Land surface parameter sensitivity of tropical forest hydrological cycle in a perturbed parameter ensemble

Kate Halladay and Peter Good (Met Office Hadley Centre)

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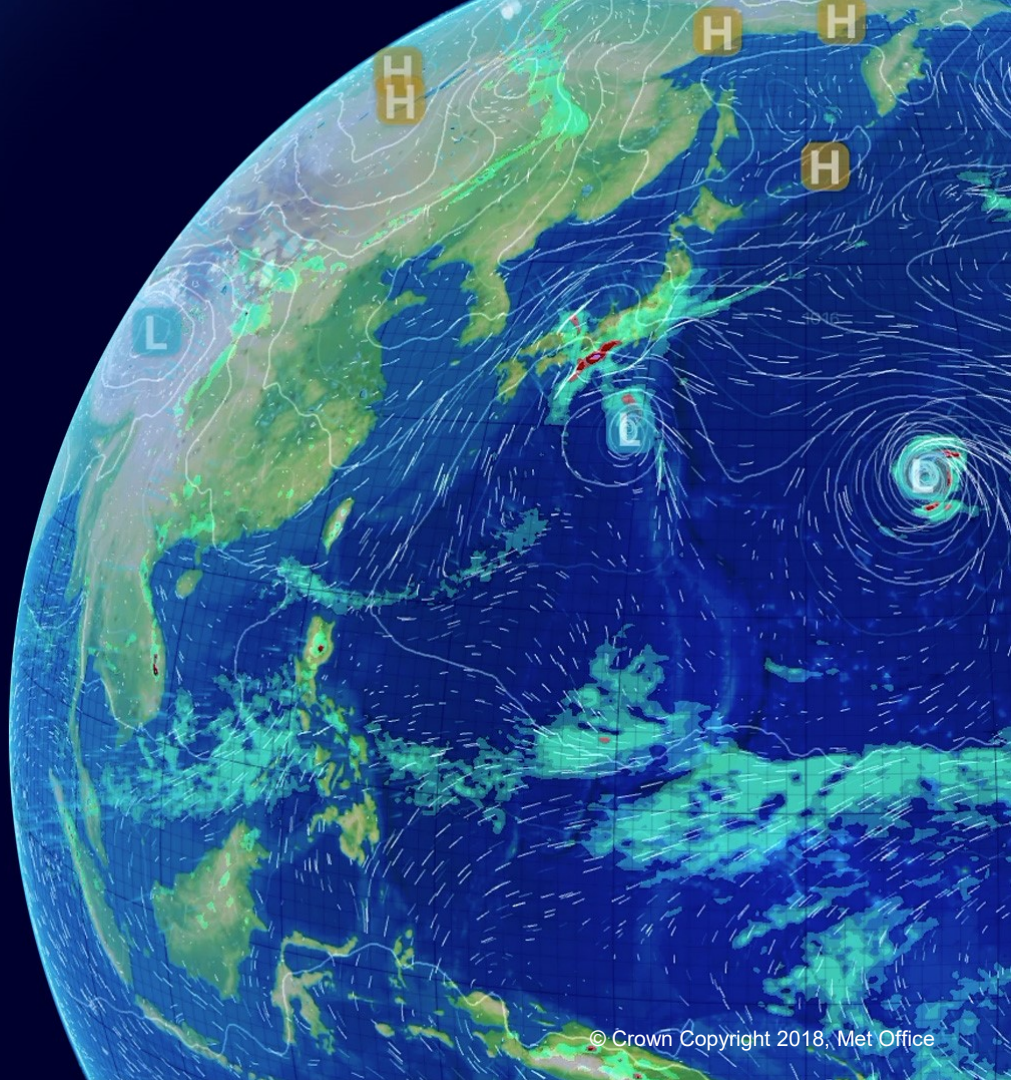
kate.halladay@metoffice.gov.uk



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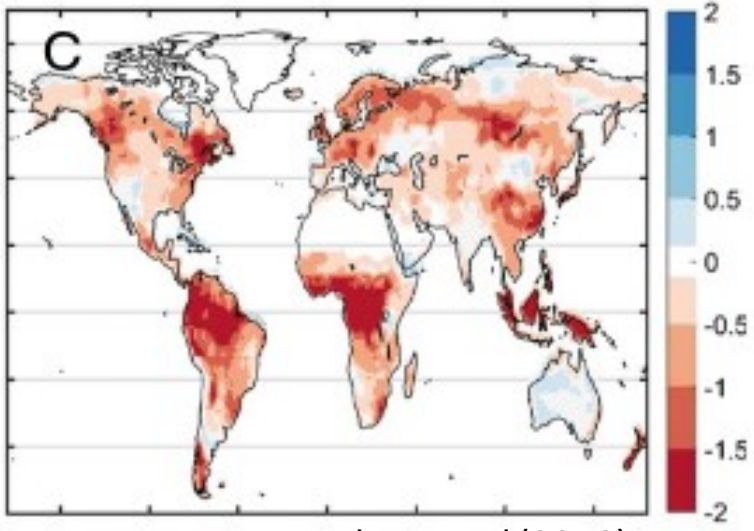
Background...

One of the responses of vegetation to increased CO_2 :
→ **stomatal closure → reduced transpiration**

This is known as **"physiological forcing"**

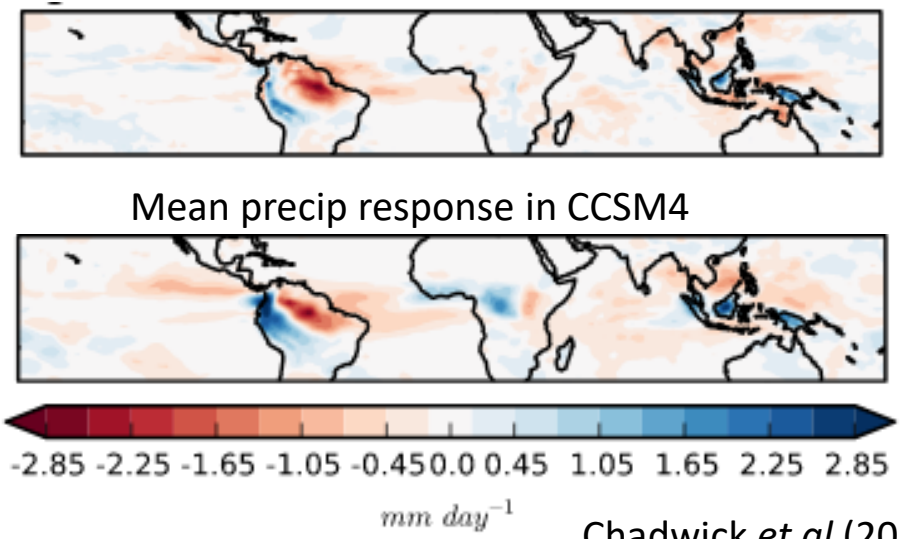
ET response to 4xCO_2 in CMIP5 models



Lemordant *et al* (2018)

Mean precip response in HadGEM2-ES

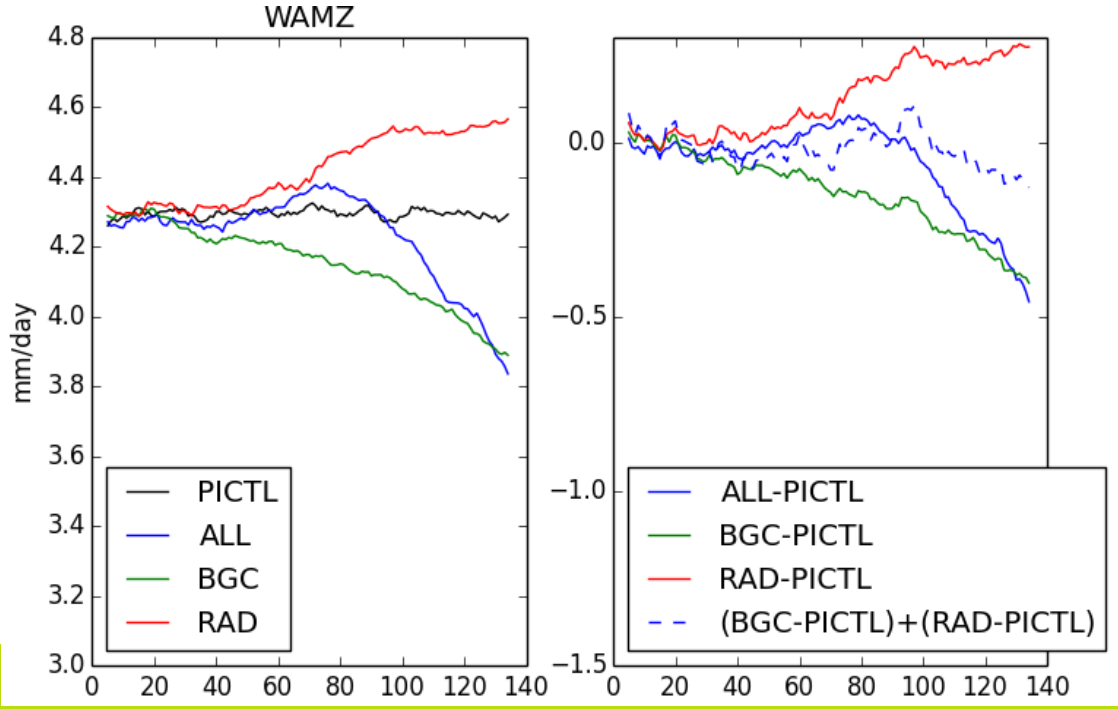
Mean precip response in CCSM4

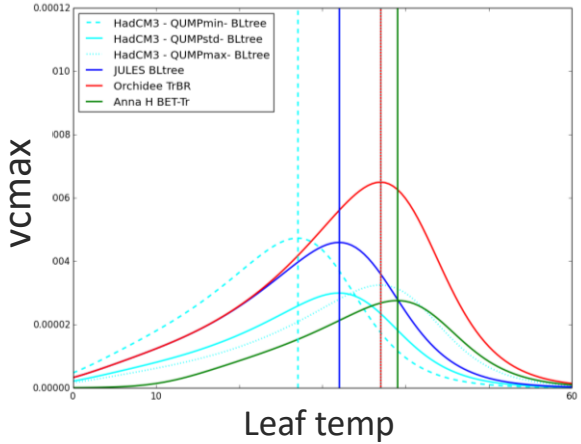


Chadwick *et al* (2017)

ET in western Amazonia from HadGEM2-ES 1% runs (CMIP5)

'ALL' (*1pcCO$_2$*) : all model schemes exposed to the CO_2 rise
'BGC' (*esmFixClim1*) : **physiological** forcing i.e. only vegetation scheme exposed to CO_2 rise
'RAD' *(esmFdbk1)* : **radiative** forcing i.e. only radiation scheme exposed to CO_2 rise





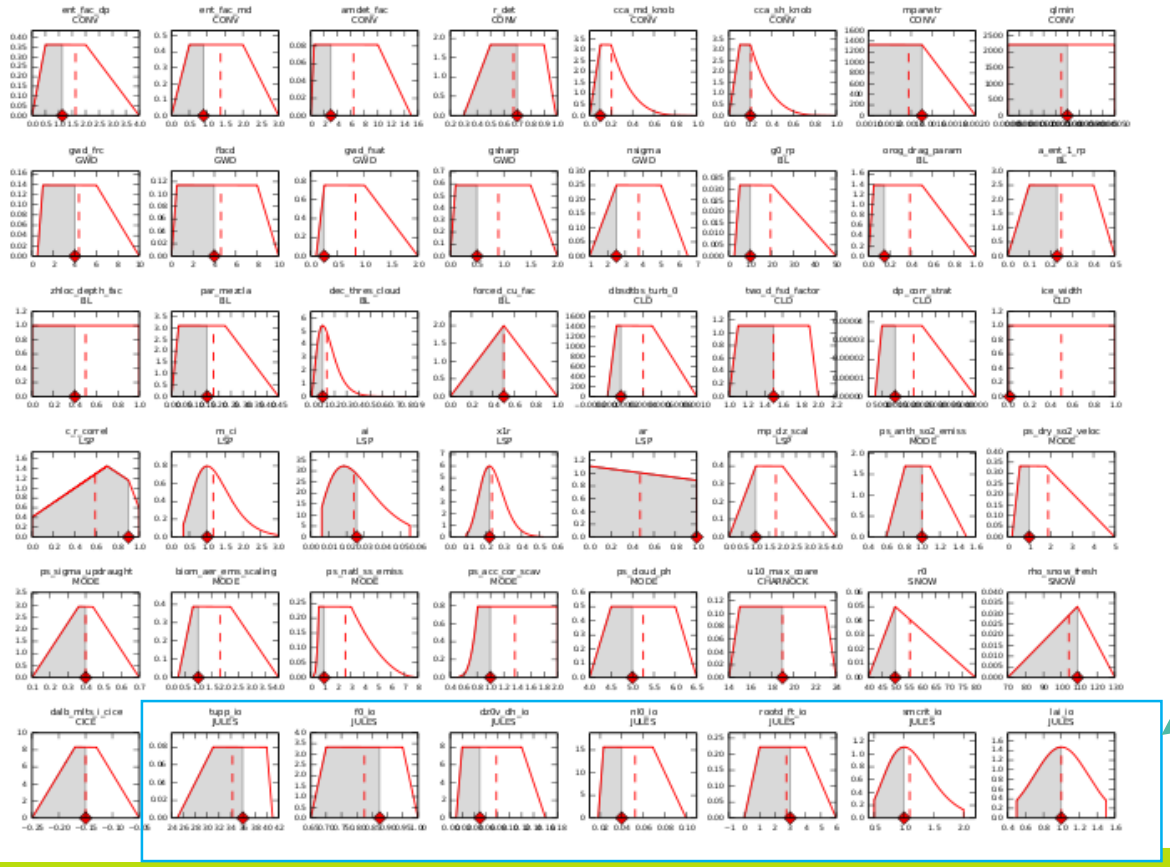
Halladay, K. & Good, P. Clim Dyn (2017)

HadGEM3 perturbed parameter ensemble (PPE)…

Upper value about 4K above Topt the optimal Temperature for photosynthesis (tupp_io)	Topt determines the turn-over point for temperature, above which further increases in temperature will drive a decline in photosynthesis.	In tropical and sub-tropical regions the optimal temperature would be expected to have the biggest impact on plant functioning, with low values for this parameter leading to greater temperature dependence of photosynthesis.
Maximum ratio of internal to external CO2 (f0_io)	Controls the gradient of CO2 between plant stomata and the ambient air.	
Top leaf Nitrogen concentration in kg N kg C (nl0_io)	Defines the top leaf ratio of nitrogen to carbon. Plant photosynthesis (Vcmax) is defined in the model to be proportional to the Leaf Nitrogen. concentration	Higher ratios are associated with higher photosynthesis.
Root depth (rootd_ft_io)	Controls the depth (in model soil levels) that soil moisture is available.	Larger values equate to deeper depths in the soil, and subsequently greater resilience to short timescale droughts.
Scaling factor for Critical and Saturation levels for Soil Moisture towards Wilt level (psm)	This pair of parameters control the critical and saturated volumetric soil moisture thresholds. The critical threshold controls the level above which evapo-transpiration is no longer soil moisture dependent.	Higher values lead to larger soil moisture regimes where soil moisture limits this evapo-transpiration, with its consequent implications for moisture and surface energy fluxes.

Sexton et al (in prep.)

HadGEM3 perturbed parameter ensemble (PPE)…



- 52 parameters varied across 2915 experiments
- All parameters varied simultaneously

Land surface parameters

Sexton et al (in prep.)

Isolating the response to each parameter

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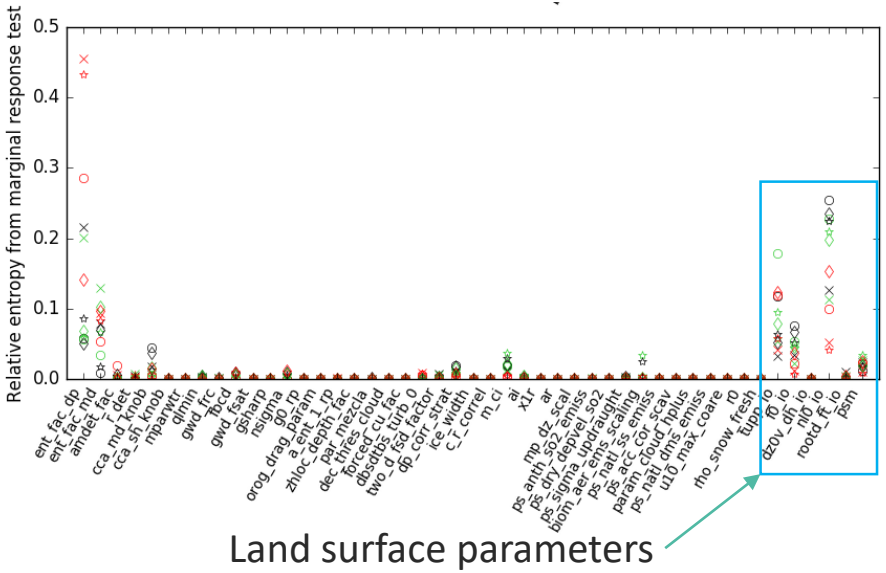
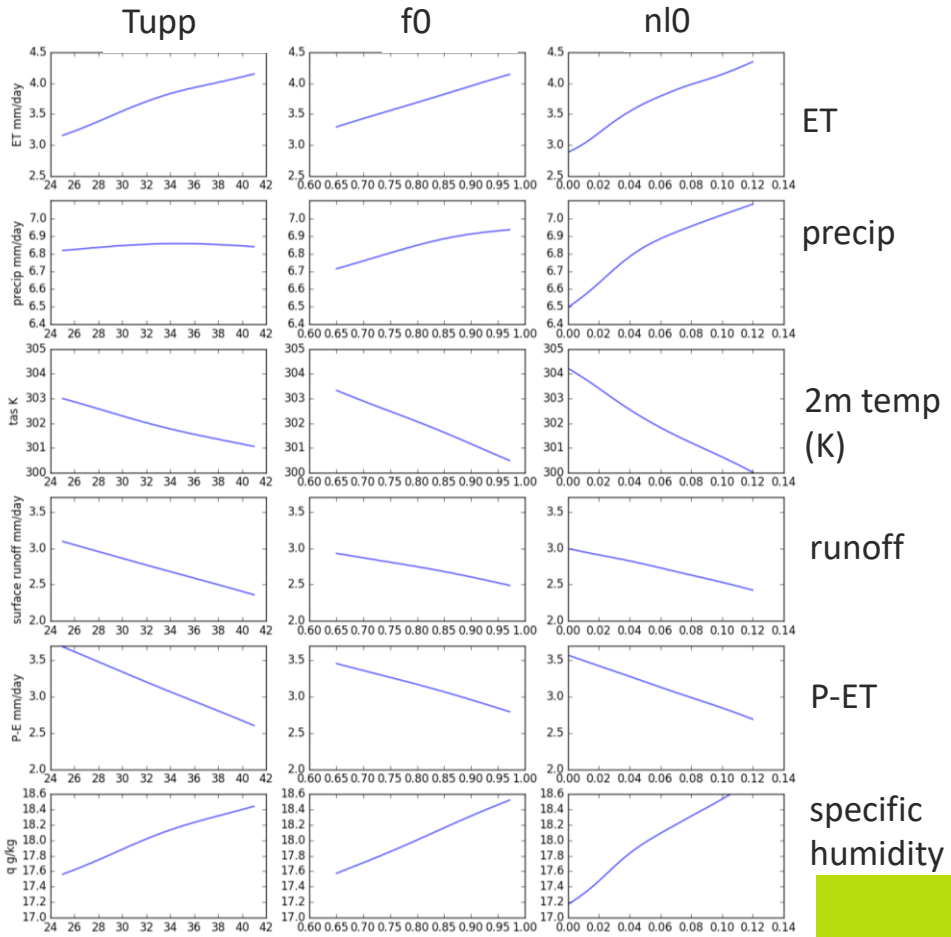
Marginal response of ET to each parameter

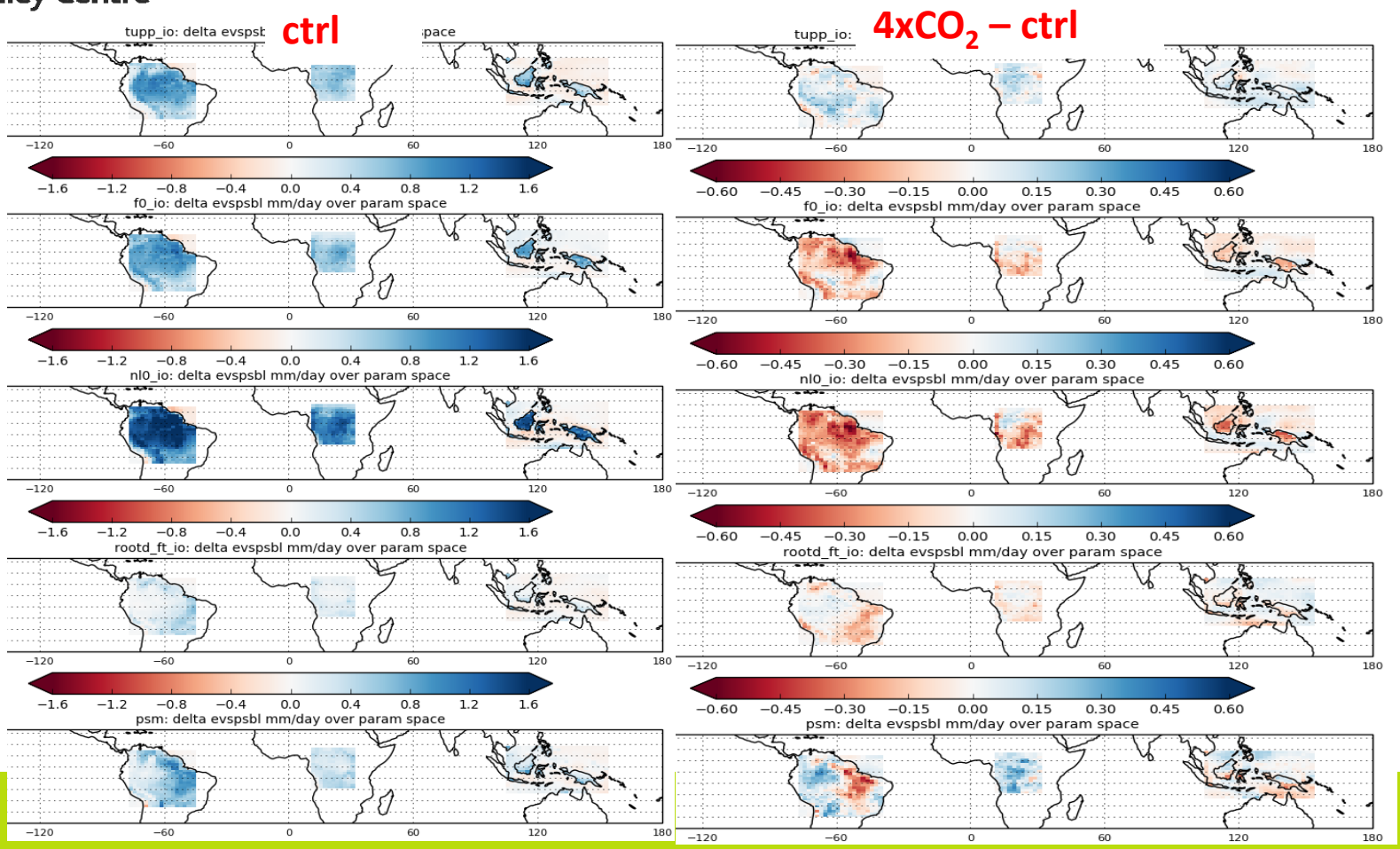


Land surface parameters

W Amazonia



Spatial variability in **ET** parameter sensitivity – ctrl and 4xCO_2



Spatial variability in **precip** parameter sensitivitv – ctrl and 4xCO_2

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ctrl

4xCO_2 – ctrl

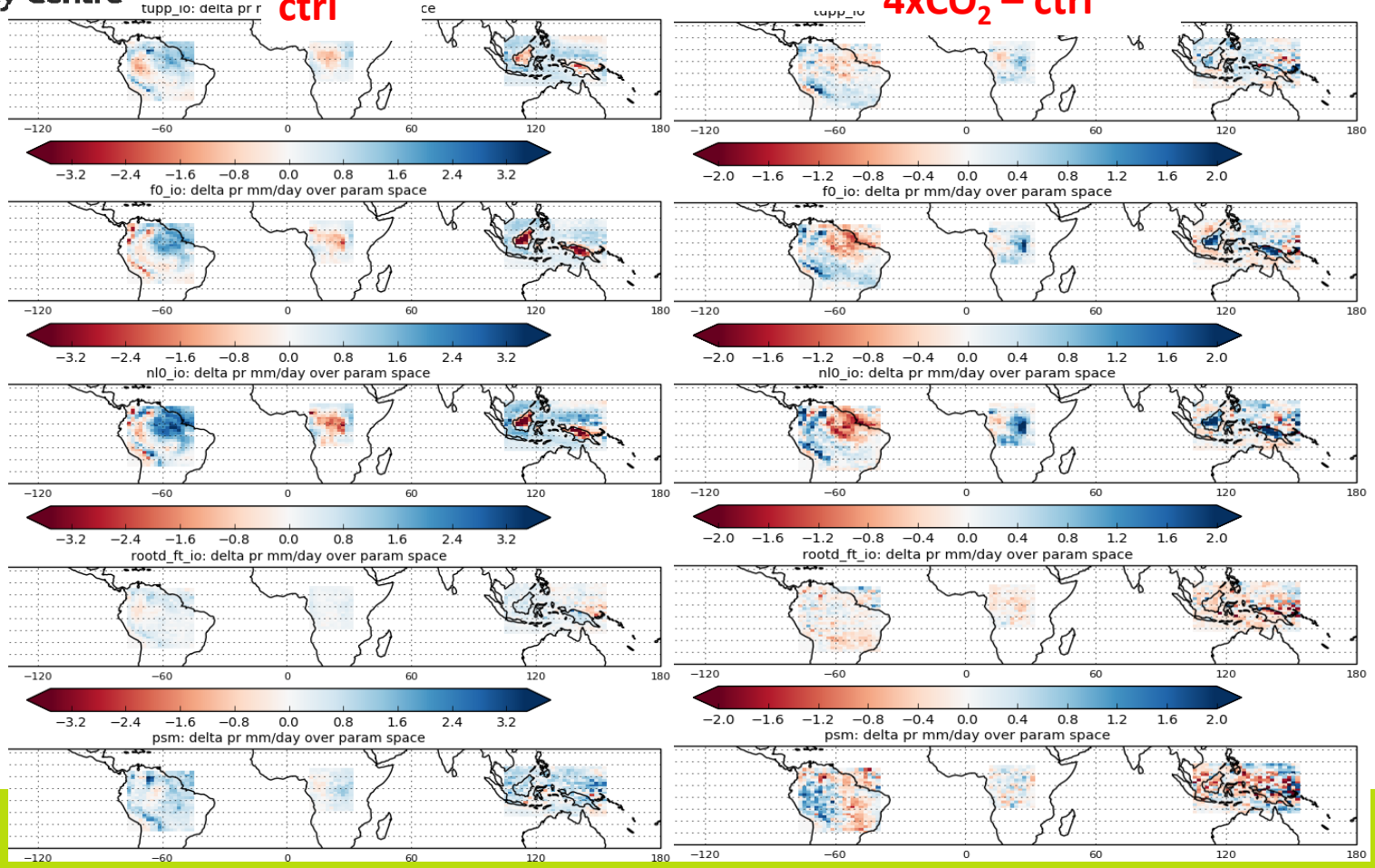
Tupp

f0

nl0

rootd_ft

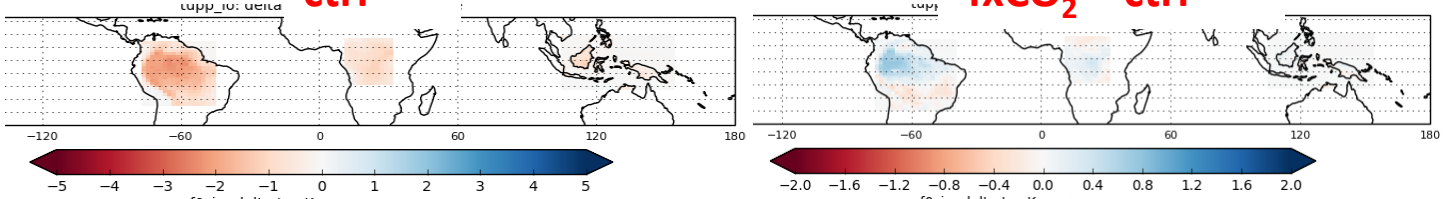
psm



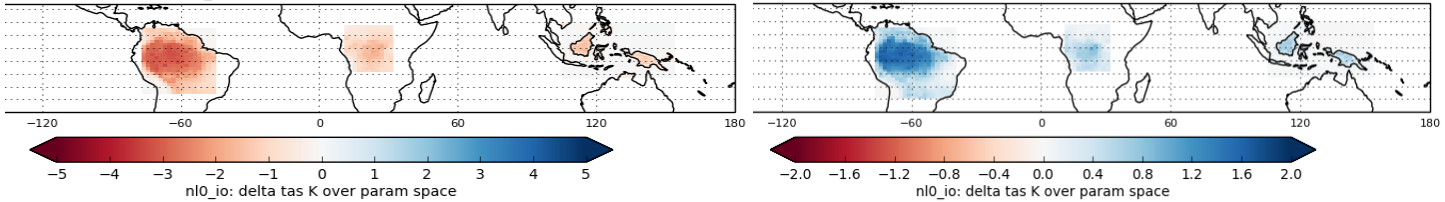
Spatial variability in **2m temp** parameter sensitivtv – ctrl and 4xCO_2

ctrl | **4xCO_2 – ctrl**

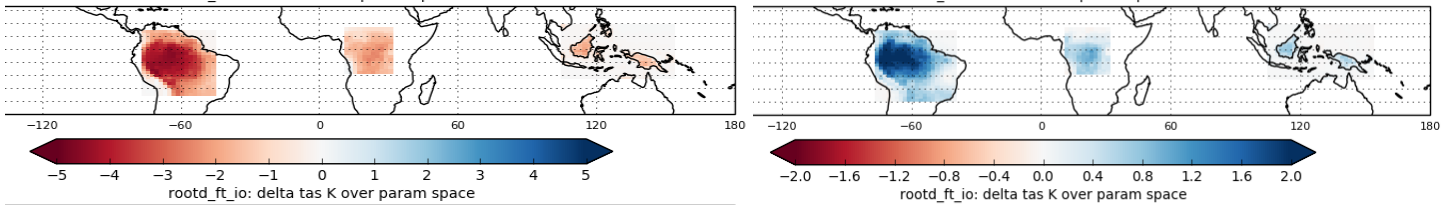
Tupp



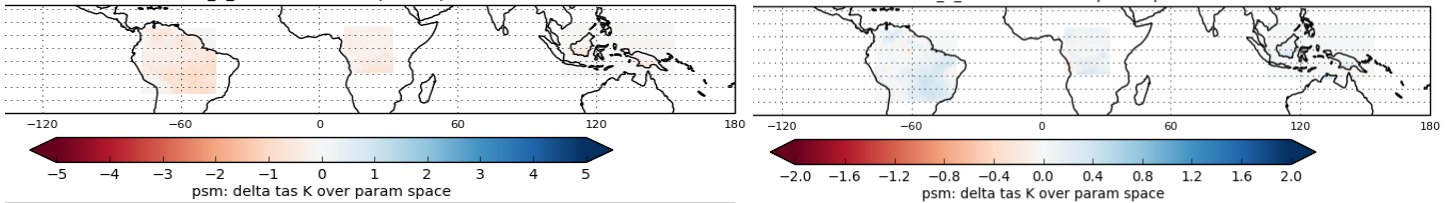
f0



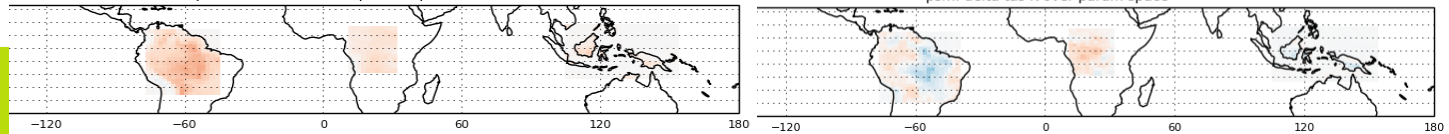
nl0



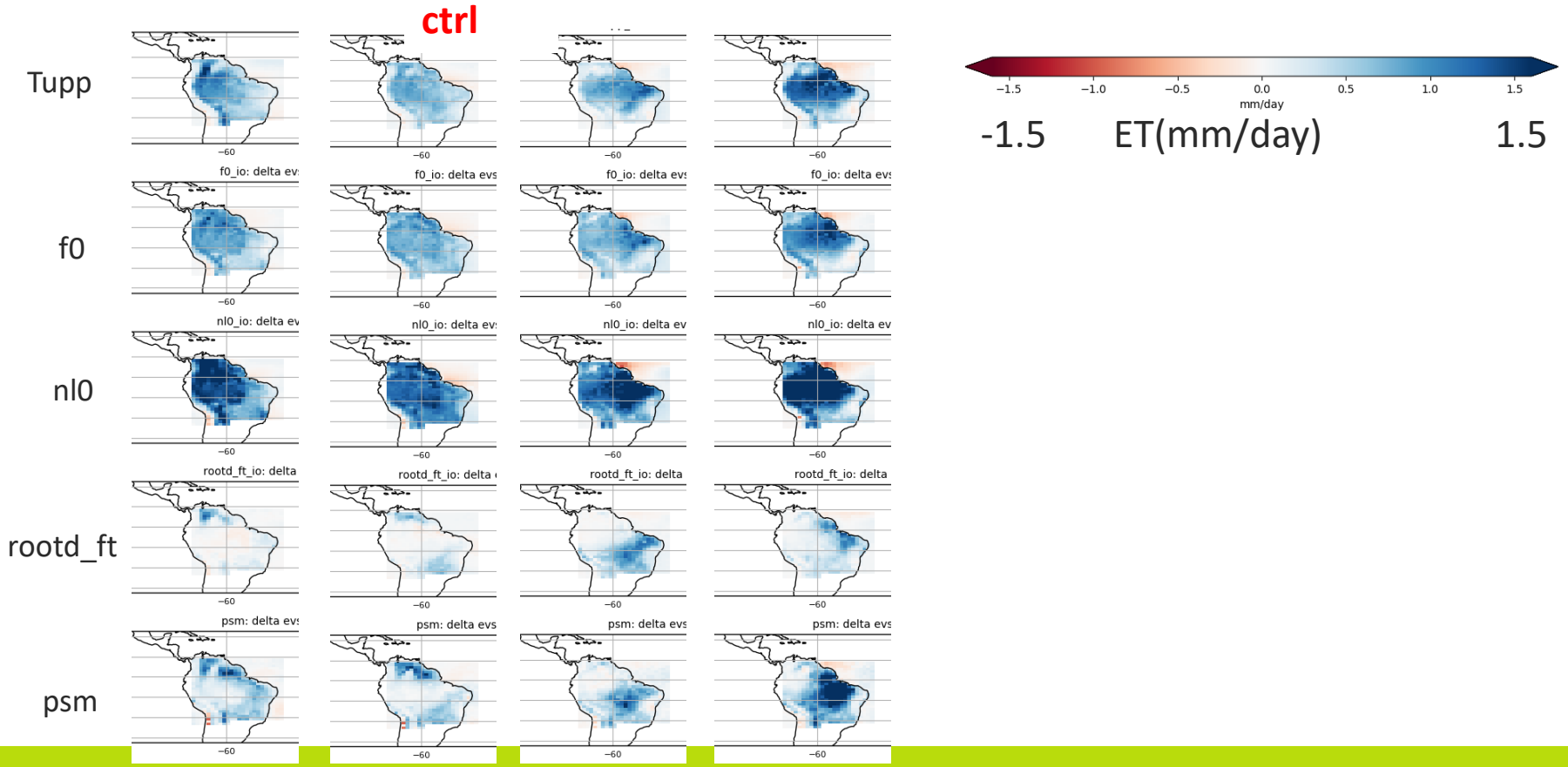
rootd_ft



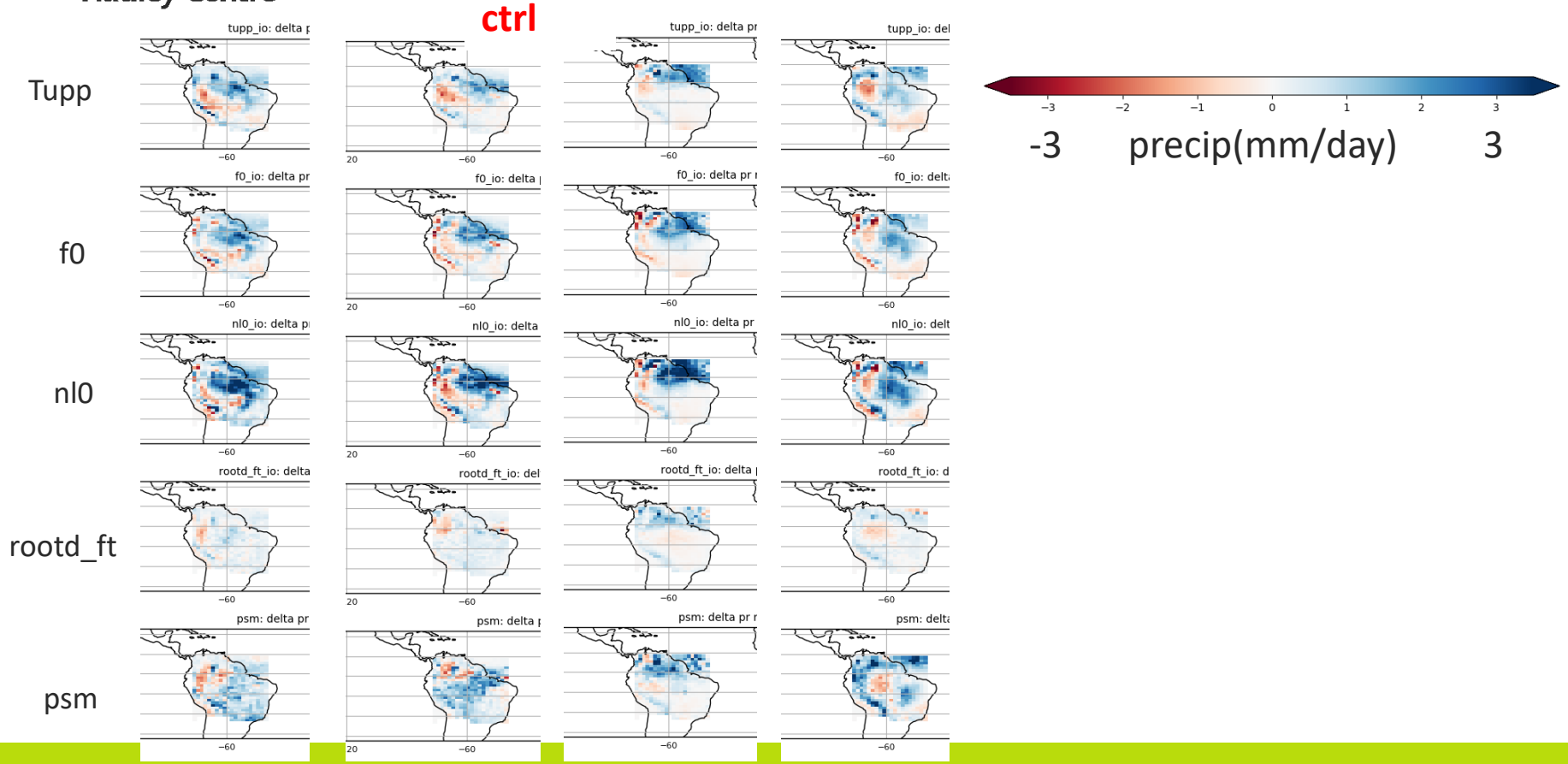
psm



Spatial (and seasonal) variability in parameter sensitivity



Spatial (and seasonal) variability in parameter sensitivity



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Summary and next steps

- Land surface parameter uncertainty is clearly significant if we believe that the chosen ranges of values are realistic!
- There are spatial and seasonal variations in sensitivity.
- Greatest parameter sensitivity occurs in tropics, especially in tropical forests (probably because transpiration is high).

- Further work required to understand the spatial and seasonal variability in parameter sensitivity.
- Can we constrain parameter value based on observations? Other studies suggest structural error may prevent this.
- How does parameter uncertainty change with higher temperatures?

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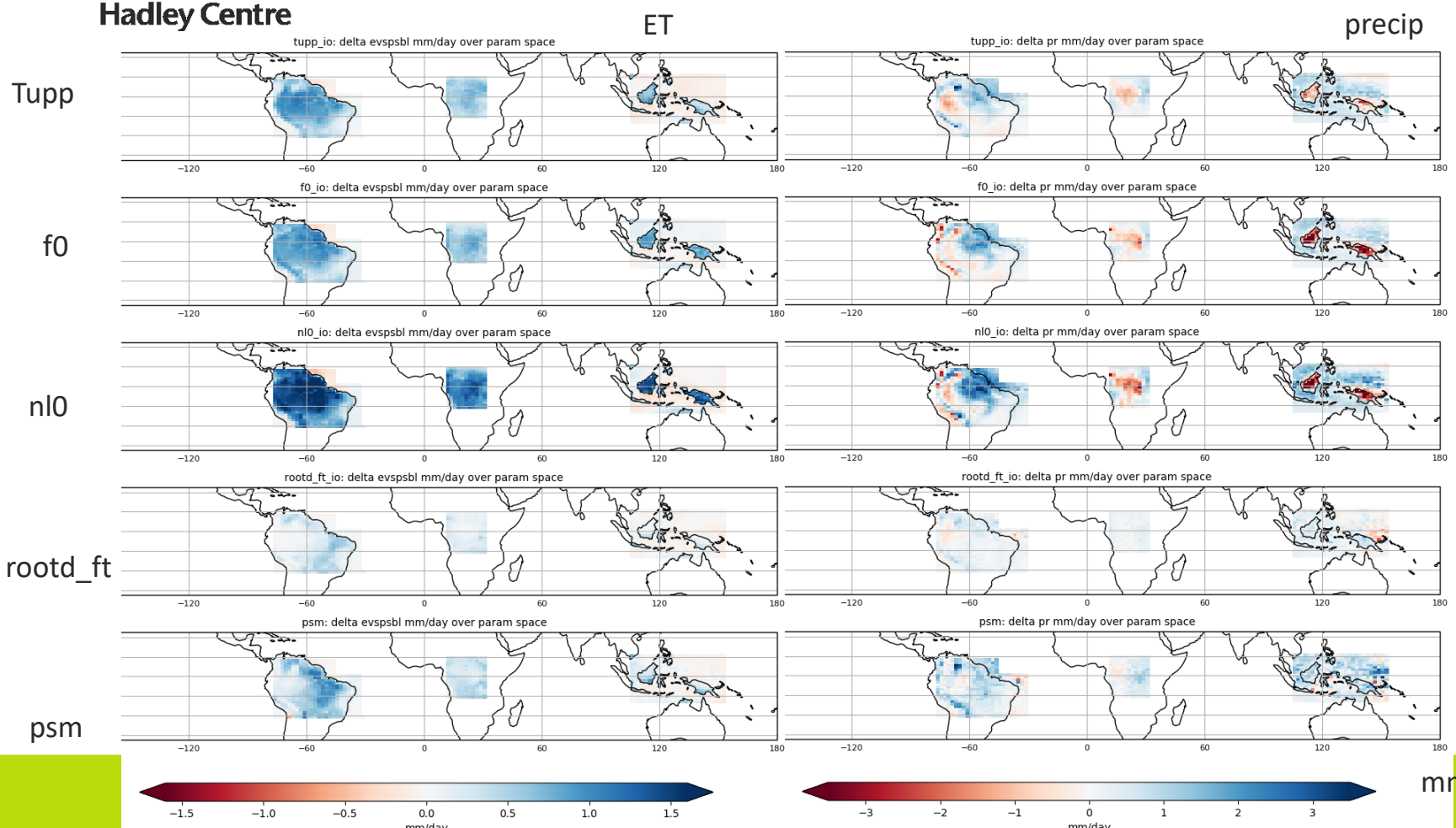
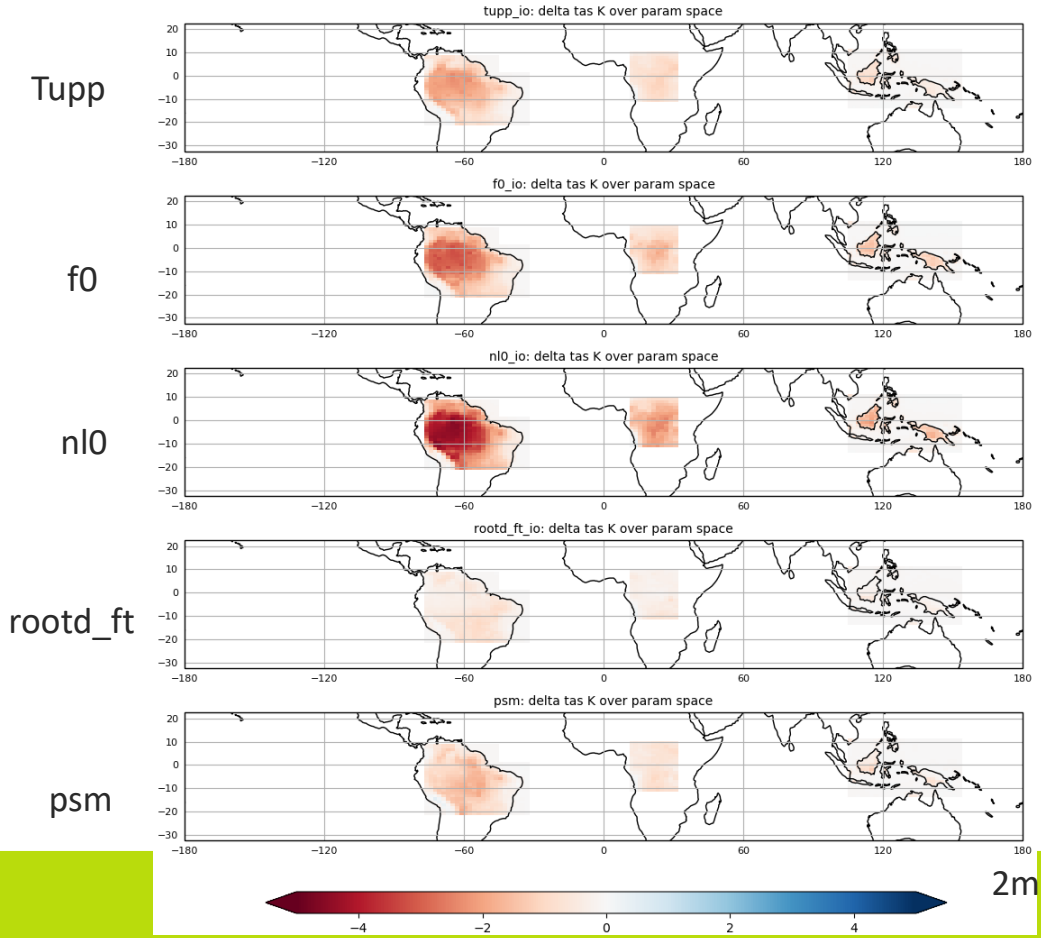
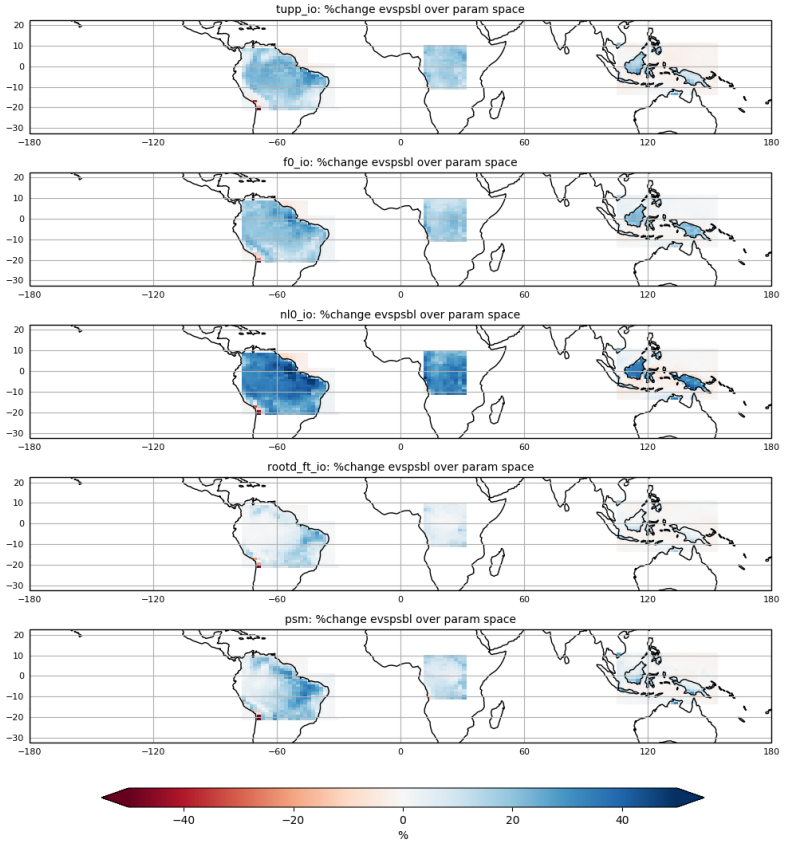
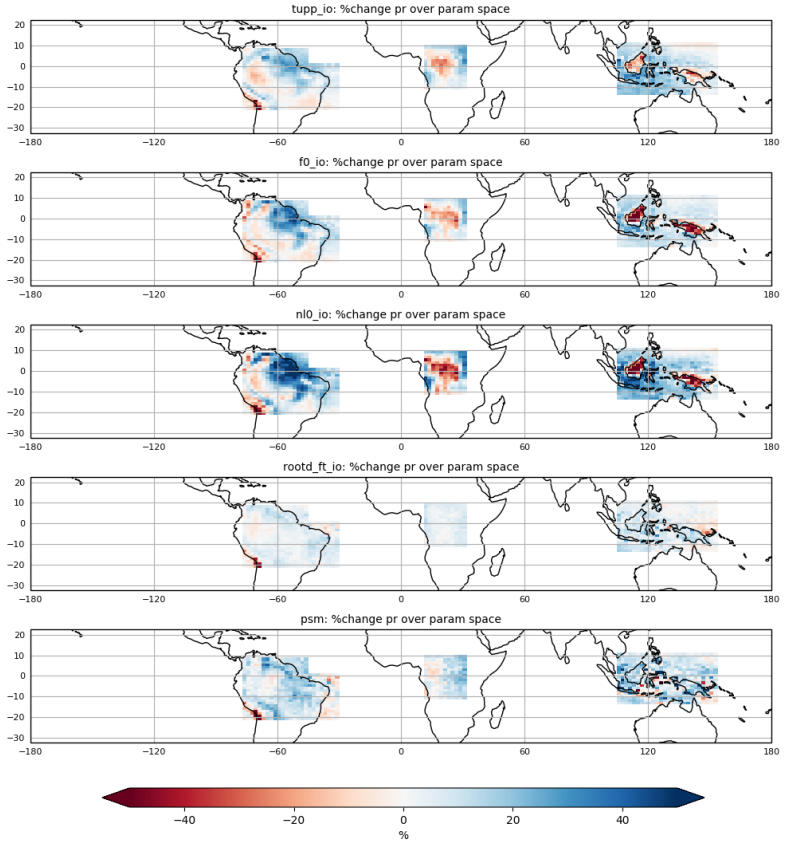
Spatial variability in parameter sensitivity



Spatial variability in parameter sensitivity



- Darker colours indicate steeper gradient (greater sensitivity to change in parameter)

- Red = negative slope
- Blue = positive slope

Spatial variability in parameter sensitivity (%)