Arctic stratospheric SO_2 injections

Blaž Gasparini[1], Ben Kravitz[2], Phil Rasch[2], Sylvaine Ferrachat[1], and Ulrike Lohmann[1]

1) Institute for Atmospheric and Climate Sciences, ETH Zürich, Switzerland
2) Atmospheric Sciences and Global Change Division, Pacific Northwest National Laboratory, USA

Contact: blaz.gasparini@env.ethz.ch

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Conclusions

•The two models used in the intercomparison study of Arctic geoengineering show considerably different behavior. The differences come from a different representation of aerosol microphysics (prescribed vs. interactive), model top boundaries (10 vs 0.1 hPa), cloud microphysics schemes, considerably different oxidation times for SO_2 and the consequent formation of liquid aerosols, etc.

Model deficiencies

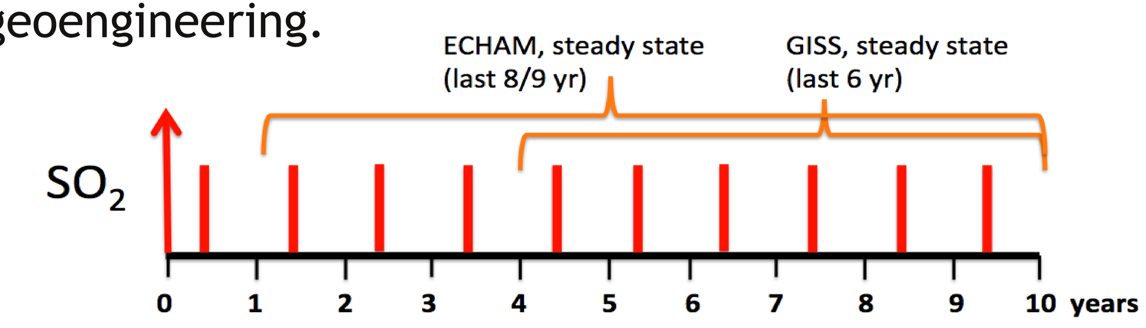
1)ECHAM: overestimation of the sulphate aerosol lower stratospheric heating effect, with T anomalies of up to 14°C, unrealistic aerosol representation for the stratosphere
2)GISS: too long SO_2 oxidation time, slow strat. aerosol sedimentation, no T anomalies, suggesting an unrealistically small effective radius for geoengineered aerosols

Next steps

Use of high-top model in ECHAM simulations with the new ECHAM6 HAM L47 setup, a more realistic aerosol distribution in GISS, modification to aerosol modes in ECHAM, etc.

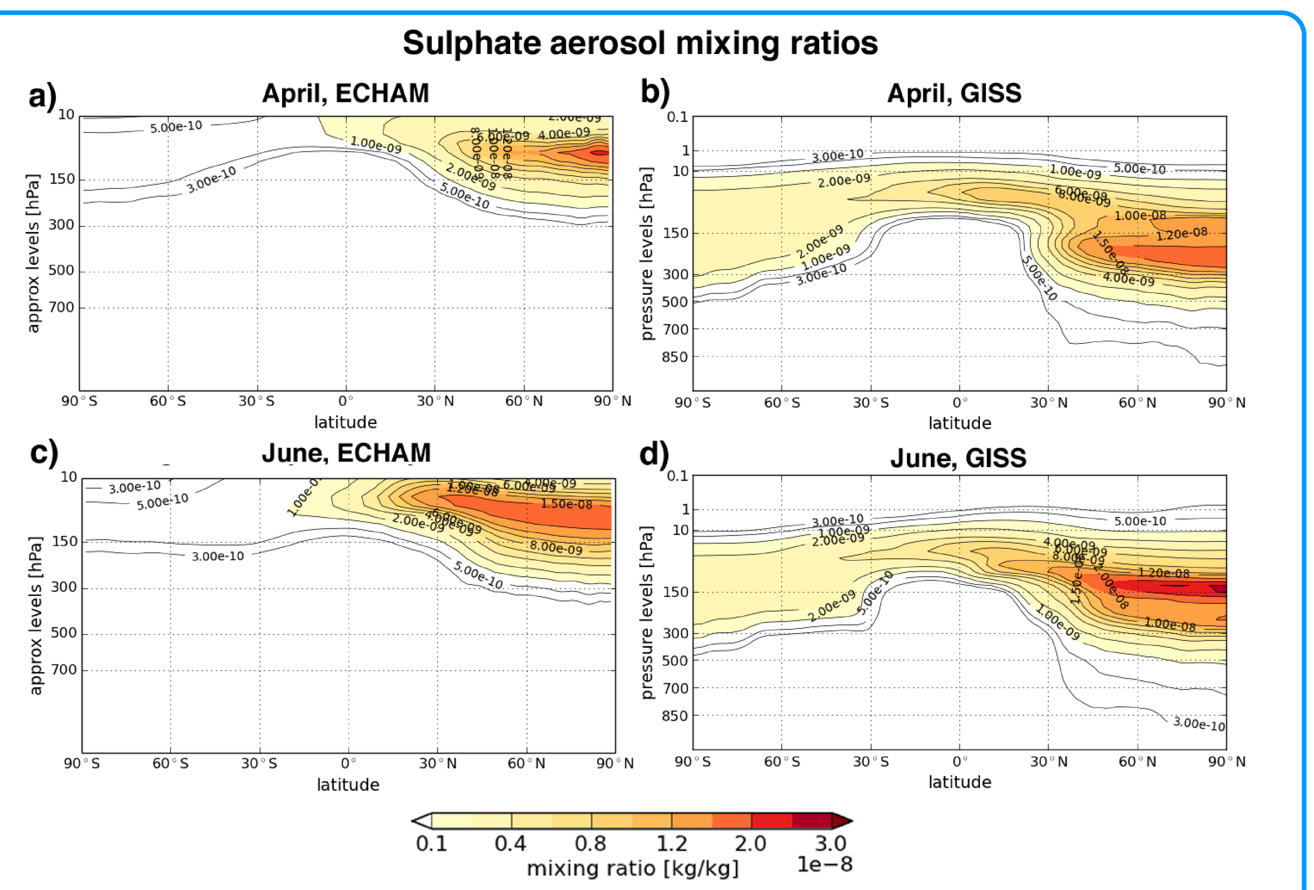
Motivation and simulation setup

This study aims at evaluating the options of mitigation of the rising polar temperatures and sea-ice retreat by stratospheric sulphur injections in NH high latitudes.
We are comparing the results from the two models to determine the mechanisms that cause similarities and differences in the modeled climate effects of Arctic geoengineering.



SO_2(g) emitted at 100 hPa over Svalbard islands (80°N)
•Emissions of 10 Mt SO_2/a emitted every April for all 10 years of the simulation
•Steady state is reached when $d(S_{strat})/dt = 0$ in the annual mean

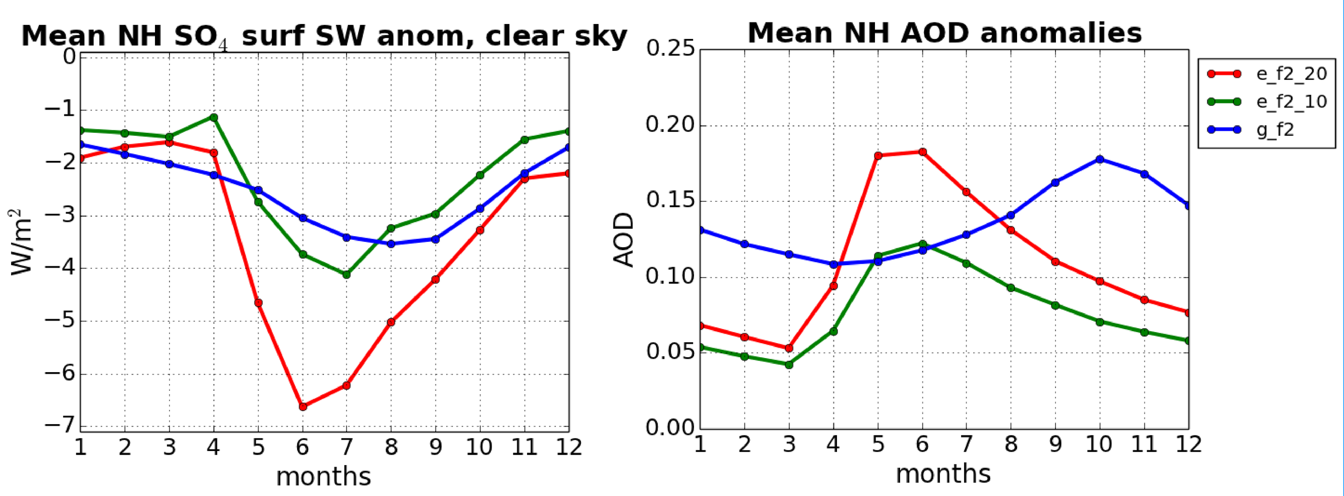
Sulphate aerosol mixing ratios



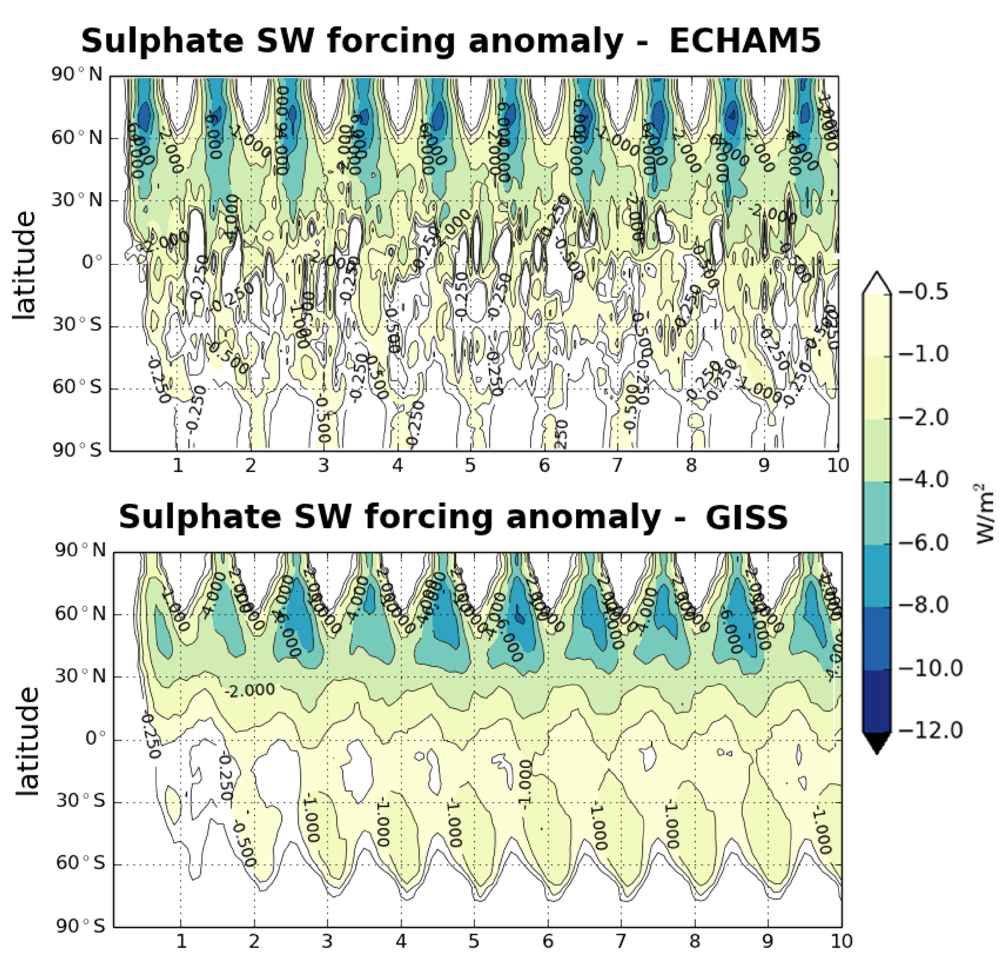
Considerably different behaviour in the 2 models:

- ECHAM: most of the aerosols form in the first month after the injection.
- GISS: the process of SO_2 oxidation takes longer due to 2-4 x smaller OH concentrations: we observe an residual aerosol layer that remains in the stratosphere over winter

NH Surface SW forcing by sulphate aerosols

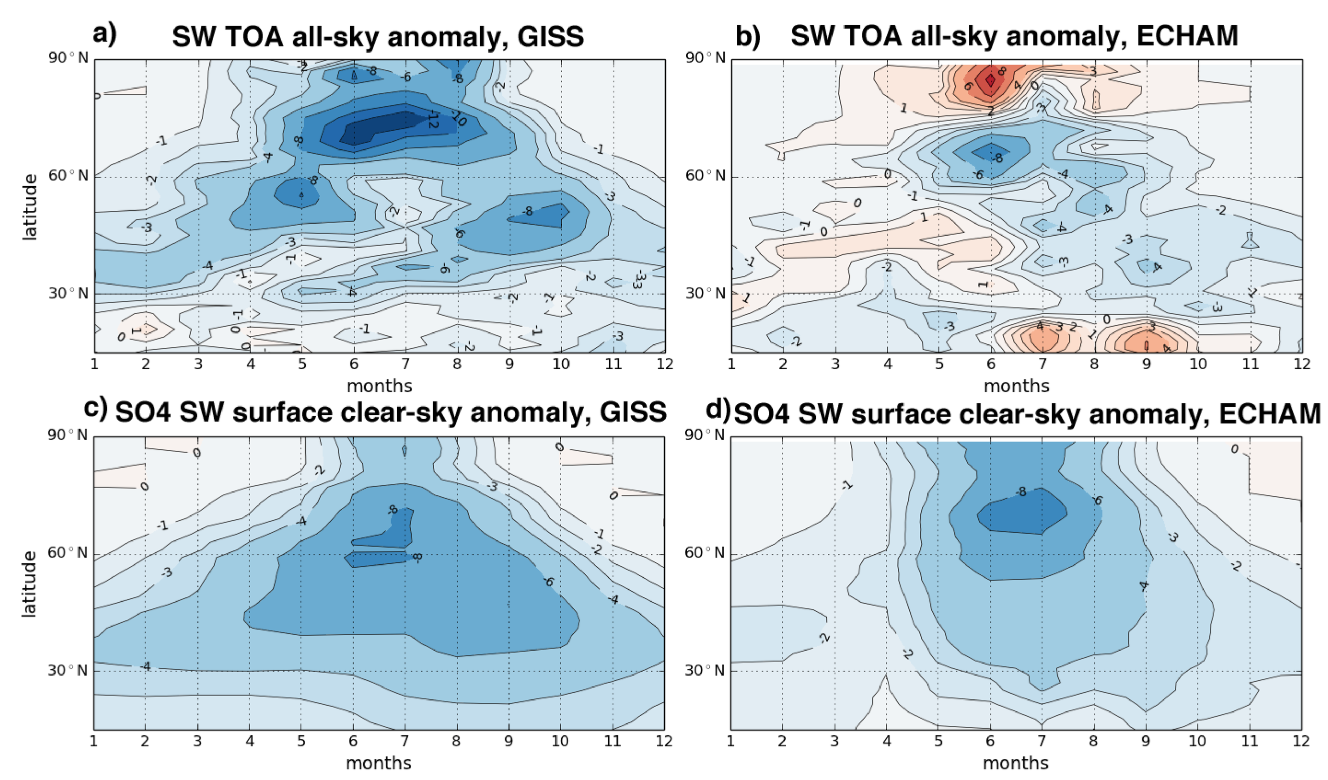


•The peak in AOD in ECHAM, averaged over the northern hemisphere, corresponds to the peak in SW anomalies.
•AOD peak in GISS is delayed due to longer aerosol nucleation time,
•and is not corresponding to the peak in SW anomalies (Aug and Sep) because of a decreasing solar radiation in autumn.
•The emission of 20 Mt SO_2 in the same setup in ECHAM (red curve) shows a 50-70% higher AOD and SW radiation anomalies.
•The AOD pattern in GISS confirms the existence of a residual geoengineered aerosol layer over winter



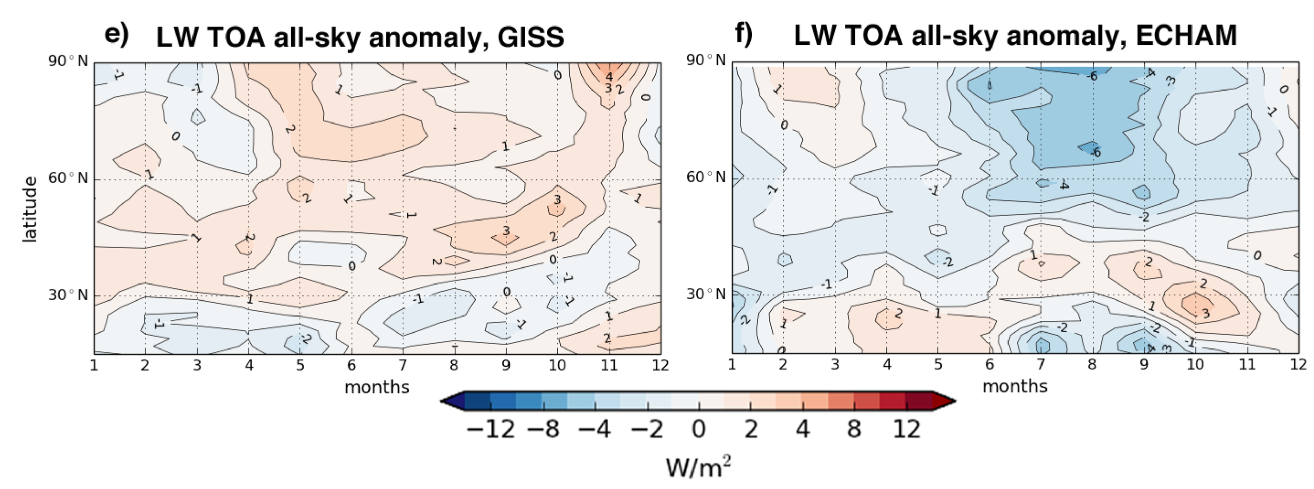
•The SW forcing is not limited to the NH
• ECHAM shows a volcanic-like SW clear-sky anomaly pattern

Shortwave anomalies



•No significant changes between the surface clear-sky and TOA all-sky values in GISS, but in ECHAM due to cloud responses affecting both the longwave and the shortwave radiation.

Longwave TOA anomalies



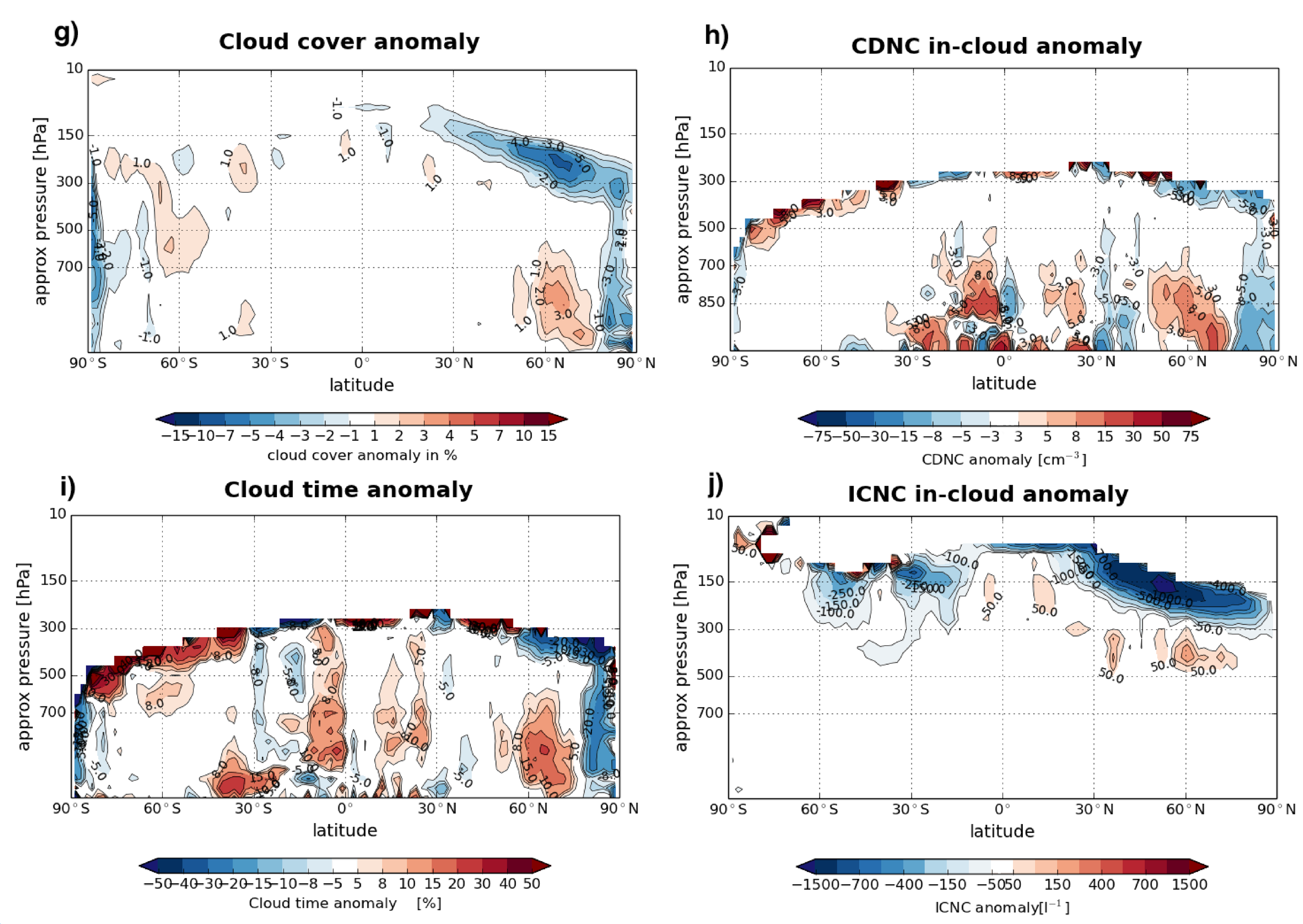
ECHAM cloud responses

The LW response is caused by a decreased NH cirrus clouds ice crystal number concentration (ICNC) and frequency.
-heating of the lower stratosphere due to near IR and LW absorption by the sulphate aerosols stabilizes the higher troposphere/lower stratosphere (Kuebbeler et al. 2012)

The SW positive anomaly in NH high latitudes is due to a decrease in cloud cover in the whole troposphere, including low level clouds (figures g-i).

On the other hand, clouds and cloud droplet number concentration (CDNC) for low level clouds are increased between 50°-70°N, corresponding to the negative peak in SW TOA anomaly.
This occurs by a destabilisation of the lower troposphere due to a negative temp. anomaly in the relevant region in most of the troposphere, and no/little change in surface temp. due to the fixed SST simulation setup.

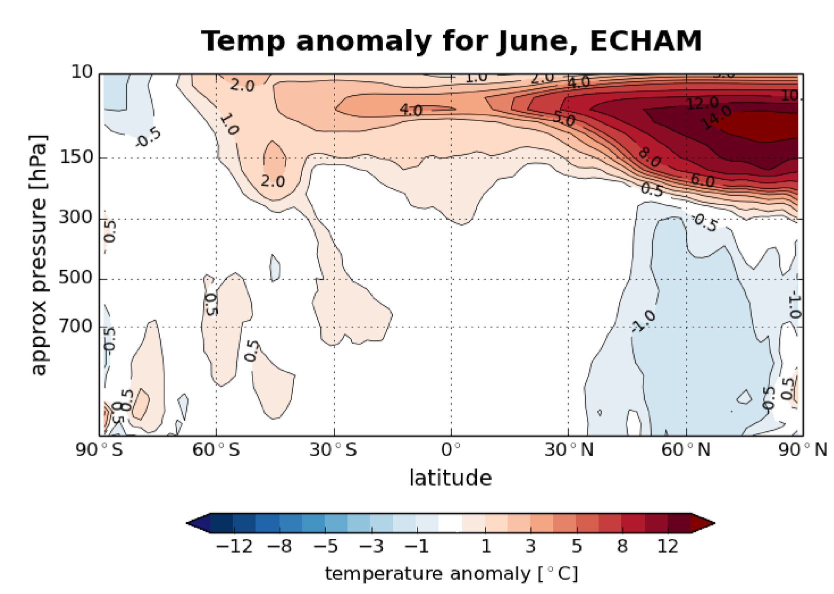
Cloud responses in June, ECHAM5-HAM2



Model description

We perform the simulations in ECHAM5-HAM2 (Zhang et al. 2012) with model top at 10 hPa and GISS Model E (Schmidt et al. 2006, model top 0.1 hPa) general circulation models.
We use the fixed SST simulation setup.
The simulation with stratosphere-resolving ECHAM6-HAM will follow in near future.

Model	Horizontal resolution (lat x lon)	Vertical resolution (layers)	Model top (hPa)	Aerosol microphys.
GISS	2°x 2.5°	40	0.1	prescribed
ECHAM5 -HAM2	1.875°x 1.875°	31	10	interactive



•Unrealistically large temperature anomaly in ECHAM, likely the main driver of the observed cloud responses

References

Zhang et al., 2012: The global aerosol-climate model ECHAM-HAM, version 2: sensitivity to improvements in process representations, *Atmos. Chem. Phys. 12*(3), 7545-7615
Kuebbeler et al., 2012: Effects of Stratospheric sulfate aerosol geo-engineering on cirrus clouds, *Geophys. Res. Lett.*, 39(23)
Schmidt et al., 2006: Present-day atmospheric simulations using GISS ModelE: Comparison to in situ, satellite, and reanalysis data, *J. Climate* 19(2),153-192

IAC ETH Institute for Atmospheric and Climate Science