Environnement et Changement climatique Canada
Environment and Climate Change Canada

Canada

CHAMP:
Coupled Hydrologic, Hydrodynamic, and Atmospheric Modelling Project

Status update,
WMO Flood Forecasting Initiative Advisory Group
December 6, 2017

Vincent Fortin and Alain Pietroniro
Environment and Climate Change Canada

Drew Gronewold and Deborah Lee
NOAA Great Lakes Environmental Research Laboratory

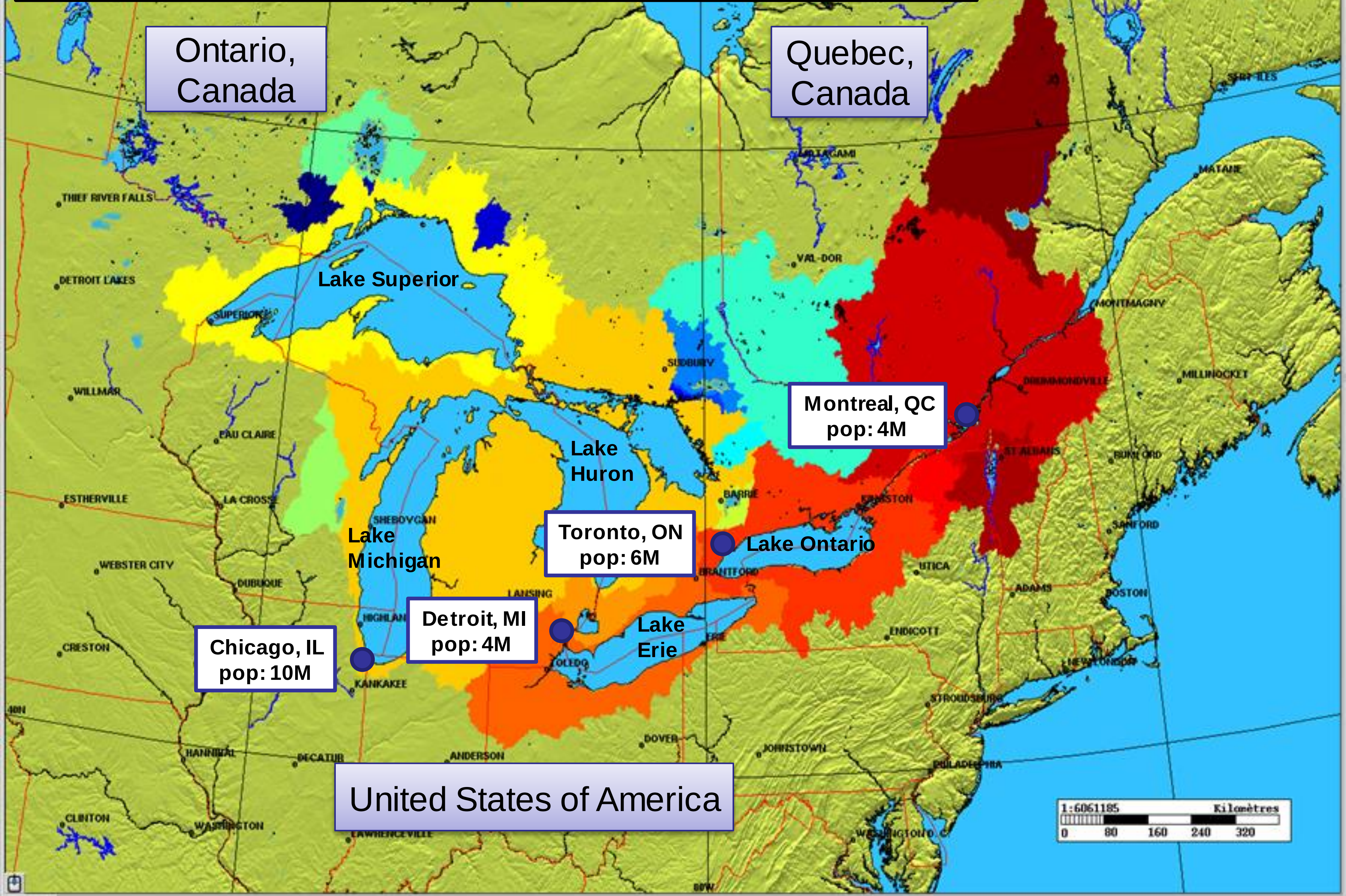
NOAA
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

GLERL
Great Lakes Environmental Research Laboratory

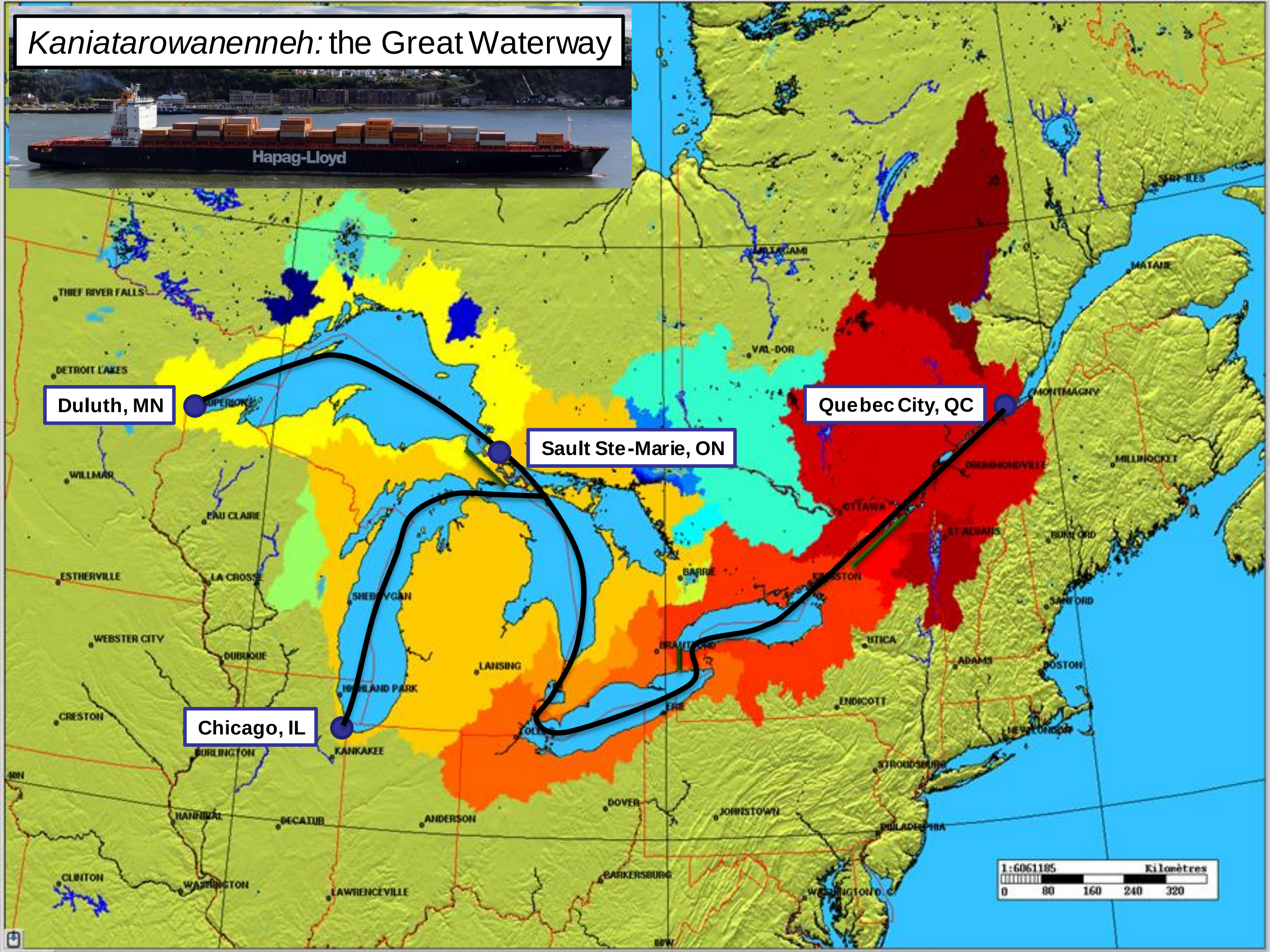
What is CHAMP?

- WMO R&D project focused on demonstrating that major improvements to atmospheric, hydrological and hydrodynamic forecasts can be obtained by:
  - improved communication between the atmospheric, hydrological and hydrodynamic scientific communities
  - improved coupling environmental models of the atmosphere, land-surface, rivers and lakes
  - sharing expertise, models and products between countries
  - using the Great-Lakes and St. Lawrence watershed as a testbed
- Builds on existing binational collaborative research initiative between ECCC and NOAA/GLERL

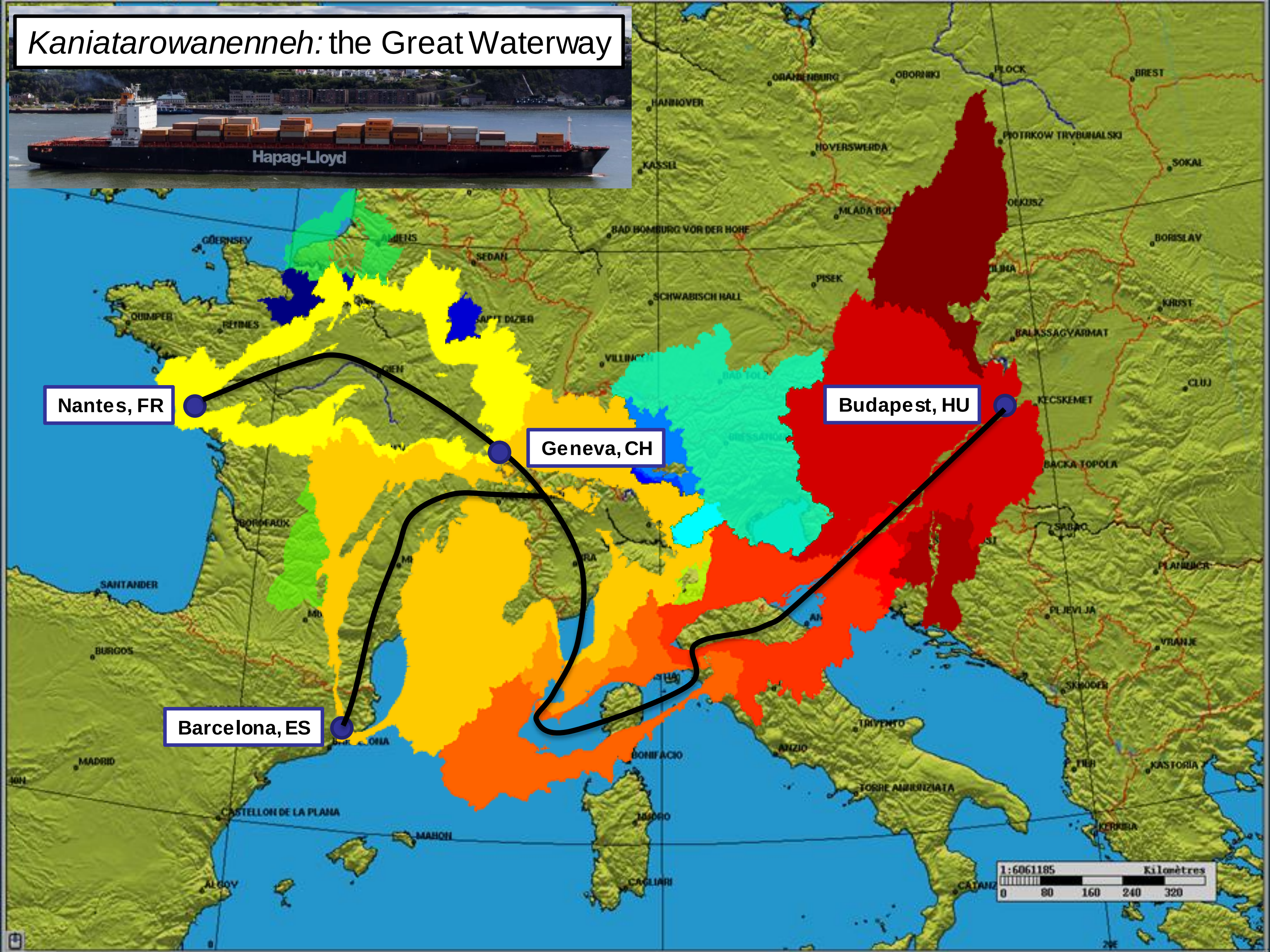
The Great Lakes and St. Lawrence River Watershed:
~1.5M km² at Quebec City, average discharge of ~10 000 cms



Kaniatarowanenneh: the Great Waterway



Kaniatarowanenneh: the Great Waterway



CHAMP implementation plan

- In both U.S. and Canada, implement an operational (24/7) chain of coupled numerical models that issues real-time forecasts of the physical state of the hydrosphere (different models in each country)
- Work on the comparison and evaluation of these systems for different purposes, identify weaknesses
- Identify and support targeted monitoring activities aimed at improving the models
- Share data and models with scientists and stakeholders
- Develop and issue joint products and services

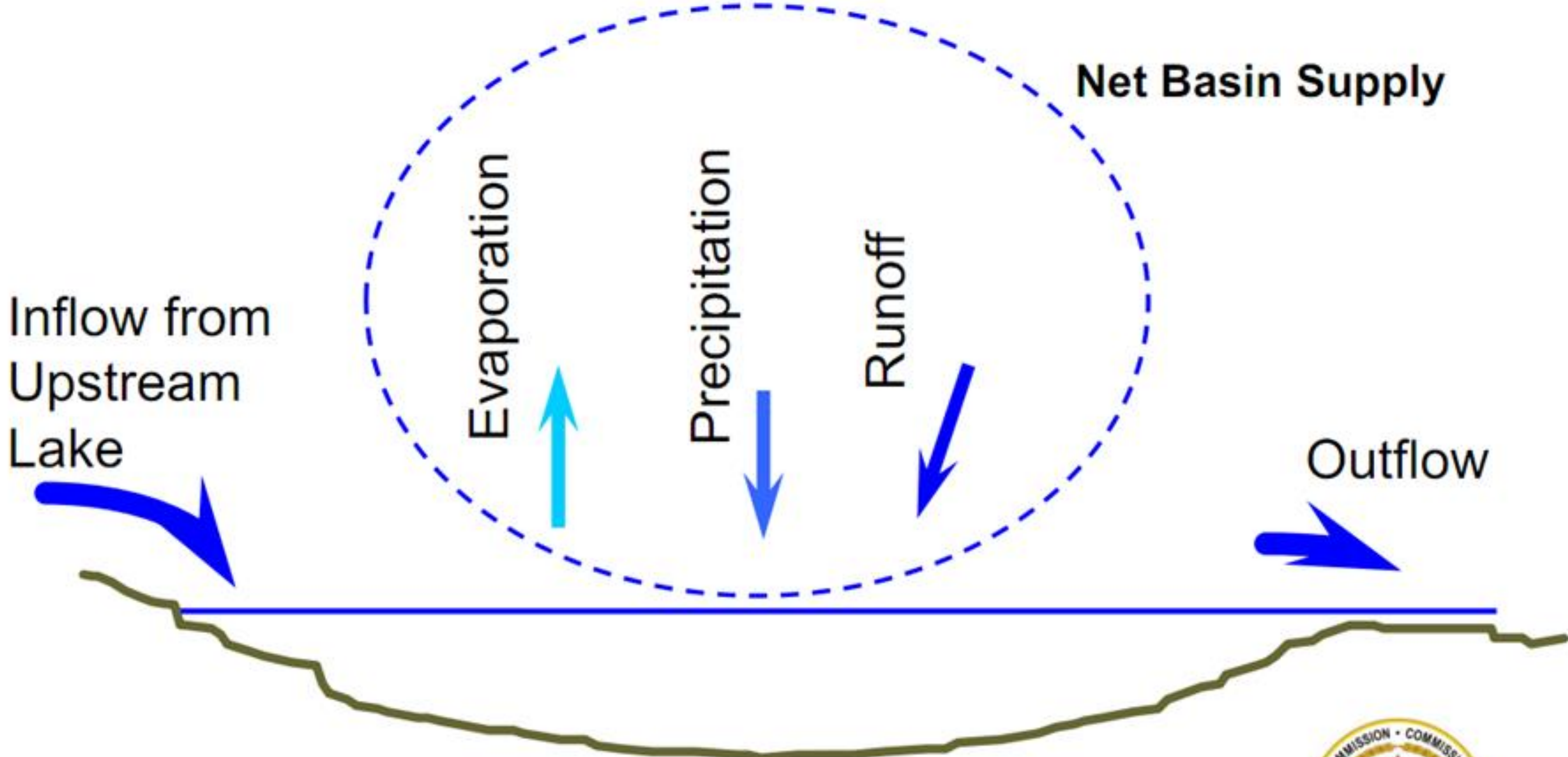
Implementation of numerical models: status update

- First version of the Water Cycle Prediction System for the Great Lakes and St. Lawrence (WCPS-GLS), based on GEM, NEMO and WATROUTE implemented by Canada in 2016
  - More on this system later

- Implementation of WRF-Hydro and FVCOM by NOAA on the whole watershed is ongoing
  - FVCOM operational on Lake Erie since 2016
  - WRF-Hydro operational on the US portion of the lakes since 2016

Great Lakes Water Supplies

(Factors Affecting Water Levels)

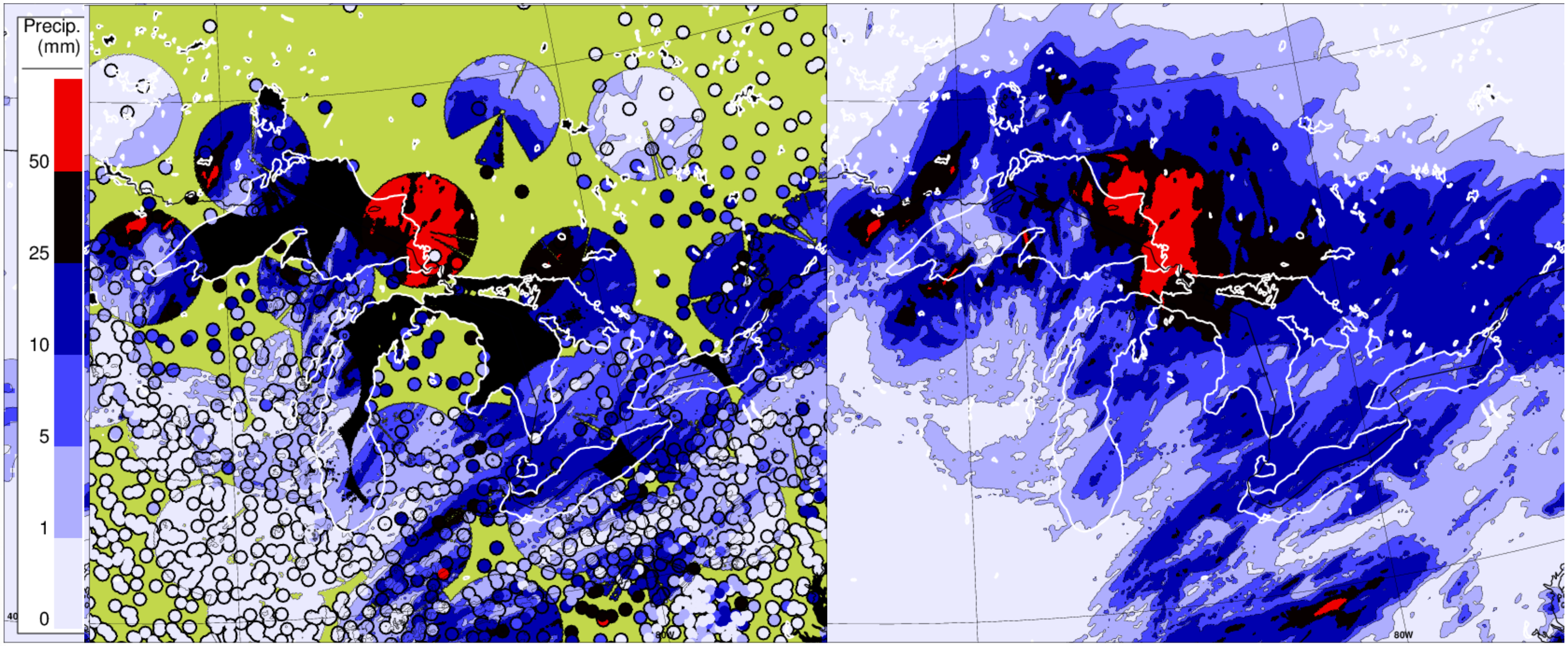


International Lake Superior Board of Control

30 August 2011

Canadian Precipitation Analysis

Gauges and radar network CaPA @ 2.5-km



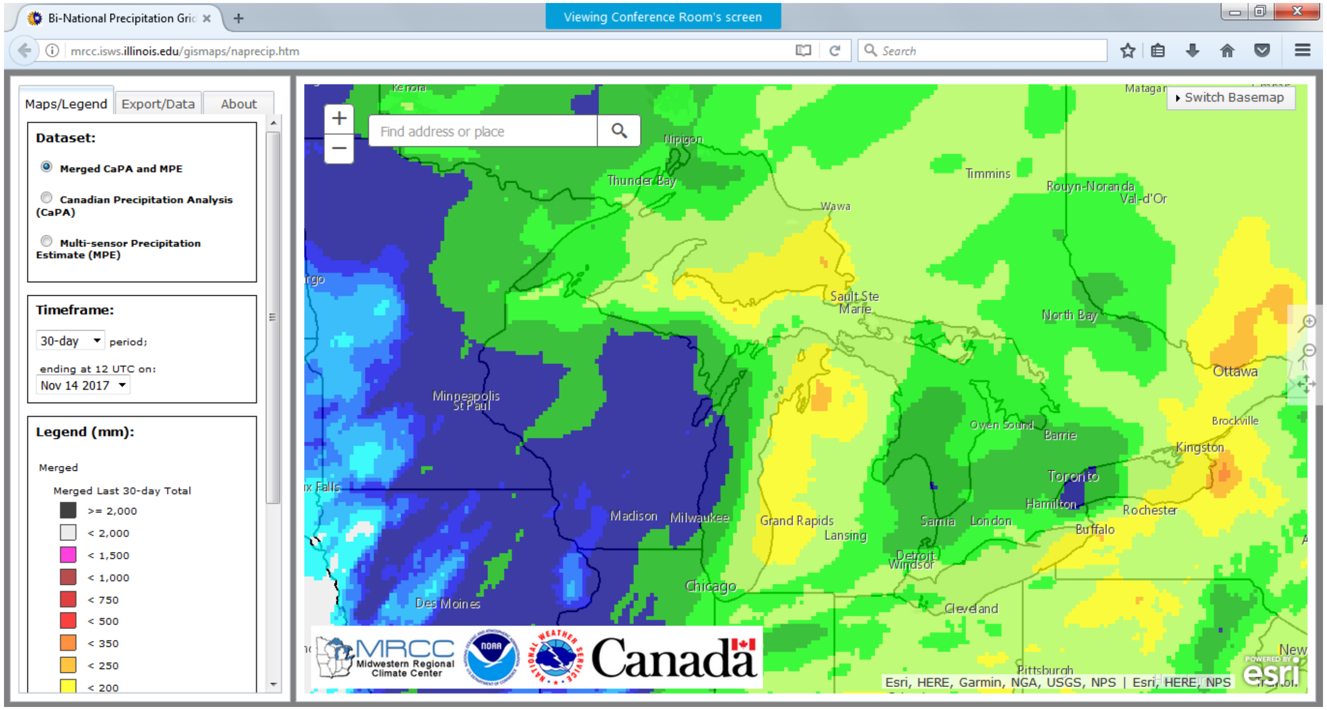
24-h precipitation total valid 2017-08-18 12

Environment Canada Environnement Canada

Canada

Precipitation

- Bi-national precipitation tool combining best real-time estimates of precipitation from NOAA and ECCC
  - Website maintained by the Midwestern Regional Climate Center



Environnement et Changement climatique Canada
Environment and Climate Change Canada

NOAA
GLERL
Great Lakes Environmental Research Laboratory

Evaporation

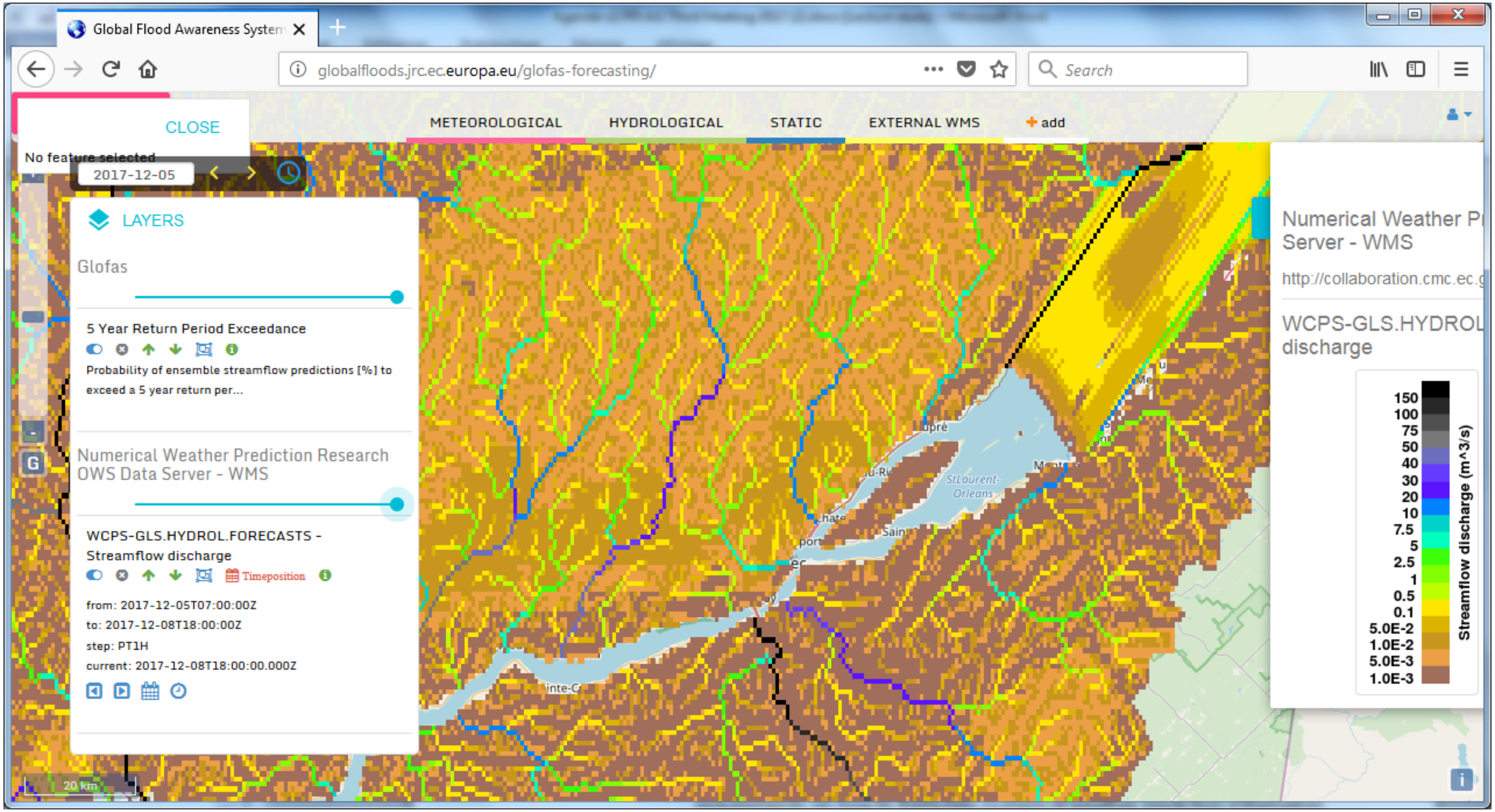
- Monitoring network to evaluate and improve models

Lake	Superior	Superior	Michigan	Huron	Erie
Location	Stannard Rock	Granite Island	White Shoal	Spectacle Reef	Long Point
Years Available	2008-2014	2010-2014	2012-2014	2009-2014	2012-2014
P.I.	C. Spence	J. Lenters	P. Blanken	P. Blanken	C. Spence

Runoff

- Great Lakes Intercomparison Projects (GRIP)
  - GRIP-M: Lake Michigan study led by NOAA/GLERL
    - Comparison of existing runoff prediction systems as a whole
    - Includes systems designed for either analysis or prediction of runoff
    - Fry et al. (2014). The Great Lakes Runoff Intercomparison Project Phase 1: Lake Michigan (GRIP-M). *J. Hydrology*.
    - Conclusion: systems relying on data assimilation of streamflow observations performed significantly better
  - GRIP-O: Lake Ontario study led by ECCC/MRD
    - Understanding the source of differences between systems: precipitation inputs, model calibration, model structure
    - Gaborit et al. (2017). Great Lakes Runoff Inter-comparison Project, Phase 2: Lake Ontario (GRIP-O). *J. Great Lakes Research*.
    - Conclusion: good performance of the CaPA precipitation analysis despite the low-resolution of the gauge network available in real-time
  - GRIP-E: Lake Erie study led by Pr. Tolson, U. Waterloo
    - Study still at the planning stage

Dissemination: collaboration with ECMWF to use the GloFAS viewer



Related publications

2017

- Resolving hydrometeorological monitoring and modeling inconsistencies across a large binational lake-dominated river basin, *BAMS*.
- Towards an operational water cycle prediction system for the Great Lakes and St. Lawrence River, *BAMS*.
- Great Lakes Runoff Inter-comparison Project, Phase 2: Lake Ontario (GRIP-O), *J. Great Lakes Res.*.
- A Hydrological Prediction System Based on the SVS Land-Surface Scheme: Implementation and Evaluation of the GEM-Hydro platform on the watershed of Lake Ontario. *HESS*.

2016

- Hydrological drivers of record-setting water level rise on Earth's largest lake system. *WRR*.
- The Great Lakes Runoff Intercomparison Project Phase 1: Lake Michigan (GRIP-M). *J. Hydrol.*

2014

- Calibrating Environment Canada's MESH Modelling System over the Great Lakes Basin. *Atmosphere-Ocean*
- Identifying gage networks for maximizing the effectiveness of large scale water balance modeling. *WRR*.

2013

- Coasts, water levels, and climate change: A Great Lakes perspective. *Climatic Change*.
- Predicting the Net Basin Supply of the Great Lakes with a Hydrometeorological Model. *J. Hydrometeor.*

2012

- Assessment of a NEMO-based hydrodynamic modelling system for the Great Lakes. *Wat. Qual. Res. J.*
- Advancing Great Lakes hydrological science through targeted binational collaborative research. *BAMS*.

2011

- Evaporation from Lake Superior: 2. Spatial distribution and variability. *J. Great Lakes Res.*

Environnement et Changement climatique Canada
Environment and Climate Change Canada

Canada

A WATER CYCLE PREDICTION SYSTEM FOR THE GREAT LAKES AND ST. LAWRENCE RIVER

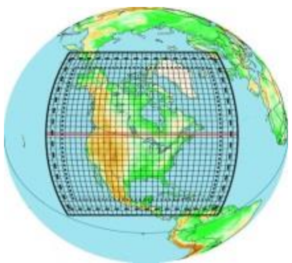
D. Durnford[*,◊,1], V. Fortin[◊,2], G. C. Smith[◊,2], B. Archambault[1], D. Deacu[1], F. Dupont[1], S. Dyck[1], Y. Martinez[1], E. Klyszejko[3], M. Mackay[2], L. Liu[3], P. Pellerin[2], A. Pietroniro[3], F. Roy[2], V. Vu[1], B. Winter[1], W. Yu[1], C. Spence[2], J. Bruxer[1], and J. Dickhout[1]

[1]Meteorological Service of Canada, Environment and Climate Change Canada
[2] Science and Technology Branch, Environment and Climate Change Canada
[3] Water Survey of Canada, Environment and Climate Change Canada

Link to BAMS paper

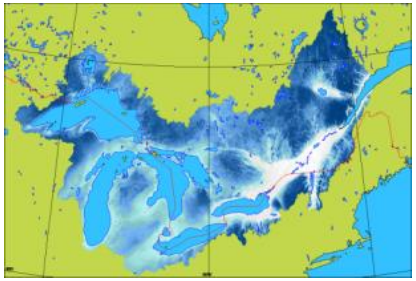
Water Cycle Prediction System for the Great Lakes

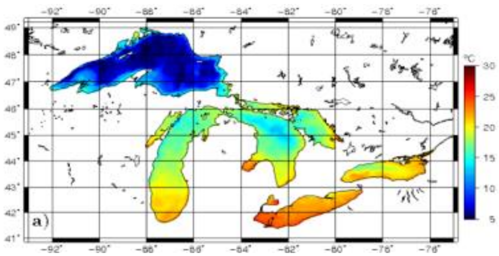
GEM RDPS (10 km) atmospheric model



GEM LAM (10 km) atmospheric model (ISBA land-surface scheme)

WATROUTE routing model (1km)





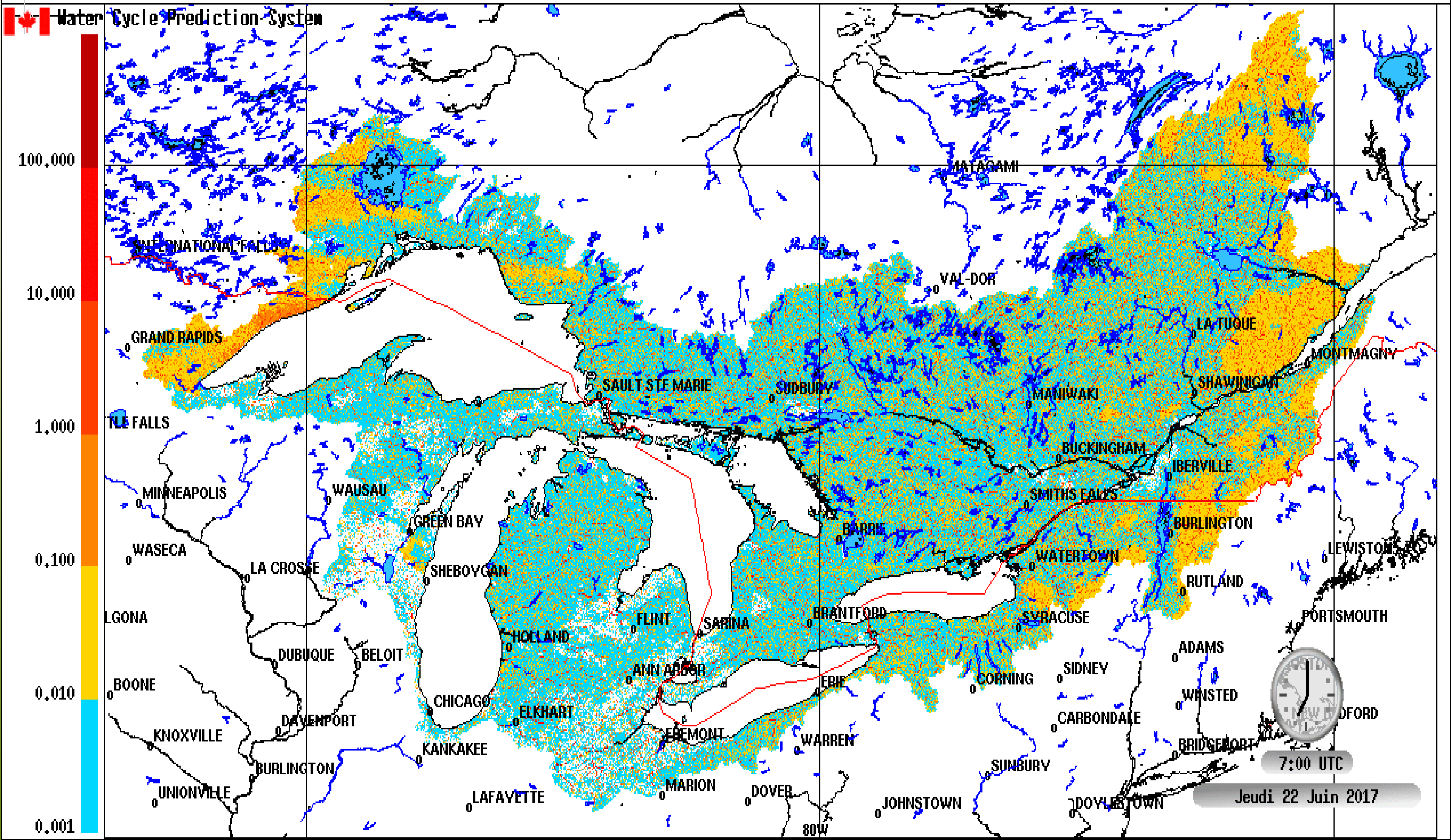
NEMO+CICE (2 km) ocean-ice model over the Great Lakes

In production since June 2016:

- 2 runs per day
- 3.5 day forecasts

Durnford et al. (2017) submitted to BAMS

Streamflow analysis cycle
2017-06-22 06Z - 2017-06-24 06Z



Streamflow analysis cycle
2017-06-22 06Z - 2017-06-26 06Z

This image cannot currently be displayed.

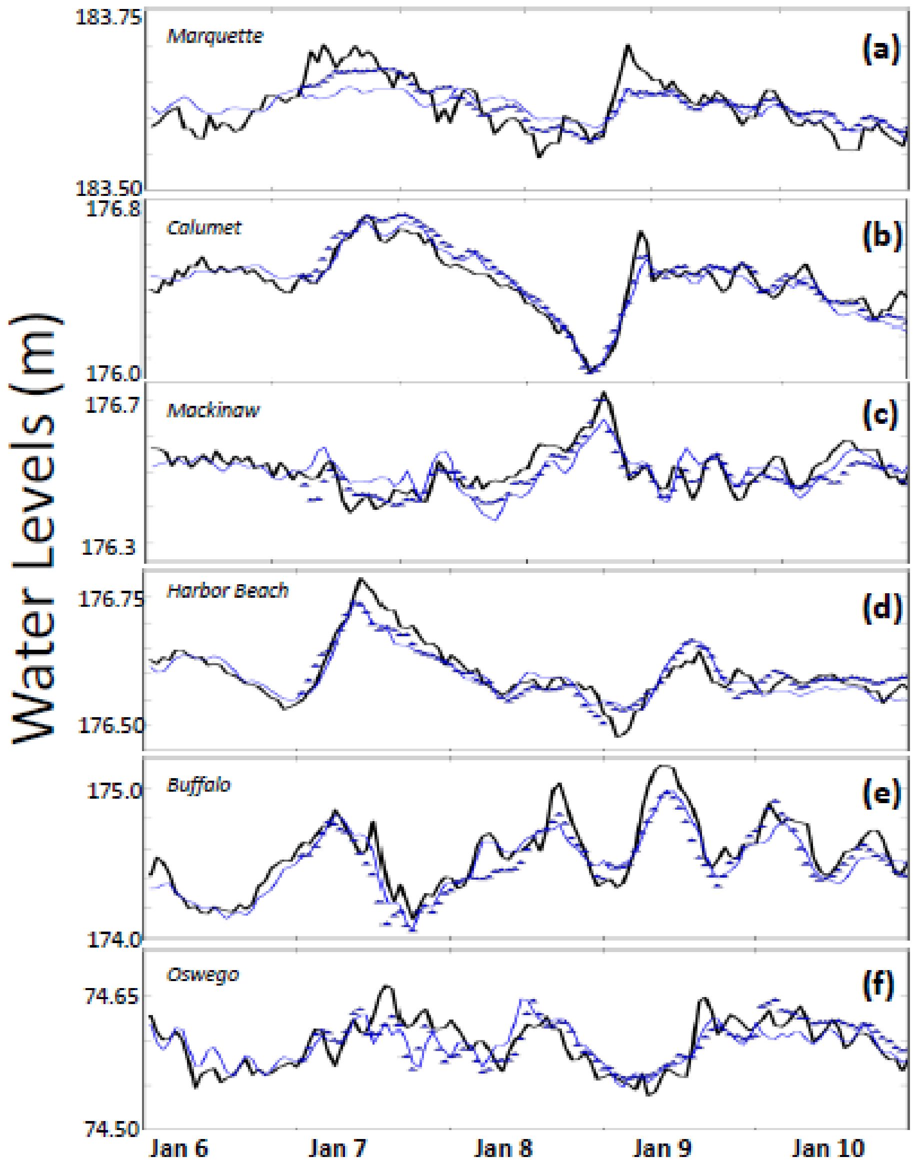
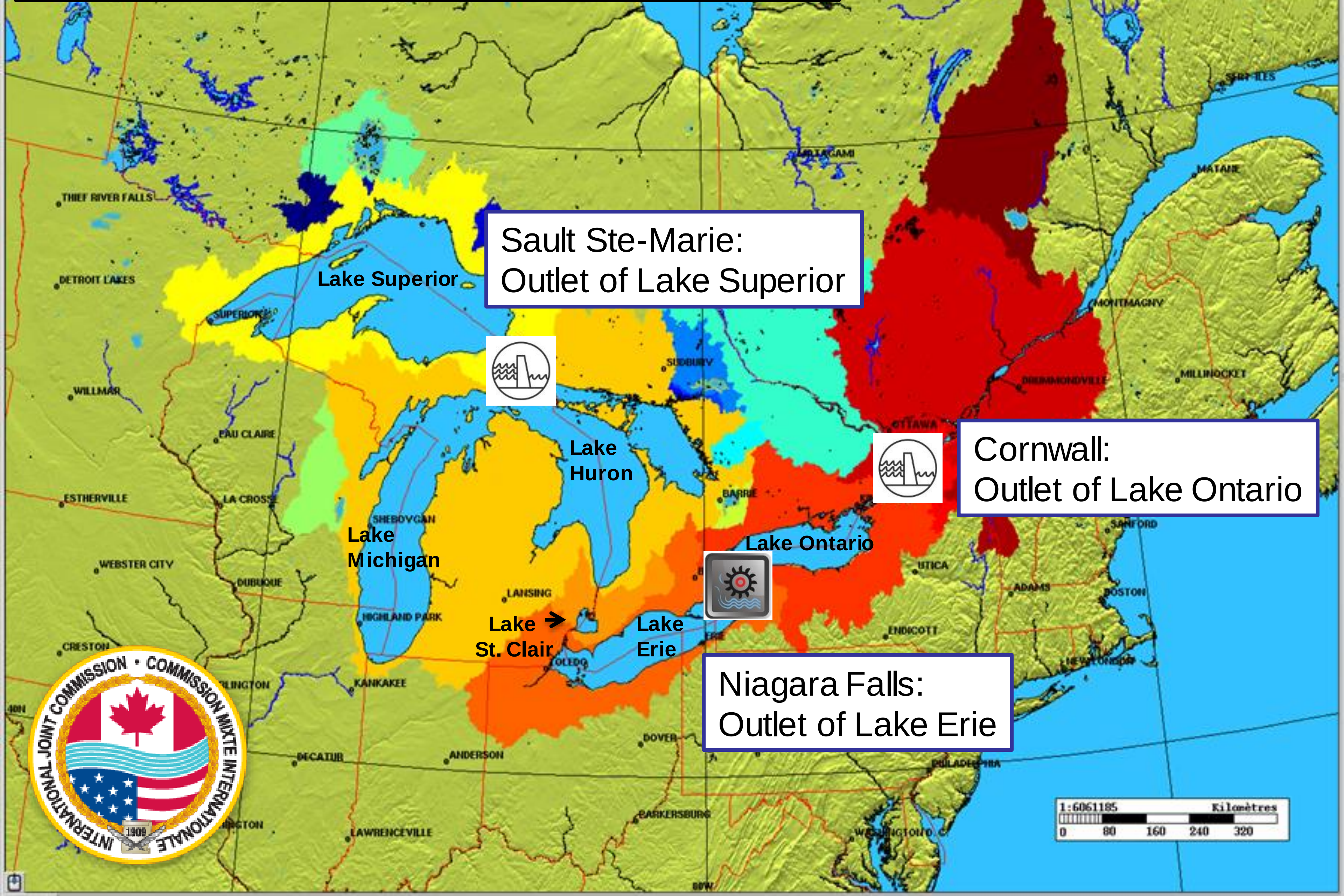
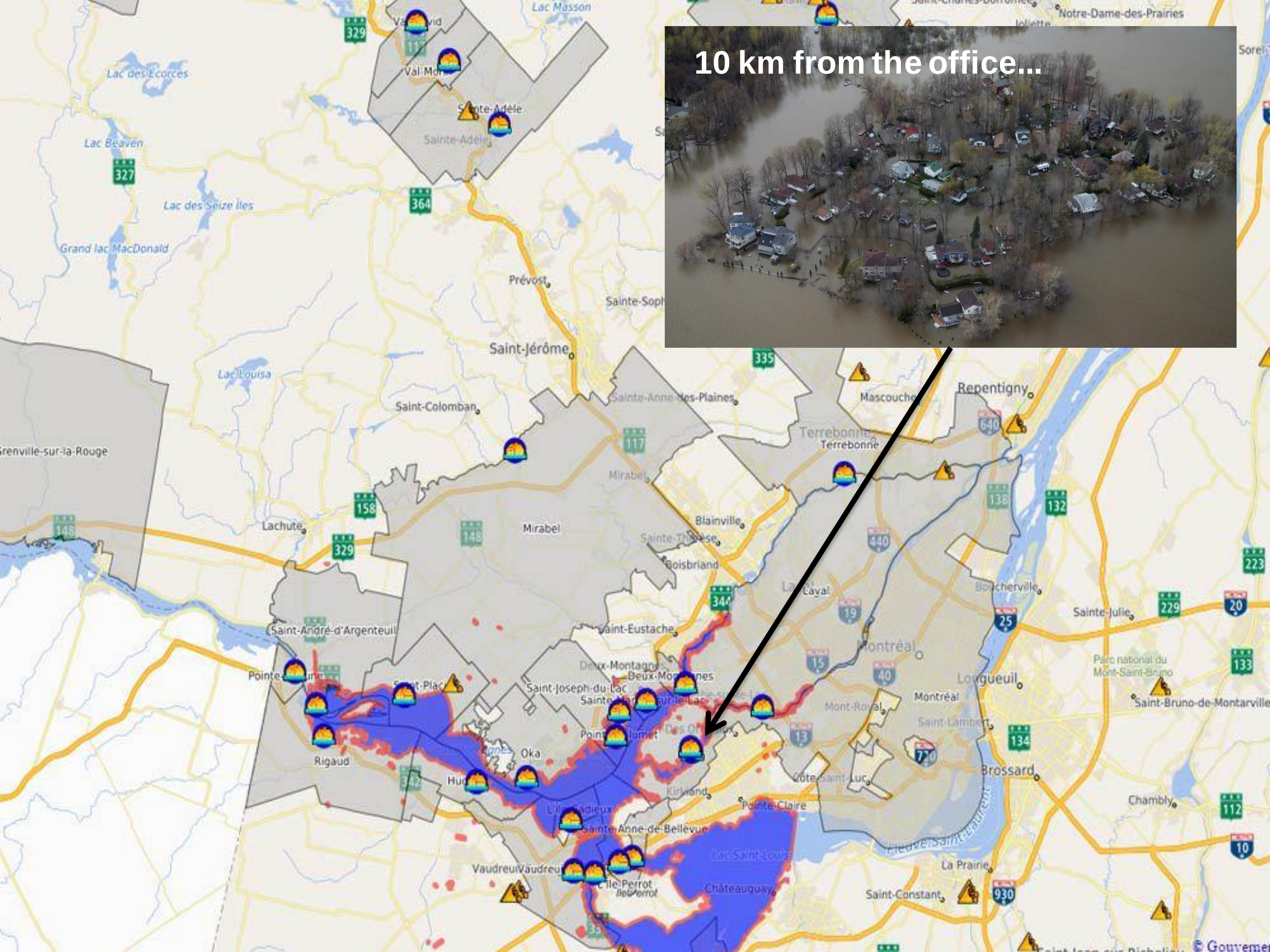


Fig. 2 Water level observations (black) and consecutive 48-hour forecasts (blue) for January 6 – 10, 2015 at: (a) Marquette; (b) Calumet; (c) Mackinaw; (d) Harbor Beach; (e) Buffalo; (f) Oswego. Day-1 forecasts (hours 1-24) are solid blue and day-2 forecasts (hours 25-48) are blue triangles.

Canada

The Great Lakes and St. Lawrence River Watershed: Control structures and power plants





10 km from the office...
Lac Masson
Notre-Dame-des-Prairies
Lac des Écorces
Lac Beaven
Lac des Seize Îles
Grand lac MacDonald
Sainte-Adèle
Prévost
Saint-Jérôme
Lac Louisa
Saint-Colomban
Sainte-Anne-des-Plaines
Mascouche
Repentigny
Terrebonne
Grenville-sur-la-Rouge
Lachute
Mirabel
Blainville
Sainte-Thérèse
Boisbriand
Laval
Boucherville
Sainte-Julie
Saint-André-d'Argenteuil
Saint-Eustache
Deux-Montagnes
Saint-Joseph-du-Lac
Montréal
Longueuil
Parc national du Mont-Saint-Bruno
Saint-Bruno-de-Montarville
Mont-Royal
Saint-Lambert
Rigaud
Oka
Kirkland
Pointe-Claire
Brossard
Chambly
Sainte-Anne-de-Bellevue
Lac-Saint-Louis
Châteauguay
L'Île-Perrot
La Prairie
Saint-Constant
Fleuve Saint-Laurent

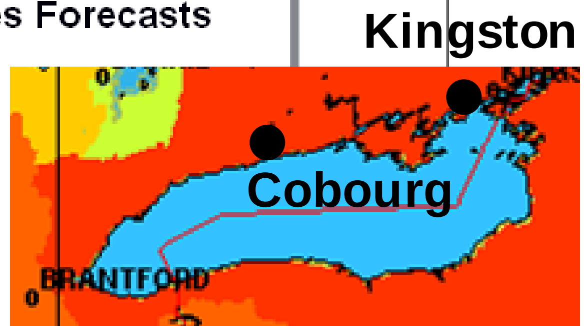

Ottawa River
(outlet @ Carillon Dam)
Ottawa River
Lake St. Lawrence
(outlet @ Moses-Saunders &
Long Sault Dam)
Ottawa, ON
Montreal, QC
Cornwall, ON
Massena, NY
Ogdensburg, NY
Lake St Louis
(outlet @ Lasalle)
St. Lawrence River
Kingston, ON
Cobourg, ON
Toronto, ON
Lake Ontario
Oswego, NY
Port Weller, ON
Niagara River
Rochester, NY
Syracuse, NY
Buffalo, NY
Lake Erie
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Experimental Water Level and Waves Forecasts for Lake Ontario

Forecast issued: 2017-08-04 07 UTC
Numerical guidance issued: 2017-08-04 00 UTC

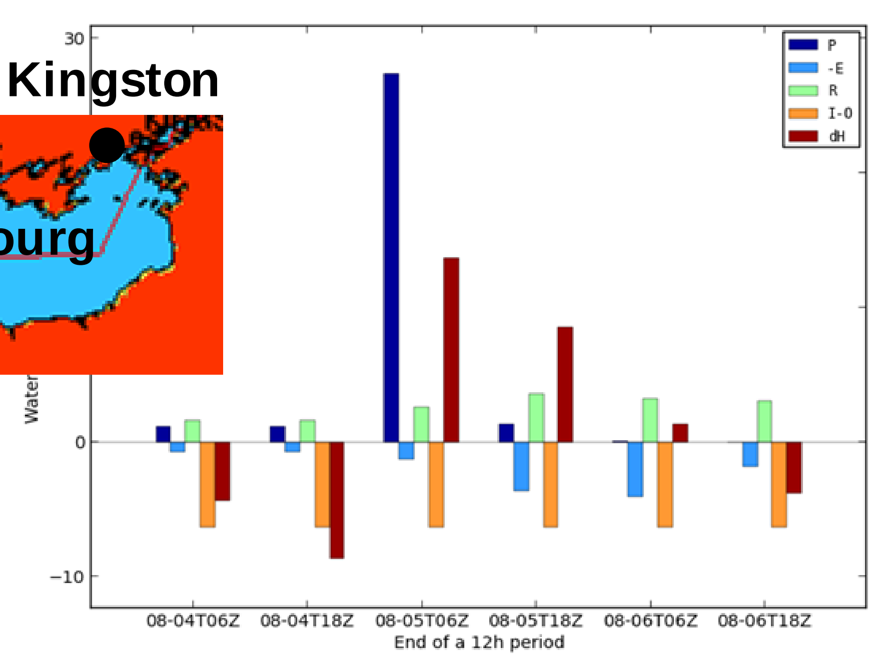
Hypotheses on connecting channel flow:

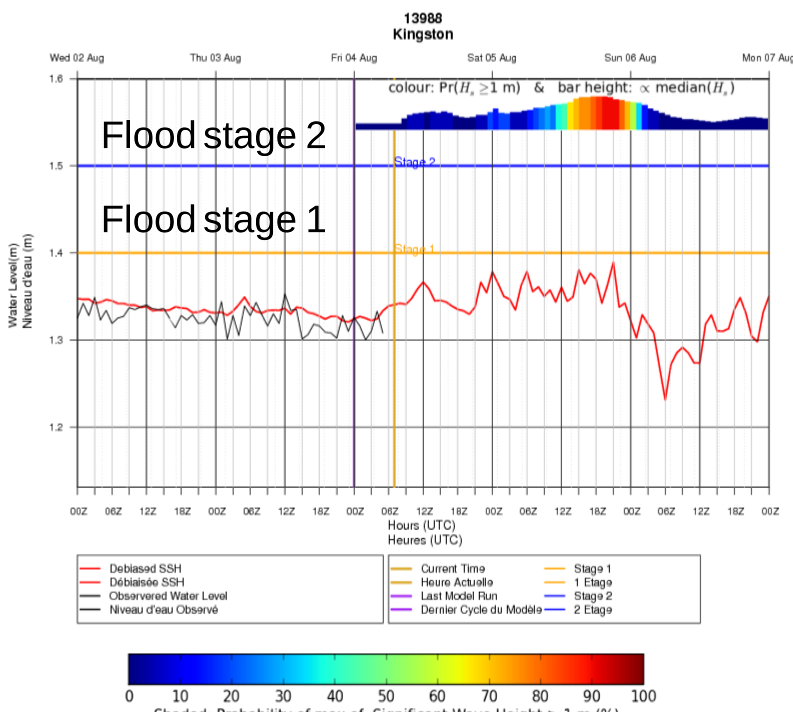
Mean inflow from Erie: 7589 m³/s or 34 mm/day
Mean outflow at Cornwall: 10377 m³/s or 47 mm/day
Mean difference in flows: 2788 m³/s or 12 mm/day

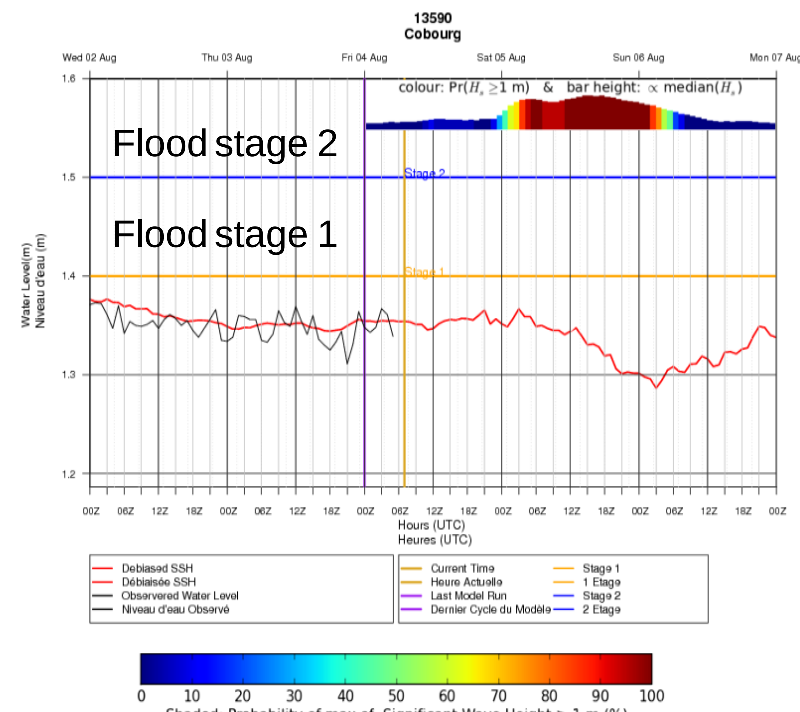


Expected changes in mean water level:

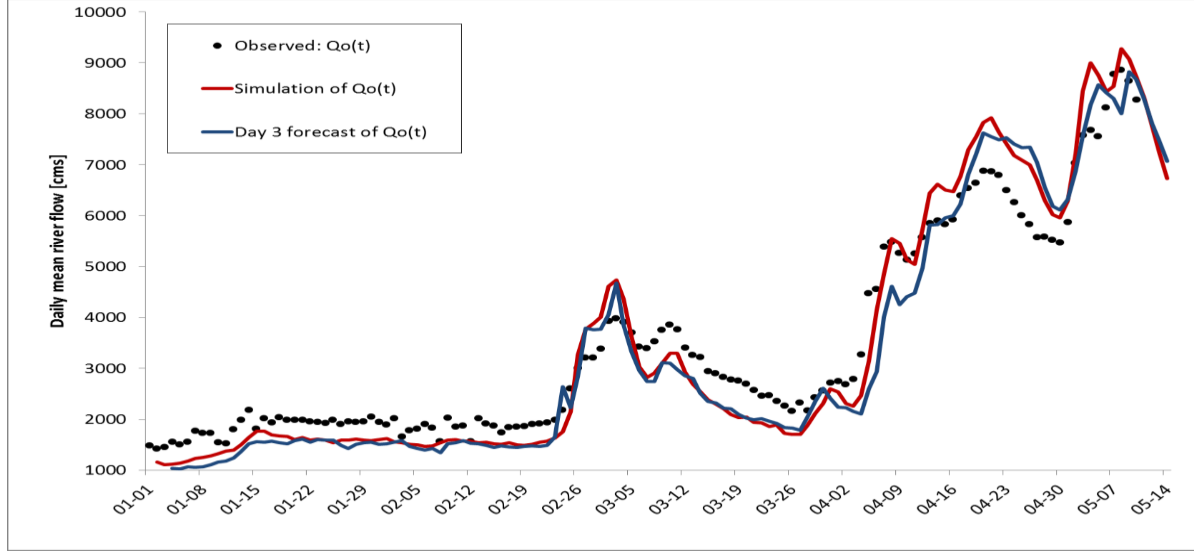
The following figure illustrates how over-lake precipitation (P), over-lake evaporation (-E), runoff from the lake's own watershed (R) and differences between inflows from lake Erie and outflows into the St. Lawrence River (I–O) are expected to change the water level of Lake Ontario (dH) over a three day period. All quantities except dH reflect the impact of the process over a 12-h period ending at the time indicated on the x axis. Note that the sign for evaporation is reversed, since evaporation lowers the lake level. The change in water level (dH) is accumulated from the start of the forecast.

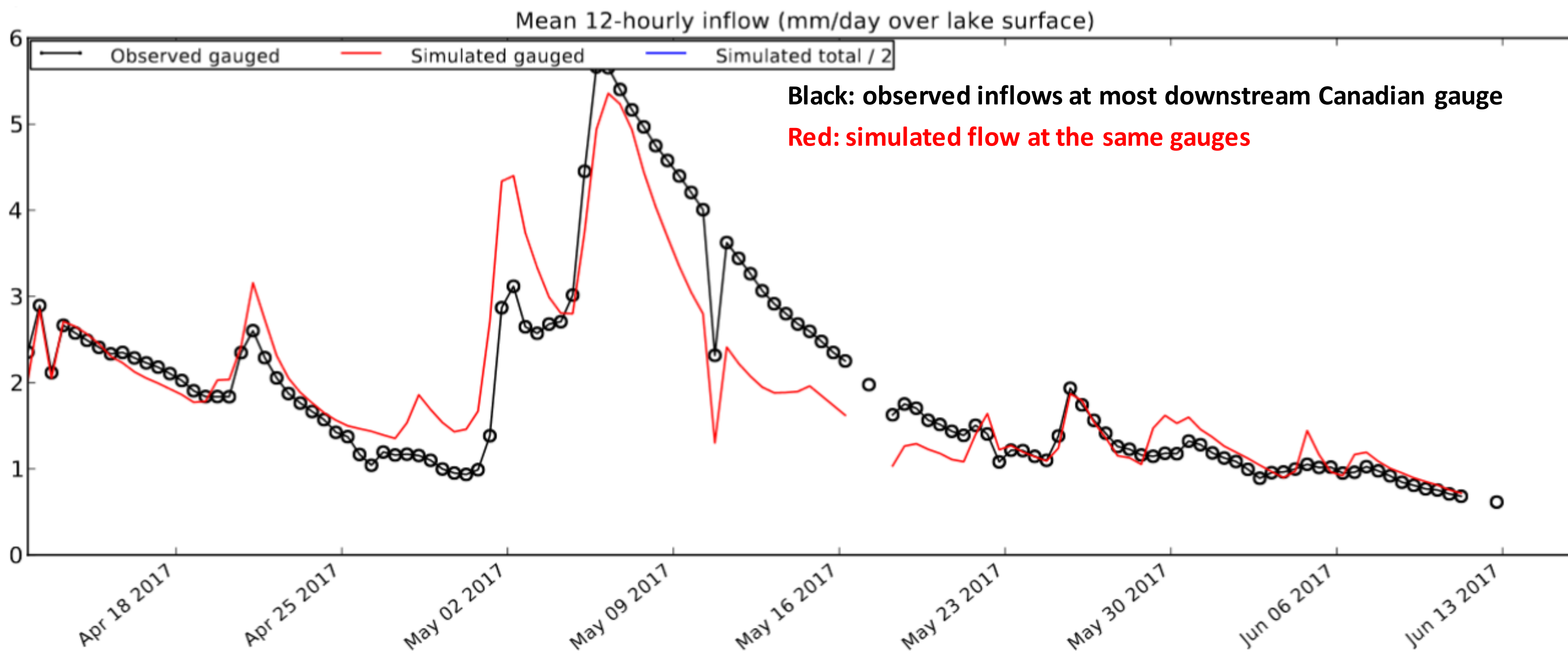







Ottawa River
(outlet @ Carillon Dam)
Ottawa River
Lake St. Lawrence
(outlet @ Moses-Saunders &
Long Sault Dam)
Ottawa, ON
Montreal, QC
Cornwall, ON
Massena, NY
Ogdensburg, NY
Lake St Louis
(outlet @ Lasalle)
St. Lawrence River
Kingston, ON
Cobourg, ON
Toronto, ON
Lake Ontario
Port Weller, ON
Oswego, NY
Niagara River
Rochester, NY
Syracuse, NY
Buffalo, NY
Lake Erie


Observed: Qo(t)
Simulation of Qo(t)
Day 3 forecast of Qo(t)
Daily mean river flow [cms]
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
01-01
01-08
01-15
01-22
01-29
02-05
02-12
02-19
02-26
03-05
03-12
03-19
03-26
04-02
04-09
04-16
04-23
04-30
05-07
05-14

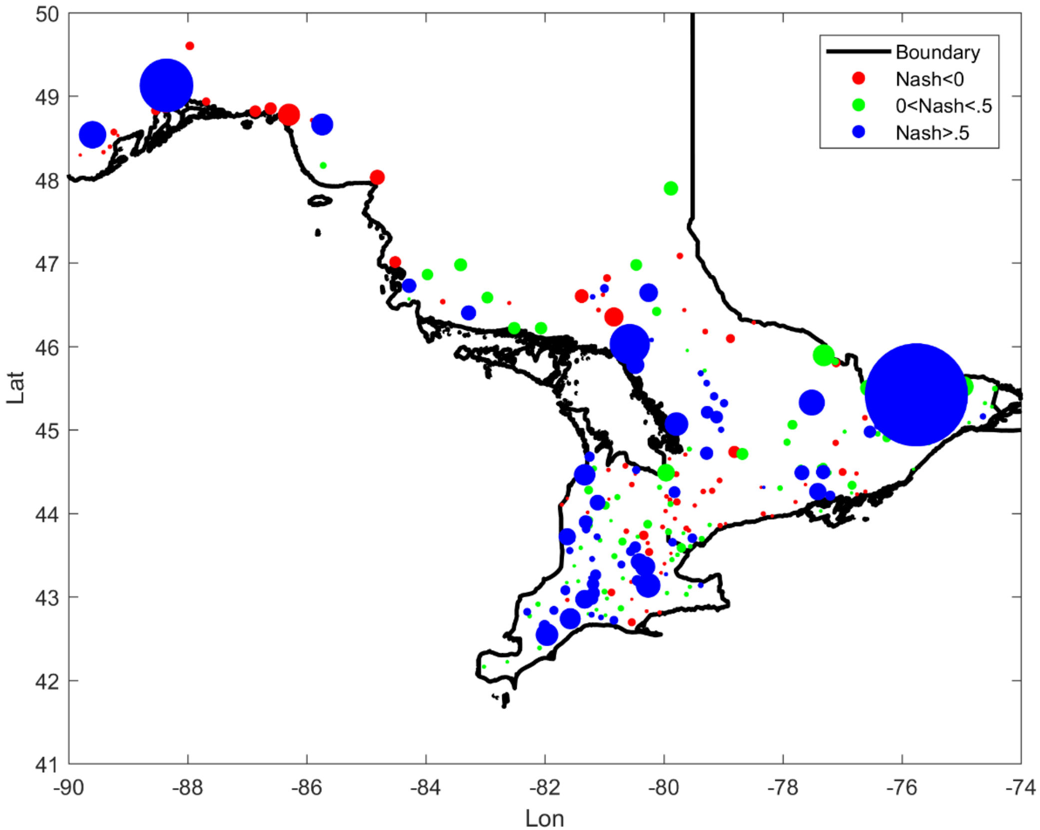

Mean 12-hourly inflow (mm/day over lake surface)
Observed gauged
Simulated gauged
Simulated total / 2
Black: observed inflows at most downstream Canadian gauge
Red: simulated flow at the same gauges
6
5
4
3
2
1
0
Apr 18 2017
Apr 25 2017
May 02 2017
May 09 2017
May 16 2017
May 23 2017
May 30 2017
Jun 06 2017
Jun 13 2017

Evaluation of streamflow forecasts created by the Water Cycle Prediction System for the Great Lakes and St. Lawrence. (WCPS-GLS)

Hussein Wazneh*[1], Vincent Fortin[2], Paulin Coulibaly[1]
[1]McMaster University, Hamilton, ON
[2]ECCC- Dorval, QC

December 2017

Performance Analysis of Analysis Cycle Data



- Output of analysis cycle was evaluated in 252 watersheds
- 33% Nash>.5 34% 0<Nash<.5 33% Nash<0
- Larger watersheds have proportionally better Nash values

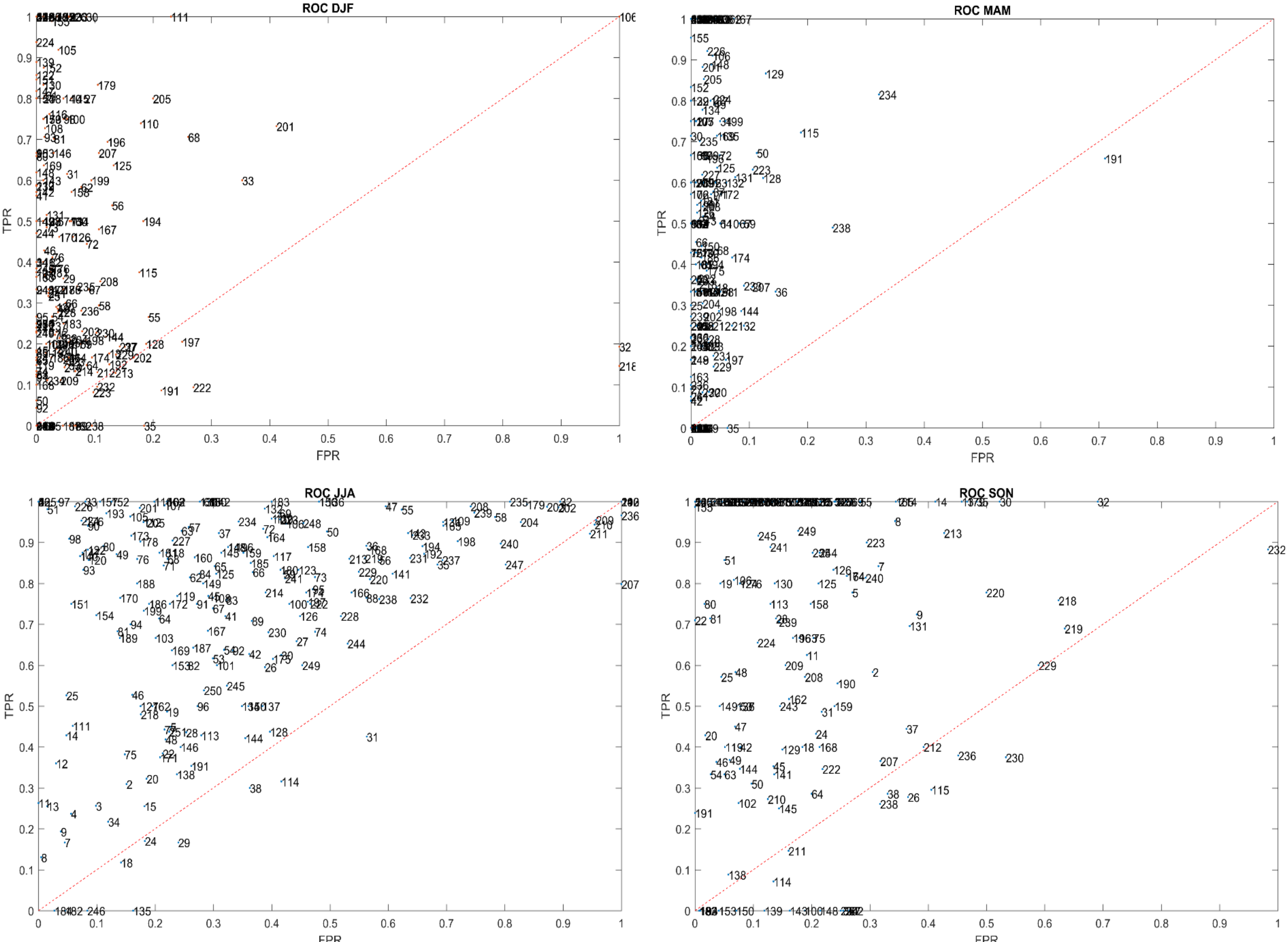
Performance Analysis of Analysis Cycle Data(Threshold exceedance)

$$True\ Positive\ Rate\ (TPR) = \frac{TP}{TP + FN}$$

$$False\ Positive\ Rate\ (FPR) = \frac{FP}{FP + TN}$$

		Obs.	
		Ex.	N-Ex.
Sim.	Ex.	TP	FP
	N-Ex.	FN	TN

- Receiver Operating Characteristic (ROC) space was used to evaluate the Analysis Cycle data in terms of threshold exc.
- TPR defines how many correct exc. are detected among all exc.
- FPR defines how many incorrect exc. results occur among all N-exc.



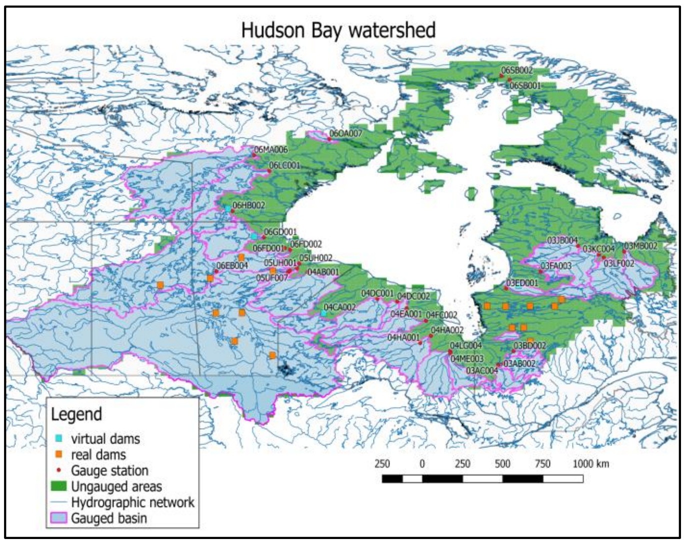
ROC DJF
ROC MAM
ROC JJA
ROC SON
TPR
FPR

Next steps

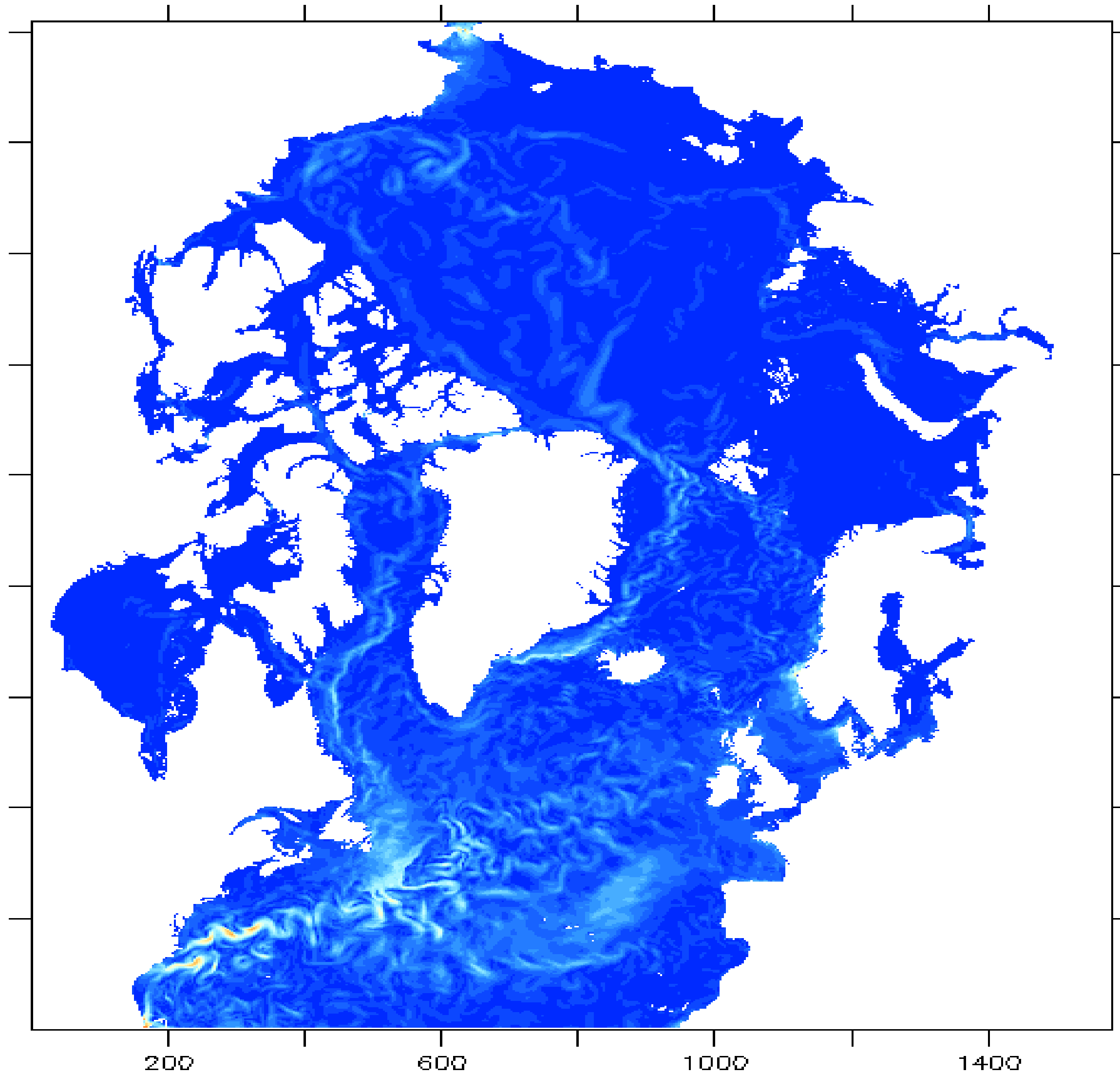
- Deterministic system
  - increase resolution of atmospheric model component from 10-km to 2.5-km
  - upgrade land-surface model (SVS) and land-data assimilation system (CaLDAS)
  - improved data assimilation of streamflow observations and lake levels (method TBD)
- Ensemble prediction system
  - increase lead time from 3.5 days to 30 days!
- Develop a similar system for the Arctic basin
  - 10-day forecasting system for the Hudson Bay currently running in experimental mode

Contribution to the Year of Polar Prediction Coupled Atmosphere-Ocean Prediction System

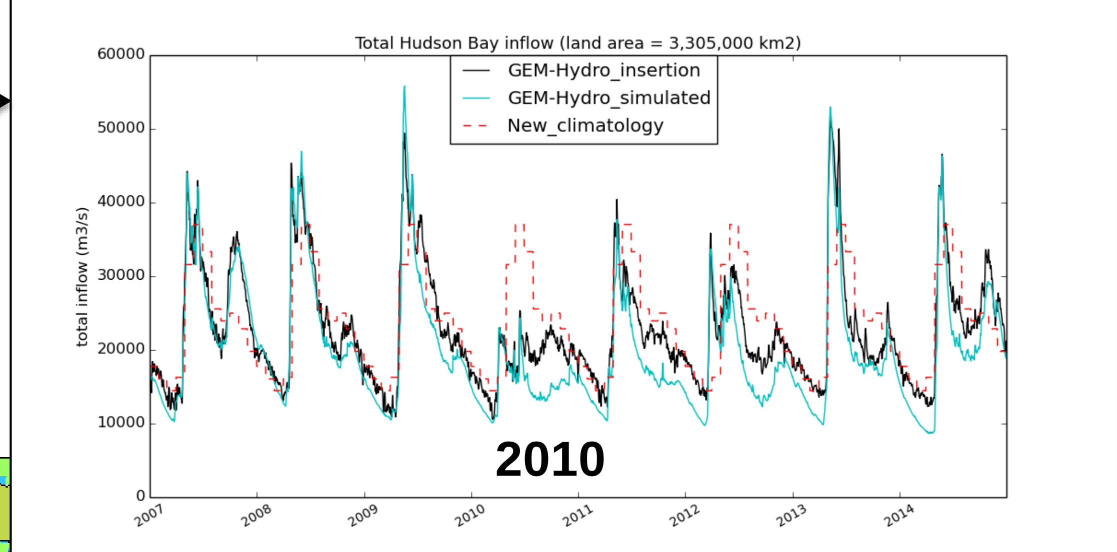
Hudson Bay watershed



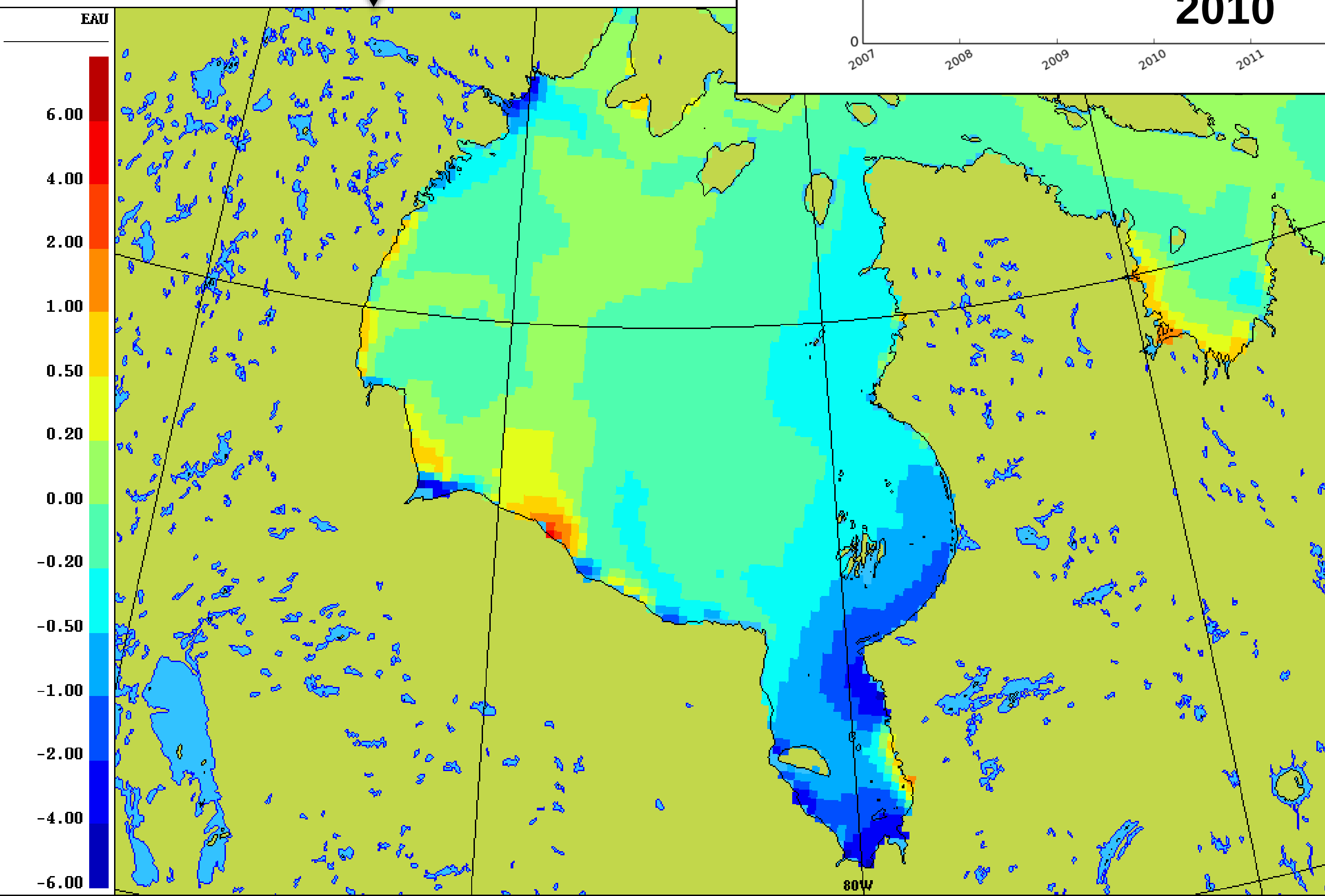
1/12° N. Atlantic and Arctic



Total Hudson Bay Inflow



Changes in average salinity (PSU)



Environment Canada Environnement Canada

CaPA analysis valid for Wednesday November 15 2017 at 00:00Z for 6h accumulated precipitation (mm)