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A spectra classification methodology of infrared hyperspectral images to reach near real-time SO₂ emission flux estimation of Mount Etna plume

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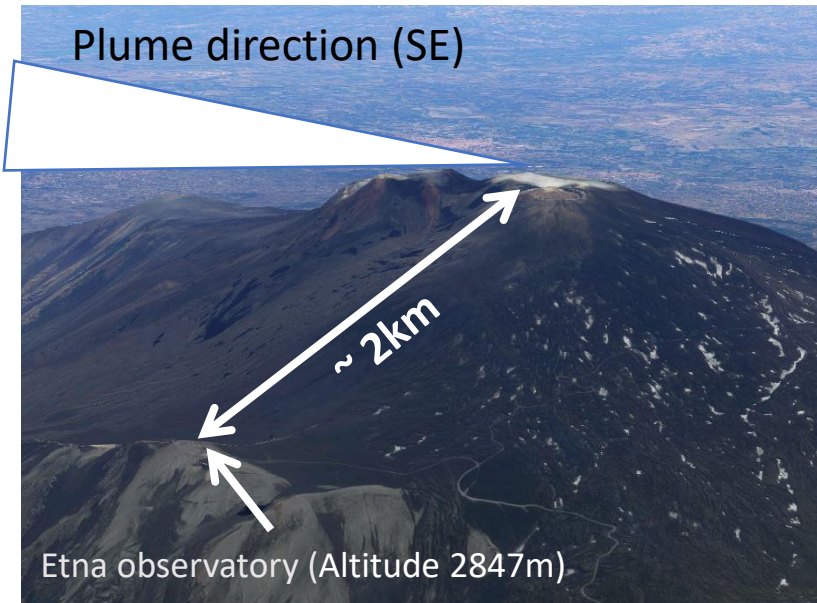
³ LMV, OPGC, Université Clermont Auvergne, Clermont Ferrand, France

Study context

IMAGETNA Campaign 21-26 June 2015 at Mount Etna during quiescent state of activity



In collaboration with:
LPC2E (Orléans, FR)
LATMOS (Paris, FR),
INGV (Italie),
ONERA (Palaiseau, FR),
LOA (Lille, FR)



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Deployment of the HyperCam LWIR (Telops Co.)

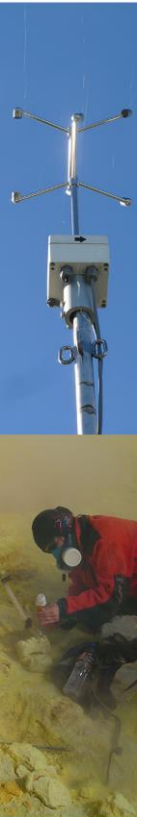
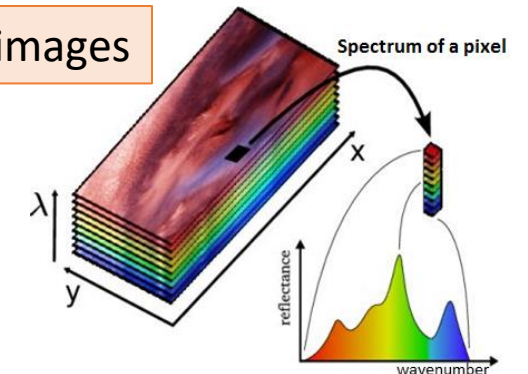
→ **Hyperspectral Imager** in TIR

[7.7 – 11.8] μm (i.e. [850 – 1300] cm^{-1})

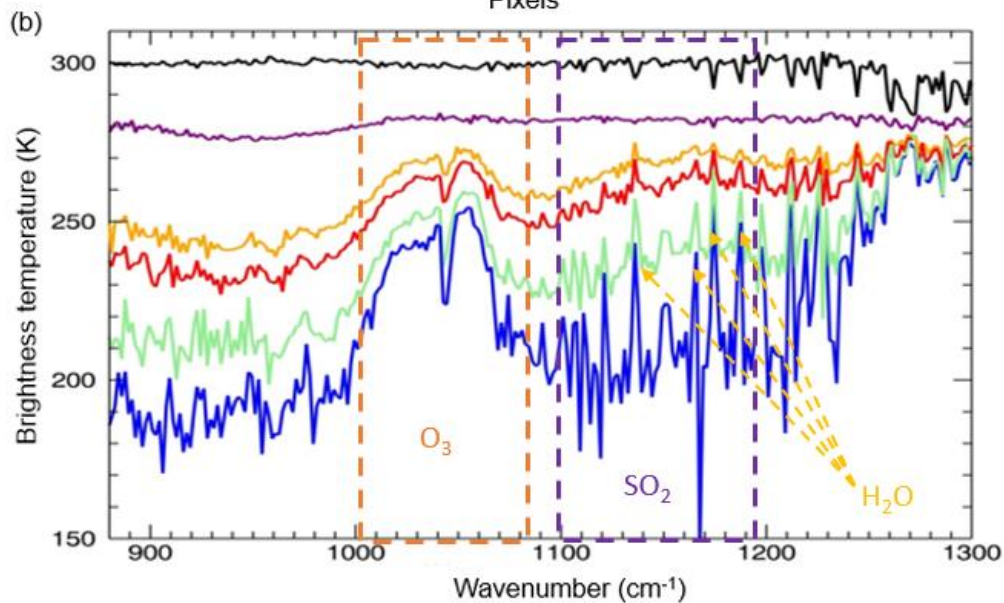
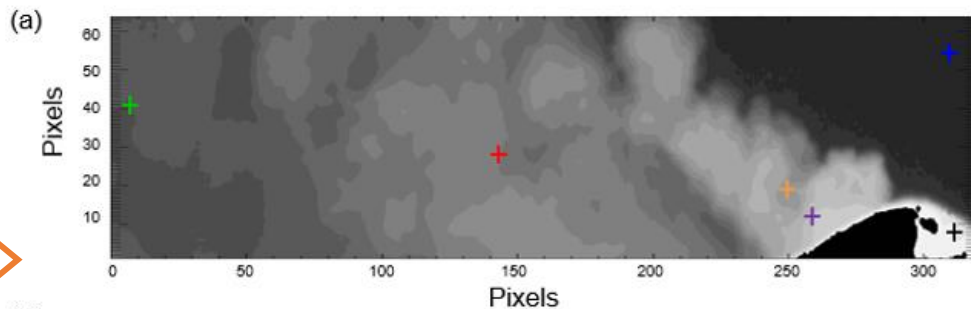
Max spectral resolution 0.5 cm^{-1}

320 x 256 pixels ; FOV: 6.4 × 5.1°

3D images

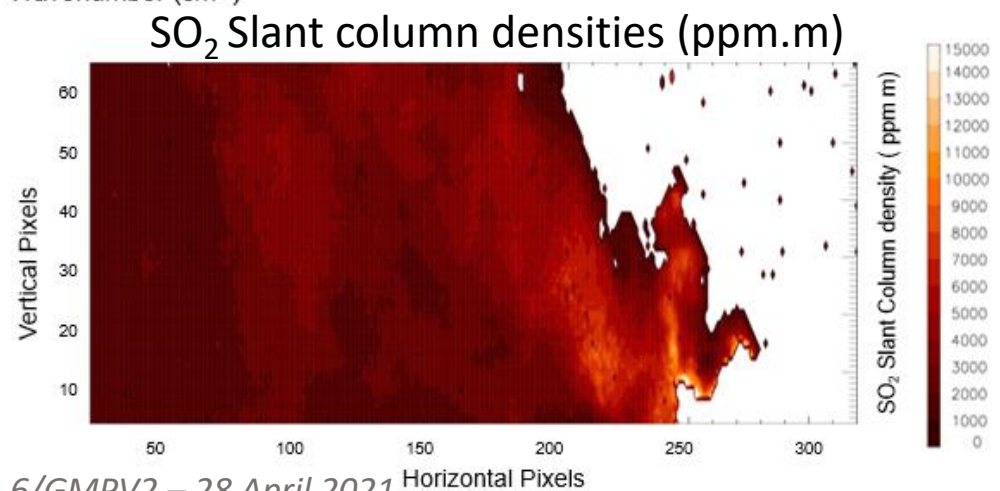


Objectives



**Optimal
retrieval**

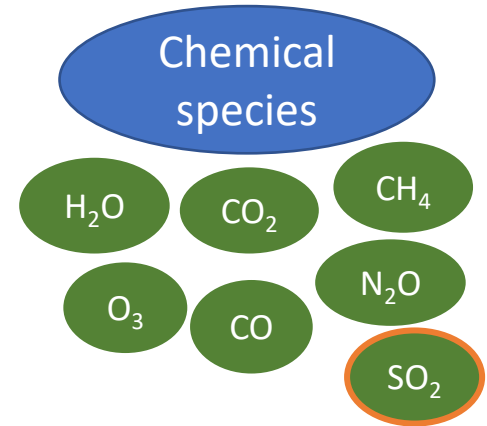
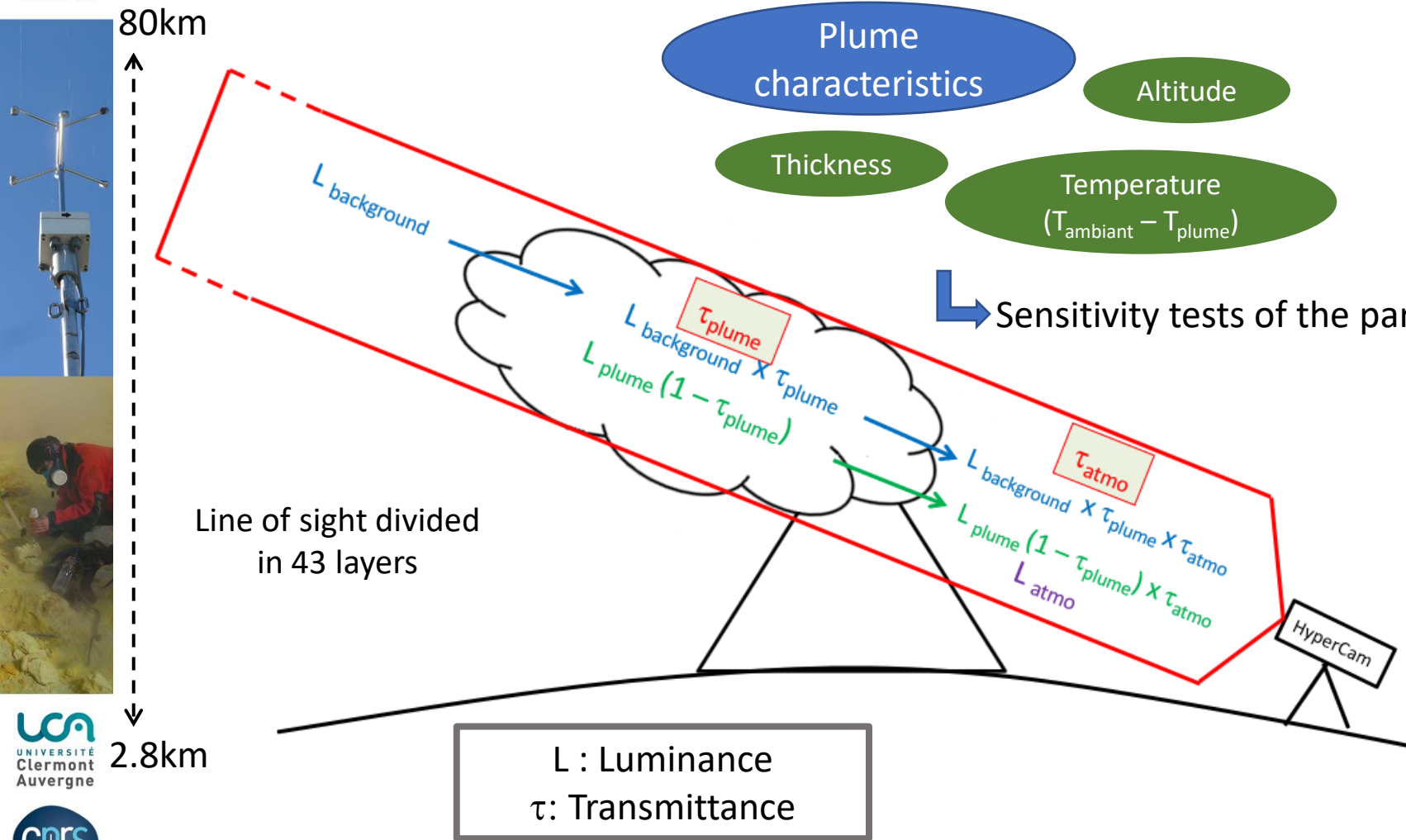
**Emission fluxes
of SO₂**



Optimal retrieval of slant column densities

Radiative transfert model + Minimization algorithm (Levenberg-Marquardt type)

→ LARA (LATMOS Atmospheric Retrieval Algorithm)¹



Vertical profile (radiosounding)

- Pressure
- Temperature

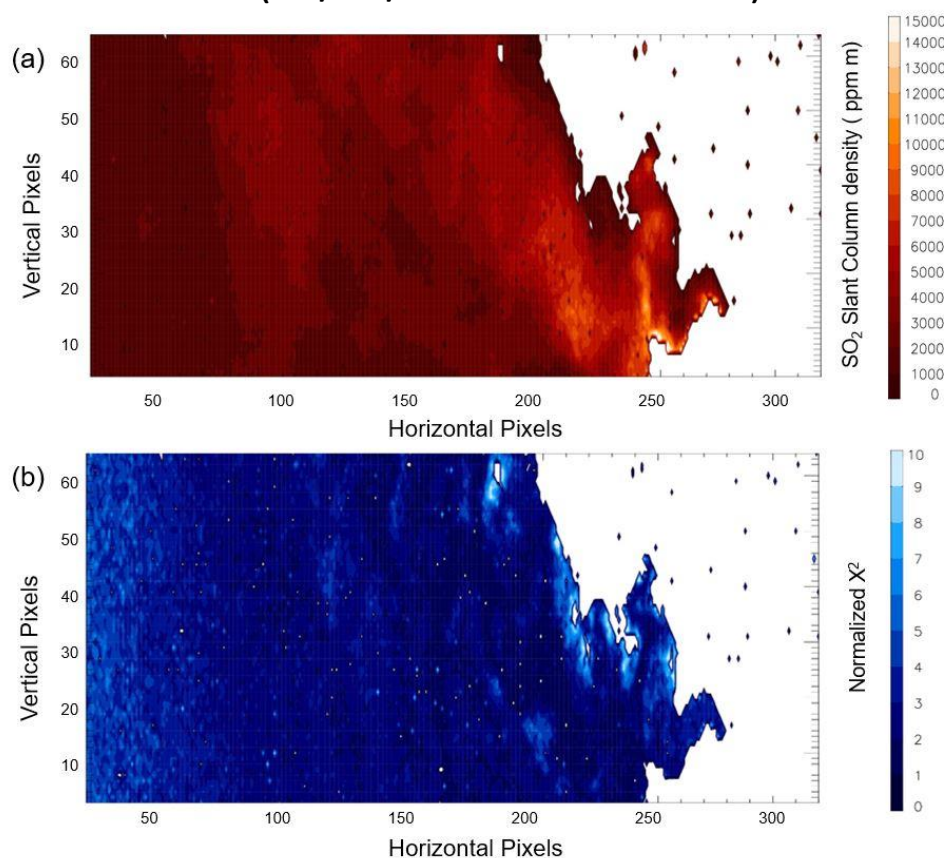
Parameterization validated
→ Robust model

¹ Payan et al. 1998, 2010



Results – Pixel-by-pixel retrieval

SO₂ Slant column densities ppm.m
(26/06/2015 – 08:27 UTC)



*Published in: Huret et al. - Remote Sensing 2019, 11, 1175
doi:10.3390/rs11101175*

- Retrieval of 1 image = 7 days of calculation on Ciclad (IPSL computers) for SO₂ micro-window
- Very good quality of retrieval with reduced $\chi^2 \leq 5$

Dataset from IMAGETNA campaign:
- 6 200 images
- 116 millions of pixels

➔ 110 years of calculation!

Development of a methodology for fast and massive retrieval of the images



Images massive retrieval: creation of a neural network

Neural network
2 layers = 2 spectral information

Training dataset
5 images = 102400 pixels

I_{O_3}

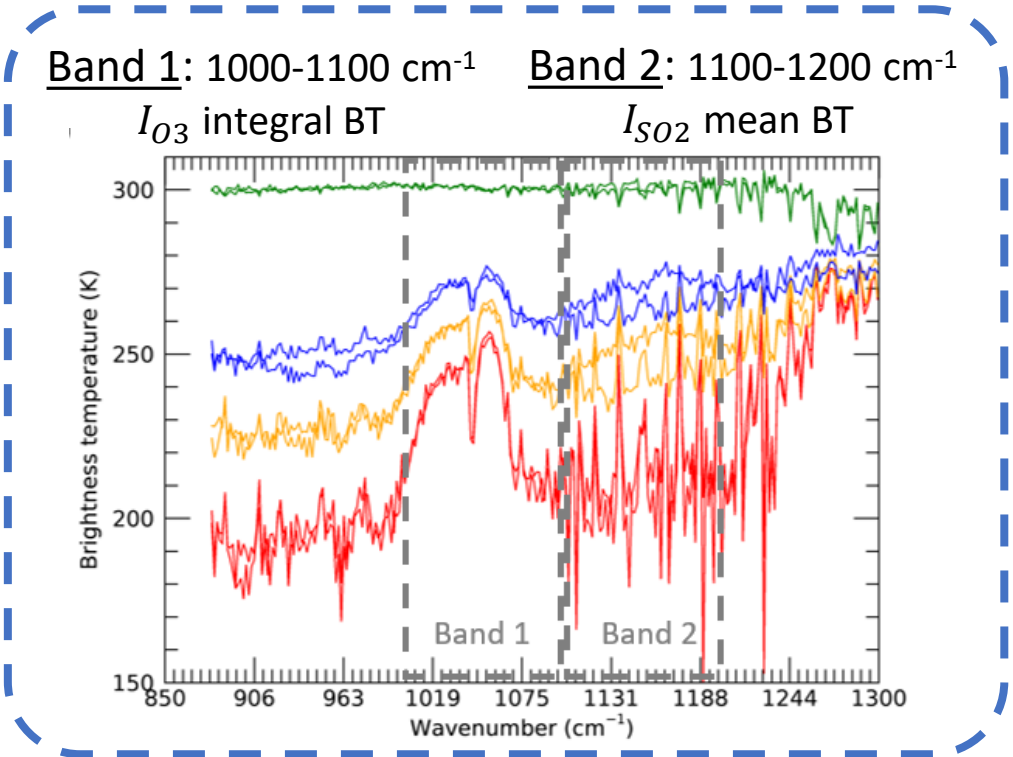


I_{SO_2}

SO₂ SCD
(ppm.m)

Library
 $SO_2 = f(I_{O_3}, I_{SO_2})$

Band 1: Atmosphere opacity Band 2: SO₂ concentration



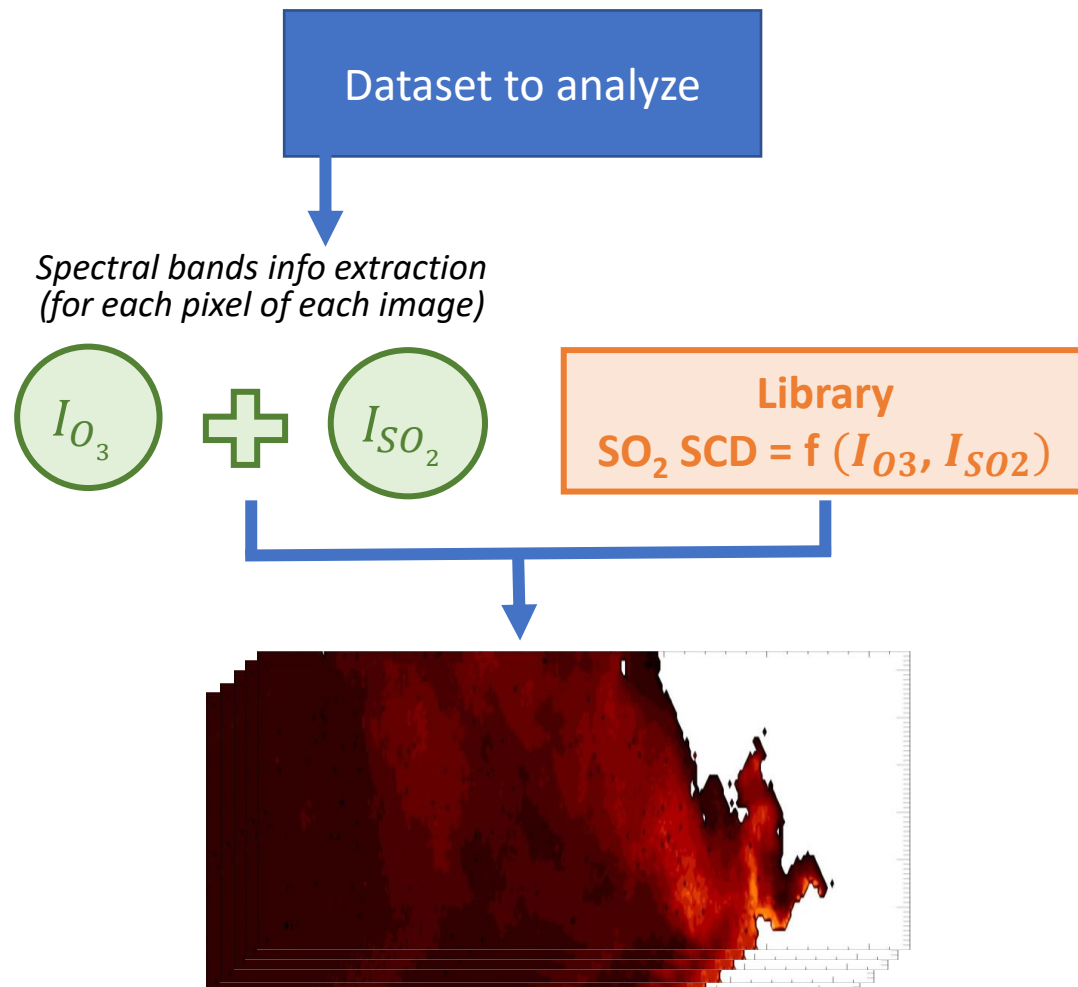
- Training dataset:
 - 5 images with SO₂ SCD retrieved pixel-by-pixel
 - Tested dataset:
 - ~ 900 images from sequences with similar geometry and weather conditions.
- Library containing 195 classes**



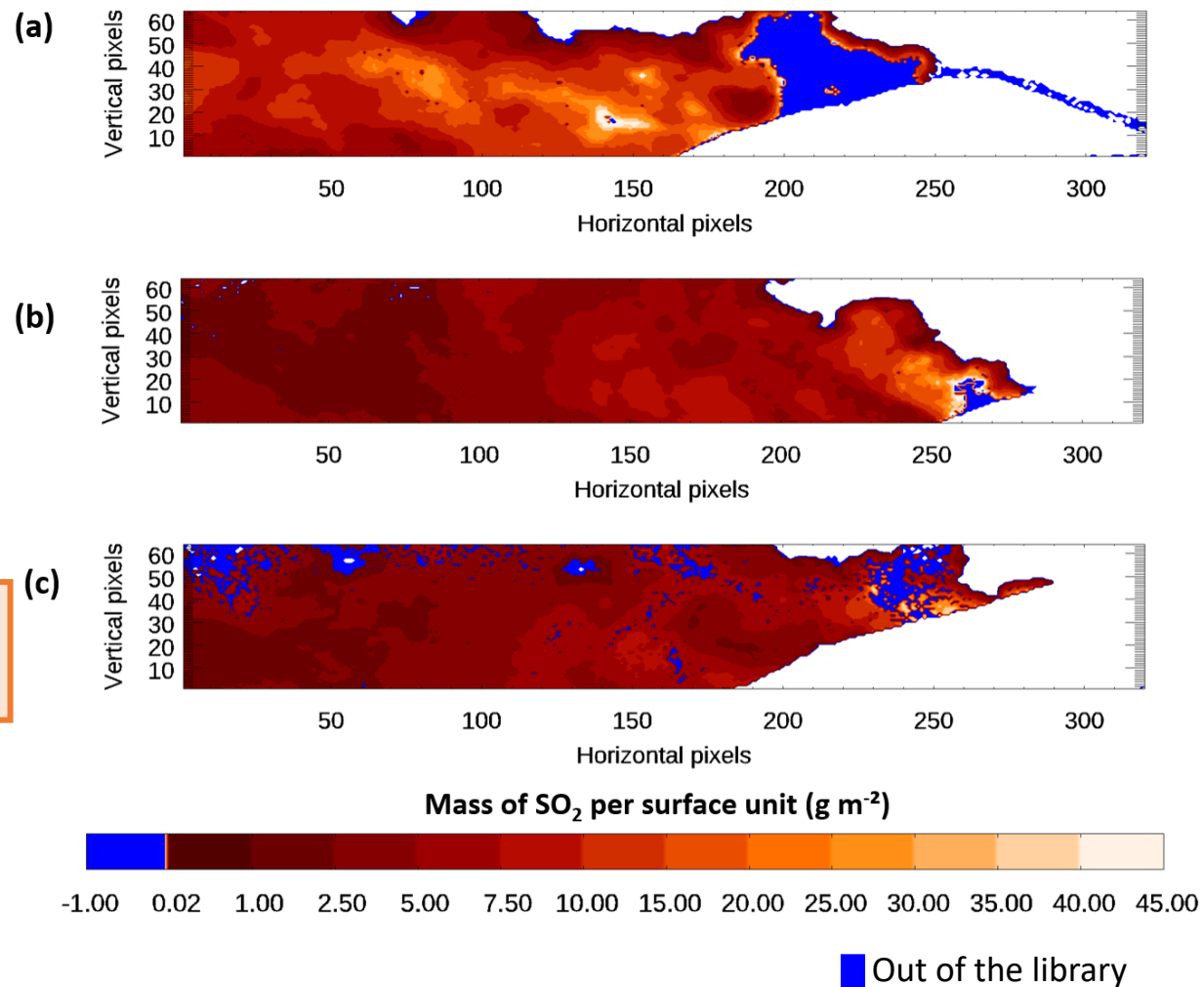


Massive retrieval : results

- Tested dataset pixels classified and images of SO₂ SCD retrieved using the library.
- ~ 15% of missing classes in the library (pixels in blue) mostly in dense plume part.



Examples of retrieved images:



1 image processed in ~40 seconds !



For more information

- **Huret, N. et al.,** *Infrared Hyperspectral and Ultraviolet Remote Measurements of Volcanic Gas Plume at MT Etna during IMAGETNA Campaign.* *Remote Sensing* **2019**, 11, 1175 (<https://doi.org/10.3390/rs11101175>)
- **Segonne, C. et al.,** *A Spectra Classification Methodology of Hyperspectral Infrared Images for Near Real-Time Estimation of the SO2 Emission Flux from Mount Etna with LARA Radiative Transfer Retrieval Model.* *Remote Sensing* **2020**, 12(24), 4107 (<https://doi.org/10.3390/rs12244107>)

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