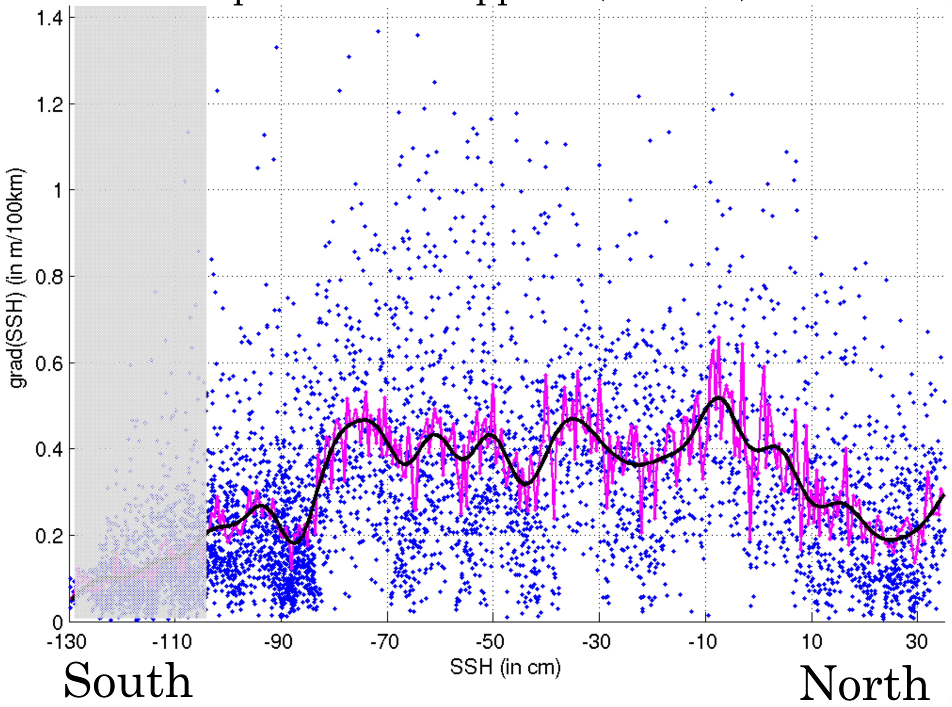
Frontal branches in altimetric long time-series ?

Systematic identification of the branches

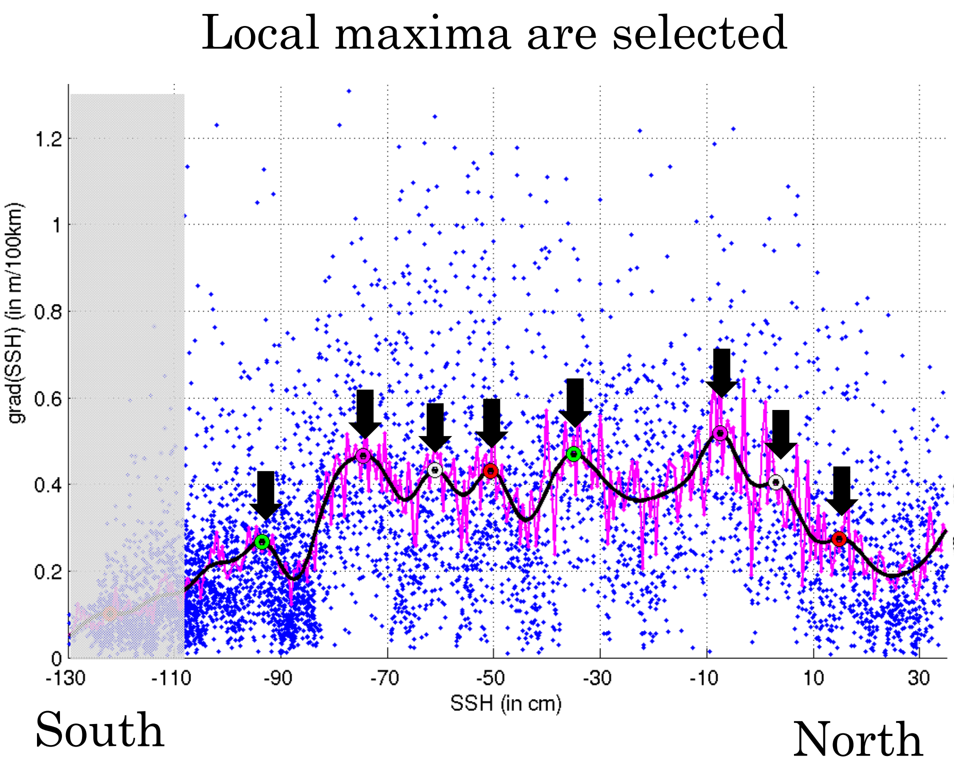
Example of the process:18 January 2006 (same as 1st study)

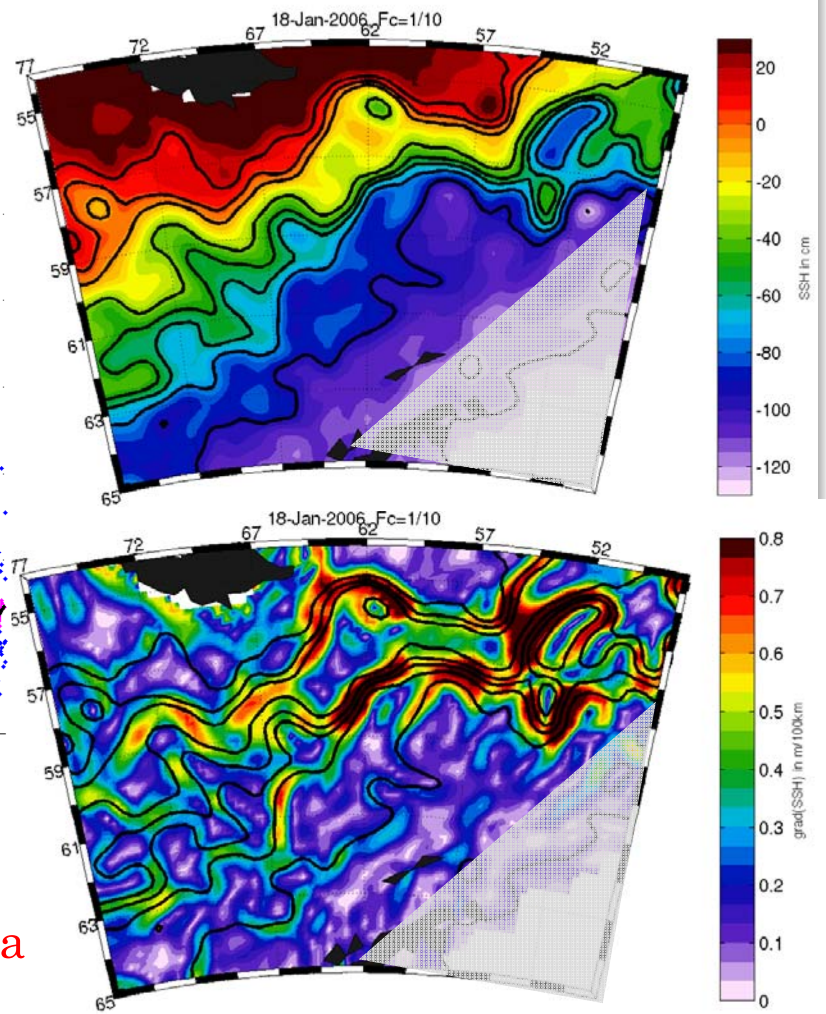


- Scatter plot: SSH vs. grad(SSH)
- An average gradient is computed (in pink)
- Low-pass filter is applied (in black)



Systematic identification of the branches



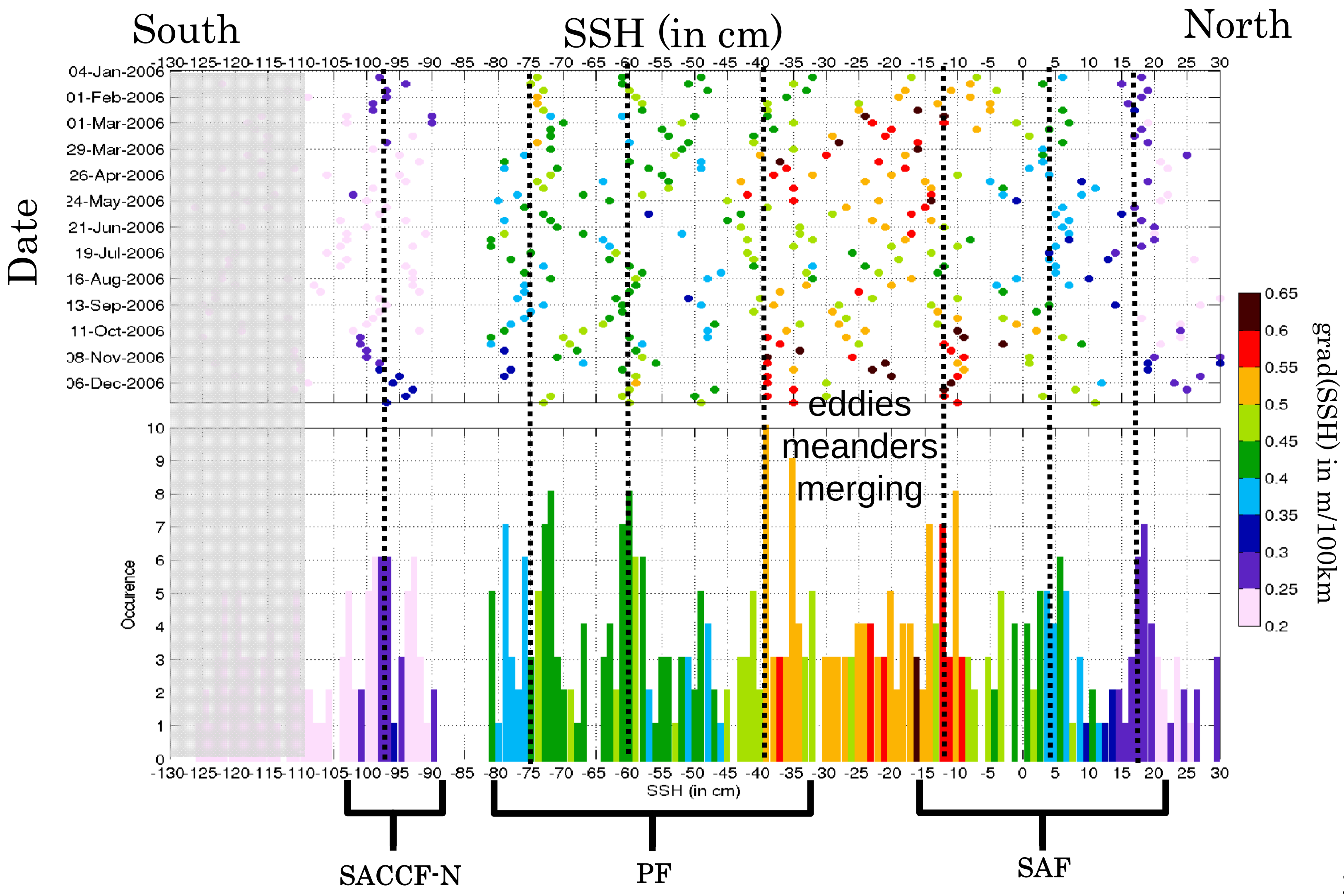


⇒ Main branches of the ACC fronts

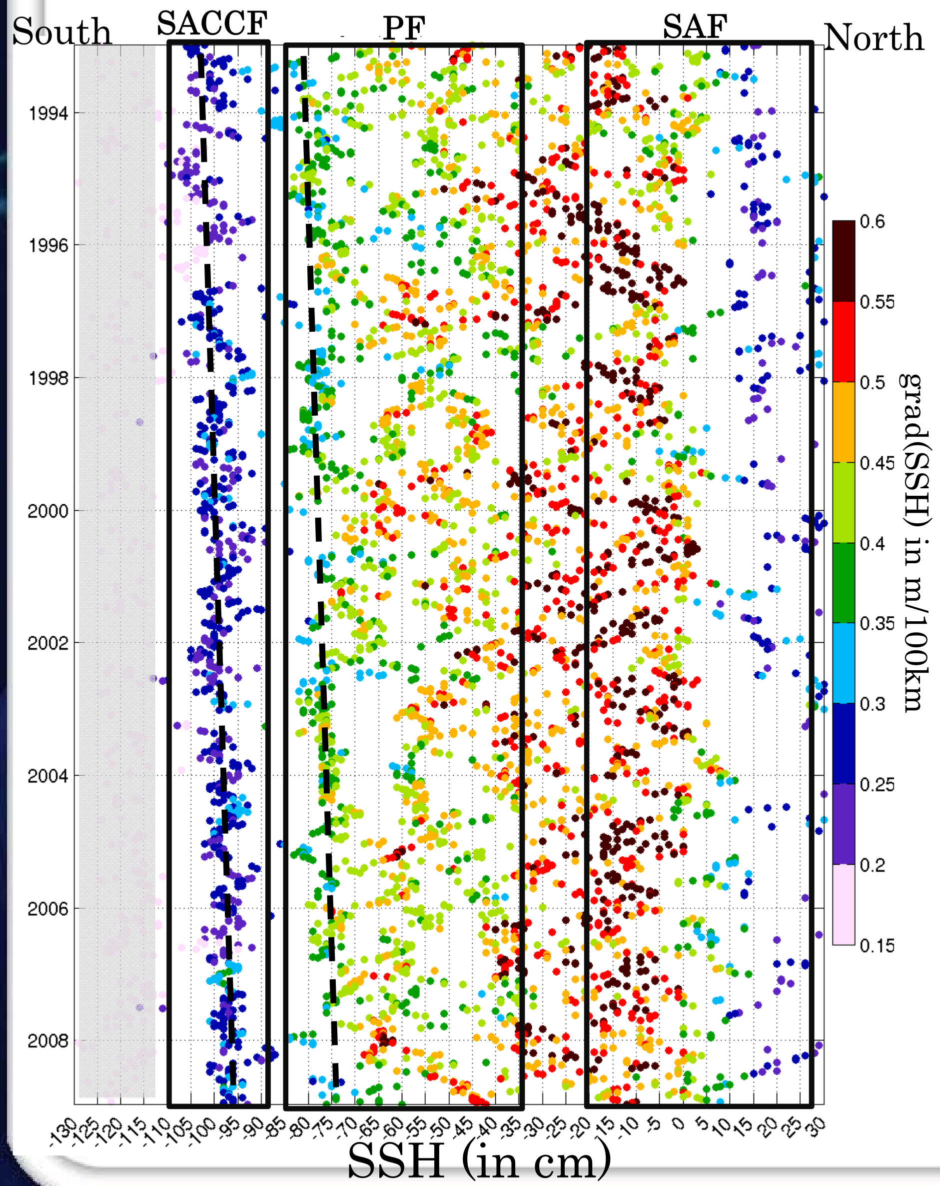
⇒ SSH isolines fit the gradient maxima

⇒ Good agreement with the 1^{st} study

Year 2006


South
SSH (in cm)
North
Date
Occurence
grad(SSH) in m/100km
eddies
meanders
merging
SSH (in cm)
SACCF-N
PF
SAF

Entire altimetric dataset



SAF northern branch:

- low gradients (<0.3 m/100km)

SAF main branch :

- intense gradients (>0.45 m/100km)

PF :

- branches merge and diverge + eddies
- cover large range of SSH (-85cm => -35cm)

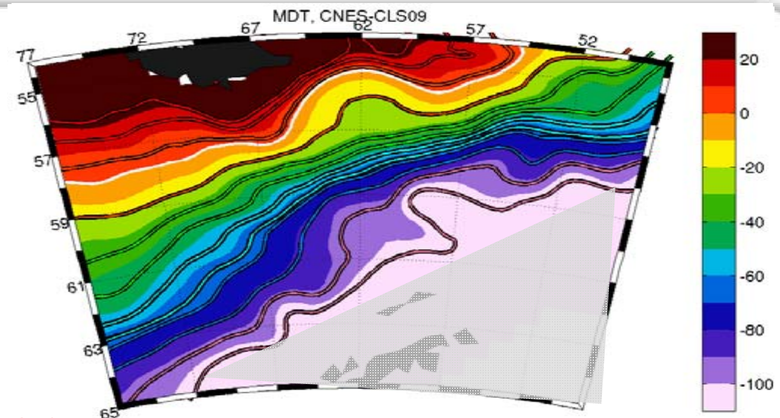
SACCF northern branch

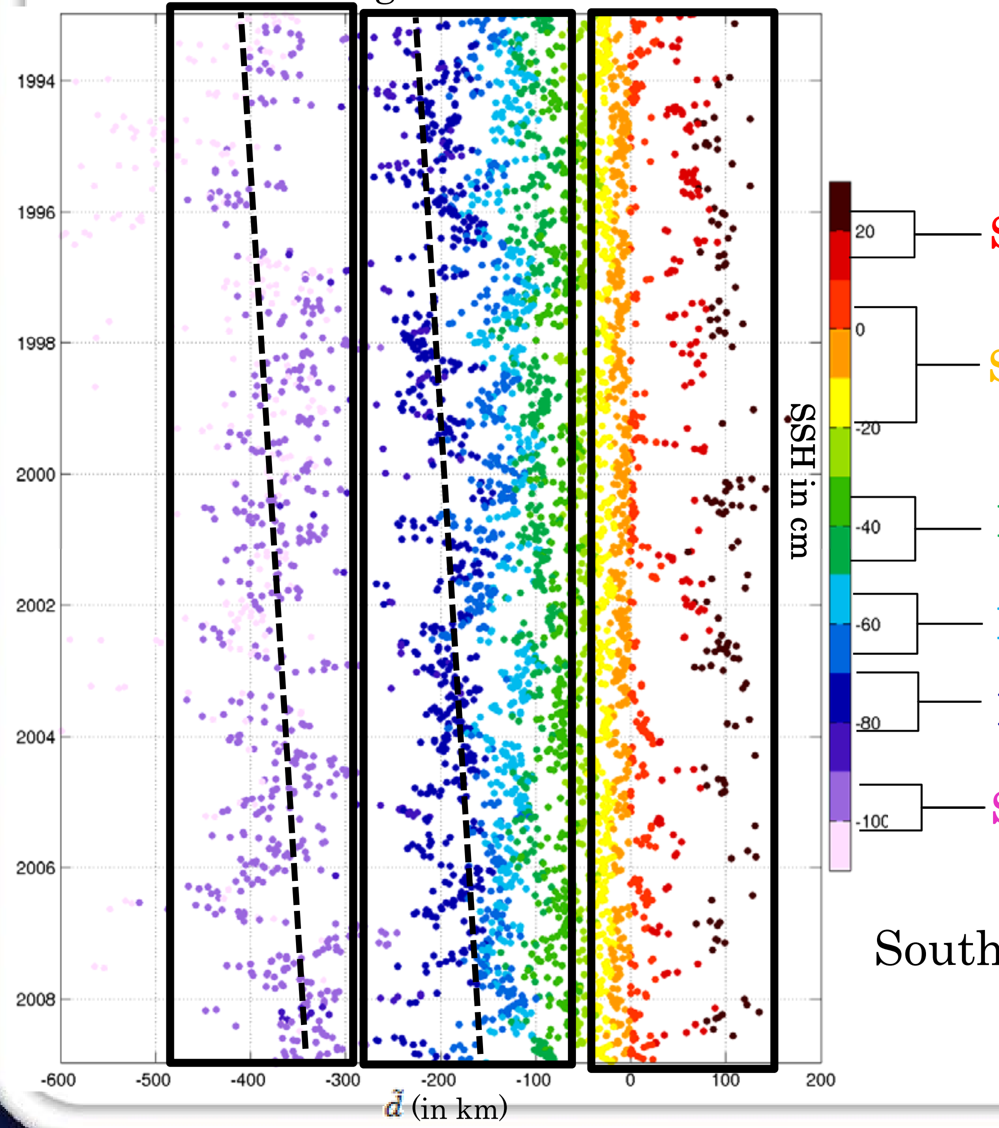
Shift towards higher values of SSH
(southern branches: SACCF-N & PF-S ~+5cm)

SSH values in time …. and space?

SSH in a space and time domain:

$$\frac{SSH}{\nabla SSH} = \tilde{d}$$ Pseudo-distance (in km), Origin = 0 cm SSH





SAF-N

~90 km

SAF-M

~60-80 km

PF-N

PF-M close to PF-N 1993-2002 close to PF-S 2002-2008

PF-S oscillates over ~100 km

SACCF-N spreads out over ~150 km

Southern branches:
shift towards the "north" ?

Summary - work in progress

- DRAKE 2006:
  - 8 branches identified precisely (2 SAF, 3 PF, 2 SACCF and 1 SB)
  - Strongly constrain by the bathymetry (SFZ) => forcing the branches to merge or diverge
  - Agreement with in situ (CTD, LADCP)

  ⇒ SSH isolines efficient to identify the branches and eddies in DP

- Frontal branches in DP over the entire altimetry dataset?
  - Branches = local maxima from a mean profile of SSH vs. gradient
  - Groups of SSH values are associated to each branch
  - Southern branches (SACCF-N and PF-S) tend to shift towards higher SSH values over the 16 years (+5 cm)

    ⇒ Is it associated to northward shift?

- Additional analyses are carried out !
  - Northward shift ? Grad(dx,dy) ?
  - Regional studies upstream & downstream DP

THANK YOU !