Multiannual simulations of ozone with the KASIMA model and comparison with observations

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SCOUT-O3

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Introduction

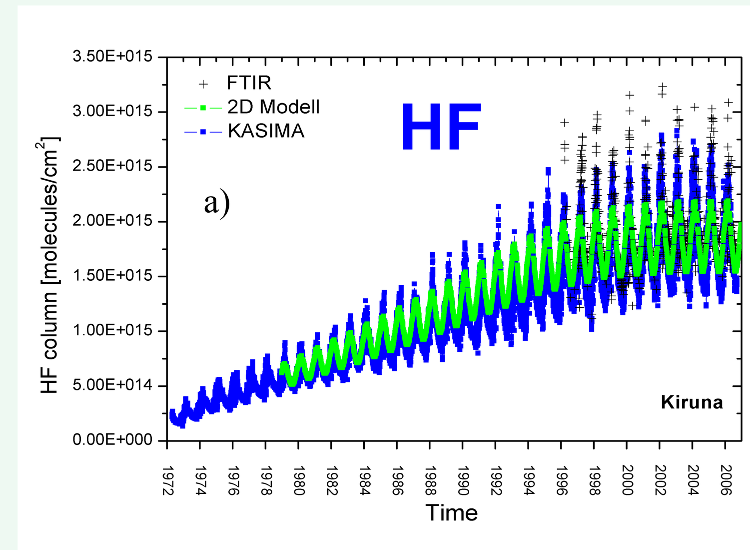
The question how much chemistry vs. dynamics contribute to recently observed changes of trends of ozone in mid latitudes and if ozone is already recovering through measures such as the Montreal protocol is still under debate as state-of-the-art CTMs generally show significant deviations from observations of total ozone which are of the order of the trend itself. In addition, CCM simulations indicate significant changes of the strength of the Brewer-Dobson circulation during the last half century which should have observable consequences for distributions of trace species. Here we analyse the results of a multiannual run of the KArlsruhe Simulation model of the Middle Atmosphere (KASIMA) spanning the ERA-40 period and compare them with satellite and ground based observations.

Model description

KASIMA is a 3D-model of the middle atmosphere with a full stratospheric chemistry scheme including processes on liquid aerosol and polar stratospheric cloud particles, for global simulations of atmospheric trace gases in the middle atmosphere between ~7 and 120 km altitude. It uses parameterizations of heating rates and gravity wave drag. The model runs in a nudged version: below 80 hPa meteorological analyses (ERA 40 / operat. ECMWF) are used, up to 1hPa the model is relaxed to the analysis with a time constant of ~4h. The model is initialized in 1957 and was run with a T21/L63 resolution (corresp. 5.6° x 5.6° horizontal and a vertical resolution of 750m in the lower stratosphere).

Model performance

Fig. 1 shows examples of comparisons with observations. Whereas generally columns as eg. For O3 and HF are well reproduced by the model, global correlation plots of altitude resolved observations generally show some scatter between model and observations. This is probably related to the relatively coarse resolution used for these multiannual simulations.



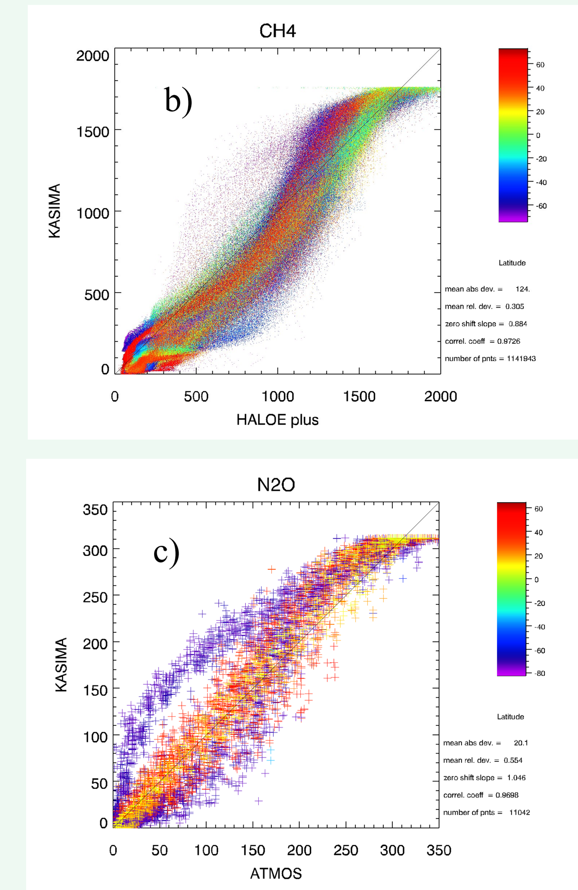


Fig.1: a) Comparison of ground based HF column observations and model simulation. b) Correlation CH4 HALOE observations/model for year 2000 c) Correlation N2O observations ATMOS flight Nov 1994/model

Mean age of air

For characterizing the transport properties of the model and possible changes of the Brewer Dobson circulation during the ERA-40 period in the model, mean age of air is used. Fig. 2 shows an example of a comparison of mean age of air derived from SF6 observation of the MIPAS instrument on ENVISAT with model results (Stiller etal. 2008). Using a chemical scheme in the model accounting for mesospheric loss of SF6, good agreement between the observation and the model is achieved in the lower and middle stratosphere. Mean age of air becomes younger in the model: at northern mid latitudes in the stratosphere a change of about 1a/30a is simulated, comparable to studies with CCMs (see Fig. 3).

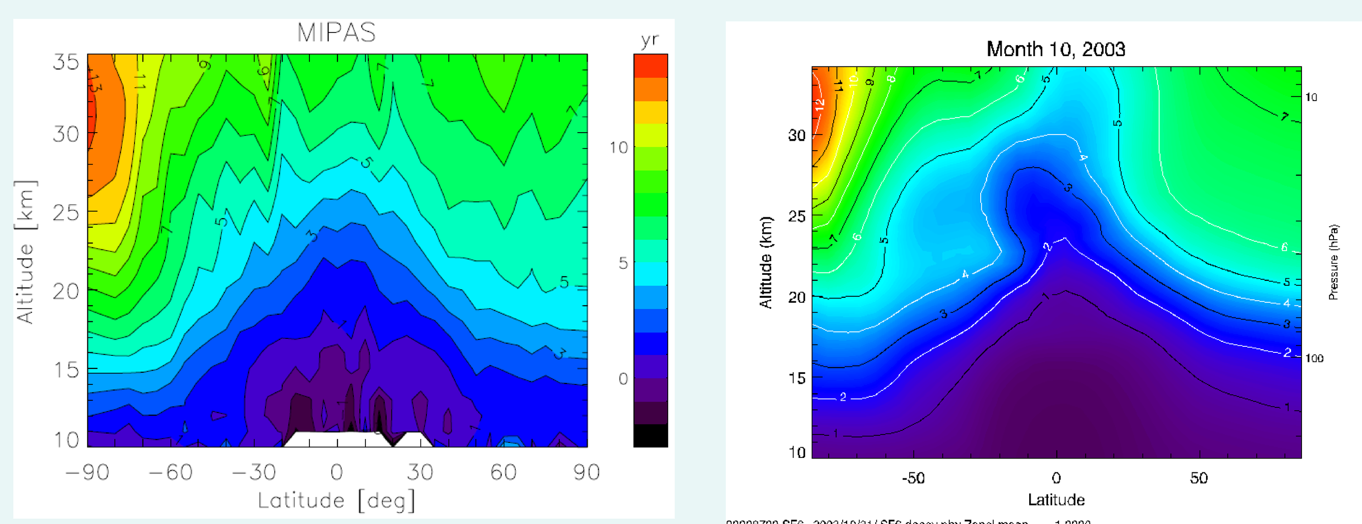


Fig. 2 Example of comparison of mean age of air. Left: mean age of air derived from MIPAS-ENVISAT SF6 observations. Right: model result where a mesospheric loss scheme for SF6 was used for the simulation (from Stiller et al., 2008, ACP)

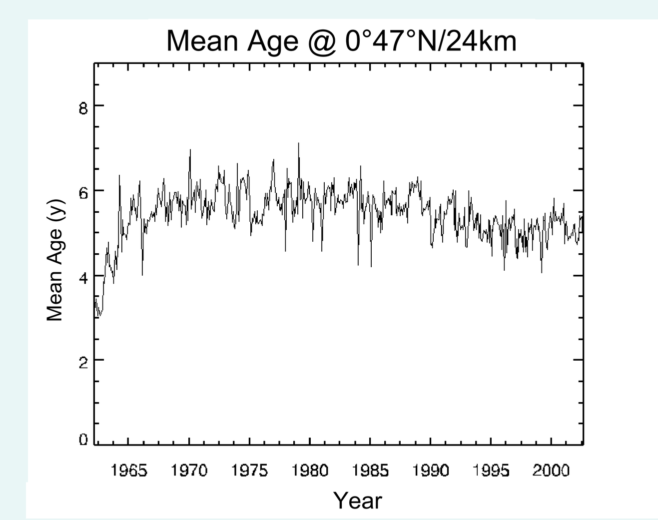


Fig. 3 Time series of mean age of air at 0° 45°N at 24 km altitude. A trend to younger air is simulated for 1975 - 2000.

Comparison with merged TOMS/SBUV data

In WMO (2006) model runs have been discussed to understand the causes of past changes in ozone. Comparisons with merged TOMS data for northern and southern mean latitudes are shown in Fig. 4, inlay. Same comparison for KASIMA (Fig. 4) for the period 1980 – 2006 show the following results:

- large deviations in late 1980s and early 1990s as in SLIMCAT comparison are not obvious, but overall agreement is worse in northern midlatitudes with weaker anomalies and KASIMA seems to overestimate QBO fluctuations in these latitudes.
- TOMS data show in the northern latitudes decreasing values until early 1990s and increasing values afterwards, whereas in the southern latitudes there's no change in the trend.
- Good agreement of TOMS and KASIMA of the southern midlatitudes

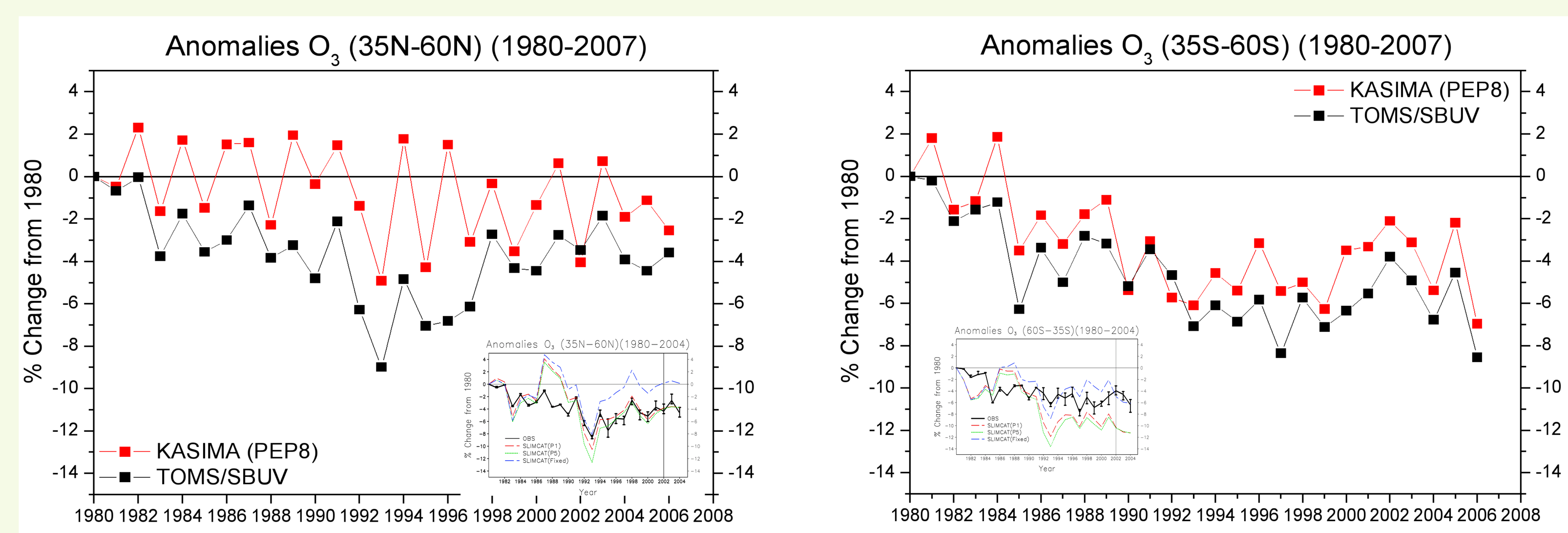


Fig.4: Time series of annual mean anomalies (with respect to 1980). Comparison of merged TOMS/SBUV data (black) with modelled data. Inlay SLIMCAT-results from WMO report 2007.

Comparison with WOUDC data records

Time series for few, selected groundbased stations have been compared, which are all part of the WOUDC (World Ozone and Ultraviolet Radiation Data Centre) (Fig.5). All chosen stations operate Brewer/Dobson-Spectrophotometers with time series starting in the 1960s.

- Generally, the model results for the mean trend agree well with the observations
- Smaller anomalies in KASIMA data than in ground-based data.

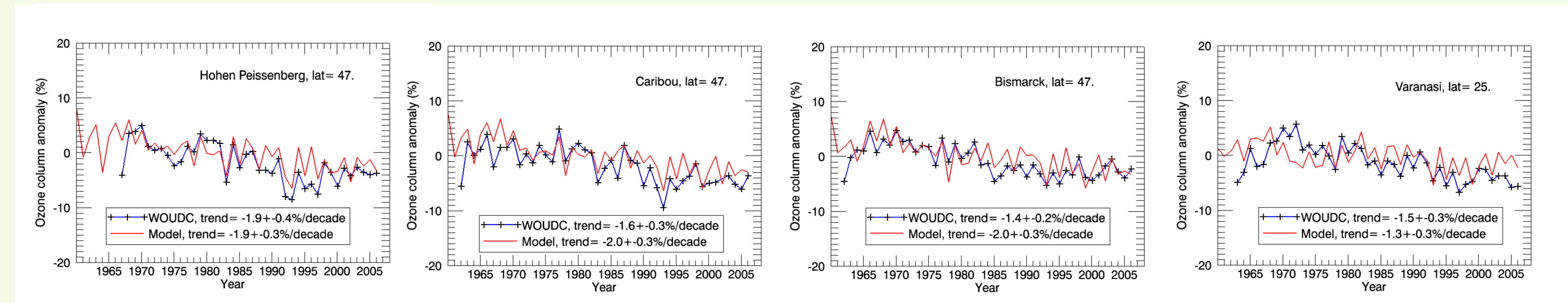


Fig. 5: Time series of annual mean anomalies (wrt mean 1975-1985). Comparison of satellite groundbased (black cross/blue line) and modelled data (red). From North to South (top left to bottom right: Hohenpeissenberg, Caribou, Bismarck, and Varanasi.

Comparison of Trends of KASIMA and TOMS

Linear trend coefficients have been calculated for every grid point between 60°N and 60°S for both KASIMA and TOMS data (Fig. 6).

- KASIMA shows trends between 0 and -0.5% with lowest values in the northern hemisphere.
- TOMS data show pattern symmetric to the equator with lower values at the equator and increasing values poleward. Trend coefficients lie here between 0 and -1% with a strong gradient in the south polar region.
- Agreement of trends derived of KASIMA and TOMS data is good in southern midlatitudes, but large deviations in northern latitudes and south polar regions.
- Differences in northern latitudes might be explained by an underestimation of chemical ozone destruction and is possibly related to the coarse resolution of the model version used.

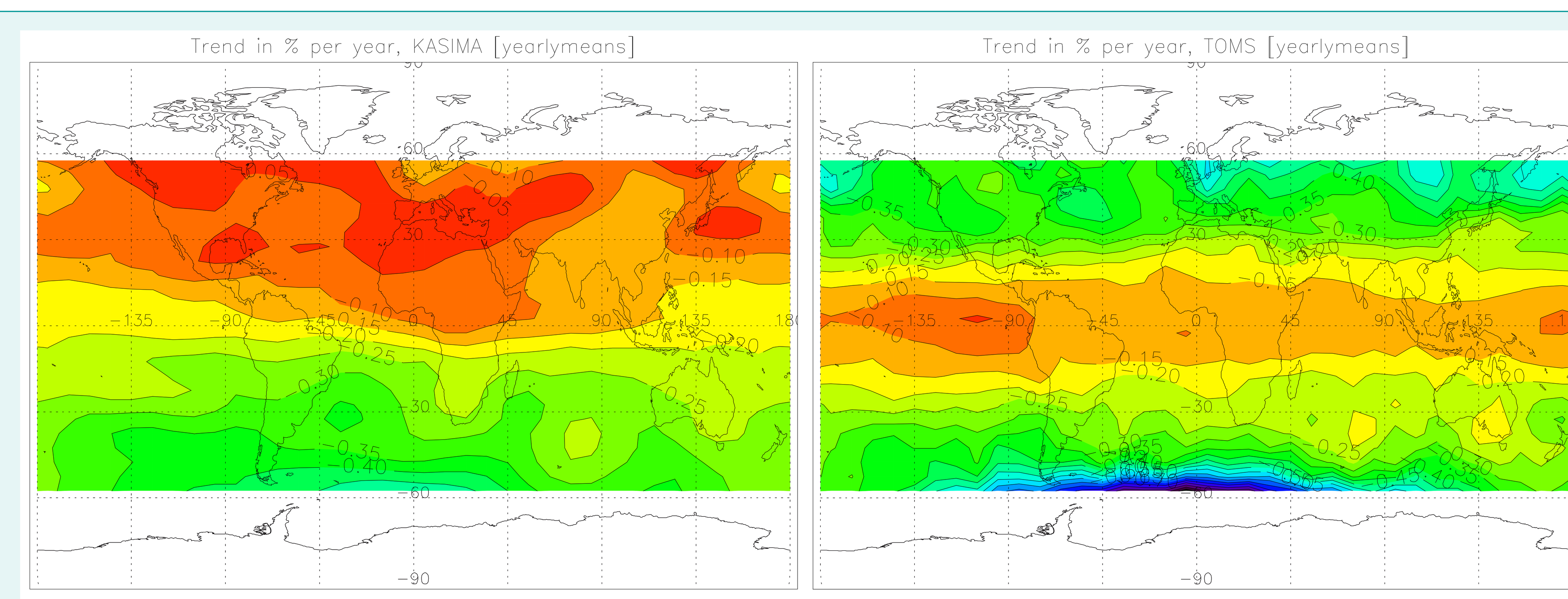


Fig. 6: Linear trend coefficients in % per year calculated for the timespan 1979-1996 for KASIMA (left) and TOMS (right), both using the same colortable. Pinatubo values (1991-1993) have been omitted.

Conclusions

The multiannual simulation with the KASIMA model using the ERA-40 data set shows reasonable agreement with observations. Differences between observations may be partially explained by the coarse resolution used. The negative trend of mean age of air is similar to results derived by CCM studies. Despite the good agreement between the results and the observations further studies are necessary to estimate if the model results are sensitive enough to allow valid conclusions about changes of transport.

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