Barrier layer variability in the Western Pacific Warm Pool during 2000-2007

Christelle BOSC [*], Thierry DELCROIX , Christophe MAES

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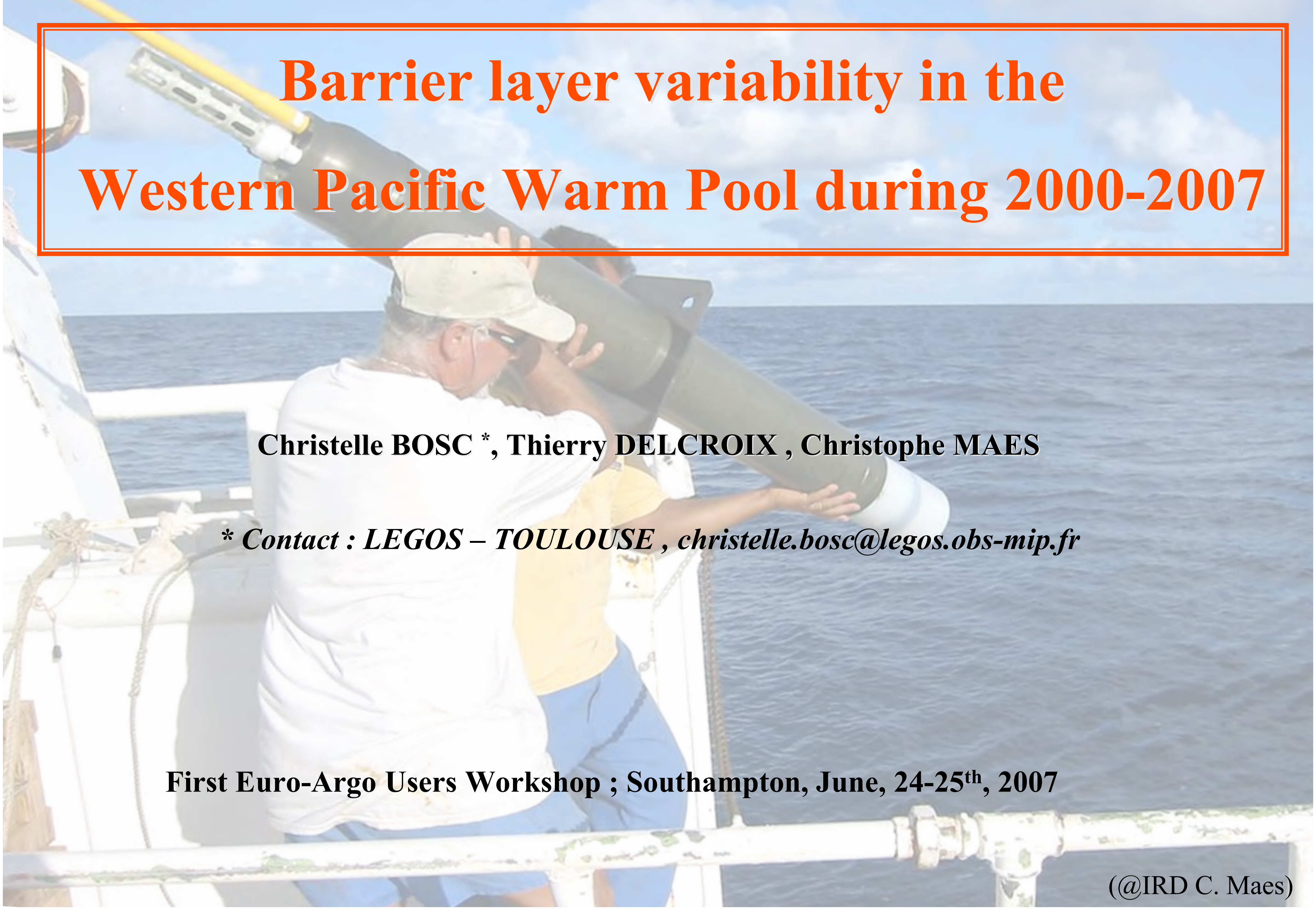
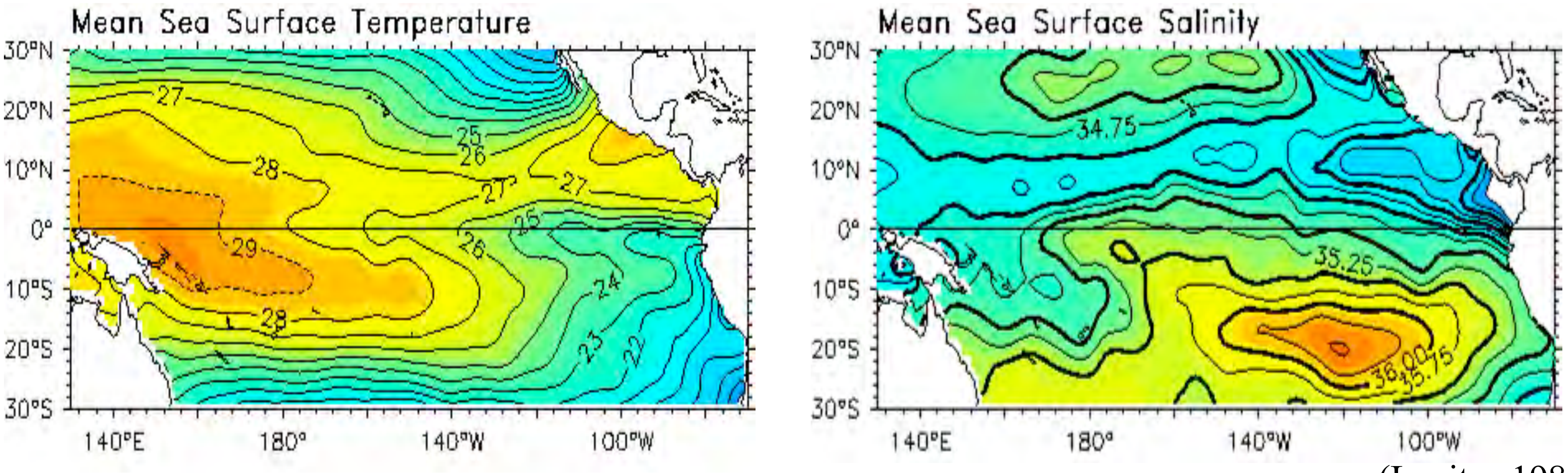
First Euro-Argo Users Workshop ; Southampton, June, 24-25th, 2007



(@IRD C. Maes)

1. Thermohaline structure of the warm pool



(Levitus 1982)

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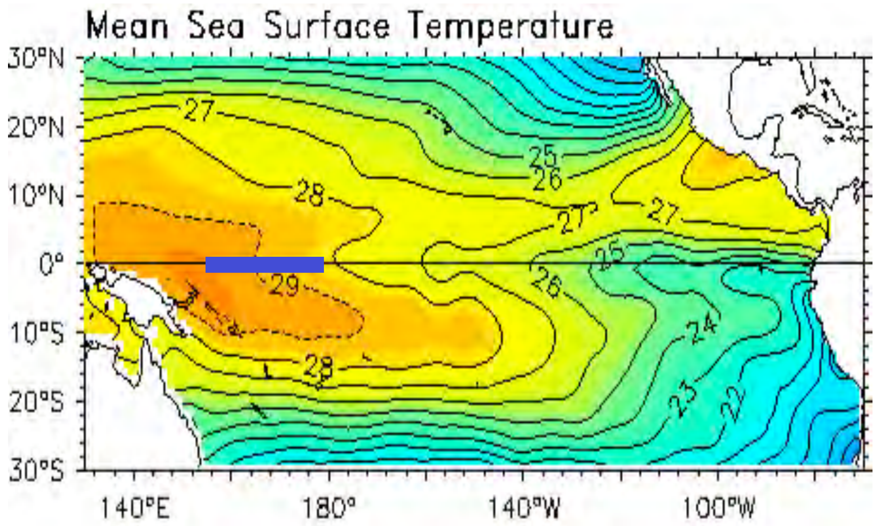
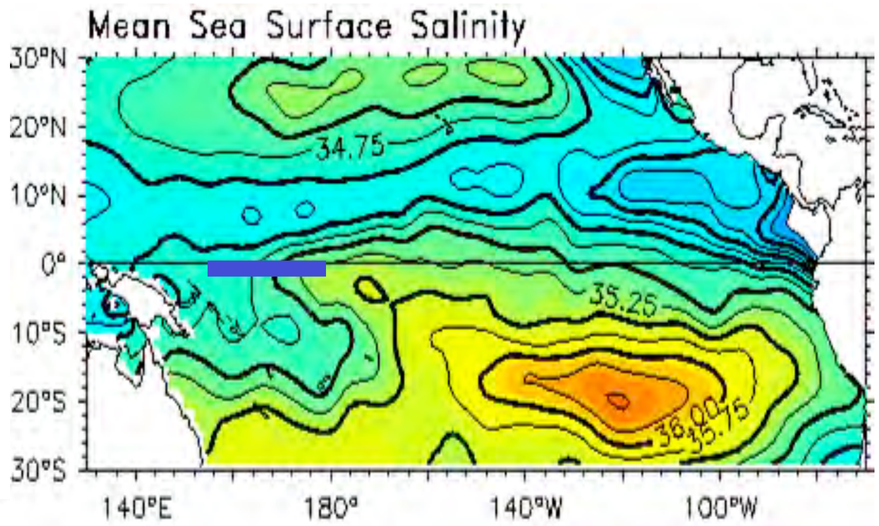
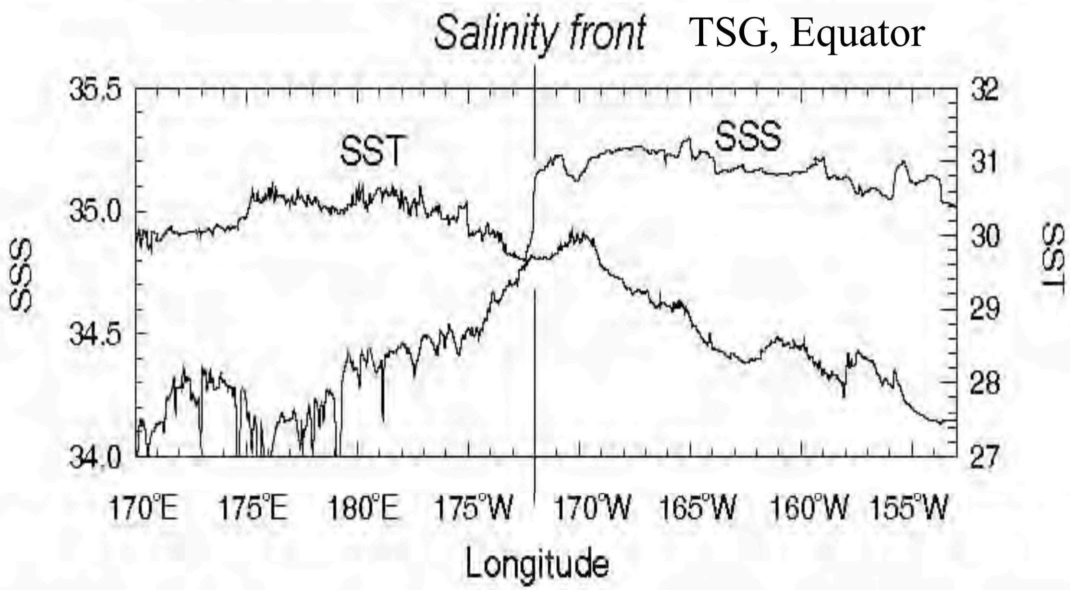




(Levitus 1982)

TSG, Equator



FLUPAC cruise
Sept.-Oct. 1994
TSG, Equator
(Eldin et al., 1997;
Rodier et al., 2000)

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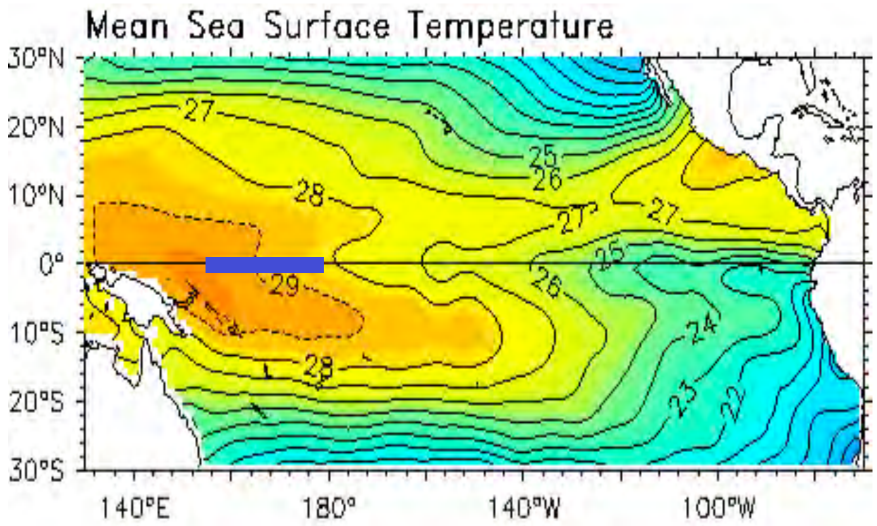
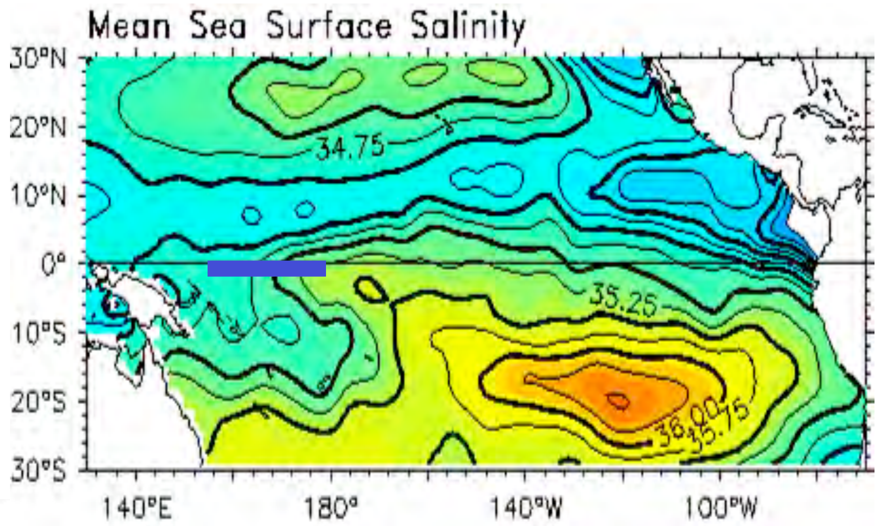
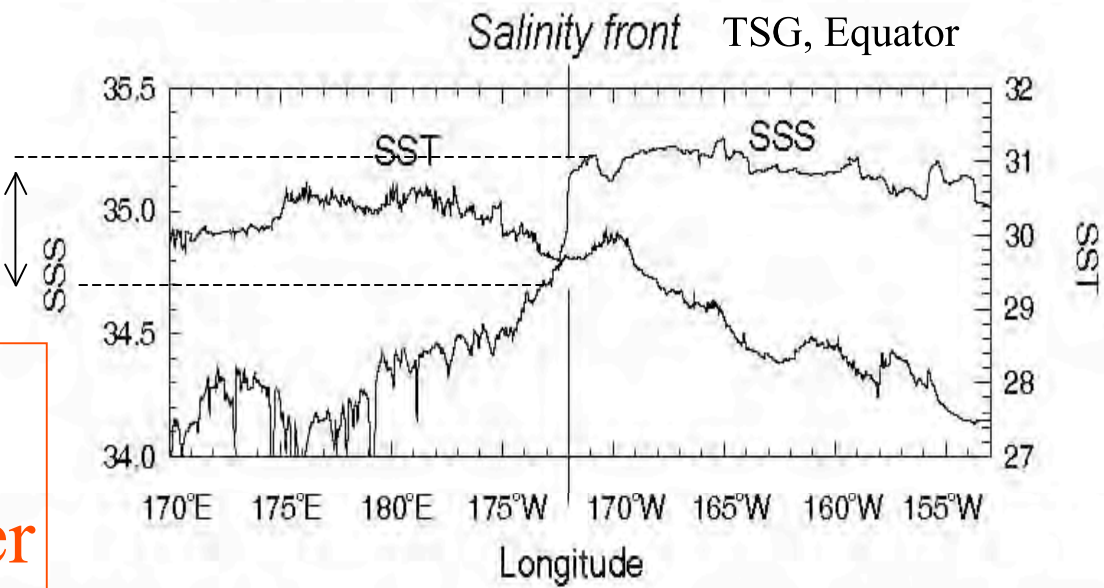




(Levitus 1982)

TSG, Equator

$\Delta S=0.5$



FLUPAC cruise
Sept.-Oct. 1994
TSG, Equator
(Eldin et al., 1997;
Rodier et al., 2000)

SSS front

Barrier layer

2.1. ARGO profiles available since 2000

Trajectories of ARGO floats located in the 5°N-5°S-120°E-120°W equatorial region

N profiles/year

3637

3046

2229

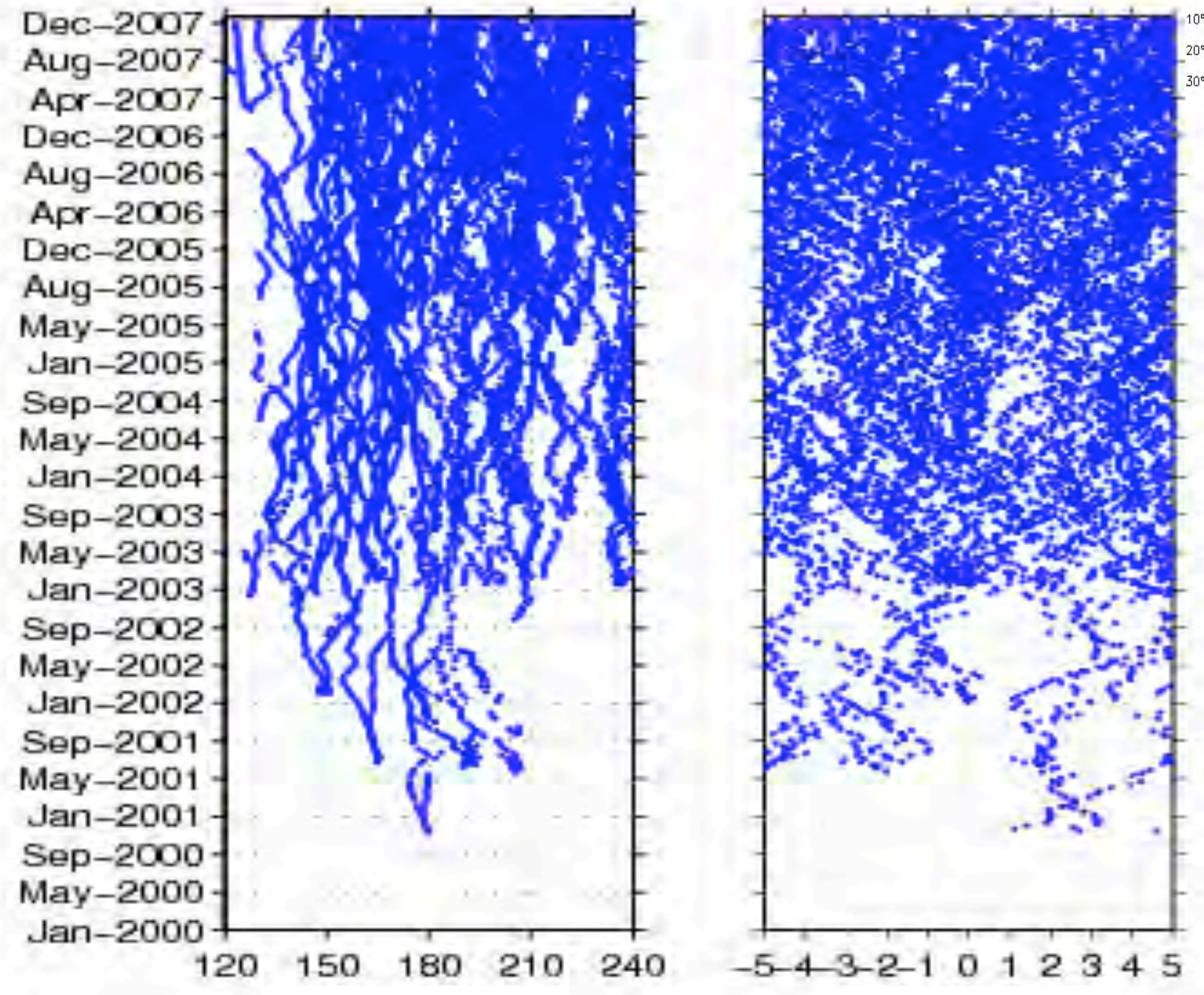
1601

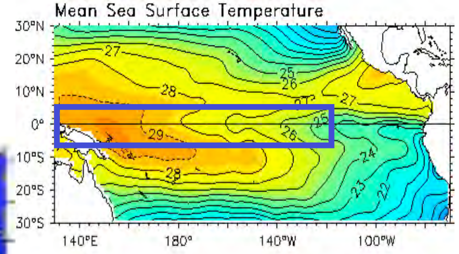
1230

372

190

8





Source:
CORIOLIS GDAC

« good data only »

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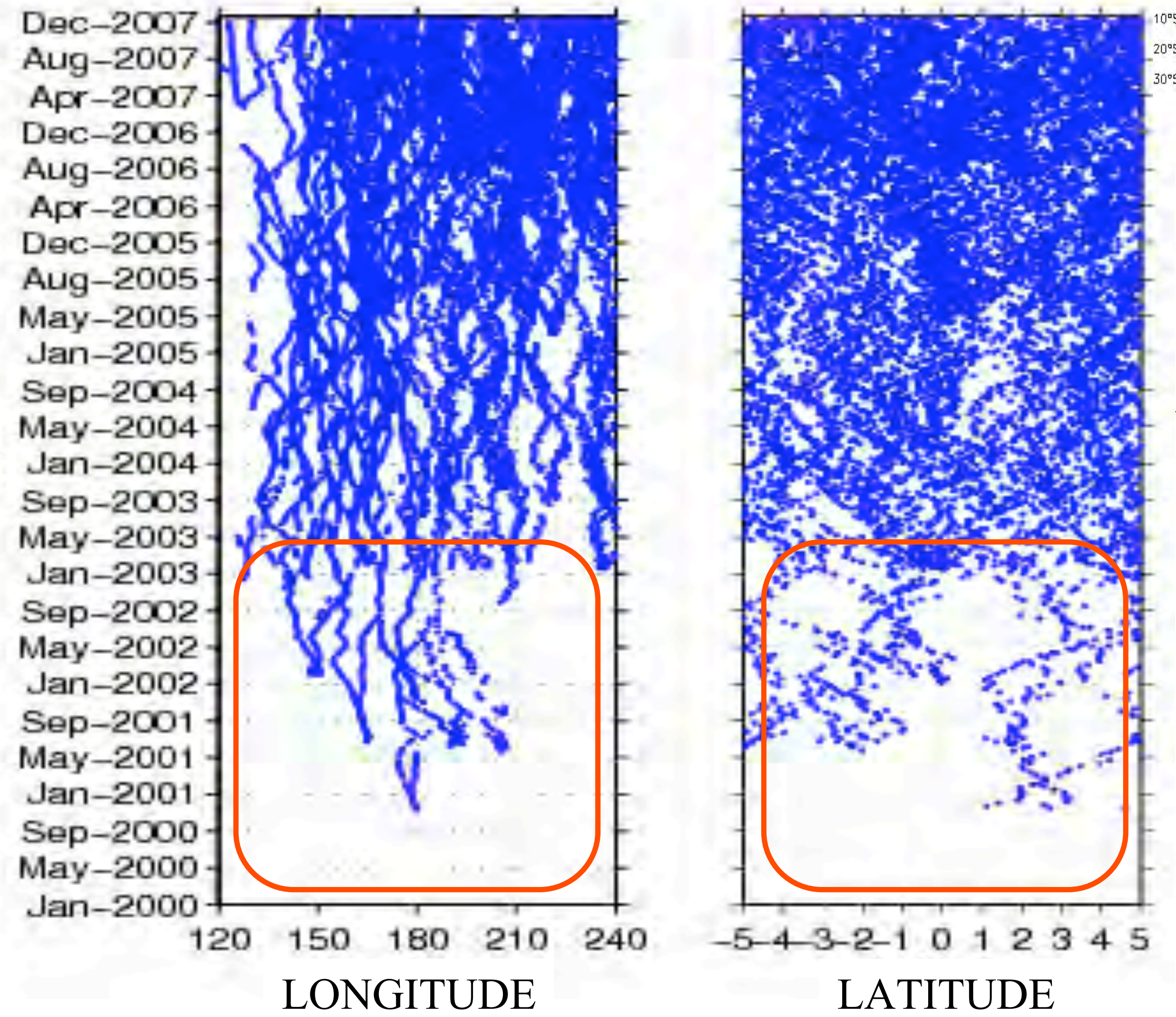
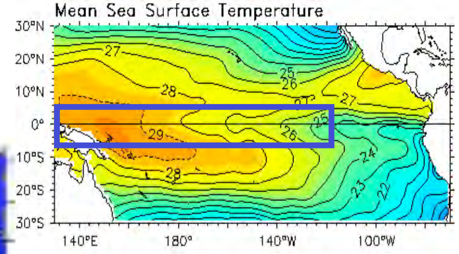


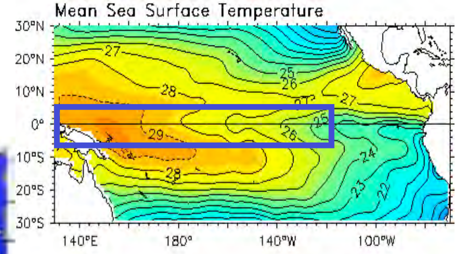


Source:
CORIOLIS GDAC

« good data only »

2.1. ARGO profiles, CTD, TSG available since 2000

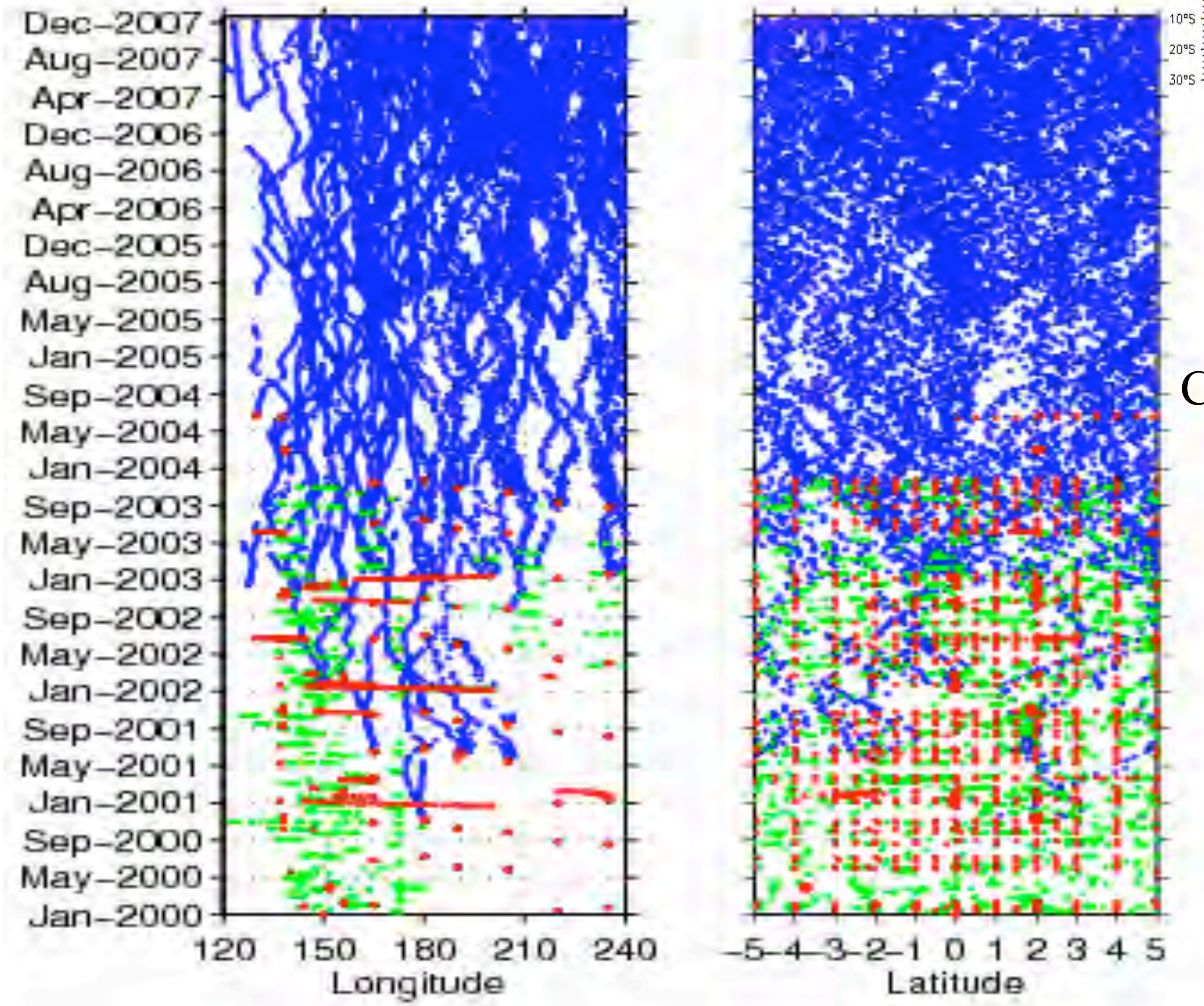
Trajectories of floats located in the 5°N-5°S-120°E-120°W equatorial region



ARGO

CTD

TSG



Sources:
CORIOLIS GDAC,
WOA05,
ORE-SSS

2.2. Validation and quality control

11 000 ARGO profiles exploitables (96%)
1 700 CTD profiles (85%)
16 500 TSG measurements

Vertical interpolation:

dz=5m ⇒ Isothermal layer depth (ILD)
Mixed Layer Depth (MLD)
from individual profiles

Gridding:

dx=5° longitude, dy=1° latitude, dt=14 days

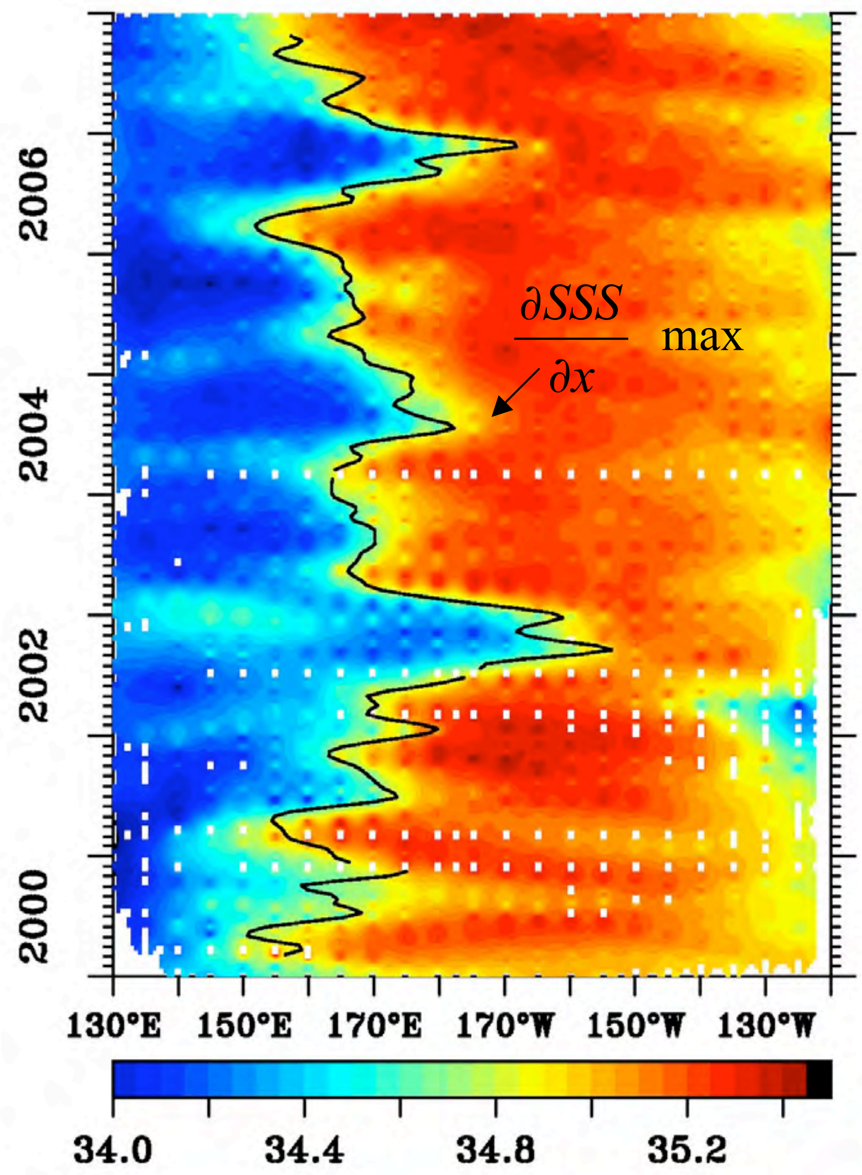
3. Thermohaline structure variability

1. Surface thermohaline structure: SSS front

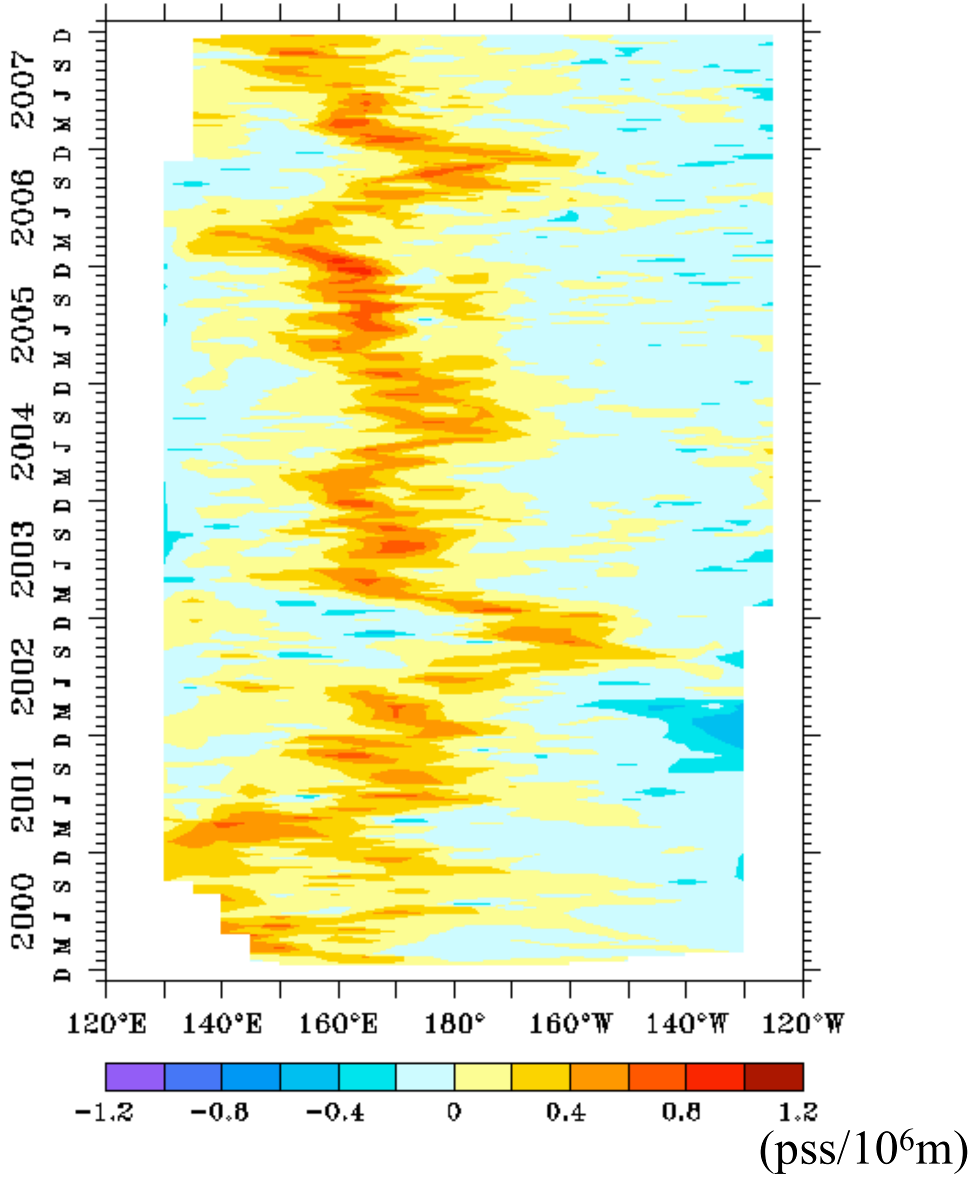
2. Subsurface thermohaline structure: barrier layer

3.1. Surface thermohaline structure: SSS front

SSS (15m) 2°N-2°S

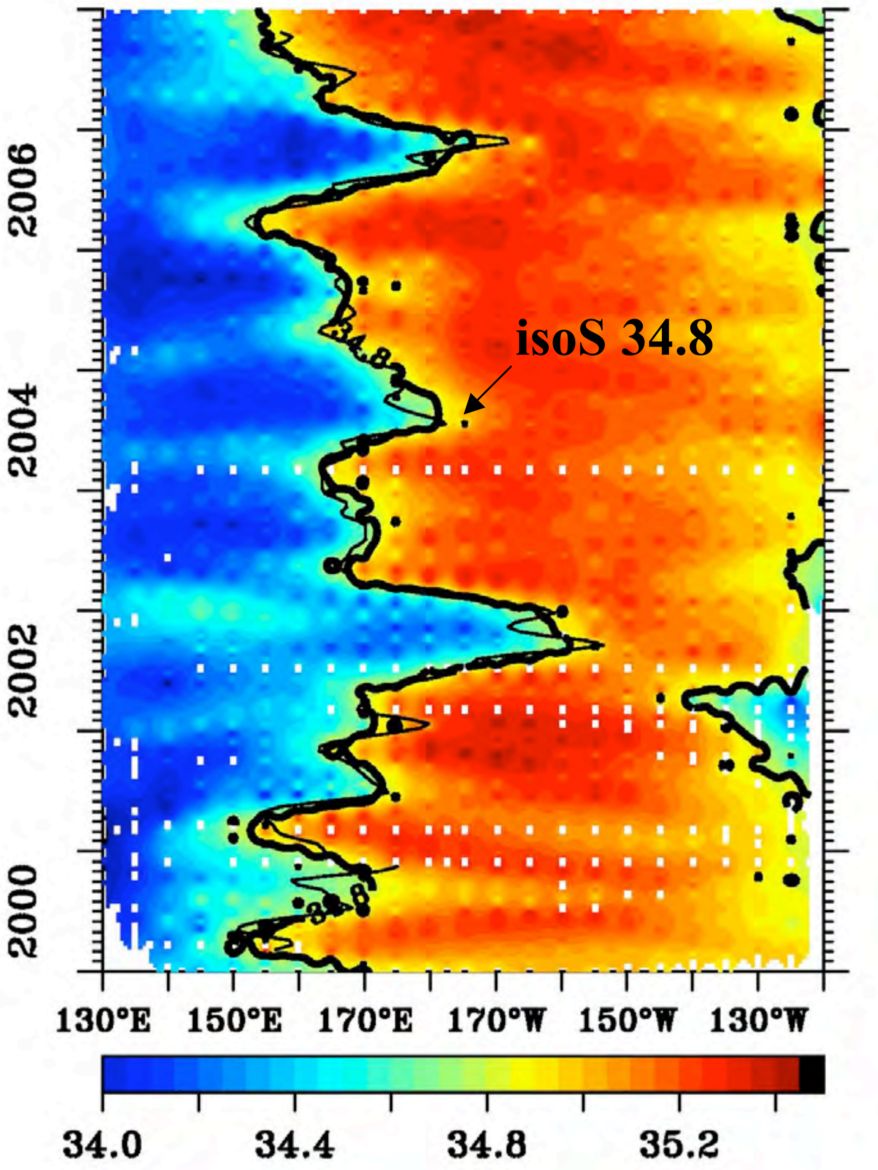


∂SSS/∂x 2°N-2°S

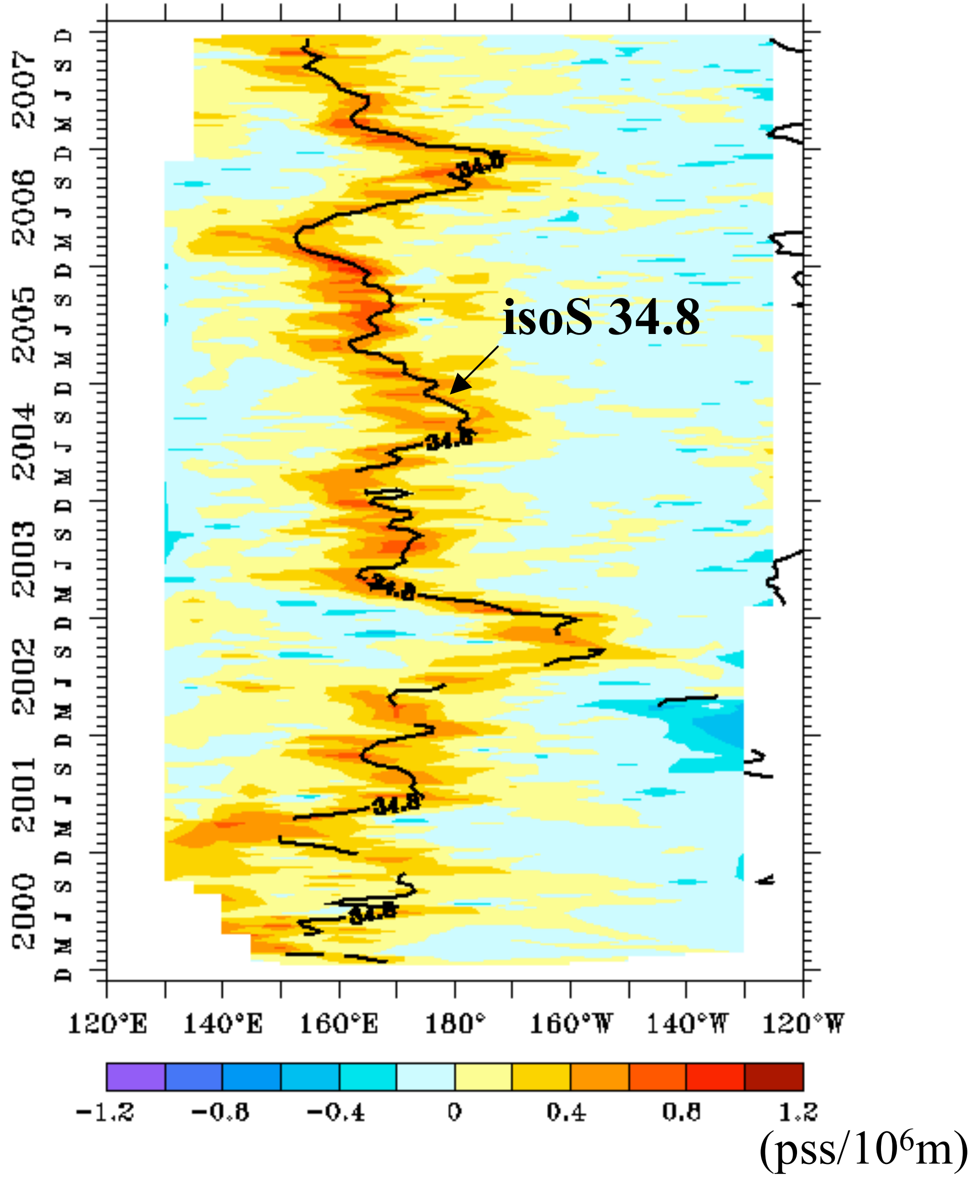


3.1. Surface thermohaline structure: SSS front

SSS (15m) 2°N-2°S



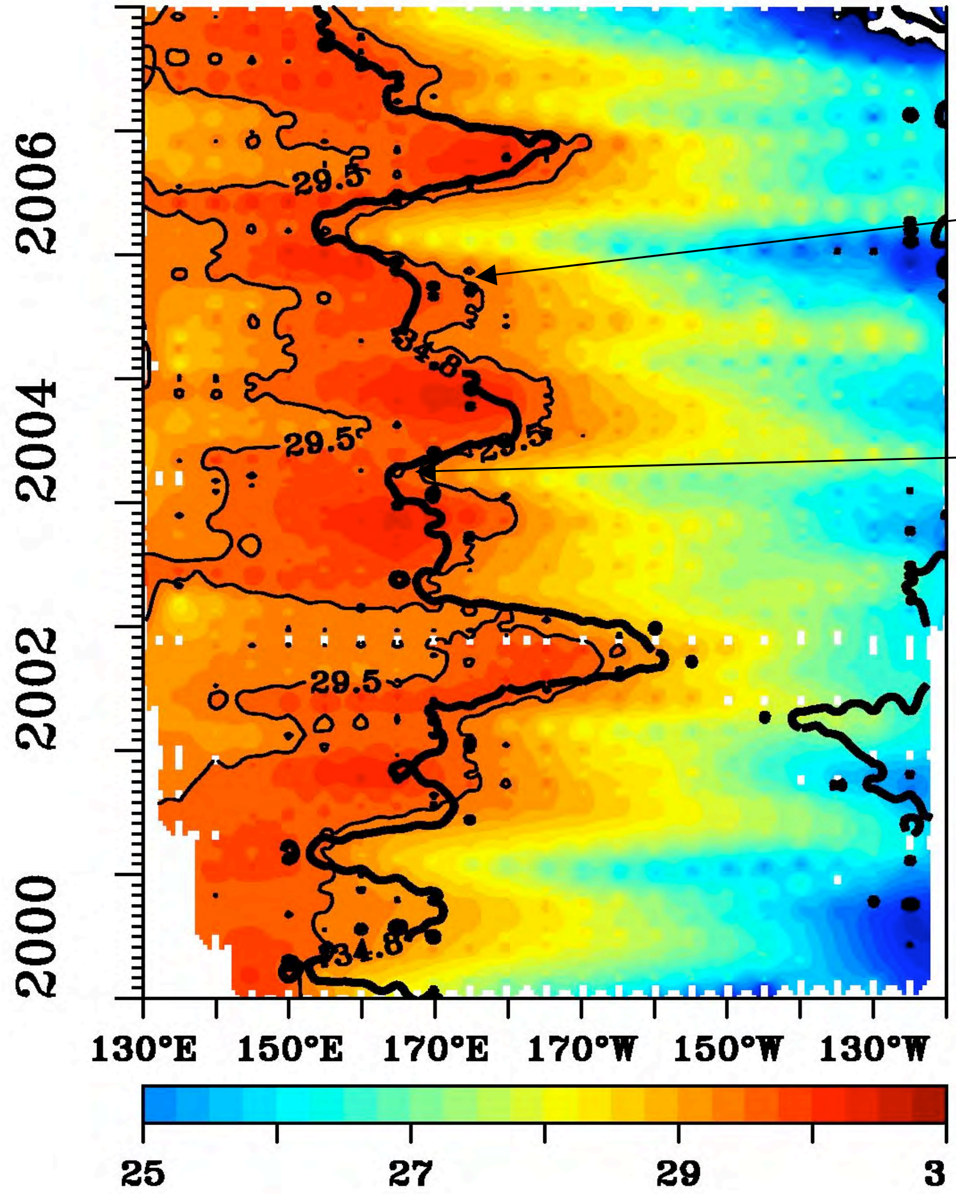
∂SSS/∂x 2°N-2°S



3.1. Surface thermohaline structure: SSS front

SST>29.5°C west of the SSS front

SST (°C) 2°N-2°S

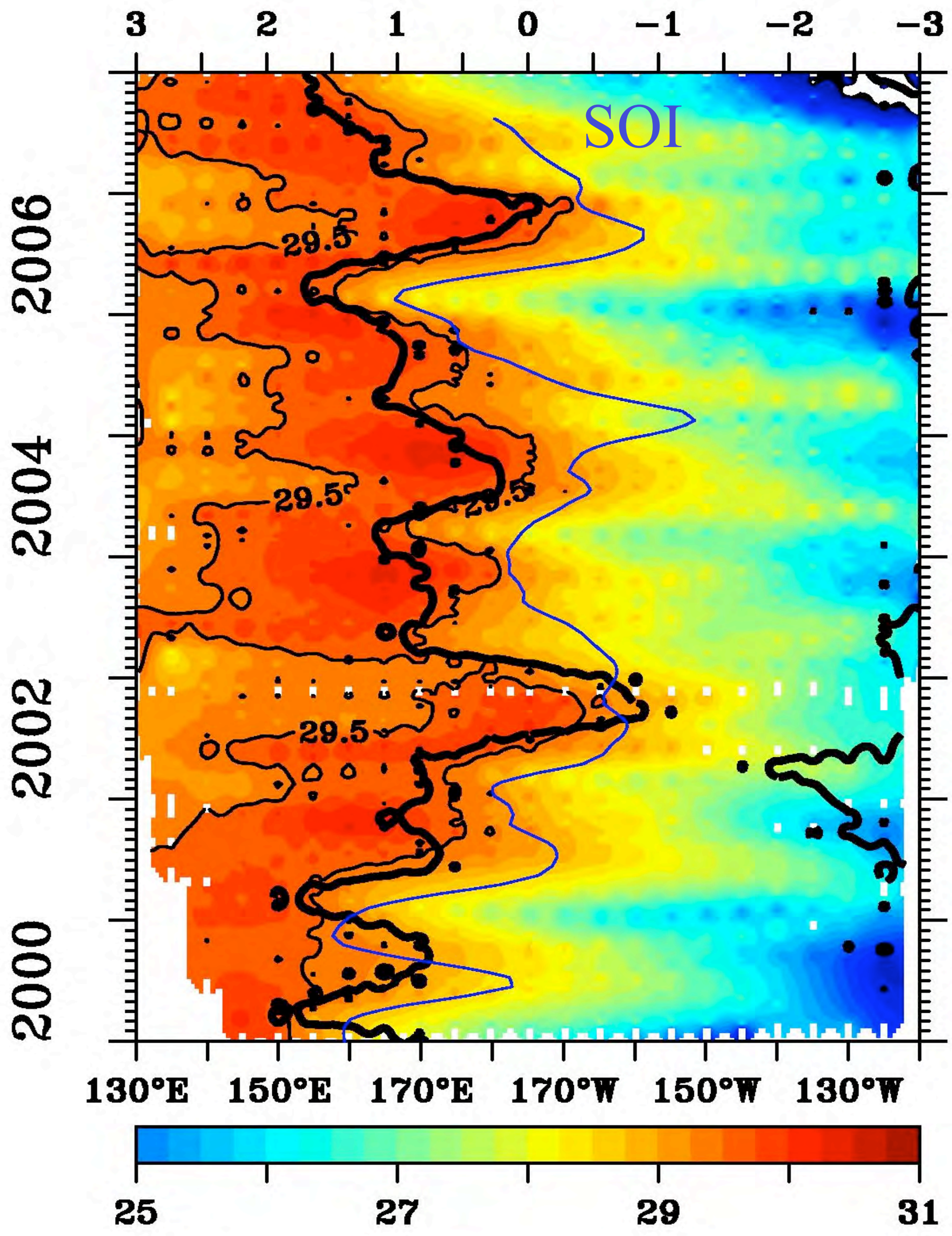


isoT 29°C Eastern Edge of the WP

isoS 34.8 Front

3.1.a- Surface thermohaline structure: SSS front

SST (°C) 2°N-2°S



Zonal displacements

-eastern edge of the WP

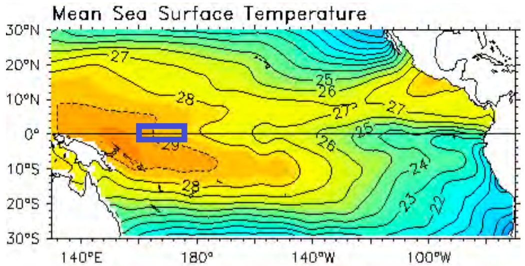
-SSS front

in phase with the SOI

Advective-Reflective Oscillator theory for ENSO

(Picaut et al., 1997)

3.2. Subsurface thermohaline structure: barrier layer (BL)



Levitus, 1982

Ref level @15 m

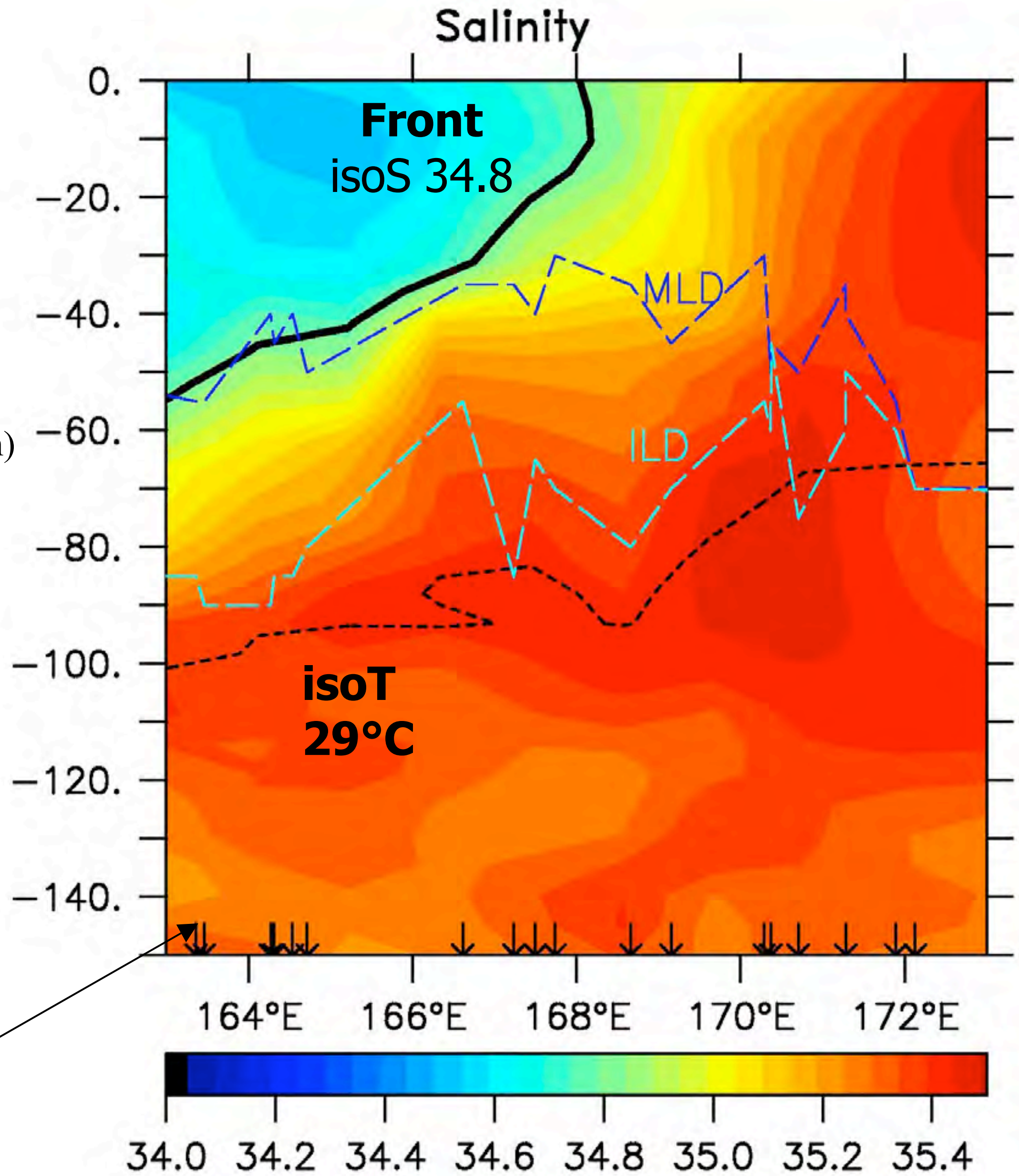
Mixed Layer (MLD)

$\Delta\rho = 0.125\ kg/m^3$

Isothermal layer (ILD)

$\Delta T = 0.5°C$

Barrier layer=ILD-MLD

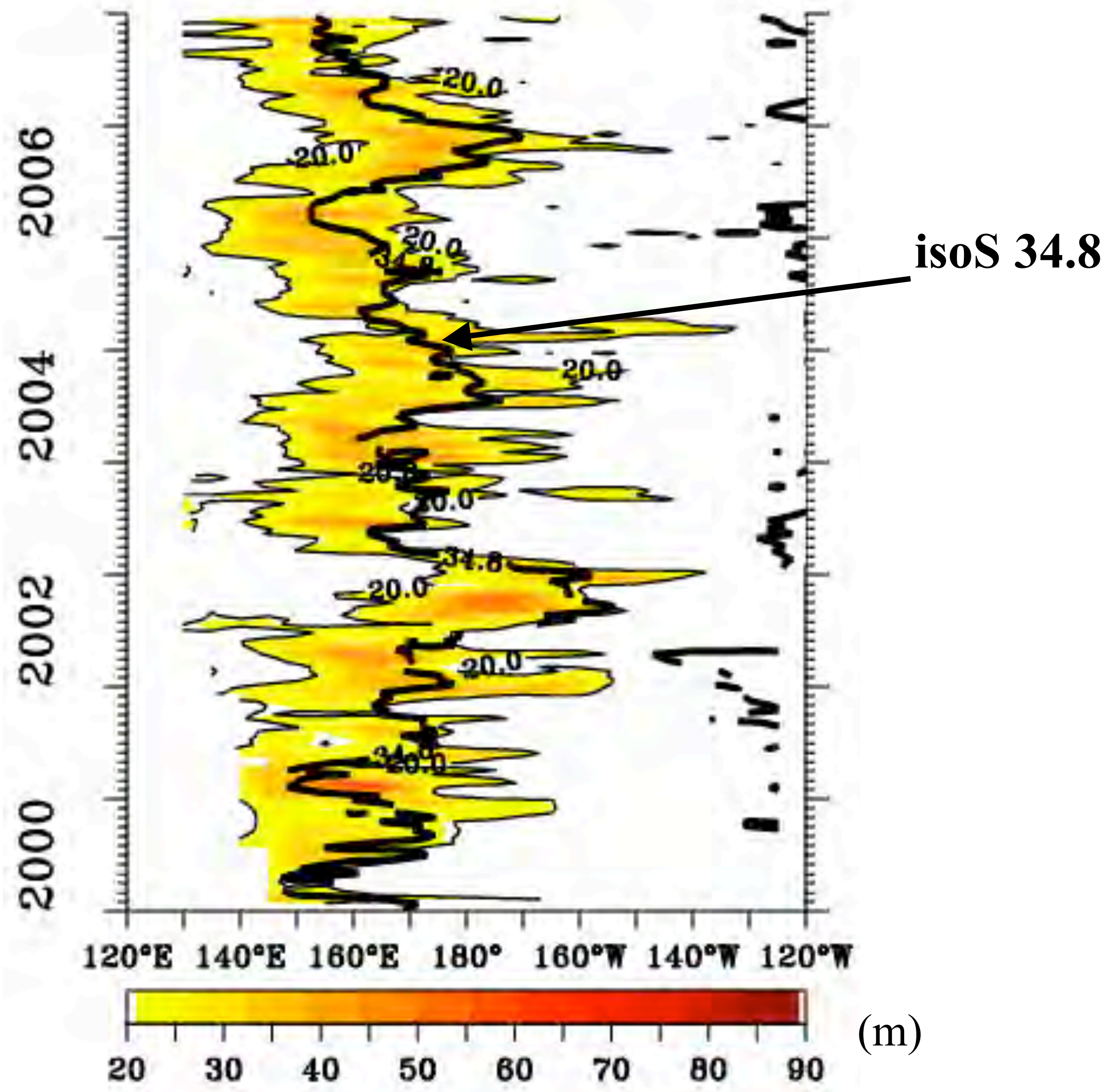


Floats presents between 1.5°N-1.5°S, during June 1-15th, 2005

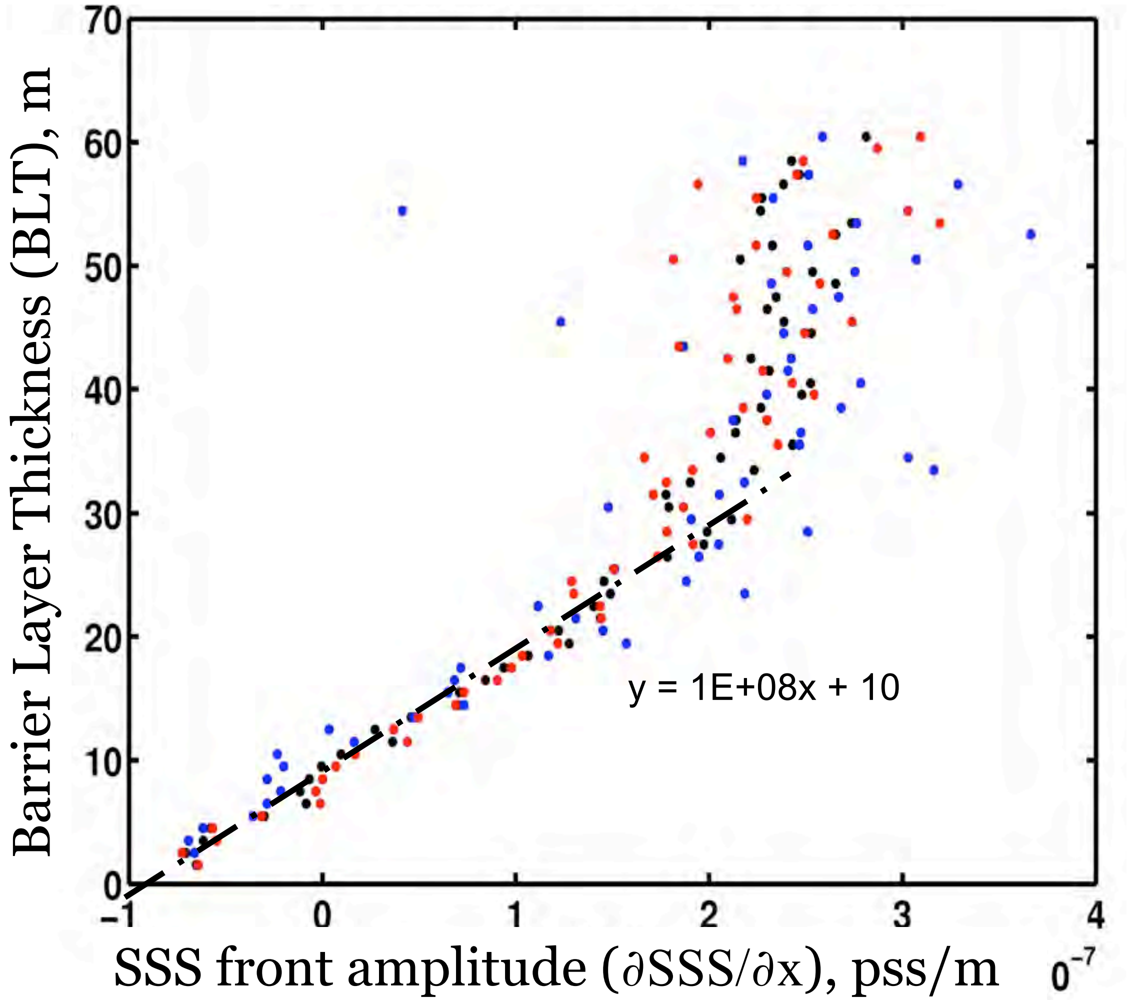
3.2. Subsurface thermohaline structure: barrier layer

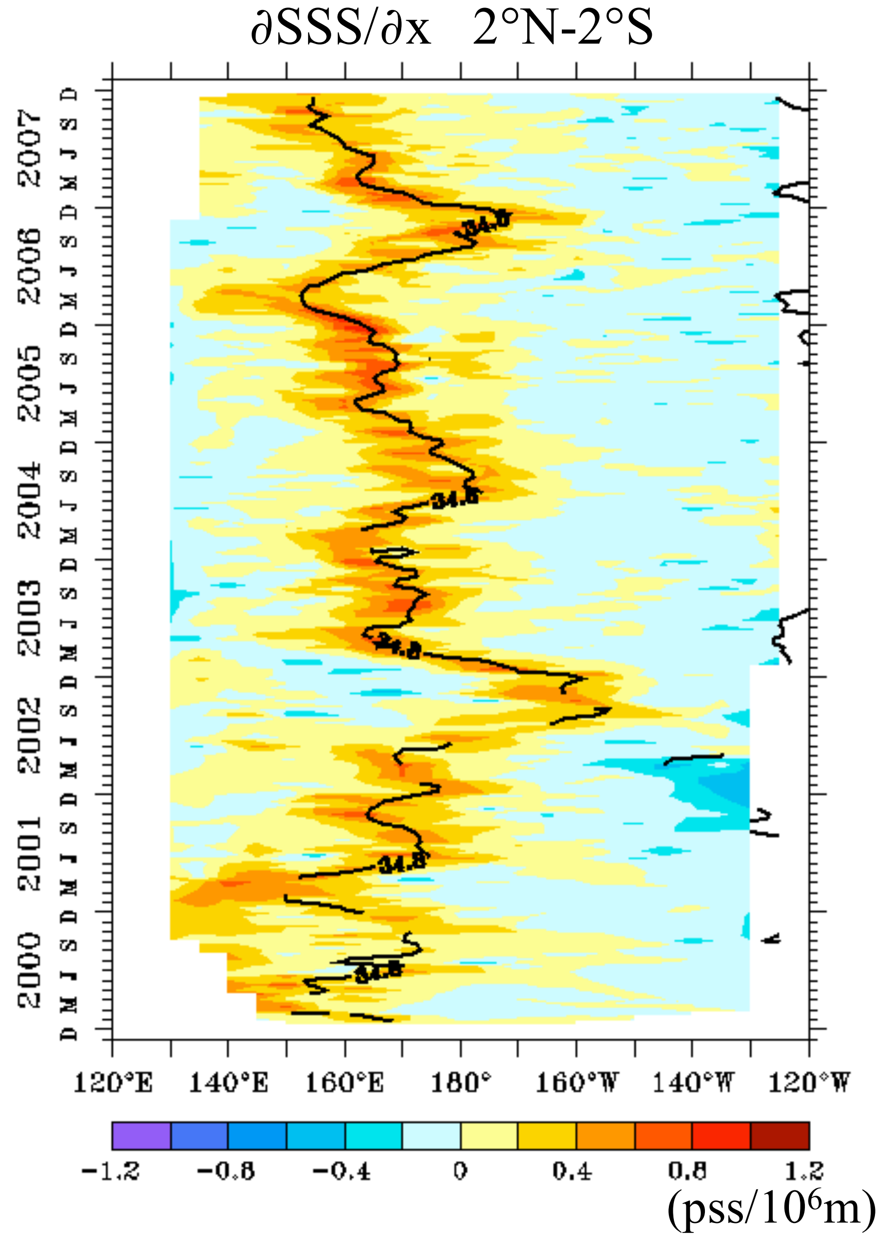
- Quasi permanent BL
- West of the front

Barrier layer thickness 2°S-2°N



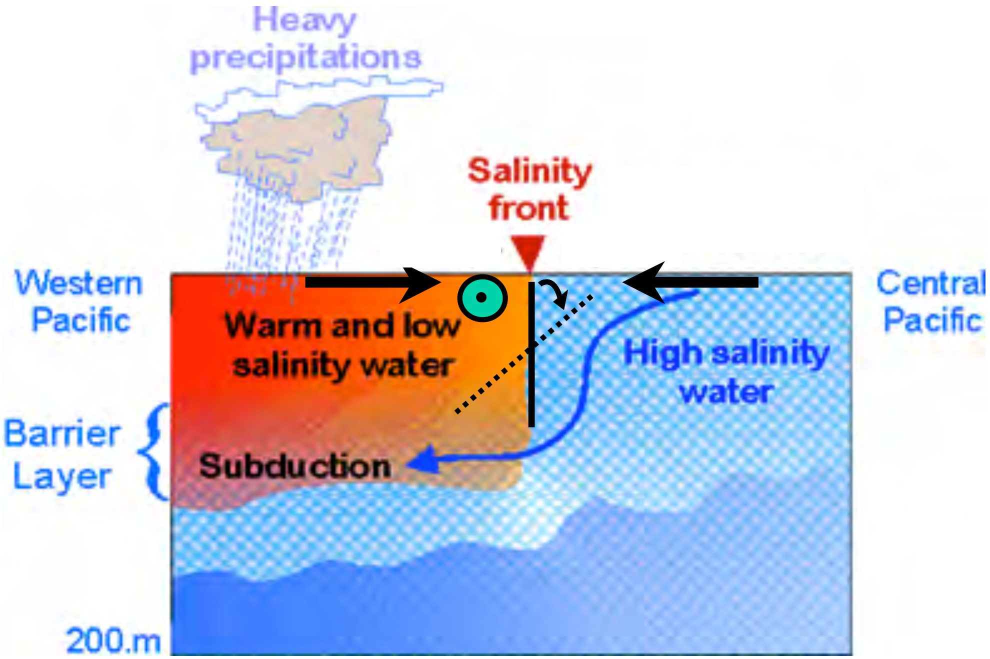
3. Thermohaline structure: SSS front and barrier layer





4. Possible mechanisms for Barrier layer formation

0. Numerous possible mechanisms

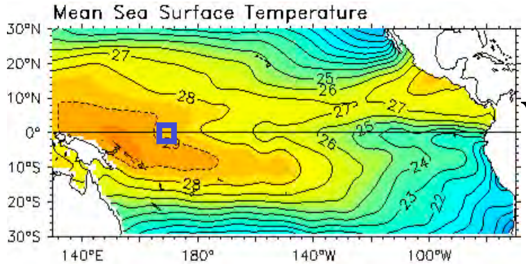


Subduction
Lukas and Lindstrom 1991
Tilting/shearing
Cronin and McPhaden, 2002
Advection
Cronin and McPhaden, 2002
Precipitation
Mignot et al, 2007

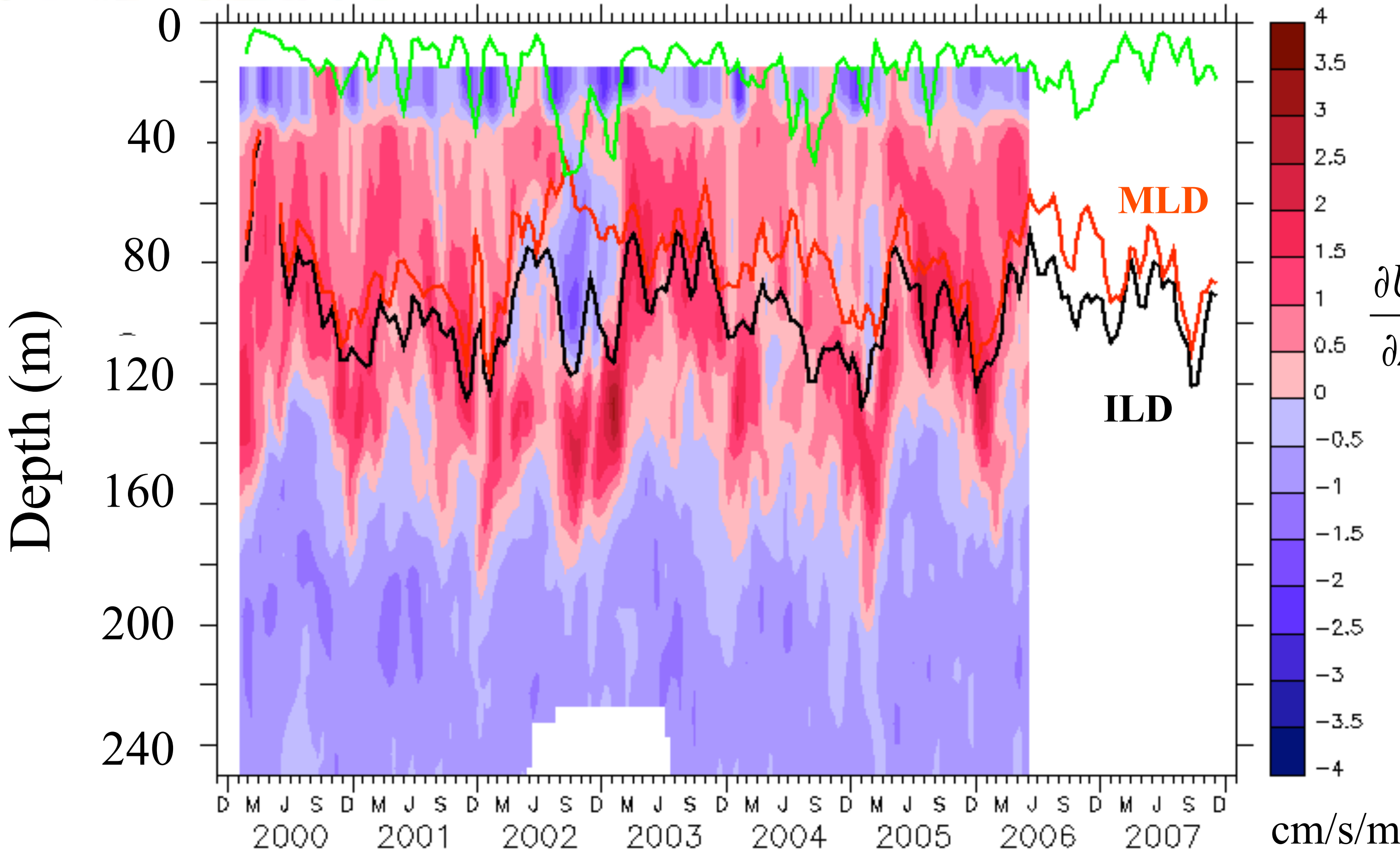
1. Local forcing

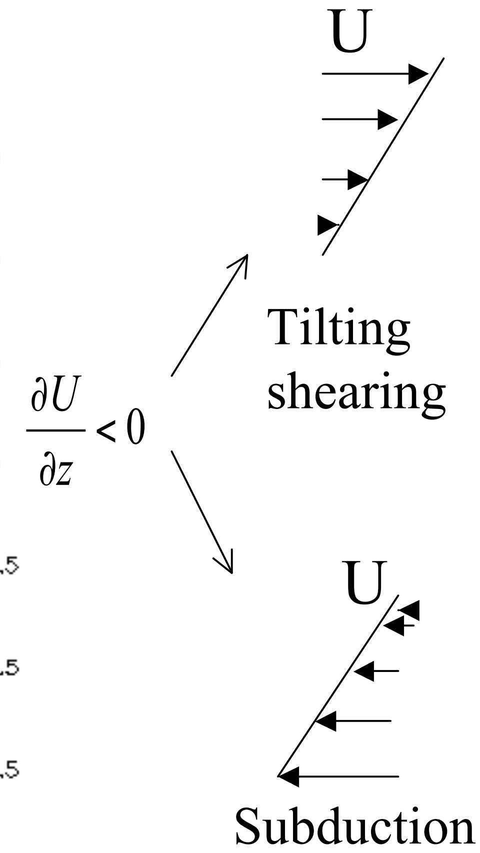
2. Remote forcing: equatorial Rossby waves

4.1. Local subsurface forcing : Subduction



Vertical gradient of zonal current ($\partial U/\partial z$): TAO, 170°W-Eq

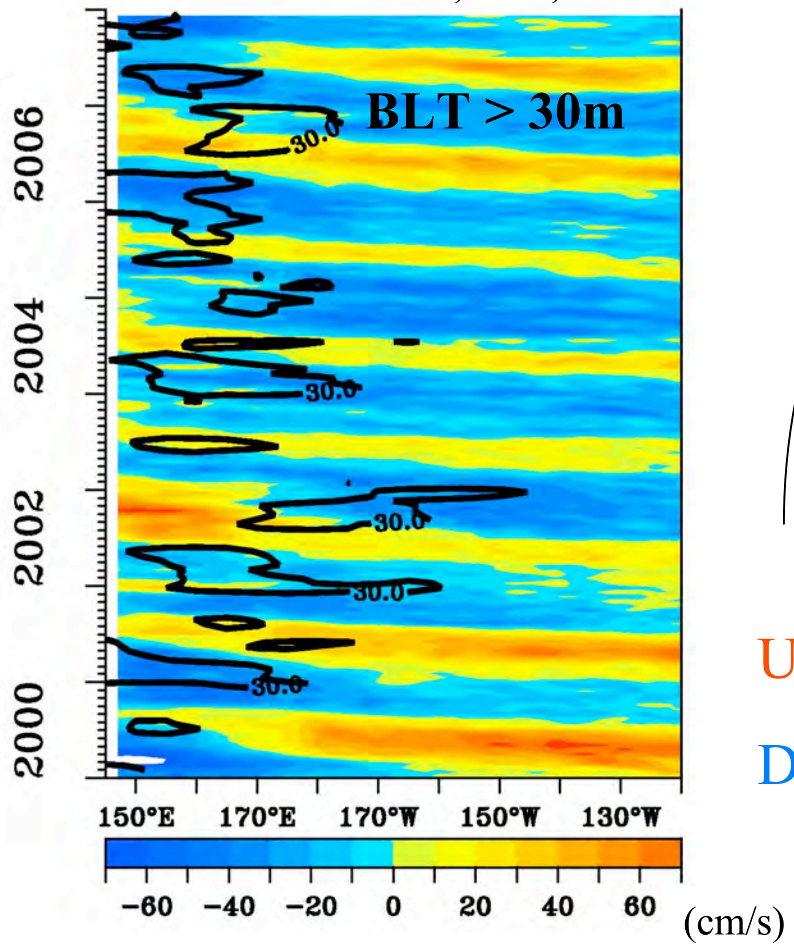




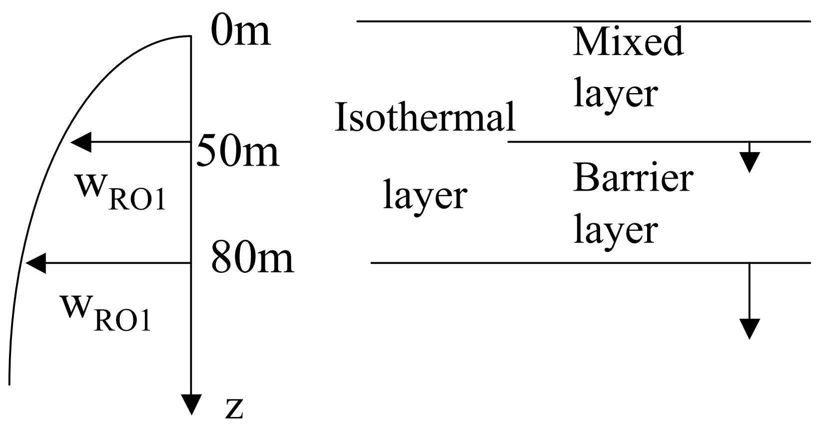
4.2. Remote forcing: equatorial Rossby waves

Ugeostrophic/Rossby1 2°N-2°S

Bosc and Delcroix, JGR, 2008



$U_{RO1}<0 \Rightarrow$Udownwelling $\Rightarrow w<0$



Upwelling Rossby wave

Downwelling Rossby wave

4.2. Remote forcing: equatorial Rossby waves

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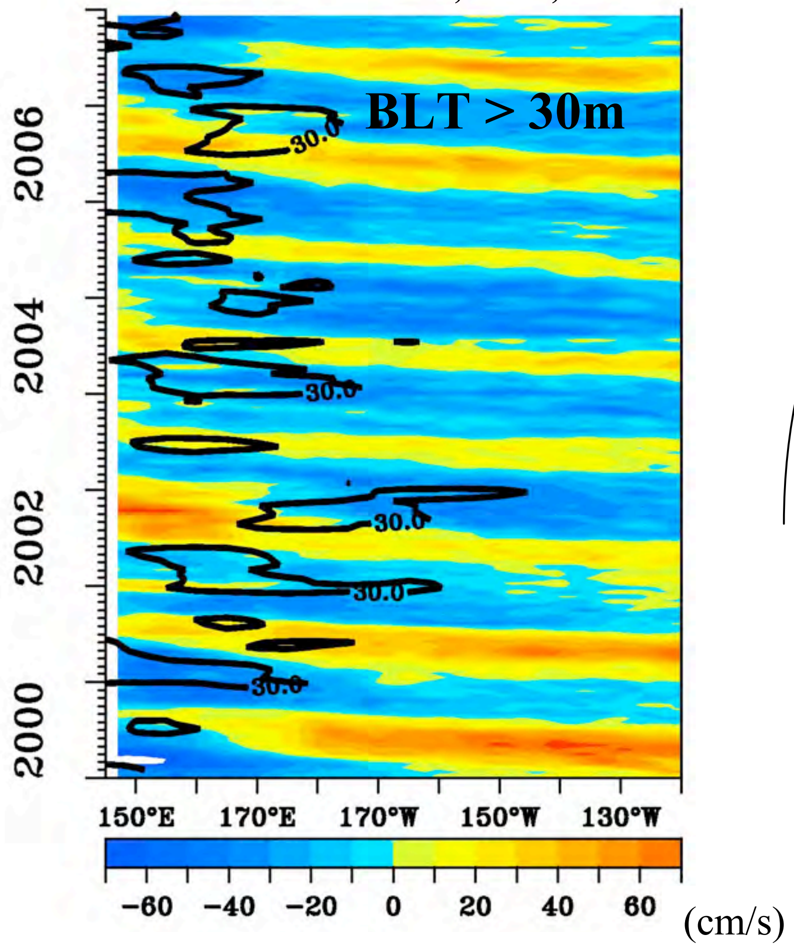
Bosc and Delcroix, JGR, 2008



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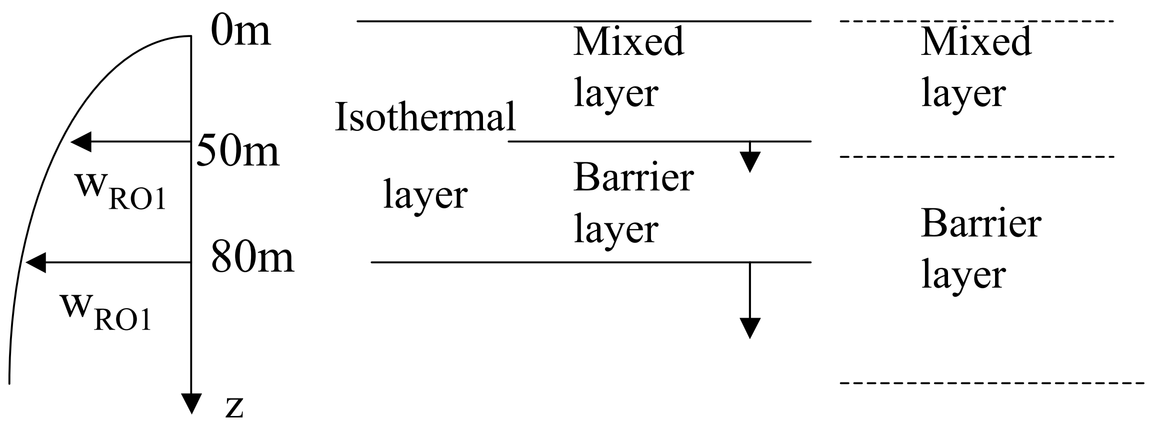
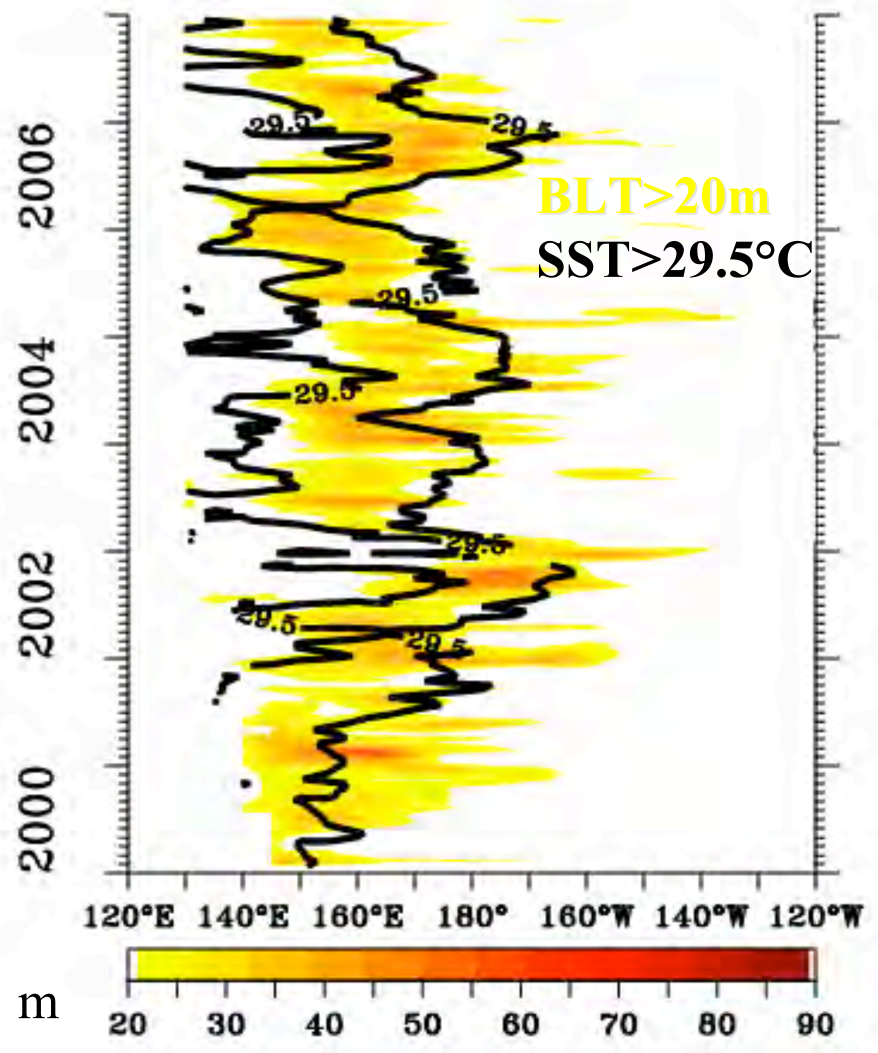
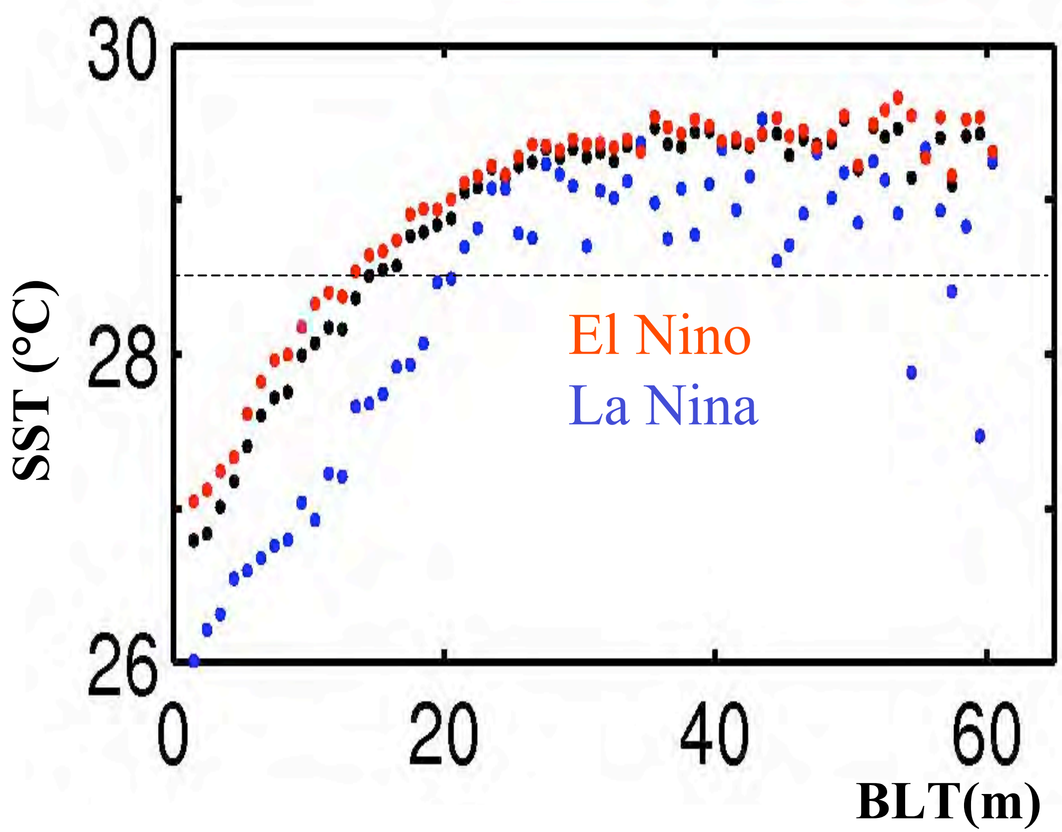


Vertical Stretching

5. Barrier layer and very warm SST (« hot spots »)

Barrier layer thickness 2N-2S





- Summary -

- Study of the thermohaline structure of the equatorial western Pacific warm pool thanks to Argo floats (2000-2007)

- Thermohaline structures of the warm pool:

  - surface: SSS front (34.8), eastern edge of the warm pool
  - subsurface : quasi permanent barrier layer (>20 m) west of the front
  - strongly related, moves zonally in phase with SOI

- Possible mechanisms for BL formation:

  - Local forcing: tilting, subduction
  - Stretching by equatorial Rossby waves

- Very warm SST in the warm pool are associated with Barrier layer

2.2. Validation and quality control ARGO

Different tests for values within 0 - 200m depth: 391 752 data, 12031 profile

- file contents (T=S column)

n_profils_colmanq= 196: T=S ou bien iparam=1 ou 2 (svt il manq S dc ca décalle T=Tadjuste

nlonbad= 0 : lon=0 on la récupère en interpolant

ndatebad= 0 : t=0, on récupère en interpolant

n_data_zbad= 6 : 0<z < 2200m

n_databad =1304 : T,S>90

- T and S range within climatic limits (min, max and vertical gradients)
  - 0<z<700: 5 <T< 35 33 <S< 37 20<rho<28
  - Z>700m: 0 <T< 7 20 < S < 35 20<rho<28
  - dT/dz <0.7 sauf pour thermocline 14<T<27

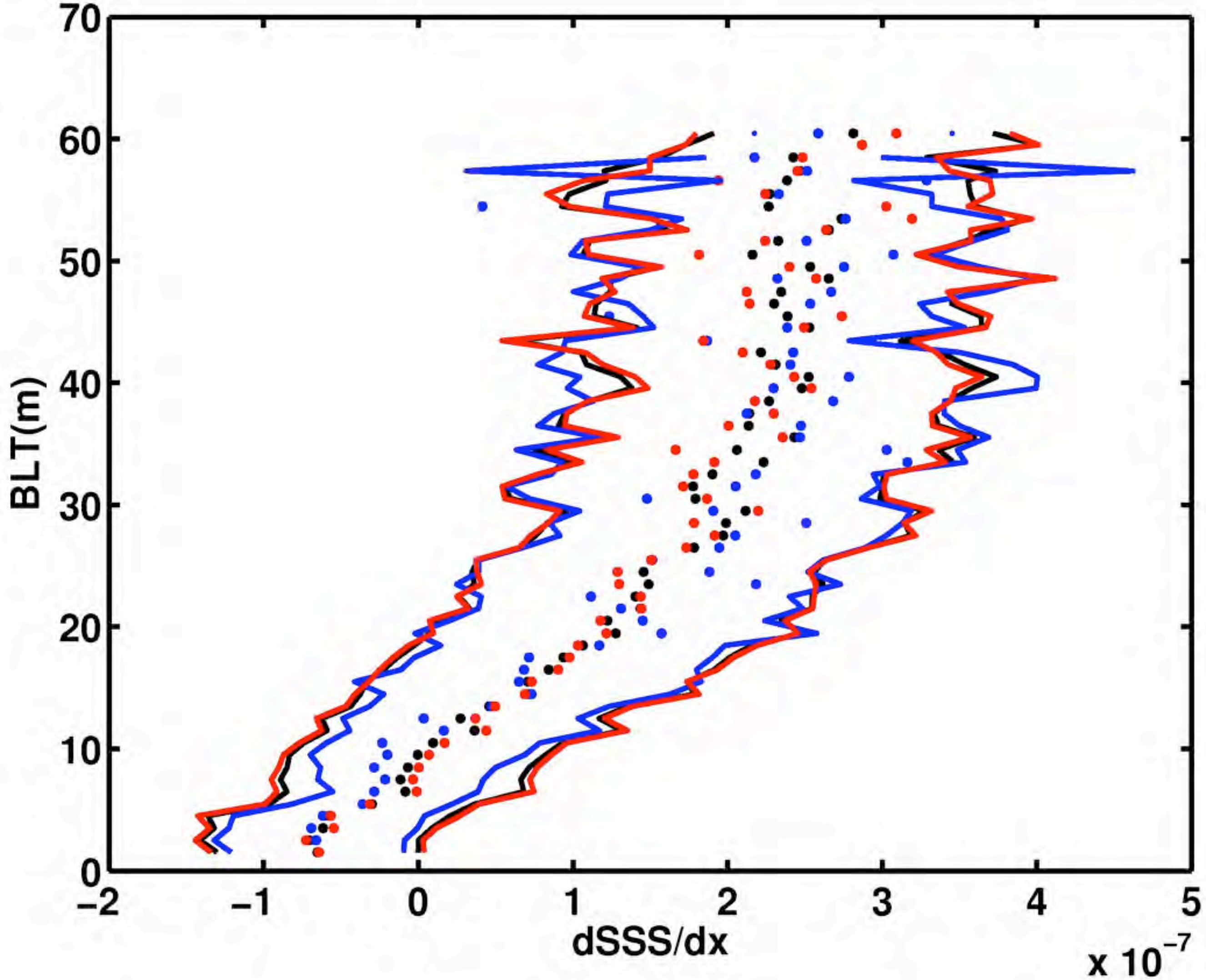
Sur 200m:75: c'est 1 profil ou y a que le delayed mode donc on lit S puis T : pb de lecture cf slide2

- Stability of the water column : drho/dz> -0.7: 0
- Profiles with 25m data gap within 0-200m depth are not considered: 64
- Profile with no data within 0-15m are not considered: SST=T(15m), SSS=S(15m): 264

Sortie: 11 555 profiles (96%), 384479 data (98%)

- **Fichier avec inversion colonnes T et S car y a que le DM (data 35)= pb de lecture**
- *FI31200497078 CO_5900645_20080211_170104   XXXX UNKNOWN
- 18/12/2004 30/12/2007 PACIFIC OCEAN
- 31 US DOC NOAA ERL PMEL SEATTLE
- UNKNOWN   Project=
- Regional Archiving= FI   Availability=P
- Data Type=H13 n= 106 QC=Y
- COMMENT
- WMO PLATFORM CODE : 5900645
- PLATFORM NAME : APEX Profiling Float
- *FI3120049707800009 Data Type=H13
- *DATE=18122004 TIME=1540 LAT=N03 58.98 LON=E179 36.96 DEPTH=   QC=1119
- *NB PARAMETERS=03 RECORD LINES=00072
- *PRES SEA PRESSURE sea surface=0   (decibar=10000 pascals)   def.=-999.9
- *PSAL PSAL_ADJUSTED   (psu)   def.=99.999
- *TEMP TEMP_ADJUSTED   (degree_Celsius)   def.=99.999
- *GLOBAL PROFILE QUALITY FLAG=1 GLOBAL PARAMETERS QC FLAGS=100
- *DC HISTORY=846 Profiling Float, APEX, SBE conductivity sensor
- *
- *DM HISTORY=Coriolis station id : 2068090
- *Station number : 00009
- *COMMENT
- *
- *SURFACE SAMPLES=
- *
- *PRES   PSAL_ADTEMP_ADJUSTED
-    6.0 35.126 29.936 111

- Pour les CTD, bcp de données de salinités sont mauvaises 25, 50 …

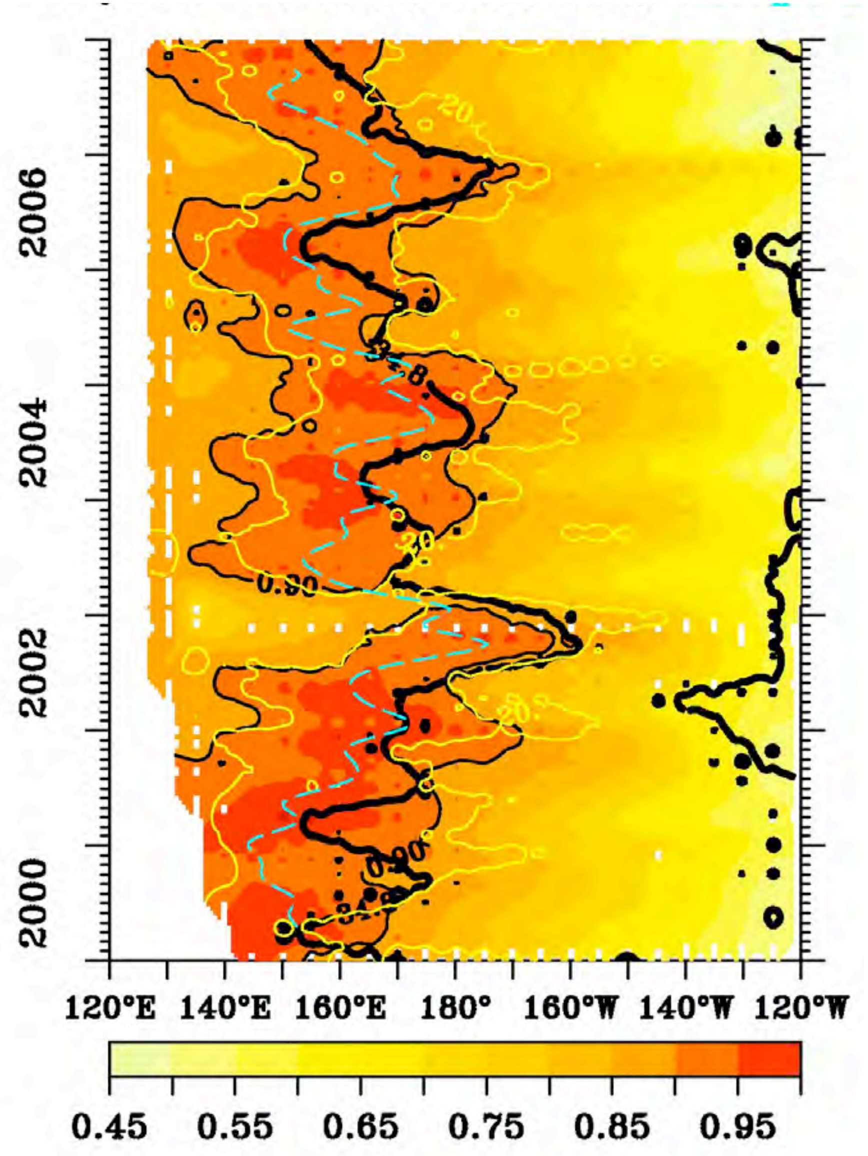


70
60
50
40
30
20
10
0
BLT(m)
−2
−1
0
1
2
3
4
5
dSSS/dx
x 10−7

4.1. Local subsurface forcing : Subduction

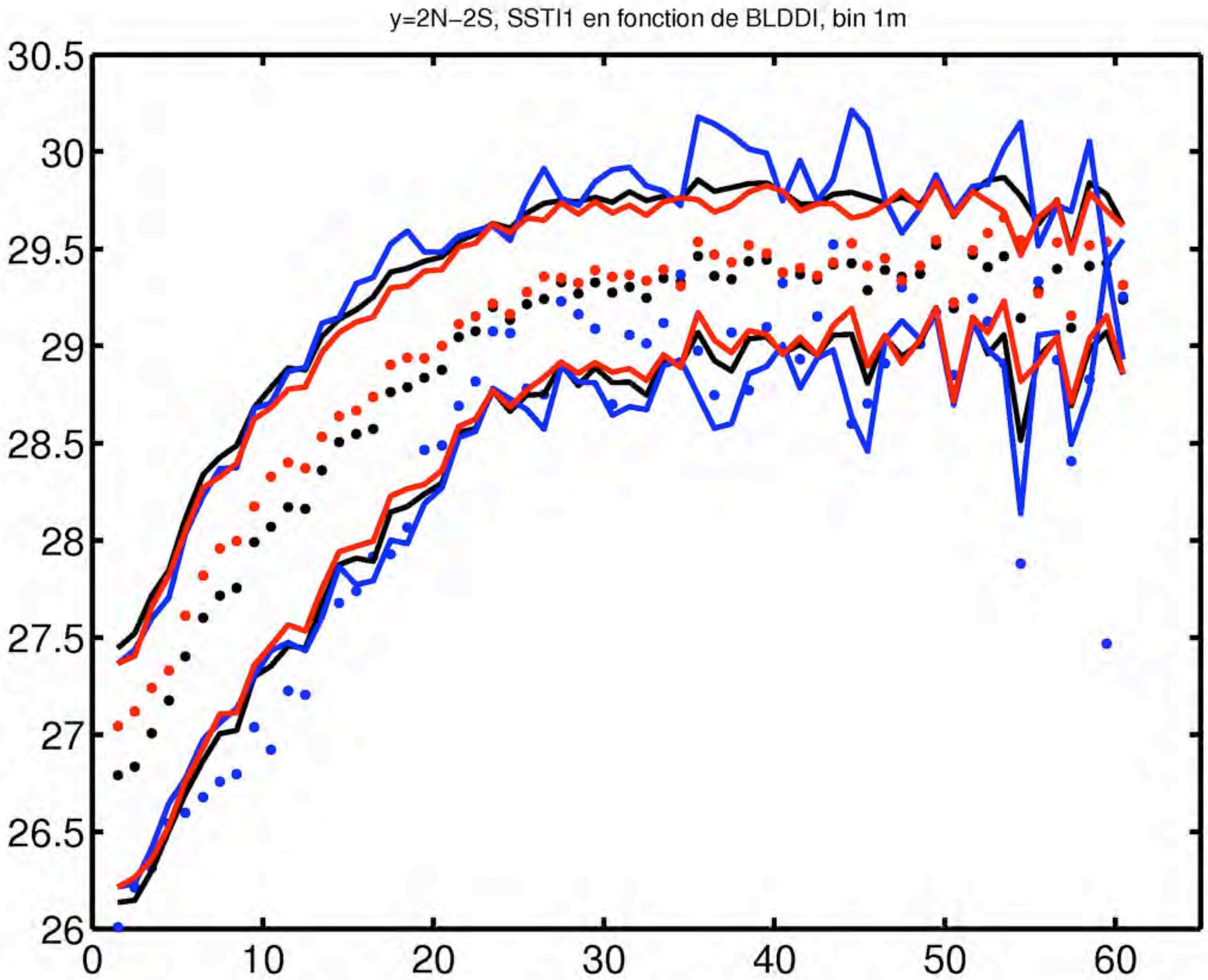
Dynamic height relative to 200 dbar 2S-2N

Convergence au front



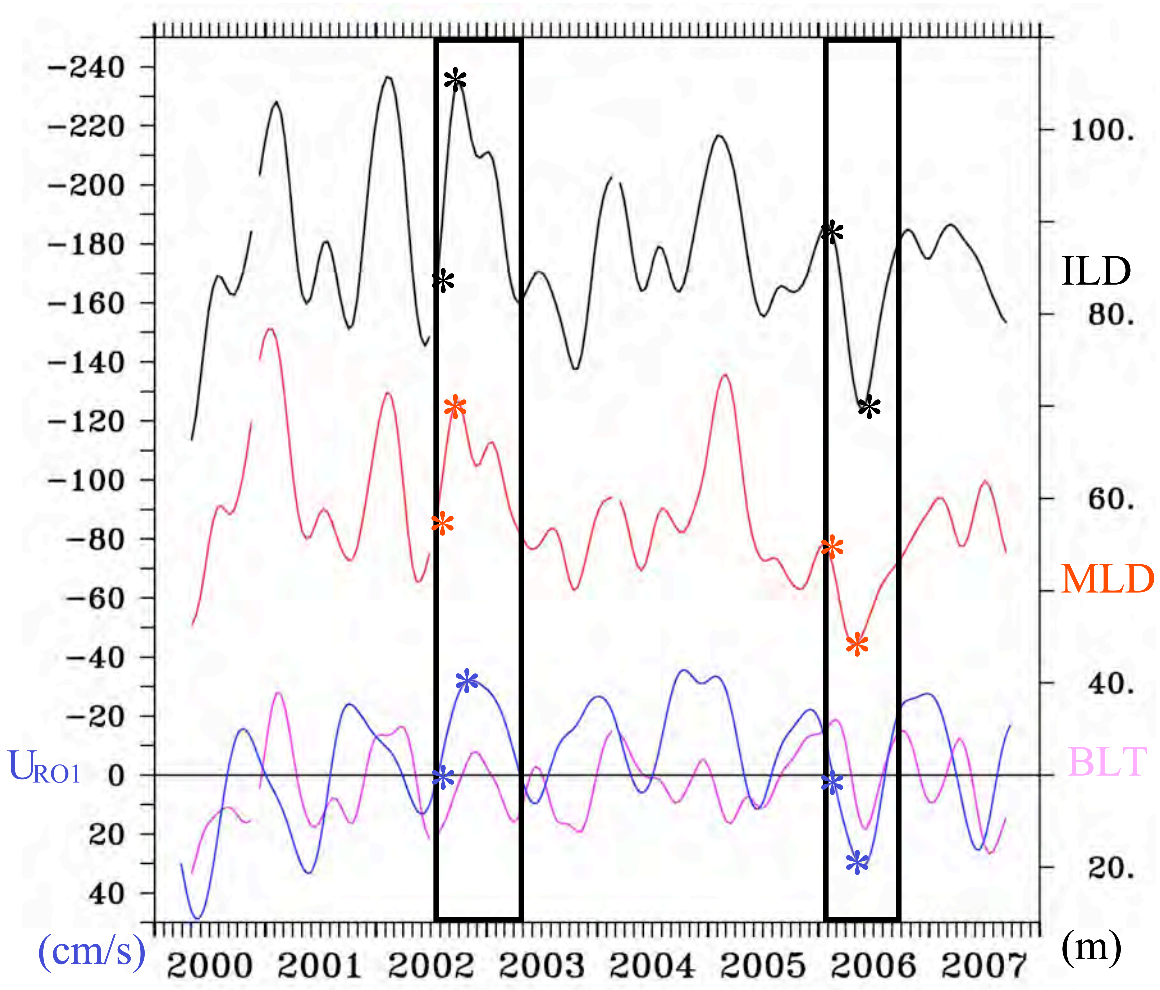
----- Maximum dynamic height

----- BLT >20m



y=2N−2S, SSTI1 en fonction de BLDDI, bin 1m
30.5
30
29.5
29
28.5
28
27.5
27
26.5
26
0
10
20
30
40
50
60

4.2. Remote forcing: equatorial Rossby waves



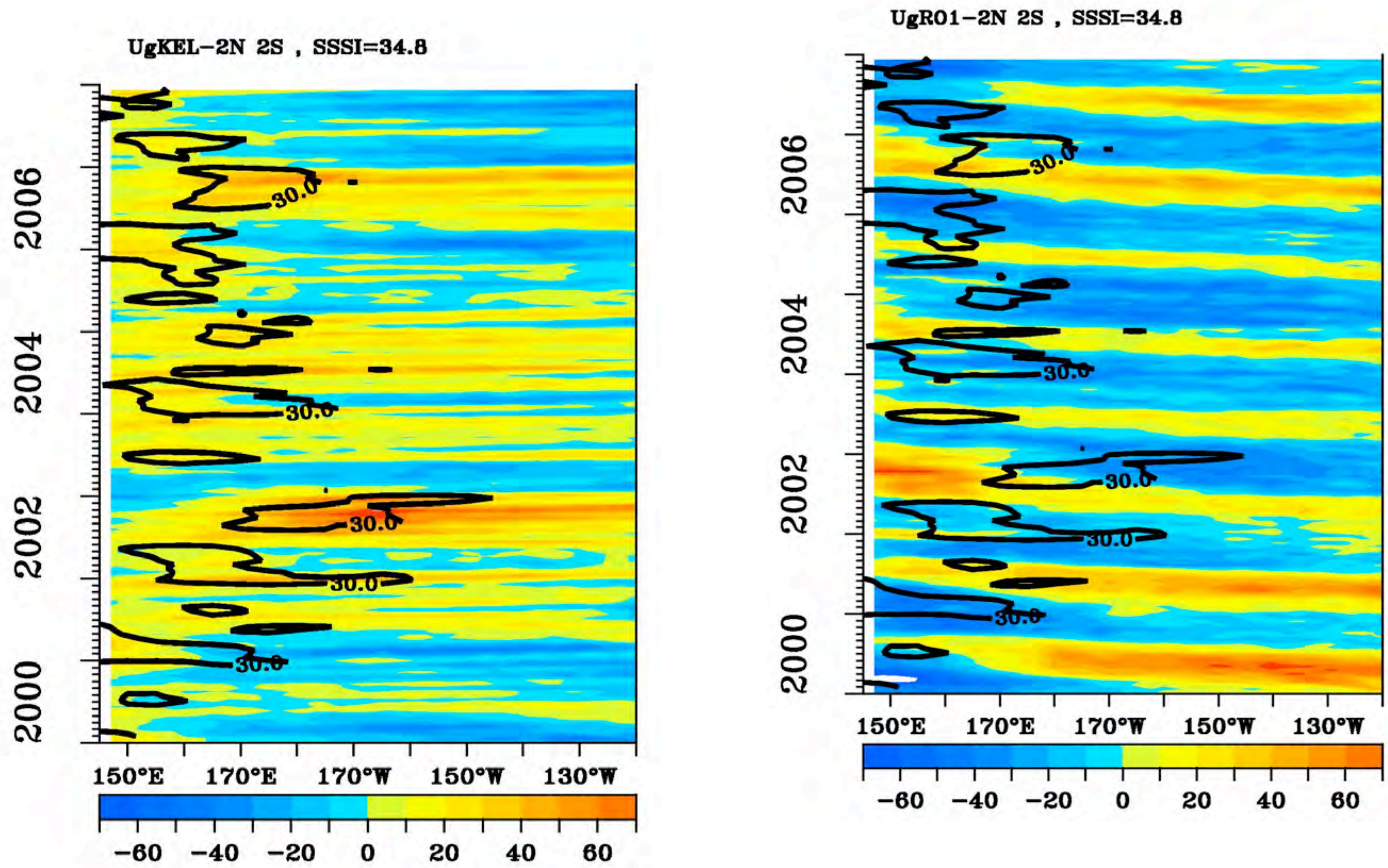
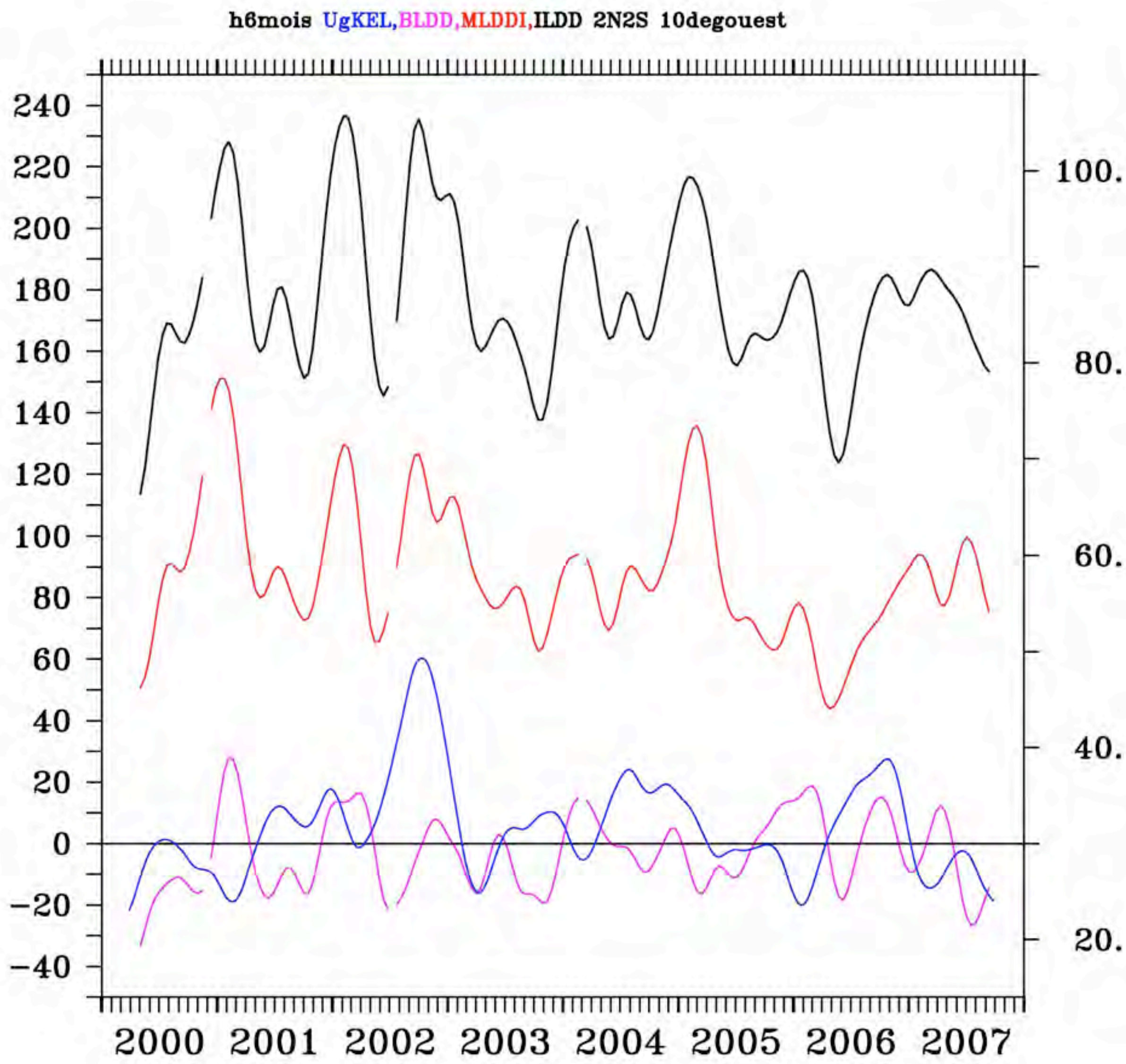
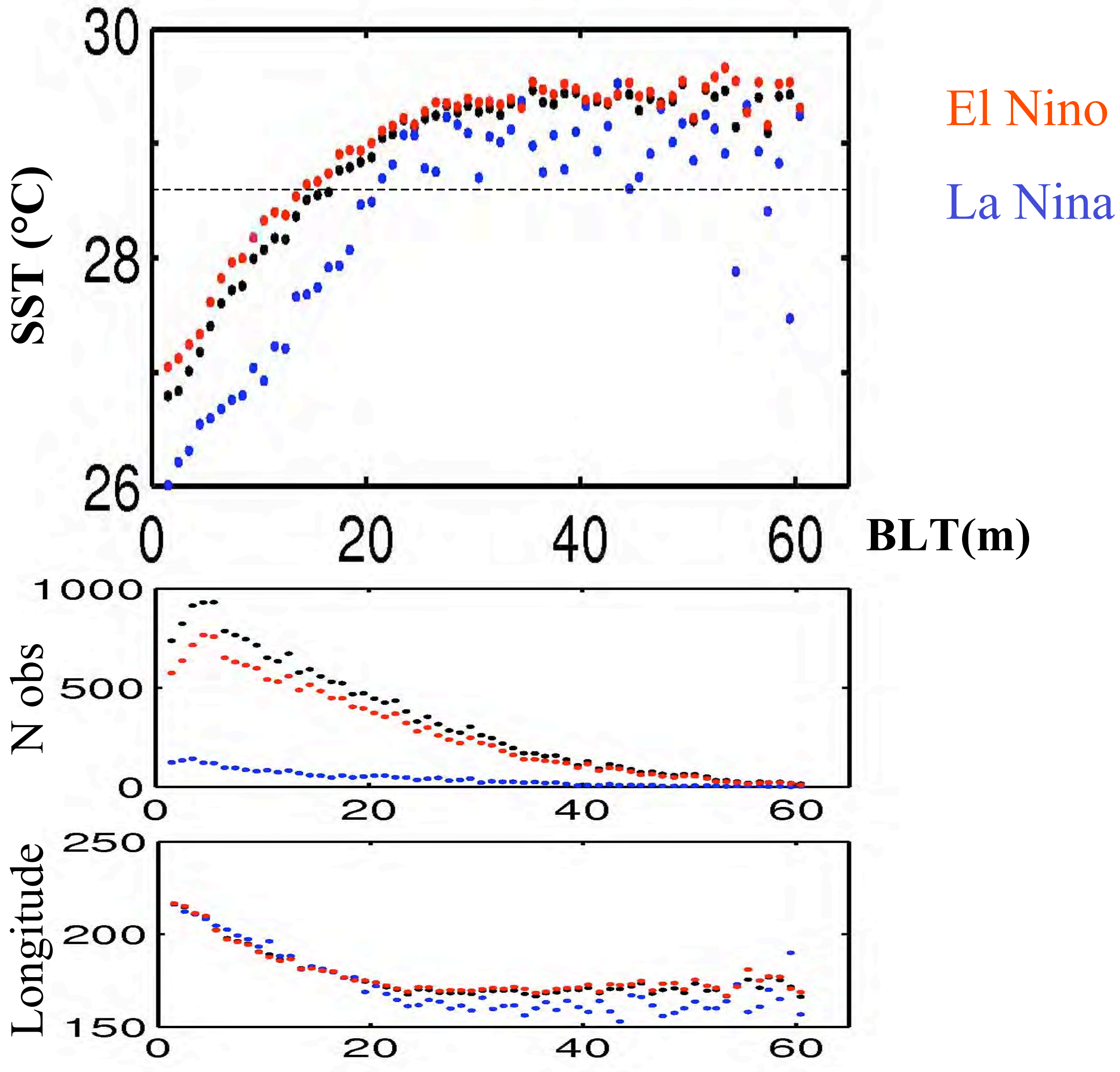

UgKEL-2N 2S , SSSI=34.8
UgRO1-2N 2S , SSSI=34.8
2000
2002
2004
2006
150°E
170°E
170°W
150°W
130°W
−60
−40
−20
0
20
40
60
30.0

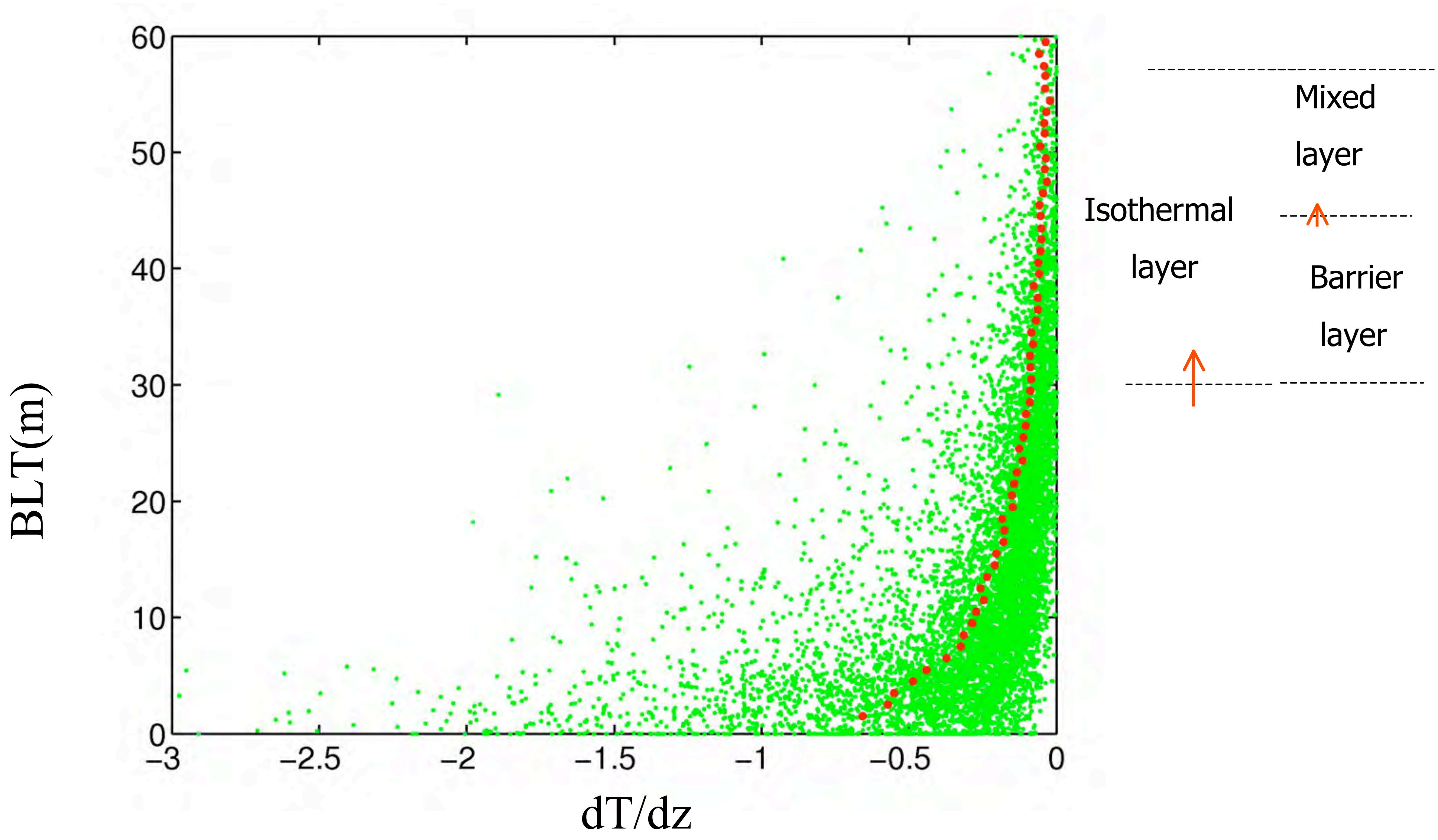
Figure 12.

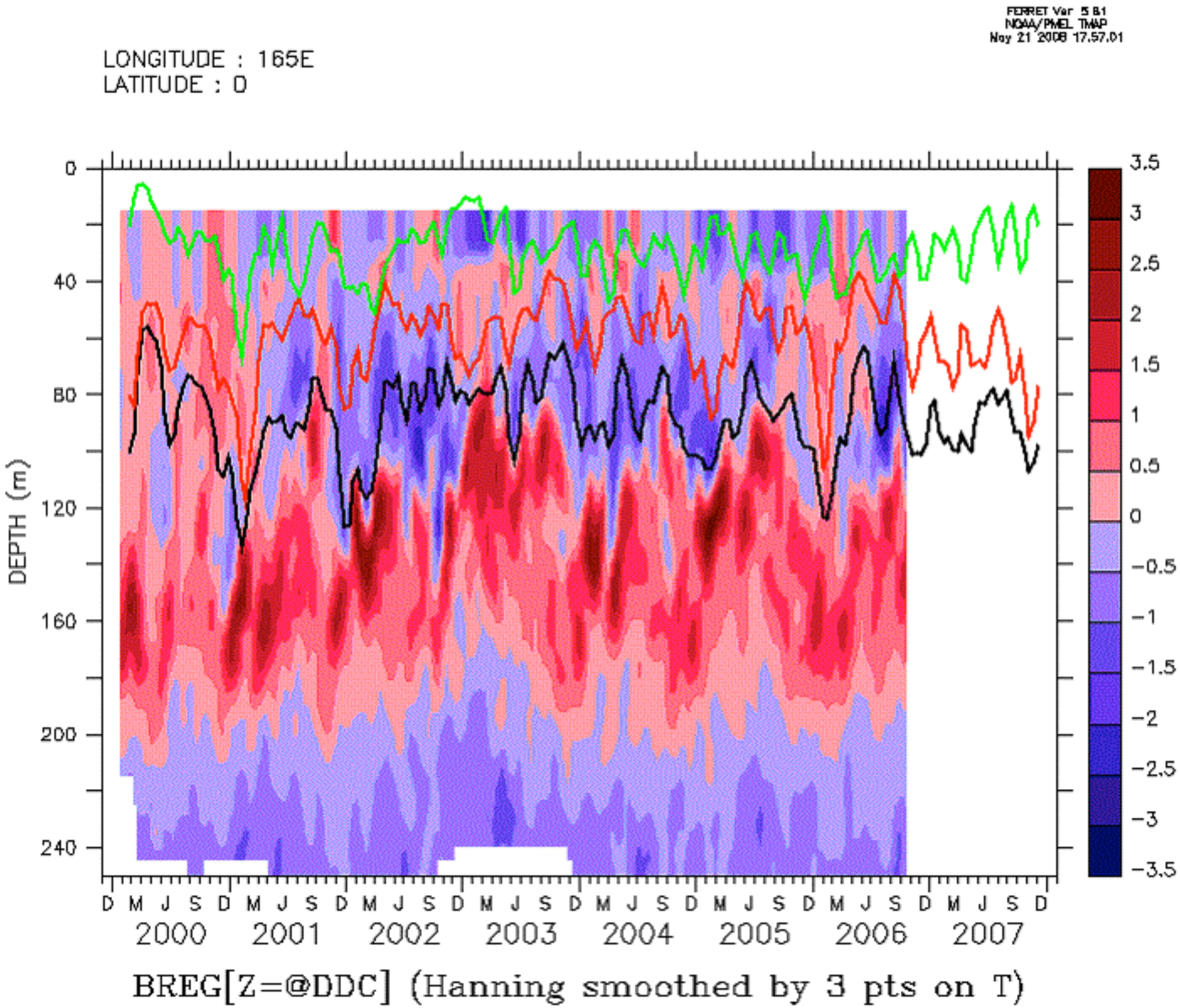

h6mois UgKEL,BLDD,MLDDI,ILDD 2N2S 10degouest
240
220
200
180
160
140
120
100
80
60
40
20
0
−20
−40
100.
80.
60.
40.
20.
2000
2001
2002
2003
2004
2005
2006
2007

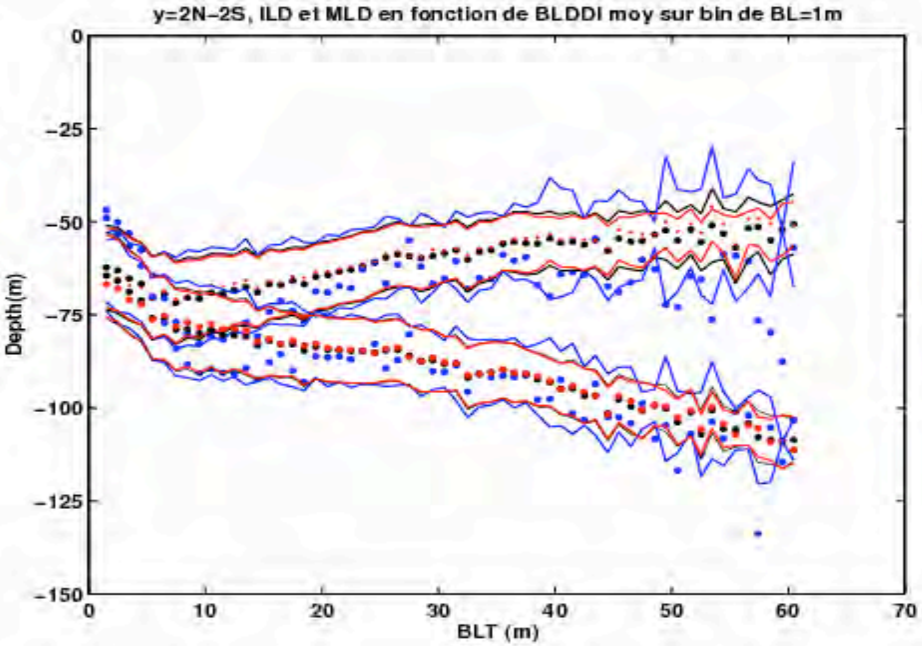
5. Barrier layer and associated surface warming

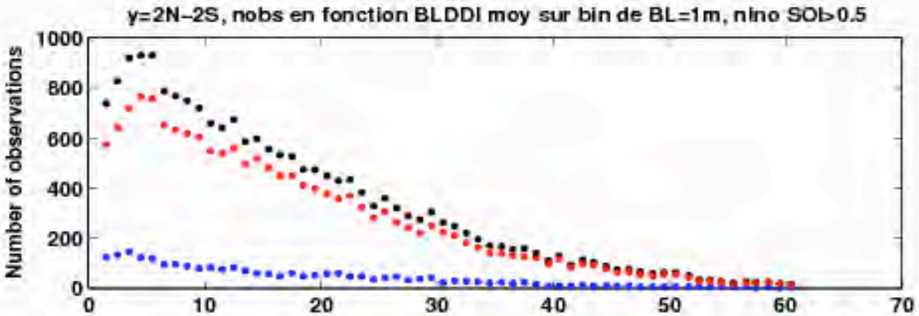


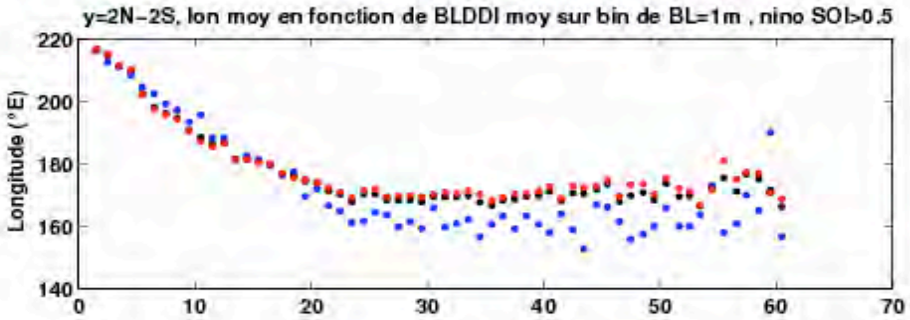
5. Barrier layer and associated surface warming

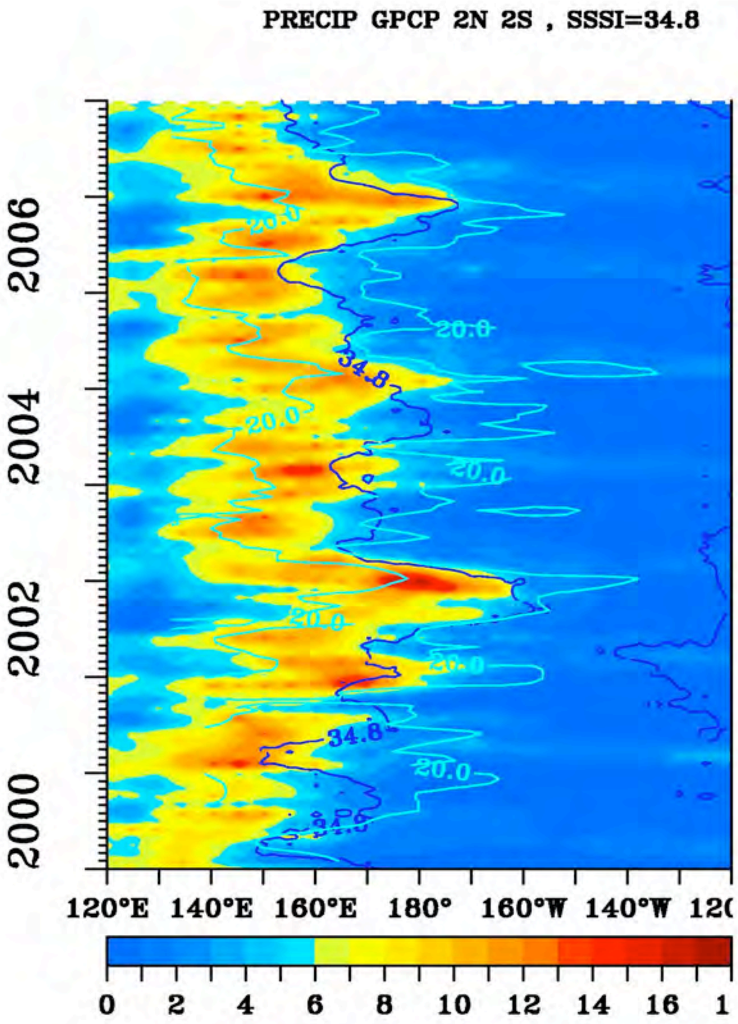


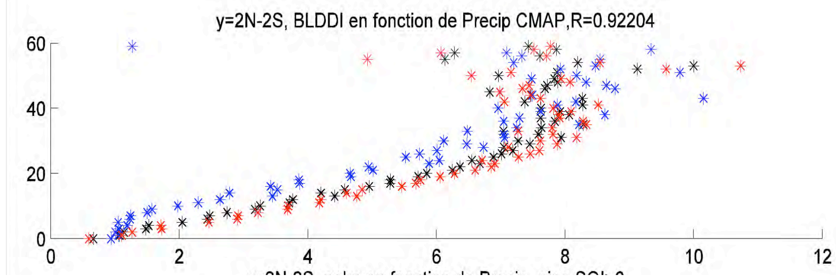

FERRET Ver 5.81
NOAA/PMEL TMAP
Nov 21 2008 17:57:01
LONGITUDE : 165E
LATITUDE : 0
DEPTH (m)
0
40
80
120
160
200
240
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
D M J S D M J S D M J S D M J S D M J S D M J S D M J S D M J S D
2000 2001 2002 2003 2004 2005 2006 2007
BREG[Z=@DDC] (Hanning smoothed by 3 pts on T)

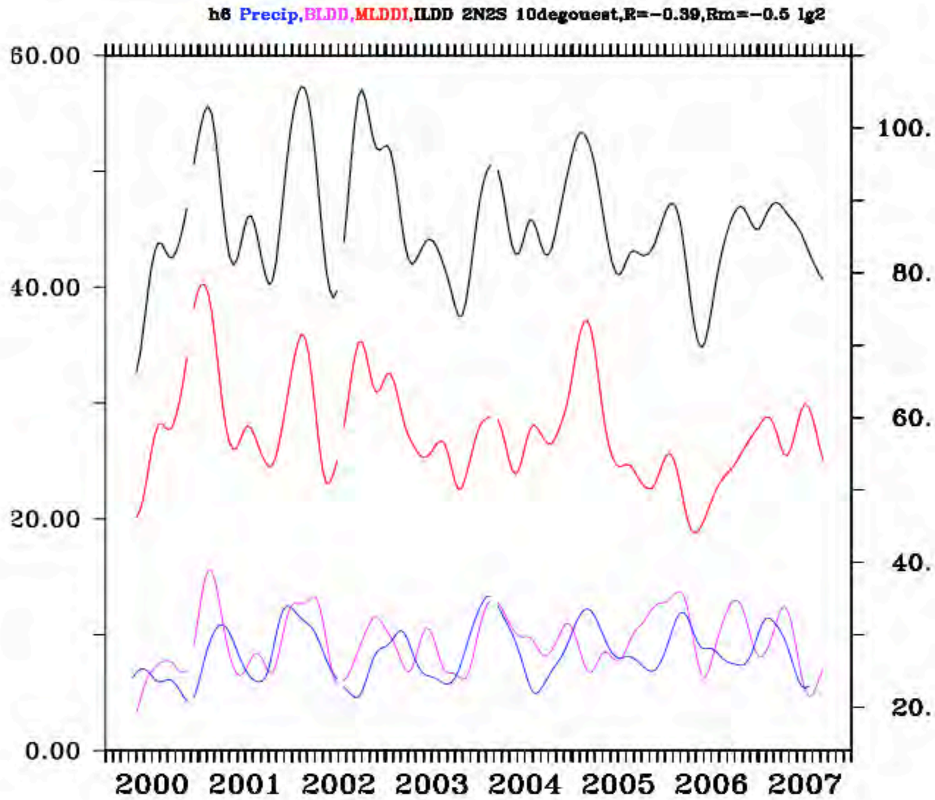

y=2N-2S, ILD et MLD en fonction de BLDDI moy sur bin de BL=1m
Depth(m)
BLT (m)
0
-25
-50
-75
-100
-125
-150
0 10 20 30 40 50 60 70

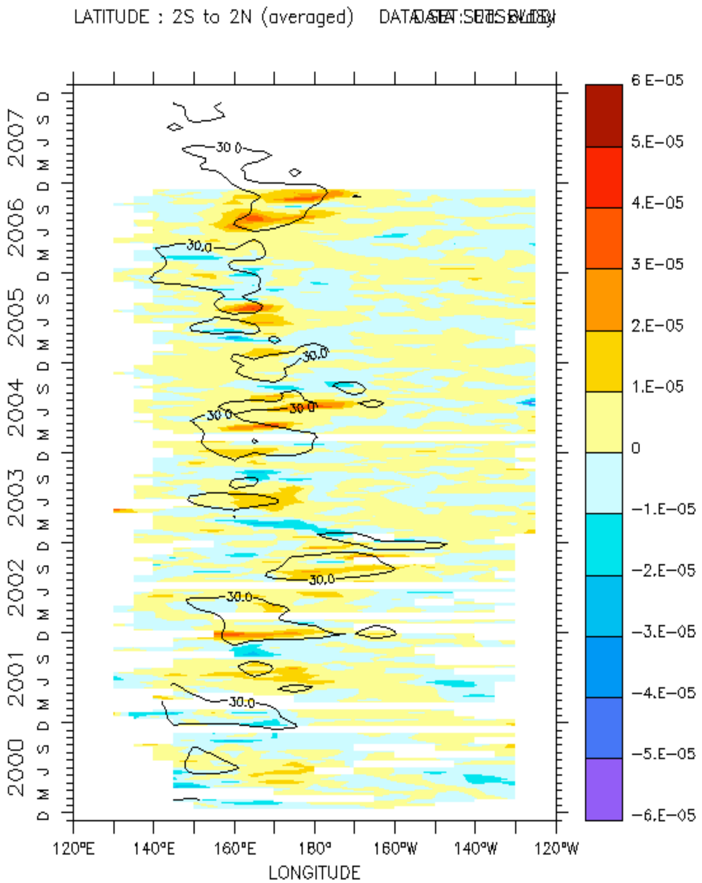

y=2N-2S, nobs en fonction BLDDI moy sur bin de BL=1m, nino SOI>0.5
Number of observations
1000
800
600
400
200
0
0 10 20 30 40 50 60 70


y=2N-2S, lon moy en fonction de BLDDI moy sur bin de BL=1m , nino SOI>0.5
Longitude (°E)
220
200
180
160
140
0 10 20 30 40 50 60 70

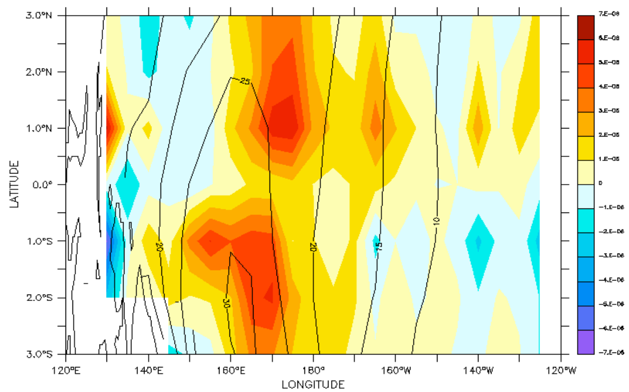

PRECIP GPCP 2N 2S , SSSI=34.8
2000
2002
2004
2006
120°E 140°E 160°E 180° 160°W 140°W 120
0 2 4 6 8 10 12 14 16 1
20.0
34.8


y=2N-2S, BLDDI en fonction de Precip CMAP,R=0.92204
0 20 40 60
0 2 4 6 8 10 12


h6 Precip,BLDD,MLDDI,ILDD 2N2S 10degouest,R=-0.39,Rm=-0.5 lg2
0.00 20.00 40.00 60.00
20. 40. 60. 80. 100.
2000 2001 2002 2003 2004 2005 2006 2007

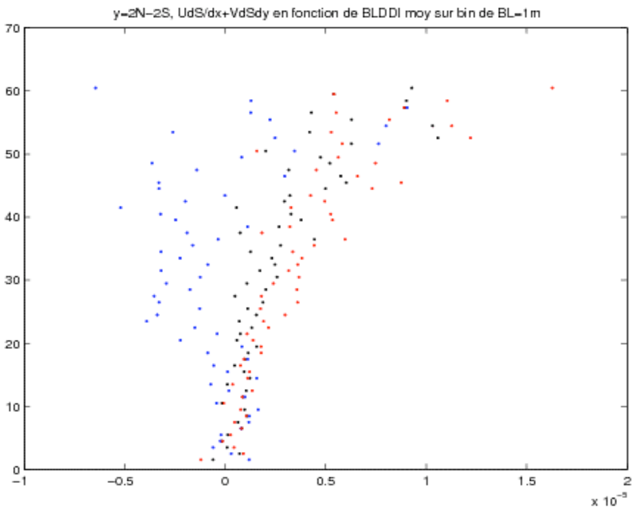


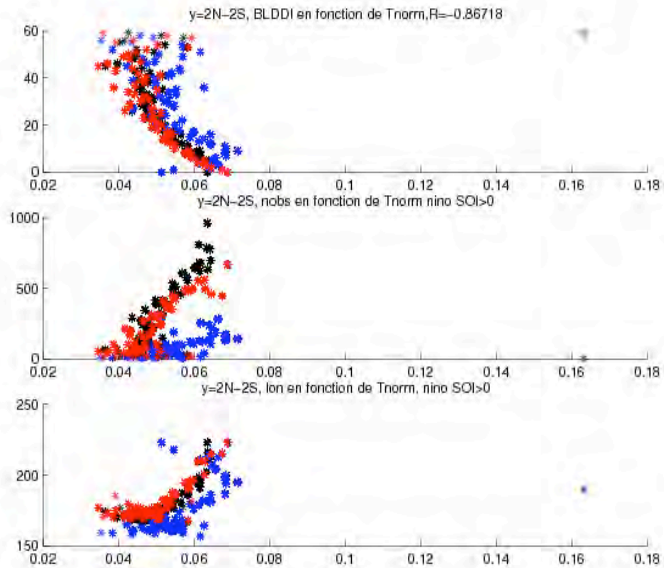
UDSDX+VDSDY

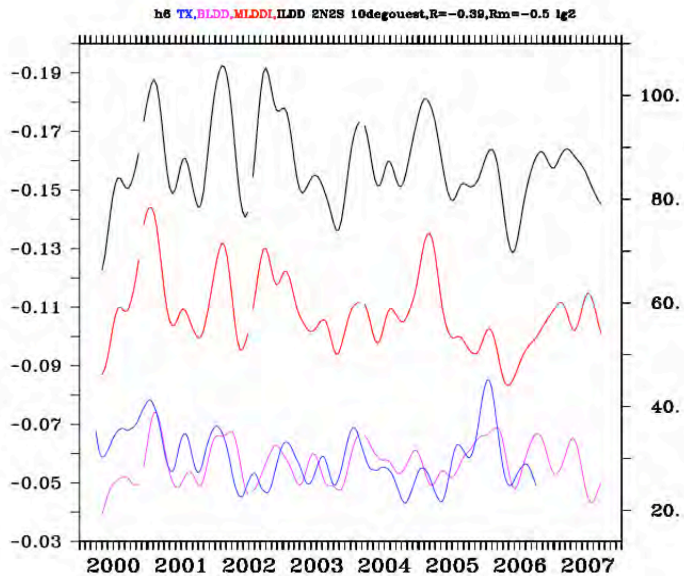


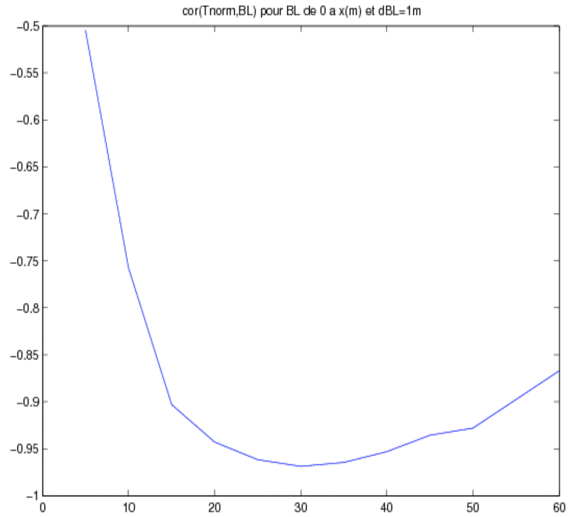
UDSDX+VDSDY

Contour BL




y=2N-2S, BLDDI en fonction de Tnorm,R=-0.86718
y=2N-2S, nobs en fonction de Tnorm nino SOI>0
y=2N-2S, lon en fonction de Tnorm, nino SOI>0


h6 TX,BLDD,MLDDI,ILDD 2N2S 10degouest,R=-0.39,Rm=-0.5 lg2


cor(Tnorm,BL) pour BL de 0 a x(m) et dBL=1m

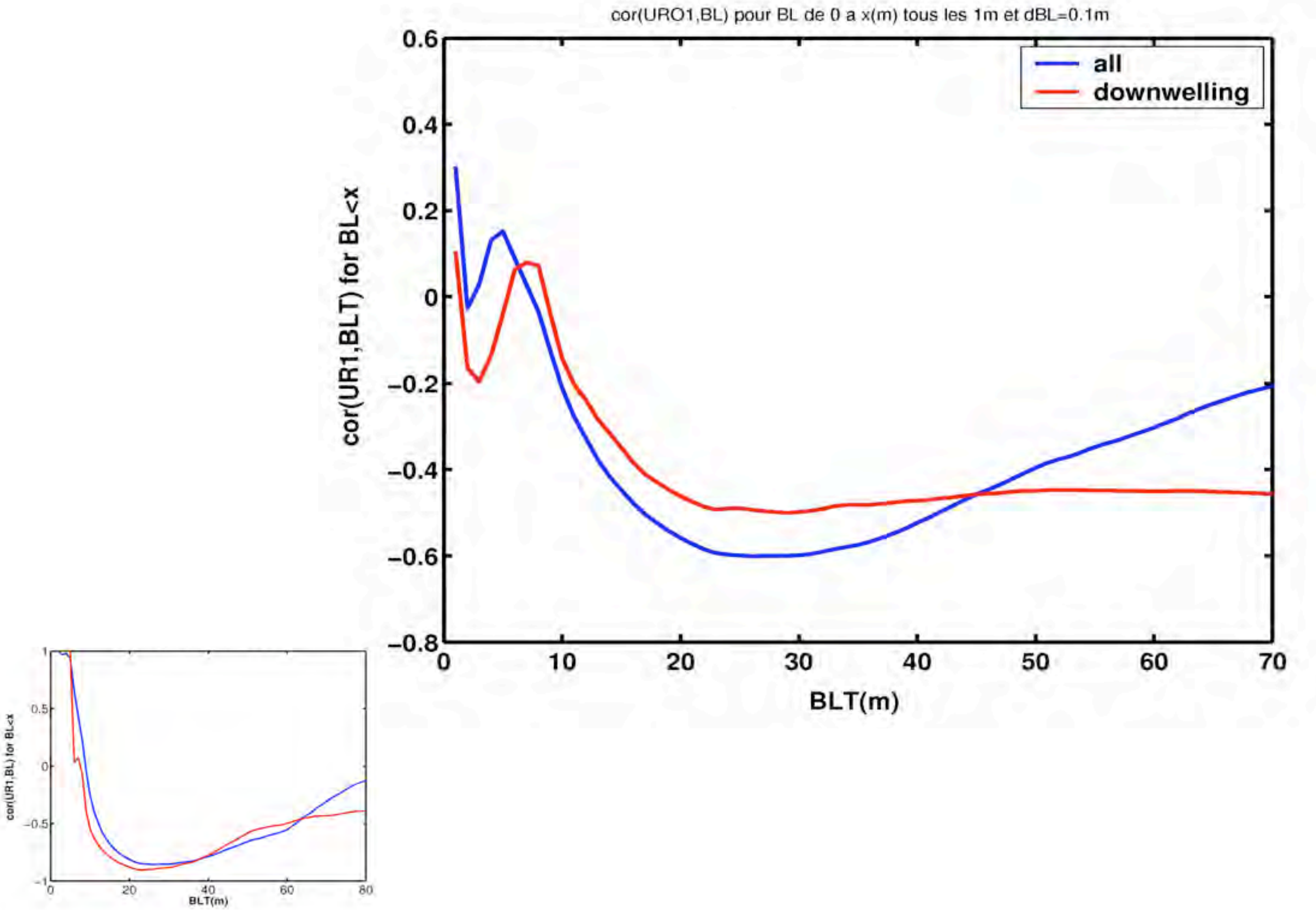
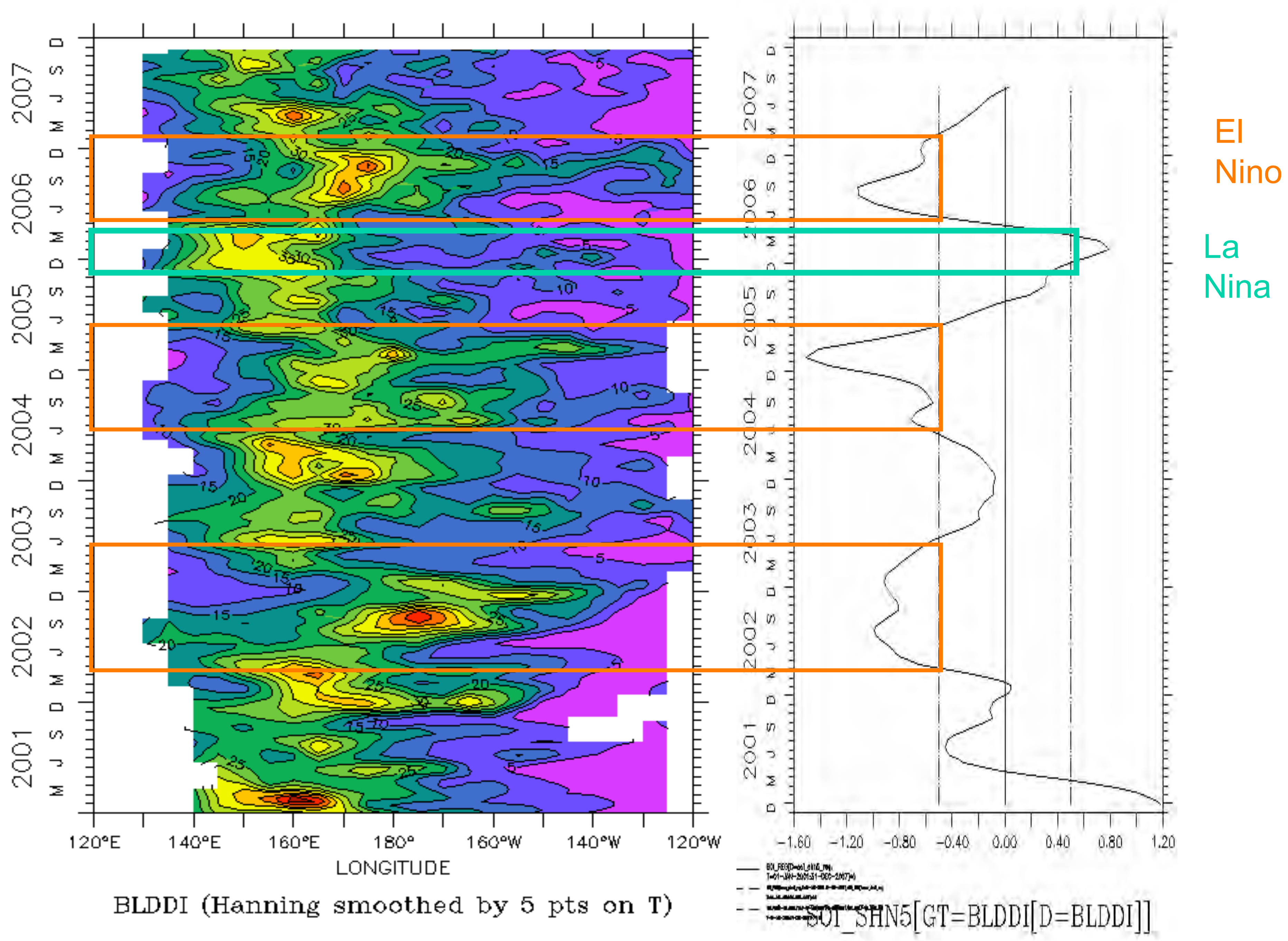
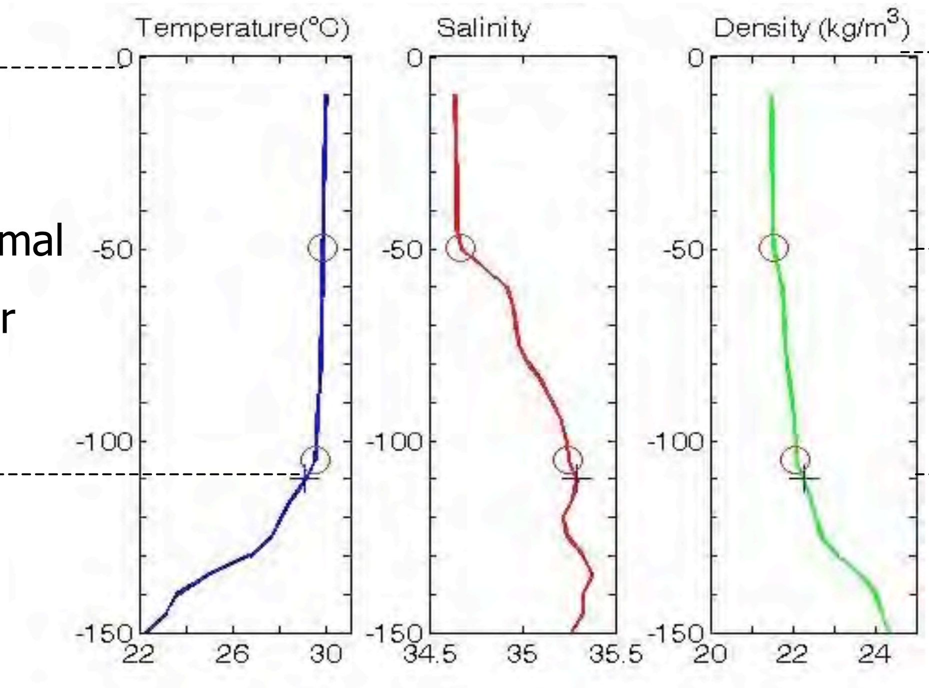

cor(URO1,BL) pour BL de 0 a x(m) tous les 1m et dBL=0.1m
all
downwelling
cor(UR1,BLT) for BL<x
BLT(m)
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
0
10
20
30
40
50
60
70
cor(UR1,BL) for BL<x
BLT(m)

Figure 14.


El Nino
La Nina
2001
2002
2003
2004
2005
2006
2007
M J S D
120°E
140°E
160°E
180°
160°W
140°W
120°W
LONGITUDE
BLDDI (Hanning smoothed by 5 pts on T)
-1.60
-1.20
-0.80
-0.40
0.00
0.40
0.80
1.20
SOI_SHN5[GT=BLDDI[D=BLDDI]]

3.2. Subsurface thermohaline structure: barrier layer

Isothermal layer



Mixed layer

Barrier layer

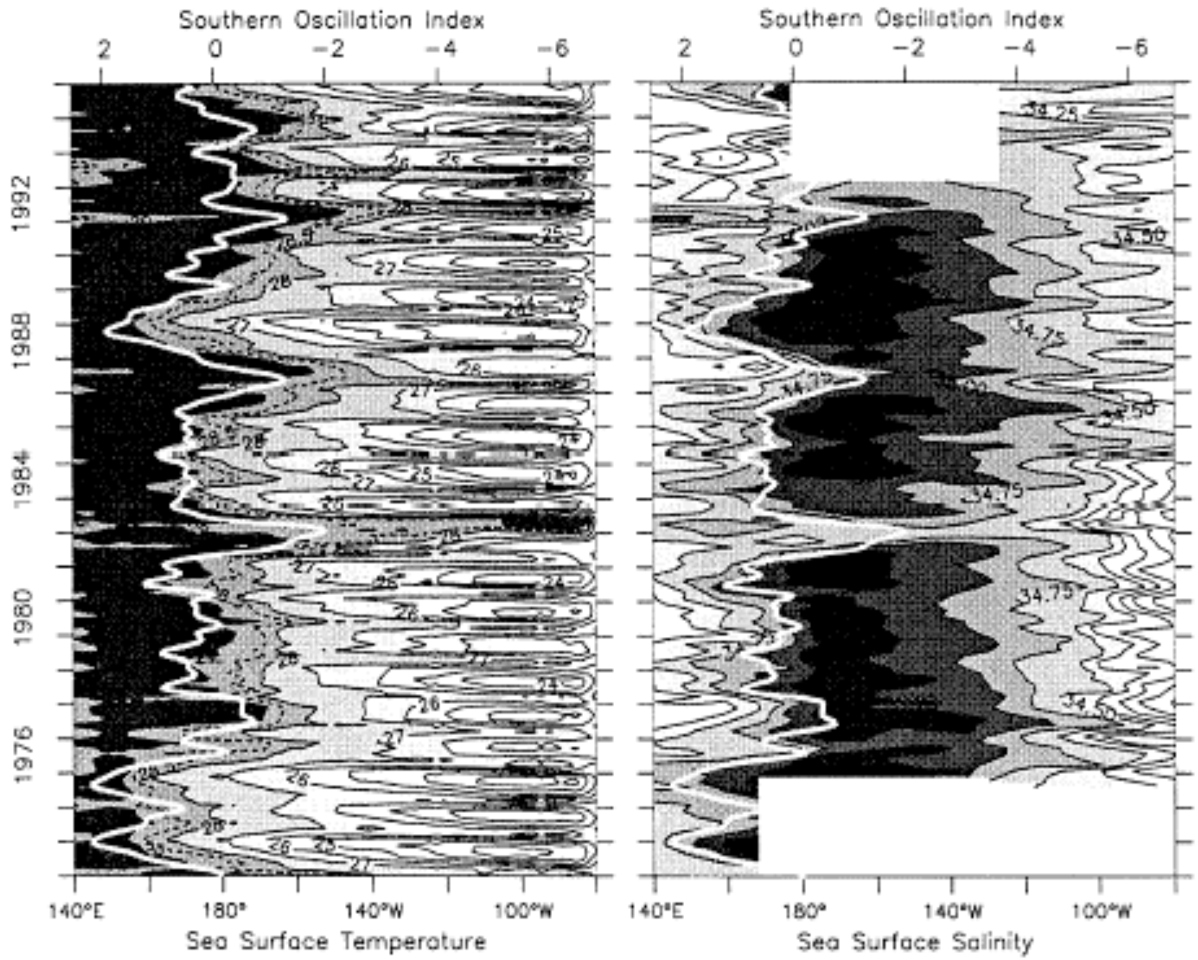
5 mai 2005, 0°-161°E.

Levitus, 1982
O O O O
Mixed layer
$\Delta T = 0.5°C$
Isothermal layer
$\Delta\rho = 0.125$ kg/m^3

Ref level @15 m

1. Thermohaline structure of the warm pool

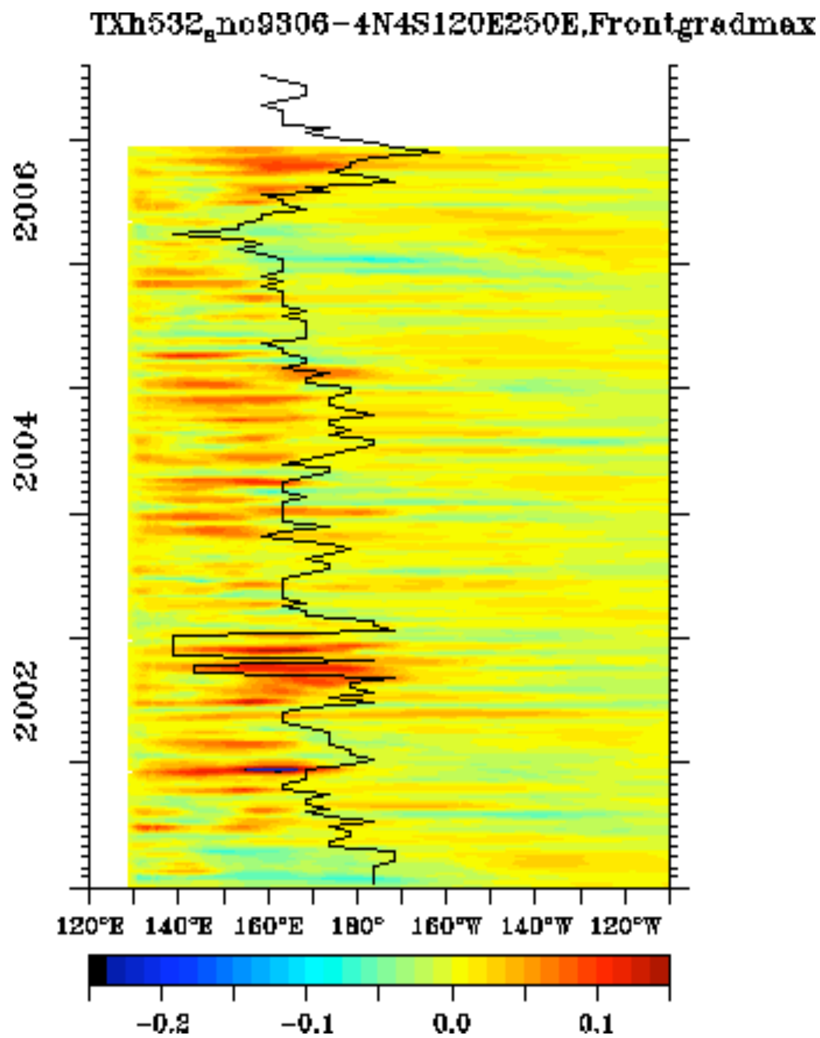
SST



SSS

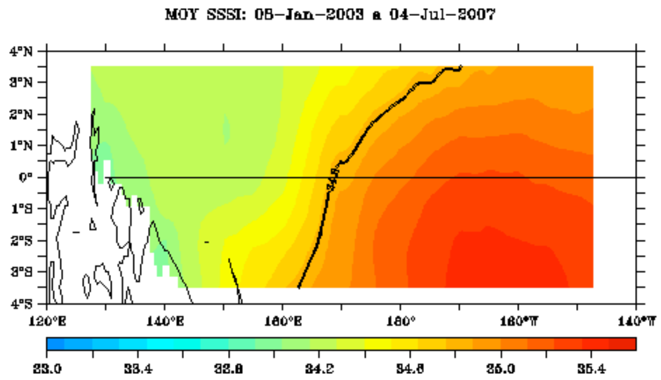
- Déplacement bord Est de la Warm Pool, front de salinité en phase avec SOI.
- L'oscillateur advectif-réflectif (Picaut et al., 1997): **zone du front au coeur de la dynamique ENSO**

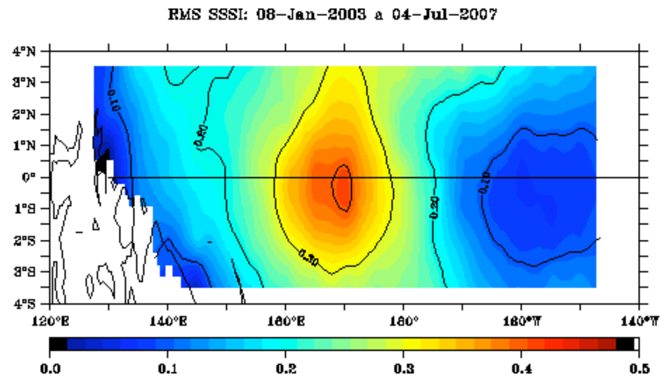
Voir la synthèse de Picaut et al, 2001

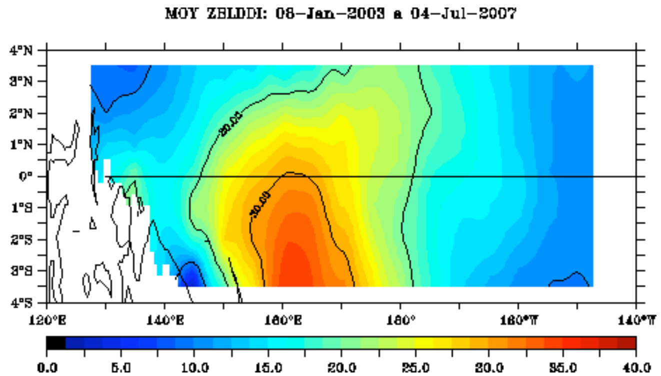


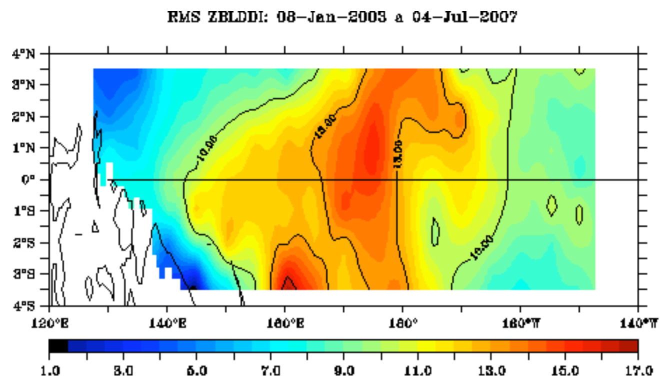
TXh532_sno9306-4N4S120E250E,Frontgradmax
2006
2004
2002
120°E 140°E 160°E 180° 160°W 140°W 120°W
-0.2 -0.1 0.0 0.1

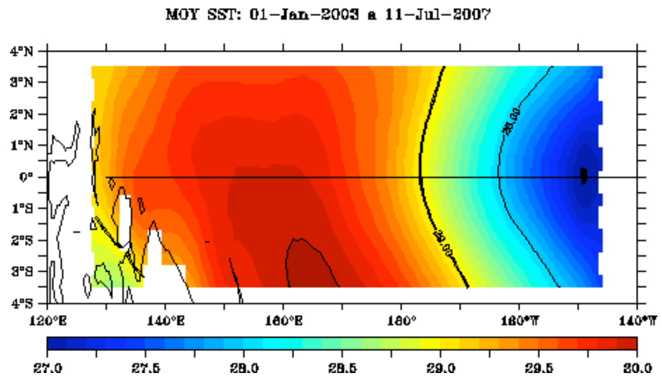
1.3. **ENSO**. Etude de la zone frontale: motivations

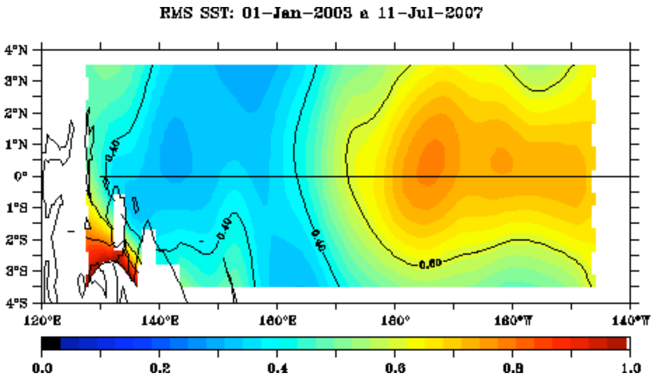


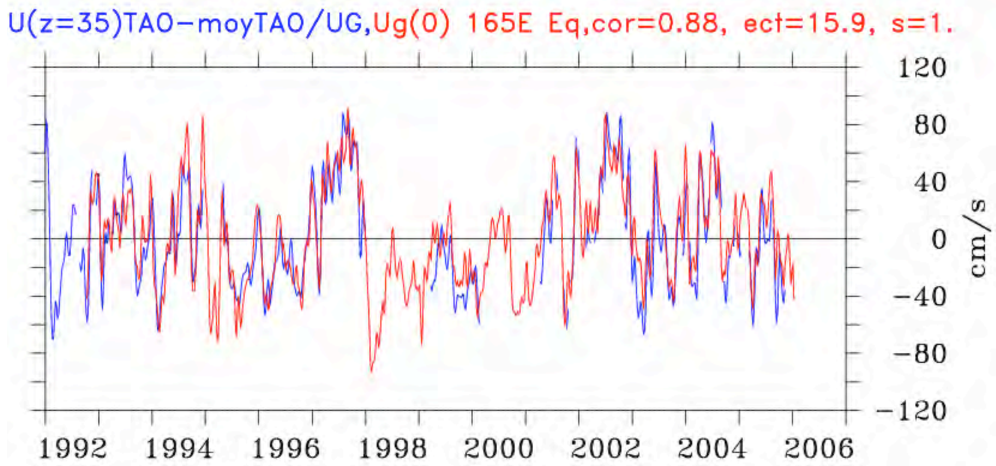






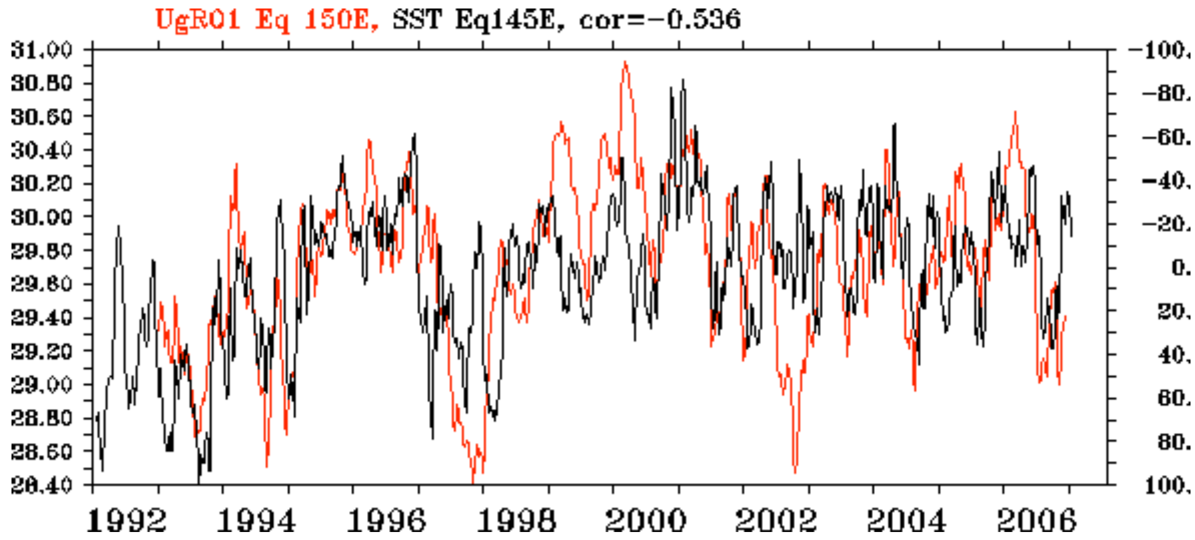


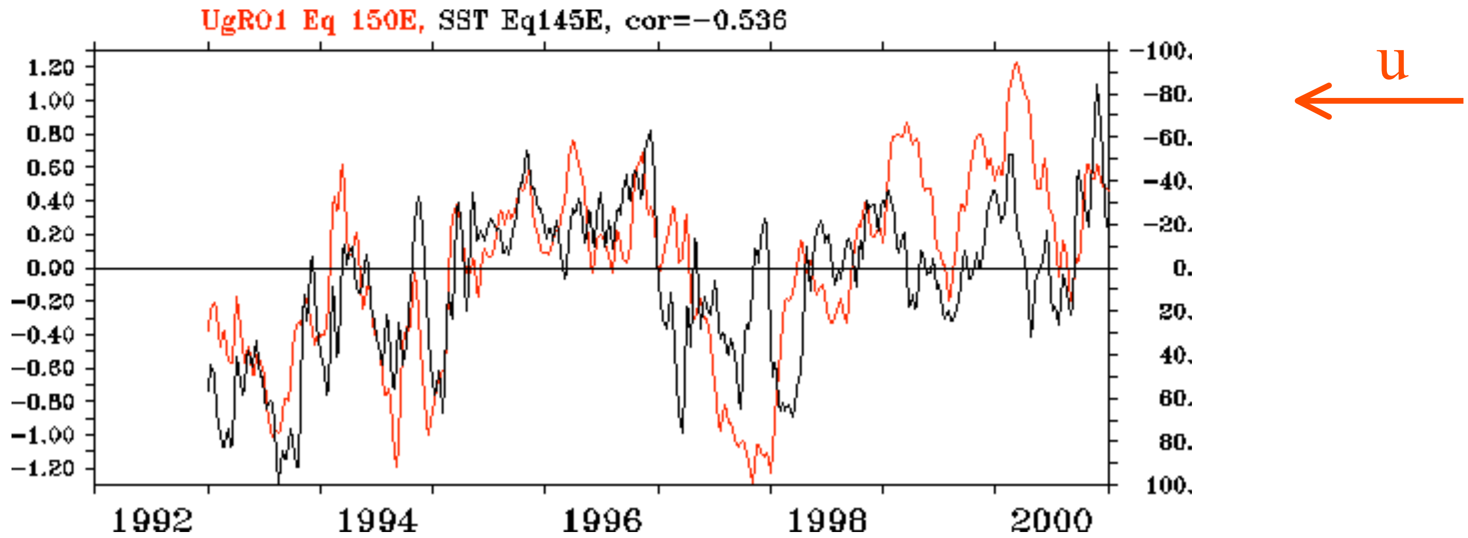




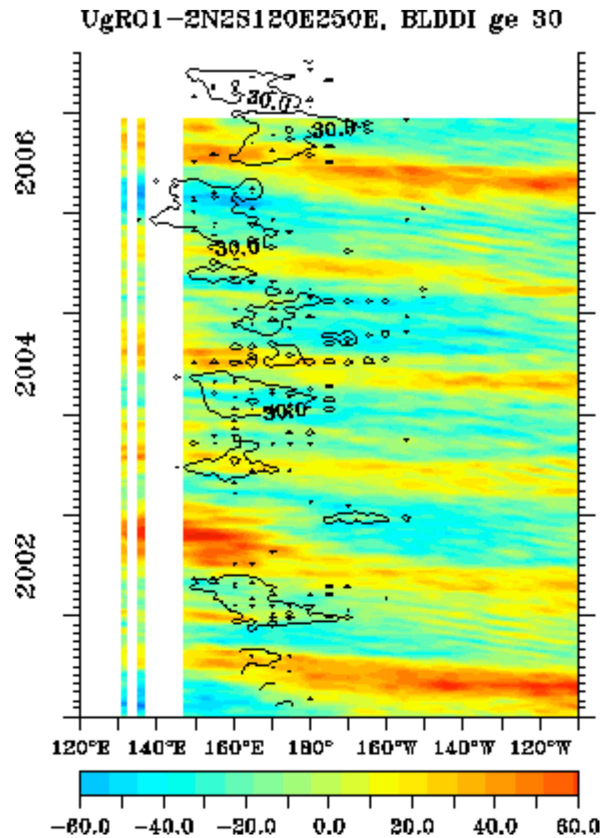
U(z=35)TAO−moyTAO/UG,Ug(0) 165E Eq,cor=0.88, ect=15.9, s=1.
120
80
40
0
−40
−80
−120
cm/s
1992
1994
1996
1998
2000
2002
2004
2006

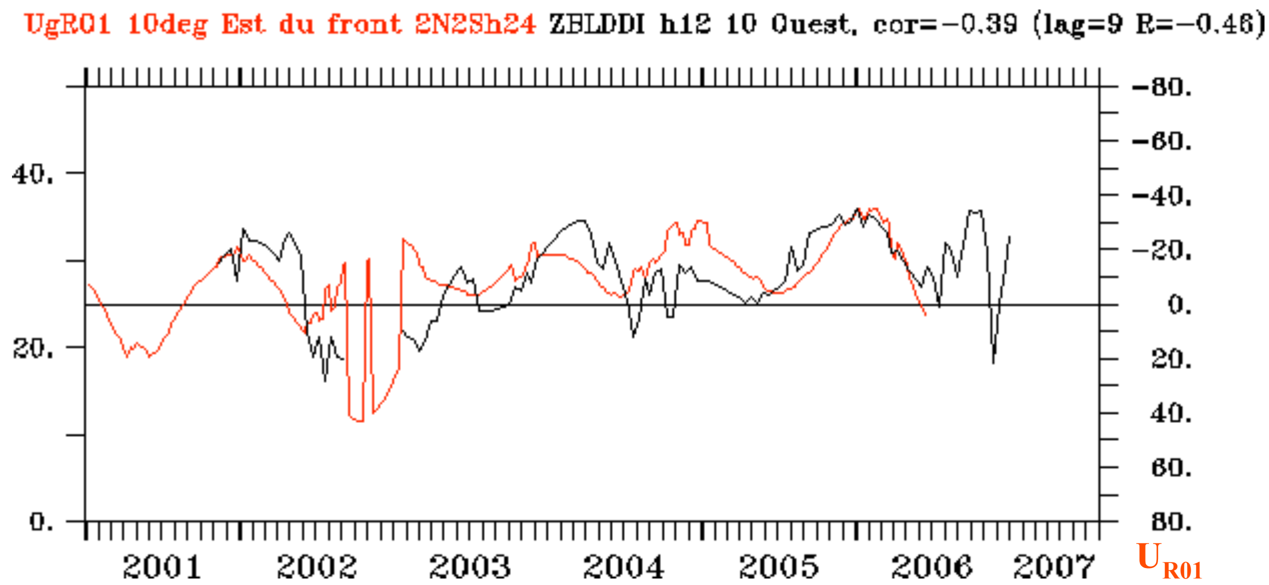
3.5. Couche barrière: entre l’océan et l’atmospohère





3.2. Mécanimes: formation de la couche barrière de sel



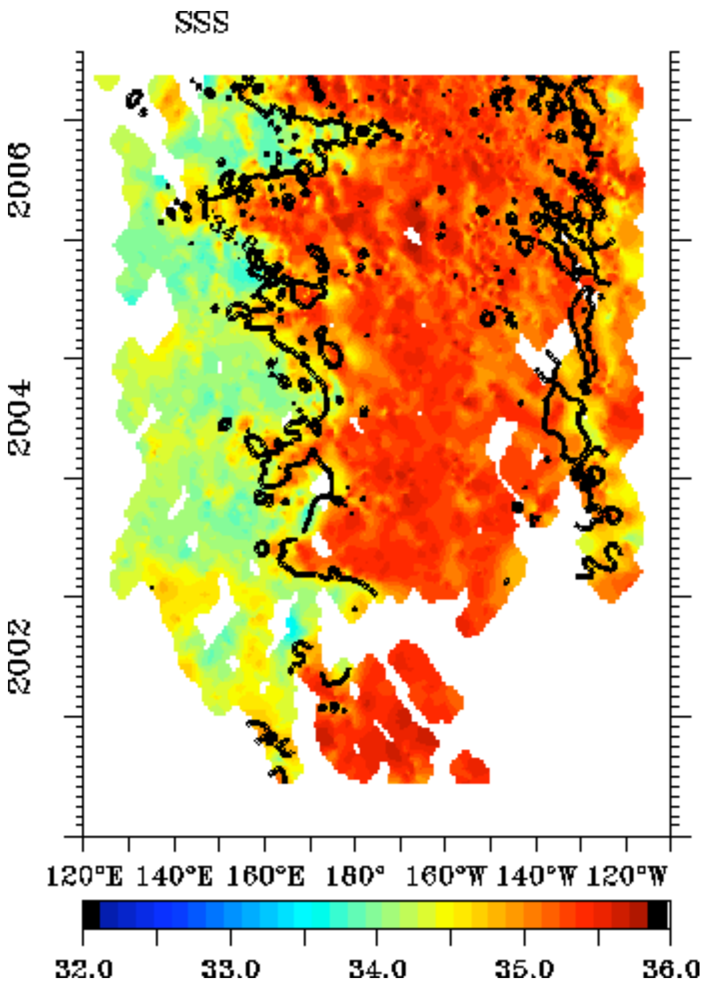


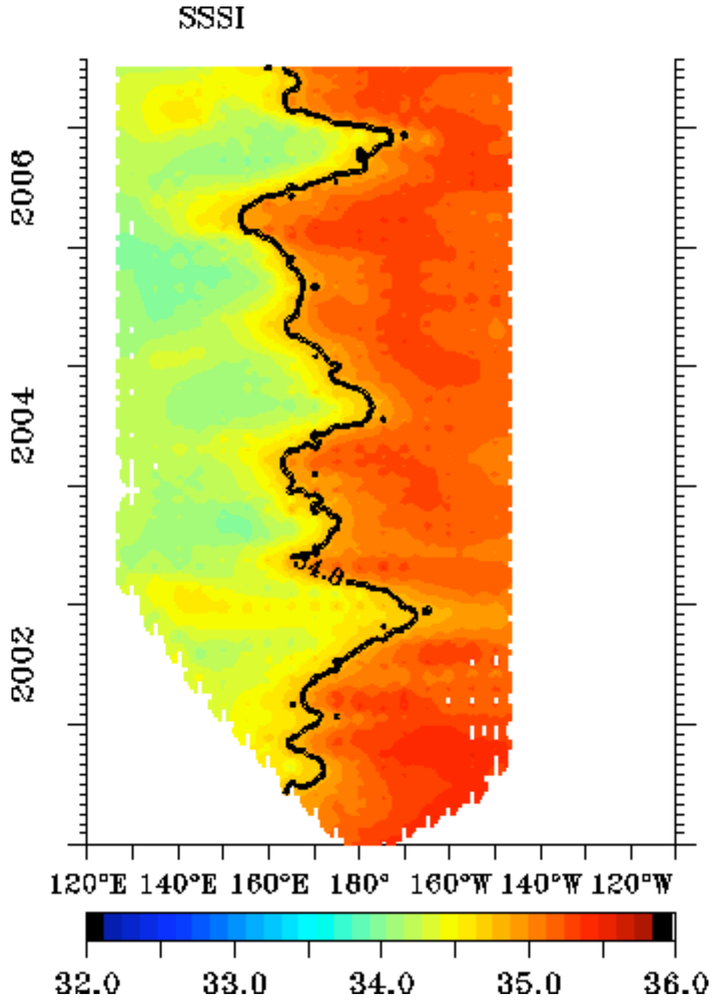
Couper 2003, ech

Schema upwell, approf

Front apparait

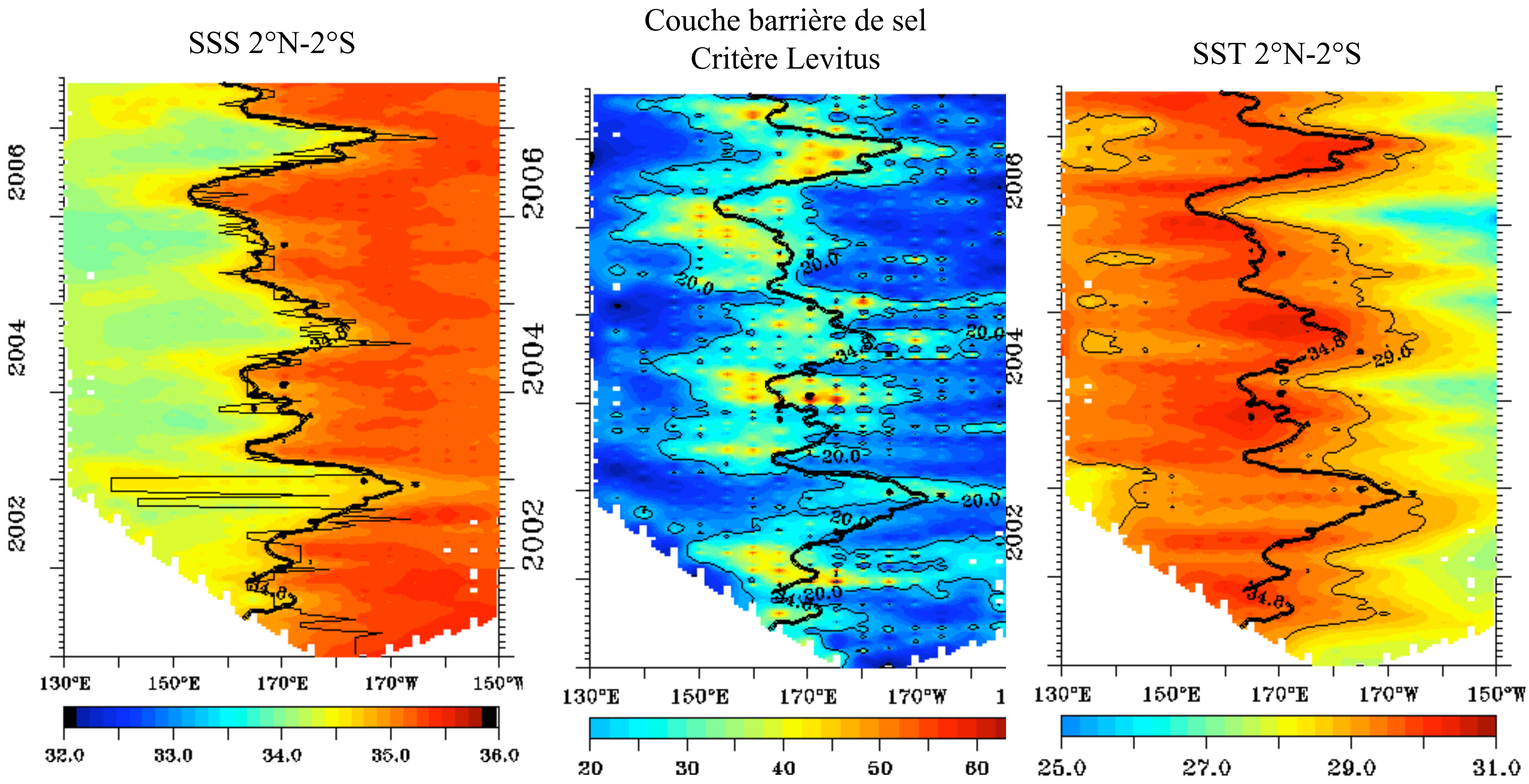
2.2. Observations disponibles depuis 2000: gridding



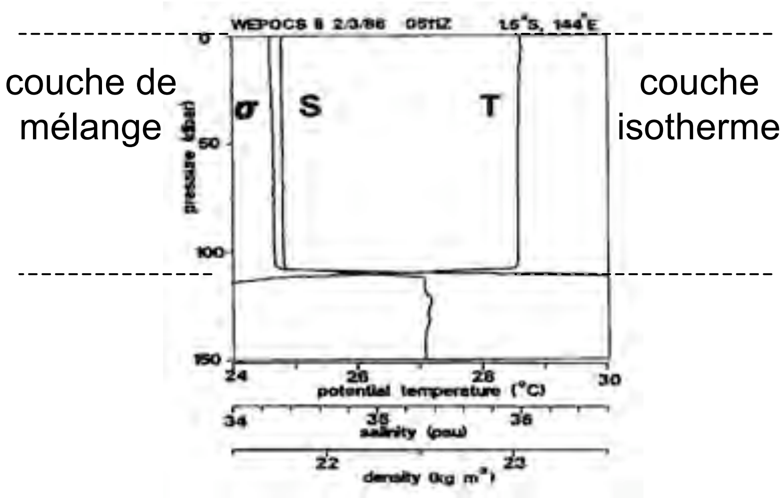


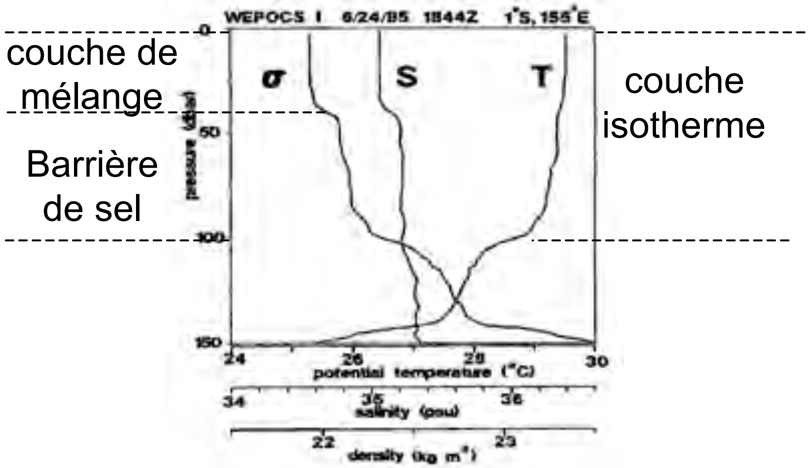
Interpolation: 5°x1°x14 jours x 5m

3.1. Observation du front: structure horizontale et verticale



1.2. **ENSO**. Etude de la zone frontale : structure thermo haline verticale





<u>Lukas and Lindstrom</u>

Couche de mélange

$\partial_z \rho = 0.01$ kg/m^4

Couche isotherme

$\partial_z T = 0.05$ °C/m

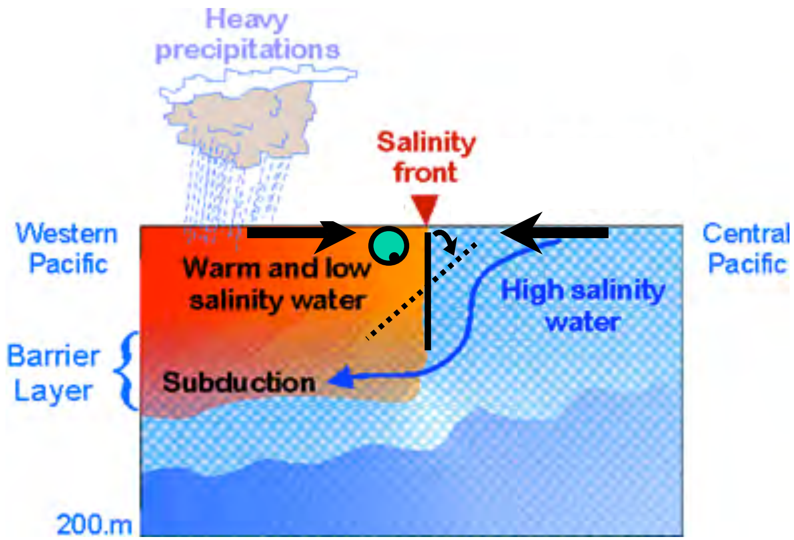
<u>Levitus</u>

$\Delta T = 0.5$°C

$\Delta \rho = 0.125$ kg/m^3

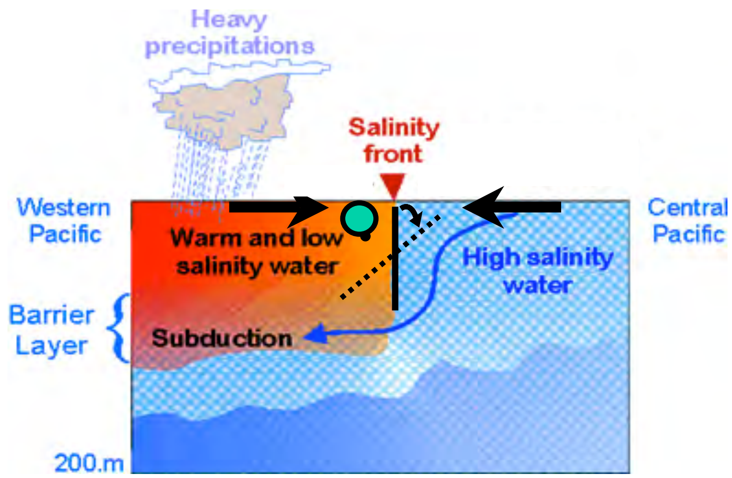
Ref level @20 m

Maes ??

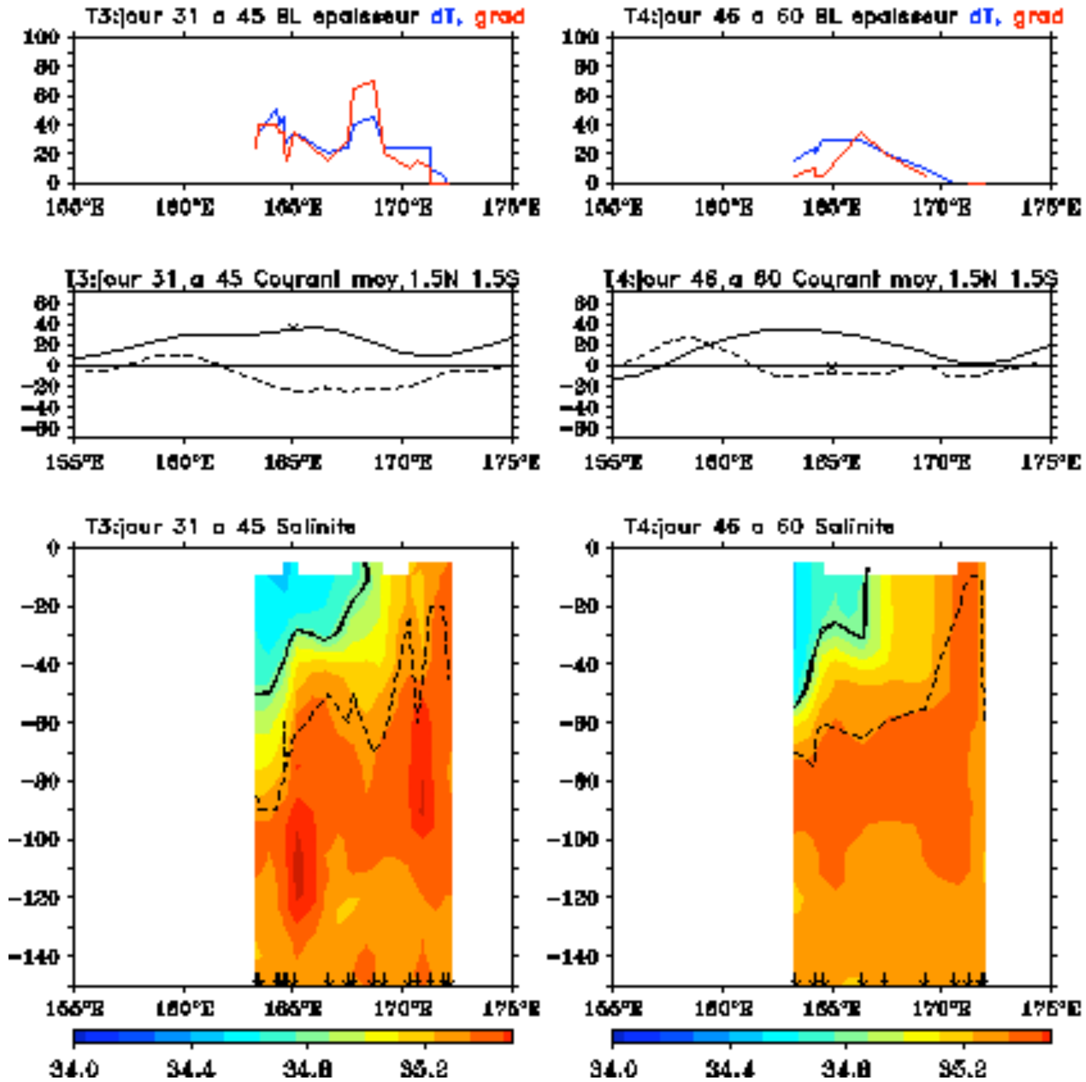


(Lukas et Lindstrom, 1991)

3.2. Front et Couche Barrière de sel



Dates?



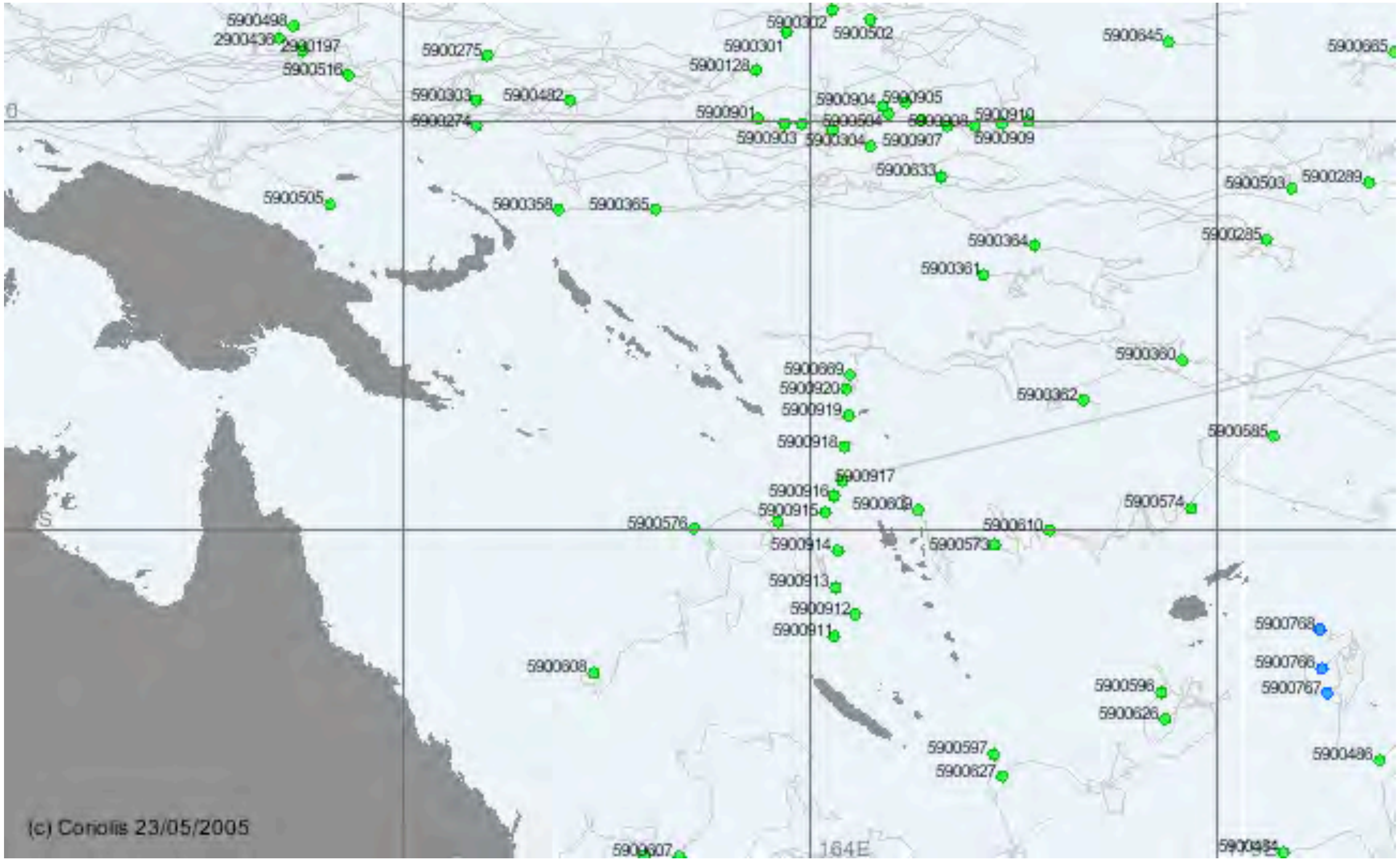
----

ndata zt ou zs=amiss, % 1793 0.334444
npro colonnes manquantes zt=zs, % 33 0.405804
ndata pb ampli et delta , % 3950.00 0.736784
ndata pb stabilité , % 0 0.
npro trous de 50m dans 0-200m, % 41 0.504181

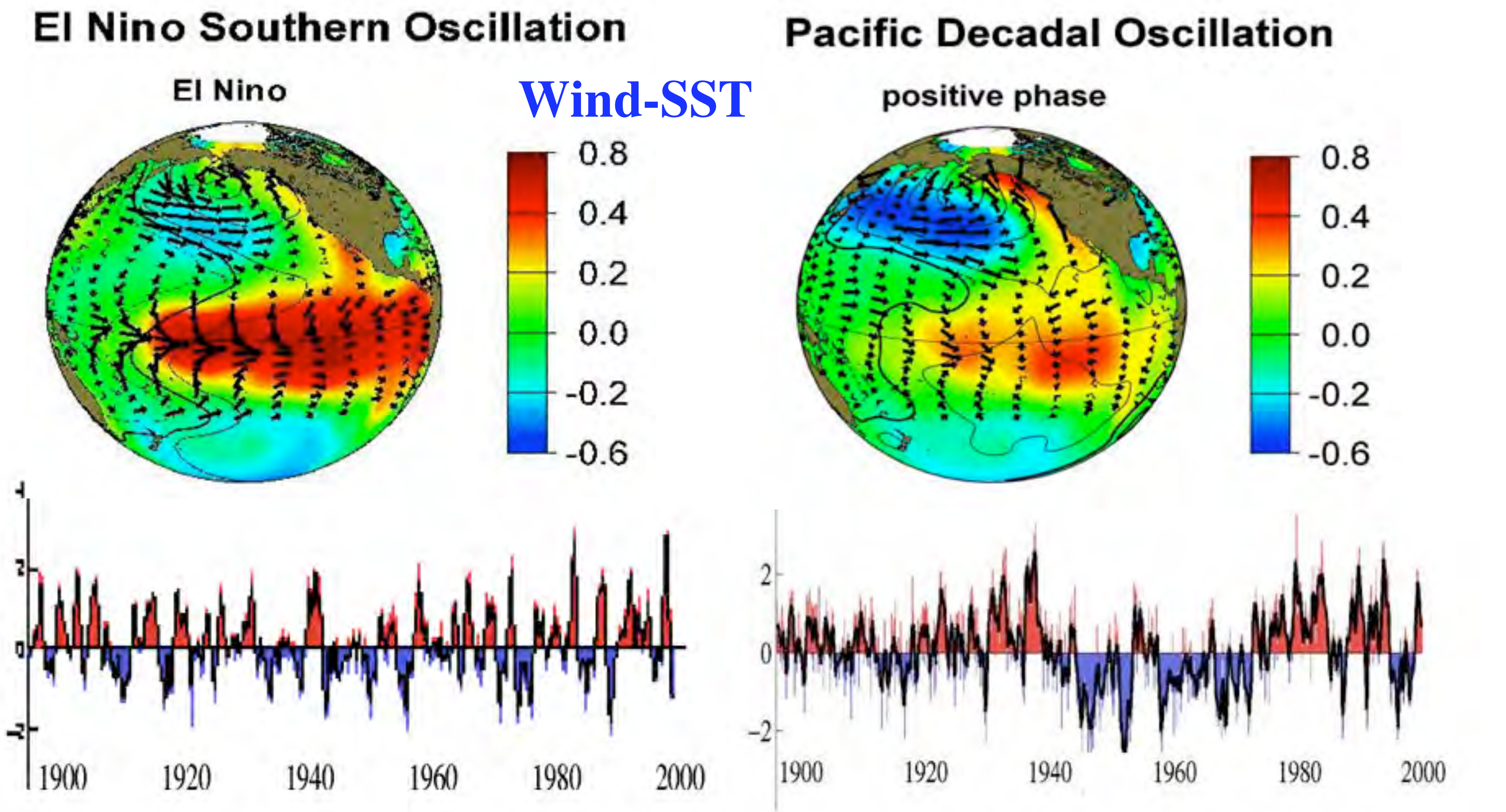
Profils:n,ndef,% 8132 165 2.02902
Data:n,ngood,% 536114 527478 98.3891
Profils BL:npro,nBL,%,zo= 20 8132 7433.00 91.4043

Déploiements Frontalis-3

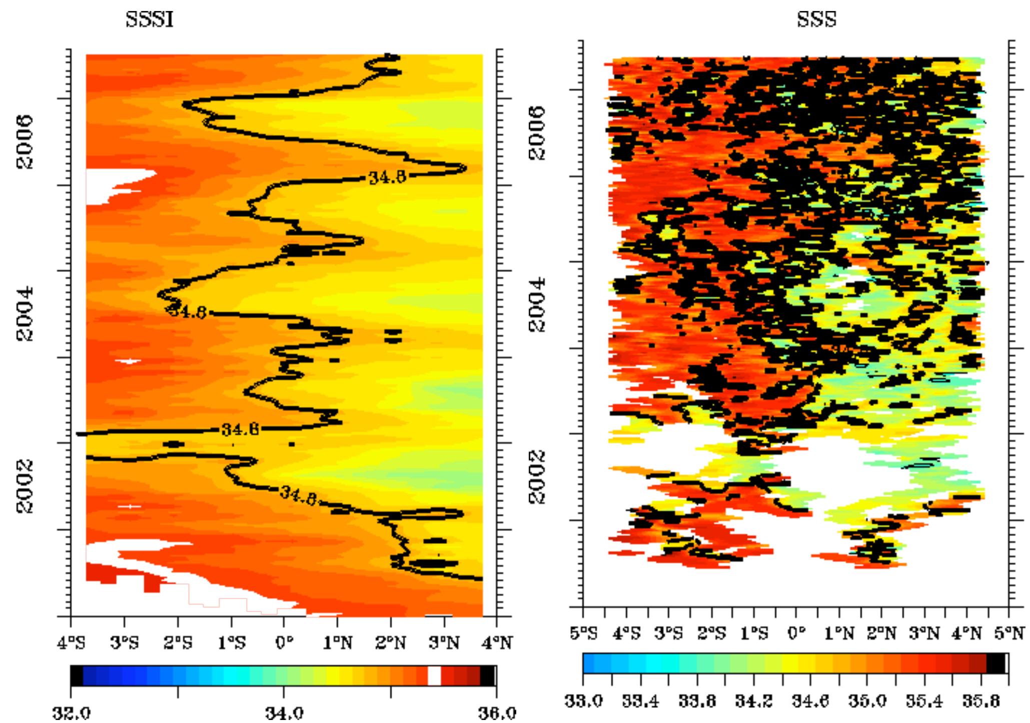
au 23 mai 2005



1.2. Variabilités **décennales** : rappel



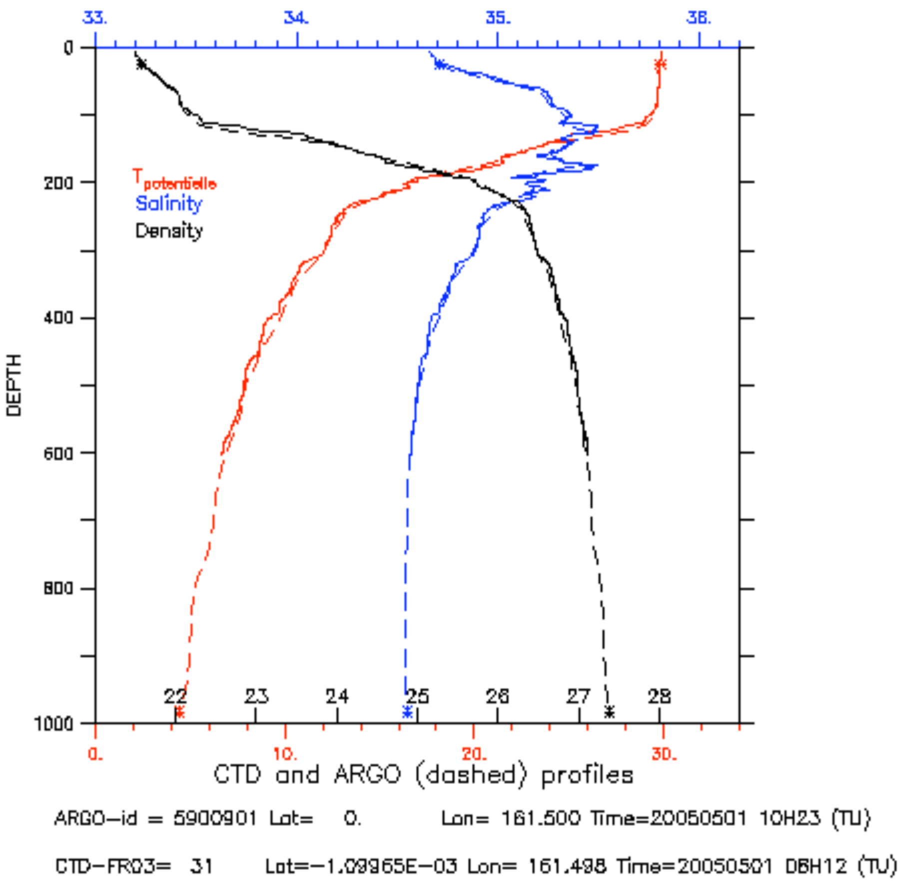
Mantua and Battisti, 1994



SSSI
SSS
2002
2004
2006
4°S 3°S 2°S 1°S 0° 1°N 2°N 3°N 4°N
5°S 4°S 3°S 2°S 1°S 0° 1°N 2°N 3°N 4°N 5°N
34.8
32.0
34.0
36.0
33.0 33.4 33.8 34.2 34.6 35.0 35.4 35.8

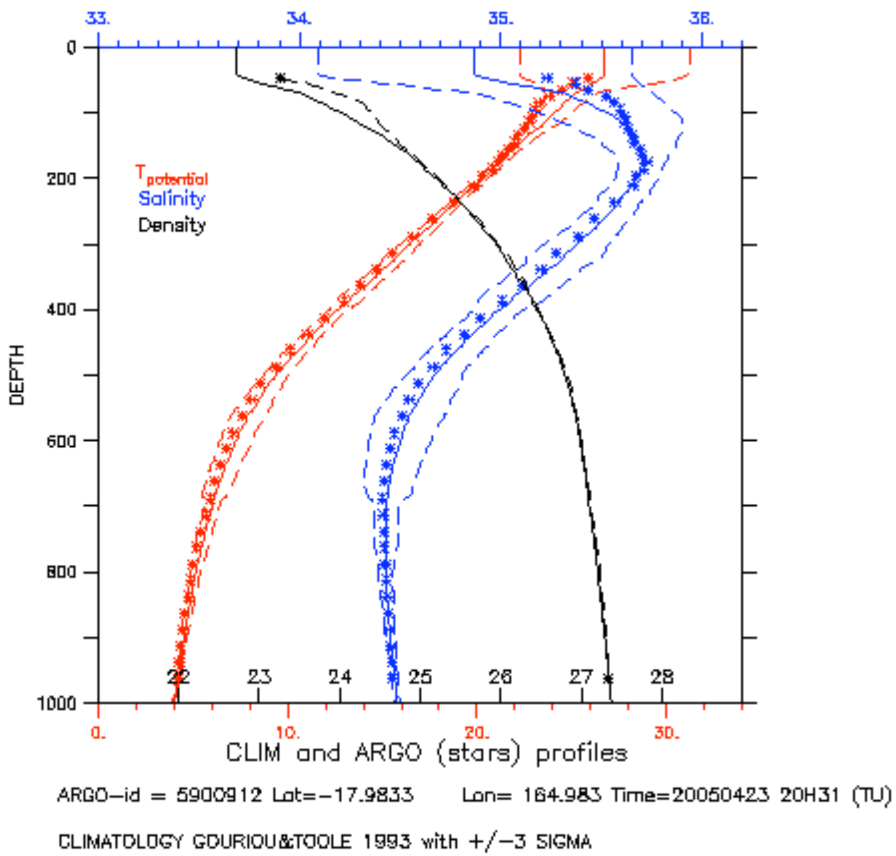
3.1. Estimation de la qualité des données récoltées au déploiement

Comparaison avec CTD simultanée



(0° - 161.5°E)

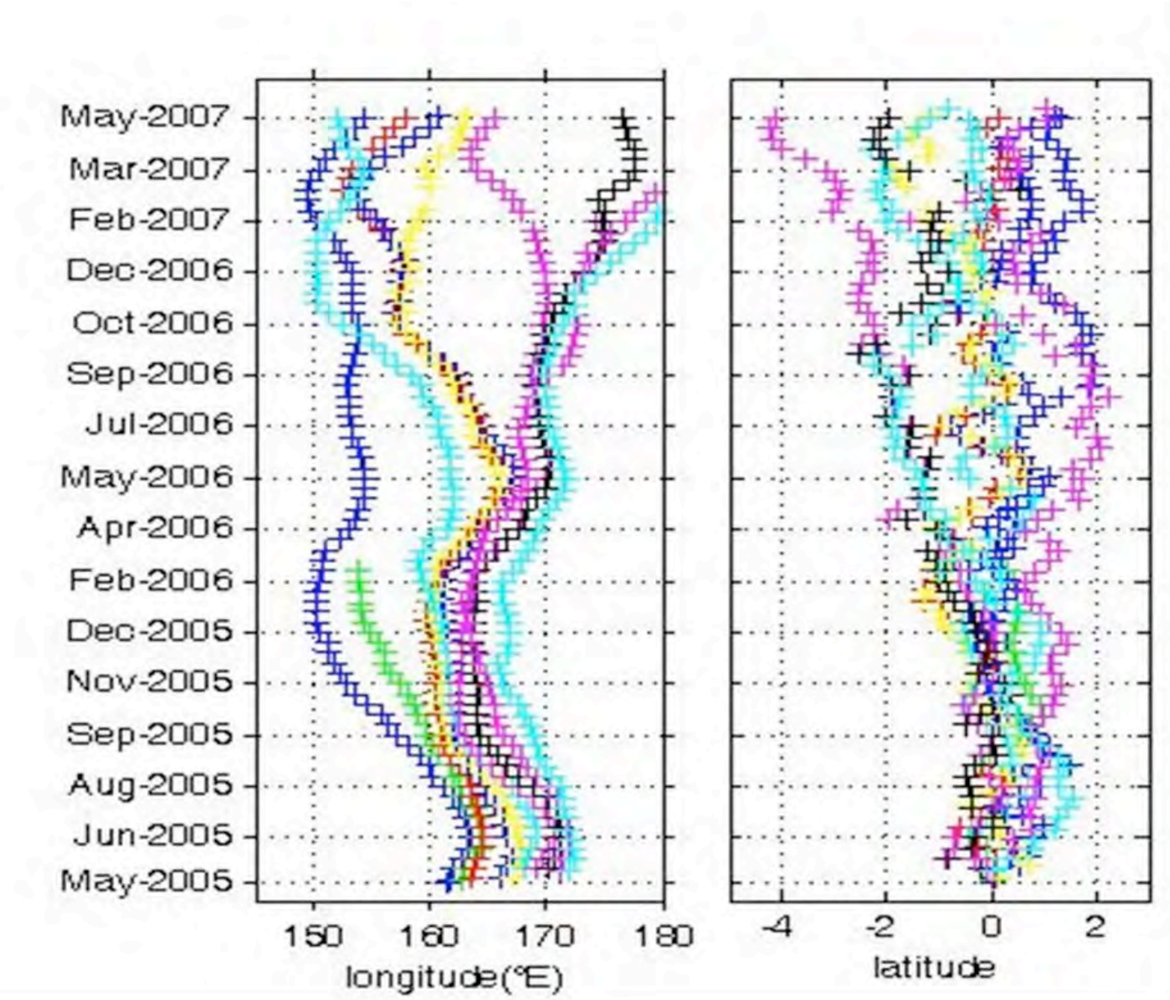
Comparaison avec la climatologie*
(Moyenne ± 3 σ)



(17°S - 165°E)

* Delcroix et al. (1992), Gouriou and Toole (1993)

2.1. Observations du front équatorial: Frontalis 3



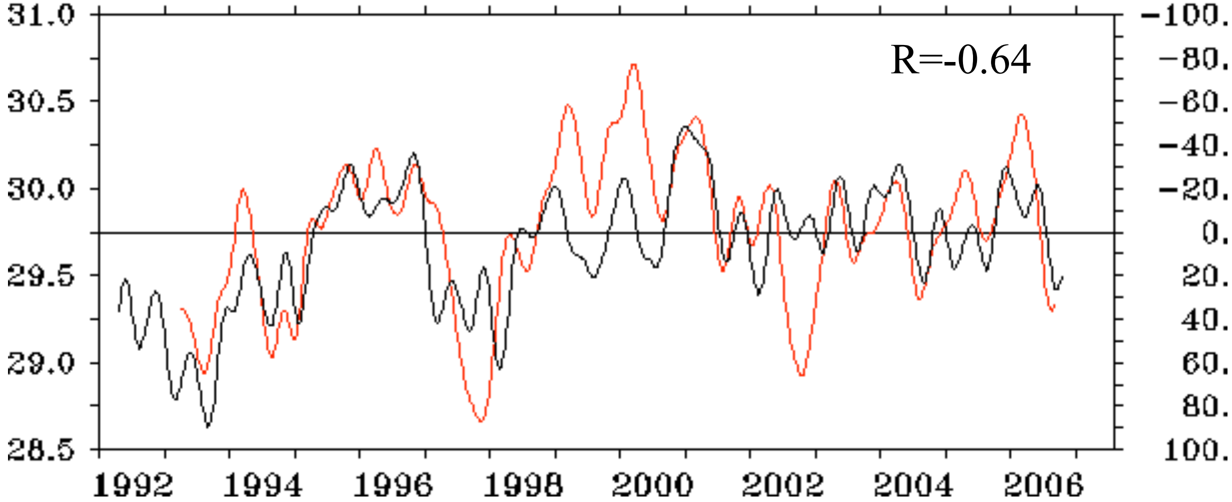
Trajectoire des flotteurs mis à l'eau pendant FRONTALIS3

1.2. ENSO. Etude de la zone frontale: motivations

SST

0°N-145°E

Filtré à 3 mois



Ugéostrophique

Rossby1

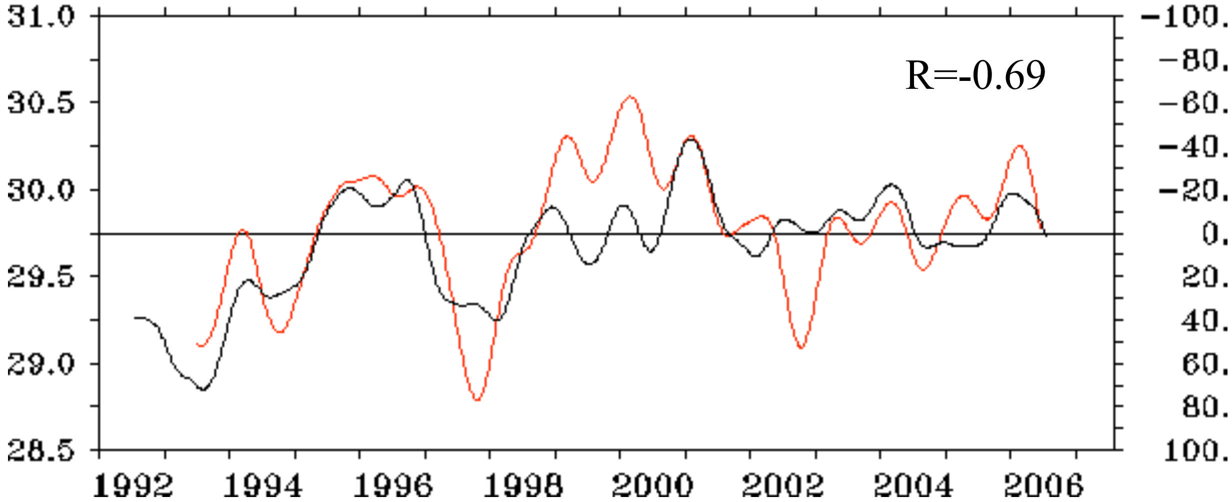
0°N-150°E

Filtré à 3 mois

SST

0°N-145°E

Filtré à 6 mois



Ugéostrophique

Rossby1

0°N-150°E

Filtré à 6 mois