

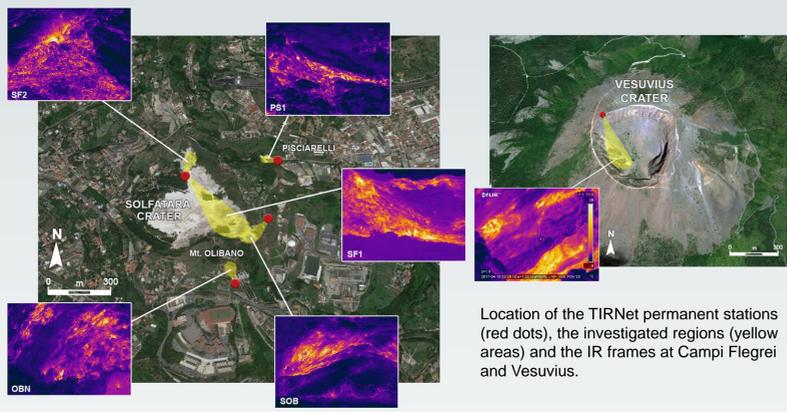
Automated processing of thermal infrared images of Osservatorio Vesuviano permanent surveillance network by using Matlab code

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1. The TIRNet

The permanent Thermal Infrared Surveillance Network (TIRNet) of Osservatorio Vesuviano (INGV) is aimed to volcanic surveillance in the Campi Flegrei caldera and the Vesuvius volcano (Italy). TIRNet is composed of 6 stations which acquire thermal infrared frames of fumarole fields in the area of Solfatara volcanic center, on the southern slope of Mt. Olibano lava dome, in the Pisciarelli area and inside the crater of Vesuvius.



Location of the TIRNet permanent stations (red dots), the investigated regions (yellow areas) and the IR frames at Campi Flegrei and Vesuvius.

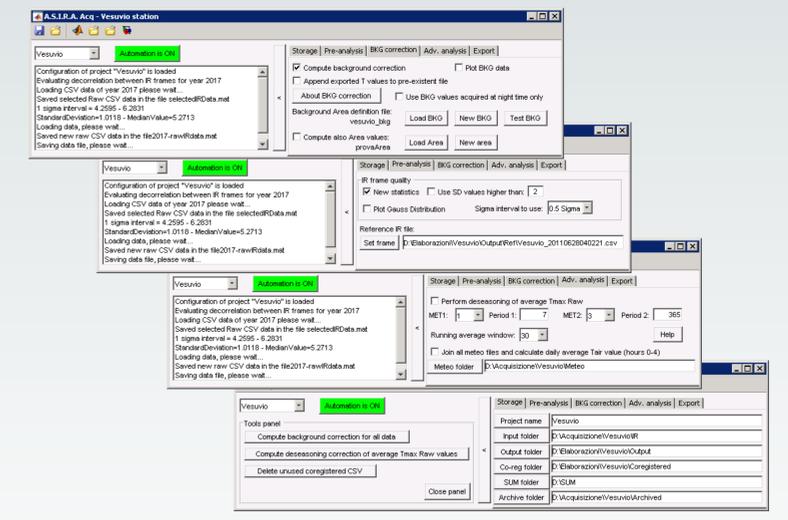
The infrared sensors are FLIR SC645/655 cameras with a Focal Plane Array (FPA) uncooled microbolometer detector, whose resolution is 640x480 pixel, spectral range is 7.5 - 14 μm , accuracy is $\pm 2\text{ }^\circ\text{C}$ and thermal sensitivity is $< 0.03^\circ\text{C}$ @ $+30^\circ\text{C}$.

3. Output

The first basic output are time-series of co-registered IR scenes which have all the pixels aligned in respect of a reference one by correcting the possible loss of alignment between sensor and target. Then a seasonal correction based on a background-removal procedure or analytic approach makes trends of maximum temperatures values of each IR station of TIRNet. Otherwise the investigation of IR scenes in terms of temperature values variations of each pixel could create maps of the annual temperature gradient which show thermal behavior in time of every single pixel.

2. Data processing

The infrared data are processed by the software **A.S.I.R.A. Acq** (Automated System of IR Analysis and Acquisition) developed in Matlab environment and with a user-friendly graphic user interface (GUI). ASIRA daily generates time-series of residual temperature values of the maximum temperatures observed in the IR scenes after the removal of seasonal effects. These time-series are displayed in the Surveillance Room of Osservatorio Vesuviano and provide information about the evolution of shallow temperatures field of the observed areas.



Temperature charts of monitored sites displayed on a monitor of the Surveillance Room of Osservatorio Vesuviano

The main features of ASIRA Acq include:

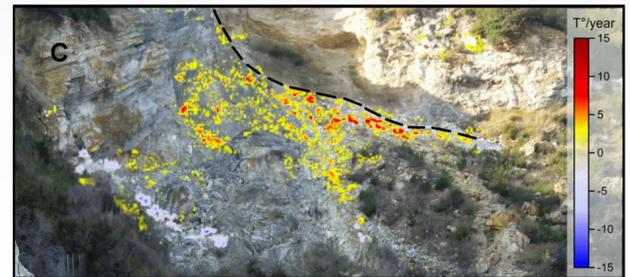
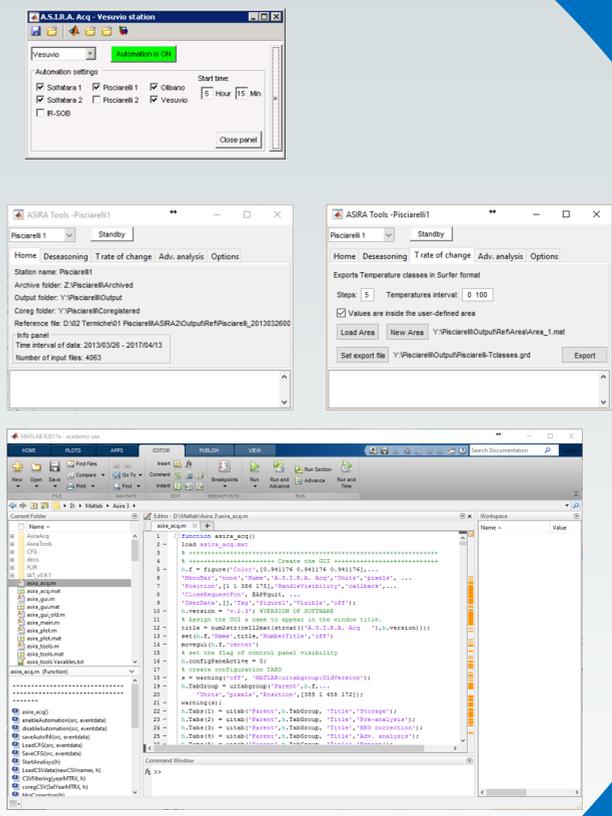
- efficient quality selection of IR scenes;
- IR images co-registration in respect of a reference frame;
- seasonal correction by using a background-removal methodology;
- total automation of procedures
- filing of IR matrices and of the processed data in shared archives accessible to interrogation.

Additional processing features are accomplished in a second phase by **ASIRA Tools** which is Matlab code with GUI developed to extract further information from the dataset in automated way.

The main functions of ASIRA Tools are:

- the analysis of temperature variations of each pixel of the IR frame in a given time interval;
- the removal of seasonal effects from temperature of every pixel in the IR frames by using an analytic approach (removal of sinusoidal long term seasonal component by using a polynomial fit Matlab function - LTFC_SCOREF);
- the export of data in different formats
- the production of graphs of temperature classes ready to be processed in Surfer.

The high efficiency of Matlab in processing matrix data from IR scenes and the flexibility of this code-developing tool proved to be very useful to produce applications to use in volcanic surveillance aimed to monitor the evolution of surface temperatures field in diffuse degassing volcanic areas.



An interesting example of data processing by ASIRA Tools is the map of the temperature changing rate, which provide remarkable information about the potential migration of fumarole activity.

Sansivero, F., G. Scarpato, and G. Vilardo (2013), The automated infrared thermal imaging system for the continuous long-term monitoring of the surface temperature of the Vesuvius crater, *Ann. Geophys.*, 56, S0454, doi:10.4401/ag-6460.

Vilardo, G., F. Sansivero, and G. Chiodini (2015), Long-term TIR imagery processing for spatiotemporal monitoring of surface thermal features in volcanic environment: a case study in the Campi Flegrei (Southern Italy), *J. Geophys. Res. Solid Earth*, 120, 812–826, doi:10.1002/2014JB011497

