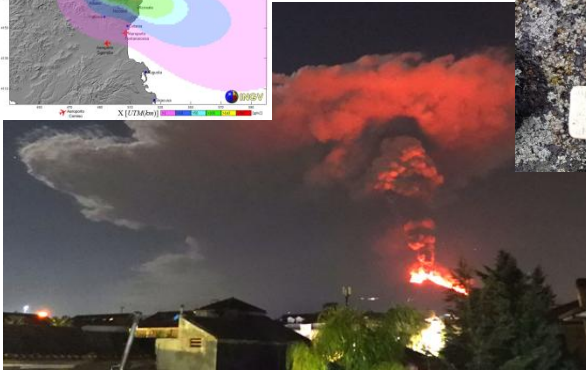
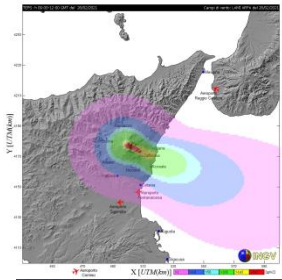
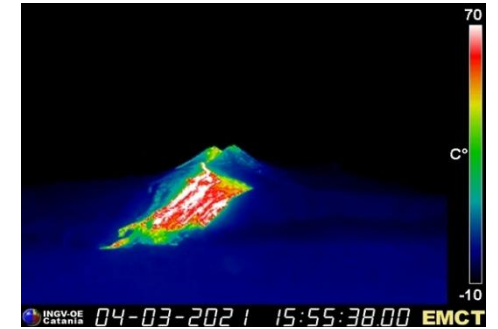
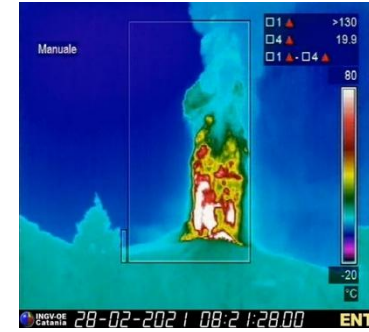


Monitoring the Etna 2021 eruption using EO optical data

Since 16 February, 2021 Etna experienced 11 paroxysmal episodes at the South East Crater (SEC) with lava fountains over 1000 m high, small pyroclastic flows, fast lava flows, sustained eruptive columns reaching more than 10 km elevation a.s.l.



Monitoring the Etna 2021 eruption using EO optical data



Contributors:

G. Ganci, E. De Beni, G. Bilotta, C. Proietti, A. Cappello – INGV Catania
S. Corradini, L. Merucci, D. Stelitano, L. Guerrieri – INGV Roma

Contact: gaetana.ganci@ingv.it



MAST (Multimission Acquisition System)

INGV – Rome [Stelitano et al., 2020]

D. Stelitano, L. Guerrieri, L. Merucci, S. Corradini

Near Real Time processing of **MSG-SEVIRI** data
with temporal resolution of 15 minutes (96 images per day)



Exploiting the TIR channels centered @
8.7, 11 and 12 μm



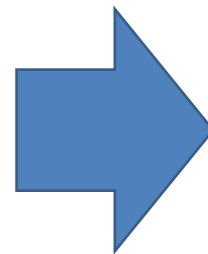
Monitoring during both
day and night

Volcanic Cloud Detection (SO_2 , Ash, Ice)

Volcanic Height Retrievals (Column and Cloud)

Volcanic SO_2 (Mass), Ash (Mass, AOD, Re),

Ice (Mass, AOD, Re) retrievals



Volcano Monitoring (DPC), Air flight Safety
(VAAC), Airport Security, Inputs for Volcanic Ash
Transport and Dispersal Models (VATDM),
Impact on environment and climate

All the 10 February-March Etna events have been detected and processed



RGB combination
(channels: 8.7, 11 e 12 μm)

Red Cloud: high Ash content

Green Cloud: high SO_2 content

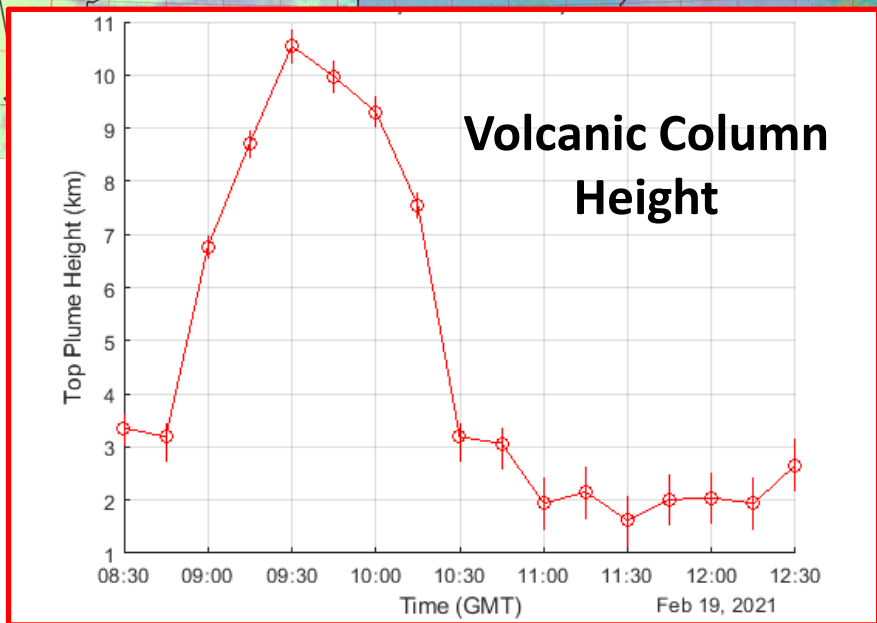
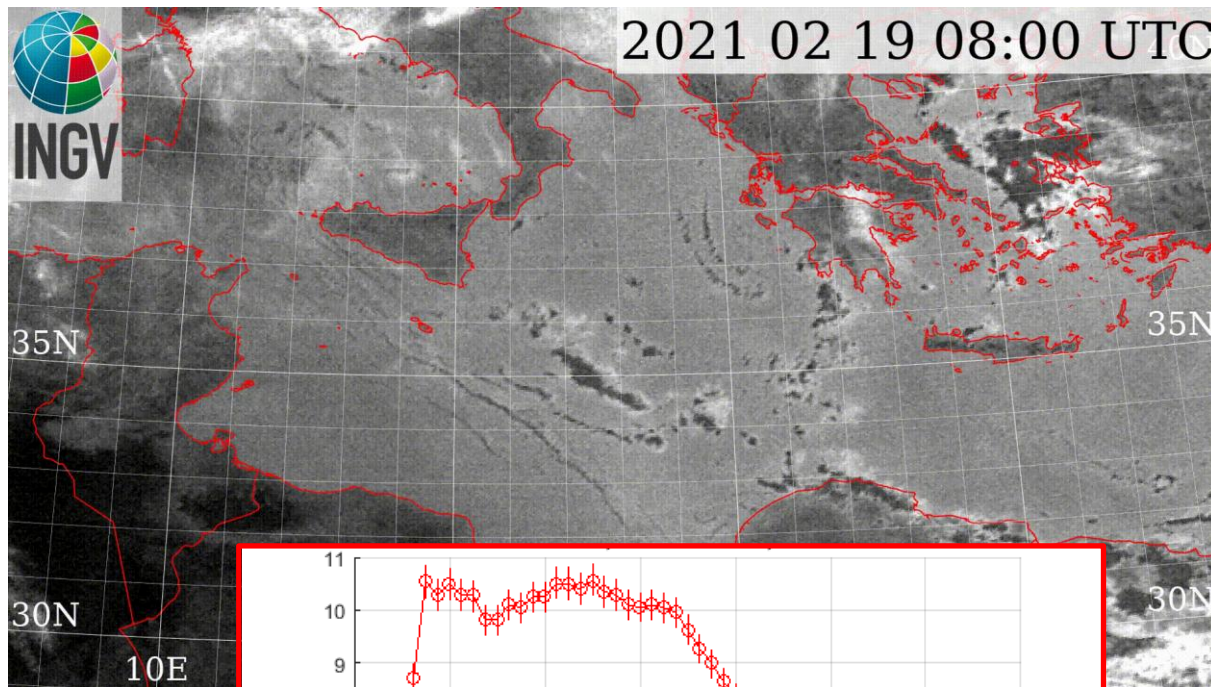
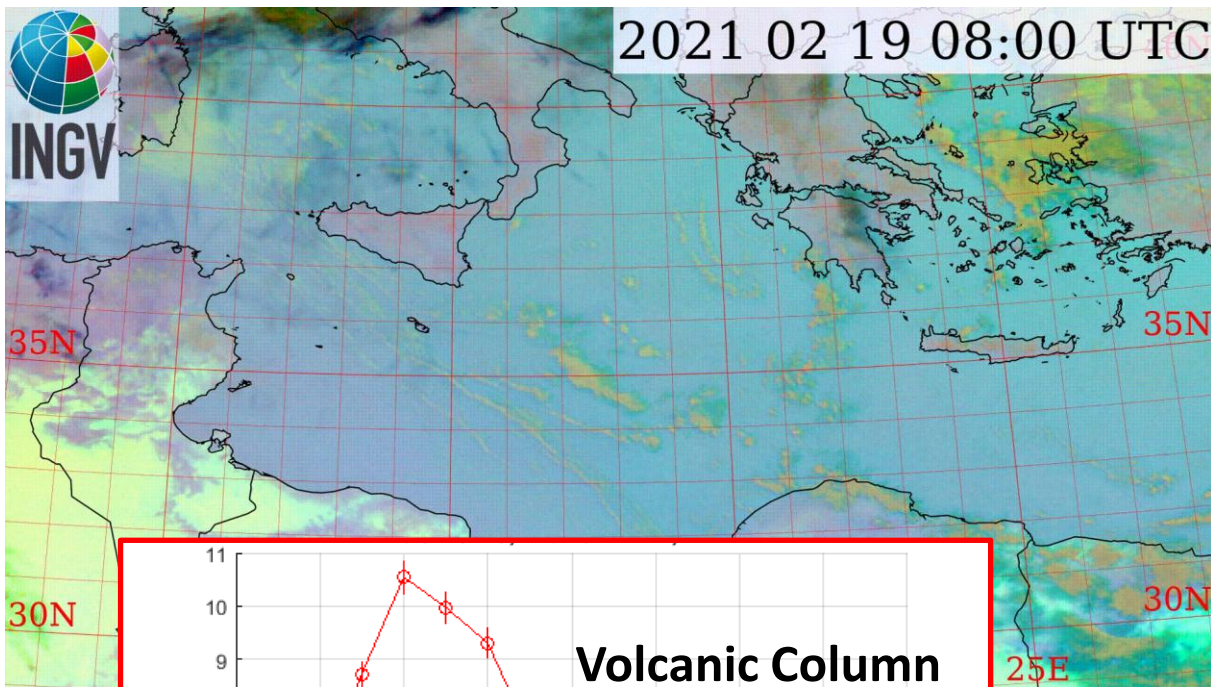
19 February 2021

Volcanic Cloud Detection

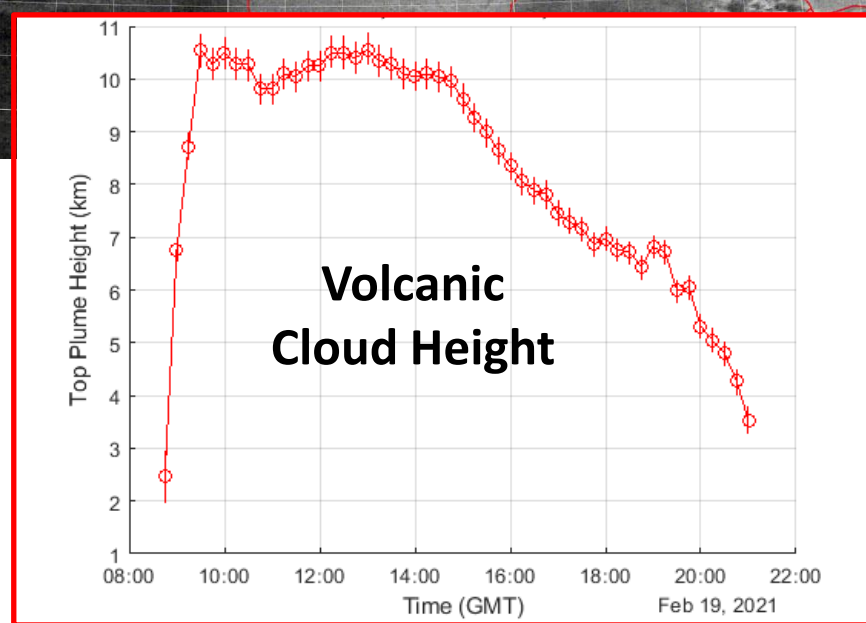
BTD ($T_b(11 \mu\text{m}) - T_b(12 \mu\text{m})$)

BTD < 0: Ash Cloud

BTD > 0: Ice cloud



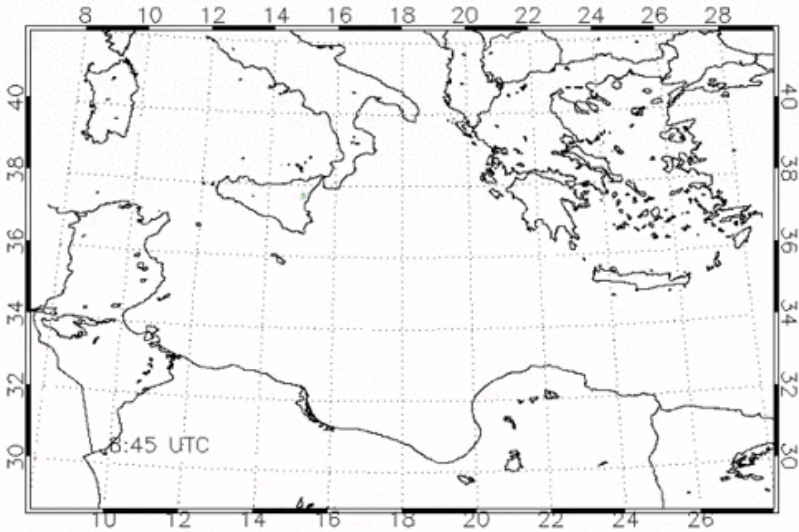
Volcanic Height Retrievals



Volcanic Cloud Retrievals

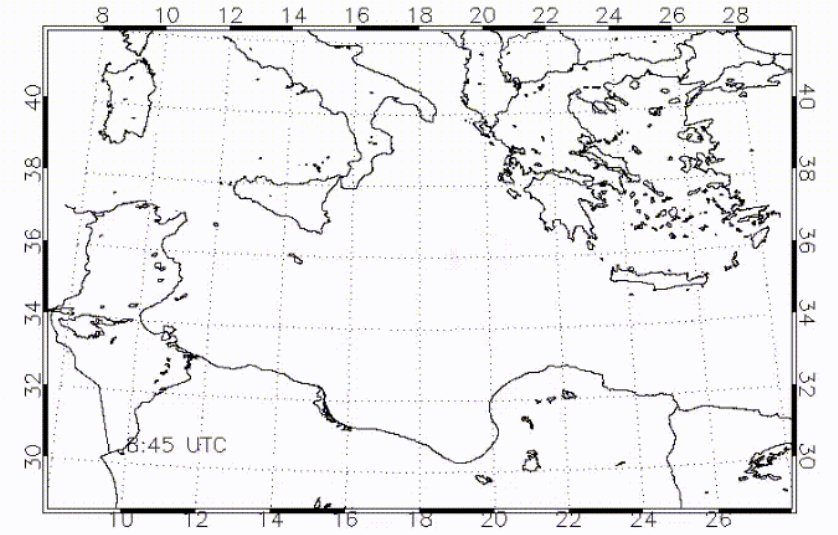
SO₂

SO₂ Columnar Abundance (t/km²)



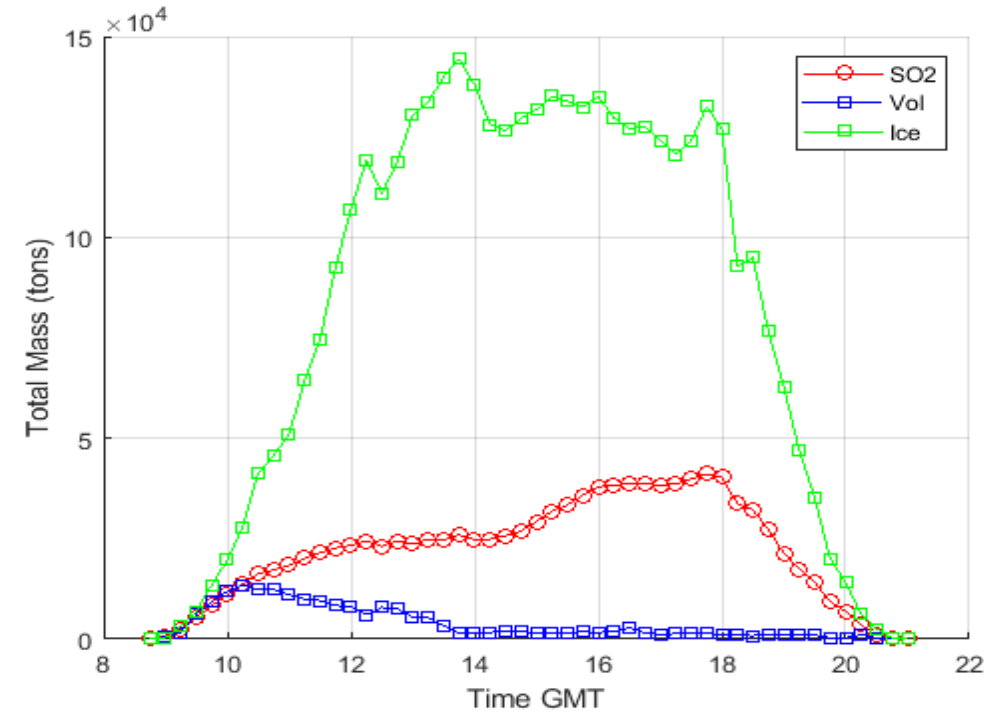
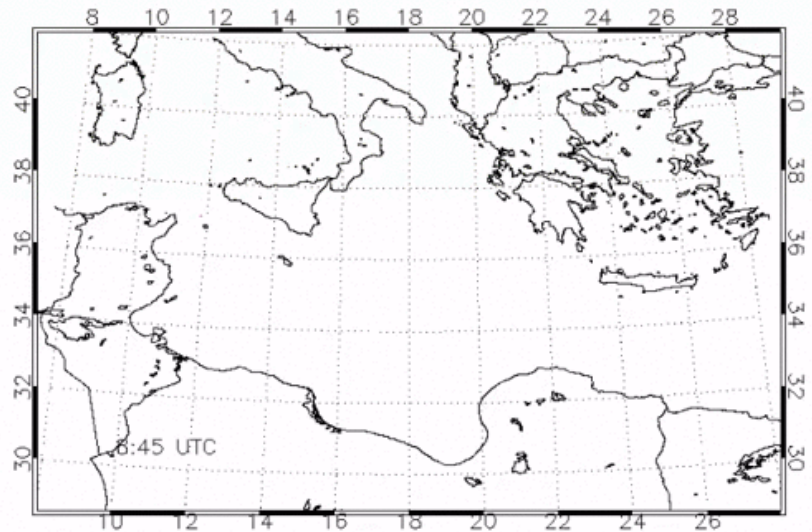
Ash

Ash Mass (t/km²)



Ice

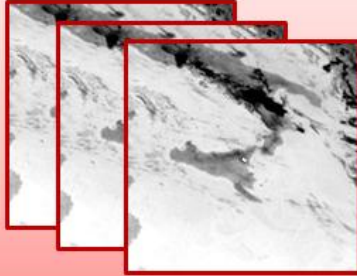
Ice Mass (t/km²)



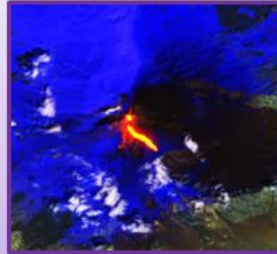
HOTSAT- Satellite Volcano Monitoring System

INPUT DATA

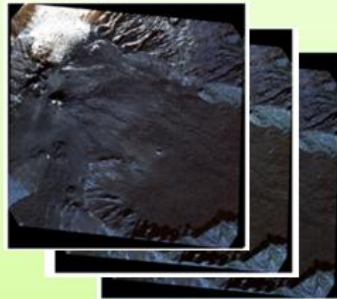
Low Spatial
High
Temporal
Resolution
Multispectral
Images



Low Temporal
High Spatial
Resolution
Multispectral
Images



High Spatial
Resolution
Optical
Images in
Stereo-
Tristere



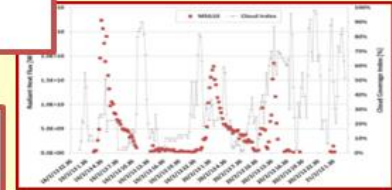
HOTSAT

PRODUCTS

1. Hotspot Detection

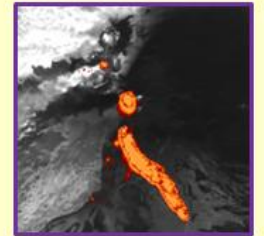


2. Radiant Heat Flux

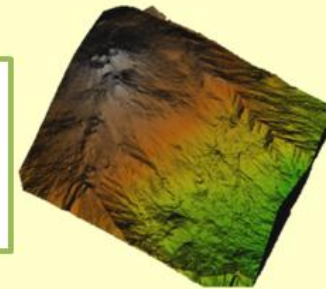


3. Effusion Rate & Volumes

4. Active Lava Flow Area



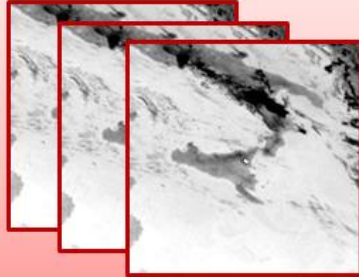
5. Digital
Elevation
Model



HOTSAT- Satellite Volcano Monitoring System

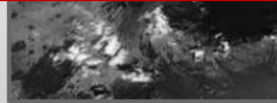
INPUT DATA

Low Spatial
High
Temporal
Resolution
Multispectral
Images

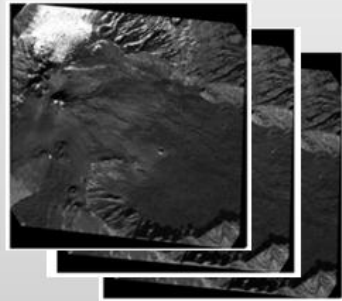


e.g. MSG-SEVIRI, EOS- MODIS,
NPP-VIIRS, etc

Multispectral
Images



High Spatial
Resolution
Optical
Images in
Stereo-
Tristere



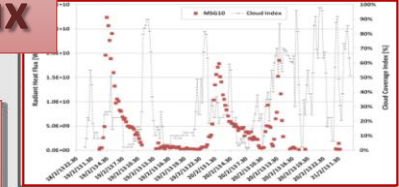
HOTSAT

PRODUCTS

1. Hotspot Detection

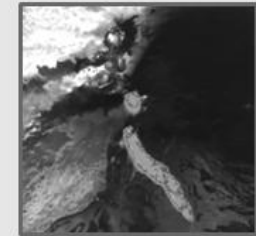


2. Radiant Heat Flux

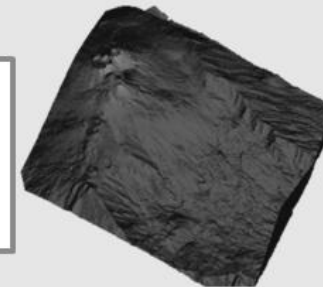


3. Effusion Rate &
Volumes

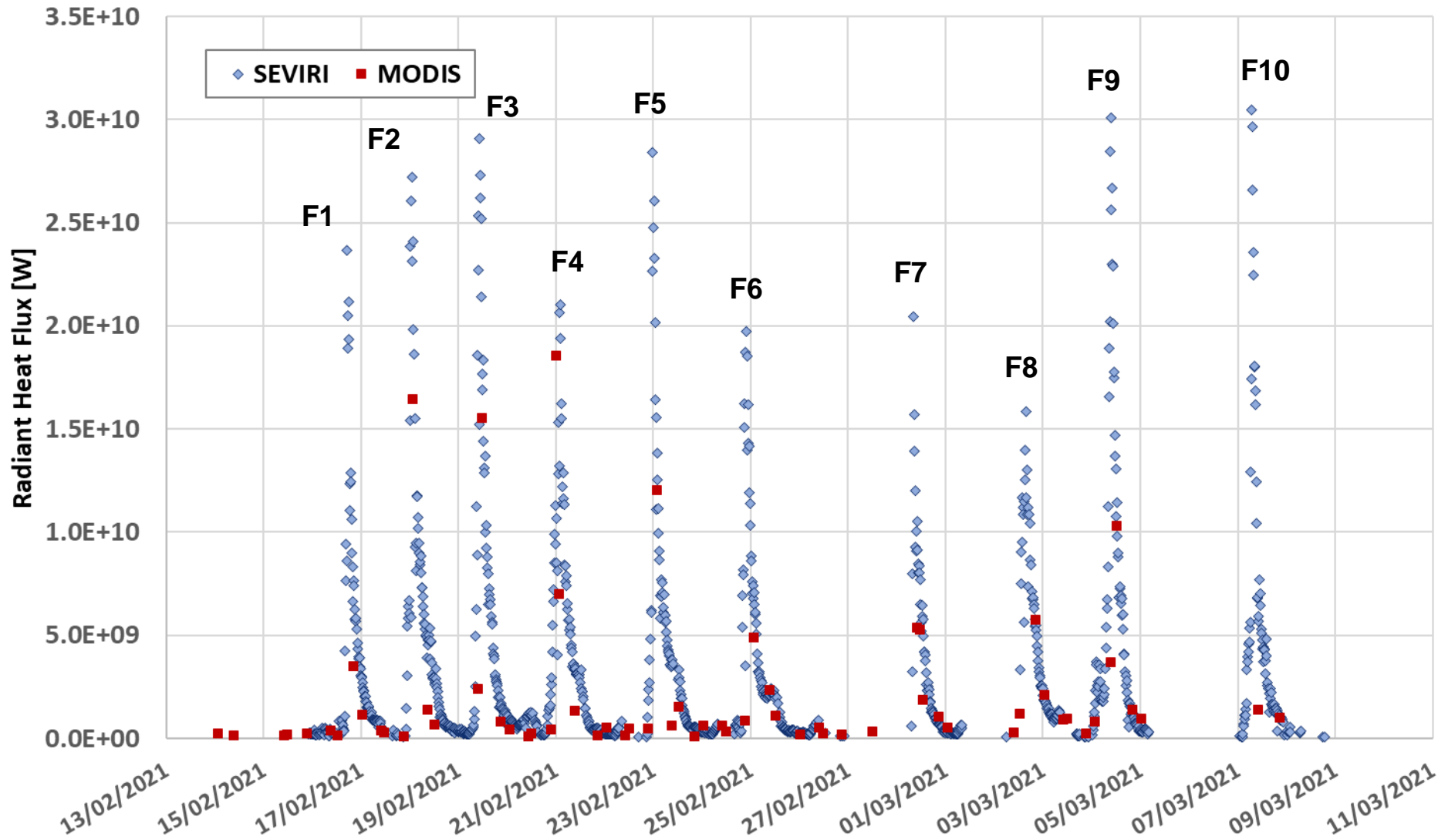
4. Active Lava Flow Area



5. Digital
Elevation
Model



Mt Etna 2021: Radiant Heat Flux from SEVIRI & MODIS

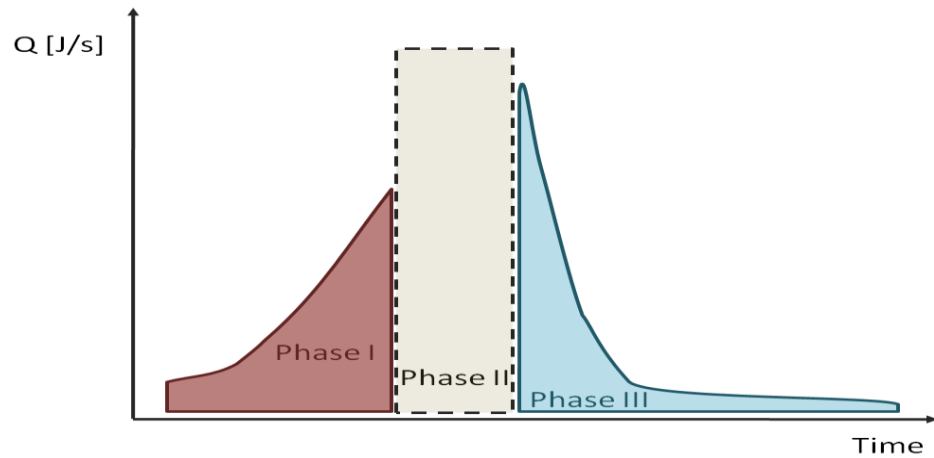


Ten Paroxysmal Events

1. 16/02/21
2. 18/02/21
3. 19/02/21
4. 21/02/21
5. 22/02/21
6. 24/02/21
7. 28/02/21
8. 02/03/21
9. 04/03/21
10. 07/03/21



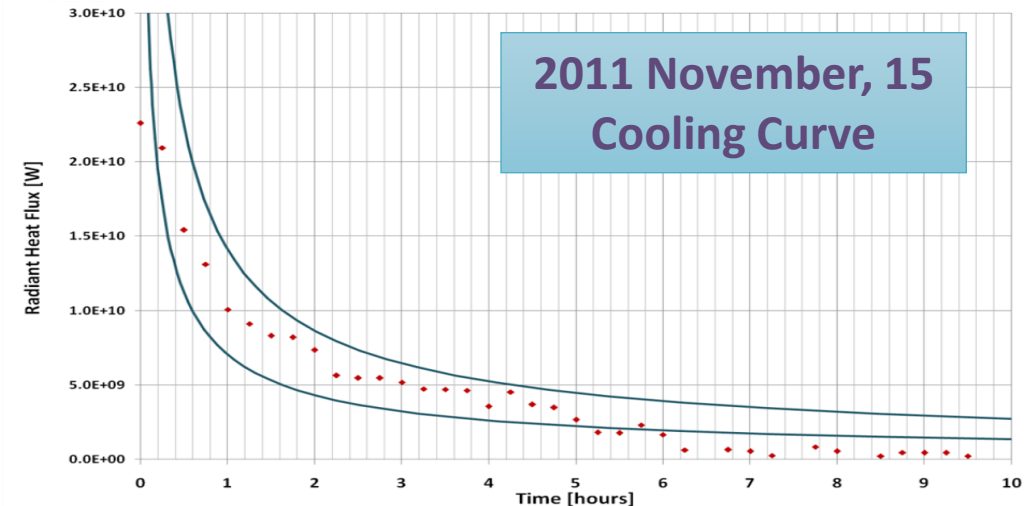
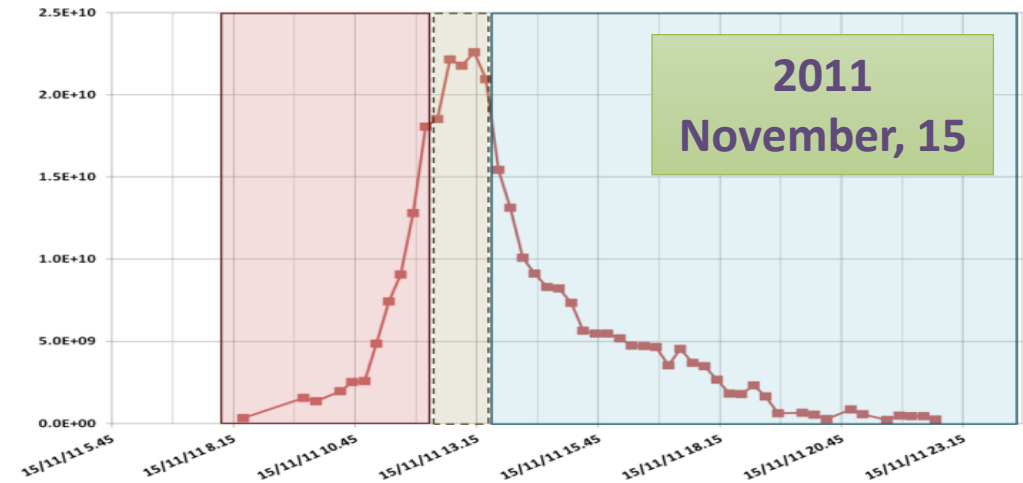
Volumes from cooling curves



PHASE I: Continuous (slow or sharp) increasing in the radiative power.

PHASE II: Discontinuous behavior often due to ash emission and saturation.

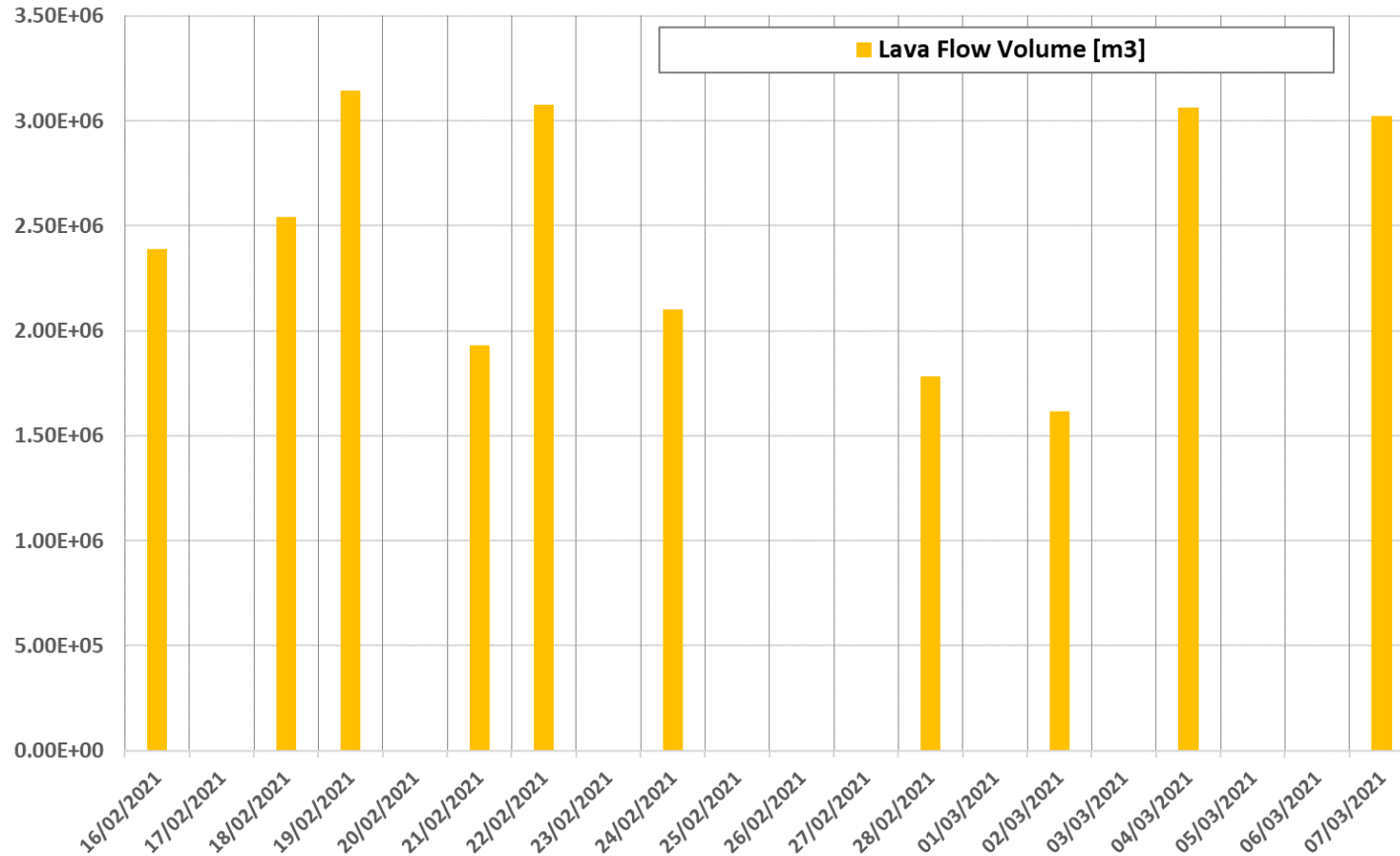
PHASE III: Continuous decreasing in the radiative power due to the cooling.



Ganci et al., 2012 GRL doi:10.1029/2012GL051026

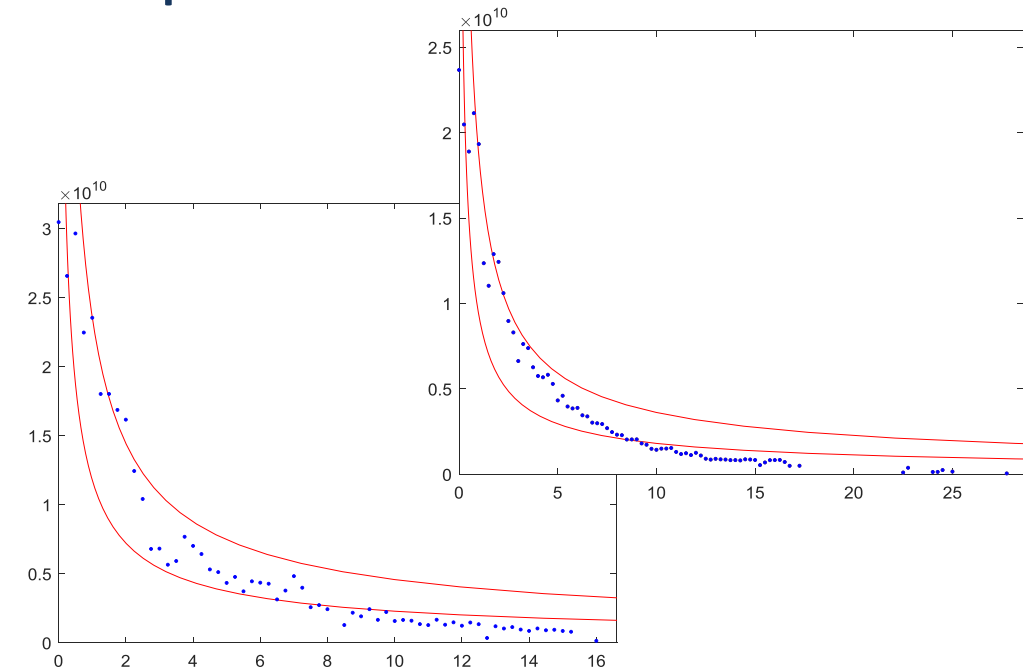


Etna 2021: Volumes from cooling curves



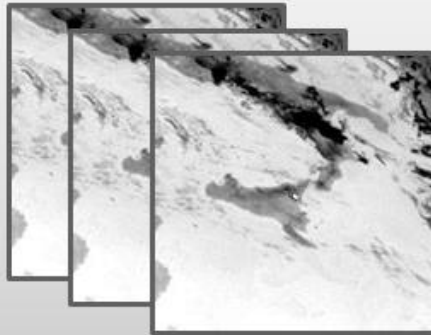
Lava flow volume per event ranges between 1.5 and 3 million of cubic meters.

A cumulative value of 25 million of cubic meters has been estimated for the ten eruptive events.

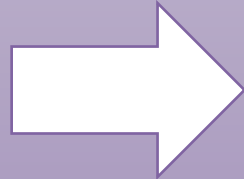
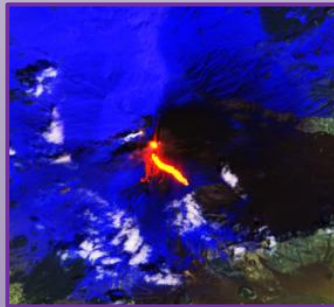


HOTSAT- Satellite Volcano Monitoring System

Low Spatial
High
Temporal
Resolution
Multispectral
Images

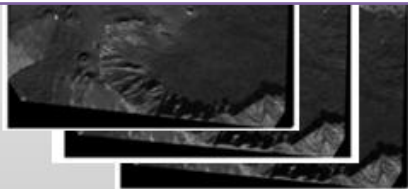


Low Temporal
High Spatial
Resolution
Multispectral
Images



e.g. Landsat 8 – OLI ,
Sentinel 2 MSI, EOS – ASTER

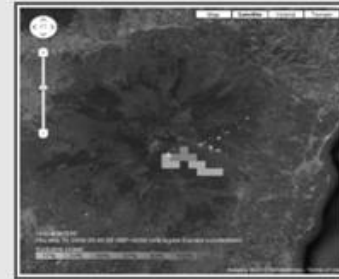
Images in
Stereo-
Tristere



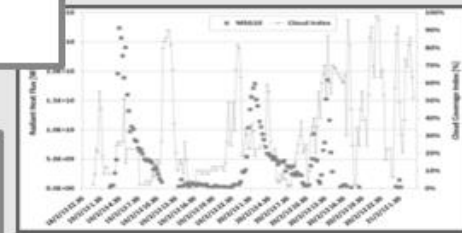
HOTSAT



1. Hotspot Detection



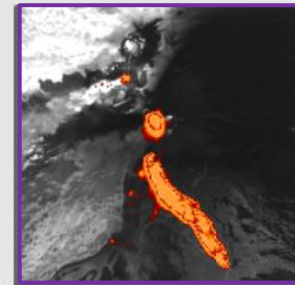
2. Radiant Heat Flux



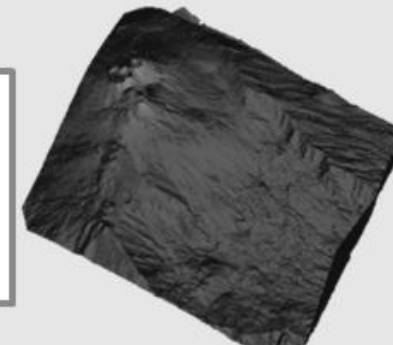
**3. Effusion Rate &
Volumes**



4. Active Lava Flow Area

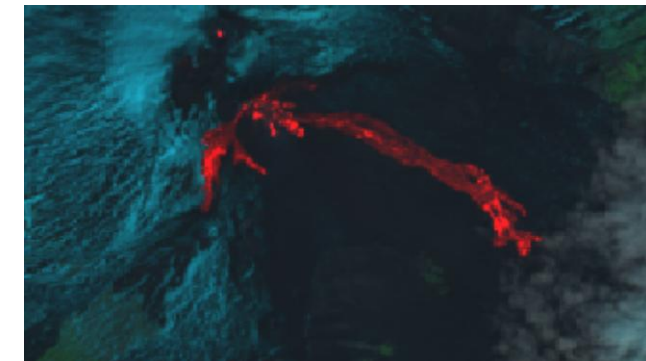
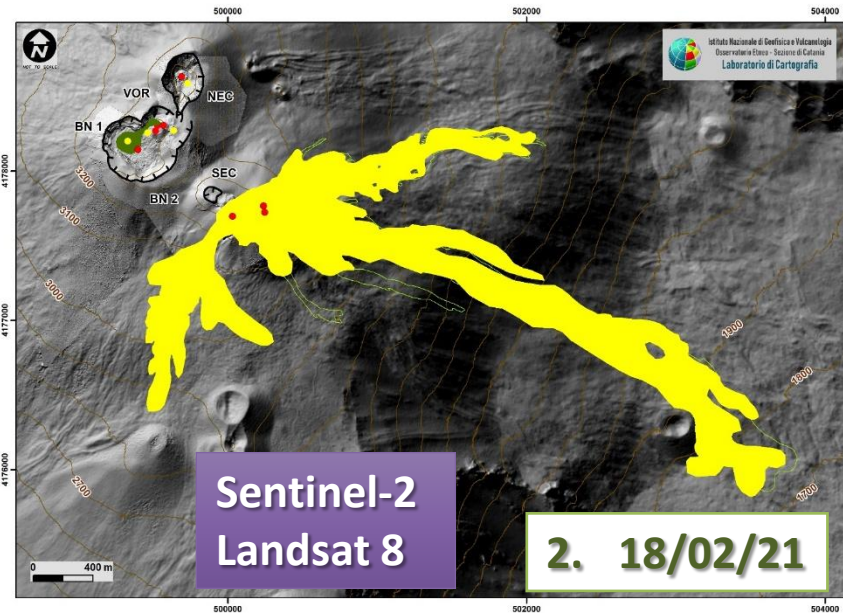
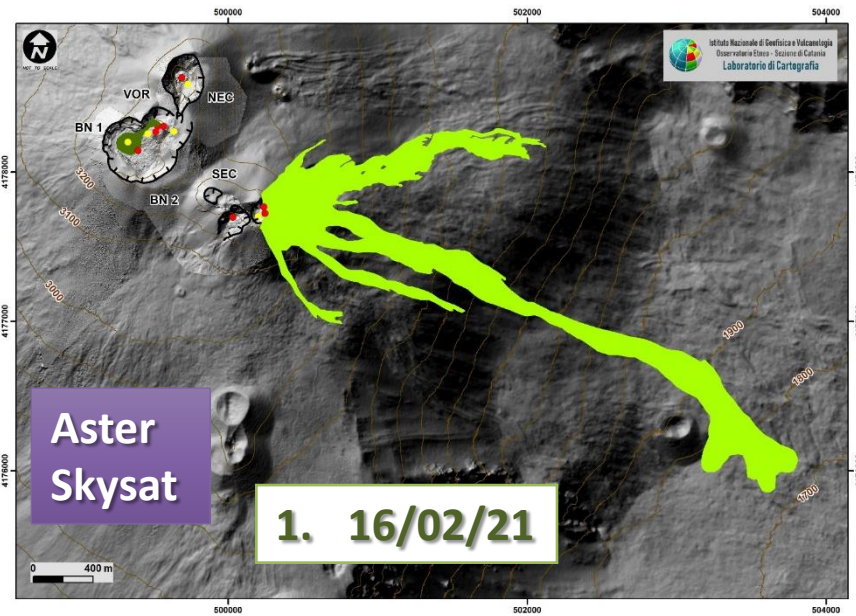


**5. Digital
Elevation
Model**

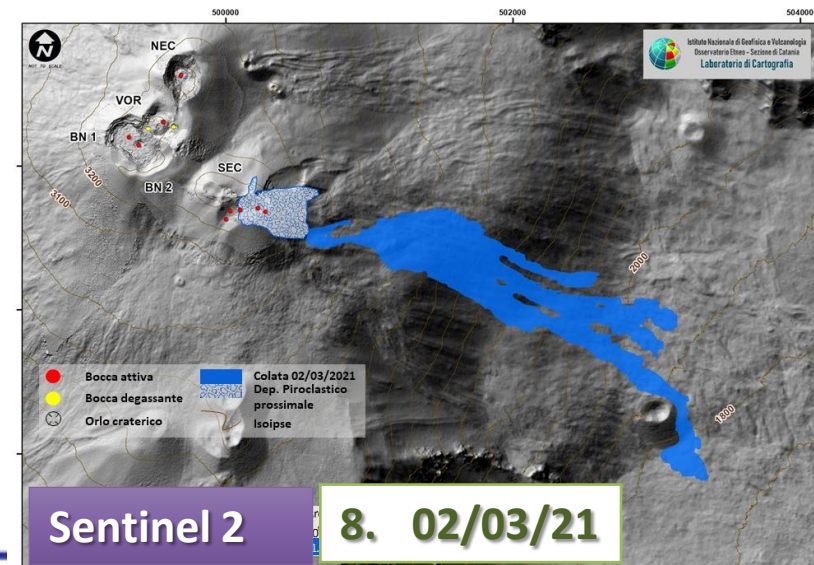
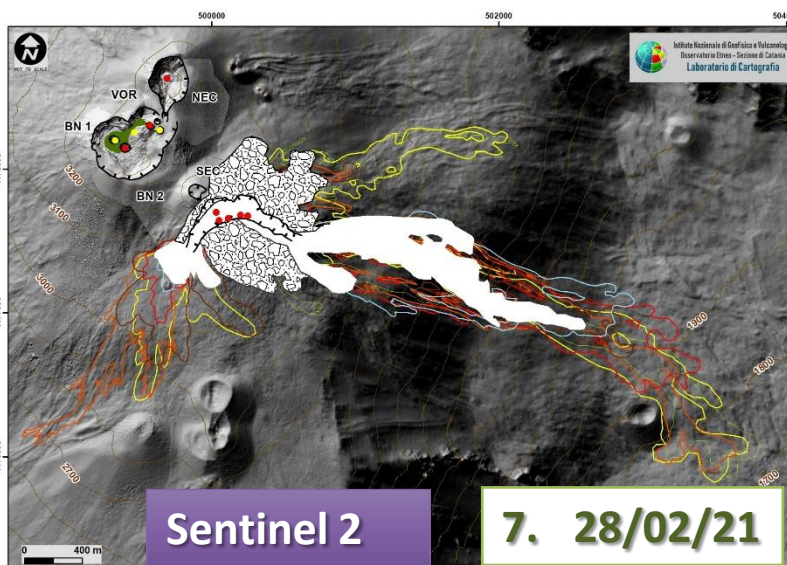
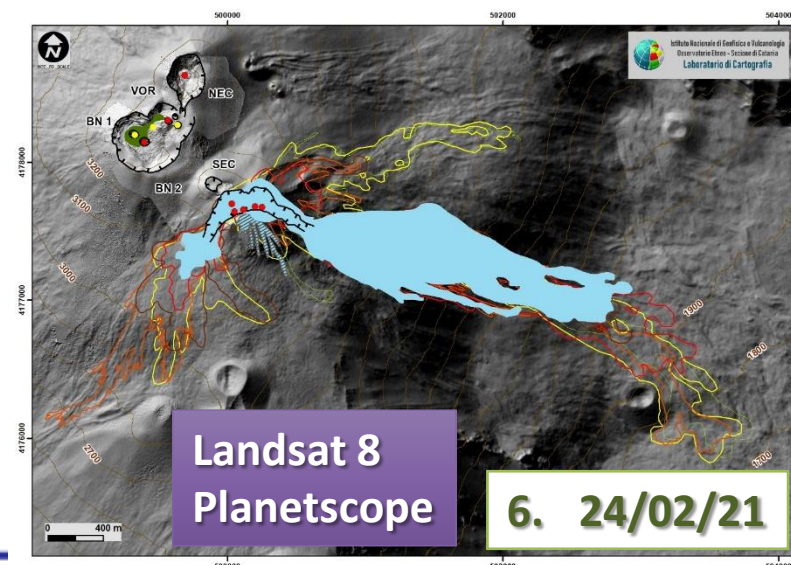
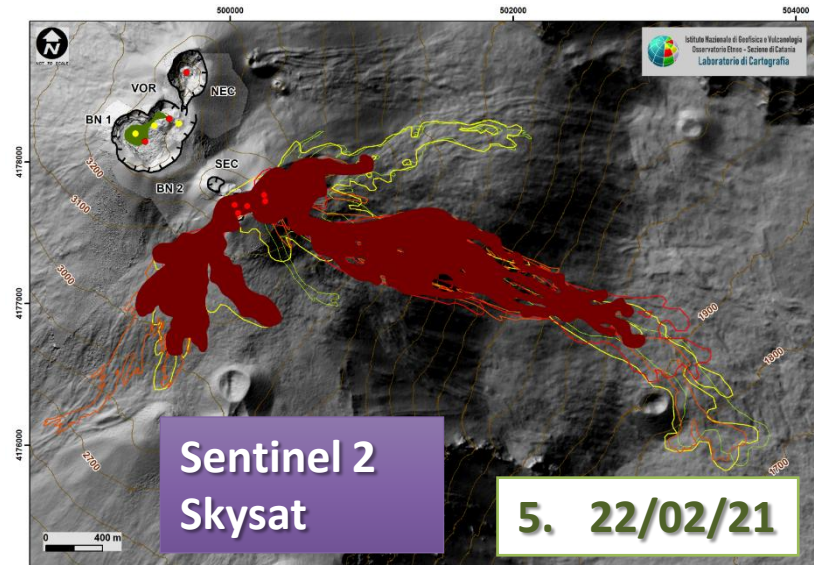
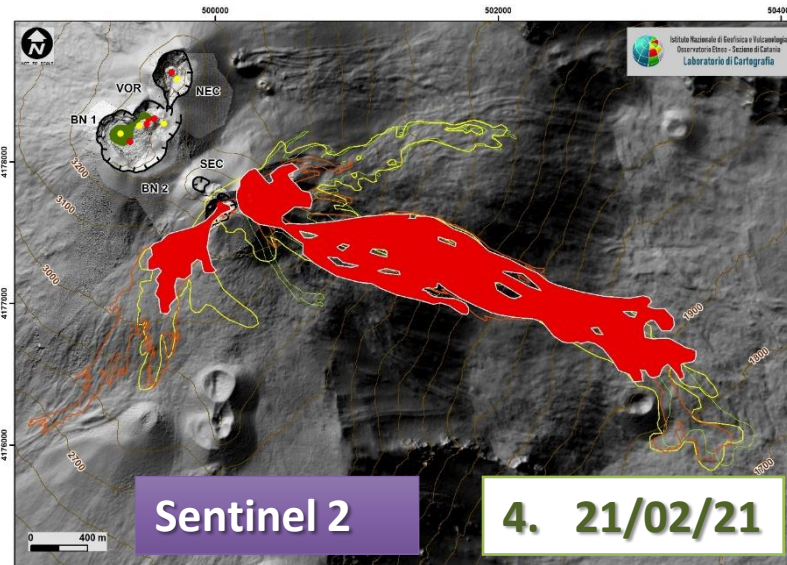
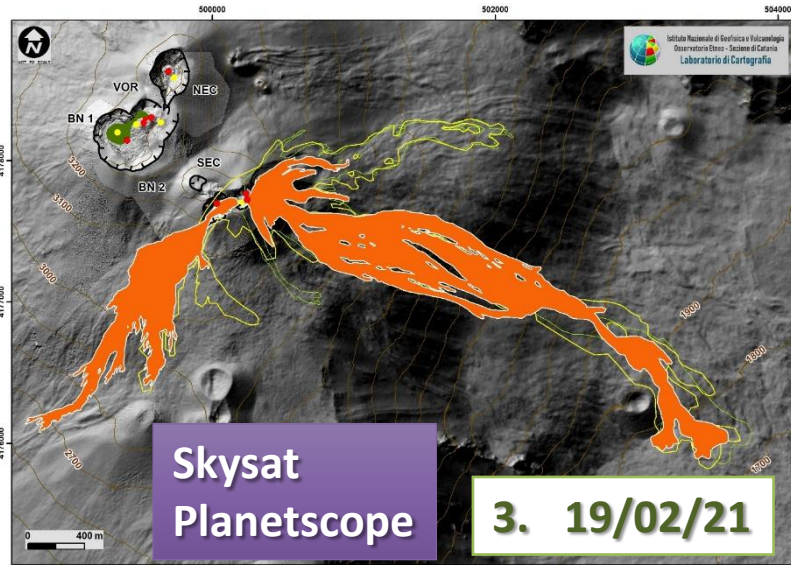


Etna 2021: Lava Flow Field from satellite imagery

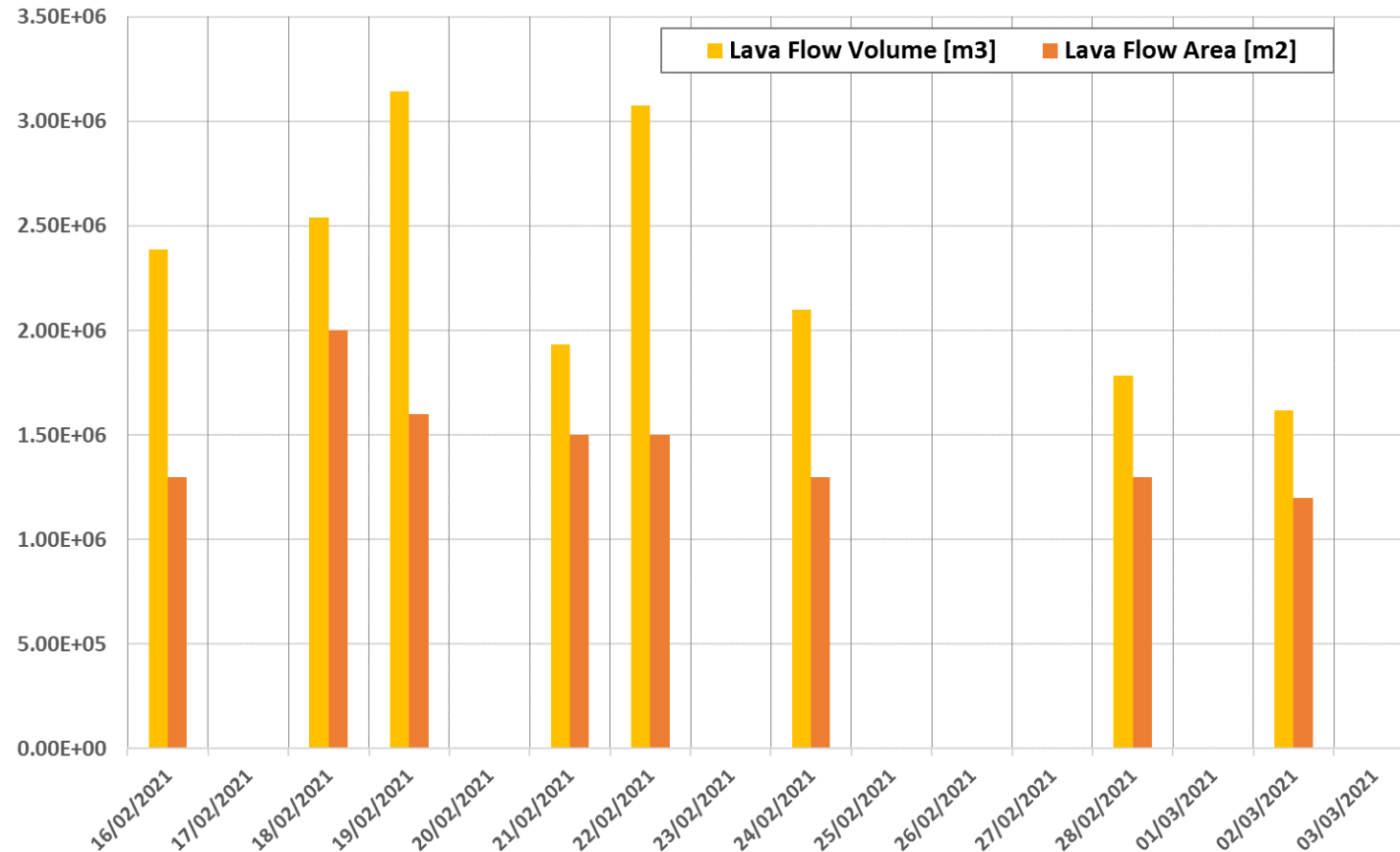
Mapping of lava flow field is performed by using: Landsat 8, Sentinel 2, Aster, Planetscope, Skysat imagery, together with ground-based fixed thermal camera data



Etna 2021: Lava Flow Field from satellite imagery



Etna 2021: Lava Flow Area and Average Thickness



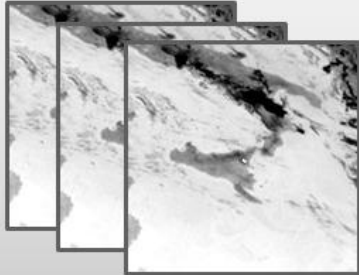
Data	Area [x 10 ⁶ m ²]	Min Elevation [m]	Length [km]	Thickness [m]
02/03/2021	1.2	1750	3.4	1.3
28/02/2021	1.3	2050	2.5	1.4
24/02/2021	1.3	1970	2.8	1.6
22/02/2021	1.5	1950	2.9	2.1
21/02/2021	1.5	1870	3.2	1.3
19/02/2021	1.6	1740	3.8	2.0
17/02/2021	2.0	1730	4.1	1.3
16/02/2021	1.3	1720	4.0	1.8



HOTSAT- Satellite Volcano Monitoring System

INPUT DATA

Low Spatial
High
Temporal
Resolution
Multispectral
Images

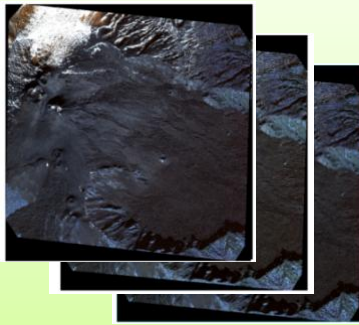


Low Temporal
High Spatial



e.g. Pleiades, SkySat,
WorldView3, EOS - ASTER

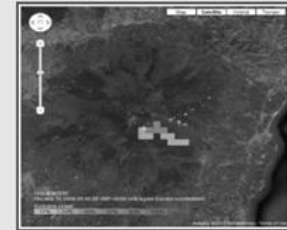
High Spatial
Resolution
Optical
Images in
Stereo-
Tristere



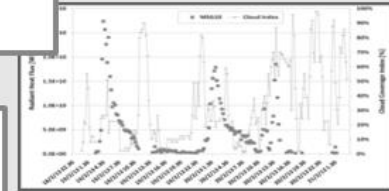
HOTSAT

PRODUCTS

1. Hotspot Detection

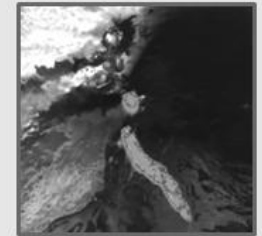


2. Radiant Heat Flux

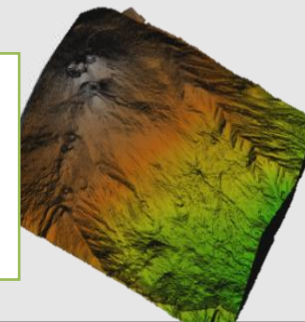


3. Effusion Rate & Volumes

4. Active Lava Flow Area

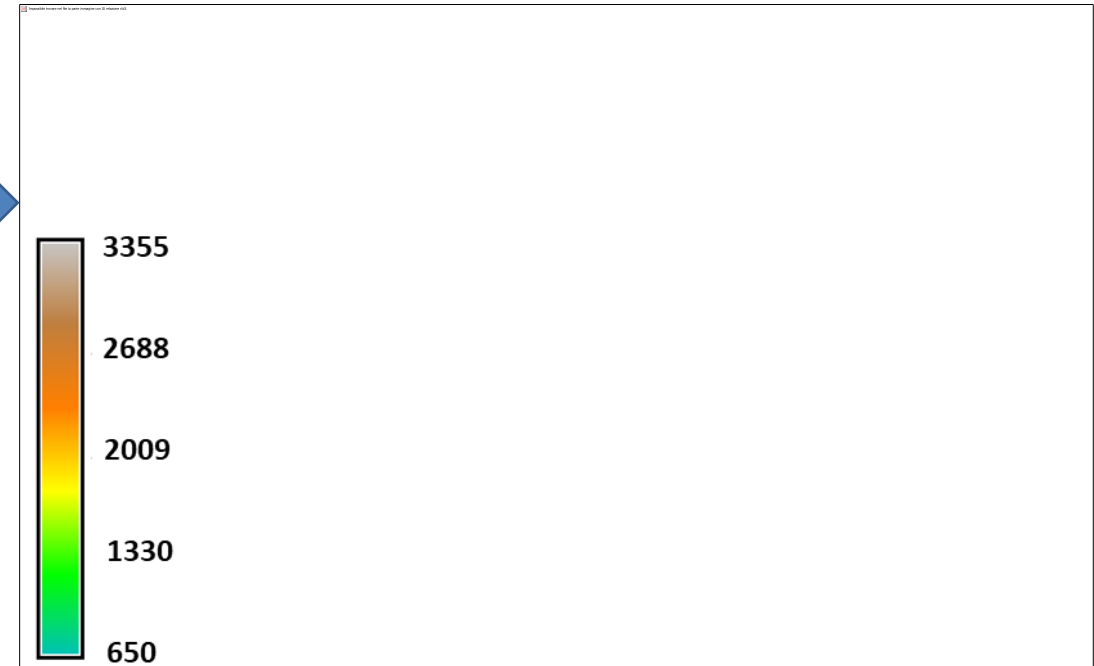
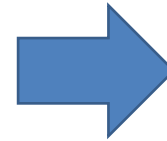
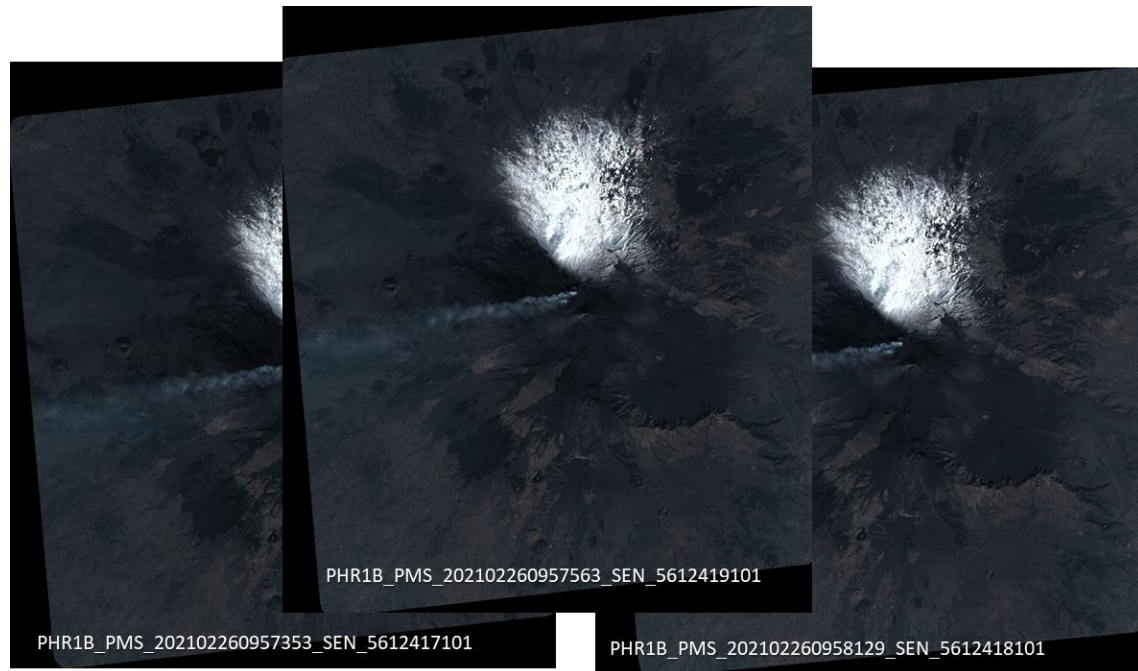


5. Digital
Elevation
Model



Pléiades Imagery at Mt Etna 2021

A cloud-free Pléiades triplet was acquired over Mt Etna on February 26, 2021. The 3D processing of the tri-stereo Pléiades imagery is performed using the free and open source MicMac (Multi-images Correspondances, Méthodes Automatiques de Corrélation) photogrammetric library developed by the French IGN (Institut Géographique National).



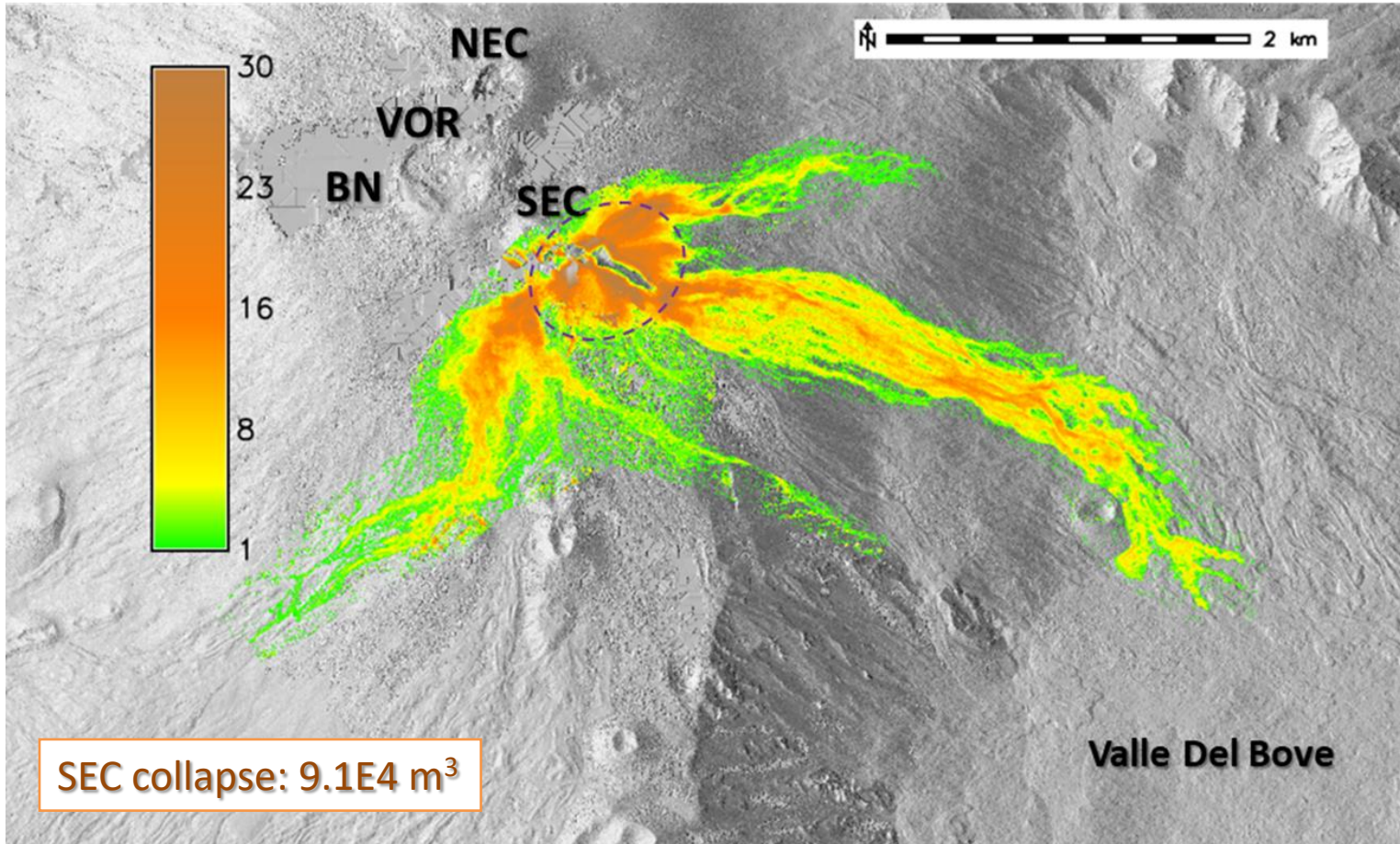
A 1-meter spatial resolution digital elevation model was produced



Pléiades Imagery at Mt Etna: February 2021 vs August 2020

Preliminary Results

By subtracting the August 2020 DEM to the 2021 DEM the volume of erupted materials can be quantified [Ganci et. al 2018]. The two DEMs were aligned by using Nuth and Käab [2011] co-registration algorithm.



12 Paroxysmal events:

1. 13 Dec 2020
2. 14 Dec 2020
3. 21 Dec 2020
4. 22 Dec 2020
5. 18 Jan 2021
6. 20 Jan 2021
7. 16 Feb 2021
8. 18 Feb 2021
9. 19 Feb 2021
10. 21 Feb 2021
11. 22 Feb 2021
12. 24 Feb 2021

Total Volume: $24.5E6 \text{ m}^3$

Total Area $3.7E6 \text{ m}^3$

Lava Flow: $18.1E6 \text{ m}^3$

SEC growth: $6.4E6 \text{ m}^3$



Satellites and sensors for Etna Volcano Monitoring

Satellite Sensor	Spatial Resolution	Revisit Time	Derived Product
MSG-SEVIRI	3 km	15 minutes	Radiant Heat Flux, TADR, Plume Height, Ash/SO ₂ retrievals
EOS-MODIS	1 km	12 h	Radiant Heat Flux, TADR, Plume Height, Ash/SO ₂ retrievals
Sentinel 3-SLSTR	1 km	12 h	Radiant Heat Flux, TADR, Plume Height, Ash retrievals
NPP/JPSS-VIIRS	375 - 750 m	12 h	Radiant Heat Flux, TADR, Plume Height, Ash/SO ₂ retrievals
Landsat 8- OLI	15 - 30 m	7-14 days	Lava flow thermal map
Sentinel 2- MSI	10 - 60 m	2-3 days	Lava flow thermal map
EOS-ASTER	15 - 90 m	On demand	DEM, Lava flow area/thickness, Plume Height, SO ₂ retrievals
Pleiades-1A, -1B	0.5 - 2 m	On demand	DEM, Lava flow area/thickness
Doves-PlanetScope	3.7 m	~1 day	DEM, Lava flow area/thickness
SkySat	0.7 - 1 m	On demand	DEM, Lava flow area/thickness

