Observing aerosol extinction in the nadir and limb using hyperspectral instruments

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Abstract

Hyper-spectral IR instruments contain huge amounts of underexploited information describing continuum scatterers and absorbers. Analysis of the MIPAS data set has concentrated on retrievals of molecular species. However, there is a significant amount of information to be obtained from the continuum, avoiding discrete molecular lines. MIPAS is an instrument well adapted to detection of aerosols. The limb view gives good vertical resolution and a deep space background that does not interfere with continuum signals.

The IR spectra contains information about aerosol "type" that is not available from measurements in the visible and so is good for the classification of aerosol signals. A spectral aerosol extinction product based on the MORSE retrieval is presented which hopes to take advantage of these properties. Classification by several methods, including simple radiance ratios and singular vector decomposition are compared.

In the nadir, IASI measurements are used to demonstrate aerosol detection and classification using measurement covariance methods that seek to minimise the significance of natural spectral variability relative to irregular events.

IASI aerosol flagging

Using the Infrared Atmospheric Sounding Interferometer (IASI) on MetOp, it is possible to flag and distinguish between various aerosol types. The methodology is very similar to that of Clarisse et al. [2013], the idea being to use a generalised error covariance that contains not only the instrument noise, but covariance due to interfering trace gases and broadband scatterers (such as unwanted aerosols and clouds) that should be unrelated to the required retrieved property. Since these signals are included in the covariance, they need not be retrieved or their variance taken account of in the forward model of the atmosphere. Figure 1 shows an IASI scene after the eruption of Eyjafjallajökull, Iceland on 9th May, 2010 with good agreement between three independent flags.

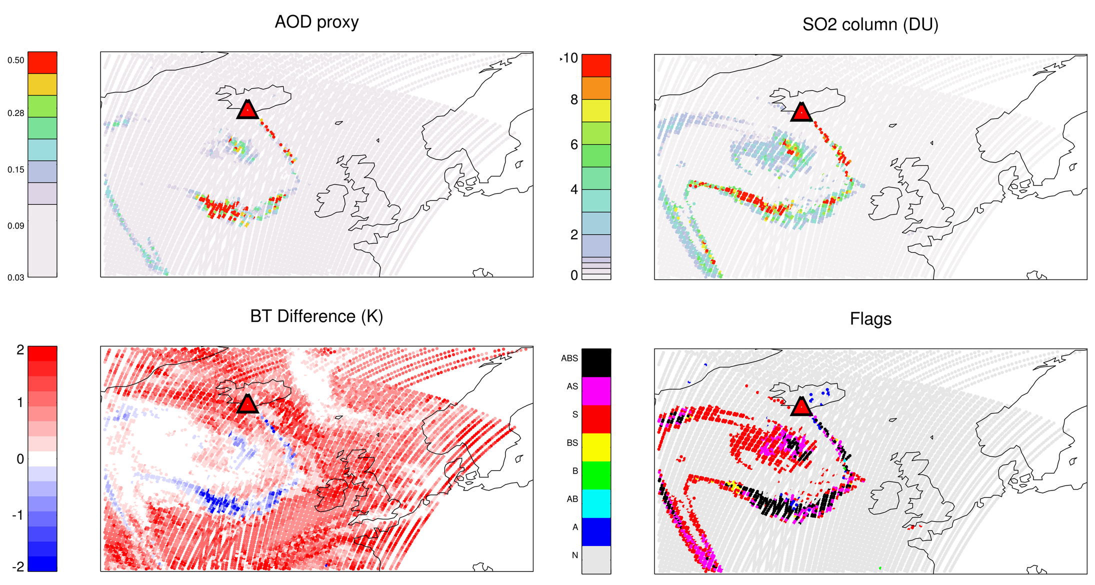

Figure 1: Showing two methods of flagging volcanic ash using IASI. A brightness temperature difference method, that can observe mineral aerosols such as desert dust and volcanic ash, and a more specific ash flag. Comparisons with an SO_2 flag [Carboni et al., 2012] are also given.

MIPAS aerosol flagging

Volcanic aerosols make excellent case studies for testing aerosol algorithms: they are discrete events with spectrally distinct IR signatures. Fig. 2 shows these volcanic signatures using simple channel ratio tests.

Using singular value decompositon, standard atmospheric variability taken from measurements before an eruption can be removed, leaving suspected volcanic signatures [Grainger et al., 2013].

The eruption of Nabro, Eritrea was extremely rich in SO_2 emissions, with very little ash. As a consequence, the volcanic singular vector is close to a sulphate aerosol, with the SO_2 ν_3 band at 1362 cm^{-1} clearly evident. Comparisons with an IASI sulphate aerosol flag show good agreement.

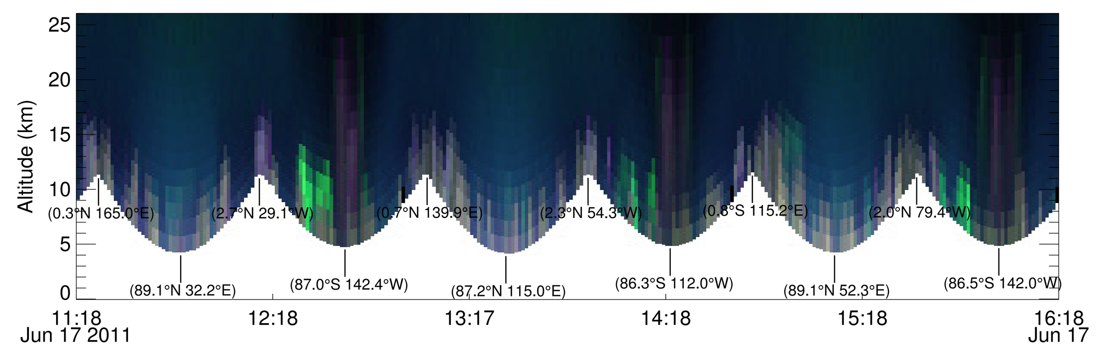

Figure 2: False colour images of MIPAS orbits from 17th June 2011 after the eruptions of Puyehue, Chile and Nabro, Eritrea. RGB colour channels have been chosen such that volcanic ash shows up as bright green.

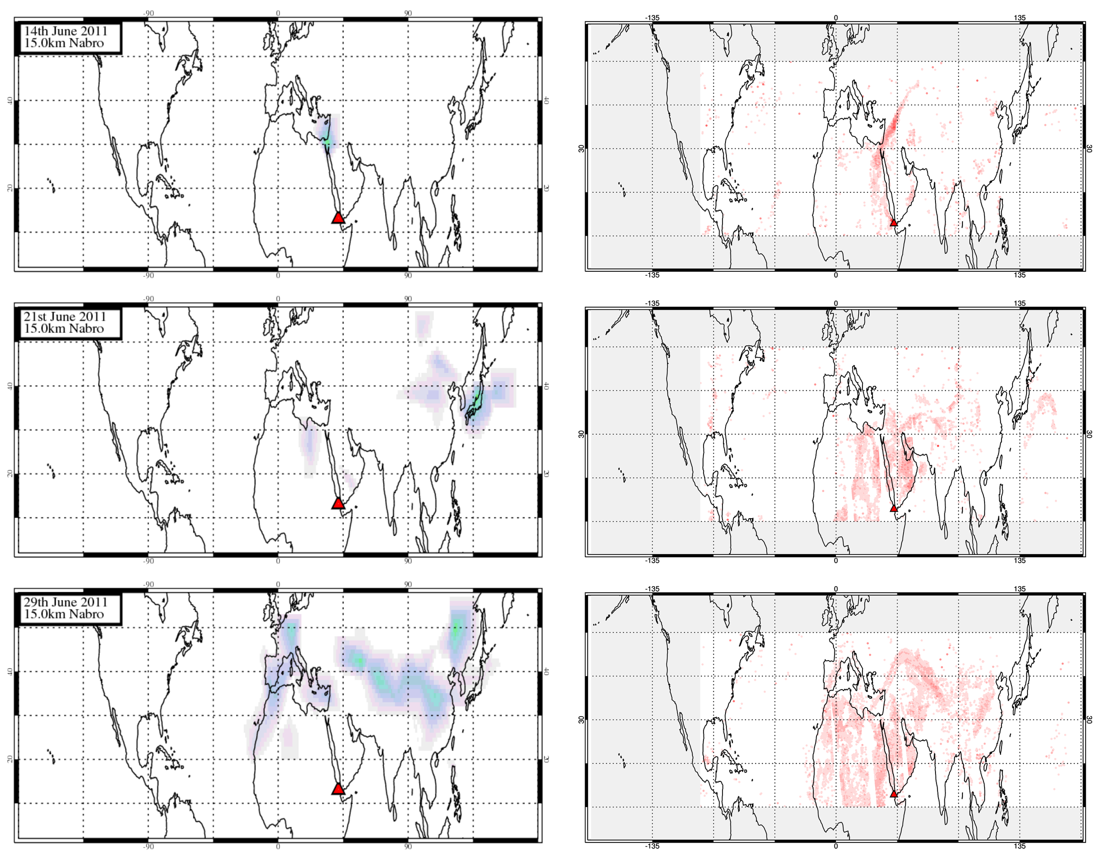

Figure 3: Snapshots showing time evolution of the plume from the Nabro eruption from MIPAS at an altitude of 15 ± 1.5 km, and from IASI. Since IASI is a nadir instrument, it samples the atmospheric column and so sees the initial plume before it reaches 15 km and is more sensitive to signatures from lower in the atmosphere.

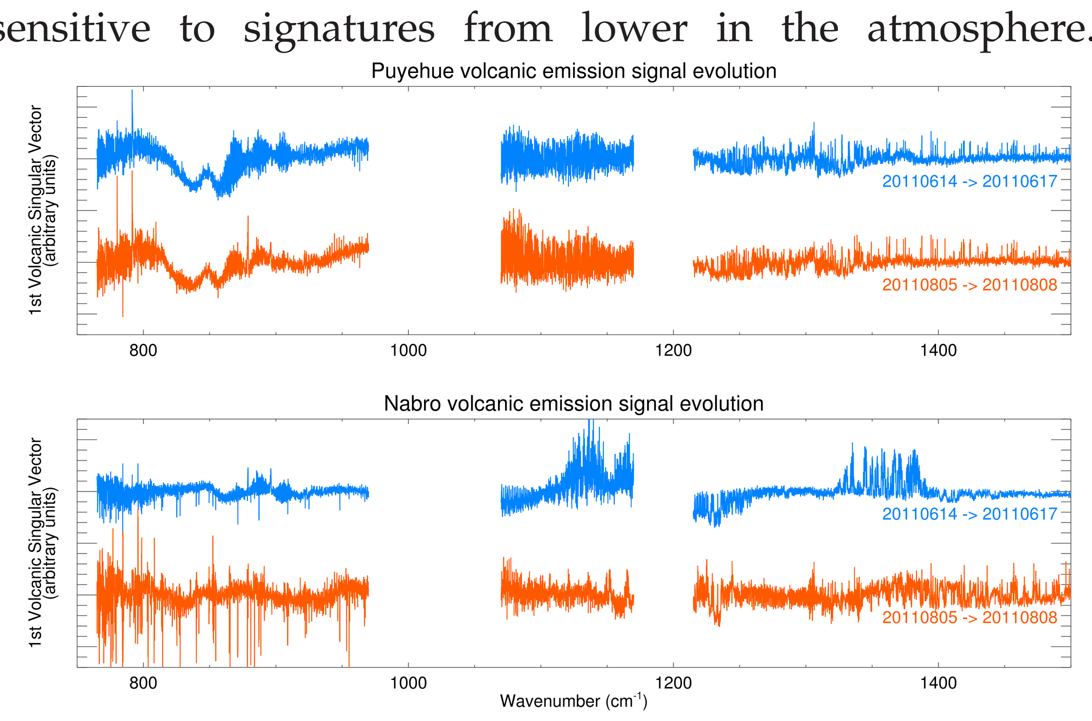

Figure 4: Evolution of plume spectral emission from the Puyehue and Nabro eruptions. Nabro shows conversion of SO_2 to H_2SO_4 aerosol, while Puyehue (which was mainly ash) has no change.

MIPAS extinction retrieval

The MIPAS Orbital Retrieval using Sequential Estimation (MORSE, www.atm.ox.ac.uk/MORSE/) is capable of retrieving a large number of atmospheric molecules, and is currently being adapted to retrieval extinction in specific regions of the MIPAS spectra. These microwindows have been selected in regions where one would expect the clearest aerosol signals, and the method has been altered so that the spectrally flat continuum is retrieved while putting as much uncertainty as possible into residual molecular features.

The preliminary results of this method are shown in the following figures. Persistent tropical clouds are seen, and potentially polar stratospheric clouds (PSCs) and ash from the Puyehue eruption. The Junge stratospheric aerosol layer is not distinct, even though elevated sulphate from the Nabro eruption was present throughout the NH summer of 2011.

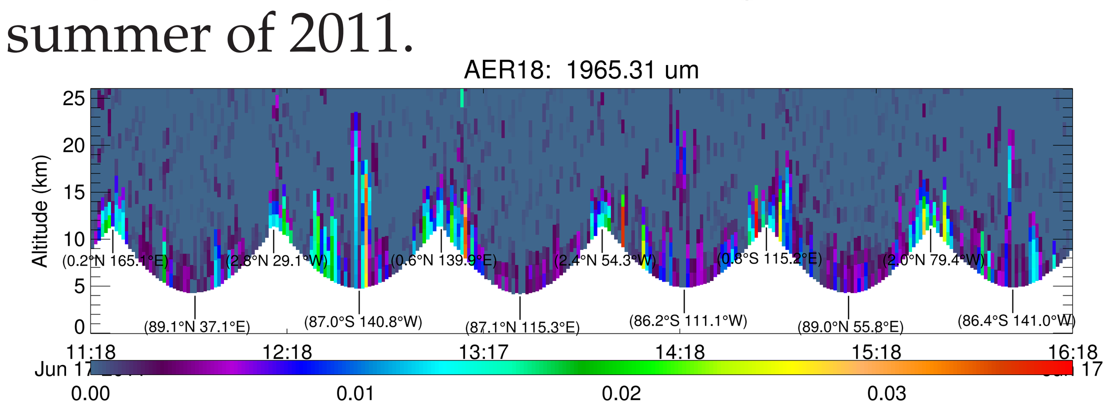

Figure 5: A MORSE extinction retrieval at 1865 cm^{-1} from 17th June 2011 with PSCs over Antarctica, tropical convective clouds close to the equator, and ash from the Puyehue eruption.

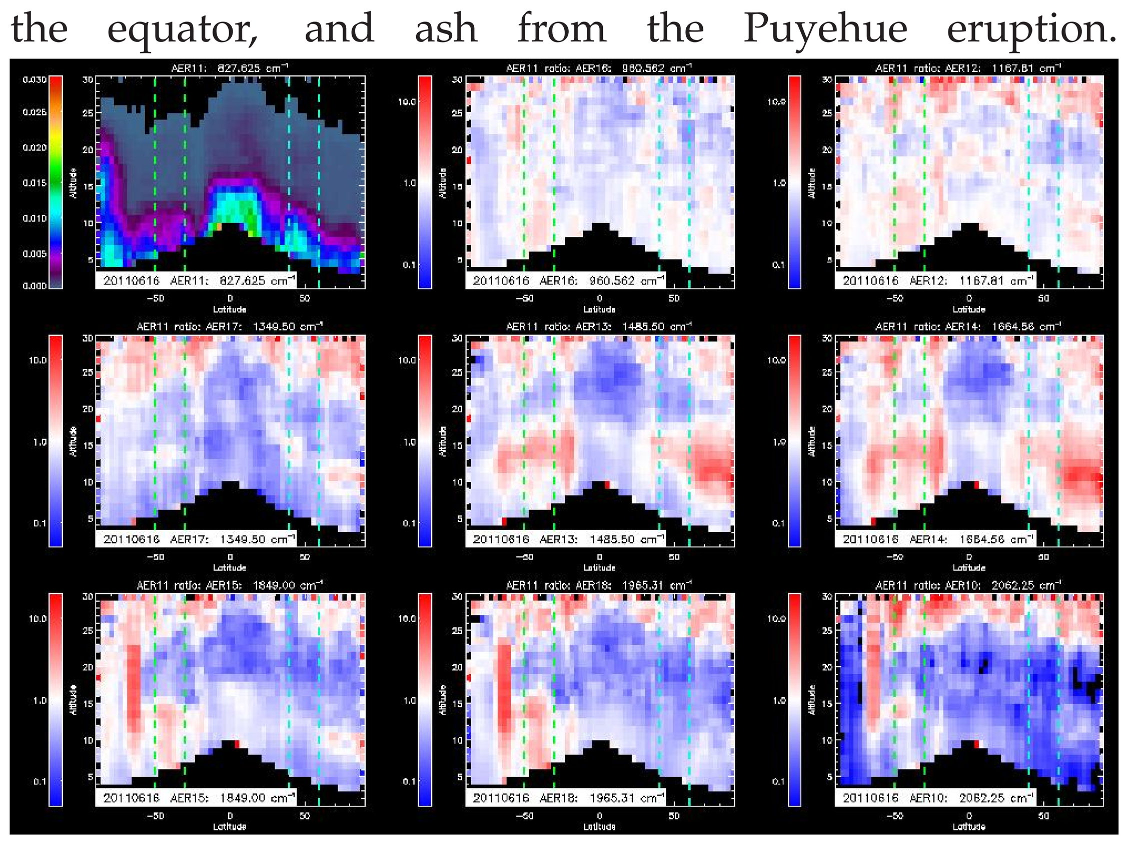

Figure 6: Smoothed zonal means of extinction in nine extinction microwindows, sorted by wavenumber for all orbits on 16th June 2011. The first panel shows absolute extinction, while following panels are normalised to the first panel.

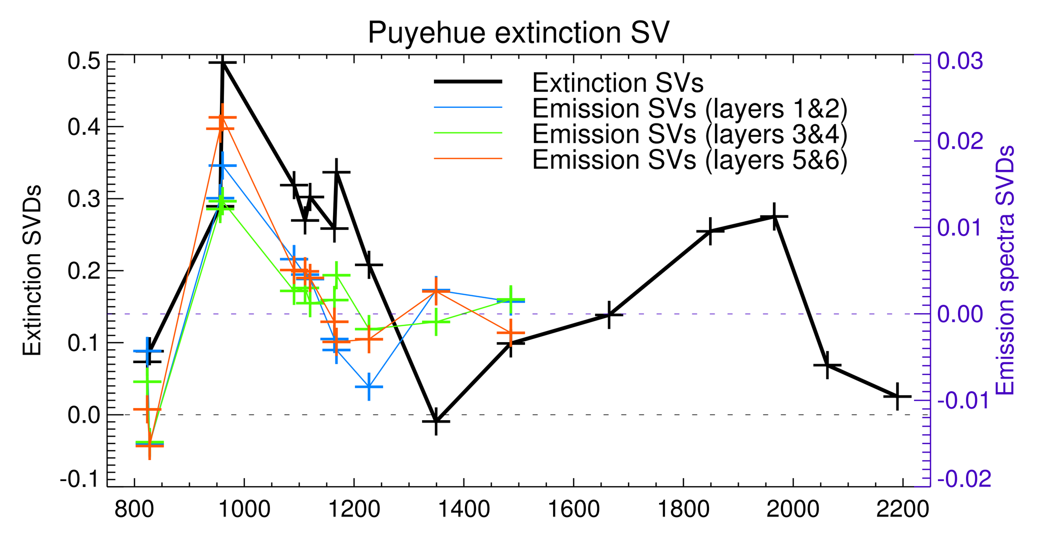

Figure 7: Comparing the emissions singular vectors for the Puyehue eruption at various altitudes (as shown in Fig. 4) to the singular value decomposition of spectral extinction of MIPAS Puyehue ash measurements.

References

Carboni, E., R. G. Grainger, J. Walker, A. Dudhia, and R. Siddans, 2012. *Atmos. Chem. Phys.*, **12**(23):11417–11434, doi:10.5194/acp-12-11417-2012.
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Grainger, R. G, D. M. Peters, G. E. Thomas, A. J. A. Smith, R. Siddans, E. Carboni and A. Dudhia, 2013. Geological Soc. Special Publication 380, doi: 10.1144/SP380.7.