Hydrology & Aquatic Carbon: Detecting Signals of Permafrost Thaw

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ABoVE ARCTIC BOREAL VULNERABILITY EXPERIMENT

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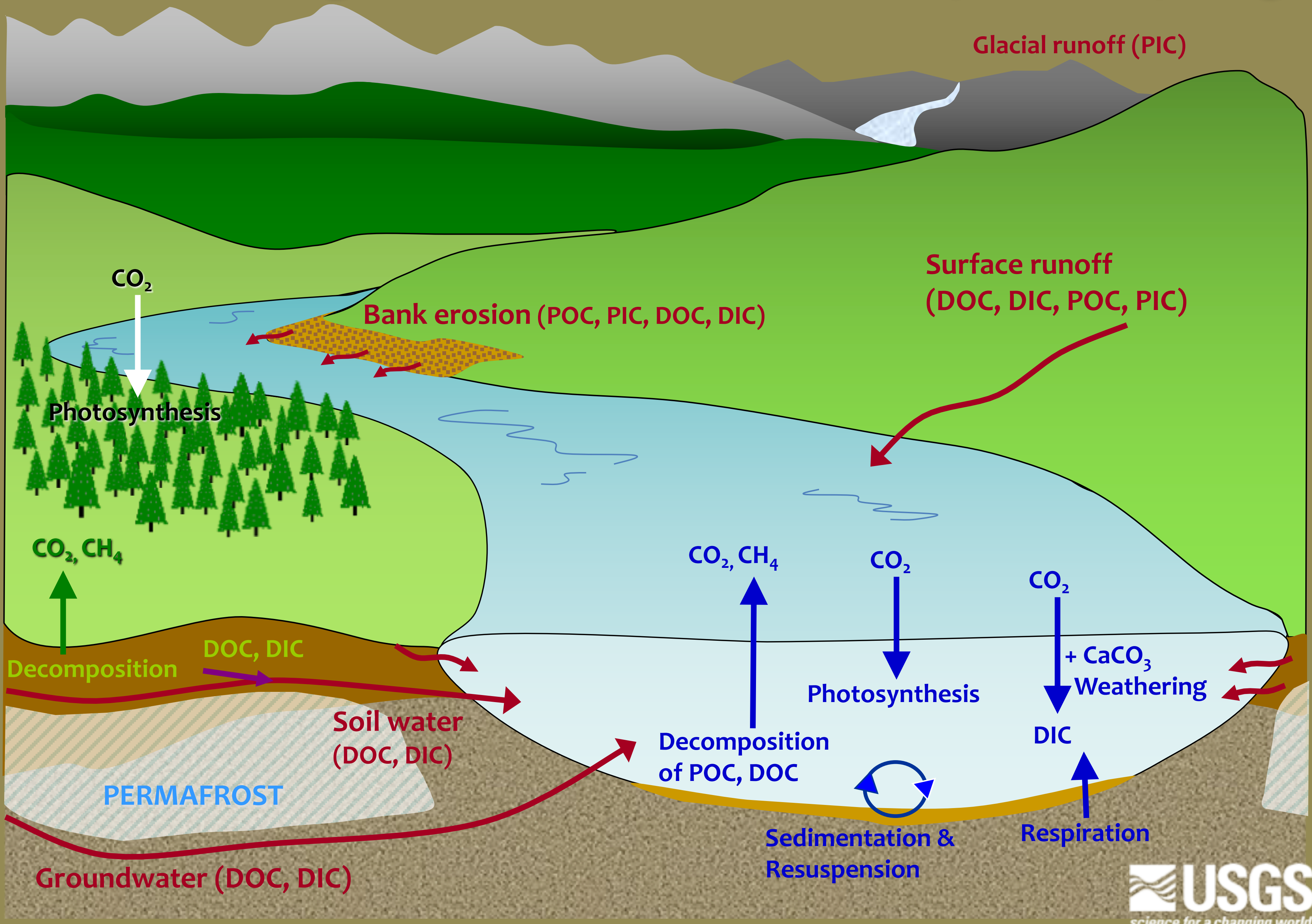
Rivers as Integrators of Terrestrial and Aquatic C Cycling

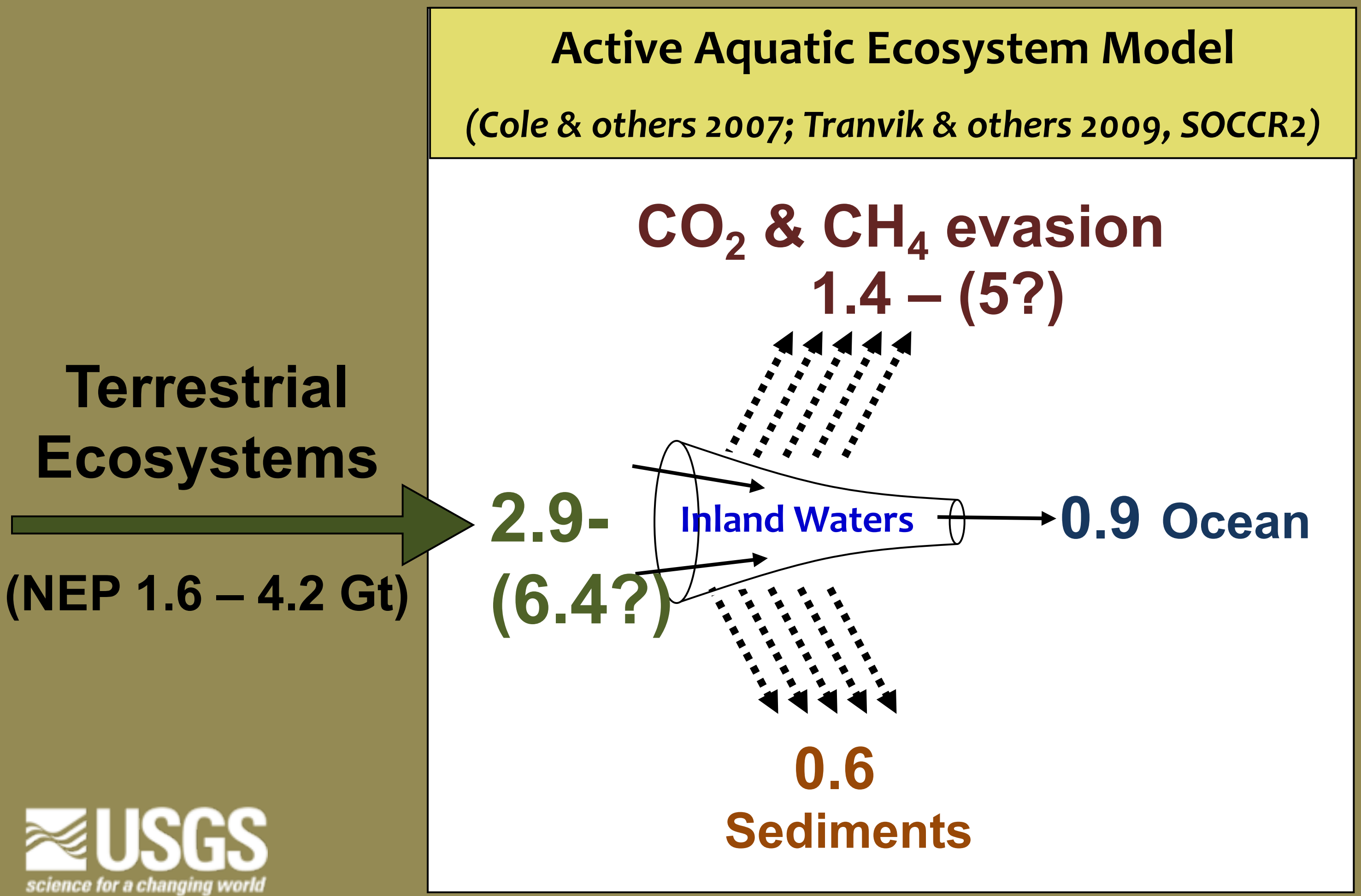


Inland Waters as Reactors of Terrestrial Carbon

~2.9 Gt C yr^{-1} enters inland waters from terrestrial sources:

30% is discharged to oceans, 20% is sequestered in sediments

50% is emitted to the atmosphere



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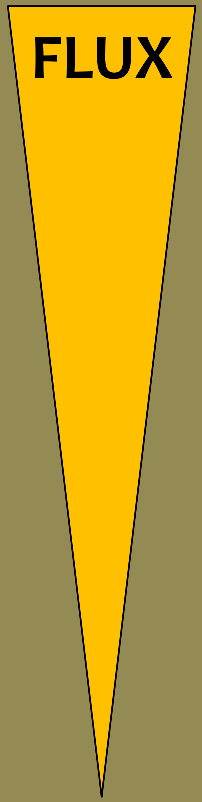
WHAT IS AQUATIC CARBON?

- Carbon Gases (**CO_2 & CH_4**)
- Dissolved Inorganic Carbon (**DIC**)
- Dissolved Organic Carbon (**DOC**)
- Particulate Organic Carbon (**POC**)
- Particulate Inorganic Carbon (**PIC**)



Exact amounts of C emission and transport are not well quantified for inland waters in high latitudes…but they are known to be changing…..

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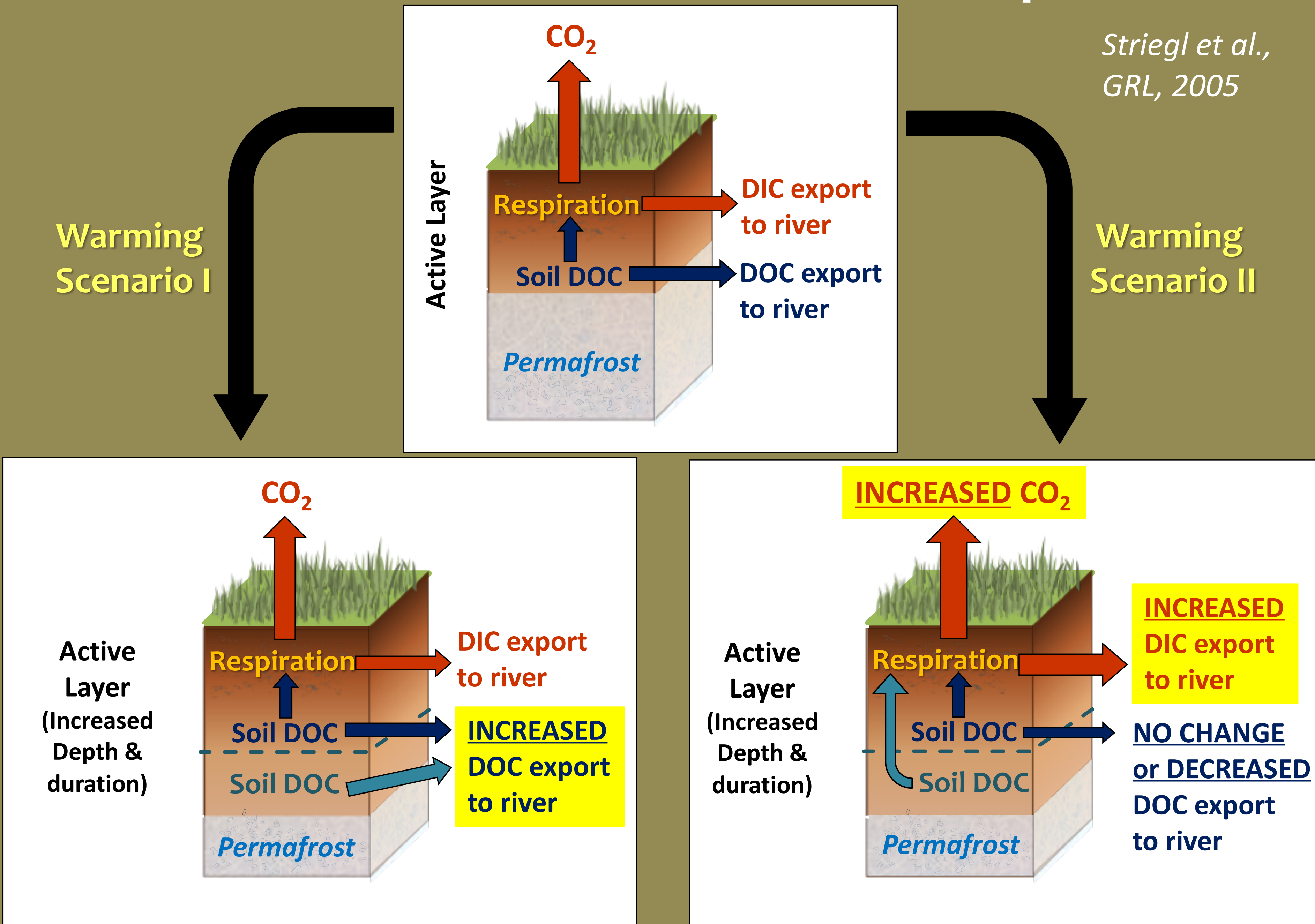
Permafrost Thaw & Lateral C Exports

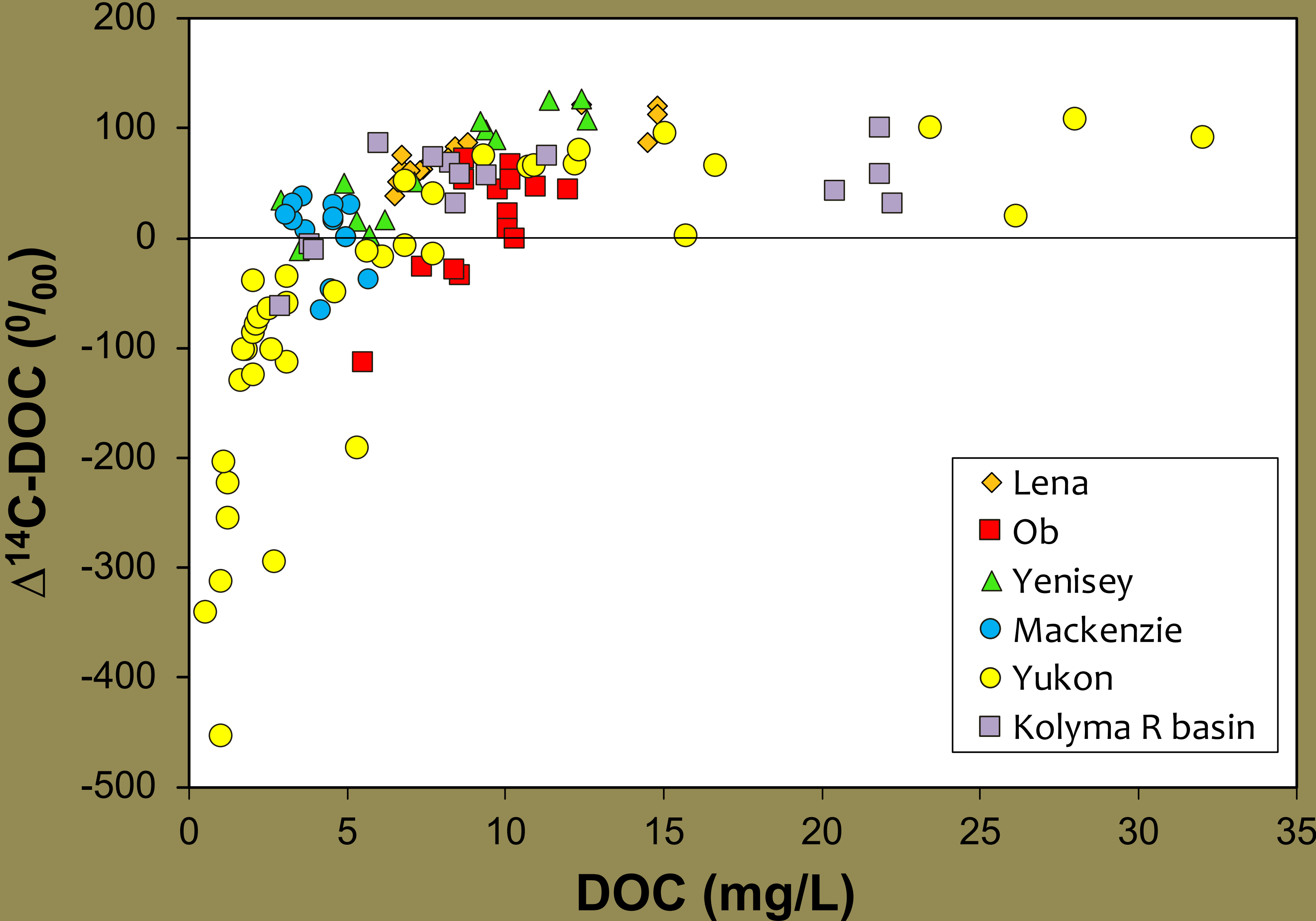
Striegl et al., GRL, 2005



Permafrost Degradation is *Inferred* by Changes in Hydrology, Mineral Weathering Products & C Exports

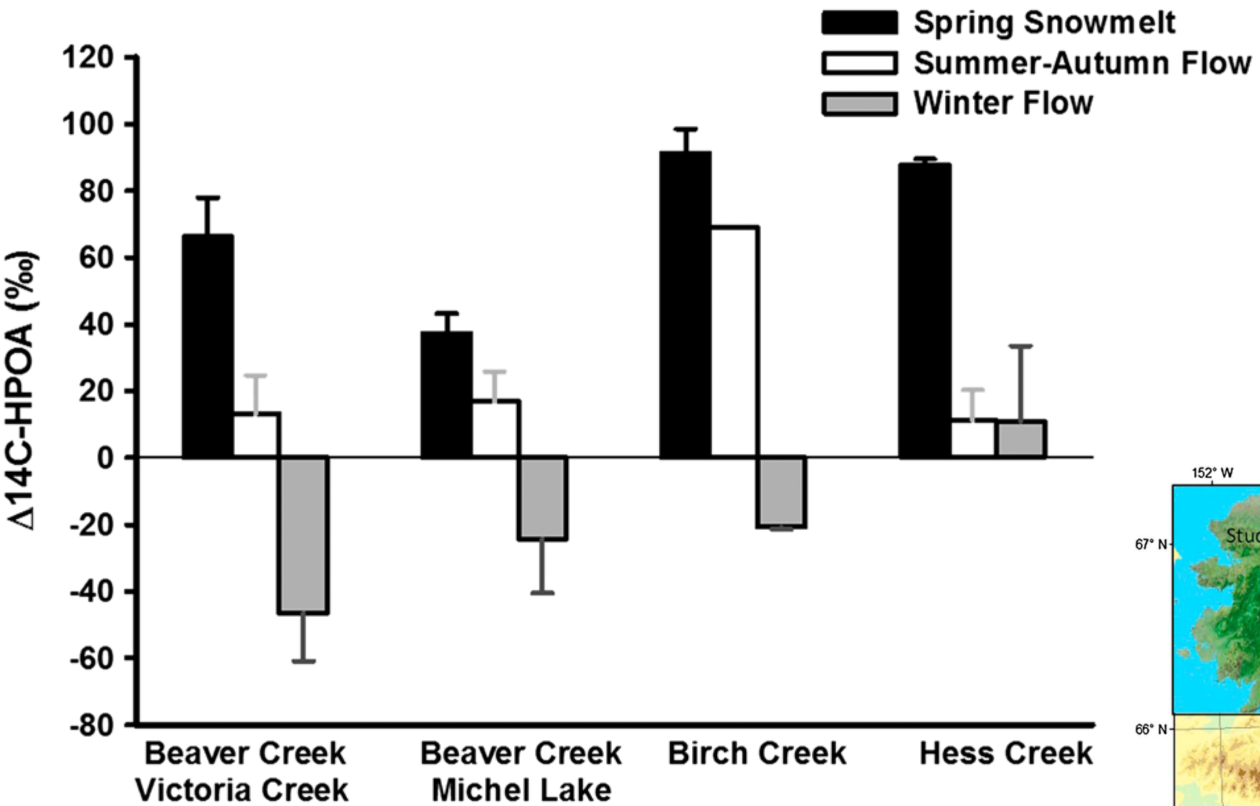
- **BASIN SCALE**
- Decadal shifts in DOC & DIC exports (Striegl et al. 2005; Frey & McClelland, 2009; Tank et al. 2016)
- Decadal increases in infiltration and baseflow (Walvoord & Striegl 2007)
- Changing lake hydrology (Wellman et al. 2013)
- Increased regional groundwater flow (Walvoord et al., 2012)
- Increased weathering product exports (Tank et al. 2012; 2016)
- **INTERMEDIATE SCALE**
- Inter-annual switching in DOC & DIC export (Dornblaser & Striegl 2015)

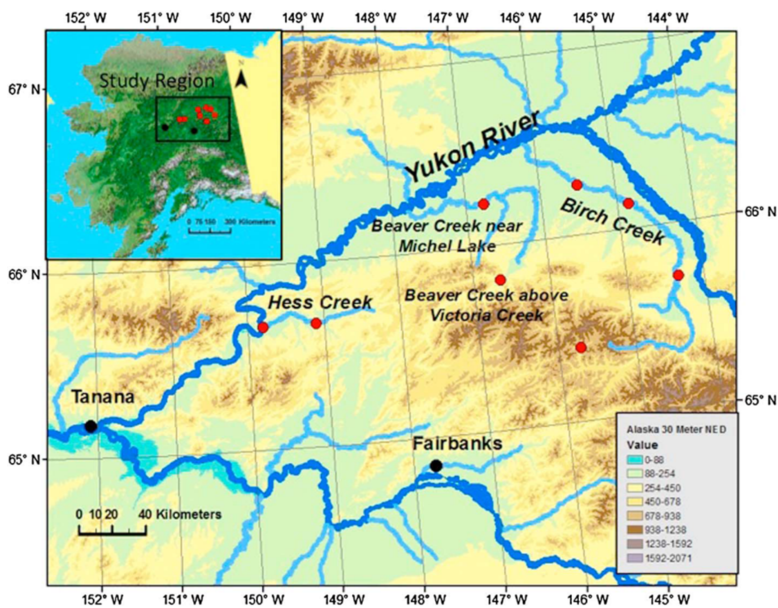
But what about an aged ^{14}C signal from permafrost thaw?



Aiken et al, 2014, GBC; Raymond et al, 2007, GBC; Neff et al., 2006, GRL

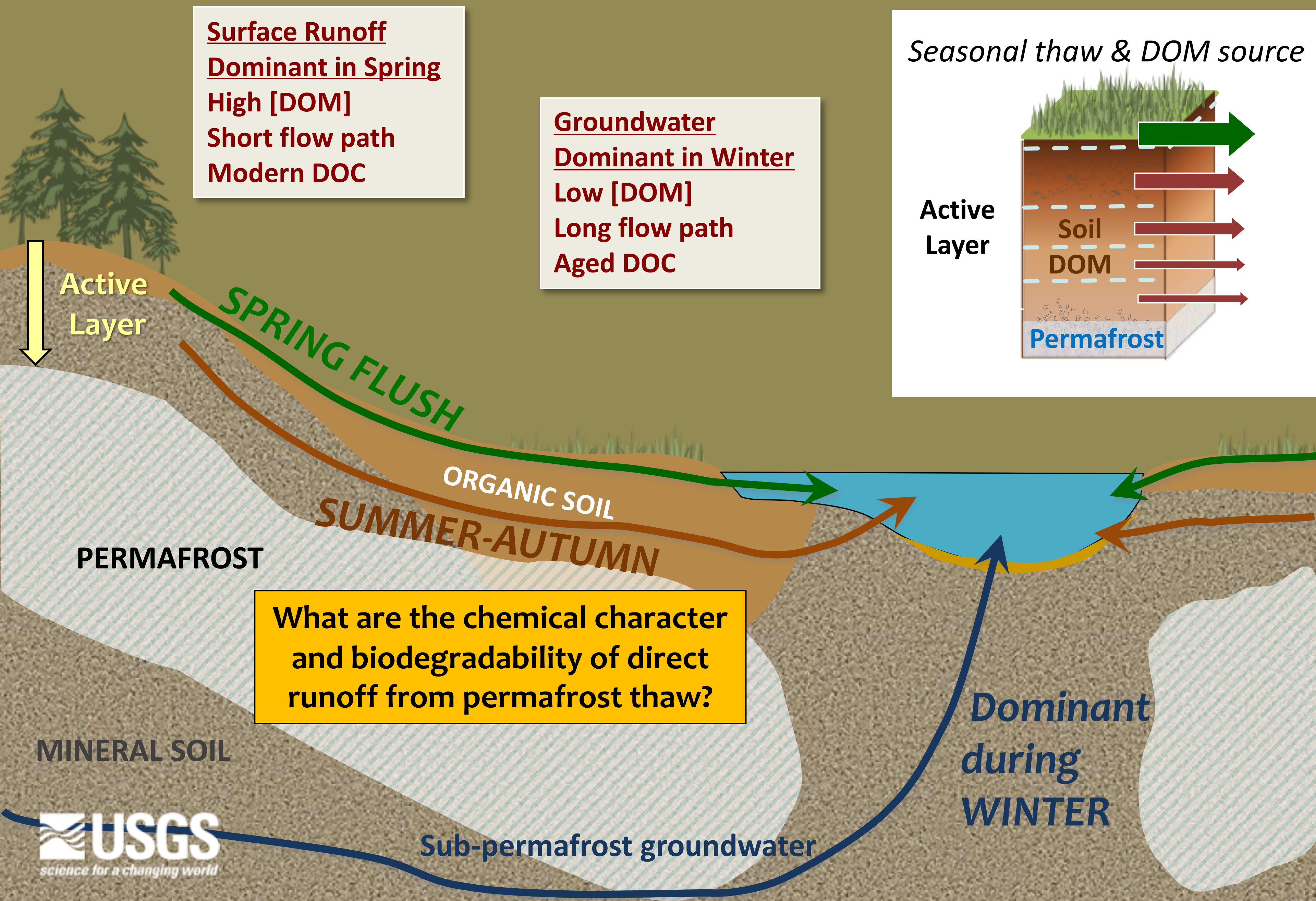
Seasonal Shifts in Δ14C Reflect Changes in Flowpath and Water Source

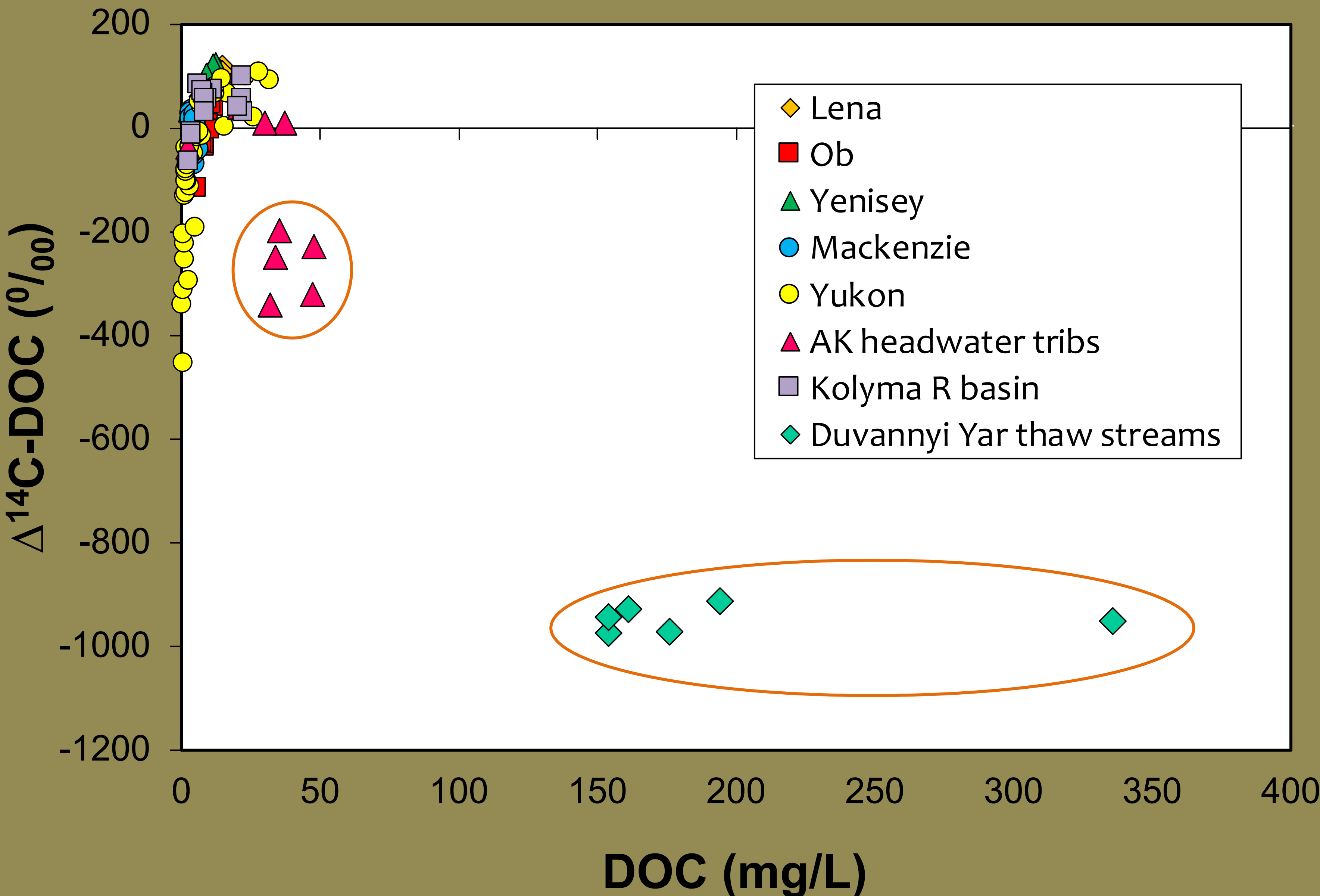




O'Donnell et al., JGR-B, 2014

Seasonal Shifts in Dominant Stream Source





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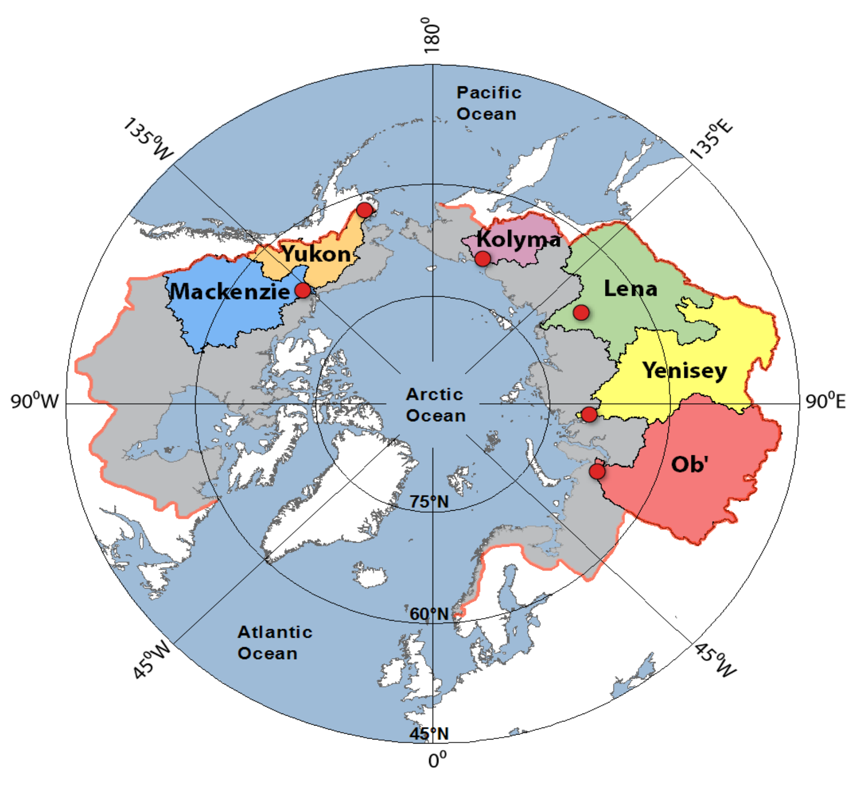
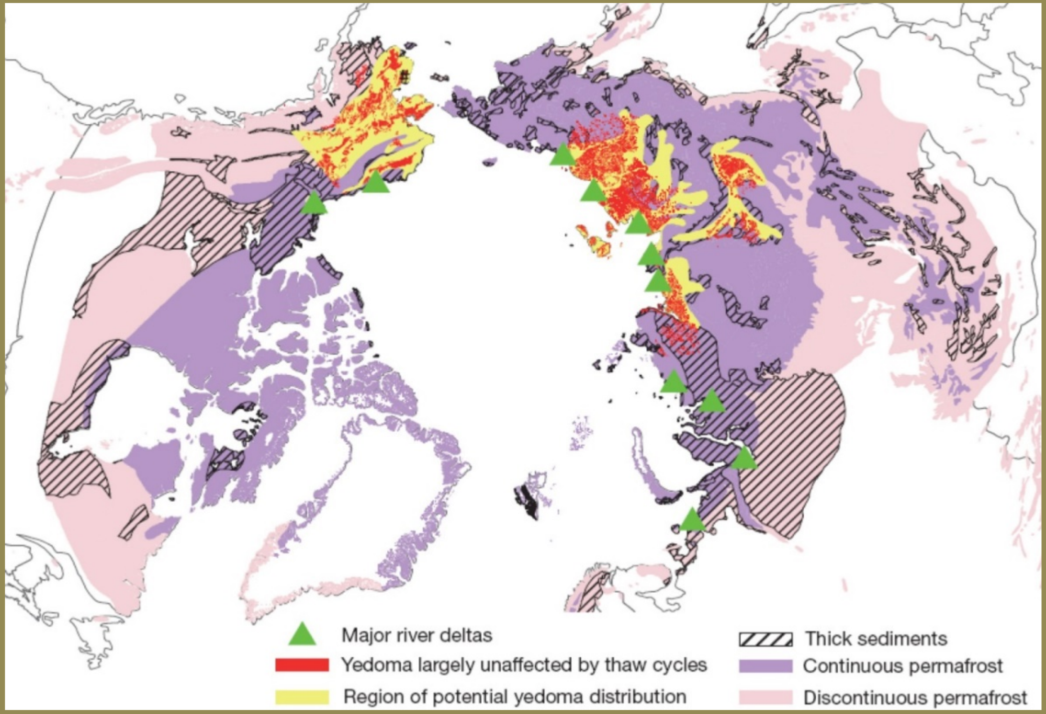
Vonk et al. 2013, GRL; Wickland unpublished data

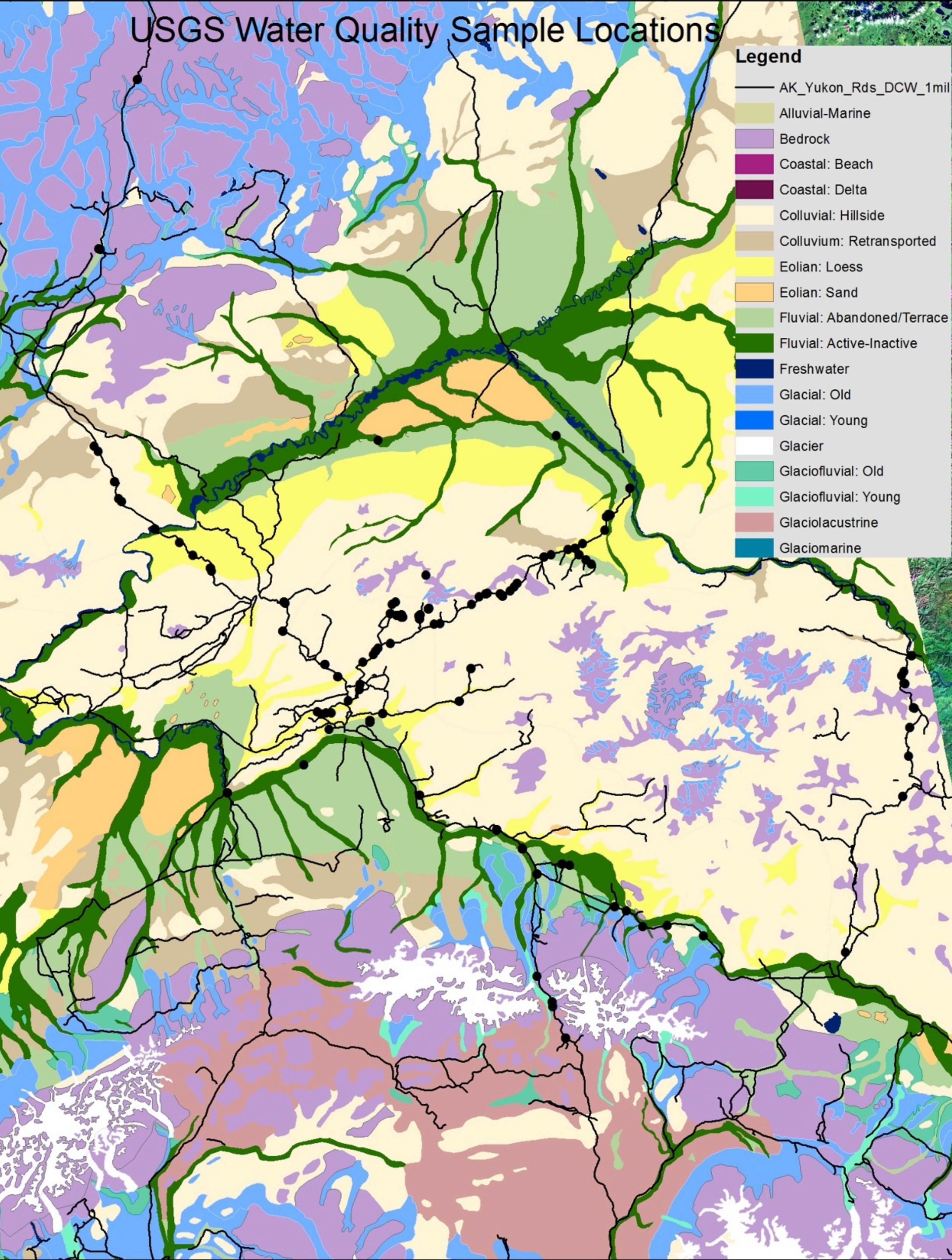


What's different about the hydrology and composition of permafrost DOC?

Recent focus: DOC from Pleistocene loess (yedoma) in the Yukon and Kolyma basins.

Vonk et al., 2013; Mann et al. 2015; Spencer et al., 2015; Drake et al., 2015





HETEROGENEOUS SYSTEMS (Not all Yedoma)

Large variability in:

I. Carbon source strength

II. Carbon & water flow path & residence time

III. Carbon chemistry & degradability

Map:Torre Jorgenson

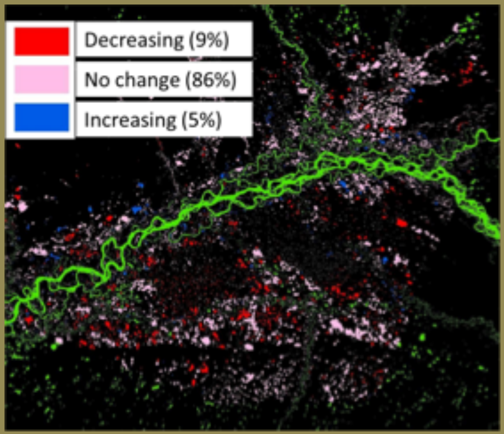
Yukon Flats, Interior ALASKA:
Physical and Chemical Characteristics of a Lake-Rich Lowland Undergoing Change

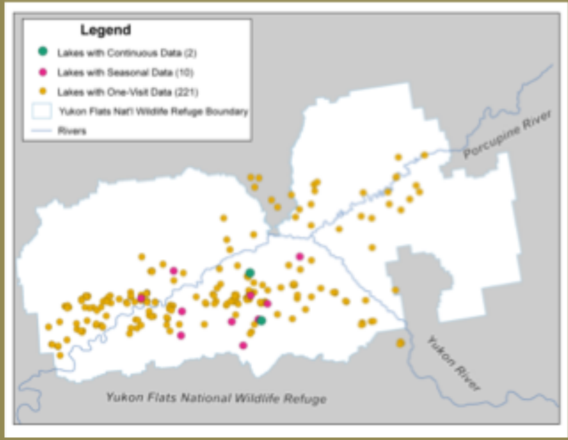
CROSS-SCALE CHARACTERIZATION

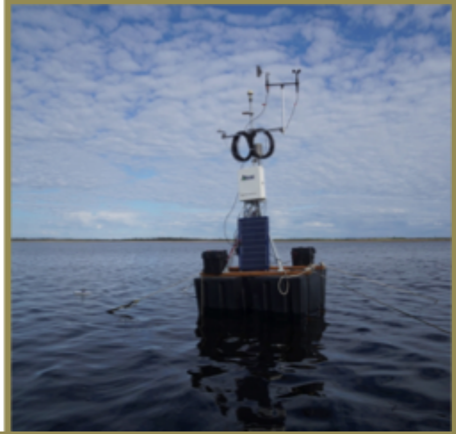
SCALE of Analysis

Satellite Remote Sensing — *Airborne Mapping* — *Synoptic Sampling* — *Intensive Field Studies*

Regional lake area dynamics (Landsat)	Airborne electromagnetic surveys	Lake & stream water chemistry surveys	Continuous hydrological &WQ monitoring







Through cross-scale investigations, we aim to coalesce process-based understanding and large-scale observations - - ultimately advancing prediction capability.

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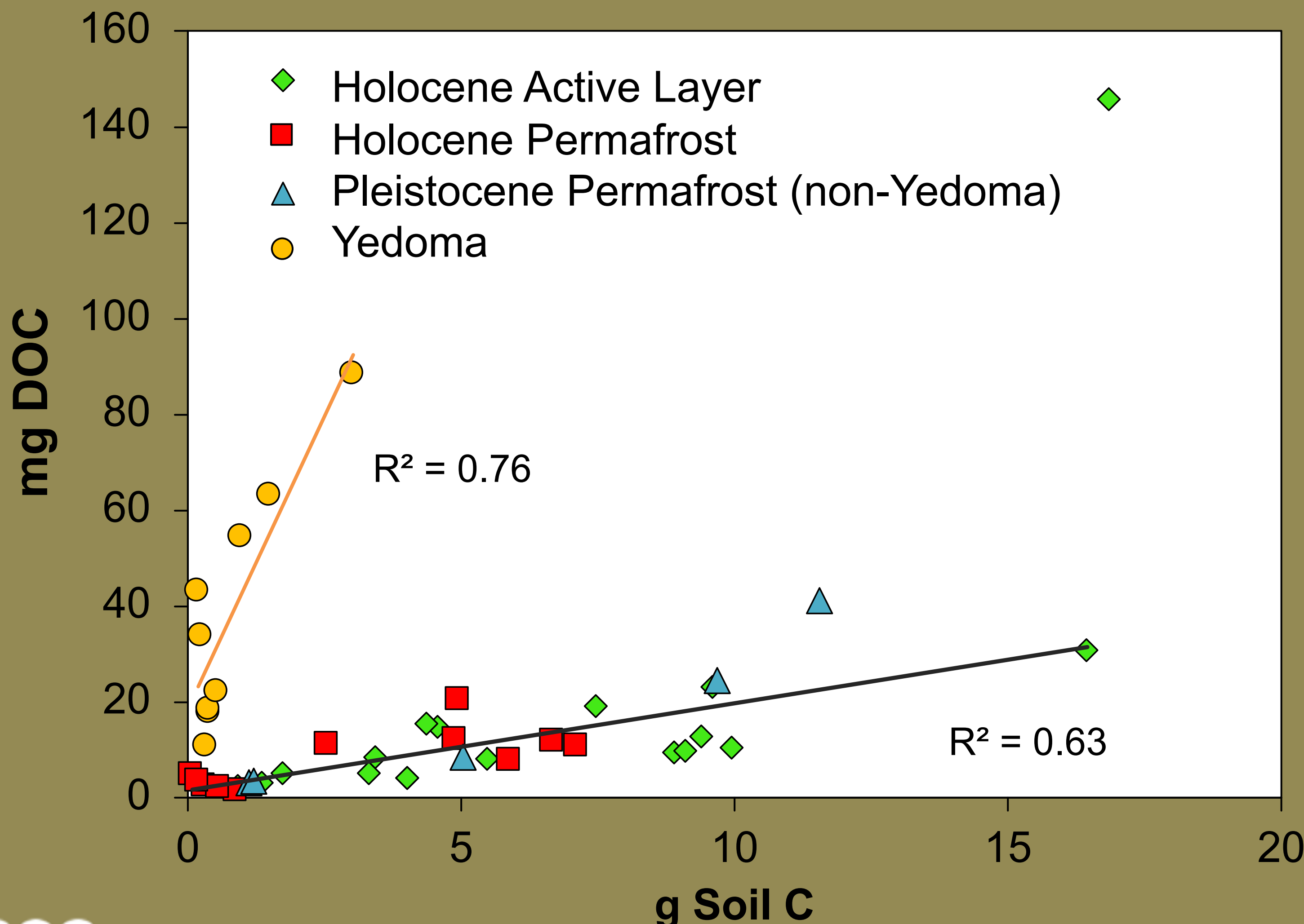
I. Carbon source strength

Wide Range in Permafrost Soil C -Content & Leachability



Wickland, unpublished

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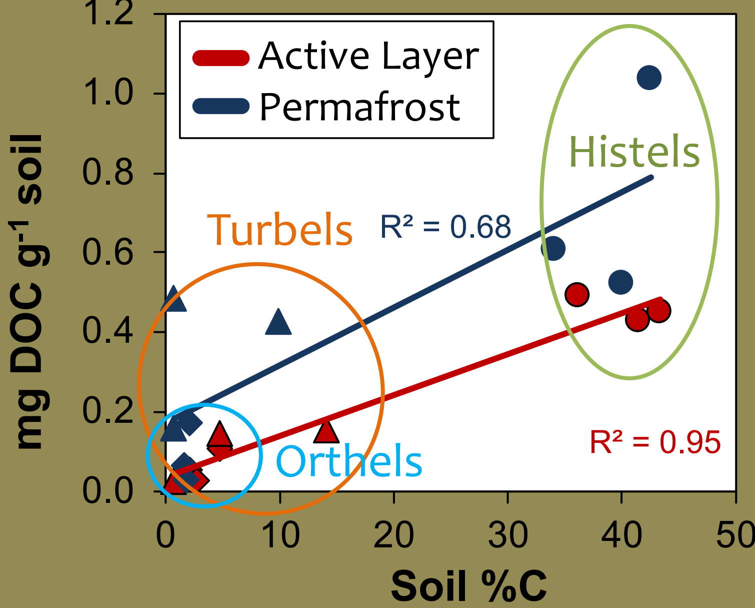
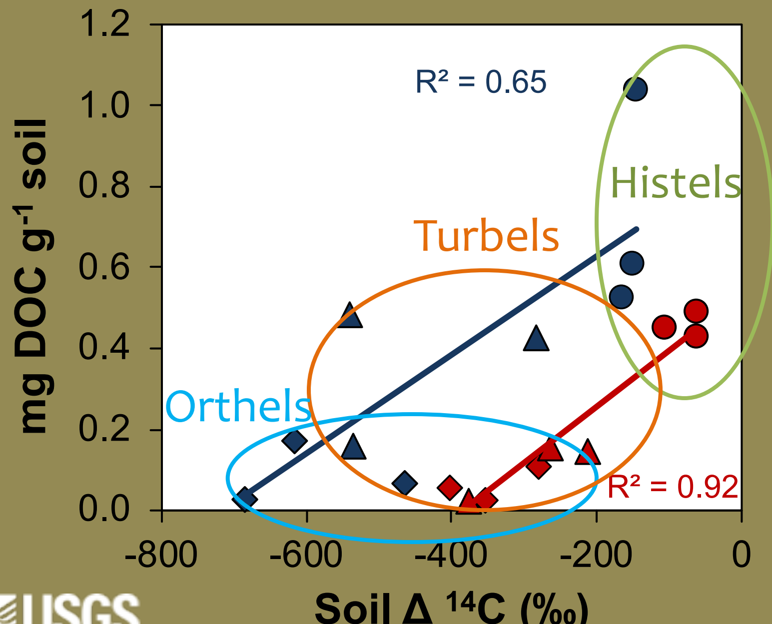
I. Carbon source strength

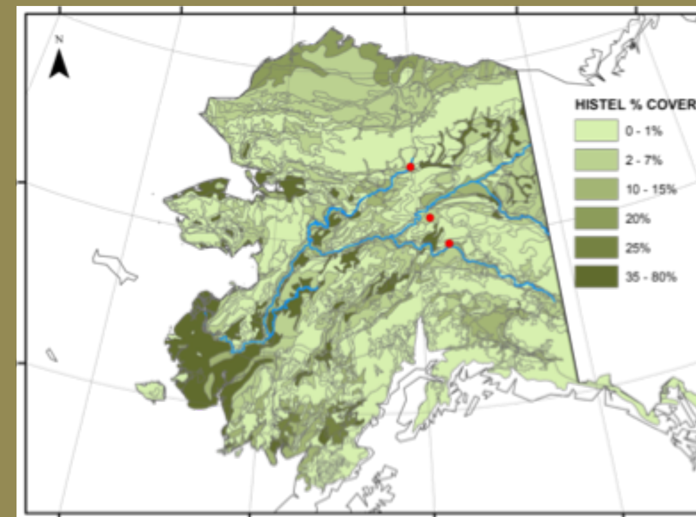
DOC Release from Active-Layer & Near-surface (<1m) Permafrost Soils

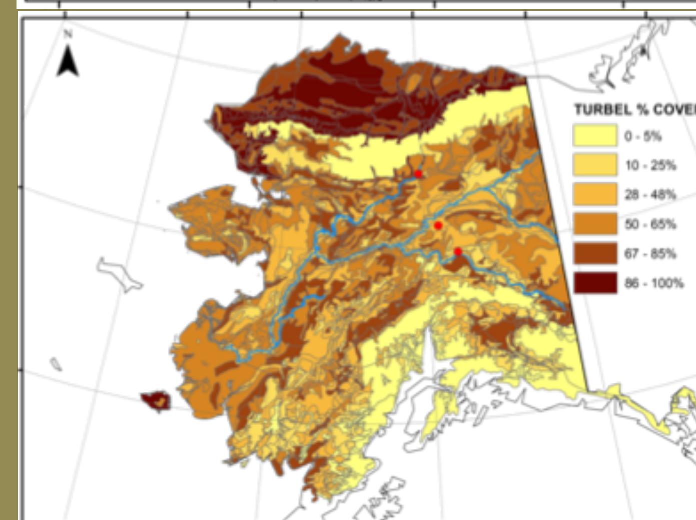


For a given soil C content or radiocarbon age, near-surface permafrost soils yield more DOC upon thaw than active-layer soils immediately above the permafrost boundary.



Histels and Turbels, the most spatially abundant permafrost soils, have the greatest potential for increased DOC release with near-surface permafrost thaw.





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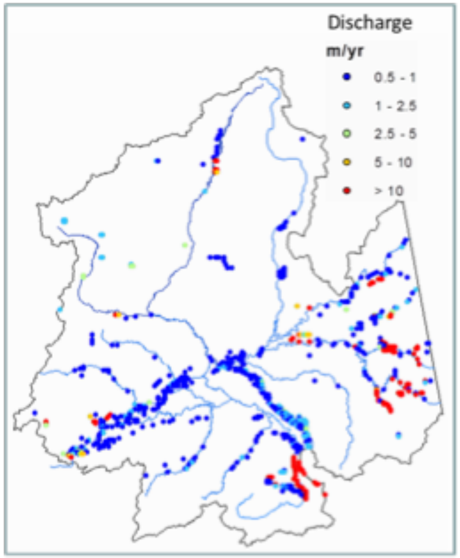
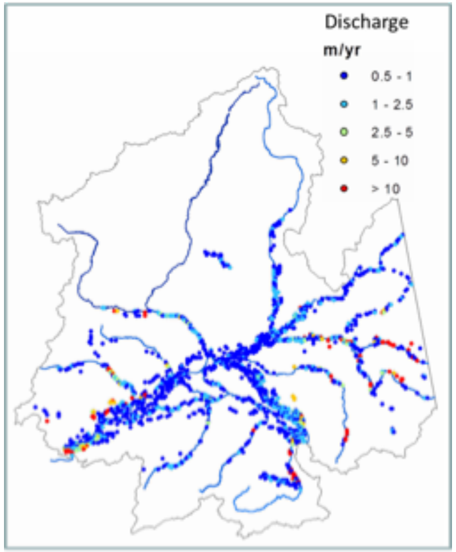
Wickland et al., submitted to ERL special issue

II. Carbon and water flow path & residence time

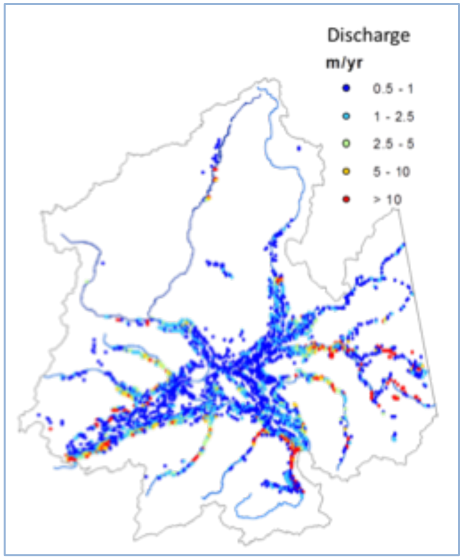
> *Thaw > Infiltration > Residence Time & GW Contribution to Flow*



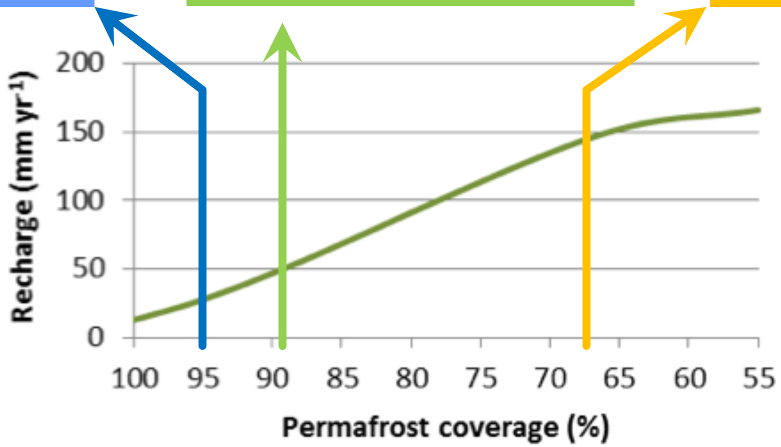
95% Permafrost coverage
Recharge = 28 mm/yr
(6% basin ppt)



89% Permafrost coverage
Recharge = 55 mm/yr
(11% basin ppt)



67% Permafrost coverage
Recharge = 146 mm/yr
(30% basin ppt)



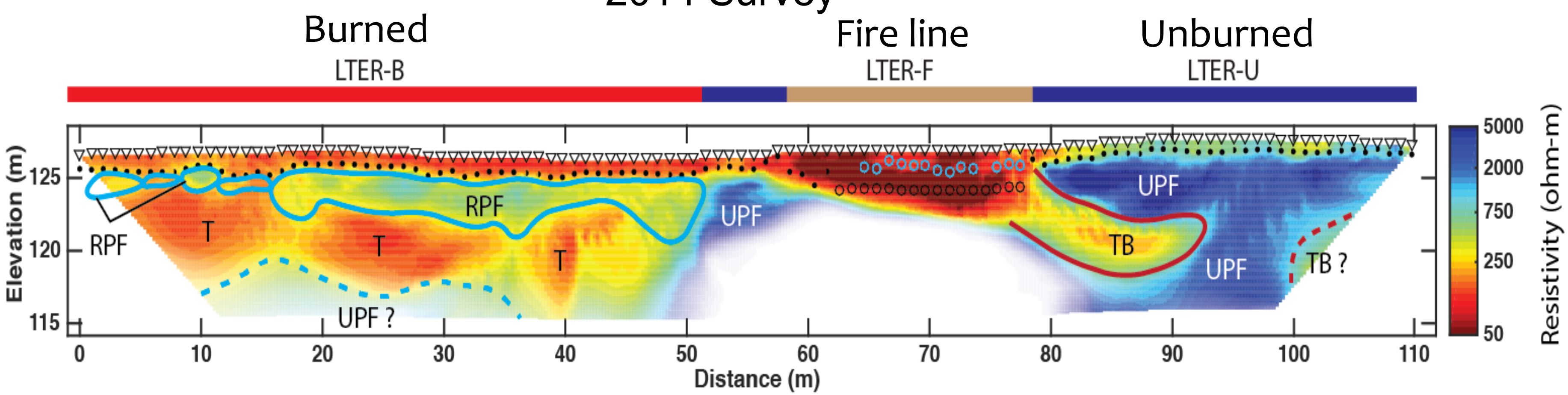
Walvoord et al., 2012, WRR

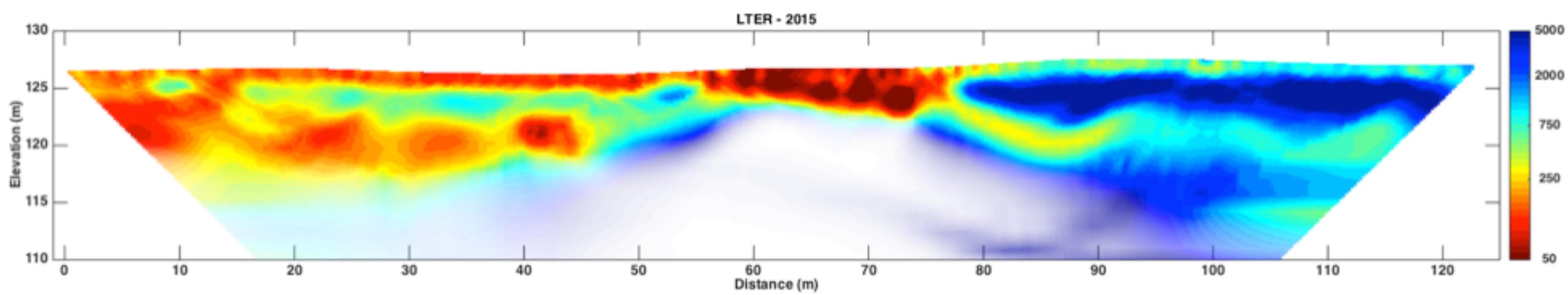
II. Carbon and water flow path & residence time

Subsurface conditions are locally variable and transient = Wide range in hydraulic connectivity & water residence time

BONANZA CREEK LTER – 1983 ROSIE CREEK FIRE

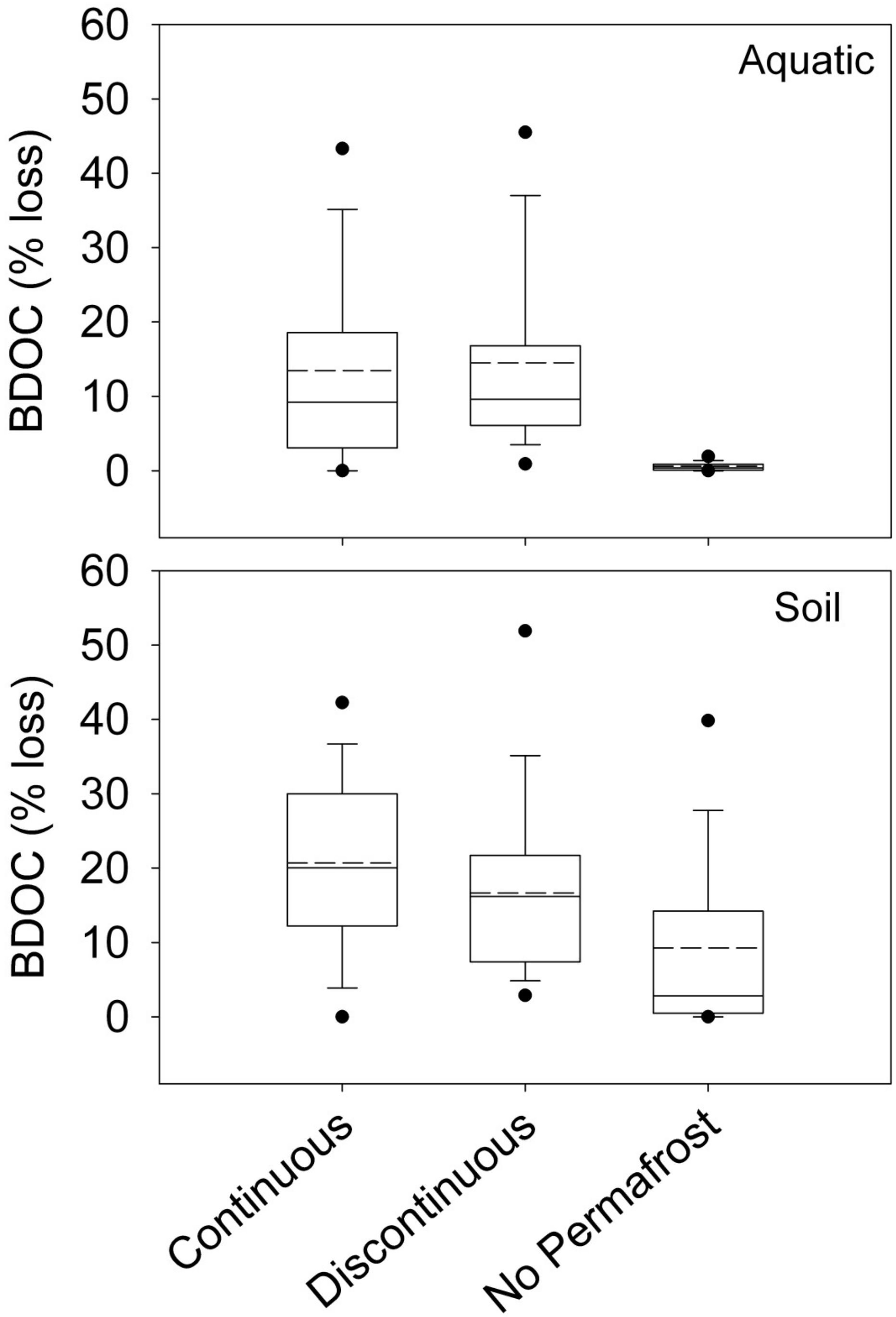
2014 Survey





Repeat survey in 2015

Figure: Burke Minsley



III. Carbon chemistry & degradability

General Trend Across the Arctic:

Biodegradability (BDOC) <u>*decreases*</u> from continuous to non-permafrost landscapes.

Vonk et al., Biogeosciences 2015

III. Carbon chemistry & degradability

RECENT ADVANCES:

- Kolyma: Yedoma DOC runoff preferentially degraded relative to modern DOC (Mann et al, *Nature Comm*, 2015)

- Kolyma: Rapid biodegradation of aliphatics in DOC from headwater streams (Spencer et al, *GRL*, 2015)

- Yukon: Large amounts of low molecular weight (LMW) organic acids (acetate) in yedoma permafrost DOM (Ewing et al, *GRL*, 2015)

- Yukon: Very rapid biodegradation of LMW organic acids (acetate & butyrate) & CO_2 production in yedoma leachates (Drake et al, *PNAS*, 2015)

- Yukon - ABoVE: Accumulation of LMW DOC in near-surface permafrost soils (Wickland et al, *submitted ERL*)

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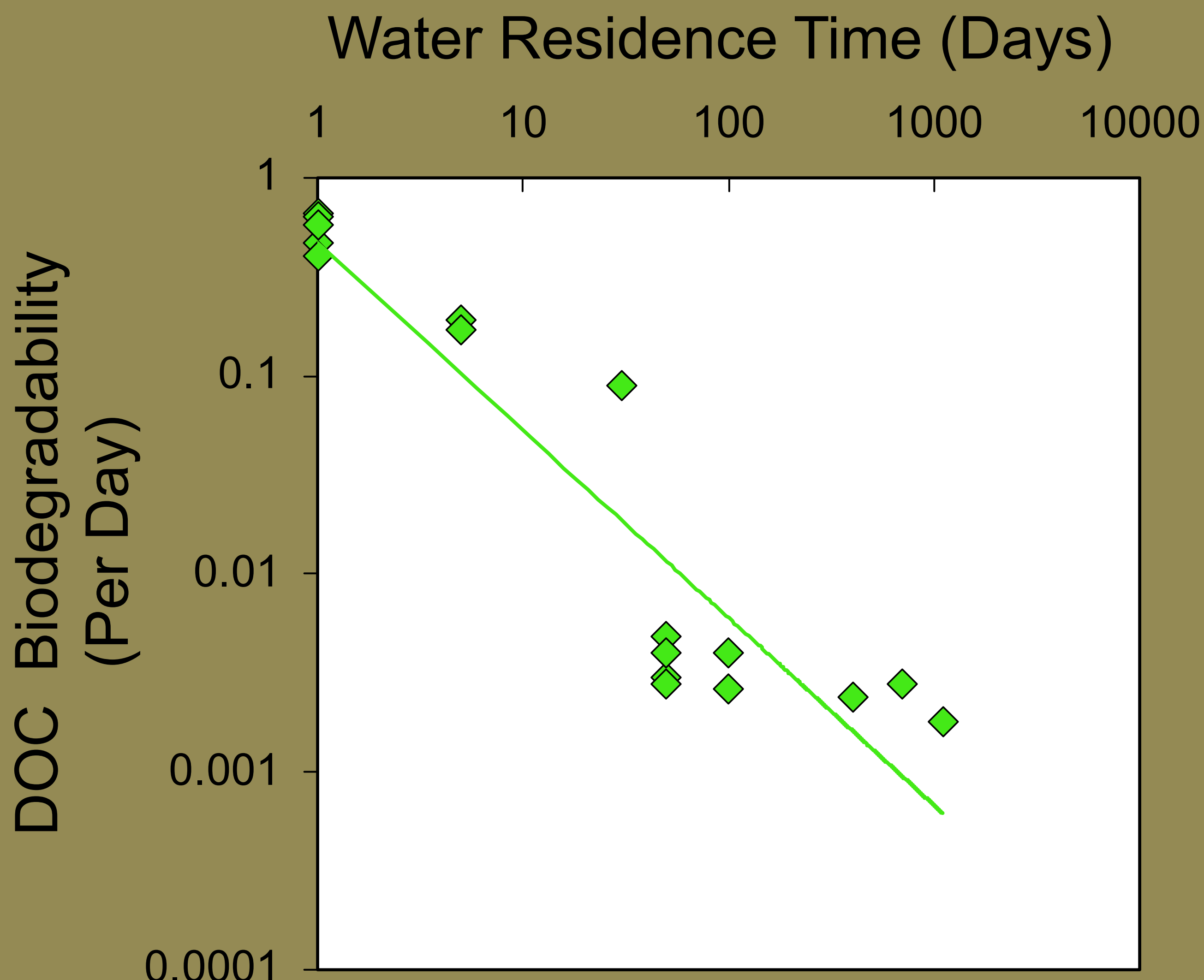
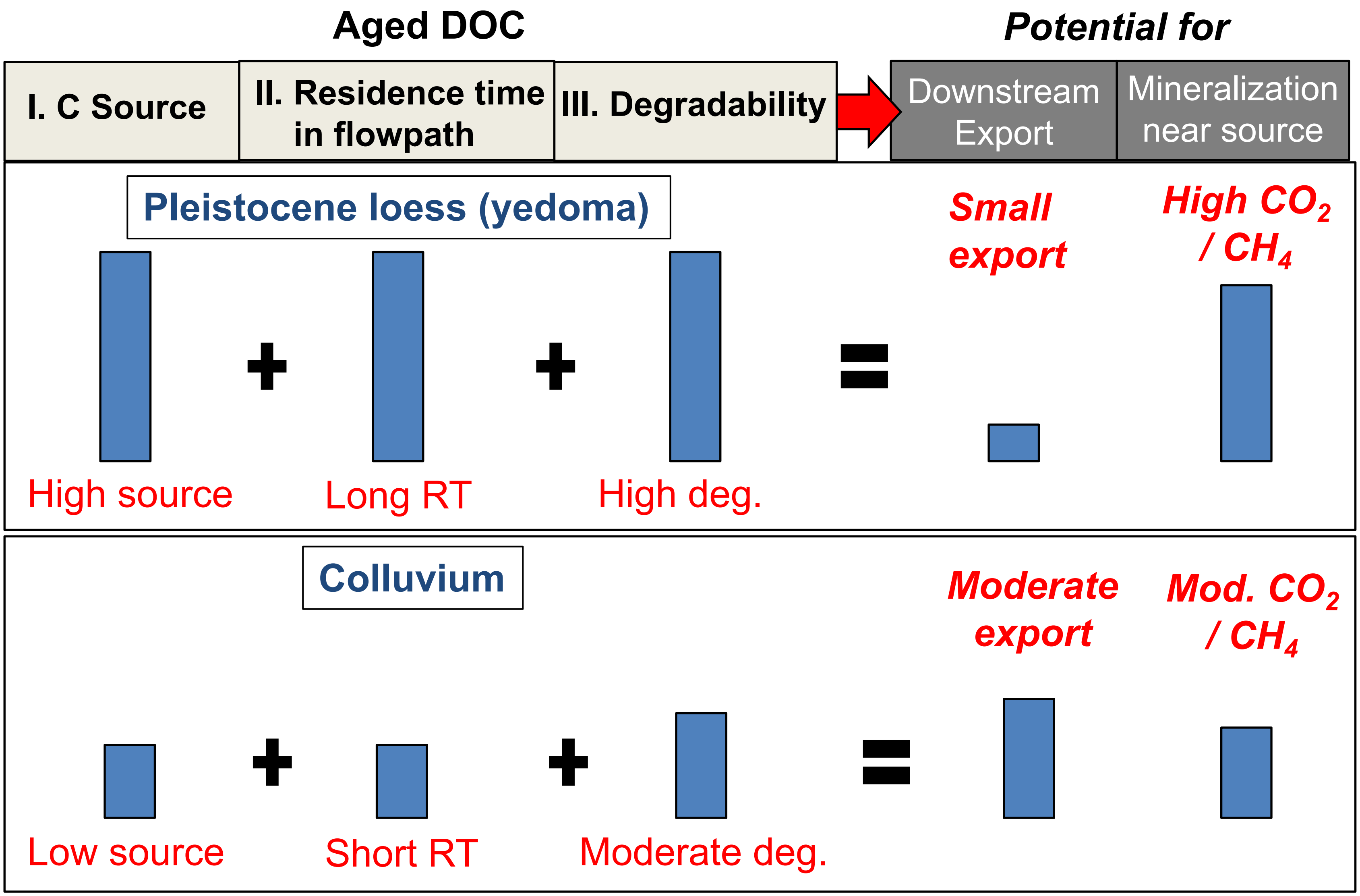
I., II., III. Carbon source, residence time & degradability



Drake et al. 2015; Spencer et al. 2015; Vachon 2015

I., II., III. Carbon source, residence time & degradability



Needs & Continued Research:

Subsurface geophysics – Characterization of permafrost extent & soil physics in undisturbed & disturbed locations.

Hydrology – Improved understanding of the partitioning & routing of surface & subsurface flow with varying permafrost.

Carbon Biogeochemistry – Amount, degradability, age, and chemical composition of permafrost carbon along aquatic flow paths.

Models - Develop field-verified reaction, chemical character & transport models of permafrost DOC, DIC, nutrients.

Thanks!

Photo credit: Heather Best, USGS

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