Impact of permafrost carbon release on global temperature

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Permafrost carbon release

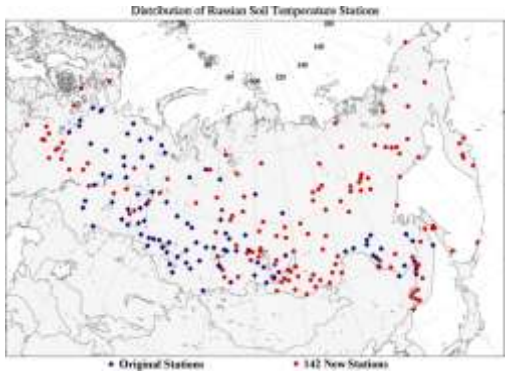
- Increased global temperature
- Loss of permafrost
- Inert old soil carbon becomes available for decomposition
- Released as CO_2 or CH_4
- Causes an additional temperature increase
- Positive feedback

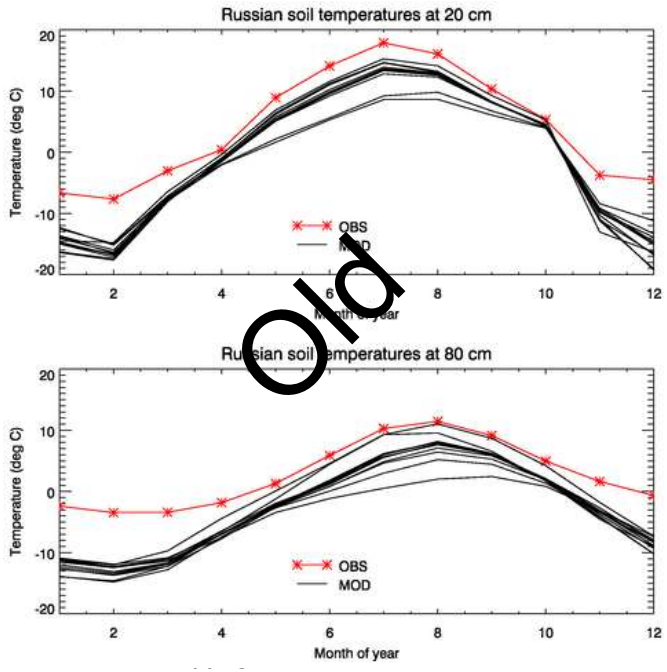
At present permafrost extent and degradation can be simulated by JULES but not the loss of permafrost carbon

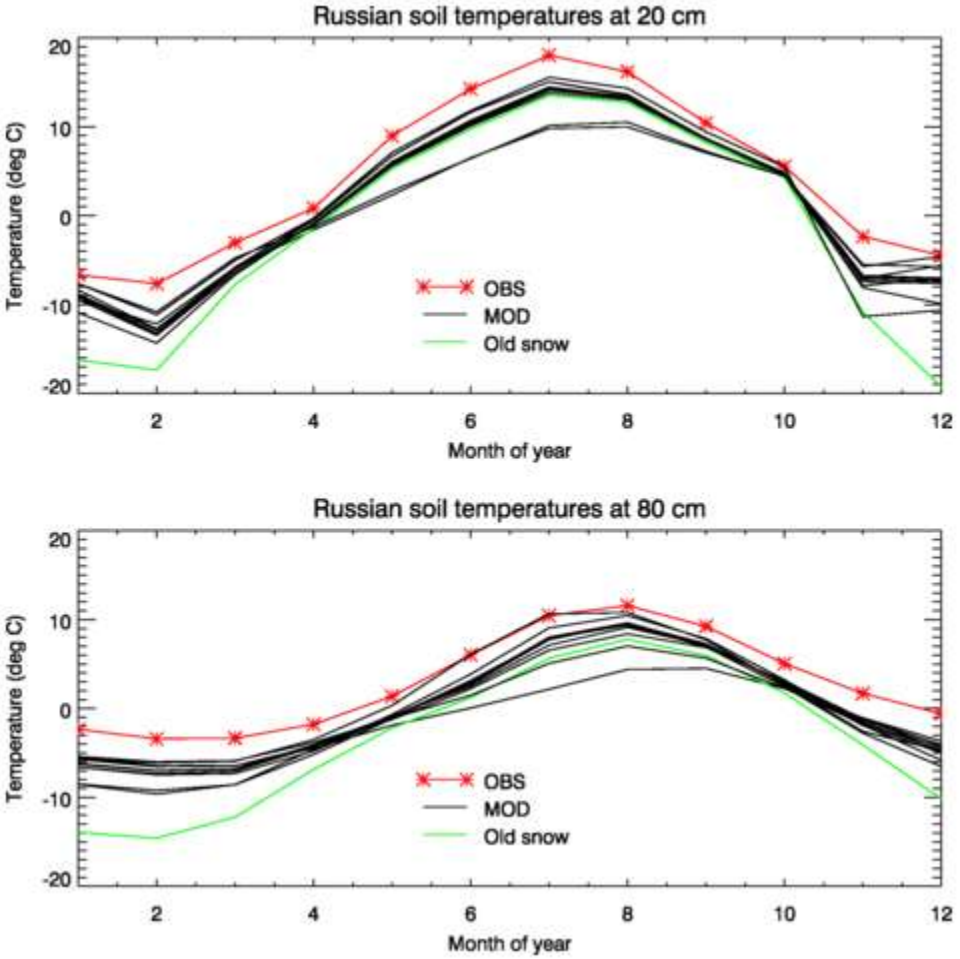
Contents

- JULES simulations of permafrost extent and degradation
- A simple framework coupling JULES with an estimate of permafrost carbon release under increased global temperature
- Explore the impact of uncertainties in permafrost degradation and carbon release on the increase in global temperature

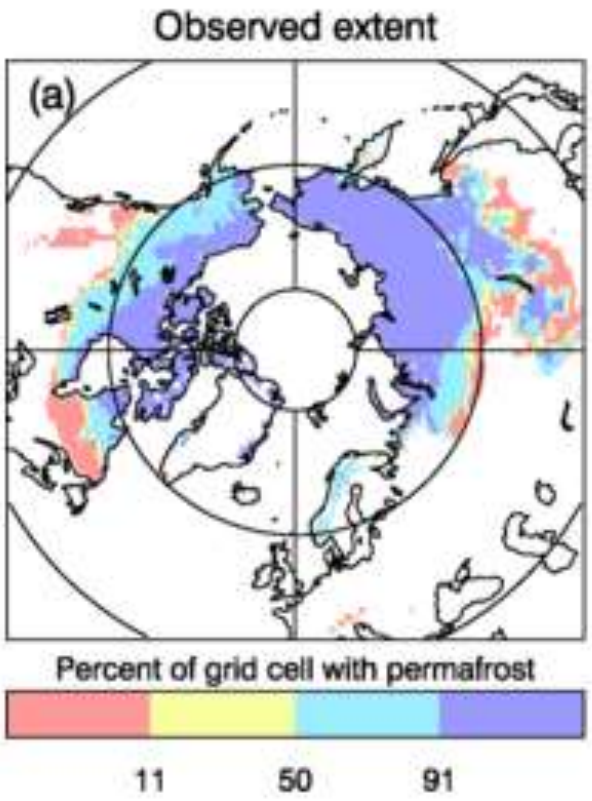
Improved JULES simulations of soil temperatures with new snow scheme

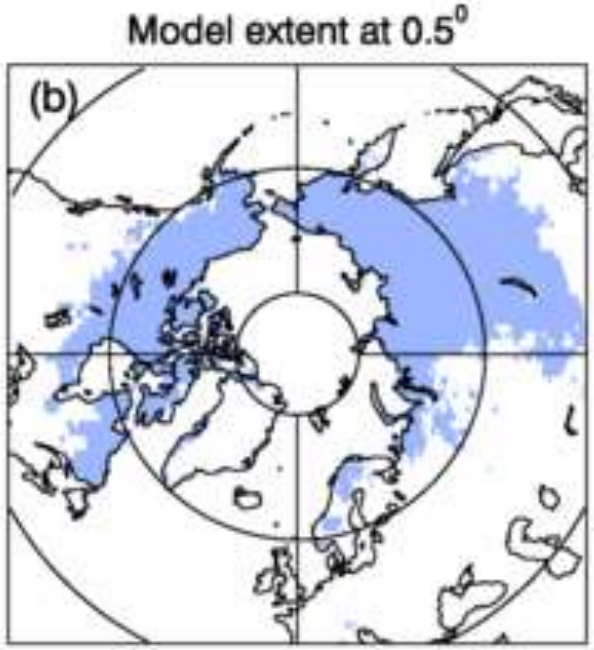






Reduced (improved) permafrost extent with new snow scheme





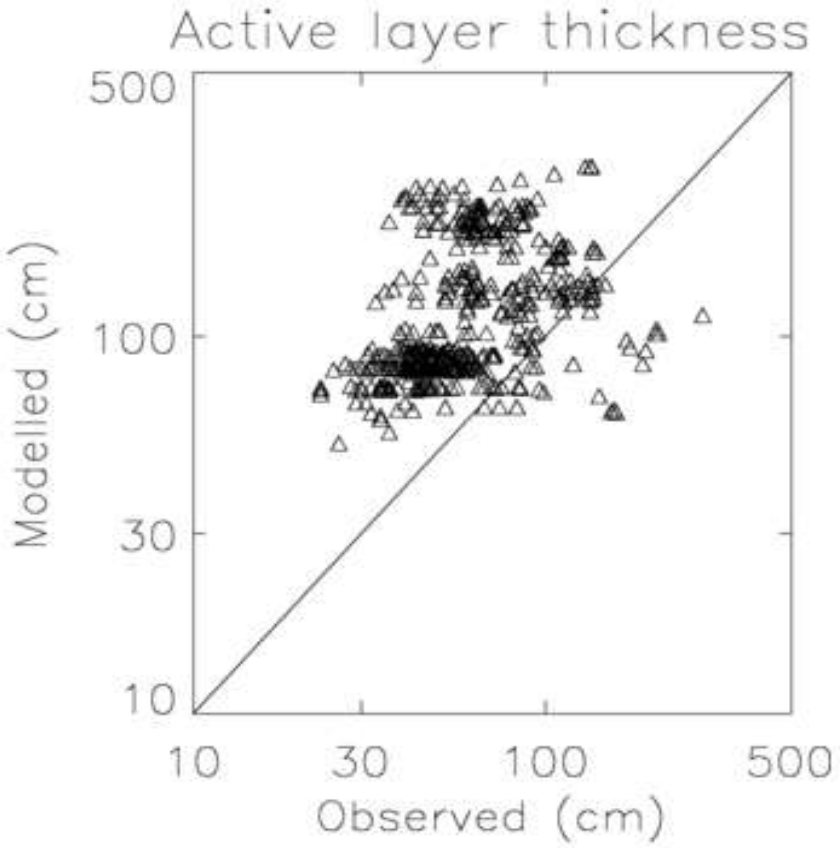
Observed

Area of grid cells with permafrost ~21 x10^6 km^2

Modelled

Area of grid cells with permafrost ~21 x10^6 km^2

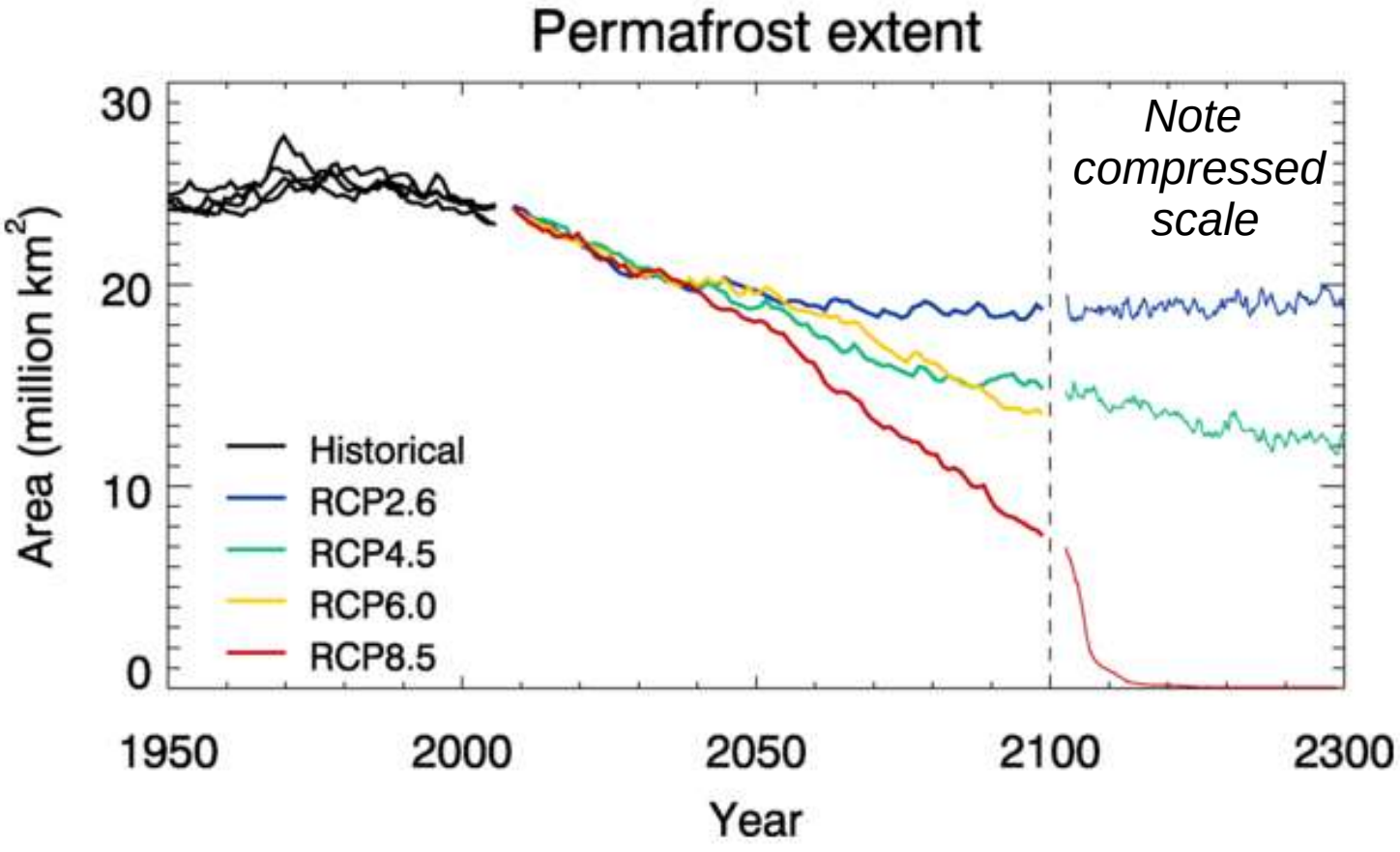
Increased biases in active layer thickness



- Modelled active layer now deeper than observed by, on average, 55 cm

- JULES still needs work! However we have used it to provide an initial estimate of permafrost degradation.

Simulation of permafrost degradation with JULES-based model in HadGEM2-ES



20th century & 4 future scenarios with HadGEM2-ES

Large scenario uncertainties

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Simple framework for permafrost carbon release

Structure of simple framework

Permafrost degradation

Changes in permafrost table, active layer thickness and duration of thawing period simulated by JULES (in this example the land surface scheme within HadGEM2-ES).

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Vulnerable carbon

Carbon available for decomposition depends on amount in thawed volume found from the Northern Circumpolar Soil Carbon Database (Tarnocai et al., 2009).

⇓

Carbon decomposition model

Decomposition rates and form of released carbon (CO_2 or CH_4) dependent on land cover (lakes, wetlands or uplands). Land cover found from the Global Lakes and Wetlands Database (Lehner & Döll, 2004).

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Impact of CO_2 & CH_4 on global temp.

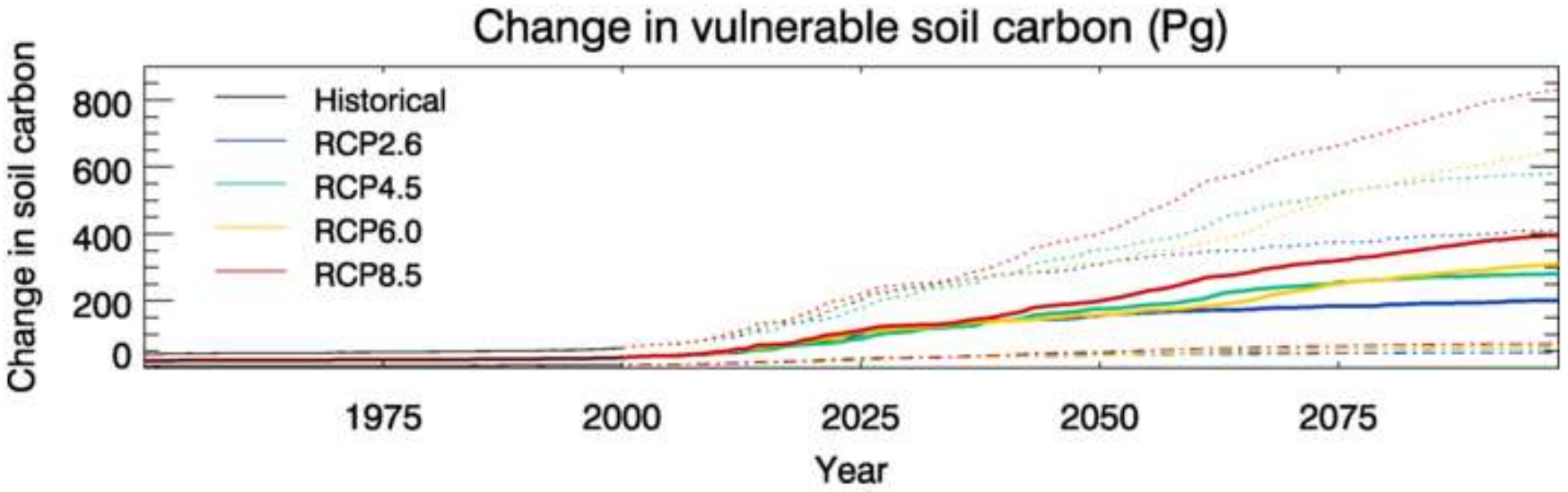
Simple energy balance model of global mean temperature change based on HadGEM2-ES.

ALL STEPS HAVE LARGE ASSOCIATED UNCERTAINTIES

Vulnerable carbon

On days that the soil is thawed any organic carbon in the thawed volume is vulnerable to decomposition.

Current atmospheric carbon content ~700 Pg.



Spread of values shows uncertainties from the distribution of soil organic carbon.

Soil carbon decomposition to CO_2

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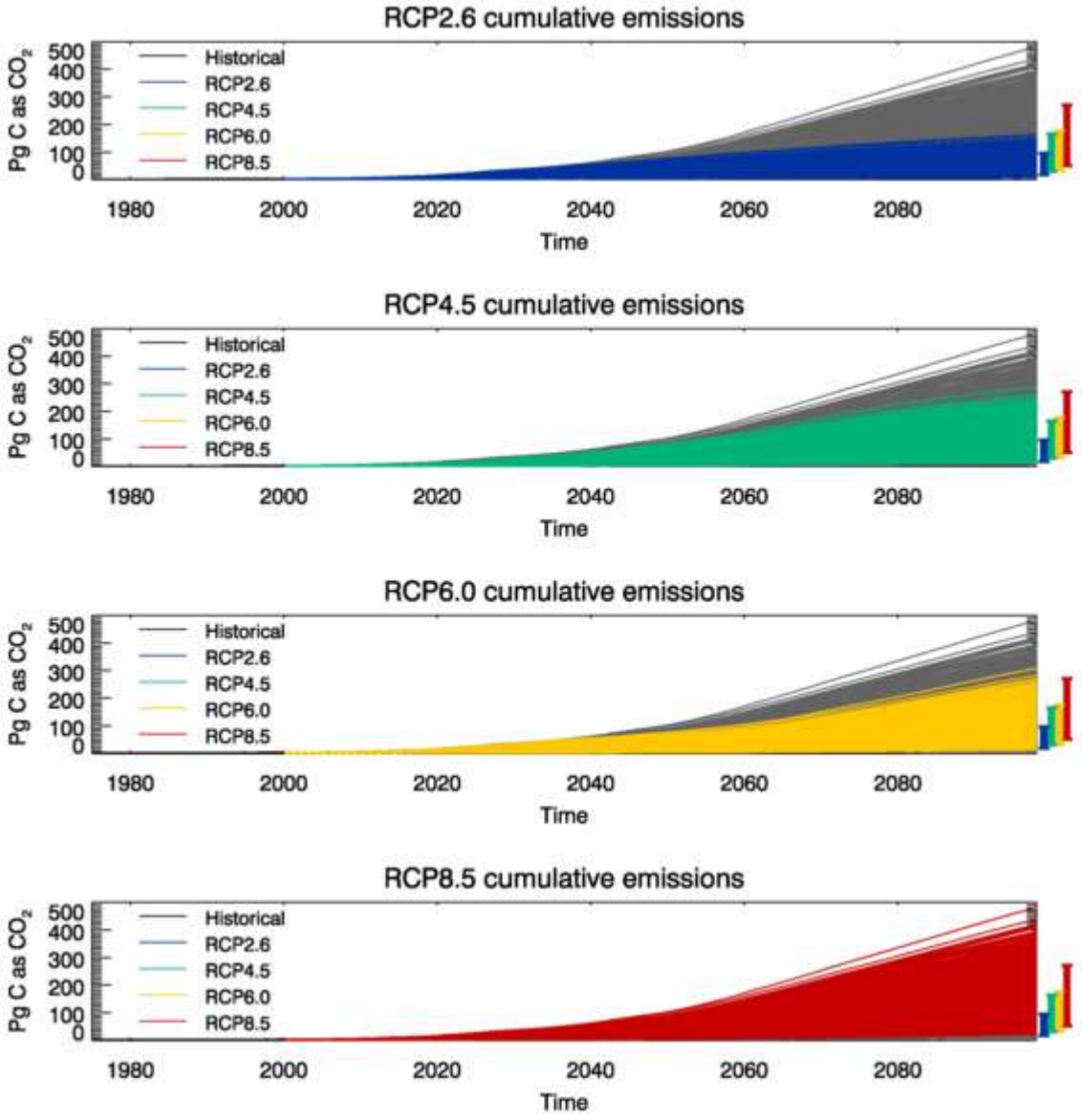
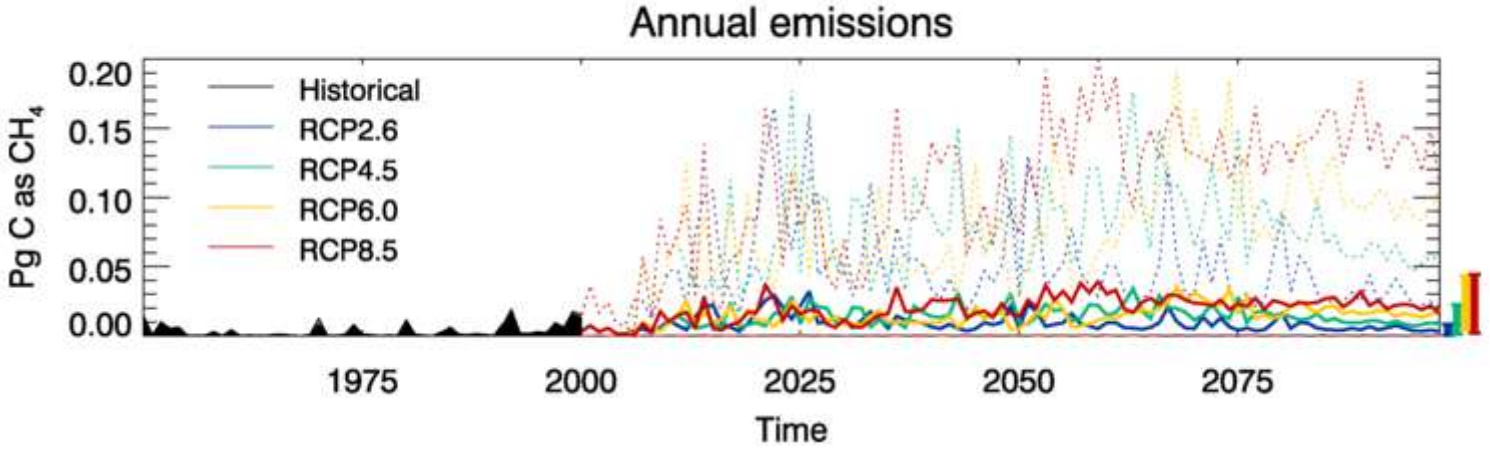
Emissions of CO_2 calculated by the soil carbon decomposition model for feasible range of parameters.



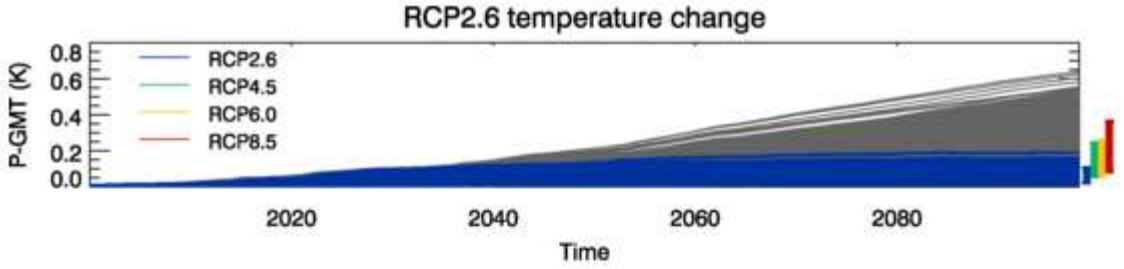
Soil carbon decomposition to CH_4

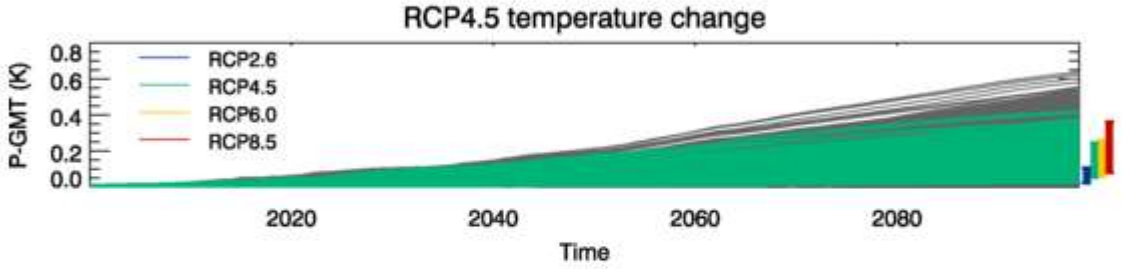
Emissions of CH_4 calculated by the soil carbon decomposition model for feasible range of parameters.

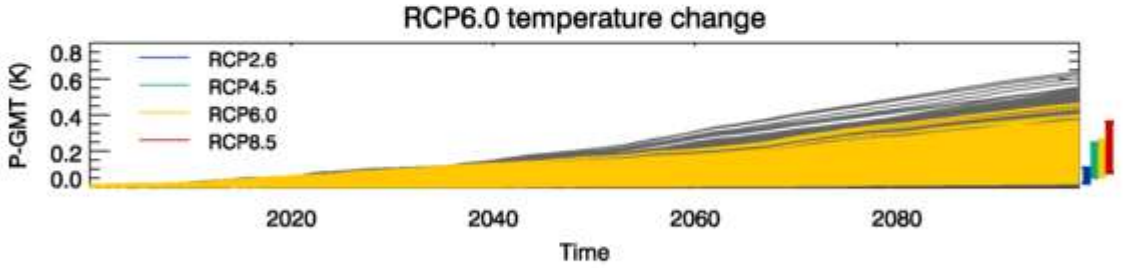


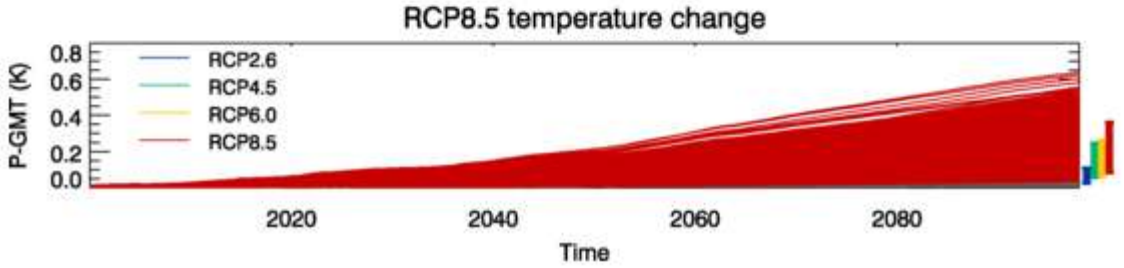
RCP8.5: 2 - 59 Tg CH_4 per year by 2100 (5^{th} – 95^{th} range)

Impact of released CO_2 & CH_4 on global mean temperature (P-GMT)

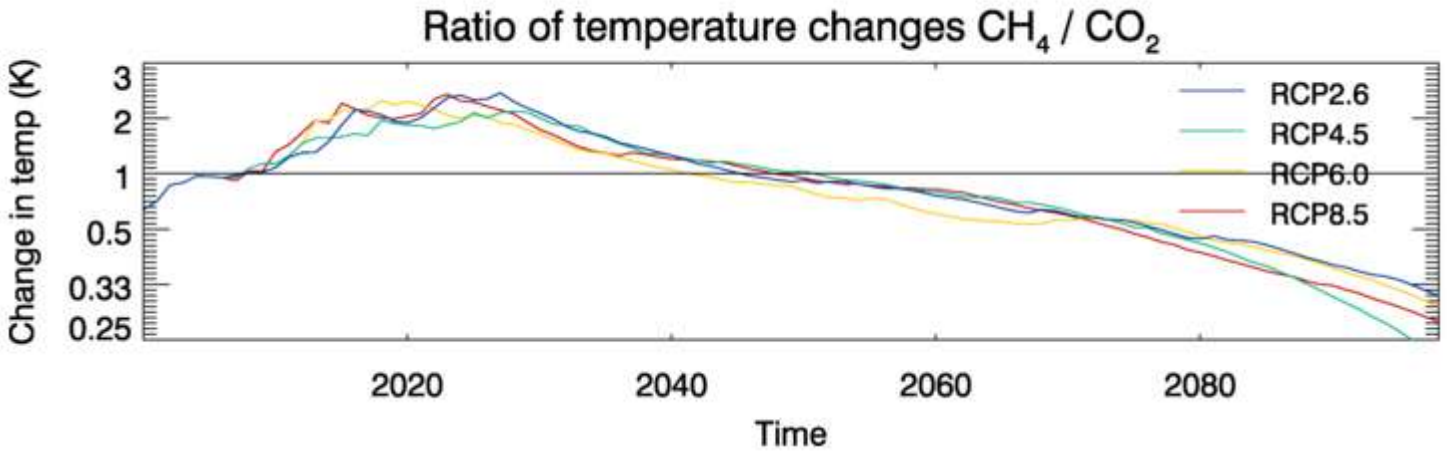








Relative impact of released CO_2 & CH_4 on global mean temperature



Is the framework too simple?

- Thermokarst development

- Future changes in vegetation, precipitation and soil water availability, wetlands, CO_2 fertilization
  - Are they adequately modelled?

- No model representation of ice wedges, mosses, peat soils, nutrient availability, fire, cryoturbation, ‘Compost bomb’, (etc)

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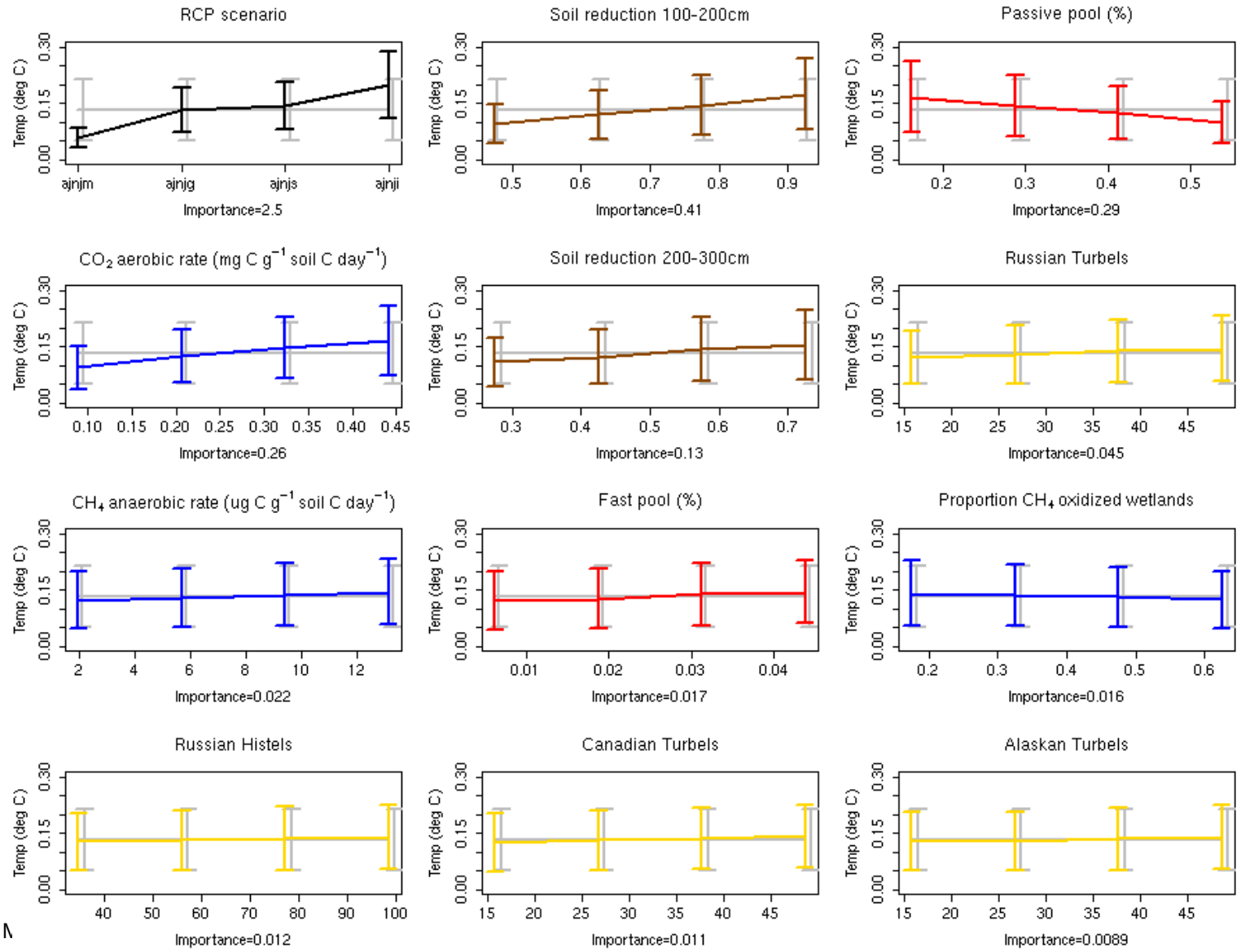
Uncertainties

Uncertainty analysis

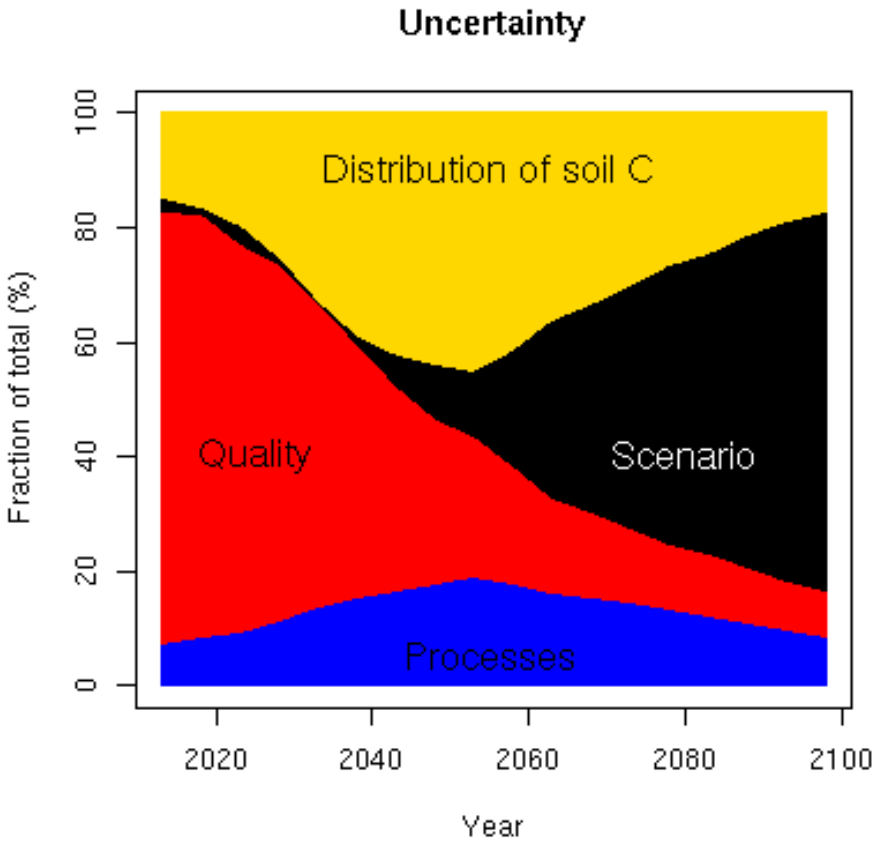
- Uncertainties included are from:
  - RCP scenarios
  - Soil carbon spatial and profile distribution
  - Soil carbon quality
  - Soil decomposition model parameters

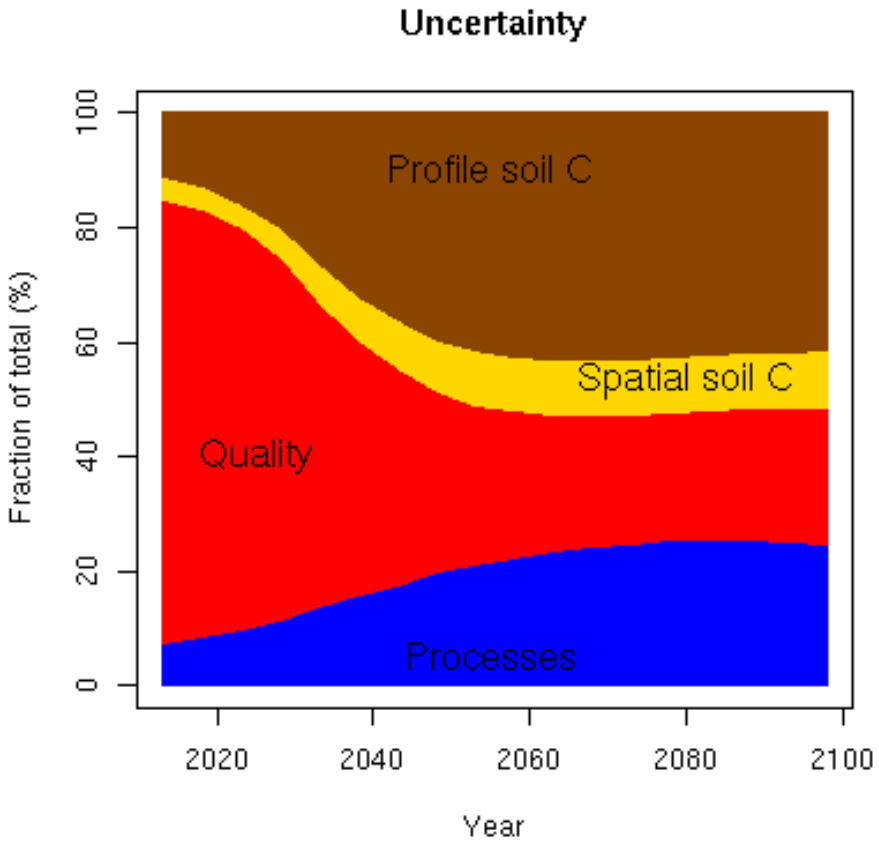
- Use many Monte-Carlo simulations where relevant processes/parameters are varied to quantify the dependence of the permafrost carbon temperature change on each of the uncertainties.

Sensitivity of temperature change to parameter values for 2100



Spread in temperature change caused by each group of parameters





Important to know soil carbon distribution

Summary

- JULES is OK at representing permafrost extent but has too deep a maximum thaw depth (could do better!)
- A simple framework for the impact of permafrost carbon release on global temperature has been developed.
- There are large uncertainties in this framework many of which could be reduced through additional observations.
- A representation of permafrost carbon release needs to be incorporated within JULES to enable the permafrost carbon feedback to be studied within the global climate model.

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Questions and answers