SIMULATION OF AT-SENSOR RADIANCE OVER VOLCANOES FOR NIRST SENSOR

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7th Aquarius/SAC-D Science Meeting, 11-13 April 2012, Buenos Aires , Argentina

Overview

- SAC-D AO proposal
- Volcanic thermal phenomena characteristics and monitoring capability of current EO missions
- First results of simulation data
- 10 years of thermal analysis of volcanoes
- ASI pre-operative project for volcanic risk management.

SAC-D AO proposal

INGV Contribute to SAC-D scientific applications:

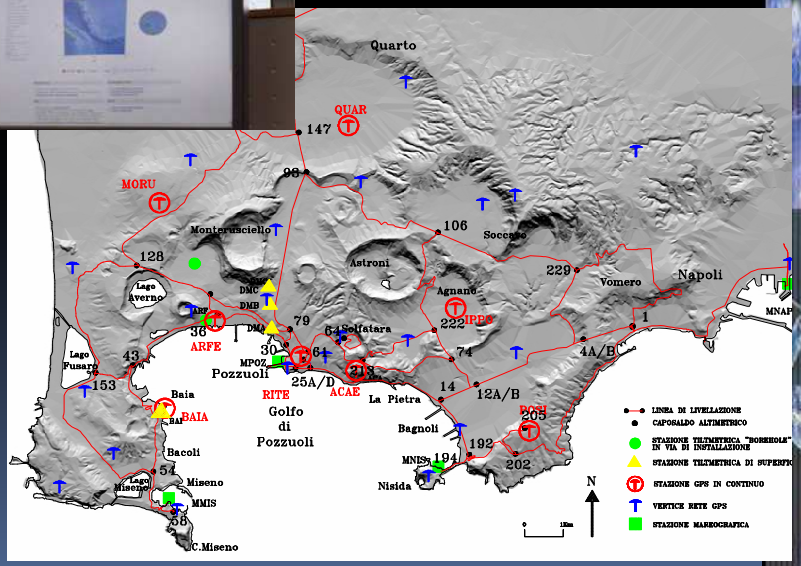
INGV team contributes to the analysis of the **New IR Sensor Technology (NIRST)** characteristics to use its capabilities to monitor the volcanic phenomena and participate to operational systems with particular focus on Italian and European volcanoes.

The analysis of products retrieved by SAC-D sensors is very important to foreseen an operational use of the mission in the monitoring procedures of Users such as Civil Protection and Volcanic Observatories.

The INGV team is very interested to collaborate with Argentina scientific groups working on volcanic applications and monitoring

The INGV develops and mantains an Integrated Monitoring System to monitor seismic and volcanic activities at local and national level

In the last years the INGV Remote Sensing Group has developed procedure to support Italian Civil Protection activities to monitor volcanic and earthquake related phenomena by means of integrated space and ground observations



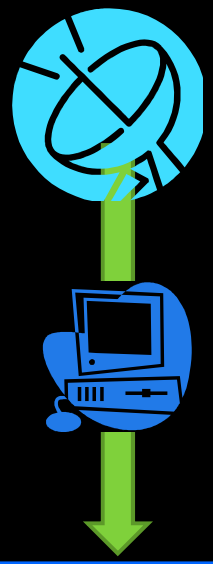
At the beginning of 2011 MS2RWS has been put in “test-operation” providing RT monitoring of Italian volcanoes

MS2RWS

system dedicated for early warning for Italian active volcanoes.

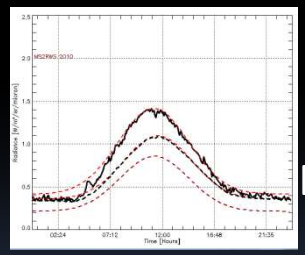
Radiance acquired by the SEVIRI 4th channel (strongly sensible to the thermal variation)

288 per day or 96 per day data



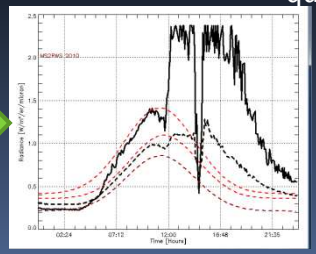
Application on volcanoes in: Italy, Spain, Iceland, Greece,…

Geo-referenced Radiance SEVIRI data → 4th channels extraction → MS2RWS

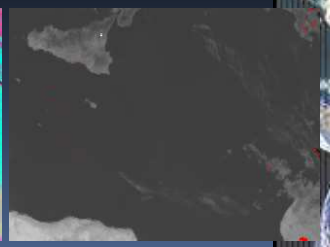


NO Eruption

Eruption



Video-Like products Decorrelation Stretch and BDT (respectively for SO2 and ASH quantitative estimation)



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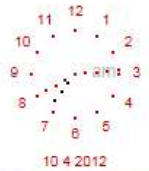
Rapid Response Web Service (MS2RWS)

Mt. Etna: Lat: 37° 45' 17", Lon: 14° 59' 44" , Height: 3300 m A.S.L.

Monitoring activity of Mt ETNA

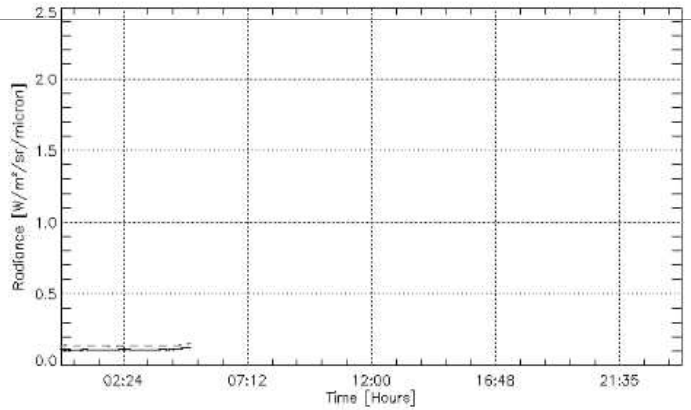
The following graphics show the radiance values and brightness temperature values derived from MSG-SEVIRI data. Each curve represents the values derived from the pixel overlapping Mt Etna

GMT



Radiance daily variation analysis by means of SEVIRI 4th channel

(3.9 micron, MSG-SEVIRI)



Black line is obtained by using the radiance value of the pixel centered over Mt Etna.

Dashed line is obtained by using the maximum value of the averaged 24 surrounding pixels

Mt Etna (from Google Earth) and pixels position : A 5*5 matrix has been defined using SEVIRI data with a ground resolution of about 5 km (N-S) and 4 Km (E-W). Dark gray indicates the centered pixel (black line in the graphs) and pale gray indicates the 24 surrounding pixels (dashed line in the graphs)

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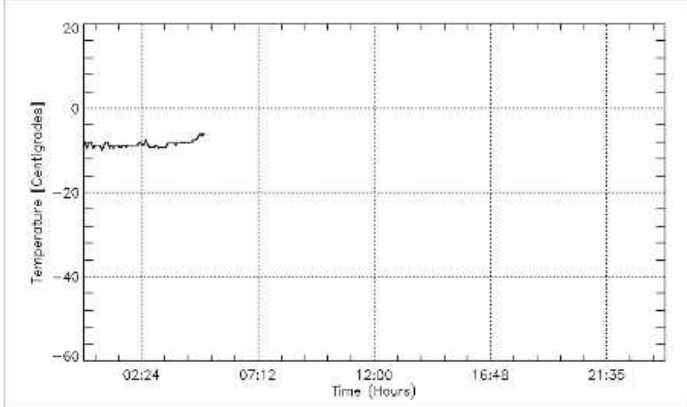
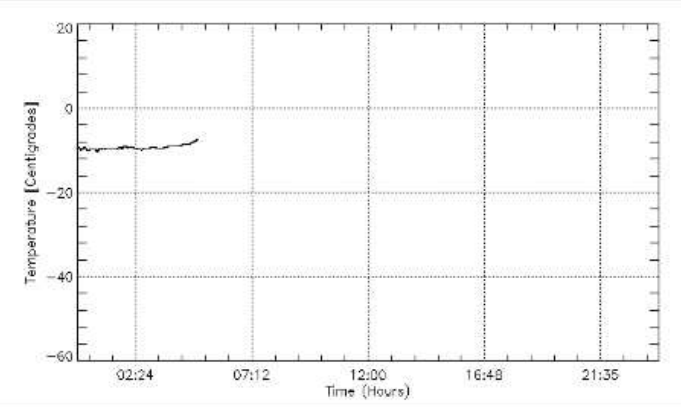
(3.9 micron, MSG-SEVIRI.)

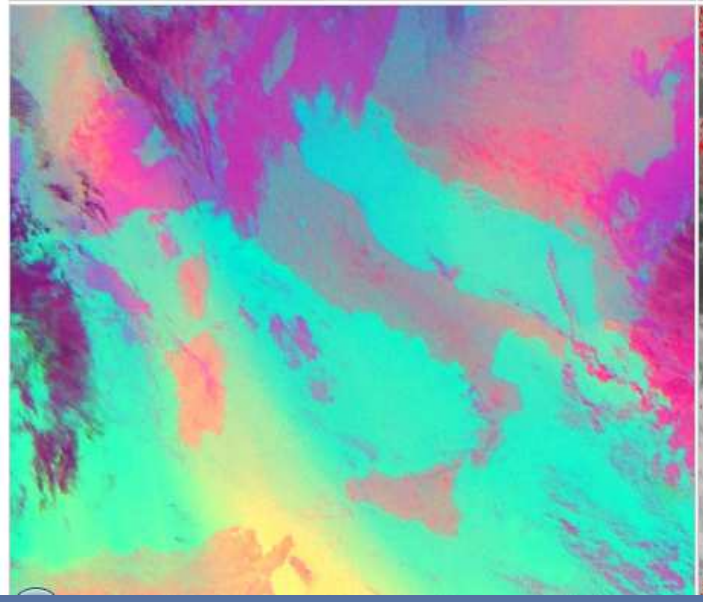


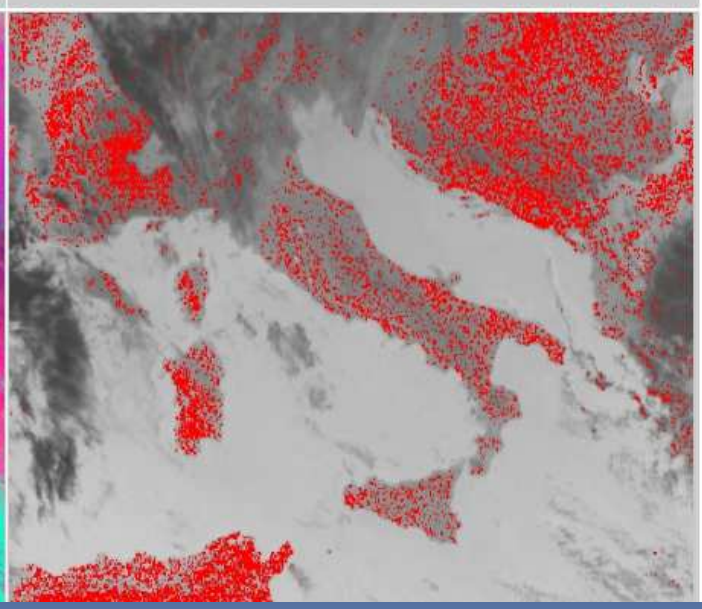
(10.8 micron, MSG-SEVIRI.)



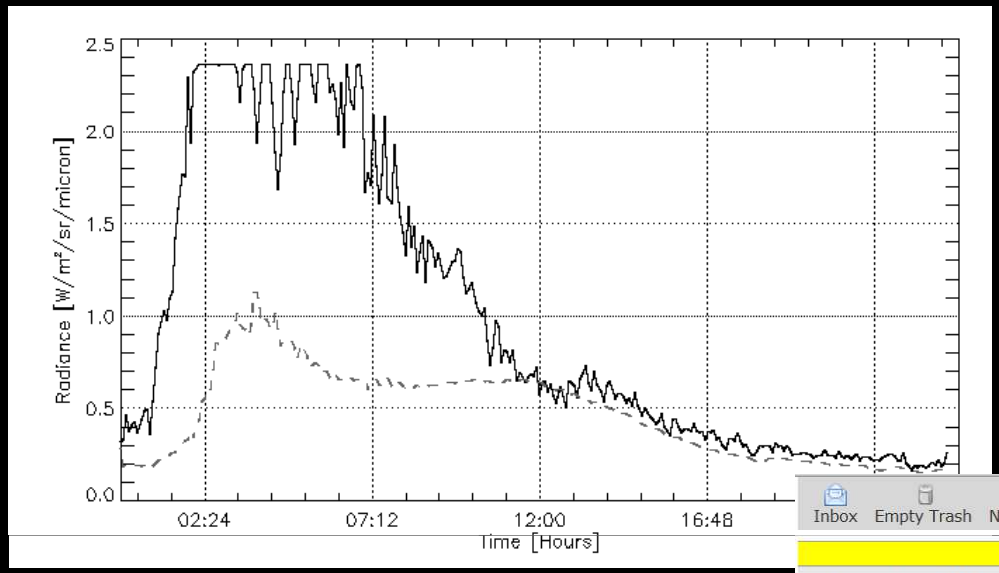
Preliminary SO2 detection analysis:
Pseudo color image generated by means of decorrelation stretch procedure using the MSG-SEVIRI channel 6, 7 and 9 centered respectively at 7.3, 8.7 and 10.8 microns. Due to the strong SO2 absorption in channels 6 and 7, the technique can be used to identify the volcanic SO2 clouds.

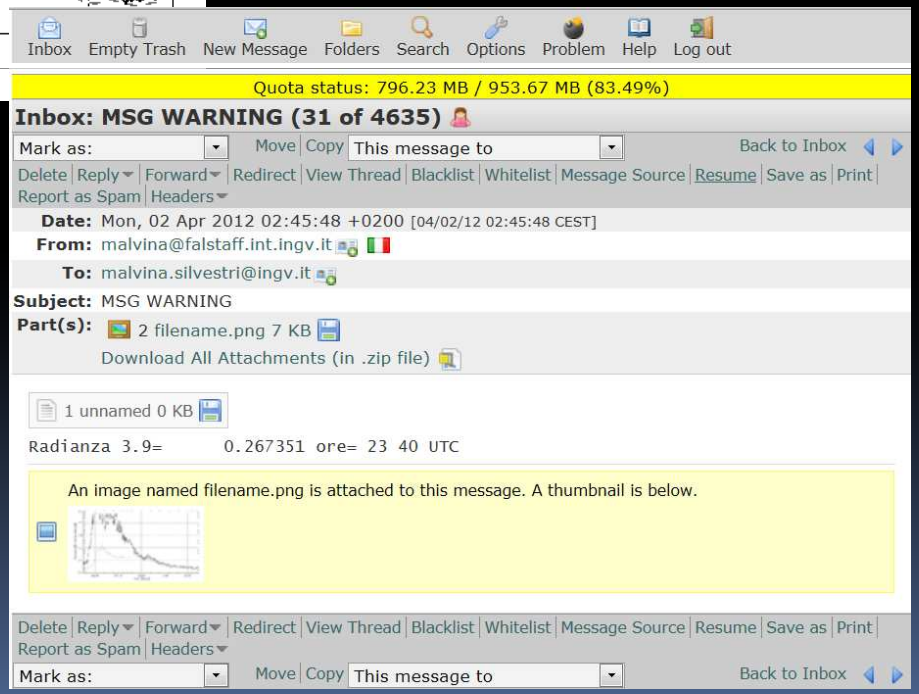
Preliminary ASH detection analysis:
Brightness temperature difference (BTD) image obtained by using the MSG-SEVIRI channels 9 and 10 centered around 10.8 and 12 microns. Negative BTD values (red pixels) may be indicative of a volcanic ash clouds presence.





Last event on Mt. Etna, 02/04/2012



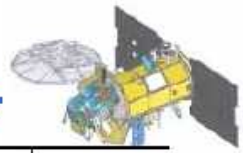


7th Aquarius/SAC-D Science Meeting, 11-13 April 2012, Buenos Aires , Argentina

AQUARIUS/SAC-D INSTRUMENTS CONSIDERED IN THE PROPOSAL

AQUARIUS/SAC-D

SAC-D Instruments Overview



INSTRUMENT	OBJECTIVES	SPECIFICATIONS	RESOLUTION	OWNER
Aquarius	Understanding ocean circulation, global water cycle and climate interaction. Soil moisture over Argentina	Integrated L- Band radiometer (1.413 Ghz) and scaterometer (1.26 Ghz) swath: 390 km	Three beams:76 x 94, 84 x 120, 96 x 156 km	NASA
MWR Microwave Radiometer	Precipitable water, winds speed, sea ice concentration, water vapour, cloud liquid water	Bands: 23.8 Ghz V Pol. and 36.5 Ghz H and V Pol. Band widht: 0.5 and 1 Ghz	Sixteen beams < 47 km	CONAE

New IR Sensor Technology (NIRST), provided by CONAE (Argentina) with CSA (Canadian Space Agency) participation: It will work at the following bands: 3.8, 10.85 and 11.85 µm

High Sensitivity Camera (HSC), provided by CONAE (Argentina): This camera will operate at 490-610 nm.

Radio Occultation Sounder for Atmosphere (ROSA), provided by ASI (Italy): To measure the atmospheric (troposphere and stratosphere) temperature, humidity and pressure profiles

TDP	Position, velocity and time inertial angular velocity determination	GPS receiver Inertial Unit Reference	Position: 20m, velocity:1m/sec Angular Random Walk: 0.008 deg/sqrt h	CONAE

Section "04" – Science Overview; S. Torrusio
Mission & Observatory CDR

10 of 27
2008

MAIN PROJECT PHASES:

- Analysis for the radiometric and acquisition characteristic of SAC-D mission furnished by CONAE and NASA for NIRST, HSC and ROSA sensors. Selection of test cases to be used in the NIRST data simulation for volcanic areas.
- Algorithms selection to retrieve HTE parameters for volcanic phenomena. Simulation of the NIRST/SAC-D data by means of existing data on the test areas (Etna, Stromboli volcanoes). Testing the NIRST on FIRES
- Analysis of atmospheric correction algorithms which uses modeled atmospheric parameters (MODTRAN) and local measurements.
- Analysis of ROSA retrieved data to assess their assimilation into the atmospheric correction procedures
- Planning of field campaign for calibration and validation purposes. **NEXT CAMPAIGN ON JUNE 2012 on Mt. Etna**
- Organization of seminars to spread the knowledge on the results obtained to the scientific community and user community.

Volcanic Phenomena Thermal Characteristics and…

Parameters	Satellite Obs. technique	Observational parameters	Typical range	Auxiliary parameter for retrieval alogrithms
Lava flow thermal characterization	Medium/High resolution IR mapping	Lava temperature	800-1500 K	Emissivity (ground) H_2O (atmospheric) CO_2 (atmospheric)
		Crust temperature	300-420 K	
Plume SO_2 emission	Medium resolution TIR mapping	Temperature	300-335 K	Emissivity (ground) H_2O (atmospheric) CO_2 (atmospheric)
		SO_2 concentration	0.01-0.05 g/m^2	
Pre-eruptive thermal anomaly	Medium/High resolution TIR mapping	Temperature	275-310 K	Emissivity (ground) H_2O (atmospheric) CO_2 (atmospheric)
Lava flow evolution	Multi-temporal low/med resolution IR mapping	Lava flow temperature	600-1500 K	Emissivity (ground) H_2O (atmospheric) CO_2 (atmospheric)
		Environmental temperature	290-310 K	

…Monitoring capability of current EO missions

Target of monitoring	Data	Sensor/platform Availability
Thermal Anomalies pre-eruptive	TIR	ASTER AIRBORNE SENSORS
Lava flow thermal Charcteristics	SWIR-MIR-TIR	AVHRR, AATSR, ASTER, MODIS, MSG, HYPERION AIRBORNE SENSORS
Volcanic Ash	VNIR-SWIR TIR UV	AVHRR, MSG, TOMS, MERIS, GOME MODIS, MISAR AIRBORNE SENSORS
Gases Composition and Flux (SO2)	UV-IR	TOMS, AIRS, SCIAMACHY,OMI ASTER, MODIS, MSG, HYPERION AIRBORNE SENSORS

THE AVAILABLE SPACE SWIR-TIR SENSOR RANGE FROM 30m to 1km

30 METERS

90 METERS

?

MODIS

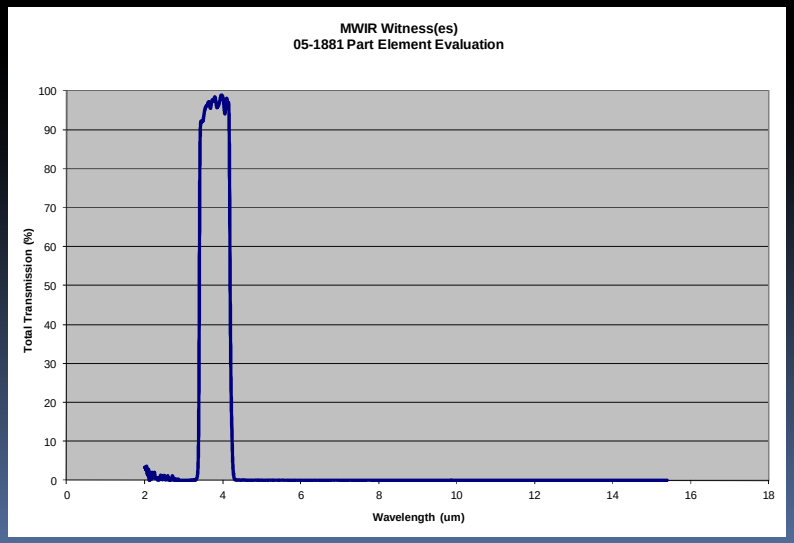
1 KM

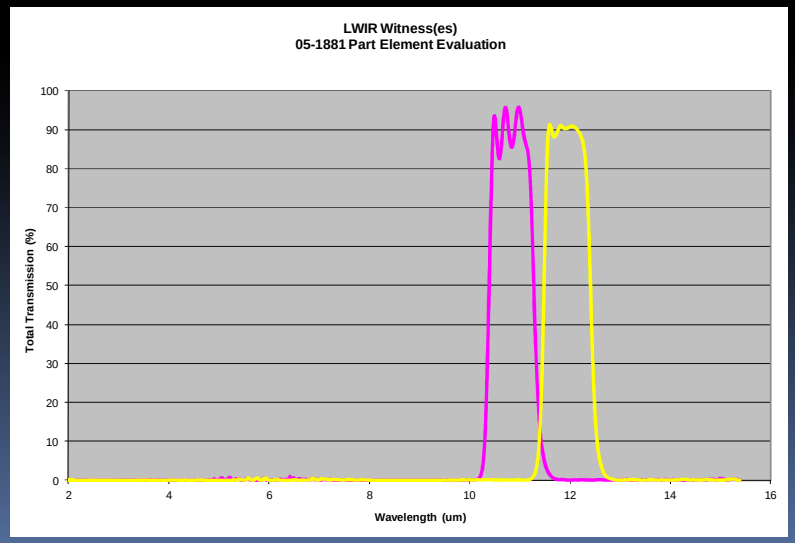
First results of simulation data

SIMULATED IMAGE HAVE BEEN PRODUCED TO TEST NIRST RADIOMETRIC CHARACTERISTICS

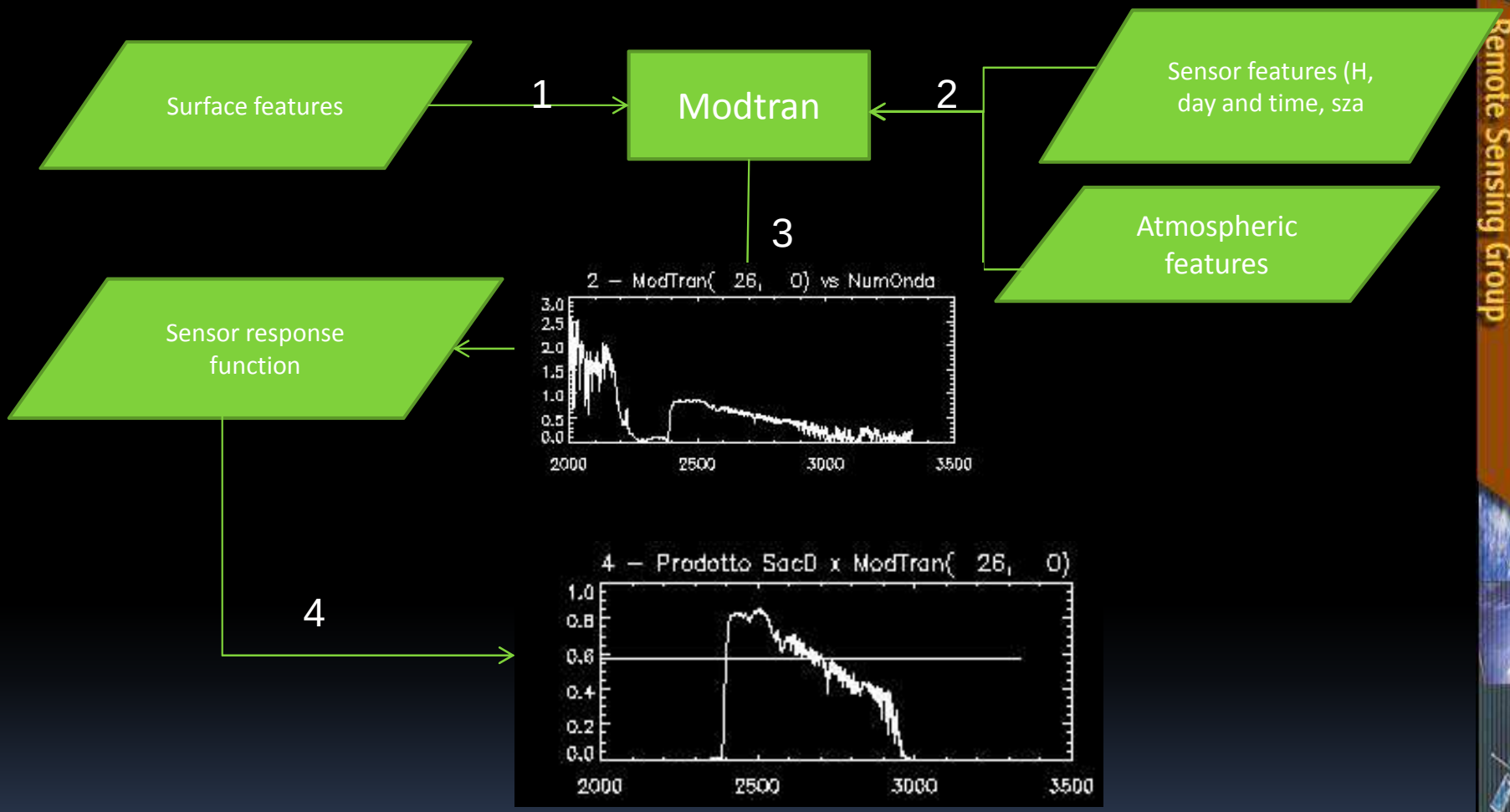
Simulation of NIRST images

- Starting from the identified observation scenarios, a set of simulated images have been generated to be used to highlight limitations and improvements with respect to the real data available
- Lava flow monitoring scenarios have been selected by using real conditions observed during Etna or Stromboli eruptions. Data set of satellite/airborne data have been used to verify the simulation
- Considering the Response Function of NIRST sensor:





Simulator scheme

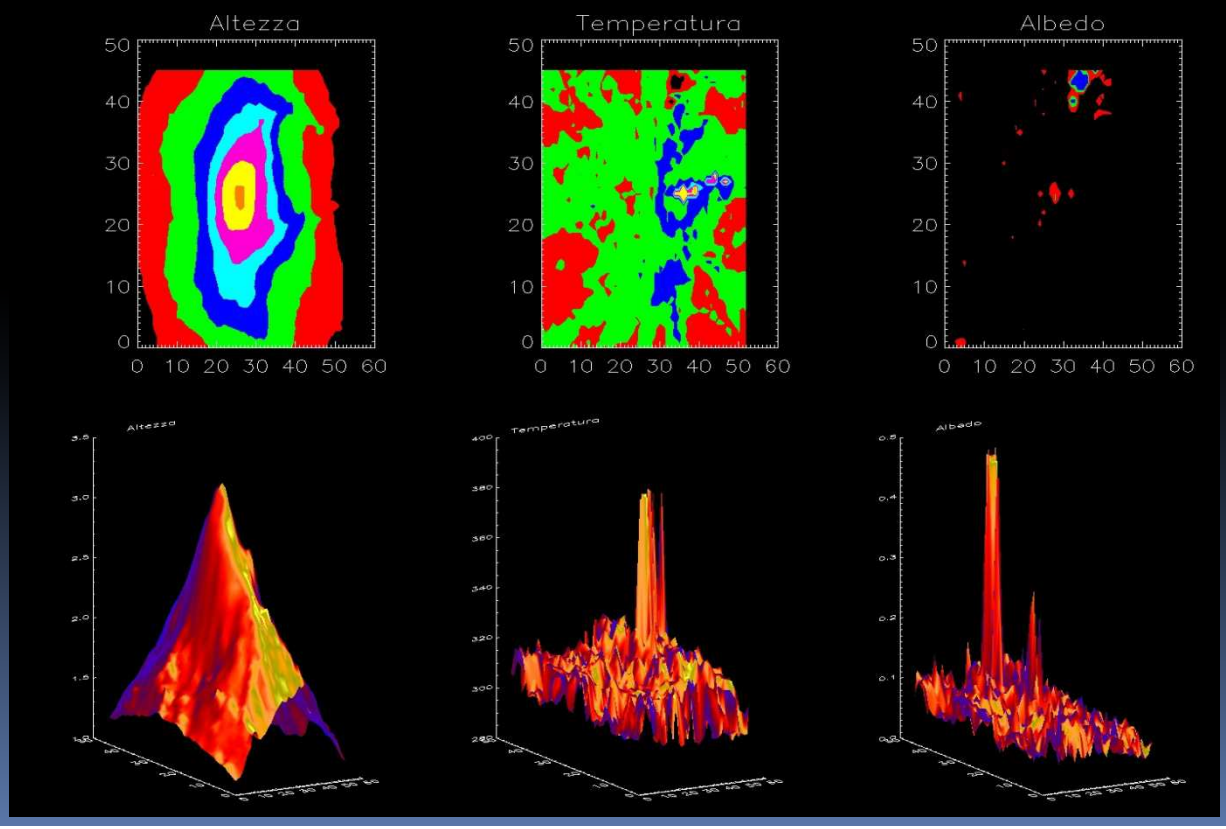


Input

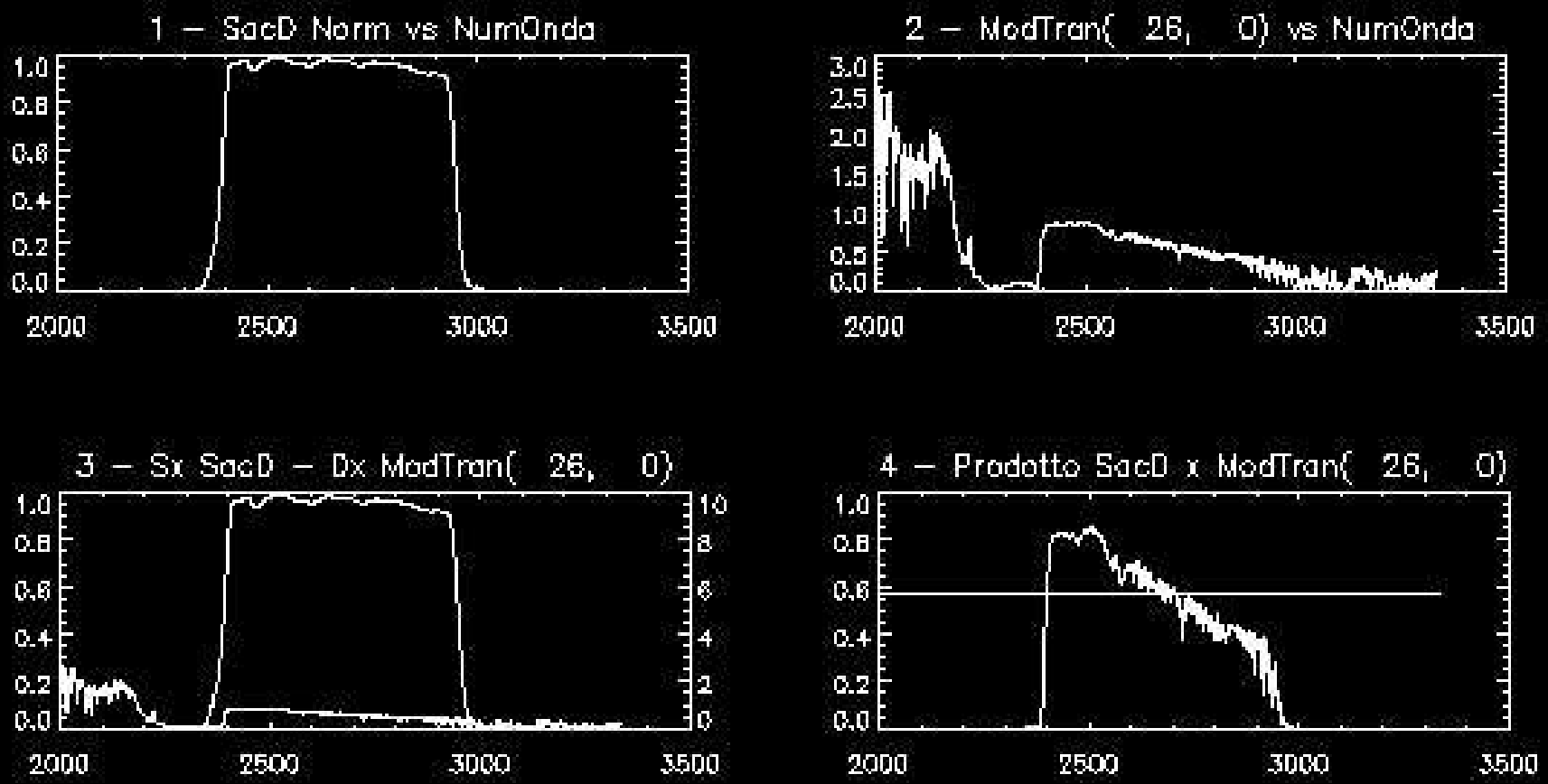
By RTM-MODTRAN, radiative transfer model simulations have been produced, each simulation represents single pixel.

Main information used in input:

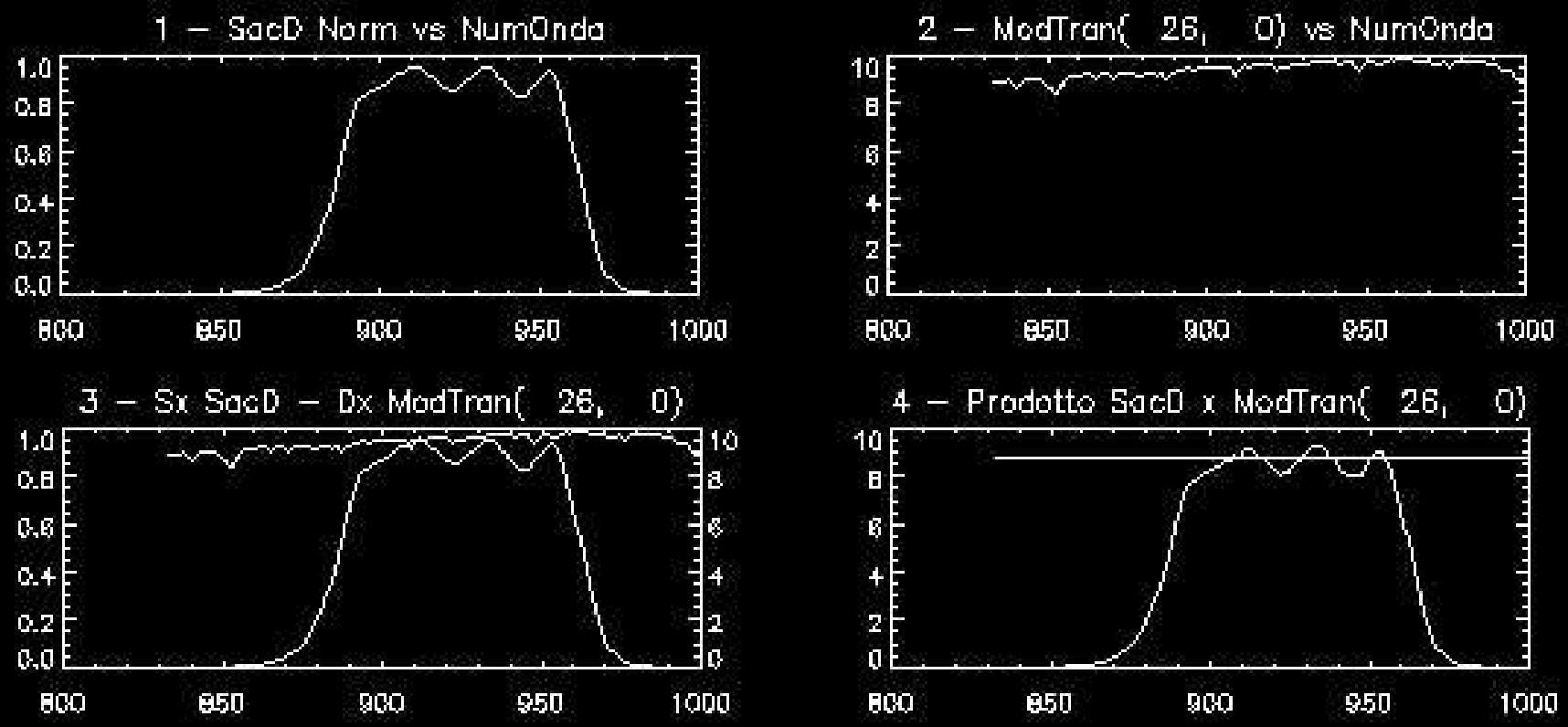
- Atmospheric Model: Mid latitude Summer (Latitudine 45° Nord)
- DEM
- Surface temperature map
- Albedo
- Satellite: 650 Km



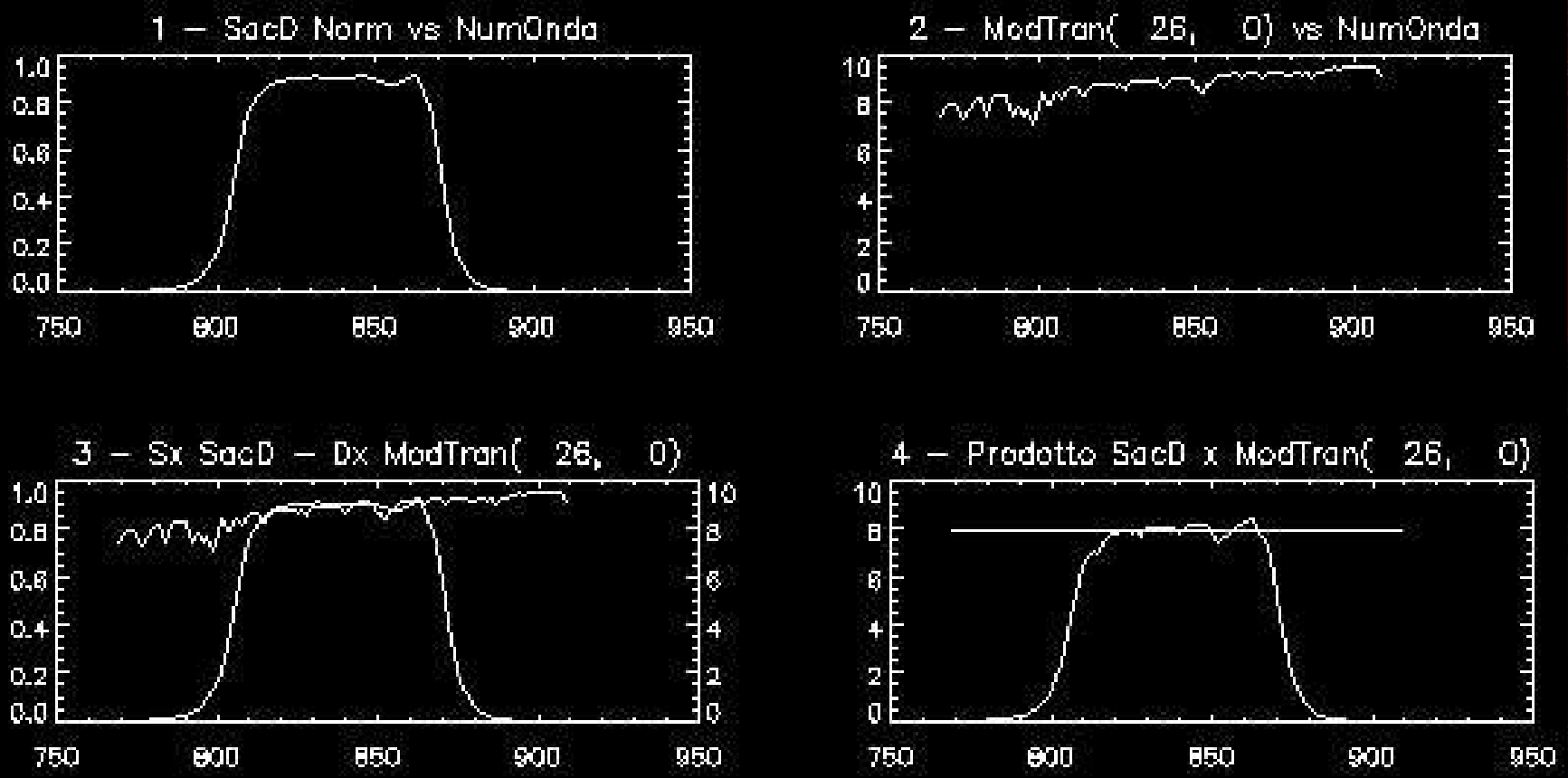
Output:
Spectral simulation: 3 – 5 micron



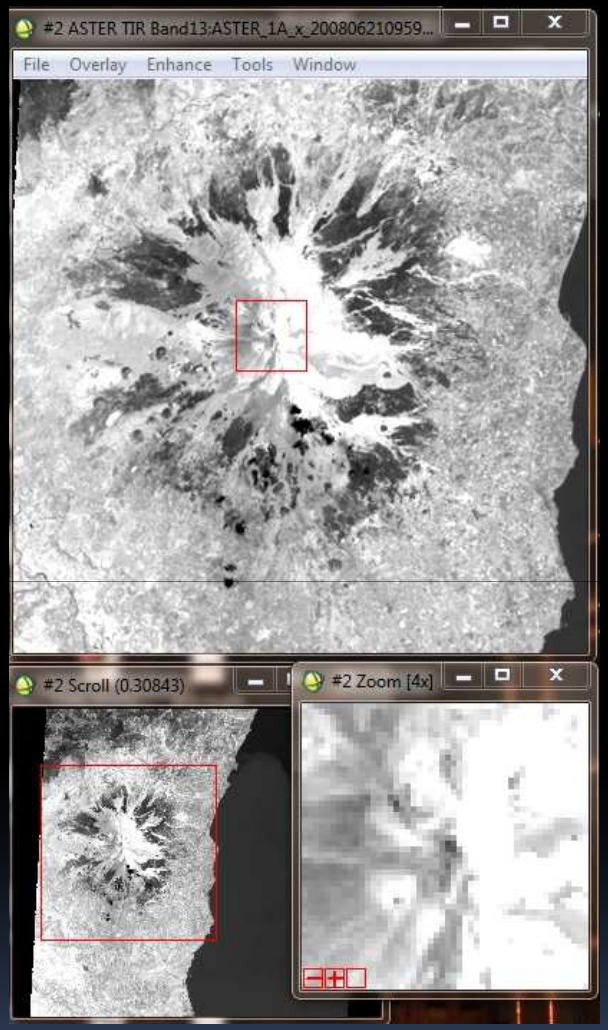
Output:
Spectral simulation: 10 – 12 micron



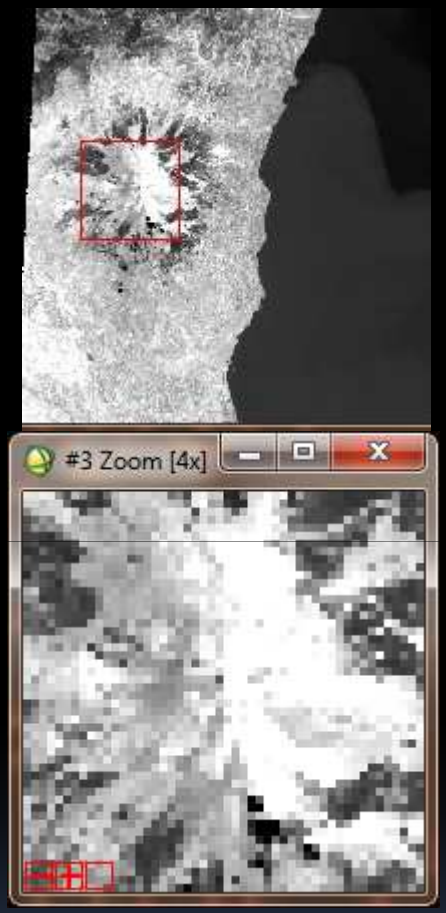
Output:
Spectral simulation: 11 – 13 micron



Simple Resize from ASTER TIR data

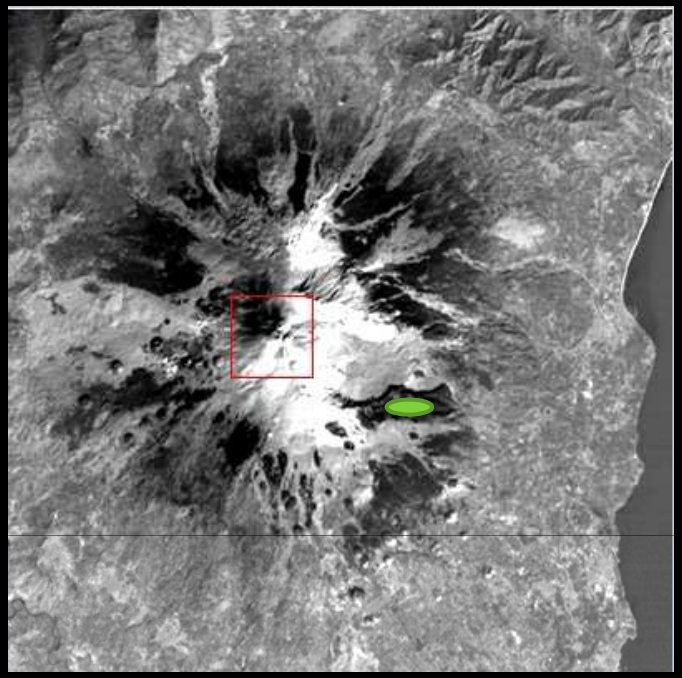


TIR ASTER original spatial resolution (about 90m)

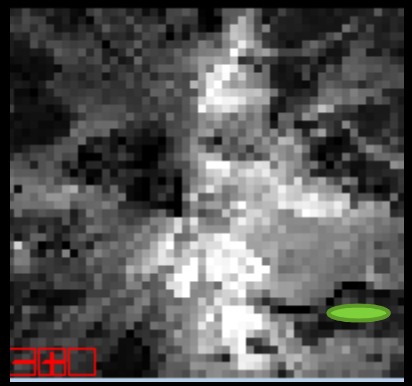


TIR ASTER resize spatial resolution (about 350 m)

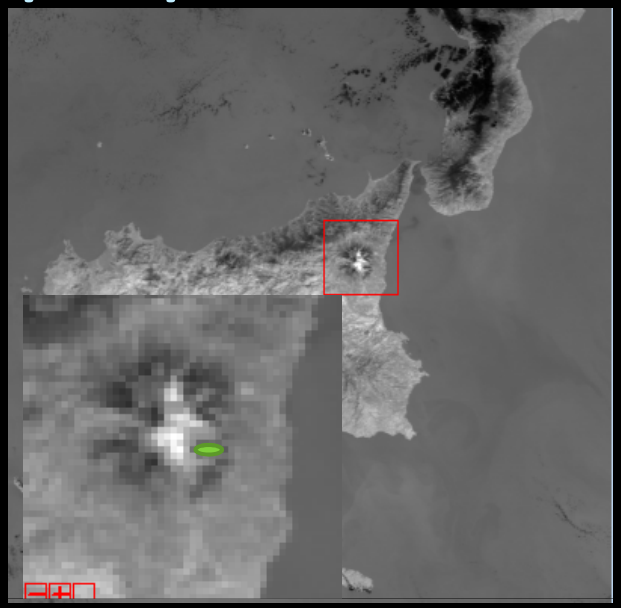
NIRST Simulated image 7/10/2009



TIR ASTER
original spatial
resolution
(about 90m)



NIRST Simulate
image at 350 m
spatial resolution
at 10.85 micron

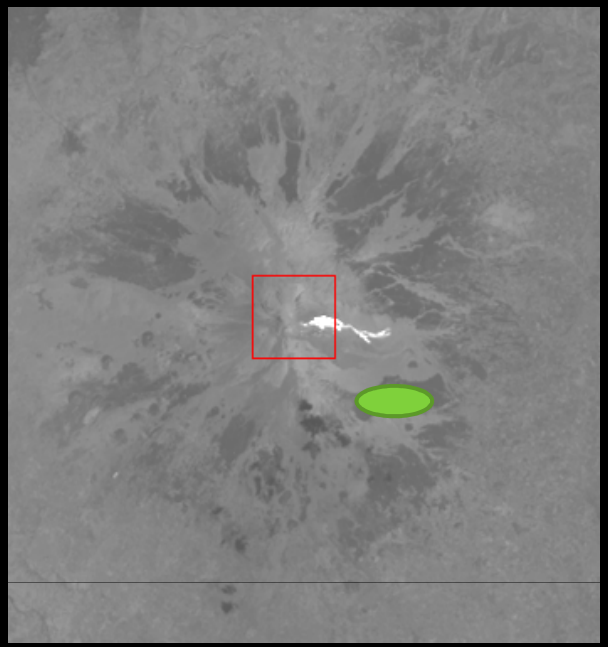


TIR MODIS
original spatial
resolution
(about 1 km)

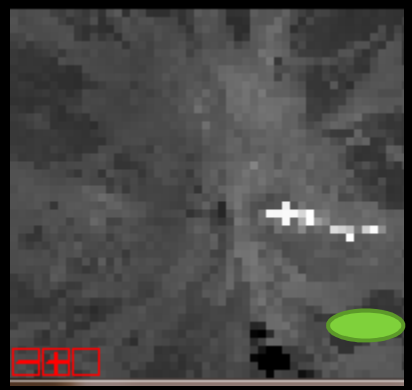
ASTER		NIRST simulation		MODIS	
Lambda	Radiance	Lambda	Radiance	Lambda	Radiance
-	-	3.8 µm	0.44	3.959 µm	0.55
10.65 µm	8.6	10.85 µm	7.76	11.030 µm	8.5
11.31 µm	8.38	11.85 µm	7.11	12.020 µm	7.96

Radiance in Watt/m2/sr/micron

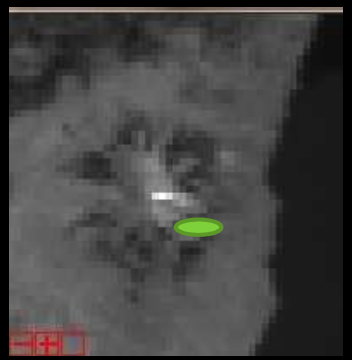
NIRST Simulated image: 21/06/2008



TIR ASTER
original spatial
resolution
(about 90m)



NIRST Simulate
image at 350 m
spatial resolution
at 10.85 micron

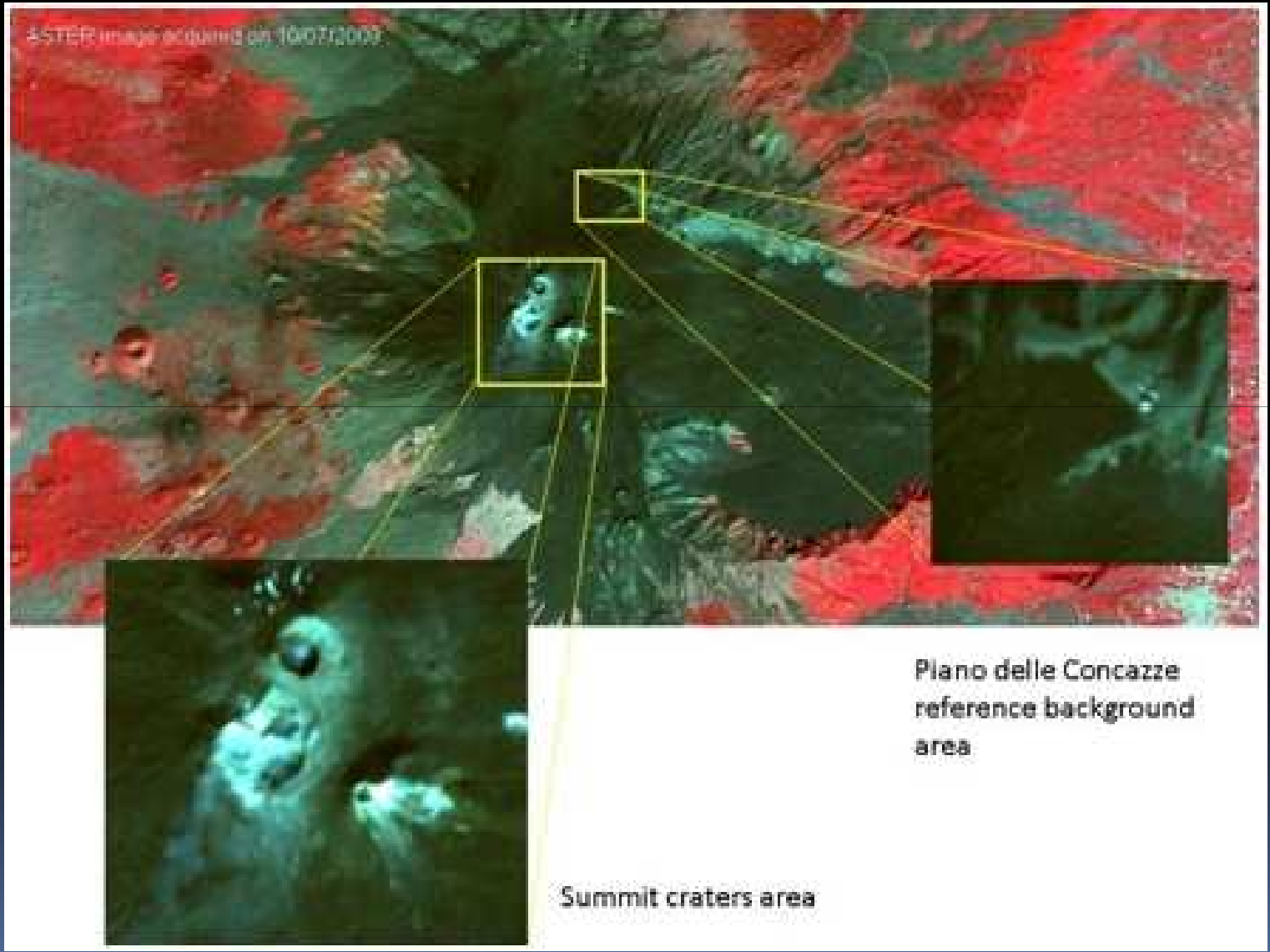


TIR MODIS
original spatial
resolution
(about 1 km)

ASTER		NIRST simulation		MODIS	
Lambda	Radiance	Lambda	Radiance	Lambda	Radiance
-	-	3.8 µm	0.6	3.959 µm	0.83
10.65 µm	9.79	10.85 µm	8.56	11.030 µm	9.55
11.31 µm	9.47	11.85 µm	7.8	12.020 µm	8.0

Radiance in Watt/m2/sr/micron

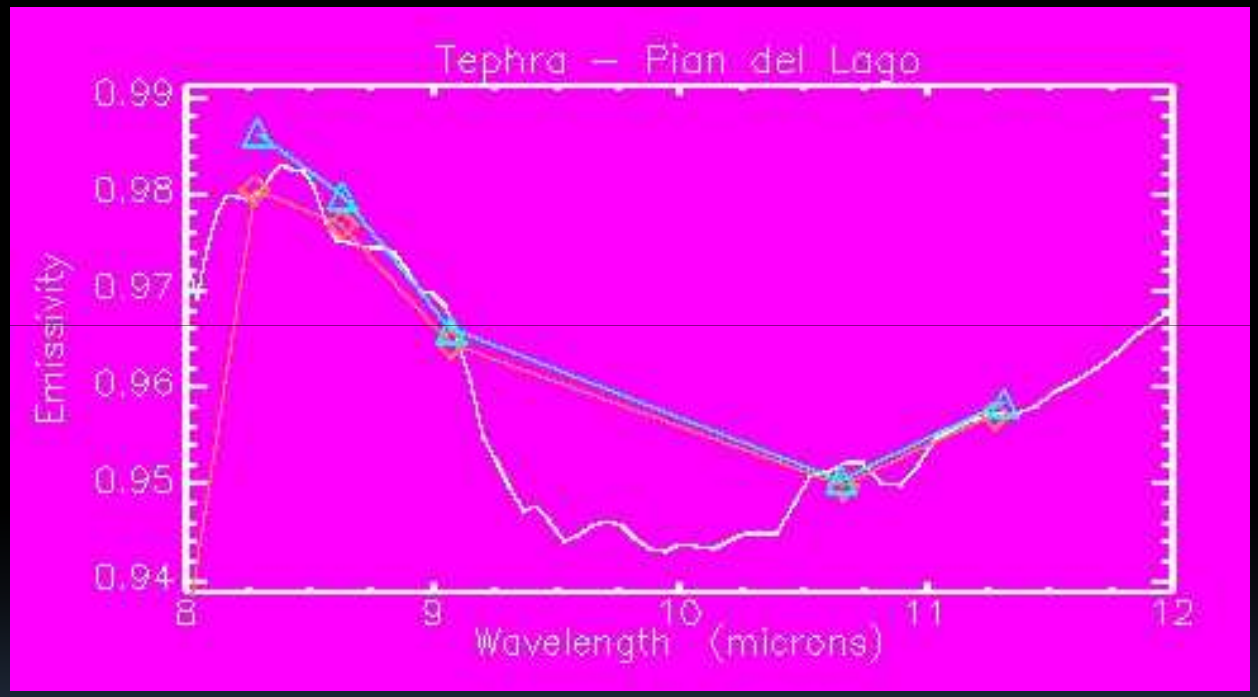
Validation site: Piano delle concazze



FTIR instrument

FTIR, Model 102F is a portable Fourier Transform InfraRed. It has two liquid nitrogen cooled detectors, HgCdTe (or MCT) and InSb, for measurements collection in the 8-14 µm and 3-5 µm atmospheric windows respectively.

	FTIR
Spectral range	2-16 µm
Spectral resolution	2, 4, 8, 16 cm^{-1}
Operating temperature range	15-35 °C (instrument temperature)
FOV	4.8° (additional input optic 2.4°)
Computer OS and type	DOS 6.22, 8GB HD, Pentium 166MHz/32MB
Input voltage range	12V DC (±10%)
Weight	7 Kg
Size	36cm x 20cm x 23cm



Field emissivity spectra (white line) resampled on ASTER TIR response functions (orange line and diamonds), compared to the emissivity spectra retrieved by TES on ASTER data

Importance of the new data simulation

- Simulation of multi-spectral images as produced by IR payload may be used in order to assess its compliance with respect to volcano monitoring requirements.
- The simulation process started from identifying the parameters whose changes have significant influence on the sensor measured radiance
- Using real data it is possible to verify the correctness of simulation

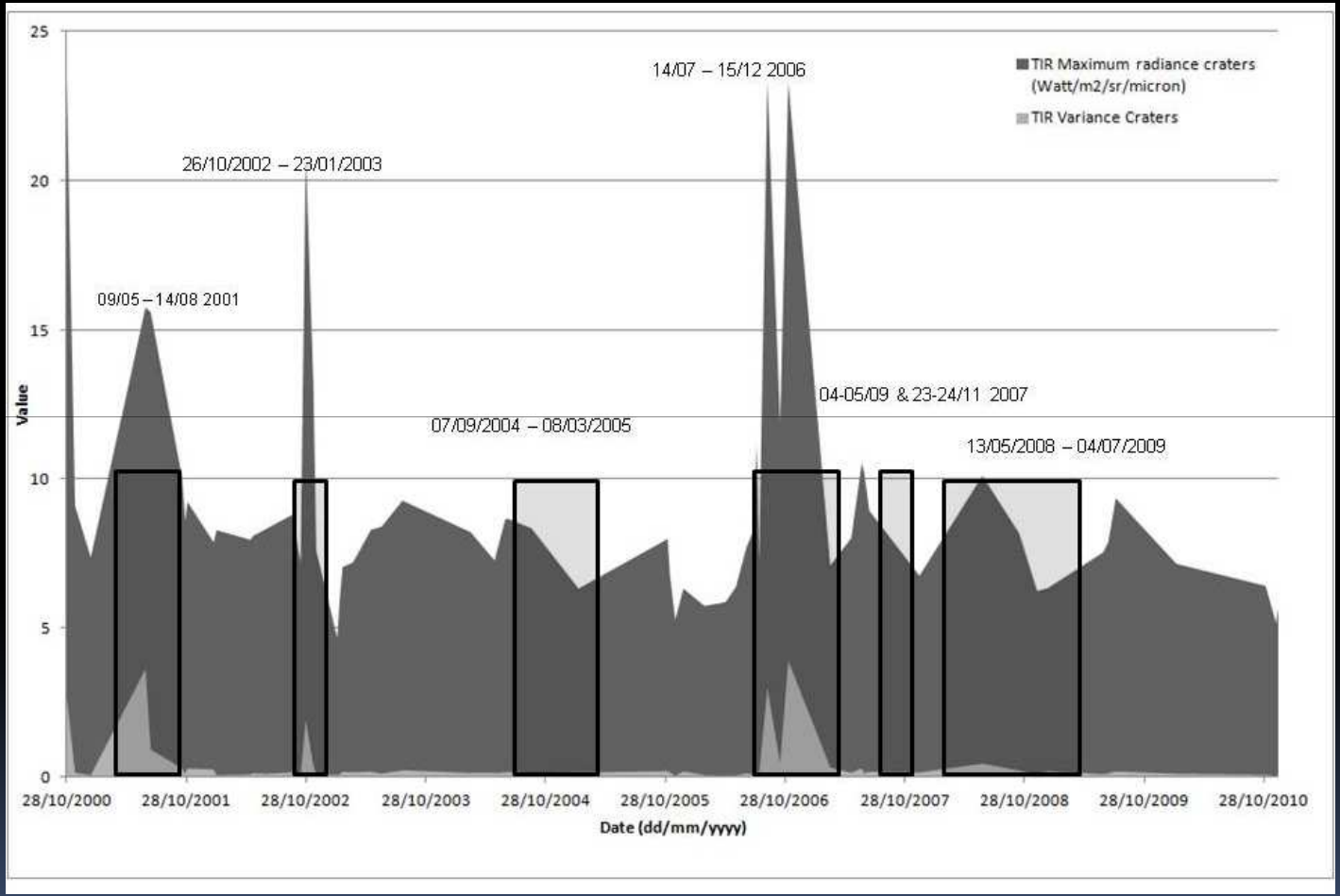
Thermal analysis of volcanoes:10 years of ASTER data on Mt. Etna

The utilization of remote sensing techniques to understand the world's volcanoes is a focus of the world's major scientific agencies and space-faring countries

Results of the analysis of 10 years Mt Etna activity using TIR high spatial resolution data by means a semi-automatic procedure which extract the summit area radiance values with the goal of detecting variation related to eruptive events

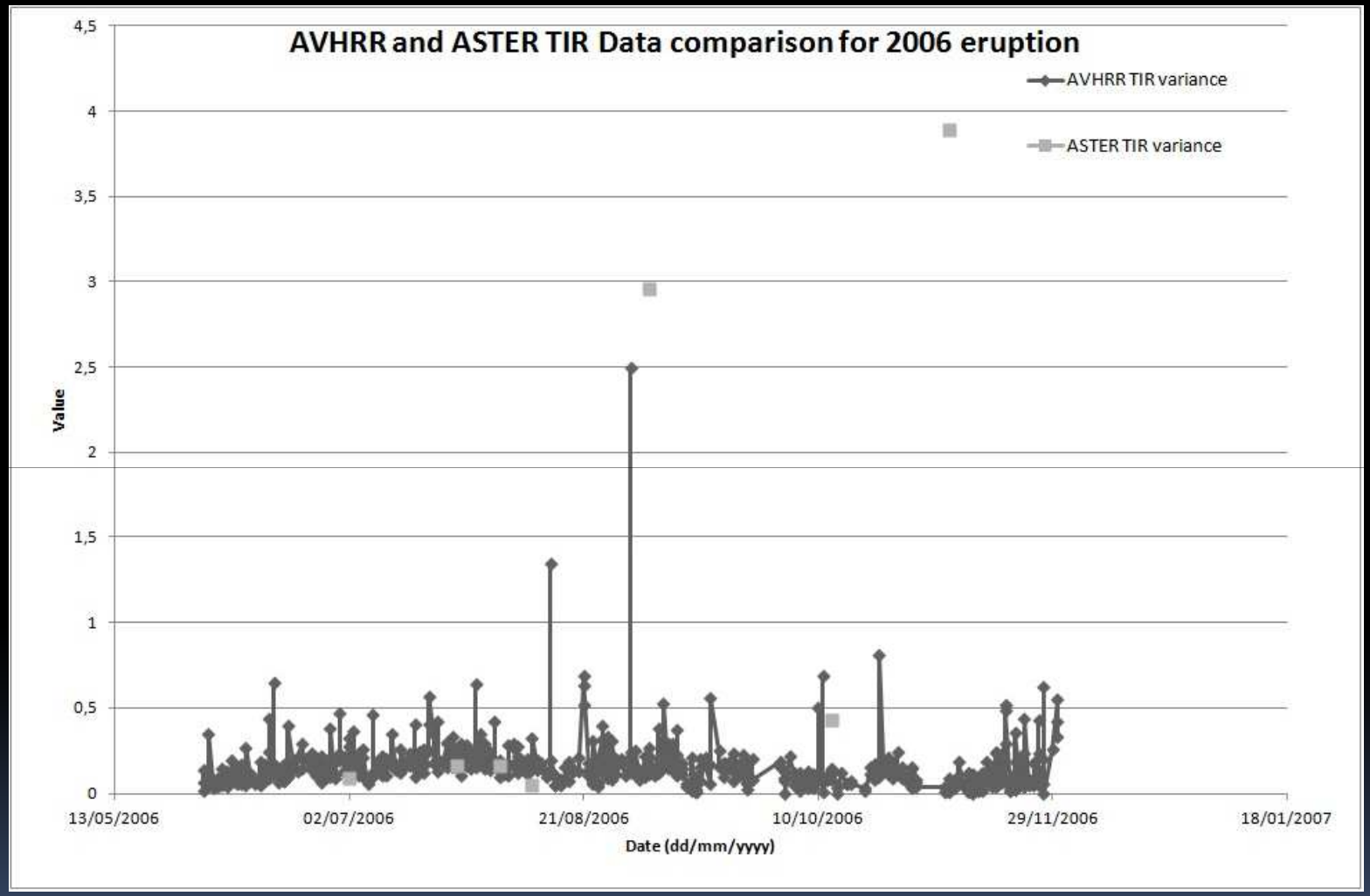
Submitted Paper: Emissivity and Thermal analysis of volcanoes: 10 years of ASTER data on Mt.Etna-**Maria Fabrizia Buongiorno, David Pieri, Malvina Silvestri**

Thermal analysis of volcanoes:10 years of ASTER data on Mt. Etna



TIR data permit to detect changes in thermal emission which may be related to impending eruption

Comparison ASTER-AVHRR data



The comparison with AVHRR in the same area confirms the ASTER measurement trend (despite different spatial resolution)

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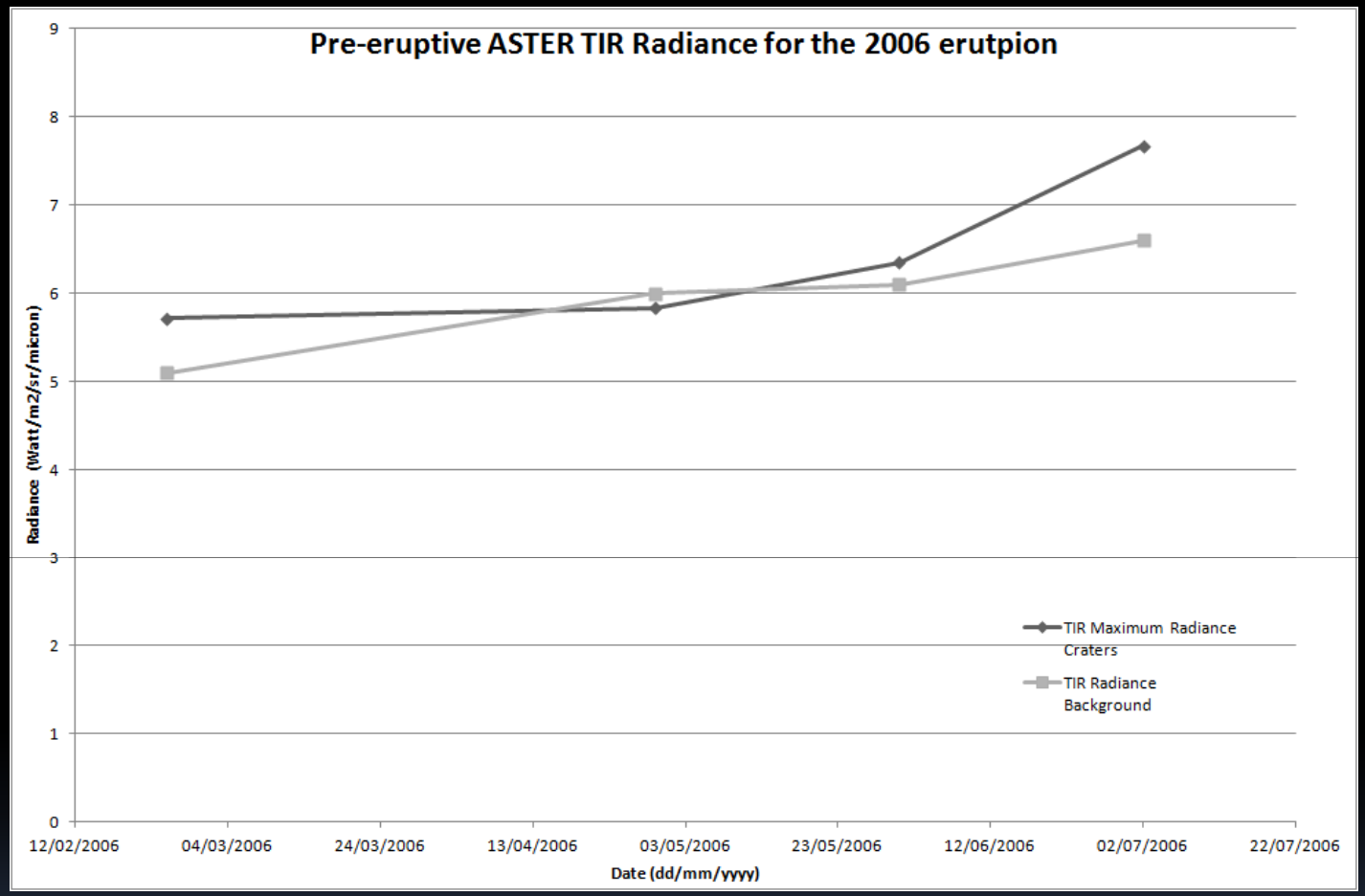
CNT Remote Sensing Group



- Opportune availability of 4 night time ASTER TIR images.
- Increase in the emitted summit crater radiance starting in May 2006.
- The relatively low frequency of the ASTER data acquisitions (night time in particular) did not permit to verify a putatively similar pre-eruptive increase in the Etna summit crater thermal activity for the 2001, 2002 and 2008 eruptions

- Report on the utilization of ASTER thermal infrared (TIR) remote sensing capabilities and the JPL ASTER Volcano Archive (AVA) as tools to systematically analyze the spatial and temporal relationships—correlated, uncorrelated, and/or anti-correlated—of volcanogenic thermal anomalies and eruptions at Mt. Etna on the Italian island of Sicily
- Demonstratation of the value of high spatial resolution TIR time-series data for monitoring significant volcanogenic hazards and risks, especially in the area of thermal precursor sensitivity and detection thresholds
- The use of NIRST data could provide volcanologists with new tools with which to measure the thermal emissions of restless volcanoes

ASI pre-operative project to support volcanic risk monitoring

The AQUARIUS/SAC-D data could be assimilated into the pre-operative systems developed by INGV (ASI project) to monitor Italian active volcanoes

The current ASI-SRV system philosophy is to implement specific modules which allow to process, store and visualize through Web GIS EO/non EO integrated products considering volcanic activity phases defined within DPC operations:

- Knowledge and prevention (K&P)
- Crisis (C)
- Post Crisis (PC)

Identification of possible volcanoes observation scenarios

Post-eruptive scenarios:
- Low Thermal Anomaly
- Volcanic Gas
- Damage Assessment

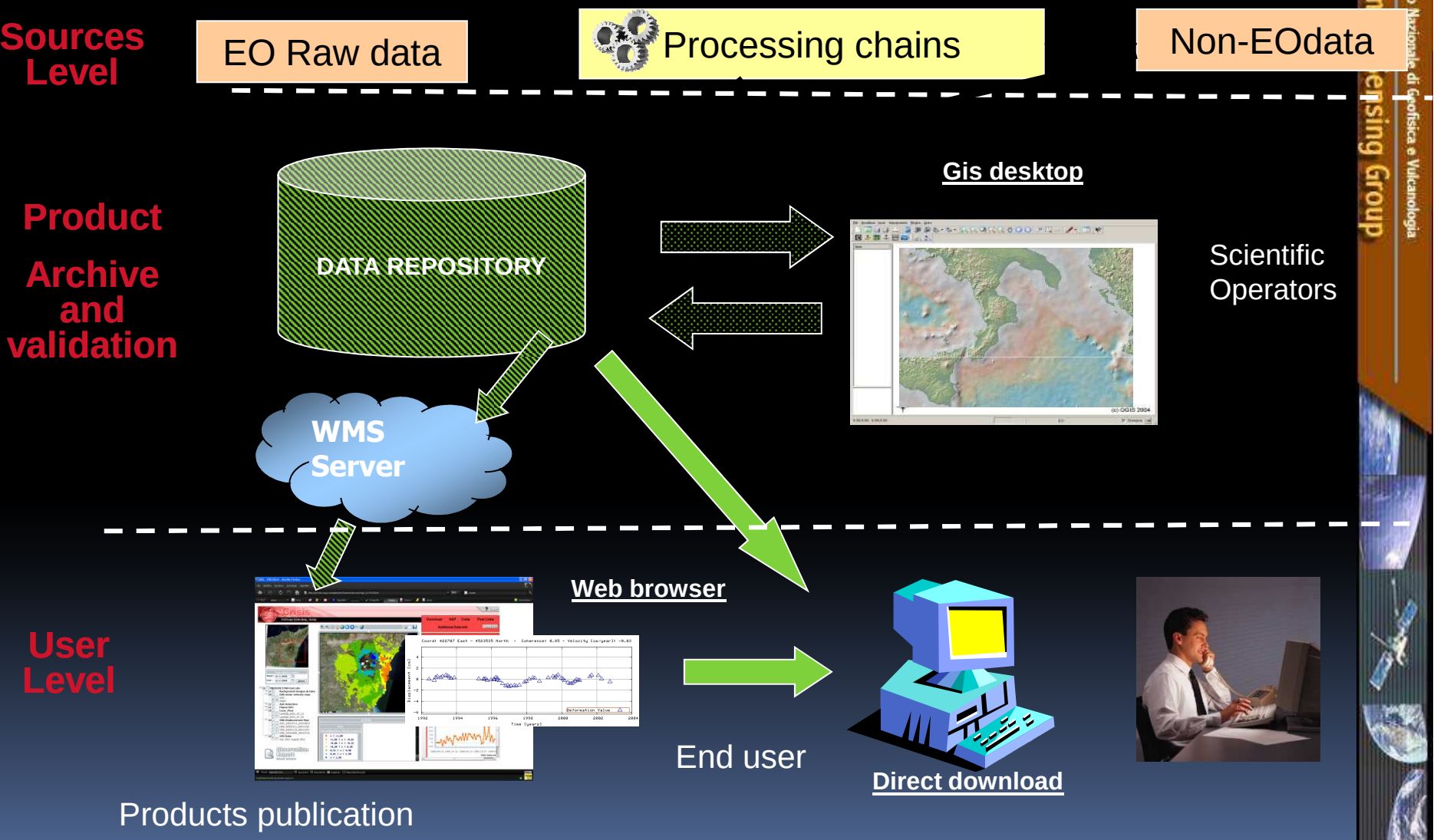
Pre-eruptive scenarios:
- Low Thermal Anomaly
- Volcanic Gas

Sin-eruptive scenarios:
- Lava Flow
- Volcanic gas

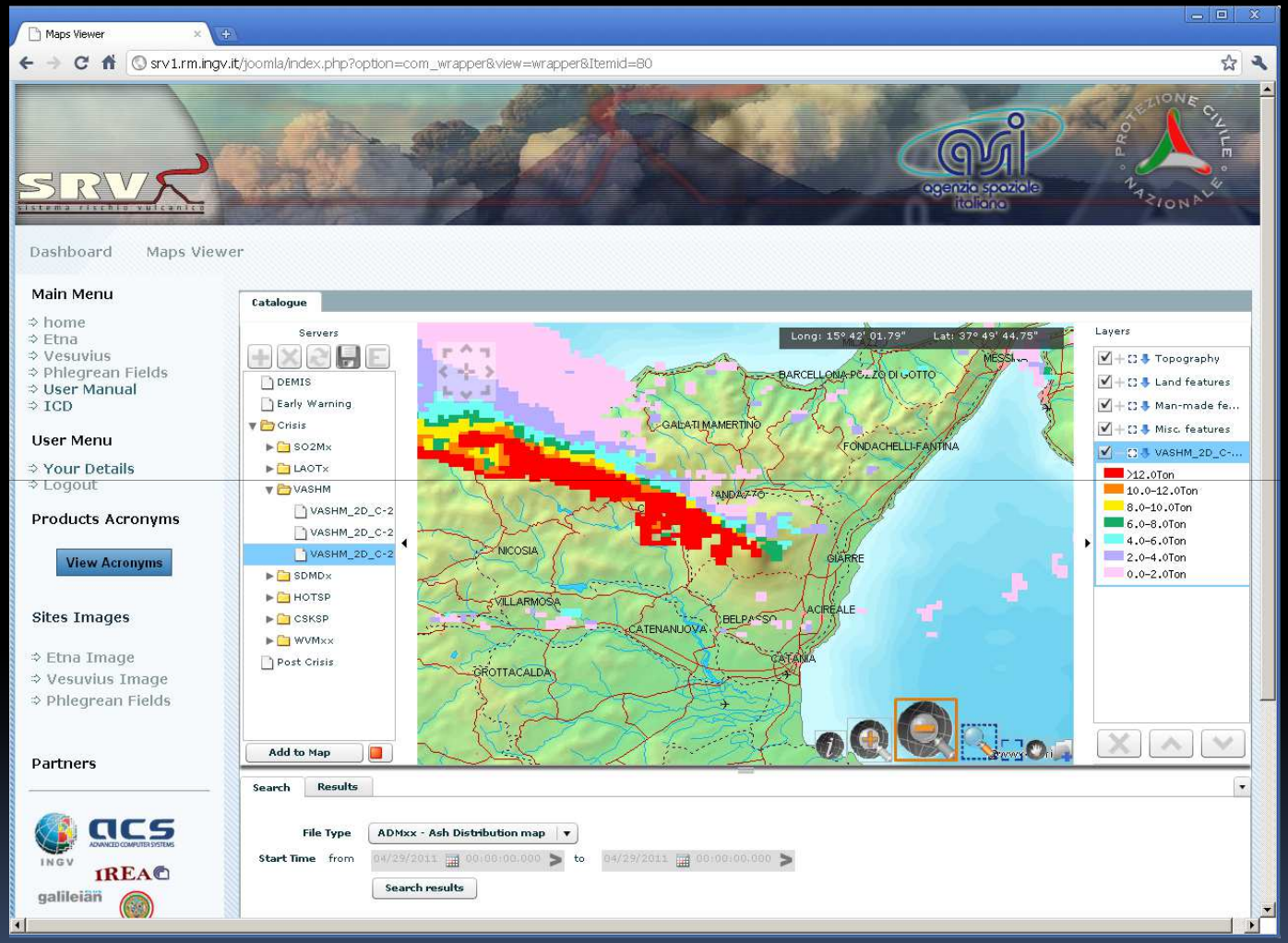
Products

PHASE	EO PRODUCTS	GEOGRAPHICAL AREA
Knowledge and Prevention	Multiparametric Analysis product	Etna and Vesuvio – Campi Flegrei
	Deformation Map from DinSAR product (time series)	Etna and Vesuvio – Campi Flegrei
	Surface temperature and Thermal flux from	Etna, Campi Flegrei, Vesuvio
	Degassing Plumes analysis product	Etna
Crisis Phase	Deformation Map from InSAR product (sin eruptive)	Etna and Vesuvio – Campi Flegrei
	Deformation Map from DinSAR produsc (time series)	Etna and Vesuvio – Campi Flegrei
	Thermal Flux, Effusion Rate	Etna
	Volcanic Plumes and Clouds analysis product	Etna
Post Crisis Phase	Deformation Map from DinSAR product (time series)	Etna and Vesuvio – Campi Flegrei
	Volcanic thickness product	Etna
	Ash and lava distribution map product	Etna

ASI-SRV scheme



Example of ASI-SRV product



Volcanic Ash Loading Map during an eruption

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Final remarks

The analysis of the NIRST sensor characteristics will be important to asses the instrument capabilities and the possible assimilation of the data in operative monitoring systems such as ASI-SRV or at European level (GMES-GEO)

Permanent calibration site on Mt. Etna

Thanks to JPL,NASA,JAXA for providing ASTER images

INGV is very happy to participate to the Science Team for SAC-D mission

THANK YOU