

MODELLING OF FRESHWATER FLOWS TO THE BEAUFORT SEA

FOR IMPROVED OFFSHORE PREDICTION BY THE METAREA OCEAN FORECAST SYSTEM

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Lance Lesack, *Simon Fraser University*

Our BREA Project Team

- Project Investigators

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- Faye Hicks, University of Alberta, Edmonton, AB
- Lance Lesack, Simon Fraser University, Burnaby, BC
- Will Perrie, Dept. of Fisheries and Oceans, Halifax, NS
- Al Pietroniro, Env. Canada, Water Survey Canada, Saskatoon, SK
- Fraser Davidson, Dept. of Fisheries and Oceans, St. John's NF
- Evan Davies, University of Alberta, Edmonton, AB
- Yuntong She, University of Alberta, Edmonton, AB
- Zhenxia Long, Dept. of Fisheries and Oceans, Halifax, NS

- Graduate Students

- Chris French, University of Alberta, Edmonton, AB
- Julia Blackburn, University of Alberta, Edmonton, AB
- Jennifer Nafziger, University of Alberta, Edmonton, AB

Project Objectives

Improve operational ocean modeling of waves and sea ice, by providing, accurate fresh water boundary conditions at the Beaufort Sea/ Mackenzie Delta interface. Specific objectives:

1. develop and implement a **hydraulic model of the Mackenzie Delta** that will provide channel flows to the Beaufort Sea;
2. develop an **off-channel water storage model** of the Mackenzie Delta to enable the hydraulic model to properly account for storage of water that greatly modifies the Mackenzie River flows to the Beaufort Sea;
3. through **linkages with the NEMO ocean model**, interactively model the coupled river and ocean system;
4. evaluate the **physical connection (transport-diffusion)** between the Mackenzie Delta hydraulic model and NEMO; and
5. provide operational delta hydraulic model code to incorporate in the operational model developed in the **Davidson et al. BREA project**.

Focus during our first year...

Improve operational ocean modeling of waves and sea ice, by providing, accurate fresh water boundary conditions at the Beaufort Sea/Mackenzie Delta interface. Specific objectives:

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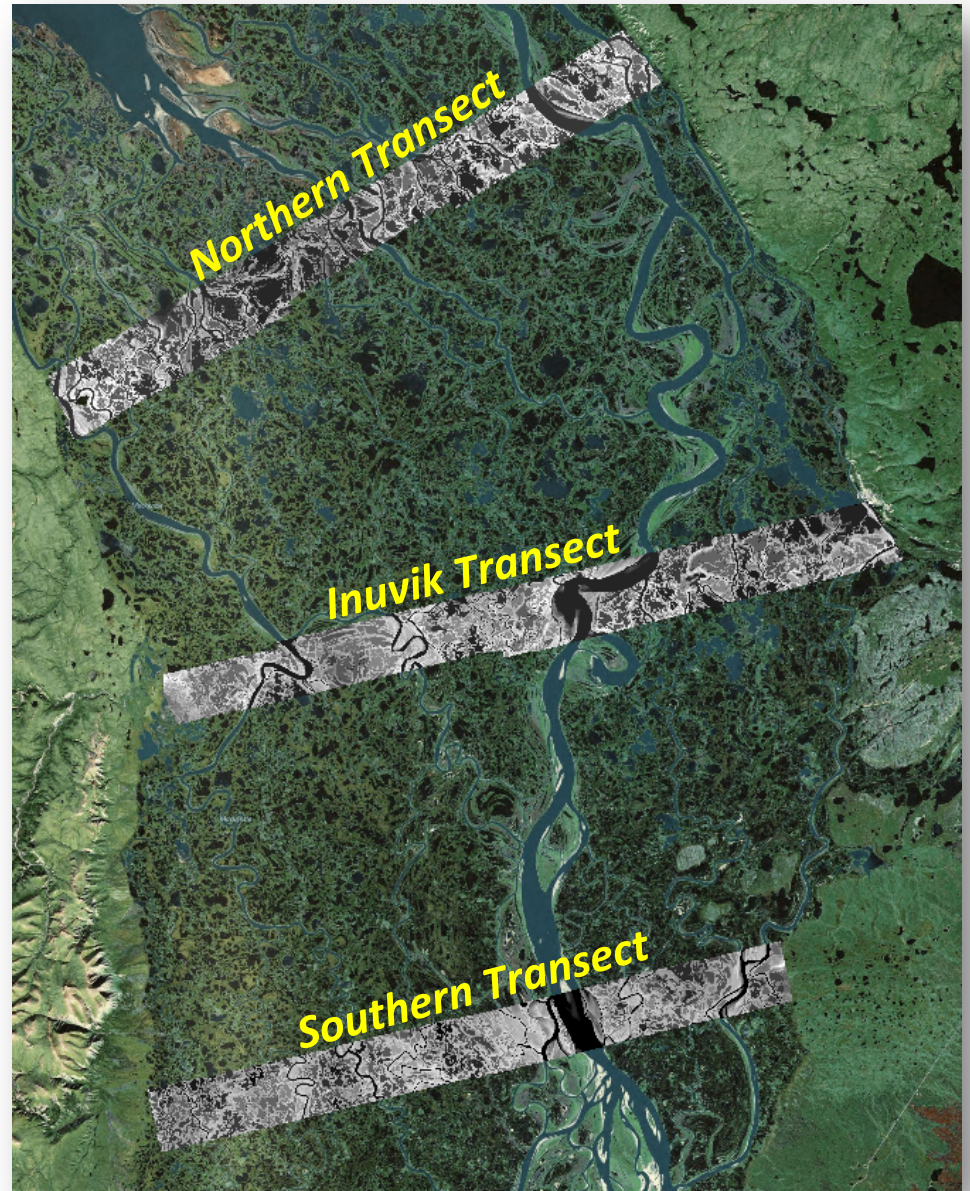
Legacy from the International Polar Year

Funding during the *International Polar Year* provided the following:

- Lidar data along 3 cross delta transects and in an area in the outer Delta (flown during August 2008)
- Analysis of ice cover conditions, water level, and discharge at key locations throughout the delta (MSc of Janelle Morley, UofA)
- Preliminary development and testing of the UofA hydraulic model (MScs of Janelle Morley, and Jennifer Nafziger, UofA)

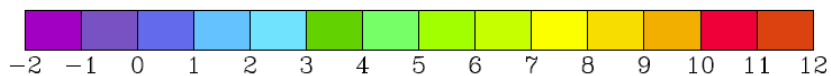
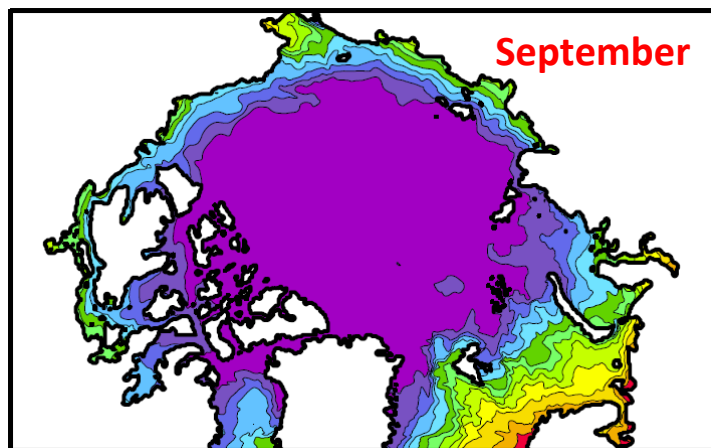
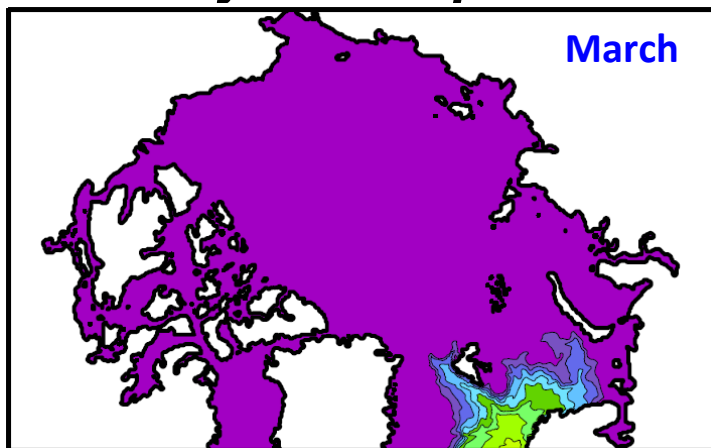
These represent the investment by the Government of Canada of many hundreds of thousands of dollars.

Without this investment, we could not proceed with the current BREA project.

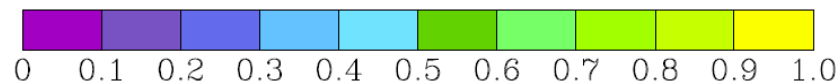
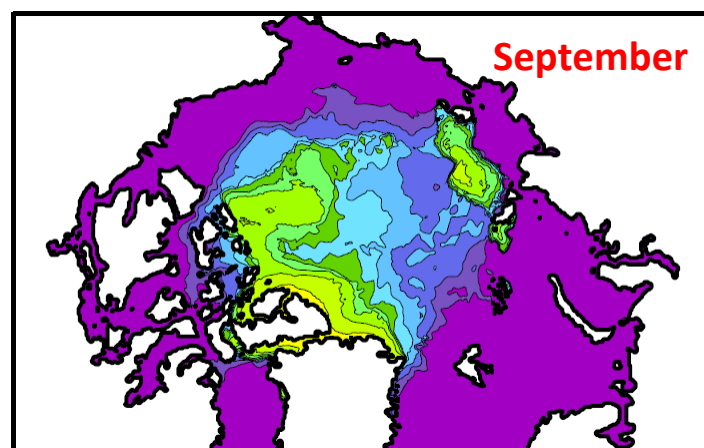
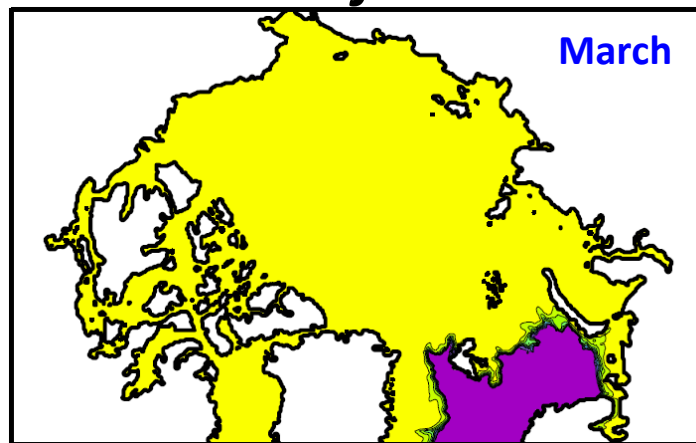


Objective 3 - NEMO ocean modeling is underway and producing stable results for summer and winter...

Sea surface temperature



Sea ice fraction



Why do we need to model freshwater flows to the sea?

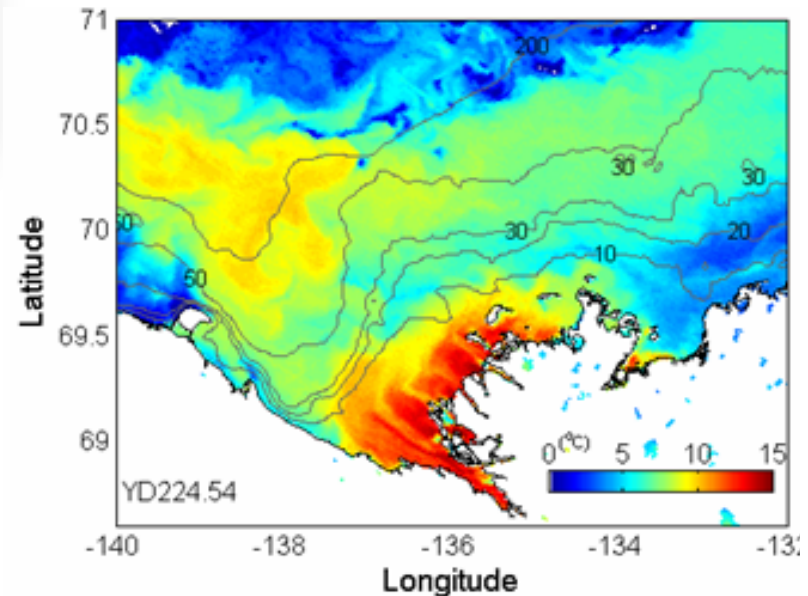


Image courtesy of Geographic Information Network of Alaska: <http://www.gina.alaska.edu/data/gina-modis-images/>

Typical **warm water plume** from the Mackenzie Delta; this can provide energy to allow storms to intensify. (e.g. Millennium storm 1999)

The *Mackenzie River Delta channels bring heat and freshwater fluxes to the Arctic Ocean:*

- average annual peak flow of $\sim 25,000 \text{ m}^3/\text{s}$ river water enters the Beaufort over a 115+ km boundary
- resulting river plume $\sim 2\text{m}$ thick, 200 km wide, several 100s km long, and responds rapidly to changes in winds



MODIS data, Image adapted from Mulligan et al. 2010

Presently...

- Due to the lack of time-dependent Mackenzie River runoff in our NEMO ocean model, modeled sea surface temperatures are too cold in the summer.
- Therefore, we underestimate storm intensity, winds, minimum sea level pressure, and resulting storm surges at the Delta.

Millennium storm 1999

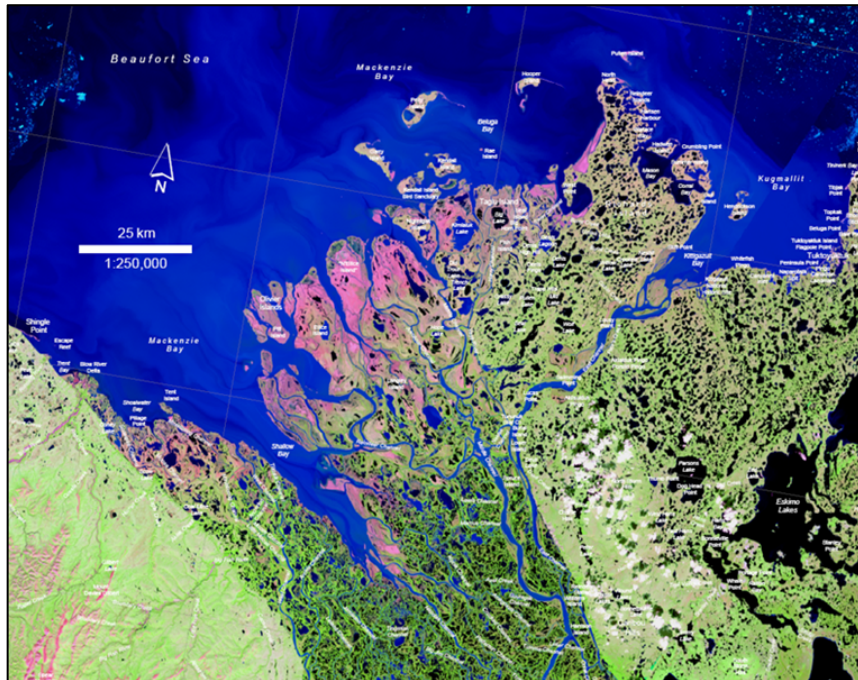


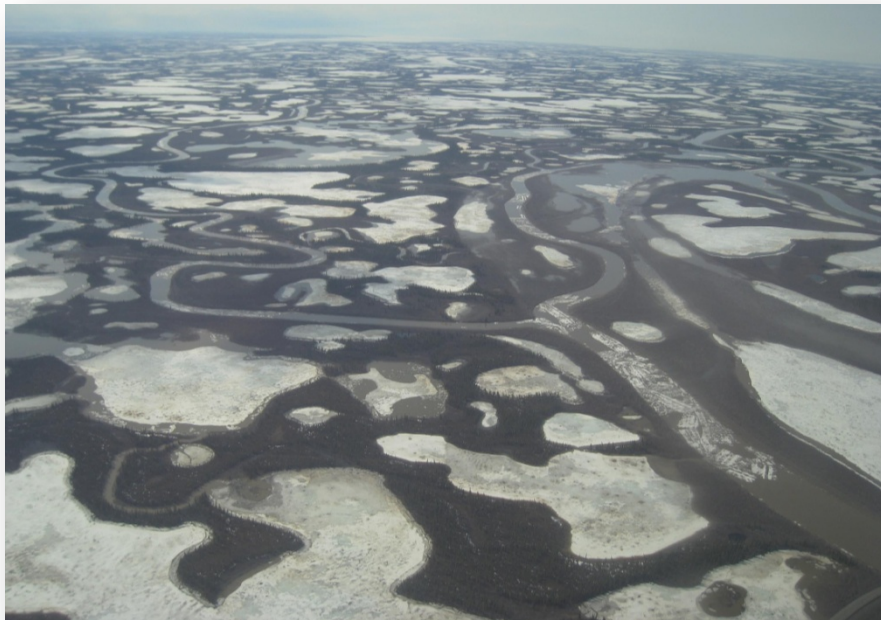
Figure source *Pisaric et al. 2011*
Pink colour shows area where vegetation was killed by storm surge.

Our plan...

- We will implement a time-dependent river runoff in our ice-ocean model to better represent physical processes between the River and the Beaufort Sea.
- We will test the model for simulations such as the 'millennium storm' of summer 1999, and impacts on storm surge at the Delta, and other storm cases.

To achieve this...

We need a hydraulic model of the Mackenzie Delta...

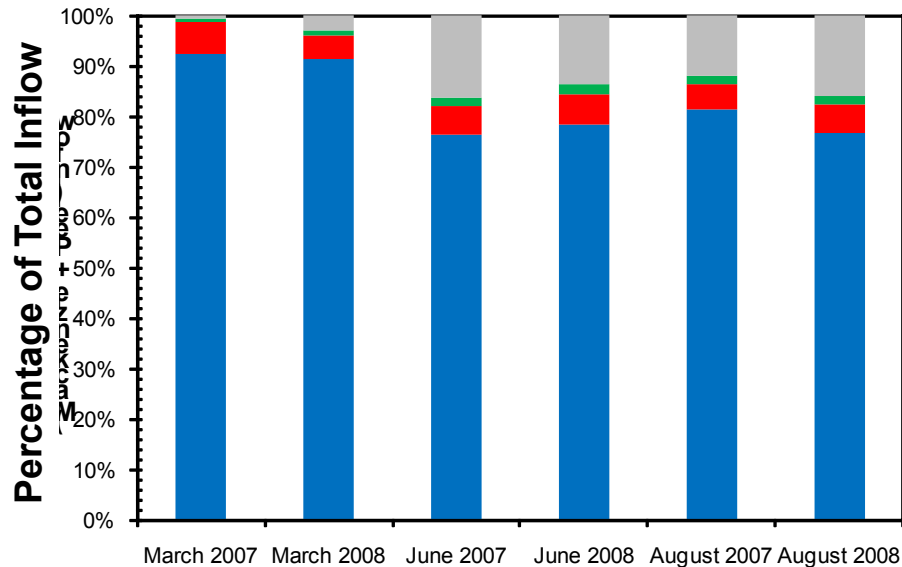


UofA PhD Students: J Nafziger and J Blackburn, MSc student: J Morley



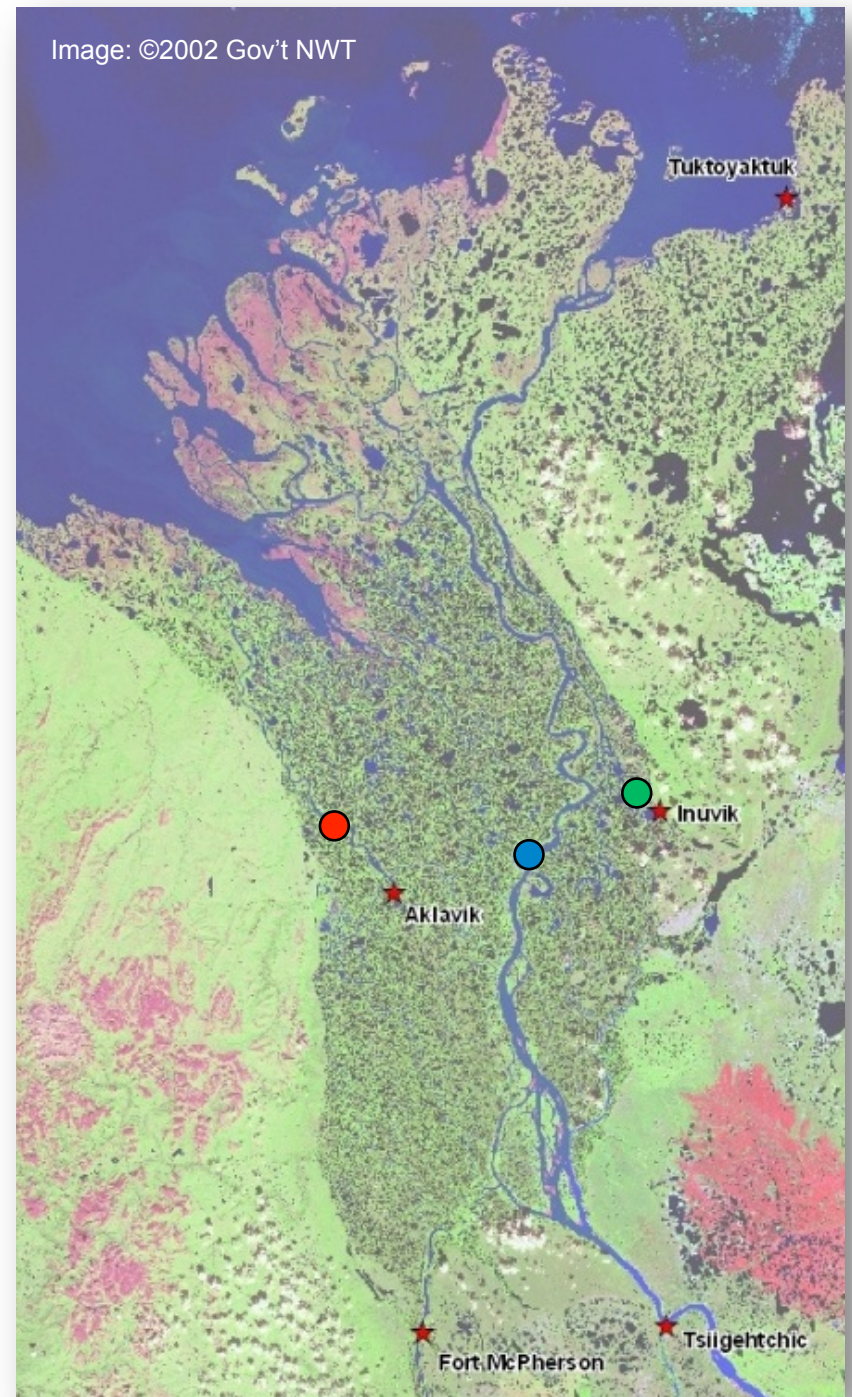
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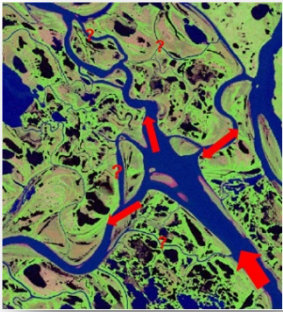
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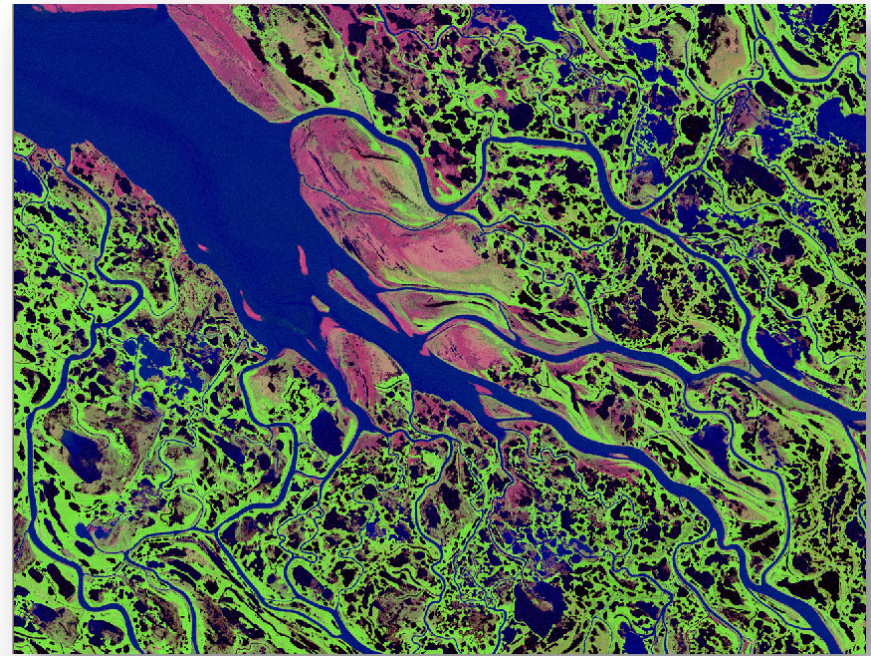
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Image: ©2002 Gov't NWT





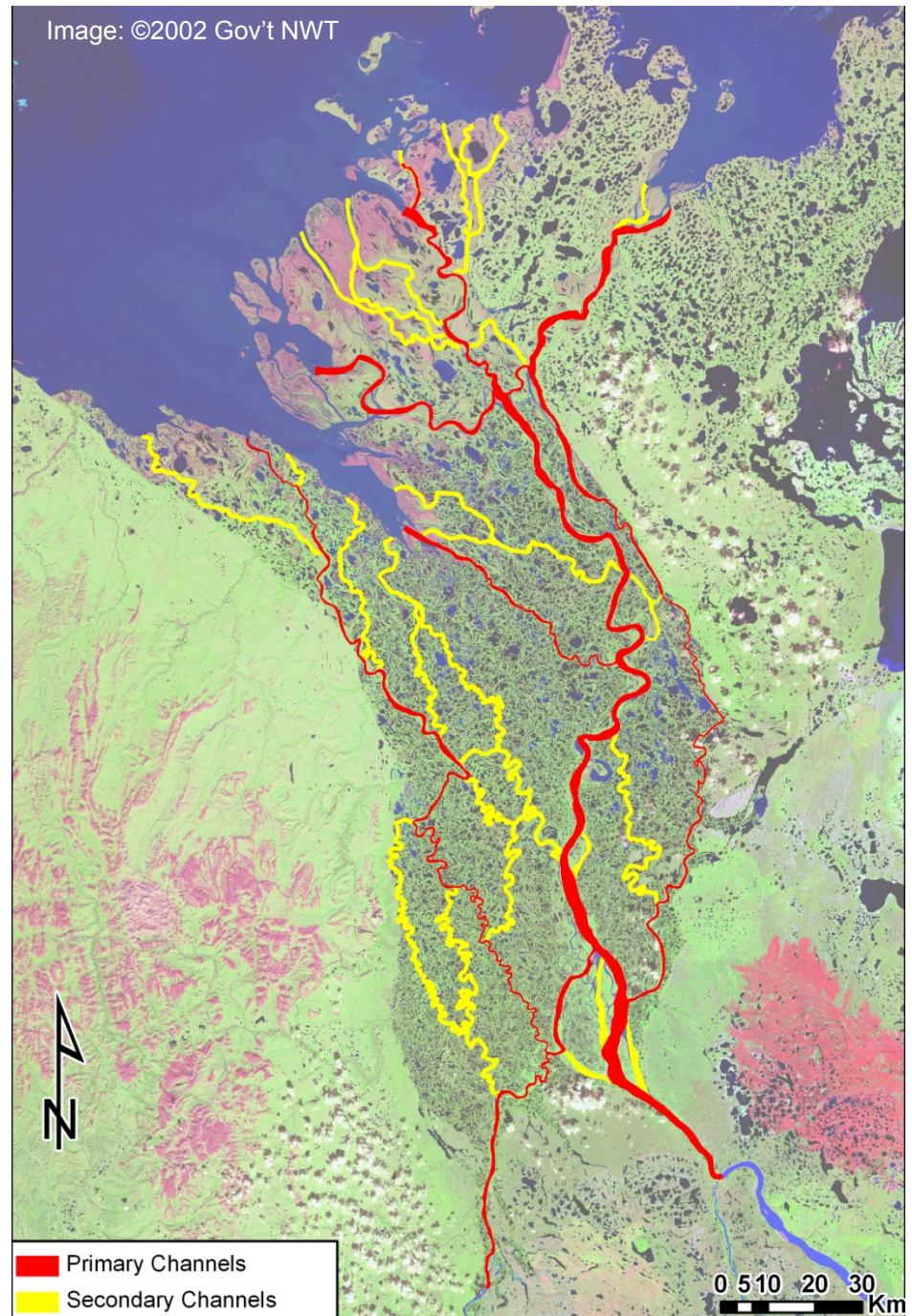
However ,there are some very complex junctions in the delta.



Also, ice jams can affect flow distributions, and affect the extent and distribution of stored water in the delta...

We can't model all of the channels, but we need to be sure we capture the (hydraulically) important ones ...

- *If needed (and possible) tertiary channels will also be considered*



We also need to understand how water is stored in the Delta's lakes and floodplains...

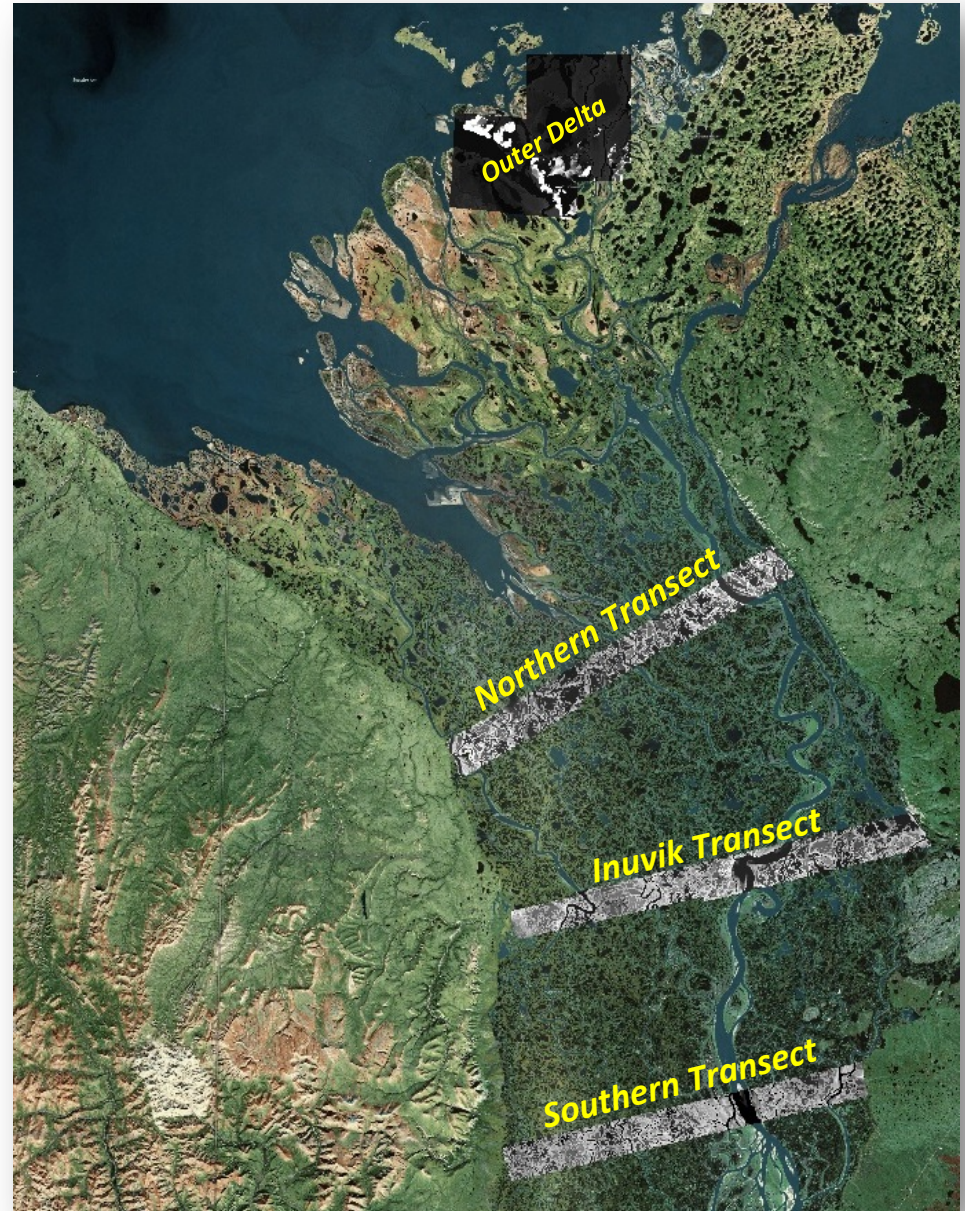


Off channel storage is very large and can affect timing and volume of flows

Available Topographic Data

Three LiDAR transects (shown in grey) were flown across the delta in 2008 to provide information on topography in the upper, central, and lower delta. Additional LiDAR coverage was flown in the outer delta.

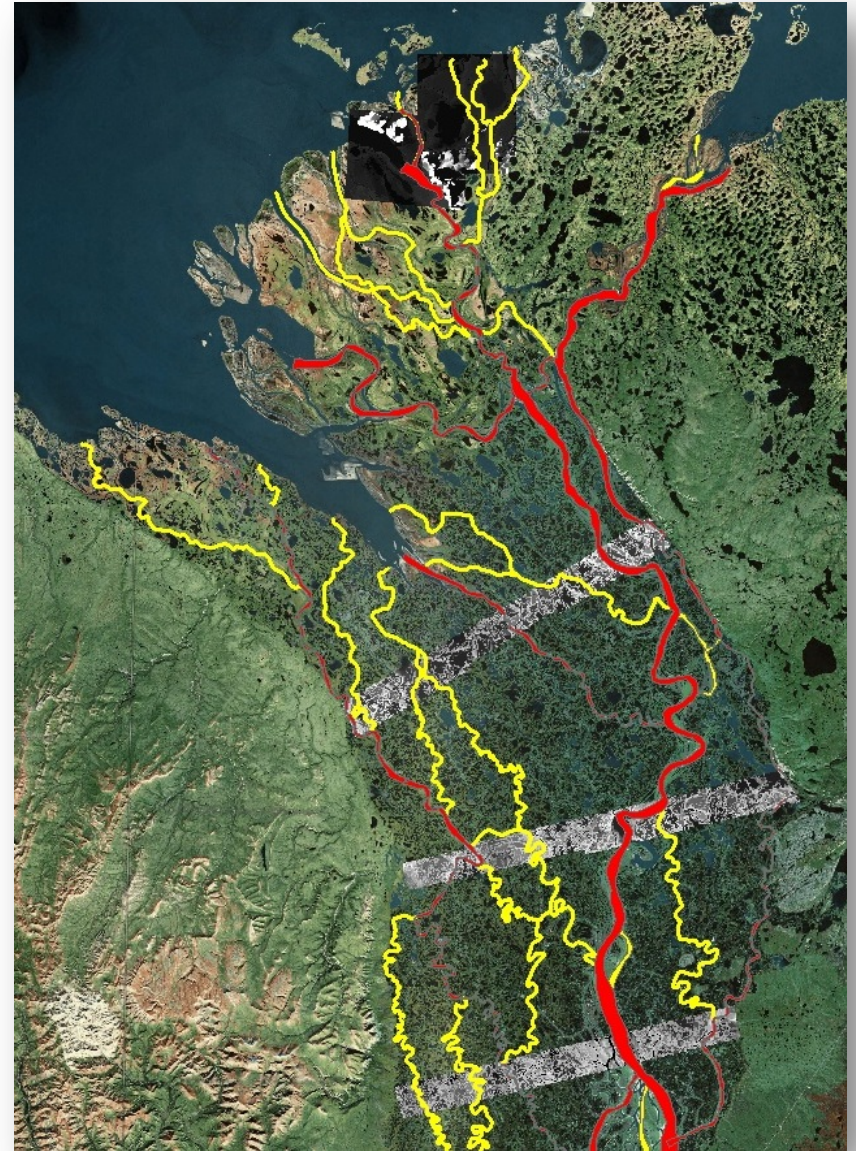
- *Conversion of Lidar data completed Nov 2012.*
- *Validation of lake/channel edges completed Dec 2012.*



Delta Storage Elements

- Storage elements were then classified and measured:
 - Lakes
 - Overbank areas
 - Major and minor storage channels*

**Channels that are not primary or secondary channels (i.e. not included in the Delta hydraulic model) are considered 'storage channels'.*

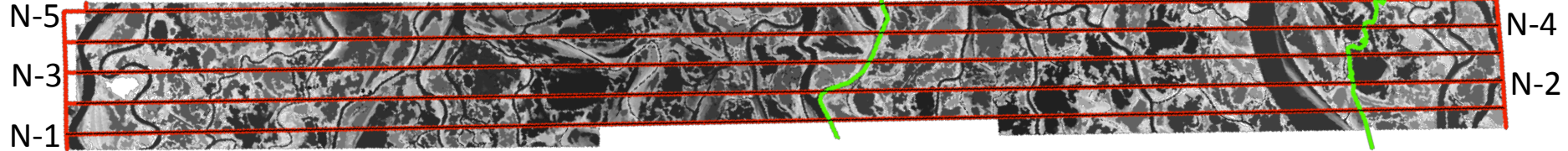


Northern Transect

West Zone

Middle Zone

East Zone

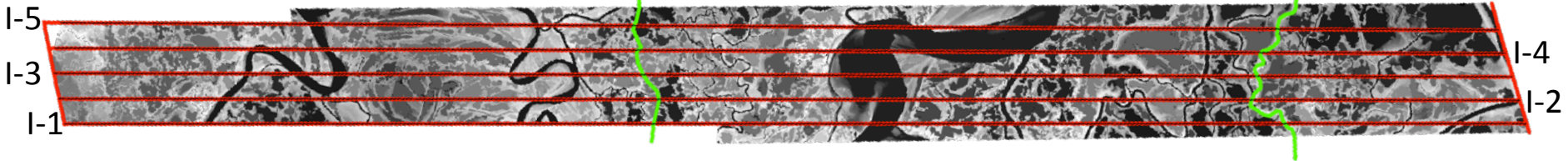


Inuvik Transect

West Zone

Middle Zone

East Zone

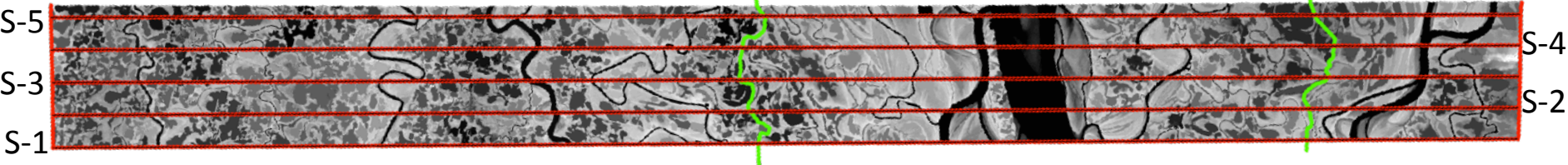


Southern Transect

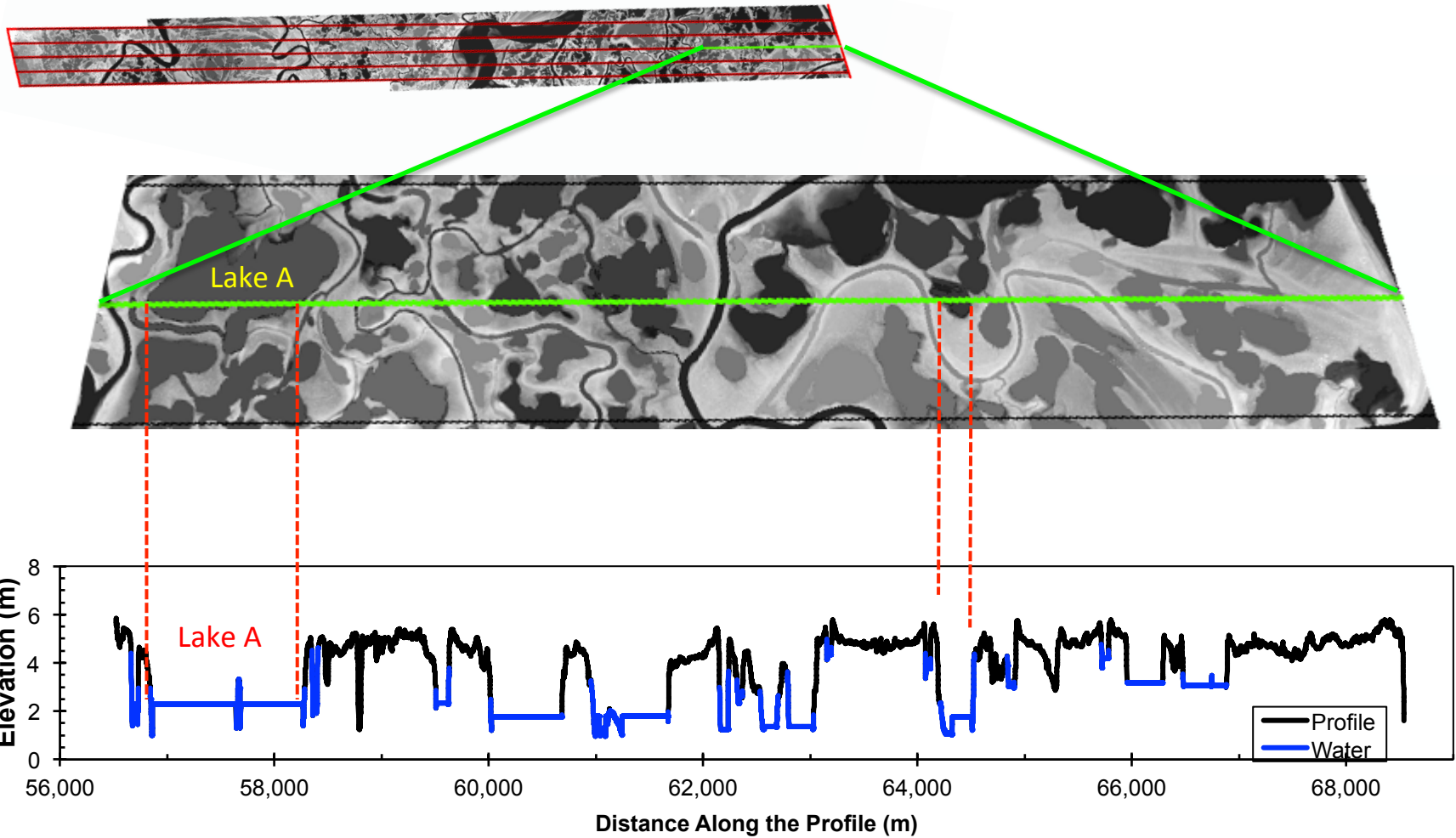
West Zone

Middle Zone

East Zone



Example – from the Inuvik Transect

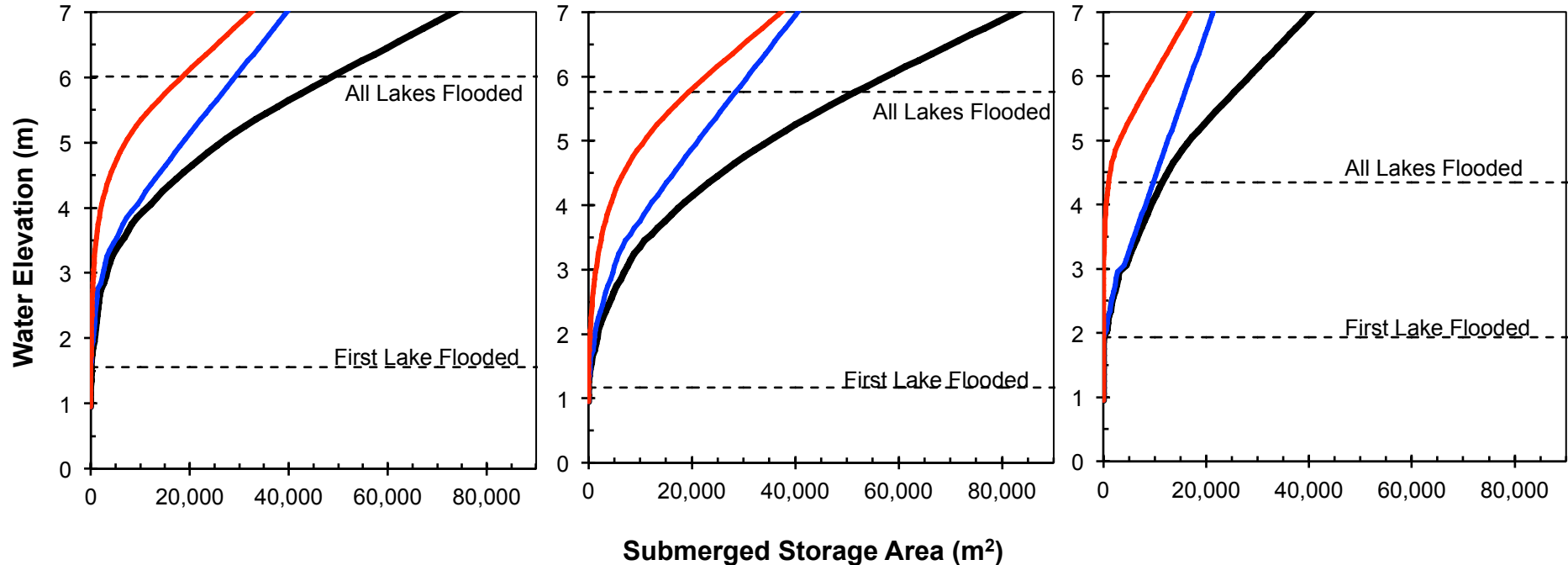


Storage Variation Across the Delta (Inuvik Transect)

West Zone

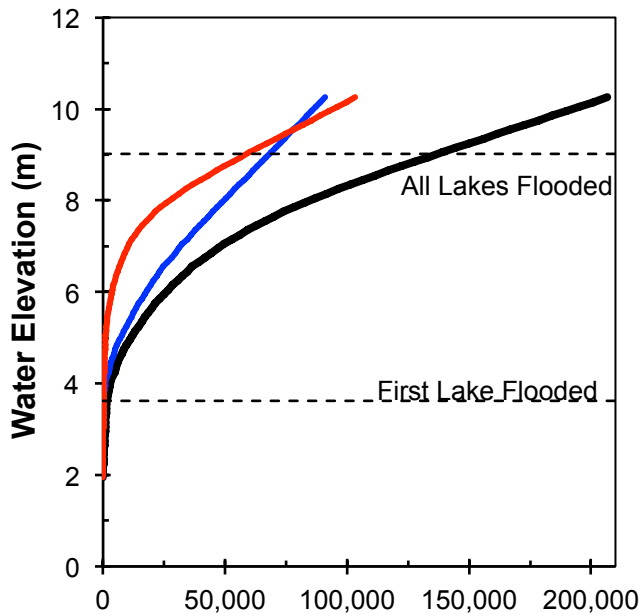
Middle Zone

East Zone

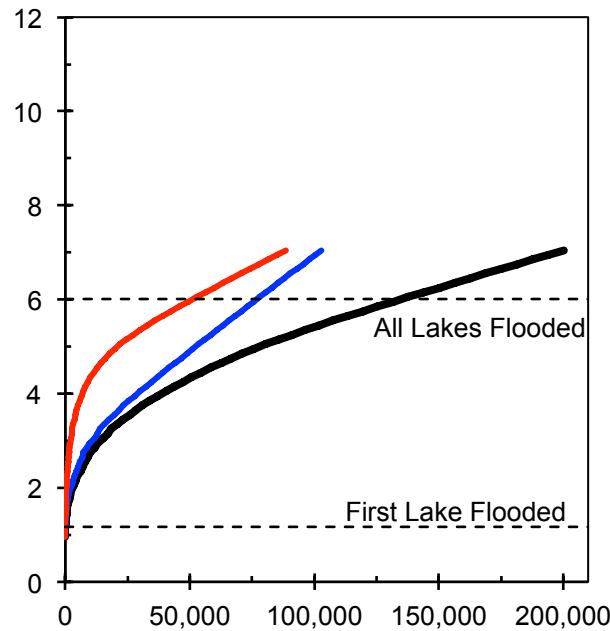


Storage Variation Down the Delta (Middle Zone)

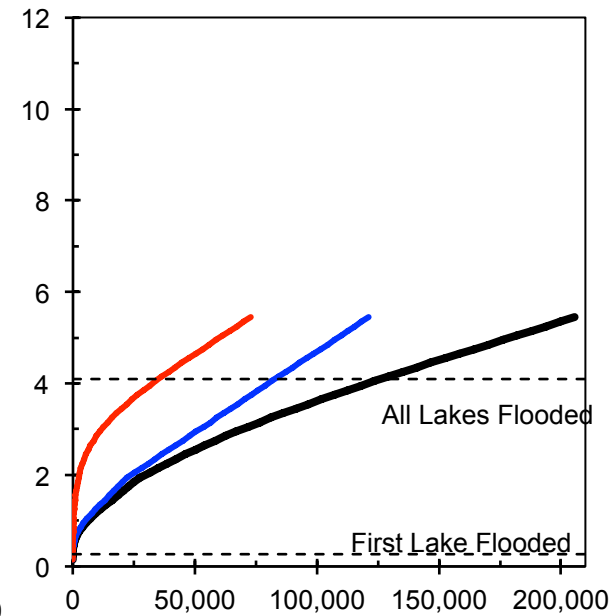
Southern Transect



Inuvik Transect



Northern Transect



Summary of progress to date...

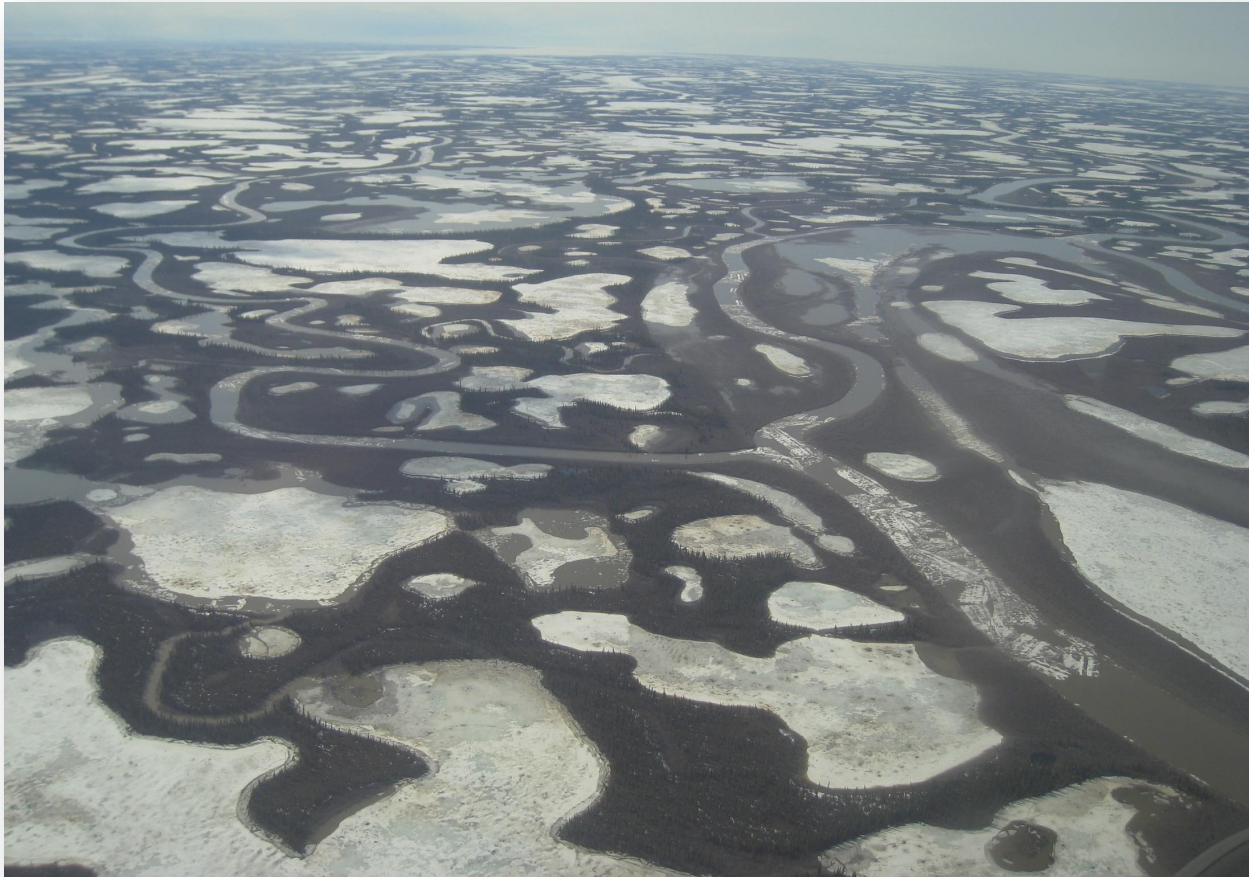
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Linkages to BREAs and Regulatory efficiencies and decisions...

- will address **BREAs Tier 1 research priority** of coupled ocean-ice-atmosphere modelling/forecasting at a fine scale.
- will provide freshwater flows from the Mackenzie Delta to the Beaufort Sea that is required to provide the boundary conditions for the **NEMO ocean model project by Davidson et al.**
- will provide support for **Environmental Assessment**, regulatory decisions, and build the capacity to simulate **oil spill trajectory** in near real-time.
- publicly available information can also be used by the **Canadian Coast Guard** in their Search and Rescue Planning software to monitor and forecast drift of search objects.
- will improve **EC/DFO NEMO operational forecasting** in this region as boundary conditions from this project will be provided to BREAs project by Davidson et al.

THANK-YOU!



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