A new JULES version with improved physical processes in the Arctic

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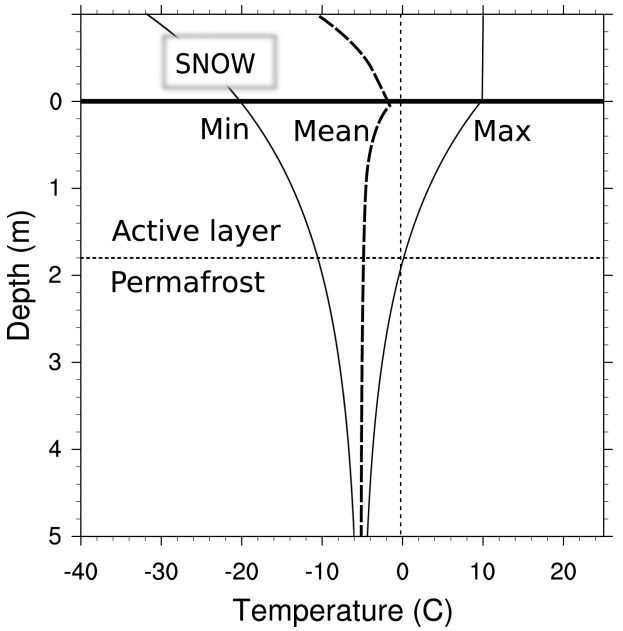
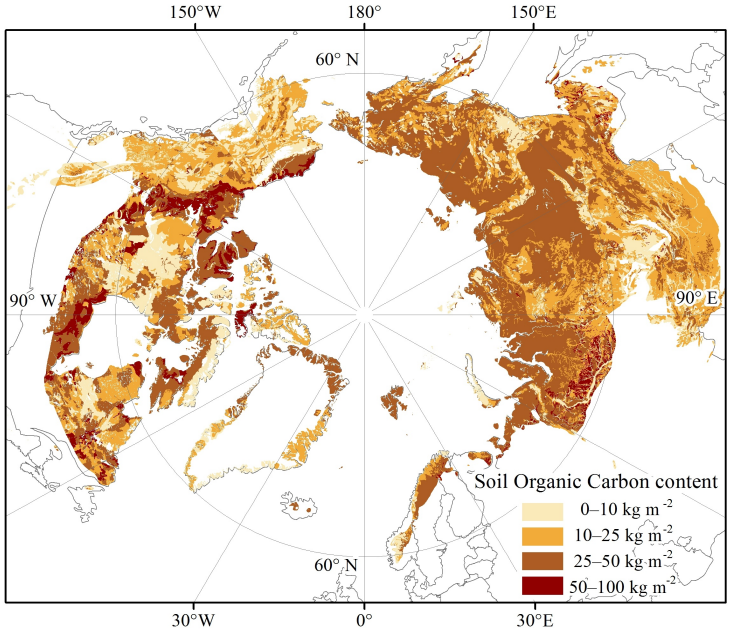
Arctic permafrost: what is it?

Any ground that remains at or below zero degrees Celsius for 2 or more years.

- Found under seasonally thawed 'active layer'
- Stores large quantities of carbon, which may be released under climate warming (feedback!)





It is important to get permafrost right in coupled models...

Plots show historical permafrost extent in CMIP5 models. The blue line is the zero-degree isotherm.

Variation appears to be more from the land-surface models than from the climate.

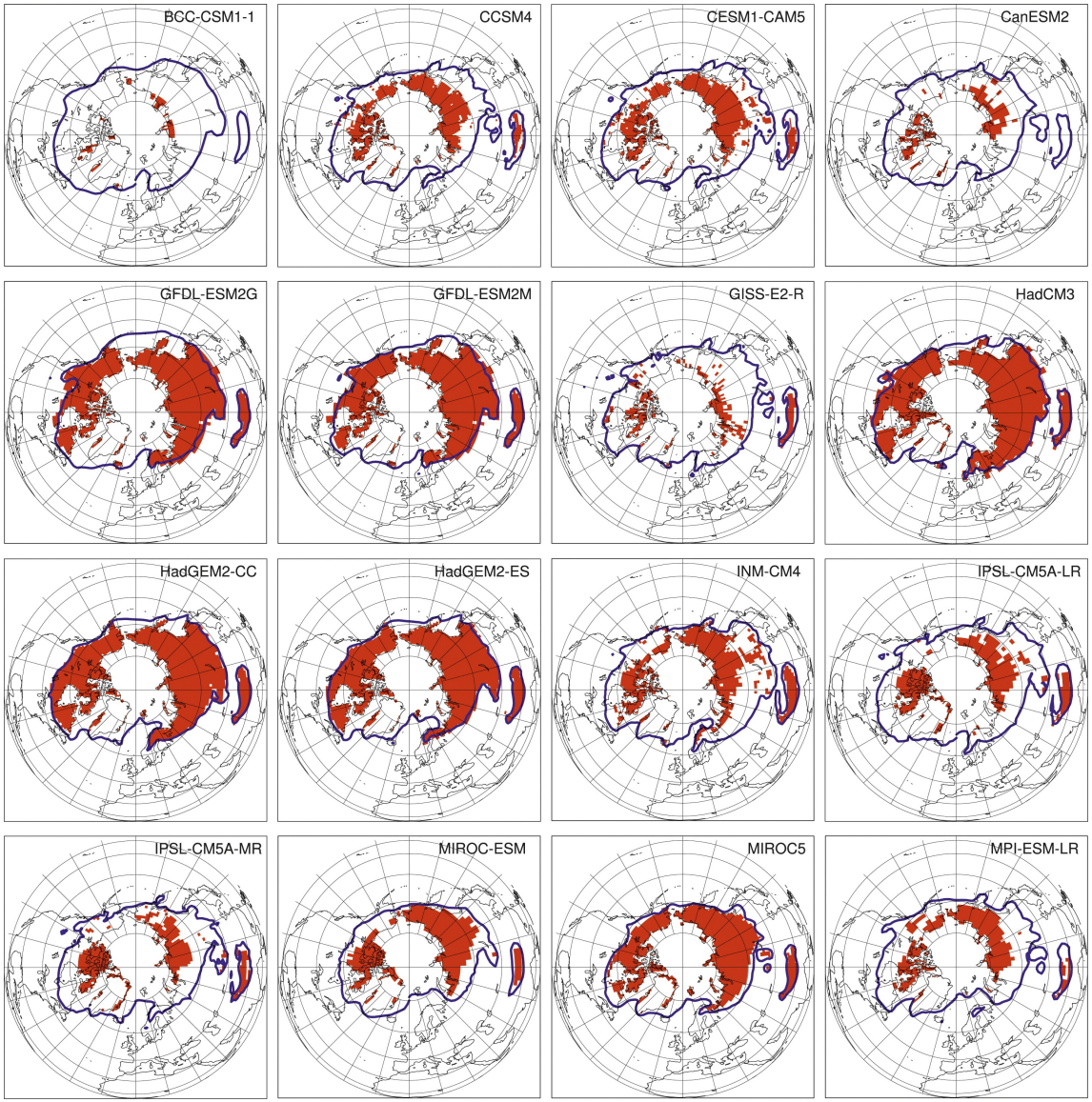
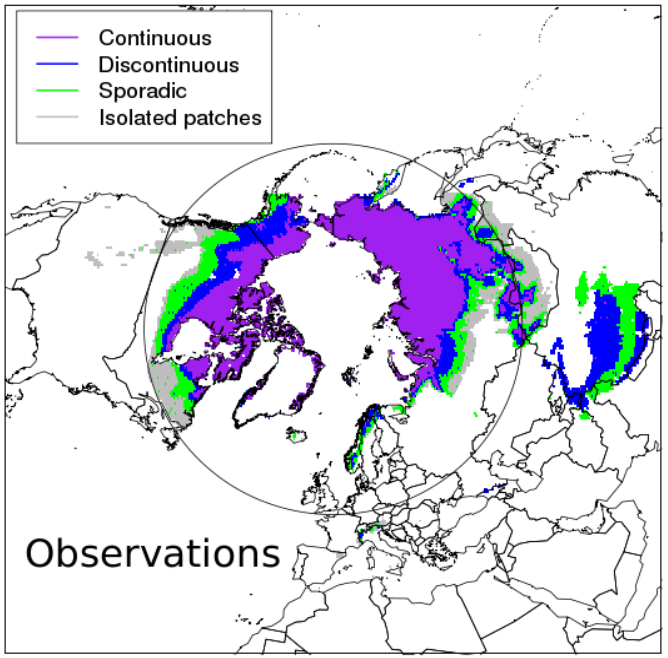
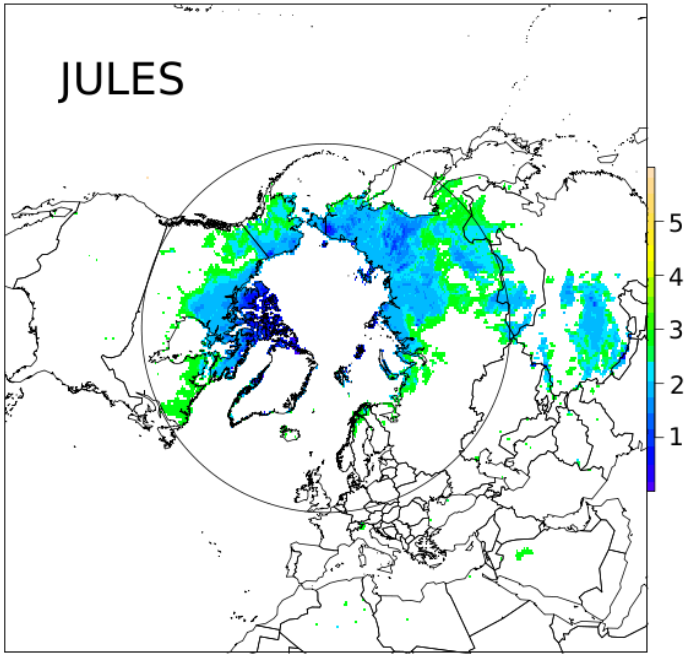


Figure from - Koven, C.D., Riley, W.J. and Stern, A. 2013. *Journal of Climate* **26**: 1877-1900.

Simulating Permafrost with JULES

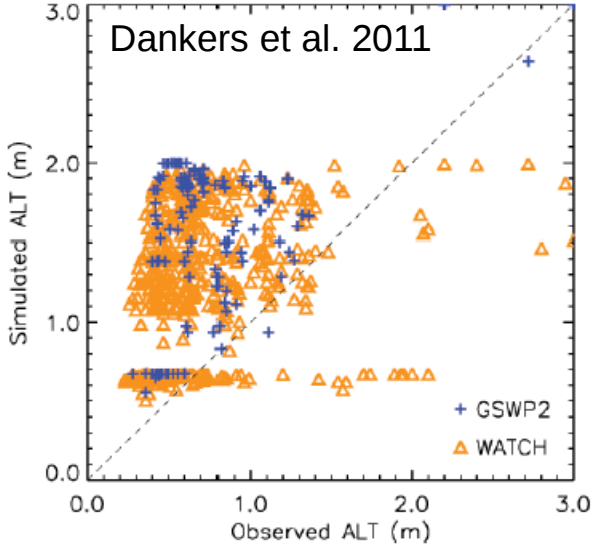


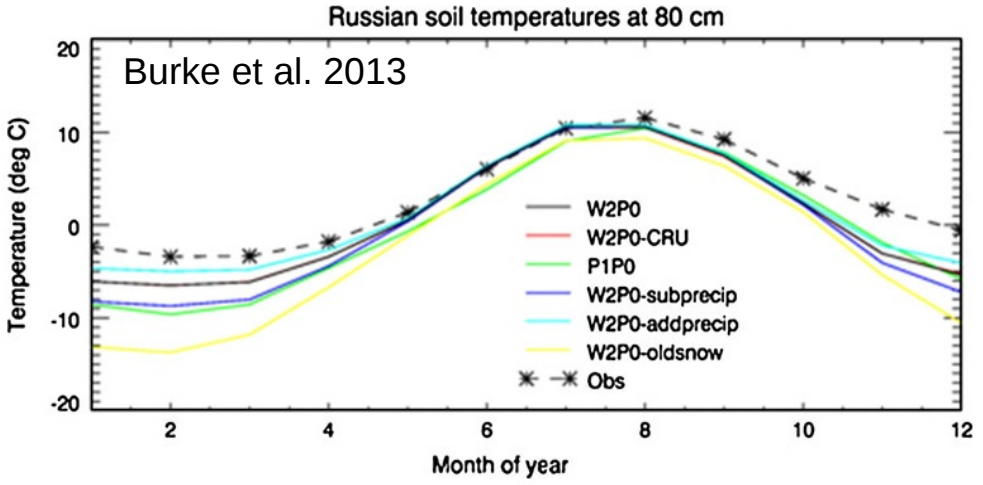


Map of simulated near-surface permafrost (active layer depth < 3m).

Colours show mean active layer thickness.

Permafrost area in JULES matches quite well with observations, but the active layer is too deep, and annual cycle of soil temperatures is too large.





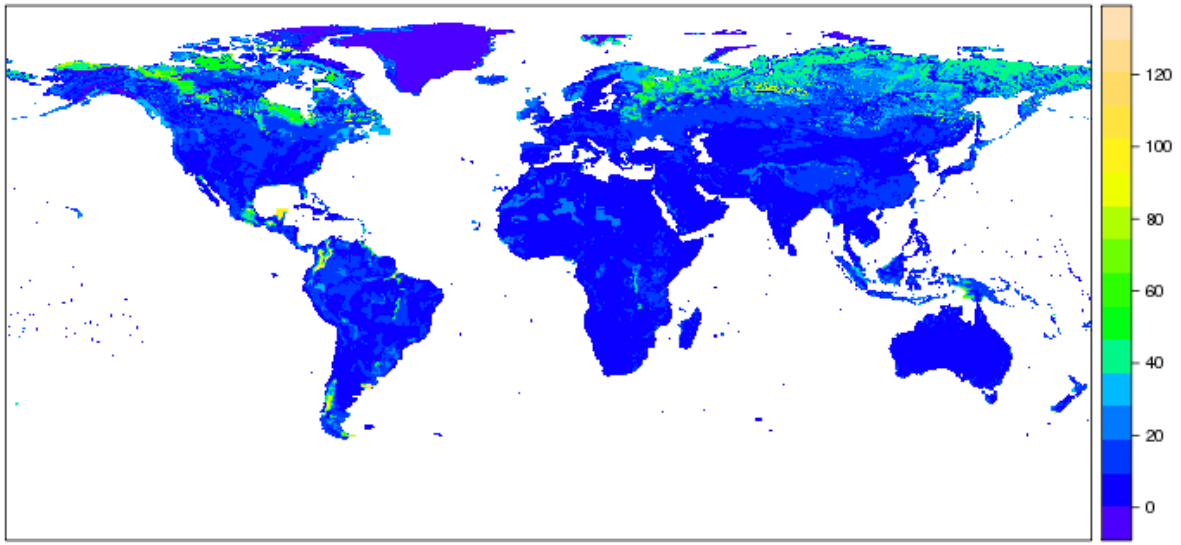
JULES model developments

- Organic soil properties
- Moss cover
- Deeper soil column with more soil layers



Organic soil properties

- Standard JULES only simulates mineral soils.
- Organic fraction derived from HWSD and NCSCD. Organic properties combined with mineral properties for each grid cell.
- Profile of carbon in top 3m of soil (estimated from observations as there is some depth distribution information). Organic properties themselves also change with depth assuming the material is more compressed.
- *Code change also required* to realise full effects of new properties.

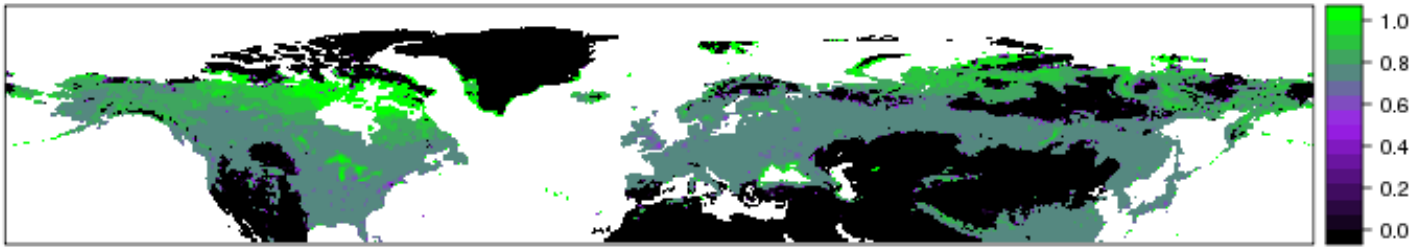


Organic carbon in top 1m of soil from HWSD and NCSCD

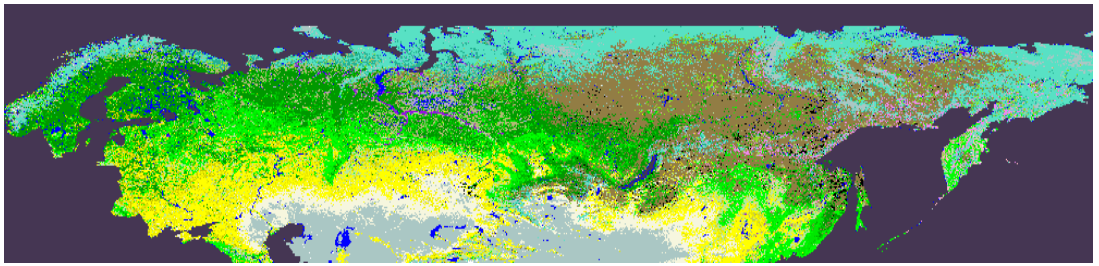
Moss Cover

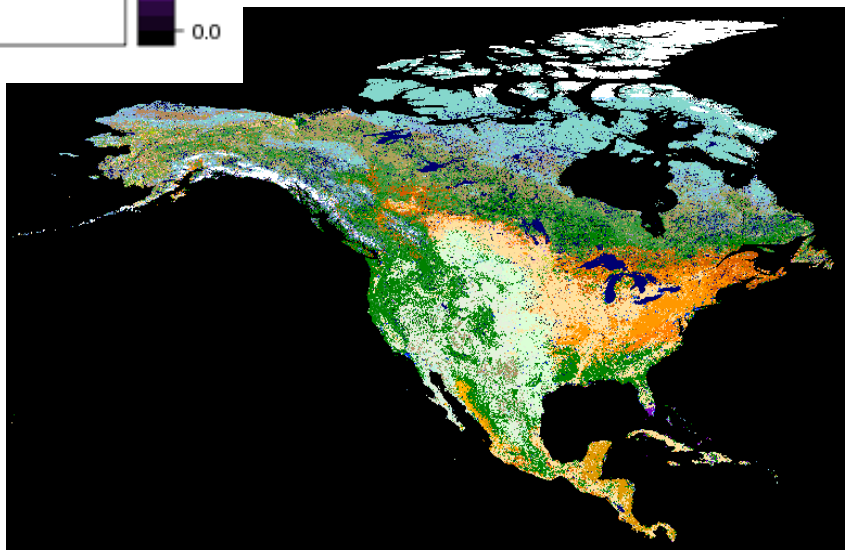
- Properties
  - Changes thermal conductivity at top of soil. Assumes water in equilibrium with top layer. Thermal conductivity of moss from Soudzilovskaia et al., 2013.
  - Growth determined by environmental conditions: water, temperature, light, snow-cover, wind speed.

- Distribution – JULES moss corresponds well to tundra and moss/lichen land-cover classes. It also grows in boreal forests.



Observations from GLC 2000

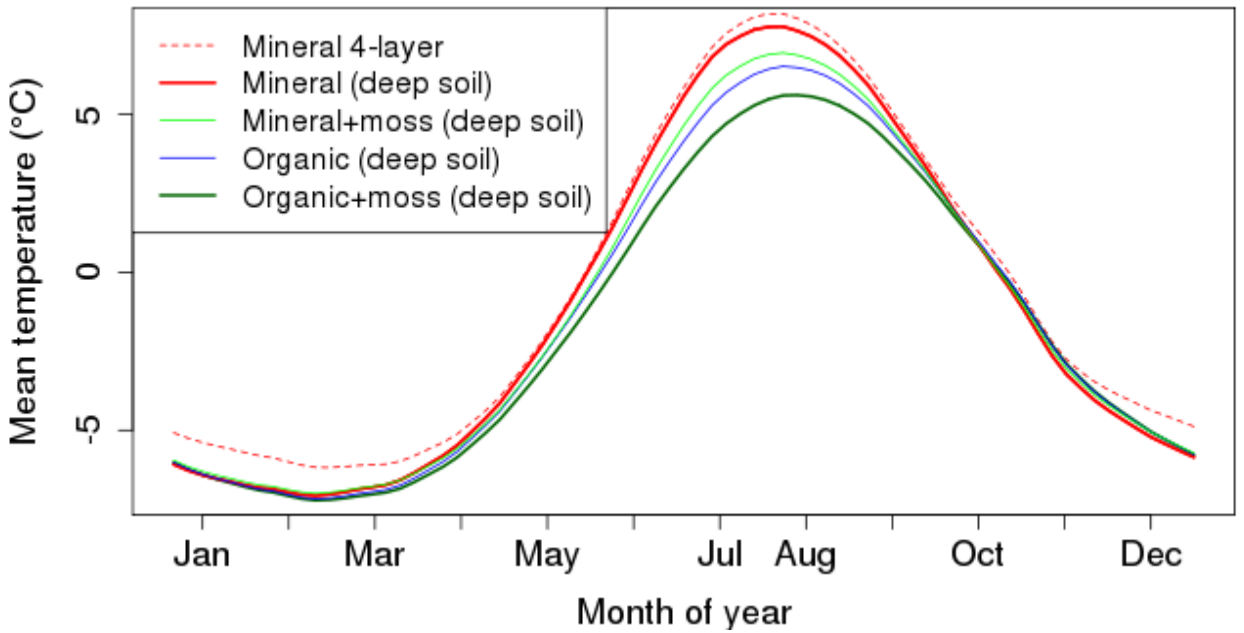




Deeper soil column

- Thermal buffer on bottom of column: only heat diffusion. Can simulate deep soil without computational load. Represents bedrock.
- We also run JULES with a higher resolution of soil layers and deeper soil hydrology.

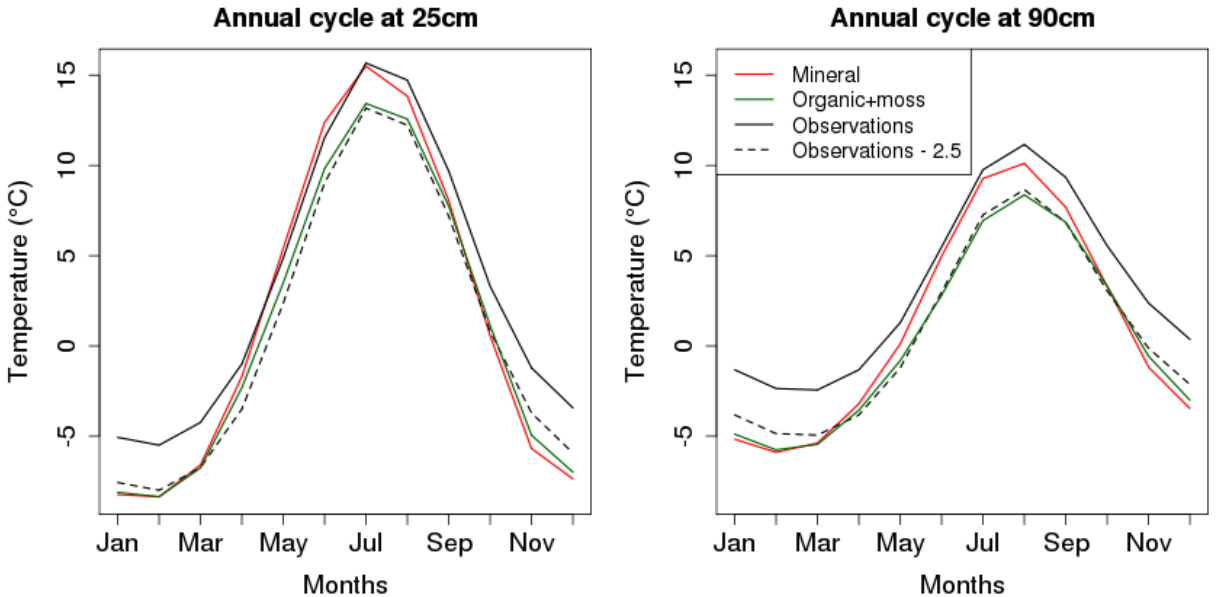
Impact of model developments on soil temperature dynamics



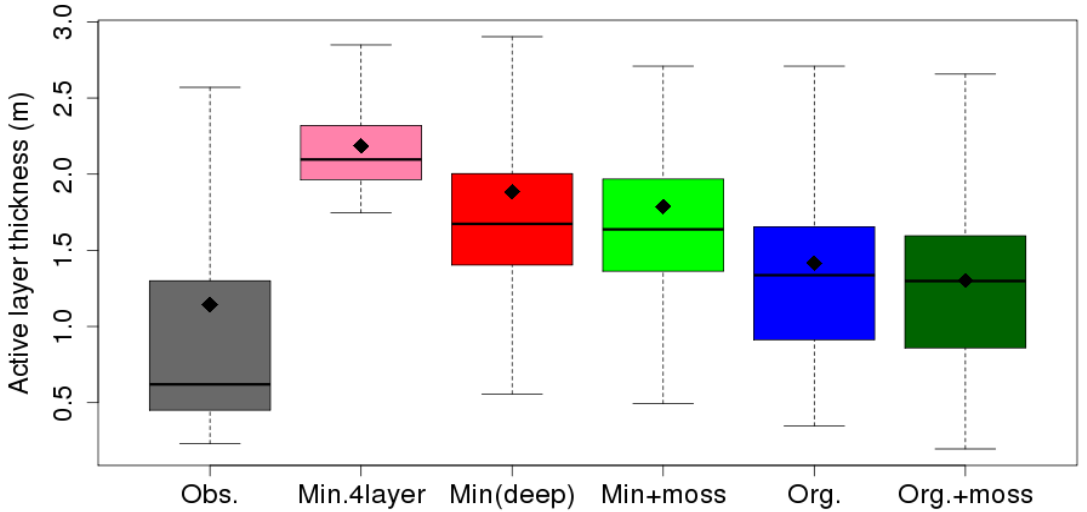
Simulated annual temperature cycle north of 50 degrees latitude at 65cm depth.

Amplitude of annual cycle of soil temperatures is reduced by soil insulation.

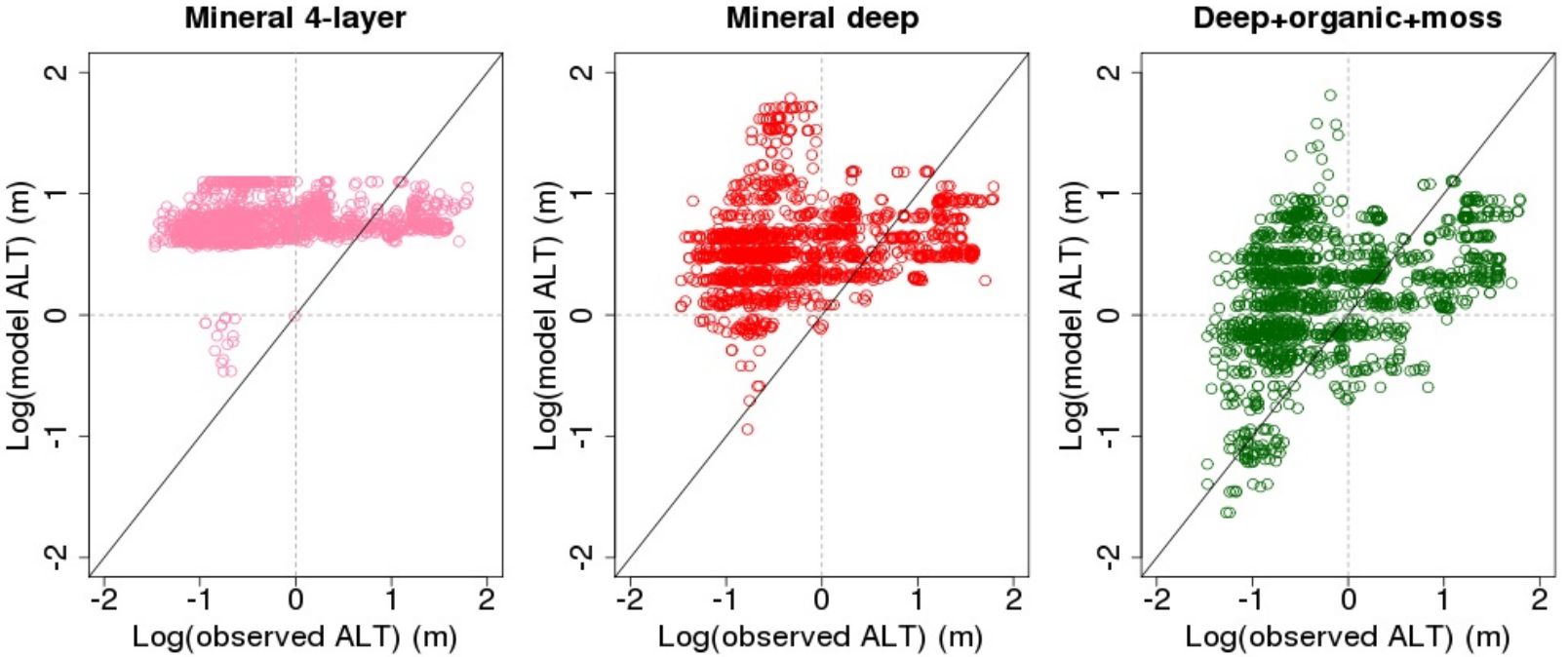
Comparison with Russian Historical Soil Temperature Data



Impact of model developments on permafrost dynamics



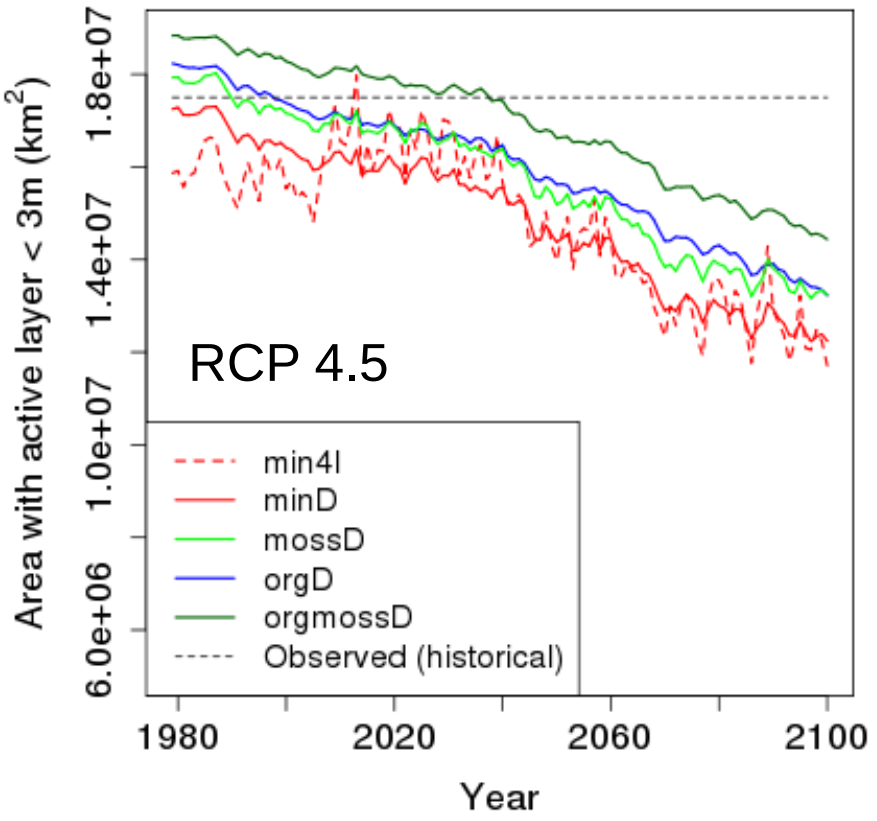
Insulating processes reduce active layer depth. Comparison with observations from CALM dataset* is improved.

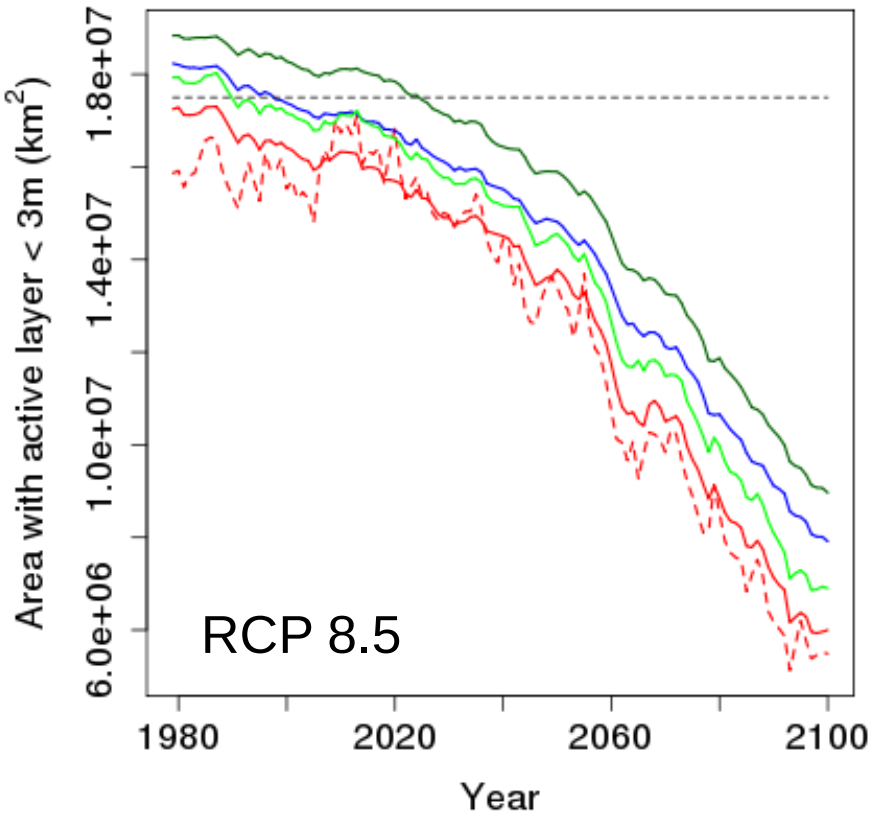


* Brown, J., Nelson, F. E., and Hinkel, K. M.: The circumpolar active layer monitoring (CALM) program: research designs and initial results, Polar Geography, 3, 165–258, 2000.

Future projections of permafrost loss

Future runs using climate anomalies from CCSM4 (as in RCN). The area with near-surface permafrost decreases dramatically and at a similar rate for all runs.





Conclusions

- Including insulating processes (moss and organic matter) and the full depth of the soil column improves the present-day permafrost dynamics in JULES, particularly the active layer depth.
- These processes increase the simulated area of near-surface permafrost in the model and reduce its inter-annual variability. However, they do not significantly change the sensitivity of permafrost loss under future climate warming.

Future...

- Current model development work: Vertically resolved soil carbon
- We are hoping to get developments into the JULES trunk soon. If you want to use the code, get in touch:

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