Impact of geoengineering on global climate
— Earth system model simulations within IMPLICC —

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IMPLICC

Implications and risks of engineering solar radiation to limit climate change

- EU FP7 Project
- Five partners:
  - MPI-M, MPI-C, UiOslo, LSCE/CNRS, CICERO
- Studies are performed with 3 Earth-system-models:
  - MPI-ESM[1], NOR-ESM[2], IPSL-ESM[3]
  - Model resolution: (T63L47, GR15L40)

Why do we study geoengineering?

- Effectiveness of most geoengineering techniques is unclear.
- Undesirable side effects and risks are not well understood.
- Debate on geoengineering should be accompanied by independent research activities.

How do we study geoengineering?

- Goal: understand efficiency, risks and side-effects of SRM techniques using numerical Earth system models (ESM).
- Perform coordinated set of experiments with 3 models.
- Simulations of climate modified through geoengineering based on CMIP5 future emission scenarios.
- Identify robust climate response features of many models.
- Partner in EU project IMPLICC and GeoMIP initiative.
- This study was performed with MPI-ESM

Balance RCP4.5 forcing with geoengineering techniques

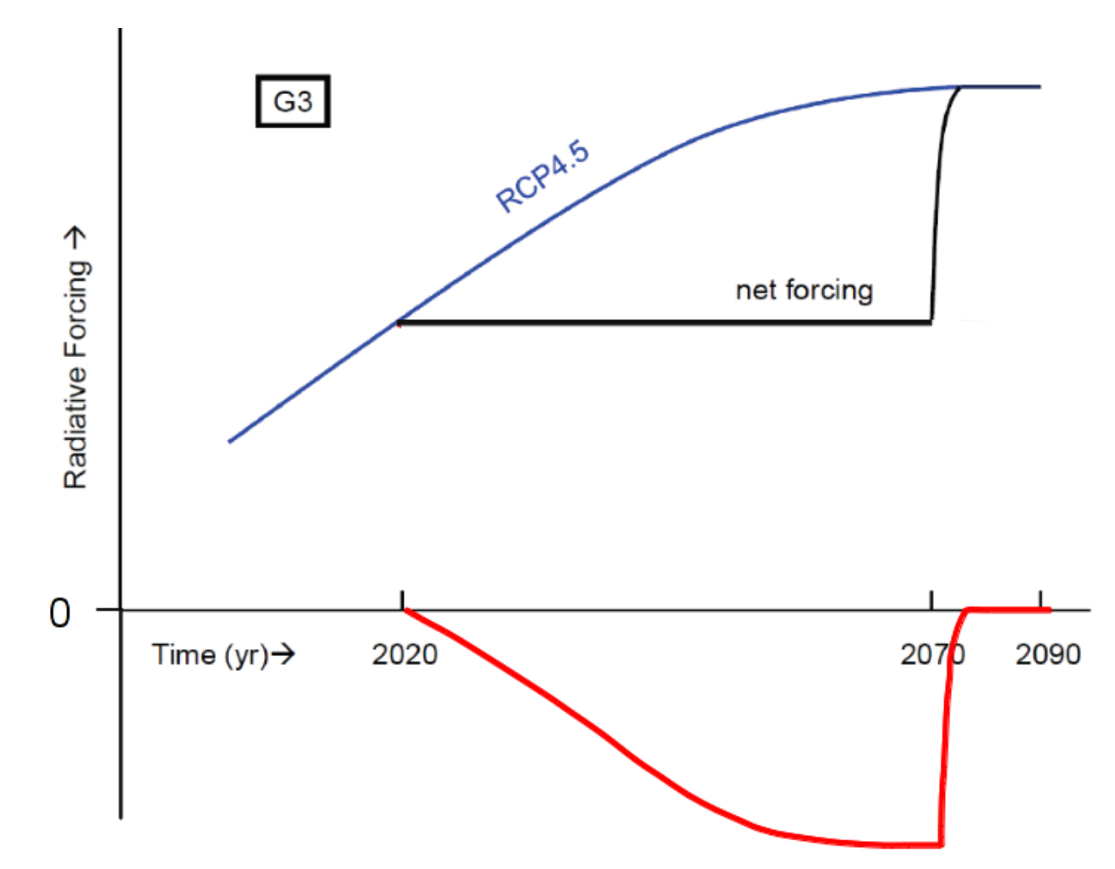

Figure 1: Schema of balancing experiments (modivied from Kravitz et al, 2011).

SULF	injection of SO_2 into the tropical lower stratosphere (Fig. 3)
SALT	emission of sea salt aerosols between 30° N and 30° S (Fig. 4)
SOL	reducing solar constant (mirror in space)
FIX	fix anthropogenic forcing to year 2020 conditions

Table 1: Geoengineering techniques used in the experiments; performed with MPI-ESM.

Experiment description:

- Balances radiative forcing from the RCP4.5 scenario (Table 1)
- Balance forcing estimates to maintain 2020 forcing conditions
- Start from RCP4.5 (2020) simulation
- Optical properties of sulfate prescribed, calculated by aerosol microphysical model ECHAM5/HAM (Fig. 2), (Niemeier et al, 2011)
- Sea salt concentration and cloud droplet number described to calculate direct radiative effect and impact on marine stratocumoulus clouds (Alterskjær et al, 2012)
- Results are compared to climatic mean value of 2020 (RCP4.5, 2006-2035)

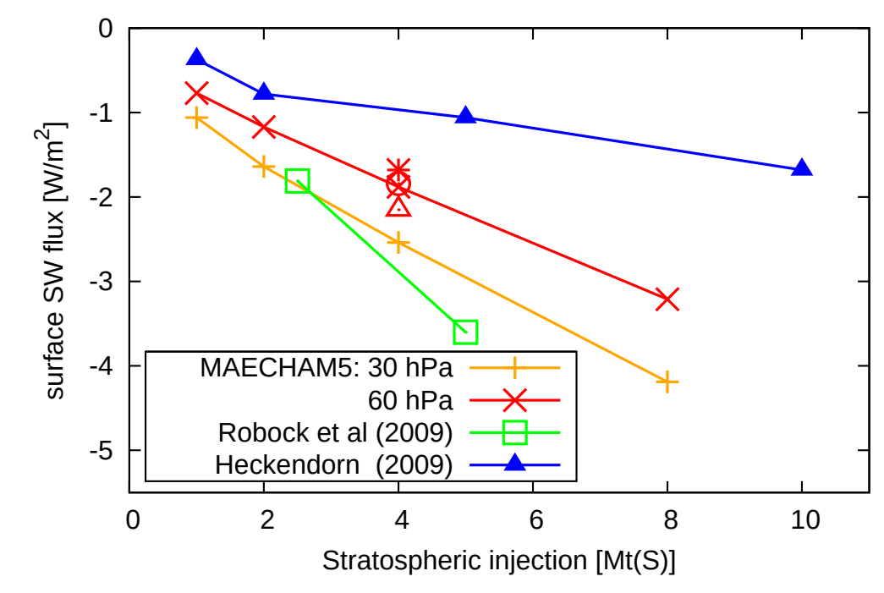

Figure 2: Radiative forcing from continuous stratospheric sulfur injections from different studies. Yellow and red: our study, Niemeier et al. (2011). Yellow and red indicate emission levels of 30 and 60 hPa. Blue and green should be compared to the 60 hPa emission scenario.

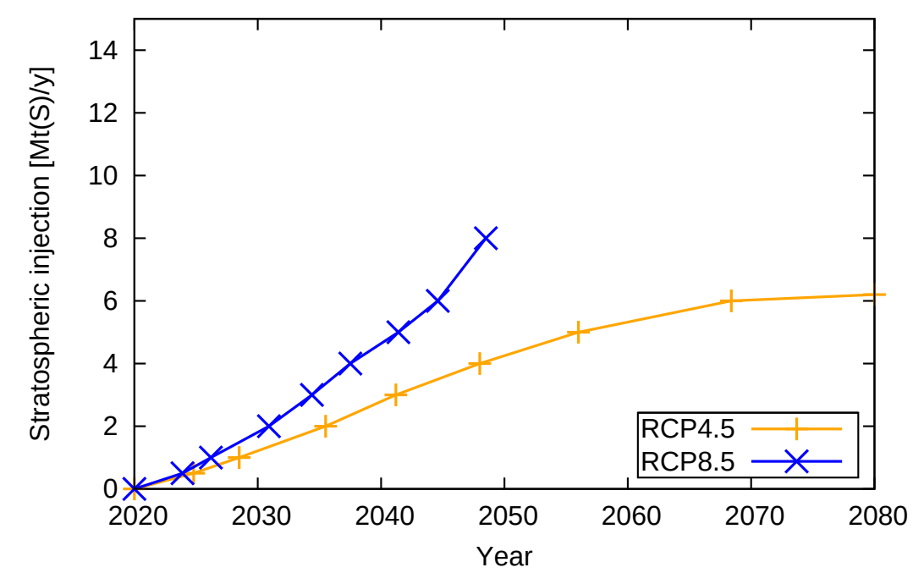

Figure 3: Stratospheric sulfur emissions necessary to balance a greenhouse gas increase following the RCP4.5 and RCP8.5 scenario to keep forcing at the level of year 2020. 8 Mt(S) were emitted during the Mt. Pinatubo eruption in 1991.

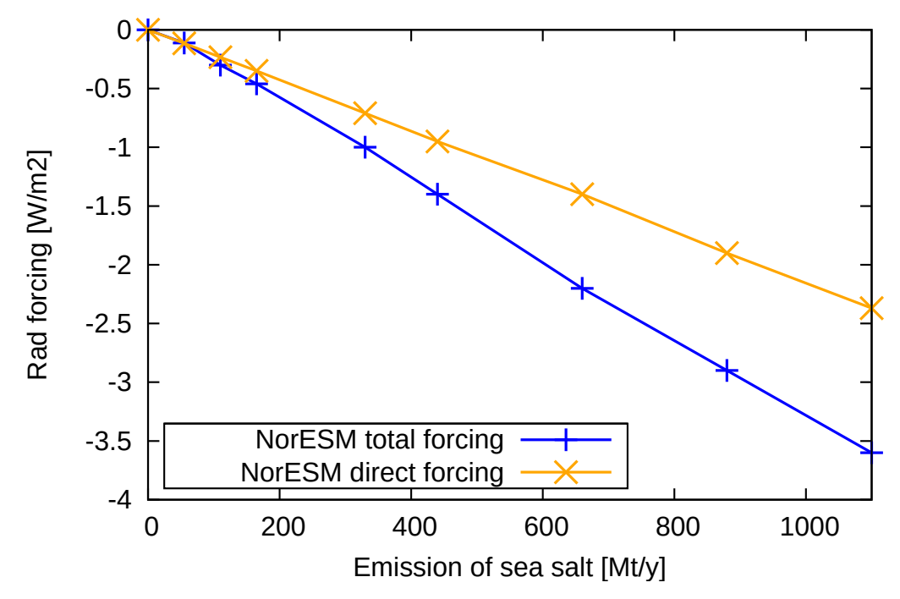

Figure 4: Forcing of artificial sea salt emissions (between 30° N and 30° S) for the direct forcing of the aerosol and the indirect forcing via modification of clouds, calculated with a cloud microphysical model within Nor-ESM.

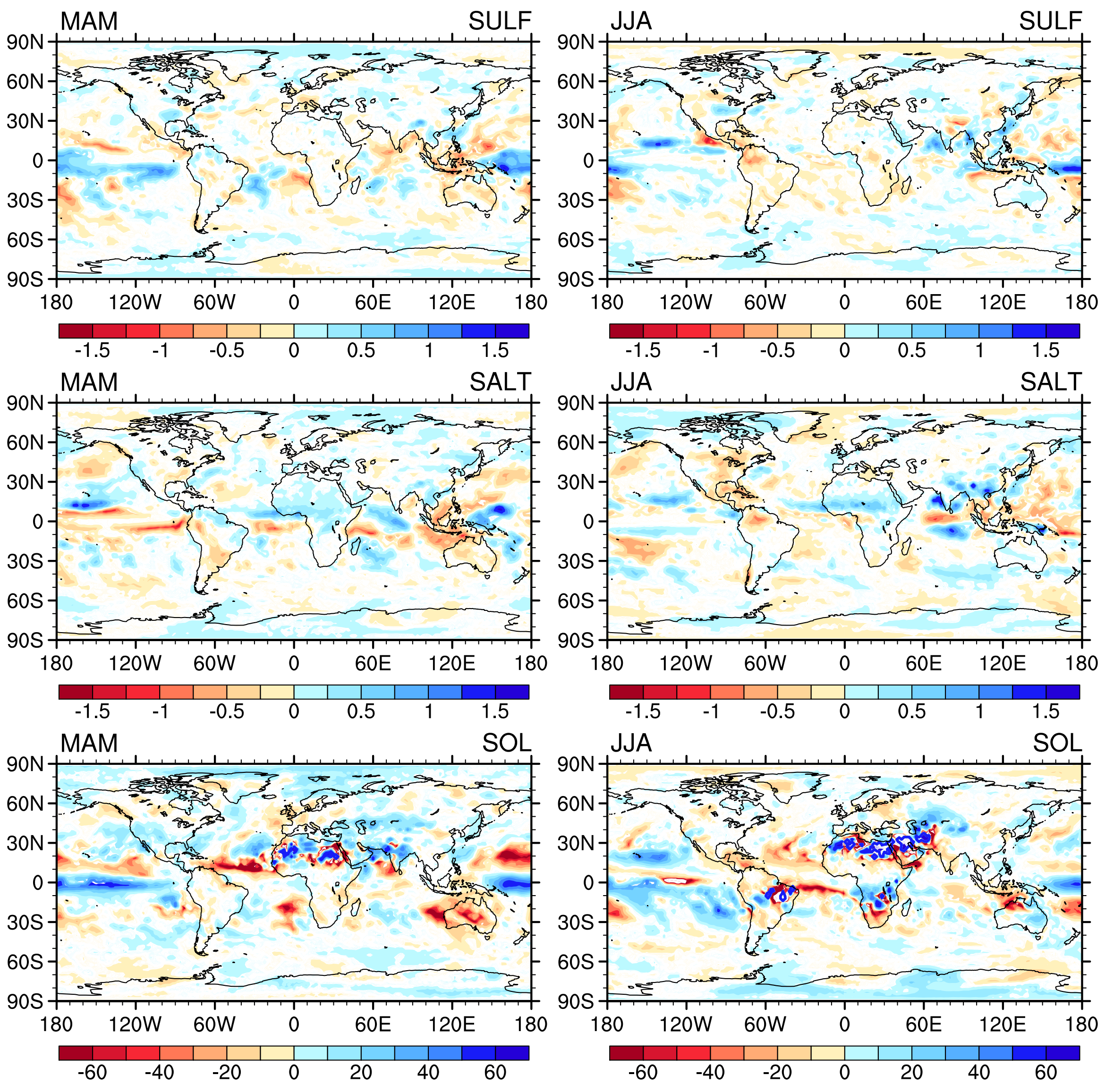

Figure 8: Seasonal precipitation anomalies [mm/day] compared to climate of the year 2020

Results

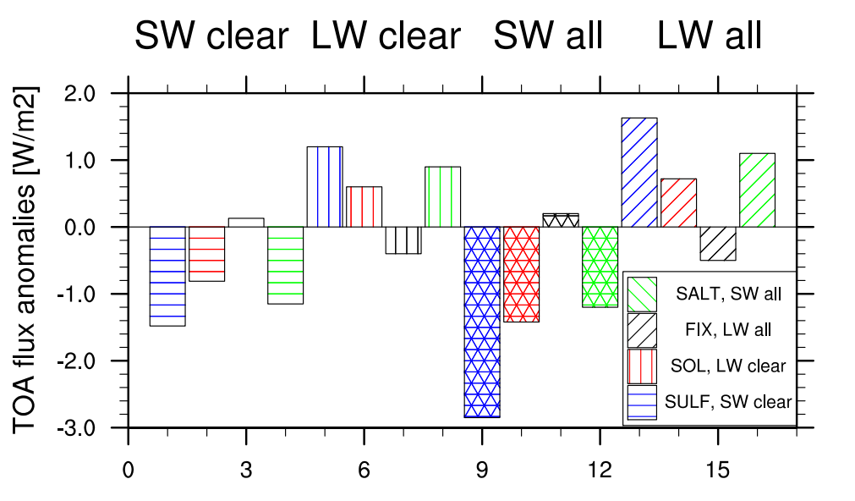

Figure: Top of the atmosphere radiative flux anomalies (mean 2060-69) compared to mean climate of the year 2020.

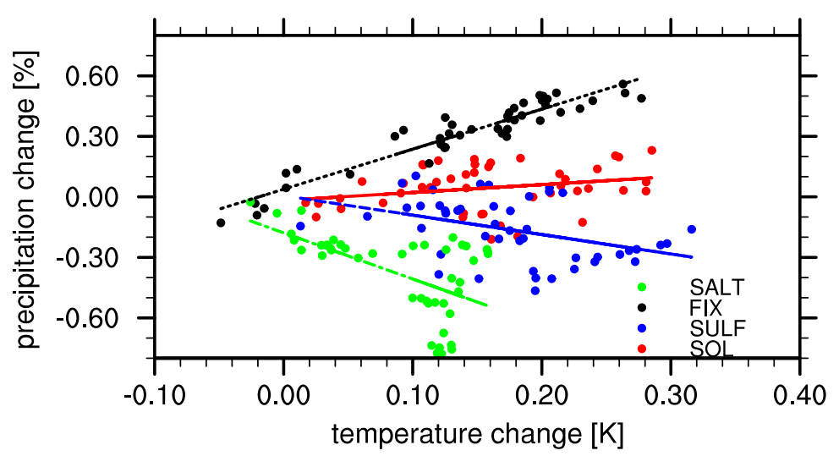

Figure 5: Precipitation versus temperature change

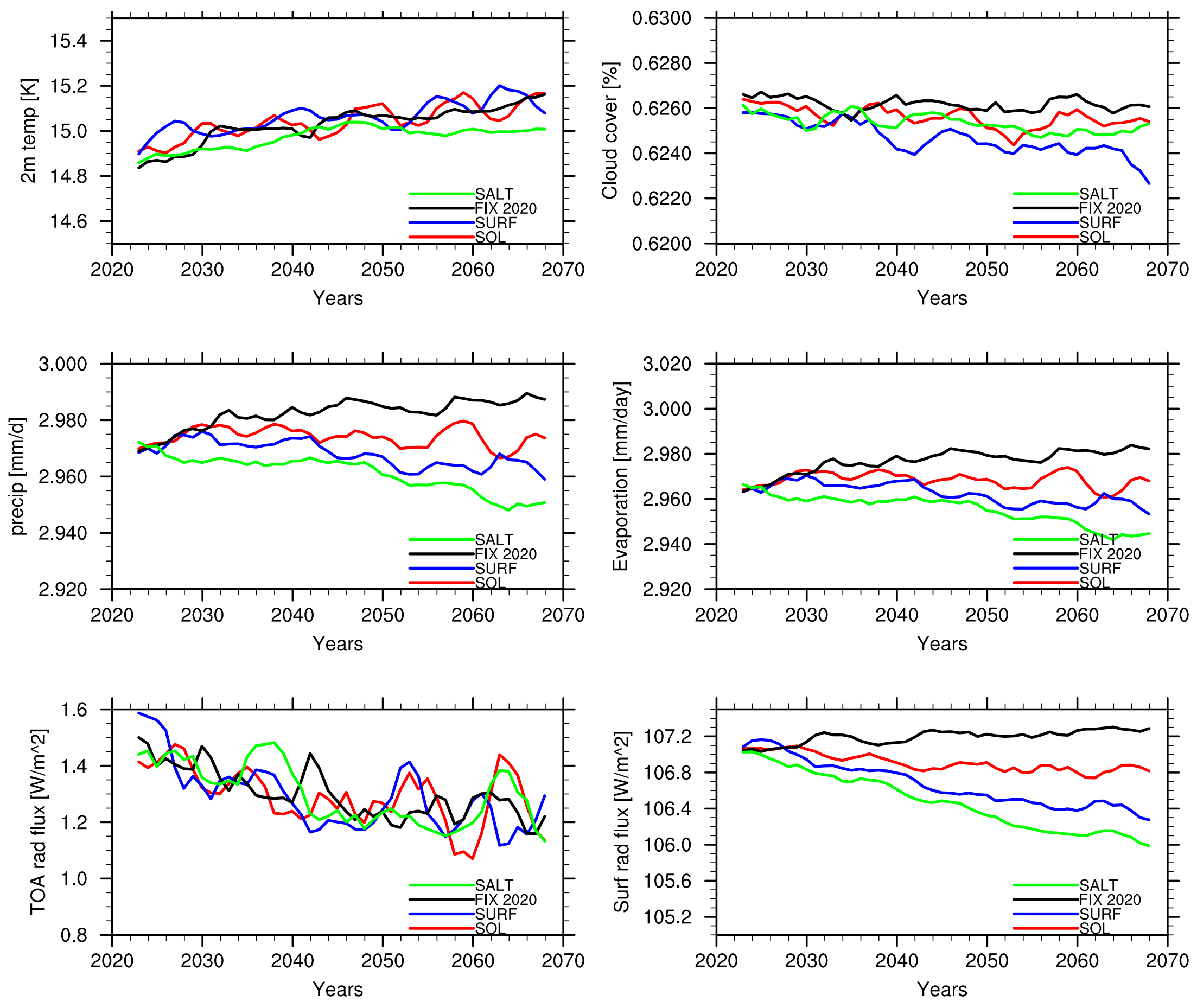

Figure 6: Timeseries of globally and yearly averaged data as a running mean over 5 years. Fluxes are positive downward.

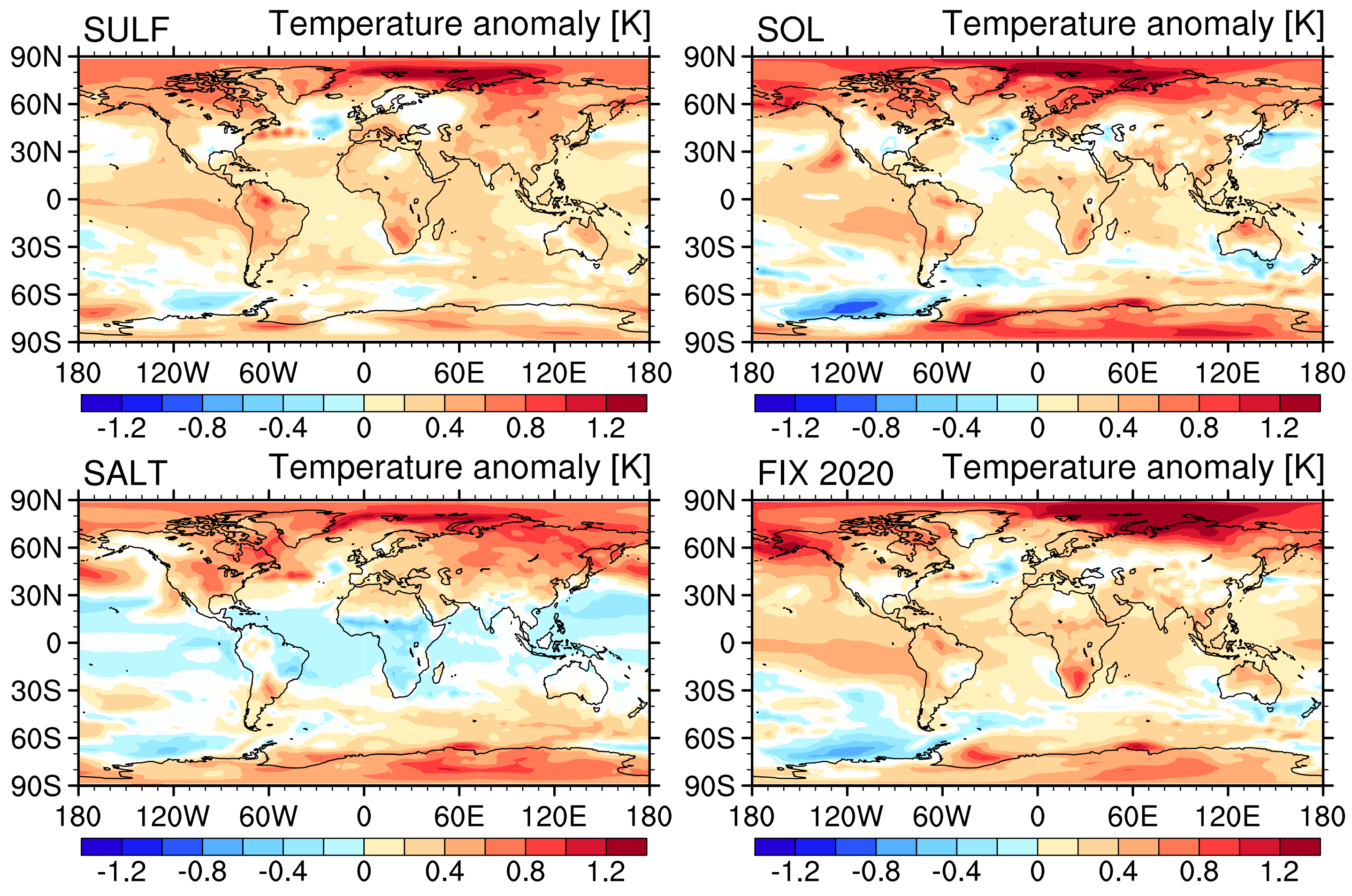

Figure 7: 2m temperature: annual mean of the ensemble (period 2060 to 2069) compared to the mean 2020 climate averaged over RCP4.5 results from 2006 to 2035.

Summary

Comparing results to averaged climate of 2020:

- Response on surface SW reduction
  - Evaporation decreases (Fig. 6)
  - Precipitation decreases (Fig. 5 + 6)
- Temperature (Fig 7 + 9)
  - Rises compared to mean 2020 climate
  - Strongest impact at the poles
  - Temperature gradient between pole and equator decreases
- Precipitation
  - Globally decrease by less than 1% and locally ± 10 to 50% (Fig. 8)
  - Strongest impacts in tropics and sub-tropics
  - Local results depend on model
- Multi-model approach necessary, especially for impact on precipitation

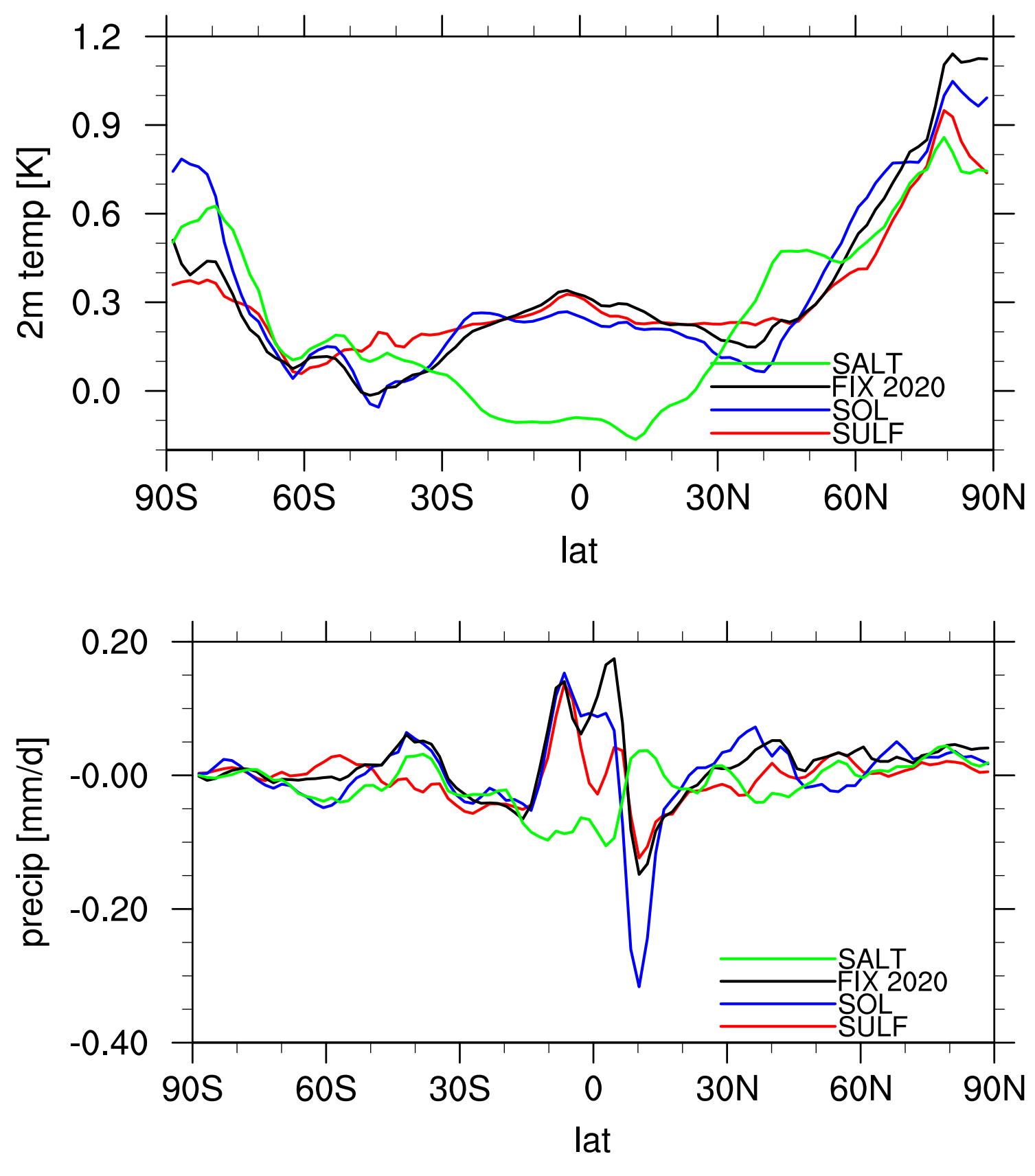

Figure 9: Zonal average of temperature (top) and precipitation (bottom) of yearly mean values compared to climate of the year 2020.

References

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SEVENTH FRAMEWORK PROGRAMME

MAX-PLANCK-GESELLSCHAFT