



Comparison of algorithms to estimate chlorophyll-a in inland and coastal waters of Brazil

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Brazil



WHO WE ARE

Main civilian organization for space activities in Brazil
Staff of ~2500

49 years in 2010



INPE headquarters, 2004, São José dos Campos, SP



MISSION

Fostering science and technology in earth and space context and be able to offer products and regular services in benefit of Brazil.

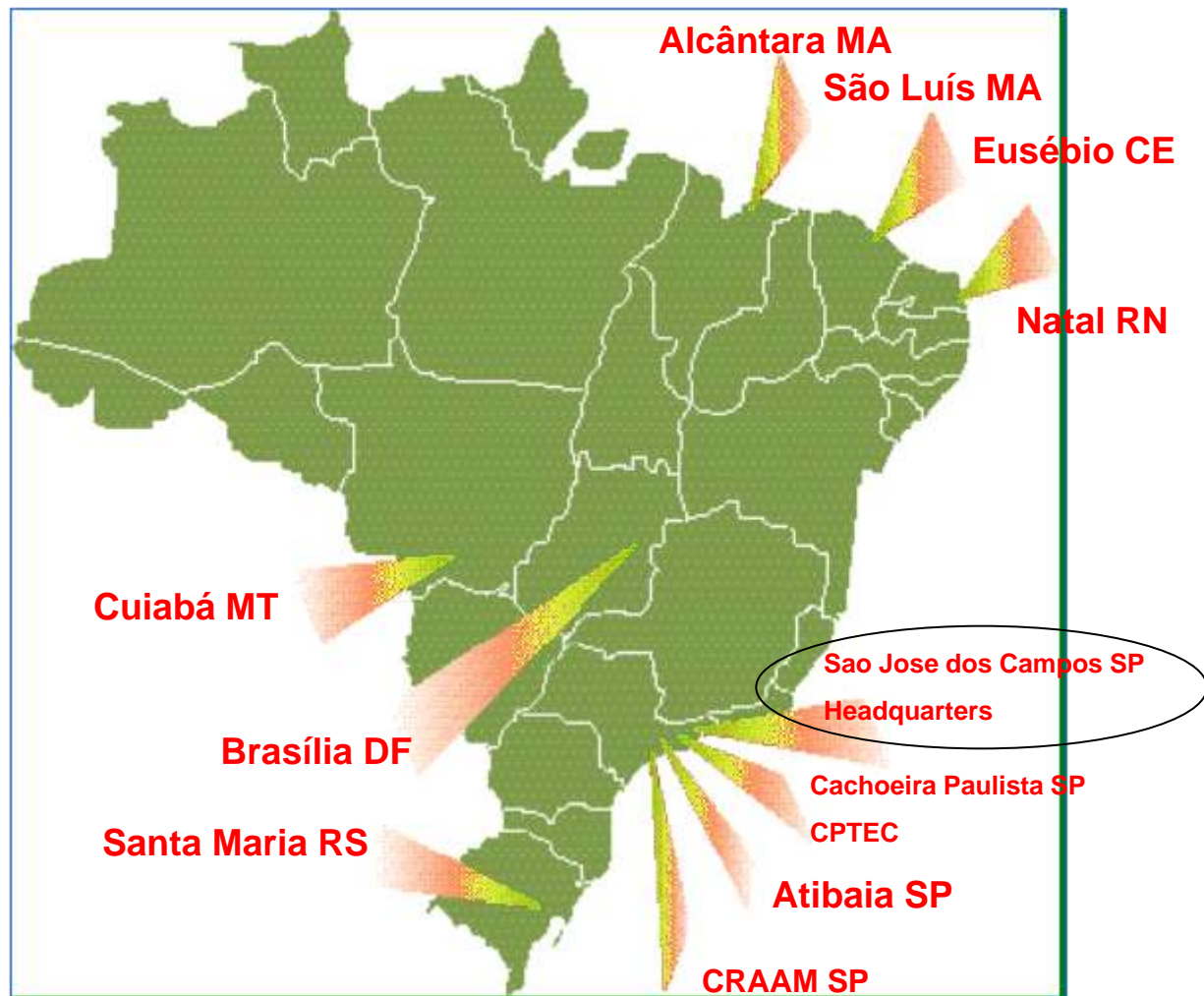


VISION

Become a National and international reference in both space and earth environment fostering knowledge and attending and anticipating demands on Brazilian society life quality progress.



Facilities





Role of Remote Sensing

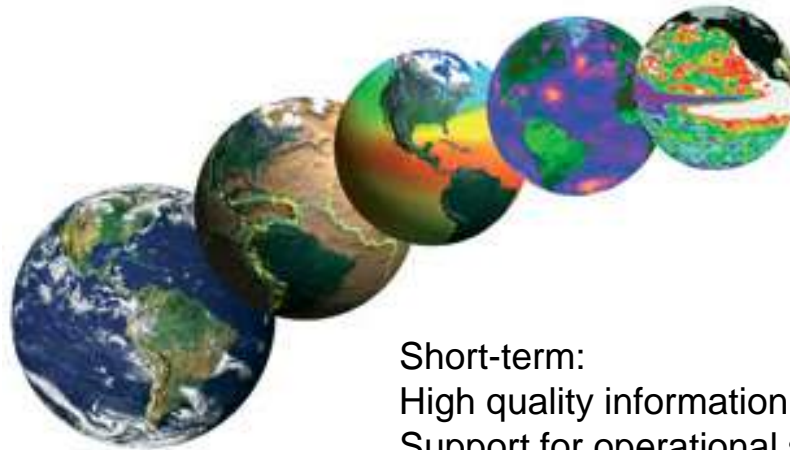
Long-term:

Time-series

Change detection

Identify anthropogenic contributions

Cal/Val models



Short-term:

High quality information

Support for operational services

oceanography

land cover/change

planning

desasters

GEOSS: Social benefits

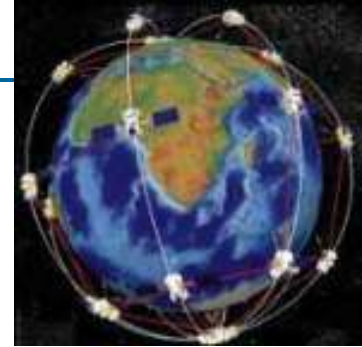


GEOS: Social benefits





CEOS Virtual Constellations



Common requirements, independent satellites, comparable data
(CEOS – Committee on Earth Observation Systems)

Athmospheric Chemistry Air quality, CO2	Land Imaging (Brazil: CBERS, Amazonia-1)
Ocean Surface Topography Climatic variability	Precipitation (Brazil: GPM-BR)
Ocean Colour (Brazil: SABIA-MAR)	Ocean Surface Winds





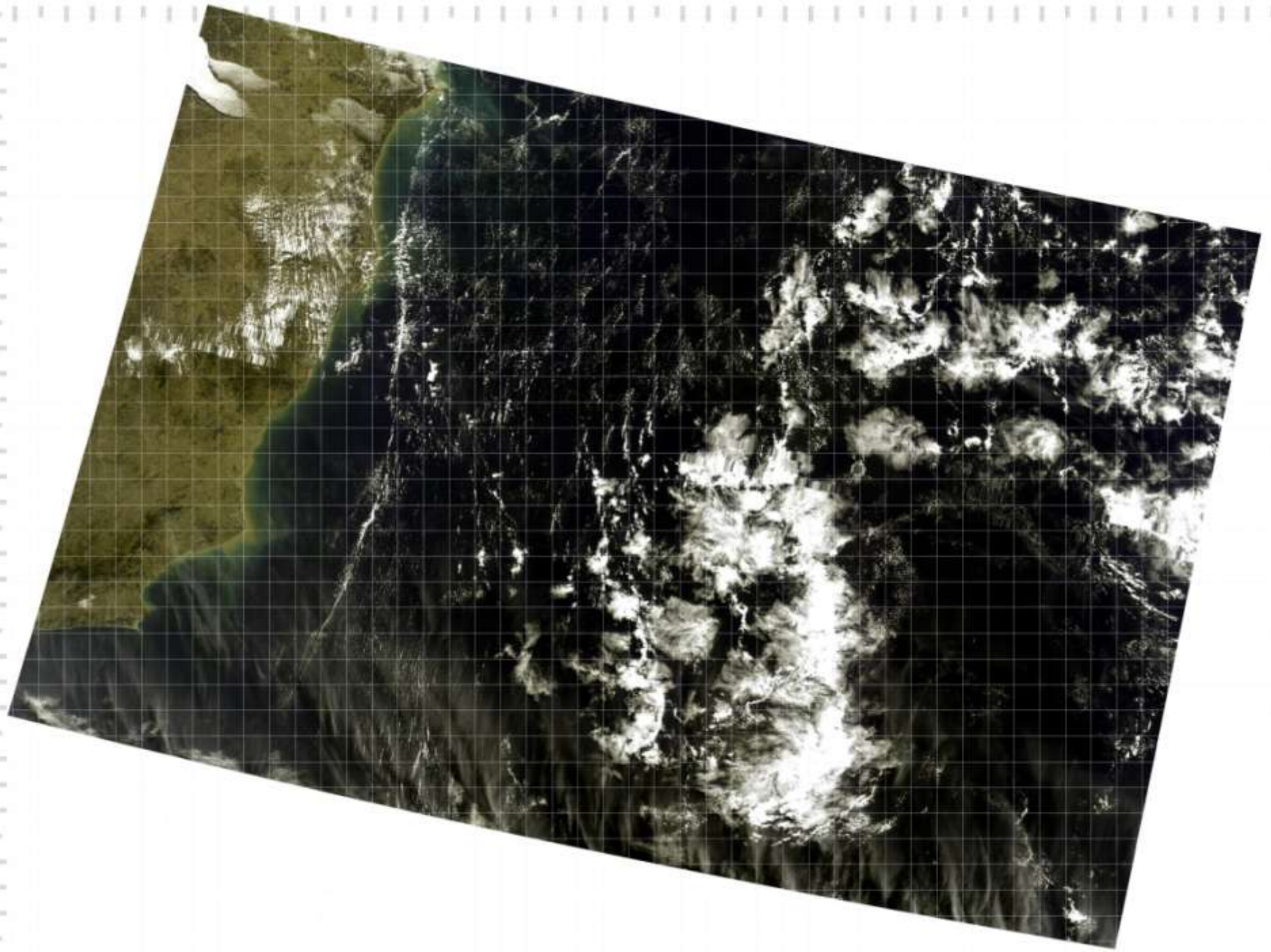
INPE's ground systems



Cuiaba image reception station

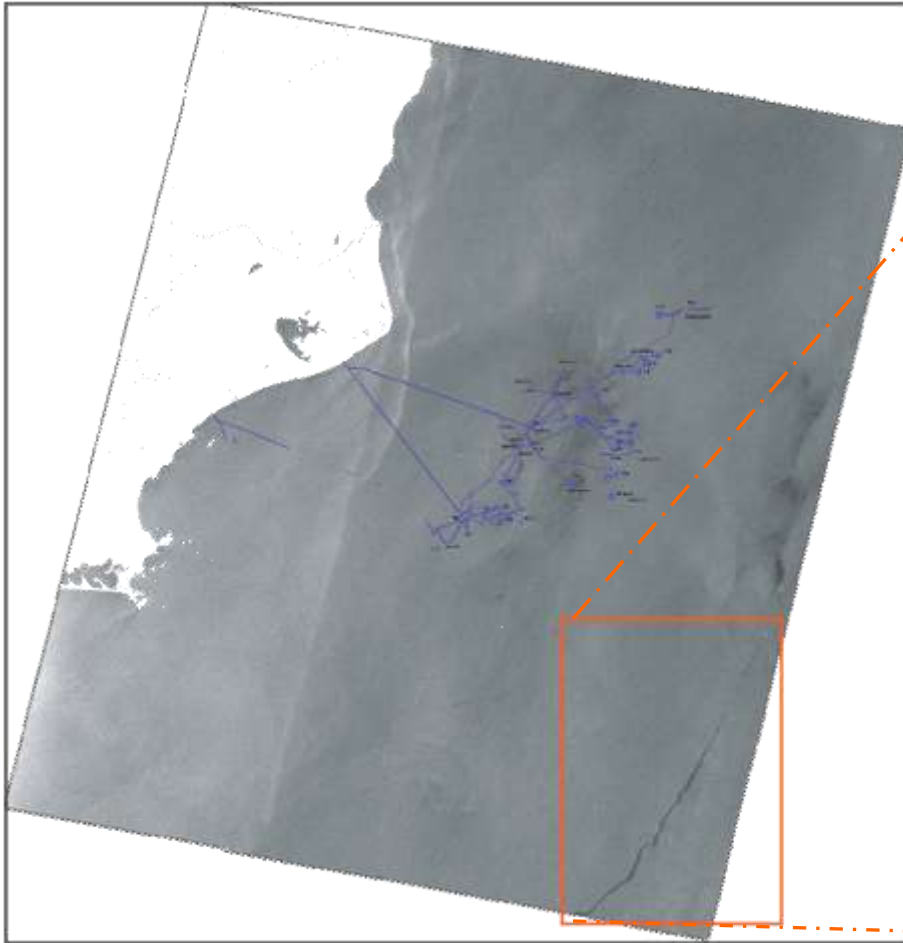


Satellite control center (São José)



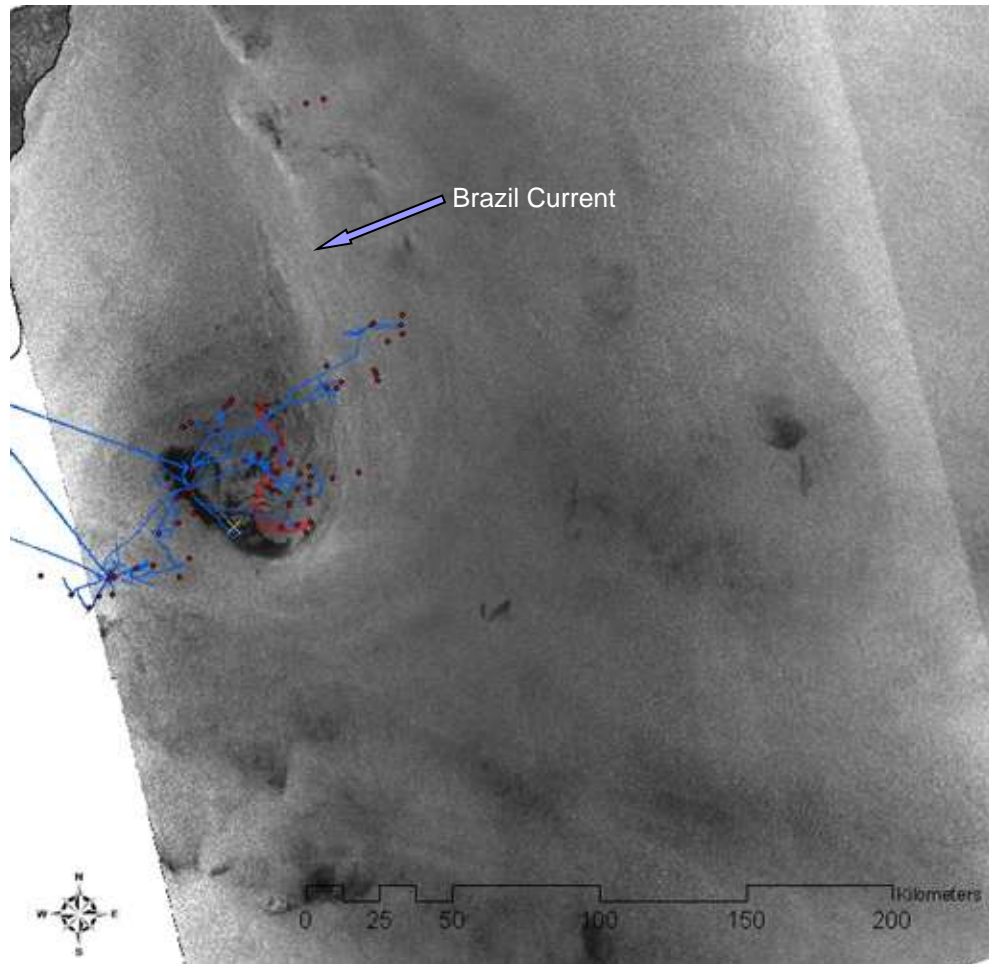


Oil spill from a ship



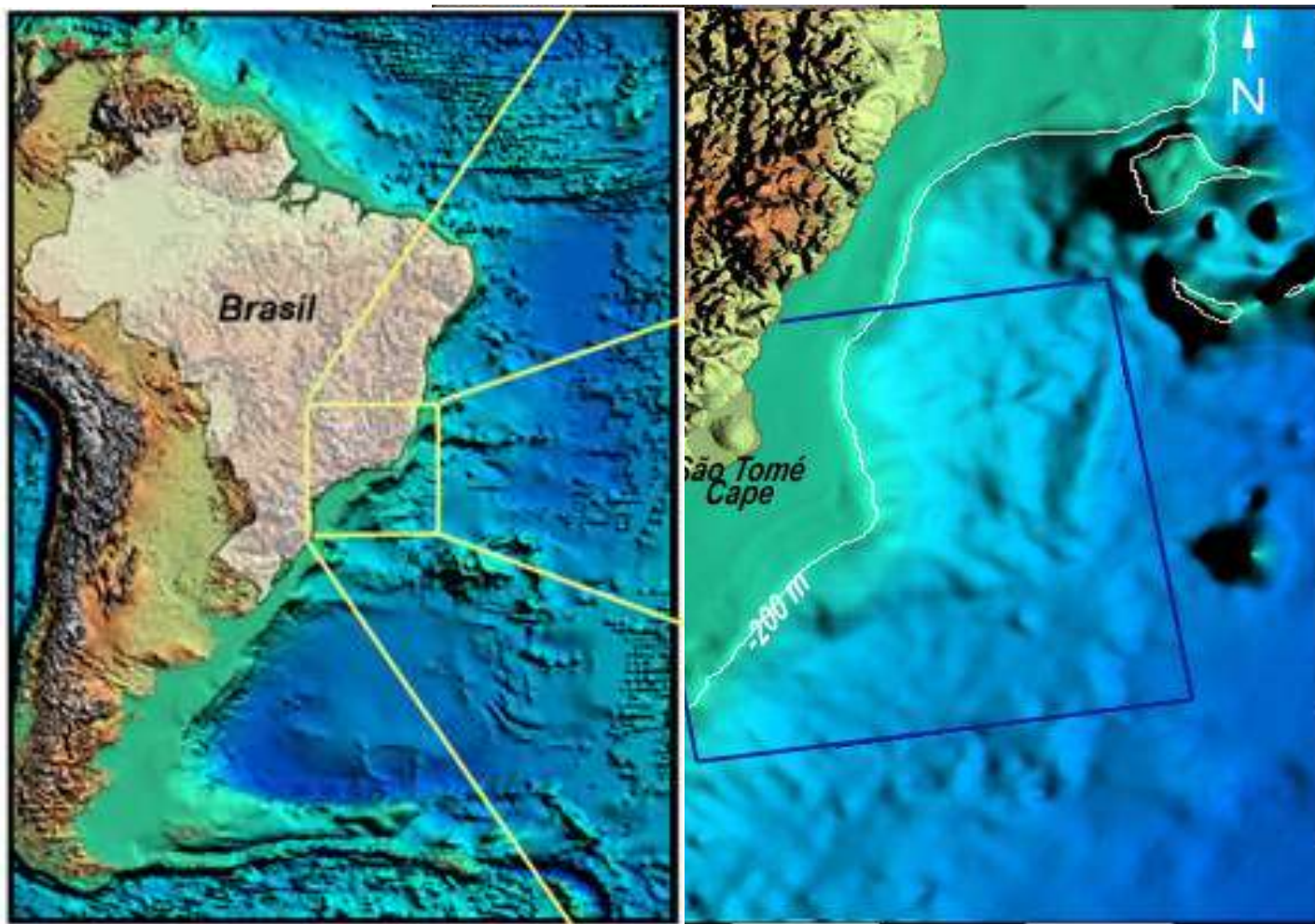


Oil seep



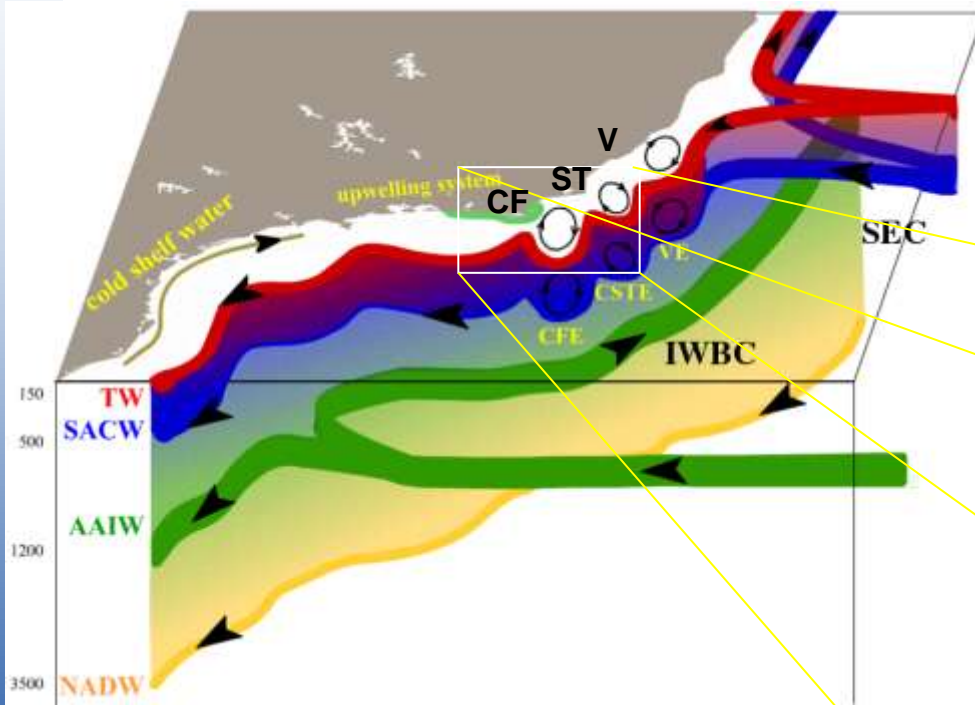
ASAR Campos Basin Brazil

Study Area



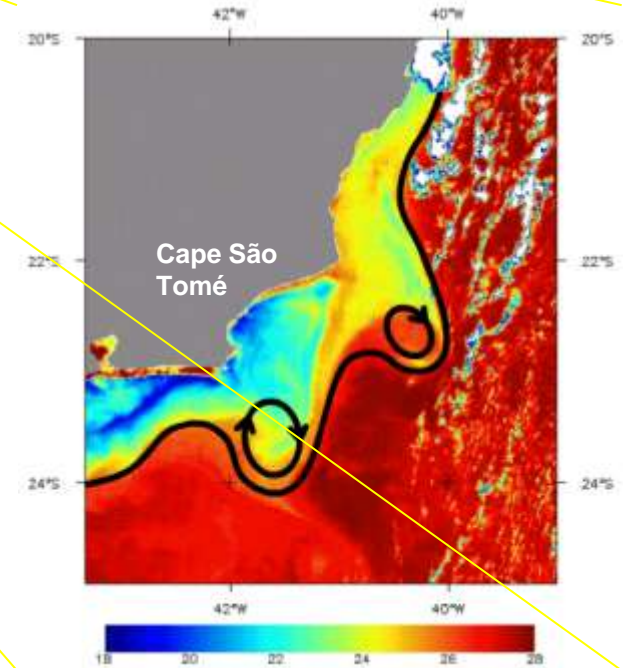


Conceptual display of Water Masses-Currents with mesoscale features for SW South Atlantic



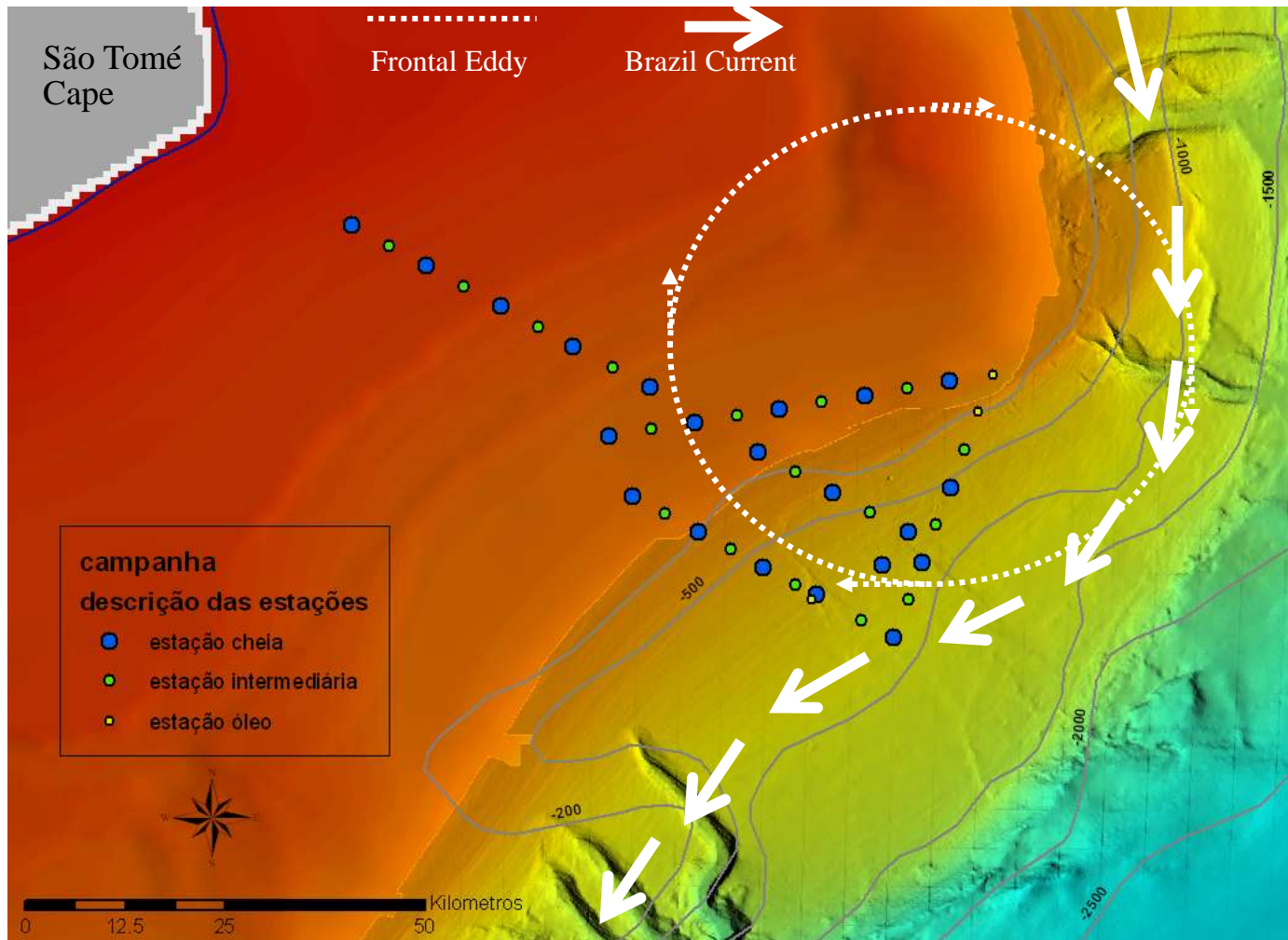
- V – Vitória Eddy
- ST – São Tomé Eddy
- CF – Cabo Frio Eddy

AVHRR SST





FITOSAT I Cruise - Bathymetry & Stations

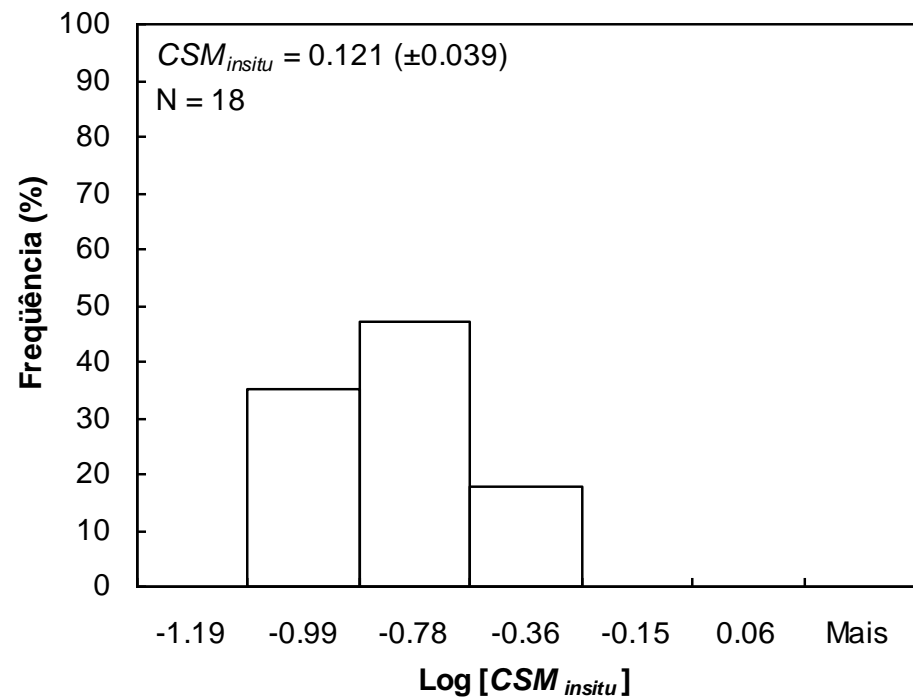


Kampel et al., 2009



In situ - Fluorometry

- 2 L surface water samples with Niskin bottles
- 18 stations, 21-25/NOV/2004
- Turner Designs TD-700 (Parsons et al. 1984)
- 0,077 a 0,197 mg m⁻³





In situ – Above-water Radiometry

- 29 stations
- Hyperspectral Spectron SE590 radiometer
- 375-1075 nm → 400-800 nm (5 nm)
- Protocol suggested by Fougnie et al. (1999) with polarizer
- SeaWiFS and MODIS bands were simulated integrating the radiometric data by the trapezoidal rule.



In situ - Above-water Radiometry

- Remote sensing reflectance

$$R_{RS}(\lambda) = \frac{L_w(\lambda)}{E_d(\lambda)} \quad \text{Eq.1}$$

$$E_d(\lambda) = L(\lambda) \times f_c \times \pi \quad \text{Eq.2}$$

- OC2v4

$$C_a = 10,0^{(0,319 - 2,336R_{2S} + 0,879R_{2S}^2 - 0,135R_{2S}^3) - 0,071} \quad R_{2S} = \log_{10} \frac{R_{490}}{R_{555}}$$

- OC4v4

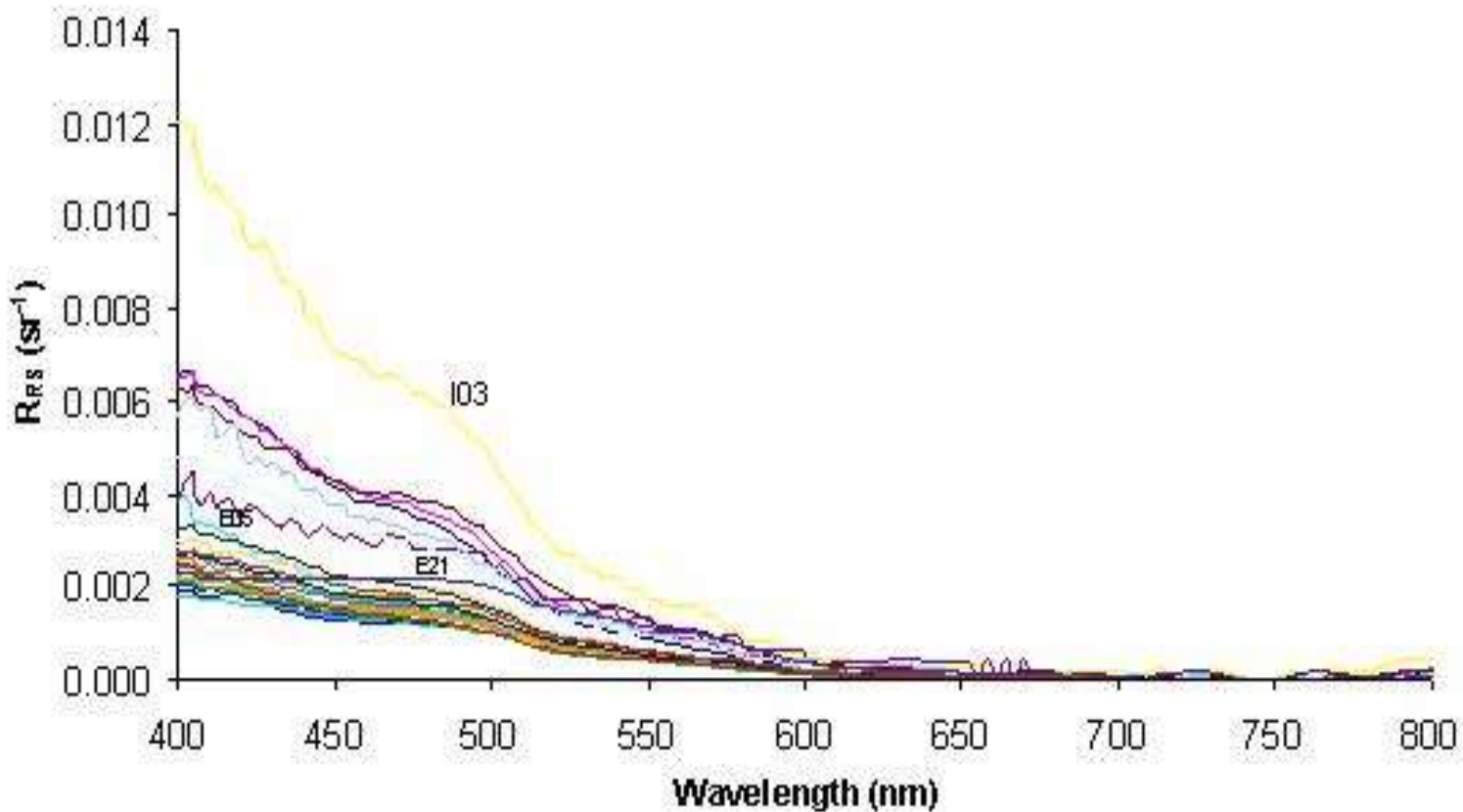
$$C_a = 10,0^{(0,366 - 3,067R_{4S} + 1,930R_{4S}^2 - 0,649R_{4S}^3 - 1,532R_{4S}^4)} \quad R_{4S} = \log_{10} \frac{R_{\max}}{R_{\min}}$$

- OC3M

$$C_a = 10,0^{(0,283 - 2,753R_{3M} + 1,457R_{3M}^2 - 0,659R_{3M}^3 - 1,403R_{3M}^4)} \quad R_{3M} = \log_{10} \frac{R_{\max}}{R_{\min}}$$

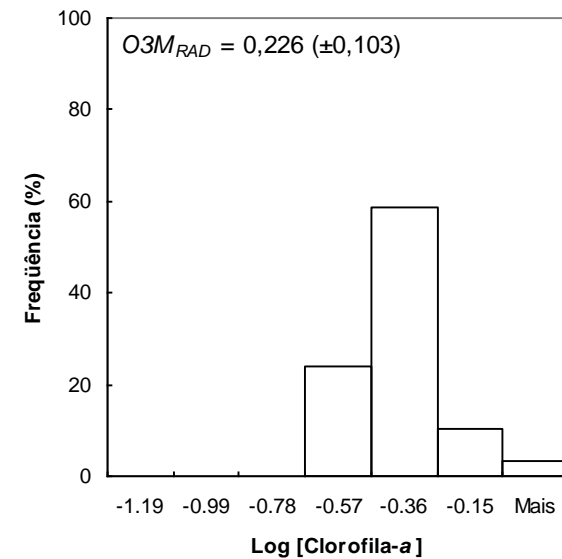
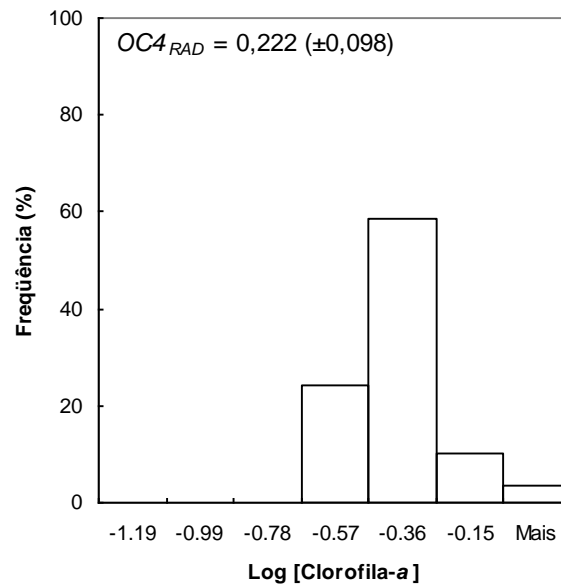
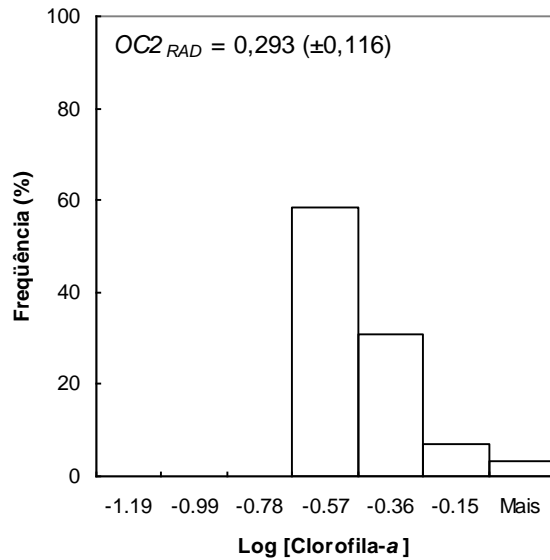


In situ - Above-water Radiometry



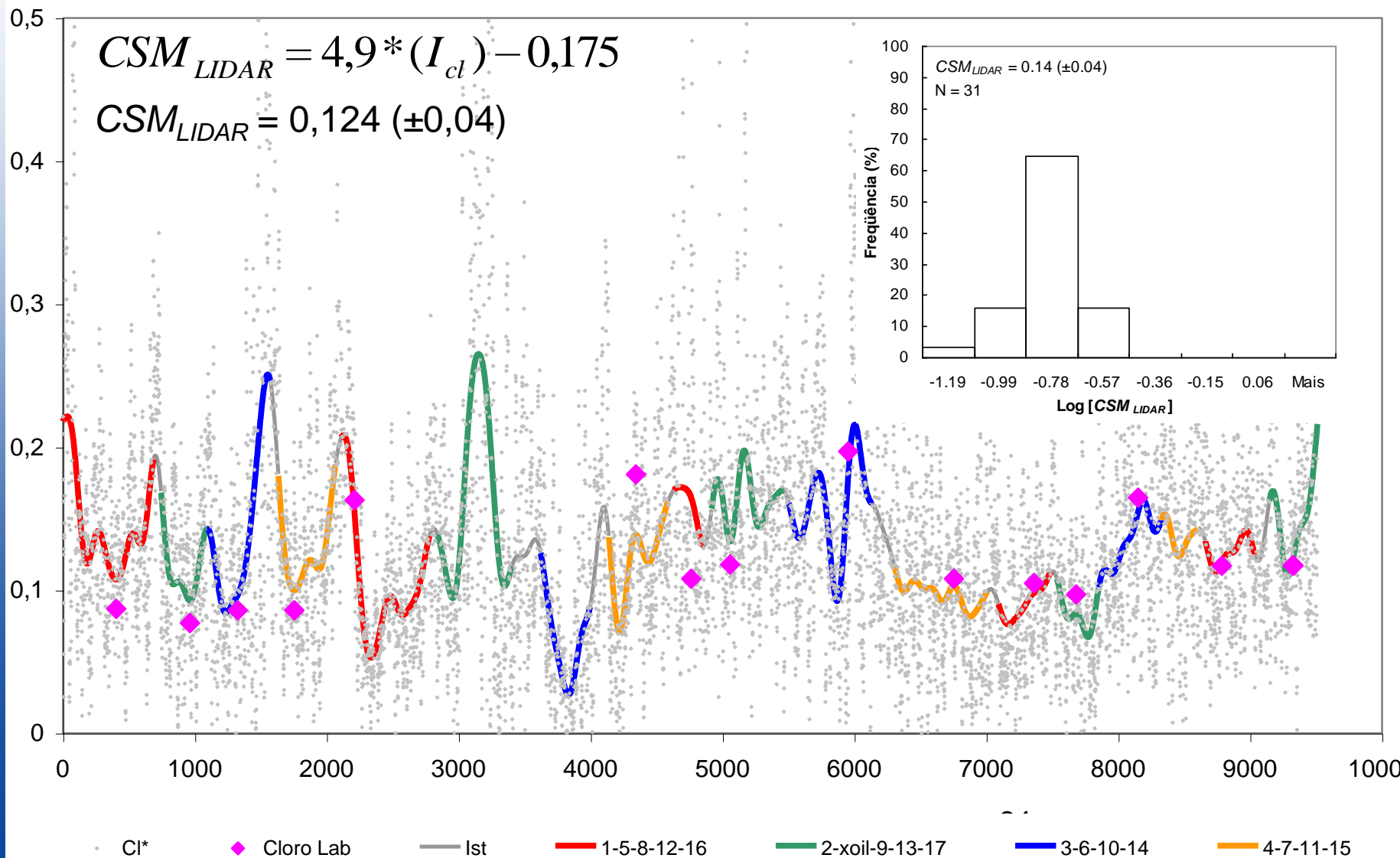
— E02	— E03	— I03	— E04	— E05	— I05	— E06	— D6	— E07
— E08	— I08	— E09	— I09	— E10	— I10	— E11	— E11b	— E12
— I12	— E13	— I13	— E14	— E12	— I15	— E16	— I16	— E17
— I17 a	— E19	— E20	— E21					

In situ - Above-water Radiometry



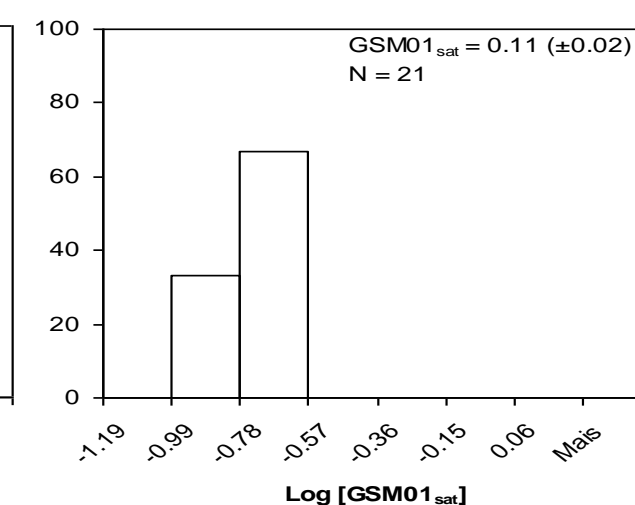
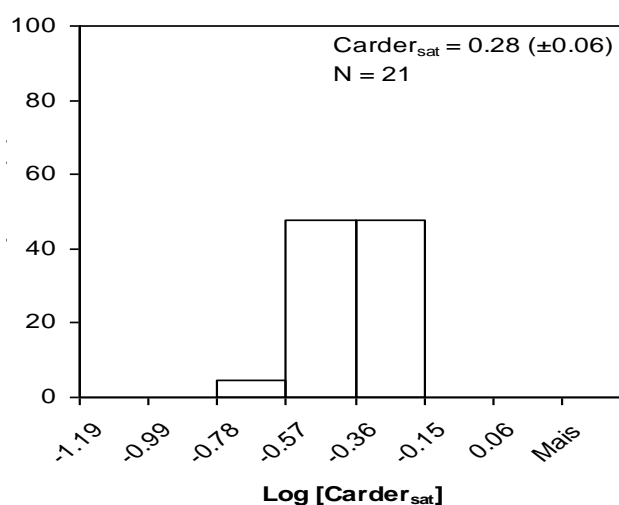
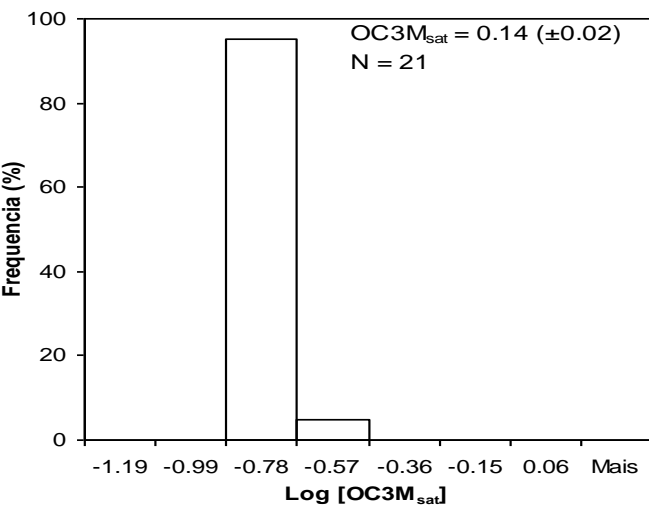
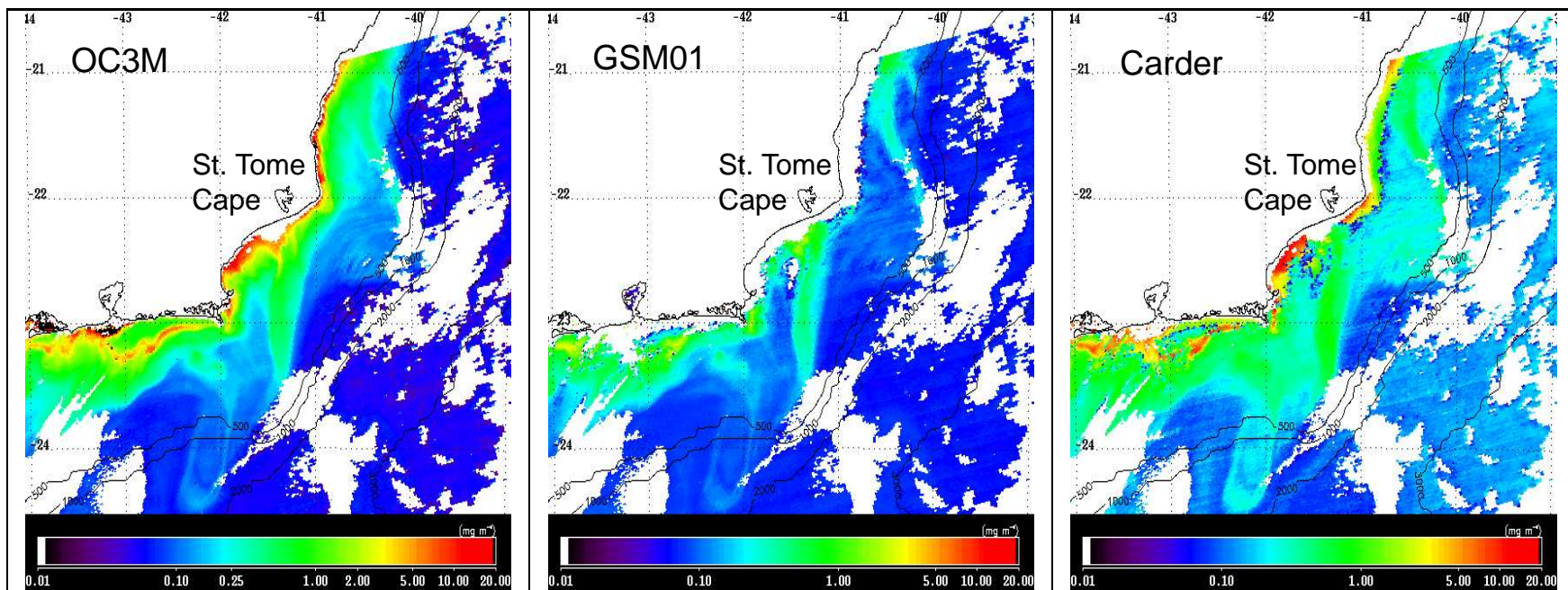


LIDAR





MODIS/Aqua

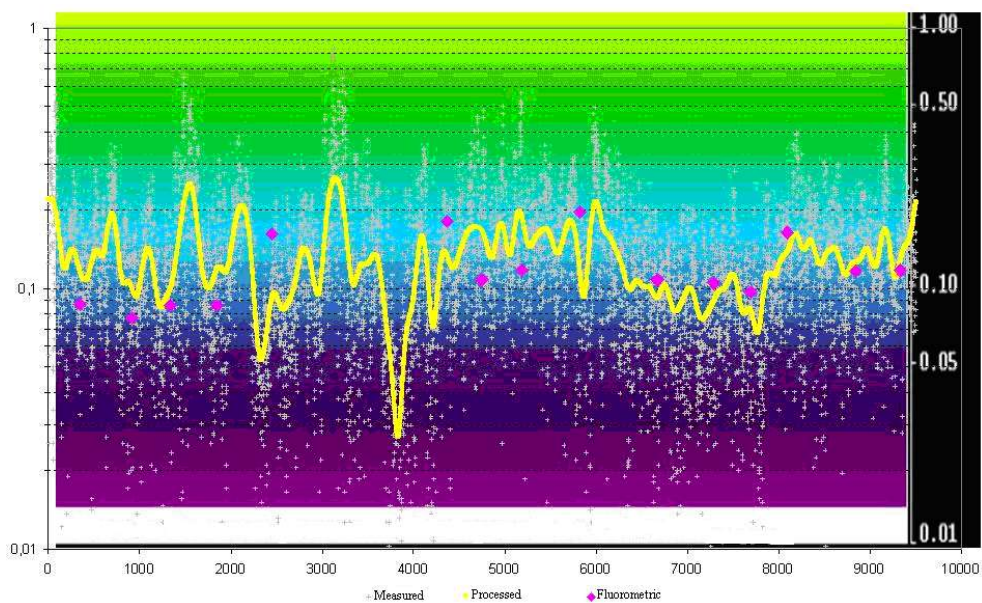
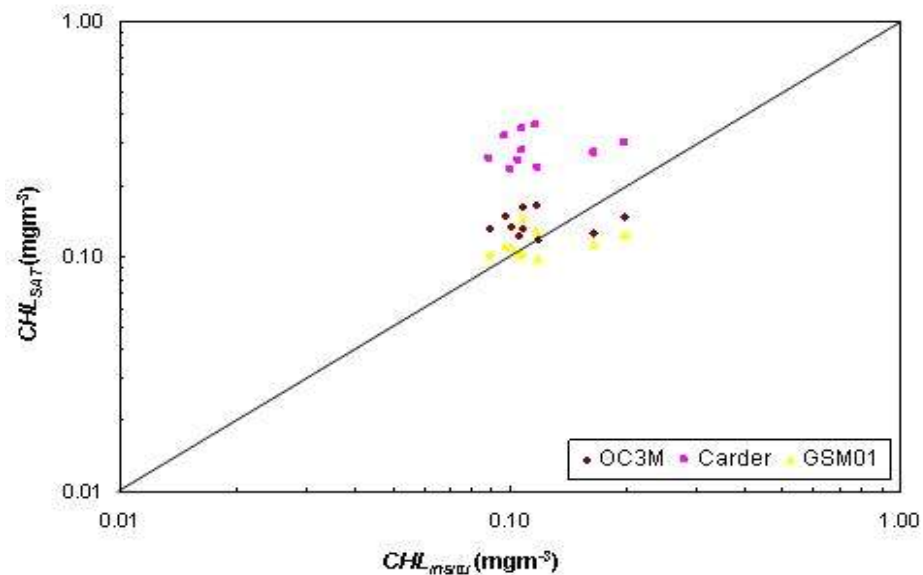
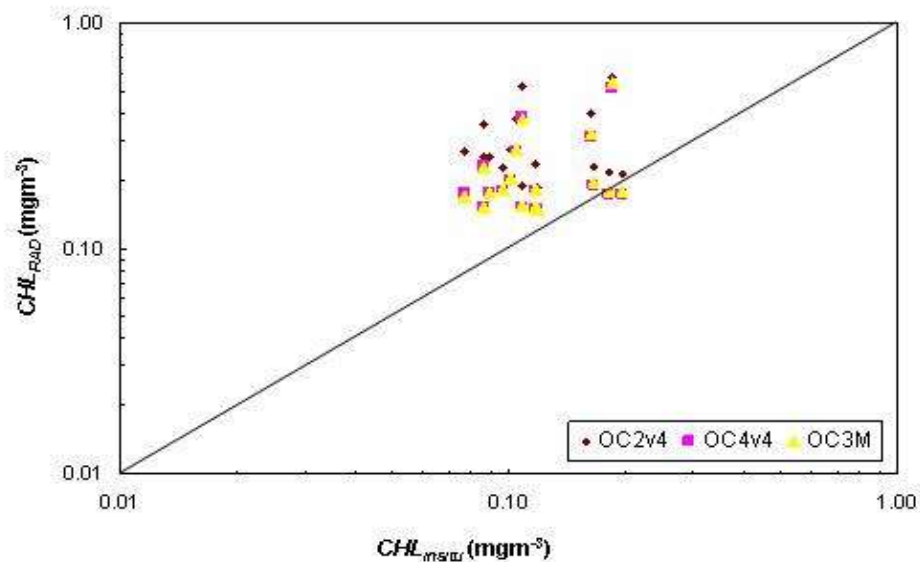




Comparisons

Algorithm/LIDAR	<i>rmse-L</i>	<i>rmse</i>
OC2v4 _{RAD}	1,36	0,40
OC4v4 _{RAD}	0,93	0,28
OC3M _{RAD}	0,93	0,28
OC3M _{SAT}	0,36	0,11
GSM01 _{SAT}	0,28	0,08
Carder _{SAT}	1,14	0,34
CSM _{LIDAR}	0,48	0,14

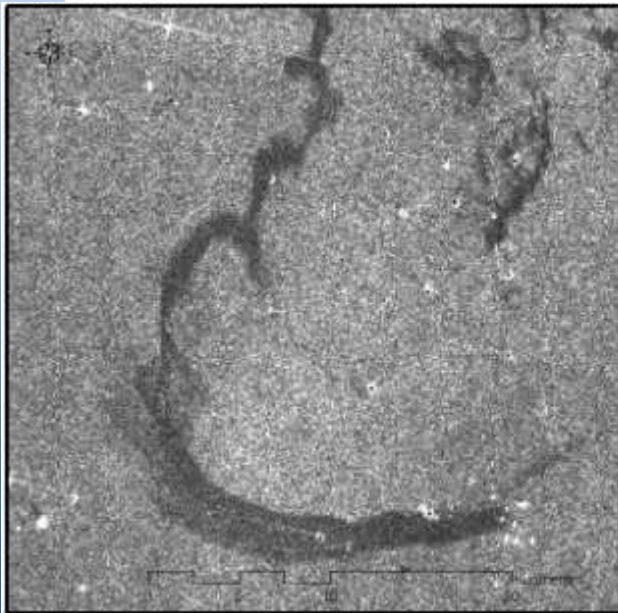
Comparisons



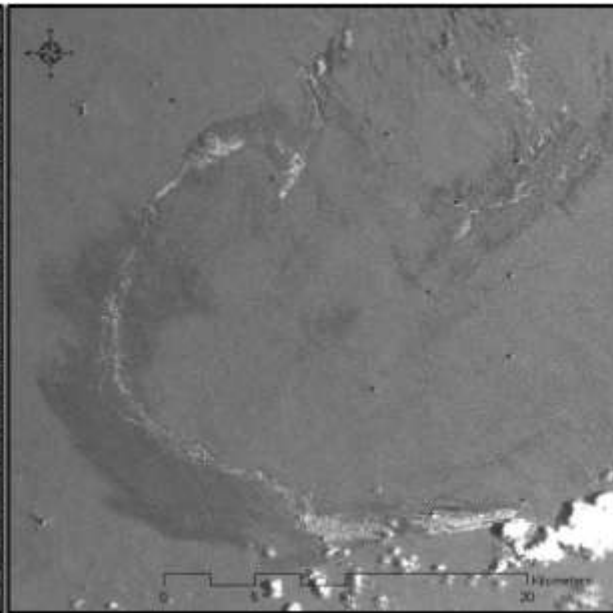


Oil Seepage

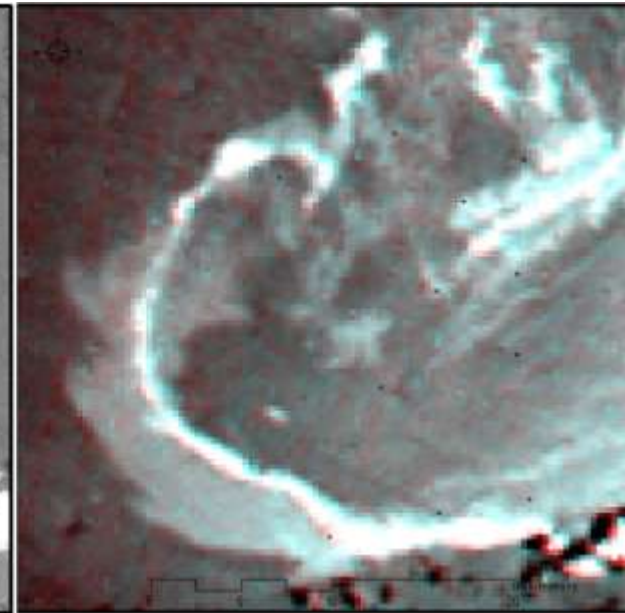
RADARSAT – Banda C
Res: 50 m



ASTER b1 (0,5-0,6 μm)
Res: 15 m

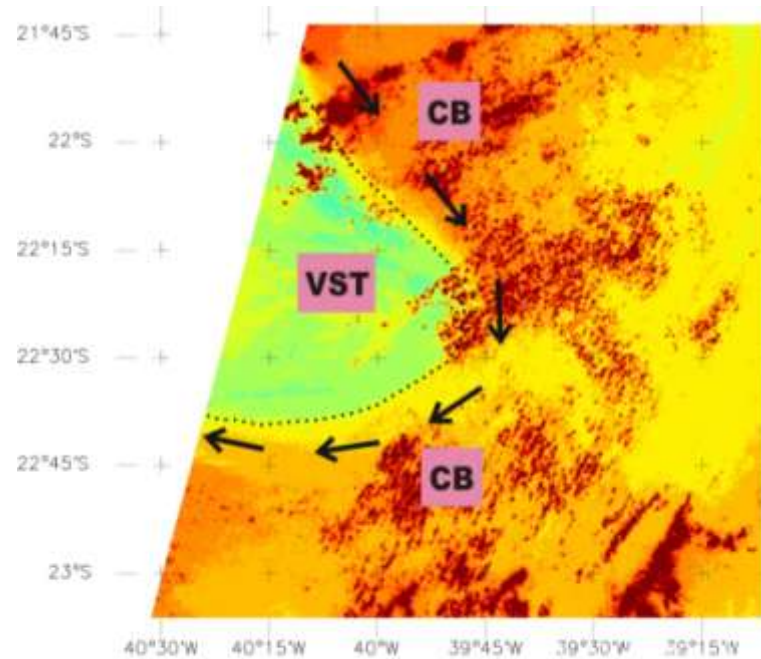
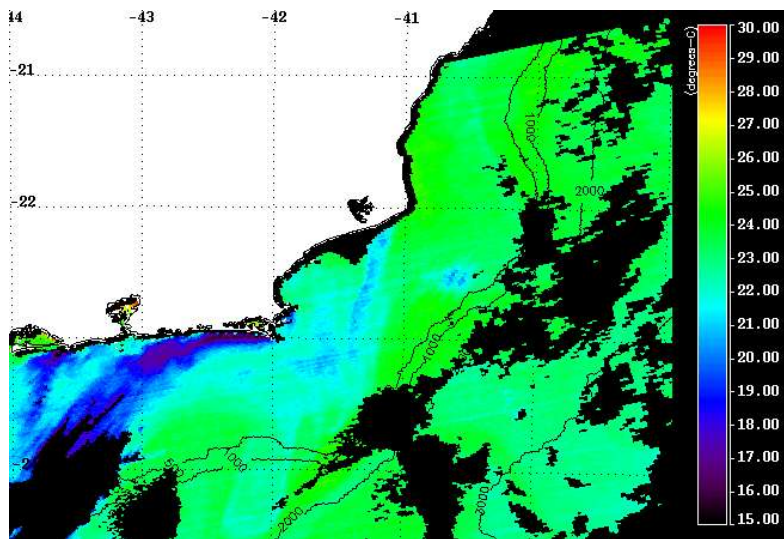
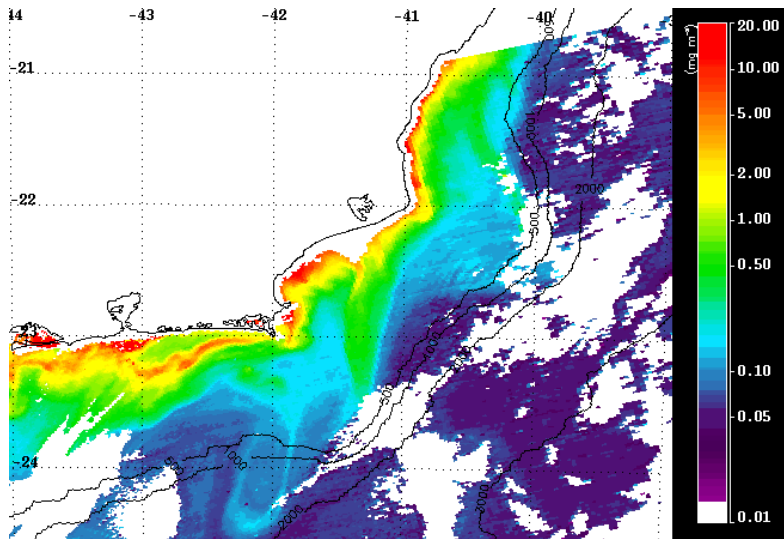


CBERS-2 2r1g1b
b1 (0,63-0,69 μm)
b2 (0,77-0,89 μm)
Res: 260 m

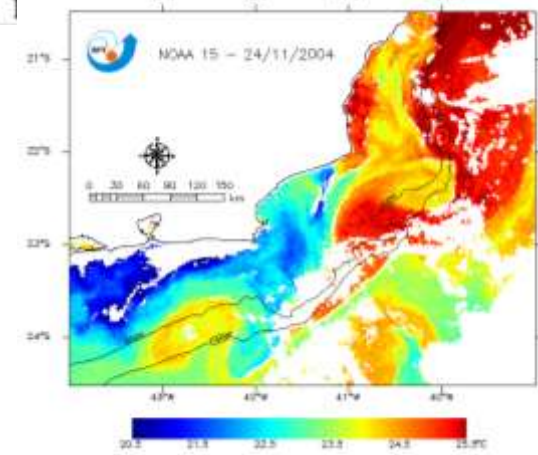




MODIS – MERIS - AVHRR

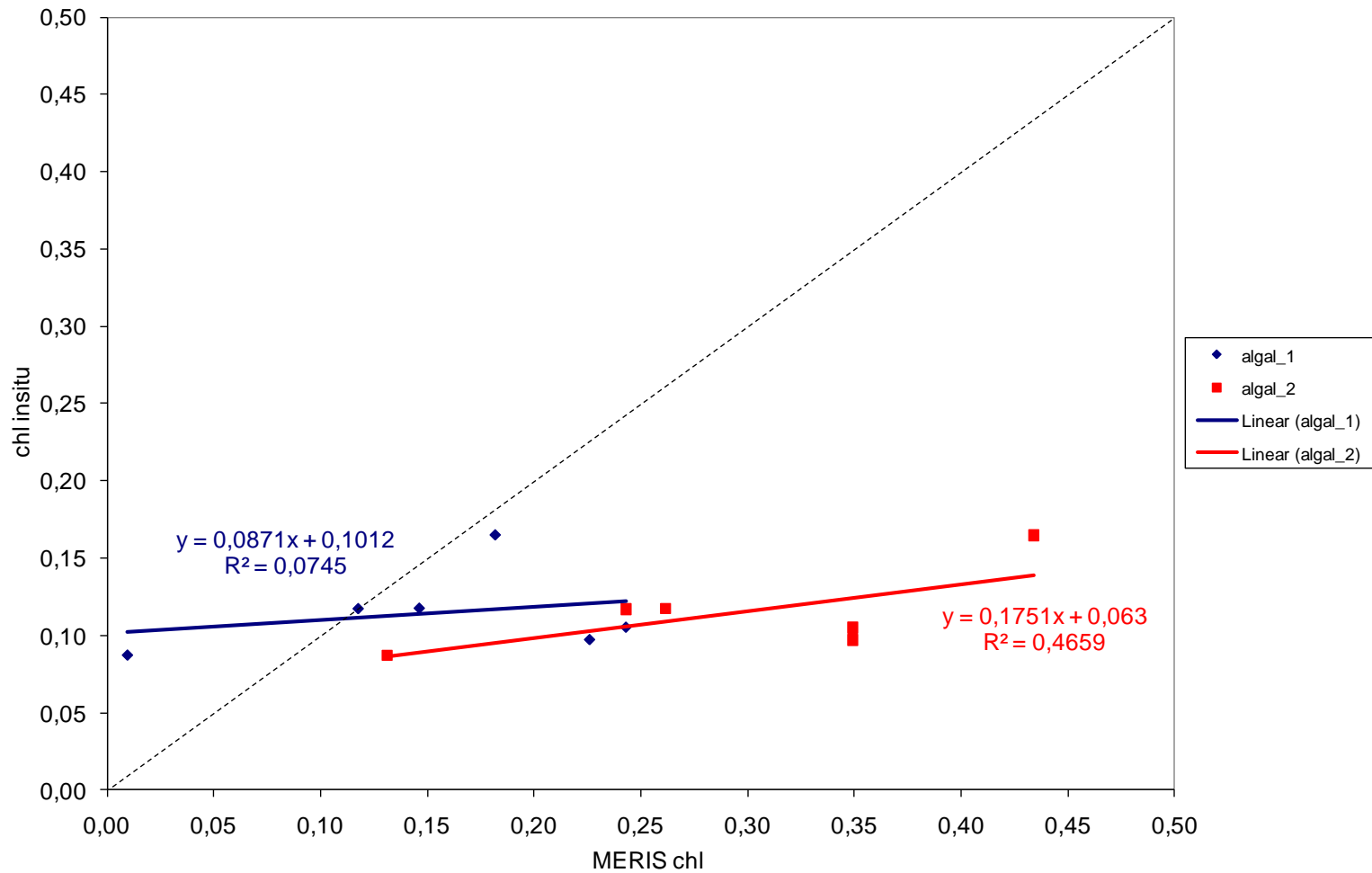


MERIS Band 1 Nov. 25, 2004

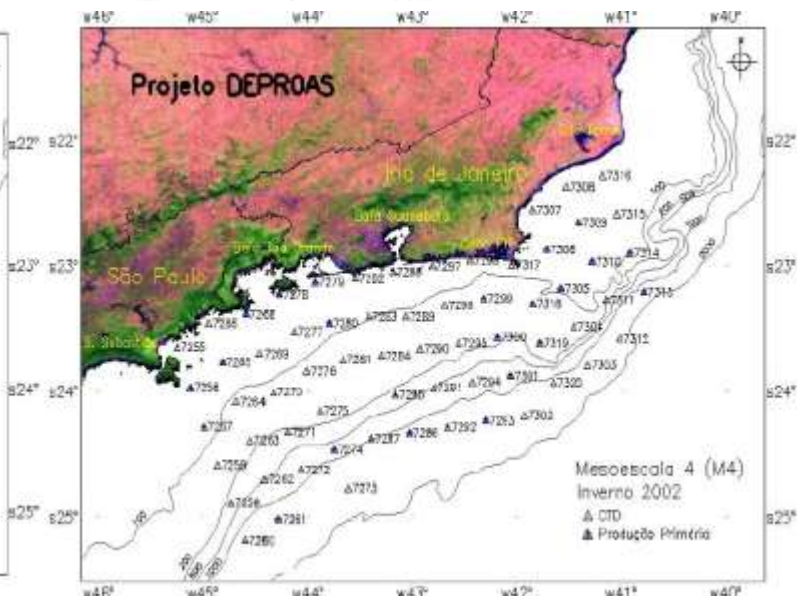
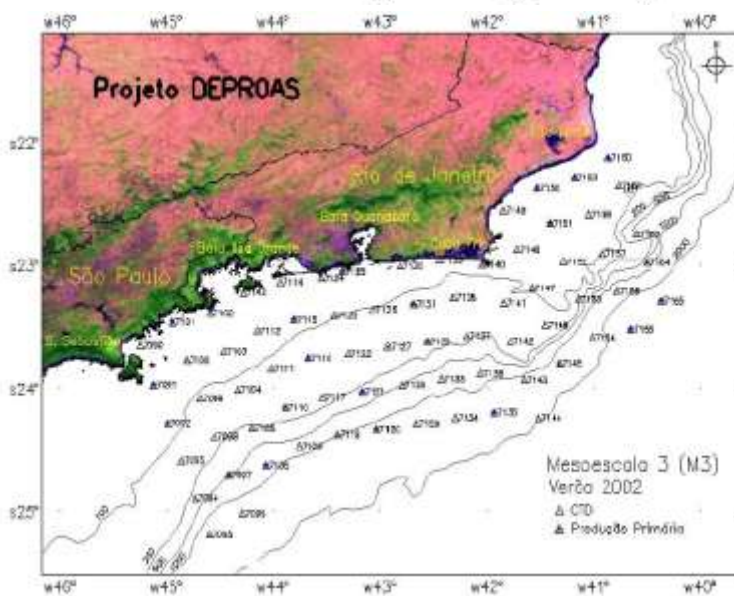




MERIS x In situ Chl Comparisons

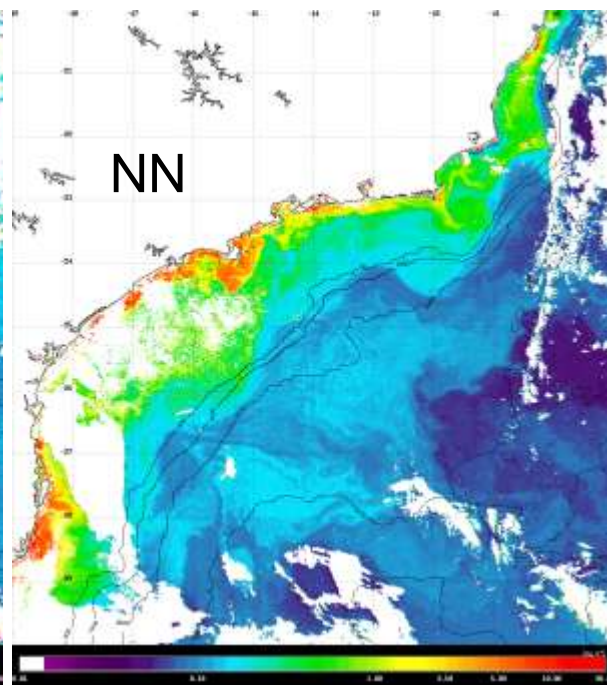
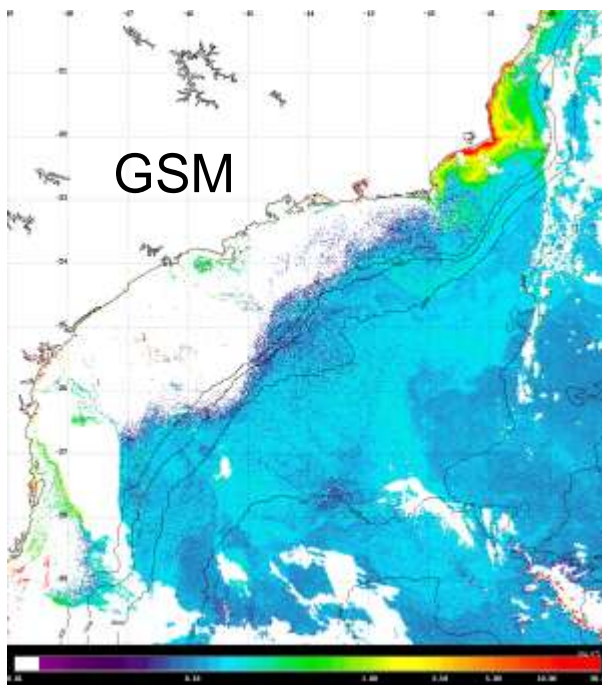
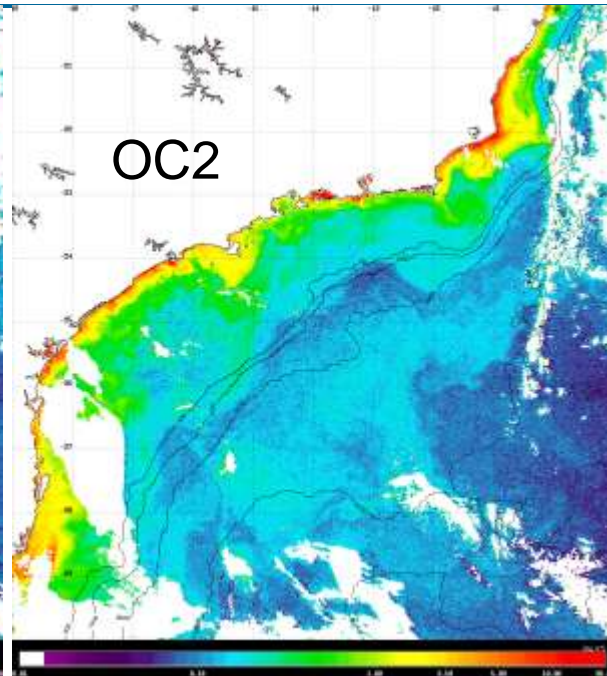
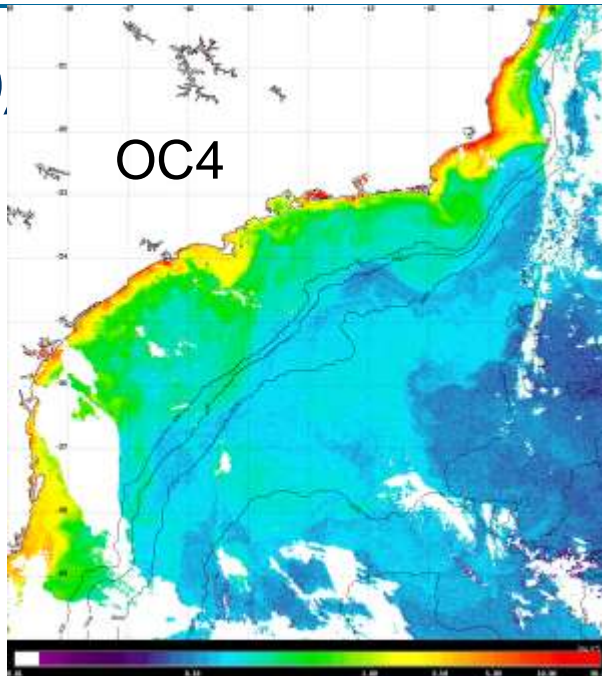


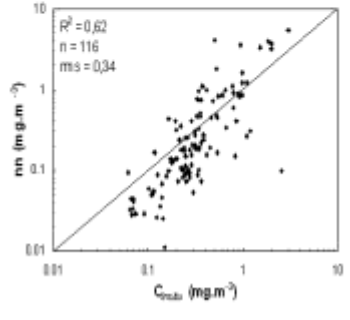
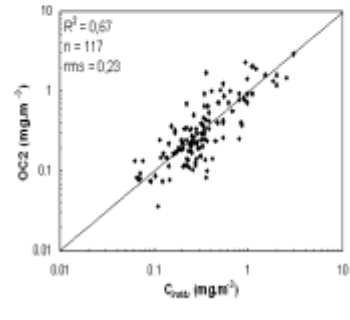
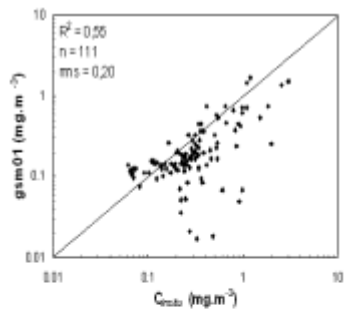
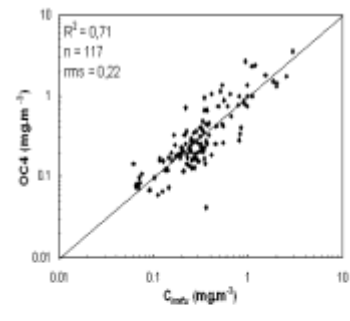
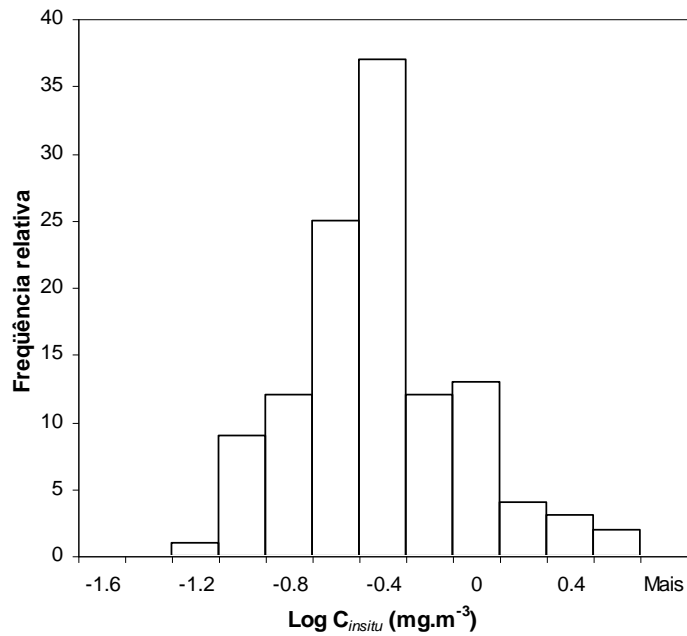
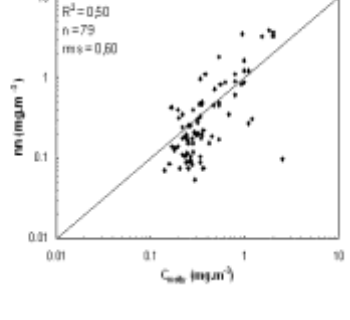
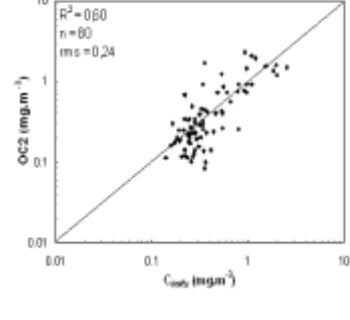
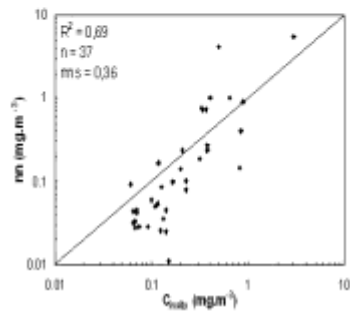
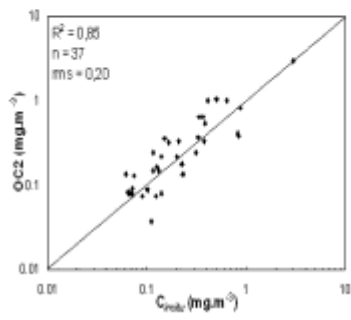
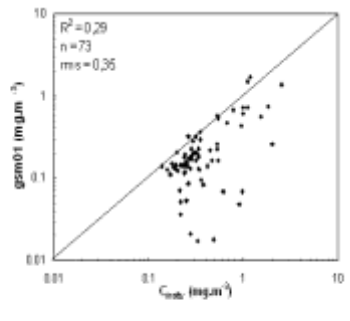
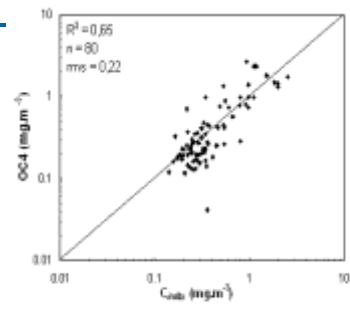
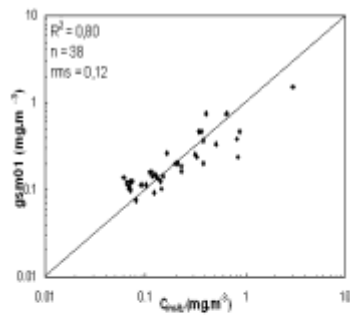
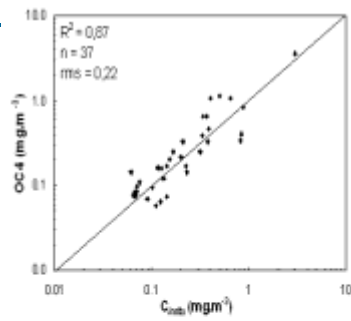
DEPROAS Project

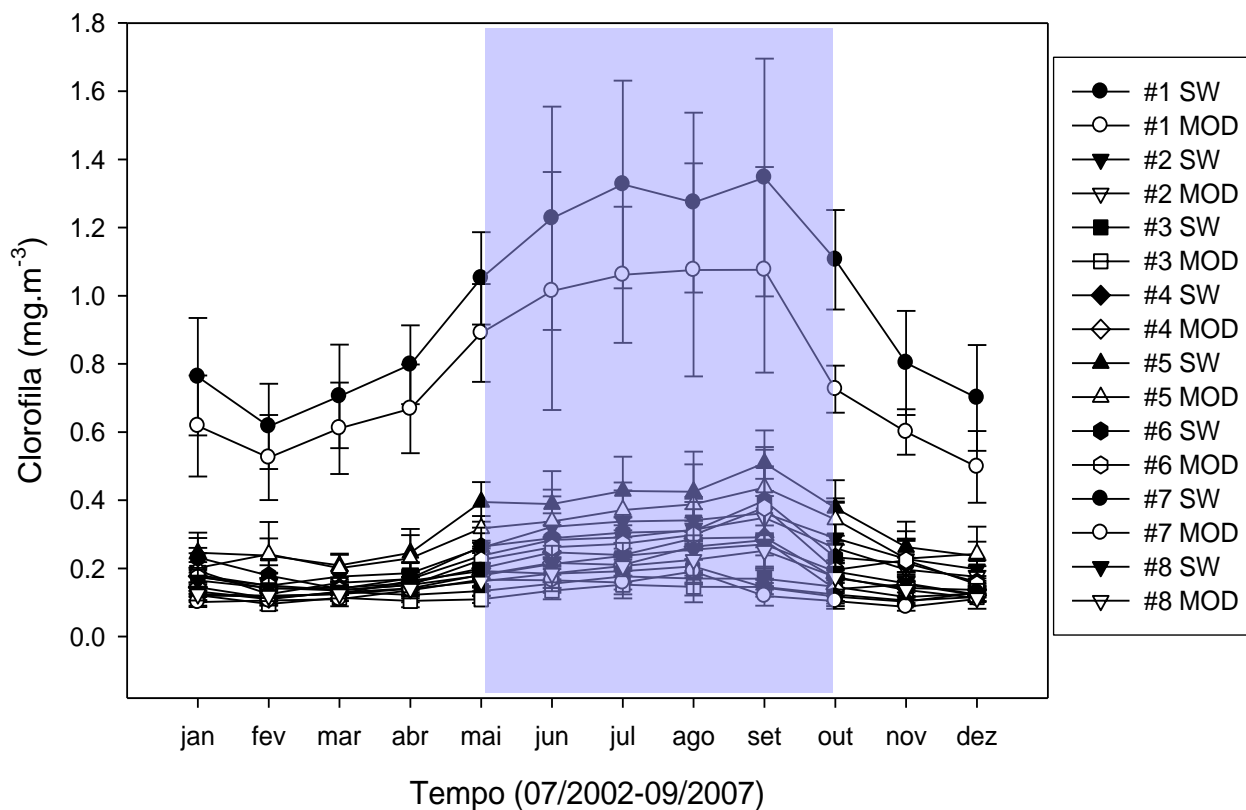




DEPRO

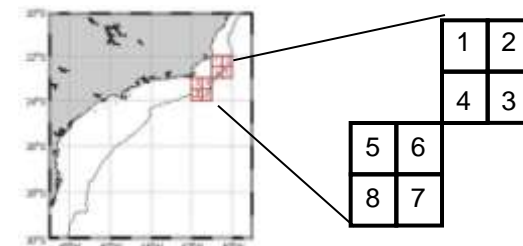




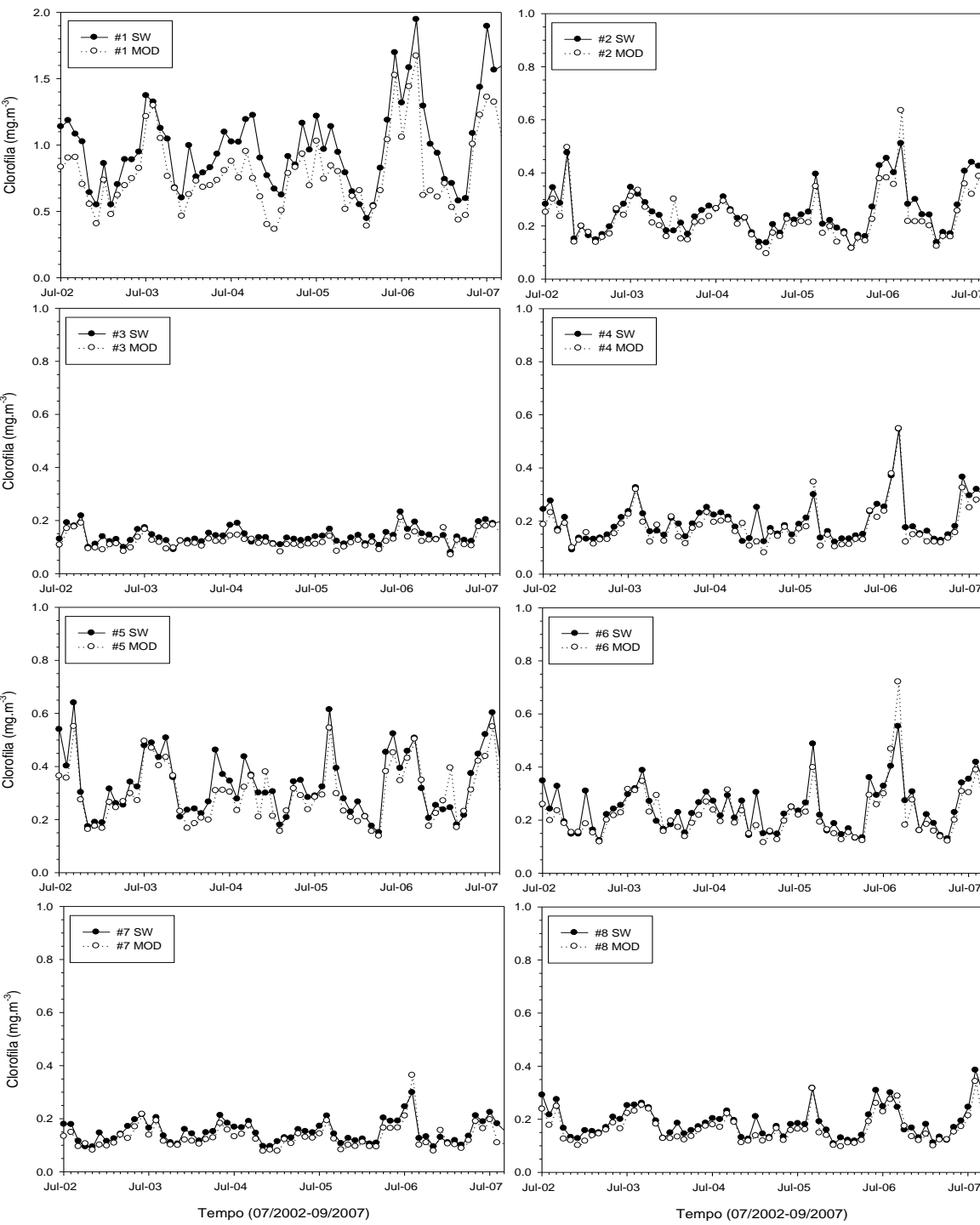


#1 – SW=0,99 MOD=0,79 mg.m⁻³

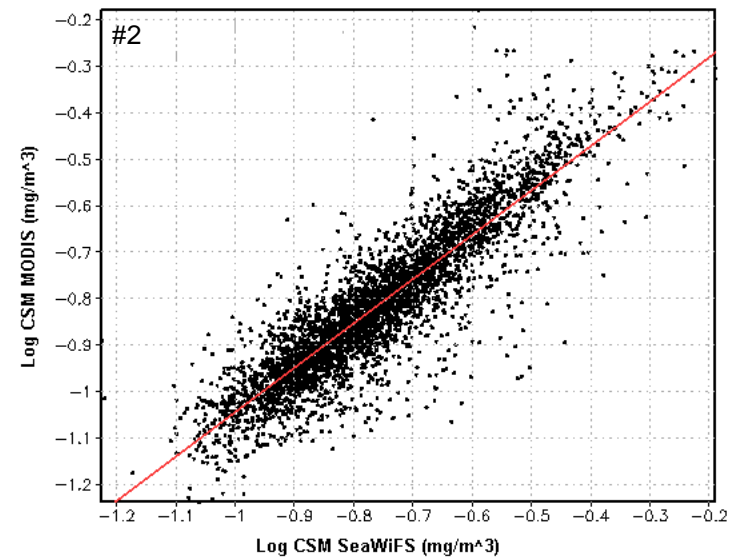
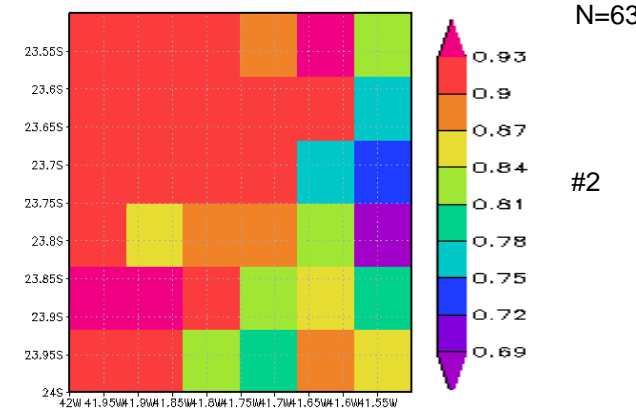
#5 – SW=0,34 MOD=0,30 mg.m⁻³



SeaWifs - MODIS

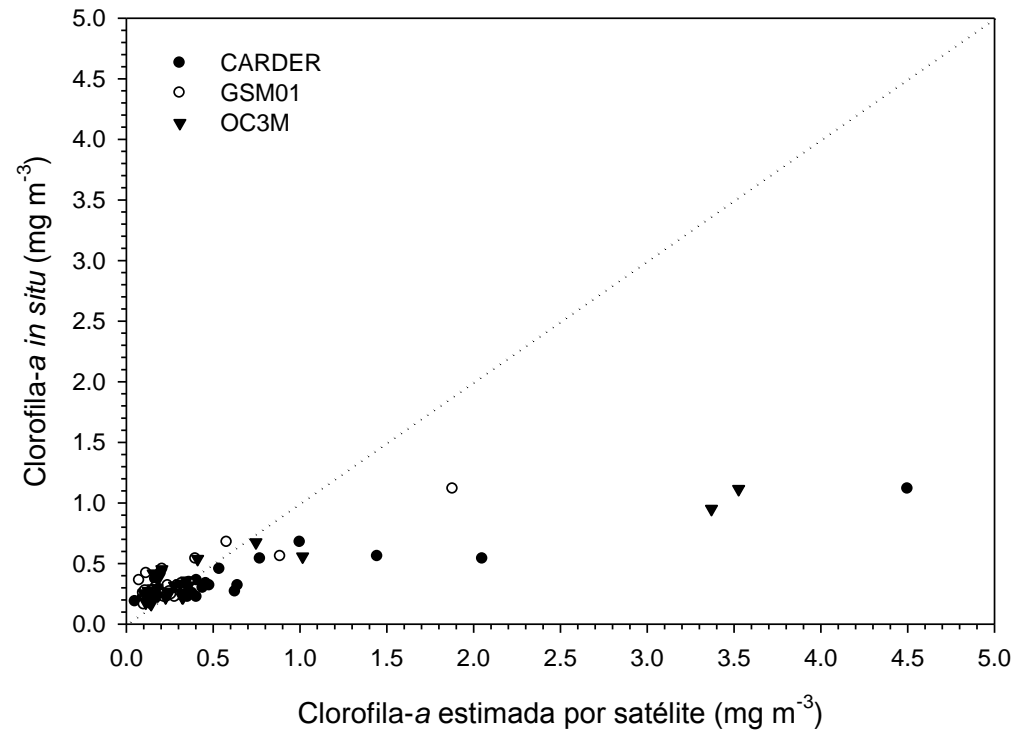


Caixas	rmse-L	RDP	r ²	Declividade	Intersecção
#1	0,41	-19,47	0.83	0.78	0.02
#2	0,24	-9,07	0.86	0.93	-0.01
#3	0,26	-12,93	0.83	0.84	0.00
#4	0,28	-10,13	0.89	0.96	-0.01
#5	0,27	-9,49	0.83	0.81	0.03
#6	0,27	-8,92	0.80	0.95	-0.01
#7	0,28	-13,68	0.85	0.99	-0.02
#8	0,24	-11,28	0.88	0.88	0.00



MODIS x in situ

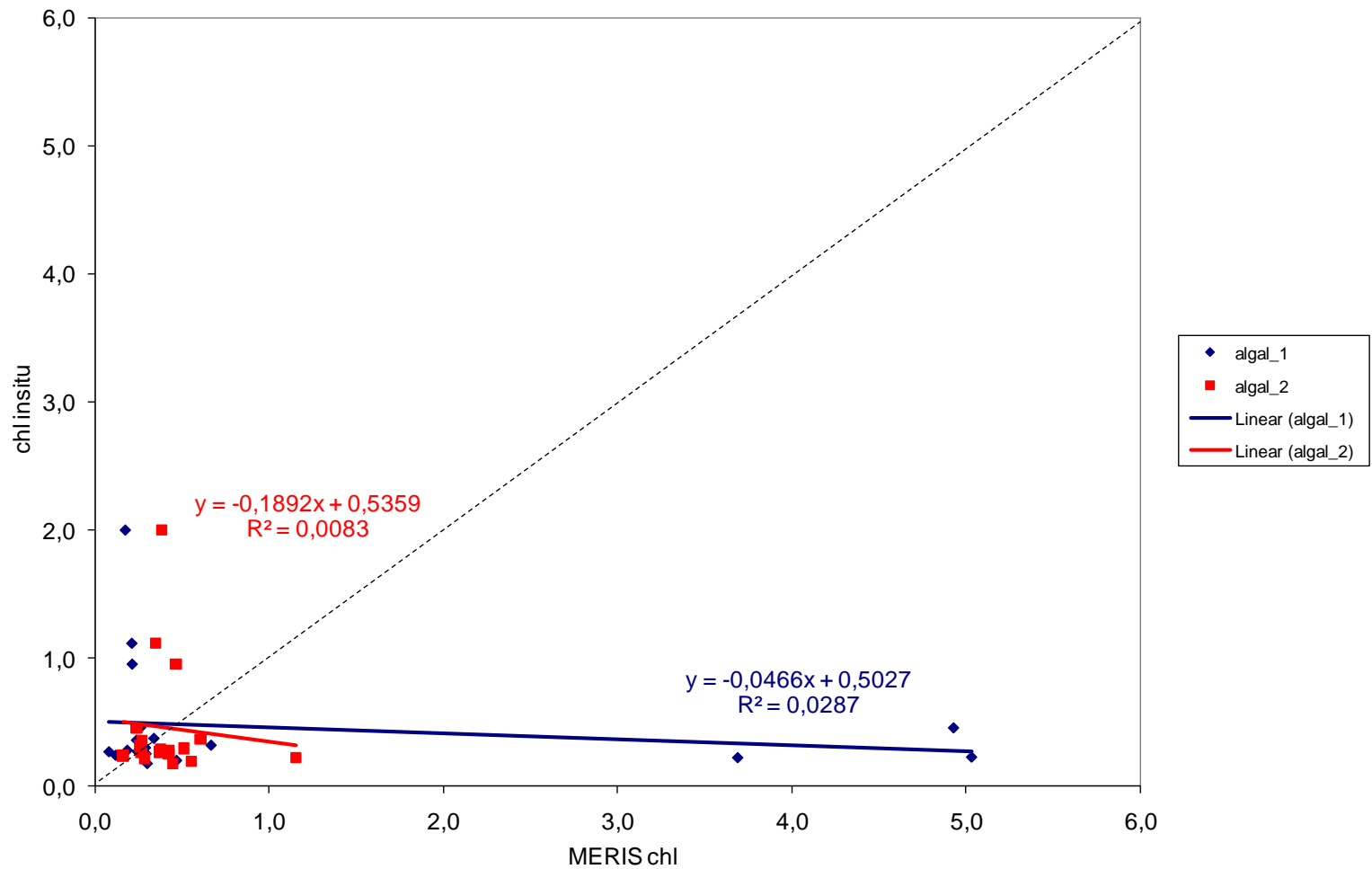
Chl = 0,14 e 2,55 mg.m⁻³, avg=0,49 (± 0,46) mg.m⁻³



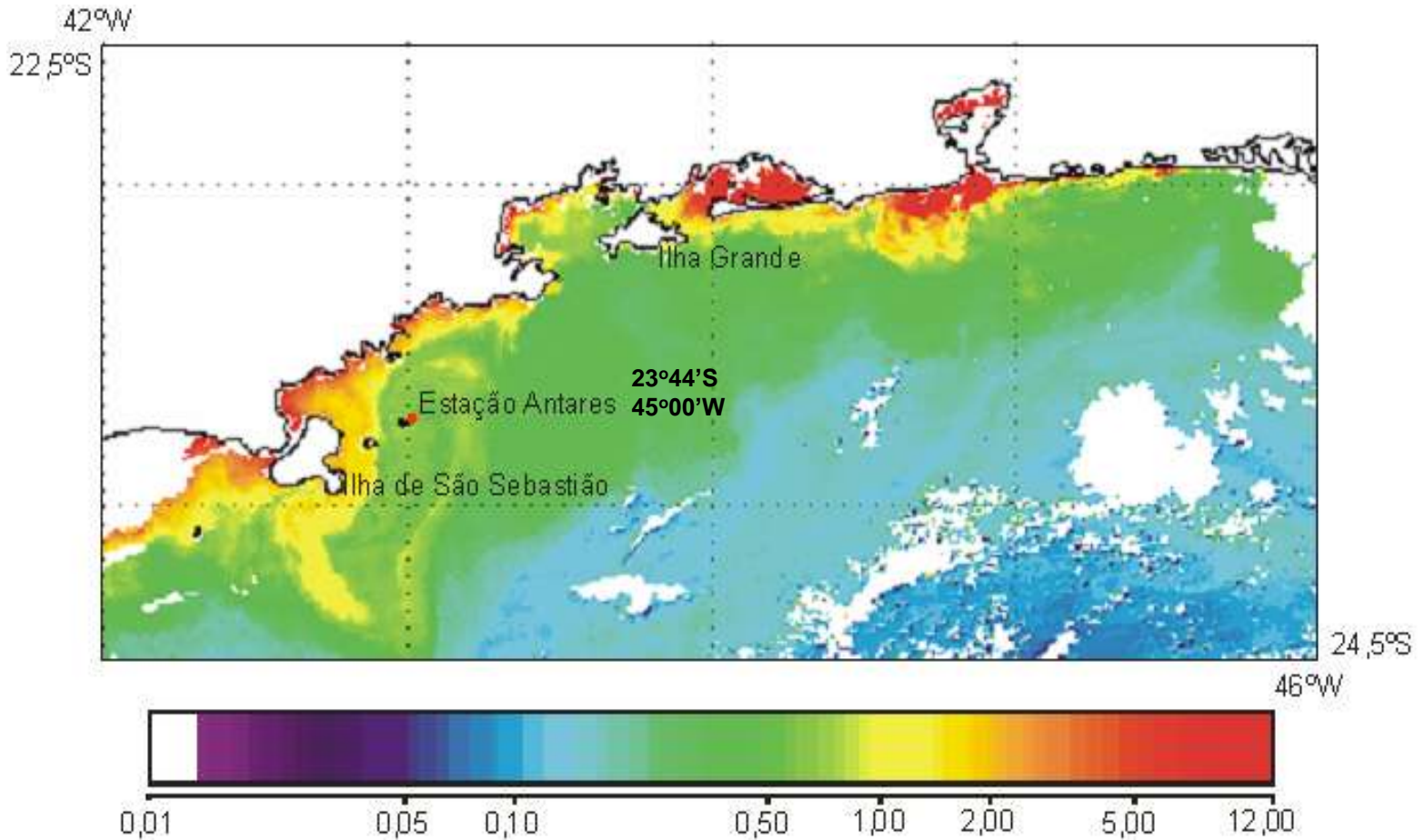
Algoritmo	rmse	rmse-L	RDP	r ²	Declividade	Intersecção	N
OC3M	0,23	0,76	1,32	0,82	3,38	-0,71	31
CARDER	0,29	0,97	32,29	0,82	4,05	-0,82	30
GSM01	0,25	0,82	-22,19	0,81	1,62	-0,24	30



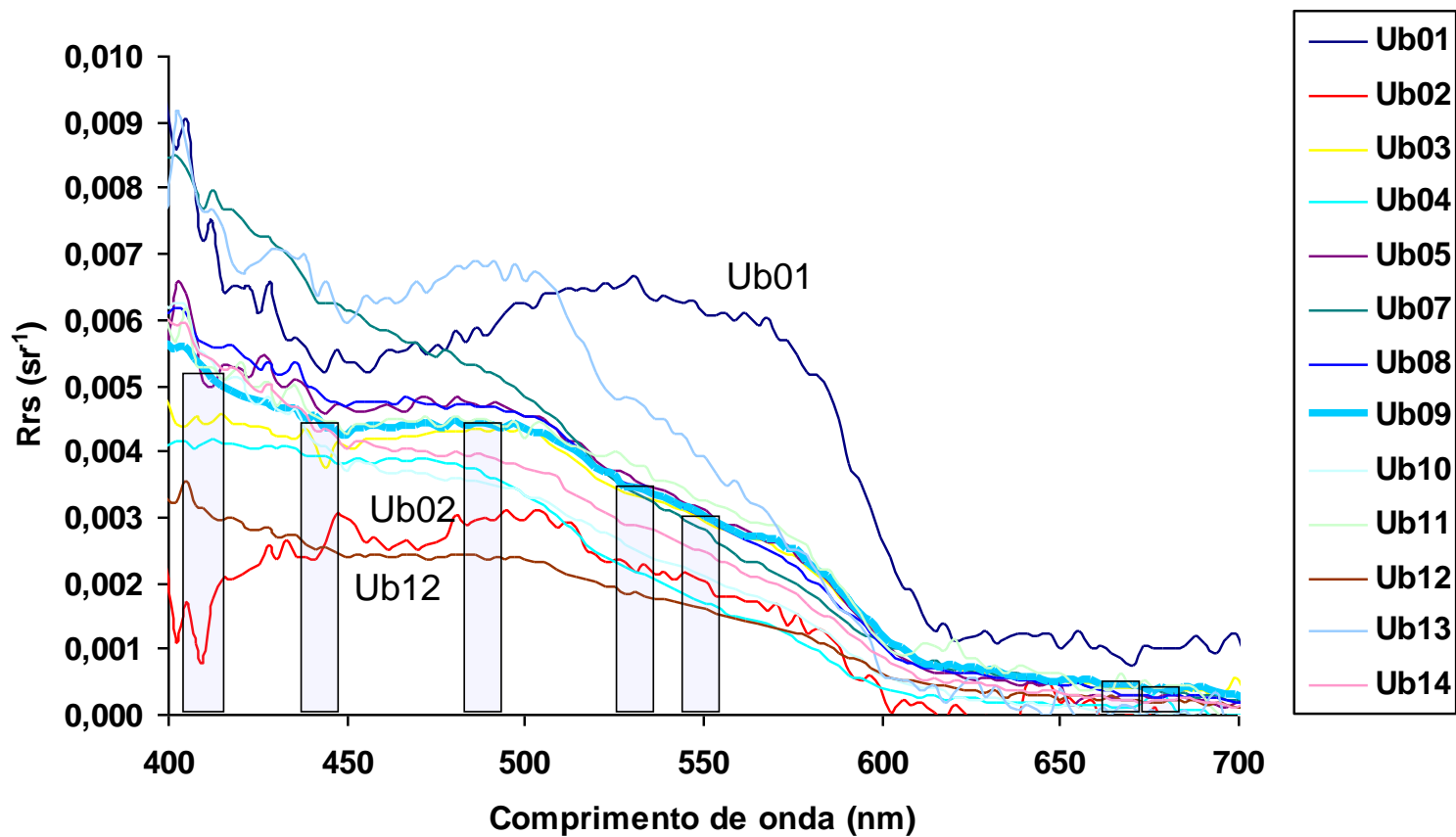
MERIS x In situ



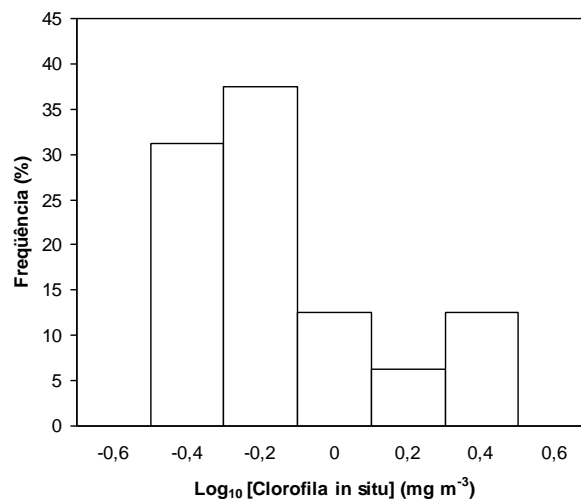
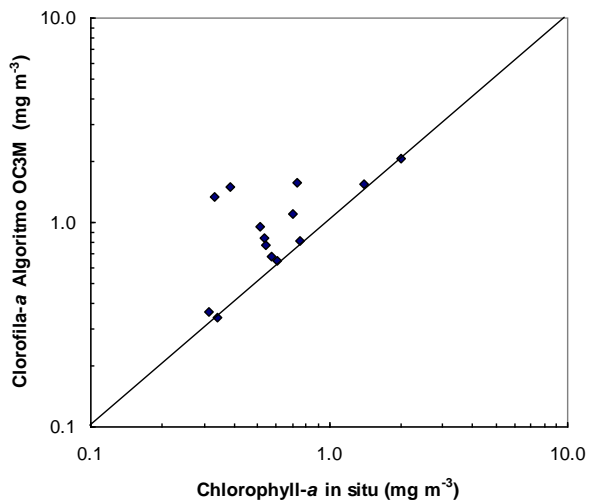
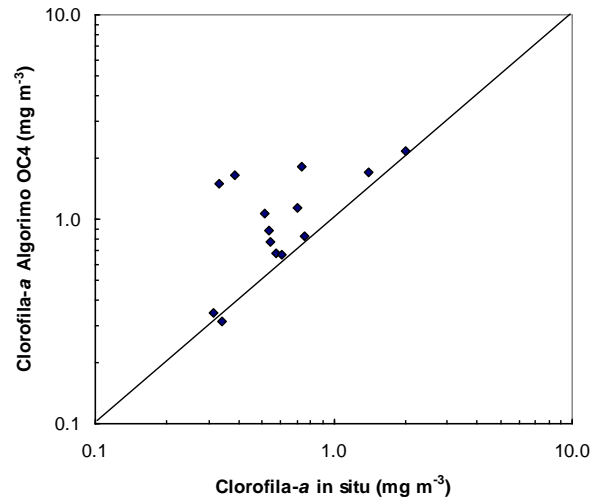
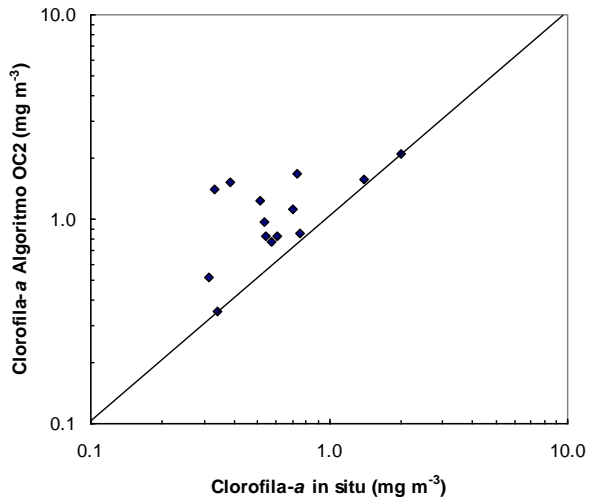
ANTARES-Ubatuba TST



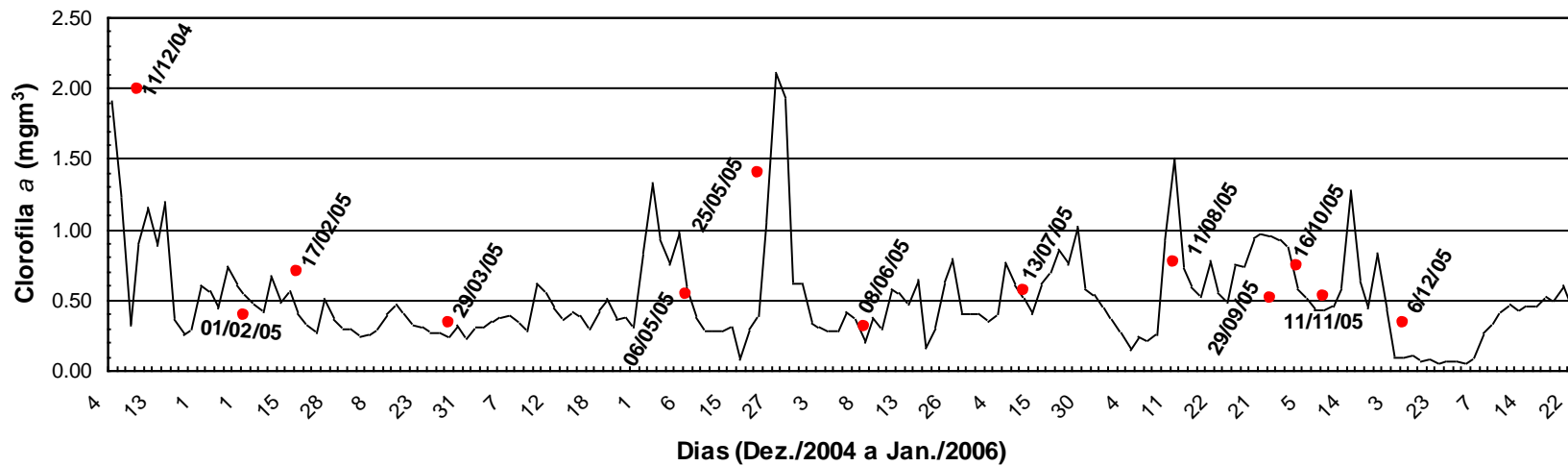
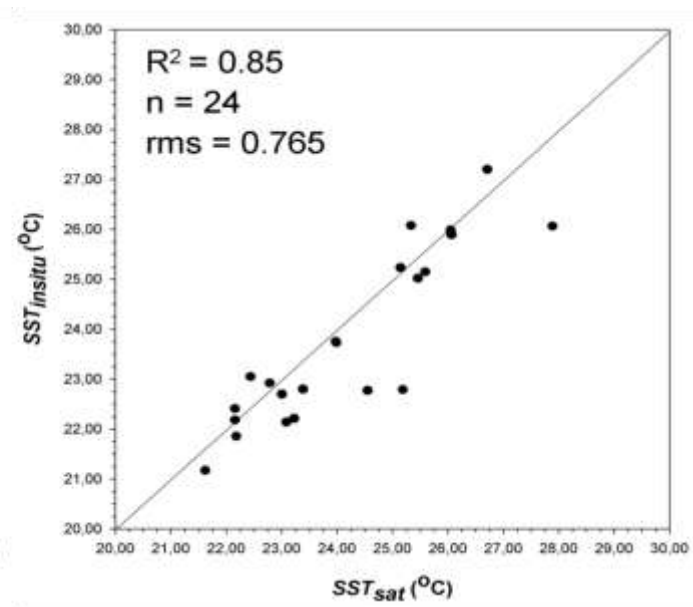
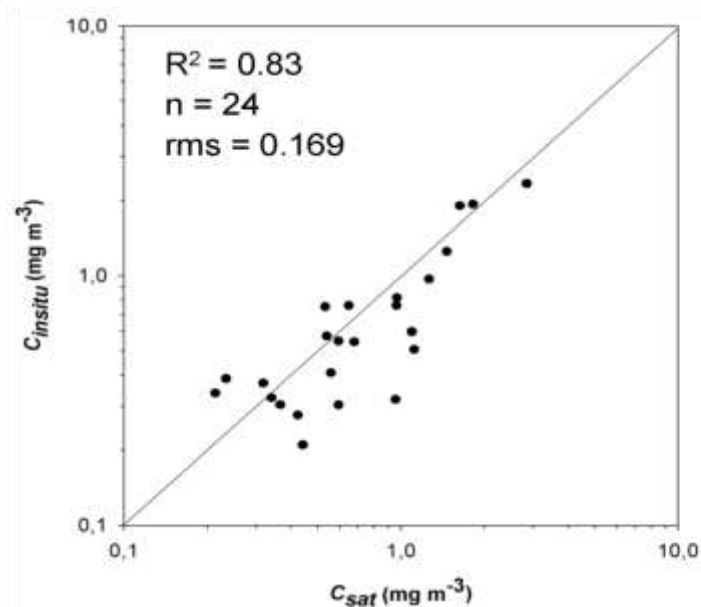
Above-water radiometry



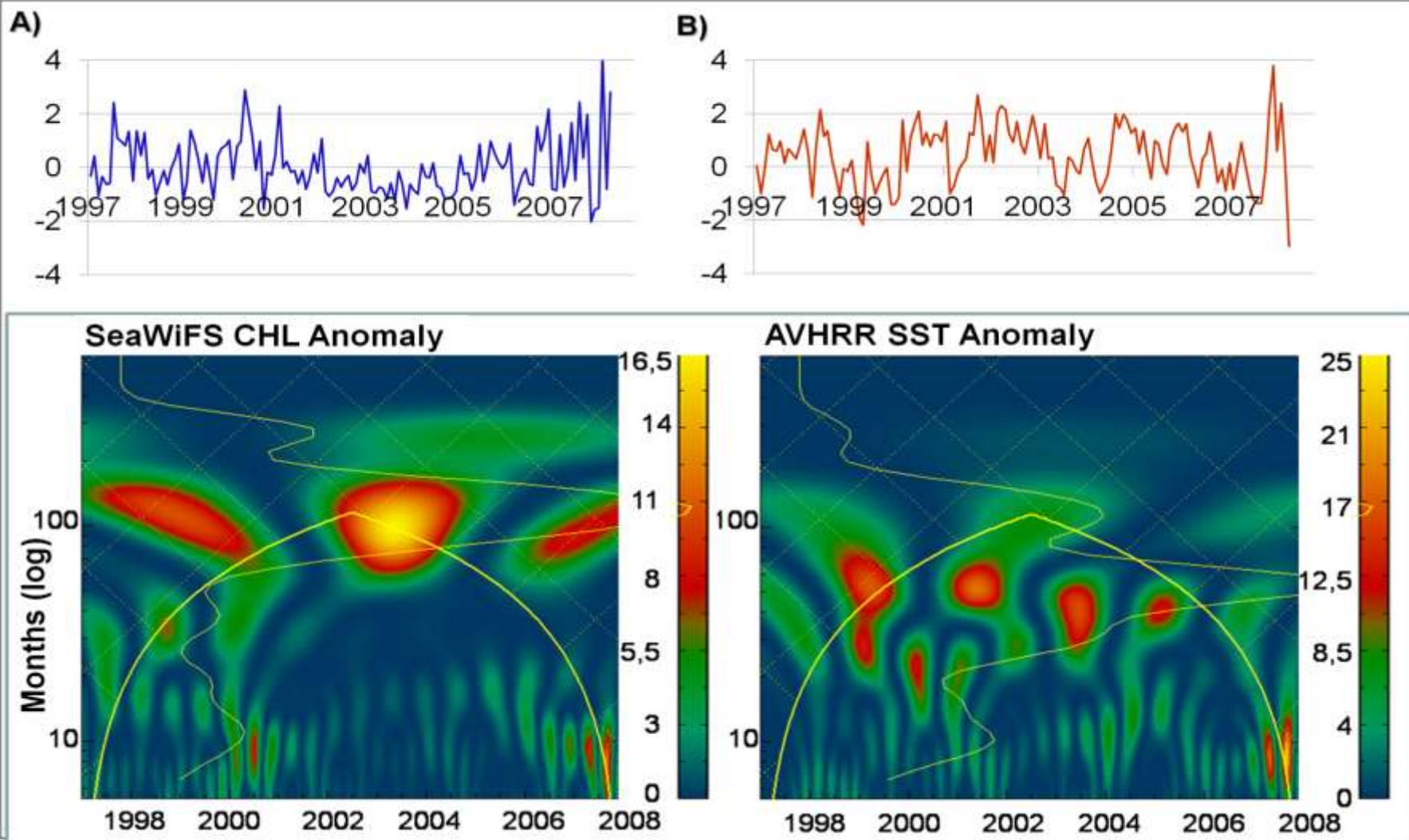
Empirical algorithms comparison

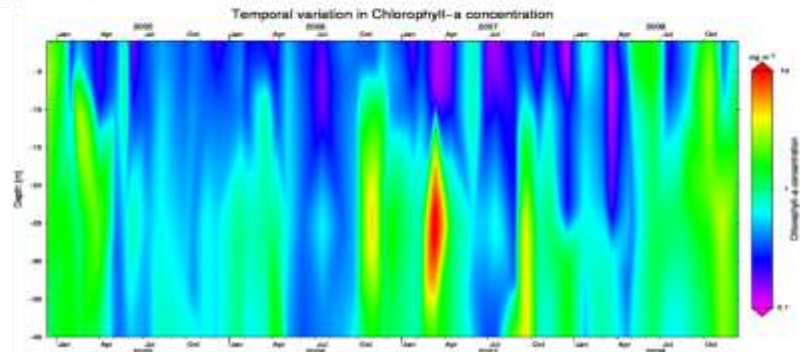
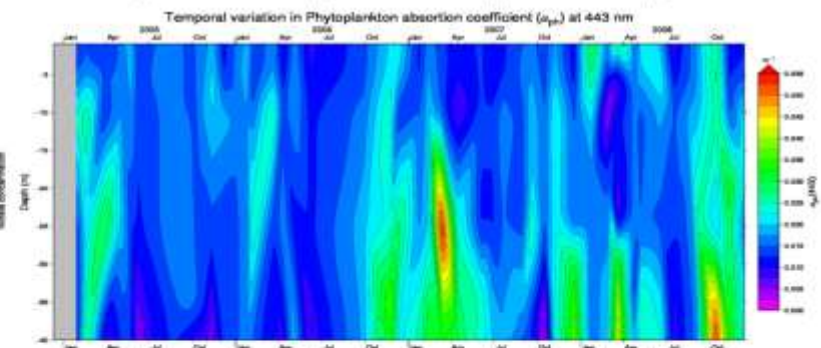
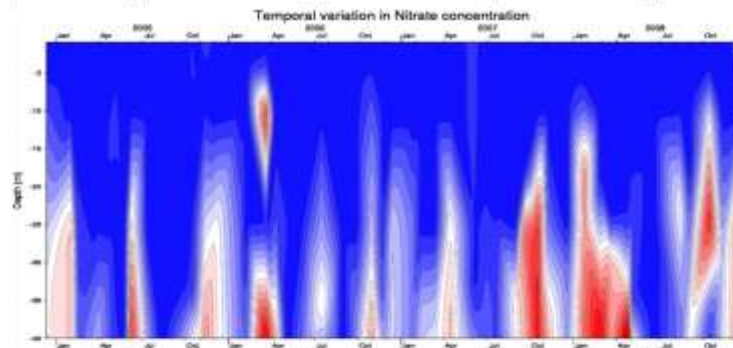
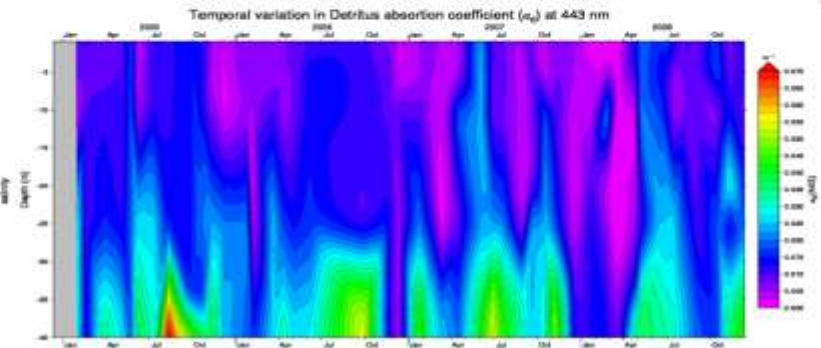
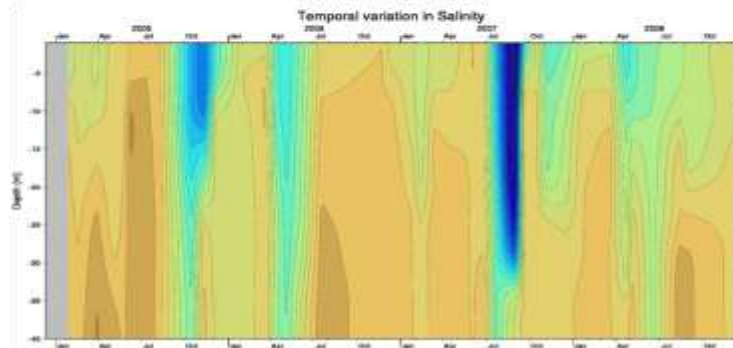
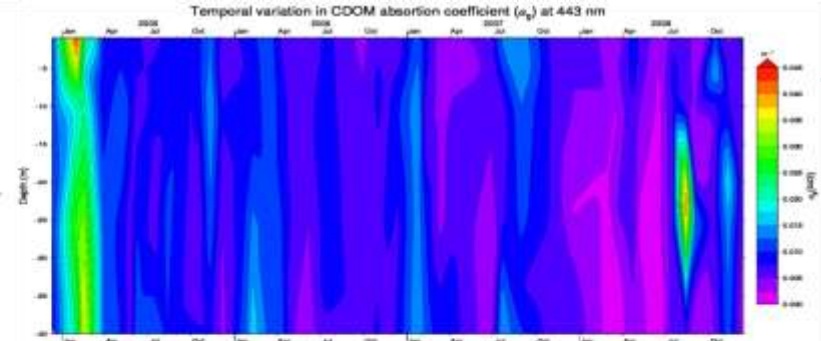
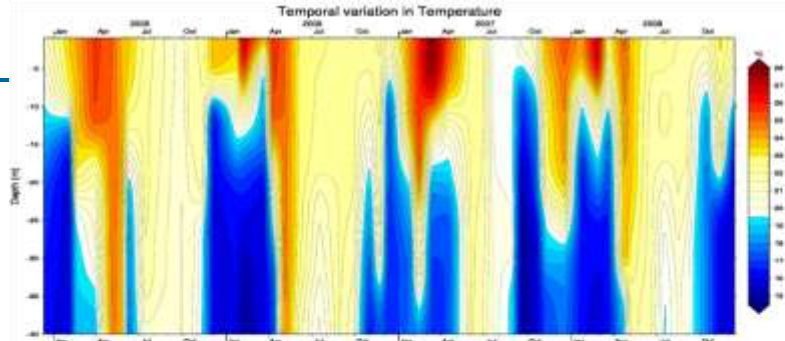


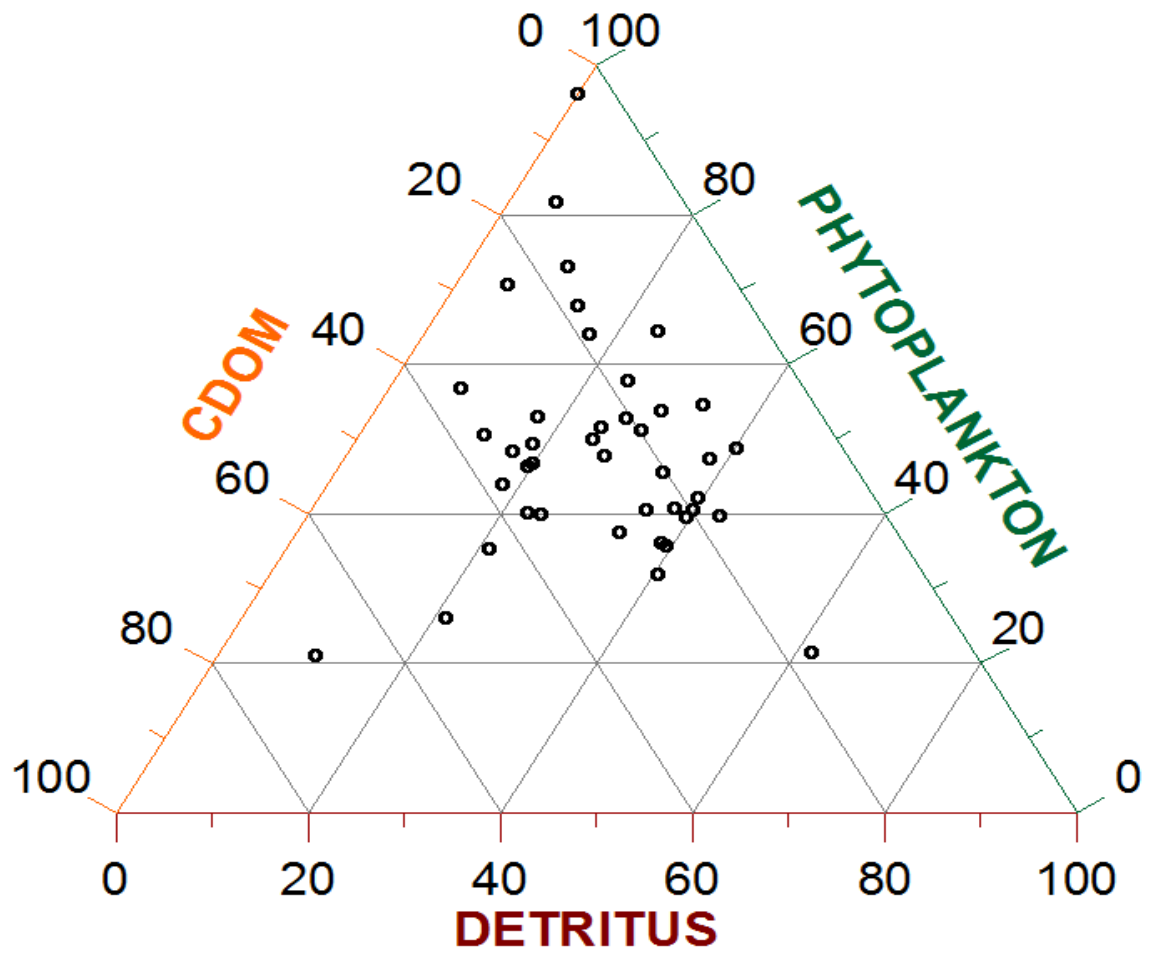
Satellite x in situ



Variability analysis

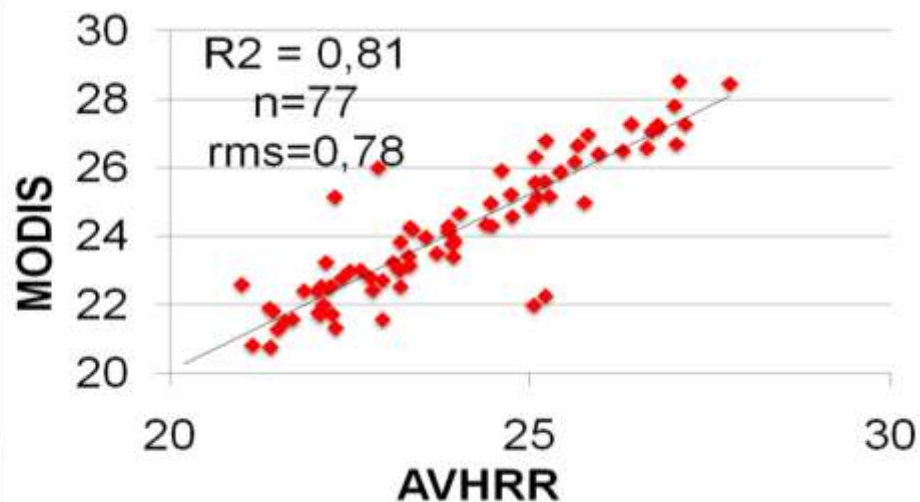
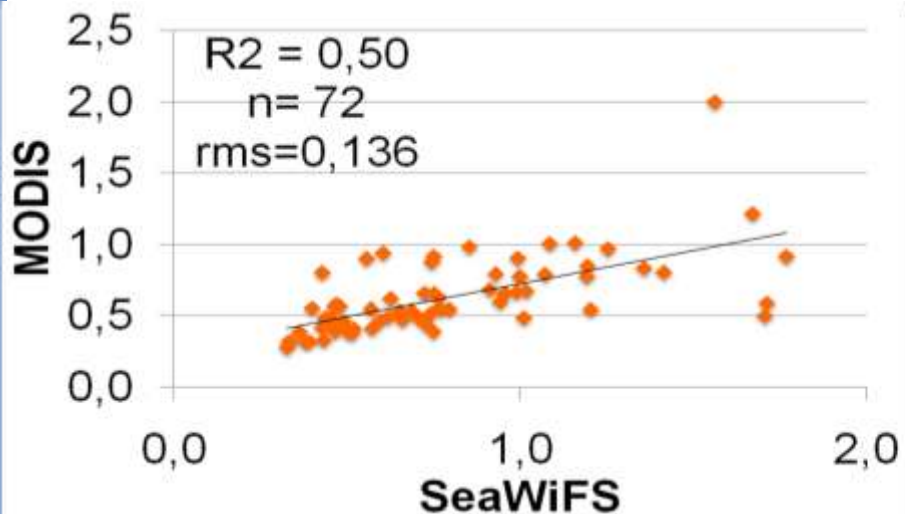
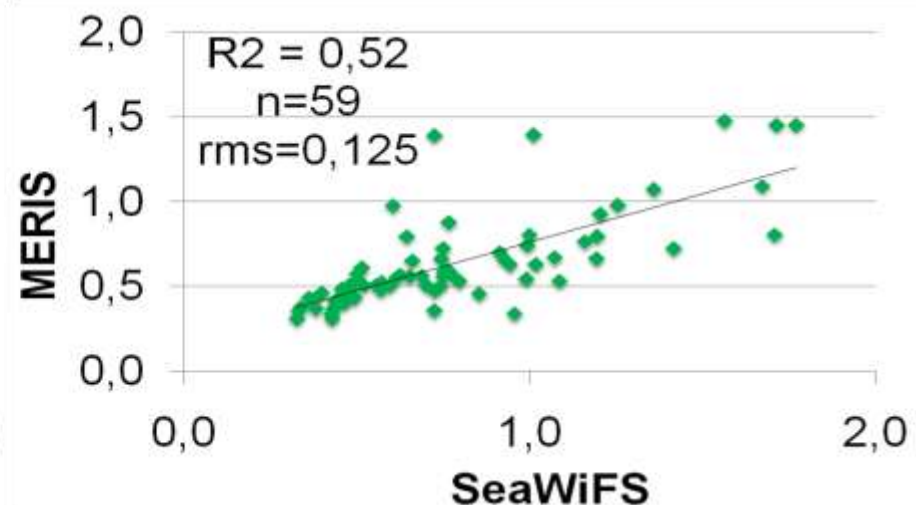
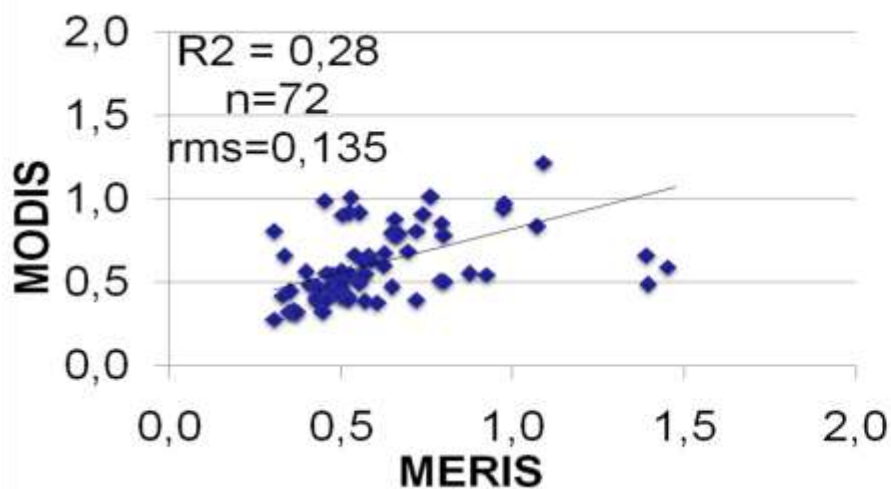


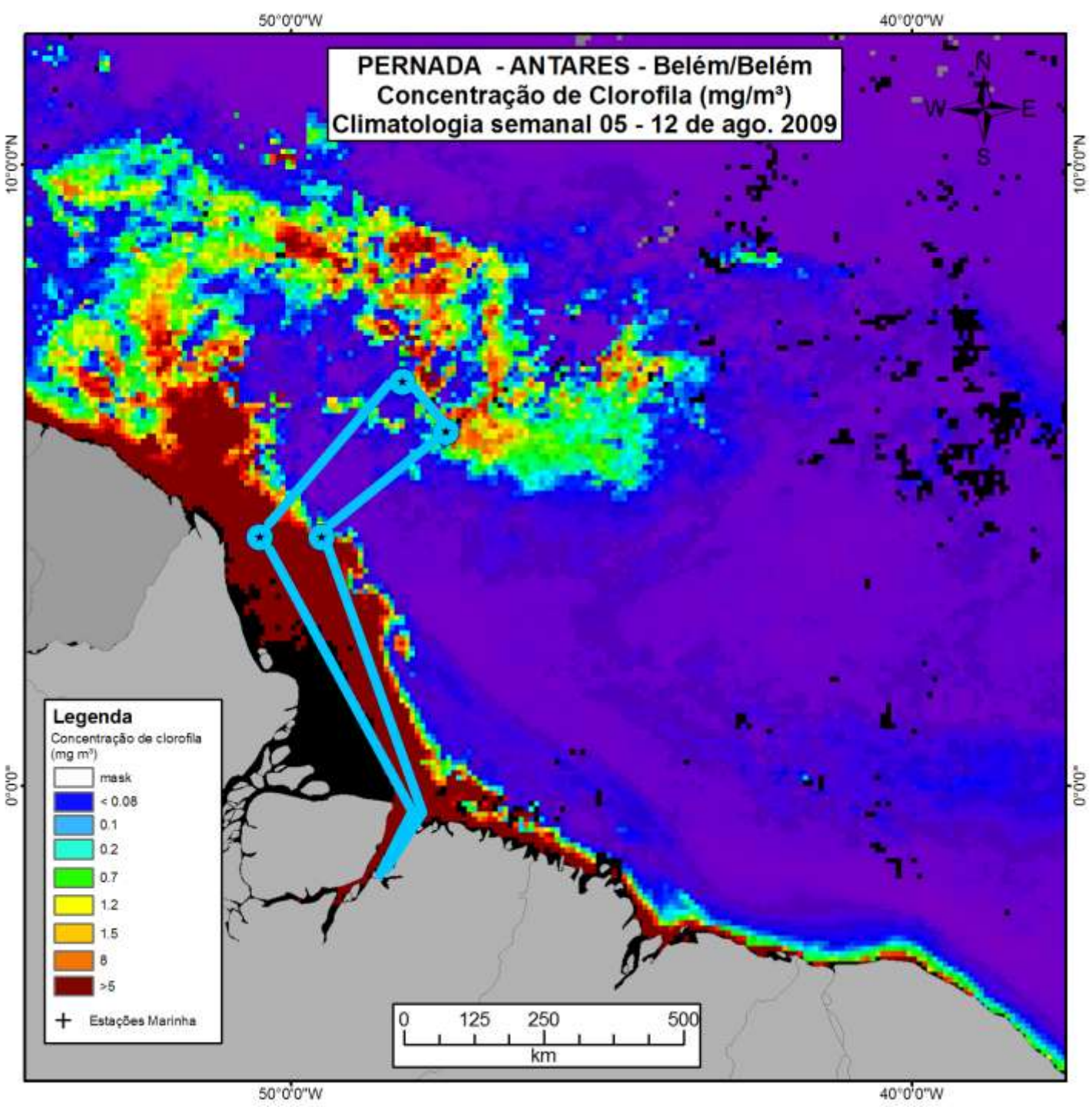


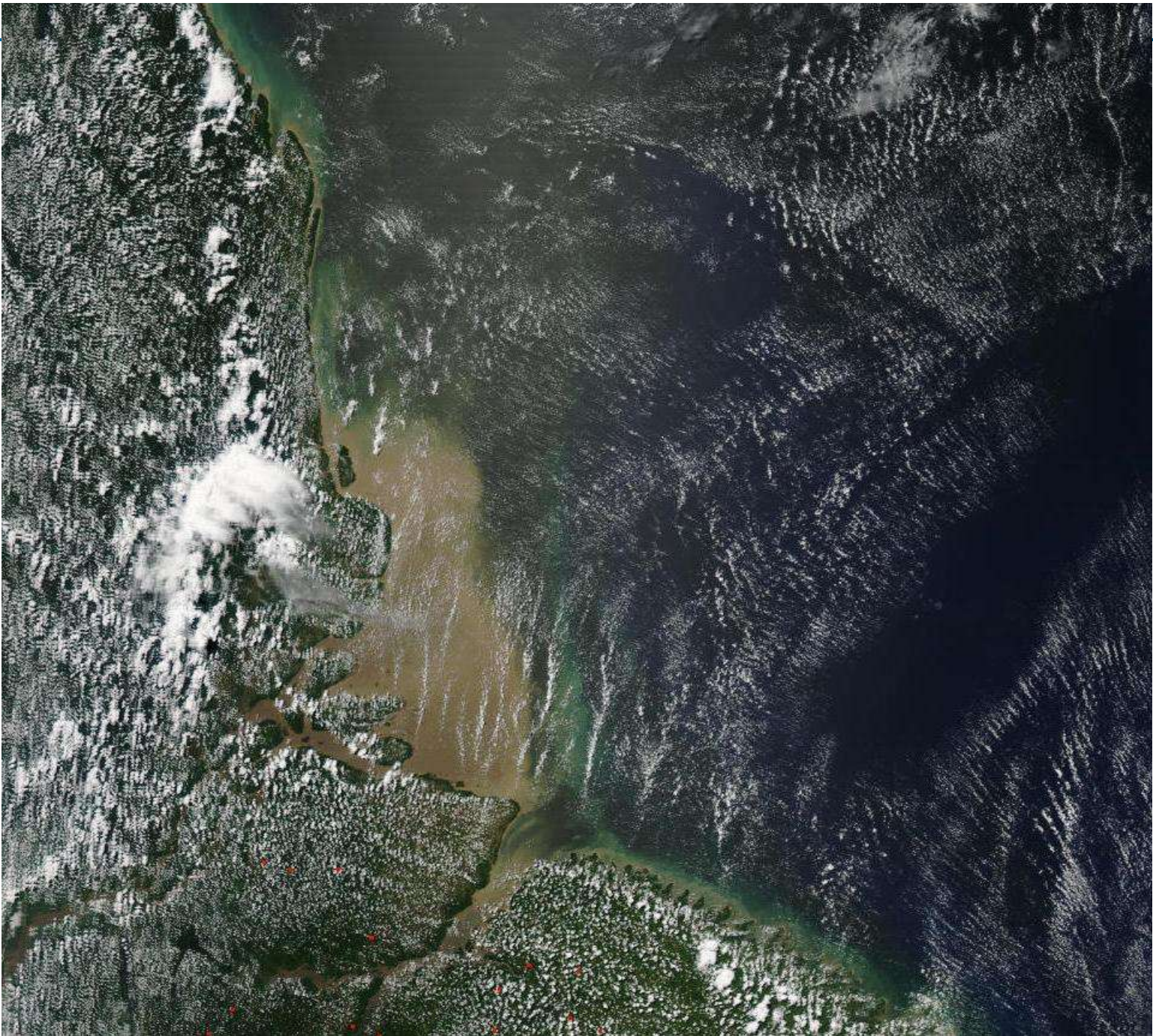




MODIS – MERIS – SeaWiFS - AVHRR





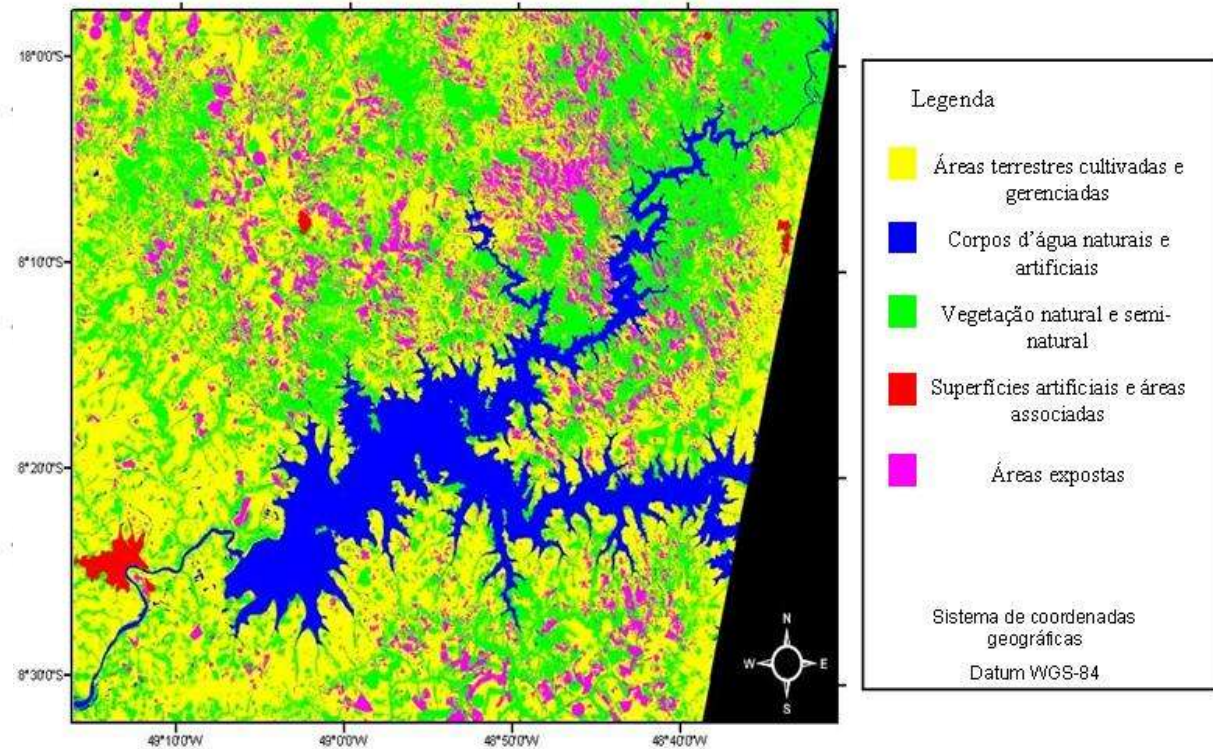




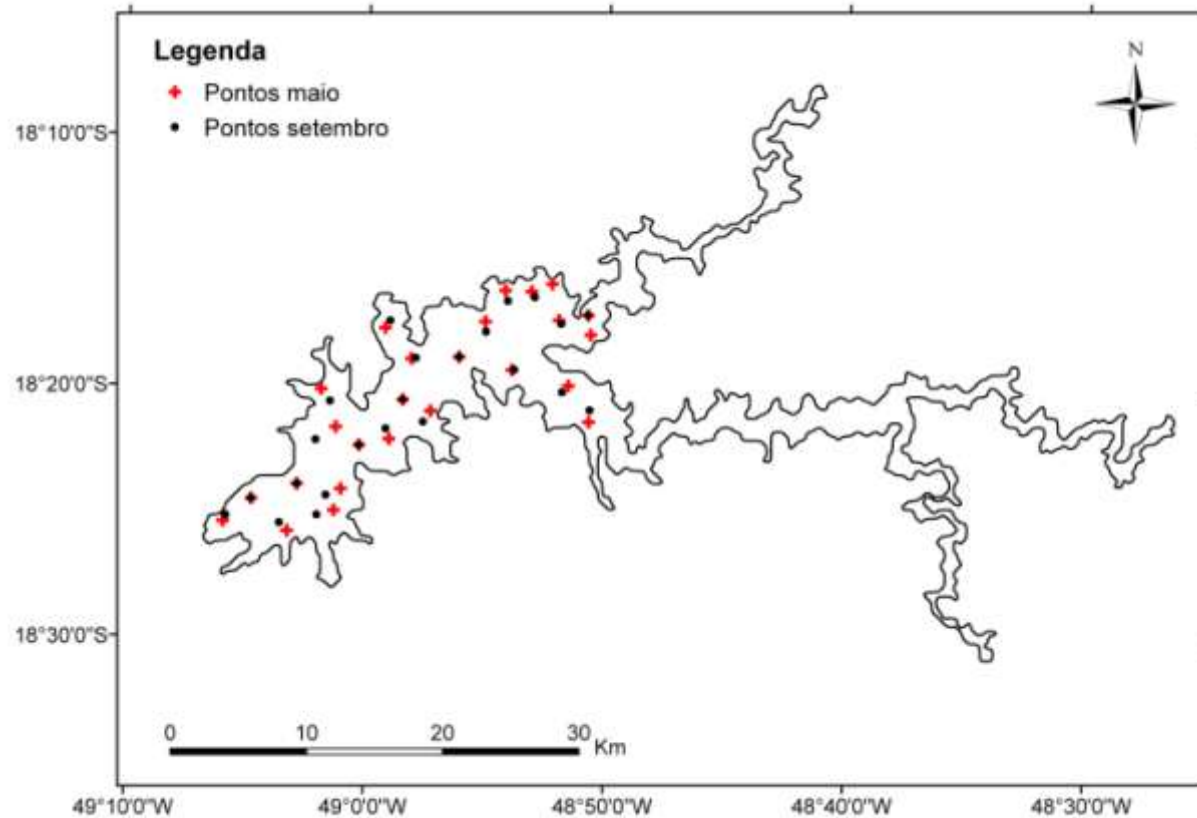
Inland waters



Itumbiara reservoár



Sampling

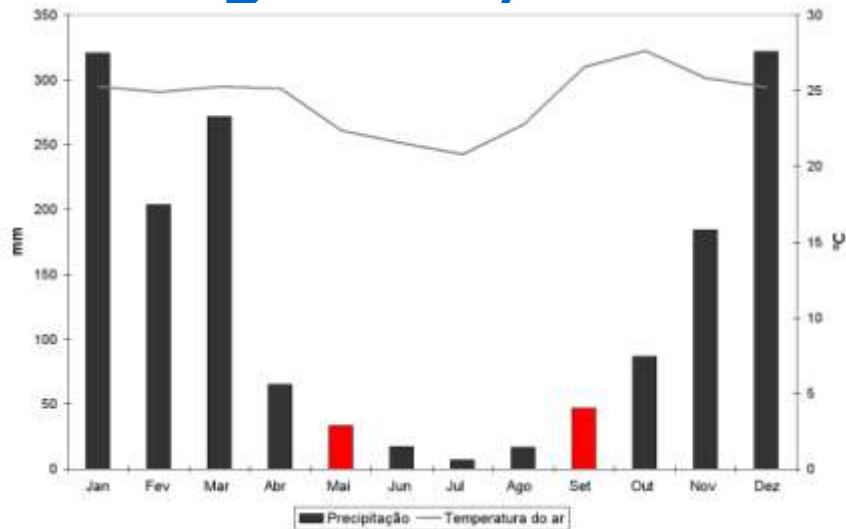


Field campaigns

- May 2009
- September 2009

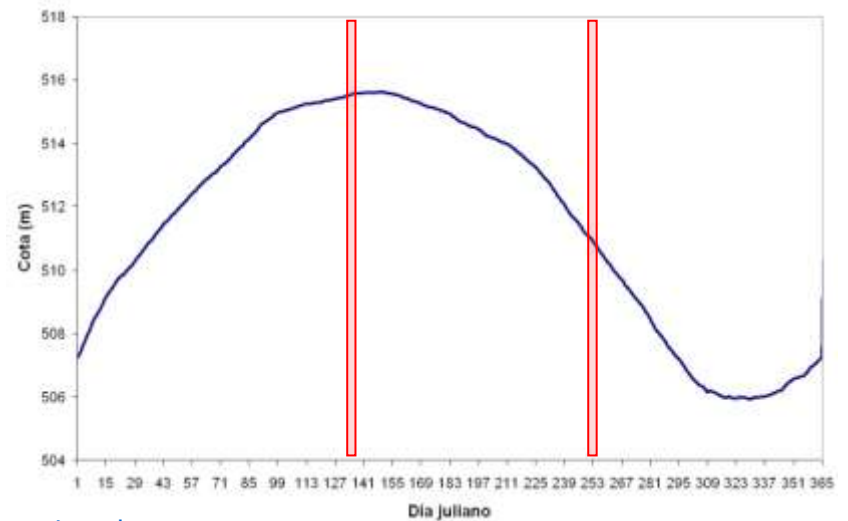


Hidrological cycle



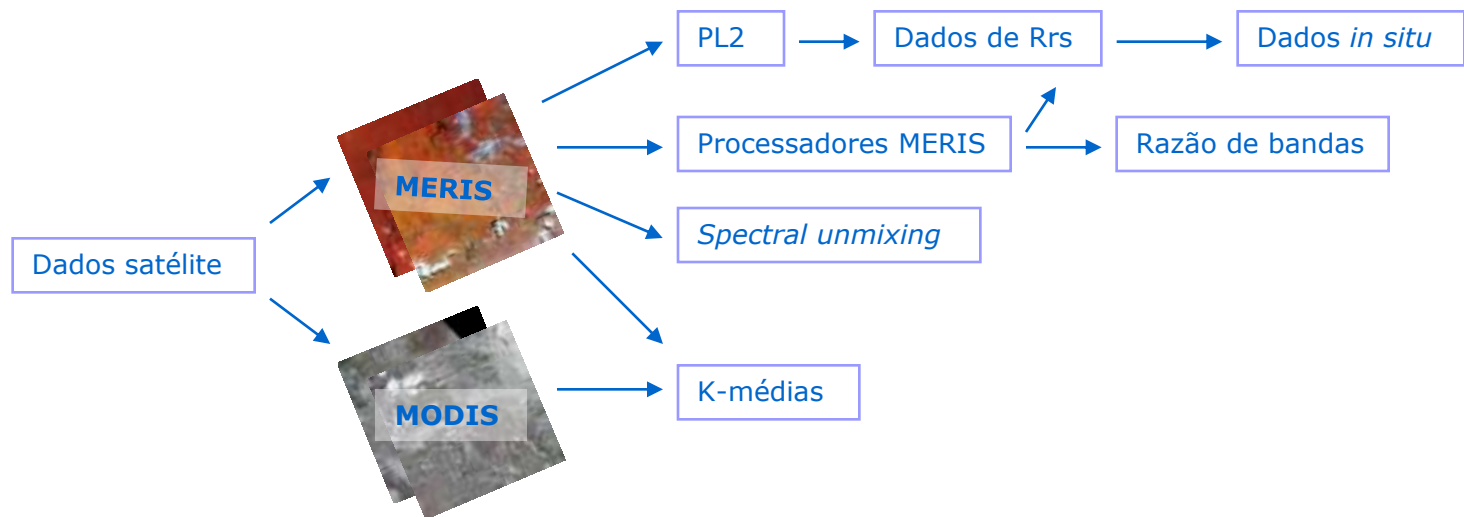
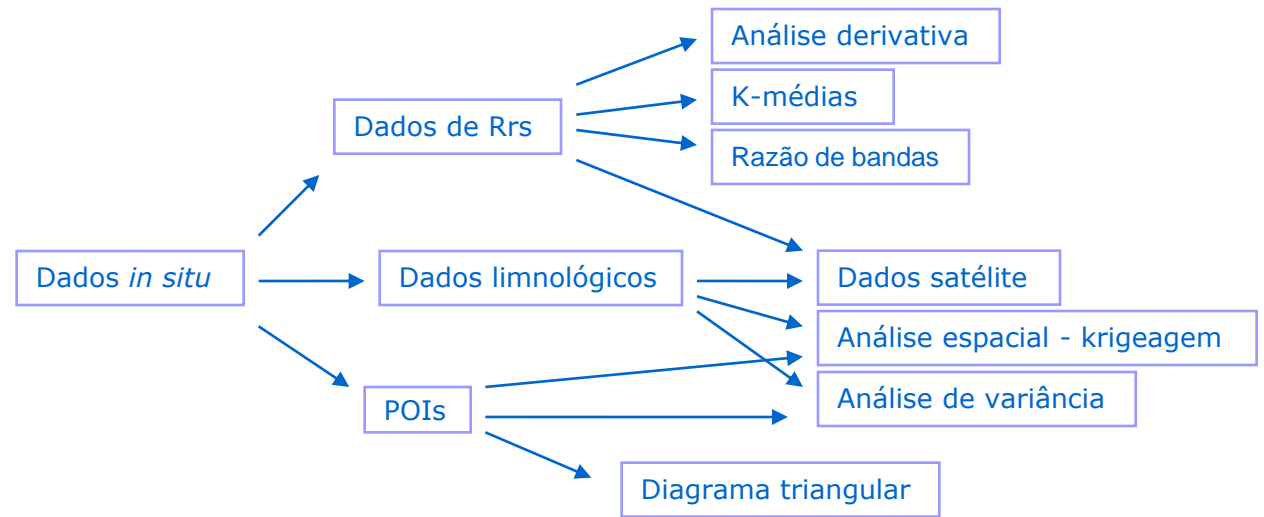
Precipitation and air temperature

Fonte: INMET



Water Level.

Data and Methods



MERIS processors



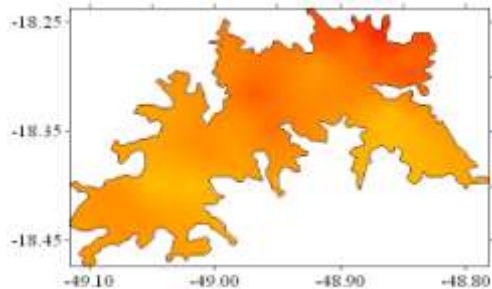
C2R (Case 2 Regional)

BOREAL

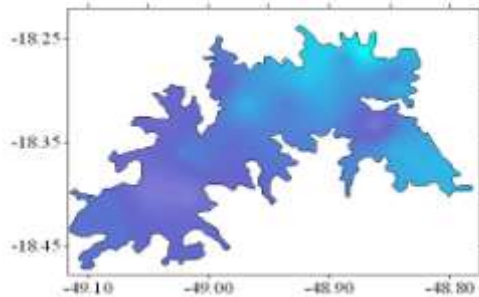
EUTROPHIC



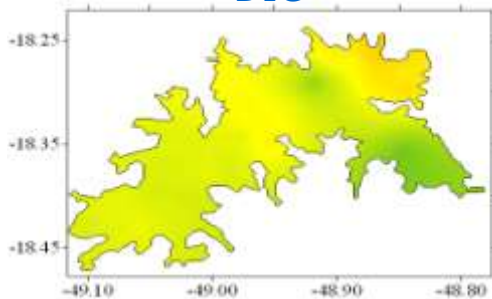
Total C



DOC

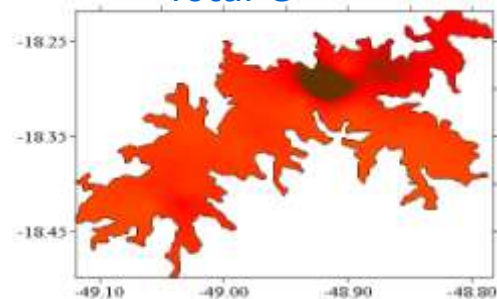


DIC

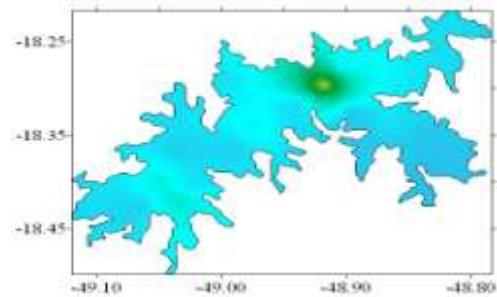


May

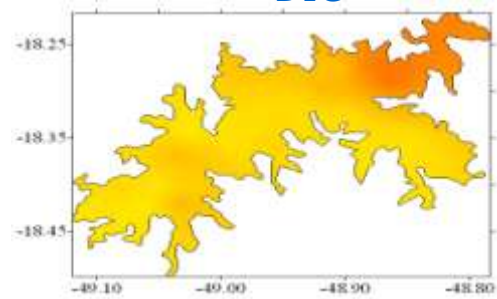
Total C



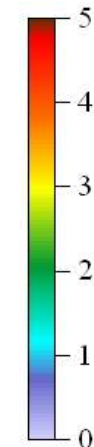
DOC



DIC



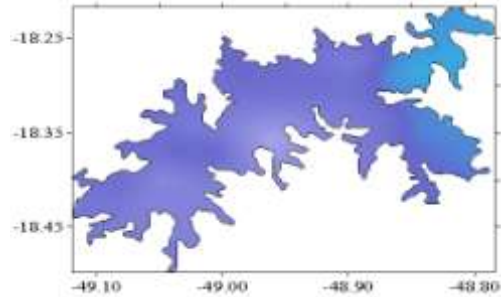
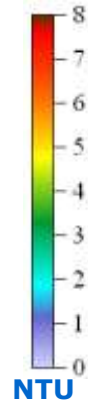
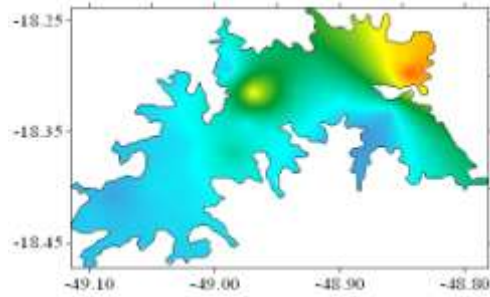
Sep



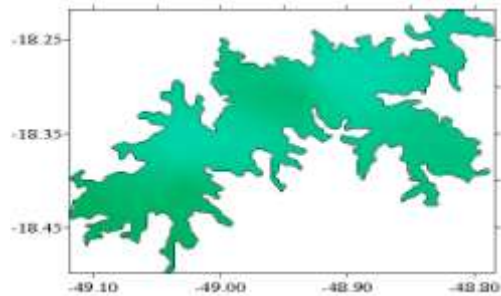
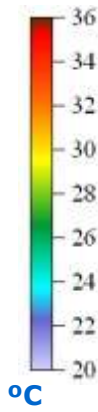
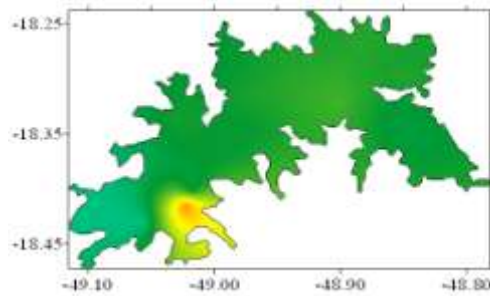
mg/L



Turbidity



Temperature

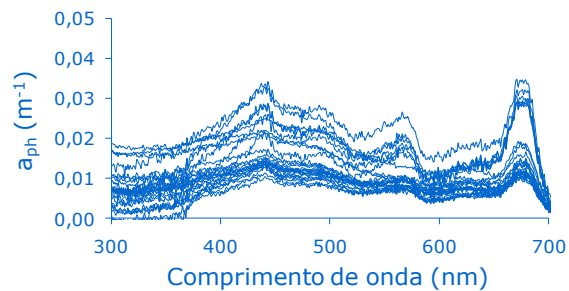


May

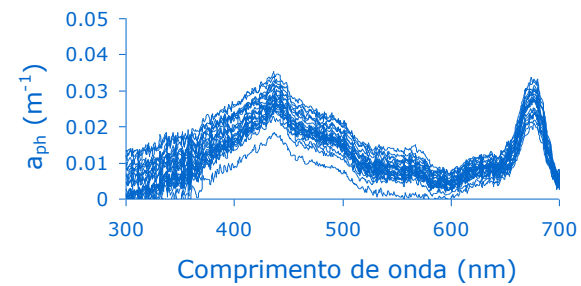
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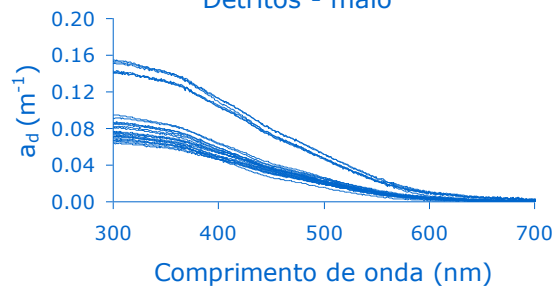
Fitoplâncton - maio



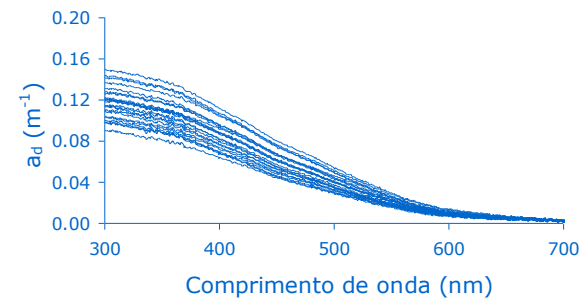
Fitoplâncton - setembro



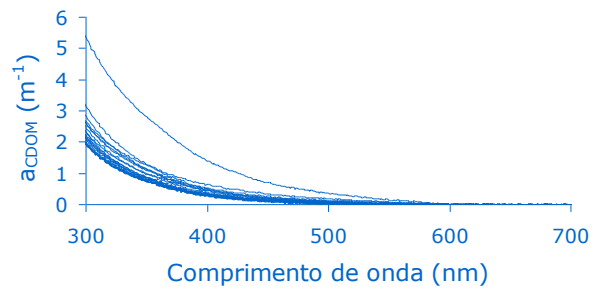
Detritos - maio



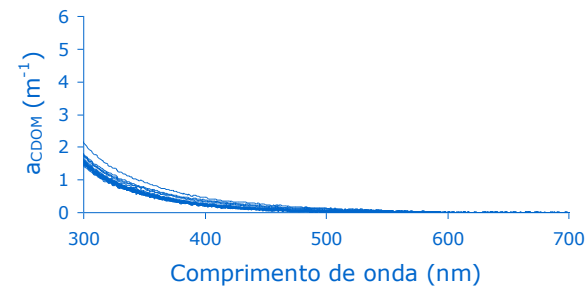
Detritos - setembro



CDOM - maio



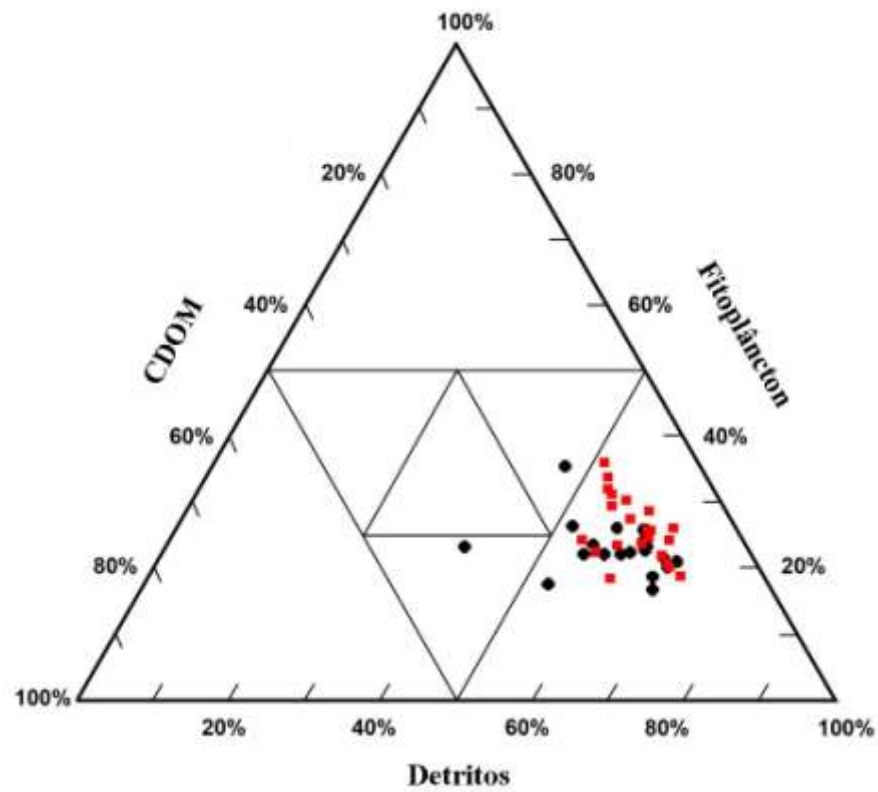
CDOM - setembro





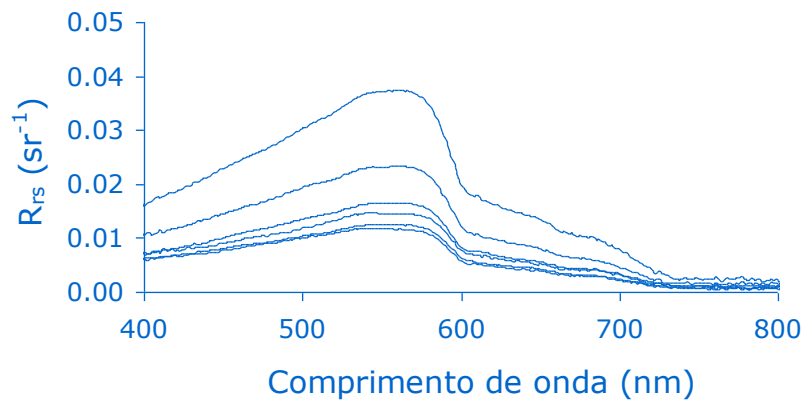
● maio

■ setembro

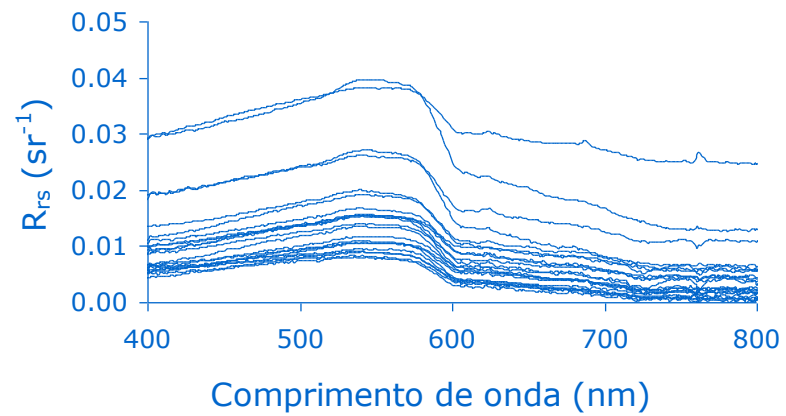


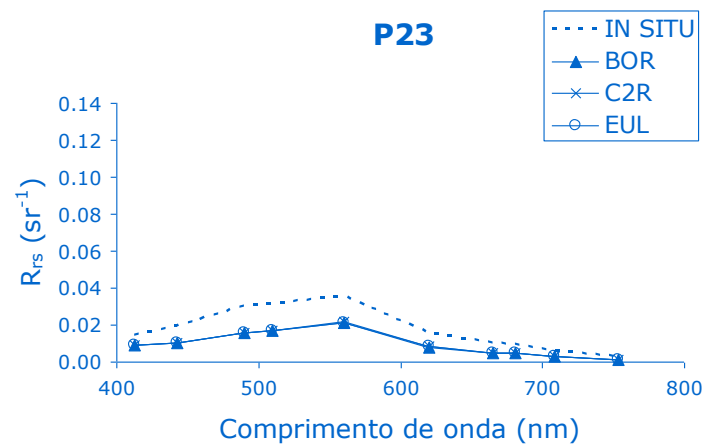
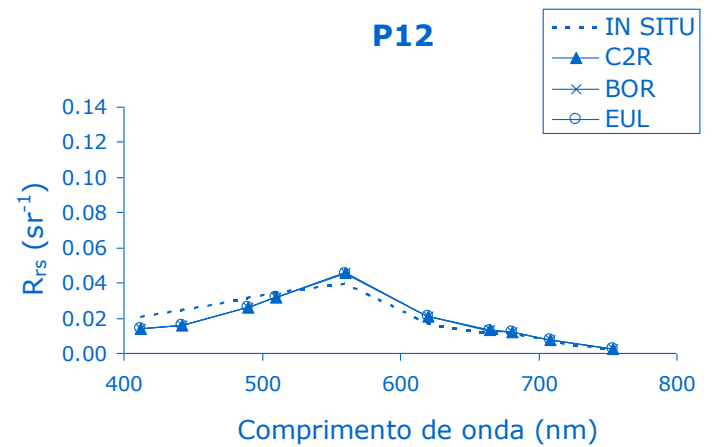
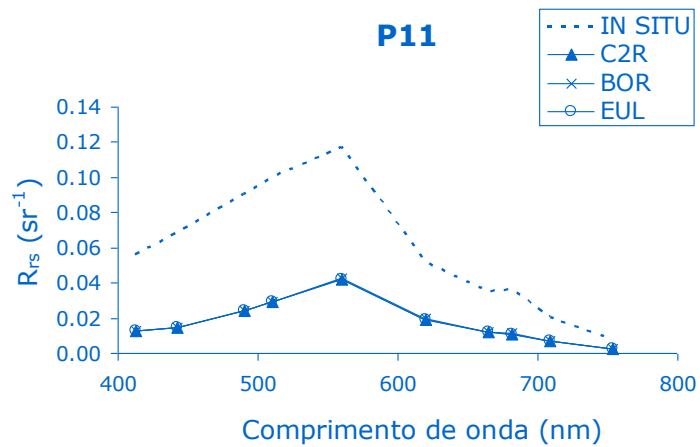


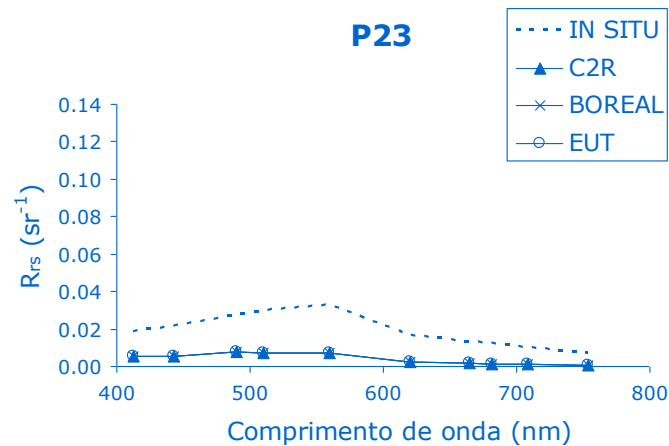
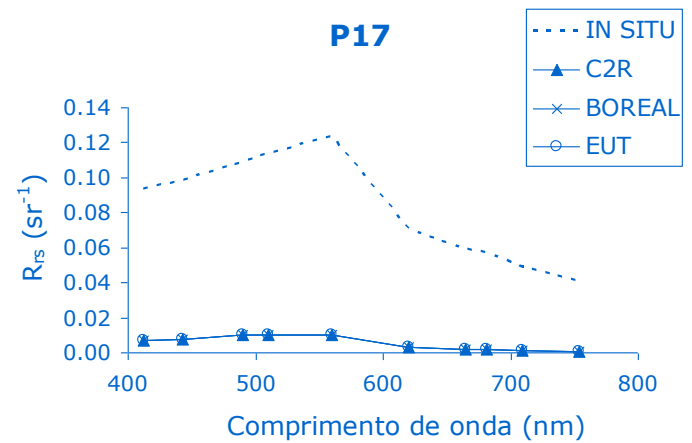
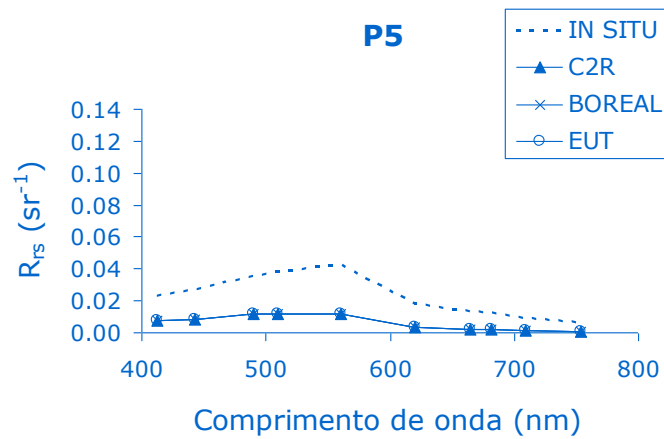
maio

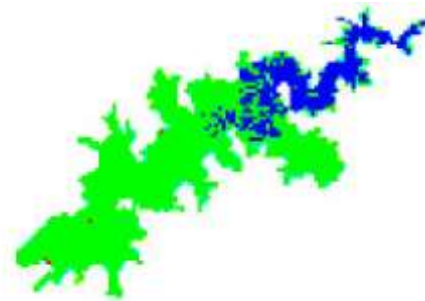


setembro

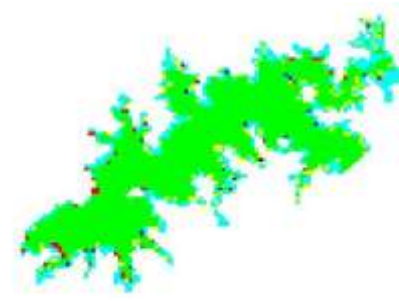




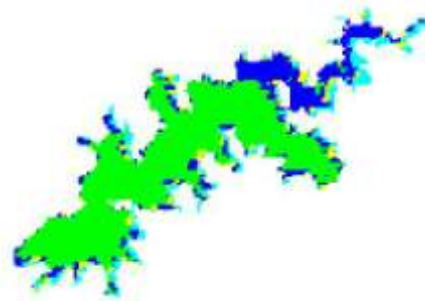




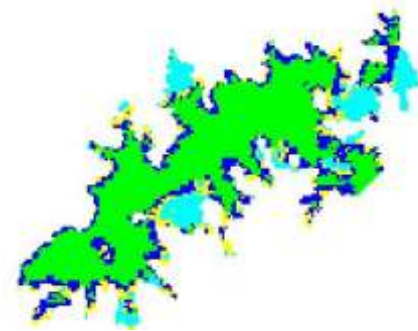
MERIS - 07/05/2009



MERIS - 12/09/2009



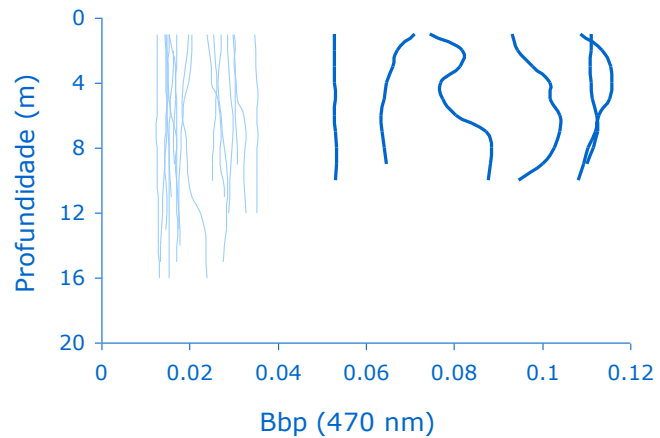
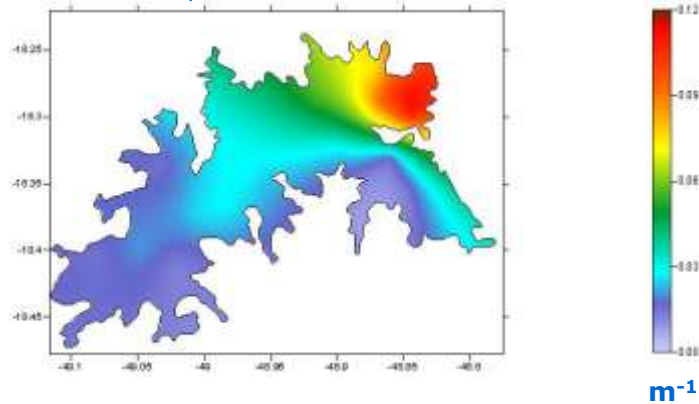
MODIS - 10/05/2009



MODIS - 10/09/2009

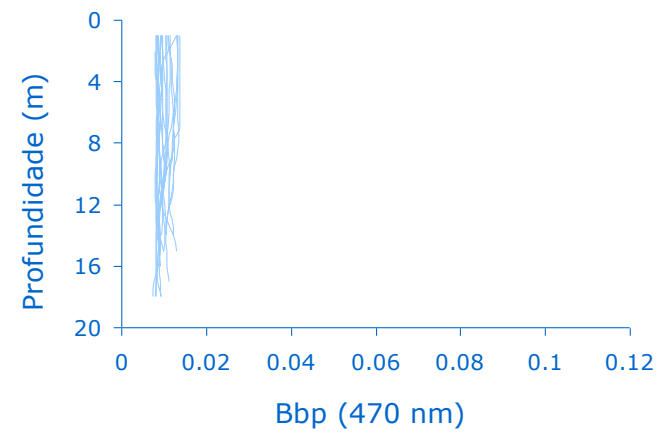
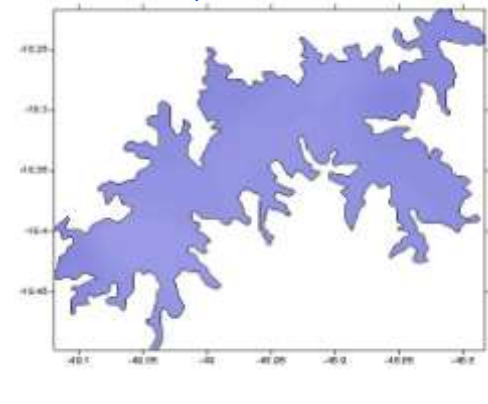


$b_{bp} - 470 \text{ nm}$



maio

$b_{bp} - 470 \text{ nm}$



setembro

Spectral unmixing



Chl



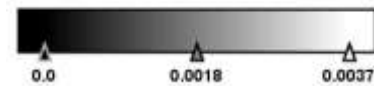
Clorofi_abundance [-]



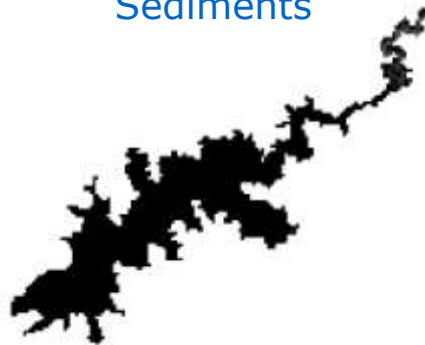
Organic matter



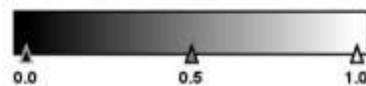
Mater_abundance [-]



Sediments



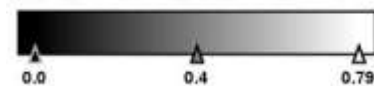
Sediment_abundance [-]



Clear water

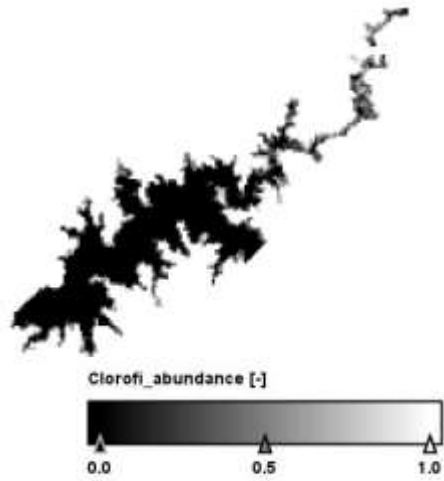


Aguac_abundance [-]

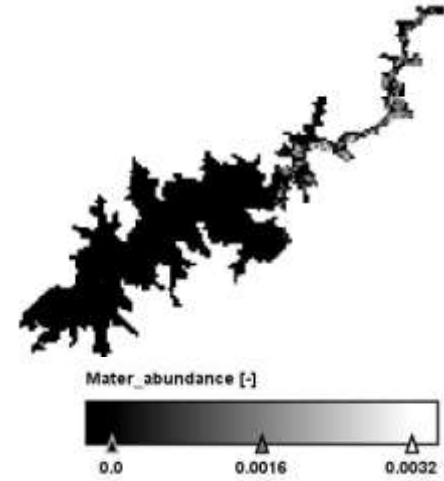




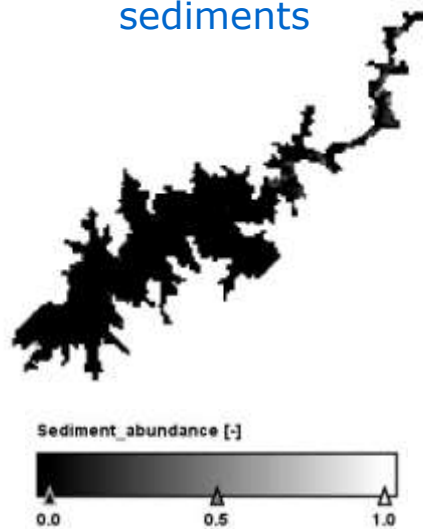
Chl



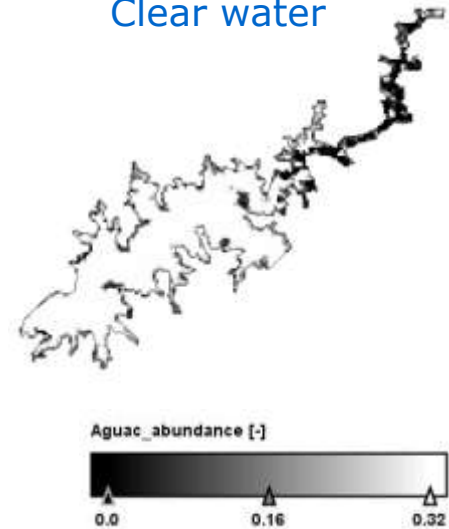
Organic matter



sediments



Clear water





Group on
Earth Observations

Open access data policies will enable the Global Earth Observation System of Systems to succeed





Thank you