Trace Gas Anomaly Detection for IASI Time-Series

Lucy Ventress, Roy Grainger, and Anu Dudhia
NCEO, Atmospheric, Oceanic and Planetary Physics,
University of Oxford
Contact: lucy.ventress@physics.ox.ac.uk

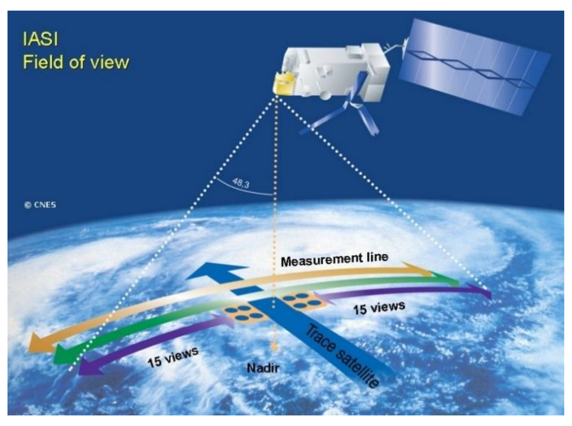
Introduction

In order to provide near real-time monitoring of atmospheric contaminants, fast and reliable methods are required to detect anomalies in the atmospheric state. Full optimal estimation retrievals are computationally expensive, therefore, faster methods are needed to identify such anomalous events and flag their presence.

IASI is a very useful tool for the observation and tracking of atmospheric pollutants, large aerosol particles (such as desert dust) and volcanic plumes. The method shown makes full use of the information from hyperspectral sounders and allows the presence of the target species to be determined in near real-time, if required.

IASI (Infrared Atmospheric Sounding Interferometer)

- Nadir viewing Fourier transform spectrometer
- Onboard MetOp-A and MetOp-B
- Spectral Range: 645 to 2760 cm^{-1} (3.62–15.5μm)
- Spectral Resolution: 0.25 cm^{-1} (unapodised)
- FOV: 2x2 matrix of 12 km (diameter) circles
- Each IASI instrument provides near global coverage every 12 hours



Detection Algorithm

- Fast detection methods based upon the work of Walker *et al.*[1] have been developed that look for departures of IASI spectra from an expected background covariance.
- An optimal unconstrained least-squares estimate (linear retrieval) of the state parameter is computed as:

$$\hat{\mathbf{x}} = \mathbf{x}_0 + \left(\mathbf{K}^{\mathrm{T}}\mathbf{S}_\varepsilon^{-1}\mathbf{K}\right)^{-1}\mathbf{K}^{\mathrm{T}}\mathbf{S}_\varepsilon^{-1}[\mathbf{y} - \mathbf{F}(\mathbf{x}_0, \mathbf{b})]$$

where $\mathbf{y}$ is the measurement vector, $\mathbf{F}(\mathbf{x}_0,\mathbf{b})$ is the reference climatological spectra calculated using a forward model, $\mathbf{x}_0$ is the climatological column amount and $\mathbf{S}_\varepsilon$ is the total error covariance matrix.

- The gain,

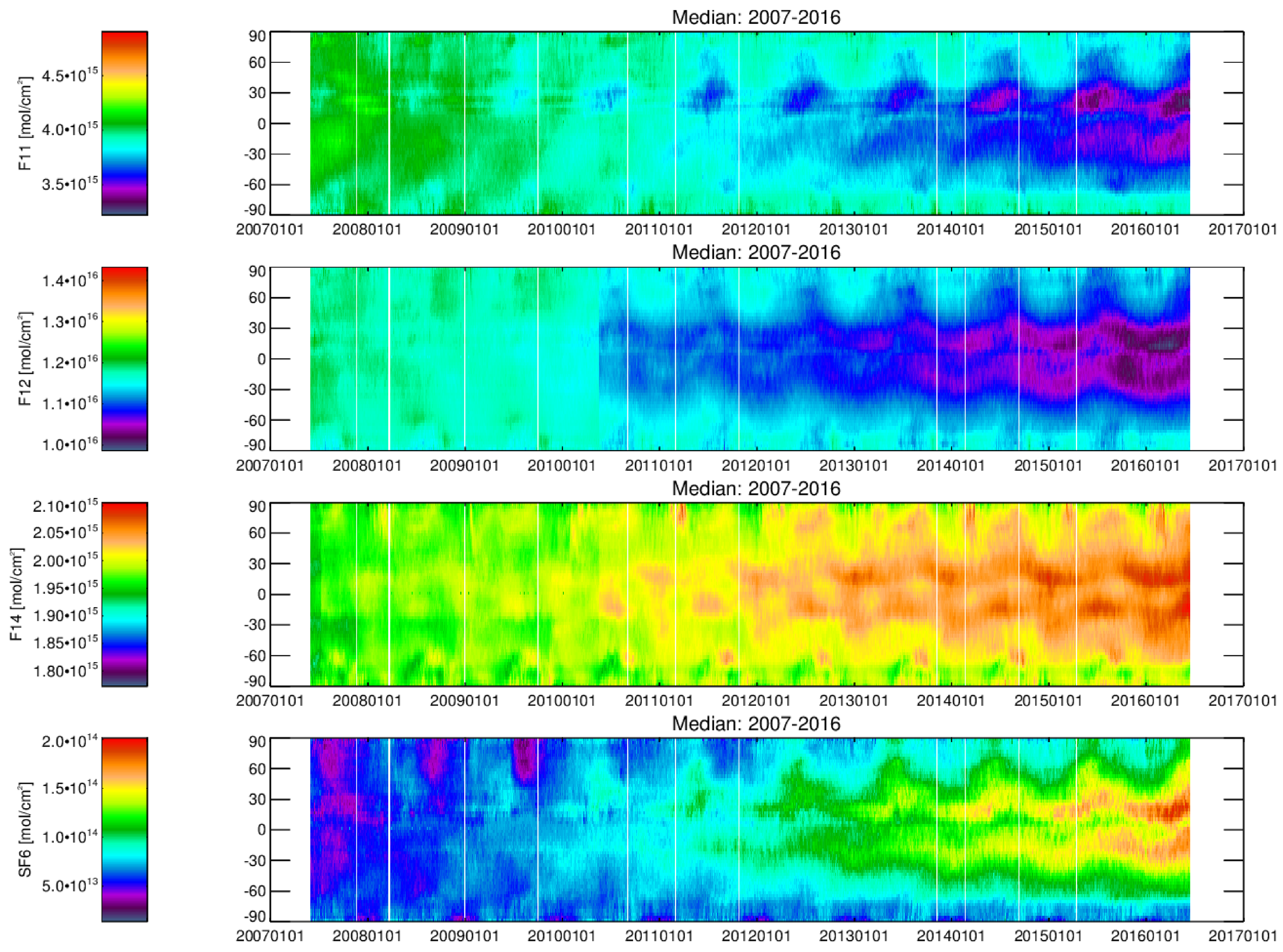
$$\mathbf{G} = \left(\mathbf{K}^{\mathrm{T}}\mathbf{S}_\varepsilon^{-1}\mathbf{K}\right)^{-1}\mathbf{K}^{\mathrm{T}}\mathbf{S}_\varepsilon^{-1}$$

is pre-computed using a Jacobian calculated from a perturbation in the troposphere of the target species assuming a mid-latitude climatology, and a generalised global error covariance created from an ensemble training set of IASI data containing the natural spectral variability caused by interfering trace species and clouds as well as the IASI instrument noise.

- The algorithm has been run over all available days in the IASI lifetime for over 20 species.

Time-Series: Long Lived Gases

Figure 1. Global daily median for 3° latitudinal bands over IASI time-series for CFC-11, CFC-12, CF_4, and SF_6. (NB. IASI calibration change in May 2010)



Example: Indonesian Fire Plumes 2015

- The Indonesian fire season was significantly enhanced in 2015 by the strong El Niño event; drier conditions than usual lead to increased biomass burning.
- This algorithm is able to detect enhancements in the atmospheric species that are important contaminants in pollution monitoring and forest fire detection.

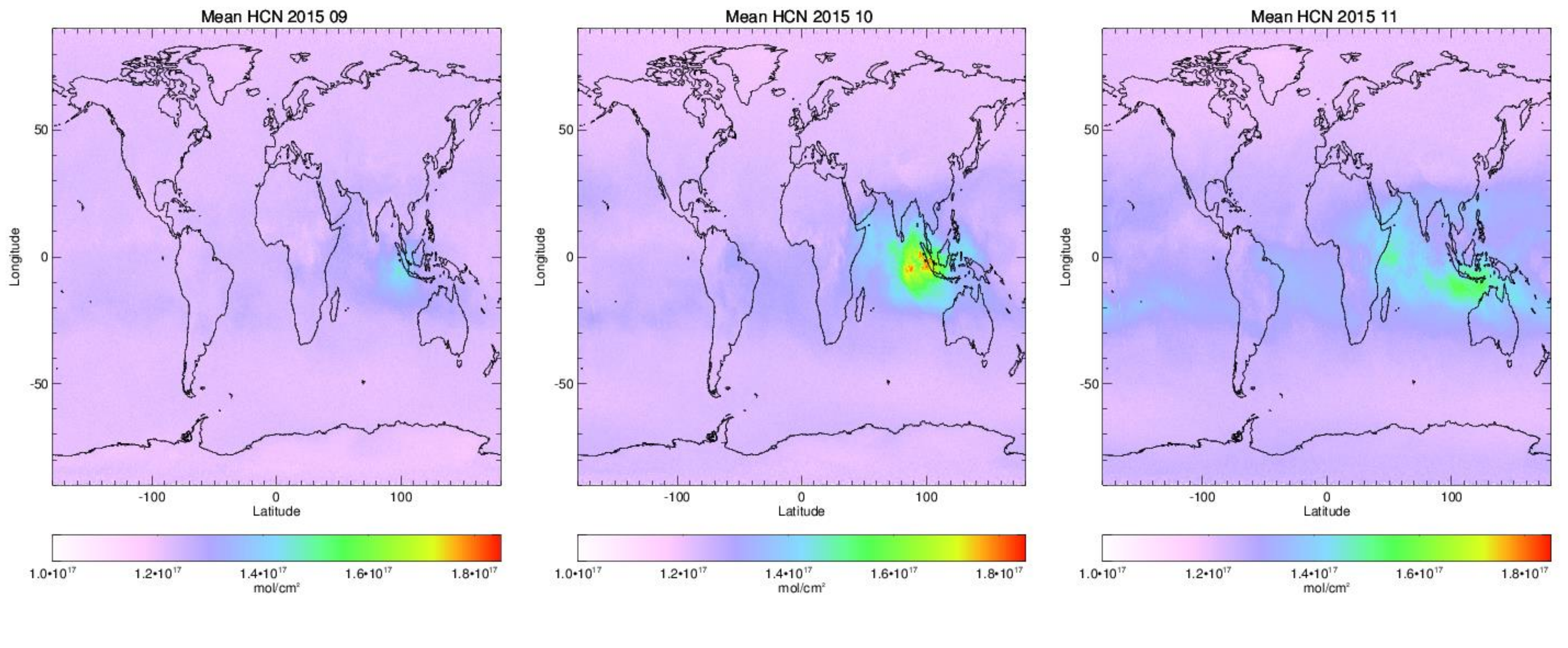


Figure 2. Monthly means tracking the HCN content in the plume from the Indonesian fires in 2015.

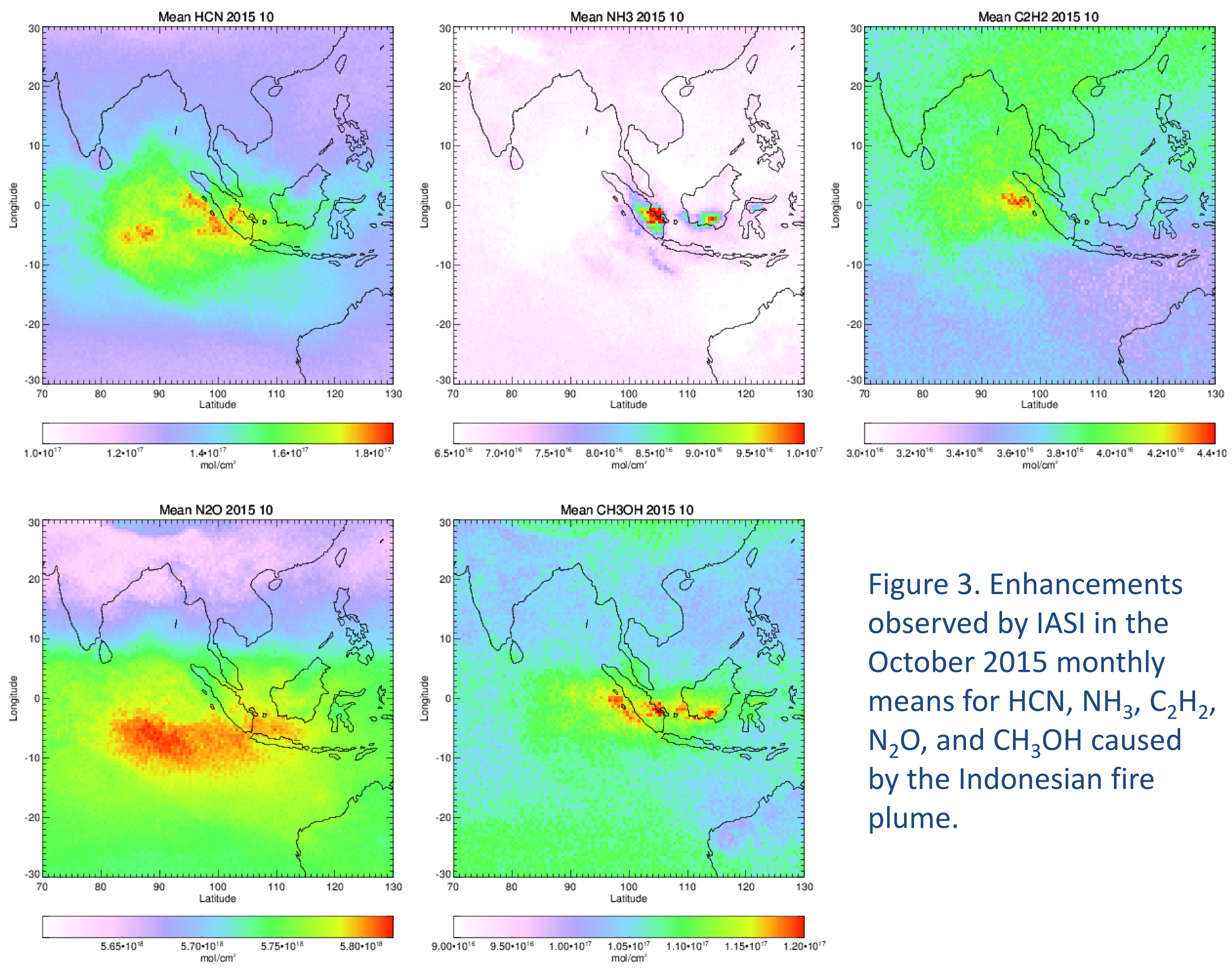


Figure 3. Enhancements observed by IASI in the October 2015 monthly means for HCN, NH_3, C_2H_2, N_2O, and CH_3OH caused by the Indonesian fire plume.

Near Real-Time Website

- The analysis algorithms are well established for the flagging of volcanic ash and SO_2.
- Further species to be added soon.
- Results are available within three hours of measurements.
- Archive of all past IASI measurements available (in development).
- Case studies for volcanic eruptions of interest, e.g. Calbuco.

www.nrt-atmos.cems.rl.ac.uk

April 26th 2015 IASI-A PM

April 30th 2015 IASI-A PM

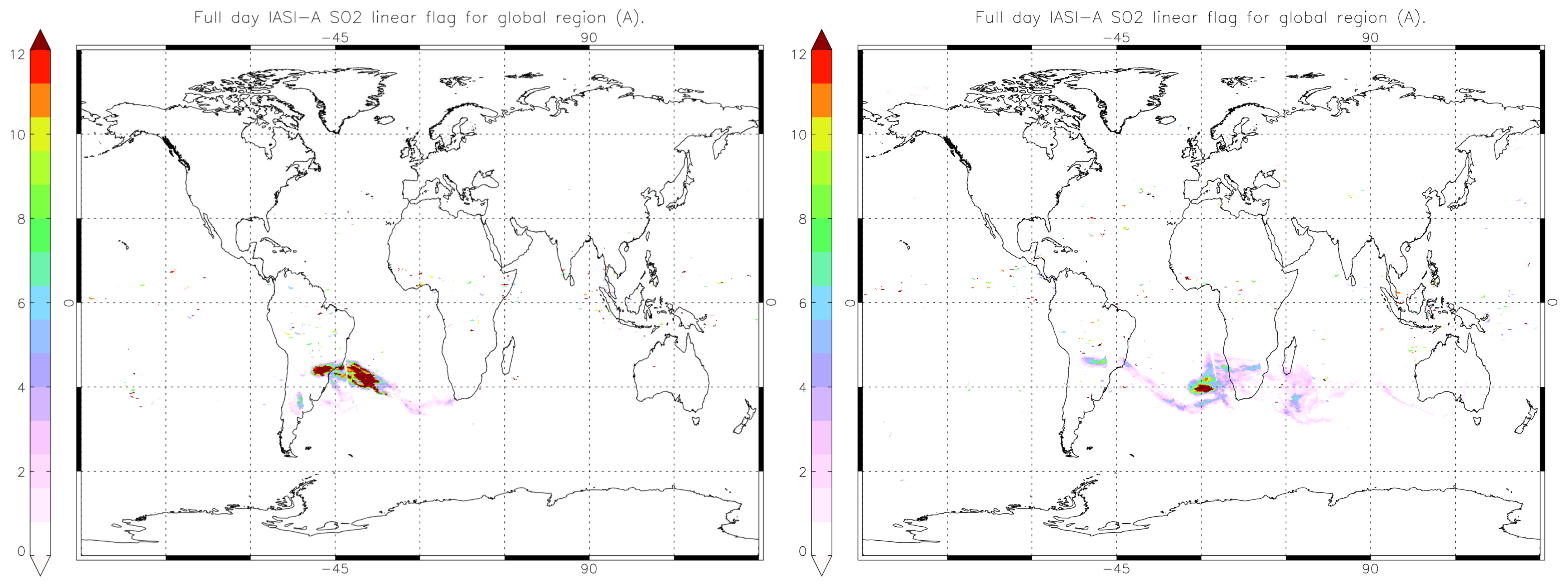


Figure 4. Tracking the volcanic SO_2 plume from the Calbuco eruption.

References
1. Walker, J., Dudhia, A., Carboni, E., An effective method for the detection of trace species demonstrated using the MetOp Infrared Atmospheric Sounding Interferometer, 2011. DOI: 10.5194/amt-4-1567-2011