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# Ozone information from high spectral resolution infrared sounders

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Met Office  ECMWF  KNMI  METEO FRANCE Toujours un temps d'avance

# Ozone information from high spectral resolution infrared sounders

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# NWP-SAF Visiting Scientist Report

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The outcomes of this study were extensive and thought to be of interest to the wider community. For this reason it was considered better to produce a journal article containing the full results and present a more brief overview of the study in this VS report. The reader is encouraged to read the full journal article when it is published in *Q.J.Roy.Meteorol.Soc*.

**Background**

Most operational global NWP systems currently have an analysis of ozone that is constrained by observations of UV backscatter from instruments such as Solar Backscatter Ultraviolet Radiometer (SBUV). However, an obvious limitation of these data is that they are not available at night time. We thus have half of the globe unobserved daily and an entire polar region unobserved for much of the winter season. Data from the Microwave Limb Sounder (MLS) on board the Aura satellite have no such sampling problems and have been identified as a valuable source of high quality ozone information. However, from the viewpoint of an operational NWP centre there is a problem in that there is no envisaged operational follow on to this instrument. There is also no heritage of similar data provided by previous instruments that could be used to support climate and reanalysis studies. While data from the MLS will be exploited by operational centres during the periods when it is available, it is unwise to develop an operational reliance upon the information provided by such observations. These considerations lead to a strong incentive to be able to extract ozone information from infrared sources. With these there are no sampling problems related to the position of the sun, a guaranteed operational provision of future data and an extensive historical record to study climate.

**Summary of results**

This study has investigated the value of assimilating ozone sensitive infrared radiances from IASI. It has been found that relative to a baseline system that has no ozone observations, the use of IASI significantly improves the fit to independent ozone estimates from the Aura MLS. Indeed this improvement is, in some areas, comparable or better than that obtained when more established ozone estimates from UV sensors are assimilated (see figure 1).

In broad terms the impact of assimilating the IASI data is largest in the upper troposphere and lower stratosphere consistent with the known sensitivity of the radiances as described by the ozone jacobian. The assimilation of IASI has only a marginal affect at altitudes near the maximum ozone concentration. This is in contrast, but therefore complementary, with the impact of assimilating UV data which tend to constrain ozone more strongly at higher levels.

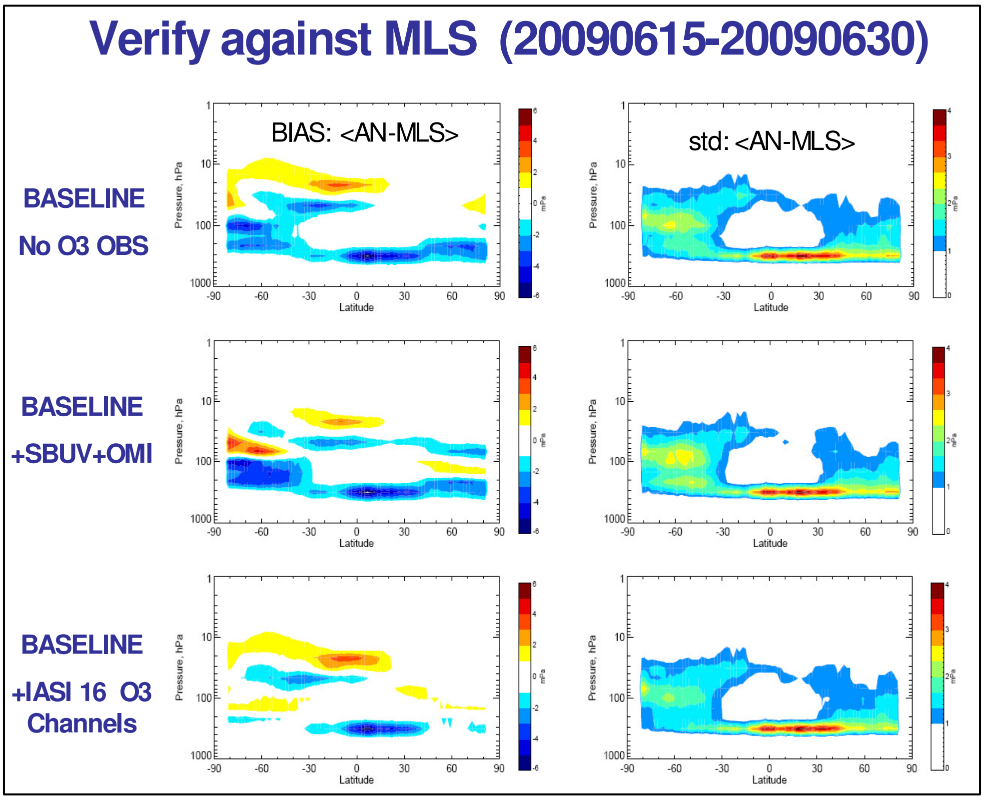


*Figure 1*
*Zonally averaged mean and standard deviation fit to MLS ozone observations for the baseline, IASI and UV assimilation systems.*

One area where the assimilation of IASI is clearly beneficial is in the winter high latitudes and southern polar night. The UV based system was seen to spread erroneous increments in to areas where there were no UV ozone data (due to an absence of sunlight). The more homogeneous coverage of infrared ozone information did not do this and crucially captured a switch from positive to negative ozone errors that the UV system missed.

While a cautious use of IASI radiances only over sea seems to capture most of the large scale mean signals over much of the globe, the additional use of IASI data over land appears to have value. The assimilation of land data was found to improve the constraint of random ozone errors in the analysis and produce a better description of ozone in the southern polar night. Despite these encouraging results, concerns remain about the potential detrimental affect that poorly modelled surface emission may have on ozone sensitive radiances. A much more detailed investigation of different land surfaces in different seasons would be required to gain more confidence in the use of radiances over land.

Results suggest that the current assimilation of a limited number of IASI channels (16) cannot constrain errors with a sharp vertical structure due to the limited vertical resolution of the data. Future studies assimilating a larger proportion of the many hundreds of ozone sensitive radiances that are measured by IASI may yield marginally better results, but are not expected to significantly improve this weakness.

It should be stressed that the results of these studies are not only indicative of the intrinsic value of the IASI (and indeed UV) ozone data, but equally sensitive to the skill of the assimilation system. Two areas are of crucial importance: Firstly, the handling of systematic errors in the data has been described, but there is considerable scope for bias corrections to be optimized. Neither observing system (IASI or UV) consistently improves the fit to MLS data in all areas (which themselves may be biased) and the NWP model is unlikely to be bias free. The exact choice of bias correction (e.g. a flat global offset or a highly air-mass dependent correction) and the choice of anchoring will have a fundamental impact on the ozone analysis. Secondly, the IASI data suffer from a lack of vertical resolution and so the role of the assimilation system in distributing information in the vertical is important (note while
the UV data are artificially retrieved onto a profile layer grid the intrinsic vertical resolution of the data is an issue). This control of increments in the vertical is achieved by the ozone background error covariance and optimization of this may again have a fundamental impact on the ozone analysis.

It is beyond the scope of this limited study, but an immediate next step is to establish an optimal blend of UV and IR ozone information in the operational analysis exploiting the complementary strengths of both. Similarly the exploitation of ozone information from other IR sounders is a near term priority. While applying the experience gained with IASI to AIRS should be relatively straightforward, low spectral resolution sounders such as HIRS and SEVIRI are more problematic. Broadband radiometers are typically more difficult to model (i.e. radiative transfer biases may be larger) and have intrinsically lower vertical resolution. Another important difficulty is that these sensors have less ozone insensitive temperature sounding channels available to assist in the detection of clouds.

An important step for the future is to investigate the potential of ozone sensitive infrared radiances from multiple platforms (in combination with UV data) to constrain errors in the analysis wind field via the 4D-Var tracing. In the current version of the ECMWF 4D-Var, ozone feature tracing is deliberately disabled (in practice by explicitly zeroing any gradient of the ozone data fit with respect to changes in the initial wind field). This pragmatic step was taken as a preventative measure against large erroneous wind and temperature adjustments in the stratosphere associated with the assimilation of biased UV observations under certain conditions. Clearly a precursor to re-activating the tracing mechanism is optimise the current ozone analysis (blending the best information from infrared and UV sources along the lines already discussed) and eliminate (as far as possible) any sources of bias.

Another important area that must be investigated in the future is how improvements in the analysis of ozone are preserved in the extended ozone forecasts. This has not been
treated in this study due to another pragmatic feature of the current ECMWF system. The radiation scheme of the forecast model does not use the ozone fields that are forecasted from the initial conditions (i.e. the ozone analysis), but reverts to a climatology estimate of ozone. It remains to be seen if an improved analysis of ozone coupled with the latest developments in ozone transport and chemistry will allow this crucial link with the radiations scheme to be reinstated.

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