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Canada

Operational Hydrological Prediction Systems and Products at ECCC

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Ocean: Fred Dupont[2], Greg Smith[1], Sarah McDermott[1]

Surface: Stephane Belair[1], Marco Carrera[1], Bernard Bilodeau[1], Daniel Deacu[2], Camille Garnaud[1], Bakr Badawy[2], Maria Abrahamowicz[1]

Geophysical databases: Vanh Souvanlasy[2]

A&P: Michael Schaffer[2]

Statistical evaluation: H. Wazneh[3], P. Coulibaly[3]

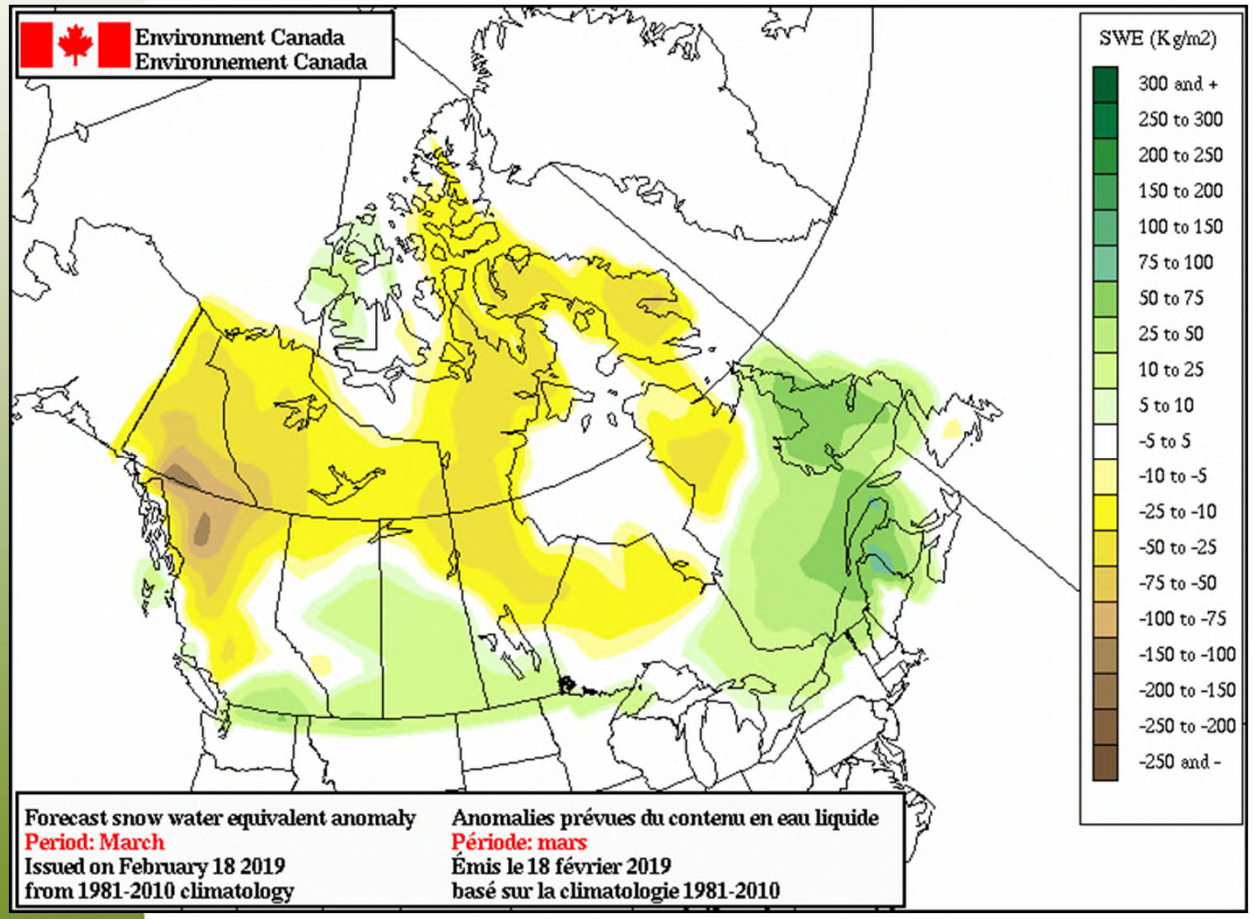
[1]Science and Technology Branch, [2]Meteorological Service of Canada, [3]MacMaster University

Workshop on Flow Forecasting, Vancouver: February 20, 2019

Sources of hydrological products

- By-products of atmospheric models
  - surface-atmosphere fluxes are calculated by a land surface scheme
  - leverage the hydrological information
  - CanSIPS: CLASS, 250km/1yr, 20 members, 20-member/30-y climatology
  - GEPS: ISBA, 40km/16d-1mth, 20 members, 4-member/20-y reforecast
  - GDPS/RDPS/HRDPS: ISBA, 15km/10d to 2.5km/48h
- Output from dedicated hydrological prediction systems
  - systems constructed to give best possible estimates of:
    - snowpacks, soil moisture, surface runoff, drainage, river flows, lake levels, evaporation
  - ISBA or SVS

CanSIPS: SWE anomaly forcast of 18 February for March 2019



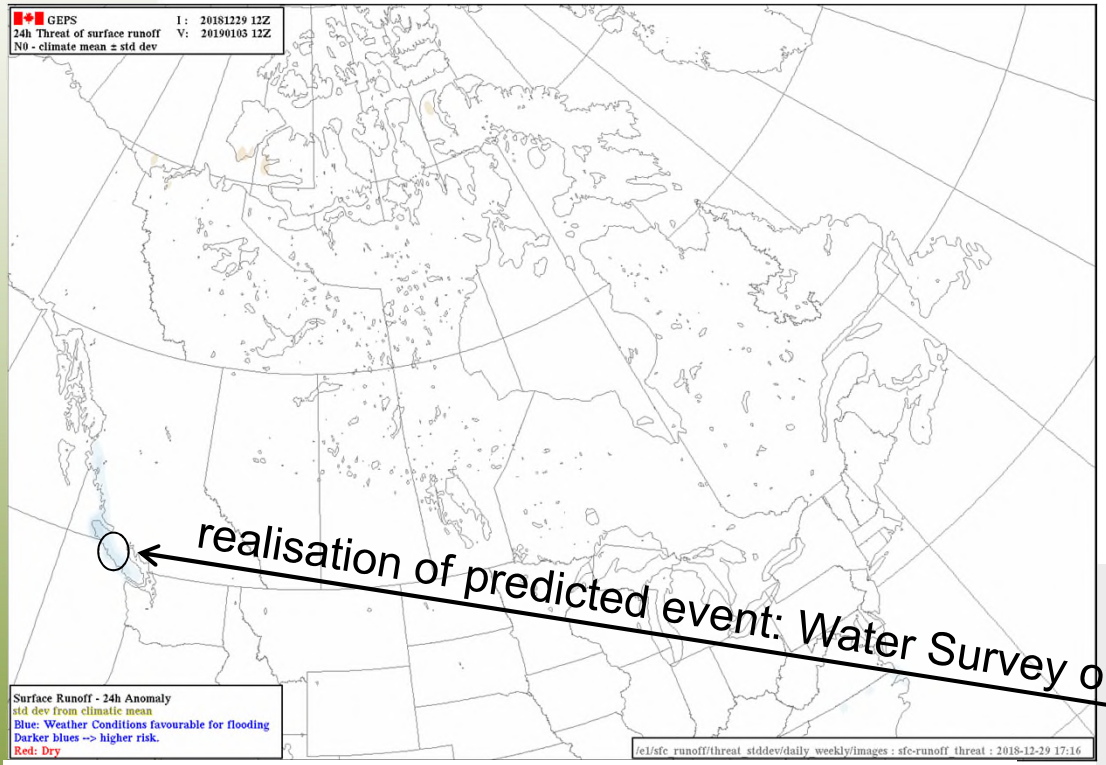
CanSIPS:

- the coarsest resolution
- the longest lead times
- the most detailed land surface scheme (CLASS)

Also available:

- soil moisture
- surface runoff: the water that enters the rivers

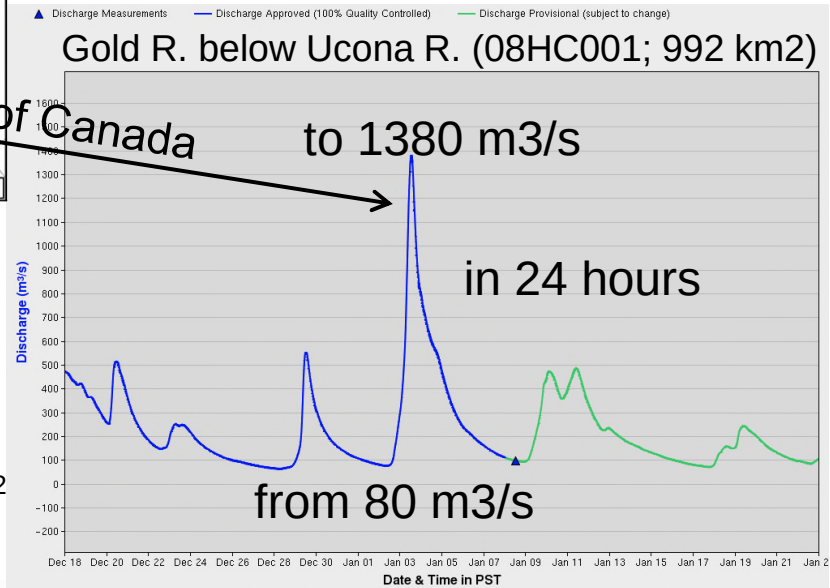
GEPS surface runoff anomaly for major flooding in Vancouver on 3-4 January 2019



geps_anomaly_24h-N0_CA2018122912_120.gif

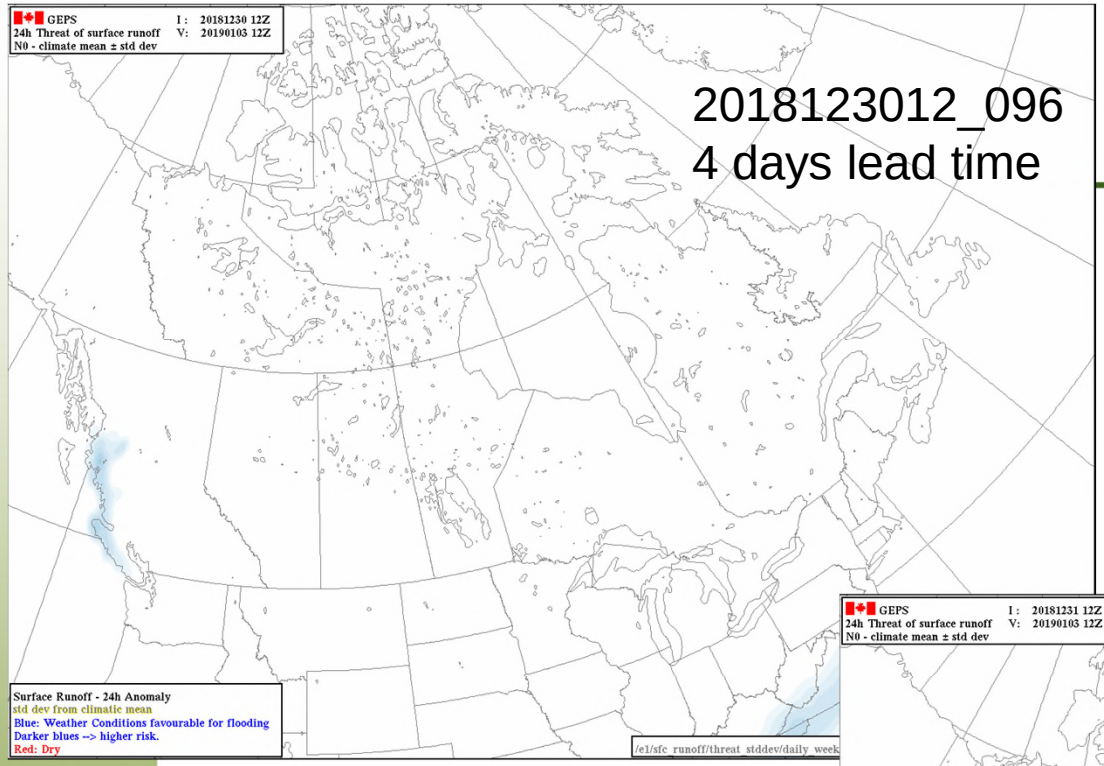
- 5 days lead time:
- warning of unusually high surface runoff for the time of year and location in the Vancouver area and along BC coast
- no warnings elsewhere in Canada
- highly localized

realisation of predicted event: Water Survey of Canada

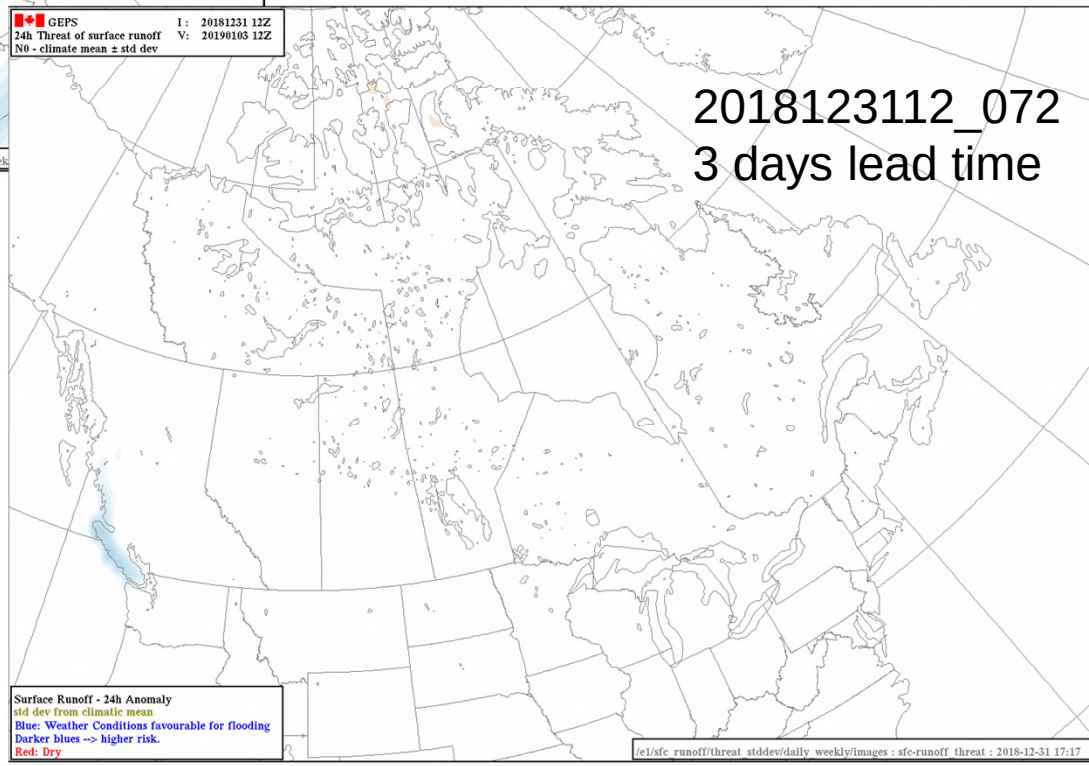


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GEPS surface runoff anomaly: 2/3



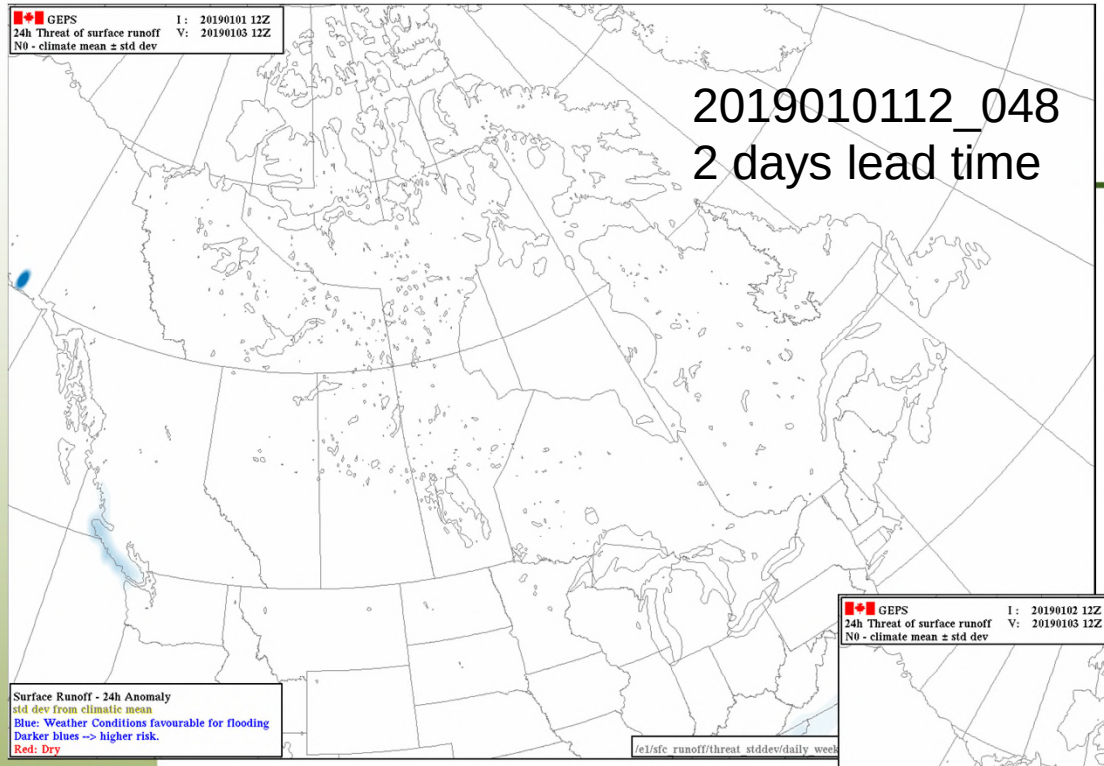
2018123012_096
4 days lead time



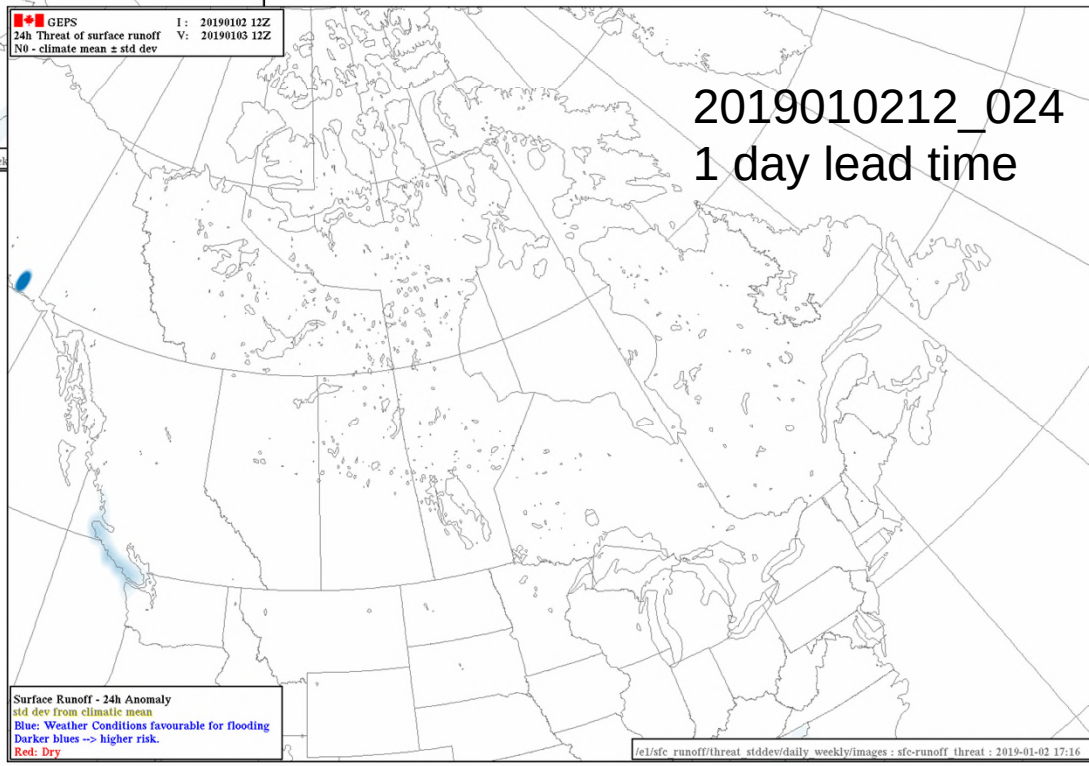
2018123112_072
3 days lead time

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GEPS surface runoff anomaly: 3/3



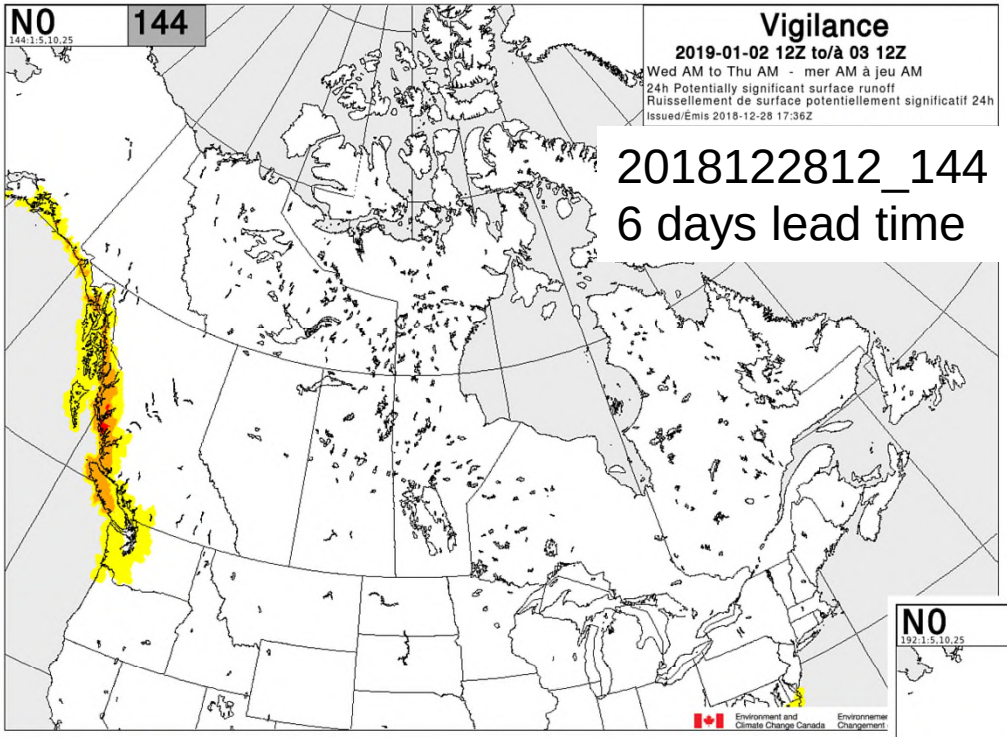
2019010112_048
2 days lead time



2019010212_024
1 day lead time

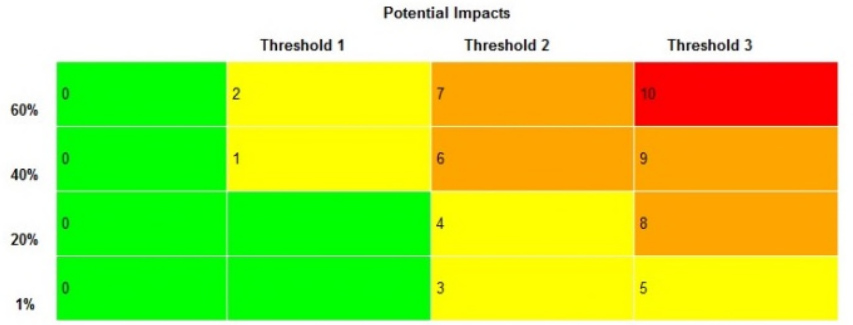
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GEPS surface runoff vigilance level



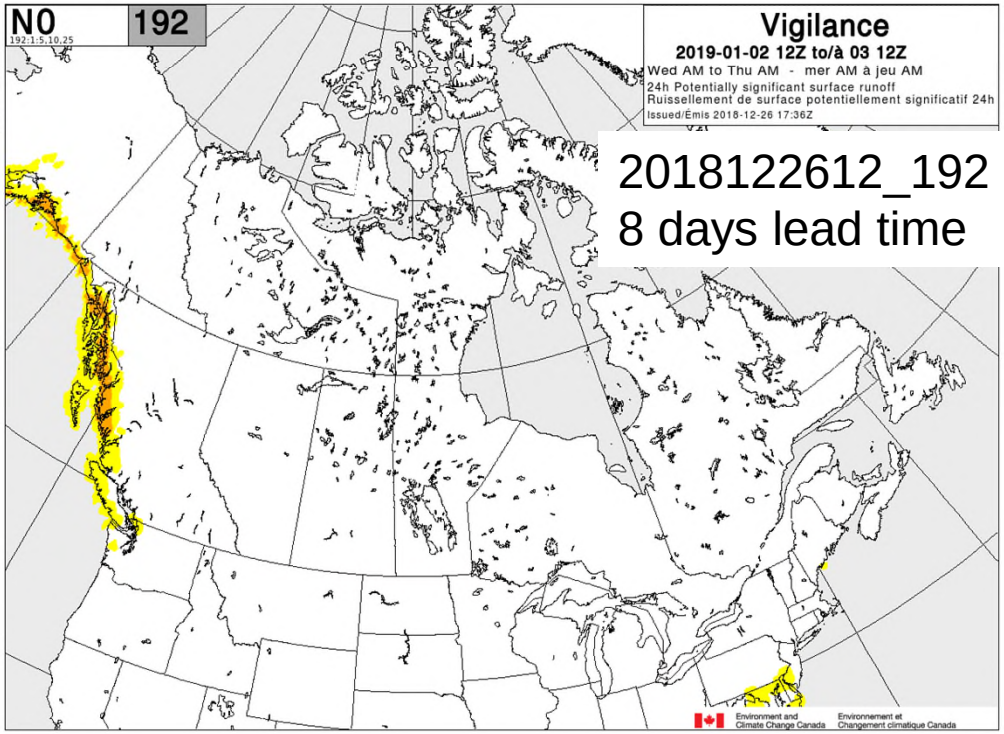
2018122812_144
6 days lead time

geps_vigilance_N0-threat_CA_2018122812_144



Be aware
Be prepared
Be extra cautious

thresholds:
5/10/25 mm



2018122612_192
8 days lead time

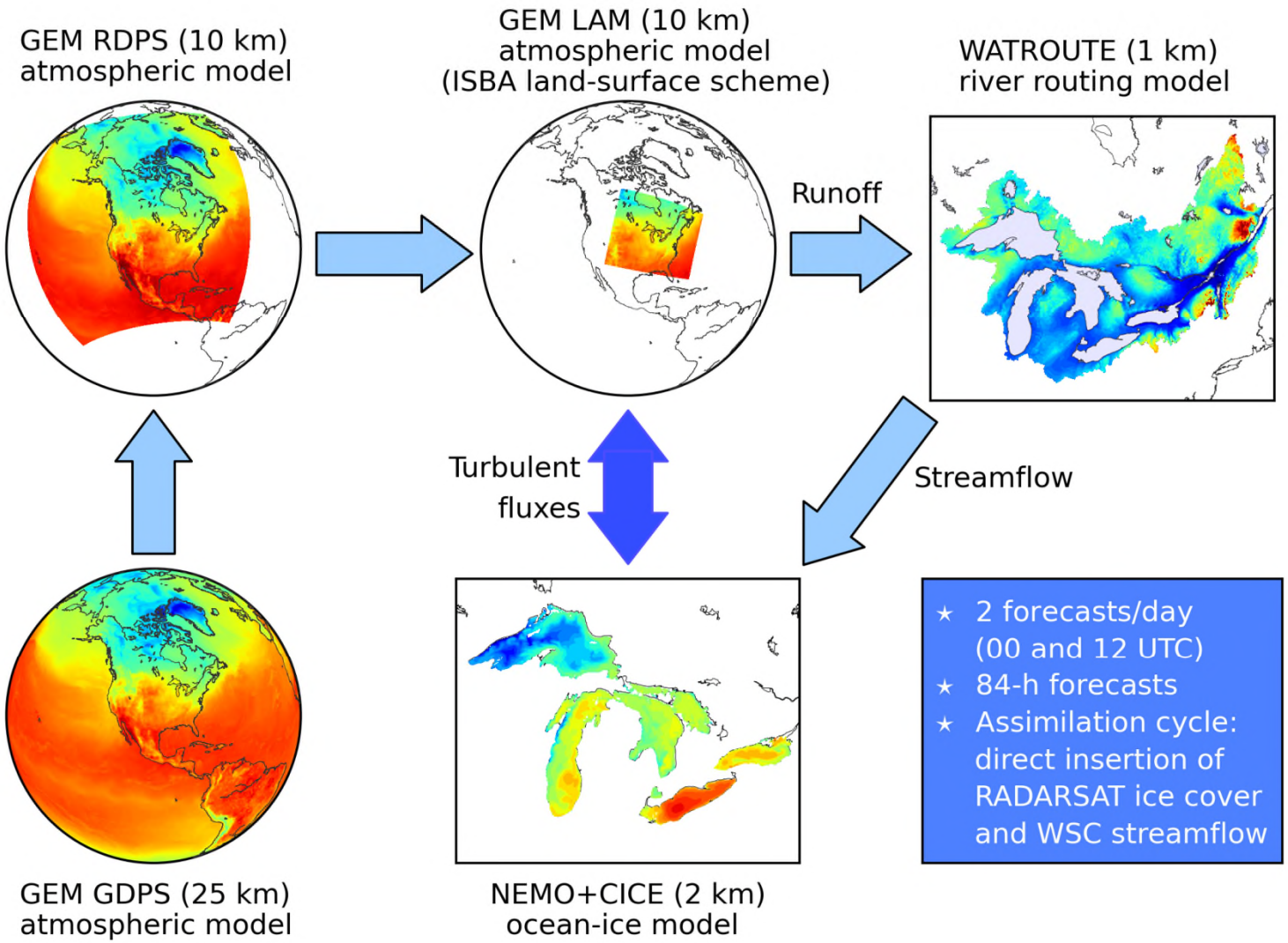
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Dedicated hydrological prediction systems

- WCPS-GLS
  - Water Cycle Prediction System – Great Lakes St. Lawrence River
  - a hydrologically closed system
    - precip → rivers → lakes → atmosphere
  - 3-day forecast
  - experimental in June 2016, operational in February 2019
- GEM-Hydro
  - weather forecasting systems optimised for hydrological performance
    - snowpack, soil moisture, surface runoff, drainage, river flows
  - initially Great Lakes - St Lawrence River and Nelson River basins, eventually: all major Canadian watersheds
  - initially 6 day forecast, extension to 10 days to be tested
  - to be presented to CPOP in 2019

WCPS-GLS: modelling system



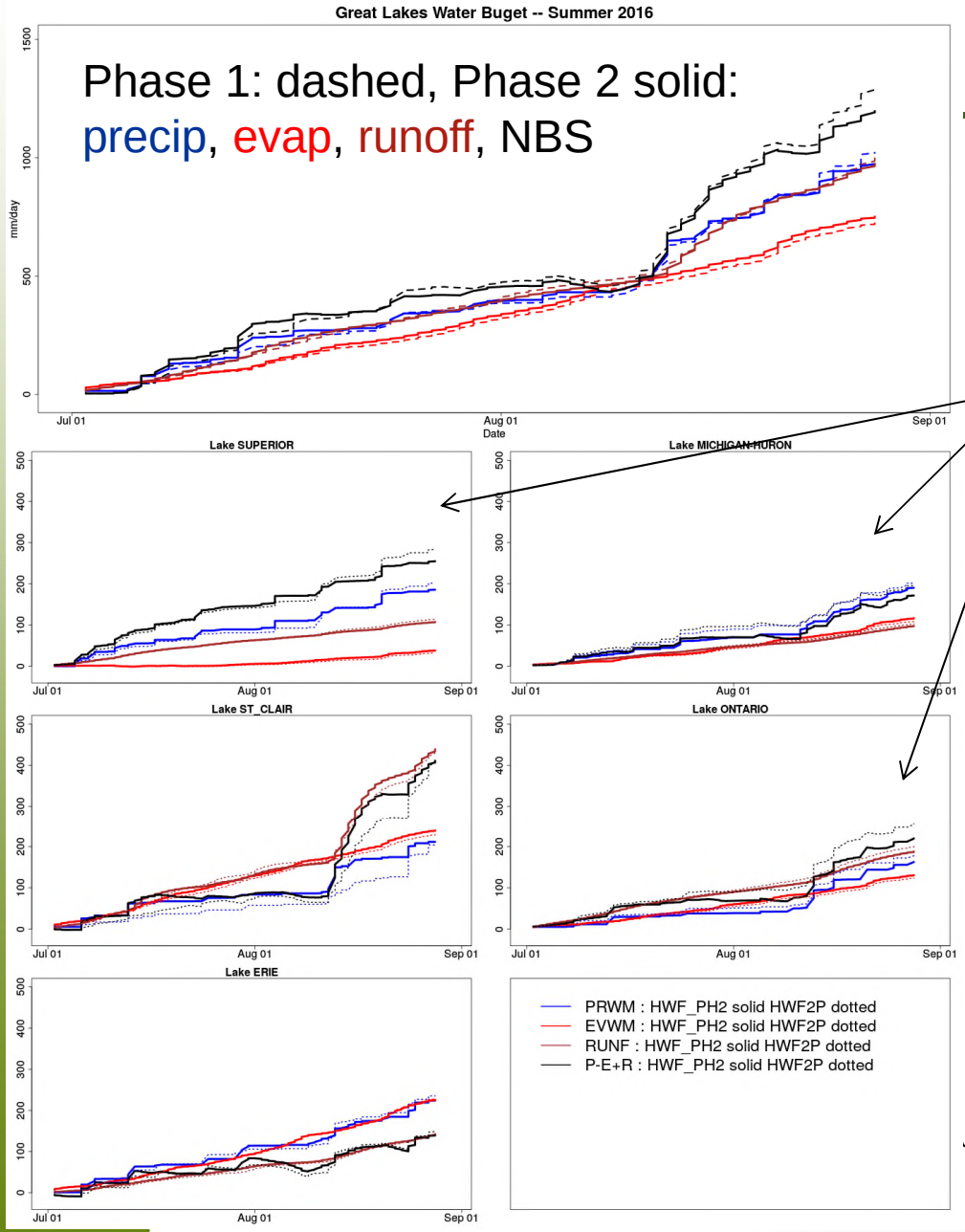
Animation

- http://iweb.cmc.ec.gc.ca/~afsgdod/movies/20180402_rain_DISC_LLA_WVMD_logo.mp4

Predicted fields of interest

- Atmosphere (10-km resolution):
  - precipitation onto lake surfaces (P)
  - surface runoff over land
- Rivers (1-km resolution):
  - terrestrial runoff into lakes (R)
  - river flows on land
- Lakes (2-km resolution):
  - evaporation from lake surfaces (E)
  - water level
- Component Net Basin Supply (NBS):
  - P – E + R

Component Net Basin Supply (NBS = P-E+R)



P: precip onto lake surface

E: evap from lake surface

R: total runoff into lake

Lakes Superior, Michigan-Huron, Ontario:

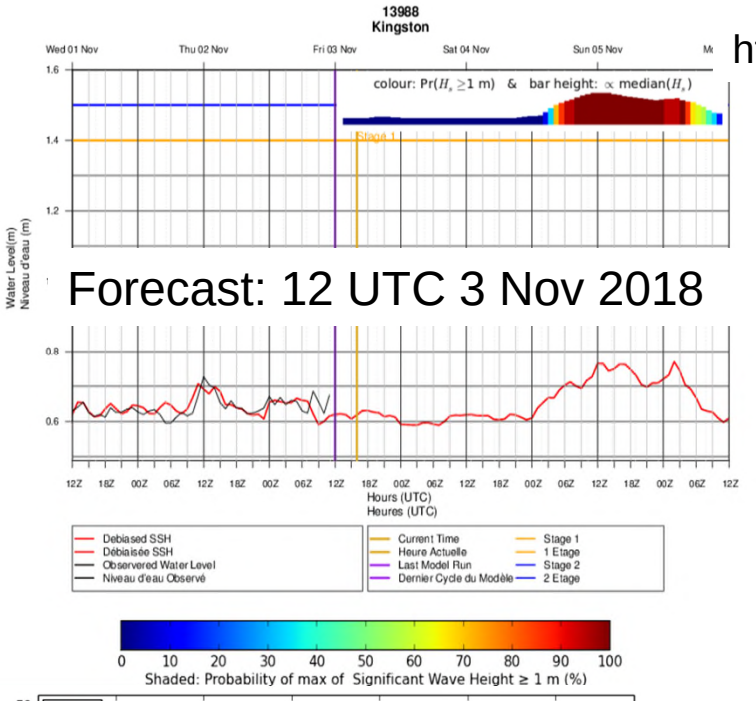
Component NBS is lower for proposed version (solid black line) vs current version (dashed black line)

Primary cause: lower precip to the lake surface in proposed version (solid blue line) vs current version (dashed blue line)

July 4, 2019

Canada

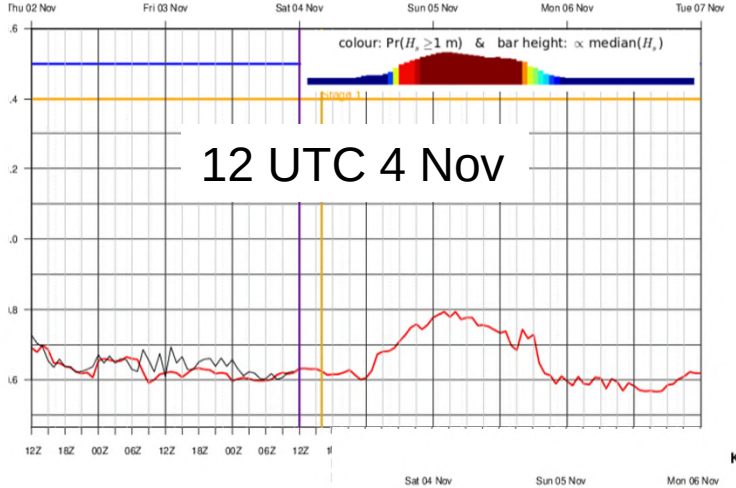
Products from WCPS forecasts to support MSC for the Lake Ontario – St. Lawrence River Board

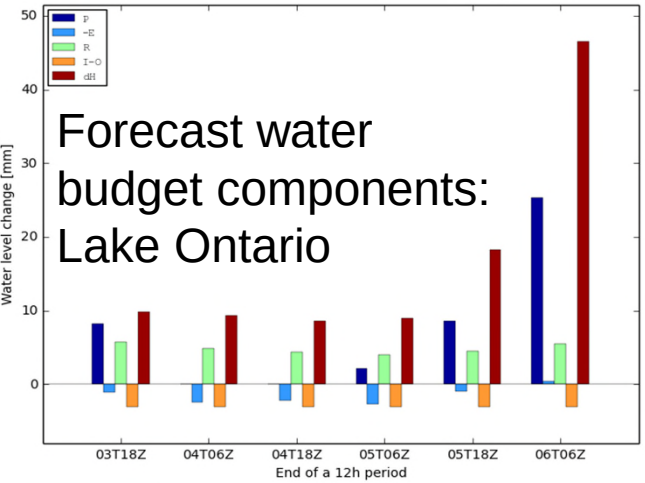


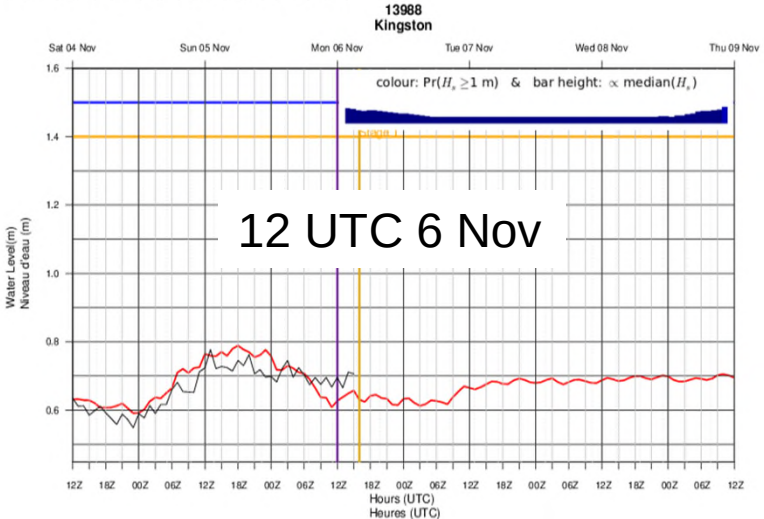
Forecast: 12 UTC 3 Nov 2018

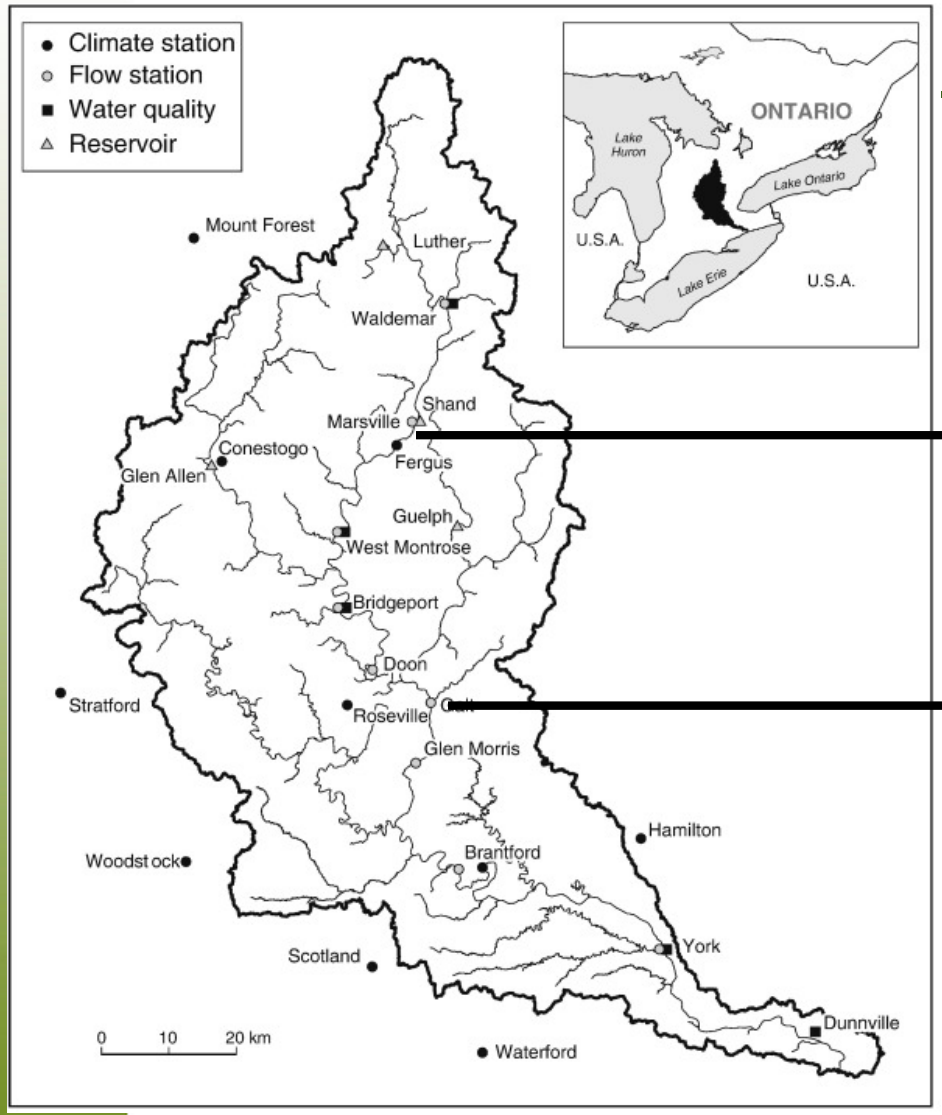
http://hpfx.science.gc.ca/~swas001/links/lsh_and_waves_ontario/

Forecast change in base water level at Kingston and forecast waves.





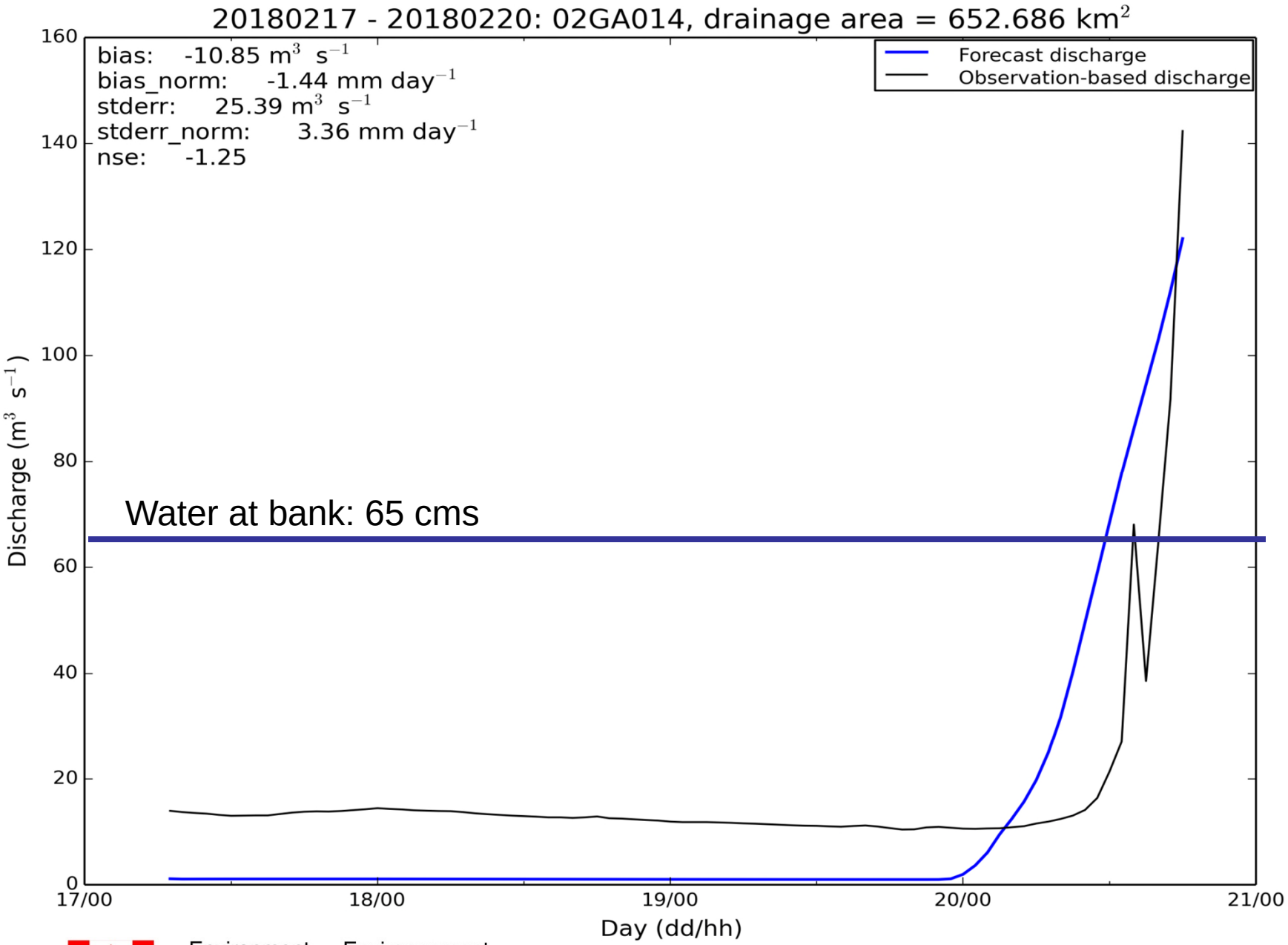




Drainage area: 650 km²
(approx. 3x2 grid points)

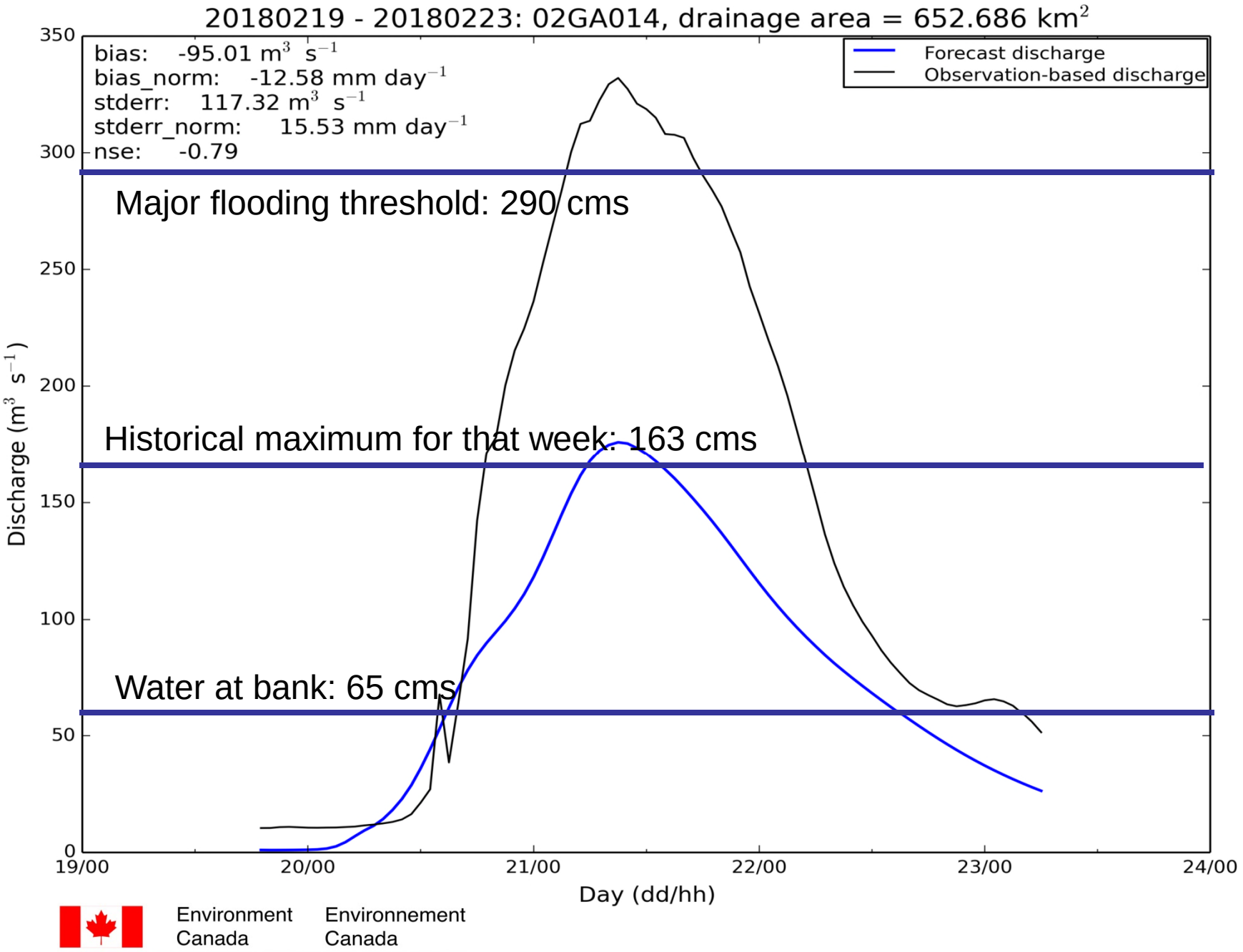
Drainage area: 3530 km²
(approx 6x6 grid points)

Forecast issued four days before the event for Grand River near Marsville



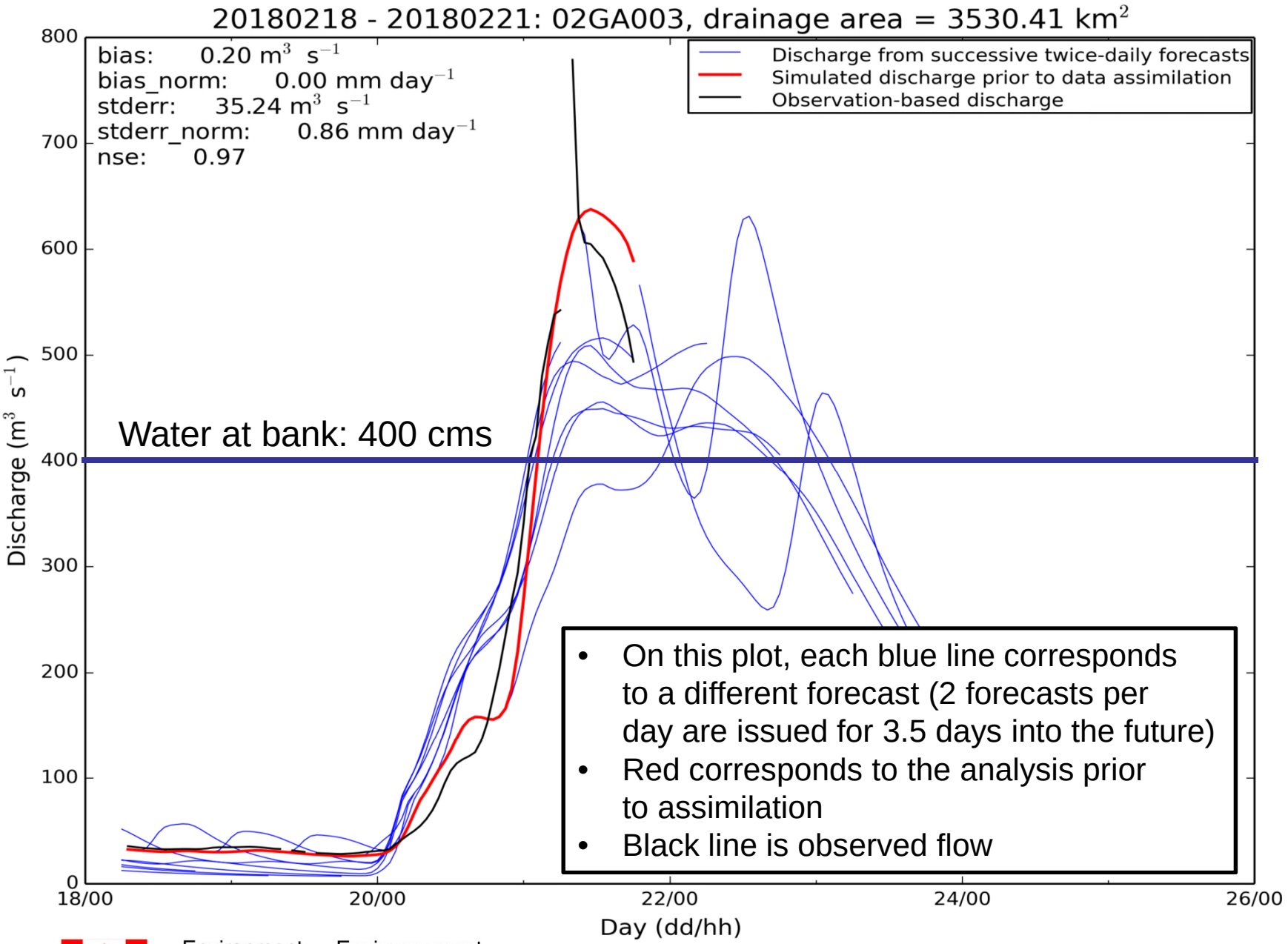
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Forecast issued one day before the event for Grand River near Marsville



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Successive twice-daily forecasts issued for the Grand River at Galt

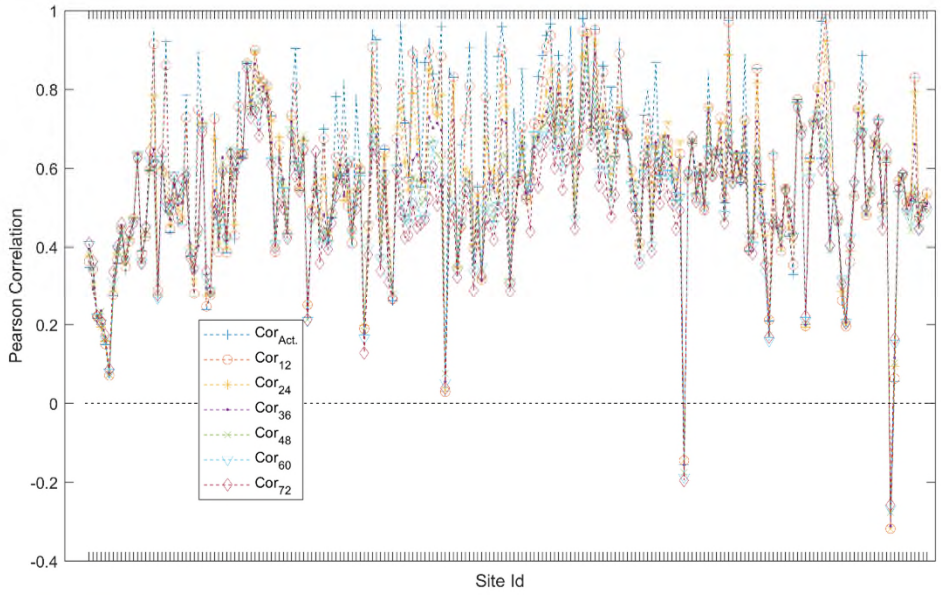


- On this plot, each blue line corresponds to a different forecast (2 forecasts per day are issued for 3.5 days into the future)
- Red corresponds to the analysis prior to assimilation
- Black line is observed flow

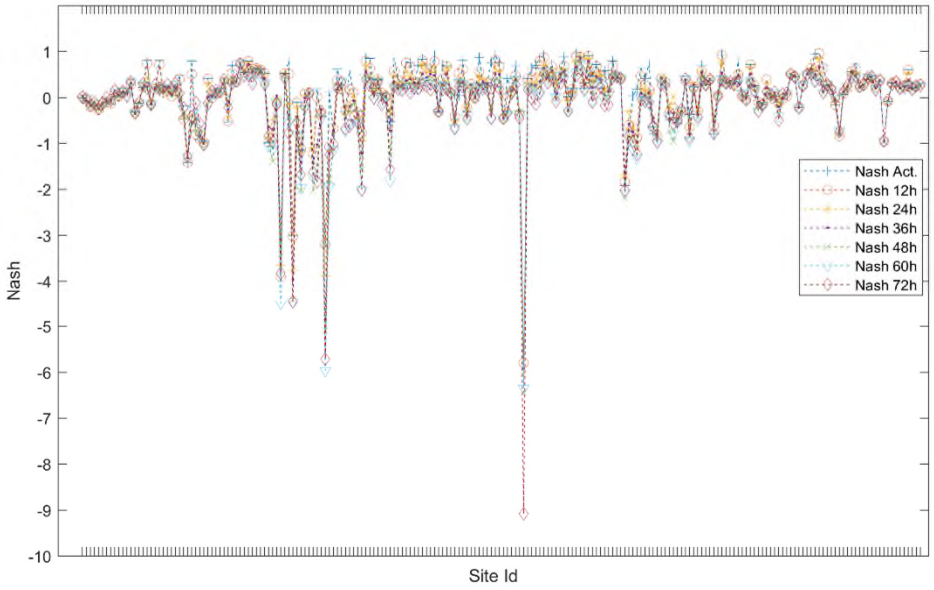
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Verification of simulated river flows: Scores by station for May 2016 – September 2017

Correlation coefficient



Nash-Sutcliffe Model Efficiency coefficient



84h forecast launched twice daily: 7 different forecasts valid simultaneously
45% of watersheds have correlation coefficients values larger than 0.65
Nash and correlation values vary little with lead time
Best scores: data assimilation cycle (hindcast)

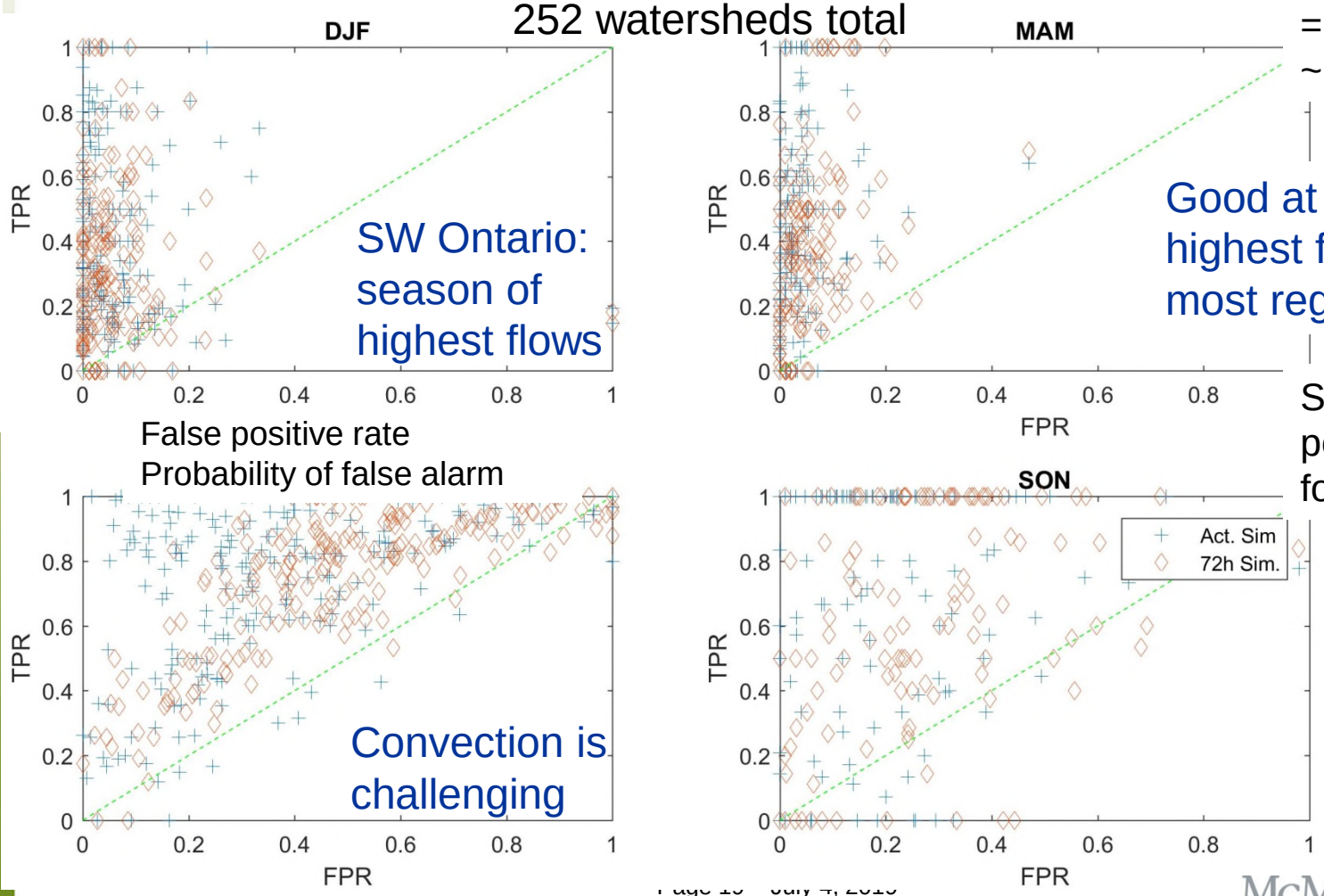
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McMaster University FloodNet NSERC Canada

Verification of simulated river flows: Receiver Operating Characteristic (ROC) curve for May 2016 – September 2017

72-h forecasts perform as well as the open loop hindcast (data assimilation cycle)

Each point represents a watershed;
252 watersheds total



SW Ontario: season of highest flows

Convection is challenging

Good at snowmelt: highest flows in most regions

For return period = 1.25 years ~ start of flood

Stats based on period of record for each gauge

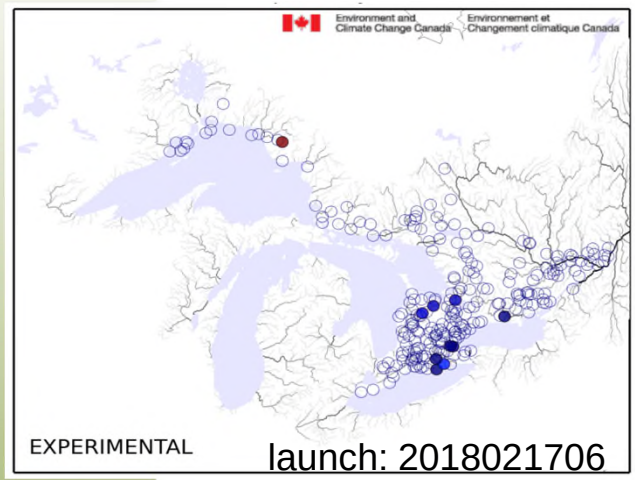
Environment Canada Environnement Canada

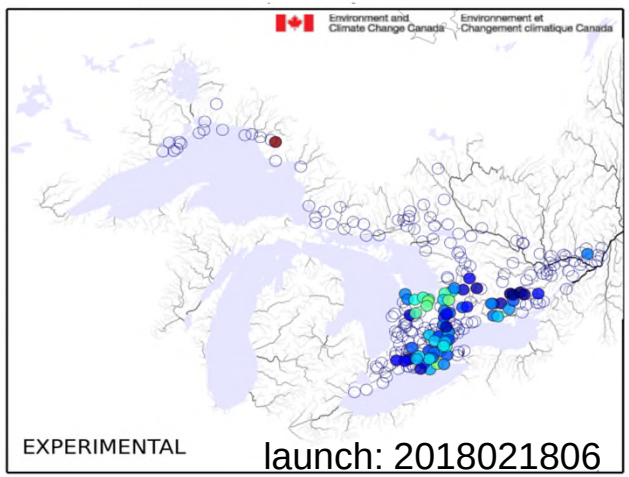
McMaster University

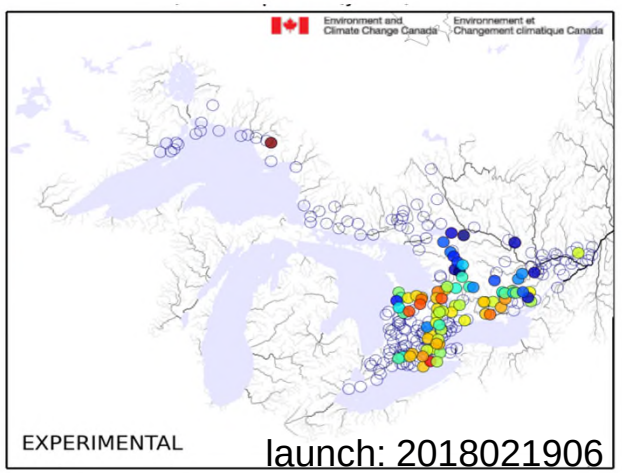
FloodNet NSERC

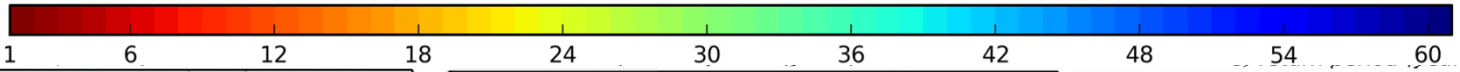
Water Cycle Prediction System

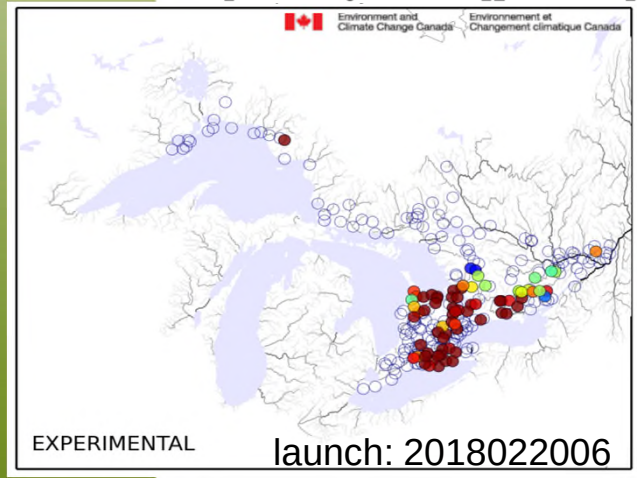
Preliminary version of planned product:
The forecast hour at which the flow of the 5-year return period is first met or exceeded

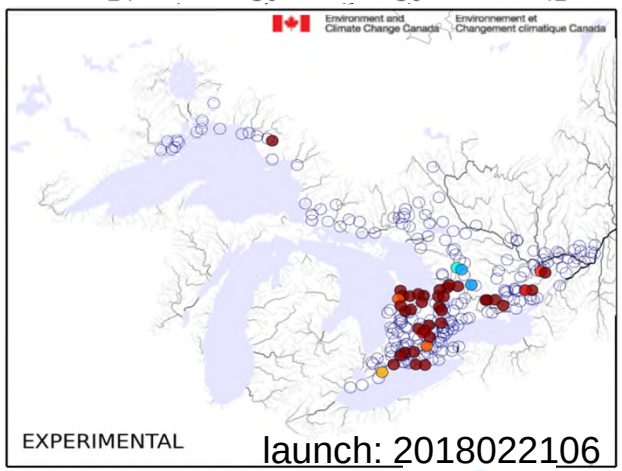


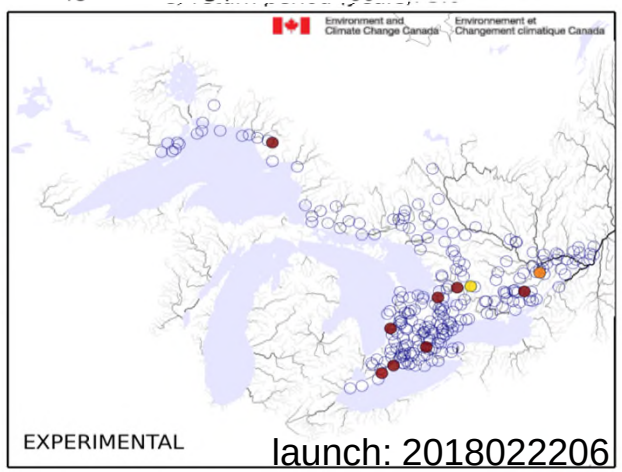










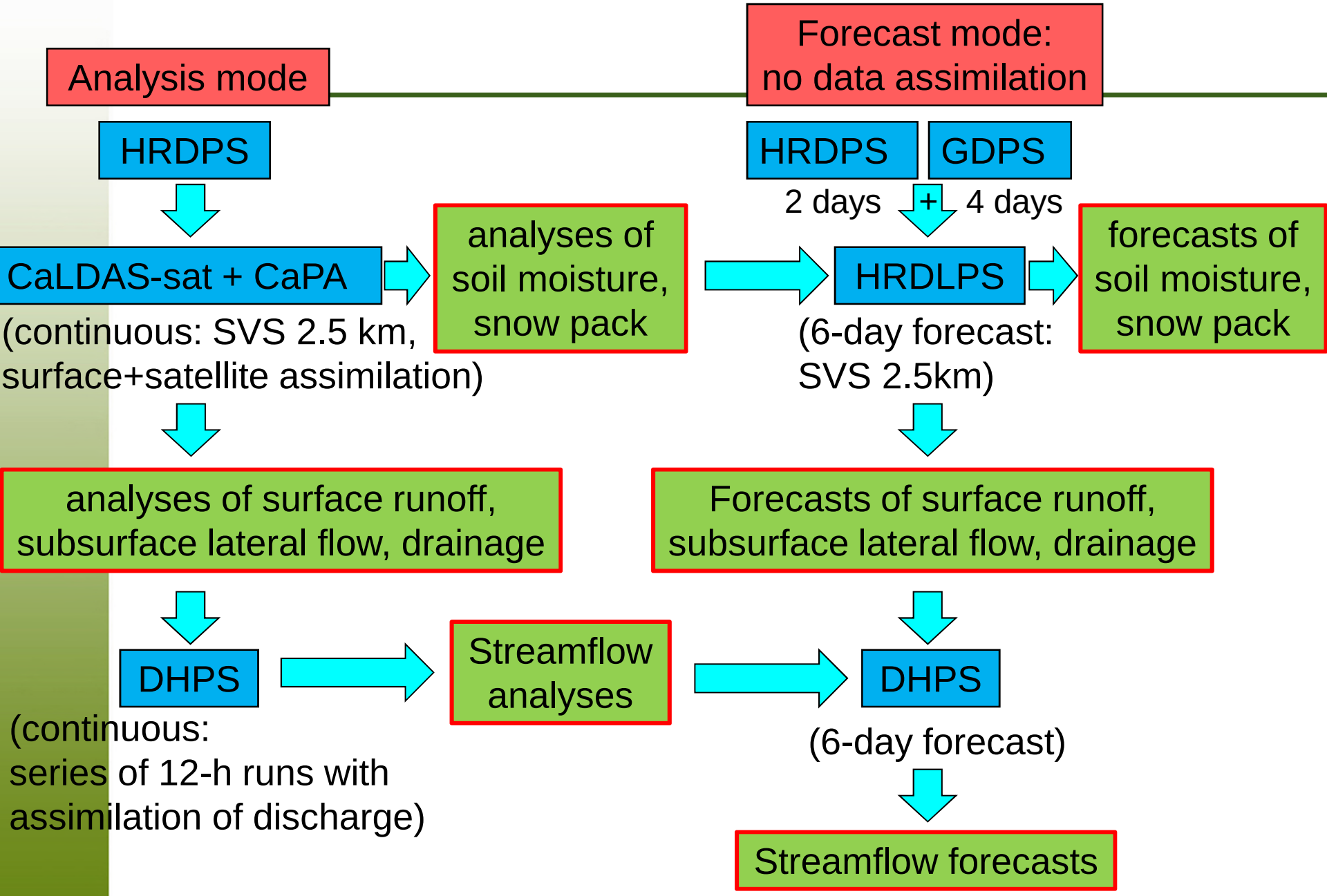


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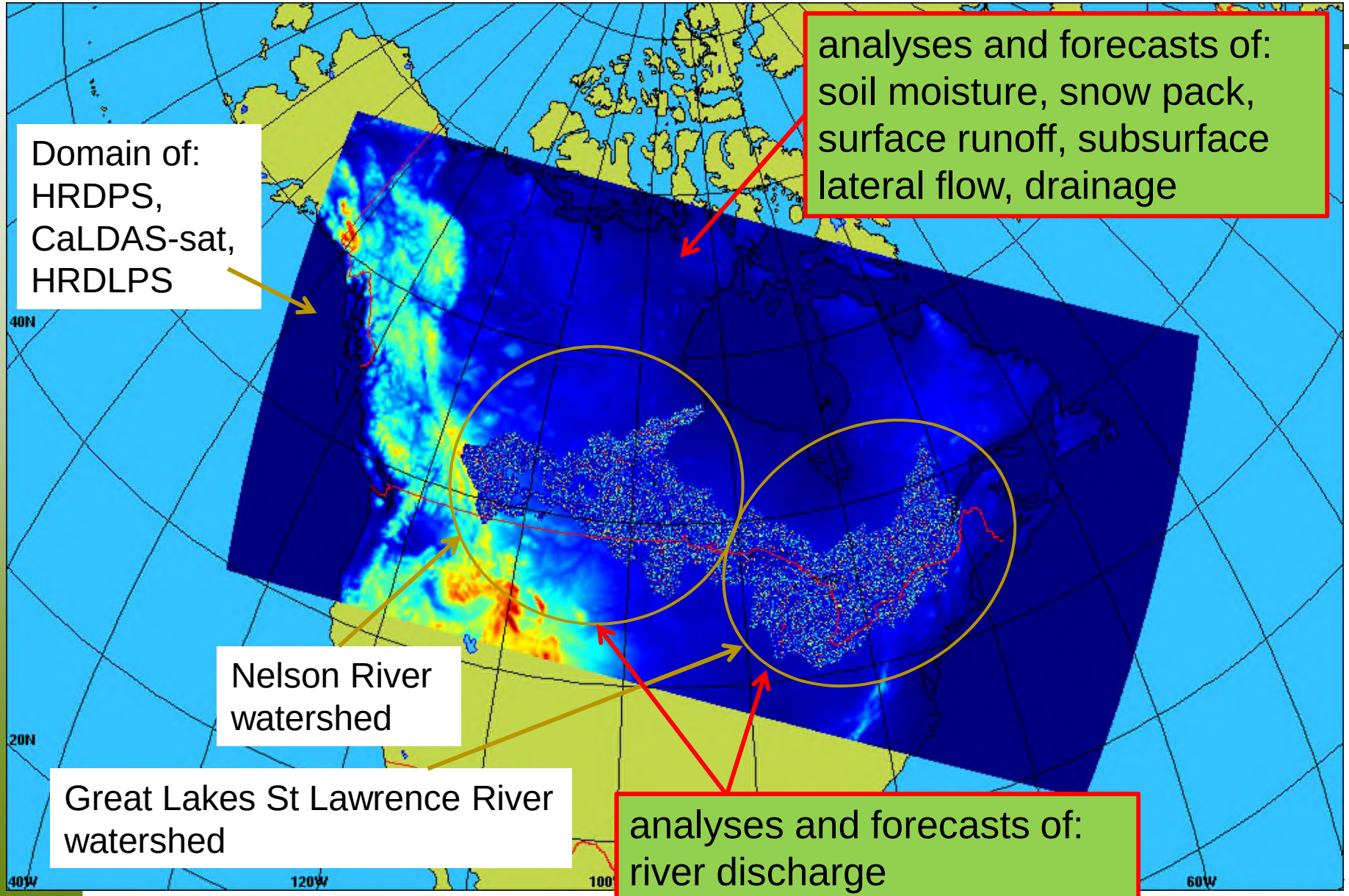
McMaster University FloodNet NSERC

Canada

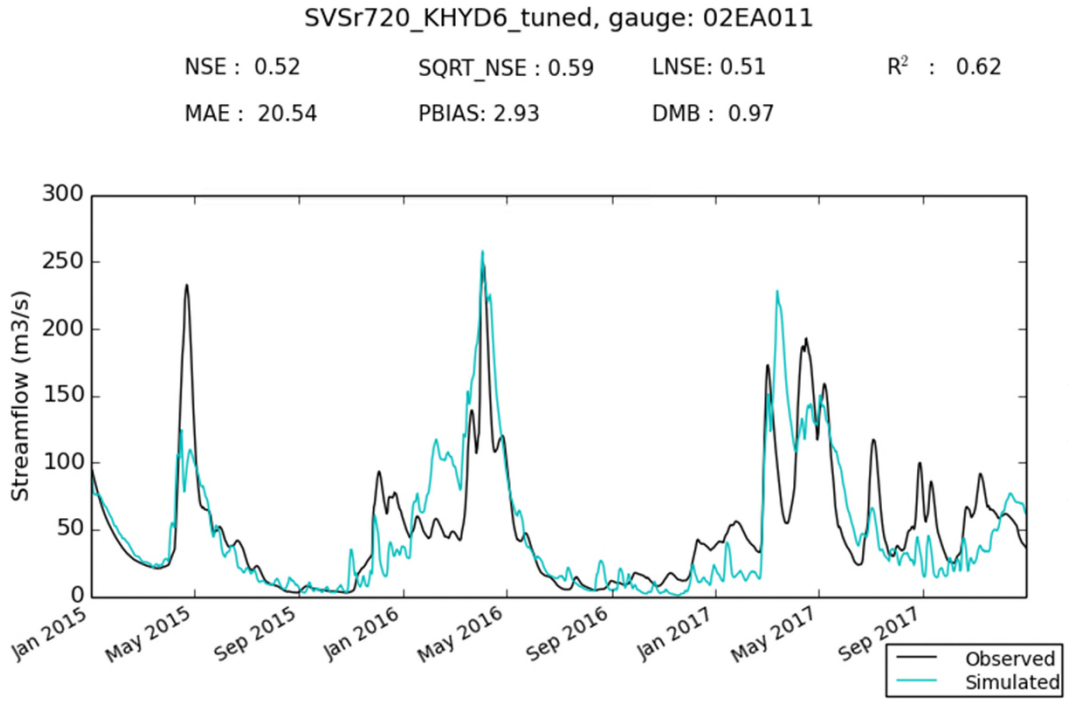
GEM-Hydro: optimized for hydrology



Watersheds for initial delivery of GEM-Hydro

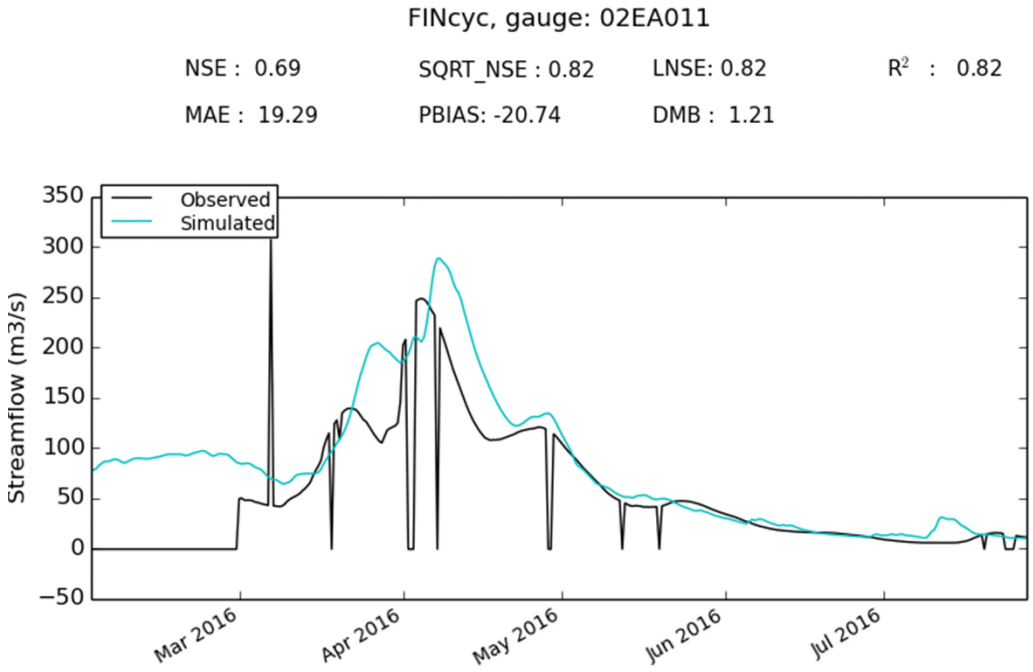


open loop run vs GEM-Hydro's streamflow analyses



Open loop multi-year run

- RDPS piloting + CaPA precip
- no discharge obs assimilated
- tuned SVS

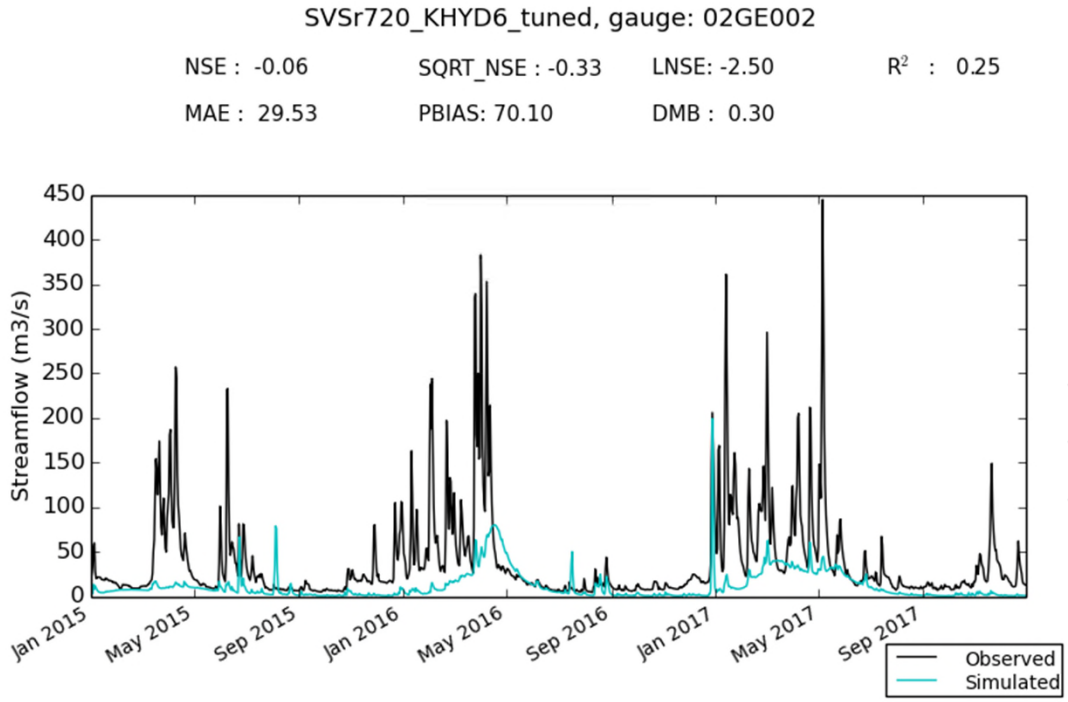


GEM-Hydro's data assimilation cycle

- surface runoff and drainage: median of CaLDAS-sat members
- insertion of discharge observations
- default SVS

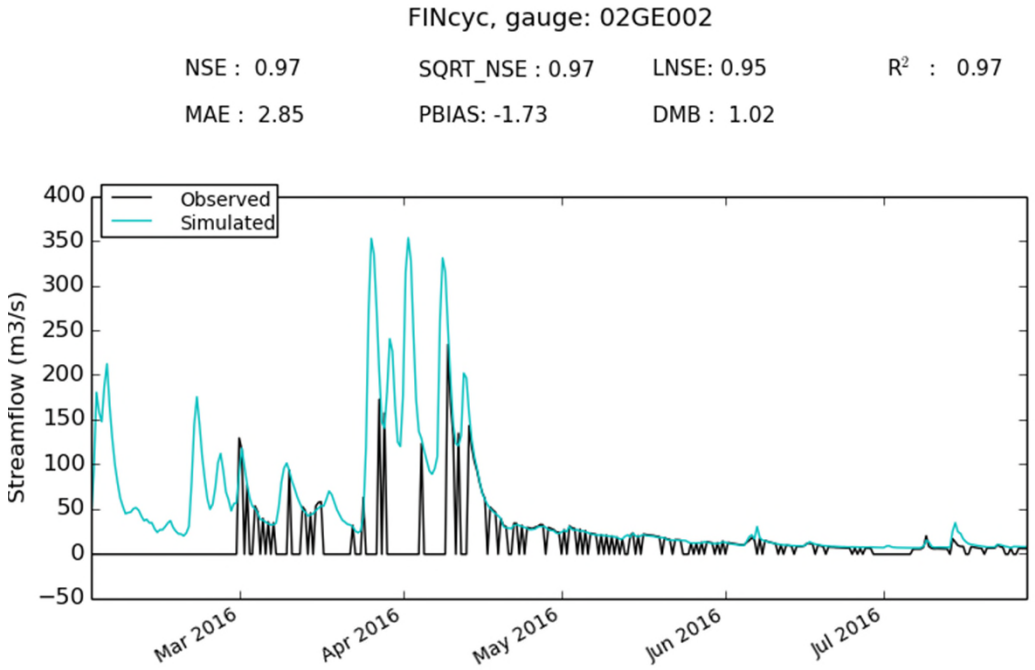
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open loop run vs GEM-Hydro's streamflow analyses



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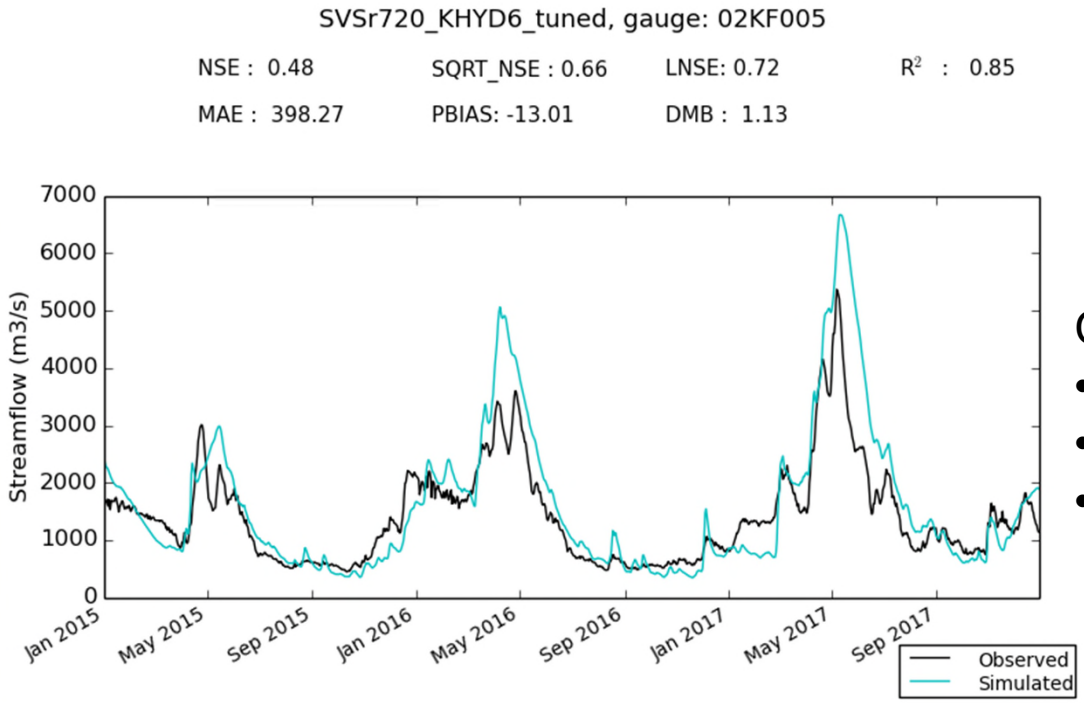
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GEM-Hydro's data assimilation cycle

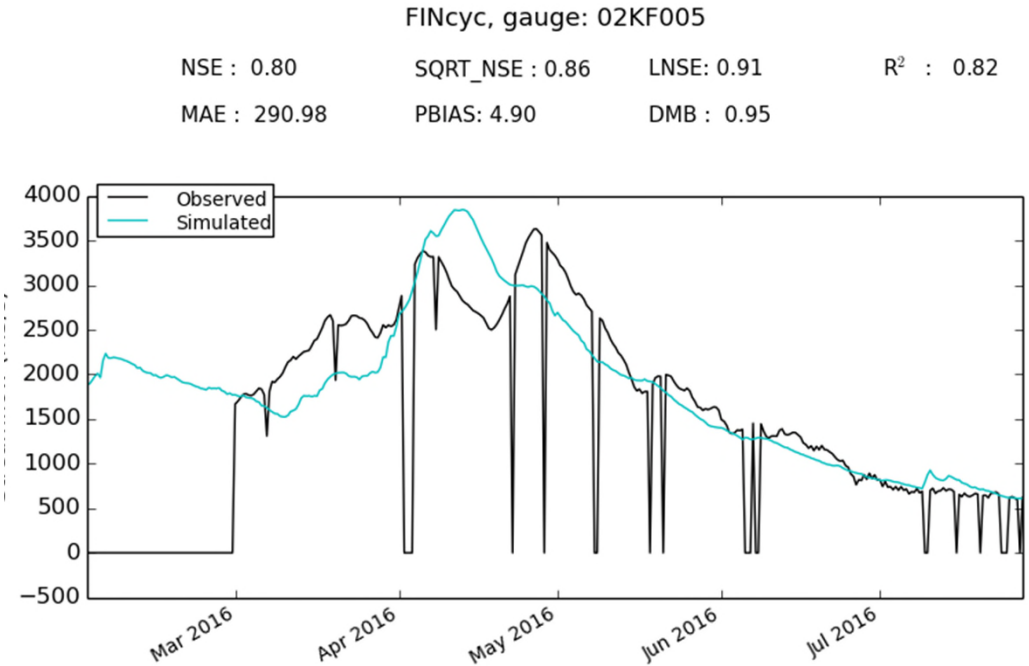
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open loop run vs GEM-Hydro's streamflow analyses



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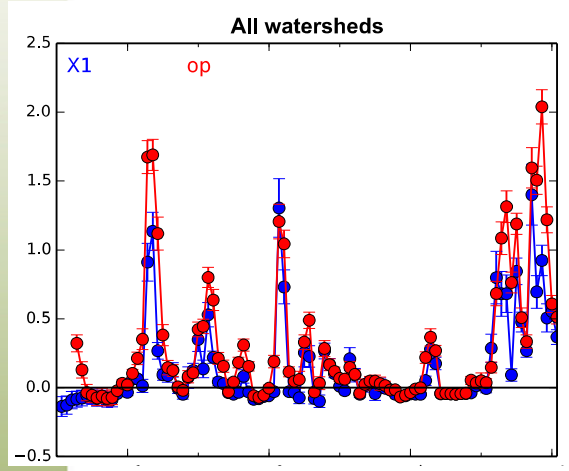
GEM-Hydro's data assimilation cycle

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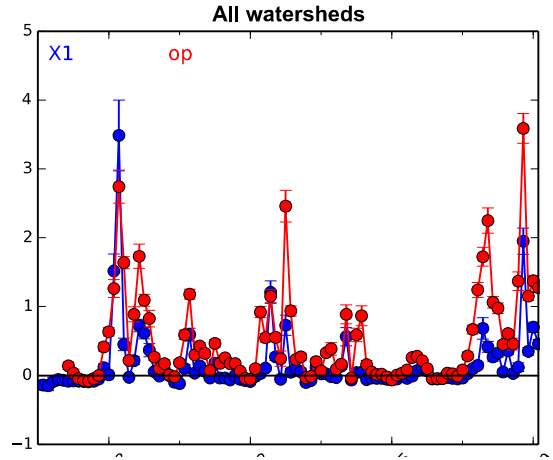
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GEM-Hydro vs DHPS piloted by HRDPS/GDPS
1 July – 19 August 2016
Great Lakes St Lawrence River watershed

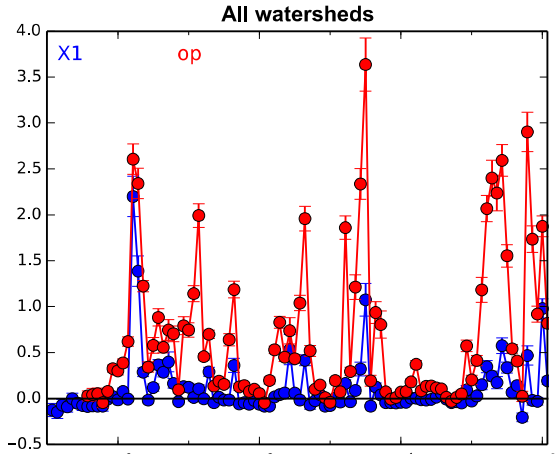
Bias normalized by drainage area (mm/day)



F036-048

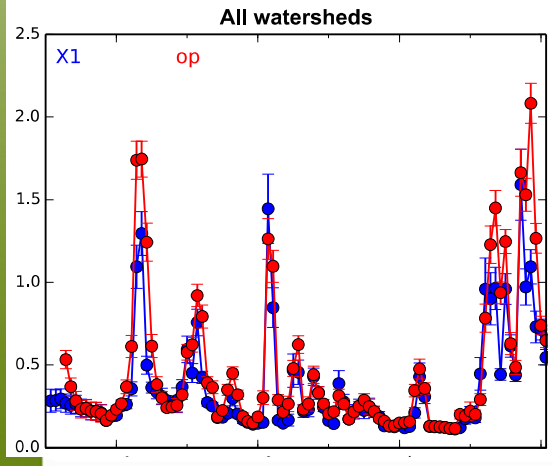


F060-072

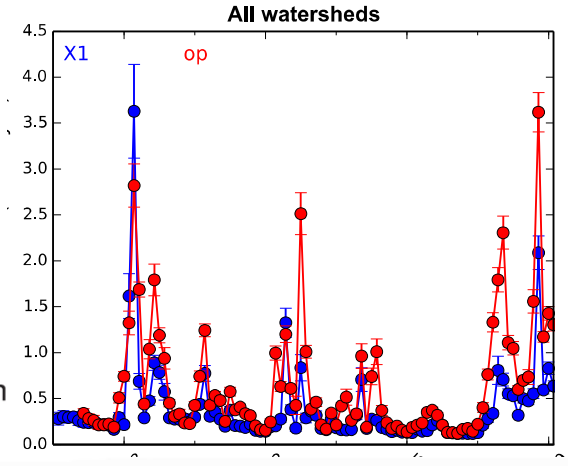


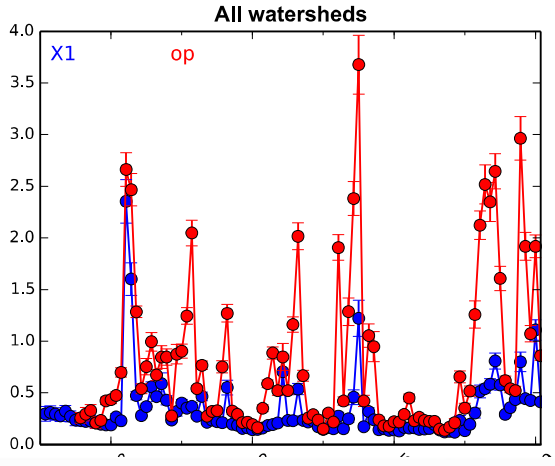
F084-096

MAE normalized by drainage area (mm/day)



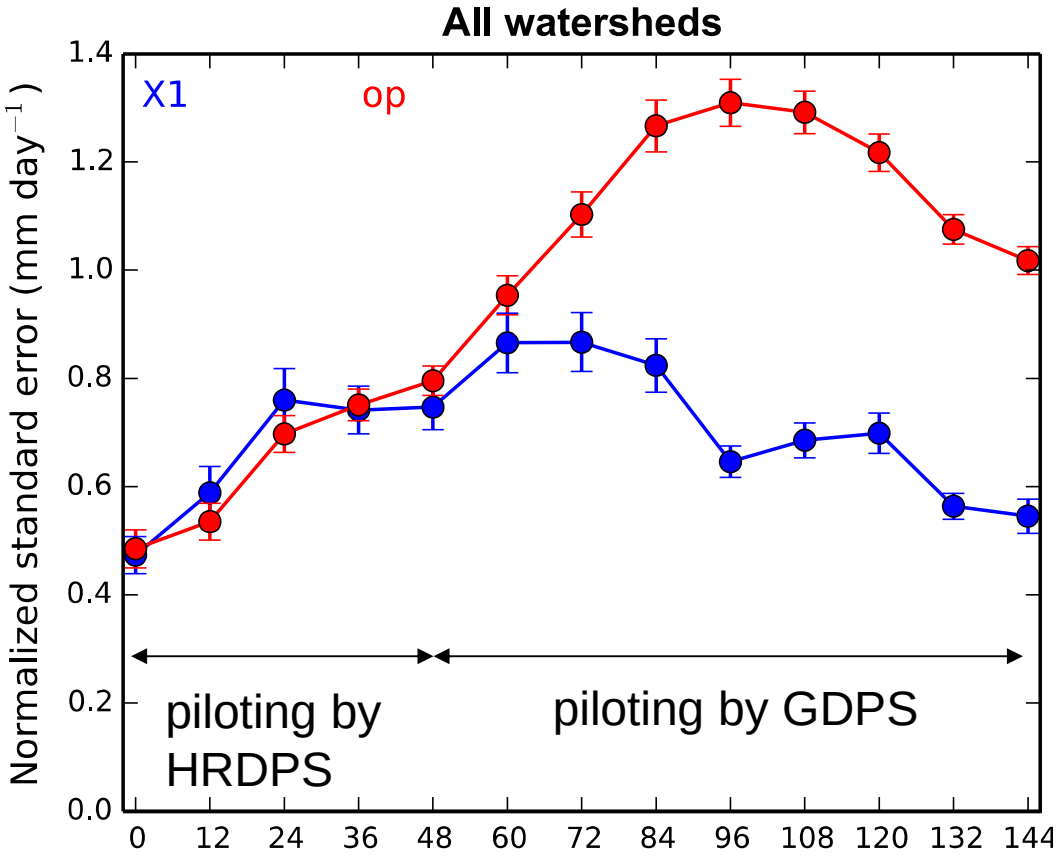
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GEM-Hydro vs DHPS piloted by HRDPS/GDPS
1 July – 19 August 2016
Great Lakes St Lawrence River watershed

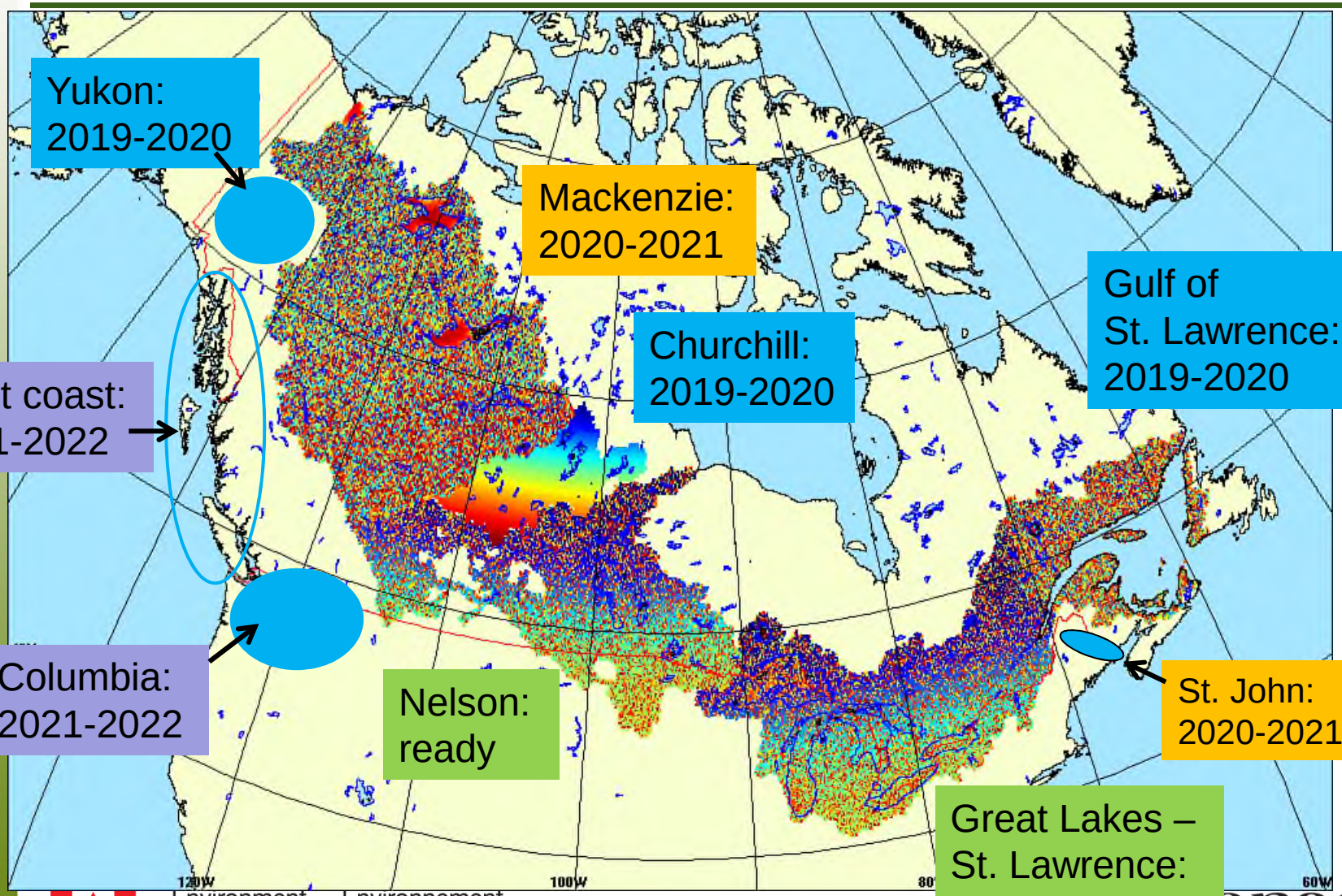
Standard error normalized by drainage area (mm/day)



The biggest gain from GEM-Hydro is after day 2

The maintenance of the scores through day 6 encourages the extension of the forecast to day 10

Watersheds to be delivered later for GEM-Hydro



Known users of hydrological estimates from atmospheric models

- Government Operations Centre (GOC)
- Regional forecasters

- These products are currently available only to internal clients
- Formal verification is underway so that they can become operational products and made available to external clients

Known users of WCPS

- Water levels, surface temperatures, surface currents, ice cover
  - Lake water management by Burlington Forecast Office (MSC)
  - Canadian Coast Guard: e-navigation trip planning system; search and rescue
  - Oil spill response for Ocean Protection Plan (OPP)
  - CIS ice charts
  - Province of Ontario
- Precipitation onto and evaporation from lakes:
  - Lake water management by Burlington Forecast Office (MSC)
  - International Joint Commission's Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic data
- River flows:
  - Lake water management by Burlington Forecast Office (MSC)
  - International Joint Commission's Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic data
  - Water Survey of Canada (WSC)
  - Department of Fisheries and Oceans (DFO)
  - Dispositif d'Alerte et de Vigilance pour les Embâcles de glace (DAVE; NRCan)
  - Provinces of Quebec and Ontario
  - Ontario Power Generation (OPG)
  - University researchers

Data dissemination for external clients: products from operational models

- Datamart:
  - output format: GRIB2
  - 24/7 infrastructure, business hours user support
  - http://dd.weather.ec.gc.ca
- GeoMet web map service (WMS):
  - output formats: GeoJSON, CSV, Shapefile etc.
  - selection and reprojection of region of interest
  - real-time and archived
  - 24/7 support
  - http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=C0D9B3D8-1
  - 6,000 layers: MSC numerical weather prediction, radar
  - Over half a billion maps/data served in 2017
- Can arrange feed of data
- Credit to ECCC should be mentioned

Data dissemination for external clients: products from experimental systems

- RPN-WMS web map service
- http://collaboration.cmc.ec.gc.ca/cmc/hydro/www/adaguc
- business hours support by R&D personnel
- can fetch data automatically using script