Monitoring earthquake and volcano phenomena through HIMAWARI-8/AHI observations

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Remote sensed data provided by meteorological satellite sensors have proven themselves as an useful tool in the field of geohazard assessment and their mitigation. In particular, data provided by satellite sensors on board of geostationary platforms, which allow to obtain information on large areas with an high time frequencies, have been exploit, for example, for the reduction of seismic and volcanic risks.

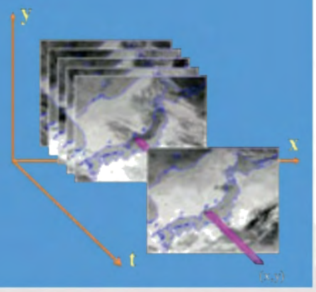
Since 1998, the general change detection approach **Robust Satellite Techniques** (**RST**; Tramutoli 1998, 2007) has show good ability to identify and to monitor phenomena associated to earthquake process, as well as volcanic process. Based only on satellite data without any use of additional information (i.e. ancillary data), the RST approach can be easily implemented on different satellite data.

In this work, in order to study earthquake- and volcano-process, and their related phenomena and products, RST approach has been implemented on radiance collected by the Japanese satellite sensor **HIMAWARI 8/9-AHI**. Here, we show the achieved results of two different RST analysis. The Sulawesi (Indonesia) earthquake of magnitude Mw~7.5 occurred on September 28, 2018 and the eruption of Mt. Agung (Indonesia) of November 2017 have been take in account as test cases.

RST

The change detection methodology, RST (Tramutoli, 1998, 2007), analyses time-series of satellite images acquired under the same observational conditions (e.g. same sensor, similar time of the day, similar month of the year, etc.). In the RST scheme, a variation of the signal is considered as 'anomalous' when it deviates significantly from its "normal" behavior as measured at a specific place (*x,y*), and time of observation *t*. Anomalies are identified using the statistically-based index ALICE (Absolutely Local Index of Change of the Environment) signal anomaly being computed as follow:

$$\otimes(x,y,t) = \frac{V(x,y,t) - \mu_V(x,y)}{\sigma_V(x,y)}$$



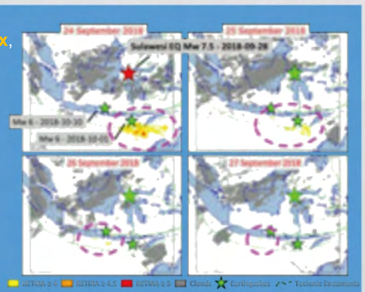
where:
- V(*x,y,t*) is the variable V value measured at location (*x,y*) and time *t*;
- $\mu_V(x,y)$ and $\sigma_V(x,y)$ are respectively the expected value (usually the time average) and the standard deviation of V(*x,y,t*) computed on locations declared as cloud-free and belonging to the chosen data set $t \in \tau$, where τ determines the homogeneous temporal domain of multi-annual satellite imagery.

Results of RST analysis at time of Sulawesi EQ (Mw~7.5 - September 28, 2018)

RETIRA (Robust Estimator of TIR Anomalies; Tramutoli et al. 2005) **index**, which derives from the more general ALICE index, is used to identify TIR (Thermal InfraRed) fluctuations possibly related to the occurrence of earthquakes, and it was defined as:

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

where $\Delta T(x,y,t) = T(x,y,t) - T(t)$ is the value of the difference between the punctual value of TIR brightness temperature T(x,y,t) measured at the location x,y acquisition time t, and its spatial average T(t) computed on the investigated area considering only cloud-free locations, all belonging to the same, land or sea, class (i.e. considering only sea pixels if x,y is located on the sea and only land pixels if x,y is located on the land).

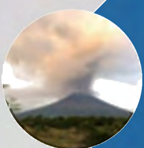


Results of long-term correlation analysis

Period	Sensitivity			Reliability		
	Number of EQ M6	Associated to SSTAs*	Not Associated to SSTAs	Number of SSTAs	Associated to EQs	Not Associated to EQs
1 July - 15 November 2015 - 2018	21	15 **71%**	6 **29%**	26	12 **46%**	14 **54%**

* **S**ignificant **S**equence of **T**IR **A**nomalies

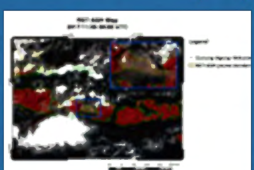
Results of RST analysis at time of *Mt. Agung eruption of November 2017*



RST_{ASH} (Pergola et al., 2004) is a multitemporal algorithm which identifies airborne ash by means of two local variation indexes defined as:

$$\otimes_{BT11-BT12}(x,y,t) = \frac{(BT11(x,y,t) - BT12(x,y,t)) - \mu_{BT11-BT12}(x,y)}{\sigma_{BT11-BT12}(x,y)}$$

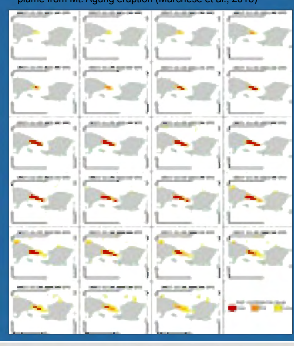
$$\otimes_{BT3.9-BT10.8}(x,y,t) = \frac{(BT3.9(x,y,t) - BT11(x,y,t)) - \mu_{BT3.9-BT11}(x,y)}{\sigma_{BT3.9-BT11}(x,y)}$$



Himawari-8 RGB (R=0.86μm, G=0.51μm, Blue=0.47μm) product at 1 km spatial resolution of 26 November at 00:00 UTC (09:00 JST). In brown, within the magnified area (at the top right side of image), the ash plume emitted by Mt. Agung (indicated in purple). Dashed lines, in yellow, correspond to borders of RST_{ASH} detections.

where *BT3.9(x,y,t), BT11(x,y,t) and BT12(x,y,t)* are the brightness temperatures (BT) measured at 3.9 μm, 11 μm and 12 μm wavelengths

RST_{ASH} maps at 10 min temporal resolution from November 25 (21:10 UTC) to November 26 (00:50 UTC), 2017 showing the space-time evolution of ash plume from Mt. Agung eruption (Marchese et al., 2018)



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