MAXIMIZING THE DETECTION AND MAPPING OF MINIMAL AREA BURN SCARS WITH A MULTI-PAYLOAD MULTI-METHOD AUTOMATED APPROACH: APPLICATION TO SUMMER FIRE SEASONS IN ITALY

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1. INTRODUCTION

Every year, frequent and small-sized summer wildfires affect the Countries of southern Europe. Fire damaged areas cannot be thoroughly mapped and inventoried without high spatial resolution, multispectral - or SAR - remote sensing observation of fire altered vegetation. However, accurate detection of short duration fires cannot be systematically performed with acceptable omission, if very high-temporal resolution remote sensed observation is not carried out.

The most effective, passive remote-sensing methods for detecting and mapping burn scars in vegetated areas, rely upon the observation of near-infrared (NIR) and short-wavelength infrared (SWIR) bands, with wavelengths comprised between 0.8 and 2.3 μm. During more than twenty years, systematic this task was systematically performed by the Landsat spacecraft family, with payloads TM (onboard Landsat 5) and ETM+ (Landsat 7).

ETM+ (Enhanced Thematic Mapper) operates in "SLC-OFF" acquisition mode since May 2003, which makes it unsuited to the quantitative, multi-temporal, spectral analysis of the territory. As for the TM (Thematic Mapper) radiometer onboard Landsat 5, we have verified that image data acquired during summer 2009 are still suited for burn scar mapping, even though the payload started displaying severe radiometric degradation from June 2002.

Fire hot-spot detection methods are based on contextual and/or multi temporal analysis of observations in MIR and TIR channels. Geostationary multispectral payloads present major advantages in hot-spot detection with respect to low Earth orbit (LEO) payloads as MODIS, AVHRR and ATSR, mostly in terms of information refresh (96 images daily, with eventual triple acquisition rate in 'rapid scan' mode).

Provided that the released instant power is sufficient, such high imaging frequency allows detecting of short lasting fires - extinguished in less than 3-4 hours - frequently missed by LEO systems. Current payload SEVIRI (Spinning Enhanced Visible and InfraRed Imager) onboard Meteosat Second Generation MSG-1 and -2 of the European EUMETSAT consortium, is the most advanced payload for multispectral geostationary Earth

Observation, in terms of spatial resolution (9 km^2 at nadir for the multispectral channels and 1 km^2 at nadir for the panchromatic channel), spectral resolution (12 channels from visible to TIR), temporal resolution (15-minute) and data quality (10-bit quantization).

2. METHOD DESCRIPTION

2.1. The SFIDE algorithm for high-frequency detection of fires

A fire detection system based on a geostationary satellite to be competitive with other systems based on LEO orbit sensors should be able to detect small and short duration fires. The detection of hot spots of very small sizes, with respect to the satellite image pixel sizes, is generally made by using the brightness temperature measured in the MIR (Middle Infra-Red) and TIR (Thermal Infra-Red) spectral channels. In particular the detection of hot spots is based on the high sensitivity of the MIR channel to the high temperature associated with fire, volcanoes, etc. Due to the characteristics of the SEVIRI (Spinning Enhanced Visible and Infrared Imager) sensor, on board of the MSG geostationary, the fire detection approach commonly used for LEO payloads will be result in a large number of undetected fires as consequence of the low spatial resolution of the sensor (9 km^2 at the equator). In order to allow the detection of small fire (< 0.2 ha) by using SEVIRI/MSG, notwithstanding its limited spatial resolution, in the last few years the CRPSM has developed an new algorithm, called SFIDE® [1], [2], capable to exploit the high sampling frequency of the MSG/SEVIRI sensor. It is based on a change-detection technique to maximize the fire-recognition capabilities of the system in spite of its limited spatial resolution.

In fact, if very small fires (compared to the pixel sizes (~4x4 km^2 at Mediterranean latitude) can be detected, thanks to the high revisit frequency of observations, a real-time system able to track the fire characteristics (behaviour, trend, size, etc.) can be settled-up.

SFIDE synthetically operates according the following steps:

- at a given instant t it compares the images, cloud free of the area of interest, acquired at t and t-1 (15 minutes apart each other) and the differences in terms of brightness temperatures in channel 4 (MIR, 4 μm) and 9 (TIR, 11 μm) are computed.
- Such differences are compared with the expected values provided by a model.
- Pixels for which the difference excesses an assigned time and spatial varying threshold are considered to correspond to hot spots.

This algorithm operate automatically on the area of interest and its final products comprising characteristics of the fire (FRP, Fire Radiative Power,. Burning temperature and burning area, etc.) are provided in different format (gml, txt, etc.). The reliability of SFIDE has been tested during the last 4 years over the Sardinia region [3].

2.2. The unsupervised procedure MYME-2 for burn scar mapping

In case of multi-temporal analysis of multispectral spaceborne data, the key is to distinguish reflectance changes originated by illumination and atmospheric conditions, sensor drift or sensor differences, from reflectance changes due to decrease in biomass content, chlorophyll absorption, water content and density in the vegetation cover. A method to separate reflectance variation due to vegetation damages from changes due to other factors influencing the at-satellite reflectance, is that of identifying pseudo-invariant features to be used as reference targets in different scenes. Such invariants must behave as Permanent Reflectors (PRs) ideally in three or more infrared bands.

We have developed and fine tuned from 2002 onwards, an automated procedure for carrying out the devegetation analysis on different platforms and on large sequences of multispectral data acquired by the Landsat, SPOT, and IRS family. The code, nicknamed MYME2 is a three-step procedure [4], [5], based on comparative analysis of reflectance associated to each image pixel and the mean reflectance value measured on pre-defined internal reference pixels (Permanent reflectors PRs). MYME2 steps are the follow:

- selected the pixels presenting a decrease in biomass content and chlorophyll absorption from acquired data of the multi-spectral image N-1 and the multi-spectral image N.
- Selected non-vegetated pixels located in the image N.
- Pixels selected in steps one and two, are considered to have undergone fire damage.

The final product of the automated procedure is a layer of polygons representing fire damaged areas between two acquisition dates, or a series of acquisition dates. The reliability of MyME2 was tested on over 150 high resolution scenes acquired by Landsat 5-TM, Landsat 7-ETM+, Terra-ASTER , SPOT4-HRVIR [6] and IRS P6 LISS 3 [7].

3. RESULTS

The combination of the two methods SFIDE and MYME2 described above, has definitely allowed improving the size threshold of discriminated and mapped burn scars. The improvement in quantity and quality of burn scars mapped at decametric resolution, came from the high-refresh rate estimate of the dynamic parameters of small and short lived fires. Summer 2009 burn scars were mapped for as much as 8 central regions of Italy (Toscana, Lazio, Campania, Molise, Abruzzo, Umbria, Marche, Emilia-Romagna: see Fig.1.1) exploiting the whole of free Landsat 5-TM scenes on tracks/rows 189/31-32, 190/30-31, 191/29-31,192/29-30 and 193/29 available at the USGS Global Visualization Viewer (http://glovis.usgs.gov/).

The analysis was purposely restricted to territory portions covered by permanent vegetation and crops (identified following the Land Cover CORINE2000), that display near-steady biomass content during the summer season. A quantitative relation between the hot-spot fire dynamic characteristics (Fire Radiative Power, burning temperature and burning area, e.g.) and location/extension of fire damaged areas is currently searched for, through the implemented SFIDE algorithm and the standard MYME2 method (Fig. 1.2 and 1.3).

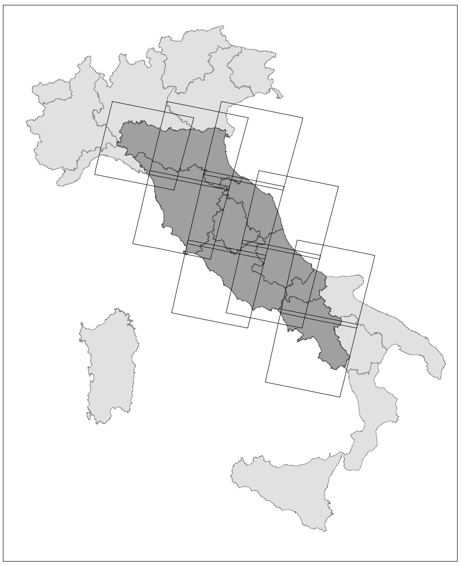

Fig. 1.1 Location map of the study area, with Landsat 5-TM frame boundaries overlie.

Fig. 1.2 Example of a series of burn scars mapped with the implemented method here proposed.

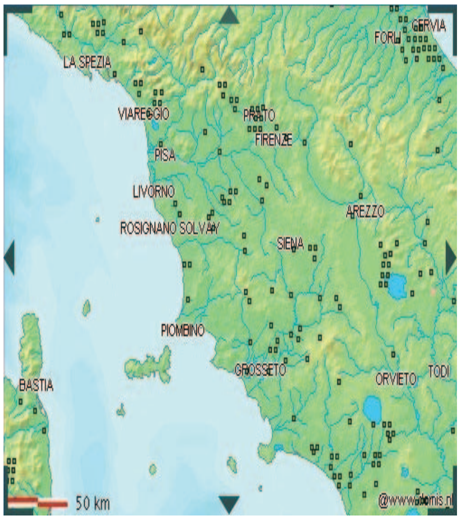

Fig. 1.3 Example of hot spots detected in Tuscany by using the SFIDE algorithm (summer 2009).

4. REFERENCES

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