Assimilation of ozone retrievals from the MIPAS instrument on board ENVISAT at ECMWF.

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Ozone retrievals from satellites have been assimilated in the operational ECMWF system since April 2002. At the beginning, total column ozone retrievals from GOME (Global Ozone Monitoring Experiment) on ERS-2 provided by KNMI's Fast Delivery Service, and ozone layers from the SBUV/2 (Solar Backscatter Ultra Violet) instrument on NOAA-16 were used in the operational assimilation system. The SBUV/2 data are given as 12 ozone layers and are combined at ECMWF into 6 layers (0.1-1 hPa, 1-2 hPa, 2-4 hPa, 4-8 hPa, 8-16 hPa, 16 hPa-surface) to reduce vertical observation error correlations. This means that the ozone data assimilated at ECMWF were in effect total column data, as the lowest SBUV layer spans from 16 hPa to the surface. The assimilation of ozone retrievals in such broad layers can lead to problems with the vertical structure of the analysed ozone field if there is a systematic bias between the model and the data (Dethof and Hólm 2003). In these situations there is not enough vertical resolution in the observations to assign the analysis correction to the right levels. Instead, the information about how to distribute the analysis correction increment in the vertical has to come from the background error covariances. The background errors, however, only describe random errors and not systematic ones, and when systematic biases are interpreted as random errors by the analysis, this can lead to corrections being applied to the wrong level.

It was hoped that the ozone analysis could be improved by assimilating ozone data with a higher vertical resolution than the data used initially at ECMWF. Such ozone data became available after the launch of the ENVISAT satellite on 1 March 2002. One of the instruments on board ENVISAT is MIPAS (Michelson Interferometer for Passive Atmospheric Sounding), a limb-viewing high-resolution Fourier-transform spectrometer, that measures atmospheric emissions in the mid-infrared part of the spectrum between 4.15 and 14.6 microns. MIPAS provides global coverage, including coverage of the polar regions, independent of illumination conditions, and allows the retrieval of ozone profiles from the model top at 0.1 hPa down to about 200 hPa with a vertical resolution of 3-5 km. This means MIPAS profiles have a better vertical resolution than the ozone data originally used at ECMWF.

The assimilation of MIPAS ozone retrievals was tested at ECMWF. It leads to a pronounced improvement of the ECMWF ozone analysis in the extratropics, both in the total column ozone field and in the vertical ozone distribution, while the impact on the forecast scores is neutral. Assimilation experiments show that in February 2003 the impact of assimilating MIPAS ozone profiles is strongest at high latitudes of the northern hemisphere (NH), where total ozone values are reduced, giving a better agreement of the ECMWF ozone field with independent TOMS data, and also a better agreement of analysis ozone profiles with ozone sondes. In August and September 2003 the impact is strongest in the southern hemisphere (SH), where the representation of the Antarctic ozone hole in the analysis is improved when MIPAS ozone data are assimilated.

Figure 1 compares ozone profiles from an experiment with (red curve) and without (green curve) the assimilation of MIPAS ozone profiles with independent ozone sonde

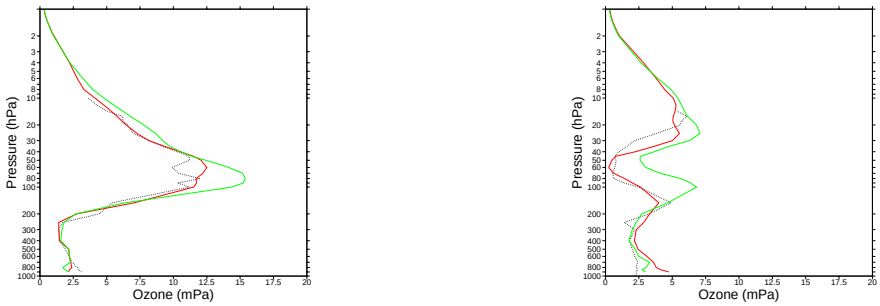

Figure 1: Ozone profiles in mPa from sondes (black), an experiment with the assimilation of MIPAS ozone profiles (red), and an experiment without the assimilation of MIPAS ozone profiles (green) from the Antarctic Neumayer station (71°S, 8°W) on 26 August (left) and 1 October 2003 (right).

observations from the Antarctic Neumayer station on 26 August and 1 October 2003. The ECMWF model has a positive ozone bias over the South Pole during southern winter and spring. During the ozone hole season, the chemistry parameterization is not able to reduce ozone values to the very low values seen in observations. At this time of year, the assimilation of MIPAS ozone data has a large impact on the shape of the analysis profile at the Antarctic Neumayer station, and the analysed ozone field is much improved if MIPAS ozone profiles are assimilated. In August the ozone layer over the South Pole has started to thin, but is not completely destroyed yet. The ECMWF analysis without the assimilation of MIPAS ozone profiles overestimates the ozone values at and above the ozone maximum. When MIPAS data are assimilated ozone values are reduced and the agreement with the sonde is good. At the beginning of October the ozone hole is fully developed, and ozone is almost completely deleted between 100-40 hPa. When MIPAS ozone data are assimilated the analysis profile agrees well with the sonde, while the analysis without MIPAS data does not reproduce the very low values seen in the observations. The resulting total column ozone field also agrees better with independent TOMS observations over the South Pole if MIPAS ozone profiles are assimilated (not shown).

The main reason the assimilation of MIPAS ozone profiles has a positive impact on the vertical structure of the analysed ozone field over most of the globe is the higher vertical resolution of the MIPAS profiles, compared to the ozone data previously assimilated at ECMWF. Information about the vertical structure of the analysis correction now comes from the data, and does not have to be inferred from the background error statistics. Furthermore, it is beneficial that MIPAS provides day and night time measurements, including coverage of the poles during the polar night.

Owing to the positive impact on the ozone analysis, the assimilation of MIPAS ozone profiles was included in the operational ECMWF system in October 2003.

References

Dethof, A., and Hólm, E.V. (2003). Ozone assimilation at ECMWF. *Quart. J. Roy. Meteor. Soc.*, 128. submitted.