The interactive chemistry climate model MAECHAM4-CHEM, longterm simulations for near past, present and near future

Part 1: Stratospheric chemistry

AFO 2000

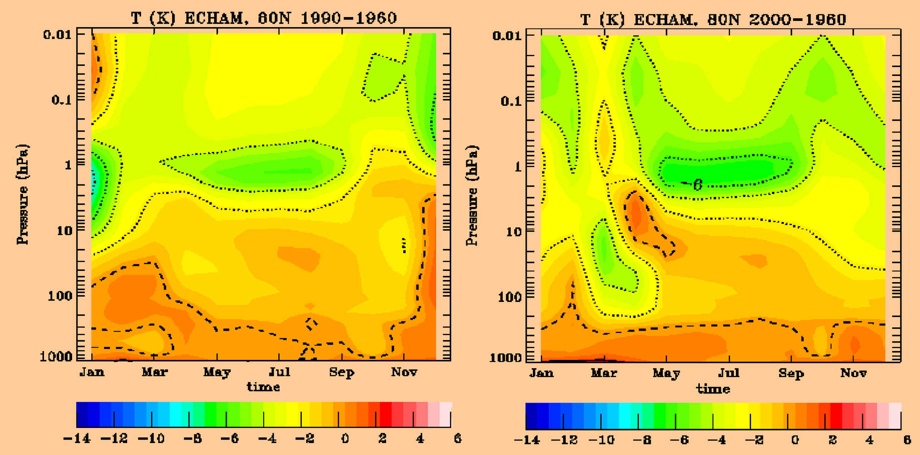
Christoph Brühl, Benedikt Steil, Max-Planck-Institut für Chemie, Mainz;
Elisa Manzini, Nat.Inst. for Geophysics and Volcanology, Bologna

MAX-PLANCK-GESELLSCHAFT

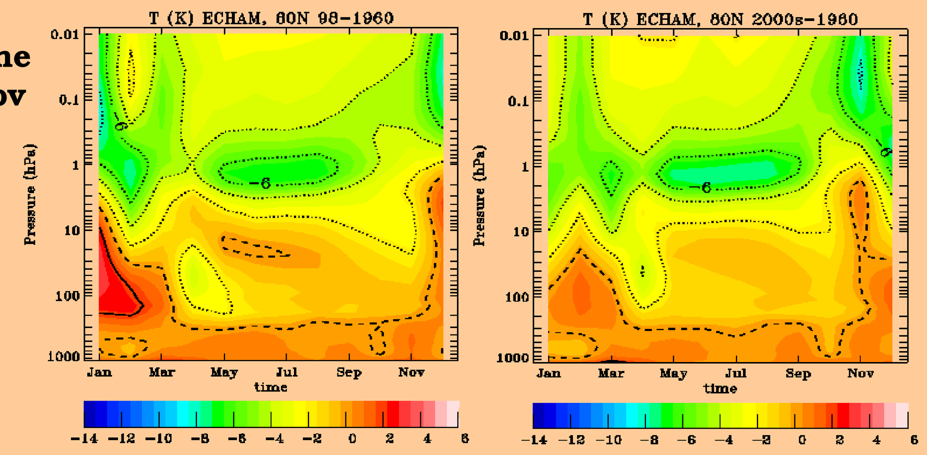
Changes for 1990 and 2000 against the 1960 scenario, including sensitivity runs on chlorine

Temperature, 80N

1990 | 2000

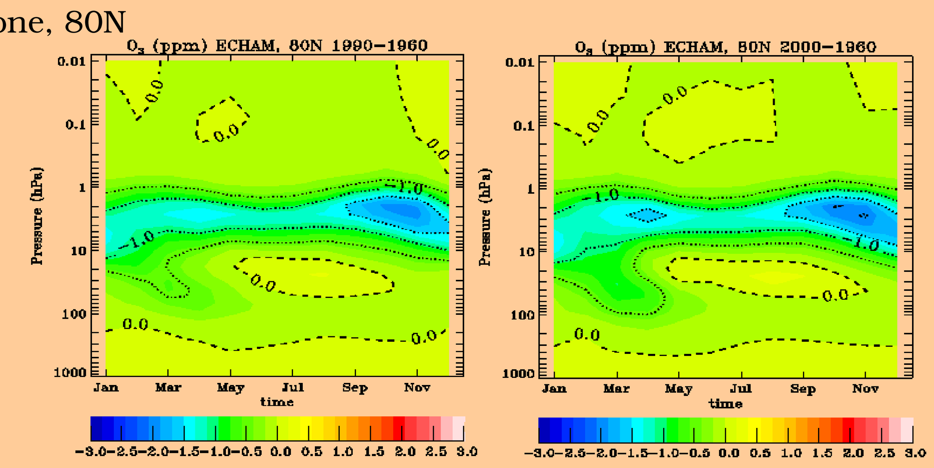


2000, chlorine 3.4ppbv | 2000, chlorine 4.1ppbv



Ozone, 80N

1990 | 2000



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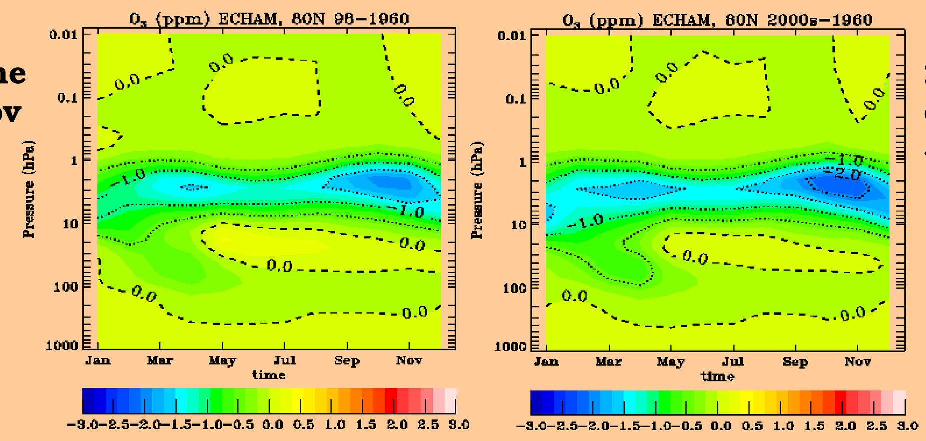


MA-ECHAM4, Middle Atmosphere version of the European Center model in Hamburg, spectral GCM with:
- -horizontal resolution : T31 3.75° x 3.75°;
- time step : 15 min
- -vertical resolution : 39 levels up to 0.01 hPa (80 km),
- -gravity waves: Manzini, McFarlane, 1998, JGR.
- Radiation, dynamics and chemistry fully interactive
- **Sea surface temperature** of GISS-HADLEY (average of 1951-1960, 1981-1990 and 1989-1999, including seasonal cycle) and OPYC-AOGC-model for 2021-2030, adjusted to the period 1989-1999, Roeckner et all, 1999 (all).

Chemical scheme:
- Very efficient due to family-concept; time step: 45 min
- Advection scheme Spitfire
- -13 advected long and medium lived gases
- Advected families and Polar Strat. Cloud particles:

HNO_3 + Type I PSC (NAT:HNO_33H_2O)
H_2O + Type II PSC (ice),
ClO_x=Cl + ClO + HOCl + 2 Cl_2O_2 + 2 Cl_2
NO_x = N + NO + NO_2 + NO_3 + HNO_4 + 2 N_2O_5 , O_x = O_3 + O + O*
- -110 photochemical reactions, implicit + analytical solver
- interactive photolysis-rates, Landgraf and Crutzen, 1998, JAS
- PSCs and sedimentation of PSCs (solid only); direct use of GCM- temperatures

7 '**time-slice'-scenarios** were integrated at least 20 years, the reference scenario was for the boundary conditions of 1960 (ozone unperturbed by chlorine).

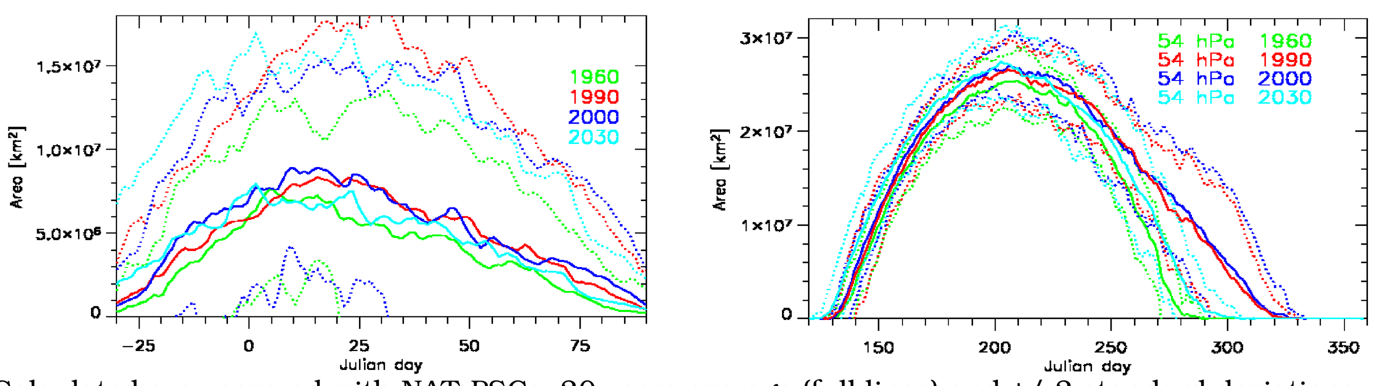
	1960	1990	2000	2030	
CO_2	317	353	372	446	ppmv
CH_4	1.26	1.69	1.75	1.90	ppmv
N_2O	295	310	320	350	ppbv
ClX	0.8	3.4	3.7	2.7	ppbv

References

Steil, B. et al, A new interactive chemistry climate model: 1. present-day climatology and interannual variability of the middle atmosphere using the model and 9 years of HALOE-UARS data. *J. Geophys. Res 108*, D9, 4290, 2003.

Manzini, E, B. Steil, C. Brühl, M. A. Giorgetta and K. Krüger: A new interactive chemistry-climate model. II. Sensitivity of the middle atmosphere to ozone depletion and increase in greenhouse gases: Implications for recent stratospheric cooling. *J. Geophys. Res.*, 108, D14, 4429, doi:10.1029/2002JD002977, 2003.

Dynamics see Part 2 of the poster, focus on interactions with the troposphere

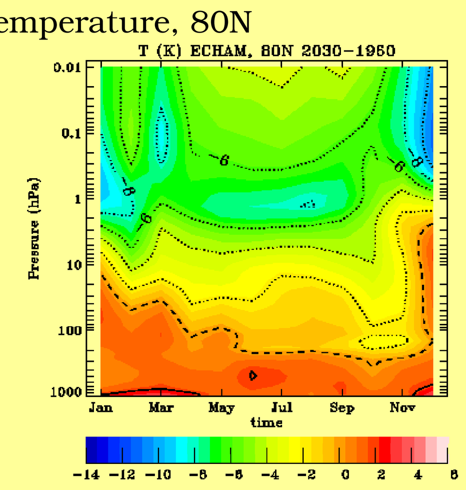


Calculated area covered with NAT-PSCs, 20 years average (full lines) and +/-2 standard deviations (dashed lines). 54hPa, Arctic left, Antarctic right.

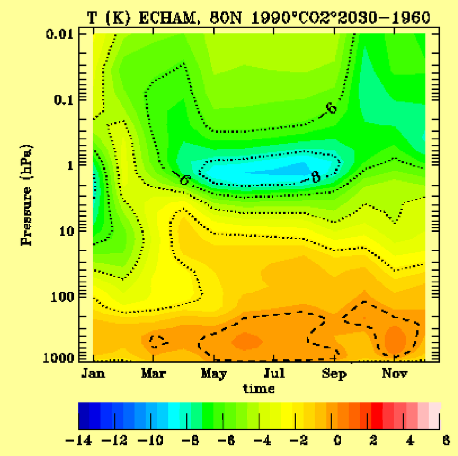
Near future, tracegases for 2030

Temperature, 80N

2030, all

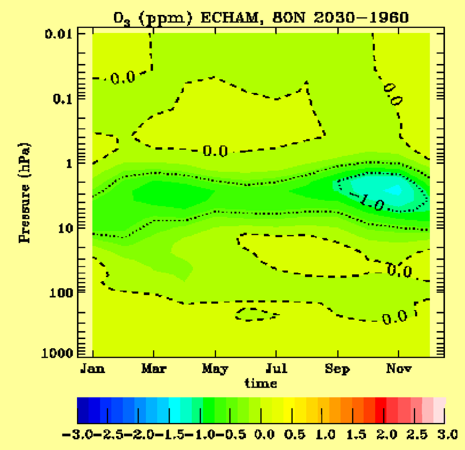


2030, CO_2 only, other as 1990

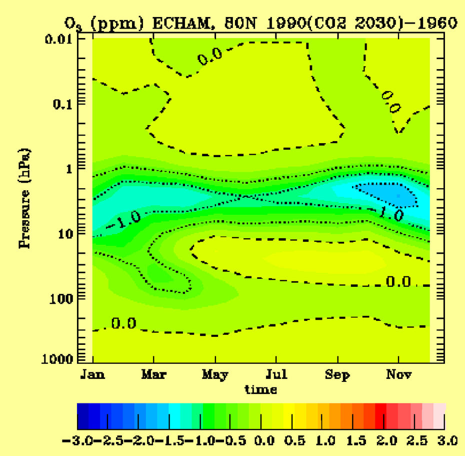


Ozone, 80N

2030, all

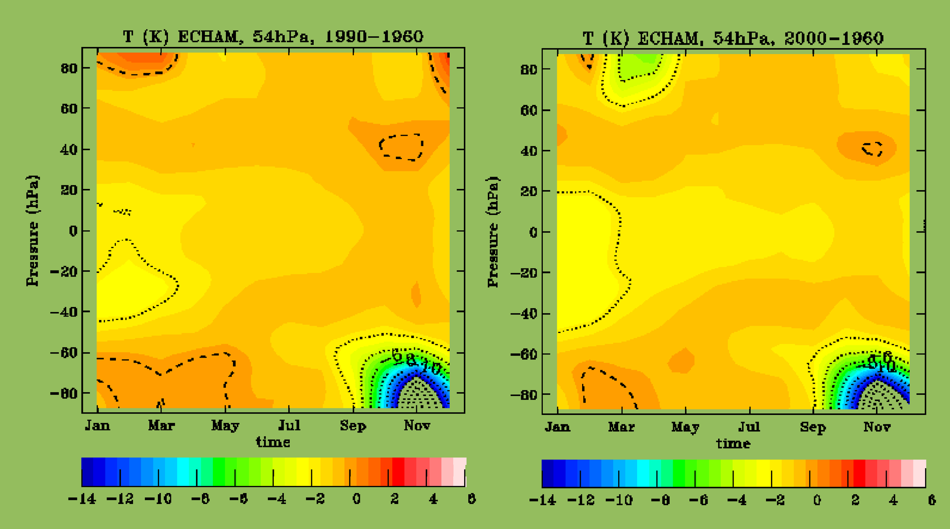


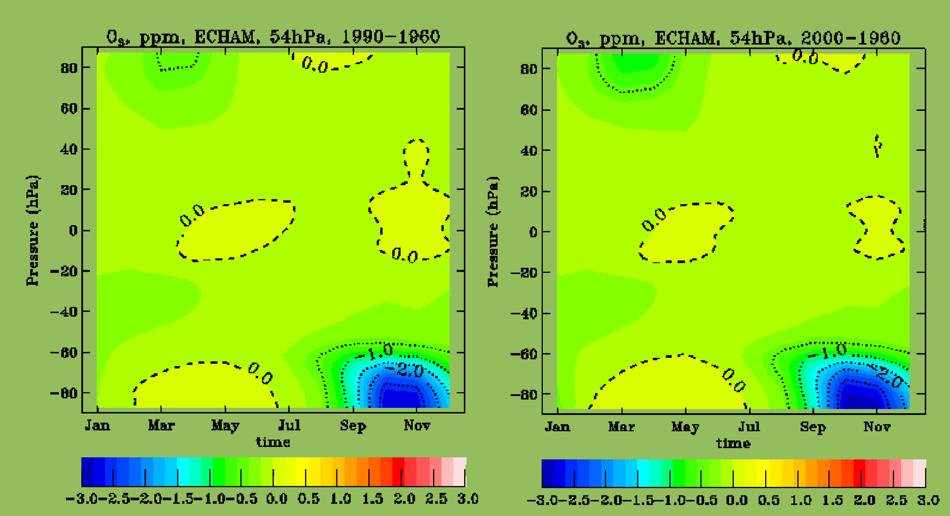
2030, CO_2 only, other as 1990



Average temperature and ozone change at 54hPa

1990 | 2000





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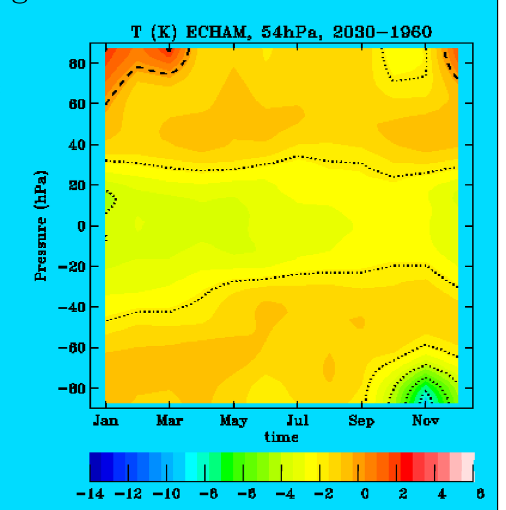
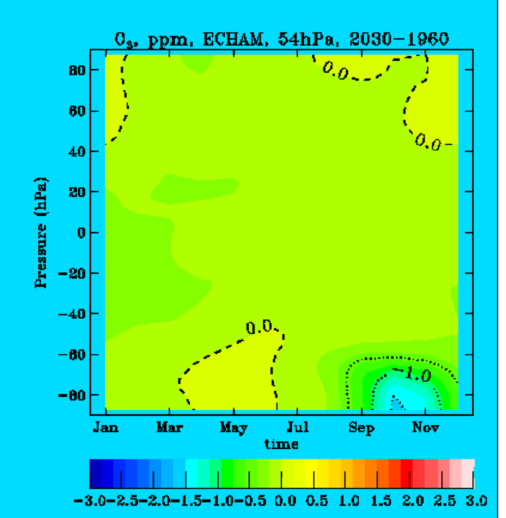
Changes at 54hPa

2030



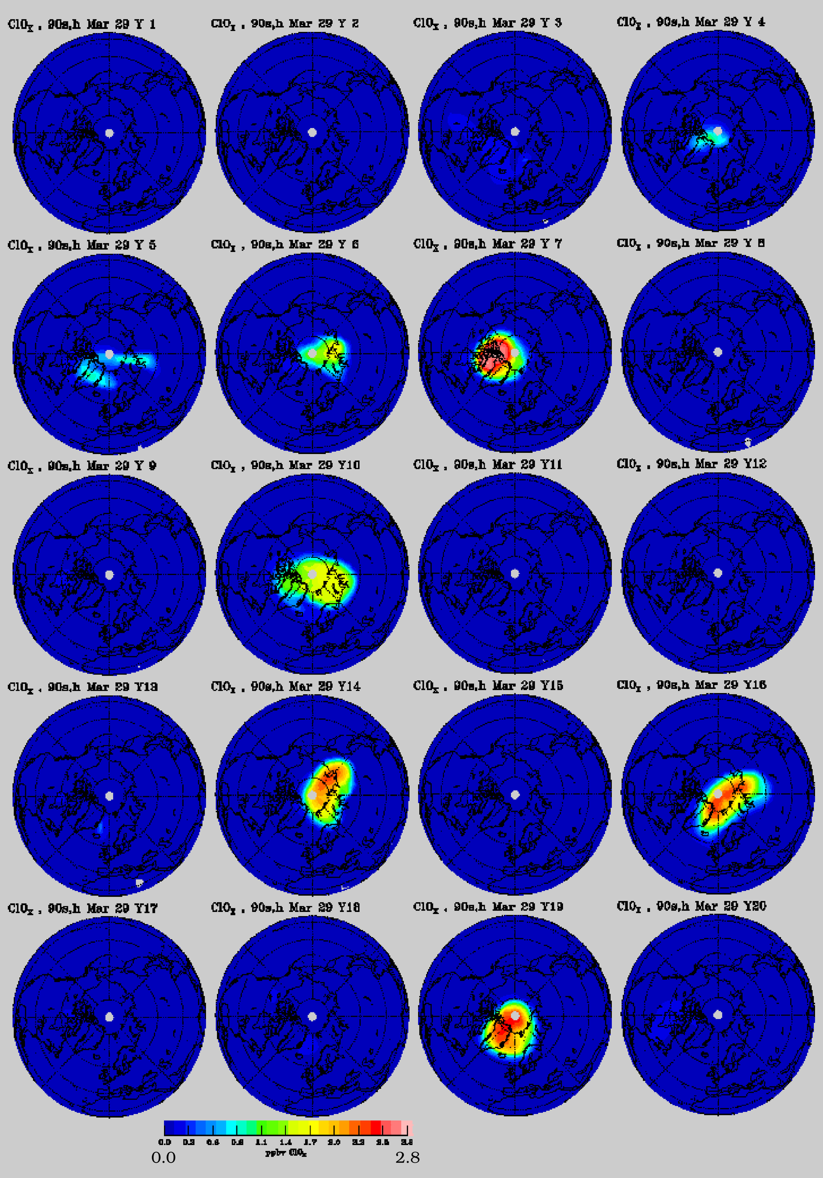


Conclusions

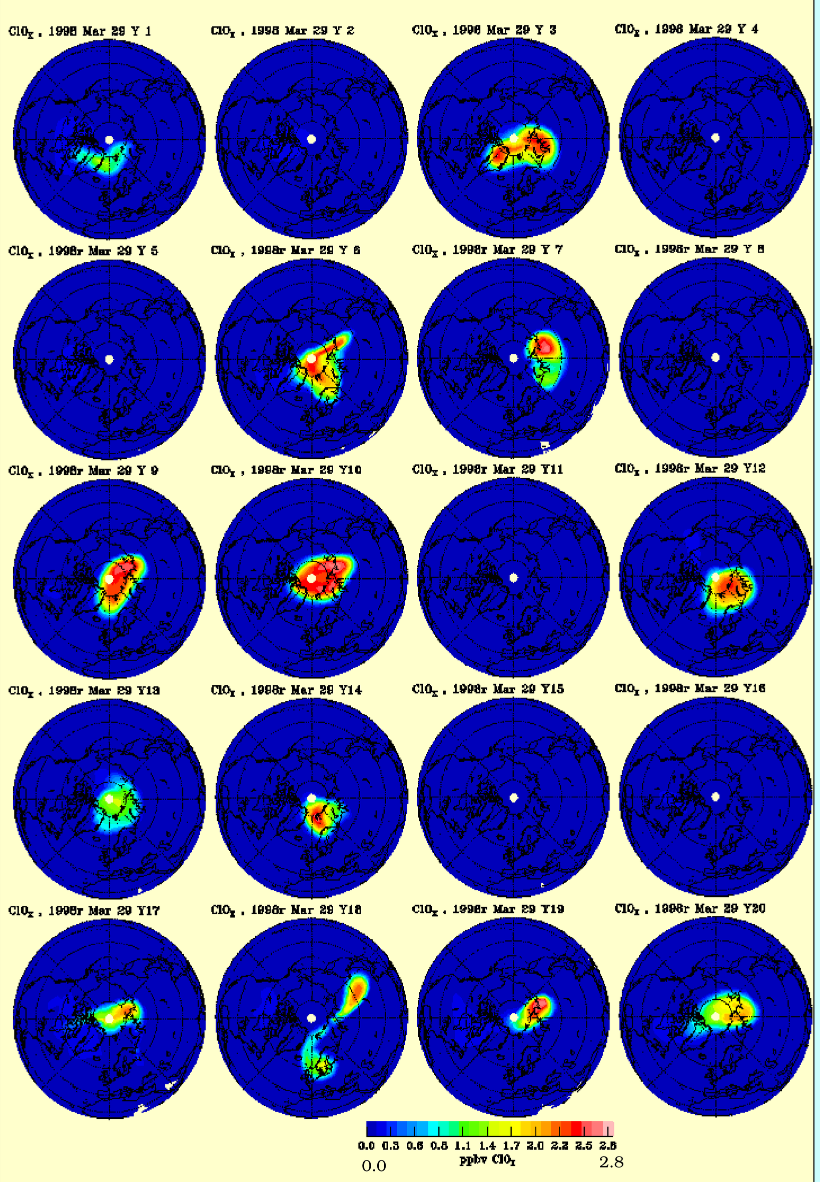
- Modelled average changes from 1990 to 2000 (and 1960 to 2000) are consistent with the observed trends in ozone and temperature.
- In the Arctic stratosphere, a significant cooling in March with respect to 1960 is found only for the 2000 simulation with observed chlorine. The reduced descent in 2000 provides a positive feedback to the chemical ozone depletion in the lower stratosphere.
- In the 1990 simulations and the 2000 sensitivity runs cooling by ozone depletion is masked by larger dynamic forcing and increased adiabatic heating by descent.
- Cooling of the lower Arctic stratosphere is limited by a negative feedback via the mesosphere and enhanced gravity wave breaking with delay of about a month
- The cooling of the upper stratosphere by increased carbon dioxide and gas phase ozone depletion causes an enhanced heating of the lower Arctic stratosphere by descent in spring.
- Cooling due to ozone depletion causes longer lasting PSCs in late spring in both hemispheres.
- Ozone changes by gas phase reactions in the middle and upper stratosphere are largest in high latitude fall and contribute to the lower ozone in spring in the lower stratosphere via descent in winter.

Activated chlorine (Cl + ClO +2Cl_2O_2 + HOCl) in late March in the Arctic vortex, individual years, 70hPa

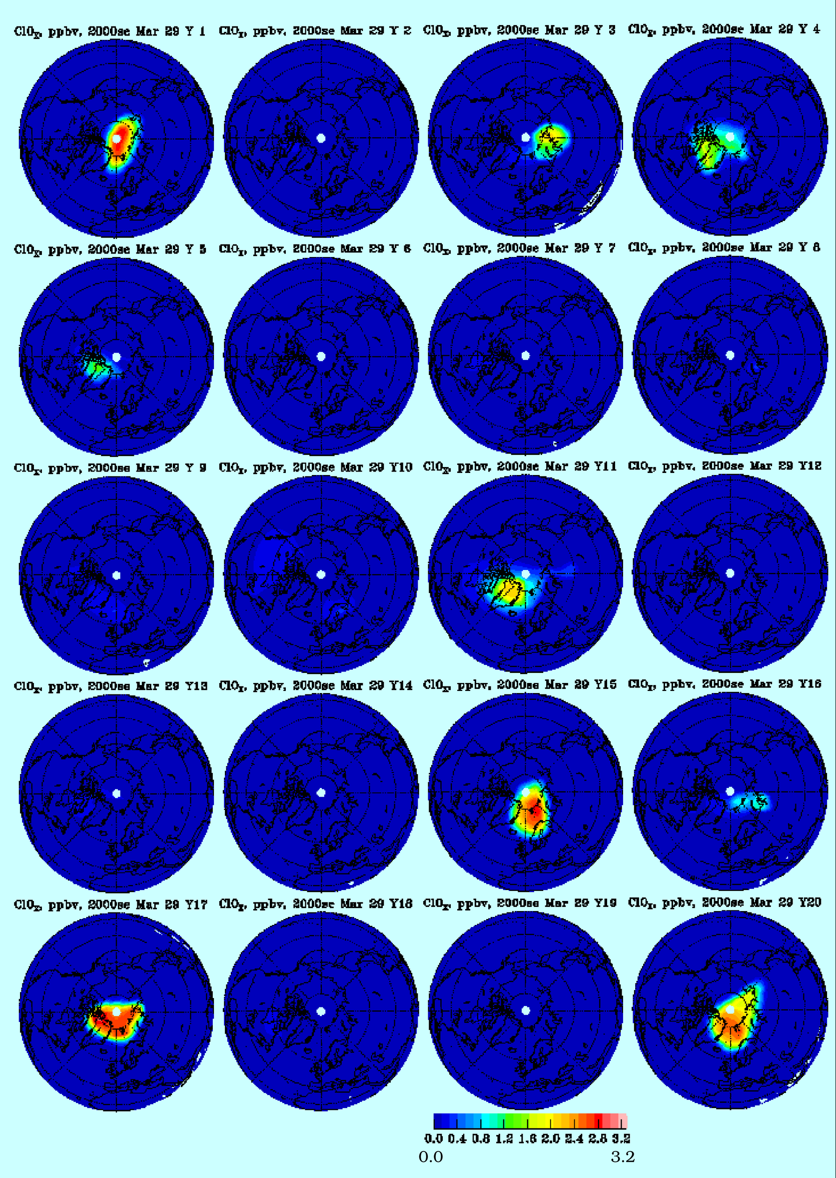
1990: 6 years



2000: 11 years



2000, high chlorine case: 6-7 years



2030: 3-4 years