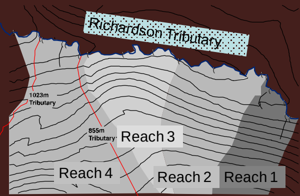
Seasonality in water, carbon, and nitrogen fluxes from an upland boreal catchment underlain by continuous permafrost

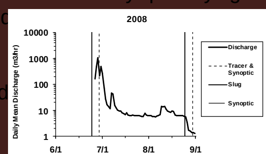
Joshua C. Koch[1,3], Robert G. Striegl[1] Robert L. Runkel[1], Stephanie Ewing[2], and Diane M. McKnight[3]

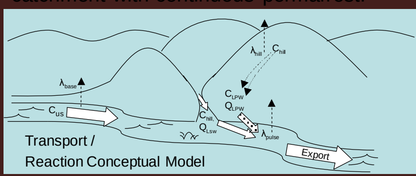
1 – U. S. Geological Survey, Boulder, CO. 2 –Montana State University 3 – INSTAAR, University of Colorado. Contact: jkoch@usgs.gov

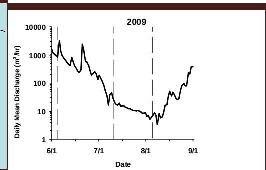
1. Why Focus on Water, Carbon and Nitrogen?



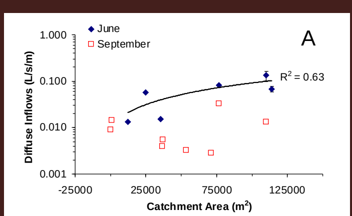
The balance between runoff and storage is critical to transport and processing of carbon (C) and nitrogen (N) in boreal catchments. Whether C and N are mineralized in soils or flushed from the catchment depends on hydrologic fluxes and has implications for ecosystem productivity and climate change feedbacks. By quantifying water and solute fluxes and modeling C and N reactivity on a north-facing hillslope, we aim to elucidate the hydrologic and biogeochemical processes controlling C and N fate and transport in an upland boreal catchment with continuous permafrost.

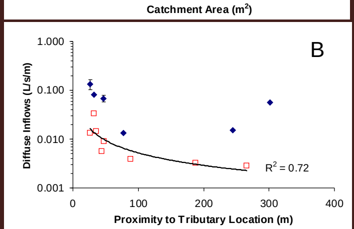






2. Preferential Flow Evidence in Runoff Trends



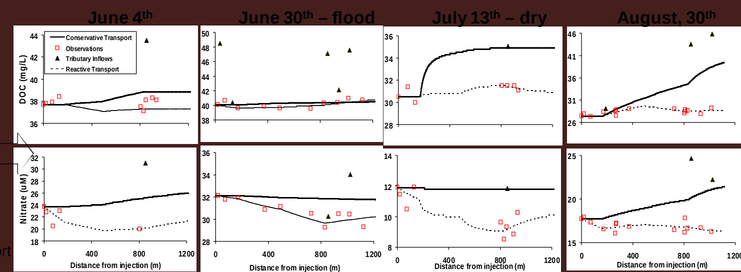


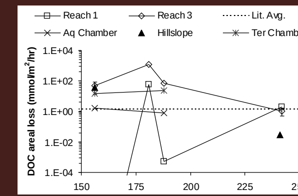
The transition from high to low hydraulic conductivity between shallow organic and deeper silt soils leads to shallow flow and topographically-controlled, rapid runoff during the wet, early summer (A). Later in the summer, hydrograph analysis indicates that flowpaths are longer, but still too rapid to be explained by matric flow. Inflows occur proximal to tributaries (B), implicating preferential flow as the primary runoff mechanism late in the season

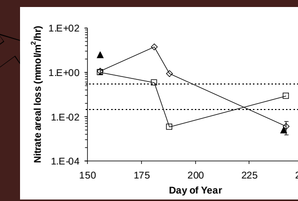
4. Summer Trends in DOC and Nitrate Loss from Soils and Streams

OTIS is a transient storage model capable of identifying stream transport and storage zone (pool, eddy, and hyporheic zone) characteristics. Given discharge, lateral inflows, and stream concentrations, our models simulate conservative stream transport. The difference between simulated and observed concentrations represent DOC and nitrate biogeochemical cycling, which was modeled as first-order decay based on concentration. Areal uptake of DOC and nitrate was highest in Reach 3, where warm, nitrate-rich "pulses" entered the stream. Lateral inflow data was coupled with pore and tributary chemistry to infer hillslope flowpath reaction rates.

Schematic of rhodamine dye transport and storage in the study stream



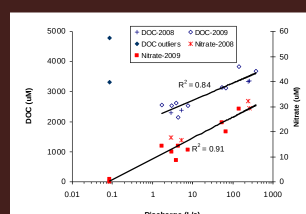


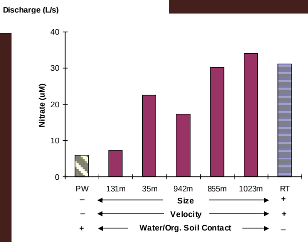


Seasonal patterns in areal uptake.

3. Leaching and Export

Stream DOC and nitrate concentrations were proportional to discharge, indicating leaching of organic matter from catchment soils. High DOC at the lowest discharge may indicate autotrophic activity, or decreased loss associated with nitrate limitation. The correlation between tributary size and nitrate concentration suggests that loss is higher in the smallest tributaries.

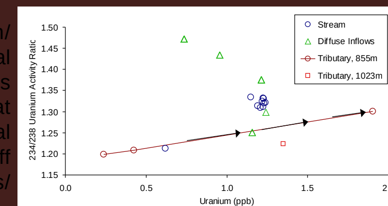




5. Uranium Isotopes and Channel/Soil Pipe Erosion

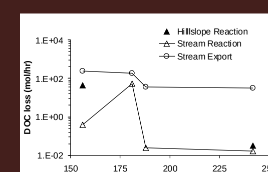
Uranium (U) samples were collected on August, 30th, 2008, when preferential flow is greatest. U concentrations and activity ratios (UARs) increase along a flowpath within the 855m tributary (evolution indicated by arrows).

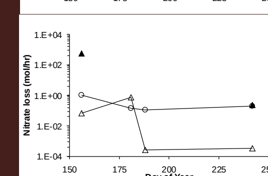
The increase in UARs may indicate erosion/ incision of the stream banks and/or mechanical weathering of silt in the steep channel of this tributary. High UARs in diffuse inflows suggest that erosion/weathering is also occurring in preferential subsurface flowpaths. This further supports runoff analysis and implicates fast flow through soil pipes/ macropores as an important late-summer flowpath.



6. Conclusions

1. Export is the main loss pathway for DOC and nitrate in this upland catchment, and likely in many other hillslopes in the loess belt of interior Alaska.
2. Organic matter export is proportional to discharge, and there is evidence of heightened biogeochemical cycling when residence times are greater, such as:
   - At lower discharge   -In small tributaries
3. Preferential flow occurs near streams and on steep slopes towards the end of the summer. This flow occurs through pipes and macropores in the mineral soils, and is rapid relative to matric flow through silt. Biogeochemical activity in these fowpaths is limited, due to high hydraulic conductivity.





Acknowledgements:

Field help was provided by Kim Wickland, Kathy Kelsey, Michelle Bourret, George Aiken, Mark Dornblaser, Doug Halm, Rob Spencer, and Jon Evans. Analytical support was provided by Paul Schuster, George Aiken, Kenna Butler, Dick Smith, Deb Repert, Charles Hart, and Briant Kimball. Data analysis was aided by Kim Wickland and Ken Bencala.