

Surface temperature observations from EO

Modules for volcanoes and environmental applications

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Automated processing chains for surface temperature monitoring on Earth's most active volcanoes and environmental applications

This processing chain can help the data user communities to quickly obtain an estimation of surface temperature and in case of volcanic eruption the detection of lava flow using optical data satellite.

The aim is to enable the easy extraction of valuable knowledge from vast quantities of satellite-sensed data now being produced by Europe's Copernicus programme and other Earth observation satellites. In this context, the estimation of surface temperature on active volcanoes around the world is considered.

Moreover, this module can offer the opportunity to produce a land surface temperature (LST) time series useful for detection of thermal anomalies using TIR satellite data (i.e. Solfatara or geothermal area of Parco delle Biancane (GR))

From MIR satellite data, in combination with TIR, it is possible to retrieve radiative power time series that can provide a quantification of thermal anomalies and that can be converted into effusion rate in case of effusive eruptions.

• SCIENTIFIC RATIONALE

THEMATIC AREA: Earth Observation

E2E processing chains have been developed for different satellite data (ASTER, Landsat8, Sentinel 3, Sentinel 2 MSI, NPP- /JPSS- VIIRS, EOS-MODIS, MSG-SEVIRI)

These chains have been implemented enabling the use of EO missions and the generation of added value product such as surface temperature map from not skilled users. This solution will enhance the use of satellite data and improve the dissemination of the results saving valuable time (no manual browsing, downloading or processing is needed) and producing time series data that can be speedily extracted from a single co-registered pixel, to highlight gradual trends within a narrow area.

APPLICATIONS

High Temperatures Events: Volcanic Eruptions, Fires

Surface temperature monitoring: Volcanic areas, Urban Heat Islands, Dump sites

• OBSERVATIONAL INFRASTRUCTURE

EO data	Band centers (μm)	Spatial Resolution (m)	Resolution time
ASTER (TIR)	8.29; 8.63; 9.07; 10.66; 11.32	90	16 days
Landsat 8 (TIRS)	10.9; 12.0	100 (delivered at 30)	16 days
Sentinel-2	0.86; 1.61; 2.20	20	4-5 days
Sentinel-3 (SLSTR)	3.74; 10.85	1000	12h
EOS-MODIS	3.96; 11.03	1000	12h
MSG-SEVIRI	3.9; 10.8	3000	5-15 minutes
VIIRS	3.74; 11.45	375-750	12h

Auxiliary data:

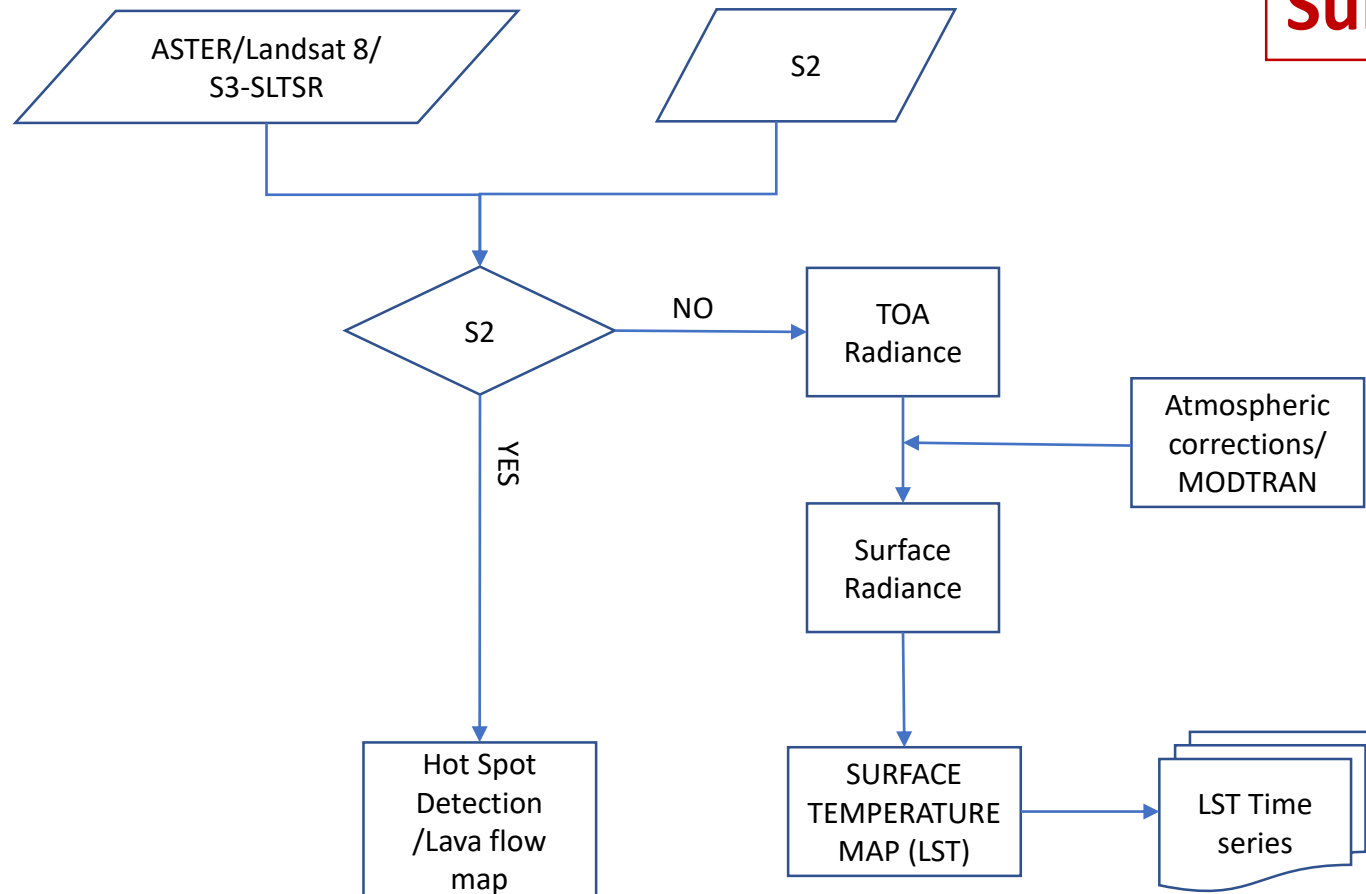
- Atmospheric profile
- Emissivity map (ASTER 05)
- Digital Elevation Model (DEM).

Other EO input data:

- PRISMA (30 m spatial resolution)
- ECOSTRESS (60/70 m spatial resolution)
- New TIR sensor (i.e. SBG mission)

• CORE PROCESSOR

Surface Temperature Monitoring



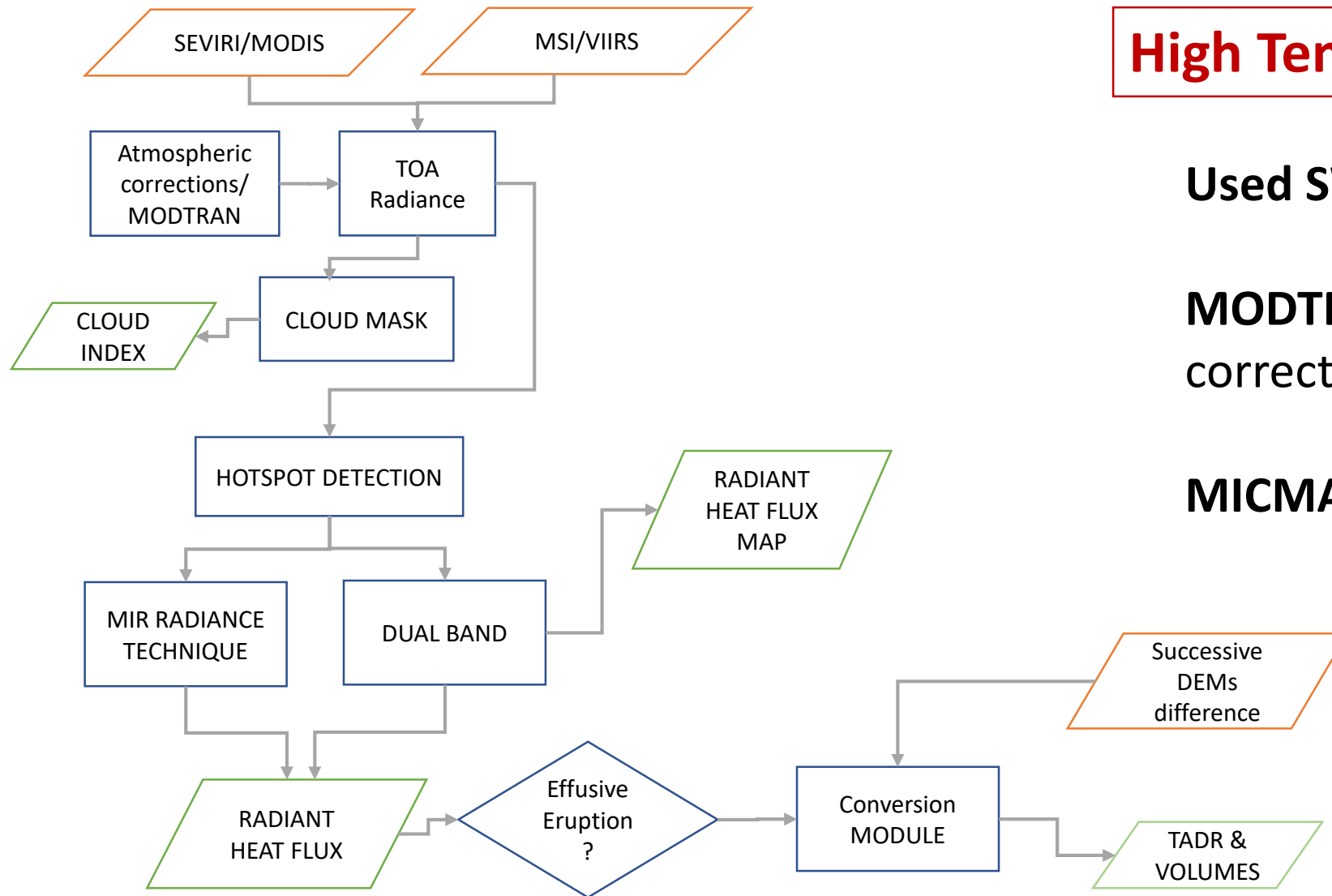
Used SW:

IDL code

MODTRAN for atmospheric correction

• CORE PROCESSOR

HOTSAT VOLCANO MONITORING SYSTEM



High Temperature Events

Used SW: IDL code

MODTRAN for atmospheric correction

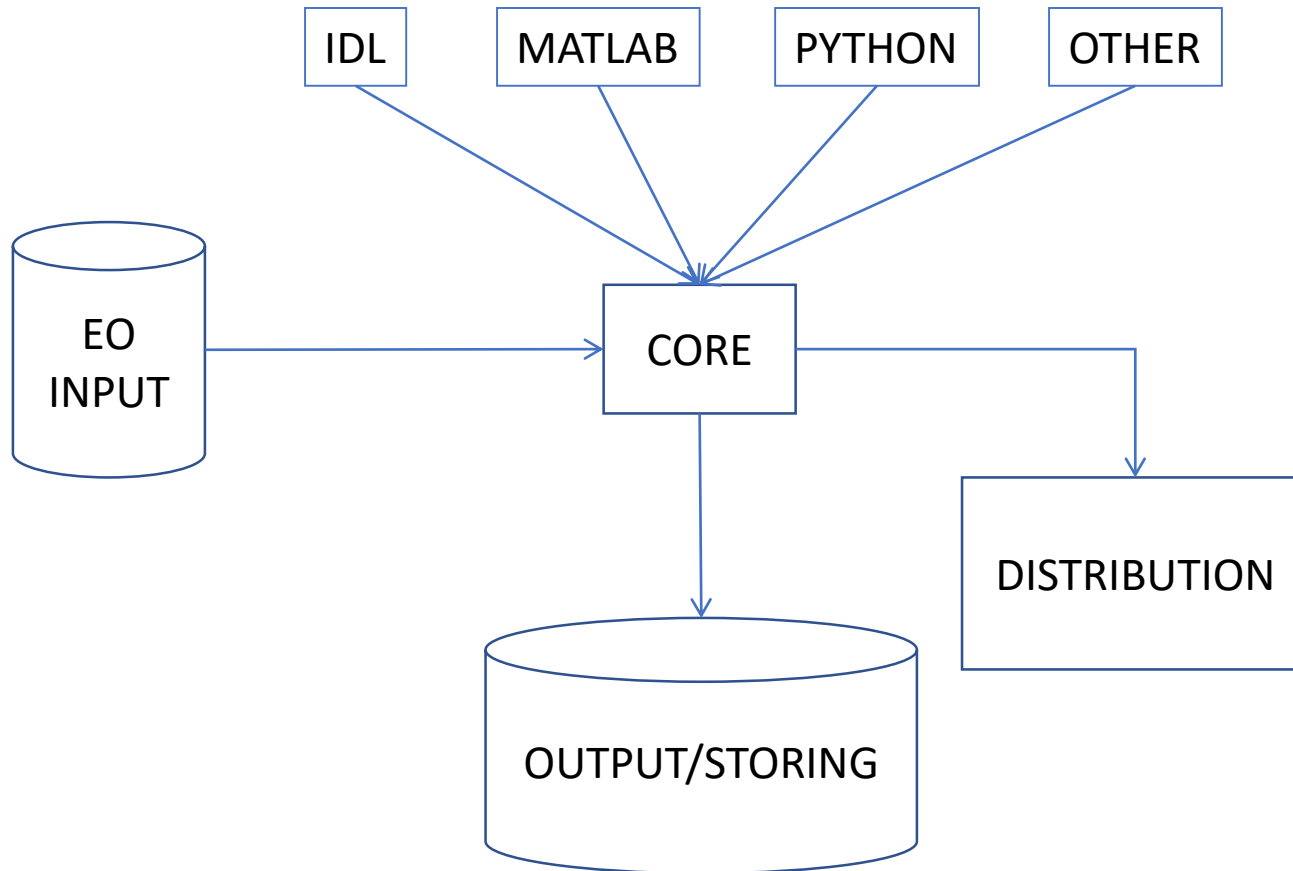
MICMAC for DEM

• INFRASTRUCTURE FOR DATA MANAGEMENT

The screenshot displays the Geohazards TEP web application. The main map shows Sicily with a thermal overlay on the eastern part, indicating surface temperature. The interface includes a search bar, a sidebar with map controls, and a right-hand panel for processing services. The 'Processing Services' panel shows details for the 'STEMP-L8' service, including its description, job title, start and end dates, volcano name (Etna), and mission (LANDSAT8). Below the map, a list of search results is visible, showing various STEMP-Surface Temperature Map entries with their respective IDs and timestamps.

A representative platform to follow is ESA-GEP platform, where automatically input data from different sensors are downloaded and processed. The output is a map of specific product (in this case surface temperature) easily downloadable

• INFRASTRUCTURE FOR DATA PROCESSING



A solution that can facilitate the building of infrastructures based on EO data processing is the cloud computing environment, often highly scalable and providing developer tools, storage, database, and networking services. Moreover the use of virtual machines can offer a robust environment to EO data processing.

• INFRASTRUCTURE FOR DATA PROCESSING

Porting on Graphic Processing Units (GPUs)

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SPEED-UP – Run times of OpenCL implementations of the thermal module in different devices (times in ms)

Graphic Processing Units (GPUs) offer very high performances in parallel computing.

kernel	Beignet/ Haswell GT2 Mobile	NVIDIA/ GeForce GT 750M	Intel/i7- 4712HQ@2.3G Hz
compute_background_radiance	0.13	0.0569	0.243
compute_hotspot_data	0.016	0.0133	0.068
compute_radiative_power	0.008	0.0091	0.078
compute_Tdiff_variance	1.943	0.3647	1.812
compute_thresholds	2.299	0.6513	1.541
find_potential_hotspots	0.007	0.0108	0.065
prepare	1.301	0.2771	3.376

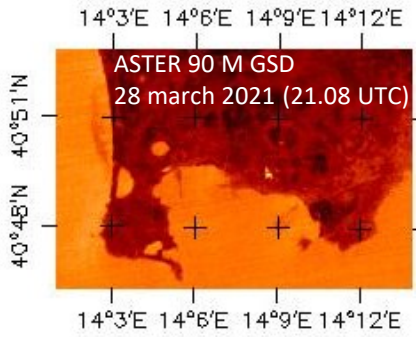
• PRODUCTS AVAILABLE

Service output	• Surface temperature map (from ASTER/Landsat 8/Sentinel 3) • Hot spot detection /Lava flow map (from Sentinel 2)
Output format	• GeoTiff raster.
Geocoding accuracy	• About 2-3 pixel (for ASTER and Landsat 8)
Temporal resolution	Depending on the used satellite and available input data: • ASTER and Landsat8: Maximum temporal frequency of 16 days. • SENTINEL-2: Maximum temporal frequency of 4/5 days. • SENTINEL-3 (SLSTR): Maximum temporal frequency of 1/2 days.
Output Spatial resolution	• ASTER: 90x90 m • Landsat8 : 90x90 m (or 30x30 m) • Sentinel 2: 20x20 - 60x60 meters • Sentinel3 (SLSTR): 1000 m
Spatial coverage	Depending on the used satellite and area of interest: • ASTER: Maximum of 100 x 100 Km. • Landsat8: Maximum of swat 185 Km. • Sentinel 2: Maximum of swat 290 Km • Sentinel 3: Maximum of swat 740 Km (maximum 1400 km)
Resources and processing constraints (SW needs)	• IDL and ENVI SW • MODTRAN for atmospheric correction • Lynx for automatic download of atmospheric profiles.

• PRODUCTS AVAILABLE

Service output	• Hot spot detection • Radiant Heat Flux map (from VIIRS, Sentinel 2, Landsat 8) • Radiant Heat Flux time series • Eruption rate time series • Volumes
Output format	• GeoTiff raster, csv
Temporal resolution	Depending on the used satellite and available input data: • SEVIRI up to 5 minutes in RSS. • MODIS, VIIRS: Maximum temporal frequency of 1/2 days. • SENTINEL-2 (MSI): Maximum temporal frequency of 4/5 days.
Output Spatial resolution	• SEVIRI: 3000x3000 m at nadir • VIIRS : 375x375 m (or 750x750 m) • Sentinel 2: 20x20 - 60x60 meters • MODIS: 1000x1000 m
Spatial coverage	Depending on the used satellite and area of interest: • SEVIRI: Full Disk (Europe, Africa); RSS (Europe, North Africa) • MODIS: Maximum of swat 2330 Km. • Sentinel 2: Maximum of swat 290 Km • VIIRS: Maximum of swat 3060 km
Resources and processing constraints (SW needs)	• IDL and ENVI SW • MODTRAN for atmospheric correction

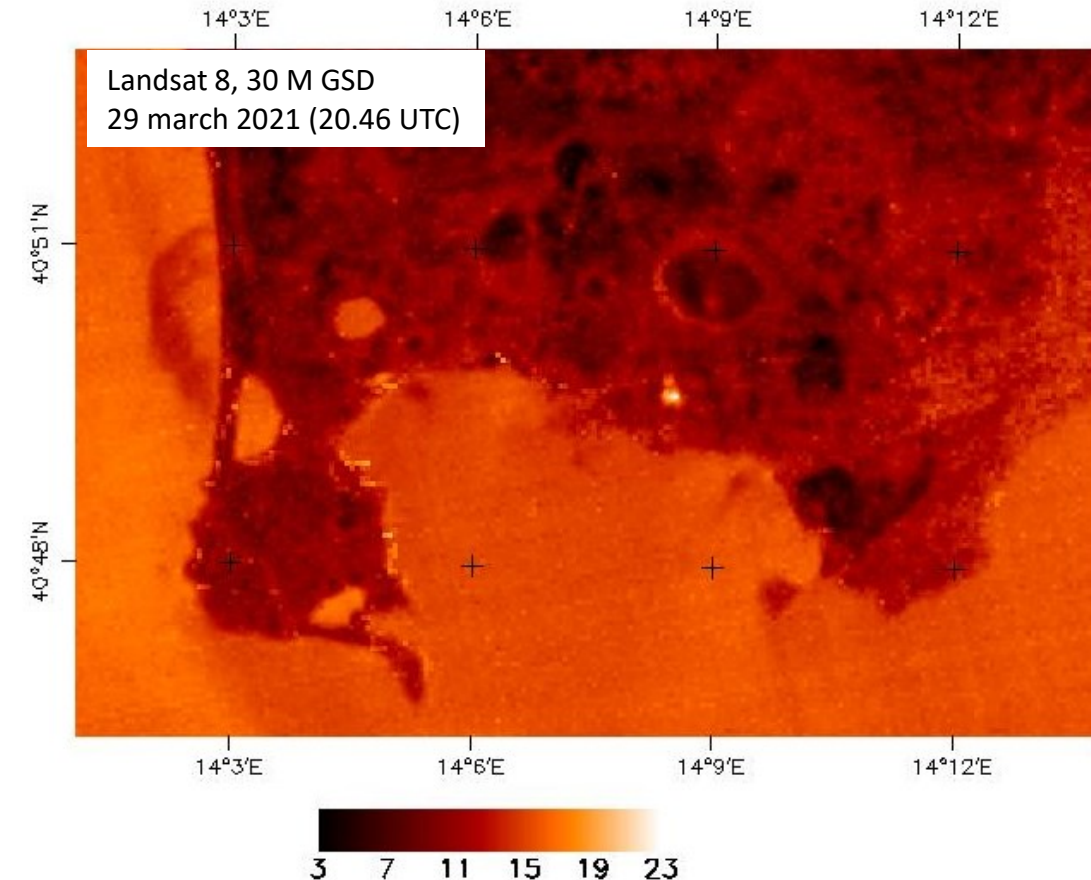
• PRODUCTS AVAILABLE



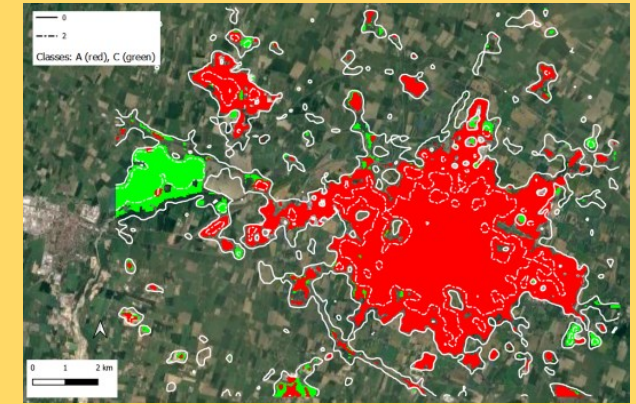
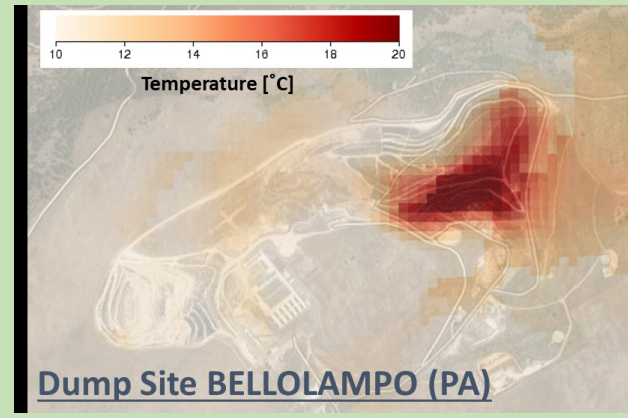
Surface temperature using TIR satellite data:

ASTER (90 m GSD (ground sample distance))

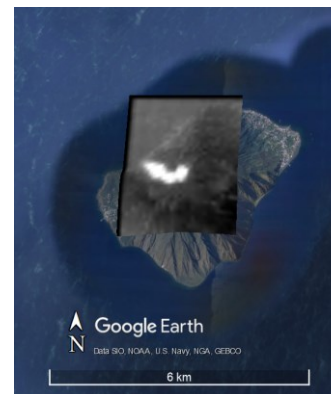
Landsat 8 (30 m GSD even if the sensor acquires at 100 m)



Landsat 8 – derived LST median values during 2019-2020 on Bellolampo Dump site



Urban Heat Island (UHI) on Modena City obtained from Landsat 8 – derived LST during 2014-2019



Sentinel 2 17 July 2019
09.50 UTC.

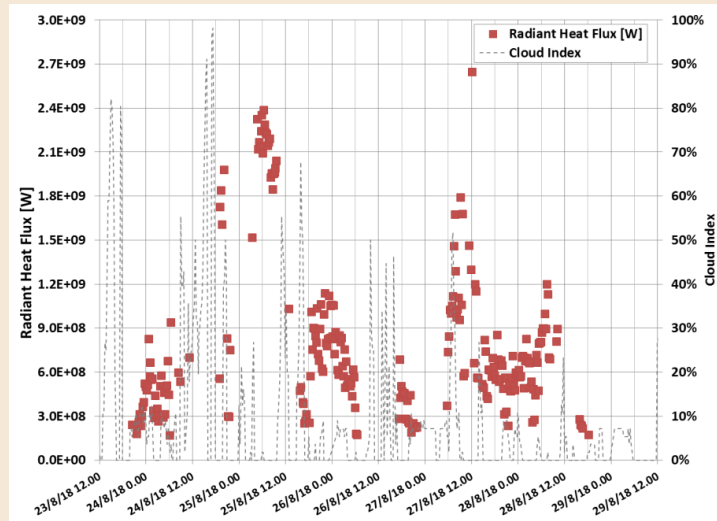


Hot Spot detection/Lava
flow map

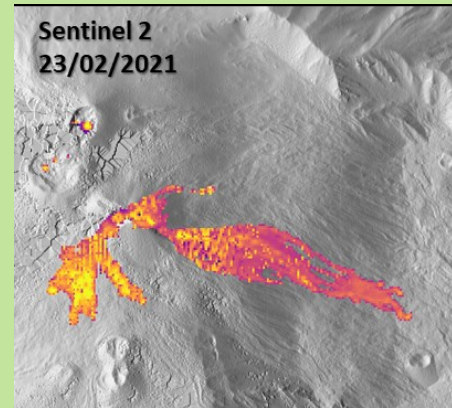
Sentinel 2 (20 m GSD)

• PRODUCTS AVAILABLE

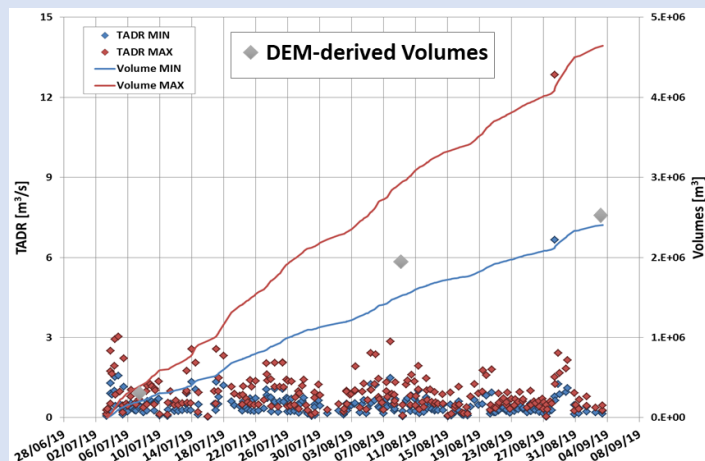
Radiant Heat Flux at Mt Etna



Radiant Heat Flux Map - Etna

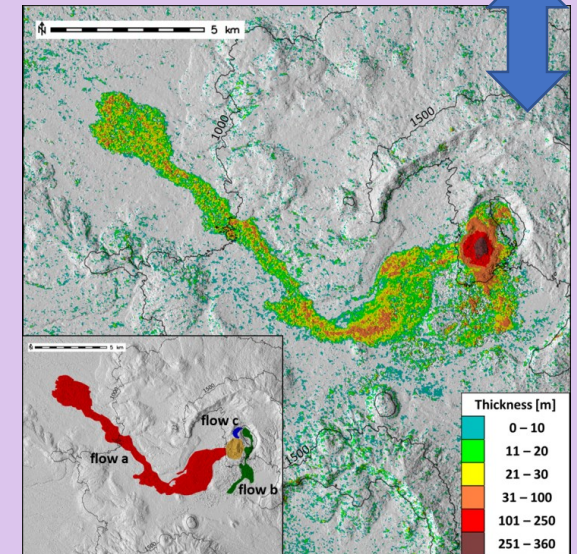
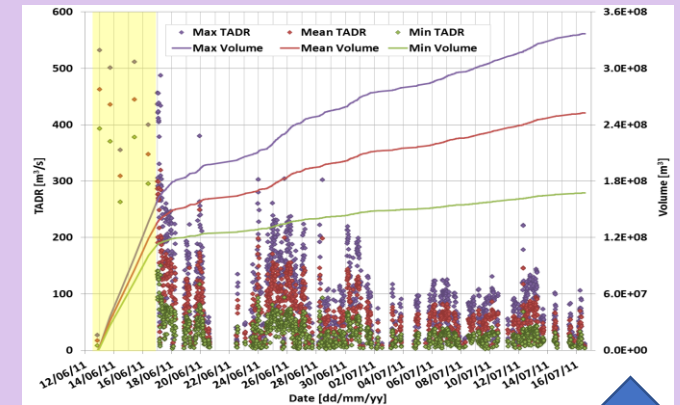
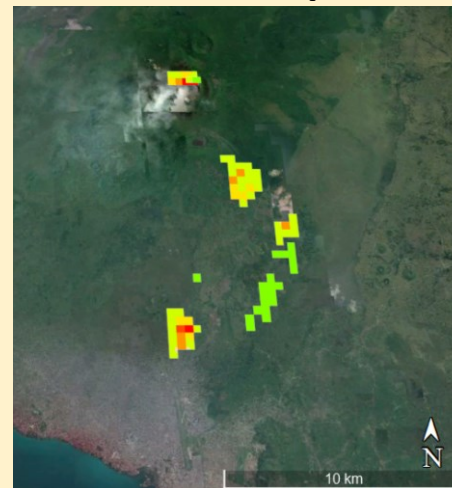


Effusion Rates & Volumes Stromboli 2019



Radiant Heat Flux Map - VIIRS

Nyiragongo 2021



DEM calibrated TADR & Volumes Nabro 2011

• CURRENT DISTRIBUTION OF PRODUCTS

The dissemination tools is the last of three steps of processing which combines modules operation, scientific operators validation with data from other technological laboratories (i.e. temperature from thermal cameras, drones measurements) and dissemination of the validated products to the final users:

- FTP
- WEB-GIS
- API

Possible users:

- Civil protection;
- Researchers;
- Observatories.

• PROGRAMS/PROJECTS OF REFERENCE

- Geohazards Exploitation Platform (GEP) – ESA (automatic chain)
- Pianeta Dinamico (ATTEMPT/BEST-CaFE A3) (manual chain)
- Supersite (Etna/Virunga) (semi-automatic chain)
- Ricerca Libera “Tune”
- DPC Allegato A (semi-automatic chain)
- DPC Allegato B2 (manual chain)

• TEAM AND AFFILIATIONS

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