HyspIRI Mission Study

CAL/VAL ACTIVITIES ON EUROPEAN VOLCANOES TEST SITES IN THE VNIR-SWIR SPECTRAL RANGE.

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Summary

- Topographic And Atmospheric Effects Removal Tool: Cirillo
- Test Sites Description and CAL/VAL activities on
  - Mt Etna
  - Pico de Teide
- PRISMA Mission and CAL/VaL test site

Introduction

- The accuracy of space measurements to monitor European active volcanoes (not only!) mainly depends on
  - The periodic validation of the data acquired by space
  - The effectiveness capability of atmospheric correction tool to remove Atmospheric and Topographic effects

TOPOGRAPHIC AND ATMOSPHERIC EFFECTS REMOVAL TOOL: CIRILLO

CIRILLO: basis

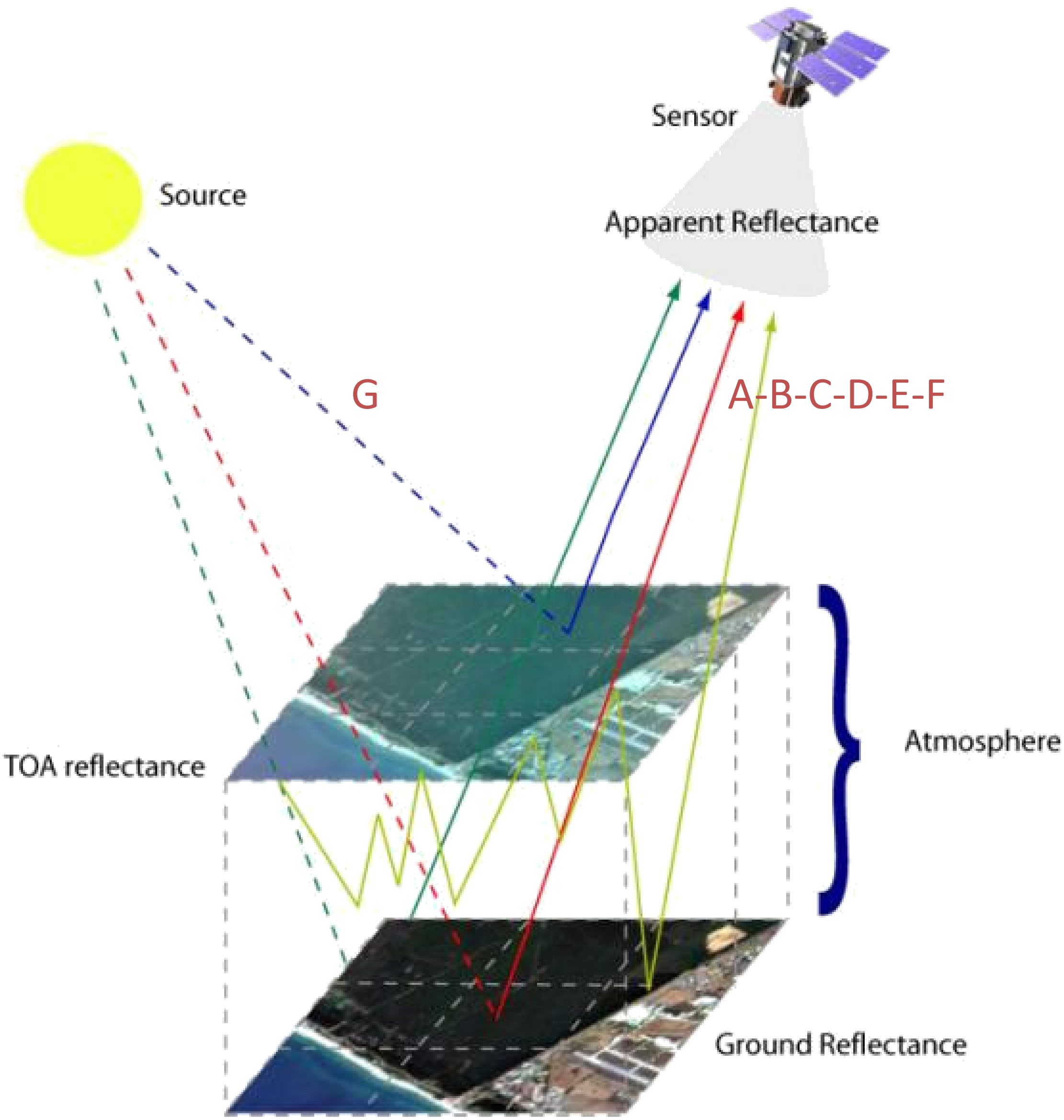
- CIRILLO is a procedure for the correction of spaceborne images acquired in the VIS-SWIR spectral range (0.40 μm 2.5 μm).

- The atmospheric terms needed by CIRILLO are computed by the well known radiative transfer models MODTRAN4.0 and 6S (adjacency effects).

CIRILLO: basis

- CIRILLO can produce the TOA ground reflectance that can be used as a first approximation of the actual ground reflectance. This option does not require any run of the radiative transfer models, hence the user has not to provide atmospheric data nor digital elevation models
- CIRILLO, starting from an at-the-sensor radiance image, produces a ground reflectance image corrected from atmospheric effects and from illumination changes due to tilted surfaces (**topographic effect**).
  - CIRILLO computes and corrects, starting from digital terrain models and solar position the illumination, changes due to relief.

Source-Target-Sensor schema



A. The sun radiance that reaches directly the pixel viewed by the sensor (target) and that is directly reflected by the target to the sensor;
B. The sun radiance that reaches directly the pixel viewed by the sensor (target) and that is reflected by the target to the sensor following a multiple scattering path;
C. The sun radiance that reaches the target following a multiple scattering path and that is directly reflected by the target to the sensor;
D. The sun radiance that reaches the target following a multiple scattering path and that is reflected by the target to the sensor following a multiple scattering path;
E. The sun radiance that directly reaches the surface surrounding the target and that is reflected by the surface to the sensor following a multiple scattering path;
F. The sun radiance that reaches the surface surrounding the target following a multiple scattering path and that is reflected by the surface to the sensor following a multiple scattering path;
G. The sun radiance that is directly scattered by the atmosphere to the sensor without reaching the ground.

All of these terms, with the exception of **G**), are also influenced by the orientation of the surface with respect to the sun illumination direction.

Radiative transfer model

$$\rho^* = Tg\left\{\rho_a + \frac{\rho}{1-\langle\rho_e\rangle s}\left[\beta\cdot\exp\left(-\frac{\tau}{\cos\theta_s}-\frac{\tau}{\cos\theta_v}\right)+t_{ds}\cdot\exp\left(-\frac{\tau}{\cos\theta_v}\right)\right] + \frac{\langle\rho_e\rangle}{1-\langle\rho_e\rangle s}\left[\exp\left(-\frac{\tau}{\cos\theta_s}\right)t_{dv}+t_{ds}\cdot t_{dv}\right]\right\}$$

$$\rho^* = (\pi\cdot L_m)/(E_s\cdot\cos\theta_s)$$

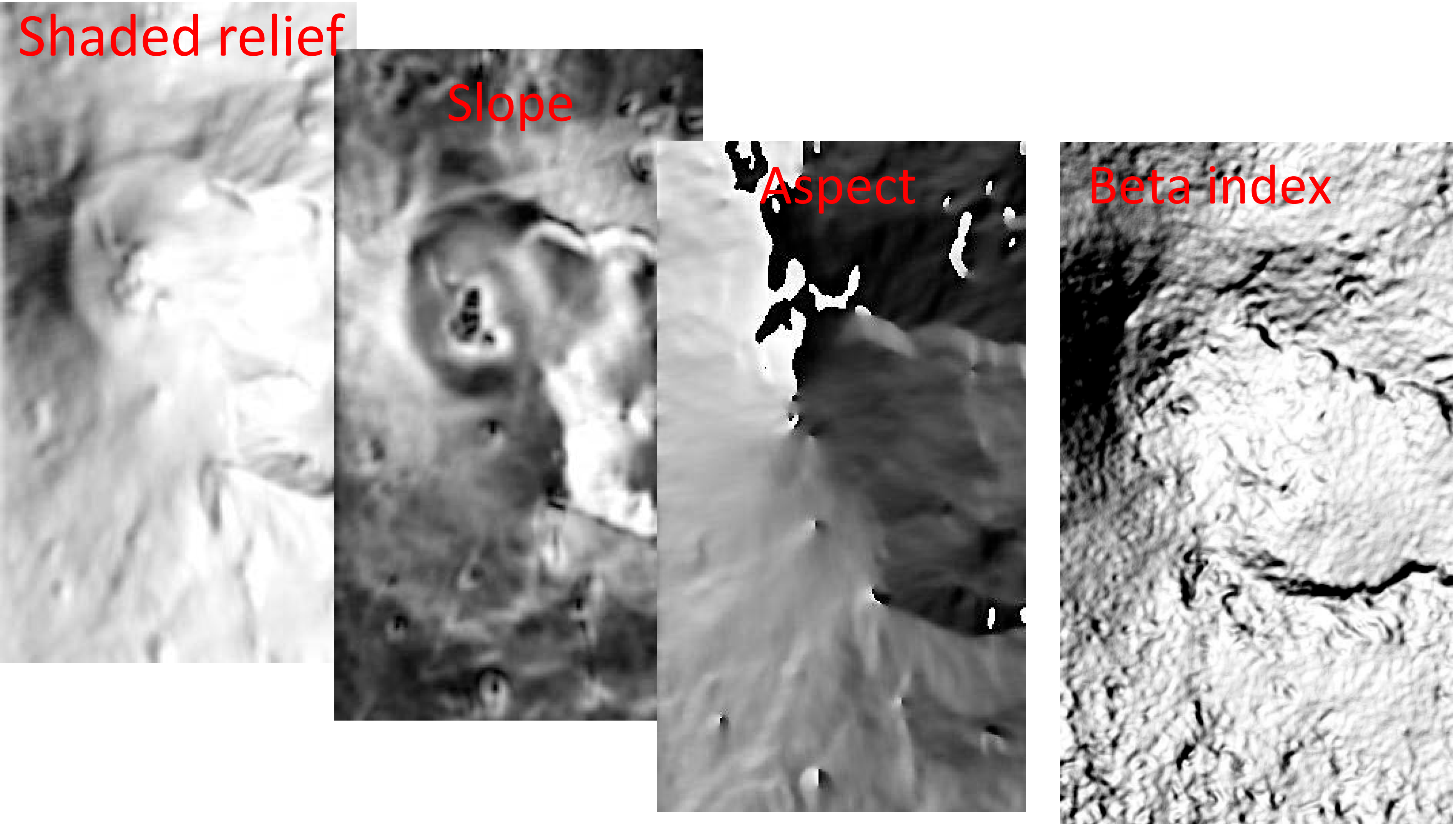
$$\beta = \cos\theta_n + \tan\theta_s \sin\theta_n \cos(\varphi_s - \varphi_n)$$

The slope is measured in degrees with the convention of 0 degrees for a horizontal plane.
The aspect angle is measured with the convention of 0 degrees to the north (up) and angles increasing clockwise.

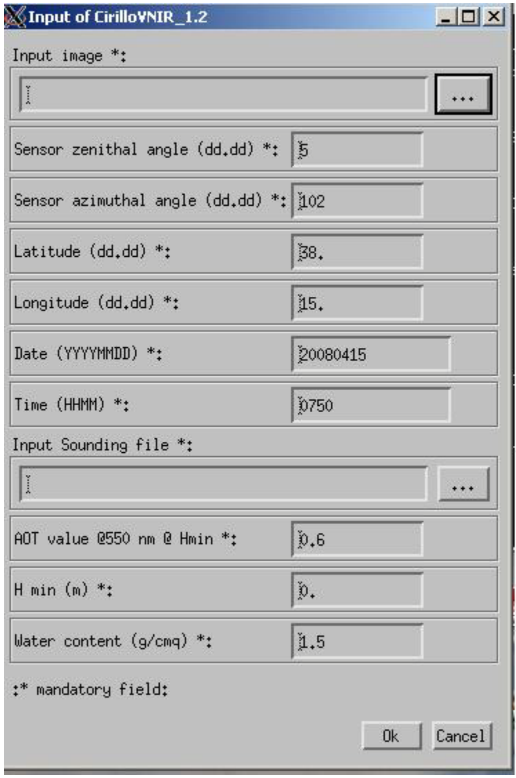
ρ * = (π·Lm)/(μs·Es): Top of Atmosphere reflectance);

ρ :	Corrected reflectance;
Lm :	Radiance measured by the sensor;
Es :	Esoatmospheric Solar flux;
θs , θv :	Solar zenith angle and view zenith angle;
ρa :	Atmospheric reflectance;
<ρe> :	Environmental reflectance;
Tg :	Atmospheric transmittance of the path sun-ground-sensor due to gas absorption;
τ :	Atmospherical Optical Thichkness;
S :	Downward spherical albedo of the atmosphere;
β :	Illumination factors for a tilted surface;
θn, ϕn :	Slope and the aspect angles of the target.

Improved topography modelling



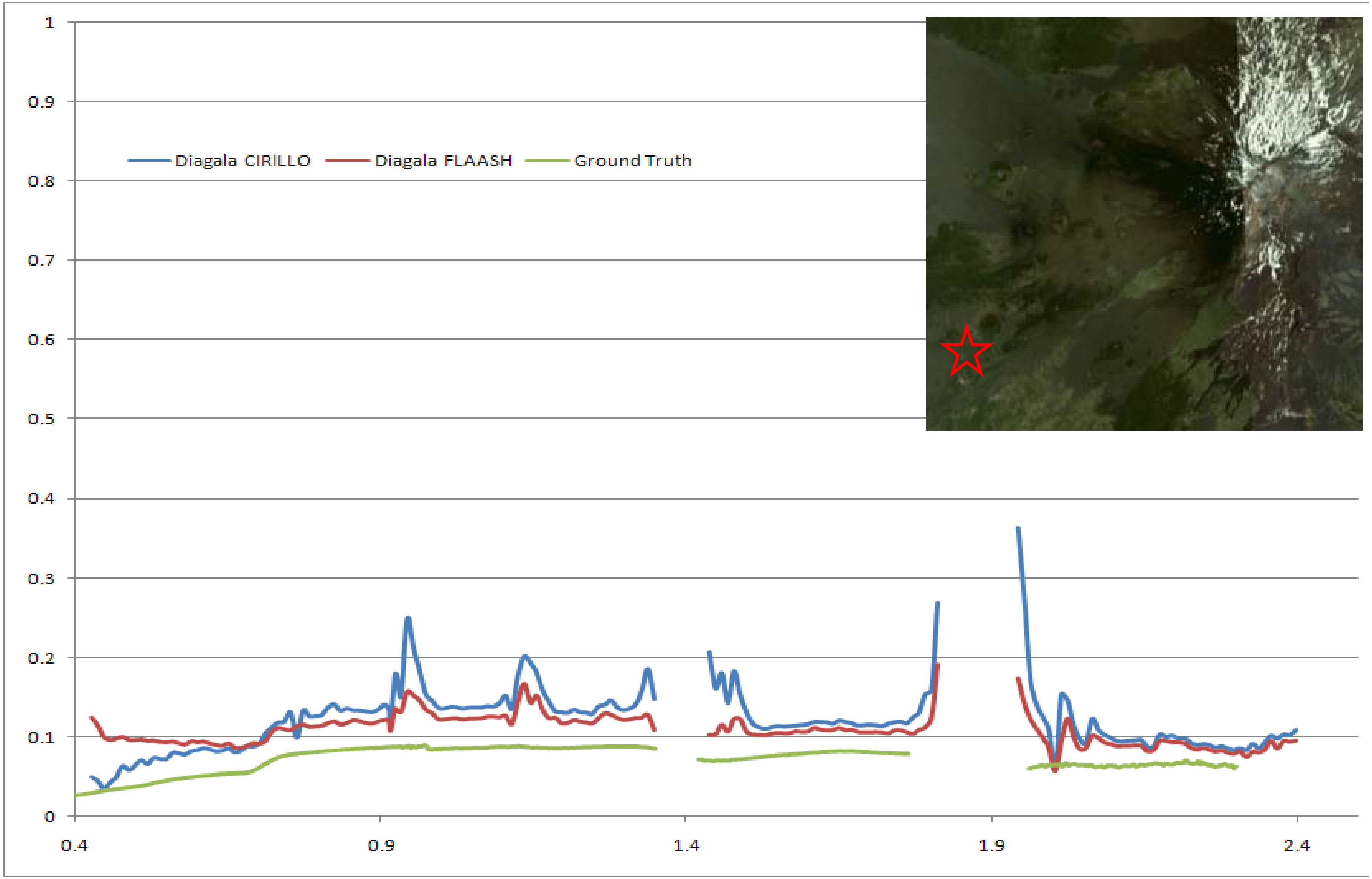
The atmospheric terms of Equation are extracted from each output run of MODTRAN4.0 and 6S in the electromagnetic range 400 nm to 2500 nm with a spectral step of 1 nm (6S has a spectral resolution of 2.5 nm, thus data are interpolated each nm) and convoluted with the response functions of the sensor to obtain in-band values



The environmental reflectance, that is the mean reflectance of the ground surrounding the pixel viewed by the sensor, is computed according the Richter method (Richter R., 1990, A fast atmospheric correction algorithm applied to Landsat TM images, Int. J. Remote Sensing, 11, pp. 159-166).

Example of Cirillo performance

Mt. Etna – Diagala del Diavolo



Example of Cirillo performance

MT. Etna:Belvedere

EUROPEAN VOLCANOES TEST SITES; CAL/VAL ACTIVITIES

Mt Etna CAL/VAL Site

Mt Etna

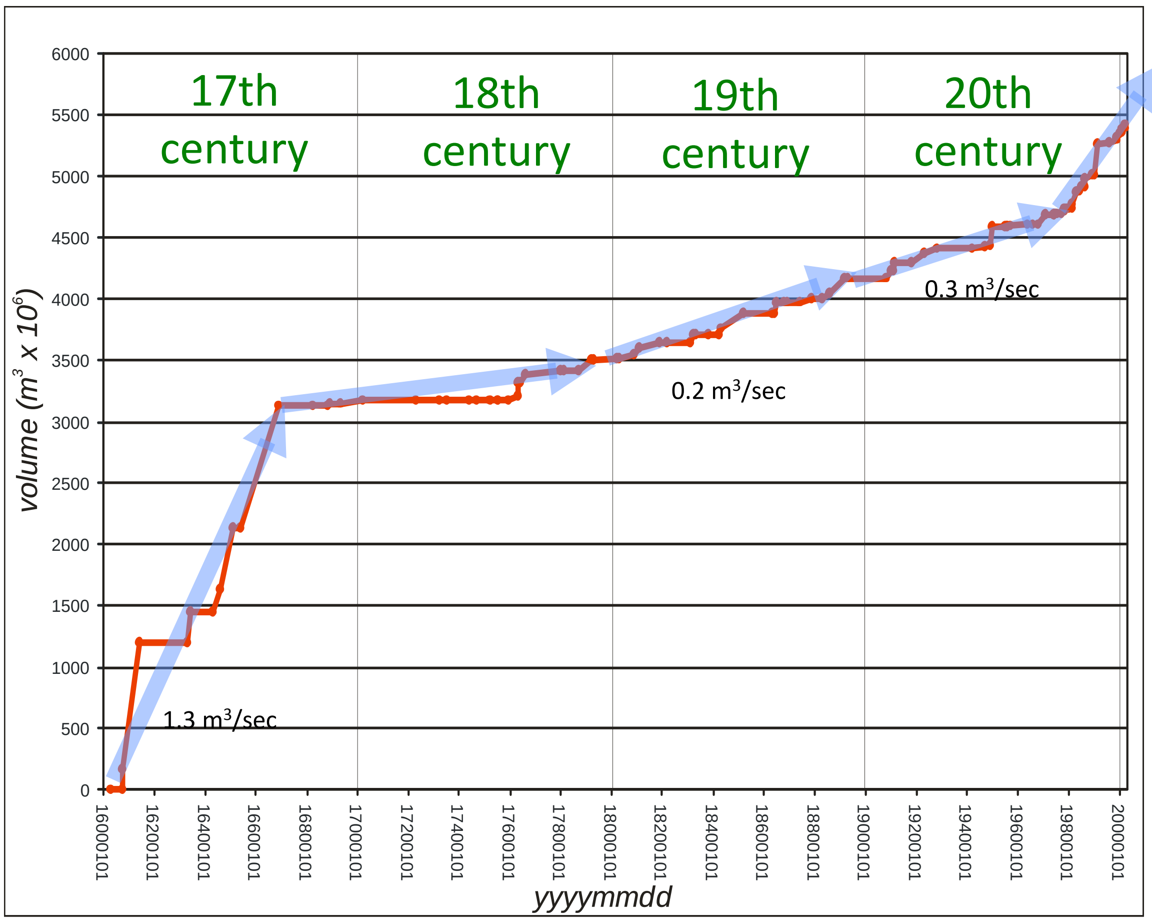
Etna summit area: Piano delle Concazze. This test site is covered by a homogeneous tephra (pyroclastic material from Central Crater, bombs, sansd, lapilli and ashs,) deposits characterized by a flat geometry with an area of approximately 12000 mq. The petrology of the outcropping rocks is quite constant: Hawaiiti/trachybasalt made of plagioclase (predominant) clinopyroxene, olivine. Rare brown amphibole

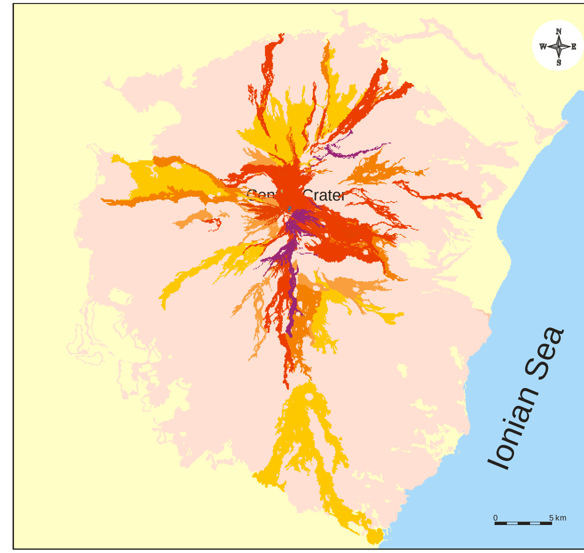
Reflectance and emissivity spectra have been measured with portable spectro-radiometers and FTIR instruments, temperature measurements have been acquired by using radiometers and thermal cameras. This test site shows a very low reflectance values (0.05) which provides information on the sensor performances on low albedo surfaces. The validation approach starts by removing atmospheric and topographic effects on the L1R Hyperion images and then compare the spectral response with the in situ data to evaluate the stability of the sensor radiometry versus time.

Volcanic activity

volume vs time

21st Century





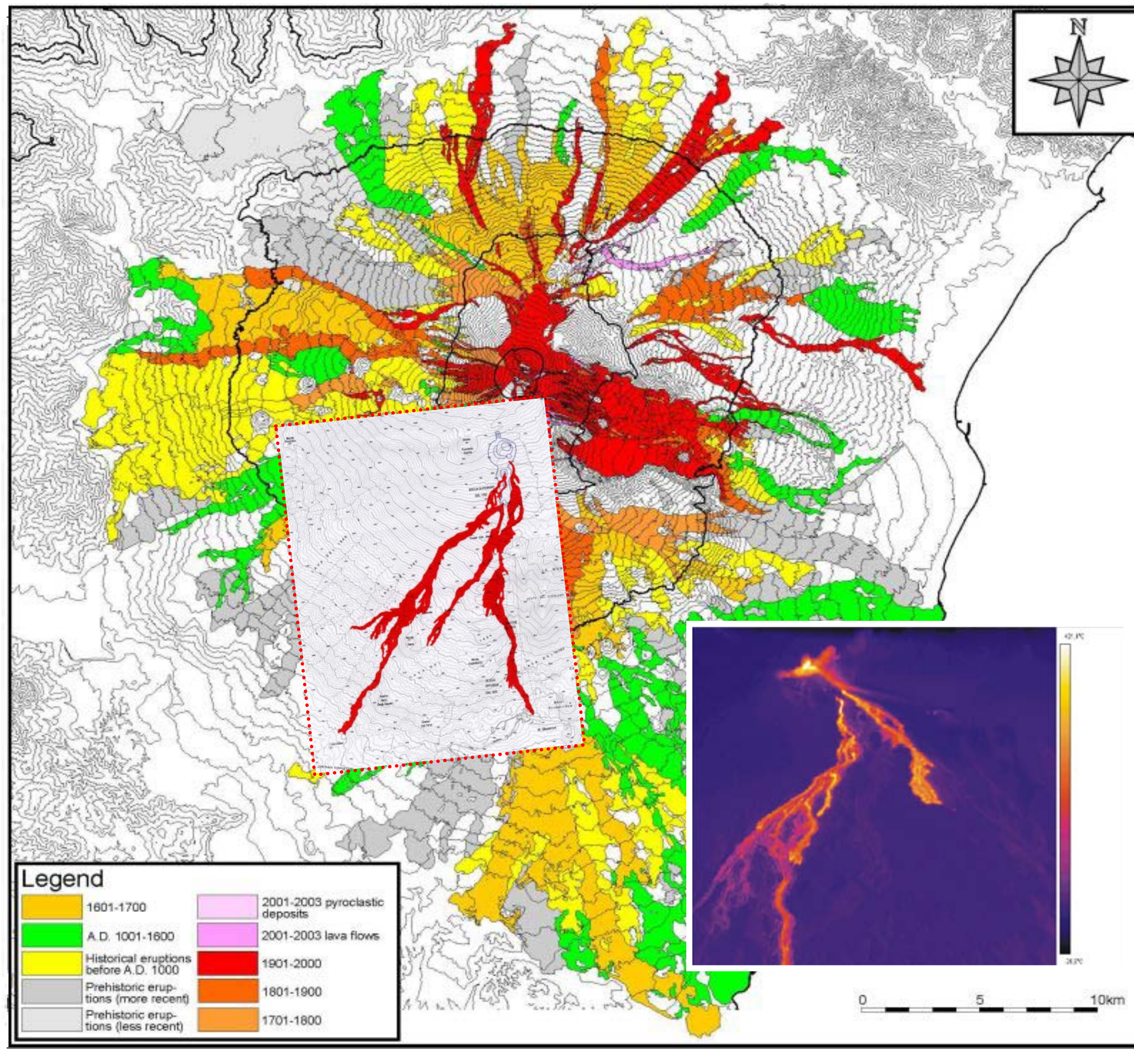
The volume of erupted products was very high during the 17th century, followed by a period of low activity lasted about 100 years.

Etna increased his effusive rate progressively between 18th and 19th centuries, culminating since 1950 in an significant increase of the volume of erupted products.

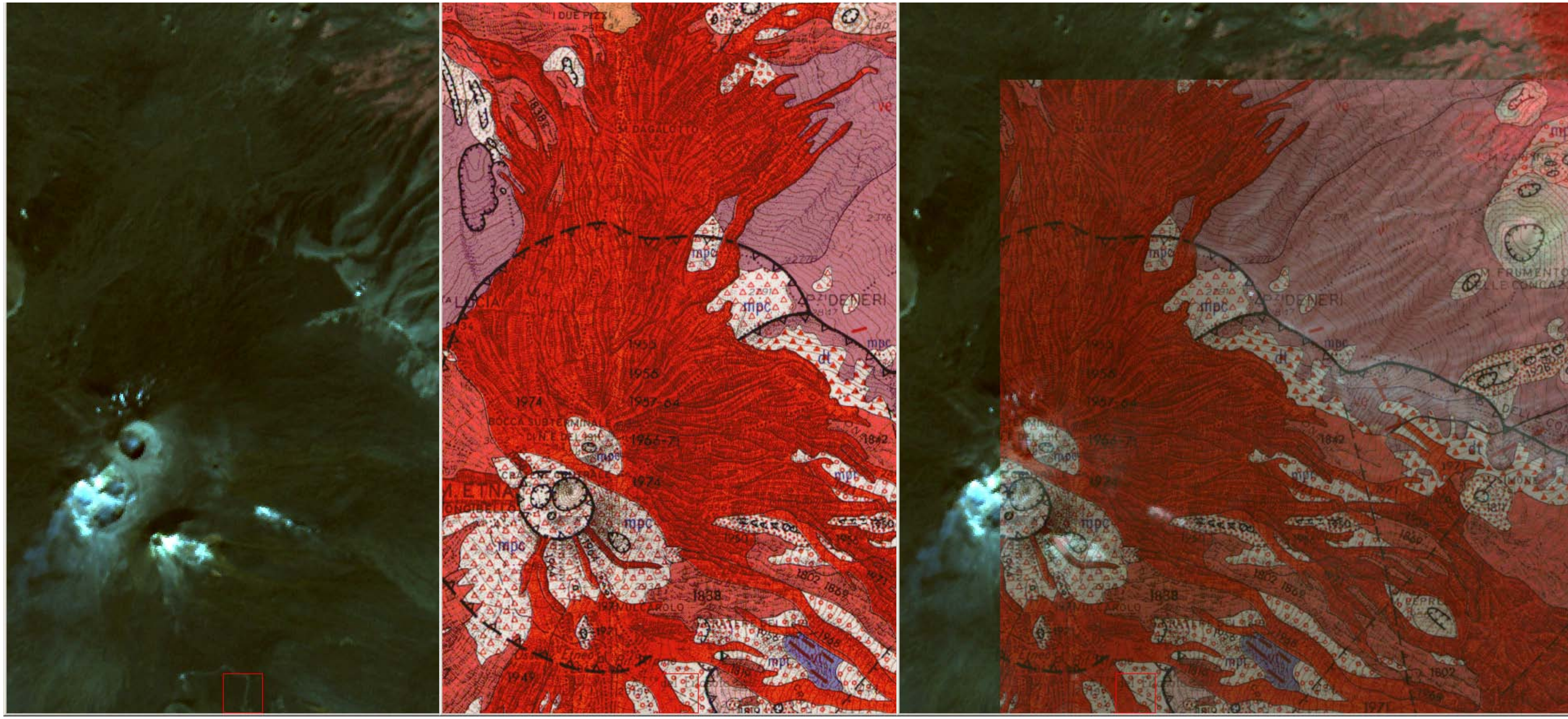
Mt. ETNA Test site: Ground data

- Discontinuous measurements
- Webcam network
- UV-scanner network for SO2 flux
- Seismic network
- GPS permanent network
- Gravimetric network
- Magnetic network

- Analysis of the erupted ash
- Analysis of the erupted products
- Geologic and structural surveys
- Thermal mapping from helicopter
- Thermal mapping from field



Mt Etna Field campaign: preliminary work

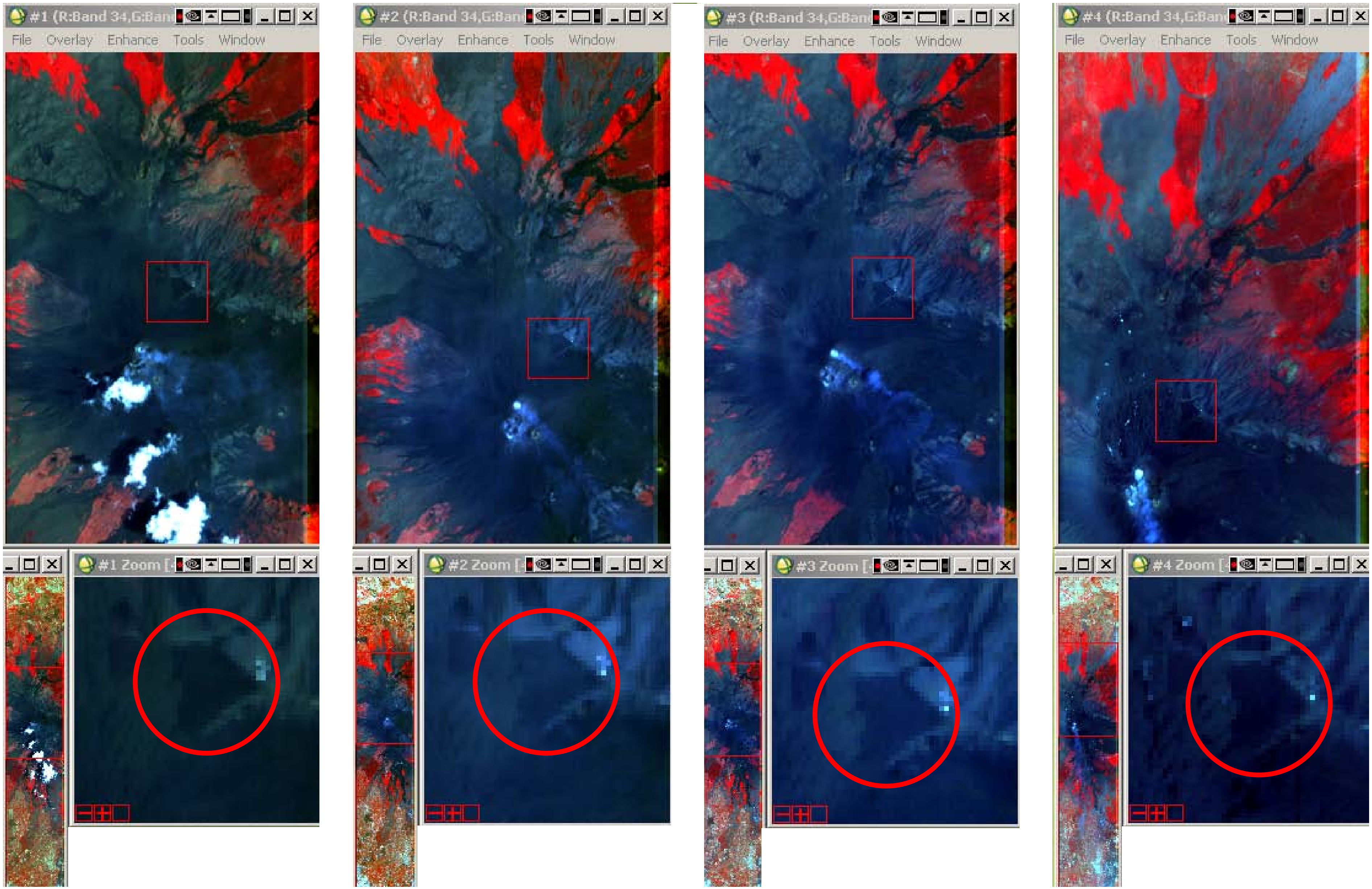


A preliminary identification of test sites was based on the following criteria:

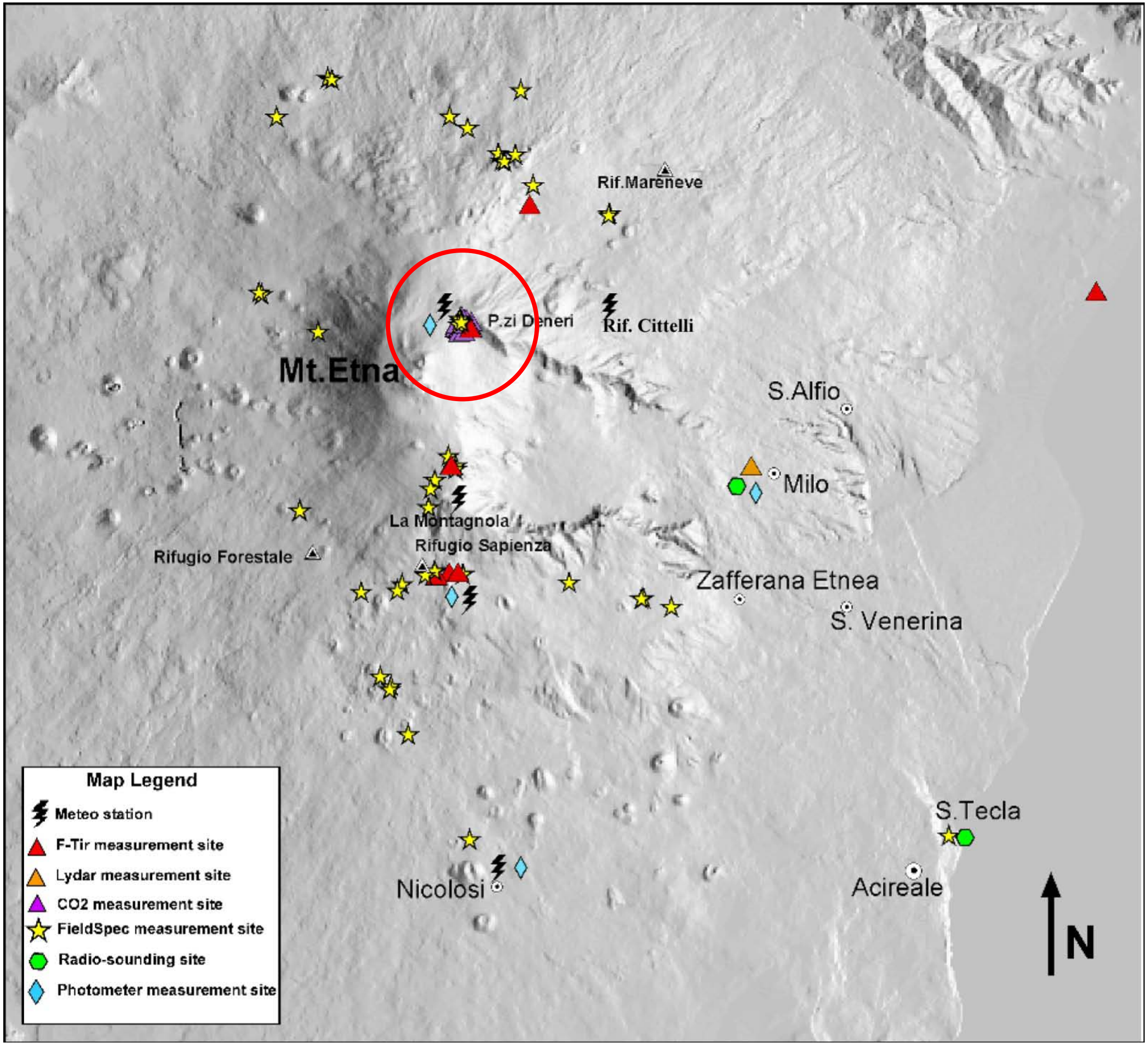
They had to be as high as possible, wide, plane and open areas of homogenous surface material.

The have to be easy to reach on the field and easy to recognize and locate on the image.

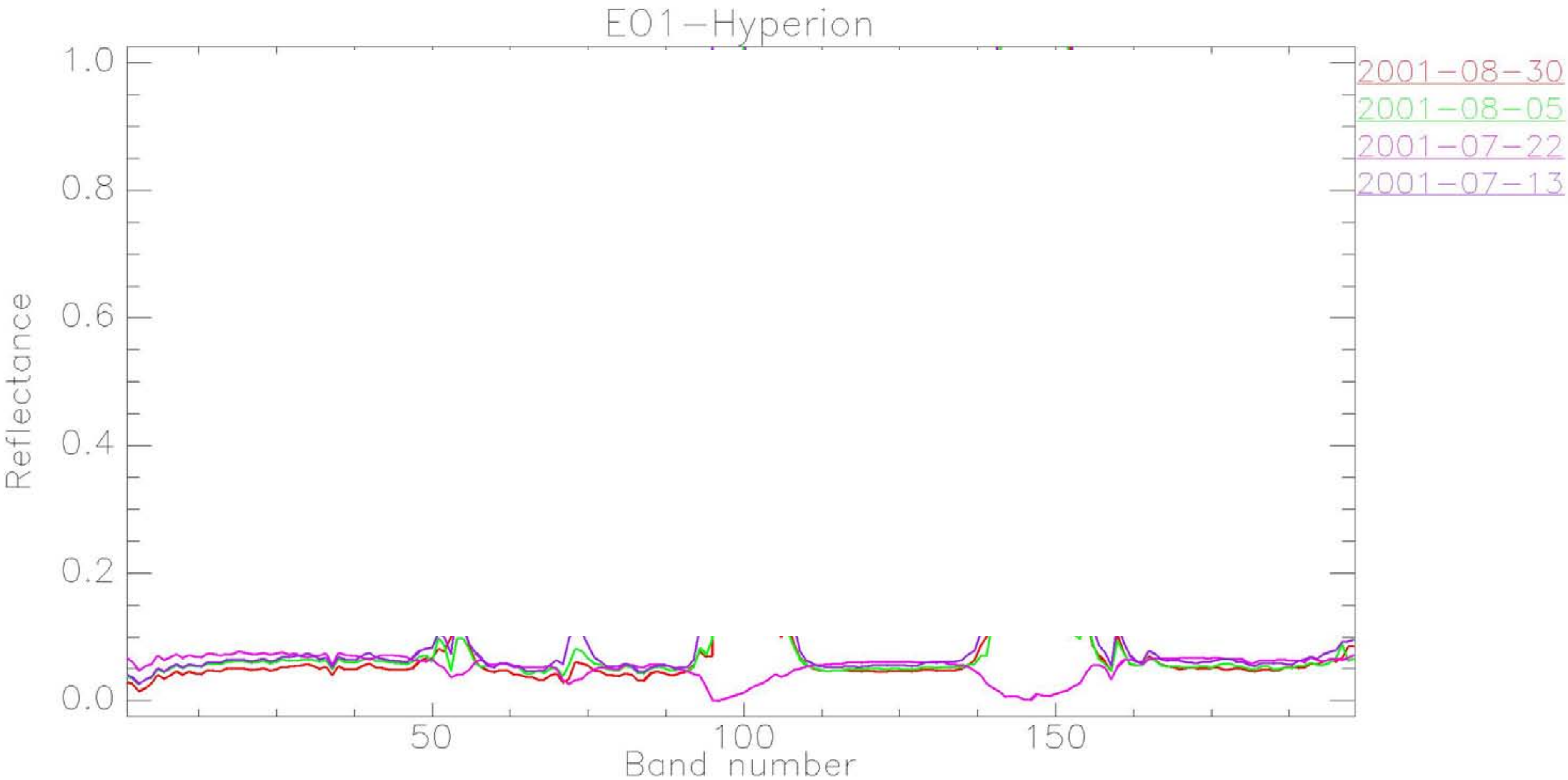
Piano delle Concazze



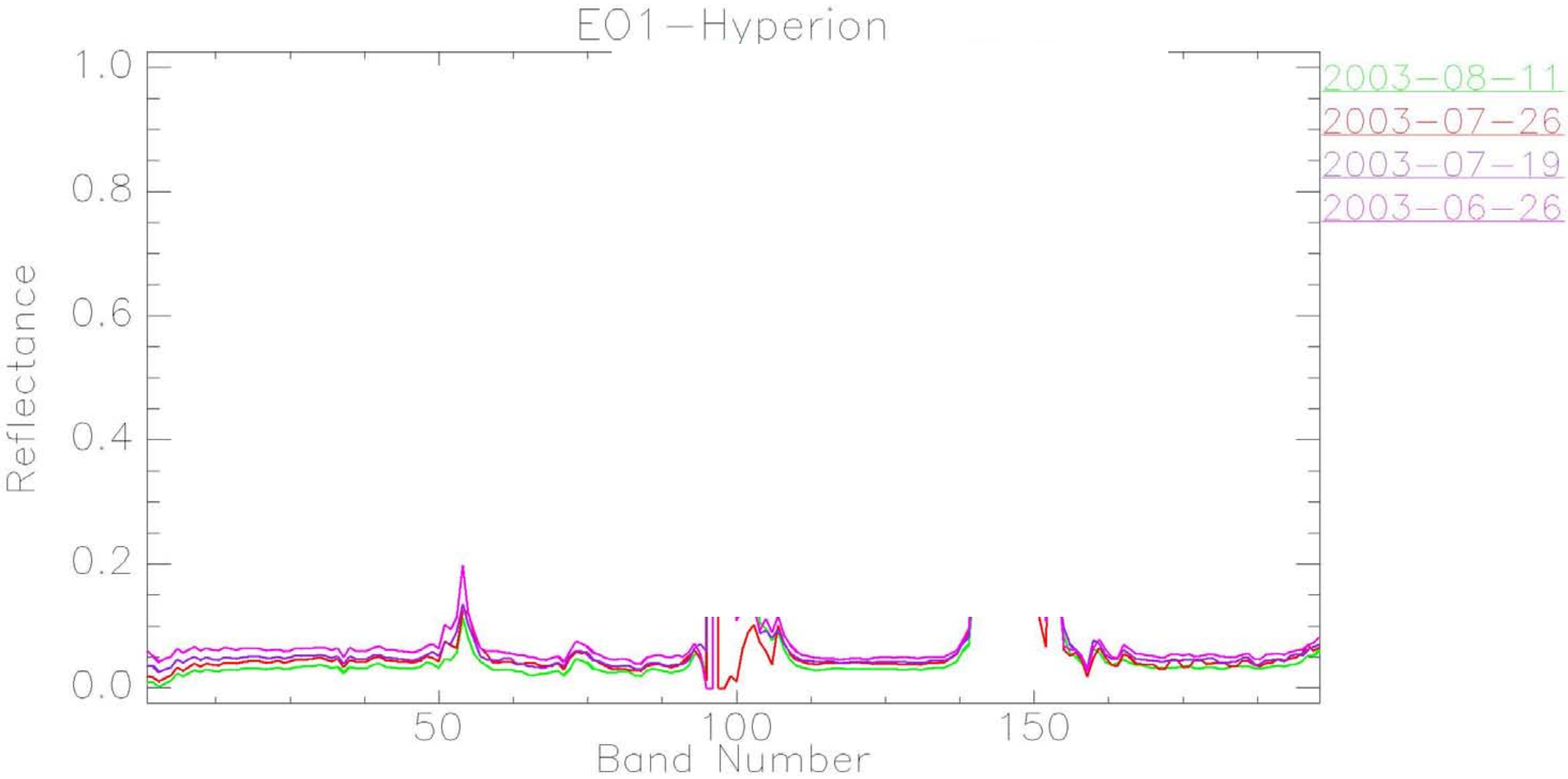
Mt. Etna – 2001-2009 sampled sites



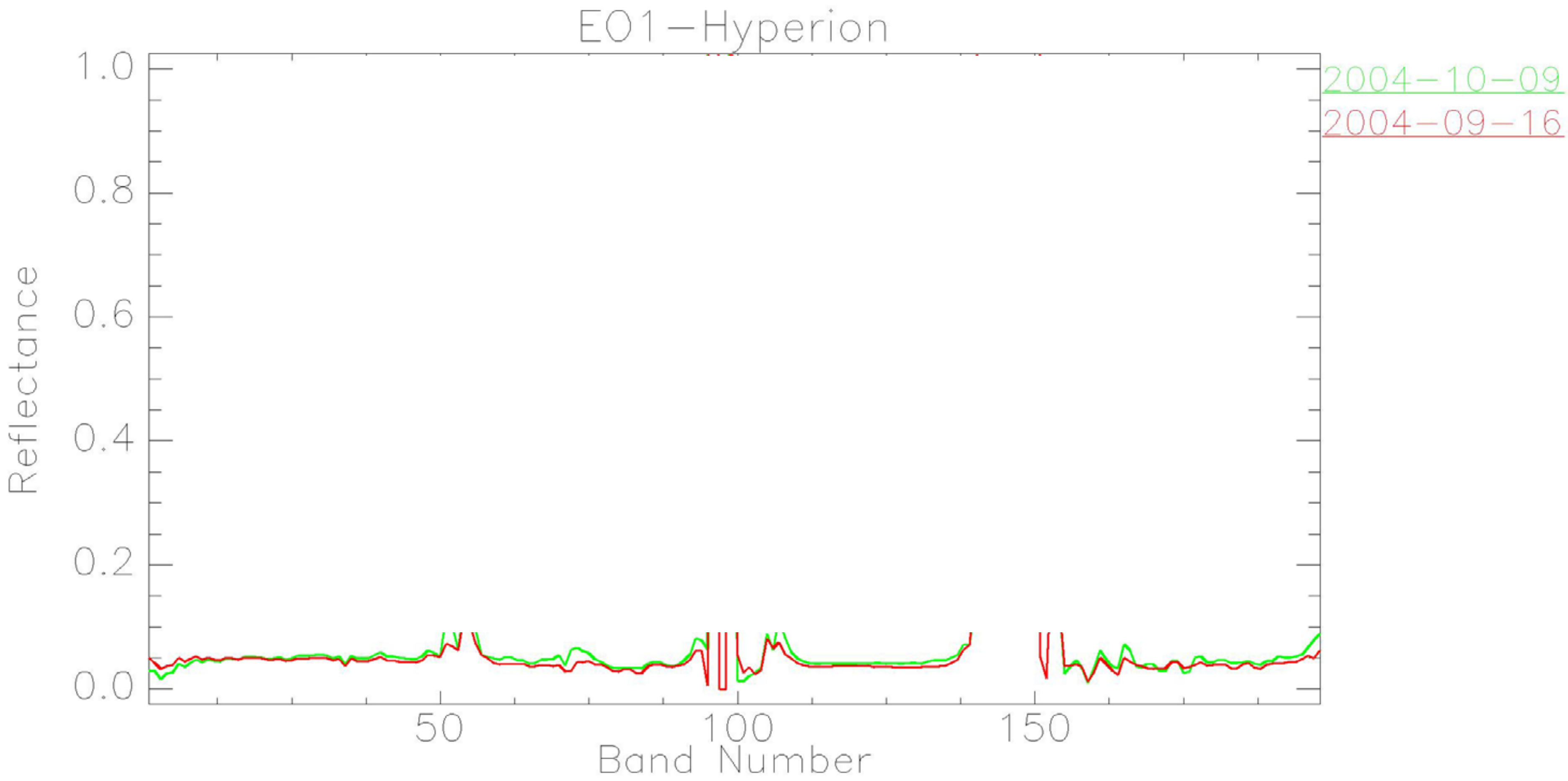
Mt. Etna – Piano delle Concazze 2001



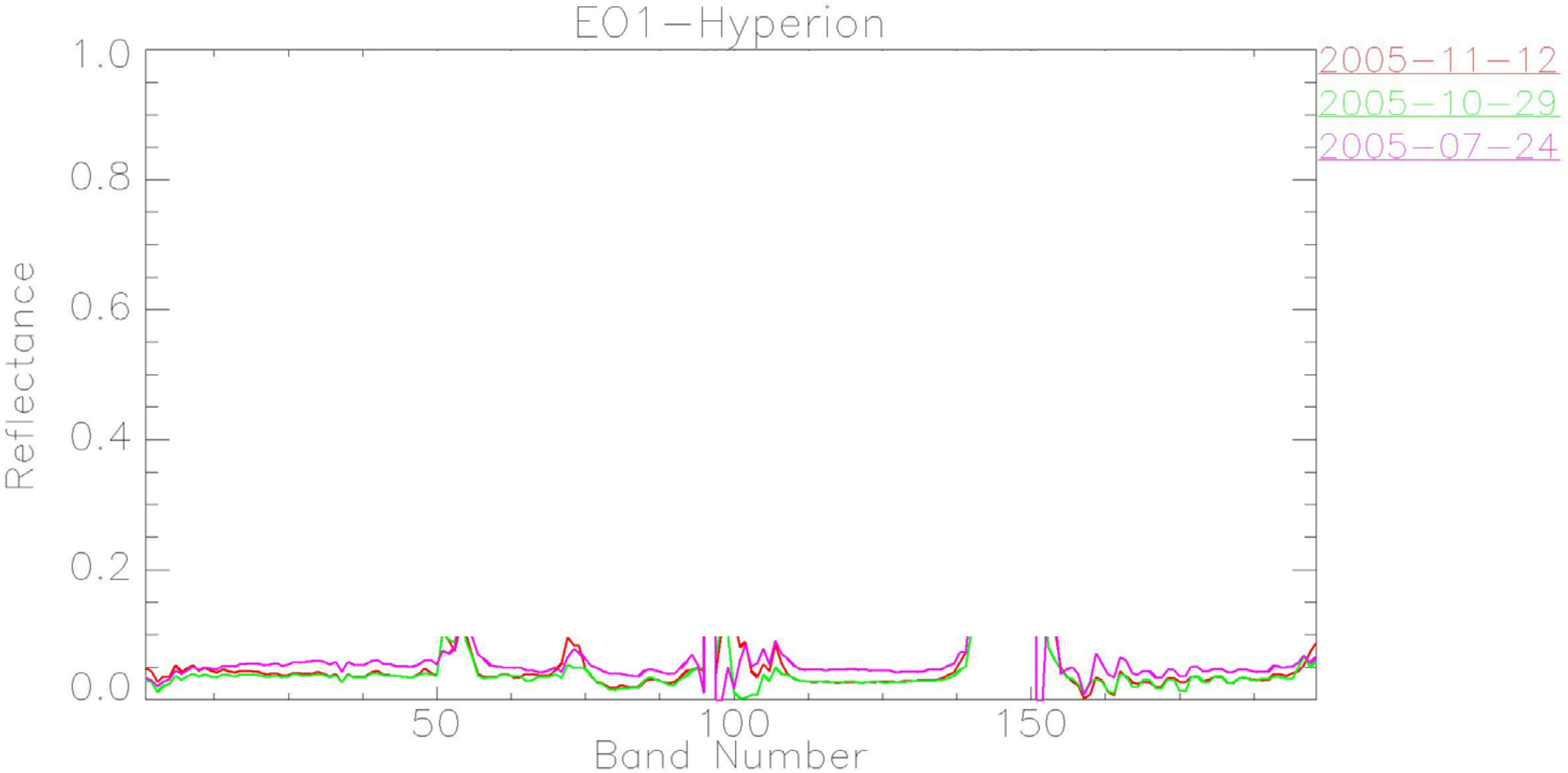
Mt. Etna – Piano delle Concazze 2003



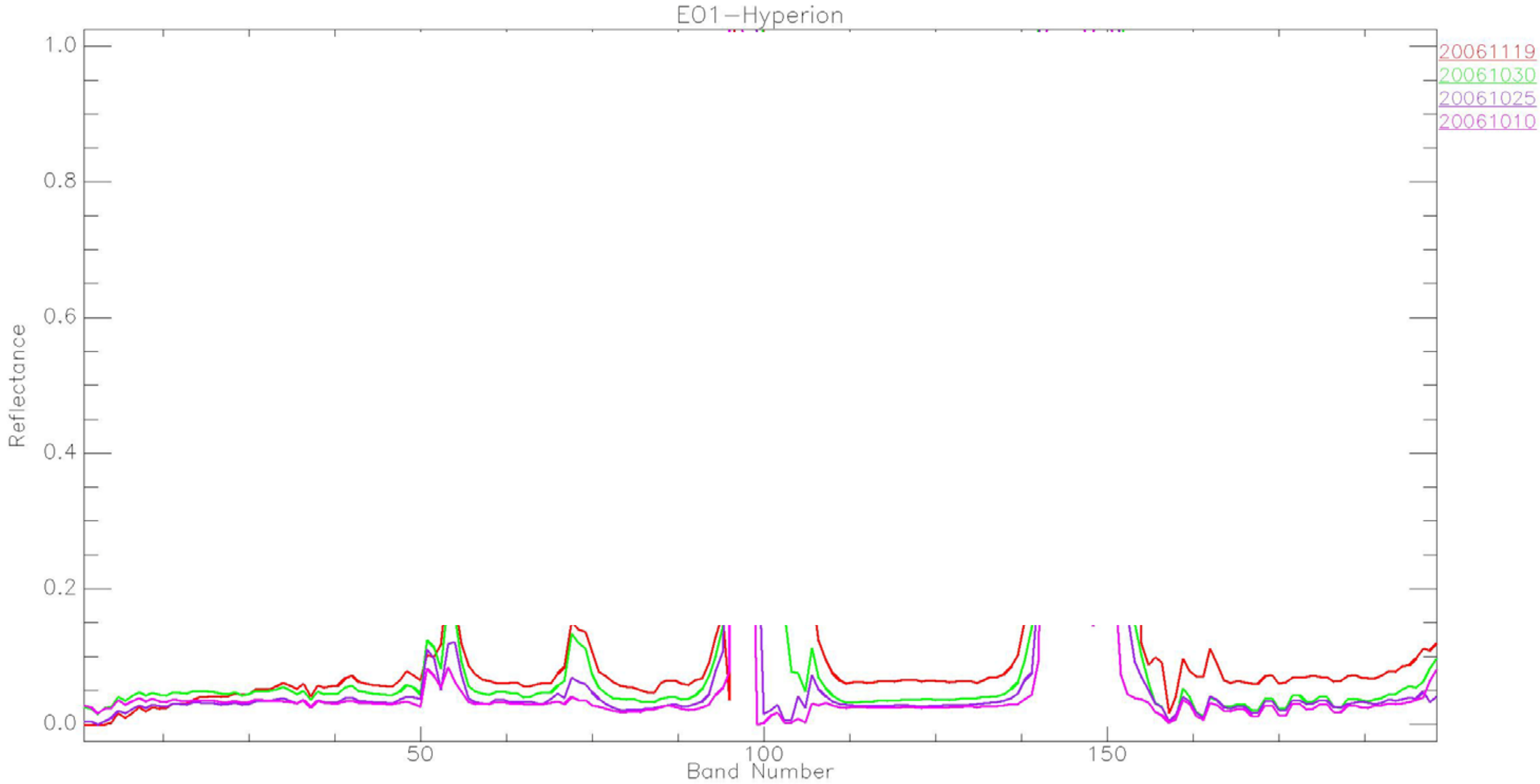
Mt. Etna – Piano delle Concazze 2004



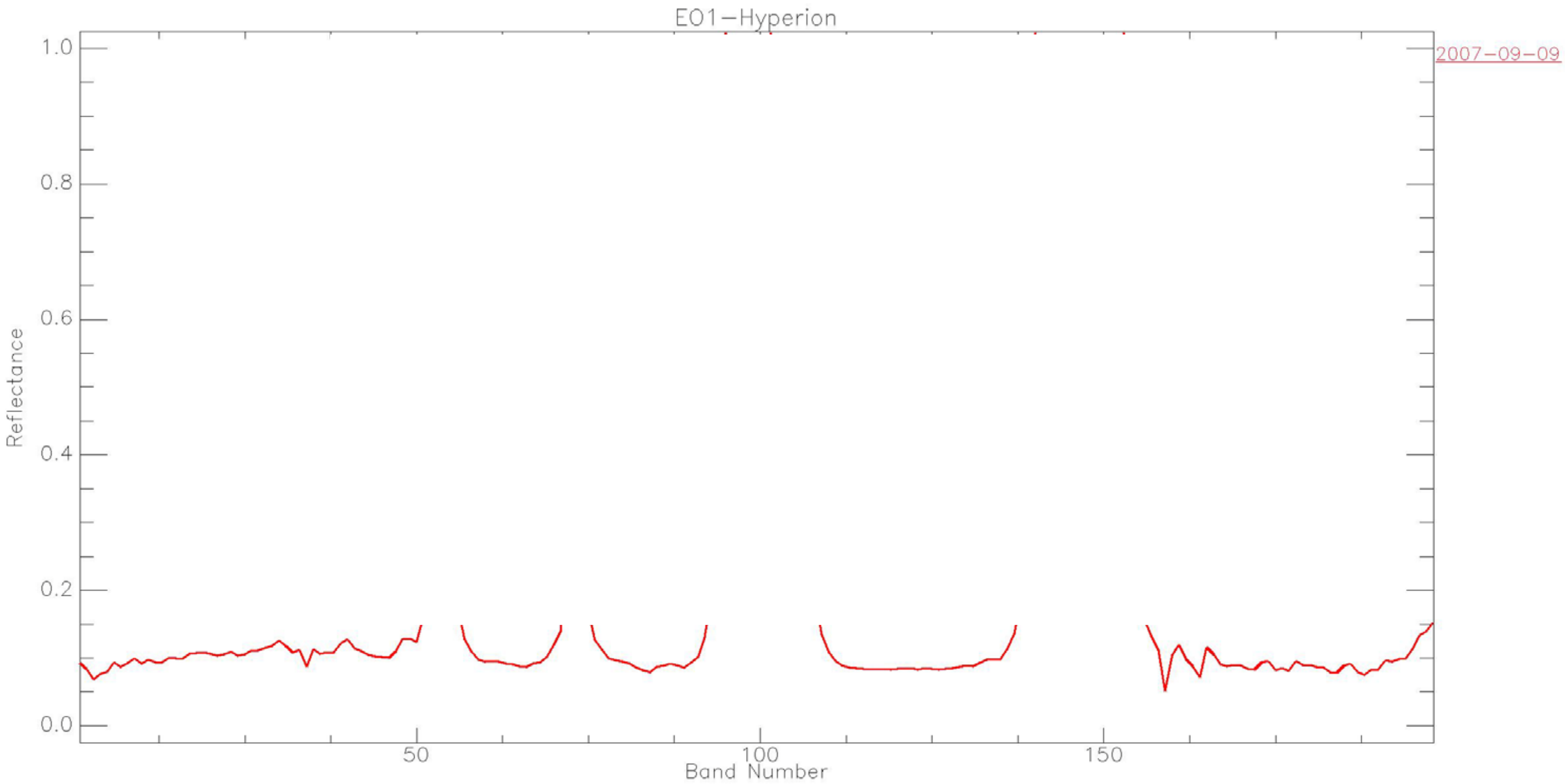
Mt. Etna – Piano delle Concazze 2005



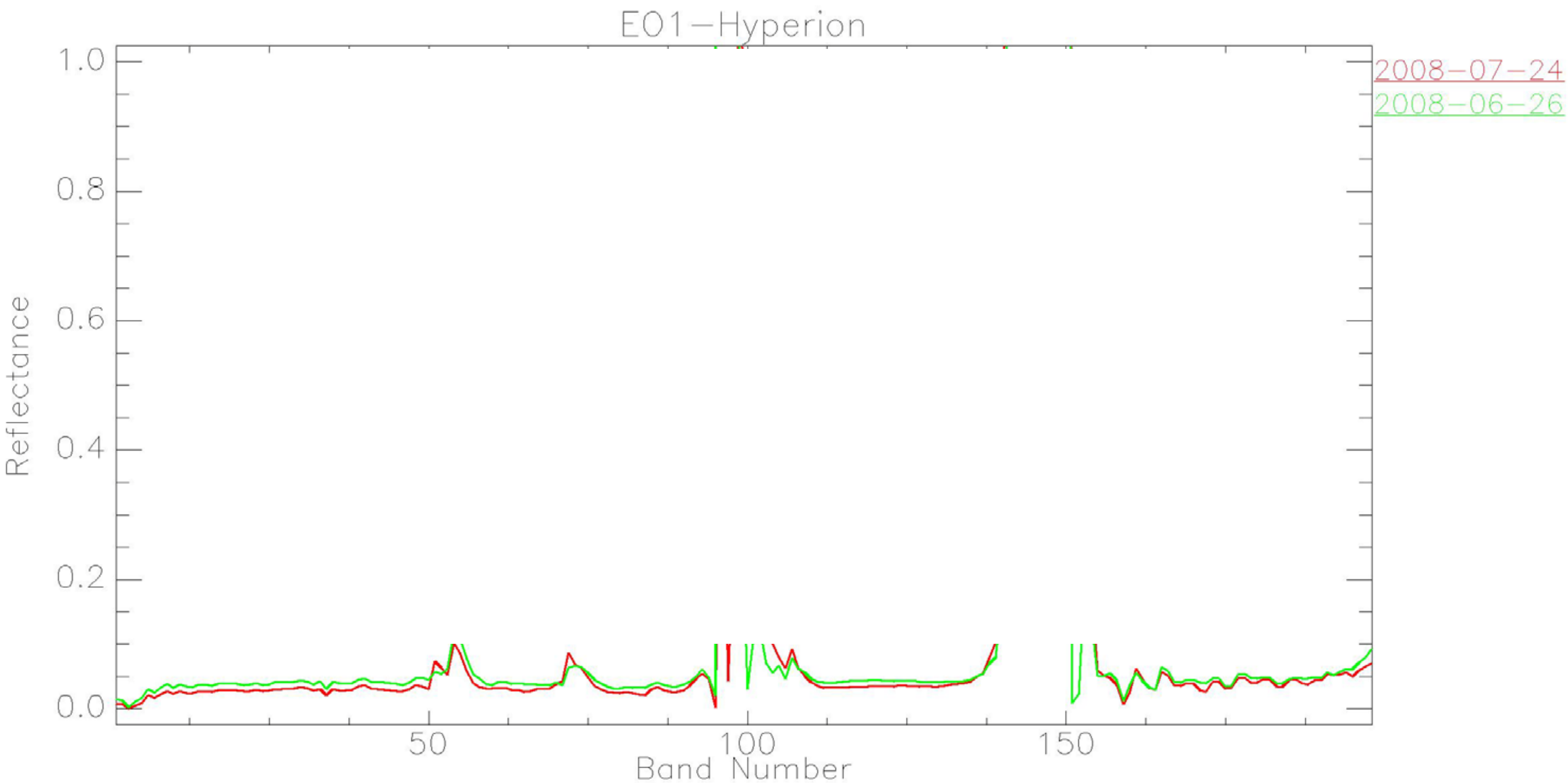
Mt. Etna – Piano delle Concazze 2006



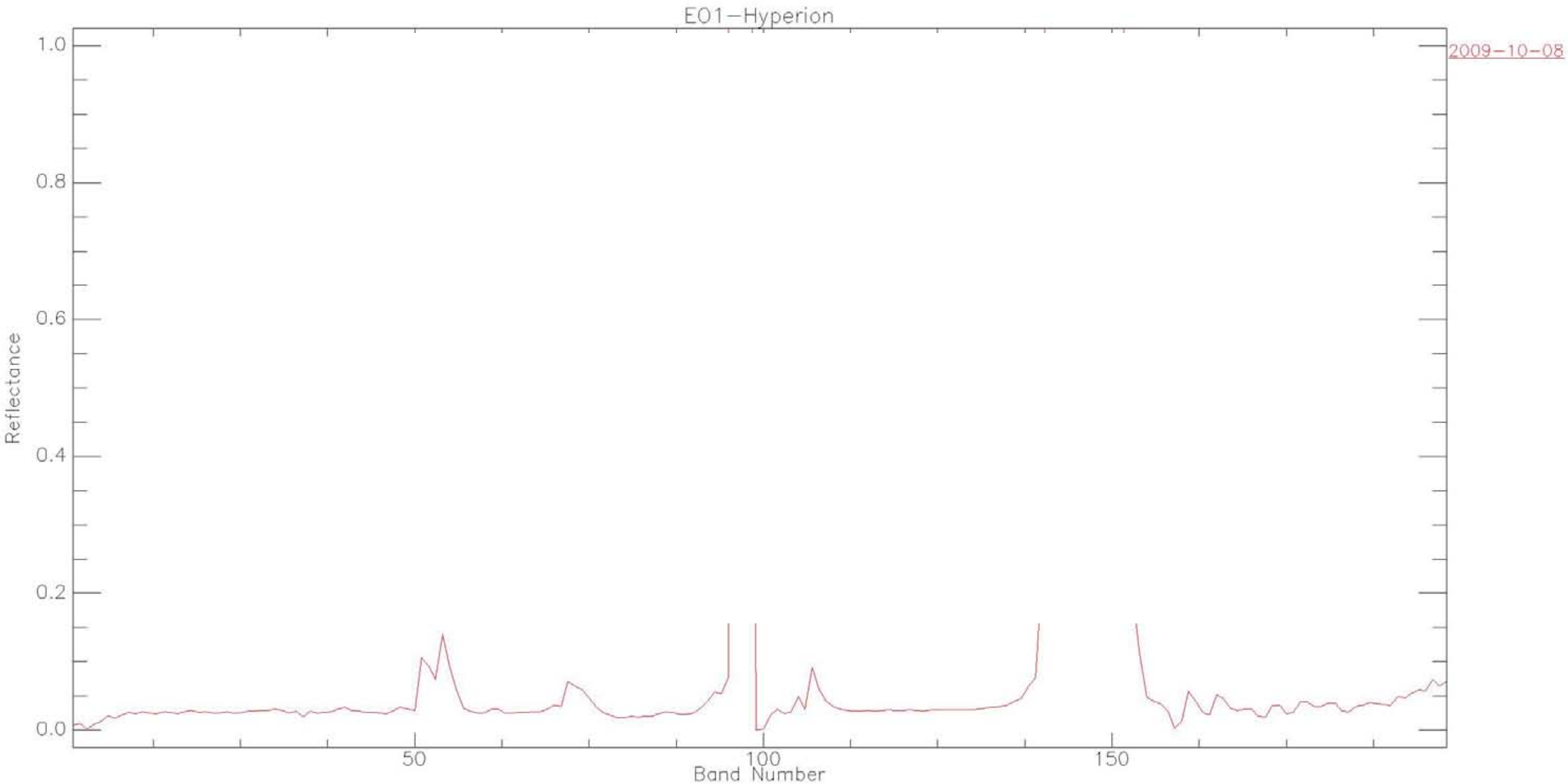
Mt. Etna – Piano delle Concazze 2007



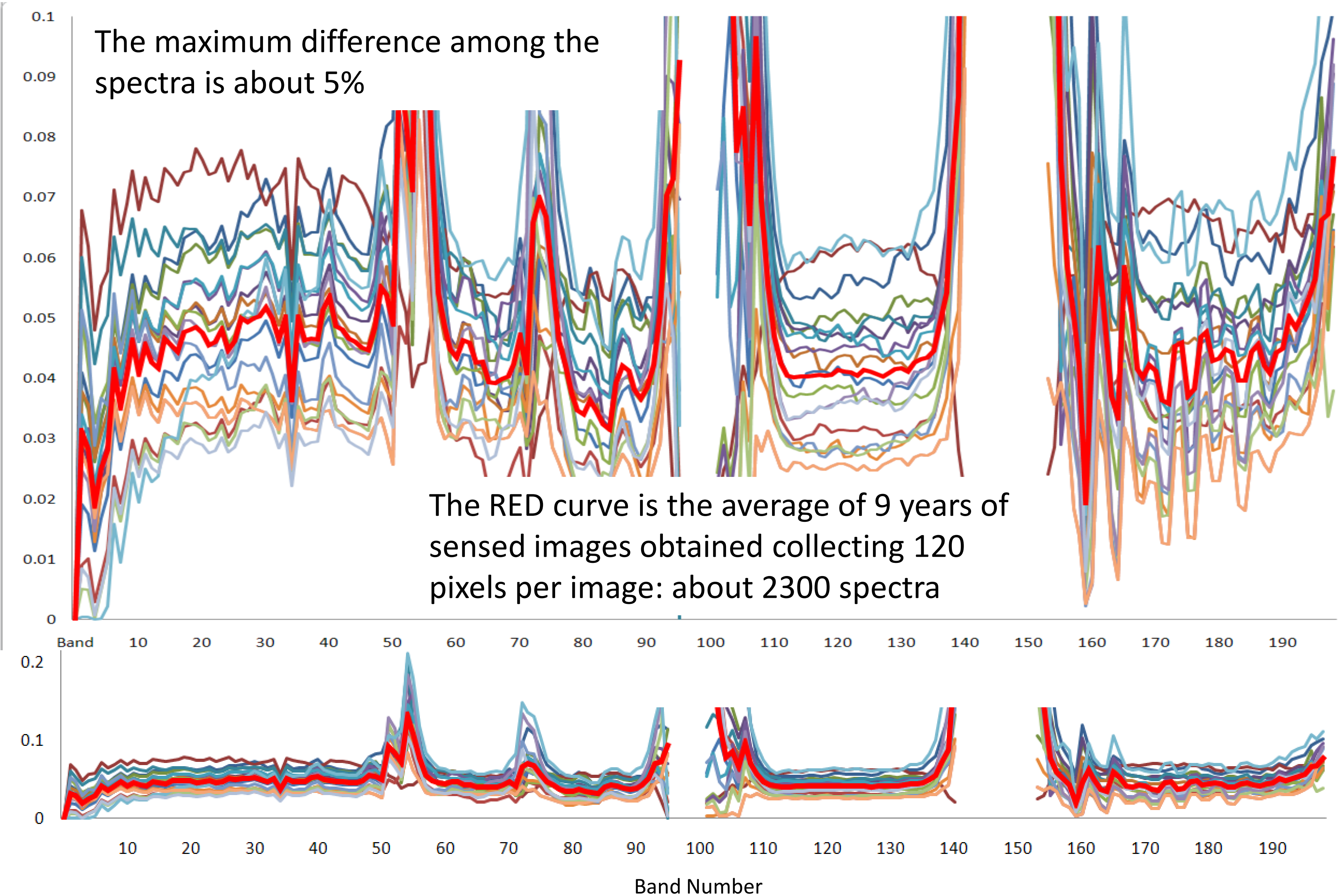
Mt. Etna – Piano delle Concazze 2008



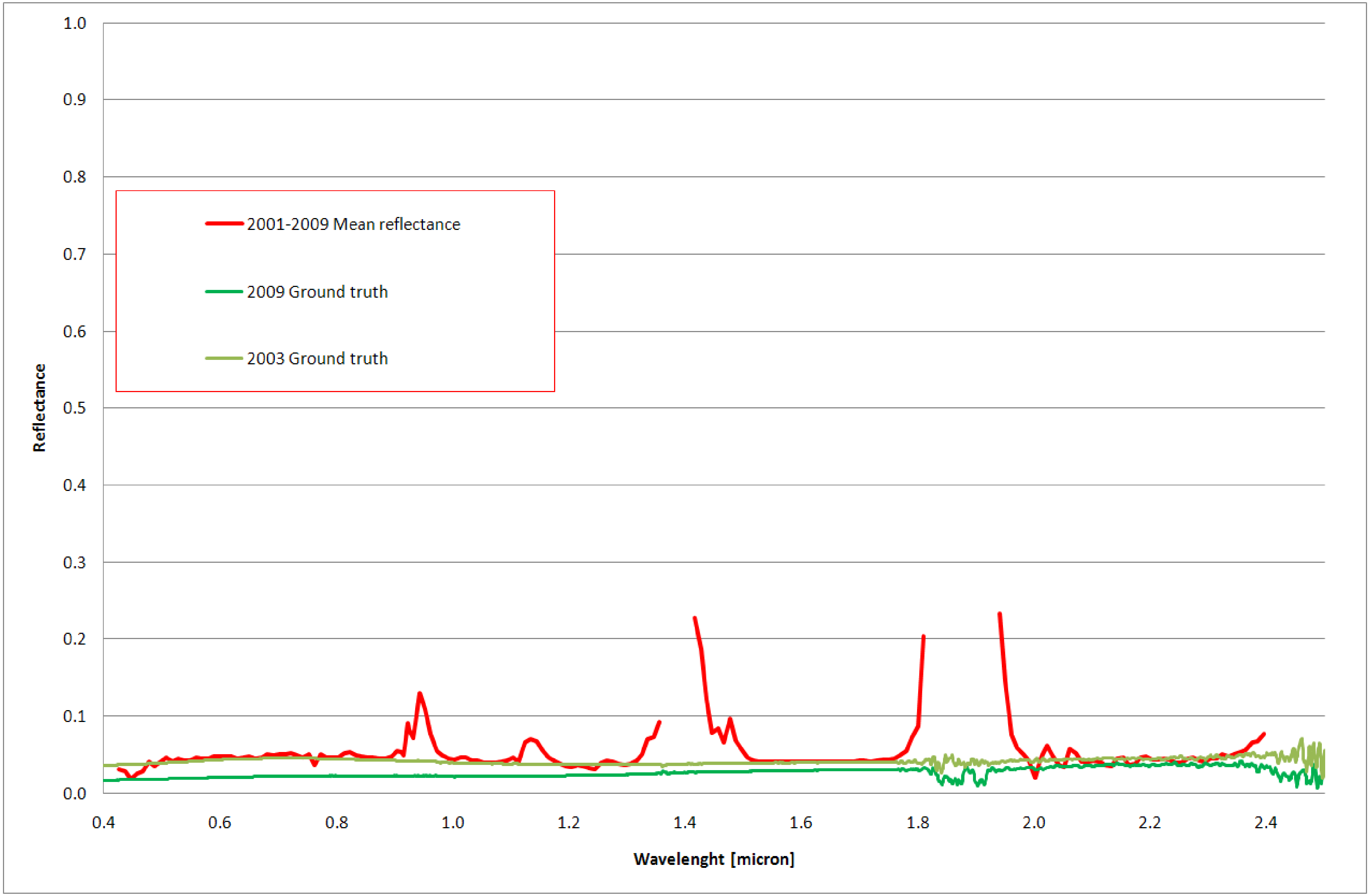
Mt. Etna – Piano delle Concazze 2009



Piano delle Concazze, 9 years of measures



From Band Number to Wavelenght

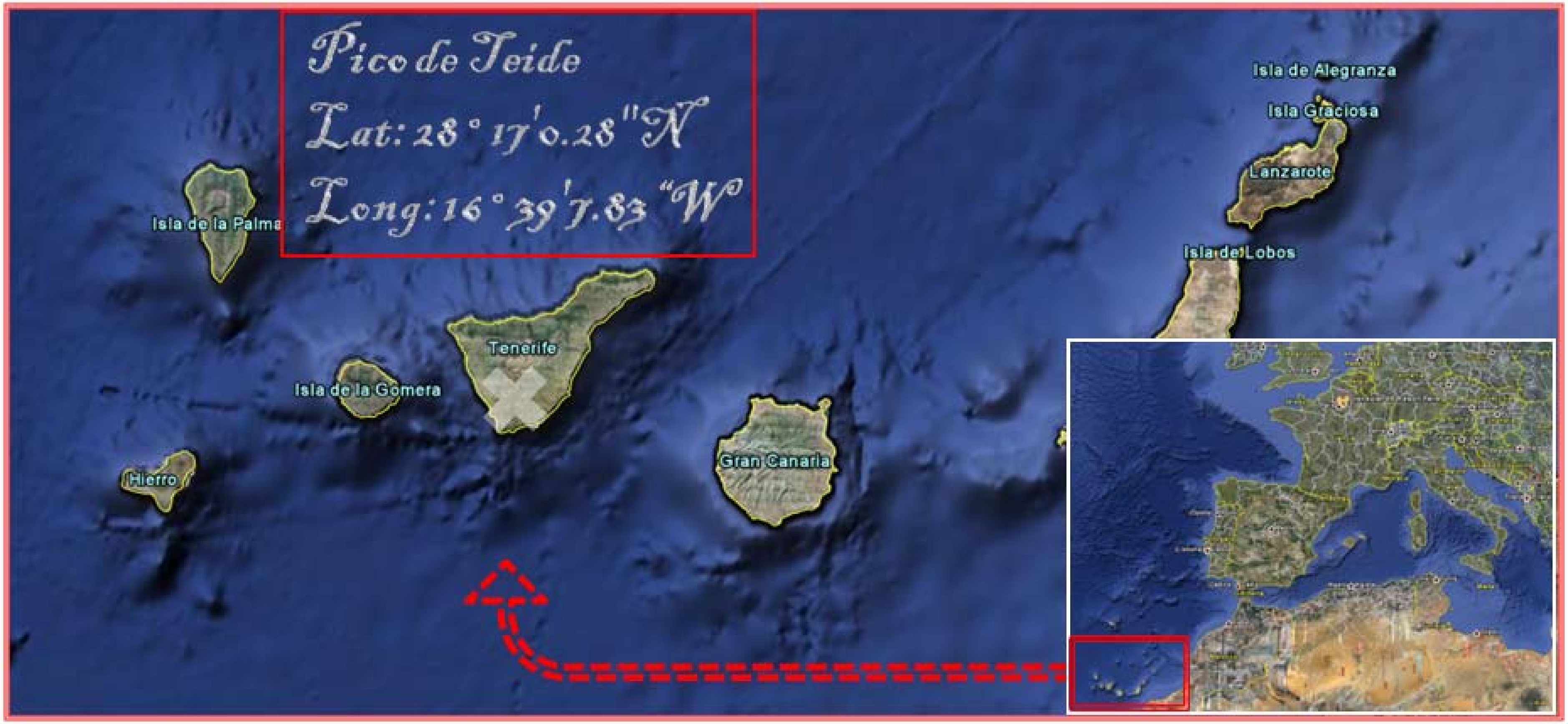


Conclusion

yyyy-mm-dd-hh-mm-ss	yyyy-mm-dd-hh-mm-ss
2001-05-26-09-26-04	2005-11-29-09-21-19
2001-06-20-09-19-37	2005-12-04-09-30-27
2001-07-13-09-25-32	2005-12-06-09-14-35
2001-07-22-09-19-25	2005-12-16-09-31-58

- Among 67 sensed images have been acquired over MT Etna by EO1-Hyperion
- Only 20 of them have been used in this analysis
- These images show that the Piano delle Concazze area represents a suitable site (in terms of constant spectral response) for VAL/CAL activities
- The used procedure for Atmospheric and Topographic removal effects well supports these VAL/CAL activities

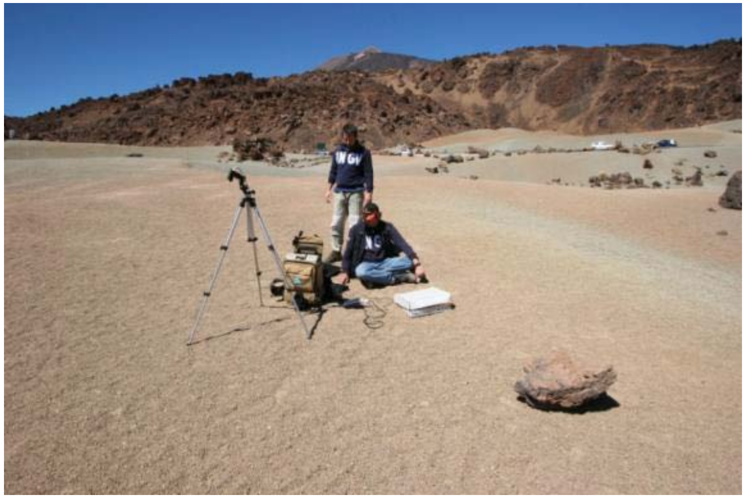
2005-11-05-09-13-25	2009-10-03-09-25-40
2005-11-12-09-08-47	2009-10-08-09-19-58



Pico de Teide CAL/VAL Site

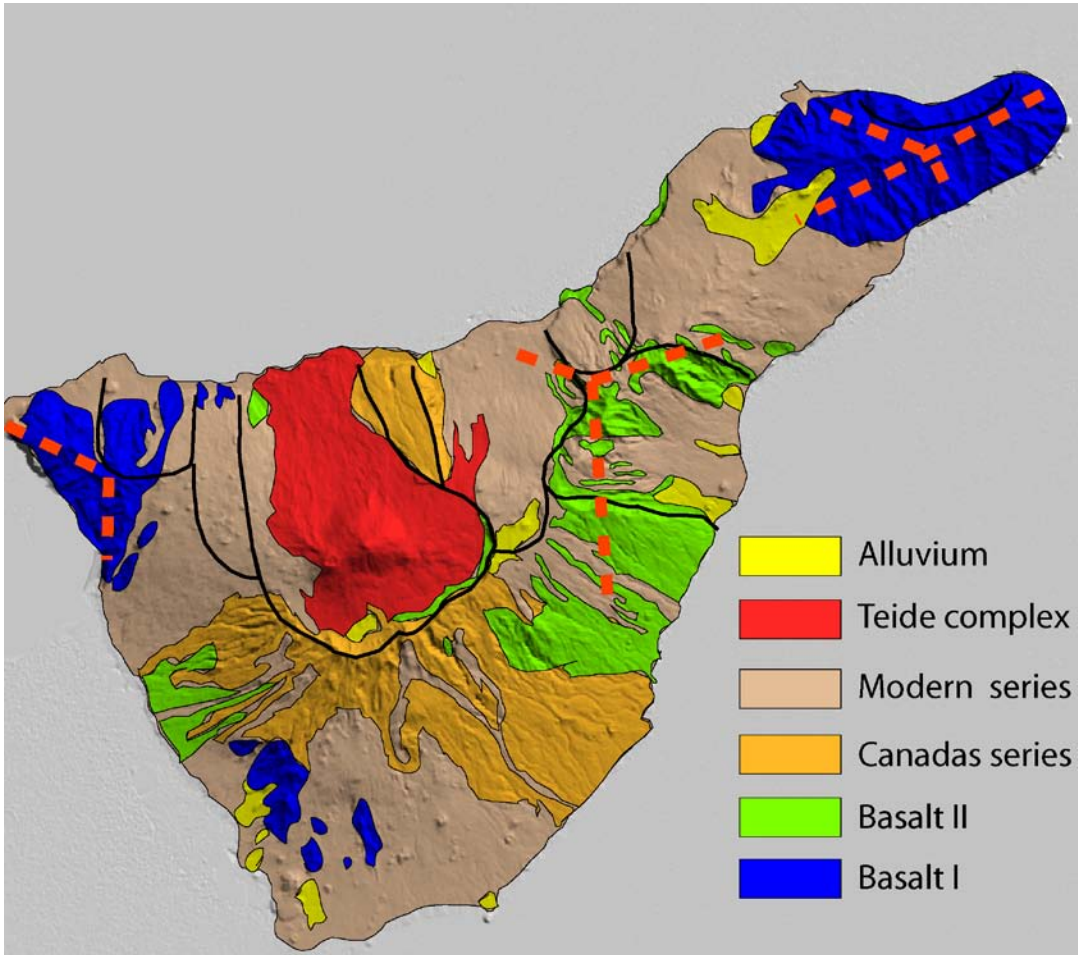
Tenerife is the exposed part of a giant volcanic construct that extends from the floor of the eastern central Atlantic at 23700 m to 3718 m at the summit of Teide volcano. The subaerial history of the island began in the late Miocene

Plio-Quaternary, post-shield volcanism on Tenerife has been characterised by the cyclic development of petrologically evolved eruptive centres. The most recent eruptive cycle has produced the twin stratovolcanoes Pico de Teide (PT) and Pico Viejo (PV), and numerous flank-vent systems, whose products collectively form the PT/PV formation.



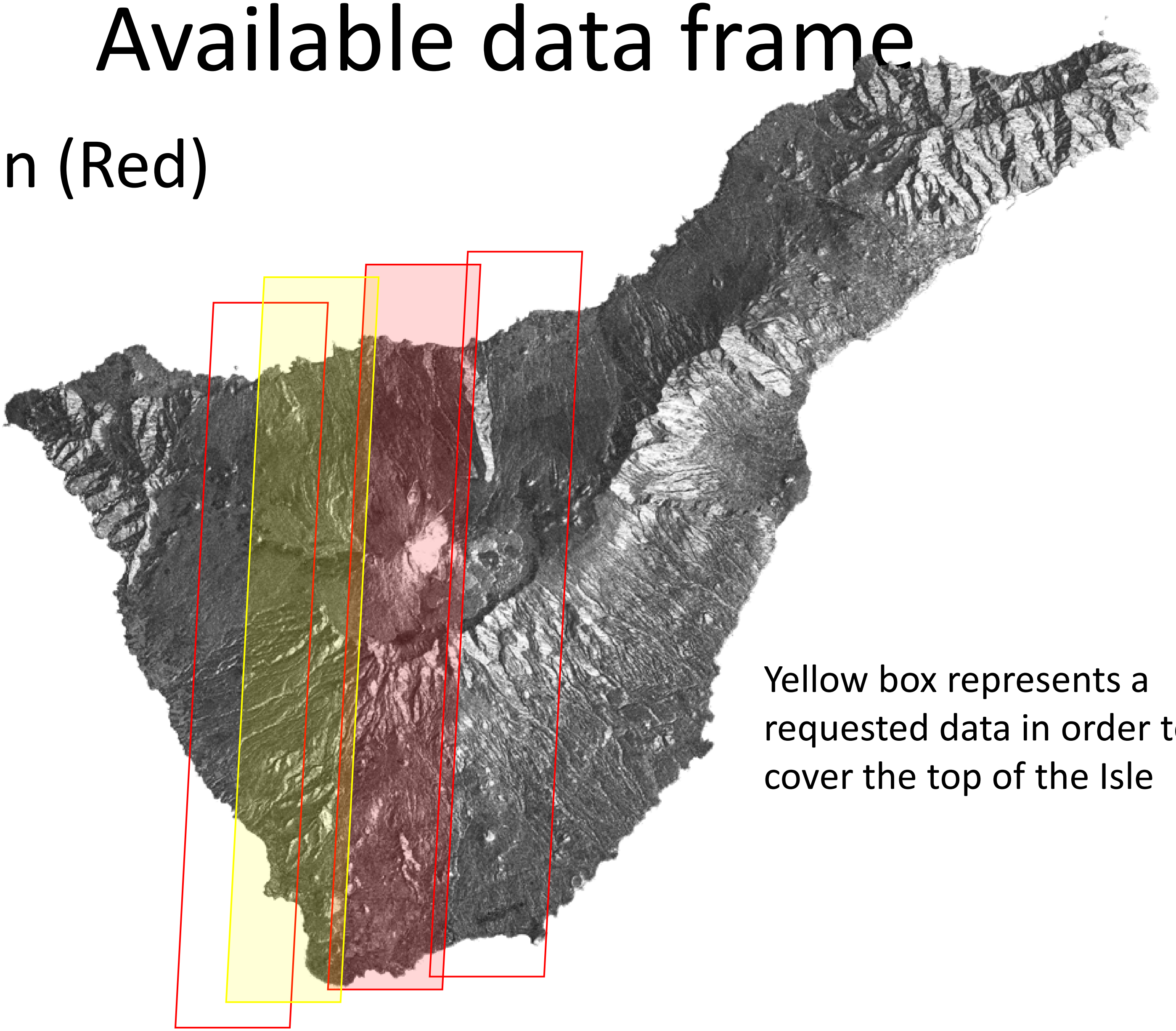
Pico de Teide Test site: Ground data

- Seismic Network
- Permanent GPS network
- Geochemical network
- Geodetic Network
- Geological Map



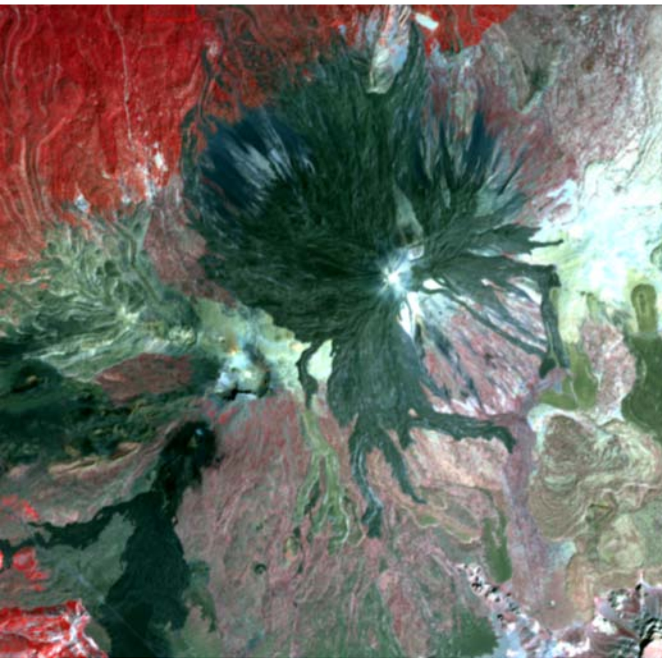
Available data frame

Hyperion (Red)



Yellow box represents a requested data in order to cover the top of the Isle

Pico de Teide Field campaign: preliminary work



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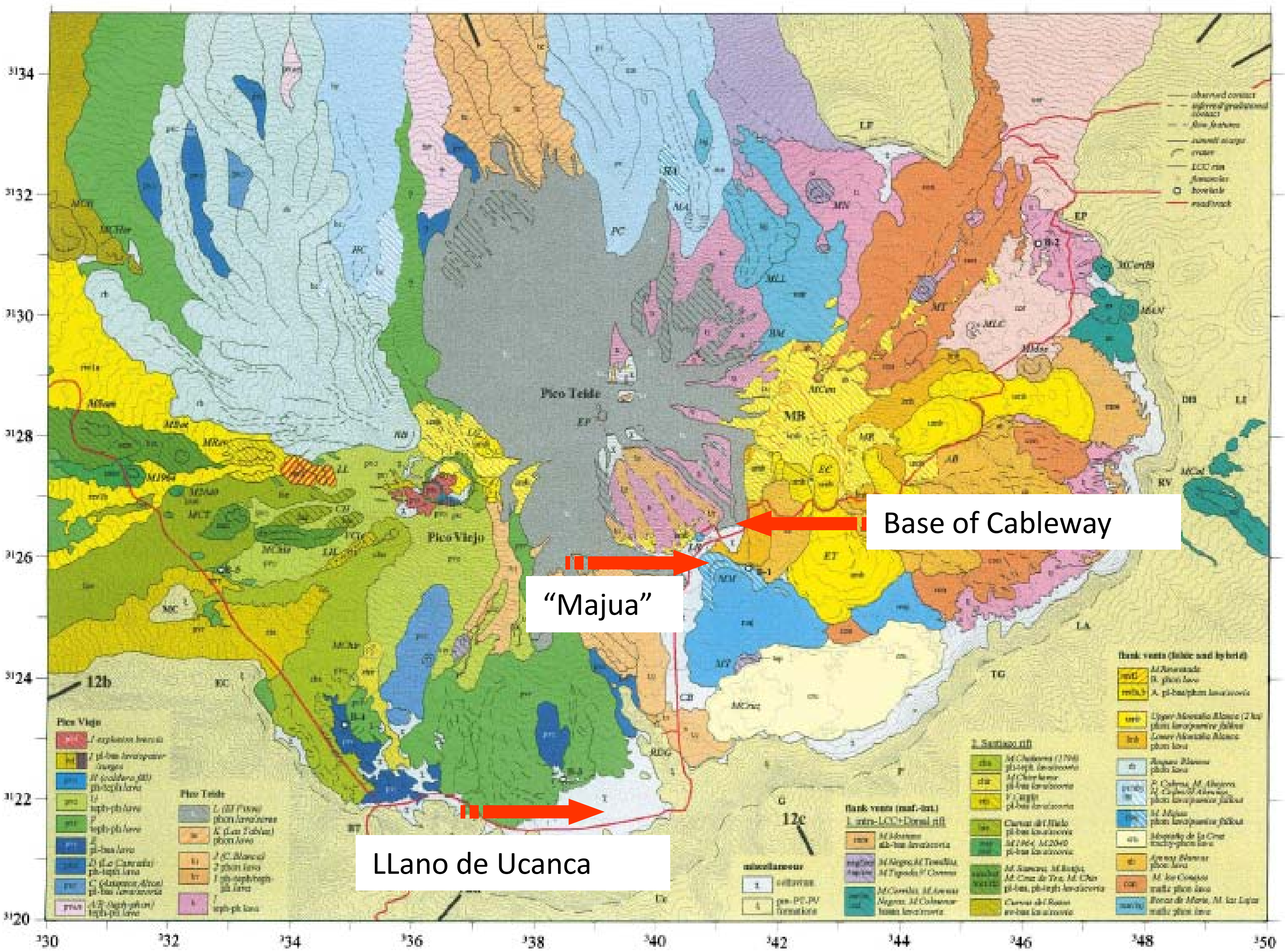
Geological Map from “G.J. Ablay, J. Martì Journal of Volcanology and Geothermal Research 103 (2000)”

Geological Map

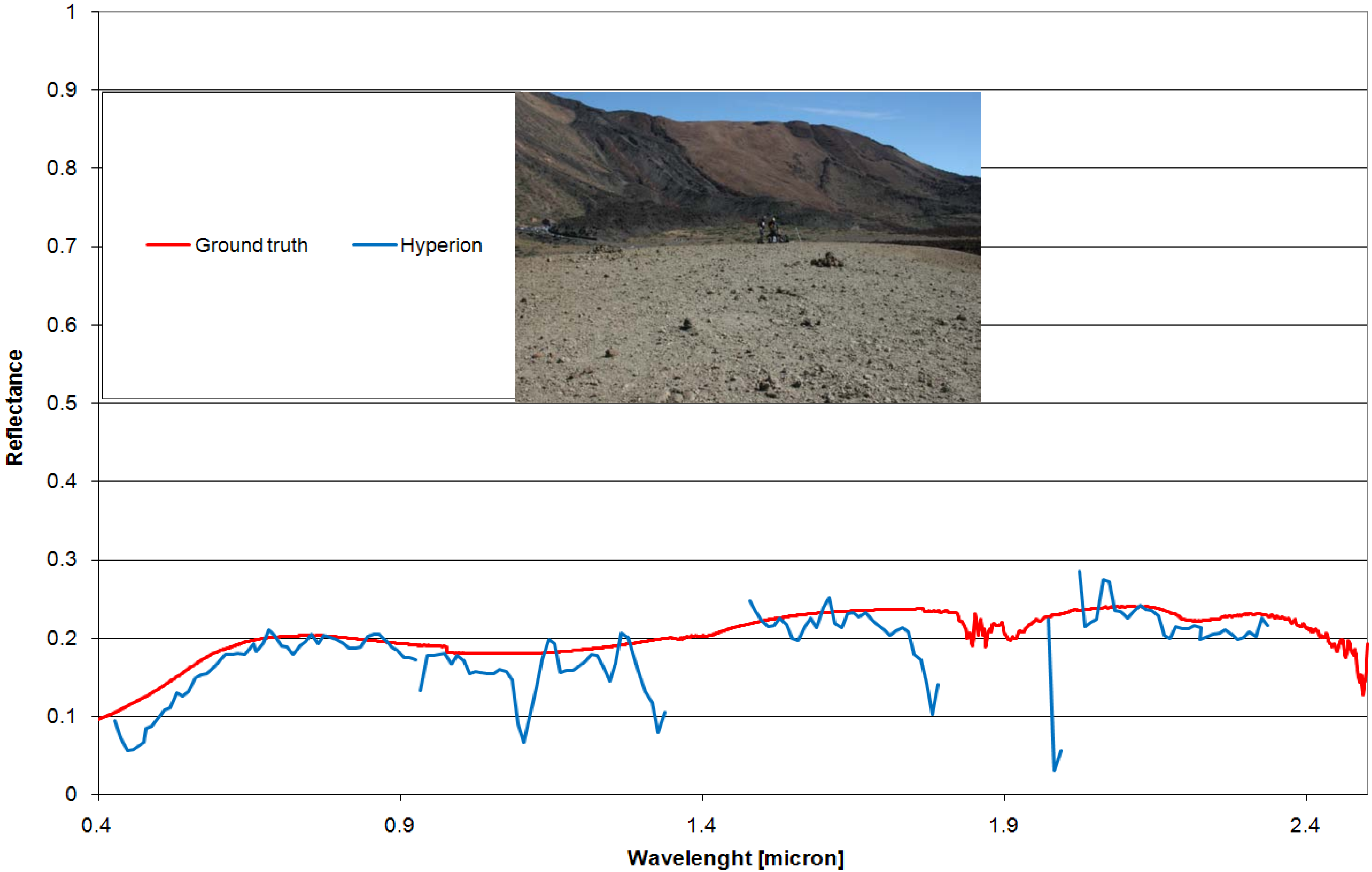


M. Majua

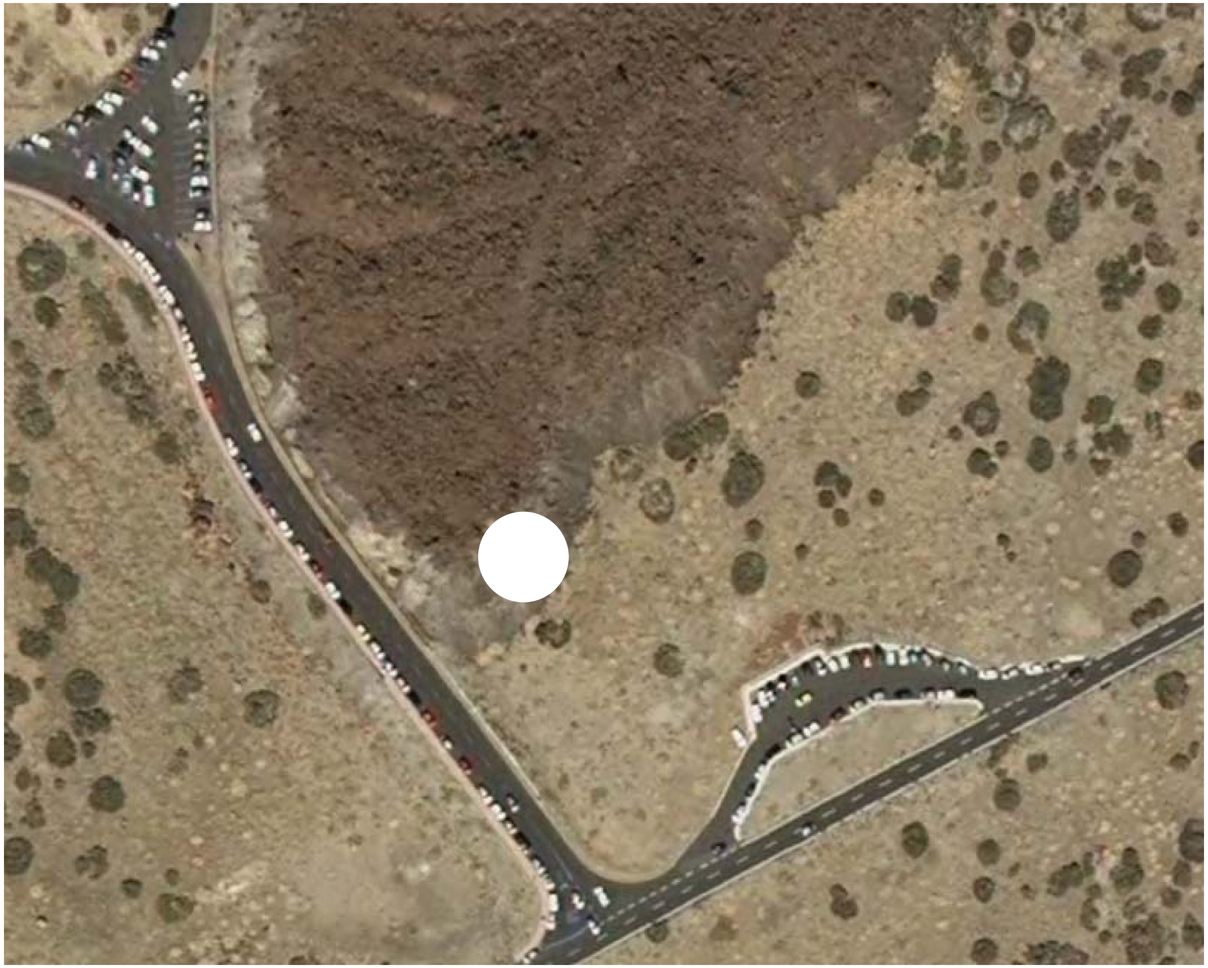
M. Majua

M. Majua is a strombolian pumice cone, 700 m in diameter and 55 m high, breached on its SE side by a wide, lobate, blocky flow of weakly evolved phonolite lava at least 30 m thick. On chemical grounds, the M. Majua member also comprises lava and spatter from Los Roques, which is a small vent on PT's lower S flank

Pico de Teide: M. Majua



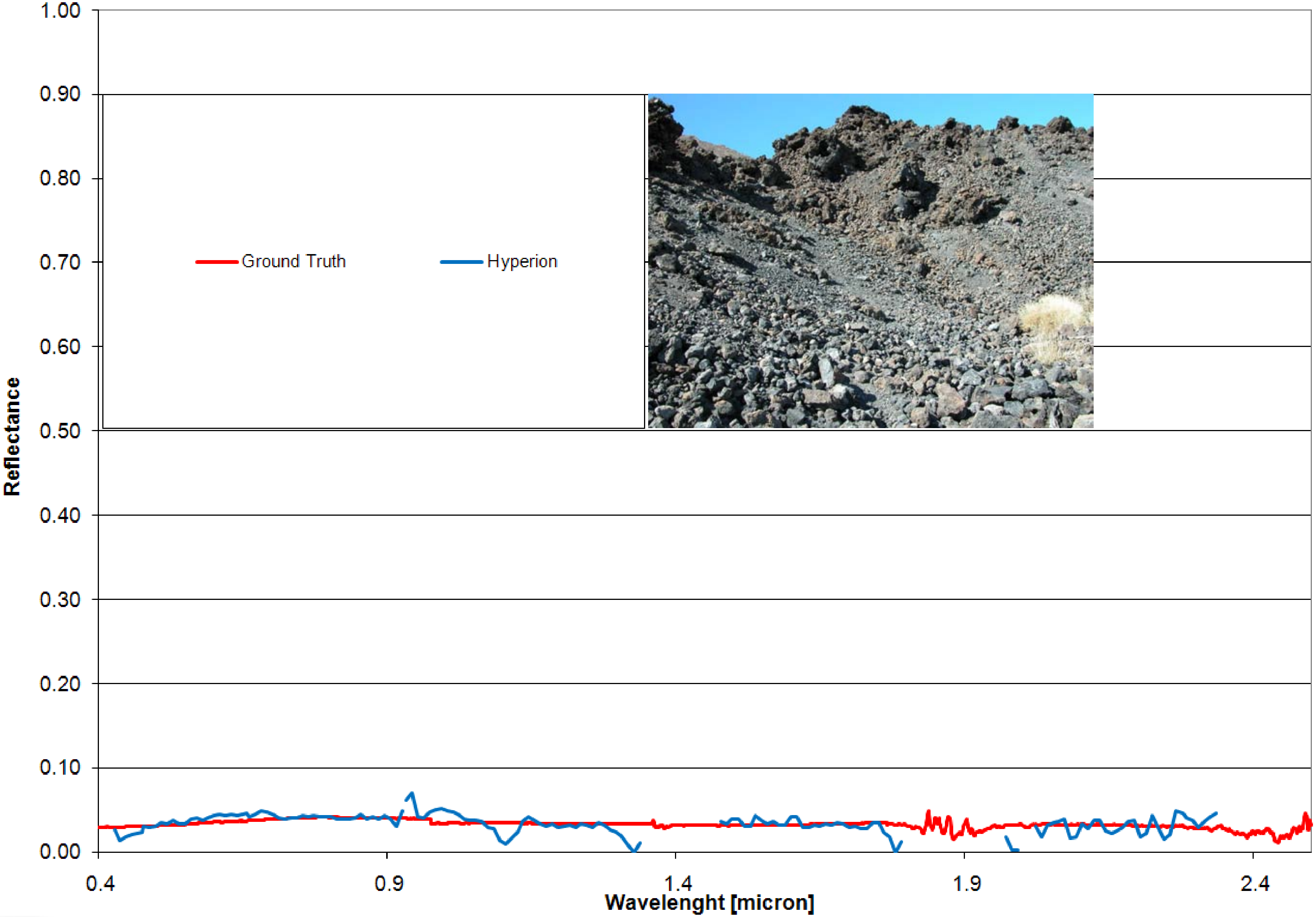
El Piton



El Piton

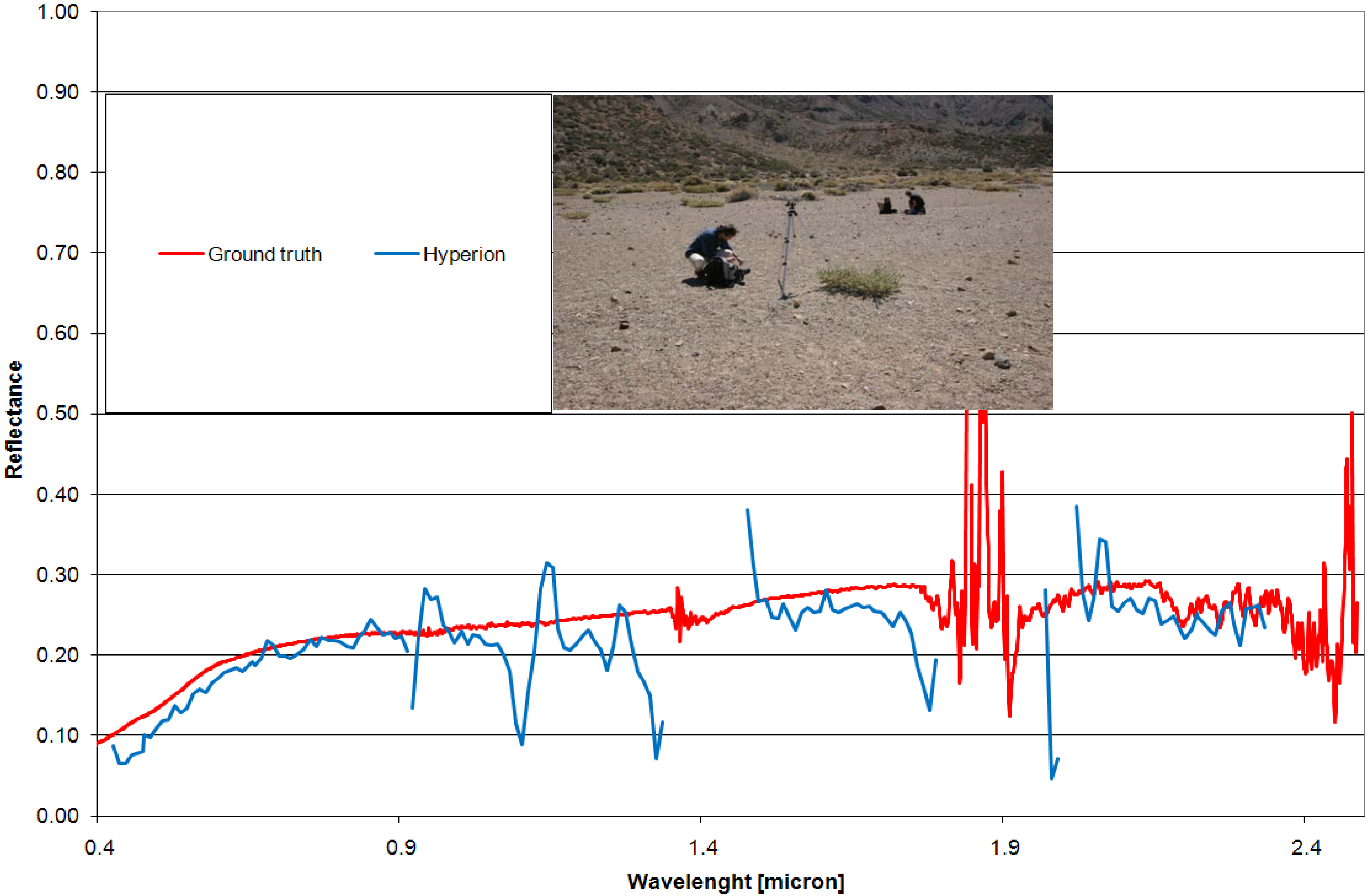
El Piton "L" member comprises many thin, blocky flows of melanocratic, glassy, porphyritic phonolite lava derived from El Piton. Flows are steepsided with prominent channels and levees on the flanks, and lobate flow fronts at the cone base. The El Piton eruption is assigned a historic date of 1380 ad based on geomagnetic secular variation studies

Pico de Teide: El Piton



Colluvium deposit in Llano de Ucanca

Pico de Teide: Llano de Ucanca



Results

- The results of the val/cal activities on Etna and Teide are presented. The large availability of ground networks and the easy access to the summit areas make of these test sites very good references for the future vicarious calibration and validation activities for the HyspIRI Sensor and for the other planned hyperspectral missions in volcanic areas

Incoming hyperspecrtal ASI mission: PRISMA Precursore IperSpettrale (Hyperspectral Precursor) of the application mission

PRecursore IperSpettrale della Missione Applicativa

- PRISMA (PRecursore IperSpettrale of the application mission) is an earth observation system with electro-optical instrumentation which combines a hyperspectral sensor with a panchromatic, medium-resolution camera.

Objectives

- PRISMA is a "small" Italian mission of demonstrative/technological and pre-operational nature.
- The fundamental objectives are the following:
  - To develop a small mission entirely in Italy for monitoring natural resources and atmosphere characteristics, taking advantage of the prior developments carried out by ASI
  - Make available in a short period of time the data necessary to the scientific community for developing new applications for environmental risk management and observation of the territory, based on high-resolution spectral images
  - Test the hyperspectral payload in orbit - the first or among the first at the European level.

Technical aspects

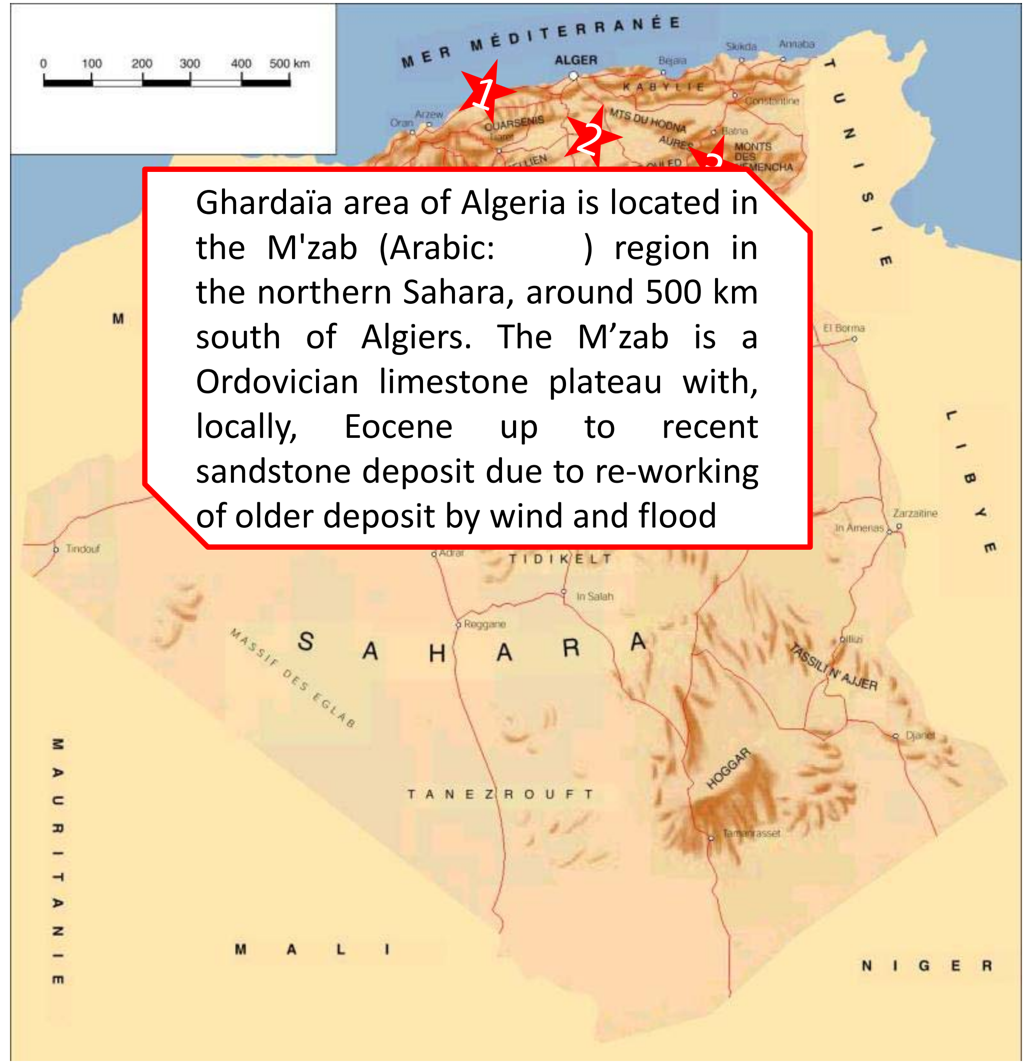
Characteristics of the System:

- A satellite in LEO SSO (700 km) orbit with planned 5-year operational life
- Hyperspectral/Panchromatic Payload
  - Space resolution: 20-30 m (Hyp) / 2.5-5m (PAN)
  - Swath width: 30-60 km;
  - Spectral range: 0.4-2.5 mm (Hyp) / .4-.7 m (PAN)
  - Continuous coverage of spectral ranges with 10 nm bands

Algeria: Geo-morphology

The country is divided from north to south into four zones:

1. The Tellian Atlas (or the Tell) is made up of the northern-most steep relief flanked by rich coastal plains such as the Mitidja in the centre, the Chelif to the west and the Seybouse plains in the east;
2. The High Plateaus;
3. The Saharan Atlas as a succession of NE-SW oriented reliefs spreading from the Moroccan border to Tunisia;
4. The Sahara desert south of the Atlas yields most of Algeria's hydrocarbon resources. the desert is composed of large sand dunes (East and West Erg) and gravel plains (regs) with dispersed oases such as Ghardaia and Djanet .



Ghardaïa area of Algeria is located in the M'zab (Arabic:) region in the northern Sahara, around 500 km south of Algiers. The M’zab is a Ordovician limestone plateau with, locally, Eocene up to recent sandstone deposit due to re-working of older deposit by wind and flood

Thank You!

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