Modelling the stratospheric polar vortex and its changes for GHGs increase and ozone depletion.

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Thanks:

B. Steil and C. Brühl (MPIfC, Mainz, DE);

M. Sigmond (KNMI, DeBilt, N); C. Land (Rinteln, DE);

M. A. Giorgetta, M. Esch, and E. Roeckner (MPIfM, Hamburg, DE)

Motivation

Characterize the response and possible feedback of the stratospheric polar vortex to changes in GHGs and ozone, as simulated by general circulation models:

What results are robust and what are very sensitive to experimental or model design? What is the role of feedbacks?

1. **Middle atmosphere, radiative response: cooling.**
2. **Dynamical response / feedback of the stratospheric polar vortex and its possible impacts on the troposphere?**

Models

- MAECHAM4: middle atmosphere general circulation model (Manzini et al JGR 1997). Top: 0.01 hPa (80 km) Parameterization of a gravity wave spectrum (Hines JASTP 1997ab)

- CHEM: chemical model for stratospheric ozone including heterogeneous chemistry (Steil et al Ann Geophys 1998)
- SPITFIRE transport scheme (Rasch and Lawrence MPI Report 1998)

=> Coupled chemistry climate model (Steil et al JGR 2003)

Results from the following simulations:

1. Near past to present: 1960, 1990, and 2000. Increase in GHGs and ozone depletion. MAECHAM4CHEM model at T30L39 (Manzini et al. JGR 2003). March cooling.
2. Present and 2xCO2. MAECHAM4 model at T42L39. (Sigmond et al. in preparation). November warming.
3. Near past to 2030: increase in GHGs and ozone recovery. MAECHAM4CHEM model at T30L39. (Brühl et al. in preparation). December and March warming.
4. Increase in GHGs and `Arctic Sea`. MAECHAM4 model at T30L39. Reduced cooling during early winter.

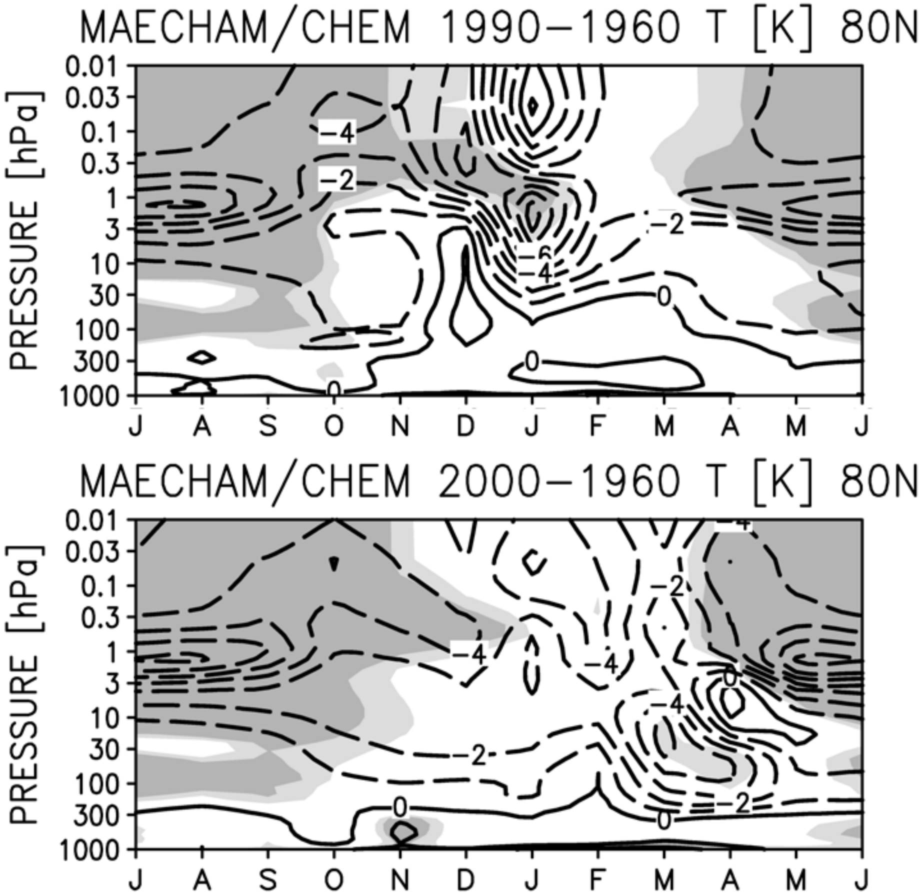
Fixed boundary conditions, specified SSTs and ICE.

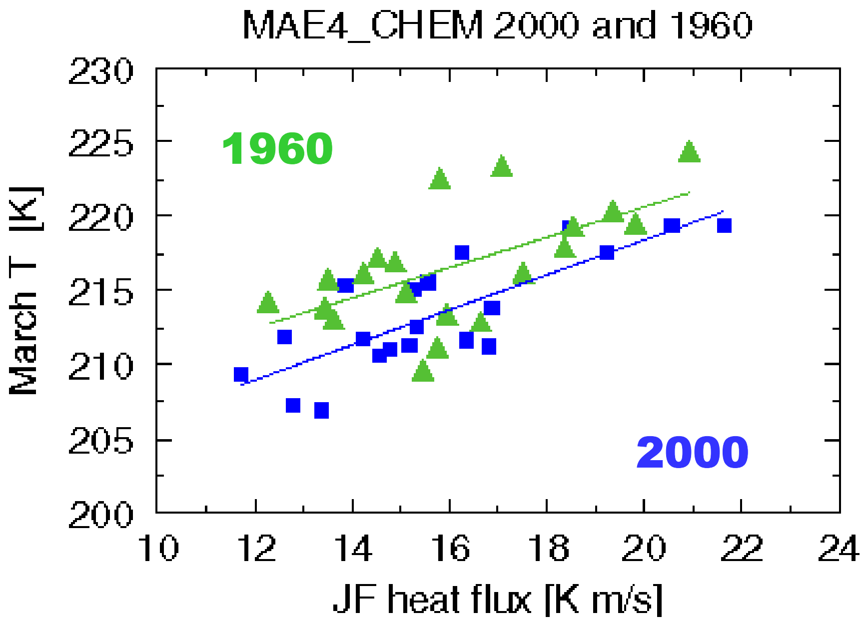
20 (or 30)-year simulations. The focus is on the Arctic.

Near past, present, and 2030 simulations

	1960	1990	2000	2030
CH_4 m. r.	1.26 ppmv	1.69 ppmv	1.75 ppmv	1.90 ppmv
N_2O m. r.	295 ppbv	310 ppbv	320 ppbv	350 ppbv
CO_2 m. r.	317 ppmv	353 ppmv	372 ppmv	446 ppmv
Org. CL m. r.	0.8 ppbv	3.4 ppbv	3.7 ppbv	2.7 ppbv
SST & ICE	GISS-Had	GISS-Had	GISS-Had	Echam4/Opyc

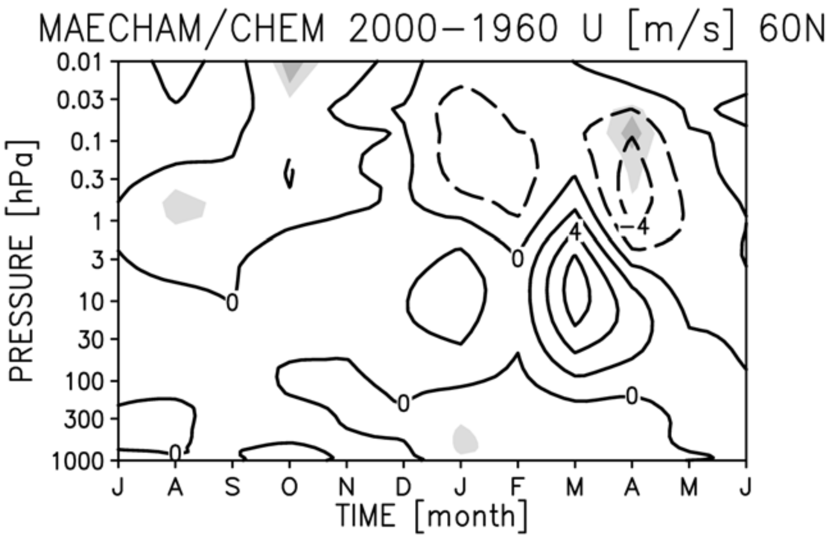
Near past to present, GHGs and ozone

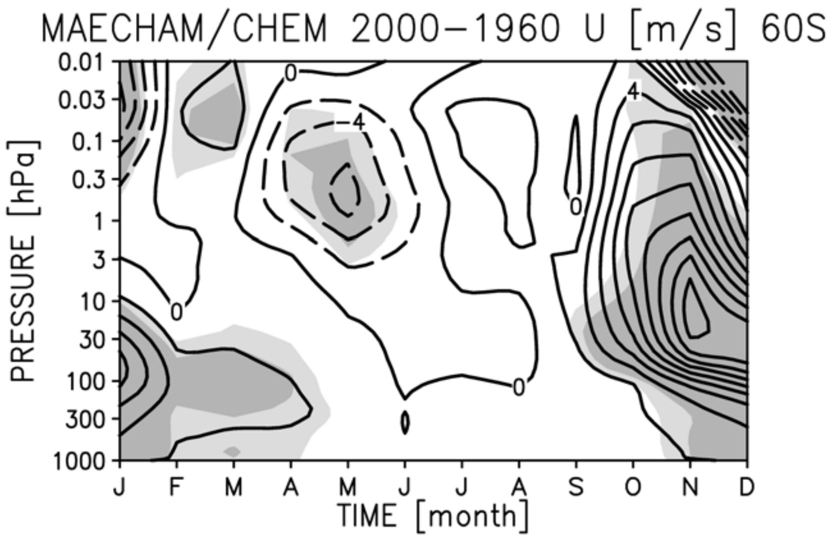


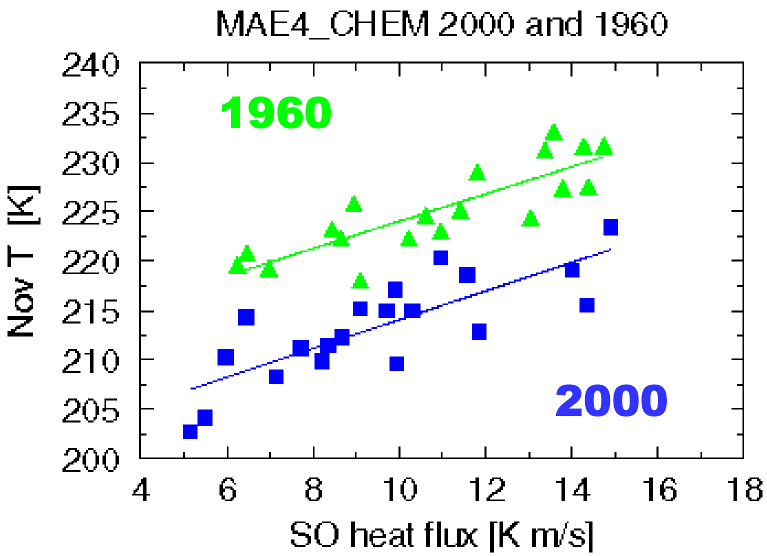


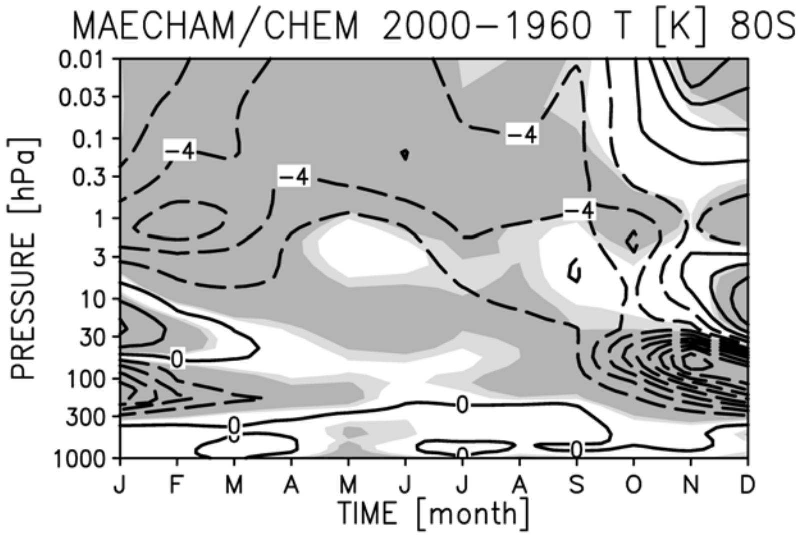
<u>Lower stratosphere:</u>
Cooling in March and April for 2000-1960.

Near past to present, GHGs and ozone

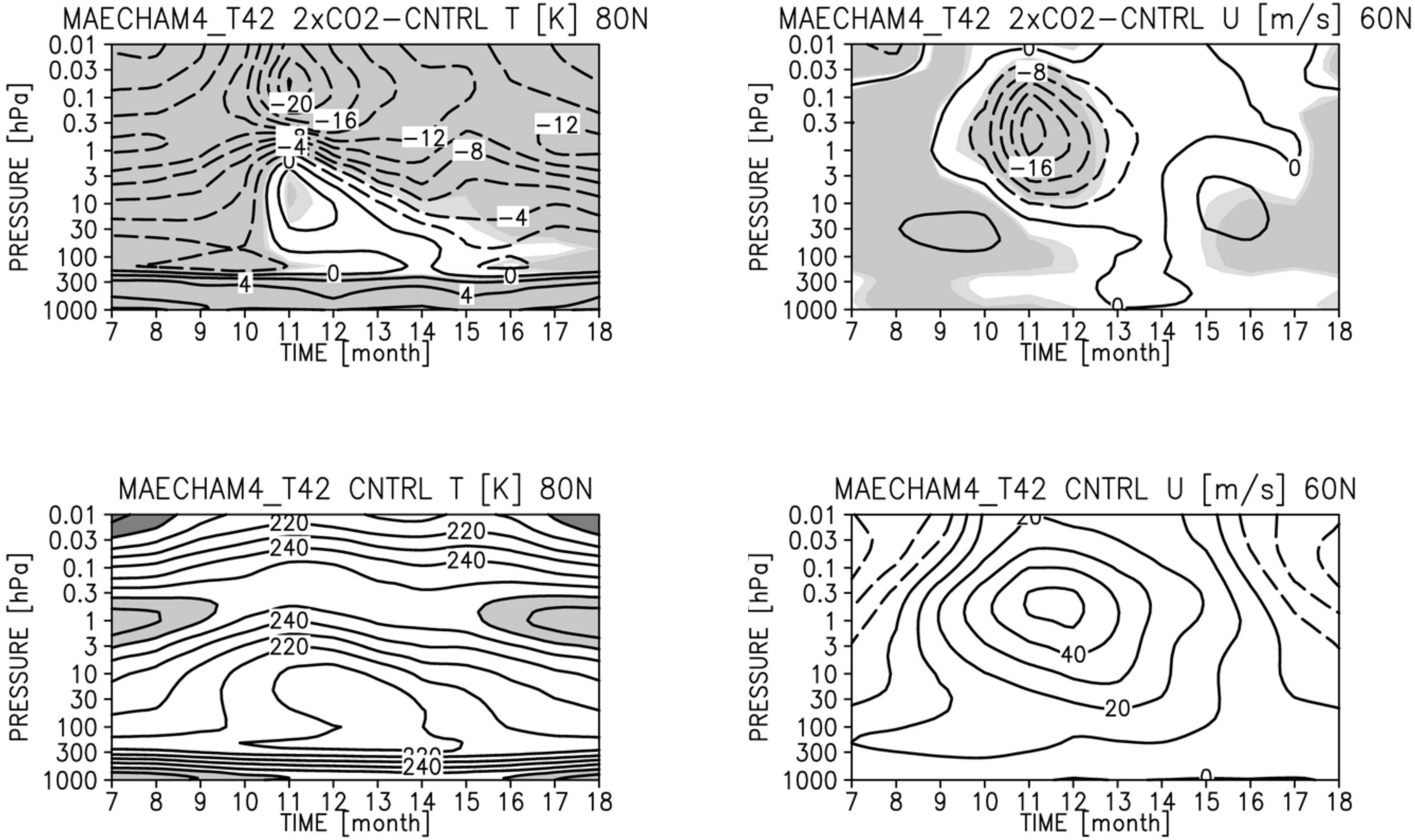




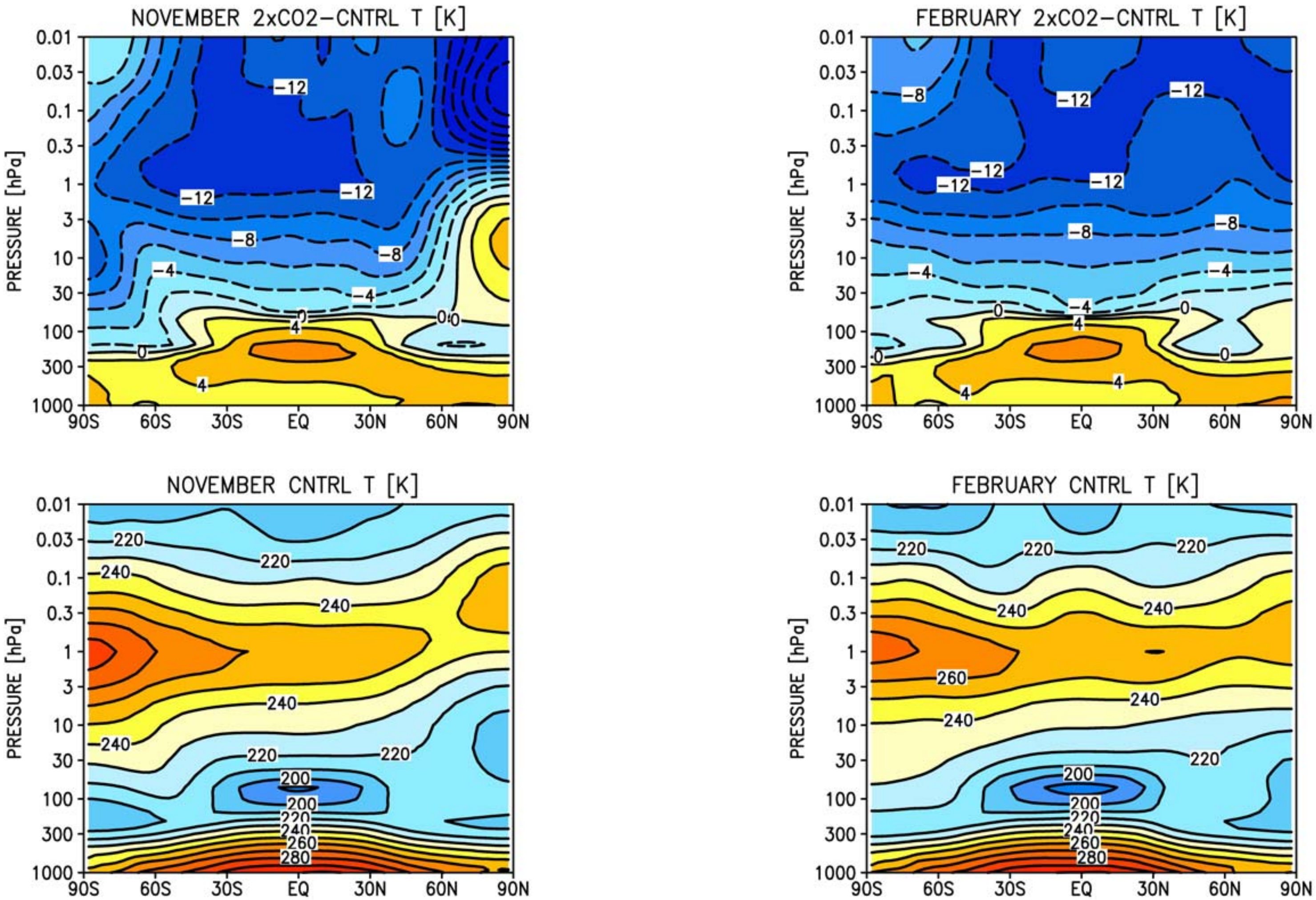




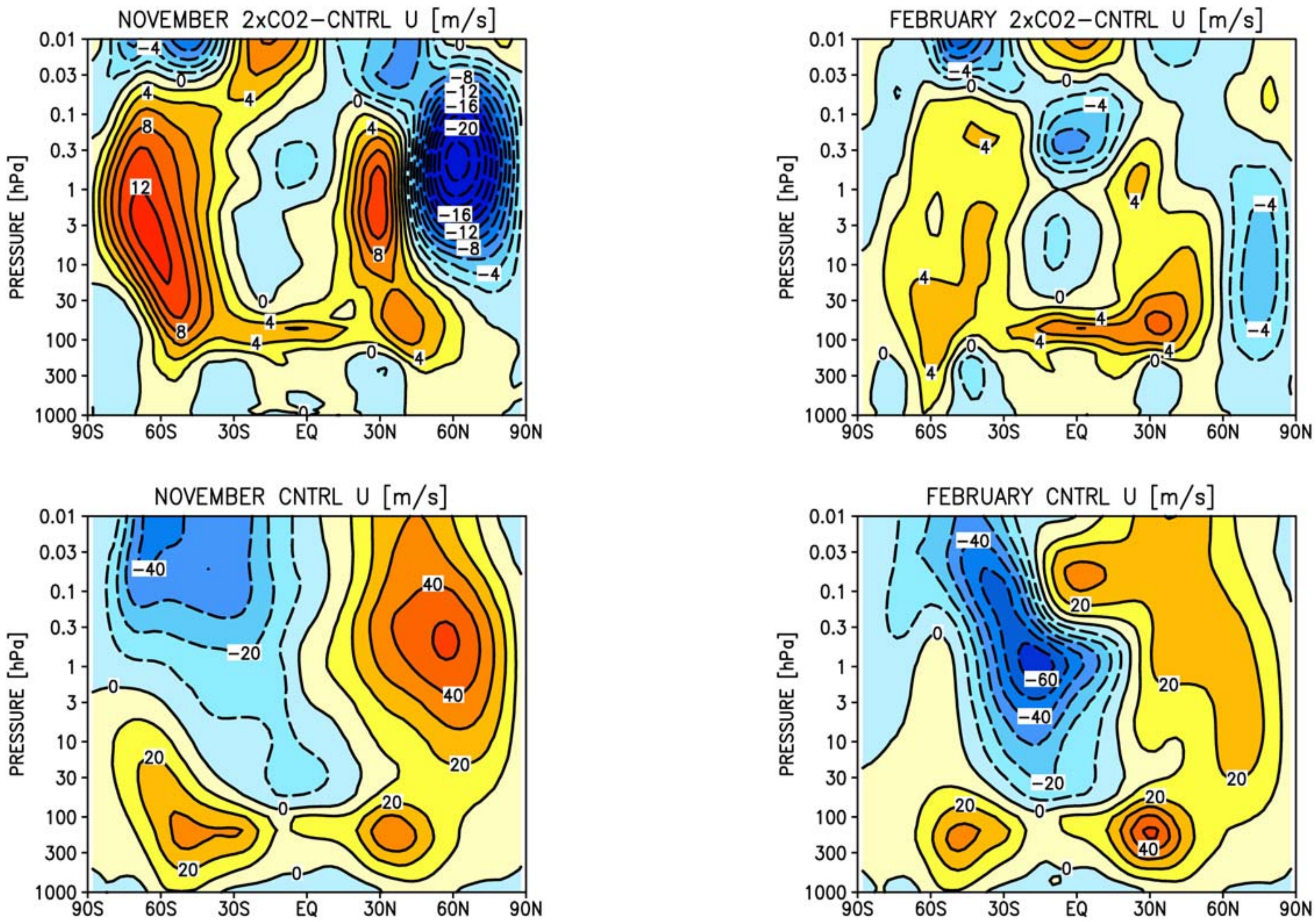
CNTRL (353 ppmv) and 2xCO2 (706 ppmv)
SST and ICE from echam4 / slab ocean



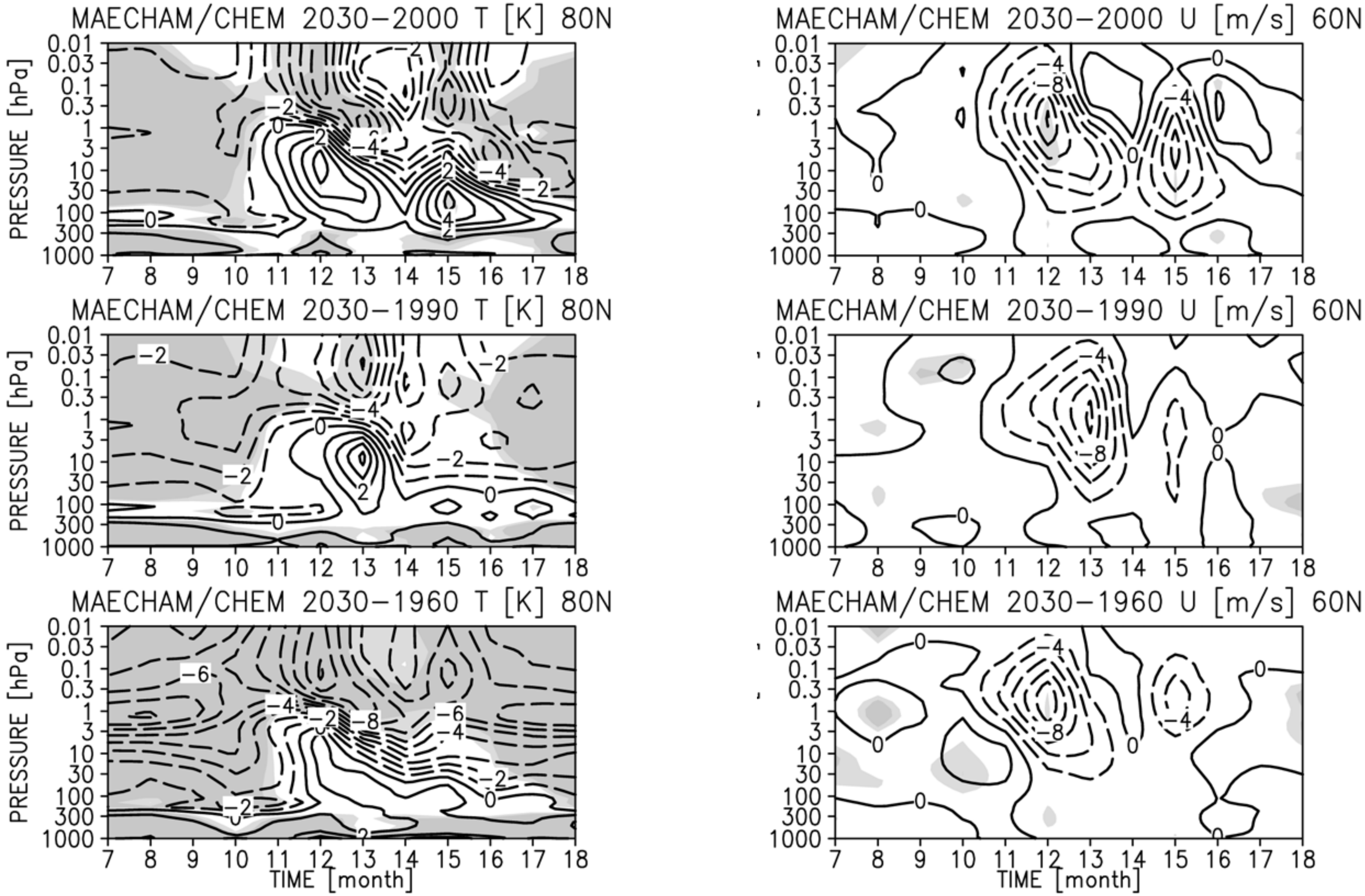
Present (353 ppmv) and 2xCO2 (706 ppmv)
SST and ICE from echam4 / slab ocean



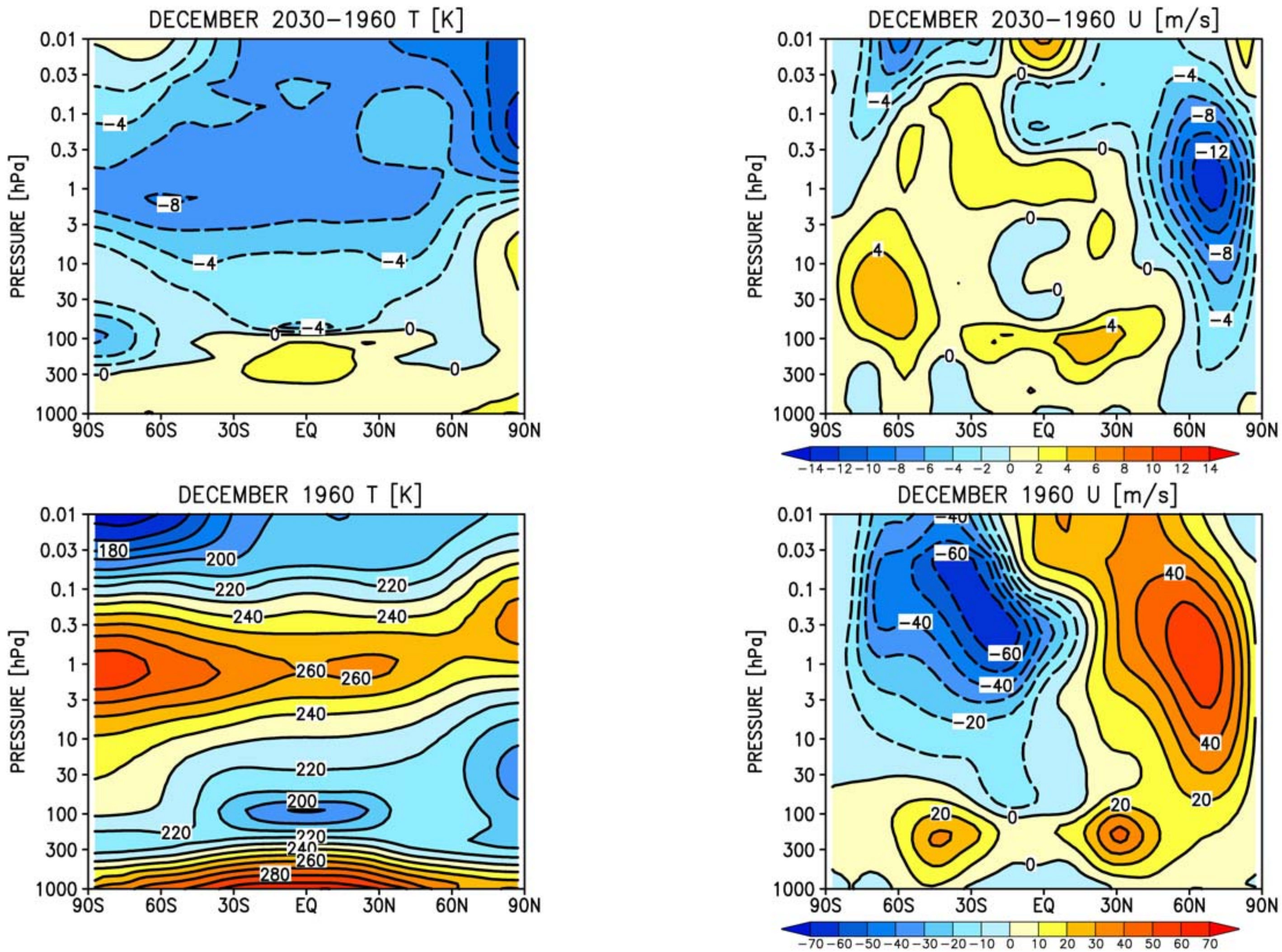
Present (353 ppmv) and 2xCO2 (706 ppmv) SST and ICE from echam4 / slab ocean



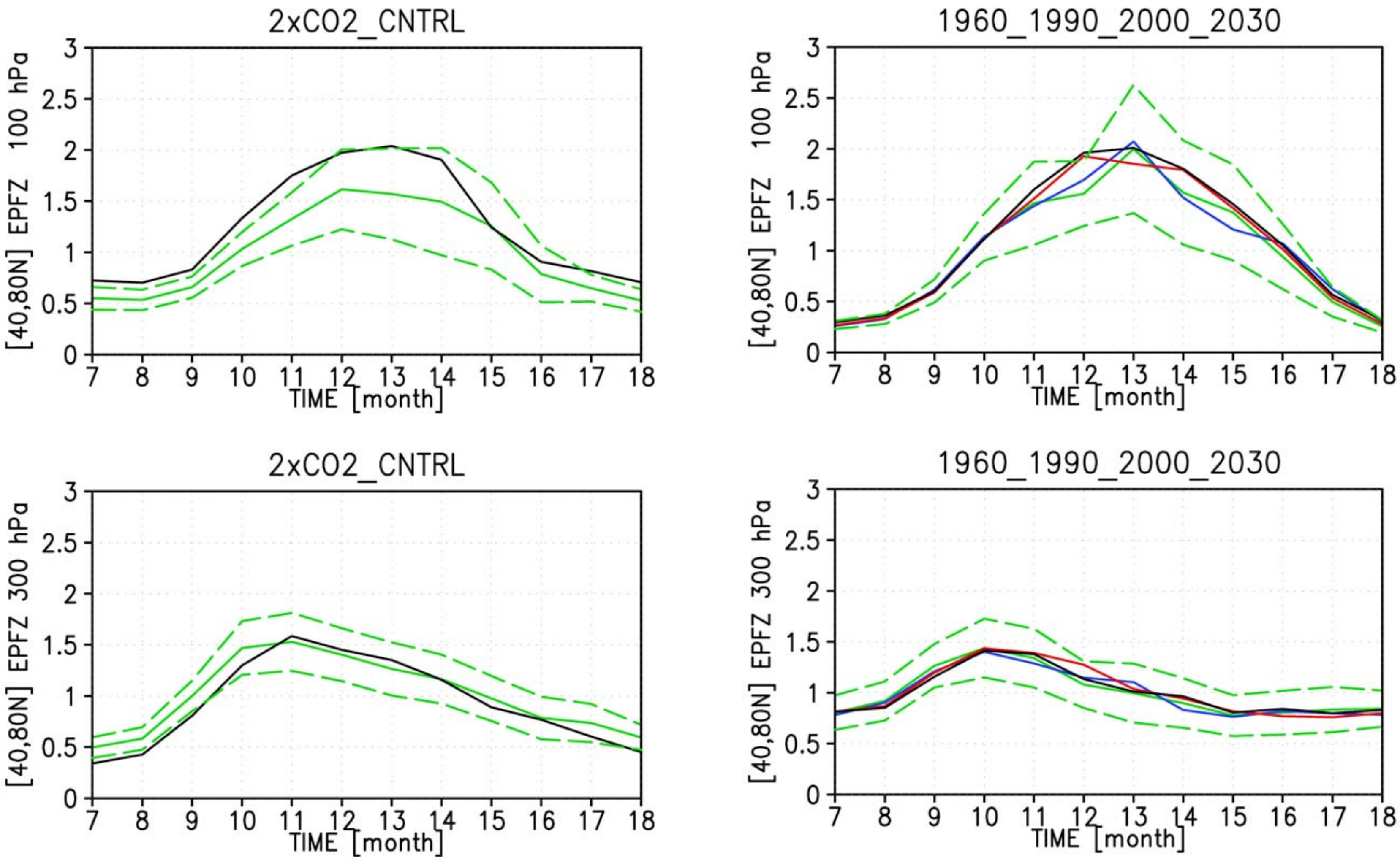
Near past, present, and 2030 simulations



Near past, present, and 2030 simulations



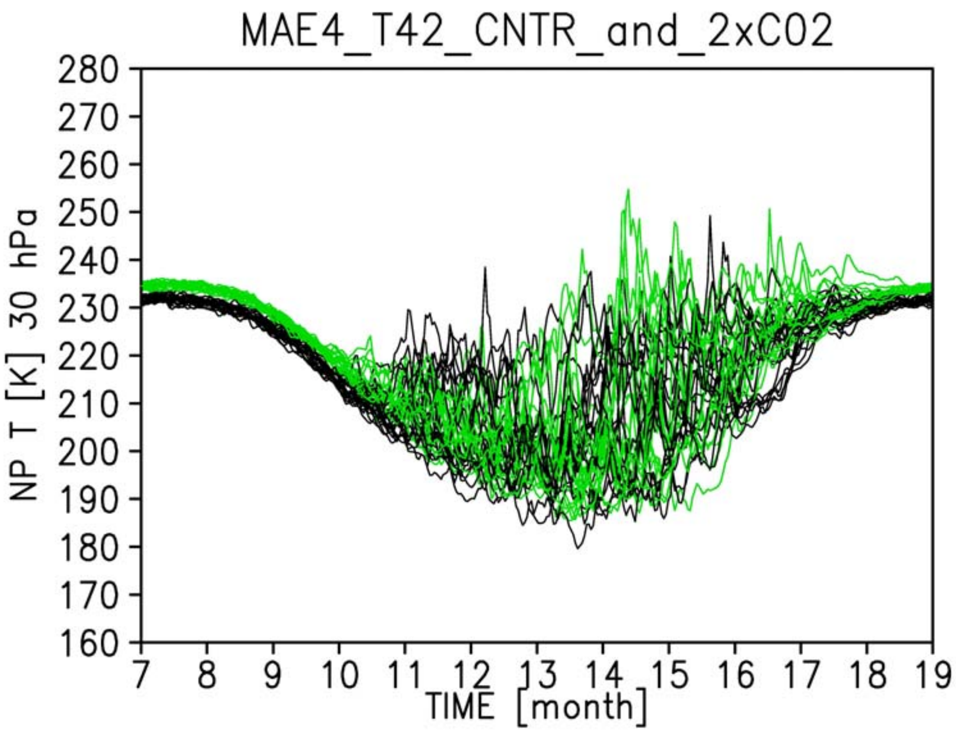
EP-Flux Vertical Component

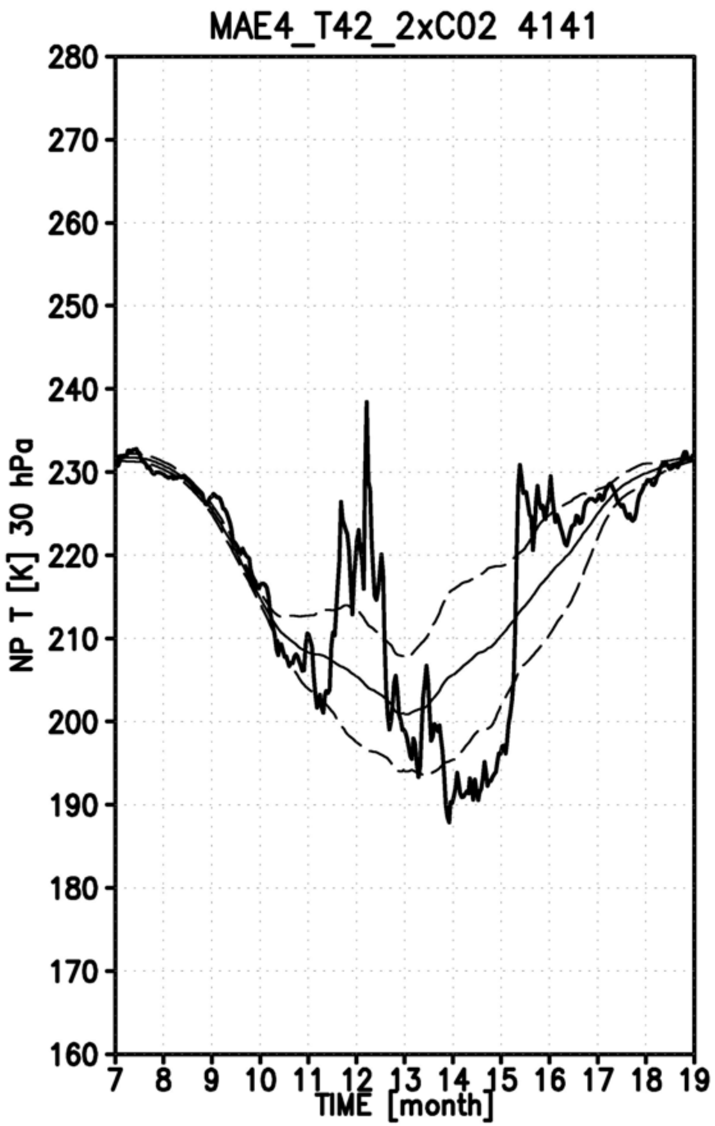


CNTRL 2xCO2

1960 1990 2000 2030

NP Temperature at 30 hPa

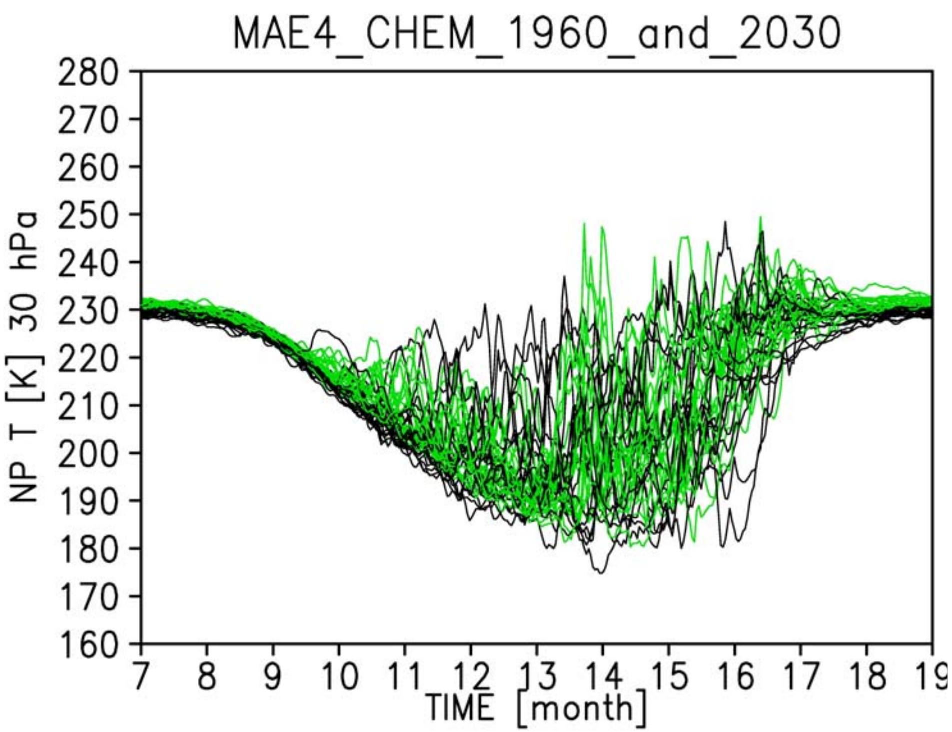


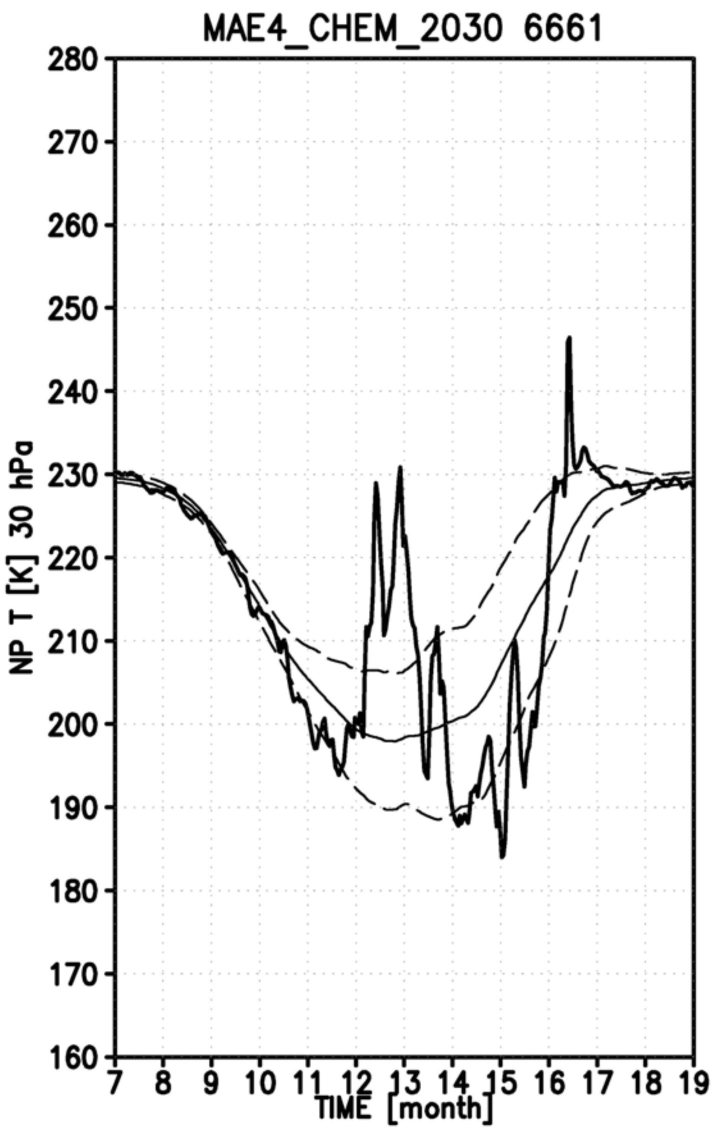


CNTRL

2xCO2

NP Temperature at 30 hPa

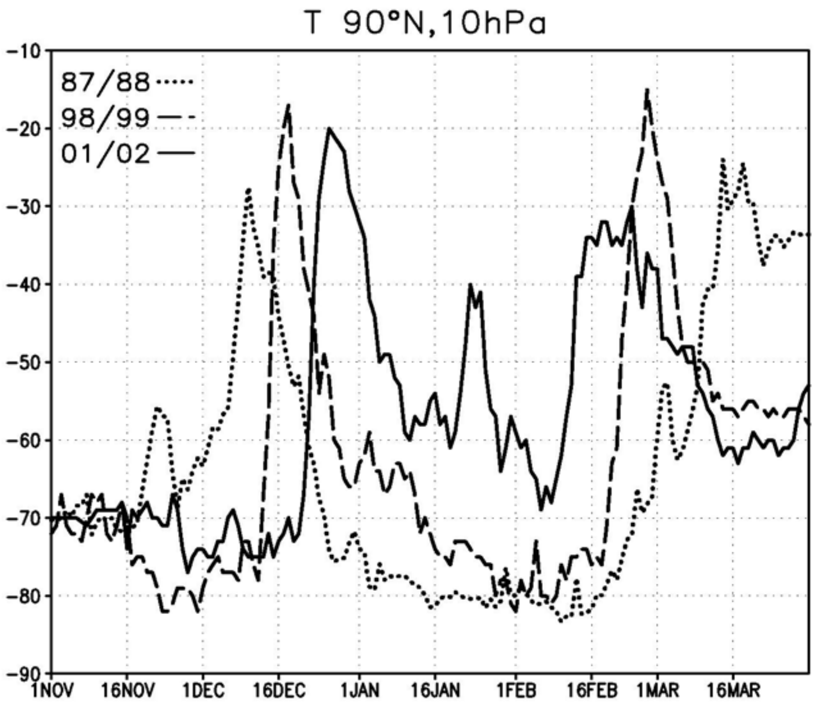




1960

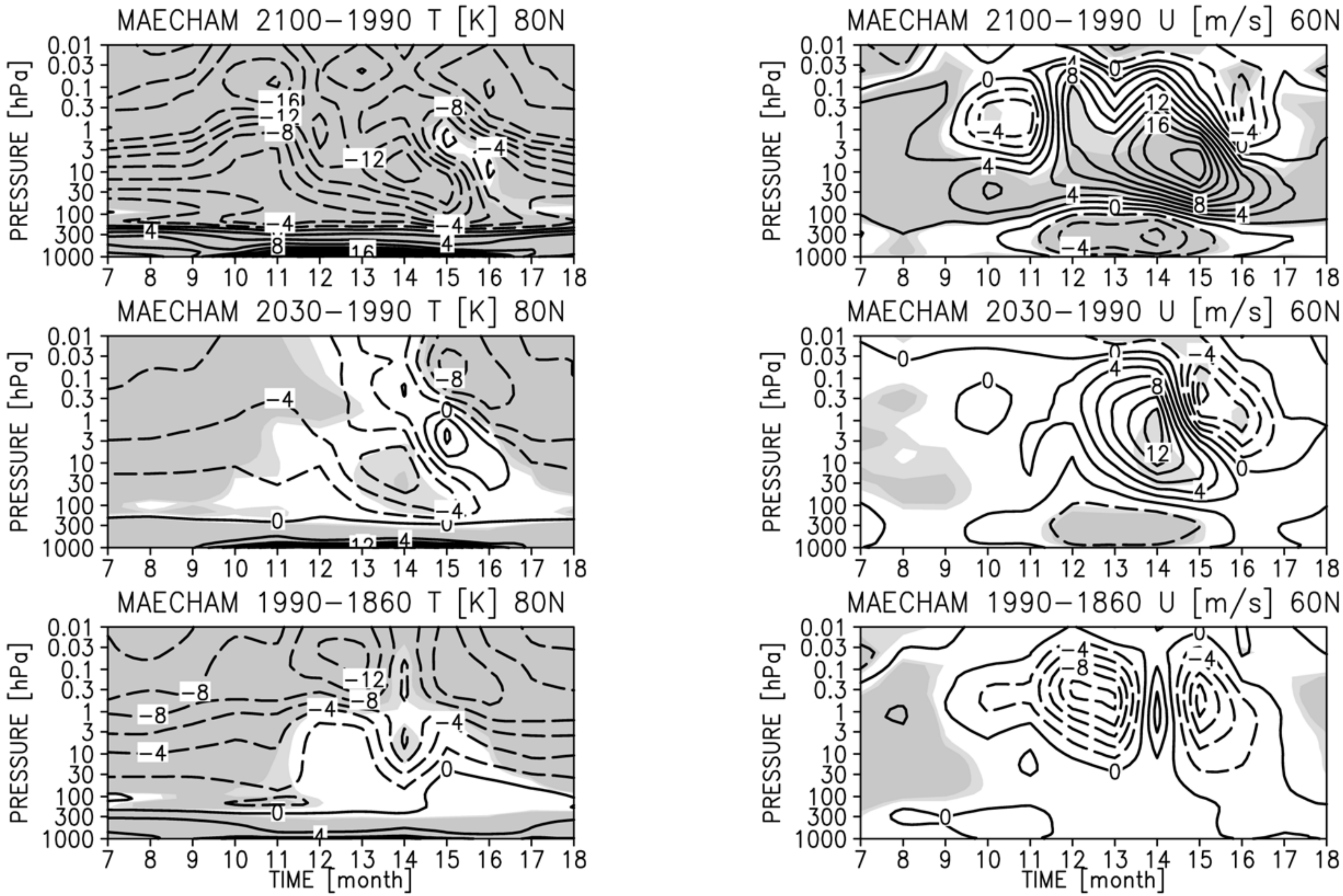
2030

Naujokat et al GRL 2002

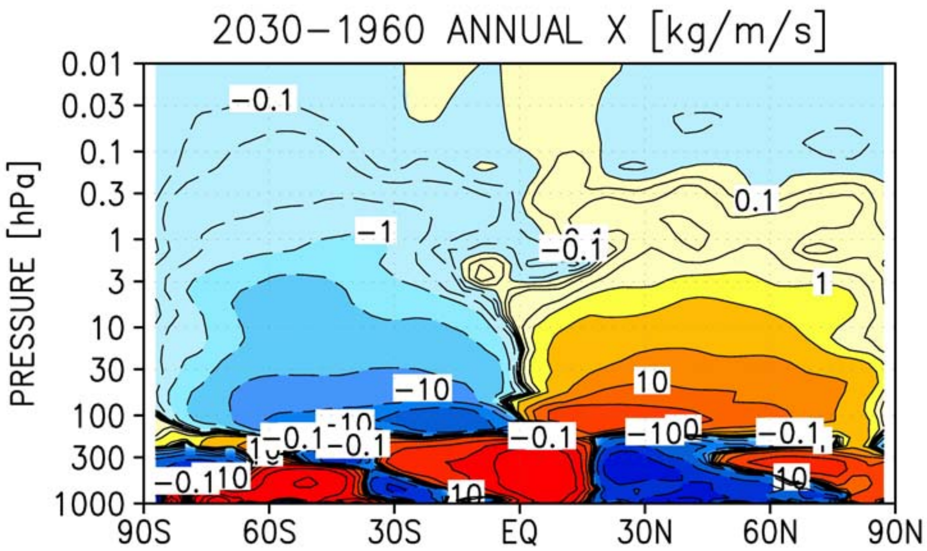


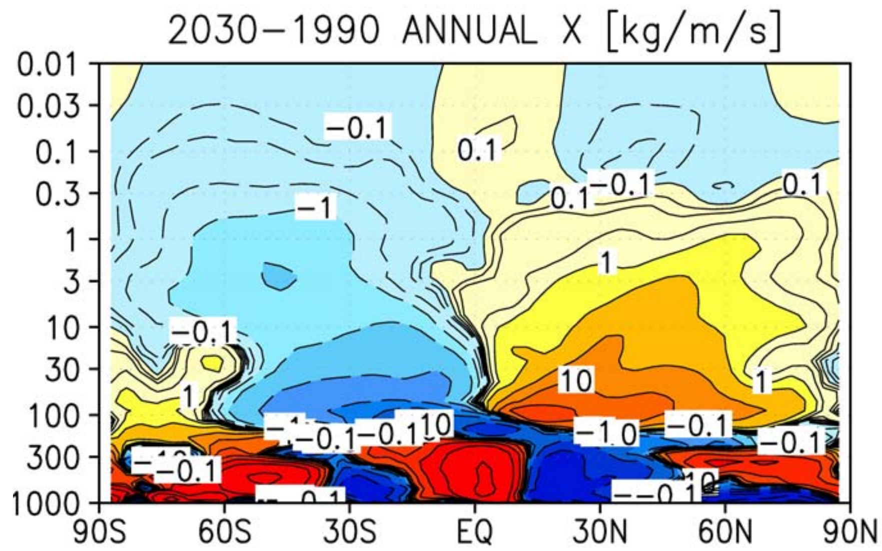
Early winter sudden stratospheric warmings are not exceptional events, although they are considered unusual (occurred in the last 15 years only)

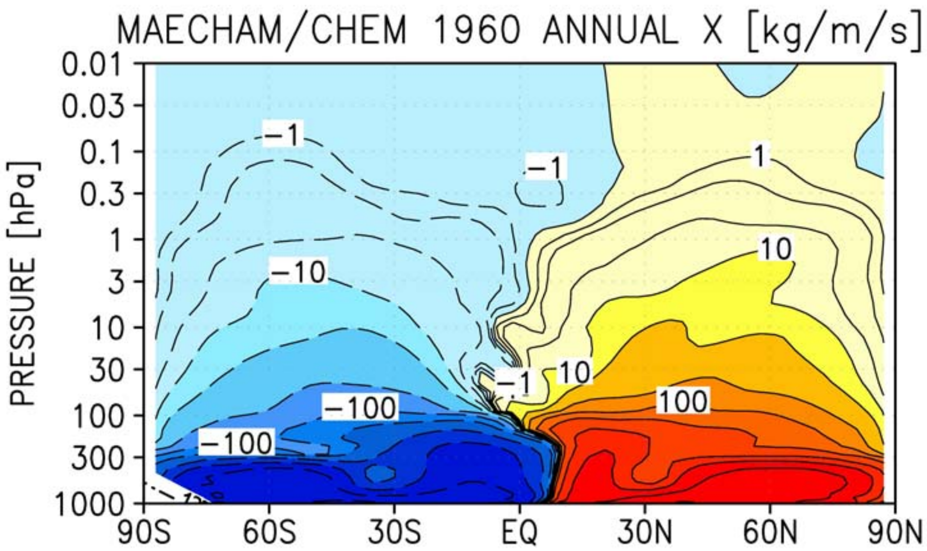
MAECHAM4 model with `Arctic Sea`



Annual Mean, Residual Streamfunction



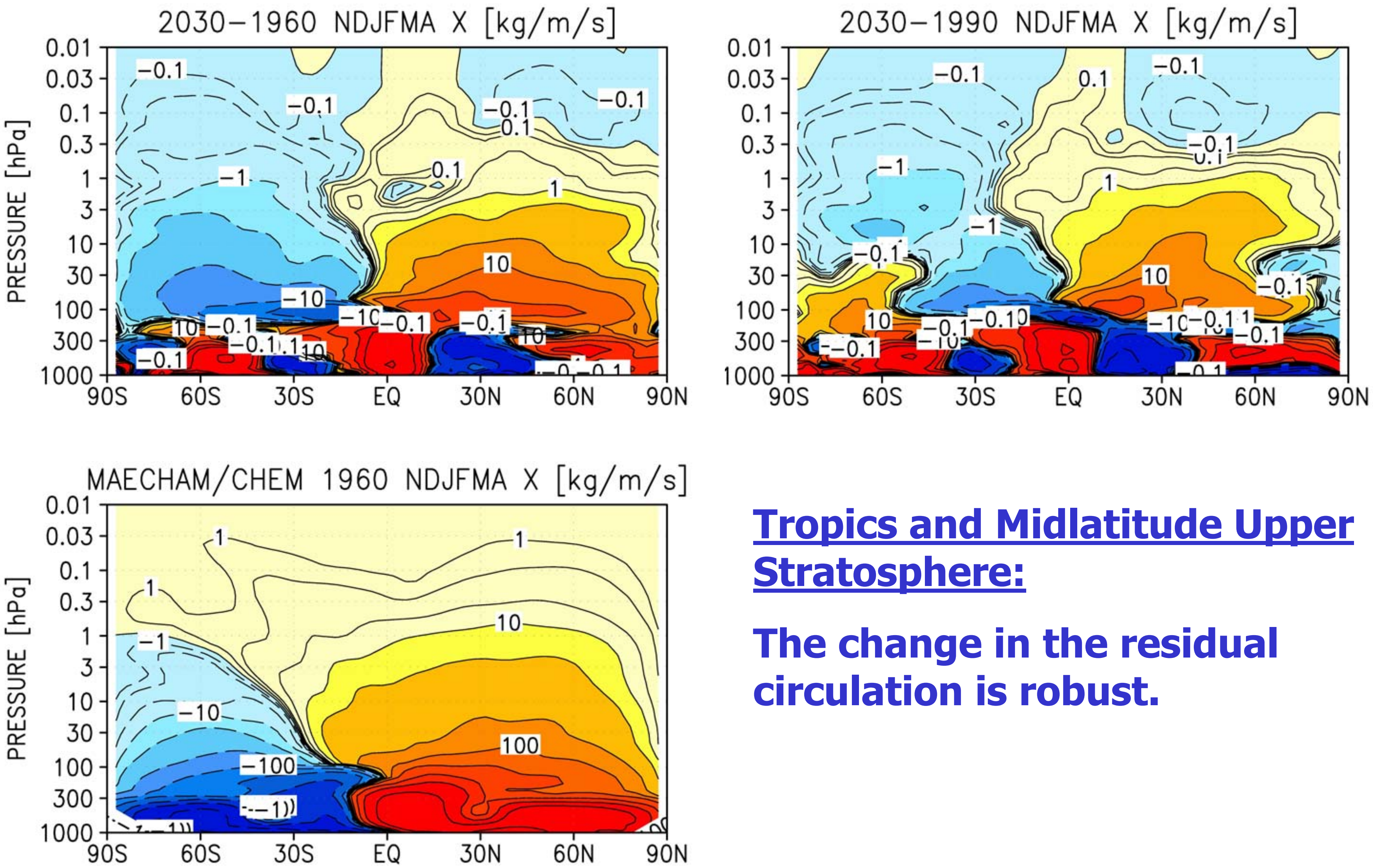




<u>Polar Lower Stratosphere:</u>

Reduction of the increase in the residual circulation for the case of MAECHAM4 `with Artic Sea`

Northern Winter, Residual Streamfunction



Tropics and Midlatitude Upper Stratosphere:

The change in the residual circulation is robust.

Remarks and Conclusions

- March cooling in the lower Arctic stratosphere, associated with ozone depletion for comparable wave activity emerging from the troposphere during winter (2000-1960, MAECHAM4/CHEM)
- Late autumn / early winter Arctic polar warming in the upper stratosphere for 2xCO2-CNTRL (MAECHAM4) and increase in GHGs (2030-1960, MAECHAM4/CHEM, some ozone depletion). Ozone recovery is favoured.
- Changes induced by the CO2 increase extend to the surface in late winter and appear to favour the negative phase of the Northern Annular Mode.
- Ozone depletion in the southern polar latitudes: stronger westerlies down to the surface in November – December (positive phase of the Southern Annular Mode).
- Arctic polar winter cooling possible (`Arctic sea´).

- Late autumn / early winter change in the Arctic stratosphere:

  - Originated in the troposphere?

  - Any role from stratospheric internal variability and/or state?