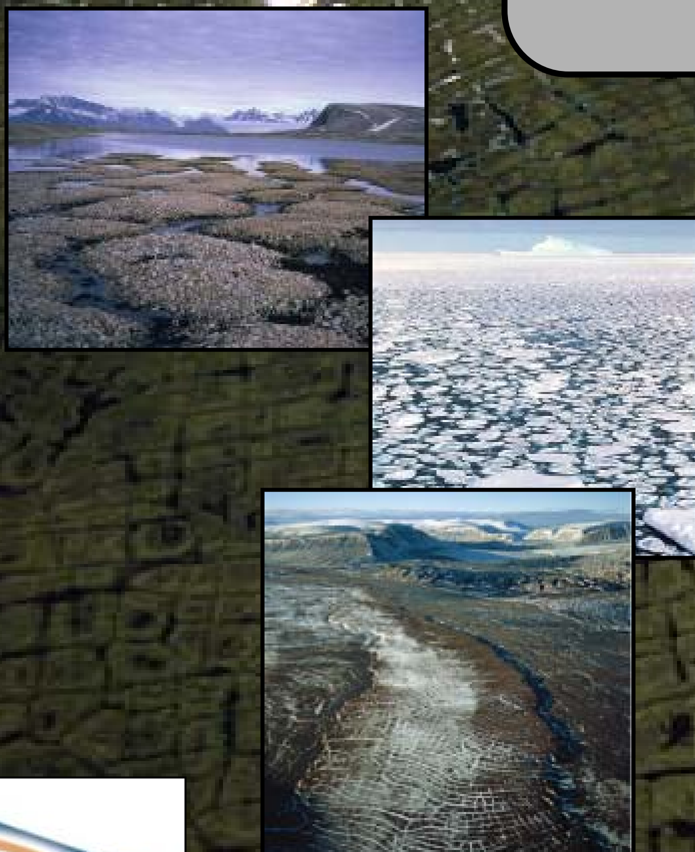
Permafrost thaw carbon-hydrology interactions in CLM4.5BGC



David Lawrence

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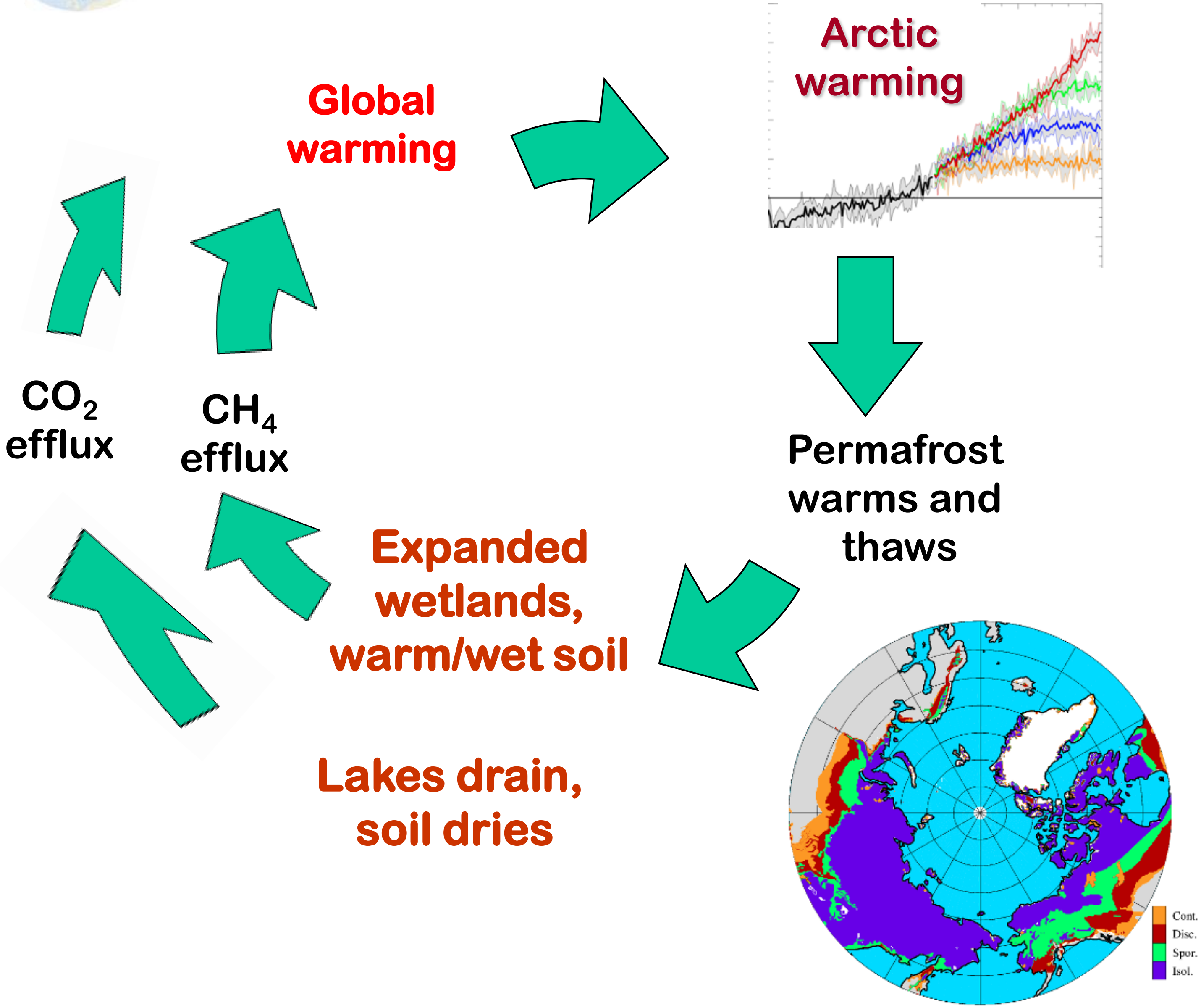
[3]LBNL, Berkeley, CA

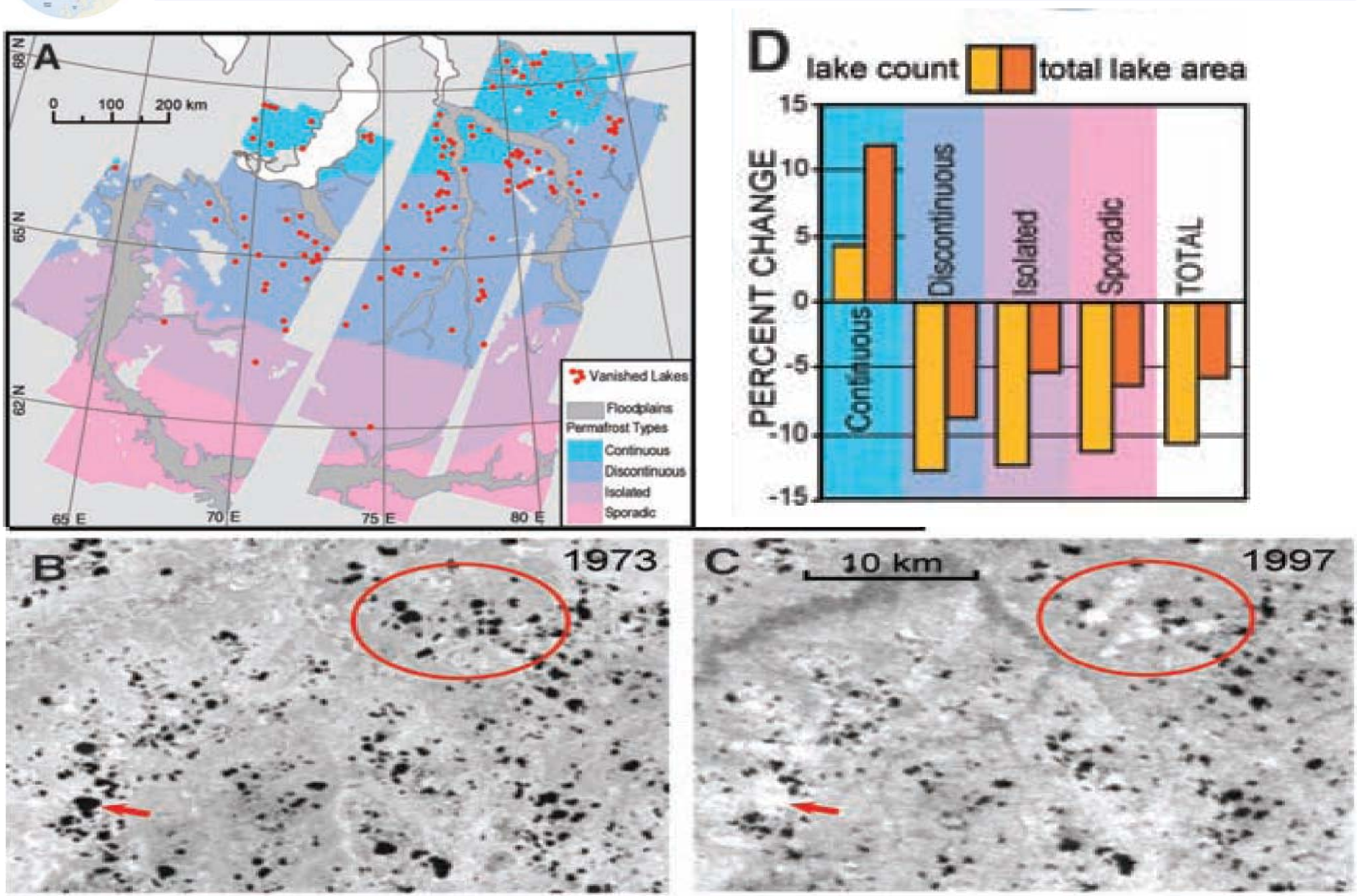
NCAR is sponsored by the National Science Foundation

Permafrost-hydrology-carbon interactions

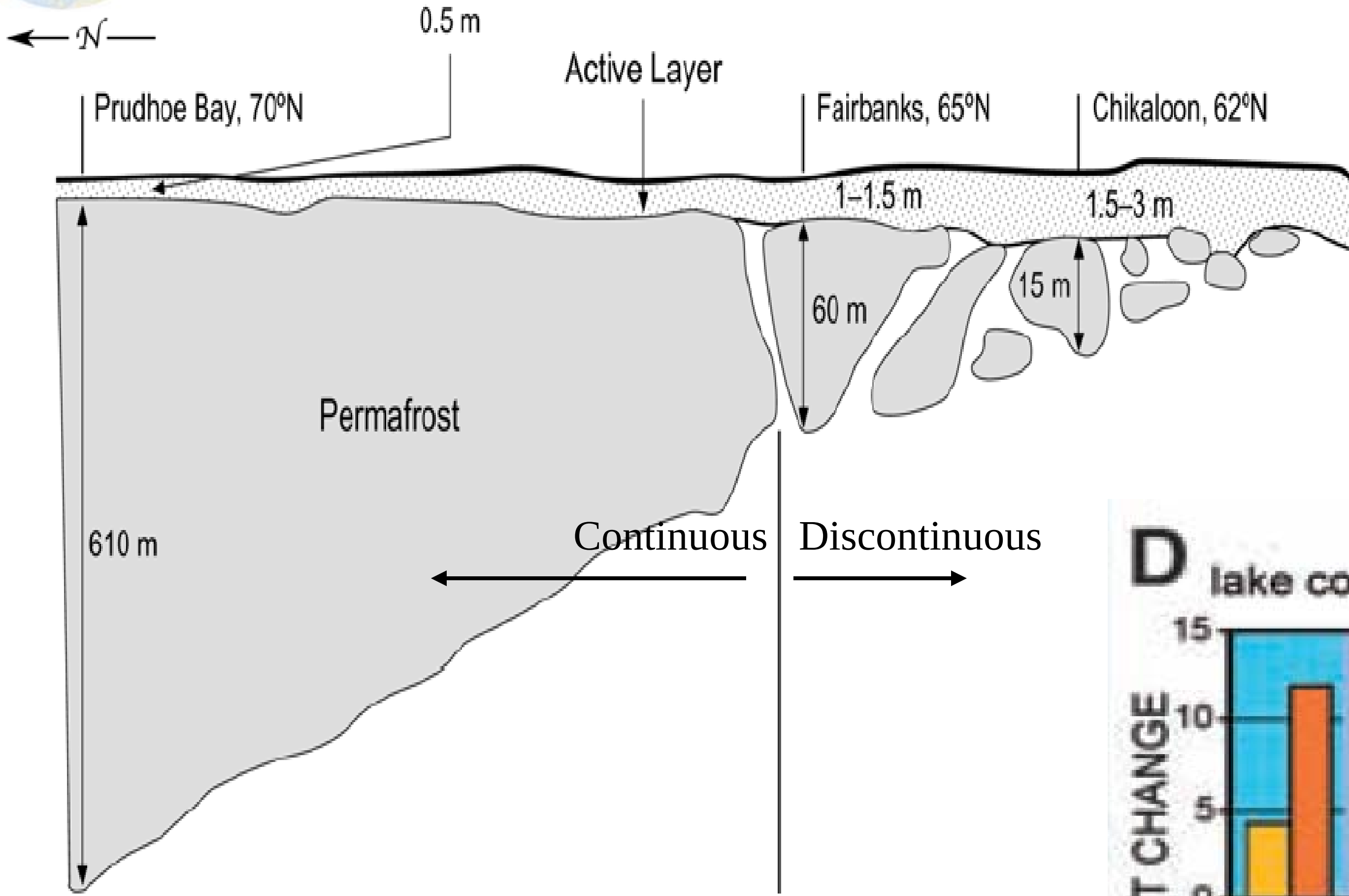


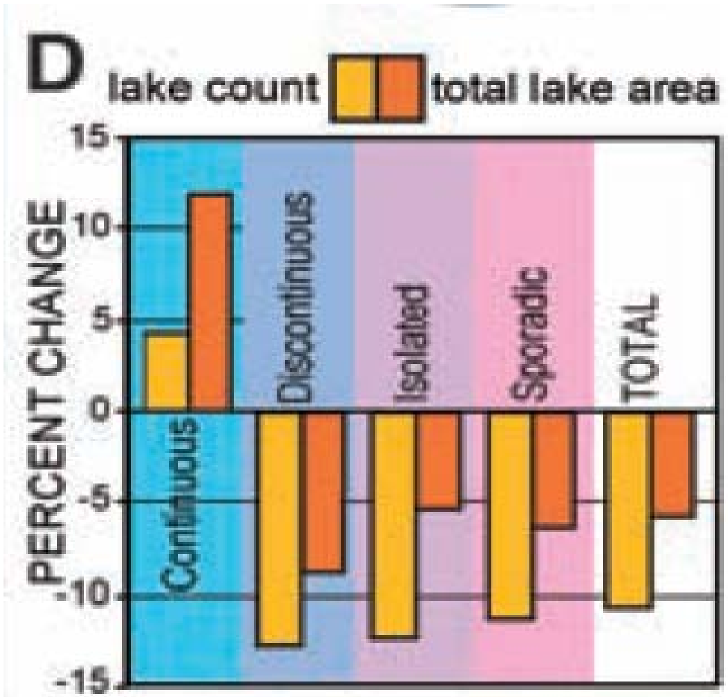
Adapted from McGuire et al., 2006

Appearing and Disappearing Lakes in Siberia (Smith et al. 2005)

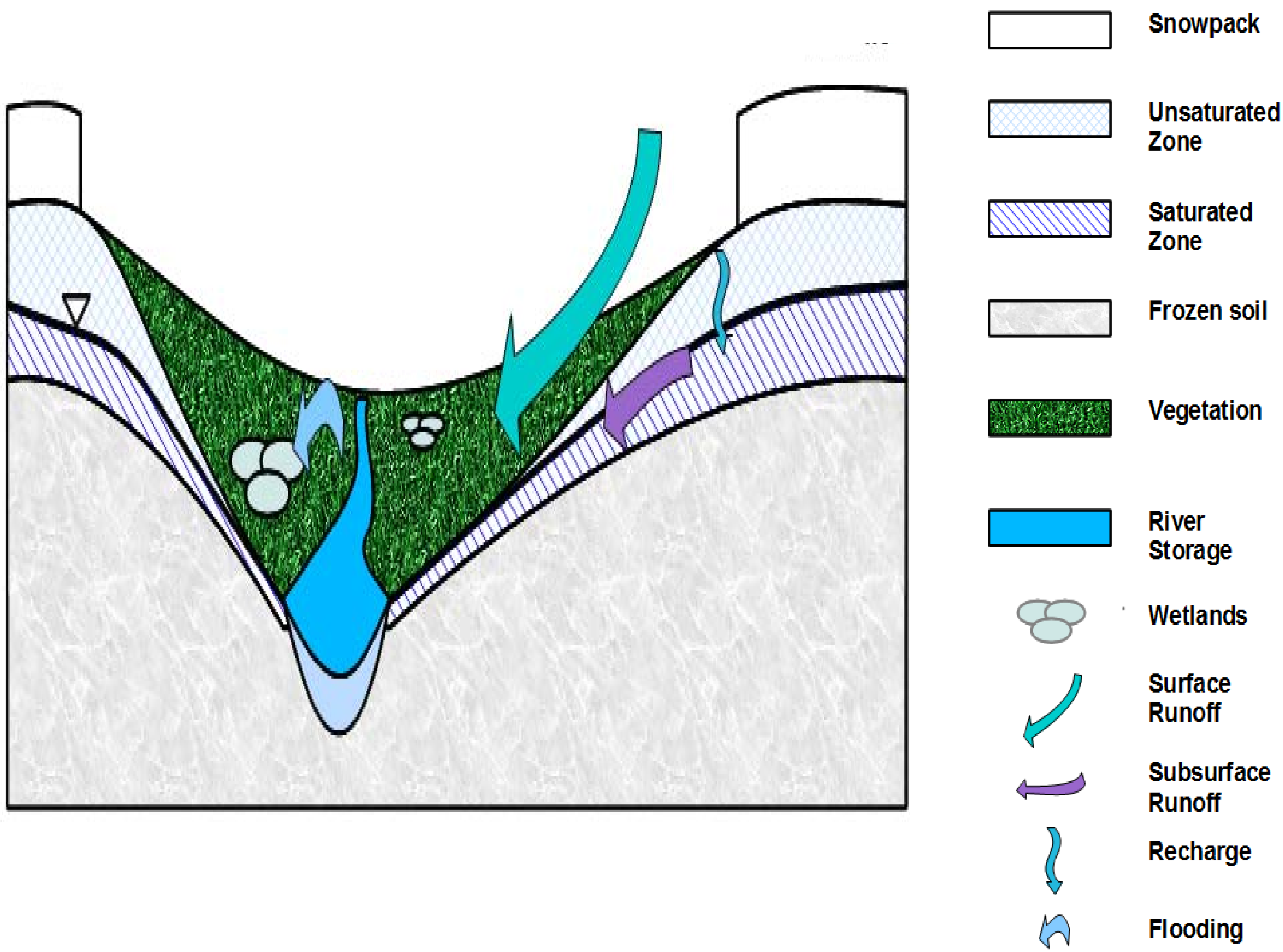


Permafrost hydrology



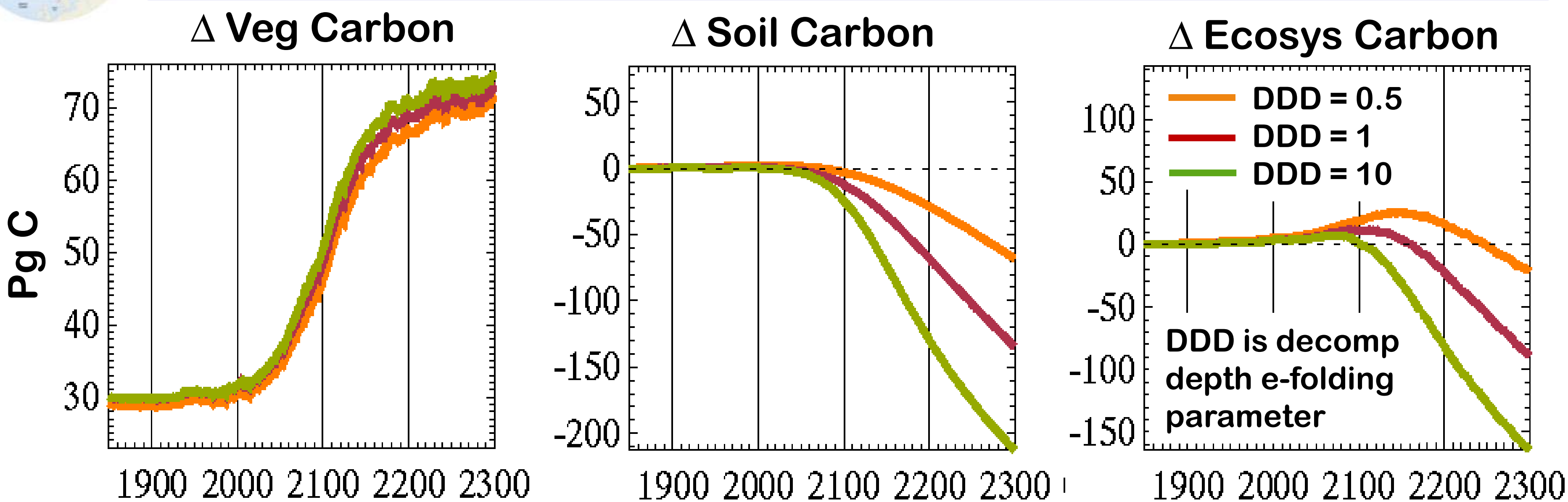


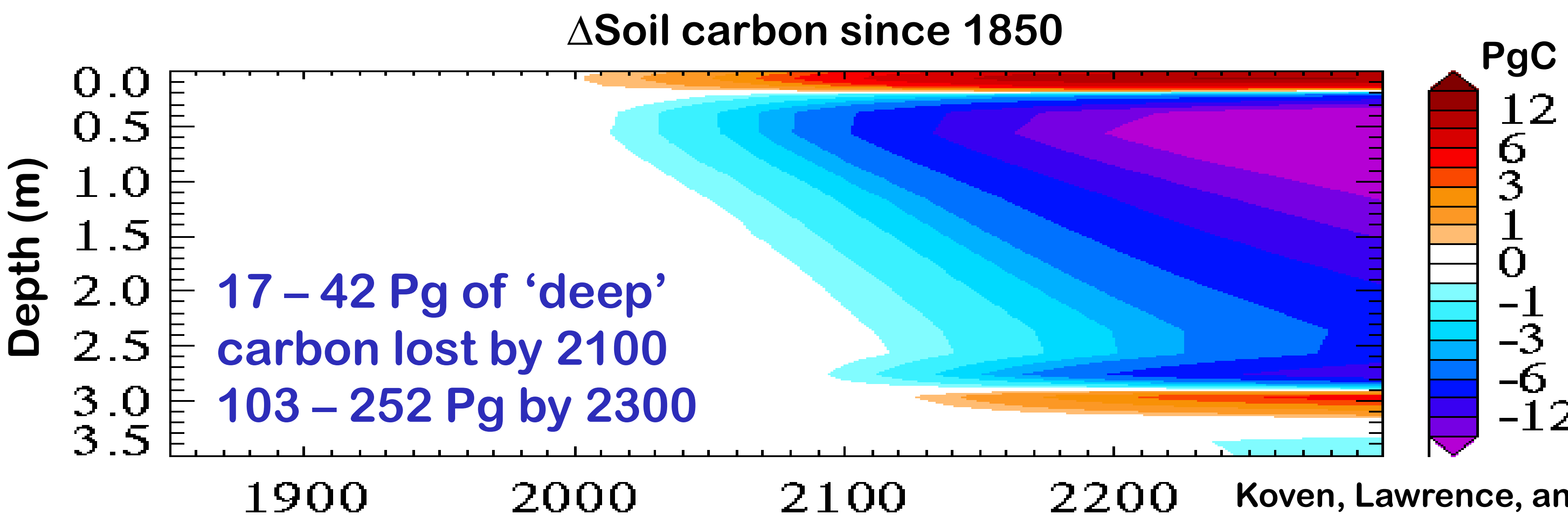
Cold region hydrology and snow in CLM4.5



Swenson et al., 2012; Swenson and Lawrence, 2012; Swenson and Lawrence, in prep

Projected carbon stock trends in permafrost zone (preliminary results, CLM4.5BGC)

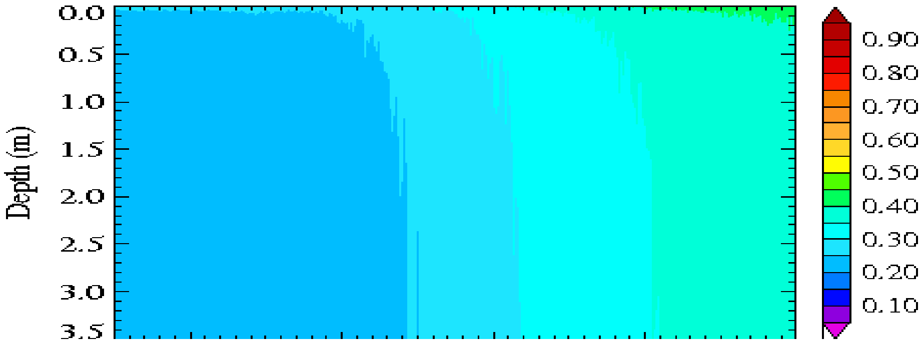




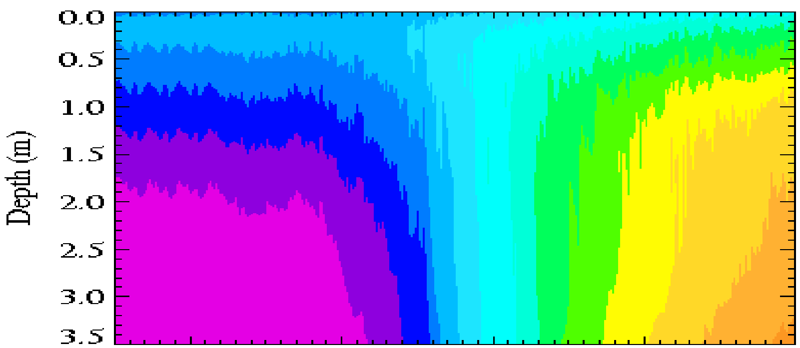
Koven, Lawrence, and Riley in prep

Soil carbon decomposition in CLM4.5
Permafrost zone (ALT < 2m in 1850)

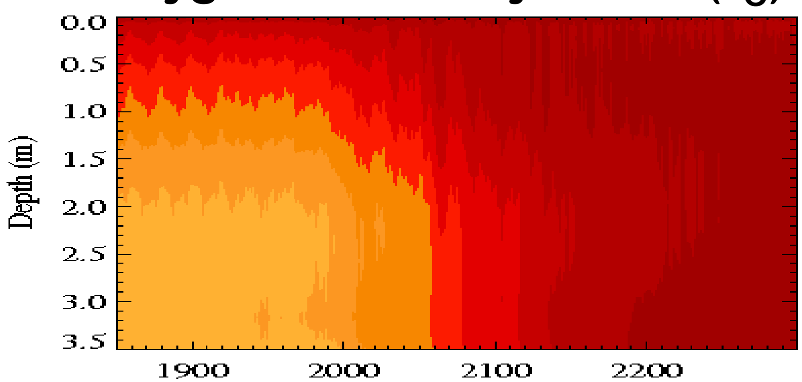
Temperature scalar (r_T)



Soil liquid water scalar (r_W)

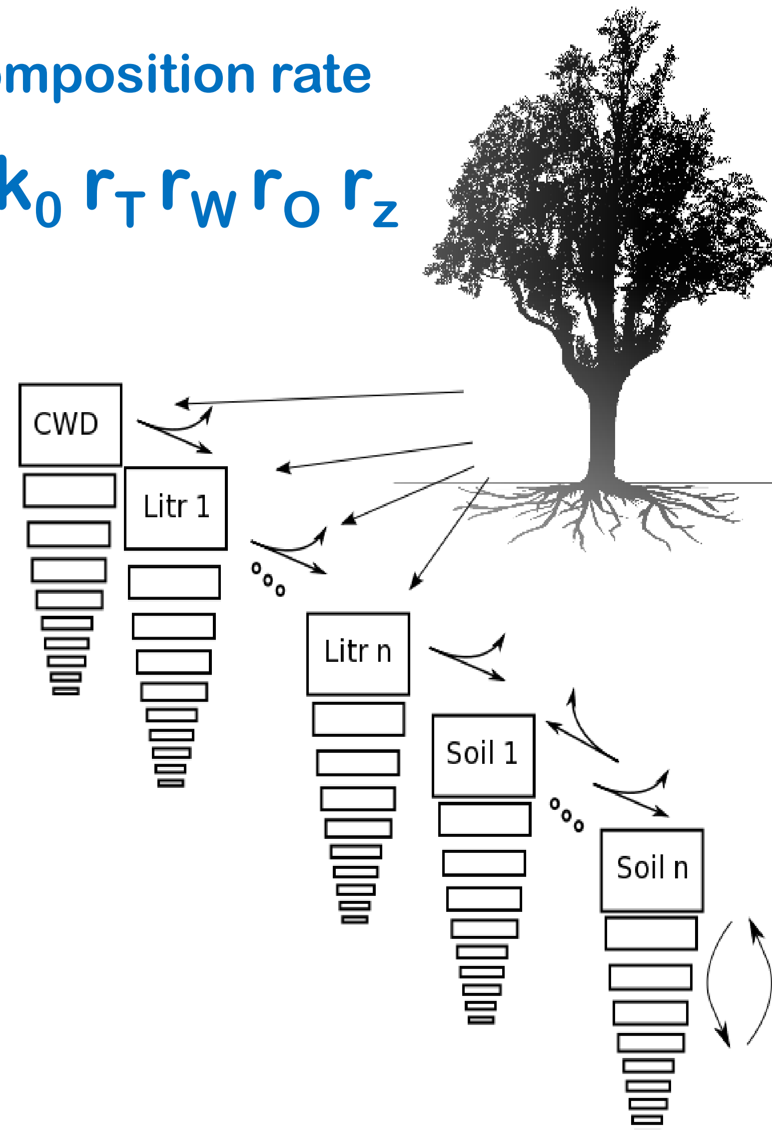


Oxygen availability scalar (r_O)



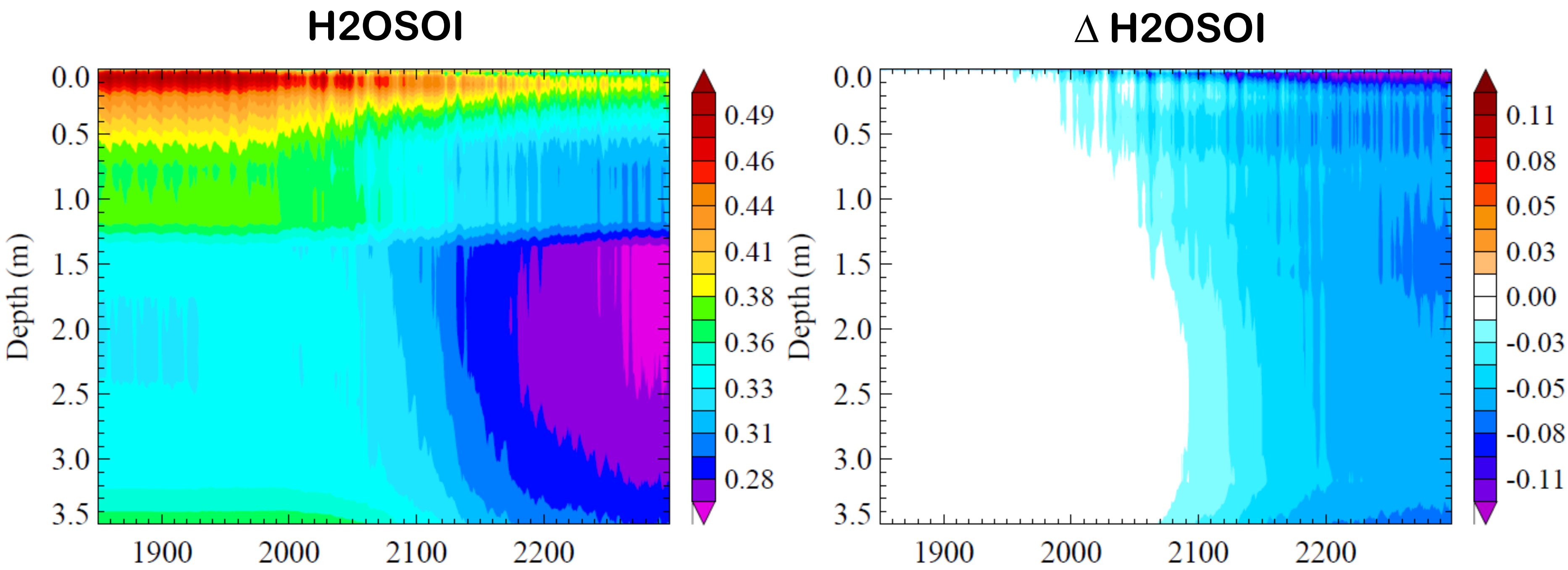
Decomposition rate

$$k = k_0 \, r_T \, r_W \, r_O \, r_z$$



Koven et al. 2012

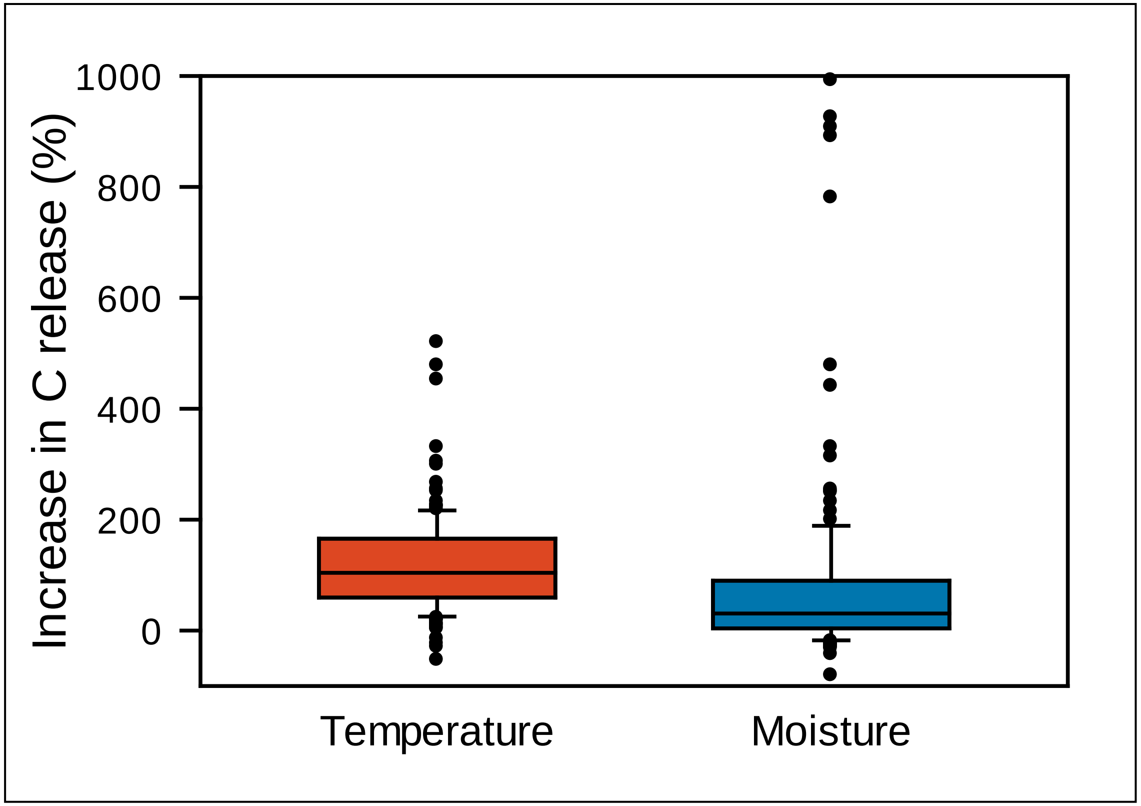
Projection of soil drying after permafrost thaw



Environmental controls and C release
Incubation synthesis study, Permafrost RCN

Increase in C release (%) for: Δ 10°C increase (5° to 15°C)
from saturated to drained

+117%
±87%



+67%
±200%

Preliminary results, courtesy Cristina Schaedel

Ask the questions

- How much of modeled soil carbon decomposition can be attributed to reduced anoxic conditions due to soil drying?

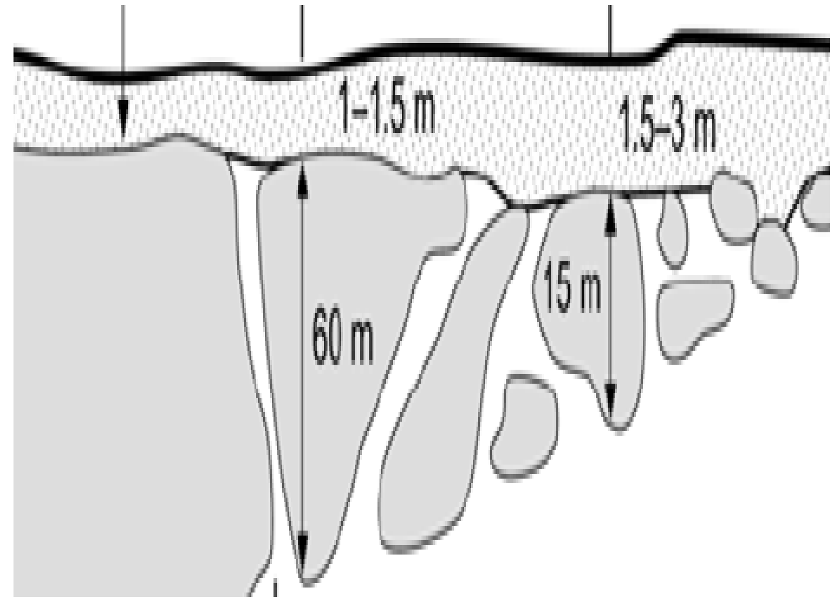
- What happens if soils dried faster through sub-grid scale vertical ice-free channels in discontinuous or sporadic permafrost?

Experiments

WET

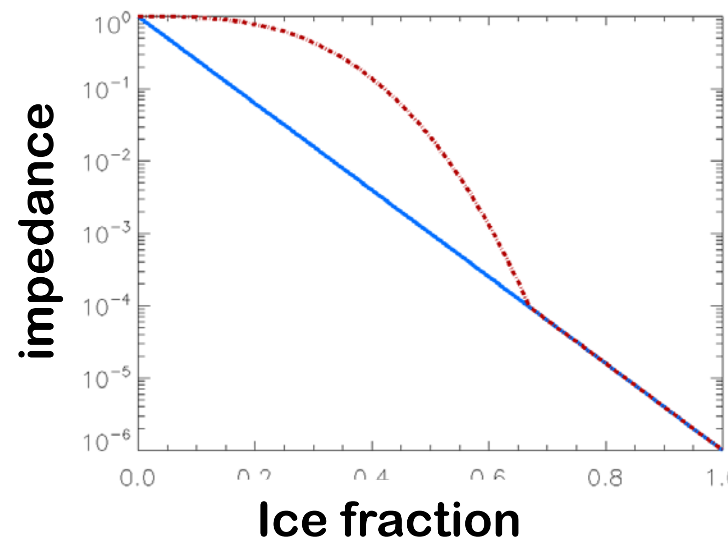
‘Maintain’ 1850 soil moist conditions by not allowing impedance to flow to change as ice melts and by always taking transpiration water from 1850 active layer

$$IMPED = 10^{-6*max[icefrc,icefrc1850]}$$

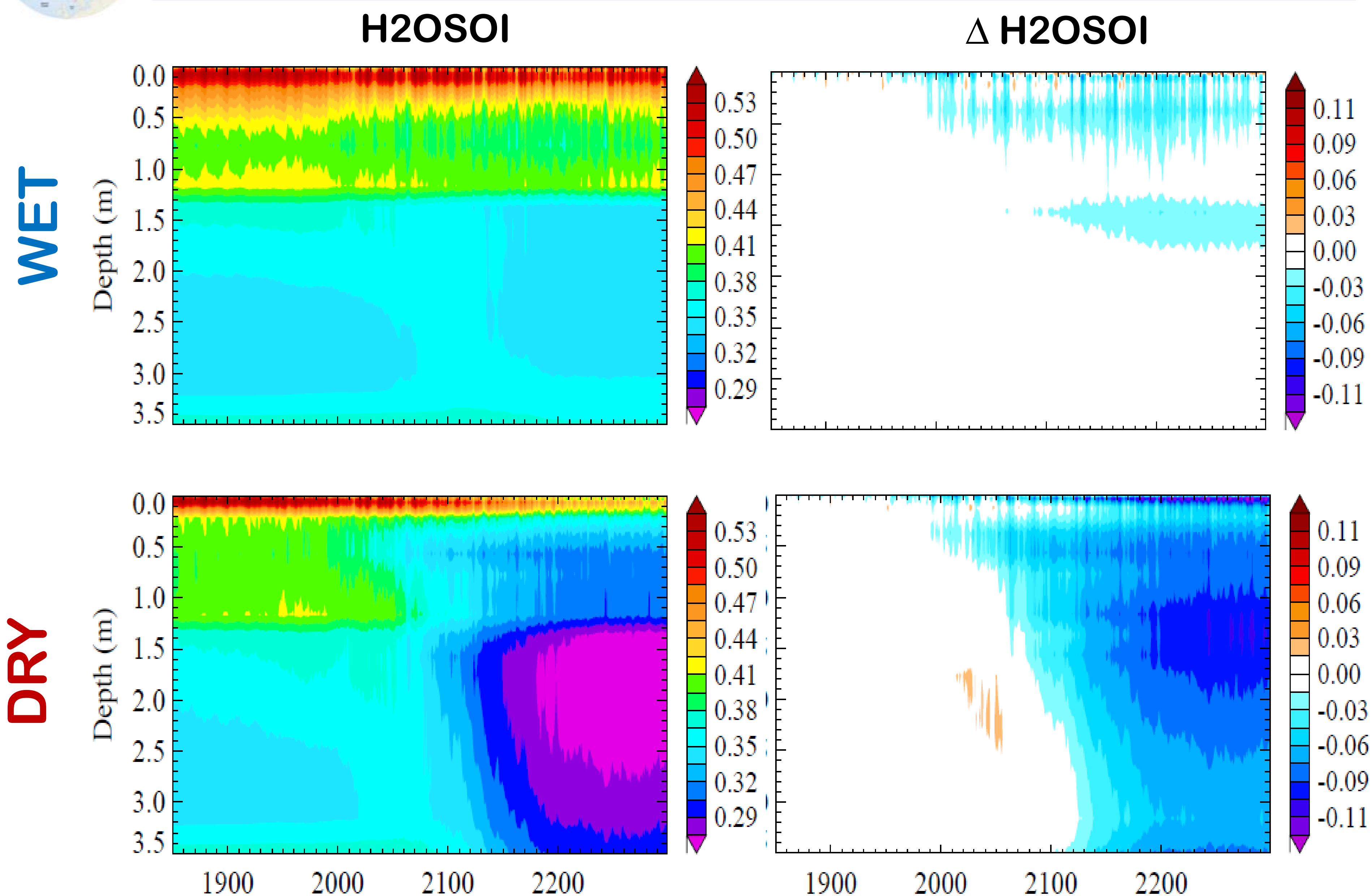


DRY

Accelerate drying by assuming that at some ice fraction threshold, impedance to water flow drops sharply



Soil moisture trends

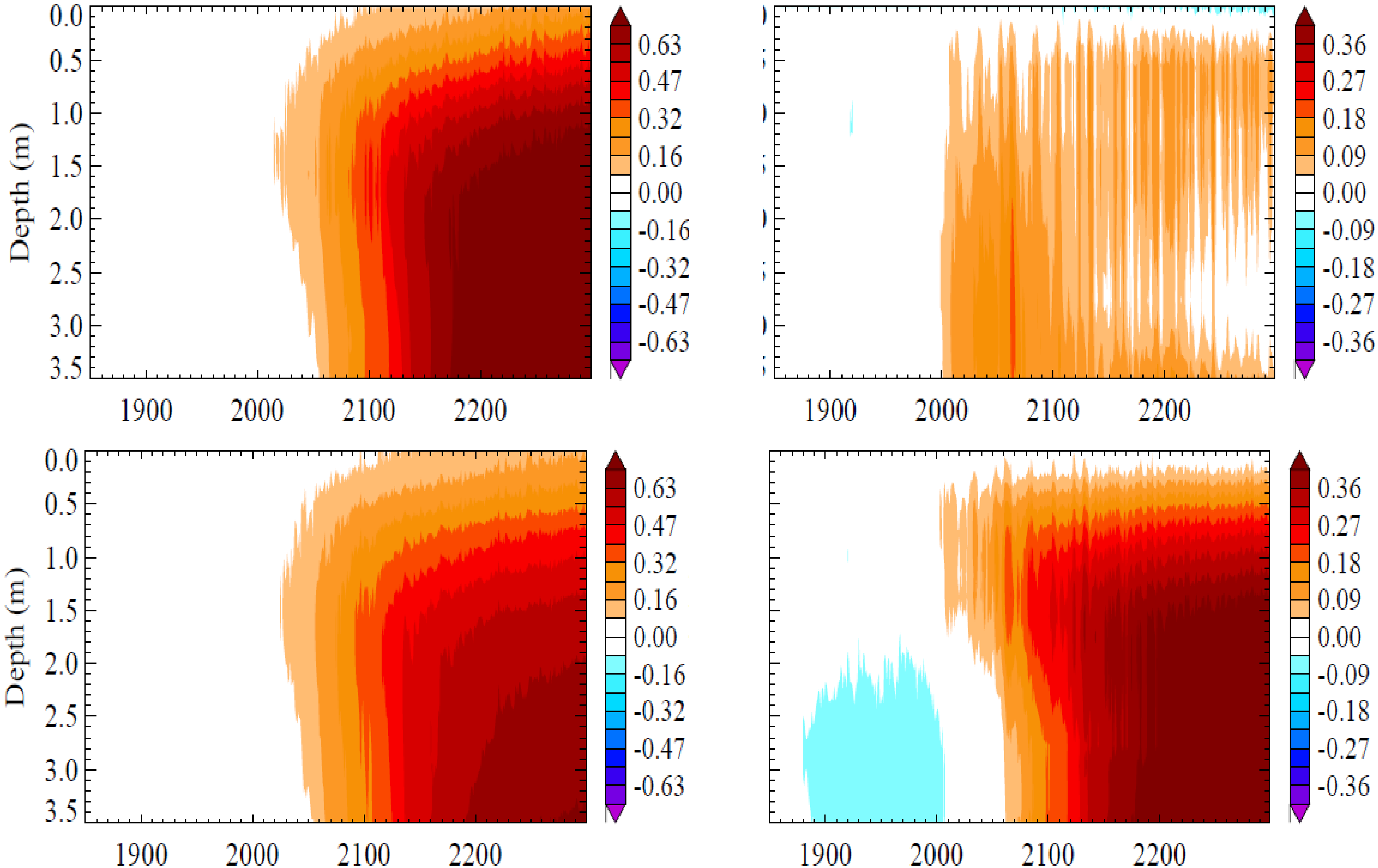


Impact on decomposition scalars

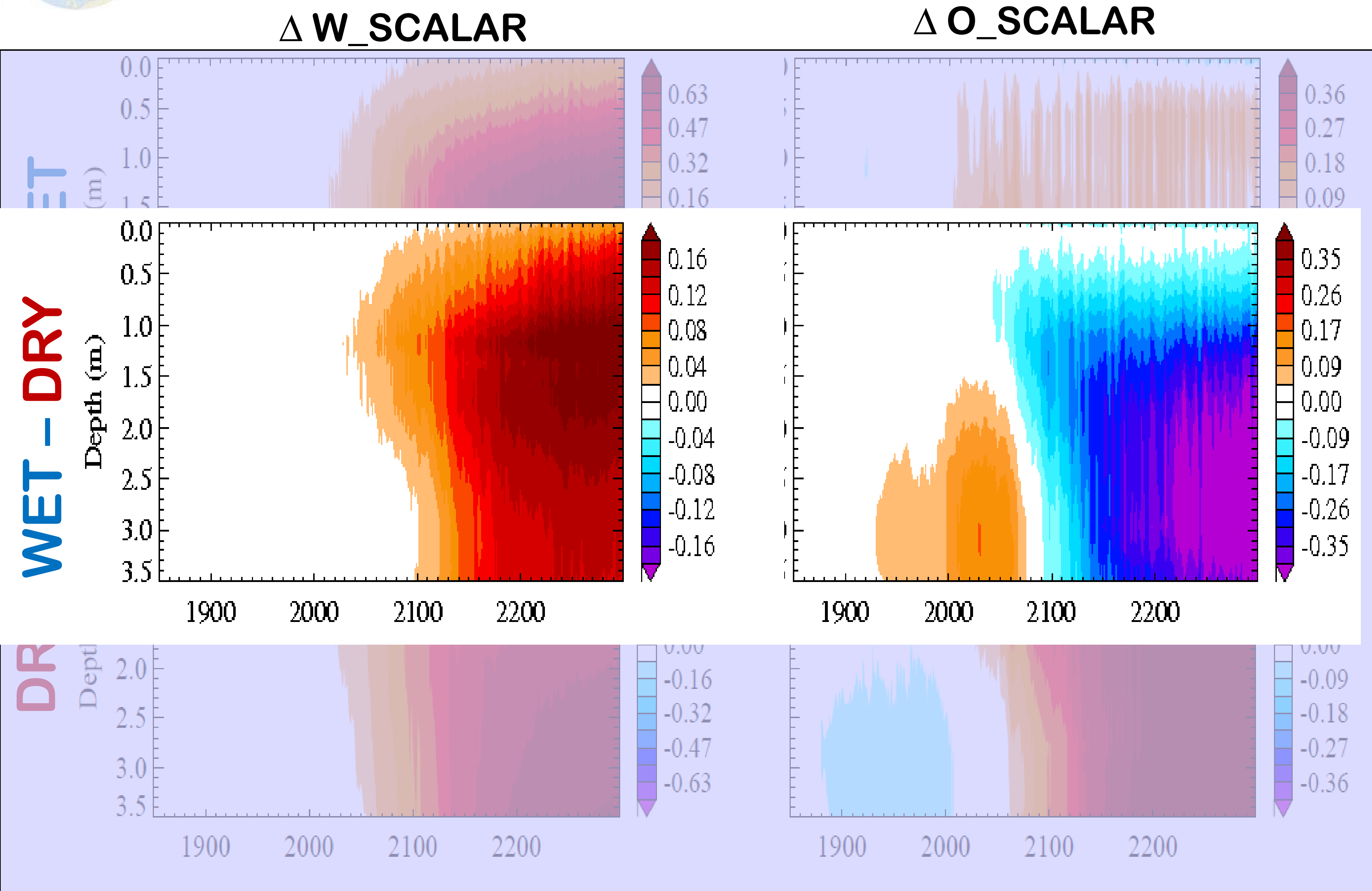
Δ W_SCALAR   Δ O_SCALAR

WET

DRY

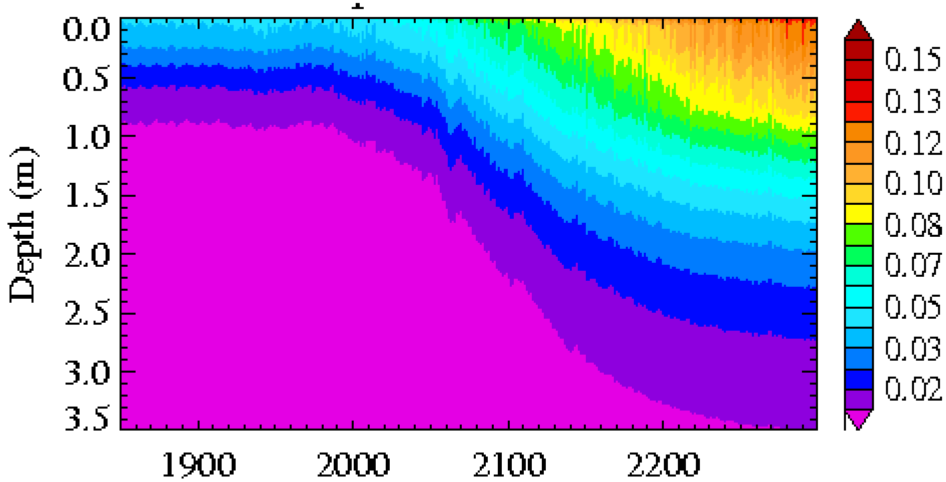


Impact on decomposition scalars

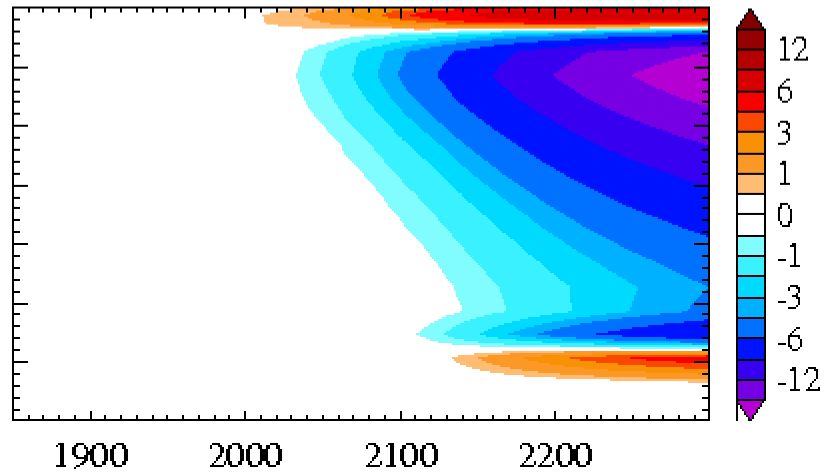


Decomposition scalar trends

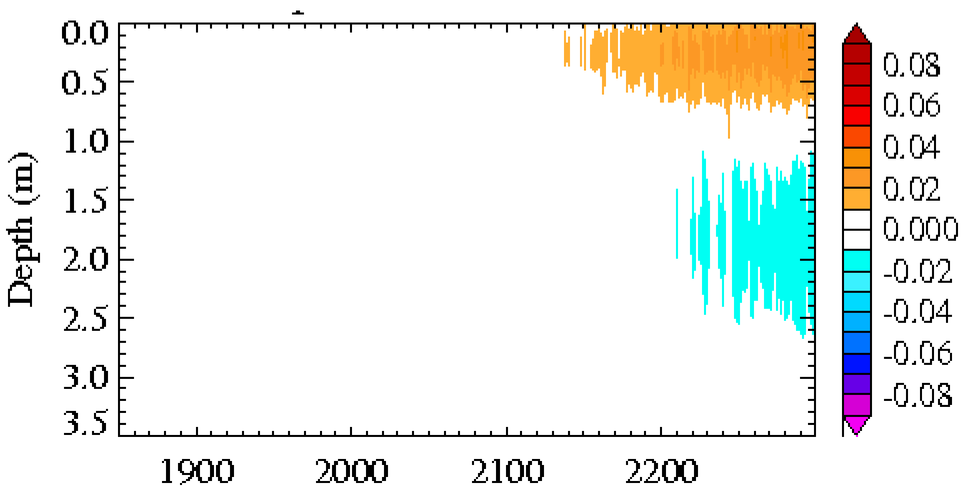
$k = k_0 \, r_T \, r_W \, r_O \, r_z$

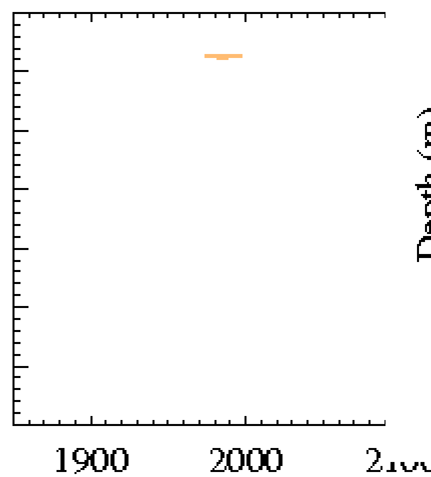


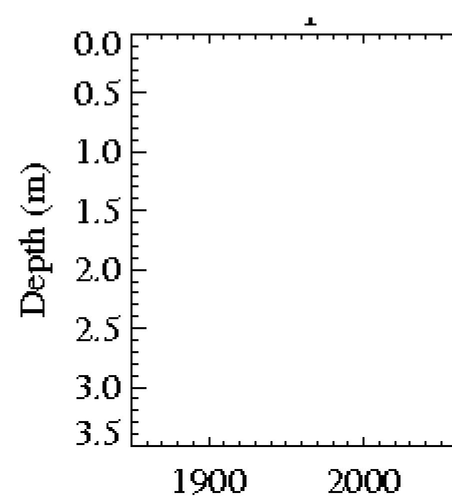
Δ TOTSOMC



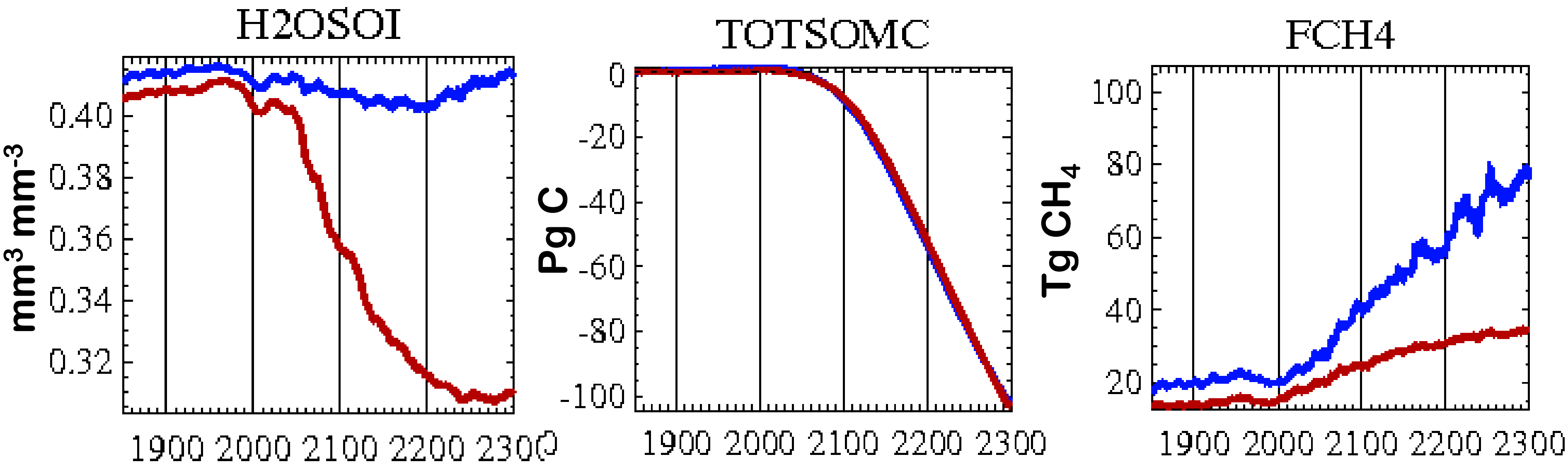
WET – DRY





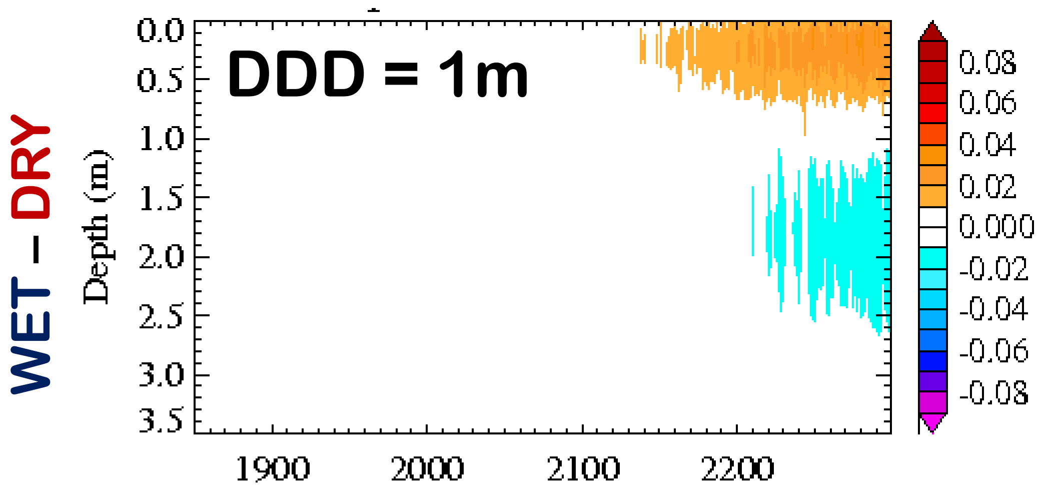


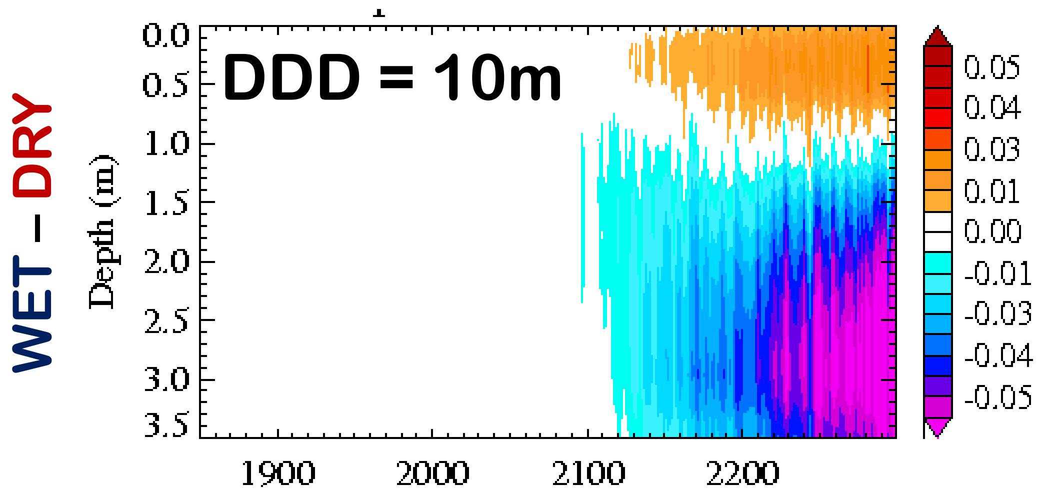
Impact on CH_4 emissions

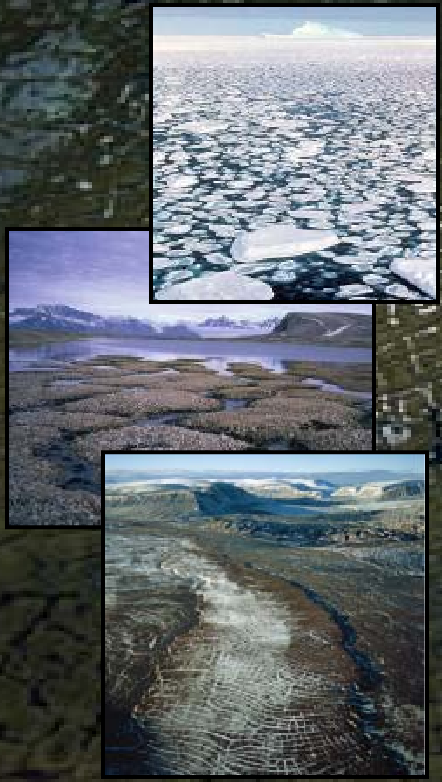


Decomposition scalar trends

$$k = k_0 \, r_T \, r_W \, r_O \, r_z$$







Summary

- CLM4.5BGC projects soil drying as permafrost thaws, affecting soil water and oxygen availability scalars that control soil carbon decomposition

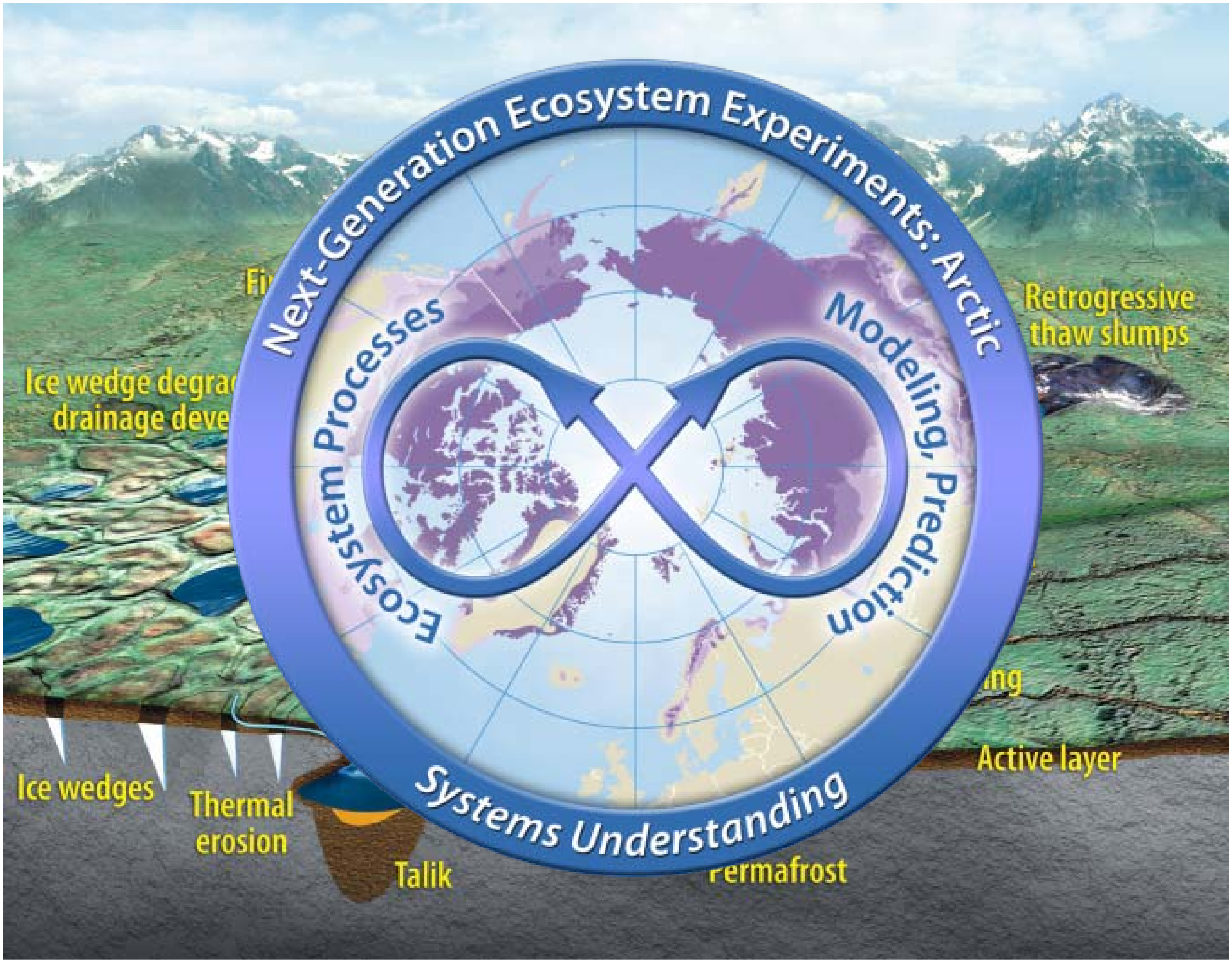
- Preliminary experiments in which we 'control' the soil moisture trends by accelerating or slowing the drying trend strongly affects the trends of these scalars

- Stronger increases in soil water scalar in WET experiment versus the DRY experiment counteract weaker increases in oxygen availability scalar → weak difference in soil carbon decomposition between WET and DRY experiments

- Methane emissions rise much more strongly (3-4x) if the soils remain wet

- The strength of the depth decomposition scalar strongly affects the impact of deep soil drying on soil carbon decomposition

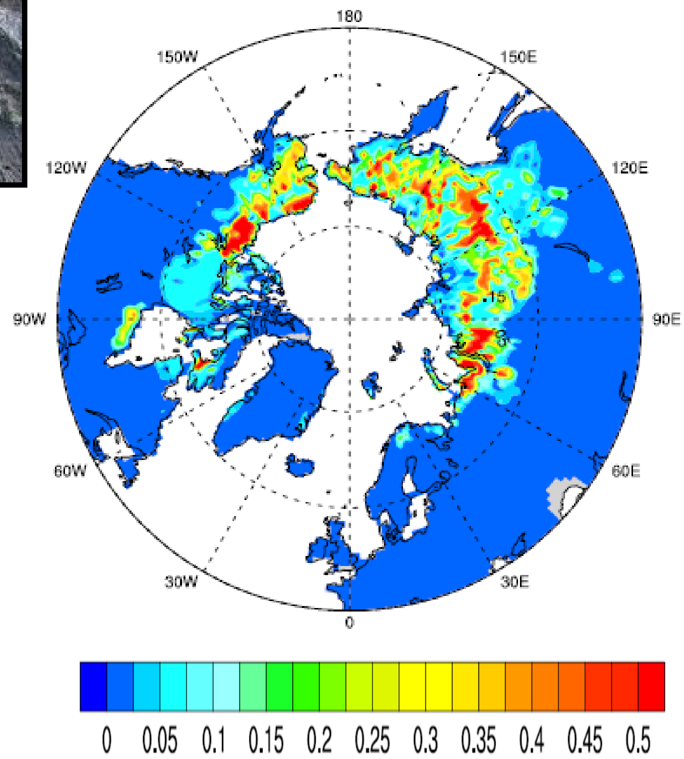
Future directions:
Model validation, heterogeneity, scale, and landscape dynamics



Rowland et al. 2010, EOS

Future directions: Modeling wetland distribution and potential for rapid mobilization of soil carbon (thermokarst)

Projected ground subsidence by 2100



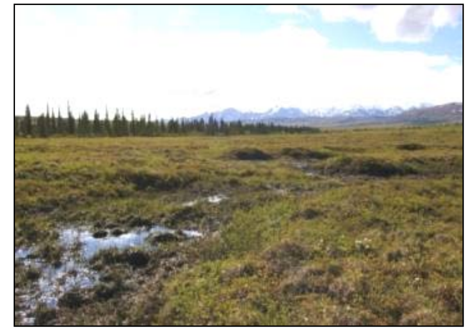
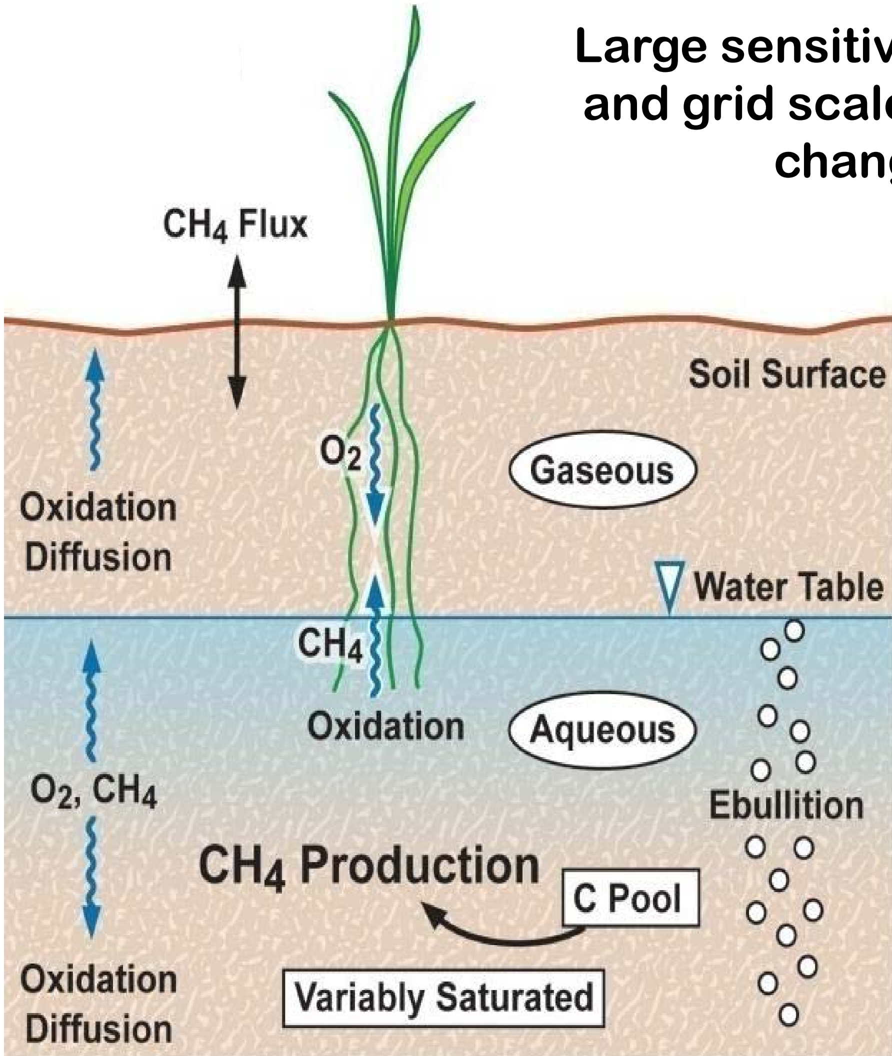


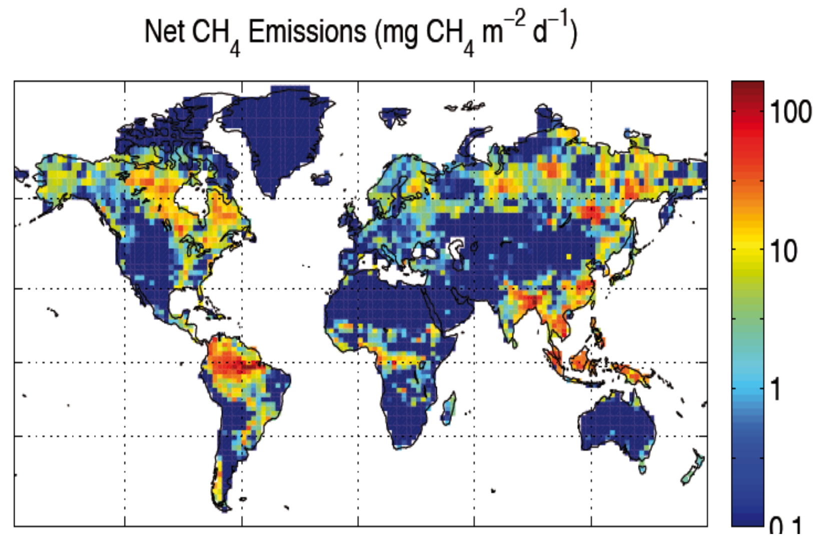
Figure courtesy Hanna Lee

Process based methane emissions model

"Barriers to predicting changes in global terrestrial methane fluxes"



Large sensitivities (up to 4x and 10x at regional and grid scales) in CH_4 fluxes from reasonable changes in model parameters



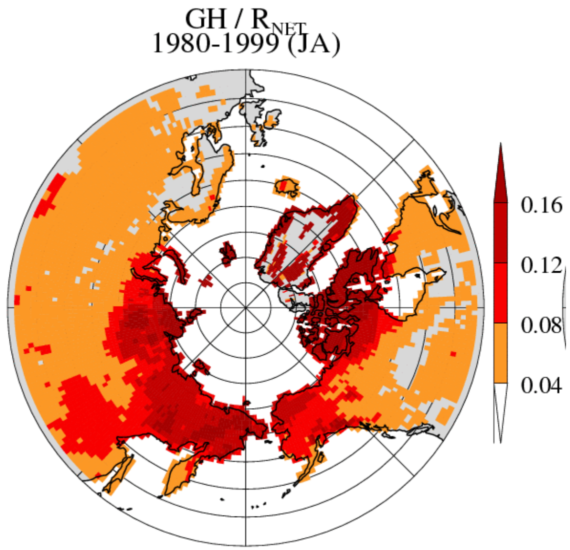
Projections highly uncertain, but with default parameters ~ +20% increase in high-lat CH_4 emissions (A1B)

Riley et al., 2011, Biogeosciences

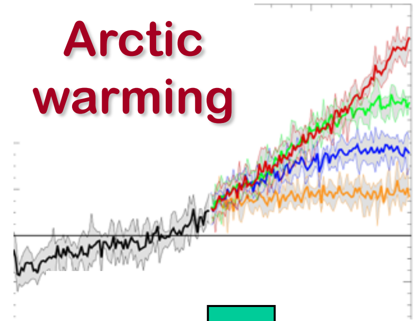
Extra Slides

Bernhard Edmaier
National Geographic

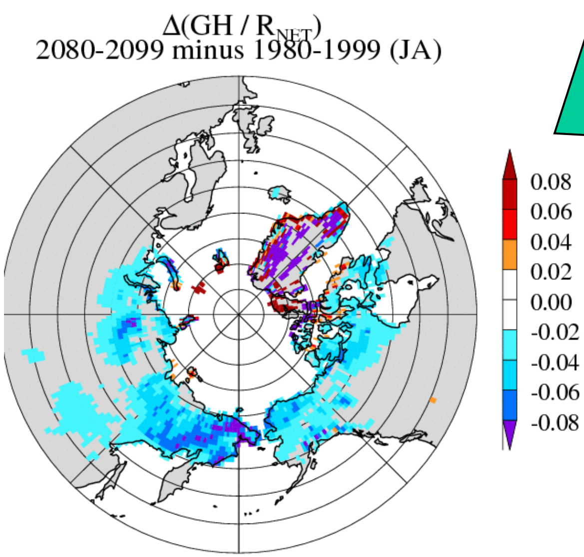
Potential Arctic terrestrial climate change feedbacks

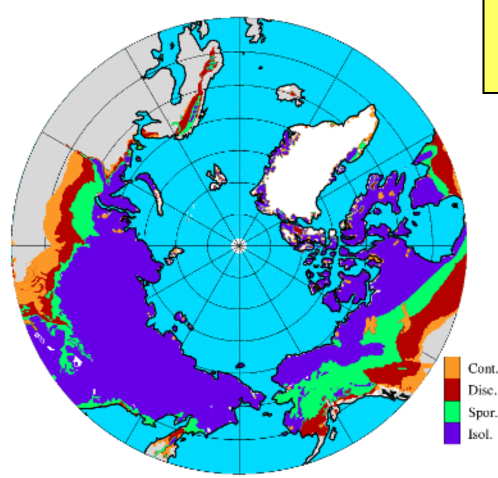


Arctic warming



Permafrost warms and thaws





Direct feedback

Surface energy partitioning

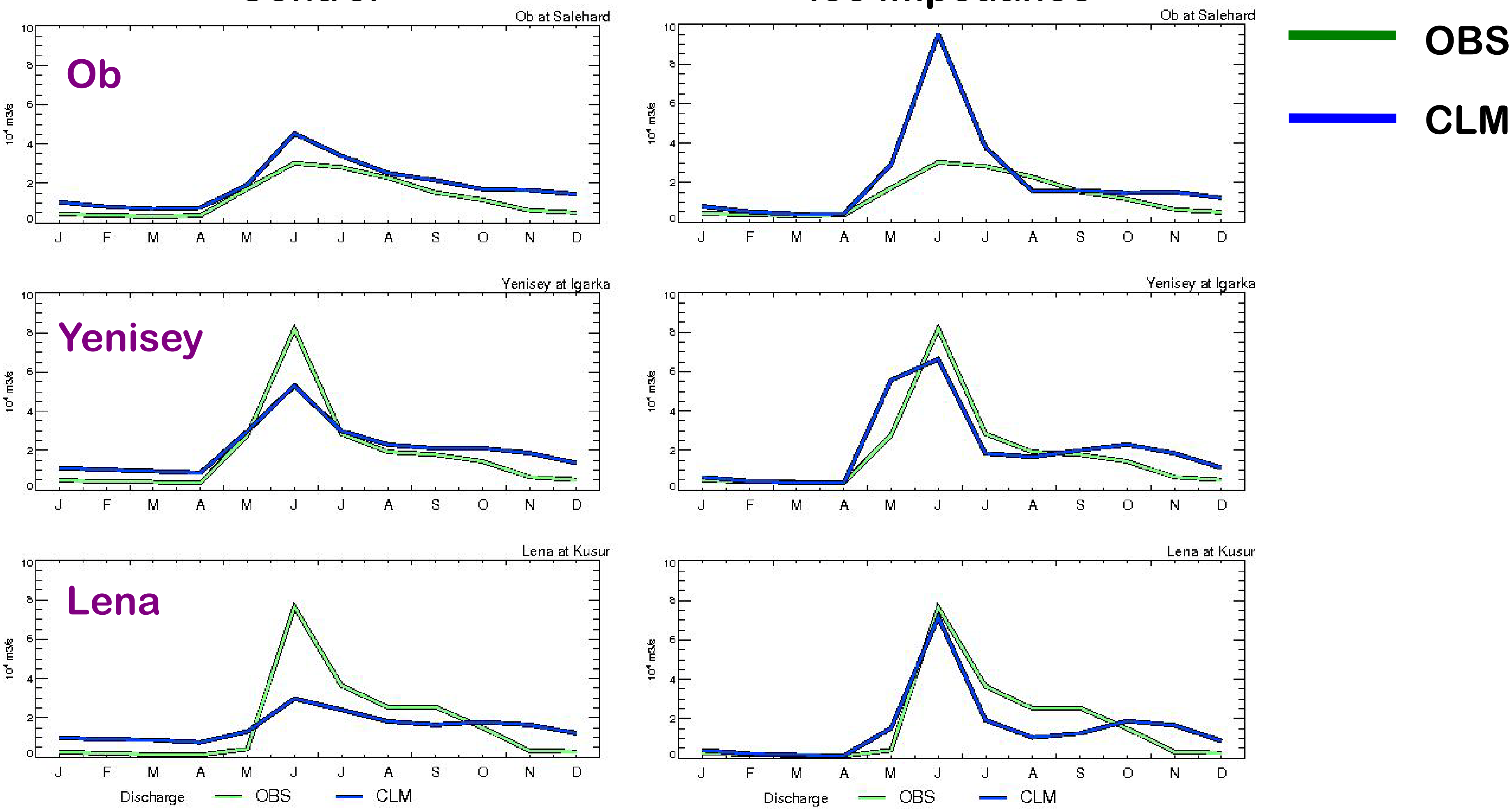
Permafrost state (especially presence or absence of soil ice) affects partitioning of net radiation into ground, latent, and sensible heat fluxes

Lawrence et al., 2012

River Discharge from Arctic river basins

Results are mixed: better hydrographs for permafrost basins, but degraded simulation in non-permafrost basin

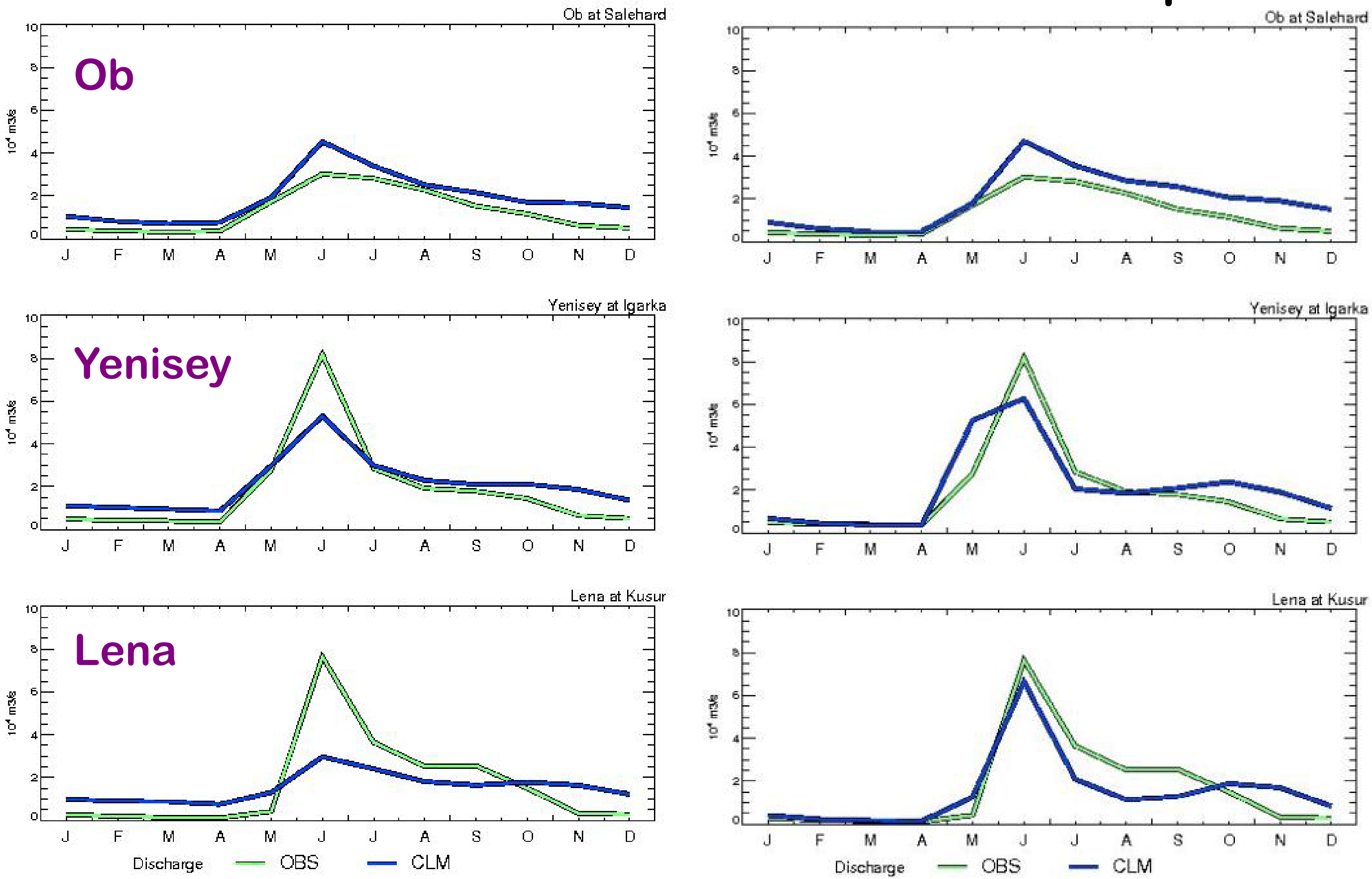
Control | **Ice Impedance**



River Discharge from Arctic river basins

Results: better hydrographs for both permafrost basins and non-permafrost basins

Control | **Surface Water + Impedance**



OBS

CLM