Update on JULES soil moisture stress JPEG

JULES annual meeting, 14 September 2021

Anna Harper, Karina Williams and the JPEG team

Summary of updates

- Paper in GMD
- Group discussions
- Recommendations for Global Land (GL) configuration
- Next steps

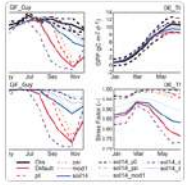
GMD paper

- Evaluated JULES GPP and LE at 40 sites from u-al752
- Focused on 11 sites with 10 different representations of soil moisture stress (β)
- Improvements in GPP with deeper soils (10.8m and 14 layers) *and* :
  - soil matric potential replaces volumetric water content in the β equation
  - Reducing threshold in soil moisture where stress begins
  - More access to deeper soil layers
- High bias in LE made worse with these changes, but seasonal cycle and variance was improved.

Model evaluation paper

03 Jun 2021

Improvement of modeling plant responses to low soil moisture in JULESvn4.9 and evaluation against flux tower measurements



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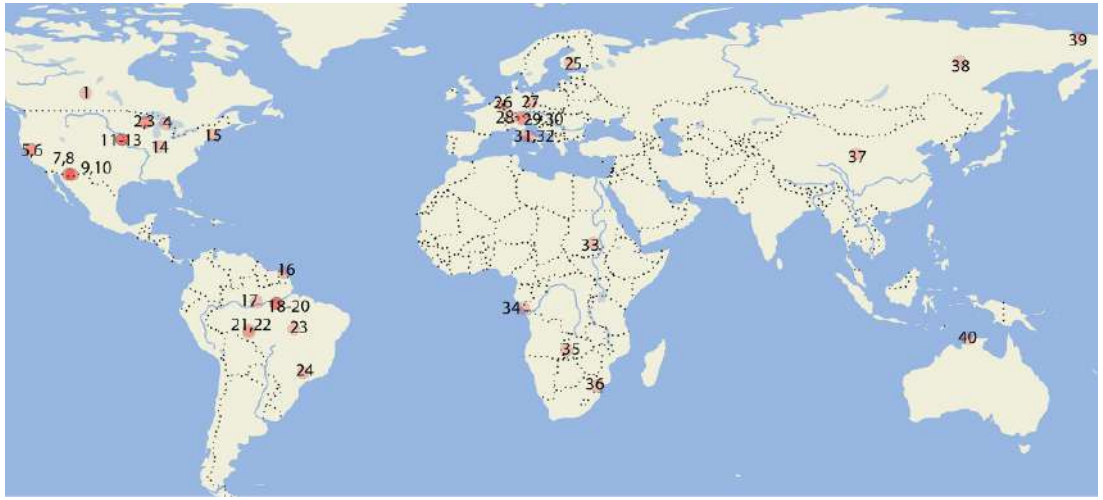
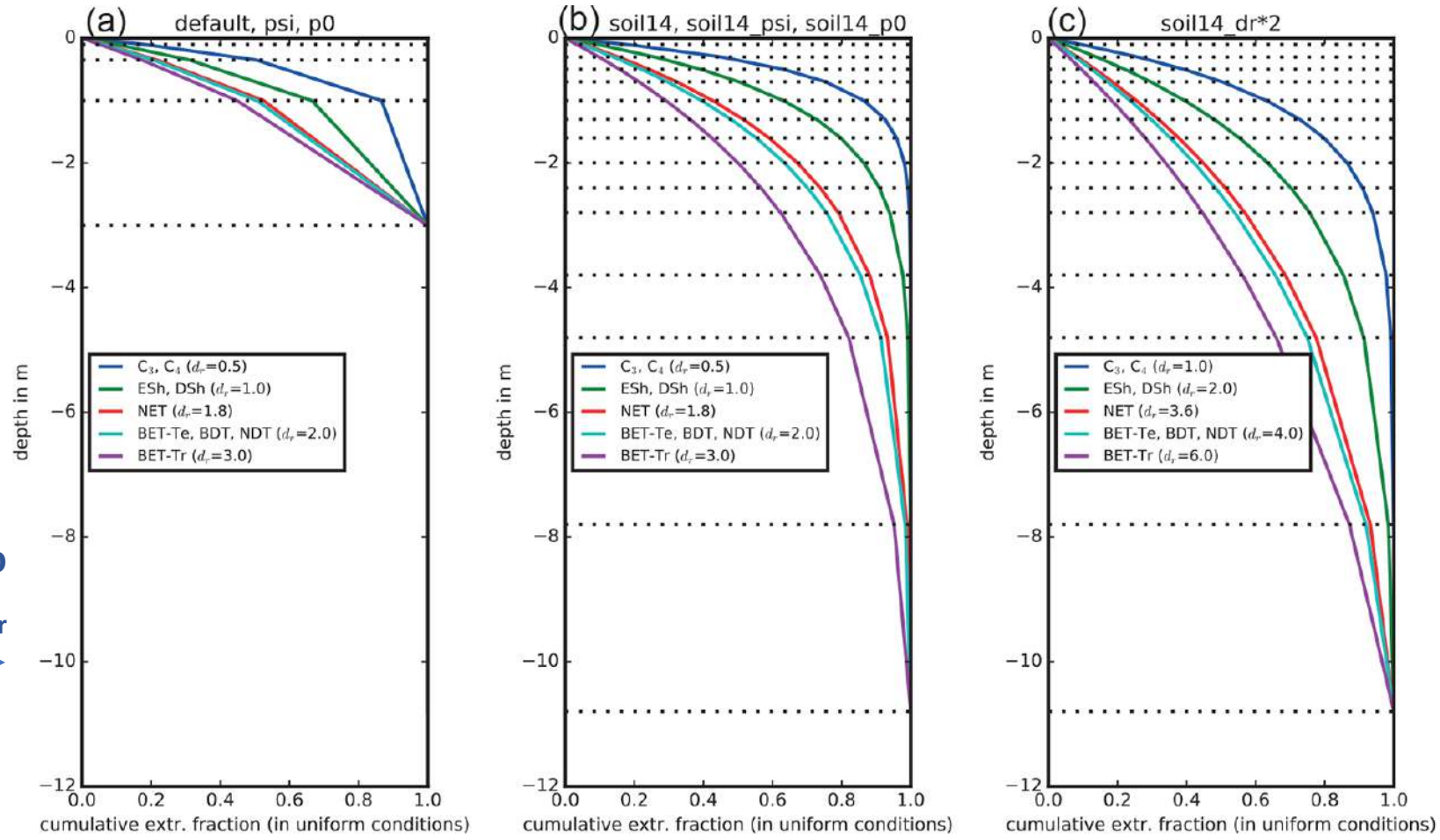


Recommendation 1: Deeper soils

- 3 layer --> 14 layer soil
- Max depth increased from 3 meters to 10.8 meters

Effective rooting profiles due to changes in soil depth and d_r



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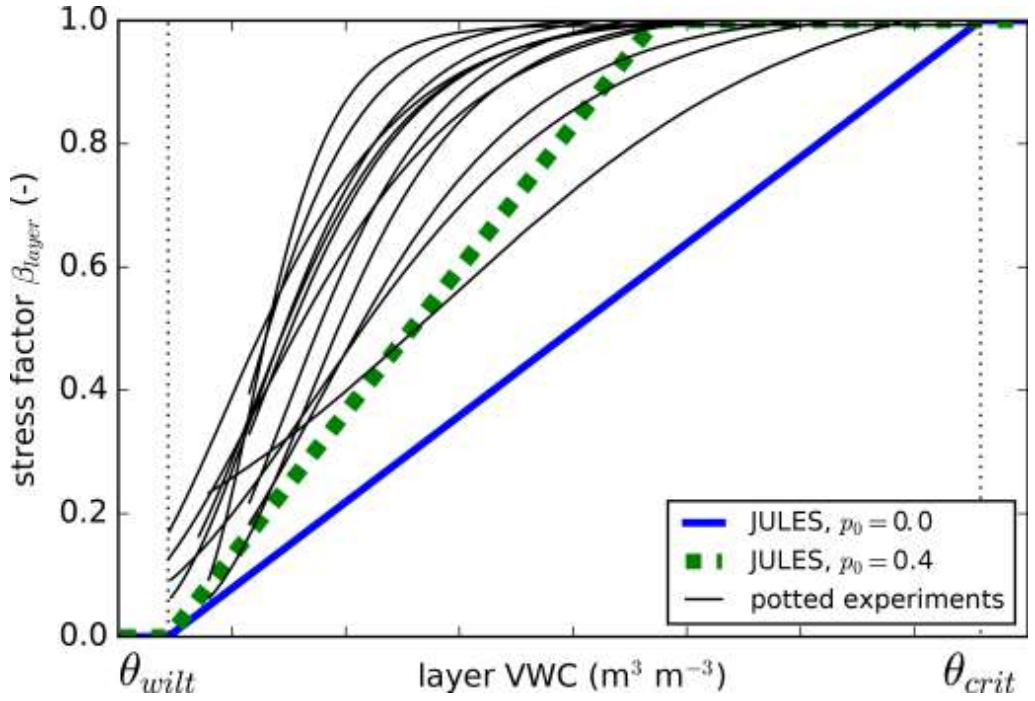
Recommendation 2: delay onset of stress to drier soils

- Non-zero p0 agrees more with observations from Verhoef and Egea (2014).



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OR

Recommendation 3: Use soil matric potential in stress equation

Default JULES uses θ (volumetric water content, $m^3\ m^{-3}$):

$$\beta_k = \begin{cases} 1 & \theta_k \geq \theta_{\text{upp},k} \\ \frac{\theta_k - \theta_{\text{wilt},k}}{\theta_{\text{upp},k} - \theta_{\text{wilt},k}} & \theta_{\text{wilt},k} \leq \theta_k \leq \theta_{\text{upp},k} \\ 0 & \theta_k \leq \theta_{\text{wilt},k} \end{cases},$$

Note: $\theta_{upp} = \theta_{crit}$ in default JULES

'psi' approach uses soil matric potential (MPa):

$$\beta_{\psi,k} = \frac{\psi_k - \psi_{\text{close}}}{\psi_{\text{open}} - \psi_{\text{close}}}$$

Potential for PFT-dependend ψ_{open} and ψ_{close} (ψ_{close} can be approximated by turgor loss point)

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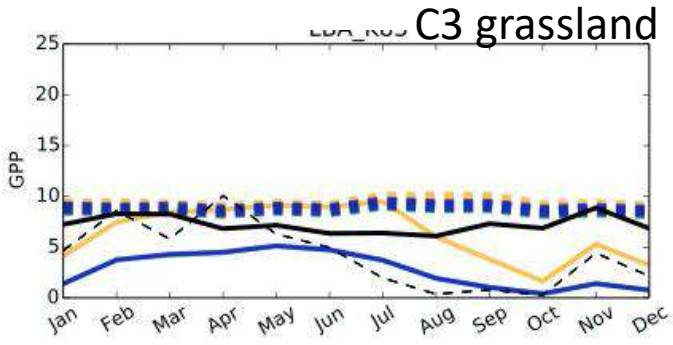
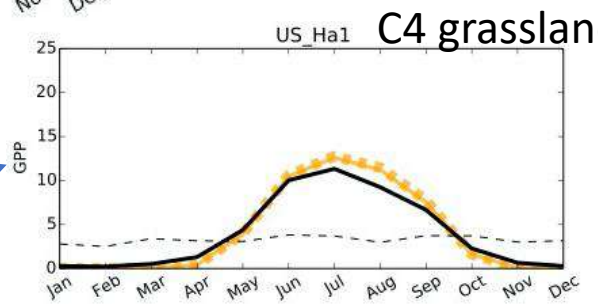
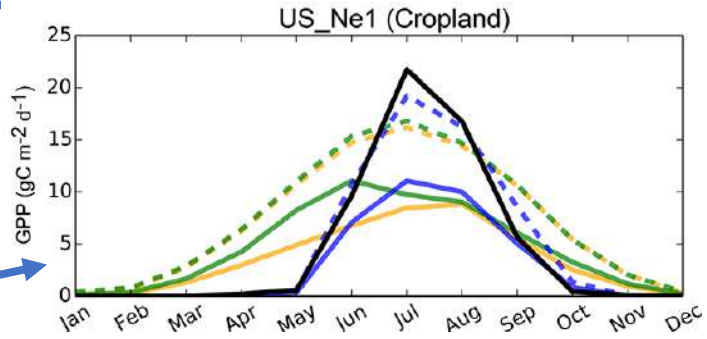
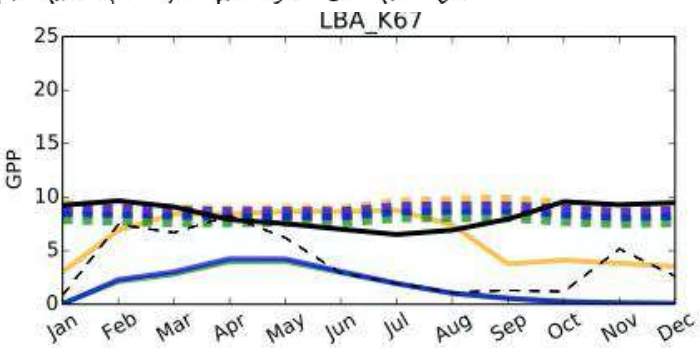
GPP evaluation

- Based on simulations with most prescribed data available (SM or SM+LAI)
- Four categories:
  - Simulated GPP was too low but not because of stress
  - Simulated GPP was too high
  - Simulated GPP was too low and removing stress improved the simulation
  - As above but other processes are also missing









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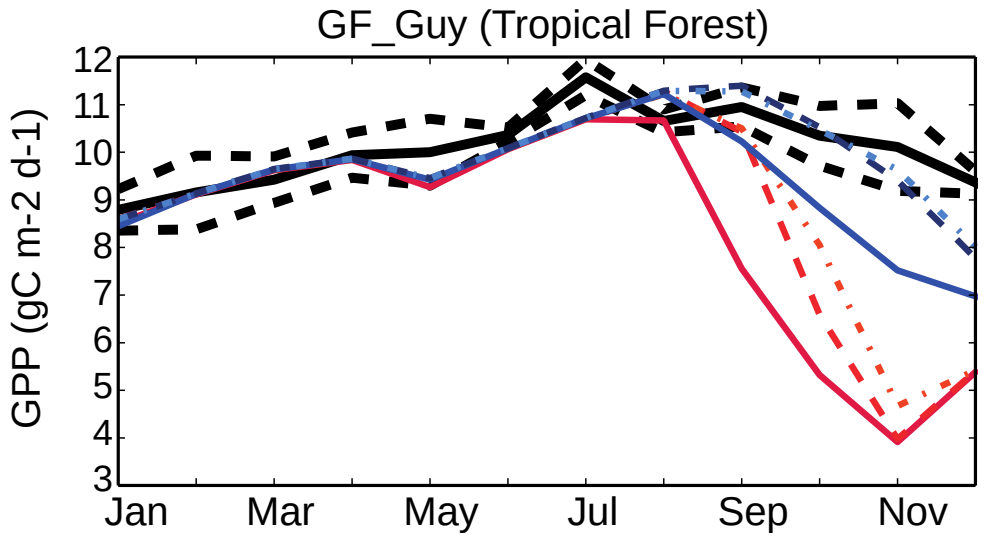
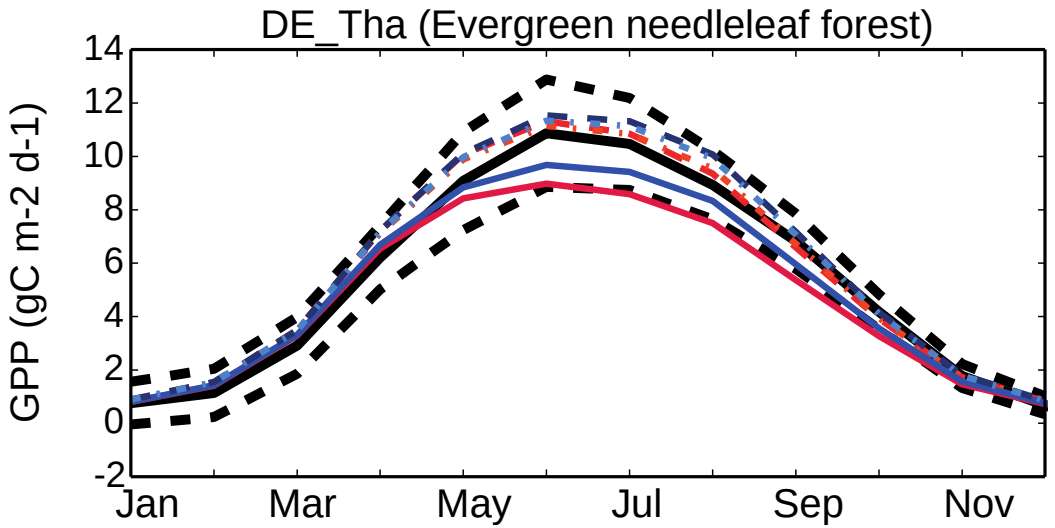
Impacts of different β experiments





9 more sites evaluated in the paper!

- Obs
- Default (4 layer, 3 m soil)
- p0 (Reduced soil moisture threshold for inducing stress)
- psi (Use soil matric potential to calculate available water)
- soil14 (14 layer, 10.8 m soil)
- soil14_p0
- soil14_psi

- **All these experiments were an improvement over the default except 'p0' with 4-layer soil**
- **On average the best results were with soil14_p0 and soil14_psi (lowest RMSE, variance ratio closest to 1, highest r)**

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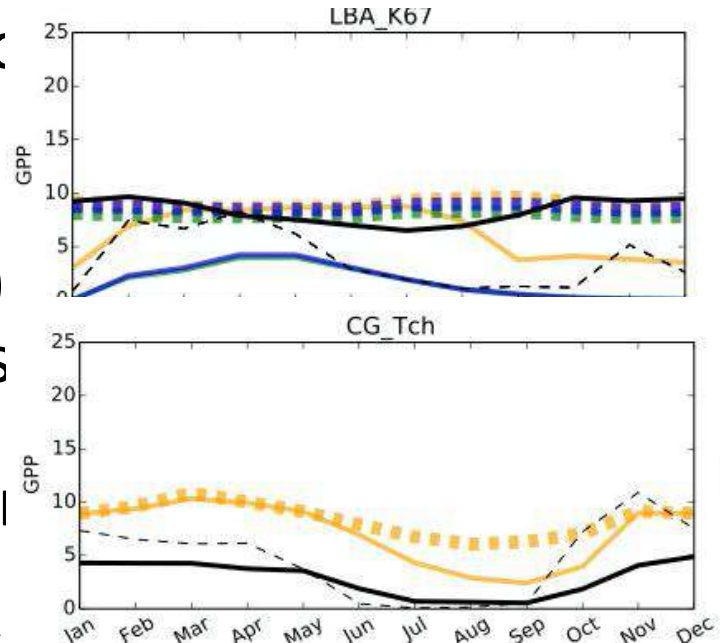
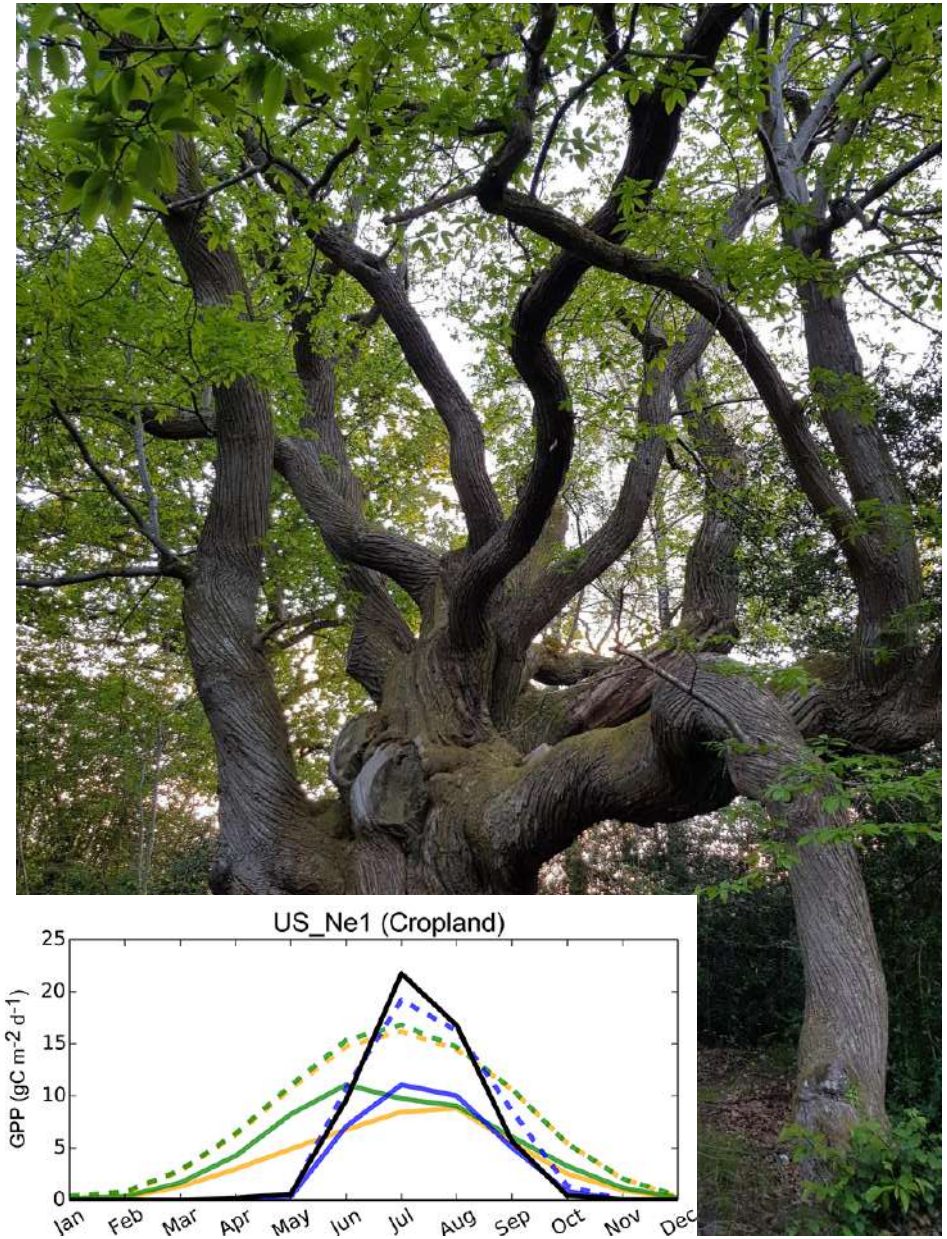
Sites for further evaluation

- LBA-K67: JULES GPP is low during dry season → Missing impact of seasonal leaf flushing (e.g. Wu et al. 2016)?
- RU-Che: GPP too l… …n due to dry soils → … or sublimation?
- CA-Oas: 2001, 200… …nt years but in 2001 s… …to high GPP. GPP was… 2004 was interesti… high precip the sta… GPP remained low → lag effects of precip anomalies





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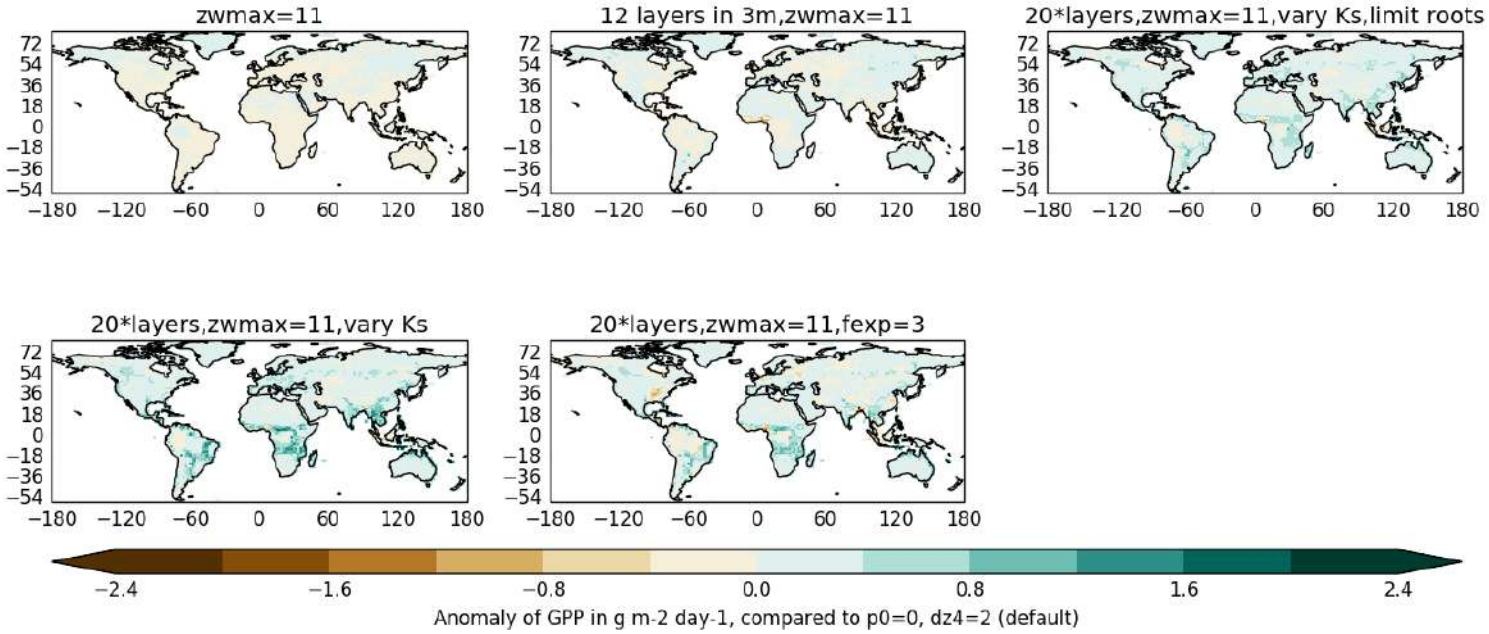
Group talks and discussions

- Jaideep Joshi: “Towards a unified theory of plant photosynthesis and hydraulics” (pre-print available at https://www.biorxiv.org/content/10.1101/2020.12.17.423132v1)
- Thanos Paschalis: “Rainfall manipulation experiments as simulated by terrestrial biosphere models: Where do we stand?” (paper in Global Change Biology: https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.15024)

Recommendations for GL configuration

- Work in progress: Impacts of deeper soil, more soil layers on global simulations
- Checking for unexpected side effects of different combinations of options (ie TOP model on/off; 20 layers extend to 7.9m (used in Eleanor Burke and Sarah Chadburn's permafrost configuration)



Changes in GPP due to different assumptions about Ks changes with depth, access of roots to deep soil moisture, number of layers and soil depth

Next steps

- What have we accomplished over 5 years and where do we want this group to go?
  - Lots of useful discussions
  - supporting student and post-doc work
  - sharing of Fluxnet rose suite
  - Recommendations for GL configuration
- Other issues have been highlighted through our work:
  - Bare soil evaporation is overestimated
  - We can only get so far with a beta parameterization of soil moisture stress, modeling soil/plant hydraulics (SOX) is important for future development

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