SATELLITE THERMAL DATA AND ONLINE TOOLS AVAILABLE

Panorama on tools and procedures that INGV is using to monitor volcanic thermal activity using satellite data

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SUMMARY

- SPACE SYSTEMS CURRENTLY AVAILABLE AND PLANNED TO MONITOR VOLCANIC PHENOMENA
- INGV THERMAL MONITORING TOOLS AVAILABLE AT GLOBAL LEVEL
- INGV-VESUVIAN OBSERVATORY: MONITORING SOLFATARA CRATER BY MEANS OF SATELLITE DATA COMBINED WITH GROUND CAMERAS AND DRONES
- INGV-ETNEO OBSERVATORY: MONITORING ETNA THERMAL ACTIVITY BY MEANS OF SATELLITE DATA

SATELLITE OBSERVATIONS

1) THE SURFACE TEMPERATURE VARIATION REPRESENTS A KEY PARAMETER TO DETECT THE CHANGE OF THE VOLCANO ACTIVTY

2) SYSTEMATIC SATELLITE TIME SERIES AT DIFFERENT SCALES IN THE TIR-MIR-SWIR RANGE DEPENDING FROM THE TEMPERATURE RANGE OF THE PHENOMENA

3) THE HIGH SPATIAL RESOLUTION IS A KEY PARAMETER TO DETECT VARIATION IN FUMAROLE FIELDS AND SUMMIT CRATERS BEFORE ERUPTIOND AND LAVA FLOWS THEMPERATURE STRUCTURE

4) THE TIME FREQUENCY IS THE KEY PARAMETER TO
   1) DETECT THE STARTING OFEFFUSIVE PHENOMENA
   2) CALCULATE THE EFFUSION RATE VARIATION VERSUS TIME

Phenomena dimension and duration

HTE	Temperature K	Area m2/km2	Duration
Thermal anomaly (fumarole fields inside craters or on the flanks)	283-360	$10\text{-}10^2$ m2	>> 1d
Lava flows	800-1500 core T 300-700 crust T	$10^2\text{-}10^5$ m2	>1d
Pyroclastic deposit	<1200	$10^3\text{-}10^7$ m2	>1d

Phenomena	Satellite Obs. technique	ORBITAL AND RESOLUTION CHARCTERISTICS
Lava flow thermal state characterization Eruption plunes	LOW/Medium/HIGH resolution IR mapping	Geostationary IR satelites VIS/SWIR/MIR/TIR
		POLAR MIR/IR 0,5-1 km res
		POLAR VIS-SWIR 30-100 m
Pre-eruptive thermal anomaly Fumarole field	High resolution TIR mapping	POLAR TIR 30-100 m
		AIRBORNE 1-10 m

ESA AND NASA MISSION TO STUDY EARTH

In the last 2 decades a gigantic increase of space data have been acquired and are accessible mostly at no cost for the scientific community

ESA EARTH OBSERVATION MISSIONS PROGRAM AND SENTINELS FOR EU-COPERNICUS SERVICES ARE VERY SUCCESSFUL EXAMPLE

THE SENTINELS

FULL, FREE AND OPEN

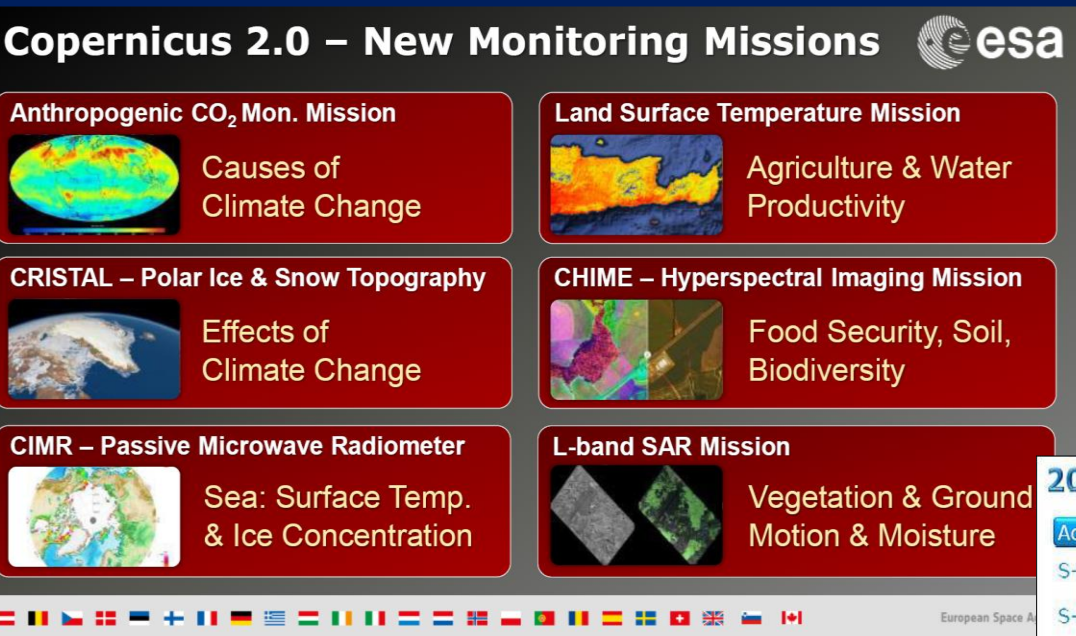
Sentinel Mission and Status		Key Features
SENTINEL-1: 4-40m resolution, 6 days revisit at equator	2 Sats in orbit	Polar-orbiting, all-weather, day-and-night radar imaging
SENTINEL-2: 10-60m resolution, 5 days revisit time	2 Sats in Orbit	Polar-orbiting, multispectral optical, high-res imaging
SENTINEL-3: 300-1200m resolution, <2 days revisit	2 Sats in Orbit	Optical and altimeter mission monitoring sea and land parameters
SENTINEL-4: 8km resolution, 60 min revisit time	1st Launch in 2020	Payload for atmosphere chemistry monitoring on MTG-S
SENTINEL-5p: 7-68km resolution, 1 day revisit	1 Sat in Orbit	Mission to reduce data gaps between Envisat, and S-5
SENTINEL-5: 7.5-50km resolution, 1 day revisit	1st Launch in 2021	Payload for atmosphere chemistry monitoring on MetOp 2nd Gen
SENTINEL-6: 10 day revisit time	1st Launch in 2020	Radar altimeter to measure sea-surface height globally

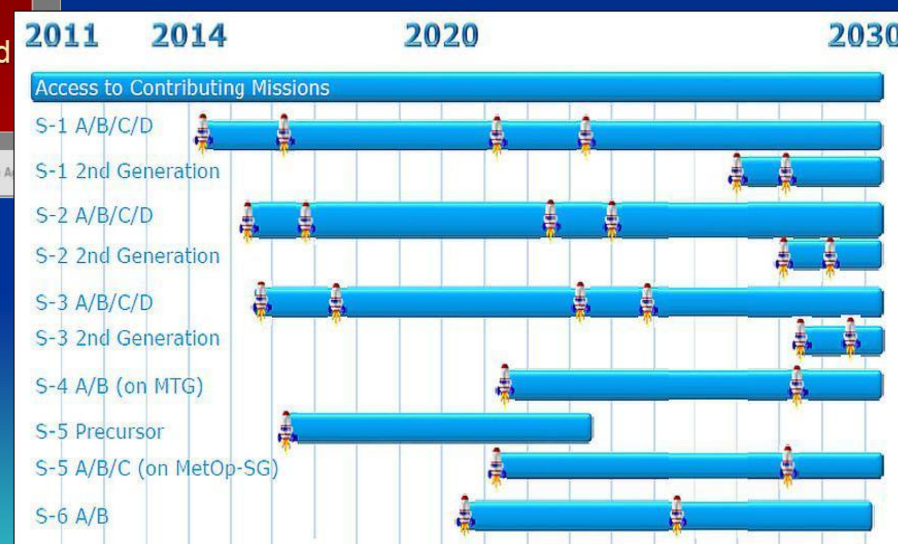
8 Copernicus European Commission

Online volcano monitoring WS- Satellite thermal data and online tools available

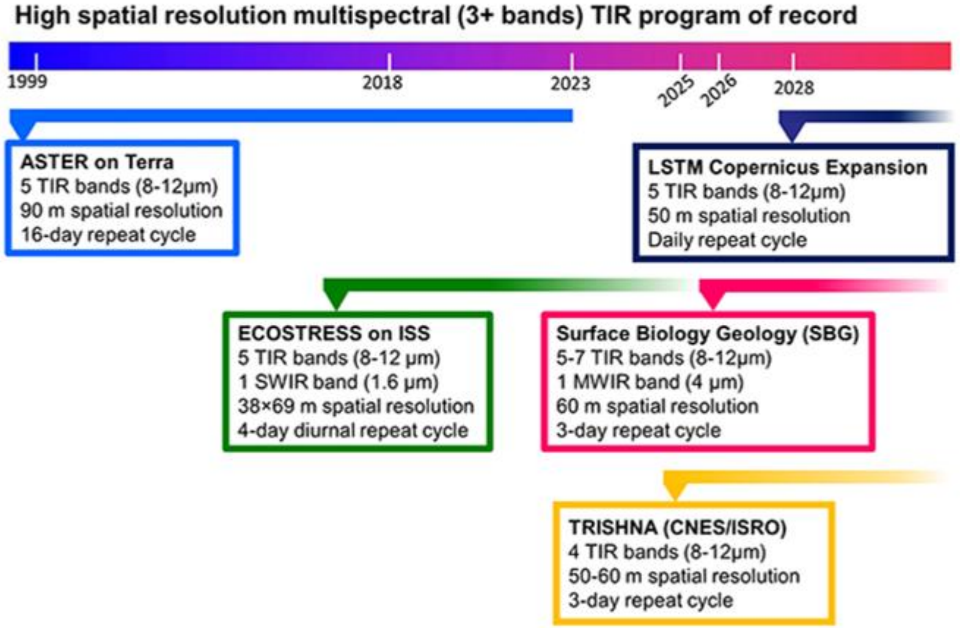
February 18-24, 2021

NEW MONITORING MISSIONS ARE UNDER STUDY IN ESA
INGV IS CURRENTLY WORKING IN THE CHIME AND LAND SURFACE TEMPERATURE MISSION STUDIES





The mission with a multispectral IR instrument is considered of high priority by the NASA's "Decadal Survey" plan, as well by ESA as one of the future Sentinels under study for the Copernicus program.



The JPL-ASI mission will fill a critical gap in the Mid and Thermal InfraRed science and represents a possible scientific precursor of ESA-LSTM mission and to other plenned missions.

Table 3. Planned satellite-borne hyperspectral sensors.

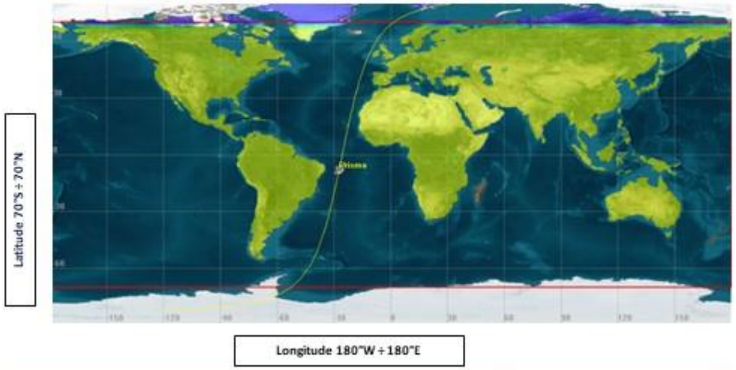
SENSOR	EnMAP	HyspIRI	HYPER-X	PRISMA
Proposed Launch	End 2012	2014	2013	2011
Number of Instruments	1	2	2	2
Bandwidth Coverage	420–2450 nm	380–2400 nm Hyper + TIR	Hyper + multispectral	400–2500 nm Hyper; 400–700 nm Pan
Spatial Resolution	30 m	60 m	15–30 m	20–30 m Hyper; 5 m Pan
Spectral Resolution	5 nm	10 nm	?	10 nm
Signal-to-Noise	> 500:1	Good	High	?
Swath	5 * 30 km	145 km	30 km	30–60 km

PRISMA: PRecursore IperSpettrale della Missione Applicativa

Messa in orbita il 22-Marzo-2019

Agenzia Spaziale Italiana

- National EO hyperspectral Mission fully funded by ASI.
- Realized by Italian Industries Consortium led by OHB Italia, Leonardo and Telespazio
- Mission conceived as a Pre-operational and technology demonstrator, with focus on
  - **Space qualification of PAN/HYP payload**
  - Development of PAN/HYP products up to Level 2D (BOA geocoded reflectance)



- PRISMA sensor operates in Pushbroom scanning mode
- Records the radiation reflected from the Earth surface (spectral cubes) in 400nm – 2505nm spectral window
  - **240 total bands in VNIR (#66, 400–1010 nm) & SWIR (#174, 920–2505 nm), partial spectral overlap**
  - High spectral Resolution (better of 14 nm)
  - Medium spatial resolution (30m) and swath (30km)
  - PAN camera offers added capability with 5m resolution

Primary mode – Manage user requests

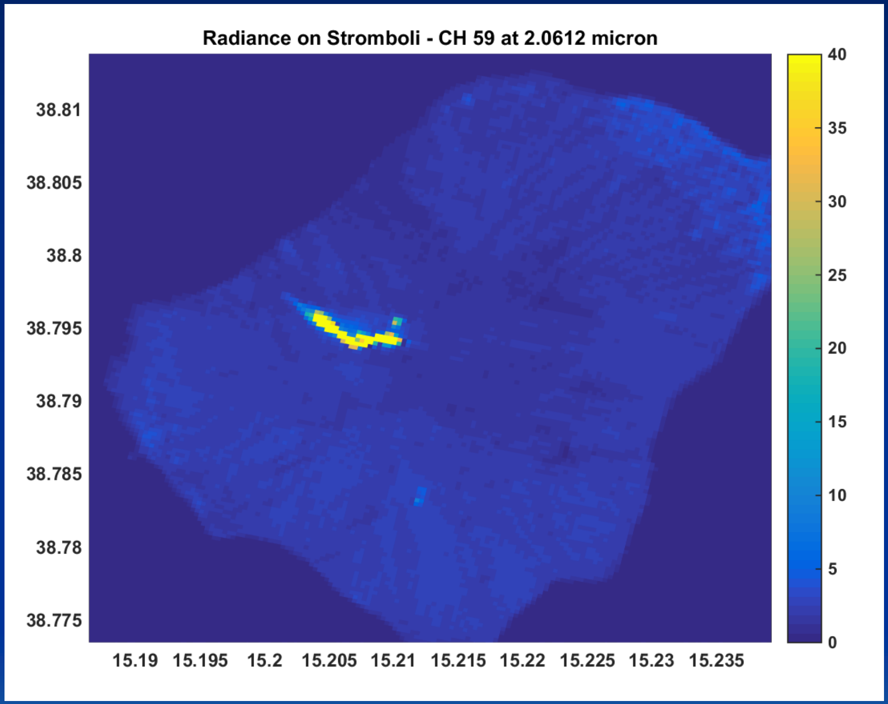
- CALVAL sites (highest priority)
- Nominal requests from all registered users, subject to quota and a priority level (depends by the user type)
- Mission Manager can promote Nominal Requests already Accepted to Very Urgent, for insertion in next day plan

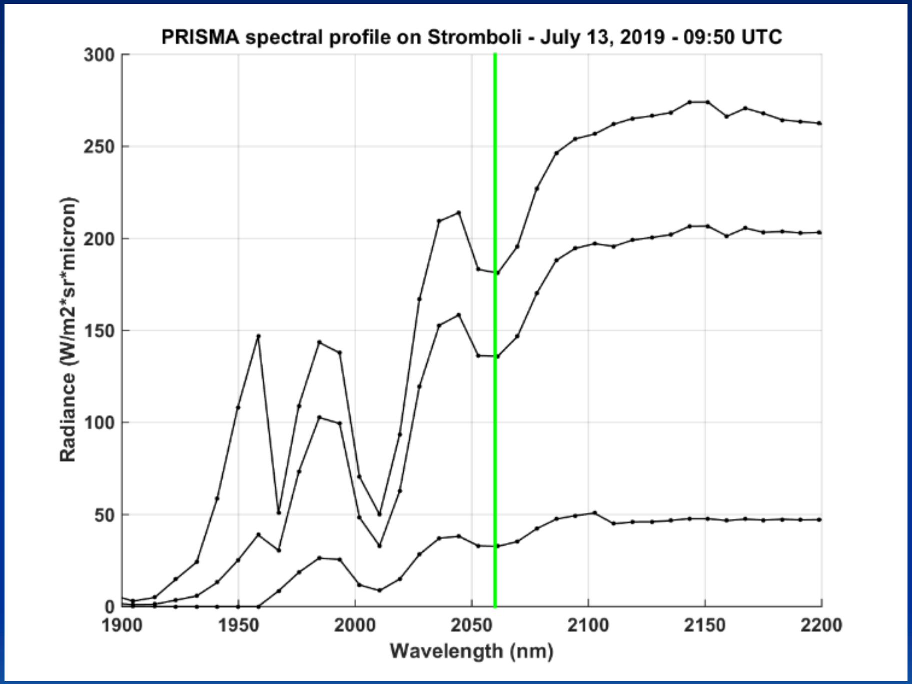
Background mission – Optimize system resources usage

- Generated to fill-up resources still available after planning of users requests or for systematic acqusitions

PRISMA DATA ACQUIRED ON STROMBOLI

PRISMA RADIANCE SPECTRUM





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PRISMA DATA INFORMATION AND ACCESS

https://www.asi.it/en/earth-science/prisma/

To access the data You need to create an account which permits to access the PRISM archive and submit requests for new acquisitions

https://prisma.asi.it

Multi-scale and multi-temporal optical satellite monitoring approach

About 3-5 km

Lower Revisit Time

Higher Spatial Resolution

Less than 30 mt

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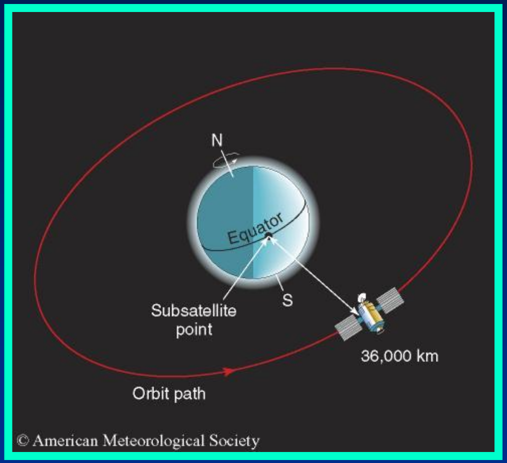
TO OBSERVE THERMAL DETAILS OF LAVA FLOWS S2, L8, ASTER, ECOSTRESS ARE ACQUIRED

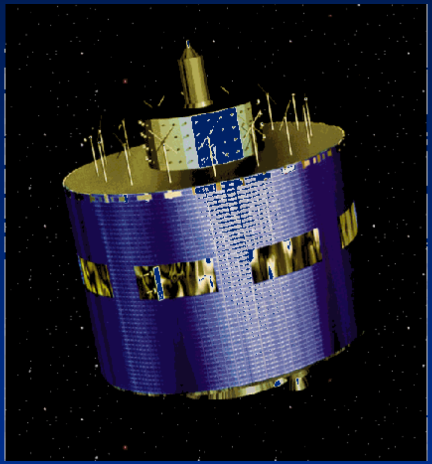
Scheme of volcano Thermal monitoring through satellite data at INGV

SENSOR	SPATIAL RESOLUTION	TEMPORAL RESOLUTION
MSG	3-5 km	5 min

SENSOR	Spatial Resolution (mt)	Temporal Resolution
ASTER	90	16 days
LANDSAT-8	100	16 days
SENTINEL-2	20	About 6 days
SENTINEL-3	1000	2 per days

INGV RT Monitoring of active volcanoes





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Responsible: Dr. Massimo Musacchio
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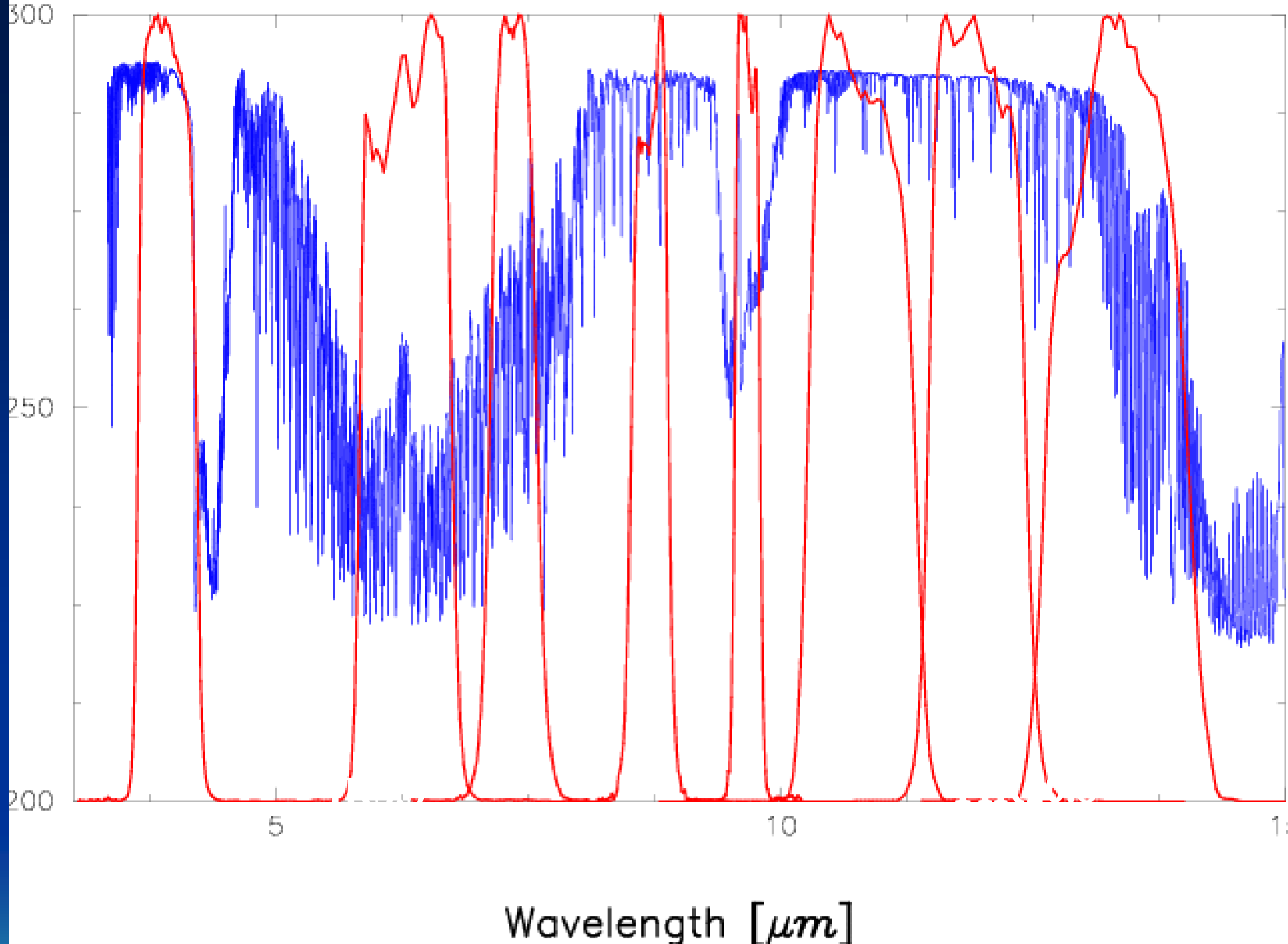


The IR3.9 channel is a window channel

Why 3,9 micron channel: **Sub-pixel response**.

Basically, the concept of sub-pixel response states that if there is variability within a field-of-view (FOV), then the radiance measured by the satellite for that FOV is the average of the individual radiances in the sub-pixels and not of their temperatures

Introduction

In order to develop a system dedicated for early warning for Italian active volcanoes, we have developed an automatic system to support the detection of the changes in the thermal state of the Etna volcano.

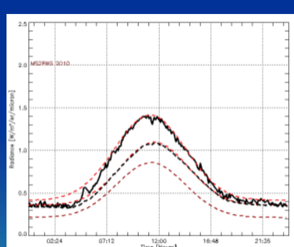
- We have focused our attention on the radiance acquired by the SEVIRI 4th channel (strongly sensible to the thermal variation)
- We have used, when available, the RSS data (288 per day) and according the EUMETSAT calendar, the less frequent acquisition (96 per day)

- We have obtained a “constant growing” time series here analyzed only for Etna.

MS2RWS: Rapid Response Web Service

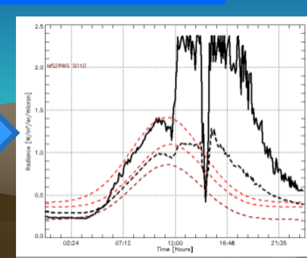
Radiance SEVIRI data → **channel extraction**

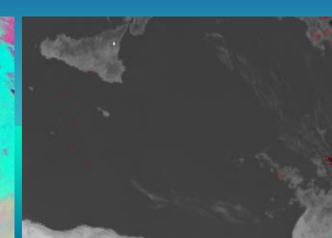
MS2RWS



NO Eruption

Eruption





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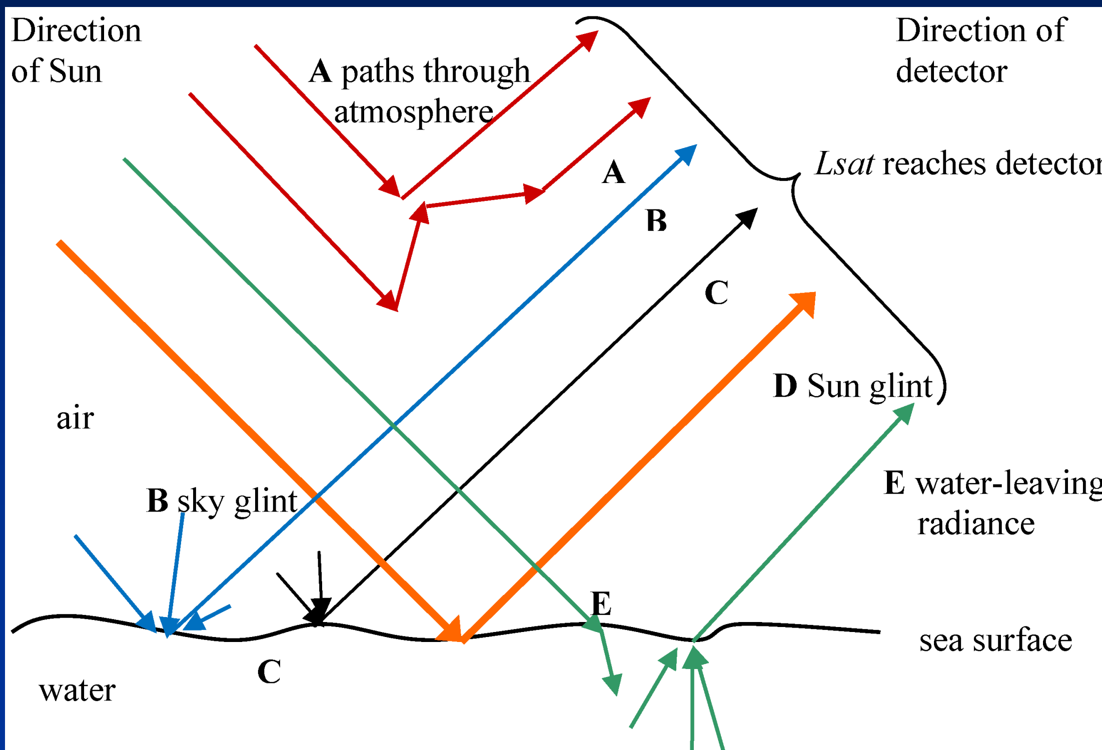
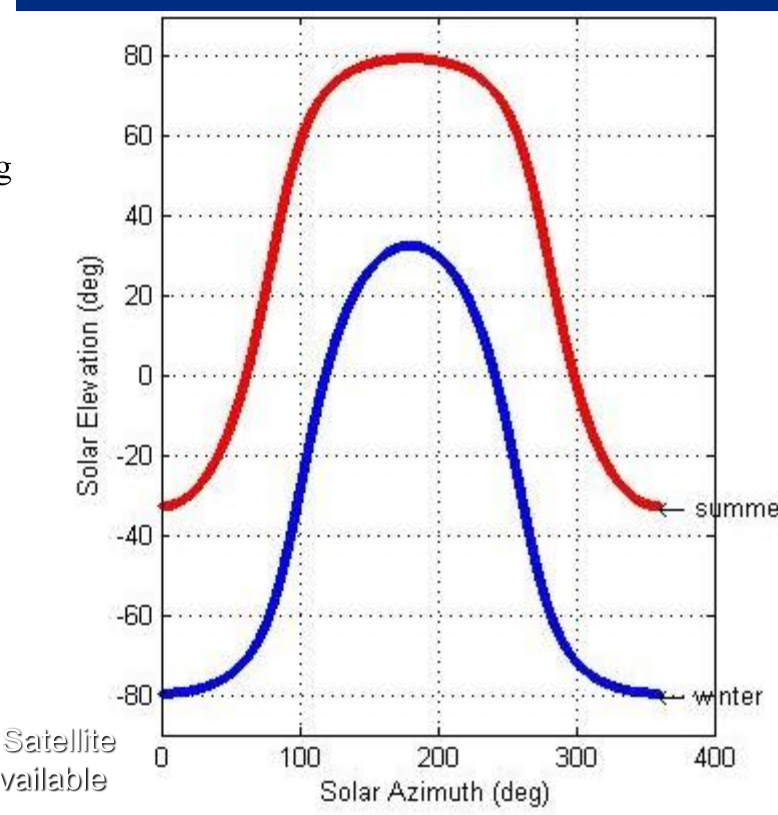
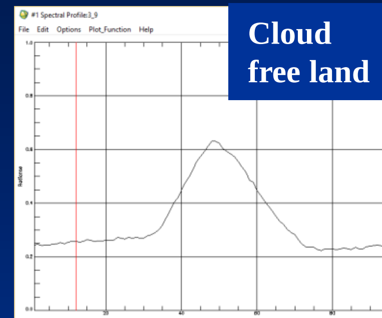
Solar elevation vs season

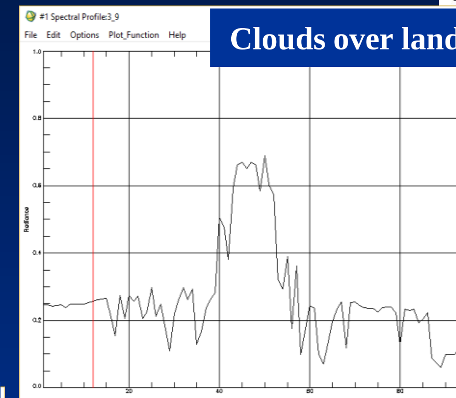




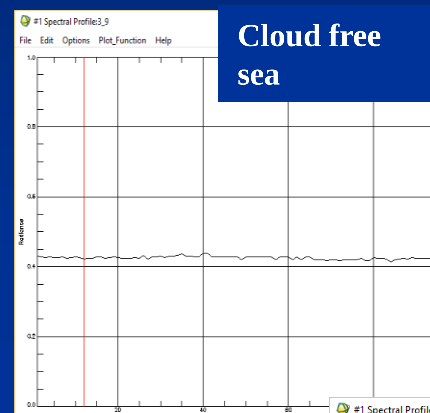
Varibility in Observation



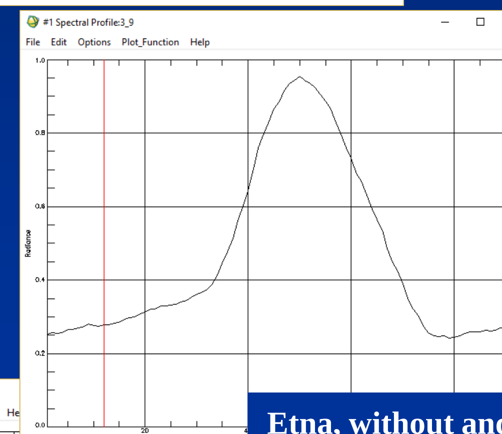
Cloud free land

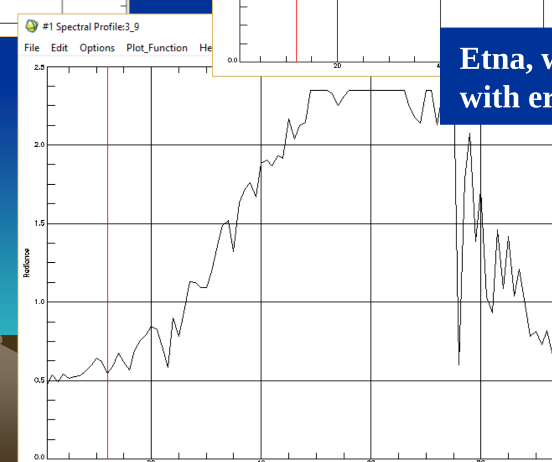


Clouds over land



Cloud free sea

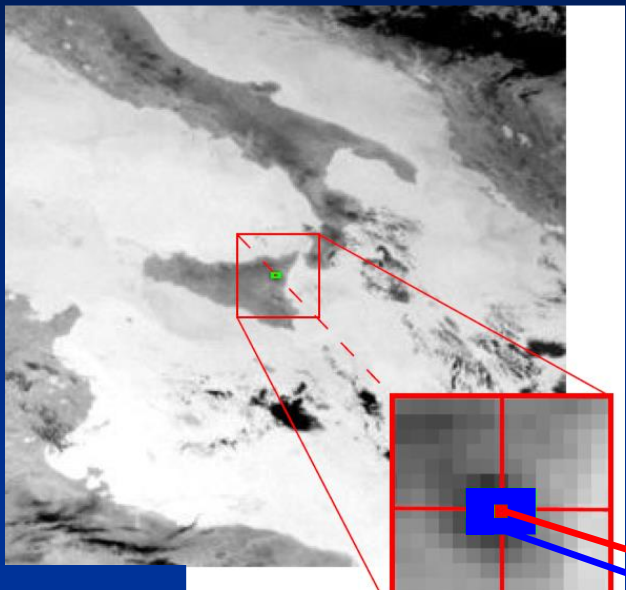


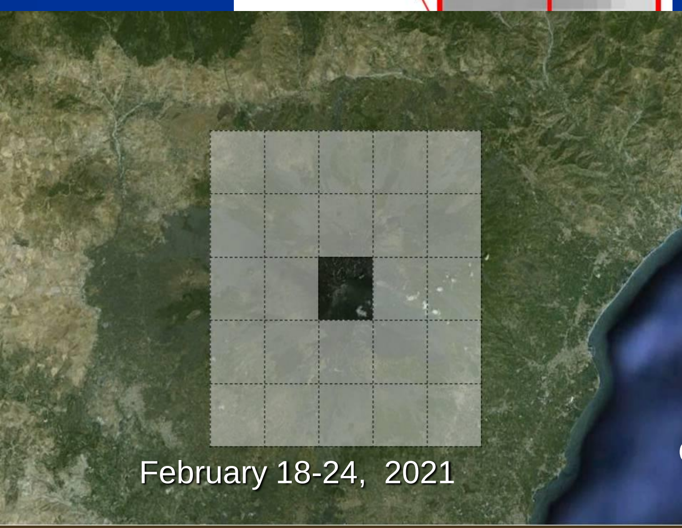


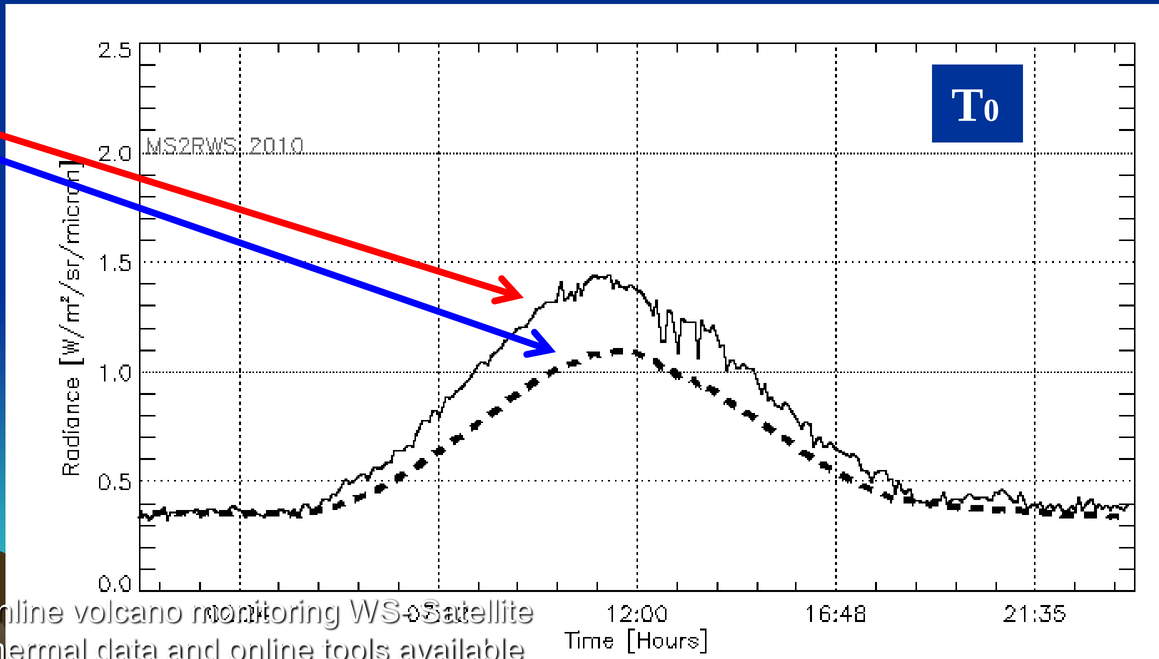
Etna, without and with eruption

Methodology

- The MS2RWS, every 5 (or 15 minutes), captures the radiance value of the pixel centered over Mt Etna and the mean radiance values of the surrounding 24 pixels







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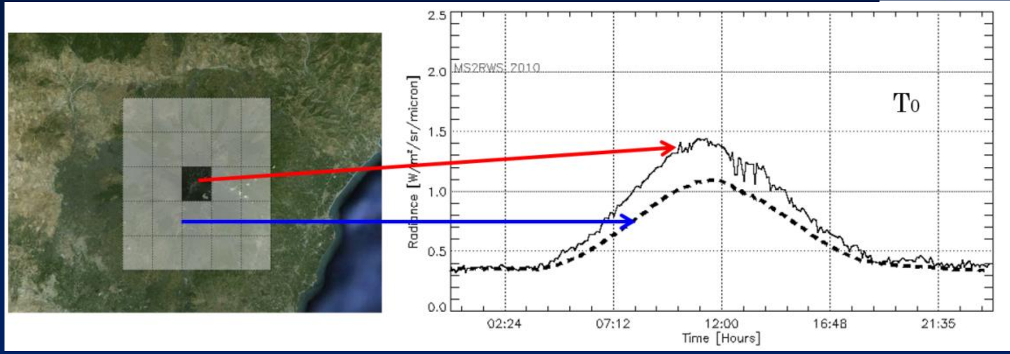
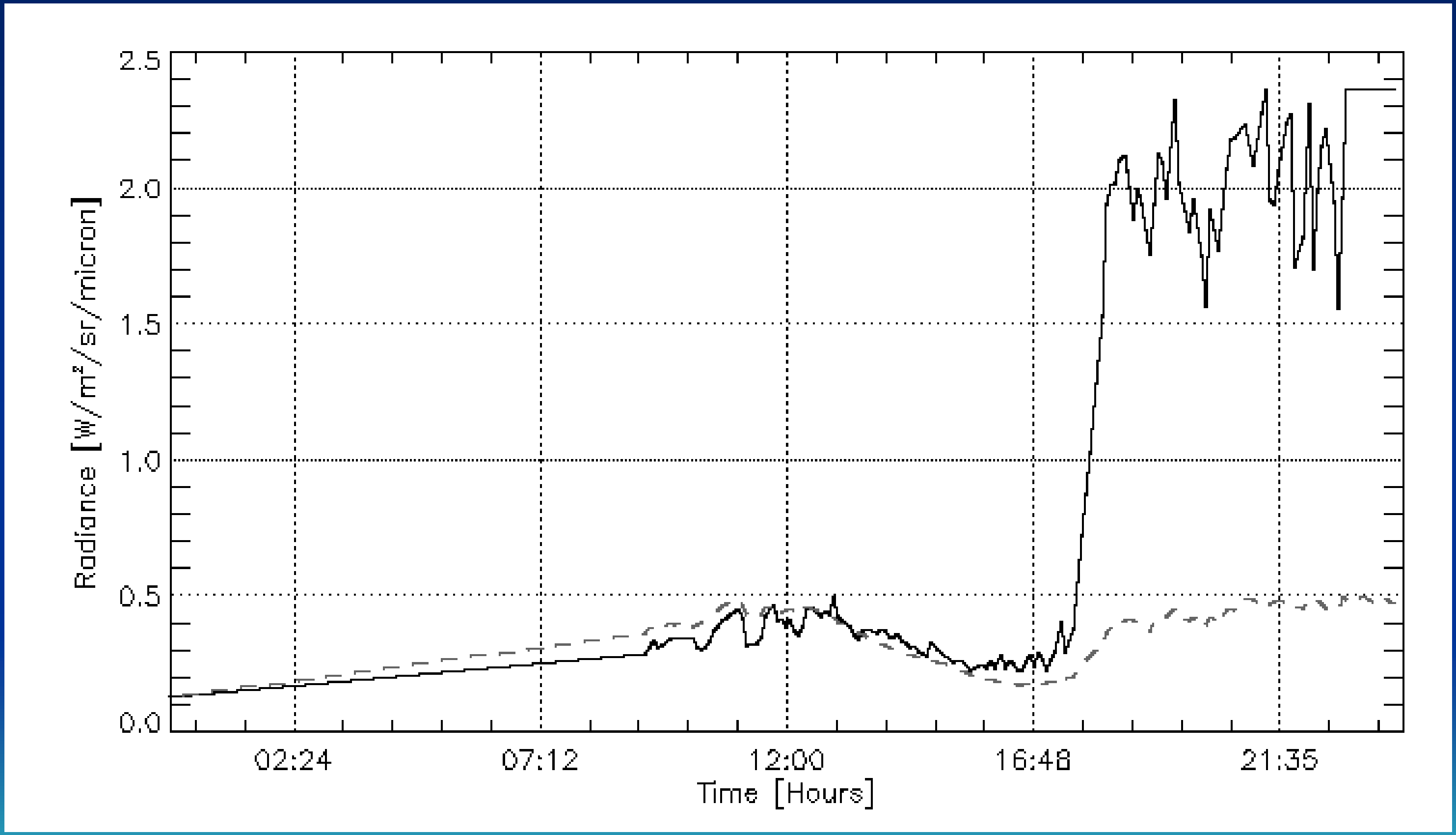
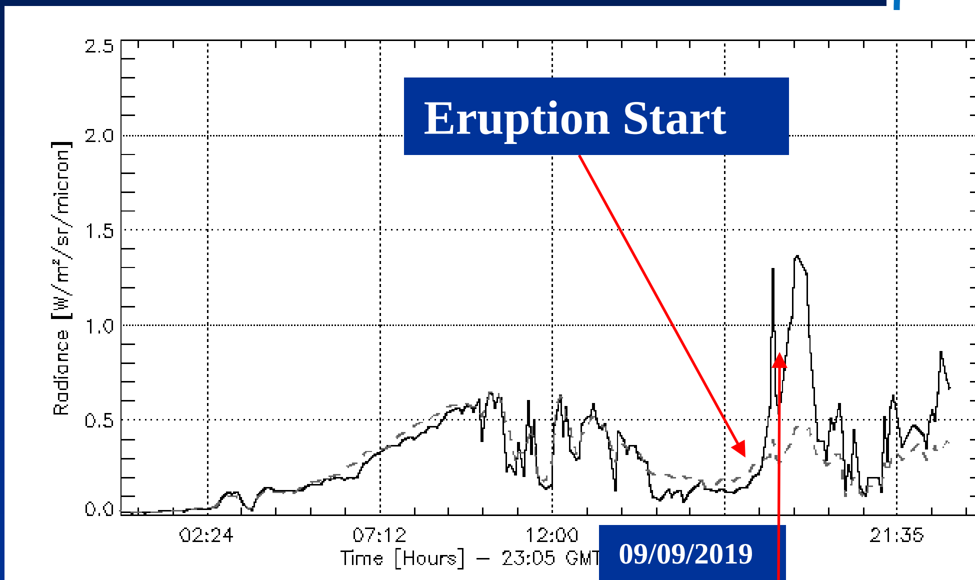
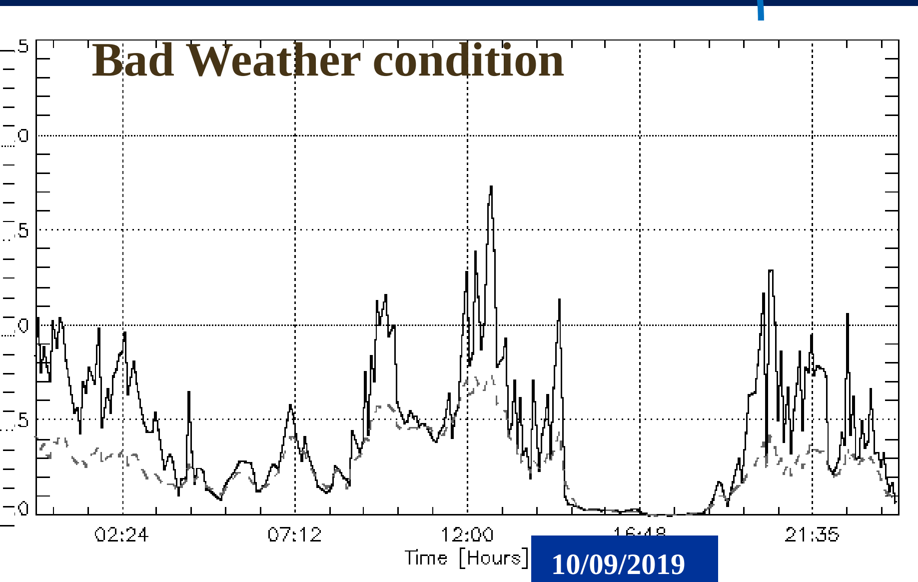
2017 February 27
Etna eruption



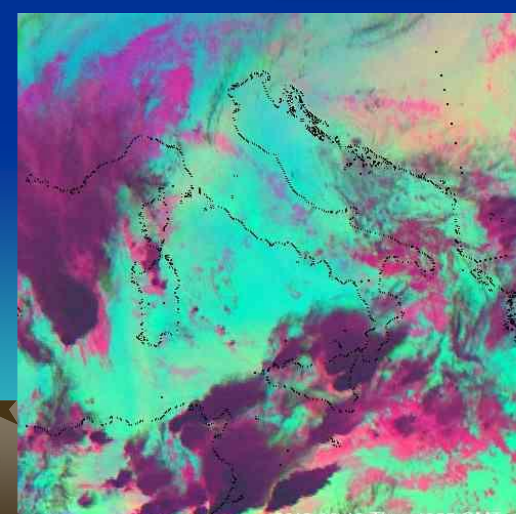


ETNA 09-10/09/2019



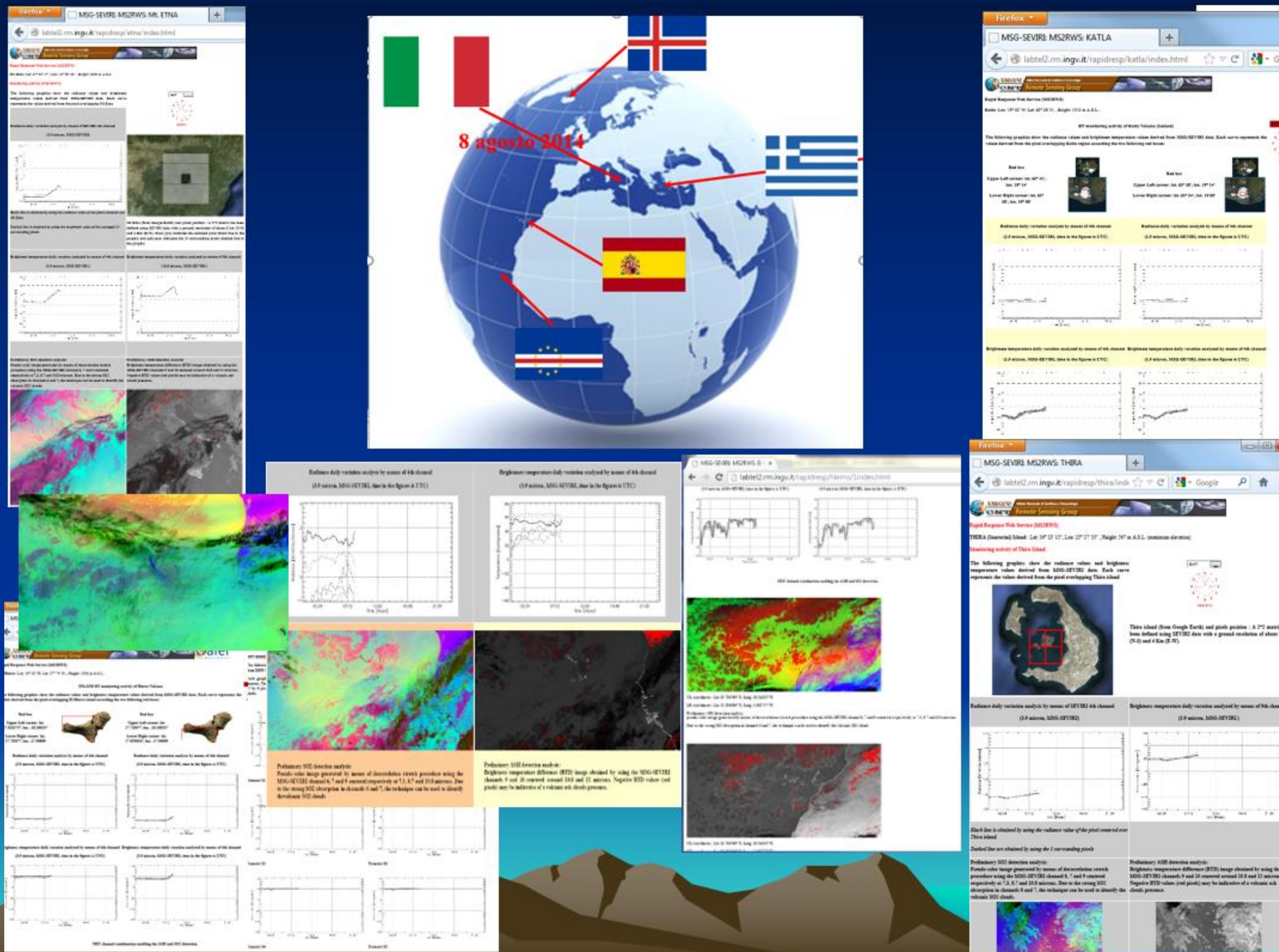


Presence of Plume
(non completely opaque)



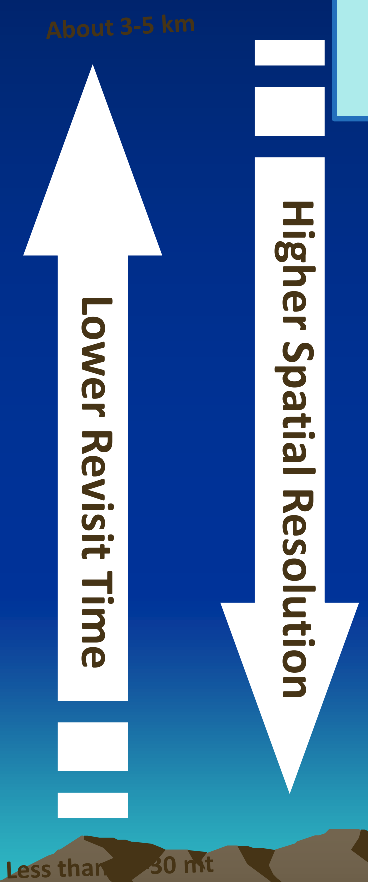
MS2RWS works as a web application and could be easily exported: We tested the MS2RWS in Canary Island, Iceland, Capo Verde and Santorini

INGV



Multi-scale and multi-temporal optical satellite monitoring approach

Scheme of volcano Thermal monitoring through satellite data at INGV



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TESA Geohazards Exploitation Platform (GEP)

ESA funded the development of an innovative tool (GEP) to demonstrate the benefits of a satellite data exploitation platform for large scale hazards mapping and monitoring and to link with Science and User networks.

The GEP Platform allows

- on demand processing for specific user needs and systematic processing to address common information needs of the geohazards community as a whole
- massive processing on multi-tenant computing resources on the Cloud that will address the challenges of monitoring tectonic areas on a global basis, and of studying a range of geohazards.

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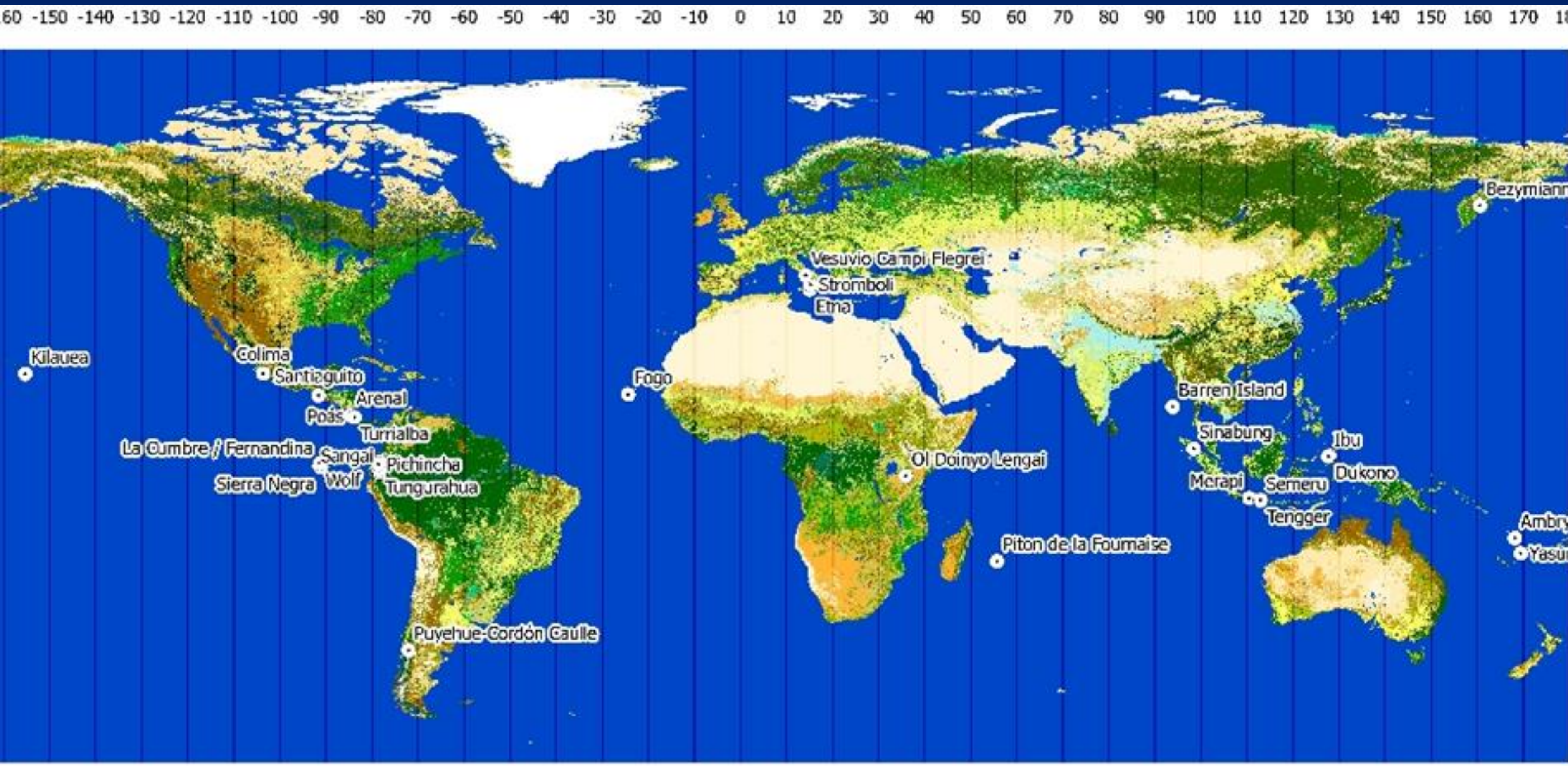
GEP and STEMP

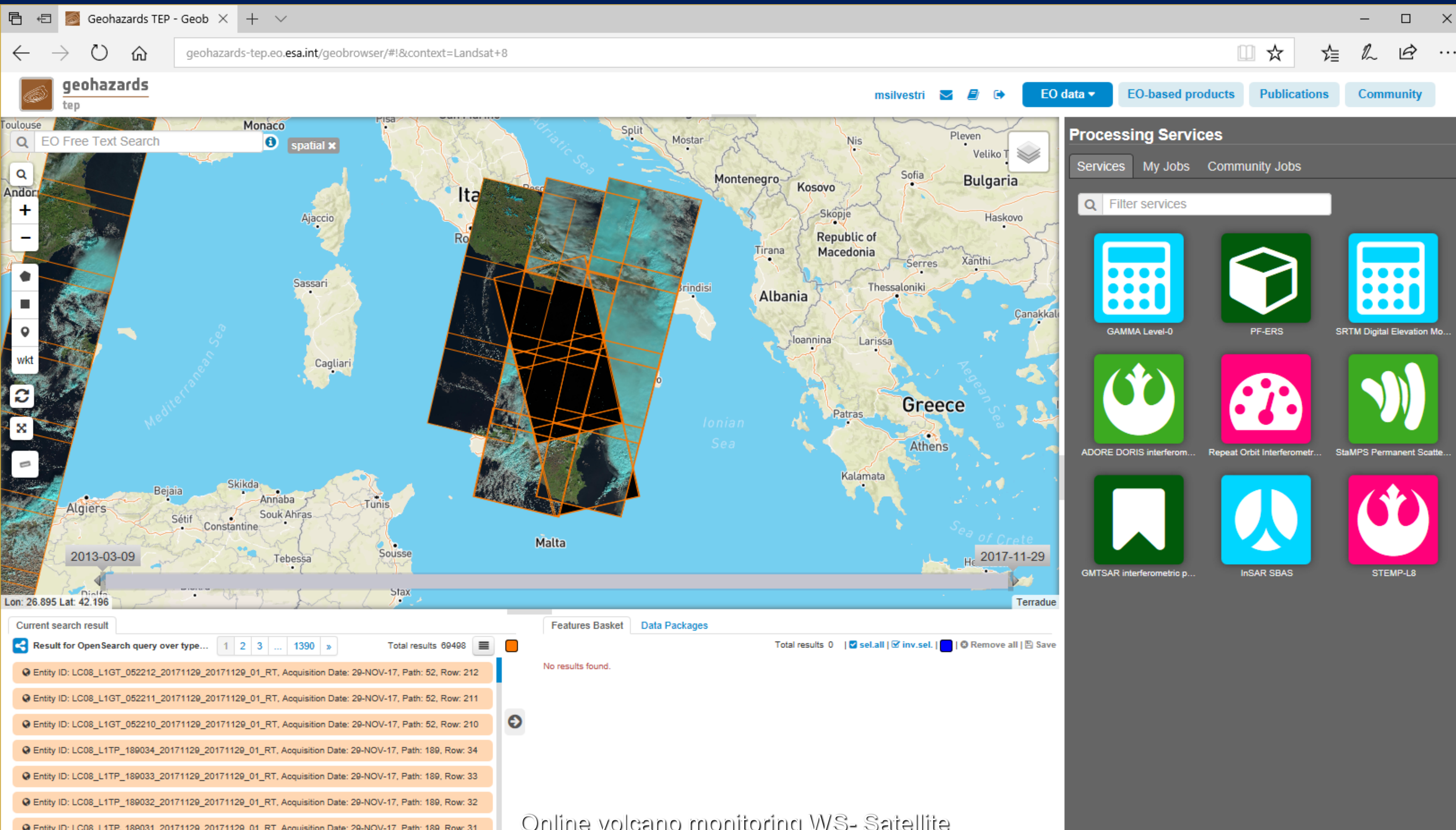
- In the context of the VOLcanoes Thermal Application (VOLTAGE) for GEP has been implemented.
- INGV has setup an end-to-end processing chain (STEMP) for the generation of surface temperature maps over volcanic areas.

- STEMP generates:
  - Surface temperature map from ASTER, Landsat-8, Sentinel-3 (volcanic activity early warning studies)
  - Hot Spot and Lava flow detection with Sentinel-2.

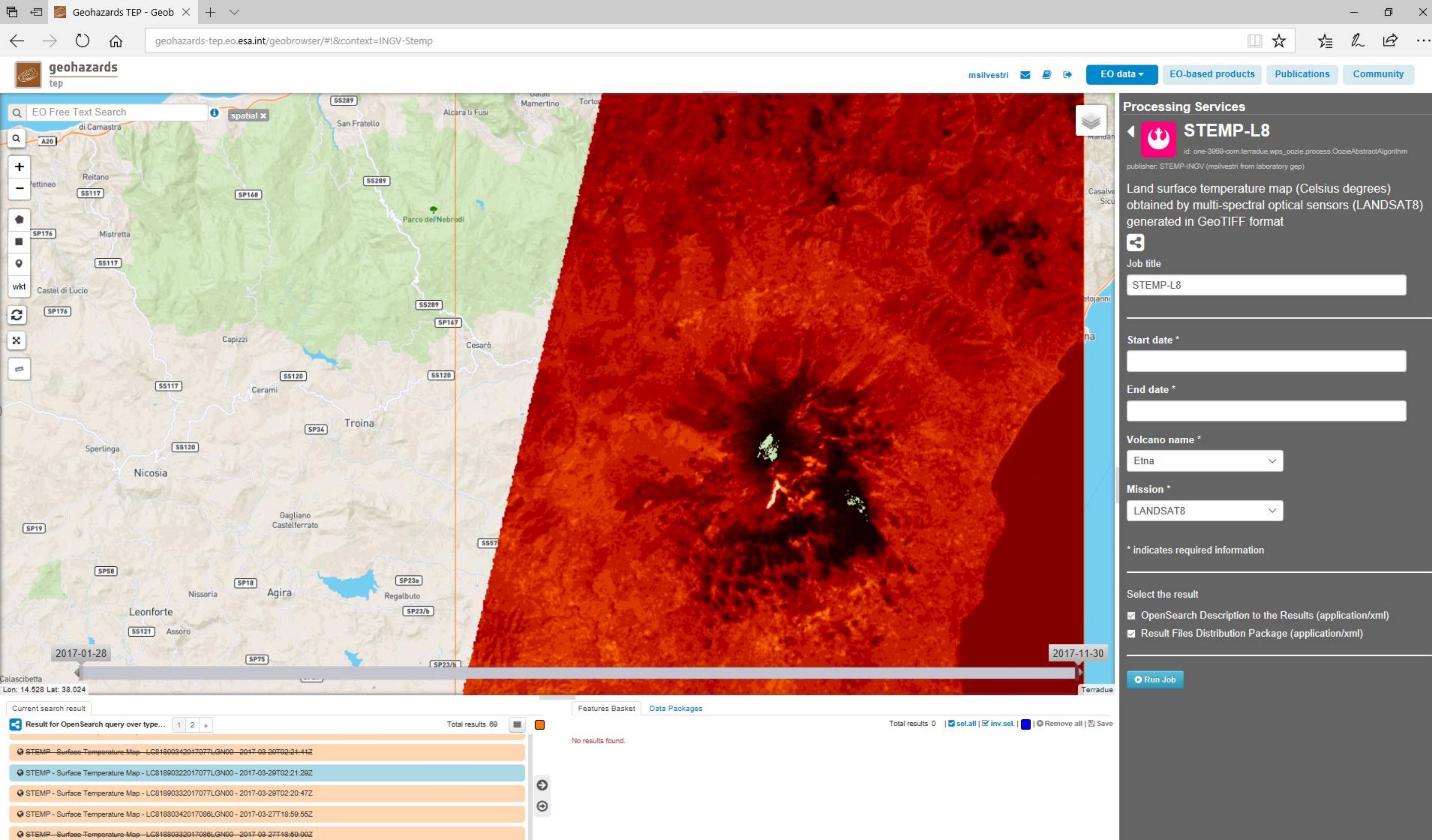
Volcano location Map



GEP: Data List (e.g.L8)



From Data to Product (based on L8)



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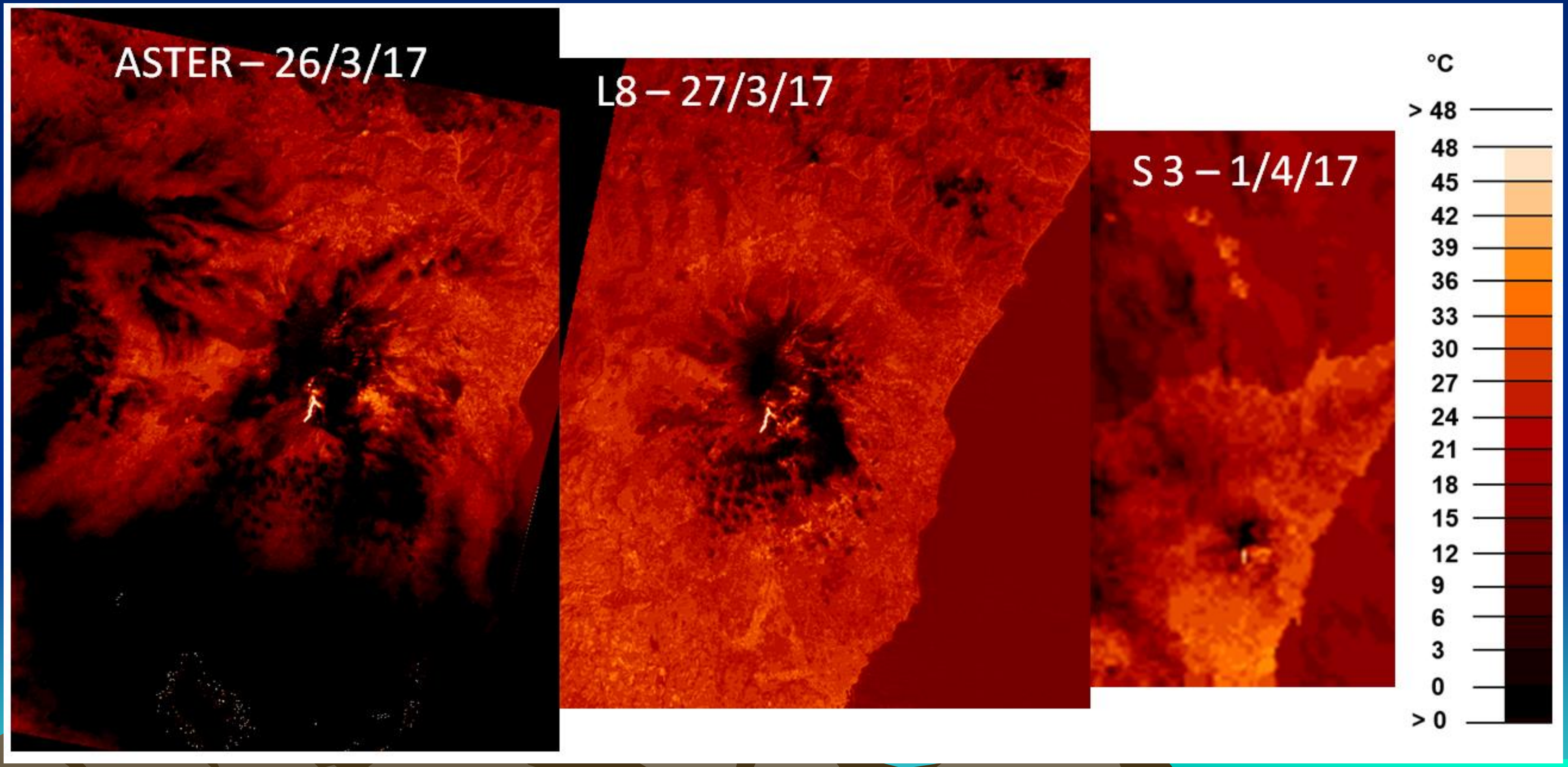
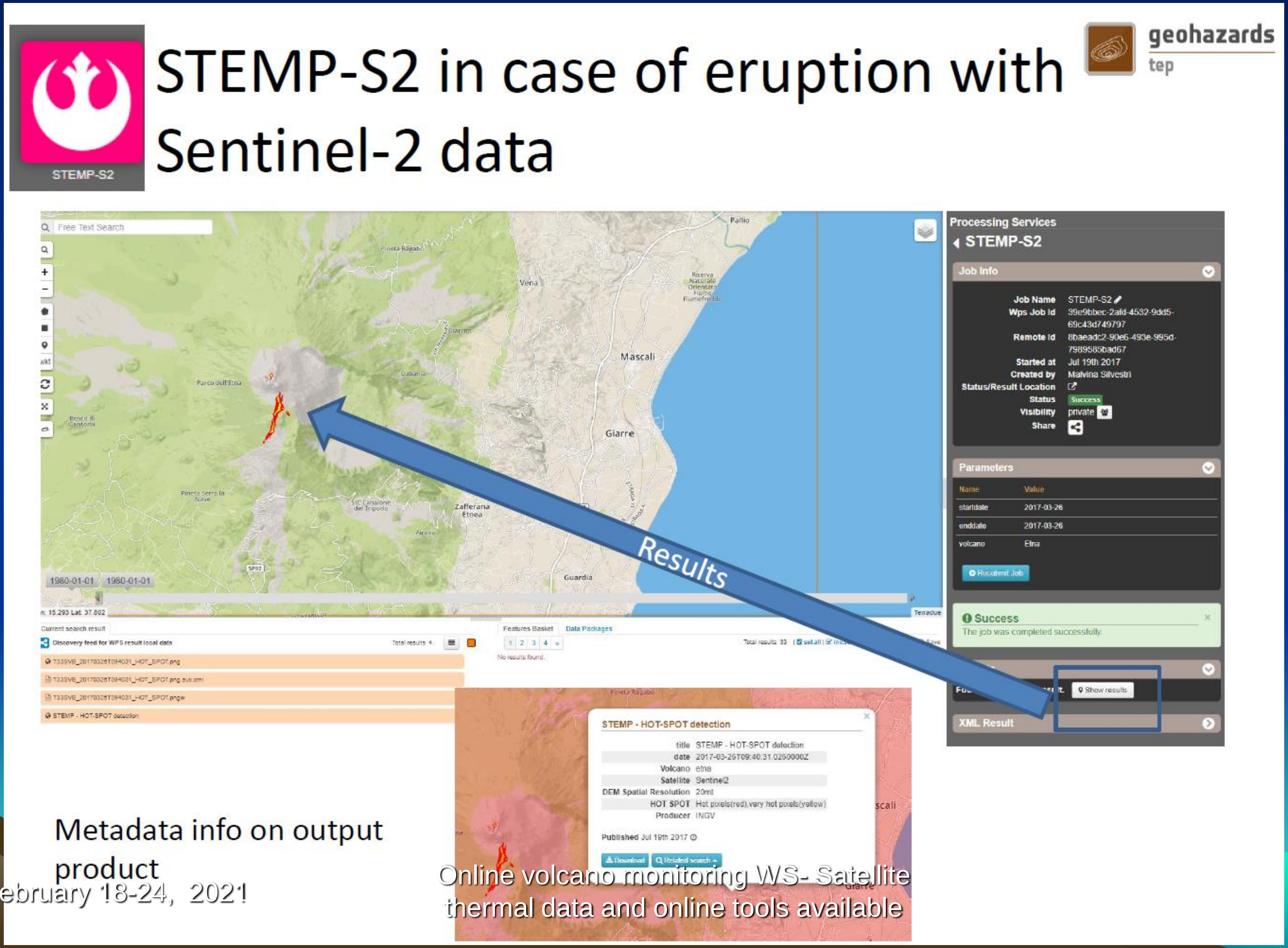
Surface Temperature map comparing different satellite data

Surface temperature using ASTER, L8, S3 on Mt. Etna volcano during the last eruption in 2017(daytime acquisition)

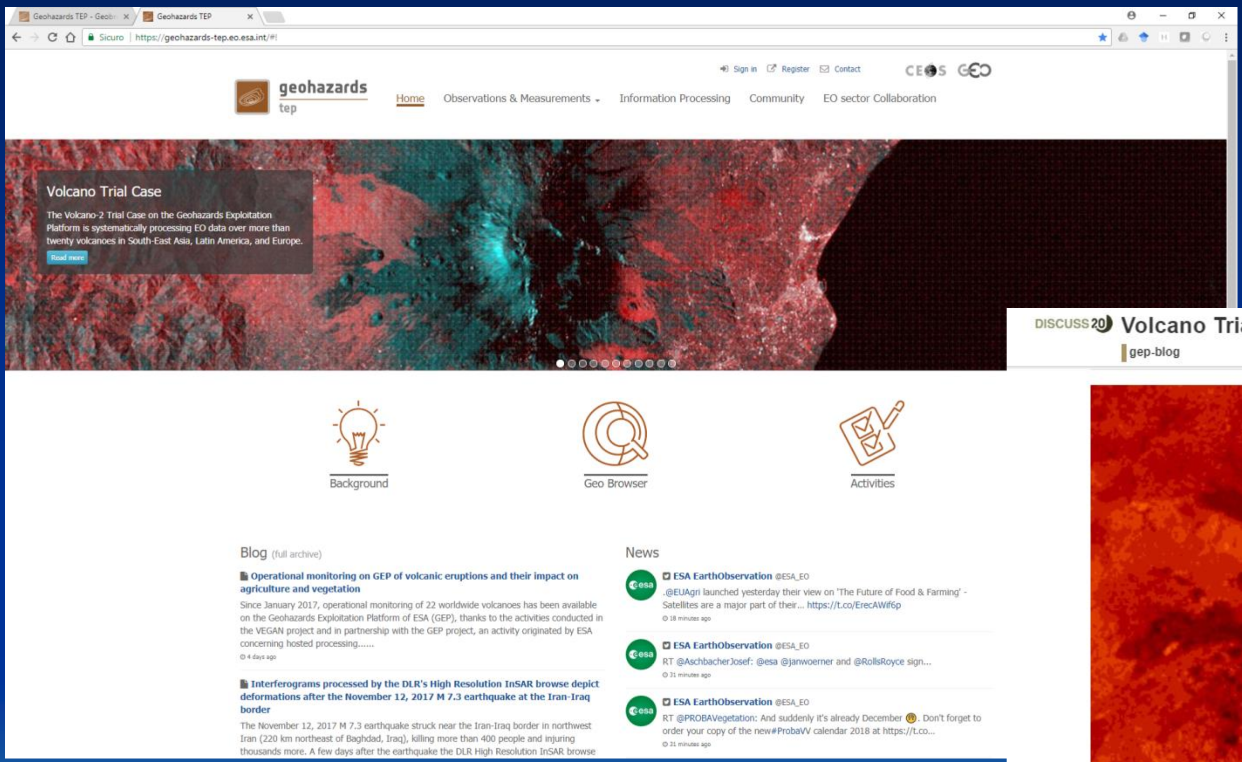


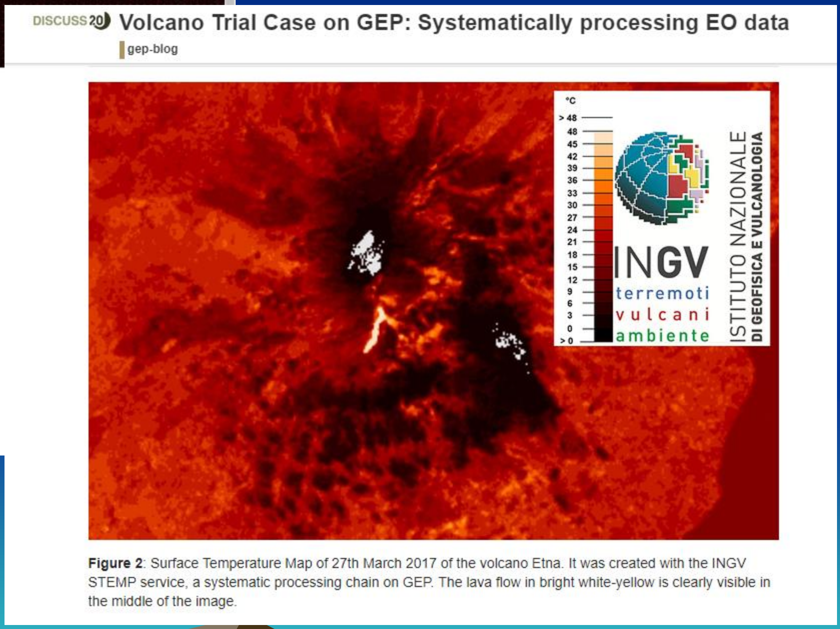
From Data to Product (based on S2)



Information on the Geohazards platform could be find at:

https://geohazards-tep.eu/#!

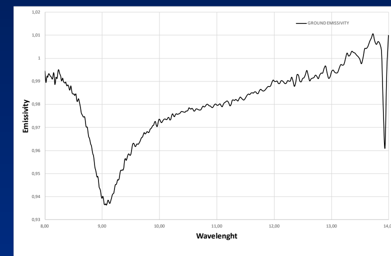




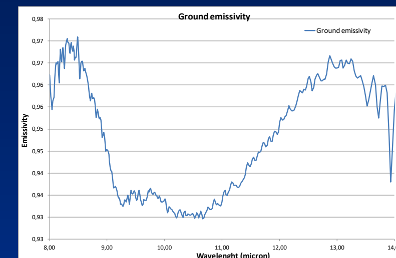
SURFACE TEMPERATURE ESTIMATION CROSS CALIBRATION

Spectral Emissivity values: Field campaign and laboratory measurements

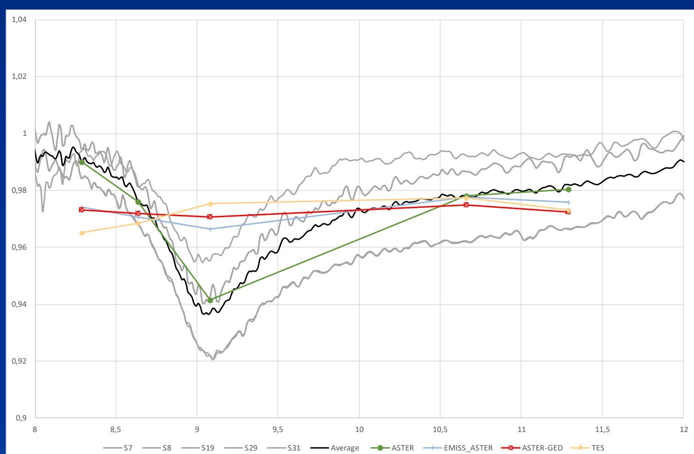
Model 102F FTIR (Fourier transform infrared) spectrometer



Campi Flegrei (Solfatara)



Mt Etna summit area



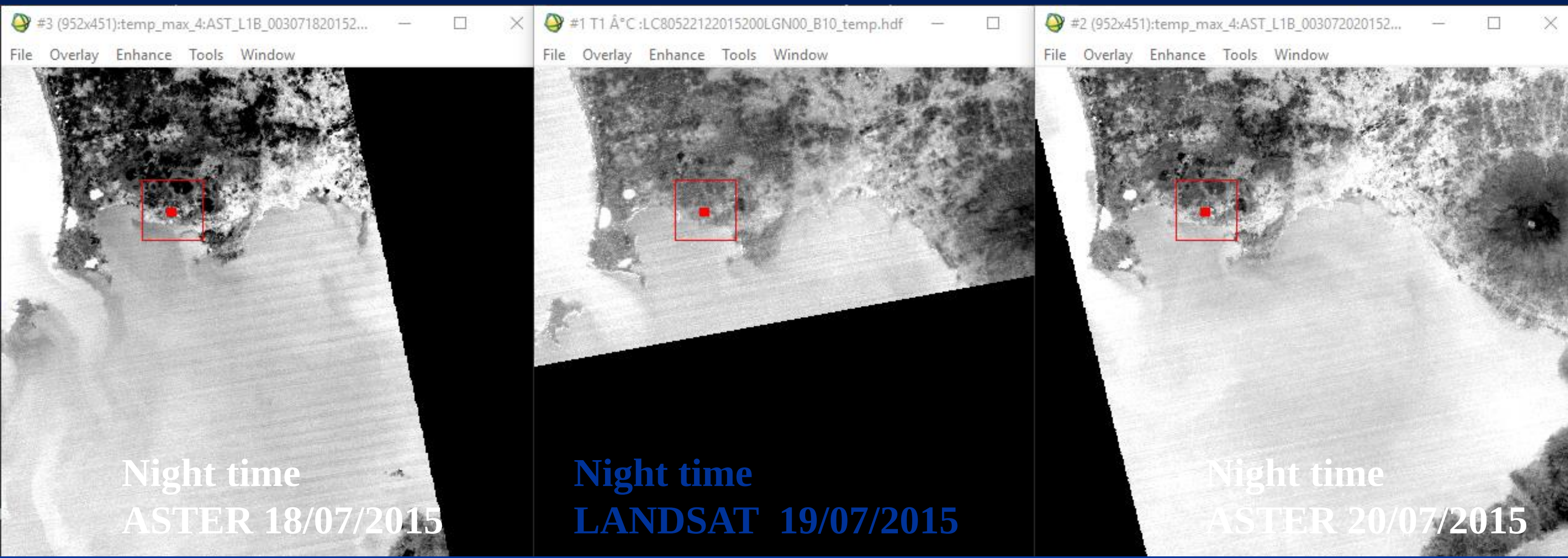
Measurements collected with FTIR and convolved on ASTER SRF

ASTER-GED: emissivity retrieved by the ASTER-GED

EMISS_ASTER: emissivity retrieved by ASTER 05 data

Emissivity retrieved using TES algorithm

Cross Comparison: ASTER vs Landsat8



ROI on 56 points	Min	Max	Mean	Stdev
ASTER 18/07/2015	24.770935	36.675934	28.535006	3.011479
LANDSAT 8 19/07/2015	25.786102	35.495209	28.911593	2.598132
ASTER 20/07/2015	25.650024	37.518768	29.153285	2.816236

Results:

- ASTER and L8 have been scaled at ASTER-TIR channel spatial resolution (90 m).
- Using two different methods (TES, BARSI) the difference in retrieved temperature show an average of less than 1°C for Mt Etna. Comparison with ground measurements also demonstrated good agreement considering that ground measurements represent very small areas compared to the satellite pixel size.
- The results obtained are very useful to understand variability of LST retrievals by remote sensing data
- They highlight the importance of precise emissivity inputs to the retrieval procedures as well as the needs of systematic calibration areas for LST satellite retrievals

Hot Spot Map: applied to S2 data

A Procedure to define the area of an active lava flow has been developed within the GEP platform by using the approach proposed by [Murphy et al., 2016] and applied to SENTINEL 2 and S8 data (VIS-SWIR channels)

SENTINEL 2 channels
and 8A: 0.865 micron and 20 mt resolution
Band 11: 1.610 micron and 20 mt resolution
Band 12: 2.190 micron and 20 mt resolution

Hot Spot Map: General Approach

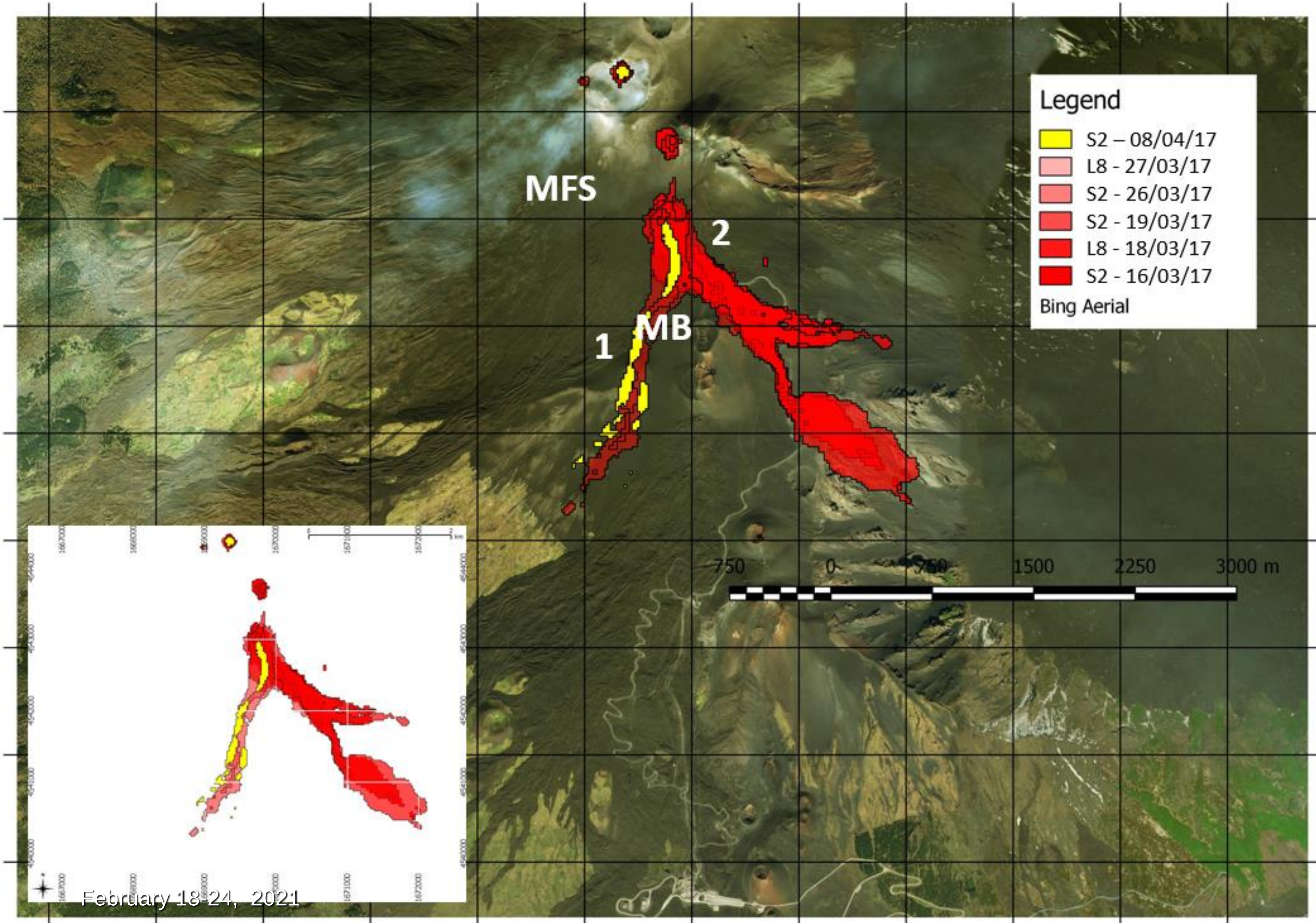
Detection algorithm proposed by [Murphy et al., 2016]:

$$\alpha = (R_{12}R_{11} \geq 1.4) \text{ AND } (R_{12}R_{8A} \geq 1.4) \text{ AND } (R_{12} \geq 0.15)$$

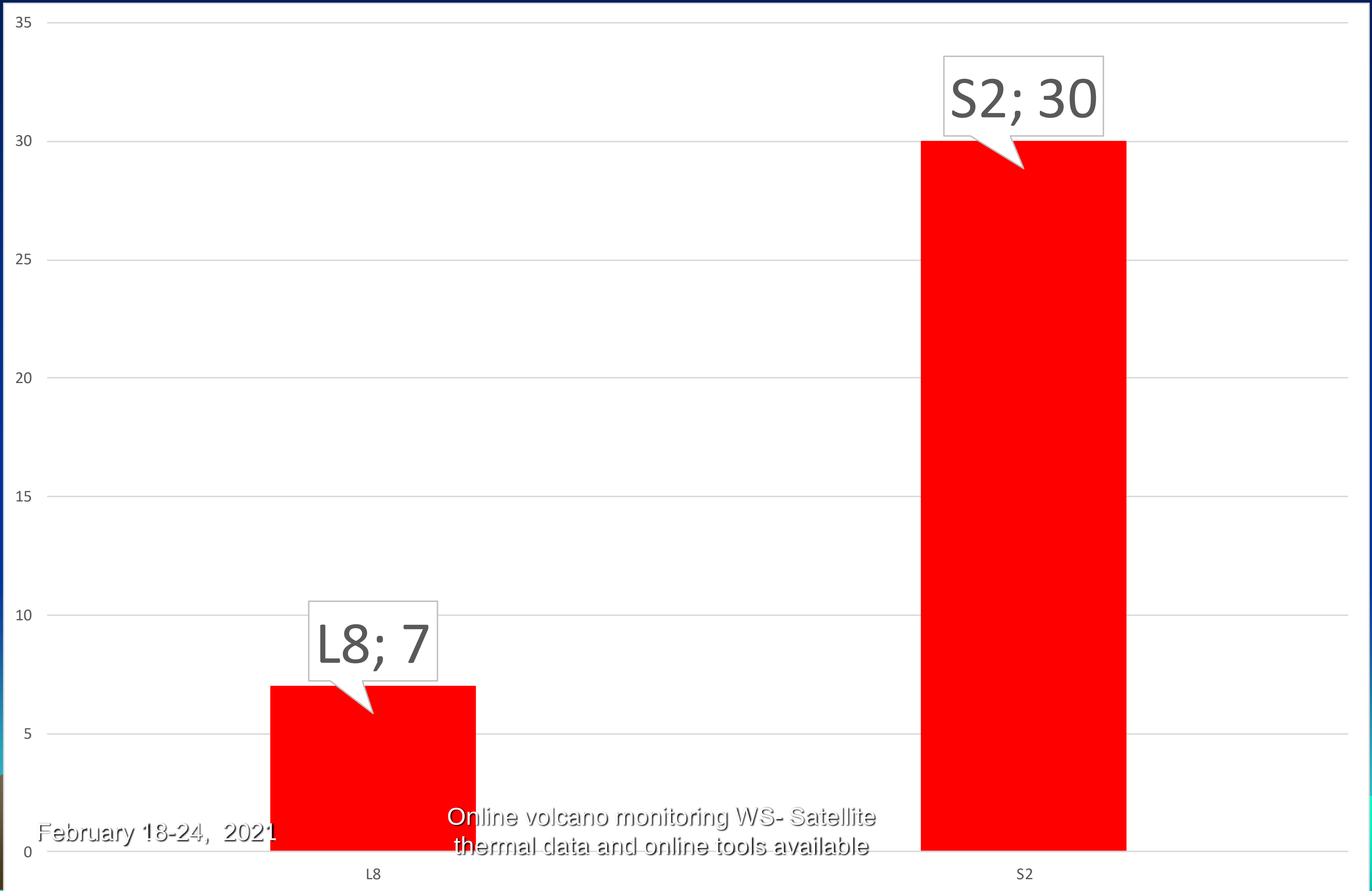
and

$$\beta = ((R_{11}R_{8A} \geq 2) \text{ AND } R_{11} \geq 0.5)$$

Band 8A: 0.865 micron and 20 mt resolution
Band 11: 1.610 micron and 20 mt resolution
Band 12: 2.190 micron and 20 mt resolution


Legend
S2 – 08/04/17
L8 - 27/03/17
S2 - 26/03/17
S2 - 19/03/17
L8 - 18/03/17
S2 - 16/03/17
Bing Aerial
MFS
2
MB
1
750
0
750
1500
2250
3000 m
February 18-24, 2021

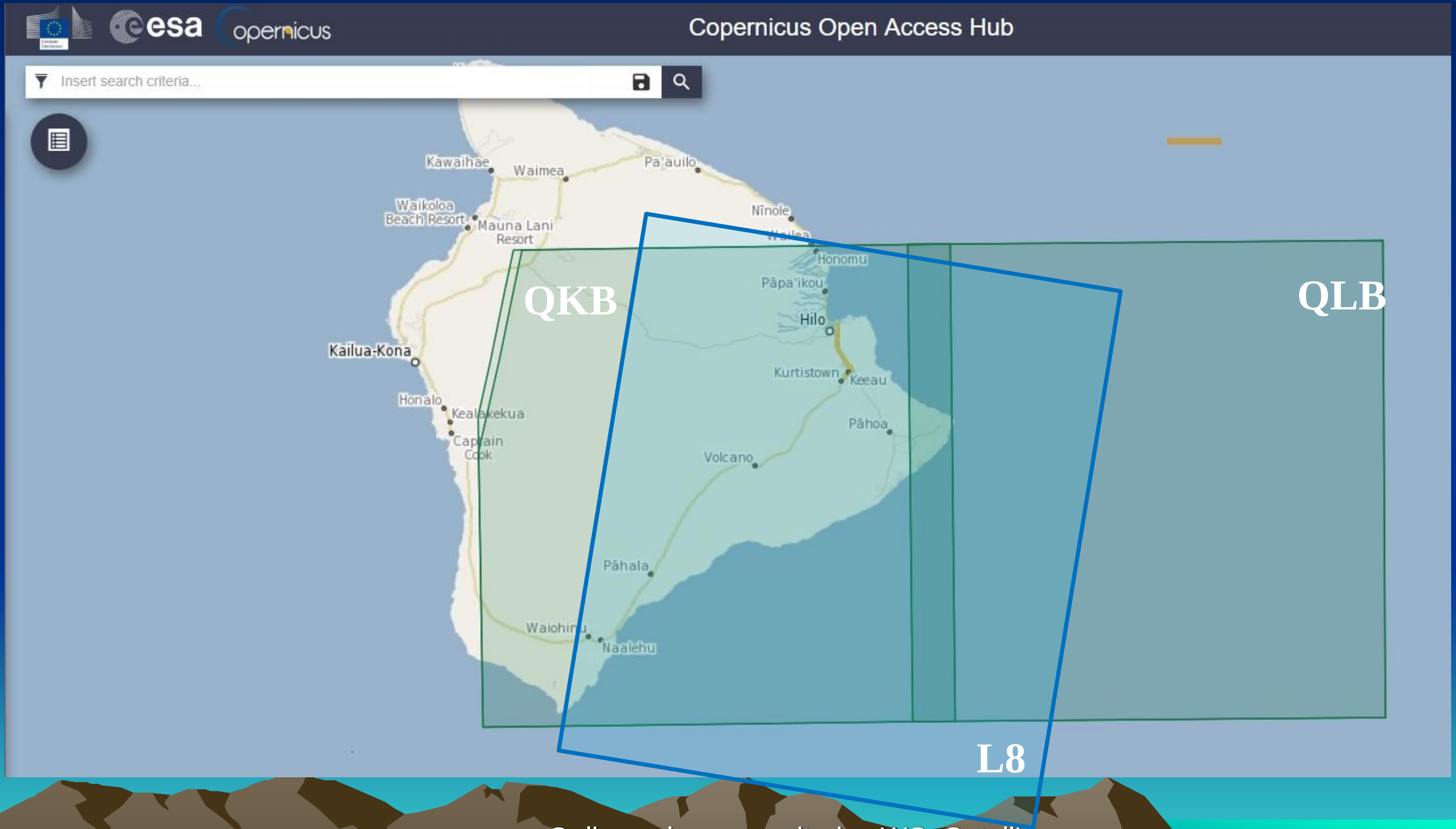
Kilauea Leilani 2018 eruption



February 18-24, 2021

Online volcano monitoring WS- Satellite thermal data and online tools available

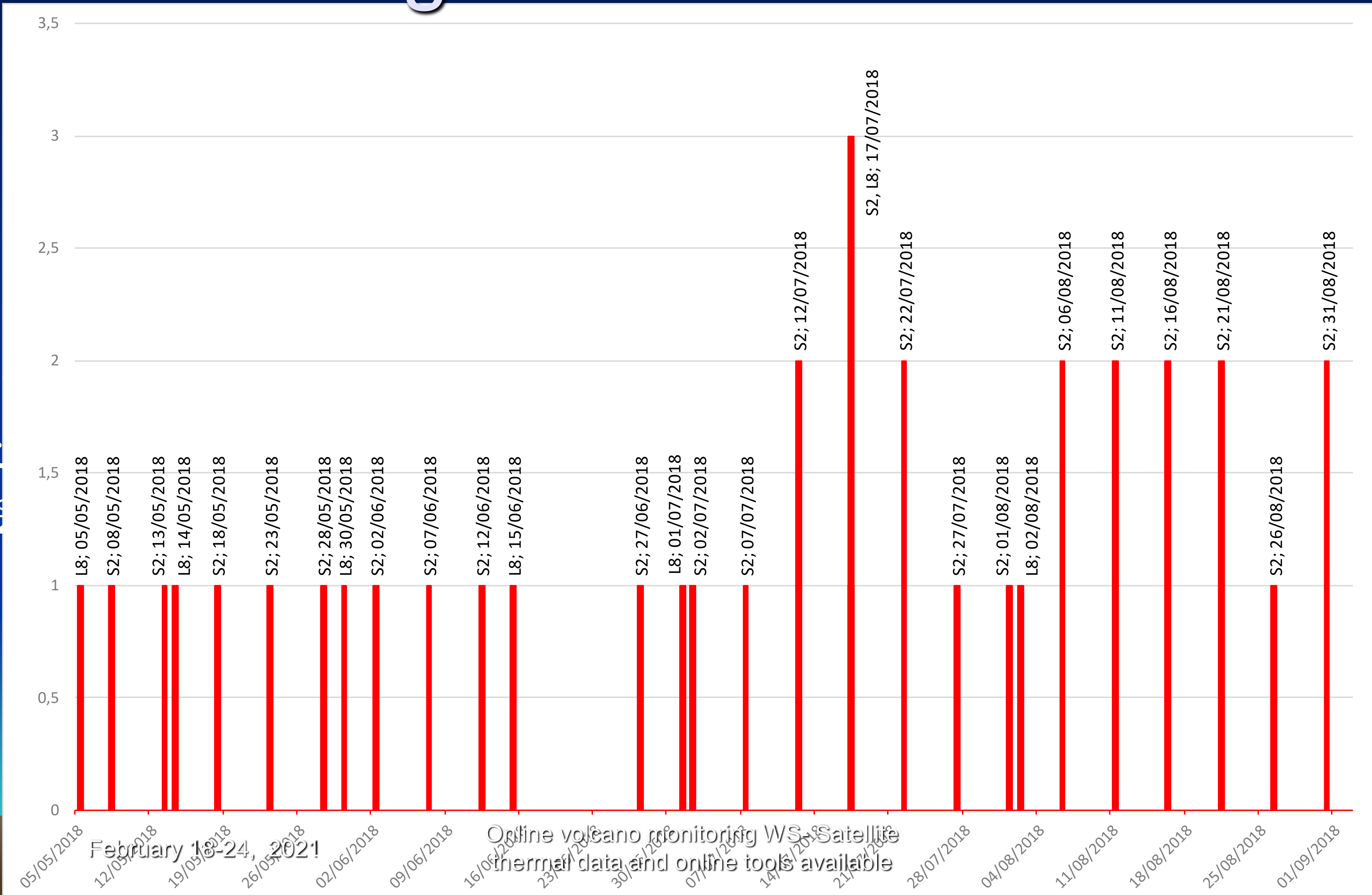
L8 AND S2 COVERAGE ON HAWAII BIG ISLAND



February 18-24, 2021

Online volcano monitoring WS- Satellite thermal data and online tools available

Timing of L8 and S2 data



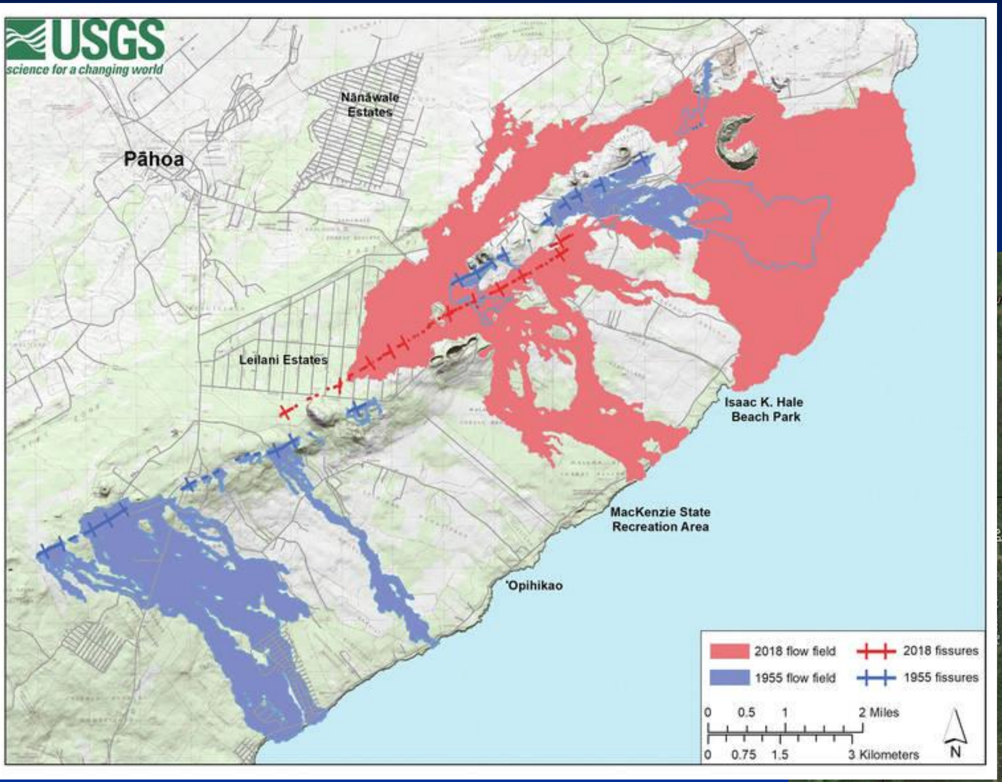
SATELLITE DERIVED MAPS ON THE EPRESENCE OF ACTIVE LAVA FIELD IN

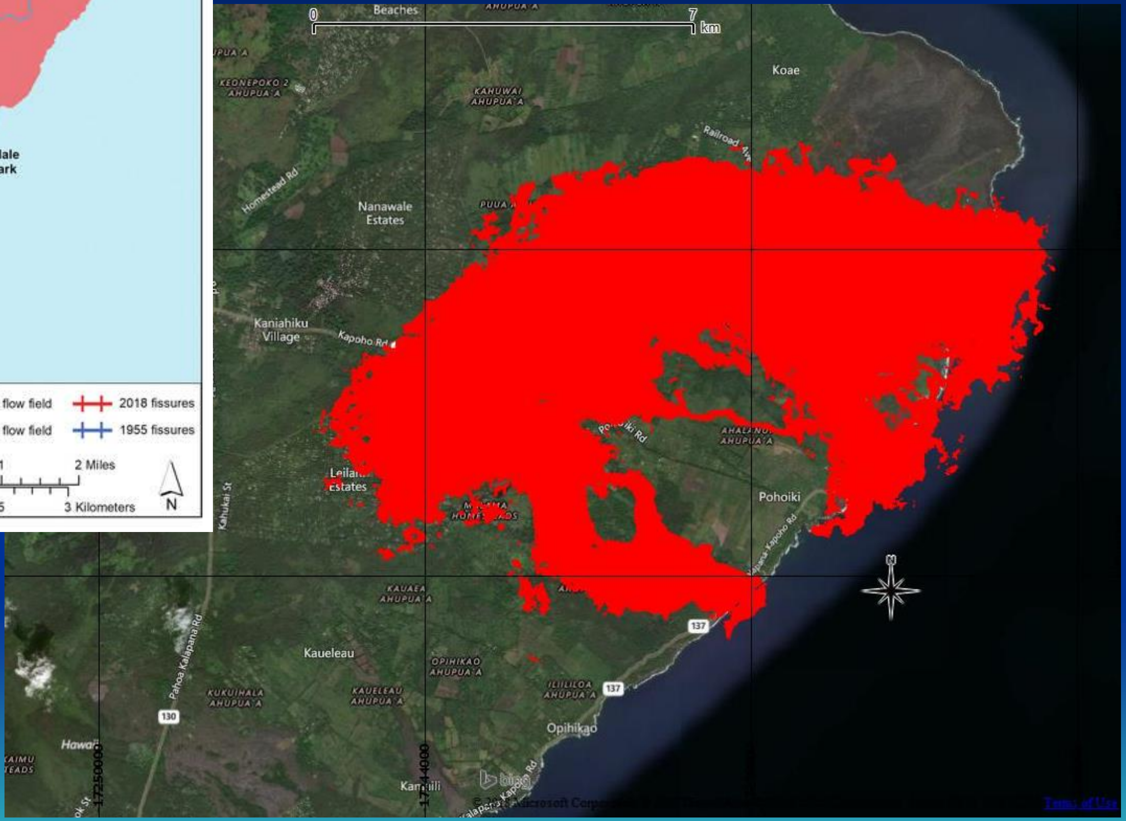
May

August

CUMULATIVE MAP

May June July August





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Massimo.musacchio@ingv.it
malvina.silvestri@ingv.it

PART II

- **INGV-VESUVIAN OBSERVATORY:**
  - **Permanent Monitoring Infrastructure**
  - **Thermal monitoring Solfatara crater by means of satellite data combined with ground cameras and drones**
- **INGV-ETNEO OBSERVATORY:**
  - **Permanent Monitoring Infrastructure**
  - **HOTSAT Satellite Volcano Monitoring System**

Test Sites: Campi Flegrei, Campania (Italy)

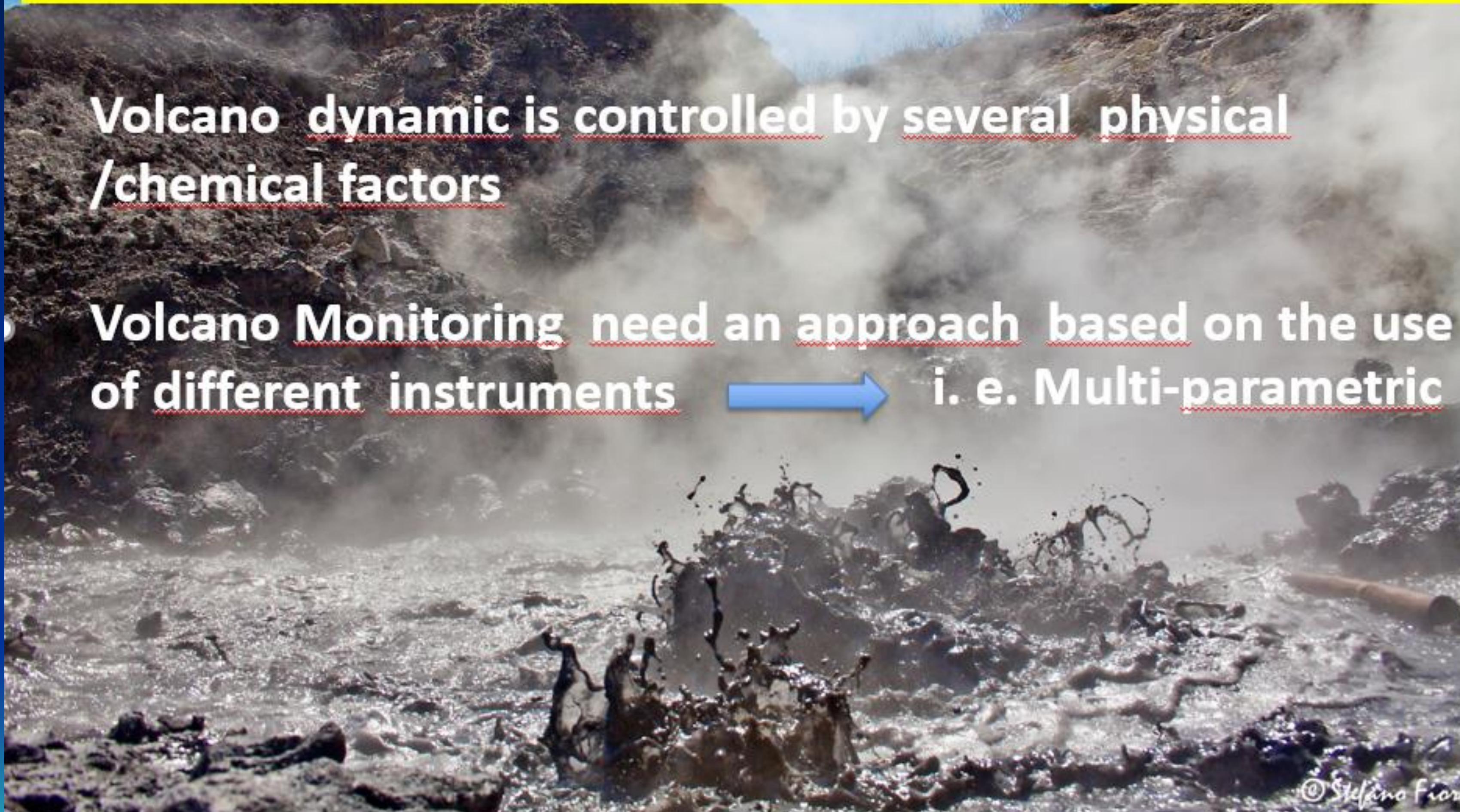
The earliest known eruptive products are dated 47,000 years before present (BP). The Campi Flegrei caldera formed following two large explosive eruptions, the massive Campanian ignimbrite about 36,000 years BP, and the >40 cubic km Neapolitan Yellow Tuff (NYT) about 15,000 years BP. Following eruption of the NYT a large number of eruptions have taken place from widely scattered subaerial and submarine vents. Most activity occurred during three intervals: 15,000-9500, 8600-8200, and 4800-3800 years BP. Two eruptions have occurred in historical time, one in 1158 at Solfatara and the other in 1538 that formed the Monte Nuovo cinder cone.

Country	Italy
Volcanic Region	Mediterranean and Western Asia
Primary Volcano Type	Caldera
Last Known Eruption	1538 CE
Latitude	40.827°N
Longitude	14.139°E
Summit Elevation	458 m 1502 ft
Volcano Number	211010

The philosophy of multi- parametric infrastructures for monitoring activities on active volcanoes

- Volcano dynamic is controlled by several physical /chemical factors

- Volcano Monitoring need an approach based on the use of different instruments → i. e. Multi-parametric



Curtesy of Francesca Bianco Director of INGV – Osservatorio Vesuviano

-Multi-parametric systems in the field (permanent)/4

The Infra Red-Thermal & Geochemical networks

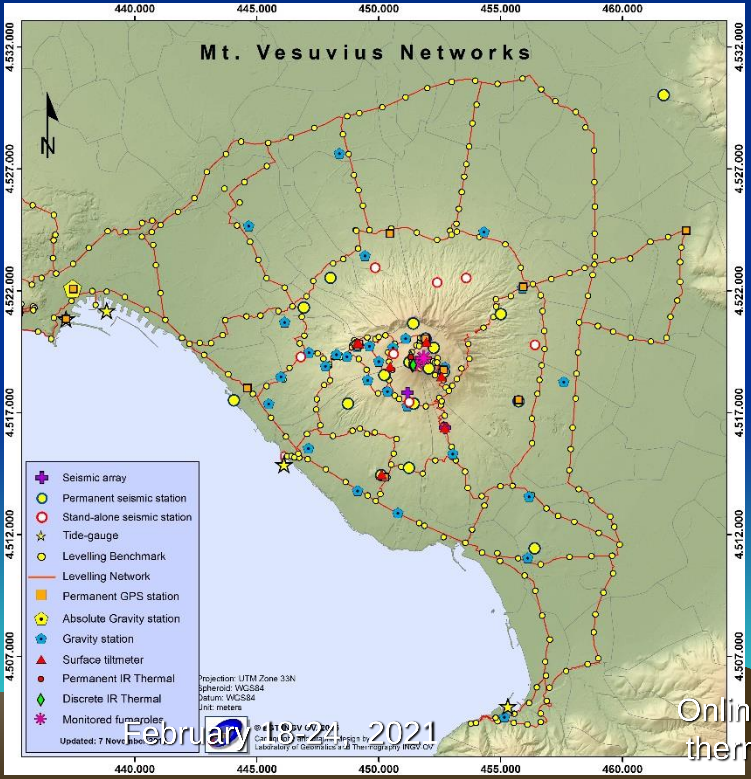
- 5 IR Thermal stations
- 2 CO_2 flux & soil T, Multigas stations

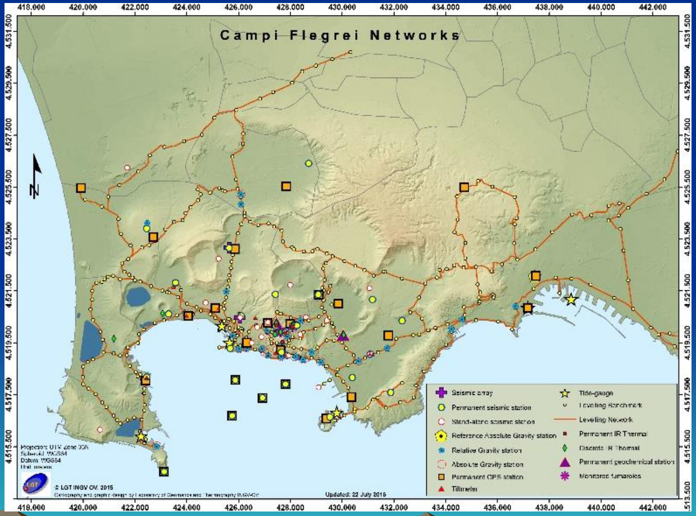
Francesca Bianco Director of INGV – Osservatorio

-Multi-parametric systems in the field /5

PERIODIC MEASUREMENTS

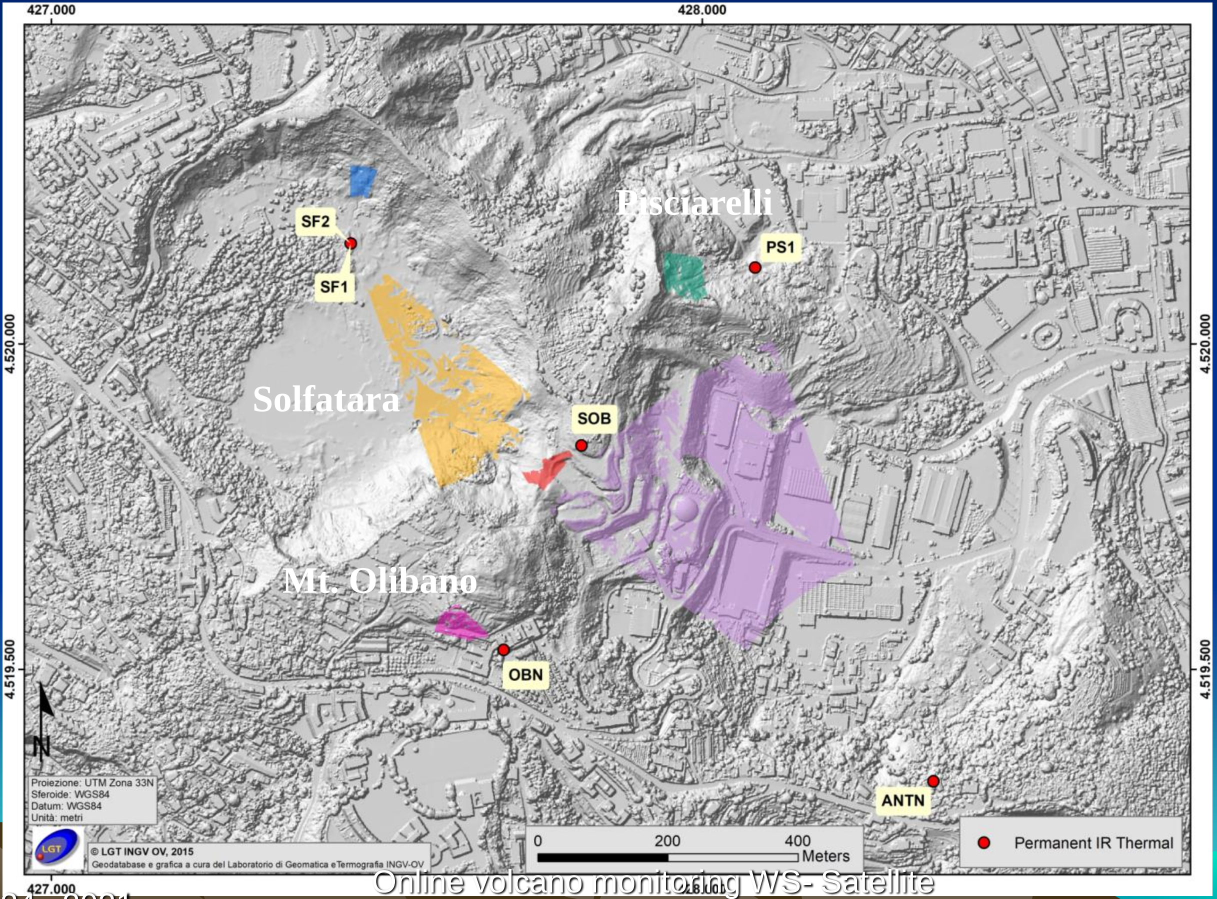
- Levelling network
- Gravity stations
- discrete IR thermal stations
- monitoring fumaroles systems

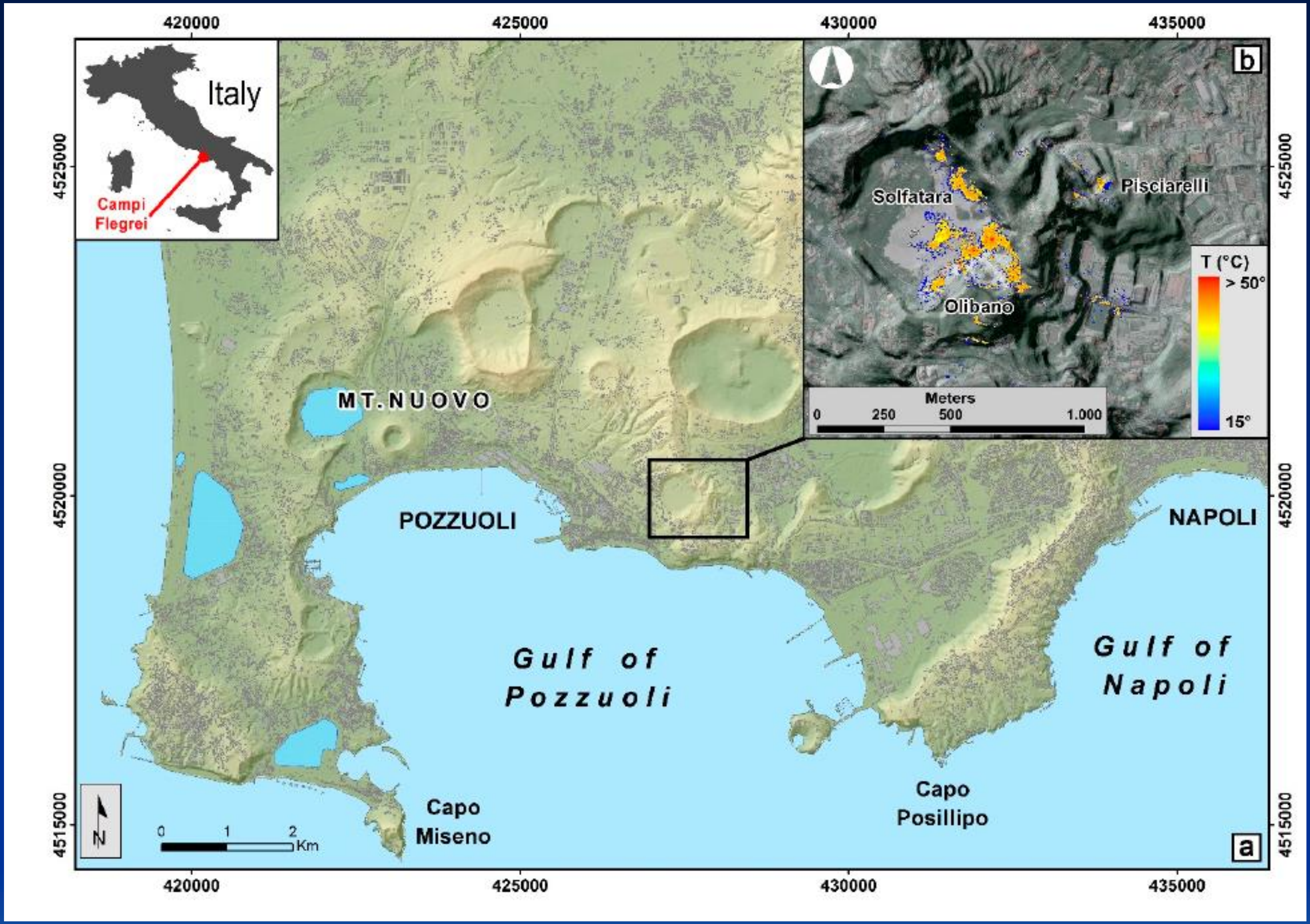




Permanent thermal cameras on Campi Flegrei

The Thermal Infrared Permanent Network (TIRNet) managed by INGV Osservatorio Vesuviano (INGV-OV) performs volcanic surveillance in the Campi Flegrei Caldera and consists of six stations which acquire thermal infrared frames of fumarole fields of the La Solfatara volcanic center (SF1, SF2, OBN, PS1, SOB and ANTN stations).



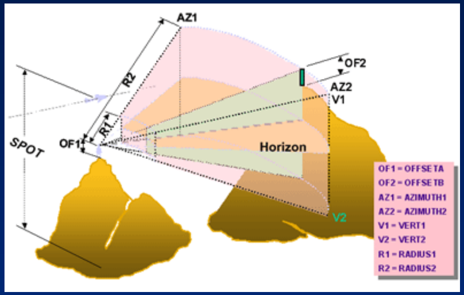


Caputo et al. :Surface Temperature Multiscale Monitoring by Thermal Infrared Satellite and Ground Images at Campi Flegrei Volcanic Area (Italy),Remote Sensing DOI: [10.3390/rs11091007](10.3390/rs11091007)

COMBINING GROUND THERMAL CAMERAS AND SATELLITE TIR DATA

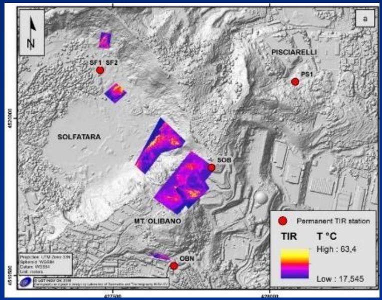
Visibility analysis

Using Field of View values of TIRNet station. This procedure was in support of the comparison analysis.



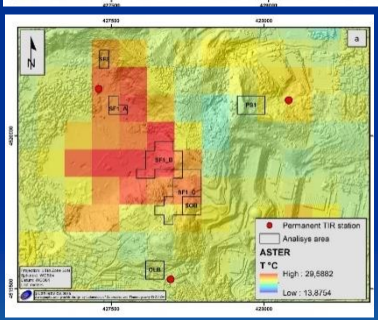
Georeferencing TIRNet images

Was been identify Ground Control Points (GCP) on TIR frames and high resolution DEM (1m) respectively. Than, was performed rectification and the geo-referencing of the TIR frames on DEM in the UTM WGS84 System.



Polygons around interest area

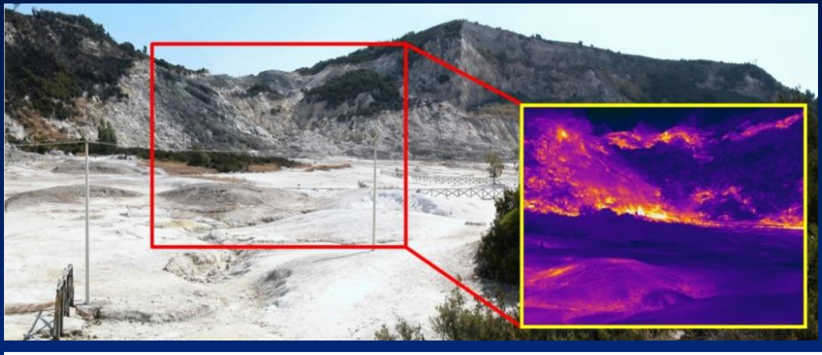
Satellite data was been resampled in a resolution of 30m. A regularly-spaced 30x30 m grid was created to compare data. By grouping 30x30m cells which contain data of TIRNet frames.



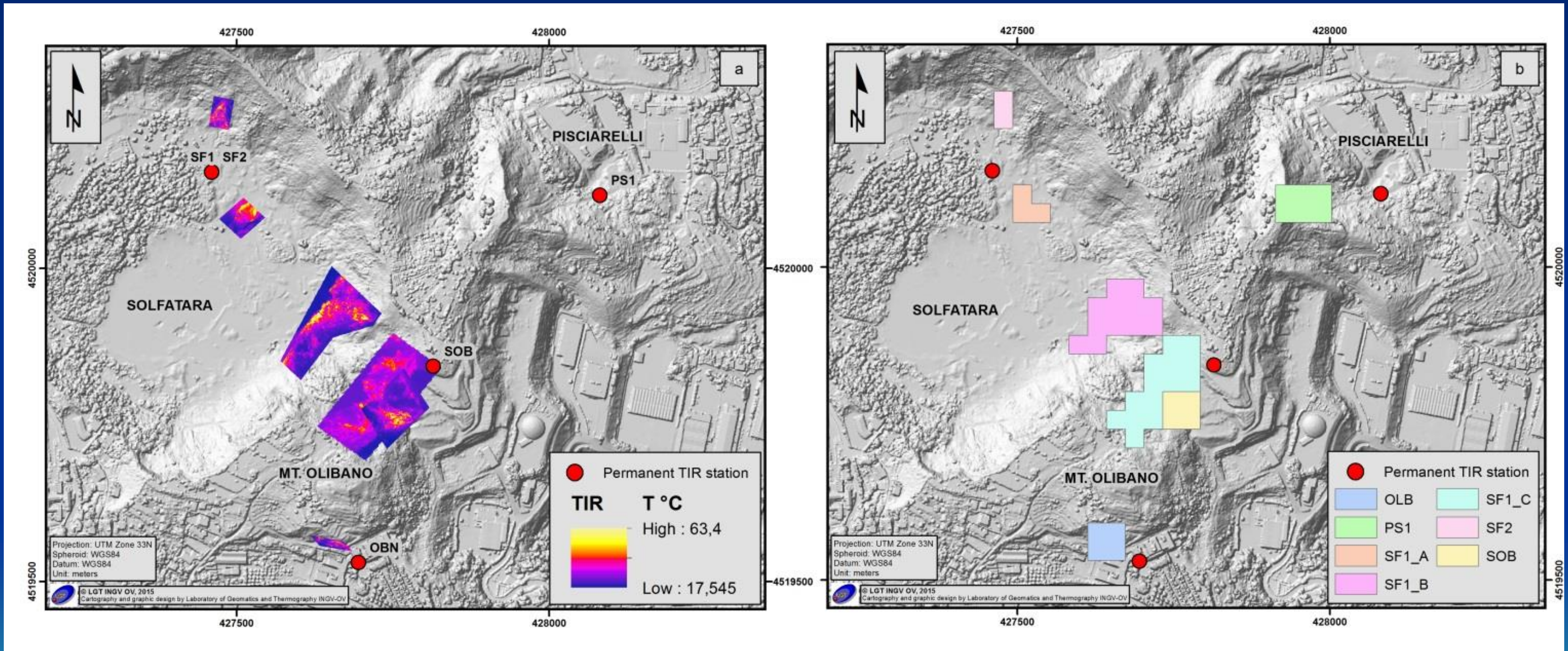
Statistic analysis TIRNet/Satellite

Statistic analysis between Satellites and TIRNet temperature data inside the selected polygons was been performed. The comparison of observed values T °C Max, T °C Mean are reported in Table.

Permanent thermal camera



The monitored areas generally correspond to areas characterized by significant thermal anomalies at diffused and high fumarolic degassing areas



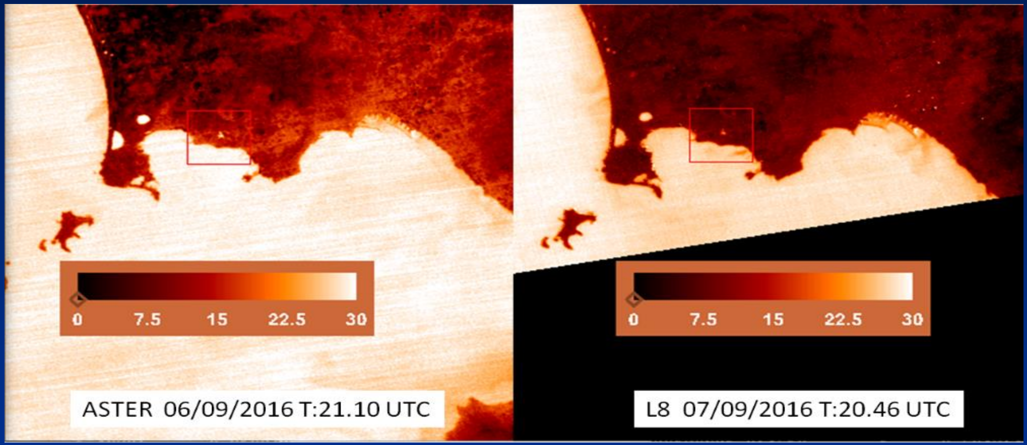
a) **Draped and georeferenced TIR images of SF1, SF2, OBN and SOB stations. The image of SF1 Station is split into three coherent parts with different focal geometry (SF1_A/B/C);**

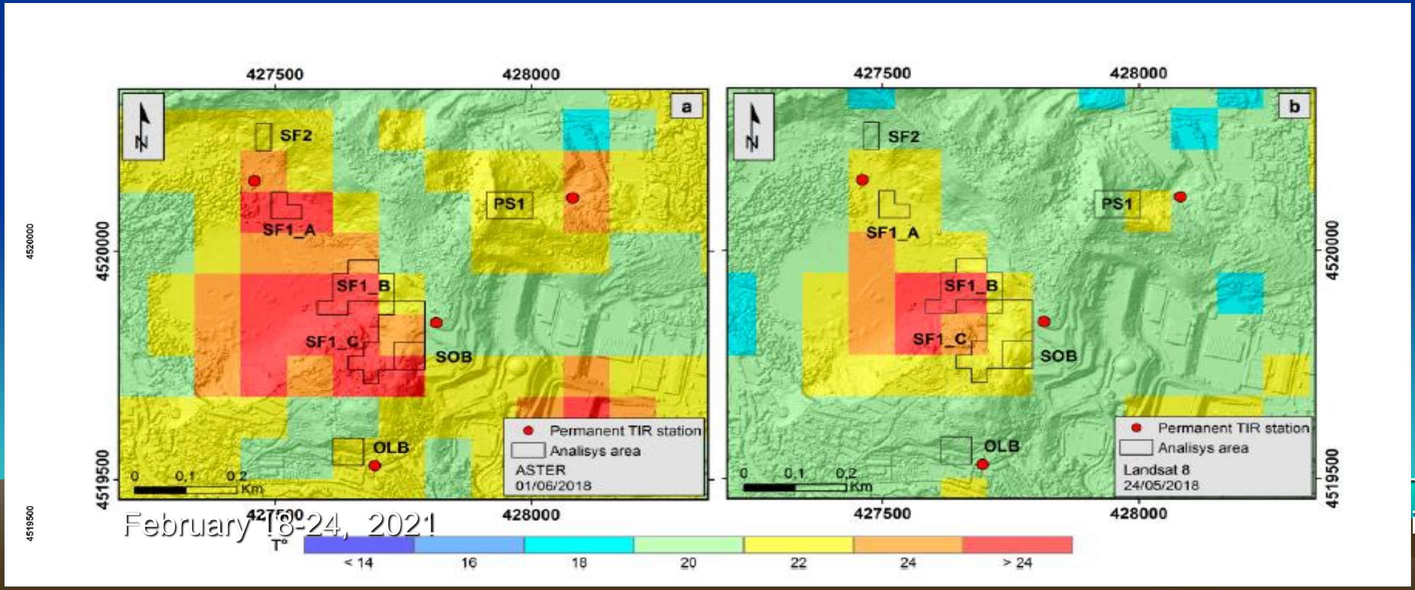
b) **Polygons obtained by grouping cells containing data from TIRNet stations**

Comparison of Satellite data with ground data

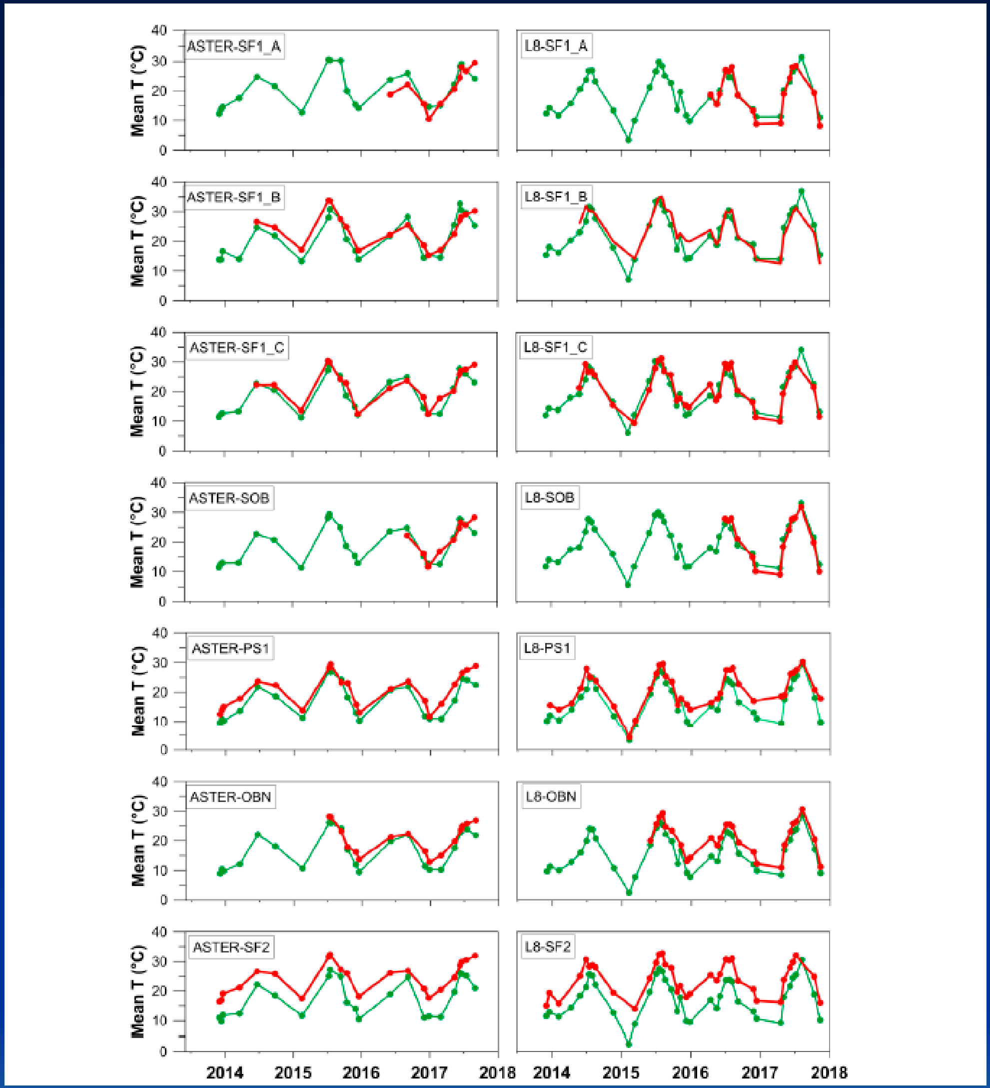
To compare the TIRNet ground data to the **Landsat-8** and **ASTER** satellite images, extra-acquisitions of the **TIRNet** have been programmed to coincide with the time of the satellite passages over the Campi Flegrei area.

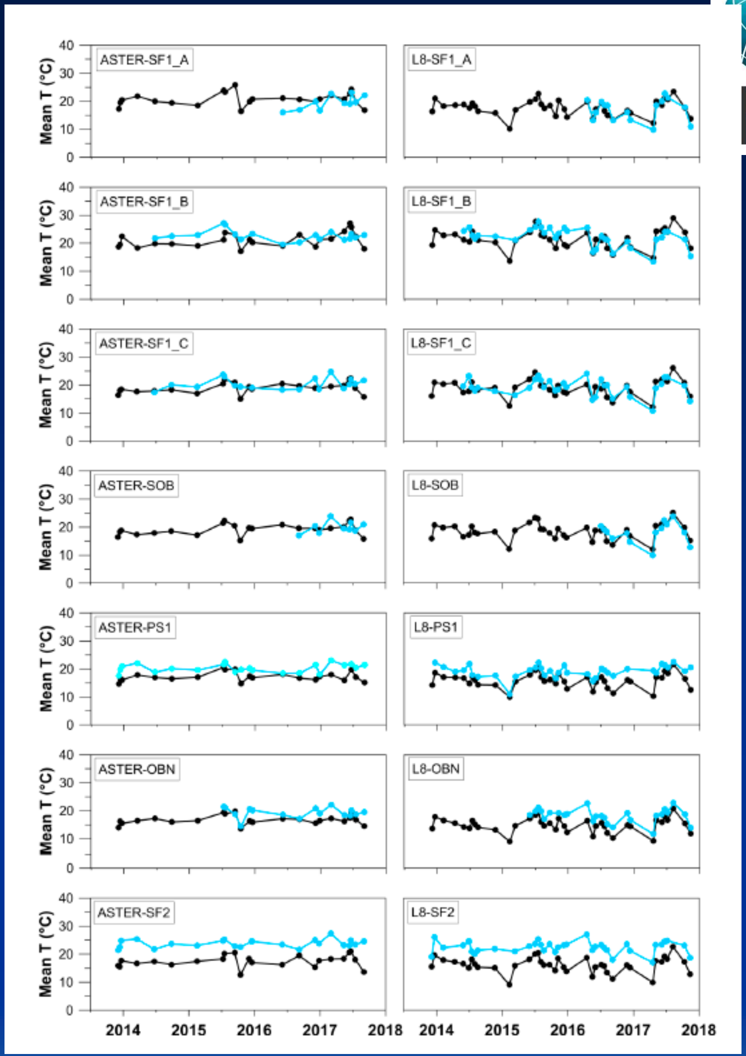
The comparison between satellite and ground images was possible only after a geometric correction of TIRNet frames which permitted the draping of these frames over a DSM (Digital Surface Model).





The involved TIRNet stations are SF1 (split in to SF1A, SF1B and SF1C), SF2, OBN and SOB.





Comparison among temperature satellite data and TIRNEt
Left: including seasonal effects
Right: seasonal effects remuved

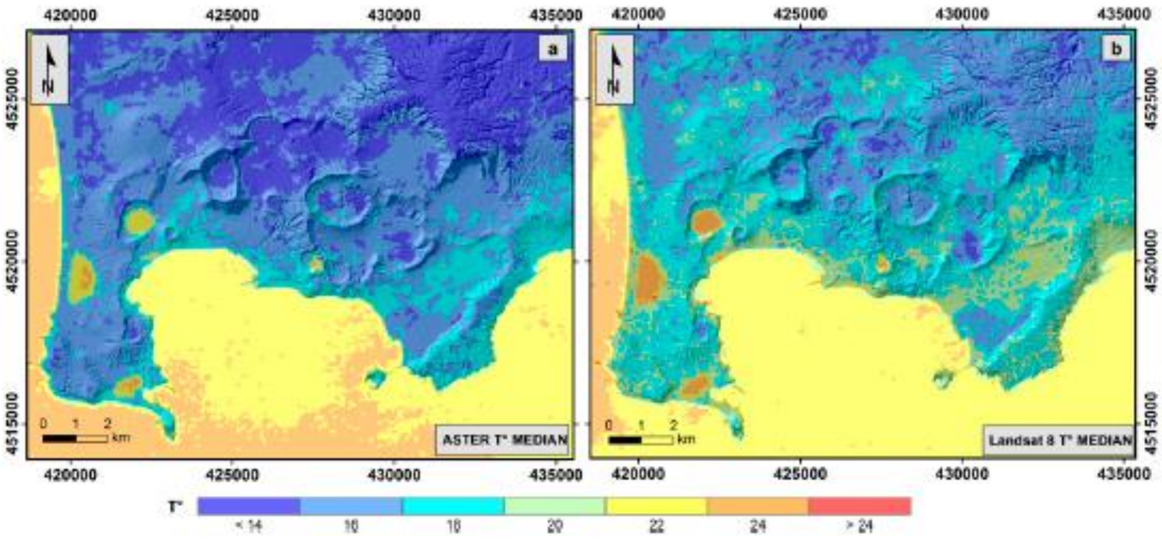
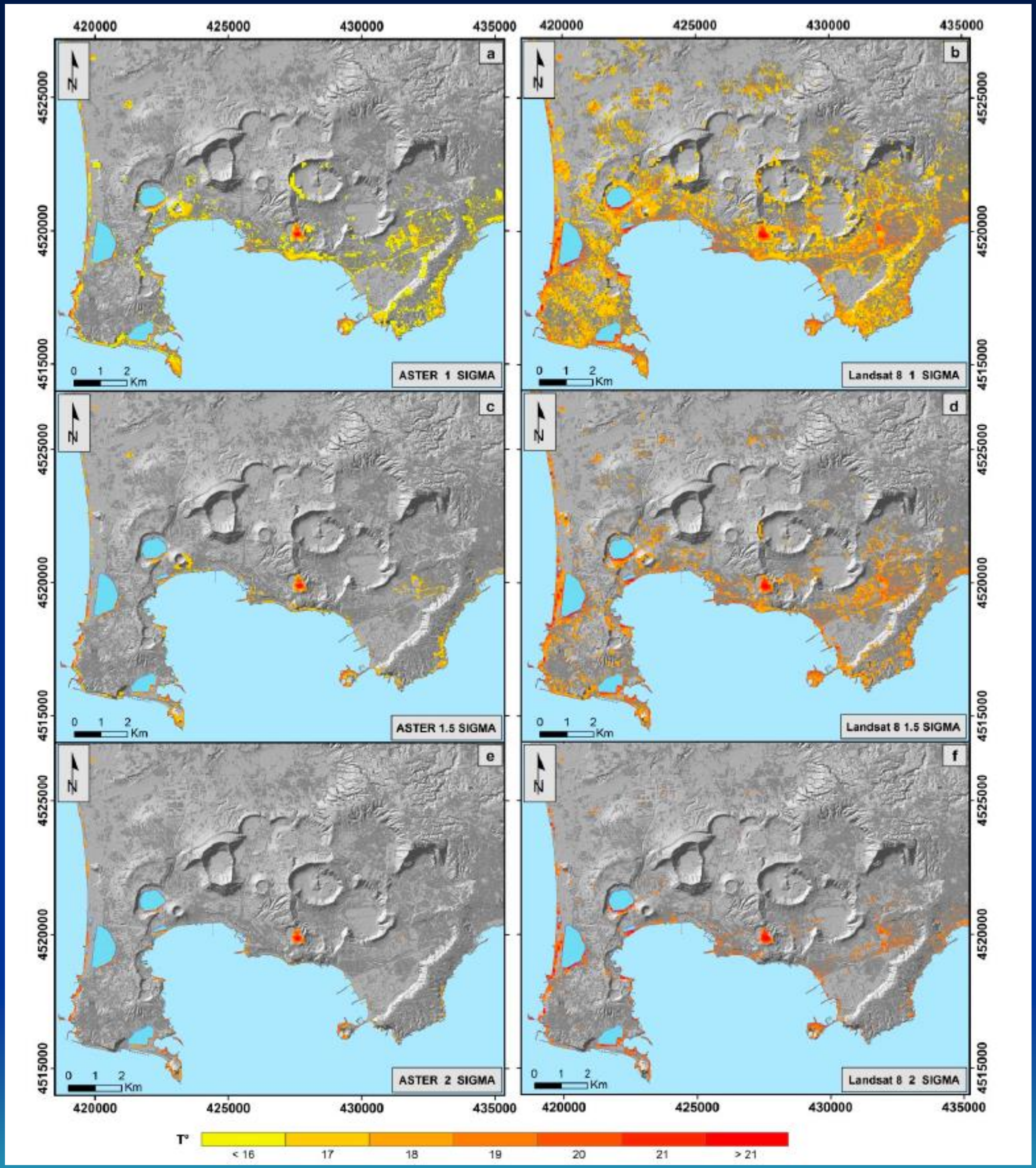


Figure 9. Maps of land surface median temperature values of ASTER (**a**) and L8 (**b**) de-seasoned time-series.

Maps of land surface median temperature values of ASTER (**a**) and L8 (**b**) de-seasoned time-series.

For further info please contact by e-mail
Teresa.caputo@ingv.it, Giuseppe.vilardo@ingv.it



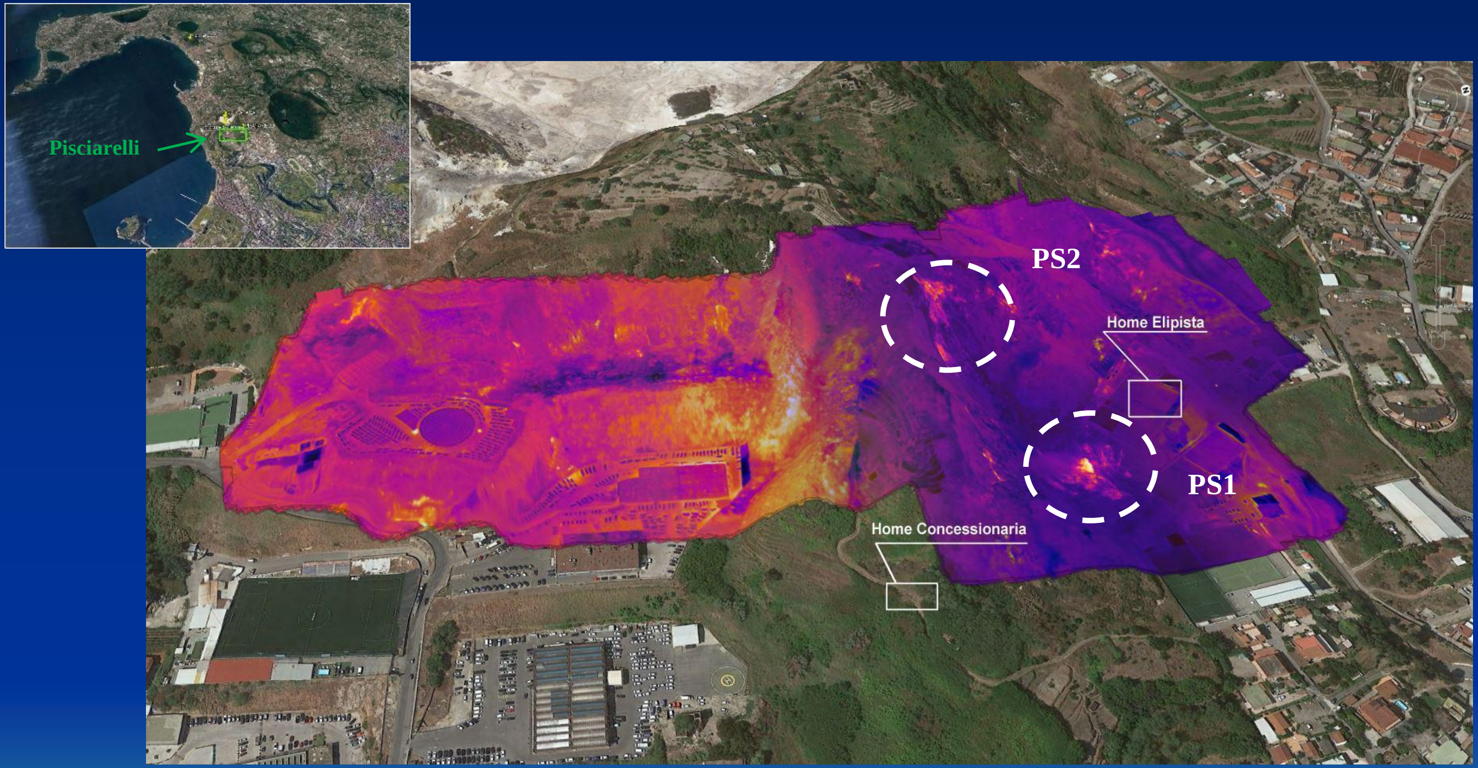
Maps of Median Temperature values greater than a Threshold Value (MTTV) of TSF with temperature thresholds of: +1 (**a**,**b**); +1.5 (**c**,**d**); 2 (**e**,**f**).

DETERMINATION OF THE HEAT FLOW BY MEANS OF GROUND THERMAL CAMERAS, DRONE AND SATELLITE ON CAMPI FLEGREI

The Study of four different areas of the Phlegraean Fields

1. Monte Olibano
2. Pisciarelli
3. Monte Nuovo

THERMAL MAPPING FROM DRONE: PISCIARELLI AREA



The thermal image composition to highlights the two main areas showing high thermal anomaly,

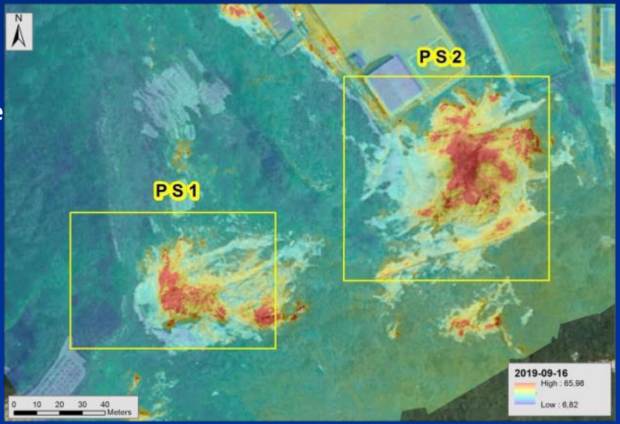
The thermal anomalies are also monitored by using satellite thermal data

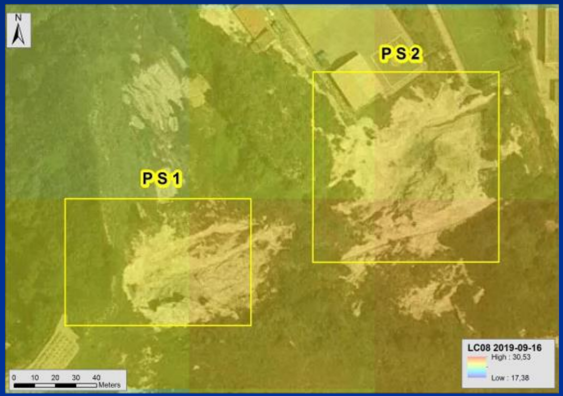
SATELLITE TIR IMAGE INTEGRATION

thermal images from satellite (ASTER and LANDSAT 8) were acquired at the same time of the drone acquisitions, the satellite images were analyzed and compared with ground data

Landsat 8 launched on 2013

Thermal image mosaic from drone acquisition on September 16 2019 PS1-PS2 are two main areas of analysis.





the Landsat8 acquired on 16 September 2019 and the two areas of analysis.

The images acquired by satellite were processed [to derive the ground temperature, with a spatial resolution of 30 m for LANDSAT 8 and 90 m for ASTER. [Caputo et al., 2019]

THERMAL COMPARISON OF SATELLITE AND DRONE

NOME AREA	TIPO ACQUISIZIONE	N. PIXEL	AREA	T_MIN	T_MAX	RANGE	T_MEAN	DATA
PS2	DRONE	303050	8106,16	1,79	73,89	72,09	10,82	07/02/2020
PS1	DRONE	194714	5208,33	2,50	47,00	44,50	10,94	07/02/2020
PS2	L8	9	8100,00	7,00	8,35	1,34	7,58	07/02/2020
PS1	L8	6	5400,00	8,81	9,00	0,19	8,90	07/02/2020
PS2	DRONE	349281	8101,67	18,25	84,70	66,45	36,62	29/05/2020
PS1	DRONE	232854	5401,12	12,05	75,53	63,48	34,96	29/05/2020
PS2	L8	9	8100,00	37,71	40,32	2,61	38,81	29/05/2020
PS1	L8	6	5400,00	35,39	36,83	1,44	36,15	29/05/2020
PS2	DRONE	342815	8099,61	21,60	69,30	47,70	28,22	17/07/2020
PS1	DRONE	115231	2722,54	24,37	76,63	52,25	32,26	17/07/2020
PS2	L8	9	8100,00	26,16	26,76	0,61	26,45	16/07/2020
PS1	L8	6	5400,00	25,22	25,88	0,66	25,57	16/07/2020
PS2	DRONE	375769	8102,33	4,85	58,56	53,71	14,80	20/10/2020
PS1	DRONE	241253	5201,89	8,63	61,70	53,07	18,71	20/10/2020
PS2	L8	9	8100,00	14,87	15,84	0,97	15,30	20/10/2020
PS1	L8	6	5400,00	15,66	15,92	0,27	15,78	20/10/2020

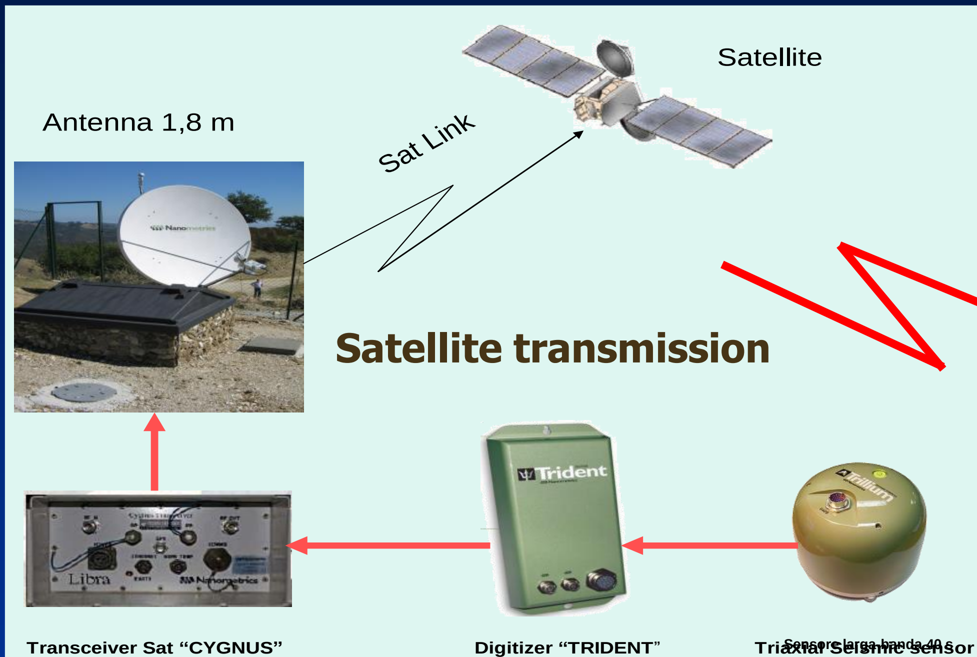
Test Sites: Mt Etna, Sicily (Italy)

Mt Etna is the largest active volcano in Europe with a diameter of 40x40 kmq and elevation of abot 3350 m a.s.l. Towering above the city of Catania on the island of Sicily, it has been growing for about 500,000 years.

Mt Etna has the longest period of documented eruptions in the world. Etna is noted for the wide variety of eruption styles.

Country	Italy
Volcanic Region	Mediterranean and Western Asia
Primary Volcano Type	Stratovolcano(es)
Last Known Eruption	2016 CE
Latitude	37.734°N
Longitude	15.004°E
Summit Elevation	3330 m 10922 ft
Volcano Number	211060

Control room – Osservatorio Etneo INGV



Operations room INGV-CT

WI-FI transmission

UHF transmission

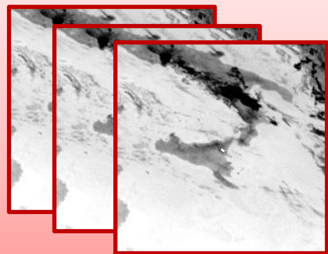
Control room - INGV-CT

All real time sygnals are acquired in Catania.

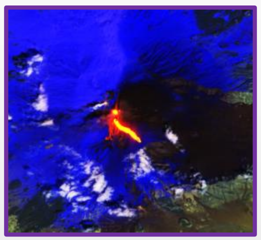
For the 24/7 suveillance of Sicilian active volcanoes, data from seismic, GPS video camera and Radar stations are used.

HOTSAT- Satellite Volcano Monitoring System

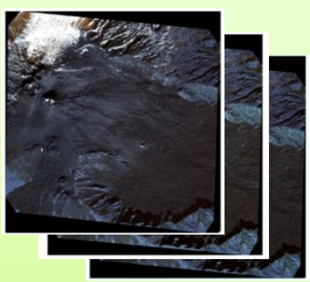
Low Spatial High Temporal Resolution Multispectral Images



Low Temporal High Spatial Resolution Multispectral Images

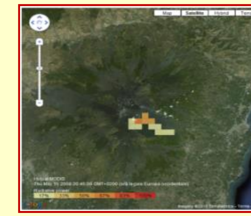


High Spatial Resolution Optical Images in Stereo-Tristereo

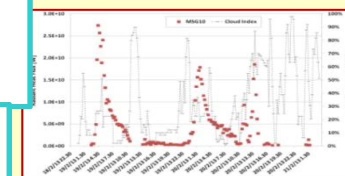


HOTSAT

1. Hotspot Detection

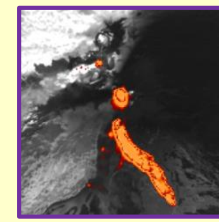


2. Radiant Heat Flux

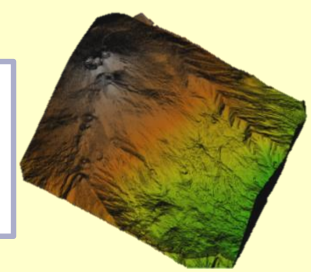


3. Effusion Rate & Volumes

4. Active Lava Flow Area

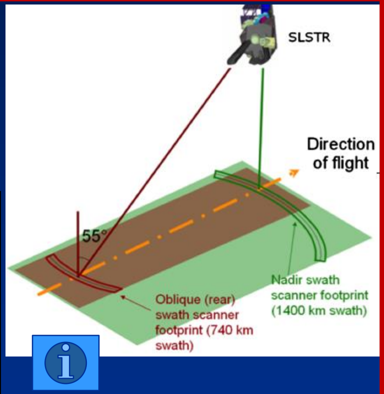


5. Digital Elevation Model



INGV-ETNEO OBSERVATORY

HOTSAT : Sentinel-3 SLSTR



$$Ts = Tn + \left(\frac{a0}{a2}\right)(Tn - To) - \left(1 + \frac{a0 - a1}{a2}\right)L - \left(\frac{a0a1}{a2}\right)(Tan - Tao)$$

Tn and To nadir and oblique temperature, Tan and Tao atmospheric temperature at nadir and oblique directions, a0,a1,a2 dependent on atmospheric parameters.

J.A. Sobrino et all.(1996)

Oblique View MIR

Nadir View MIR

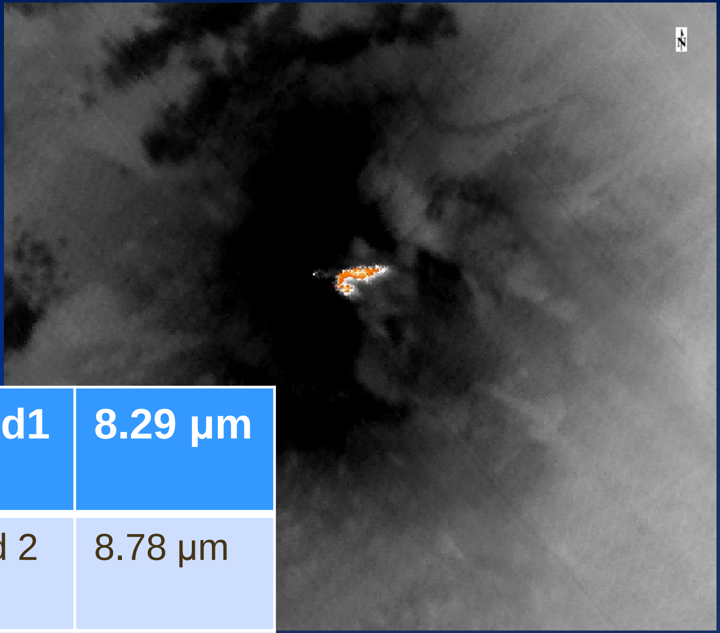
Radiometric Calibration → **Atmospheric Correction** → **Dual-Angle Algorithm**

Thermal Anomalies detection → **Three components analysis**

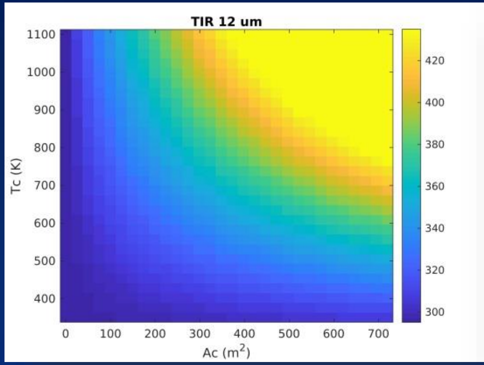
INGV-ETNEO OBSERVATORY

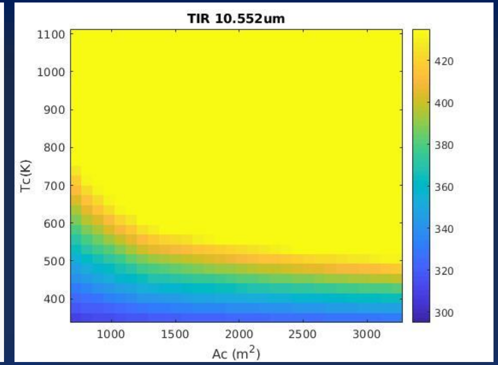
HOTSAT : Ecostress

Etna: Ecostress image of 27 August 2018 at 04:58



Band1	8.29 µm
Band 2	8.78 µm
Band 3	9.20 µm
Band 4	10.49 µm
Band 5	12.09 µm





$$L_{pixel}(\lambda, T_{int}) = p_h L(\lambda, T_h) + p_c L(\lambda, T_c) + p_b L(\lambda, T_b)$$

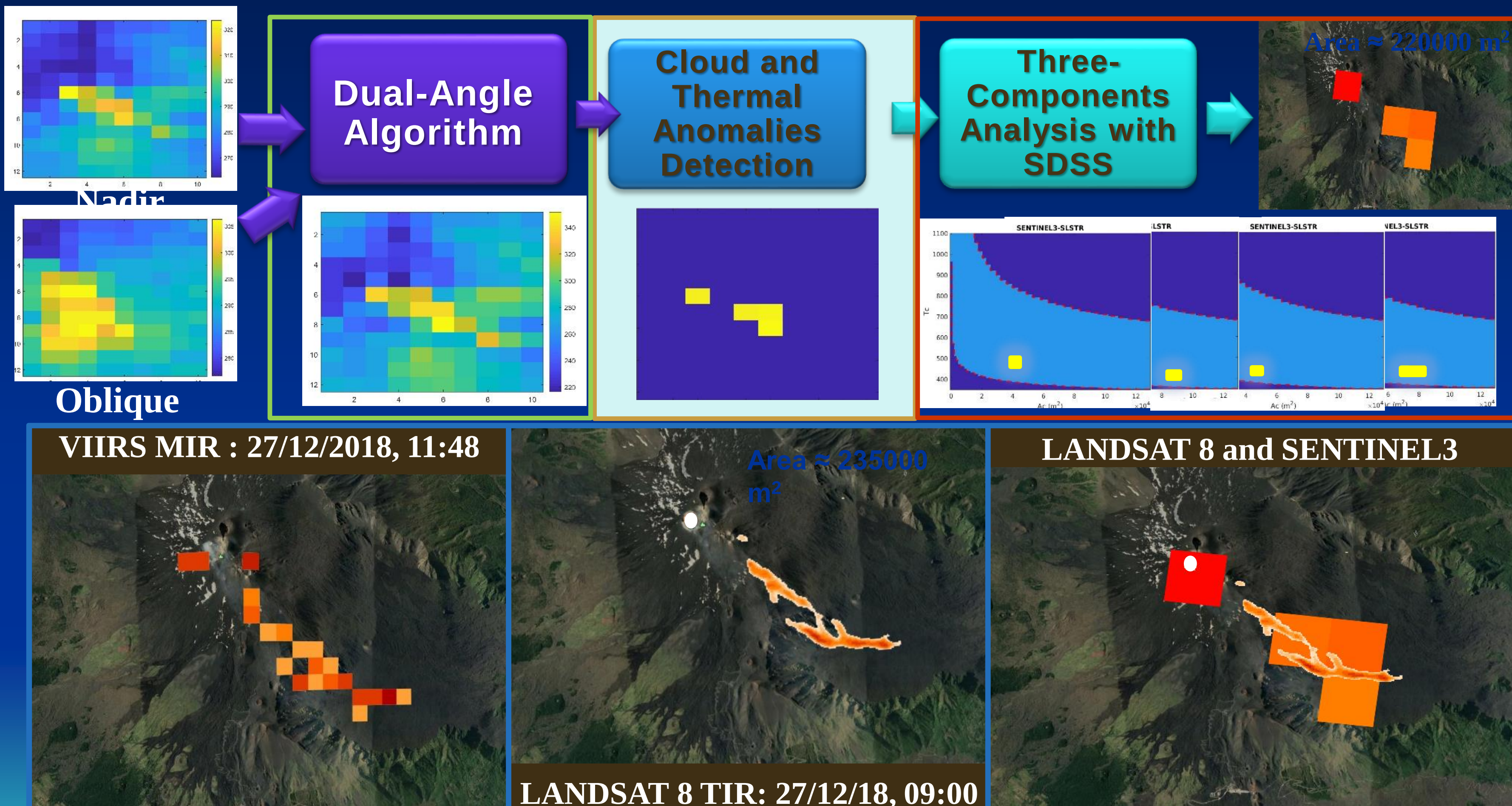
Area≈2.5e5± 1.3e5 m^2

Radiant Heat Flux: 5.5e8 ±2.1e8 W

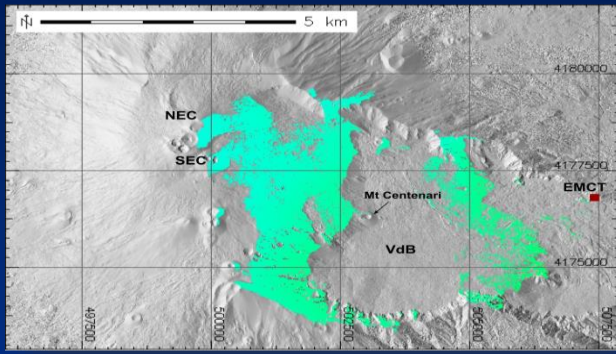
INGV-ETNEO OBSERVATORY

HOTSAT : Case of Study 2018: Etna eruption 27/12/2018

Sentinel 3-SLSTR MIR Band 27/12/2018 9.35



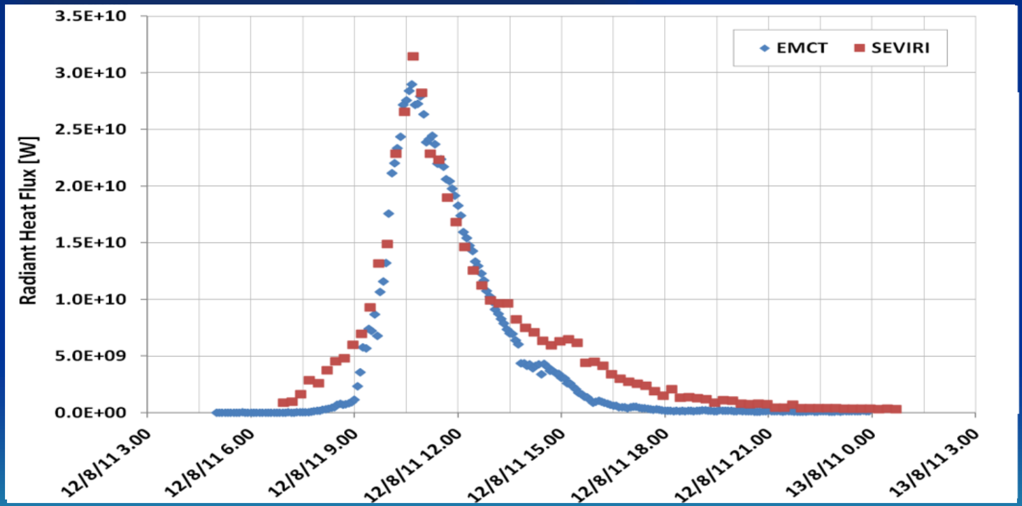
SEVIRI vs Thermal Camera data



FLIR A 320

Detector type: Focal plane array (FPA), uncooled microbolometer 320 x 240 pixels

Installed on 11/08/11
at Mt Cagliato (EMCT)



Ganci et al., 2013 GRL doi:10.1002/grl.50983

INGV-ETNEO OBSERVATORY

Mapping cooled new lava flow field using BNN (1/2)

Non-Supervised Classifier

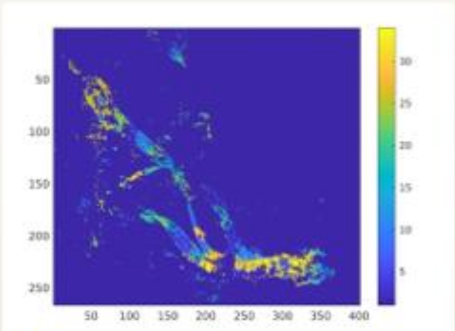
34 classes identified for the cool lava field

TRAINING INPUT:

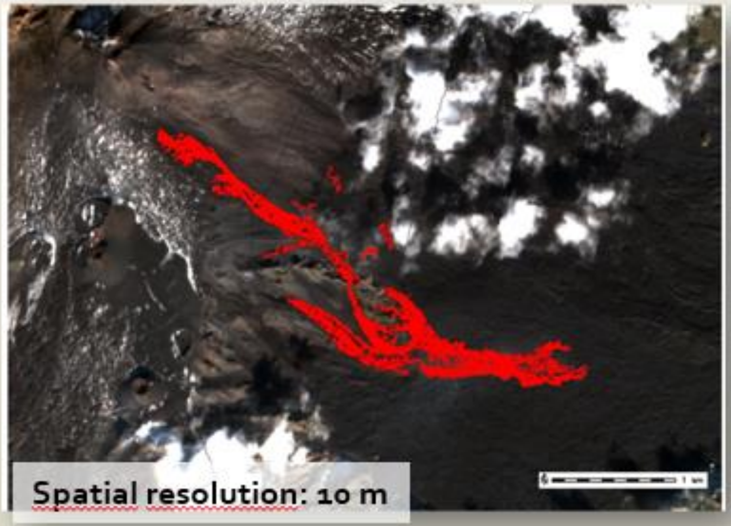
34 training pixels each one belonging to one of the 34 classes

Bayesian Neural Network (BNN)

Corradino et al., 2019 Rem. Sens. doi:10.3390/rs11161916

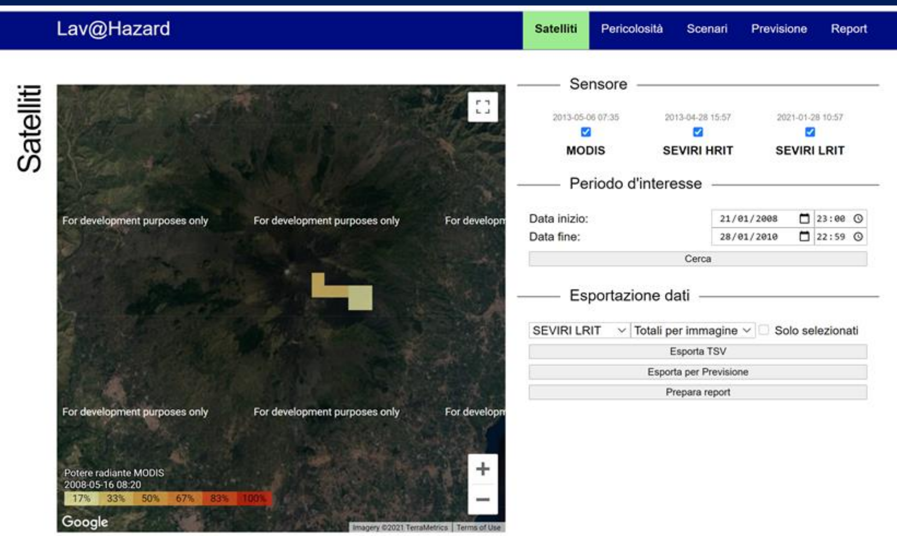


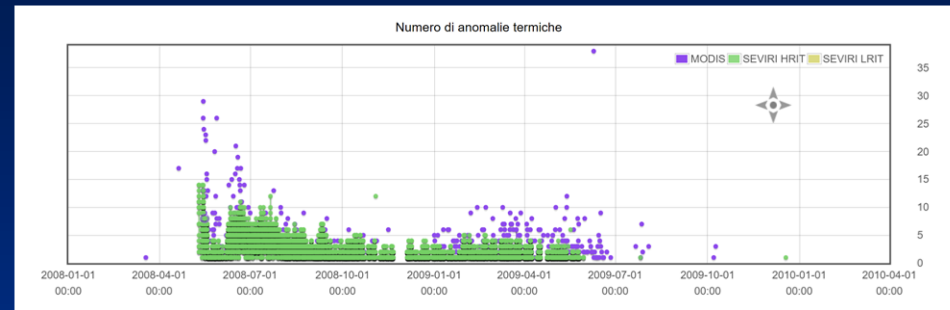
For each MSI image, Band 2 (492.4 nm), Band 3 (559.8 nm), Band 4 (664.6 nm), and Band 8 (832.8 nm) were considered.

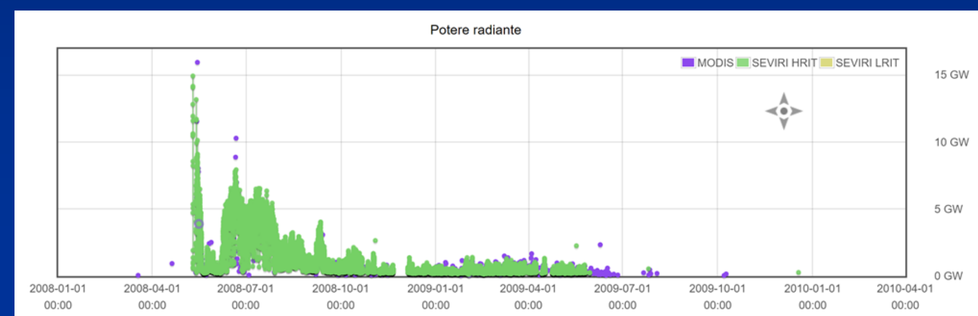


INGV-ETNEO OBSERVATORY

HOTSAT: Web-GIS Interface

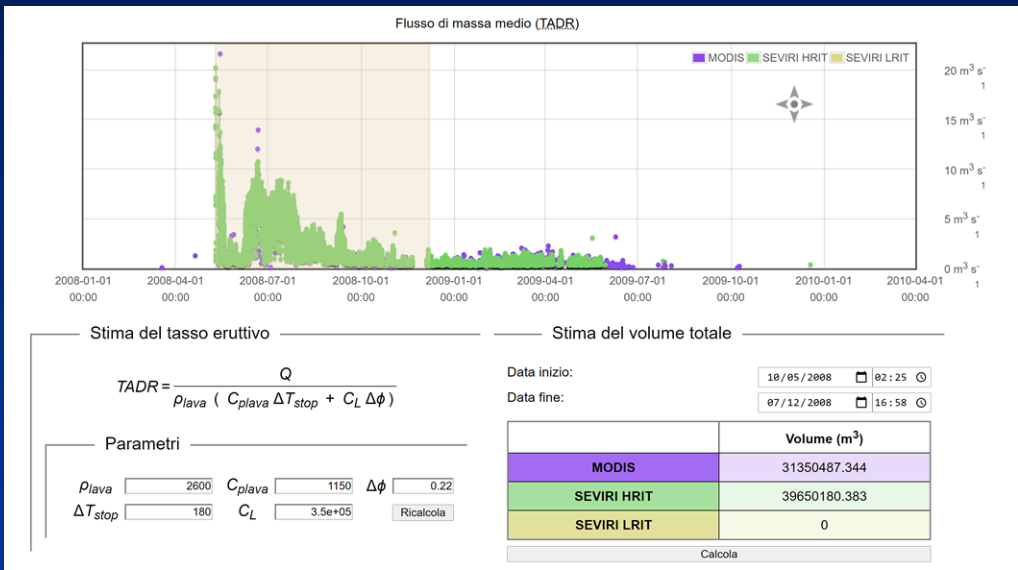




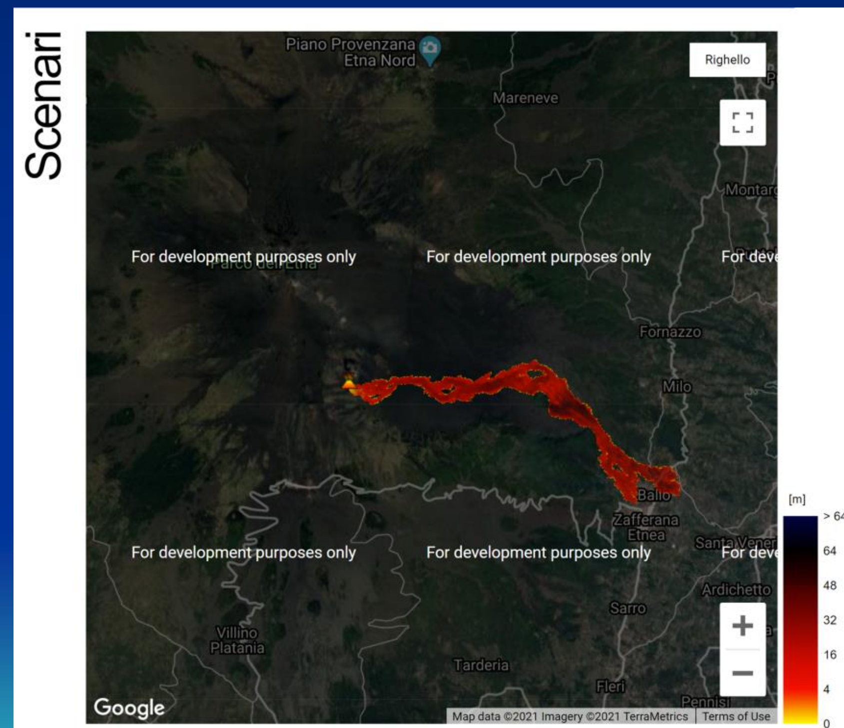


The HOTSAT system is accessible at: www.ctmgweb.ct.ingv.it (password protected)
Via the Lav@Hazard web-GIS for Civil Protection purposes

HOTSAT: Web-Gis Interface



In case of eruption, the radiant heat flux is converted to TADR, i.e. an estimation of the effusion rate.



This parameter is given as input to the MAGFLOW lava flow model in order to produce near real time lava flow forecasting scenarios.

Trans-national Access (TNA) activities in the European Volcanological Community

Overview

EU fosters and supports TNA activities in the frame of the implementation of the European Research Infrastructures (ESFRI roadmap)

TNA may be either Physical or Remote:

- **Physical access type is access involving hands-on access of any user, i.e., the users physically visit the RI installation**
- **Remote access type is the non-physical and limited access of a user at the installation. This is remote access to sensors, remote access to calibration facilities for instrument calibration, access to machine time, distribution of reference samples etc.**

Past and ongoing volcanological TNA activities

- ENVRIPlus Project (2015-2018): Mt. Etna (Italy)
- EUROVOLC Project (2018-2020): Italy, Iceland, France, Spain, Portugal

Future European Earth Science TNA activities

- **EPOS ERIC (under implementation): Italy, Iceland, France, Spain, Portugal, …..**

ENVRIPlus – Physical Access to RIs

ENVRIplus mult-disciplinary test platforms

ETNA-INGV (EPOS)

Geographical localisation - RI associated

Facilities

Pizzi Deneri Observatory

INGV Main building

For further info please contact me by e-mail: Giuseppe.Puglisi@ingv.it

ENVRIPlus – Physical Access to RIs

ENVRIplus mult-disciplinary test platforms

Pictures from one of the TNA Projects

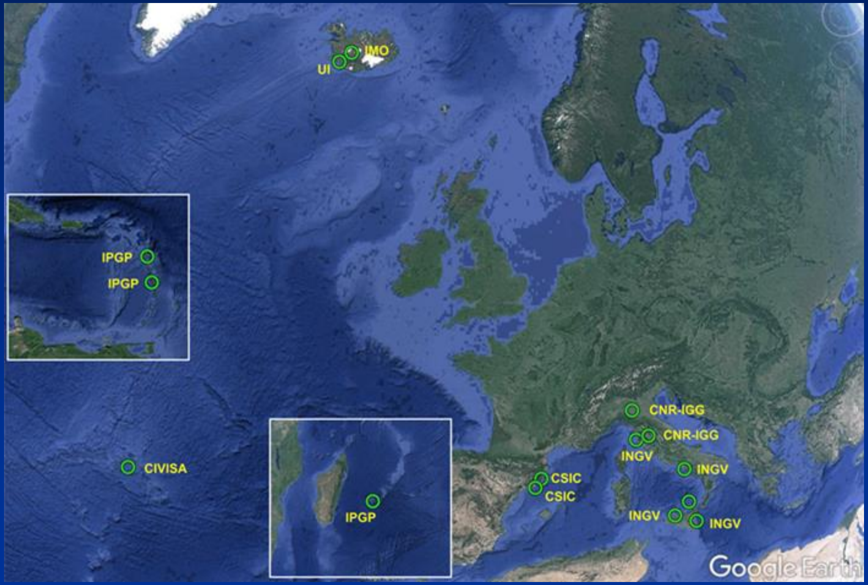
Volcanic Airborne Gas Monitoring using the miniGAS and miniature Mass Spectrometer UAV based Systems (VAMOS-UAV)

PI: Jorge Andres Diaz (UCR, Costa Rica)

EUROVOLC

INGV

TransNational Access activities in EUROVOLC Project



13 Research Infrastructures
28 Installations
63 Facilities

Portfolio of the EUROVOLC TA offer

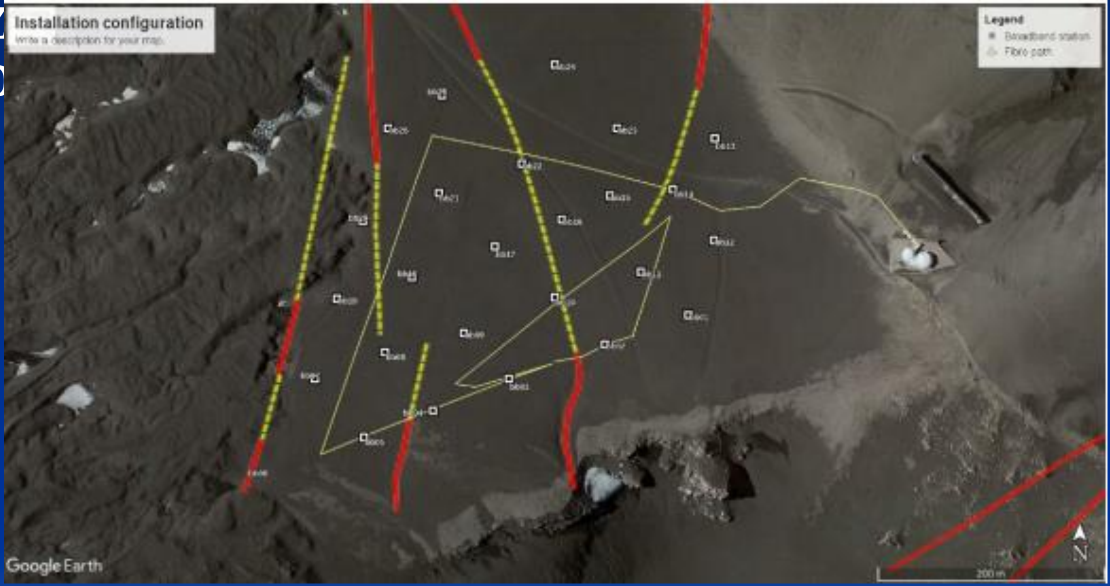
Access provider	Infra-structure	Installation Nr	Installation Short name	Country
IMO	IVO -	1	Office Facilities	IS
	IVO	2	Field work type1	IS
	IVO	3	Field work type 2	IS
UI	UI	1	Facility Access	IS
	UI	2	Fieldwork in Summer	IS
	UI	3	Fieldwork in Winter	IS
INGV	OE – Catania	1	Lab. of sedimentology	IT
	OE – Catania	2	Pool of mobile instruments	IT
	OE – Catania	3	Lithotheque	IT
	OE – Catania	4	Rock sampling survey	IT
	OE - Catania	5	Pizzi Deneri Observatory	IT
	Palermo	1	Lab. of geochemistry	IT
	Palermo	2	Pool of mobile instruments	IT
	Palermo	3	“M. Carapezza” Volcanological centre	IT
	OV – Naples	1	Lithotheque	IT
	OV – Naples	2	Rock sampling survey	IT
	VDCC – Pisa	2	Fast Performing Model	IT
	VDCC - Pisa	2	Transient Multi-Dimens. Transport Model	IT
CNR	IGG – Pisa	1	Lithotheque	IT
	IGG – Pisa/Pavia	2	Lab. of geochemistry	IT
CSIC	ICTJA	2	On-site Hazard tools	ES
	ICTJA	1	On-site modelling	ES
CIVISA	AZVO	1	Azores Volc. Observatory Facilities	PT
	AZVO	2	Fieldwork	PT
IPGP	OVPF	1	Access to Observ. Volc. Piton de la Fournaise	FR
	OVSG	1	Access to Observ. Volc. Sism. Guadeloupe	FR
	OVSM	1	Access to Observ. Volc. Sism. Martinique	FR

EUROVOLC – Physical Access to Ris

Pictures from one of the TNA Projects

Fibre optical cable: an Alternative tool for Monitoring volcanic Events (FAME)

PI: Philippe Philippe Jousset (FFZ
TNA Facility: Osservatorio Pizzi D



Project FAME: Installation configuration: the thin yellow line is the fibre optic deployed array; it starts from the Observatory. The broad-band sensor locations are white squares; the faults (red and yellow lines).


Questions?


Thank YOU!

KNOWLEDGEMENTS

I

INGV SECTIONS

INGV-ONT Remote Sensing Unit , Cosenza Laboratory

INGV-OV Vesuvio Observatory, Naples

INGV-CT Etna Observatory, Catania