The Camamu Basin Offshore Environmental Monitoring through Remote Sensing

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Abstract. In this paper, multispectral remote sensing data from MODIS-Aqua were used to caracterize the Camamu offshore basin and to monitor 6 production wells located in the Manati field, eastern Brazil, showing their great potential for environmental monitoring for the oil drilling and gas industries. Results were based on the interpretation of SST, Chlorophyll-a and K490 derived from the Aqua satellite passes on march 4th and july 12th, as well as, monthly time series for each of these geophysical parameters. SST values show an opposite behaviour when compared to Chlorophyll-a and K490, with the last two parameters changing one order of magnitude seasonally.

Key words: coastal monitoring, oil and gas drilling, Manati field, Satellite Oceanography, MODIS, K490, Chlorophyll-a, SST.

1. Introduction

Offshore gas and oil activities may impact benthonic and pelagic biota, contaminating commercial key species, affecting fishing stocks as well as migratory species, and increasing turbidity and chemically contaminating coastal habitats during drilling, exploration activities and transport.

The Camamu basin is located at the South-southeastern portion in Atlantic ocean along the eastern Brazilian continental shelf. In a region whose surface circulation is dominated by a closed system known as the South Atlantic subtropical gyre (Peterson & Stramma, 1991). This anticlockwise gyre reaches the Brazilian shelf, and bifurcates between 8°S and 10°S, forming the southward Brazil Current (BC). The BC flows along the continental margin, parallel to the coastline until it reaches 36°S of latitude, where it separates from the coast and veers offshore (Olson et al.1988; Lentini, 2002).

The Camamu basin borders the Almada basin to the south, and the Jacuípe and the Recôncavo basins to the north. It is a sedimentary basin that reaches 8000m in the depocenters (Gonçalves et al 2000) and has a north-south extension of 125km by and is 70km wide. It is part of the Brazil's eastern continental margin which had a tripartite geotectonic evolution: (i) an initial pre-rift phase dominated by sedimentation in a sineclises from Late Jurassic to Early Neocomian; (ii) followed by a rift phase with an intensive distensive tectonic regime (Neocomian to Aptian); and (iii) a post-rift period characterized by the installation of a marine platform in a passive margin setting (Kuchle et al 2005).

Its 7000km^2 offshore area has been subject of reevaluation since the end of the 90's and then, implemented the hidrocarbon industry. Nowadays, several exploratory blocks and production fields occur in the area. Awarded blocks offered during rounds 2-7 includes continental shelf blocks BM-CAL-4 (Round 2), BM-CAL-5 (Round 3), BMCAM-40 (Concession area -Petroleum Law - art.33) and the production fields of Sardinha and Manati.

The Manati field (Figure 1), administrated by joint-companies Petrobras/Queiroz Galvão/Norse energy, started operation in 2006 and is currently the major natural gas producer in the Brazilian northeast region, and the 3rd most productive in the whole country being responsible for 61,4% of Bahia state natural gas production and 8,9% of the total Brazilian's production (ANP, 2009). Since Aug/2009, $8x10^6 m^3 day^{-1}$ of natural gas is provided to the market.

The natural gas and condensate from Manati field is transported via 175km-long pipeline until the treatment station in Sao Francisco do Conde, where the treated gas is tranfered to the benefiting network of Landulpho Alves Refinery (RLAM), Romulo Almeida termoeletric plant, a fertilizing facility and the market, via Bahiagas distributor.

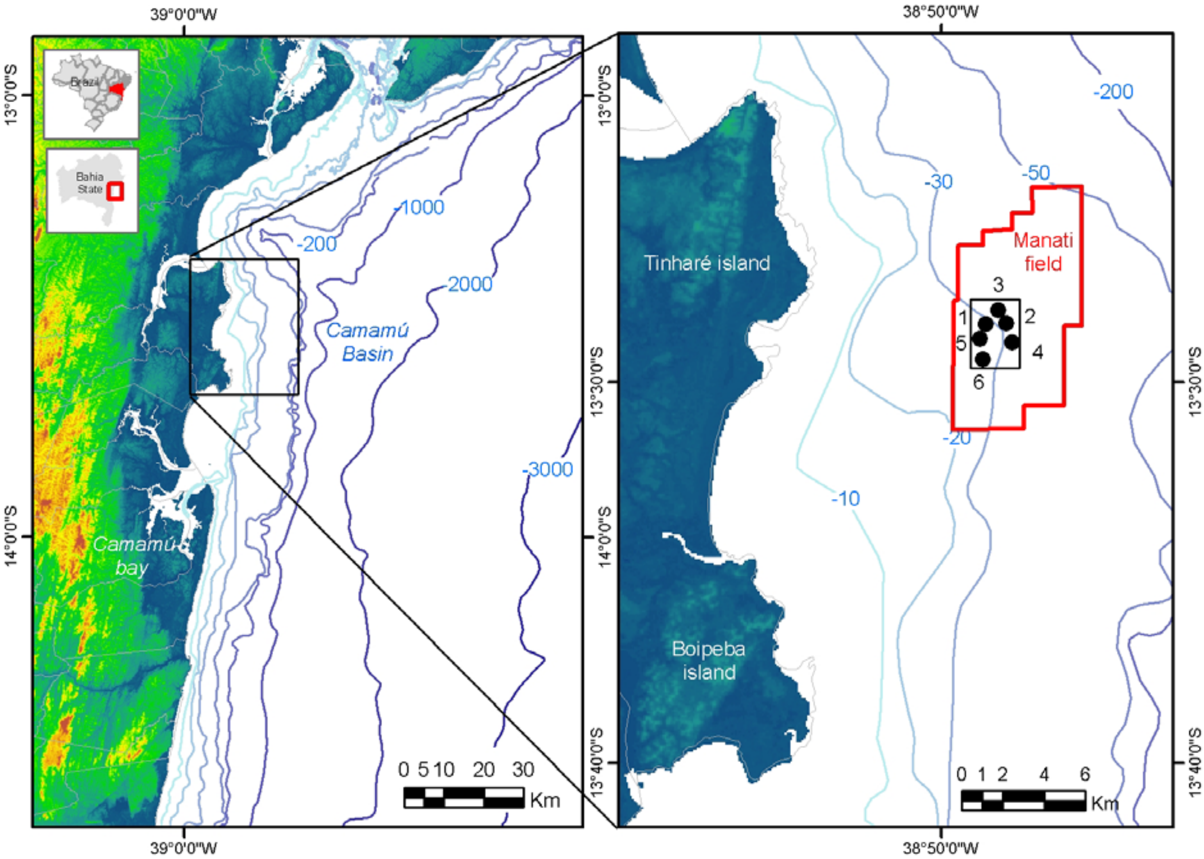

Figure 1- Location maps of Camamu basin (left), monitoring area (13.47S-13.49S & 38.80W-38.82W) and production wells #1 to 6 (right).

In this paper, multispectral Remote sensing data from MODIS were used to monitor 6 production wells located in the Manati field, eastern Brazil, showing their great potential for environmental monitoring. Results were based on the interpretation of K490, SST and Chlorophyll-a derived from the AQUA satellite passes on March 4th 2009 and July 12th 2009, as well as monthly time series data for each of these geophysical parameters. The characterization of hydrodynamical physical processes such as the identification of upwelling regions, surface fronts, vortex and eddies (Denman & Abbott 1994), associated to the phytoplankton development and changes in surface temperatures can help to monitor the ocean's state during drilling, exploration and transport activities in the Manati field and its surroundings .

2. Methodology

Modis is a sensor for multiciplinary targets and purposes, well fitted to study the land, the sea surface and the atmosphere (Esaias et al, 1998). Following the launching of the first

MODIS sensor, in 1999, by NASA onboard Terra satellite, the second MODIS sensor, an instrument similar to the previous, was lauched onboard the Aqua satellite in 2002. With its 2330 Km viewing swath flying onboard Aqua, the MODIS sensor covers the entire surface of the Earth in 36 high spectral resolution bands between 0.415 and 14.235µm with spatial resolution of 250m (2 bands), 500m (5 bands), and 1000m (29 bands). The radiance measure by MODIS at high spatial resolution provides improved and valuable information about the physical structure of the Earth's atmosphere and surface (Barnes et al., 1998).

The 2009 monthly averaged horizontal maps were generated for the coastal areas off the Bahia state. 9Km monthly mean data from July/2002 to January/2010 retrieved from the Giovanni dataset (http://reason.gsfc.nasa.gov/Giovanni/) were specifically used to monitor the area encompassed by the 13.47S-13.49S & 38.80W-38.82W region

A search into NASA's archive on http://daac.gsfc.nasa.gov/MODIS/ was performed and 2 good quality images of 2009 were chosen to be processed. One, taken in March 4th and the other, in July 12th. The processing procedure was done using the ocean colour software SEADAS, (http://oceancolor.gsfc.nasa.gov/seadas), and helped to distinguish particularities among 6 production wells in the Manati field.

Two Hierarchical Data Format (HDF) downloaded arquives were projected using the attached geolocation arrays in the HDF filles, and then were submited to atmospheric correction, before performing any 250m-pixel SST, Chlorophyll-a or K490 concentration calculation.

Skin temperature (e.g., satellite-derived SST), which is strongly influenced by solar irradiance at the top first 0.1mm of the ocean thin surface layer, may differ from in situ bulk temperatures in the water column.

Chorophyll-a is expressed in mg.m^{-3} and indicates the concentration of photosyntetic active pigments, the most common "green" chlorophyll in the ocean, estuary and lake areas (Acker and Leptoukh 2007).

K490, which is the normalized diffuse attenuation coefficient at 490nm, is an indicator of water transparency. It expresses the how deeply visible light in the blue-green region of the electromagnetic spectrum penetrates into the water column (Acker and Leptoukh 2007).

3. Results and Discussion

SST time series from June/2002 to Jan/2010 indicate high temperatures occurring during the months of February, March and April, whereas low surface temperatures take place in July, August and September, with the highest and lowest averaged monthly temperatures registered in Mar/2003 (29,54°C) and in Aug/2004 (24,86°C), respectively. Year 2009 was characterized by higher temperatures during the lower temperature months, with temperatures not dropping below 26.3°C, in August (Figure 2).

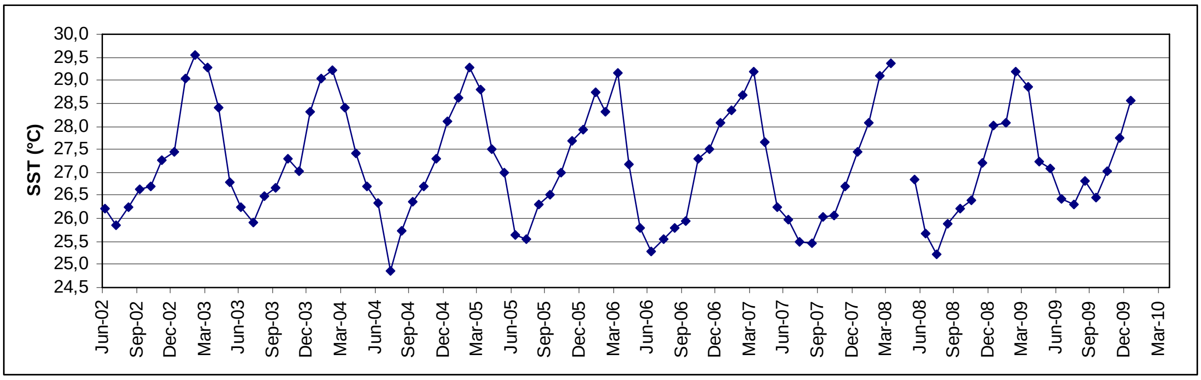

Figure 2- Time series of monthly mean SST for the monitoring area between 13.47S-13.49S & 38.80W-38.82W

2009 monthly average SST horizontal maps (Figure 3) show the warming intensification of the Brazilian current in march/april and the persistance of waters higher than 26°C in july and august, which characterizes the seasonal SST cycle.

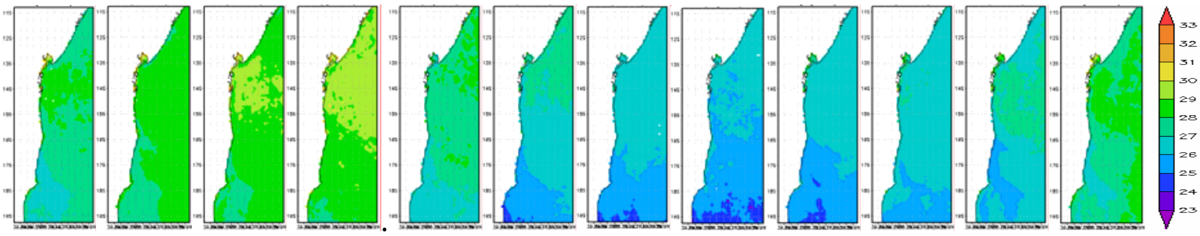

Figure 3- Horizontal monthly maps of SST (°C) retrieved for the coast of Bahia for the year 2009.

The two 250m-images unfolded acentuated differences between them (Figure 4). Image of March 4th 2009 showed the presence of a warm core SST value located at E-NE of Tinharé island, just above the Salvador Canyon, and a SST drop of at least 2°C south of Boipeba island. Averaged SSTs over the production wells #1-6 reached 29.85°C (+/- 0.23°C), while the 12/7/2009 image showed a mean SST value of 26.93°C (+/- 0,08°C).

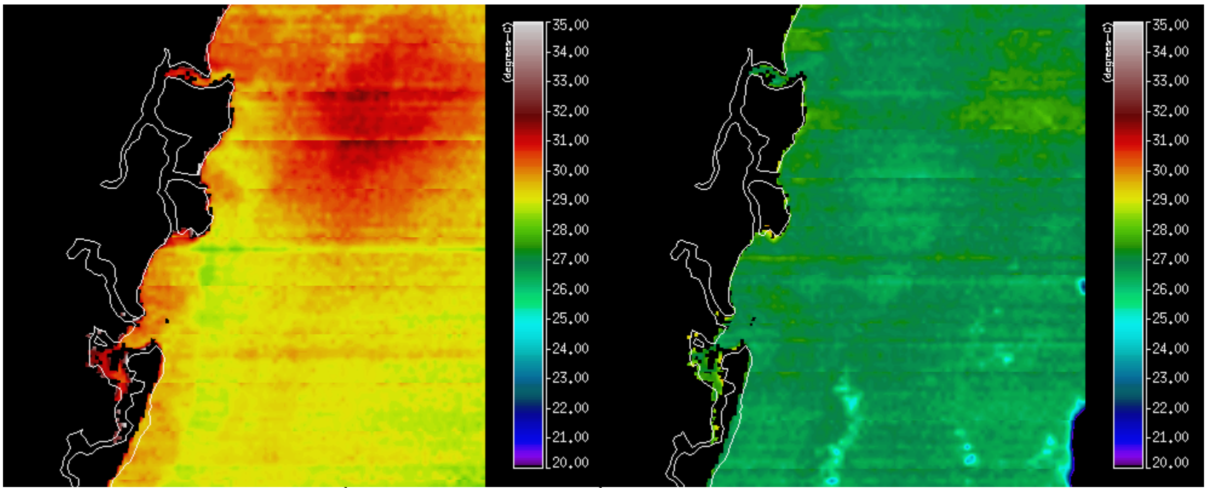

Figure 4- March 4th and (left) and July 12th (right) 2009 250-m SST processed images.

Time series of Chlorophyll-a concentrations during the 91 months reached 1 mg.m^{-3} twice (Figure 5). The first time happened in June/2003 and the second, in May/2009. During 2005 and 2006 austral winter seasons, high concentrations reached values of 0.96 mg.m^{-3} and 0.92 mg.m^{-3}, respectively, while, Chlor-a concentrations stayed below 0.8 mg.m^{-3} for the other years. Low concentrations occurred in the summer months when Chlor-a was reduced to aproximately 0.1 mg.m^{-3}, excepted during austral summer of 2004 when concentration remained around 0.2 mg.m^{-3}.

2009 monthly average Chlor-a horizontal maps clearly show the oligotrophic waters of the south-Atlantic ocean, and its well delimitated higher values towards the shelf and eutrophic waters in the estuarine areas. From april to july/2009, chlor-a concentration in the area, exceded 0.5 mg.m^{-3}(Figure 6).

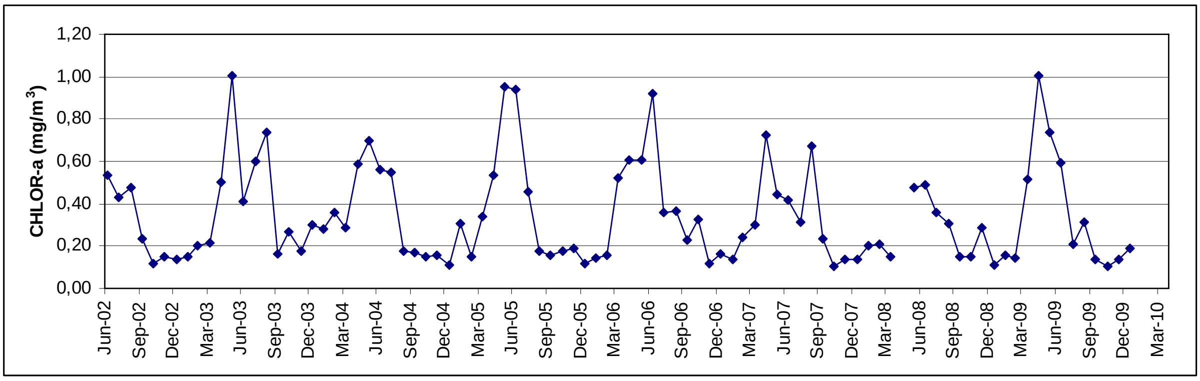

Figure 5- Same as Figure 2, except it is for Chlorophyll-a concentrations.

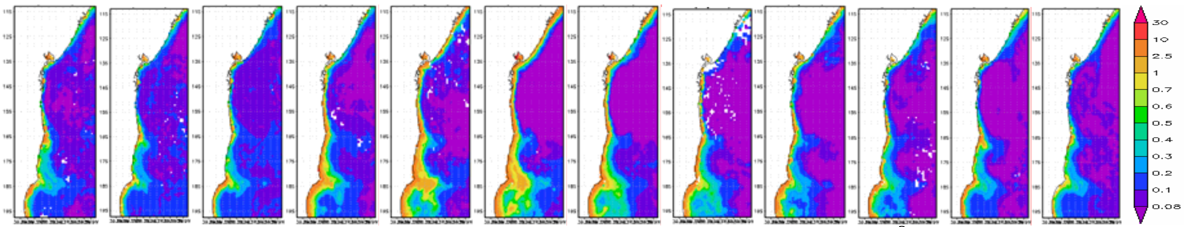

Figure 6 – Same as Figure 3, except it is for Chlor-a (mg.m^{-3}) .

While monthly Chlor-a reached 1mg.m^{-3}, only two times in 8 years, Chlor-a reached between 1.96mg.m^{-3} (well #4) and 2.38mg.m^{-3} (well #5) in the 12/7/2009 image (figure 7). This relatively high result, when compared to the 0.59mg.m^{-3} registered for july/2009 (figure 5), might reflect the local low tide scenario during the image acquisition. Wells #1, 5 and 6 located closer to the coastline registered the highest values. The 4/3/2009 image registered a mean value of 0.16 mg.m^{-3} for wells #1-6, in agreement with the monthly mean value.

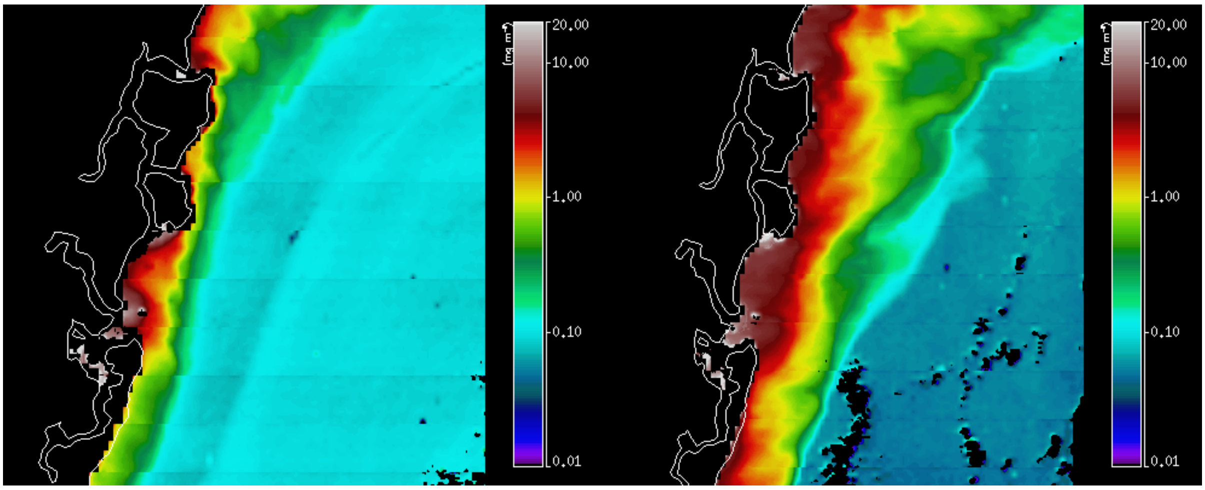

Figure 7: Same as Figure 4, except for Chlorophyll-a concentrations

K490 time series (figure 8) indicate an increasing turbidity in the production wells around the month of june, with the highest K490 value during all the monitoring period recorded in May/2009 (0.118/m), followed by June/2005 (0.116/m), June/2006 (0.113/m) and June/2003 (0.112/m). The low turbidity period occurs between September and March.

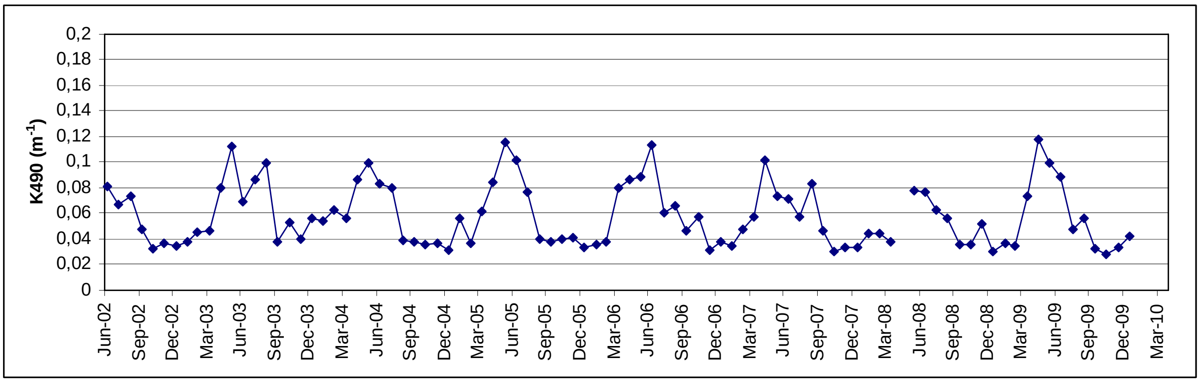

Figure 8- Same as Figure 2, except for K490

2009 horizontal monthly averaged maps (figure 9) show an increased K490 starting in April and persisting until September, despite the considerable drop registered in August. According to Lentini (personal commm., 2010) these values reflect the dry (wet) season period when austal winter (summer) atmospheric frontal systems are more (less) frequent and vigorous (weak) over the eastern Brazilian continental shelf.

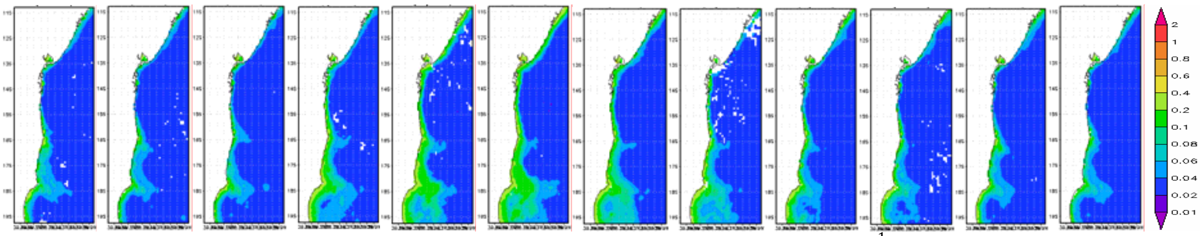

Figure 9- Same as Figure 3, except it is for K490 (m^{-1}).

The 250m-K490 images (Figure 10) provided turbidity patterns similar to the chlorophyll-a one. A low scenario in March 4th and a high tubidity scenario in July 12th, with more turbidy waters over the shelf and even reaching the water surface above the continental slope. K490 values for wells #1-6 were 1 order of magnitude lower in March, 4th (mean=0.03/m), when compared to July, 12th (mean=0.19/m).

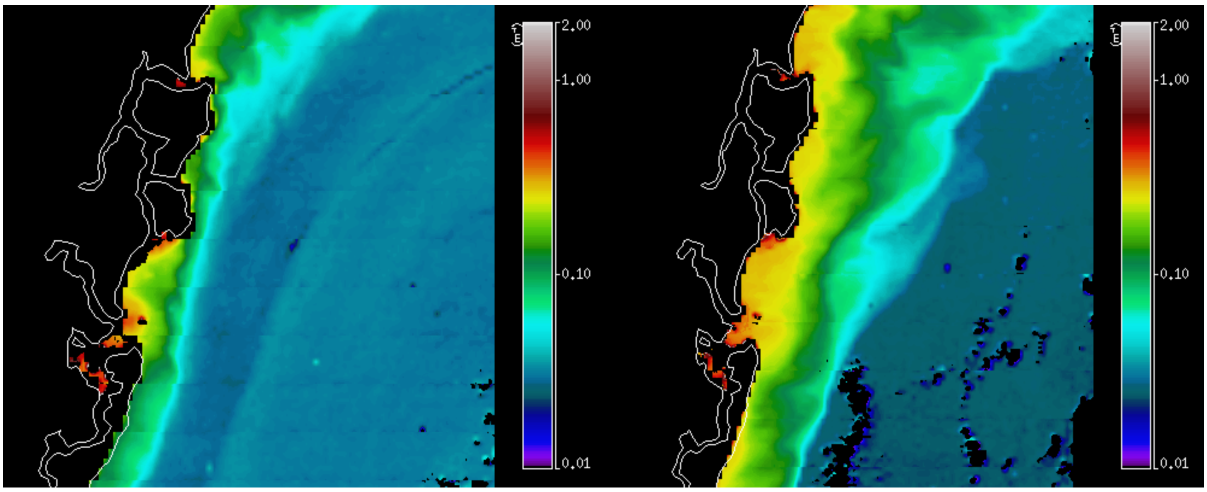

Figure 10: Same as Figure 4, except it is for K490 images.

4. Conclusions

Since 2002, the behaviour of Chlor-a and K490 was caracterized by high values around June and low ones between September and March, acting differently from SST, which increases until March-April and reaches its lowest values between July and September.

In the two SEADAS processed images, SST, Chlorophyll-a and K490 didn't varyed much among wells 1-6, however a seasonal change of one order of magnitude could be observed for Chlorophyll and K490.

The 250m-MODIS images allowed a better coastal and oceanic monitoring capacity to fulfill environmental gaps due to its capability of distinguishing between surface features up to the sensor's highest spatial resolution. The oil and gas industry may take advantage of this technology and remotely monitor its activity in order to reduce possible impacts during seismic research, drilling, exploration and transport of oil and gas products.

5. Acknowledgements

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