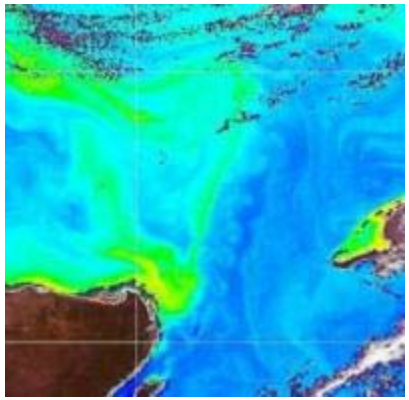
The Loop Study in Mexican Waters: The Loop Current Along the Yucatan

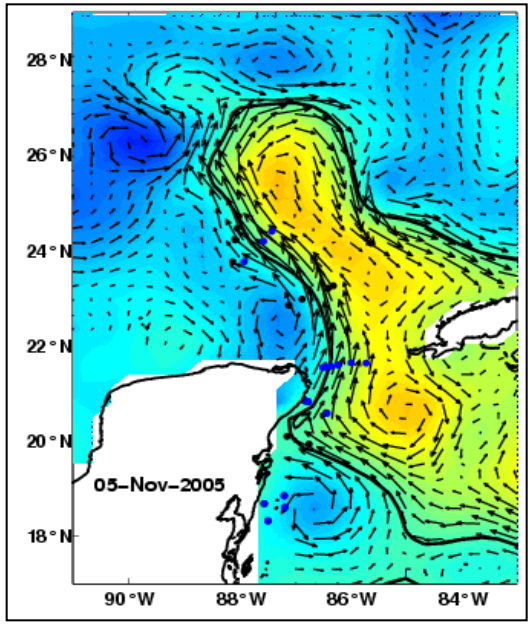


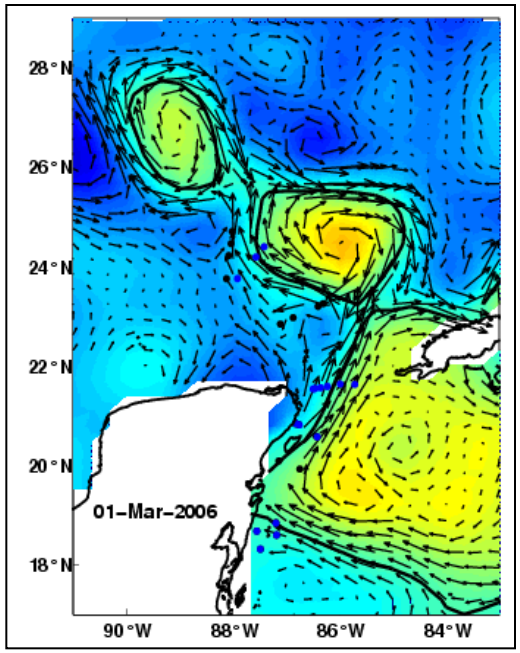
BOEMRE INFORMATION TRANSFER MEETING, New Orleans, March 2011

- Julio Sheinbaum
- Julio Candela
- José Ochoa
- Gabriela Athié
- Fernando Andrade
- Enric Pallas-Sanz

Physical Oceanography

CICESE





Bureau of Ocean Energy Management

30 años CICESE

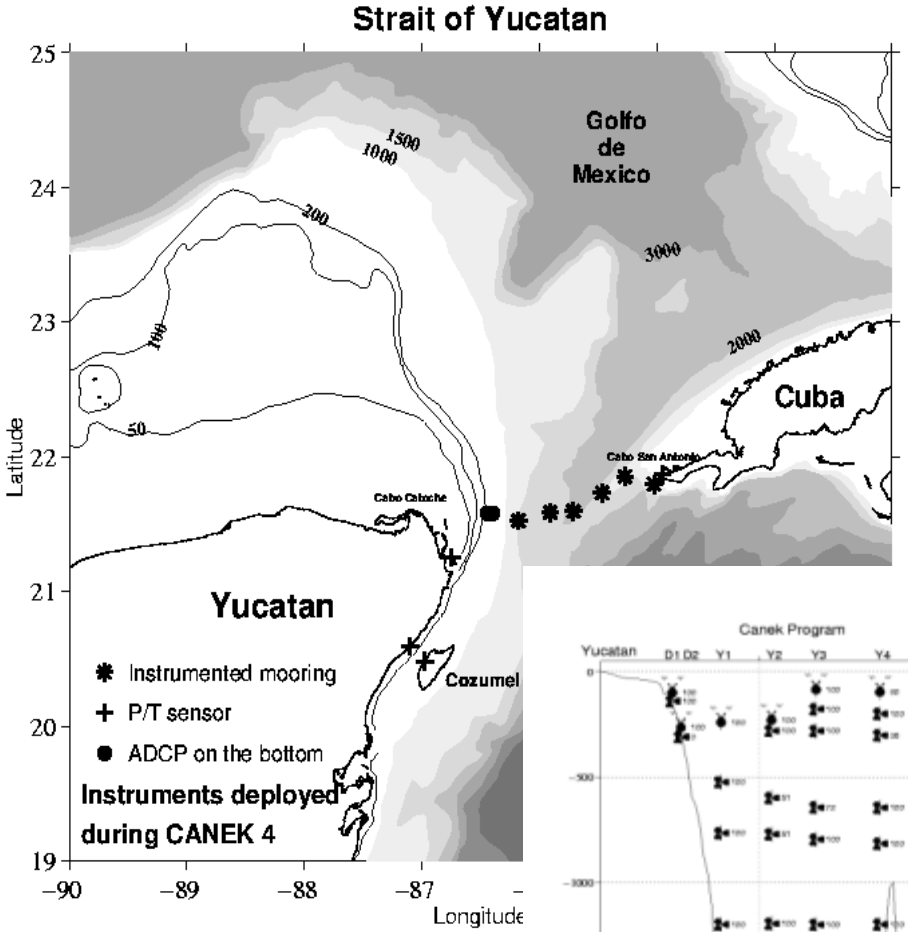
CONACYT 40 AÑOS

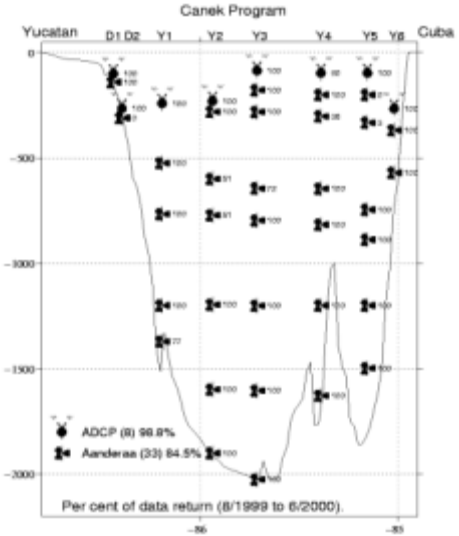
Summary

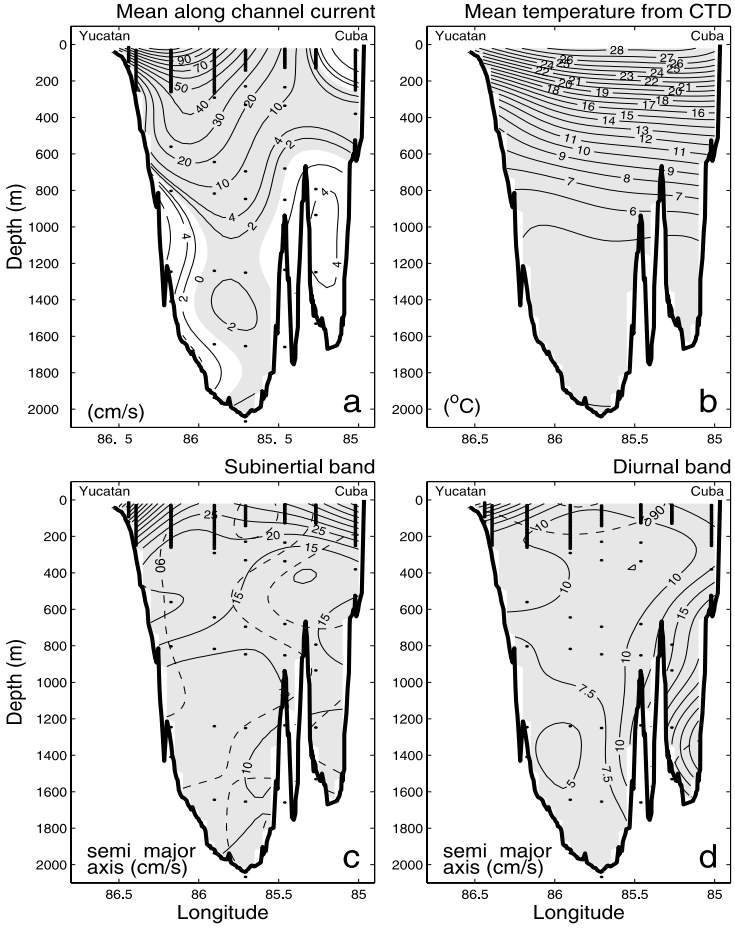
- Brief history of measurement program
- Main features of the YC and LC along the Yucatan
- LCE eddy separation:
  1. Meanders and Shears: Displacement to the east
  2. Hurricane Wilma: Western Caribbean cyclonic eddies and LCE detachment
  3. Propagation of signals along the Yucatan coast
- A Lagrangian view of LCE separation: Can we determine when it will be fully detatched?
- Summary and future work

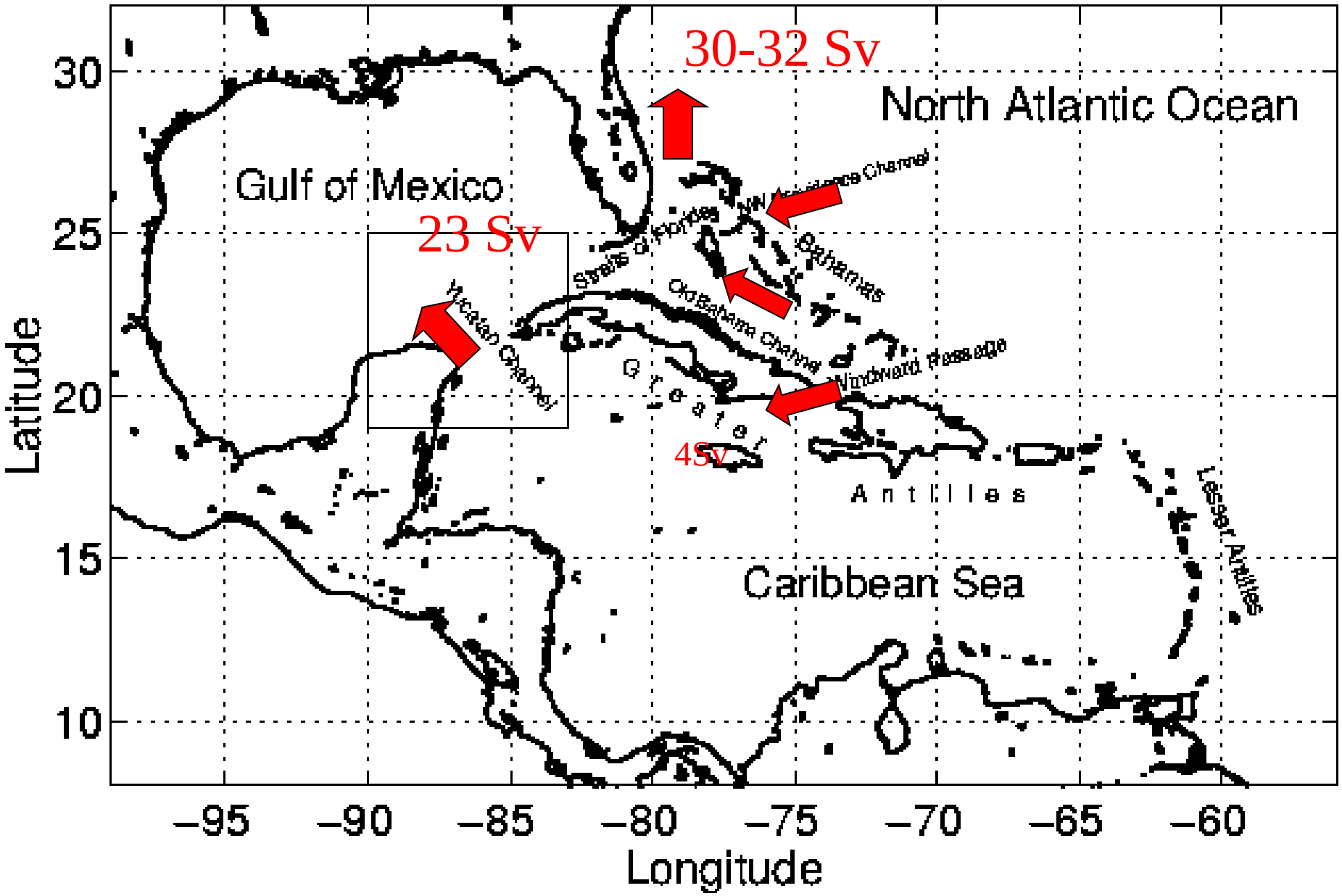
THE FLOW THROUGH YUCATAN CHANNEL

Observation Period 8/1999 – 7/2001

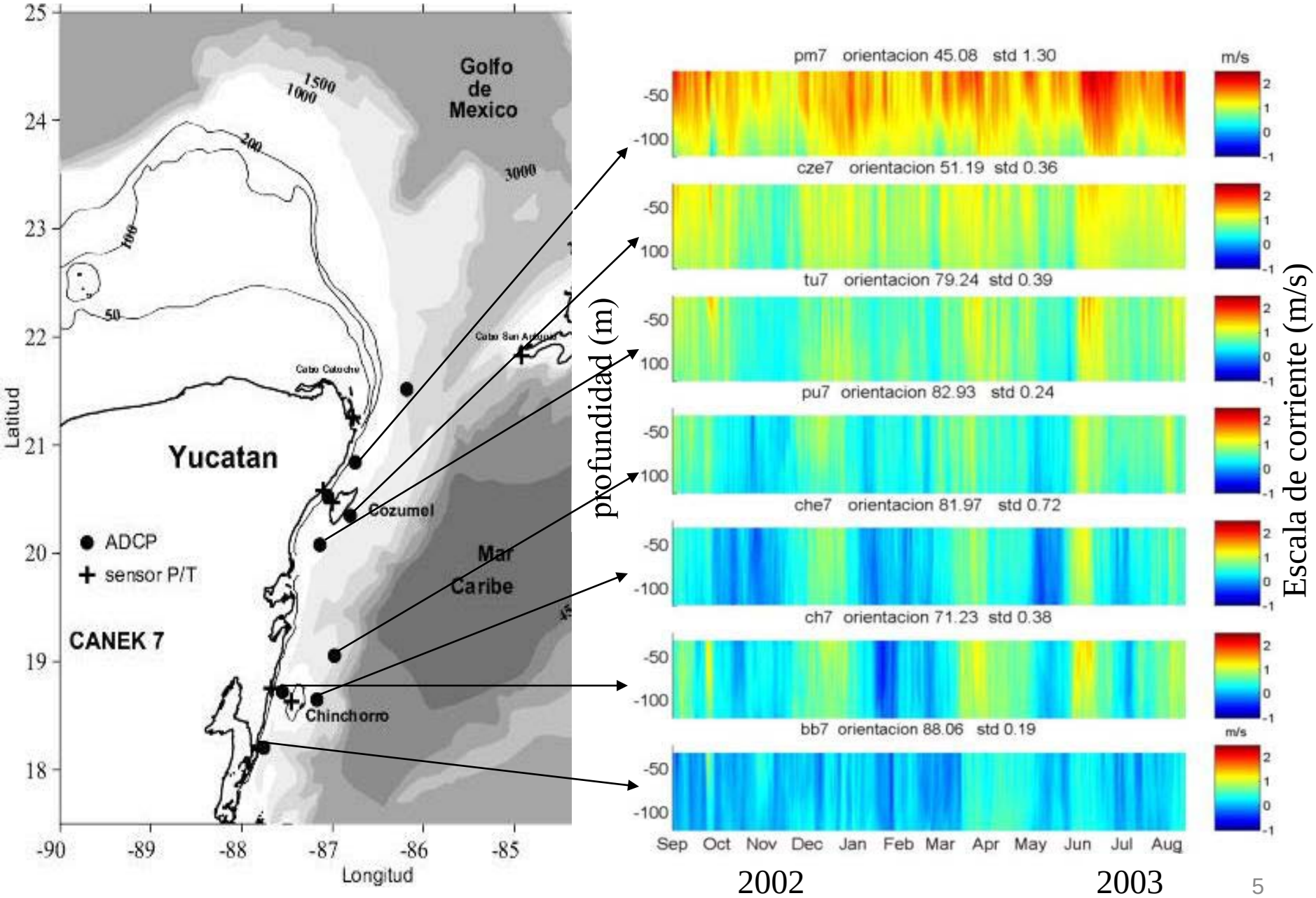




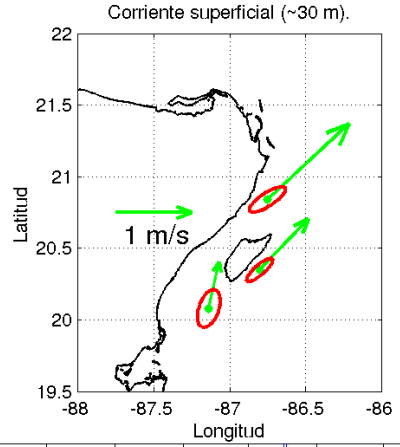


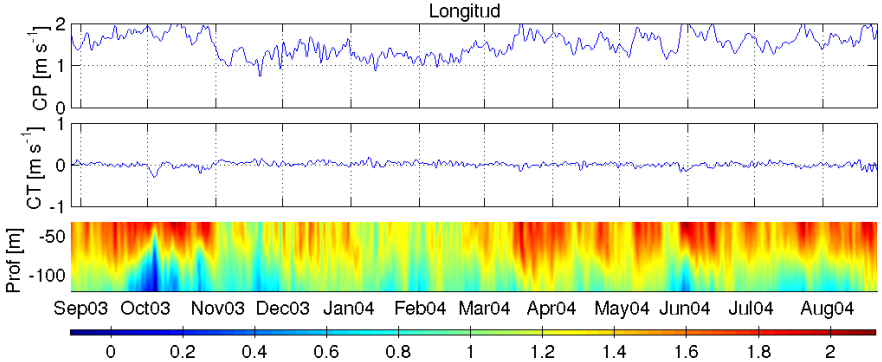

30-32 Sv
North Atlantic Ocean
Gulf of Mexico
23 Sv
Yucatan Channel
Straits of Florida
NW Providence Channel
Bahamas
Old Bahama Channel
Windward Passage
Greater
Antilles
45v
Lesser Antilles
Caribbean Sea
Latitude
Longitude
30
25
20
15
10
−95
−90
−85
−80
−75
−70
−65
−60

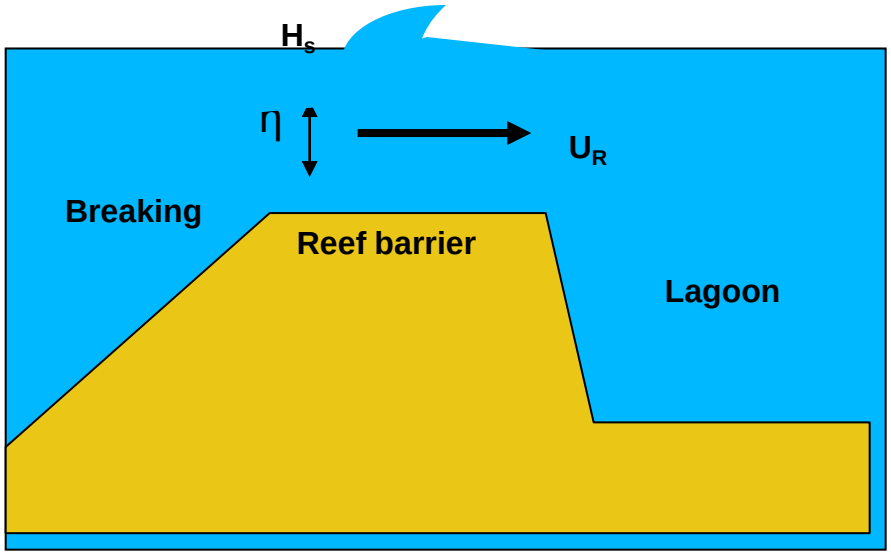
Observed currents along their principal axis.

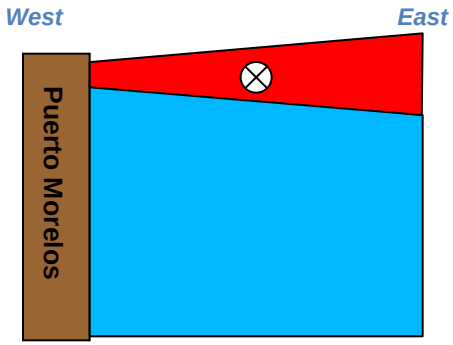


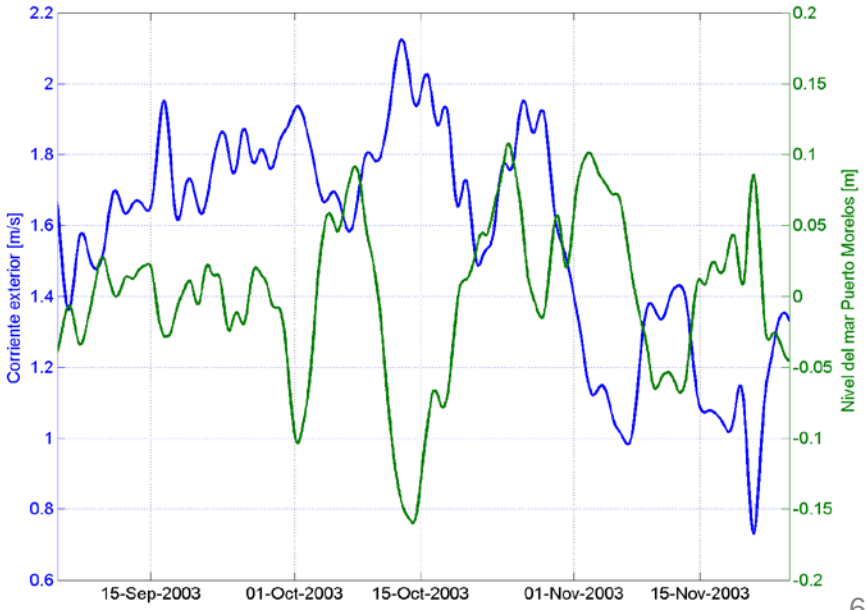
The strong connection between the Yucatan Current and the flow in the reef lagoon (Coronado 2007)



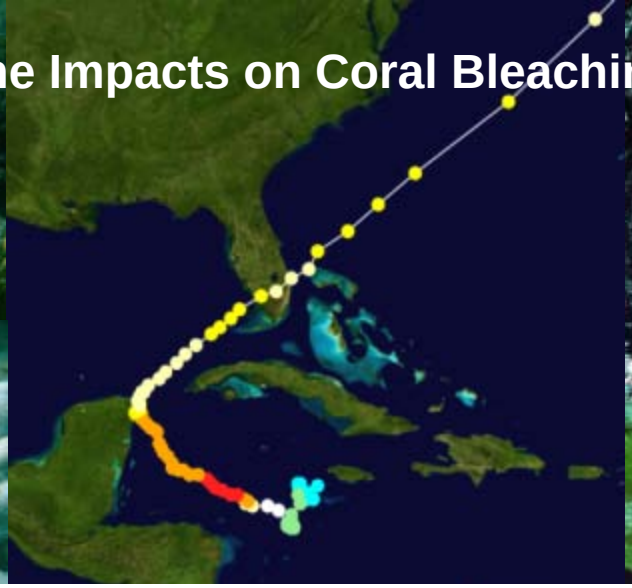


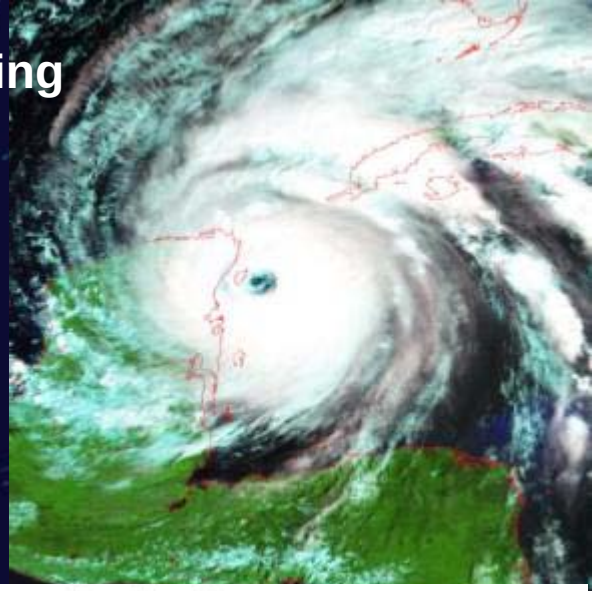


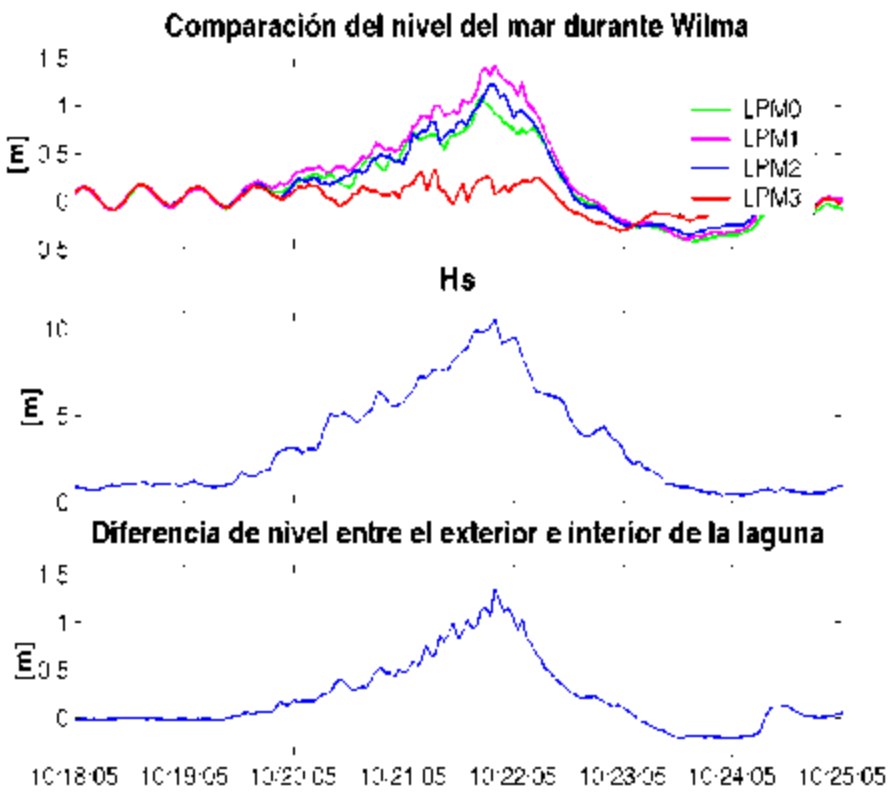


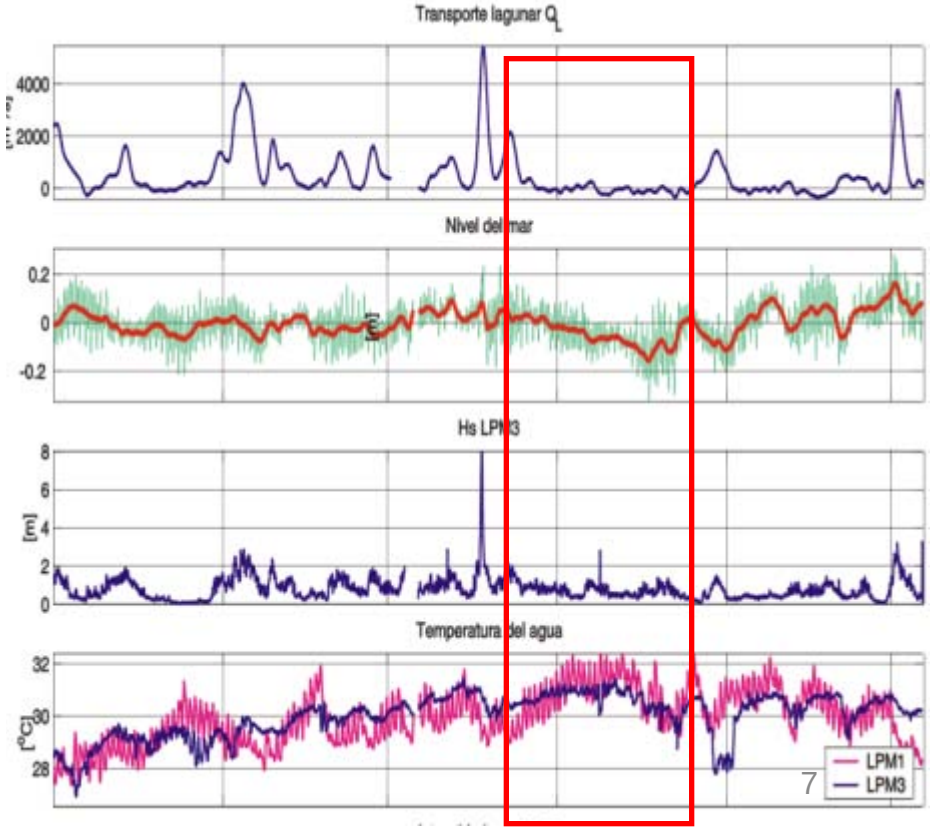


Hurricane Impacts on Coral Bleaching







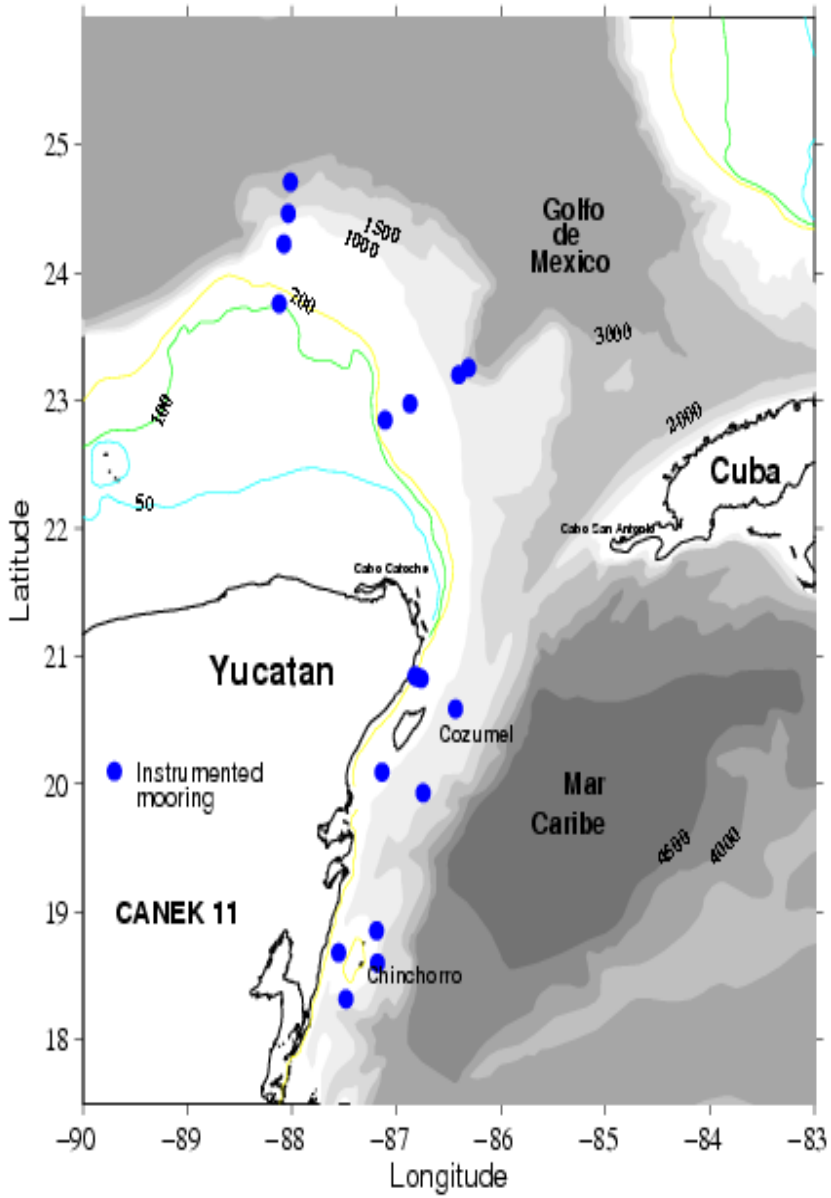


Summary of Mooring Measurements Canek Project

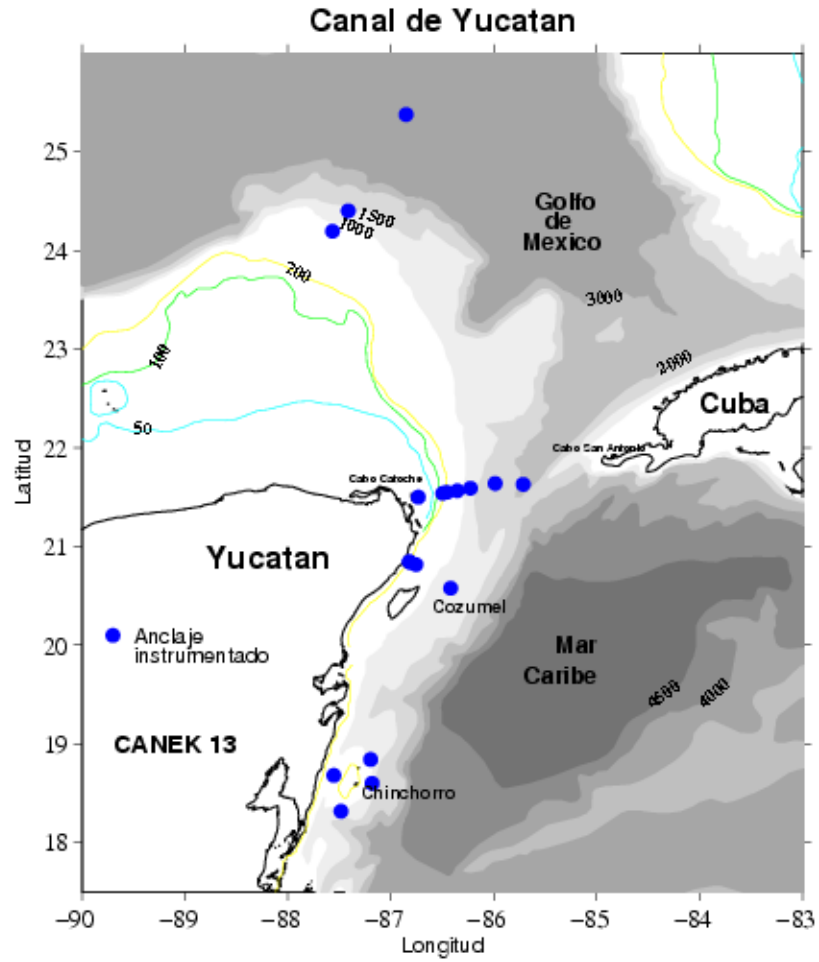
Summer	Caribbean	Yucatan	Loop Current
1999		X	
2000		X	
2001		X	
2002	X		
2003	X		
2004	X		
2005	X		
2006	X		X
2007	X		X
2008	X	X	X
2009	X	X	X
2010	X	X	X
2011	X	X	X
2012	X	X	X

Instrumentation in the Caribbean and the Gulf of Mexico

Moorings in place from 04/2006 to 02/2008 (~22 months).



Moorings in place from 02/2008 to 06/2009 (~15 months)

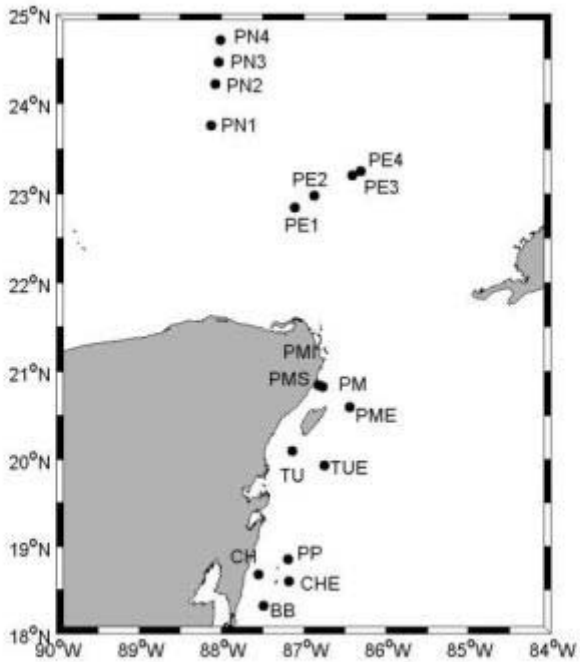


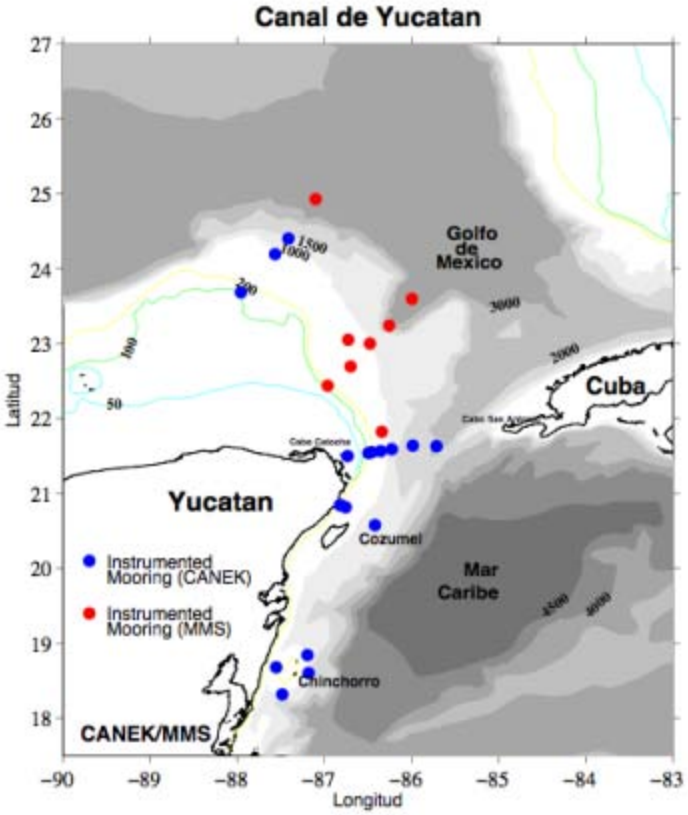
2009 LC STUDY (BOEMRE)

SUPPORT FOR 8 MOORINGS

Bureau of Ocean Energy Management, Regulation and Enforcement

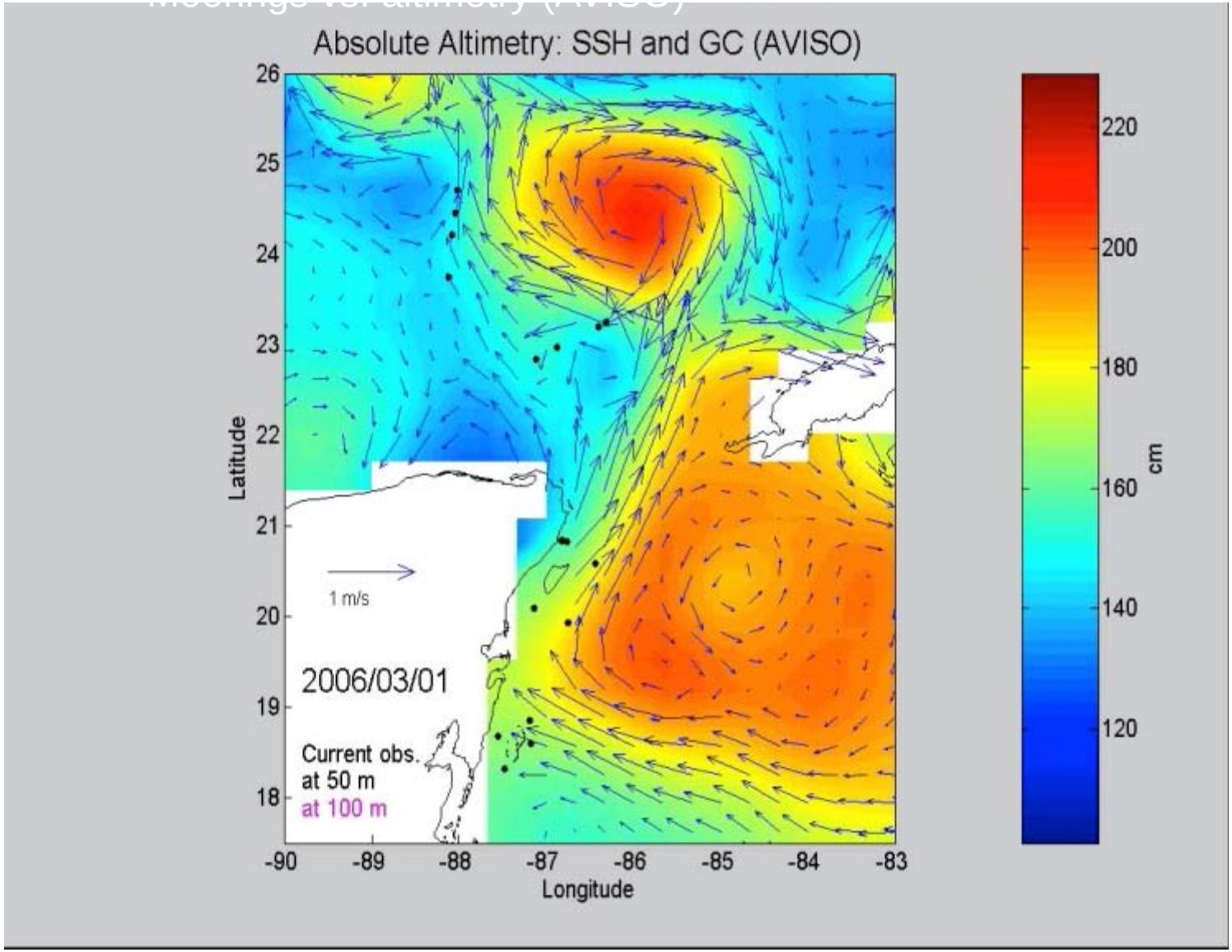
ARRAY 2006–2008



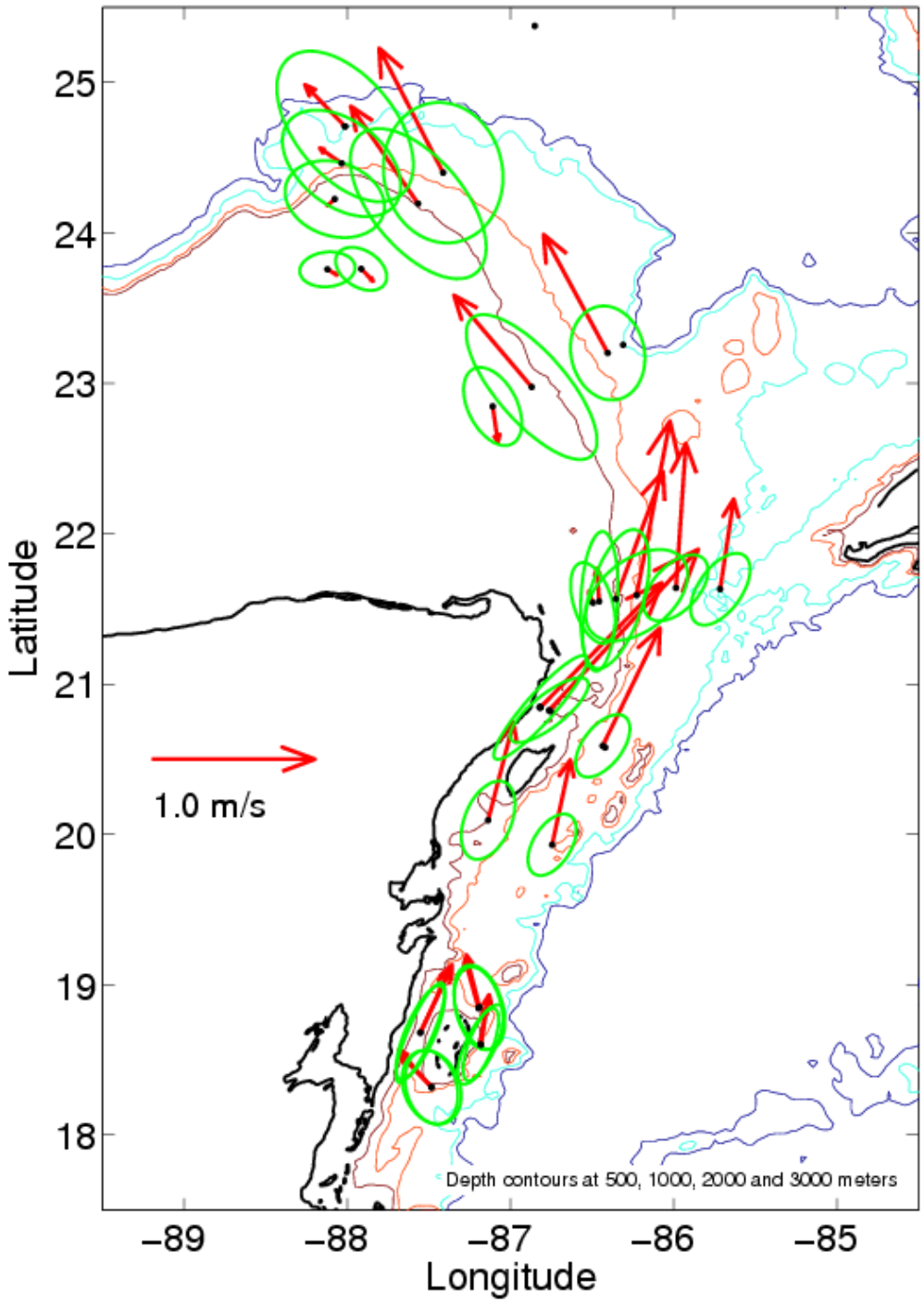


2009–2010

Mooring Velocities vs AVISO Geostrophic Velocities



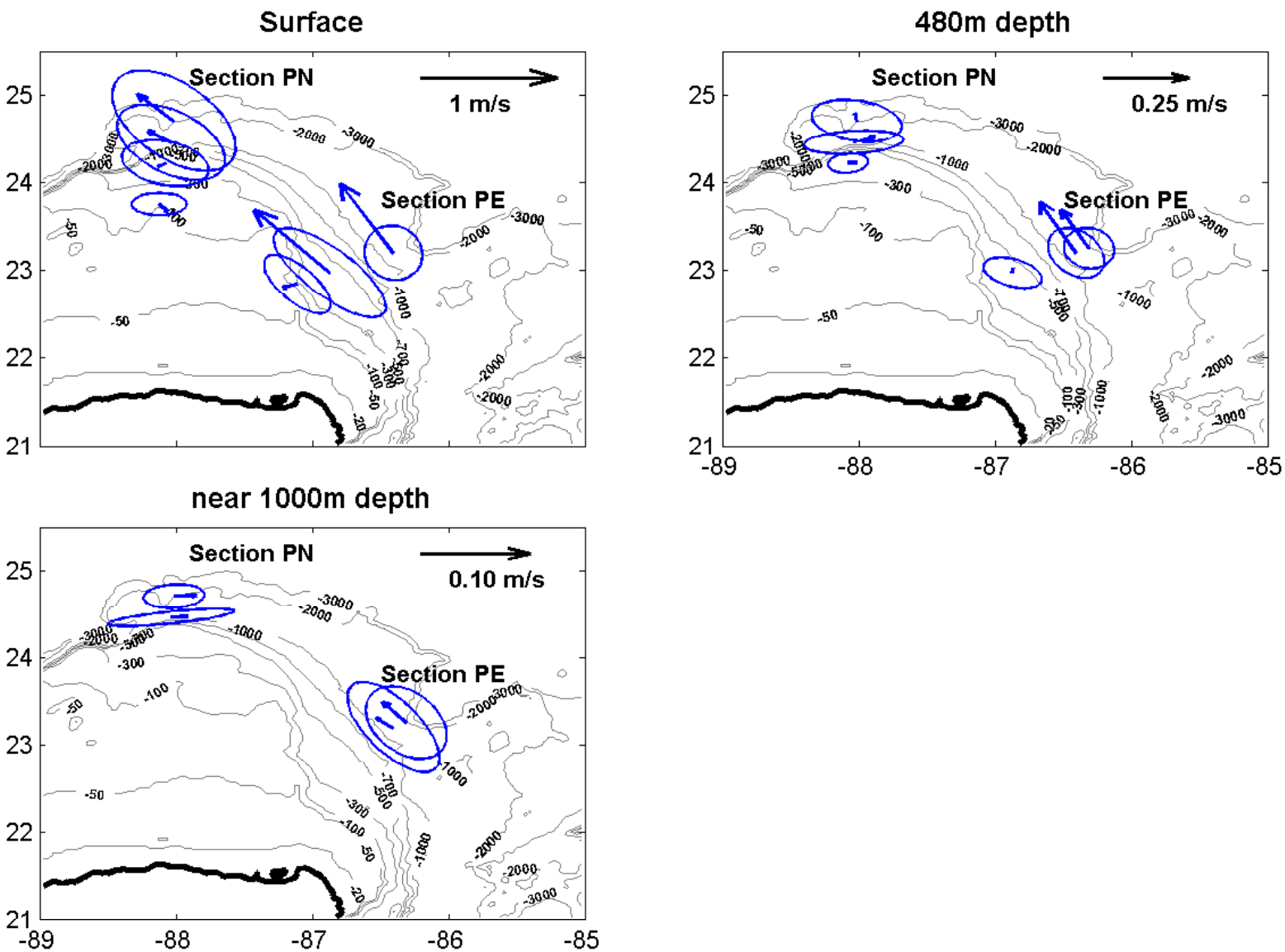
The altimeter products were produced by Ssalto/Duacs and distributed by Aviso, with support from Cnes (http://www.aviso.oceanobs.com/duacs/)



Mean Current and Variability Ellipse at 50 m

Statistics made with more than 1 year of observations at each location

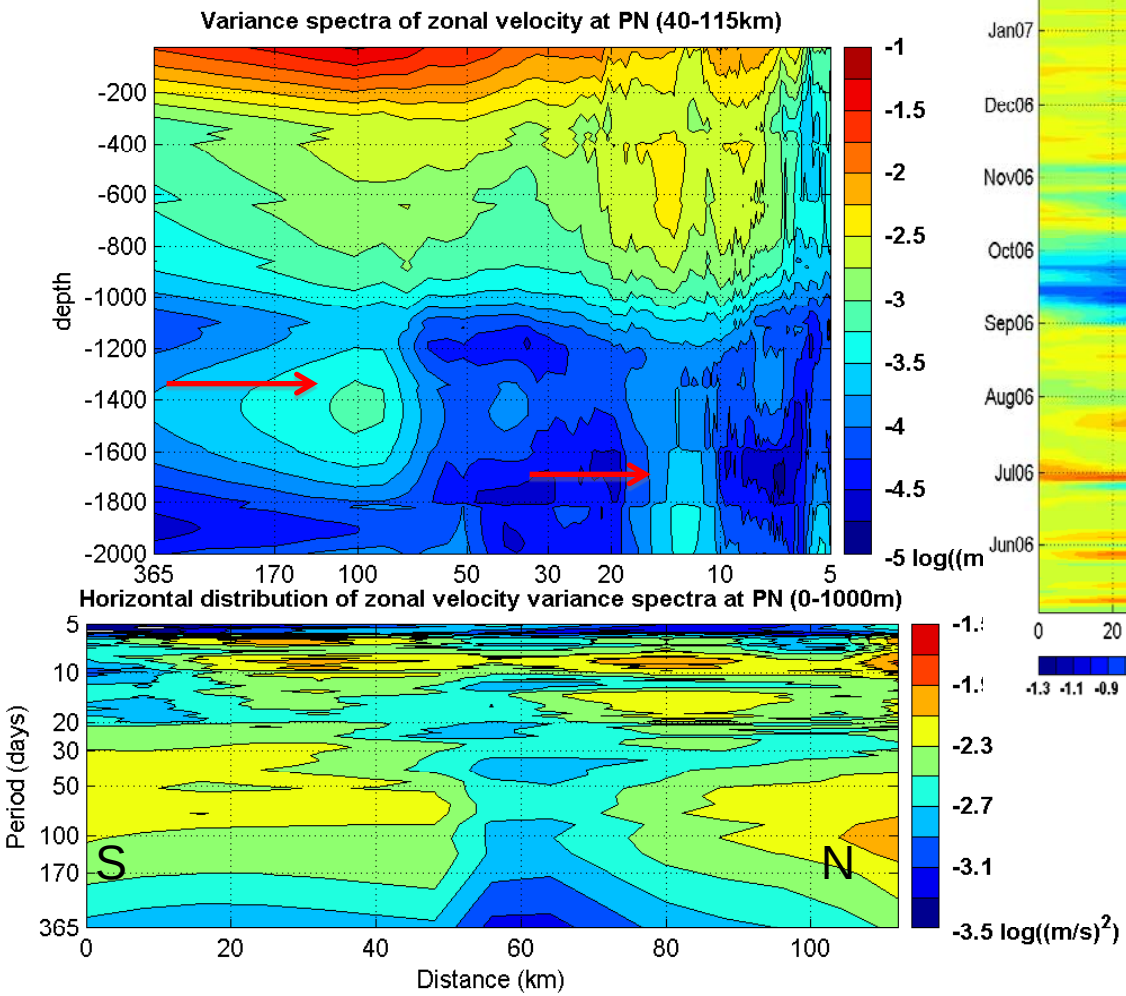
Deep Flow Signals

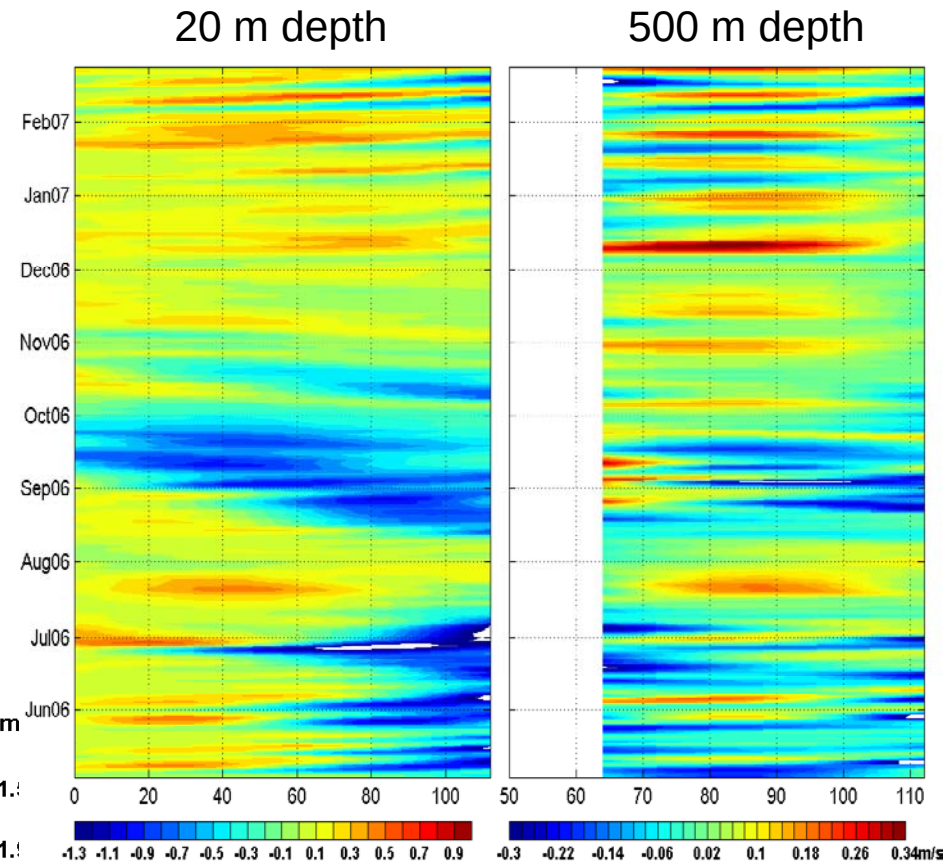


- Topographic control of deep flow

Variability on Section PN

Variance spectra of surface zonal velocity at PN (frequency vs depth)



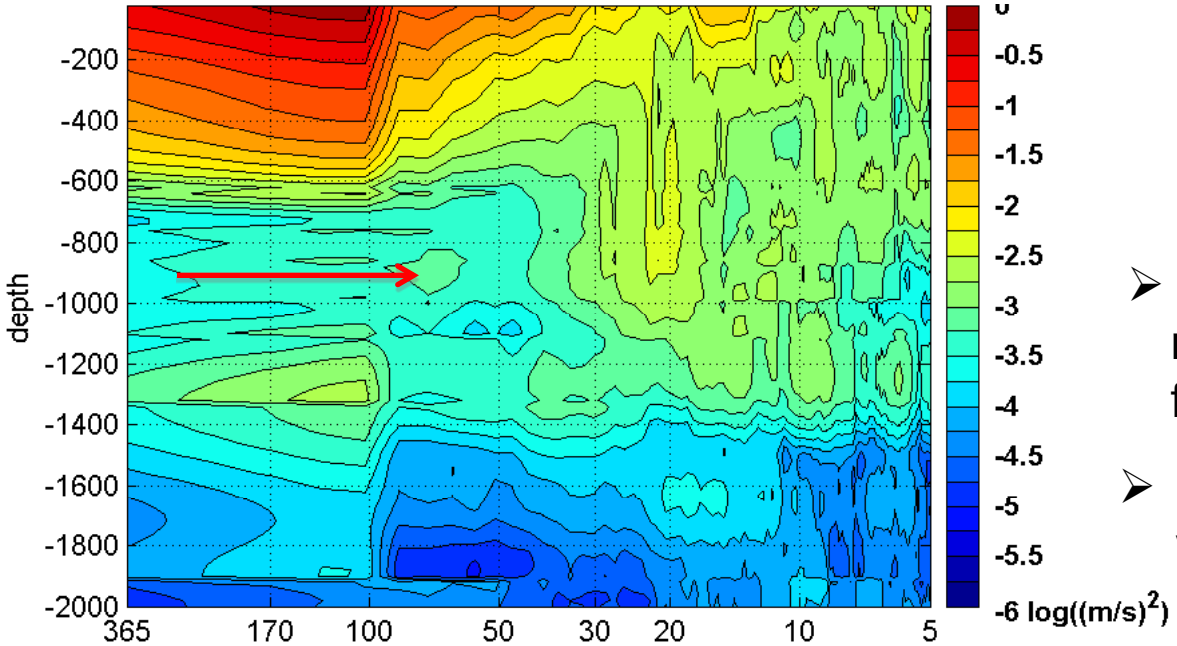


- ✓ Surface flow dominated by low-frequencies
- ✓ Deeper flow: higher frequency variability

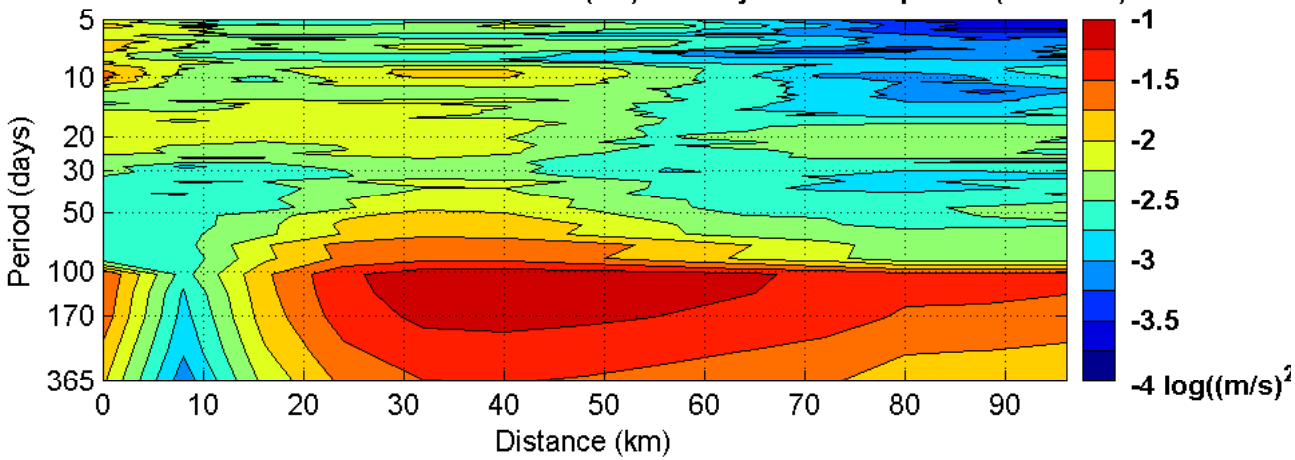
Horizontal frequency distribution (distance vs period between 01,000m depth)

High-frequency signal is also present in section PE

Velocity variance spectra (40-100 km mean) in section PE (frequency vs depth)

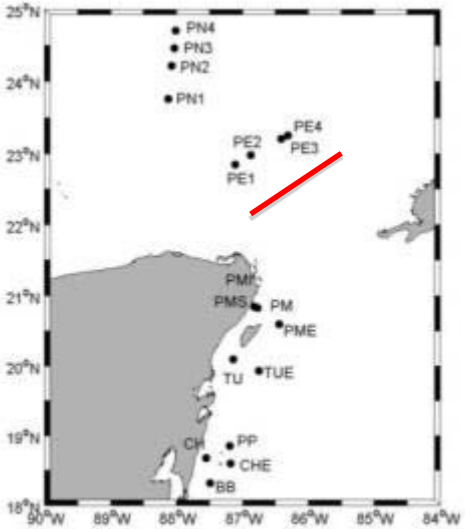


Horizontal distribution of across section (PE) velocity variance spectra (0-1300m)

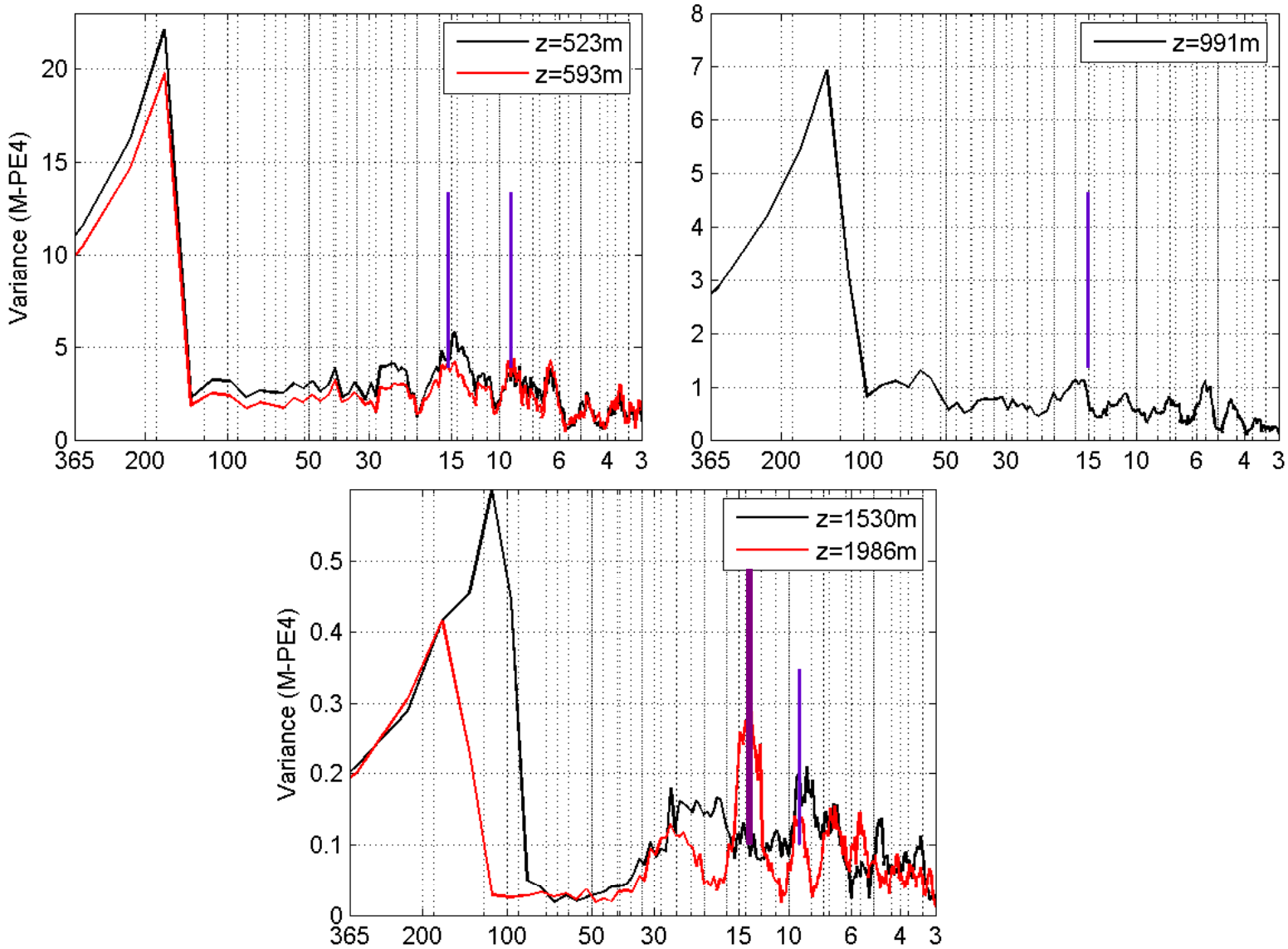


Horizontal distribution of frequencies (0–1,300m depth)

- All frequencies present near surface (low frequency dominant)
- 15-20 days deep flow variability

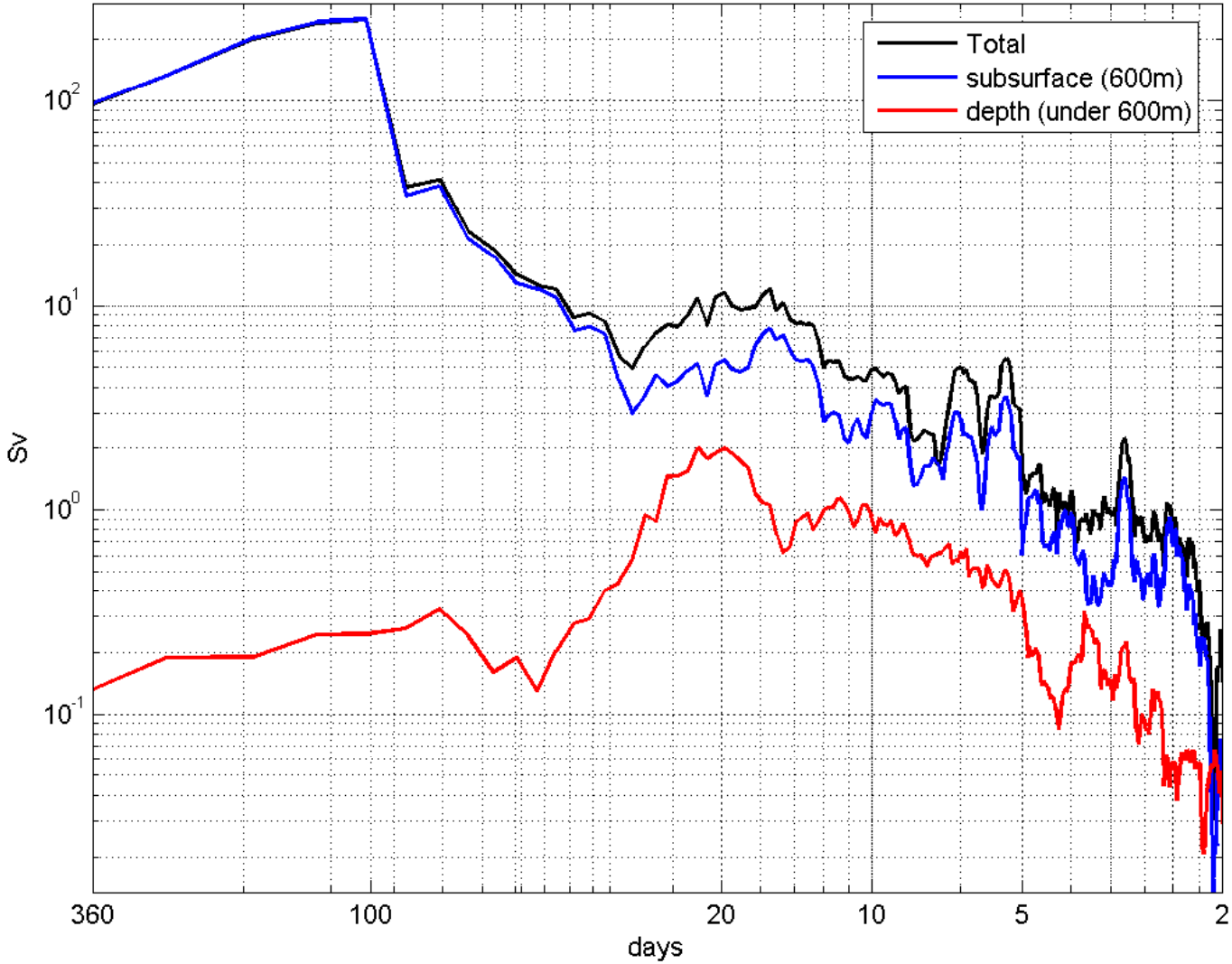


Spectra on the PE section at different depths



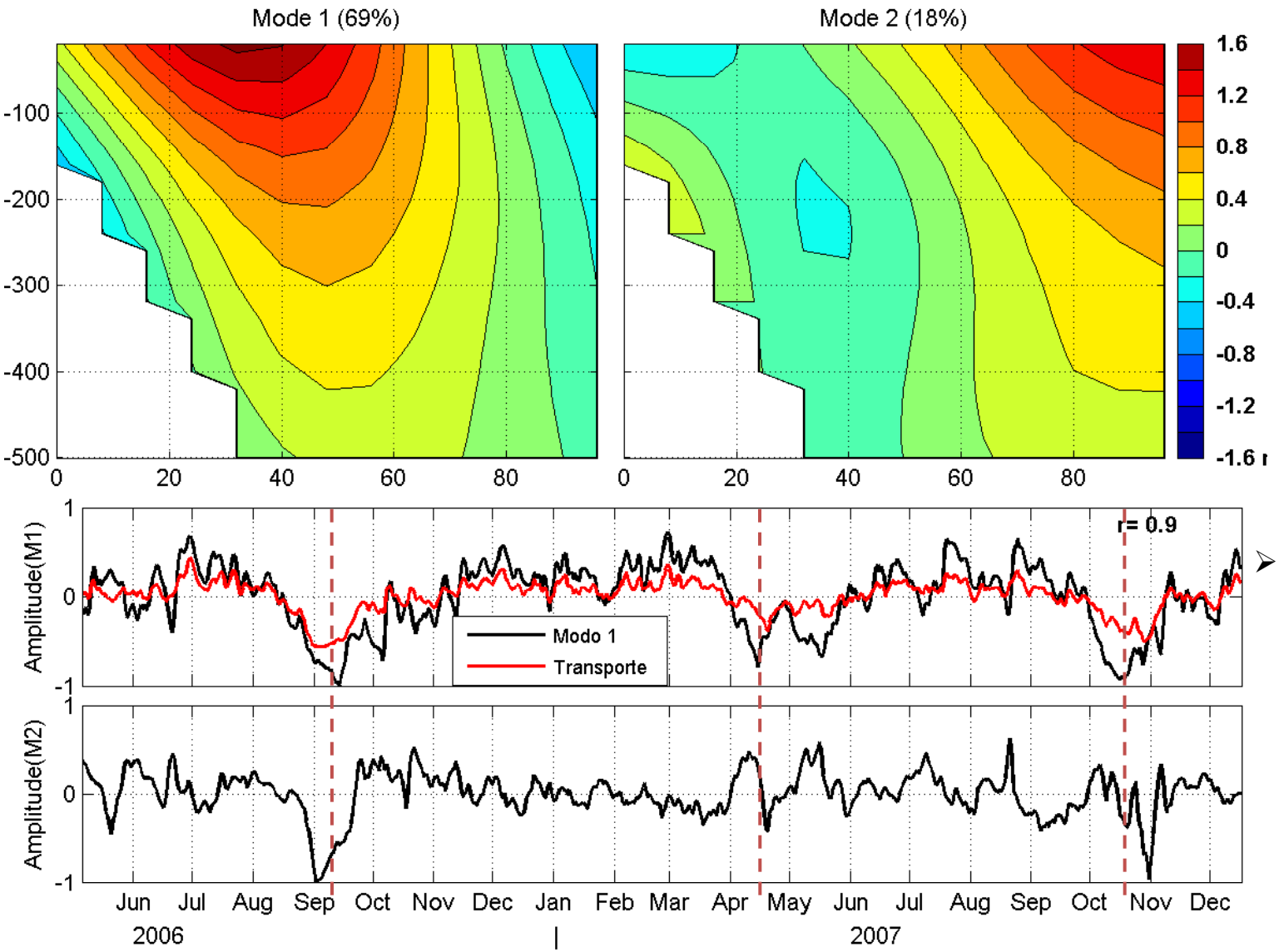
- Amplification of high frequency signals at the bottom

Spectral analysis of transports through section PE



- Above 600m depth: peaks at 100 days, 7 days and 5 days
- Bellow 600m depth: high-frequency peaks (<40 days)

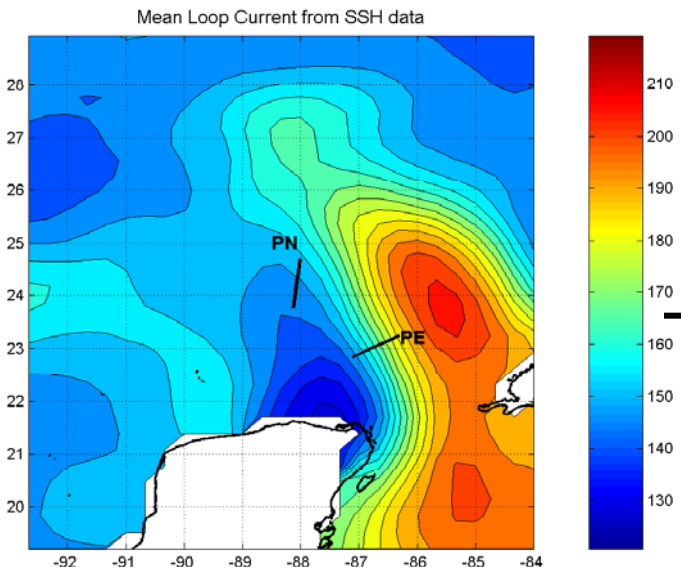
FEOs (EOF) of the sectionPE

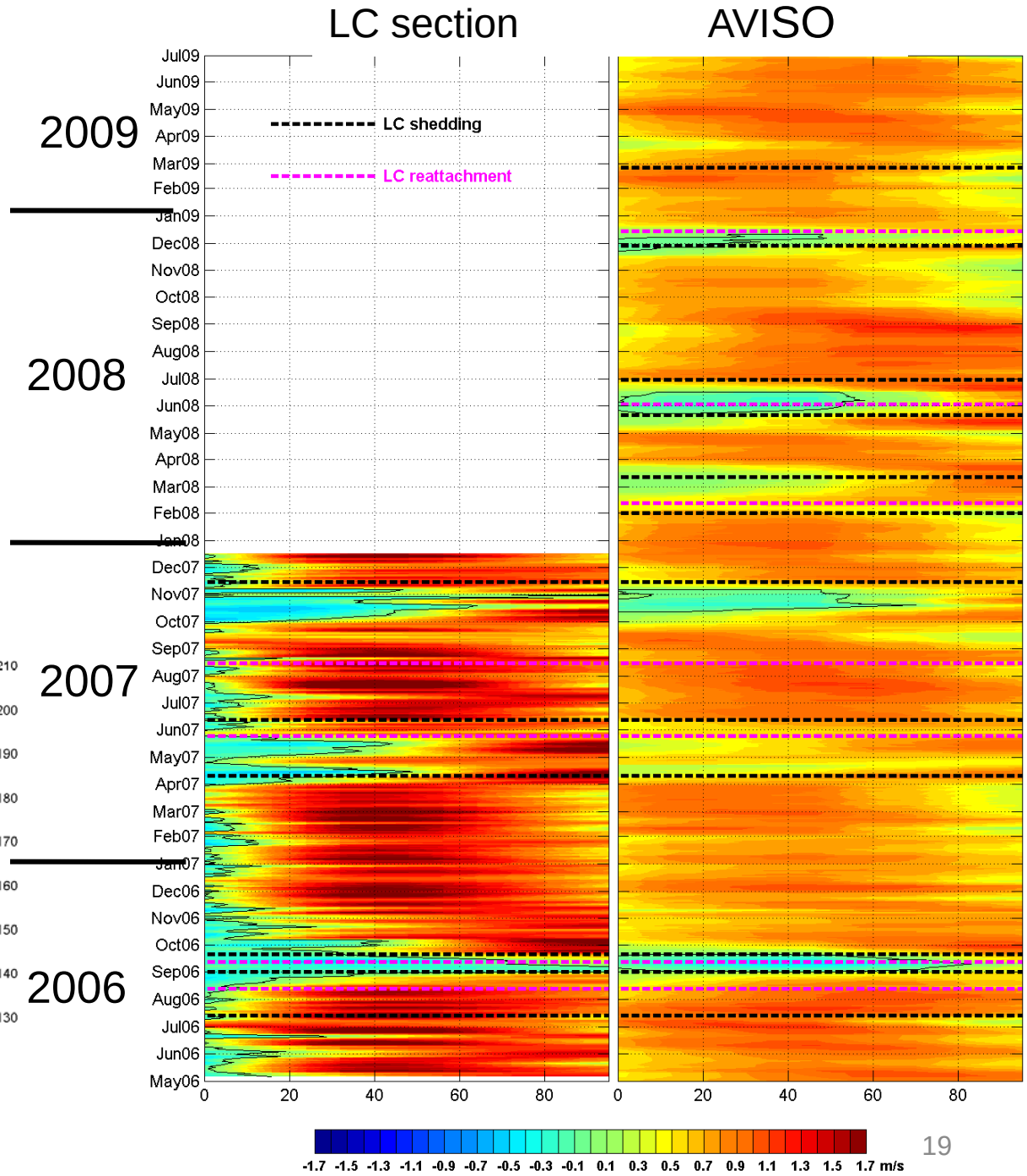


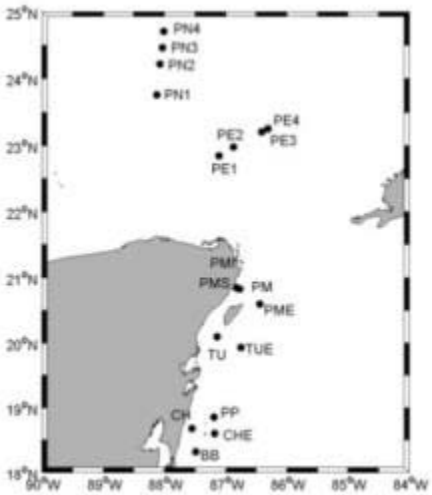
- Surface transport vs Mode 1 (r= 0.9)

- Surface modes associated with meandering Loop Current

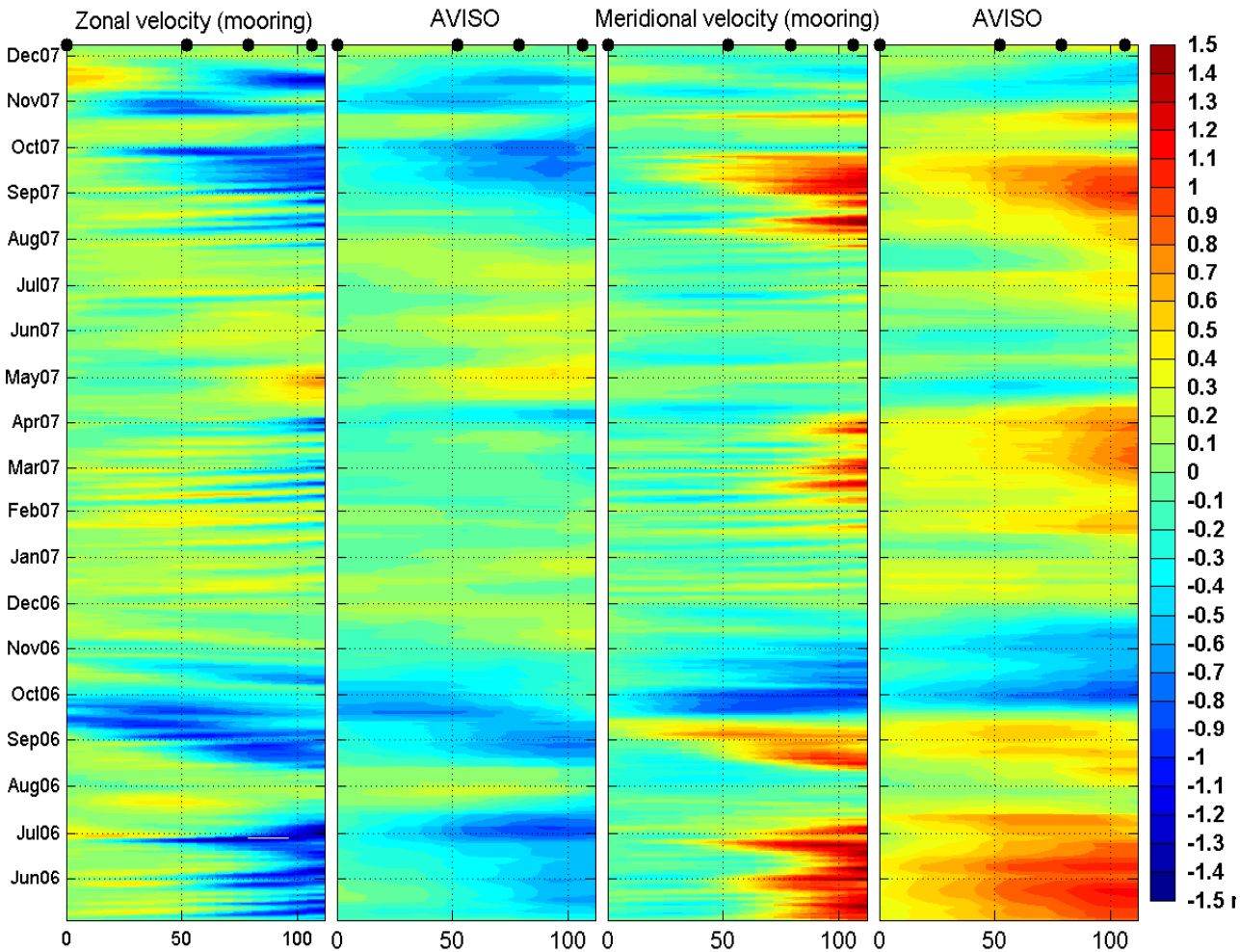
- LC core to the east before or during LCE release: from moorings and AVISO



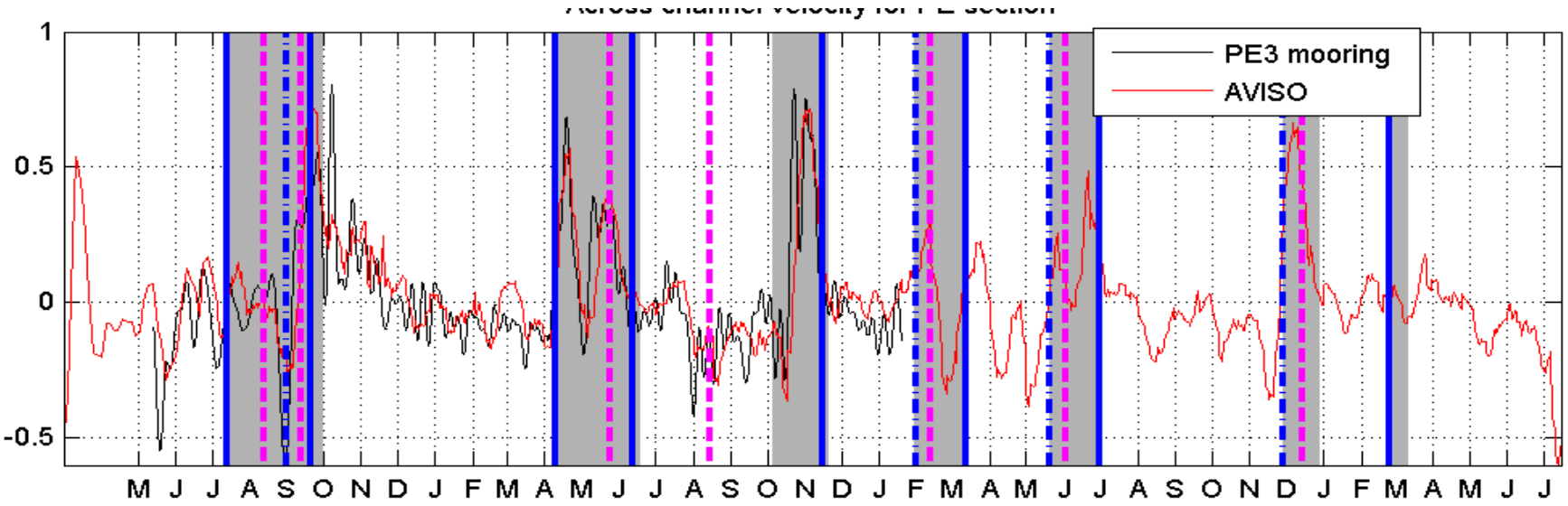




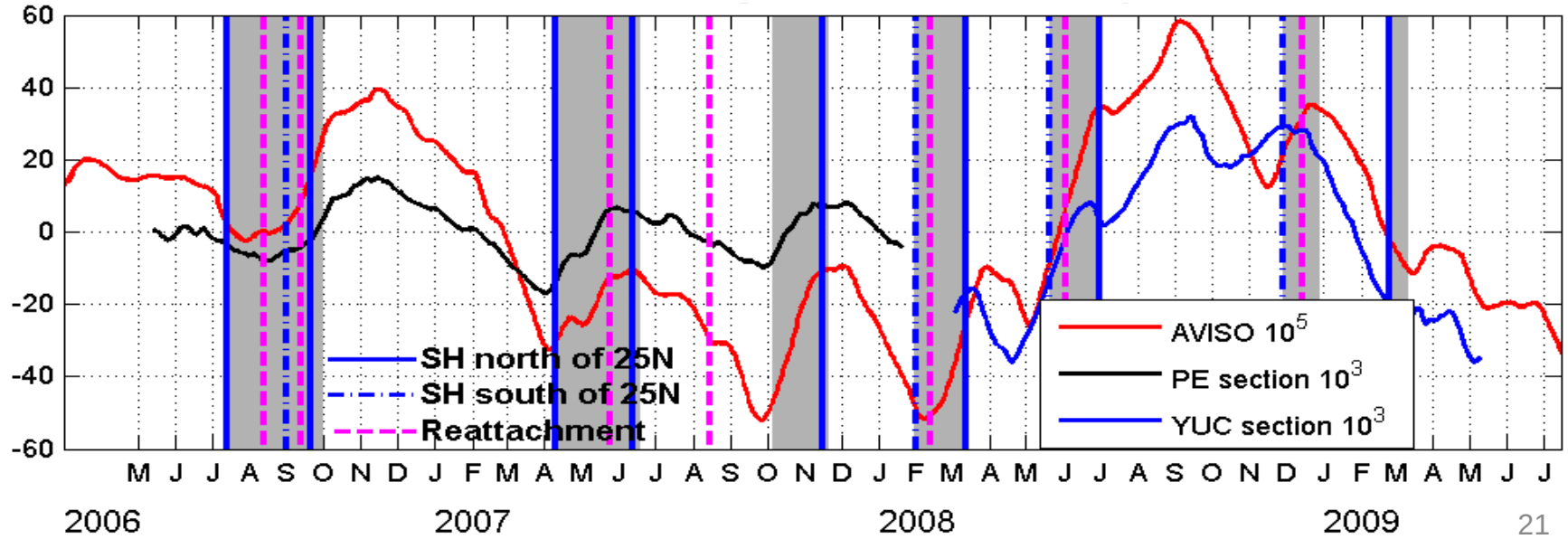
Mooring velocities vs AVISO data PN line

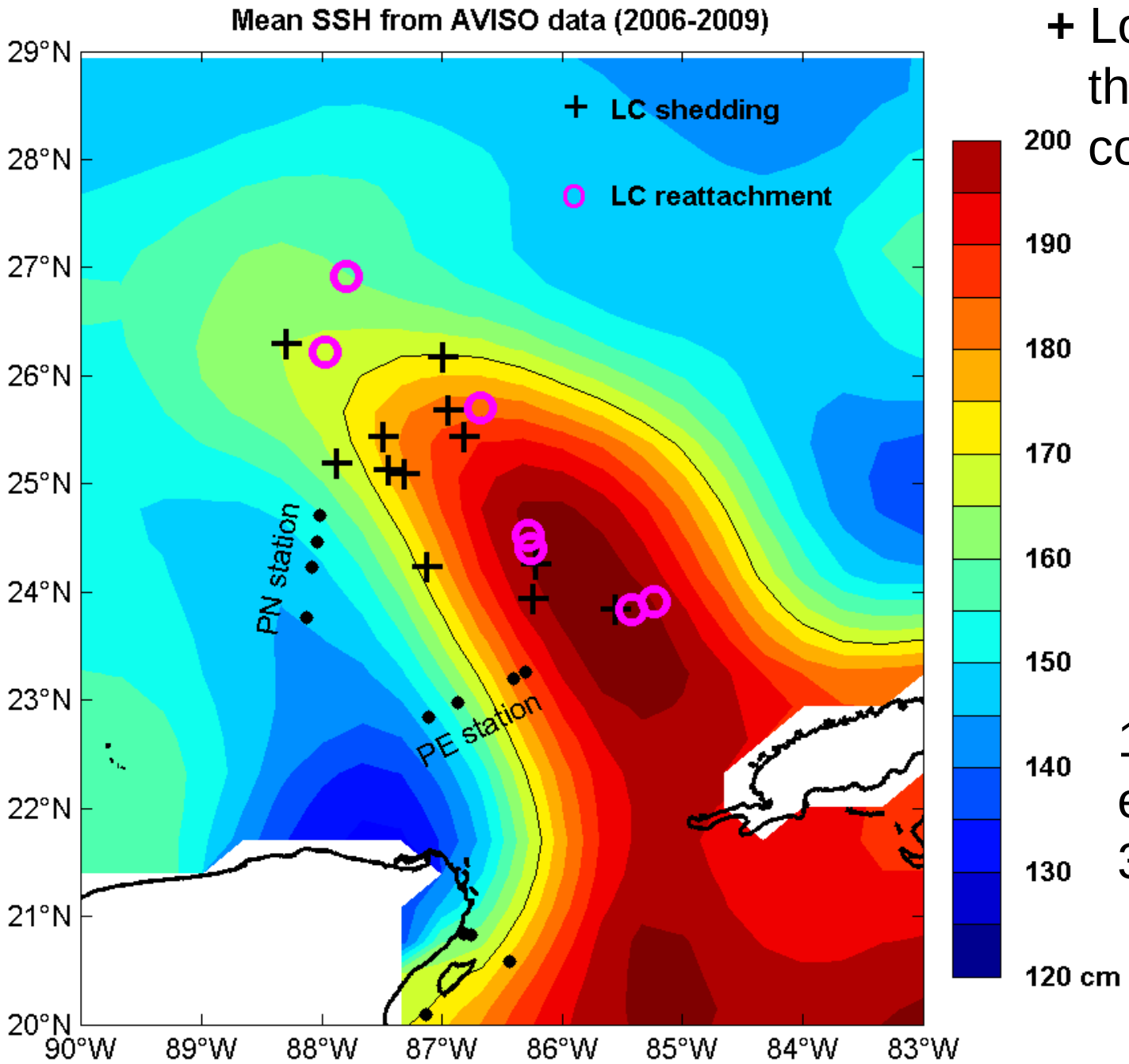


Velocity parallel to section PE



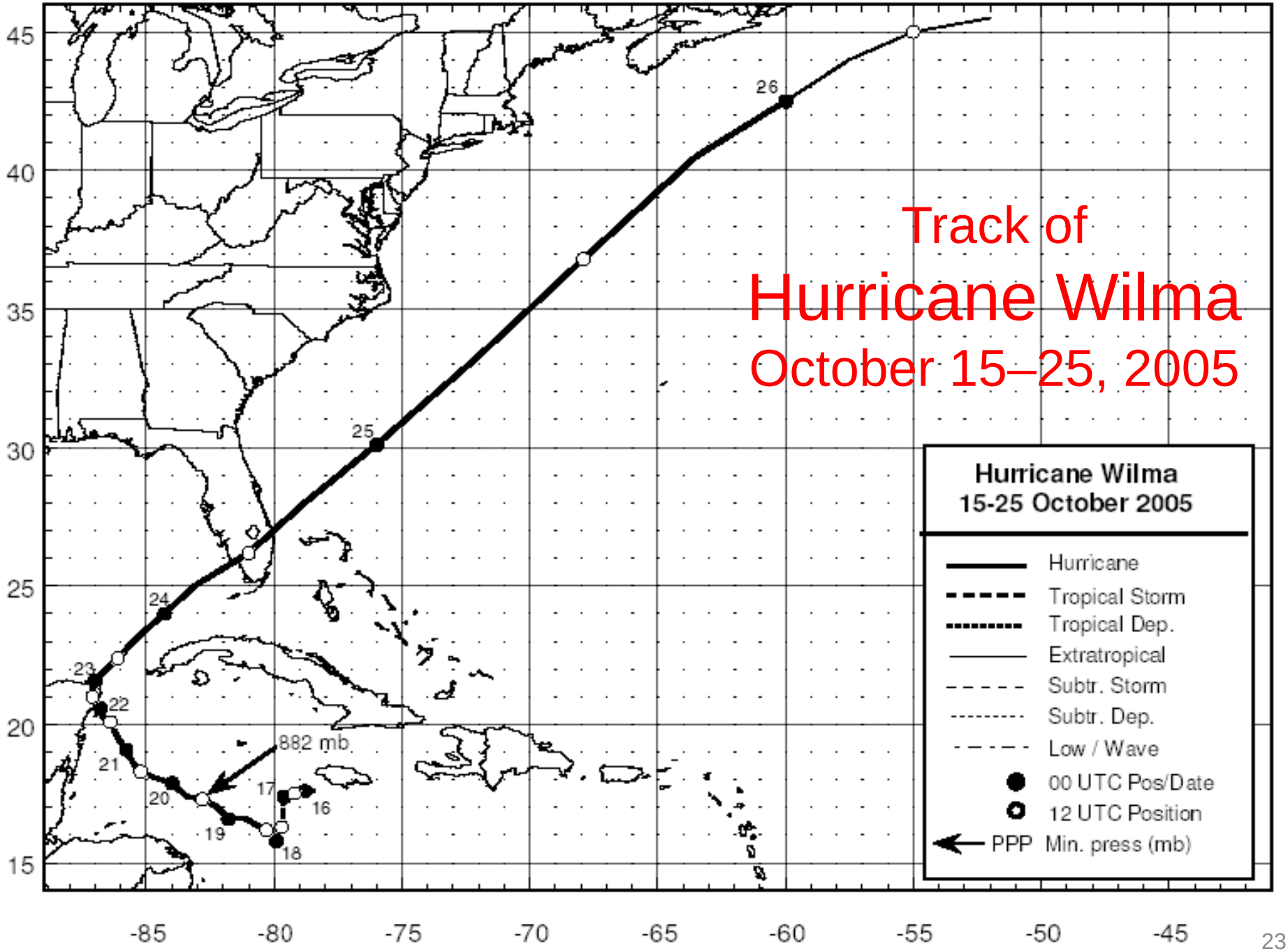
Detrended time integral of the horizontal shear velocity section PE





+ Location where the 170 cm contour breaks.

12 shedding events in 3 years


Track of
Hurricane Wilma
October 15–25, 2005
Hurricane Wilma
15-25 October 2005
Hurricane
Tropical Storm
Tropical Dep.
Extratropical
Subtr. Storm
Subtr. Dep.
Low / Wave
00 UTC Pos/Date
12 UTC Position
PPP Min. press (mb)
882 mb
15
16
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-85
-80
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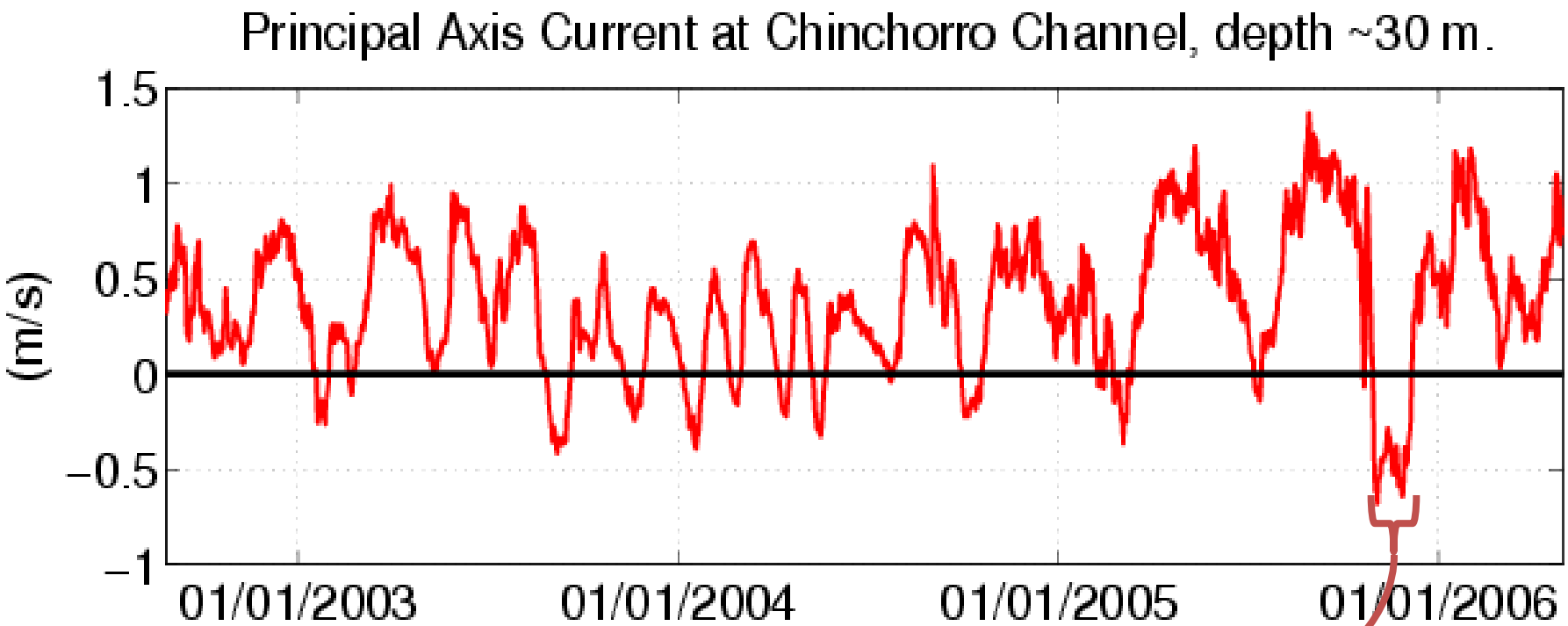
-60
-55
-50
-45

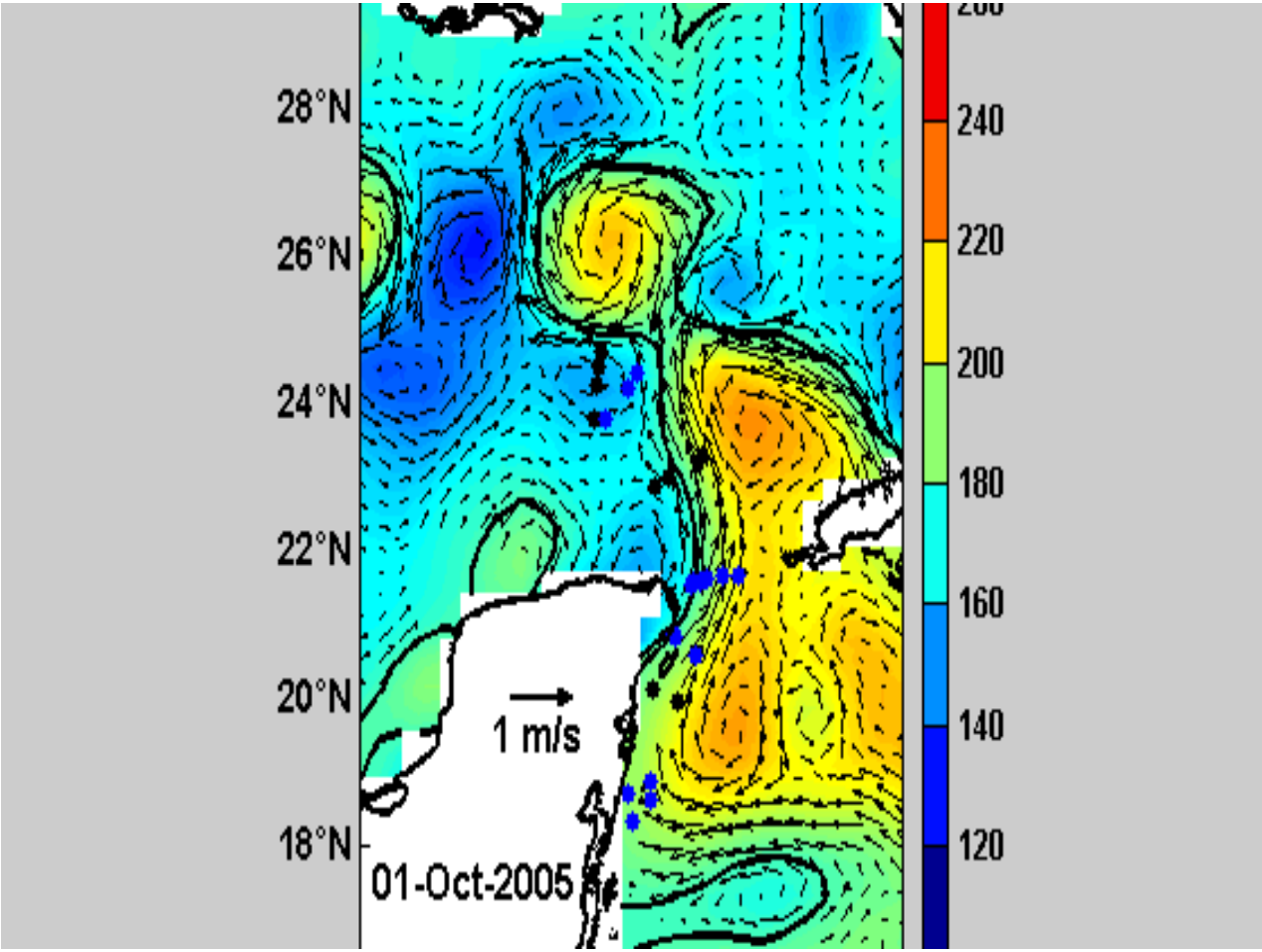


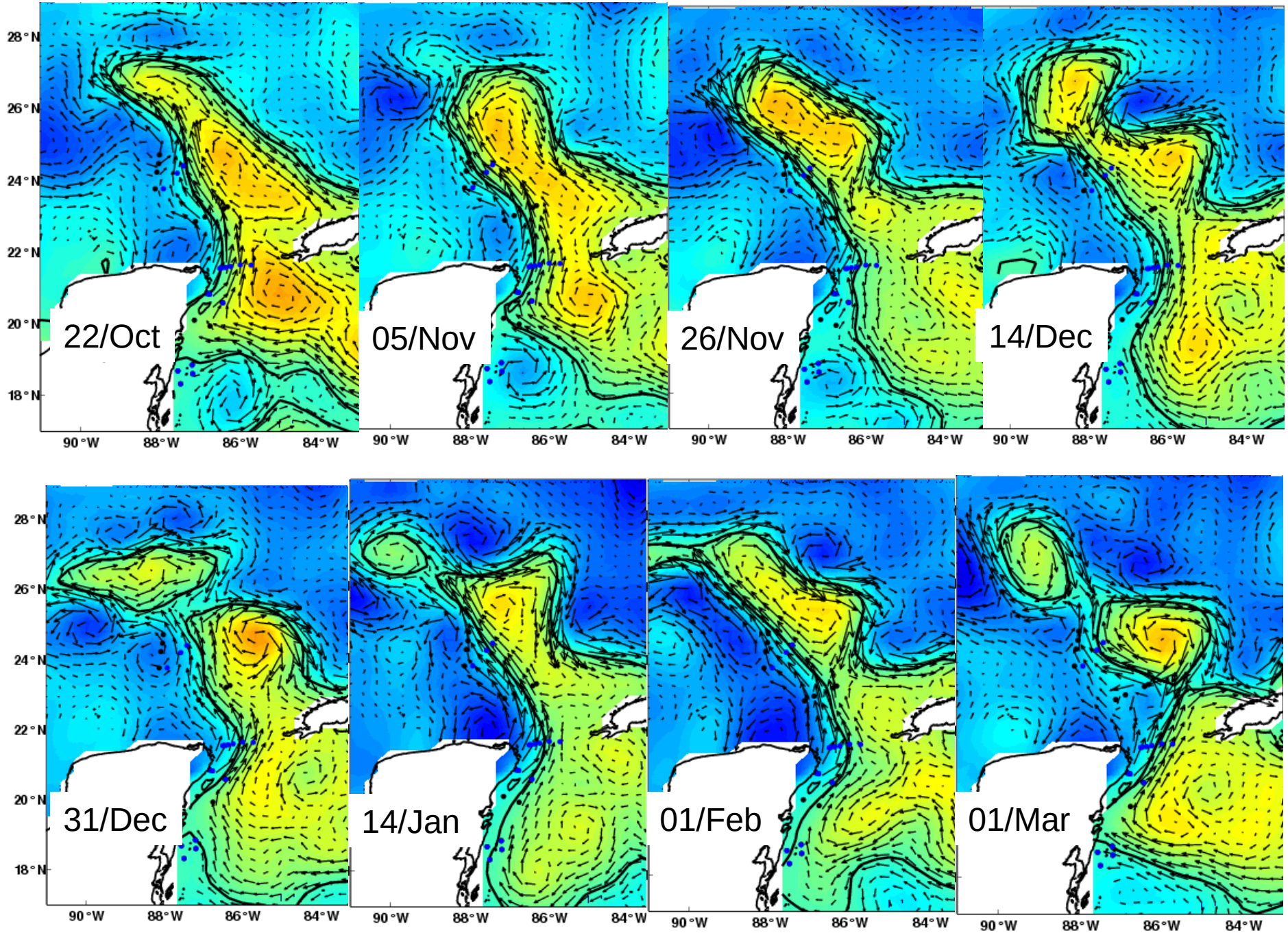
~37 days

- A cyclonic eddy remained at Chinchorro Bank during the passage of Hurricane Wilma (from late October to early December)
- Subsequently four anticyclonic eddies were dettached from the Loop Current in two months (12/28, 01/14, 02/08 and 03/01)

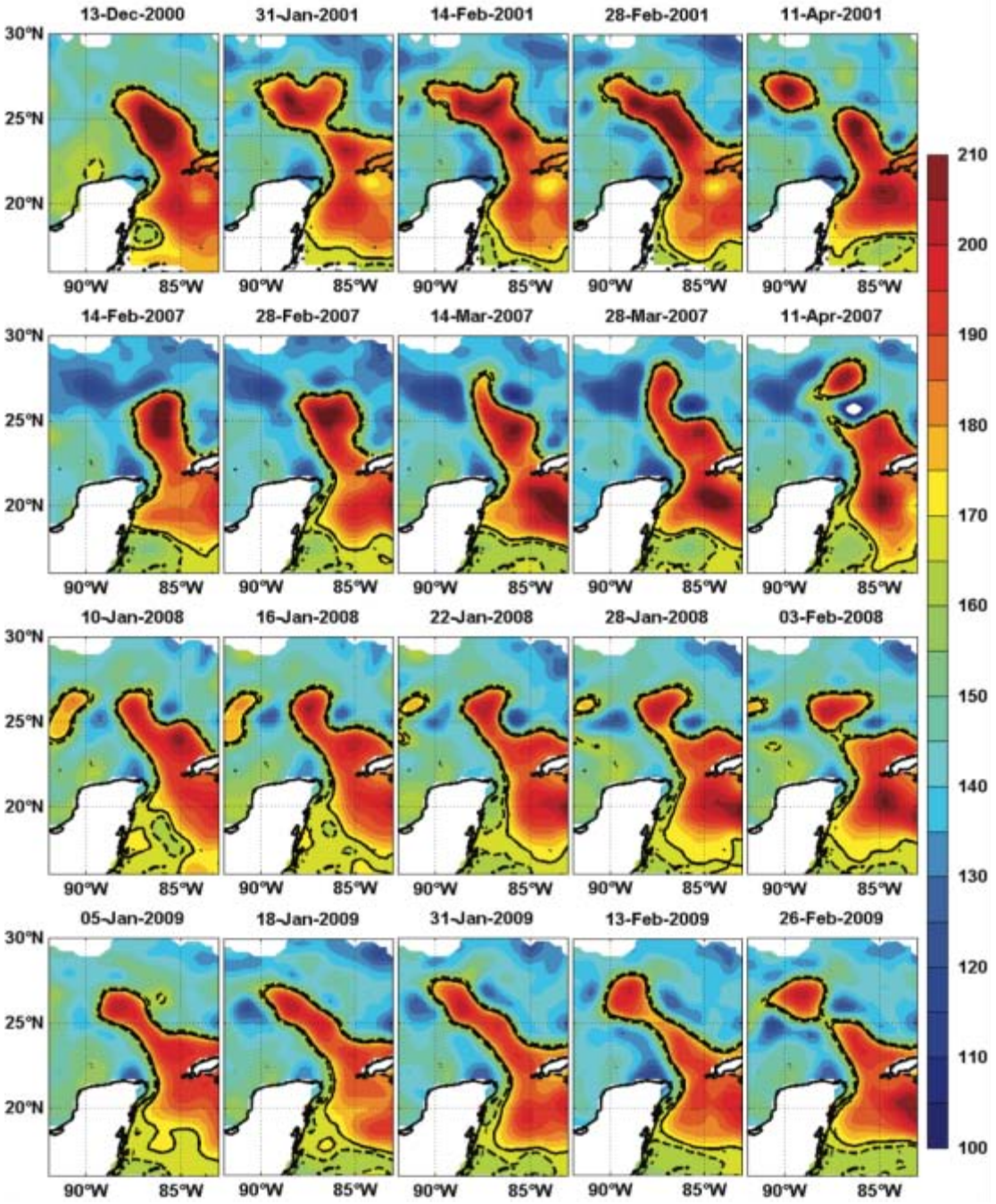
Loop Current Evolution after the Passage of Hurricane Wilma

1) Arrival of cyclone to Chinchorro Bank
2) Offshore shift of Yucatan Current
3) The amplitude of the Carribean cyclone appears to decrease
4) Subsequent increase of the cyclonic eddy in the Campeche Bank
5) Yucatan Current shifts back toward the shelf
6) The Loop Current releases an eddy




22/Oct
05/Nov
26/Nov
14/Dec
31/Dec
14/Jan
01/Feb
01/Mar
28°N
26°N
24°N
22°N
20°N
18°N
90°W
88°W
86°W
84°W

A cyclone (or cyclonic circulation) over the western Caribbean near Chinchorro Belize-Guatemala-Honduras precedes (on many occations) the release of an LCE

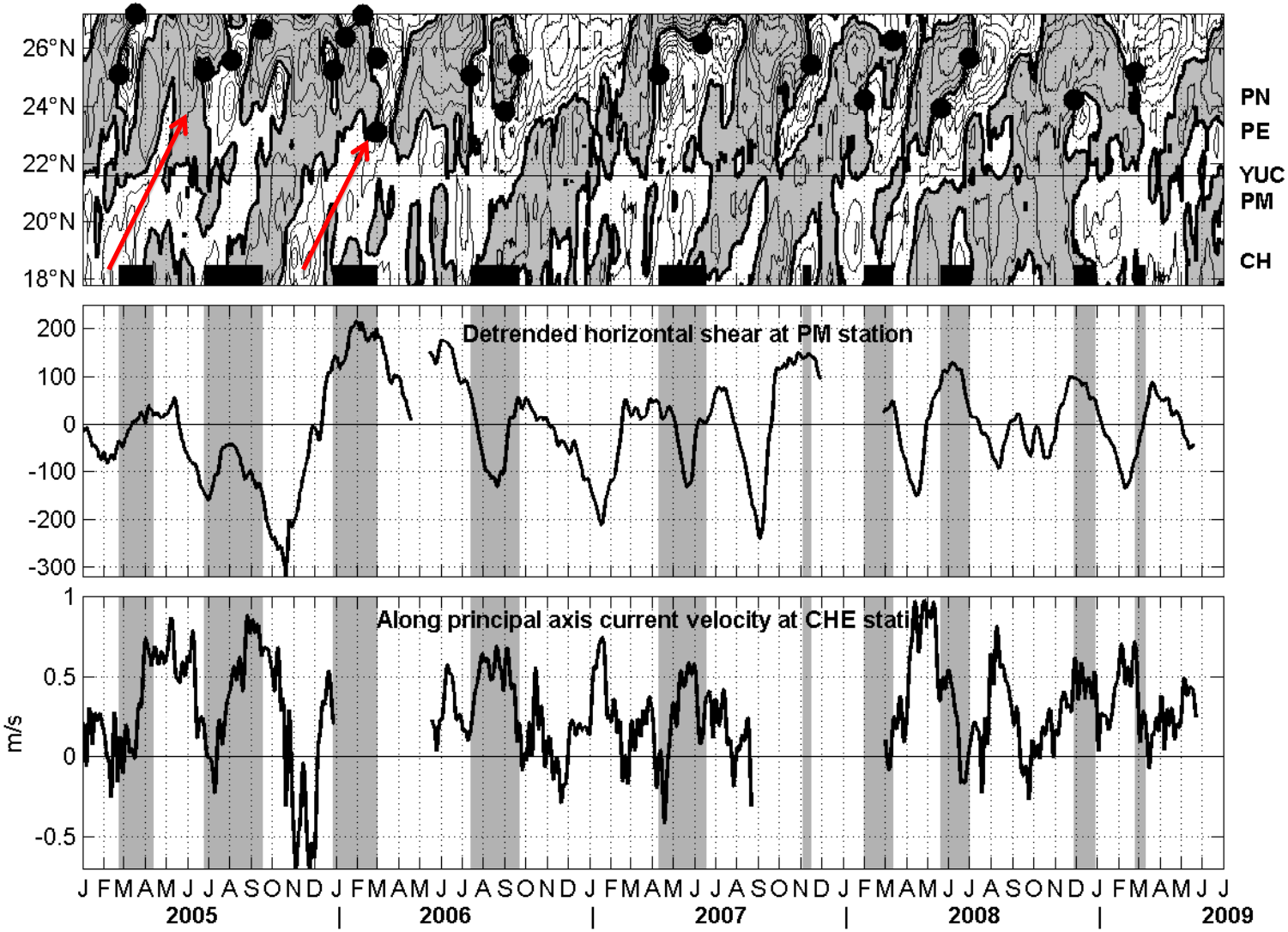


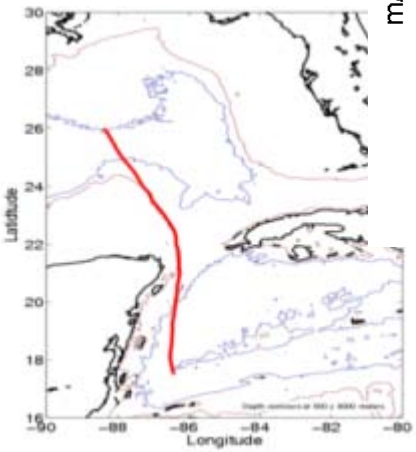
Altimetry anomalies along Caribbean transect (2005 – 2009)

White:cyclonic

Detrended shear
At Pto Morelos

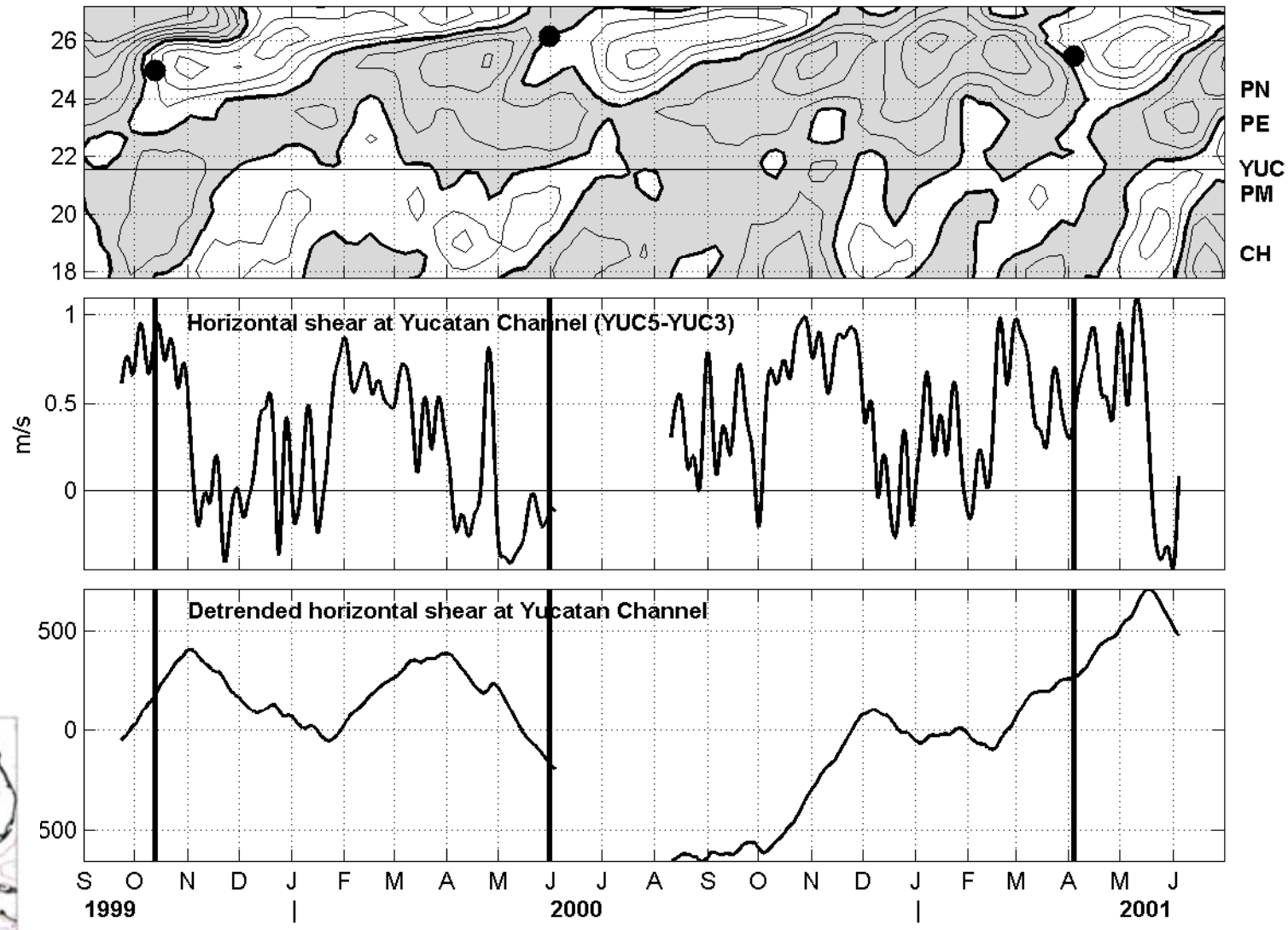
Current at CHE

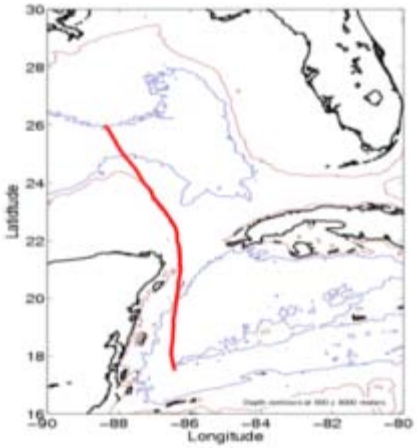


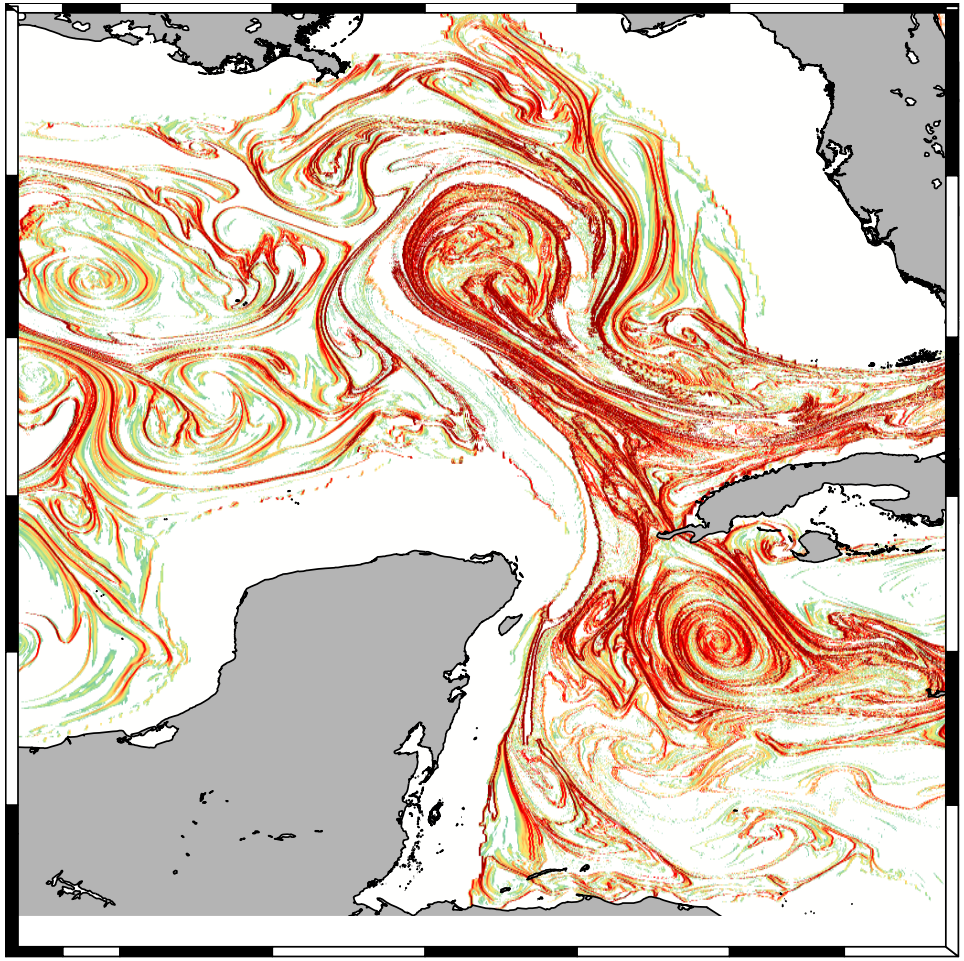


● Shedding event

Altimetry anomalies along Caribbean transect (1999 – 2001)

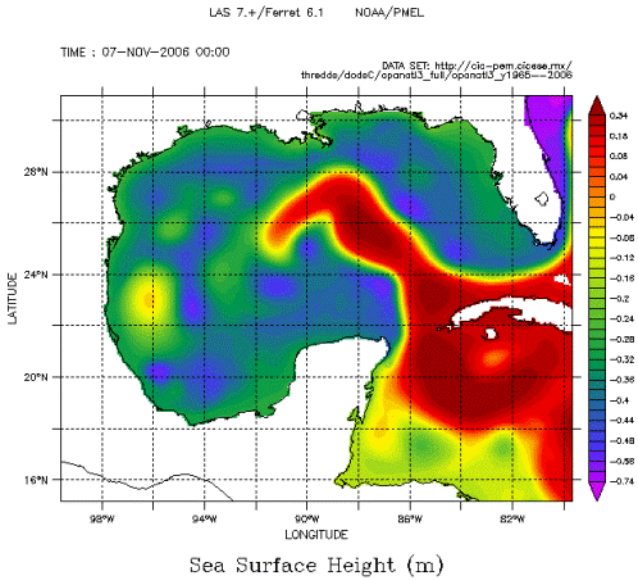






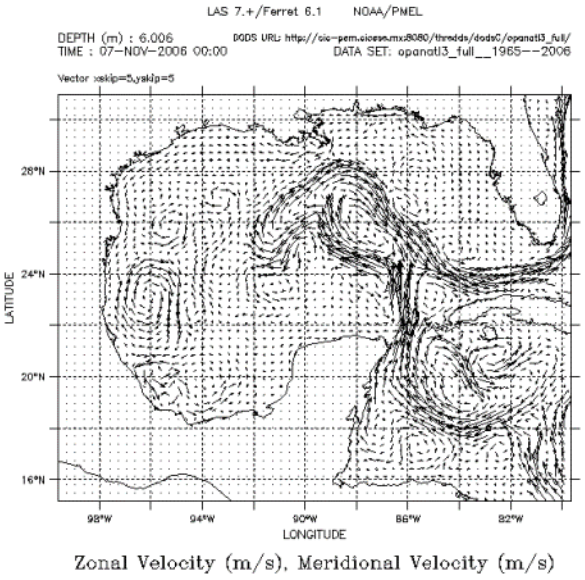
A Lagrangian view of LCE separation:

Can we determine unambigously if and when an LCE will definitely separate?

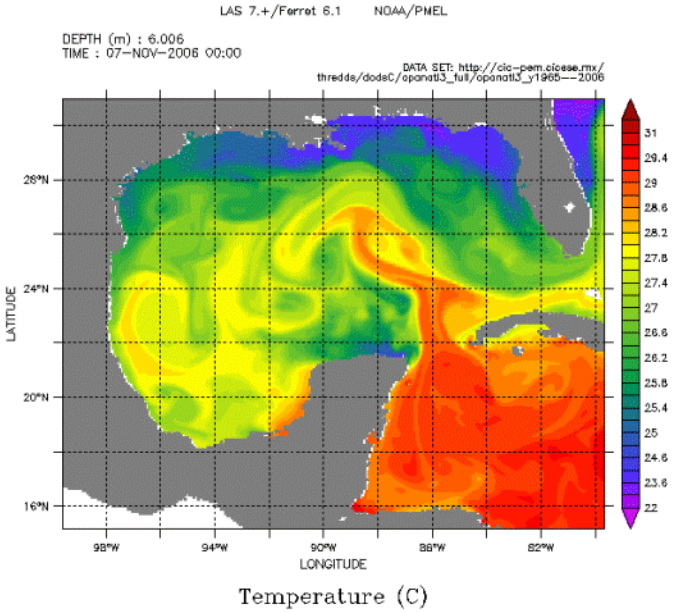


ssh

surf vel

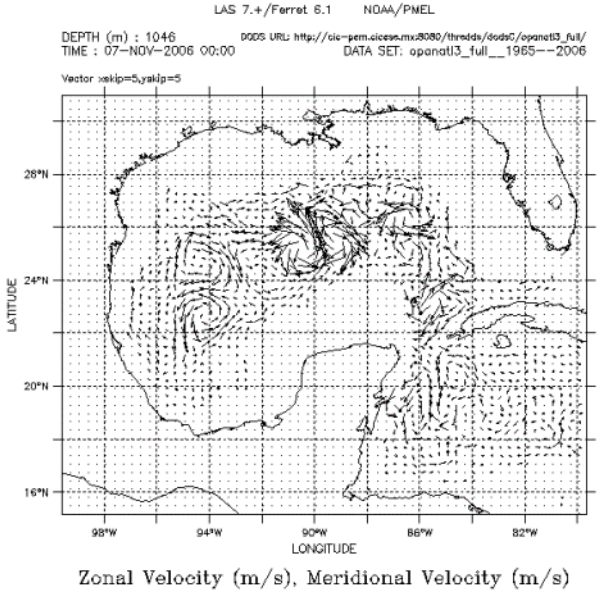


USE LCE SHEDDING NEMO-AGRIF Jouanno et al. 2009

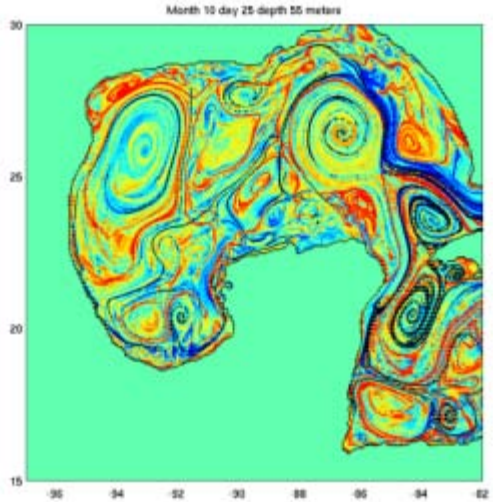


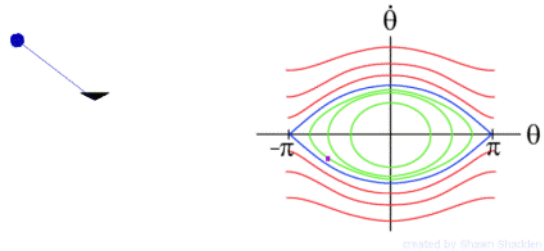
sst

v@1,000m

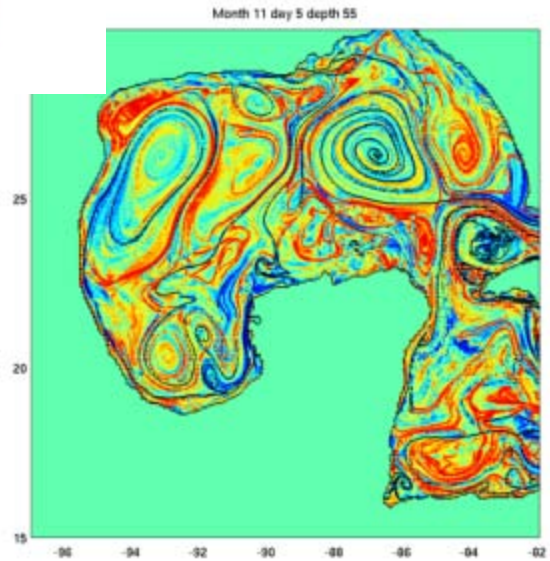


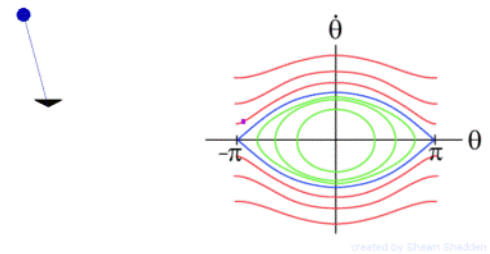
S. Shadden
http://mmae.iit.edu/shadden/LCS-tutorial/

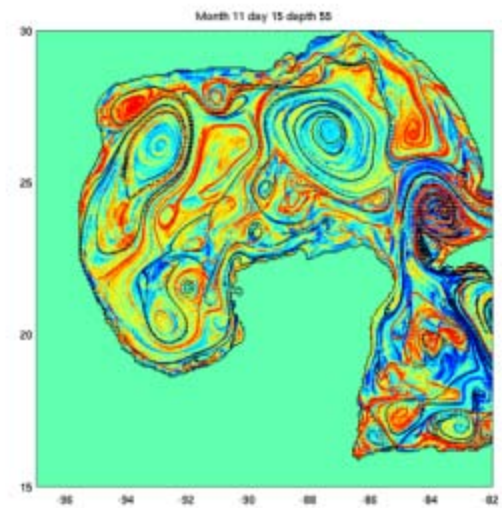




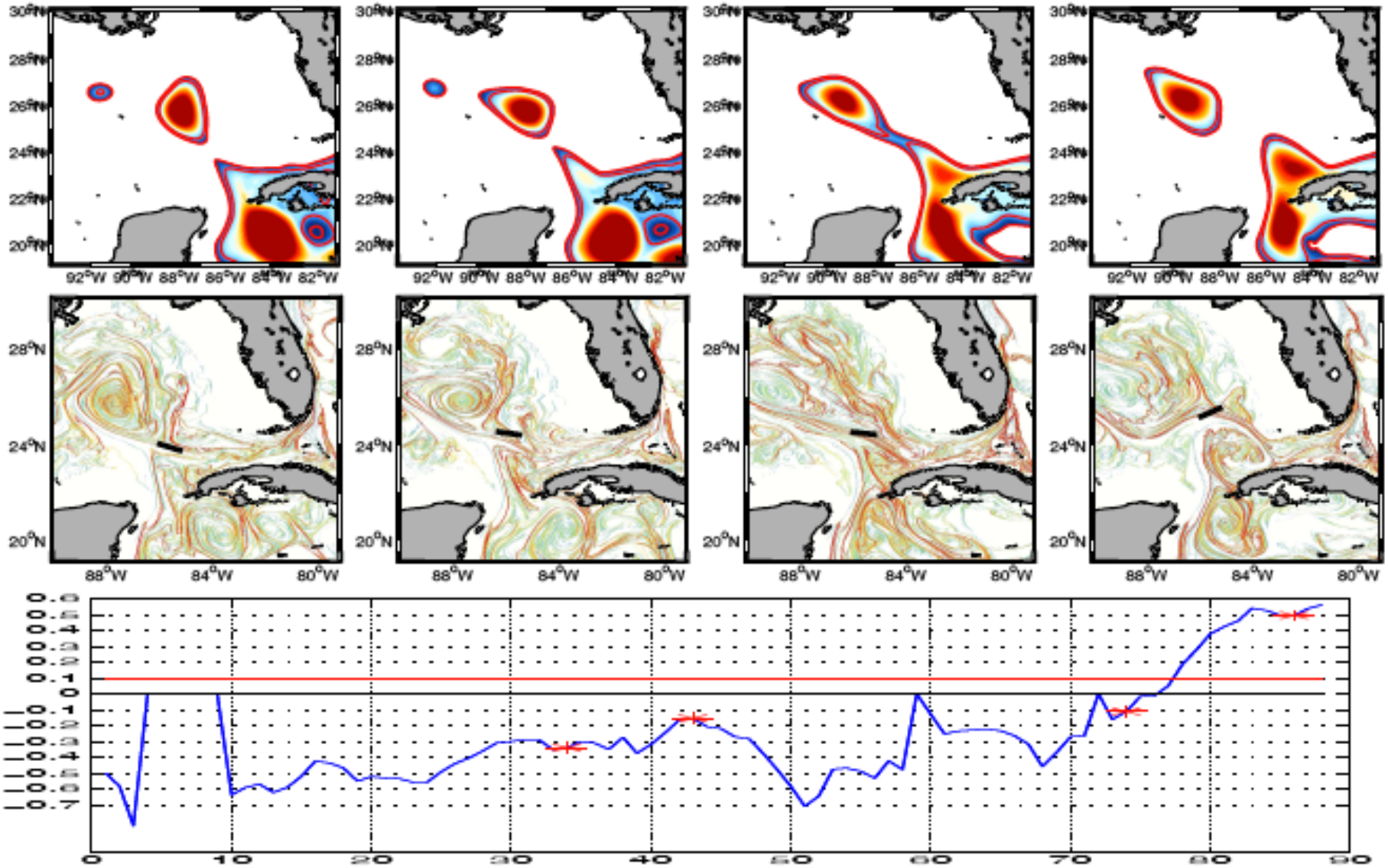
Use dynamical systems theory to determine regions of different dynamical behavior. Generalize concept of unstable- stable- manifolds to attracting and repeling material lines **Langrangian Coherent Structures** (LCS)







Eddy shedding Criteria based on FTLE and slope of straining material direction (Fernando Andrade)


30°N
28°N
26°N
24°N
22°N
20°N
92°W 90°W 88°W 86°W 84°W 82°W
28°N
24°N
20°N
88°W 84°W 80°W
0 10 20 30 40 50 60 70 80 90

SUMMARY AND FUTURE WORK

- LCE separation a “multimodal” and complicated process.
- Western Caribbean cyclones precede LCE separation events on several occasions.
- These cyclonic signals propagate along the Yucatan Coast. Trigger LCFE growth and LCE detachment.
- Meandering of the YC core (eastward movement) before or during LCE detachment. This is in agreement with cyclonic triggers but can also be related to other shedding mechanisms.
- Higher frequencies dominant in the deep flow. Flow intensification near the bottom clearer on section PN.
- Interesting Hurricane-LC interaction: exploring other cases similar to Hurricane Wilma. Near-inertial response of the LC also extremely interesting (E. Pallas in preparation)
- Lagrangian view of LCE separation: promising tool for characterizing and predicting LCE detachment (F. Andrade thesis)

REFERENCES

Andrade F., J. Sheinbaum, J. Candela, and O. Velasco. A Lagrangian view of Loop Current eddy shedding. (To be submitted)

Coronado, C., J. Candela, R. Iglesias-Prieto, J. Sheinbaum, M. López, F.J. Ocampo-Torre. 2007. On the circulation in the Puerto Morelos fringing reef lagoon. Coral Reefs 26:149–163, doi: 10.1007/s00338-006-0175-9.

Jouanno, J., J. Sheinbaum, B. Barnier and J. M. Molines. 2009. The mesoscale variability in the Caribbean Sea. Part. II: Energy sources. Ocean Modelling 26:3–4, doi: 0.1016/j.ocemod.2008.10.006.