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To cite this version:

HAL Id: insu-03183348
https://insu.hal.science/insu-03183348
Submitted on 1 Mar 2022

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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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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)

Plume direction (SE)

Etna observatory (Altitude 2847m)

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

Emission fluxes of \( \text{SO}_2 \)

Optimal retrieval

\( \text{SO}_2 \) Slant column densities (ppm.m)
Optimal retrieval of slant column densities

Radiative transfer model + Minimization algorithm (Levenberg-Marquardt type) → LARA (LATMOS Atmospheric Retrieval Algorithm)$^1$

- Sensitivity tests of the parameters
- Line of sight divided in 43 layers
- Pressure, Temperature, Vertical profile (radiosounding)
- Chemical species: H$_2$O, CO$_2$, CH$_4$, O$_3$, CO, N$_2$O, SO$_2$
- Plume characteristics: Altitude, Thickness, Temperature ($T_{\text{ambient}} - T_{\text{plume}}$)
- Parameterization validated → Robust model

$^1$ Payan et al. 1998, 2010

vEGU 2021 – #15239 – PICO session ITS3.6/GMPV2 – 28 April 2021
Results – Pixel-by-pixel retrieval

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

- 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

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

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

110 years of calculation!
Images massive retrieval: creation of a neural network

Training dataset
5 images = 102400 pixels

Neural network
2 layers = 2 spectral information

\[ SO_2 = f(I_{O_3}, I_{SO_2}) \]

Library containing 195 classes

➢ Training dataset:
  • 5 images with SO\(_2\) SCD retrieved pixel-by-pixel

➢ Tested dataset:
  • ~ 900 images from sequences with similar geometry and weather conditions.

\begin{itemize}
  \item Band 1: 1000-1100 cm\(^{-1}\)
  \item Band 2: 1100-1200 cm\(^{-1}\)
\end{itemize}
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.

Dataset to analyze

Spectral bands info extraction (for each pixel of each image)

\[
I_{O_3} + I_{SO_2} \rightarrow SO_2 \text{ SCD} = f(I_{O_3}, I_{SO_2})
\]

Examples of retrieved images:

- 1 image processed in ~40 seconds!
For more information


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