

PRODUCTS FOR VOLCANIC CLOUD MONITORING

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Pardini F., Costa A., De Michieli Vitturi M., Esposti Ongaro T., Macedonio G., Neri A.



ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA 

- (BRIEF) INTRODUCTION

Merge of 3 Modules

Merucci L., et al.

Stima dell'altezza della nube vulcanica.

Sistema di acquisizione di dati satellitari multimissione MAST (Multimission Acquisition SysTem) installato presso la sede INGV di Roma dal 2018 per acquisizione e processamento dati satellitari in tempo quasi reale (NRT).

Corradini S., et al.

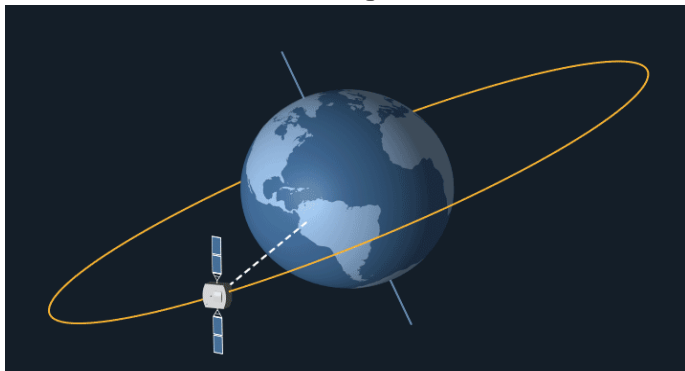
Produzione di mappe di cenere (massa, spessore ottico e raggio effettivo delle particelle) ed SO₂ (massa) presente nelle nubi vulcaniche, utilizzando strumentazione satellitare geostazionaria (SEVIRI) e polare (MODIS, SLSTR).

Pardini F., et al.

Sviluppo una procedura di Data-Assimilation (DA) volta a migliorare le previsioni numeriche del trasporto e dispersione di cenere e SO₂ prodotti da eruzioni vulcaniche utilizzando osservazioni satellitari acquisite in real-time durante l'eruzione.

- **SCIENTIFIC RATIONALE**

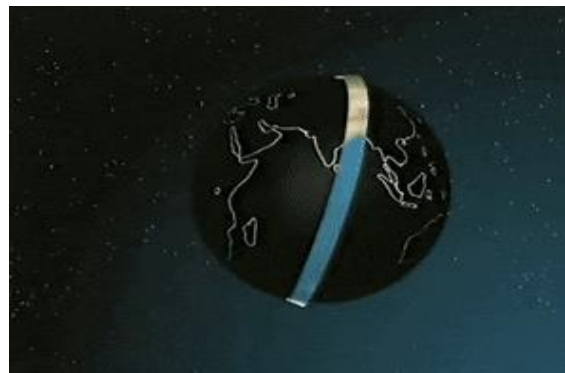
Geostationary satellites



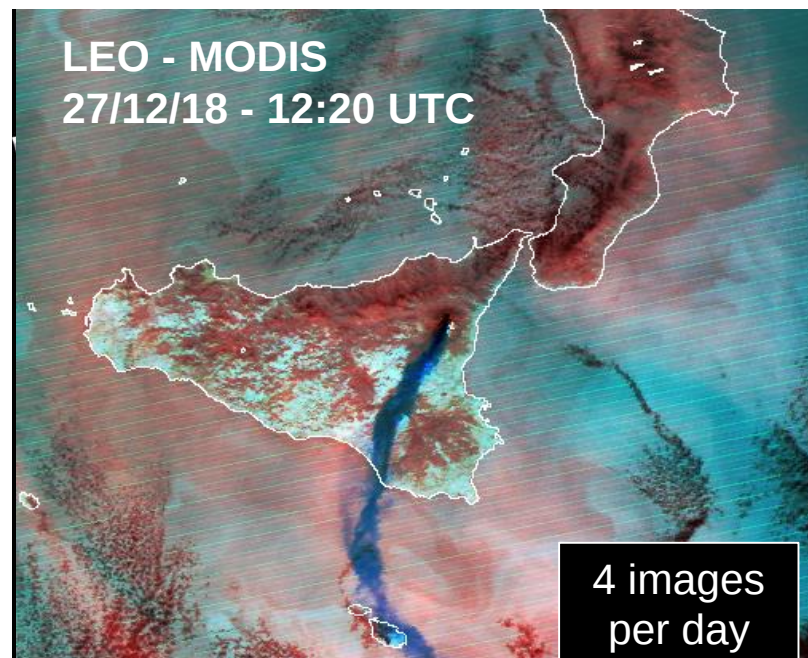
Low spatial resolution, High temporal resolution



Polar satellites



High spatial resolution, Low temporal resolution



SO₂ retrievals:
 $\lambda \sim 7.3, 8.6 \mu\text{m}$

Ash/VCTH retrievals:
 $\lambda \sim 11, 12 \mu\text{m}$

All measurements
in the TIR spectral
range



Monitoring during
day and night

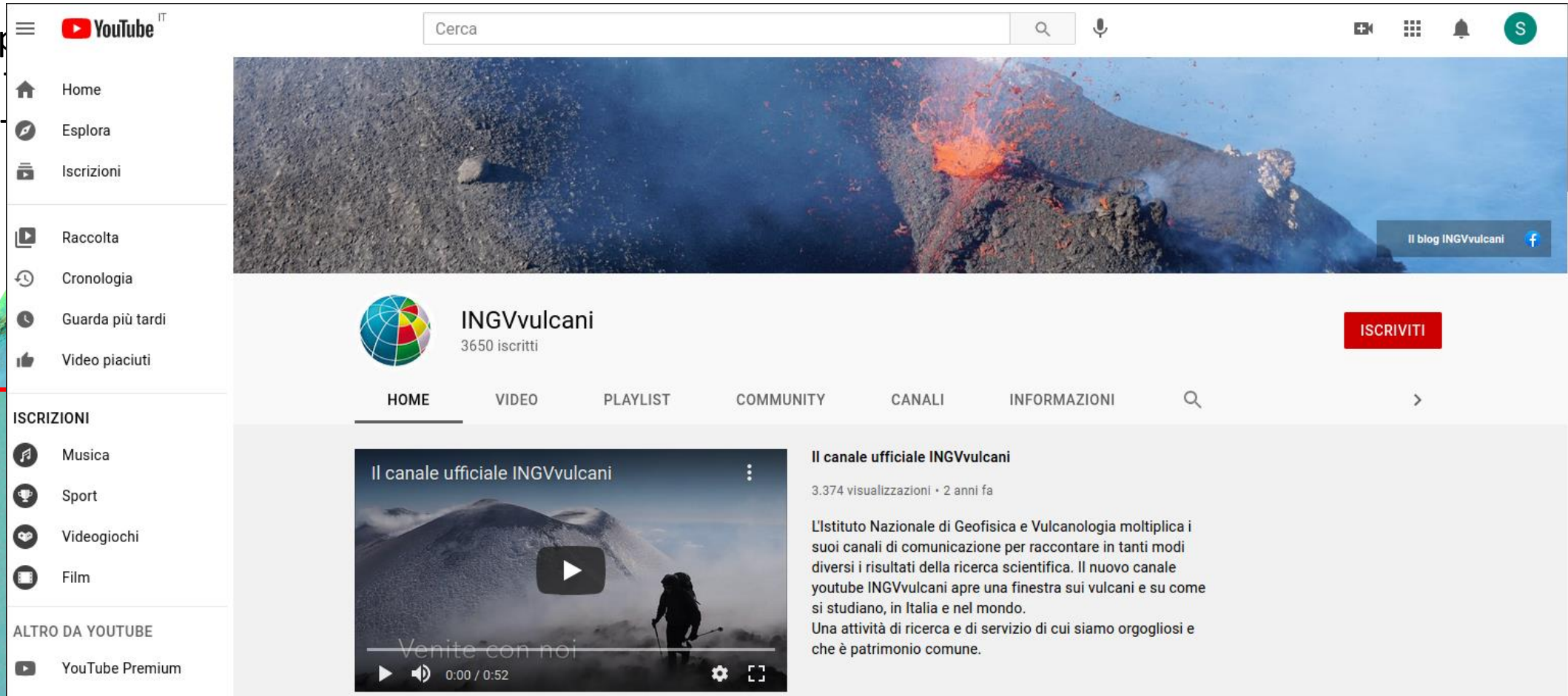
• SCIENTIFIC RATIONALE – SO₂/Ice/Ash Detection e Retrievals

RGB comp

R: $T_{b,8.7}$

G: $T_{b,12}$

B: $T_{b,10.8}$



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ALTRO DA YOUTUBE

YouTube Premium

INGVvulcani

3650 iscritti

ISCRIVITI

HOME VIDEO PLAYLIST COMMUNITY CANALI INFORMAZIONI

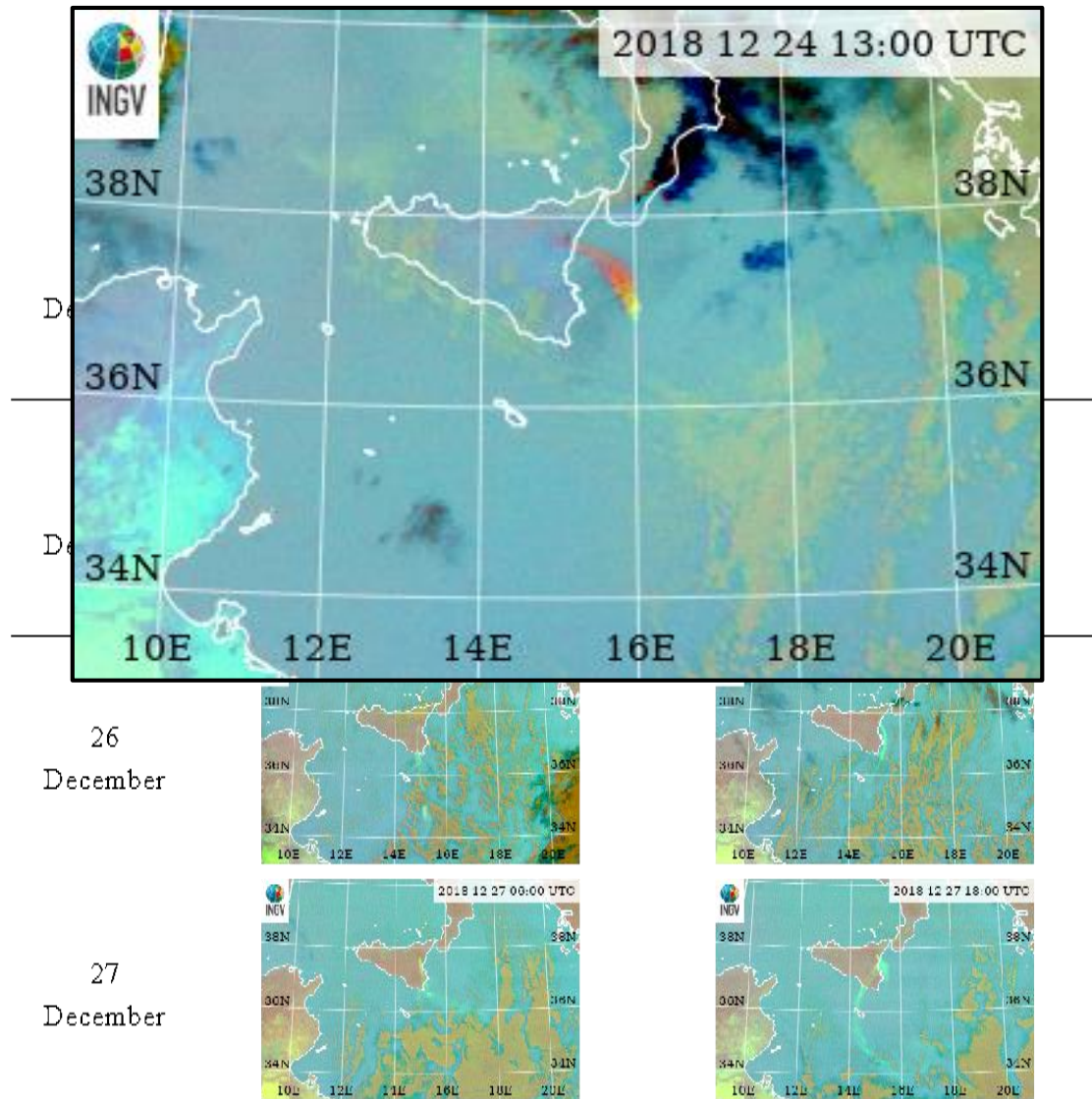
Il canale ufficiale INGVvulcani

3.374 visualizzazioni • 2 anni fa

L'Istituto Nazionale di Geofisica e Vulcanologia moltiplica i suoi canali di comunicazione per raccontare in tanti modi diversi i risultati della ricerca scientifica. Il nuovo canale youtube INGVvulcani apre una finestra sui vulcani e su come si studiano, in Italia e nel mondo. Una attività di ricerca e di servizio di cui siamo orgogliosi e che è patrimonio comune.

IONI

- SCIENTIFIC RATIONALE – SO₂/Ice/Ash Detection e Retrievals

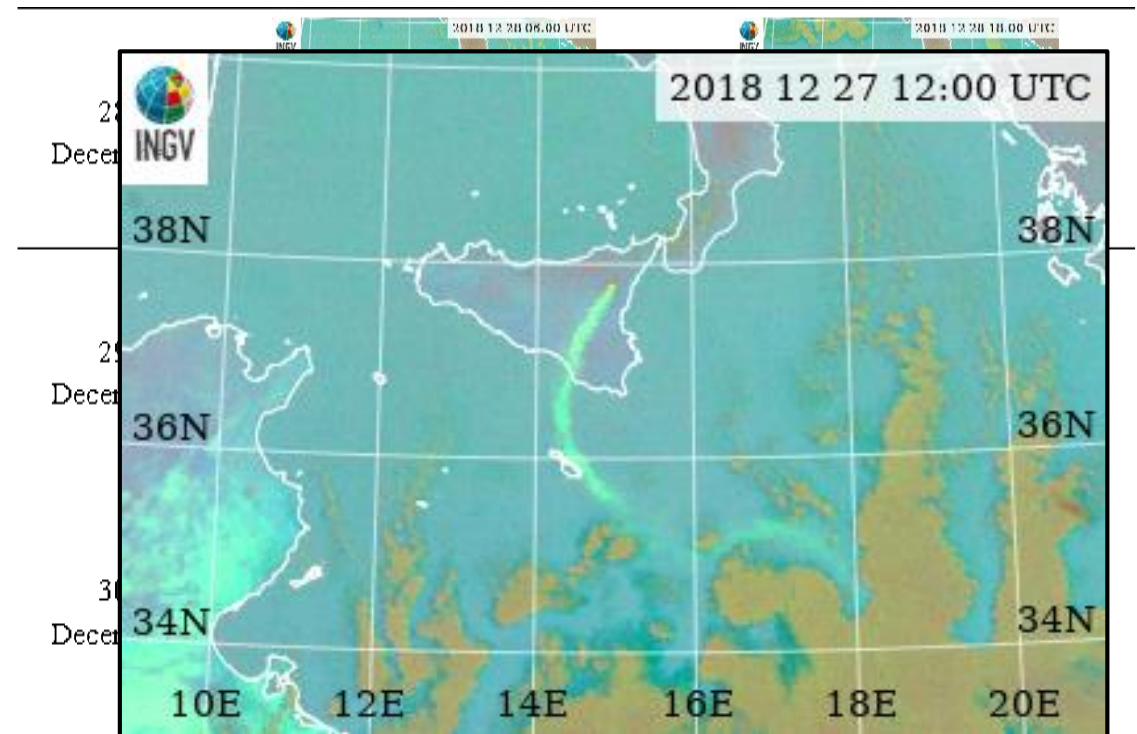


RGB composite:

$$R: T_{b,8.7} - T_{b,10.8} ;$$

$$G: T_{b,12} - T_{b,10.8} ;$$

$$B: T_{b,10.8}$$



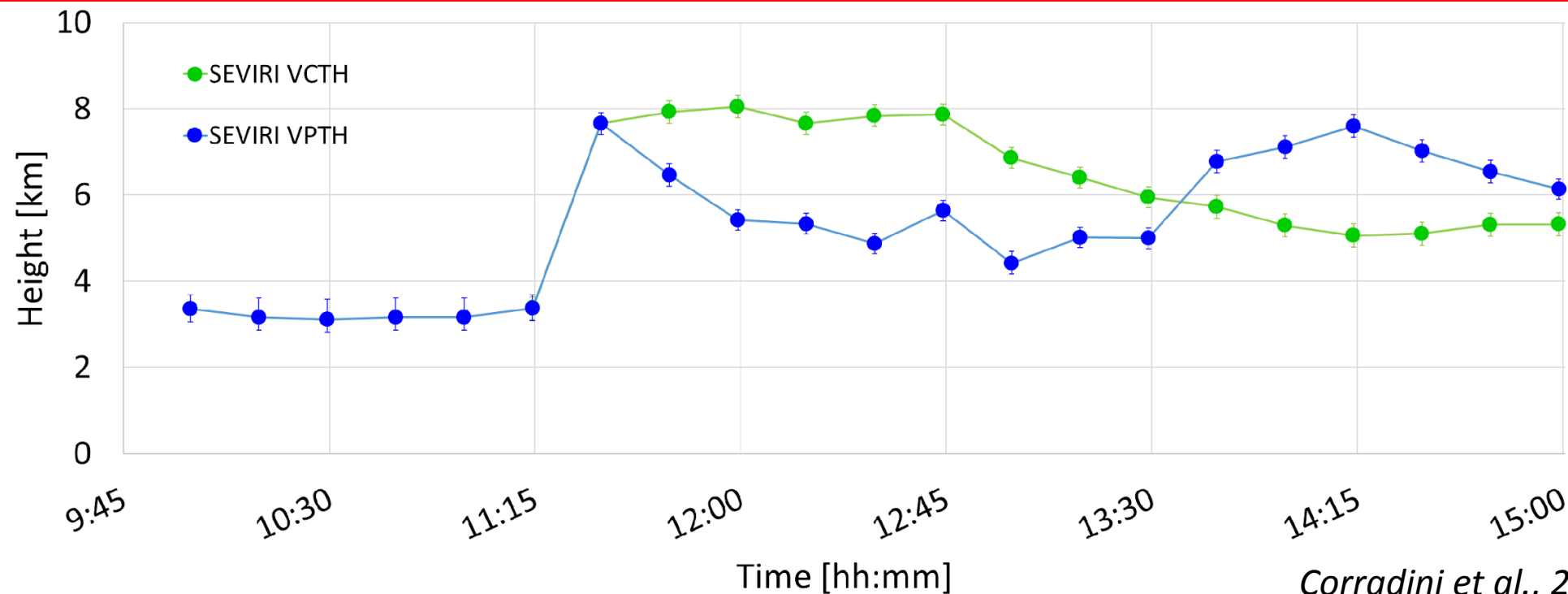
- SCIENTIFIC RATIONALE – Volcanic Plume Top Height

24 Dec. 2018 12:00 UTC

T_b @ 10.8 mm

Darkest pixels procedure

The volcanic cloud altitude is obtained by comparing the satellite image 'darkest pixels' T_b with the of the 2001]



Corradini et al., 2020

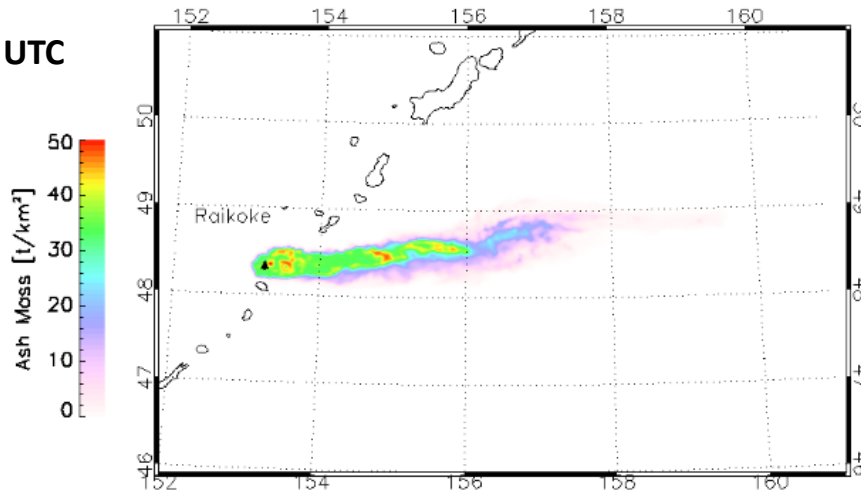
SCIENTIFIC RATIONALE – Volcanic Ash/SO₂ Retrievals

**Raikoke, SLSTR,
22 June 2019, 00:07 UTC**

Ash Mass

Total Mass:

0.41 +/- 0.16 Mt

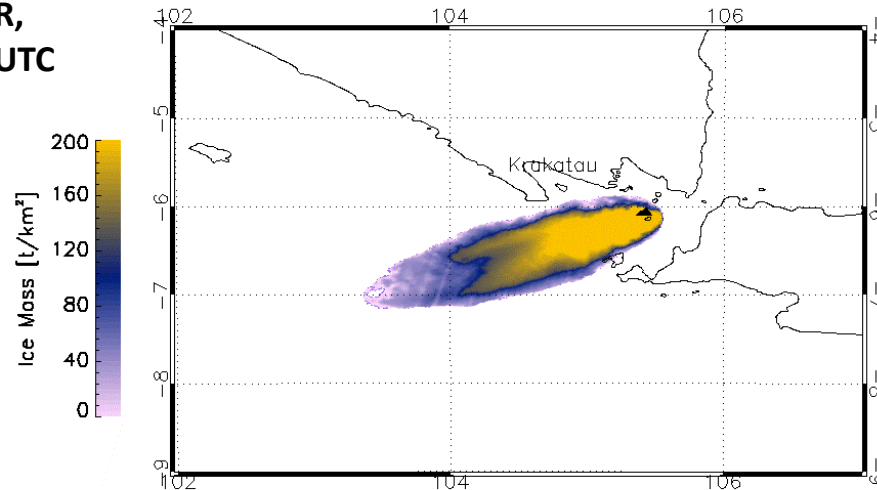


**Anak Krakatau, SLSTR,
23 Dec. 2018, 02:57 UTC**

Ice Mass

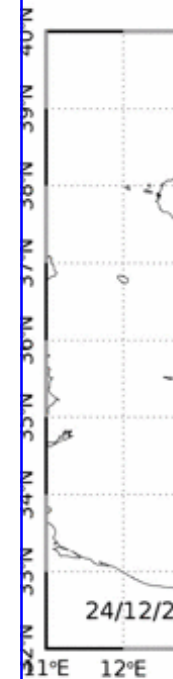
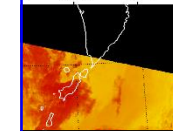
Total Mass:

2.07 +/- 0.83 Mt



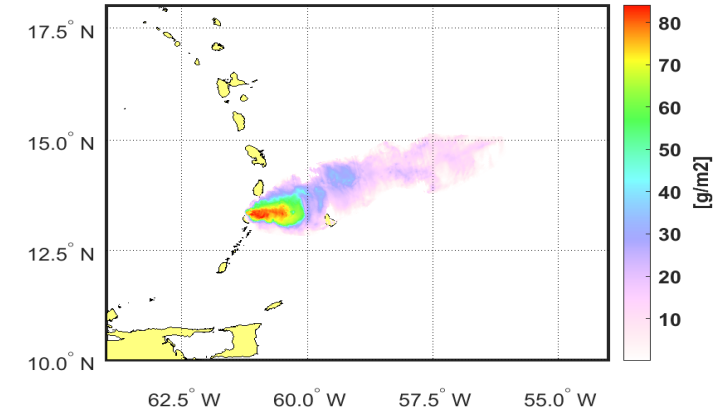
Volcanic
[Pugna]

Interpolation
without volcanic
spheric mass

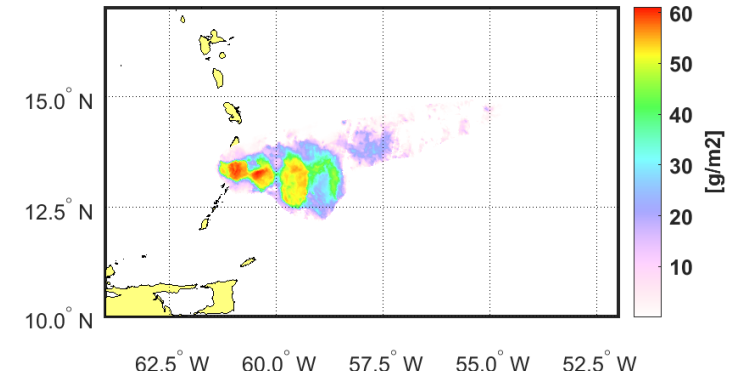


Soufriere (San Vincent), SLSTR, April, 2021

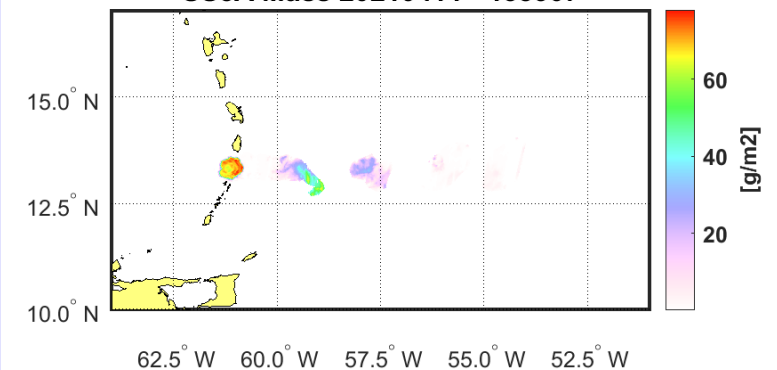
SS3A Mass 20210410 - 015623



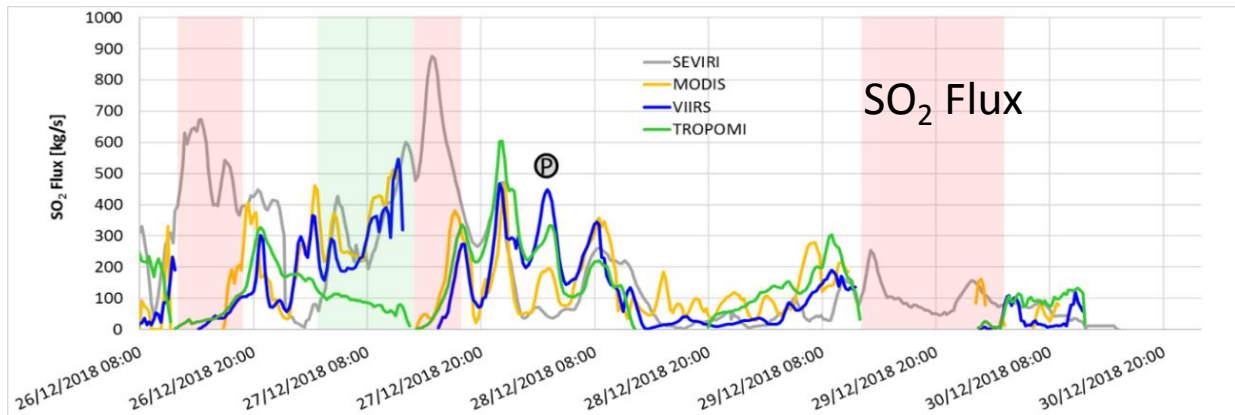
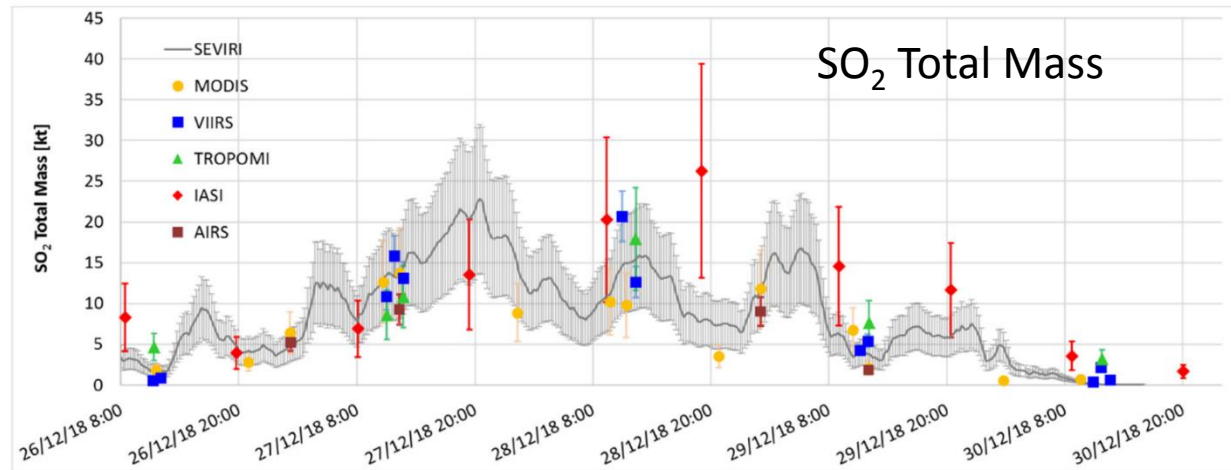
SS3B Mass 20210410 - 134547



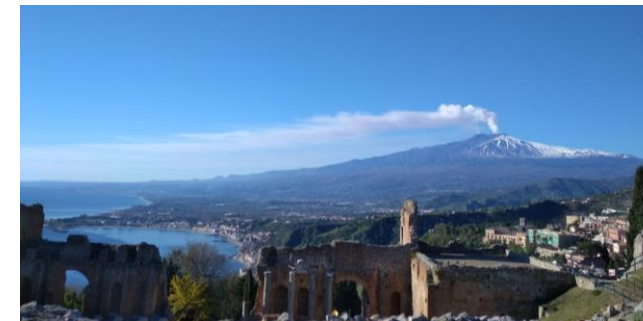
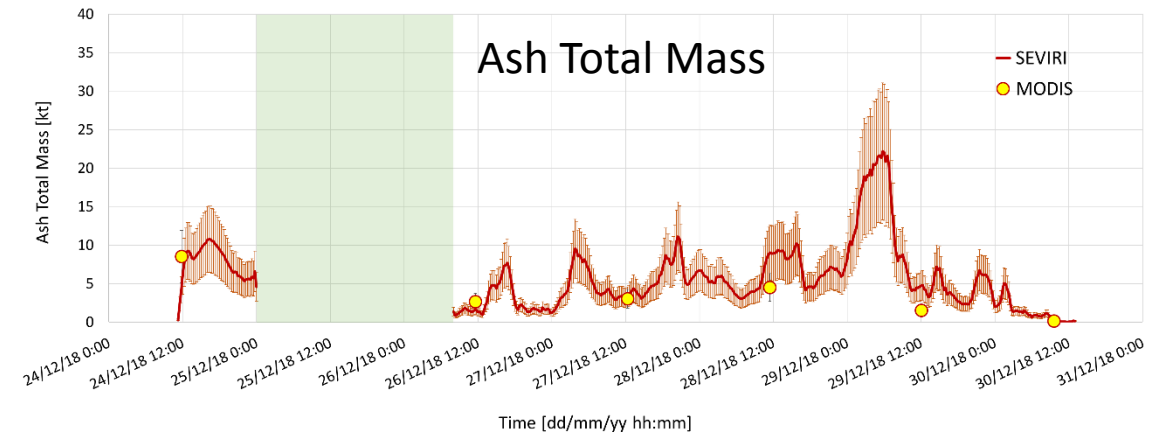
SS3A Mass 20210411 - 135907



- SCIENTIFIC RATIONALE – Validation



Etna, December 2018



Corradini et al., 2020; 2021

• SCIENTIFIC RATIONALE – Volcanic ash automated forecasting workflow for Etna

ARPA-SIM data
downloaded every day at 08:00 (00) and 20:00 (12)

Meteo data

VONA
Satellite data

Daily forecast Run every day at 09:00 (and 21:00)
Continuous emission from 12 UTC (00 UTC) for 6 hours
4 simulation cycles starting at 12/18/00/06 (00/06/12/18)
2 eruptive scenarios: weak and strong

Forecast start hour: $h_0 = 12$ (00)

Time loop:
4 cycles
each
from h_0
to
 $h_i = h_0 + 6h$

- Read input files
- Initialize ensemble members at h_0
- Perform PLUME-MoM/HYSPLIT simulations from h_0 to h_i
- Create output files (.res) and images (.png)
Mean and variance states of ash CC
Mean and variance states of ground load
Probability maps (ground and air)
Mean concentration at different FL (air only)
- Upload images on FTP-Server
- $h_0 = h_i$

Real time forecast Run when RED VONA is released
1 eruptive scenario
Forecast start hour: $h_0 = h_{VONA}$

Time loop:
N cycles
each
from h_0
to
 $h_i = h_0 + 1h$

- Read input files and VONA
- Check for new VONA
- Check for satellite data
- Update eruptive scenario
- Initialize ensemble members at h_0
- Perform PLUME-MoM/HYSPLIT simulations from h_0 to h_i
- If satellite data, perform **data assimilation** at h_i
- Create output files (.res) and images (.png)
Mean and variance states of ash CC
Mean and variance states of ground load
Probability maps (ground and air)
Mean concentration at different FL (Air only)
- Upload images on FTP-Server
- $h_0 = h_i$

- SCIENTIFIC RATIONALE – Simulating Setting

Daily forecast

Eruptive scenario	Weak	Strong
Reference eruption	2001/2002-03 flank eruption. 2006 SEC. (Barsotti et al, 2010)	1986 (NEC), 1990 (SEC), 1998 (VOR). (Barsotti et al, 2010)
Column height	uniform pdf 1-4km above the vent (Barsotti et al, 2010)	uniform pdf 8-13 km above the vent (Barsotti et al, 2010)
TGSD mu	gaussian pdf: 2+-0.5 (Scollo et al., 2007)	gaussian pdf: 2.3+-0.5 (Scollo et al., 2008)
TGSD sigma	gaussian pdf:1.5+-0.5 (Scollo et al., 2007)	gaussian pdf:1.5+-0.5 (Scollo et al., 2008)
Meteo data	ARPA-SIM	ARPA-SIM
Nwind	10	10
Nesp	15	15
N	150	150

Real-time forecast

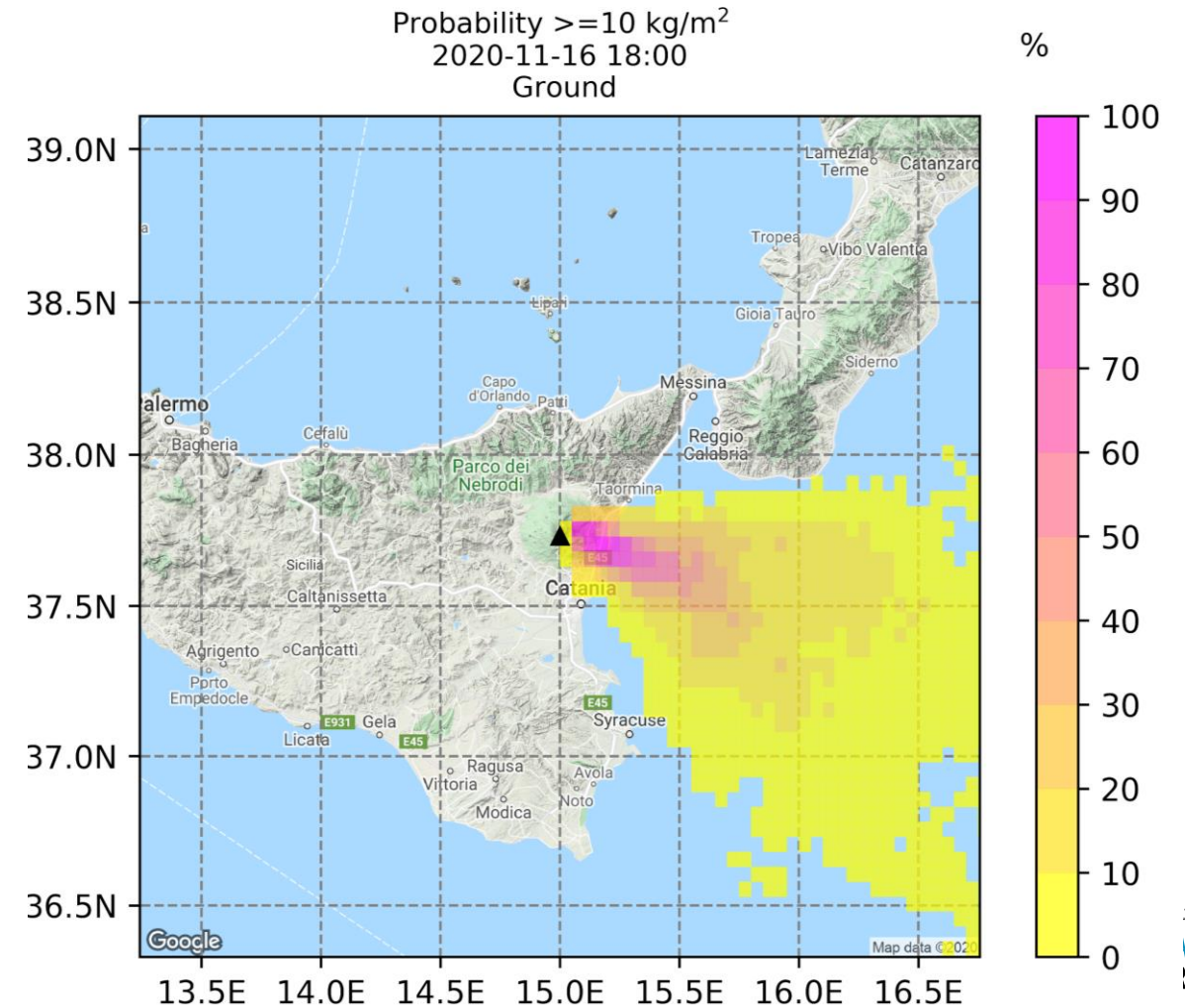
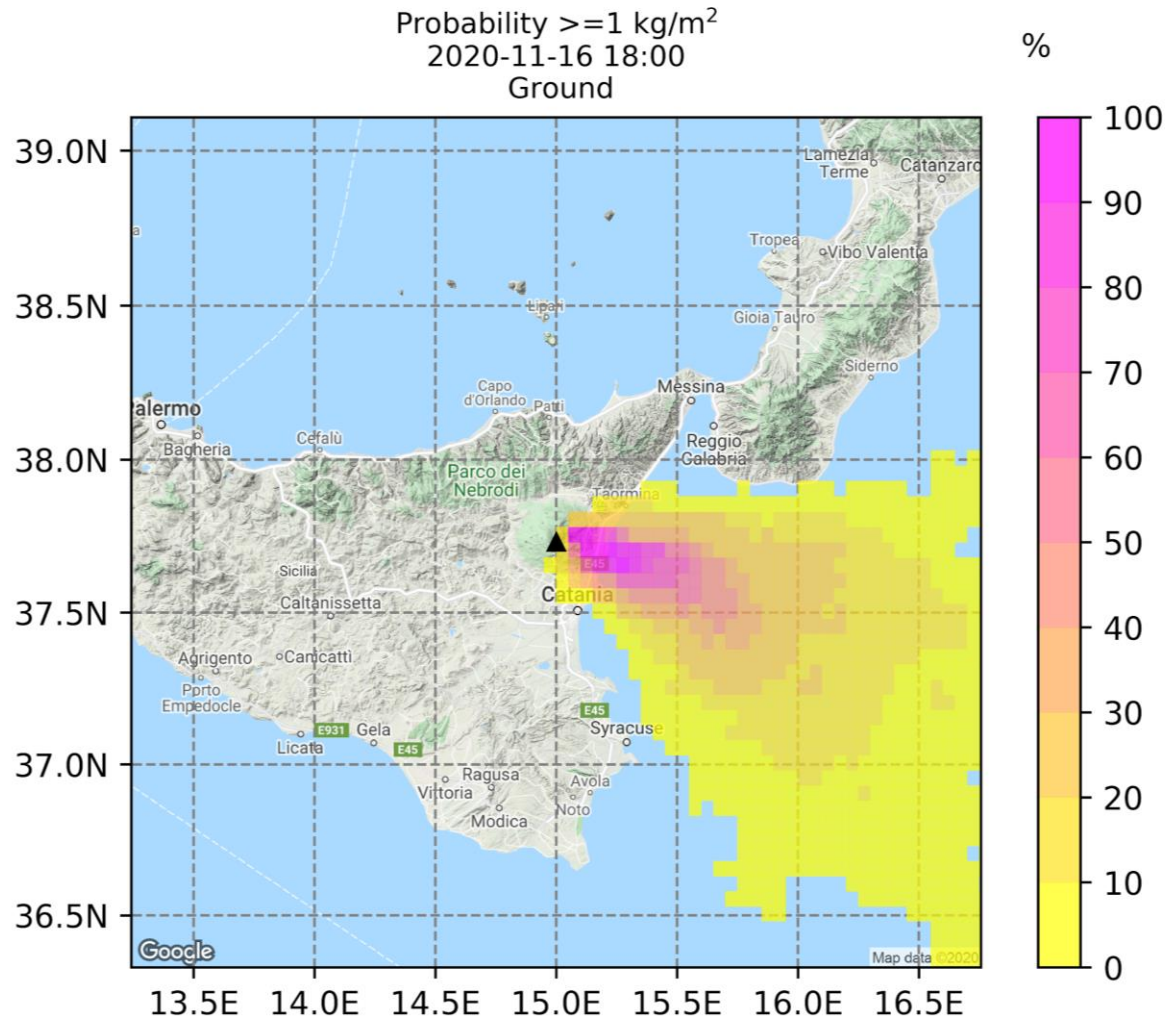
Eruptive scenario	Vona scenario
Column height	from the Vona or uniform pdf 2-8 km above the vent
TGSD mu	gaussian pdf: 2+-1 (Scollo et al., 2007)
TGSD sigma	gaussian pdf:1.5+-1 (Scollo et al., 2007)
Meteo data	ARPA-SIM
Nwind	10
Nesp	15
N	150

• SCIENTIFIC RATIONALE – Volcanic ash automated forecasting workflow at Etna

RESULTS: Daily forecast run at 09:00 on 16/11/2020

Strong scenario

Probability ash maps: ground loading

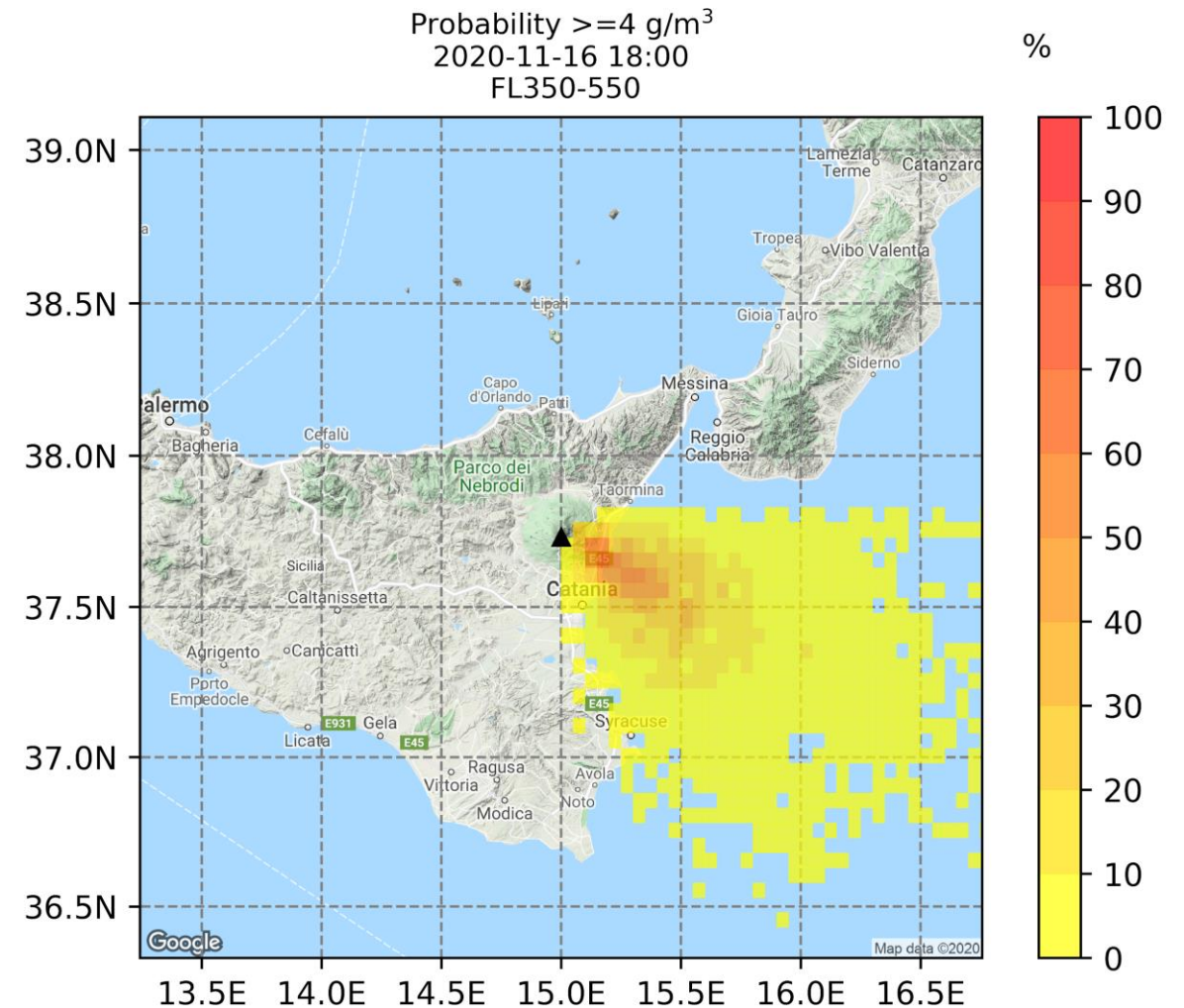
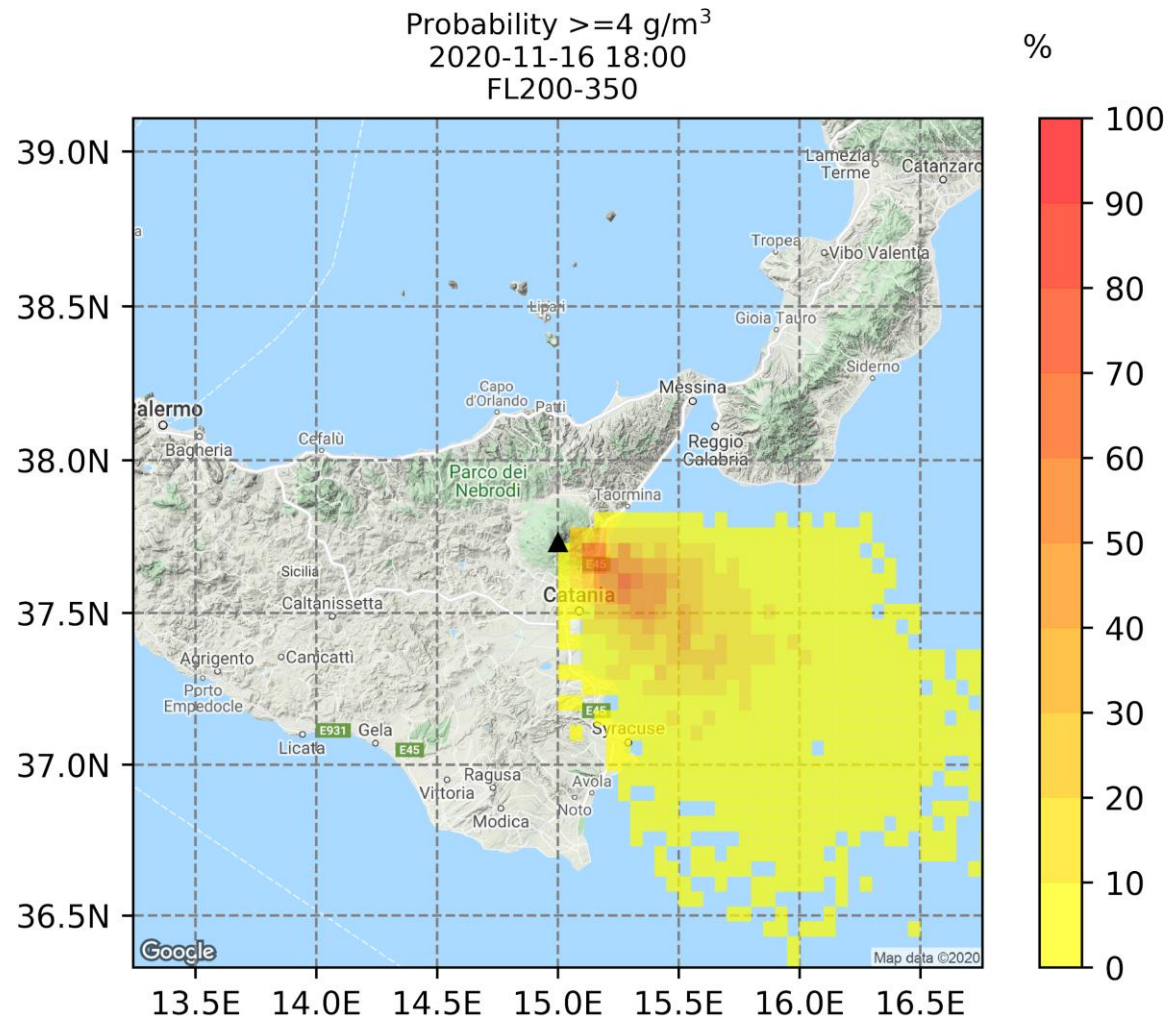


• SCIENTIFIC RATIONALE – Volcanic ash automated forecasting workflow at Etna

RESULTS: Daily forecast run at 09:00 on 16/11/2020

Strong scenario

Probability ash maps: atmospheric ash concentration between two flight levels (FL)

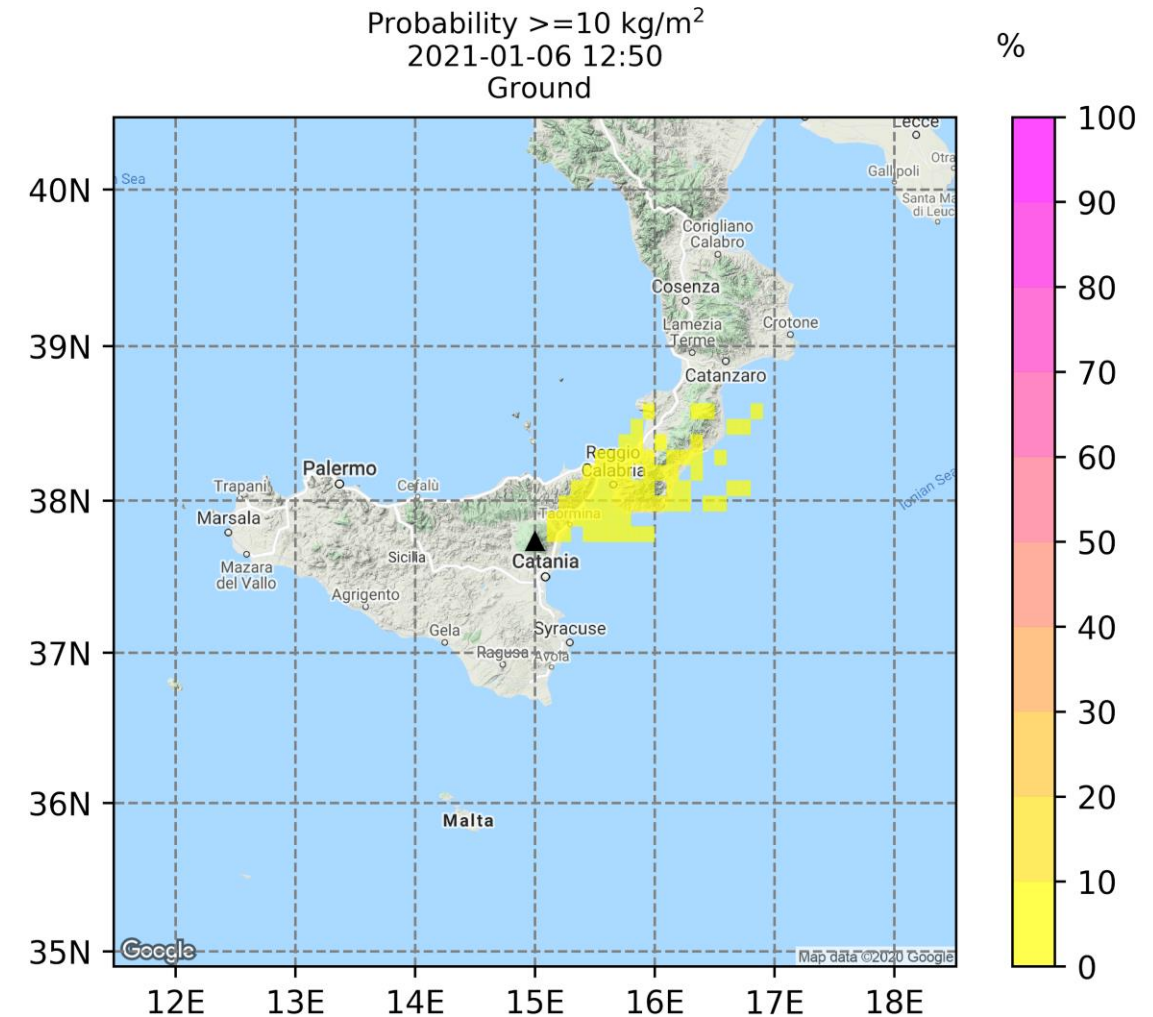
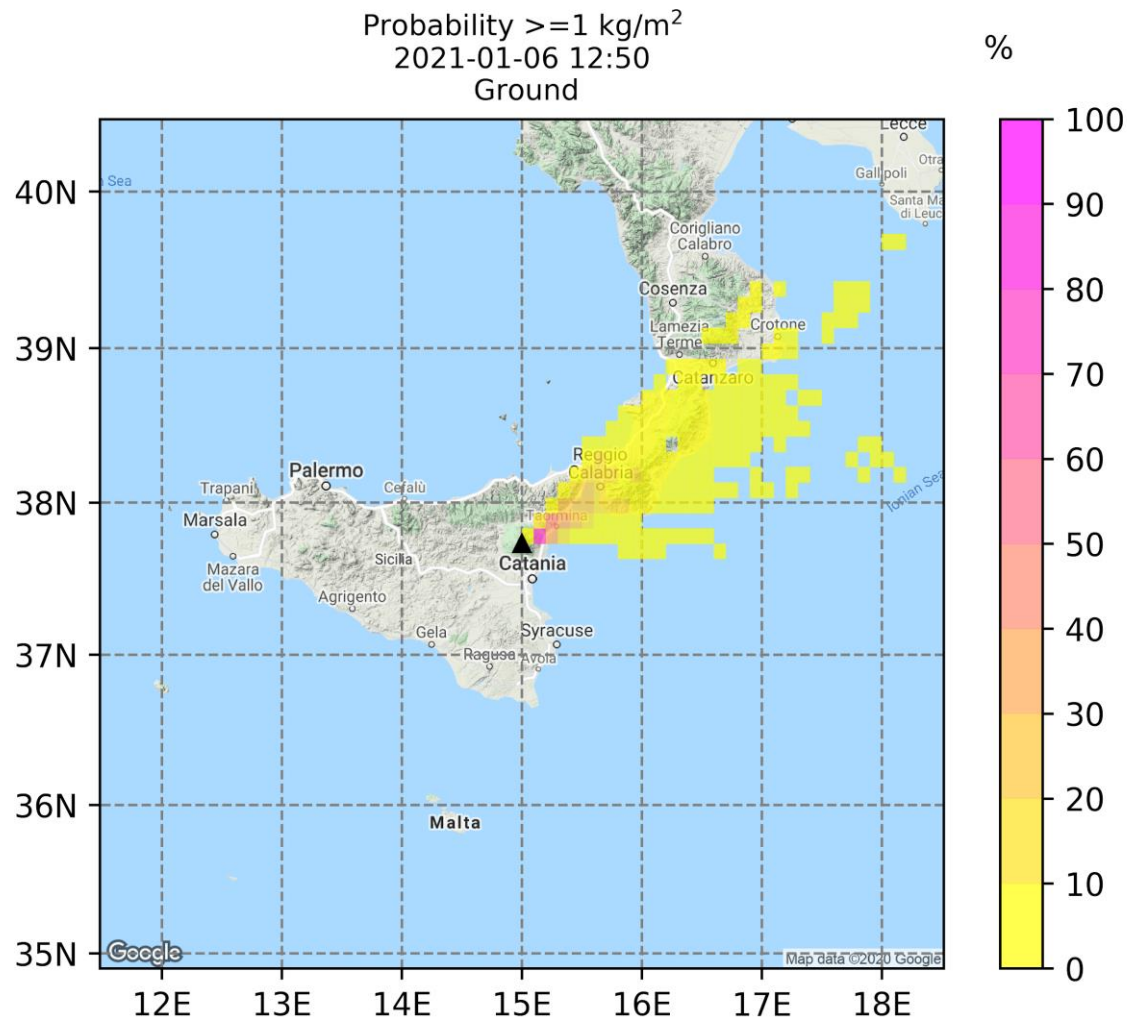


• SCIENTIFIC RATIONALE – Volcanic ash automated forecasting workflow at Etna

RED VONA bulletin issued on 06 January 2021 at 09:51 UTC

RESULTS: Real-time forecast
loading

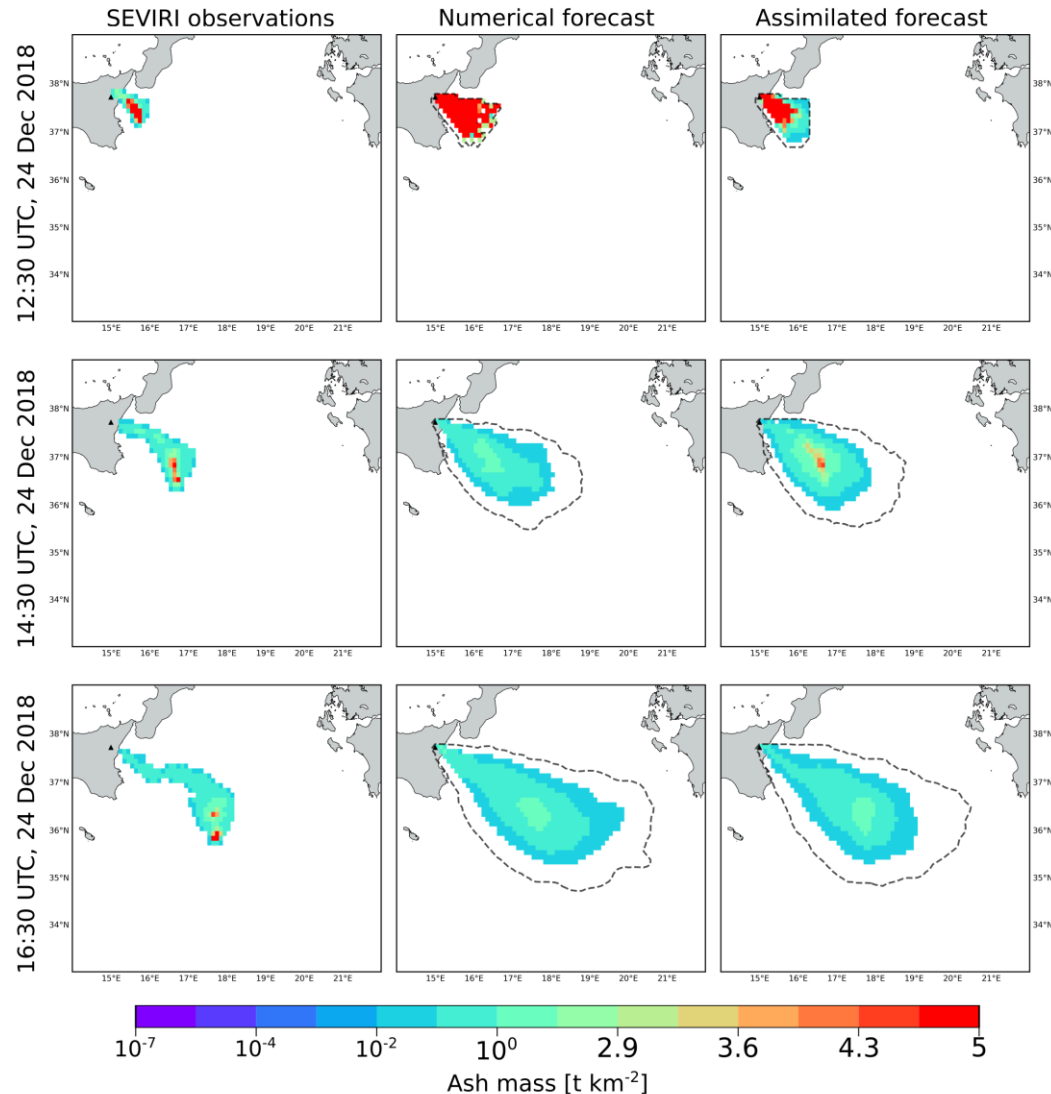
Probability ash maps: **ground**



• SCIENTIFIC RATIONALE – Volcanic ash automated forecasting workflow at Etna

Data-assimilation of satellite observations of atmospheric ash amount into Volcanic Ash Transport and Dispersal Models

(Pardini et al., 2020)



- Case study: explosive eruption occurred at Mt. Etna on 24 December 2018
- Ash dispersal is modeled with PLUME-MoM-TSM and HYSPLIT
- Ensemble-based Kalman Filters are applied to improve numerical forecasts by assimilating satellite observations of atmospheric ash amount.
- A new assimilated forecast is produced with minimized uncertainties with respect to numerical forecast and observations.

• OBSERVATIONAL INFRASTRUCTURE



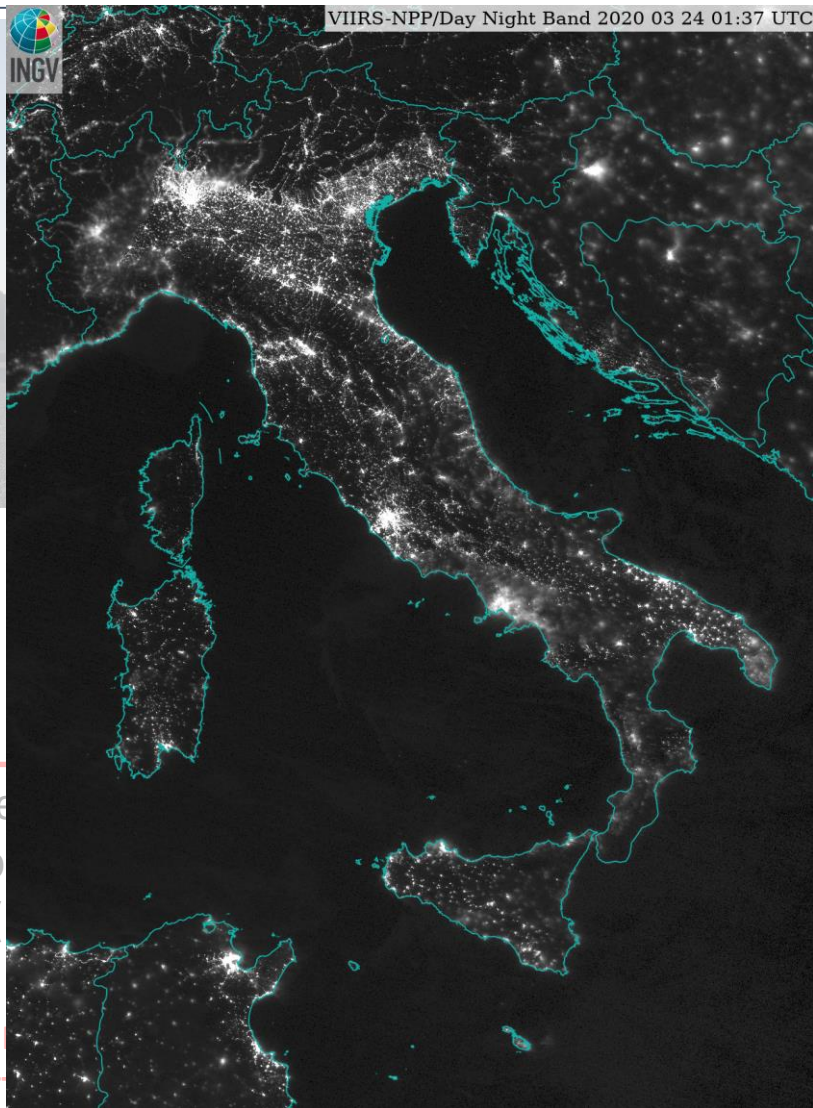
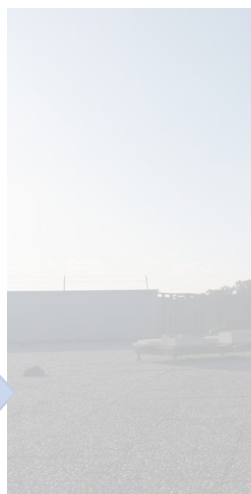
MAST MULTIMISSION
ACQUISITION SYSTEM

Reuse of 1.8 m

Nanometrics antenna,
from seismic stations
(Posta Fibreno-POFI)

Data reception reliability
99.9%

Soon, installation of a
second antenna for
redundancy



**Light Pollution During COVID-19
Lockdown Period (March 24, 2020).
VIIRS-NPP /Day Night Band**

<https://ingvambiente.com/2020/03/24/linquinamento-luminoso-dallo-spazio/>



Software for
data
elaboration



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Pia
AT

• OBSERVATIONAL INFRASTRUCTURE: Data Available in Near Real Time

RICEVUTI AD OGGI

SSMIS
RDS-EARS-ASCAT
RDS-EARS-ATMS
RDS-EARS-ATOVS
RDS-EARS-AVHRR
RDS-EARS-CrIS
RDS-EARS-IASI Level 1
RDS-EARS-IASI Level 2
RDS-EARS NWC
RDS-EARS VASS (Regional FY-3C Sounder Service)
N20 EARS-VIIRS
GDS-Multi-Metop Wind Products
GDS-Metop-B: AMSU-A Level 1
GDS-Metop-B: ASCAT L1 Sigma0 at Full Sensor Resolution **
GDS-Metop-B: ASCAT Soil Moisture
GDS-Metop-B ATOVS Sounding Products
GDS-Metop-B: AVHRR Level 1
GDS-Metop-B: AVHRR Polar Winds
GDS-Metop-B: GOME-2 Level 1 **
GDS-Metop-B: GRAS Level 1
GDS-Metop-B: HIRS Level 1
GDS-Metop-B: IASI Level 1: All Spectral Samples **
GDS-Metop-B: IASI Level 1: Principal Component Scores
GDS-Metop-B: IASI Level 1: Reduced Spectral Samples (500 channels)
GDS-Metop-B: IASI Sounding Products//Africa
GDS-Metop-B: IASI Sounding Products//Europe
GDS-Metop-B: MHS Level 1
GDS-Metop-C: AMSU-A Level 1
GDS-Metop-C: ASCAT L1 Sigma0 at Full Sensor Resolution **
GDS-Metop-C: AVHRR Level 1
GDS-Metop-C: AVHRR Polar Winds
GDS-Metop-C: GRAS Level 1
GDS-Metop-C: MHS Level 1
GDS-Metop-B Polar Multi-sensor Aerosol Product
GDS-NOAA-19: AMSU-A Level 1
GDS-NOAA-19: ATOVS Sounding Products
GDS-NOAA-19: AVHRR Level 1
GDS-NOAA-19: HIRS Level 1
GDS-NOAA-19: MHS Level 1
EPS-SERVICE
FMI Products
FY-2
All other Meteorological Products//Set 4//Europe/Africa
MODIS Products: Thinned Level 1 Products
0deg SEVIRI Level 1.5 Image Data: 1/4 hourly data transmissions
0deg SEVIRI Level 1.5 Image Data: 1/2-hourly data transmissions **
0deg SEVIRI Level 1.5 Image Data: 1-hourly data transmissions
IODC SEVIRI Level 1.5 Image Data: 1/4-hourly data transmissions **
IODC SEVIRI Level 1.5 Image Data: 1/2-hourly data transmissions **
IODC SEVIRI Level 1.5 Image Data: 1-hourly data transmissions

MODIS

All other Meteorological Products - IODC
All other Meteorological Products//Set 1//Europe/Africa
All other Meteorological Products//Set 3//Europe/Africa
All other Meteorological Products//Set 1//Europe only
All other Meteorological Products//Set 1//Global
All other Meteorological Products//Set 2//Europe/Africa
RSS Meteosat Meteorological Products
RSS Meteosat Meteorological Products
RSS SEVIRI Level 1.5 Image Data **
GDS-SNPP/NOAA-20: VIIRS EDR
MODIS Products: Global Ocean Colour Products
CM SAF Products
ROM SAF Products
H-SAF Products
H-SAF Products//Global
LSA SAF Products//Africa LSA SAF Products//Europe
LSA SAF Products//Global
LSA SAF Products//Americas
AC SAF Products//Africa
AC SAF Products//Europe
OSI SAF Products//Europe
OSI SAF Products//Global
UNS-general
VIIRS Fire Product
Copernicus Global Land service: Africa
Copernicus Global Land service: South and Central America
NCEP Products
RDS-EARS-ATMS
RDS-EARS-CrIS
RDS-EARS-VIIRS
GDS-Metop-A: AMSU-A Level 1
GDS-Metop-A: ASCAT L1 Sigma0 at Full Sensor Resolution **
GDS-Metop-A: ASCAT Soil Moisture
GDS-Metop-A: AVHRR Level 1
GDS-Metop-A: AVHRR Polar Winds
GDS-Metop-A: GOME-2 Level 1 **
GDS-Metop-A: GRAS Level 1
GDS-Metop-A: HIRS Level 1
GDS-Metop-A: IASI Level 1: All Spectral Samples **
GDS-Metop-A: IASI Level 1: Principal Component Scores
GDS-Metop-A: IASI Level 1: Reduced Spectral Samples (500 channels)
GDS-Metop-A: IASI Sounding Products//Africa
GDS-Metop-A: IASI Sounding Products//Europe
GDS-Metop-A: MHS Level 1
GDS-Metop-A: Polar Multi-sensor Aerosol Product
GDS-SNPP/NOAA-20: ATMS SDR
GDS-SNPP/NOAA-20: CrIS SDR
GDS-SNPP/NOAA-20: ATMS SDR
GDS-SNPP/NOAA-20: CrIS SDR
Aeolus Level 2 Products

SEVIRI

VIIRS

GOES-East (GOES-16) ABI Level 2 Products
GOES-East (GOES-16) GLM Level 2 Products
GOES-East (GOES-16) ABI 10 minute image data
GOES-East (GOES-16) Space Weather Data
GOES-East (GOES-16) Space Weather EXIS and SUVI products
GOES-West (GOES-17) GLM Level 2 Products
GOES-West (GOES-17) ABI 10m image data
GOES-West (GOES-17) ABI half-hourly image data
Himawari-8 10-minute image data

RICEVUTI CON L'IMPLEMENTAZIONE DELLA NUOVA PARABOLA

S3A OLCI L1B Reduced Resolution NRT
S3B OLCI L1B Reduced Resolution NRT
S3A OLCI L2 Ocean Colour Reduced Resolution
S3B OLCI L2 Ocean Colour Reduced Resolution
SSP L2 Aerosol Index
SSP L2 Aerosol Layer Height
SSP L2 CLOUD Cloud Fraction Albedo top Pressure
SSP L2 Carbon Monoxide
SSP L2 HCHO Formaldehyde Total Column
SSP L2 NO2 Nitrogen Dioxide
SSP L2 O3 Ozone Total Column
SSP L2 SO2 Sulphur Dioxide
S3A SLSTR L2 Aerosol Optical Depth
S3B SLSTR L2 Aerosol Optical Depth
S3A SLSTR L2 Fire Radiative Power
S3B SLSTR L2 Fire Radiative Power
S3A SLSTR L2 Sea Surface Temperature NRT
S3B SLSTR L2 Sea Surface Temperature NRT
SNPP Marine Products
SNPP Atmospheric Products

RICEVUTI CON L'IMPLEMENTAZIONE DI TERRESTRIAL

S3B OLCI L1B Full Resolution NRT
S3A OLCI L2 Ocean Colour Full Resolution NRT
S3B OLCI L2 Ocean Colour Full Resolution NRT
SSP - Solar Irradiance Measurements - SWIR module
SSP - Consolidated Earth Radiances Measurements
SSP - Solar Irradiance Measurements - UVN module
SSP L2 Aerosol Index
SSP L2 Aerosol Layer Height
SSP L2 CLOUD Cloud Fraction Albedo top Pressure
SSP L2 Carbon Monoxide
SSP L2 HCHO Formaldehyde Total Column
SSP L2 NO2 Nitrogen Dioxide
SSP L2 O3 Ozone Total Column
SSP L2 SO2 Sulphur Dioxide
S3A SLSTR L1B NRT
S3B SLSTR L1B NRT

SLSTR

- **PRODUCTS AVAILABLE**

Products	Sensors/Models	Availability (MAST)
Ash/Ice/SO ₂ detection maps	SEVIRI, MODIS, VIIRS, SLSTR	Real Time
Ash/Ice/SO ₂ retrievals	SEVIRI, MODIS, VIIRS, SLSTR	On Demand
Ash/Ice/SO ₂ fluxes	SEVIRI, MODIS, VIIRS, SLSTR	On Demand
Volcanic cloud (plume) top heights	SEVIRI, MODIS, VIIRS, SLSTR	On Demand
Ash hazard forecast maps (on ground and atmosphere)	HYSPLIT (work in progress: simulations with FALL3D and DA with EO data from space)	Daily Forecast / Real time

• CURRENT DISTRIBUTION OF PRODUCTS



Date
2021-06-09

Hour: 13

Minutes: 15

Dataset
IR_108

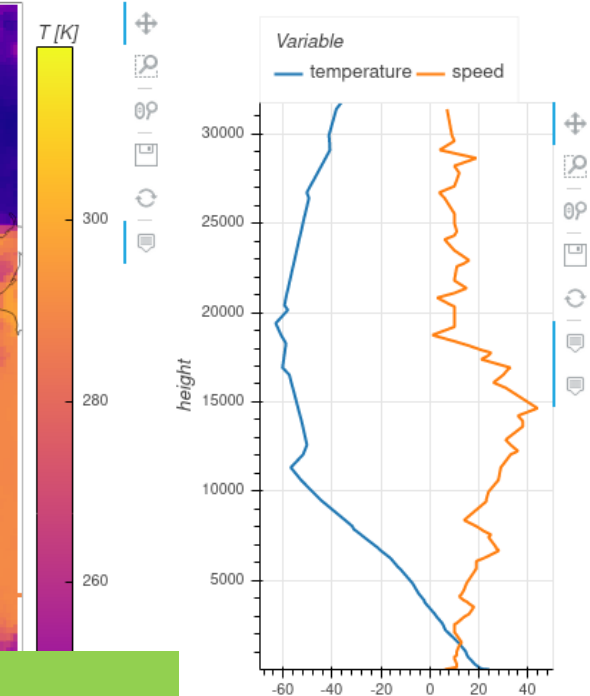
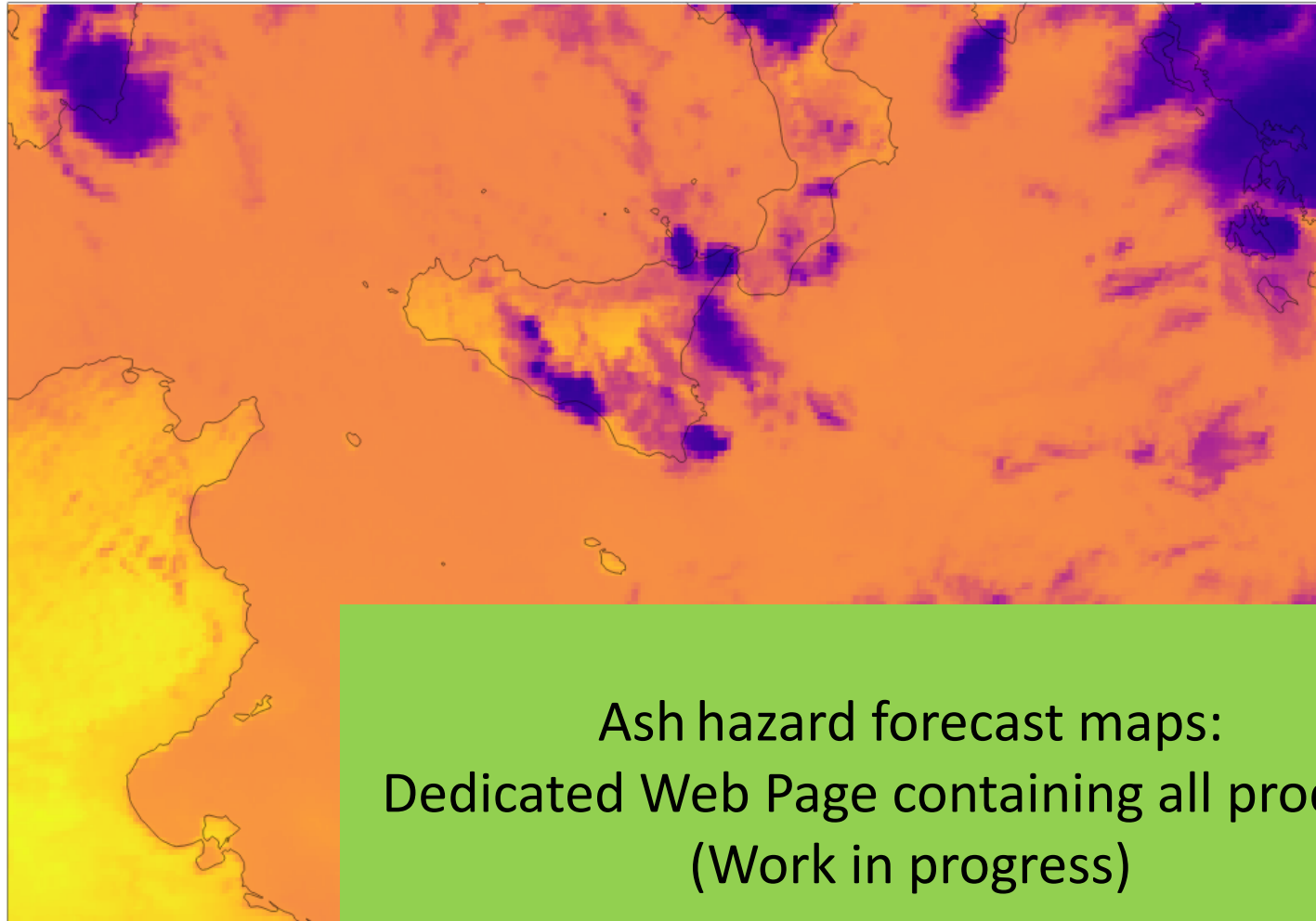
Platform
MSG4

Area
Etna

Tiles
False

Color
Plasma

Status. If it is not white, it is working



Ash hazard forecast maps:
Dedicated Web Page containing all products
(Work in progress)

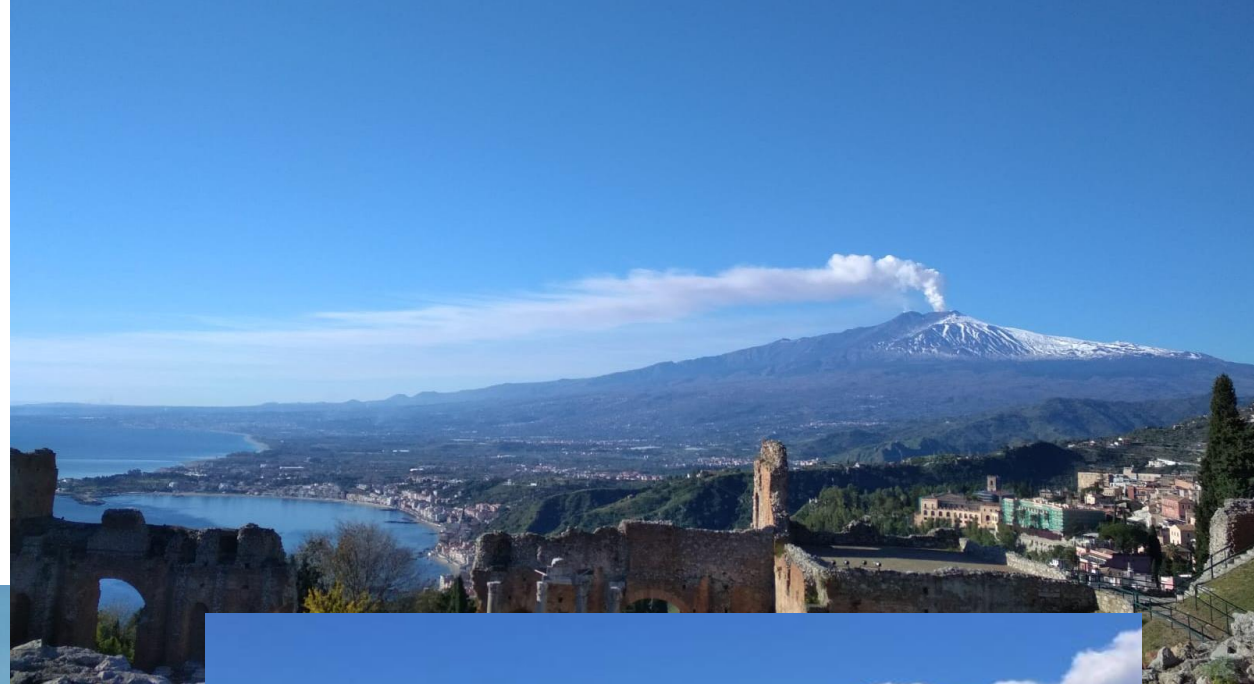
- PROGRAMS/PROJECTS OF REFERENCE

	Name	Deadline
European	FP7-Aphorism	-
	FP7-EVEREST	-
	FP7-EUROVOLC	2021
	ESA-VISTA	2021
	H2020-RELIANCE	2022
INGV	FISR	-
	Ash-resilience	2021
	Pianeta-Dinamico 1 (PD1), Task V3	2022
	PD2-ATTEMPT	2023
	DPC All.A	2020 founding

- TEAM AND AFFILIATIONS

Name	Affiliation
Corradini Stefano	Roma-ONT
Merucci Luca	Roma-ONT
Guerrieri Lorenzo	Roma-ONT
Stelitano Dario	Roma-ONT
Pardini Federica	Pisa
Costa Antonio	Bologna
De Michieli Vitturi Mattia	Pisa
Esposti Ongaro Tomaso	Pisa
Macedonio Giovanni	Napoli
Neri Augusto	Pisa

Thanks for your attention



- INFRASTRUCTURE FOR DATA MANAGEMENT AND PROCESSING

