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HYPE Experience

Dr. Trish Stadnyk, P.Eng.
Matt MacDonald, Stephen Déry, Andrew Tefs, Marie Broesky and Matthew Hamilton

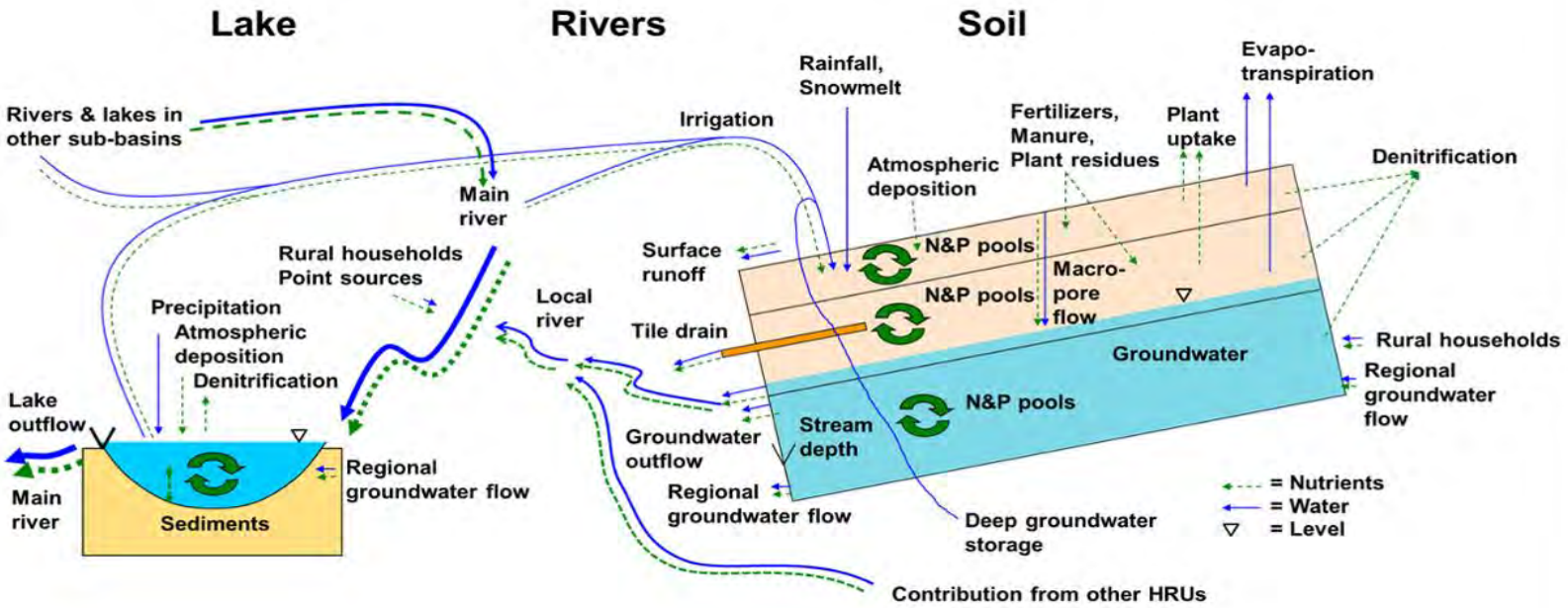
UNIVERSITY OF MANITOBA

Outline

- HYPE
- UM-WRE add-ons
  - Frozen Soils
  - Prairie Non-contributing Area
  - Portage Diversion
  - Basin Regulation
- Model Setups @ UM-WRE
  - Hudson Bay Drainage Basin (HBDB-HYPE)
  - Nelson-Churchill Basin Regulation
  - Pan-Arctic (A-HYPE)
- Future Directions

HYPE hydrological model

- **Hy**drologic **P**redictions for the **E**nvironment
- Developed by Swedish Meteorological and Hydrological Institute for continental-scale runoff
  - Open source code (Fortran)
  - Water + nutrients
  - Open source data



https://www.smhi.se/en/research/research-departments/hydrology/hype-1.7994

HYPE Research @ UM-WRE

- Several projects required predictions & projections of continental-scale runoff
- HYPE chosen because:
  - Open source, collaboration with SMHI
  - Fortran source code
  - Comparable hydrologic structure to other models of interest (e.g., WATFLOOD, VIC, MESH)
  - Cold regions hydrology (i.e., frozen soils, snow & glacial hydrology)
  - Representation of land cover & lakes
  - Water quality (nutrient) capabilities
  - Fast & efficient run times
  - Effective calibration strategy

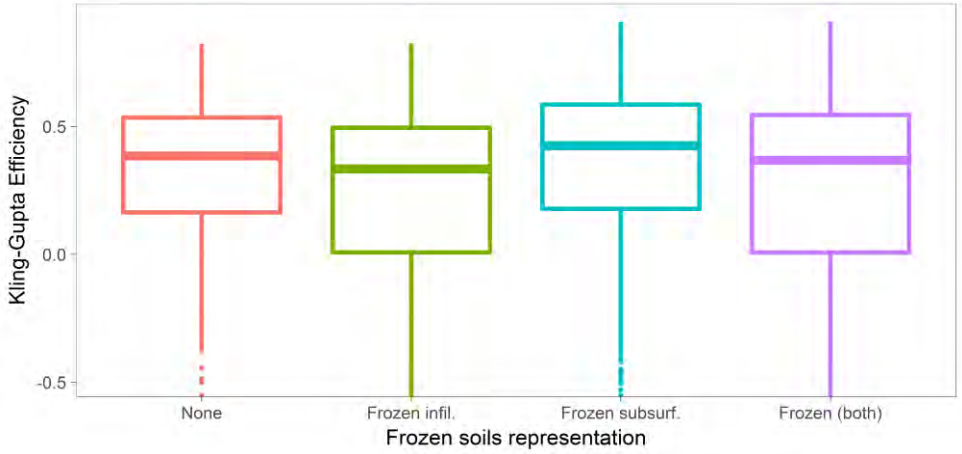
HYPE Enhancements by UM

- Before using HYPE for the Nelson-Churchill and Hudson Bay domains, several desired model improvements were identified:

1. Frozen soils
2. Lakes
3. Prairie non-contributing areas
4. Portage diversion
5. Regulation rules (Nelson-Churchill basin)

Frozen Soils

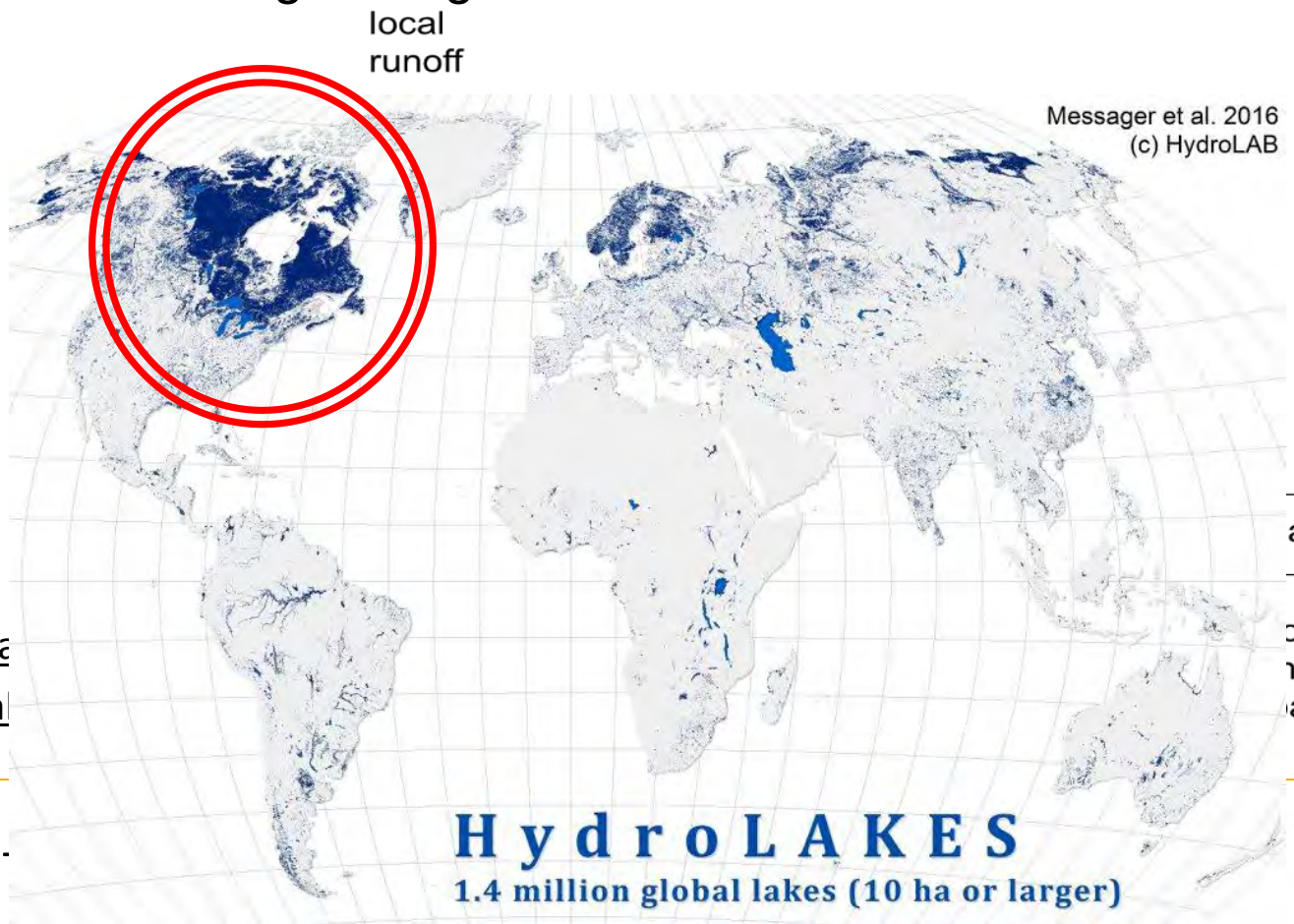
- Four schemes were attempted:
  1. None (A-HYPE)
  2. Limited infiltration
  3. Limited subsurface flow
  4. Combined 2 & 3



MacDonald et al., submitted (Hydrological Processes)

Lakes

- HBDB has amongst the greatest concentrations of lakes in the world



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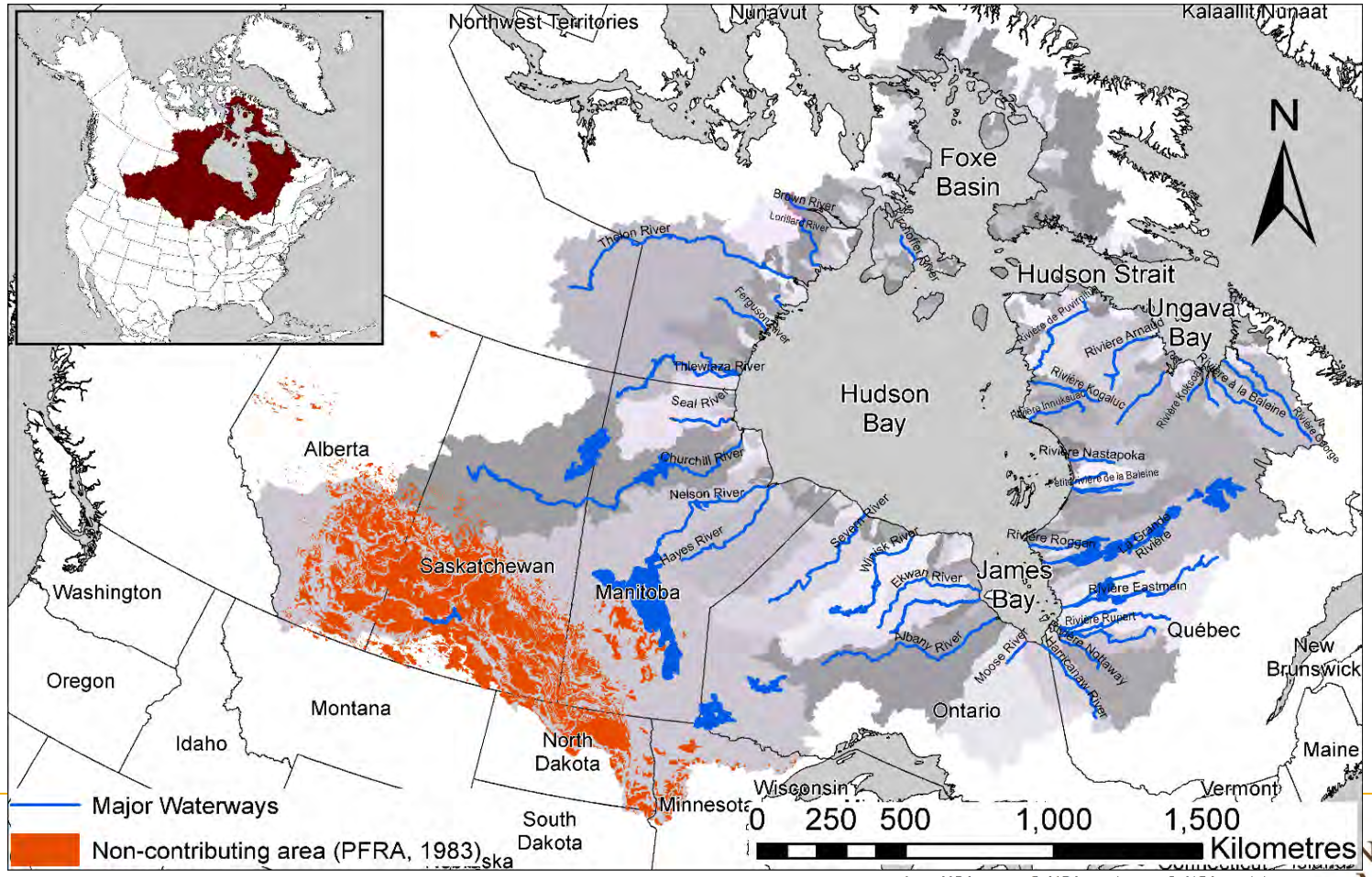
Prairie Non-Contributing Area

- 

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MacDonald et al., submitted (Hydrological Processes)

Portage Diversion (and others…)

- Developed rules based on Assiniboine River upstream and downstream flow record + Manitoba Infrastructure published rules
- Coded flow threshold values (based on flood reports):
- More accurately represent system withdrawals and inputs

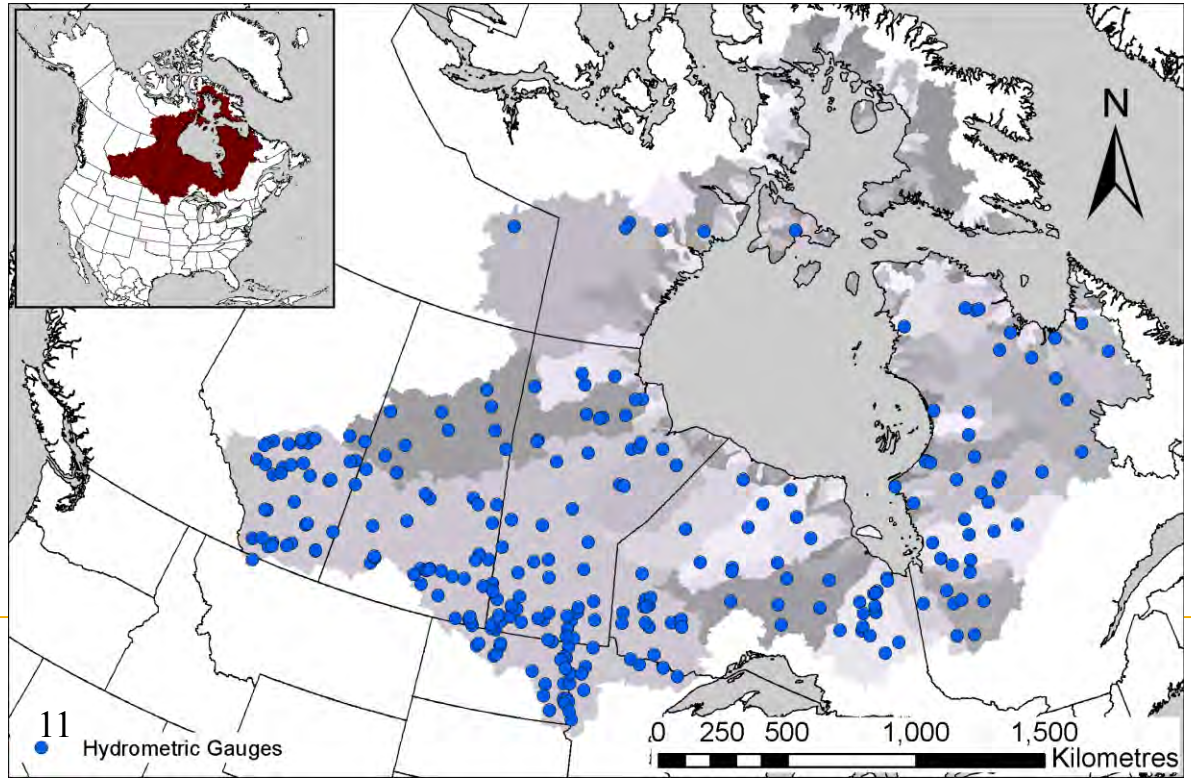
Basin Regulation

- Nelson-Churchill River basin is highly regulated

- Requires coding of specific and complex rule curves
  - Developed in collaboration with Manitoba Infrastructure & Manitoba Hydro
  - Review of operating guidelines & published (flood) reports
  - Calibrated to historical long term flow data (LTFD) record
  - Two types of regulation coded
    - In-line dams
    - Off-Channel/Bifurcation/Diversion (OCBD)
  - Regulation can be turned on or off

HBDB-HYPE model

- Hudson Bay Drainage Basin (HBDB) model developed by UM
  - 'BaySys' project
  - Assess the relative contributions of regulation and climate change

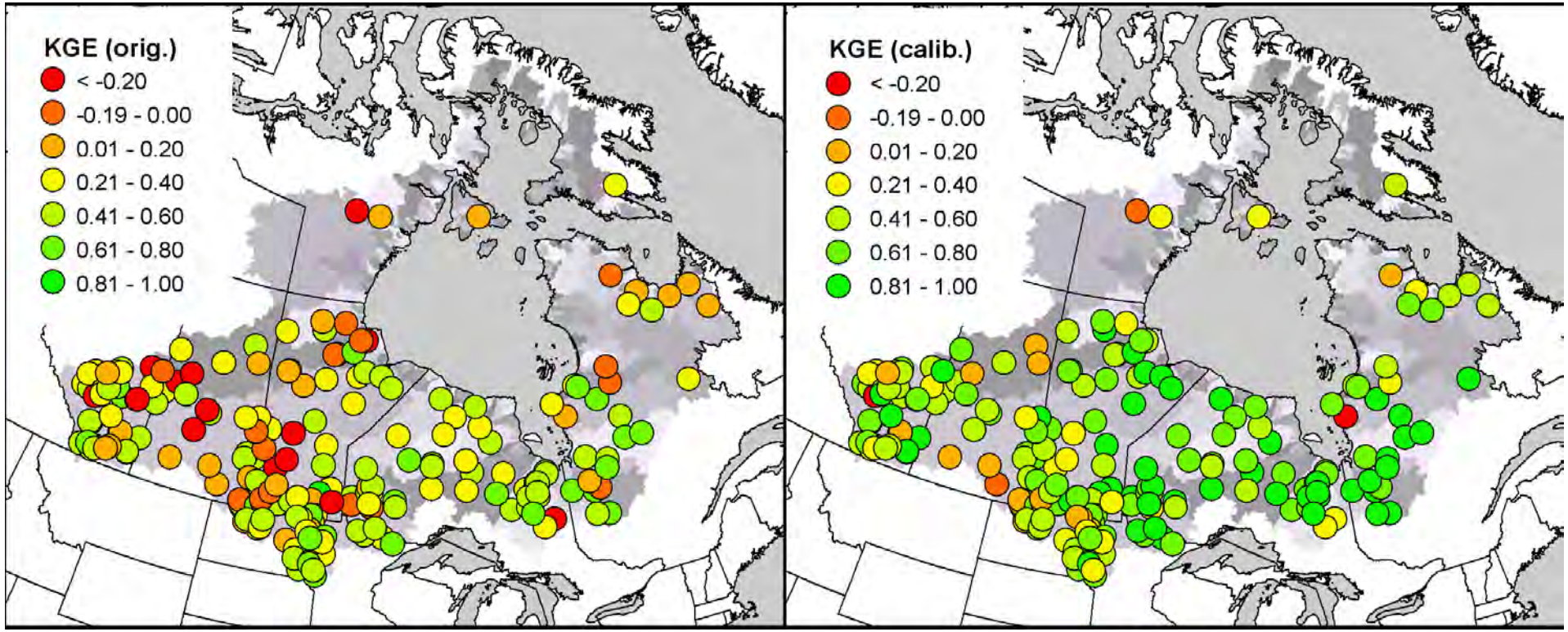


- Δt: daily
- Area: ~4 million km^2
- Mean subbasin area: 657 km^2
- Precip & Temp: WFDEI
- Topography: Hydro1K
- Soils: HWSD
- Land use: Globcover
- Lakes & wetlands: GLWD
- Basic dam types:
  - flood control
  - hydropower,
  - irrigation, supply
  - diversions

HBDB Calibration

Before enhancements

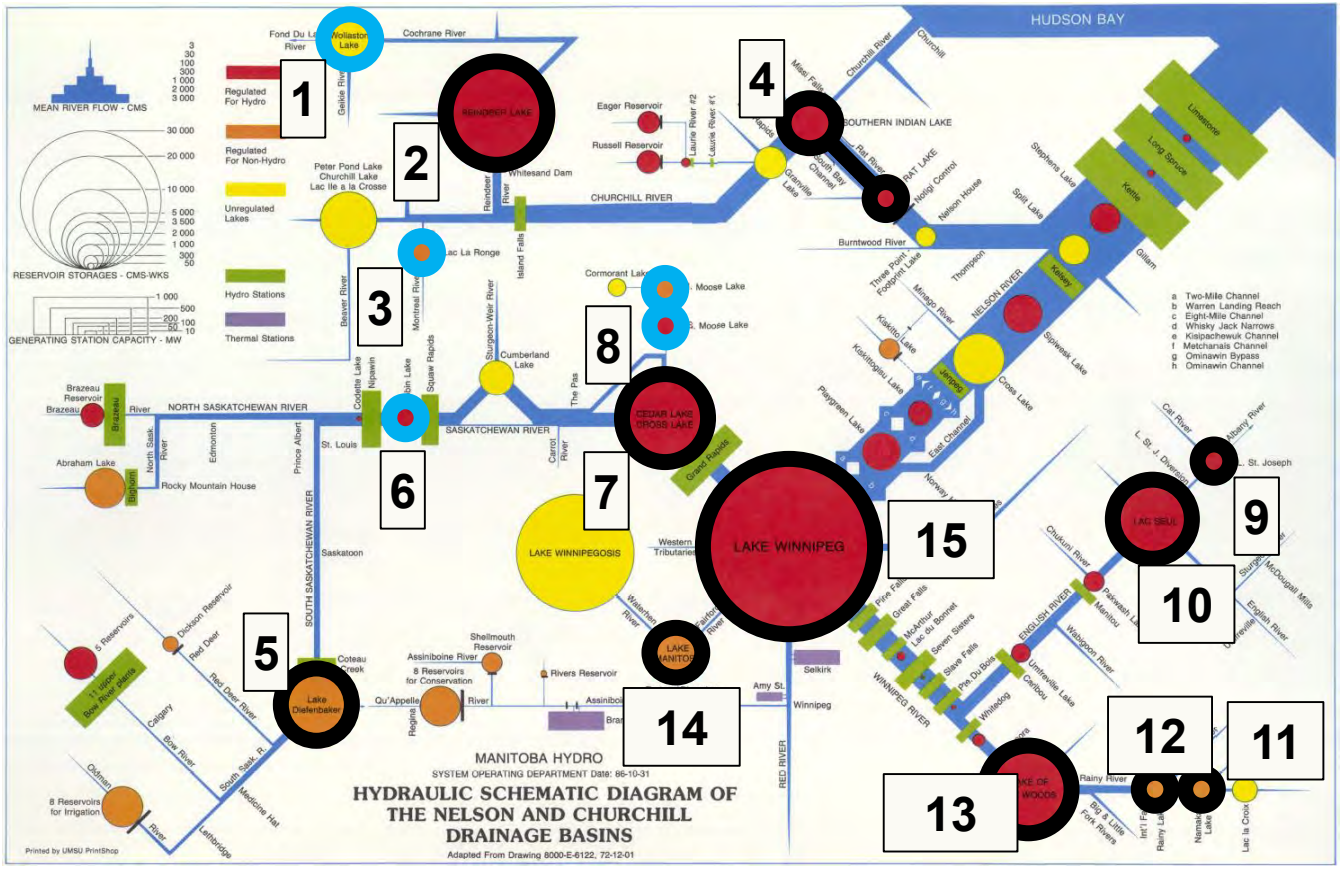
After enhancement



KGE: Kling-Gupta Efficiency

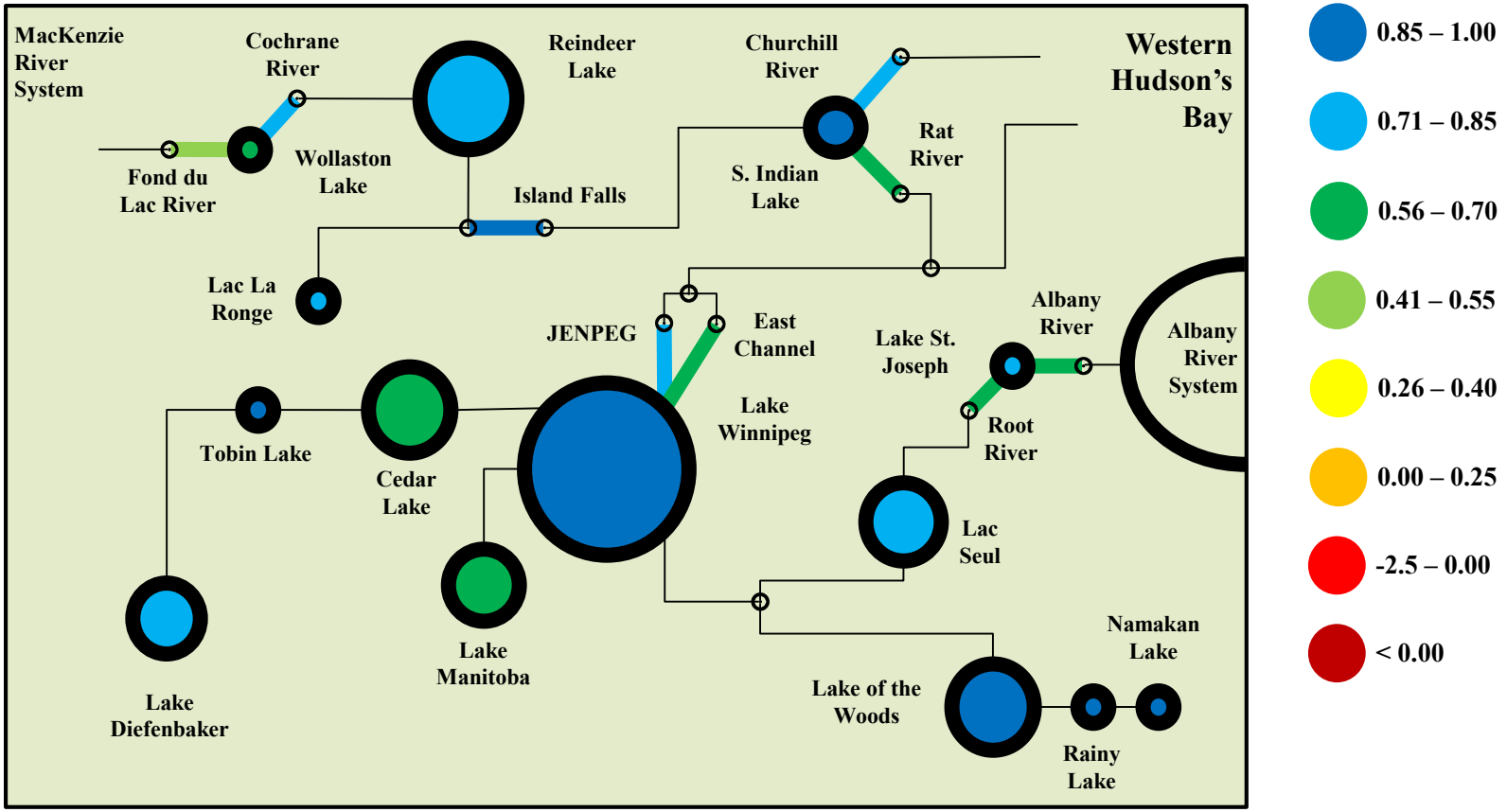
MacDonald et al., submitted (Hydrological Processes)

Nelson-Churchill Basin Regulation



1. Wollaston Lake (OCBD)
2. Reindeer Lake (OCBD)
3. Lac La Ronge (IL)
4. S. Indian Lake (OCBD)
5. Lake Diefenbaker (IL)
6. Tobin Lake (IL)
7. Cedar Lake (IL)
8. Moose Lake (IL)
9. Lake St. Joseph (OCBD)
10. Lac Seul (IL)
11. Namakan Lake (IL)
12. Rainy Lake (IL)
13. Lake of the Woods (IL)
14. Lake Manitoba (IL or OCBD)
15. Lake Winnipeg

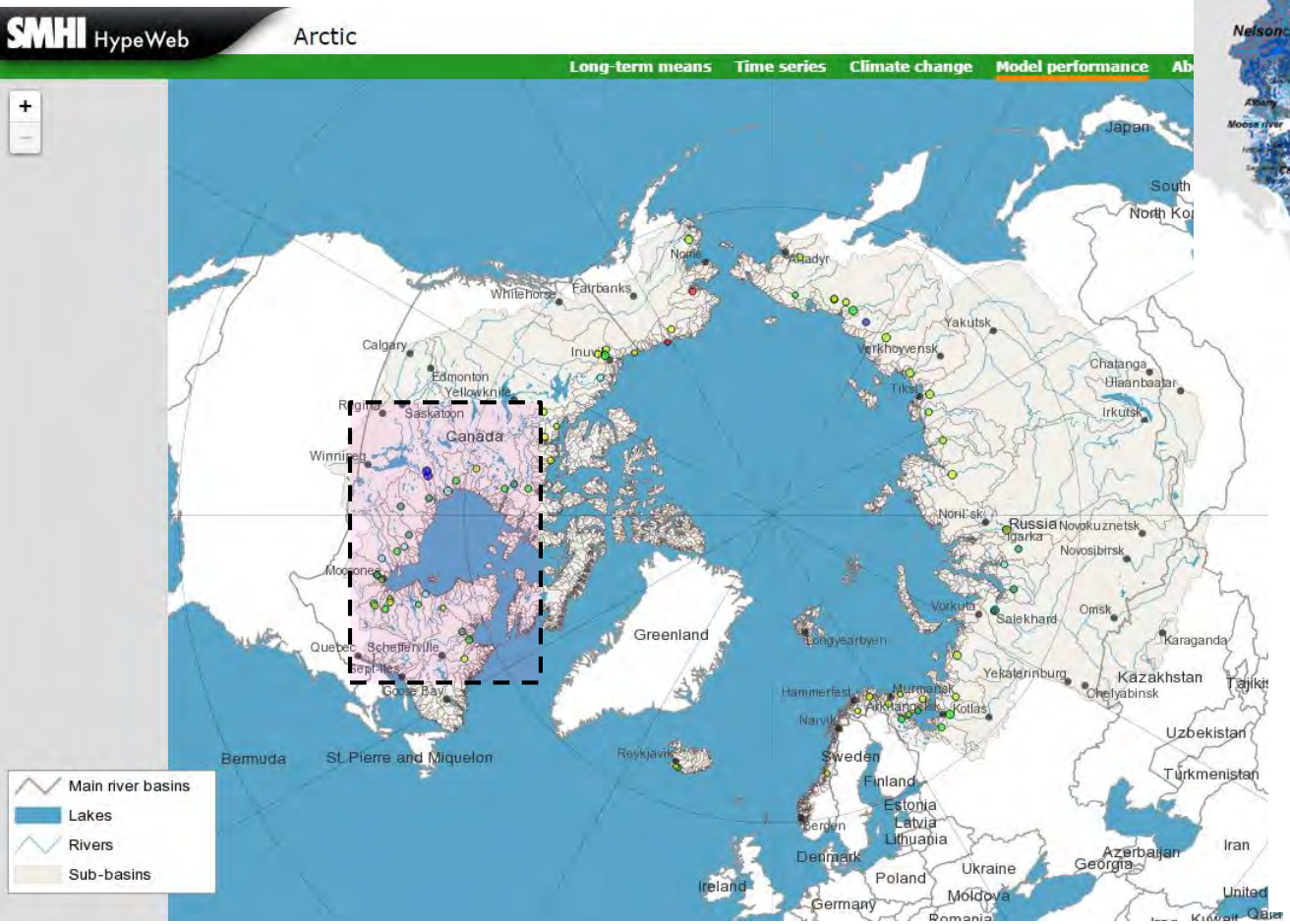
Regulated System Results

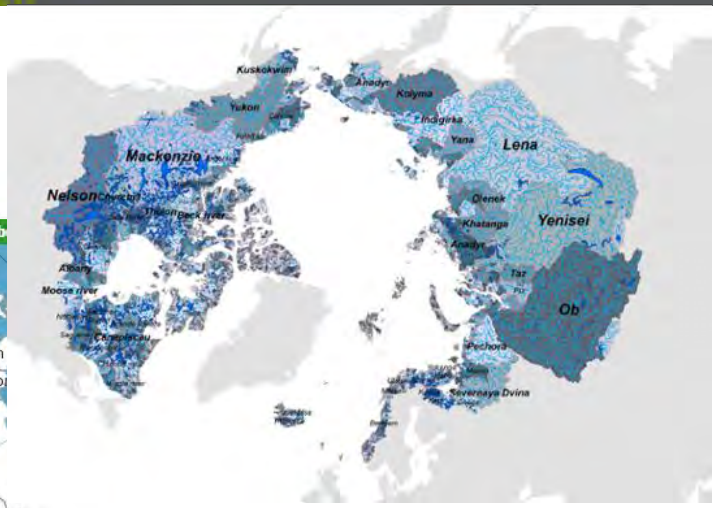


Kling Gupta Efficiency

Courtesy: A Tefs, M Hamilton

Arctic-HYPE



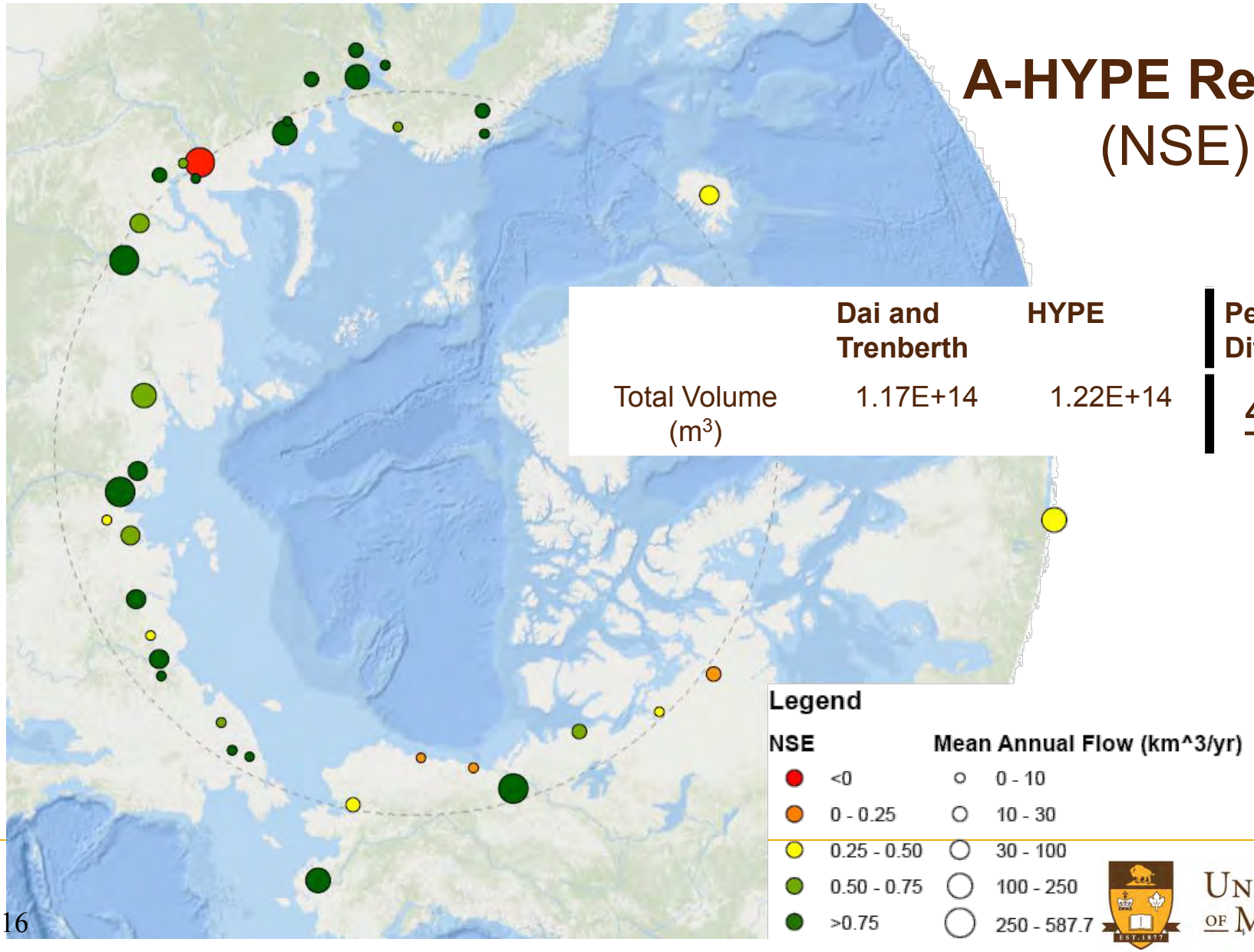


- Δt: daily
- Area: 23.3 million km^2
- Mean subbasin area: 756 km^2
- Precip & Temp: WFDEI
- Topography: Hydro1K
- SWE: GlobSnow

- Runoff above 70^{o}N latitude (Arctic circle)
- Calibrated to Dai & Trenberth

A-HYPE Results (NSE)

	Dai and Trenberth	HYPE	Percent Difference
Total Volume (m^3)	1.17E+14	1.22E+14	4.97%



On-going work

- Regulation in LaGrande R (eastern HBDB)
- Recalibration of HBDB-HYPE with regulation
- Analysis of system regulation
  - Déry et al., submitted (HP)
- Projected runoff scenarios (2100-2070) in HBDB
  - MacDonald et al., in preparation (GRL)
- “Naturalized” (1979-2010) Nelson River scenarios
  - Pre-CRD conditions during historic record
- Uncertainty in projections
  - Impact of climate model selection, input data, and parameters
- A-HYPE
  - Projecting changes in Arctic Ocean runoff
  - Link to Arctic Ocean circulation patterns and climatology

Acknowledgements

- SMHI Hydrology group (*Berit Arheimer, David Gustafsson, Kristina Isberg, Charlotta pers)*
- Ouranos
- ArcticNet
- Manitoba Infrastructure
- Manitoba Hydro
- Water Survey of Canada

Questions?

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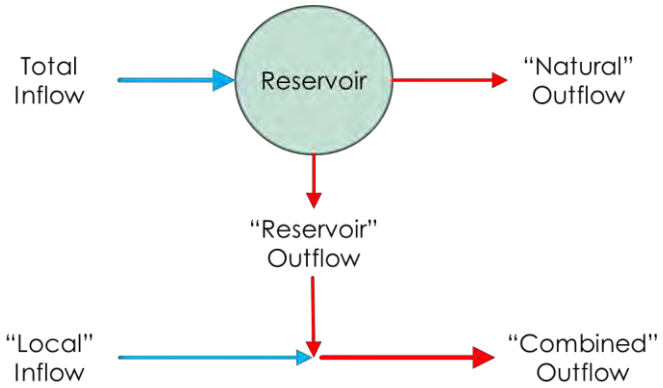
Inline v. O.C.B.D. Reservoir Models

OR



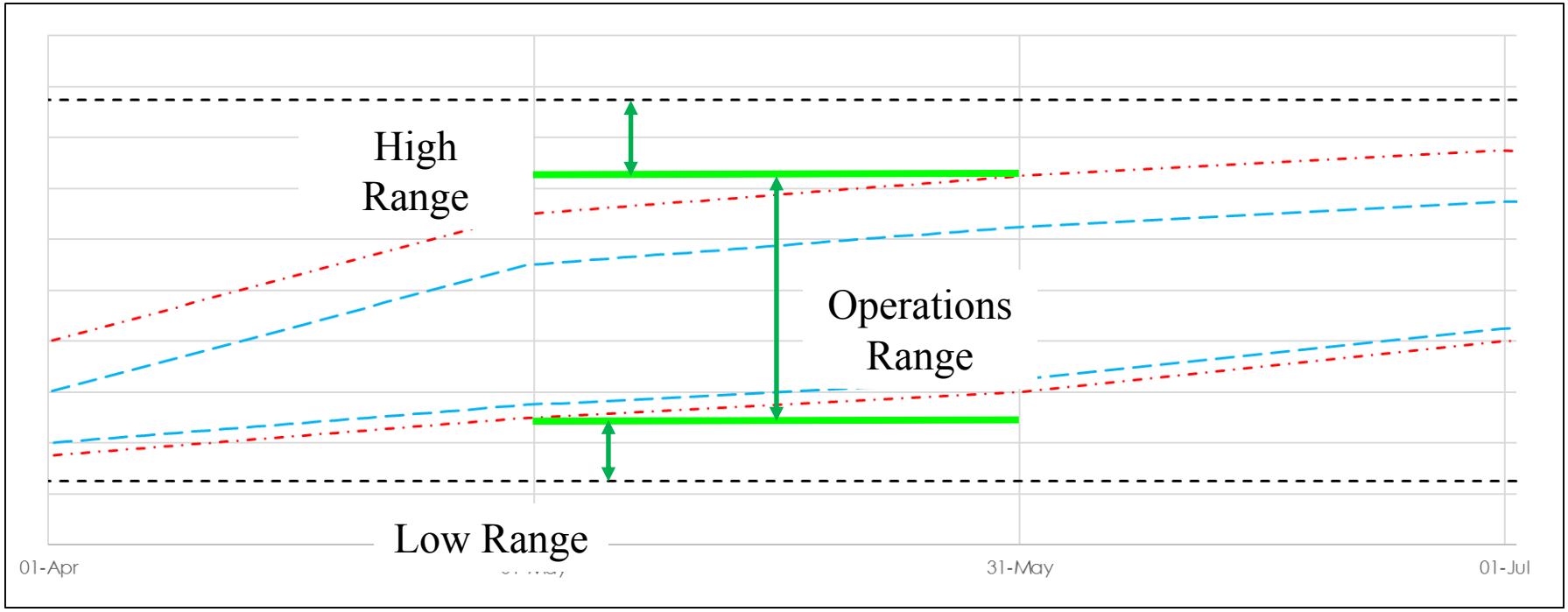
Inline Reservoir

OR

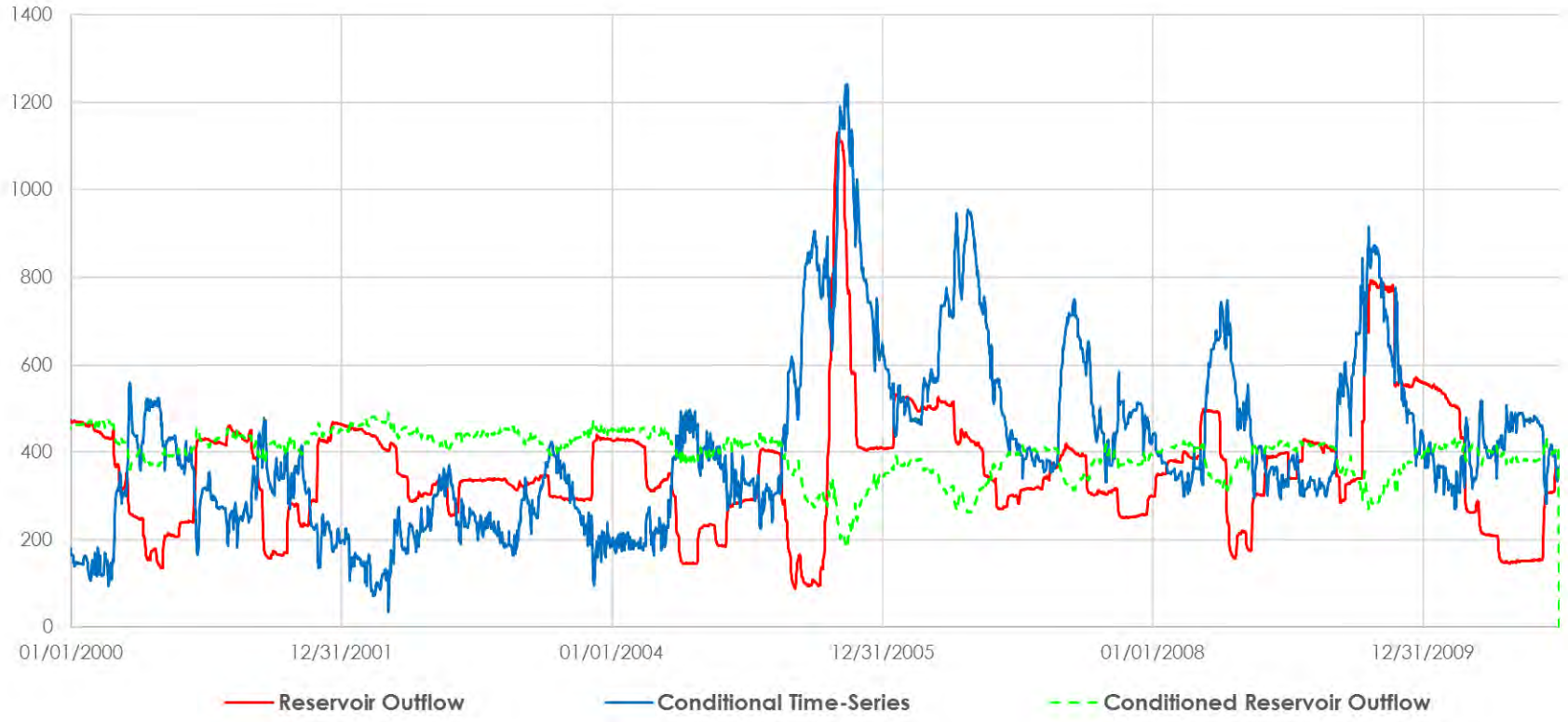
Off-**C**hannel Storage
Bifurcation Lake
Diversion Storage

The In-Line Model

- Regressions:
  - Range for Low, Mid and High range flows change month-to-month

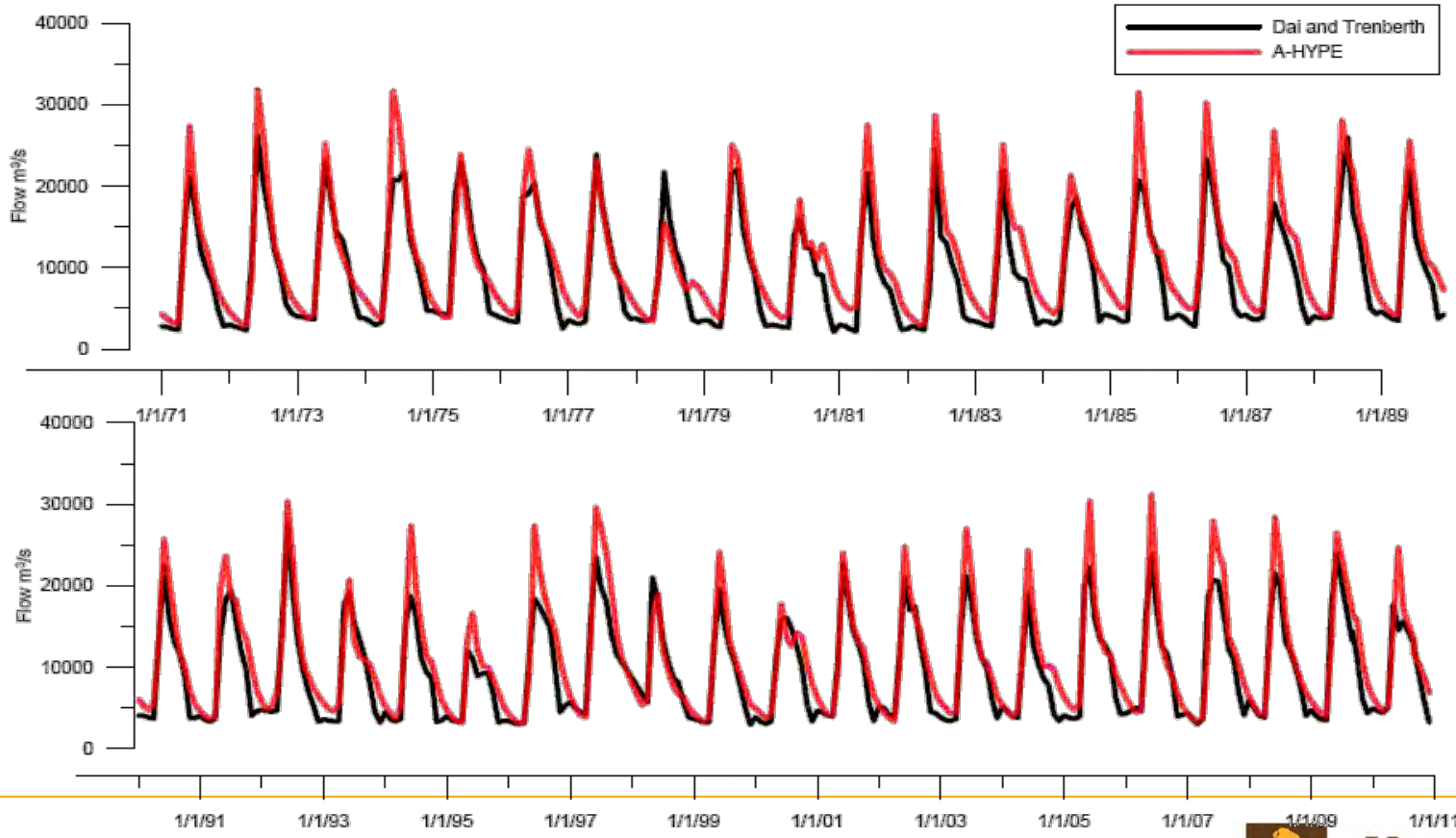


The O.C.B.D. Conditioning

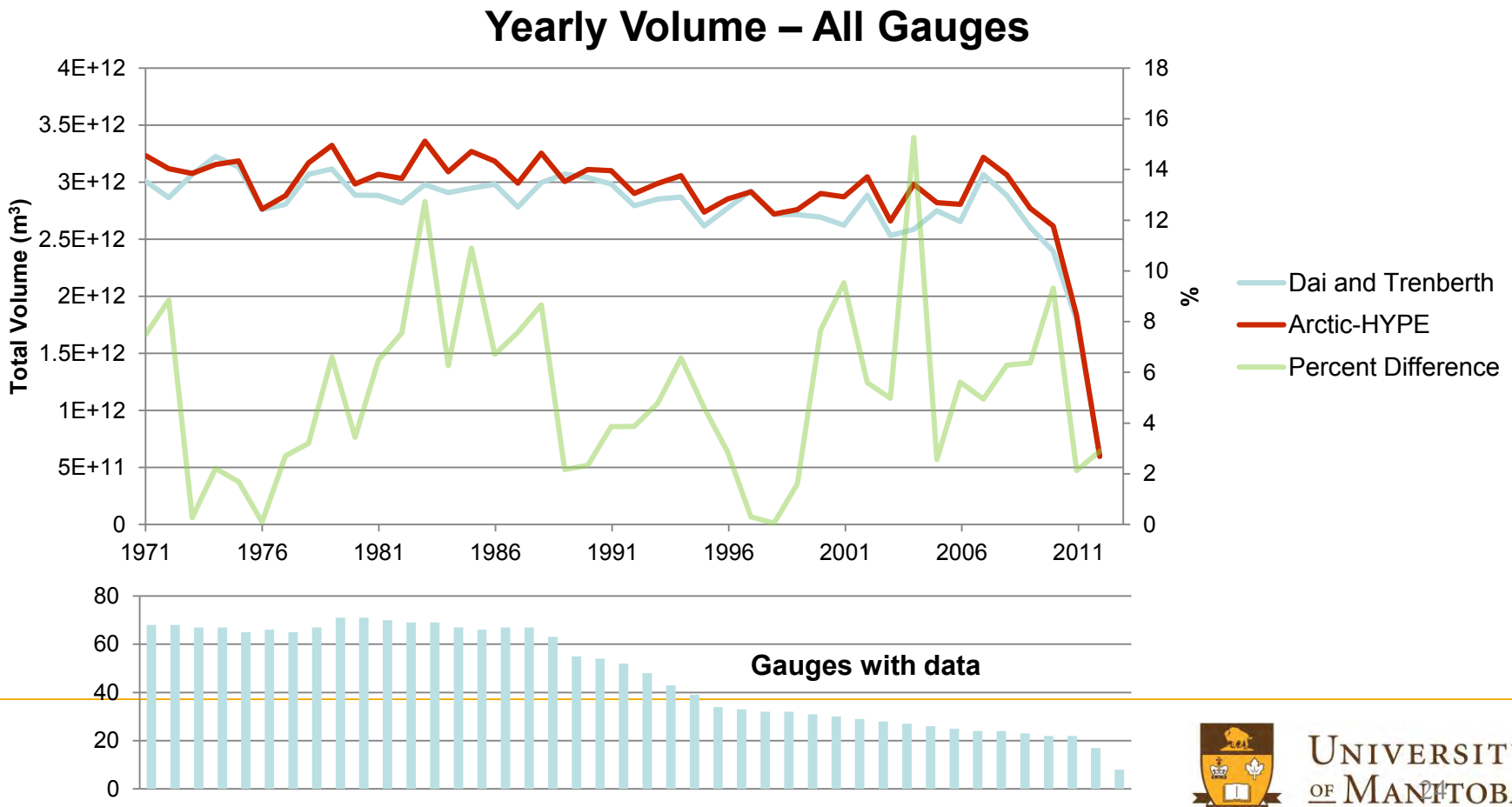


A-HYPE (Mackenzie)

NSE	Percent Bias	KGE
0.77	19.77	0.80



Overall


Yearly Volume – All Gauges
Total Volume (m³)
4E+12
3.5E+12
3E+12
2.5E+12
2E+12
1.5E+12
1E+12
5E+11
0
1971
1976
1981
1986
1991
1996
2001
2006
2011
%
18
16
14
12
10
8
6
4
2
0
Dai and Trenberth
Arctic-HYPE
Percent Difference
80
60
40
20
0
Gauges with data