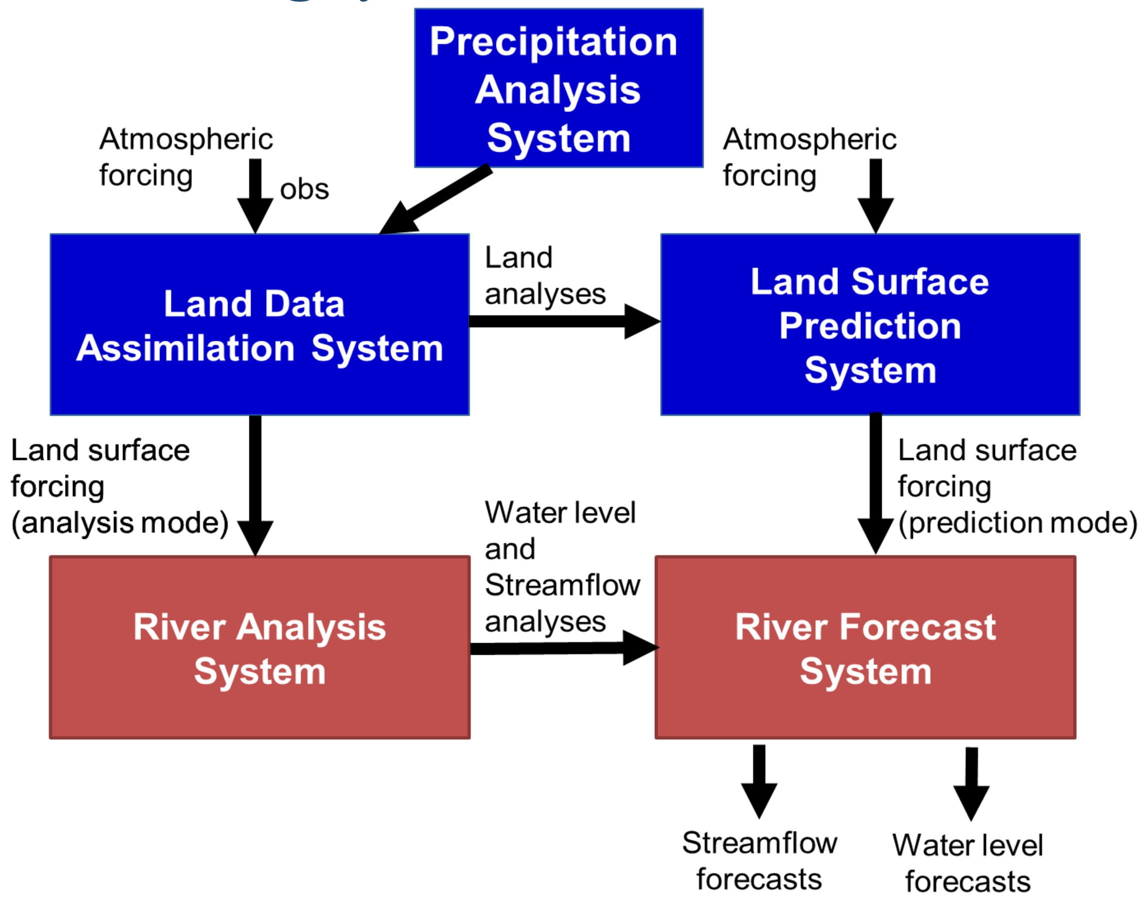
Preparing for SWOT data assimilation in a coupled atmosphere-surface-hydrology-hydrodynamics prediction system

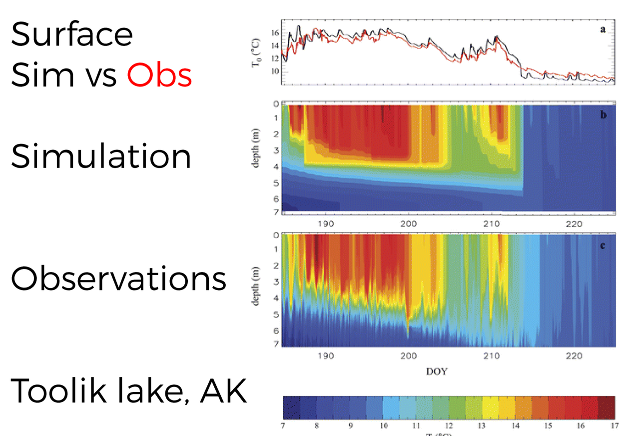
V. Fortin, M. Dimitrijevic, P. Matte, C. Garnaud, É. Gaborit, M. Mackay, Meteorological Research Division
N. Gauthier, D. Durnford, Canadian Centre for Meteorological and Environmental Prediction
Environment and Climate Change Canada

Schematics of the Canadian National Surface and River Prediction System (NSRPS) based on the GEM-Hydro modelling system

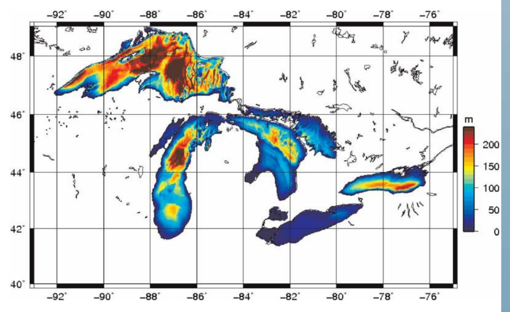


Representation of surface waters

CSLM
1D model for small lakes

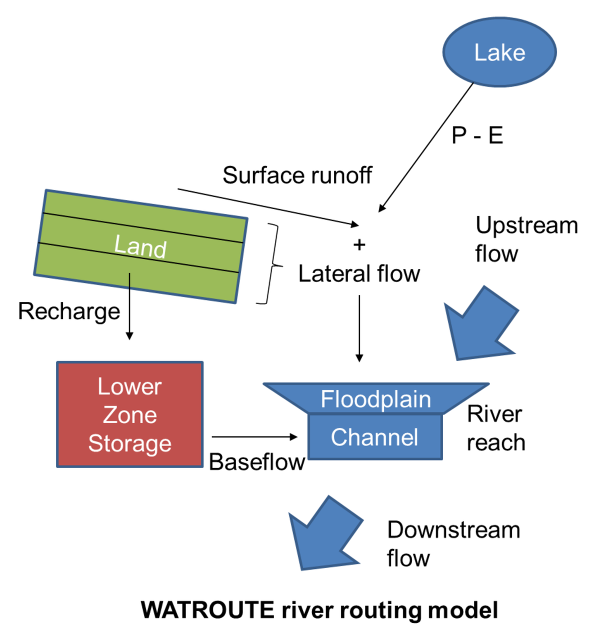


NEMO
3D model for large lakes

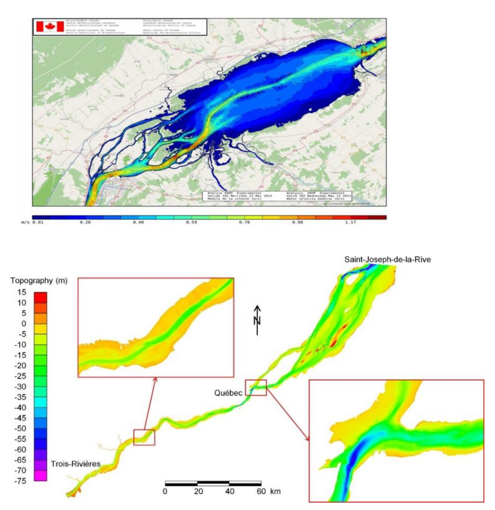


Great Lakes NEMO model (2km resolution)

WATROUTE
1D model for small rivers



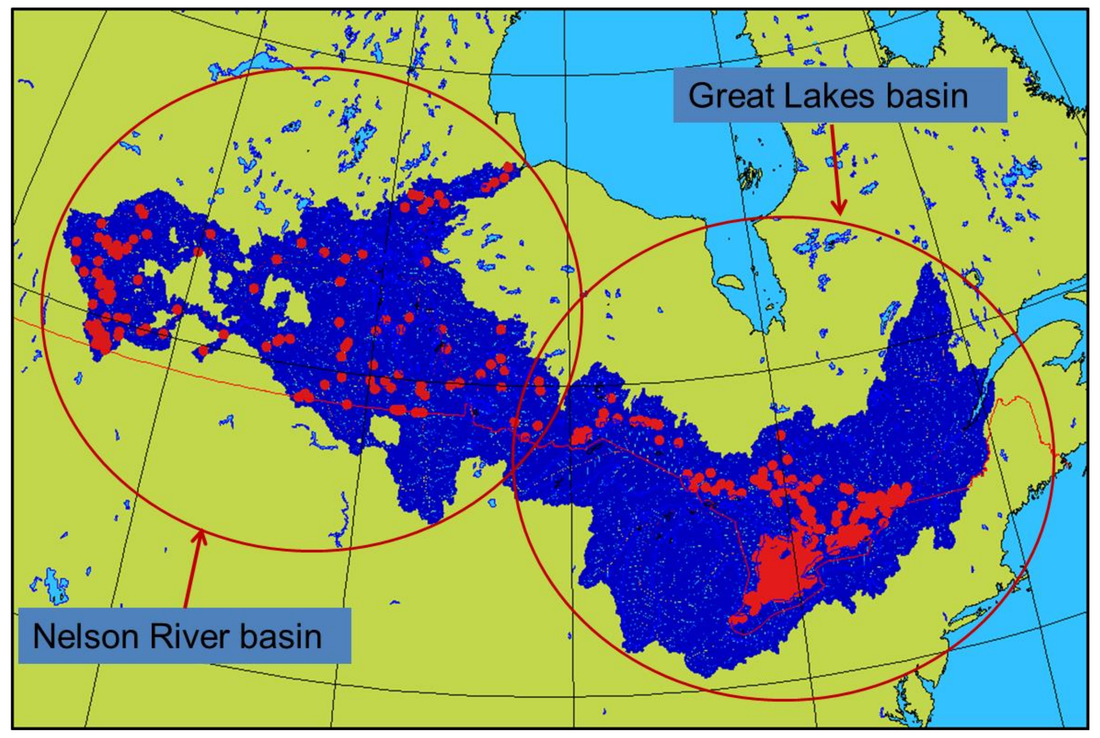
H2D2
2D model for large rivers



Finite-element model of the St. Lawrence River

Environment and Climate Change Canada

Watersheds modelled with NSRPS

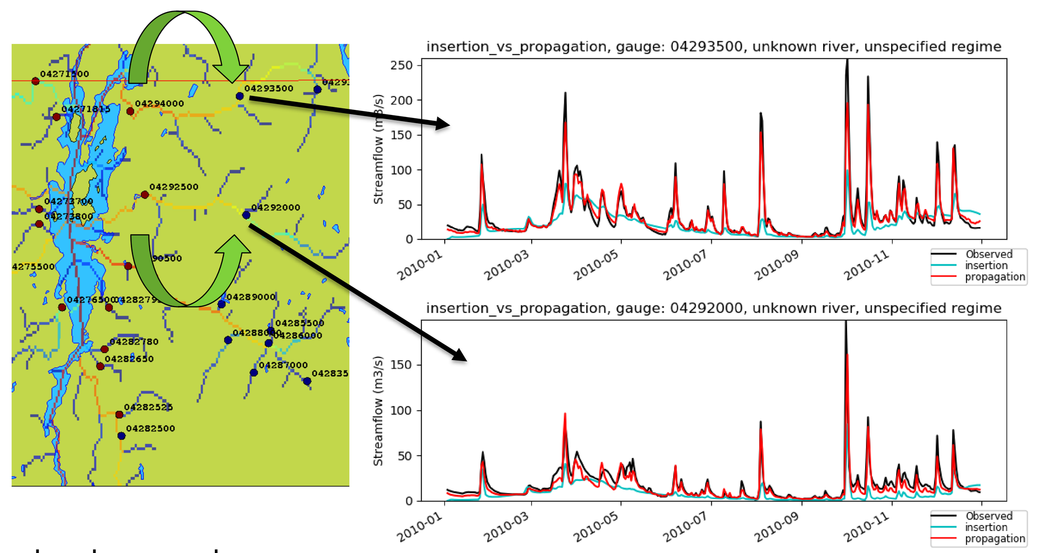


Red dots: Assimilated Canadian streamflow gauges

Assimilation of in-situ flow data in WATROUTE

1. Operational:
   - Direct insertion of observed flows
2. Currently being tested:
   - **Upstream propagation** in the channel and floodplain of the streamflow observation using an area-ratio method
   - **Correction of the Lower zone storage** compartment and surface runoff in order to maintain the balance between the fluxes going into the river from the land and the flow of water in the river
3. Other methods that we would like to test in the future:
   - Local Ensemble Transform Kalman Filter
   - Ensemble-Variational method

Illustration of upstream propagation for two tributaries of Lake Champlain



Black: observed
Blue: simulated with direct insertion of downstream gauge
Red: simulated with upstream propagation of downstream gauge

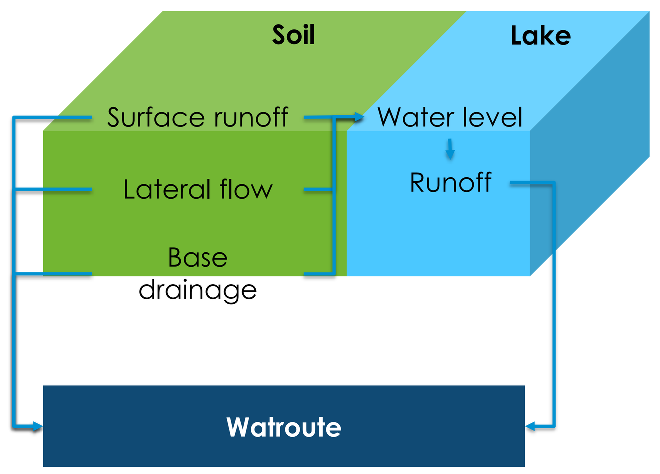
General strategy for assimilation of SWOT altimetry data in NSRPS

Challenges for rivers:
- Many ungauged rivers will not be resolved by SWOT
- Need to map SWOT levels into WATROUTE flows
- SWOT revisit frequency is an issue given the rate at which streamflow changes
- Data denial experiments can still be performed with existing data assimilation for flow (limiting observation frequency to that of SWOT)

Opportunities for lakes:
- Vast number of ungauged Canadian lakes will be resolved by SWOT
- Assimilation of SWOT data in CSLM and NEMO is straightforward
- Should positively impact river flow if the lakes are properly connected to the river network
- Artificial reservoir levels can also be assimilated
- Water levels of lakes and reservoir typically do not change as fast as streamflow
  - SWOT revisit frequency is adequate

Opportunities for estuaries:
- Water level and flow in estuaries depends on complex tides that cannot be fully characterized by the limited number of tide gauges available
- SWOT offers the opportunity to better characterize tides and provide improved downstream boundary information to H2D2 hydrodynamic model
- St. Lawrence River estuary is under SWOT cal/val orbit

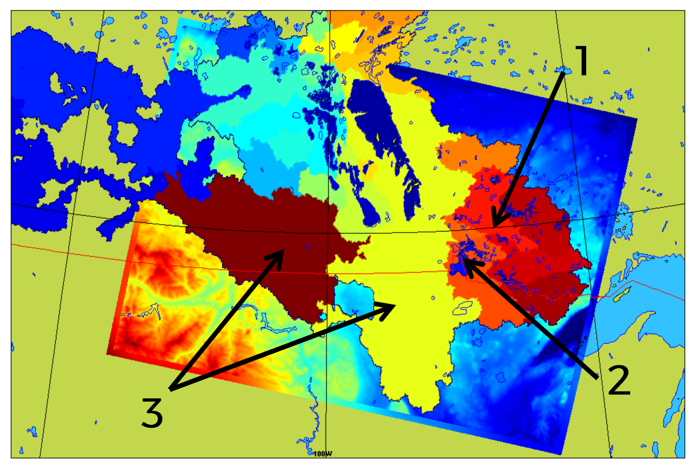
Preparing for assimilation of lake levels in Canadian Small Lake Model



Water exchanges in GEM-Hydro: part of the runoff/lateral-flow/drainage from the land model is diverted through the lake model before the water goes to the routing model

- Implementation of 1D lake model (CSLM) in GEM-Hydro: (water exchanges within GEM-Hydro)
- Implementation of CSLM in the Canadian Land Data Assimilation System (CaLDAS) and preparation for SWOT observed lake water levels assimilation through the use of SWOT simulated data

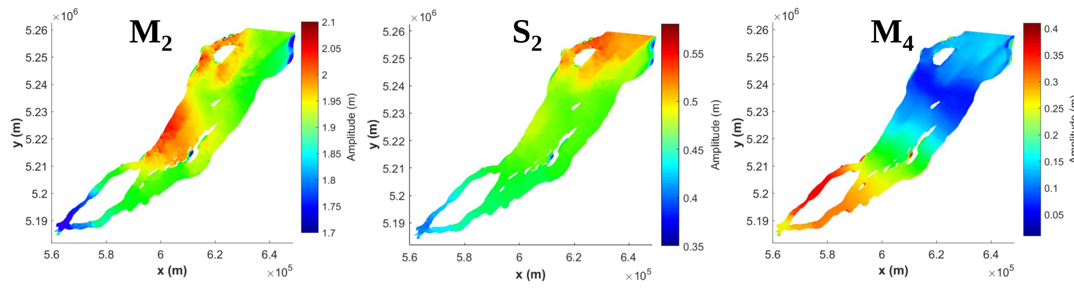
The domain for evaluation includes:
1. ELA: large region of instrumented lake
2. Lake of the Woods (in the 1-day repeat orbit)
3. Red and Souris rivers watershed



Preparing for estimation of estuarine tides from SWOT

Estuaries are characterized by:
- Multi-scale signals (river flow, tides, storm surges)
- Large range of variability within a finite geographical region

The St. Lawrence Estuary:
- Macro-tidal (tidal range <7m)
- Increasing influence of river discharge upstream
- 2D variability in tides
  - e.g. M_2, S_2, M_4 tidal constituent amplitudes:

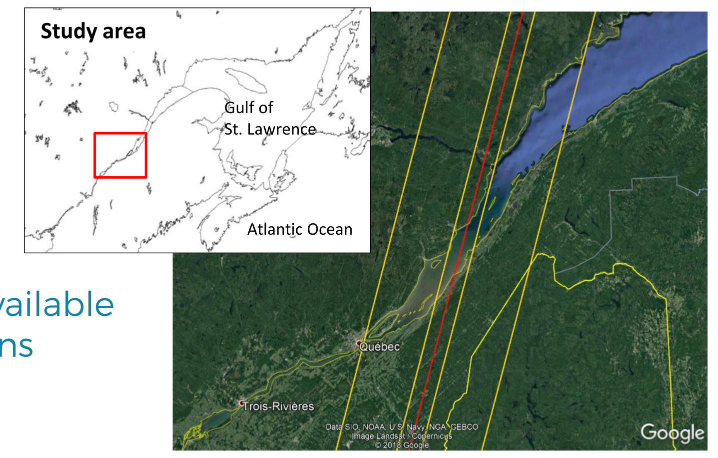


- Will SWOT capture this variability?
  - New methods are being developed using a combination of tide gauges and simulated SWOT data, with promising results

SWOT Cal/Val activities in the St. Lawrence Estuary

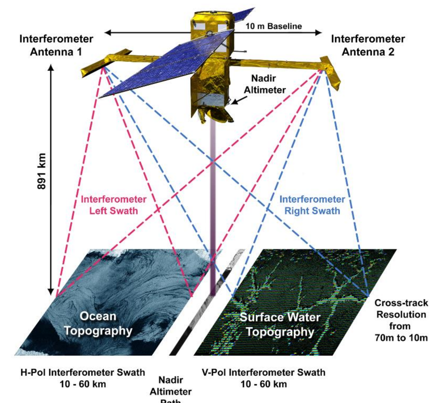
The St. Lawrence Estuary is under the SWOT cal/val orbit

- Tier 1 site for SWOT
- No other estuarine cal/val site of this size
- Very energetic and dynamically complex (e.g. internal tides)
- Operational models available
- Plurennial field missions



Objectives:
- Pre-launch phase
  - Test instrumentation and monitoring strategies
  - Characterize the 2D variability in water levels and currents by boat and remotely-sensed (e.g. LiDAR, HF radar)
  - Improve numerical models
  - Test algorithms for data assimilation
- Post-launch phase
  - Calibrate SWOT with updated models and field data
  - Assimilate SWOT data in NSRPS

	Calibration/Validation (fast-sampling) orbit	Science orbit
Phase duration	3 months	3 years
Repeat cycle duration	0.99349 days	20.86455 days (average revisit time of 11 days)
Number of orbits per cycle	14	292



Conceptual illustration of the SWOT mission measurement concept.
Over land, it will resolve 100 m wide rivers and lakes of 250x250 m in size, with a water level accuracy of 10 cm (over 1 km²) and a slope accuracy of 1.7 cm/km.

Source: https://swot.jpl.nasa.gov/