Model intercomparison of idealized global deforestation experiments

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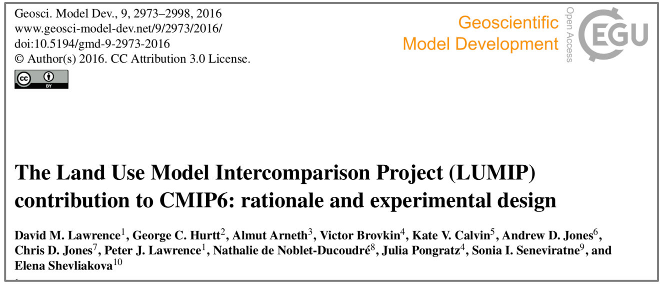
A novel, idealized global deforestation experiment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Geoscientific Model Development

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The Land Use Model Intercomparison Project (LUMIP) contribution to CMIP6: rationale and experimental design

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Global climate response to idealized deforestation in CMIP6 models

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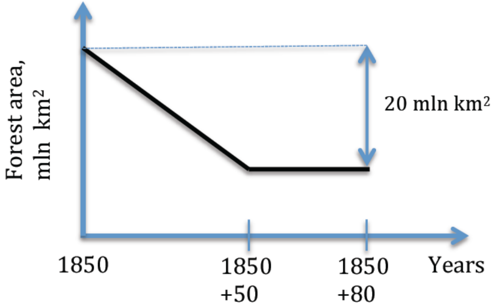
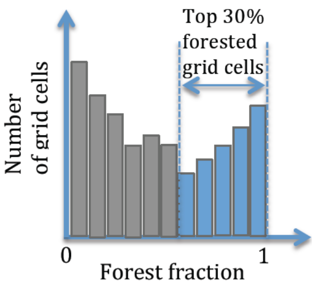
Experimental set up:

- Branching off PI-control; coupled land-atmosphere-ocean; CO_2 and land-use fixed in 1850
- **20 million km² of forest linearly removed over 50 years** (historically: ~10 mio km²)
- Only from 30% most forested grid cells (→ same pattern across models)





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Novelty

- Straightforward implementation
  → comparability of models
- Robust detection: strong deforestation signal (> historical or RCP)
  → Similar to 1%/yr CO_2 experiments
- Transient simulations
  → signal over time
- Biogeophysical and carbon cycle effects in one run

Model	MPI-ESM1.2-LR	IPSL-CM6A-LR	CESM2	BCC-CSM2-MR	CNRM-ESM2-1	CanESM5	MIROC-ES2L	EC-Earth3-Veg	UKESM1-0-LL
years	150	80	80	80	80	90	150	80	80
realizations	7	3	3	1	1	1	1	1	1

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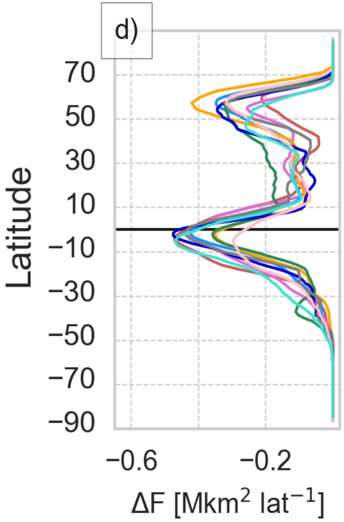
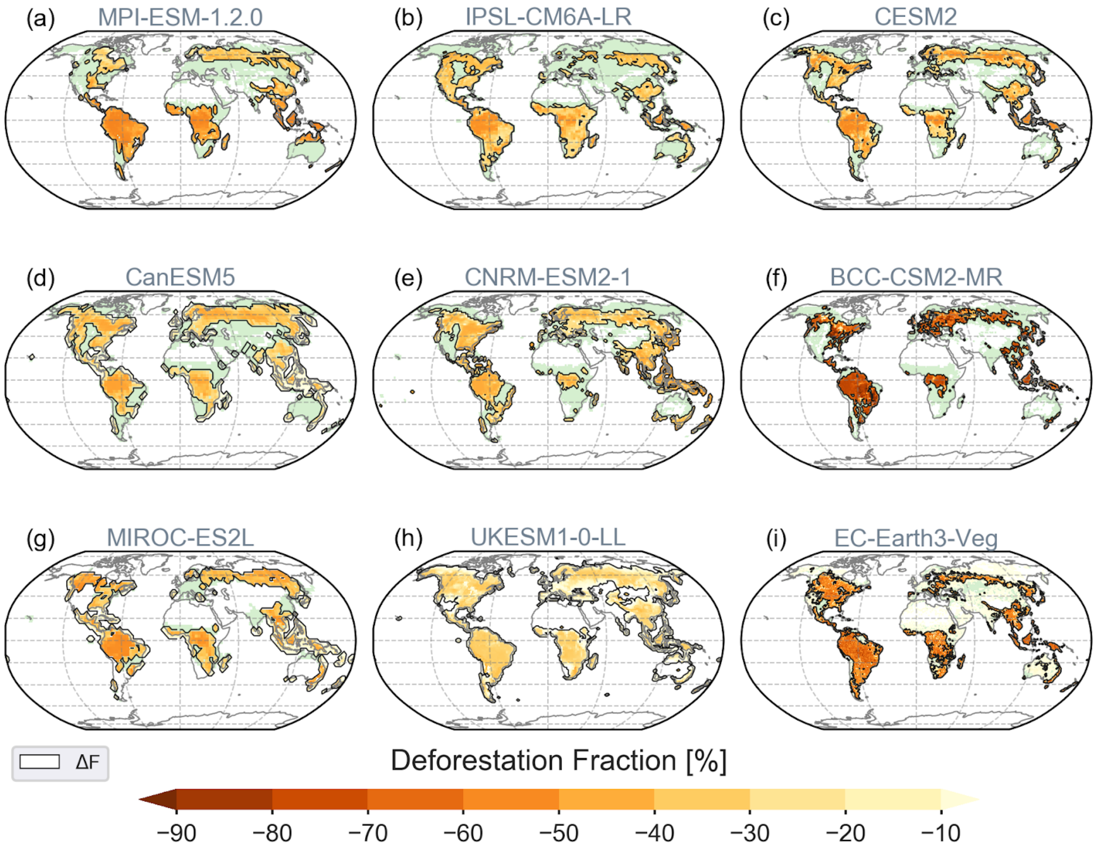
Deforested fraction

Predominantly **tropical deforestation;** second peak in **boreal region**





Initial forest area: 36 - 66 10^6 km^2

Model	**Initial forest cover [$\mathrm{Mkm^2}$]**
MPI	48.15
IPSL	56.25
CESM	46.98*
CNRM	66.39*
BCC	35.96*
CanESM	56.48
UKESM	45.53
EC-Earth	37.75
MIROC	40.86
Model mean	48.26

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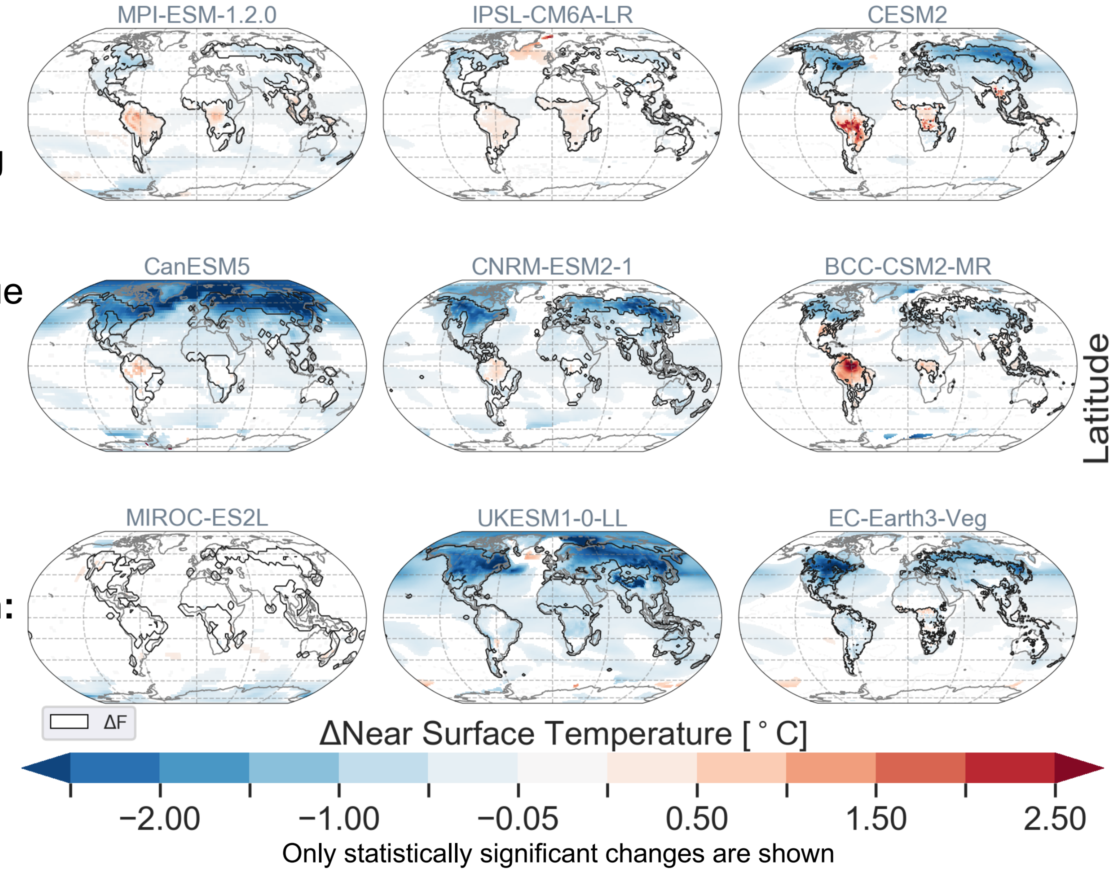
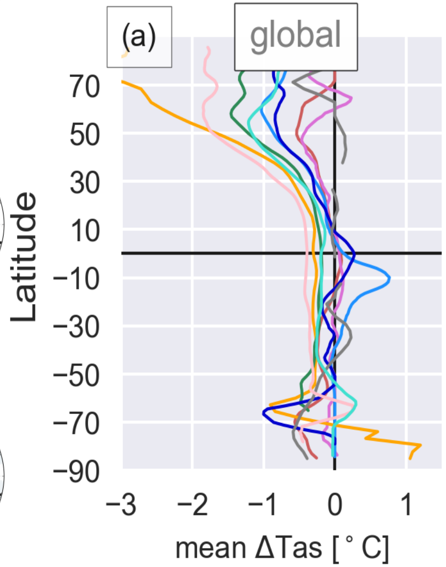
Temperature response to deforestation (last 30 years)

Generally, no surprises:
- Extratropical cooling due to albedo increase
- Tropical warming due to a reduction in evapo-transpiraion

Unexpected:
- cooling in UKESM and EC-Earth, also over land in tropics
- **multi-model mean: -0.22±0.21° C**





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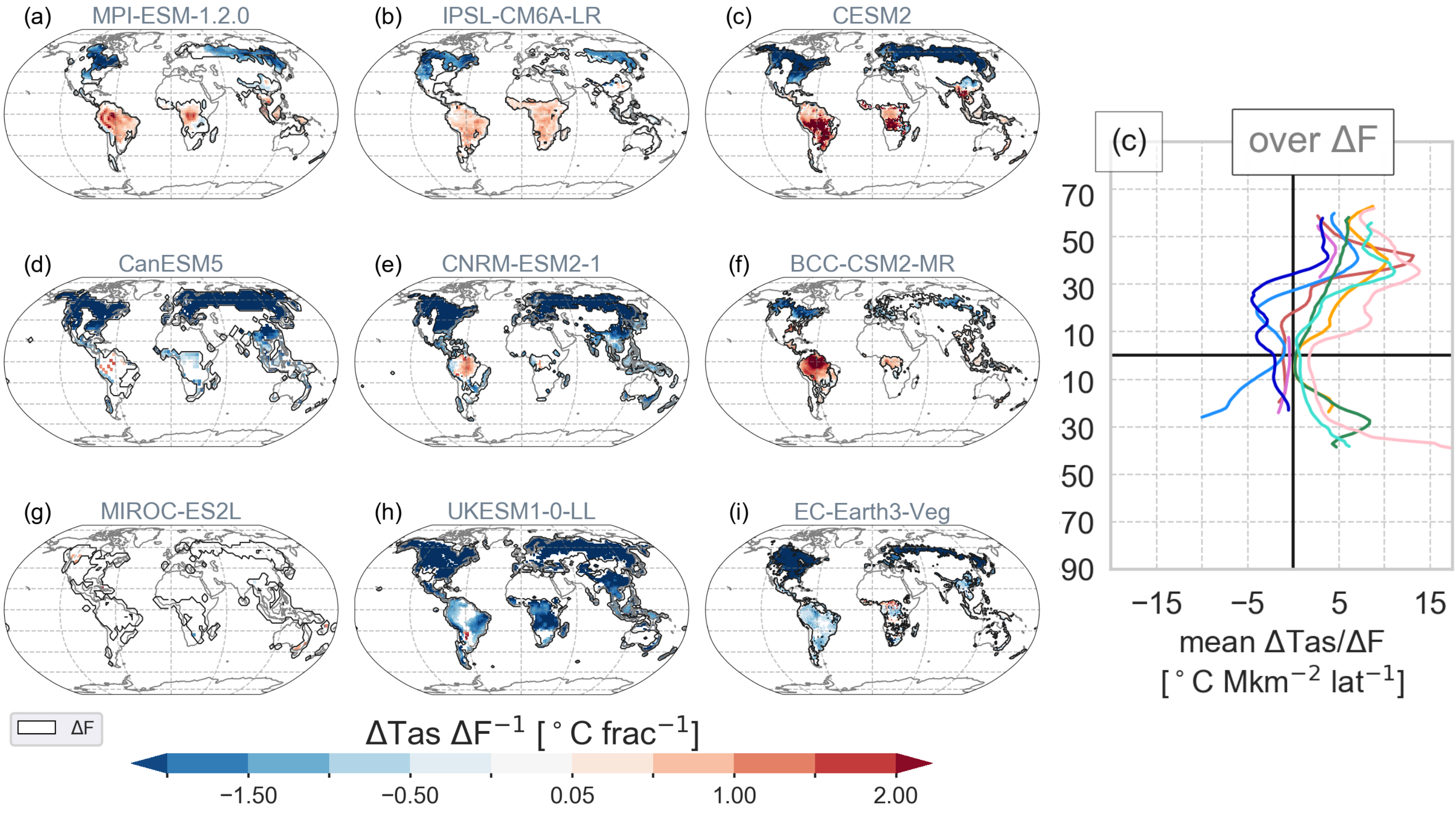
Temperature sensitivity to deforestation: ΔT/ΔF

Changes in Tas per unit of tree fraction (ΔT/ΔF): if universal, could be used for any landuse change scenario

A complication: Mixed local and non-local effects



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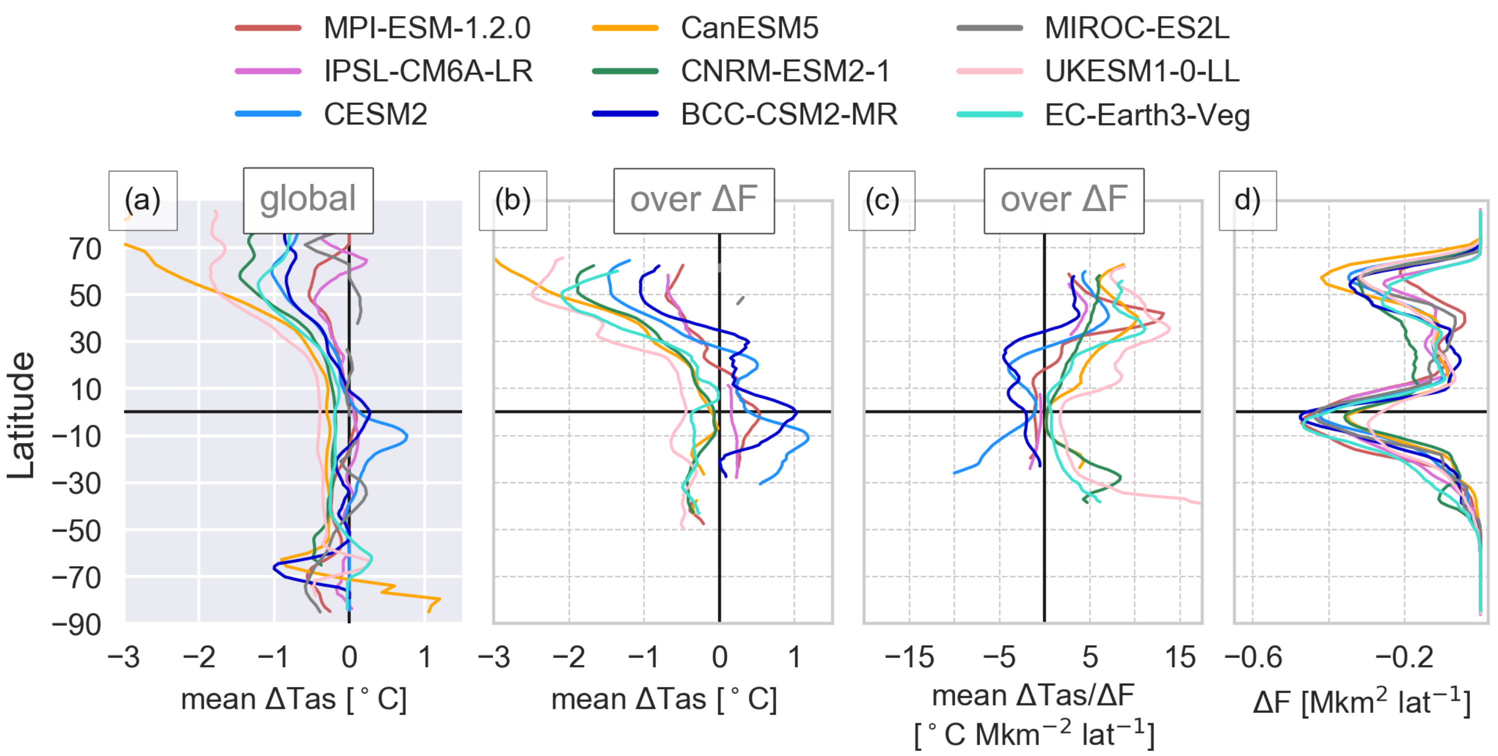
Zonal changes in temperature & zero latitude

Model	Zero lat
MPI	17.7°N
IPSL	11.4°N
CESM	26.9°N
BCC	34.2°N

multi-model mean:
23° N

Zero Latitude: Latitude of ΔT sign changes in Northern Hermisphere



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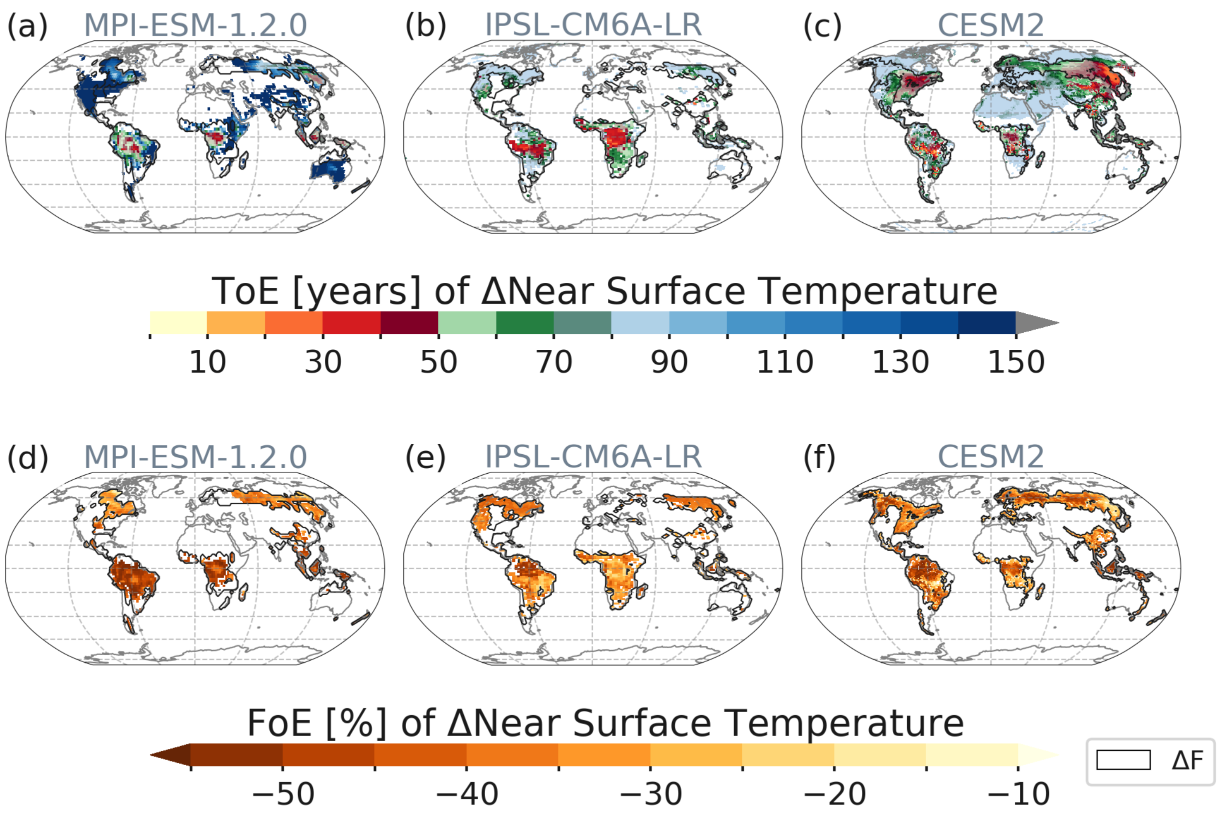
When do changes emerge (ensemble mode)?

Time/fraction of emergence:
When is the signal > noise?

(mean of trends) > (1 σ of trends)

- "Time of emergence": within 50 years over the strongly deforested tropical regions
- The signal propagates from the centre of deforestation to the edges
- The "fraction of emergence" is more similar among the models than the "time of emergence"



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Conclusions

- The **biogeophysical effect** on global annual near-surface temperature ranges from no significant change to a cooling by 0.55°C, with **multi-model mean of -0.22±0.21°C**

- The latitude of changing the sign from warming to cooling ranges from 11 to 34°N, with a multi-model mean of 23°N. **Above 23°N, reforestation would lead to biogephysical warming not accounted in simple models**

- For those models that provided several ensemble members (MPI, IPSL and CESM2), the near-surface **temperature changes emerge within 50 years** over the tropical regions of strongest deforestation

- The biogeochemical effect of multi-model mean of land carbon reduction by 274±113 PgC calculated offline would be a warming by 0.52±0.22°C, suggesting that **the net effect of deforestation is a warming**

- **Sensitivities such as $\Delta T/\Delta F$, $\Delta cLand/\Delta F$** in idealized runs could be compared with variable landuse scenarios in the CMIP6 runs, providing a basis for "realistic" CMIP6 simulations and **usage in climate-carbon emulators**

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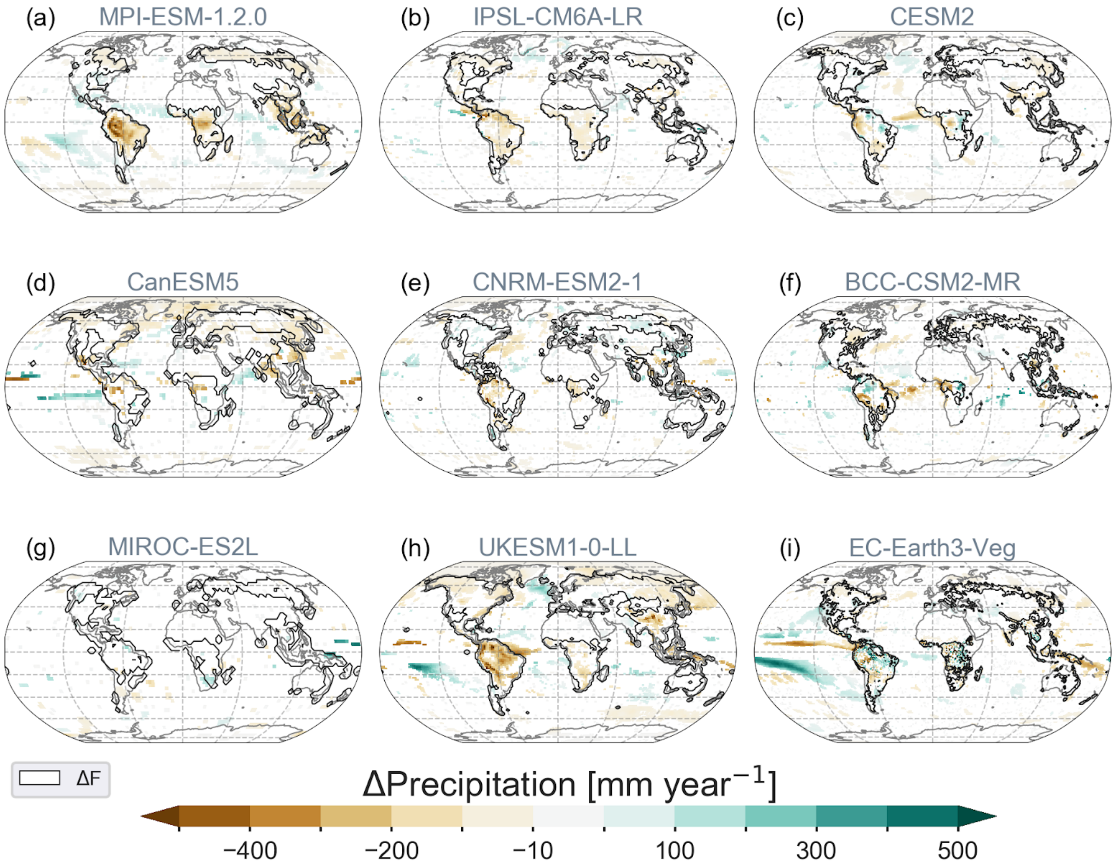
Precipitation response to deforestation

Reduction of hydrological cycle in tropics: transpiration of grasses < forests in tropics (exc. BCC and EC-Earth)



Only statistically significant changes are shown

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