Istituto Nazionale di Geofisica e Vulcanologia

PRISMA

PRISMA MISSION

Volcanic Carbon dioxide measurements from Hyperspectral data

C. Spinetti, M.F. Buongiorno

2013 HyspIRI Science Symposium, 29-30 May, Maryland

Picture courtesy of B. Behncke

summary

- PRISMA MISSION OVERVIEW
- ASI-AGI PROJECT PRODUCTS TO FOR VOLCANIC APPLICATIONS
- CO_2 RETRIEVAL LGORITHM REVIEW
- CONCLUSION
- PRISMA AND HYSPIRI MISSION MUTUAL BENEFITS

PRISMA MISSION OVERVIEW AND DEVELOPMENT STATE

PRISMA (PRecursore IperSpettrale della Missione Applicativa) Hyperspectral Payload is an Electro-Optical instrument composed of a high spectral resolution spectrometer optically integrated with a medium resolution panchromatic camera.

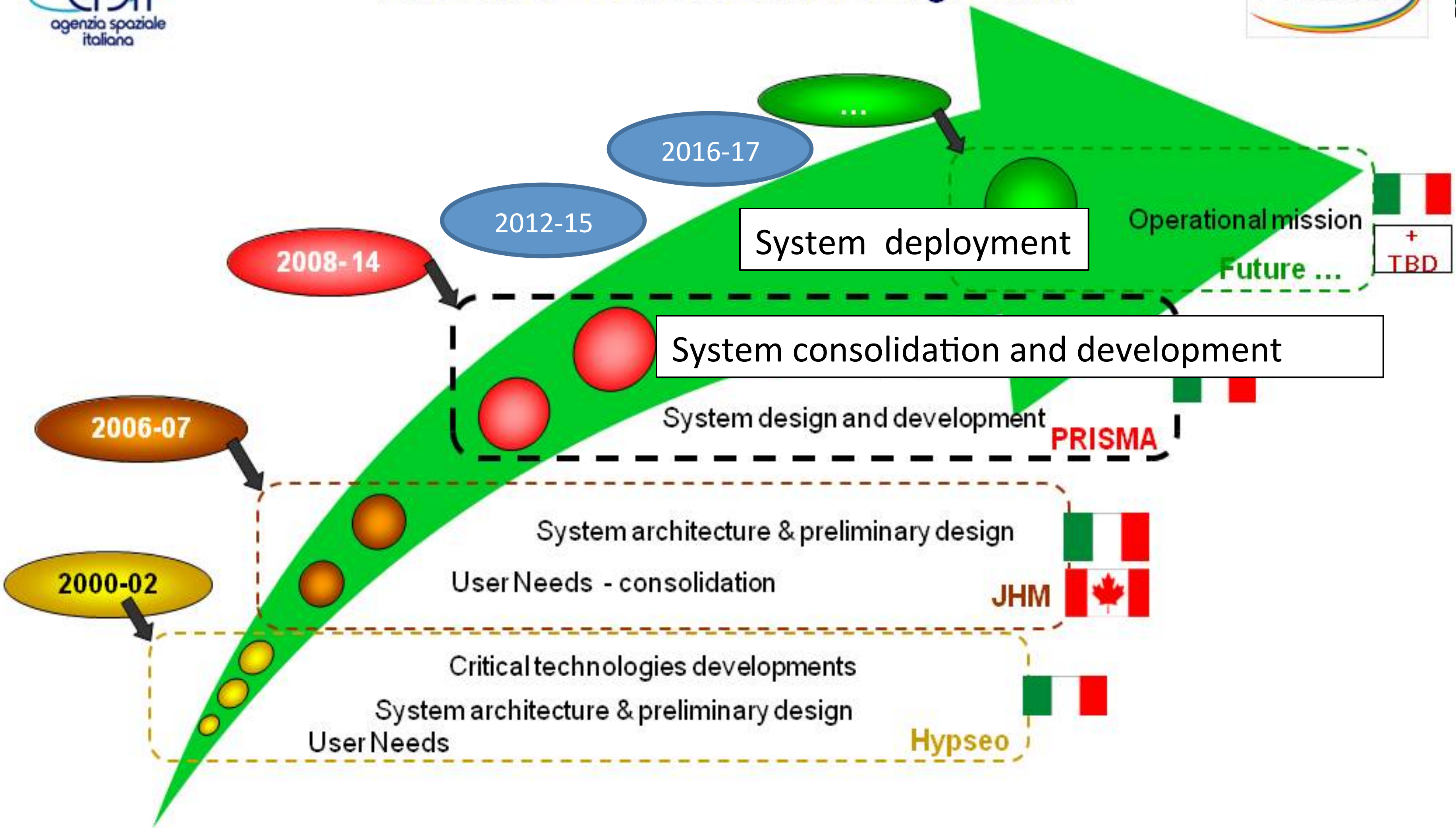
The instrument is the focus of the Earth Observation PRISMA mission, fully funded by ASI (Agenzia Spaziale Italiana) and developed by a consortium of Italian companies, lead by CGS as S/C responsible. PRISMA is: “a pre-operative small Italian hyperspectral mission, aiming to qualify the technology, contribute to develop applications and provide products to institutional and scientific users for environmental observation and risk management …”

In this context SELEX Galileo has the full responsibility of the Electro-Optical Payload (**Hyperspectral and Pancromatic cameras**); in addition, SELEX Galileo provides the following items: a) PhotoVoltaic Assembly (PVA); b) Power Control & Distribution Unit (PCDU) for the S/C; c) AA-STR Autonomous Star Tracker for S/C attitude control and is also responsible of Data Products management (Level 0 and Level 1).

PRISMA Mission is based on previous experiences carried out by SELEX Galileo under ASI studies for Earth Observation, namely the programs **HypSEO** phase B (first study) and **JHM** (Joint Hyperspectral Mission) phase A (mission and instruments refinement).

The launcher baseline (which will be provided by the Agency) is **VEGA**, but the Mission design will be compatible also with other launchers to maintain the maximum flexibility.

PRISMA - context and background



Program: PRISMA
Event: Third Annual Hyperspectral Imaging Conference
Topic: PRISMA Mission
Date: Rome, 15 May 2012

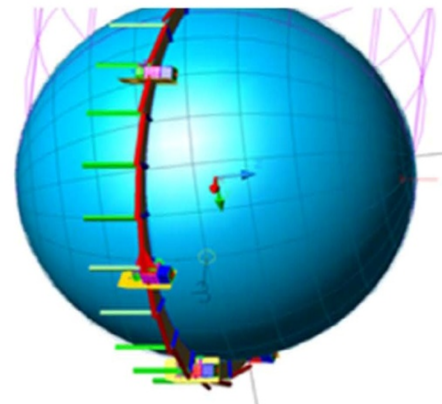
PRISMA MISSION OVERVIEW (Courtesy of SELEX-GALILEO)

SELEX GALILEO
A Finmeccanica Company

PRISMA

PRISMA Mission Overview

Orbit	sun synchronous
Orbital Altitude	615 Km
Inclination	97.851°
LTDN	10:30 a.m.
Orbital period	about 97 min (5819.7 sec)
Average eclipse duration	about 34 min (2048sec)
Beta Angle	from 16.1 to 26.6 deg
Repeat cycle	29 days (430 orbits)
Relook time	7 days
Area Of Interest (AoI)	longitude from 10°W to 50°E, latitude from 30°N to 70°N
Outside AoI	40° latitude window per orbit at every latitude in the range 70°N – 60°S
Swath / GSD	30 Km / 30m
Off- Nadir	18.2°
AoI access duration	Average Duration 8.44 min Maximum Duration 11.19 min
Lifetime	5 years



Primary area of interest

SELEX GALILEO

PRISMA

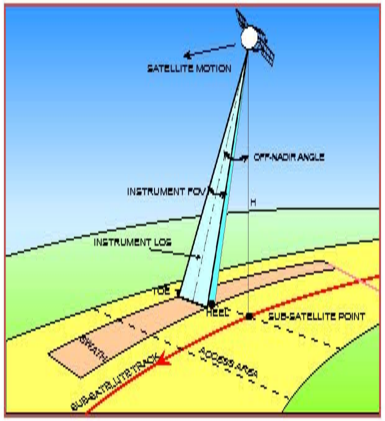
PRISMA Payload features

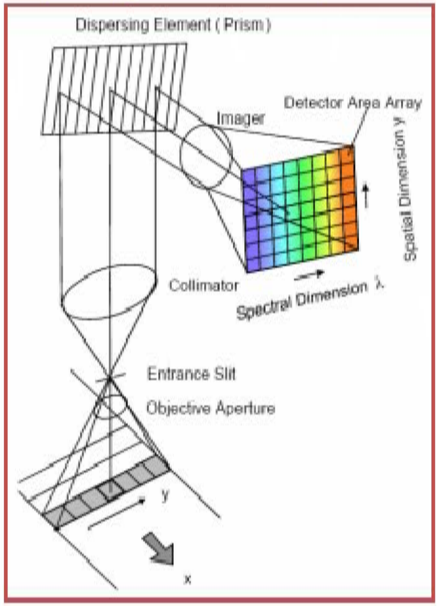
The PRISMA hyperspectral camera utilizes a prism to obtain the dispersion of incoming radiation on a 2-D matrix detector. At each shot, a full across track line is imaged.

The “instantaneous” spectral and spatial dimension (across track) of the spectral cube are given directly by the 2-D detector, while the “temporal” dimension (along track) is given by the satellite motion. This image scanning concept is defined as “**Pushbroom**”; the advantages of this concept being: a uniform spatial resolution, a good geo-reference, no scanning mechanism need, availability of a long pixel integration time.

The key PRISMA Payload technical features are:

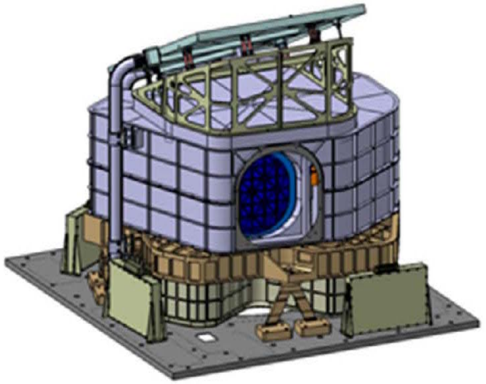
- Spatial GSD: **30 m (Hyper)** / **5m (PAN)**;
- Swath width: **30 km**;
- Daily data collection: > 100.000 km^2 ;
- Uninterrupted acquisition: up to 1800 km ;
- Spectral range: 0.4-2.5 µm (Hyp) / 0.4-0.7 µm (PAN);
- Continuous coverage of spectral range with spectral bands of **12 nm** width;
- Absolute radiometric accuracy better than 5%.





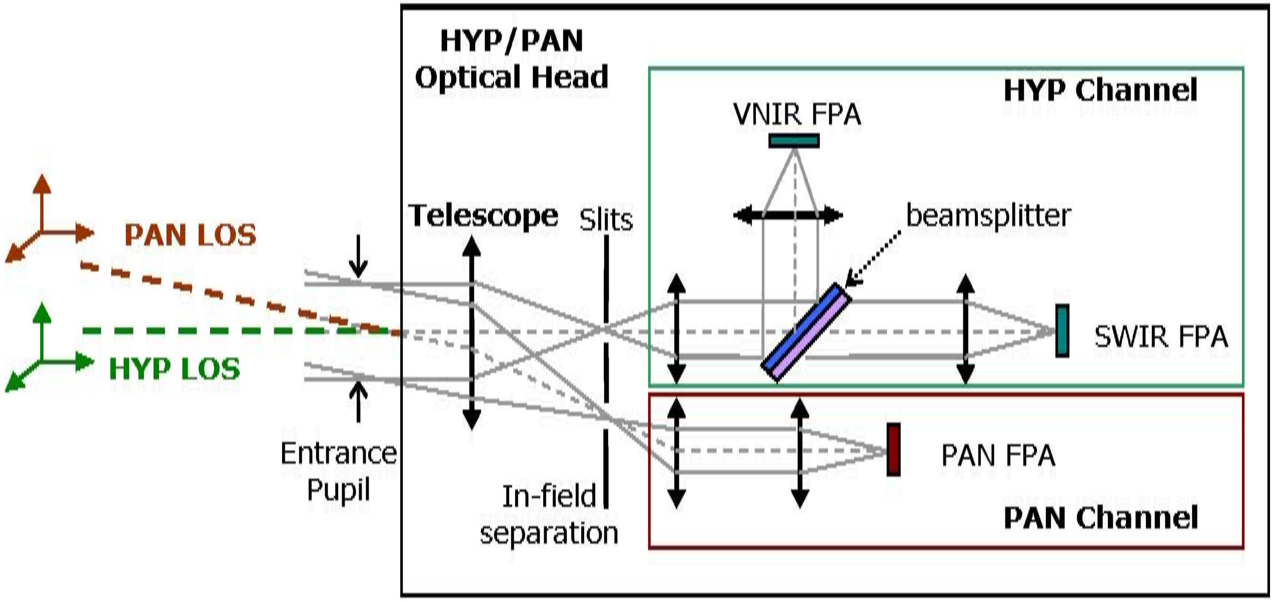
PRISMA Payload Overview

Reference Orbit Altitude	615 Km
Swath / FOV	30 Km / 2.77°
GSD	Hyperspectral: 30 m PAN: 5 m
Spatial Pixels	Hyperspectral: 1000 PAN: 6000
Pixel Size	Hyperspectral: 30x30 µm PAN: 6.5x6.5 µm
Spectral Range	VNIR: 400 – 1010 nm SWIR: 920 – 2500 nm
Spectral Sampling Interval (SSI)	≤ 11 nm
Spectral Width	≤ 12 nm
Cross-Track Variation of Centre Wavelength (Smile)	< +/- 0.1 SSI
Spatial registration of spectral sampling (incl. Keystone)	≤ 0.1 pixel
Spectral Calibration Accuracy	+/-0.1 nm
Radiometric Quantization	12 bit
VNIR SNR	> 200:1 on 400 – 1000 nm > 600:1 @ 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%
Aperture Diameter	210 mm
MTF	VNIR @ Nyquist Frequency > 0.3 SWIR @ Nyquist Frequency > 0.3 PAN @ Nyquist Frequency > 0.2
Cooling System	Passive Radiator
Lifetime	5 years



View of the Optical Head

- Three mirror anastigmat (TMA) telescope common to all channels.
- Prism based VNIR and SWIR Spectrometers.
- Three mirror design Panchromatic Camera.
- Internal Calibration Unit optical relay, with high reflectance integrating sphere and parabolic mirror to image Sun light and spectral lamps.

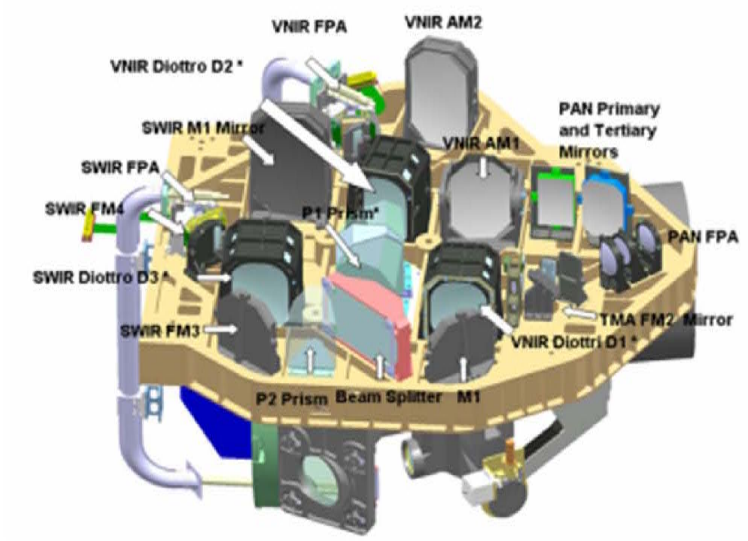


The overall instrument spectral radiation (400-2505nm) is split into **two channels** (VNIR and SWIR), adopting two different focal plane arrays:

- the VNIR , range [400nm - 1010nm] with 66 spectral bands
- the SWIR, range [920nm- 2505nm] with 171 spectral bands.

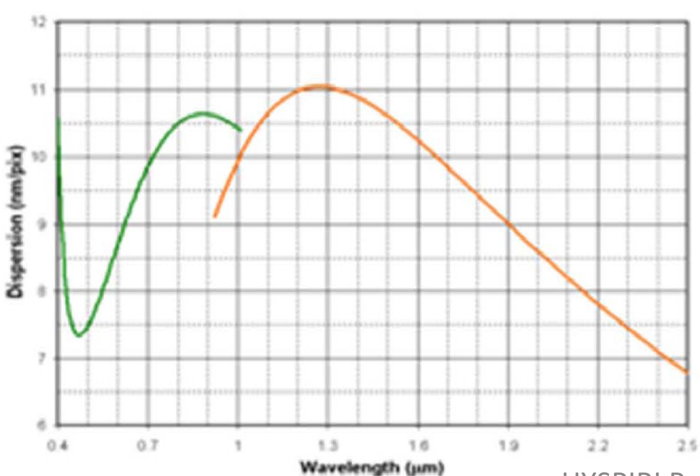
The spectral dispersion is achieved by prisms placed in parallel beams and designed in order to optimize the spectral dispersion. The advantages of this solution are:

- Excellent optical quality, in terms of PSF, Smile and Keystone effects;
- High flexibility of arrangement;
- Large clearance around focal planes;
- High optical transmission to achieve high SNR ratio while assuring required maximum spectral dispersion.

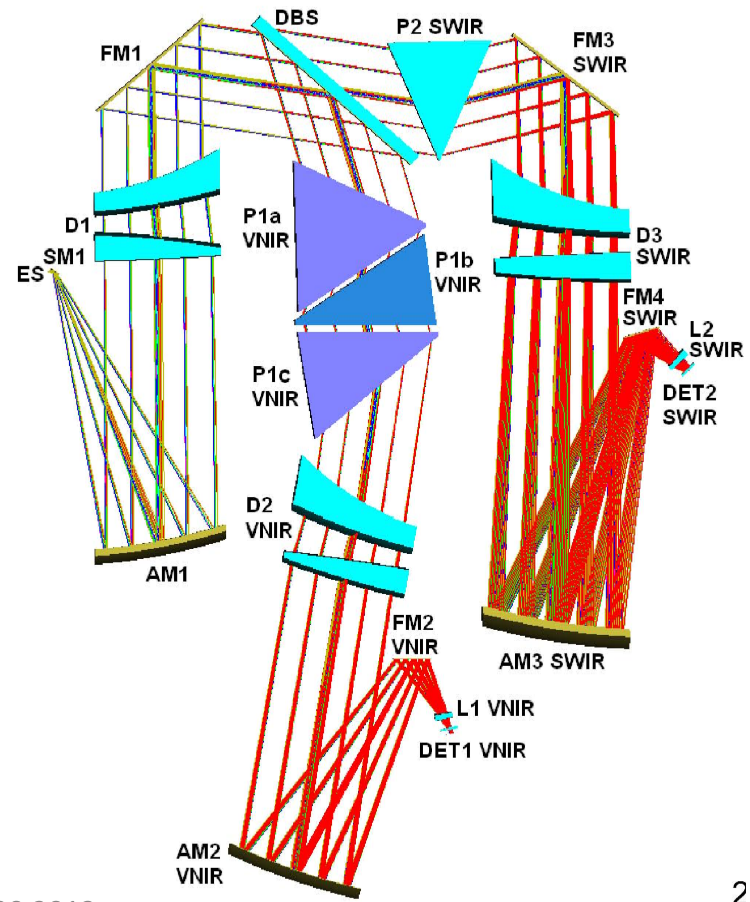


The selected design layout for the Spectrometer is the band separation, obtained with dichroic beam splitter (DBS). The main advantages of this configuration are the same field of view for both VNIR and SWIR channel (i.e. same entrance slit) and the use of several common optical elements for both channels.

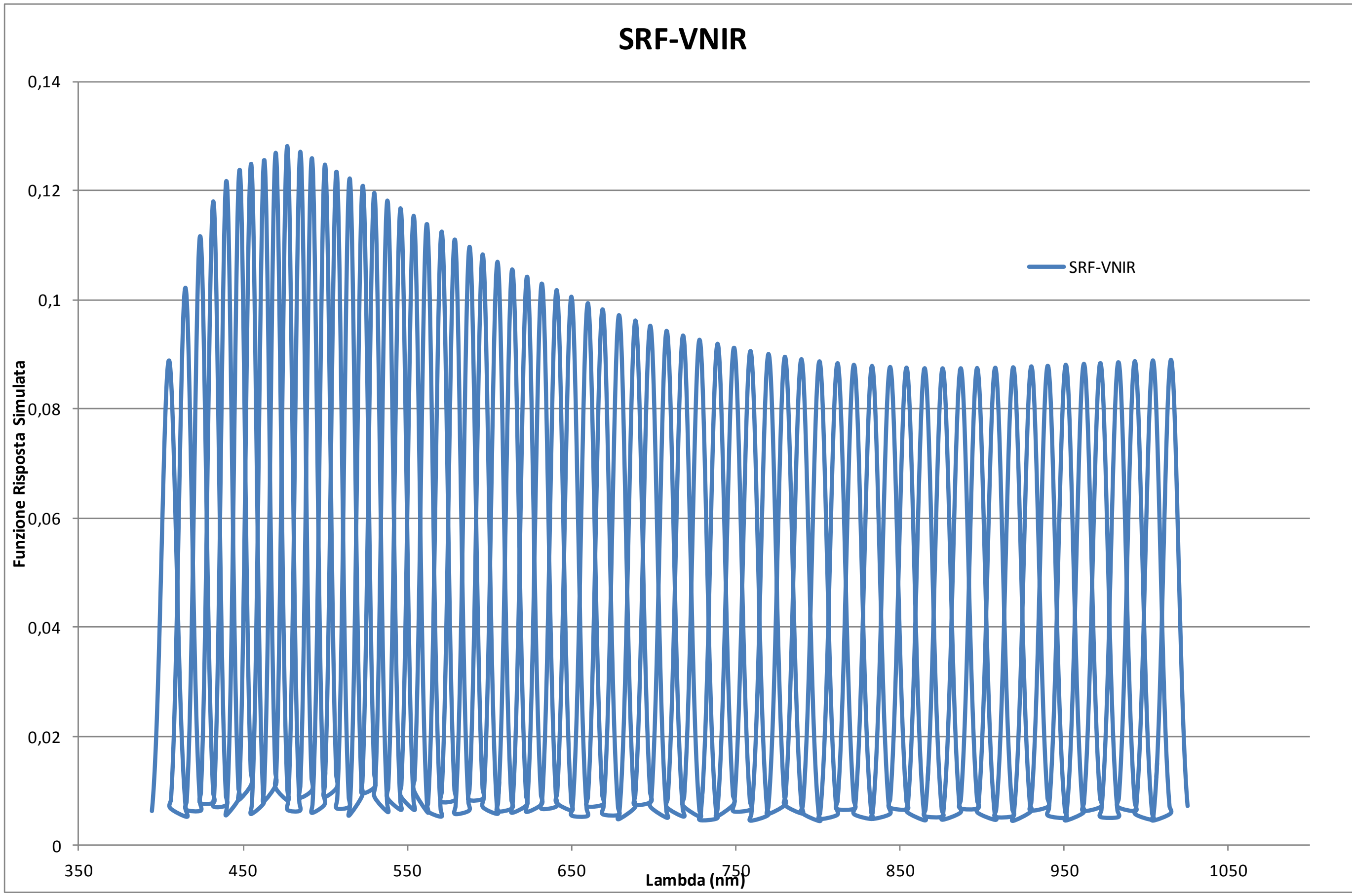
- Smile and the Keystone effects are contained within 10% of the pixel, for both VNIR and SWIR bands.
- Each VNIR and SWIR spectrometer channel has a magnification such to match the detector pixel.
- Detectors: 1000x256 pixels, with pixel size of 30x30 µm – working temperature 185 K (passive cooling).
- Spectrometer entrance slit: 30 mm x 30 µm.



Total spectral dispersion



PRISMA Response function simulation VNIR 66 bands

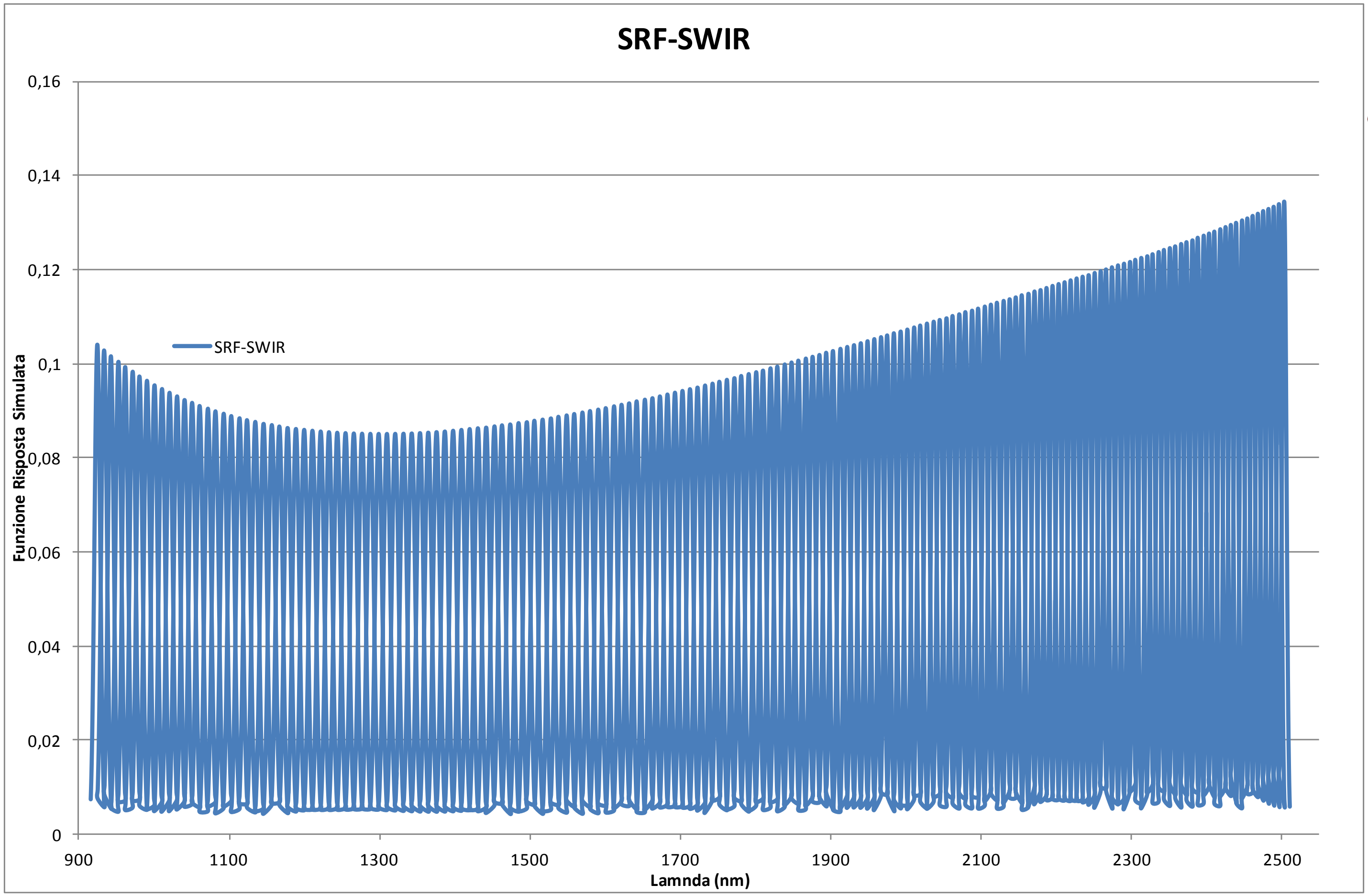


$$f(x) = \frac{1}{\sqrt{2\pi\sigma_j^2}} e^{\frac{(x-x_j)^2}{2\sigma_j^2}}$$

$$\sigma_j = \frac{FWHM_j}{2(2Ln2)^{1/2}}$$

Con FWHM le ampiezze delle singole bande

PRISMA RESPONSE FUNCTION FOR SWIR 171 bands

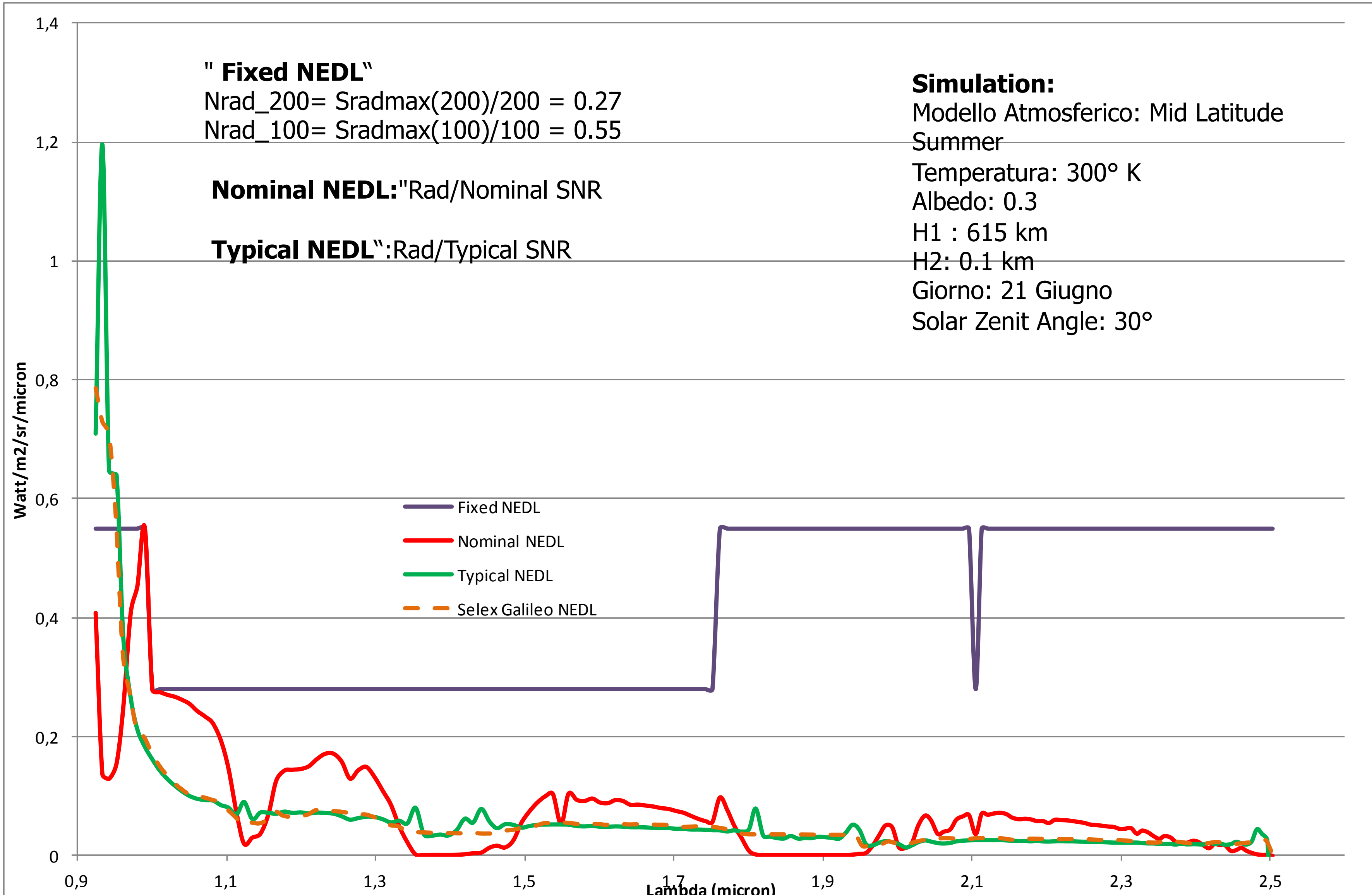


$$f(x) = \frac{1}{\sqrt{2\pi\sigma_j^2}} e^{\frac{(x-x_j)^2}{2\sigma_j^2}}$$

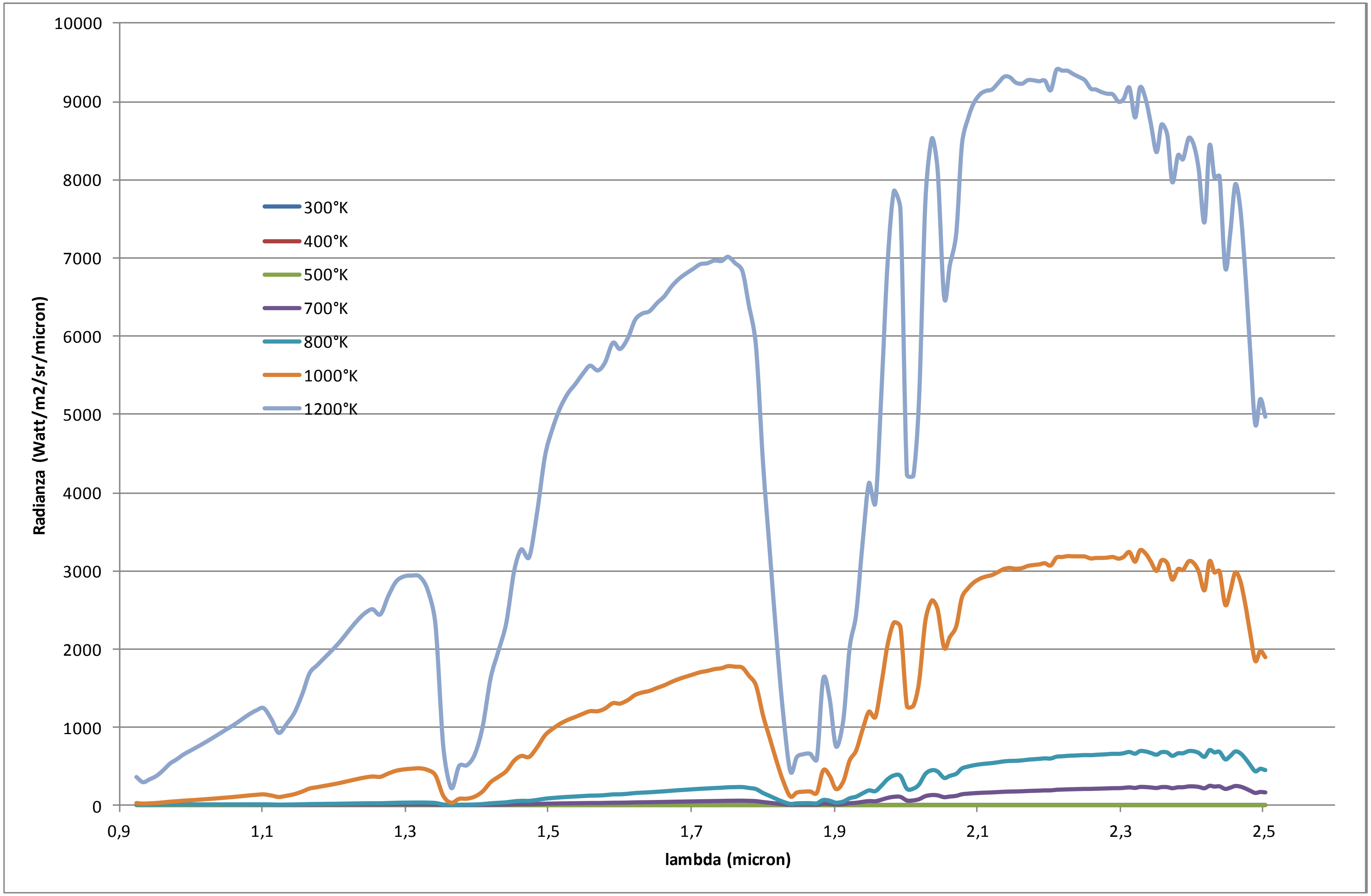
$$\sigma_j = \frac{FWHM_j}{2(2Ln2)^{1/2}}$$

Con FWHM le ampiezze delle singole bande

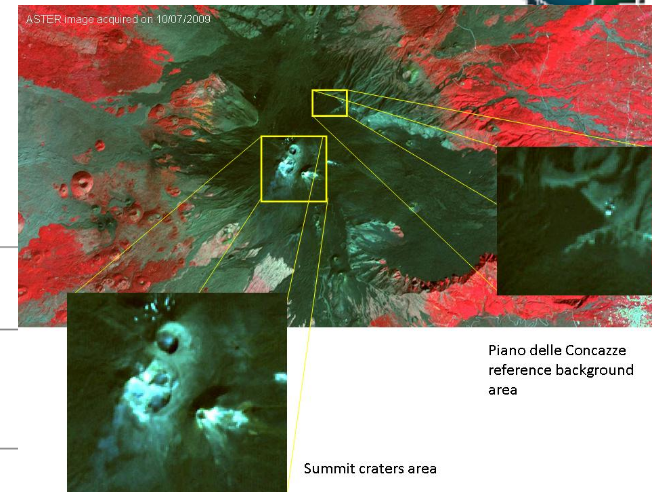
SIMULATED NDL FOR PRISMA

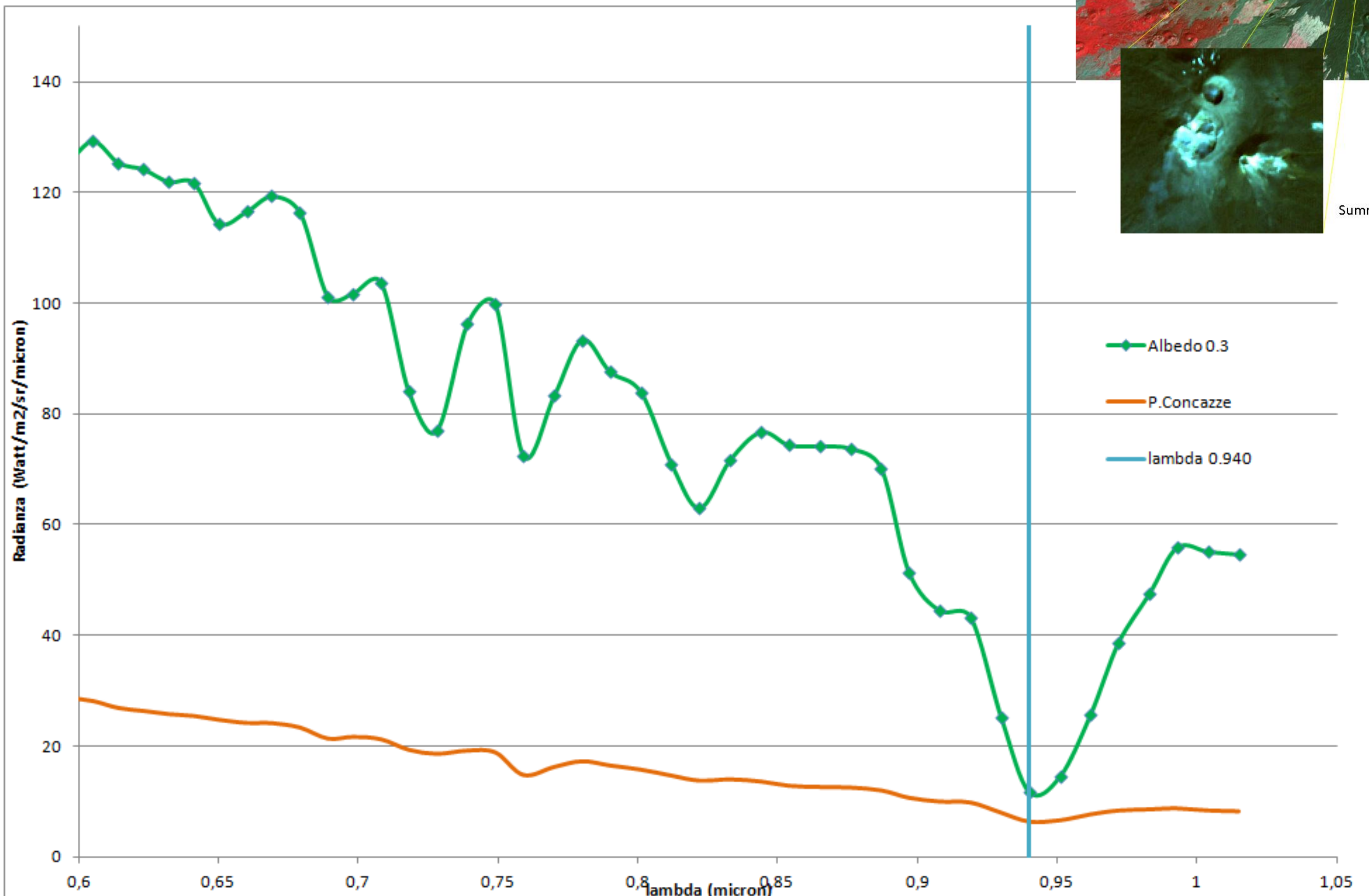


SIMULATION OF RADIANCES FOR DIFFERENT MATERIALS AND TEMPERATURE

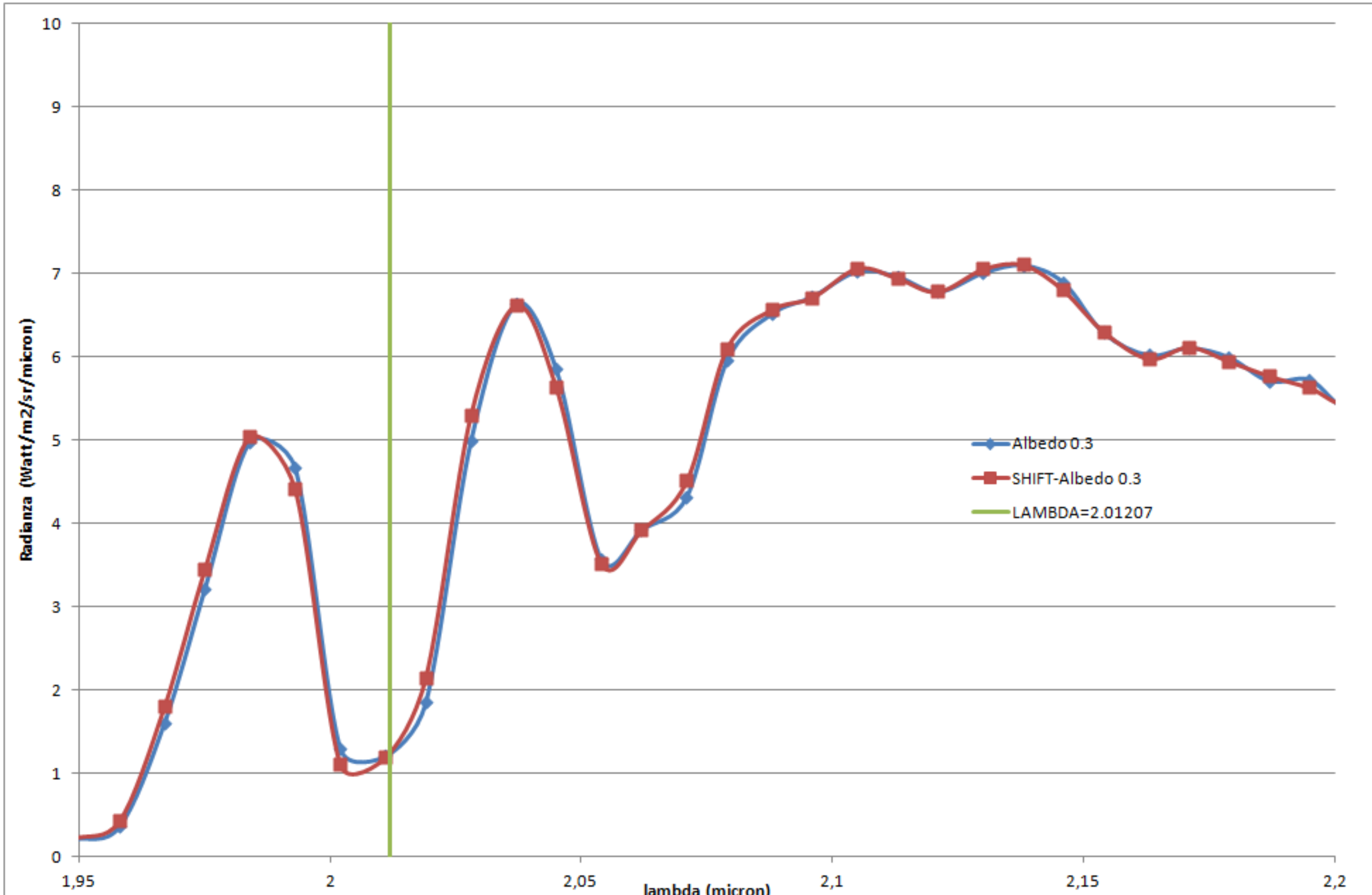


Water absorption at 940 nm





CO_2 SWIR absorption 2.01207 micron

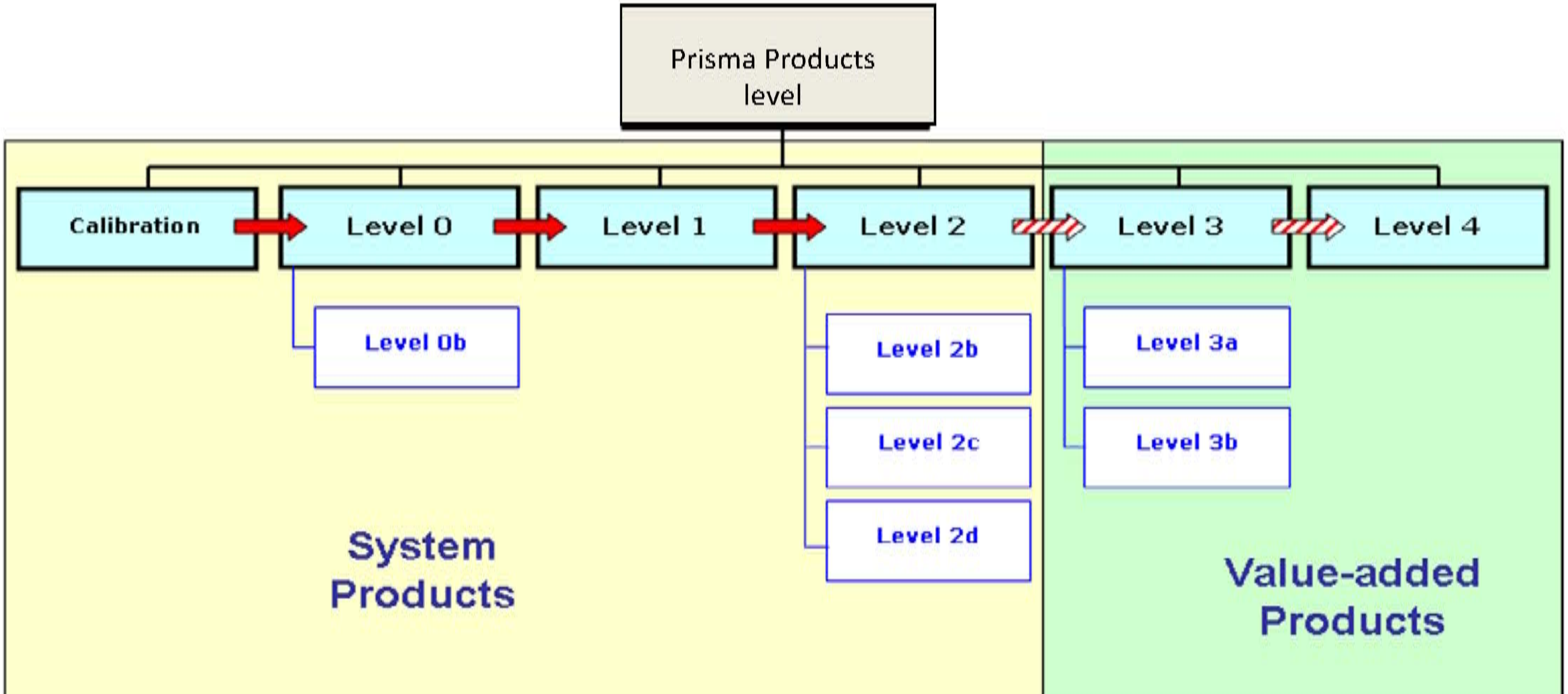


In-Flight Calibration

Sources
- External ⇨ Sun (absolute radiometric calibration)
- Internal ⇨ A system of two Internal Sources (lamp and led) optimised for SWIR and VNIR (relative radiometric calibration, spectral calibration)

- Goal: maintain PRISMA calibration accuracies throughout the whole mission operational lifetime (**5 years**), by using Internal Calibration Unit (ICU) for quantifying calibration uncertainty and updating the Key Data Parameters (KDP) set.
- Strategy: systematic measurements of the reference radiance from the **internal sources** (lamp, led) and the **Sun**. These activities doesn't impact on the Satellite manoeuvring and they can be executed with a high repetition frequency.
- Additional in-flight calibration reference sources: External Flat-Field, Earth Specific Targets and Moon Observation (Specific S/C manoeuvres - more rarely execution respect to the ICU's one).
- Monitored ICU degradation by Moon radiance acquired periodically; independent measurement of the ICU transmittance degradation (KDP ITF updating).

Products are classified as **"System Products"**, generated within IDHS facility and **"Value-Added Products"**, playing a key role in the applications definition.



TITLE	Name of the institute	
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

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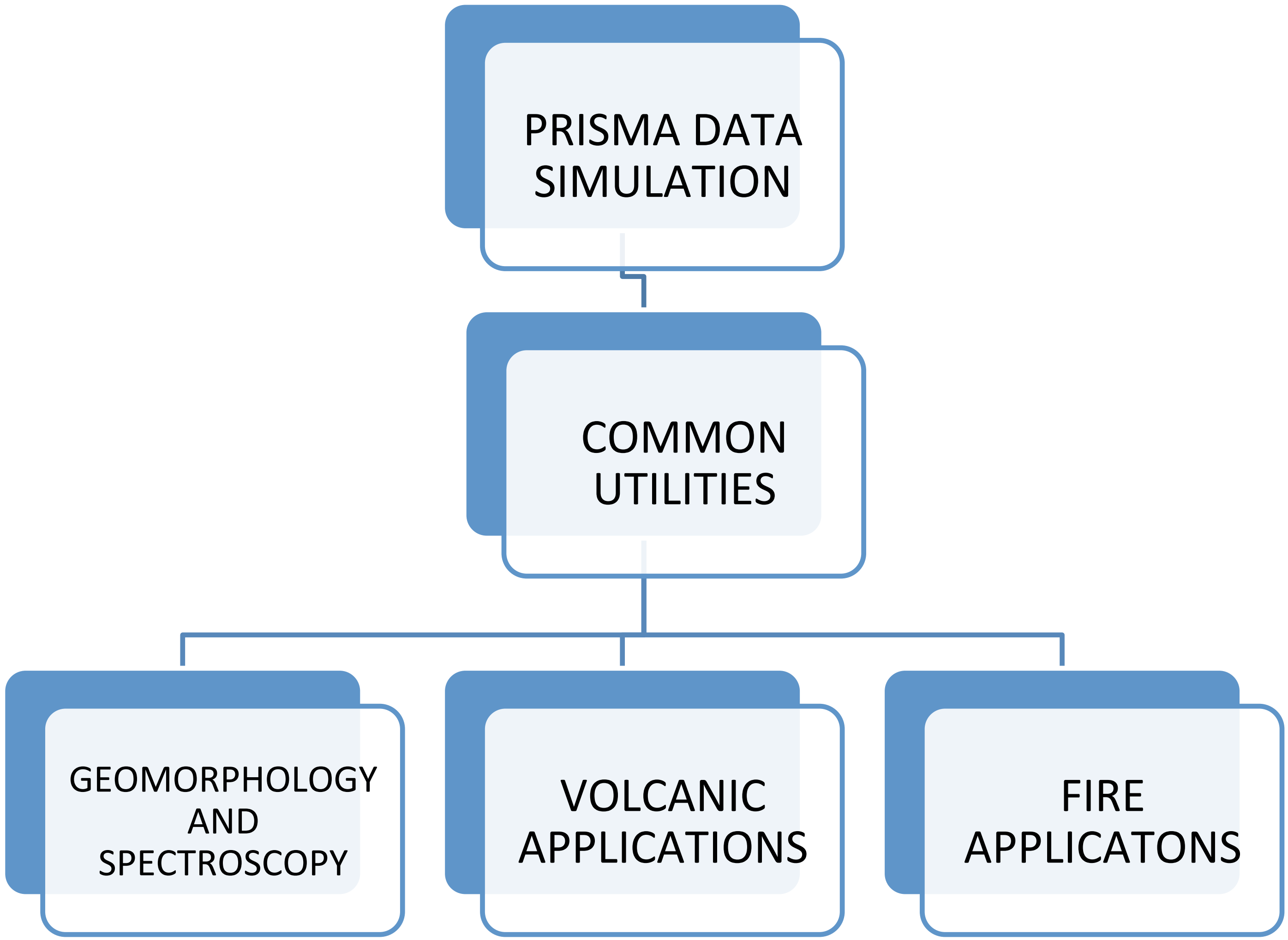
For any further information on the scientific studies please contact

cristina.ananasso@asi.it

PRISMA GEOPHYSICAL APPLICATION PRODUCTS (ASI-AGI)



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

Product description portfolio Heritage from GMES projects

Service WP 30210 Volcanoes (E&V) Services		
Providers Identification *(in previous projects)*		INGV
Providers Identification *(in SAFER)*		INGV
General Service Description		The following products have been selected and will be delivered taking into account that objectives of SAFER project aimed to the crisis phase. • **HTE (high temperature events)** • **ASH detection** • **SO2 concentration and flux** • **Ash Dispersion models** • **Sineruptive maps** All the products will be delivered to the EU and Non EU focal point and they will be in the appropriate standard format according to the OGC requirements and to the INSPIRE indications
Targeted Users *(in previous projects and now)*		
Spatial coverage *(in previous projects)*		
Technical validation *(achieved in previous projects)*	Validation dossier reference	
	Technical validation content *(short summary: volume of tests done, purpose of the tests, conclusions etc)*	
Operational validation *(achieved in previous projects)*	Volume of products delivered	
	End users' feedback	
Product description *(in case more than one product is delivered by the service, please describe each product)* 1. Product		
2. Product		
3. Product ...		

Service WP 30210 Volcanoes (E&V) Services	
Are all products delivered per activation? Can single products be chosen? *(only to be answered by those service providers who offer more than one product)*	
Delivery Format Please indicate the format *(e.g. jpg, tiff, shp….)*	
Map	
Analyses data (Vector/Raster)	
kml	
Online service	
Others	
1. Sustainability **Required Input Data/Software:** 1. EO-Data	VHR, HR, MR, LR optical data VHR, HR radar data
2. Non EO-Data	GPS
3. List of used Software for the processing	ITT platform (ENVI/IDL)+ GAMMA + home made SW,
Is there a sustainable supply of relevant EO- and non EO-data for the provided product (GSCDA quota and sensor availability ensured)	All the product will be generated trough the ensured data provided by ESA.
Is a support of the used software ensured (and how)?	Yes it is
2. Transferability Risk Areas covered by the product/service	Etna all events that will occur during the lifetime of the project Piton de la Furnaise all events that will occur during the lifetime of the project World Wide test Service on demand for events in the South America or South Pacific area
Transferability of the product t o other areas	World Wide test Service on demand for events in the South America or South Pacific area
In which scale range can the product be used?	From 1:50000 up to 1:250000

Products for volcano monitoring

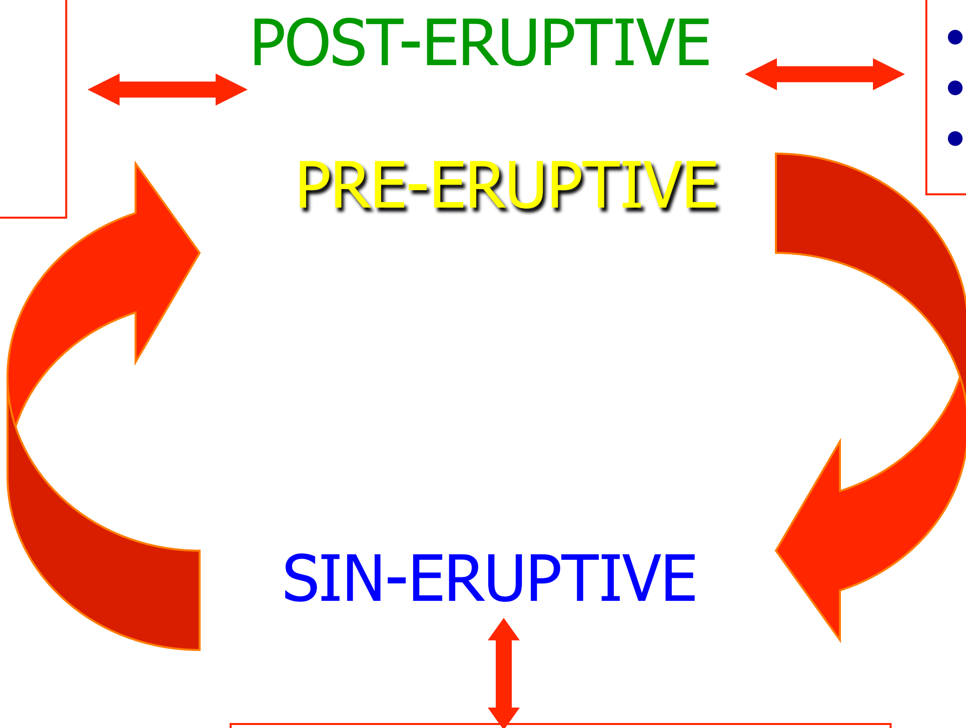
LOCATION OF ITALIAN

ACTIVE VLOCANOES

(in red)

products related to Volcanic Risk Phases

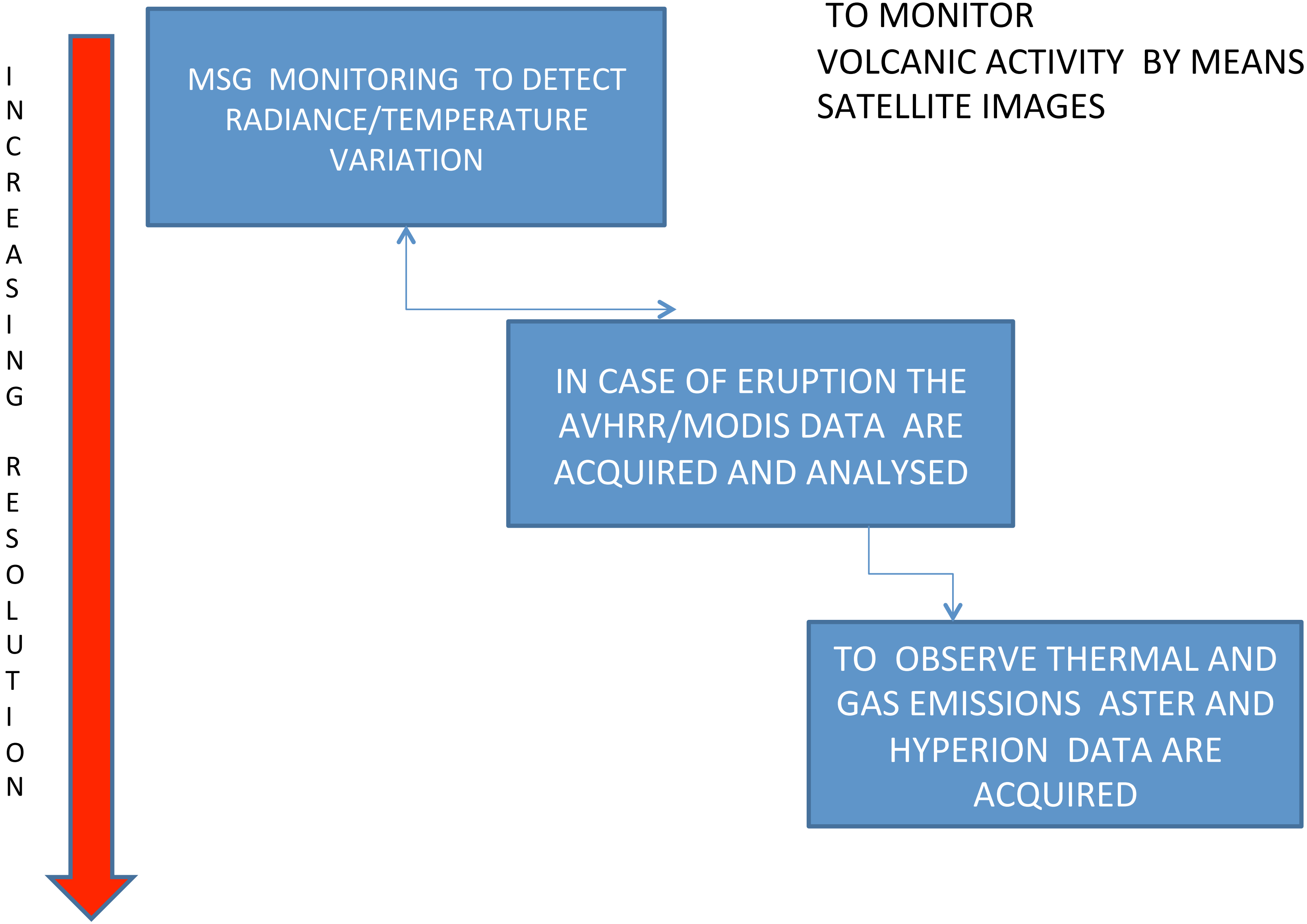
- lava flows mapping
- lava flows thikness
- Ash depostis
- surface deformation



- thermal anomalies
- surface deformation
- gas emissions
- volcanic aerosols

- Lava flow T flux effusion rate
- sin-eruptive deformation
- ash clouds
- So2 eruptive plumes

WORKFLOW SCHEME
TO MONITOR
VOLCANIC ACTIVITY BY MEANS OF
SATELLITE IMAGES



VOCANIC GAS EMISSIONS PRODUCTS FROM PRISMA

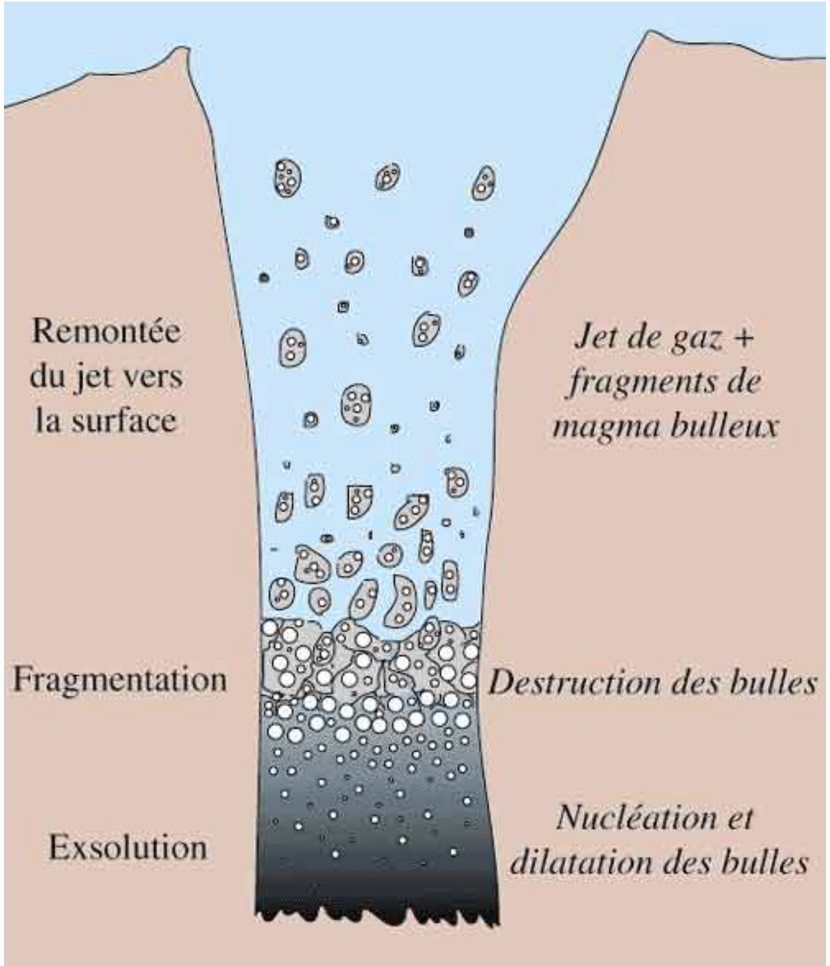
Algorithms: Review of the CBRW modified algorithm
development of new algorithm LIR based on hyperspectral sensors data in the SWIR range

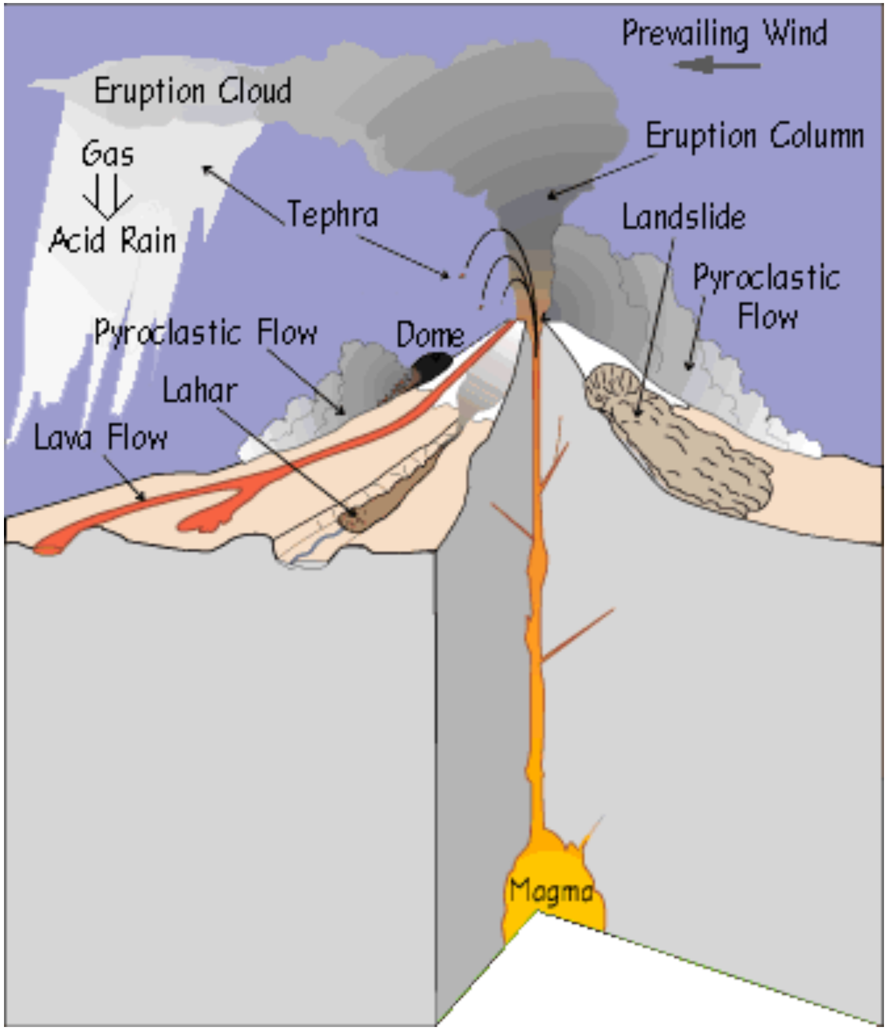
Objective: Analysis of the absorption bands of CO_2 and CH_4 in volcanic plumes and degassing cold fumaroles

Products: maps to show degassing areas in volcanic zones
CO_2 concentration and flux in volcanic plumes

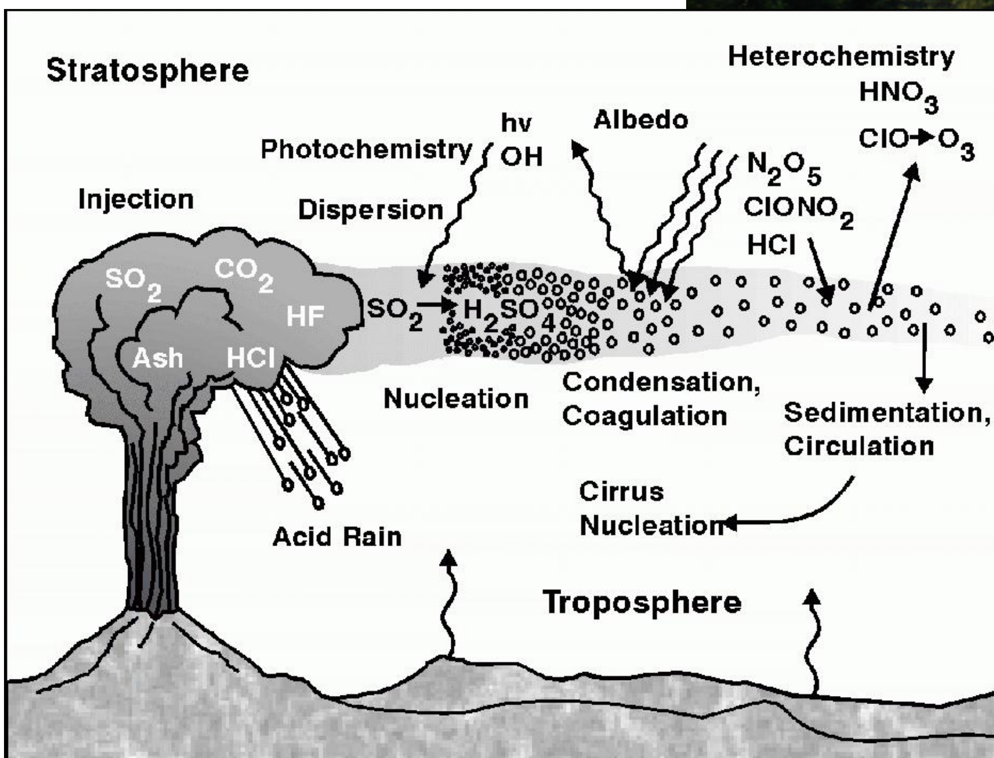
Volcanic emissions in atmosphere

italiana





Volcanic plume



- ✓ Volcanoes inject in the troposphere H2O, CO2, SO2, H2, CO and in lower quantities H2S, HCl, HF, He, …
- ✓Those gases can be responsible of acid rains, pollution of aquifers, ….
- ✓ More globally, the volcanic plumes have an impact on the climate.
- ✓ Some historical eruptions are known to have induced colder climate during some years

Volcanic gases flux (1975-1995)

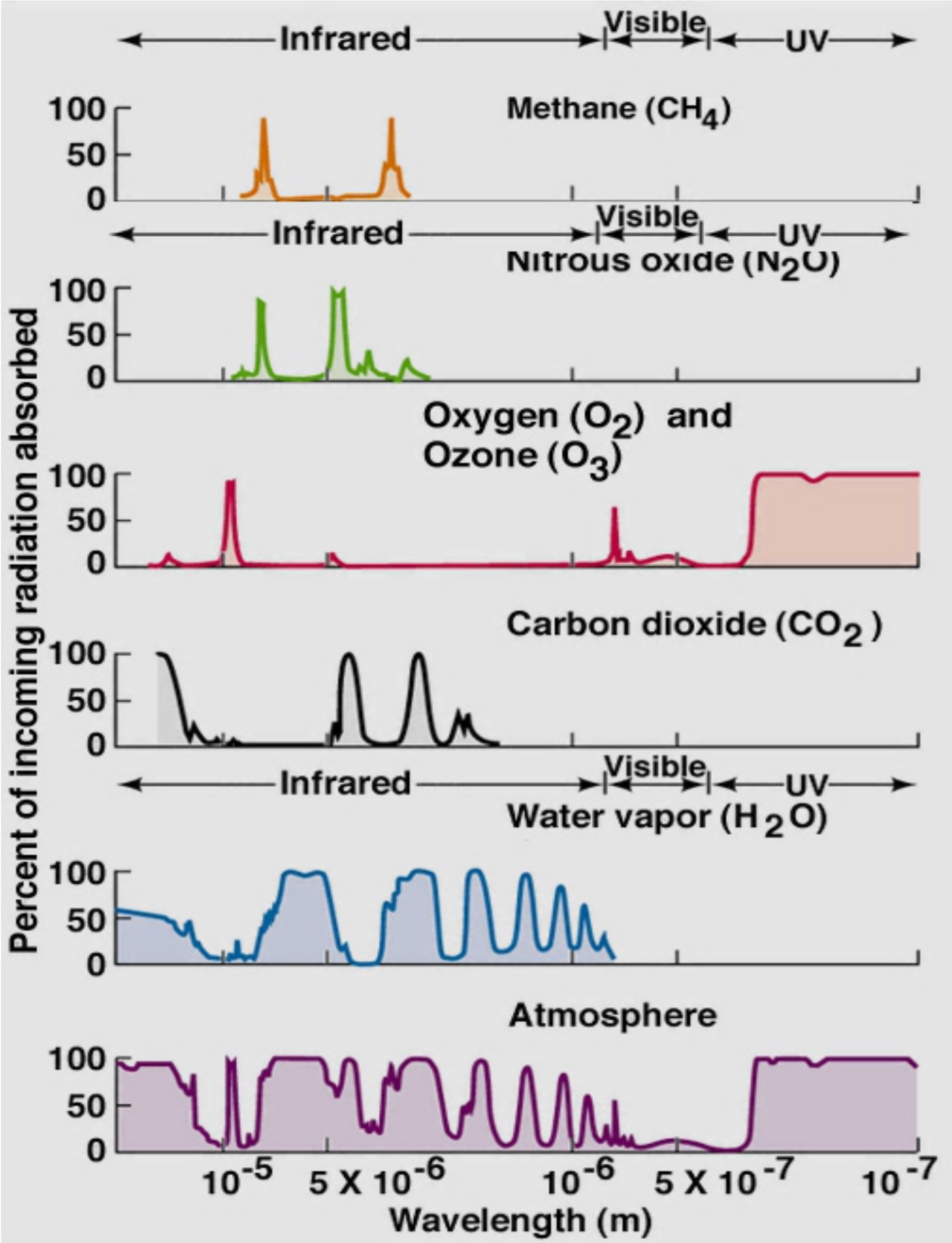
Species	Global Volcanism (Gg/yr)	Etna/Global Volcanism
H_2O	$5.0 \cdot 10^6$	10%
CO_2	$(8\text{-}20) \cdot 10^4$	(7-16)%
SO_2	$1.3 \cdot 10^4$	11%
HCL	$(4\text{-}110) \cdot 10^2$	9%
HF	60-6000	8%
Br	77	2.6%
Zn	9.6	51%
Cu	9.4	5.9%
Mn	42	0.6%
Pb	3.3	4.5%

Volcanic CO_2 emissions

Volcano	CO_2 (T/d)
Mt. Etna	11000-70000
Popocatepetl	6400-40000
Oldoinyo Lengai	7200
Augustine	6000
Mt. St. Helens	4800
Stromboli	3000
Kilauea	2800
White Island	2600
Erebus	1850
Redoubt	1800
Grimsvotn	360
Vulcano	270

DATA SOURCE:

Symonds et al., 1994; Gerlach et al., 1997; Allard et al., 1998; Varley et al., 1998; Delagdo et al., 1998; Kopenick et al., 1996; Allard et al., 1991; Wardell and Kyle, 1998; Brantley et al., 1993; O'Keefe, 1994

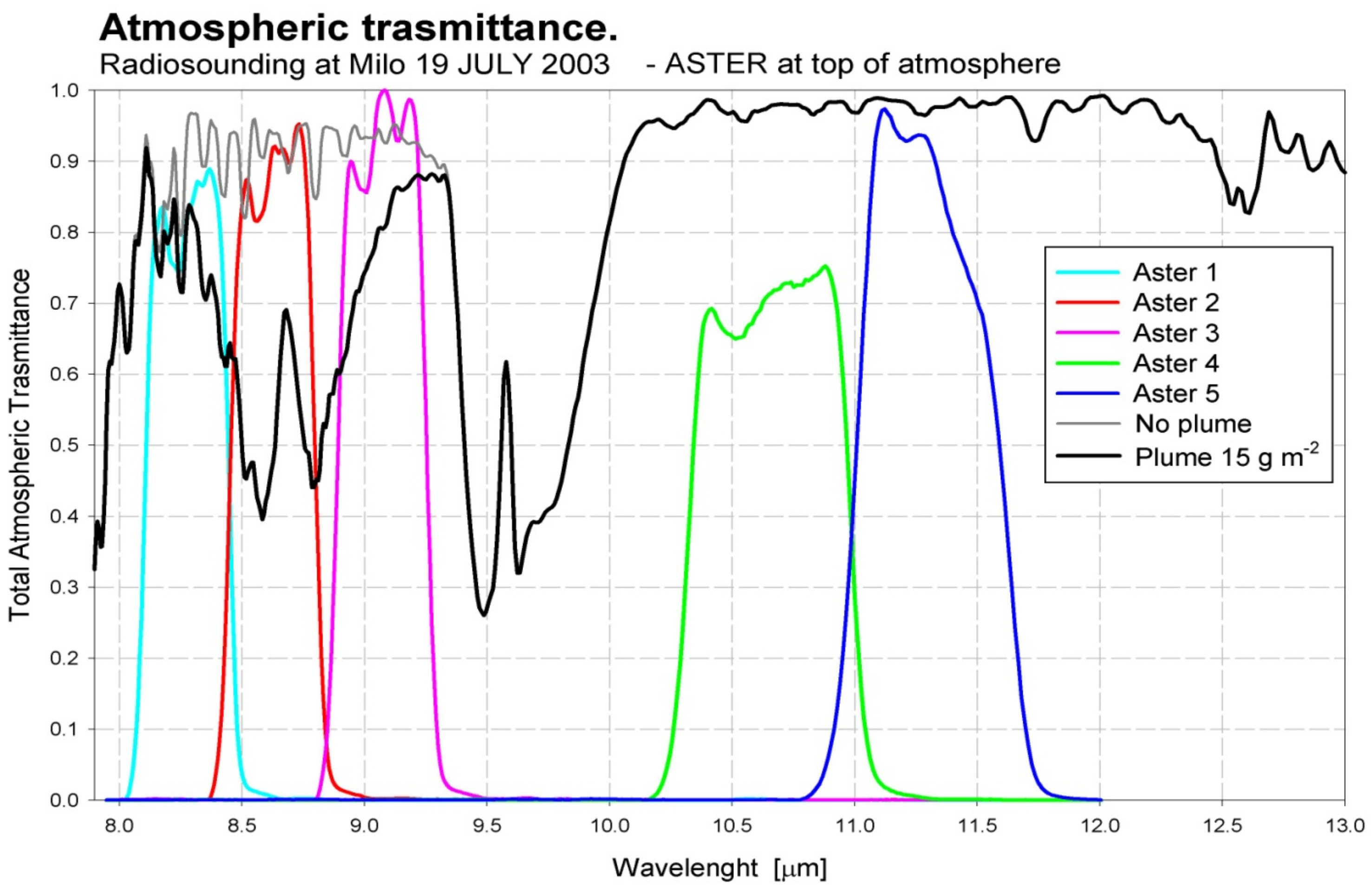


atmospheric absorption features

volcanic

volcanic

VOLCANIC SO2

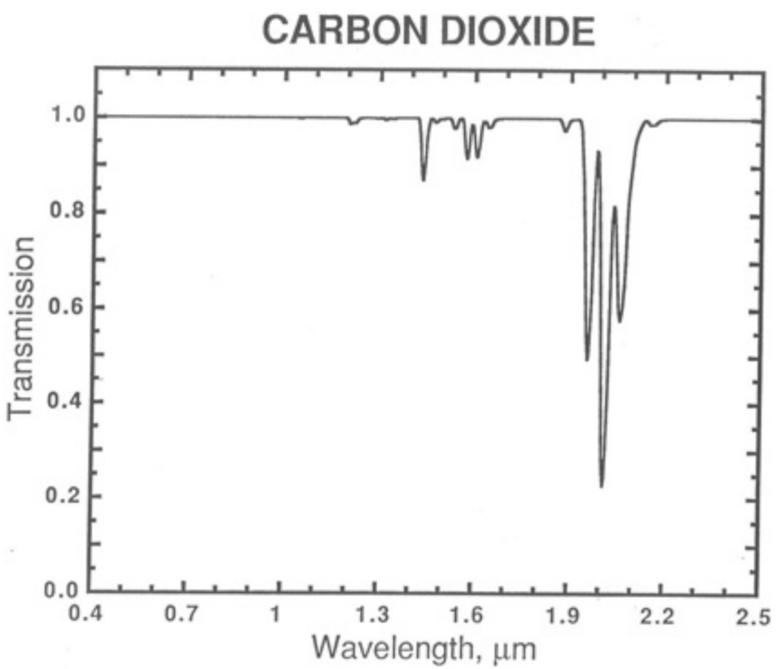


Volcanic Carbon Dioxide Retrieval

CO_2 absorption lines are present in the spectral range of hyperspectral imaging spectroradiometer VNIR-SWIR

weak absorption 1270 nm and 1610 nm

strong absorption 1950 nm and 2100 nm



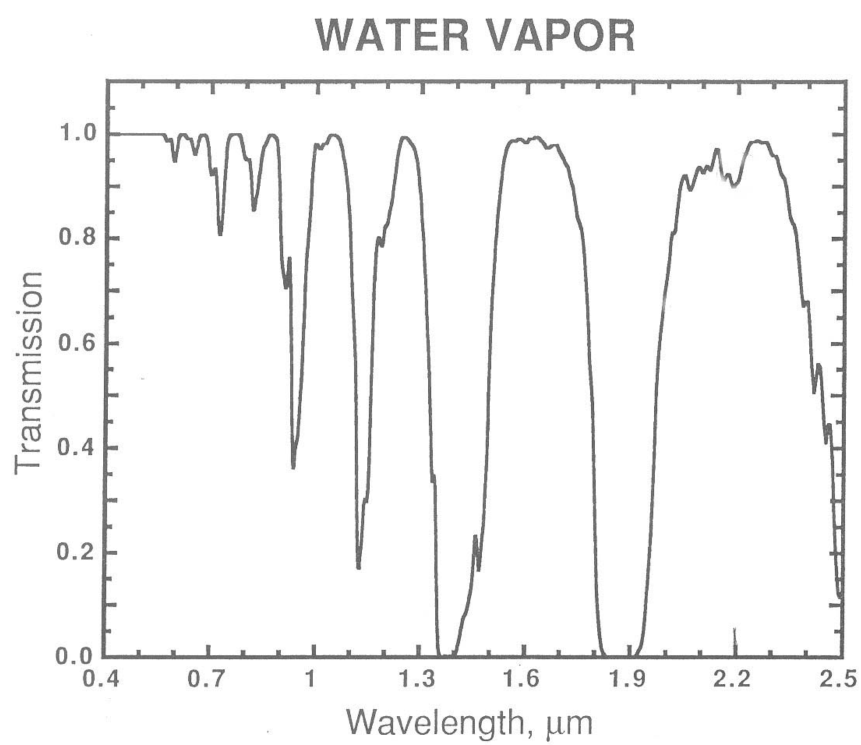
Atmospheric transmisson simulated using Modtran with the only presence of CO_2 in standard condition with 10 nm of spectral resolution

Water Vapour absorptions in the VNIR-SWIR spectral range

Water Vapour Absorption lines are present in the spectral range of hyperspectral imaging spectroradiometer:

weak absorption
940 e 1125 nm

very strong absorption
1350 e 1900 nm



Atmospheric transmisson simulated using Modtran with the only presence of water vapour in standard condition

The CIBRW retrieval alghoritm

In order to retrieve the tropospheric volcanic plume Carbon Dioxide abundance, an inversion technique has been developed for remote sensing hyperspectral data (*Spinetti et al., 2008, RSE*). The algorithm is based on the assumption that there is a relationship between the dip in the atmospheric spectrum curve, due to the gas absorption, and the gas concentration in the atmospheric column. The retrieval is based on solving the equation:

$$CIBRW = \exp(-\alpha(w)\cdot[CO_2]^{\beta(w)})$$

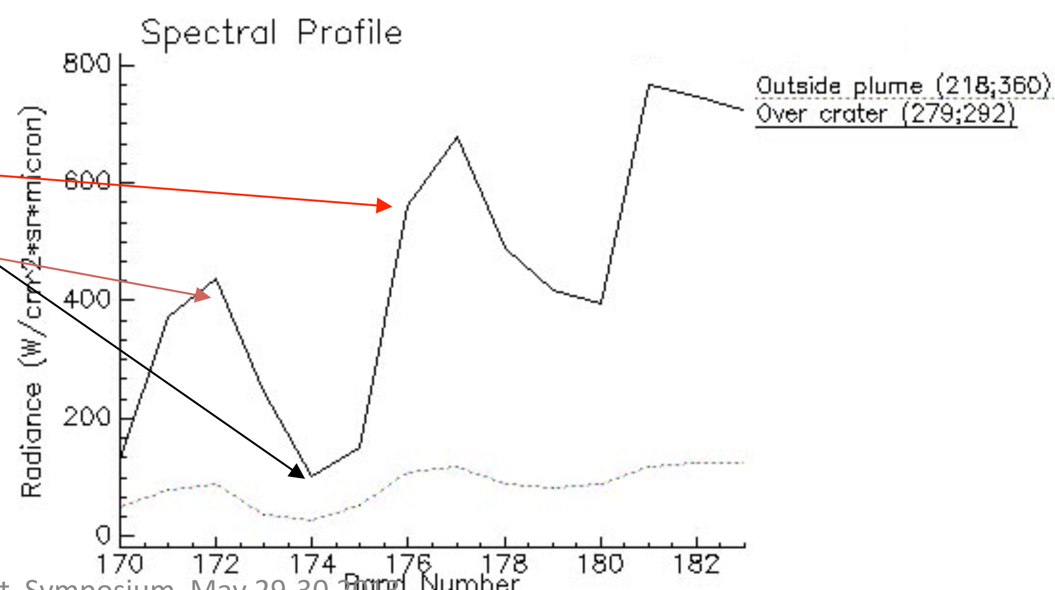
- $[CO_2]$ is the unknown carbon dioxide columnar abundance ($kg\cdot m^{-2}$);

- α e β parameters related to the model variables, volcanic water vapor abundance and volcanic aerosol presence;

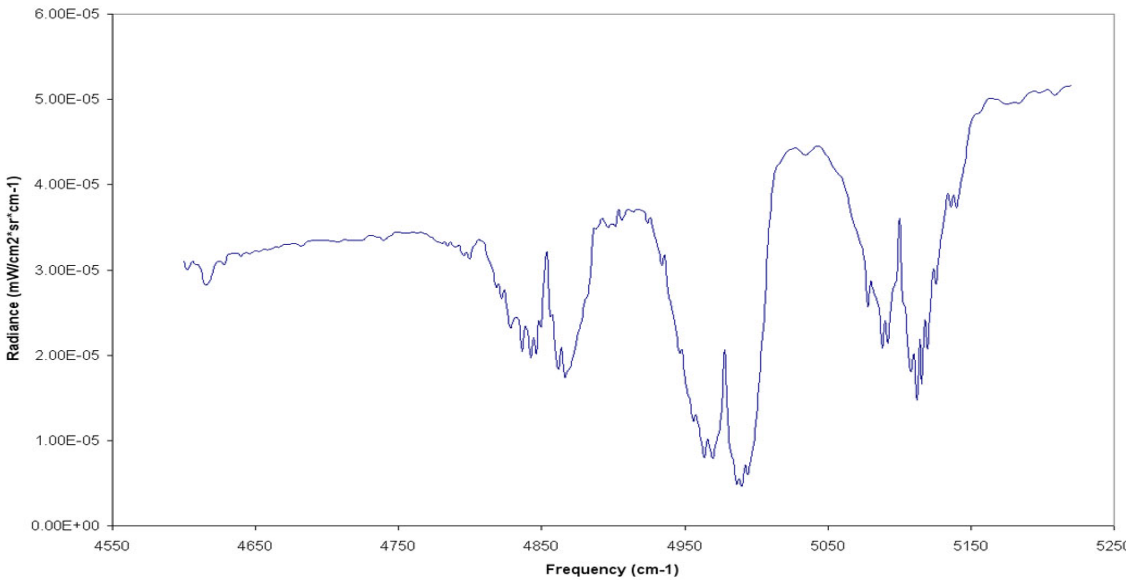
- CIBR is given by the following ratio:

$$CIBR = \frac{R_a}{A\cdot R_1 + B\cdot R_2}$$

- R_a is the radiance corresponding to the minimum of absorption
- A and B are the weighting constants
- R_1 and R_2 are the radiances of the continuum

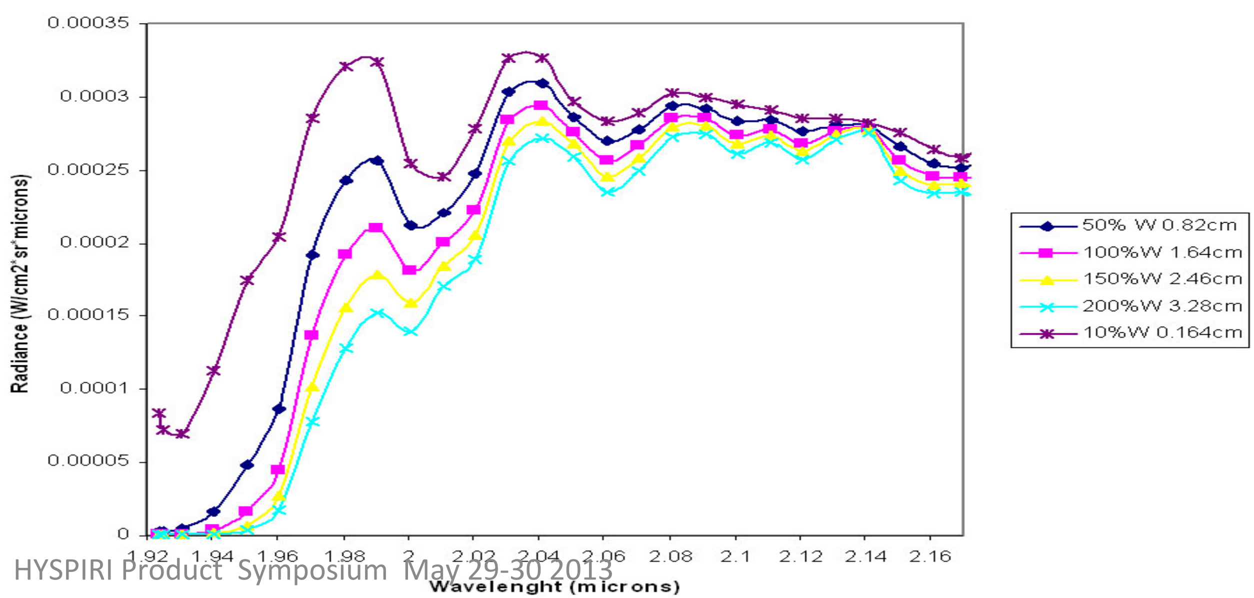


The water vapour influence



Considering 10 nm of spectral resolution, CO_2 lines partially overlap with the water vapor lines. The presence of water vapor influences the CO_2 absorption bands cancelling the signal of the first CO_2 absorption band and modifying the other two bands depending on the amount of water vapor.

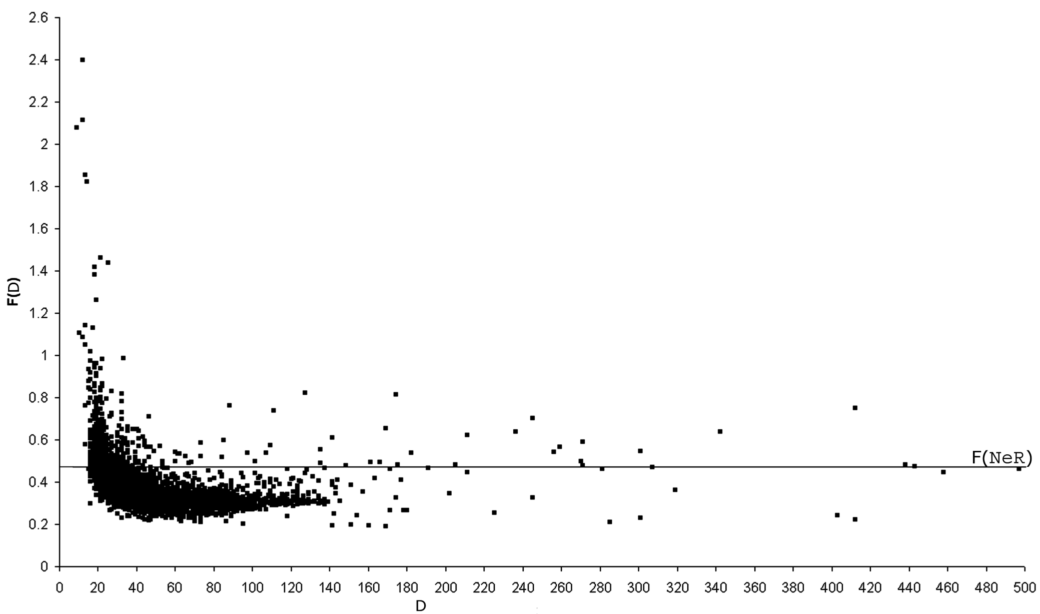
Modtran Radiance simulation at standard atmospheric conditions with the atmospheric concentration of CO_2 and the presence of different values of water vapour in the atmospheric column.



Signal Sensitivity Analysis

In order to quantify the signal sensitivity with respect to the CO2 absorption line variations, a sensitivity function F(D) has been defined:

$$F(D) = \left| \frac{D(\lambda)|_{\lambda=\lambda_m}}{D(\lambda)|_{\lambda=\lambda_{C1}} + D(\lambda)|_{\lambda=\lambda_{C2}}} \right|$$



λ_m= 2011nm is the CO2 absorption channel; λ_{c1} = 1981nm and λ_{c2} = 2031nm are channels in the continuum;

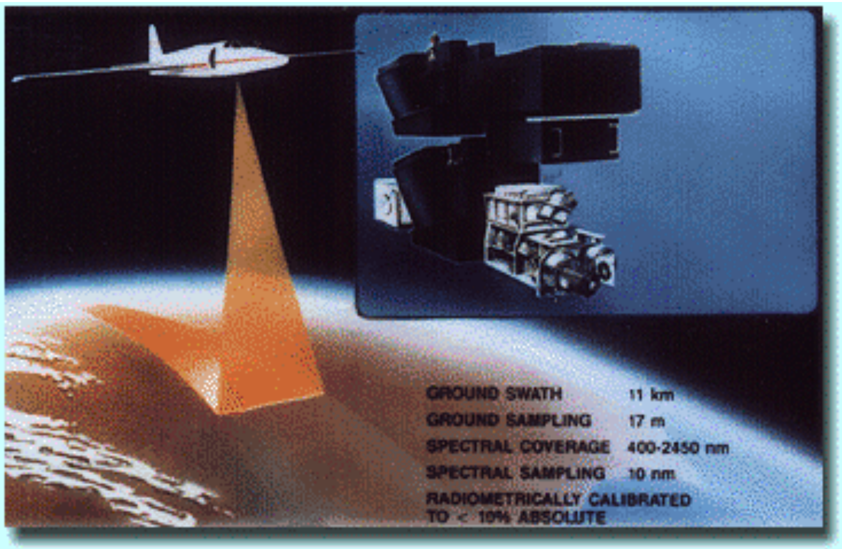
$D = (R_{Plume} - R_{Atm})$ where R_{Plume} is the volcanic plume radiance and R_{Atm} is the atmospheric radiance outside the plume

The CO2 retrieval is possible only if the signal contains the information on volcanic CO2 above the atmospheric background, i.e. where F(D) assumes values greater than the noise equivalent radiance:

$$F(D) > F(NeR)$$

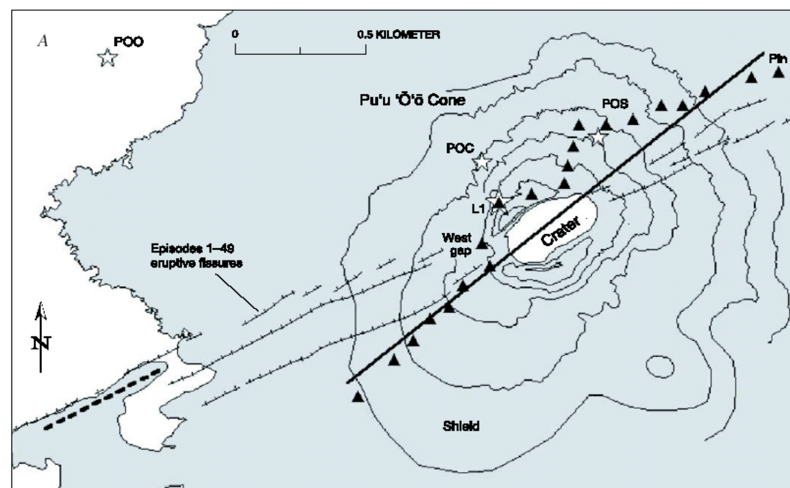
AIRIS

Airborne Visible/InfraRed Imaging Spectrometer



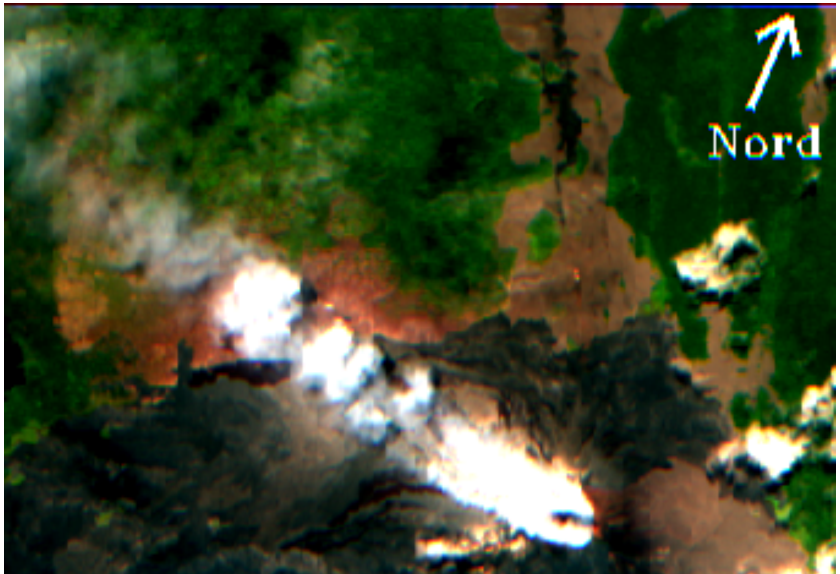
"Whisk broom" scanning

Spectral coverage	**400-2450 nm**
Spectral sampling interval	**9.6-9.9 nm**
Spectral channel width	**9.8 12.5 nm**
Number of spectral channel	**224**
Number of pixel scan line	**614**
Number sca/sec	**12**
IFOV	**1.0 mrad**
Rad. Calib. accuracy	**6%**
In-flight stability	**1%**
Spectral calib.accuracy	**2+- nm**



Water vapour abundance map of Pu'o'O Vent plume at Kilauea volcano

AVIRIS campaign April 26th 2000

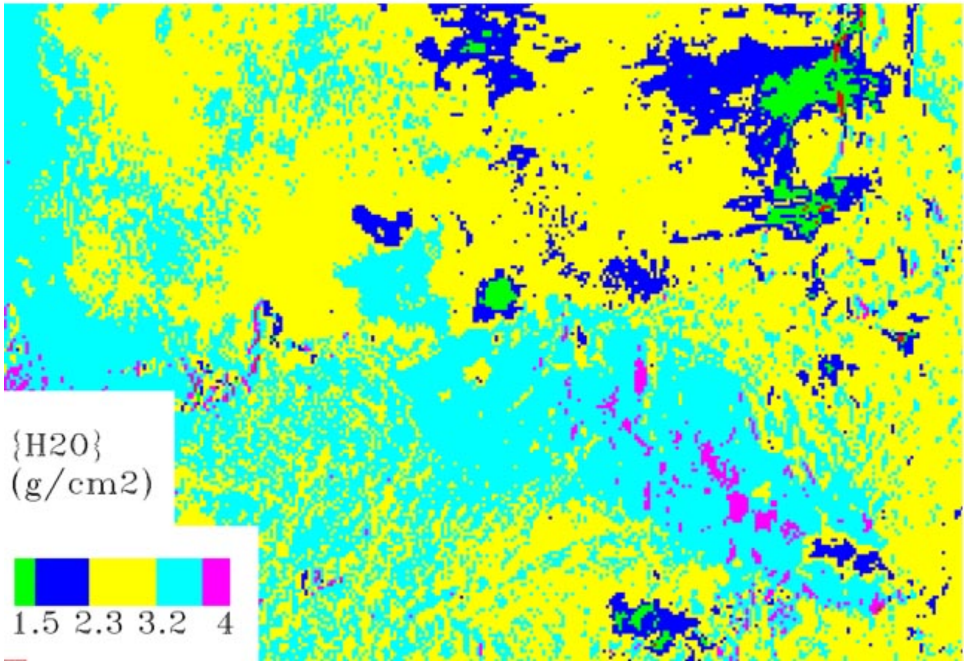


Pixel dim.

20x20 m^2 @ crater

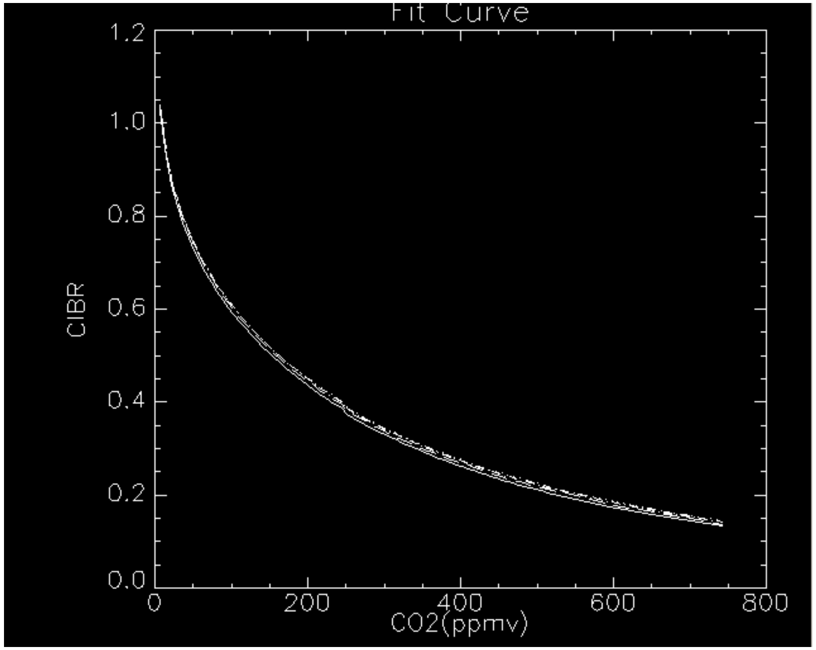
R 676.31± 0.11nm
G 529.43 ± 0.11nm
B 452.08 ± 0.11nm

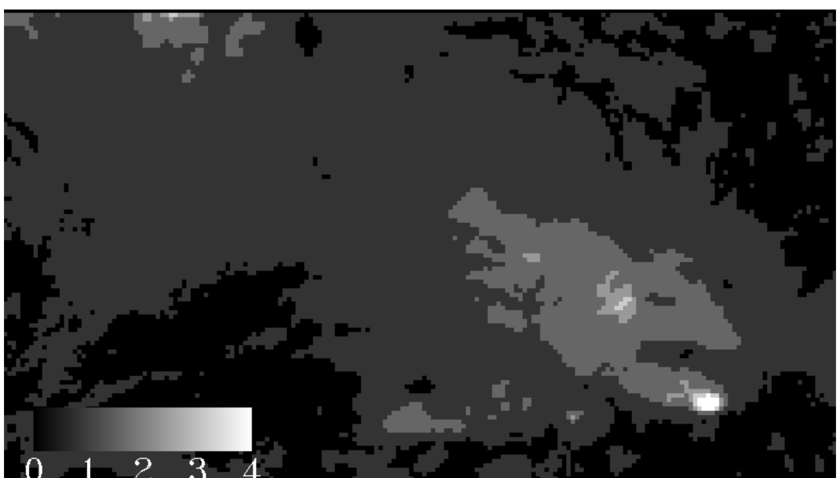
Water vapour map retrieved using 940 nm absorption band



Spinetti and Buongiorno 2004, IEEE Trans

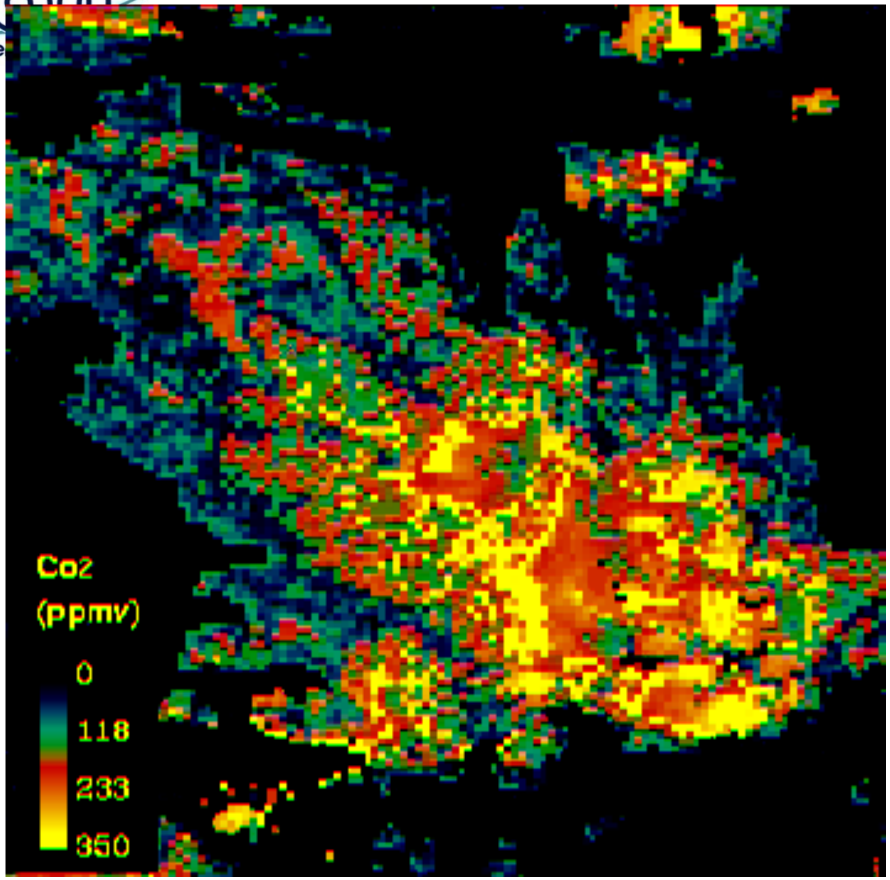
Paramaters α and β depending on water vapour content



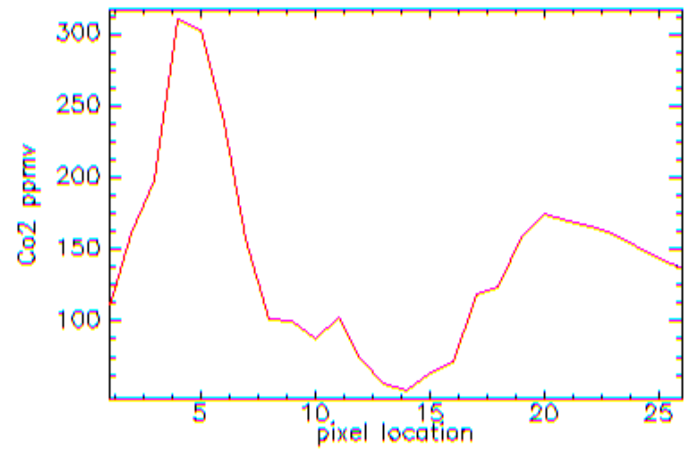


Index	W (g/cm2)	α(w)	β(w)	Correlation fit (R^2)
0	2.3	0.0160669	0.740992	0.989785
1	2.8	0.0141277	0.759783	0.986303
2	3.2	0.0133723	0.766998	0.984544
3	3.4	0.0135917	0.763602	0.984492
4	4	0.0141354	0.756234	0.985672

Map of CO_2 abundance in the Pu'o'O Vent plume



26-4-00



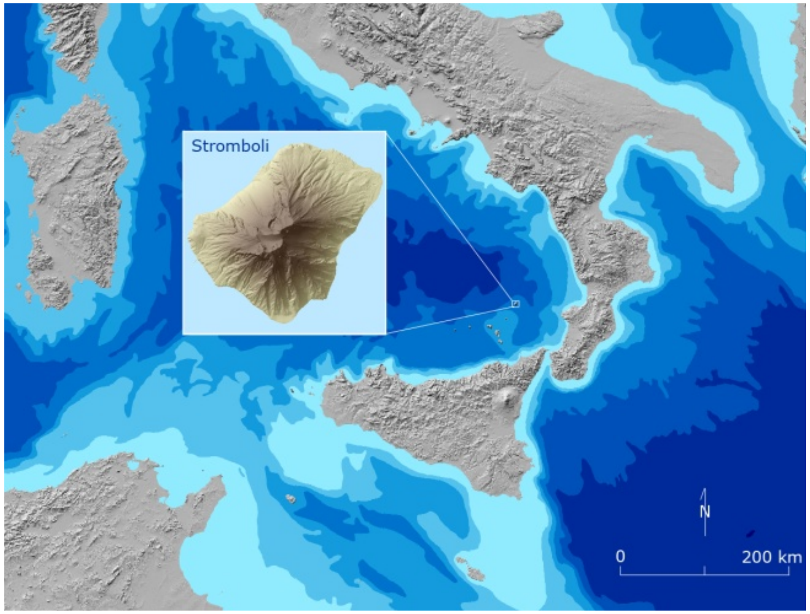
$\Phi_{CO2} = 396\pm138 \text{ t d}^{-1}$

Accordance with ground sampling data

Figure 13. Lava from crater of Pu'u 'Ō'ō flows through west gap in cone. View eastward; photograph by J.P. Kauahikaua, taken October 20, 1997.

Figure 14. Crater of Pu'u 'Ō'ō. Fumes rise from several vents on crater floor, which is covered with pāhoehoe erupted in 2002. View westward; photograph taken April 11, 2002.

italiana

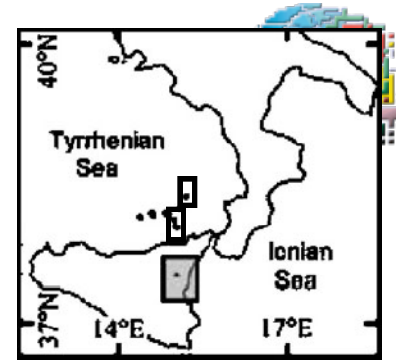


Located on the north-eastern part of the eolian arcipelago Stromboli is an open-conduit volcano active from more then 1,000 years.

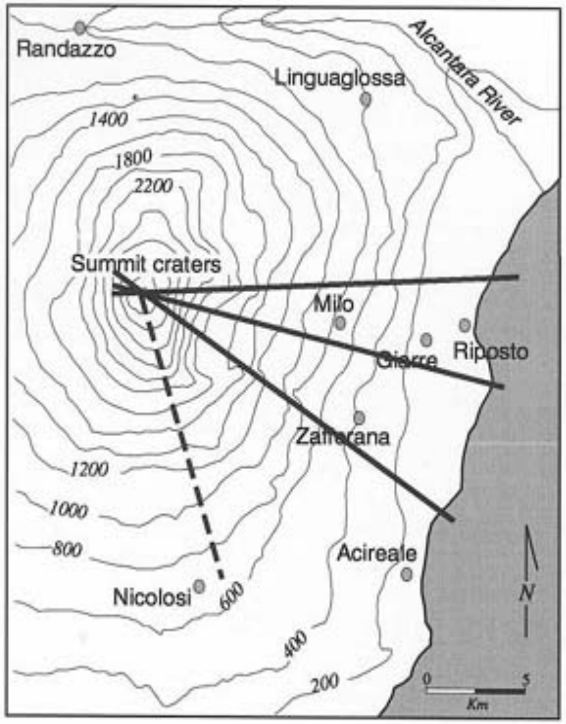
The typical activity is characterized by regular explosions emitting small volumes of lava spatter and pyroclasts up to 50–100 m above the craters every 15–20 min. Whilst activity of Stromboli volcano is mainly of *low intensity*, Strombolian explosions are occasionally interrupted by *major explosions, paroxysmal events, effusive activity as lava flow and landslides*.

When such events happen, the risk level of the vicinity of the volcano poses a serious hazard for people on the volcano especially in the crater area.

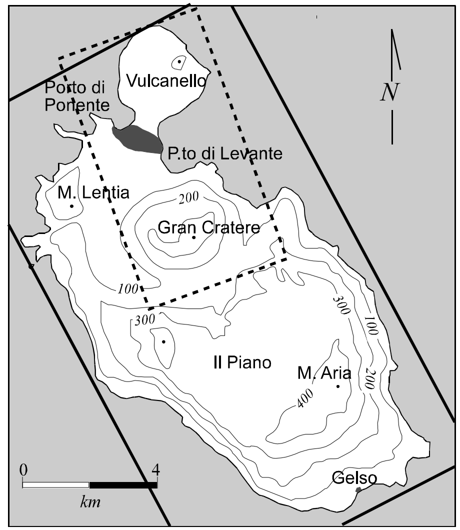
Airborne Measurement Campaigns MIVIS on Etna, Vulcano e Stromboli

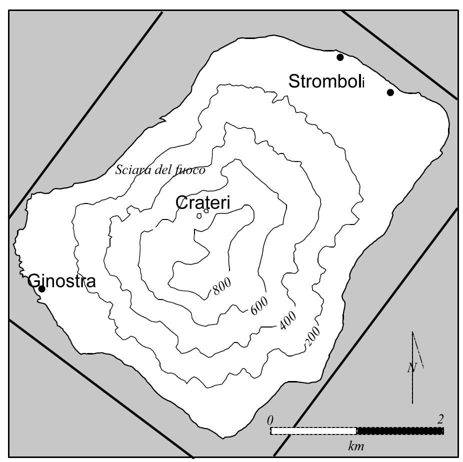


July 1994 | **June 1997** | **July 2001**



"MVRRS Campaign: MIVIS Mission on Sicilian Volcanoes and Ground Measurements" 1999 Publication of Quaderni di Geofisica



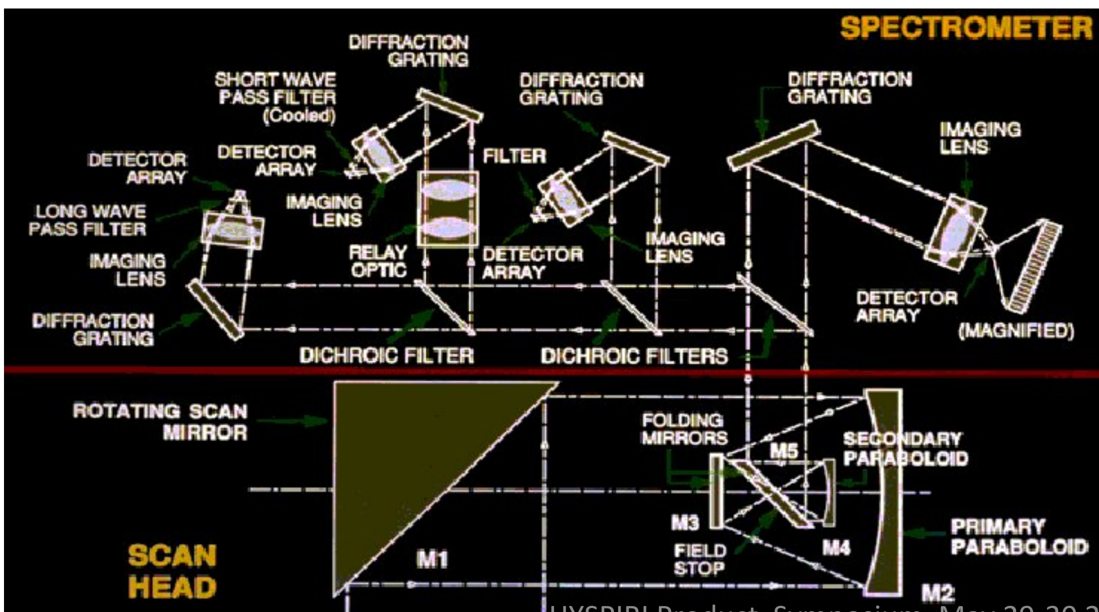


Daedalus AA5000 MIVIS
Multispectral Infared and Visible Imaging Spectrometer

102 spectral bands simultaneously sampled and recorded

Optical port	Spectral Range	Number of channels	Spectral resolution
1 (VIS)	431-833 nm	20	20 nm
2 (NIR)	1.150-1.550 µm	8	50 nm
3(SWIR)	1.985-2.479 µm	64	9 nm
4 (TIR)	8.210-12.700 µm	10	340-540 nm

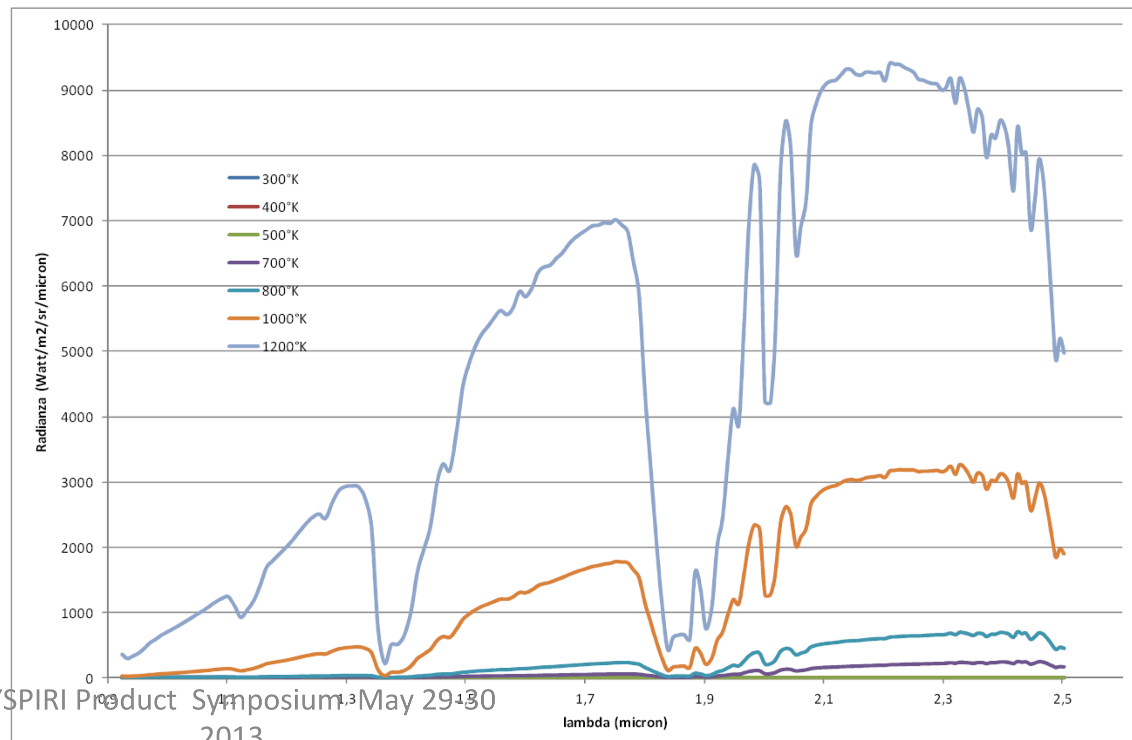
MIVIS Scan Head and Spectrometer



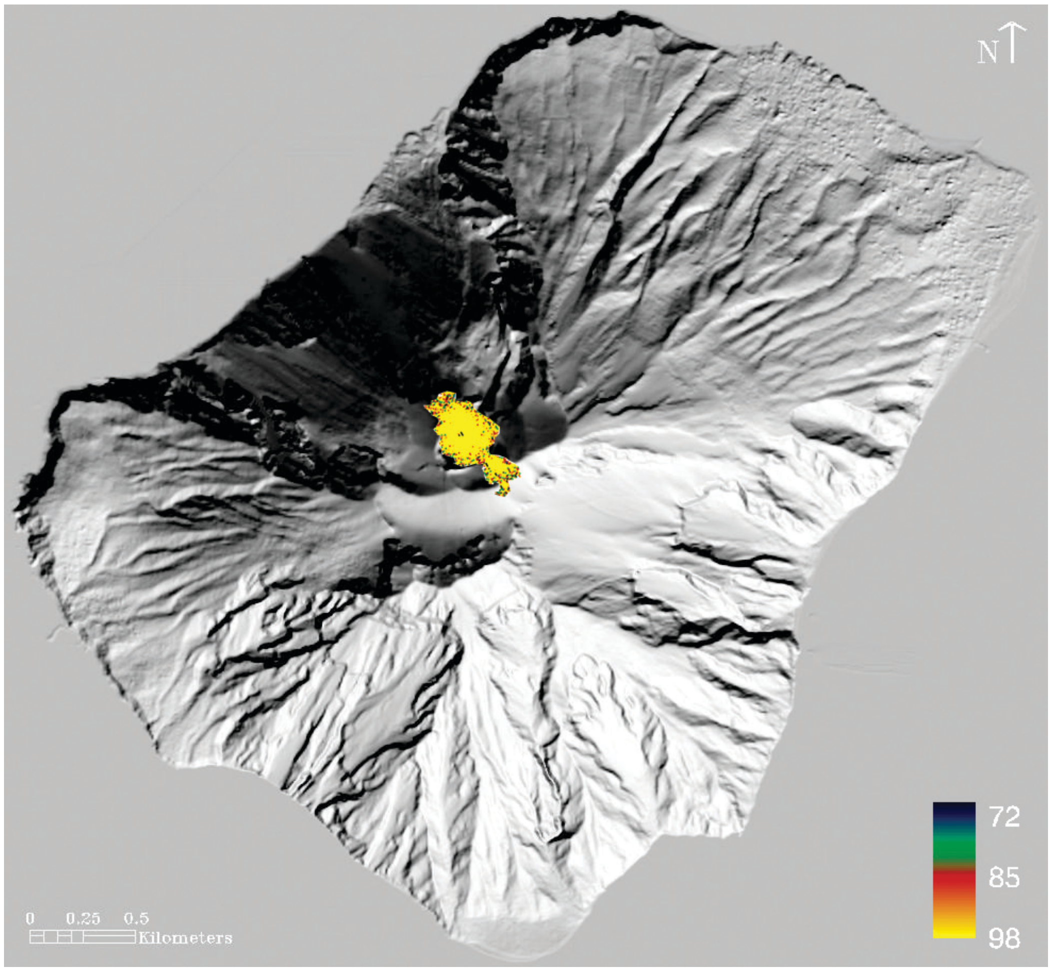
LARA System

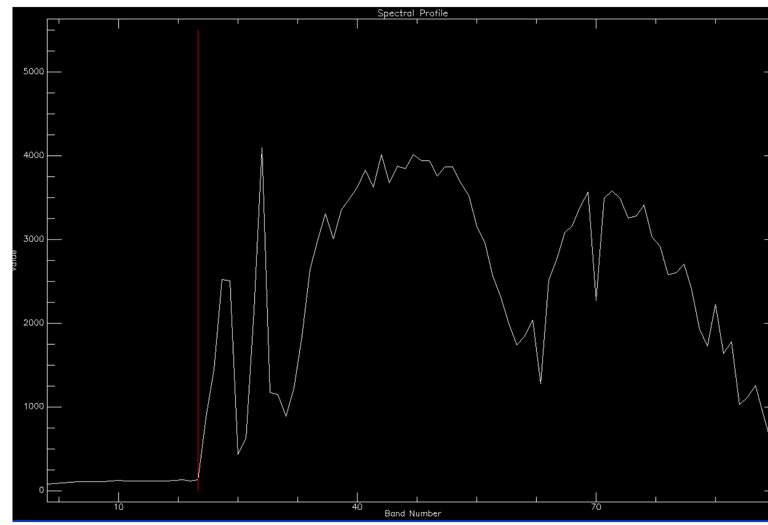
Radiating source

The radiating source is represented by an hot spot in a scene. The radiance shows an increment in the CO2 lines. This appends during Strombolian explosions. Temperature has been derived using the plank equation applied to radiance data. The temperature of the plume has been used as input in the Modtran simulations.



CO_2 map (ppm) retrieved from MIVIS data July 97





CO2 map @ 3 m res

Flight level 11500 ft 3.5 km

Spinetti et al., 2012

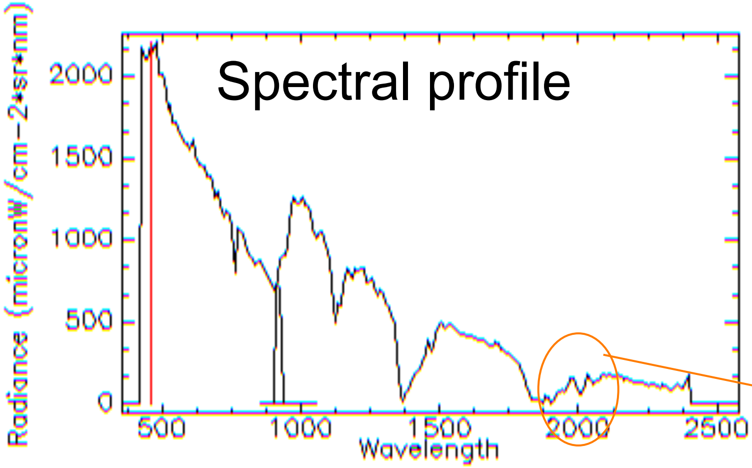
HYPERION

hyperspectral spaceborne imaging spectrometer

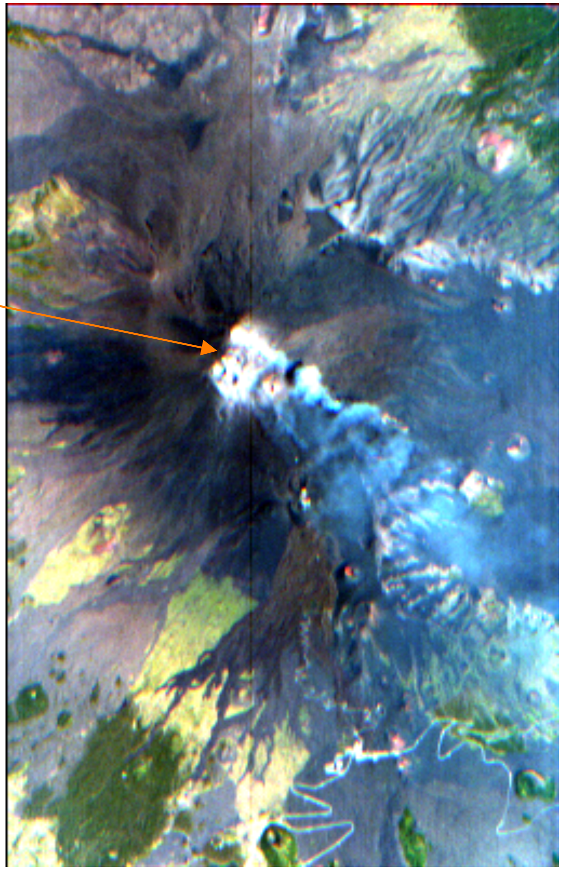
Morning constellation
709 km orbit
EO-1 launched on 2000

"Push broom" scanning
242 channels 400 – 2500 nm. 10 nm nominal channel bandwidth.
224 Hz frame rate. 12 bit data encoding.
0.61 degrees total field of view. 42.4 microrad Instantaneous Field of View.
On-board Accuracy Radiometry 3.40% VNIR SNR (550 - 700nm) 140- 190 SWIR SNR (~ 1225nm) 96 SWIR SNR (~ 2125nm) 38

Hyperion data analysis



Mt. Etna volcano



R
G
B

Pixel dim.
30*30 m^2

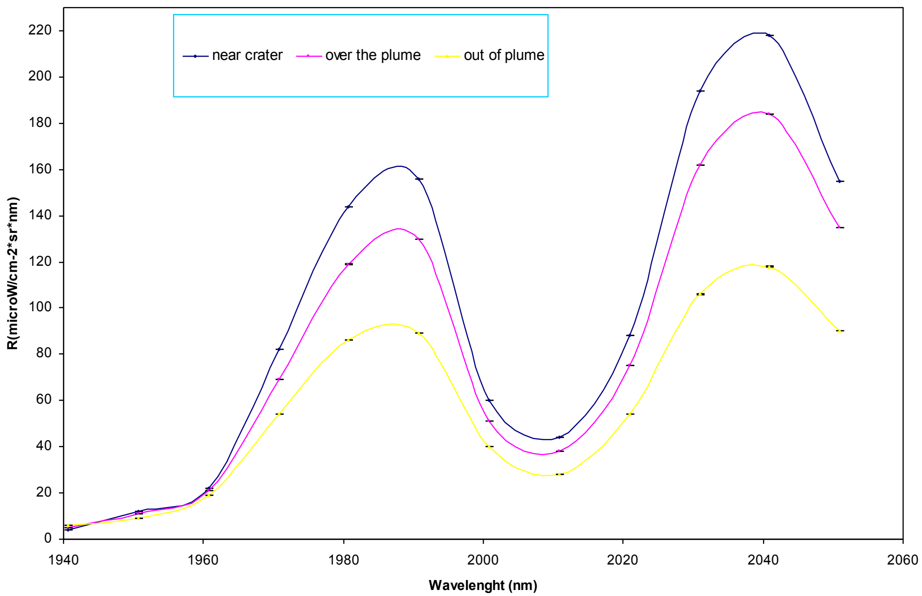
Hyperion 19-7-03

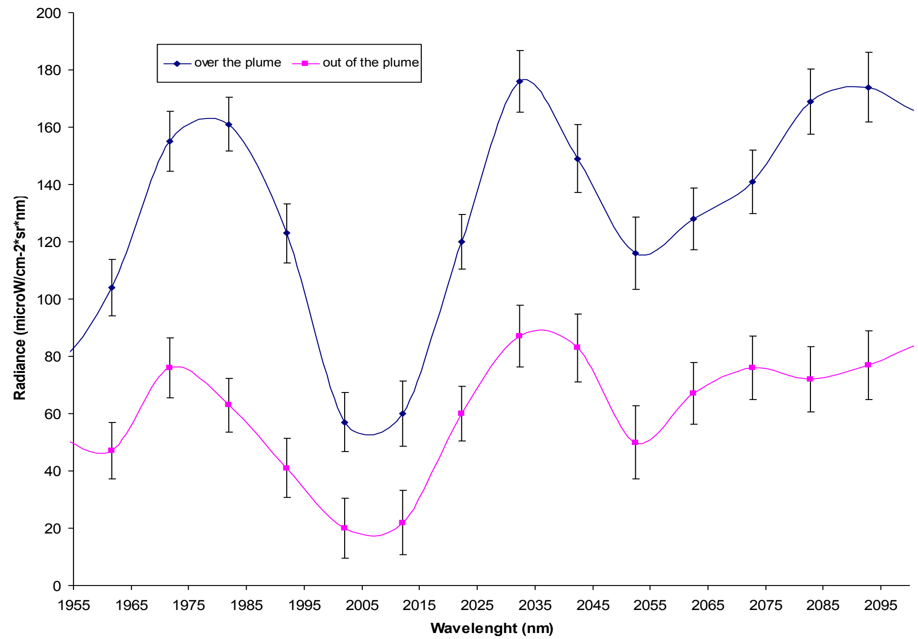
Mt. Etna N-E crater picture

Signal Sensitivity Analysis

Sensitivity function

$$F = \frac{|(R_{Plume} - R_{Atm})|_{ch174}|}{|(R_{Plume} - R_{Atm})|_{ch172} + (R_{Plume} - R_{Atm})|_{ch176}|}$$





F(min) ≥ NeΔR

Hyperion data have a very limited sensitivity compared to Aviris

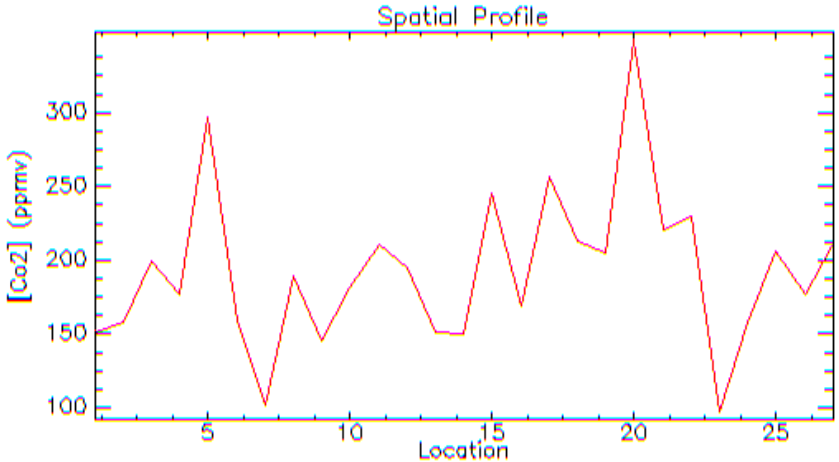
Signal to Noise Ratio

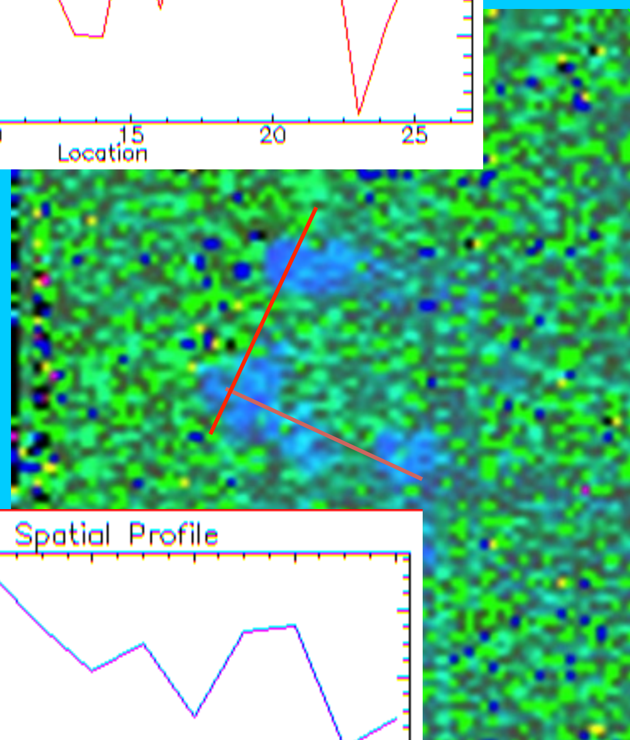
Gao and Homogeneus area methods

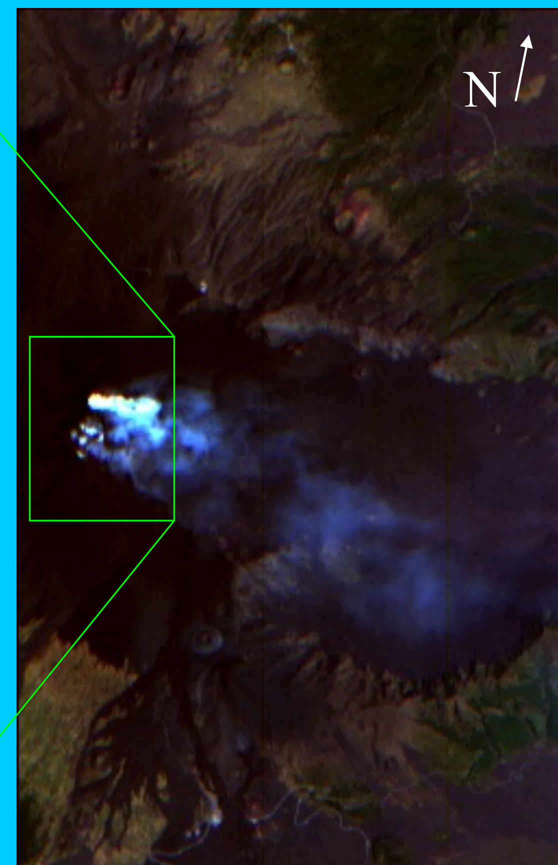
Data	Water vapour absorption bands	Carbon dioxide absorption bands
AVIRIS 2000	940nm SNR>>10	2.005 μm SNR>>10
Hyperion 2001	1.125μm SNR>10	2.005 μm SNR≥10
Hyperion 2003	1.125μm SNR>10	2.005 μm SNR≈10

Mt. Etna CO_2 plume

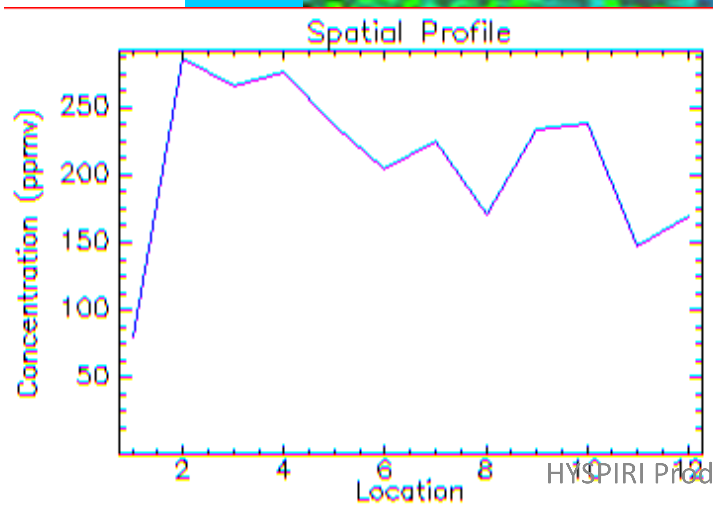
For the end of August 2001 the CO2 map detecting two of the degassing crater after an intense period of eruption. After 2 month another intense eruptive activity started at Mt. Etna 2002-2003 eruption.



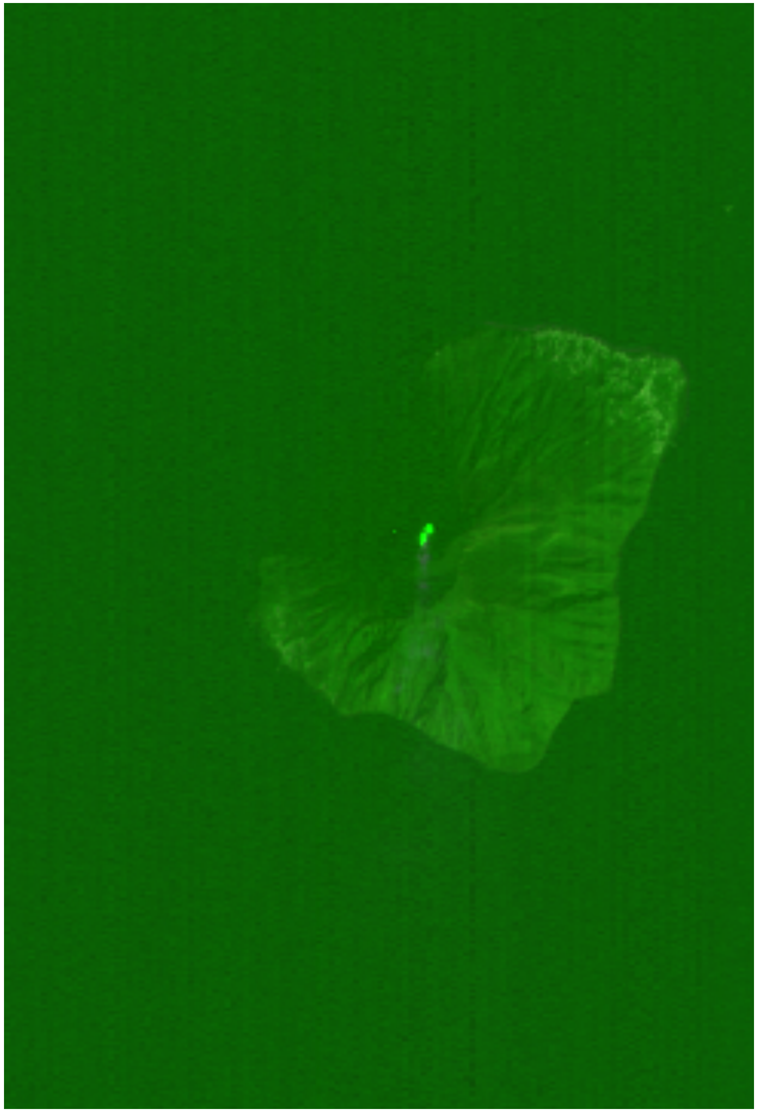


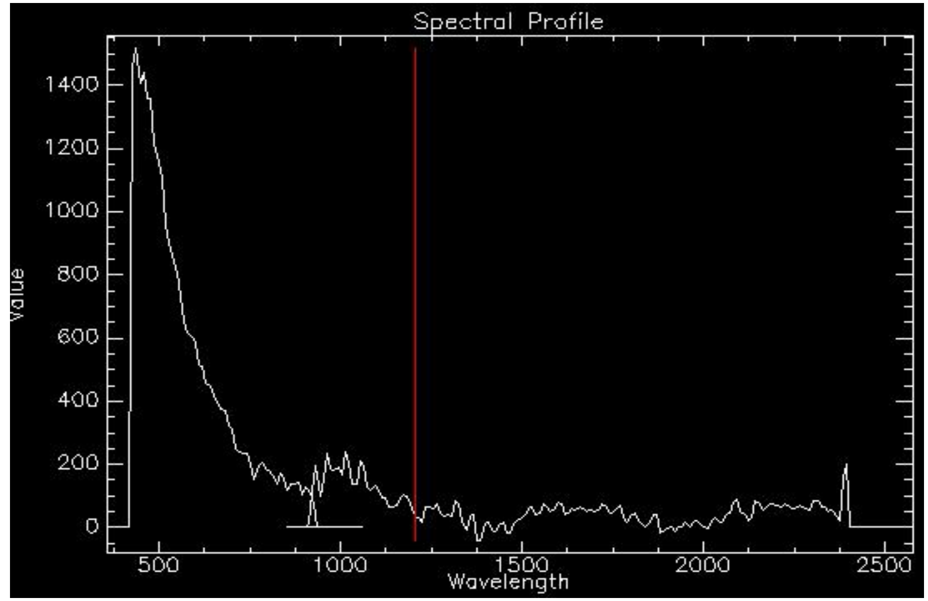


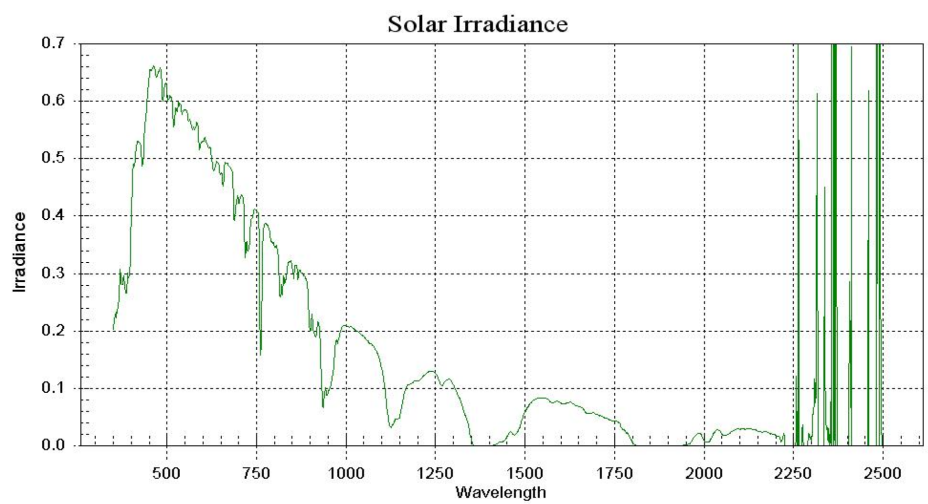
Hyperion 30-8-2001



Volcanic plume CO2 test retrieval using EO-1 Hyperion data







F(min) >> NeDR

The condition is not satisfied for Hyperion data over Stromboli

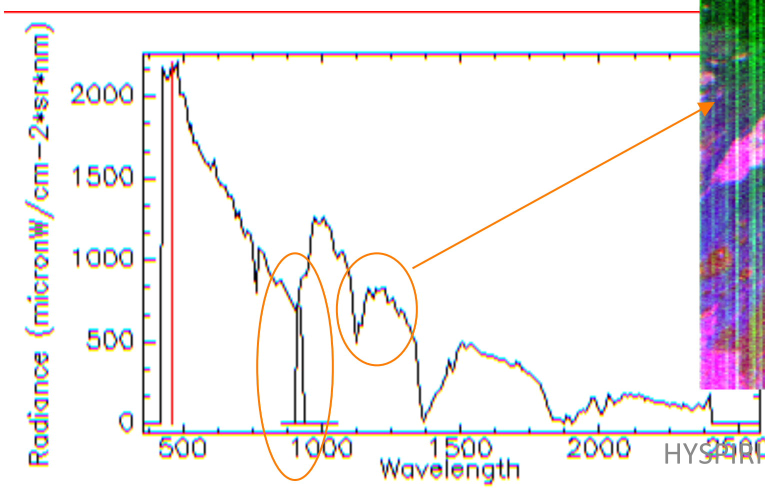
Hyperion data anlysis to retrieve H_2O e CO_2

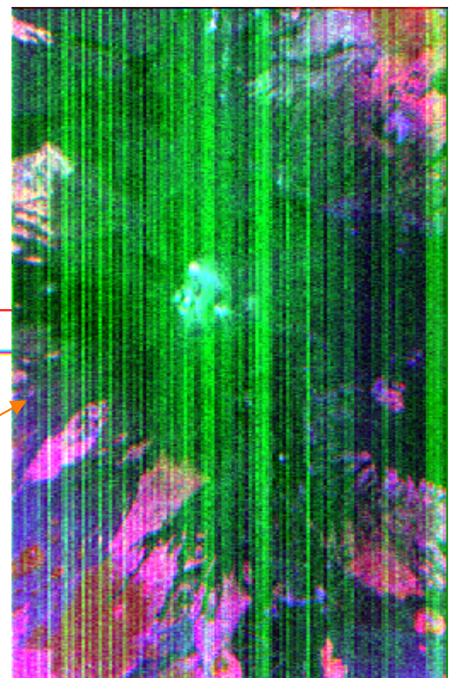
The absoprtion band at 940 nm is located in and overlap zone between two spectrometers which gives a lower sensitivity

A strong Striping is visible when the albedo <5% and atmospheric transmittance <10%

We observed on calibrated data pixels with radiances <0

Striping





Radiometric calibration

Conclusions

- PRISMA mission should ensure appropriate products for geophysical application starting from levl0-1 up to level 2-3 products
- To detect and estimate volcanic emitted CO_2 by means of hyperspectral imager is necessary high spectral resolution and high radiometric accuracy and calibration considering that volcanic areas have generally a very low albedo (as basalts)
- The developed algorithm needs an instrument capable to measure water vapor and aerosol content which make the hyperspectral imagers the best choice if they improve the radiometric accuracy and band location for water and CO_2.
- At the moment only AVIRIS has fulfilled the algorithms requirements to retrieve CO_2 concentration from volcanic plumes
- The test performed on HYPERION showed its limitation in terms of SNR and lack of usable 940 nm band for water content retrieval

Prisma And Hyspiri Mission Mutual Benefits

- PRISMA is composed by an hyperspectral imager VIS-SWIR range and a pancromatic camera for data fusion and pansharpening the ground resolution is 30 m and 5m (pancromatic) and swath is 30 km

- HYSPIRI i s composed by an hyperspectral camera VIS-SWIR and a MIR-TIR multispectral imager the ground resolution is 60 m and swath 145(VIS-SWIR)-600 km (MIR-TIR)

- it could be very desirable to have increase the cooperation between the two missions in terms of opportune orbital characteristics and instruments calibration

- for volcanic applications the HYSPIRI configuration would be the most desirable since both co2 and so2 could be retrieved. Moreover SWIR-TIR spectral region assure a more precise thermal analysis for lava flows, lava lake and fire


Thank
you
Istituto Nazionale di
Geofisica e Vulcanologia
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