A numerical study of the 1997-98 El Nino off Peru

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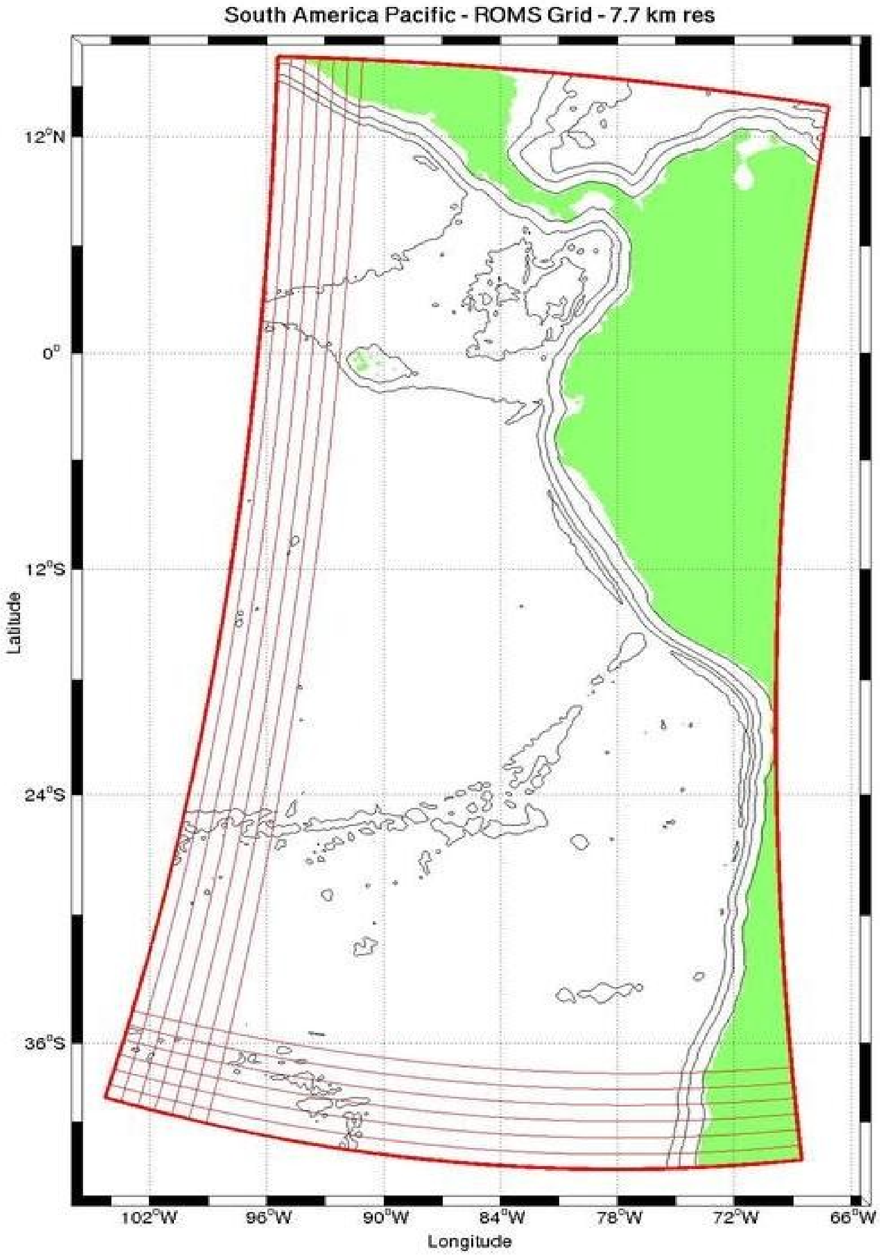
2007 ROMS/TOMS User Workshop

South America West Coast – Peru/Chile Upwelling System



A coastal wave guide for equatorial perturbations :
upwelling eastern boundary region in
direct connection with the equatorial region
=> System strongly affected by interannual
variability and intense ENSO events

ROMS model configuration designed :

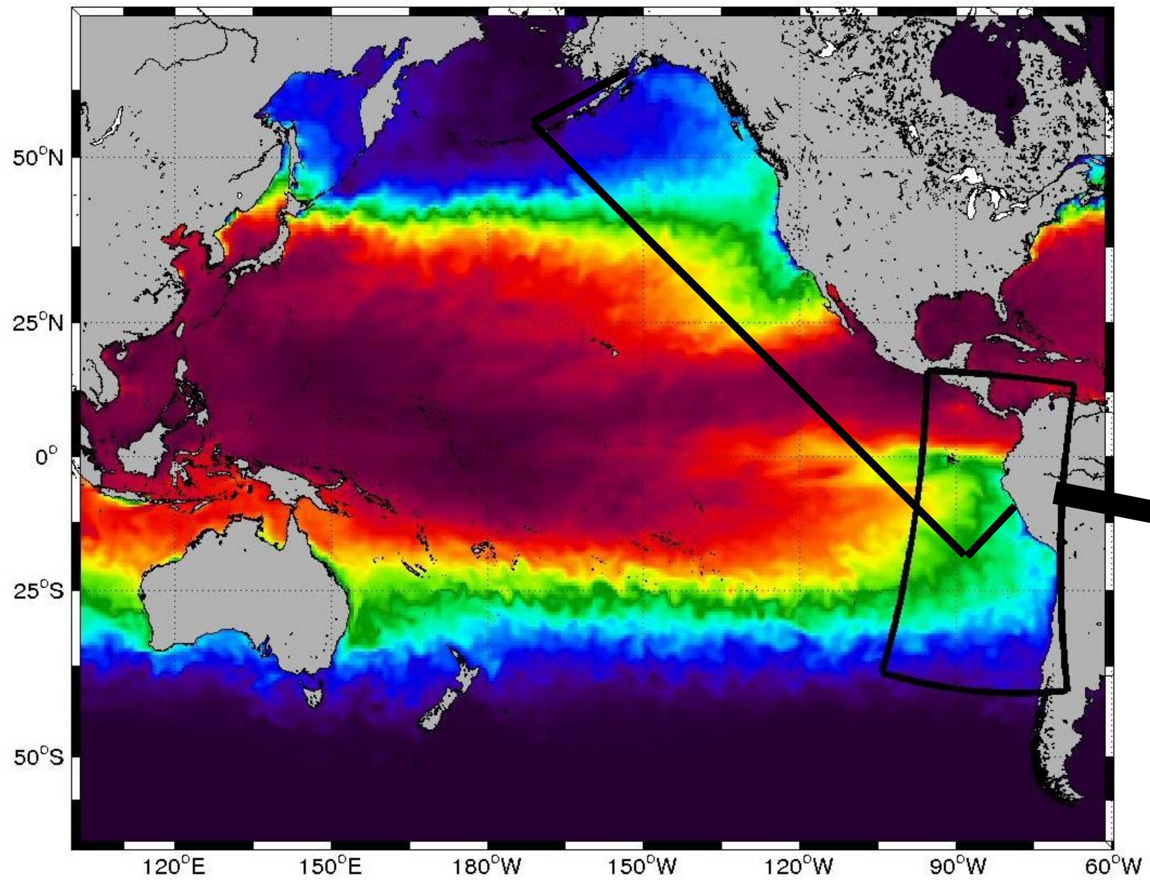
Resolution ~ 7.5km – 30 vertical levels

15°N/40°S & 100°W/coast

(North and East boundaries closed)

Preliminar run (spin-up) in climatological mode.
Quasi-equilibrium solution – initial state for IA run

Interannual Variability - SAWC configuration

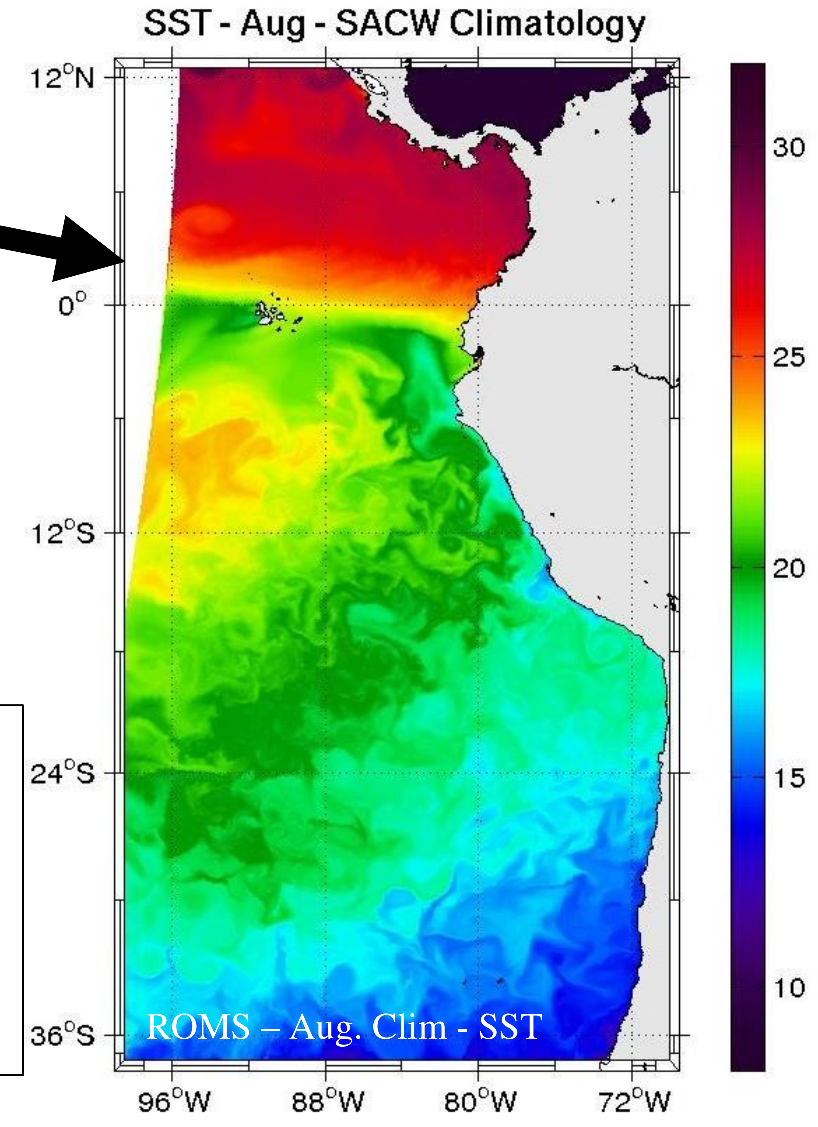


POP – Aug.1994 - SST

"Parent model" POP-CCSM (1/2°)

(Large & Danabasoglu 2006)

(SODA reanalysis – ROMS Pacific)



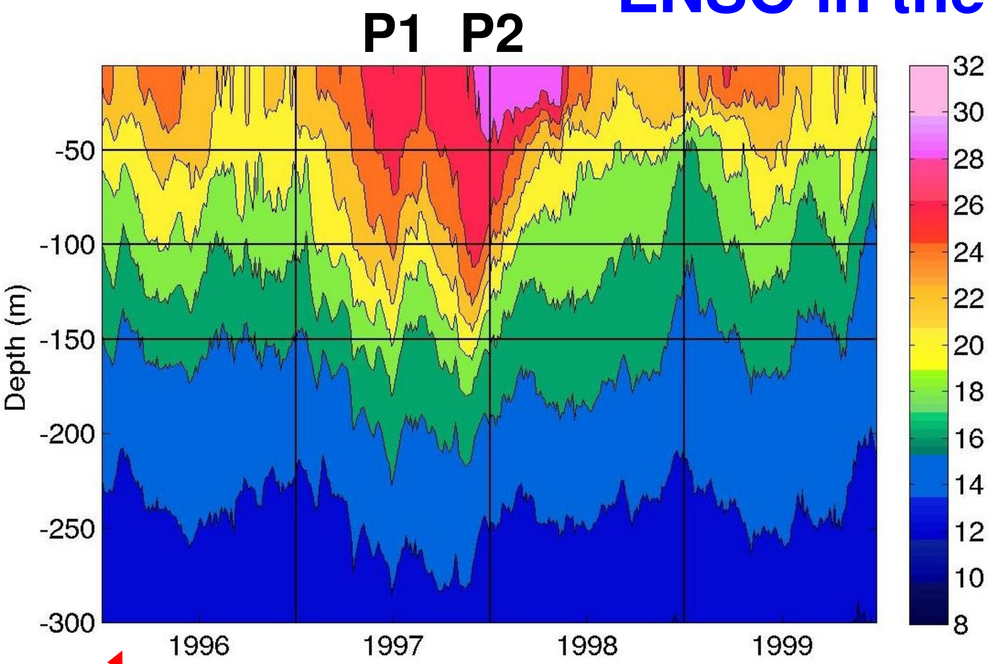
Downscaling : global oceanic model to regional model

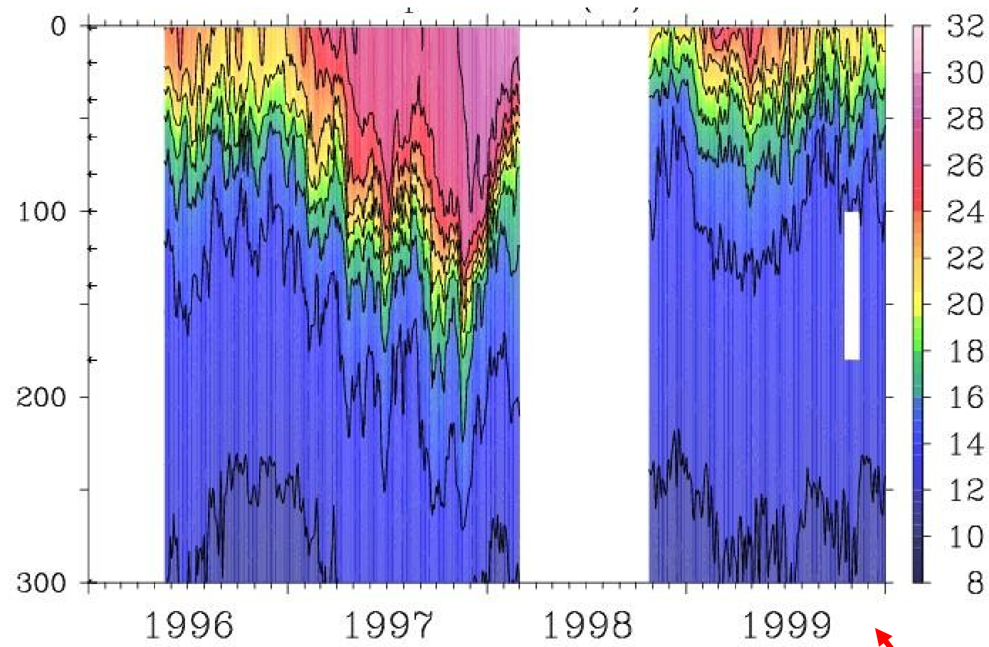
Open boundaries conditions updated every **4 days**.

[**1993/1999**] - ERS Wind (week), AVHRR SST (month)

Others fluxes : climatology COADS

ENSO in the global model



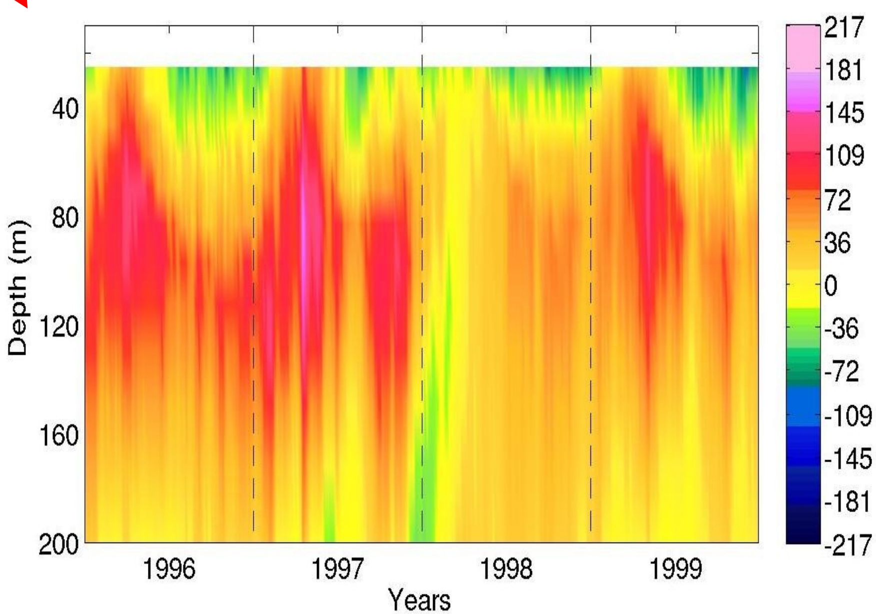


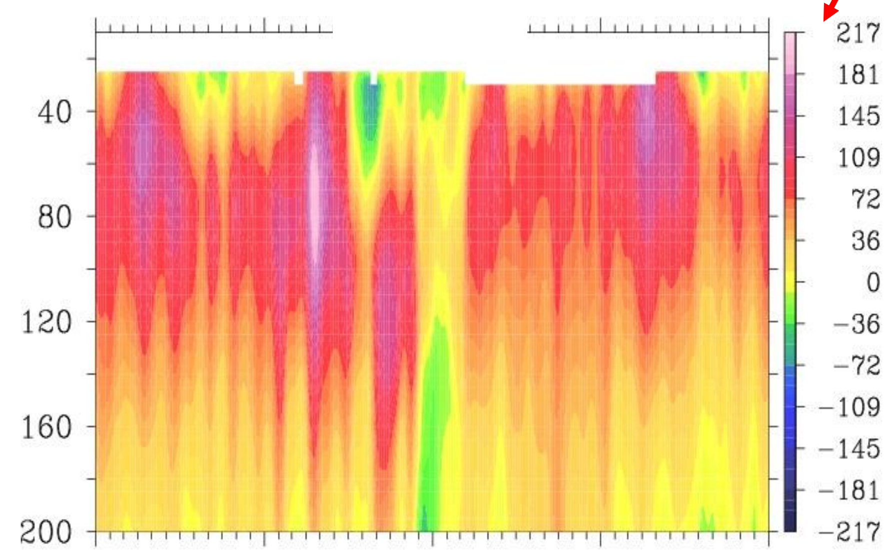
POP

Temperature 110 W/0N. 1996/1999

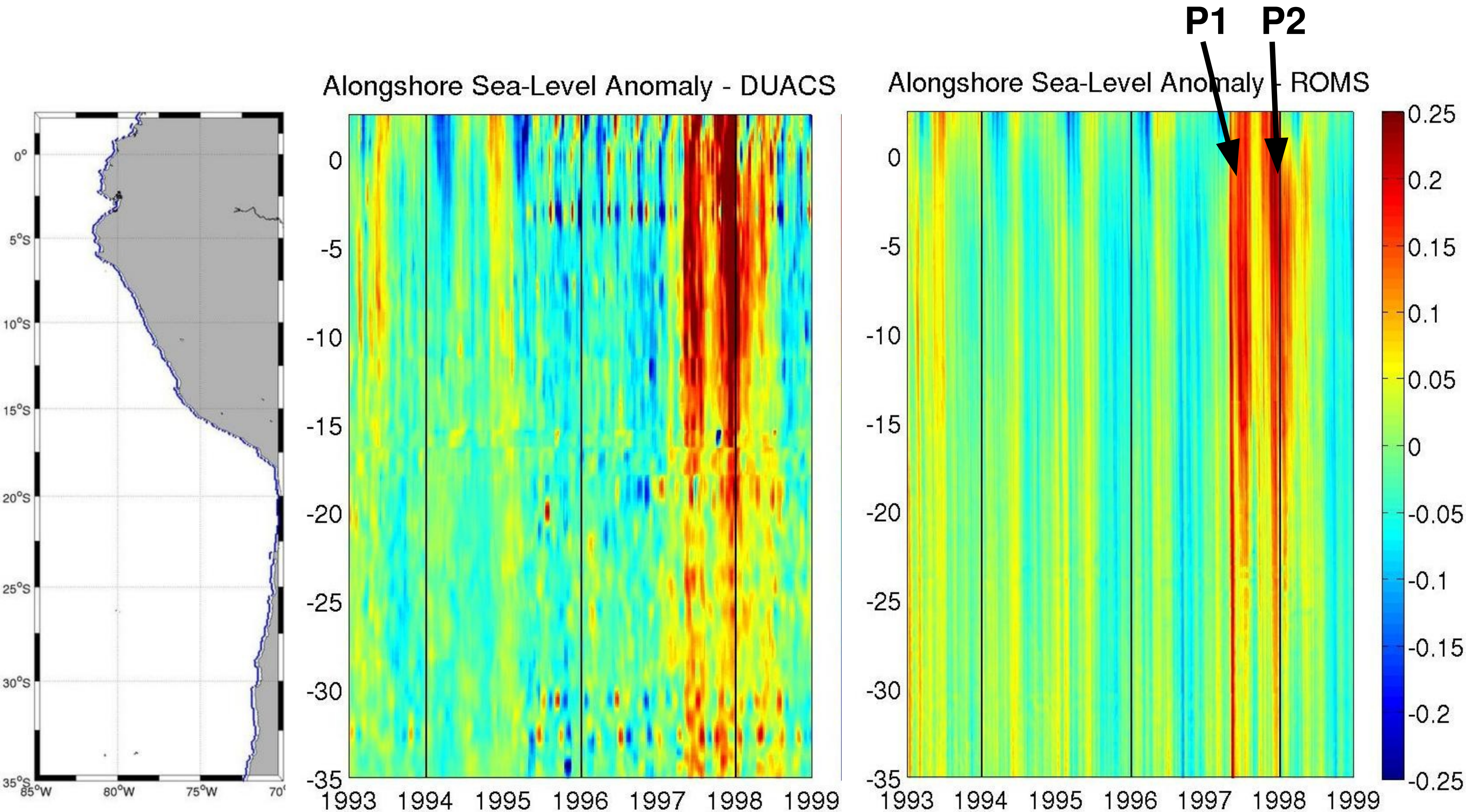
Zonal Velocity profiles 110W/0N. 1996/1999

TAO Data





Interannual Variability – Alongshore Sea Level Anomaly

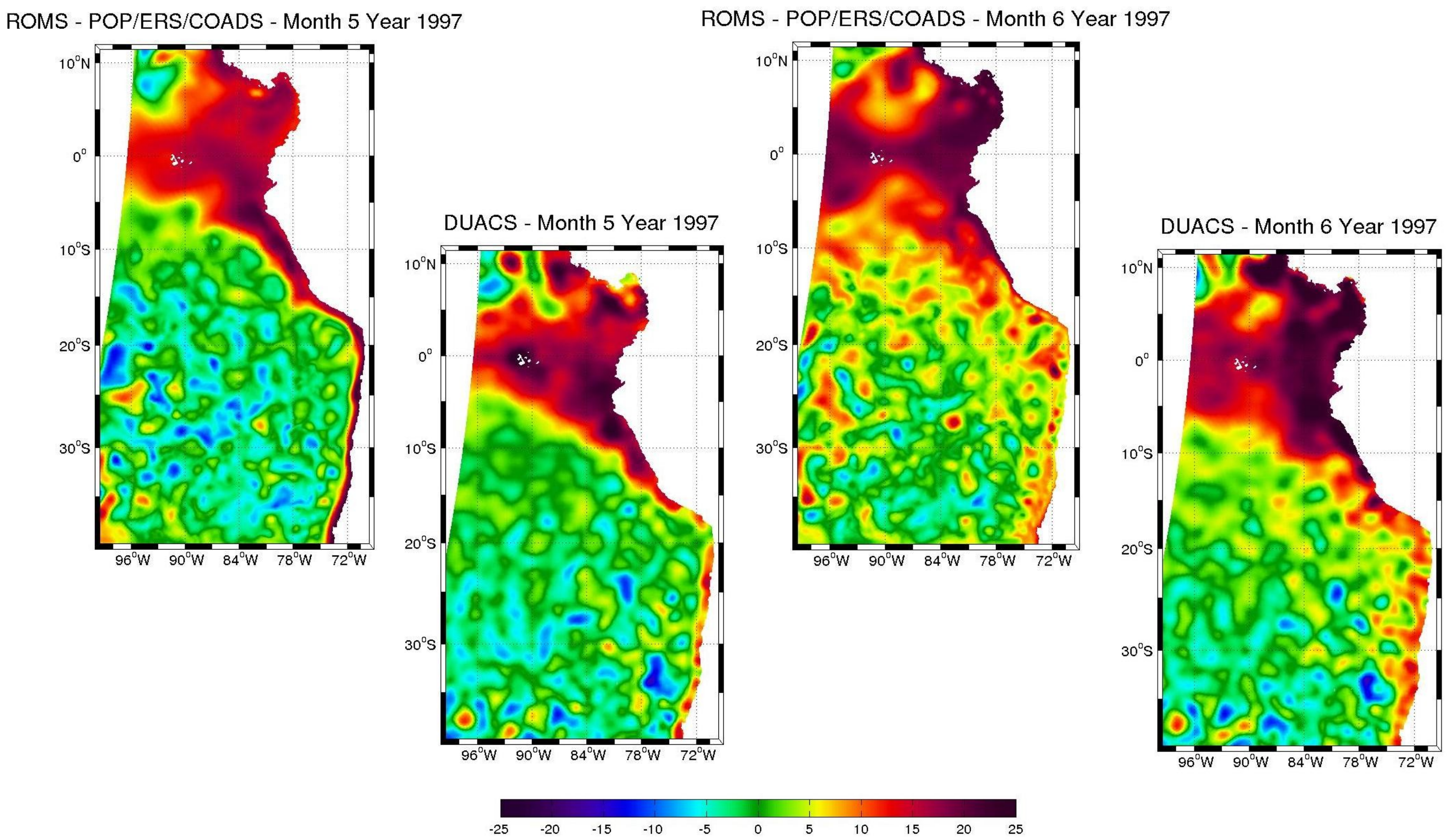


Correct timing for the 2 strong SLA peaks (P1 & P2) – P2 slightly too weak

Relaxation between P1 & P2 captured

Anomaly propagates down to 35S

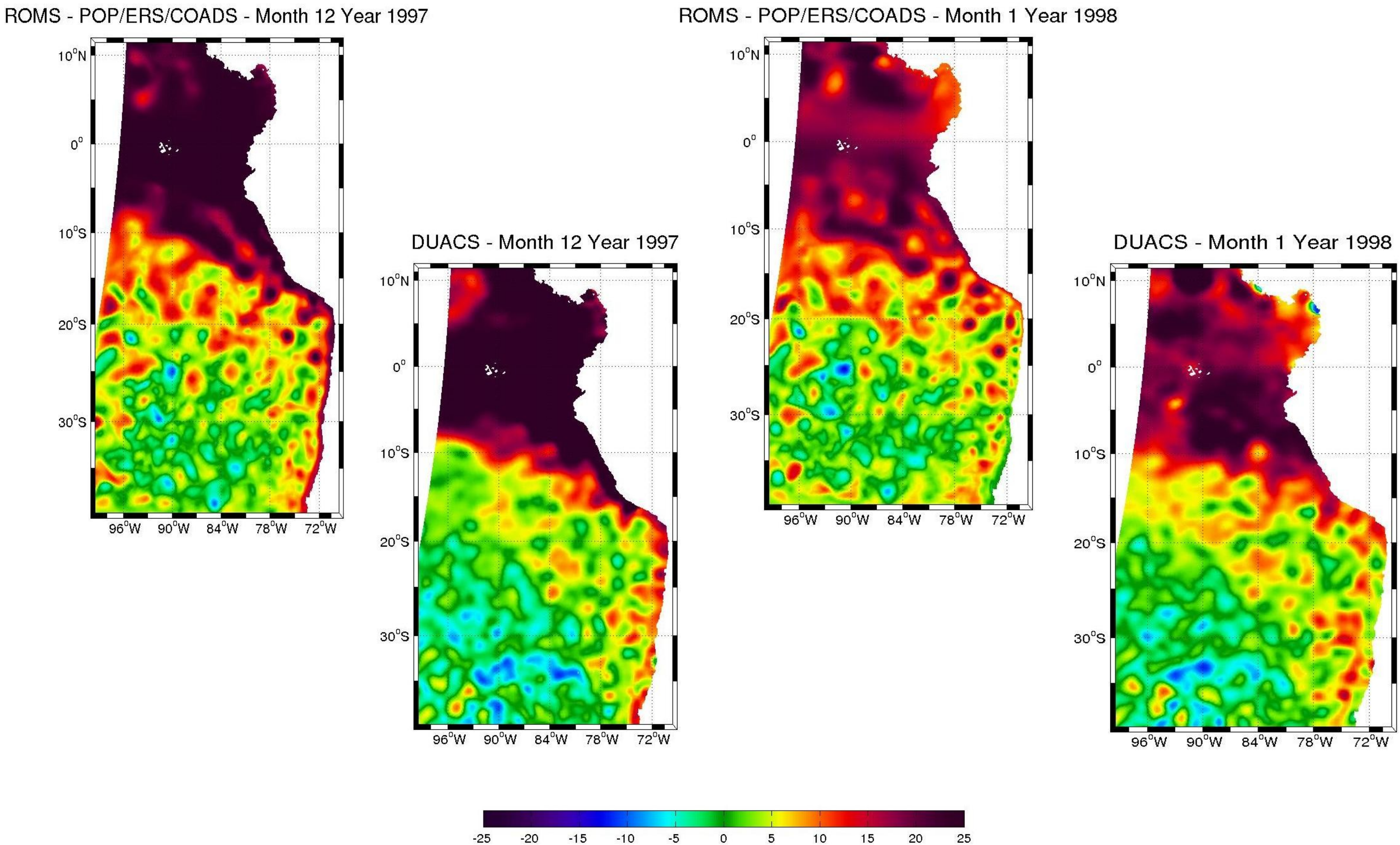
Interannual Variability – Sea Level Anomaly



ENSO : signal propagates poleward along the coast -

Strong mesoscale activity near-shore : meanders, eddy formations

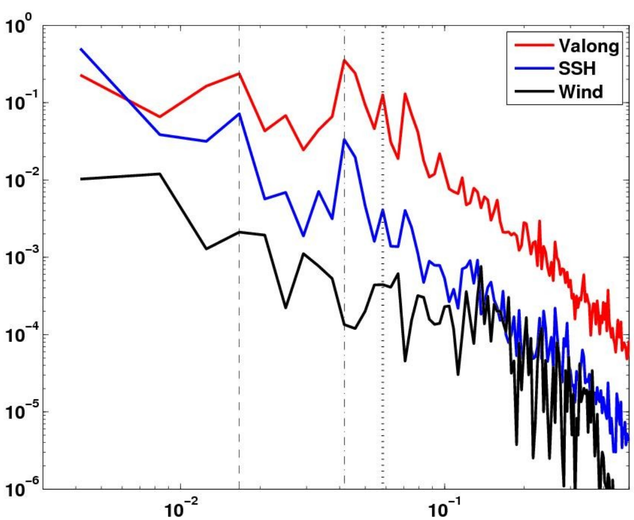
Interannual Variability – Sea Level Anomaly



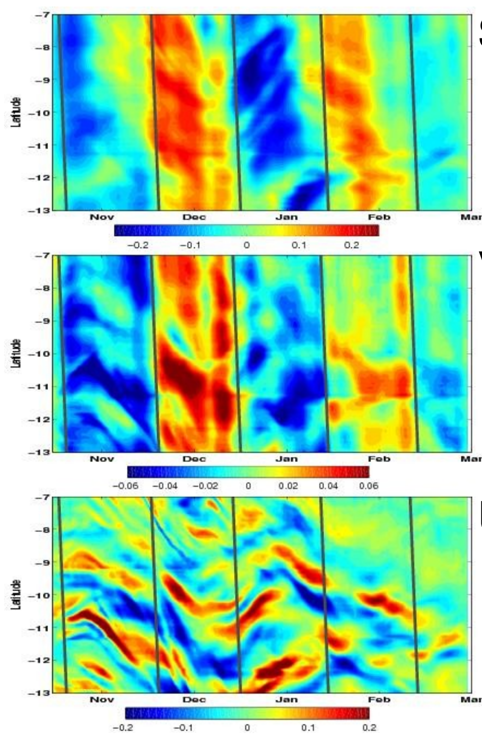
Interannual Variability – Alongshore Sea Level Anomaly poleward coastal waves

ROMS vs Tide gauges : rms error < 5cm – 2nd SLA peak underestimated ~ 20%
correct timing of the 2 peaks and attenuation form north to south

Equatorial variability transmits as coastal-trapped waves especially in the range [50-70 days^{-1}] – model dynamics consistent with this description



V & SSH peak in this range
(also present in POP at the equator)
nor for the local wind



Sea level

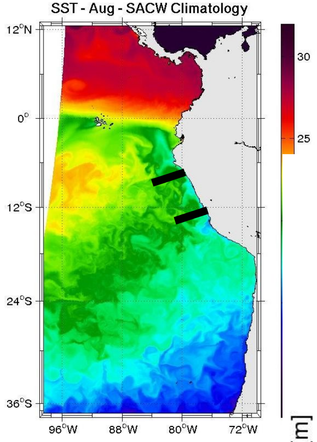
V along

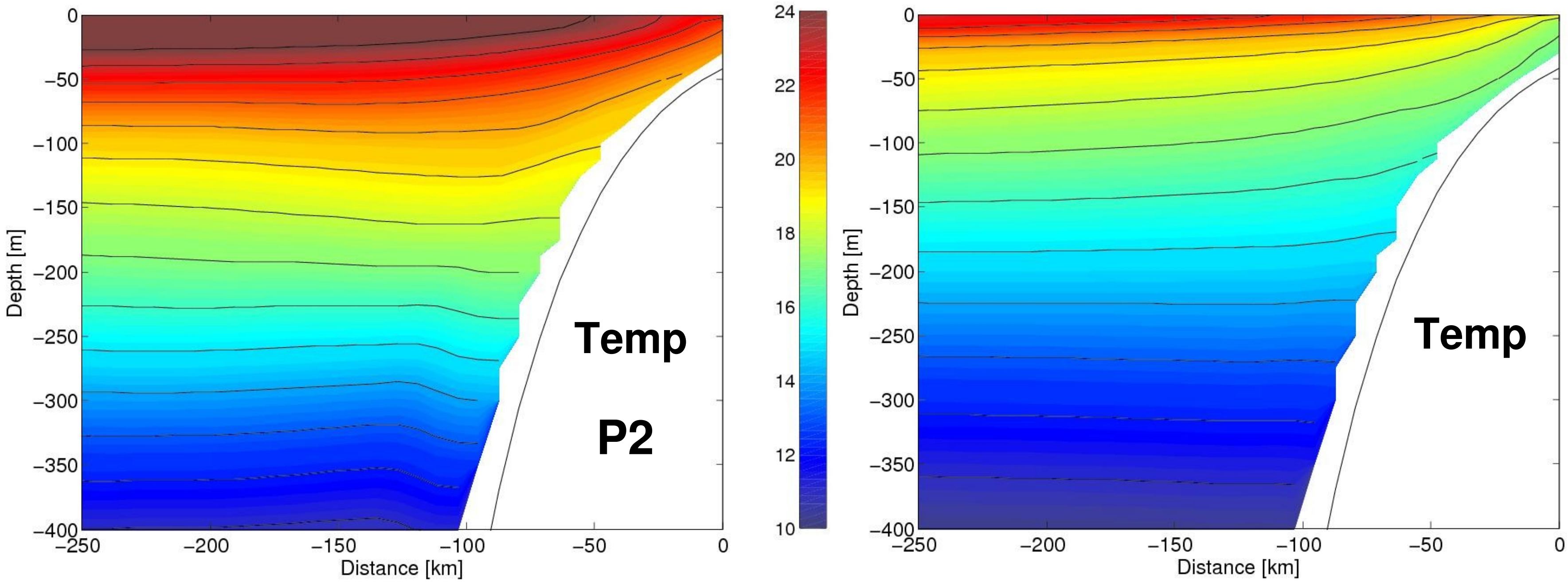
U cross

band pass [80-12] days^{-1}
oct 97 to mar 98

Poleward propagation ~ 3.2 m/s – consistent with observations
V along ~ geostrophic, correlated with SLA
U cross : no clear propagation (expected from CTW models)

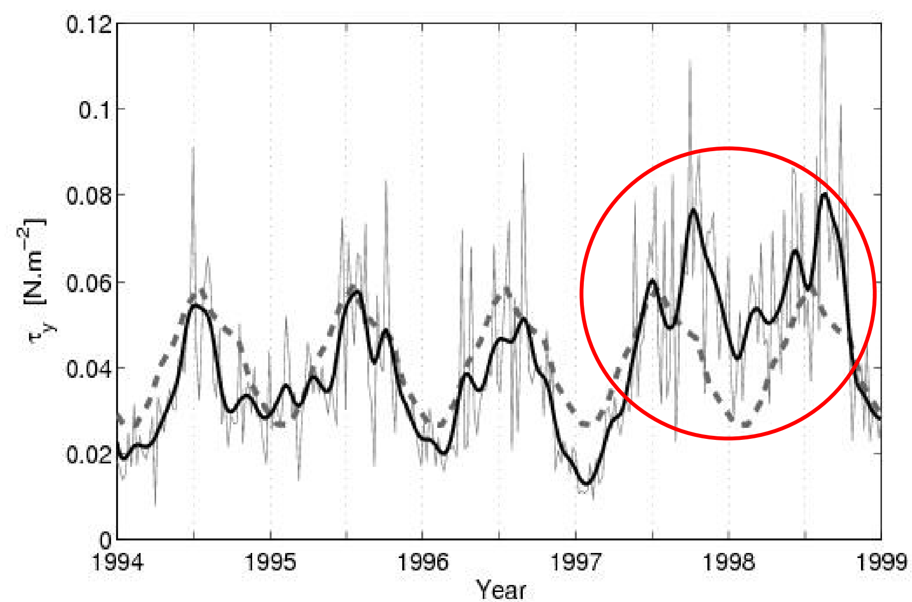
Interannual Variability – Cross-shore Section (avg 7S/13S)

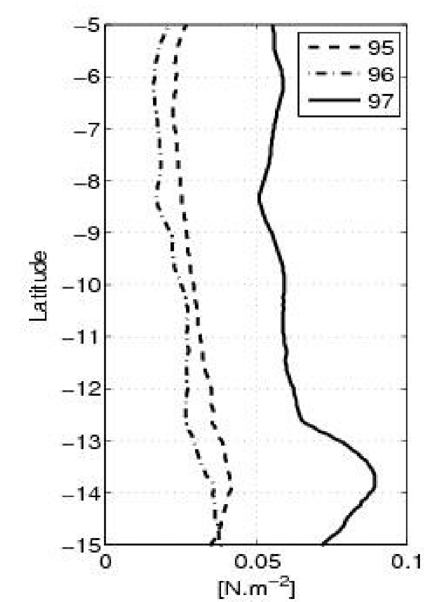




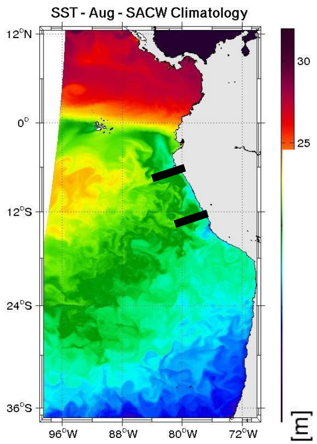
Oct97/Feb98 | **Oct/Feb Clim**

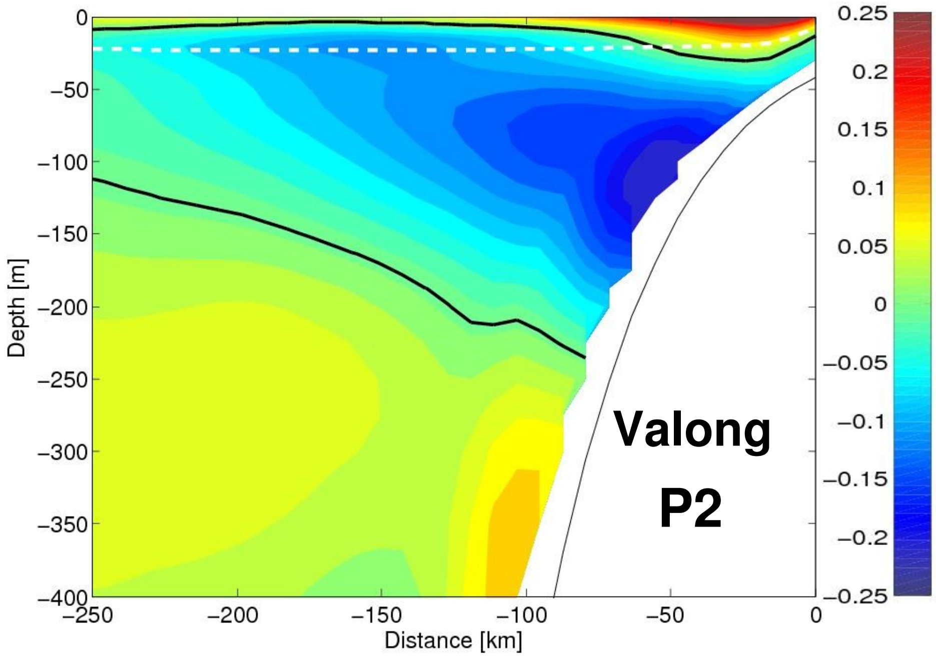
Alongshore wind-stress

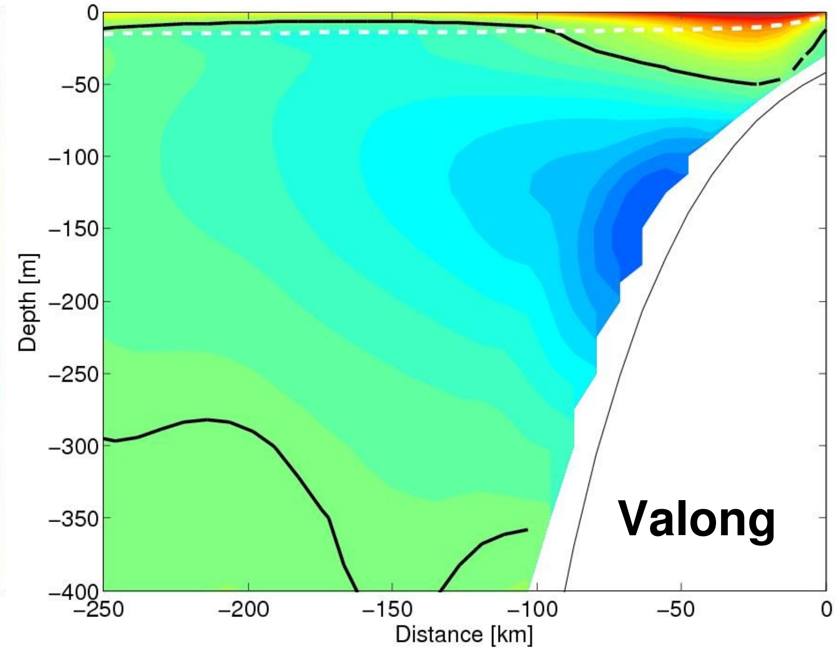




Interannual Variability – Cross-shore Section (avg 7S/13S)

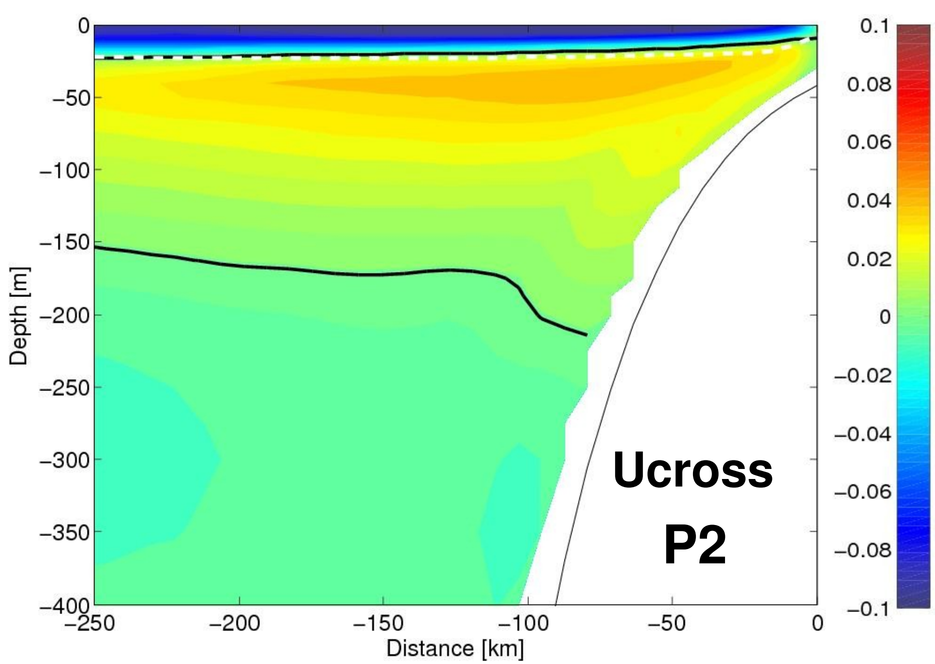


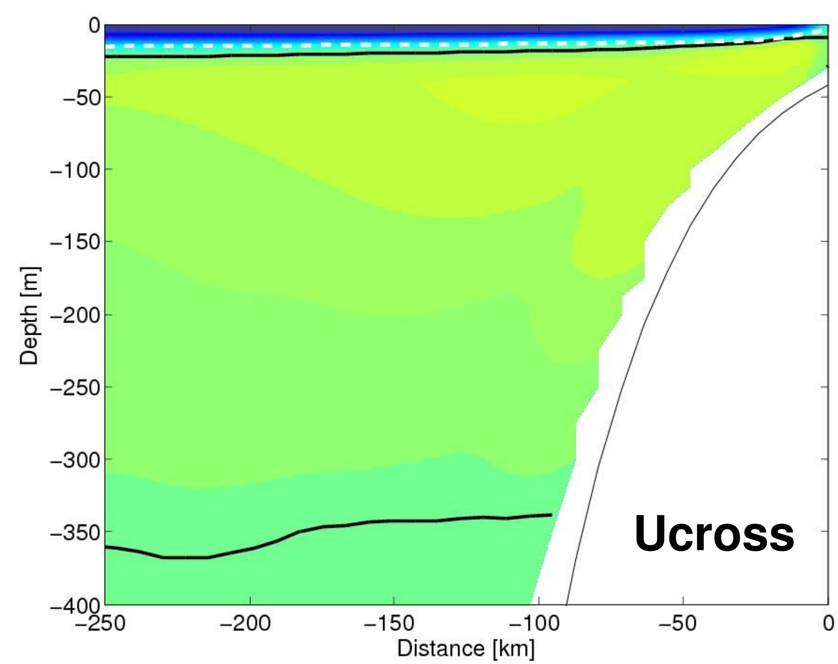




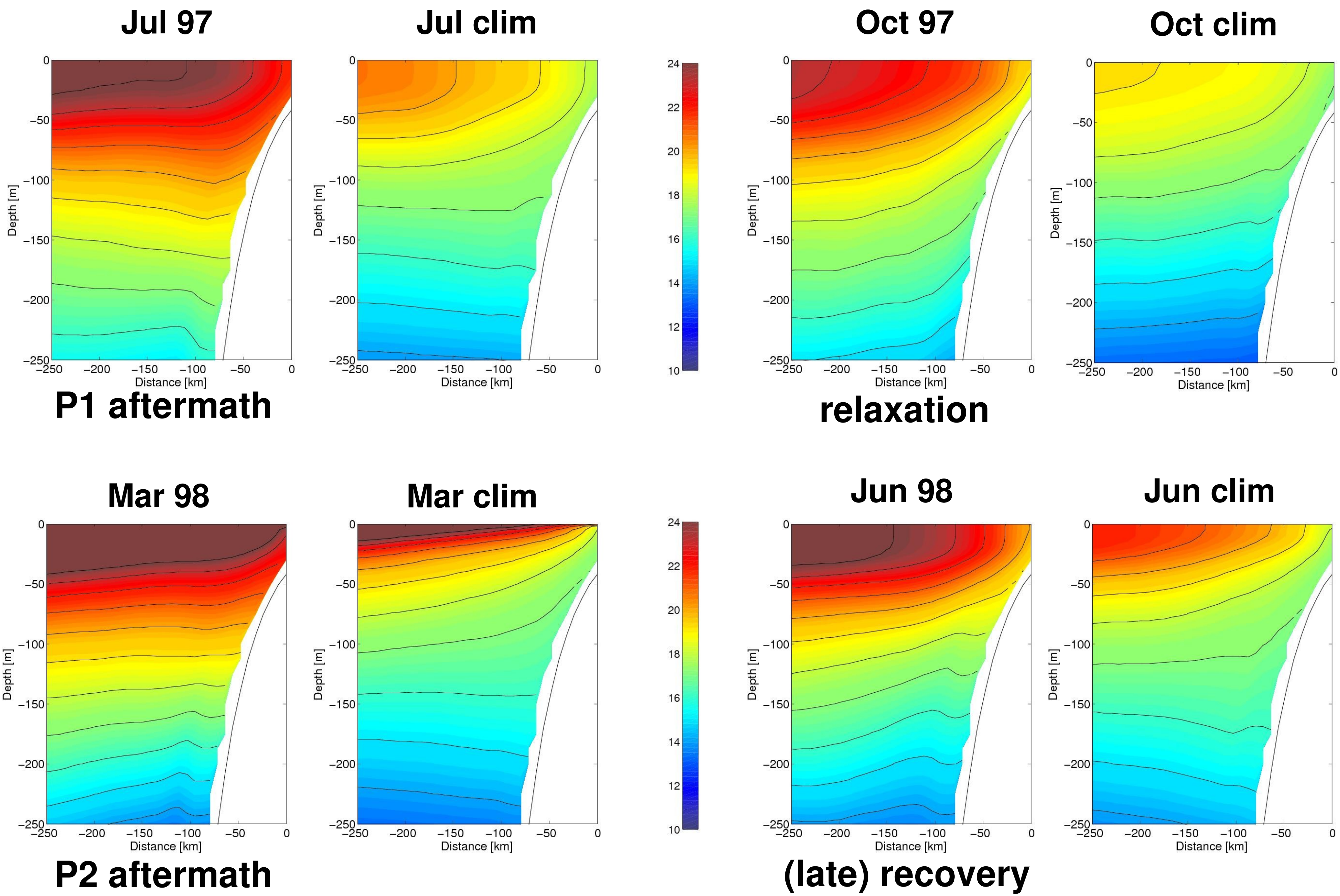
Oct97/Feb98

Oct/Feb Clim

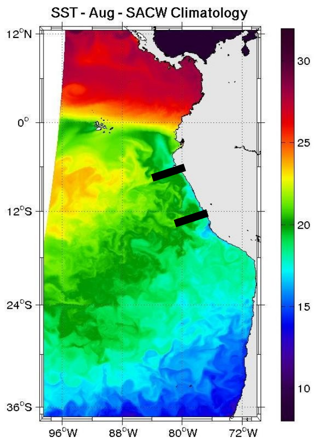


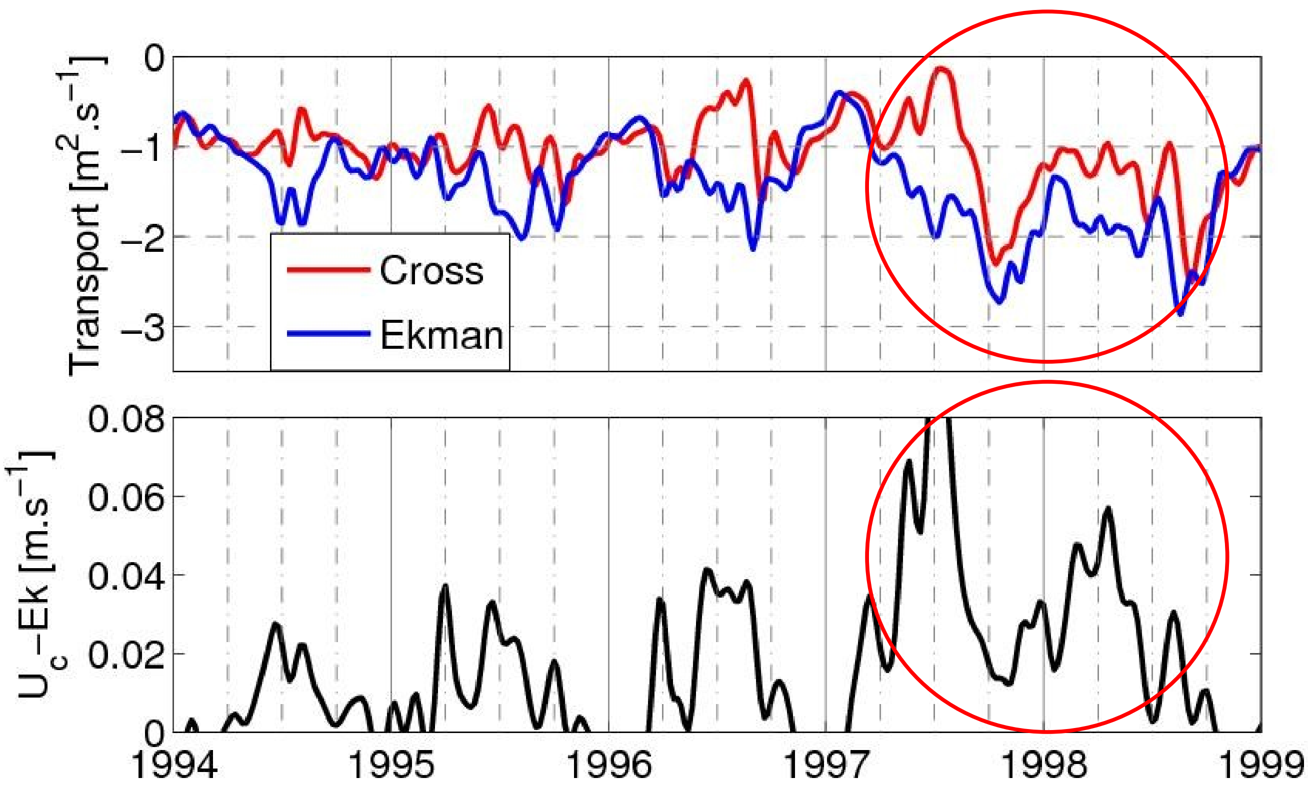


Upwelling and ENSO – Cross-shore Section (avg 7S/13S)

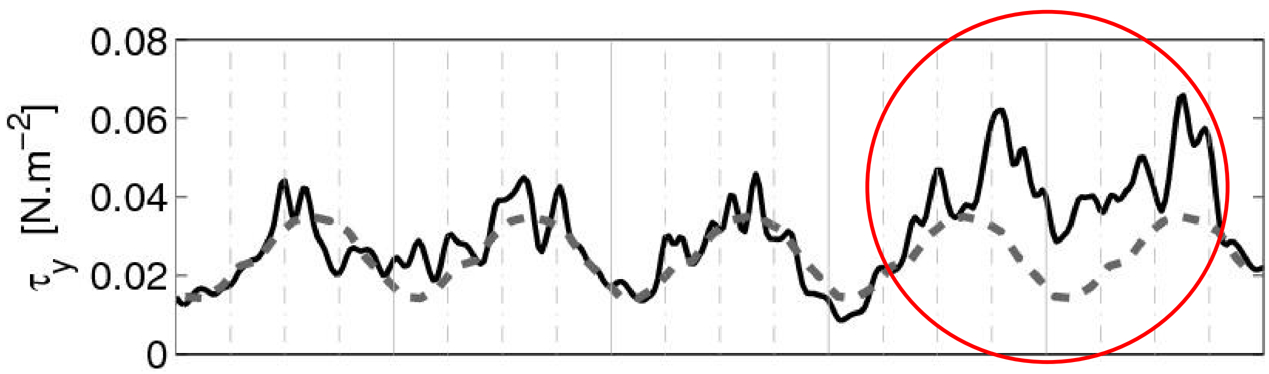


Upwelling and El Nino off Peru



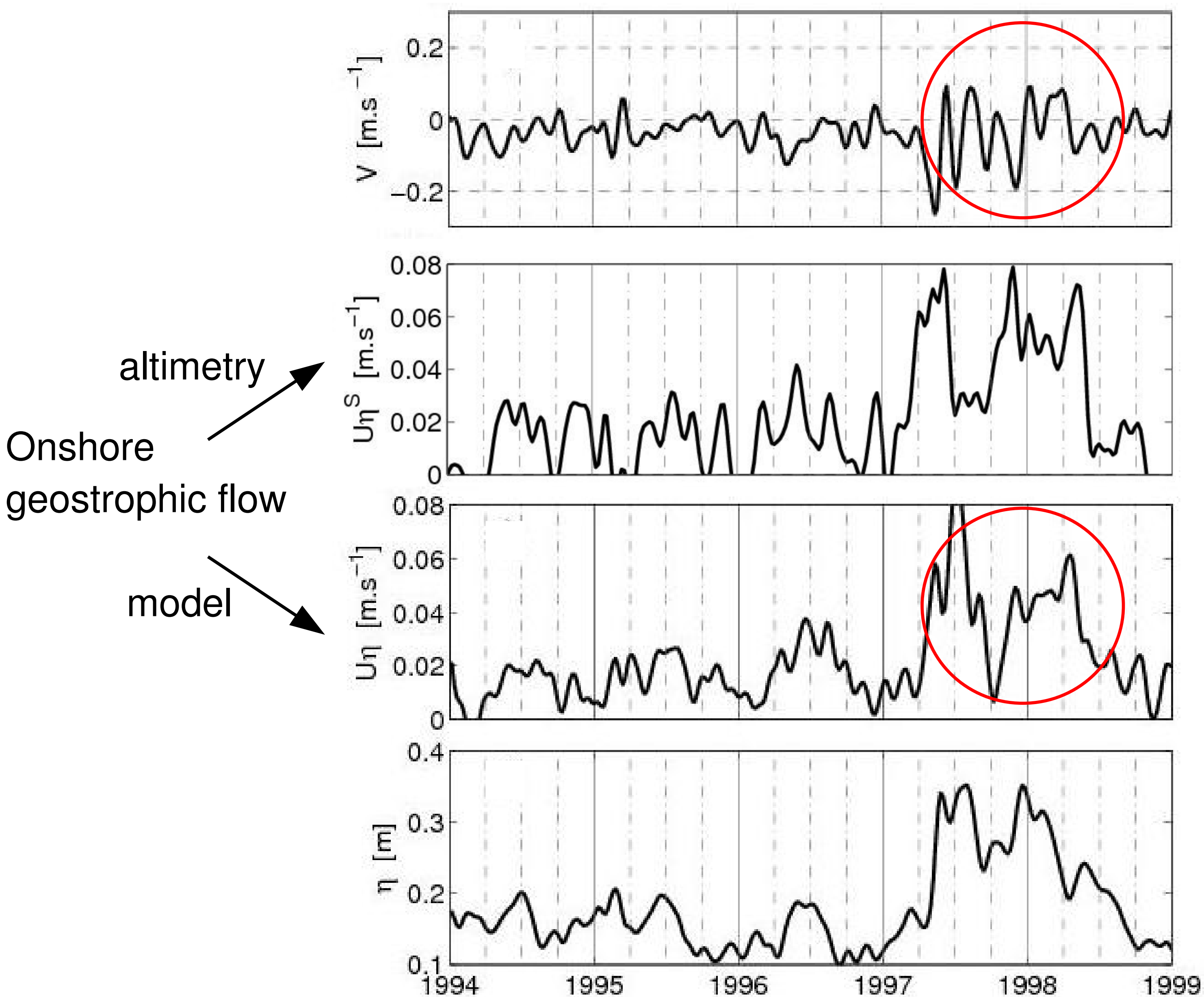


Alongshore wind-stress



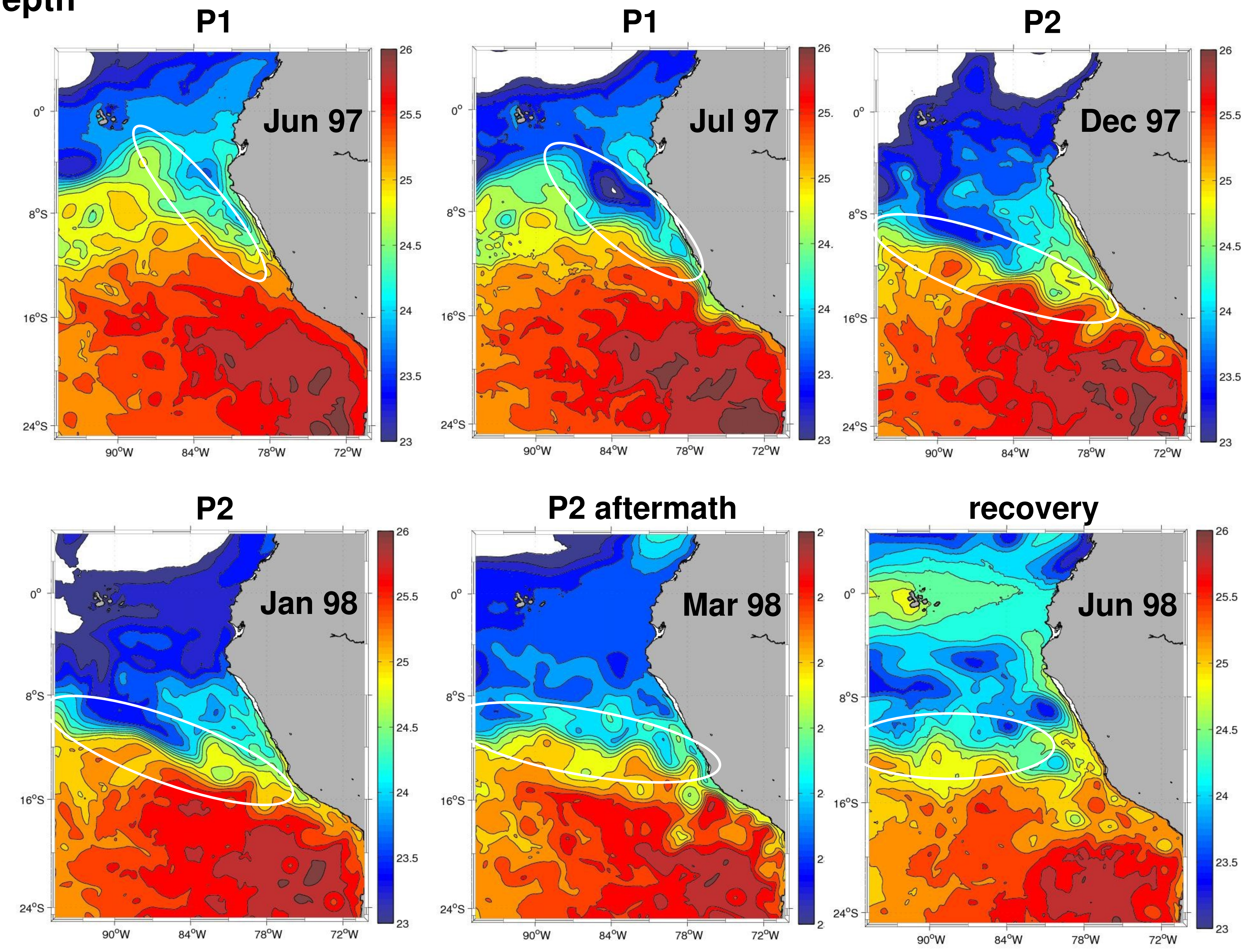
Geostrophic onshore flow counteracting Ekman offshore flow (suggested by Huyer (1987) for a short period of 82/83 ENSO

Upwelling and El Nino off Peru



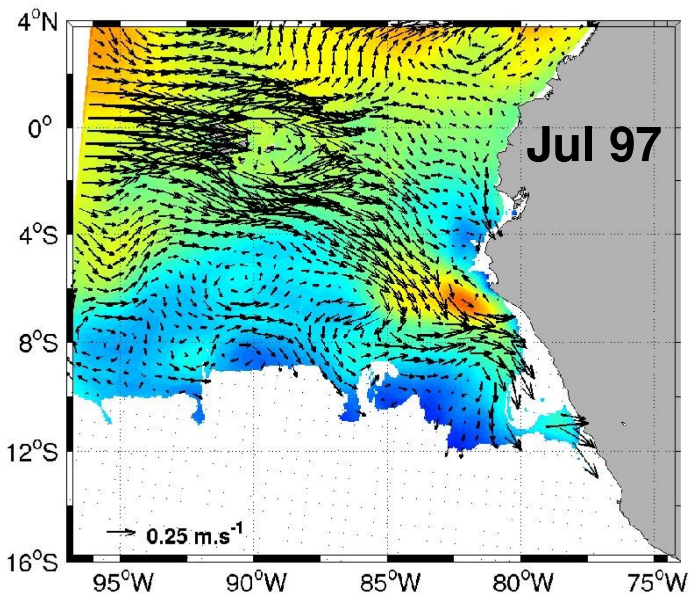
rho_p
50m depth

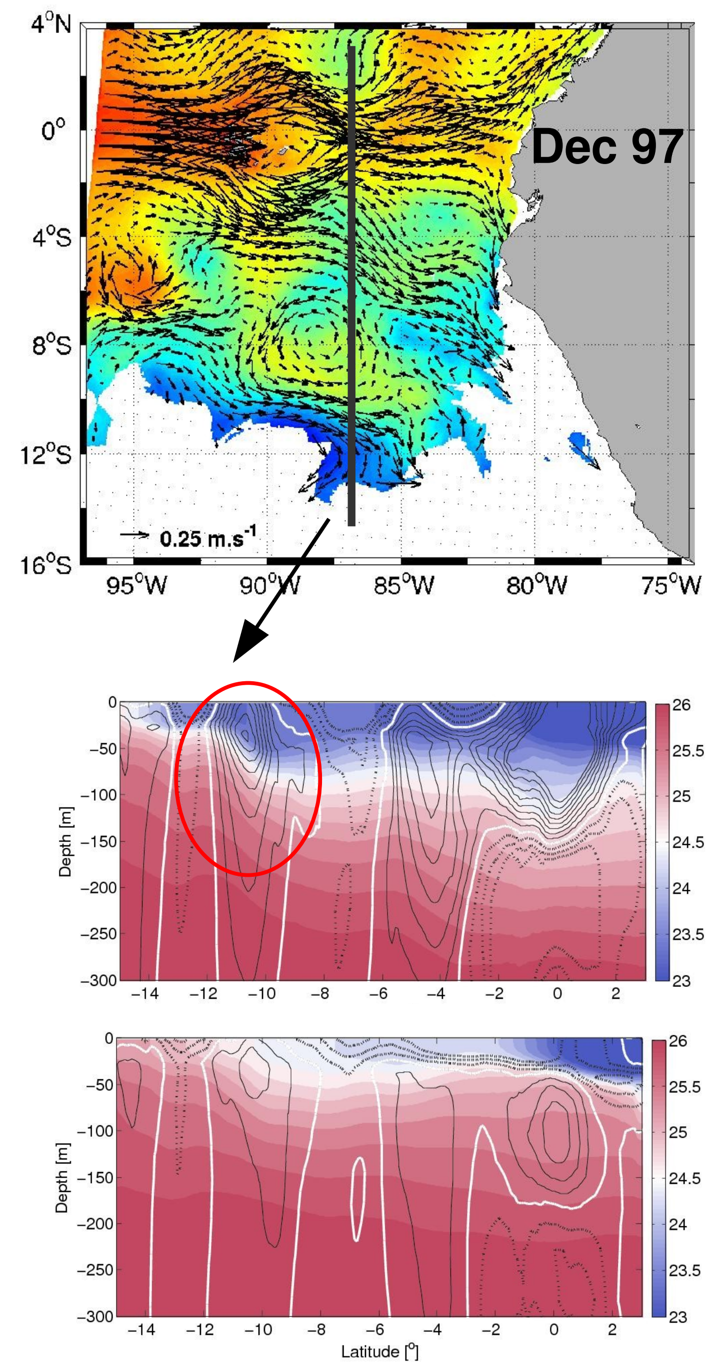
Upwelling and El Nino – water mass off Peru



Upwelling and El Nino – water mass off Peru

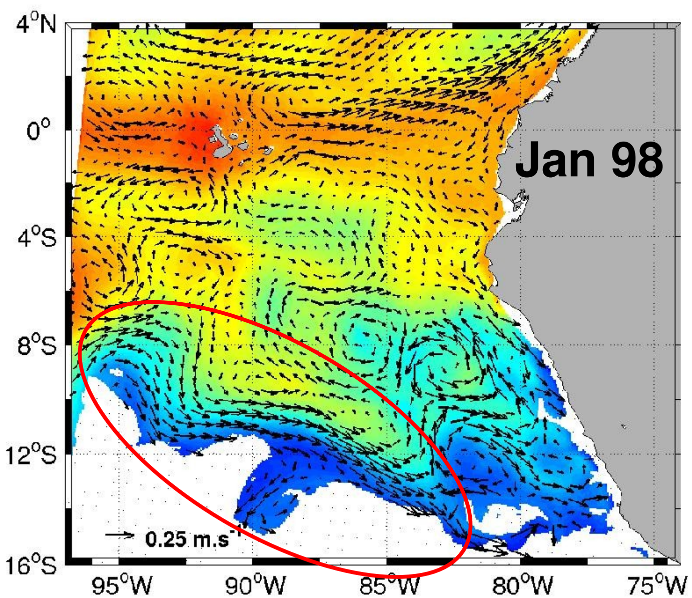
velocity on 1024 kg.m-3 isopycnal surface



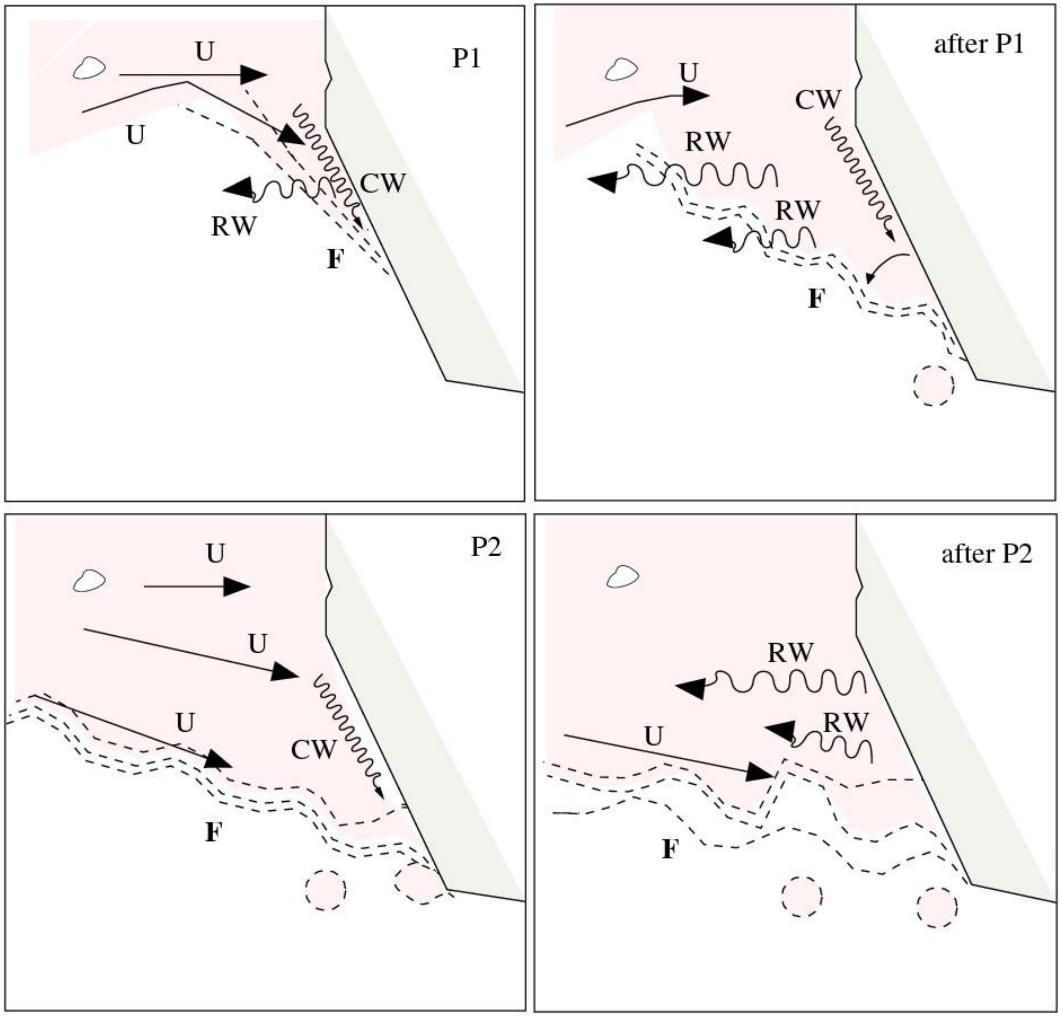


Dec 97

Dec clim

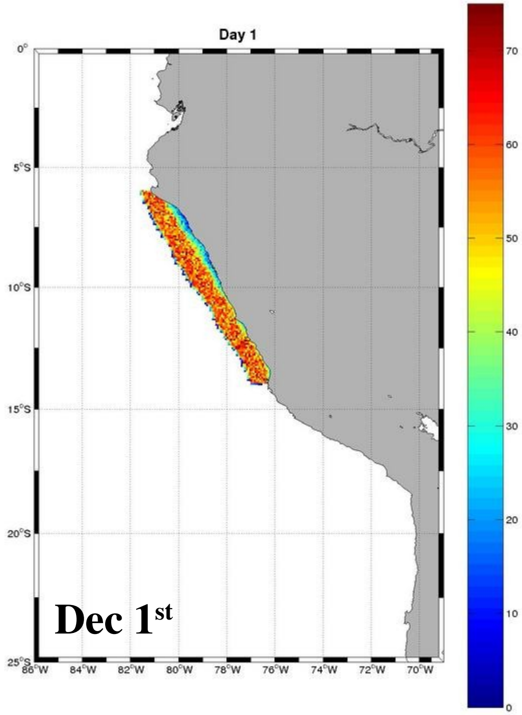


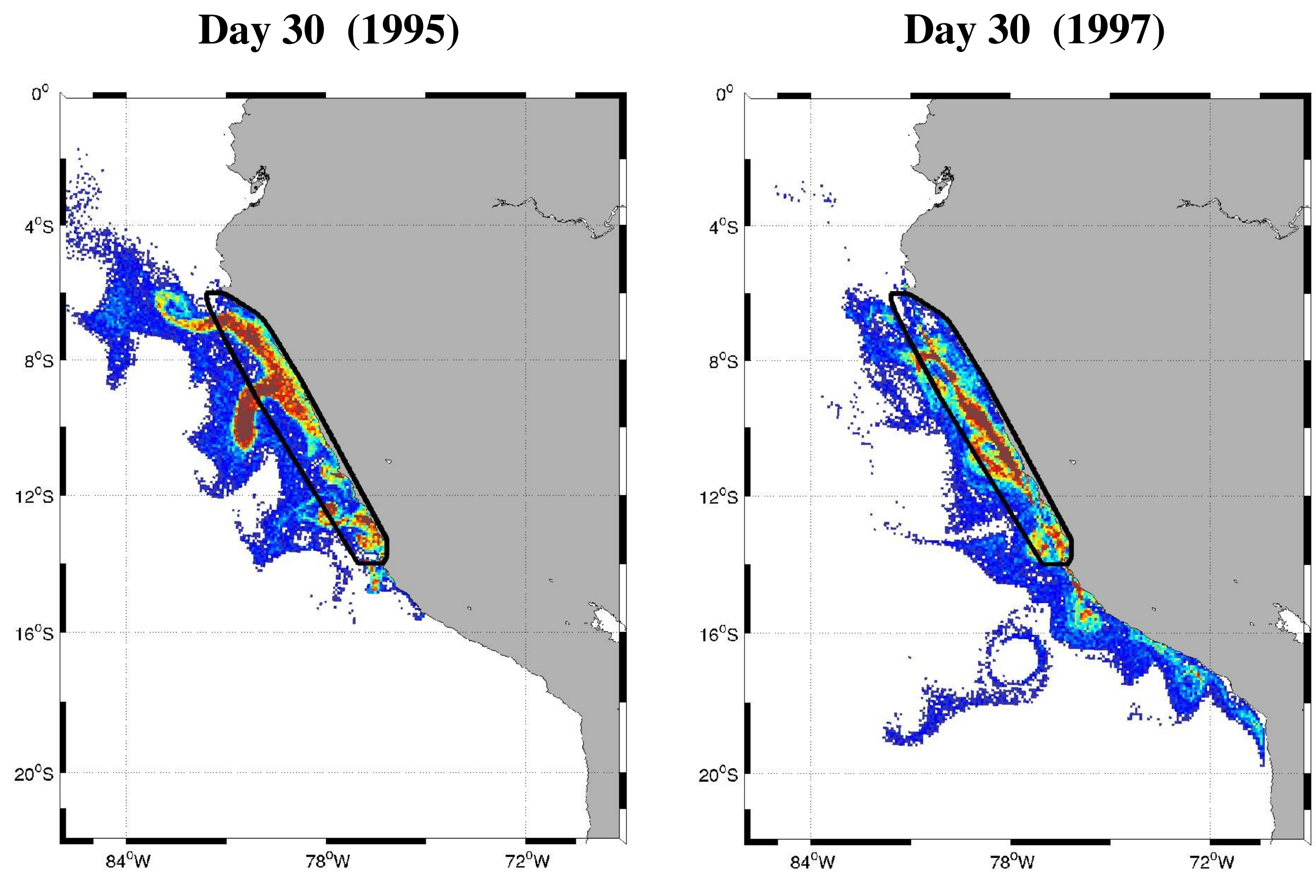
El Nino off Peru



Impact on material dispersion : lagrangian view

100 000 particles advected "offline" during 2 months. Released over the Peruvian Shelf during the strong El Nino event (P2).





Changes in retention/dispersion patterns
Larger alongshore dispersion / Reduced offshore dispersion
Consistent with geostrophic flow counteracting Ekman transport
Mitigate the negative effect of upwelling intensity reduction

Satisfactory level of realism to simulate a strong ENSO event in the regional domain – favorable comparison with altimetry

- Strong modification of currents structure and thermocline structure
- Ubiquitous modification of the mesoscale activity near-shore

- Upwelling intensity controled by cross-shore geostrophic flow (not related to CTWs) - upwelled water with different characteristics (different origins).
- Onshore geostrophic maybe an useful El Nino indicator
- Equatorial variability in the near-shore region through CTWs (alongshore current more intense)
- Late recovery of upwelling : advection (larger scale) of warm-water mass

Controling processes of the accumulation of the equatorial water mass off Peru (ex: front)

Modulation of the mesoscale activity

To conclude

- Discrepancies in the solution : (as usual !) Boundary conditions ? Atm Fluxes? ... others ... ?
- but ... Satisfactory level of realism to simulate a strong ENSO event in the regional domain

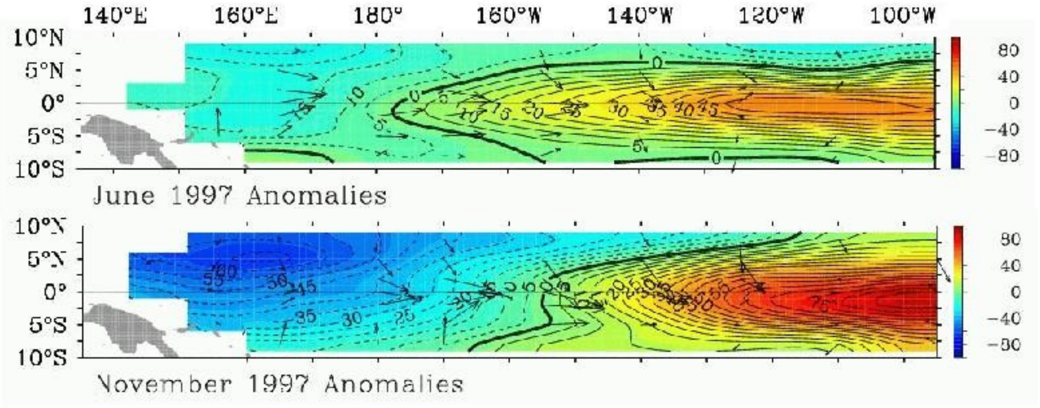
- Strong modification of currents structure and thermocline structure
- Upwelling still present, but upwelled water with different characteristics (different origins)
- Ubiquitous modification of the mesoscale activity near-shore

- Important change in term of particles transport and mass exchange along the coast : weak change in cross-shore retention, alongshore dispersion dramatically enhanced

First step and useful “tools” toward a better understanding of ENSO impact on the upwelling system and its important influence on the biological activity.

Just an exemple for Central Peruvian Shelf – analysis could (should) be extended to other sub-regions along Peru/Chile coast.

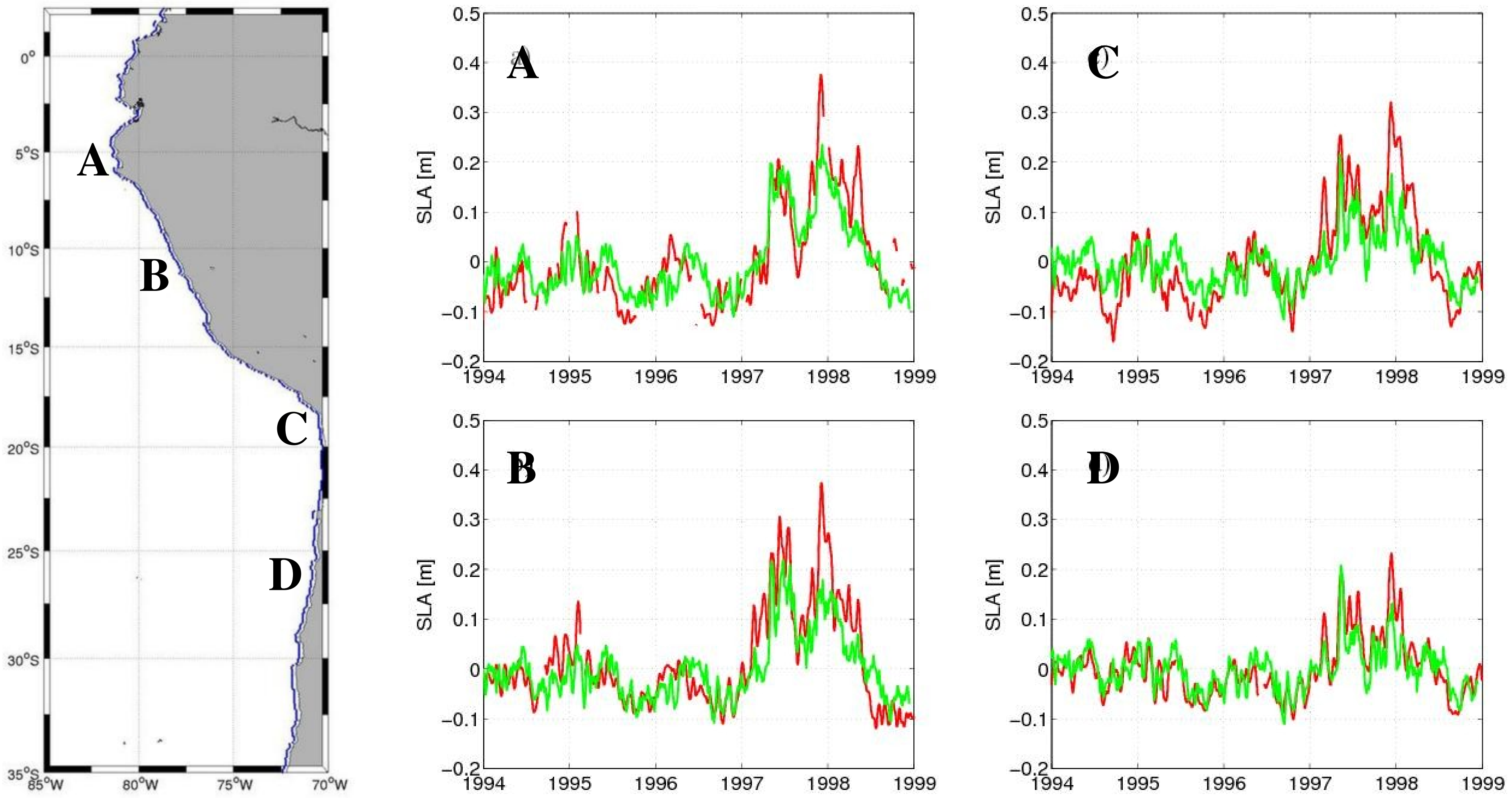
Upwelling and El Nino – water mass off Peru



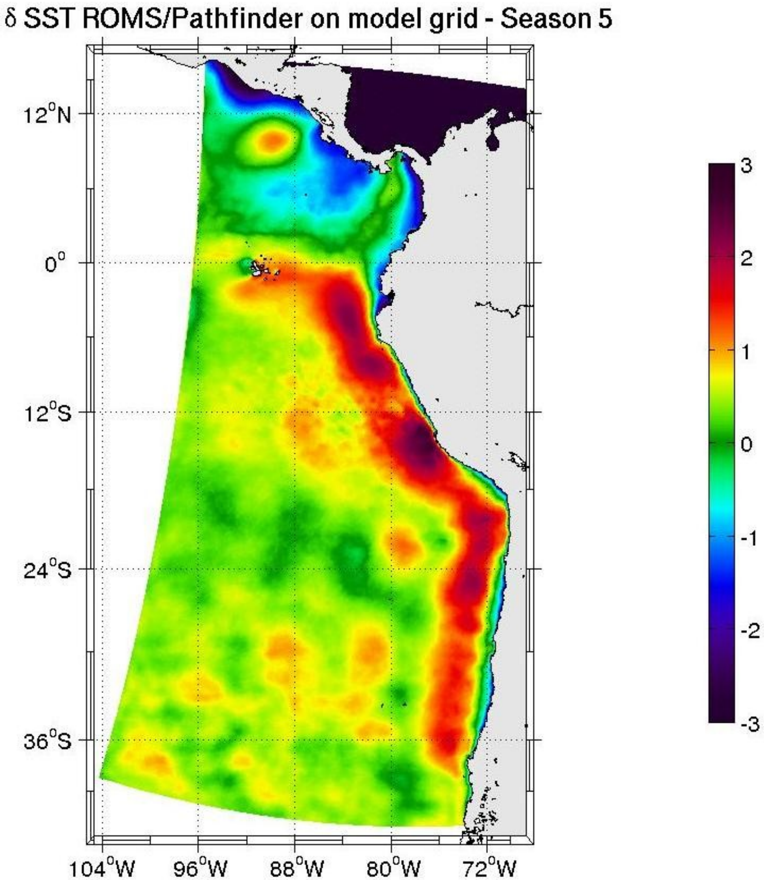
P1

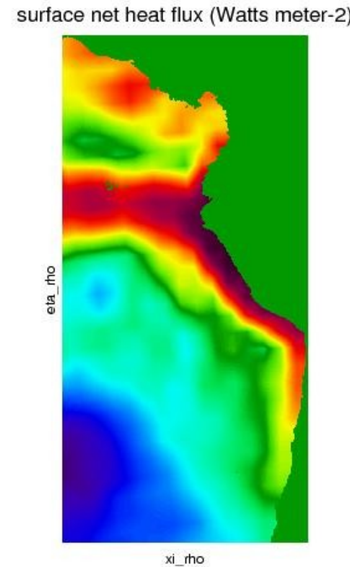
P2

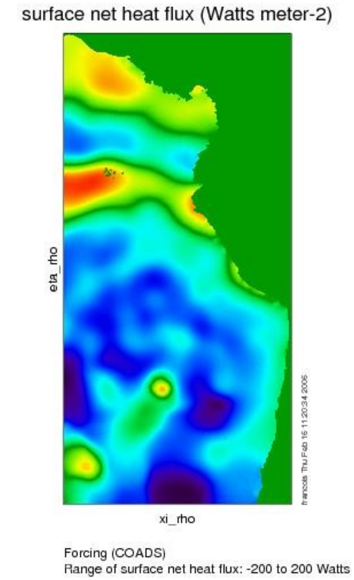
Interannual Variability – Alongshore Sea Level Anomaly

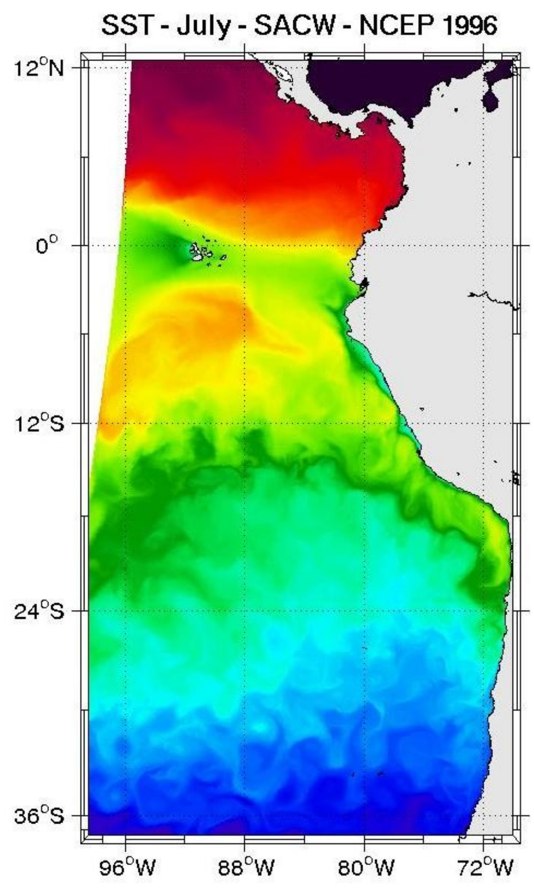


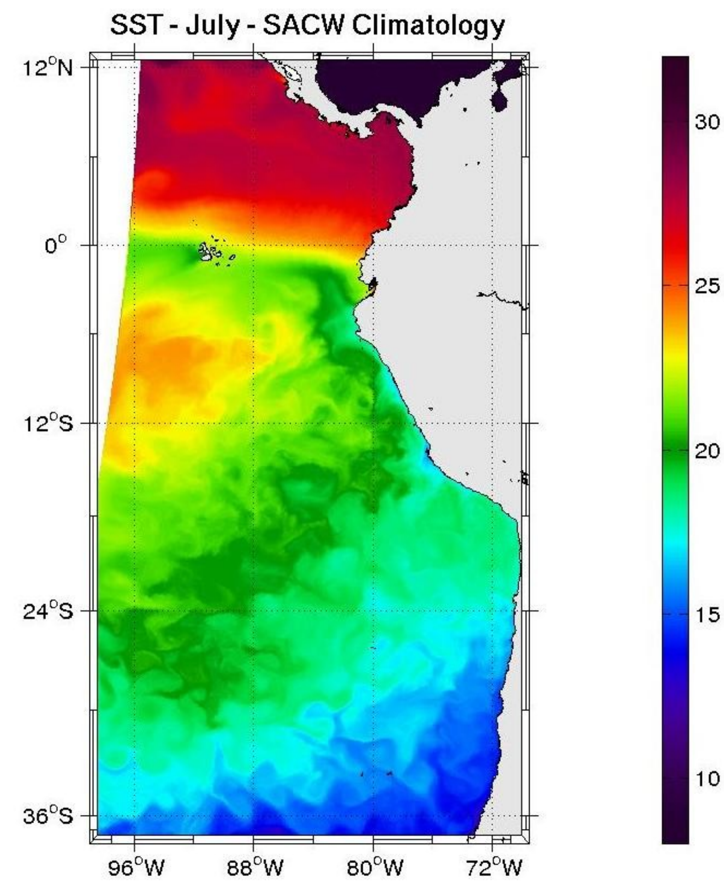
ROMS vs Tide gauges


δ SST ROMS/Pathfinder on model grid - Season 5
12°N
0°
12°S
24°S
36°S
104°W
96°W
88°W
80°W
72°W
3
2
1
0
-1
-2
-3


surface net heat flux (Watts meter-2)
eta_rho
xi_rho


surface net heat flux (Watts meter-2)
eta_rho
xi_rho
Forcing (COADS)
Range of surface net heat flux: -200 to 200 Watts


SST - July - SACW - NCEP 1996
12°N
0°
12°S
24°S
36°S
96°W
88°W
80°W
72°W

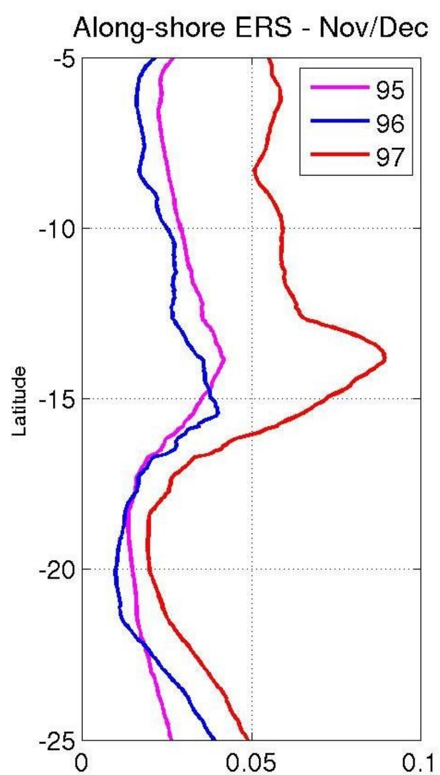

SST - July - SACW Climatology
12°N
0°
12°S
24°S
36°S
96°W
88°W
80°W
72°W
30
25
20
15
10

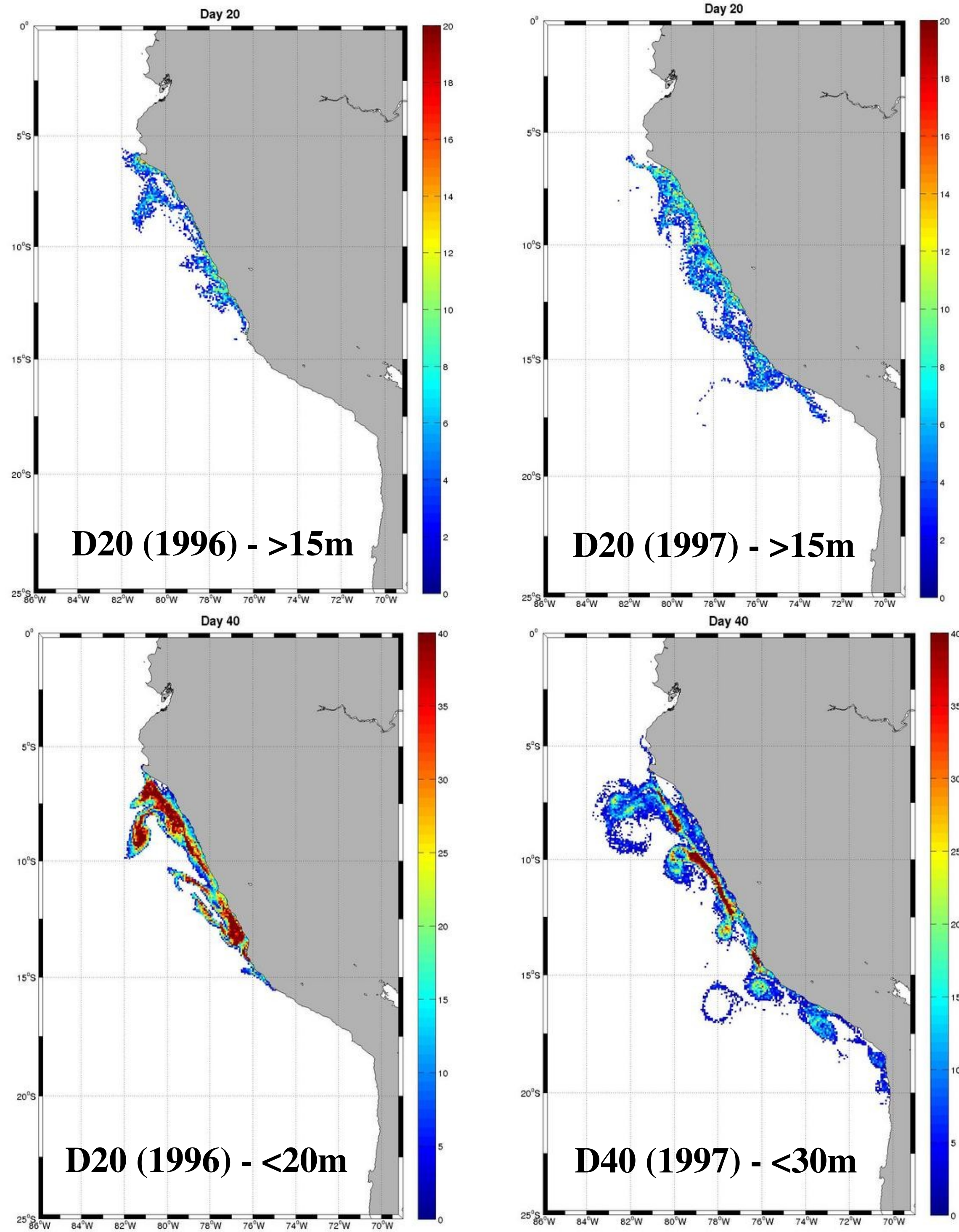
Impact on material dispersion : lagrangian view

Particles initially released below

30m depth

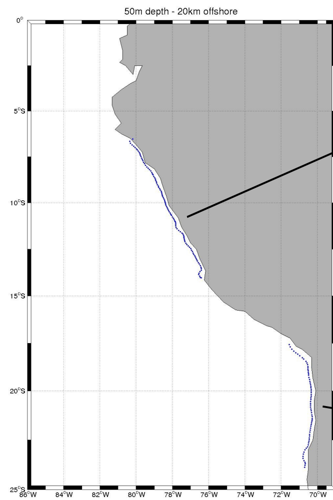
over the Peruvian Shelf

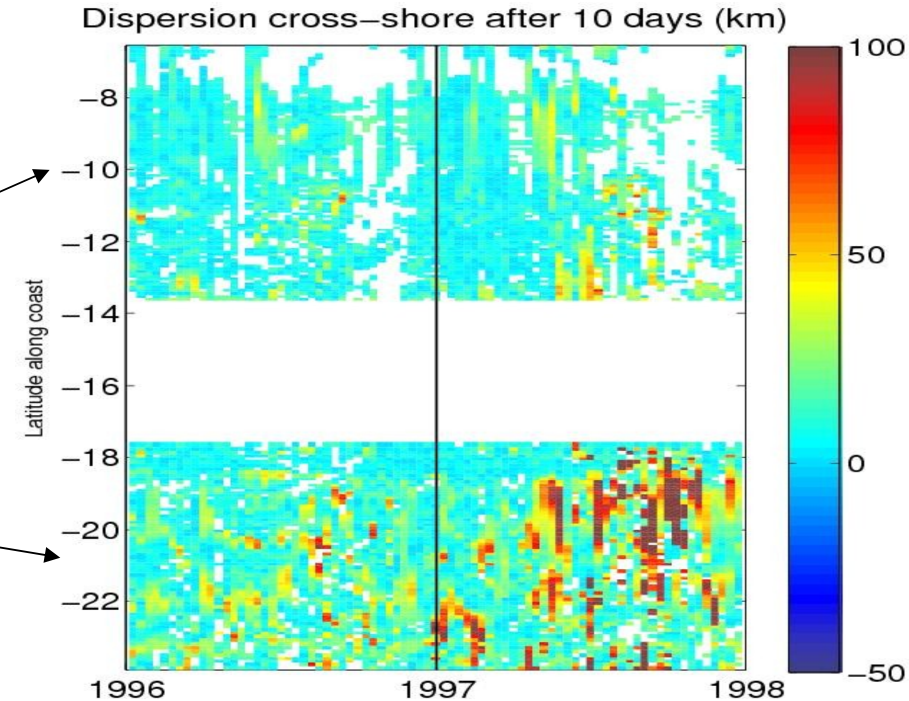




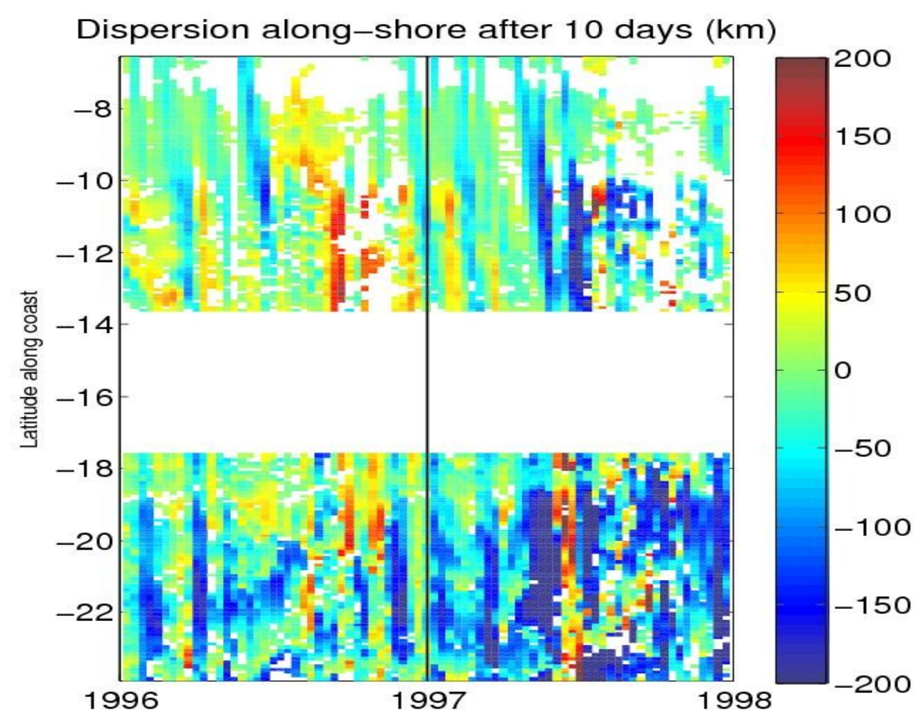
Impact on material dispersion : Lagrangian view

Particles 50m depth, 20km offshore, released every 9 days during 1996 and 1997



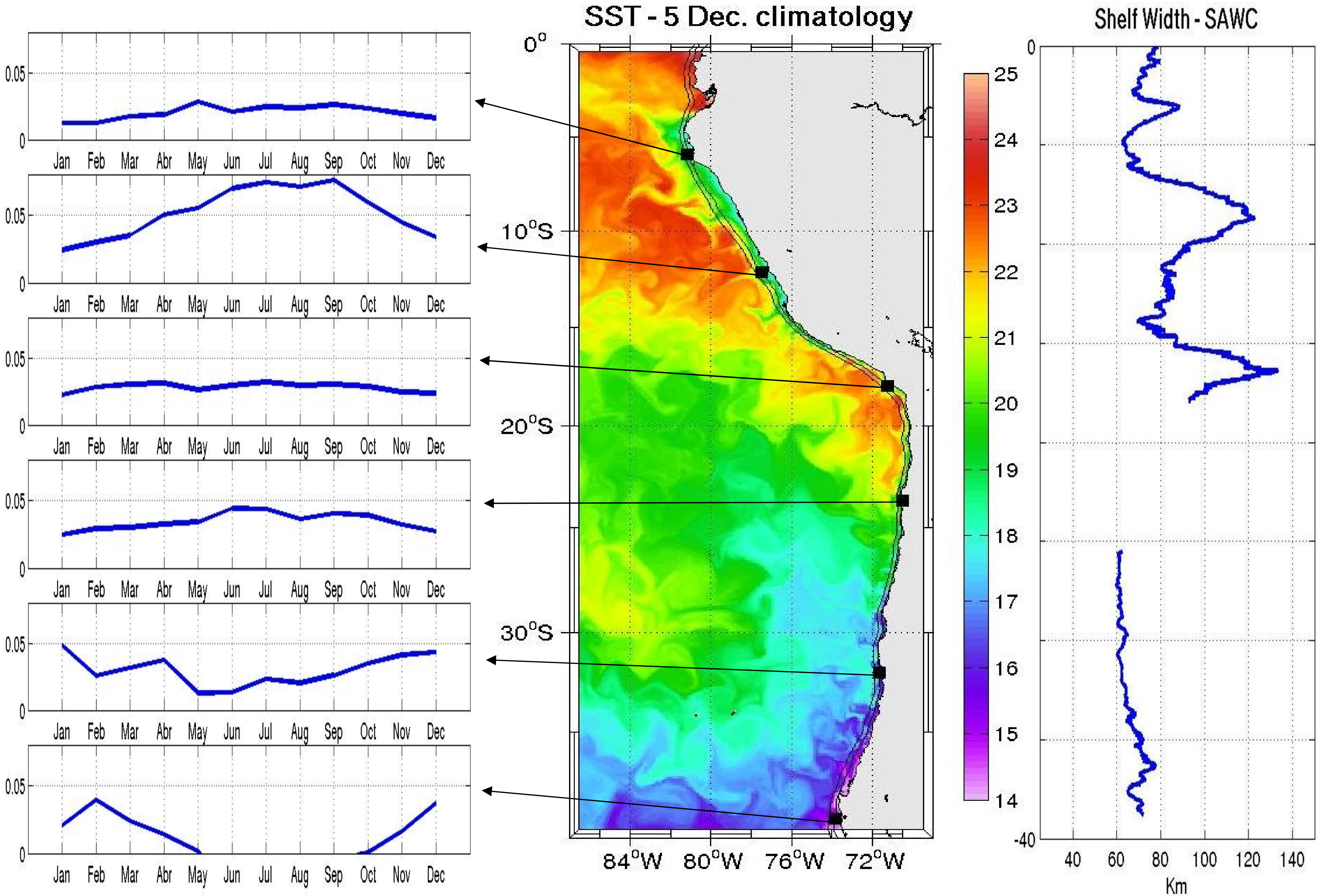


(Particles upwelled (>20m after 15 days) not shown)



ENSO : "retention" cross-shore not reduced during el Nino (except for Northern Chile, associated with eddies formation), but...

strong alongshore displacements (poleward).


SST - 5 Dec. climatology
Shelf Width - SAWC
0.05
0
Jan
Feb
Mar
Abr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0°
10°S
20°S
30°S
84°W
80°W
76°W
72°W
25
24
23
22
21
20
19
18
17
16
15
14
-40
40
60
80
100
120
140
Km