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Assessing the RST_{VOLC} algorithm implementation on infrared Sentinel 3 SLSTR data

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Goals:

- To implement the RST_{VOLC} algorithm on Sentinel 3 SLSTR data, for which a less populated multiyear dataset of satellite observations is currently available.

- To simulate the spectral reference fields in order to run the algorithm.

- To integrate information from different sensors (AVHRR; MODIS; VIIRS; SLSTR), increasing the continuity of satellite observations at the monitored volcanic areas.

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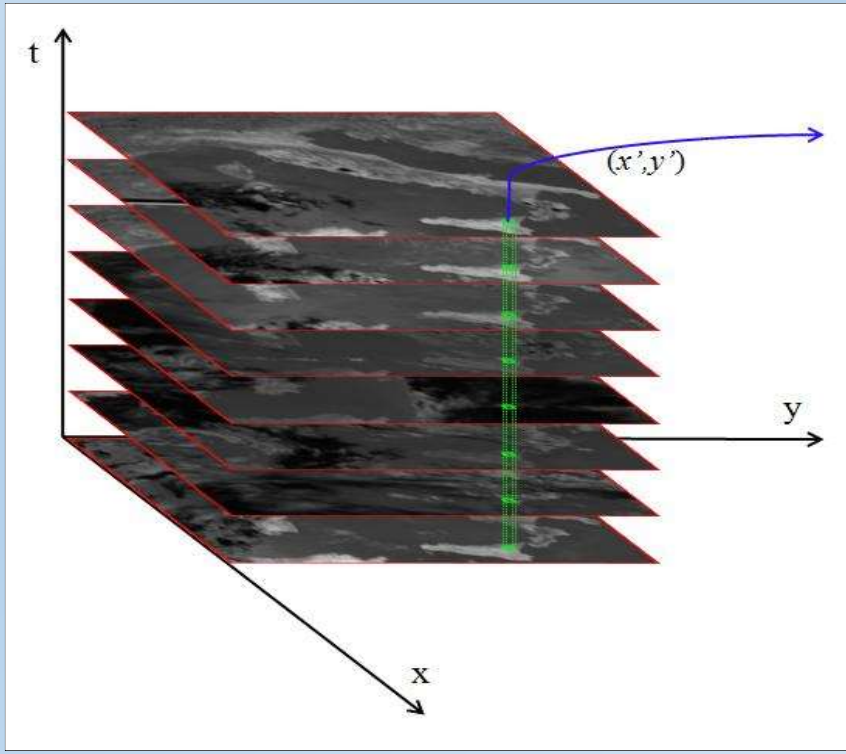
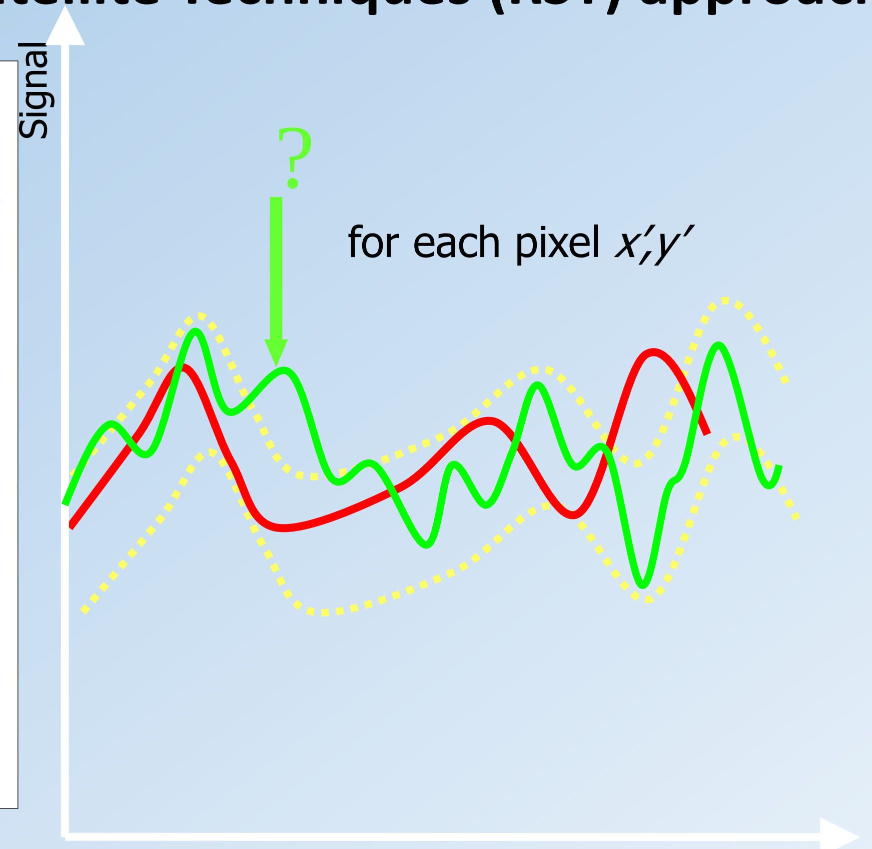
Method: Robust Satellite Techniques (RST) approach



Multitemporal analysis, performed according to the RST scheme, for the generation of spectral reference fields starting from homogenous cloud-free satellite records (same month, overpass time and spectral channel/s)



Tramutoli, V. (2007, July). Robust satellite techniques (RST) for natural and environmental hazards monitoring and mitigation: Theory and applications. In *2007 International Workshop on the Analysis of Multi-temporal Remote Sensing Images* (pp. 1-6). IEEE.

Computation of the **ALICE (*Absolutely Local Index of change of Environment*) index to** detect anomalous variations of the signal.

$$\frac{V(x_i, y_i, t) - V_{ref}(x_i, y_i)}{\sigma(x_i, y_i)}$$

Reduction of:

- "Site" effects
- Seasonal effects
- "False Alarms"

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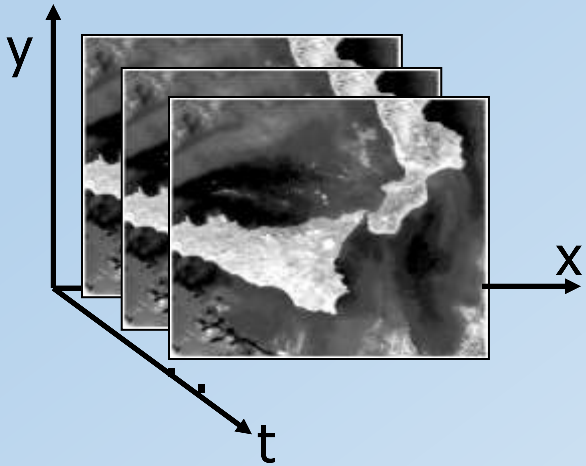
A RST-based algorithm for volcanological applications: RST_{VOLC}

RST_{VOLC} combines two local variation indices to detect volcanic hotspots on both nighttime and daytime data (Marchese et al., 2011).



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

$$\otimes_{MIR-TIR}(x,y,t) = \frac{\left[\left(T_{MIR}(x,y,t) - T_{TIR}(x,y,t)\right) - \mu_{MIR-TIR}(x,y)\right]}{\sigma_{MIR-TIR}(x,y)}$$

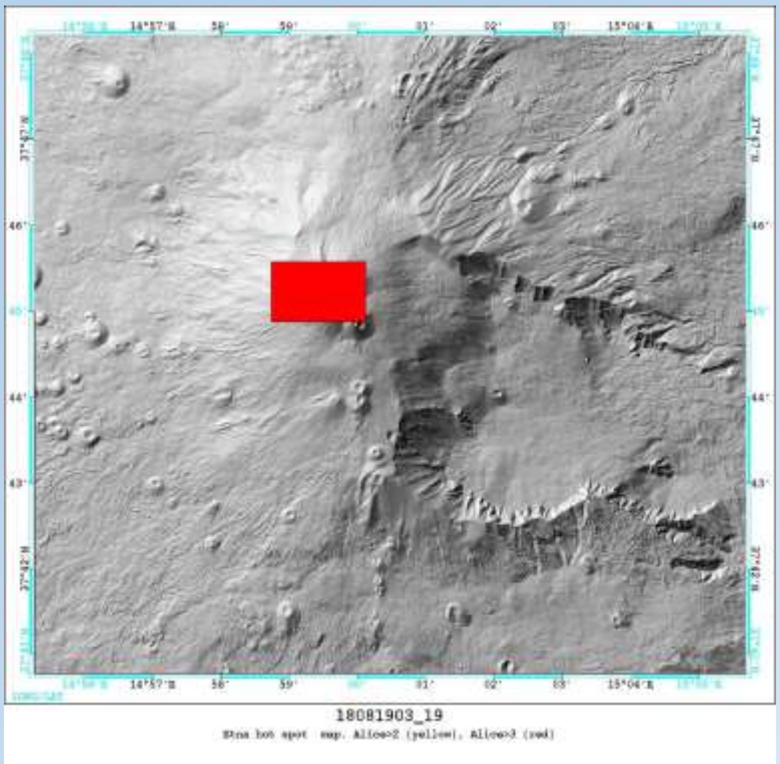
RST_{VOLC} runs operationally at IMAA **since 2011** to monitor Italian volcanoes in near-real time **using AVHRR and MODIS** data (Pergola et al., 2015).

Marchese, F., Filizzola, C., Genzano, N., Mazzeo, G., Pergola, N., & Tramutoli, V. (2011). Assessment and improvement of a robust satellite technique (RST) for thermal monitoring of volcanoes. *Remote Sensing of Environment*, *115*(6), 1556-1563.

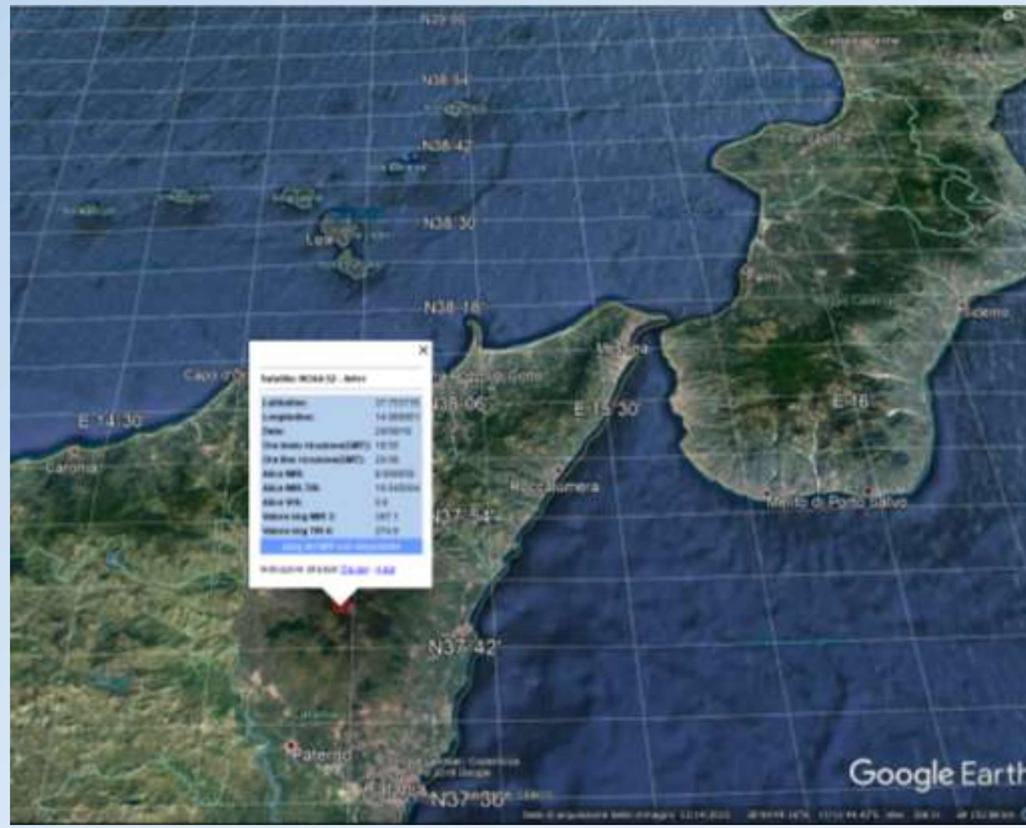
Pergola, N., Coviello, I., Filizzola, C., Lacava, T., Marchese, F., Paciello, R., & Tramutoli, V. (2016). A review of RSTVOLC, an original algorithm for automatic detection and near-real-time monitoring of volcanic hotspots from space. Geological Society, London, Special Publications, 426(1), 55-72.

Example of hotspot products automatically generated by the RST_{VOLC} system using AVHRR and MODIS data

Thermal anomaly map (red pixels)

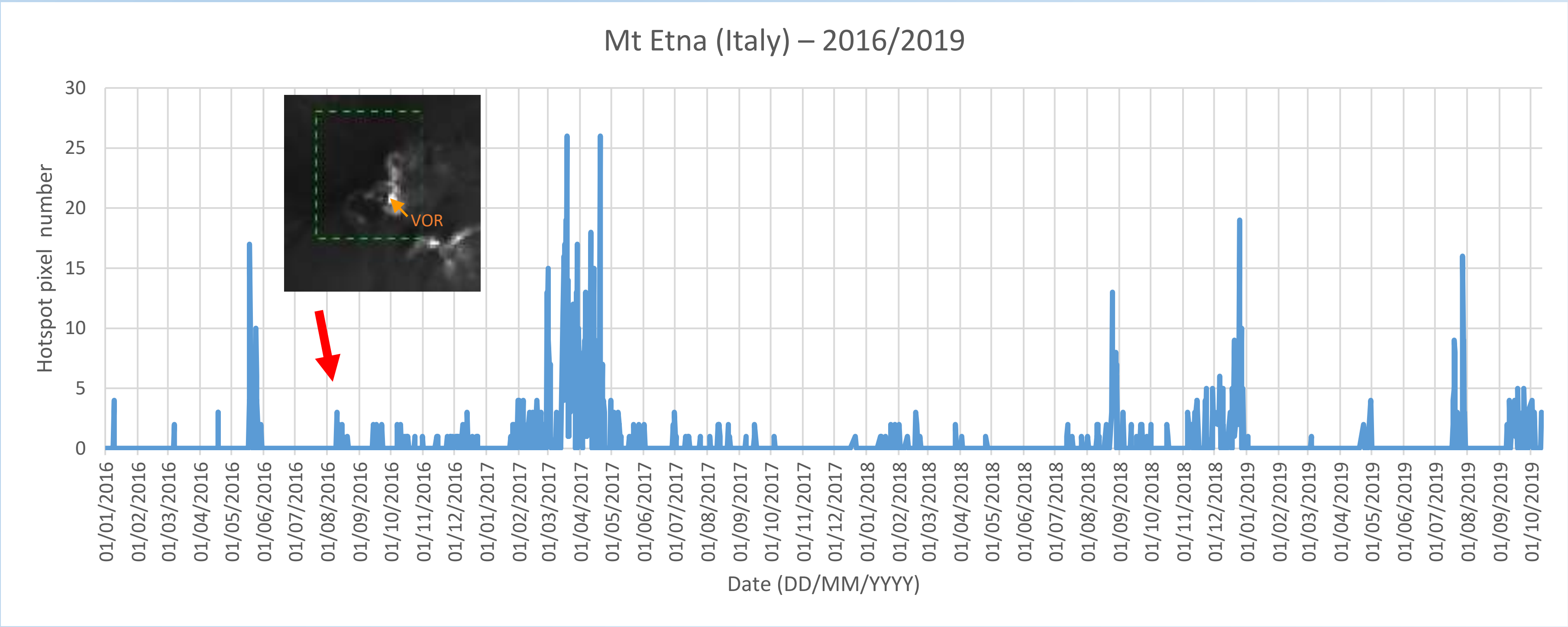


RST_{VOLC} products may be provided to the users under request.



Kml file reporting information (e.g. date and time of observation, hotspot intensity) about detected thermal anomalies

Monitoring changes of thermal volcanic activity at Mt. Etna (Italy) using NOAA/Metop-AVHRR data



Time series analysis of **Mt. Etna (Italy) thermal activity of 2016-2019** investigated using RST_{VOLC}. Note the identification of both intense and **subtle hotspots,** including a thermal anomaly preceding the opening of a new degassing vent at the Voragine crater (VOR) on 7 August 2016 (in green the AVHRR pixel overlapped to the Landsat 8 OLI sub-scene of 6 August 2016) (Marchese et al., 2018).

Marchese, F.; Neri, M.; Falconieri, A.; Lacava, T.; Mazzeo, G.; Pergola, N.; Tramutoli, V. The Contribution of Multi-Sensor Infrared Satellite Observations to Monitor Mt. Etna (Italy) Activity during May to August 2016. Remote Sens. 2018, 10, 1948.

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Current data implementation

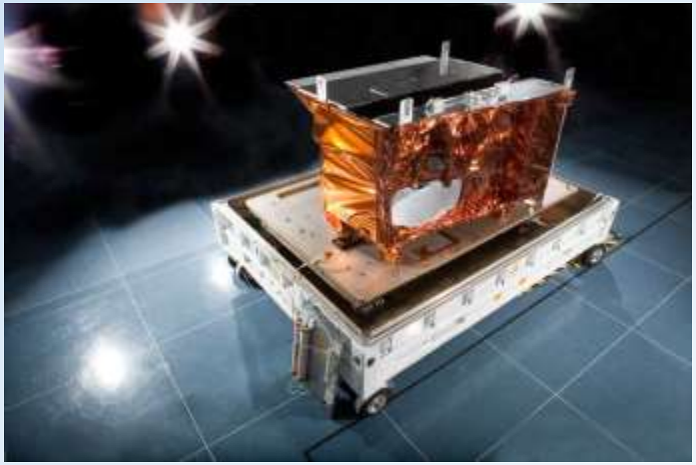
Visible Infrared Imaging Radiometer Suite (VIIRS)

✓ One of the 5 key instruments onboard the Suomi National Polar-Orbiting Partnership (Suomi NPP) spacecraft, which was successfully launched at 5:48am EDT on October 28, 2011, from Vandenburg Air Force Base in California

✓ A whiskbroom radiometer, collects visible and infrared imagery and radiometric measurements of clouds, aerosols, ocean color, surface temperature, fires and albedo

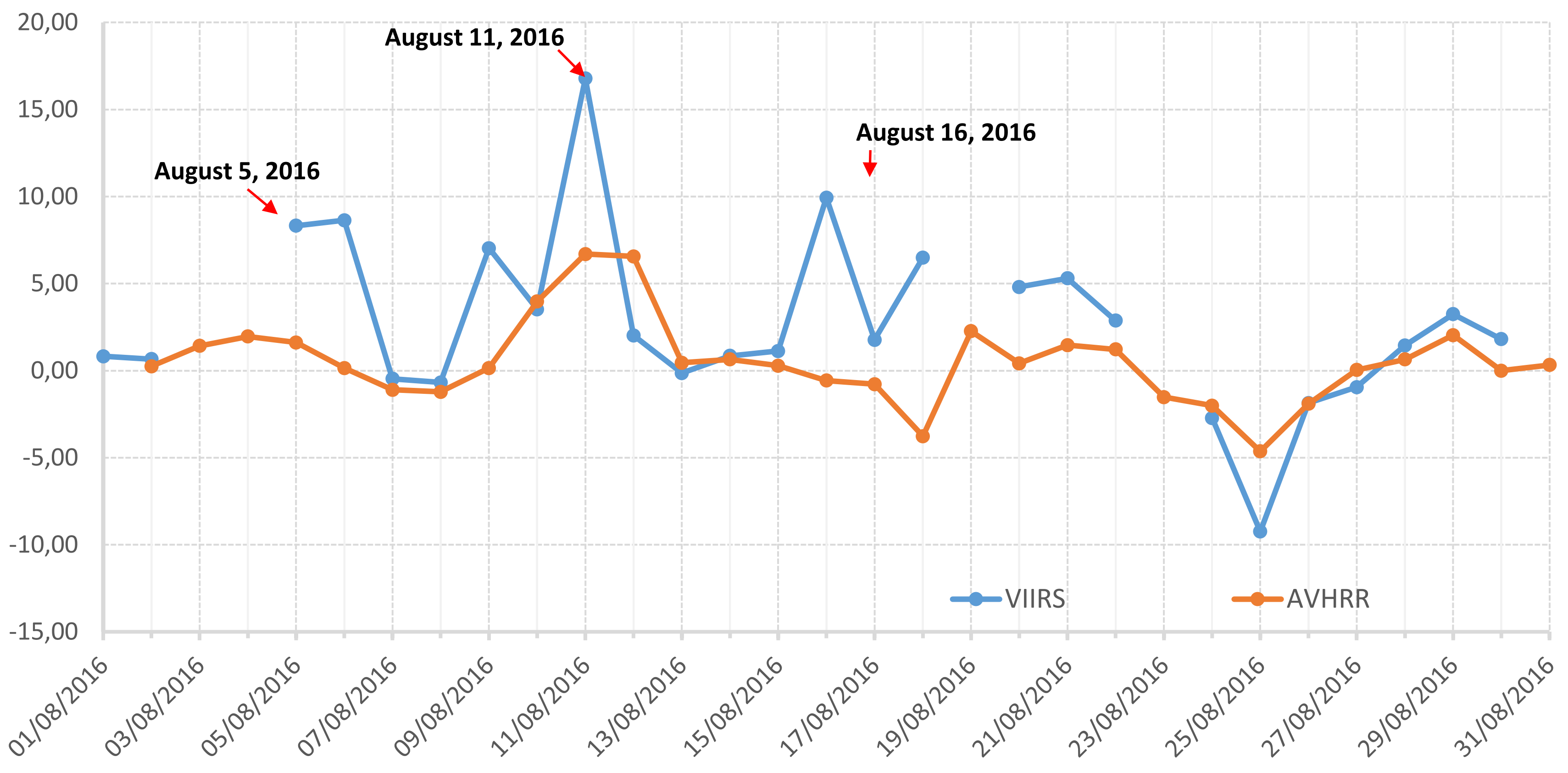
✓ 22 radiometric bands covering wavelengths *from 0.41 to 12.5 mm*

- 16 Moderate bands (M-bands) (750 m spatial resolution)
- 5 Imaging bands (I-bands) (375 m spatial resolution)
- Day Night Band (0.7 μm) (750 m across full scan)



VIIRS Photo courtesy of Raytheon Space and Airborne Systems

Preliminary comparison of RST_{VOLC} detections from AVHRR and VIIRS data



Temporal trend of the $\otimes_{MIR}(x,y,t)$ index over Mt. Etna (Italy) crater area from nighttime AVHRR and VIIRS data (max 2 hrs apart). The use of VIIRS data could further increase the RST_{VOLC} sensitivity to low-level thermal anomalies.

Next data implementation

Sea and Land Surface Temperature Radiometer (SLSTR) onboard Sentinel 3

Launch Date:
•Sentinel-3A - 16 February 2016
•Sentinel-3B - 25 April 2018

SLSTR sensor (Credit: Selex-Galileo & Jena-Optronik)

about four years of SLSTR observations are currently available to generate the temporal mean and standard deviation images required to run the RST_{VOLC} algorithm

Features of SLSTR sensor (in red the used bands at 1 km spatial resolution)

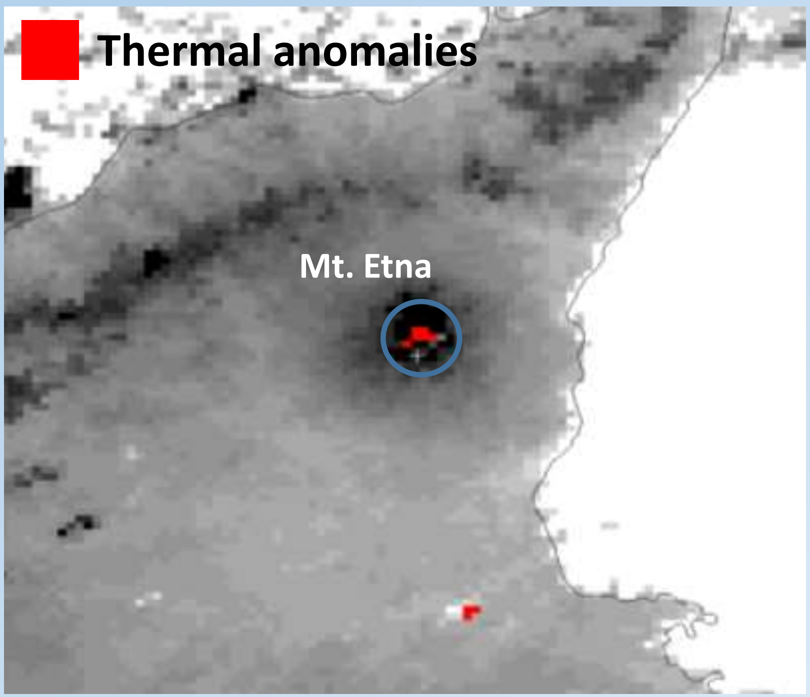
Band	Central Wavelength (nm)	Bandwidth (nm)	Function
S1	554.27	19.26	Cloud screening, vegetation monitoring, aerosol
S2	659.47	19.25	NDVI, vegetation monitoring, aerosol
S3	868.00	20.60	NDVI, cloud flagging,Pixel co-registration
S4	1374.80	20.80	Cirrus detection over land
S5	1613.40	60.68	loud clearing, ice, snow,vegetation monitoring
S6	2255.70	50.15	Vegetation state and cloud clearing
S7	3742.00	398.00	SST, LST, Active fire
S8	10854.00	776.00	SST, LST, Active fire
S9	12022.50	905.00	SST, LST
F1	3742.00	398.00	Active fire
F2	10854.00	776.00	Active fire

https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-slstr/resolutions/radiometric

Work in progress..

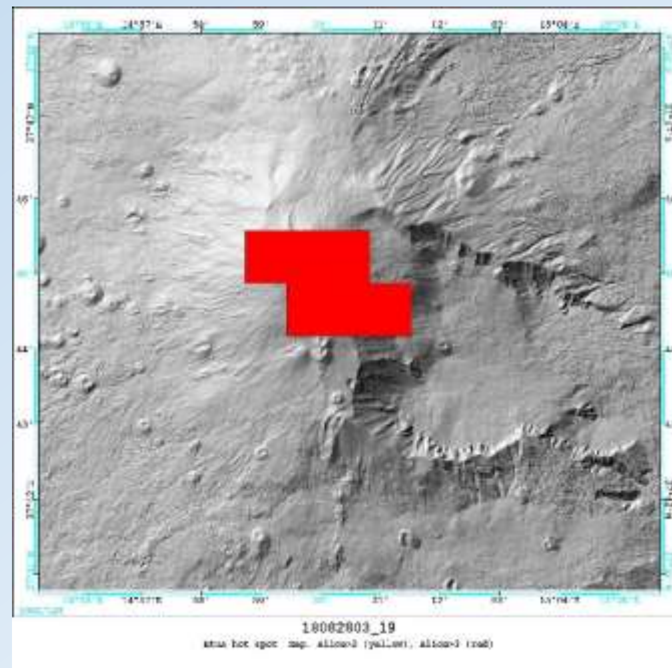
Since the **SLSTR dataset** is **less populated than VIIRS** (covering about nine years of data), some analyses are currently in progress to simulate the spectral reference fields required to run the RST_{VOLC} algorithm.

RST_{VOLC} product from SLSTR data of 27 August 2018 at 20:44 UTC showing a thermal anomaly associated to a documented thermal activity (GVP, 2018).



generated starting from AVHRR spectral reference fields of 19-22 UTC.

RST_{VOLC} map covering Mt. Etna area automatically generated at IMAA **from NOAA-AVHRR** data of **28 August at 03:25 UTC,** showing advantages of data integration.



Global Volcanism Program, 2018. Report on Etna (Italy) (Crafford, A.E., and Venzke, E., eds.). *Bulletin of the Global Volcanism Network*, 43:12. Smithsonian Institution. https://doi.org/10.5479/si.GVP.BGVN201812-211060.

Future perspectives

- The full RST_{VOLC} implementation on VIIRS data (at both 375m and 750 m spatial resolution) will guarantee further improvements in detecting subtle thermal anomalies.

- The next implementation of RST_{VOLC} on SLSTR data will further increase the continuity of satellite observations at the monitored volcanic areas.

- The use of SLSTR F1 band should increase performance of the RST_{VOLC} system towards the characterization of active lava flows.