LAVERO – Lagrangian Modelling of Vertical Transport and Chemical Ozone Destruction (07ATF44)

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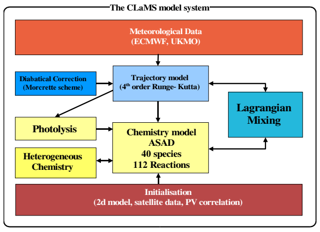
CLaMS: A Cluster of Models



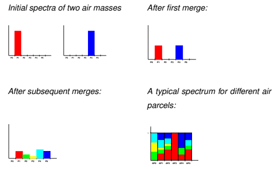
The Chemical Lagrangian Model of the Stratosphere CLaMS is used to quantify the chemically induced ozone destruction in the stratosphere. As a case study a simulation of the winter 1999/2000 has been performed. Results of both isentropic and nonisentropic simulations are displayed and compared to observations obtained during the campaigns SOLVE and THESEO2000.

Another important aspect of stratospheric ozone depletion is its interaction with climate change. In order to get information about the evolution of the ozone destroying processes in future climates and to validate the climate models, a first CLaMS simulation driven by the dynamics taken from a GCM has been performed. A preliminary comparison of the model results is shown.

Dynamical processes in the tropopause region substantially modify the budget of chemically and radiatively active atmospheric constituents, thus having a strong impact on the chemistry of the UT/LS region and on climate. The effects of cross-tropopause transport by advection and mixing processes are studied with CLaMS. Model results from simulations covering the campaigns STREAM and SPURT are shown.

The Spectrum of Air Mass Origins

Air masses are initialized with inert tracers depending on their positions at the beginning of the simulation, e. g. the tracer P0 shown in the box below has been initialized with 1 in tropospheric air masses and with 0 elsewhere.



Quantification of Ozone Destruction during the Winter 1999/2000

A simulation of ozone depletion in spring 2000 was performed using the 2d version of CLaMS, thus accounting for isentropic motion only. The simulations were carried out for the Northern hemisphere on 4 isentropic levels between 400 K and 475 K. The initialization for early February was based on observations obtained by satellite (HALOE, POAM-3), balloon (Triple) or aircraft (ER-2), if possible. For some constituents tracer/tracer correlations were used, in other cases we used results from the Mainz 2d model mapped onto equivalent latitudes. Some data used for initialization are shown in Figure 1 below.

Since significant denitrification has been observed, a parameterization for this process based on NO_y and N_2O observations made on board the ER-2 and the temperature history of the air masses considered was introduced into the model. The results concerning denitrification and ozone loss are shown in Figure 2.

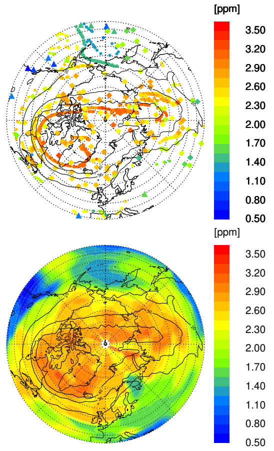
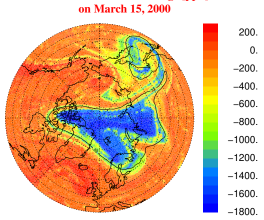


Figure 1: Ozone initialization on 450 K for February 10, 2000. The upper panel shows the locations of air parcels measured by ER-2 (circles), POAM (diamonds) and HALOE (triangles) mapped onto a synoptic date. The CLaMS initialization derived from these data are shown in the lower panel.

Accumulated Ozone change [ppb] on March 15, 2000



Comparison between ER-2 observations and CLaMS results

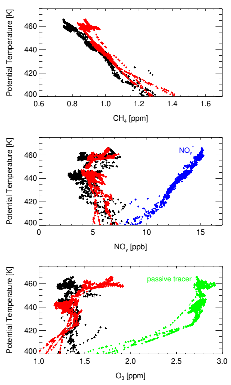


Figure 2: Results from an isentropic CLaMS simulation for spring 2000: Accumulated Ozone change in ppb on 450 K for March 15, 2000 (upper panel); Comparison between ER-2 observations (black) and model results (red) for the flight on March 12 (lower panel).

A 3d version of CLaMS has been developed to allow longer simulations for several months under realistic conditions. The results of first runs without chemistry utilizing ozone and methane observations obtained by OMS and Triple are shown in Figure 3. Comparisons between observed and simulated methane in December 1999 and March 2000 show that CLaMS is capable of simulating the descent inside the vortex quite well. A similar comparison concerning ozone allows to estimate the chemical ozone loss inside the vortex, with a resulting maximum loss of 60% in the lower stratosphere.

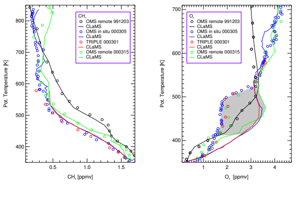


Figure 3: Vertical profiles of methane (left) and ozone (right) obtained by observations (circles) in December 1999 and March 2000 compared to profiles derived from CLaMS simulations.

To study mixing across the vortex edge an additional tracer was initialized on December 1, 1999 with values of 1 inside the vortex and values of 0 outside. The distribution of this tracer describes the motion and composition of the vortex air. Mixing strongly influences the composition of the vortex in December when the vortex edge is still formed, while large scale intrusions, coinciding with enhanced planetary wave activity, occur later in January (see Fig. 4). The vortex remained well-isolated until mid of March in the altitude range 500-600 K.

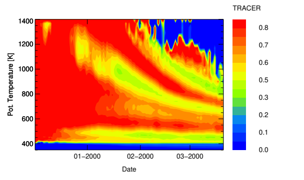


Figure 4: Temporal evolution of the vortex averaged tracer (see text above) The vortex edge was defined using the Nash criterion.

Quantifying Transport in the Tropopause Region

To investigate the effects of mixing in the tropopause region high resolution CLaMS simulations with a suite of inert tracers (see box above) have been performed. Comparisons with observations obtained during STREAM (1998) and SPURT (2001) (see poster) show good agreement. Having the ability to distinguish between different mixing regimes, this new method allows a better quantification of cross-tropopause transport.

Case Study: STREAM (1998) | **Case Study: SPURT-IOP1 (2001)**

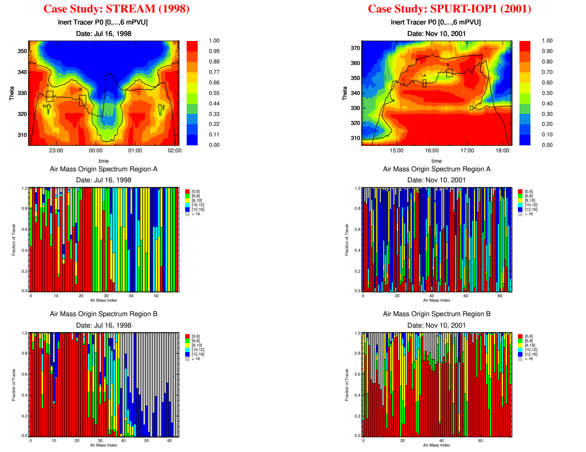


Figure 5: Mixing properties in the tropopause region shown by the distribution of the inert tracer P0 (see box above) along sections defined by the flight paths of measurements carried out during STREAM (left) and SPURT (right). The middle and lower panels show spectra of air mass origin in the regions A and B, respectively.

Interaction between Stratospheric Chemistry and Climate Change

To investigate the impact of the greenhouse effect on stratospheric chemistry, a first CLaMS simulation driven by the dynamics taken from the 1990 time slice experiment of an ECHAM4.L39(DLR)/CHEM run has been performed. Because of its high resolution (50 km for this simulation) CLaMS is able to simulate small-scale mixing and to resolve filamentary structures from meterological conditions provided by the GCM. The first results of a comparison considering methane as an inert tracer are shown below. Note that for the CLaMS simulation the tracer was initialized using results from the Mainz 2d model mapped onto equivalent latitudes. In addition to the large-scale features evident in both models, CLaMS reveals filaments of methane-rich air which are mixed into the polar vortex from mid-latitudes and persist for weeks. We expect this small-scale variability within the vortex to have a significant effect on ozone chemistry and estimates of future ozone loss.

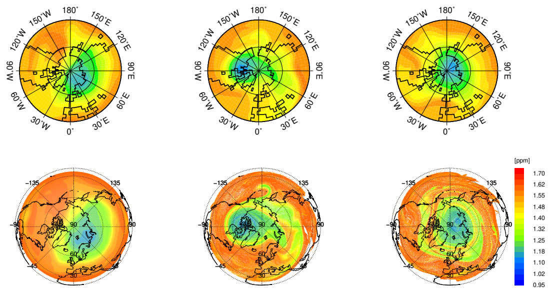


Figure 6: Methane on the 475 K isentropic surface on January 1, 16 and 30 (left to right) taken from the 1990 time slice experiment (year 43) of ECHAM4.L39(DLR)/CHEM (upper panel). Results from a CLaMS simulation with the same background dynamics are shown in the lower panel.