Robust satellite techniques (RST) for forest fire detection

Carolina Filizzola[2], Francesco Marchese[1], Giuseppe Mazzeo[1], Nicola Pergola[2], Valerio Tramutoli[1,2]

[1] DIFA (Dipartimento di Ingegneria e Fisica dell'Ambiente), Università della Basilicata (Potenza)

[2] IMAA-CNR (Istituto di Metodologie per l'Analisi Ambientale) Tito Scalo (Pz)

ABSTRACT

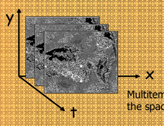
In this work, the RST (Robust Satellite Technique) approach, which has already been successfully applied for the monitoring of major natural and environmental risks, explores MSG-SEVIRI potential for forest fire detection.

The RST scheme is based on a multi-temporal analysis of co-located satellite records and on an automatic change detection scheme.

The index of local (in space and time) change, which is at the basis of the classical RST approach, is here integrated with a differential index, computed by using RST prescription as well, which permits us to identify the very start of a forest fire event, exploiting the high temporal repetition of the sensor. Preliminary field tests demonstrating the potential of this approach are also shown.

RST APPROACH

RST approach (Tramutoli 1998, Tramutoli, 2005) provides an univocal and robust definition of "thermal anomaly" considering it, in the space-time domain, as a significant deviation from a normal state which is specific for each place and time of observation. To identify forest fires an index called ALICE (Absolutely Llocal Index of Change of the Environment) is computed as:

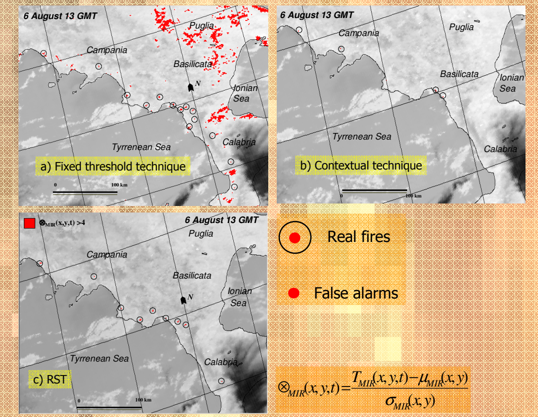


Multitemporal analysis of satellite data in the space time domain

$$\otimes_{MIR}(x,y,t)=\frac{V_{MIR}(x,y,t)-\mu_{MIR}(x,y)}{\sigma_{MIR}(x,y)}$$

where $V_{MIR(x,y,t)}$ is the signal measured in MIR channel at place (x,y) and time t, $\mu_{MIR(x,y)}$ and $\sigma_{MIR(x,y)}$ are the temporal mean and the standard deviation of $V_{MIR(x,y,t)}$ computed at the same place (x,y) using a long-term multi-temporal cloud-free satellite records. The reference fields, $\mu_{MIR(x,y)}$ and $\sigma_{MIR(x,y)}$, represent the signal behavior, in terms of expected value and natural fluctuations measured in unperturbed conditions and are computed using homogenous historical data sets: calibrated and co-located satellite data are stratified according to the same spectral channel, the same month of the year and the same acquisition time; only cloud-free records (selected by using the OCA scheme, Pietrapertosa et al. 2001, Cuomo et al., 2004) are considered to construct the $\mu_{MIR(x,y)}$ and $\sigma_{MIR(x,y)}$ reference fields. RST technique demonstrated (see for instance Cuomo et al., 2001 but also Pergola et al., 2004, Di Bello et al., 2004) to be capable of correctly detecting and monitoring hot spots strongly reducing false alarm rate due to site (bare soil reflection, elevation, etc.) and observational (time of the day, season, etc.) effects, and thanks to its tunability to identify forest fires of different extension and/or intensity (due to, for instance, a different kind of fuel). It should be underlined that $\sigma_{MIR(x,y)}$ is strongly dependent on both natural and observational, known and unknown sources of signal variability including those associated to co-location errors, ground cell resolution and air mass variations consequent to satellite view angle variations etc.

Comparison between traditional techniques and RST approach using AVHRR data

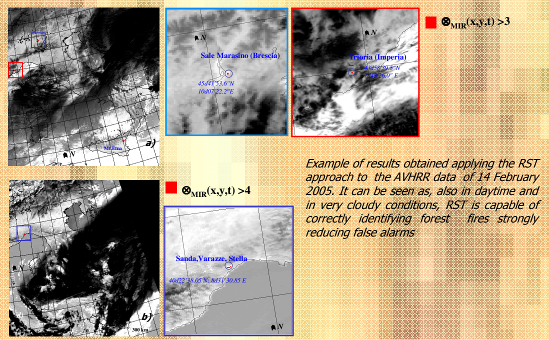


$$\otimes_{MIR}(x,y,t)=\frac{T_{MIR}(x,y,t)-\mu_{MIR}(x,y)}{\sigma_{MIR}(x,y)}$$

Figures show, in the case of fire events which affected southern Italy on 6 August 1998, as RST approach is capable of strongly improving forest fire detection reducing omission errors and false alarms, compared to some traditional techniques (a) Kaufmann et al., 1990; (b) Flasse et al., 1996)

Examples of recent RST results using AVHRR data

$$\otimes_{MIR}(x,y,t)=\frac{T_{MIR}(x,y,t)-\mu_{MIR}(x,y)}{\sigma_{MIR}(x,y)}$$



Example of results obtained applying the RST approach to the AVHRR data of 14 February 2005. It can be seen as, also in daytime and in very cloudy conditions, RST is capable of correctly identifying forest fires strongly reducing false alarms

AVHRR MIR images of 14 February 2005 at 02 *(a)* and 13 GMT *(b)*. Thermal anomalies detected by RST are depicted in red. A zoom of forest fires identified is reported on the right side of the image. Reference fields used for the computation of the local variation index were constructed using ten years of MIR satellite data, acquired in February month between 00-03GM T and 12-14 GMT (from Marchese et al., 2006, submitted)

FROM POLAR TO GEOSTATIONARY PLATFORM:

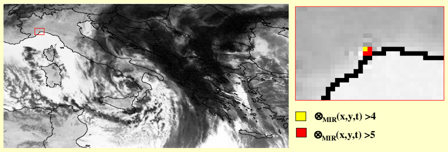
The use of geostationary satellite data instead of the polar ones allows us to reduce the most important observational noise sources:

The same location is observed, at each revisiting time, under the **same satellite angle** (with the same resolution cell size)

imagery co-location is straightforward and precise.

quite **fixed observational time** (in a time slot not longer than 30 min) guarantees higher homogeneity of imagery time series further reducing that contribution to signal variability due to the image-to-image observational time changes (even several hours) specific to polar satellite

RST approach applied to SEVIRI data for *fire monitoring*

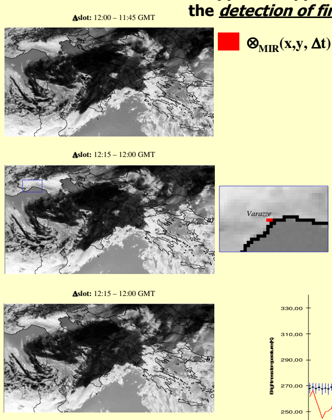


$$\otimes_{MIR}(x,y,t)=\frac{T_{MIR}(x,y,t)-\mu_{MIR}(x,y)}{\sigma_{MIR}(x,y)}$$

SEVIRI image of 15 feb 2005 h 00:00 GMT , ch 3.9 μ

Example of results obtained applying the RST approach to the MSG-SEVIRI data of 15 February 2005. It should be noted that the same fire event (Varazze fire) which is detected by RST on AVHRR data by lower values of the ALICE index is better highlighted on SEVIRI images thanks to the higher sensitivity of the local variation index on geostationary data.

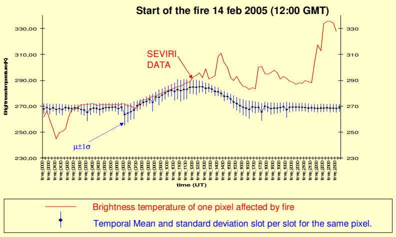
RST approach applied to SEVIRI data for the *detection of fire event beginning*



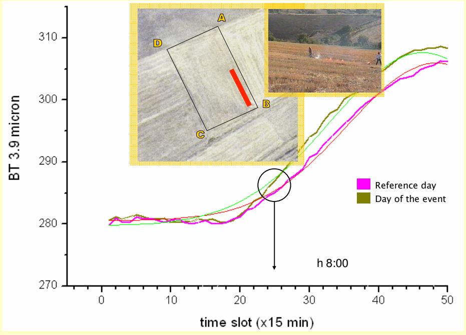
SEVIRI image of 14 feb 2005, ch 3.9 μ

$$\otimes_{MIR}(x,y,\Delta t)=\frac{\Delta T(x,y,\Delta t)-\mu_{\Delta T}(x,y)}{\sigma_{\Delta T}(x,y)}$$

The very high temporal resolution of geostationary satellite sensors (15 minutes in the case of SEVIRI) allows us to apply RST approach in a differential mode which gives the possibility to monitor not only the dynamics of the fire event, but also the beginning of the event itself.



SENSITIVITY ANALYSIS TOWARD VERY SMALL FIRES DETECTION IN FIELD TEST



CONCLUSIONS

An automatic approach to detect and monitor forest fires in near real time has been proposed. It has been first applied to AVHRR data allowing to correctly detect and monitor forest fires reducing false alarms and omission errors at very low levels in comparison with traditional multichannel and contextual algorithms.

RST technique can be used in whatever observational condition (day/night, summer/winter) without any significant difference in terms of reliability, being not sensitive to reflected solar radiation effects by bare soil and clouds, variation of surface emissivity etc., that generally represent an evident cause of false identification for many satellite techniques developed to detect fires.

This approach not requiring any ancillary information can be easily implemented on whatever satellite platform to monitor forest fires at a global scale. In particular its recent implementation on new geostationary satellites MSG-SEVIRI has shown further improvements both in terms of sensitivity and efficiency. Even at a lower spatial resolution (3 km compared to 1.1km of AVHRR MIR/TIR bands) and thanks to the geo-stationary attitude, SEVIRI offers, in fact, an accurate geo-correction and a natural image-to-image co-location, as well as constant (for each location) view-angles, that may strongly reduce the observational noise. The observed higher signal/noise ratio should allow us, in fact, to correctly identify short-time changes in the intensity of the thermal signal to promptly recognize the beginning of new fire events.

In such a case a differential index $\otimes_{MIR}(x,y,\Delta t)$ based on the difference $\Delta t = T_{MIR}(x,y,t1) - T_{MIR}(x,y,t0)$ have to be computed to detect possible abrupt "anomalous" changes in the thermal signal observed between two contiguous time slot.

Furthermore, thanks to a temporal resolution of 15 minutes, SEVIRI sensor offers a great opportunity to to develop a robust Early Warning System capable of timely identifying forest fires, when they are still at Early stage, and to monitor them in real time, strongly contributing to the mitigation of the fire risk.

Corresponding author address: Dr Francesco Marchese
e-mail: fmarchese@imaa.cnr.it

References

- Cuomo, V., Lasaponara, R., and Tramutoli, V. (2001), Evaluation of a new satellite based method for forest fire detection. *International Journal of Remote Sensing*, 22, 1799–1826.
- Cuomo, V., Filizzola, C., Pergola, N., Pietrapertosa, C., Tramutoli, V. (2004). A self sufficient approach for GERB cloudy radiance detection. *Atmospheric Research* 72, 39-56.
- Di Bello, G., Filizzola, C., Lacava, T., Marchese, F., Pergola, N., Pietrapertosa, C., Piscitelli, S., Scaffidi, I., Tramutoli, V. (2004). Robust Satellite Techniques for Volcanic and Seismic Hazards Monitoring, *Annals of Geophysics*, 47 (1), 49-64.
- Flasse, S. P., and Ceccato, P., 1996, A contextual algorithm for AVHRR fire detection. *International Journal of Remote Sensing*, 17, 419–424.
- Kaufman Y. J., Tucker C. J. and Fung I., 1990, Remote sensing of biomass burning in the tropics, *Journal of Geophysical Research*, 95, 9895-9939.
- Pergola, N., Marchese, F., Tramutoli V. (2004). Automated detection of thermal features of active volcanoes by means of Infrared AVHRR records, *Remote Sensing of Environment* Volume 93, Issue 3, pp. 311-327.
- Pietrapertosa, C., N. Pergola, V. Lanorte, and V. Tramutoli (2000): Self-adaptive algorithms for change detection: OCA (the One-channel Cloud-detection Approach) – an adjustable method for cloudy and clear radiances detection. *XI TOVS Study Conference*, Budapest, 281-291
- Tramutoli, V. (1998). Robust AVHRR Techniques (RAT) for Environmental Monitoring theory and applications. In *Earth Surface Remote Sensing II*, Giovanna Cecchi, Eugenio Zilioli; Editors, SPIE 3496, 101-113.
- Tramutoli, V. (2005). Robust Satellite Techniques (RST) for natural and environmental hazards monitoring and mitigation: ten years of successful applications. In *The 9th International Symposium on Physical Measurements and Signatures in Remote Sensing*, Shunlin Liang, Jiyuan Liu, Xiaowen Li, Ronggao Liu, Michael Schaepman Editors, Beijing (China), ISPRS, Vol. XXXVI (7/W20), pp.792-795, 2005. ISSN 1682-1750