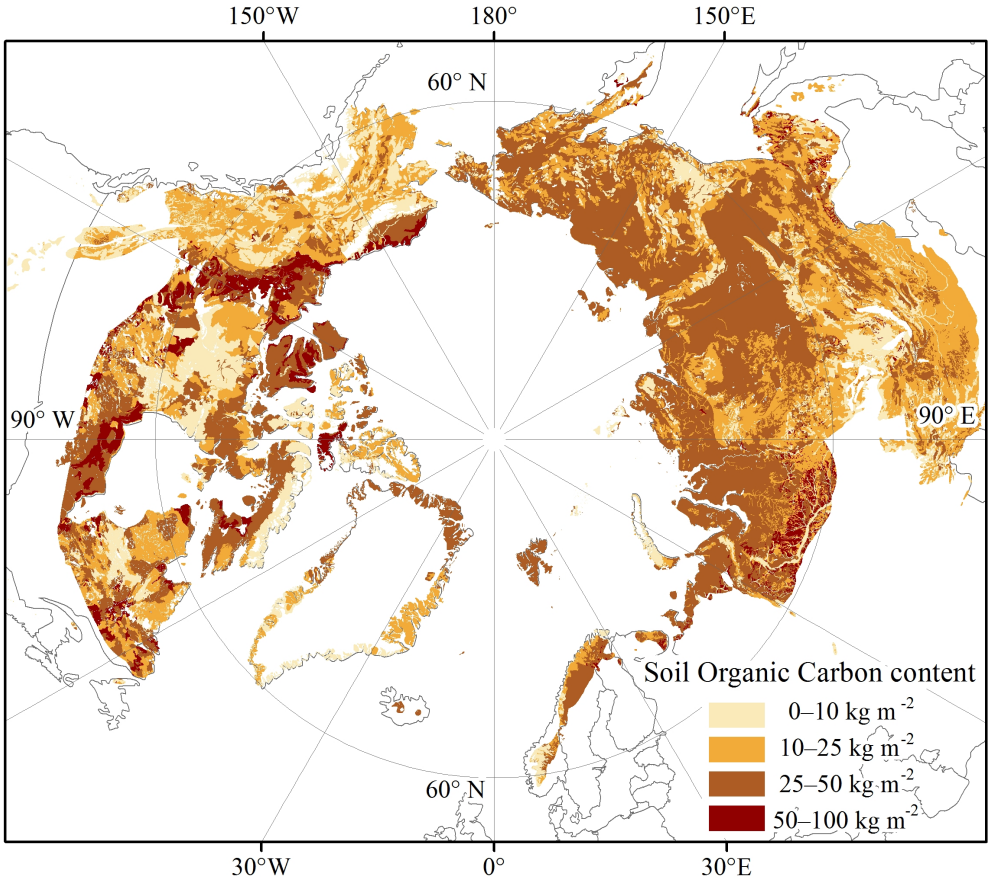
Vertically discretised soil carbon in JULES

Sarah Chadburn, Eleanor Burke, Altug Ekici, Antoine Mariscal, Pierre Friedlingstein

JULES meeting, Reading
01-07-2015

Motivation: permafrost carbon

Arctic permafrost contains old, stored carbon deep in the soil, which may be released under future climate warming, causing a potentially important climate feedback. We are therefore working towards representing permafrost carbon more realistically in JULES.



Current soil carbon model in JULES

RothC model: 4 pools
Organic carbon input is split into:
- **R**esistant **P**lant **M**aterial
- **D**ecomposable **P**lant **M**aterial

Each pool decays at its own rate releasing CO_2

RPM and DPM pools feed into the other two pools: microbial **BIO**mass and **HUM**ified organic matter pools, which also transfer carbon between themselves.

Rate of decay of each pool modified by temperature function and soil moisture function.

Updated soil carbon model

- A set of pools in every soil layer.
- Addition of vertical processes:

  - Mixing: represents bioturbation/cryoturbation.

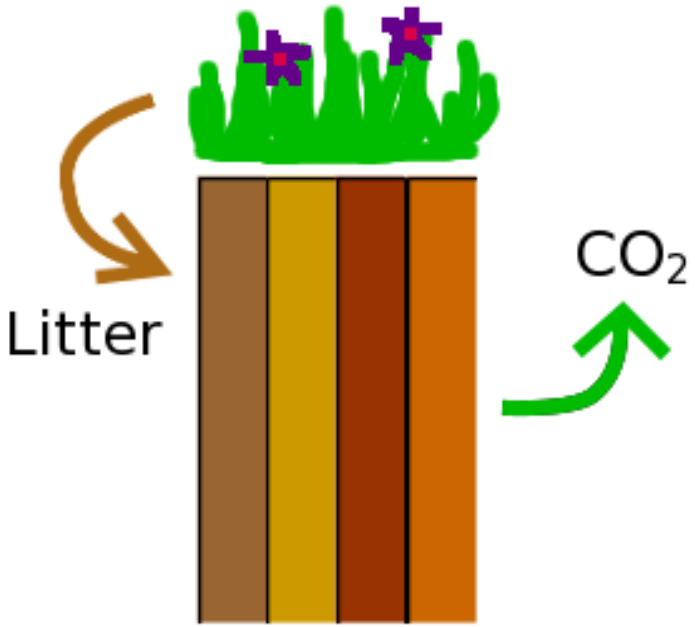
  - Depth profile for litter inputs.

  - Extra decay term on soil respiration with depth.

Based on parametrisation in CLM:

Koven, C. D., et al: The effect of vertically resolved soil biogeochemistry and alternate soil C and N models on C dynamics of CLM4, Biogeosciences, 10, 7109-7131, doi:10.5194/bg-10-7109-2013, 2013.

Changes to soil carbon scheme

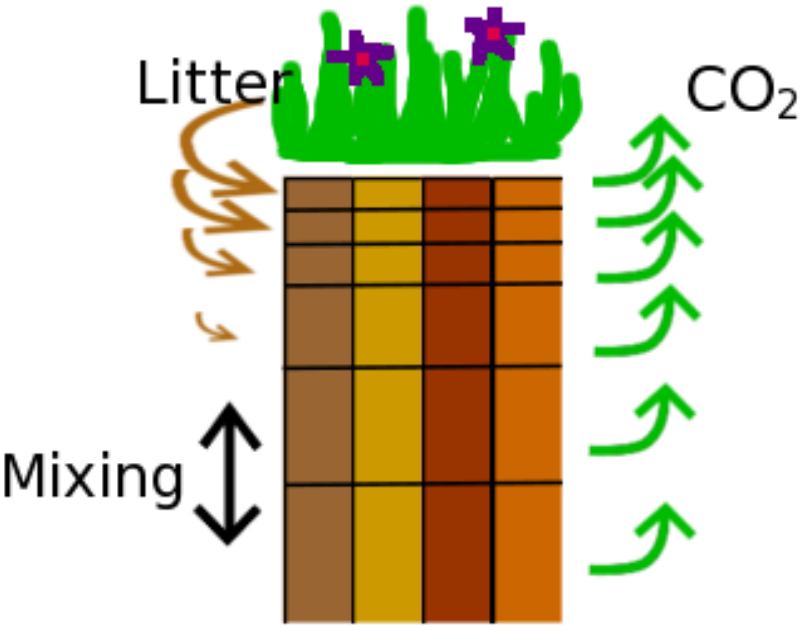


Original scheme

4 soil carbon pools

Decomposable plant material
Resistant plant material
Biomass
Humus

No structure with depth



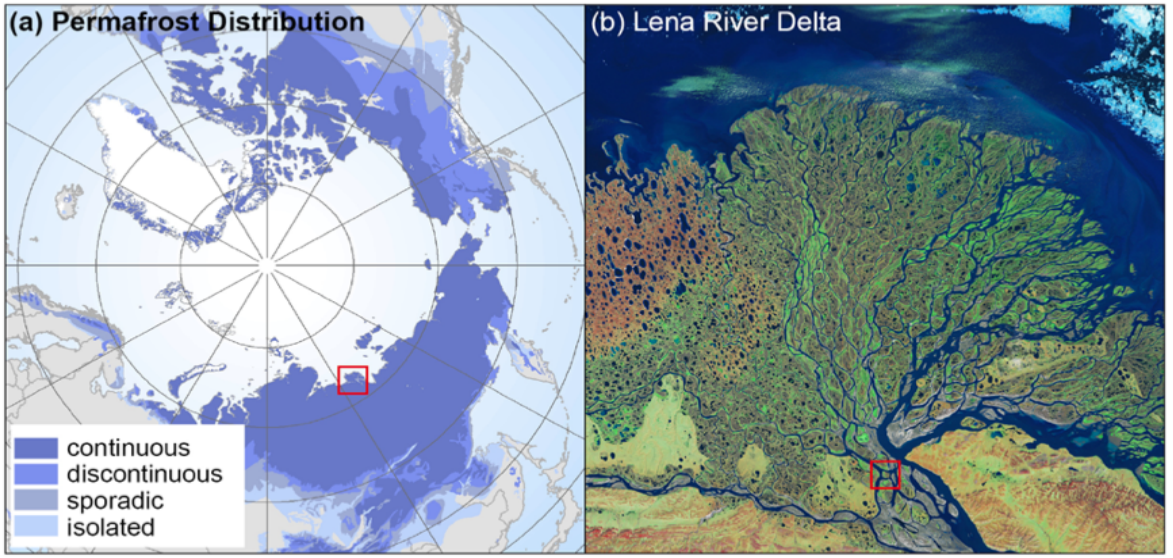
New scheme

4 soil carbon pools - layered

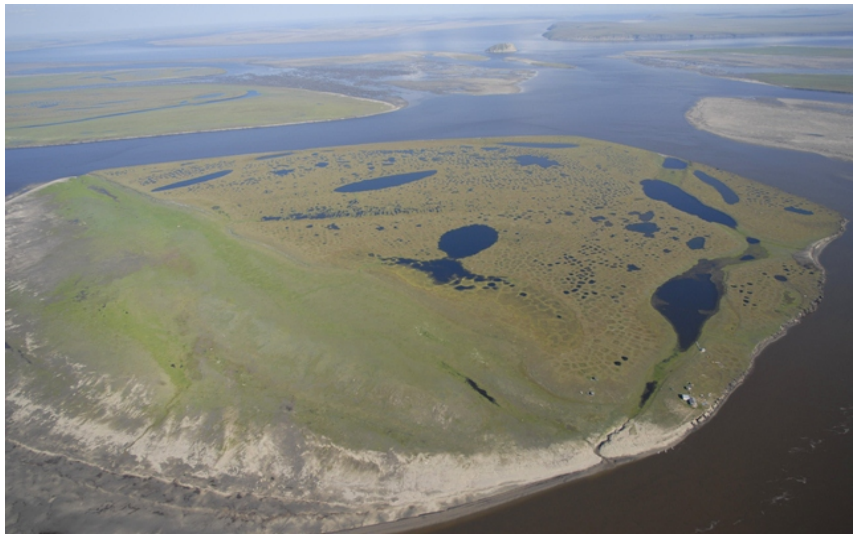
Decomposable plant material
Resistant plant material
Biomass
Humus

Initial site level results

- Initial runs at Samoylov Island site, Siberia.
- We have worked extensively on the physical processes so we have confidence in the physical simulation (or at least we know where it is wrong!)

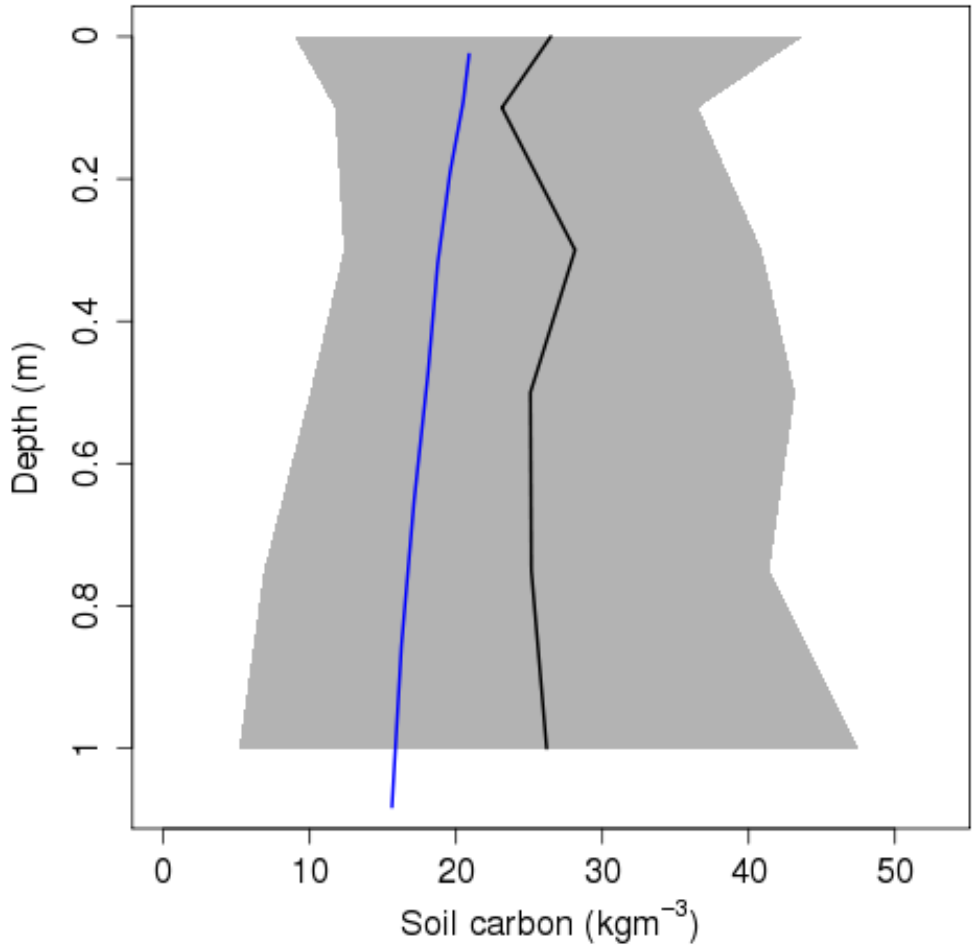


Samoylov Island: Polygonal tundra. Thick moss cover and organic matter in the soil.



Site level results: carbon stocks

- Spun-up state of soil carbon compares reasonably with observations...

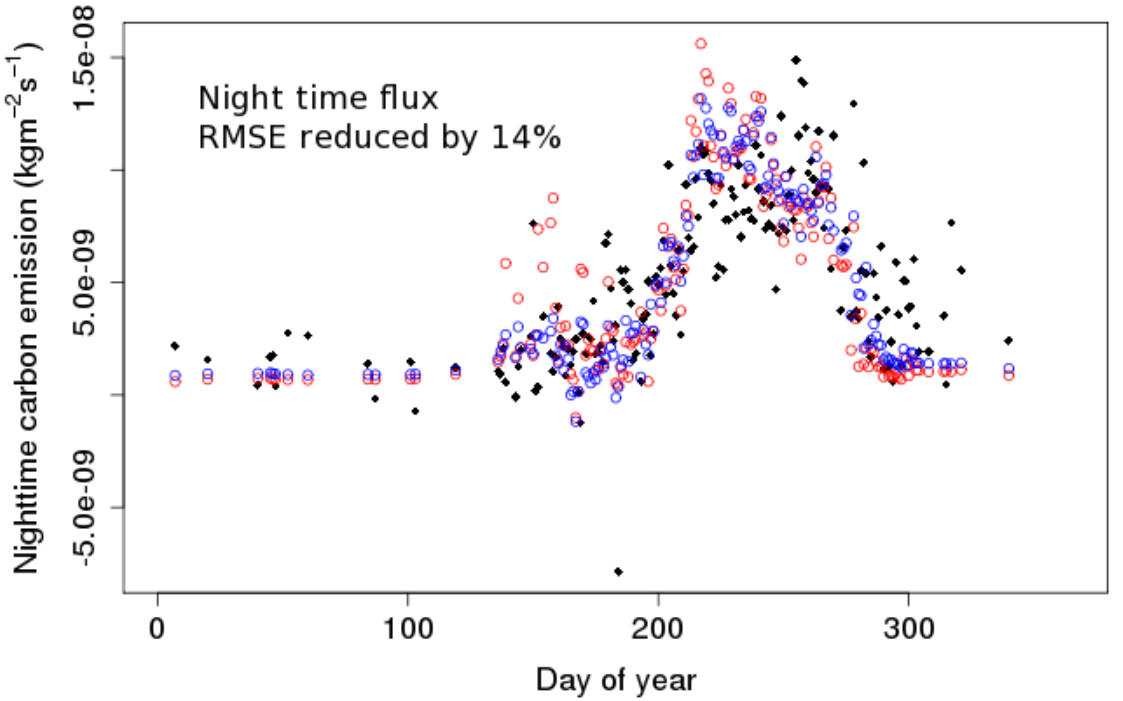


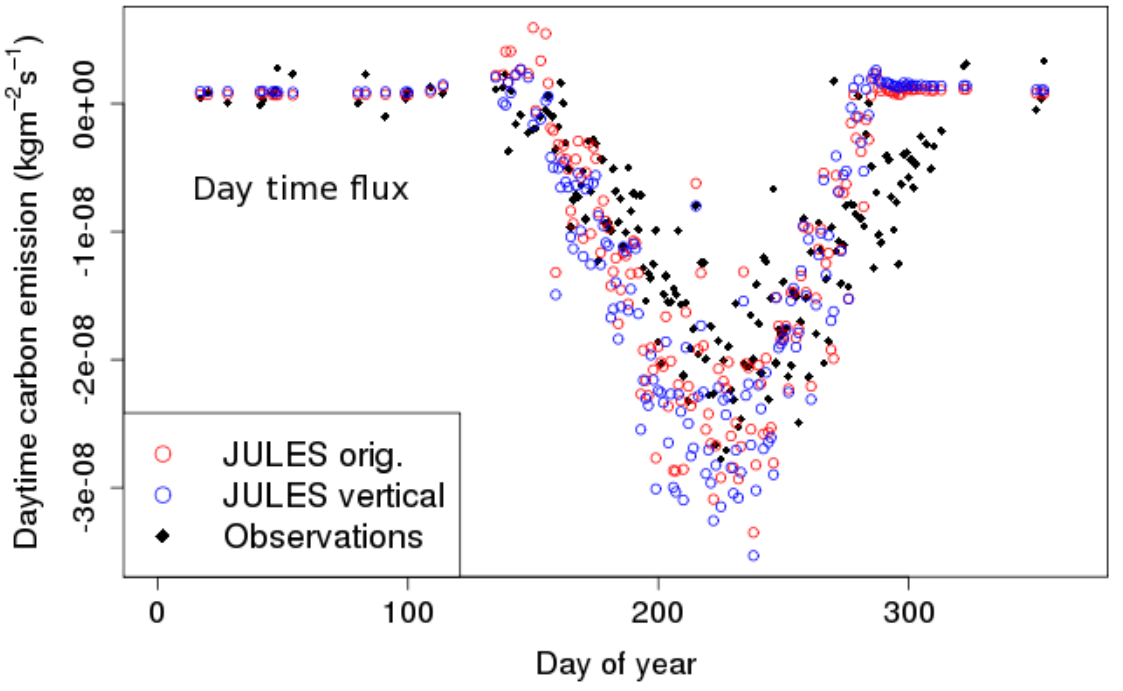
Black: Observations.

Blue: JULES simulation.

Site level results: Carbon fluxes

- Respiration is improved.
- Daytime carbon uptake is too high.
- This suggests the GPP is too high. (Nitrogen limitation required?)

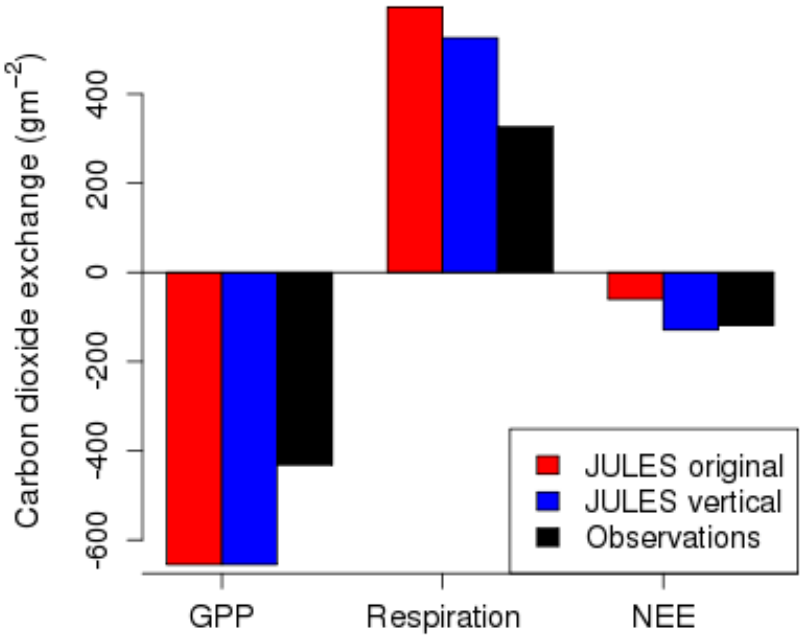




Site level results: Carbon balance

Estimate of growing season carbon budget 2003-2004:

Observations from Kutzbach et al. (2007) Biogeosciences, 4, 869–890



Both photosynthesis (GPP) and respiration are too large, but respiration is a little better in the new version.

Initial results: global

It takes a very long time to spin up to equilibrium

Use an equilibrium code which solves the JULES equations for an equilibrium state but calculation time is basically instant.

This allows us to look at sensitivity of the equilibrium state to the **vertical parameters** and also the functions already in JULES such as the **dependence of respiration on temperature and moisture**.

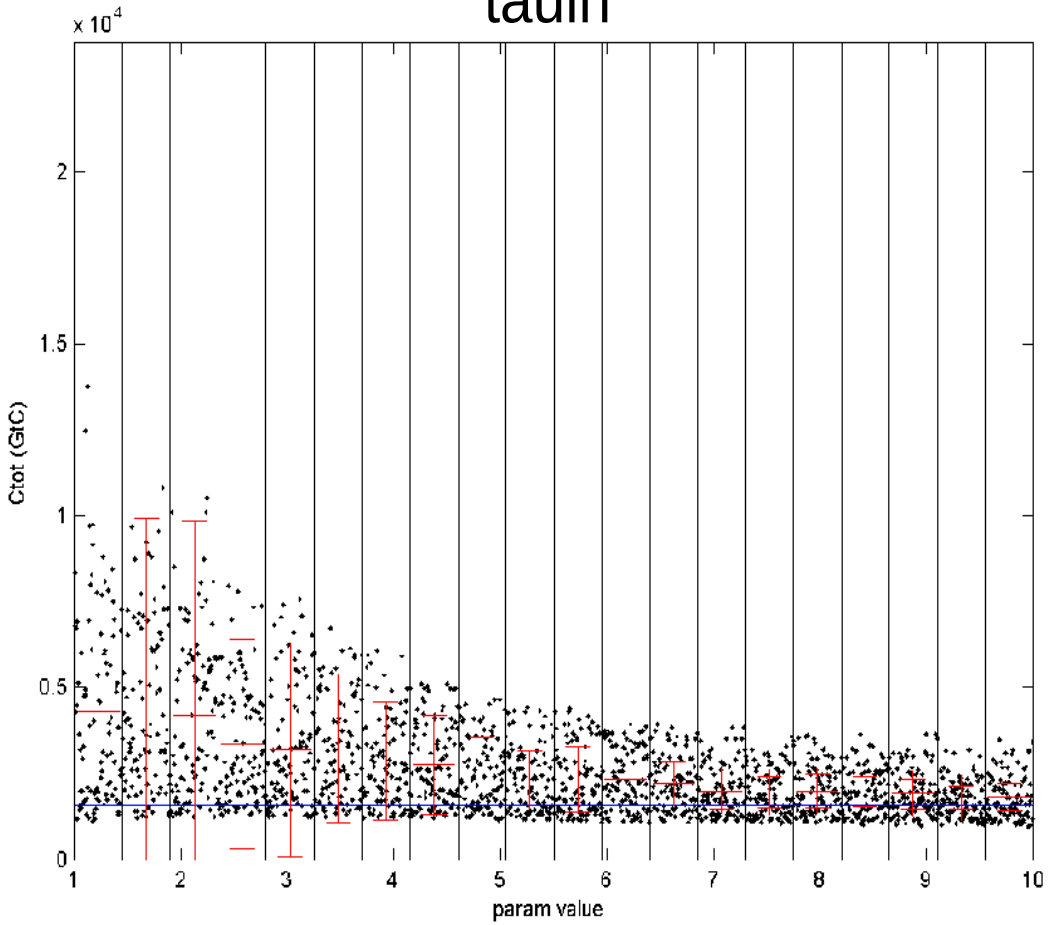
Parameter sensitivity

(Antoine Mariscal - Masters project)

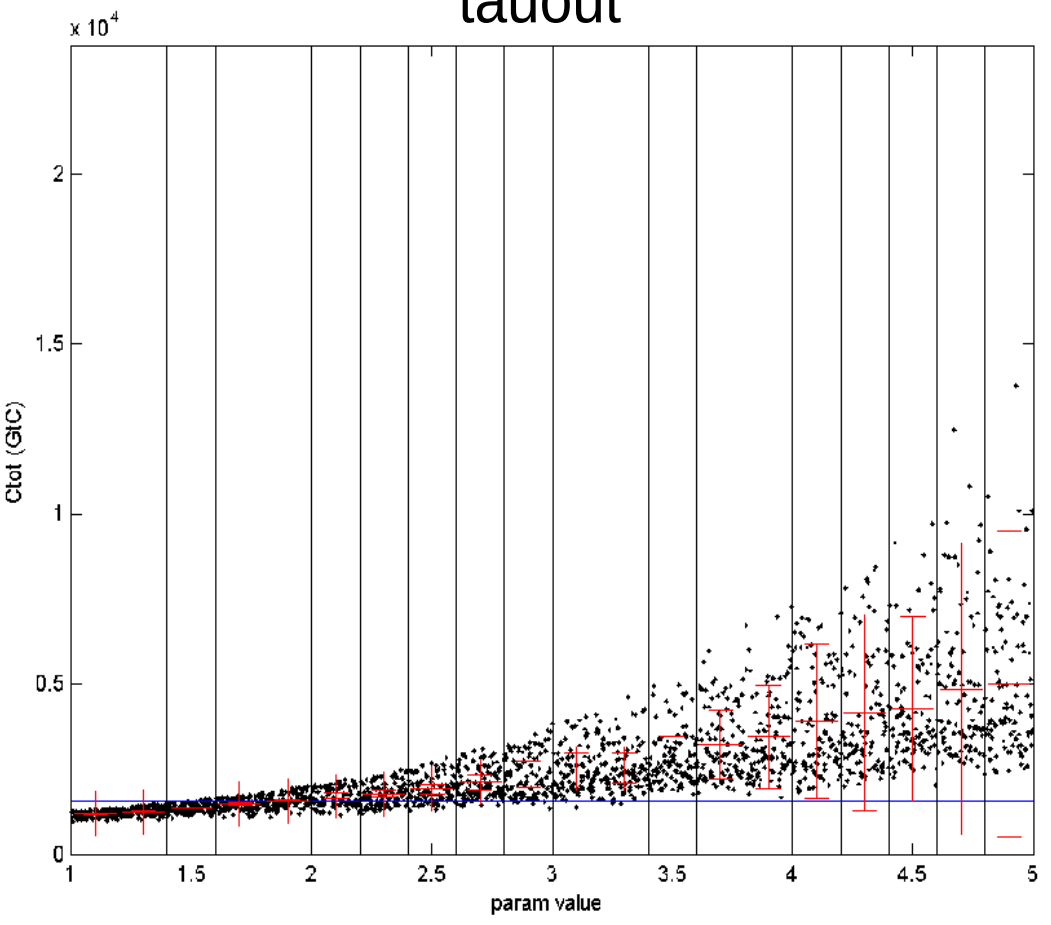
Key vertical parameters are the profile of litter inputs and the decay of soil respiration with depth.

The decay of respiration with depth (tauout) is really the biggest uncertainty, and it doesn't have a well-understood physical origin.

tauin

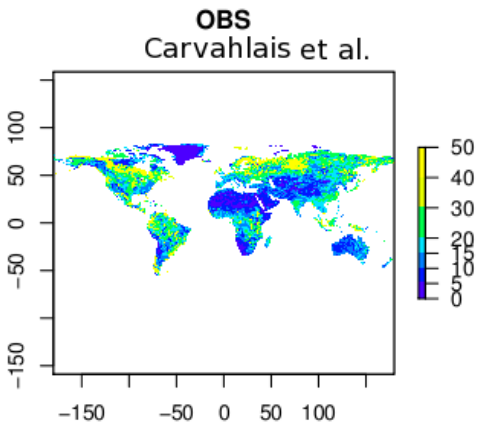


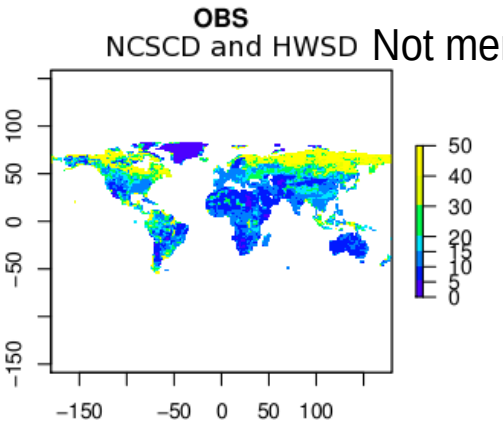
tauout



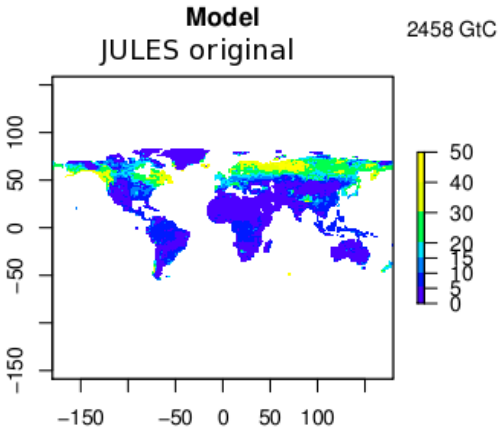
Initial results: global

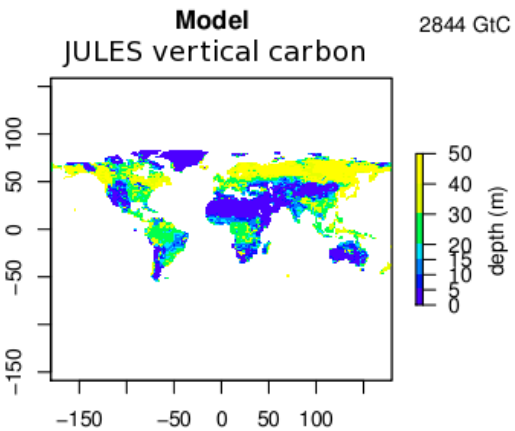
Best observational estimate →

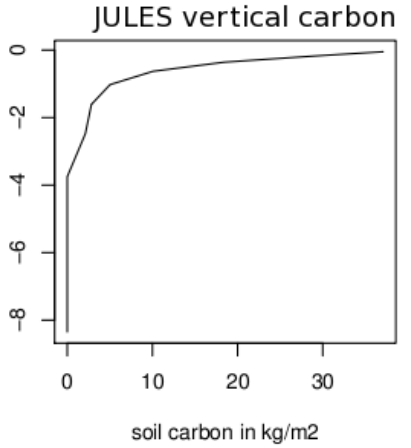




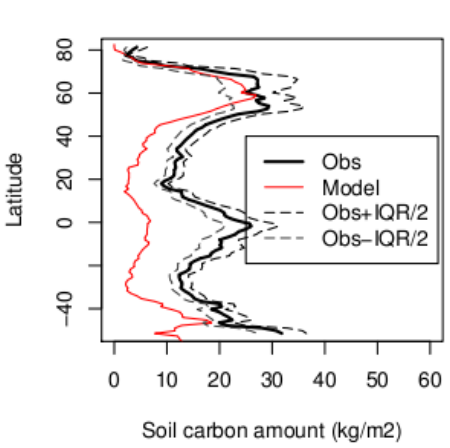
Not merged

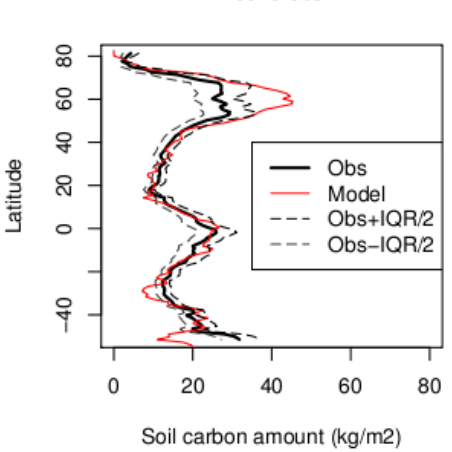






Vertical profile increases total soil carbon due to extra carbon at depth.

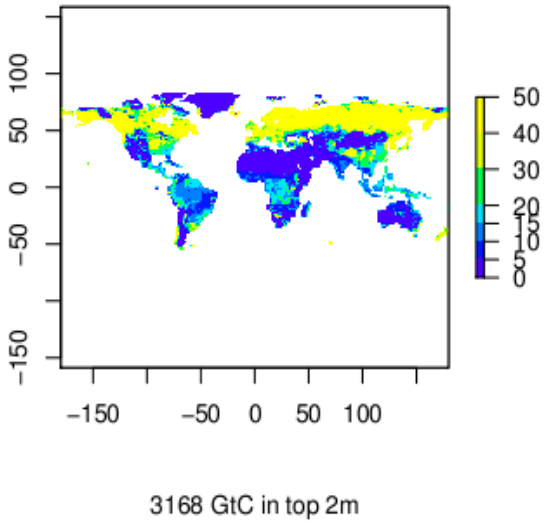


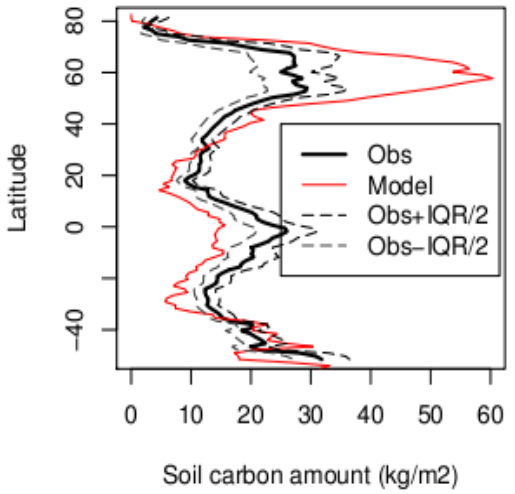


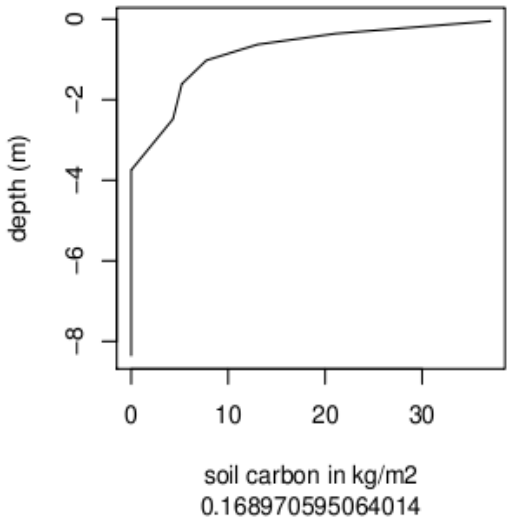
Change of temperature function (Q10 → 1.4) better captures ratio between NHL's and tropics. Mahecha et al. 2010

Initial results: global

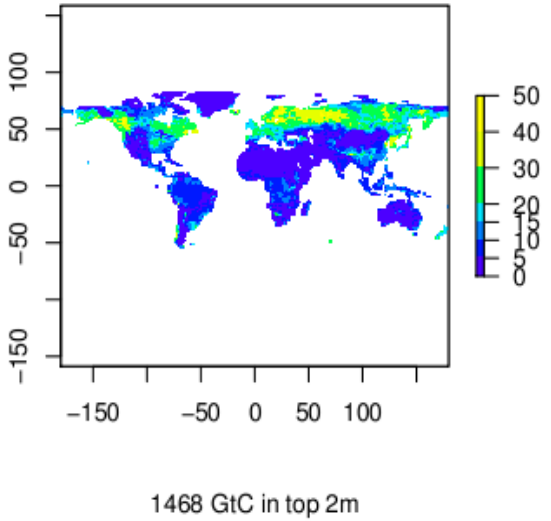
Vertical decay of respiration with depth, decay depth 50cm:

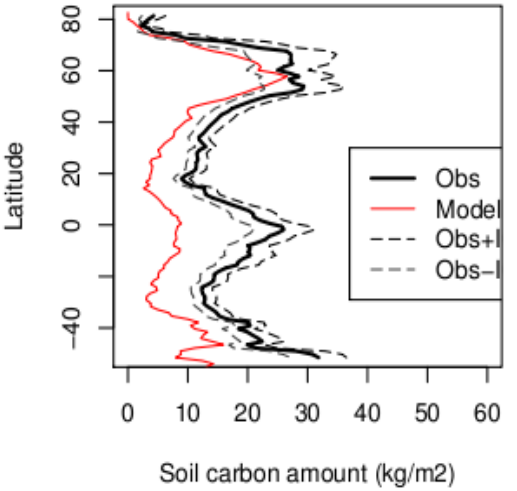


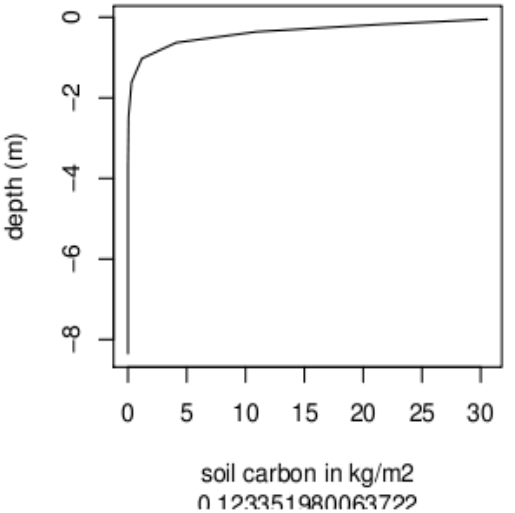




No additional decay of respiration with depth:







Demonstrates large uncertainty from unknown term (tauout).

Ongoing & future developments

- Include soil nitrogen model in vertical discretisation.
- Link litter inputs to rooting depth (tried but need more roots for NHL PFT's).
- More appropriate high latitude PFT(s). More roots, lower LAI...
- Couple soil carbon to soil properties.

Other model development plans

- Hydrology: Change calculation of water table depth and soil physics to work for vertically varying soil properties.
- Sub-grid variability in soil properties/temperatures.

Thanks for listening!