Circum-arctic biodegradability of fluvial dissolved organic carbon: A meta-analysis

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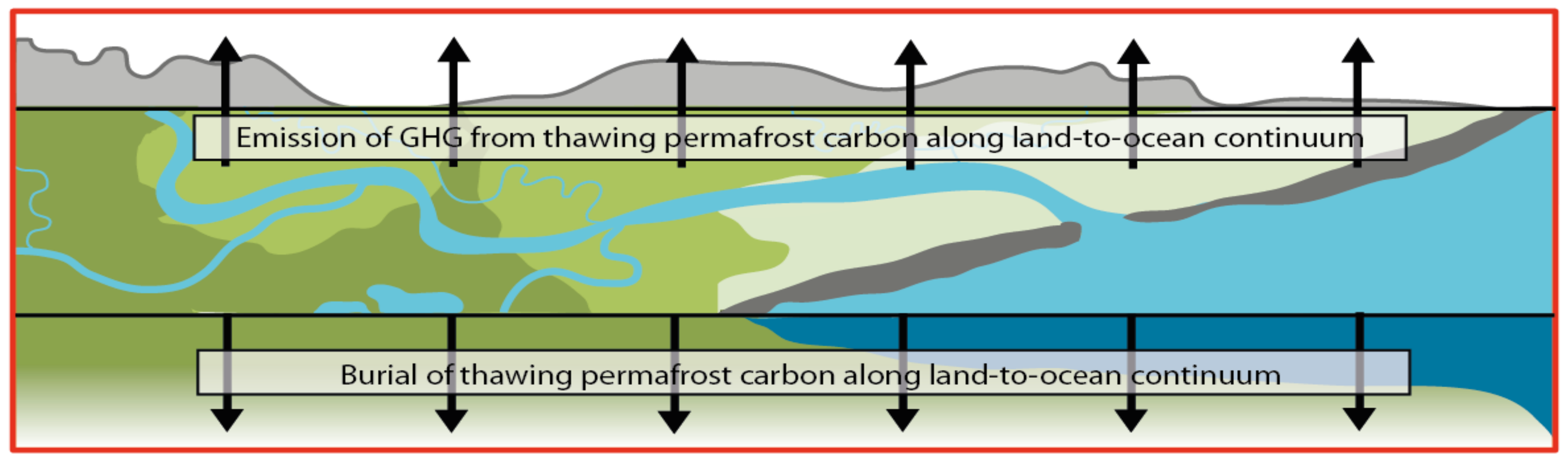
Background

- Arctic frozen soils store twice as much carbon[1] (C) as is currently in atmosphere
- Climate-warming induced permafrost thaw will release C into the aquatic system
- During lateral transport, C is processed + generates greenhouse gases[2] (GHG)
- The flux of greenhouse gases will depend on the **biodegradability** of aquatic C



Synthesis Product

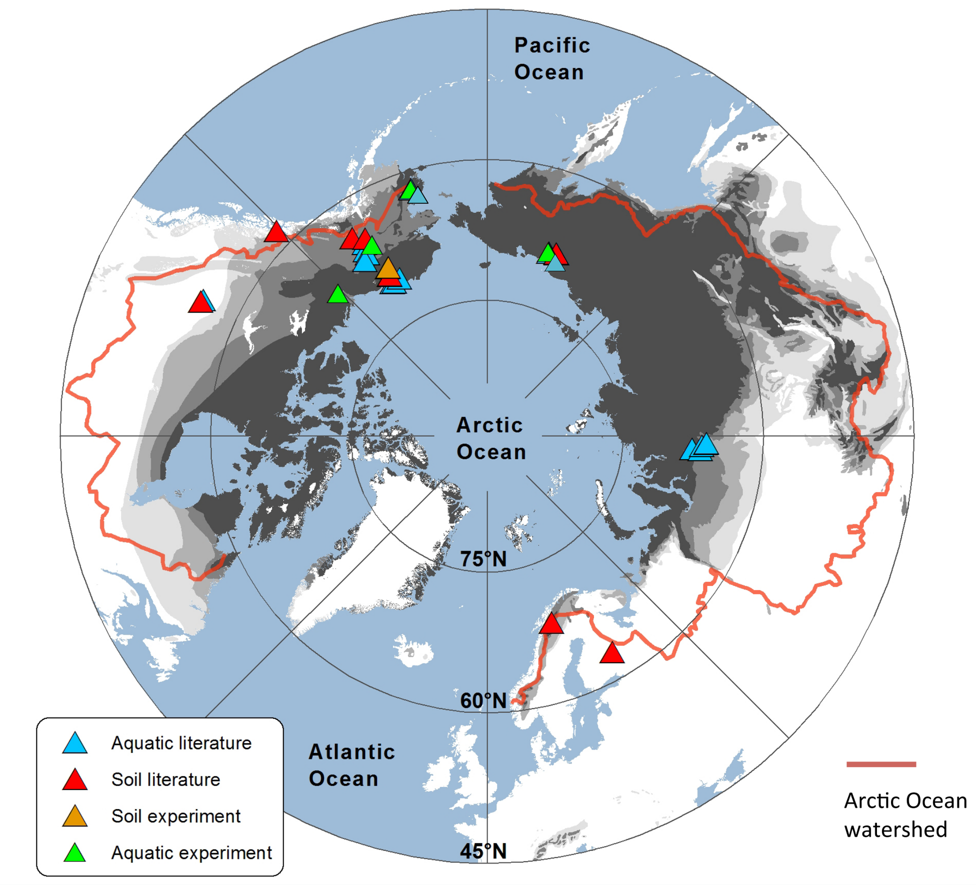
- We target **dissolved organic C** (DOC) rather than particulate OC as (i) Arctic rivers transport ~ 35 Tg DOC annually[3] (ca. 10x POC) and (ii) DOC is more readily available for biological processing[4].
- We compiled available literature and conducted a meta-analysis of soil and water lability experiments.

Literature

- 13 available studies (refs. 5-17)
- located in Arctic Ocean watershed or nearby
- soil leachates, streams, lakes and rivers
- analysis of DOC lability through DOC loss or CO_2 evasion

Circum-Arctic experiment

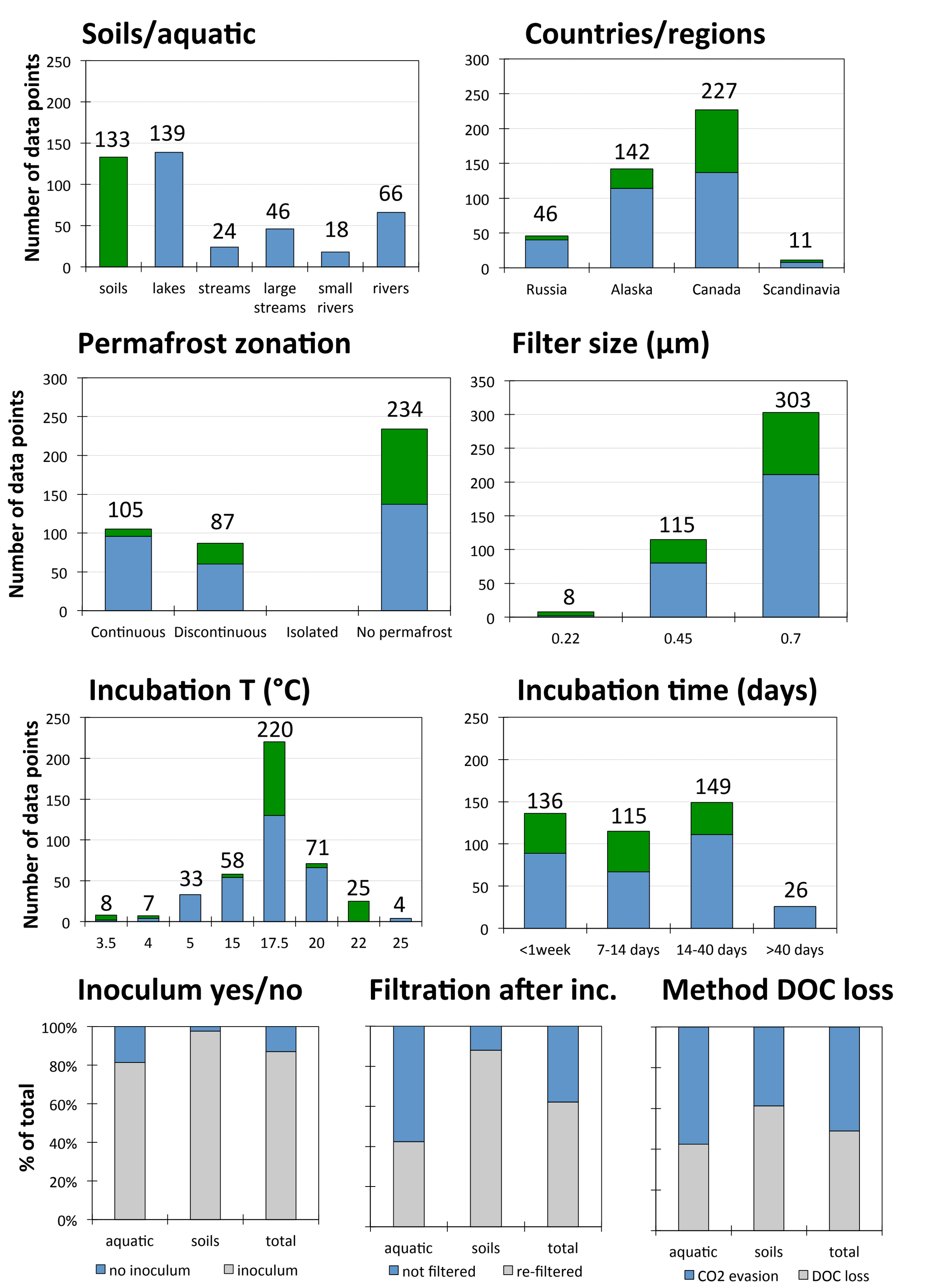
- We performed a large-scale experiment to assess the validity of comparing historic datasets in a meta-analyses of differing methods. We used standardized protocols to assess effects of different methods used in previous studies (see methods)
- Spatial: 2 streams/3 rivers/3 soil core leachates (Alaska, Russia, Canada)
- Temporal: late Spring, Summer and Fall 2013



Literature results

Environmental/method characteristics of literature data:

- total number of data points is n=426;
- six upper plots: n=.. listed above bar; **green** is soil leachate data, **blue** is aquatic data
- three lower plots: method parameters used in %of total.



- The method diversity in literature is huge. Most common: **17.5°C** incubation T, **0.7µm** filter size, addition of **inoculum**, incubation time **14-40days**.
- All "no permafrost" data are in S-Canada (Mackenzie watershed)

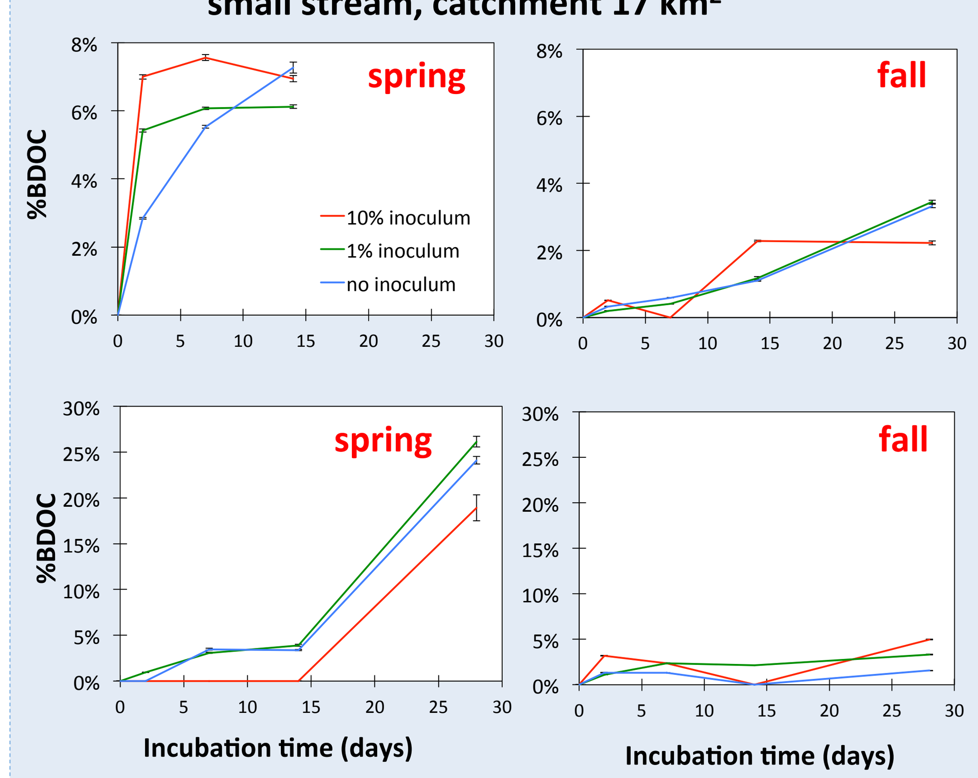
Circum-arctic experimental methods:

- Filter water samples and soil leachates through **0.7µm GF/F** (pre-combusted)
- Set up triplicate incubations in 40mL glass vials (pre-combusted) with loose caps (**dark at 20°C**)
- One sample set **without inoculum**, one set with **1% inoculum**, and one set **10%** (1.2µm filtered)
- At each time point (**0, 2, 7, 14, 28 d**), filter again (0.7µm), acidify with HCl and cap.
- Samples where either analyzed onsite (Cherskii, Russia) or shipped to WHRC (US) for analyses.
- Samples where kept **cold but *not* frozen**.

First experimental results (i)

AQUATIC

Y3 NE Siberia, 68.76°N161.45°E small stream, catchment 17 km²



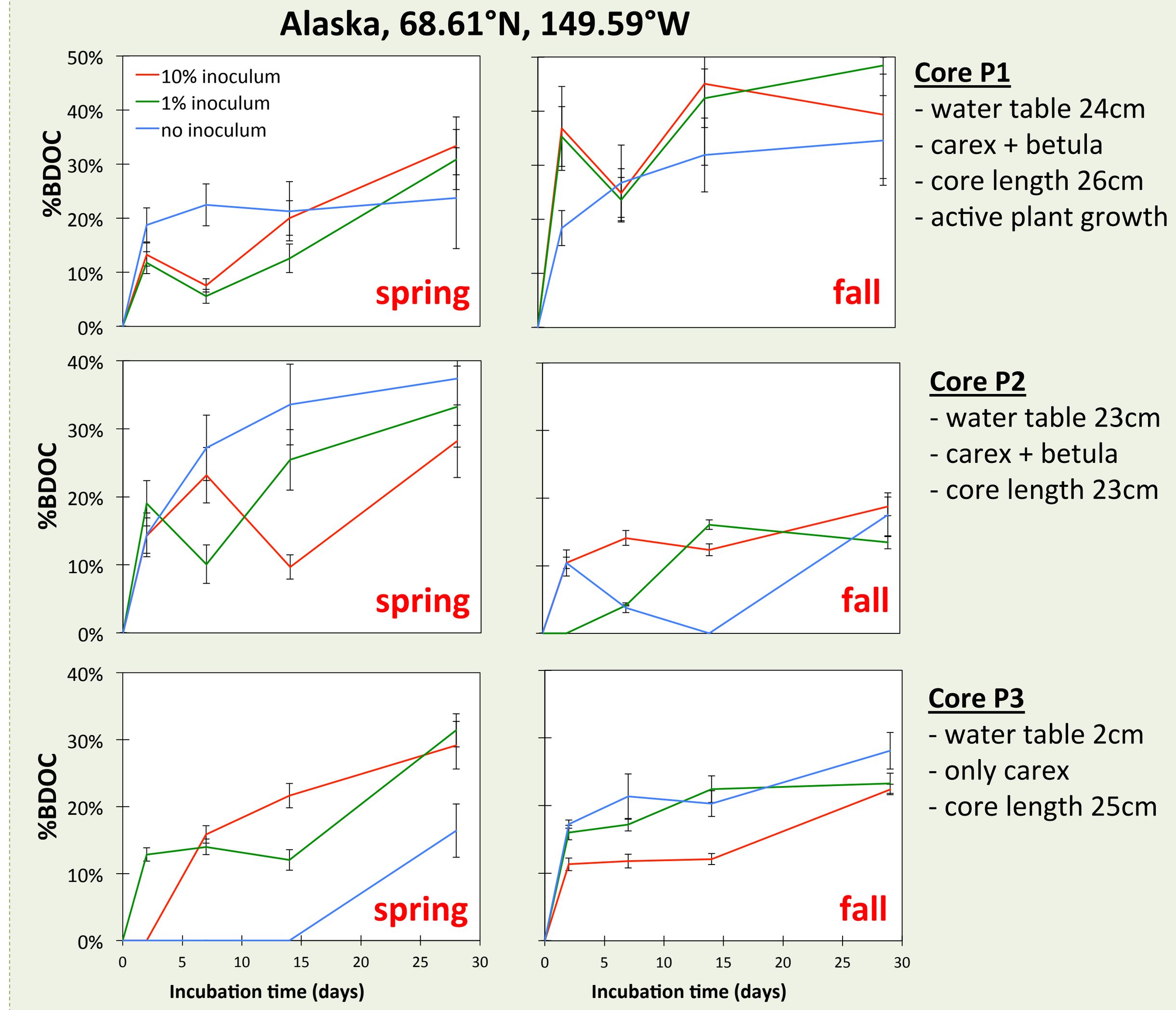
Kolyma NE Siberia, 68.74°N, 161.28°E large river, catchment 653000 km²

- %BDOC during spring is higher than in fall
- no distinct inoculum effect

First experimental results (ii)

SOIL CORE LEACHATES

Alaska, 68.61°N, 149.59°W



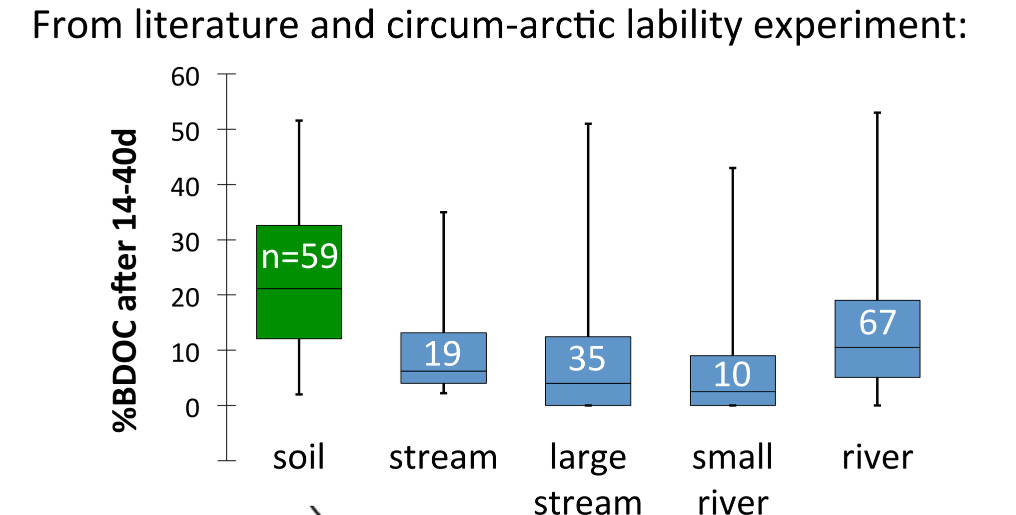
- Core 1 (active plant growth): higher %BDOC than other cores and increasing %BDOC in fall c/w spring

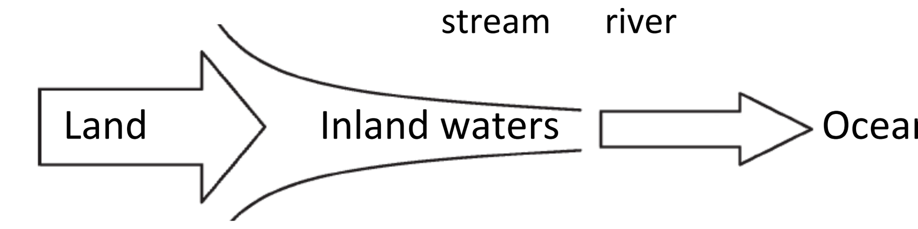
→ Soil leachates have higher %BDOC (14-48%, mean±stdev 28±9%) than streams/rivers (2-26%, 10±10%)

→ More results coming soon for Siberia (summer incubations), and Alaska/Canada (spring/fall incubations)

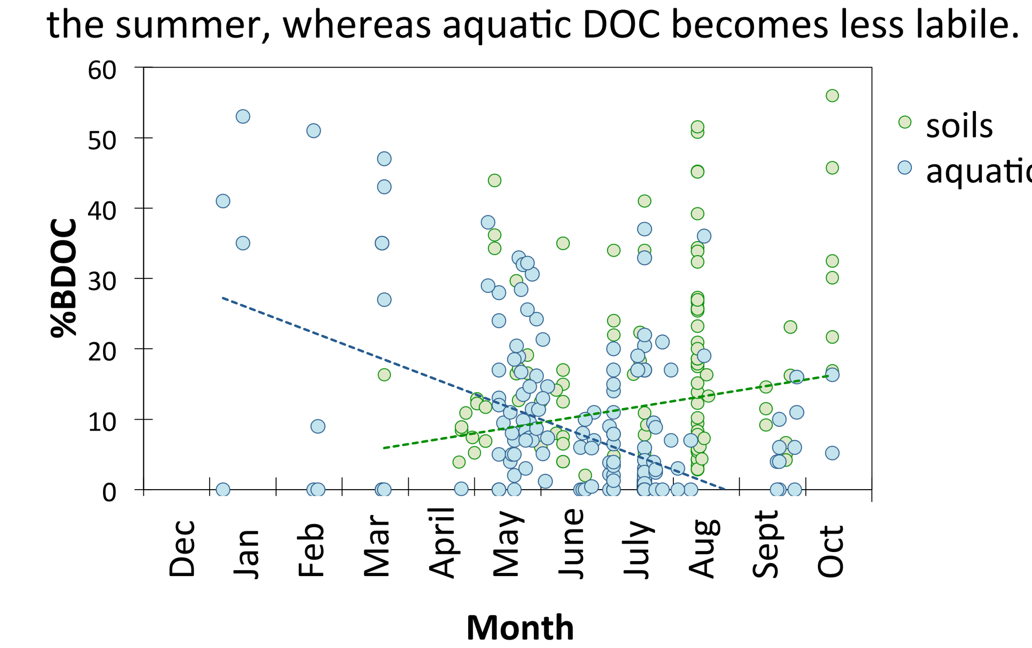
Compiled data

From literature and circum-arctic lability experiment:





- We generally observe a decreasing DOC lability further down the "microbial funnel"[5] or "active pipe"[18,19], when material is transported from land-to-ocean.
- Data variability can partly be explained by seasonality: soil leachate DOC tends to become more labile during the summer, whereas aquatic DOC becomes less labile.



Conclusions

→ Meta-analyses of 13 available papers with n=426 data points (soil: 127, aquatic 299) show a huge method diversity. Most frequent parameters used: incubation T **17.5°C**, filter size **0.7µm** filter size, **inoculum** addition, incubation time **14-40d**.

→ Soil DOC tends to become more labile during the growing season (Spring through Fall) while aquatic DOC seems to become less labile

→ We observe a general decrease in DOC lability from land to streams, large streams, and small rivers. Large rivers (watersheds >500,000km²) have a relative high lability, potentially affected by a sampling bias towards the freshet.

References: 1. Tarnocai et al., GBC 2009, 2. Vonk&Gustafsson, Nature Geoscience 6, 2013, 3. Holmes et al., E&C, 2011, 4. Battin et al. Nature Geoscience 1, 2008, 5. Wickland et al. Ecosystems 10, 2007, 6. Roehm et al. JGR, 2009, 7. Holmes et al. GRL 2008, 8. Wickland et al., GBC, 2012, 9. Mann et al. JGR, 2012, 10. Kawahigashi et al., GCB, 2004, 11. Balcarczyk et al. BGC, 2009, 12. Michaelson et al., JGR, 1998, 13. Olefeldt et al., BGS, 2013, 14. Vonk et al. GRL, 2013, 15. Vonk et al. ERL, 2013, 16. Olefeldt et al. Ecosystems, 2013, 17. Kiikkilä et al. SB&B, 2011, 18. Cole et al., Ecosystems, 2007, 19. Tranvik et al. L&O, 2009. **Acknowledgements:** We would like to thank Greg Fiske for help with spatial analyses. For financial support, we would like to thank the Dutch NWO (Veni grant #863.12.004), the RCN "Vulnerability of Permafrost Carbon, and the US-NSF (Arctic Great Rivers Observatory, The Polaris Project #1044610, and "Detecting the signature of permafrost thaw in Arctic rivers #1203885).

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