The PROMOTE 3D ozone record service: Overview and first evaluation of stratospheric ozone reanalysis based on satellite observations between 1992 and 2004

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Reanalyses of historic satellite data

Within SPARC CCMVal data assimilation of atmospheric constituents is becoming more and more important as the number and quality of satellite observations increases. The European ESA/GMES project PROMOTE applies three CTM-based state-of-the-art assimilation systems to derive long-term records of stratospheric ozone and related species. Mainly ozone observations from three instruments are used: UARS/MLS, ERS2-GOME/NNORSY and ENVISAT/MIPAS (including additional species) covering the years 1992 to 2004. The sequential assimilation model ROSE/DLR (Baier et al., 2005) and the 4D-Var systems SACADA (Schwinger, 2006) and BASCOE (Errera and Fonteyn, 2001), are applied to generate daily chemical analyses and error statistics (figure 1 and text box to the right). We present first validation results using independent satellite observations. By means of cross-comparison possible model influence on analysis results is discussed.

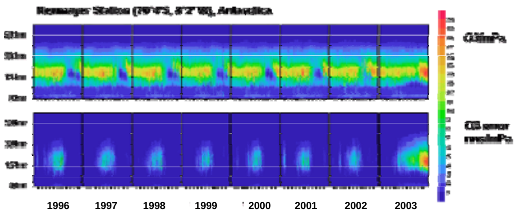

Figure 1: GOME-ROSE ozone partial pressure and respective analysis error for Neumayer station. Note the increasing error in 2003 d.t. instrument tape recorder failure.

First validation results

Comparisons of assimilated ozone records to HALOE, SAGEII and POAM3 observations in general show deviations well within expected instrument errors. Assimilation of GOME-NNORSY (1996-2003) ozone profile data (Müller et al., 2003) results in mean rms deviations near 10% when compared to HALOE in the stratosphere (see figure 2). Mean bias remains clearly below 5%. However, an annual trend can be observed in GOME-ROSE results. The change from ERA40 to daily standard ECMWF analysis coincides with a jump to negative bias. With respect to latitude and height, a global positive bias above 1hPa is found in GOME-SACADA results while both ROSE and SACADA analyses show a latitude dependent bias between 10 and 1 hPa (figure 4). For the MIPAS analysis period 2002-2004, MIPAS-BASCOE agrees well with respective POAM3 data (figure 3). A small negative bias is found c.t. HALOE above 1 hPa (Errera et al., 2008).

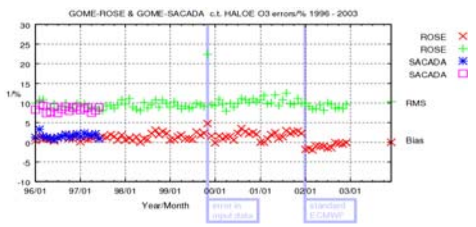

Figure 2: GOME-ROSE/SACADA results compared to HALOE covering all stratospheric levels during the period 1996-2003. High values: RMS errors, Low values: respective Bias.

Model cross-comparison

Results for identical time periods are in general very consistent, albeit different models and input data were used. Only for some time periods more significant differences have been identified (see figure 5). With respect to Antarctic ozone hole conditions, for example, during the 2003 vortex split-up, MIPAS-BASCOE analysis shows stronger horizontal ozone gradients c.t. GOME-ROSE (figure 7). Comparison of the first-guess values to GOME observations shows greatest deviations at the vortex edge. All three assimilation systems benefit from observations in data void regions.

Summary and outlook

In most cases assimilation results are consistent showing errors well within expected error bars. However, in data void regions errors can increase considerably (figure 6). There are also critical regions and time periods where model results are strongly influenced by dynamics or heterogeneous chemistry (figure 7). Initial validation by ground-based observations confirm these findings. Assimilation results for GOME-SACADA and MIPAS-SACADA are expected for the end of 2008. Recently the SACADA system has also been applied to METOP-A GOME2 observations.

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We are very grateful to all data providers, namly the GOME, MLS and MIPAS teams!

Validation data used was derived from the following sites
HALOE: http://code916.gsfc.nasa.gov/Public/Analysis/UARS/urap/home.html
POAM3: http://eosweb.larc.nasa.gov/PRODOCS/poam3/table_poam3.html

Models and available data sets

Model Version	BASCOE 4.0	SACADA 2.0*	ROSE/DLR 3.2
Resolution	37 layer, 0-65km 5° x 3.75° lon-lat grid *hybrid level*	42 layer, 0-65km 250km isocahedron grid *hybrid level*	43 layer, 0-56km 3.75° x 2.5 ° lon-lat grid *pressure level*
Chemistry •*reaction rates* •*photolysis rates* •*source gases*	 *JPL14-2003* *Madronich and Flocke, 1998* *CFC11,CFC12, CH3Br,etc.*	 *JPL15-2006* *Smith, 2007* *CFC11,CFC12,CH3Br,etc.*	 *JPL14-2003* *Stamnes, 2003* *CFC11, CFC12, CH3Br*
Het. chemistry	Aerosols, Ice, NAT	Aerosols, Ice, NAT, STS	Aerosols, Ice, NAT
Advection	Lin and Rood, FFSL	semi-Lagrange	Lin and Rood, FFSL
Data assimilation	4D-Var	4D-Var	OI/KF
**German Weather Service GME model as meteo driver*			
Data Version	**v4q09**	**GOME_O3DS v2**	**GOME_O3DR v3.2**
Input data •*species* •*coverage*	UARS/MLS *O3 only* 1992-1999	GOME-NNORSY2 O3 *O3 only* 1996-1997 *(tbc)*	GOME-NNORSY 2 *O3 only* 1996-2003
Meteo analysis	ECMWF ERA40	ECMWF ERA40 / ECA	ECMWF ERA40 / ECA
Resolution	37 layer, 1000-0.1.hPa 5° x 3.75° lon-lat grid	33 layer, 147-0.3hPa 3.75° x 2.5 ° lon-lat grid	33 layer, 147-0.3hPa 3.75° x 2.5 ° lon-lat grid
Output species	*O3*	*O3 plus reactive species and reservoirs*	*O3, O3-loss, PSC I+II*
Data Version	**v4q30**	**MESA_O3DS v2**	**MESA_O3DR v3.2**
Input data •*species* •*coverage*	MIPAS ESA 4.61/62 *O3, HNO3, NO2, N2O, CH4* Jul 2002 – Mar 2004	MIPAS ESA 4.61 *O3, HNO3, NO2, N2O, CH4* *Jul 2002 – Mar 2004 ***	MIPAS-ESA 4.61 *O3, HNO3, NO2, N2O, CH4* *Jul 2002 – Mar 2004 ***
Meteo analysis	ECMWF ECA	ECMWF ECA	ECMWF ECA
Resolution	37 layer, 650-01.hPa 3.75° x 2.5° lon-lat grid	33 layer, 147-0.3hPa 3.75° x 2.5 ° lon-lat grid	33 layer, 147-0.3hPa 3.75° x 2.5 ° lon-lat grid
Output species	*O3*	*O3 plus reactive species and reservoirs*	*O3, O3-loss, PSC I+II*
Data format	HDF4	NetCDF	NetCDF

**ECA= Standard daily ECMWF analyses* ***completion expected for the end of 2008*

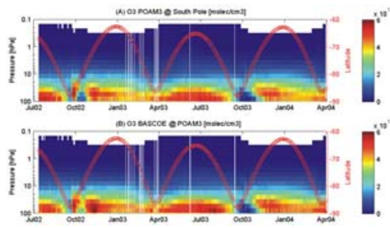

Figure 3: POAM3 (top) and MIPAS-BASCOE (bottom) ozone mixing ratios during 2002 and 2003.

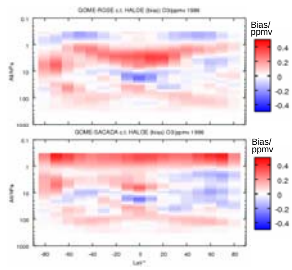

Figure 4: Comparison of GOME-ROSE (top) and GOME-SACADA (bottom) ozone results to HALOE for 1996.

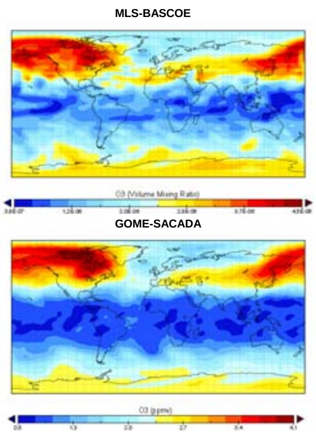

Figure 5: Ozone analysis of mixing ratios in ~20 km altitude for March 2, 1996: MLS-BASCOE (top), respective GOME-SACADA (bottom) results.

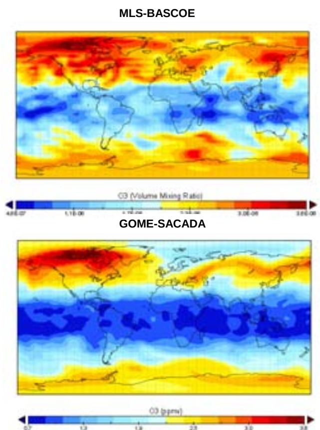

Figure 6: Same as figure 5, but for April 10, 1997: Note differences due to missing MLS observations north of 34°N before April 10.

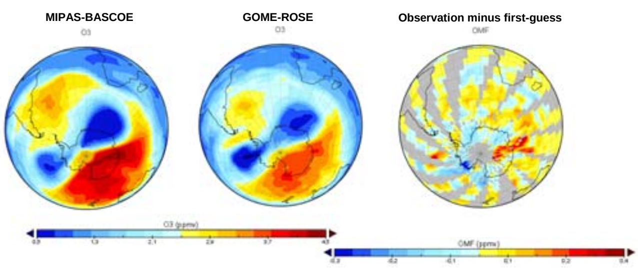

Figure 7: Ozone analysis of mixing ratios in ~20 km altitude for September 23, 2002 (vortex split event): From left to right: MIPAS-BASCOE, GOME-ROSE results and respective 36h observation minus first-guess errors before 12:00 GMT analysis time on ROSE model grid.

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