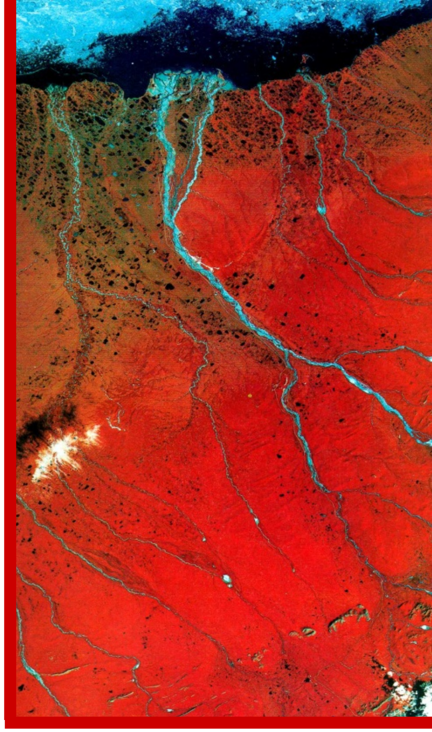
Arctic LTER

Landscape Interactions



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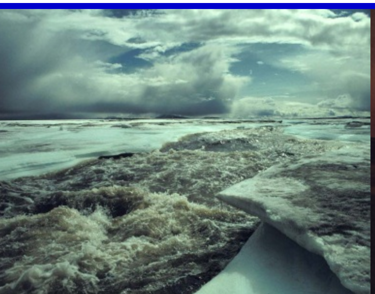
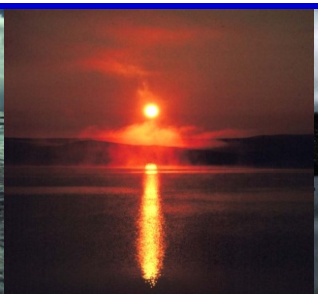
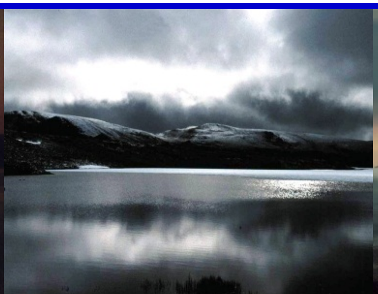





Mapping ArcLTER Proposal Questions to Land-water Research

ArcLTER Shared Questions:

1. How does climate control ecosystem states, processes, and linkages?

- **Basic research on ecological processes** (decomposition, nutrient cycling and export, community change)
- **Focus on carbon and nutrient cycling** (driven by microbes, whose composition and activity are linked)
- **Land-water "linkages" - the integration of ecosystems** (terrestrial, streams, lakes)

2. How do disturbances change ecosystem states, processes, and linkages?

- **Disturbance**
  - *Pulse* – Fire, thermokarst failures
  - *Press* – Climate change, permafrost thaw

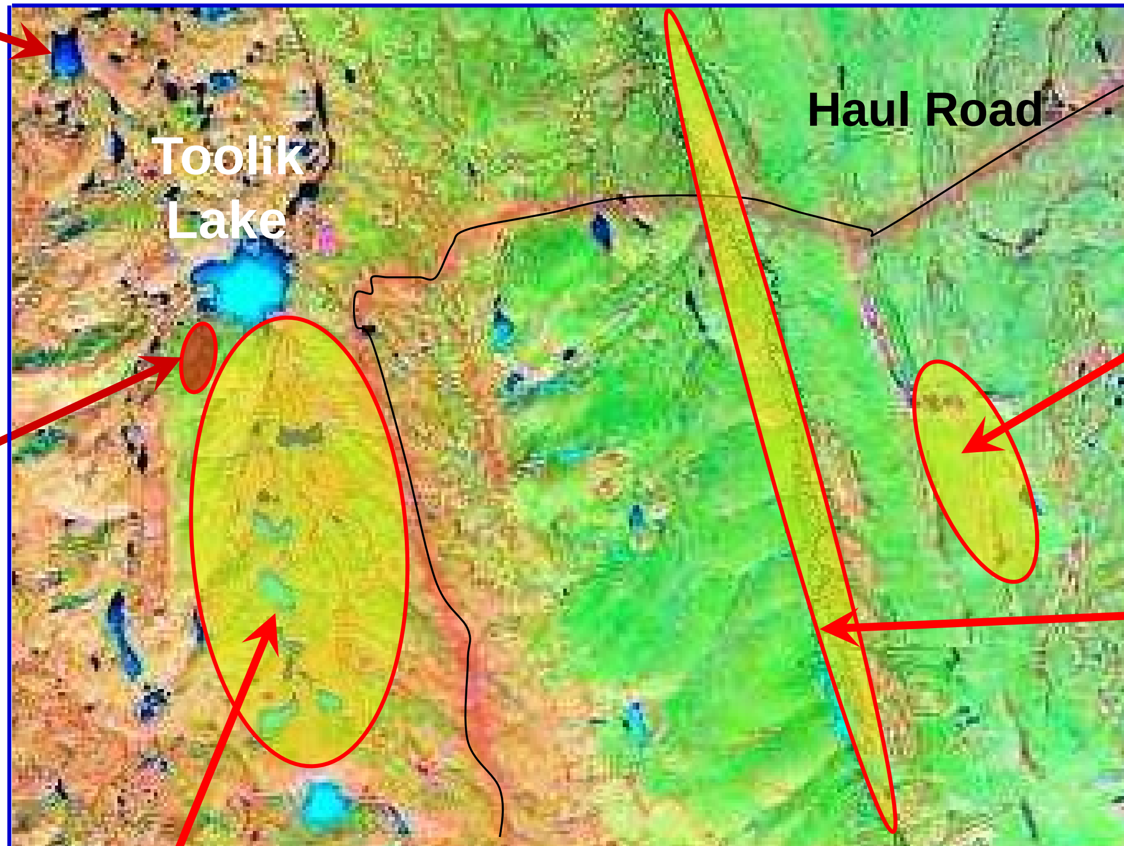
3. How do climate and disturbance interact to control biogeochemical cycles and biodiversity at catchment and landscape scales?

- **Scaling in space and time** (regional to global relevance and implications of basic research)

Land-water interactions:
Common study sites & monitoring

Lake NE14
Thermokarst disturbance

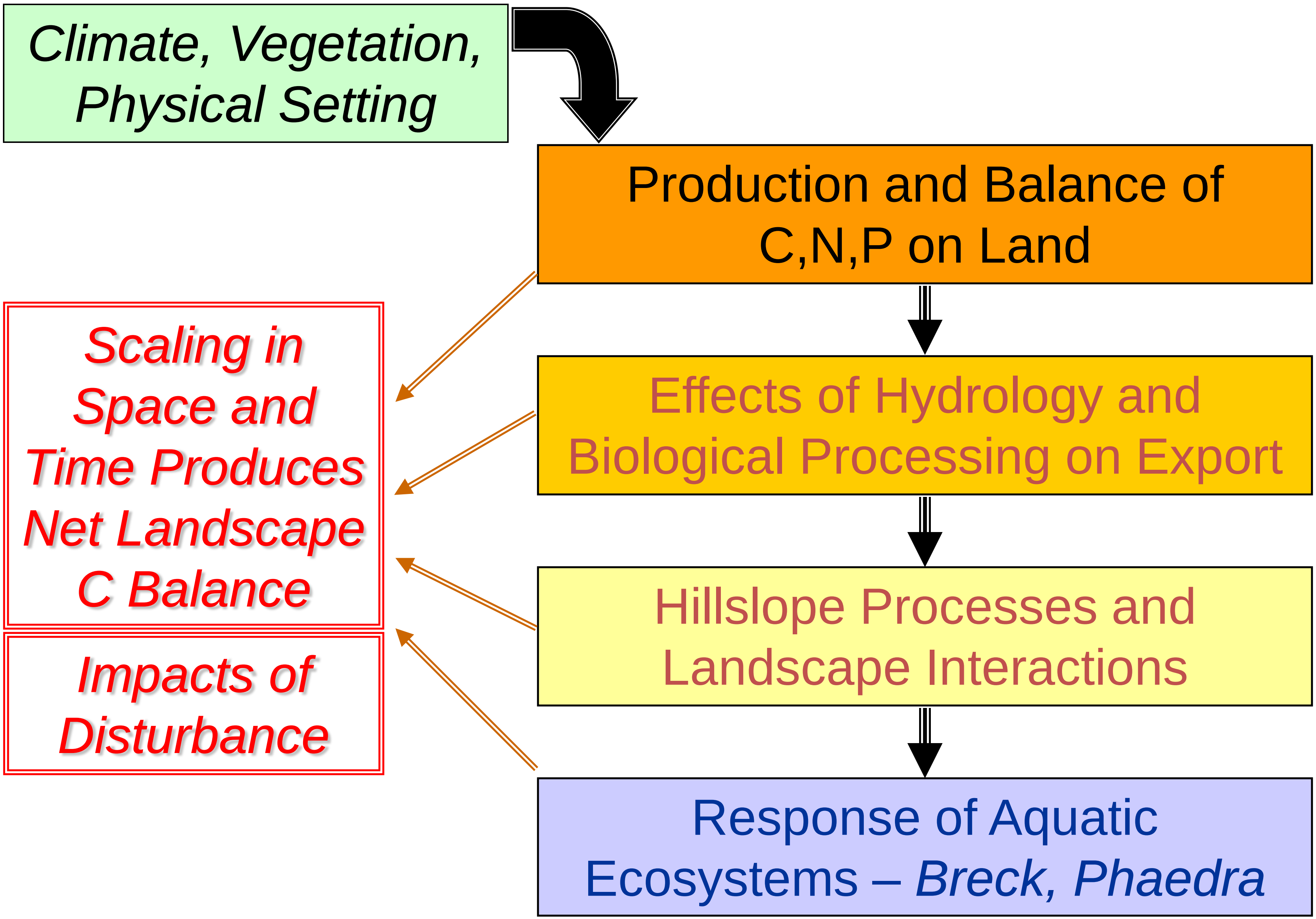
Tussock Watershed
Water & soil chemistry; thaw dynamics



Imnavait Creek
Water & soil chemistry; thaw dynamics

Kuparuk River
Photo-Bio processing of carbon

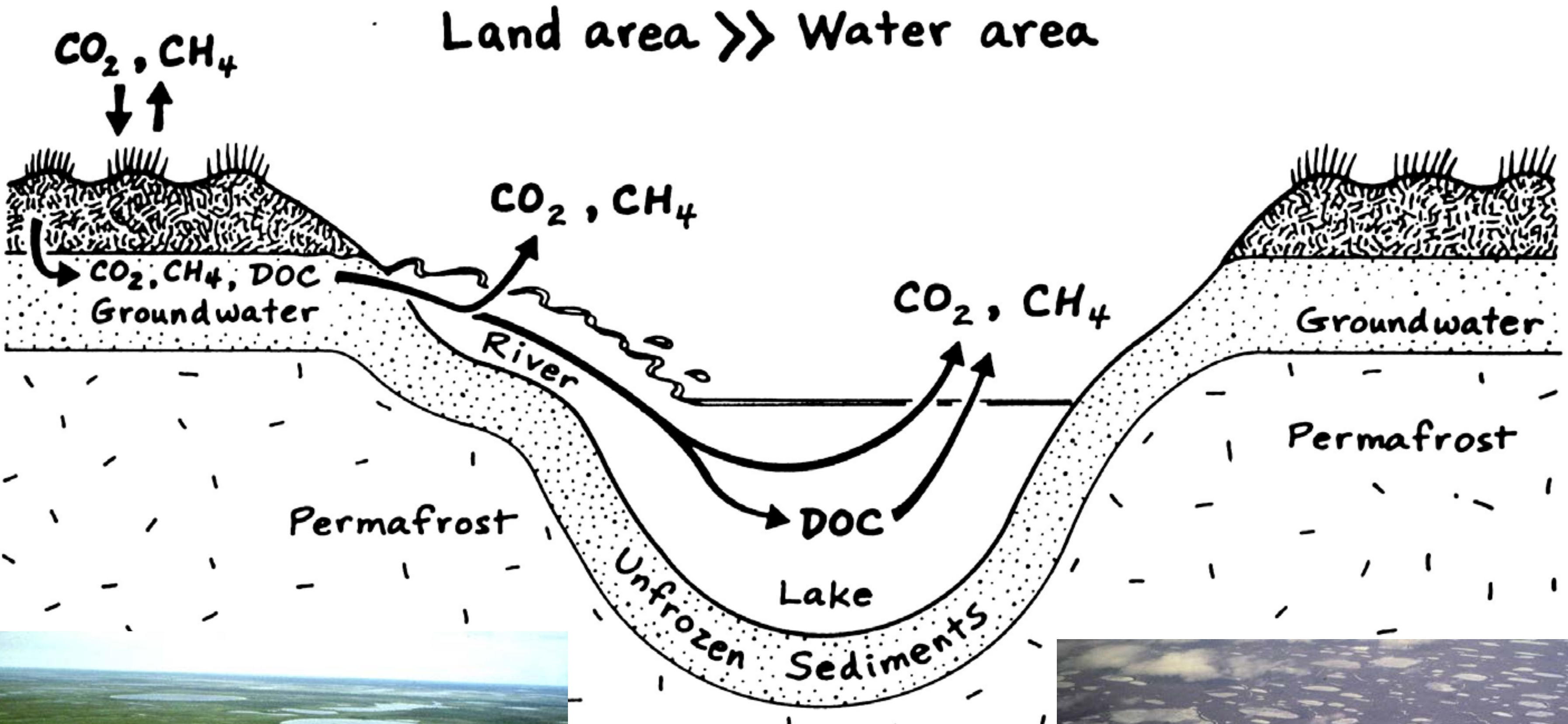
Toolik Inlet series of Lakes and Streams
Interactions between lakes and streams; influence of terrestrial inputs


Climate, Vegetation, Physical Setting
Production and Balance of C,N,P on Land
Effects of Hydrology and Biological Processing on Export
Hillslope Processes and Landscape Interactions
Response of Aquatic Ecosystems – Breck, Phaedra
Scaling in Space and Time Produces Net Landscape C Balance
Impacts of Disturbance

Arctic Carbon Balance

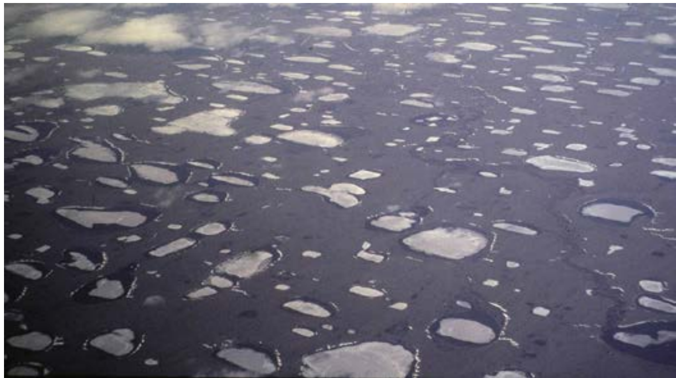
On Land: 10 – 30 g C/m^2/yr <u>storage</u>

Freshwater: 20 – 30 g C/m^2/yr <u>loss</u>

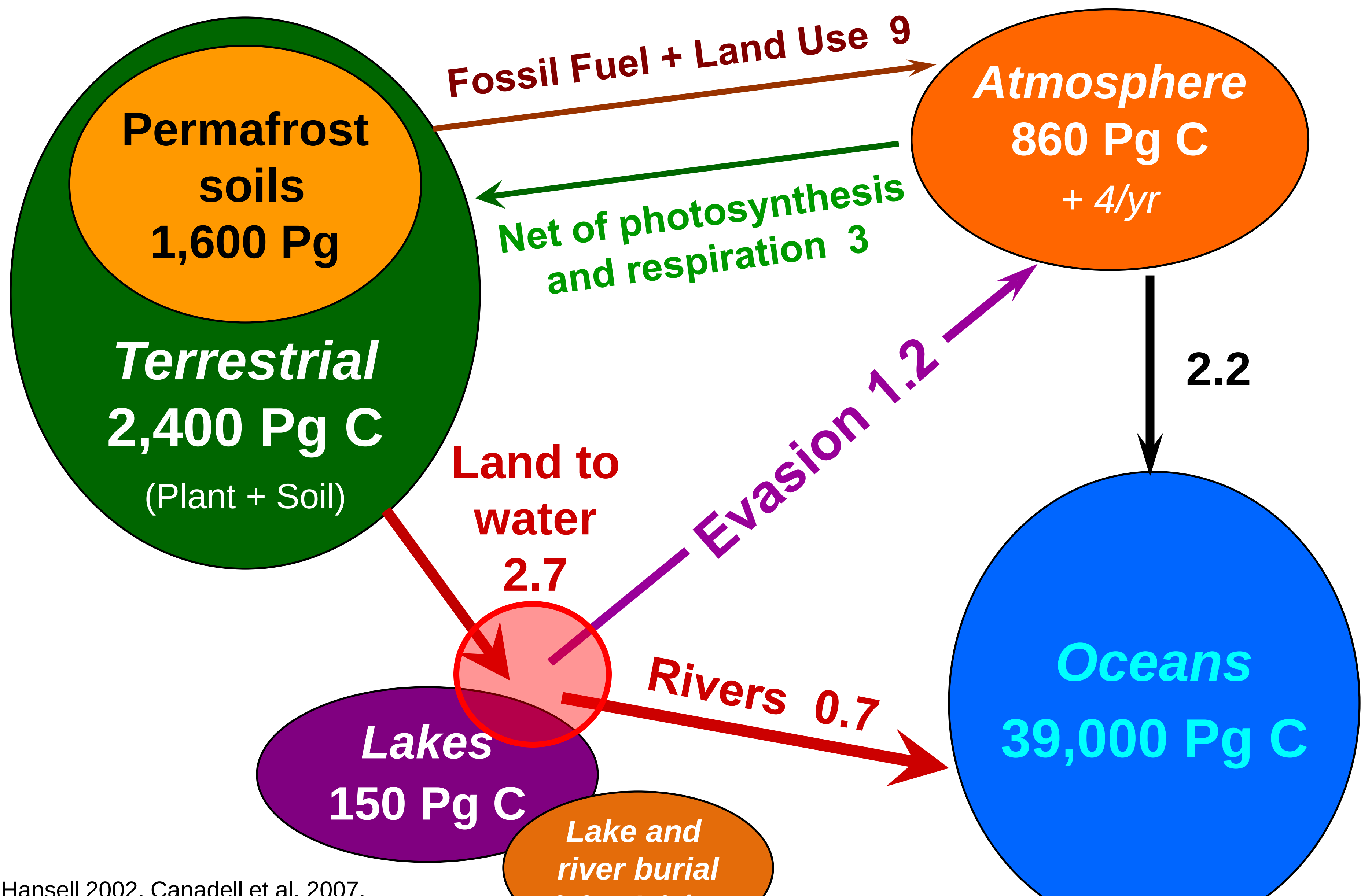


Arctic Tundra – High Lake Density

Up to ~80% of total surface area



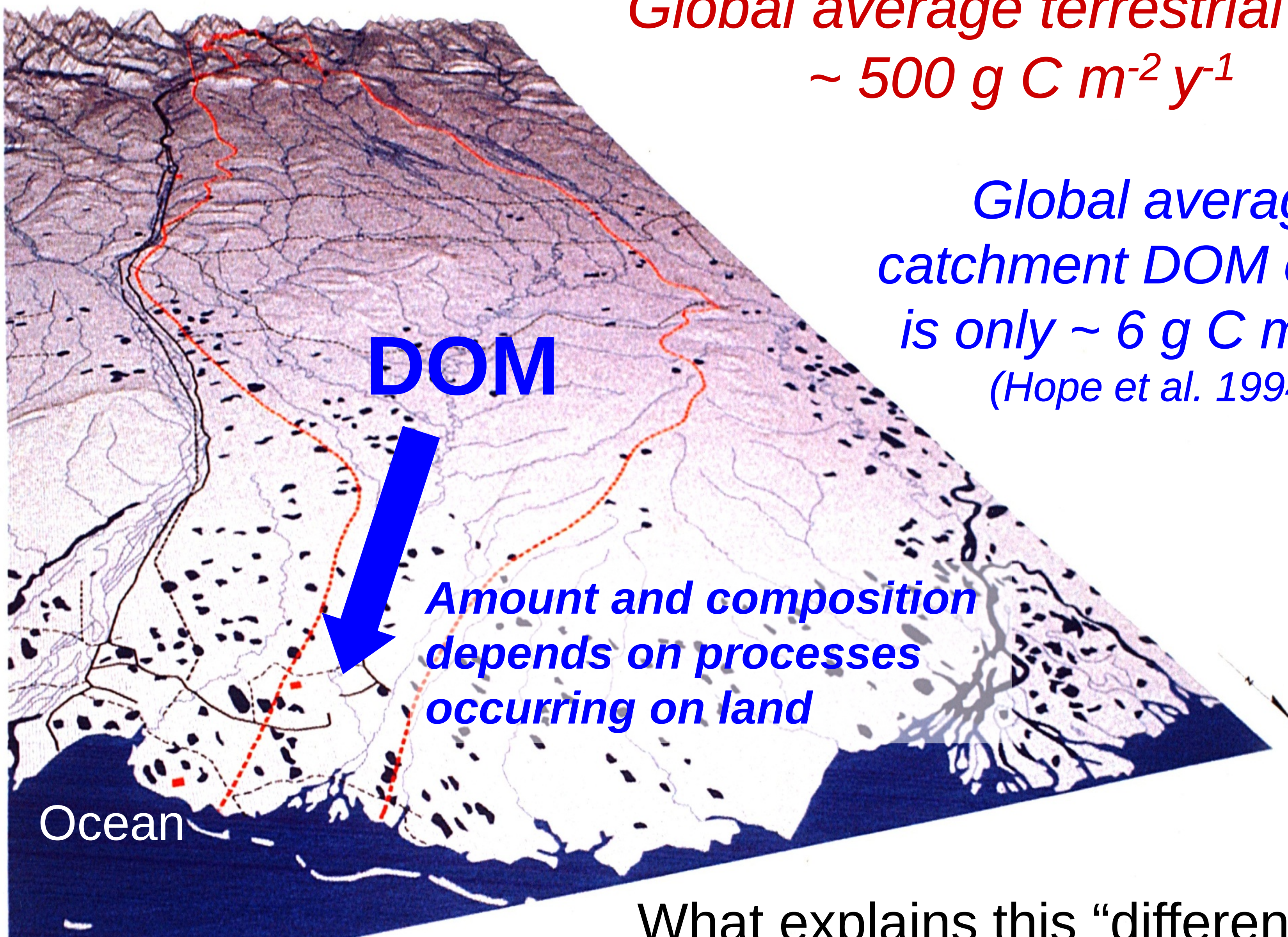
Global Carbon Pools and Fluxes (Pg C and Pg C y^{-1})



Hansell 2002, Canadell et al. 2007, Battin et al. 2009, Aufdenkampe et al. 2011, Tarnocai et al. 2009, Batjes 1996

Global average terrestrial NPP
~ 500 g C m^{-2} y^{-1}

Global average catchment DOM export is only ~ 6 g C m^{-2} y^{-1}
(Hope et al. 1994)



What explains this “differential” of production and export?

Ecosystem C mass balance

1. Plant root exudation rate (arctic tundra):

DOC ~ 1.5 – 4 g C/m^2/day *{Gross Flux}*

2. Total catchment DOC export:

only ~ 2-4 g C/m^2/ YEAR ! *{Net Flux}*

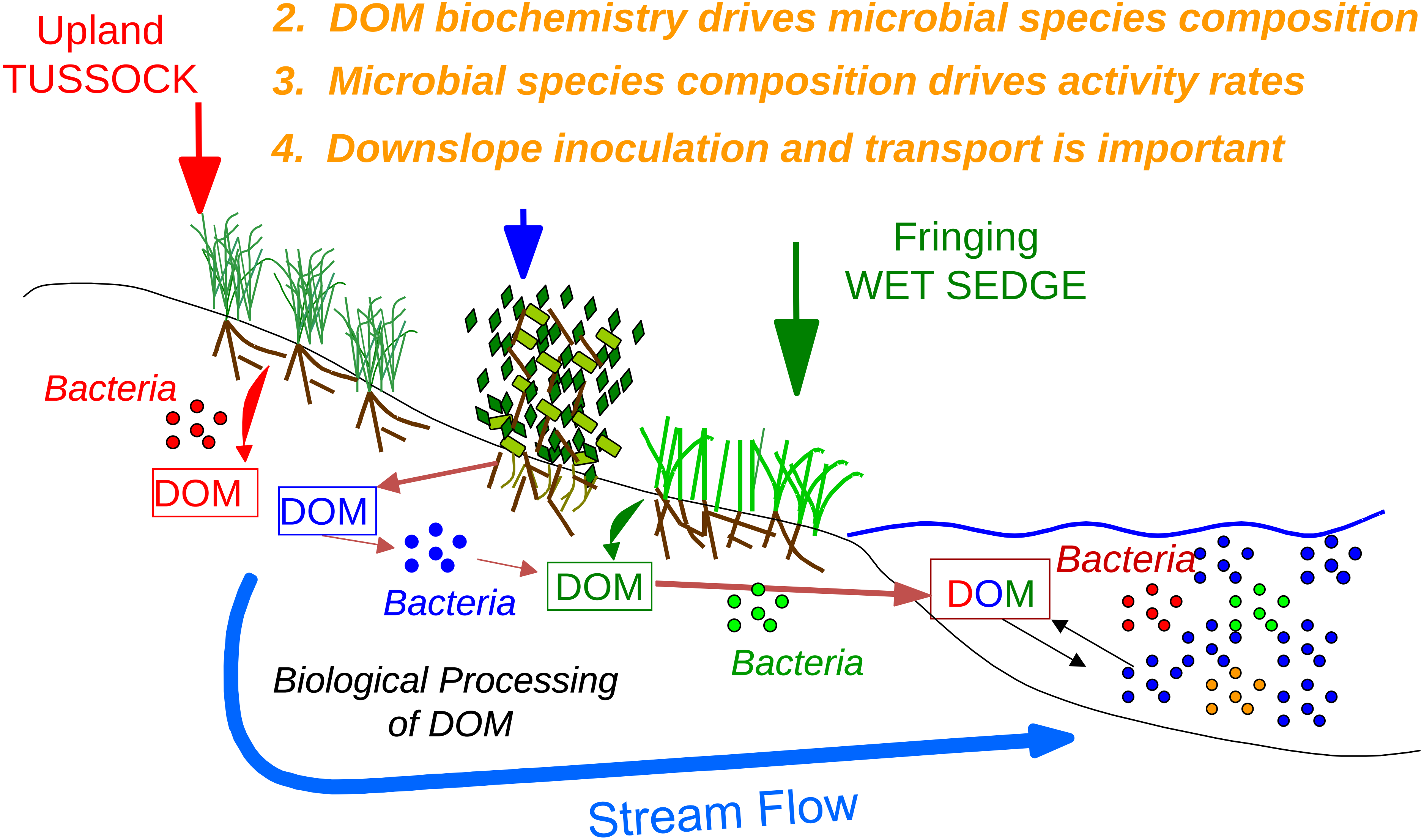
Therefore, microbial and photo processing of DOC across the landscape may be 2 orders of magnitude higher than the net flux from the catchment.

Judd & Kling. 2002. *Biogeochemistry*

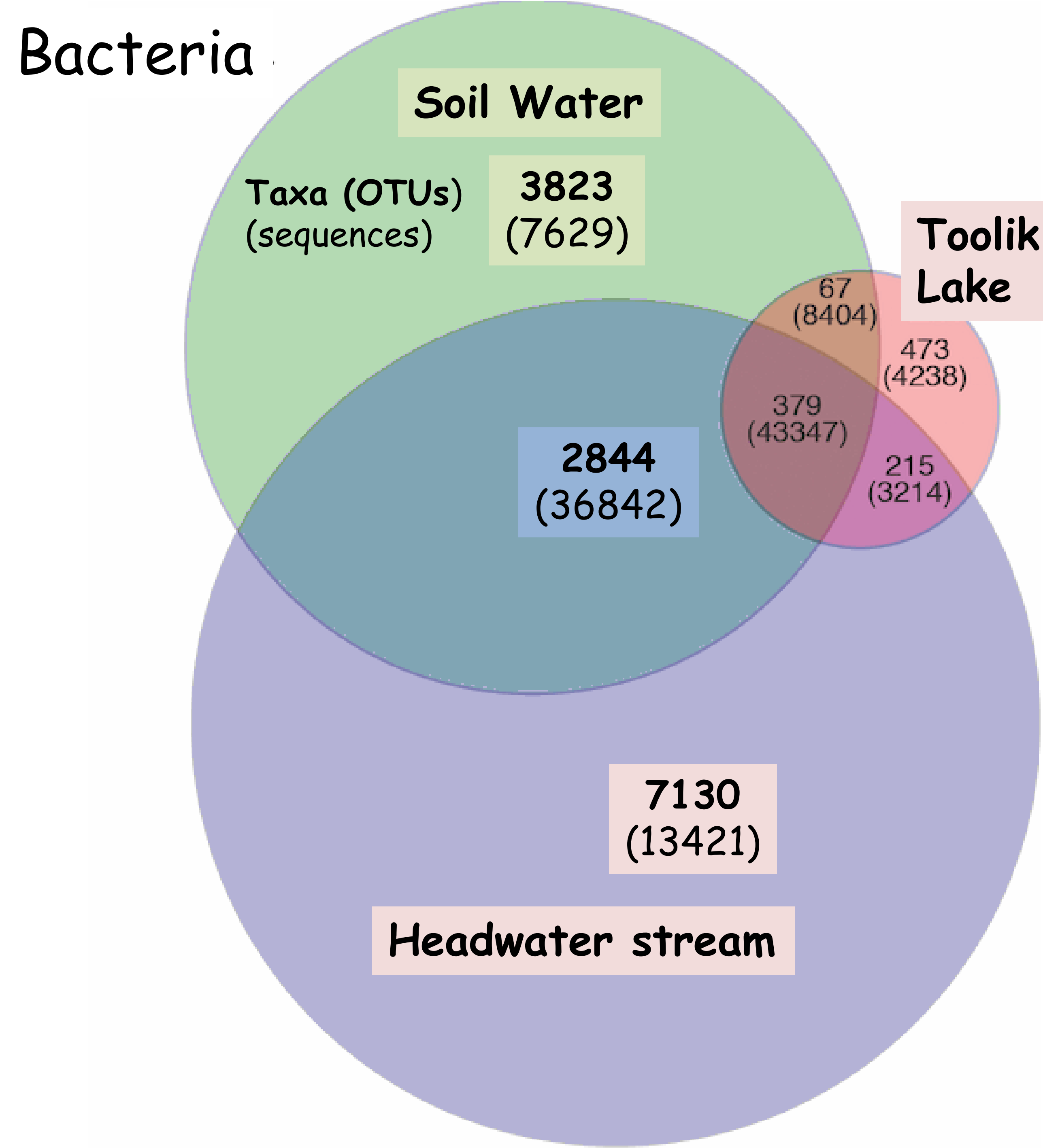
Kling, Nadelhoffer, Sommerkorn, unpublished

Landscape Diversity and Microbial Dynamics

1. *Vegetation controls soil-water DOM biochemistry*
2. *DOM biochemistry drives microbial species composition*
3. *Microbial species composition drives activity rates*
4. *Downslope inoculation and transport is important*



Judd et al. 2006, 2007. Crump et al. 2007, Zak & Kling 2006



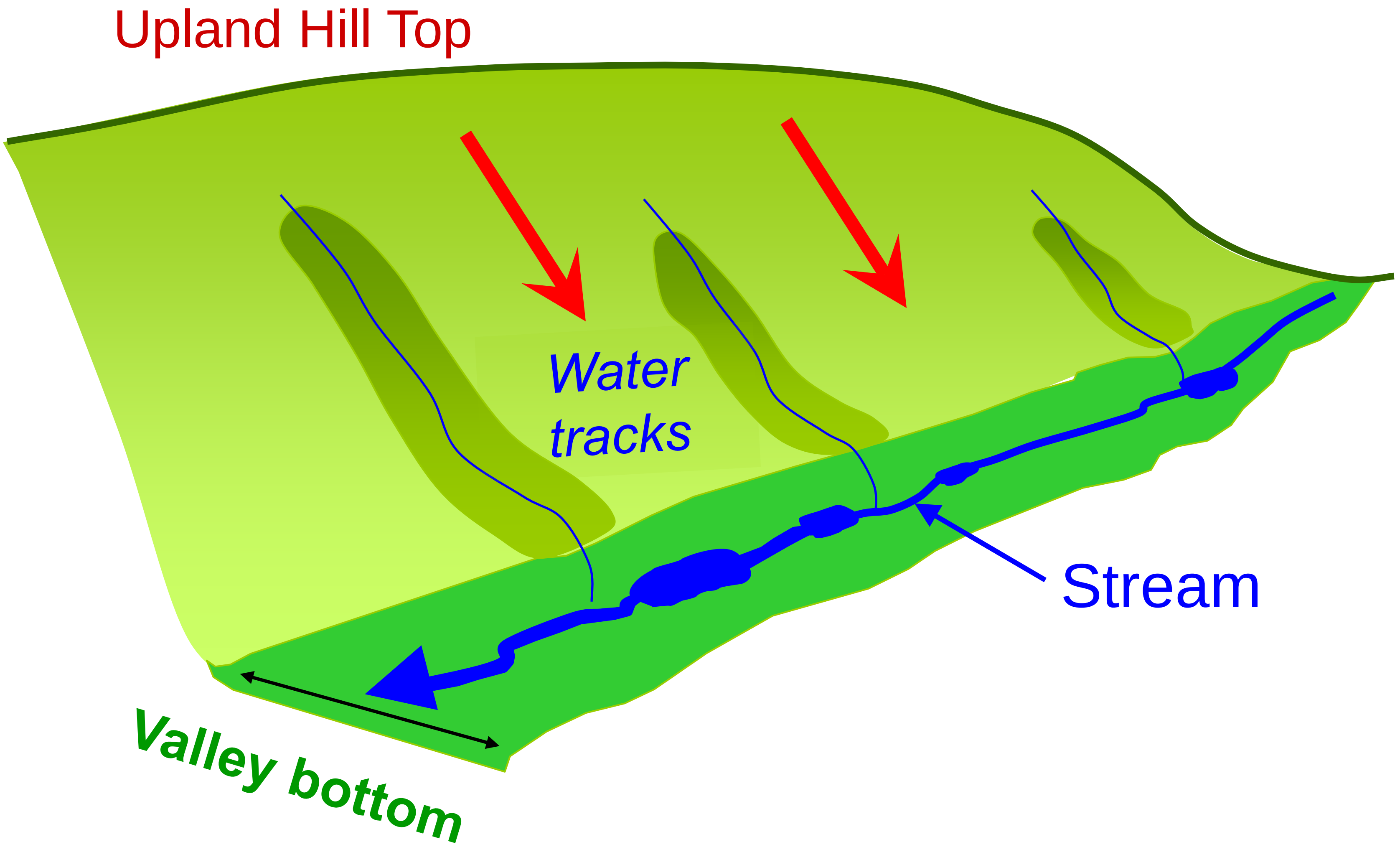
In Toolik Lake

58% of Bacteria
43% of Archaea

shared with soil waters

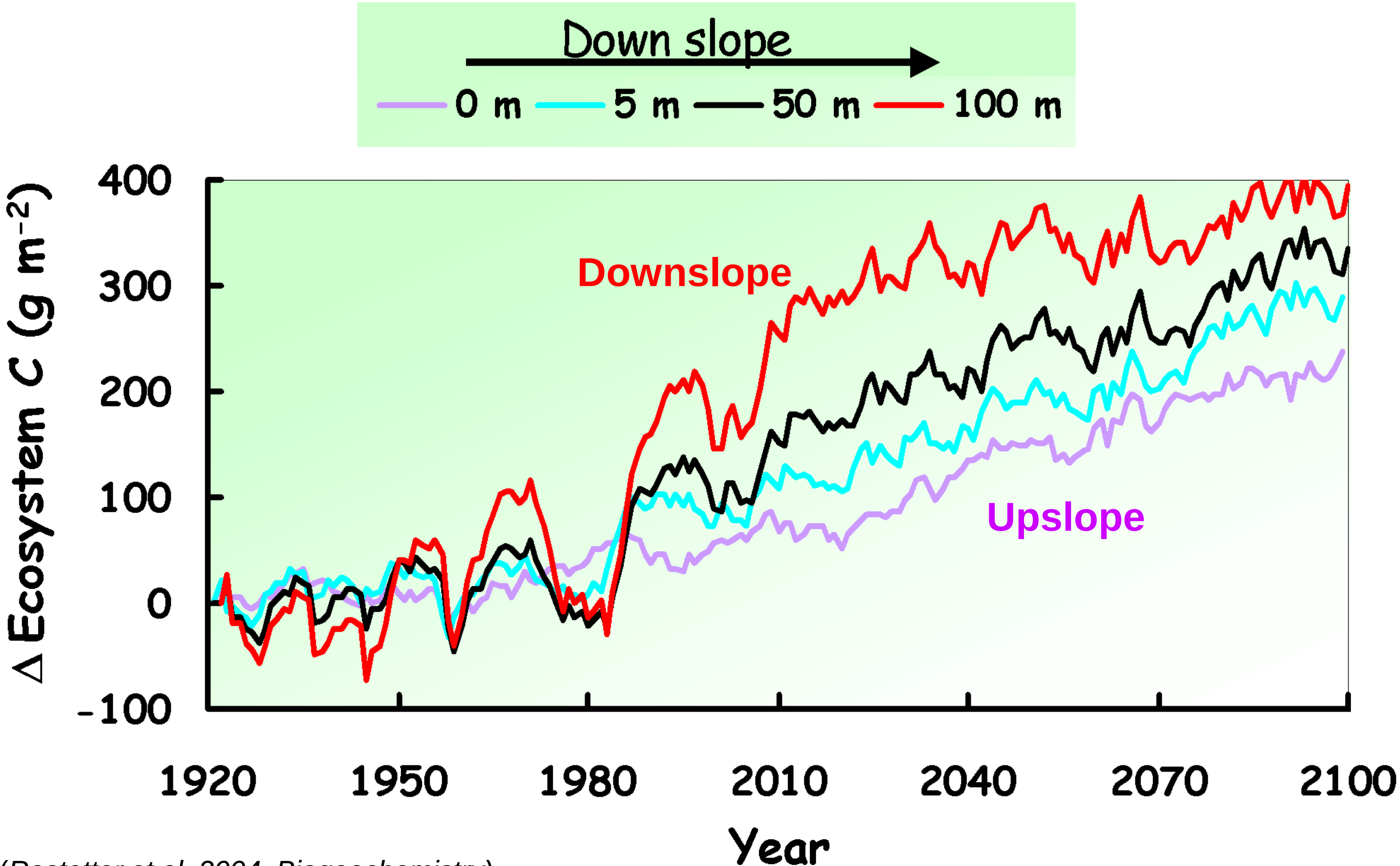
Crump et al. 2012, ISME
454 pyrosequencing results

The Hillslope Scale in terrestrial ecosystems

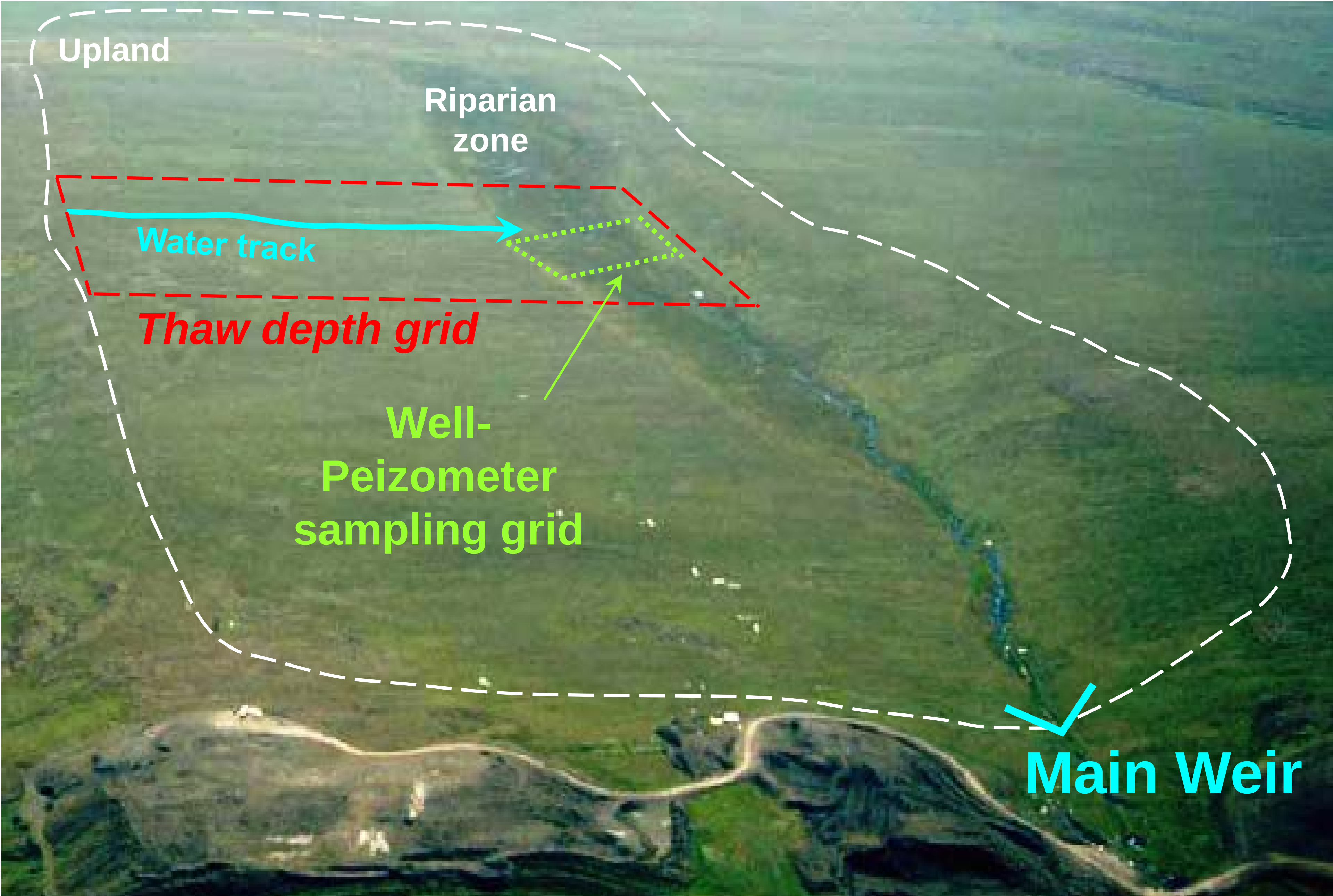


In terrestrial ecosystems the hydrologic flow and transfers of nutrients downslope can influence C storage

Terrestrial C storage is enhanced by downslope movement of nutrients and water

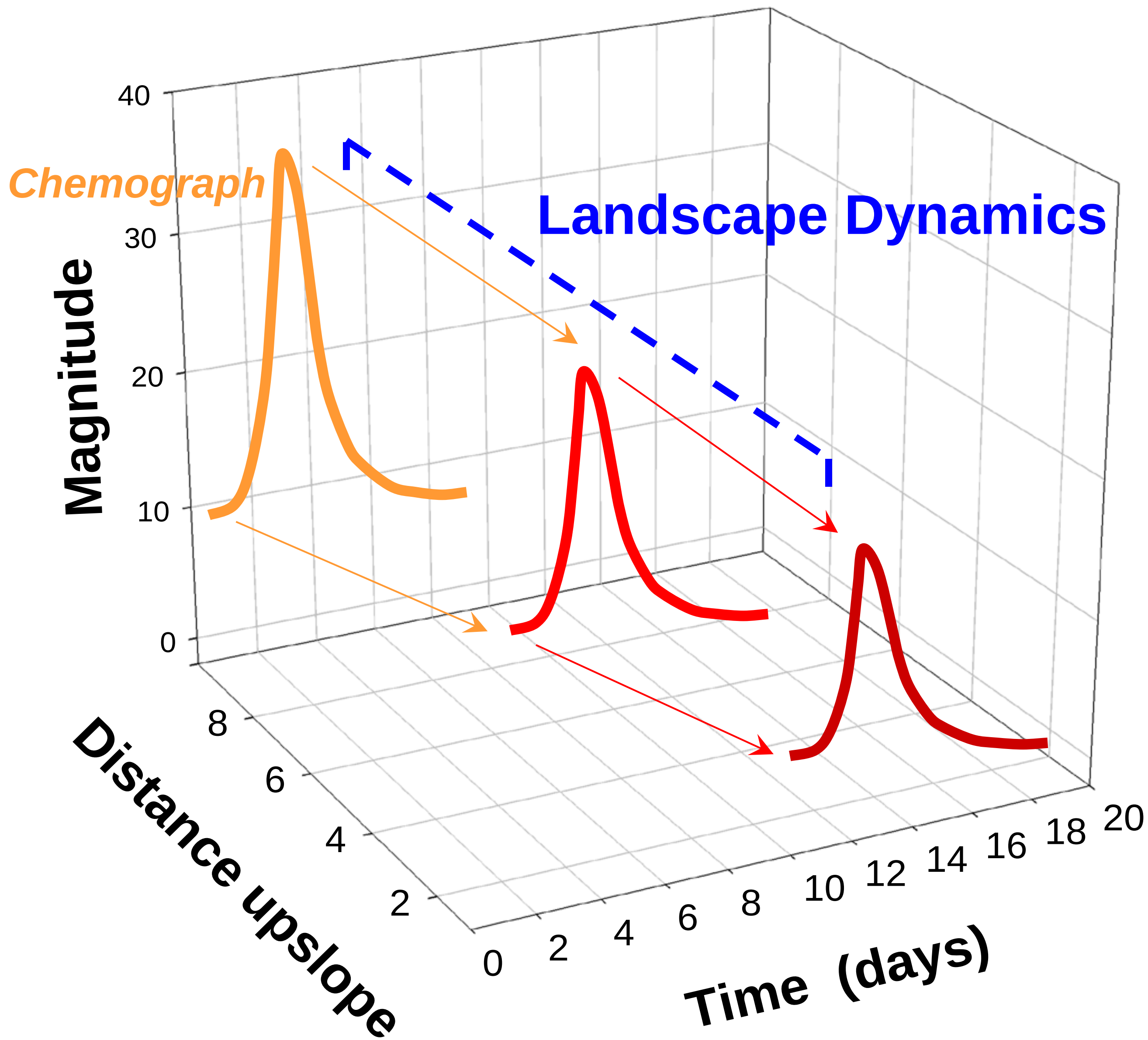


(Rastetter et al. 2004, Biogeochemistry)

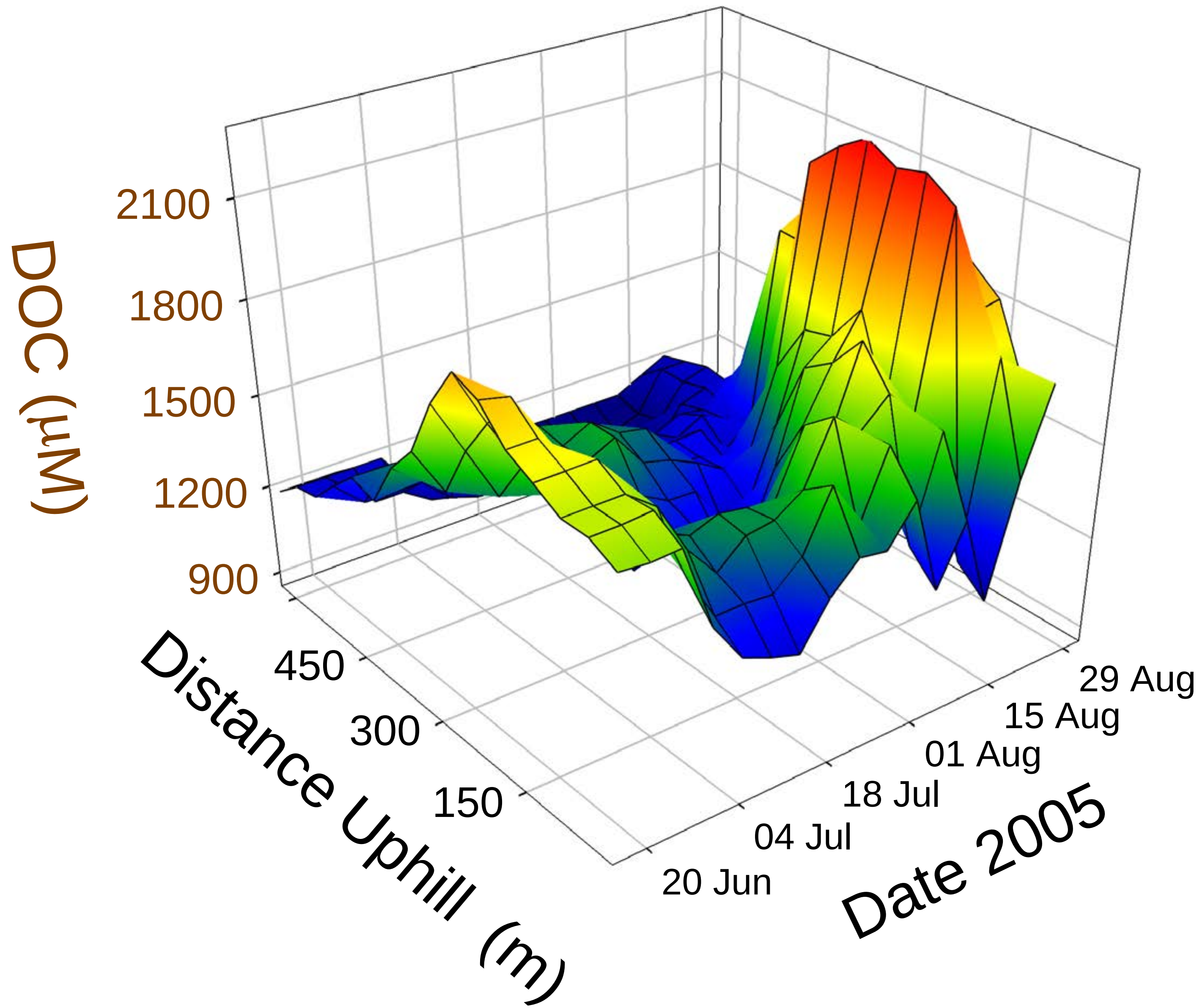


Imnavait Creek watershed, 2.2 km^2

Controls on biogeochemical processes and catchment export

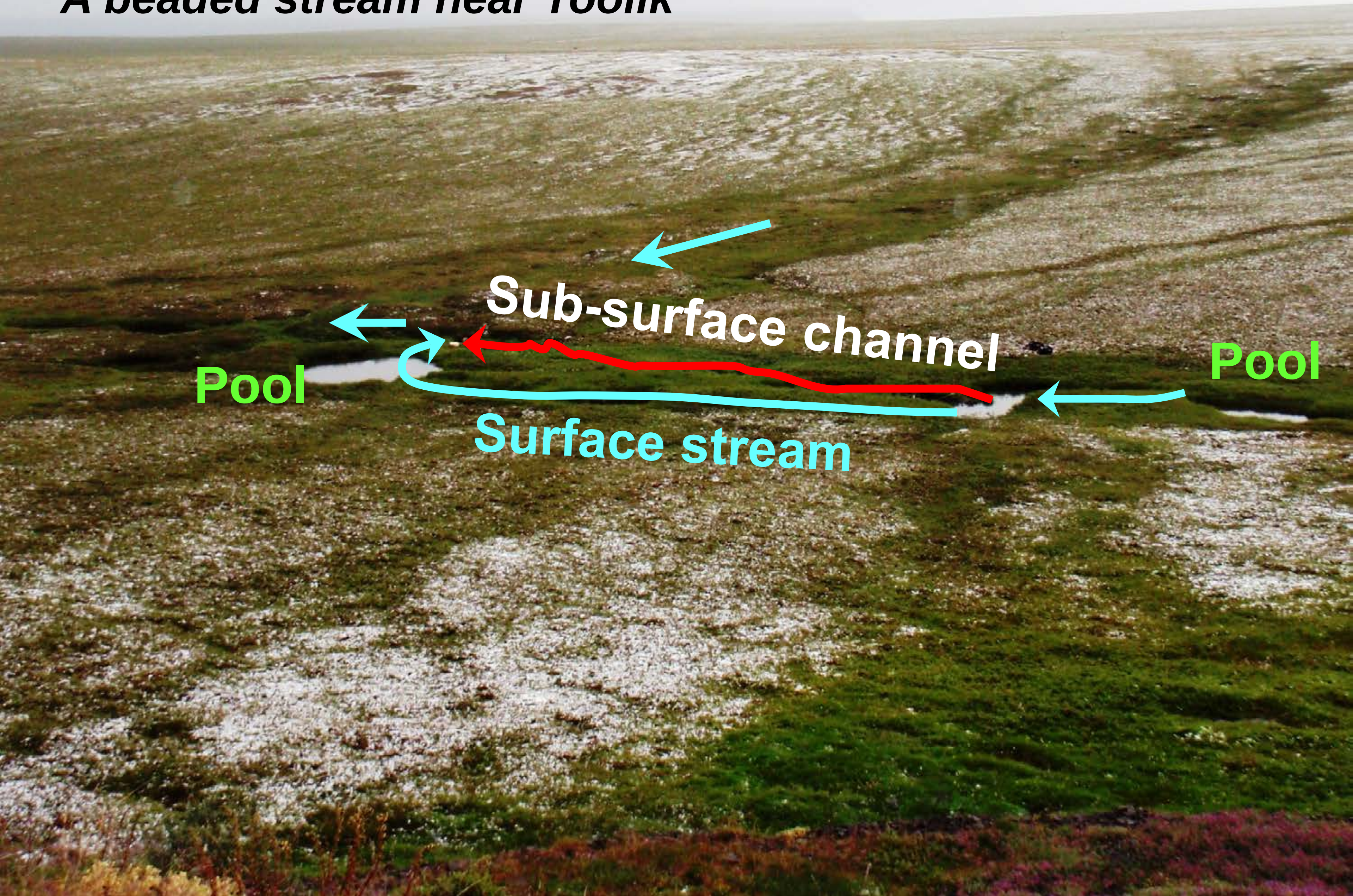


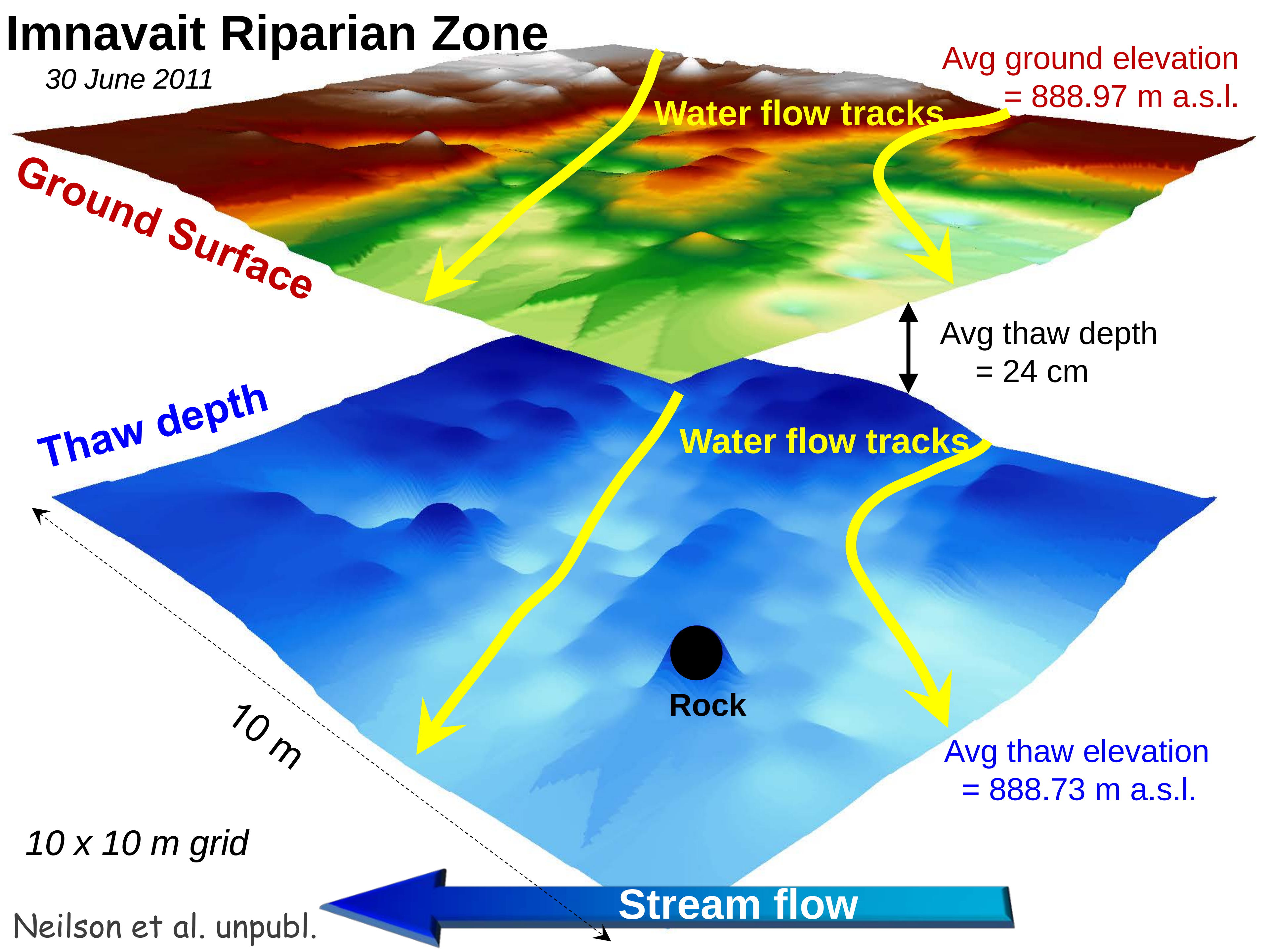
Hillslope Patterns of soil-water DOC



Imnavait Creek

A beaded stream near Toolik




Imnavait Riparian Zone
30 June 2011
Ground Surface
Water flow tracks
Avg ground elevation
= 888.97 m a.s.l.
Avg thaw depth
= 24 cm
Thaw depth
Water flow tracks
Rock
10 m
Avg thaw elevation
= 888.73 m a.s.l.
10 x 10 m grid
Stream flow
Neilson et al. unpubl.

DISTURBANCE

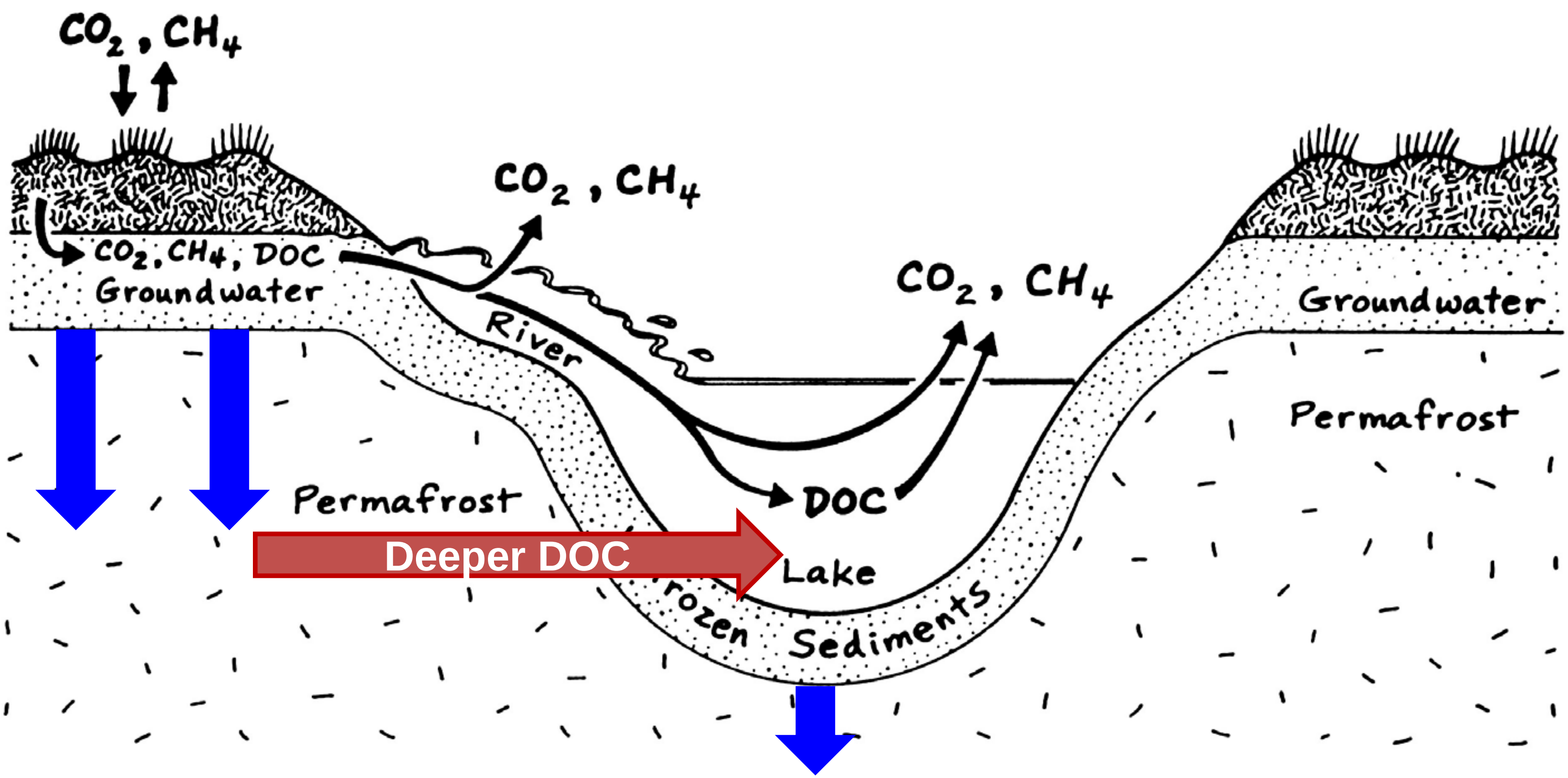
1. Fire = *"Pulse"*

2. Thermal erosion

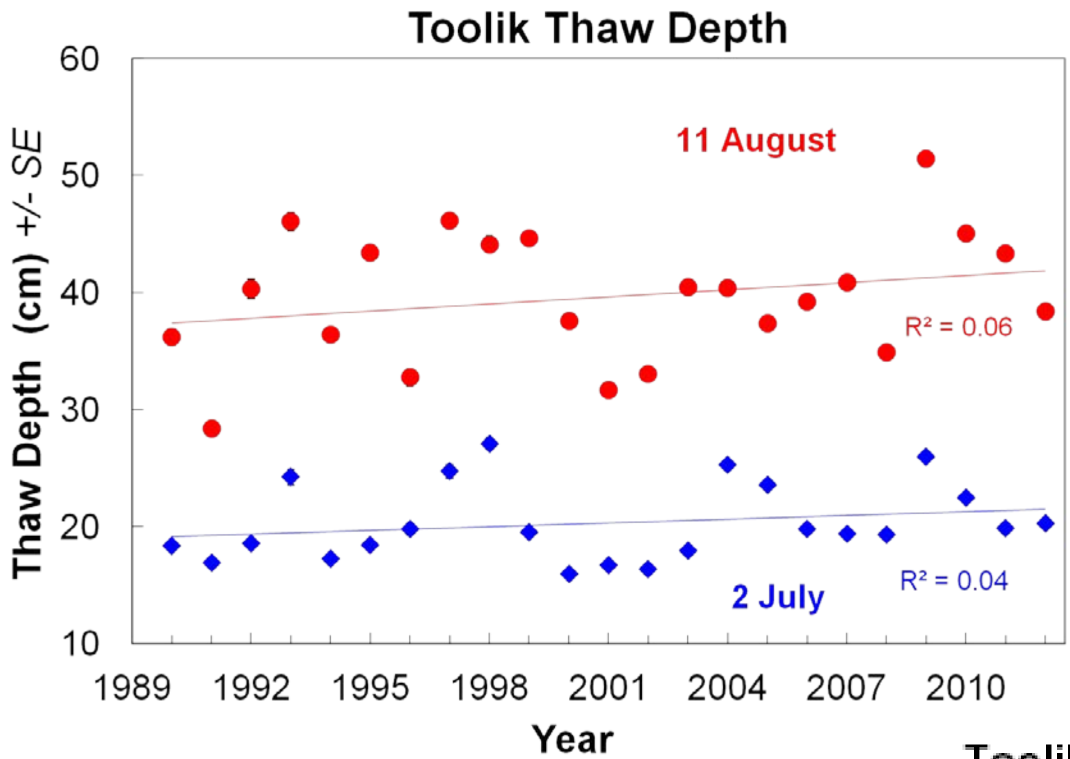
Permafrost thaw = "Press"

Thermokarst failure = "Pulse"

Thawing permafrost will increase C movement and exposure *(even without thermokarst failures)*

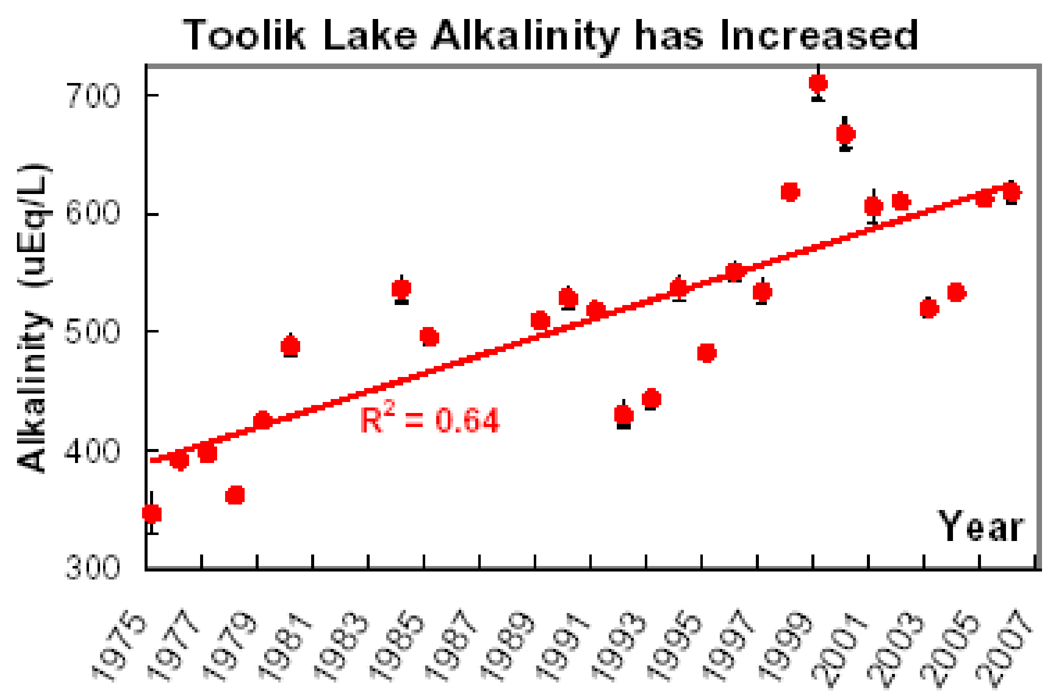


Kling 1995

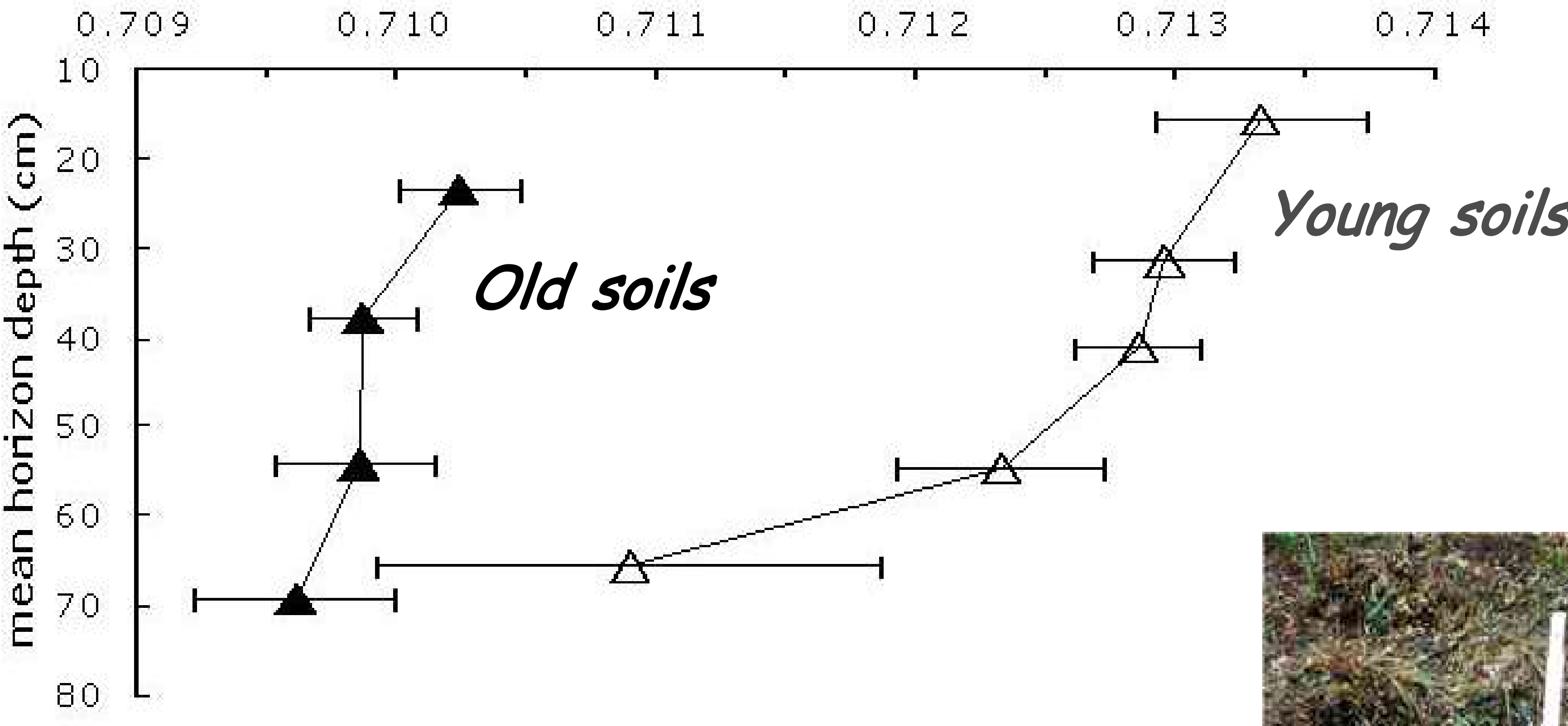


The thaw depth around Toolik Lake has not deepened over time

But there have been large, long-term changes in Toolik Lake chemistry



Strontium ratios ($^{87}Sr/^{86}Sr$) decrease with depth in soils

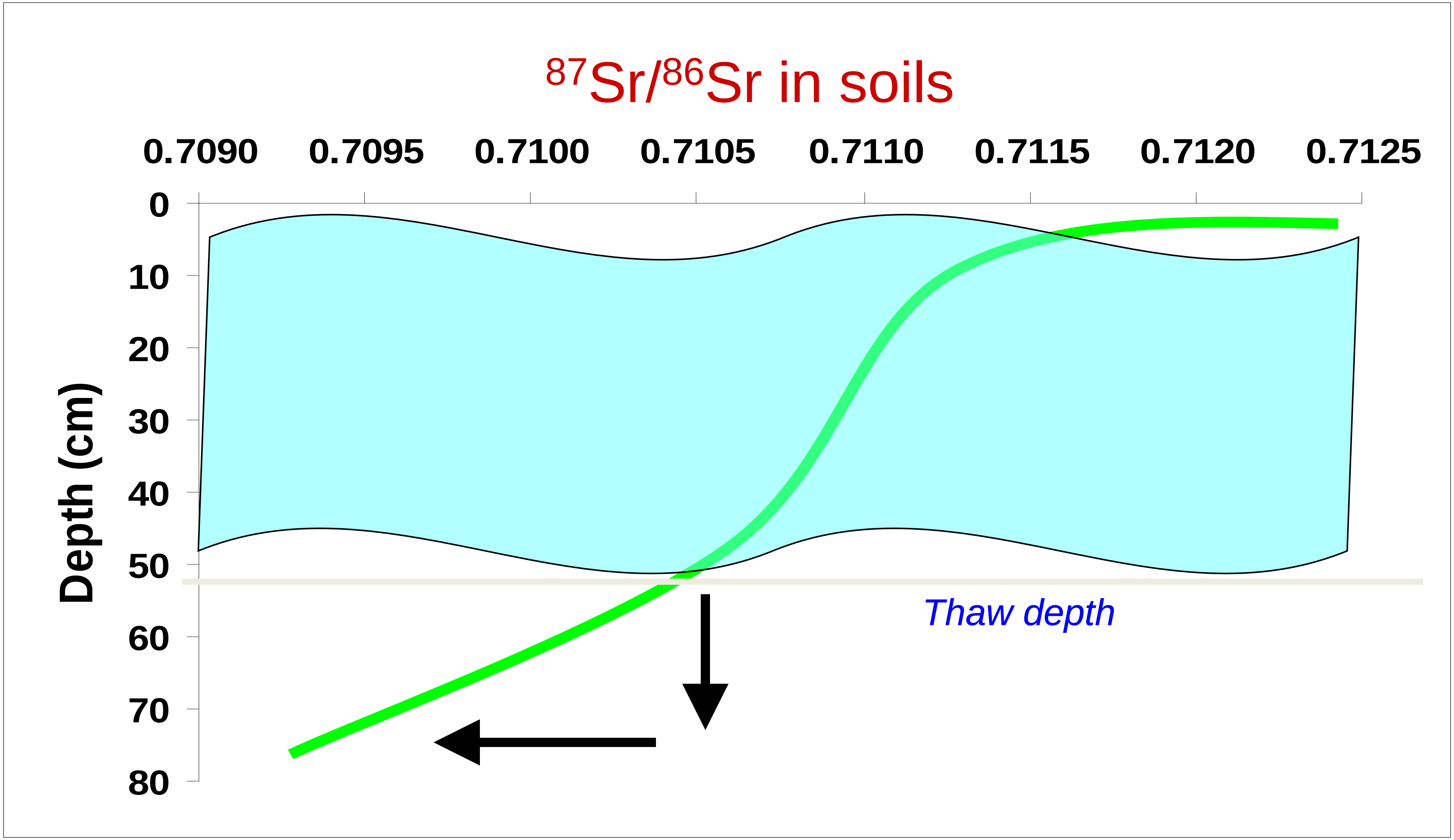


Geochemical Patterns in Soils:

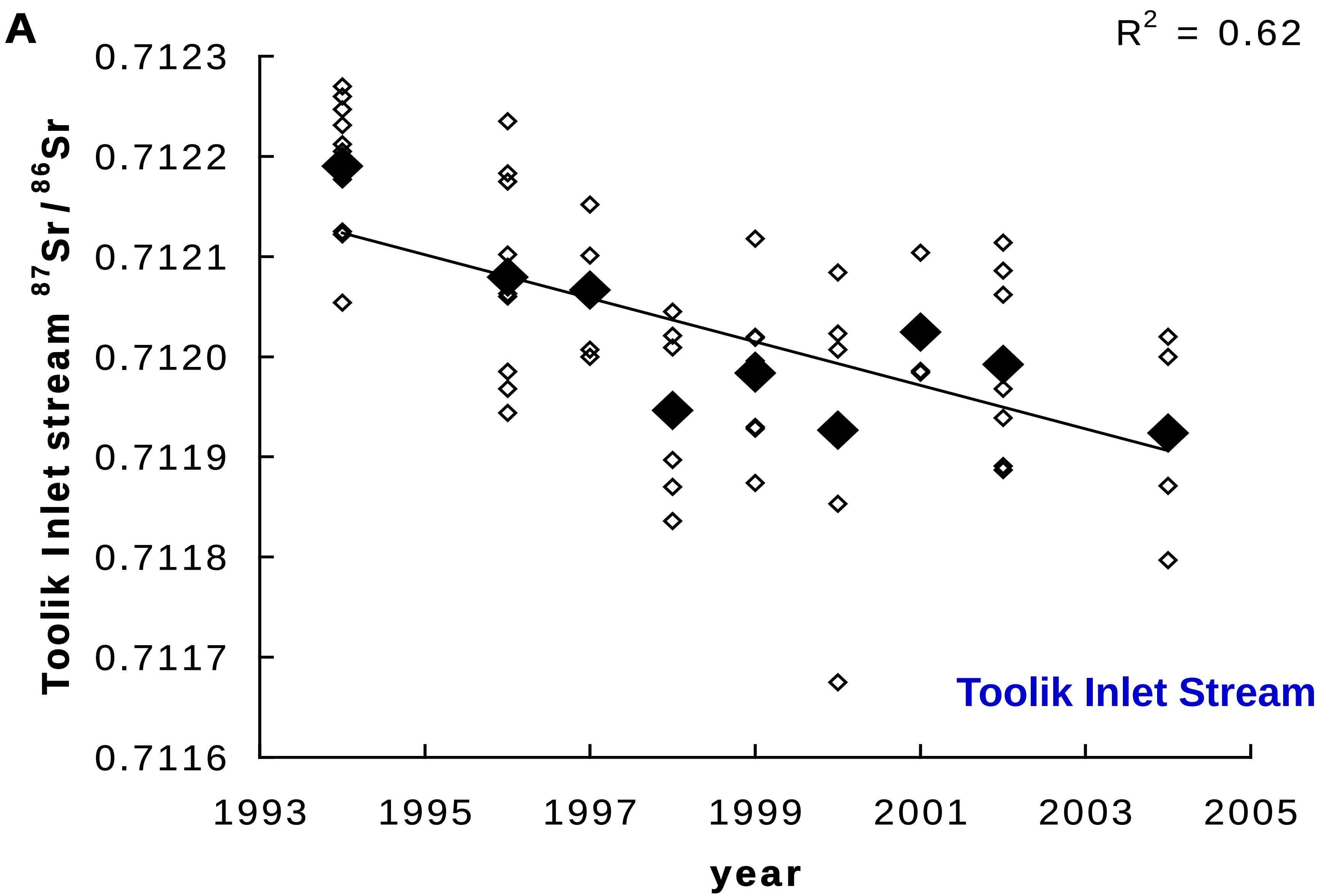
- *Less weathering at depth*
- *More carbonate at depth*

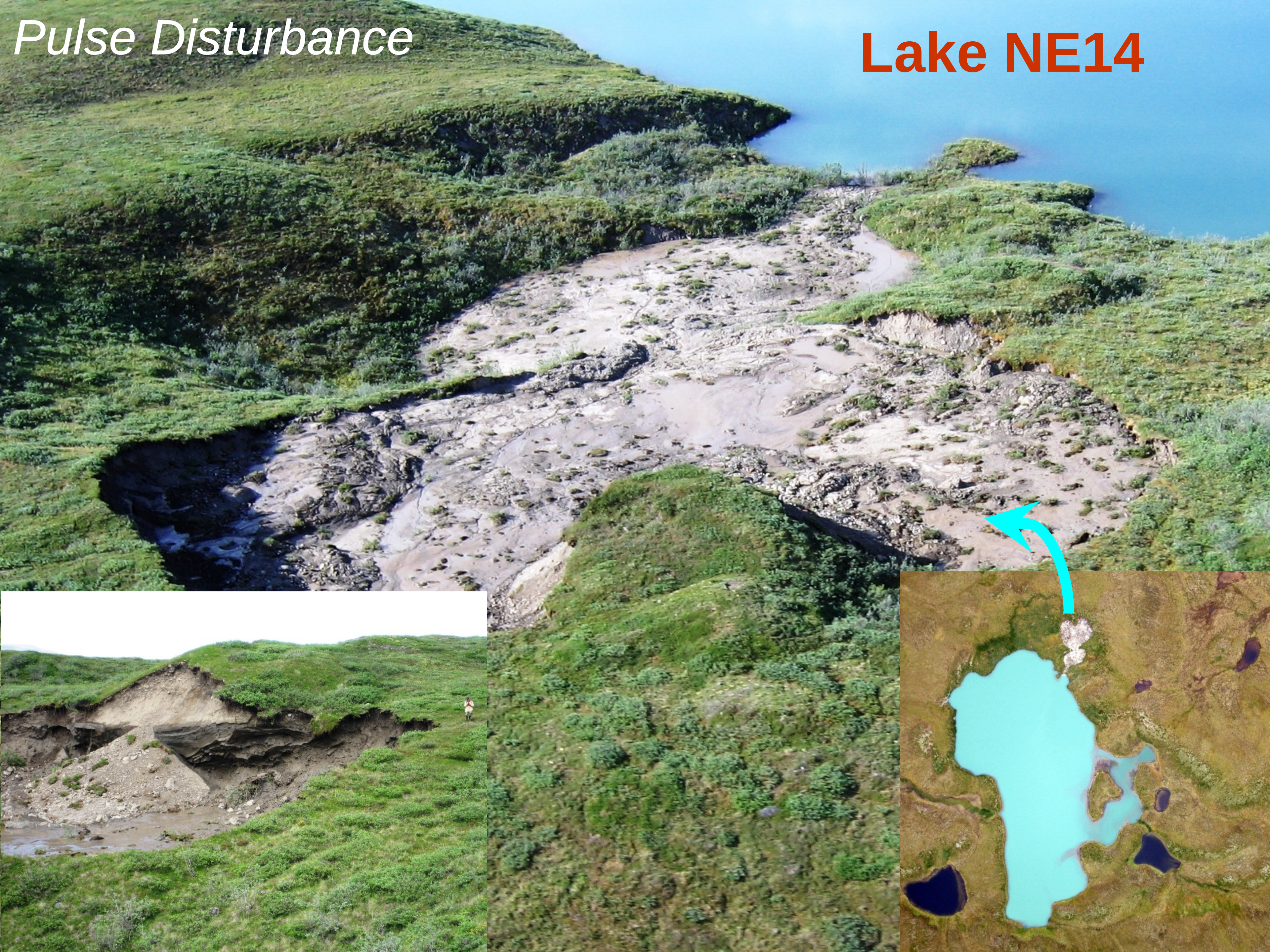
Keller et al. 2007

Stream geochemistry should reflect ***hydrologic flowpaths*** **in soils.**

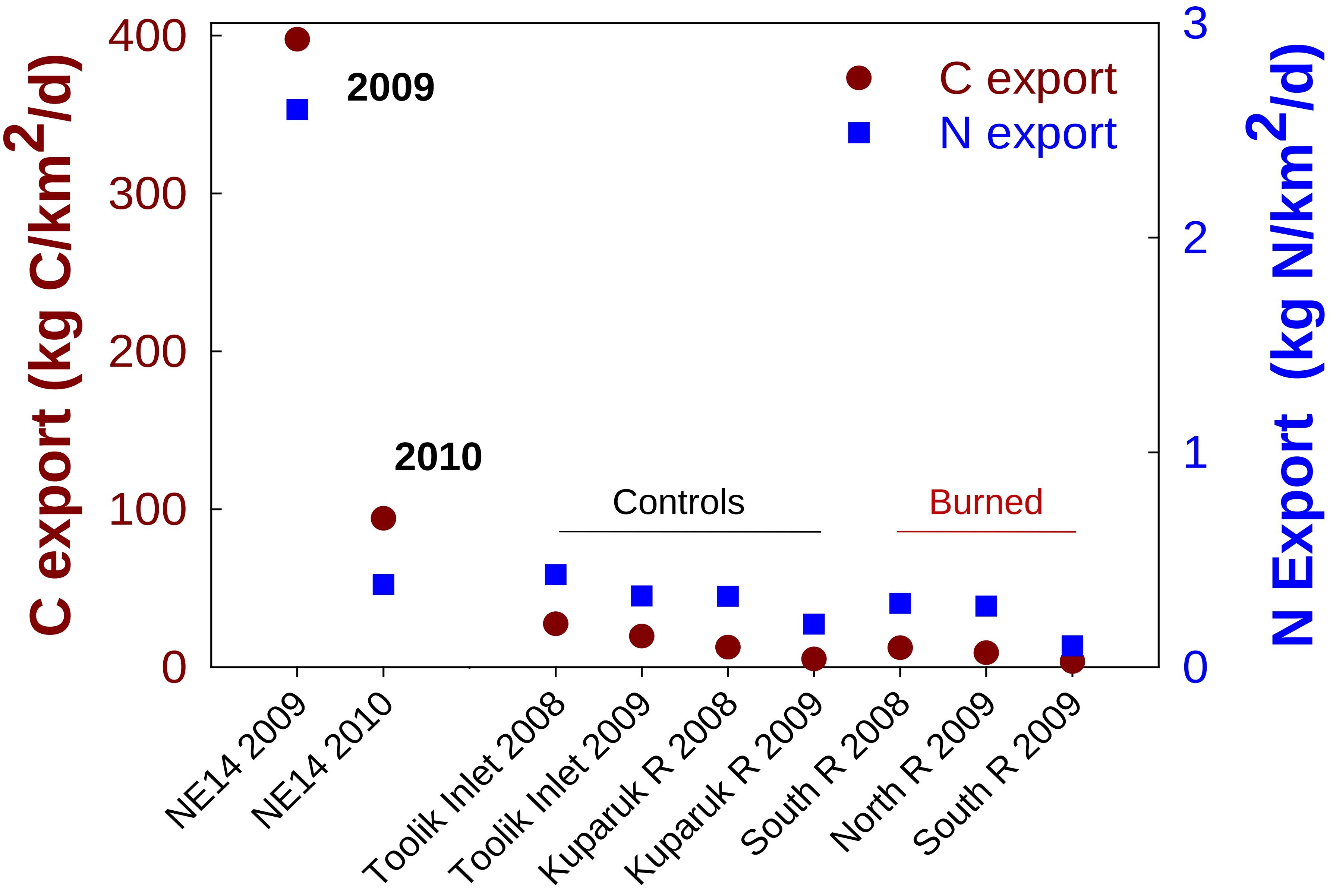


Stream water $^{87}Sr/^{86}Sr$ decreases over time




Pulse Disturbance
Lake NE14

C and N export from Lake NE14 was higher than control or burned catchments, 4 years after

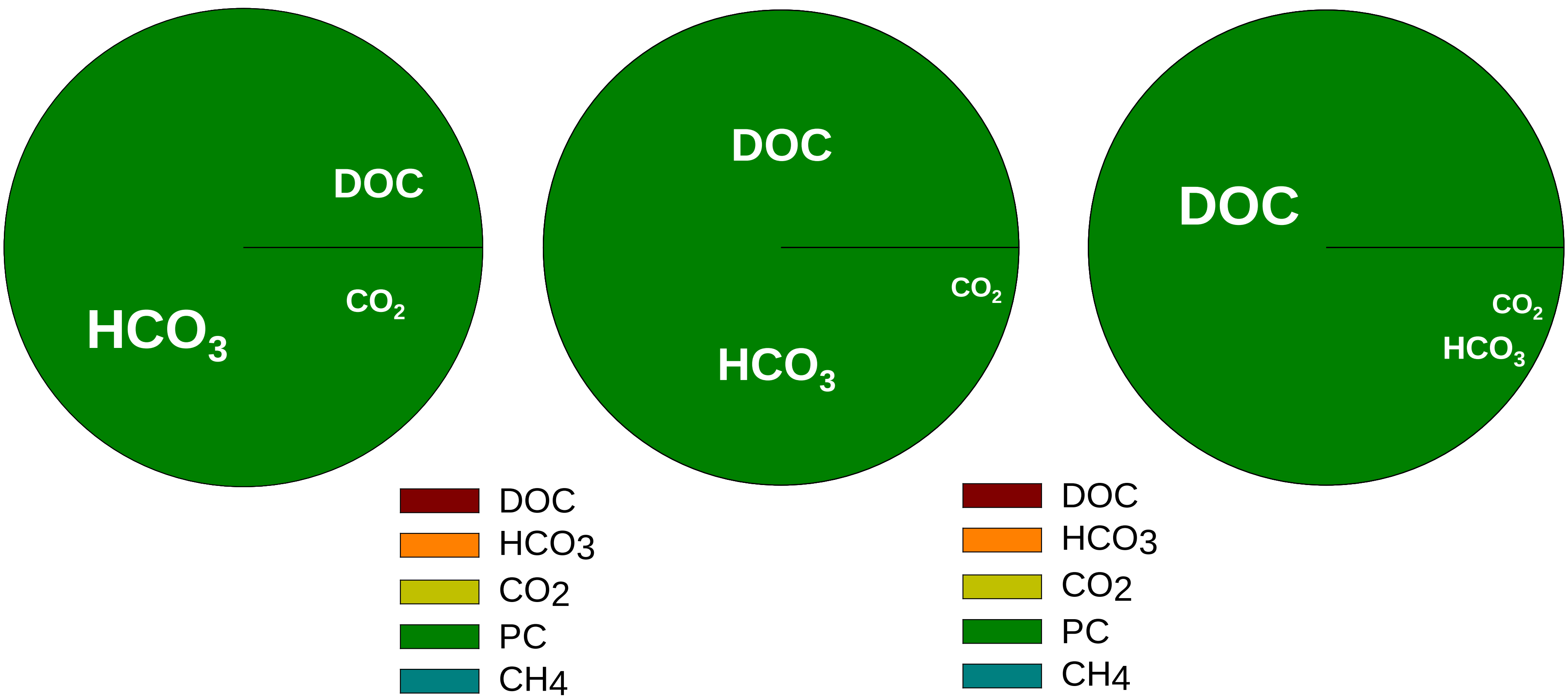


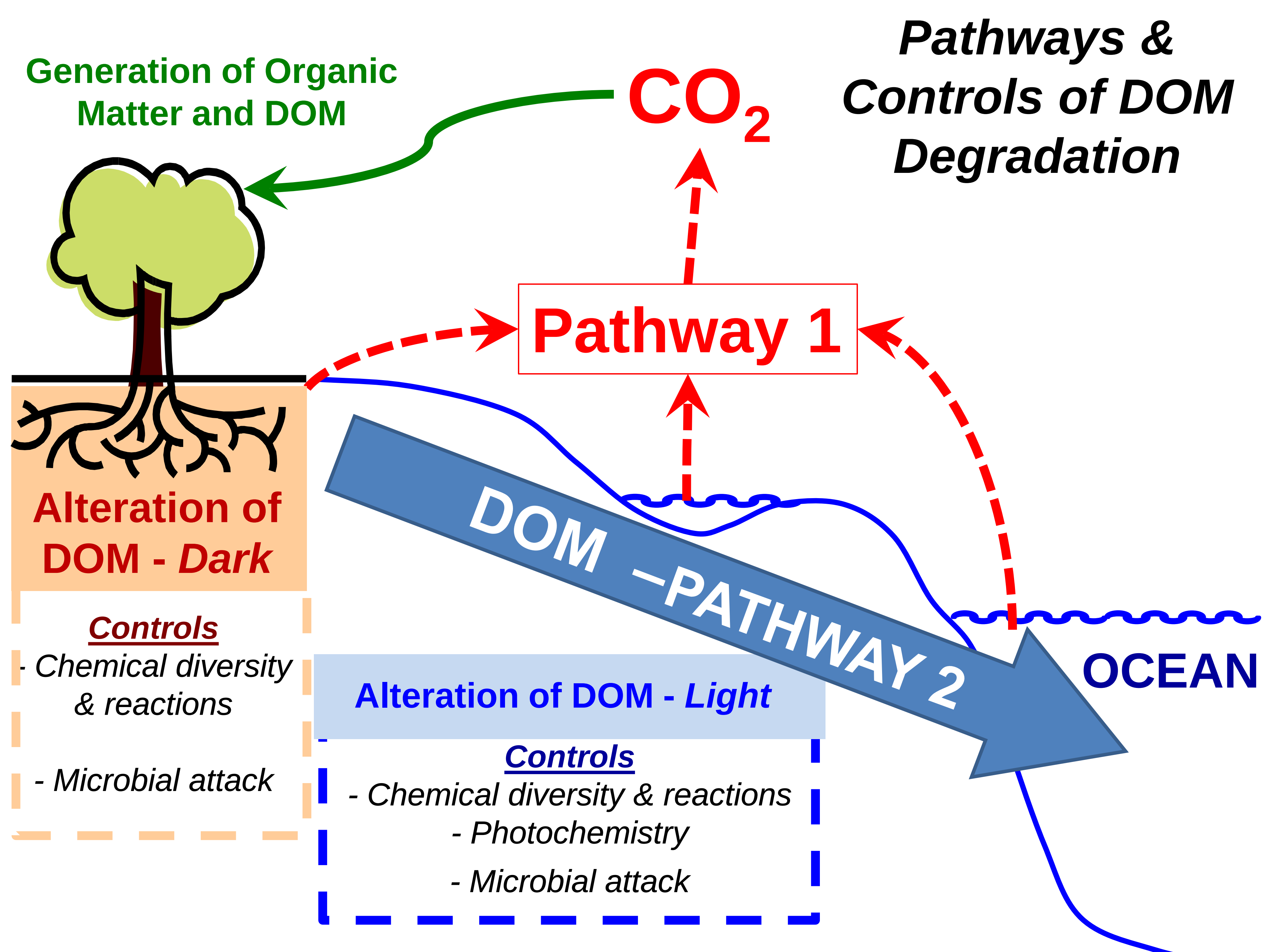
Disturbance type strongly influences carbon species export

NE14 Outlet
Thermokarst

Toolik Inlet
control

South River
Burned catchment



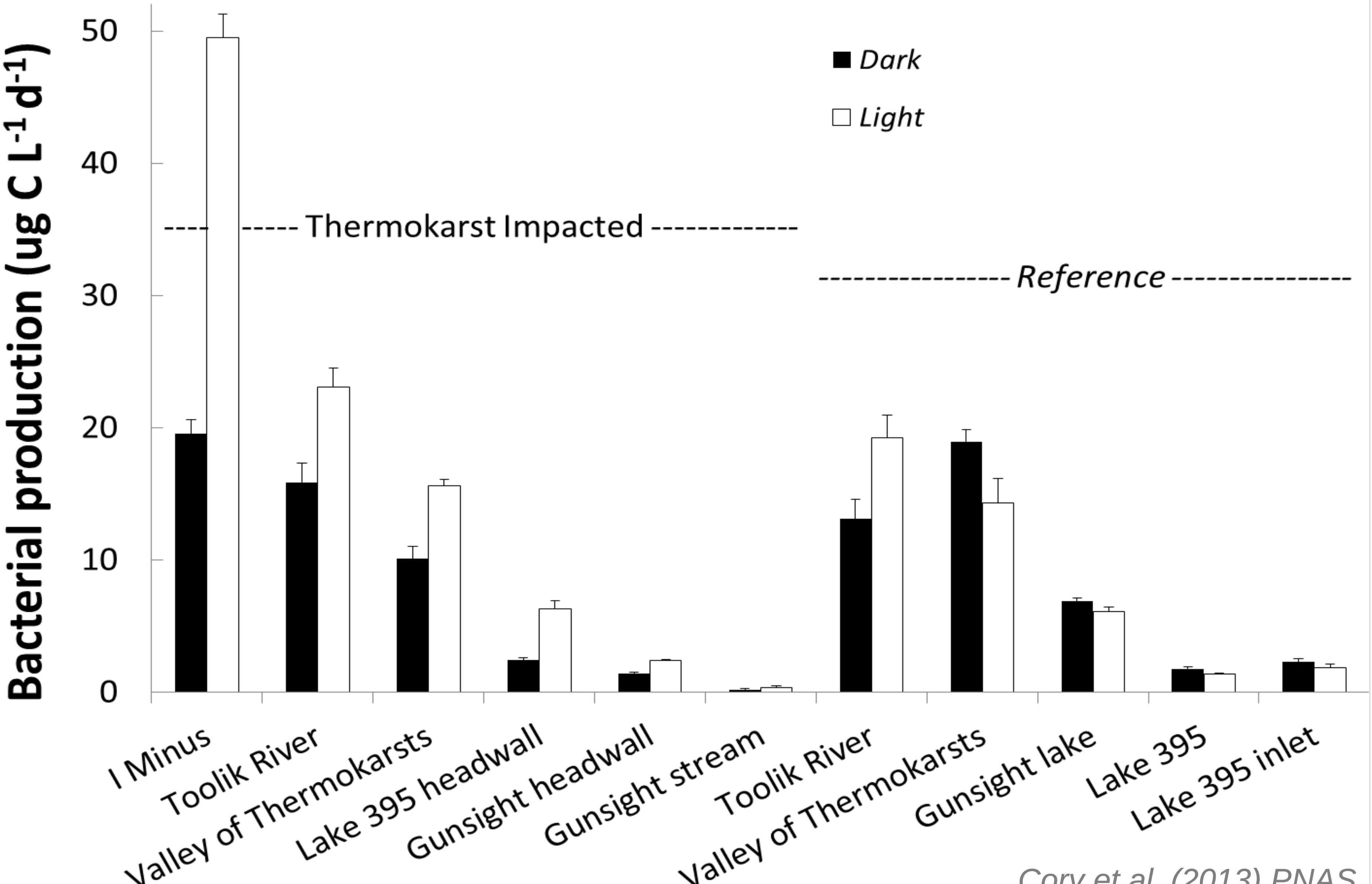


Pathways & Controls of DOM Degradation
Generation of Organic Matter and DOM
CO_2
Pathway 1
Alteration of DOM - Dark
Controls
- Chemical diversity & reactions
- Microbial attack
DOM –PATHWAY 2
OCEAN
Alteration of DOM - Light
Controls
- Chemical diversity & reactions
- Photochemistry
- Microbial attack

Photochemical and biological processing of DOM across the landscape

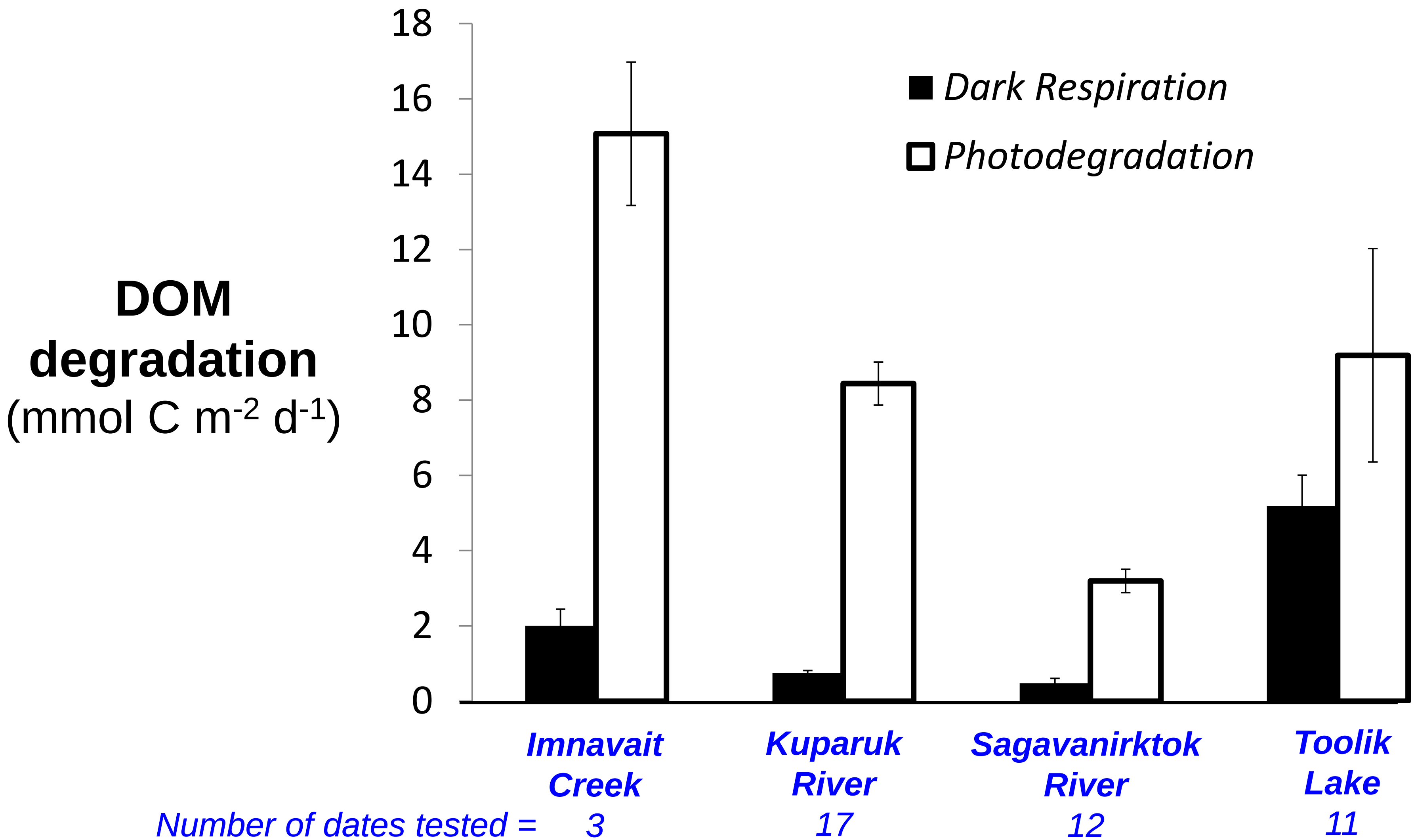
The fate of permafrost C depends on water residence time (e.g., light exposure), and the character of exported DOM

Light exposure increases bacterial activity in thermokarst-impacted sites

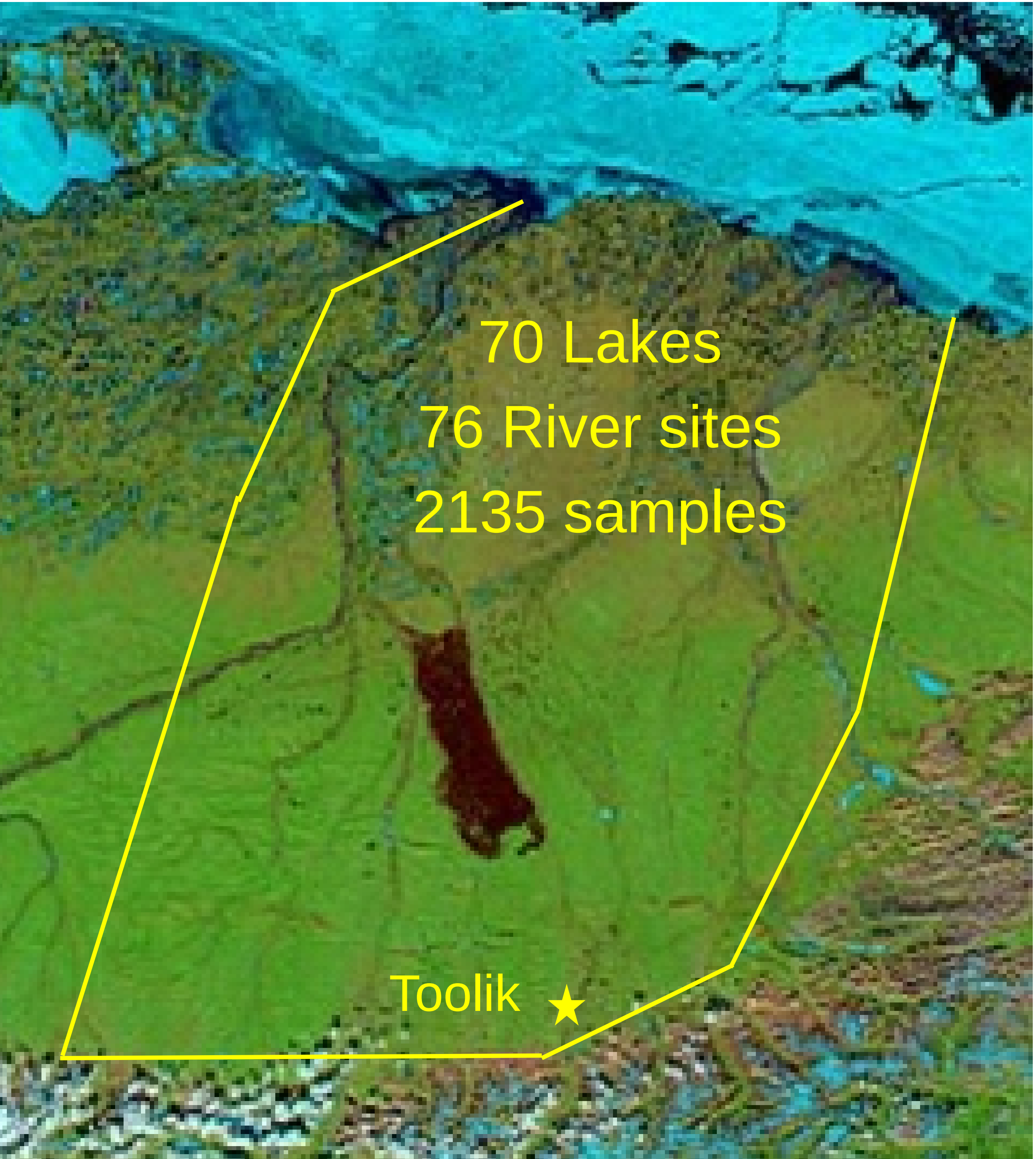


Cory et al. (2013) PNAS

Water column rates of DOM photodegradation equal or exceed dark bacterial degradation



Cory et al. unpublished



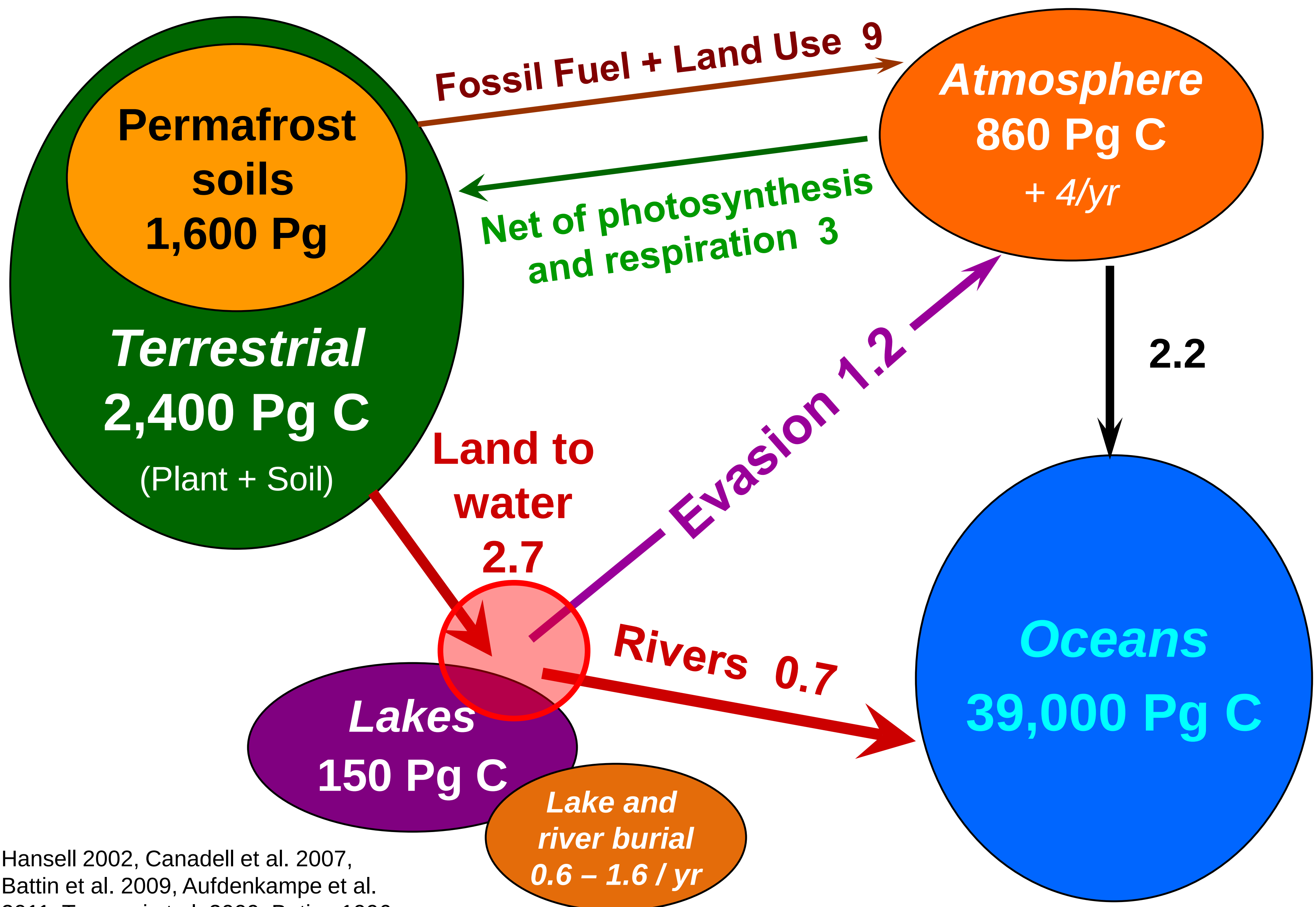
LTER Samples 1988 - 2012

C processed in surface waters,
% of total C export

Kuparuk R.	26%
Colville R.	23%

Cory et al. unpublished

Global Carbon Pools and Fluxes (Pg C and Pg C y^{-1})



Hansell 2002, Canadell et al. 2007, Battin et al. 2009, Aufdenkampe et al. 2011, Tarnocai et al. 2009, Batjes 1996

Conclusions

- Microbial processing of C produced on land strongly controls land-to-water transfers.
- Both *Pulse* and *Press* disturbances are interacting with climate change to alter biogeochemical processing and land-water linkages.
- Photo-bio processing in surface waters determines the relative balance between soil C released to the atmosphere versus exported to the ocean.
- The Arctic influence on global warming will depend on the response to pulse and press disturbances from climate change.