Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Forschungszentrum Karlsruhe GmbH, Institut für Meteorologie und Klimaforschung,
Postfach 3640, 76021 Karlsruhe, Germany

Roland Ruhnke, Thomas Reddmann, and Wolfgang Kouker

KASIMA long-term simulations of the stratosphere performed with ERA-40 reanalyses

Introduction

Chemistry-Transport-Models (CTMs) using meteorological analyses of the wind and temperature fields are a useful tool for the simulation and interpretation of atmospheric processes. The quality of the calculations with respect to transport or temperature dependent processes as for example denitrification in the polar winter stratosphere depends on the quality of the meteorological analyses as well as on the technique how they are used to force the meteorology (CTM or nudging).

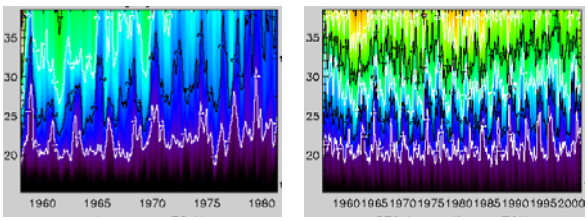
Model description

The 3-D CTM KASIMA has been used with a horizontal resolution of approx. 5.6 x 5.6 degrees. The vertical domain extends between 10 and 120 km with a vertical resolution of 750 m below 25 km pressure altitude. Two model runs were performed:

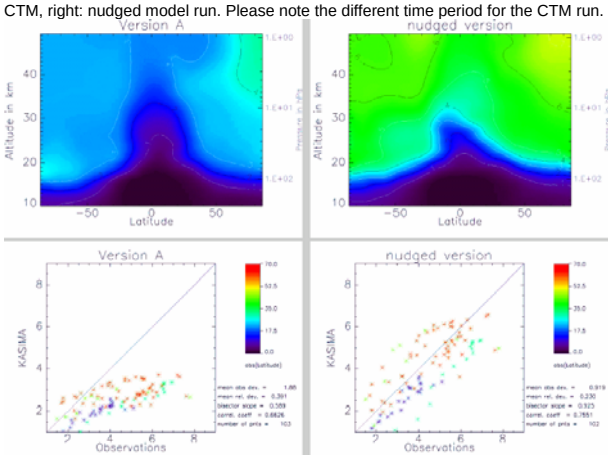
- In a **CTM** run (with simplified chemistry) the 6 hourly ERA-40 reanalyses are used to force the model's meteorology.
- In a **nudged** run with full chemistry the reanalysed temperature is combined with the solution of a prognostic meteorological model by a Newtonian cooling term up to the upper limit of the reanalyses.

Above the upper limit of the reanalyses (~48 km), the prognostic meteorological model is used for both runs.
The full chemistry run was initialised on September 1, 1957. The volume mixing ratios of the source species (i.e., CFC's, Halons) were prescribed in the upper tropical troposphere. The values are taken from the IPCC baseline scenario Ab (WMO, 2003). The surface area density of liquid aerosols has been taken from the satellite data compilation of D. Considine (WMO, 2003) for the years 1979-1999. Before 1979 and after 1999 the first and last year, respectively, has been repeated in the simulations to account for background conditions for this time period.

Age of Air

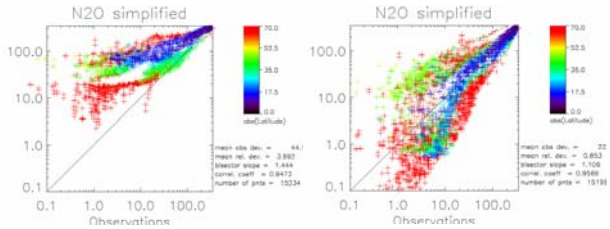


Time Series of the age of air vertical profile at the equator derived from SF_6. Left: CTM, right: nudged model run. Please note the different time period for the CTM run.



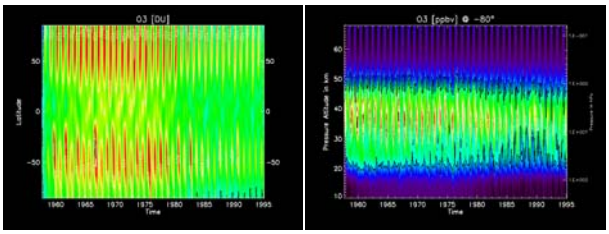
Top: Zonal mean distribution of the age of air derived from SF_6. Bottom: Correlation of the calculated age with observations (A. Engel, pers. comm.). Left: CTM model run, right: nudged model run. Please note that the colour scale denotes the latitude.

Correlation of modelled N_2O with ATMOS observations

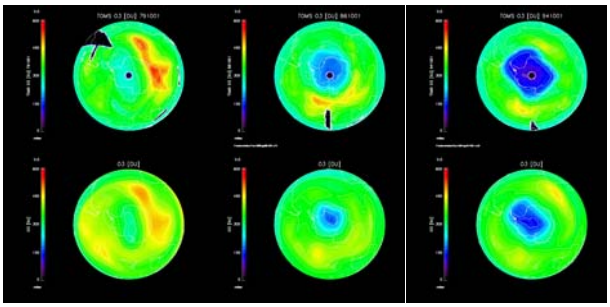


Correlation of modelled N_2O (with simplified chemistry) with ATMOS observations of the CTM model run (left) and the nudged model run (right). Please note that that the colour scale denotes the latitude.

Full chemistry nudged ERA-40 model run



Calculated Ozone distribution in nudged ERA-40 model run from Sep 1957 till Feb 1995 . Left: Total Ozone in DU. Right: Vertical Ozone distribution at 80°S in ppbv.



Ozone total column above the southern hemisphere in DU for TOMS (top) and KASIMA (bottom). Shown are October 1st of 1979 (left), 1986 (middle), and 1994 (right).

Discussion

- Long-term KASIMA calculations performed with ERA-40 reanalyses produces more realistic tracer distributions in a nudged mode than simulations performed in a CTM mode.
- The maximum age of air in the CTM model run is about 4 years (too young by a factor of 2) revealing a too strong stratospheric circulation (ascent in the tropics, transport from the tropics in mid-latitudes) in the ERA-40 reanalyses over long time periods.
- Consequently, the correlation of N_2O with HALOE data after 40 years of simulation is better in the nudged model run than in the CTM model run.
- In full chemistry nudged model run, the first ozone holes with values below 200 DU appear in the early eighties in agreement with measurements.
- Due to the coarse model resolution the gradient at the ozone hole edge is influenced by numerical mixing resulting in smaller ozone hole areas (and also higher minimum values) compared to the measurements.