Atmospheric trace gas anomaly detection using IASI

Lucy Ventress[1,3], Catherine Hayer[3], Elisa Carboni[2,3], Roy Grainger[1,3], and Anu Dudhia[1,3]

[1]NCEO, [2]COMET, [3]Atmospheric, Oceanic and Planetary Physics, University of Oxford

Contact: lucy.ventress@physics.ox.ac.uk

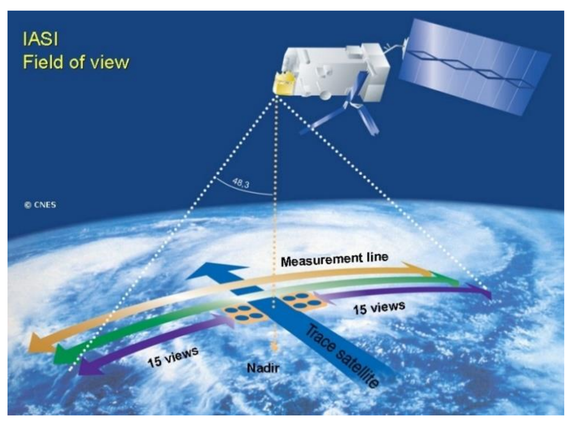
Introduction

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 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 spectral 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



Current Detection Algortihm

- Fast detection procedures 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:

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

where **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,

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

is pre-computed using the Jacobian calculated from a perturbation of the target species and a generalised error covariance.

- An ensemble training set of IASI data, assumed to contain no extraordinary concentrations of the target, is used to create a generalised error covariance matrix that contains the spectral variability caused by interfering trace species and clouds as well as the IASI instrument noise.
- This method aims to assign more weight to changes in spectral regions largely affected by the presence of the target and less weight to changes in spectral regions affected by the variation of other atmospheric variables.

Examples: Volcanic Ash

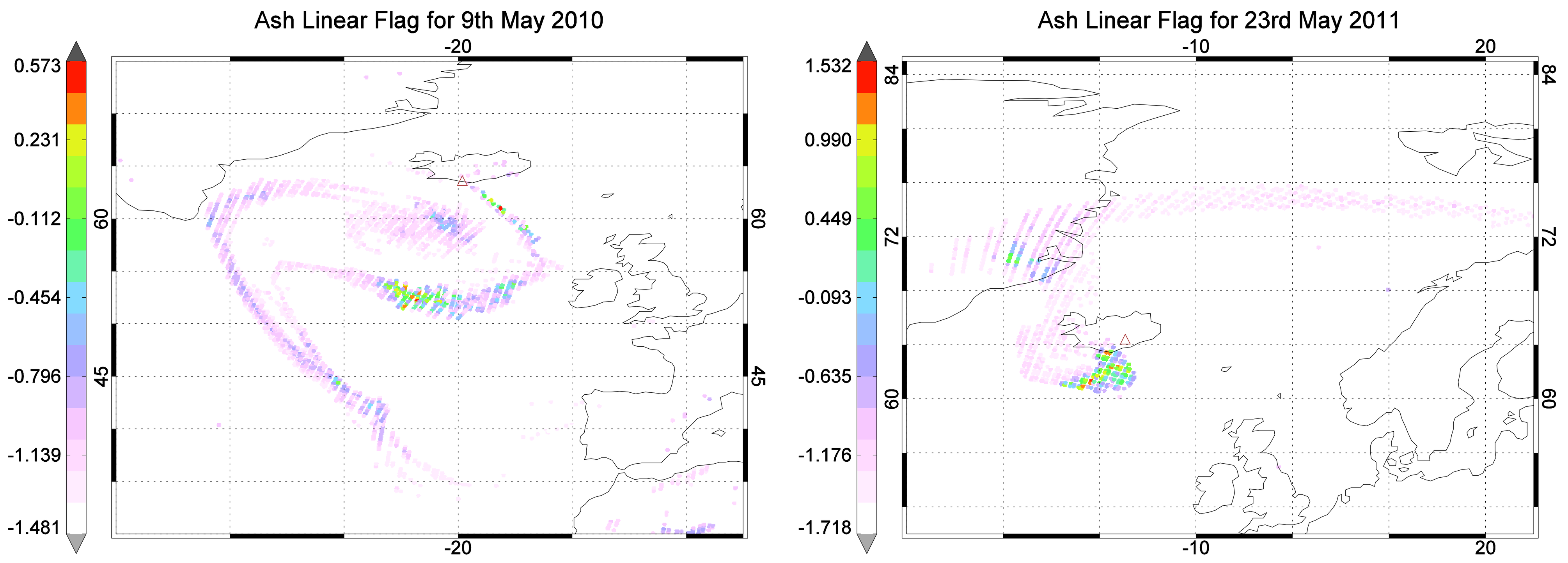


Figure 1. Log(AOD) from linear ash flag at 600mb during the Eyjafjallajökull (left) and Grimsvötn (right) eruptions.

Developments and Future Work

- Detect enhancements in additional atmospheric species, such as CO and NH_3, which are important contaminants in pollution monitoring and forest fire detection.
- Implement gain matrices tailored to the latitudinal location and season of the scene.

Examples: NH_3

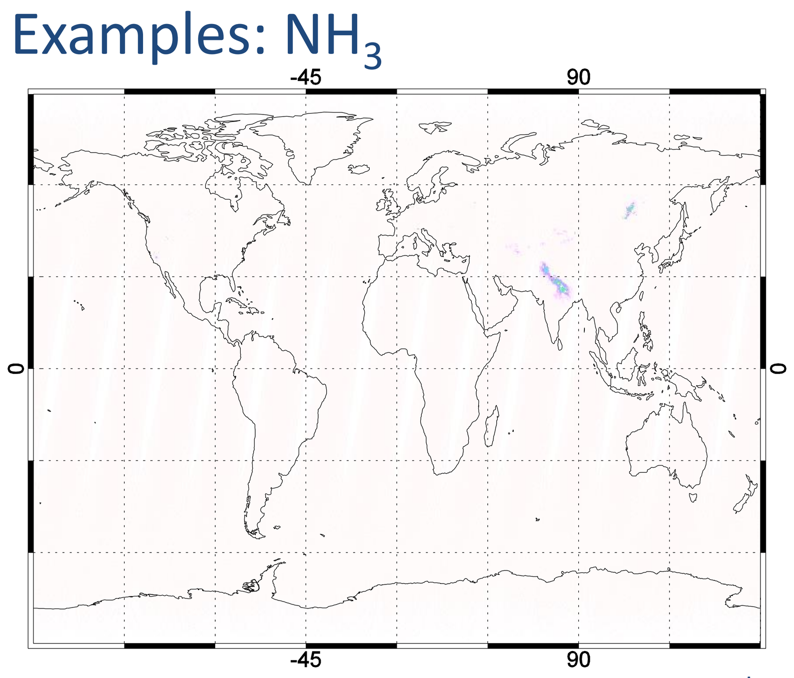


Figure 3. NH_3 anomaly detection for 13th May 2008 using covariance trained for spring and latitude band 10°N–30°N.

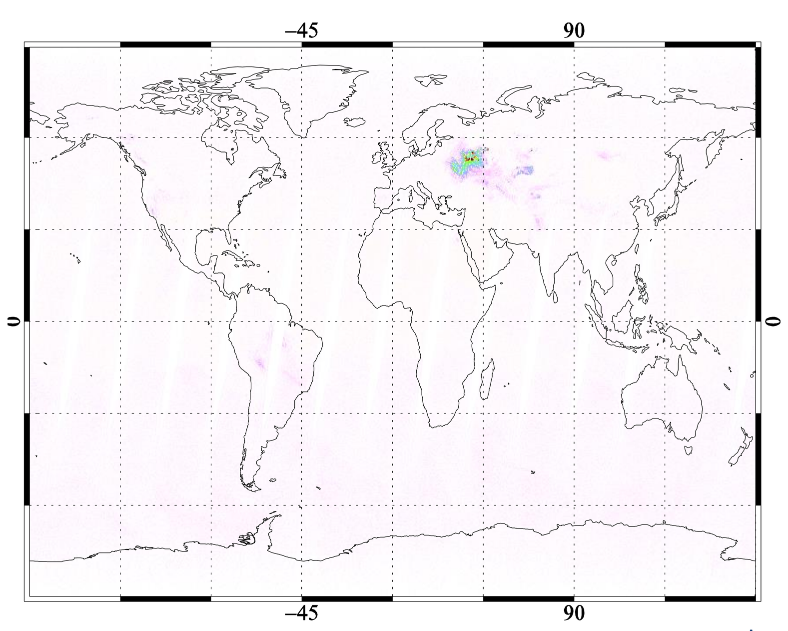


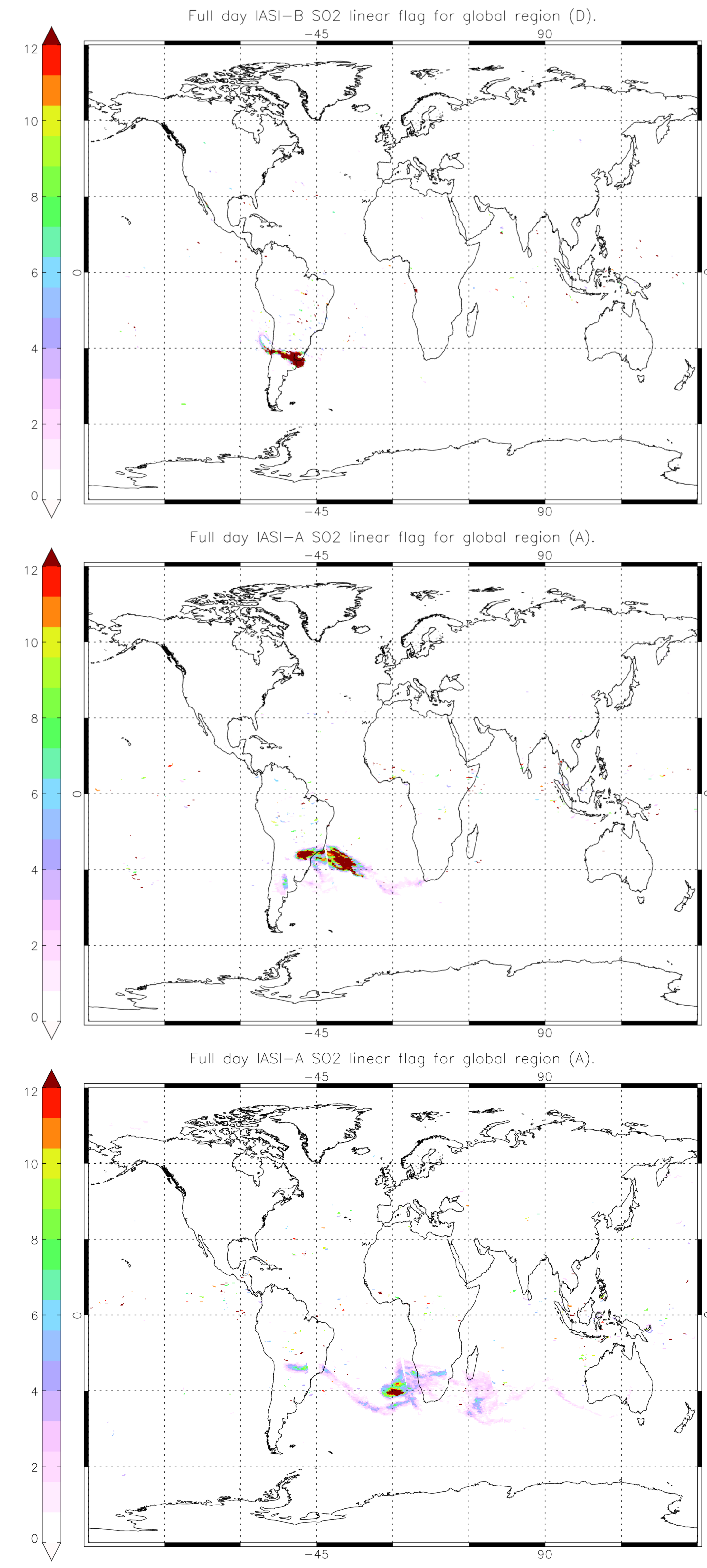
Figure 4. NH_3 anomaly detection for 15th August 2008 using covariance trained for summer and latitude band 30°N–70°N.

Initial tests for a NRT NH_3 flag have been promising. E.g. Figure 4 observes the anomaly caused by the large Russian fires in Summer 2010 (seen by Van Damme *et al.*, 2014) .

Near Real Time Website

- The analysis algorithms are well established for the flagging of volcanic ash and SO_2.
- 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.

Calbuco: April-May 2015



April 24th IASI-B AM

April 26th IASI-A PM

April 30th IASI-A PM

Figure 2. Tracking the volcanic SO_2 plume from the Calbuco eruption.

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

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
2. Van Damme, M., Clarisse, L., Heald, C.L., Hurtmans, D., Ngadi, Y., Clerbaux, C., Dolman, A.J., Erisman, J.W., Coheur, P.F., Global distributions, time series and error characterization of atmospheric ammonia from IASI satellite observations, 2014. DOI: 10.5194/acp-14-2905-2014