



# **2012 Hyperspectral airborne campaign on Etna: multi data acquisition for ASI-PRISMA data simulation and algorithms development**

Maria Fabrizia Buongiorno

Istituto Nazionale di Geofisica e Vulcanologia



# summary

- PRISMA MISSION OVERVIEW
- ASI-AGI PROJECT
- JUNE 2012 AIRBORNE CAMPAIGN

# PRISMA Mission

Analdi Intero Hyperspettrali per  
Applicazioni Geofisiche Integrate



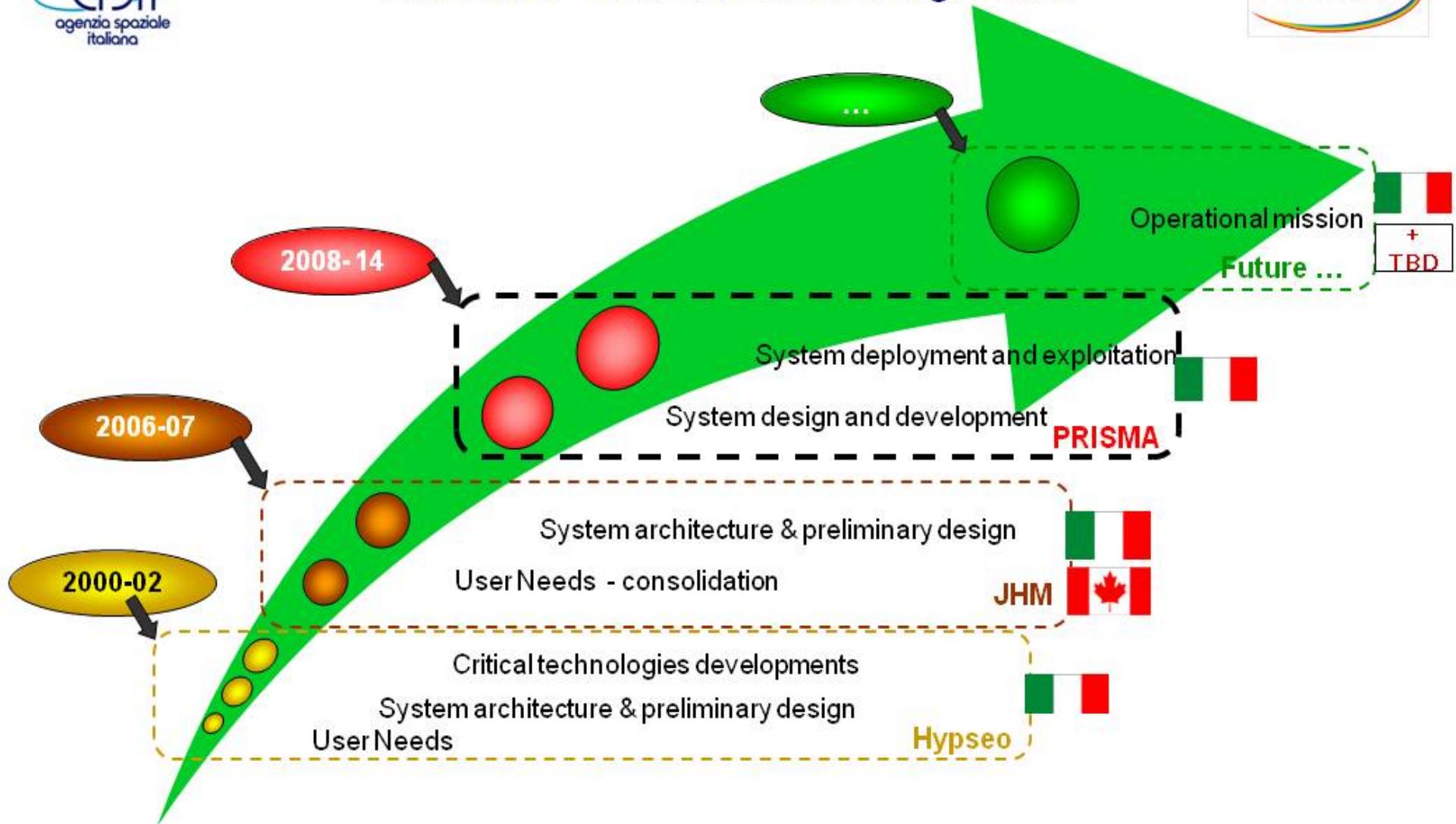
- Mission Statement:

“....A pre-operative small Italian hyperspectral mission, aiming to qualify the technology, contribute to develop applications and provide products to institutional and scientific users for environmental observation and risk management ...”

- Mission objectives:

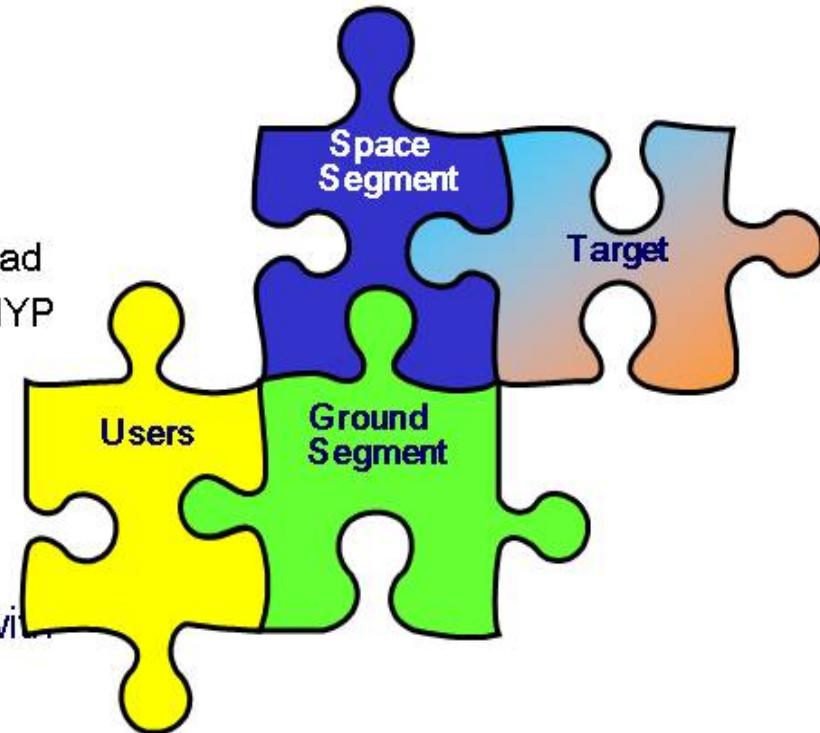
- In orbit demonstration and qualification of an Italian state-of-the-art hyperspectral/panchromatic camera;
- Implementation of a pre-operative mission, with demonstrative/technological features;
- Validation of end-to-end data processing able to develop new applications based on high spectral resolution images for Earth observation and to manage the environmental risks.
- Capitalization of ASI heritage, considering the Hypseo mission and the Italian-Canadian Joint Hyperspectral Mission (JHM) study

# PRISMA - context and background



## Programme overview

- PRISMA = PRecursore IperSpettrale della Missione Applicativa
- Mission Objectives:
  - Pre-operational and technology demonstrator nature
  - Focus on
    - Space qualification of PAN/HYP payload
    - development and production of PAN/HYP products
- Program Highlights:
  - National program
  - Fully funded by ASI
  - Mission includes System, interacting with Target and Users
  - System B2/C/D/E1 contract running
  - CDR is on-going
  - Launch: within 2014



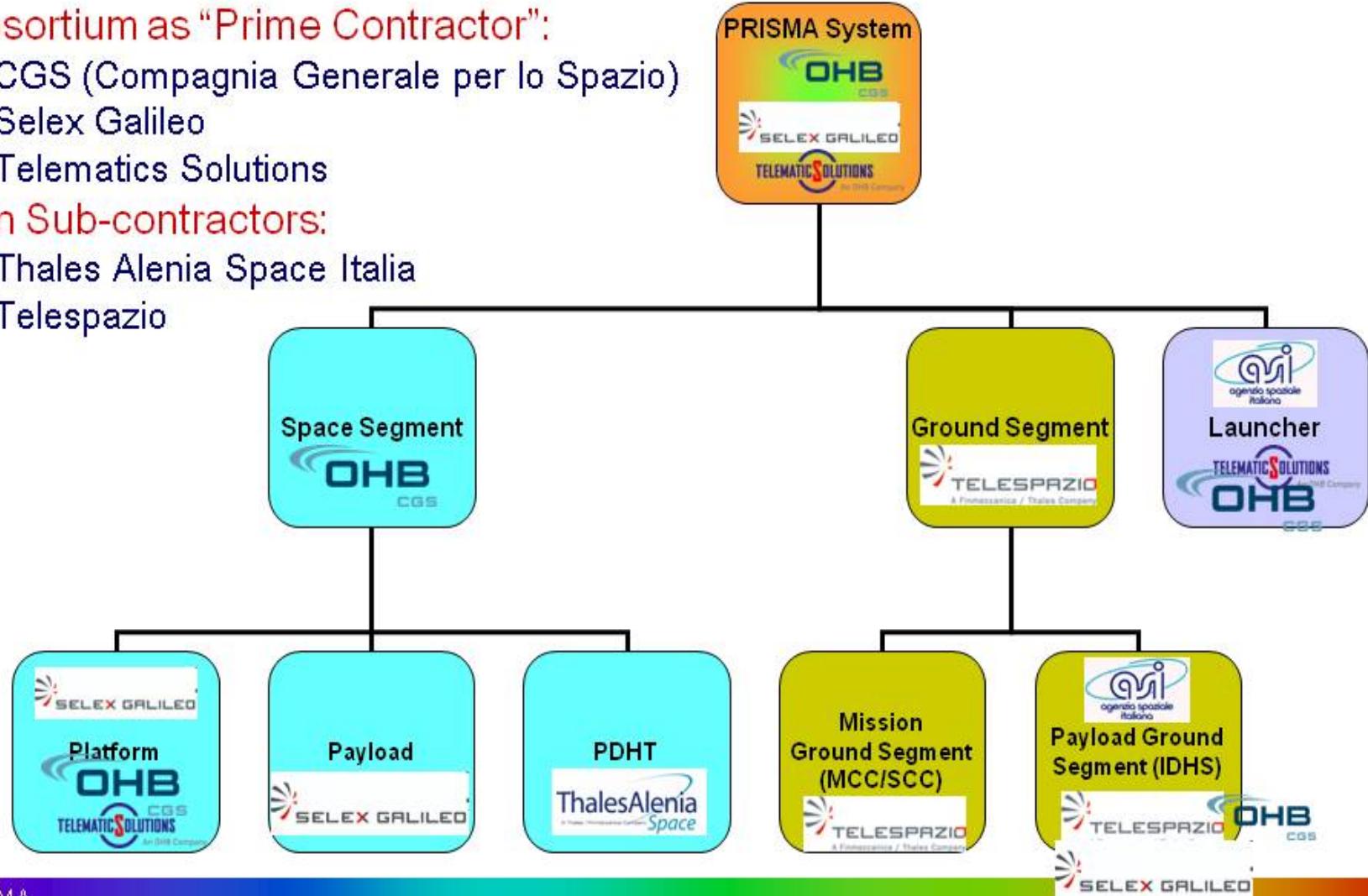
# Industrial Organization (Phase B2/C/D/E1)

## ■ Consortium as "Prime Contractor":

- CGS (Compagnia Generale per lo Spazio)
- Selex Galileo
- Telematics Solutions

## ■ Main Sub-contractors:

- Thales Alenia Space Italia
- Telespazio

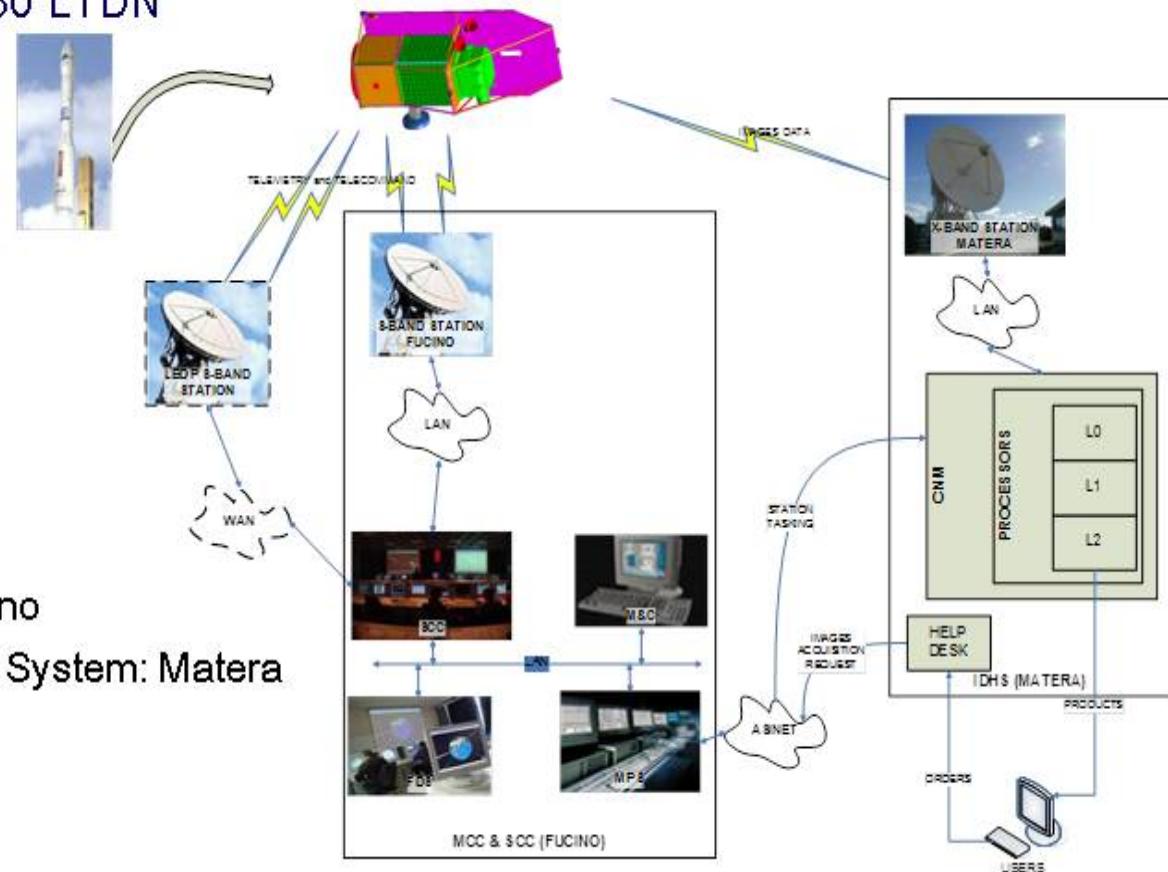


## ■ Orbit and lifetime:

- LEO SSO, 620km, 10.30 LTDN
- 5 years lifetime

## ■ System elements:

- 1 “small” Satellite
  - Platform
  - Pan/Hyp Payload
  - PDHT
- Ground Segment
  - MCC/SCC/FDS: Fucino
  - Image Data Handling System: Matera
- Launch Segment
  - VEGA (baseline)



# Mission highlights

- Coverage:
  - World-wide
  - Specific Area of interest (AoI)
- System Capacity:
  - Acquired data volume:
    - Orbit: >50.000 km<sup>2</sup>
    - Daily >100.000 km<sup>2</sup>
  - Daily products generation: 30 HYP/PAN
- System Latencies (inside AoI):
  - Re-look time: < 7 days
  - Response time: < 14 days
- Mission modes:
  - Primary: User driven
  - Secondary: Data driven (background mission)

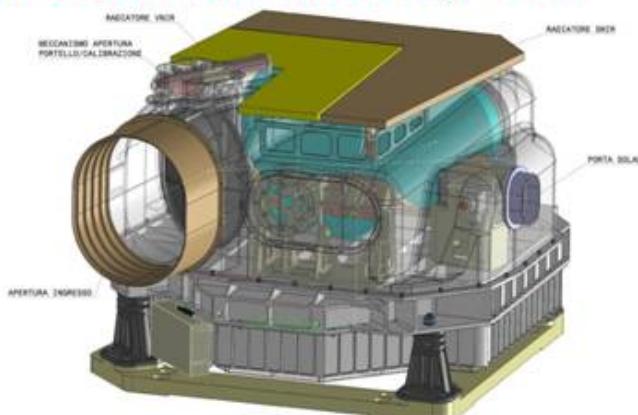


# Key imaging and payload requirements

- Swath / FOV: 30 km / 2.45°
- Spatial GSD (elementary geom. FoV):
  - PAN: <5 m (2x6000 pixels)
  - HYP: <30 m (1000x256 pixels)
- Spectral ranges:
  - PAN camera: 400-700 nm
  - HYP instrument (contiguous spectrum)
    - VNIR: 400-1010 nm
    - SWIR: 920-2500 nm
- Spectral resolution: 10 nm
- Aperture diameter: 210mm
- MTF (@Nyquist frequency)
 

PAN	> 0.30
VNIR	> 0.30
SWIR	> 0.20

- Radiometric Quantization: 12 bit
- SNR
  - PAN: 240:1
  - VNIR: 200:1 (400-1000 nm)  
600:1 (@650nm)
  - SWIR: 200:1 (1000-1750 nm)  
400:1 (@1550nm)  
100:1 (1950-2350 nm)  
200:1 (@2100nm)
- Absolute radiometric accuracy: <5%



Program: PRISMA

Event: Third Annual Hyperspectral Imaging Conference

Topic: PRISMA Mission

Date: Rome, 15 May 2012

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HYPERSPECTRAL Scientific & Application specific needs							
	Forestry & Agriculture	Environmental monitoring	Urban areas	Geology & volcanic and seismic risks	Glaciers and Snow Surface	Coastal and Inland waters	Biosphere & Climate Change
<i>Swath width</i>	20-	$\geq 40$ km	$\geq 30$ km	20-	>	30-	30-
<i>Ground Sampling Distance</i>	20- VIS, SWIR 2,5-5m PAN	20- VNIR, 20- SWIR 1- PAN	VNIR, SWIR	20- VNIR, SWIR 2,5- PAN	20- VNIR, SWIR PAN	2 0 - 3 0 m VNIR	VNIR, SWIR
<i>Spectral coverage</i>	0,4 - 2,5 $\mu$ m PAN channel	0.4 - 2.5 $\mu$ m PAN channel	0.4 -2.5 $\mu$ m PAN channel	0.4-2.5 $\mu$ m PAN channel	0.4-2.5 $\mu$ m PAN channel	0.4-2.5 $\mu$ m	0.4-2.5 $\mu$ m
<i>Spectral resolution (FWHM)</i>	$\leq 10$ nm	$\leq 10$ nm	10 nm	$\leq 10$ nm	10 nm	10nm (5 nm near 685nm)	10nm
<i>Spectral sampling interval</i>	1 sample per FWHM	5 - 10 nm	1-2 nm	1 sample per FWHM	10 nm	5 nm	10 nm
<i>SNR@30%refl; 30°SZA:</i> <i>VNIR</i>	600:1	600:1	800:1	800:1	500:1	1000:1	600:1
<i>SWIR</i>	450:1	450:1	500:1	500:1	500:1		400:1
<i>Radiometric Quantization</i>	12 - 16 bit	$\geq 12$ bit	12-16 bit	12-16 bit	> 12 bit	14-16 bit	12-16 bit
<i>Radiometric calibration accuracy</i>	$\leq 5\%$ goal 3%	$\leq 5\%$	$< 0.01 \mu\text{Wcm}^{-2}\text{nm}^{-1}\text{sr}^{-1}$	$\leq 5\%$ goal 1%	< 5%	$< 0.01 \mu\text{Wcm}^{-2}\text{nm}^{-1}\text{sr}^{-1}$	$\leq 5\%$
<i>Spectral calibration accuracy</i>	0.1nm	0.1 nm	0.3 nm	0.1 nm	0.3 nm	0.3 nm	0.1 nm
<i>Equator crossing time day</i>	9:30 – 11:00 local time	10-12 local time	10 local time	9:30 - 10:30 local time	11-12 local time	10:00 – 11:00 local time	10:00 – 11:00 local time
<i>Night acquisition time</i>				10:30 night on the ascending orbits			

- National competition for 5 scientific projects
- Duration: 4 years
- 2 main tasks:
  - Research on specific theme reffering to the ASI list of applications using simil-PRISMA data and, after launch, PRISMA data
  - Scientific support to ASI PRISMA project team
- Identification of 5 Principal Investigators (PIs) in a Scientific Advisory Team
- Common Kick Off: 14/04/2011

<b>TITLE</b>	<b>Name of the institute</b>	
Development of algorithms and products for applications in agriculture and land monitoring to support the PRISMA mission (SAP 4 PRISMA)	Istituto di Metodologie per l'Analisi Ambientale IMAA CNR	Vincenzo Cuomo
Singergistic use of PRISMA products with high resolution meteo-chemistry simulations and their validation from ground and satellites (PRIMES)	CETEMPS - Univ. de L'Aquila	Guido Visconti
Hyperspectral systems analisys for integrated geophysical applications (ASI-AGI)	Istituto Nazionale di Geofisica e Vulcanologia (INGV)	Fabrizia Buongiorno
Advanced methodologies for analysis, integration and optimization of PRISMA level 1 and 2 products - OPTIMA -	Istituto di Fisica Applicata Nello Carrara (IFAC -CNR)	Ivan Pippi
Coasts and Lake Assessment and Monitoring by PRISMA HYperspectral Mission (CLAM PHYM)	Institute of Marine Sciences (ISMAR - CNR)	Luigi Alberotanza



For any further information on the PRISMA mission,  
please contact  
the ASI Program Manager

**[roberto.formaro@asi.it](mailto:roberto.formaro@asi.it)**

For any further information on the scientific studies  
please contact

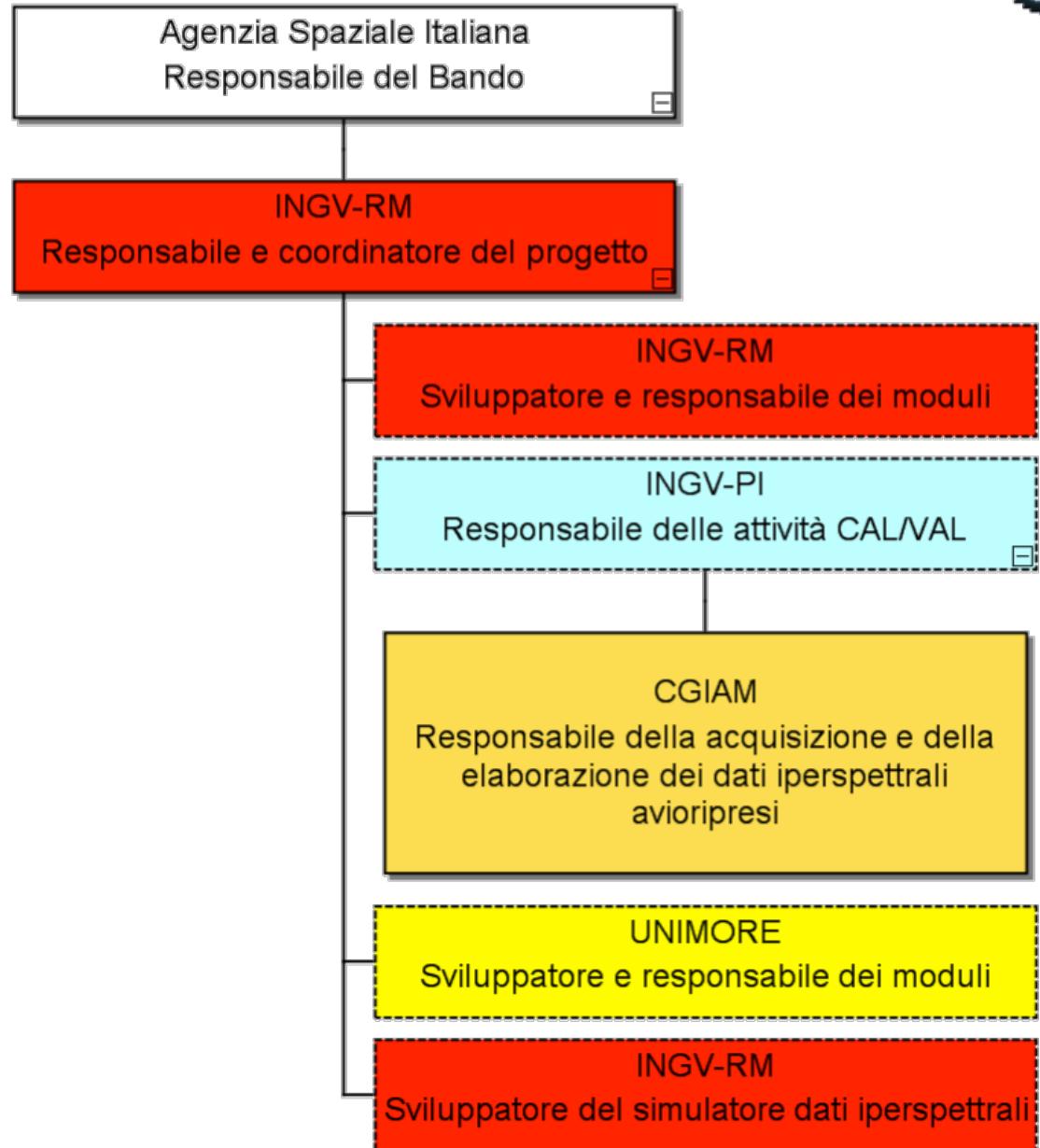
**[cristina.ananasso@asi.it](mailto:cristina.ananasso@asi.it)**

# ASI-AGI

Analisi Sistemi Iperspettrali per le  
Applicazioni Geofisiche Integrate



# Project Structure





# ASI-AGI PROJECT ACTIVITY SCHEME

Common utilities

Atmospheric correction

Pan Sharpening

Topographic Correction

Information extraction modules

Superficial Classification

Lava Thermal analysis

Volcanic emitted gases  
analysis

Fire Spectral  
Characterization

CAL/VAL Activities  
and data simulation

Flight campaigns.  
Calibration sites

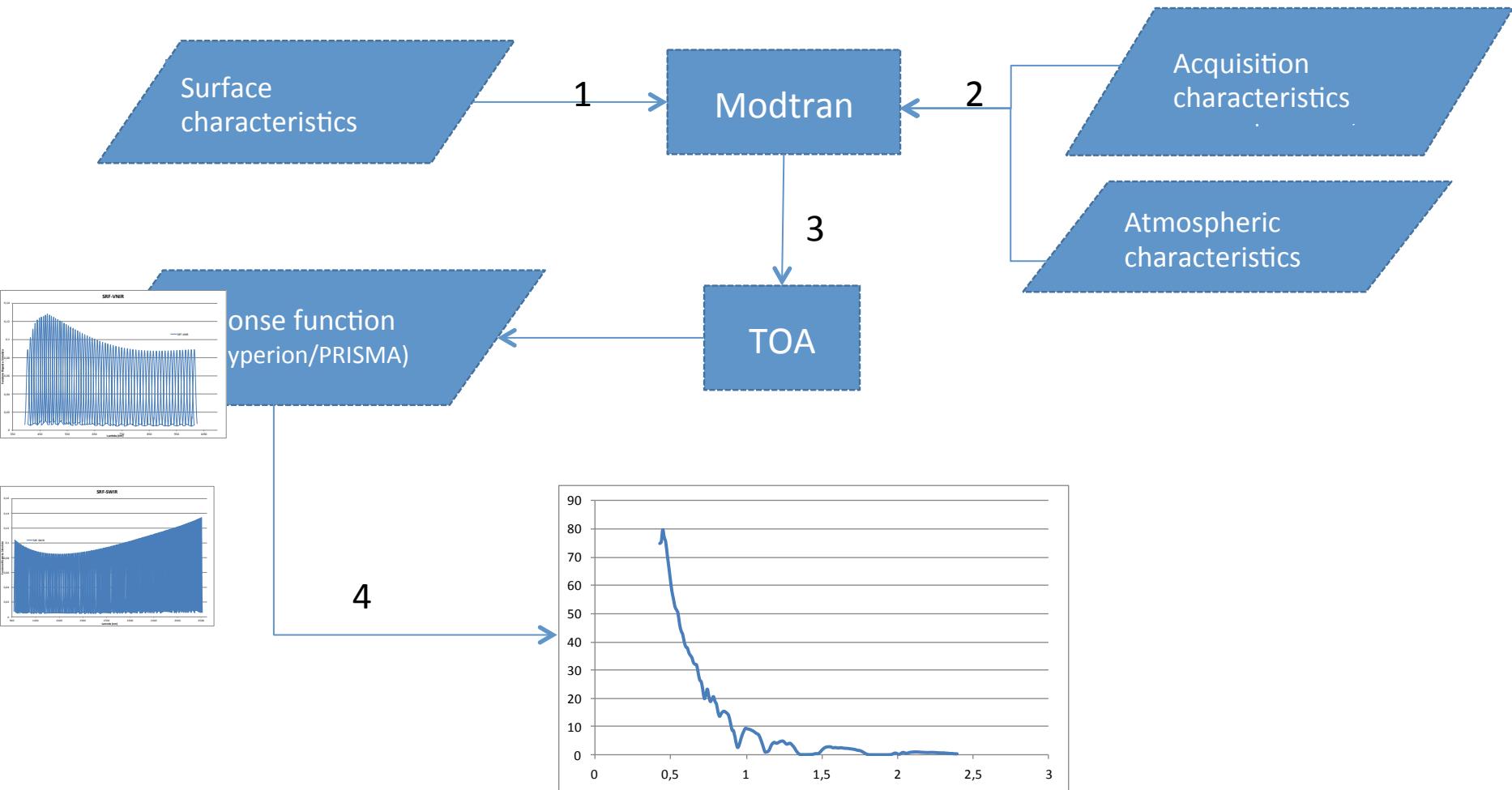
PRISMA data Simulator

# PRISMA SIMULATOR

- Module developed in IDL which will take in input the PRISMA instrument response functions, S/N, view geometry furnished by ASI
- to calculate
  - simulated radiance
  - Simulated path radiance
  - Simulated Spectral and spatial response of the instrument
  - Simulated N/S



# Prisma Radiance Simulator



## PHASE 1

MODTRAN has been used to model the sensor and atmospheric parameter for each pixel  
the considered PRISMA sub set of 10000 pixels

- Surface temperature 290 K (circa 17° C)
- Mid latitude Summer (Latitude 45° Nord)
- Satellite altitude 700 Km
- Albedo: Reflectance map calculated by means of Hyperion image acquired on Mt. Etna
- Spectral Range: 0.842-0.844

## PHASE 2

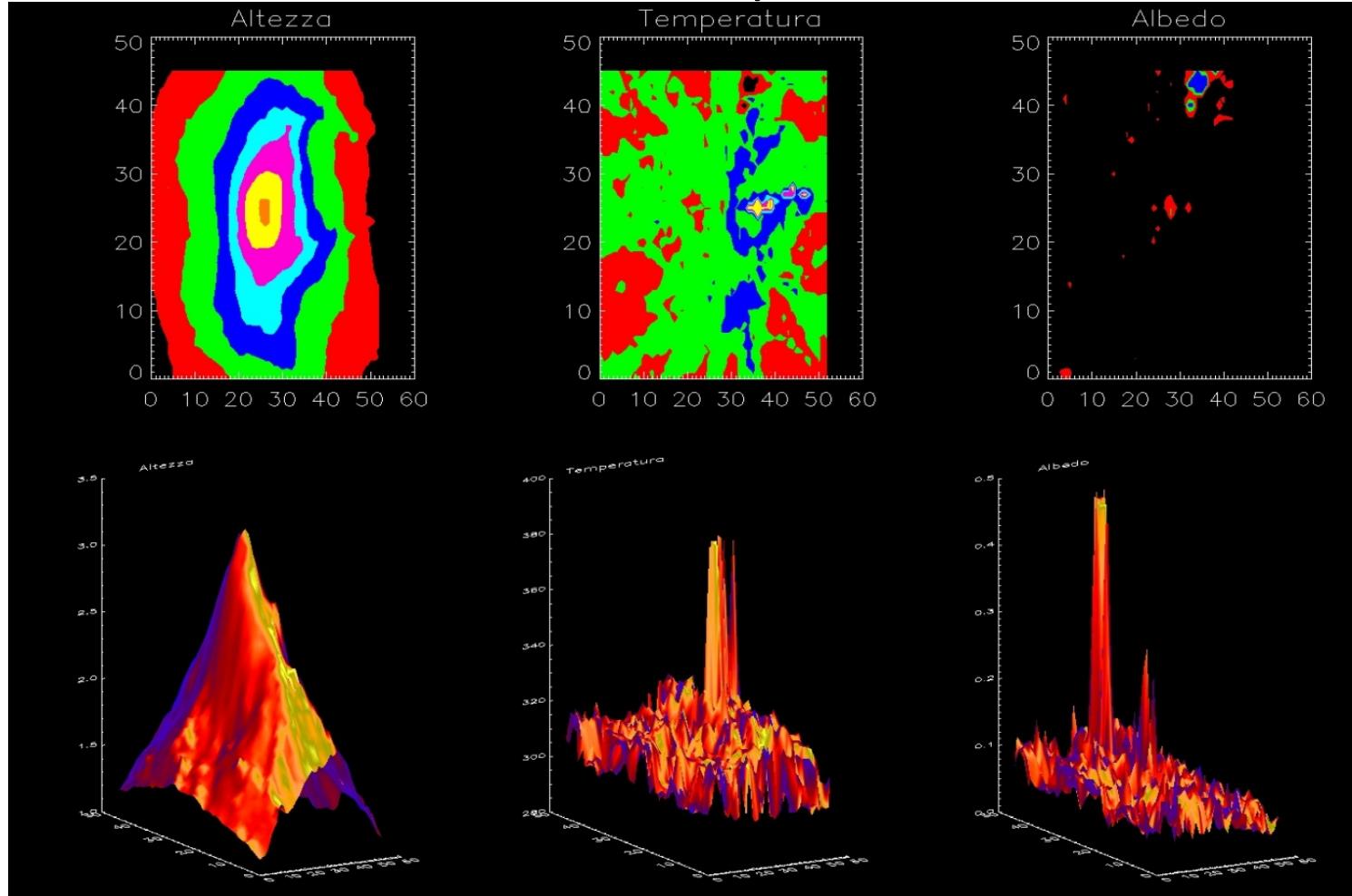
On beginning of 2012 the industrial team started the calibration measurements of system optical components in laboratory

In order to improve the simulation products we introduced the information provided by the industrial team

- Prisma laboratory simulated response function.
- Simulated NdL of the instrument



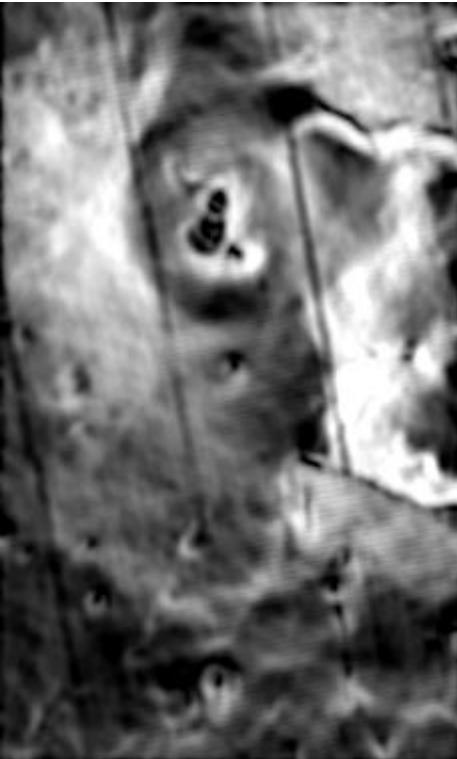
To make the modeling more complex we have introduced the DEM information and temperature map of the surface for the select day



Topographic information and surface geometry informations as "aspect" e "slope" to calculate the contribute from adjacent pixels .



aspect



slope



Radianza



Adjacency effect



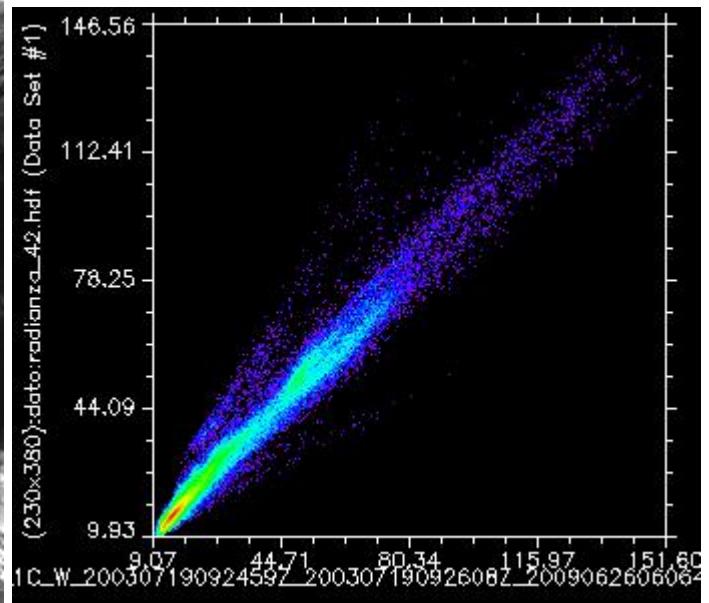
# Phase 2 results



Radianza reale



Radianza simulata



230x380 pixels

# AIRBORNE CAMPAIGN ON ETNA

## JUNE 22-28 2012

### Participants

Stefania Amici(1), Laura Colini(1), Fawzi Doumaz(1), Valerio Lombardo(1),  
Francesco Mazzarini(1), Massimo Musacchio(1), Malvina Silvestri(1), Claudia  
Spinetti(1), Massimiliano Favalli(1), Ilaria Isola(1), Marco Neri(1), Salvo  
Giammanco(1), Tommaso Caltabiano(1), Giuseppe Salerno(1), Alessandro La  
Spina(1) Giuseppe Puglisi(1), Sergio Teggi(2), Valentina Sarli(3), Giovanni Mancini  
(4), Paolo Cafaro(4), Salvatore D'Andrea(4), Gabriele Curci(5) and Cristina  
Ananasso(6).

1 Istituto Nazionale di Geofisica e Vulcanologia

2 Università di Modena e Reggio Emilia

3 Centro di Geomorfologia Integrata dell'Area del Mediterraneo (CGIAM)

4 Corpo Capitanerie di Porto

5 Università degli Studi dell'Aquila CTEMS

6 Agenzia Spaziale Italiana

## The CAL/VAL activities are based on 4 specific goals

1. Organize an airborne campaing on MT. Etna which is the main test site for ASI-AGI PROJECT and acquire a suitable hyperspectral data set to simulate the PRISMA data and test the developed algorithms,
2. Get possibly contemporaneous Hyperion and ASTER data to use the data set also to simulate HyspIRI data
3. Organize a contemporary in situ campaign to acquire surface and atmospheric parameters and validate the airborne data and complete a spectral library for Mt. Etna different lava flows.
4. Define a vicarious test site in Noth Africa in the Algerian desert year



# Etna airborne campaign 2012



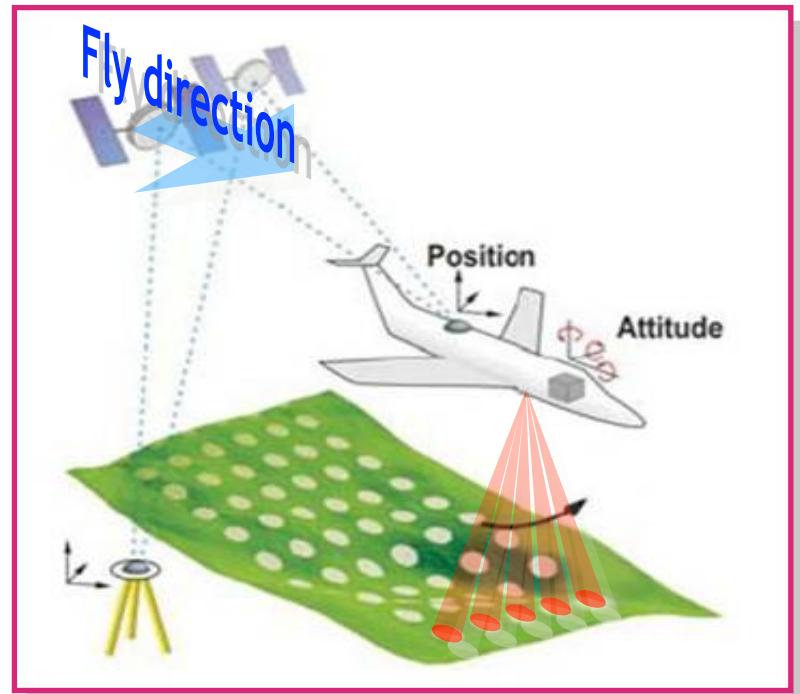
	GROUND ACTIVITIES	AIRBORNE AND SPACEBORNE ACQUISITION
23.06.2012	<b>MILO</b> Logistic activities Ground instrument TEST and fieldspec measurements	Hyperion acquisition
24.06.2012	<b>BRONTE</b> Start ground measurements FieldSpec <b>ETNA</b> Set up sun photometer <b>Paterno</b> Site ispection	TEST FLIGHT BY CGIAM
25.06.2012	<b>ETNA</b> Thermal termica, Unilogger FTIR (Pian del Lago) FieldSpec (Strada Forestale ed Etna Nord)	TERRA-ASTER  <b>Flight over ETNA</b> Flight altitude: 5000 slm Time sart : 8:00 (local)
26 .06 2012	<b>PATERNO'</b> FieldSpec, Unilogger Laser Scanning	EO1- HYPERION  <b>Flight over PATERNO</b> Flight altitude: 1000m slm Time stat: :9:00-9:30 (local)
27. 06-2012	<b>FORNAZZE</b> FieldSpec	

# AIRBORNE SYSTEM

**CGIAM PARTNER WAS IN CHARGE OF THE AIRBORNE  
SYSTEM AND FLIGHTS**

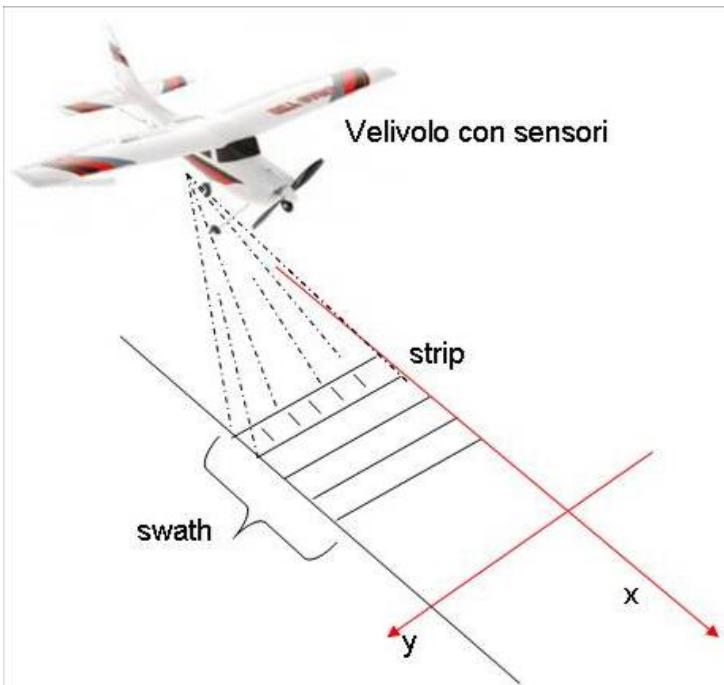
## ▶ NAVIGATION AND RECORDING SYSTEM

1. **CCNS** – (Computer Controlled Navigation System) finalizzato al controllo del volo e dei sensori.
2. **AEROcontrol** System for positioning , it integrates GPS data at 24 channels at 2Hz and data from **IMU-IIId** (Inertial Measurement Unit) a 256 Hz based on gyro in fiber optics fibra ottica. The computer also ensure the registration on data card of raw data from **IMU** and **GPS**



# SENSOR SYSTEM

- ▶ HYPERSPECTRAL CAMERA
- ▶ LIDAR
- ▶ THERMAL CAMERA
- ▶ OPTICAL CAMERA
- ▶ NAVIGATION AND REGISTRATION SYSTEM
- ▶ SYSTEM BOARD

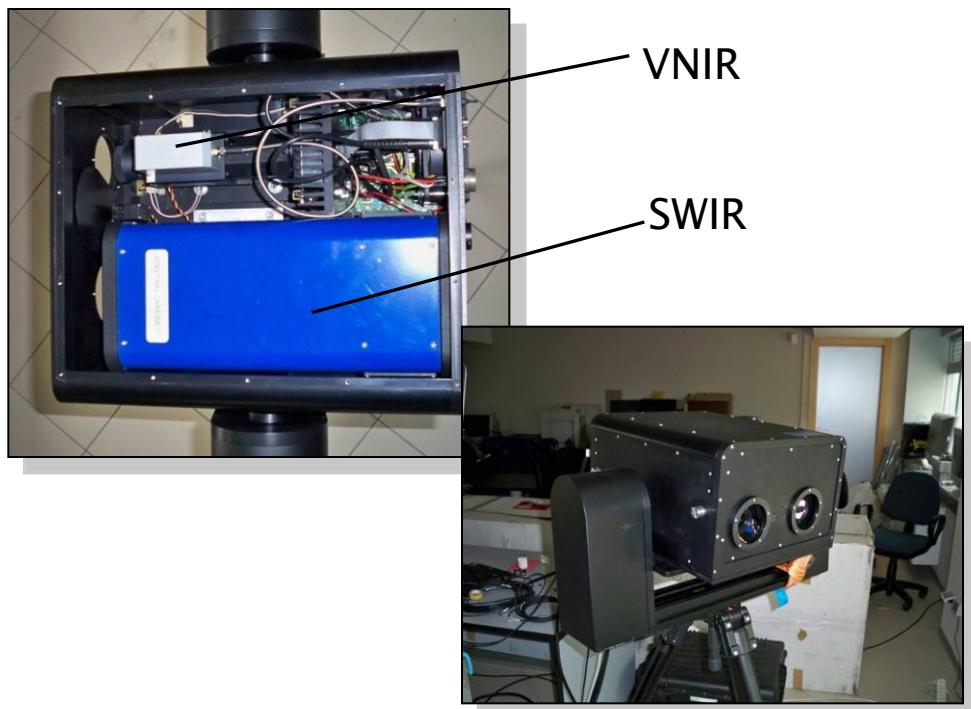


# HYPERSPECTRAL CAMERA



PUSH-BROOM system with 2 spectrometer in the VNIR-SWIR range, the spectrometer were purchased from SPECIM

The systems case permits to operate the cameras also from the ground



	VNIR	SWIR
<b>Spectrometer Name</b>	ImSpector V10E / Specim	ImSpector N25E / Specim
<b>Spectral Range</b>	400-1000 nm	1000-2500 nm
<b>Spectral Resolution</b>	2.8 nm	10 nm
<b>Spectral Sampling</b>	1.2 nm	6.3 nm
<b>Spectral bands</b>	504	239
<b>Spatial pixels</b>	1024	320
<b>Digital resolution</b>	12 bit	14 bit
<b>FOV</b>	68.64°	36°
<b>Focal length</b>	9 mm	15 mm

# LIDAR

The LiDAR (Riegl LMS-Q560) permits the Full Waveform Analysis .

.

The laser beam (Eye Safety Class) the works in the near IR frequency inviato

CARATTERISTICHE LASER	
Lunghezza d'onda	1550 nm
Durata dell'impulso	3.5 ns
Divergenza del fascio	0.5 mrad
Classe del laser	Classe 1
Distanza di sicurezza	0 m
METODOLOGIA ACQUISIZIONE	
Metodo di scansione	Specchio Poligonale Rotante
Velocità di rotazione specchio	5 – 160 KHz
Frequenza impulsi	40 – 240 KHz
Massimo angolo di scansione	60°
Numero Massimo di echi registrati	Illimitato
Frequenza di campionamento Digitalizzatore	1 GHz
Metodo rilevamento impulso	Full Waveform
Range dinamico intensità segnale	16 bit
PRECISIONE E RISOLUZIONE	
Precisione Range (2 sigma)	2 cm
Precisione elevazione (2 sigma)	6 cm @ 1,000 m AGL
Precisione planimetrica complessiva (2 sigma)	0.30 cm @ 1,000 m AGL
Max. # punti/m <sup>2</sup>	156 points @ 50 m AGL, 30 kts

# THERMAL CAMERA DigiTHERM



CARATTERISTICHE CAMERA TERMICA	
Range Spettrale	7.5 - 14 $\mu$ m
Dimensione del pixel	25 $\mu$ m
Dimensione della testa del sensore	16 X 12 mm
Range di Temperatura	- 40° -120° C
Intervallo di temperatura per l'operatività	-15 +50°C
METODOLOGIA ACQUISIZIONE	
Microbolometro non raffreddato FPA (Focal Plane Array)	640 X 480 pixel
Massima Frequenza di scatto	6 Hz
Range dinamico	16 bit
PRECISIONE E RISOLUZIONE	
Accuratezza di misura	+/- 1.5K(0°...100°C) Altrimenti +/- 2K

DigiTHERM è un sistema professionale di camera termica aereotrasportato.

- METRIC CAMERA DigiCAM H-39

- Resolution: 39 Megapixel
- Storage: 2 disk 100 Gbyte
- Acquisition interval : 1,9 sec
- Filters: Color (VIS) and Color-infrared (CIR)

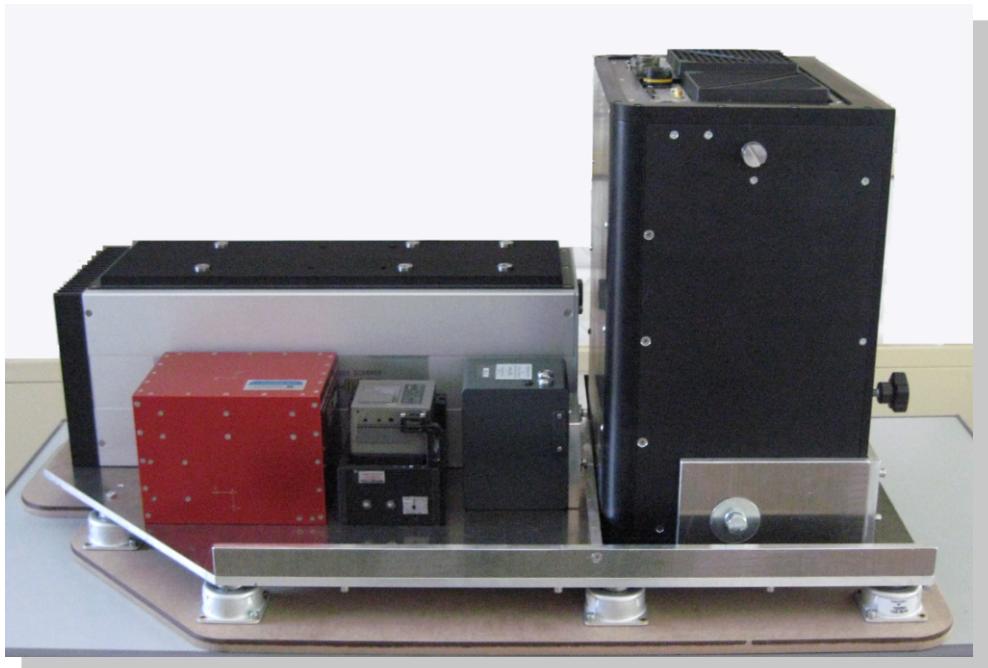




# Sistema aereo di acquisizione dati

- ▶ System board

The systems are mounted on allumiun plate with dampers to avoid system vibration.



# FLIGHT SCHEDULE

## Calibration flight

- 23.06.2012 a calibration flight to test all the system functionality on the aircraft was performed in Perugia
  - definition of the "boresight" angles for each sensore
  - sensor tests

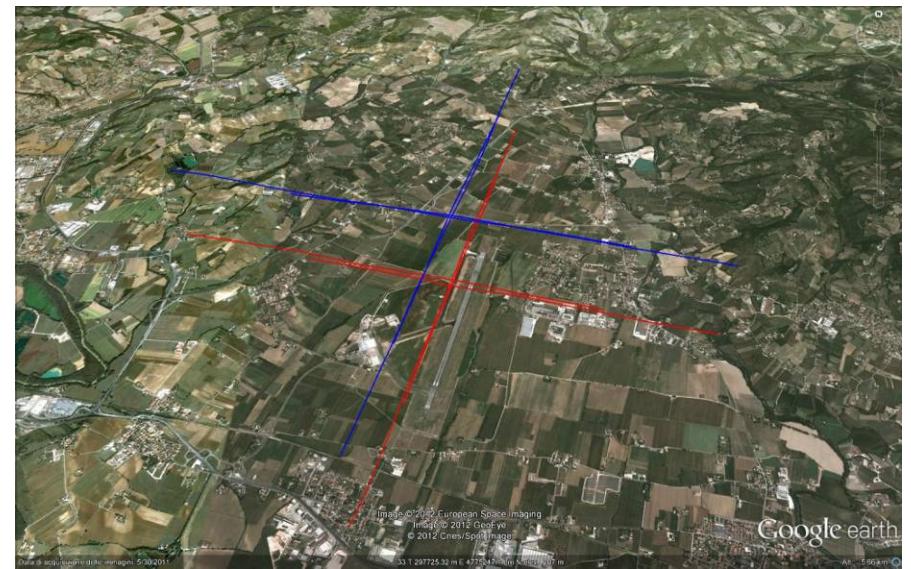
- Flight parameters

Quota: 700 m – 1400 m agl

time: 10.40 – 11.15 locale

N. Flight lines 8

Directions W-E, E-W, N-S, S-N



Volo di calibrazione eseguito sull'aeroporto di Perugia il giorno 23.06.2012.  
In rosso le linee di volo a quota 700 metri agl, in blu quelle a 1400 metri agl.

# Flight test on Mt.Etna

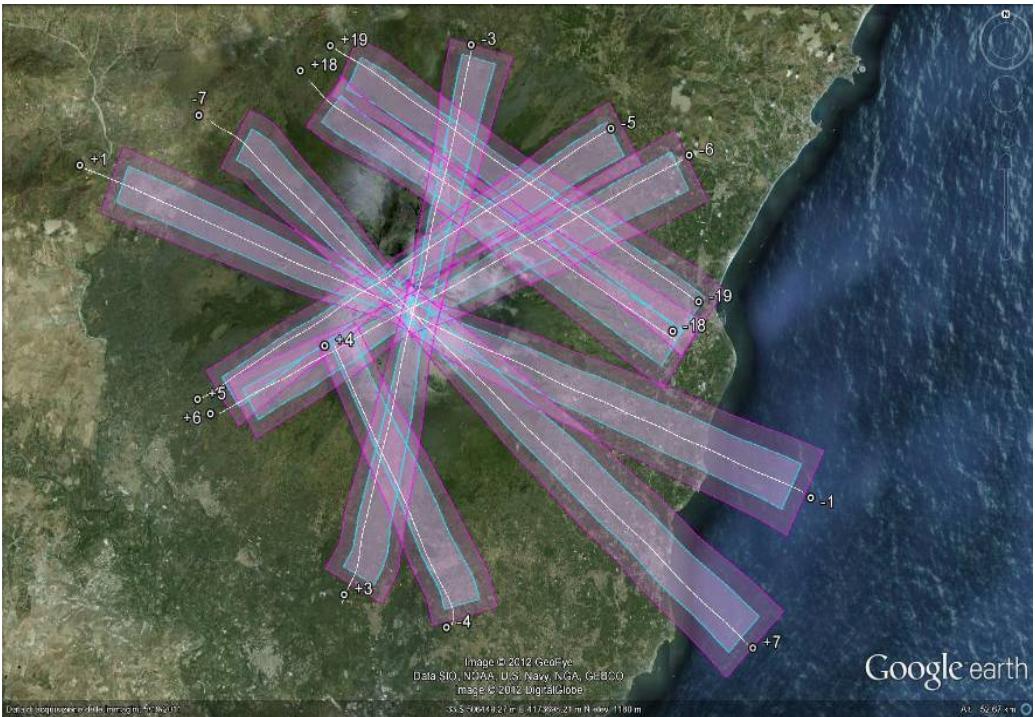
- On 24.06.2012 the system performed a test flight on Etna to verify
  - Acquisition parameters (e.g. time integration, frame rate, flight velocity)
  - Operational condition at the required flight altitude (4500–5000 m)
- flights parameters  
Quota: 4500 m sml  
time: 9 – 11 local  
N flights 3  
Flight dir NW–SE, SW–NE



Strisce acquisite sull'Etna il giorno 24.06.2012.  
In celeste le strisce nello SWIR, in fucsia le strisce nel VNIR, in bianco le linee di volo.

# Volo su Mt.Etna

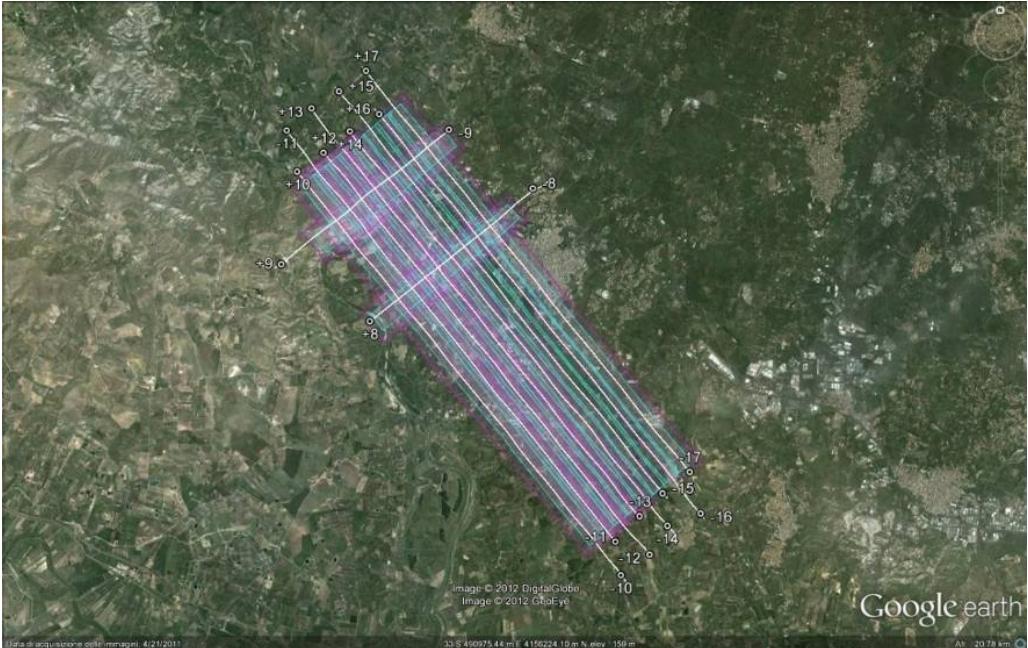
- 25.06.2012 flight campaign on Etna
  - Hyperspectral data
  - Thermal camera
  - Optical camera
- Flight parameters  
Quota: 4500 m sml  
time: 9 – 11 local  
N flights lines; 8  
Flight direction NW-SE, SW-NE, SE-NW



Strisce acquisite sull'Etna il giorno 25.06.2012.  
In celeste le strisce nello SWIR, in fucsia le strisce nel VNIR, in bianco le linee di volo.

# Flights on Paternò area

- 26.06.2012 flight campaign on Paternò :
  - hyperspectral data
  - Lidar data
  - thermal camera
  - optical camera



- flight parameters on Paternò

Quota : 1000 m agl

time: 9.15 – 10.15 local

N flights lines: 10

Direction SE-NW, NW-SE

Strisce acquisite su Paternò il giorno 26.06.2012.

In celeste le strisce nello SWIR, in fucsia le strisce nel VNIR, in bianco le linee di volo.



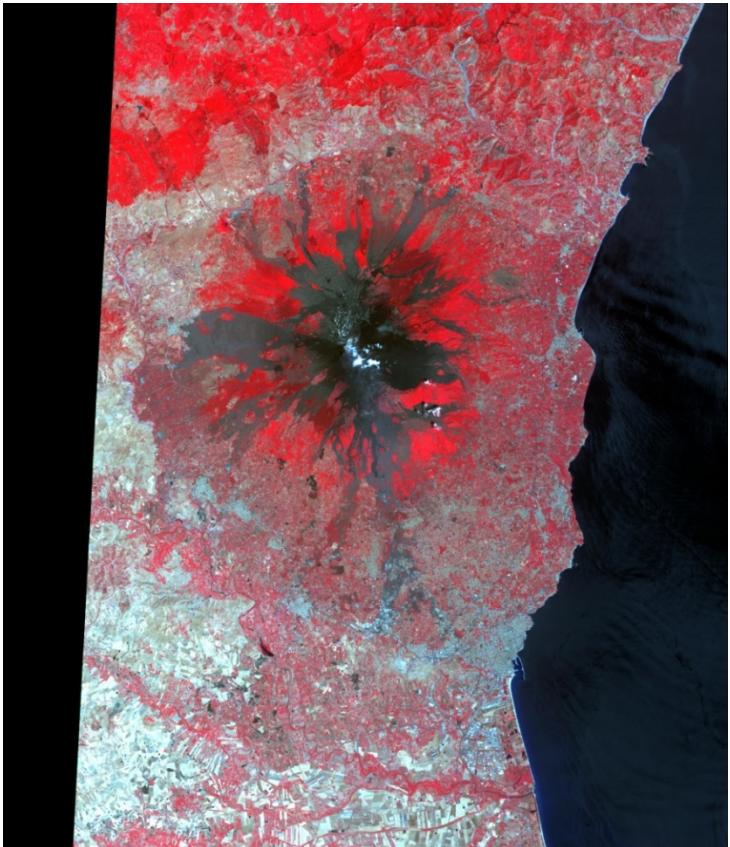
# SATELLITE DATA ACQUISITION

Thanks to the collaboration and support of NASA-GODDARD and NASA-JET PROPULSION LABORATORY

HYPERION and ASTER have been acquired during the flights over Etna and Paternò area



# Acquired Satellite Data



Aster 25 Giugno 2012 – 09:53 UTC



Hyperion 23 -26 - 28 Giugno 2012



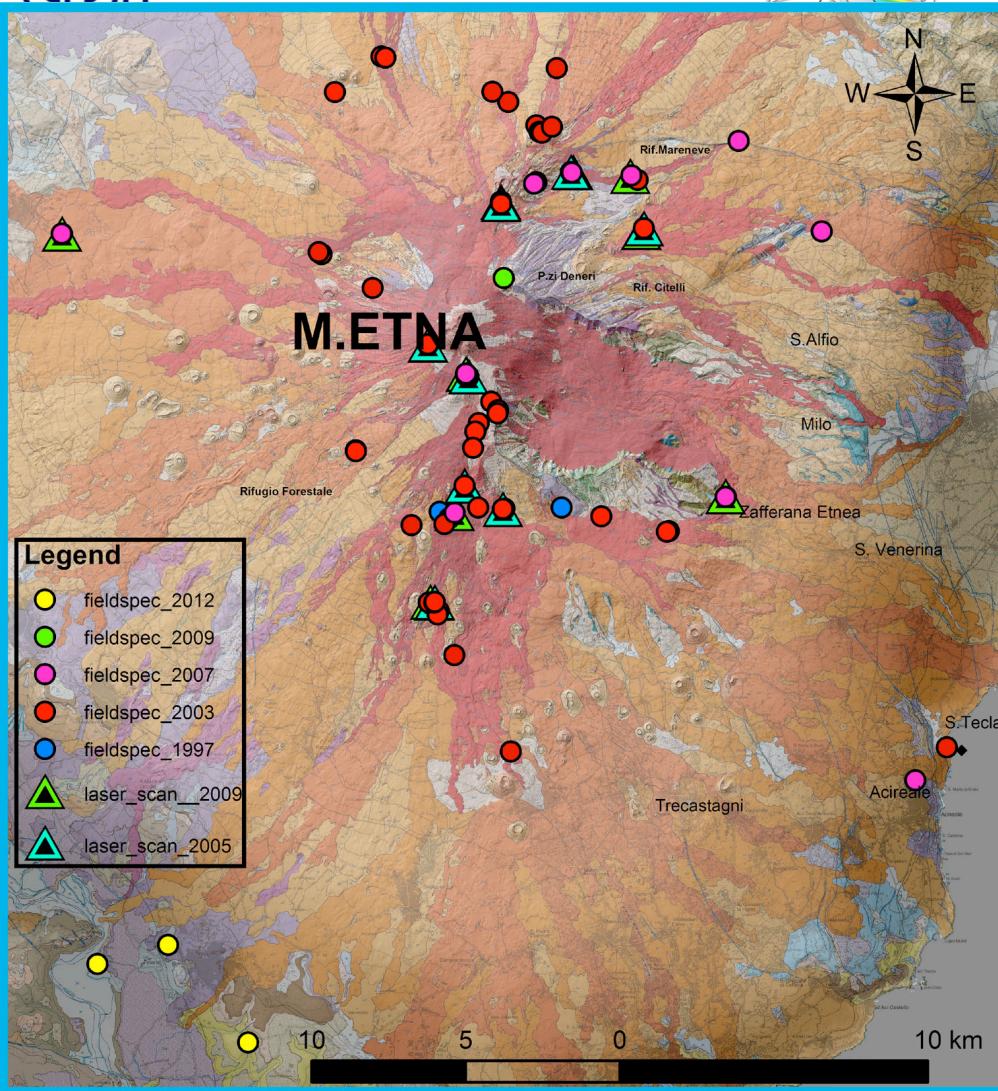
# FIELD CAMPAIGN

The field campaign has been dedicated to acquire surface spectral characteristics, texture, temperature, emissivity and local atmospheric parameters

The data will be used to validate both airbone and spaceborne data

Instrument used :

- FieldSpec
- ground Laser Scanning
- GPS
- thermal camera
- sun photometer
- Unilogger to record continuous meteo station data and ground temperature
- Micro-FTIR



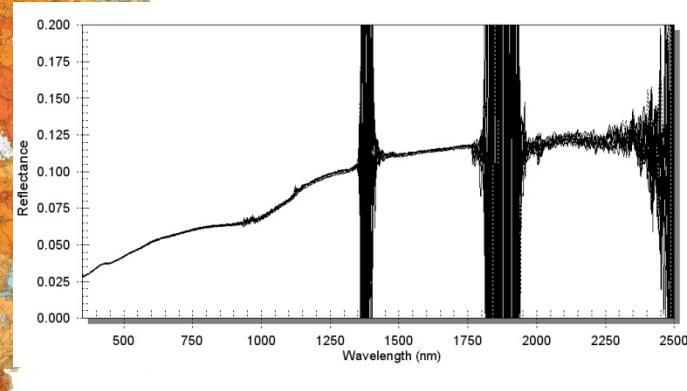
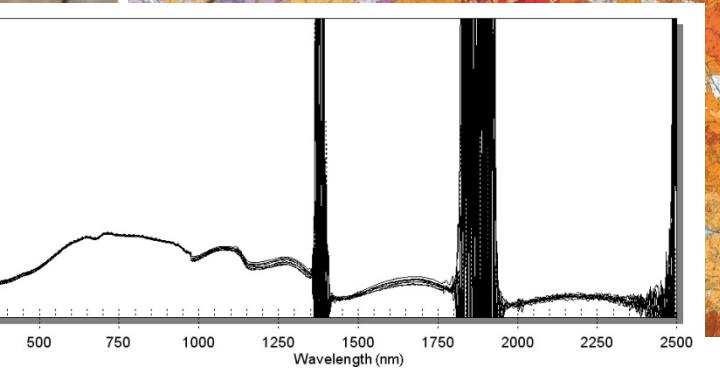
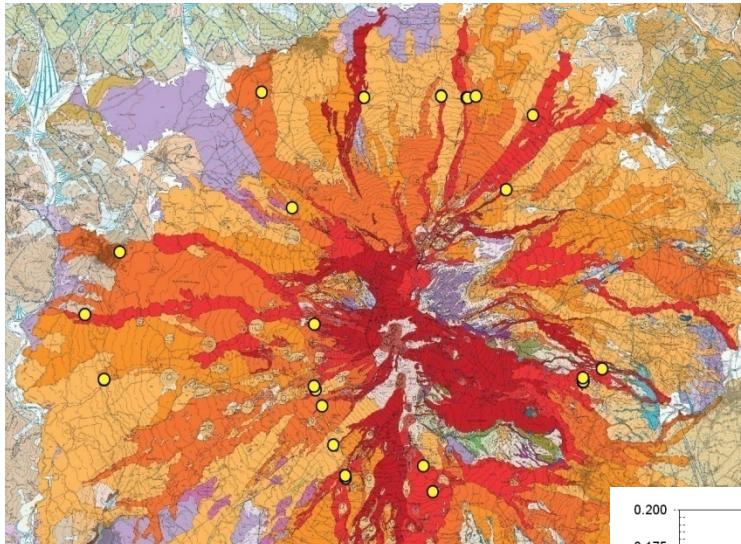
I dati sono divisi per strumentazione (FieldSpec o Laser 3D) e per periodo di acquisizione. I dati sono proiettati sulla nuova cartografia geologica alla scala 1:50000 dell'Etna.

## Measurement sites

- rock spectra related to different Etna lava flows
- Ground laser scanner to analyse the surface texture

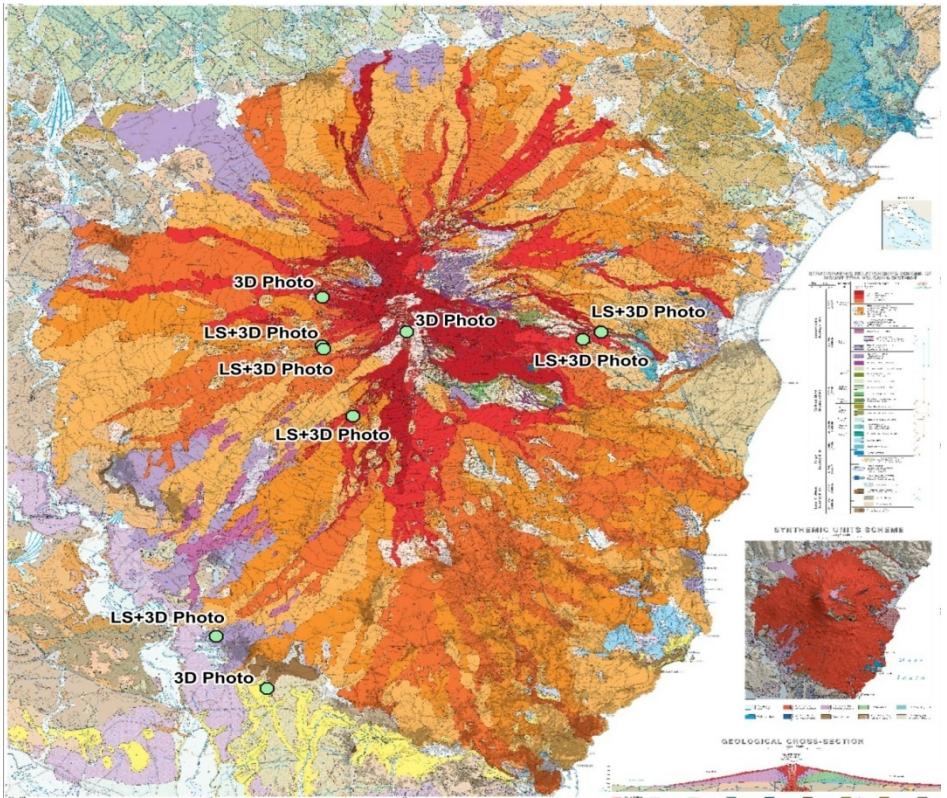


# Fieldspec measurements



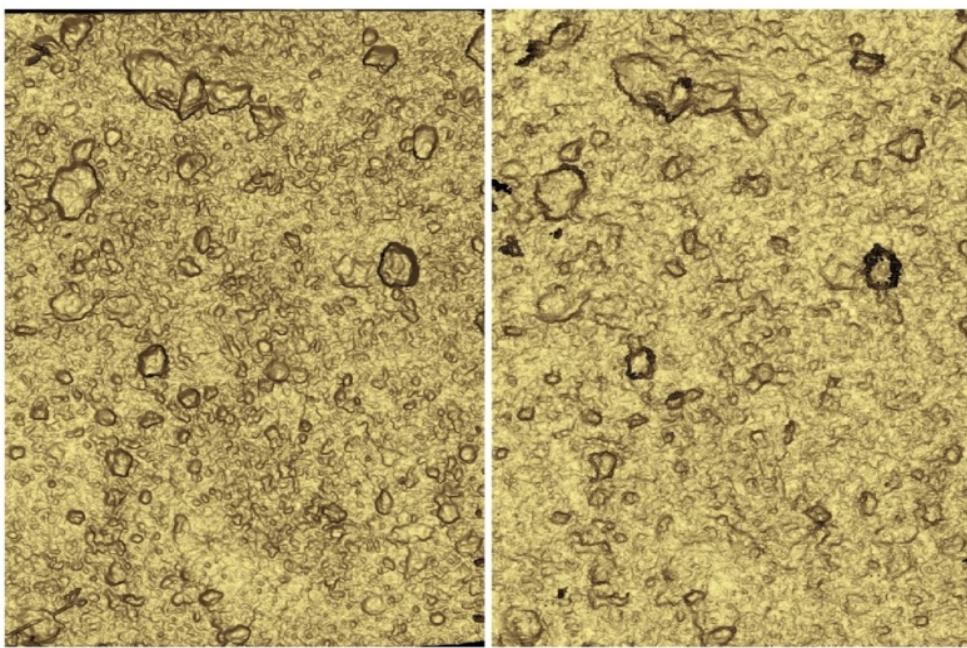


# Laser Scanning





Campione preso sulla colata 1852-1853 tra Milo e Fornazzo



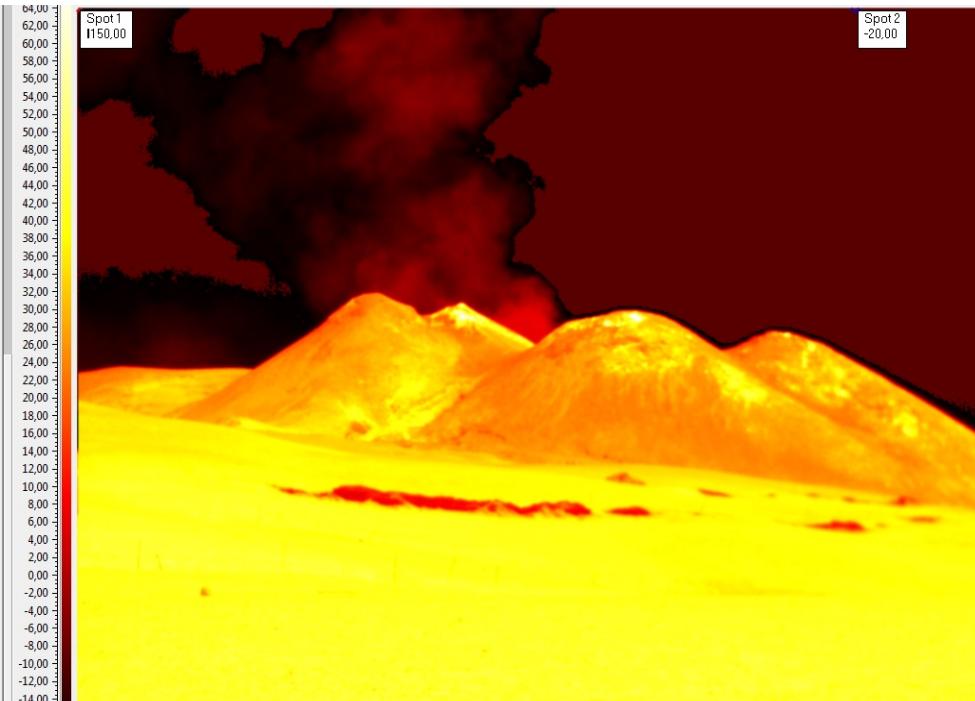
Modello acquisito con il laser Konica Minolta VI-910 3D

Modello ricostruito con tecnica "Structure from Motion" da una sequenza di foto.

Lava optical photo and foto 3D models derived from Laser 3D and from the system "structure from motion"

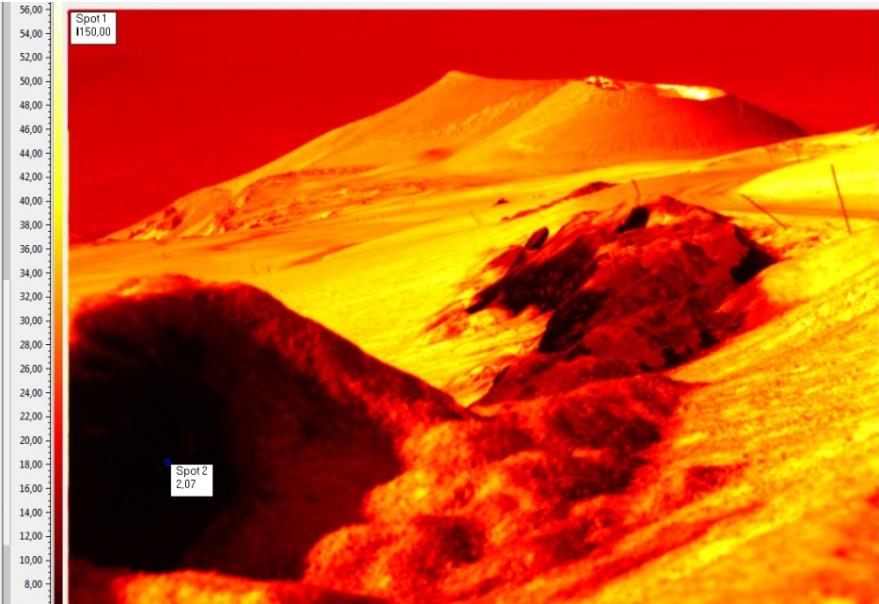
# THERMAL CAMERA

Thermoteknix System Ldt VisIR 640



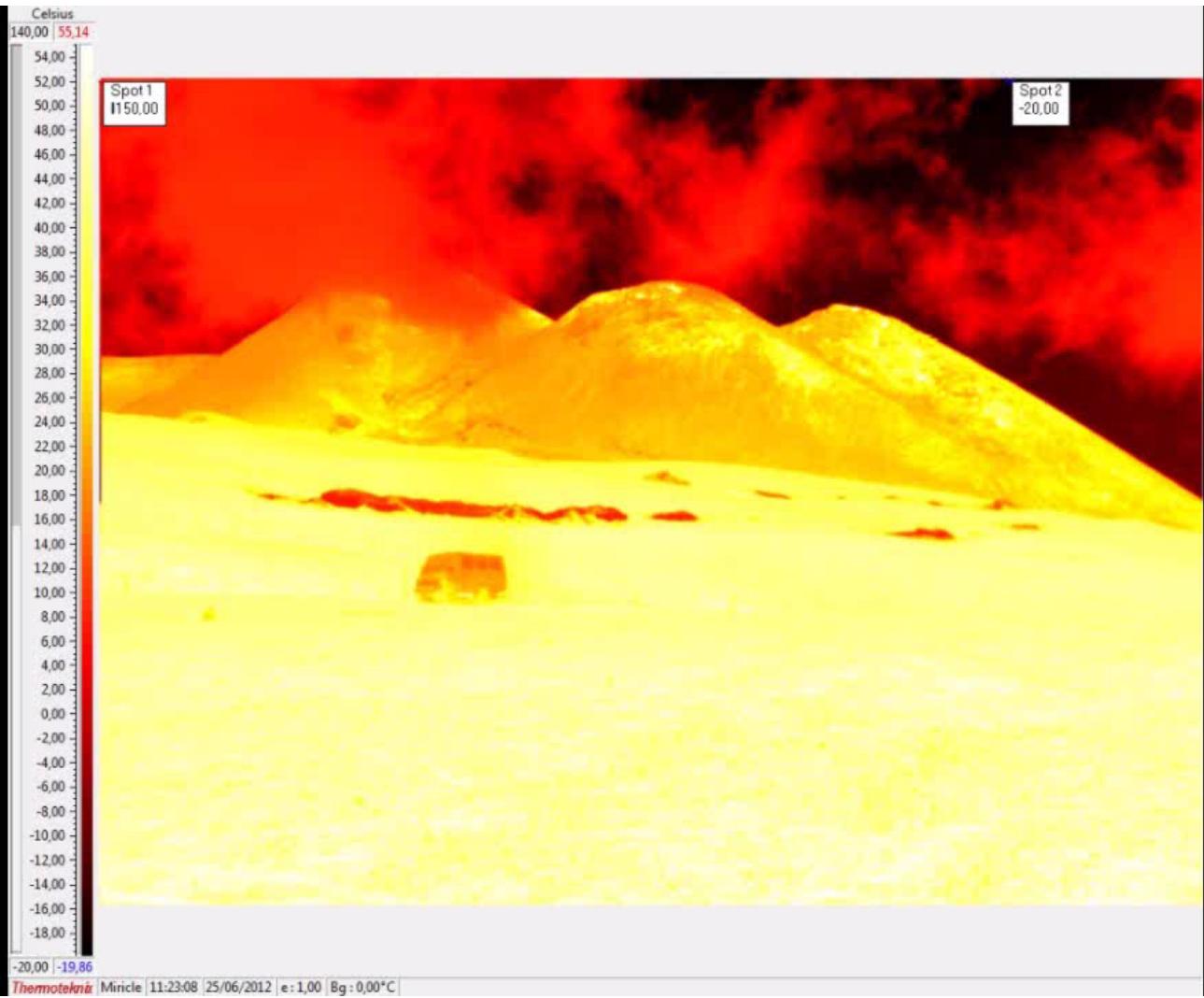


The collected images have been acquired from  
9.40 AM local time up to 12.26 AM local time



Snow deposits covered by ash





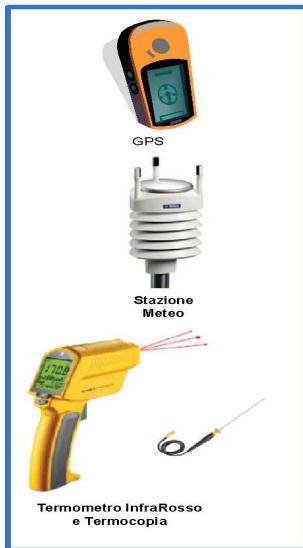


# UNILOGGER

The sun photometer e l'unilogger have been used to acquire information on the atmosphere



Alimentazione a energia solare e erogata a diverse tensioni per i diversi strumenti e computer portatile

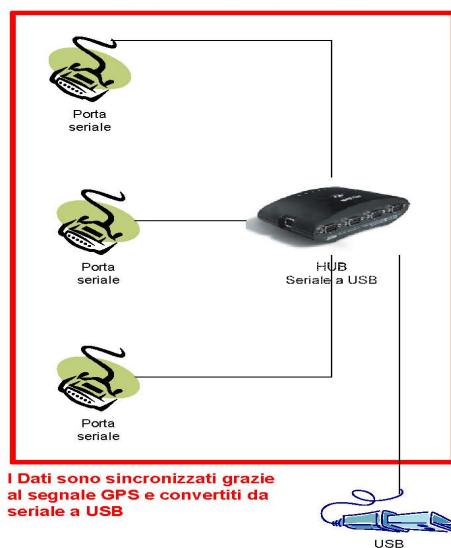


- GPS:**
- Tempo e posizione geografica
  - Sincronizza l'acquisizione dei dati
  - Aggiorna il clock del PC portatile

**Stazione Meteo:**

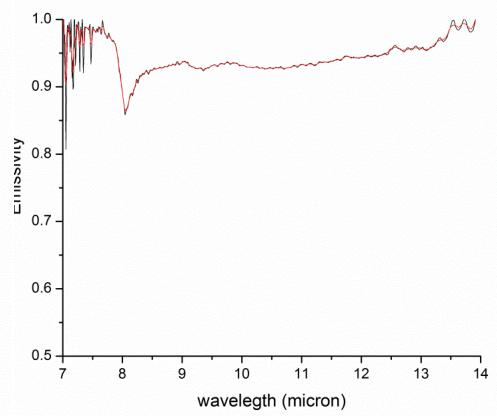
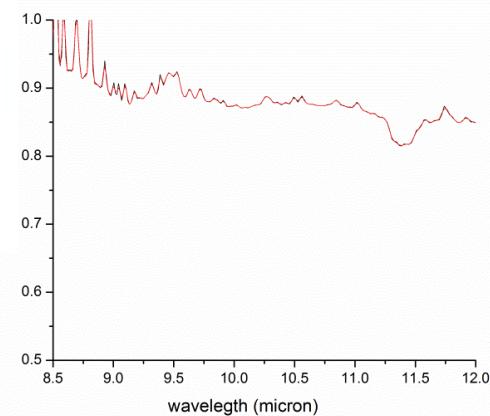
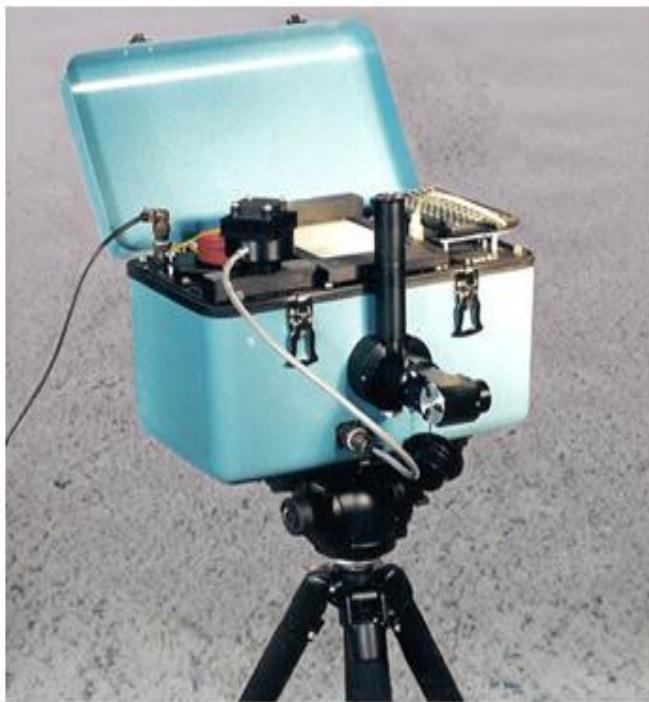
- Temperatura dell'aria
- Velocità del vento
- Pressione atmosferica
- Precipitazioni

- Termometro infrarossa e termocoppia**
- Temperatura radiometrica/emissività
  - Temperatura al contatto (Probe)





# MicroFTIR



# PRELIMINARY DATA ANALYSIS

HYPERSPECTRAL DATA :

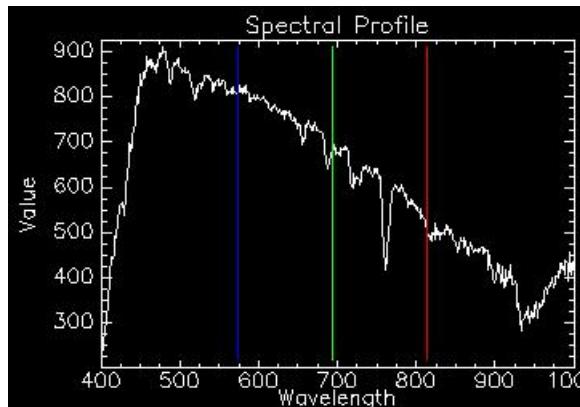
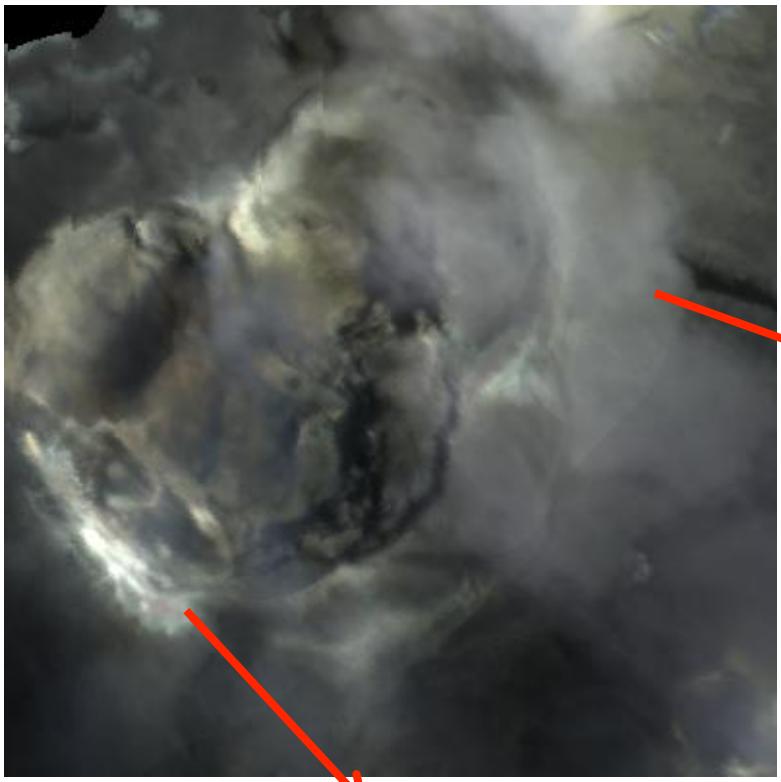
DN calibration to radiance

Preliminary geocoding

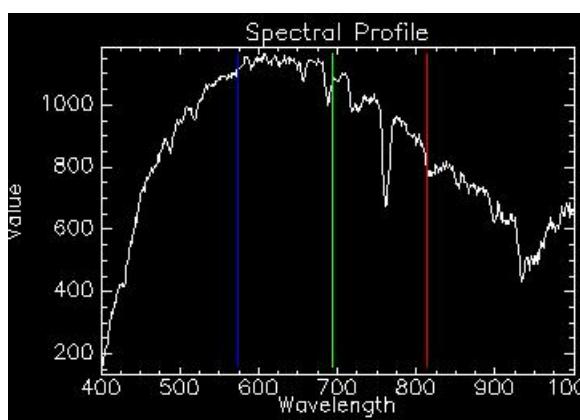


Strip 1 su M. Etna –Composizione CIR ( 814.66nm 694.03nm 574.20nm )

## VNIR SPECTROMETER IMAGE

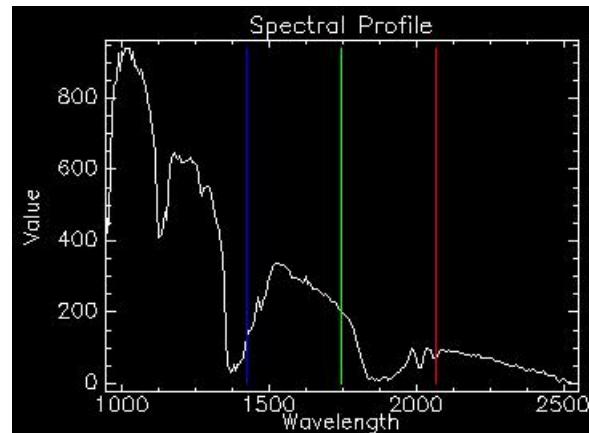
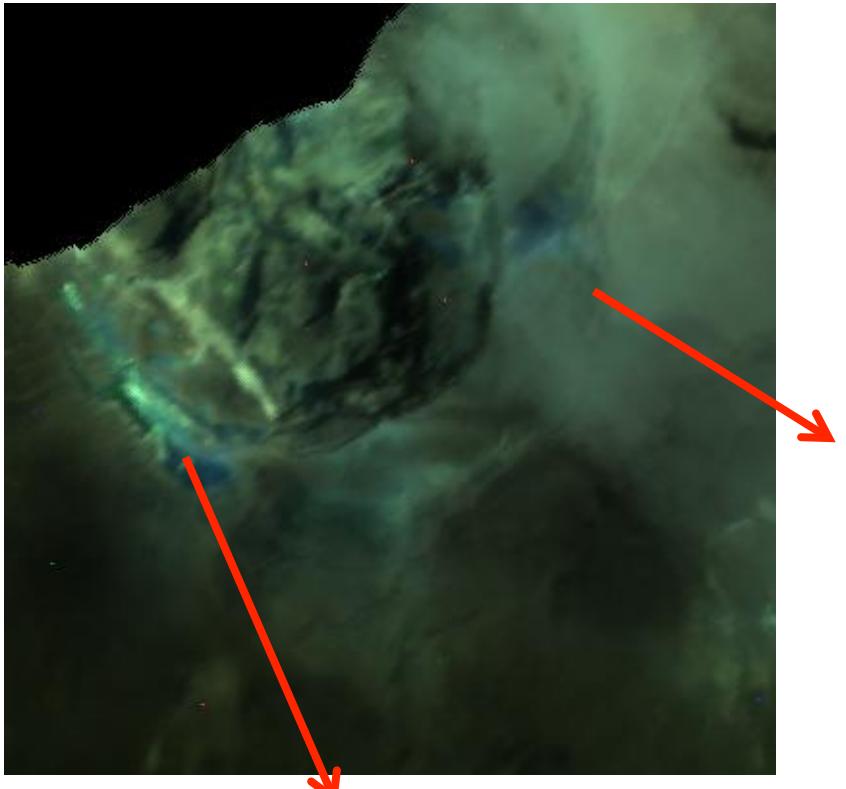


Spectra inside the plume

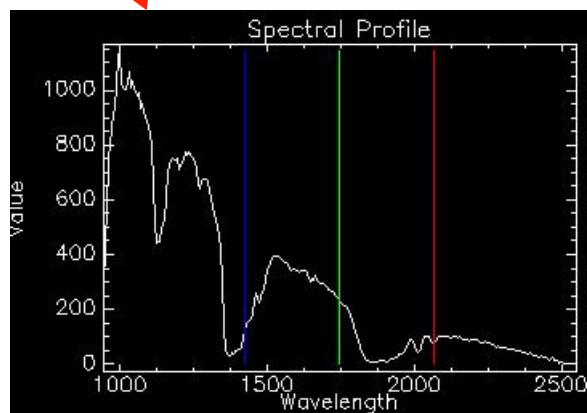


Spectra on the sulfur deposits

## SWIR SPECTROMETER IMAGE



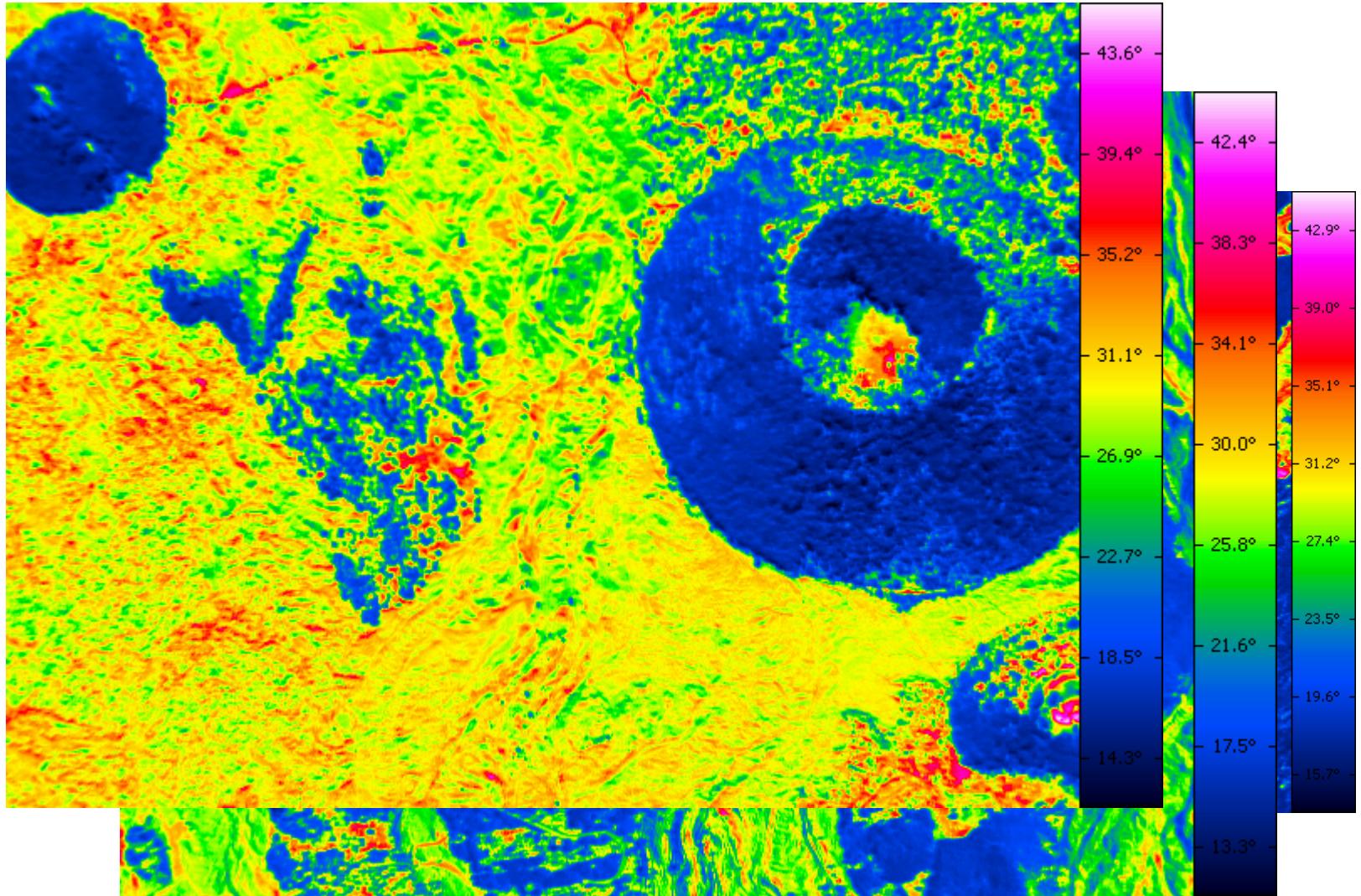
Spectra inside the plume



Spectra on the sulfur deposits



## THERMAL CAMAERA :



# OPTICAL CAMPERA

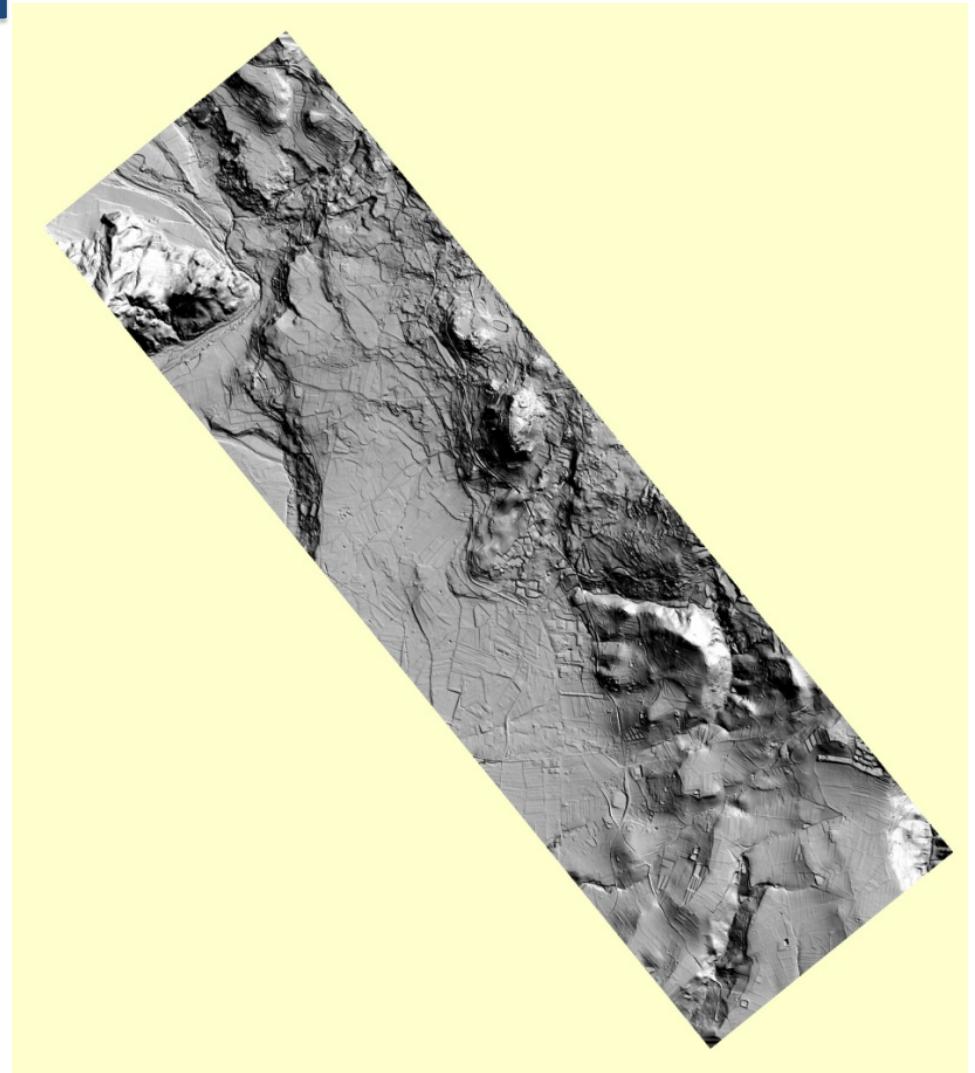
- radiometric correction
- geometric correction





# Airborne Lidar Data

- Conversion of impulse
- Geocoding of acquired points





## CONCLUSION

In the coming months both ground measurements analysis and airborne data calibration will continue in order to prepare suitable data set for the algorithms developed in the ASI-AGI project

Atmospheric corrections will be applied to selected flight lines

The satellite data will be also processed to retrieve reflectance and emissivity

Ground data will be prepared to create a spectral library for Etna lava flows end members

A complete campaign report will be published in english in the next months

We are available to collaborate with HyspIRI scientists interested to the data set

**WE ARE VERY THANKFUL TO**

**ALL THE ASI-AGI CAMPAIGN TEAM and INGV COLLEAGUES FROM  
CATANIA WHO HELP US IN ALL THE MEASUREMENTS ON ETNA and  
PATERNO**

**ASI PRISMA TEAM**

**THE NASA-GODDARD and JET PROPULSION LABORATORY FOR  
CONSTANT SUPPORT IN ACQUIRING HYPERION AND ASTER DATA**

Thank  
you

