KODYACS

Investigation of mutual influences of greenhouse effect and changes of dynamic and chemical processes in the UT/LS employing model simulations and observations

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Introduction and Goals

A valuable tool to investigate the interaction of atmospheric chemistry and climate is the coupled chemistry-climate model ECHAM4.L39(DLR)/CHEM (E39/C) which is operated at DLR. Several time-slice experiments have been performed with the model; these climate simulations for the years "1960", "1980", "1990", and "2015" have been run in a steady-state mode with constant boundary conditions over 20 years each. The model has proven with these simulations that it is able to represent the climatological mean state and also the observed interannual and seasonal variability of dynamic and chemical values and their trends during recent decades (Hein et al., 2001; Schnadt et al., 2002). Studies of transient and stationary wave activity and the North Atlantic Oscillation (NAO) index have been performed to investigate the causes of dynamic and chemical changes in the troposphere and the stratosphere as e.g., the warming of the northern polar stratosphere in winter from "1990" to "2015".

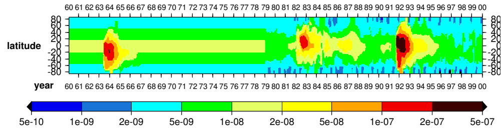
Additionally, a transient model simulation with the E39/C model has been defined jointly with other KODYACS members for the years 1960-2000 where boundary conditions vary from year to year, e.g. sea surface temperatures, the distribution of stratospheric aerosol, the zonal mean lower stratospheric winds in the tropics and subtropics (QBO), and the chemical conditions at the upper boundary of the model. This simulation will be employed for further investigations with respect to identifying key chemistry-climate interaction processes.

Transient Climate Simulation

The transient climate simulation with E39/C has been running since July 2002. The simulation configuration and requirements have been extended as great interest in specific results has been shown by groups at DLR and other national atmospheric research institutions. Consistent and uniform boundary conditions varying over time had to be prepared in order to perform such a transient simulation. The following data sets have been constructed and used:

Sea Surface Temperatures	from Hadley Center
QBO	from MPI Hamburg
Solar Cycle	from MPI Mainz
ClX and NO_y at top model level	from MPI Mainz 2D model
CFCs	from MPI Mainz 2D model
NO_x emissions	from SRES IPCC
Volcanic aerosol/radiation	from MPI Hamburg
Volcanic aerosol/chemistry	from SAGE data

Sulfate Aerosol Surfaces at 30 hPa from SAGE data [cm^{-1}]



Waves in the Atmosphere

Motivation

Model results for the timeslices "1990" and "2015" show an increase of stratospheric polar temperatures in DJF (Figure 1a). The NAO index as computed from the timeslices shows an increase from "1960" to "1990" and eventually a decrease from "1990" to "2015" (Figure 1b). An extreme NAO index composite study of heat fluxes for the "1990" timeslice shows that in the negative NAO phase, more stationary and less transient waves are generated than in the positive NAO phase (Figure 1c).

Figure 1a: ΔT [K]

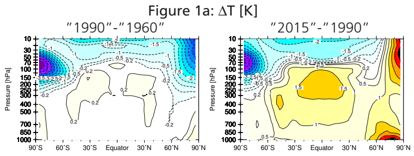


Figure 1b: Evolution of NAO Index over Timeslices

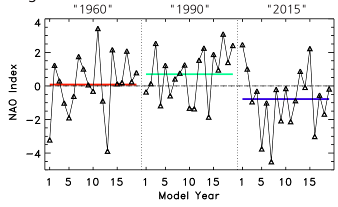
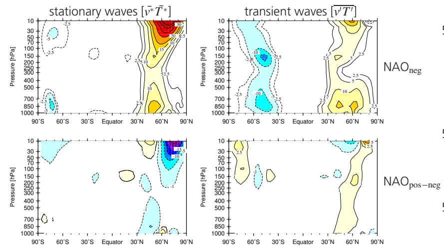


Figure 1c: Heat flux analysis "1990" [K m/s]



Stationary Waves

A positive model NAO index is connected to a stronger and colder polar vortex (not shown); the stationary waves analysis confirms this relationship. The temperature and geopotential height (GPH) of the polar vortex at 50 hPa decrease from "1960" to "1990" (2a, 2b), but remain fairly constant at 500 hPa indicating a radiative cooling by greenhouse gases in the stratosphere. From "1990" to "2015", however, the GPH at 500 hPa increases induced by a warming of the troposphere (2c, 2d). The warming of the polar vortex at 50 hPa by enhanced waves of wavenumbers 2 and 3 (2c) further increases the GPH of the polar vortex.

Figure 2a: Geopotential Height Difference "1990"-"1960"

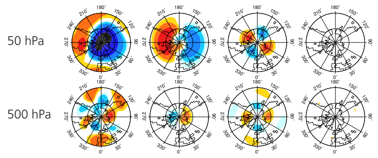


Figure 2b: Temperature Difference "1990"-"1960"

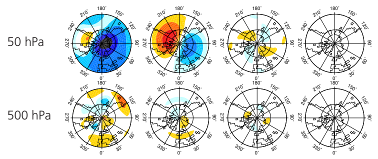


Figure 2c: Geopotential Height Difference "2015"-"1990"

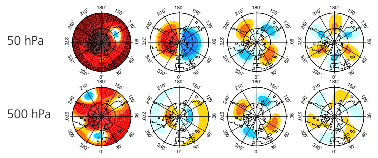
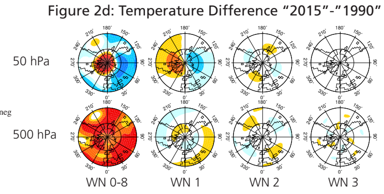


Figure 2d: Temperature Difference "2015"-"1990"



Transient Waves

A wavenumber-frequency analysis proves that the model is able to reproduce the observed distribution of frequencies and amplitudes of transient planetary waves at distinct wavenumbers (Figures 3a, 3b). The analysis of the timeslices reproduces the results of the heat flux computations (Figure 1c): an increase of the NAO index (Figure 1b) implies more transient waves from "1960" to "1990", a decrease of the index implies less transient waves from "1990" to "2015" (Figure 3c).

Figure 3a: Sum Transient Waves Model vs. Observations, DJF

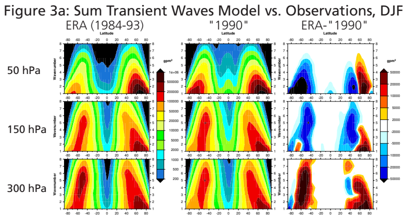


Figure 3b: Transient Waves Model vs. Observations, DJF

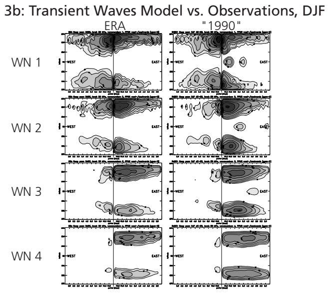
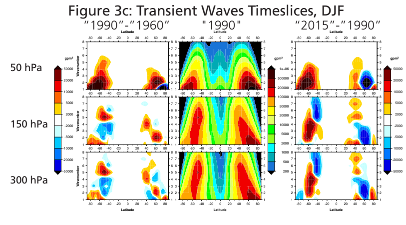


Figure 3c: Transient Waves Timeslices, DJF



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