ToA Radiance Simulator for the New Hyperspectral Missions: STORE (Simulator of TOA RadianCE)

Malvina Silvestri

Istituto Nazionale di Geofisica e Vulcanologia

ASI-AGI and STORE

In the frame of the Italian Space Agency (ASI) Hyperspectral Mission PRISMA (Precursore IperSpettrale della Missione Applicativa), the Istituto Nazionale di Geofisica e Vulcanologia (INGV) is coordinating the scientific project ASI-AGI (Analisi Sistemi Iperspettrali per le Applicazioni Geofisiche Integrate) to develop specific algorithms and products for various geophysical applications.

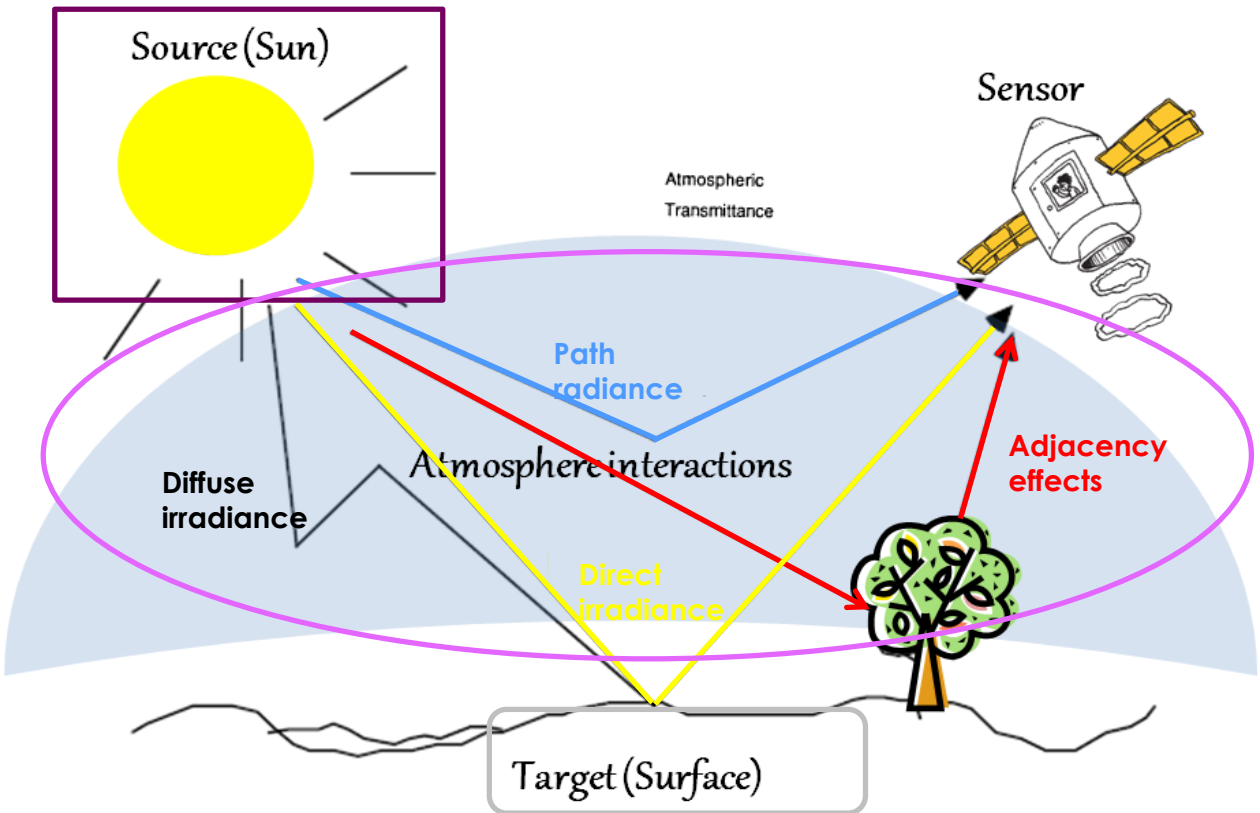
In the ASI-AGI project a PRISMA-like data simulator to test the specific algorithms during the developing phases of the PRISMA mission has been developed.
STORE (Simulator of TOa RadiancE) is an image satellite sensor simulator developed to generate a simulated hyperspectral data.

Hyperspectral data simulation

Why an hyperspectral simulator

It allows the generation of realistic satellite images based on detailed models of the surface, the atmosphere, and the sensor; it also can be used to study the effect of system parameters on an output measure, such as classification accuracy or other applications; it allows to assess the capacity of existing and future satellite sensors to meet the user requirements for hypothetical applications

The sensed image depends on the interaction among the **source**, the **atmosphere** and the **target**



In order to properly simulate by means simulator tool the hyperspectral images, with a spectral range from 0.4 to 2.5 μm, several inputs have to be used. The confidence of the simulated images depends on the capability to constrain the input data.

During the design phase, we have considered inputs related to the earth-atmosphere-sensor geometry and spectral response function as baseline for obtaining a suitable simulated image. The study **does not consider** parameters related to sensor technical characteristics such as Signal-to-Noise Ratio (SNR) of sensor and the electro-mechanical noise due to sensor functionalities.

The following inputs have to be used to obtain at-sensor radiances in different channels of the sensor:

- **Radiative Transfer Model**, MODTRAN, that is the main core of STORE; this code offers the possibility to simulate under different atmospheric and surface conditions the interaction among sensor and target;

- **Atmospheric features** in terms of visibility, water vapour amounts, aerosol types and depth, etc, to correctly model the atmosphere's optical properties

- **Surface characterization**/field campaigns in terms of surface temperature, land surface spectral response (known also as albedo or surface reflectance) and topography (or altitude) to allow to describe the image viewed by the sensor;

- **Sensor information**/SRF in terms of satellite attitude (considering the geometry among source, sensor and target), day and time of acquisition, spectral response function (SRF), spectral channels resolution and distribution to proper define the correct acquisition geometry.

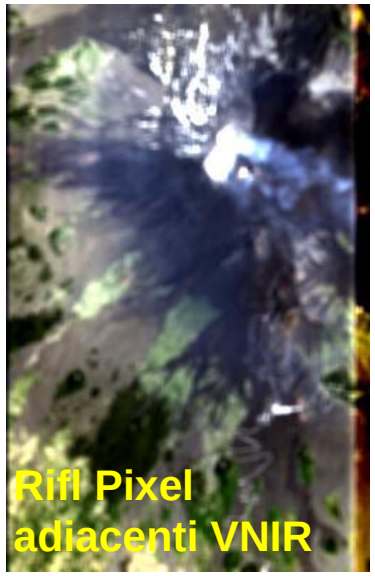
Hyperspectral data simulation: Test site

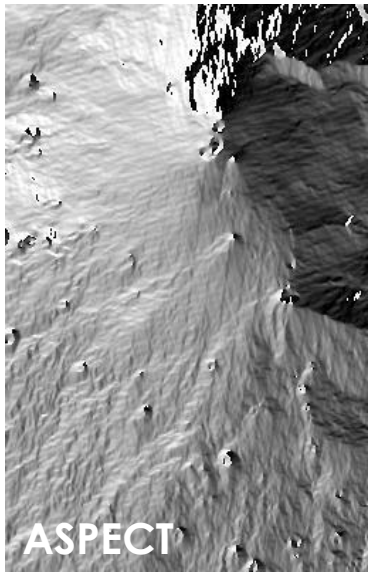
A precise characterization of surface spectral response represents a reliable parameter to feed the simulator, in particular on the proper definition of the surface spectral albedo used to generate the simulate TOA radiances. Piano delle Concazze on Mt. Etna volcano represents a suitable natural laboratory to provide validation for surface parameters such ground reflectance

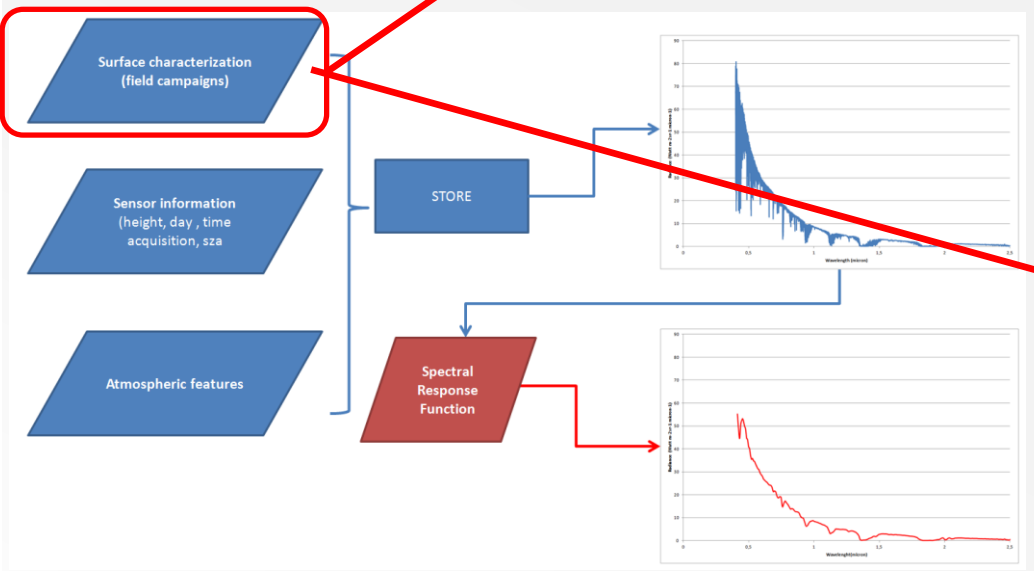
Hyperspectral data simulation: Input

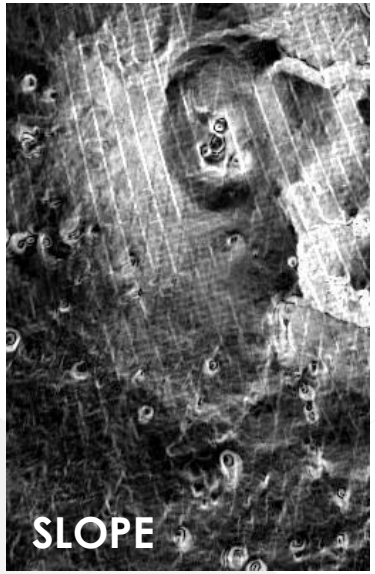
Test Site

- HYPERION, Etna area, 26/06/2012
- 198 bands with spectral range from 0.4 to 2.4 µm and 30m spatial resolution
- Co-registered DEM (credits: INGV)





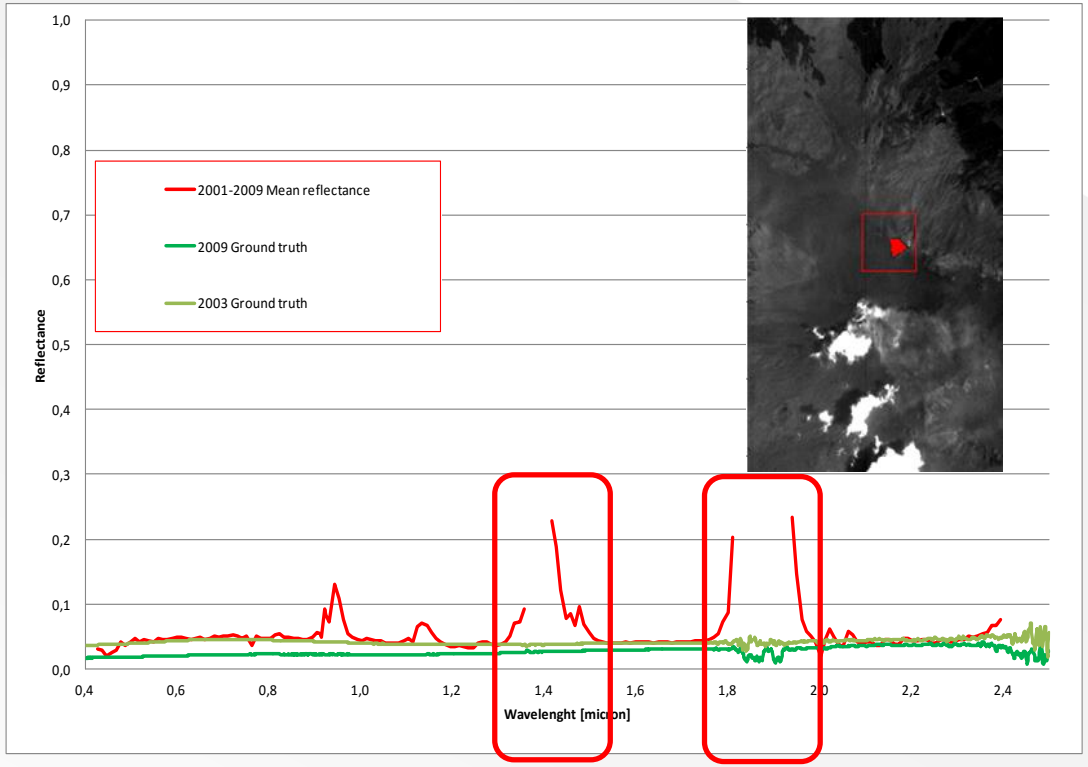




Hyperspectral data simulation: Surface reflectance

Reflectance input data derived by:

- HYPERION , Etna **Field campaign**, 26/06/2012
- Atmospheric correction on **HYPERION data**
- 2003 and 2009 **ground truths**

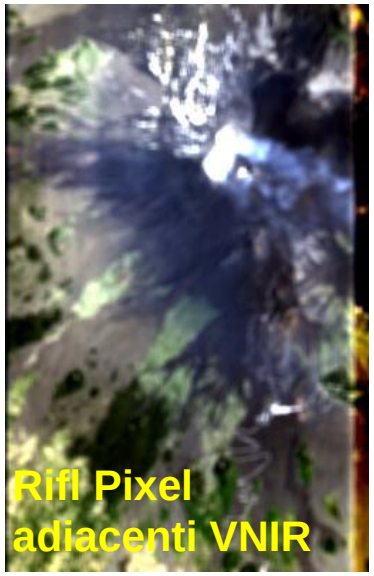


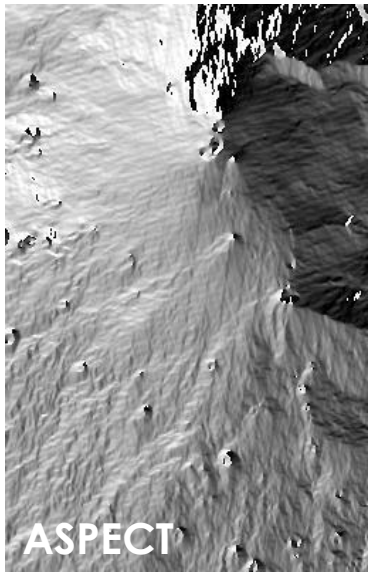
Curves show a similar trend, shapes and values with the exception of bands characterized by strong atmospheric absorption features

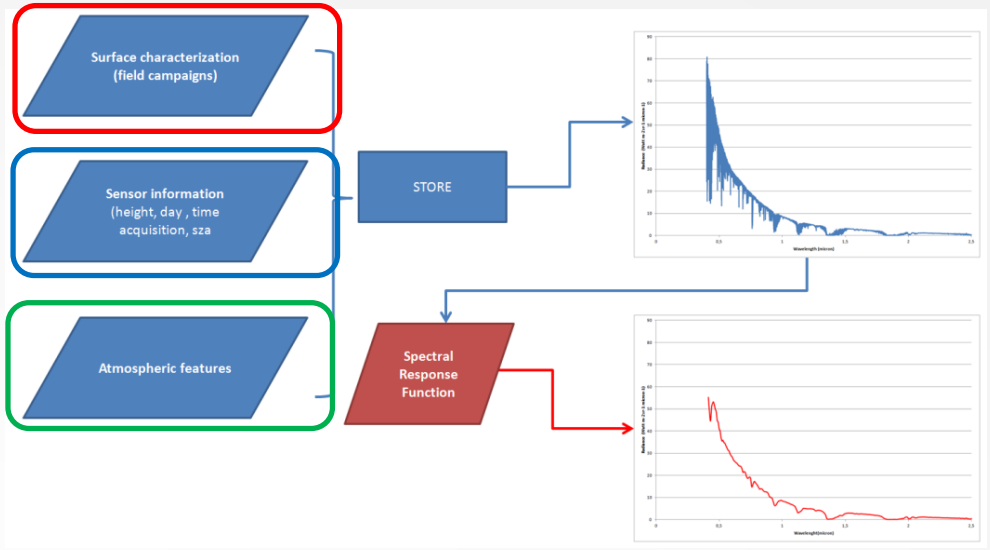
Hyperspectral data simulation: Input

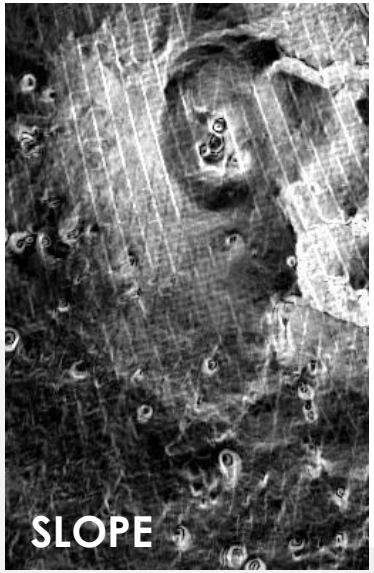
Test case:

- HYPERION, Etna area, 26/06/2012
- 198 bands with spectral range from 0.4 µm to 2.4 µm and 30m spatial resolution
- Co-registered DEM (credits: INGV)
- Atmospheric features: Mid-Latitude Summer / more info MODTRAN
- Sensor information: simulated SRF

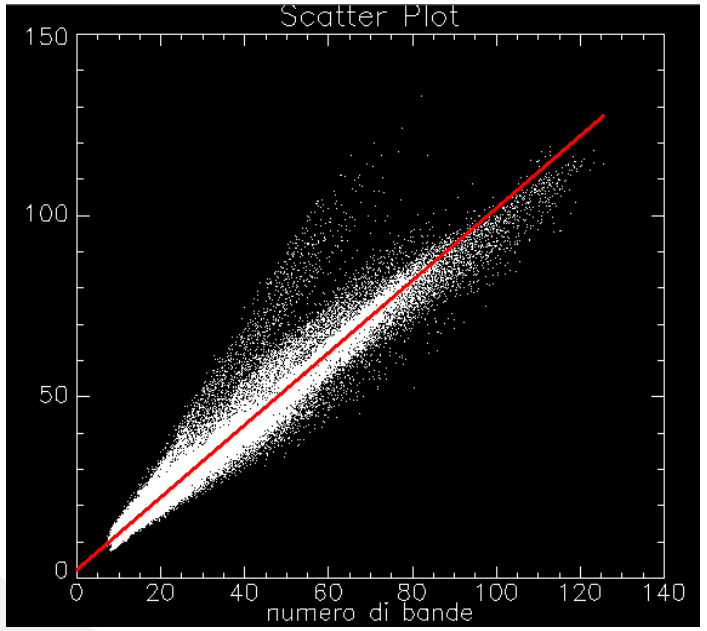


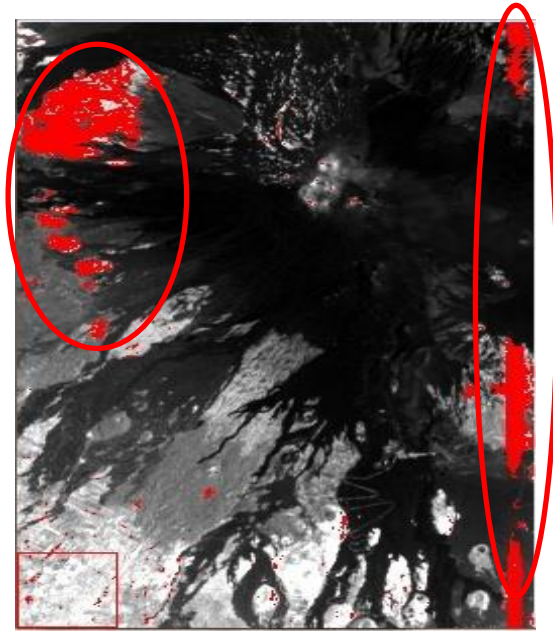




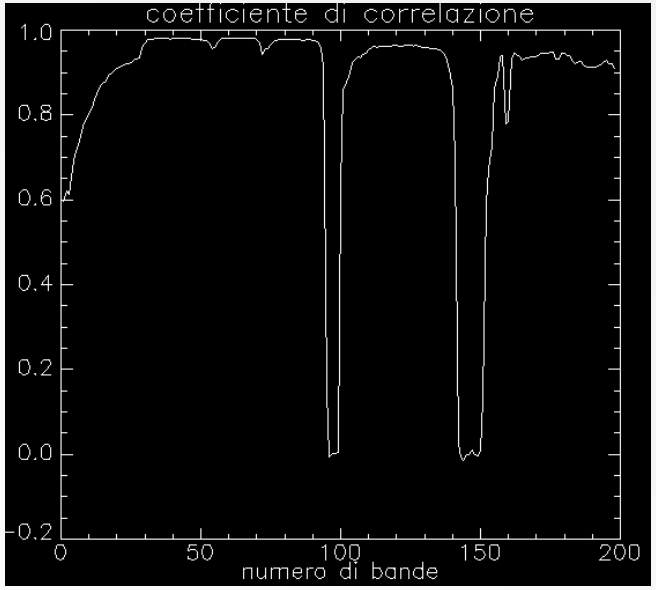


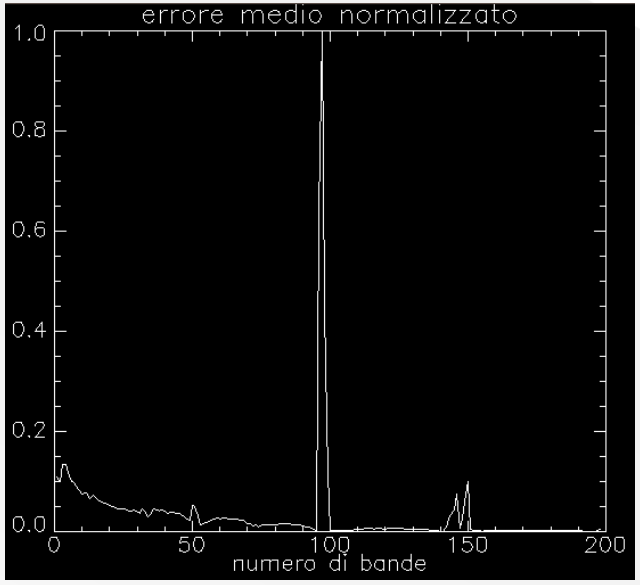
Hyperspectral data simulation: Application on HYPERION simulation





Correlation:
low correlation areas





Correlation between real and simulated all VNIR and SWIR bands

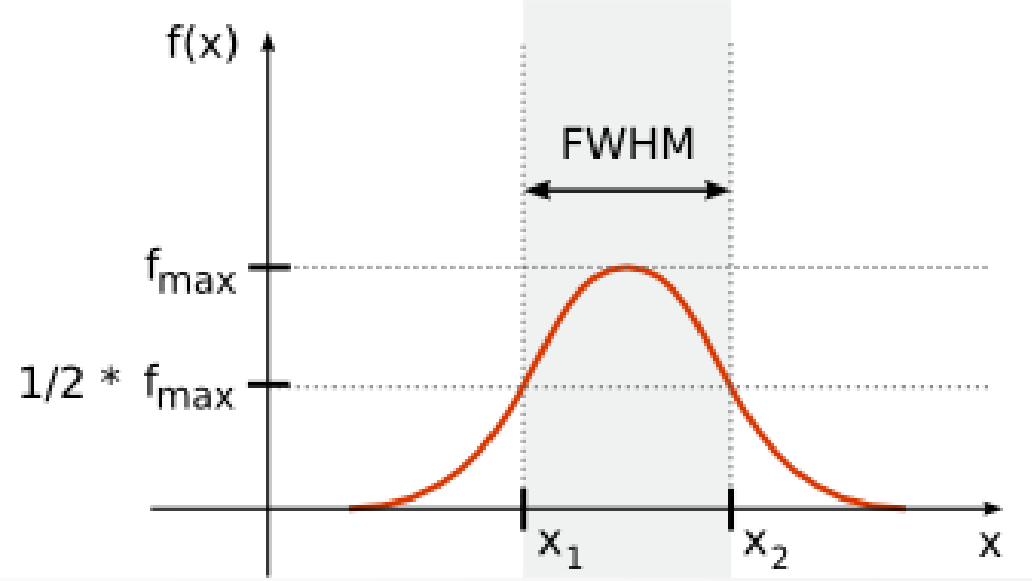
Hyperspectral data simulation: SRF

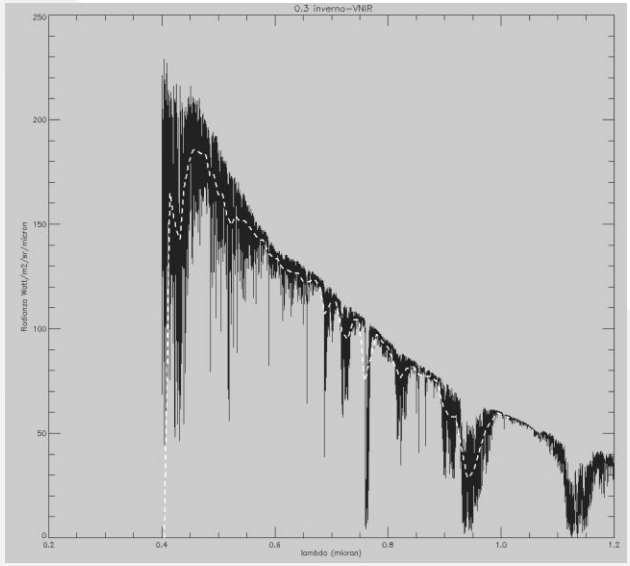
The incoming TOA radiance collected by the hyperspectral sensor is acquired by each channel according to the SRF, that describes the sensitivity of the channel regarding the energy in a certain range of the electromagnetic spectrum. The SRF is not always available from the manufacturer of the camera, especially in the first phases of instrument design. For this reason we have decide to test simulator with a SRF as a Gaussian $f(\lambda_j)$

FWHM= λ_{maxj}-λ_{minj}

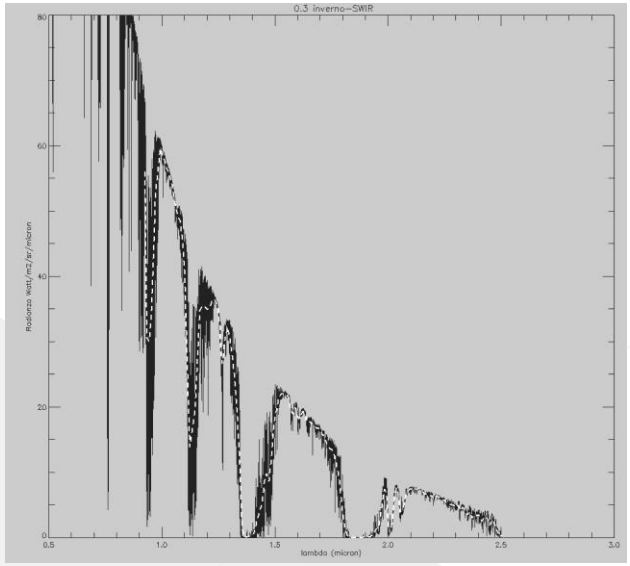
$$\sigma_j = \frac{FWHM_j}{2\sqrt{2\,Ln\,2}}$$

$$f(\lambda_j) = \frac{1}{\sqrt{2\pi\sigma_j^2}} e^{\frac{(\lambda_j - \lambda_{cen,j})^2}{2\sigma_j^2}}$$



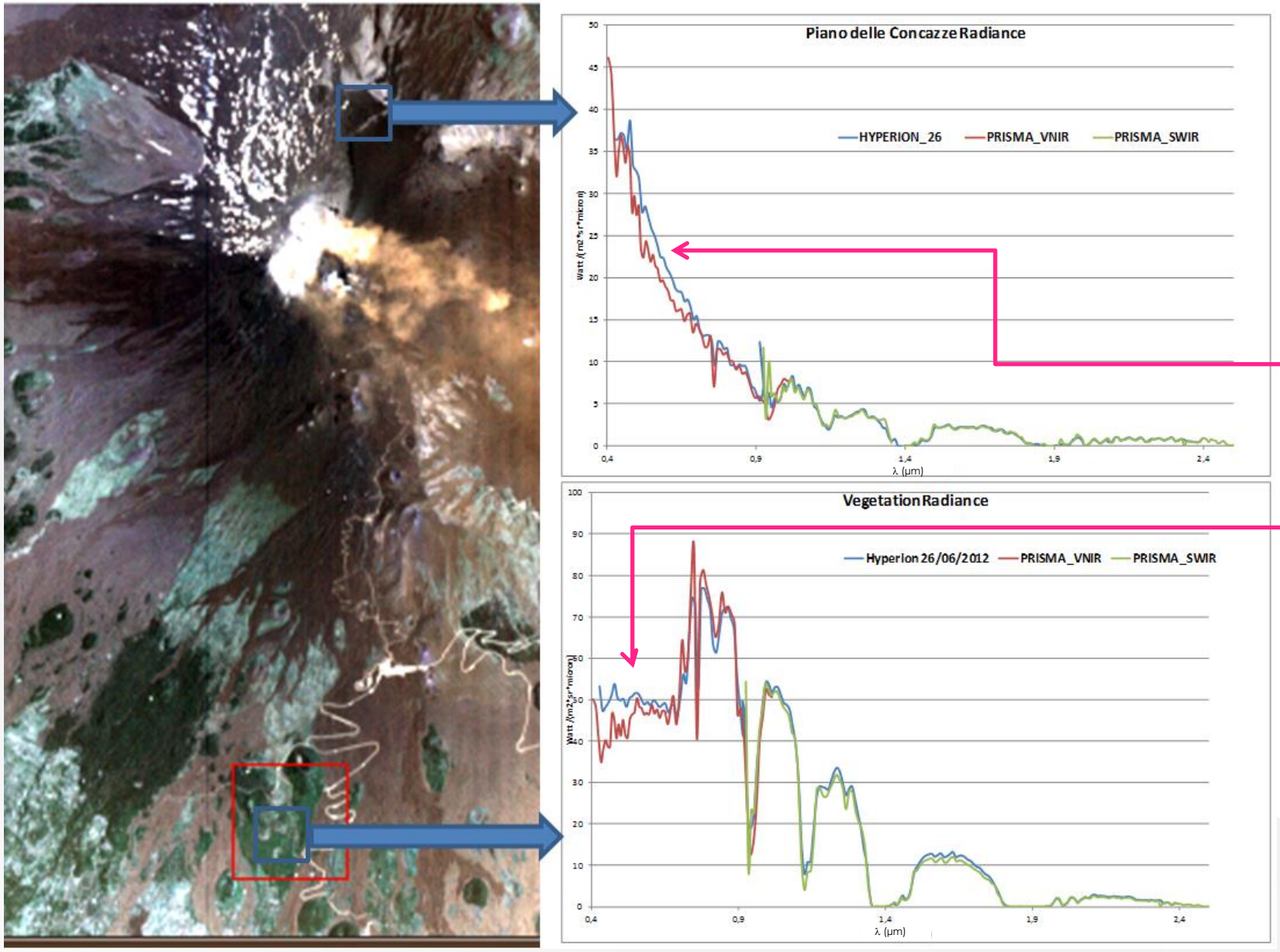


VNIR



SWIR

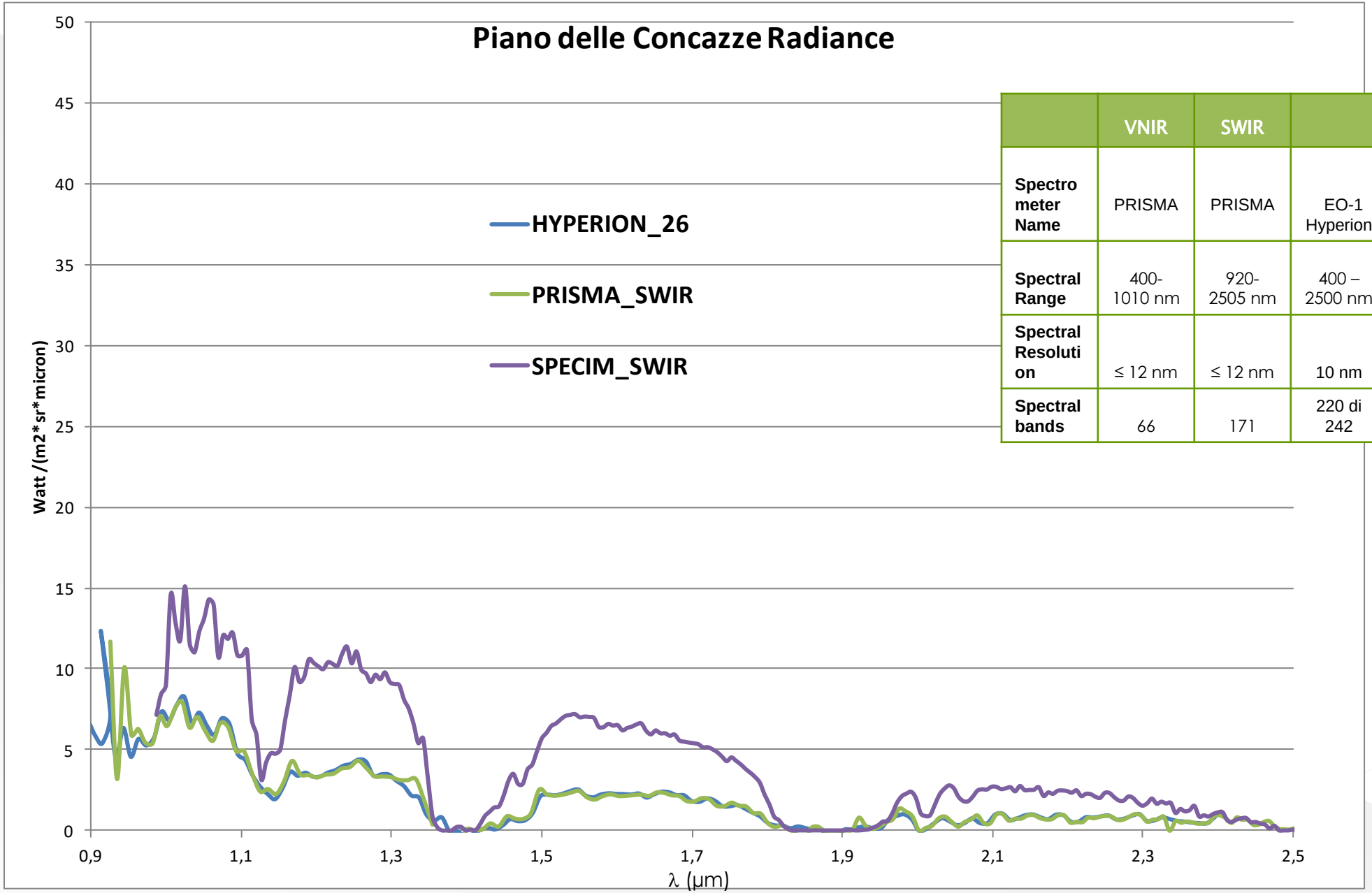
Hyperspectral data simulation: Application on PRISMA-like data



Main differences are due to atmospheric contribute:

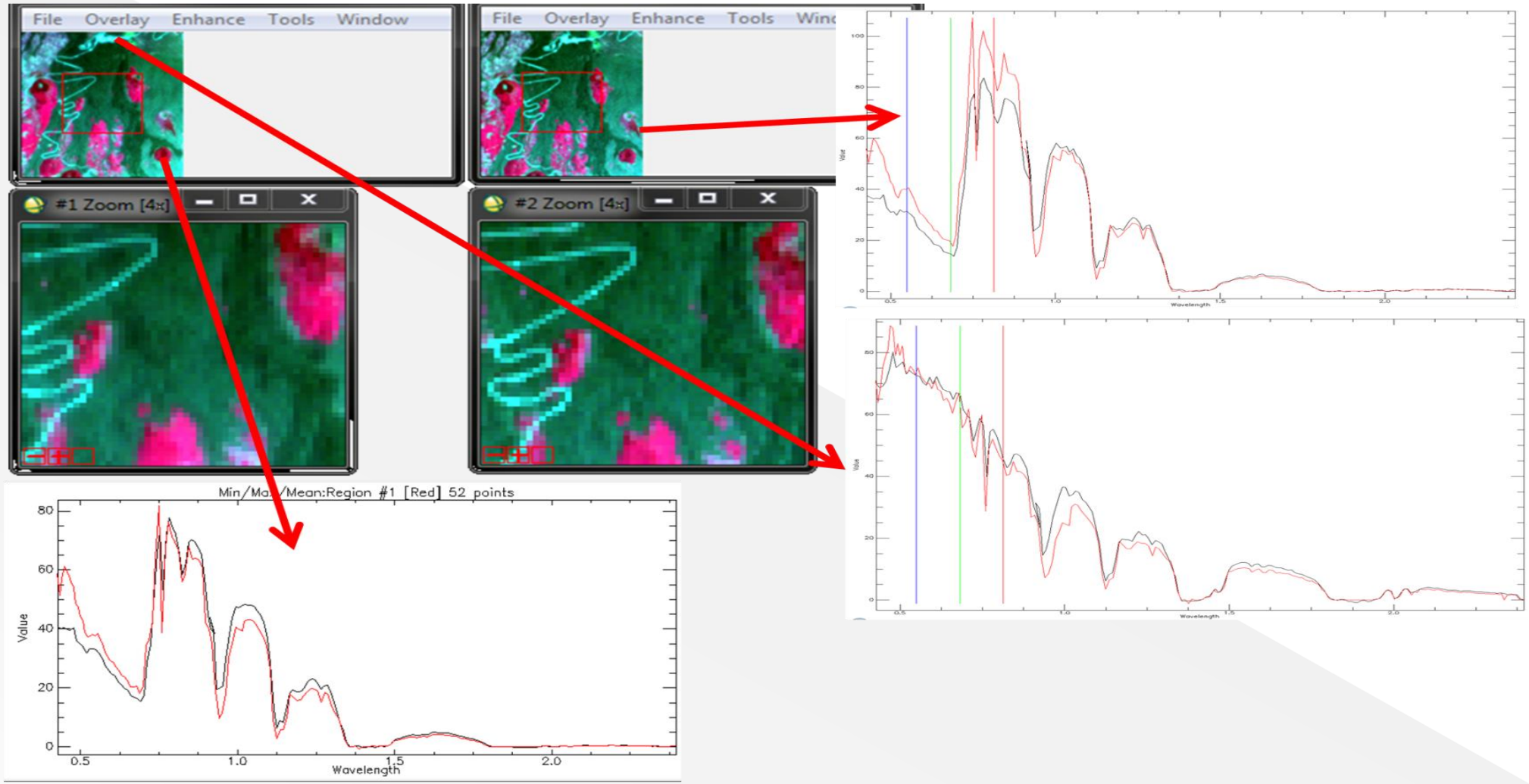
- real data for Hyperion
- Modtran default value for simulation

Hyperspectral data simulation: Application and comparison



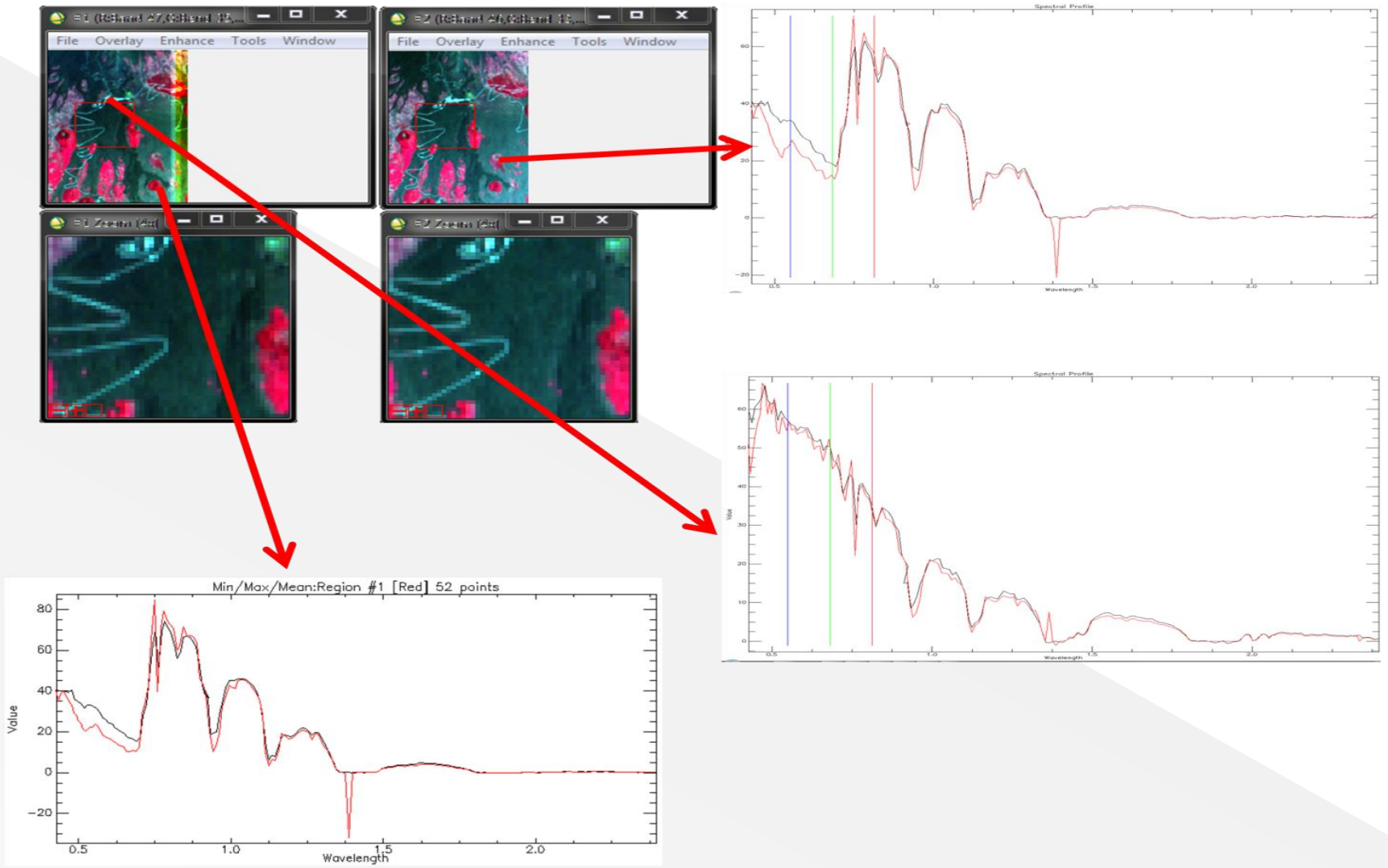
	VNIR	SWIR		VNIR	SWIR
Spectrometer Name	PRISMA	PRISMA	EO-1 Hyperion	ImSpector V10E /Specim	ImSpector N25E /Specim
Spectral Range	400-1010 nm	920-2505 nm	400 – 2500 nm	400-1000 nm	970-2500 nm
Spectral Resolution	≤ 12 nm	≤ 12 nm	10 nm	2.8 nm	10 nm
Spectral bands	66	171	220 di 242	504	239

Hyperspectral data simulation: example of application



Comparison among radiance spectra HYPERION real data (right) and PRISMA-like simulated (left); black color HYPERION spectra, red color PRISMA-like data.

Hyperspectral data simulation: example of application



Comparison among radiance spectra HYPERION real data (right) and PRISMA-like simulated (left); the simulation has be done with a visibility of 100 km; black color HYPERION spectra, red color PRISMA-like data.

Conclusion

- A scheme for simulating the at-sensor radiance channels hyperspectral sens presented. Such scheme is quite useful in understanding the at-sensor signals in th osphere–surface scenario before the launch of a satellite.

- First check on simulation using HYPERION real d ION simulated data. A PRISMA-like simulation has been done using a

- Simulated data has been com ne hyperspectral sensor (SPECIM) and PRISMA-like simulated dat

- Analysing th its it is important to remark the role of the atmospheric paramete

- This study does not consider parameters related to sensor technical characteristics such as Signal-to-Noise Ratio (SNR) of sensor and the electro-mechanical noise due to sensor functionalities and a simulated SRF has been considered.

Thank You for attention