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

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One of the responses of vegetation to increased CO$_2$:

$\rightarrow$ stomatal closure $\rightarrow$ reduced transpiration

This is known as “physiological forcing”
ET in western Amazonia from HadGEM2-ES 1% runs (CMIP5)

‘ALL’ (1pcCO₂): all model schemes exposed to the CO₂ rise

‘BGC’ (esmFixClim1): physiological forcing i.e. only vegetation scheme exposed to CO₂ rise

‘RAD’ (esmFdbk1): radiative forcing i.e. only radiation scheme exposed to CO₂ rise
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Example Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper value about 4K above Topt</td>
<td>Temperature for photosynthesis (tupp.io)</td>
<td>Determines the turn-over point for temperature, above which further increases in temperature will drive a decline in photosynthesis.</td>
</tr>
<tr>
<td>Maximum ratio of internal to external CO2</td>
<td>(f0.io)</td>
<td>Controls the gradient of CO2 between plant stomata and the ambient air.</td>
</tr>
<tr>
<td>Top leaf Nitrogen concentration in kg N kg C</td>
<td>(nl0.io)</td>
<td>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.</td>
</tr>
<tr>
<td>Root depth</td>
<td>(rootd.ft.io)</td>
<td>Controls the depth (in model soil levels) that soil moisture is available.</td>
</tr>
<tr>
<td>Scaling factor for Critical and Saturation levels for Soil Moisture towards Wilt level</td>
<td>(psm)</td>
<td>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.</td>
</tr>
</tbody>
</table>

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.

Higher ratios are associated with higher photosynthesis.

Larger values equate to deeper depths in the soil, and subsequently greater resilience to short timescale droughts.

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.
HadGEM3 perturbed parameter ensemble (PPE)...

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

Land surface parameters

Sexton et al (in prep.)
Marginal response of ET to each parameter

Land surface parameters

- Tupp
- f0
- nl0

- ET
- precip
- 2m temp (K)
- runoff
- P-ET
- specific humidity

W Amazonia
Spatial variability in ET parameter sensitivity – ctrl and 4xCO₂

- **Tupp**
- **f₀**
- **nl₀**
- **rootd_ft**
- **psm**
Spatial variability in **precip** parameter sensitivity – ctrl and 4xCO$_2$
Spatial variability in 2m temp parameter sensitivity – ctrl and 4xCO₂

Tupp

ctrl

4xCO₂ – ctrl

f₀

nl₀

rootd_ft

psm
Spatial (and seasonal) variability in parameter sensitivity

- Tupp
- f0
- nl0
- rootd_ft
- psm

ET (mm/day)

DJF  MAM  JJA  SON
Spatial (and seasonal) variability in parameter sensitivity

- Tupp
- f0
- nl0
- rootd_ft
- psm

 ctrl
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?
Spatial variability in parameter sensitivity

- **Tupp**: ET and precip
- **f0**: ET and precip
- **nl0**: ET and precip
- **rootd_ft**: ET and precip
- **psm**: ET and precip
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 (%)