

The Relevance of Soil Moisture for Land Carbon Sink Projections

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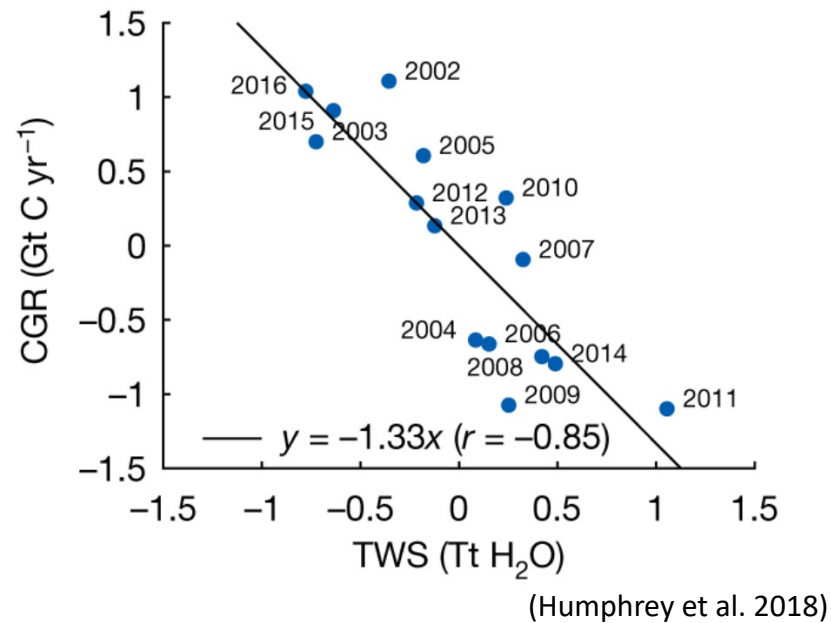


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Motivation

- Land C sink (NBP) projections are typically analyzed in terms of β (PgC/ppm) and γ (PgC/°C), while soil moisture is not explicitly considered (Arora et al. 2020).
- Observations show a sensitivity of global NBP to global terrestrial water storage (Humphrey et al. 2018).
- Large influence of soil moisture on future NBP based on 4 models from GLACE-CMIP5 (Green et al. 2019).

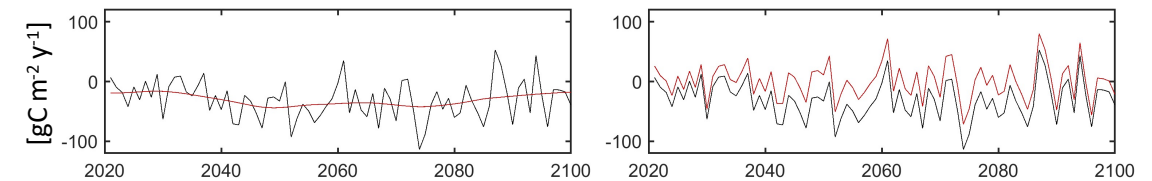


Objective

Analyze the relevance of soil moisture (SM) for CMIP6 land carbon sink (NBP) projections globally and locally.

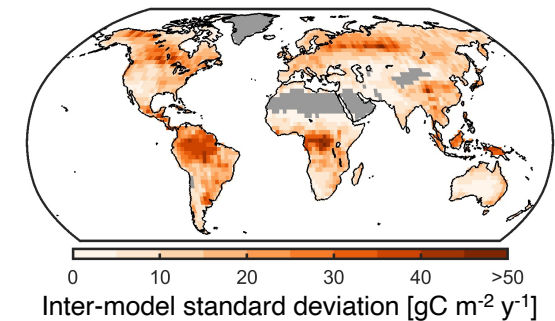
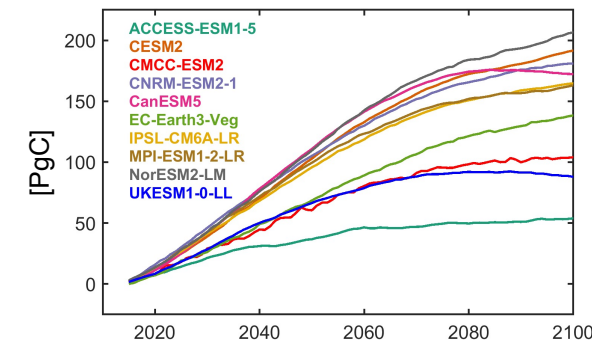
Part 1:

Detrended interannual variability of NBP (NBP_{iaV})

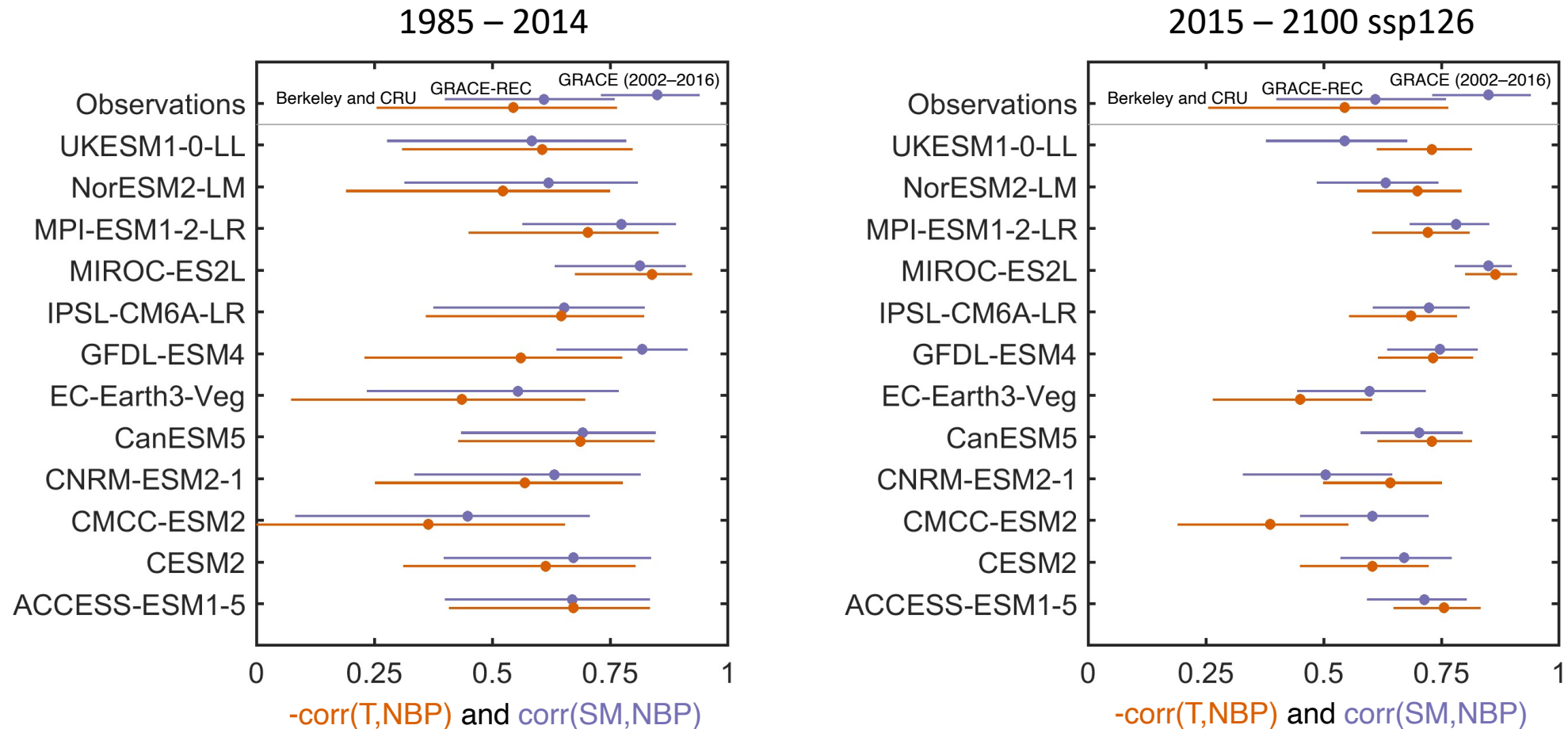


Part 2:

Cumulative projected NBP



Interannual correlation of global NBP with global temperature and soil moisture

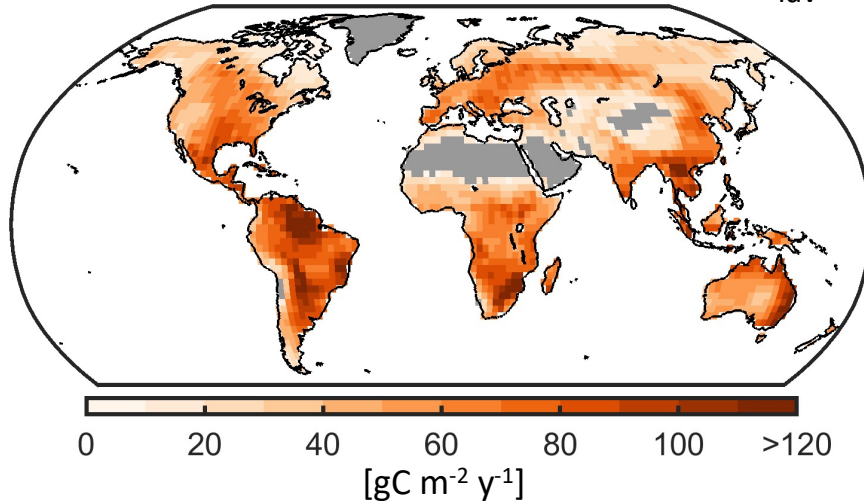


- All models show a sensitivity to global **T** and to global **SM**.
- Potential underestimation of the correlation with global **SM** relative to GRACE observations (2002 – 2016).
- Some indication of inter-model differences in the sensitivities of NBP to **T** and **SM** for the projections.

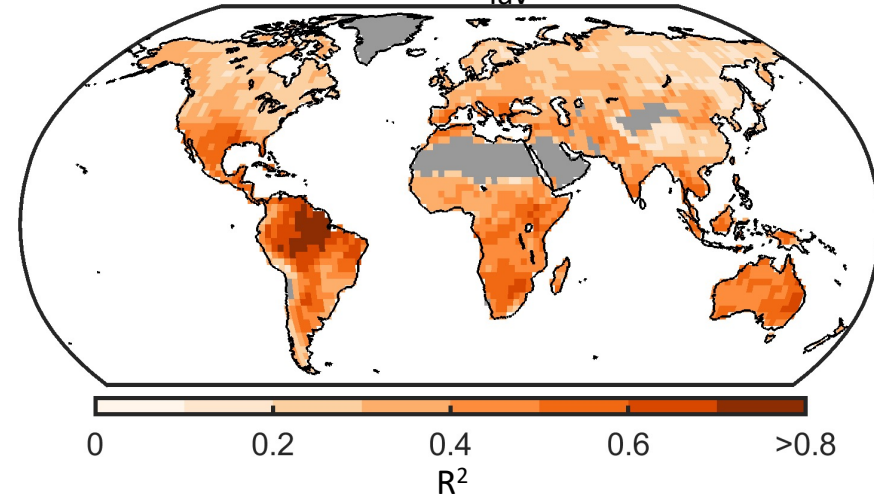
T and SM control the detrended interannual variability of NBP

Stepwise linear regression (SLR) at every grid cell for each model $\rightarrow \text{NBP}_{\text{ia}} = a + b_i \cdot X_i$, where X_i is warm season T and SM.

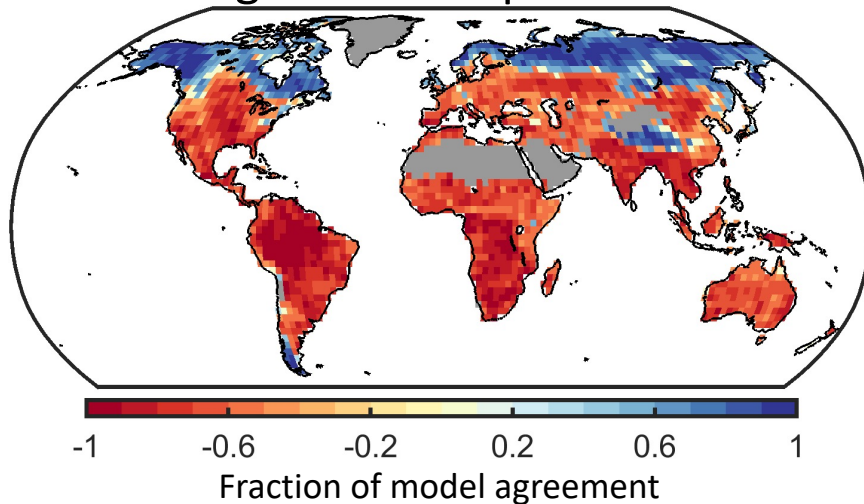
MMM standard deviation of NBP_{ia}



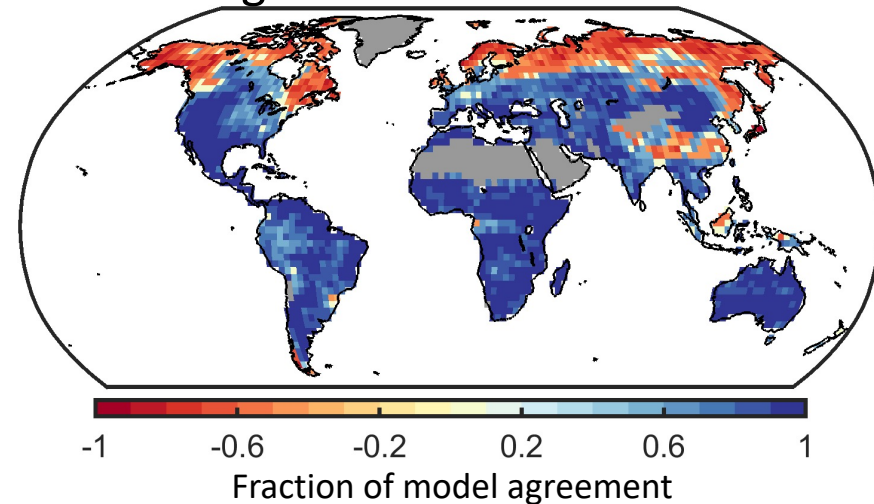
MMM R^2 between NBP_{ia} and SLR estimate



Sign of b: Temperature

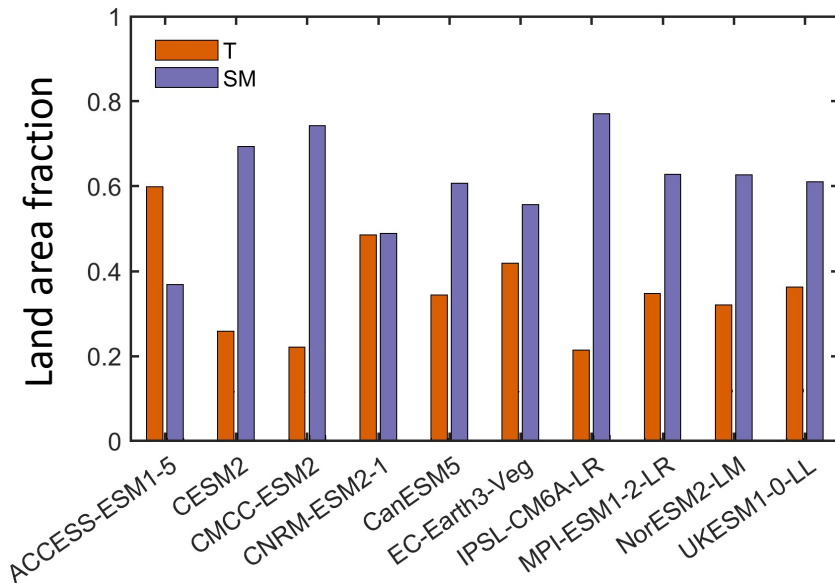
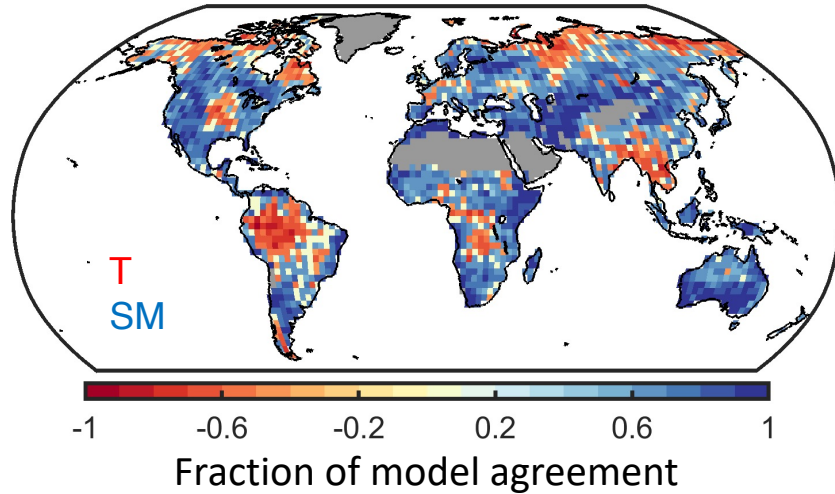


Sign of b: Soil moisture

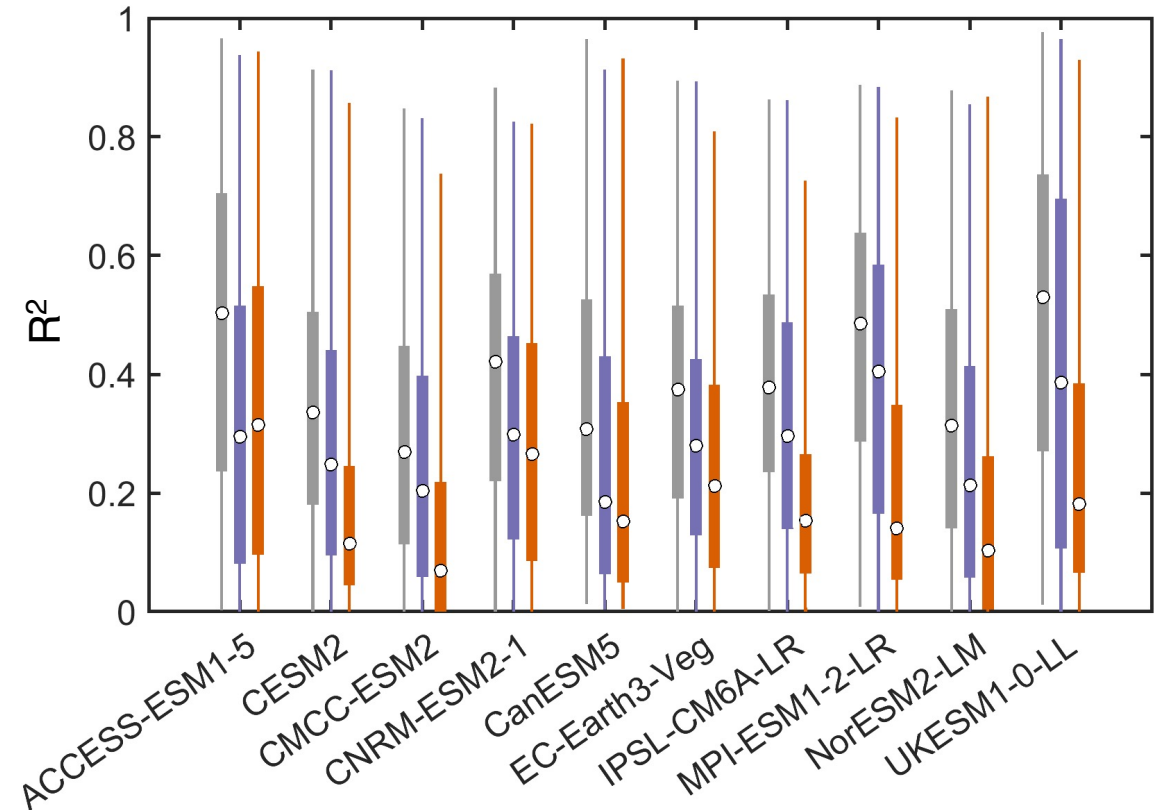


SM is the main control of NBP_{iaV} for most models and regions

1st control added to stepwise linear regression

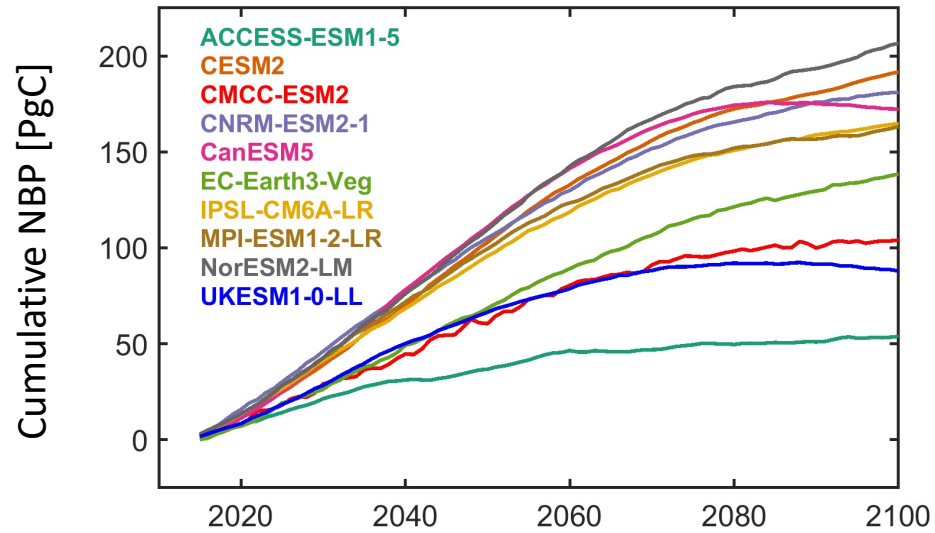


R^2 between NBP and regression estimate

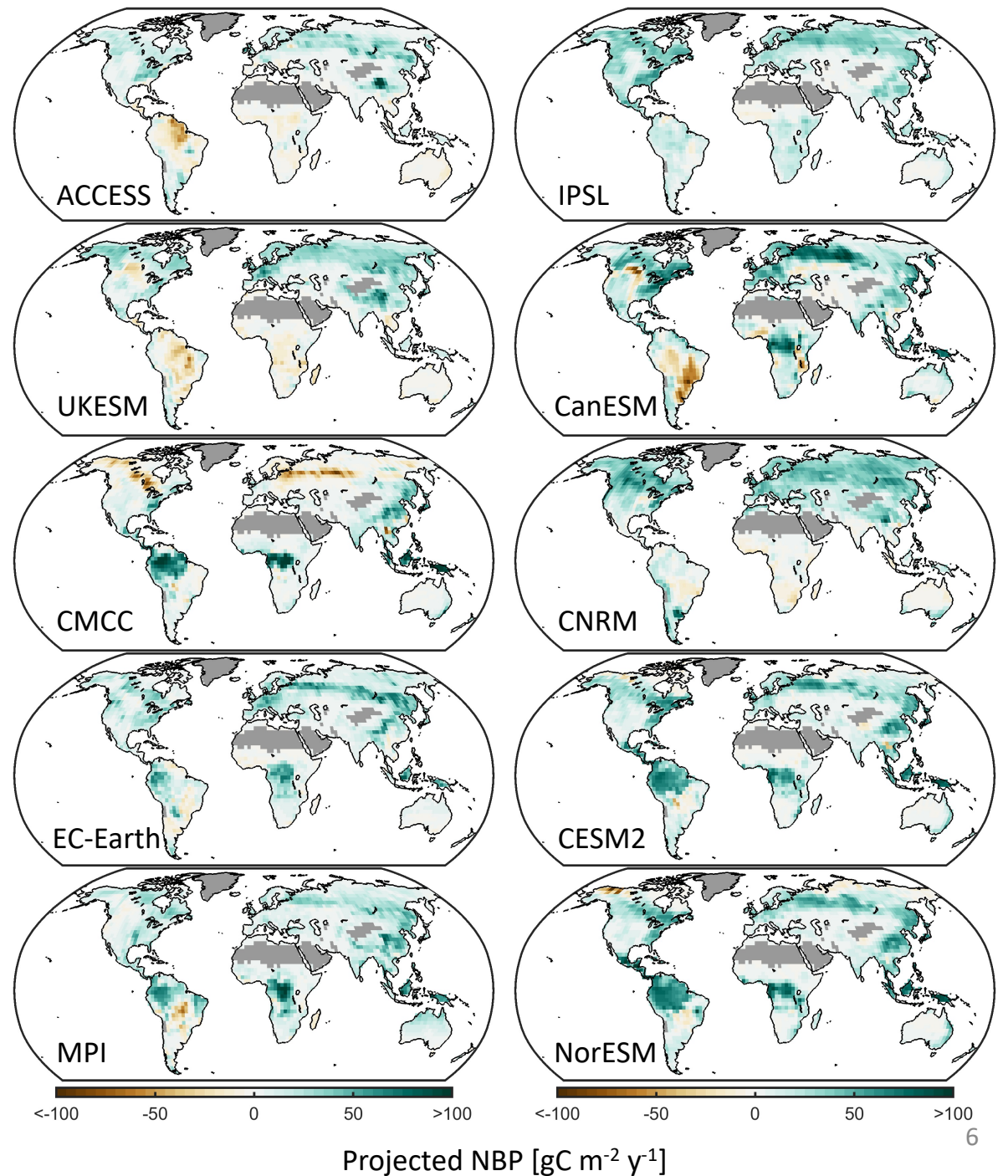
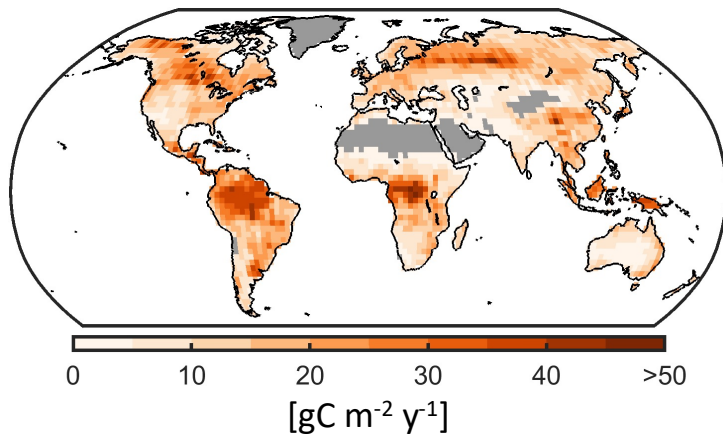


Results for ssp126 in the period 2021-2050 and top 1m SM. Results are consistent across scenarios and time periods. For top 30cm SM the dominance of SM is clearer in many models, except for MPI-ESM1-2-LR where it is lower.

Cumulative projected NBP under ssp126



Inter-model standard deviation of NBP



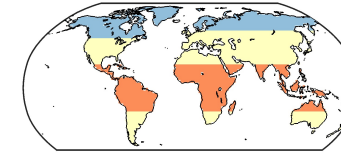
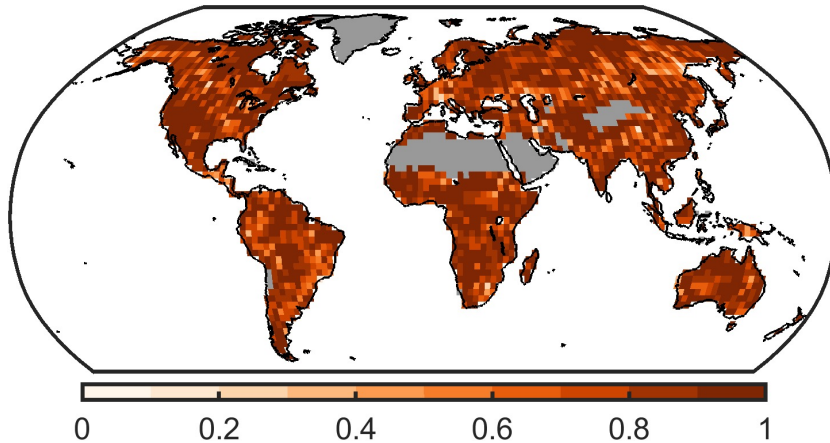
Explaining inter-model differences in NBP projections

Multiple linear regression at every grid cell $\rightarrow \text{NBP}_{\text{mdl}} = a + b_i * X_i$

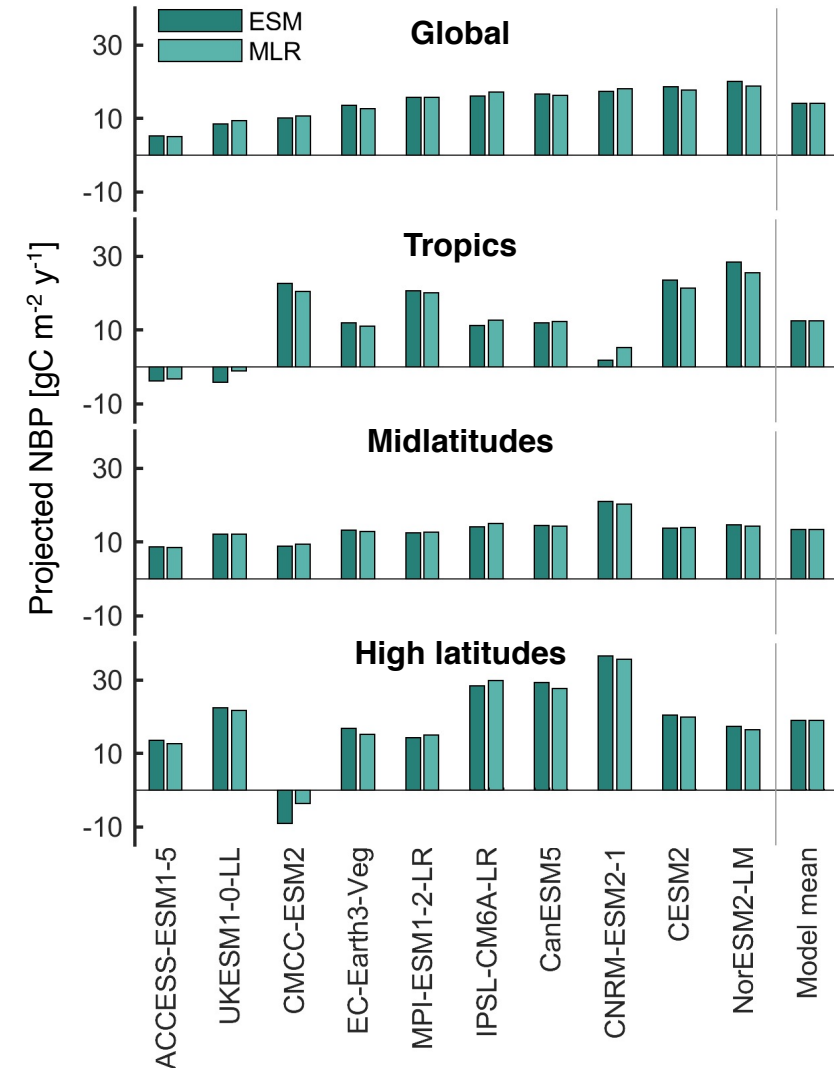
Proposed controls X_i :

- Sensitivity to CO_2 ($s\text{CO}_2$): $\text{cov}(\text{NPP}_{\text{rm}}, \text{CO}_2)$ from bgc run
- Long-term average T
- Sensitivity to T (sT): $\text{cov}(T_{\text{iav}}, \text{NBP}_{\text{iav}})$
- Long-term average SM
- Sensitivity to SM ($s\text{SM}$): $\text{cov}(\text{SM}_{\text{iav}}, \text{NBP}_{\text{iav}})$

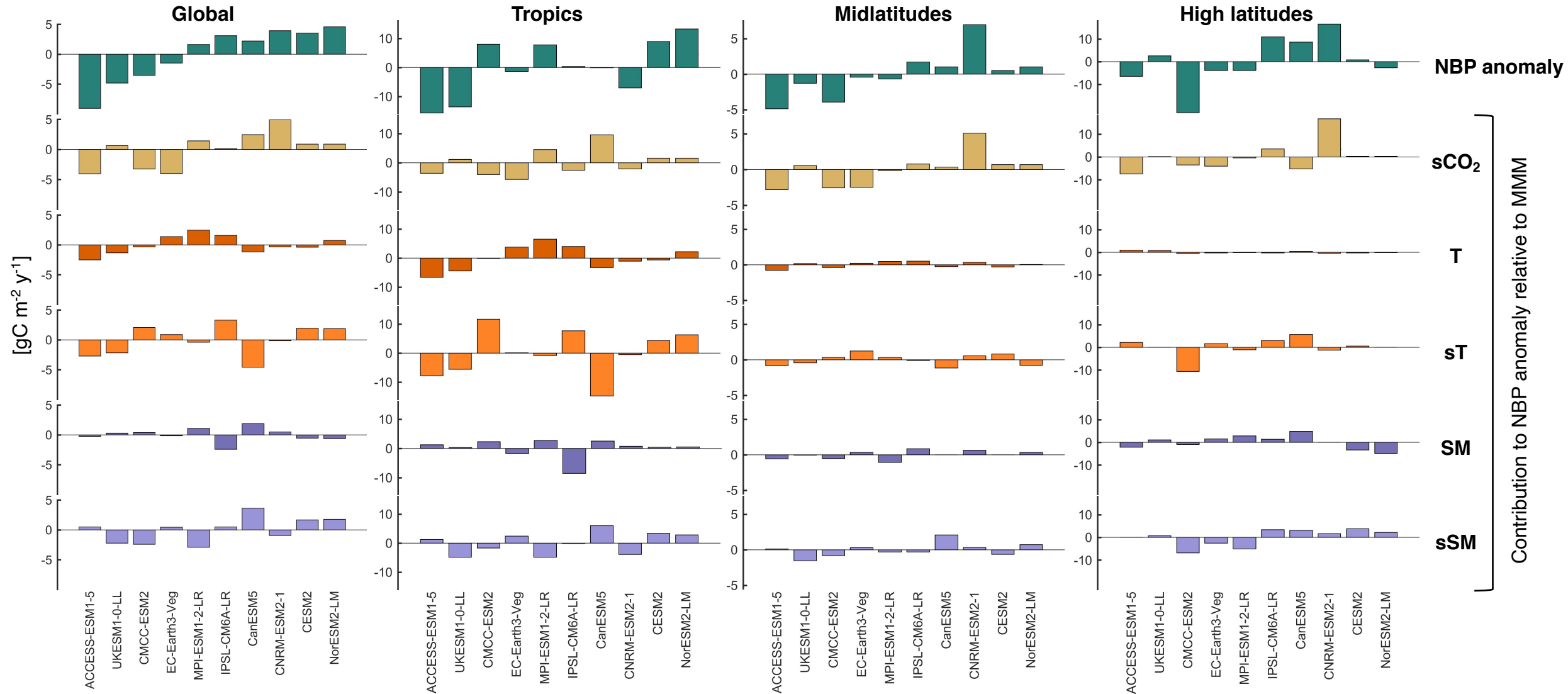
R^2 between NBP_{mdl} and regression estimate



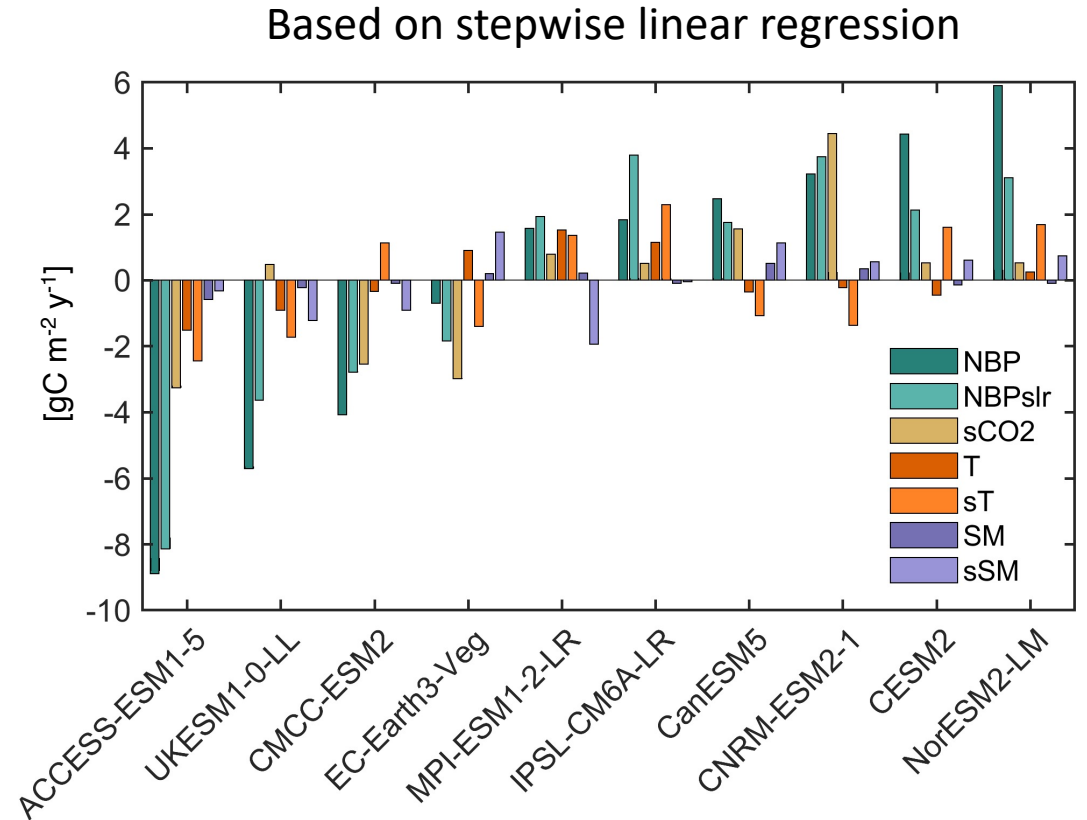
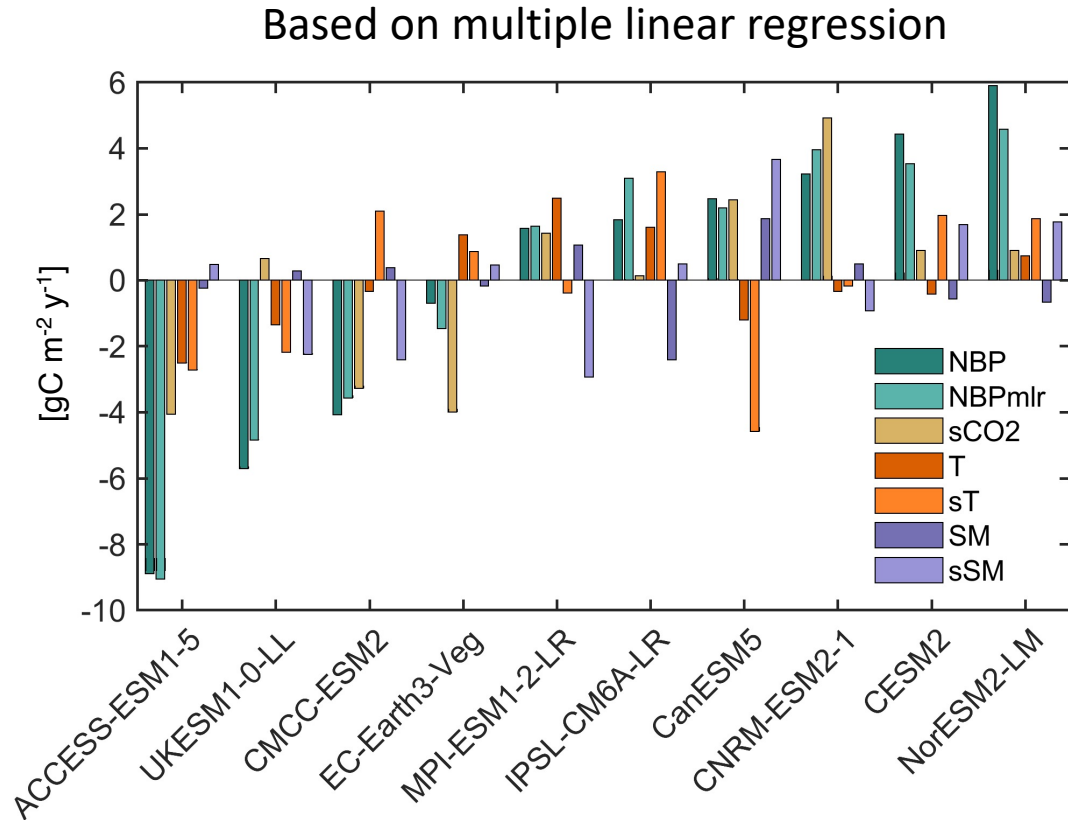
Tropics: 36%
Midlatitudes: 44%
High latitudes: 20%



Contributions to inter-model differences in NBP projections



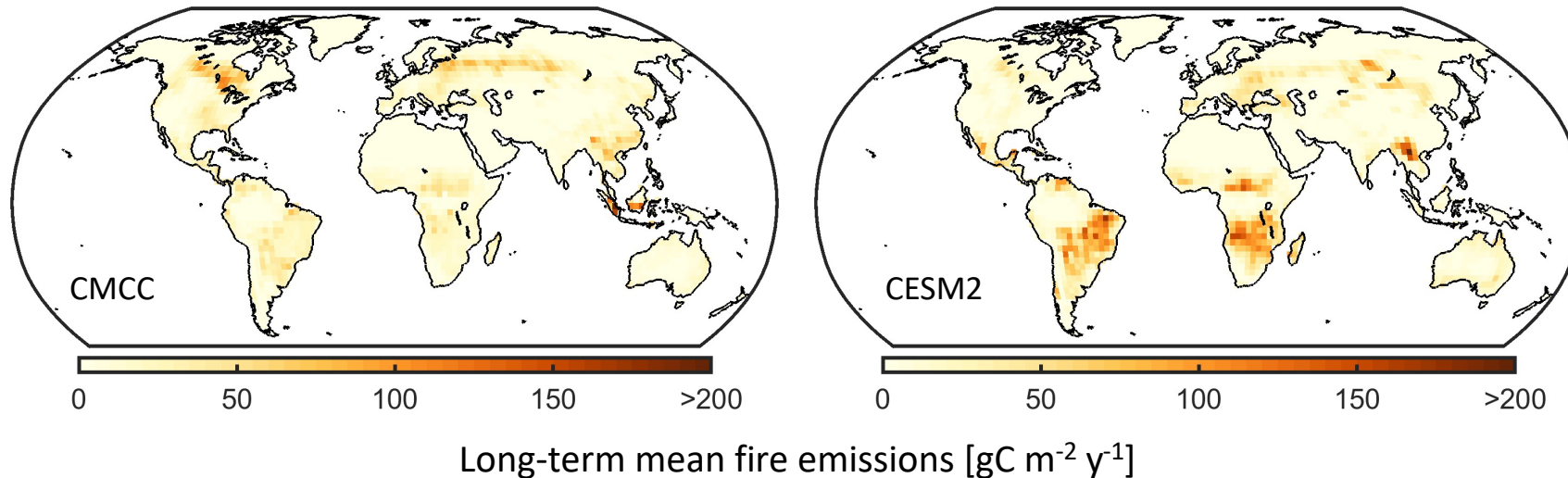
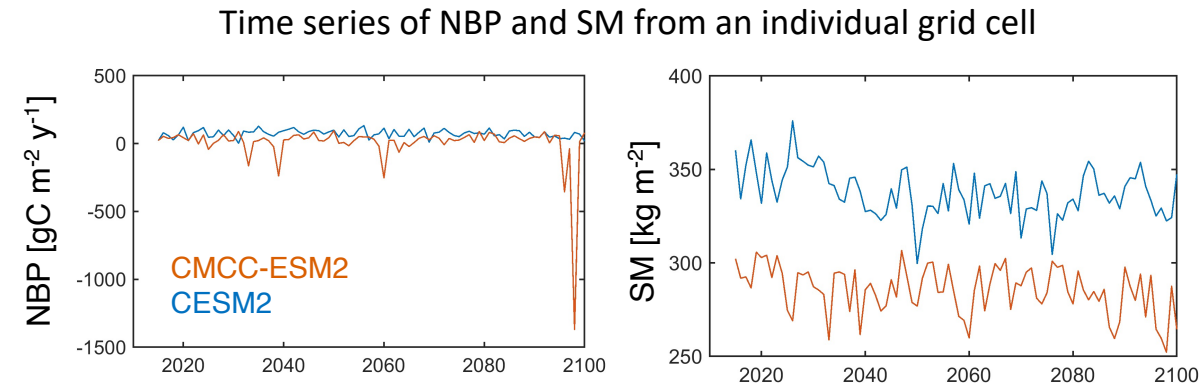
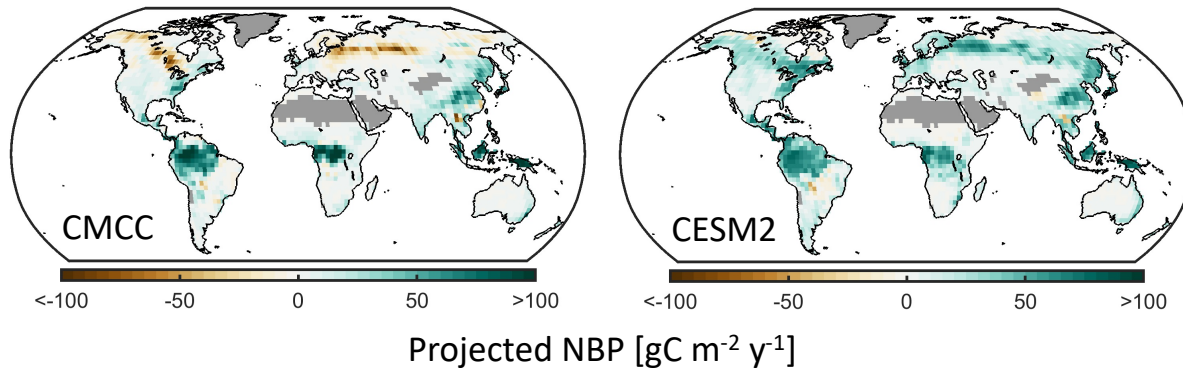
Contributions to inter-model differences in global NBP projections: A model-focused view



Consistent results between multiplied and stepwise linear regression.

Contribution of fire emissions to inter-model differences in NBP projections

CMCC-ESM2: Low NBP in boreal forests resulting from fires associated with low SM and high T.



Conclusions

Part 1: Detrended interannual variability of NBP (NBP_{iaV}):

Potential model underestimation of the correlation between global NBP_{iaV} and SM_{iaV} .

Global SM_{iaV} and T_{iaV} explain much of NBP_{iaV} in all models and are of similar importance.

Local SM_{iaV} and T_{iaV} explain much of local NBP_{iaV} in all models.

Local SM_{iaV} is more important than local T_{iaV} in the majority of models and regions with notable exceptions in the tropics.

Future work should evaluate the local sensitivity of NBP_{iaV} to SM_{iaV} and T_{iaV} with observations.

Part 2: Cumulative projected NBP:

CMIP6 models show large inter-model differences in the projections of the land C sink.

Models with similar global land NBP can have very different and compensating regional NBP.

Detailed regional contributions of differences in $s\text{CO}_2$, T , sT , SM and $s\text{SM}$ to explain inter-model differences in NBP are estimated.

Important contribution of differences in $s\text{SM}$ and SM , e.g. related to fires in boreal forests.

