Do forests cool the planet?

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1. Motivation

Afforestation is often proposed as a method to mitigate climate change. However, it affects land surface properties such as albedo, roughness length and evapo-transpiration. Both, biogeochemical and biogeophysical effects, have to be considered. Previous modelling studies (Claussen et al., 2001, Bala et al., 2007) suggest that on a large scale forests exert a cooling influence in the tropics and a warming influence in boreal latitudes.

2. The model

We use the earth system model of the Max Planck Institute for Meteorology (MPI-ESM) to study the sensitivity of the coupled system to large scale changes in forest cover. MPI-ESM consists of the circulation models ECHAM5 and MPIOM, the land biosphere model JSBACH and the ocean biogeochemistry model HAMOCC5 and thus includes a closed carbon cycle.

3. Experiments

Boreal deforestation — Tropical deforestation
Boreal afforestation — Tropical afforestation

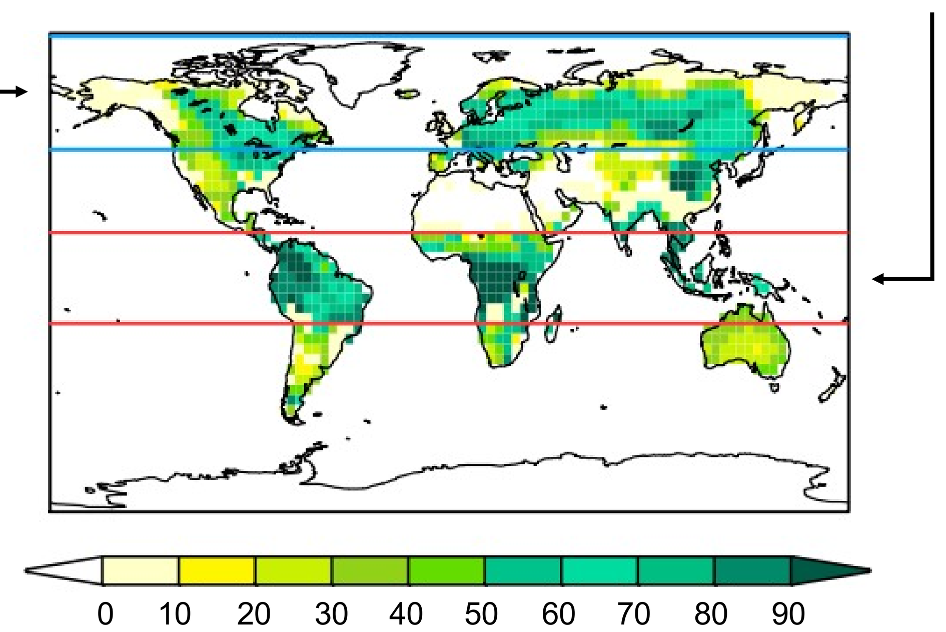

Fig. 1: Forest cover in % in the control run

Deforestation: Trees are replaced by grass and shrubs. Half of the vegetation carbon is put into the atmosphere, half into soil and litter pools.

Afforestation: Forest cover is set to 100%. No immediate carbon fluxes result.

4. Results

Temperature

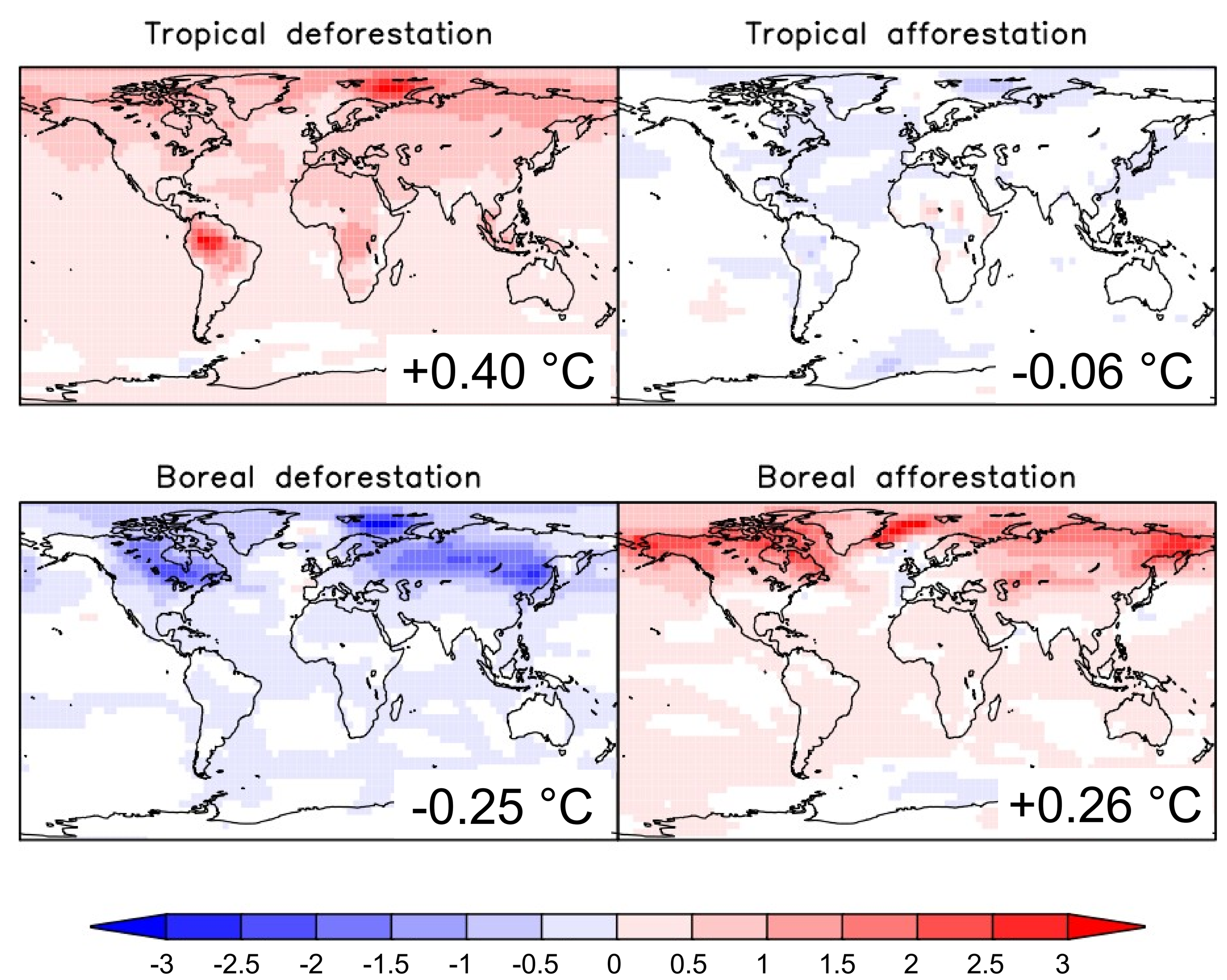

Fig. 2: Temperature anomalies in °C (years 100 - 300) with 95% significance

- Tropical deforestation: Global warming is pronounced over the deforested areas because of reduced evapotranspiration. In Amazonia, this effect is enhanced due to reduced moisture convergence.

- Tropical afforestation: Changes are mostly of opposite sign but smaller, because of the smaller affected land area and because forest is expanded towards unproductive areas. In Africa, large albedo differences between forest canopy and soil lead to a local warming.

- Boreal experiments: Temperature changes mainly result from short-wave forcing due to the masking of snow by forests in spring. Meridional overturning in the Atlantic is enhanced after deforestation and reduced after afforestation.

- Despite many model differences, the temperature changes per converted forest area are similar to CLIMBER-2 results by Claussen et al., 2001.

Carbon Cycle

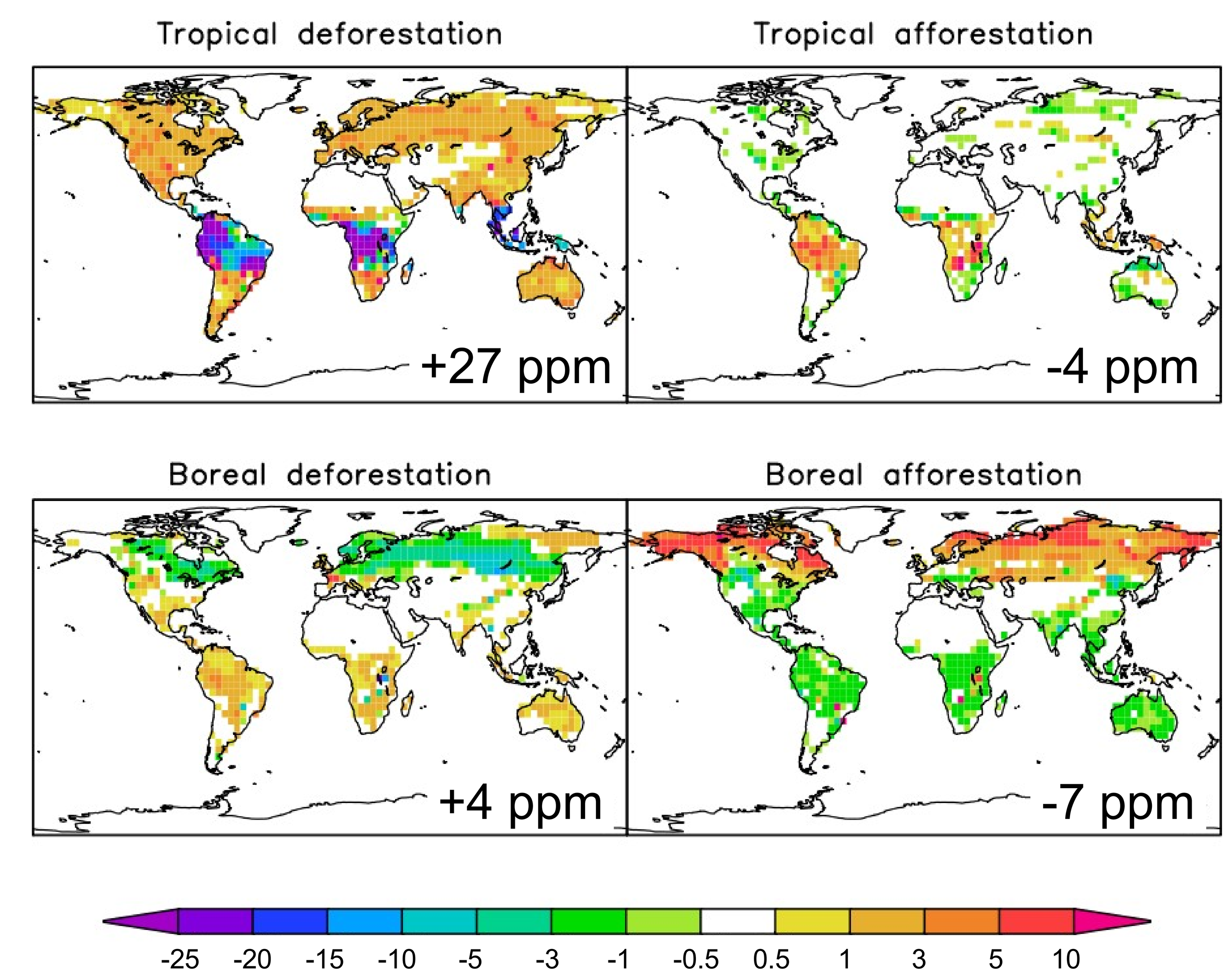

Fig. 3: Anomalies of terrestrial carbon pools in kg/m² and atmospheric CO_2 anomalies after 300 years

- For some land cells, a negative relation between forest cover and carbon storage is obtained (Fig. 3), because of climate - carbon cycle feedbacks and because grass and shrubs can be more productive than trees (e.g. in dry regions).

- In the afforestation experiments atmospheric CO_2 only decreases by a few ppm due to the compensation by the ocean and the remaining land areas (Fig. 4).

- Tropical deforestation leads to large emissions, while emissions after boreal deforestation are small.

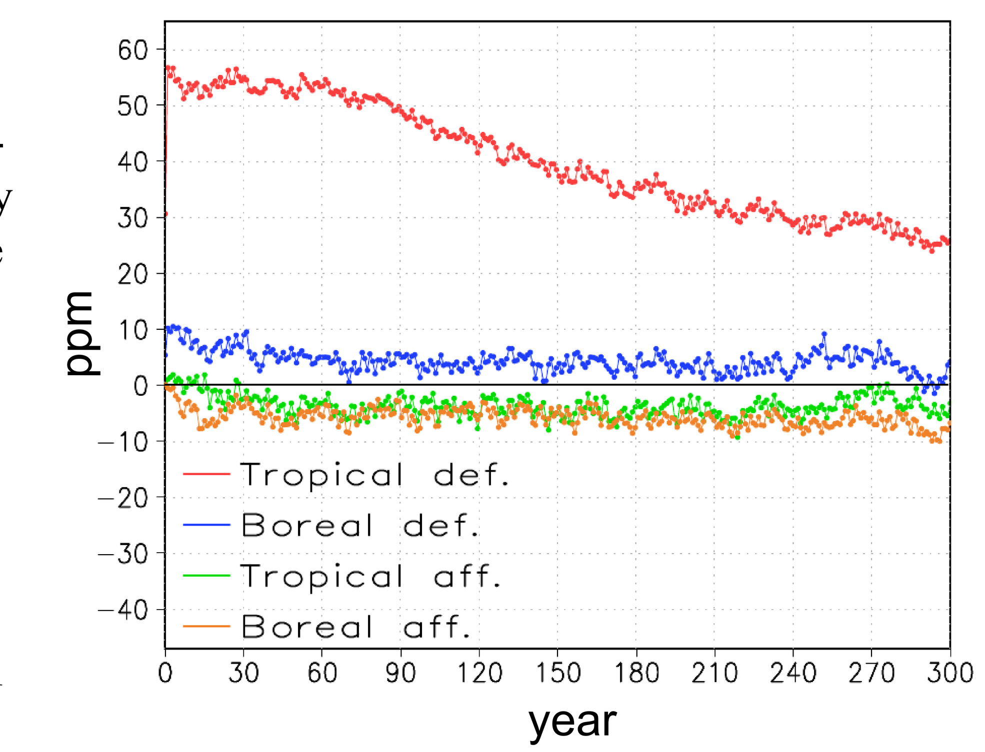

Fig. 4: Atmospheric CO_2 anomalies over time

5. Conclusions

- ► In MPI-ESM forests are cooling in the tropics and warming in boreal latitudes.
- ► The sign and magnitude of changes in temperature as well as carbon storage depend on the location.
- ► Therefore, this rule is only true on the global scale.

6. References and Affiliations

Bala, G., Caldeira, K., Wickett, M., Phillips, T. J., Lobell, D. B., Delire, C., and Mirin, A.: Combined climate and carbon-cycle effects of large-scale deforestation, P. Natl. Acad. Sci. USA, 104, 6550-6555, 2007.

Claussen, M., Brovkin, V., and Ganopolski, A.: Biogeophysical versus biogeochemical feed-backs of large-scale land cover change, Geophys. Res. Lett., 28, 1011-1014, 2001.

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