# Monitoring volcanic $SO_2$ emissions with the Infrared Atmospheric Sounding Interferometer

Isabelle A. Taylor, Elisa Carboni,
Tamsin A. Mather, Roy G. Grainger and Simon A. Carn

**Study Aims:**

- To investigate how the IASI instrument and University of Oxford linear $SO_2$ retrieval can be used to assess ongoing emissions of $SO_2$ at volcanoes across the globe
- To explore the strengths and weakness of a new emission rotation algorithm which is used to isolate and enhance the $SO_2$ signal. It is then used to assess ongoing changes.
- To create a dataset that is complementary to existing methods for assessing long term volcanic activity.

UNIVERSITY OF OXFORD

Michigan Technological University 1885

EODG
eodg.atm.ox.ac.uk

CENTRE FOR OBSERVATION & MODELLING OF EARTHQUAKES, VOLCANOES & TECTONICS

NERC SCIENCE OF THE ENVIRONMENT

DOCTORAL TRAINING PARTNERSHIP ENVIRONMENTAL RESEARCH

| Summary of the IASI instrument | |
|---|---|
| Satellites | MetOp-A, B and C |
| Launch | 2006, 2012, 2018 |
| Spectral Range | 645 – 2760 $cm^{-1}$ (3.62 – 15.5 µm) – covering three $SO_2$ absorption bands |
| Spectral Resolution | 0.5 $cm^{-1}$ |
| Swath Width | 2200 km |
| Spatial resolution | Circular pixels - 12 km diameter |
| Temporal resolution | Global coverage twice a day |

© Authors. All rights reserved

isabelle.taylor@physics.ox.ac.uk

@IA_Taylor

# Methods

## Linear Retrieval

Developed by Walker *et al.* (2011; doi:10.5194/amt-4-1567-2011).

**Purpose:** Detects elevated levels of $SO_2$

**Method:**

- spectral background represented within covariance matrix

**Advantages:**

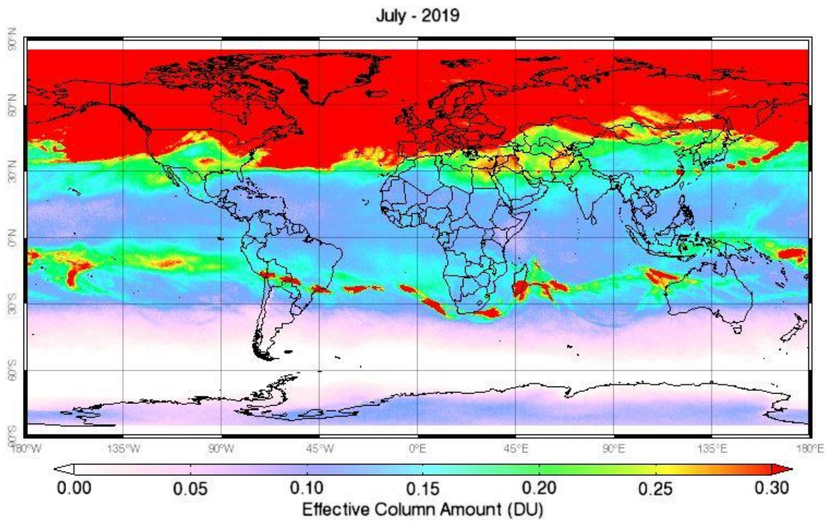
- Fast
- Using full spectrum in $\nu_3$ absorption band = increased sensitivity

**Assumptions:**

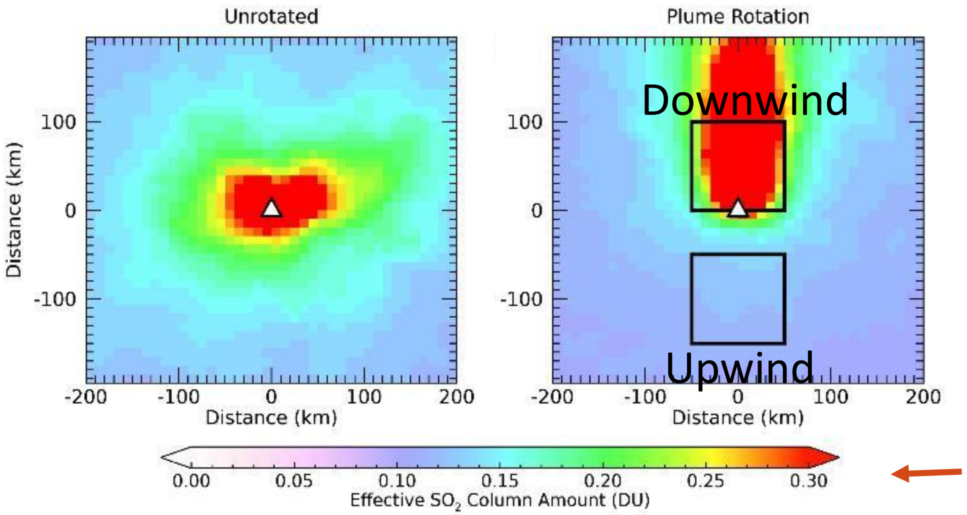
- Background covariance matrix
- Plume altitude

**Application in this study:**

Applied globally to IASI-A data from 2007 to 2017




↑ Example of the linear retrieval averaged for July 2019. It is possible to see plumes from Raikoke (Kamchatka) and Ulawun (Papua New Guinea)




## Emission Rotations

To investigate how the retrieval performs at volcanoes across the globe we developed an emission rotation algorithm.

- At each volcano, if a plume is identified in an IASI orbit, the linear retrieval output is rotated so that it appears that the plume is travelling to the north of the volcano
- If no plume is identified then the linear retrieval output for that orbit is rotated with the wind direction at the volcano's vent (using ECMWF data)
- The unrotated and rotated data are then averaged over different time periods: monthly, annual and multi-annual

This helps to **isolate and enhance the $SO_2$ signal.**

To evaluate the long term emission changes we compute an **emission index** which is the difference between the mean column amount in the downwind (signal) and upwind (noise)

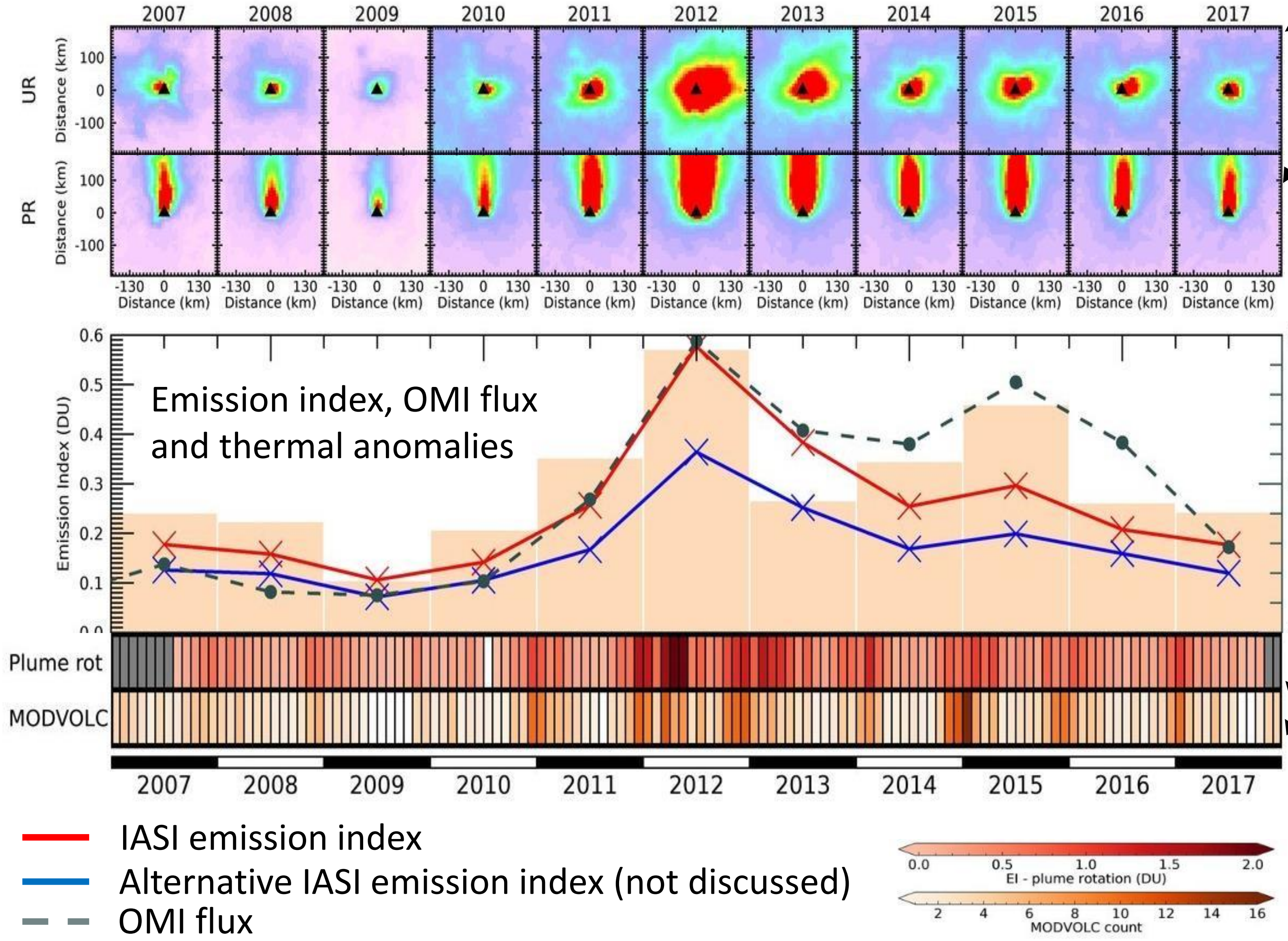
← Examples of annual averages – before and after rotations at Popocatepetl (2015)

© Authors. All rights reserved

isabelle.taylor@physics.ox.ac.uk
@IA_Taylor

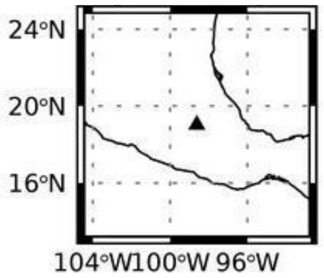
© Authors. All rights reserved

# Popocatepetl




Annual averages (unrotated)

Annual averages (rotated)




Example of the rotation scheme applied at Popocatepetl.
The emission index has been compared to fluxes generated by Carn *et al.* (2017; doi: 10.1038/srep44095) and the frequency of thermal anomalies detected with MODVOLC (Wright *et al.* 2004; doi:10.1016/j.jvolgeores.2003.12.008) There is good agreement between these.

MODVOLC data was downloaded from: http://modis.higp.hawaii.edu/ (April 2019)
MEaSURES $SO_2$ flux dataset was downloaded from https://so2.gsfc.nasa.gov/measures.html (March 2019)

Monthly emission index

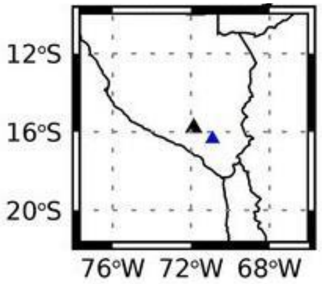
Monthly frequency of thermal anomalies

IASI emission index
Alternative IASI emission index (not discussed)
OMI flux

isabelle.taylor@physics.ox.ac.uk
@IA_Taylor

© Authors. All rights reserved

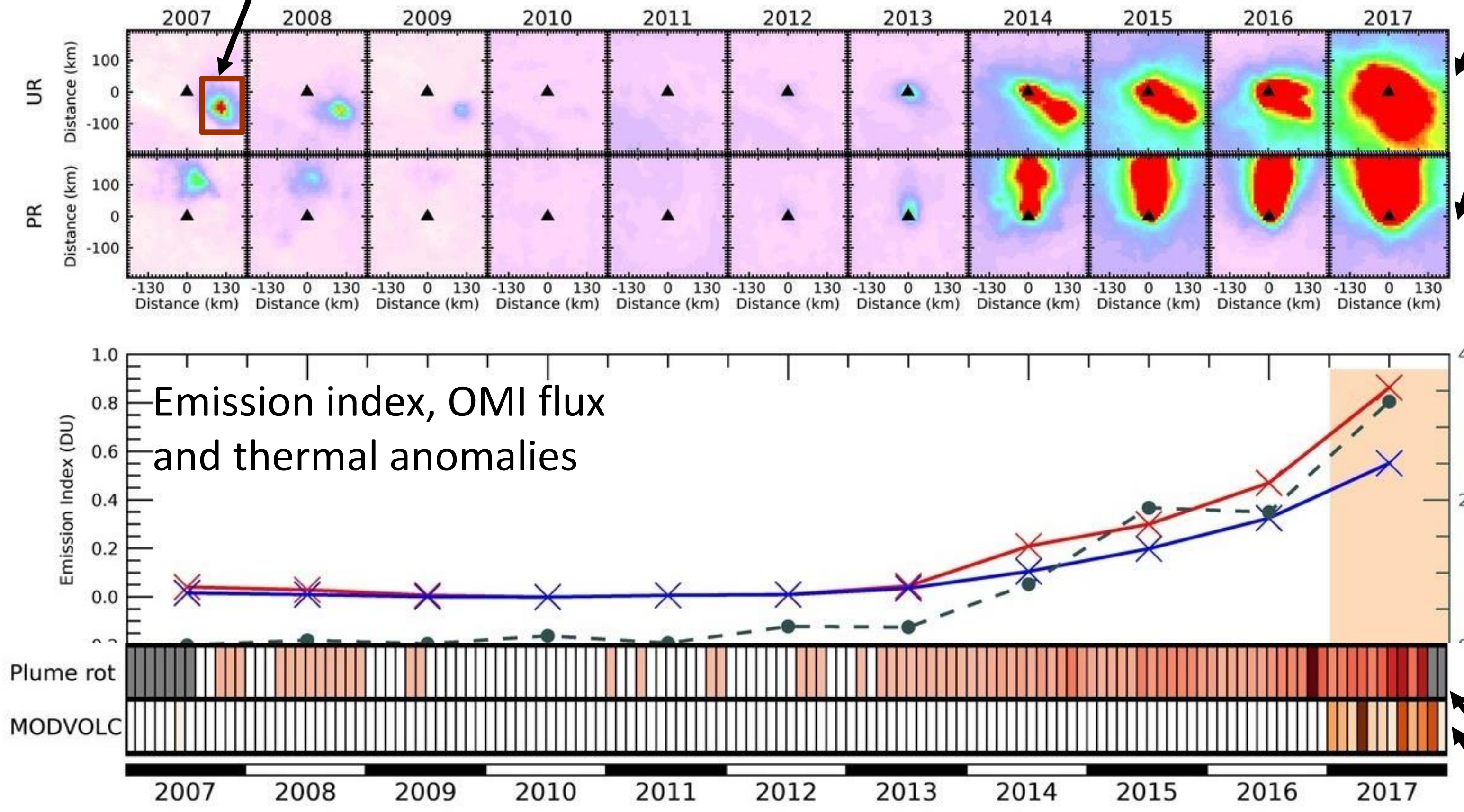
# Sabancaya




Sometimes results can be affected by neighbouring volcanoes. In this case Ubinas.

Annual averages (unrotated)

Annual averages (rotated)

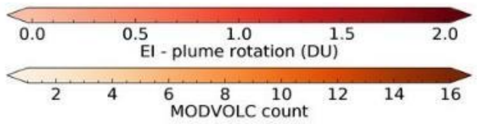



Example of the emission index at Sabancaya volcano in Peru. Here an increase in the IASI emission index and OMI flux can be seen 3 years before the onset of an eruption, marked by the emergence of the thermal anomalies.

Occasionally, there are false detections due to the neighbouring Ubinas volcano.

MODVOLC data was downloaded from: http://modis.higp.hawaii.edu/ (April 2019)
MEaSURES $SO_2$ flux dataset was downloaded from https://so2.gsfc.nasa.gov/measures.html (March 2019)

- IASI emission index
- Alternative IASI emission index (not discussed)
- OMI flux



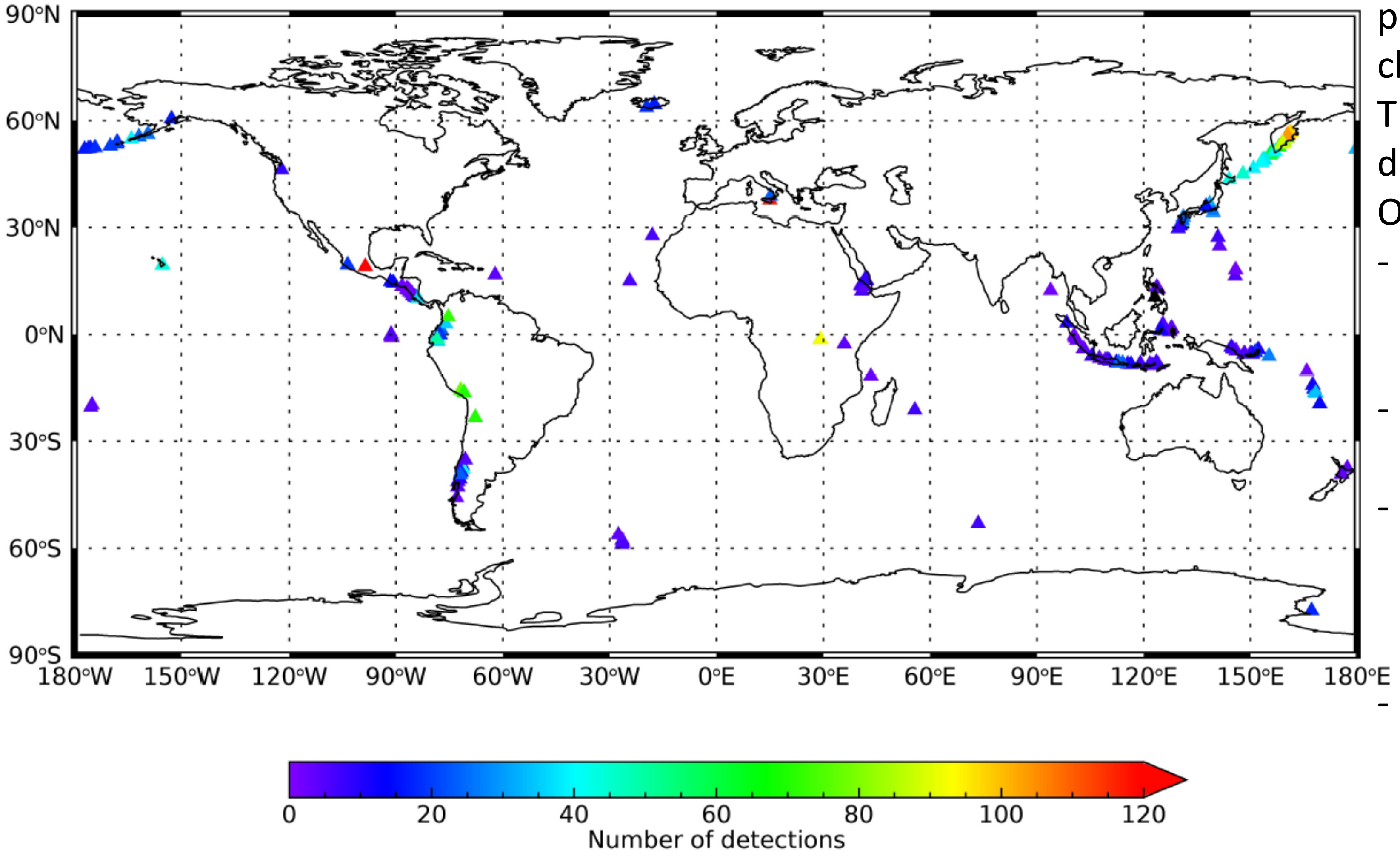

Monthly emission index

Monthly frequency of thermal anomalies

isabelle.taylor@physics.ox.ac.uk

@IA_Taylor

# Global Picture




The rotation scheme was applied to 166 volcanoes worldwide. Where the downwind signal was greater than the upwind signal plus two standard deviations of the upwind is classed as a detection.

The plot of the left shows the frequency of detections worldwide.

Observations:

- Greatest number of detections are at high altitude volcanoes (e.g. those in Central and South America)
- Less detections at lower altitude volcanoes (e.g. those in Asia)
- Numerous detections in Kamchatka – here volcanoes are in close proximity leading to plumes spanning multiple volcanic centres and false detections.
- A number of detections occur in high latitude winters making this a valuable resource which is complementary to UV datasets

© Authors. All rights reserved

isabelle.taylor@physics.ox.ac.uk
@IA_Taylor