The contribution of ASTER, CBERS, R99/SIPAM e OrbiSAR-1 data to improve the oceanic monitoring –

An example of oil and frontal eddy detection

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***Abstract*— This paper presents some results using a series of satellite and airborne sensors to monitor the environmental conditions of an oceanic area in the SW South Atlantic off Brazil. The following sensors were used: RADARSAT-1, VNIR-TIR/ASTER Terra, WFI-CCD/CBERS, OrbiSAR-1 and R99 SAR/SIPAM. The analysis presented refers to the data collected during the occurrence of a large meso-scale Brazil Current frontal eddy and a concurrent but uncommon sea floor oil seep event. The surface expression of the oil seep was captured by the eddy. The integrated data set analysis showed that the availability of this set of images made it possible to obtain spatial and physical details of these two features, which could not have been achieved using solely one single sensor alone.**

Oil slick; orbital and airborne remote sensing; sensor synergy; ocean monitoring

I. INTRODUCTION

Orbital images have been used systematically for the monitoring of the oceanic environment in relation to the activities of exploration, production and transport in the basins on the continental margin of the Southeast of Brazil [1]. Aiming to advance scientifically and technically the current remote sensing data analysis procedures a two years research project is being conducted by PETROBRAS R&D Center and research partners. One of the project stages involved an campaign with the simultaneous acquisition of *in situ* and remote sensing data, in the Campos Basin region, Brazilian Southeast continental margin. The simultaneous data acquisition enabled the meteo-oceanographic contextualization of the *in situ* collection and made viable the evaluation of the remote sensing products. During the cruise, a Brazil Current (BC) cyclonic frontal eddy (Fig. 1) was present coincidentally with an oil seepage event. The surface expression of the seepage was detected by different orbital and airborne sensors, with only a few hours of time difference, providing a rare opportunity to evaluate and compare the response of these systems. In this work the results obtained are presented, with emphasis on the contribution of the orbital sensors ASTER (*Advanced Spaceborne Thermal Emission and Reflection Radiometer*), and CBERS-2 (*China-Brazil Earth Resource Satellite*); as well the airborne SAR R99/SIPAM (Amazon Protection System) and OrbiSAR-1, which have never been used in the oceanic monitoring of the study area.

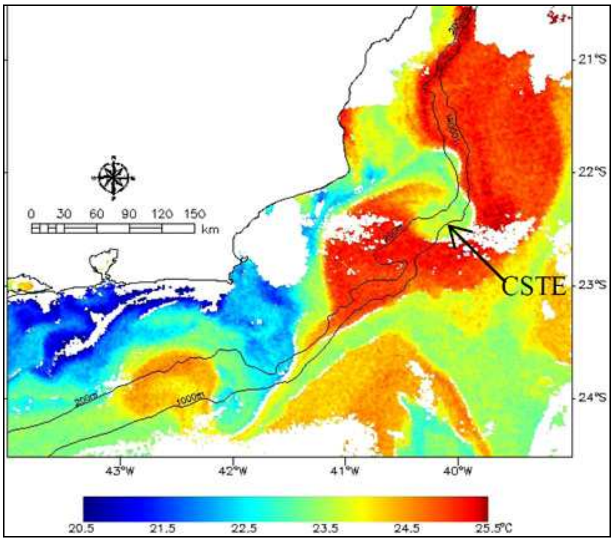

Figure 1. Sea Surface Temperature (SST) AVHRR/NOAA-15 (November 23, 2004). CSTE: Cabo de São Tomé Eddy.

II. REMOTE SENSING DATASET

Orbital dataset includes acquisition from RADARSAT-1, Terra/ASTER and CBERS-2. Table I presents the principal characteristics of the orbital sensors used.

TABLE I. CHARACTERISTICS OF THE ORBITAL SENSORE USED.

Satellite/Sensor	Spatial Resolution	Swath Wide	Spectral Bands
RADARSAT-1	50 m (ScanSAR N)	300 km	C, HH
ASTER	15 m (VNIR), 90 m (TIR)	60 km	VNIR, TIR
CBERS-2	20 m (CCD), 260 m (WFI)	113 km 890 km	VNIR

VNIR: Visible-Near Infrared, TIR: Thermal Infrared, WFI: Wide Field Imager, CCD: Couple Charged Device.

Data from the airborne OrbiSAR-1 and R99/SIPAM sensors completed the dataset. The acquisition of the

R99/SIPAM airborne data was made possible through the scientific cooperation between the INPE and Aeronautical Technology Centre. The flyovers with the OrbiSAR-1 system were made by the ORBISAT Company, as a demonstration of the system. Table II shows the image configuration used by the OrbiSAR-1 and R99/SIPAM sensors.

TABLE II. AIRBORNE SENSORS CONFIGURATIONS.

	OrbiSAR-1	**R99/SIPAM**
Swath	50 x 100 km	120 x 120 km
Band (Pol.)	X (VV)	L (VV)
Spatial Resolution	5 - 25 m	18 m
Flight Height	3.048 m	10.668 m

III. RESULTS

The RADARSAT-1 image acquired on 23/11/2004 – 08:02 GMT (Fig. 2a) clearly shows the oil seepage surface expression, shaped by the joint action of the cyclonic eddy and the wind field. The oil slick can be clearly seen to develop from its point of emergence on the surface, initially towards the West due to the wind (E) and then towards the North, with a behavior compatible with a reverse circulation of BC caused by the eddy. *In situ* observations revealed that the oil slick detected in the image was produced by a micrometrical thin oil film, with an iridescent silver appearance. The presence of the oil modified the ocean's surface tension, producing different degrees of attenuation on wind induced capillary and gravitational waves. Therefore the slick areas appear in SAR images as dark patches due to the lower roughness and consequently lower backscatter of the microwave incident pulses, in relation to the surrounding areas.

On the same day, approximately five hours later, an ASTER/VNIR scene (Fig. 2b) manages to show the patch with a better spatial resolution (15 m). In the band 2 (0,63-0,69 µm) image the slick area appears sometimes darker and sometimes brighter than the oil free sea surface. The presence of clouds can be seen in the SE extreme of the scene. One minute before the ASTER acquisition, the area was viewed by the WFI/CBERS-2 sensor (Fig. 2c). The slick is perfectly visible, brighter than the surrounding oceanic areas, in band 1 (0,63-0,69 µm) image. Again just as in the VNIR/ASTER image, the patch presents distinct reflection patterns, caused by films with different oil thickness, as showed by in situ observation.

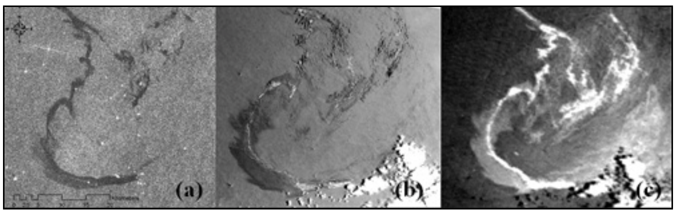

Figure 2. Detail of the RADARSAT-1 (a); ASTER/VNIR - band 2 (b), and CBERS-2/WFI - band 1 images (c); acquired on 23/11/2004 at 08:02, 12:54 and 12:55 GMT, respectively.

Field observations support the inference that the slick areas, that appear brighter in both images -VNIR/ASTER and WFI/CBERS-2, correspond to relatively thicker oil films. According to [2] the oil spectral signature in the VNIR depends on the geometry of the acquisition, as well as the type and thickness of the film. However, for the same geometry of acquisition, thicker films tend to present higher values of reflection.

Note that the patch detected in the SAR image (Fig. 2a) is narrower than that detected by the sensors using the VNIR (Fig. 2b and c). This observation is compactible with support that sensors in the VNIR present higher sensitivity for the detection of very thin oil films, sometimes invisible, or with little contrast in the microwave sensors, under the same wind conditions.

In the WFI/CBERS image the oil film appears with a positive contrast in relation to the surrounding areas throughout all its extent, however in the VNIR/ASTER image only the relatively thicker films appear brighter. Studies demonstrate that in the VNIR, the same thickness of oil can present positive or negative contrasts, in relation to those neighboring, depending on the satellite viewing geometry. For the majority of acquisition geometries, the oil films produce dark patches, due to the local reduction of the effective cone of scattering. Nevertheless, in images acquired close to the specular reflection cone [2] the slicks will appear with higher reflectivity, than the adjacent oceanic areas. Since the CBERS-2 image, was acquired looking as close as 1 deg. to the specular point, the slicked surface appear brighter than the background.

In the TIR/ASTER, band 13 (10,25-10,95 µm) (Fig. 3a) it is visible the BC cyclonic eddy with relatively colder water in its center. The small red points (higher temperature values) correspond to the oil rig flares. The fusion of the TIR- band 13 with the VNIR- band 2 (Fig. 3b) illustrates the capture of the oil slick by the eddy.

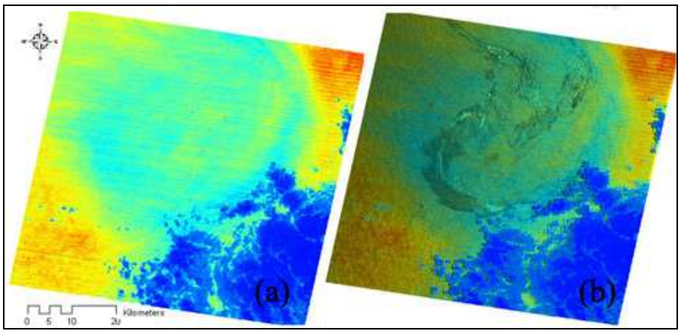

Figure 3. ASTER data on 23/11/2004 - 12:55 GMT, (a) TIR - band 13 with pseudo-color look-up table where the blue colors correspond to the colder temperatures. (b) RGBI composition with pseudo-colored TIR - band 13 (RGB) and VNIR - band 1 (Intensity).

The comparison of the acquired images on 23/11/2004 highlights how complementary the different sensors are to each other. The contrast between the oceanic surfaces with or without oil, as well as the localization of the vessels and platforms are unmistakable in the SAR image. The capacity of the imaging through clouds is another advantage of the SAR products. The combination of the higher spatial resolution of the VNIR/ASTER and the thermal imaging - TIR/ASTER -

offers details that are imperceptible in the other products. Only with the VNIR/ASTER and WFI/CBERS-2 products was it possible to discern the difference between the various thicknesses of the oil films.

In the WFI/CBERS-2 image (Fig. 4a), acquired on 26/11/2004 - 12:54 GMT, the patches resulting from the oil seep is only perceptible with the image zoom (Fig. 4b). The highest spatial resolution of the CCD product (Fig. 4c) permits a more detailed observation of the slicks.

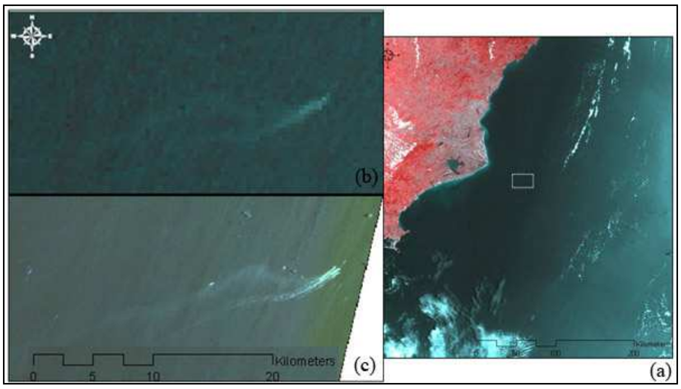

Figure 4. CBERS-2/WFI R(2)G(1)B(1), acquired on 26/11/2004 - 12:54 GMT (a). Zoom of the images CBERS-2/WFI (b) and CBERS-2/CCD (c) R(2)G(1)B(1).

On the 28/11/2004 airborne OrbiSAR-1 data were acquired. The OrbiSAR-1 is a SAR system that could operate simultaneously in the P and X bands. Only band X/VV was used. The OrbiSAR-1 data with spatial resolution of 5 meters (Fig. 5a), offers a better detection of the slick, also visible in the RADARSAT-1 image on the same day (Fig. 5b).

On the 30/22/2004, acquisitions with the R99 SAR were made. Fig. 5c shows part of the resulting L Band/VV, right looking image acquired with flight direction orientated to the SE. It is clear two elongated slicks appearing at the same point on the sea surface.

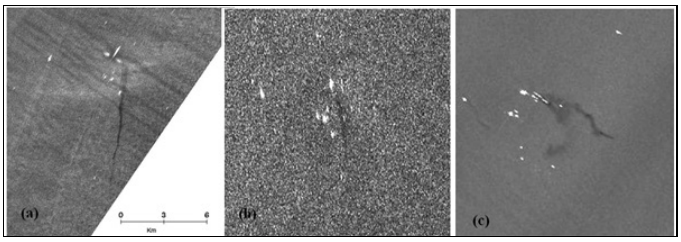

Figure 5. Detail of the OrbiSAR-1 mosaic (a) and of the RADARSAT-1 SNB image, acquired on 28/11/2004 – around 21:00 GMT (b). Detail of the R99/SIPAM image, acquired on 30/11/2004 – around 10:00 GMT (c).

IV. CONCLUSIONS

The best spatial resolution from VNIR/ASTER and CCD/CBERS-2 images permitted the visualization of spatial details, imperceptible in other products. Nevertheless, some factors limit the operational use of these sensors, among them; the narrow swath, the low temporal resolution, as well as the limitations imposed by the eventual presence of clouds.

The results demonstrate that the sensors in the VNIR present highest sensitivity for the detection of thin iridescent oil films, as well as for the thickness variation detection, imperceptible in the RADARSAT-1 image of the same day.

Among the sensors that operate in the VNIR, the WFI/CBERS-2 demonstrated the best potential for operational use, due to its wide swath (890 km) and reasonable temporal resolution (3-5 days). The spatial resolution of 260 m was effective in the slick visualization, presenting results comparable with those obtained with the VNIR/ASTER imagery. The WFI/CBERS products could become an important oceanic environmental monitoring tool, if near real time processing and delivery was implemented.

The mosaics acquired with airborne OrbiSAR-1, band X/VV, presented better mapping conditions for oil slicks, when compared with the RADARSAT-1 images of the same day. The system's technical viability for the near real time sea surface oil mapping was demonstrated.

The airborne images obtained with the R99/SIPAM, L/VV, presented good results for the detection of the slicks. The results demonstrated the viability of using the SIPAM aircraft in emergency situations in coastal and oceanic areas.

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