Isentropic, global, variational assimilation of MIPAS ozone and water vapour

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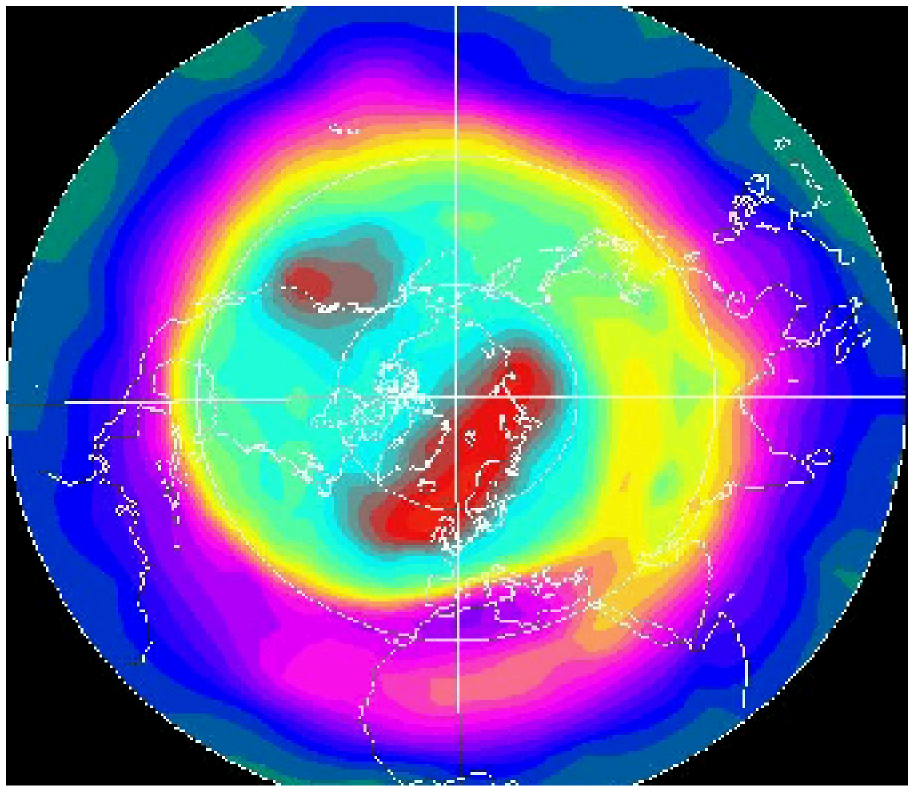


Chiara

AOPP,

Generic outline

Equations

Colour plots

Results

Mathematical definition

THE PENALTY FUNCTION

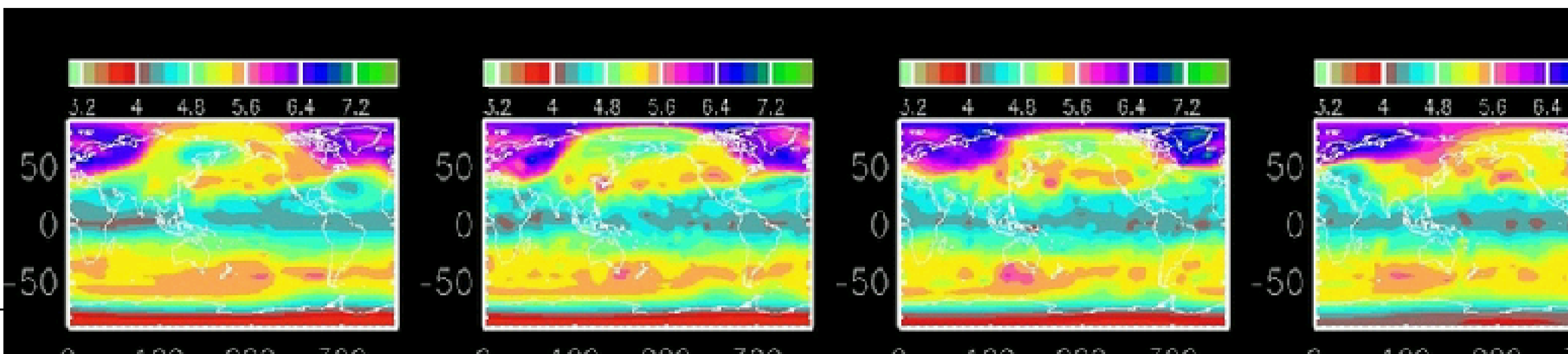
The analysis is defined as the field which minimises the following quadratic penalty function:

$$\mathcal{J} = w_{\text{ap}} \int\int \left[\chi_t + \boldsymbol{u} \cdot \nabla\chi \right]^2 dA dt$$

$$+ w_{\text{num}} \int\int \left| \left(c_1 \frac{\partial}{\partial t}, \nabla \right) \left[c_1^2 \frac{\partial^2 \chi}{\partial t^2} + \nabla^2 \chi \right] \right|^2 dA dt$$

$$+ \sum \frac{\left[\chi_i - \chi(\lambda_i, \phi_i, t_i) \right]^2}{\sigma_i^2},$$

where χ is the species mixing ratio, $\boldsymbol{u}$ is the horizontal wind taken from ECMWF operational analyses, χ_i and σ_i are the observations and noise estimates interpolated onto the isentropic surface. w_{ap}, w_{num}, c_1 and w_{obs} are constants.



Quasi-elliptical formulation

THE ANALYSIS EQUATION

Minimising the penalty function over a time interval t_0 to t_1 gives the following analysis equation:

$$-w_{\mathrm{ap}}\frac{D^2\chi}{Dt^2} - w_{\mathrm{num}}\left(c_1^2\frac{\partial^2}{\partial t^2} + \nabla^2\right)^3 \chi$$

$$+\sum\Big[\chi(\lambda_i,\phi_i,t_i) - \chi_i\Big]\delta(t-t_i)\delta(\lambda-\lambda_i)\delta(\phi-\phi_i) = 0.$$

The boundary conditions at t_0 and t_1 are

$$\frac{D\chi}{Dt} = 0$$

and

$$\frac{\partial}{\partial t}\left(c_1\frac{\partial^2}{\partial t^2} + \nabla^2\right)^k \chi = 0, \qquad k = 1, 2.$$

Information flow

Kalman Filter

$$\begin{array}{ccccc}
 & & O_{t+1} & & O_{t+2} \\
B_t & \overset{M,M^T}{\Rightarrow} & \Downarrow B_{t+1} & \overset{M,M^T}{\Rightarrow} & \Downarrow B_{t+2} \\
x_t & \underset{M}{\Rightarrow} & x_{t+1} & \underset{M}{\Rightarrow} & x_{t+2}
\end{array}$$

4D-VAR

$$\begin{array}{ccccc}
\lambda_t & \underset{M^T}{\Leftarrow} & \lambda_{t+1} & \underset{M^T}{\Leftarrow} & \lambda_{t+2} \\
\Downarrow B_t & & \Uparrow O_{t+1} & & \Uparrow O_{t+2} \\
x_t & \underset{M}{\Rightarrow} & x_{t+1} & \underset{M}{\Rightarrow} & x_{t+2}
\end{array}$$

Residual Minimisation

$$\begin{array}{cccccc}
 & O_t & & O_{t+1} & & O_{t+2} \\
 & \Downarrow & & \Downarrow & & \Downarrow \\
\substack{\Leftarrow \\ \Rightarrow} & x_t & \underset{M^T M}{\overset{\Rightarrow}{\Leftarrow}} & x_{t+1} & \underset{M^T M}{\overset{\Rightarrow}{\Leftarrow}} & x_{t+2}
\end{array}$$

All methods involve Q and H.

Experimental details

- Single minimisation for January, 2003.
- MIPAS ozone interpolated to 850K isentrope.
- No background field.
- $\Delta x \approx 400$km, $\Delta t = 4$hours.
- Nominal model residual variance: 0.2ppmv/day.
- Multi-grid relaxation algorithm.

The code is Fortran 95, and runs without changes on a Dec Alpha using Digital Fortran or on a Linux PC using either Intel or Portland Group compilers.

A global assimilation of 30 days duration at 4 degree resolution takes about 4 minutes on a 1.8GHz Linux PC.

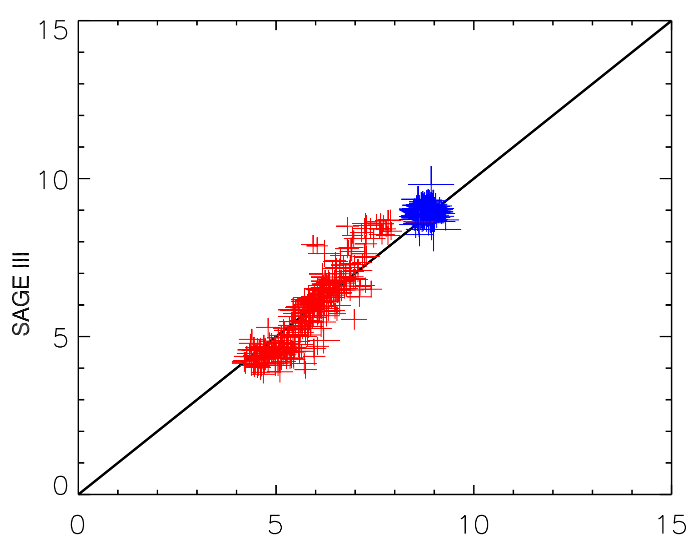
Validation (1)

SAGE III

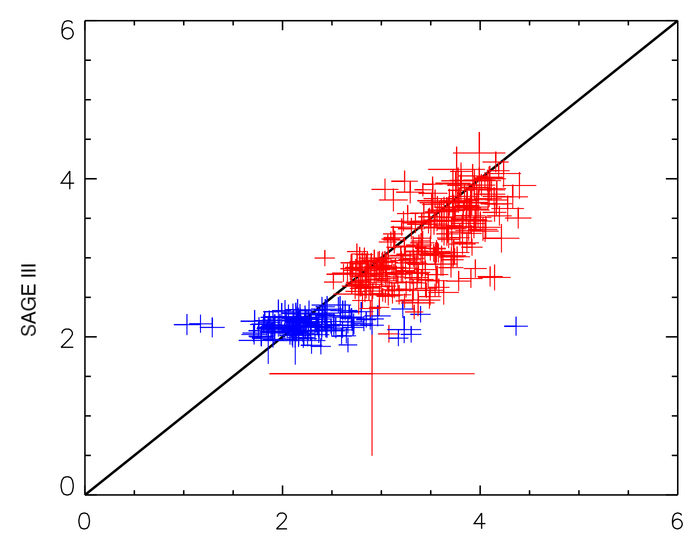
SAGE III (Stratospheric Aerosol and Gas Experiment) is mounted on the Russian Meteor-3M satellite. It is an occultation instrument. The observations used here are derived from solar occulation events which occur twice per orbit. The coverage is much lower than obtained from MIPAS, but the vertical resolution is greater and it provides an independent source of information against which to validate the MIPAS observations.

Red: northern hemisphere, blue: southern.

Scatter plot, comparing SAGE III and assimilated MIPAS ozone concentration (ppmv) on 850K



Scatter plot, comparing SAGE III and assimilated MIPAS ozone concentration (ppmv) on 500K



Validation (2)

VALIDATION

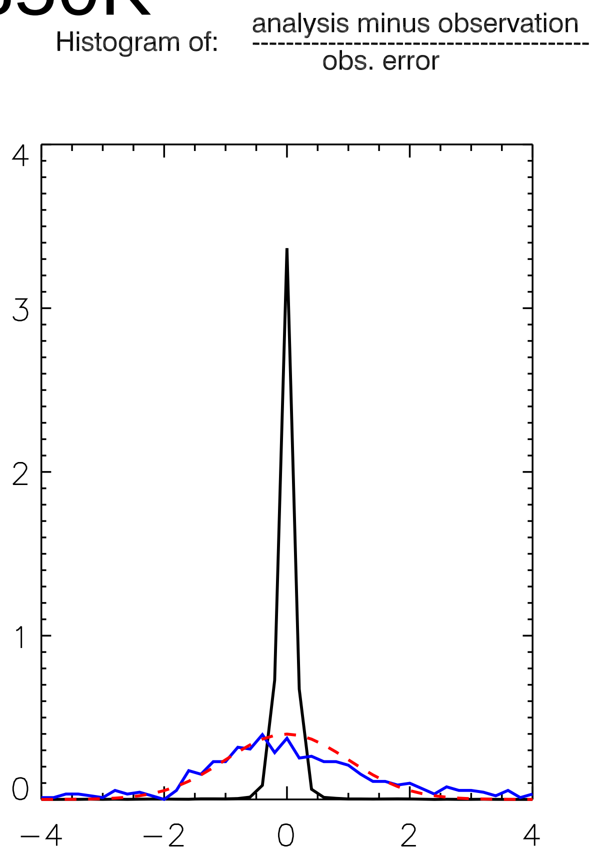
The intercomparison uses 10866 MIPAS profiles and 470 SAGE III profiles.

Agreement is very good at 850K and acceptable at 500K.

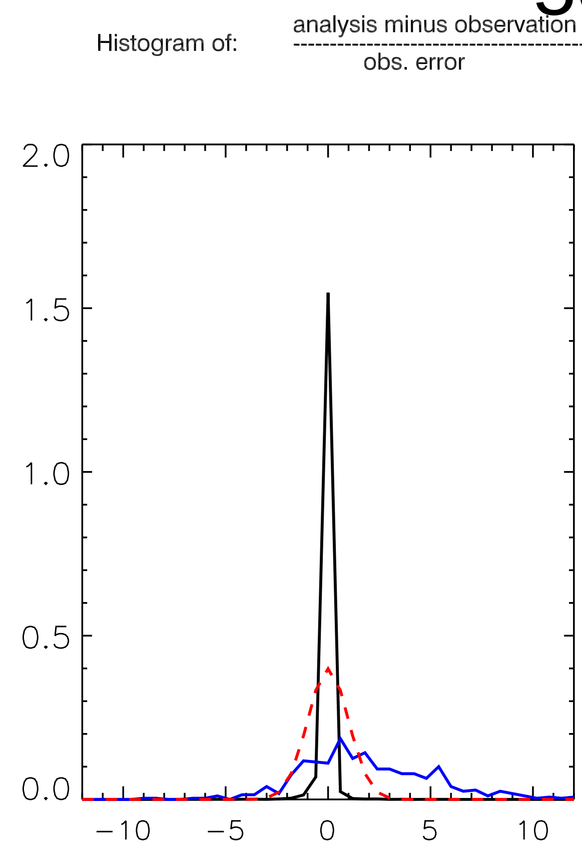
Histograms of differences between analysis and observations, normalised by the estimated SAGE retrieval error, show a distribution close to the unit variance Gaussian at 850K.

This means that the total error, analysis plus SAGE, is close to the estimated SAGE retrieval error.

850K

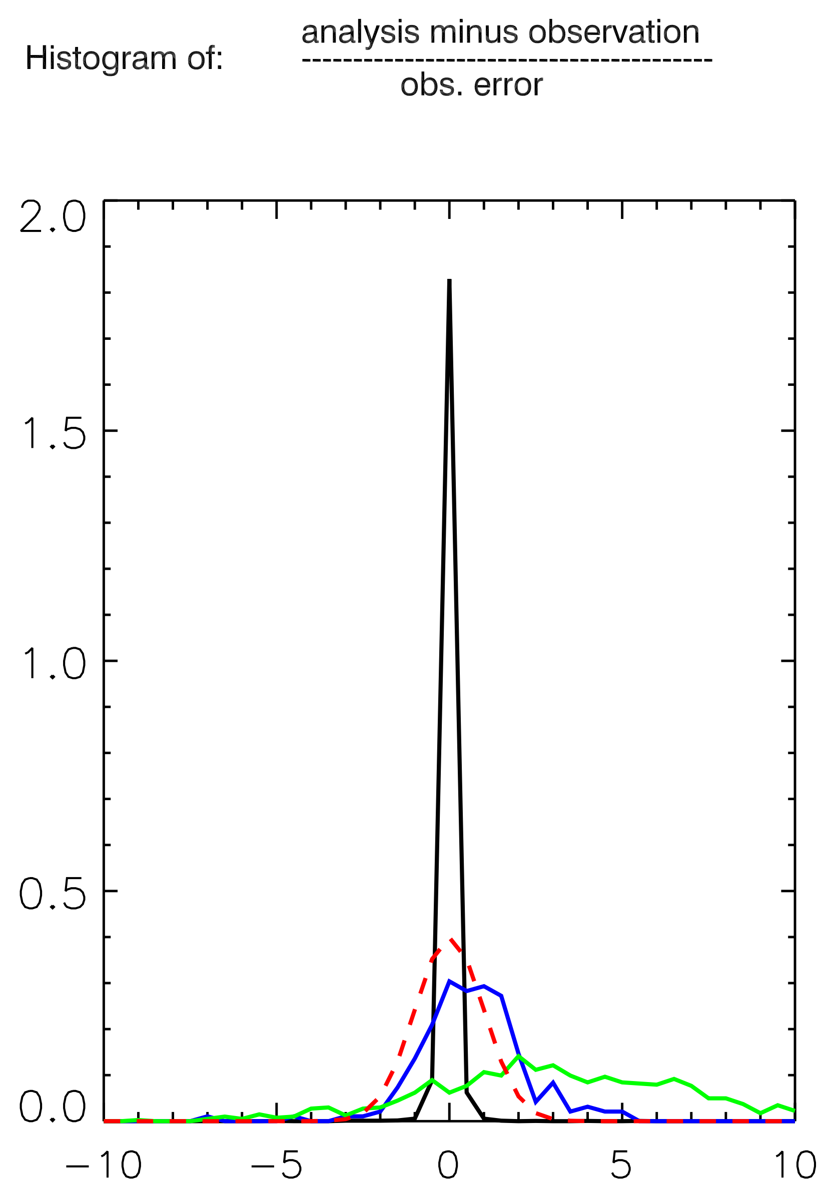


500



GOME (preliminary), September 20-28, 2002

Red: unit Gaussian
Black: MIPAS
Blue: SAGE III
Green: GOME



CONCLUSIONS

The isentropic analysis gives a good quality global analysis.

This analysis method can be used to compare spatially and temporally separated observations.

The results suggest that MIPAS and SAGE III are consistent to within advertised error estimates. The agreement is better in the upper stratosphere than in the lower stratosphere.

Results from GOME show some disagreement, but different vertical resolution has not yet been accounted for.

The residual minimisation method produces a low cost, accurate analysis with the isentropic advection model: it remains to be seen how it works with more complex models.