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HYPE Modelling in the Nelson River Basin

A Multi-Model Assessment

Integrated Modelling Program for Canada

IMPC

Global Water Futures

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Contributors to this Work

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- Jack Kostick, Matthew Hamilton, Marie Broesky, Rodell Salonga

Acknowledgements to our Partners

OURANOS

Environment Canada Environnement Canada

SMHI

Manitoba Hydro

University of Manitoba

Water Survey Relevés hydrologiques

UNIVERSITY OF SASKATCHEWAN
Global Water Futures
GLOBAL INSTITUTE FOR WATER SECURITY
GWF.USASK.CA

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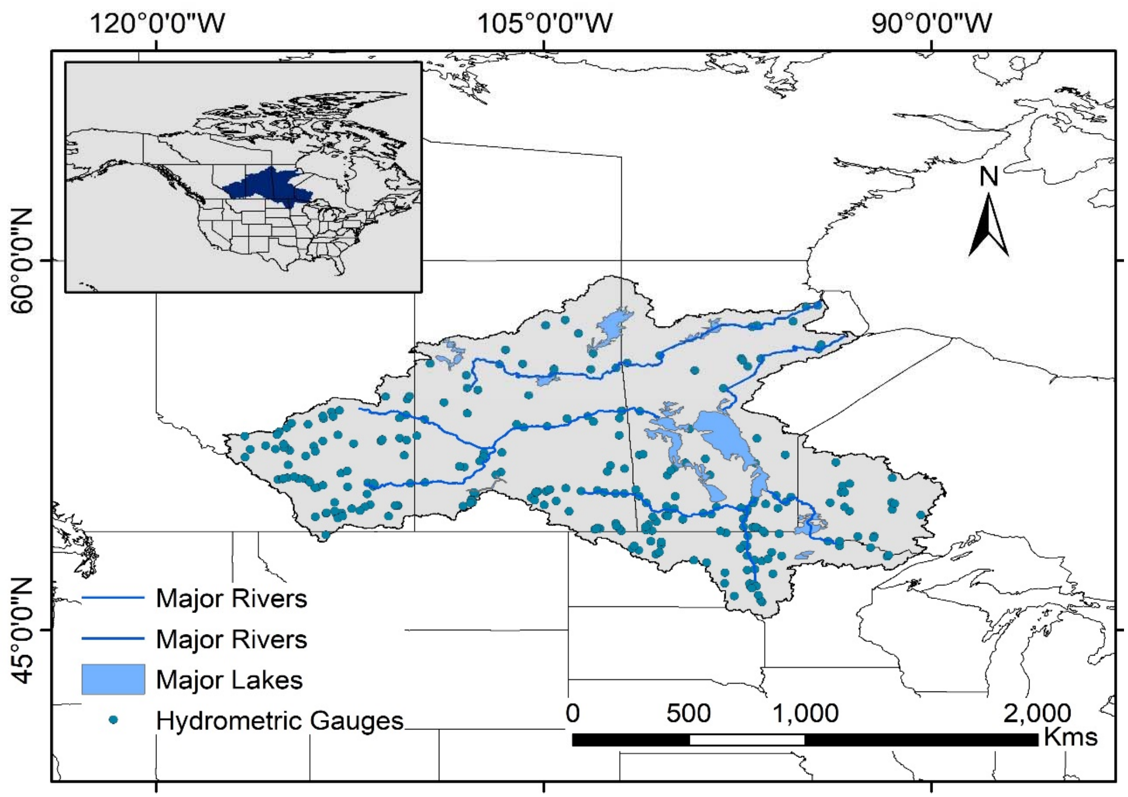
Outline

1. HYPE modelling
   - Nelson Churchill River Basin (NCRB)
   - Reservoir Regulation
2. Multi-model study: Nelson R.
3. Projected trends in NCRB Hydrology
4. Knowledge Mobilisation
5. On-Going Work
6. Summary

1. NCRB HYPE Model

- Nelson-Churchill River Basin (NCRB) Hydrologic Predictions for the Environment (HYPE) model developed by UM
  - Sub-basin of the Hudson Bay domain
  - 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

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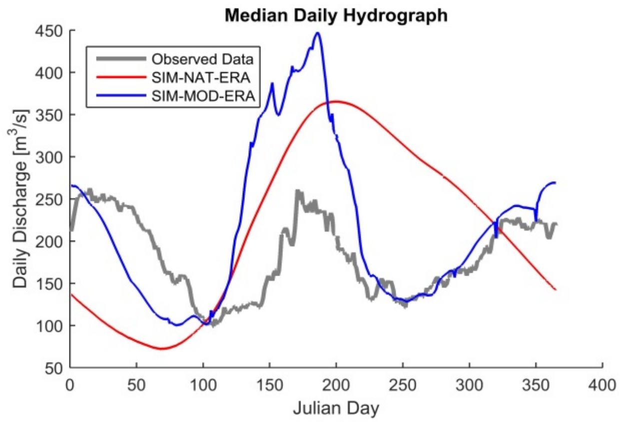
Reservoir Regulation

- Nelson-Churchill River basin is highly regulated
  - Original SMHI code (A-HYPE) utilized sine curve function
  - Proved inadequate for many reservoirs in the NCRB
- Required coding of specific and complex rule curves (H-HYPE)
  - Developed in collaboration with Manitoba Infrastructure & Manitoba Hydro
  - Review of operating guidelines & published (flood) reports
  - Calibrated to historical long term flow data (LTFD) record
- Facilitate true 'pre-construction' scenario analyses
  - Compare regulated system to 're-naturalized' for *same time period* (i.e., same climatic conditions)



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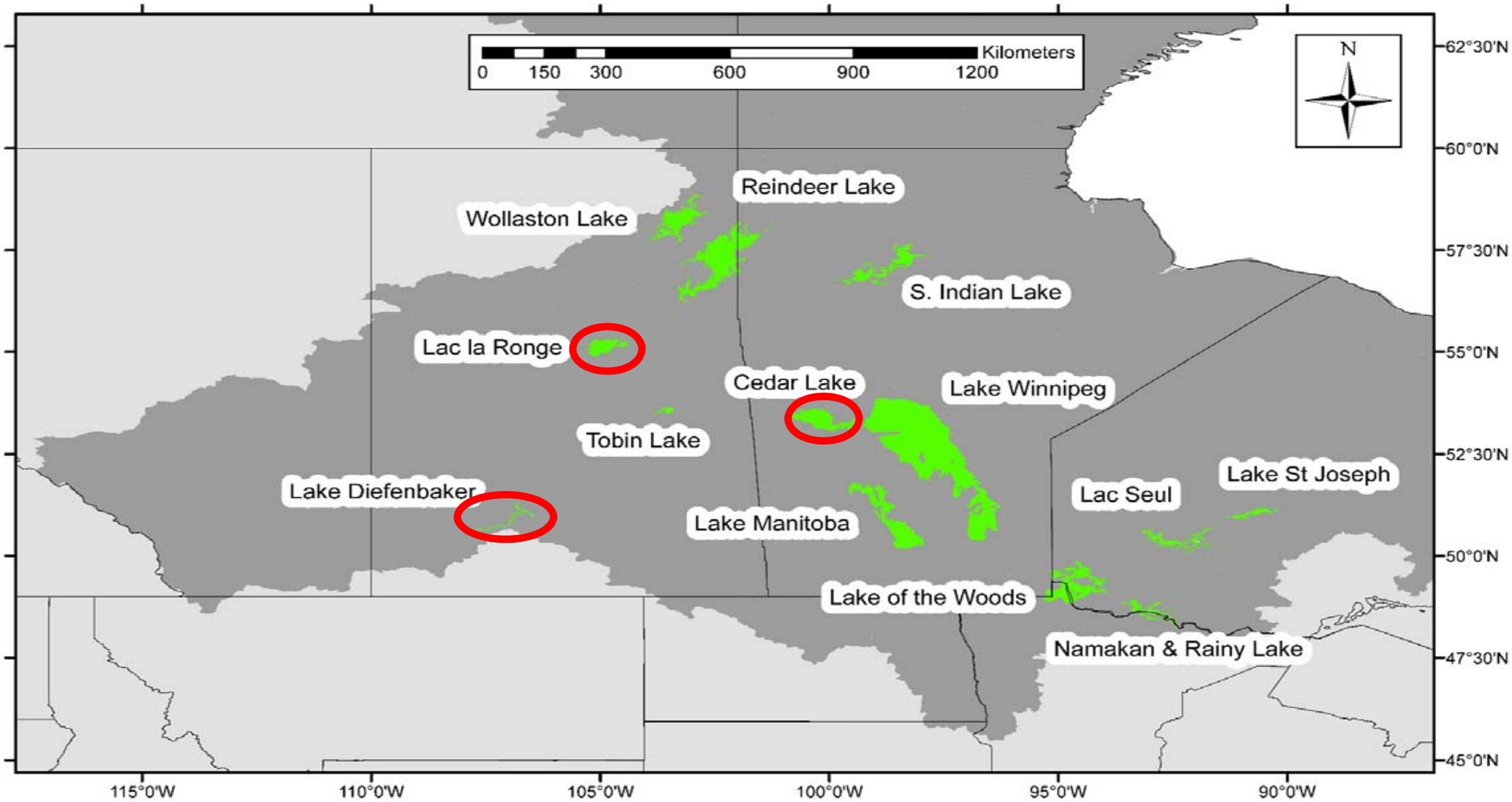
Tefs et al., in prep.

HYPE Reservoir Regulation



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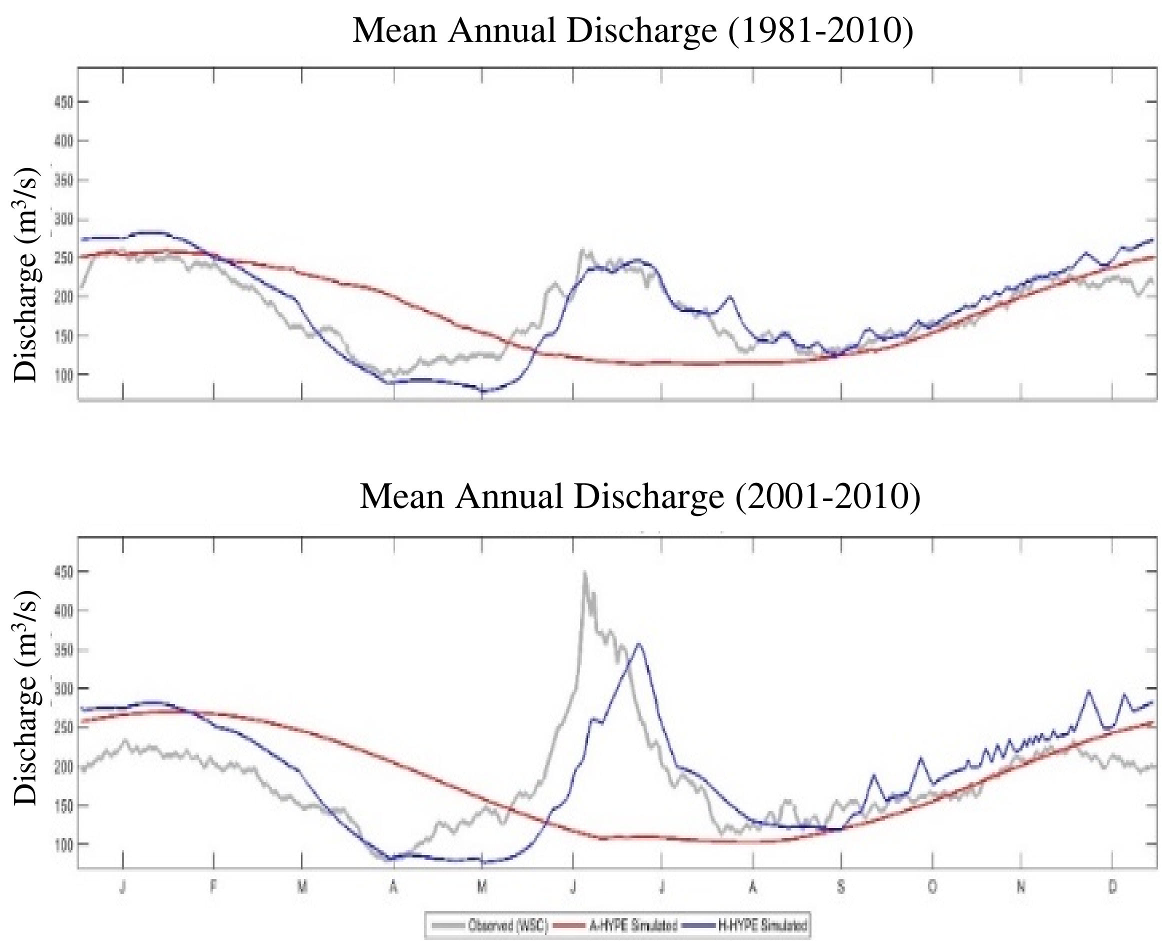
Tefs et al., in prep.

Lake Diefenbaker

- Persistence of sine curve with A-HYPE model
- H-HYPE more reactive to climate cycles governing operations longer-term
- H-HYPE uses ideal monthly discharge and daily safe water yield levels



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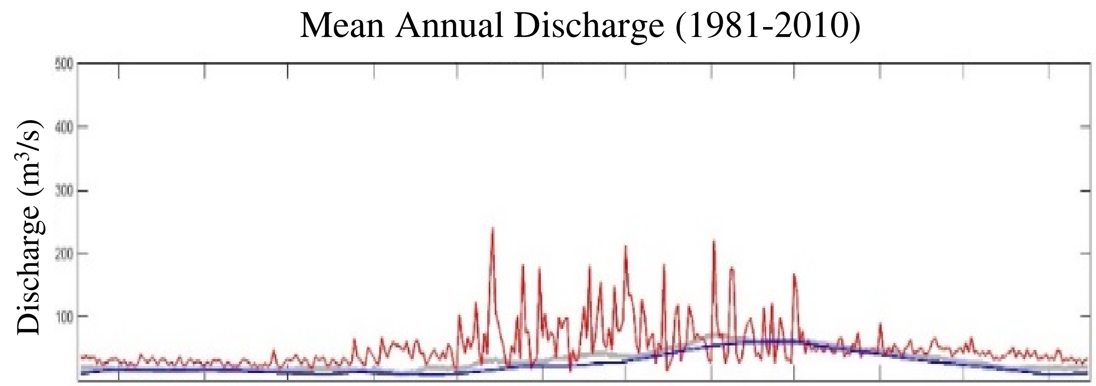
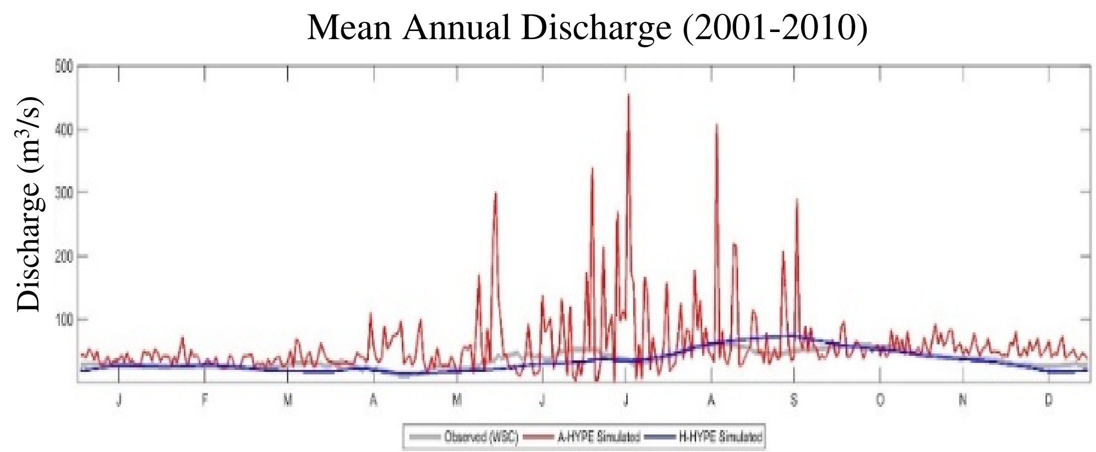
Tefs et al., in prep.

Lac la Ronge

- Smaller reservoir
  - No inflow record
- Generated synthetic inflow
  - Relationship between Q_{in}, Q_{out} and WSL
- A-HYPE reacts to wind-induced storage change
- H-HYPE smooths wind-effects and simulates operational change





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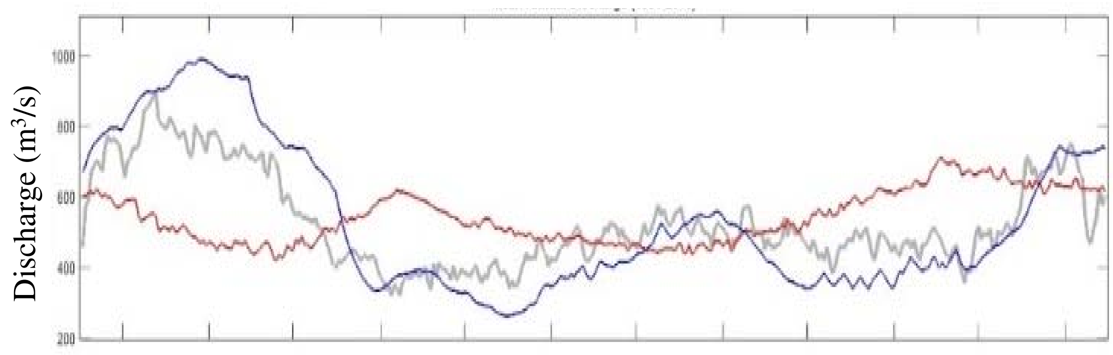
Tefs et al., in prep.

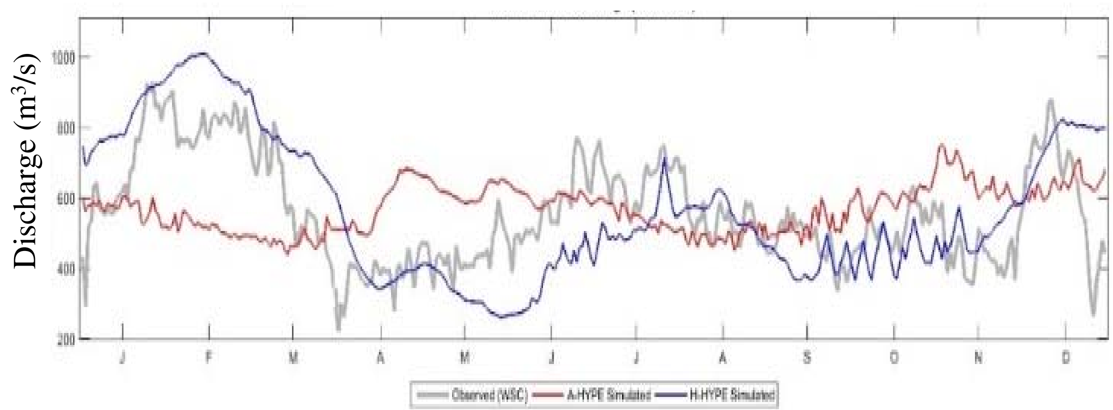
Cedar Lake

- Complex operations:
  - Large reservoir
  - Large operating range
  - Swing station for Jenpeg
- A-HYPE oscillates around Minimum Operating Level
- H-HYPE adds buffer (transition) zone and low-flow operations guideline

Mean Annual Discharge (1981-2010)



Mean Annual Discharge (2001-2010)

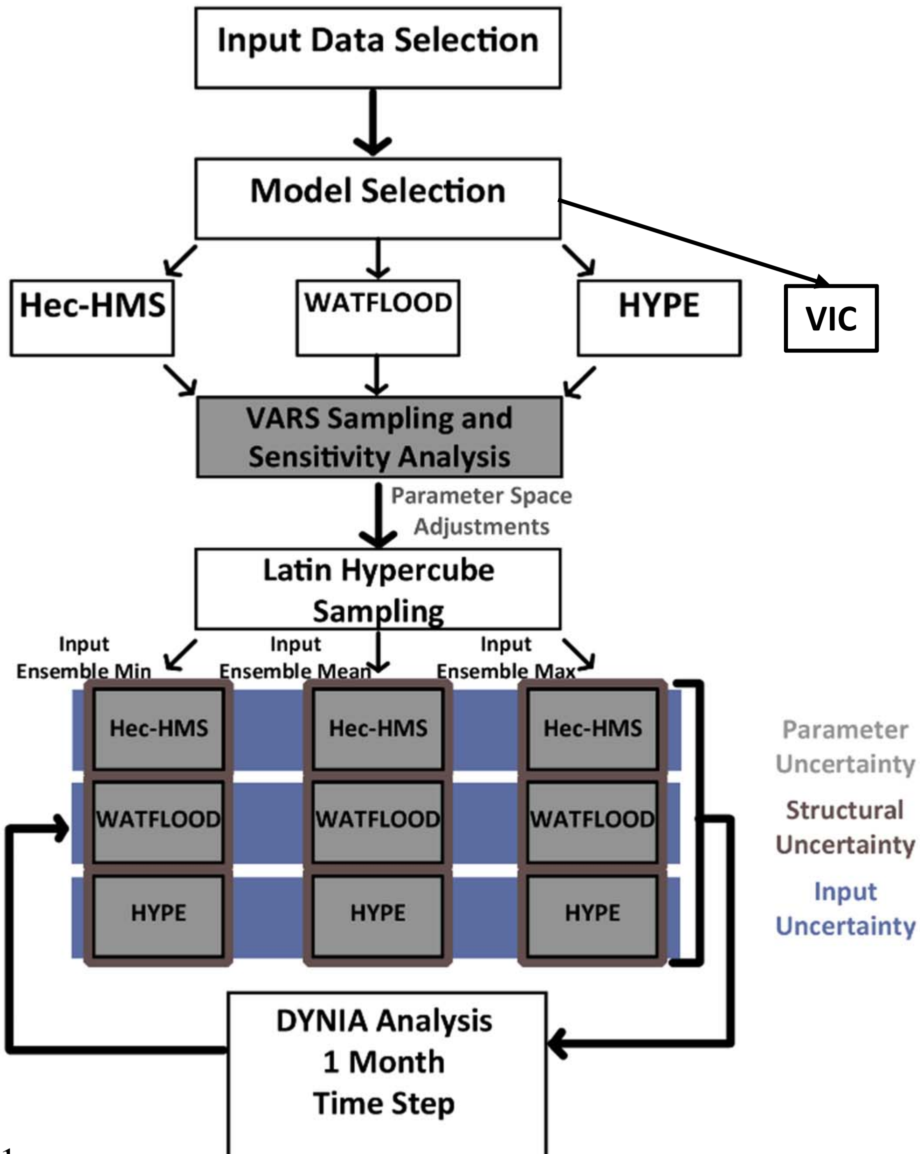


2. Multi-Model Study: Nelson R.

- ***Objective: to quantify changes in the hydrologic cycle and net freshwater discharge resulting from***
  - **Climate-induced change**
  - **Operational (regulated) change**
  - **Uncertainty in modelling process**

- <u>Methodology</u>: use an ensemble of hydrologic models, including HYPE (regulated model), to simulate hydrology for
  - Historic period (1981-2010)
  - Future period (2021-2070)
- Quantify sources of uncertainty and their *propagation* through to hydrologic prediction

Pokorny et al., in prep.



Study Design

- 5 gridded climate datasets
- 2 observed datasets
- 4 hydrologic models
  - Run VARS to define (seasonal) parameter sensitivity
  - Random selection from parameter space as a function of # model parameters
  - Generate ensembles (min/mean/max)
- Uncertainty assessment
  - Input data
  - Parameter
  - Structural
  - Output data

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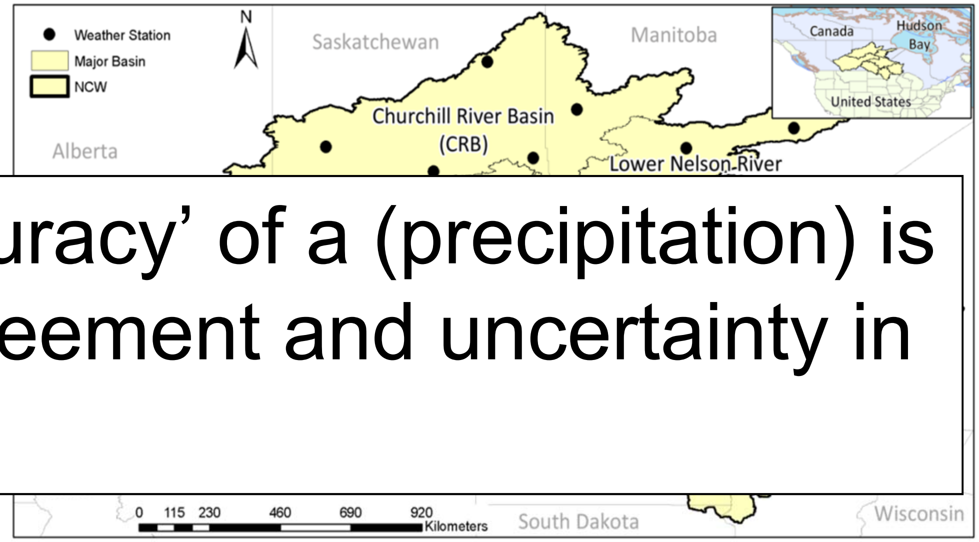
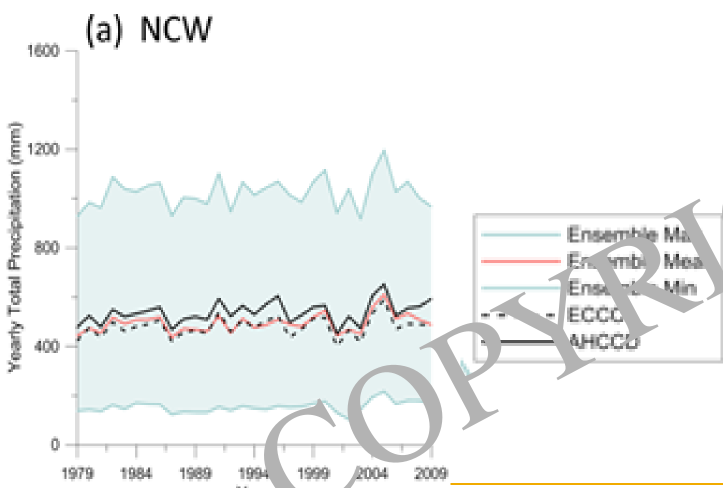
Pokorny et al., in prep.

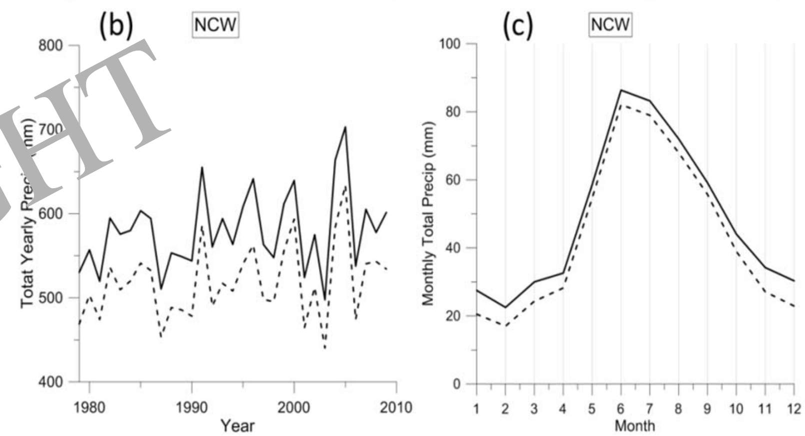
Input Data Uncertainty

(a)



Evaluation of the ‘accuracy’ of a (precipitation) is complicated by disagreement and uncertainty in the observations.





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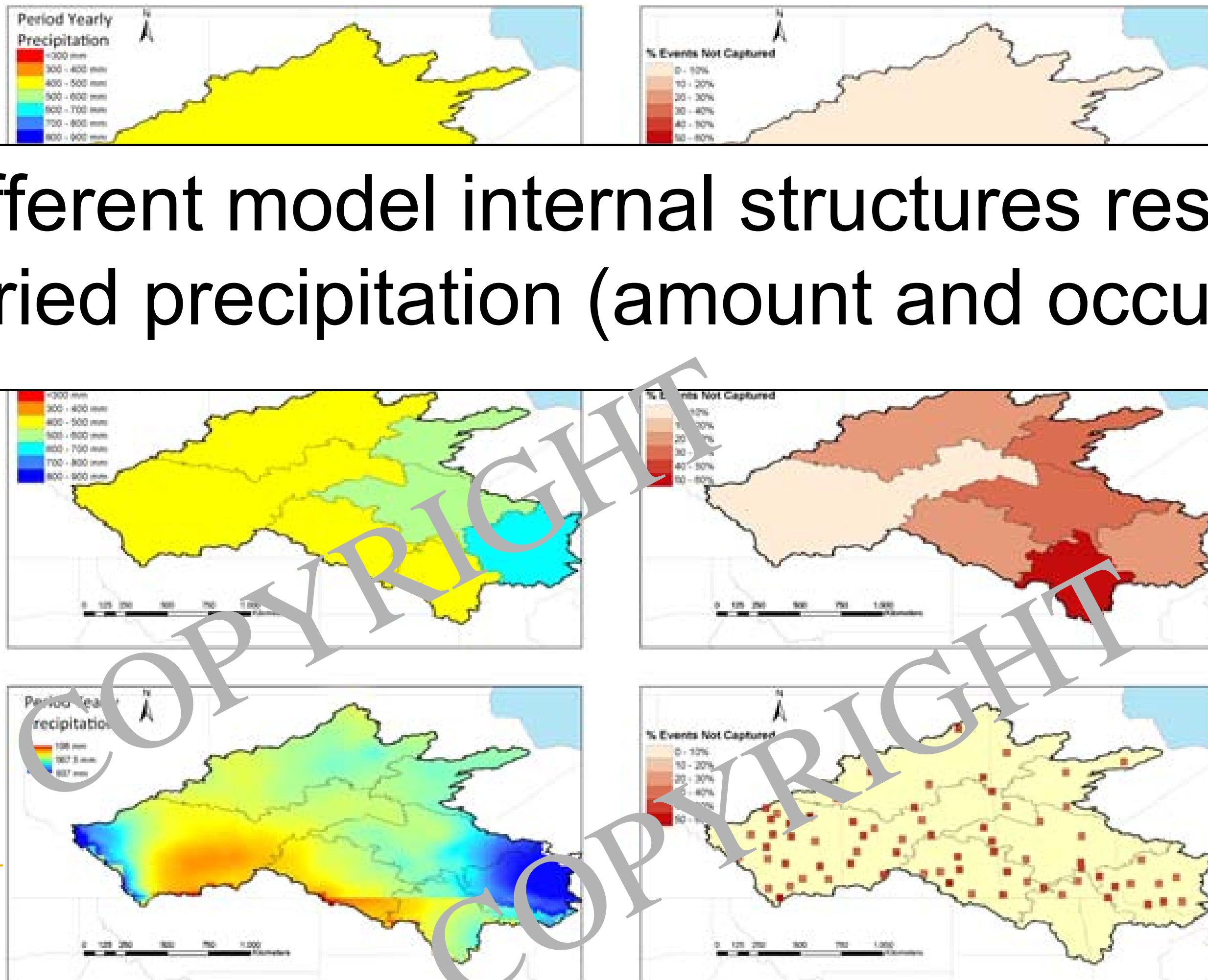
Model Structural Uncertainty



Different model internal structures result in varied precipitation (amount and occurrence)

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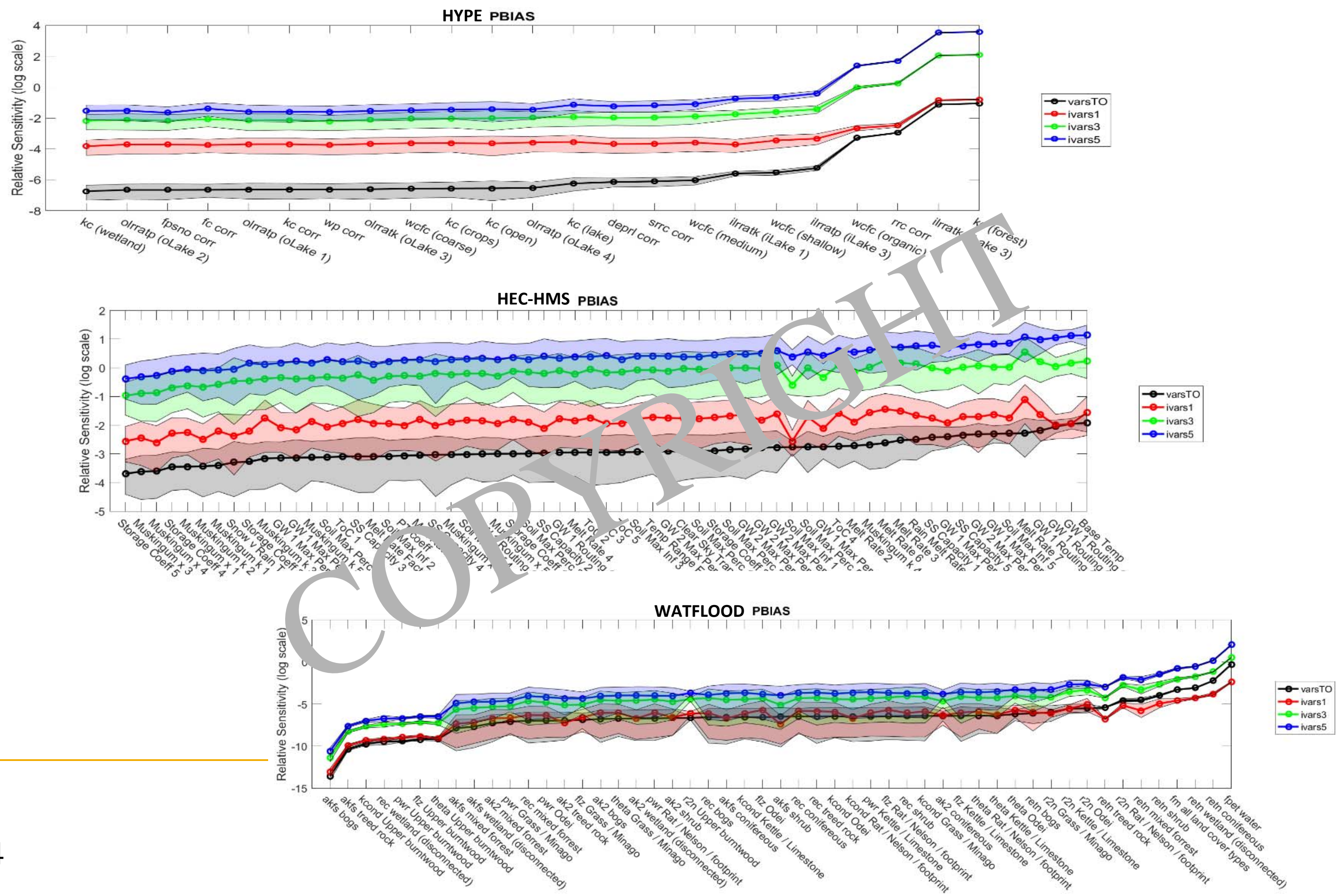
Pokorny et al., in prep.

Parameter Uncertainty: Identifiability



Increasing model (parameter space) complexity

Decreasing parameter identifiability

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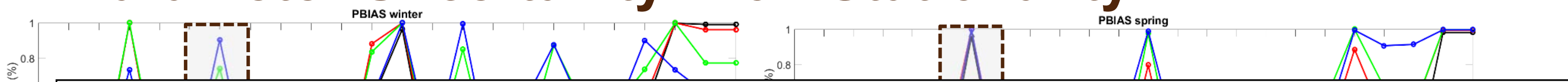
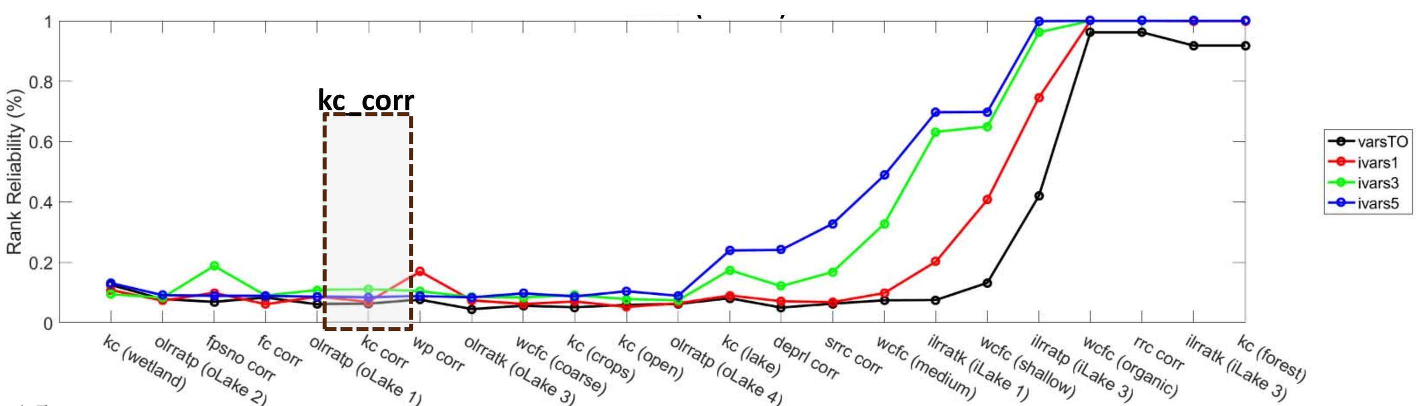
Pokorny et al., in prep.

Parameter Uncertainty: Non-Stationarity



Model calibration is an infinite exercise, and inherently *cannot* be ‘standardized’ due to differences in model structure, (seasonal) influence of, and (unequal) number of parameters.



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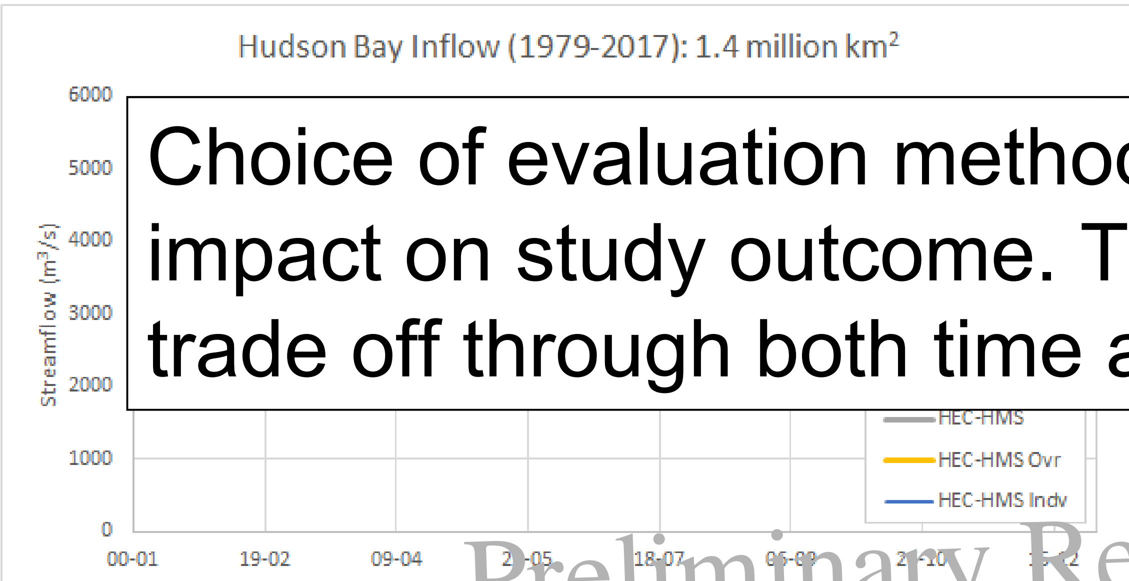
J. Kostick

Output Uncertainty: Model Evaluation

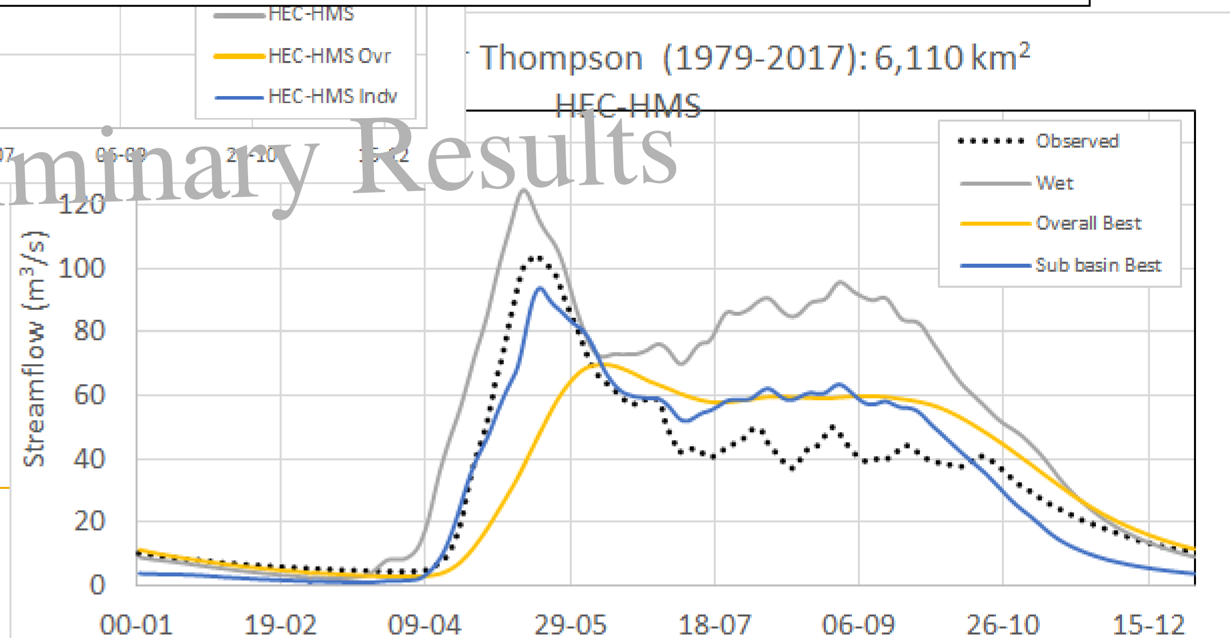


HudBay	HEC (Wet)	HEC (Ovr)	HEC (Sub)	WF
				-1
				.1
				.6

Choice of evaluation method has a distinct impact on study outcome. There is error trade off through both time and space.

Preliminary Results

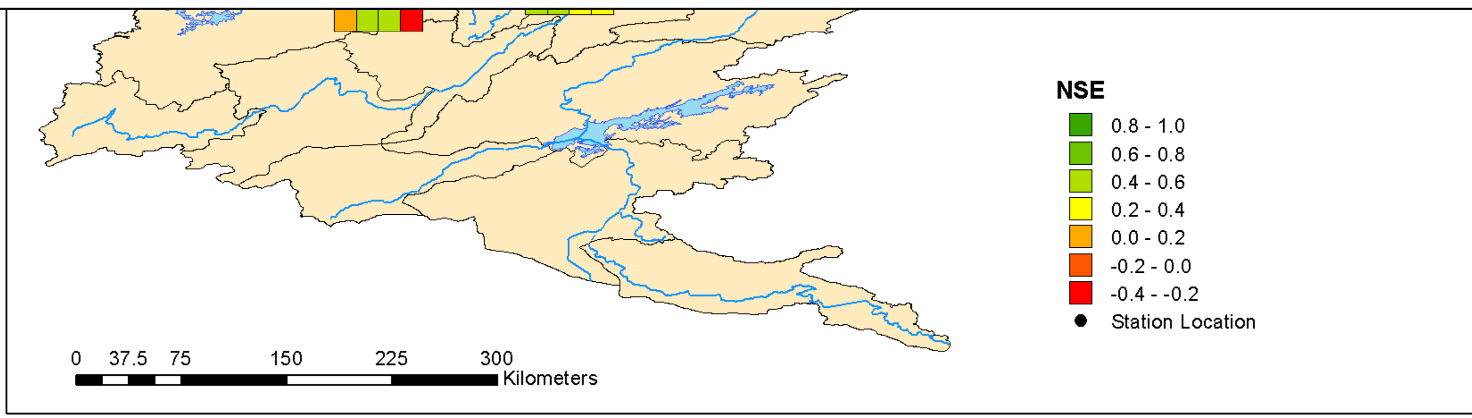
Odei R	Wet	Ovr	Sub
%Dv	52	2.3	-0.4
Log(%Dv)	11	-1	-11
NSE	0.2	0.5	0.9
KGE	0.5	0.7	0.9



Pokorny et al., in prep.

Output Uncertainty: Evaluation Philosophy

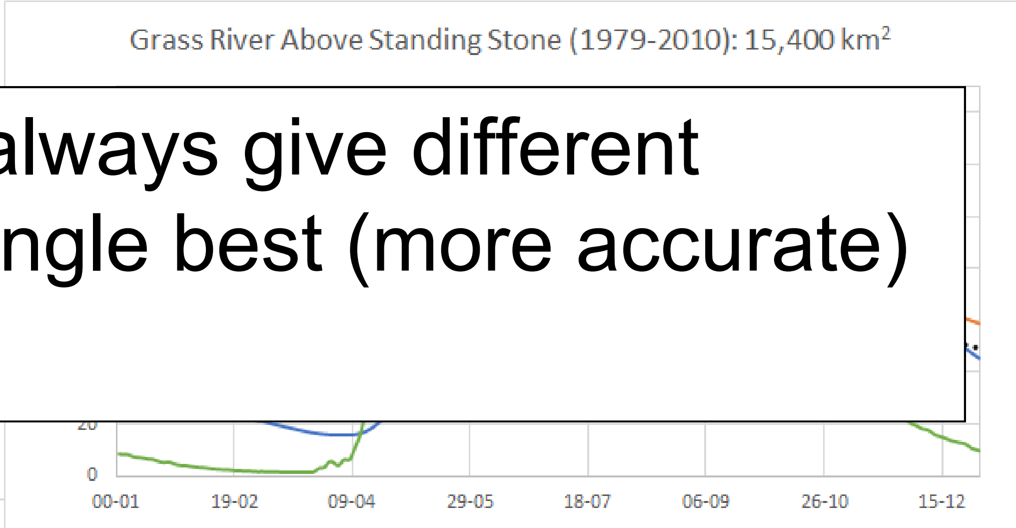
Each model has a different development (therefore, evaluation) philosophy. Consideration must be given to internal process accuracy versus optimal outlet discharge.



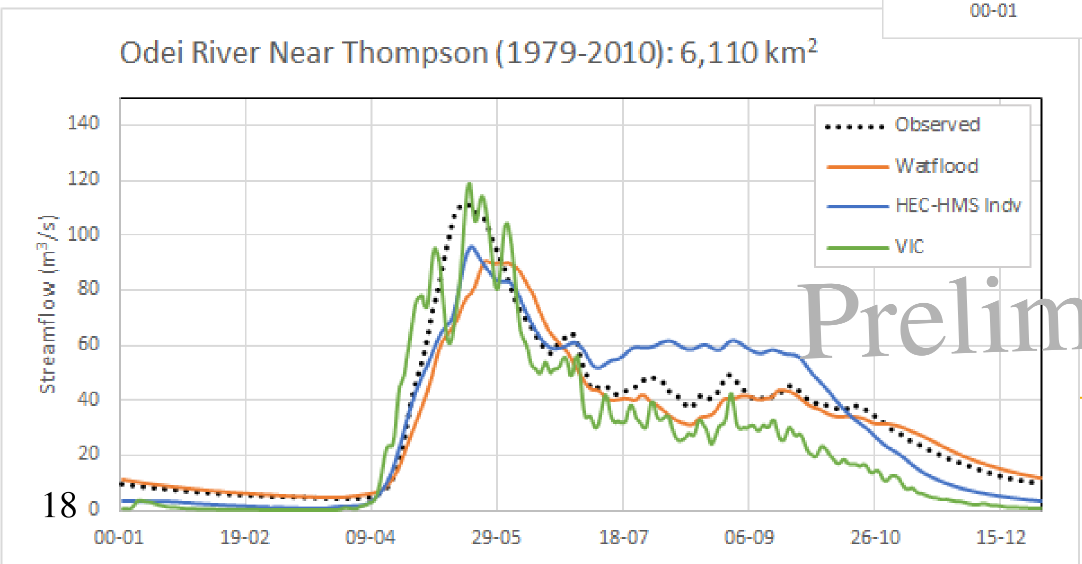
Models (left to right): HEC-HMS, WATFLOOD, HYPE, VIC
1981-2009

J. Kostick

Output Uncertainty: Model Choice



Different models will always give different results. There is no single best (more accurate) model.



Preliminary Results

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Lessons Learned (so far…)

1. Uncertain (unreliable) observations make quantifying model/input data accuracy impossible
2. ‘Standardizing’ input is impossible due to model structural constraints
3. Model calibration exercise is infinite and not easily ‘standardized’
4. Evaluation metrics determine study outcome; outcome changes depending on metrics selected.
5. To be unbiased, evaluation must account for differing evaluation philosophies
6. There is no single ‘best’ model.

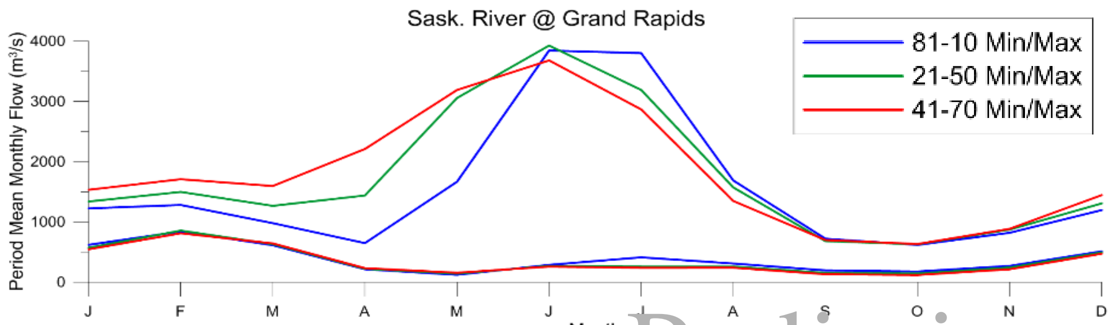
S. Pokorny & A. Tefs

3. Projecting Trends in NCRB Hydrology

- Analysis of future NCRB climate from CMIP5 models
  - Ensemble of 19 GCMs selected
  - Representing >87% of variability from 154 GCM simulations
- Assess future relative to a 1981-2010 baseline
  - 2030s (2021-2040) & 2050s (2041-2070)
- Use HYPE to determine *range* (ensemble min/max) in hydrologic response to
  - Climate-induced change
  - Regulation of future hydrologic regime
- Evaluate statistical trend in 3x 30-year ensemble means of monthly average discharge (precip and temp)
  - Mann-Kendall at 5% significance

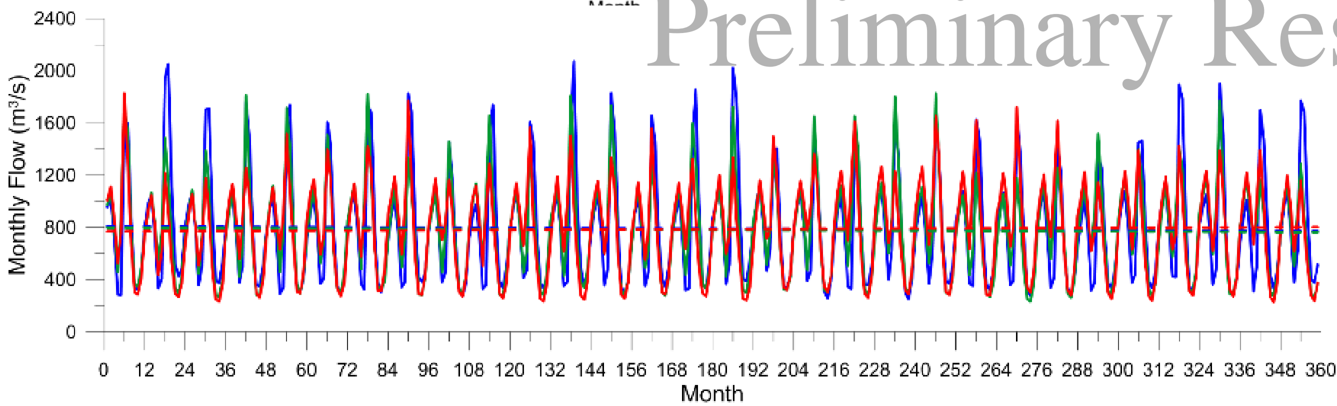
S. Pokorny & A. Tefs

Trend Analysis: Saskatchewan R.



- HYPE ensemble projecting shift to *earlier* peak flows
- Similar operating range to historical period

Preliminary Results



- Insignificant ‘*zero change*’ in mean monthly discharge through time
- Weak evidence of higher peaks (near future) and lower lows (far future)

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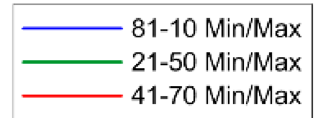
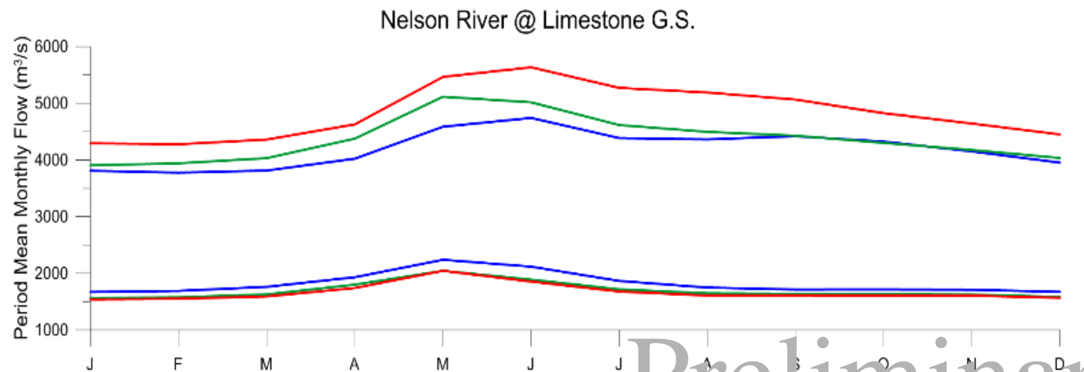
S. Pokorny & A. Tefs

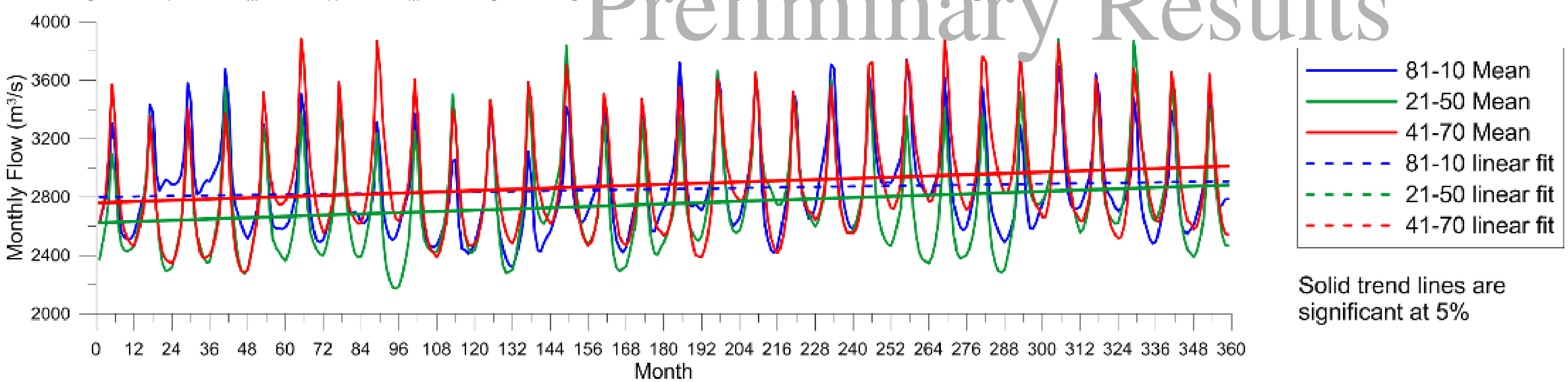
Trend Analysis: Nelson R.





- HYPE ensemble projecting shift to *higher magnitude, earlier* peak flows
- Increased operating range relative to historical period

Preliminary Results



- Shift to significant *increasing* trend in future mean monthly discharge
- More extreme *high* and *low* flows in future periods

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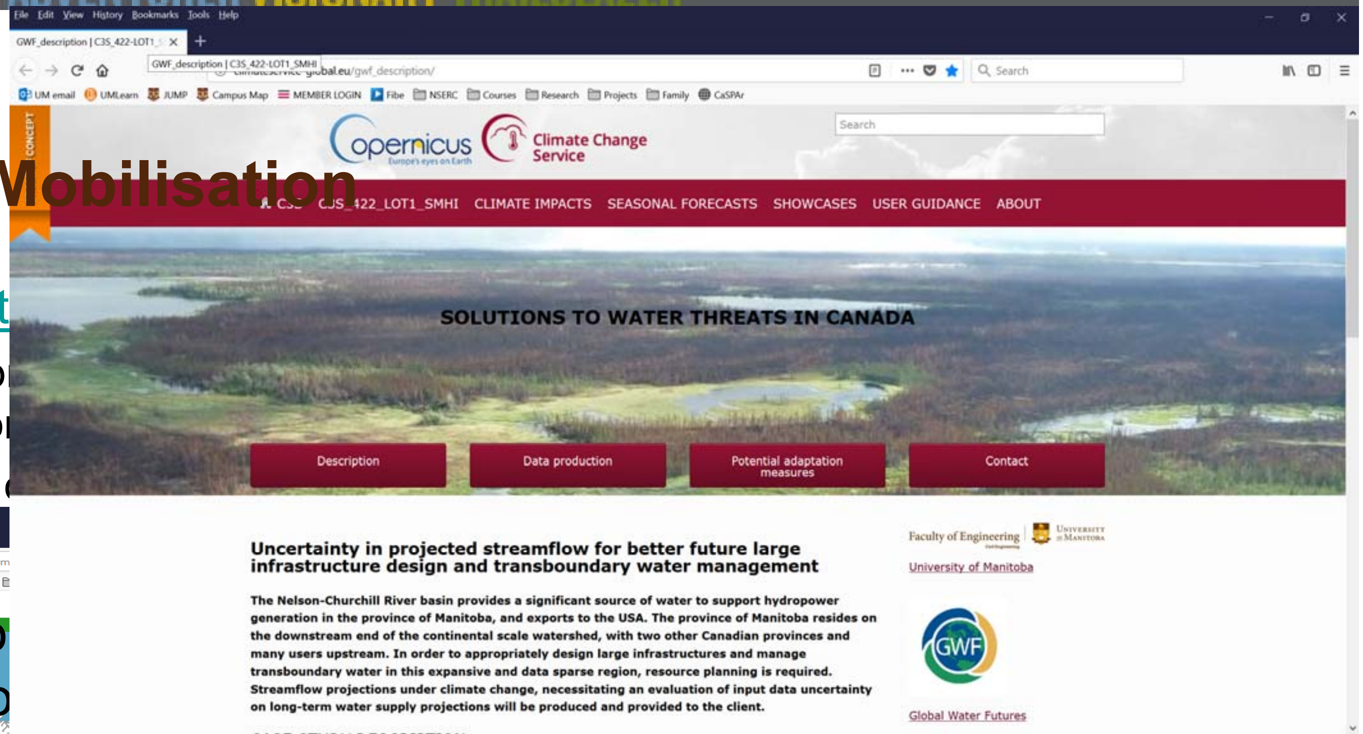
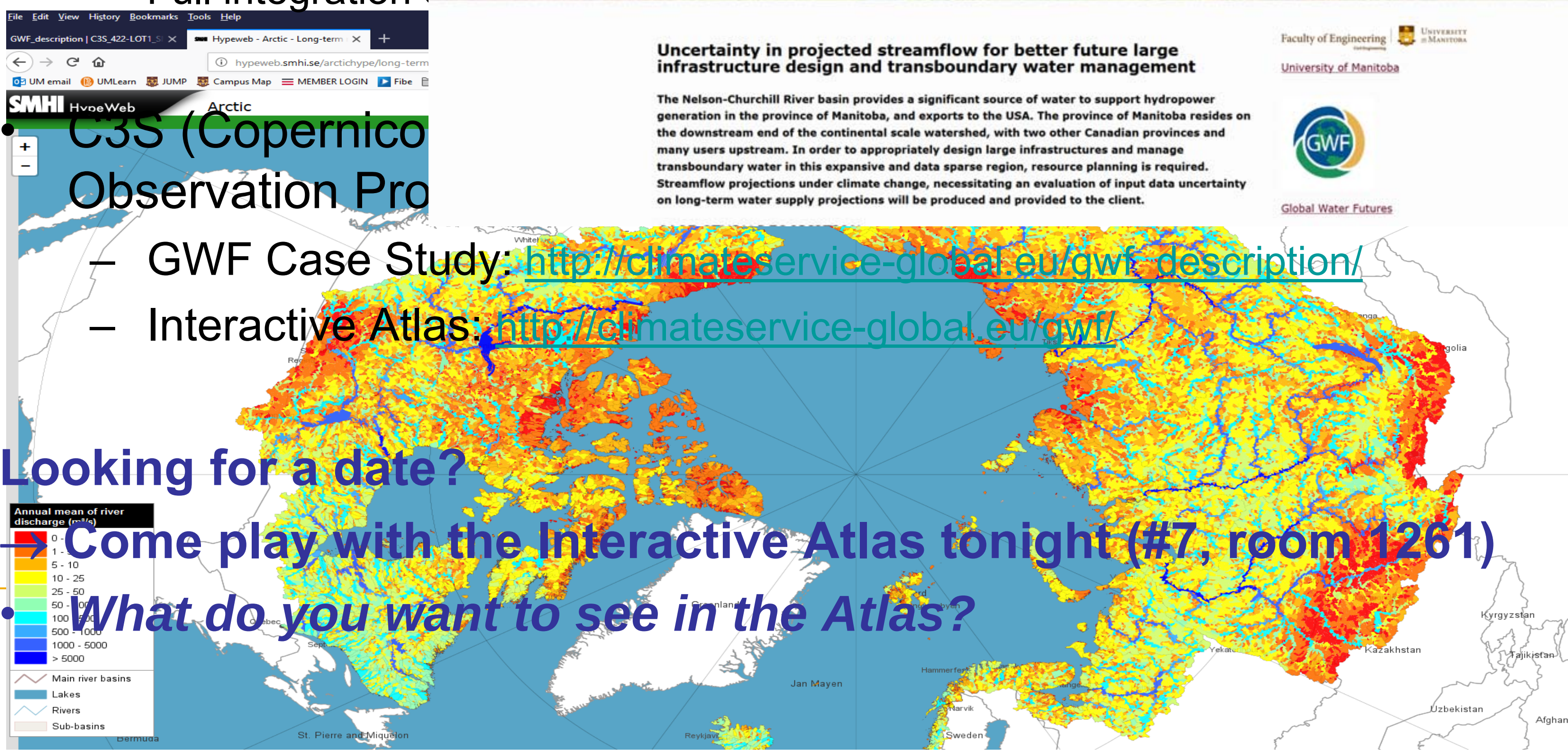
4. Knowledge Mobilisation

- A-HYPE web: ht
  - UM HYPE calib
    Hudson Bay do
  - Full integration
- C3S (Copernico
  Observation Pro
  - GWF Case Study: http://climateservice-global.eu/gwf_description/
  - Interactive Atlas: http://climateservice-global.eu/gwf/





Looking for a date?

→ Come play with the Interactive Atlas tonight (#7, room 1261)

- ***What do you want to see in the Atlas?***

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5. On-Going GWF-IMPC Work

Theme A2: HYPE Modelling

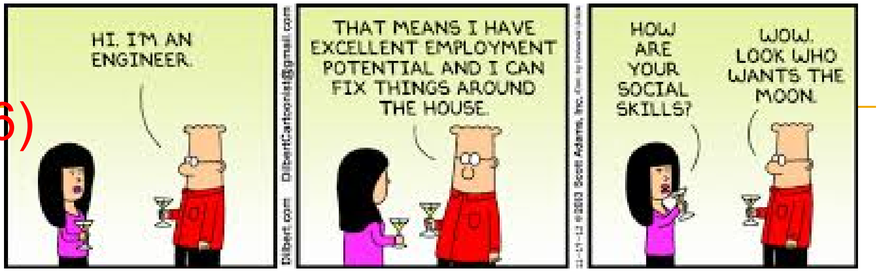
- See **Bajracharya poster #11** (rm 1114)

Theme A5: Multi-Model Assessment

- GRIP-E: Apply HYPE to Lake Erie domain
- Assist with WATFLOOD contribution (F. Seglenieks) to GRIP-E

Theme B1: Integrated Water Resources Management Modelling

- Use multi-model ensemble NCRB flows to drive IWRM for Nelson R.
- Dr. Asadzadeh's talk (Day 1)
- See **Beiraghdar poster #4** (rm 2266)



6. In Summary, our team has

- E[illegible]d an improved HYPE model for the NCRB
  - Imp[illegible]ed representation of basin regulation
  - Mo[illegible]epresentative frozen soil and prairie pothole processes

- [illegible] experience from on-going m[illegible]ti-model study in the [illegible]elso[illegible] R.
  1. [illegible]d for well defined *desi[illegible]d o[illegible]tcome* to guide multi-model study c[illegible]ces
  2. C[illegible]r communication of study scope (expectations) to stakeholders

- [illegible] future trends using HYPE & CMIP5 simulation[illegible]
  - [illegible]nt increases in precip and temp across the NCRB
  - [illegible]creases in discharge for all basins *except* Sask [illegible]

- Investe[illegible] in kn[illegible]ge mobilisation through C[illegible]eract[illegible] Atlas
  - We wa[illegible] feed[illegible]hat you'd like to[illegible]

Food for Thought…

Bas[illegible] on [illegible]e past year of interactions, we'd like to se[illegible]re

- [illegible] cross-linkages between themes (models)
  - Inn[illegible]ation in IMPC lies at the intersection of our individual expertise
- [illegible]egu[illegible] interaction with "satellite" GWF project groups
  - M[illegible] frequent and defined meetings would be welcomed
  - C[illegible]ider mobility of HQP to be truly pan-Canadian in our training?
- Enga[illegible]ment of stakeholders willing to guide *process* (not [illegible]st ou[illegible]ome)
  - [illegible]ould welcome the opportunity to have stakeholders at the ta[illegible] the [illegible]rocess, and leverage their resources/expertise
- F[illegible]xplicitly defining our deliverables/outcomes
  - [illegible]ver-arching goals and how we address stakeho[illegible]
  - E[illegible] indi[illegible]al theme projects link up with integrated s[illegible]es
- Knowle[illegible]ge *in[illegible]ing*, not just knowledge m[illegible]tion
  - Collecti[illegible] I believ[illegible]et a new stand[illegible]arch and user e[illegible]gement

EXPLORER INNOVATOR ADV

REBEL ADVENTURER TRAILBLAZER

INNOVATOR CHALLENGER REBEL VISIONARY

REBEL PIONEER CREATOR EXPLORER TRAILBLAZER INNOVATOR

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