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Progress with HYPE Hydrological Modelling

Theme A2 & A5 Contributions

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University of Manitoba

HQP Contributing to this Work

- Ajay Bajracharya, SJ Kim, Marie Broeky, Andrew Tefs, Scott Pokorny, Rodell Salonga

Acknowledgements to our Partners

Climate Change Service
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Manitoba Hydro
University of Manitoba
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University of Saskatchewan
Global Water Futures
Global Institute for Water Security
GWF.USASK.CA

University of Manitoba

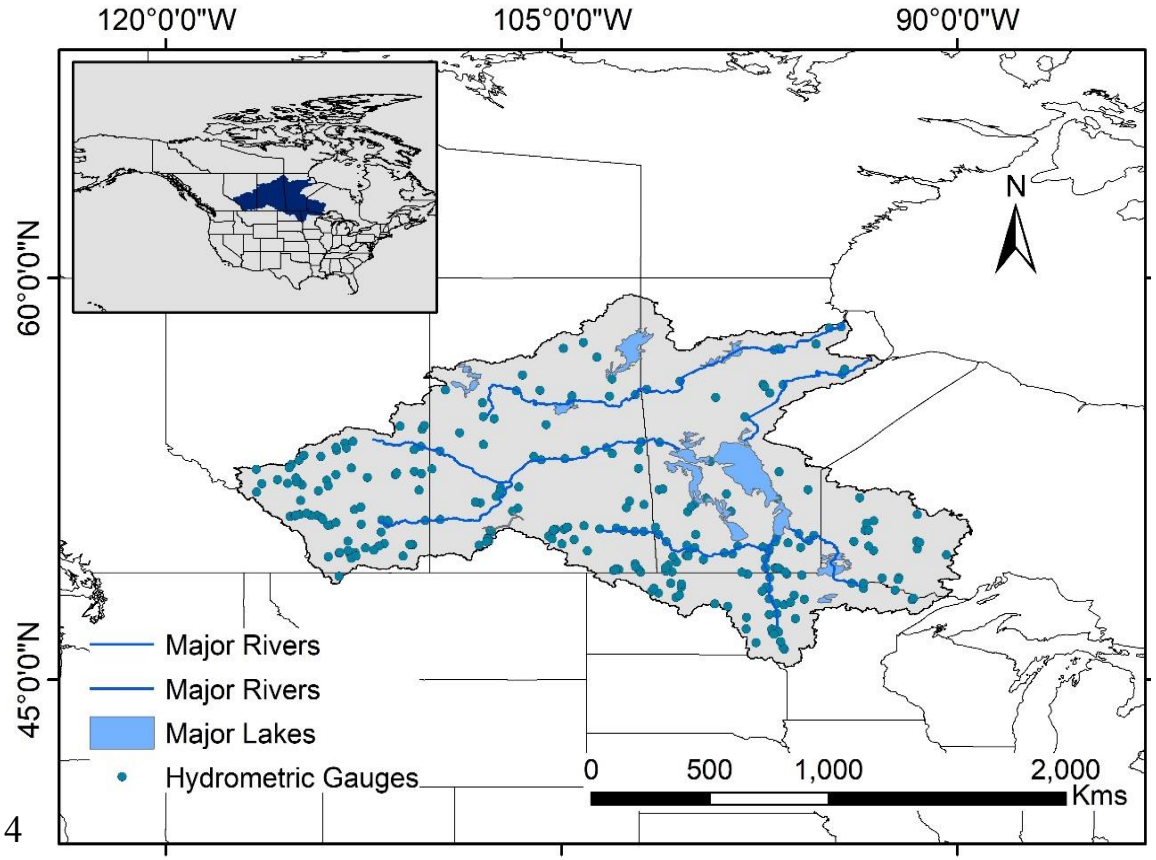
Outline

1. HYPE Modelling
   - From regional to pan-Arctic implementations
   - Interfacing with Theme B1
2. C3s Project
3. Theme A2: Frozen Soil Validation
4. Theme A5: GRIP-E multi-model study
   - HYPE in the Lake Erie Basin
5. Contributions over past year

1. HYPE Modelling

MacDonald et al., in review
Stadnyk et al., in press

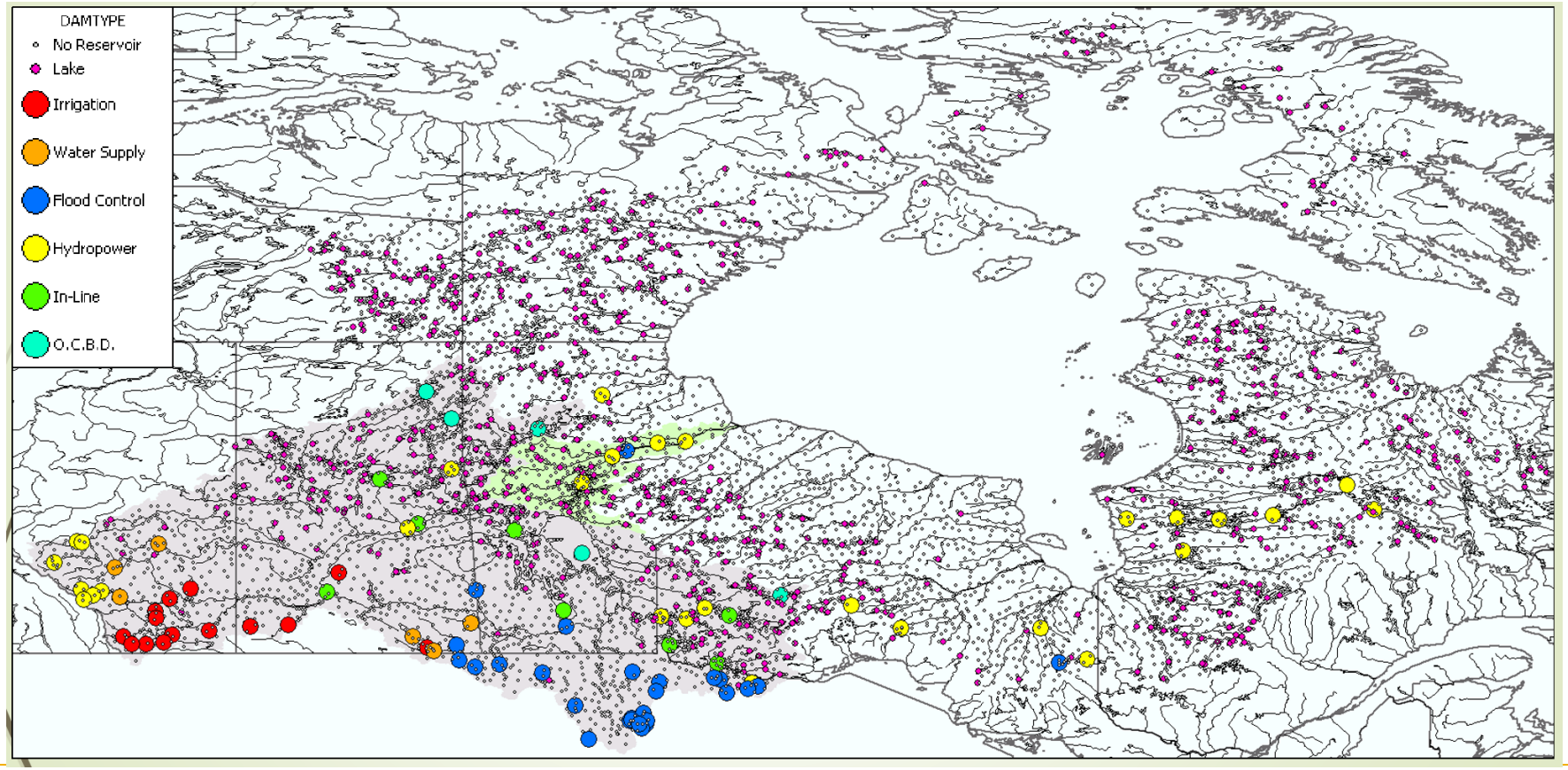
- Nelson-Churchill River Basin (NCRB) Hydrologic Predictions for the Environment (HYPE) model developed by UM
  - Added lakes, frozen soils, prairie potholes, diversions, and reservoir regulation



- Δt: daily
- Area: 1.4 million km^2
- Precip & Temp: WFDEI
- Topography: Hydro1K
- Soils: HWSD
- Land use: Globcover
- Lakes & wetlands: GLWD
- Basic regulation types:
  - flood control
  - hydropower
  - irrigation supply
  - diversions

Tefs et al., in prep.

HYPE Regulation: Hudson Bay Drainage Basin (HBDB)



Andrew Tefs
Scott Pokorny
Stadnyk et al (in press)

Continental-Scale Climate Change (HBDB)

I.iv

The Freshwater System

AUTHORS
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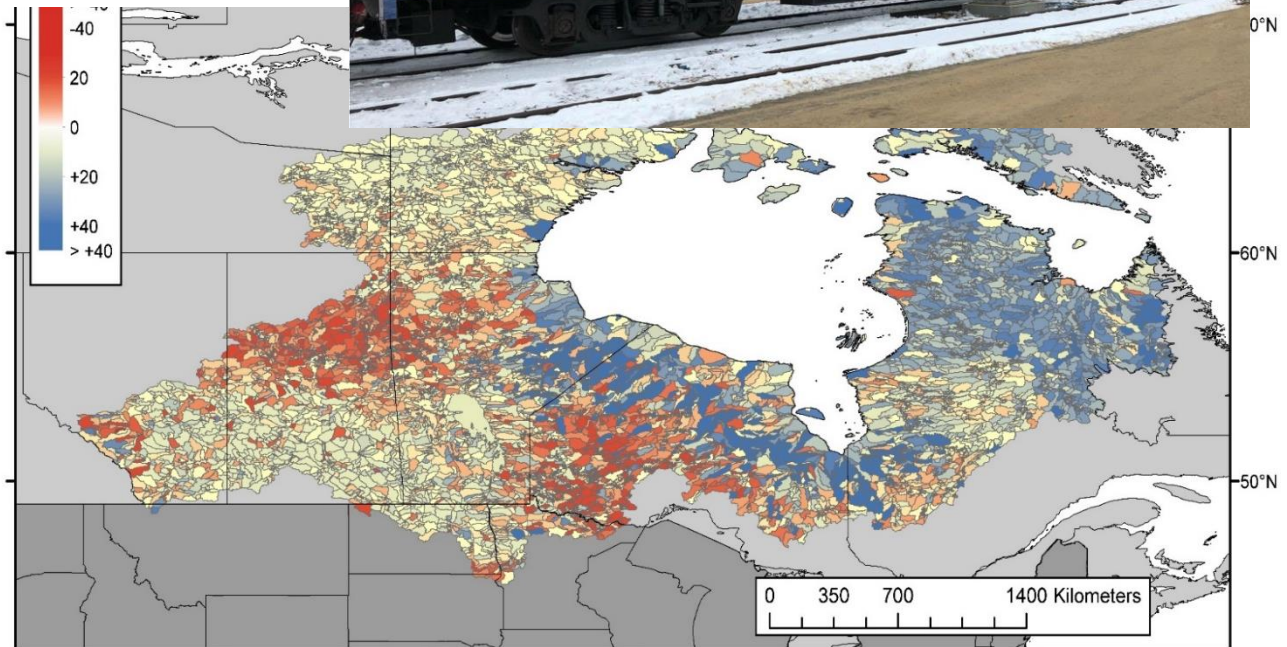
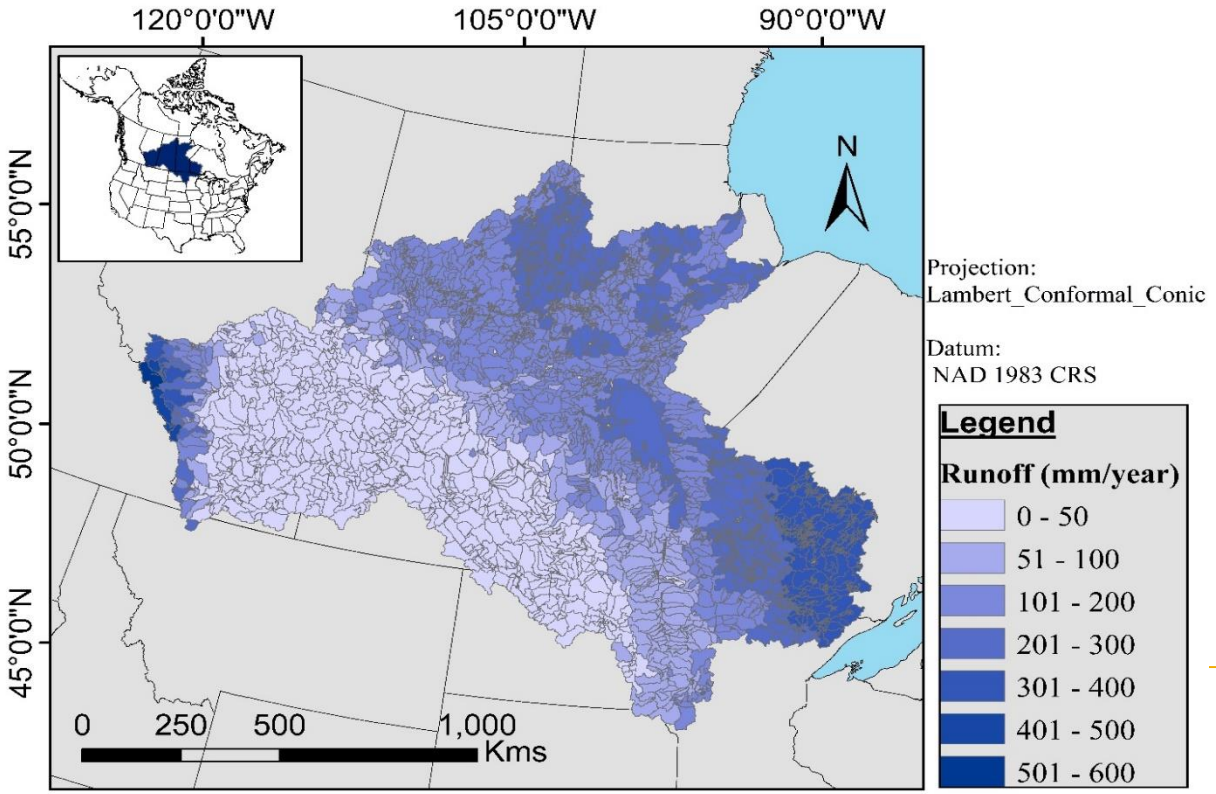
Summary



- Results publish
  Regional Impac
- Knowledge Mo
  www.expeditionchu

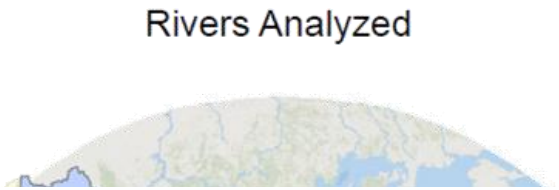
Application: ECCC Network Optimisation

- Provided ungauged runoff in the NCRB to assist with network optimisation exercise for ECCC



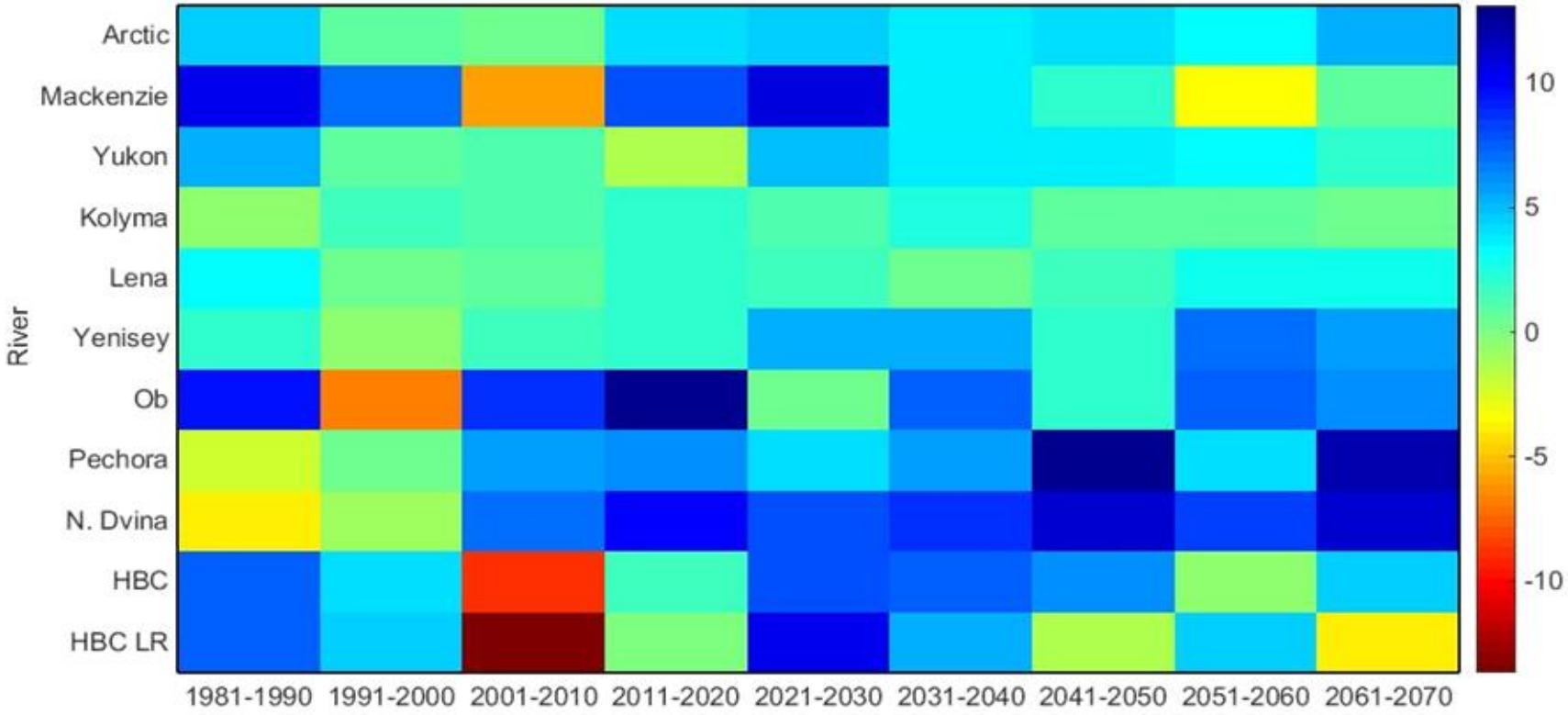
Marie Broesky

Pan-Arctic Domain



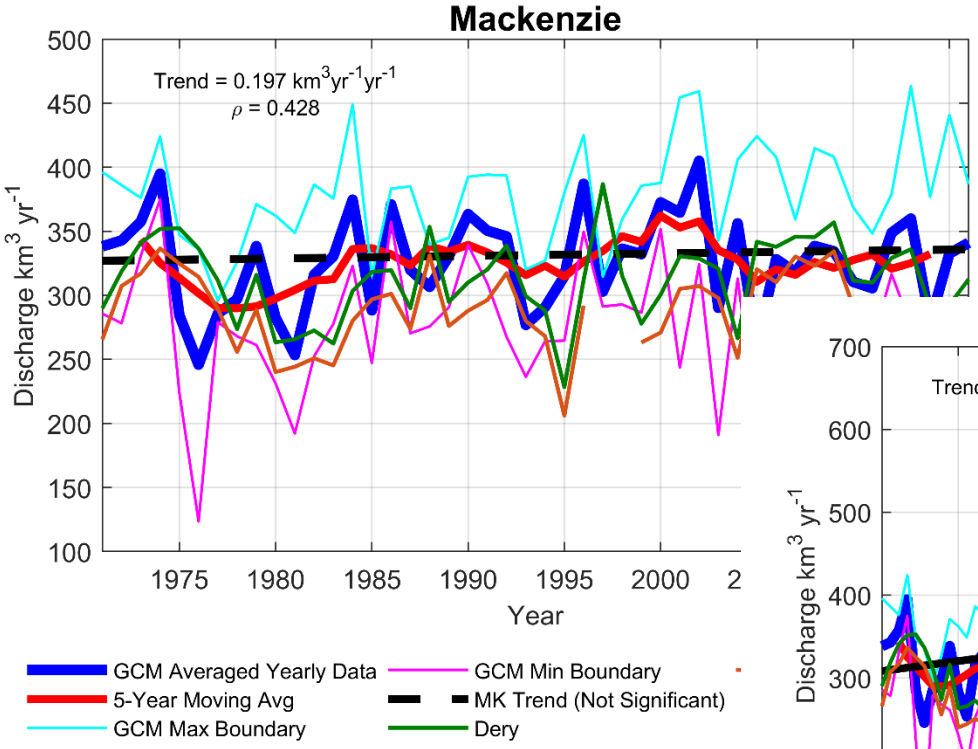
NSE/KGE
- <0
- 0 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75

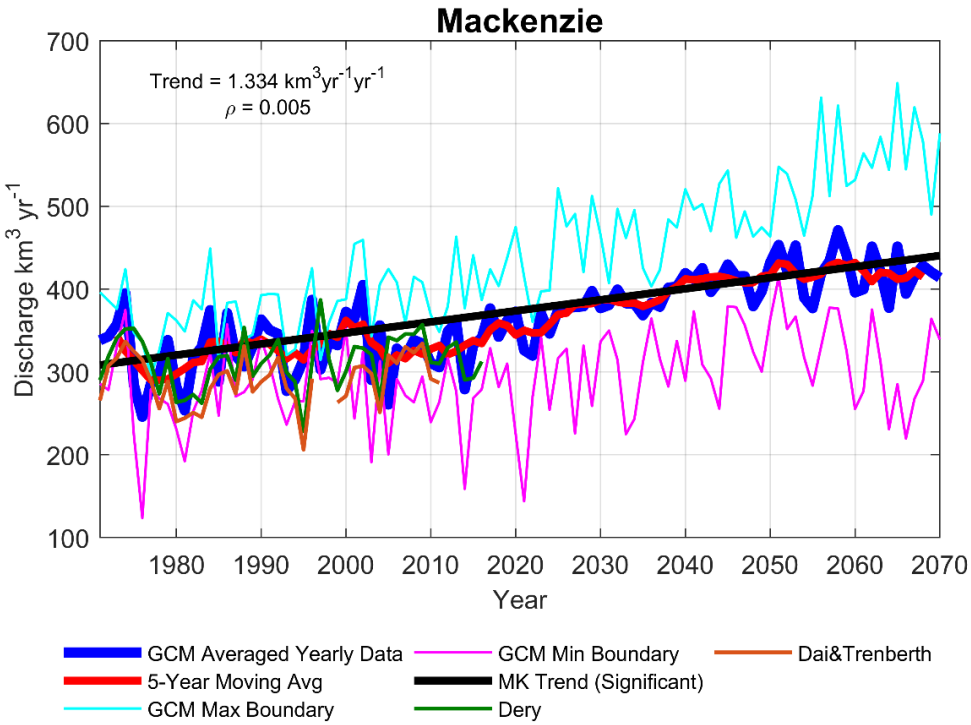
Annual Flow (km3/yr)
- 0 - 10
- 10 - 30
- 30 - 100
- 100 - 250



Rodell Salonga

E.g., Trends in Mackenzie River Discharge

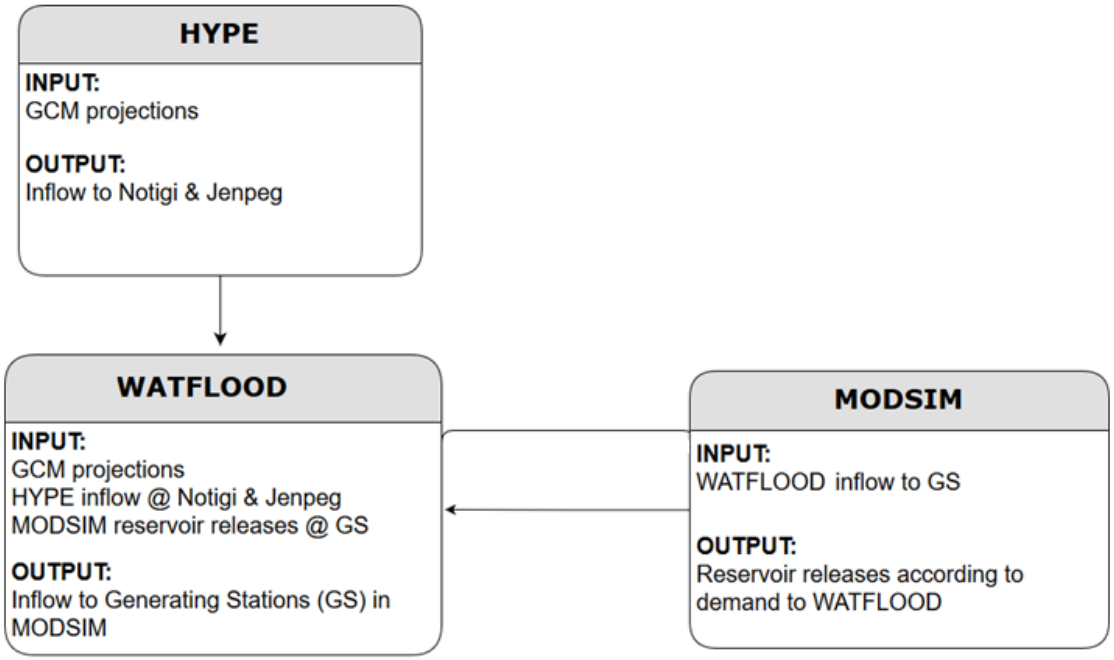




SJ Kim

Interface with Theme B1: HYPE and MODSIM

Study objective: To assess the effects of climate change on current hydropower operations in the Lower Nelson River Basin.



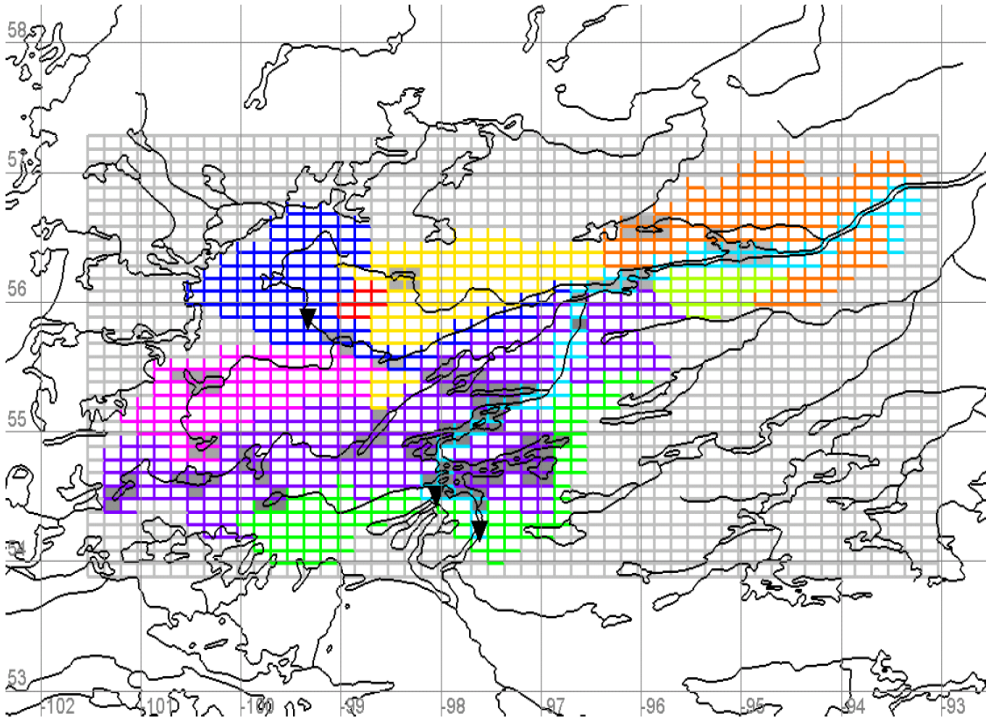
Schematic of hydrologic-operations coupling using WATFLOOD

- Coupled hydrologic model (WATFLOOD or HEC-HMS) to operations model (MODSIM-DSS) to simulate both physical hydrology and complex reservoir operations
- Requires boundary forcing from HYPE at Notigi CS and Jenpeg GS controls

See poster by Su Jin Kim

SJ Kim

HYPE Forcing for IWRM Scenarios

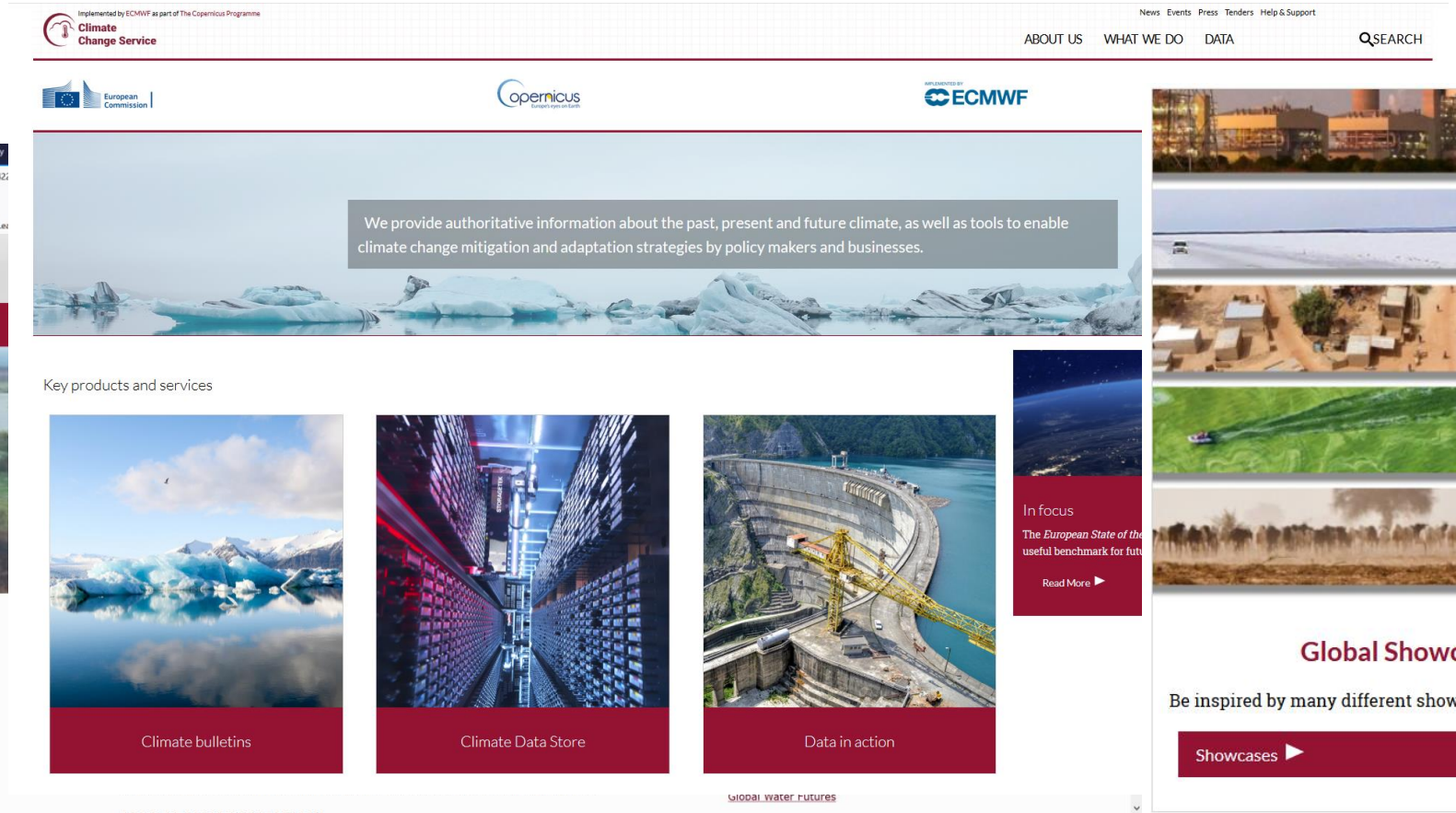


Schematic of Lower Nelson River Basin in WATFLOOD; black triangles denoting forcing locations[1].

- HYPE forcing downstream of Notigi CS and Jenpeg GS
- 19 climate scenarios chosen out of 150 representing uncertainty range of ensemble
- 19 forcing flows extracted by running HYPE for climate scenarios
- Coupled hydrologic-operations model will run with boundary forcing

2. c3s: Copernicus Climate Change Service

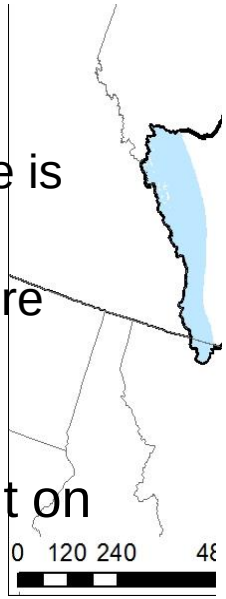
- C3S (Copernicus Climate Change Service) is an European Union Earth Observation Programme for past, current and future states

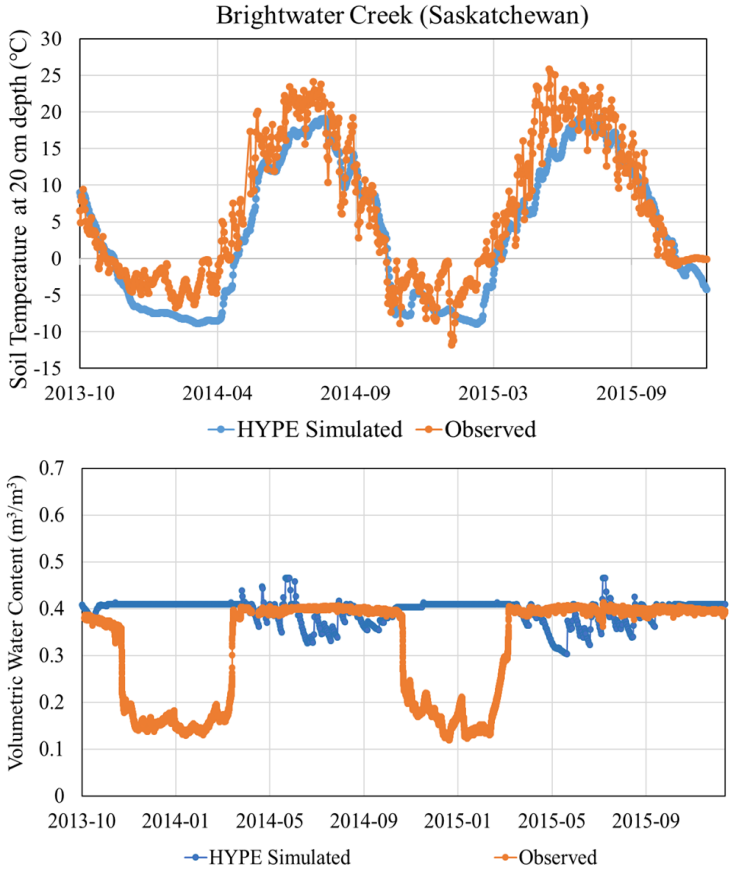


Ajay Bajracharya

3. Theme A2: Frozen Soil Validation

- Validation of HYPE frozen soils
  - Temperature OK, but soil moisture is problematic
  - Need depth-dependent temperature thresholds for freezing
- Canadian basins highly dependent on frozen soil processes
  - Changing distribution with climate change
  - Launched study looking at uncertainty in runoff projections associated with frozen soils





Summary

Check out the c3s HYPE Atlas

- See **Stadnyk interactive display**

Theme A2: HYPE Modelling

- See **Bajracharya poster #20**

Theme A5: Multi-Model Assessment

- GRIP-E: Apply HYPE to Lake Erie domain
- See **Awoye poster #21**

Theme B1: Integrated Water Resources Management Modelling

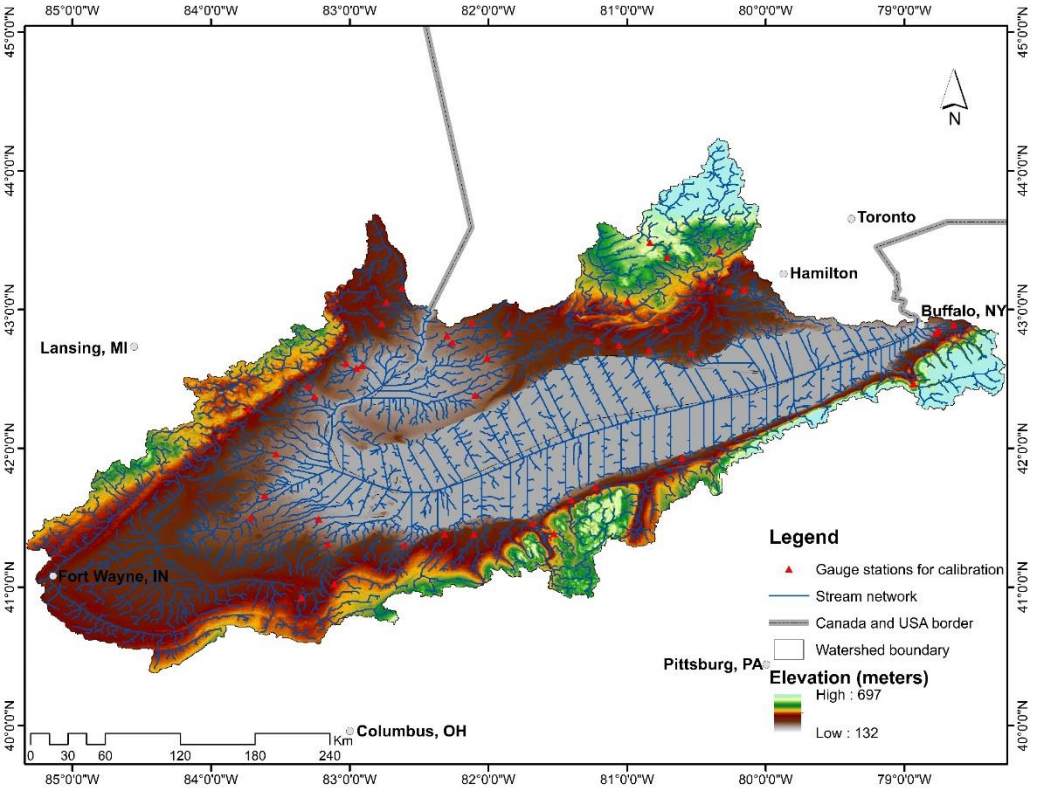
- Use multi-model ensemble NCRB flows to drive IWRM for Nelson R.
- Dr. Asadzadeh's talk (Day 2)
- See **Kim poster #27**

4. Theme A5: Multi-Model Assessment & HYPE

Dr. Hervé Awoye

4.1 LEB HYPE Model for GRIP-E…

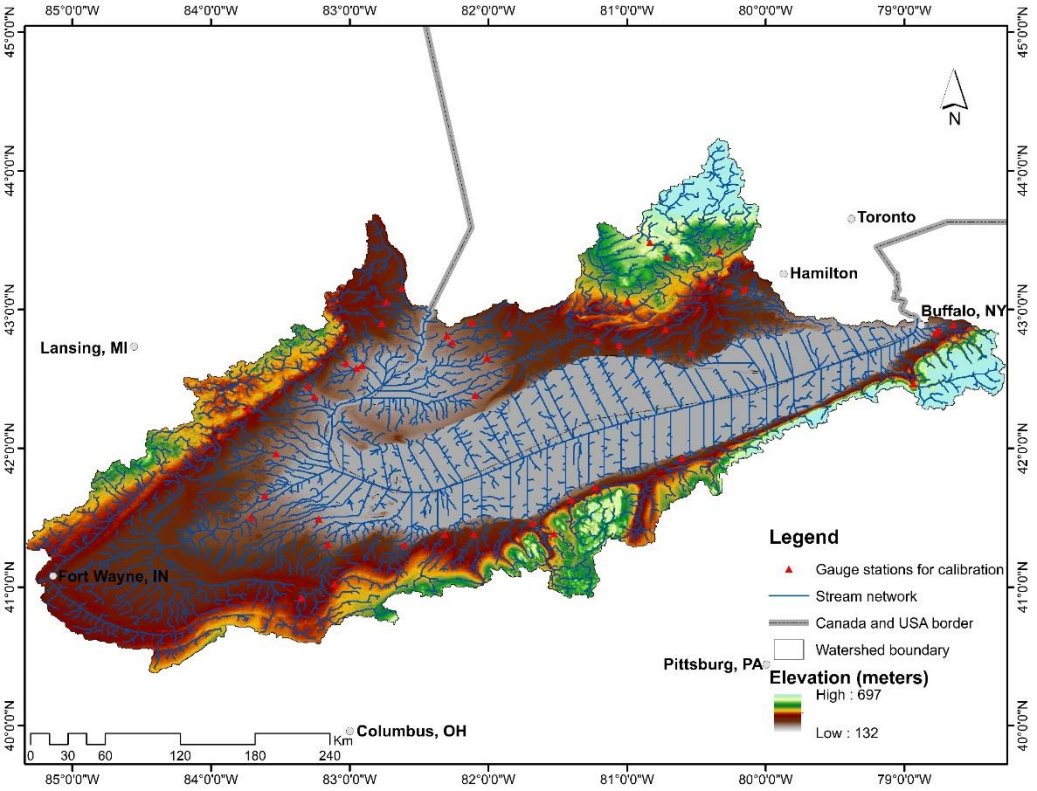
- Lake Erie Basin (LEB) Hydrologic Predictions for the Environment (HYPE) model developed by UofM for Phase 1 of GRIP-E



- Δt: daily
- Basin area: 103,666 km^2
- Watershed discretization in 644 sub-basins
- DEM, DIR, ACC: HydroSHEDS 30”
  Meteorological forcings: RDRS -15 km, 2010-2014
- No regulation

4.1 LEB HYPE Model for GRIP-E

- Lake Erie Basin (LEB) Hydrologic Predictions for the Environment (HYPE) model developed by UofM for Phase 1 of GRIP-E



- Land Cover: GlobCover 2009 v.2.3
- Soil type: HWSD v1.21
- Soil layer depth: Soil Landscapes of Canada v.3.2 & Global 1-km gridded thickness of soil, regolith, and sedimentary deposit layers[1]
- Stream depth: Global patterns of groundwater table depth[2]

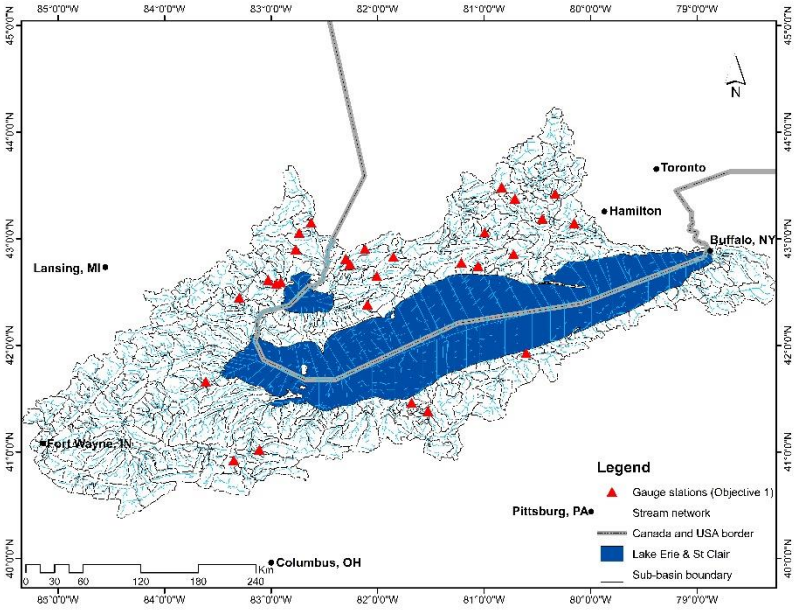
[1]Pelletier et al. 2016. Global 1-km Gridded Thickness of Soil, Regolith, and Sedimentary Deposit Layers. ORNL DAAC, Oak Ridge, Tennessee, USA. DOI: 10.3334/ORNLDAAC/1304

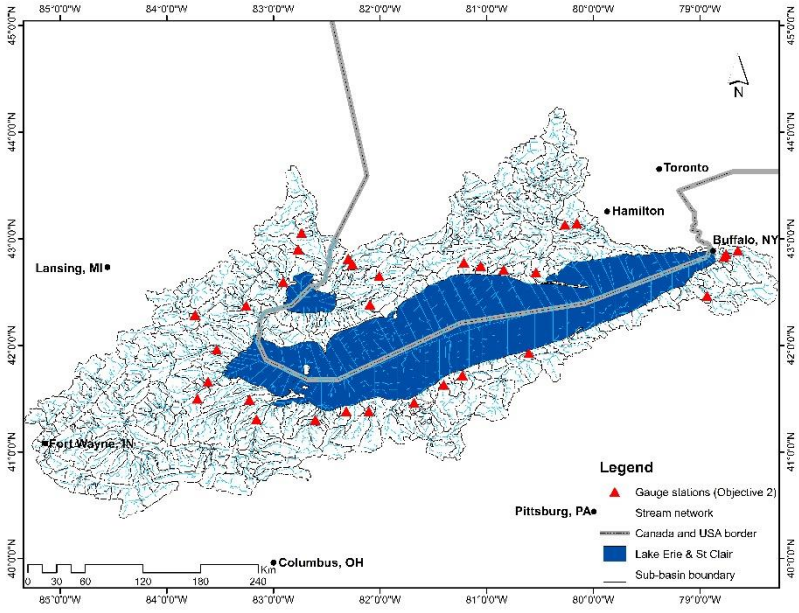
[2]Fan, Y., H. Li, G. Miguez-Macho 2013. Global patterns of groundwater table depth, Science, 339 (6122): 940-943, DOI: 10.1126/science.1229881

4.2 Model calibration…

- Objective 1: Modelling every location of Lake Erie watershed (naturalized monitoring points) ➔ 28 WSC & USGC gauge locations

- Objective 2: Modelling only inflows to Lake Erie watershed ➔ 31 WSC & USGC gauge locations

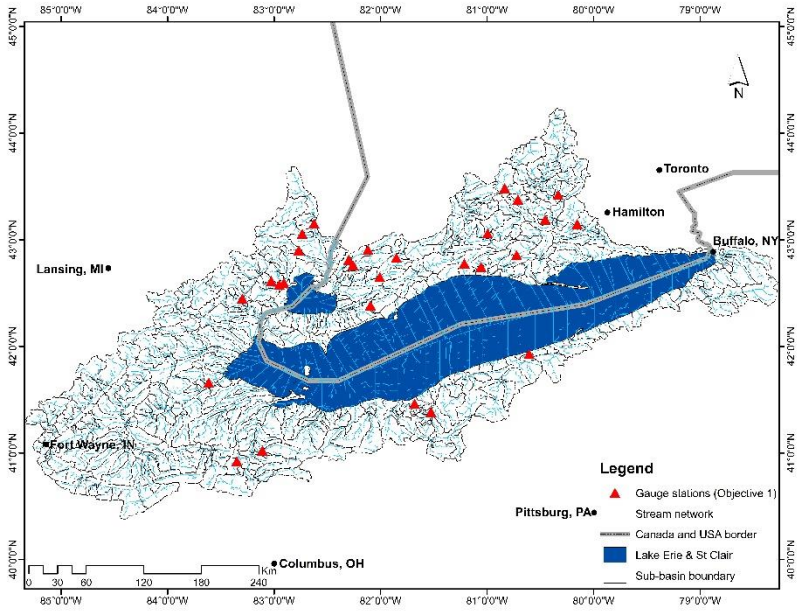


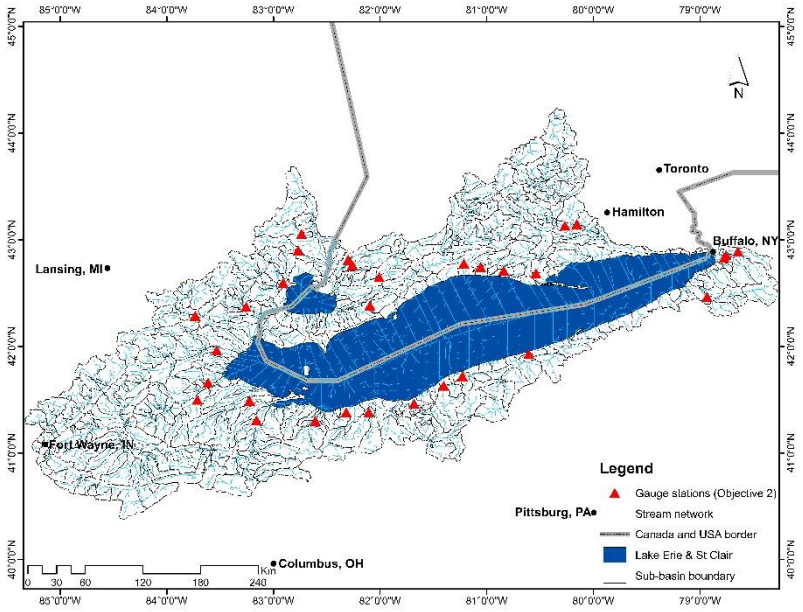


4.2 Model calibration

- Stepwise calibration of HYPE model parameters for 2011-2014 using a Differential Evolution Markov Chain algorithm

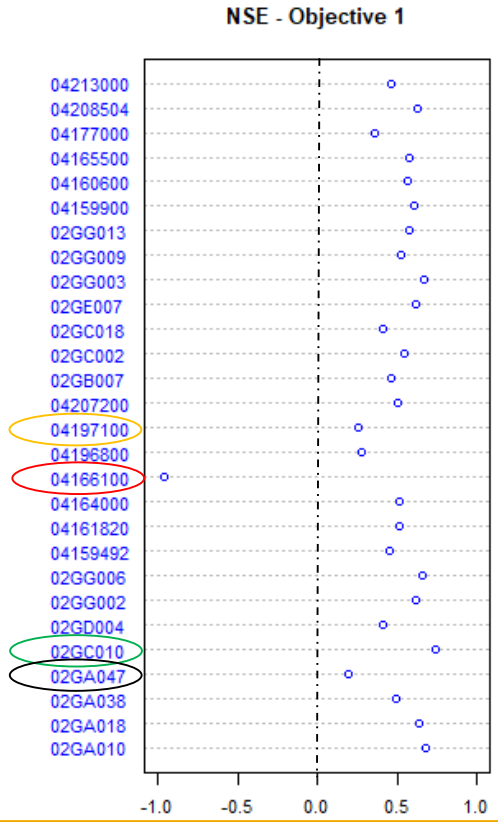
- Single objective function combining NSE and PBIAS (0.7NSE+0.3PBIAS)

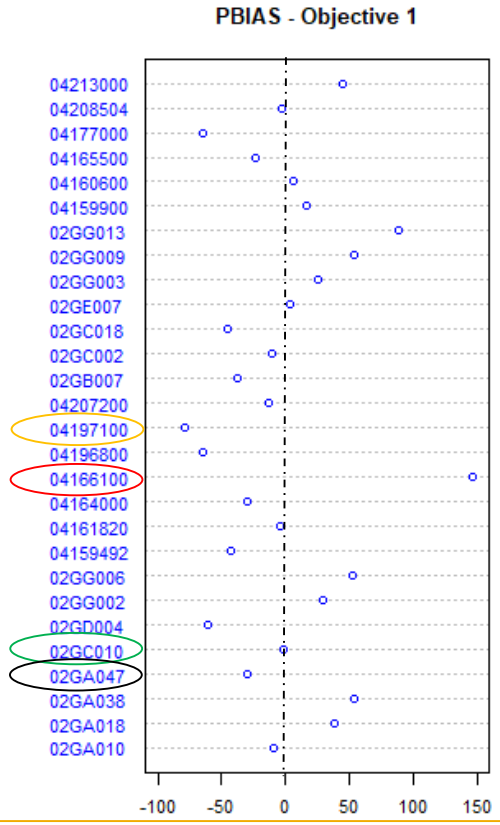




4.3 Calibration results…

- For objective 1 the median values of NSE and PBIAS are 0.52 and -3.8 respectively



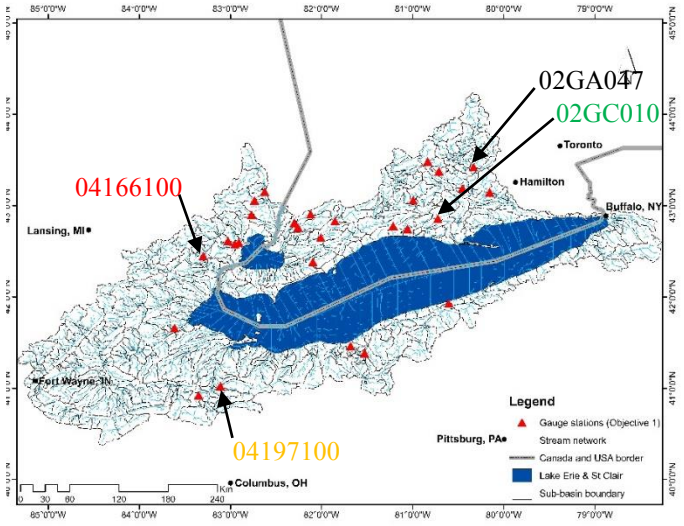


02GC010 Nith River near Canning

02GA047 Speed River at Cambridge

04197100 Honey Creek at Melmore OH

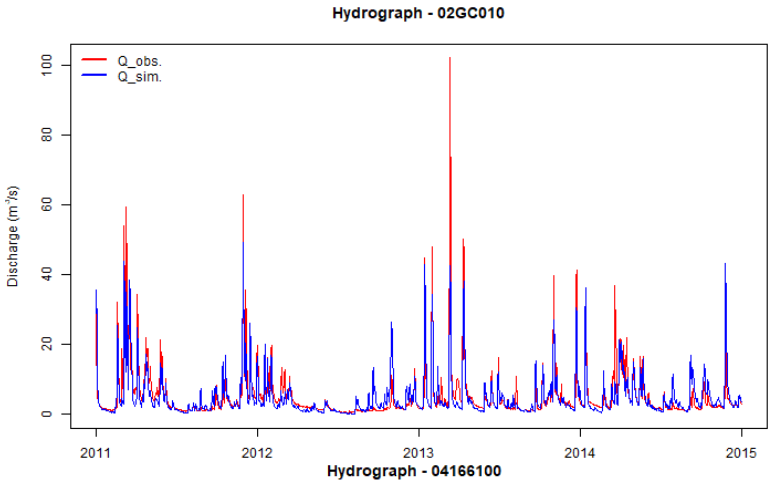
04166100 River Rouge at Southfield MI

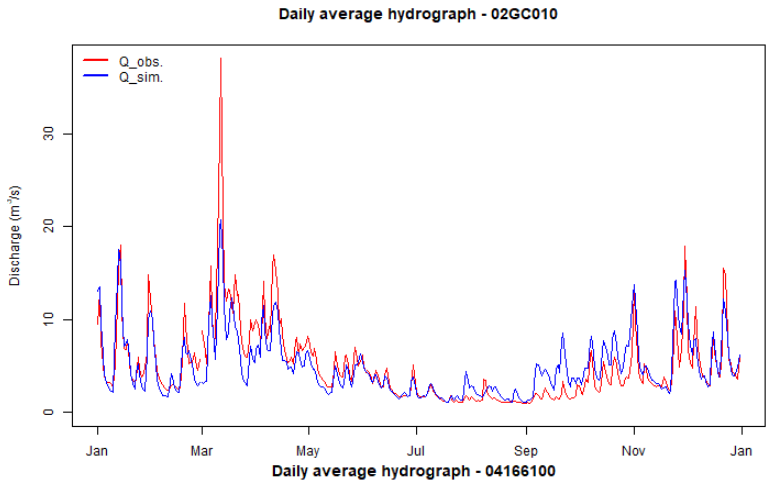


4.3 Calibration results…

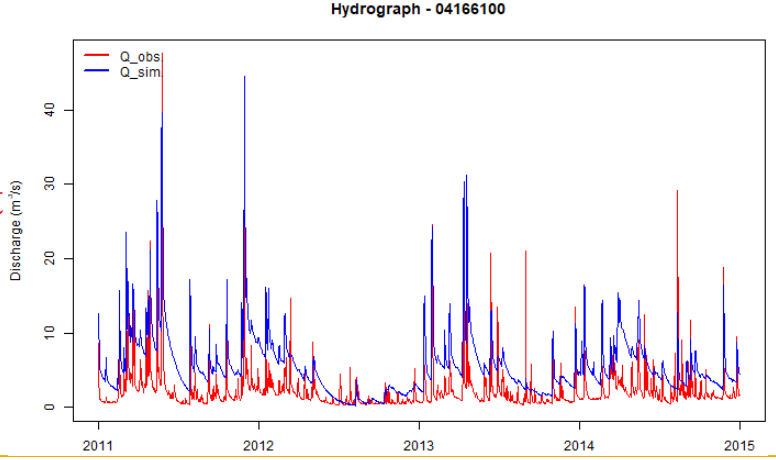
- For objective 1

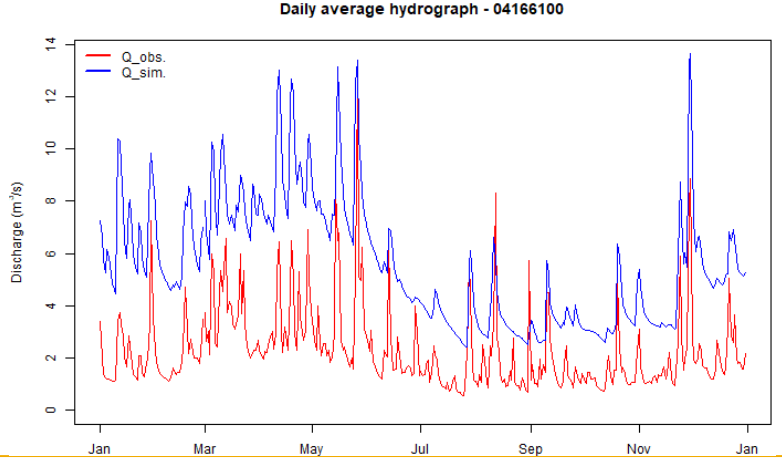
Nith River near Canning





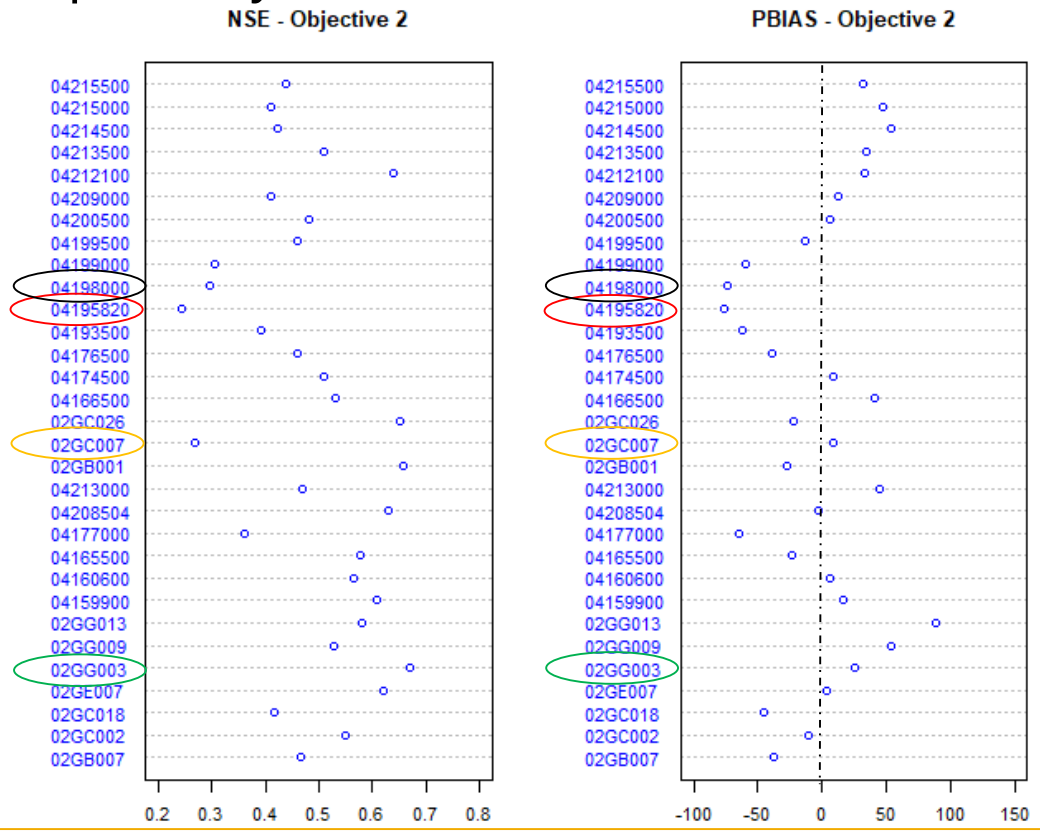
River Rouge at Southfield MI





4.3 Calibration results…

- For objective 2 the median values of NSE and PBIAS are 0.48 and 5.9 respectively

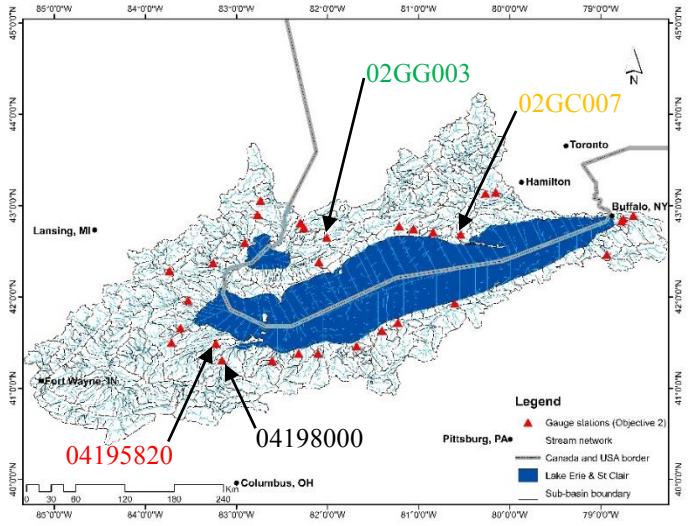


02GG003 Sydenham River at Florence

04198000 Sandusky River near Fremont OH

02GC007 Big Creek near Walsingham

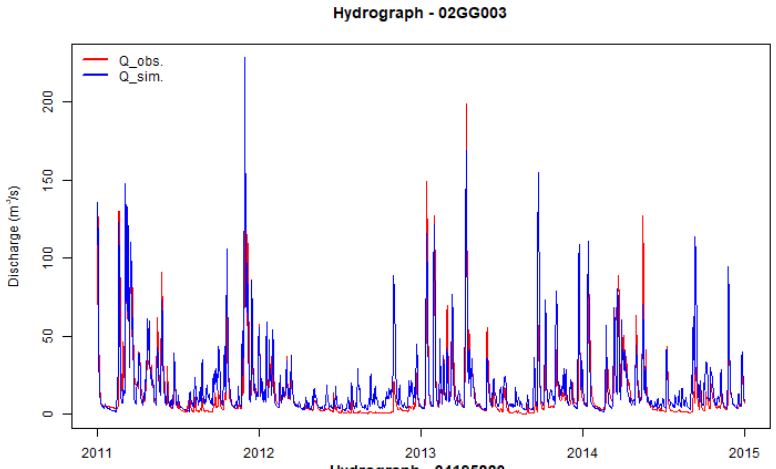
04195820 Portage River near Elmore OH

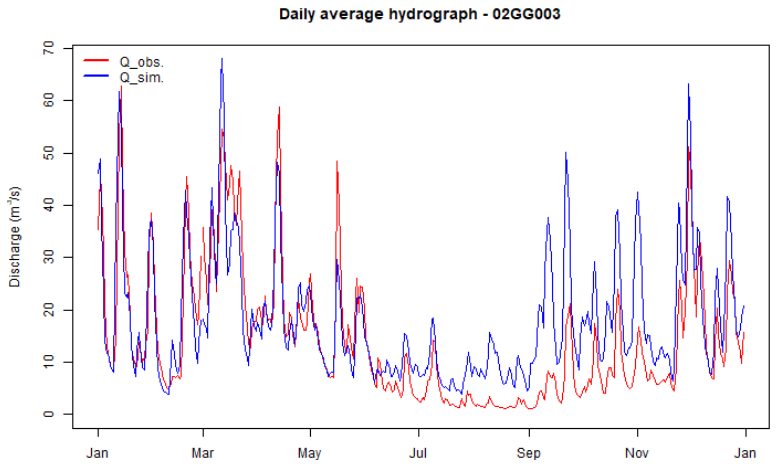


4.3 Calibration results…

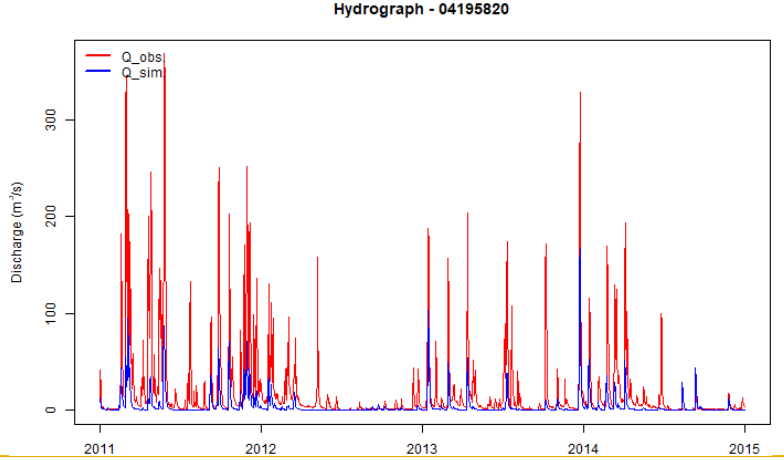
- For objective 2

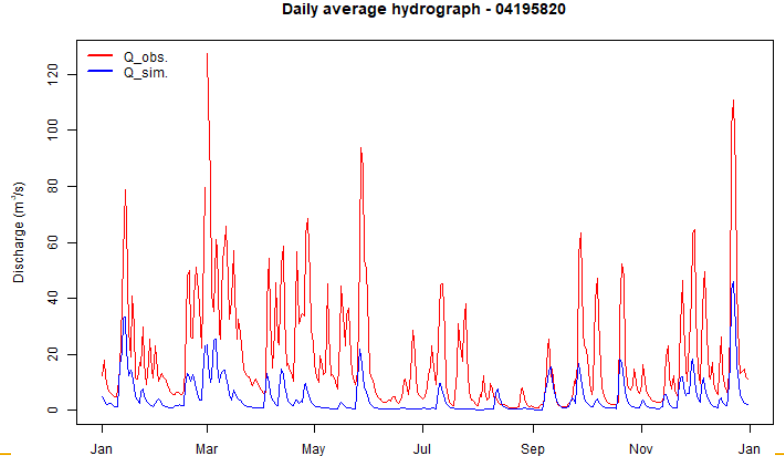
Sydenham River at Florence





Portage River near Elmore OH





4.4 Next steps

- Contributing to Phase 2 and Phase 3 of GRIP-E with HYPE
  - Phase 2: Lake Erie Basin
  - Phase 3: Great Lakes Basin
- Leading of Phase 4 of GRIP-E on the Nelson Churchill River Basin
  - 4 models interested: WATFLOOD, MESH, HYPE, GEM-Hydro + others??
  - Interested in joining Phase 4: contact

    Hervé (Oyemonbade.Awoye@umanitoba.ca) or

    Trish (Tricia.Stadnyk@ucalgary.ca)

5. In the past year, our team has

- Established pan-Canadian HYPE models
  - Canadian continental-scale regulation embedded within Pan-Arctic domain model
  - Working on developing improved frozen soil processes
- Projected future trends using HYPE & CMIP5 simulations
  - Trends are highly sensitive to region and time period of analysis
- Gained experience from GRIP-E multi-model study
  - Moving forward: a multi-model study in the Nelson-Churchill basin
- Significant investment in knowledge mobilisation
  - c3s Interactive Atlas
  - Hudson Bay IRIS
  - Expedition Churchill e-book and public outreach campaign

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