OZONE PROFILE RETRIEVAL FROM GOME2 / METOP

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Abstract

Early results of the application of the well established RAL GOME Ozone retrieval scheme to GOME2 measurements are presented. The scheme applies the measured GOME2 slit functions in the Huggins Bands to obtain information about tropospheric Ozone. The scheme uses a reference solar spectrum to improve the accuracy of the wavelength calibration. We have begun to examine the origins of the mean fit residuals which represent attributes of the atmosphere that are not fully represented in the forward model, with a view to optimising the fit. There is some evidence that they arise from a combination of the limitations of the temperature dependent ozone cross section data, modelling of the ring effect and the wavelength resolution at which parts of the retrieval are run. Despite this potential area for improvement, current retrievals show a good agreement with ozone sondes, including in the lower atmosphere. There is also a suggestion of good qualitative agreement with both IASI and simulations from a chemistry transport model, after Eremenko *et al*., (2008). Work has begin to incorporate both the GOME2 cloud product and aerosol and cloud information from AVHRR into the retrieval, with the intention to combine the GOME2 ozone retrievals with an IASI product in a synergistic approach to utilise information available from MetOp.

INTRODUCTION

The RAL GOME Ozone scheme (Siddans *et al*., 2003; Munro *et al*., 1998) successfully demonstrated that exploitation of both the Huggins and more traditional Hartley ozone bands could yield information about the ozone profile in the troposphere as well as in the stratosphere. Early results with GOME measurements indicated that a tropospheric bias in ozone concentration arose due to the assumed character of the instrument slit functions, which were not measured prior to launch. The need to properly characterise the slit-function for GOME-2 was further established through Eumetsat studies, which lead to its pre-flight characterisation (Siddans *et al*., 2006). GOME2 began operation in 2006, and advances over GOME-1 by having smaller ground-pixel size and large swath.

METHODOLOGY

As described in Munro *et al*., (1998), the RAL GOME Ozone retrieval is a sequential scheme. Hartley Band spectra (265 nm-307 nm) are first used to retrieve via optimal estimation (Rodgers 2000), the ozone profile, contributing information predominantly in the stratosphere. This profile is used as a priori for a retrieval from the Huggins Bands (323 - 335 nm) which contributes information on the lower atmosphere, due to the temperature dependence of the absorption cross-section. This latter step requires a spectral fit of greater than 0.1%. In this spectral range, only the differential absorption spectrum is fitted (the logarithm of the sub-normalised radiance is taken, and a polynomial subtracted to form the input measurement vector). This removes errors in radiometric calibration with low-order spectral structure which would otherwise prevent fitting to the required level. However, even fitting the differential spectrum, systematic fit residuals are found, which have characteristic spectral shape. In order to improve fit precisions, the systematic residual spectrum is obtained by taking the mean fit residual spectrum considering one orbit of data. Subsequent retrievals then subtract this fit-residual spectrum from observations, multiplied by a scaling parameters whose value is retrieved on a ground-pixel by ground-pixel basis. The origins of these mean fit residuals were unclear in GOME-1 data but are re-examined in this paper for GOME-2.

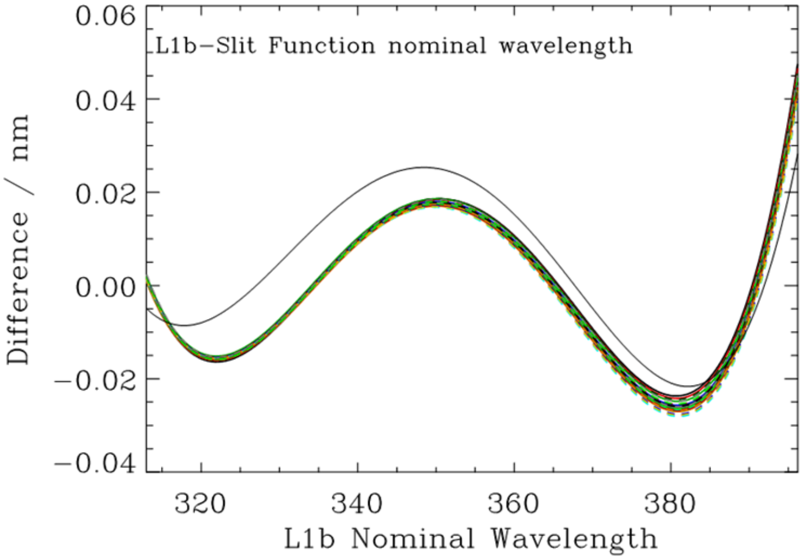

Figure 1: **The coloured lines show the difference between the GOME2 level 1b nominal pixel wavelengths and those that are obtained by fitting a high resolution solar reference spectrum, convolved with the GOME-2 slit-functions, to the daily solar calibration measurement. Results are shown here for March 2007-February 2008. The black line shows the difference between the level 1b nominal pixel assignment and the central wavelength of the slit function for that pixel.**

WAVELENGTH CALIBRATION

An accurate wavelength calibration of the GOME2 pixels is required in order to ensure an optimal fit with the model, with regard to spectroscopic information about atmospheric constituents. This is achieved by retrieving a 'shift and squeeze' polynomial to the wavelength associated with the measurements, derived using a high resolution reference solar spectrum convolved with the GOME2 slit functions and the daily solar calibration measurement used to derive the sun normalised radiance. Figure 1 shows the characteristic shape of this polynomial and its evolution over a period of 1 year.

The quality of the slit functions was also evaluated using a similar exercise, where polynomials for gain and offset were also retrieved using equivalent Gaussian, stretched, squeezed or reversed slit functions. In the Huggins Bands in particular, the slit functions depart from a pure Gaussian and are asymmetrical. In all cases the cost of the fit of the modelled solar spectrum was higher than using the GOME2 slit functions indicating that the slit functions are well characterised.

EXAMINATION OF MEAN FIT RESIDUALS

This paper is primarily concerned with deriving tropospheric ozone, since the retrieval of stratospheric ozone, in particular with GOME, is well established. The standard retrieval scheme uses Bass-Paur (Bass and Paur, 1981) ozone absorption cross sections and the Huggins-band wavelength range of 323-335 nm. 7 pixels in this range are omitted which degrade the fit. Figure 2 shows the scaling factor for the systematic residual spectrum normalised by the geometric air mass factor for an orbit. In a correlation study this factor was found to correlate most strongly with the total column ozone and the modelled Ring effect scaling parameter, shown in figure 3. The Ring effect is modelled to account for rotational Raman scattering, assuming single-scattering by air molecultes. A scaling factor is retrieved to account for effects of multiple scattering by air and/or scattering by clouds or reflection from the surface.

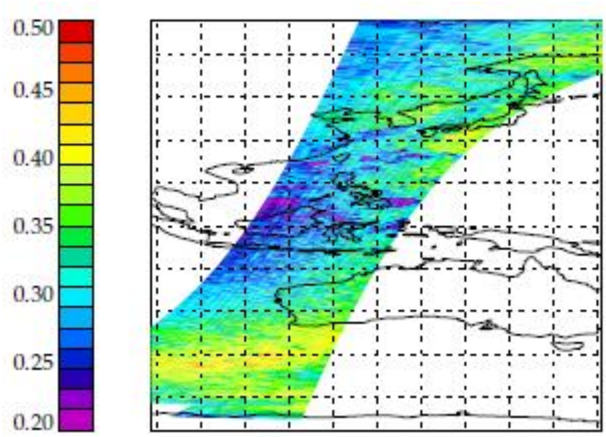

Figure 2: **The retrieved residual scaling factor normalised by the geometric air mass factor.**

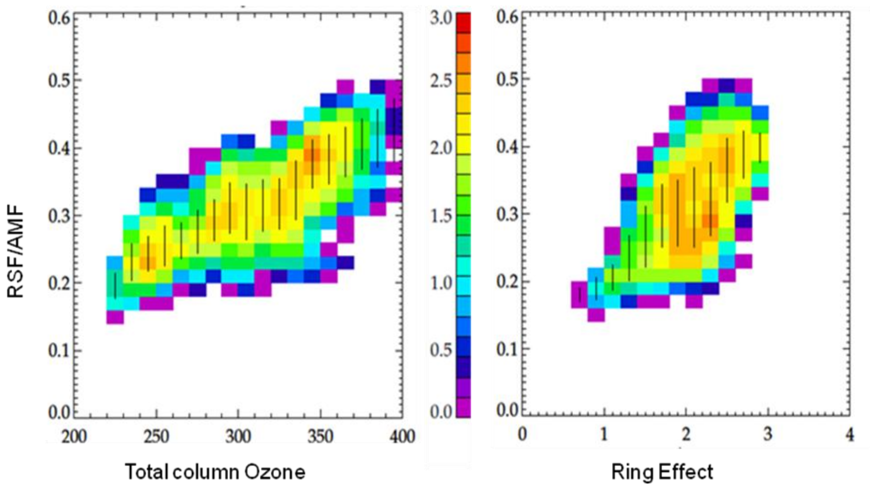

Figure 3: **The left panel shows the correlation between the residual scaling factor normalised by the air mass factor (shown in figure 2 above), with the retrieved total column ozone. The right panel shows the same correlated with the modelled ring effect scaling parameter, as explained in the text.**

These mean fit residuals were present in the GOME retrievals but their origin was unclear. Figure 4 (top panel) shows the comparative mean fit residuals for the two versions of the instrument, and for GOME2 some of the features are similar to those for GOME but exacerbated. These larger features are coincident with the peaks in the ozone absorption cross section, as shown by figure 4 (middle panel). Liu *et al*., (2007) demonstrated the affect of using different ozone absorption cross sections on retrieved Ozone for the GOME instrument. In a similar exercise the RAL GOME2 ozone scheme has experimented with using a range of ozone absorption cross section data. Each yield slightly differing ozone amounts, and the comparative mean fit residuals are shown in the bottom panel of figure 4.

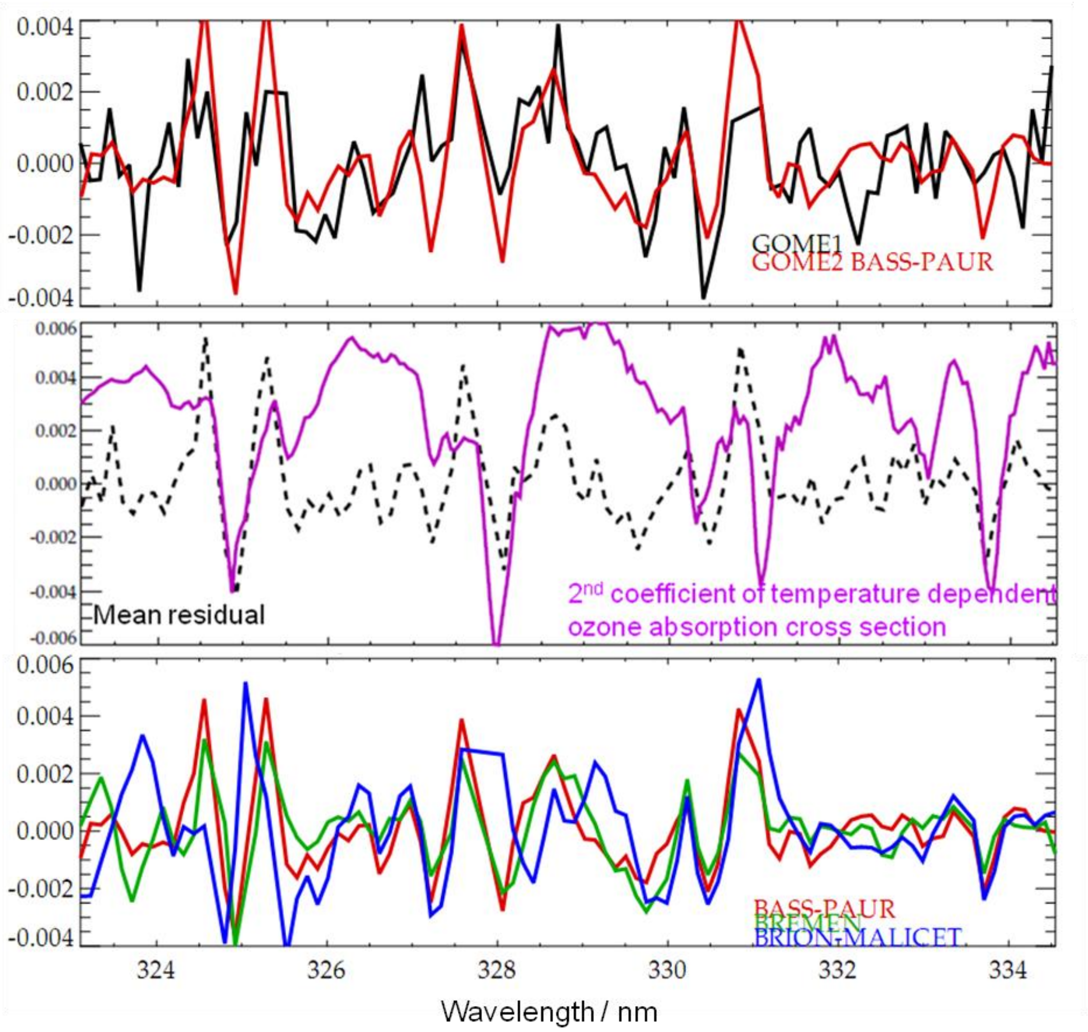

Figure 4: (Top panel) **The black line shows the mean fit residual used for GOME retrievals. The red line shows the equivalent for GOME2, where the features are similar but enhanced above those for GOME.** ***(MIddle panel)*** **The pink line shows the second order coefficient for the temperature dependent ozone absorption cross section (Bass-Paur), with the mean fit residual plotted as a dashed line.** ***(Bottom panel)*** **The coloured lines show the mean fit residuals additionally using two other ozone absorption cross section data from the University of Bremen and Brion/Malicet (Brion *et al*., 1993). They share features with the original Bass-Paur results, the largest of which are coincident with the primary ozone absorption features of the Huggins Band.**

EARLY RESULTS

To test and examine the retrieval scheme, the month of July was processed. Figure 5 shows examples of some sonde comparisons to retrieved ozone profiles. It is encouraging that the retrieved profile follows the sonde, particularly when it departs significantly from the a priori, indicating that the scheme is performing as expected. A full validation with ozone sondes will be performed including a comparison of retrievals using the alternative ozone absorption cross section data.

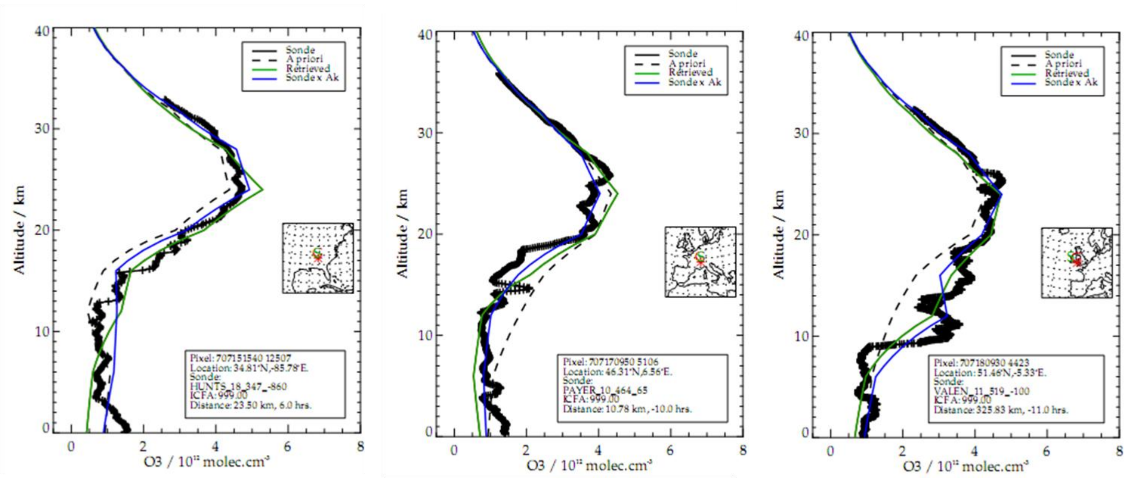

Figure 5: **Three example retrieved profiles as compared to ozone sondes. The black line shows the sonde data itself, the blue is the sonde averaging kernel; the dashed line is the a priori and the green line the GOME2 retrieved profile.**

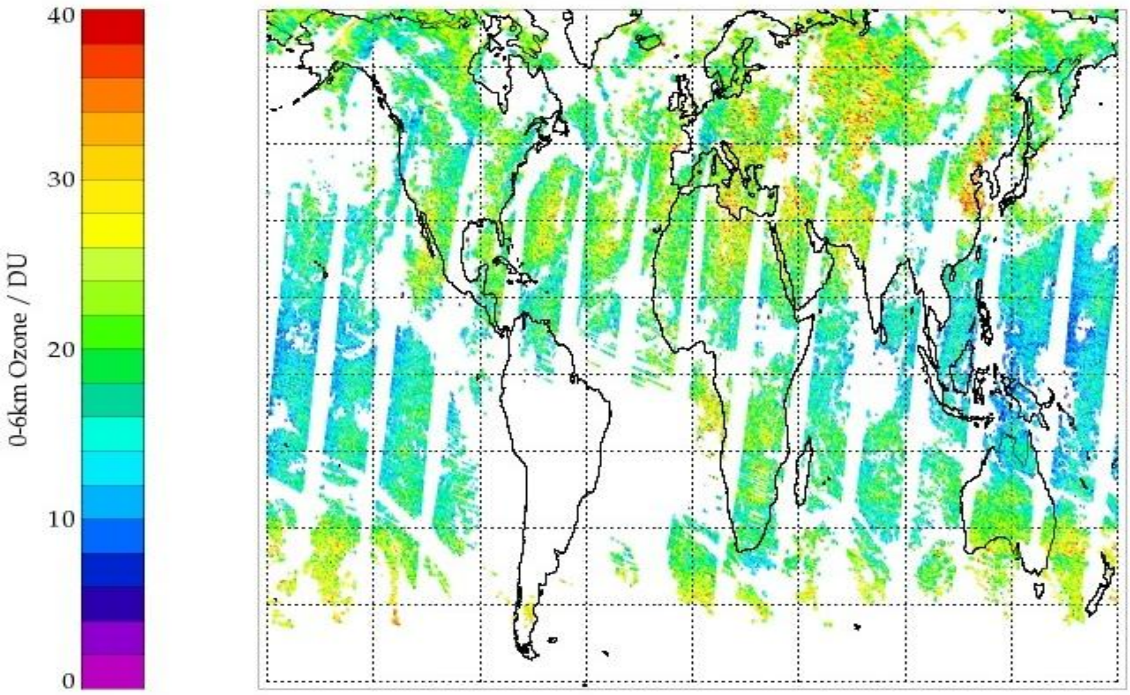

Figure 6: **16th July 2007 0-6km ozone, cloud cleared.**

Figure 6 shows an example global map of 0-6km ozone retrieved from GOME2 measurements, that has been cloud cleared with a conservative cloud flag using the GOME2 level 1b cloud product cloud fraction limited to 0.2. In the presence of cloud, the retrieved tropospheric ozone is reduced as the instrument effectively 'sees' less of the column. The scheme is currently being extended to utilise cloud and aerosol information from the AVHRR instrument in order to improve the cloud handling in the ozone retrievals.

Figure 7 shows a comparison between 0-6km ozone as represented in a chemistry transport model and retrieved using the IASI instrument, presented by Eremenko *et al*., (2008). They examine an enhanced ozone event in Europe in July 2007. For a qualitative comparison, the corresponding ozone as retrieved by the RAL GOME2 ozone retrieval scheme is plotted.

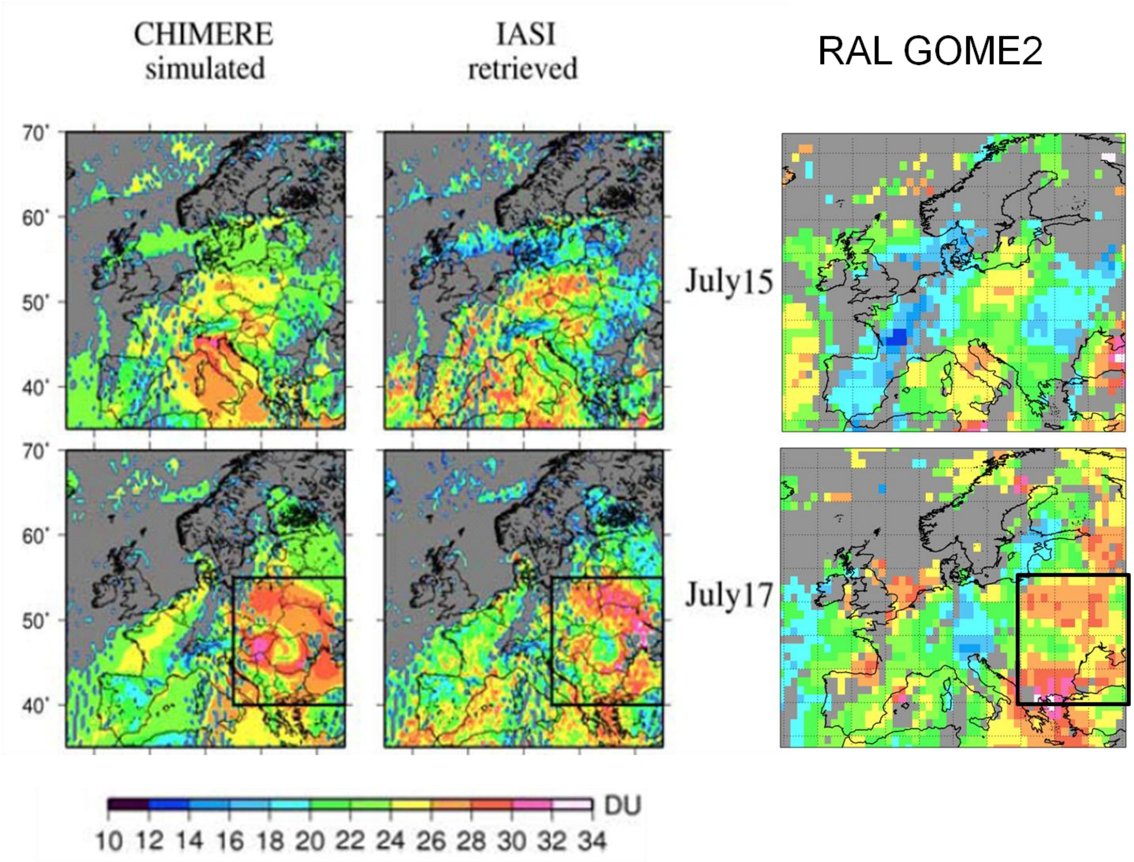

Figure 7: **15th and 17th July 2007 0-6km ozone over Europe. The left four panels are directly from Eremenko *et al*., (2008).**

CONCLUSIONS

The RAL GOME ozone retrieval scheme has been applied to GOME2 measurements and demonstrated to work successfully. Using the accurately characterised slit functions and the enhanced spatial coverage of the GOME2 instrument has lead to clear advances over the GOME-1 scheme. Early results on tropospheric ozone are encouraging. In parallel to extending the scheme to use cloud and aerosol information from AVHRR, investigations are underway to better understand fit-residuals in the Huggins Bands. Both advances are expected to lead to improved tropospheric ozone results in the course of the coming year. Large scale processing will commence shortly to allow systematic validation against ozone-sondes. Data will be made available via the BADC in due course. Those interested in advance access to experimental data-sets are encouraged to contact the author.

Acknowledgements
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