# SYNERGETIC EXPLOITATION OF METEOROLOGICAL GEOSTATIONARY PAYLOADS «SEVIRI» AND «JAMI» FOR QUANTITATIVE, REAL-TIME, GLOBAL VOLCANO MONITORING

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## 1. INTRODUCTION

The eruptive unrests of active volcanoes are always associated to the emission of molten rocks at temperatures between 900-1500K, and to power releases typically above $10^9$ Watts. Such high-temperature, surface volcanic features present overall moderate size, spanning in width between a few tens of meters (small active lava flows) and several hundred meters (large active lava flows, molten lava lakes, extruding domes of viscous lava). They typically occupy several pixels of infrared channels in decametric resolution payloads (as TM, ETM+, ASTER, HRVIR, HRG and LISS-III, e.g.), appreciable sub-pixel fractions in kilometric resolution payloads (as MODIS, AVHRR and ATSR, e.g.), and very small sub-pixel fractions of low spatial resolution payloads onboard geostationary meteorological platforms, as Imager (onboard GOES West and East), JAMI (Japanese Advanced Meteorological Imager onboard MTSAT-R1) and SEVIRI (Spinning Enhanced Visible and InfraRed Imager, onboard Meteosat Second Generation MSG-1 and -2).

Despite the loose spatial resolution, geostationary multispectral payloads present major advantages in Earth observation of volcanoes, in terms of (i) temporal resolution, with information refresh at rates as high as 24 to 96 images daily, (ii) global scale of the observation (Fig.1), and (iii) long term observation worldwide, guaranteed by the continuity of meteorological geostationary satellite programs for at least 10 years on. We present a successful attempt at detecting, measuring and tracking simultaneously a large sample of eruptive activity occurring between 2006-2009 at ten volcanoes in the disk of SEVIRI (Fig. 1.1, located at 0°E) and twelve volcanoes in the disk of JAMI (Fig. 1.2, located at 140°E), differing in location, eruptive style, duration and magnitude of eruptions.

## 2. STATE OF ART

Volcanic observations are in the target of infrared remote sensing since the pioneering works carried out early in the '80s [1][2]. Whatever the footprint, sub-pixel fractions at melt temperature are approached by use of multispectral payloads provided with at least one MIR (Mid InfraRed) and one TIR (Thermal InfraRed) unsaturated channels. Robust detection of such 'hot-spot' pixels is done on most mid/low resolution payloads by use of contextual methods '$T_{MIR}$-$T_{TIR}$' [5], based on the difference between pixel brightness temperatures in MIR and TIR, or 'NTI' (Normalized Thermal Index) [6]-[8], based on the differences between MIR and TIR pixel radiances. Pixels marked 'hot-spot' are subsequently considered for radiant flux and effusion rate determination. Theory has provided two different formal solutions for characterizing hot-spot fractions in temperature and flux, respectively known as the "Dual-band" [2]-[3] and the "Three-endmember" [4]-[6],[8] methods.

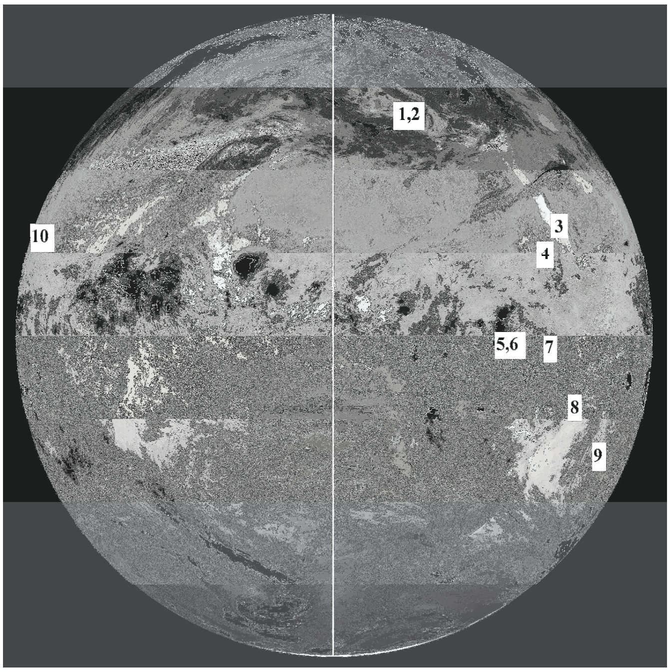


Fig. 1.1. Instantaneous field of view of SEVIRI.
**1-2** Stromboli and Etna (Italy), **3** Jebel-al-Tair (Yemen), **4** Manda Hararo (Ethyopia), **5-6** Nyiragongo and Nyamuragira (Congo), **7** Ol Doinyo Lengai (Tanzania), **8** Karthala (Comoros), **9** Piton de la Fournaise (Reunion Island, France), **10** Soufriere Hills (Montserrat, B.W.I).

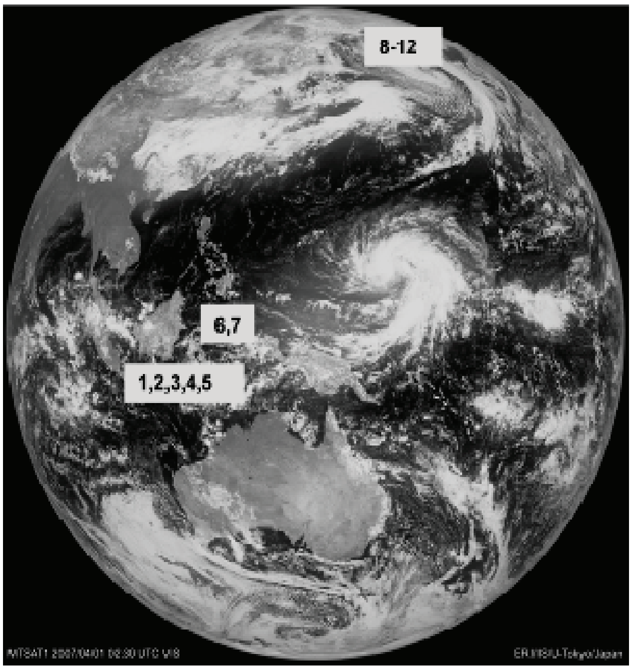


Fig. 1.2. Instantaneous field of view of JAMI.
**1-3** Krakatau, Merapi and Semeru (Java, Indonesia), **4, 5** Rinjani and Batu Tara (Lesser Sunda Islands, Indonesia), **6** Soputan (Indonesia), **7** Karangetang (Sangihe Islands,Indonesia), **8-12** Bezymianny, Karymsky, Kliuchevskoi, Koryaksky and Shiveluch (Kamchatka)

## 3. METHOD

Operations on data streams composed of 96 (SEVIRI) and 24 (JAMI) images daily, were carried out by an expanded version of a routine nick-named MyMET [8], developed earlier for SEVIRI alone. MyMET accomplishes automated full processing from observation of at-satellite radiances to computation of radiant fluxes and lava effusion rates (where applicable).

In consideration of the large size of SEVIRI and JAMI pixels, and the comparatively small pixel occupancy of the high-temperature volcanic features dealt with, the required number of components is $n$=3. The three endmembers are: a 'hot' temperature $T_h$ corresponding to molten lavas, a 'crust' temperature $T_c$, and a 'background' temperature $T_b$ unrelated to volcanic activity. The sum of areal fractions ( $f_h$ , $f_c$ , $f_b$ ) associated to the three components is assumed to equal one.

In hot-spot pixels singled out with NTI analysis, radiances $R_{\lambda,Thermal}$ observed in one MIR ($\lambda$=3.7-3.9 μm) and in two TIR channels ($\lambda$=10.8 μm and $\lambda$=12 μm) allow determining endmember temperature $T_n$ and fraction $f_n$ , after analytical solving of the three-equation system $R_{\lambda,\mathrm{Thermal}} = \sum_n f_n R(\lambda,T_n)$ , with n={1,..,3}.

The total instant radiated energy is obtained as the 'radiant flux' $Q_R = A\ \varepsilon\ \sigma \sum_l T_e^4$ (in Watts) following a thermal model by Pieri et al.[5]. In $Q_R$ , $T_e=[f_h T_h^4 + f_c T_c^4]^{1/4}$ is the 'effective temperature', $l$ is the number of hot-spot pixels, σ the Stephan-Boltzmann constant, $\varepsilon$ the mean emissivity, and $A$ the pixel area.

## 4. RESULTS

JAMI presents spatial resolution (ranging from 16 $km^2$ at nadir to over 50 $km^2$ at the disk border), spectral resolution (5 channels, from visible to TIR), temporal resolution (30-minute repeat) and data quality (8-bit) same as those of GOES Imager. SEVIRI presents significantly improved spatial resolution (from 9 $km^2$ at nadir to over 35 $km^2$ at the disk border in multispectral channels), spectral resolution (12 channels from visible to TIR), temporal resolution (15-minute standard repeat) and data quality (10-bit quantization).

Considering both payloads at once, the MyMET procedure [8] summarized above was run on a spatial subset of the 2006-2009 archive, corresponding in space to the broad neighbourhood of the volcanoes marked in Figures 1.1 and 1.2, and selected in time subordinately to the detection of thermal anomalies (hot-spot pixels) with the the NTI indexing technique. After discarding the scenes carrying no information, the demonstration data set is composed of ca. 30,000 SEVIRI scenes, and slightly less than 5,000 JAMI scenes.

Eruptions detected, analyzed and monitored in SEVIRI (example in Fig 2.1), were those of Manda Hararo (Ethyopia), Jebel-al-Tair (Yemen), Karthala (Comoros), Nyiragongo and Nyamuragira (Congo), Piton de la Fournaise (Reunion Island, France), Ol'Doinyo Lengai (Tanzania), Stromboli and Etna (Italy) and Soufriere Hills (Montserrat, B.W.I.).Those detected, analyzed and monitored in JAMI, conversely, are Krakatau, Merapi, Semeru, Rinjani, Batu Tara, Soputan and Karangetang (in Indonesia), and Bezymianny, Karymsky, Kliuchevskoi, Koryaksky and Shiveluch (Kamchatka).

For each volcano monitored with geostationary data a systematic, parallel calibration-and-validation study was carried out on higher spatial resolution data (1 $km^2$) acquired by MODIS onboard Terra and Aqua platforms (example in Fig 2.2).

According to the results of the thorough test outlined above, we may conclude that SEVIRI and JAMI together satisfactorily fulfil the requirements for monitoring a broad variety of high-temperature volcanic features as lava flows, lava lakes, and lava domes worldwide, with tactical revisit frequency, thus candidating as the reliable and global EO payloads for the after-MODIS.

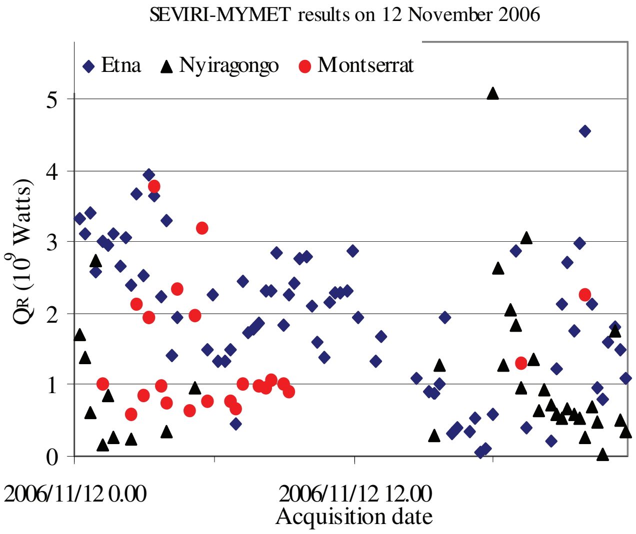


Fig 2.1. SEVIRI: simultaneous measurement of radiant fluxes at unresting volcanoes Mt. Etna (Italy), Mt. Nyiragongo (Congo) and Soufriere Hills (Montserrat).

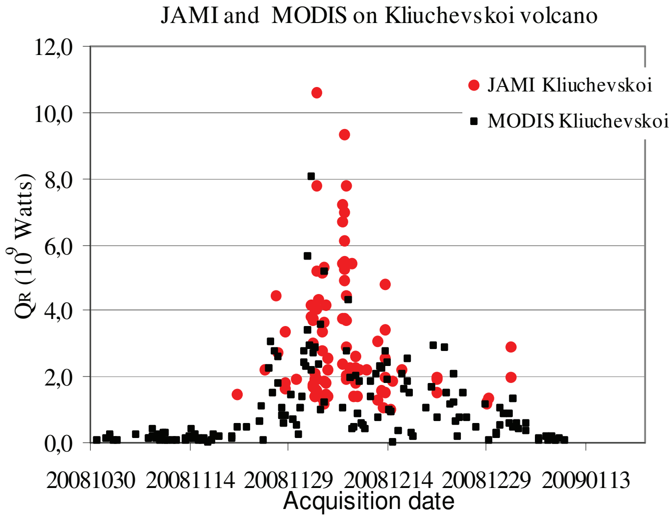


Fig 2.2. Radiant fluxes of the start of the 2008-2009 eruption of Kliuchevskoi (Kamchatka, Russia) measured with geostationary JAMI and LEO MODIS payloads.

## 5. REFERENCES


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