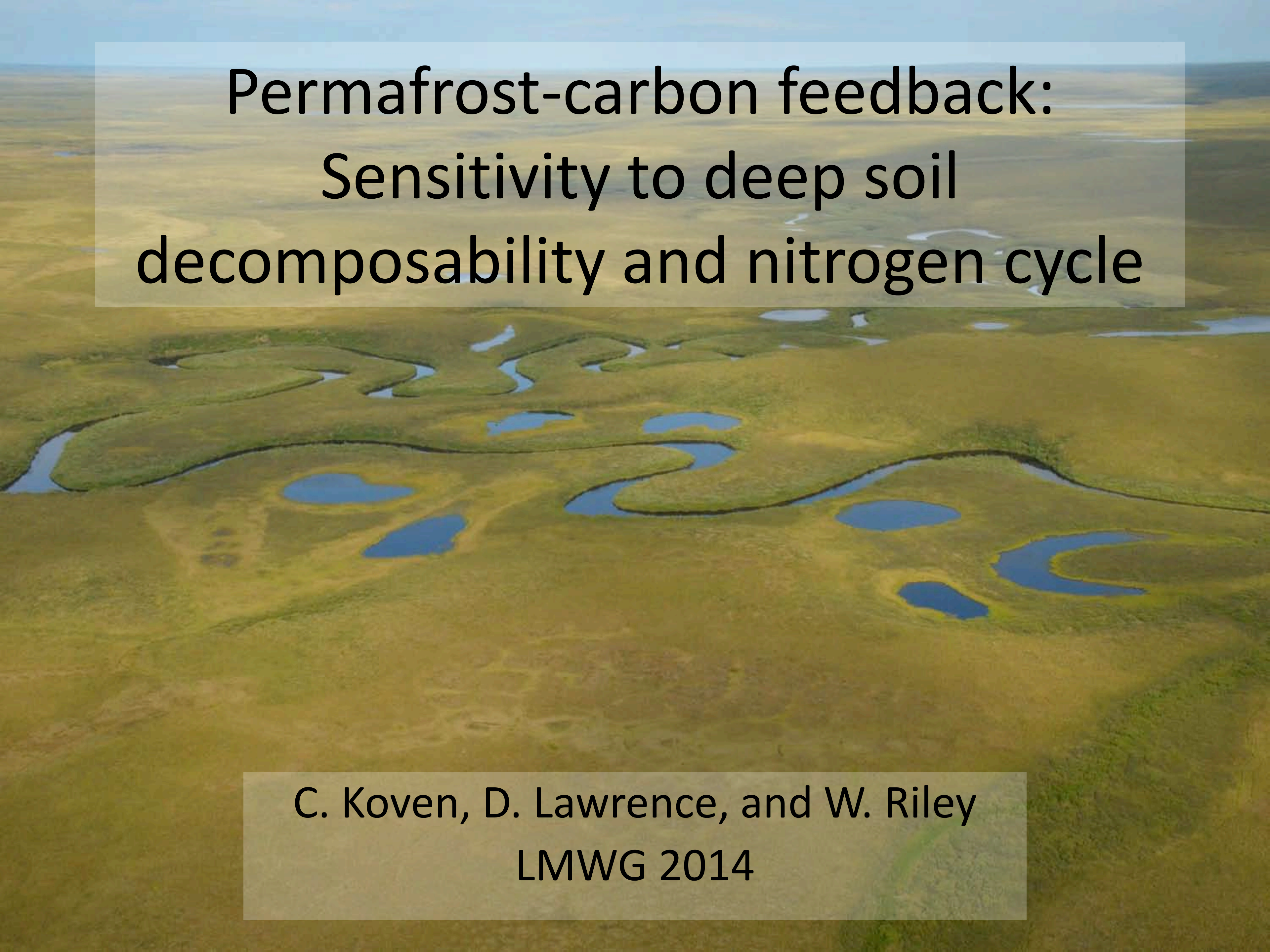
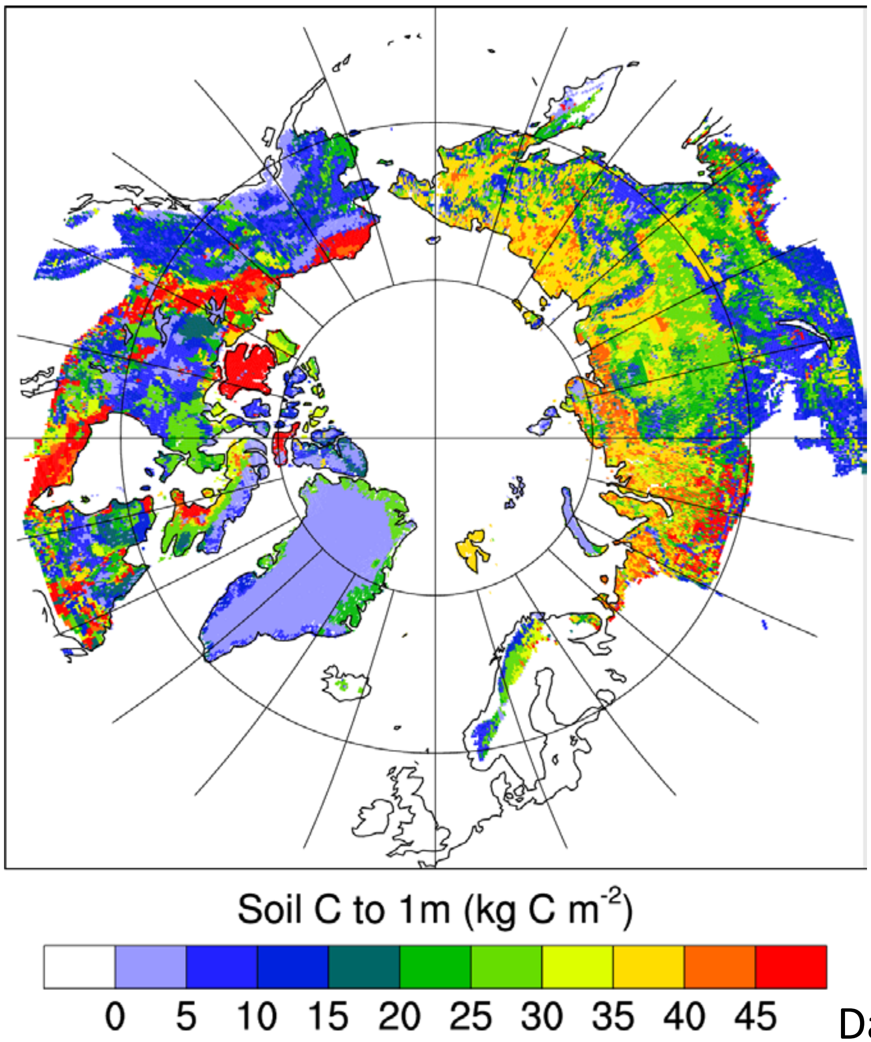


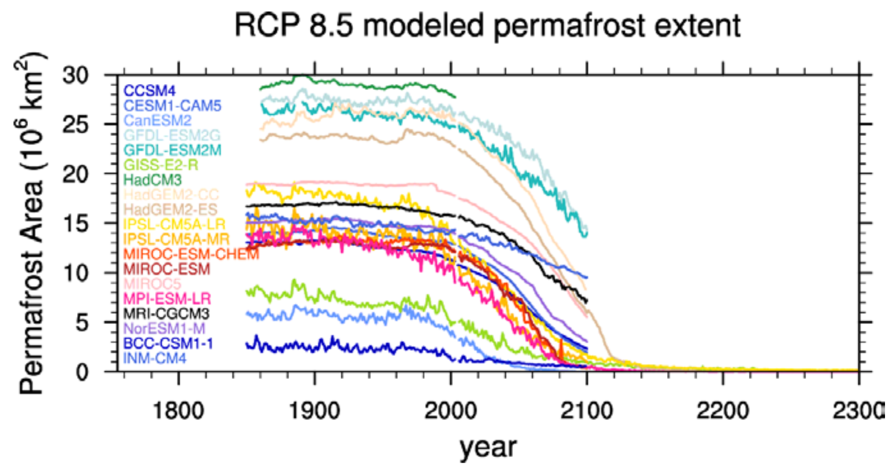
Permafrost-carbon feedback: Sensitivity to deep soil decomposability and nitrogen cycle

C. Koven, D. Lawrence, and W. Riley

LMWG 2014

Motivation: Enormous stocks of C in permafrost soils, whose stability is contingent on being frozen. What happens to this SOM under warming?

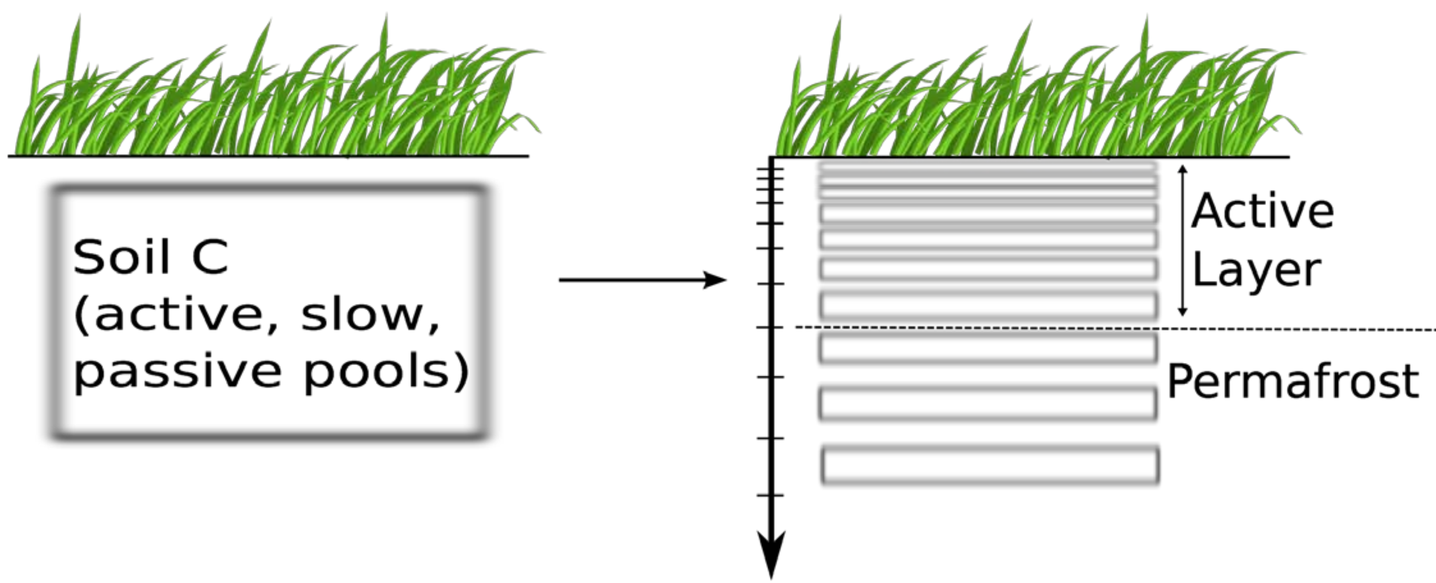




Koven et al., 2013

Data: NCSCD (Tarnocai et al., 2008, Hugelius et al., 2012)

CLM4.5BGC: Simplest approach to represent 1-D permafrost processes (active layer deepening) by including the vertical dimension in SOM cycling, to represent the physical controls on mixing and decomposition rate in soils.



Controls on Soil Turnover in CLM4.5BGC:

base rate, temperature, moisture, oxygen, and depth modifiers

$$k_i = k_{0,i} r_T r_w r_O r_z$$

Q_{10} (of 1.5)

Matric potential of (unfrozen) water

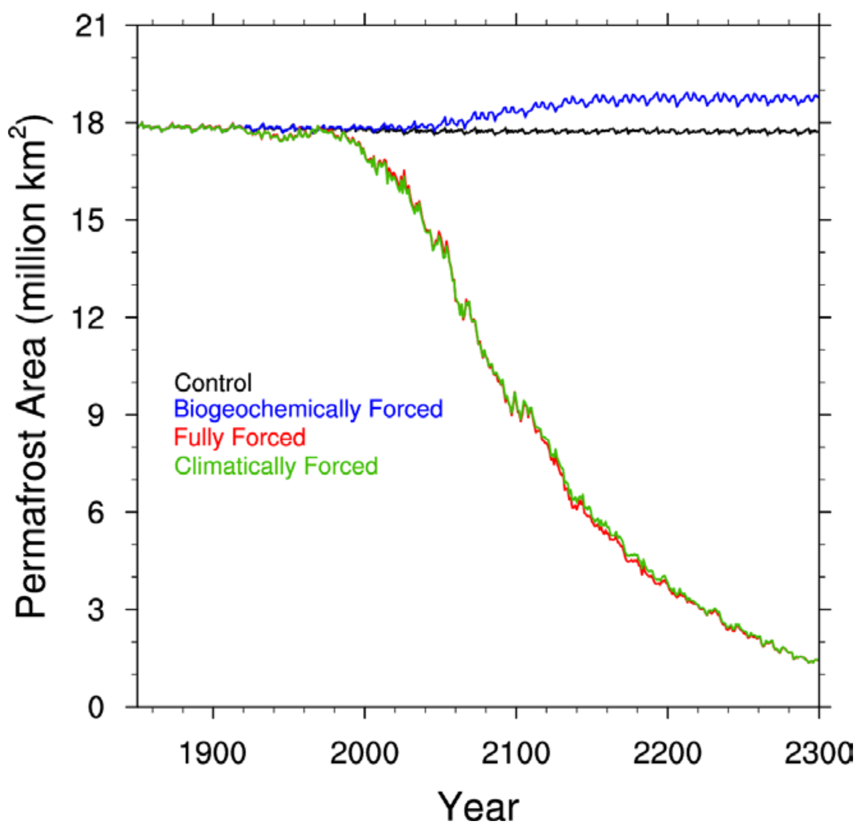
Stoichiometric oxygen supply vs. demand

$$r_z = \exp\left(-\frac{z}{z_\tau}\right)$$

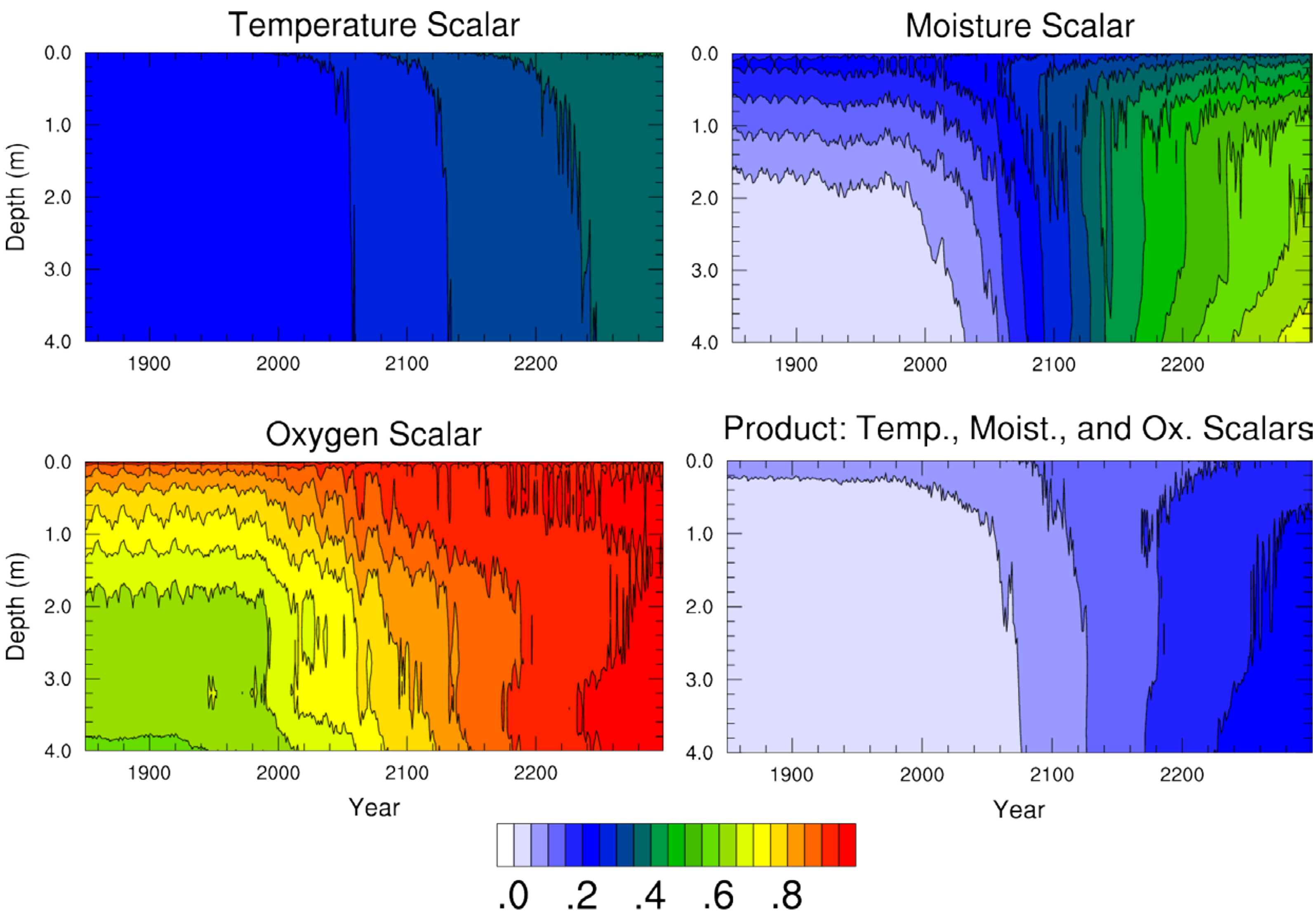
Experimental Design: Use Z_τ to assess the sensitivity of response to the decomposability of deep SOM

Full experimental setup in CLM4.5 :

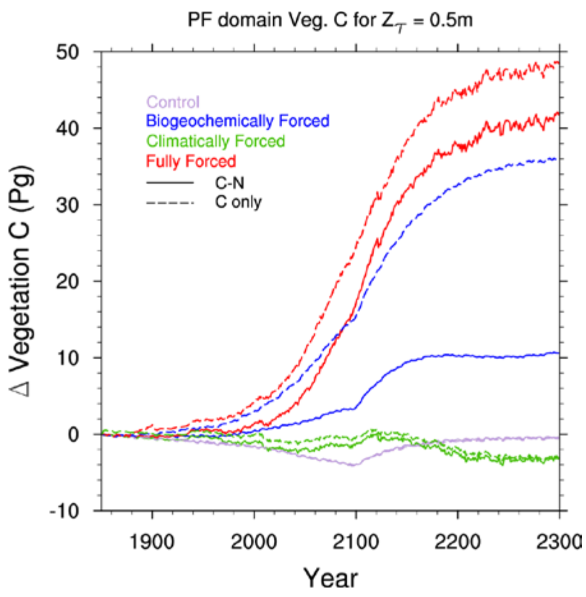
1. Forced by offline transient historical+RCP8.5 warming and/or CO_2 scenarios to calculate physical and biogeochemical responses to climate change, CO_2 fertilization, and interactions
2. CLM4.5BGC including N feedbacks vs. C-only version of CM4.5BGC to assess role of N feedbacks
3. Vary Z_τ to assess role of deep SOM

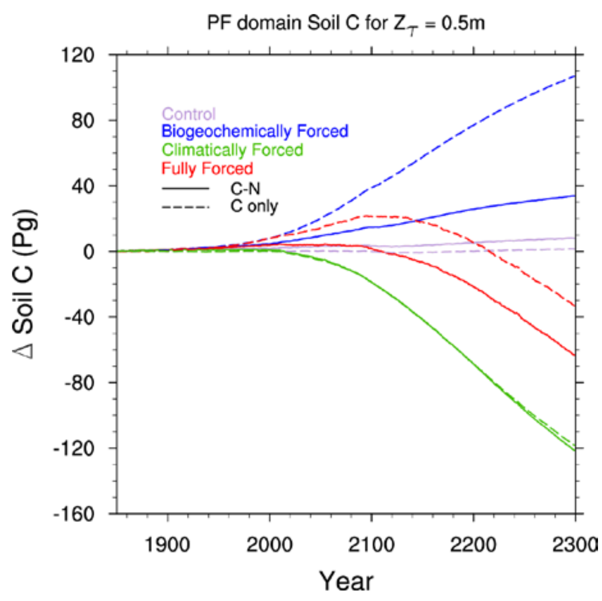


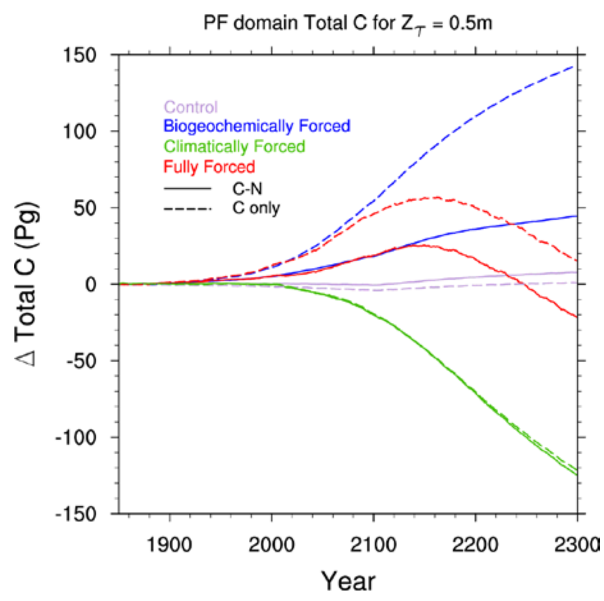
Reversal of vertical profile in environmental decomposition limitation as permafrost changes to seasonally frozen ground. Note that strongest control is via the (liquid) moisture scalar.



C cycle response with non-responsive deep permafrost: sensitivity to C-N coupling and experimental forcing

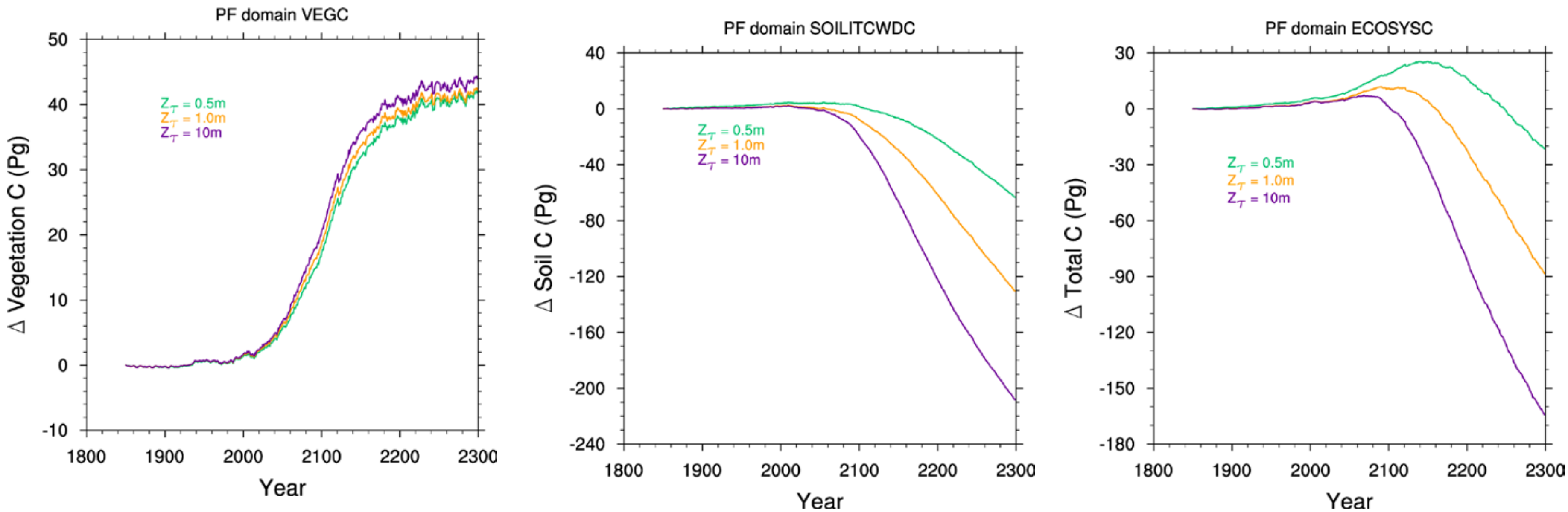






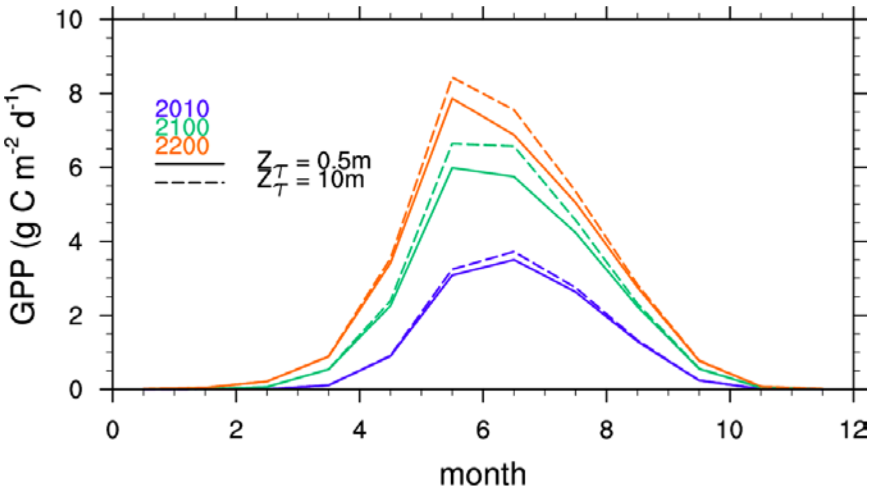
In the absence of decomposable deep SOM, CO_2 fertilization and soil C losses nearly balance each other out for a small net change

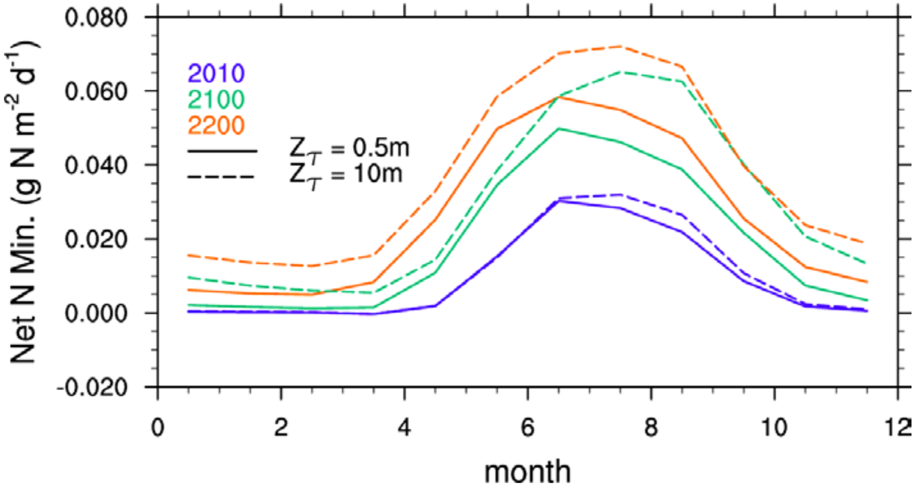
Full response as a function of deep soil decomposability



With decomposable deep SOM, soil C losses dominate and lead to a large positive feedback from the permafrost region

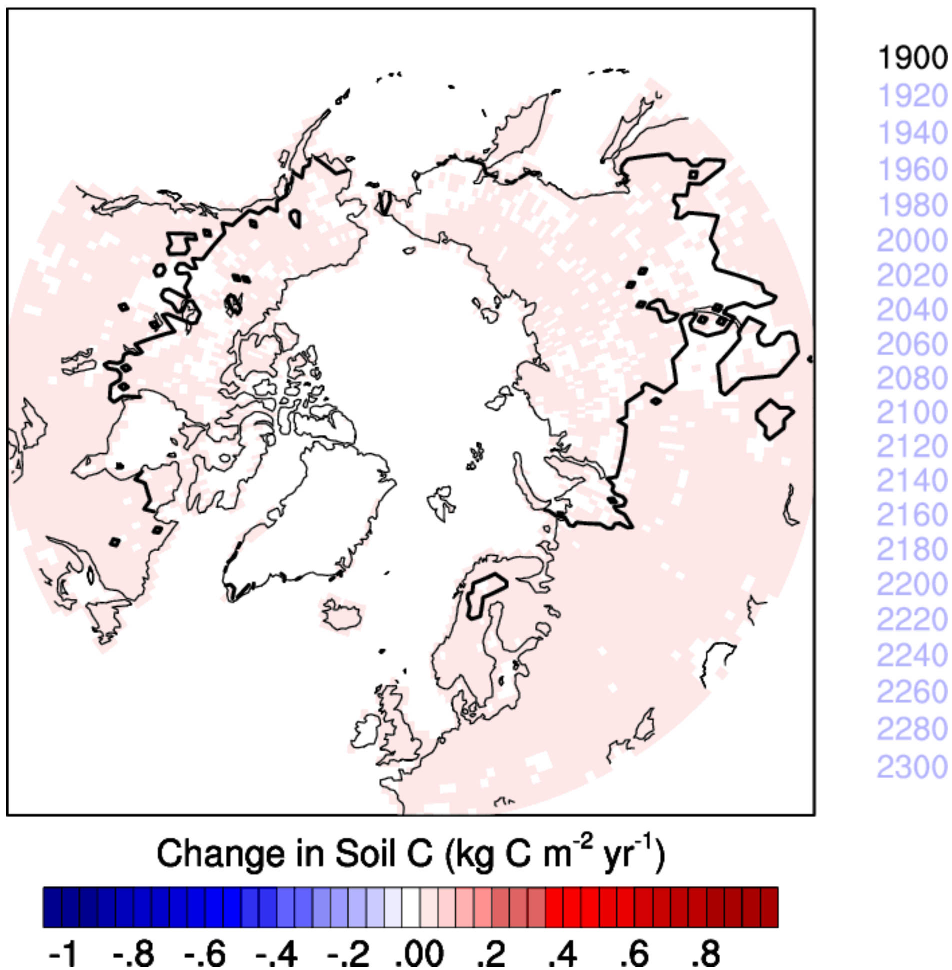
Why small response of vegetation to additional N from mineralizing deep N?



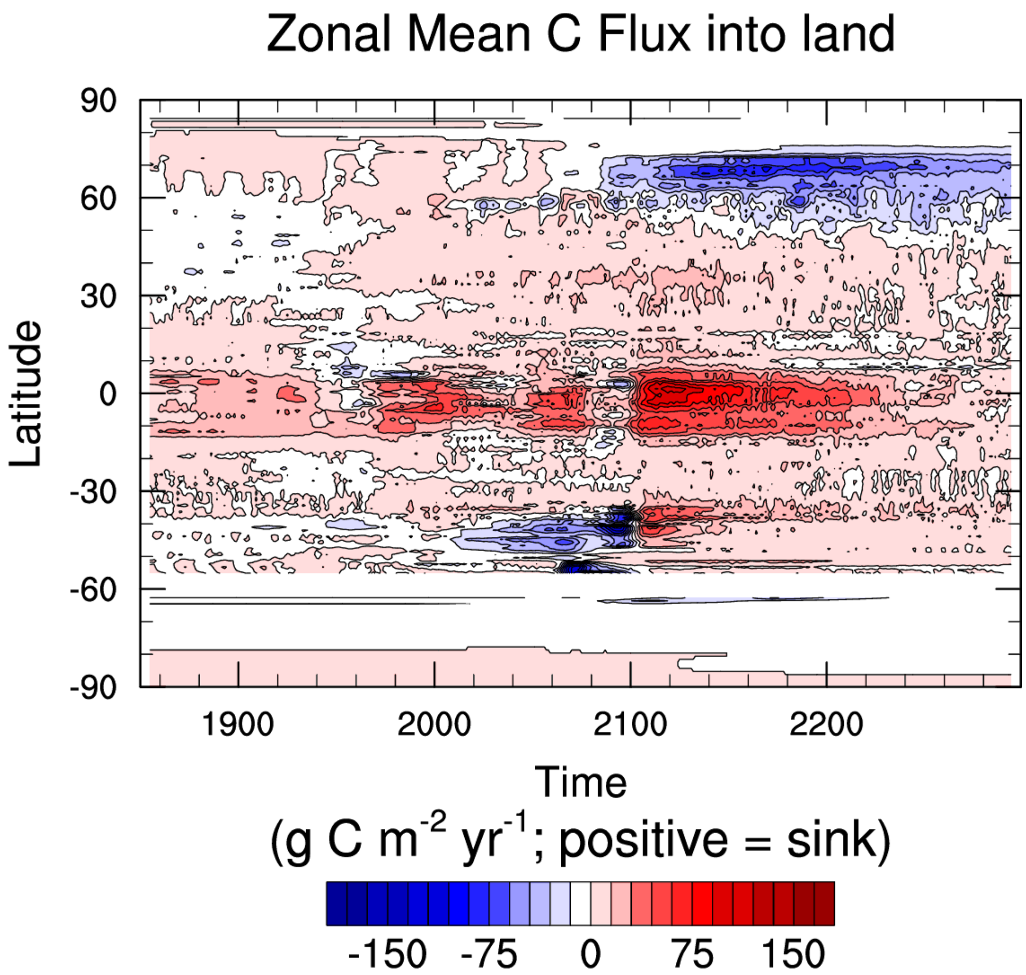


Seasonal asynchrony between N demands and extra N supply means that deep SOM not as available for plant uptake;
Also, plants already getting extra N from shallow soils

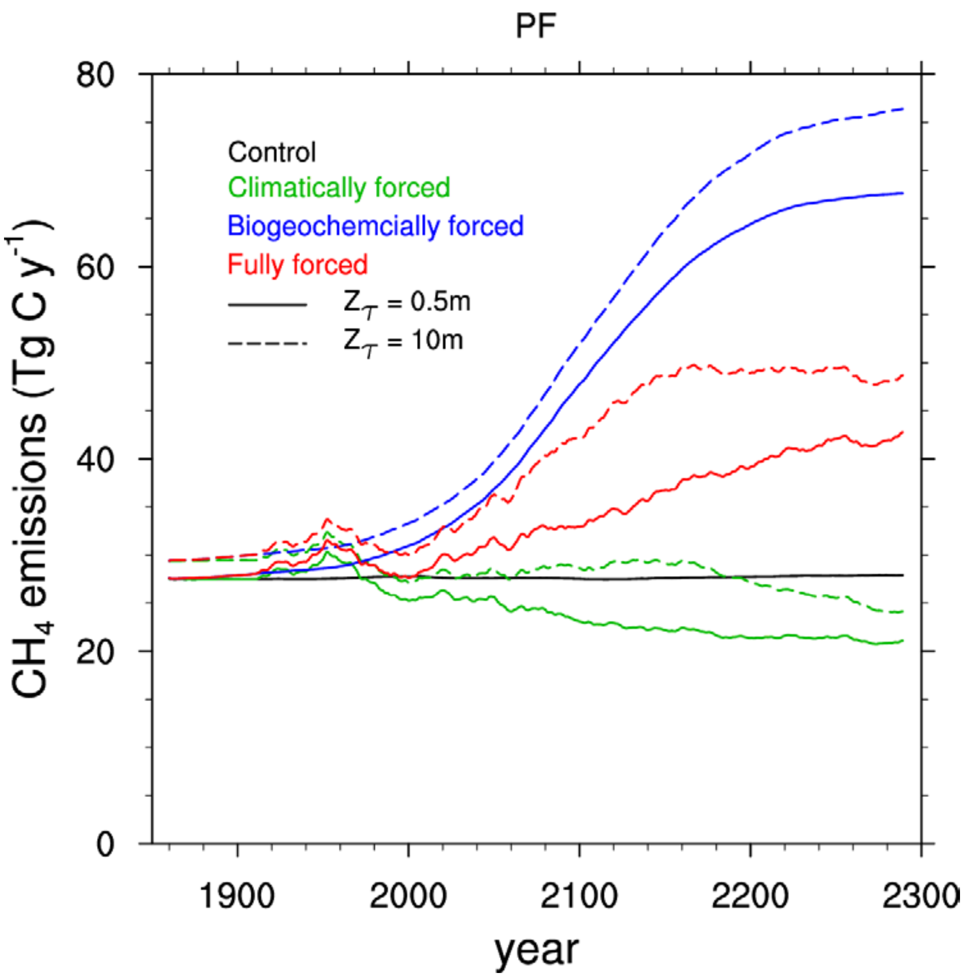
Projected soil C emissions follow the retreating permafrost boundary and persist long after permafrost has thawed



Global relevance of permafrost C-climate feedback



CH_4 emissions from deep C are present but projected to be much smaller contribution to feedback (~10% in 100-yr GWP) than CO_2 emissions and partially offset by drying associated with warming and thawing soils. However CH_4 model highly uncertain and sensitive to subgridscale hydrology that is not represented in model.



Conclusions

- Deeper (0.5-3m) SOM decomposability is crucial determinant of permafrost C feedback
  - Without deep C, weak response; with it large positive feedback
- However, it doesn't seem to matter as much for stabilizing N feedbacks
- Results support idea that this could be a powerful, though perhaps delayed, C cycle feedback
- CLM4.5 is a useful tool for exploring these effects, however the list of potentially important things *not* included in this model is still very long
- **Need to understand what controls the fate of deep carbon in thawing permafrost systems**