Exploitation of the Synergy between ERS ATSR-2 and GOME: A comparative analysis of ATSR-2 temperatures and reflectances with GOME NO_2 data to investigate the pollution effects of burning activities.

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Abstract

The capability of Along-Track Scanning Radiometer Near IRfrared and VISible channels to detect the presence of fires during the night on the bases of 3.7 μm channel saturation and smoke detection during the day by VIS channels has been used to retrieve useful information to be compared in synergy with Global Ozone Monitoring Experiment monitoring of trace gases concentration in the atmosphere in relation to fire events.

ATSR Rush and SADIST-2 images produced for fire detection and GOME level 2 products have been used to investigate the variation of the NO_2 trace gas columnar concentration associated to the anthropogenic activities and burning biomass.

Both the ATSR-2 and GOME results are in good agreement and are discussed in terms of image analysis and statistical and error analysis respectively.

1. Introduction

Since 1997 the European Space Agency has provided a fast service through the Internet to the international community on the monitoring of environmental disasters, such as fire events (Ref. 1). On the base of the interest demonstrated by the user community we have extended our investigation to the pollution effects of different burning activities.

To detect and localize the sources of atmospheric pollution, measurements from two instruments on board of ERS-2 satellite have been elaborated, precisely data acquired by the ATSR-2 (Along Track Scanning Radiometer) and GOME (Global Ozone Monitoring Experiment).

For our analyses Gridded Brightness Temperature ATSR-2 products have been used generated with RAL's SADIST-2 ATSR data processor (Ref, 2), and GOME Level 2 data produced operationally by the ground segment GOME DATA PROCESSOR located at DFD of the DLR, which is part of the official ESA Data Processing and Archiving Facilities (D-PAF) of GOME.

The methods used for the data analysis are well described in the (Ref, 1) and (Ref, 4) for the ATSR and GOME data respectively.

NO_2 concentration variations retrieved from GOME data, correlated with biomass burning and industrial pollution, detected as hot spots in ATSR night fire products, have been analysed during different period of 1998 and 1999. Our attempt to retrieve useful information on the nitrogen dioxide production relevant to the hot spots presences appear to be quite successful.

2. Industrial pollution: a case study in North Africa.

The following case study shows interesting results of the analysis carried out combining both ATSR-2 and GOME data regarding the possibility to monitor pollution effects over strongly industrialized areas. The area considered is located in Algeria (North Africa) exactly in Arzew area.

Algeria is one of the major oil and gas producer in Africa, and the oil refinery at Arzew is a topping and reforming refinery with a nameplate distillation capacity of 3,000 ktonnes per annum (Ref, 5). Moreover, following the country's expansion of its gas reserve (Algeria has the fourth largest natural gas reserves in the world) the Arzew refinery is undergoing a major rehabilitation of its GL1-Z and GL2-Z gas liquefaction plant.

Fig. 1 shows a temporal sequence of hot spots detected in the industrial area of Arzew, using ATSR-2 near-infrared 3.7 µm channel. The same locations of the hot spots and their persistence over a long period, from June 1998 to April 1999, give us the possibility to exclude the occurrence of occasionally hot spot events, but underline the presence of stable sources of high temperatures. In addition to hot spots detection, NO_2 concentration analysis over the same area has been carried out, using GOME data.

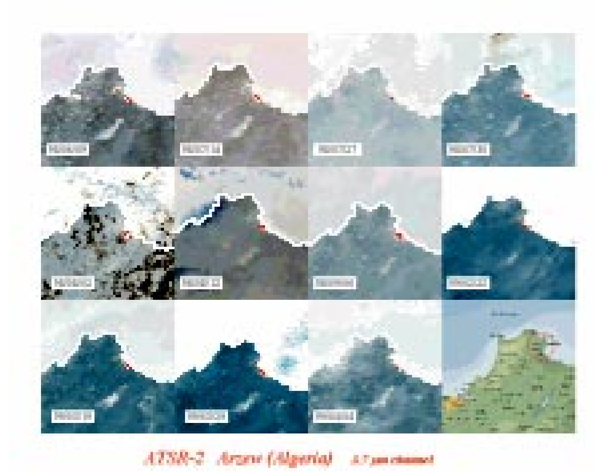

Fig. 1 Hot spots detected in industrial area of Arzew from June 98 to April 99.

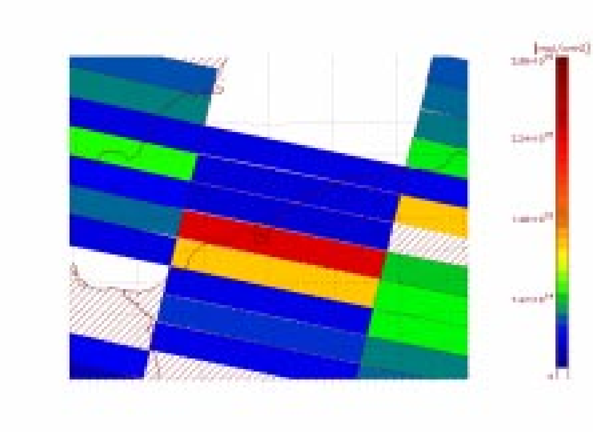

Fig. 2 Example of NO2 tropospheric emissions detected by GOME on June 9 1998, over Arzew area..

Fig. (3) shows the NO_2 tropospheric emissions over the Mediterranean Basin for the period June-August 1998. This emission map has been produced analyzing more than 200 orbits, following the methods described in (Ref. 4). High values can be found in correspondence of all the main cities (i.e. Rome, Athens, Istanbul, Barcelona, Madrid, Milan, Munich, Naples, Ankara, Budapest, Bilbao), and over the highly urbanized regions (e.g. Northern Italy).

The two circled sites correspond to Taranto and Arzew, for which a large number of ATSR hot spots have been detected. In the Arzew case the NO_2 values are doubled with respect to the neighborhood, while over Taranto the effect is smaller. This is probably due to differences in the amount of emitted gases, in the combustion processes and in the chemical composition of the burned substances, namely oil, gas, and coal. It should be noted that the pollution effect detected by GOME is relative to an area of 12800 km^2 (the ground pixel is 40 X 320 km^2) while the size of the two industrial sites is few km^2: the NO_2 concentration over this sites is probably an order of magnitude higher.

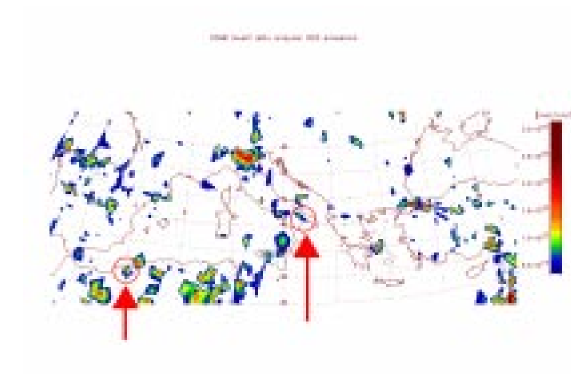

Fig. 3 NO_2 emission over the Mediterranean Basin. Values are measured over a period of three months (June-August 1998) and are expressed in [mol cm^{-2}].

3. Smoke over Yucatan region

The good synergy between ATSR-2 and GOME data is well demonstrated in the analysis applied to the study of fire events.

Central America has been affected, during 1998, by a huge amount of fire events. Using the 1 km resolution ATSR-2 IRR gridded Brightness Temperatures and reflectances products it has been possible to detect these dramatic events. The spectral analysis of visible, near-infrared channels of ATSR-2 gave good results in monitoring the smoke cover on the Yucatan Peninsula. While the NIR 1.6 µm channel seems to be poorly sensitive to attenuation by smoke, in fact the reflectance of smoke particles appear very low (fig. 4c), the visible channel 0.55 µm (fig. 4b) well detects the presence of smoke. Cloud structures in the region has been excluded on the bases of the high temperature resulting from the analysis of 11 µm thermal channel data.

In fact, whilst usually clouds are highly reflective and have low temperature, the image sequence shows high temperature and low reflectance in the region covered by the smoke (fig. 4d).

Using a false color combination of visible and near-infrared reflectance channel the presence of smoke particles has been well detected over land sea near the coast (fig. 4a), while the high concentration of fires at the two different ATSR-2 acquisition dates is well demonstrated in the relevant fire distribution map (fig. 5). Because of the severe limitations on the collection of visible channel data, due to the limited telemetry on ERS-2, the images over Yucatan region are shown with their reduced swath, with respect to the real size of 512x512 km.

The GOME NO_2 results from the analysis of fire events over Yucatan area in the reference time period can be found in Ref. (4).

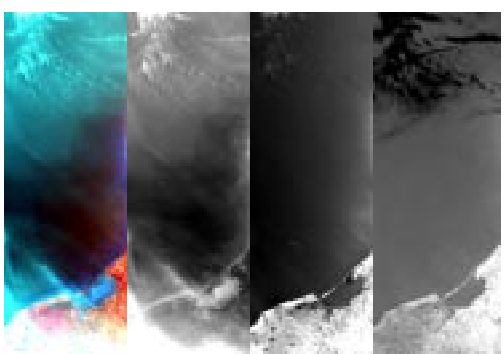

Fig. 4 Set of visible, near infrared and thermal infrared channels of ATSR2 image over Yucatan Peninsula on 13 May 1998. a) False color combination of VIS and NIR channels (Red: average of 0.87 and 1.6 µm; Green: 0.67 µm; Blue: 0.55 µm); b) 0.55 µm channel c) 1.6 µm channel; d) 11 µm channel.

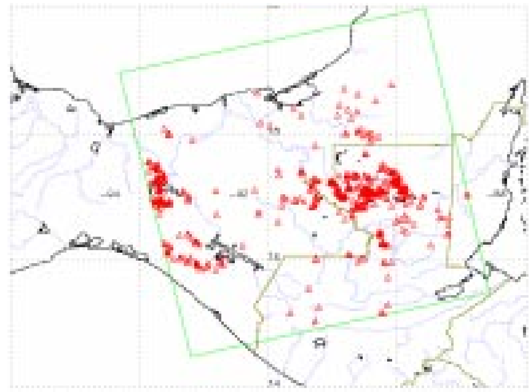

Fig. 5 ATSR-2 fire maps in Central America, a) 10 May 1998 and b) 13 May 1998. The first image shows the strong presence of fires on 10th May and the second their dramatic increasing three days later in the same region.

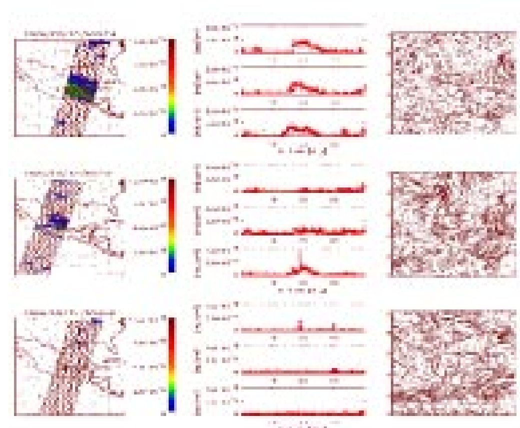

Fig. 6 Time evolution of the NO_2 emission from the mean for the period 13-19 of May. Plot (a) refers to May 13th, plot (b) to May 15th, plot (c) to May 19th. The arrow plots show the closest in time wind intensity and direction (ECMWF analysis).

Fig. (6) shows the time evolution of the NO2 emissions for the Mexico Gulf area in the period ranging from May 13 to May 19, and 10m wind field analysis (ECMWF) relative to the closest in time available. For each day three graph are presented reproducing the deviation values at their geographical location (left plot), deviation vs. latitude along with the related uncertainty (center plot) for the left (upper), central (center) and right (lower) GOME pixel, and wind field in which the arrow length is proportional to the wind intensity.

4. Conclusions

The aim of this paper has been to underline how it is possible, using optical and multispectral instruments, to monitor, over relatively long time periods, the effects of both environmental disasters and industrial pollution. The variation of NO_2 concentration (derived from GOME data), associated to high temperatures (hot spots detected by ATSR-2), can be monitored both for events which occur frequently (e.g. pollution related to industrial activity) and more irregularly (e.g. fires).

The ATSR radiometry products offer high confidence in the detection and localization of hot spots, even if the point source of high temperature is less than pixel size of 1 km^2. Therefore, as has been demonstrated in this paper, the simultaneous acquisitions of both instruments provides a good synergy between ATSR-2 and GOME instruments.

5. References

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