A ROBUST SATELLITE TECHNIQUE (RST) FOR DUST STORM DETECTION AND MONITORING: THE CASE OF 2009 AUSTRALIAN EVENT

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1. INTRODUCTION

Several techniques have been up to now proposed in order to characterize dust clouds from satellite observations. These satellite methods generally take into account the reverse absorption behaviour showed by silicate particles, in comparison with ice crystals and water droplets, at 11 and 12 µm wavelengths [1, 2]. Therefore, the brightness temperature differences BT_{11}-BT_{12} measured in these spectral bands have often been used in order to evaluate the competing effects of the silicate dust particles and of water and ice [3 and reference herein]. However, performances of split window methods depend on observational conditions (day/night, land/sea, etc.) as well as on specific aerosol properties (mainly size distribution and complex refractive index). As observed by several authors, optically thick dust plumes over water initially are characterized by a depression of the difference BT_{11}-BT_{12}, but as the optical thickness increases the BT_{11}-BT_{12} value becomes higher and may even change sign [4,5]. Moreover, even suspended aerosols, that vary significantly in concentration, may alter the observed BT_{11}-BT_{12} values [6]. Finally when the plume spreads out spatially, the mixing with the surrounding air cause a large variation in the BT_{11}-BT_{12} values for a single dust event [6]. In this paper, an original scheme of data analysis named RST (Robust Satellite Technique, [7]), already successfully used to study and monitor several natural and environmental hazards [8,9,10,11,12,13,14,15,16,17,18,19], has been applied to a recent dust storm occurred in Australia in September 2009 [20]. This event has been analyzed implementing RST on MTSAT-1R (Multi-functional Transport Satellite-1Replacement) Japanese geostationary satellite data, which are make available on line by Kochi University of Japan [21]. Some preliminarily results of this study will be shown in the following, discussing RST performances in comparison with traditional split window satellite techniques.

2. RST TECHNIQUE

The RST approach performs a multi-temporal analysis of satellite records acquired on several years (variable in dependence of the availability of homogeneous historical data-set {T}), devoted to characterize the signal in terms of its expected value and variation range, for each pixel of the satellite image to process. Anomalous signal patterns are then identified by using a local change detection index, named ALICE (Absolutely Local Index of Change of Environment [4]), defined as:

$$\otimes_V(\mathbf{r},t') \equiv \frac{\lfloor V(\mathbf{r},t') - V_{ref}(\mathbf{r}) \rfloor}{\sigma_V(\mathbf{r})} \tag{1}$$

where V($\boldsymbol{r}$,t') is the signal to analyze, $\boldsymbol{r} \equiv (x,y)$ the geographic coordinates of the image pixel centre and t' the time of acquisition of the satellite image. $V_{ref}(\boldsymbol{r})$ and $\sigma_V(\boldsymbol{r})$ respectively represent a reference field for the signal V($\boldsymbol{r}$,t) (e.g. minimum, maximum, mean, etc.) and its standard deviation. These reference fields are computed on the pre-selected homogeneous data-set {T} of cloud-free satellite records, collected at location $\boldsymbol{r}$ in the same time-slot (hour of the day) and in same period (e.g. month) of the year ($t' \in$ {T}). Depending on the specific application a different signal is taken into account. In the case of dust storms the RST-DUST technique is implemented computing a specialized local variation index ALICE defined as:

$$\otimes_{\Delta T}(\mathbf{r},t') \equiv \frac{\lfloor \Delta T(\mathbf{r},t') - \mu_{\Delta T}(\mathbf{r}) \rfloor}{\sigma_{\Delta T}(\mathbf{r})} \tag{2}$$

In the equation (2), $\Delta T(r,t')$ is the difference of brightness temperatures (BT_{11}-BT_{12}) measured at 11 and 12 µm, while $\mu_{\Delta T(r)}$ and $\sigma_{\Delta T(r)}$ respectively represent the temporal mean and temporal standard deviation of the same spectral signal difference. Detection/discrimination thresholds so defined are then absolutely local, both in space and time, and are dynamically derived from the observations, as a result of the multi-temporal statistical analysis.

3. THE CASE OF 2009 AUSTRALIAN DUST STORM

The RST-DUST was tested during a large event occurred in Australia in September 2009. This event took place in the southern part of this region on 22nd September moving towards the northern part of the region some days later ([20] see Fig. 1). In figure 2 an example of preliminarily results obtained applying RST-DUST to MTSAT1R data of 24th September at 12.00 local time (02 GMT) is reported. As can be seen from the figure, this techniques was capable of successfully detecting the dust cloud in the area where it occurred after two days from the beginning of the event and so in a more dispersed manner (see Fig. 1). It should be noted the presence of some (and more isolated) "dust" pixels detected in correspondence of meteorological clouds. These observations are justified considering that dusts operate as a condensation centre for clouds formation. These preliminarily results, even if a more detailed analysis is required on other geographic areas, confirm the potential of RST-DUST in detecting and monitoring dust storms. Therefore, the use of *llocal* thresholds, dynamically derived processing historical satellite records, may allow us to strongly reduce the dependence on observational and environmental conditions, improving dust cloud detection and discrimination in comparison with traditional split window techniques.

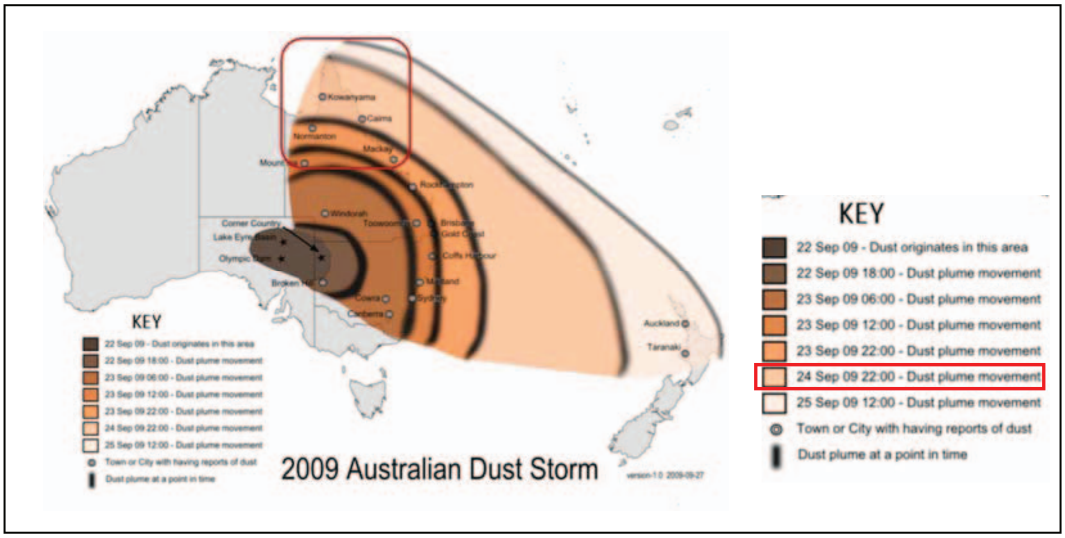

Fig. 1 - Time-space evolution of the dust storm occurred in Australia during September 2009 [14]. In red

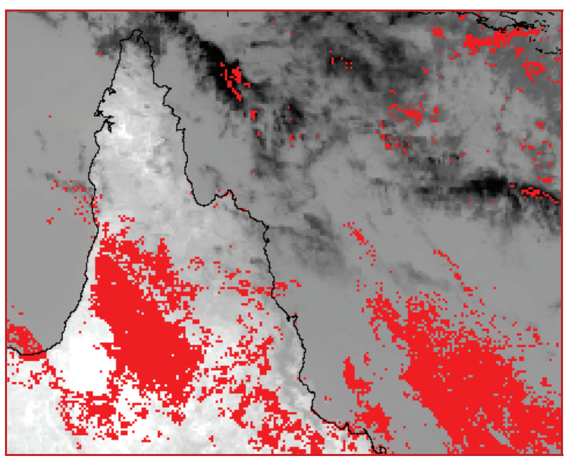

Fig. 2 – Dust pixels (depicted in red over the 11µm image) detected by RST-DUST on 24 September 2009 on MTSAT-1R ROI sub-scene (identified by red square of Fig.1), at 12:00 local time (02 GMT).

4. CONCLUSIONS

In this paper, the preliminarily results of a dust cloud event occurred in Australia during September 2009 analyzed by RST-DUST technique have been reported. This approach has been implemented on MTSAT1R data, for which an archive is freely available on the web. Four years of satellite records (about 120 images) acquired from 2005 and 2008 have been used to construct the spectral reference fields, analyzing a ROI centered over the Australian region. The preliminarily results confirm the RST-DUST potential in successfully detecting dust storms both over land and sea, even when the dust plume is more dispersed. These results encourage us to further improve performances of such a technique for its full implementation on geostationary satellites, like MSG-SEVIRI, that, offering the best time repetition frequency currently available (i.e. 15 minutes), are the most suitable for operational purposes.

4. REFERENCES

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