Procesos de mistura e de circulação das águas da plataforma continental do sul do Brasil

Osmar O. Möller Jr.

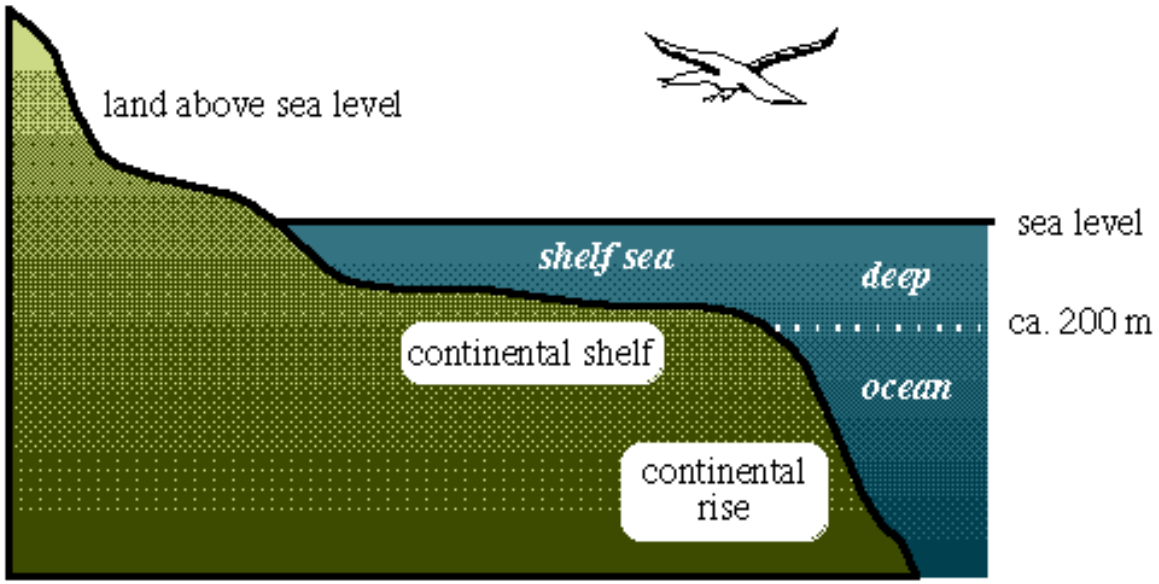
FURG

Instituto de Oceanografia

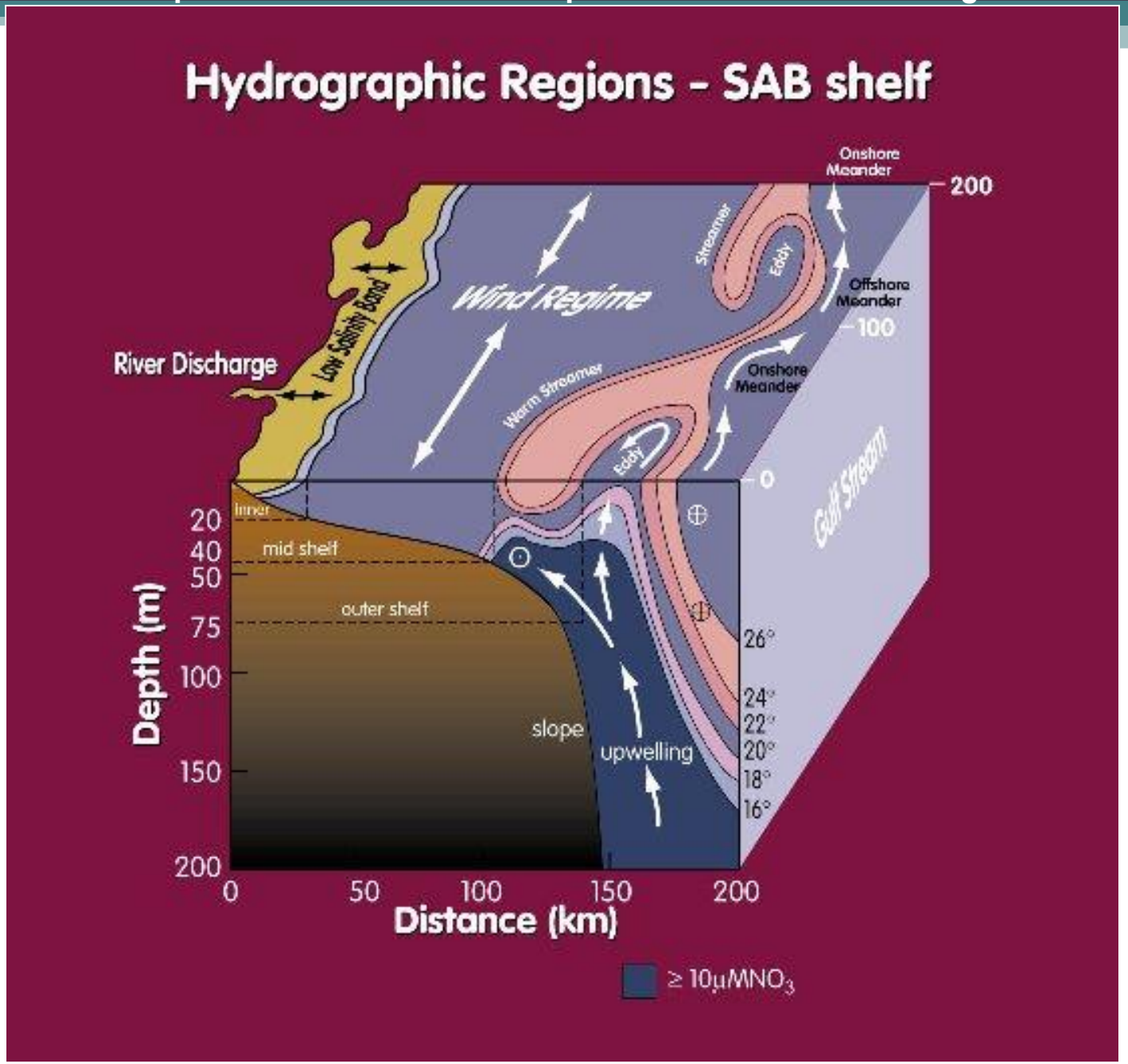
LOCOSTE

Plataforma Continental

- Área de transição
- Complexa pela interação de processos
- Forçantes:
  - Maré
  - Vento
  - Gradientes
  - Efeito de descarga fluvial

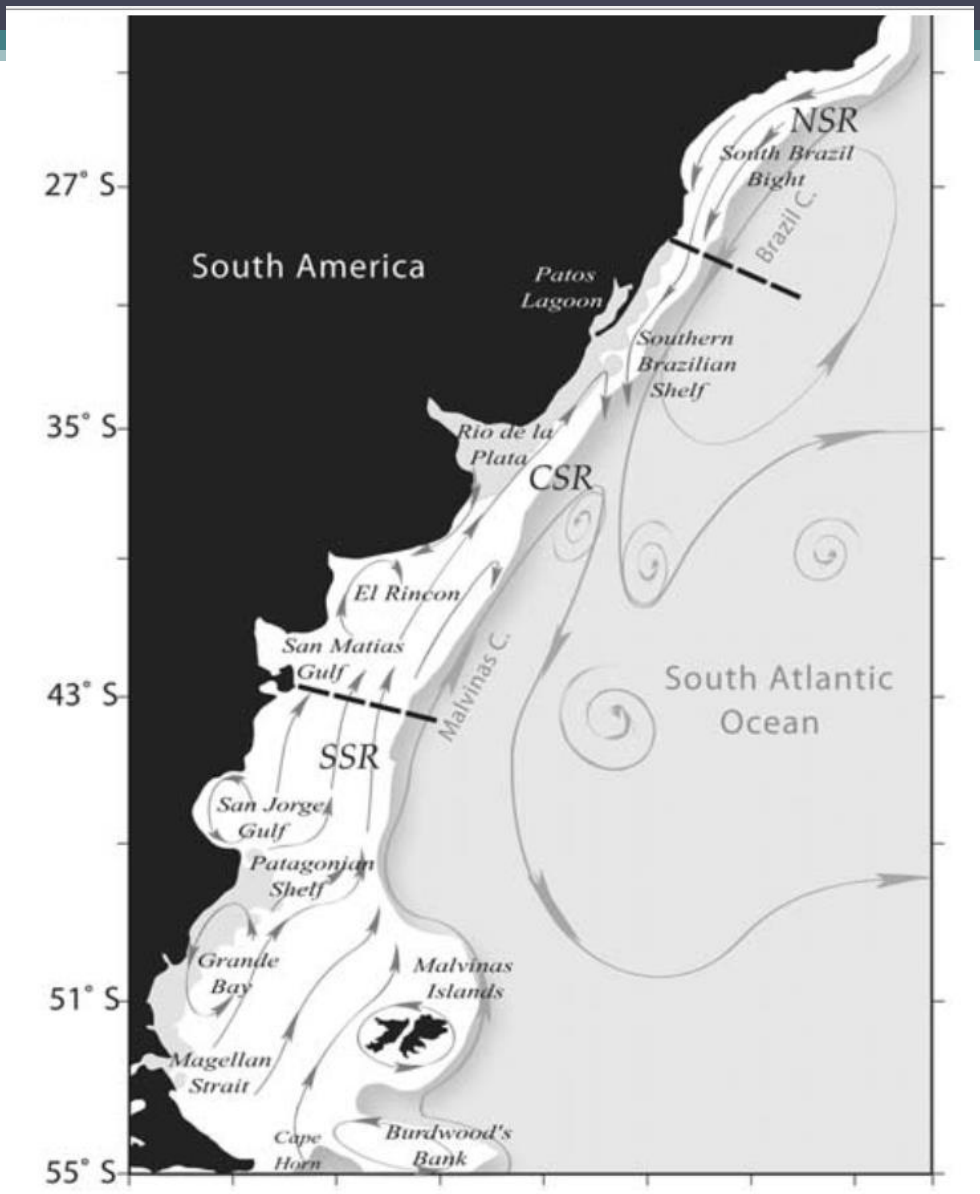

land above sea level
sea level
shelf sea
deep
ca. 200 m
continental shelf
ocean
continental rise

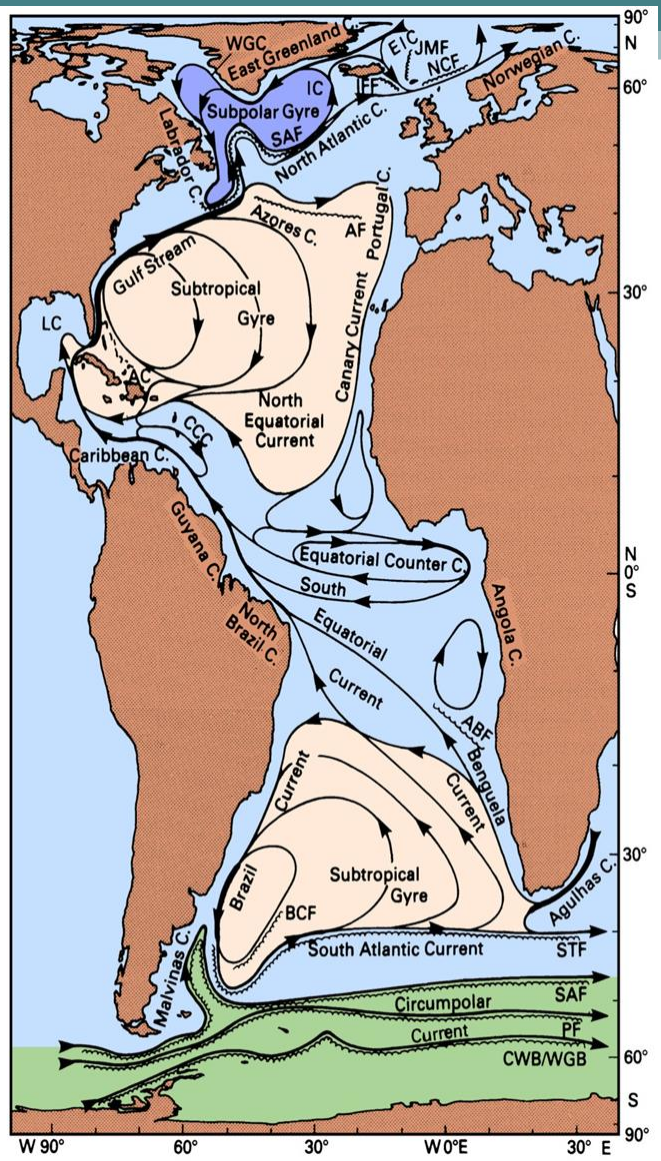
Importance of shelf break depth on shelf/ocean exchange



Processos em Áreas de Plataforma

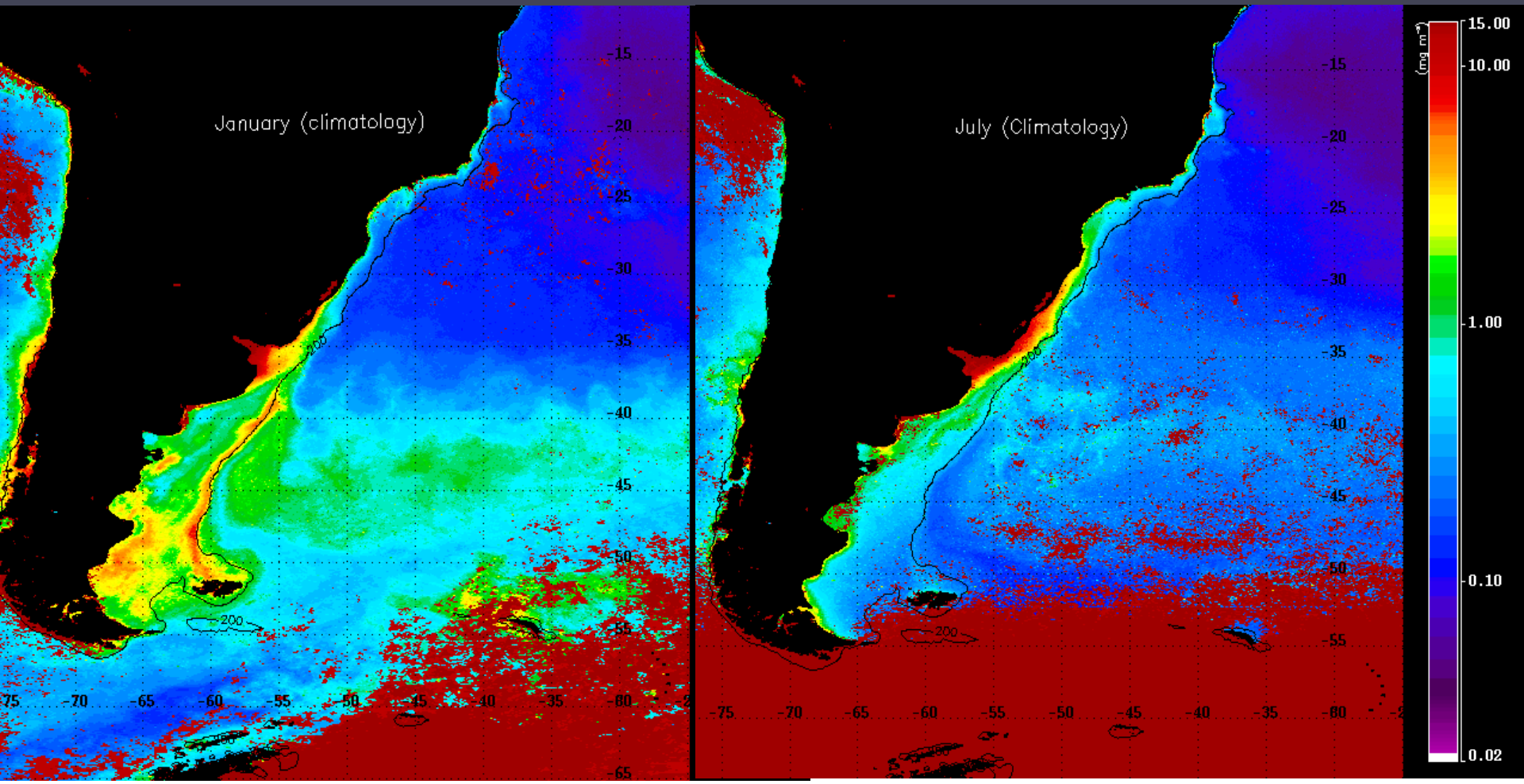
- Ondas
- Marés
- Circulação gerada por vento
  - Ressurgência
  - Subsidência
- Correntes devidas a gradientes de densidade
- Frentes


NSR
South Brazil Bight
Brazil C.
South America
Patos Lagoon
Southern Brazilian Shelf
Rio de la Plata
CSR
El Rincon
San Matias Gulf
Malvinas C.
South Atlantic Ocean
SSR
San Jorge Gulf
Patagonian Shelf
Grande Bay
Malvinas Islands
Magellan Strait
Cape Horn
Burdwood's Bank
27° S
35° S
43° S
51° S
55° S

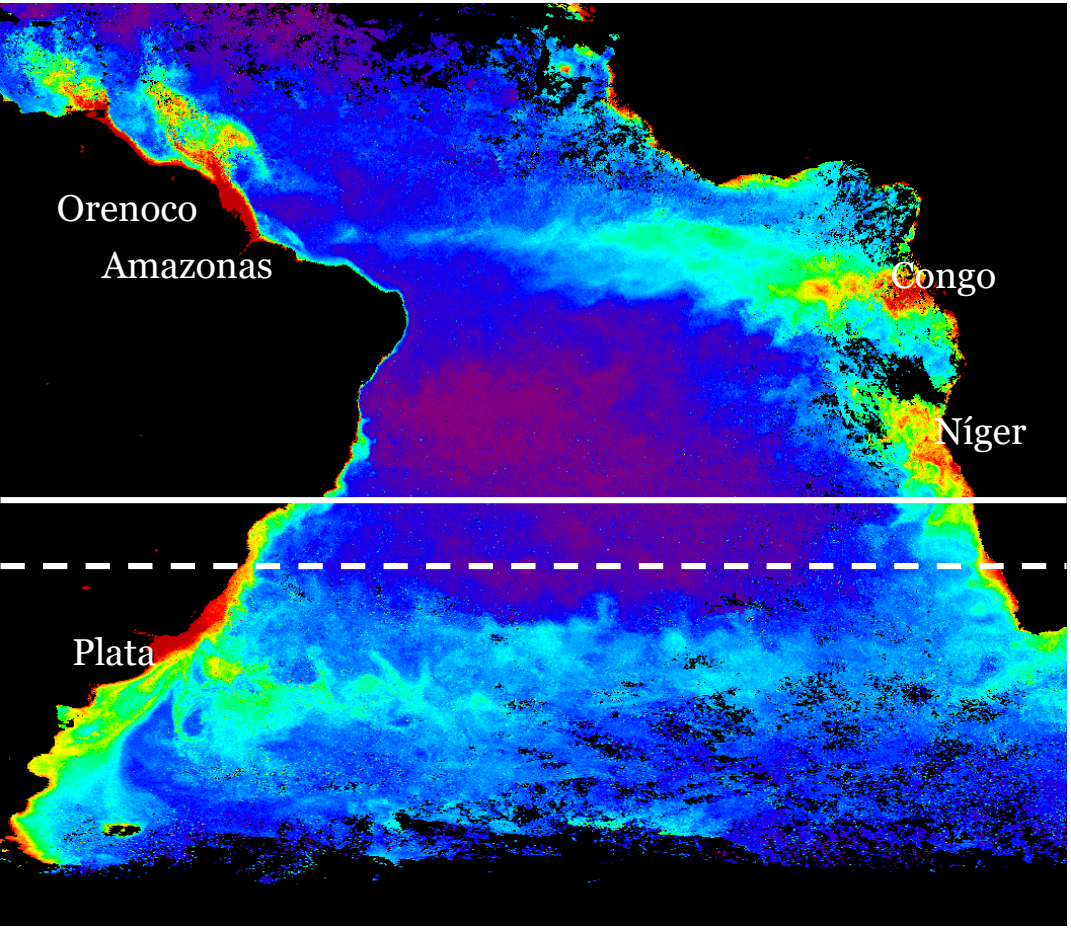

WGC
East Greenland C.
EIC
JMF
NCF
Norwegian C.
IC
IF
Subpolar Gyre
SAF
North Atlantic C.
Labrador C.
Azores C.
AF
Portugal C.
Gulf Stream
Subtropical Gyre
LC
AC
Canary Current
North Equatorial Current
CCC
Caribbean C.
Guyana C.
North Brazil C.
Equatorial Counter C.
South Equatorial Current
Angola C.
ABF
Benguela Current
Brazil Current
Subtropical Gyre
BCF
Agulhas C.
South Atlantic Current
STF
Malvinas C.
Circumpolar Current
SAF
PF
CWB/WGB
90° N
60°
30°
N 0° S
30°
60°
S 90°
W 90°
60°
30°
W 0°E
30° E

CSAT

Romero (2008)

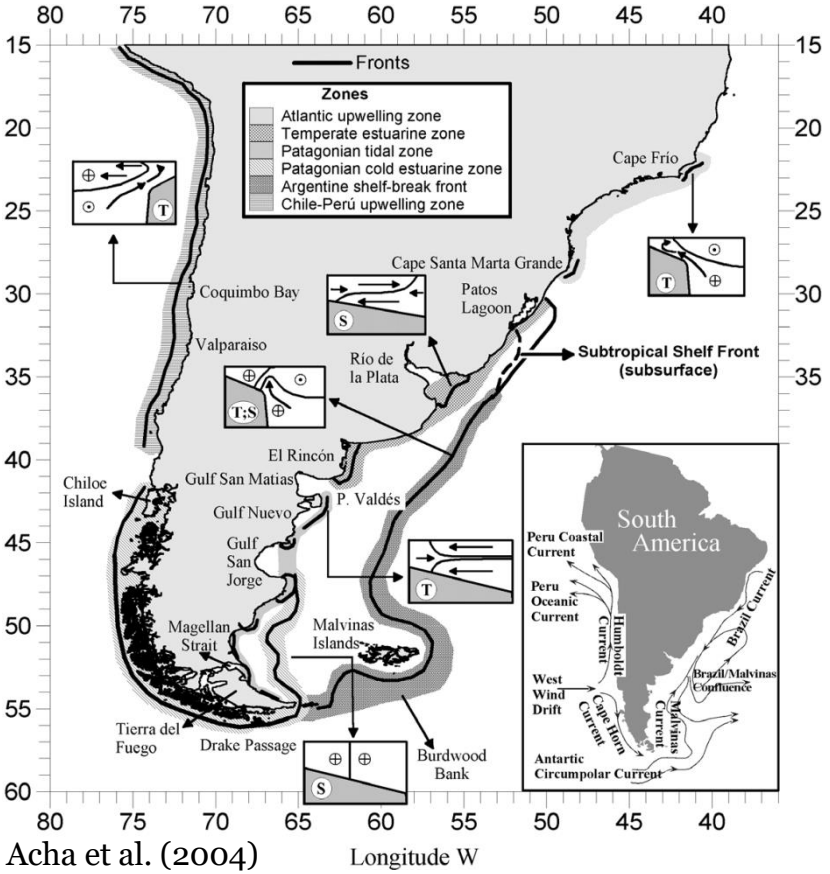


As águas do sul do Brasil, em que são diferentes?

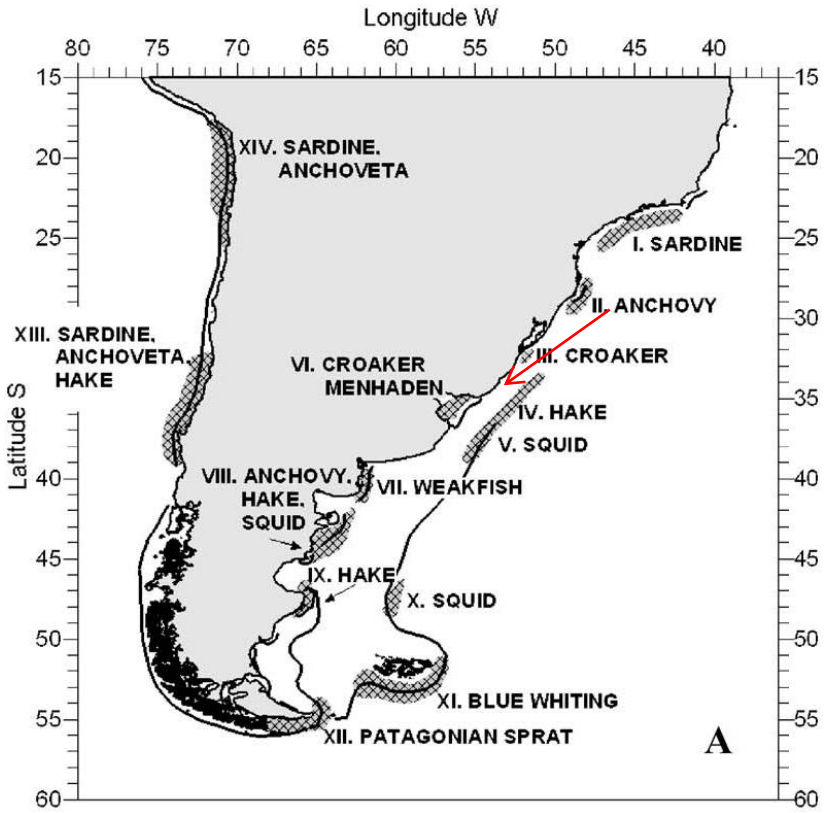


- Clima regional: subtropical
- Pouca influência das marés (a ~0.3 m)
- Regime de ventos: NE/SW
  NE – primavera/verão
  SW - mais frequentes no outono/inverno – frentes variabilidade interanual
- Presença de rio de grande caudal – Plata
- Influência de águas subantárticas da plataforma argentina;
- Presença de duas frentes;
- Zona de ressurgência estacional
- Região de alta produção pesqueira;

As frentes



Acha et al. (2004)



As frentes

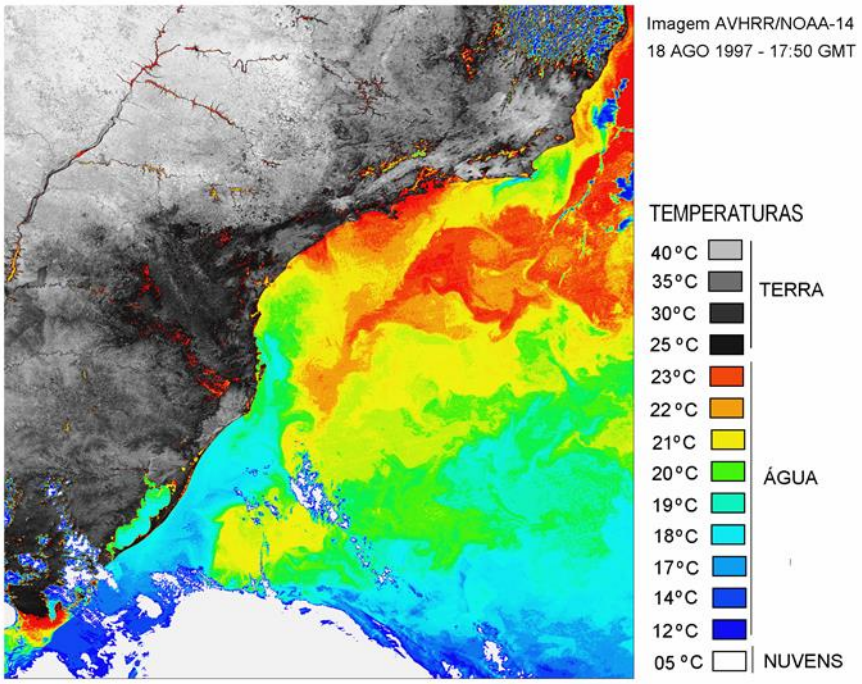


Imagem AVHRR/NOAA-14
18 AGO 1997 - 17:50 GMT
TEMPERATURAS
40 °C
35 °C
30 °C
25 °C
TERRA
23 °C
22 °C
21 °C
20 °C
19 °C
18 °C
17 °C
14 °C
12 °C
ÁGUA
05 °C
NUVENS

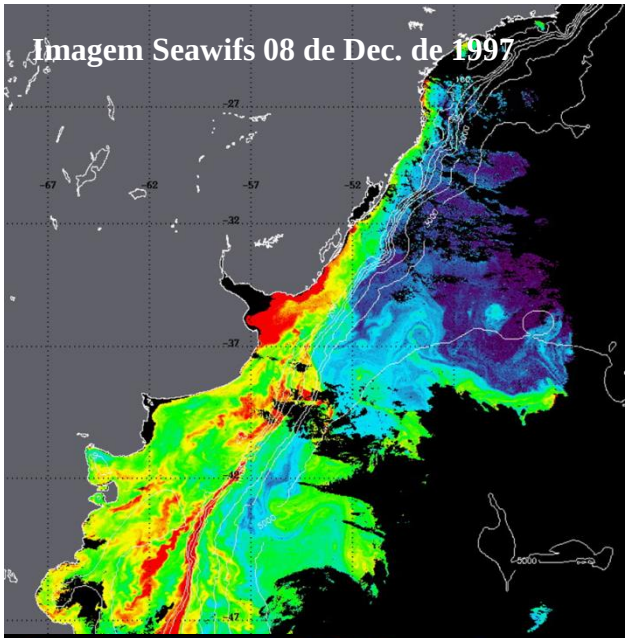
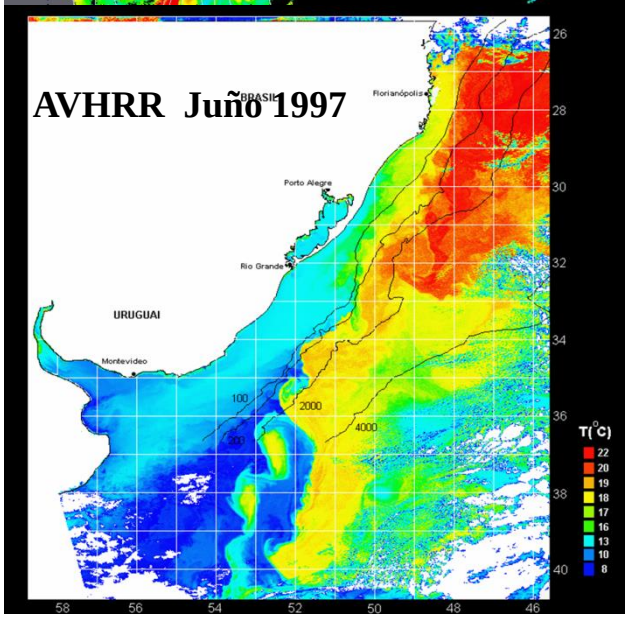
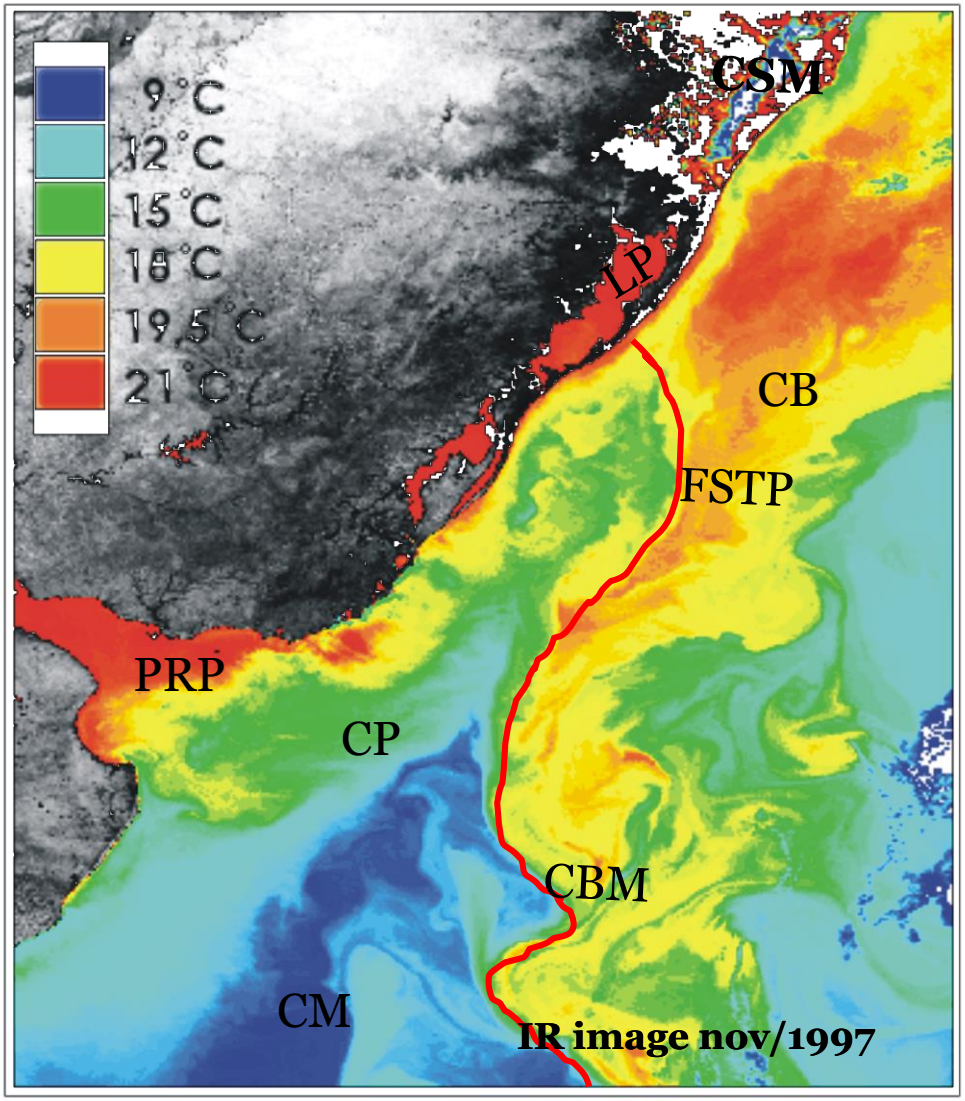


Imagem Seawifs 08 de Dec. de 1997


AVHRR Junho 1997
BRASIL
Florianópolis
Porto Alegre
Rio Grande
URUGUAI
Montevideo
100
2000
4000
T(°C)
22
20
19
18
17
16
13
10
8

Correntes e massas de água



CB – Corr. Brasil – Água Tropical e Central (ACAS) +

CM – Corr. Malvinas – Águas Subantárticas

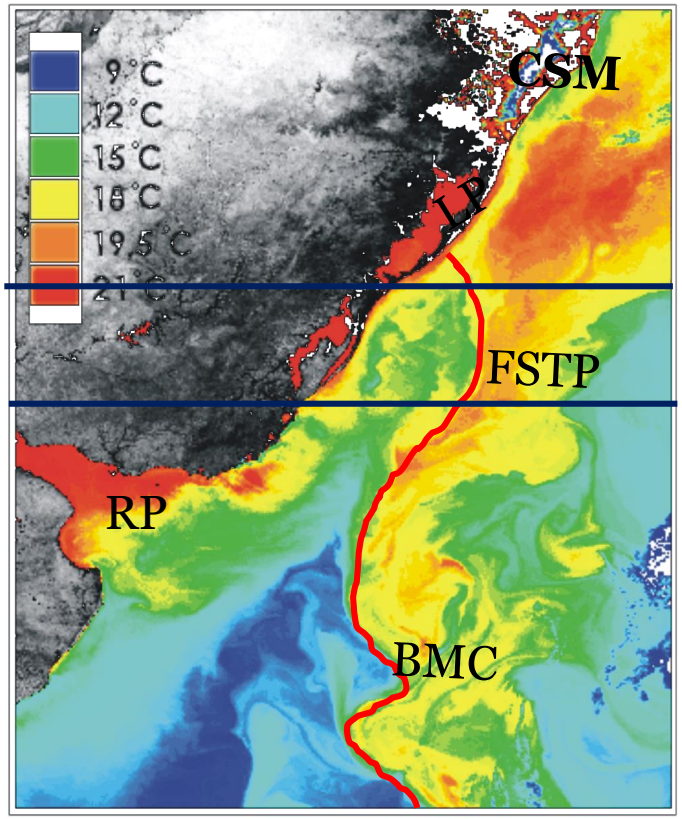
PRP – Pluma do Rio da La Prata – Águas Costeiras /CCSB (Souza e Robinson, 2004)

CP – Corr. Patagônia – Águas Subantárticas de Plataforma

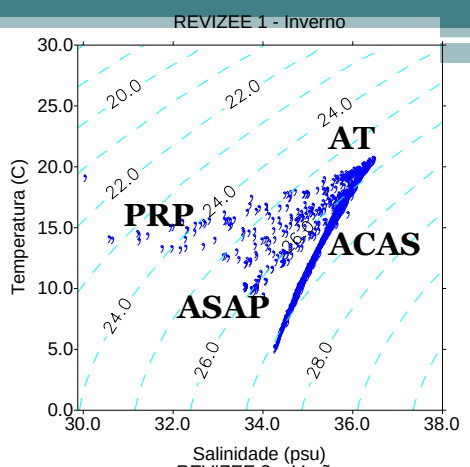
LP – Lagoa dos Patos – Águas Costeiras – pluma sobre pluma

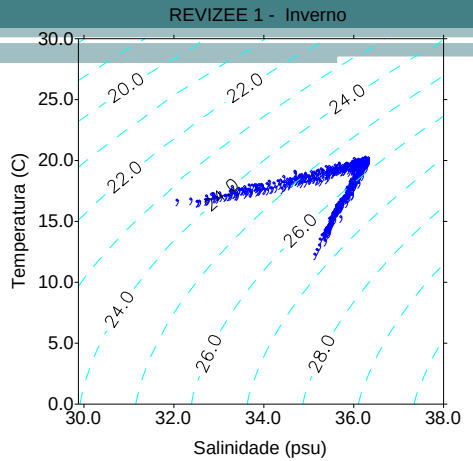
CBM – Confluência Brasil-Malvinas

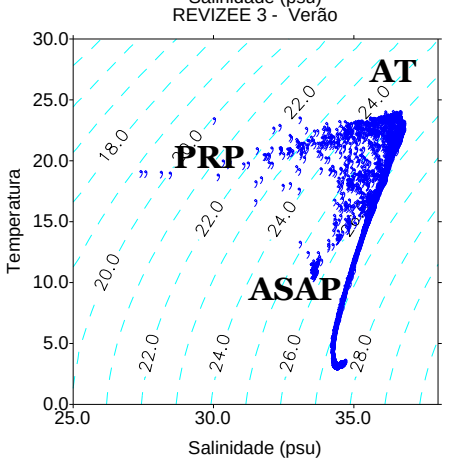
FSTP – Frente Subtropical de Plataforma

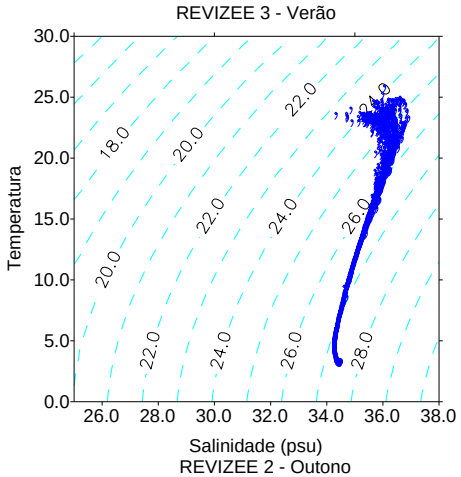


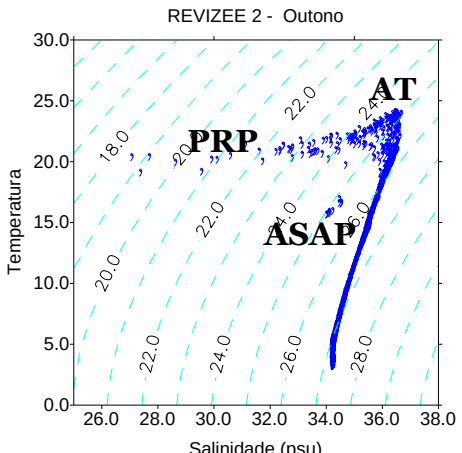
Diagramas TS
Projeto REVIZEE
Prof. > 100 m

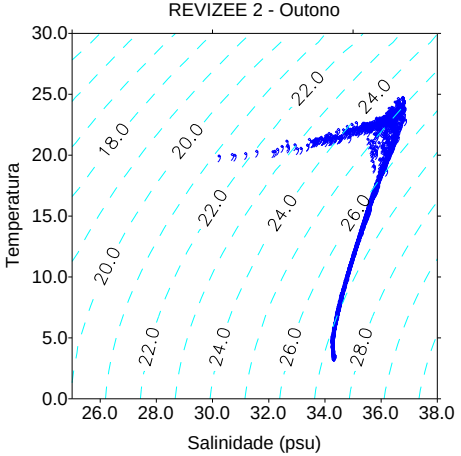




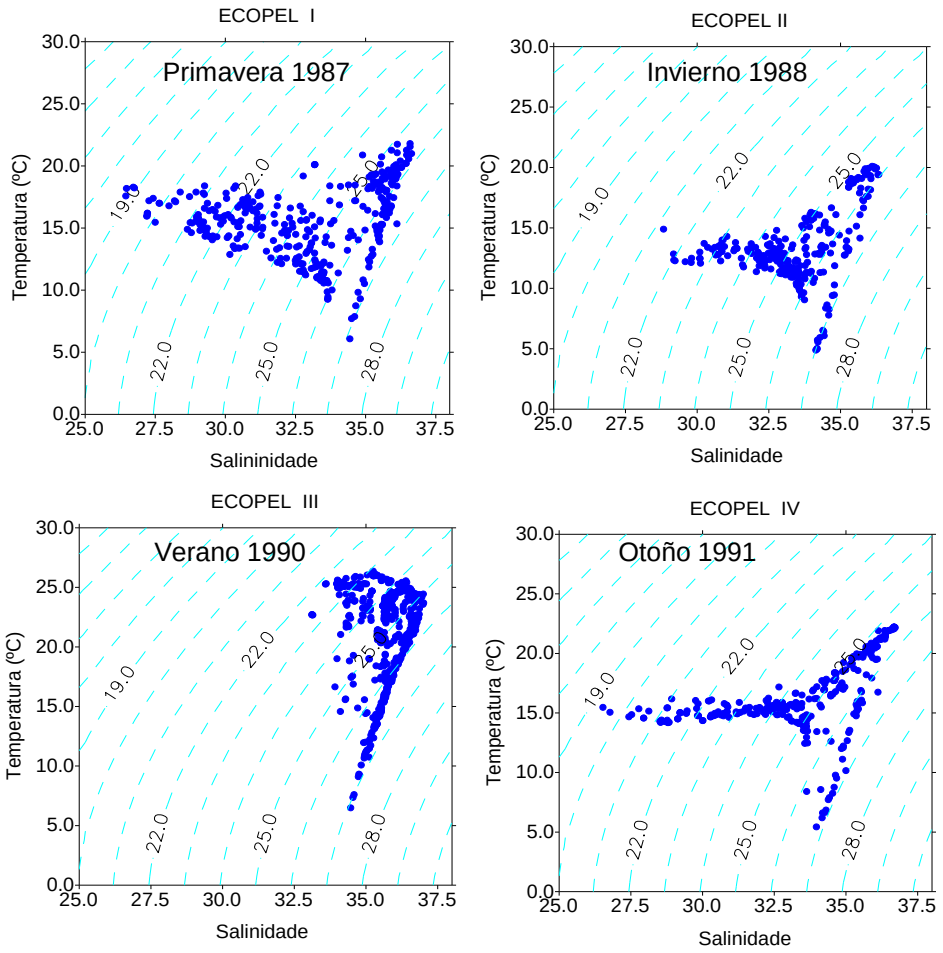








Diagramas TS – ECOPEL –Entre Chuí e Rio Grande

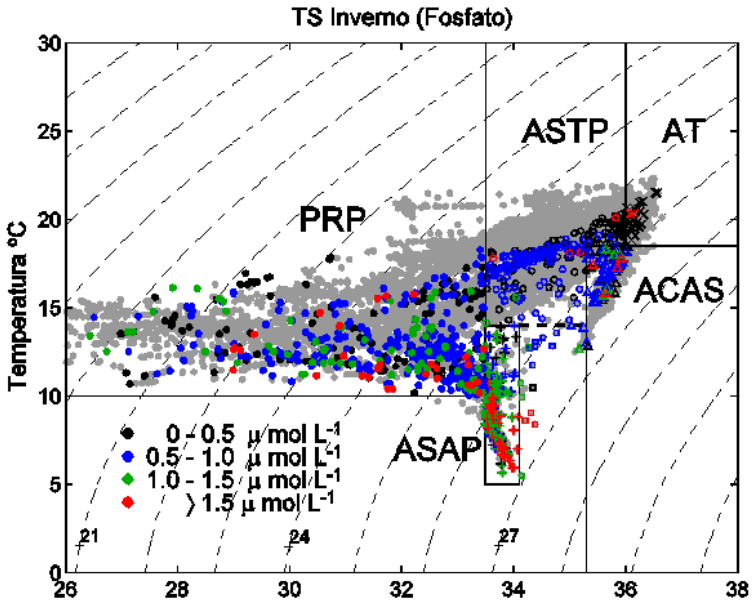


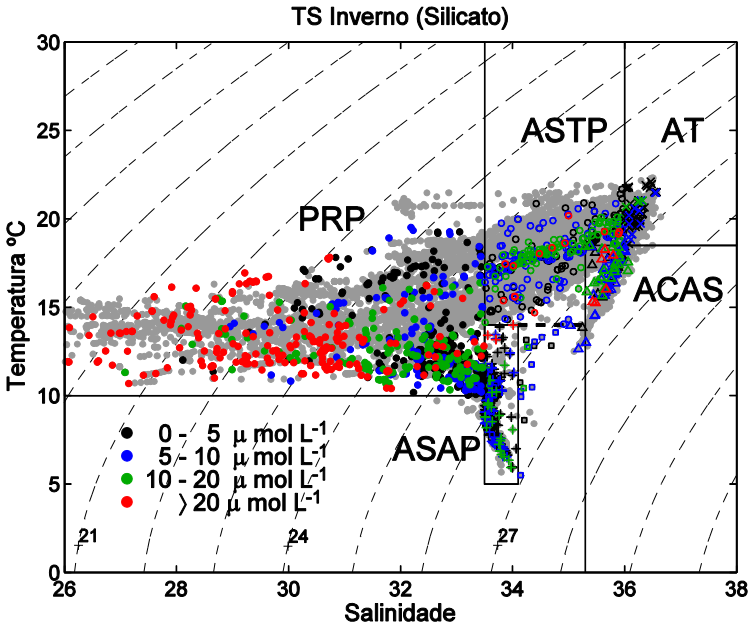
Soares y Möller (2001)

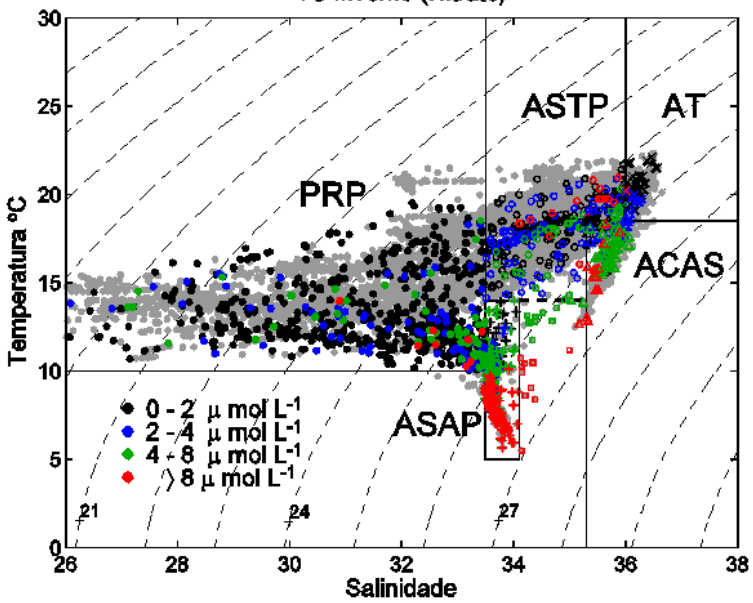
PRP – com exceção do verão está presente em todas as estações do ano.

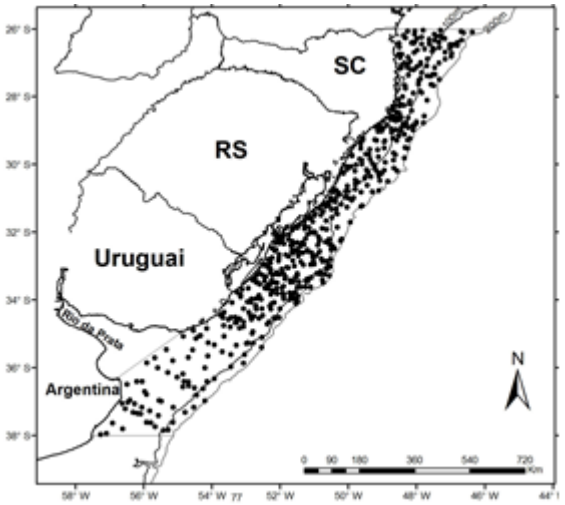
ASAP – presente em todas as estações do ano.

Diagramas TS-nutrientes para inverno



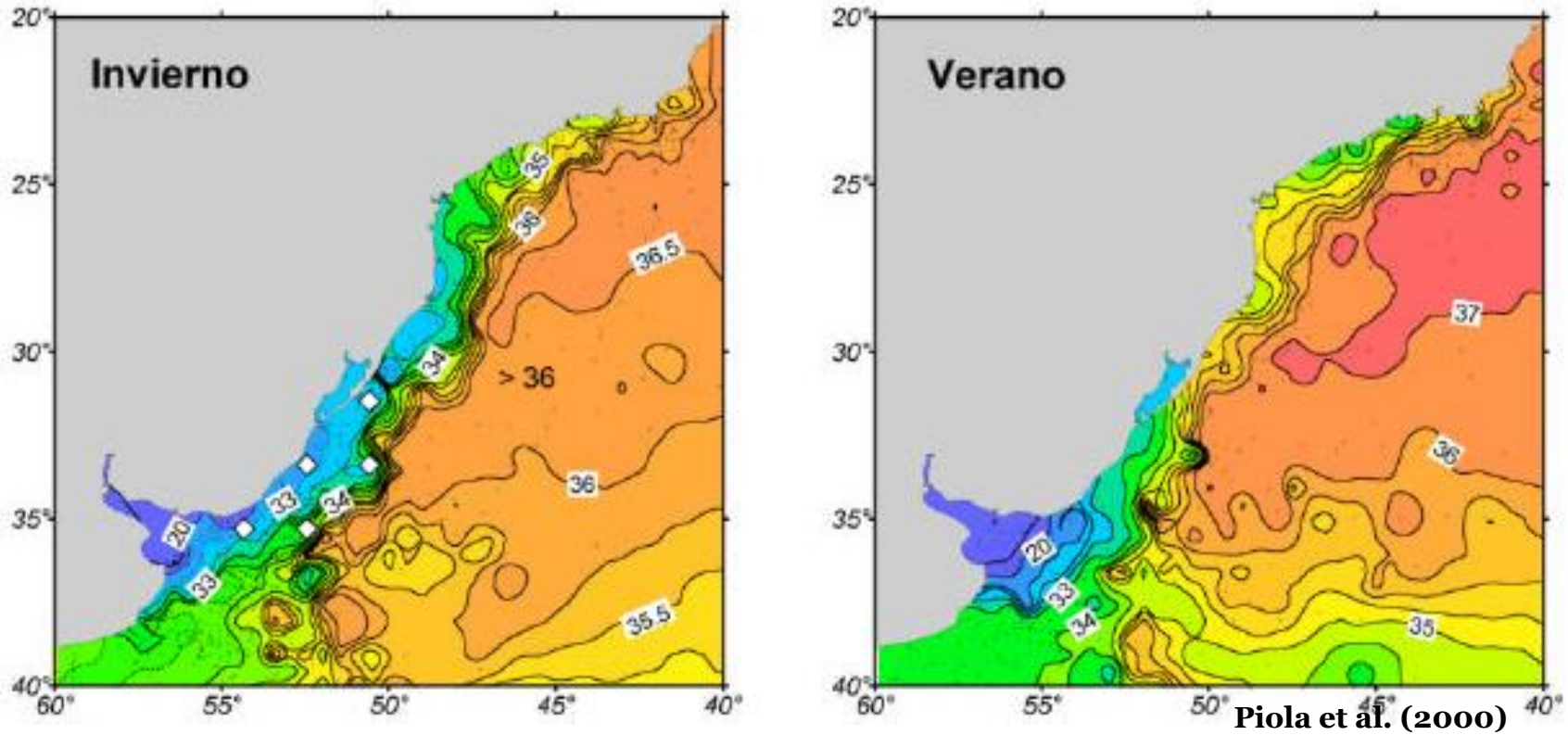






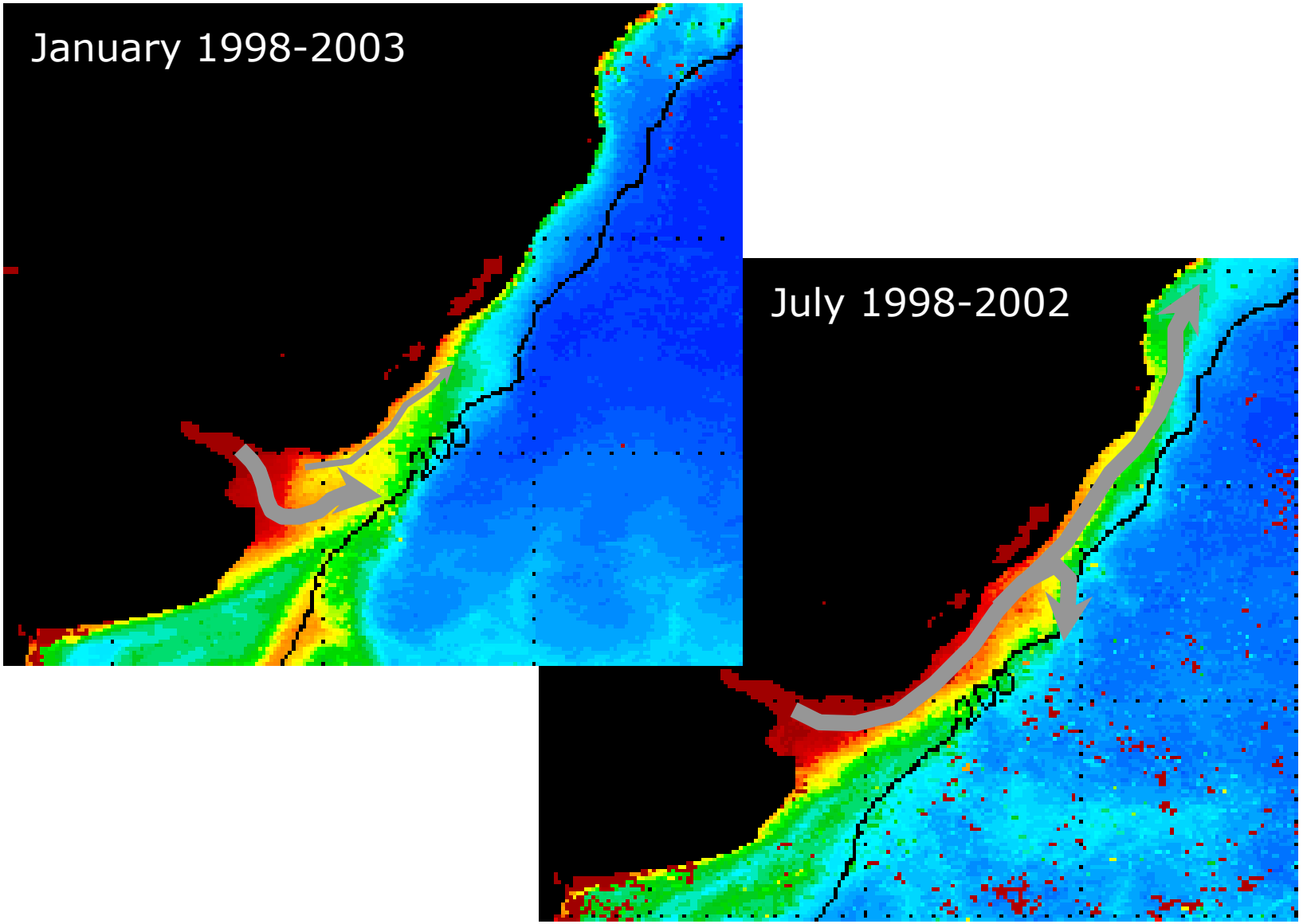
Aseff (2009)

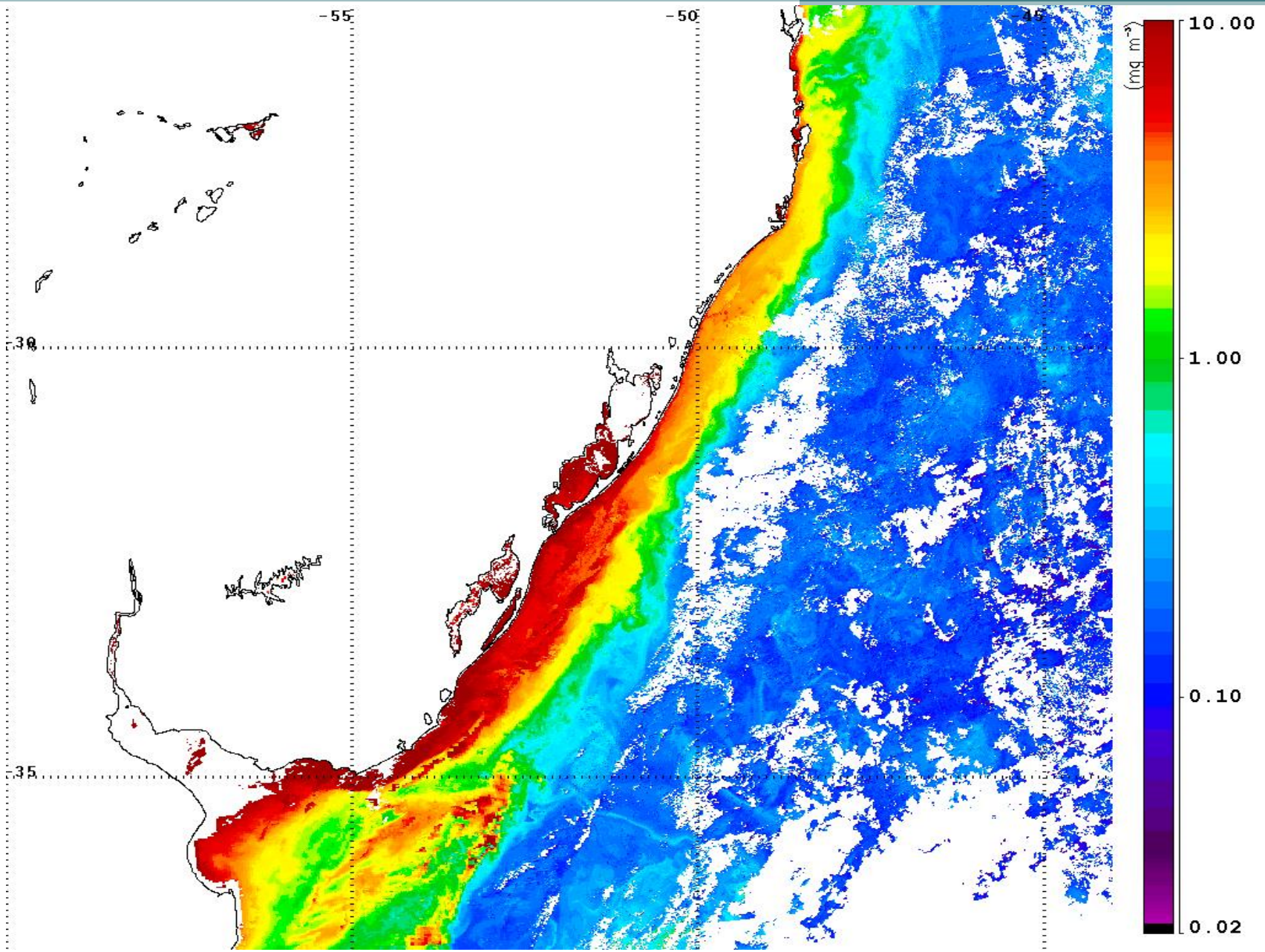
Historical data analysis



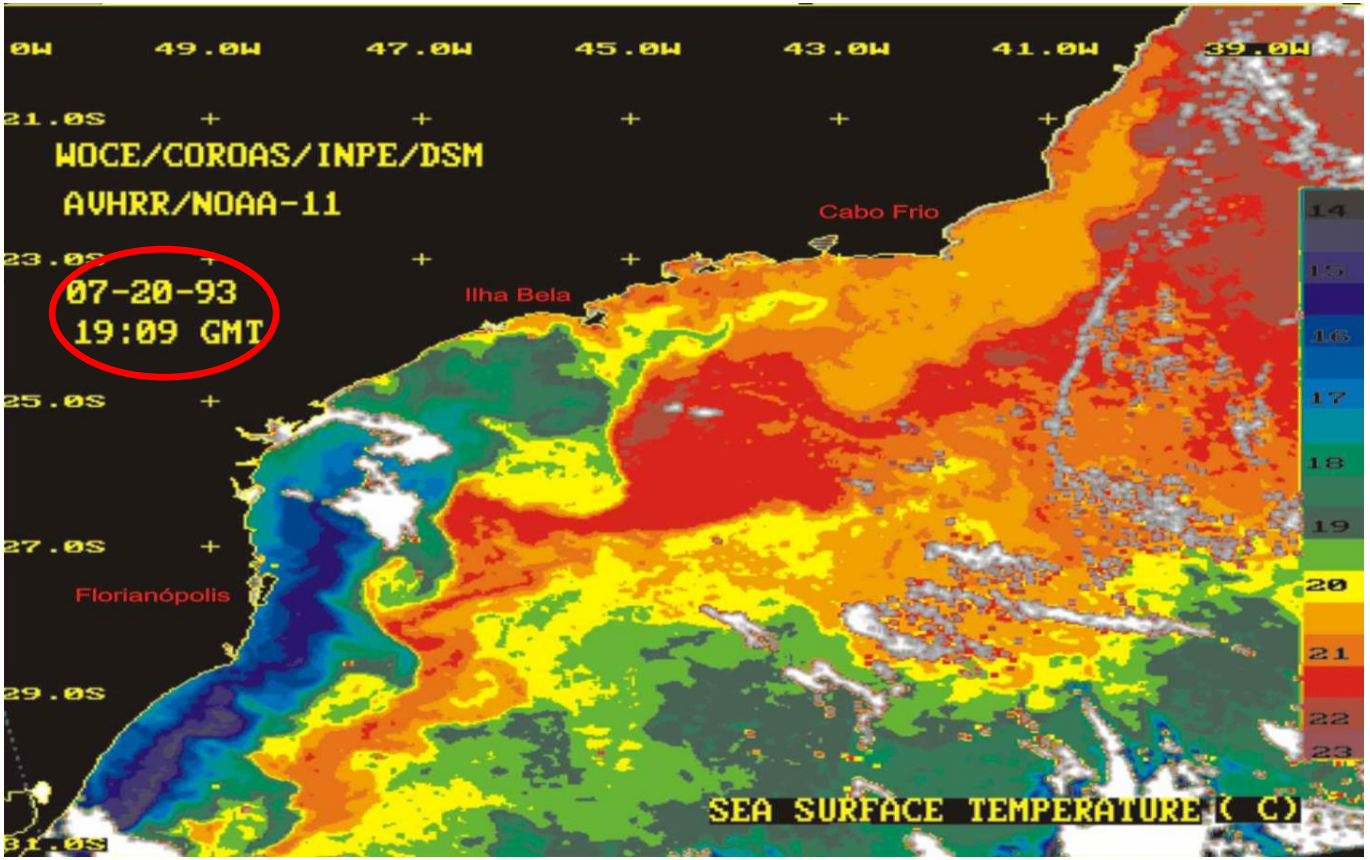
Piola et al. (2000)

Evidence from satellite data




-55
-50
-45
-30
-35
(mg m⁻³)
10.00
1.00
0.10
0.02

Impact on SST



Plata Basin

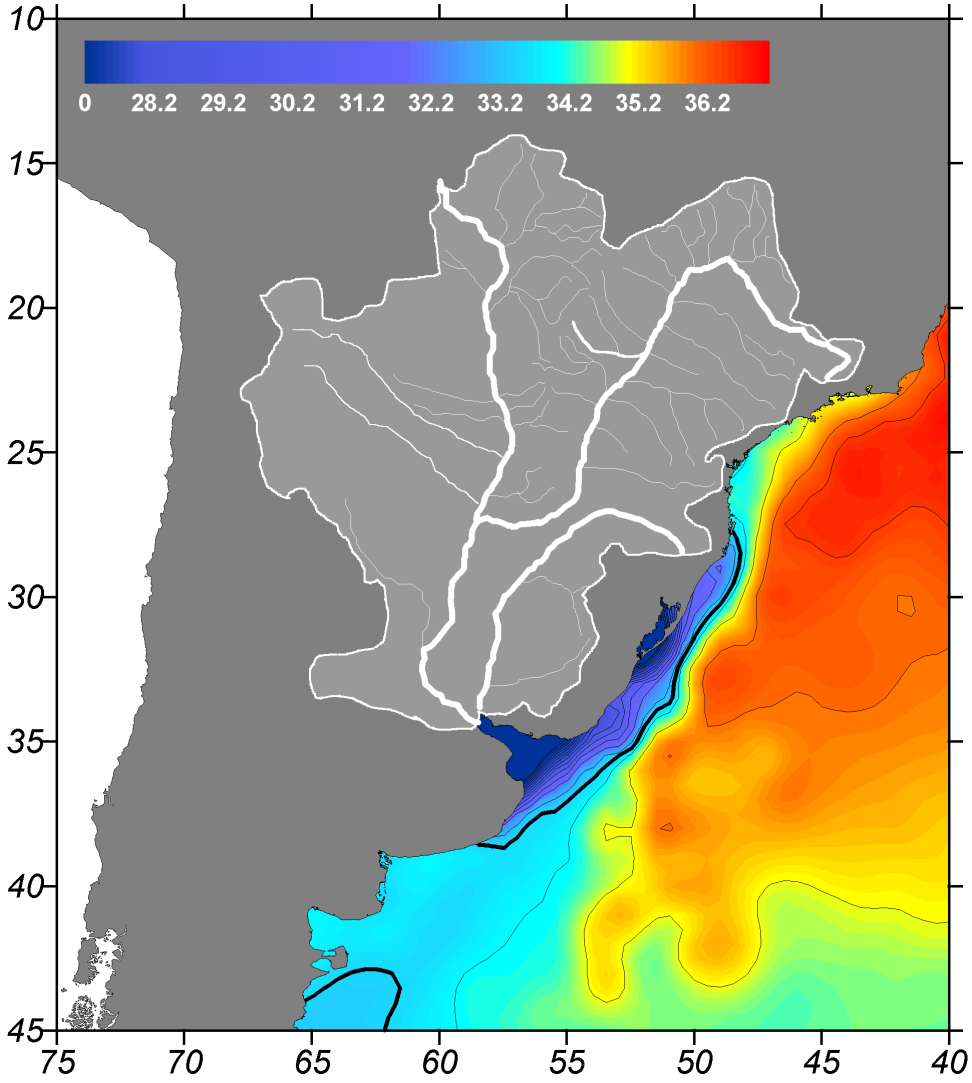
~ 3.1x10^6 km^2 (#5, 20% of South America)

~ 23000 m^3/s (#6)

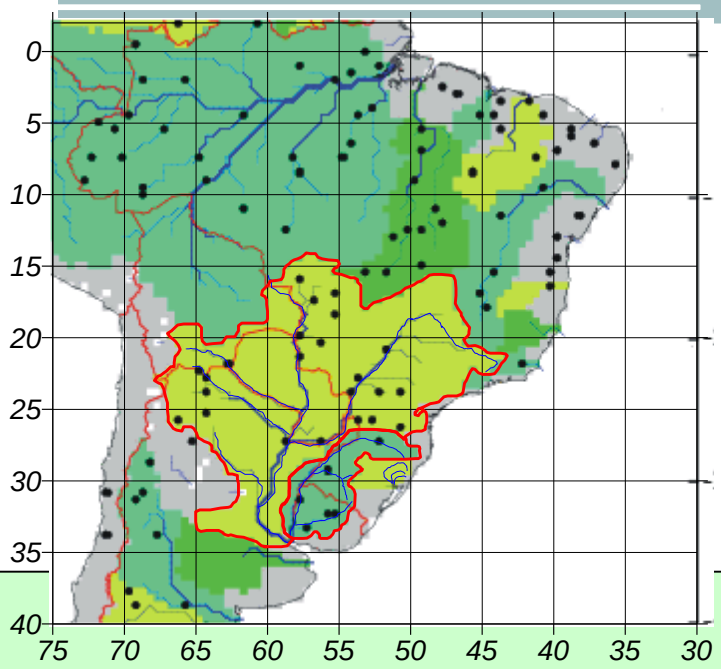
Large input source of

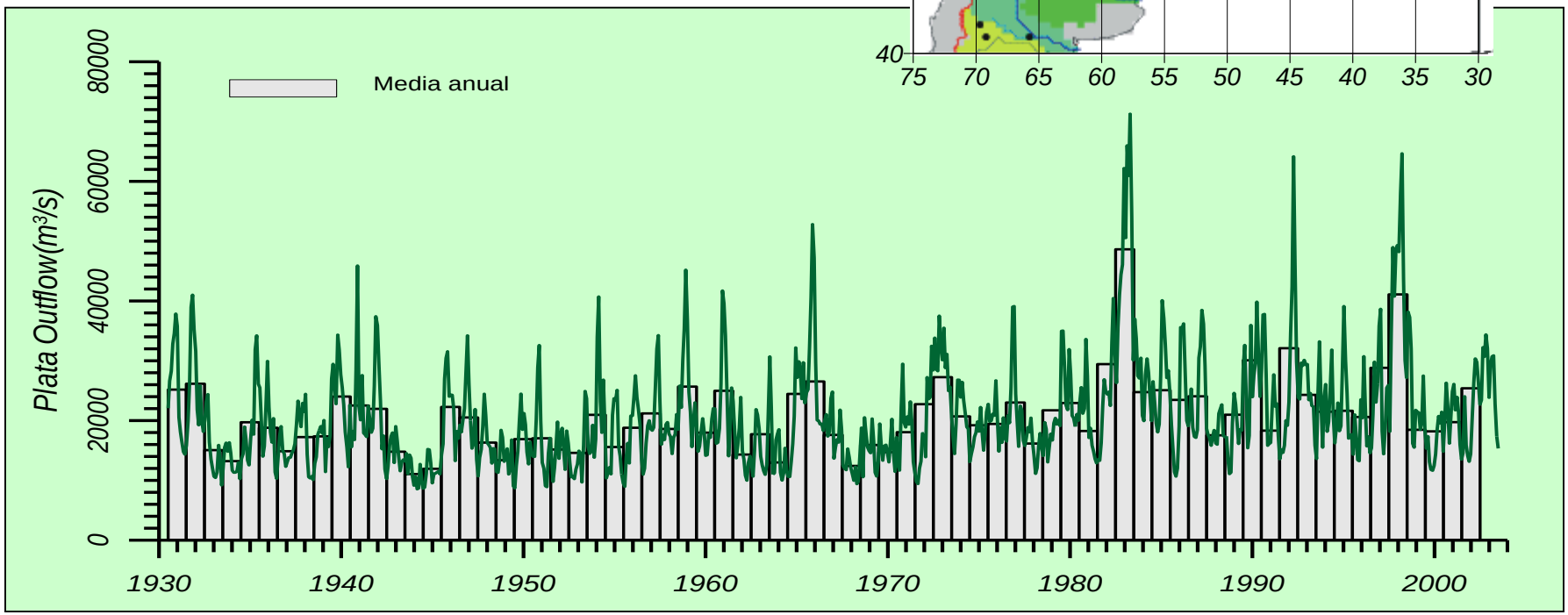
Nutrients

Suspended sediments



Plata Hydrographical Basin



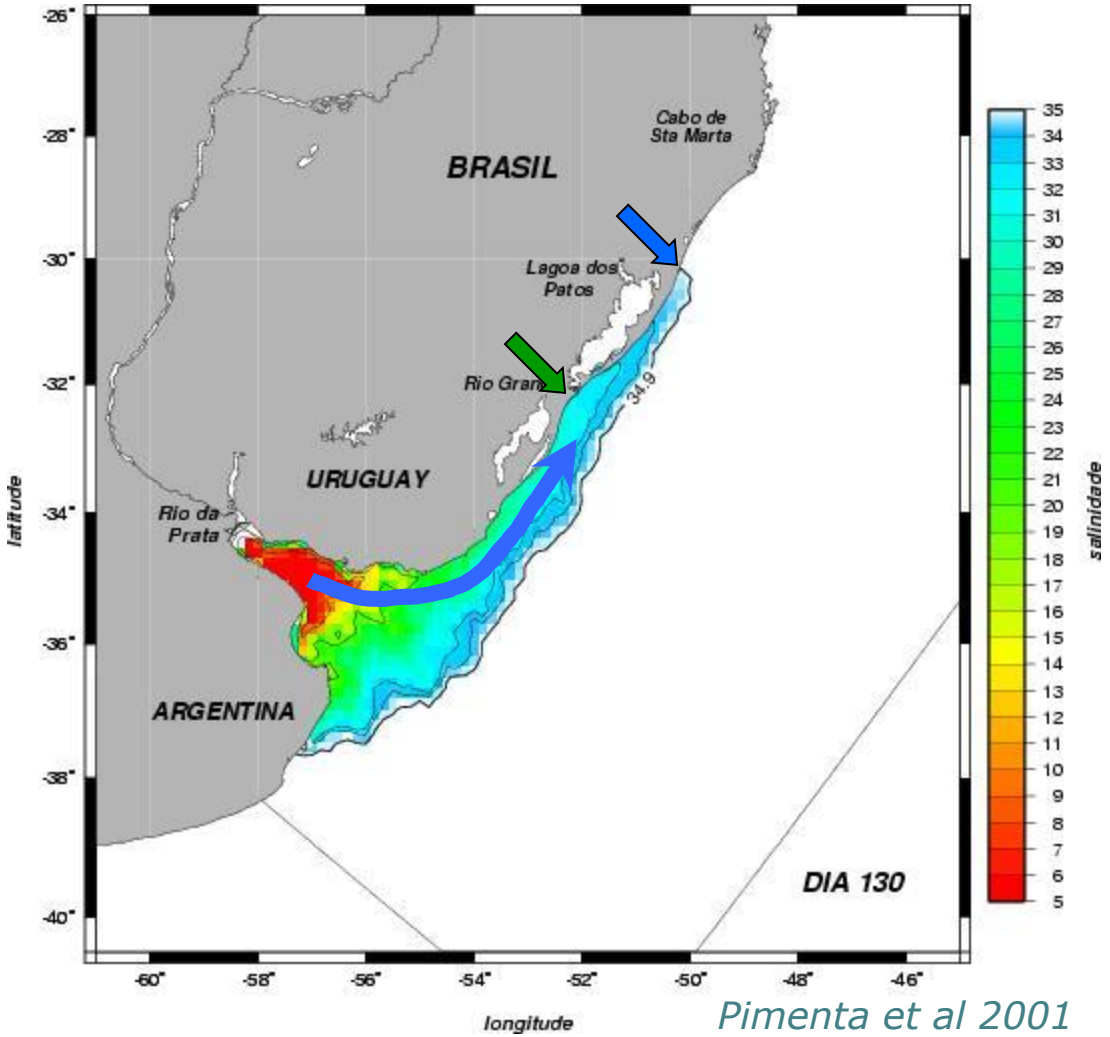


Theory

Low salinity (density) plume introduced in the ocean through river discharge must flow to the left of the river because of the effect of Earth rotation

The extension of the plume is dependent on the amount of river discharge

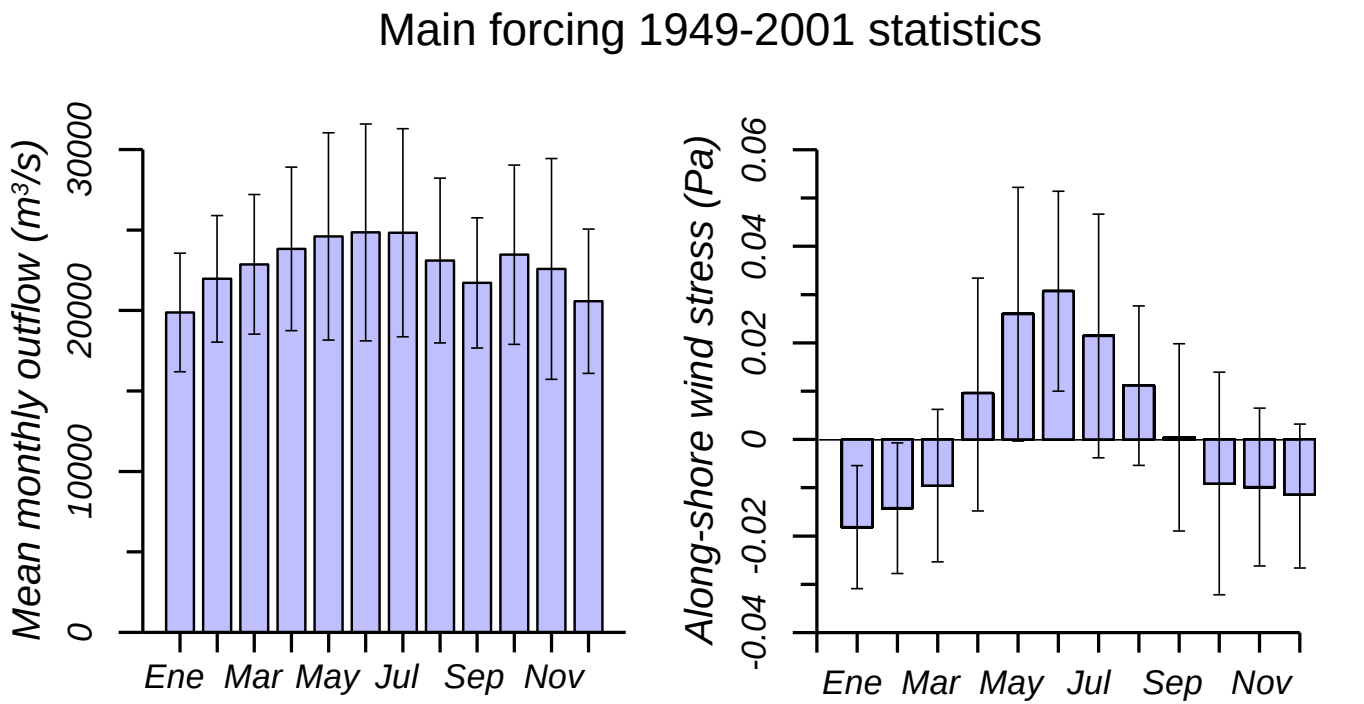
Numerical experiments



Pimenta et al 2001

***R25* → 25 x 10^3 $m^3.s^{-1}$ (mean river discharge)**

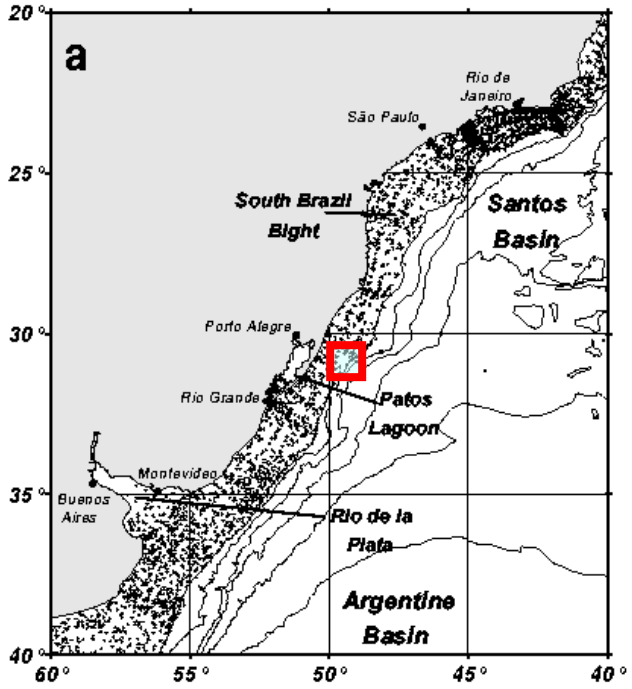
River discharge and wind monthly means

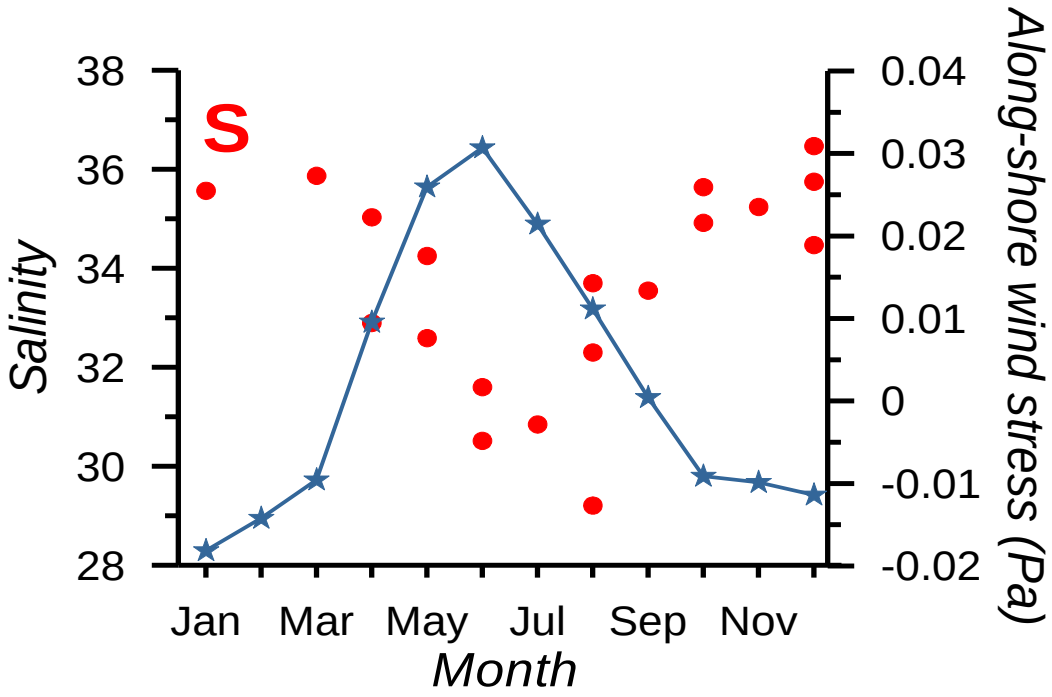


Piola et al. 2005

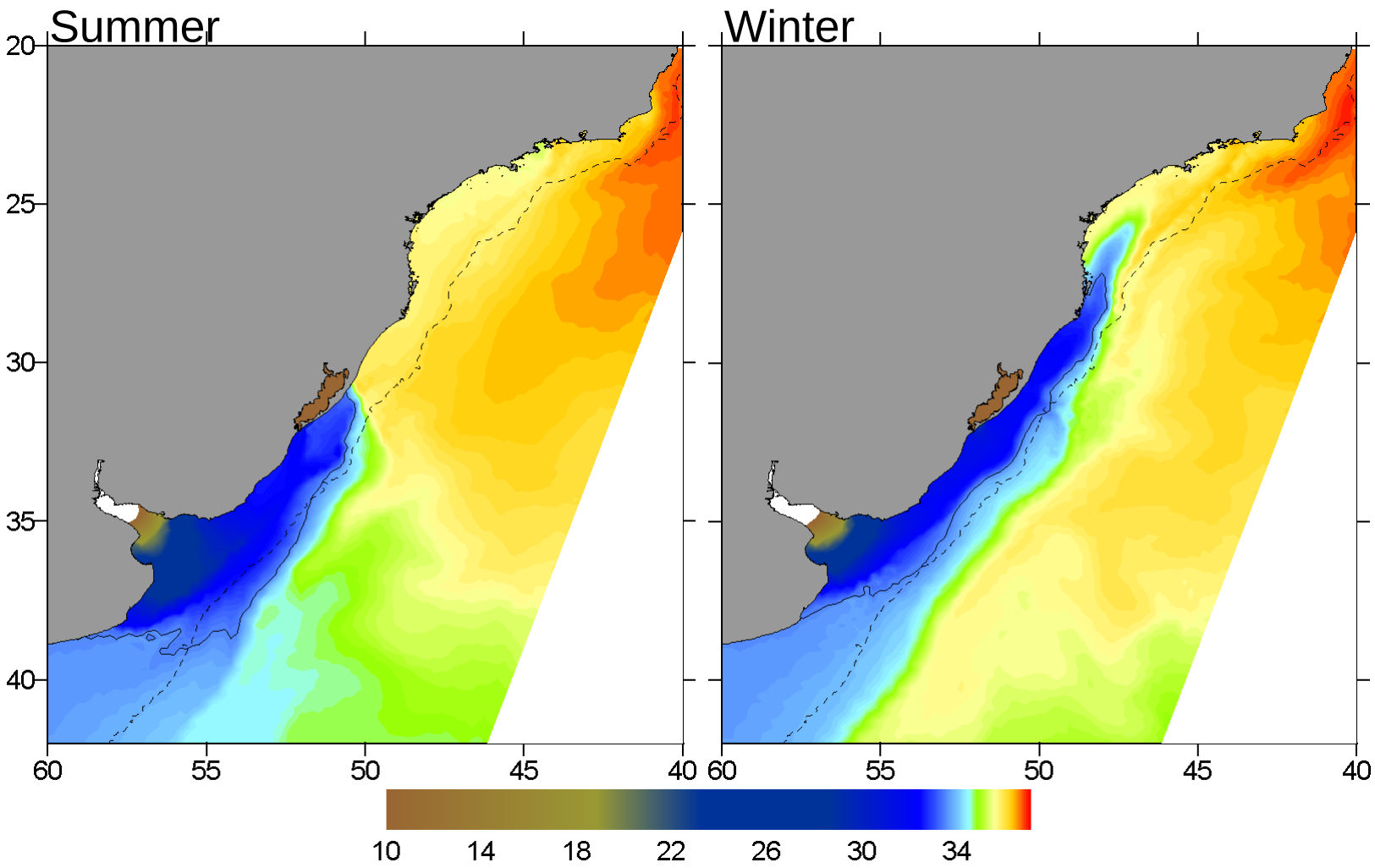
The way salinity reacts to the seasonal wind variation

Piola et al. 2005



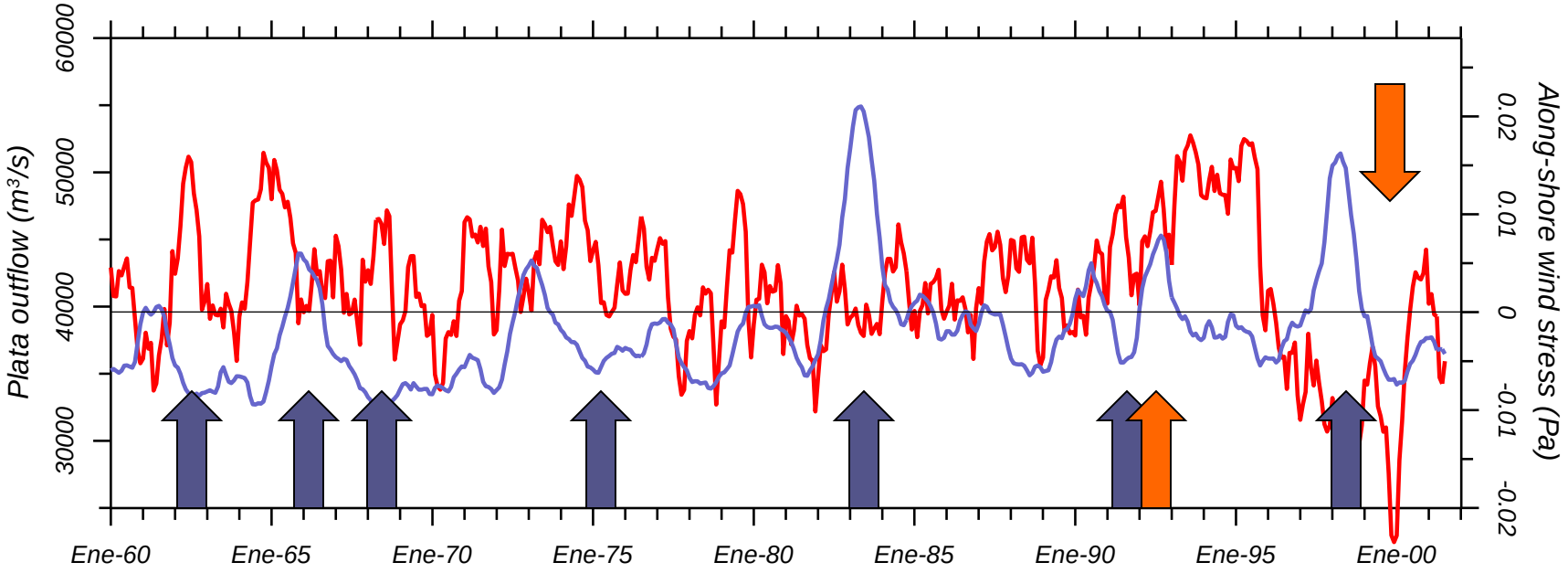


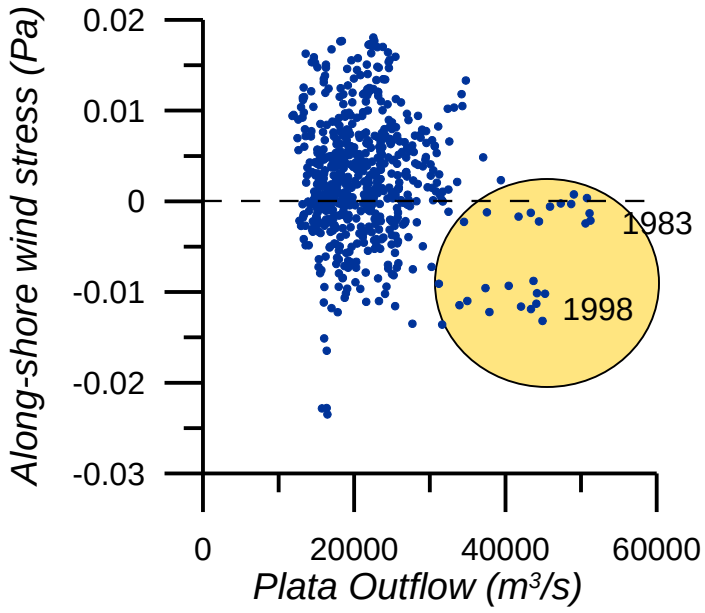
Numerical simulations (seasonal)



Numerical simulations are being used to study specific events and system response to interannual wind and outflow variability

The wind - outflow dilemma



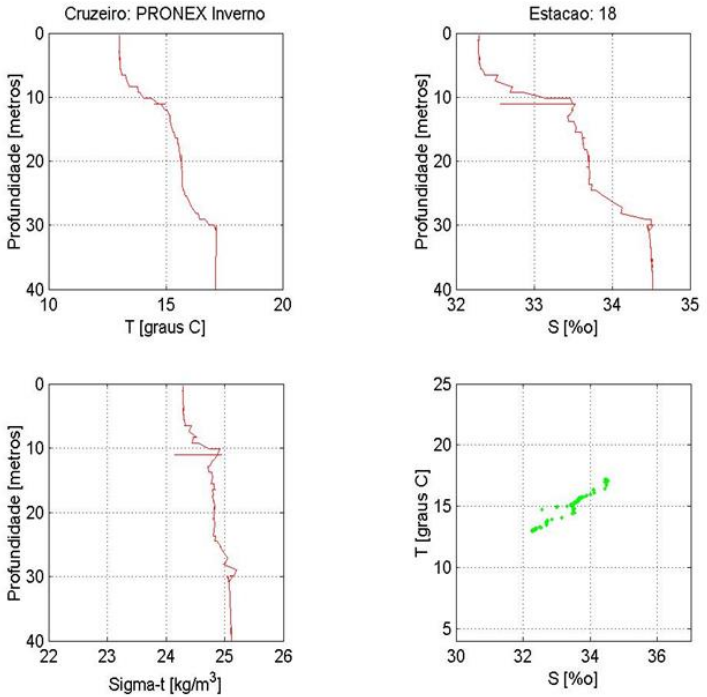


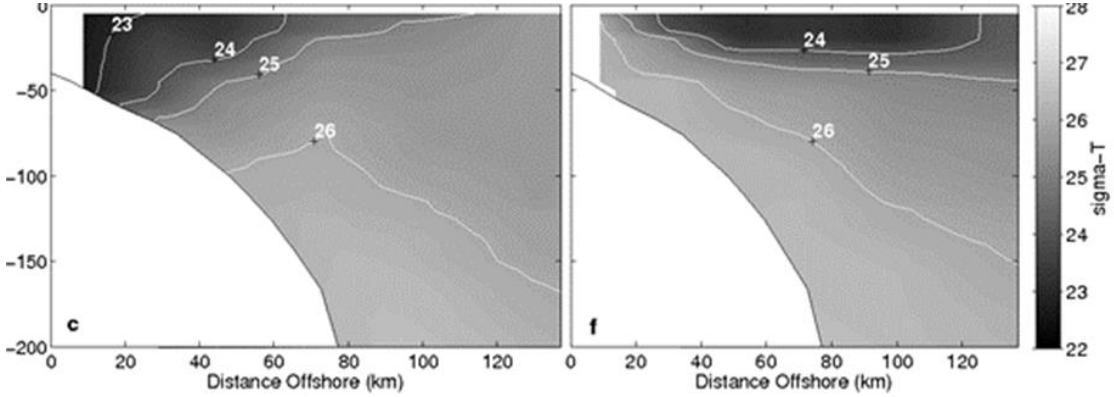
At "low" frequency (<1yr) wind and outflow tend to be 180° out of phase, e.g. the most intense outflows (82-83 & 97-98) occur with negative wind stress (from NNE).

Regardless of the large outflow prevailing winds strongly limit the growth of the coastal plume

As águas do Prata

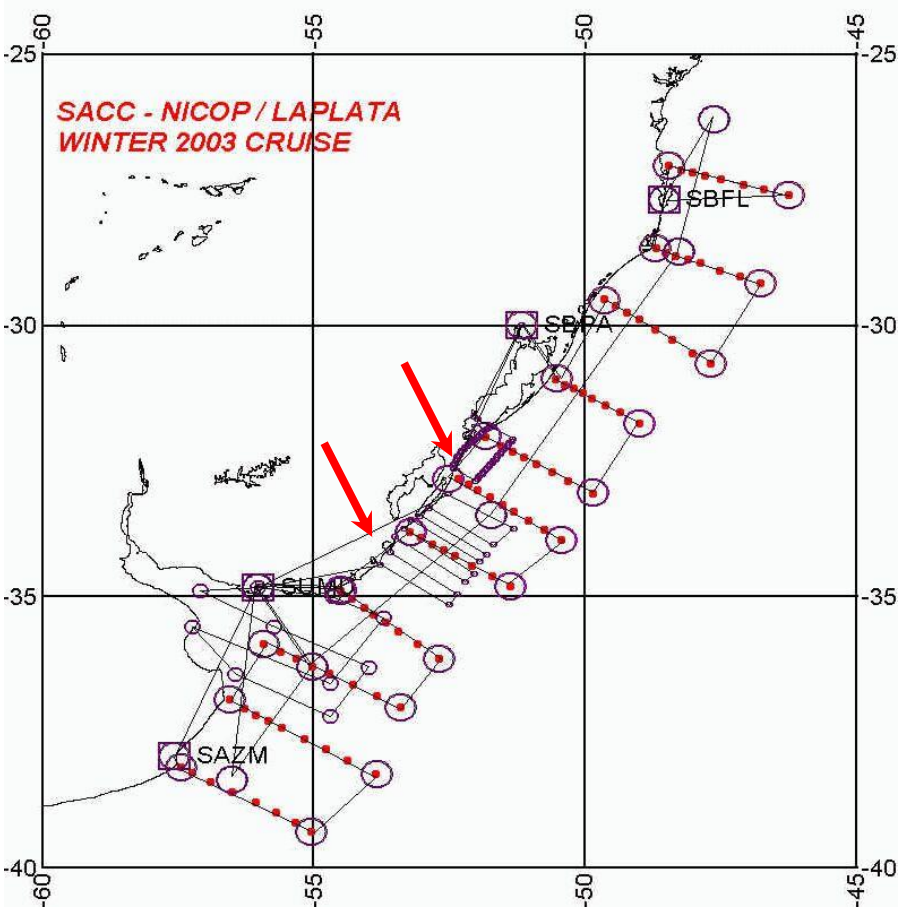
- **Fluxo residual para o Norte (Pereira, 1989; Zavialov et al., 1998; Zavialov et al., 2002).**
- **Estabilidade (Castello and Möller, 1977; Zavialov et al., 2003)**
- **A termoclina invertida (Castello and Möller, 1977; Zavialov et al., 2003)**
- **Nutrientes (Ciotti et al, 1995; Guerrero et al., 1997)**
- **Impactos en la distribução de espécies (Castello et al., 1990)**
- **Variabilidade estacional e interanual (Miranda, 1973; Piola et al., 2000; Piola et al., 2005): ventos e descarga;**

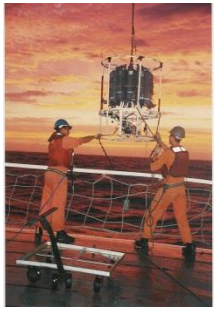


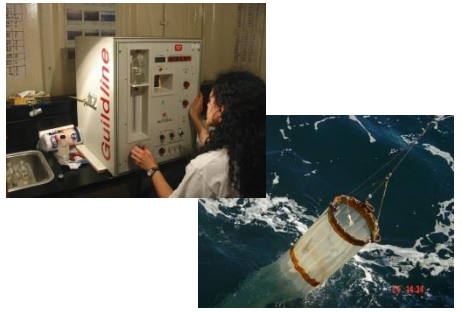


Entretanto:
Os dados existentes foram coletados durante cruzeiros de longa duração (3 meses);
Falta de sinoticidade;
Limitados por fronteiras políticas;
Poucos estudos multidisciplinares

O Projeto LA PLATA







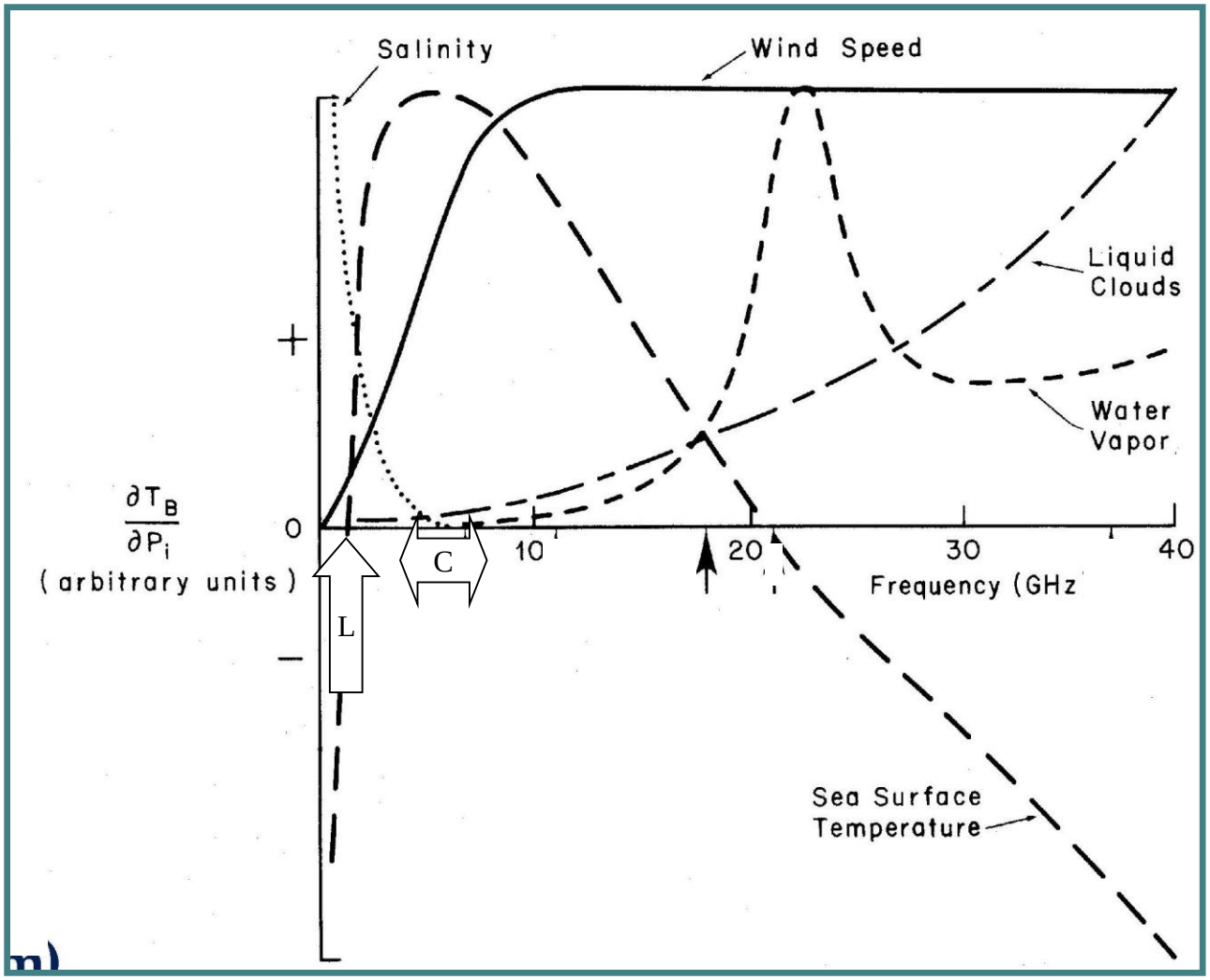
AERIAL SURVEY - C-212 Aviocar - Fuerza Aérea Uruguaya

Photo taken by: Alvaro Solari

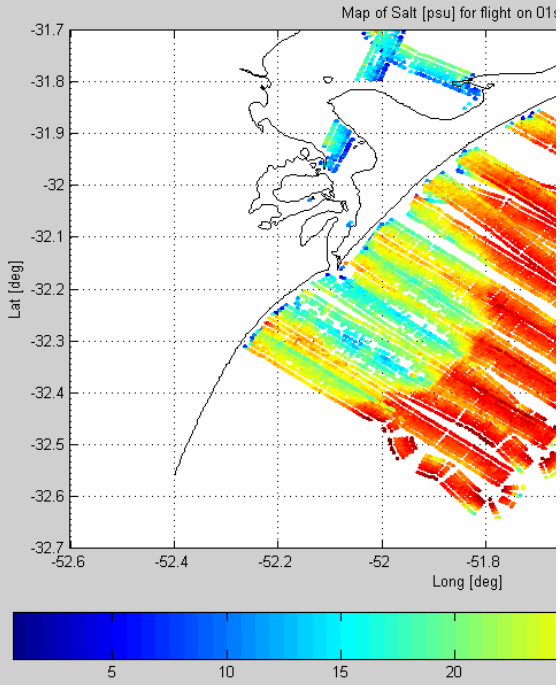
AERIAL SURVEY - Salinity, Temperature, and Roughness Remote Scanner (STARRS)

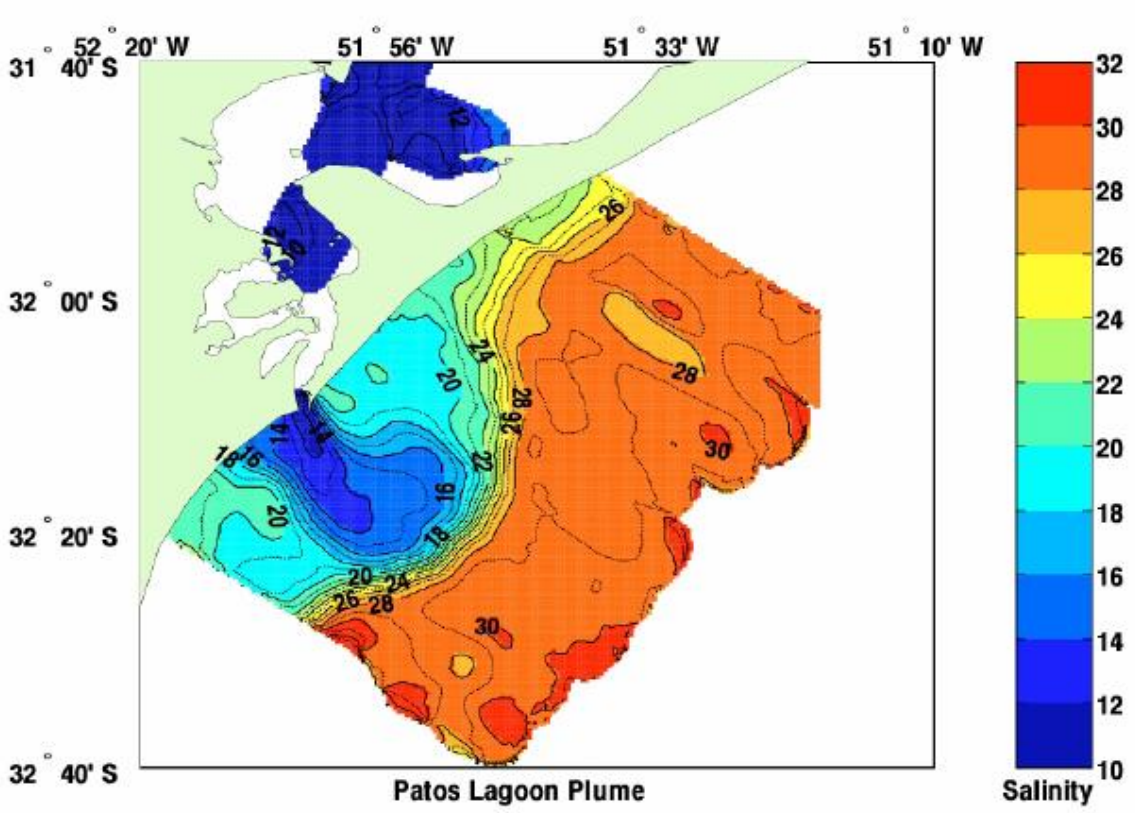

2003 8 21

AERIAL SURVEY - Salinity, Temperature, and Roughness Remote Scanner (STARRS)

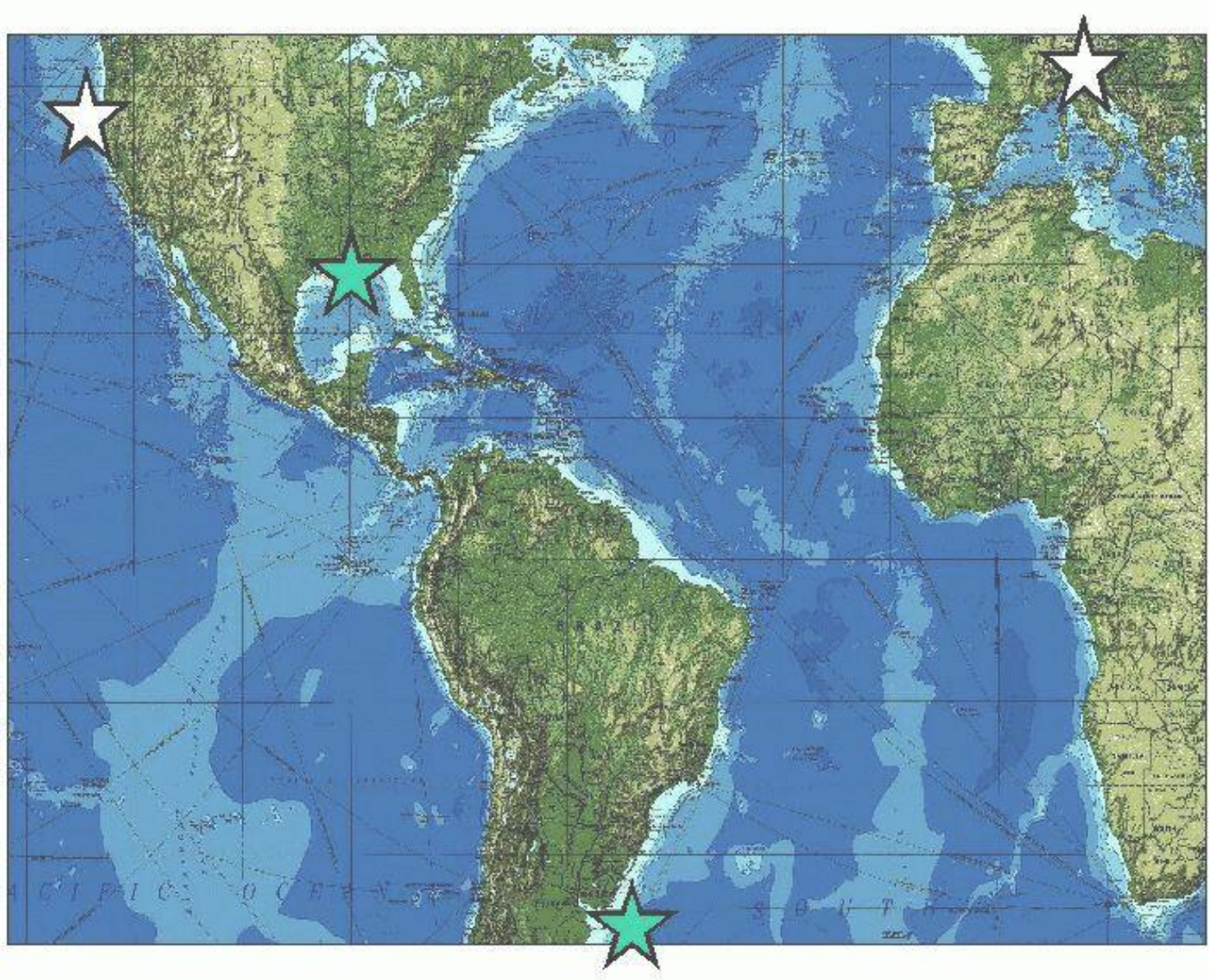


AERIAL SURVEY - Results





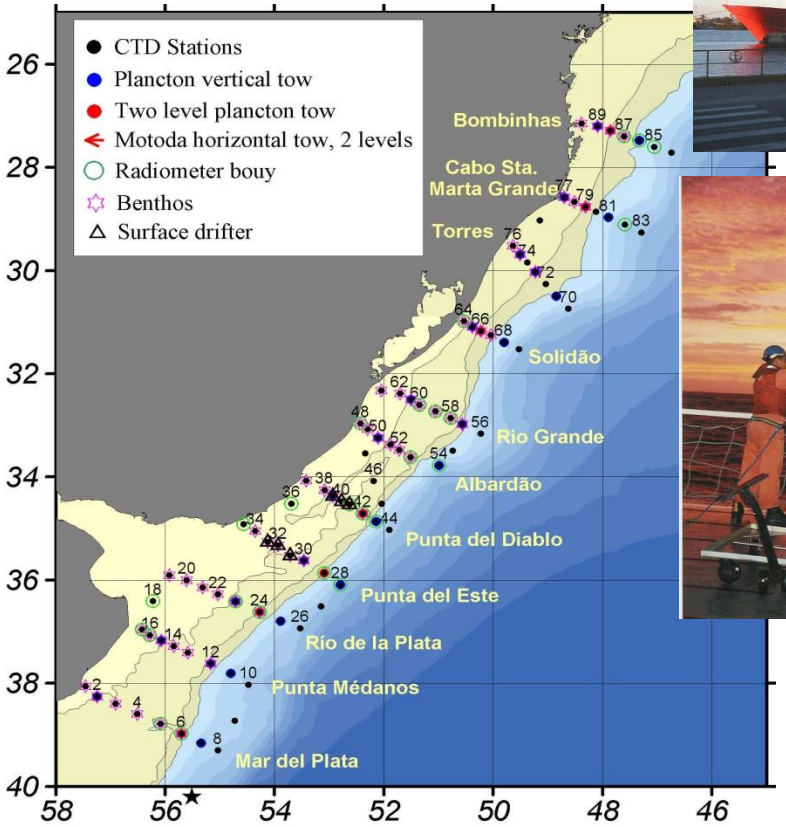
STARRS surveys



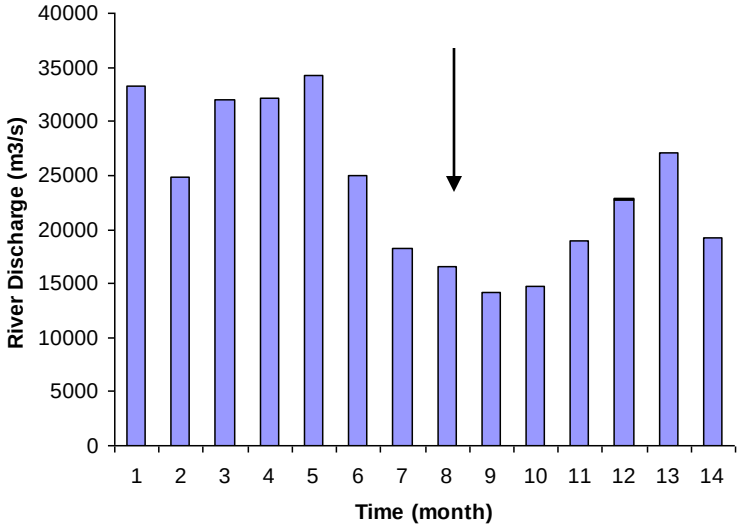
Methodology
Winter (08/2003) and Summer (02/2004) Cruises

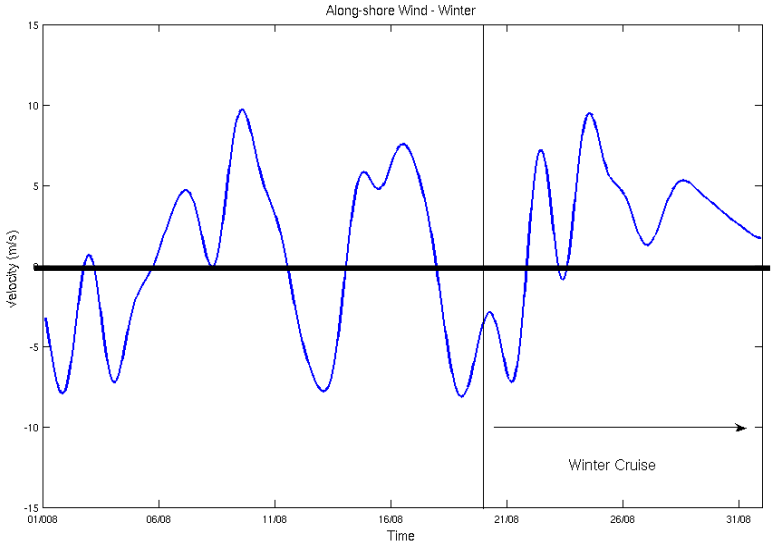
Winter cruise: 12 days

Summer cruise 17 days



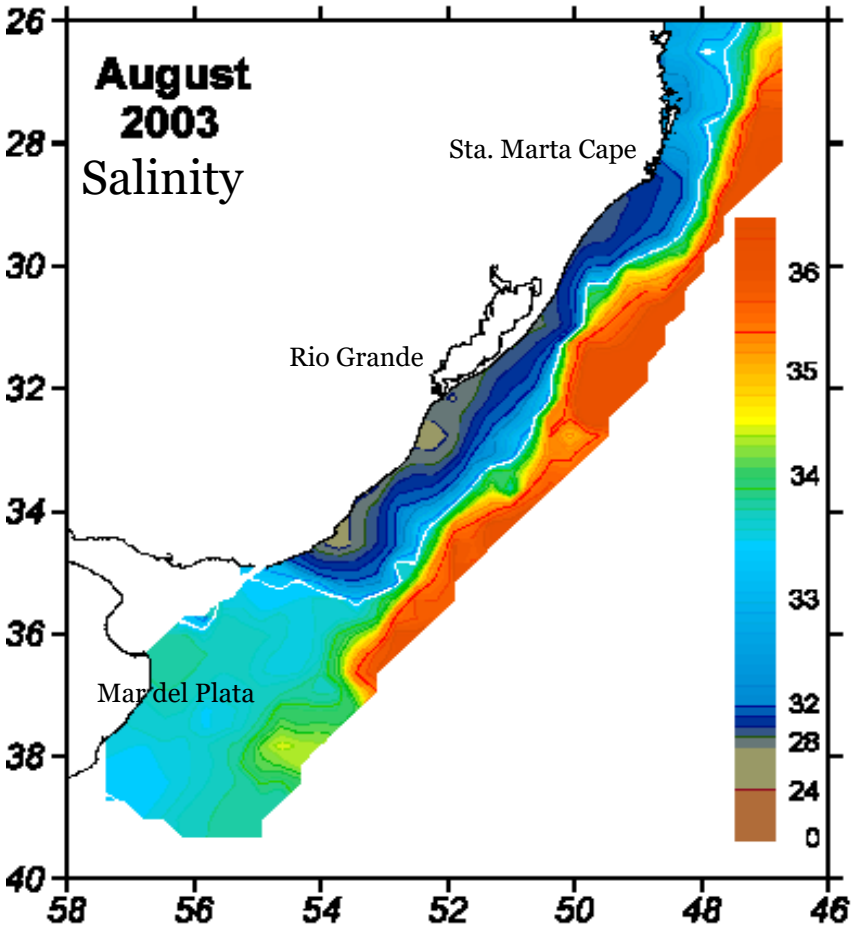
Winter Cruise Results: river and wind conditions

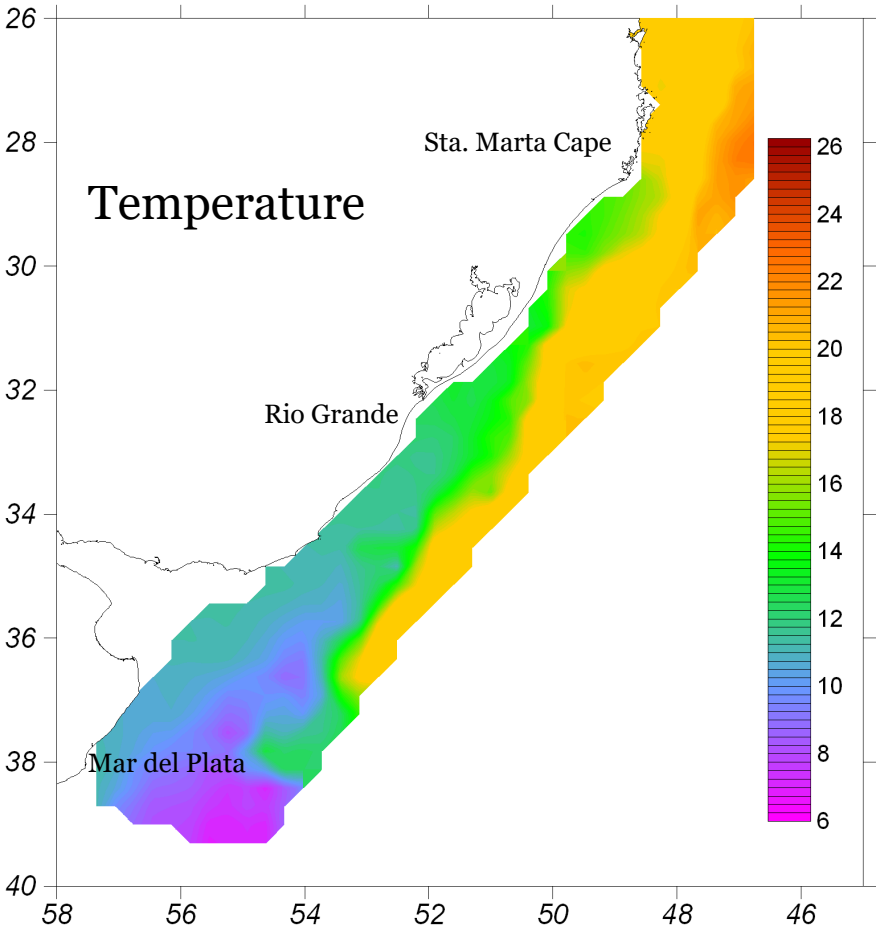


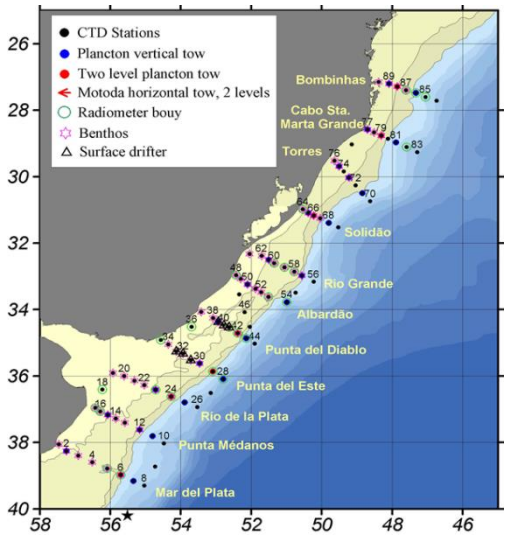


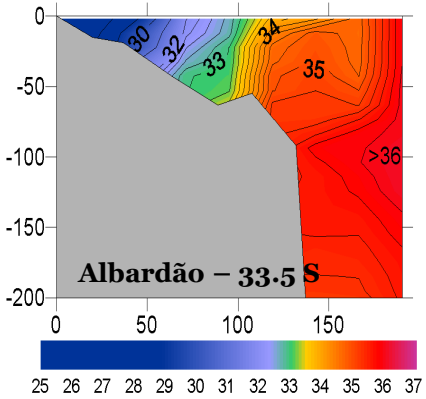
Left) La Plata river discharge starting in January 2003. The arrow points the cruise month. Right) Longitudinal wind component measured at Rio Grande starting 15 days before the cruise

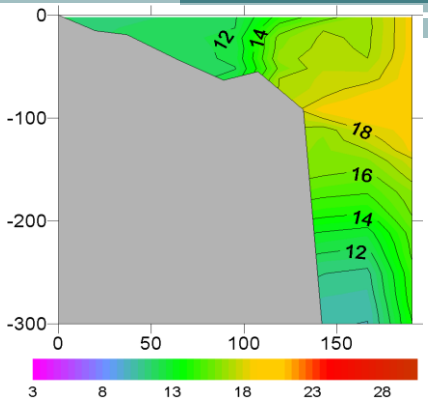
Winter Cruise Results

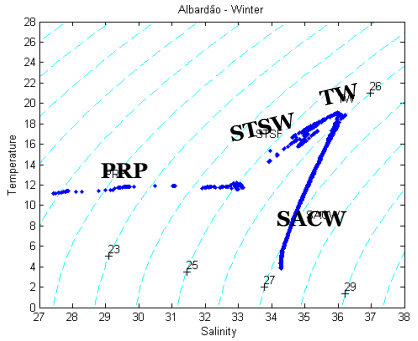


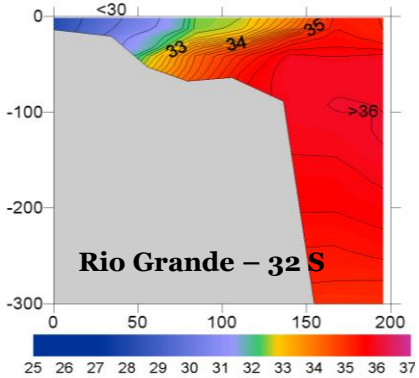


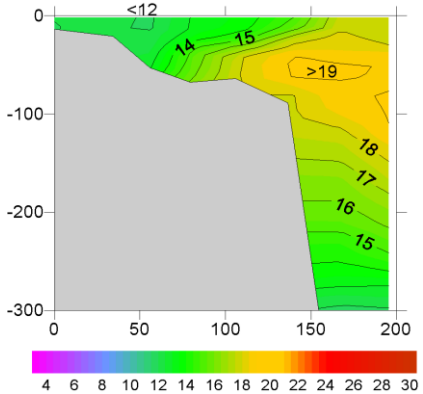

CTD Stations
Plancton vertical tow
Two level plancton tow
Motoda horizontal tow, 2 levels
Radiometer bouy
Benthos
Surface drifter
Bombinhas
Cabo Sta. Marta Grande
Torres
Solidão
Rio Grande
Albardão
Punta del Diablo
Punta del Este
Rio de la Plata
Punta Médanos
Mar del Plata

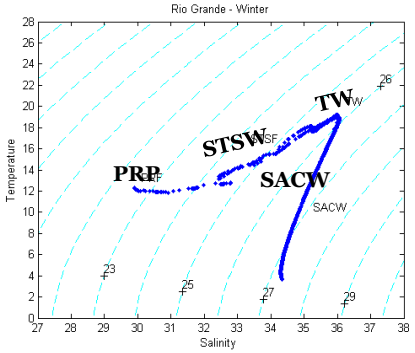

Albardão – 33.5 S

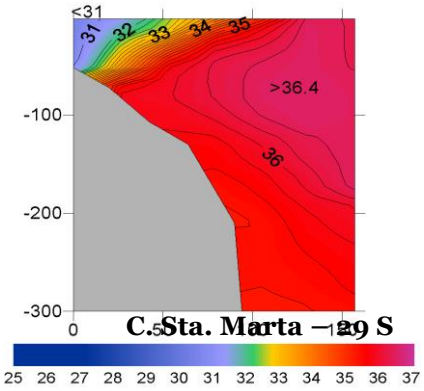


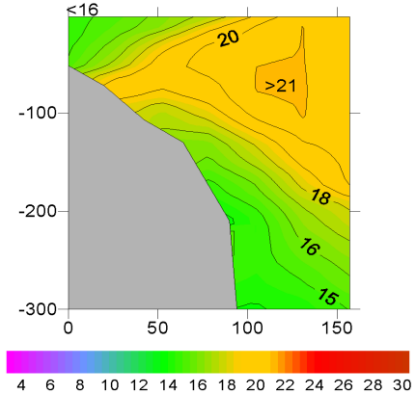

Albardão - Winter
TW
STSW
PRP
SACW
Temperature
Salinity

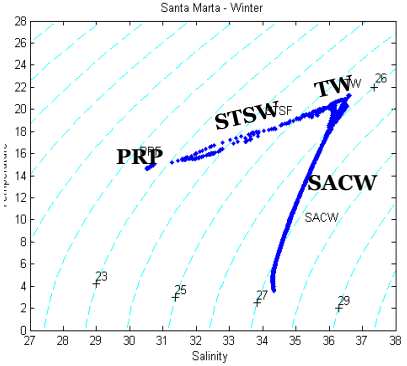

Rio Grande – 32 S



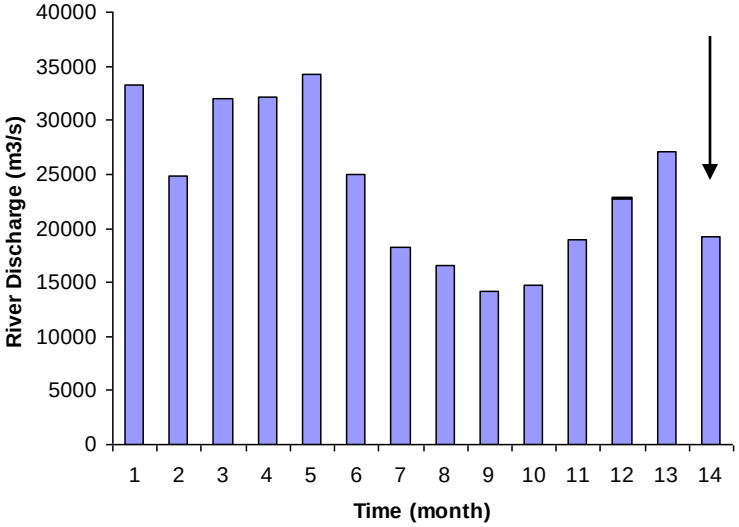

Rio Grande - Winter
TW
STSW
PRP
SACW
Temperature
Salinity

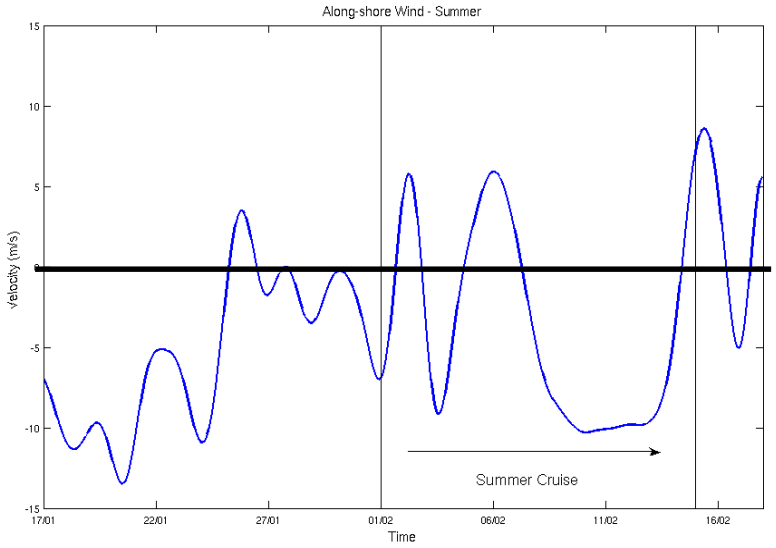

C.Sta. Marta – 29 S




Santa Marta - Winter
TW
STSW
PRP
SACW
Salinity

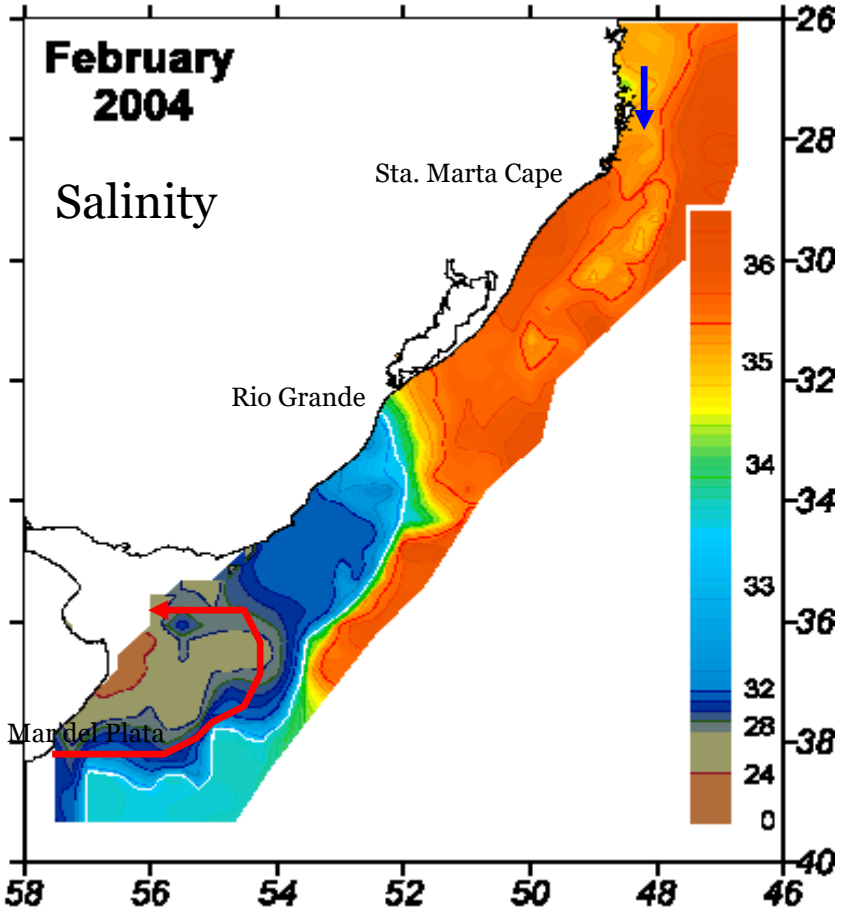
Summer Cruise Results: river and wind conditions

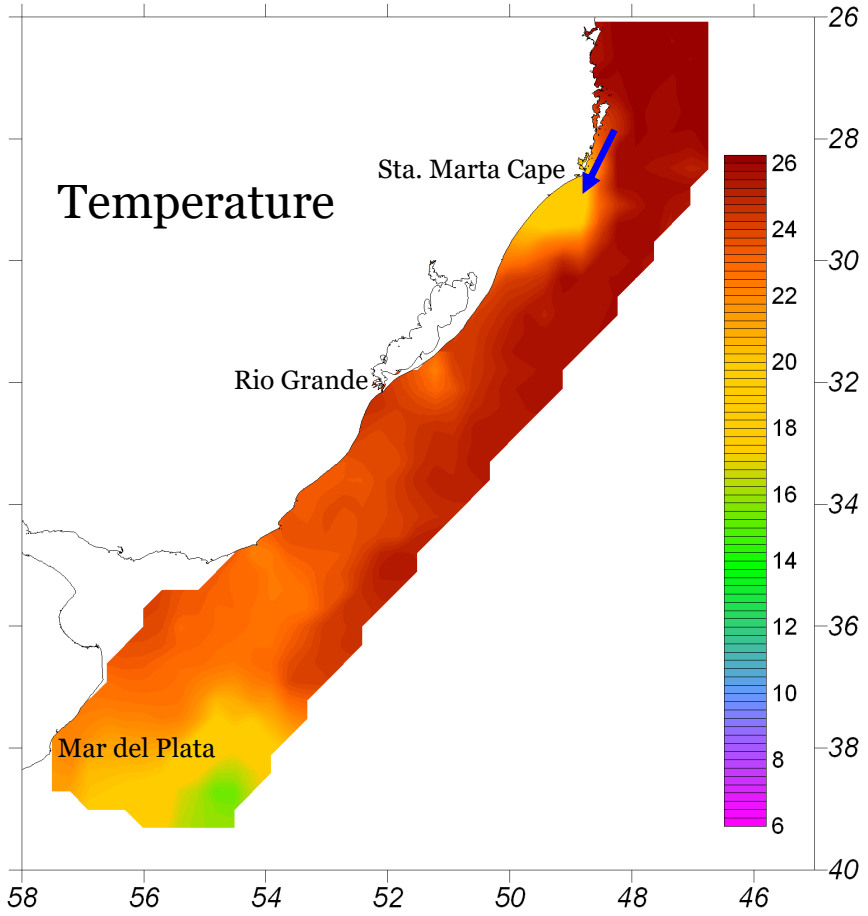


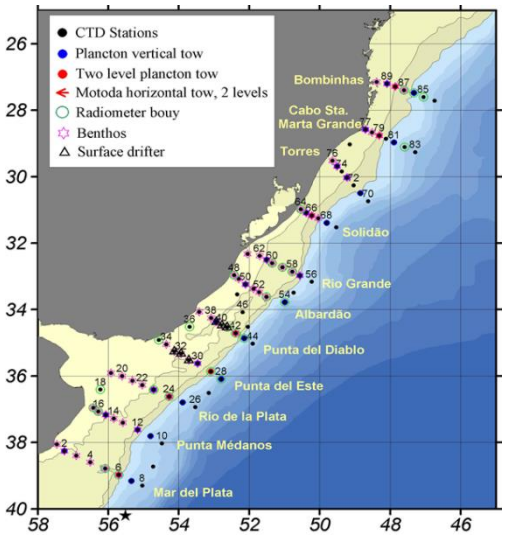


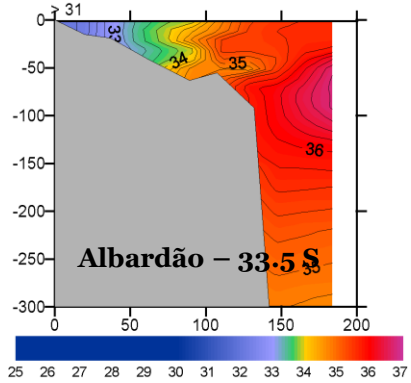
Left) La Plata river discharge starting in January 2003. The arrow points the cruise month. Right) Longitudinal wind component measured at Rio Grande starting 15 days before the cruise

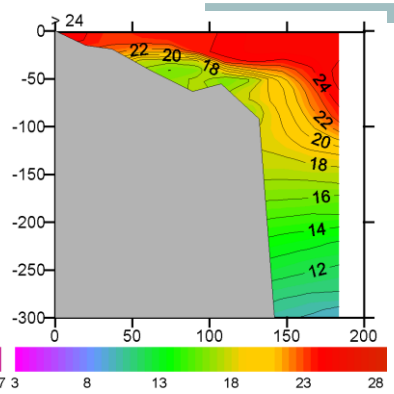
Summer Cruise Results

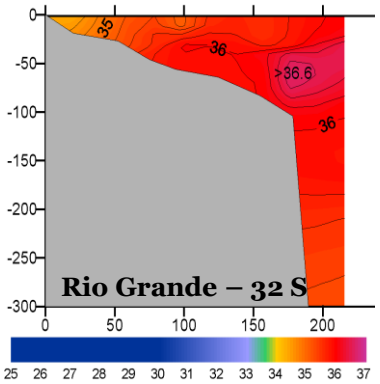


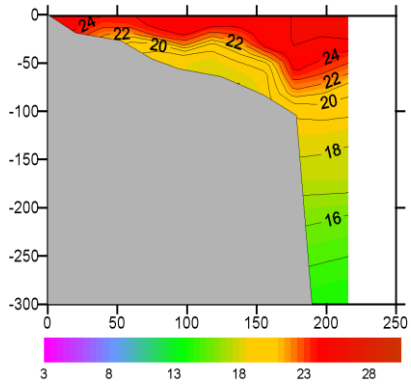


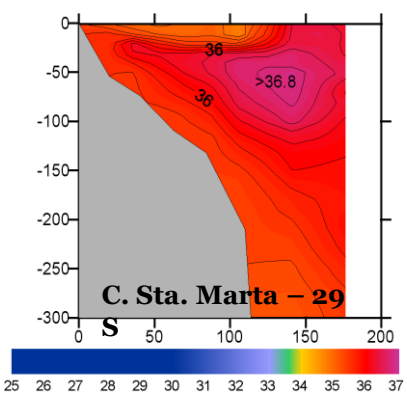

CTD Stations
Plancton vertical tow
Two level plancton tow
Motoda horizontal tow, 2 levels
Radiometer bouy
Benthos
Surface drifter
Bombinhas
Cabo Sta. Marta Grande
Torres
Solidão
Rio Grande
Albardão
Punta del Diablo
Punta del Este
Rio de la Plata
Punta Médanos
Mar del Plata

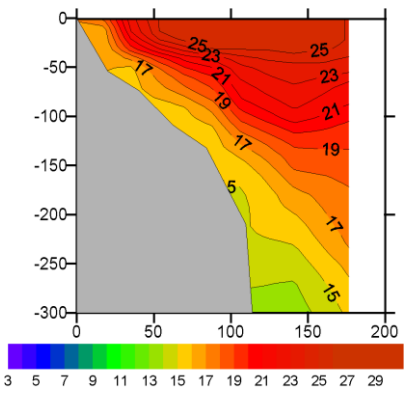

Albardão – 33.5 S

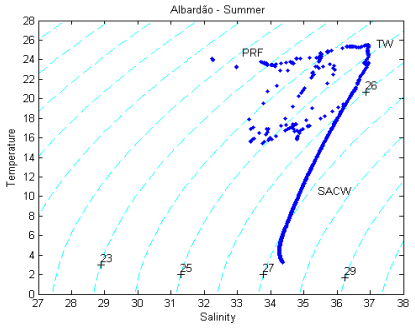


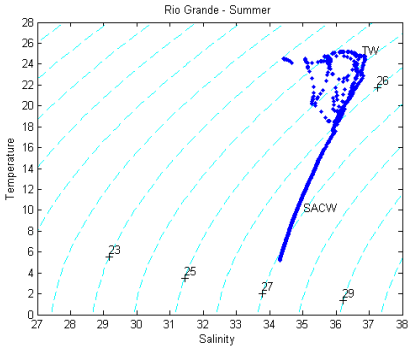

Rio Grande – 32 S

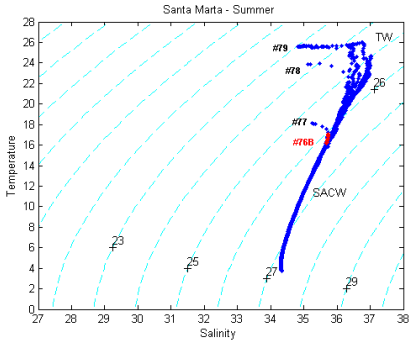


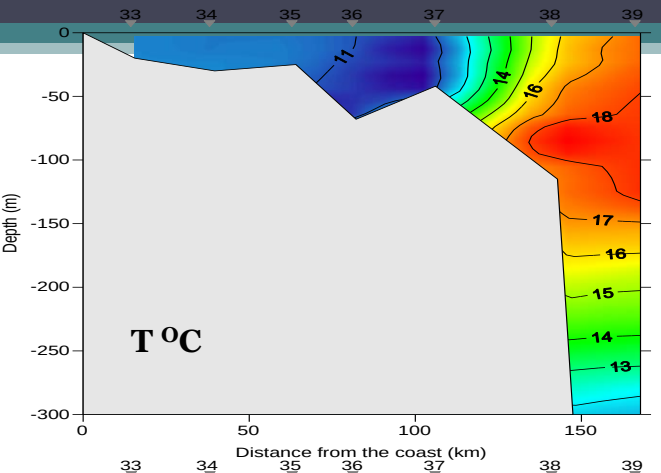

C. Sta. Marta – 29 S

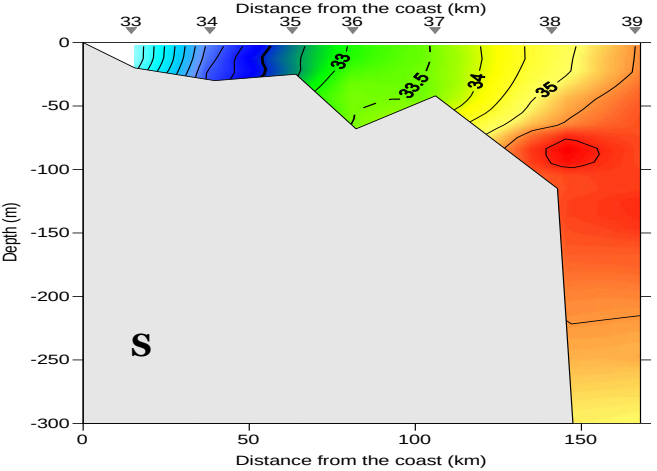


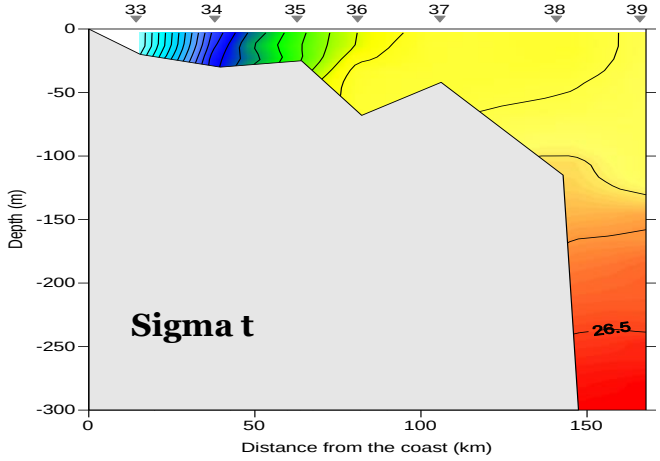

Albardão - Summer
PRF
TW
SACW
Temperature
Salinity

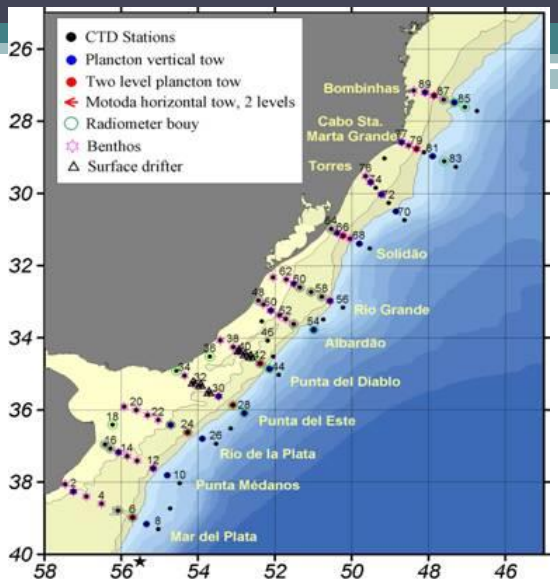

Rio Grande - Summer
TW
SACW
Temperature
Salinity


Santa Marta - Summer
TW
SACW
Temperature
Salinity



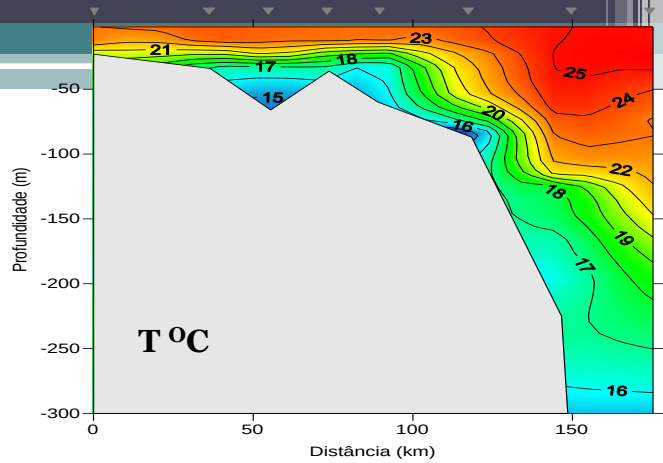


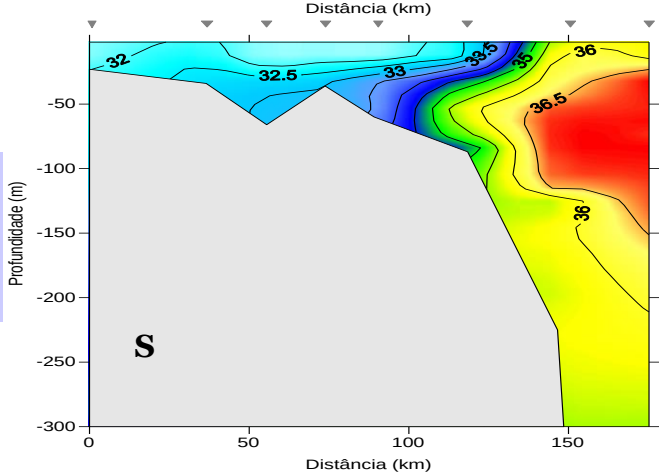


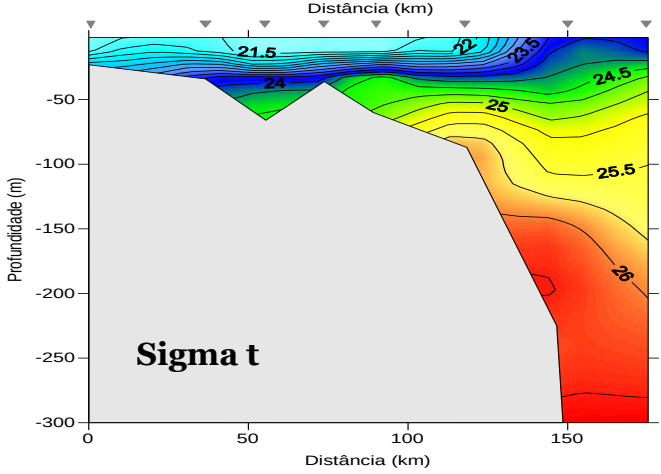


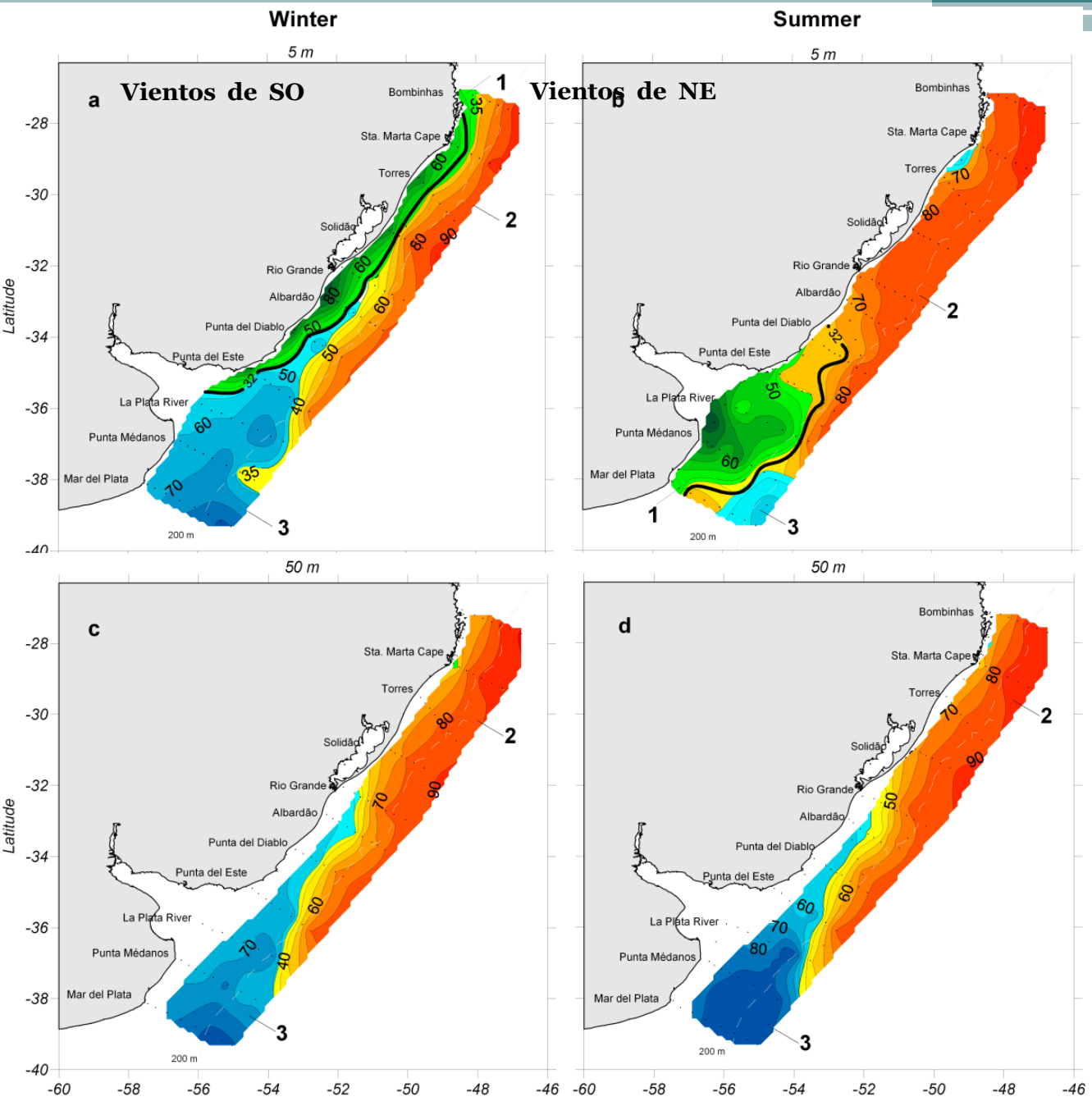
Punta del Diablo

Winter Summer

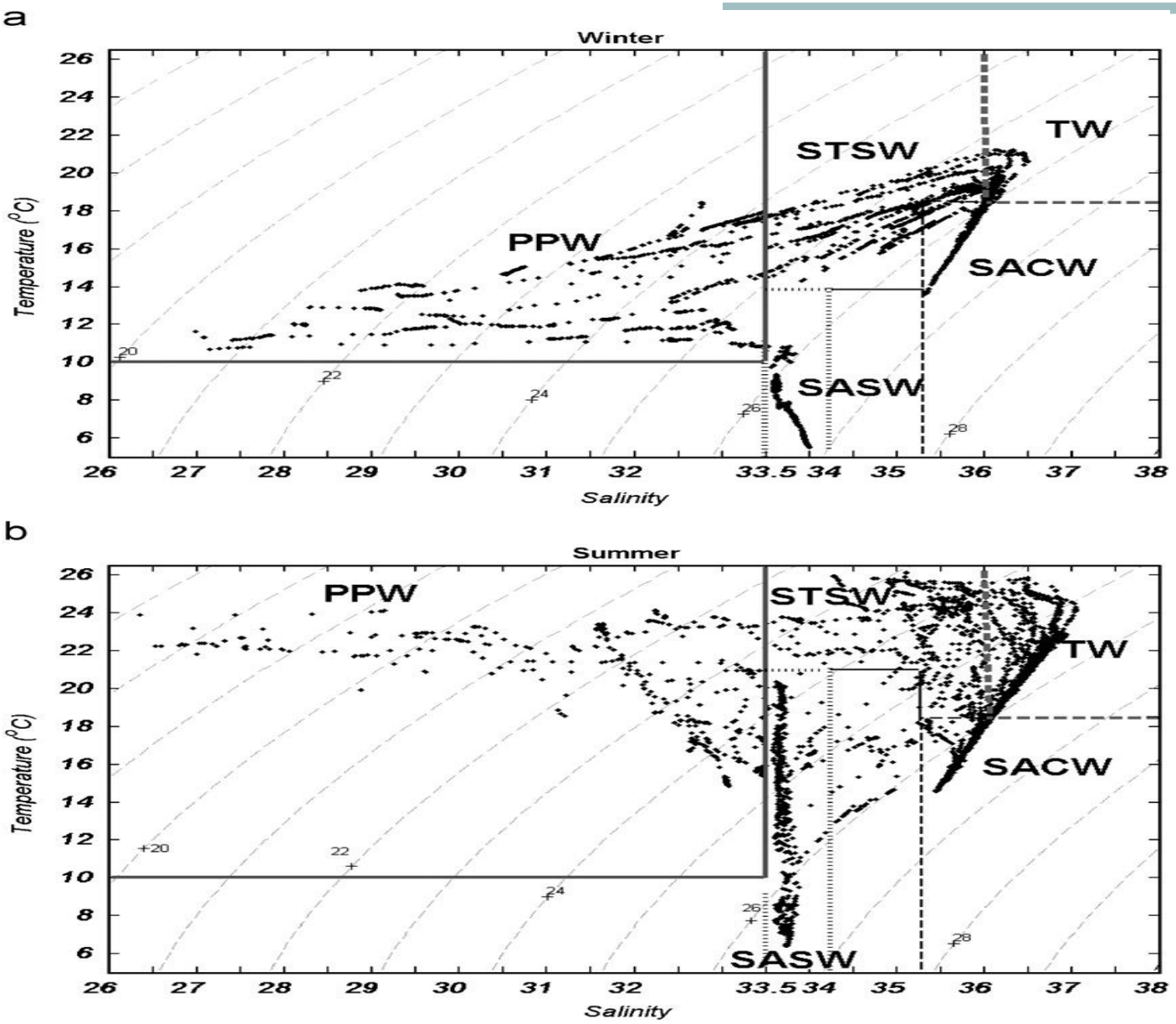






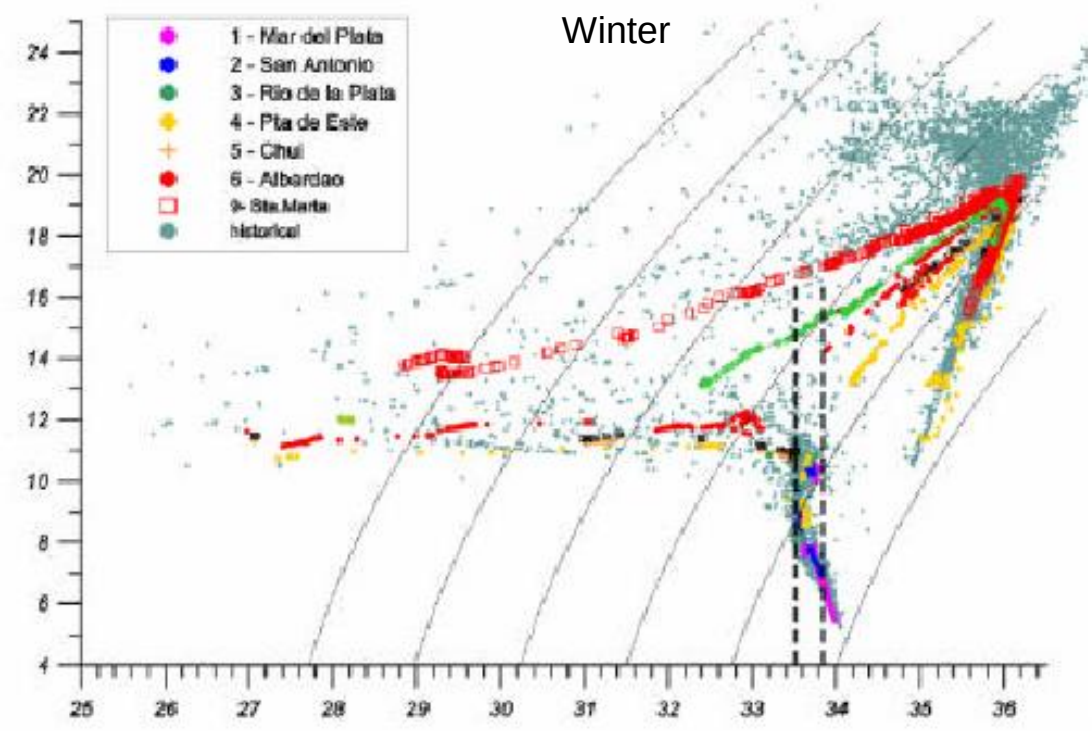


Möller et al. (2008)

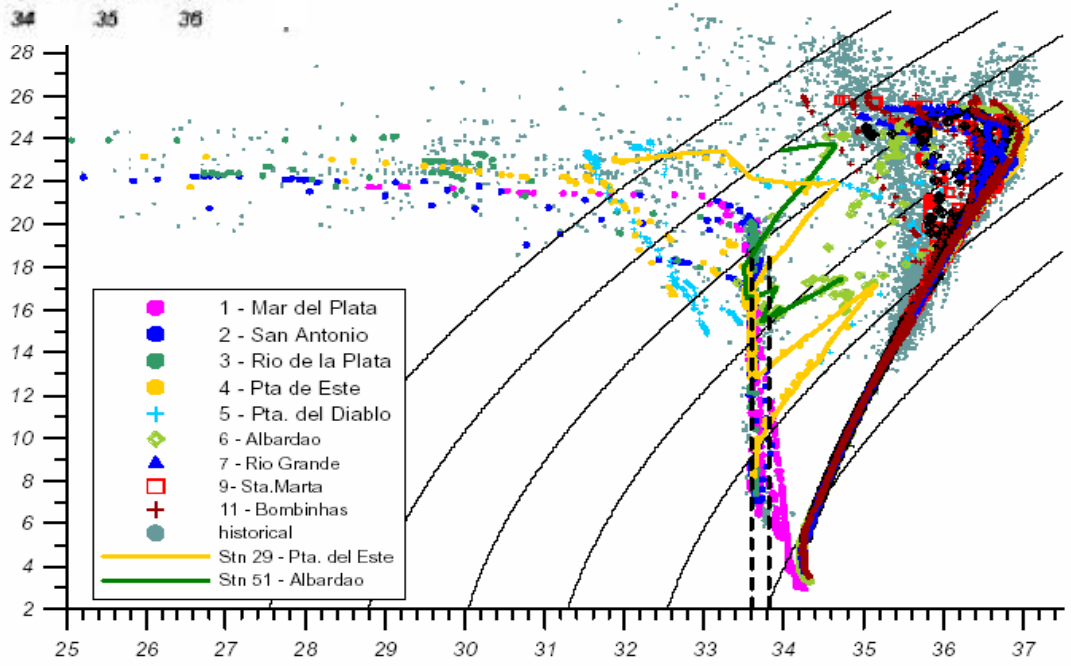


Möller et al., 2008

Winter

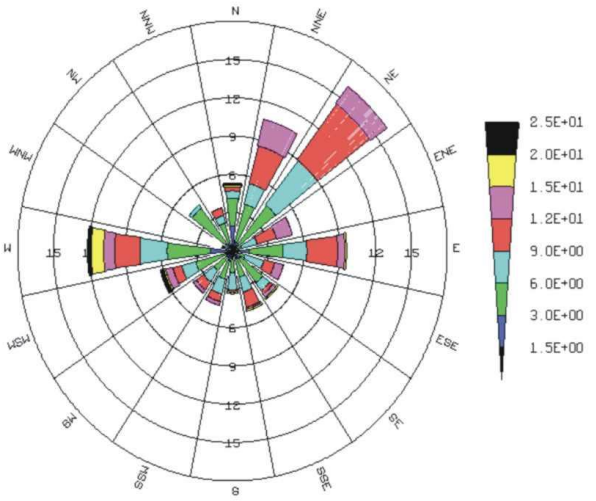


Summer

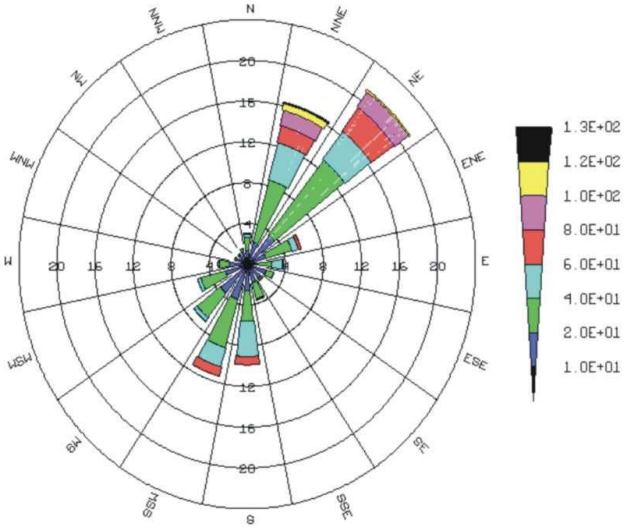


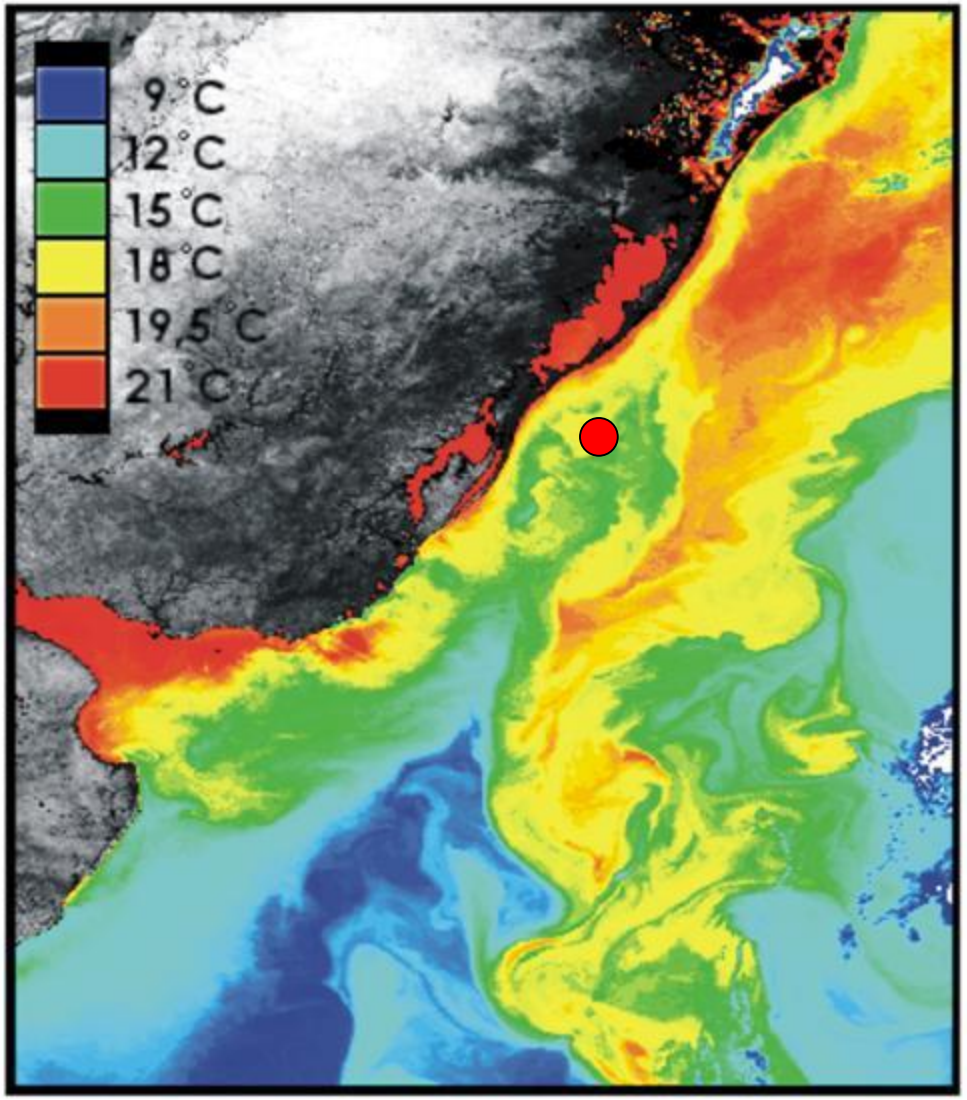
50 m mooring data

Wind



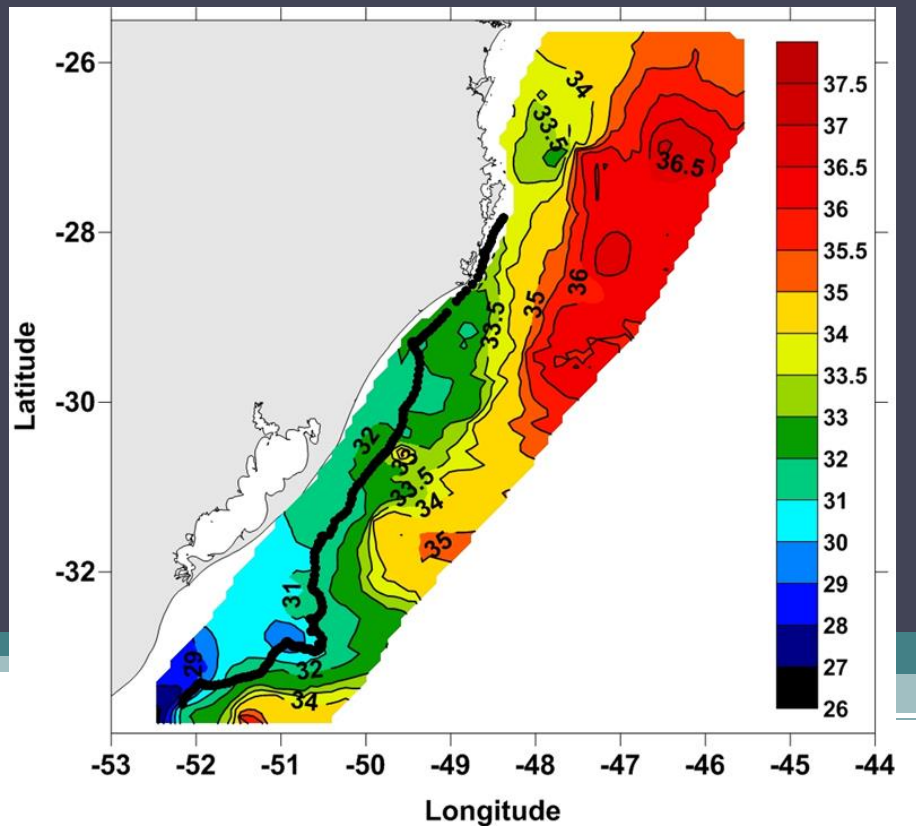
Current 15 m





Möller et al. 1998

Derivador de baixo custo (LCD) lançado em 20/06/2012 - ~0.3 m/s

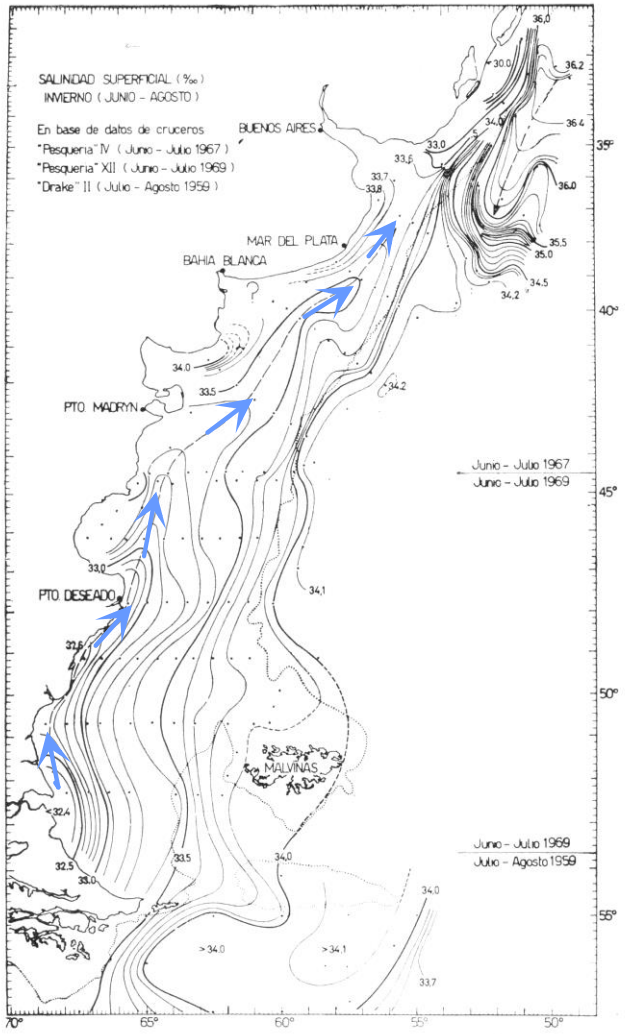


Mesmo ventos fortes de NE não eram capazes de reverter o deslocamento para o norte do LCD. A causa: fluxo para o norte devido ao gradiente de pressão formado pela presença de águas de baixa salinidade e temperatura derivadas do Rio da Prata

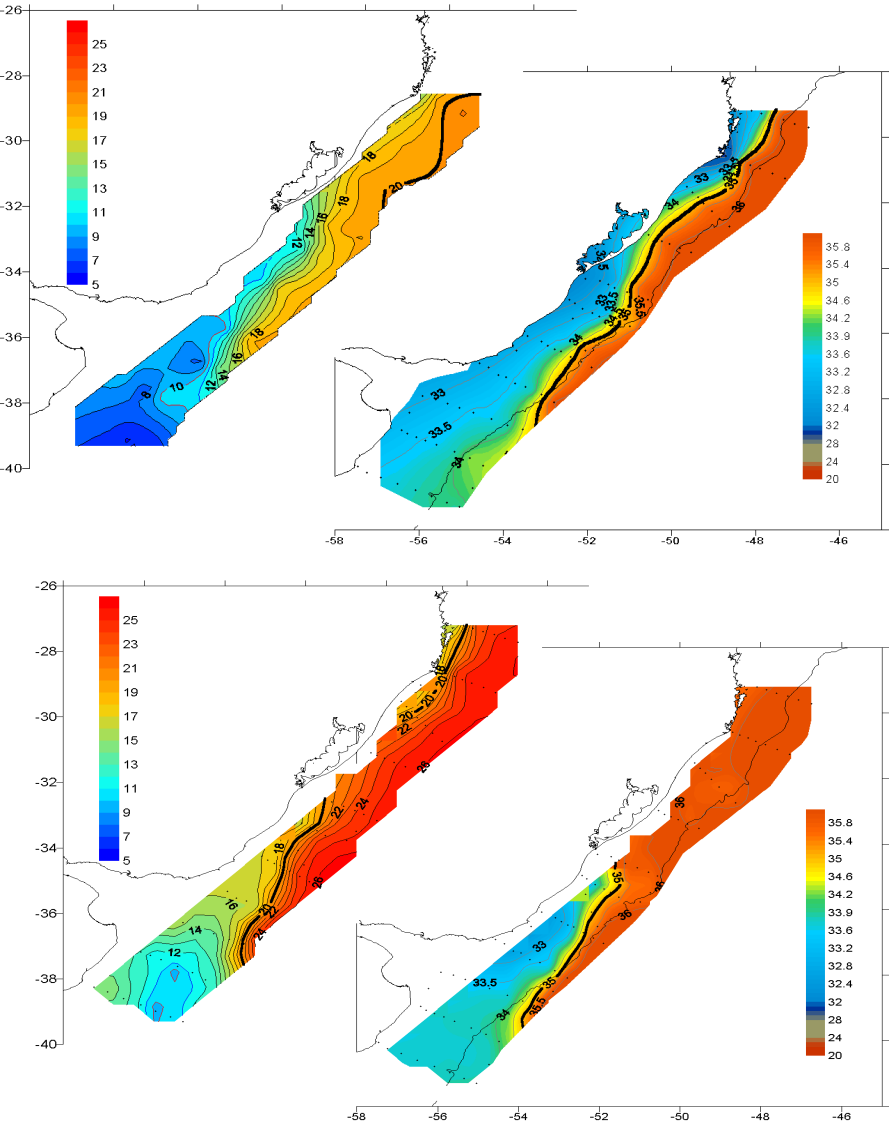
La Corriente Patagónica

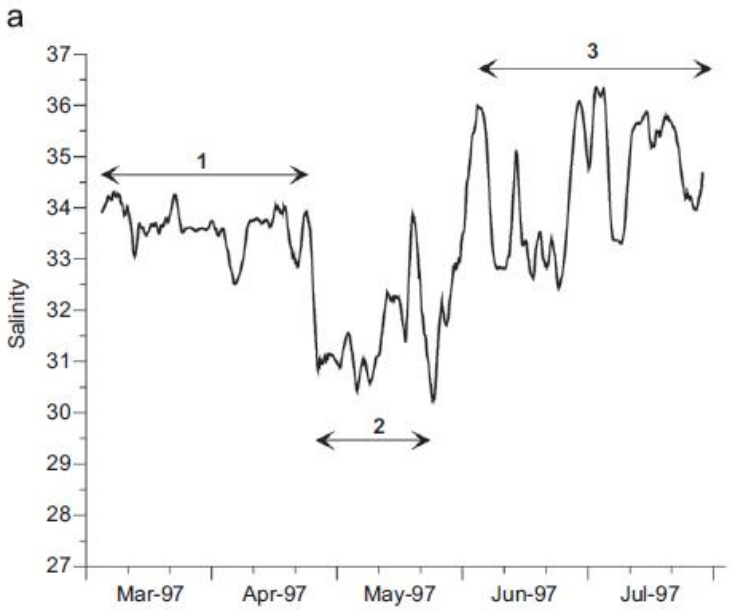
fuente: Brandhorst y Castello, 1971

Based on the tongue-like low sea surface salinity extending northward from the eastern end of the Strait of Magellan to about 39°S, Brandhorst and Castello (1971) suggested the existence of a northward flow referred to as the Patagonian Current



Subtropical Shelf Front (winter 2003 – top) and the variability of water masses – mooring data.

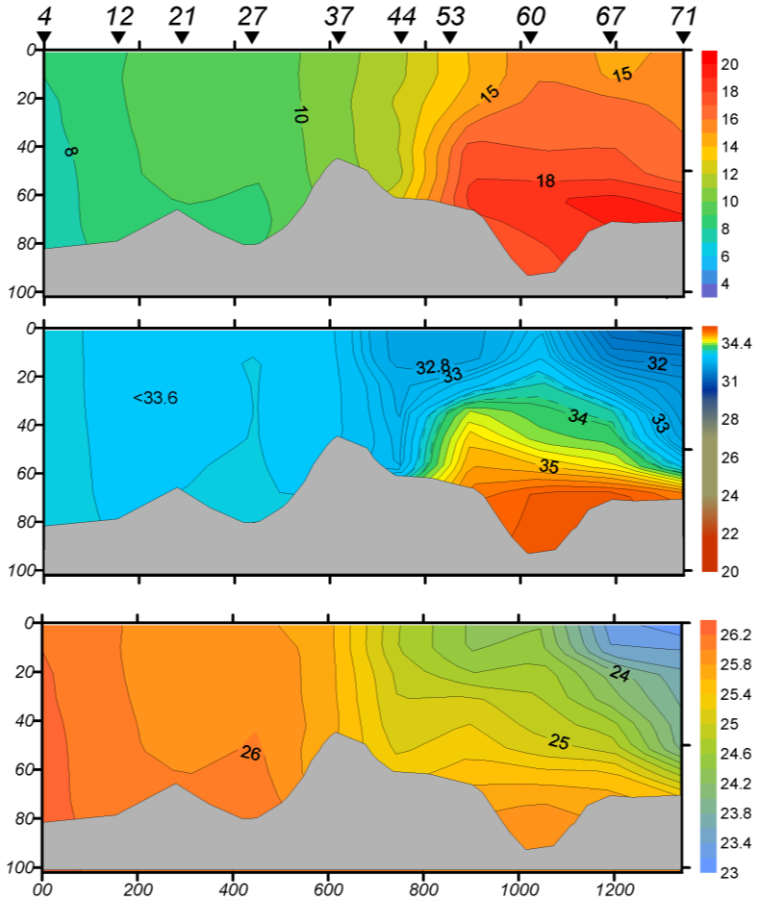




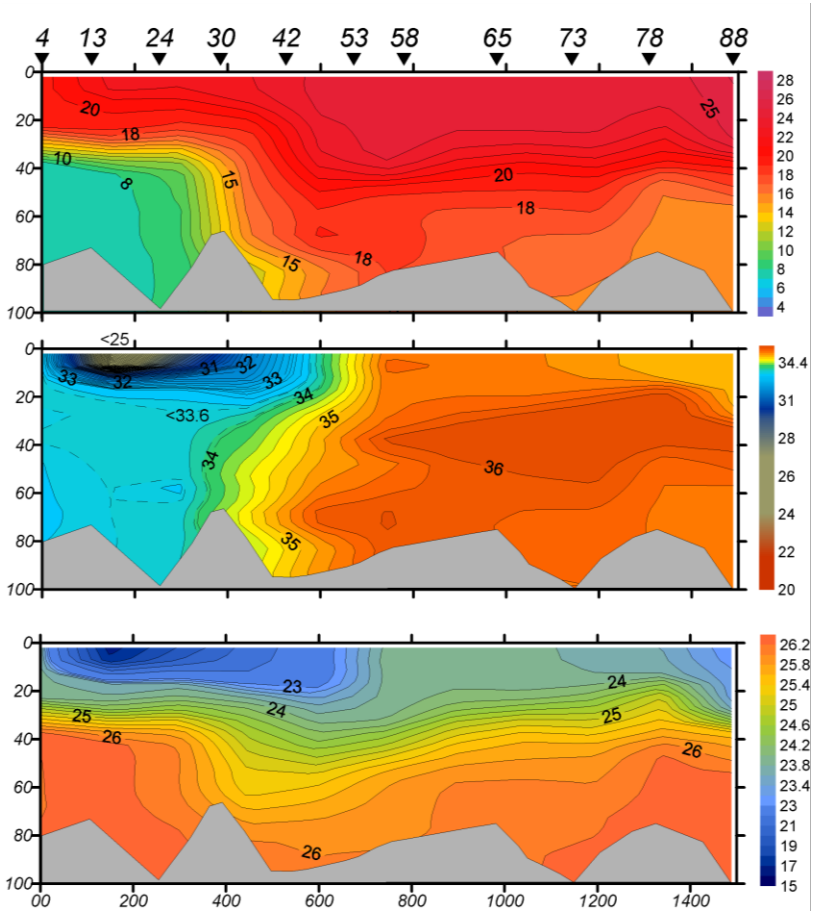
1 – SASW; 2 – PPW; 3 – STSW (Piola et al. 2008)

A Frente Subtropical de Plataforma em inverno (esq.) e verão

La Plata Agosto 2003



La Plata – Fevereiro 2004



No inverno a densidade está associada à salinidade enquanto que no verão à temperatura.

Conclusions and Remarks

-The Plata/Patos outflows induce an extraordinary impact on the continental shelf off Uruguay and southern Brazil.

- The low salinity near-coastal plume presents very large seasonal variations. In winter it can extend beyond 1000 km from the Plata estuary.

- Freshwater dominated continental shelf:

A) In areas where river discharge influences Subtropical Shelf waters are kept away from the coastal region.

B) When the influence of freshwater decreases NE wind action can induce a coastal upwelling system near Cabo de Santa Marta.

-The seasonal variation of the wind is the most important factor for the plume dynamics:

A) SW winds dominating in winter force the northward spreading of the plume to low latitudes even during low river discharge periods.

B) NE winds retain the plume in the southern area and spreads it all over the entire width of the continental shelf east of the estuary. The coastal upwelling observed near Cabo de Santa Marta is another important effect of NE winds.

-Winds also exert an important effect on the transversal circulation of the continental shelf

-Two types of fronts are observed in the region: a haline front – La Plata river waters front and a thermo-haline front, the STSF.

- There is a large seasonal variation in the volumes of water masses that occur in this area

SACC – South Atlantic Climate Change Consortium – glaucus.fcien.edu.uy/pcmya/sacc