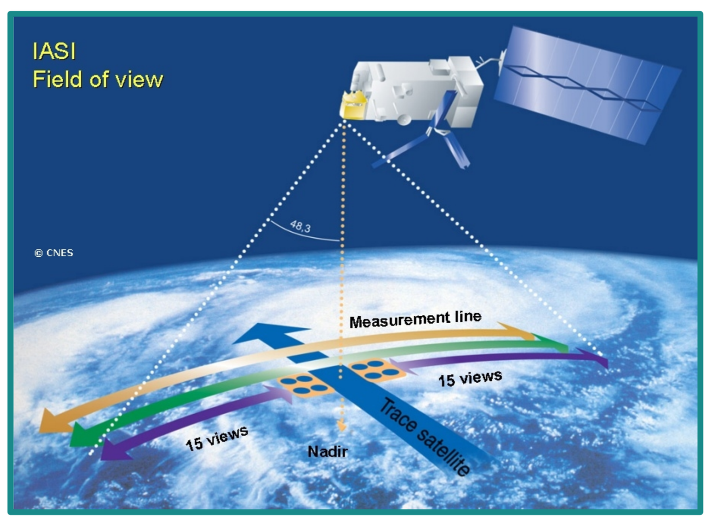
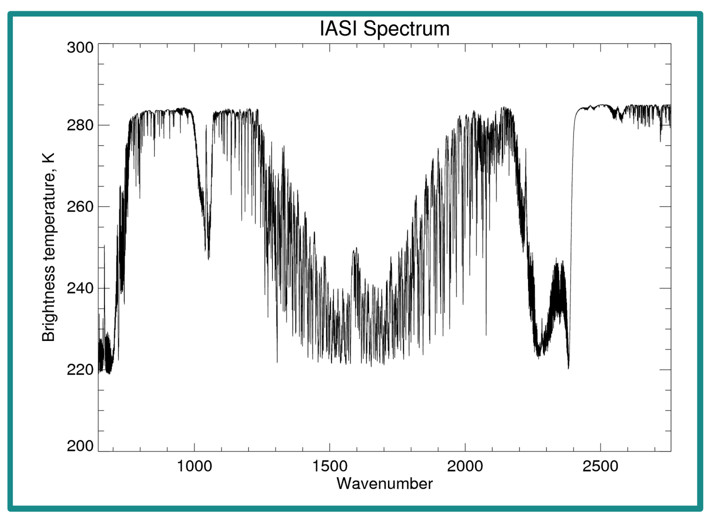
Atmospheric Sounding using IASI

Lucy Ventress
University of Oxford





Abstract

This study investigates how accurately an atmospheric profile can be retrieved by the IASI instrument for different atmospheric gases, and how errors in our knowledge of atmospheric parameters propagate through the retrieval. Methods used to decrease the volume of data used, whilst maintaining its accuracy are also discussed.

The Infra-red Atmospheric Sounding Interferometer (IASI) instrument on board the METOP-A satellite is a nadir viewing Fourier transform spectrometer, which passively measures the radiance from the Earth's surface and atmosphere to provide atmospheric temperature and water vapour profiles for use in Numerical Weather Prediction (NWP).

IASI achieves global coverage and provides measurements twice a day at each location, at a local time of 09:30, from a low altitude, sun synchronous orbit. IASI covers the spectral range 645–2760cm^{-1} with a spectral resolution of 0.5cm^{-1} (apodized) providing a total of 8461 channels in each IASI spectrum.

Error Propagation

Profile and column retrievals can be affected by the lack of knowledge of many atmospheric parameters, such as surface temperature or emissivity.
From optimal estimation we know how the measurements, y, contribute to the retrieval, x,

$$x=\left(K^T S_y^{-1} K+S_a^{-1}\right)^{-1} K^T S_y^{-1} y=Gy$$

where S_a is the a priori error covariance matrix, and K is the jacobian matrix. This gives us,

$$\delta x=G\delta y$$

where δy is the difference between the atmospheric spectrum with no error and the spectrum assuming a perturbation equal to the error in our input parameter. In these calculations surface temperature has been retrieved simultaneously with each gas and, hence, its error is negligible.

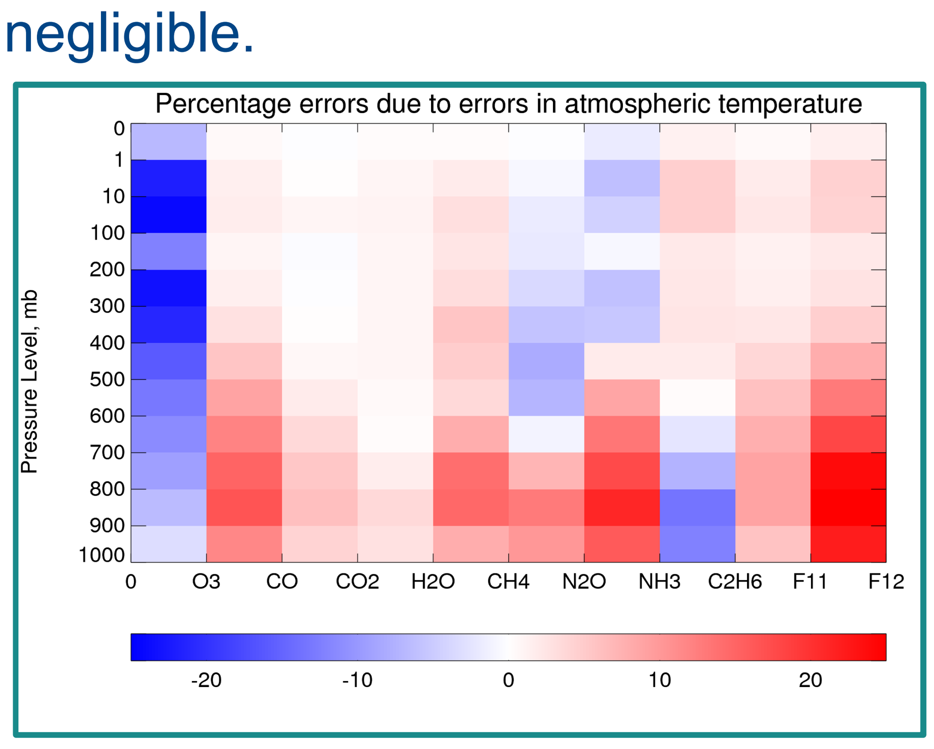


Figure 1

Figure 1 shows the percentage change in retrieved column amount for errors of 1K in the atmospheric temperature at decreasing pressure levels in the atmosphere. The largest error tends to occur in the 900–800mb layer, even though the concentrations may be higher in the lowest layer. This is due to IASI not being able to sound all the way to the surface. The exception is ozone; the errors are largest much higher in the atmosphere, nearer the stratosphere, where the ozone concentration is greatest.

Figures 2 and 3 are examples of column amount errors caused due to errors in other input parameters. Noticeably for water vapour the error due to a 1% change in surface emissivity is very large, implying we need a good understanding and measurement of it if we wish to retrieve water vapour to high accuracy.

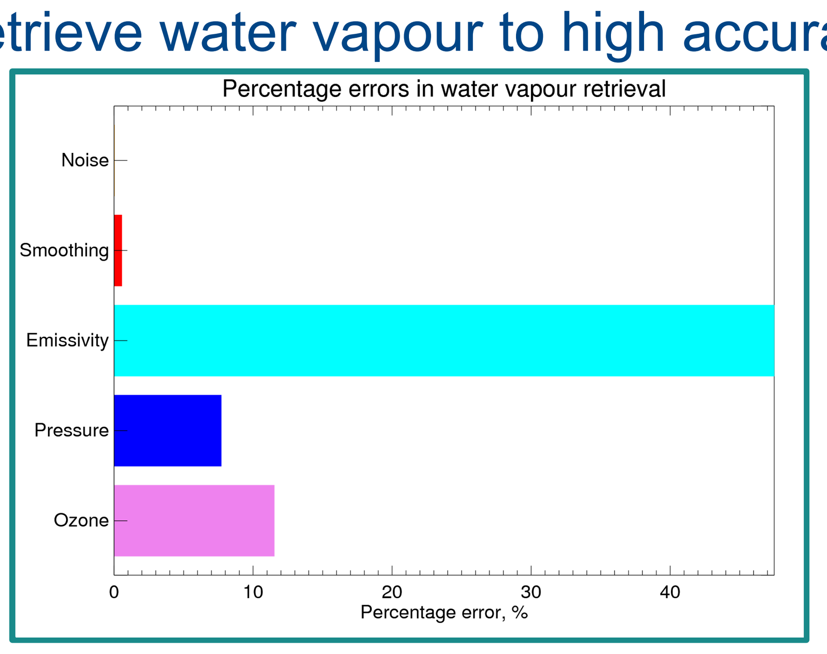


Figure 2

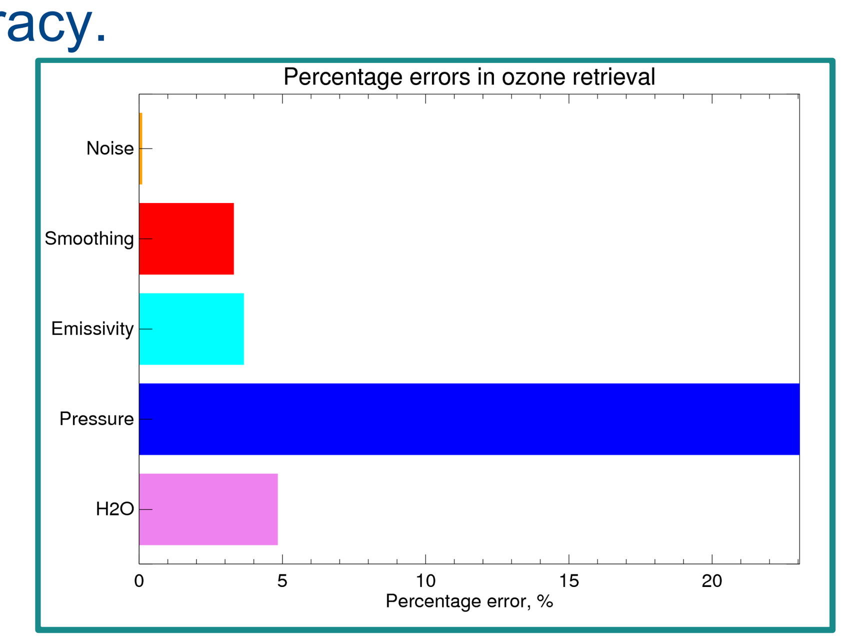


Figure 3

Channel Selection

Choosing an optimal subset of wavenumber channels is an established method to reduce the large volume of data provided by IASI. The 'iterative method' of channel selection, used in this study, calculates the impact of each channel upon a figure of merit, the information content, H, which is defined to be the factor by which knowledge of a quantity is improved by making the measurement.

$$H=-\frac{1}{2}\ln\left(S_x S_a^{-1}\right) \quad \text{Where,} \quad S_x=\left(K^T S_y^{-1} K+S_a^{-1}\right)^{-1}$$

Figure 4

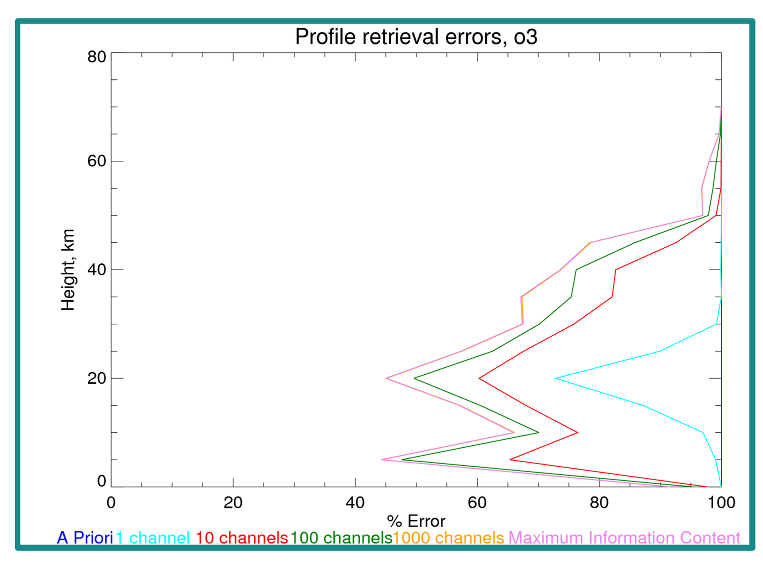
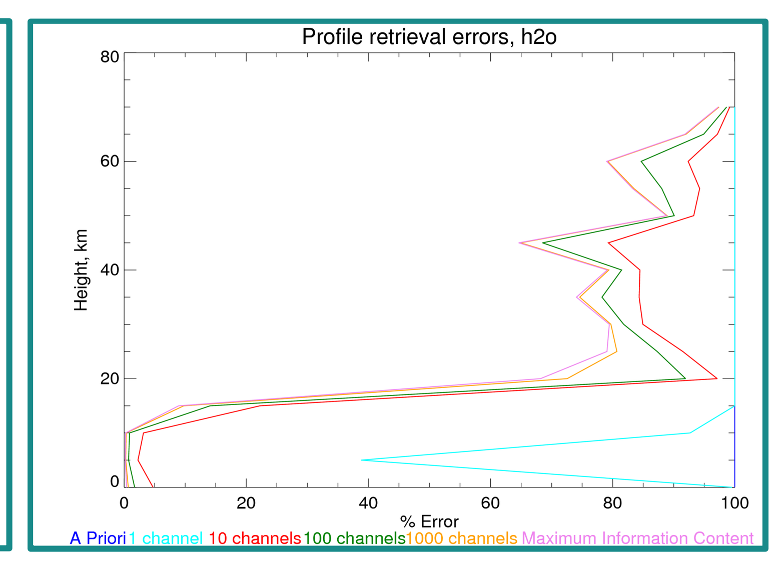


Figure 5



The channel with the greatest H value is chosen and the a priori covariance matrix (initially having an error of 100%) is updated to contain the information gained from the selected channel. H is recalculated for all channels and the process is repeated selecting the next best channel from those remaining until a set threshold has been reached.

Figure 6

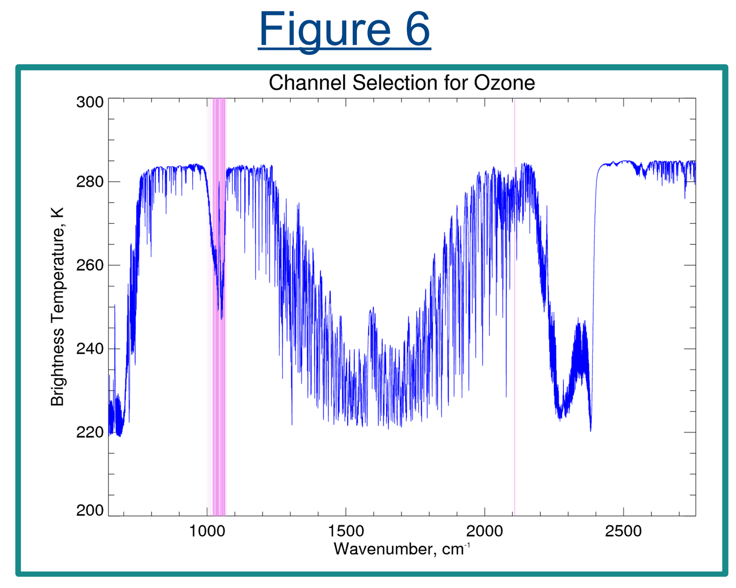
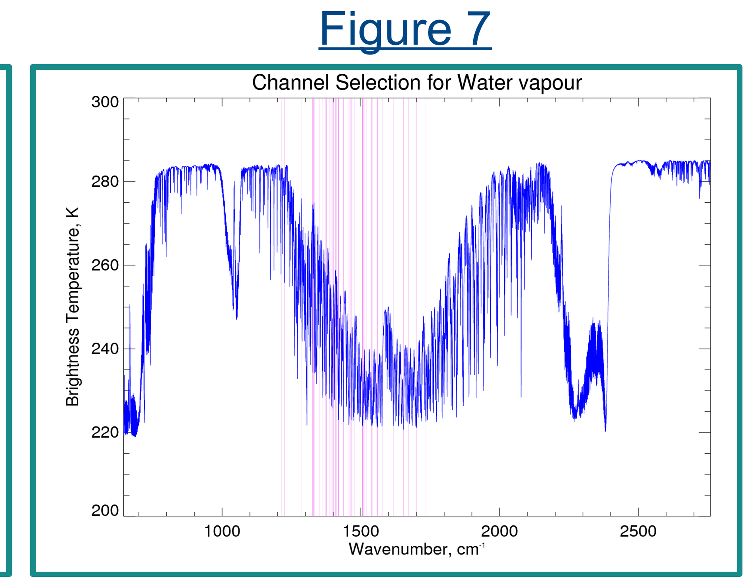


Figure 7



Figures 4 and 5 are examples of how the percentage error in retrieved column amount changes with the inclusion of more channels. In both cases it can be seen that the increase in knowledge is minimal between using 100 channels and using all the channels that contain any information, which in the cases of water vapour and ozone is O(10^3). It is for this reason that in data assimilation for numerical weather prediction, only a selected set of O(10^2) are used. The locations of the best 100 channels for ozone and water vapour are shown in figures 6 and 7.

Summary

- A subset of channels can yield results with similar accuracy to those using all available channels whilst significantly decreasing computer processing time.
- For accurate profile retrievals, surface emissivity and tropospheric temperature must be well known.
- Future work will involve including the full error analysis in the choice of channels, to maximise our knowledge of the atmospheric parameters.