Studi e missioni iperspettrali nel VIS-SWIR : contributo della missione PRISMA allo studio di fenomeni geofisici

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Workshop Data Exploitation della missione PRISMA, precursore delle missioni iperspettrali nazionali

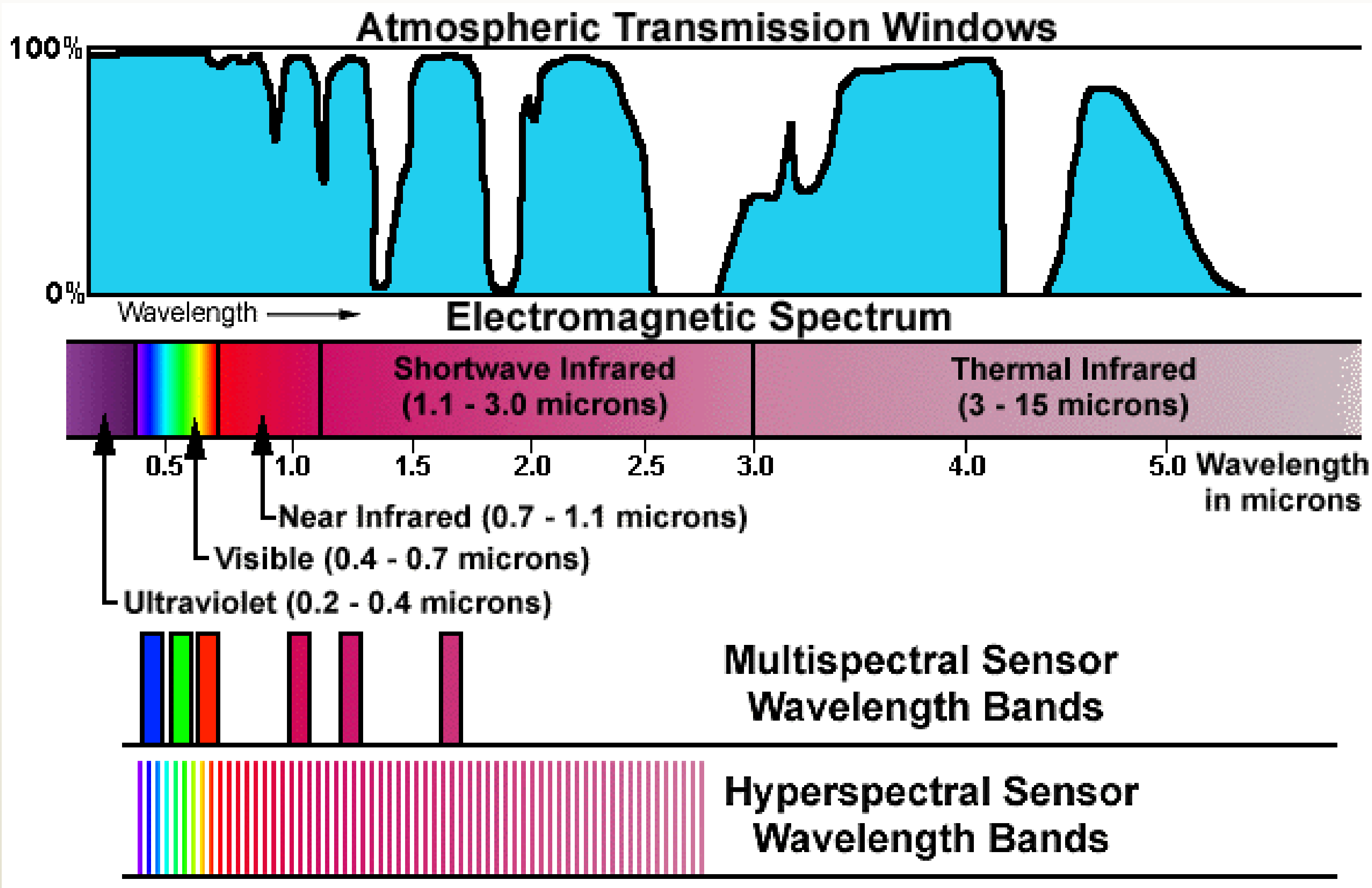
Roma 11-3 Marzo 2017

SUMMARY

1. Image spectrometers :satellite missions
2. Hyperspectral images data to monitor Geophysical hazards

1. ASI-AGI Project applications
2. Processing chains concept
3. Some results
4. Conclusion

IMAGE SPECTROMETER (HYPERSPECTRAL SENSORS SPECTRAL RANGES VIS-IR



Hyperspectral Missions – Launch and Lifetime

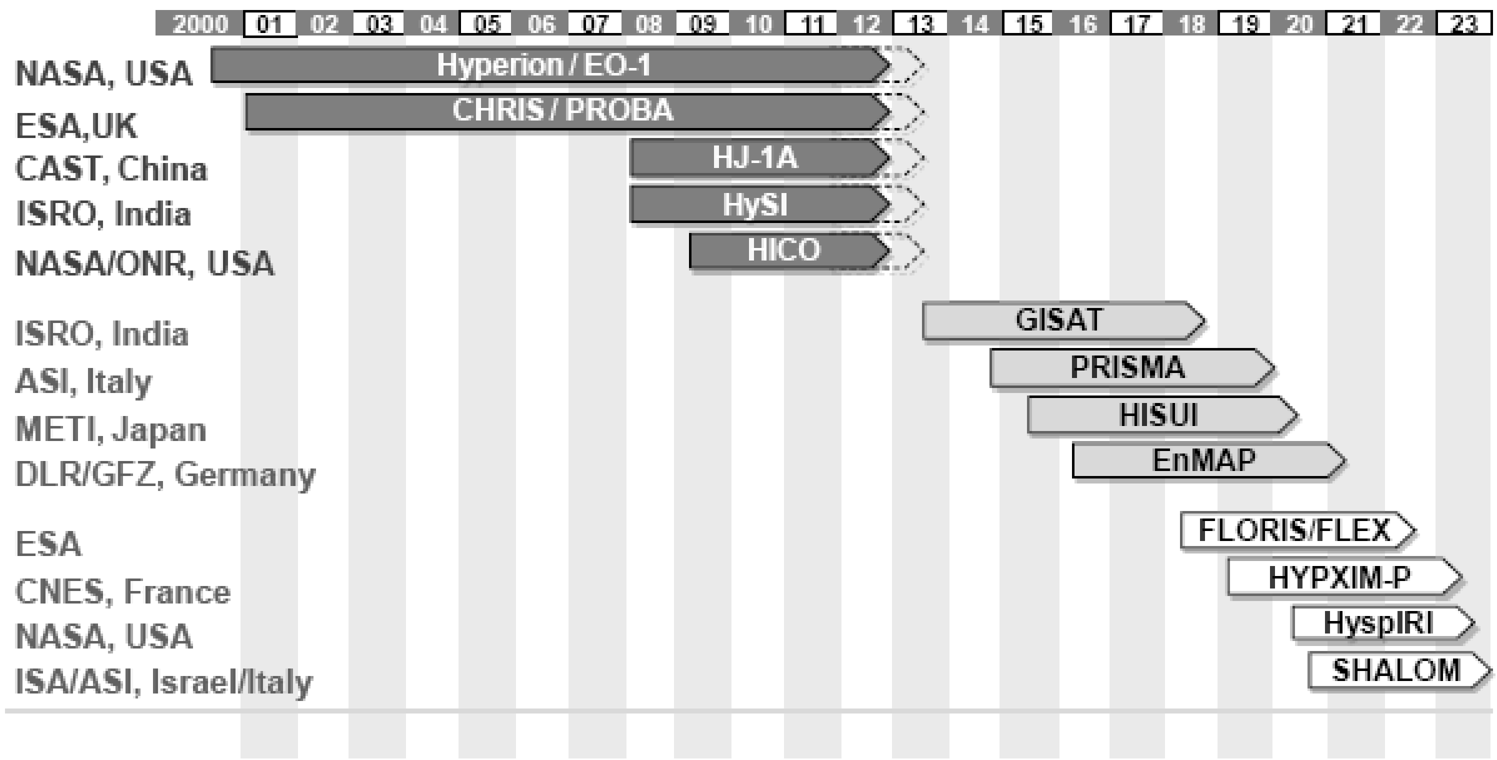
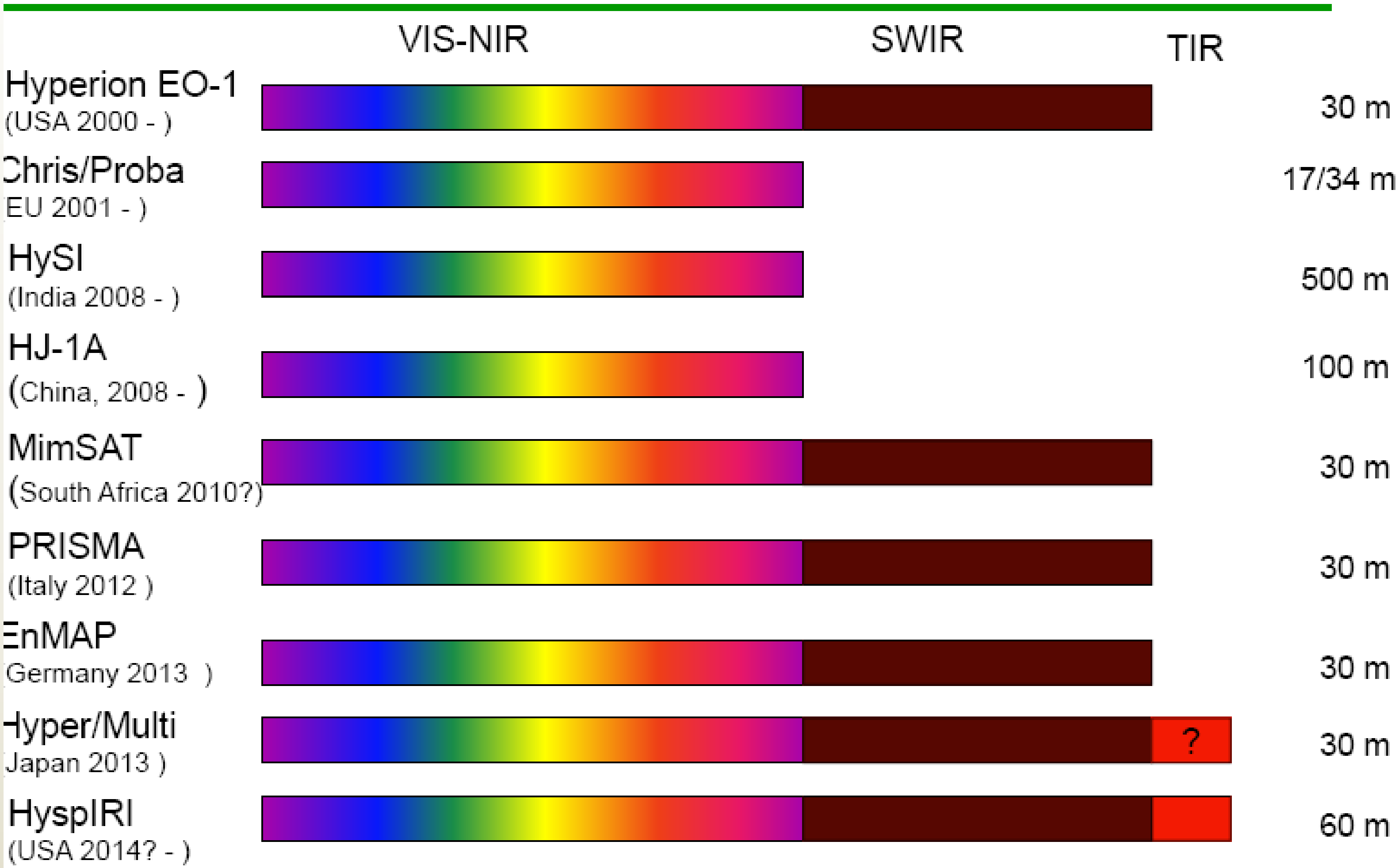
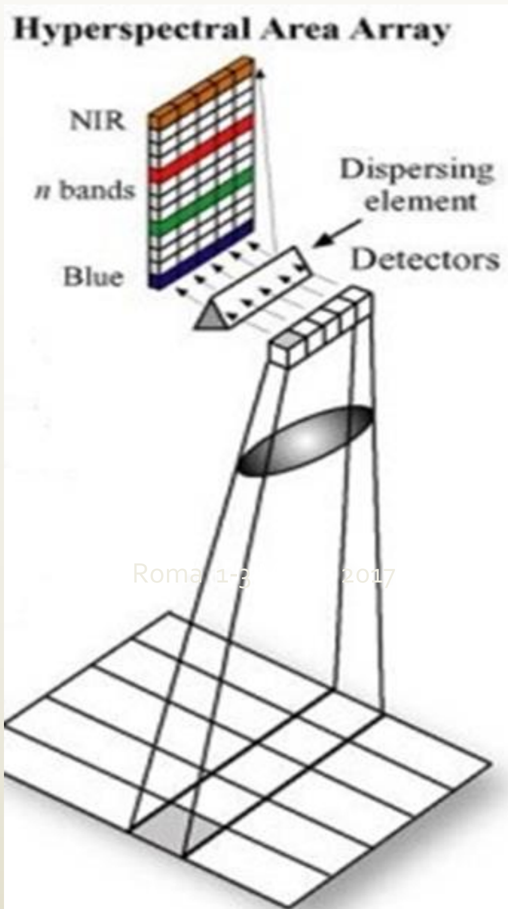


Figure 2: Spaceborne imaging spectroscopy mission launch dates and lifetimes (▇ missions currently in operation, ▭ missions under construction, ▭ missions in a planning stage).

Current and Planned Civilian Satellite Missions



The PRISMA Payload is an Electro-Optical instrument based on a pushbroom scanning technique, consisting of a high spectral resolution imaging spectrometer. It operates in the spectral range 0.4-2.5 μm and is optically integrated with a medium resolution Panchromatic camera operating in the spectral range 0.4-0.7 μm.

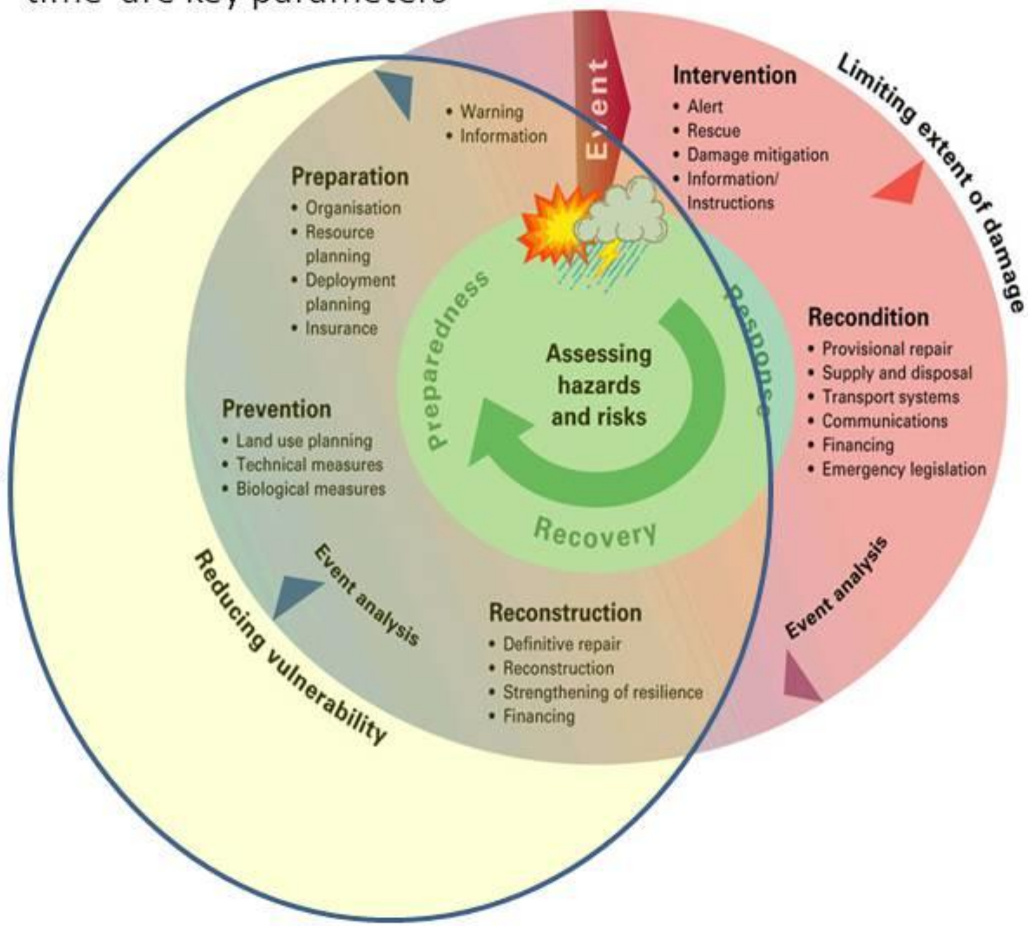


Courtesy of ASI

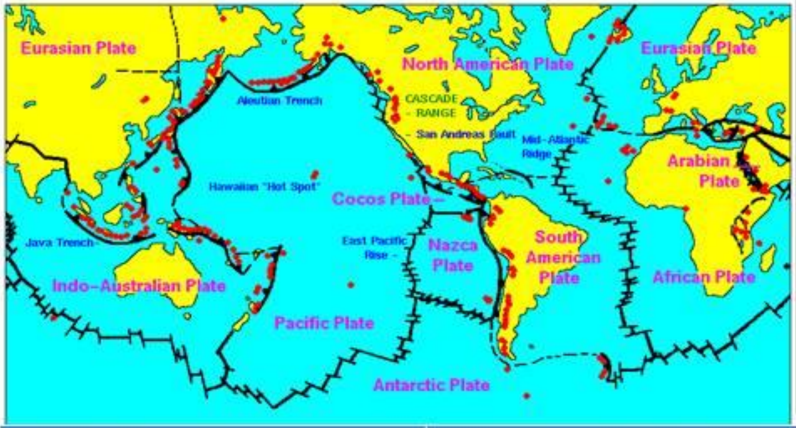
Instrument Main Characteristics	
Swath / FOV	30 km / 2.45°
GSD	• Hyperspectral: 30 m • PAN: 5 m
Spatial Pixels	Hyperspectral: 1000 PAN: 6000
Spectral Range	VNIR: 400 – 1010 nm SWIR: 920 – 2505 nm
Spectral Resolution	≤ 12 nm
Spectral Bands	VNIR: 66 SWIR: 171
Radiometric Quantization	12 bit
VNIR SNR	> 200:1 on 400 – 1000 nm > 500:1 @ 650 nm
SWIR SNR	> 200:1 on 1000 – 1750 nm > 400:1 @ 1550 nm > 100:1 on 1950 – 2350 nm > 200:1 @ 2100 nm
PAN SNR	> 240:1
Absolute Radiometric Accuracy	Better than 5%

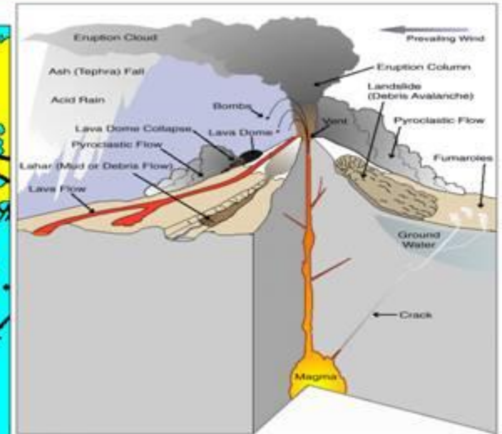
Hyperspectral data could provide important information in all the Disater management Phases with a specific contribute to: **Preparation, Mitigation and Recovery Phases**. Spectral, spatial resolution and satellite revisit time are key parameters

PRISMA APPLICATIONS



PRISMA PRODUCTSTO MONITOR VOLCANOES





RISK PHASE	PRISMA PRODUCTS	SPECIFICATIONS
Prevention Phase	Lava product mapping: mineral analysis Vegetation growth and weathering Ash deposits	Full spectral range Data fusion with panchromatic
	Degassing plumes analysis (H_2O, CO_2), volcanic aerosols	Full spectral range Water and CO_2 bands mandatory
Crisis Phase	active lava flow Thermal Flux, Effusion Rate	SWIR range multi-channel approach, avoid saturation
	Mapping the development of new Lava flows	SWIR channels, data fusion with panchromatic
Post Crisis Phase	Volcanic products impact on soil and vegetation	Full spectrum, integration with ground measurements
	Update of geological maps and risk maps	Full spectrum, data fusion with panchromatic, geometric corrections

INGV infrastructure and services based on EO data in support of the Civil Protection Department (DPC) also considered for COPERNICUS services

1991-2000

- Partecipazione alla campana MAC EUROPE 91
- Progetti di ricerca DPC
- Sviluppo procedure per l'analisi EO per applicazioni vulcanologiche e sismiche dati OTTICI e SAR
- Progetti MADVIEWS ed EMPEDOCLE

2001.2006

- Acquisizione dati EO in modo sistematico (sistemi di acquisizione RT)
- Sviluppo procedure operative su requisiti forniti da DPC
- Monitoraggio con dati EO viene introdotto nelle convenzioni DPC-INGV

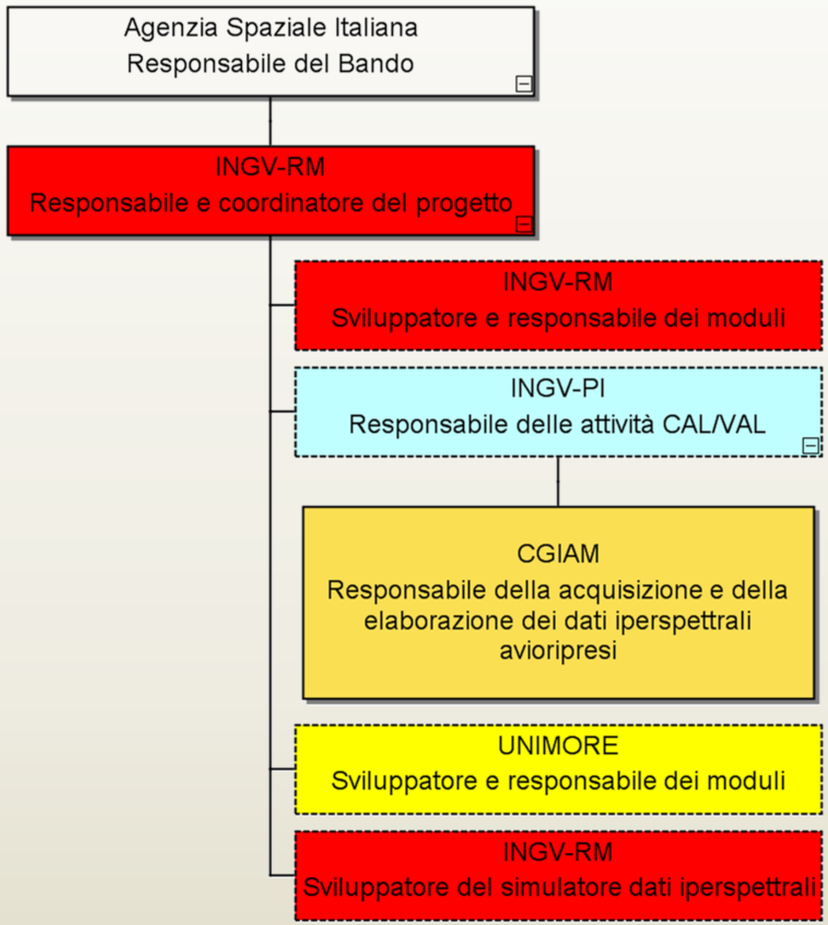
2004-2011

- 2004 -2011 Sviluppo PROGETTI PILOTA ASI per il supporto al rischio Vulcanico e Sismico
- Requisiti dei prodotti sono definiti del DPC

2006-2014

- INGV ha partecipato allo sviluppo del sistema GMES-COPERNICUS guidando il settore VULCANI e TERREMOTI per i servizi del CORE SERVICE EMERGENCY

ASI-AGI:
ANALISI SISTEMI IPERSPETTRALI PER LE APPLICAZIONI GEOFISICHE INTEGRATE



PRISMA GEOPHYSICAL APPLICATION PRODUCTS (ASI-AGI)

- PRISMA DATA SIMULATION
  - COMMON UTILITIES
    - GEOMORPHOLOGY Rock and Minerales SPECTROSCOPY
    - VOLCANIC APPLICATIONS
    - FIRE APPLICATONS

PRODUCTS DEVELOPMENT APPROACH

COMMON UTILITIES

Atmospheric correction	Pan Sharpening	Topographic Correction

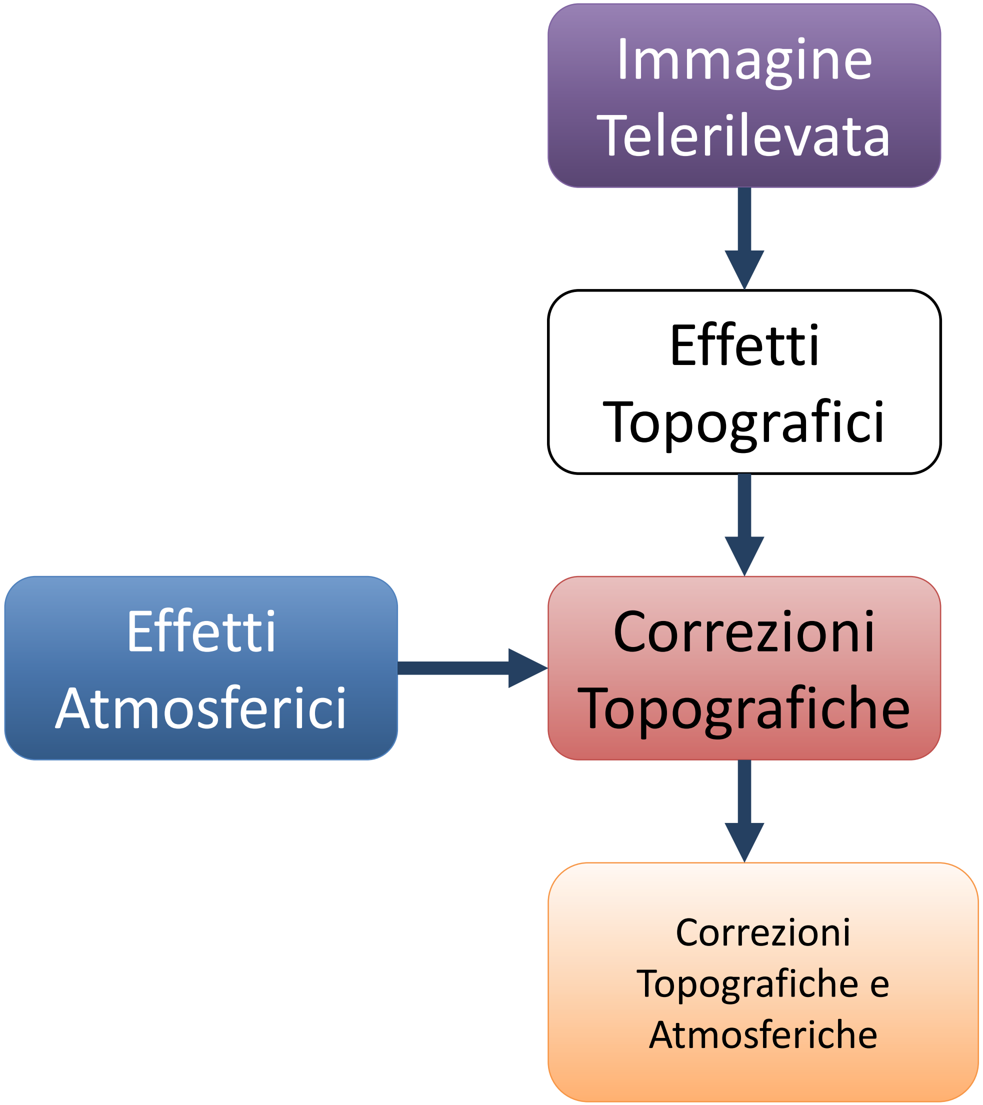
ADDED VALUES VOLCANIC PRODUCTS

Volcanic products Classification	Lava Thermal analysis	Volcanic gases analysis

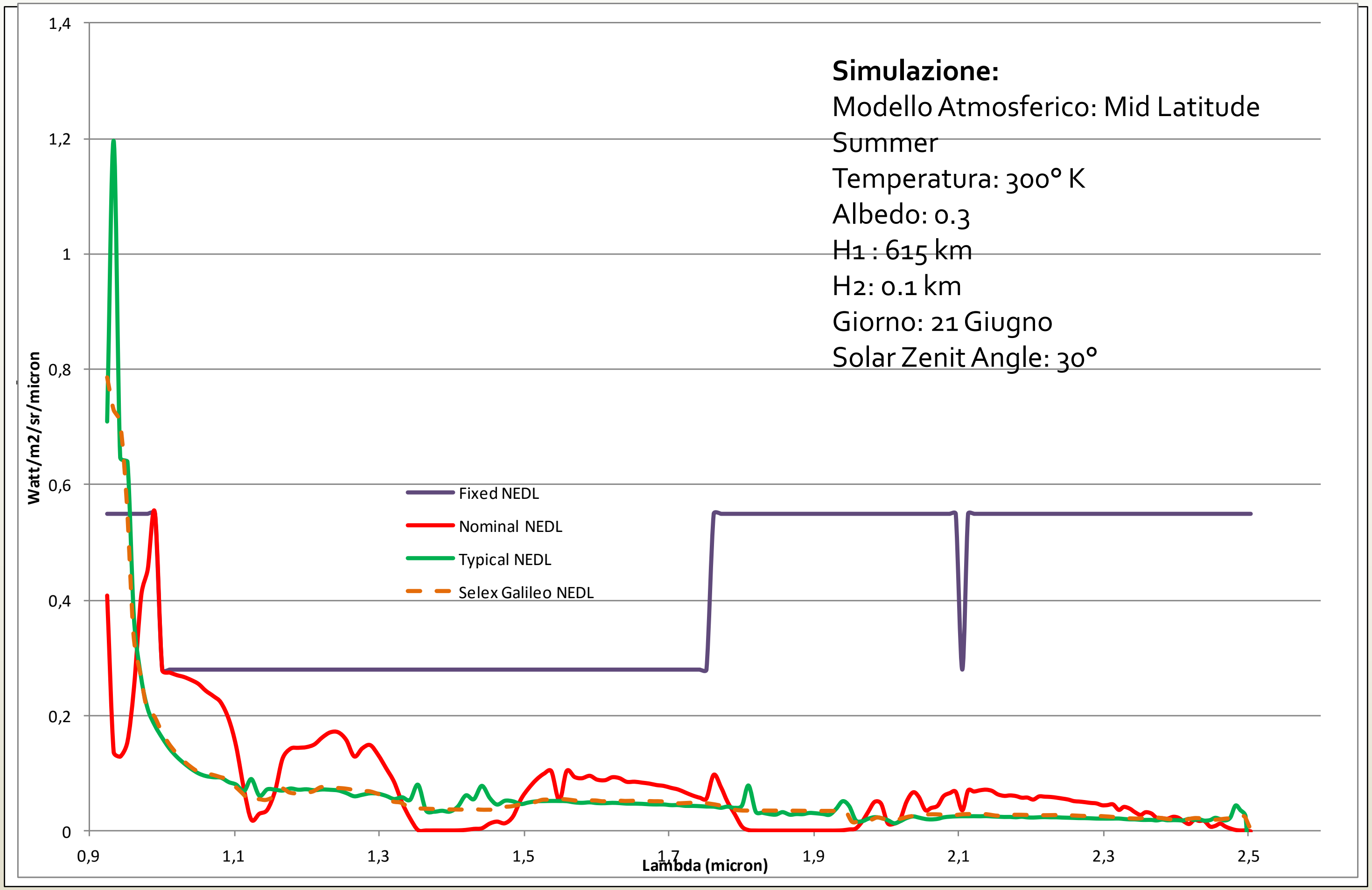
CAL /VAL ACTIVITIES

PERMANENT TEST AREAS	MT. Etna spectral library

Correzione Topografiche e Atmosferiche

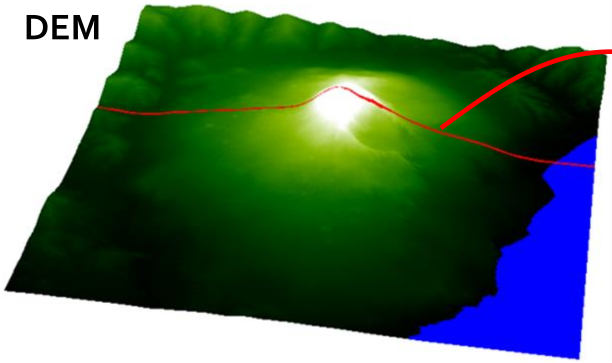


PRISMA SIMULATED TRANSMITTANCE RADIANCE and NeDL

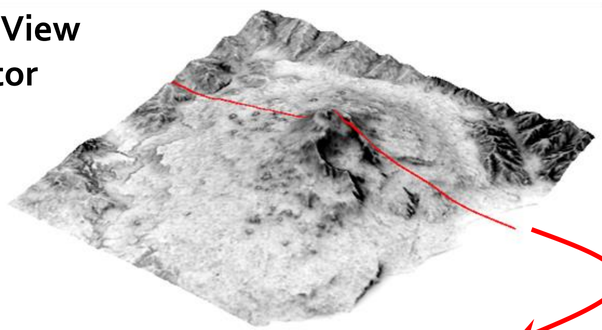


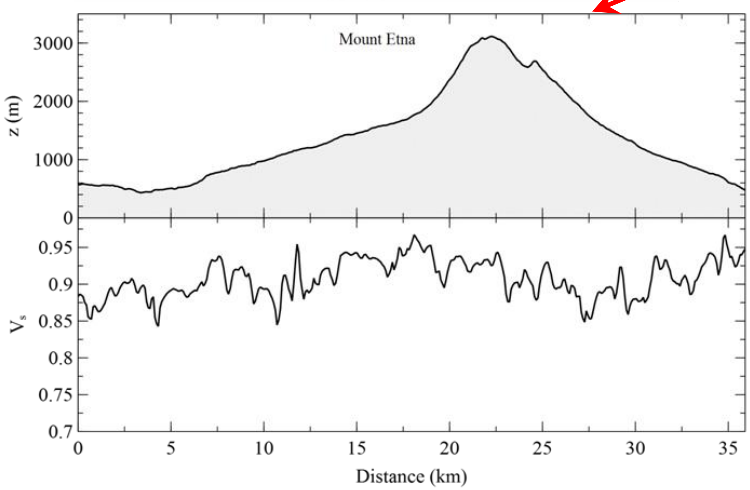
WP 2.1 Correzione topografica: "Screenshoots"

DEM

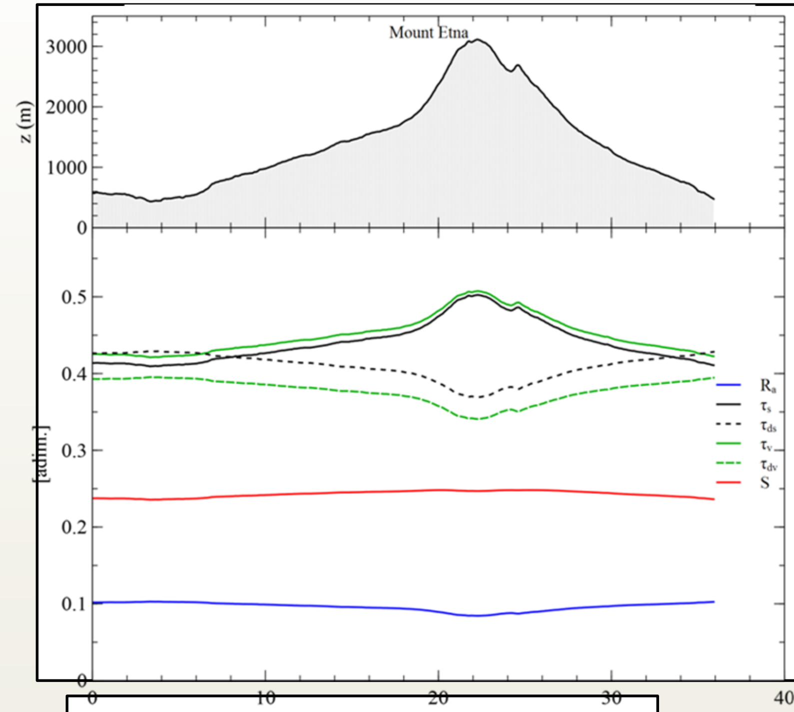


Sky View Factor

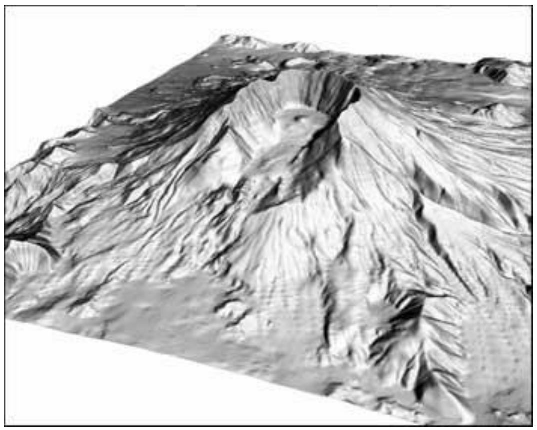




Termini di correzione atmosferica

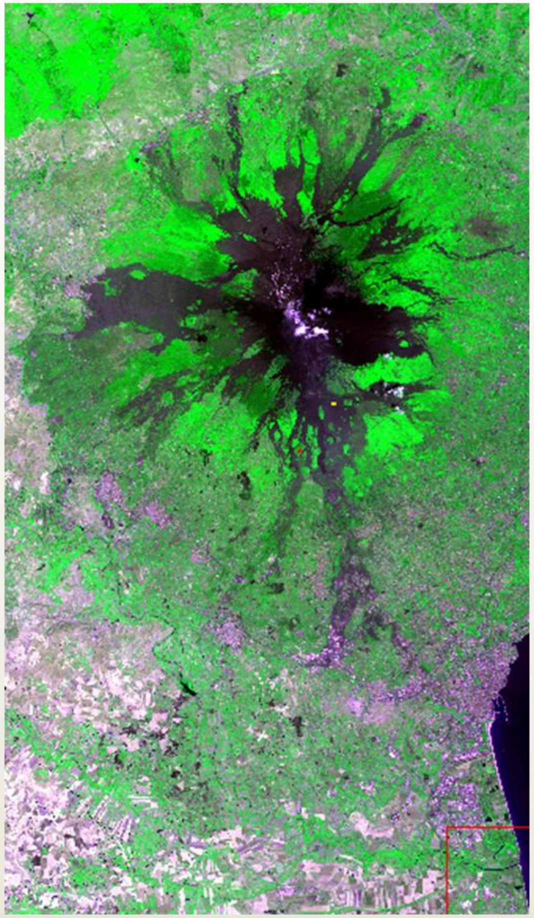


Fattore di illuminazione

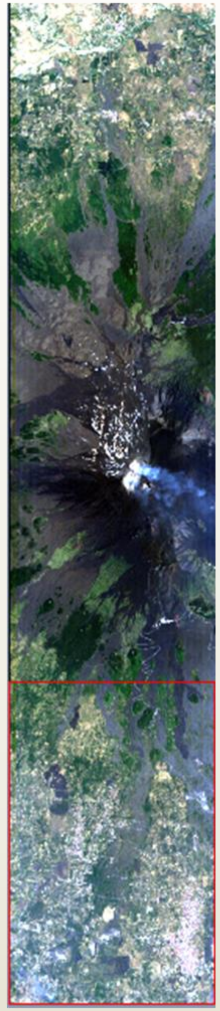


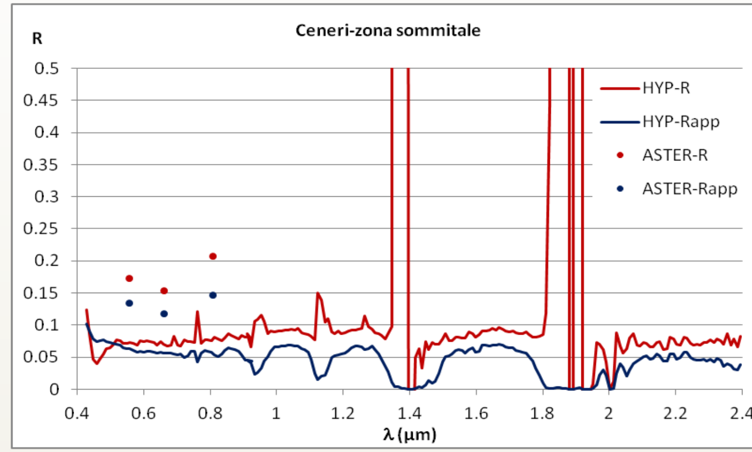
ASTER
25/06/2012

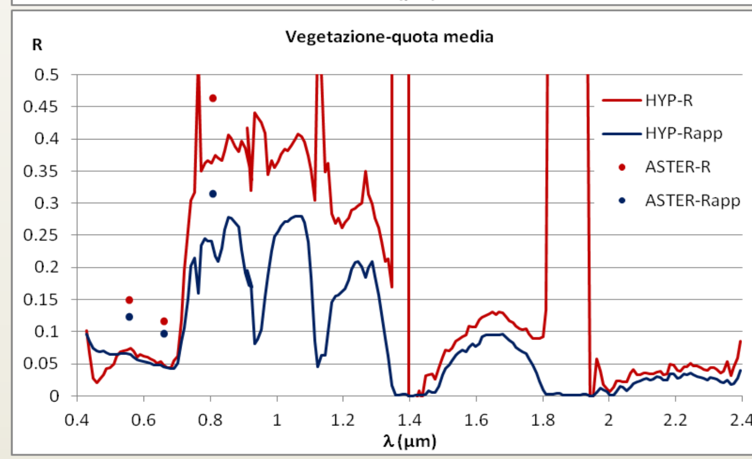
HYPERION
26/06/2012



ASTER: Solo le bande (3) VIS-VNIR







Riflettanze apparenti e corrette dalle TAC estratte da due aree comuni sulle immagini ASTER e HYPERION
Problemi di Calibrazione!

topographic corrections: Some results

INTRODUZIONE

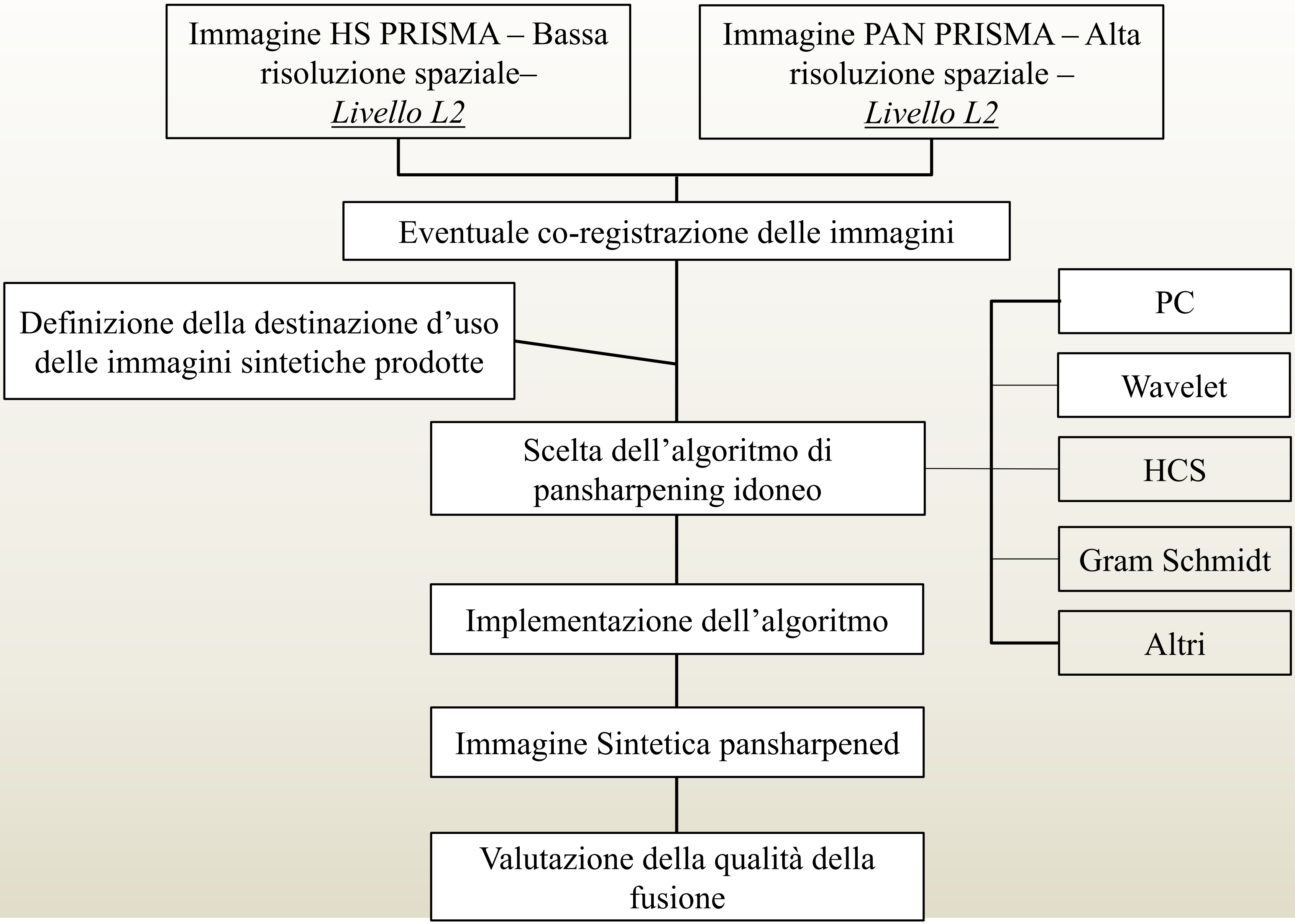
CARATTERISTICHE DEL SENSORE PRISMA DI INTERESSE:

Sensore Iperspettrale (HS)	Sensore Pancromatico (PAN)
0.4 – 2.5 μm (risoluzione spettrale: 10 nm)	0.4 – 0.75 μm
210 canali	1 canale
Risoluzione spaziale: 30m	Risoluzione spaziale: 5m

SCOPO: "Fusione" delle due immagini acquisite in modo da ottenere una nuova immagine sintetica con la risoluzione spaziale del sensore PAN e la risoluzione spettrale del sensore HS

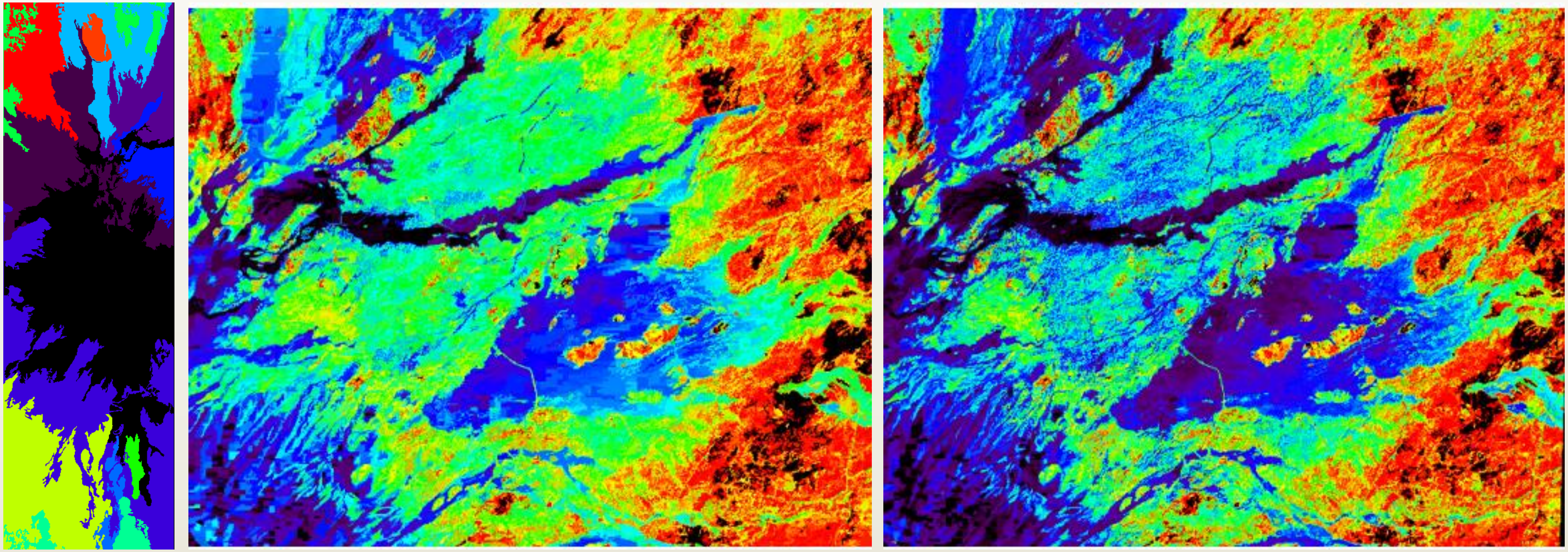
Pan sharpening

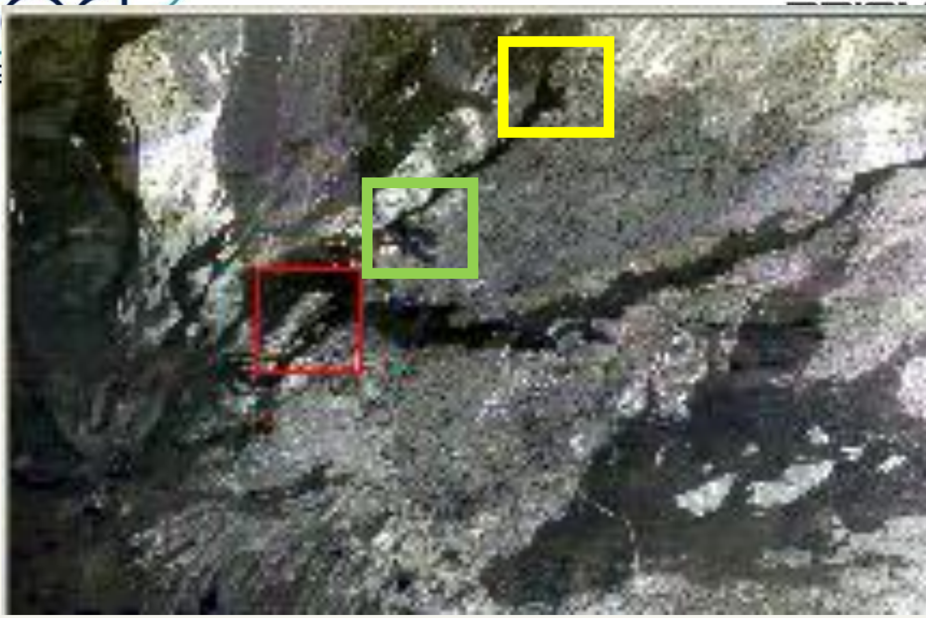
DESCRIZIONE DELLA PROCEDURA

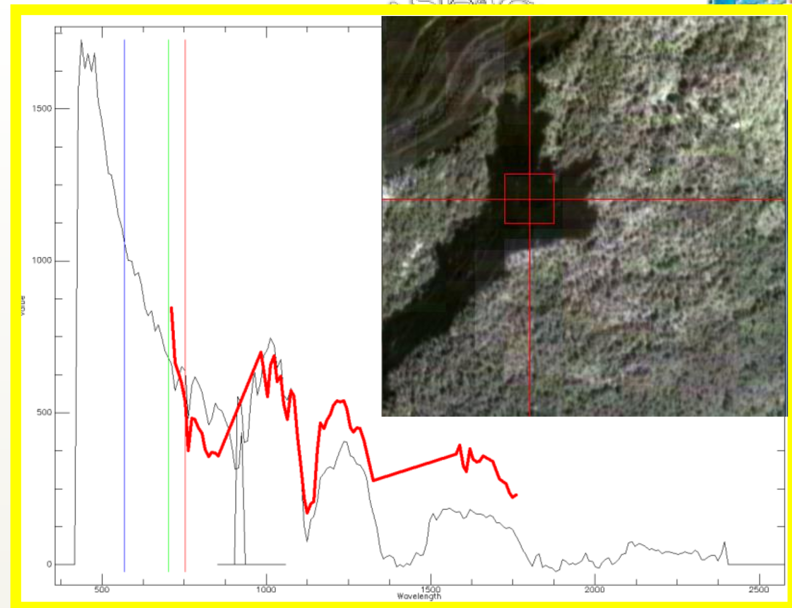


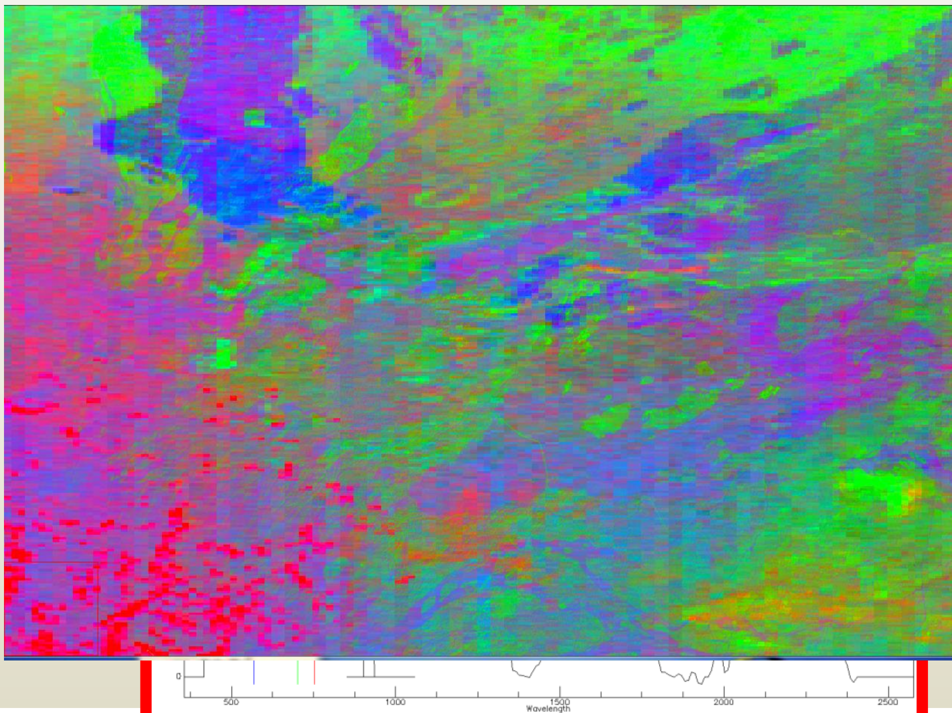
VOLCANIC PRODUCTS CLASSIFICATION USING PAN SHARPENING TECHNIQUES

EO1-Hyperion, EO1-Hyperion+Quickbird, EO1-Hyperion (ridotto a 65 bande)+QB.






1500
1000
500
0
Value
500
1000
1500
2000
2500
Wavelength


0
500
1000
1500
2000
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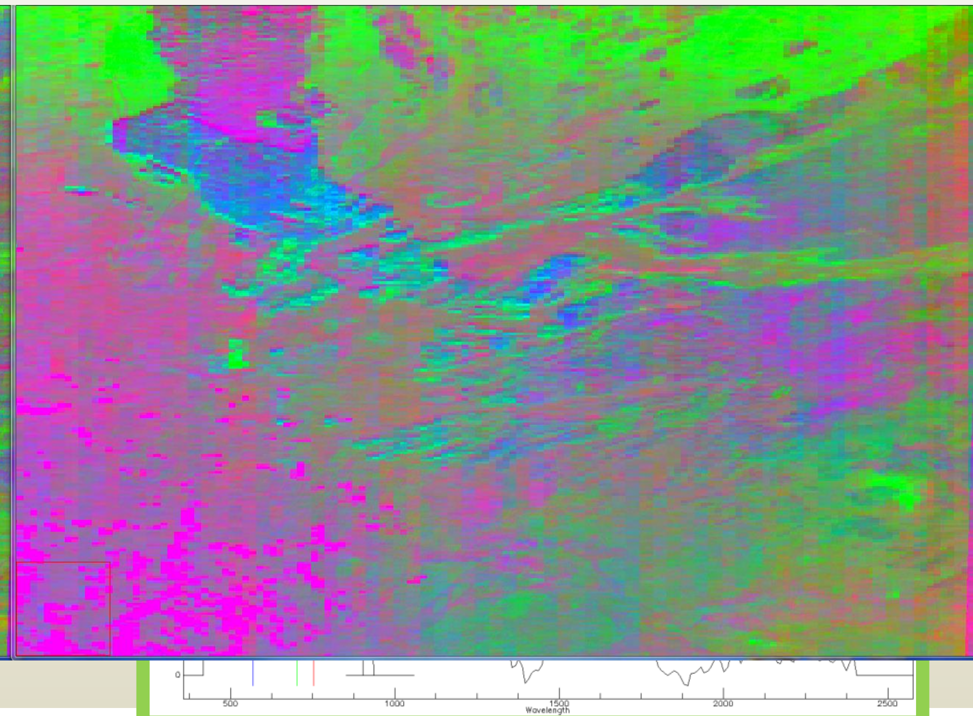
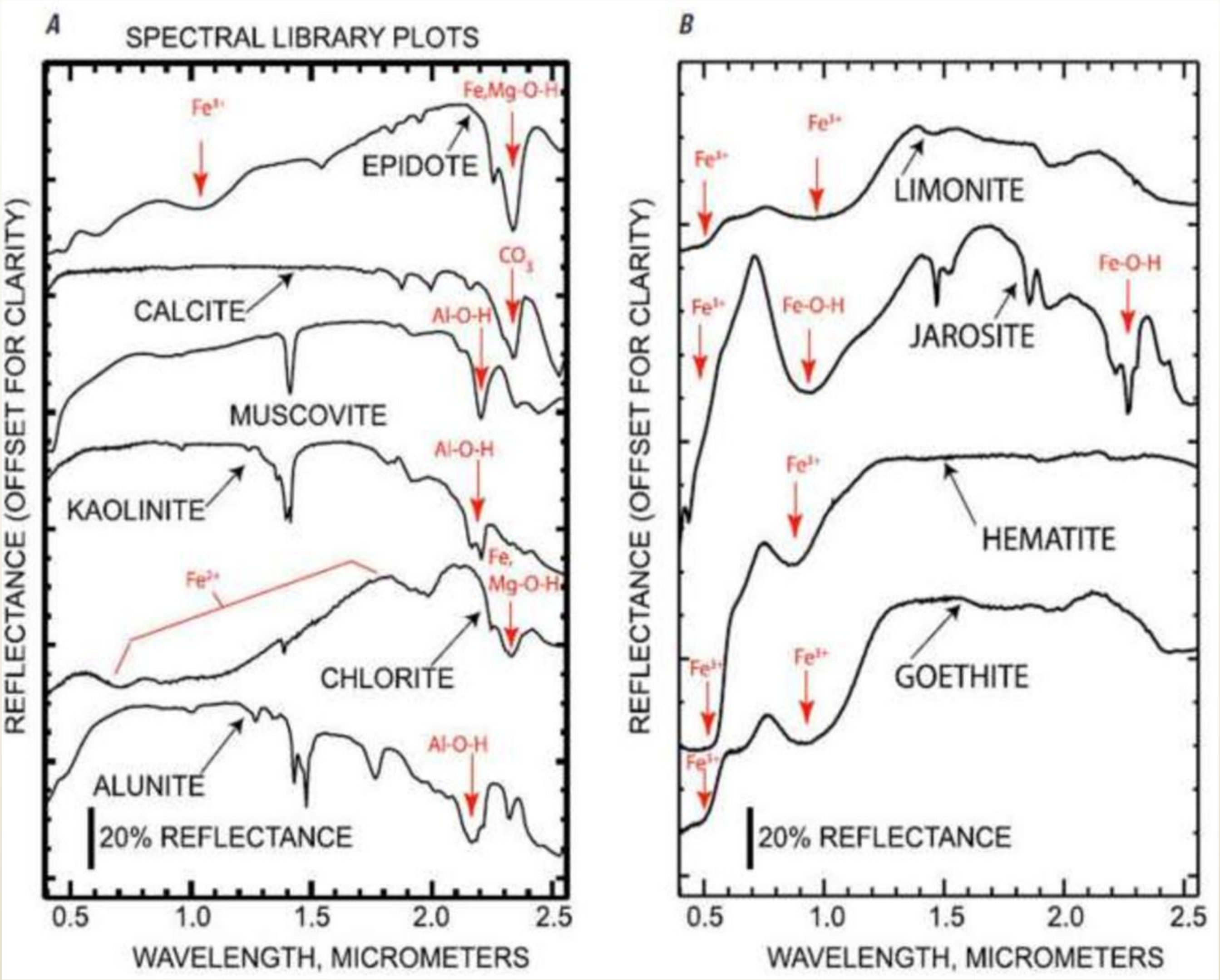
Wavelength

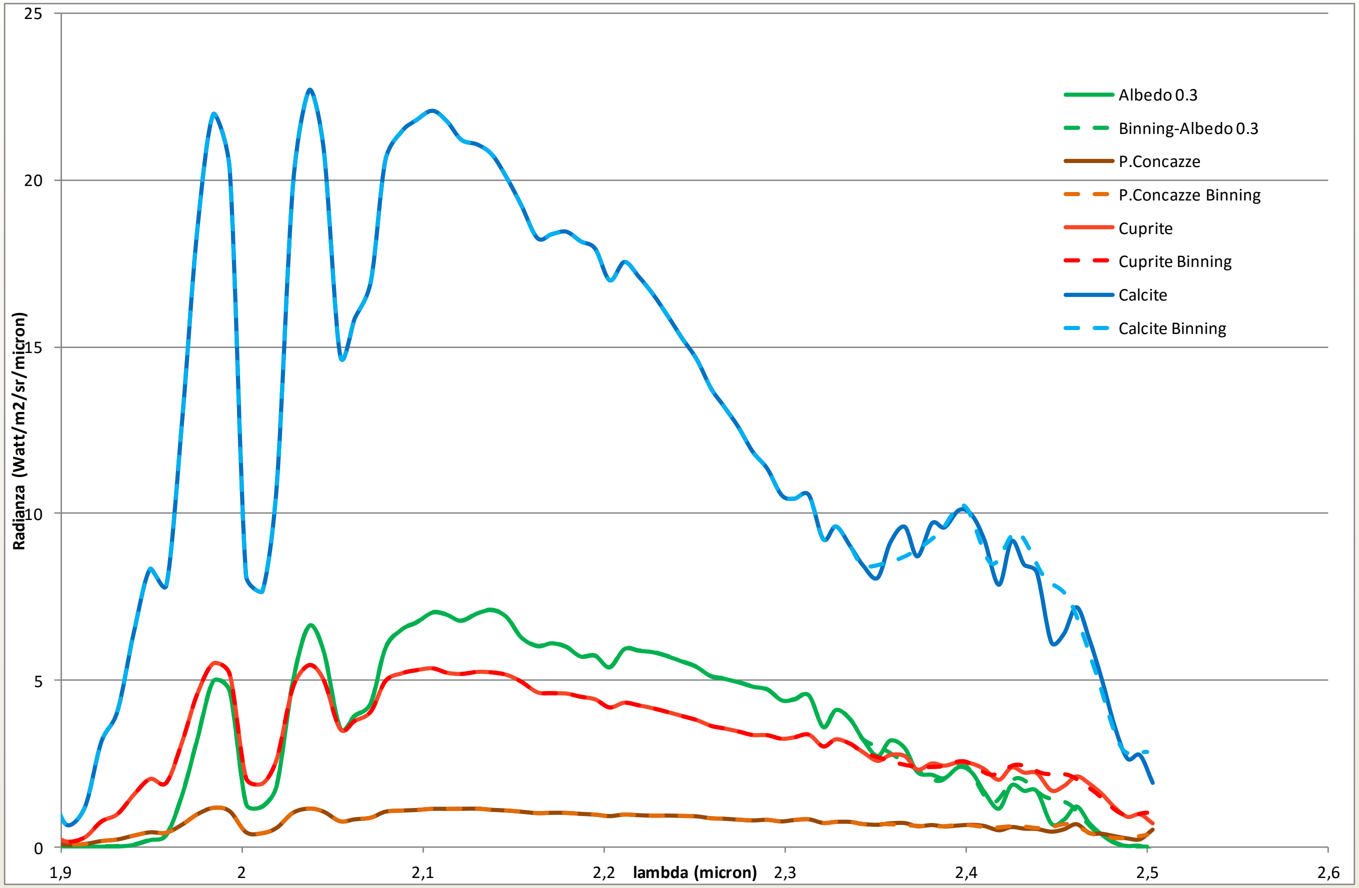

0
500
1000
1500
2000
2500
Wavelength

- The precision with which it obviously depends on the quality of remote sensing data and also used by the algorithm that will be used. The spatial resolution of the available sensors are matched by the spectral resolution whereas the characteristics of hyperspectral remote sensing is a viable source of alternative information and support to geological mapping, lithology and soil. Since the hyperspectral sensor observes an area of finite extension (30 x 30 m) that contains a variety of different materials, the spectrum of reflectance of the pixels in the remotely sensed images can be generally interpreted as a "mixture" of endmember spectra

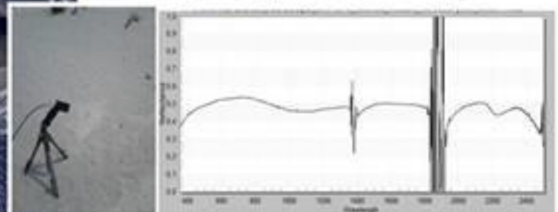
MINERALOGY AND SOIL ANALYSIS

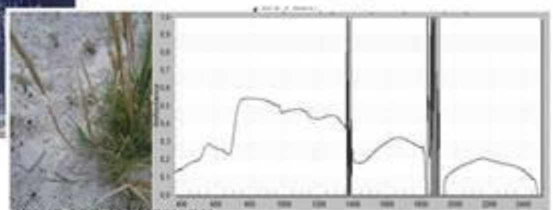


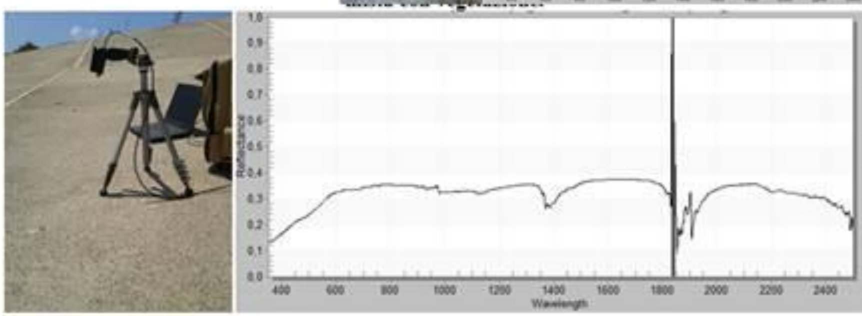
SIMULATION OF RADIANCES FOR DIFFERENT MATERIALS AND TEMPERATURE

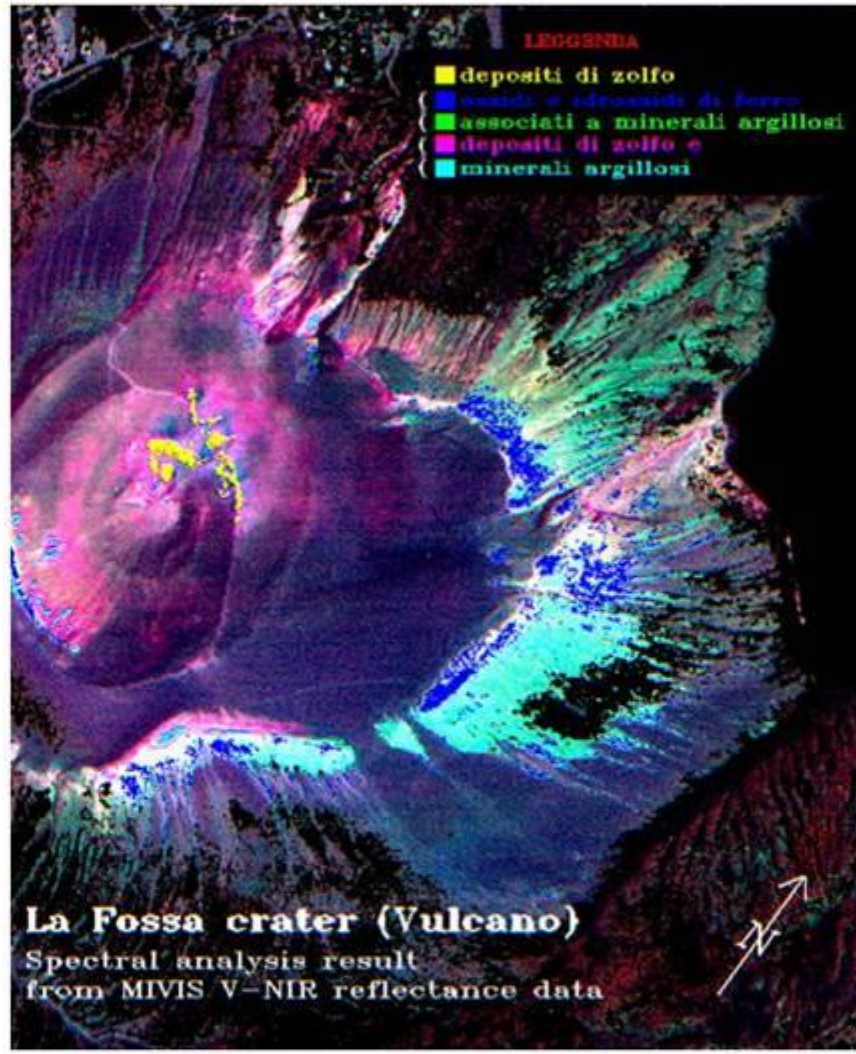


Radianza simulata PRISMA-like considerando come albedo: 0,3 (verde), calcite (azzurro), cuprite (rosso) e Piano delle Concazze (marrone). La linea continua rappresenta la radianza ottenuta considerando le 171 bande nello SWIR, in tratteggiato la radianza ottenuta considerando il binning sulle ultime bande dello SWIR (e quindi su 160 bande)

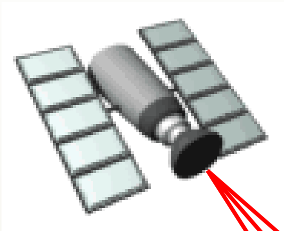




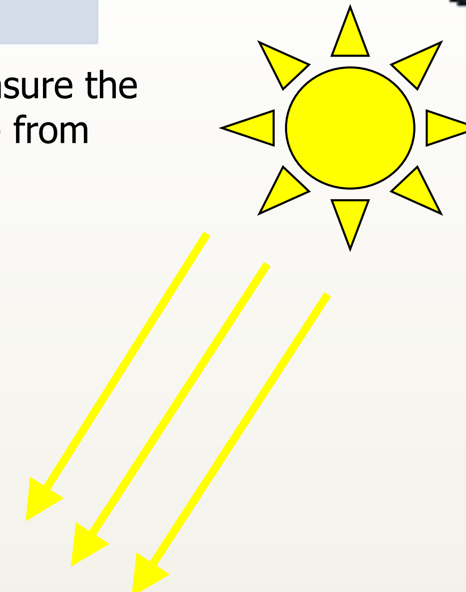

Reflectance
Wavelength


LEGGENDA
depositi di zolfo
associati a minerali argillosi
depositi di zolfo e
minerali argillosi
La Fossa crater (Vulcano)
Spectral analysis result
from MIVIS V-NIR reflectance data

Lava Thermal analysis

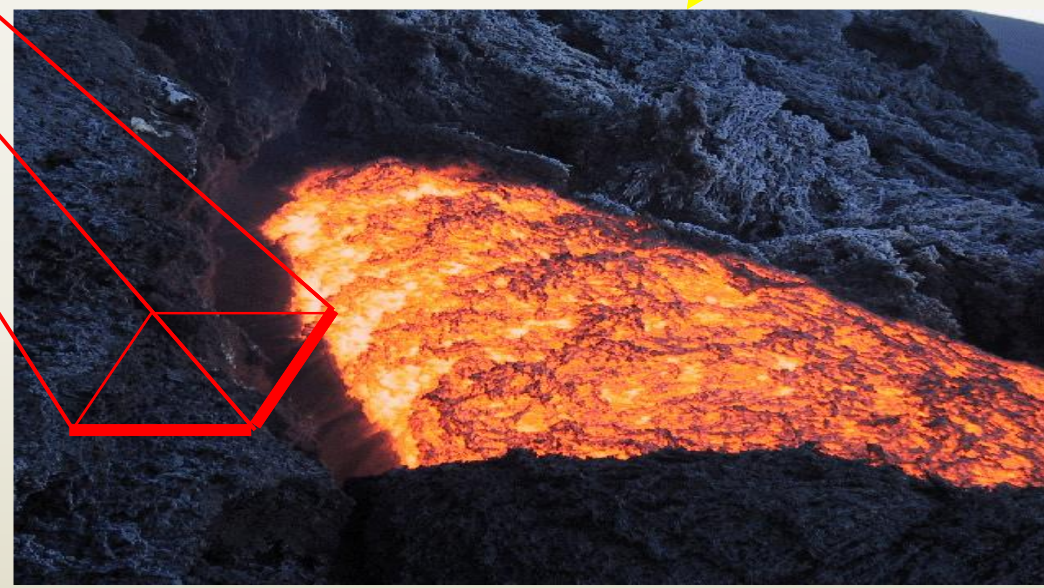


- The sensors measure the spectral radiance from the Earth

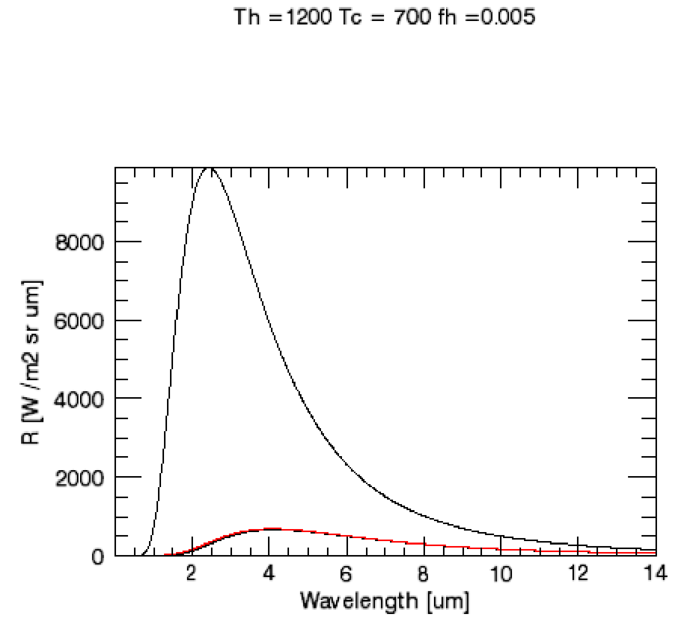


•The radiance measured is not directly related to the surface temperature but depends on:

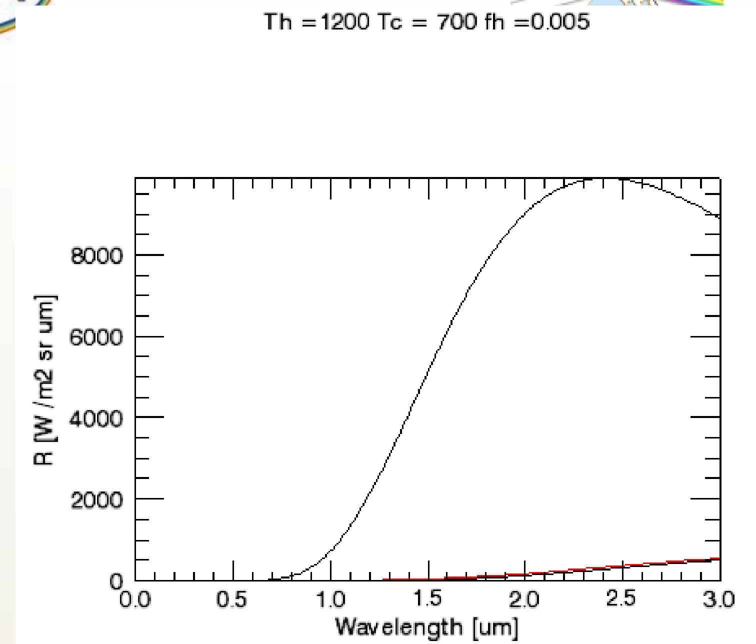
- The surface emissivity
- Atmospheric absorption
- The solar radiation



Dr. Valerio Lombardo



Radianza teorica tra 0.5 e 14 micron



Radianza teorica tra 0.5 e 3 micron

In the case of radiant pixels occupied by lava, the emission peak (Planck curve) moves towards the shorter wavelengths as the temperature increases. At the spatial resolution of PRISMA pixels can be considered to be occupied by a predominant fraction of the crust at a temperature Tc and a complementary fraction of molten lava that radiates at higher temperature Th. Since the crust occupies a portion much larger than the one occupied by the molten lava, the integrated curve (red curve in Figures) corresponds to Tc of crust. Using a temperature of the molten part (Th) of 1200 ° K and a temperature of the crust (Tc) at 700 ° K is obtained an integrated theoretical radiance

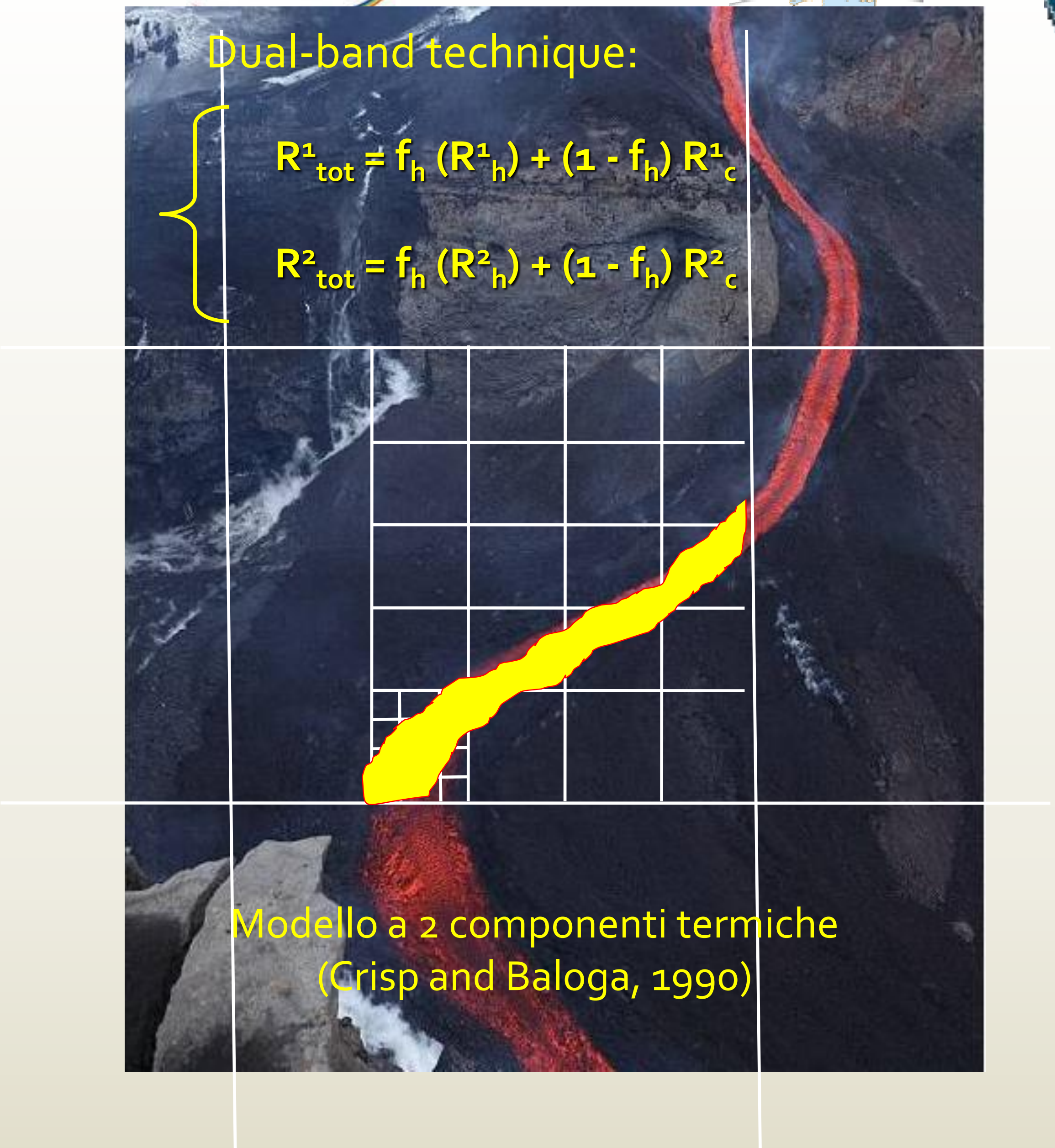
The temperature of the lava flows at pixel scale is never homogeneous but there are always at least two separate thermal components:

Th (hot)

Tc (cold)

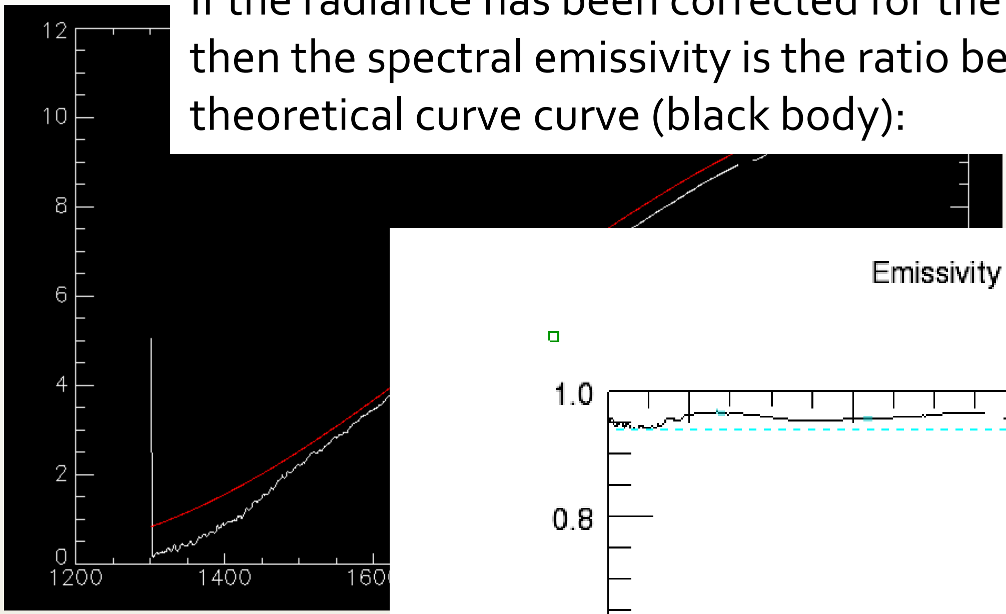
Occupying a fraction of the pixels (fh).

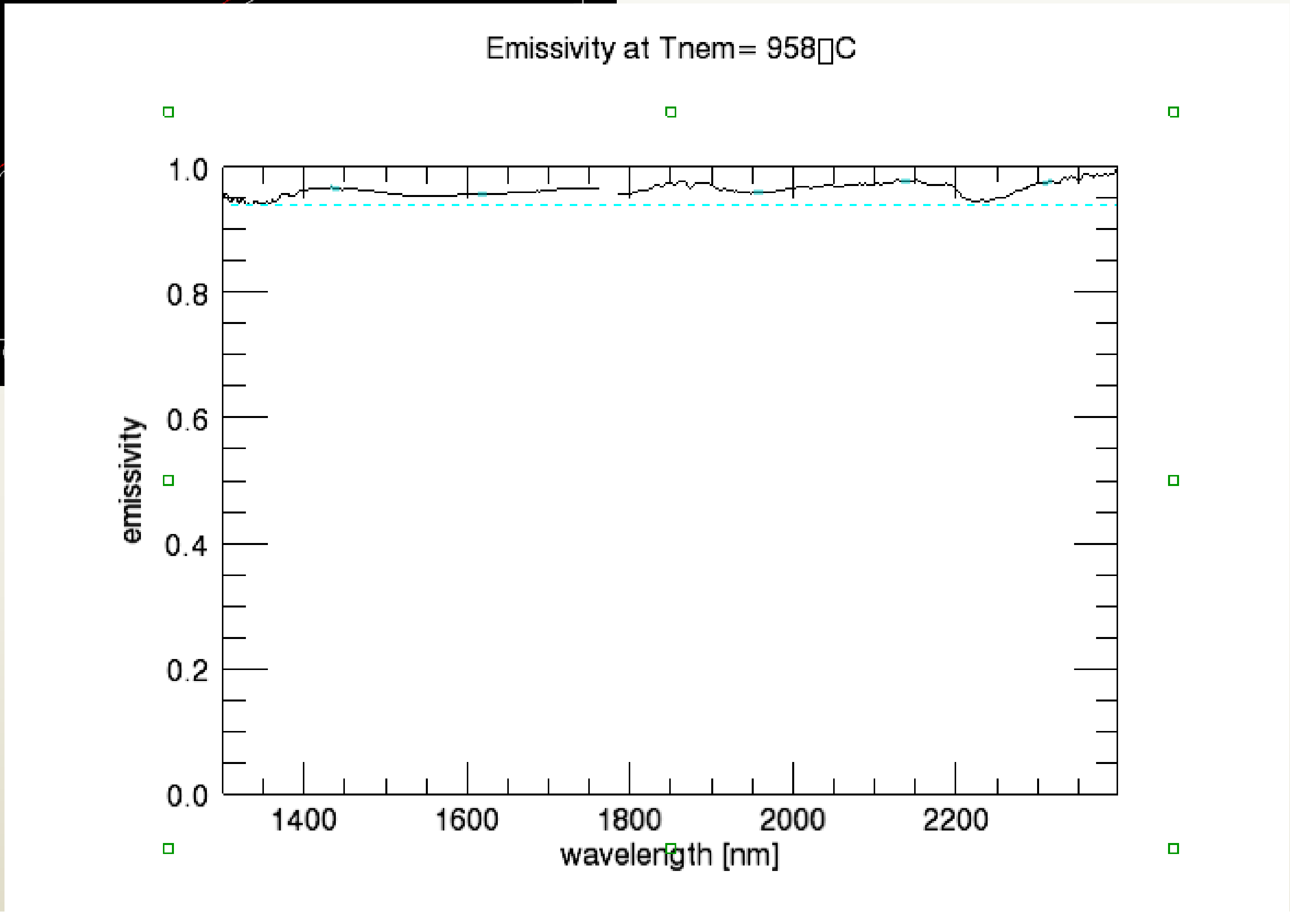
So it has been developed a new algorithm to determine simultaneously the spectral emissivity and the various thermal components using the spectral and radiometric characteristics provided for PRISMA



Temperature/Emissivity Separation

If the radiance has been corrected for the solar and atmospheric contribution then the spectral emissivity is the ratio between the experimental and theoretical curve curve (black body):



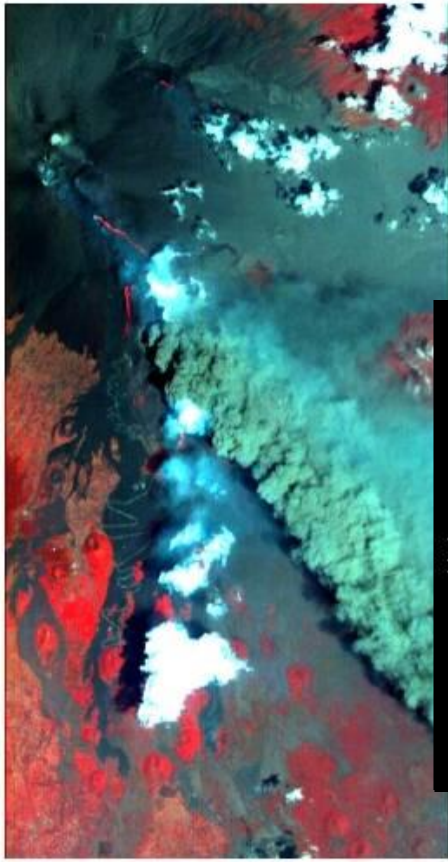


Algoritmo “*Draping*”

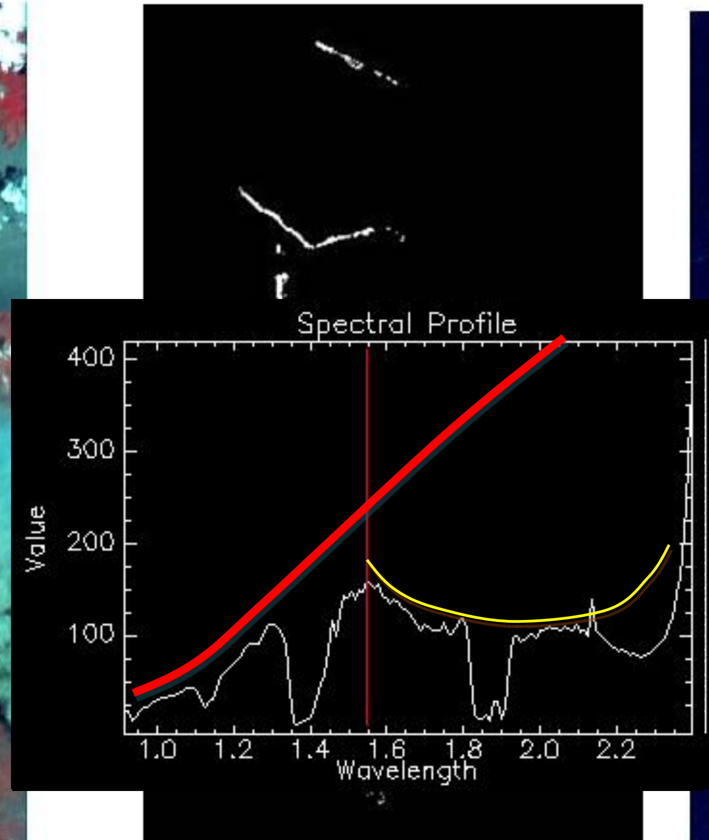
For this reason, a new algorithm called "draping" was implemented. The "draping" algorithm allows the simultaneous calculation of Th, Tc, fh, and and spectral through a series of iterations between the radiance of the experimental curve and a set of theoretical curves calculated by varying Th, Tc, in the previous equation fh imposing Rtot always equal to Rmax at the wavelength lmax wave.

Requirements for application of the algorithm:
Ipespettrale SWIR (PRISMA)
High radiometric resolution
Radiometric data unsaturated

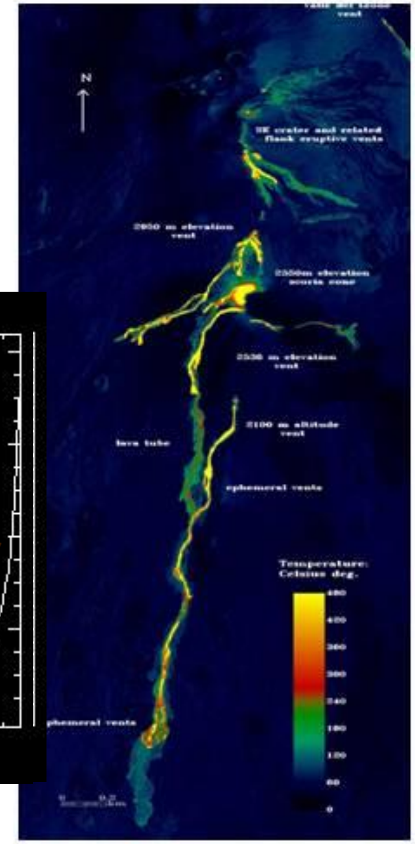
EO-1 Hyperion



Hot spot detection

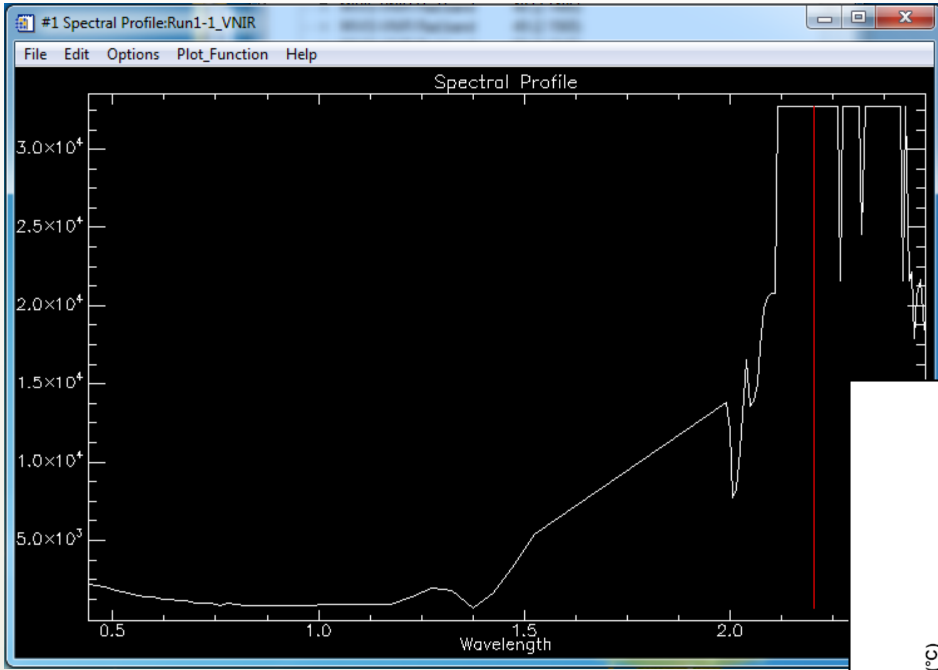


Temperature retrieval



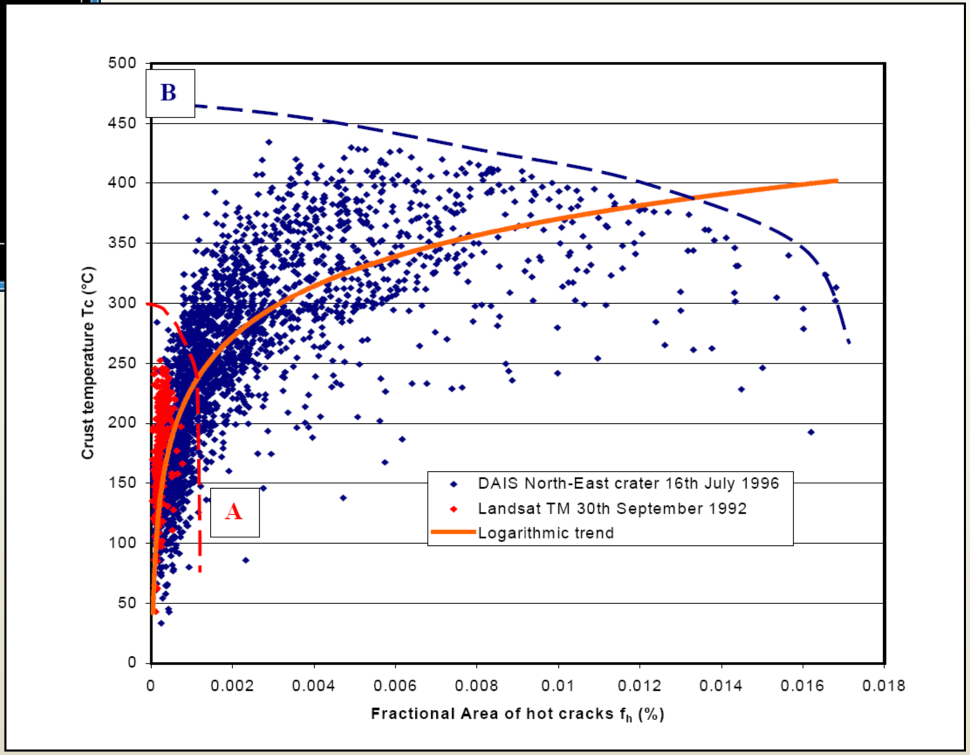
Hot-Spot Detection (Hyperion and MIVIS) and temparature retriaval during the Etna eruption (2001)

Applicazione su dati aerei

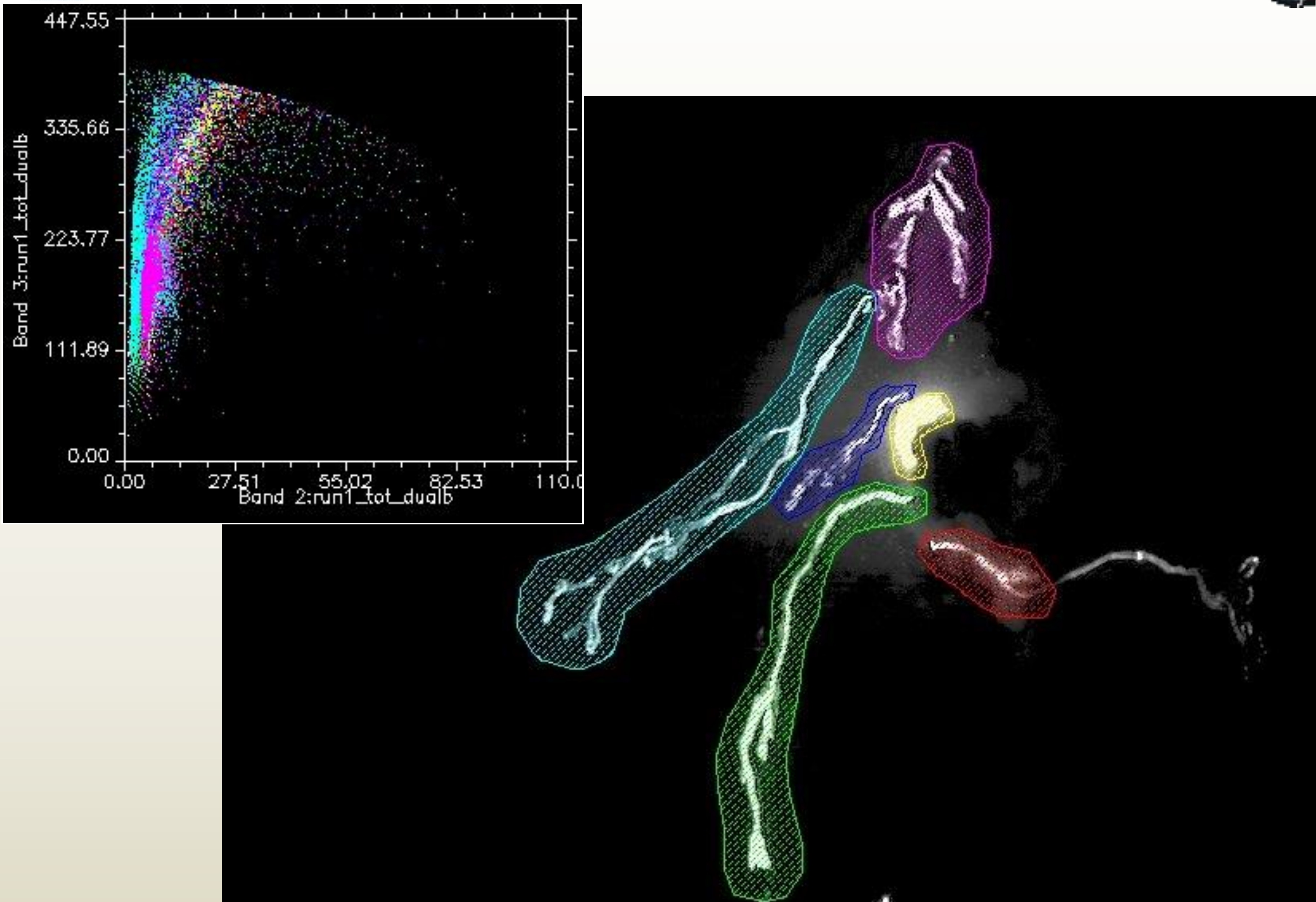


Confronto tra soluzione Tc vs fh ottenute con dati DAIS e dati ASTER.

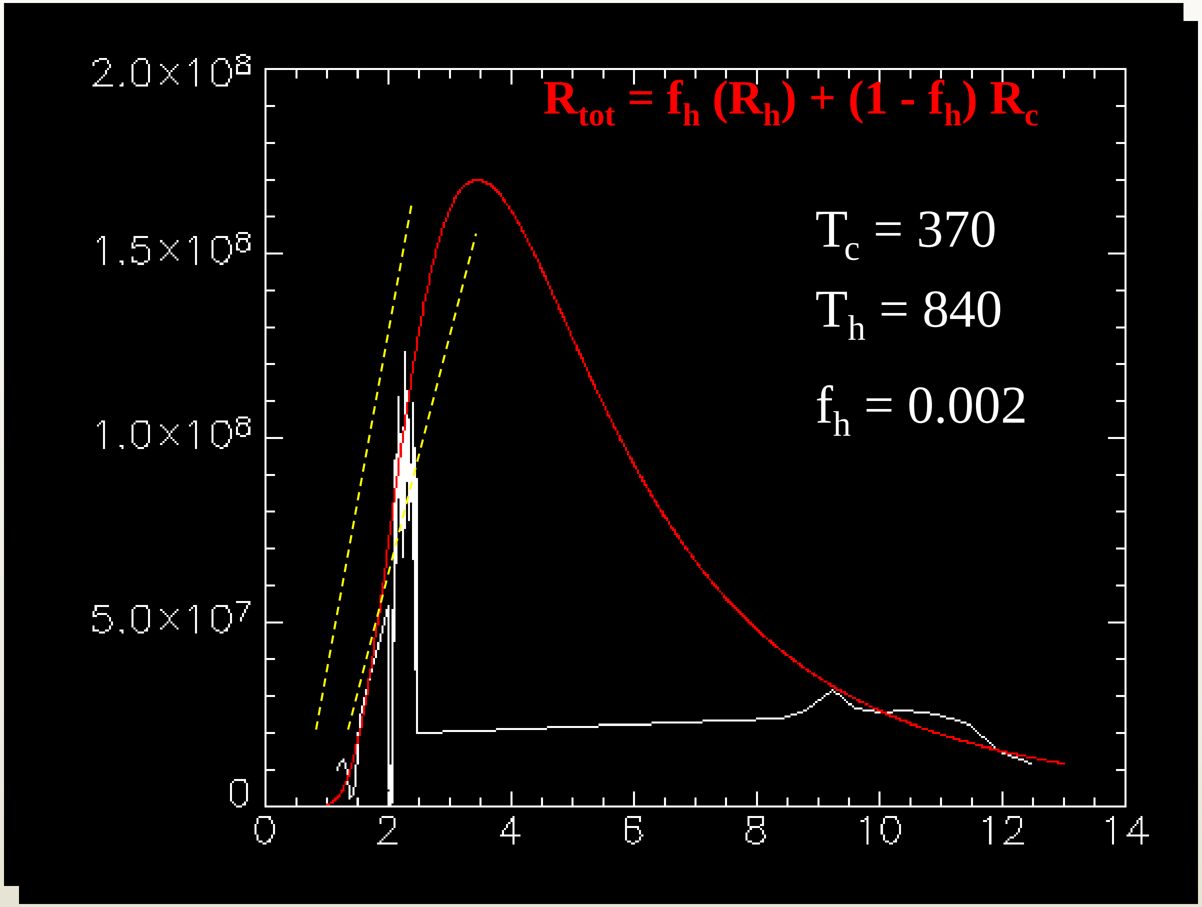
I dati aerei come il MIVIS permettono il settaggio del *gain* e *offset* e quindi di innalzare il limite di saturazione



THERMAL ANALYSIS OF THE DISTINCT LAVA FLOWS

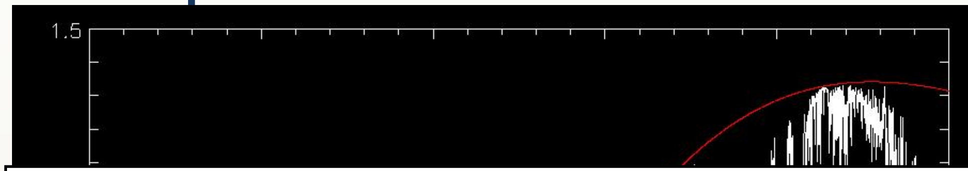


VIS-SWIR channels are not enough to constrain the planck curve at specific temperature



Integrated curve: theoretical curve (red) and real spectrum as detected by MIVIS sensor (white).

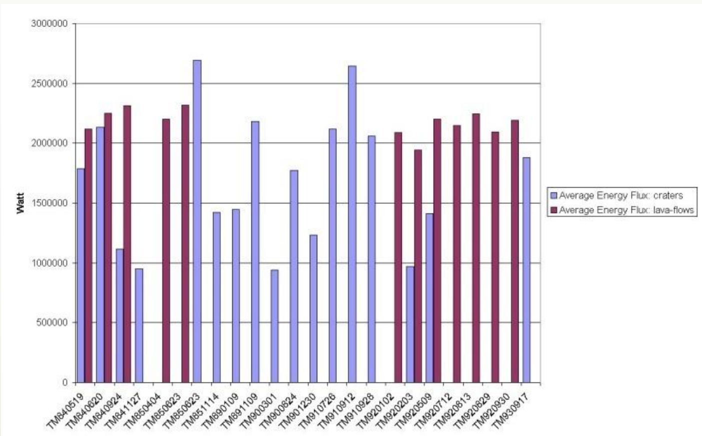
Requisiti del sensore

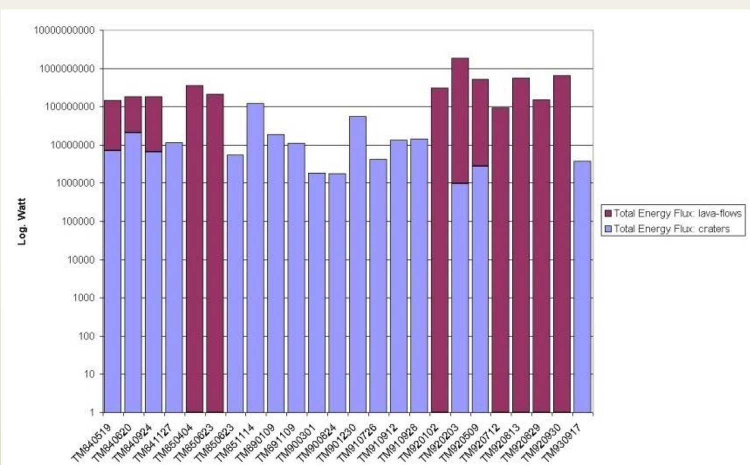


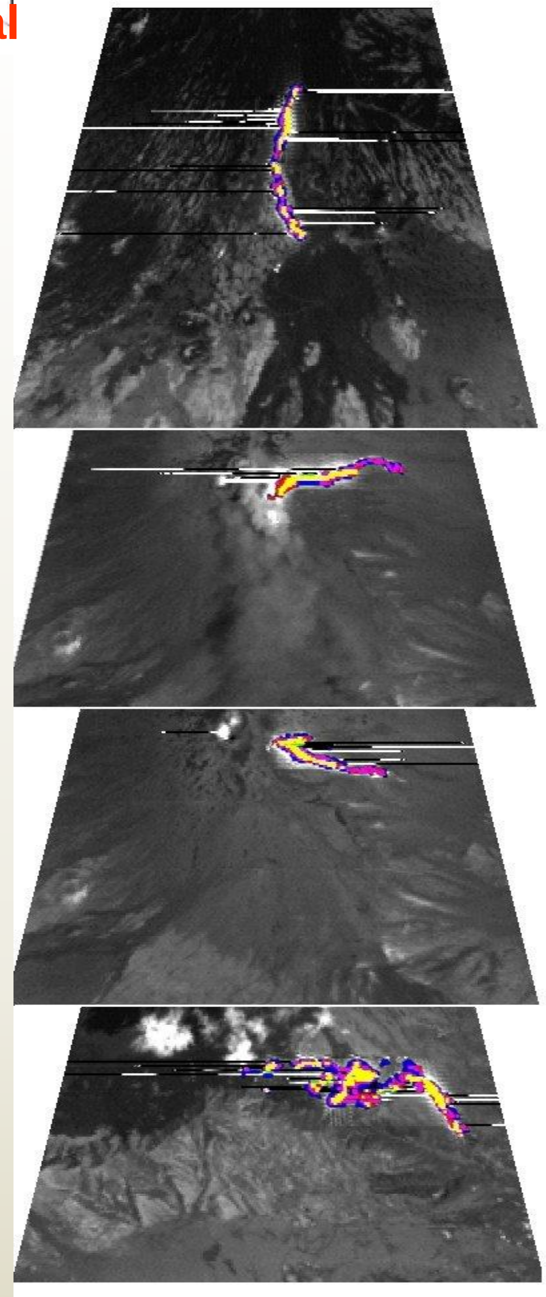
Simulazione MODTRAN

Simulazione PRISMA inserendo spettro di radianza a 1000°C. Si è notata solo una leggera saturazione.

Temporal Comparison of Thermal and Geometrical Features







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PRISMA PRODUCTS

Starting from the radiance of SWIR bands with the algorithm of "Draping" will be able to get from the data PRISMA the spectral emissivity and the sub-pixels temperatures.

Number of SWIR bands envisaged for PRISMA would apply this algorithm

Along with this requirement a dynamic range, however, it must be provided which prevents the saturation of the signal in the presence of high temperatures (as happens for Hyperion data).

A saturation value of 1000 ° C would be ideal to ensure the observability of volcanic phenomena and fires. 500 ° C are the theoretical limit of applicability of the algorithm.

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CONCLUSION

- PRISMA DATA COULD EFFECTIVELY SUPPORT VOLCANIC RISKS MANAGEMENT
- DATA FUSION WITH TIR DATA AND SAR DATA COULD BE OF HIGH INTEREST
- ATMOSPHERIC AND TOPOGRAPHIC CORRECTIONS ARE VERY IMPORTANT TO PRODUCE HIGH QUALITY DATA
- HIGH TEMPERATURE OBSERVATION ARE IMPORTANT BUT REQUIRES NON SATATURATED PIXELS

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PRISMA

ASI-AGI

remote sensing

IMPACT FACTOR 3.036

Special Issue

Widespread Applications Based on Hyperspectral Technologies from Space

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Deadline for manuscript submissions:
30 June 2018

Message from the Guest Editors

Dear Colleagues,

The aim of this Special Issue is to highlight the impact of the past hyperspectral missions and foresee the effectiveness of the future ones. We would like to invite submissions on the following topics:

- Integration and comparison of new hyperspectral image data/constellation;
- Natural processes and human activities and their interactions, including archaeology;
- Environmental and natural hazards and risks reduction;
- Coastal systems, including inlands waters, and their interaction with the land;
- Geology, soil and agriculture;
- Atmospheric correction and atmospheric constituent characterization;
- Hyperspectral data processing for defence and security;
- Astrophysics and planetary exploration;
- Hyperspectral sensors synergy with the other missions;
- Sensor calibration including vicarious calibration.

Dr. Stefano Pignatti
Dr. Maria Fabrizia Buongiorno
Dr. Bing Zhang
Guest Editors

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