Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Tamlin Pavelsky, PhD - Associate Professor
University of North Carolina Department of Geological Sciences
Hydrology Science Lead, NASA SWOT Mission

Alain Pietroniro, PhD, P.Eng – Executive Director –
ECCC National Hydrological Service, Meteorological Service of Canada,
Canadian Lead SWOT Hydrology

Daniel Peters, PhD, P.Geo. - Research Scientist
Environment & Climate Change Canada
Watershed Hydrology & Ecology Research Division, WSTD
Water & Climate Impacts Research Centre, University of Victoria, BC
Canadian SWOT Hydrology Team

Hydrologic Science and Applications from SWOT in Canada

SWOT AGM Montreal QC June 26 2018

Contributions and Partners

ECCC

- Daqing Yang & Daniel Peters – WHERD, Water Science and Technology
- Vincent Fortin – Atmospheric Science and Technology
- Doug Stiff, JM Fiset & Jeff Woodward – Engineer NHS
- Scott Hill, Corey Hein, Cody Garbutt, Tim Ma, Cuyler Onclin, Tom Carter, Mark Russell ++

CSA

- Robert Saint-Jean – Program manager

Universite de Sherbrooke - GREAUS

- Robert Leconte & Melanie Trudel + team of PDFs & Graduate Students (Sebastien Langlois, Jean Bergeron, Gabriela Llanet Siles, Nicolas Desrochers)

U of Saskatchewan

- Partnering with the GWF programme

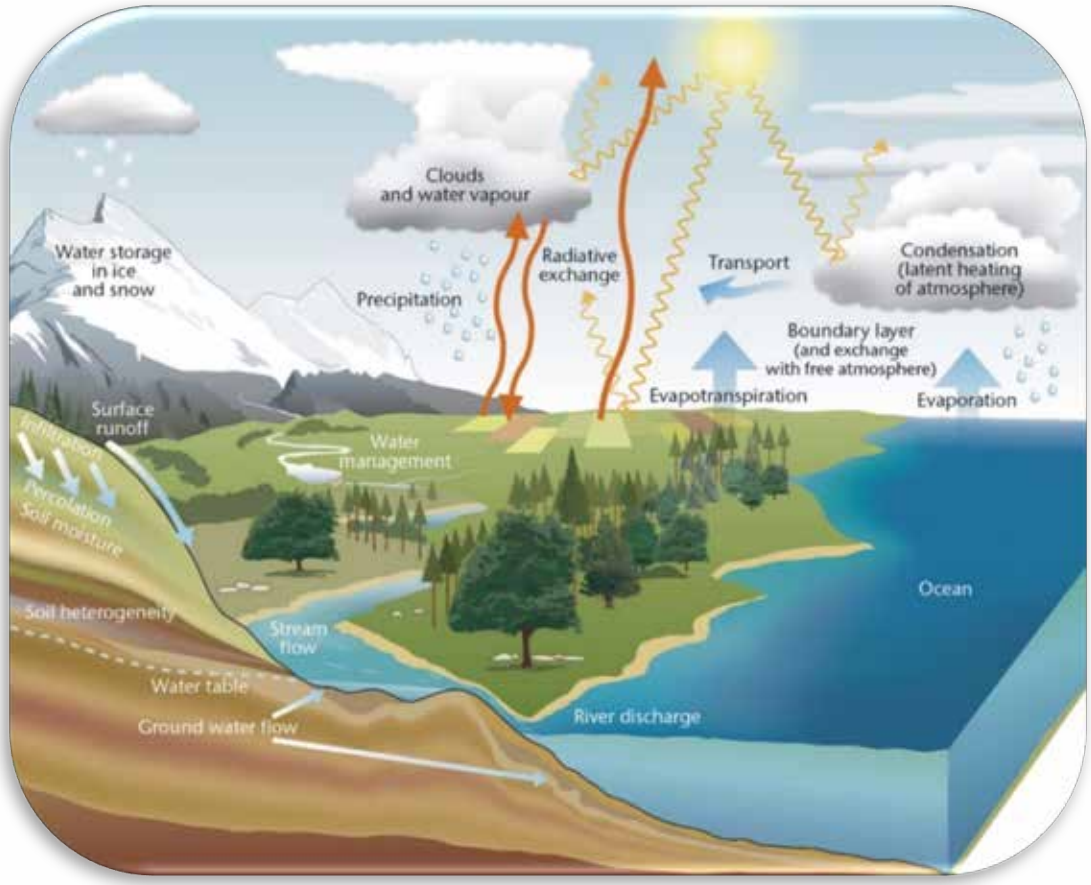
U of Victoria

- Collaborating with Hyperspectral & LiDAR Lab

- **US Colleagues**
- Tamlin Pavelsky, Univ. North Carolina, Department of Geological Sciences
- Larry Smith – former UCLA (now Brown) – Department of Geography
- Colin Gleason – University of Massachusetts – Civil Engineering
- Toby Minear – NCAR – Boulder Colorado

Hydrologic Science

- Dealing with occurrence, movement, distribution, and properties of the waters of the solid earth and its atmosphere.
- eg, timing and quantity of streamflow, surface storage, and connectivity
- Many of the environmental problems that society is facing today are related to hydrologic or water issues.



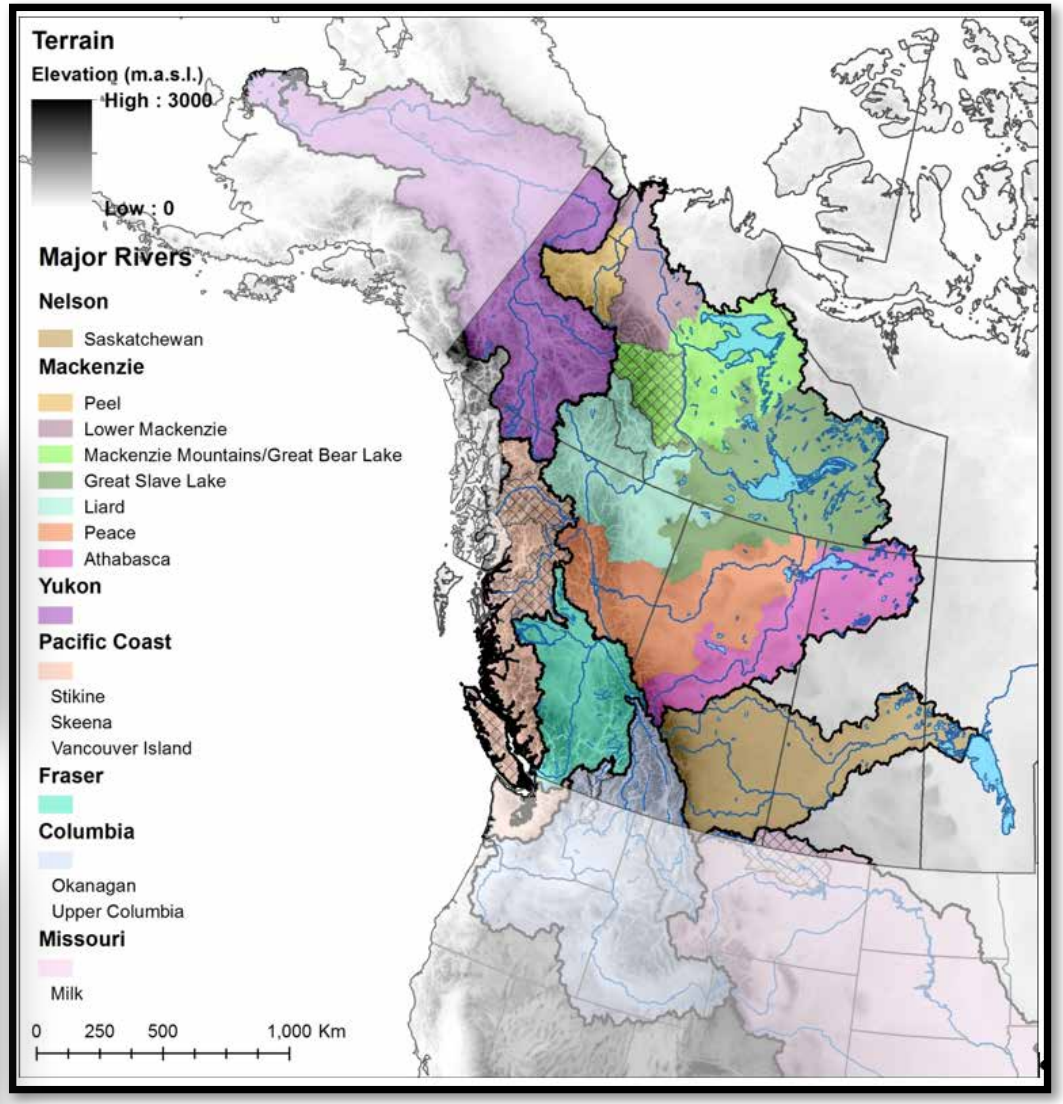
Western Water Resources Issues of concern:

Changing climate and water availability (quantity/timing) + increasing resource development

Permafrost Degradation

Irrigation

Loss Wetlands

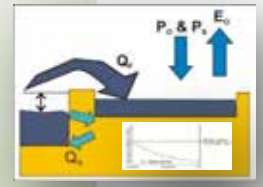


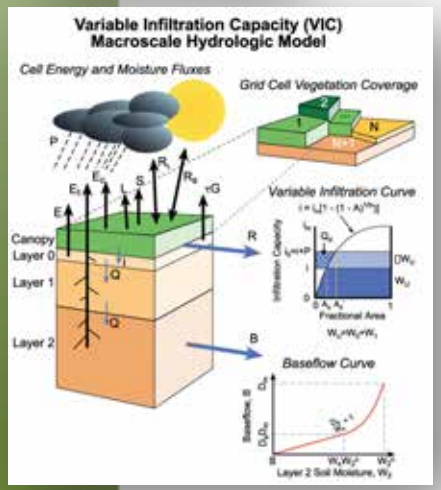
Hydro Dam Reservoirs

Oil Sands Mining

Fracking Gas

Typical Project and Research Approach





Future Climate Model Data

Historical Climate & Hydrometric Data

Feedbacks

Climate Data Downscaling

Spatial & Temporal Analysis

1st Order Impact Processes / Models

eg, River Flow, Lake Level, Water Supply, Ice Cover

2nd Order Impact Processes / Models

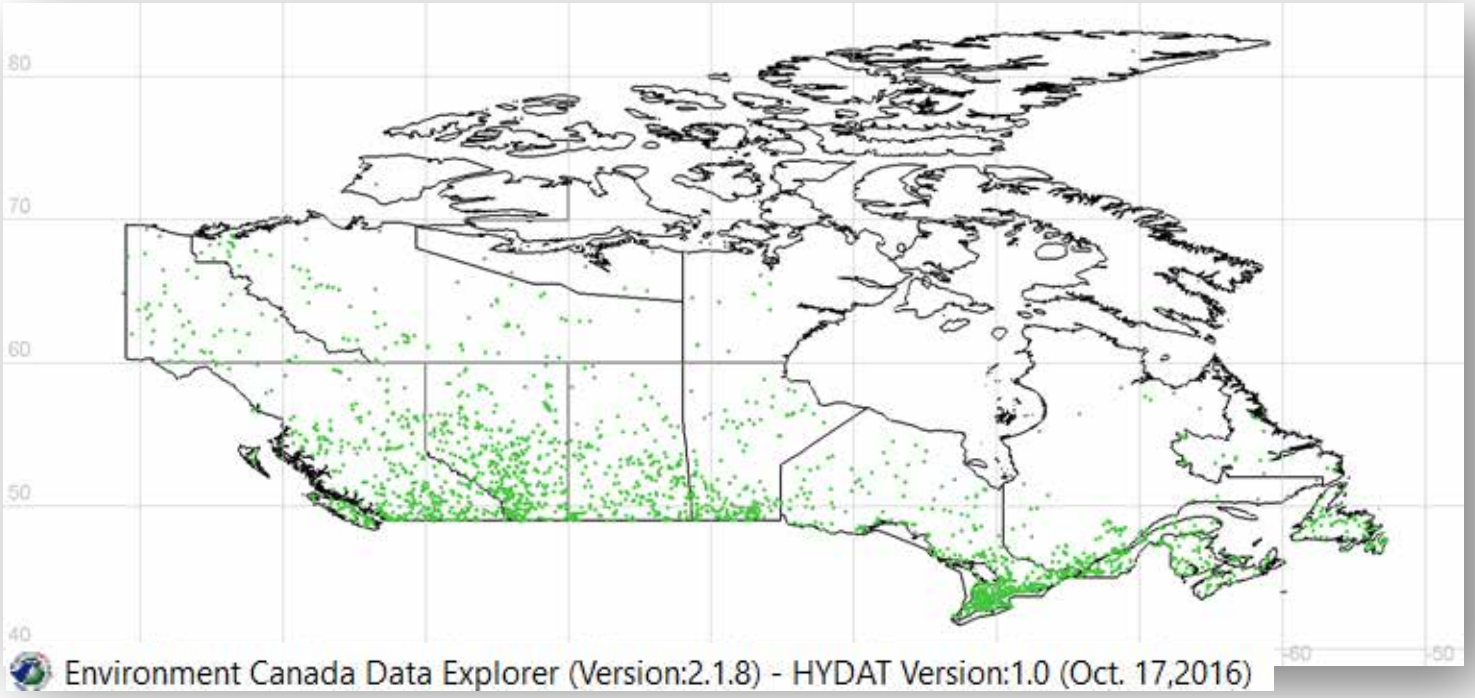
eg, Water Temperature, Water Quality

3rd Order Impact Processes / Models

eg, Aquatic Biota Diversity & Productivity

Hydrometric Data Needed for Research & Monitoring

- National Hydrometric Program is responsible for collecting, interpreting and disseminating surface water availability (quantity).
- Water Survey of Canada (WSC) operates most of the 2 800 hydrometric stations on behalf of most provinces and all territories.



- In Quebec, the province collects its water quantity information on behalf of the Government of Canada under a similar agreement.

Example Trend Analyses Canada - Rivers

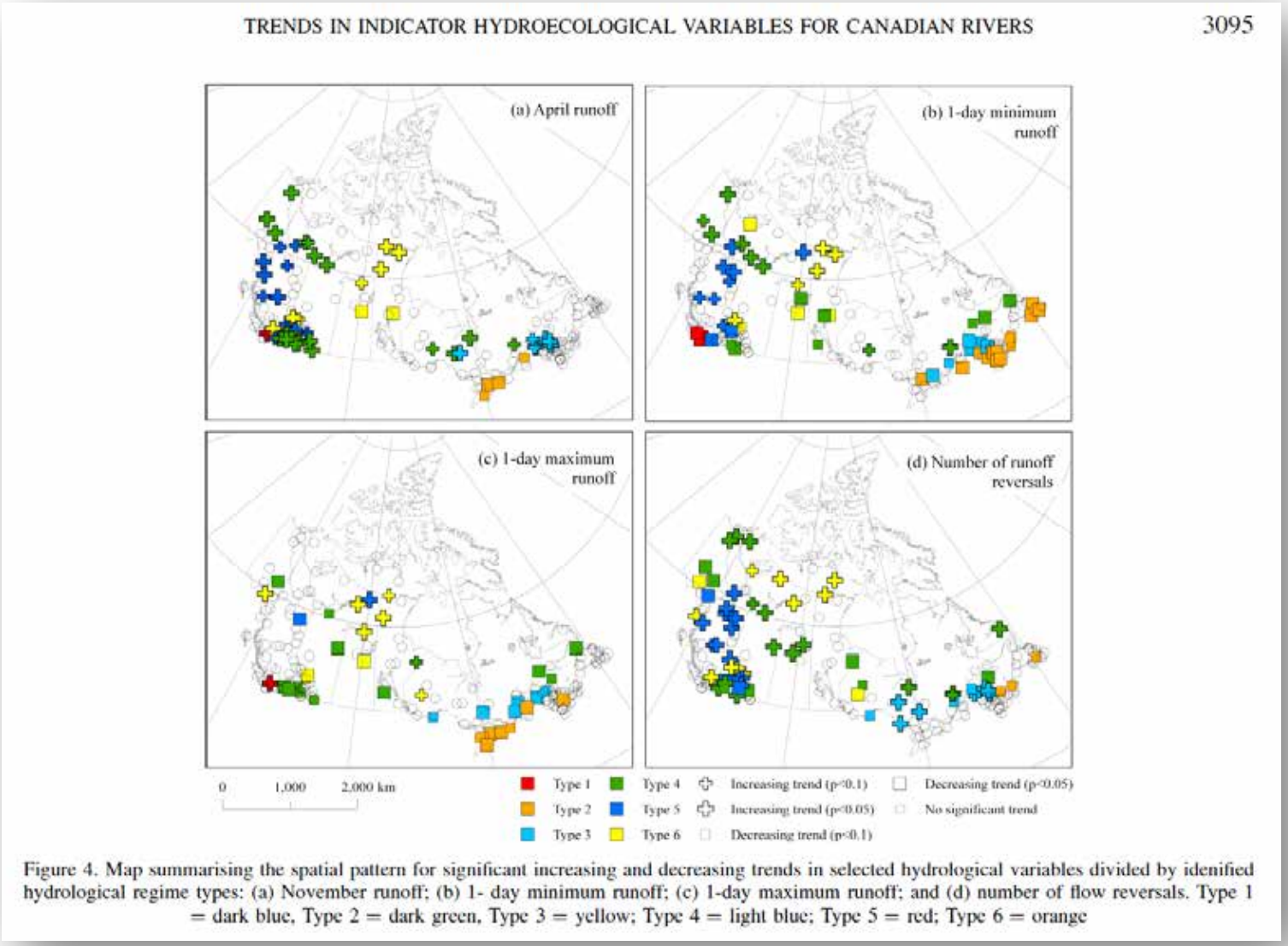
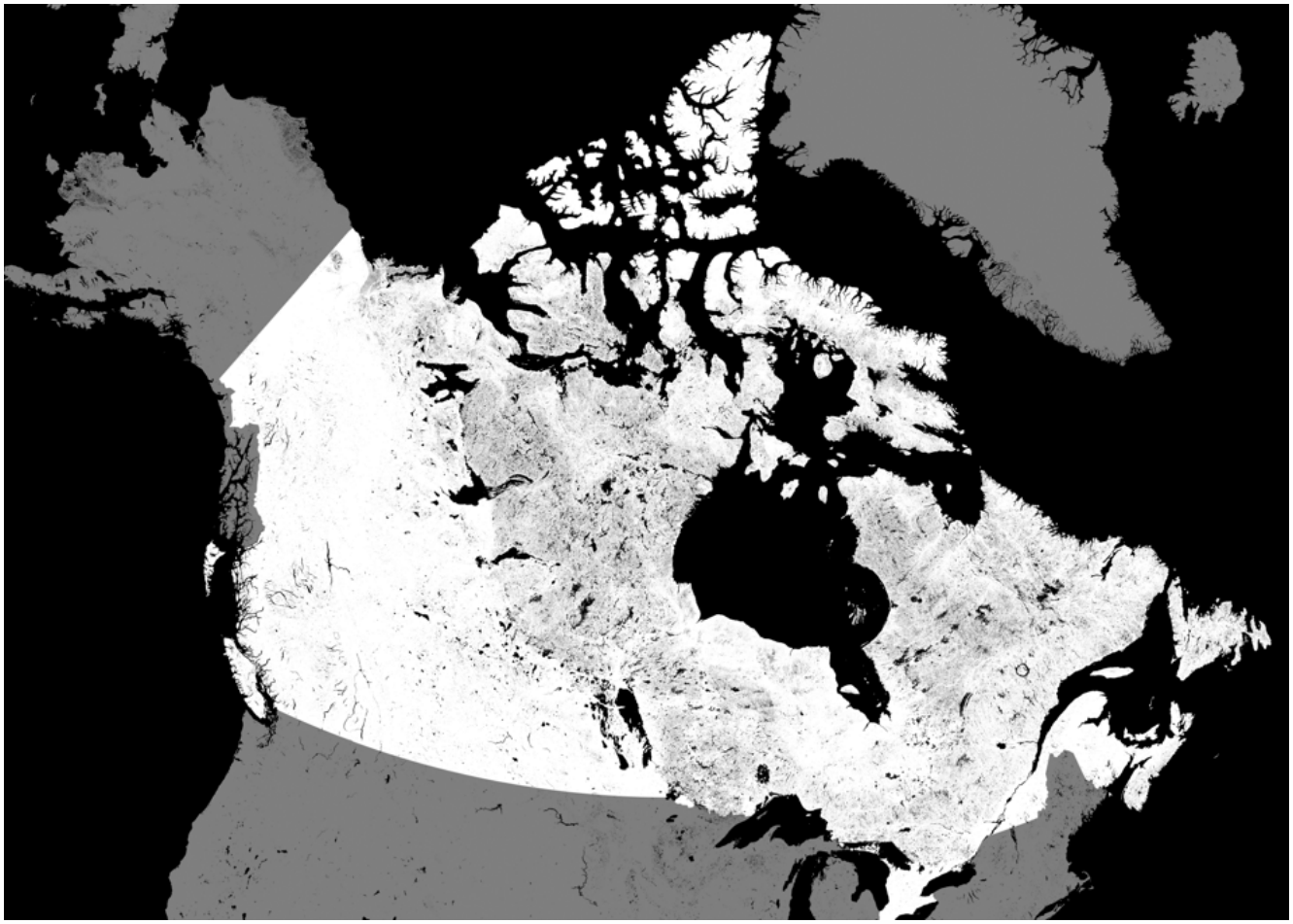


Figure 4. Map summarising the spatial pattern for significant increasing and decreasing trends in selected hydrological variables divided by idenified hydrological regime types: (a) November runoff; (b) 1- day minimum runoff; (c) 1-day maximum runoff; and (d) number of flow reversals. Type 1 = dark blue, Type 2 = dark green, Type 3 = yellow; Type 4 = light blue; Type 5 = red; Type 6 = orange

Monk et al 2011 Hydrological Processes

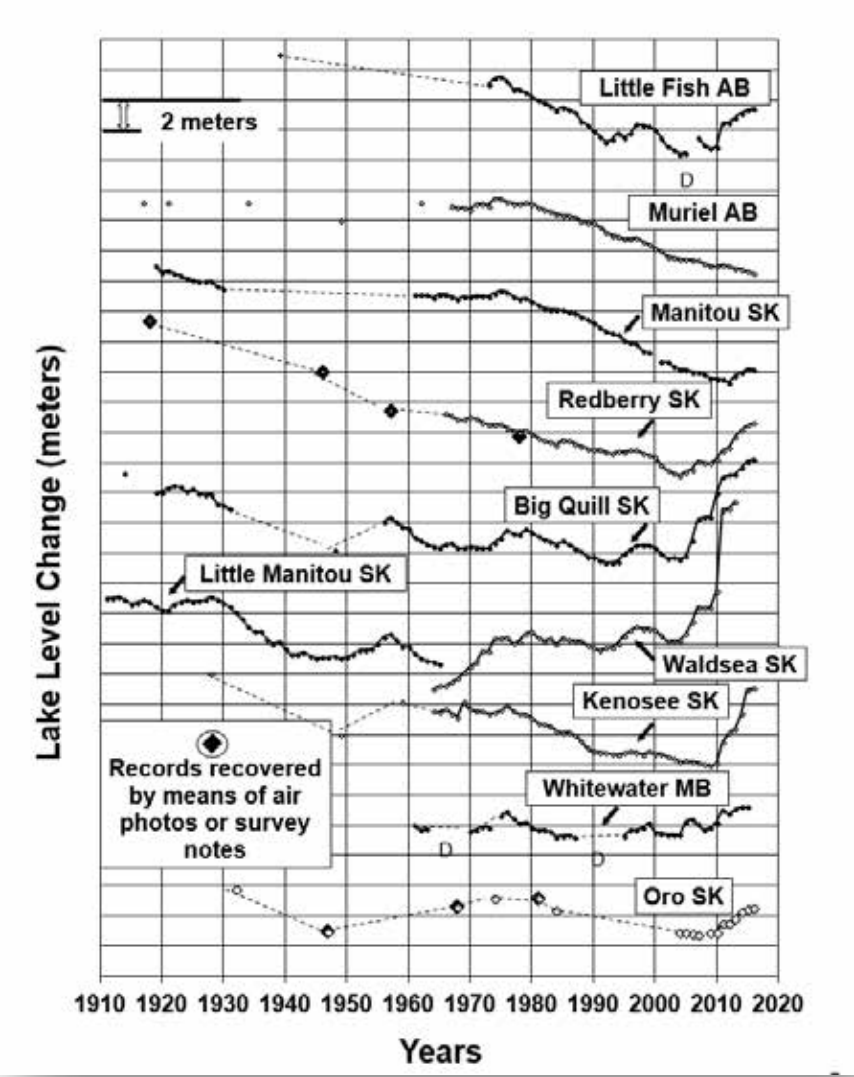
Canada is a surface water “rich” country but vastness and remoteness makes it difficult to monitor extensively

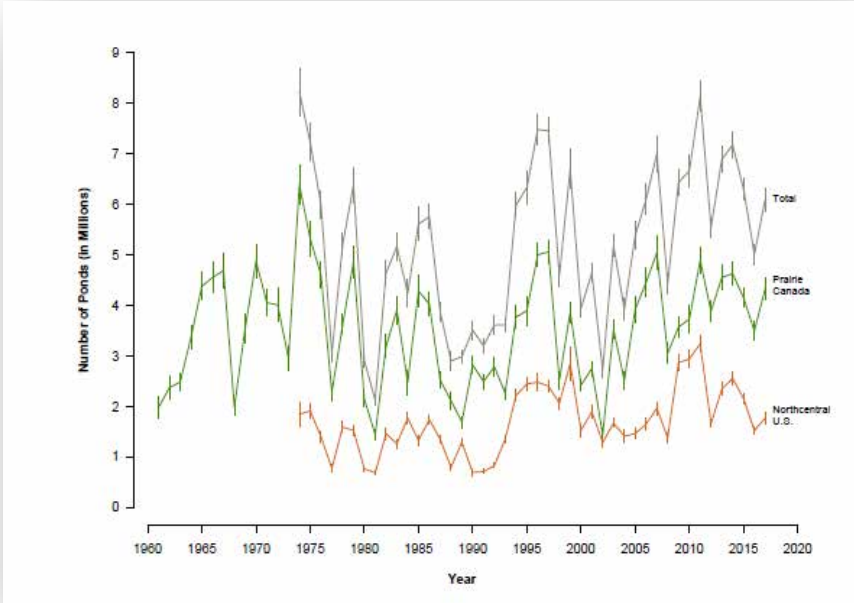
Remote sensing derived map of lakes (Dark areas) in Canada >> 1 000 000



- Need for spatially extensive surface water monitoring approach

Example Trend Analyses Canada – Lakes



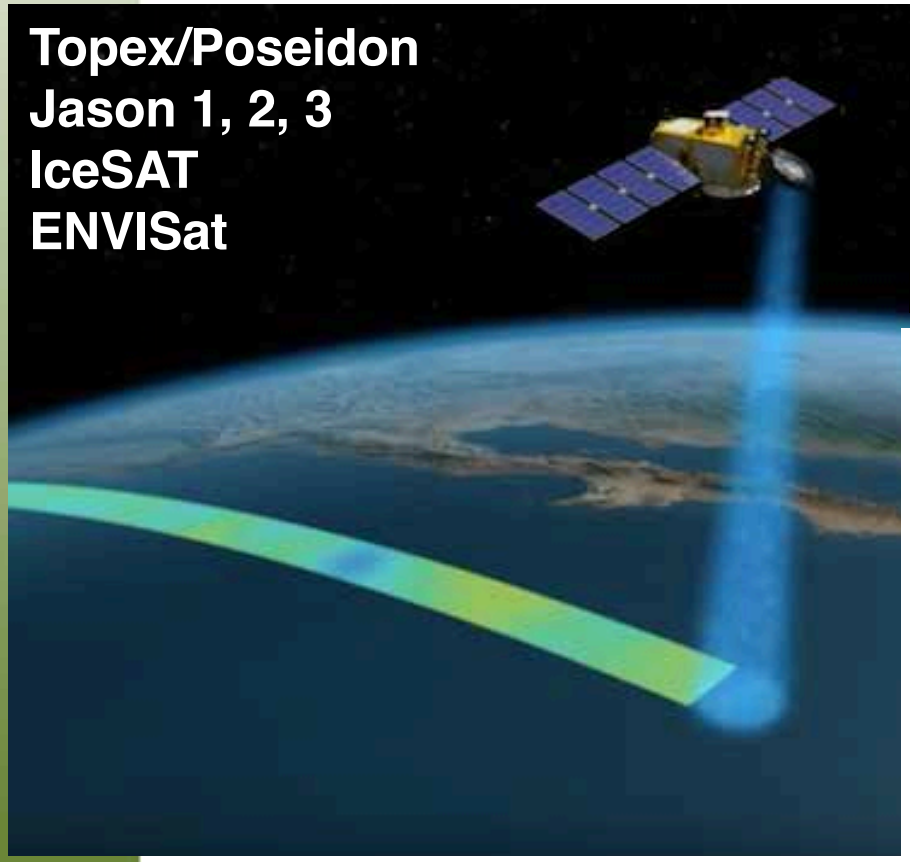


van der Kamp et al. (2008); data updated through 2016 by G. van der Kamp.

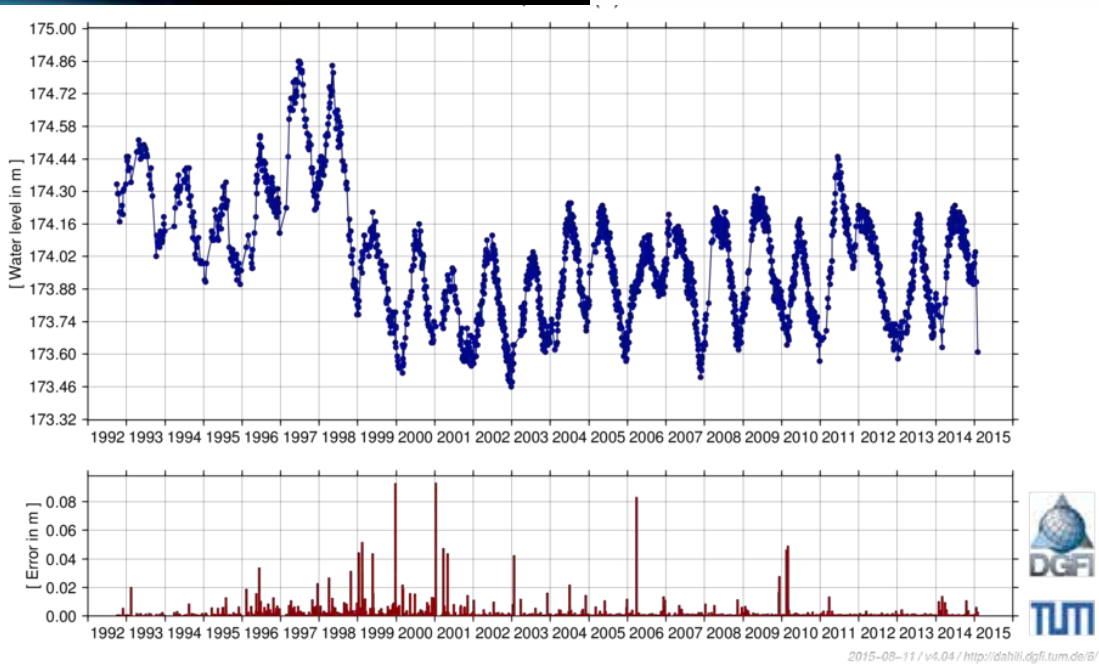
What about Remote Sensing?

Goal: measure variations in water storage and fluxes.

Data Source 1: Water surface elevation from satellite altimeters



Altimeters designed for the ocean can also provide heights over large rivers and lakes

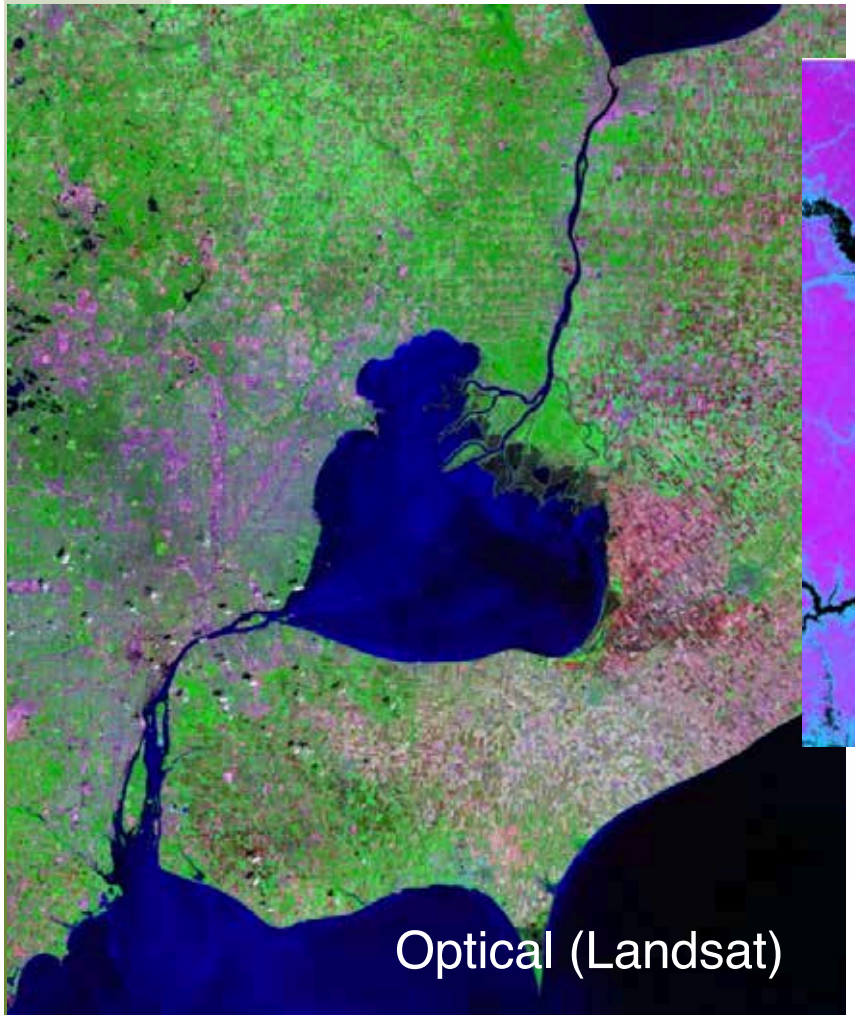


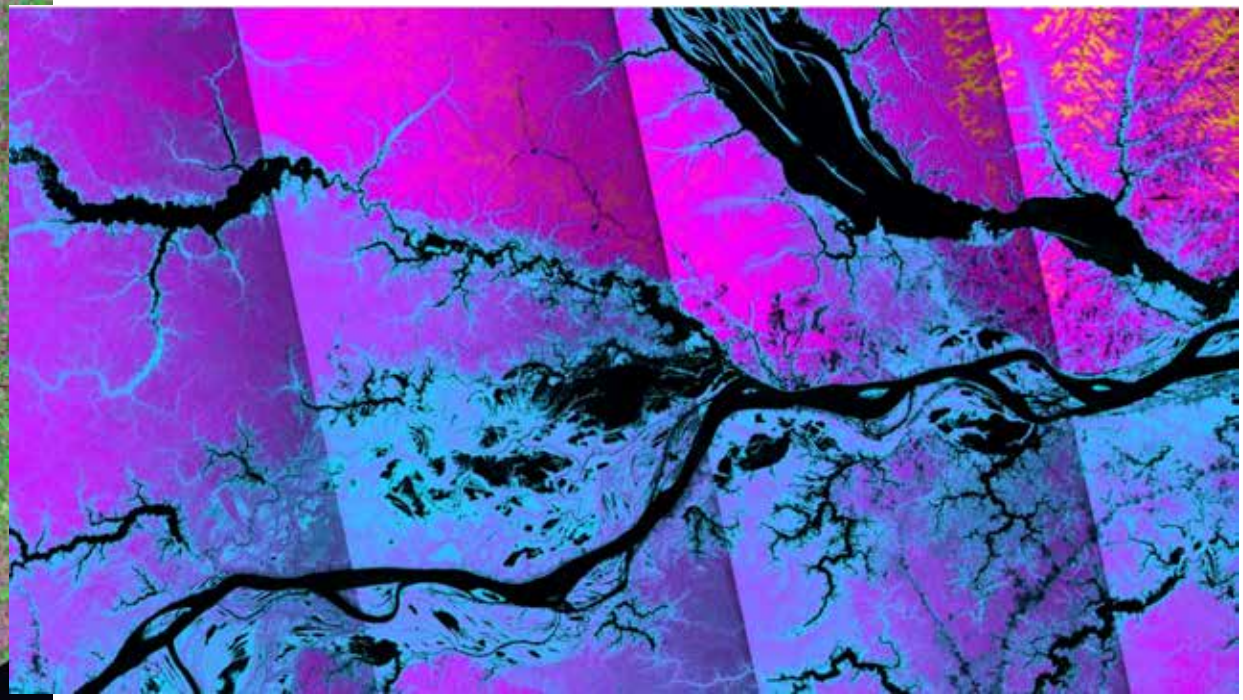
Example: Lake Erie

What about Remote Sensing?

Goal: measure variations in water storage and fluxes.

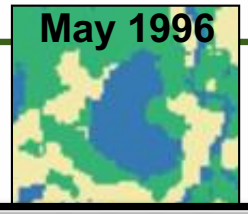
Data Source 2: Inundation extent from imagery

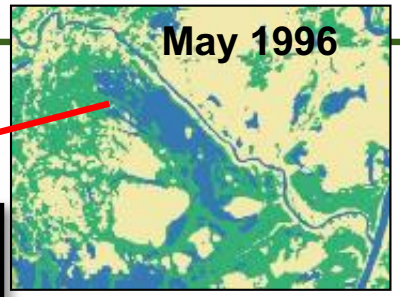


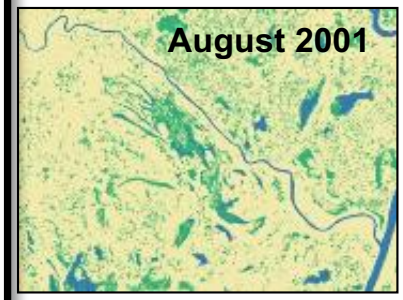


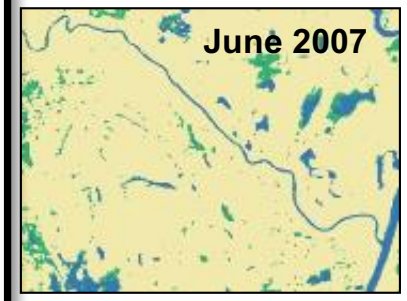
Radar (Radarsat, ALOS PALSAR)

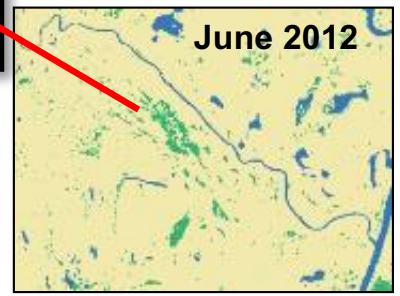
Remotely Sensed Water Conditions

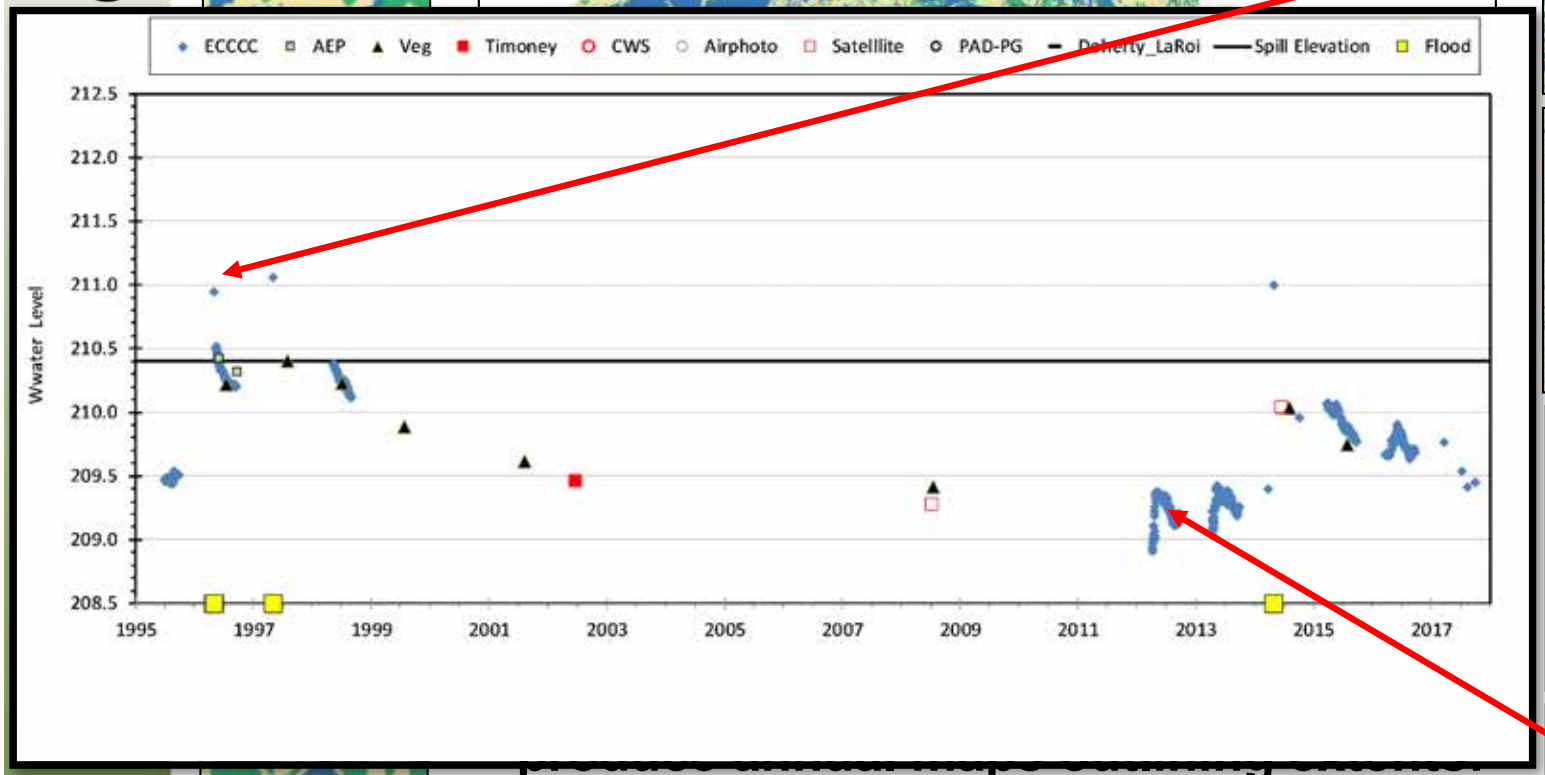


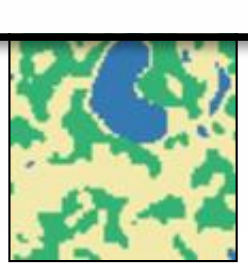












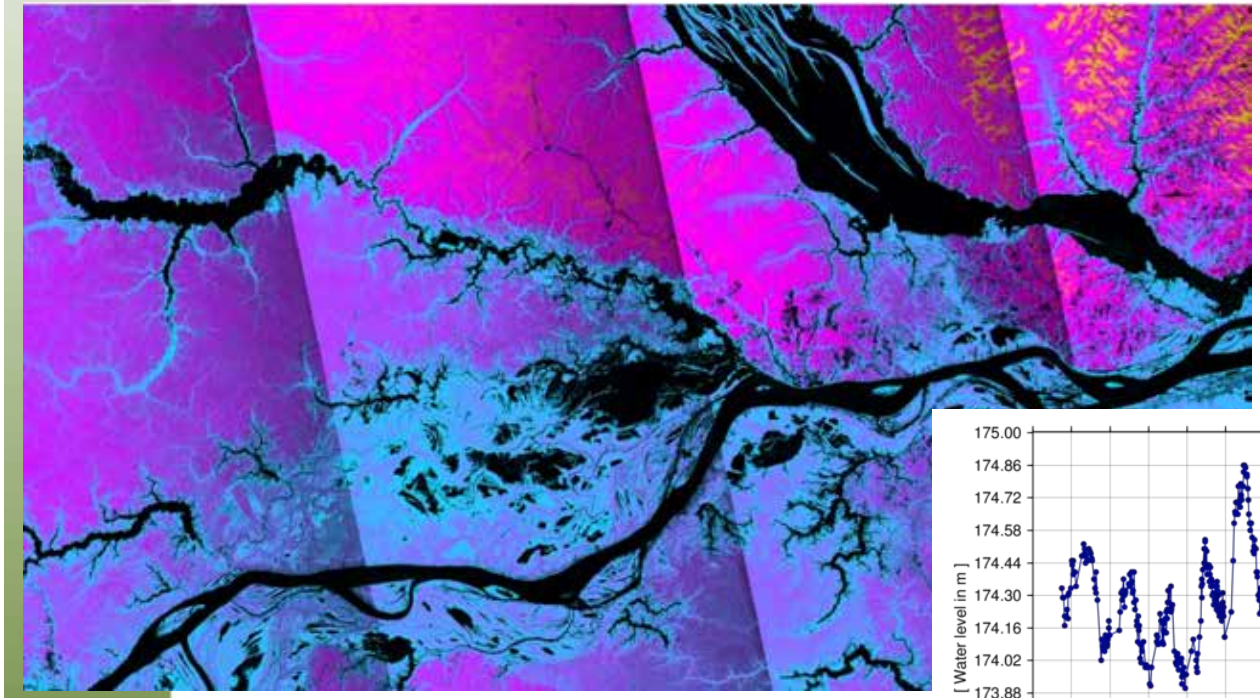
- Open water (Blue)
- Flooded vegetation (Green)
- Non flooded land (pale yellow)

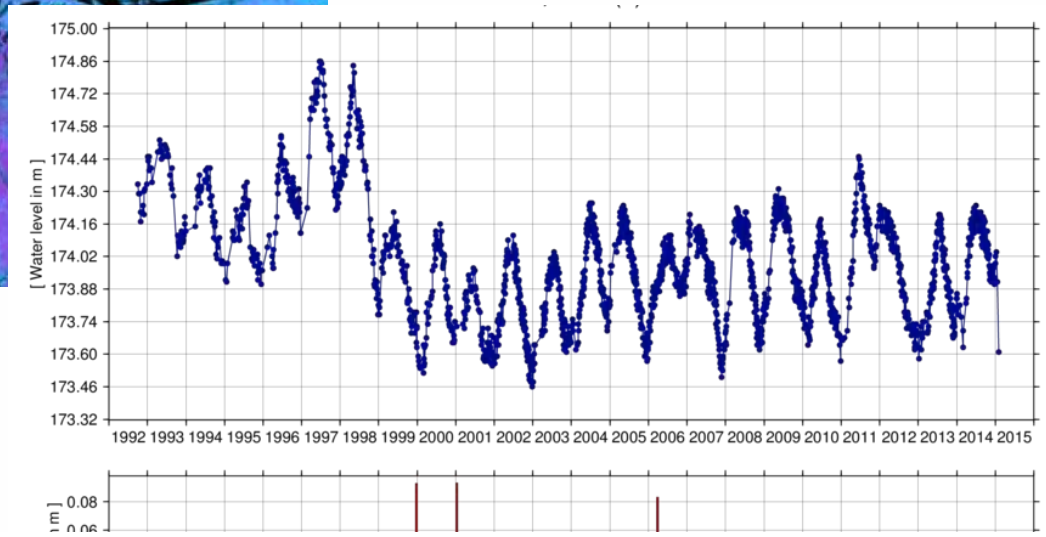
Toyra & Pietroniro (2005). Remote Sensing Environment

Egg Lake

What about Remote Sensing?

Problem: in order to measure changes in storage and fluxes, we need simultaneous, two dimensional information about inundation extent and water surface elevation

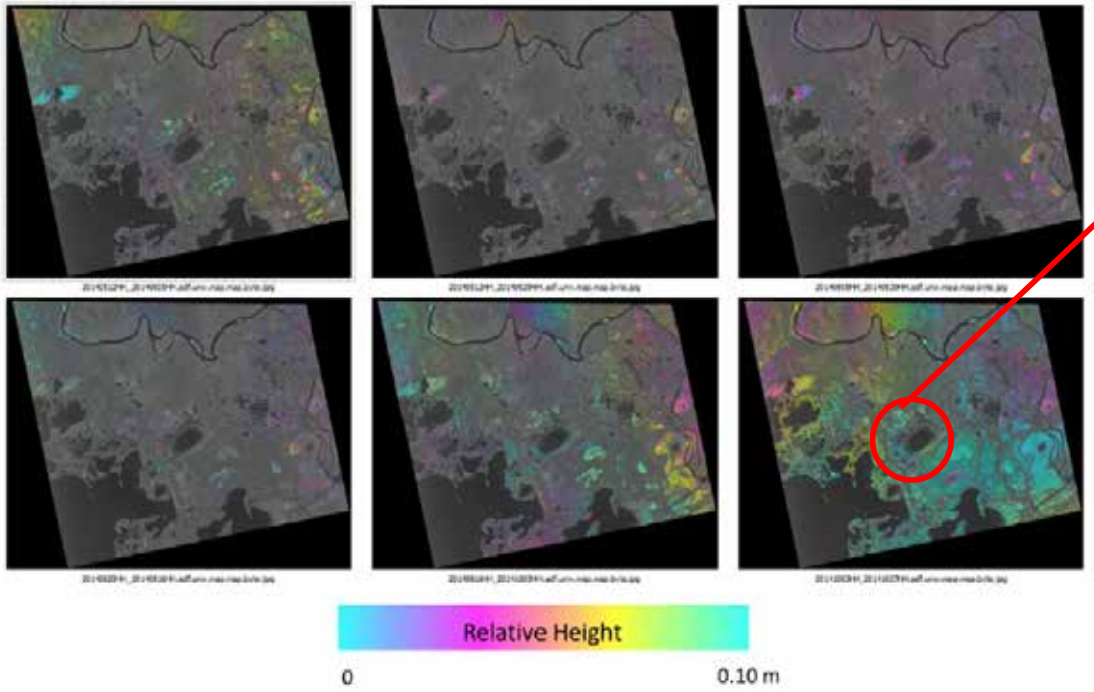




Emerging RS Science and Monitoring

- NRCan RadarSat 2 Derived Relative Water Level Change

  Brisco et al. 2015



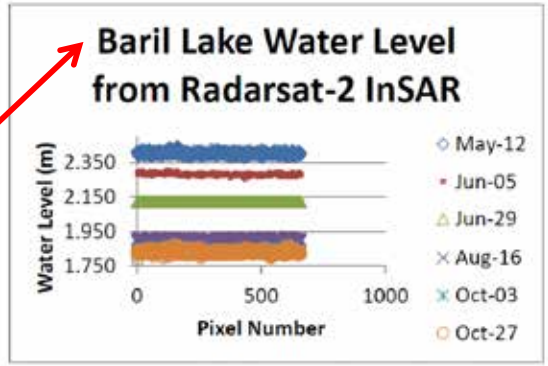
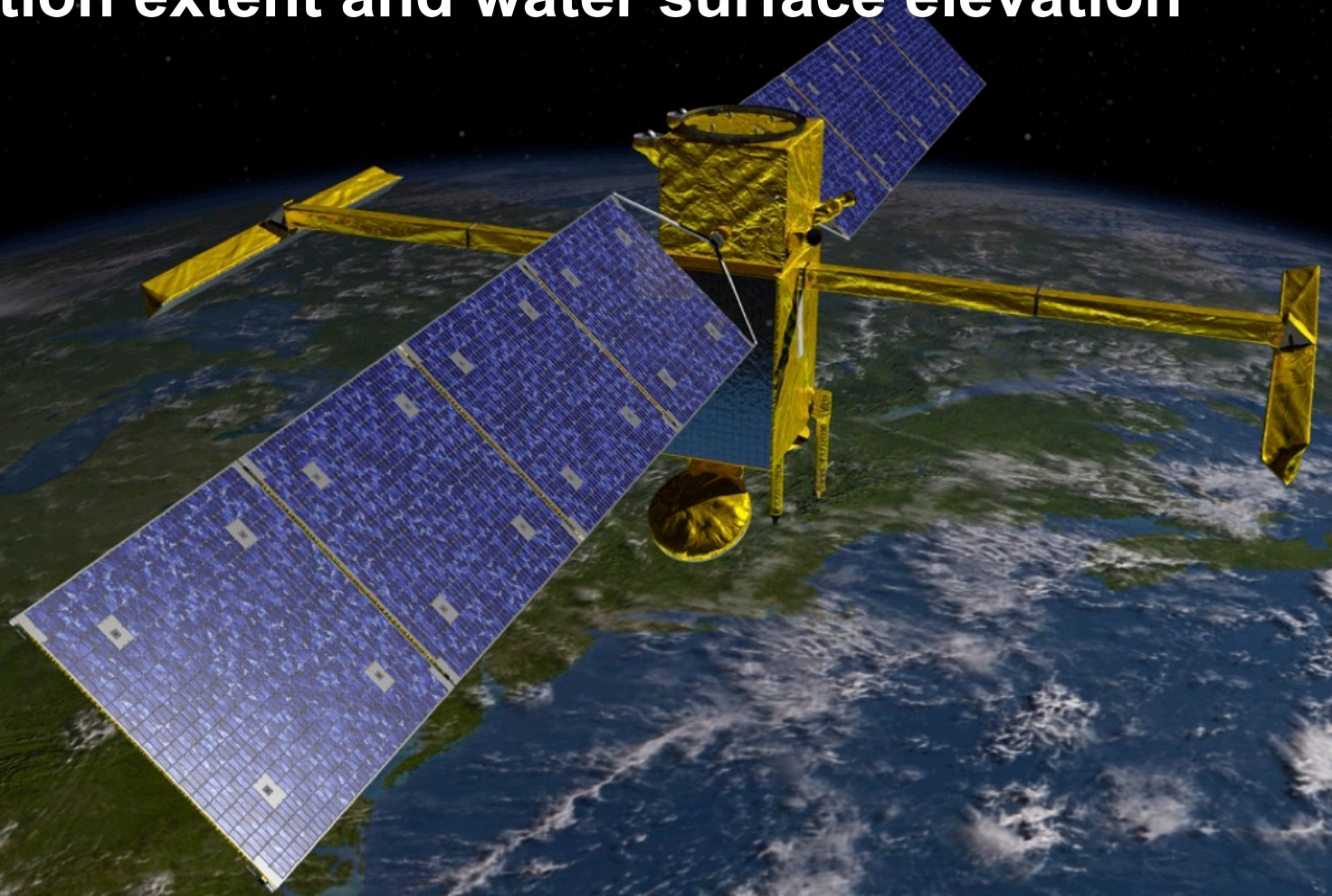


Figure 4.15. Absolute water level change product example for Baril Lake in 2014.

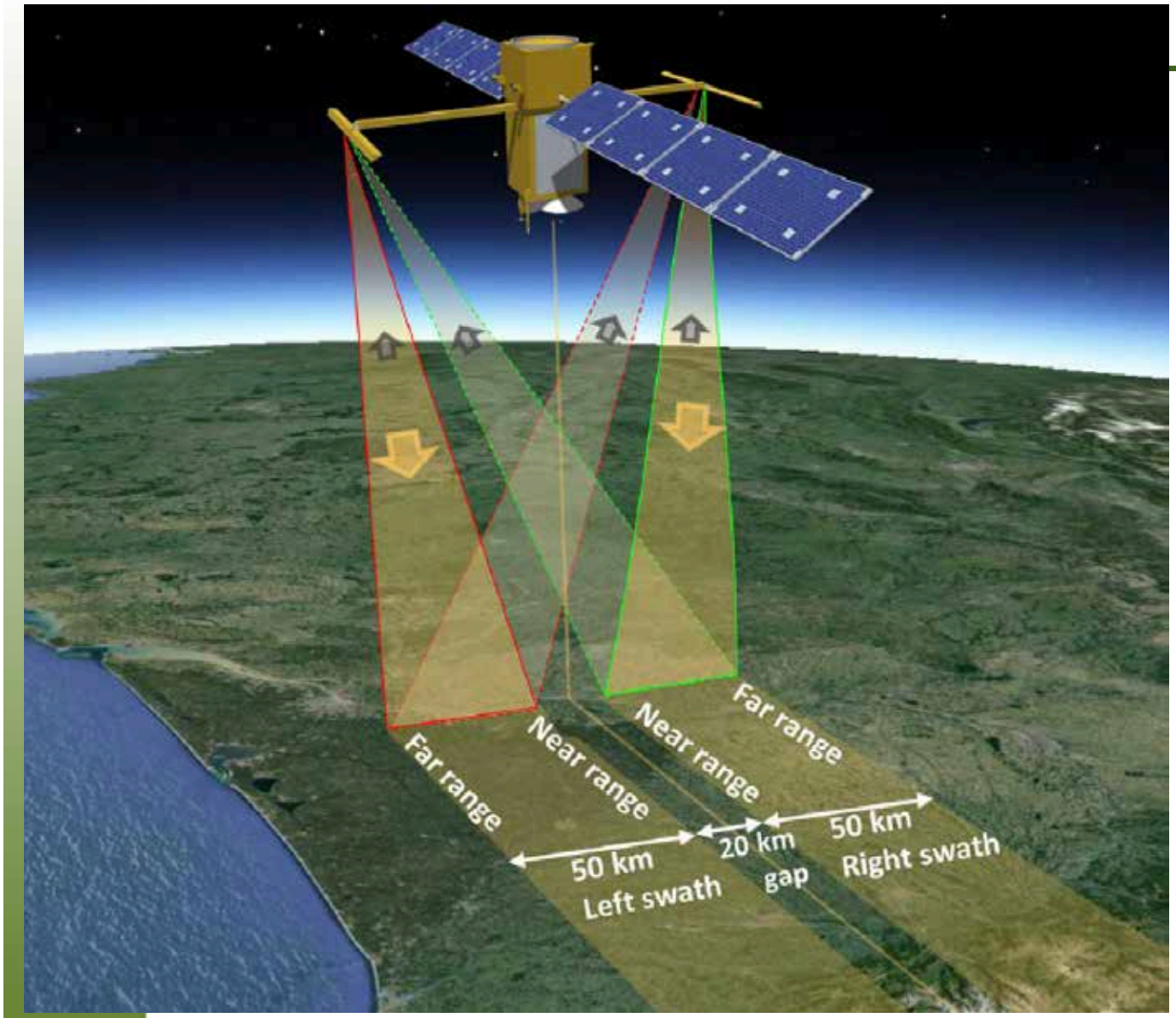
Figure 4.14. Relative water level change products from May to October 2014 for the PAD.

Problem: in order to measure changes in storage and fluxes, we need simultaneous, 2 –D information about inundation extent and water surface elevation



How SWOT can help ?

The Surface Water and Ocean Topography Mission



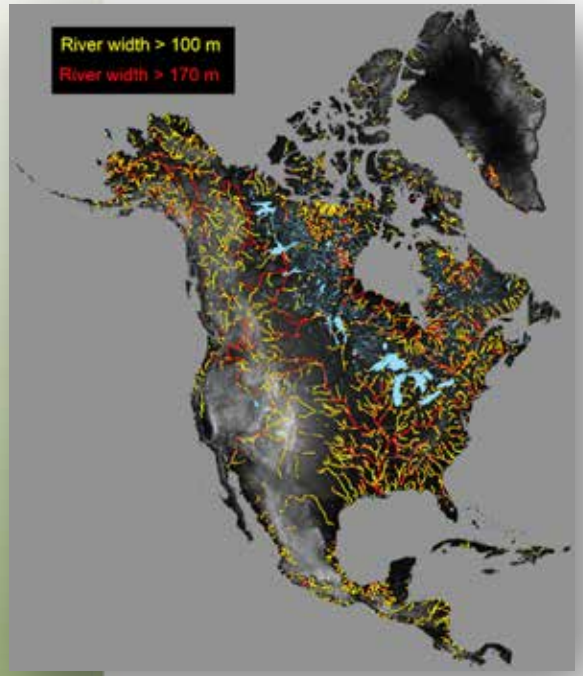
Biancamaria, Lettenmaier, and Pavelsky, *SoG*, 2016

Principal payload on SWOT is a Ka-band Radar Interferometer (KaRIn) operating at 35.75 GHz (8.6 mm) with **twin 50 km swaths** pointing 1-4.5° off nadir.

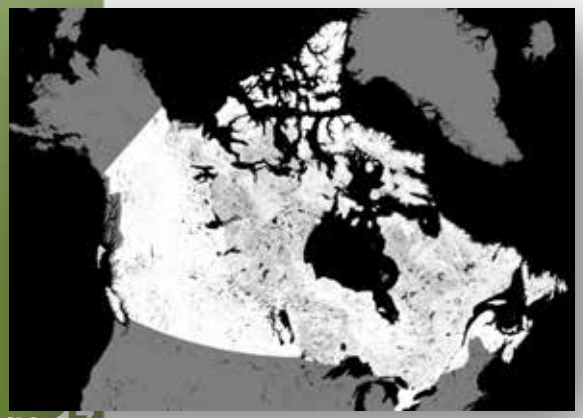
- 21-day repeat orbit at 890 km.
- **Simultaneously measures inundation extent and water surface elevation**

SWOT Measurement Capabilities for Rivers & Lakes

- **Canadian sites selected to test these capabilities**



From Allen and Pavelsky, GRL (2015)



- Inundated Area/River Width:
  - 15% error for 100 m wide rivers over 10 km reach.
- Water surface slope:
  - 17 mrad (2 cm/km) error for above specs.
- Water surface elevation:
  - 10 cm error for 1 km^2 area and 25 cm error for between (250 m^2) and 1 km^2.
- Lake Inundated Area:
  - 15% accuracy for larger than (250 m^2) (baseline)
  - 15% accuracy for larger than 1 km^2 (threshold)
- Lake Water Surface Height:
  - 10 cm accuracy for larger than 1 km^2 and 25 cm accuracy for between 1 km^2 and (250 m^2) (baseline)
  - 11 cm accuracy for larger than 1 km^2 (threshold)

Canadian SWOT Project

- Canadian SWOT-Hydrology team formed 2013
- Led by Environment & Climate Change Canada
  - Science Team focused on site-specific applications
- The Government of Canada has approved CSA to allocate ~17M$ for the SWOT-C project until 2024.
  - ~13M for the EIKs
  - ~4.5M to support ‘new’ Science
  - MOUs with ECCC (Hydrology) and DFO (Oceanography)
  - Research Grants to academia.

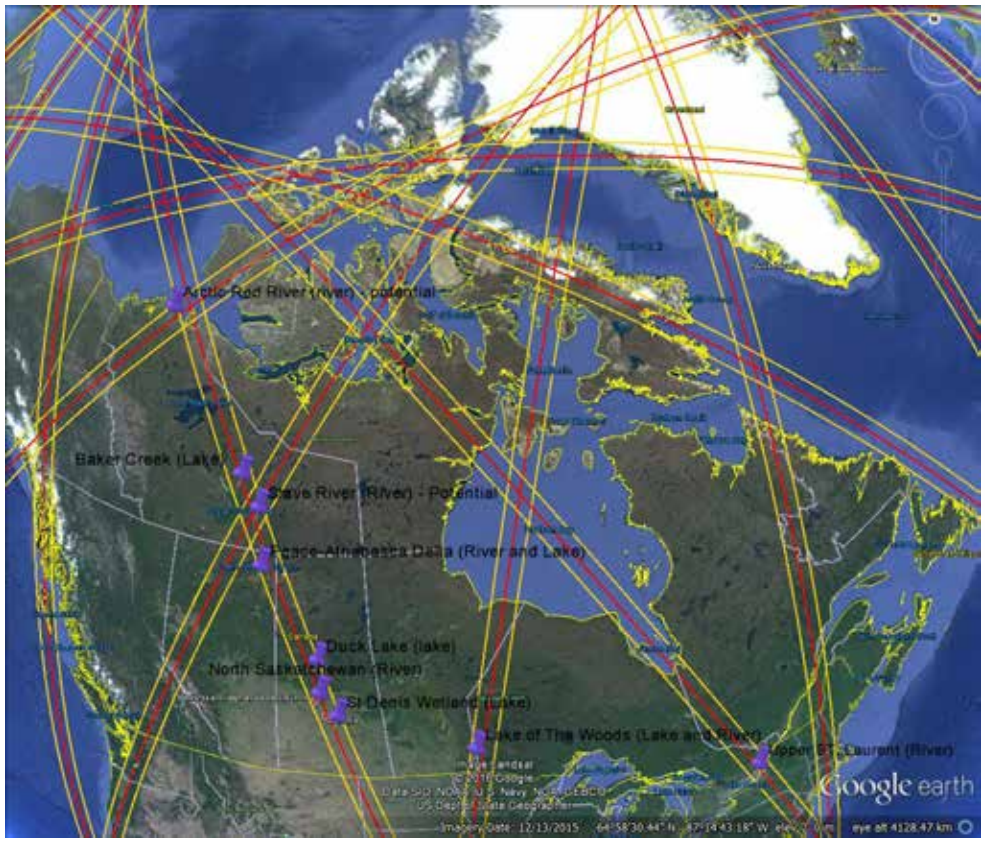
Phase II began April 2017 for 4 years

- Finalizing CSA funding for phase II
  - Significant direct and in-kind funding from WSC
- Partnering with Brown University (Smith) and UMass (Gleason) on Permafrost transect for science and Cal/Val
- Partnership with Tamln Pavelsky and Michael Durand on discharge algorithms and cal/val
- Seeking Partnership with USGS on cross-agency collaboration
- Participating on the cal/val team
- Outreach to WMO

Canada Cal/Val Sites (Rivers & Lakes)

River Sites

Yes: Upper St. Laurent, N. Saskatchewan R
Yes – Rainy-Namakan (sort of a river)
Maybe : Artic Red/Mackenzie, Slave River
.



Lake Sites

Possible : Duck Lake, SK; St. Denis, SK, Baker Lake, NWT, Rainy-Namaken chain of lakes

Science Sites

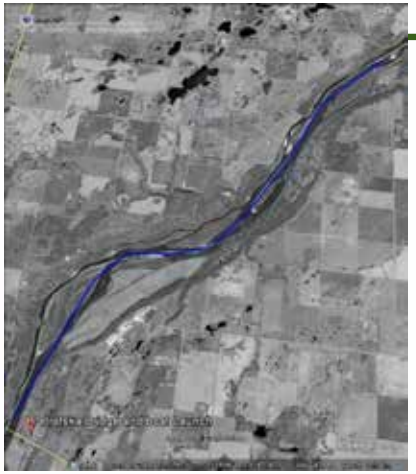
PAD: Existing network of lake gauges in summer, implementation of a full 2-D model and reasonable network of gauges.

Redberry Lake: Close link to WHERD WSTD Climate Change Program

Great Lakes: NEMO model operational and some interests in assimilation

St. Laurent: H2D2 operational 2D model - interest in assimilation

North Saskatchewan River



- On Sept. 12 2016 a field recon of a potential SWOT cal/val site along the North Saskatchewan River was completed.
  - Low slope over ~45k m reach
  - Width – between 200 and 300 m
  - Flow – can range from 200 CMS to 1200 CMS
  - No major tributary inflows & no controls
- Monitoring Plan
  - Between 10 to 20 pressure transducers operated during ice-off period (season April to October)
  - Lower-cost installation using screw-piles, mono pole, single transducer and GOES transmit for real-time water level. Solar Panel.
- Challenges and consideration
  - Bifurcations - Typically every 2 to 3 km
  - Ephemeral (can be dry or may disappear depending on water level)
- Accuracy requirements
  - Very low slope river
  - Location of transducers

Saint-Lawrence River

Existing Products:

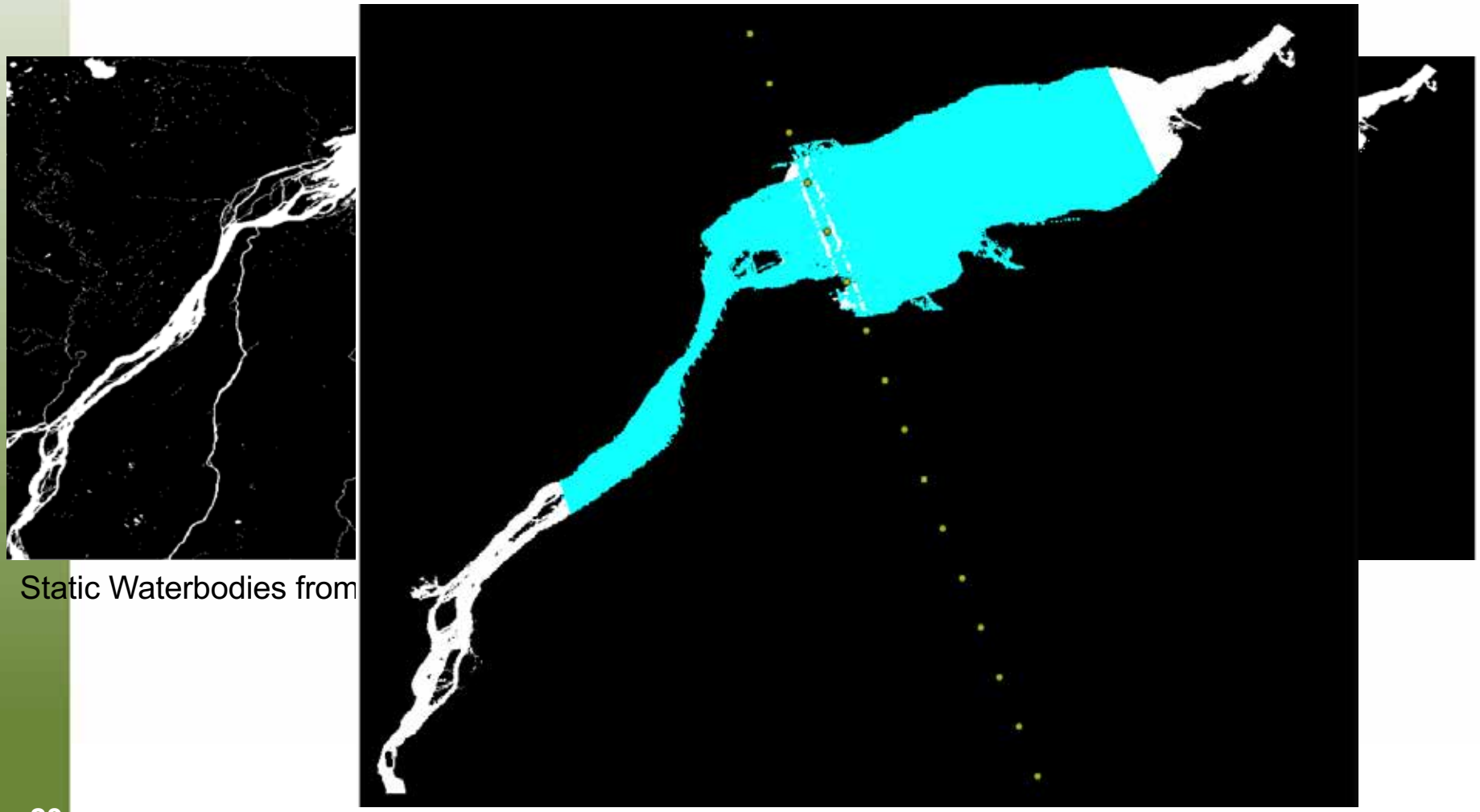
- LiDAR DEM
- Bathymetry and Manning N estimates
- Permanent hydrometric stations
- Operational 2D Hydrodynamic model
- Hydrological model for total tributary inflow to the whole basin

- Daily Water Level estimates for the entire river – Kingston to Quebec City available operationally
- Water level (and flow gauges where flow is estimated) are available in near real time (relative elevation only)

- To do:
  - SWOT simulations will be programmed to coincide with orbit and provided on web.
  - Gap in H2D2 model for small reach near Cornwall
  - Survey water level to NAGeoid2013 standard

SWOT Simulations

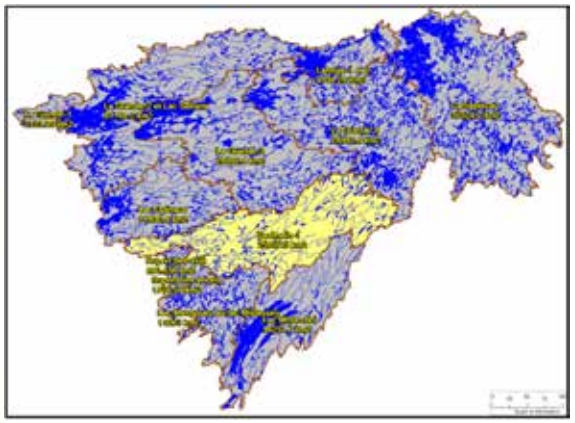
May 2017 flood



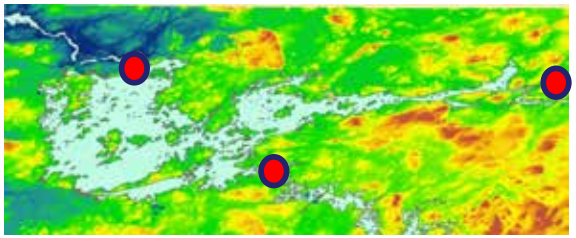
Static Waterbodies from

Eastmain Reservoir

- Evaluate the potential of SWOT to :
  - improve water surface elevation knowledge
  - reduce noise of net inflow in the water balance equation

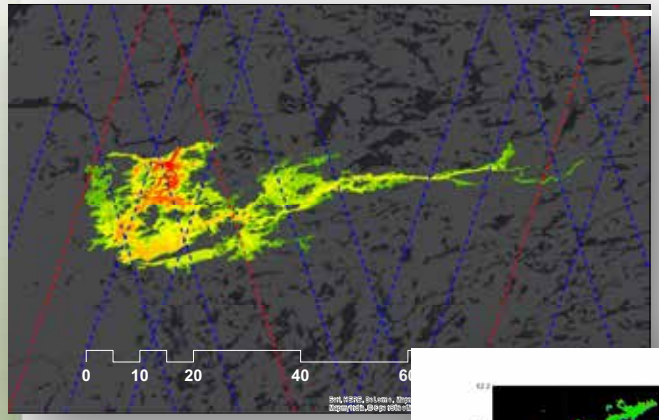


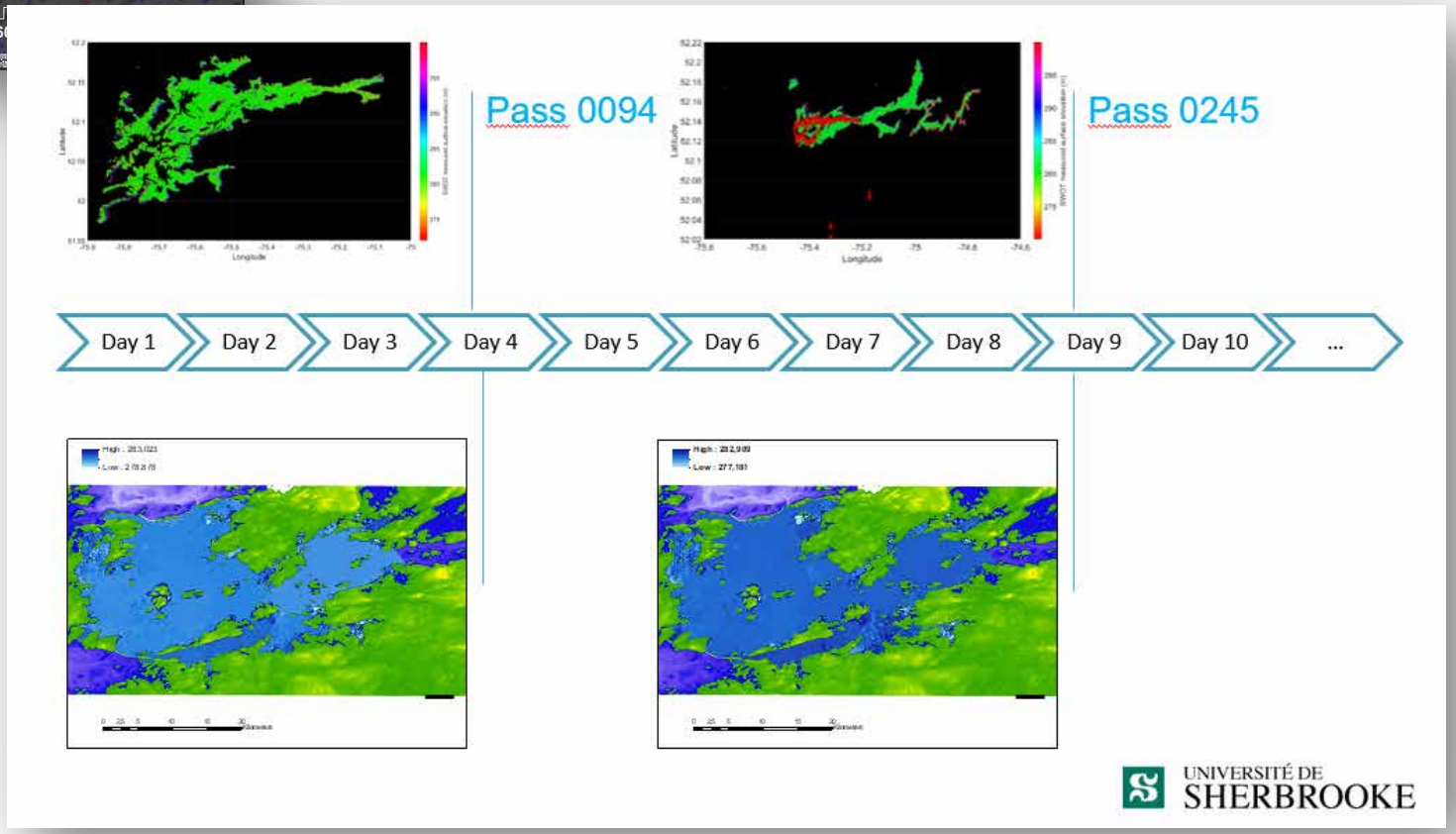
- Eastmain-1 watershed
  - Watershed area : 25 850 km^2
- Eastmain-1 reservoir :
  - Area : 603 km^2 (2,3 % of watershed)
  - Storage : 4210 hm^3



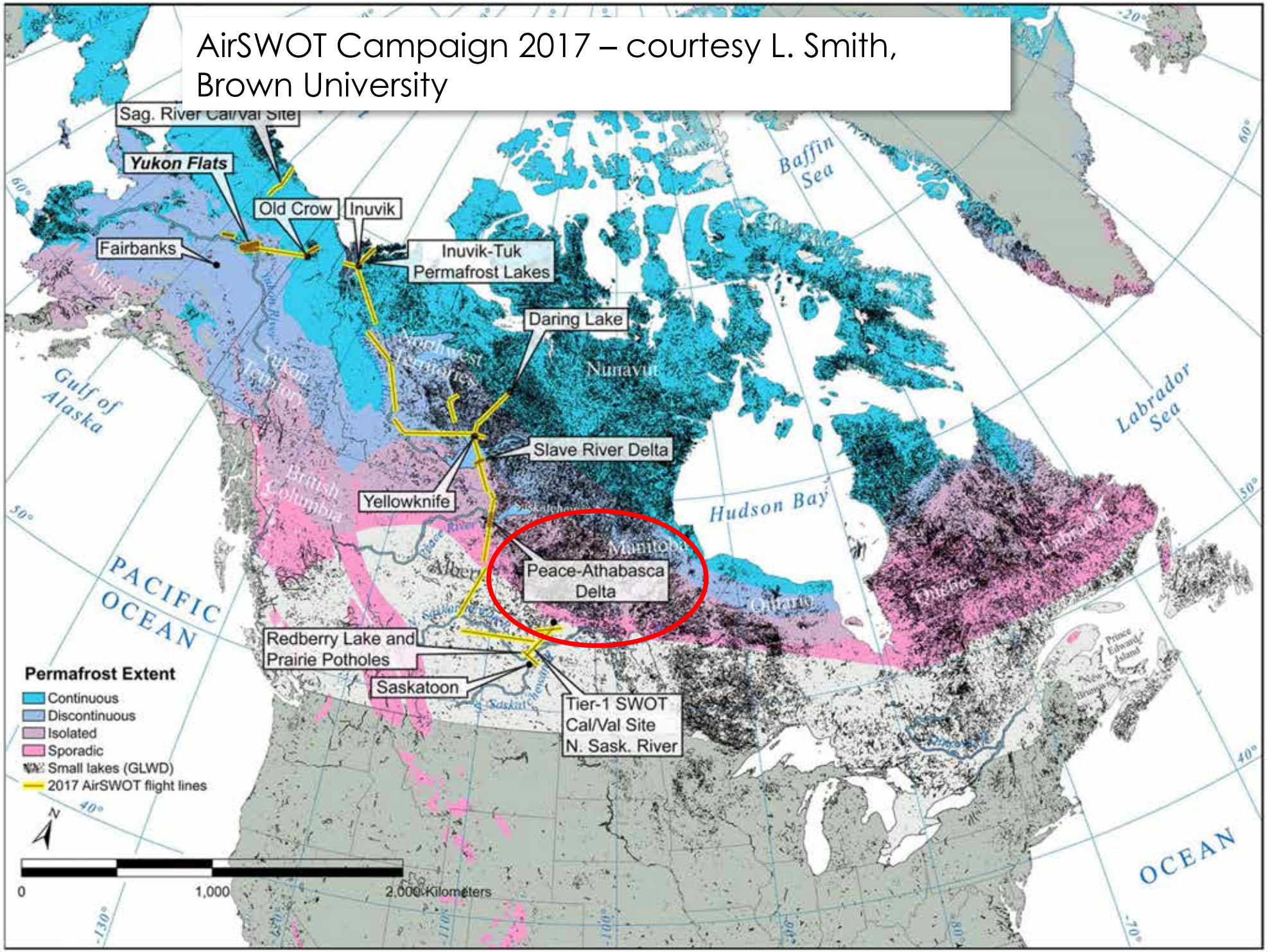
- Discharge measurments :
  - 85-90 % is gauged
  - Available 2005 to 2017
- 2- Dimension hydraulic model

Eastmain Reservoir – SWOT Simulations

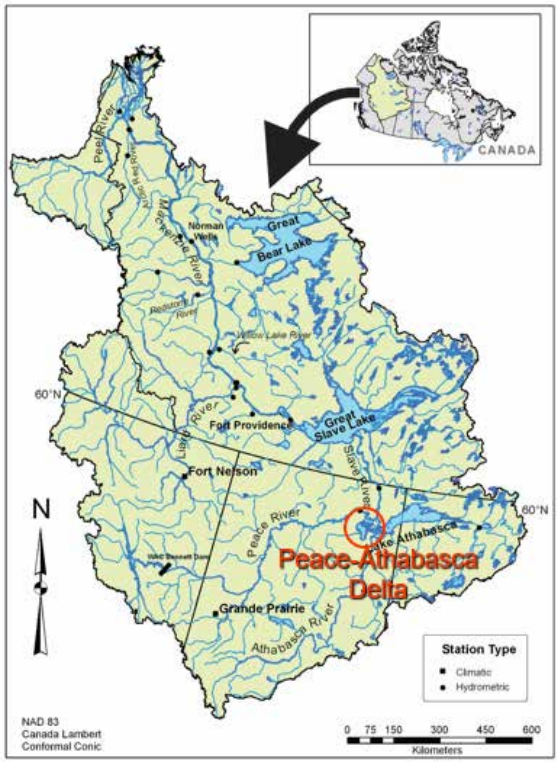




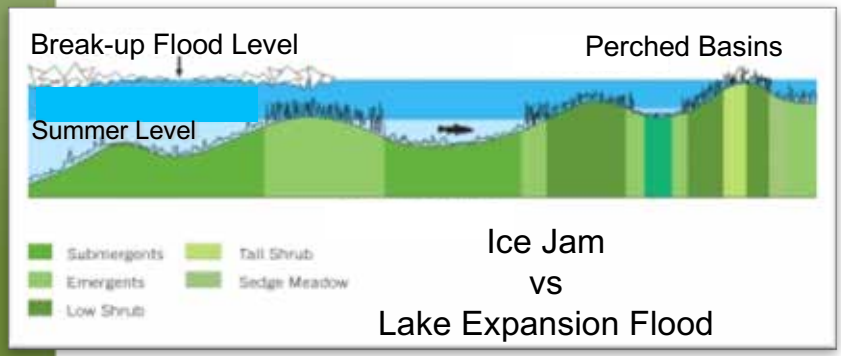
AirSWOT Campaign 2017 – courtesy L. Smith, Brown University



Peace-Athabasca Delta



- One of the Largest Inland Freshwater Deltas in the World
- Perched Basins Hydro-Ecologically Significant

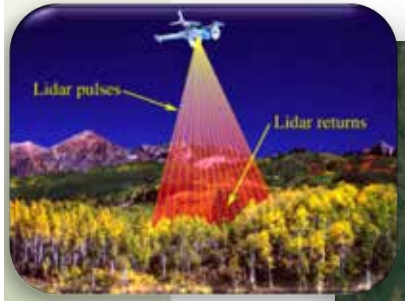


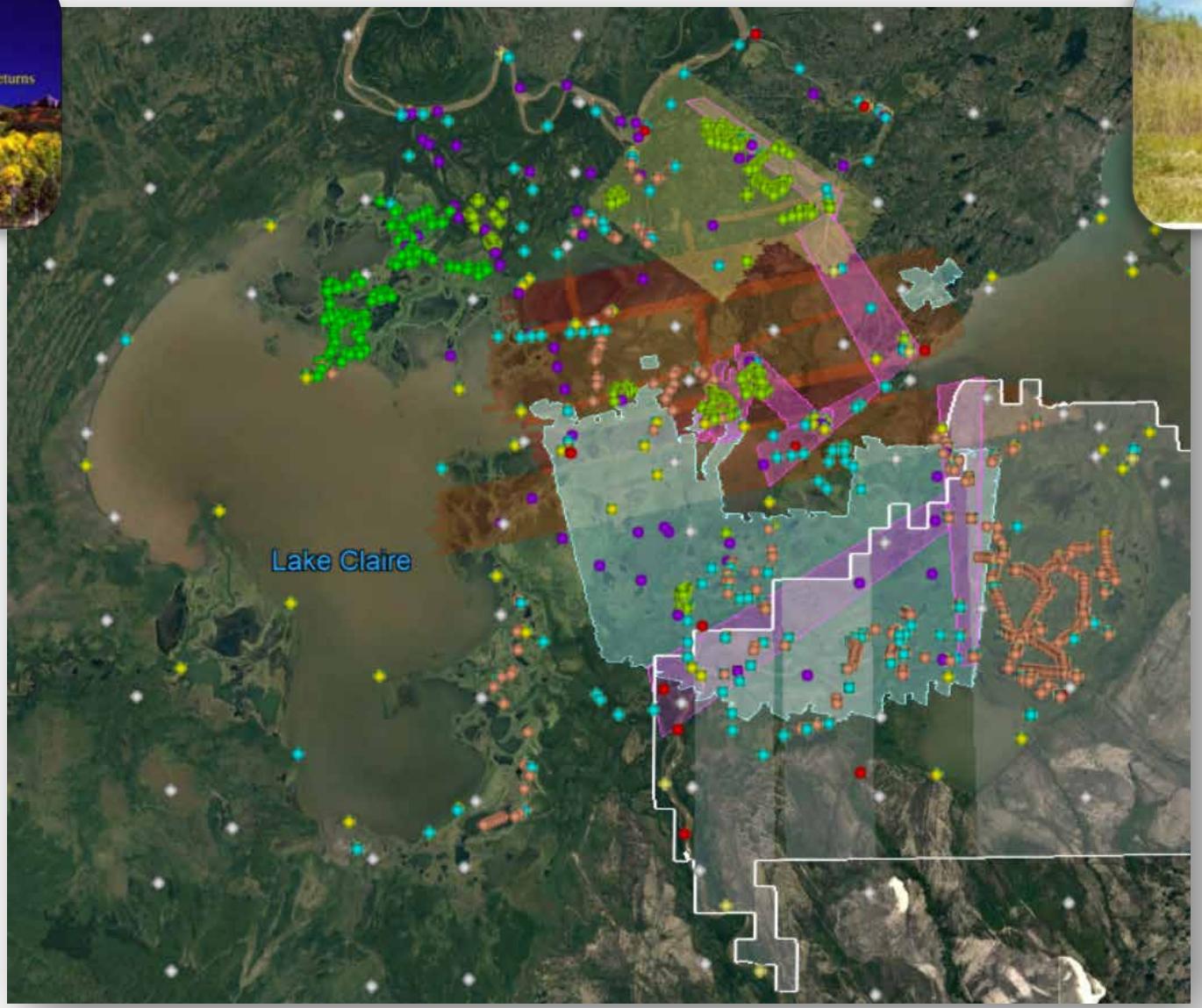
Ice Jam
vs
Lake Expansion Flood

Emerging Science and Monitoring

- Building on previous and parallel projects (OS, CCA) + Parks Canada partnership has enabled the Canadian Space Agency funded SWOT project to accomplish:
- Expanded high resolution Digital Elevation Model (DEM) of the PAD
  - Bathymetric surveys of large lakes and rivers
- Development of 2D hydraulic model for LA-PAD
  - Update existing model to provide capability to address knowledge gaps
  - Velocity and discharge measurements via ADCP
  - University of Sherbrooke in collaboration with ECCC
- Provide a set of high resolution wetlands, lakes, and channel sites for 2017 AirSWOT project collaborations
  - Calibration/Validation sites

LiDAR & Ground Surveys





2017 AirSWOT - calibration/validation and science support instrument for the NASA/CNES/CSA SWOT mission.

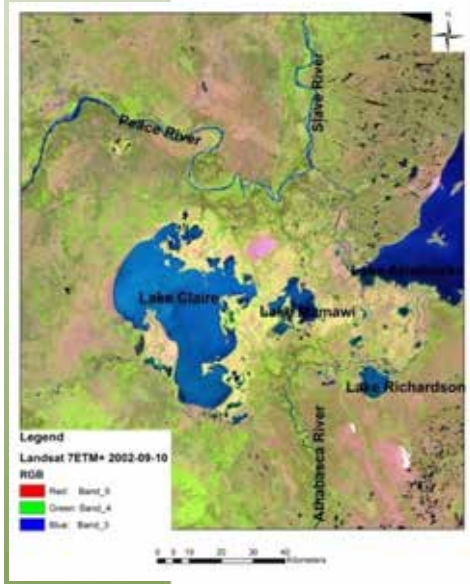
PI Larry Smith
Brown Univiversity

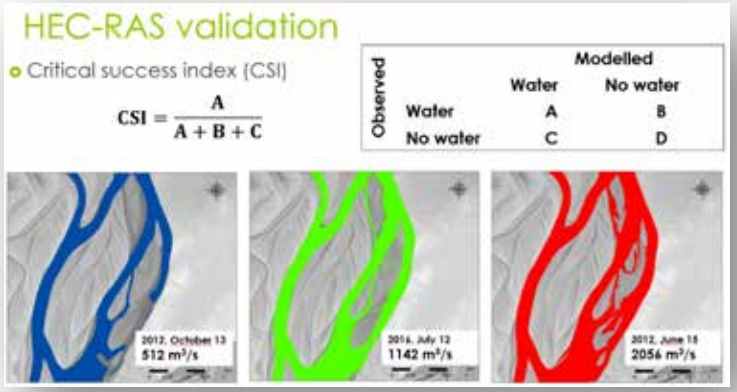
Next step – compare AirSWOT to ground based water elevations

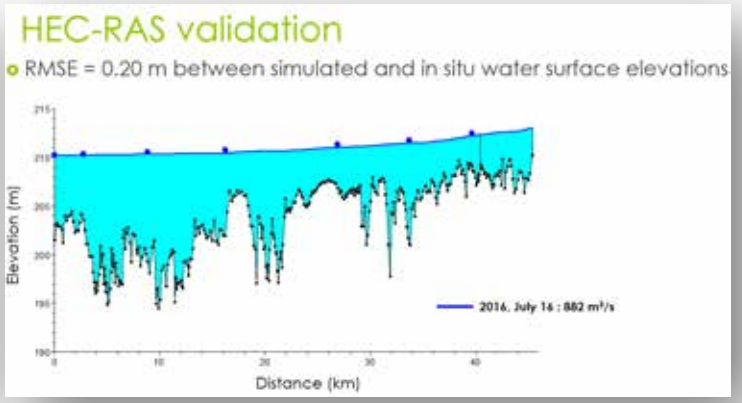
Lake Claire

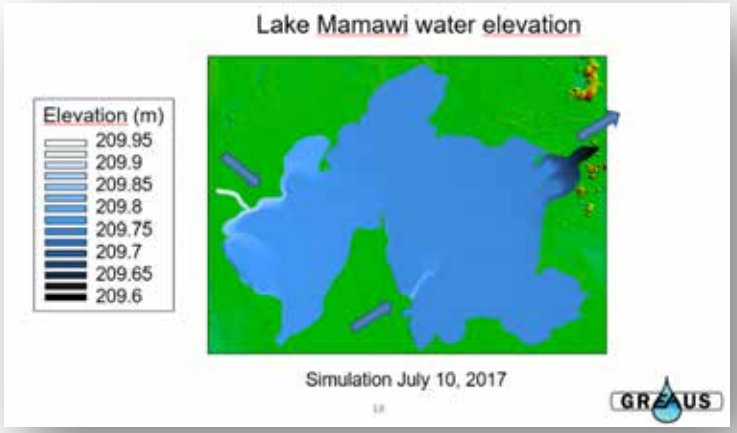
PAD 2-D Hydrodynamic Model & SWOT Simulations

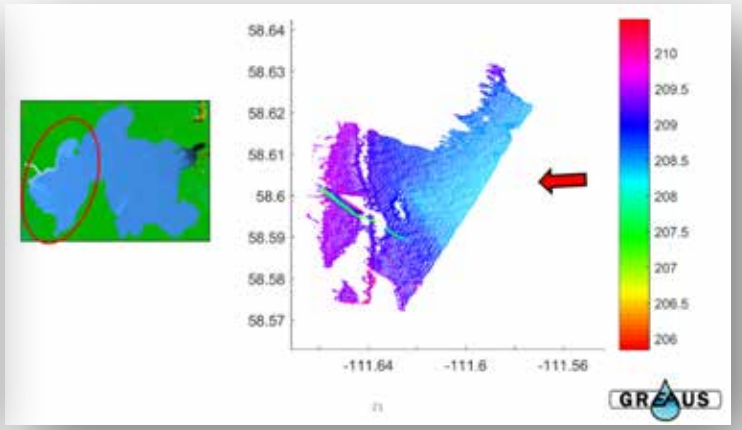
Lower Athabasca River Reach – Calibrating hydraulic model









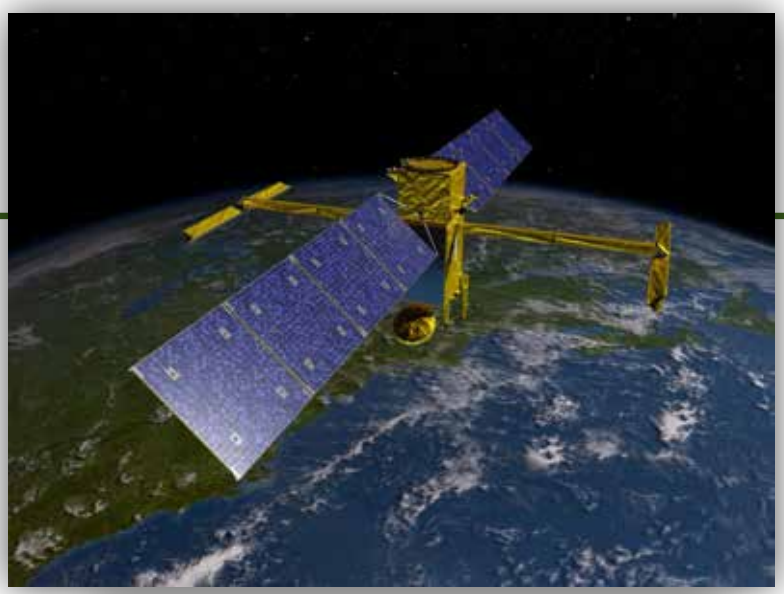


Mamawi Lake – Assess capability closing water balance

Summary

- Canada initiated field & simulation work at Cal/Val sites across Canada
- Hydraulic Models have been and/or in development for several sites
- SWOT simulation work initiated at several sites
- Ready to start work with 2017 AirSWOT & Gearing up for Launch
- Expanding collaborations at Canadian sites eg US and CDN Universities
- SWOT is transformative technology, especially for Canada
- Implications for SWOT are multiple – ungauged rivers/lakes, calibration/validation of model, enable pan-Canadian assessments of water bodies, enhance novel aquatic health monitoring frameworks eg Oil Sands region
- **Special Thanks to CSA for assisting & supporting the work**

Thank You



I see it.
Looks like a lot more fieldwork to be done across Canada.