The Biogeochemistry of the Mackenzie River, Canada

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The Mackenzie River is the primary source of freshwater and sediment to the North American Arctic Ocean. In contrast to the sediment loads of large Russian Arctic rivers such as the Ob (40 mg per liter), Yenisey (10 mg per liter) and Lena (33 mg per liter) rivers, the Mackenzie River is rich in suspended sediment (~130 mg per liter). Its drainage basin is characterized by complex bedrock geology, large lakes that trap sediment, permafrost cover in its northern and high altitude reaches, and varied vegetation cover. The basin is still relatively pristine, with less than 1 person per square kilometer, no dams on the main stem of the Mackenzie River, and limited areas (~3%) used for agriculture. Most importantly, this river basin is part of the NSF-funded Arctic Great Rivers Observatory that this part of the Global Rivers Observatory (www.globalrivers.org). The river water, but not the sediment, has been sampled near Inuvik about once every month for almost a decade, with the aim of better understanding the changing land-derived inputs to the coastal Arctic Ocean.

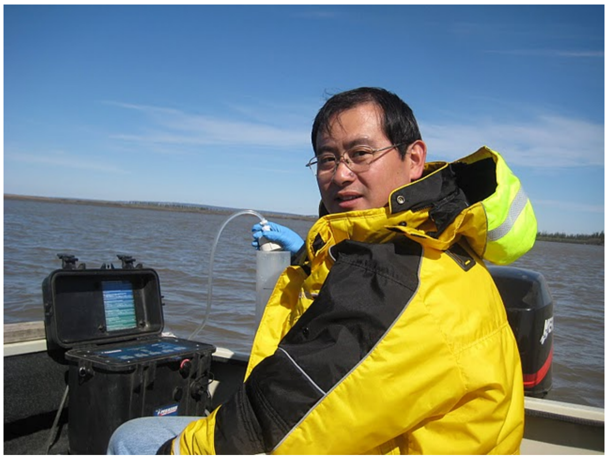
As part of this project the suspended loads of the Mackenzie River and its major tributaries were sampled over three field campaigns in July 2009, September 2010 and June 2011 (see Fig 1).

***Figure 1**: Dr. Valier Galy using a suspended sediment sampler from a small boat on the Mackenzie River.*

These sampling campaigns encompassed a wide range of hydrologic conditions from peak flow in June to low flow in September. We employed a sampling protocol aimed at capturing the natural variability of the sediment load of large rivers. This protocol consists of collecting suspended and bed sediments along vertical depth profiles. Large volumes of water – up to 100 liters – where filtered to obtain sufficient mass of suspended sediments to perform several analysis, including compound specific radiocarbon dating. Freshly exposed flood deposits were also sampled when possible (see Fig. 2) in an effort to establish fresh bank sediments as proxy samples for river suspended sediment.

***Figure 2**: Dr. Valier Galy (gray shirt) sampling fresh riverbank sediment along the Mackenzie River.*

We determined the elemental, molecular and isotopic composition of organic carbon carried by the Mackenzie River and its tributaries at different flow regimes in order to assess the source and flux of organic carbon in this rivers system. The analyses demonstrate that the observed spatial variability is linked to the distribution of permafrost in the basin. The Liard River that drains sporadic-discontinuous permafrost has organic carbon compositions reflecting an important input from contemporary C3 biomass. As the proportion of the catchment area underlain by continuous permafrost becomes more important, contributions from aged organic carbon derived from permafrost increases. Particulate organic carbon delivered to the Artic Ocean thus derives from the mixture of three main sources: rock-derived fossil carbon, recent C3 biomass, and aged permafrost organic carbon. Finally, we used a three end-member mixing model to propose the first quantification of permafrost-derived organic carbon in this river system. An important implication of this study is that thawing of permafrost may shift the balance of carbon sources to older organic carbon that has been stored for thousands of years in permafrost soils.



Another important component of this study was an investigation of the inorganic carbon system. Most natural waters contain dissolved carbon dioxide, CO_2 (including CO_2 gas and carbonic acid, H_2CO_3), bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}) ions in various amounts that collectively constitute the inorganic carbon system. These carbonate species are mainly derived from rock weathering, degradation of organic matters, and respiration.

Figure 3*: Dr. Aleck Wang, sampling the Mackenzie River near Inuvik to determine important parameters (pH, alkalinity, dissolved inorganic carbon, partial pressure of CO_2) of the inorganic carbon system that provides insights into whether the Mackenzie River is a source of CO_2 to the atmosphere or – like seawater – a sink for atmospheric CO_2.*

The inorganic carbon system can be defined by any two of the four measurable parameters: pH, partial pressure of CO_2 (pCO_2), total dissolved inorganic carbon (DIC), and total alkalinity (TA). The concentrations of these species define the state of the inorganic carbon system and determine how much CO_2 will either be taken up from or released to the atmosphere. Such an air-water exchange of CO_2 plays a fundamental role in regulating the atmospheric CO_2 level, and thus the Earth's climate.

The data collected as part of this project indicate significant daily and seasonal variations of inorganic carbon parameters. For instance, DIC concentrations and TA are negatively correlated with river discharge, meaning that higher river discharge decreases the magnitude of these two parameters. In general, DIC and TA increase in the direction of the Mackenzie River delta. We also found that the Mackenzie River generally releases CO_2 to the atmosphere year round because it has a higher CO_2 concentration than the atmosphere. There is a small, but significant amount of dissolved CO_2 (~5% of DIC concentration) in the river water, five times higher than that of seawater.

The results from this study have been presented at the 2012 Ocean Sciences Conferences in Salt Lake City by Aleck Wang and Katherine Hoering under the title "Temporal and Spatial Variabilities of the Riverine Inorganic Carbon System in the Mackenzie River and Beyond" and will be submitted to a peer-reviewed journal later this year.

Finally, the project also allowed us to extend the "My River, My Home" student art project to the Mackenzie River (Fig. 4). Dr. Jorien Vonk, on one of her visits to Inuvik, worked with local school teachers and their art classes to encourage students to bring to paper what the Mackenzie River means to their life.

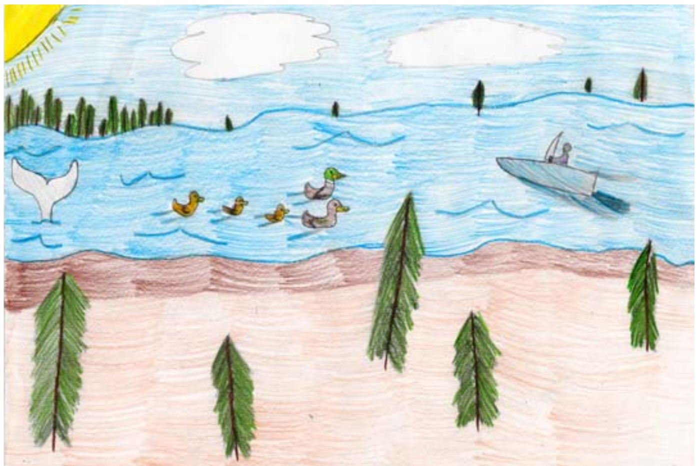


Figure 4*: Student art from schools in Inuvik, showing life on the river during the summer season. This artwork is part of the "My River, My Home" student art and science project. The first multi-river art and science exhibition will open on September 27, 2013 at the Fraser River Discovery Center in New Westminster, B.C., Canada.*

Artwork from the Mackenzie River has been incorporated into the greeting cards showcasing the Mackenzie River as part of the Global Rivers Observatory. We are indebted to The Clark Arctic Research Initiative whose generous support made this research possible. Funding from the WHOI ARI will be acknowledged in all future publications that report on the results from this project.