

Remote ground-based observation of volcanic degassing

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• SCIENTIFIC RATIONALE

- Remote observation of volcanic SO₂ column amounts and emission rates by spectroscopy approach (COSPEC, DOAS UV scanning FLAME network and UV camera)
- Retrieval: inversion of UV spectra in SO₂ Cross-section profiles and into SO₂ mass flux
- Validation of SO₂ column amounts and mass flux
- UV camera

• SCIENTIFIC RATIONALE

The chemical compositions and emission rates of volcanic gases carry important information about underground magmatic with application in eruption forecasting.

Volcanic plumes are also studied because of their impacts upon the atmosphere, climate and human health

Ground based optical passive/active remote sensing methods give the opportunity to measure both variations of gas compositions and fluxes.

Validation space-based retrieval

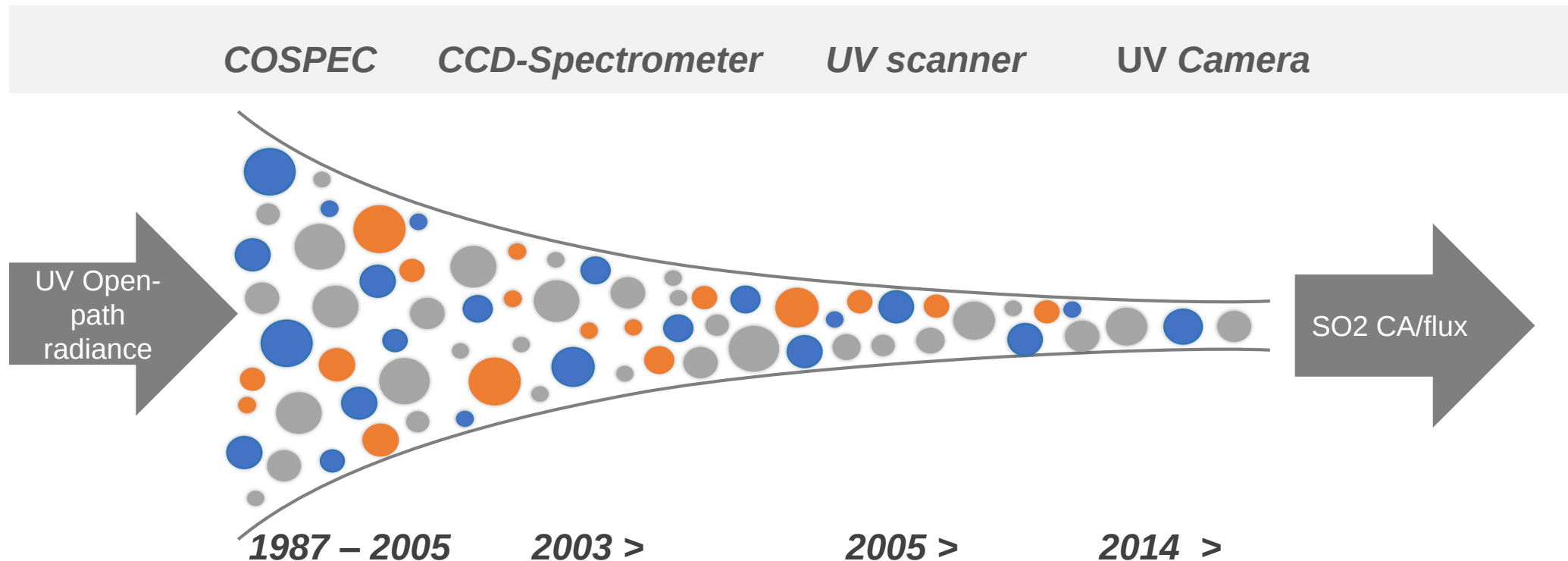
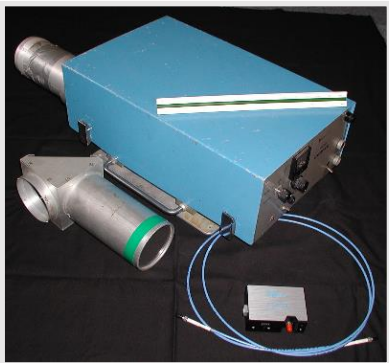
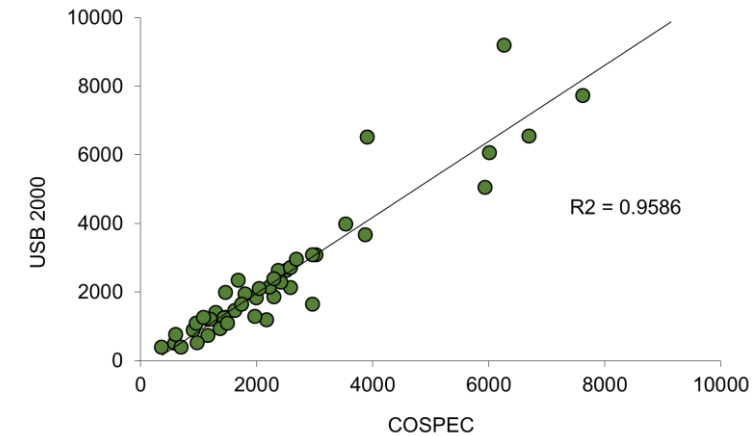


• SCIENTIFIC RATIONALE



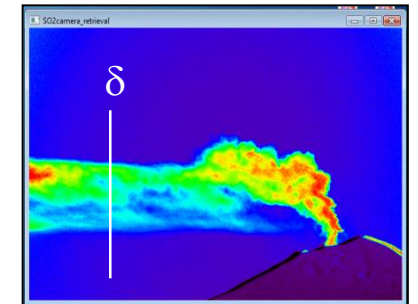
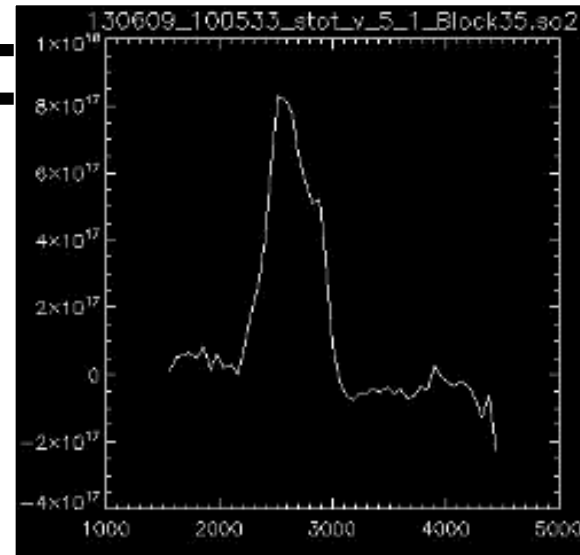
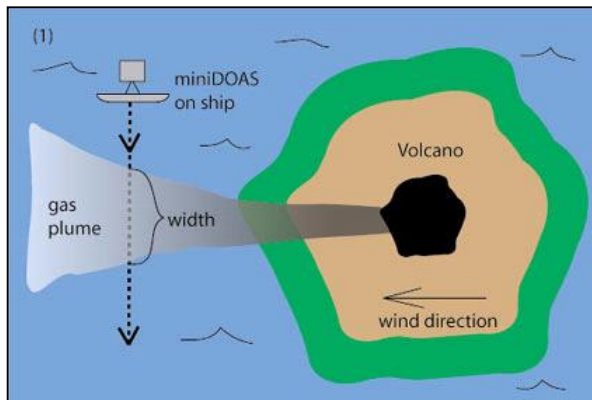
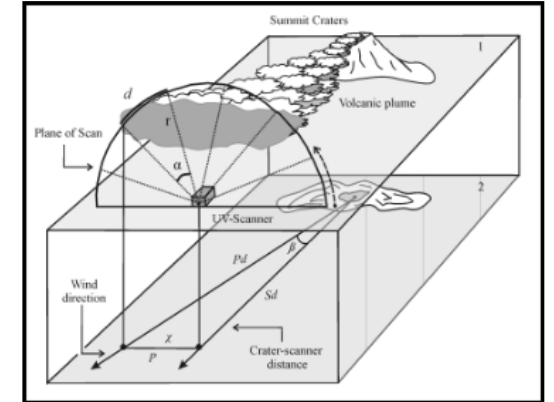
Daylight remote observation of volcanic degassing at Sicilian active volcanoes since 1987

Scatter plot between SO₂ flux measurements recorded simultaneously by COSPEC & USB2000 between Jan and July 2005, R²: 0.96

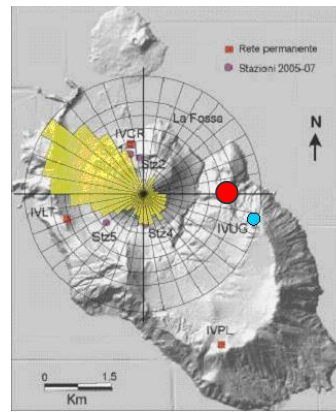
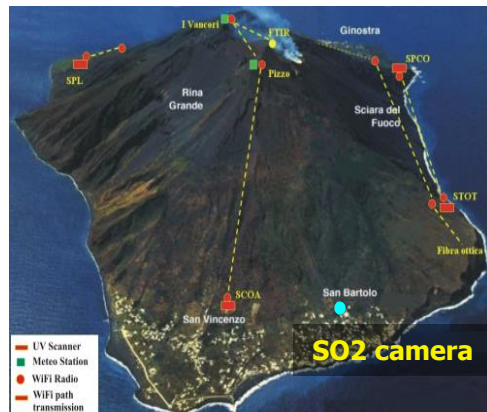


• OBSERVATIONAL INFRASTRUCTURE

Remote observation of volcanic degassing is pioneering carry out at Sicilian active volcanoes, from tens to hundred data per day through COSPEC, Scanner-FLAME to UV-Camera



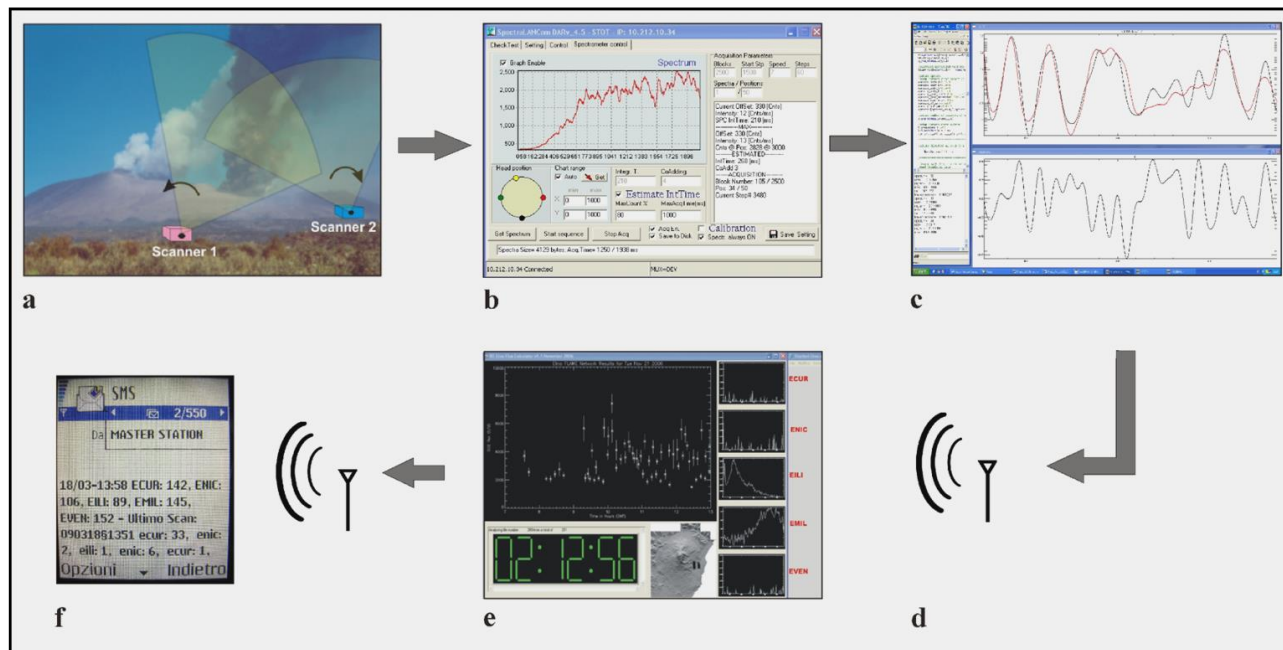
• OBSERVATIONAL INFRASTRUCTURE



Remote observation of volcanic SO₂ flux by the DOAS UV scanning spectrometer FLAME network

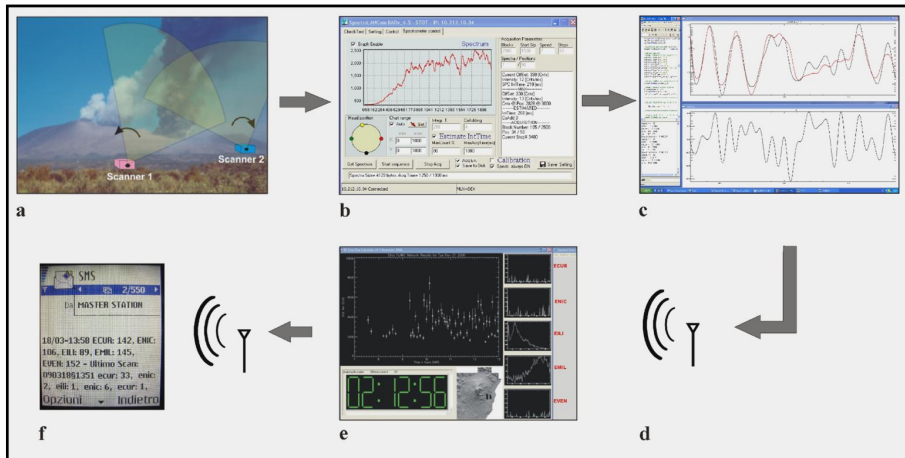
- Each UV-Station scans the sky horizon to horizon
- spectra are reduced in SO₂ column amounts by DOAS using a no-volcanic polluted modelled sky spectrum $I_o(\lambda)$
- Retrieved SO₂ cross section are in real-time transmitted to INGV where flux is computed
- SO₂ flux every ~5 minutes

Ten at Etna, Four at Stromboli, One at Vulcano



Chaparrastique, El Salvador (2014)

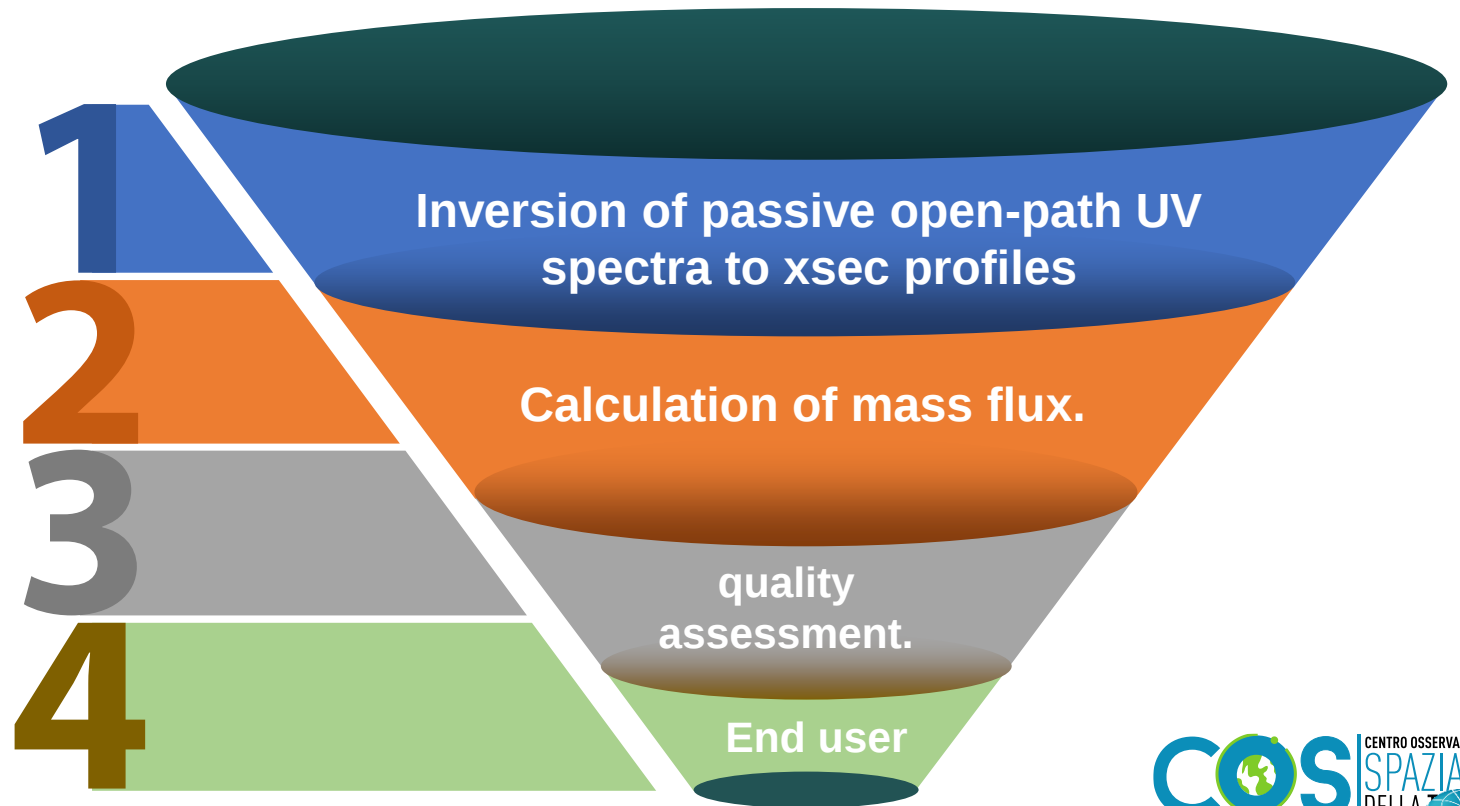
• OBSERVATIONAL INFRASTRUCTURE



Automatic Retrieval of SO₂

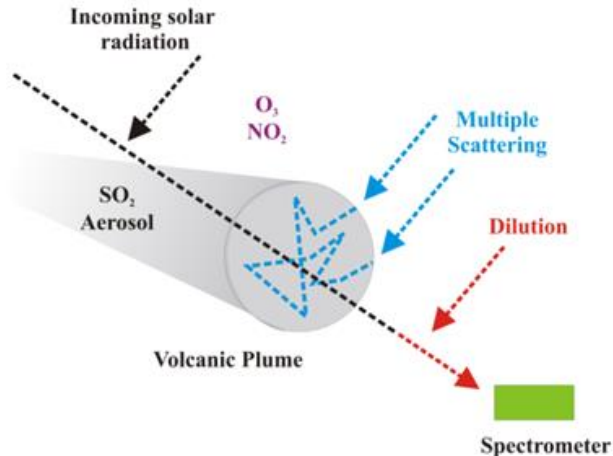
BrO and NO₂ can be inverted
for specific purpose of
validation/research

Data processing



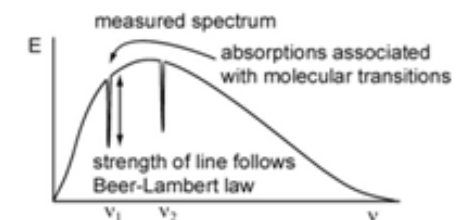
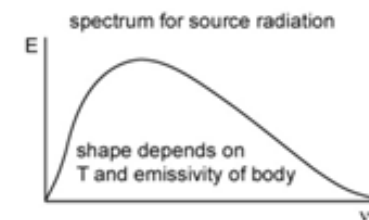
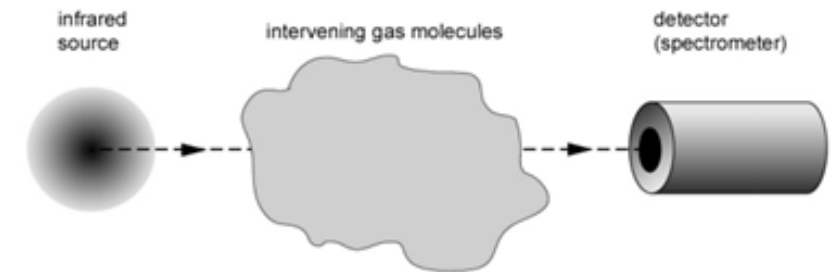
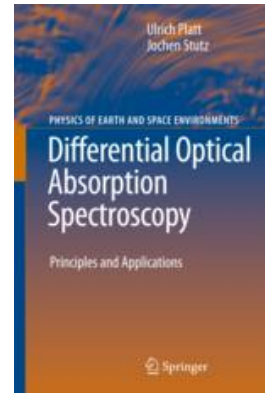
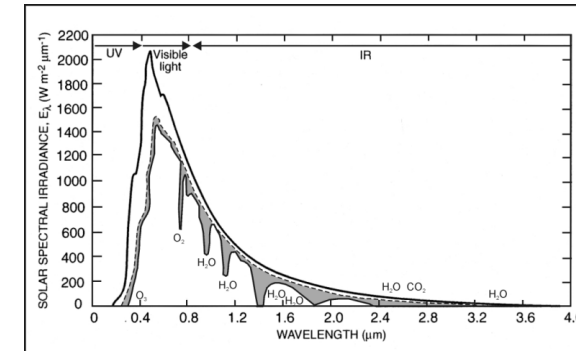
• SCIENTIFIC RATIONALE

- Absorption spectroscopy, depletion of light absorbed by gas at a given wavelength.
- Function of wavelength and frequency,
- Each molecules of gas absorbs at specific wavelength, and has defined spectral features
- Absorption follow the Beer-Lambert Law
- Retrieval of volcanic SO₂, BrO, NO₂, H₂S (active)



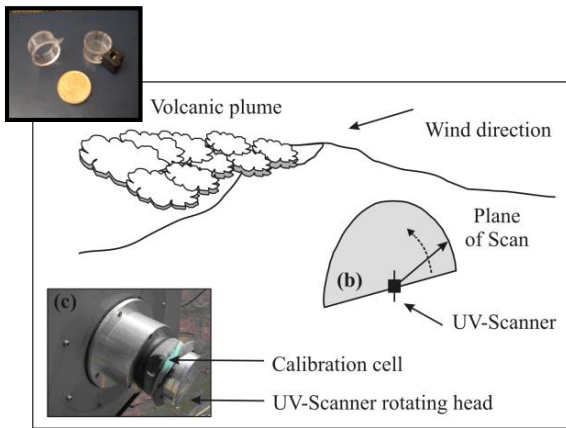
multiple scattering and dilution of the radiation might underestimate retrieved column amounts

Underestimations due to sustained ash curtain



• Retrieval: inversion of passive UV open-path radiance in SO₂ xsec

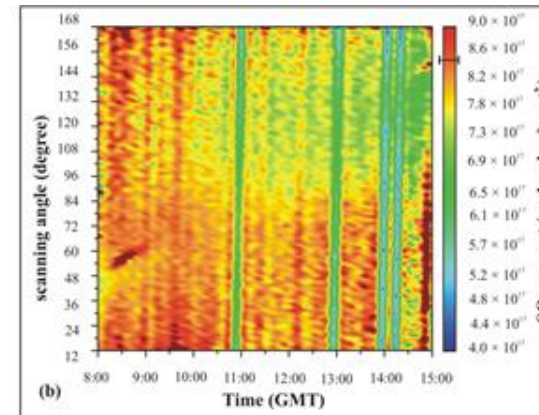
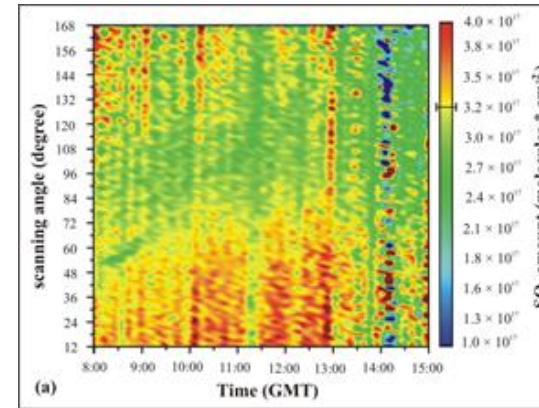
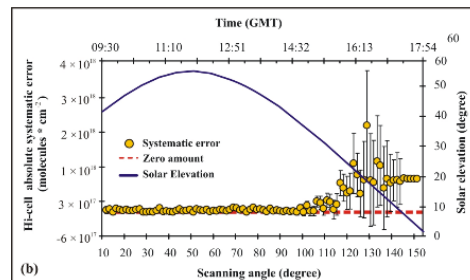
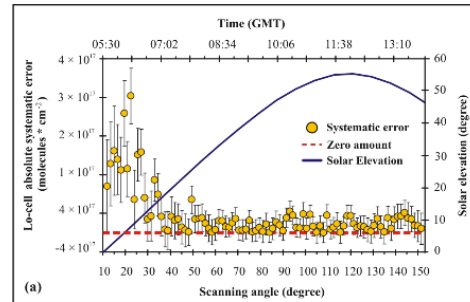
Challenge of permanent scanning spectrometer is the SO₂-free reference spectrum. Open-path UV spectra are inverted in DOAS using a modelled reference spectrum based on an high-resolution solar spectrum



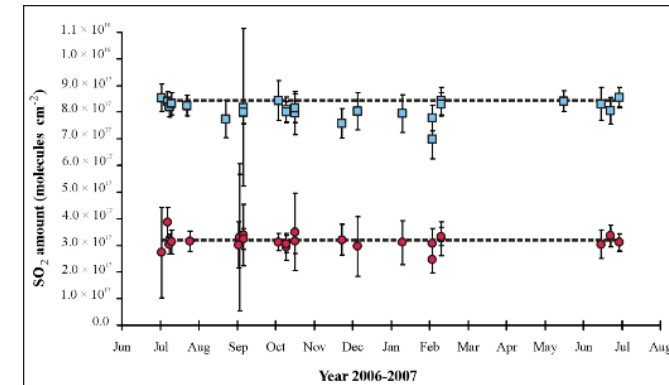
100 calibrated SO₂-spectra collected for each scanning angle to estimate the accuracy of the retrieval

Calibrated SO₂ quartz-cell spectra

Sensitivity analysis on retrieval scenario in terms of best S/N and minimum error



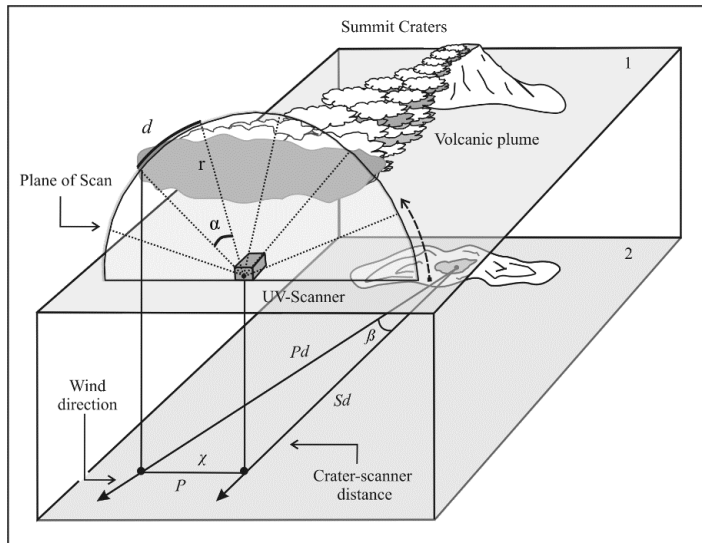
Error mostly dependent on the S/N of the spectra and therefore can vary mainly as factors of the time of the day and secondly of the viewing angle. Error budget of 12%



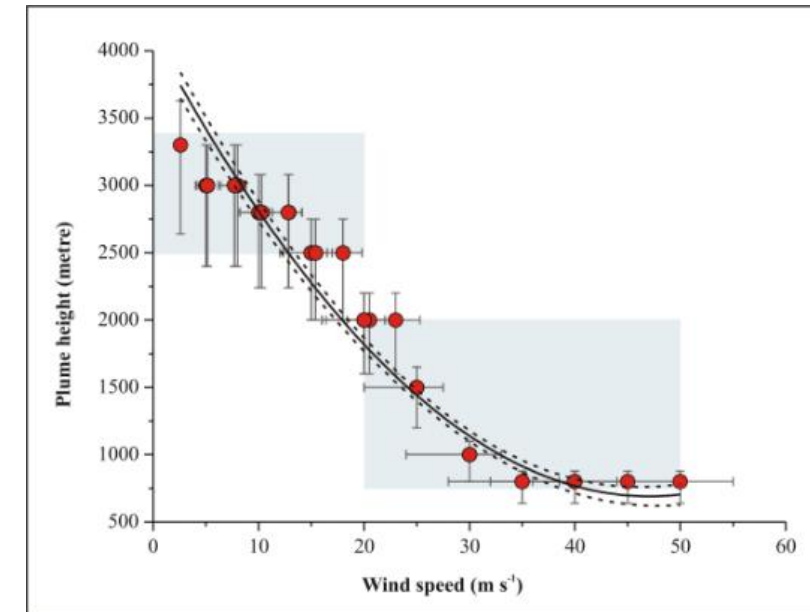
Simulation of retrieval behaviour over a day

• Retrieval: Conversion of SO₂ plume xsec profiles into SO₂ flux

- Plume Geometry resolved by radian geometry coupled with a data quality assessment on quality plume profiles
- Mass flux of SO₂ automatically calculated using wind speed data from a high-resolution meteorological model (LAMI - ECMWF)
- Accuracy depends mostly on plume geometry and data quality

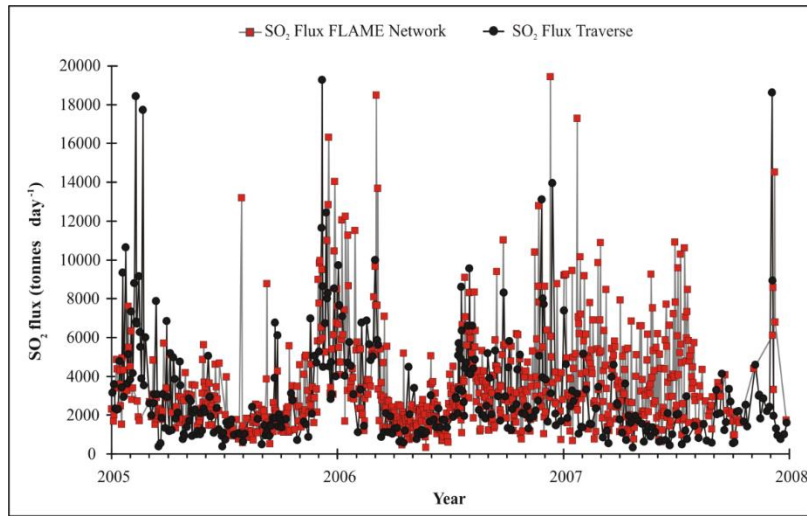


- plume height is empirically retrieved by a linear relationship between systematic variation in plume height and wind speed
- It works very well for passive degassing, moderate eruption but not for paroxysmal eruption in which height might be up to 10 km, mass flux needs to be re-process

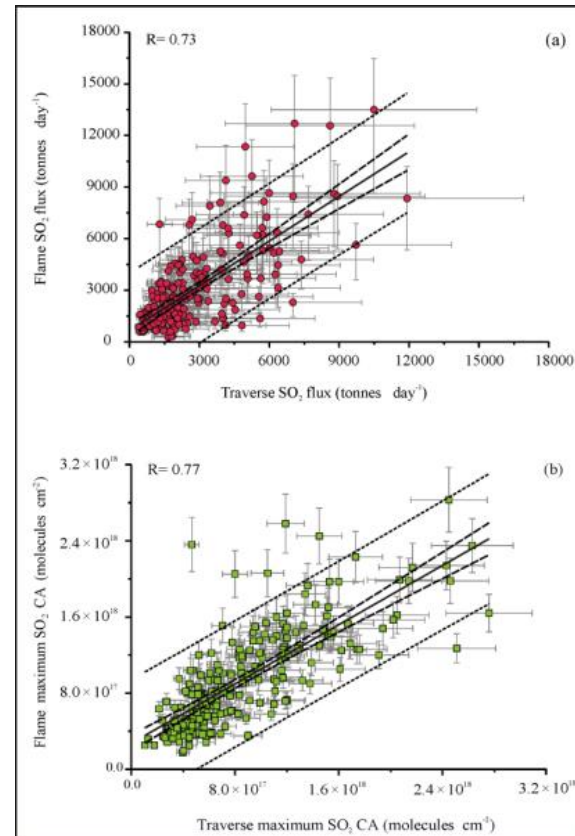


Uncertainty in flux is of -22 and +36% due to spectra retrieval, multiple scattering, wind-speed, plume-height, plume-geometry

• Validation of SO₂ column amounts and mass flux

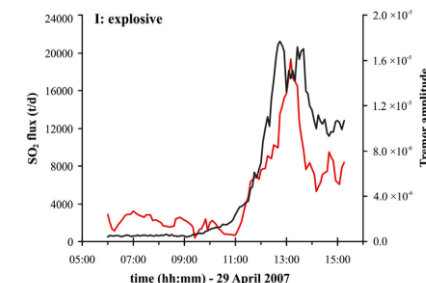
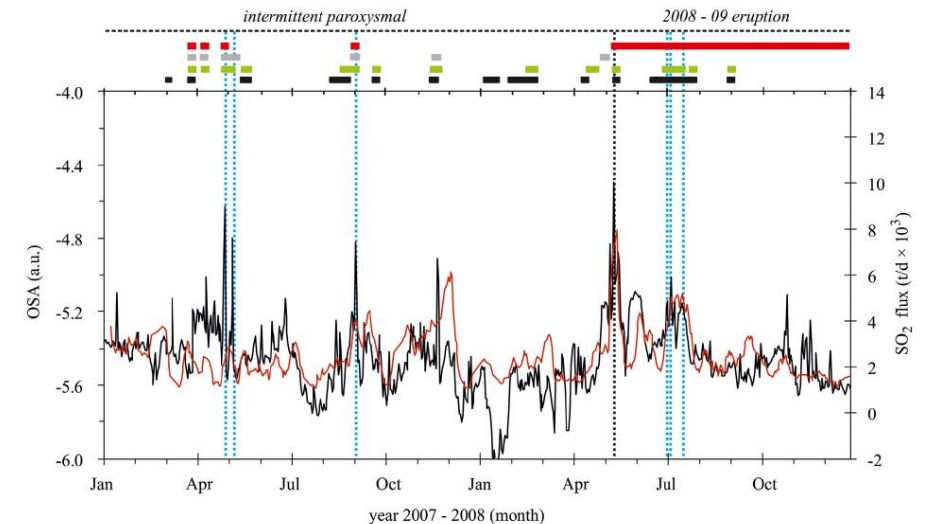


Comparison between measured scanning fluxes with those obtained by conventional car-based traverses Daily averaged SO₂ flux (in red) and daily averaged overall spectral amplitude of the volcanic tremor (in black) in 2007 and 2008.

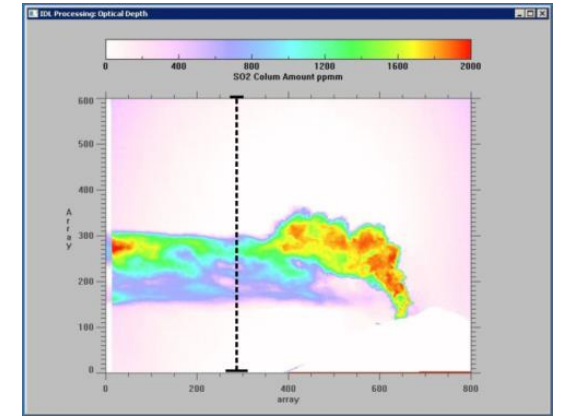
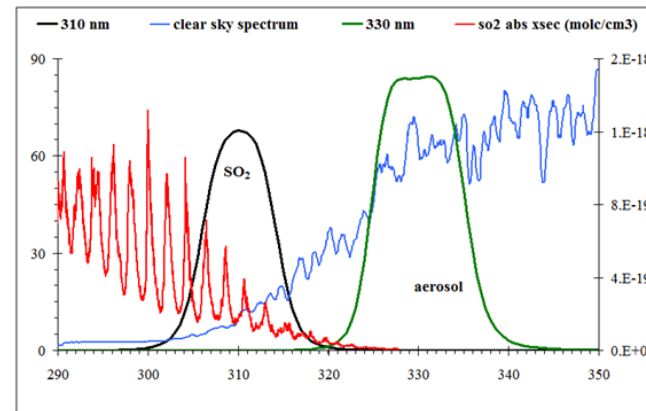


Scatter plots for the averaged flux (a) and the maximum CA (b) measured by the network vs. those recorded by traverses, correlation factors of 0.73 and 0.77, respectively

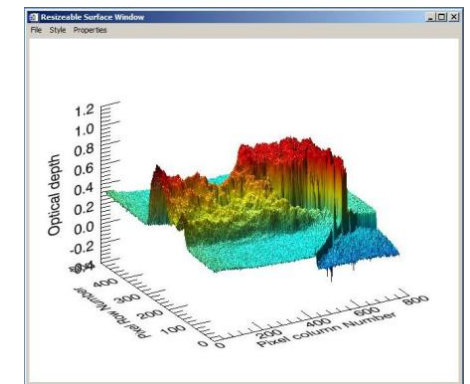
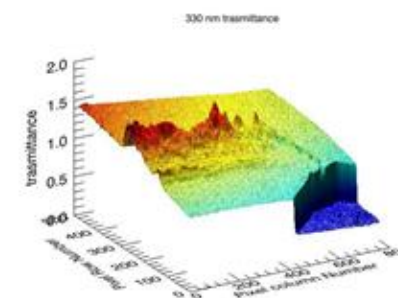
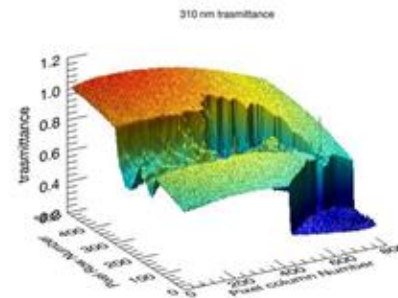
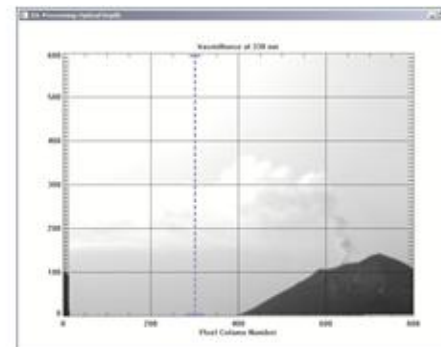
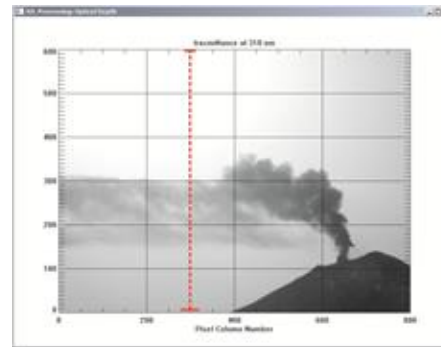
Bulk SO₂ flux and seismic tremor between 2007 and 2008. A good agreement was found between the datasets, both in terms of magnitude and temporal variations



• Retrieval: UV camera



- Considering wavelength in which there is and there is not SO₂ absorbance, e.g, 310 and 330 nm
- Vignetting by clear-plume normalization
- Inversion in absorbance by Beer-Lambert
- Convert apparent SO₂ column amounts in absolute using SO₂ cells/DOAS
- Retrieval of the plume-transport speed
- Calculation SO₂ flux



• PRODUCTS AVAILABLE

Open-path UV spectra (passive/active)
SO2 Column amount,
BrO;NO2 column amount inverted for specific purpose of research/validation
Automatic Bulk SO2 CA/Flux

• CURRENT DISTRIBUTION OF PRODUCTS

Monitoring purpose, Department of civil Protection
Research: eruptive processes, satellite validation, climatic impact
Projects

• TEAM AND AFFILIATIONS

Giuseppe Salerno (researcher)
Tommaso Caltabiano (Technologist, fellow INGV OE)
Filippo Murè (Technicians)
Paolo Principato (Technicians)
Roberto Maugeri (Technologist)