HYPE Modelling in the Nelson River Basin
A Multi-Model Assessment

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Contributors to this Work

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

Acknowledgements to our Partners
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

- $\Delta t$: daily
- Area: 1.4 million km²
- Precip & Temp: WFDEI
- Topography: Hydro1K
- Soils: HWSD
- Land use: Globcover
- Lakes & wetlands: GLWD
- Basic regulation types:
  - flood control
  - hydropower
  - irrigation supply
  - diversions
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)
HYPE Reservoir Regulation
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
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

Tefs et al., in prep.

Mean Annual Discharge (1981-2010)

Mean Annual Discharge (2001-2010)
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
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

- **Methodology:** 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**
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
Input Data Uncertainty

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

Different model internal structures result in varied precipitation (amount and occurrence)
Parameter Uncertainty: Identifiability

Increasing model (parameter space) complexity

Decreasing parameter identifiability
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.
Output Uncertainty: Model Evaluation

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

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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.
Output Uncertainty: Model Choice

Different models will always give different results. There is no single best (more accurate) model.
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.
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
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)
Trend Analysis: Nelson R.

**Preliminary Results**

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

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

• A-HYPE web: http://hypeweb.smhi.se/arctichype/long-term-means/
  – SMHI HYPE calibrations are an improvement over those shown by SMHI for
    Hudson Bay domain
  – Full integration of model codes and calibrations anticipated in near future
• C3S (Copernicous Climate Change Service) is an EU Earth Observation Programme
  – GWF Case Study: http://climateservice-global.eu/gwf_description/

Looking for a date?
→ Come play with the Interactive Atlas tonight (#7, room 1261)

• What do you want to see in the Atlas?
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

- Established an improved HYPE model for the NCRB
  - Improved representation of basin regulation
  - More representative frozen soil and prairie pothole processes
- Gained experience from on-going multi-model study in the Nelson R.
  - Need for well defined desired outcome to guide multi-model study choices
  - Clear communication of study scope (expectations) to stakeholders
- Projected future trends using HYPE & CMIP5 simulations
  - Insignificant increases in precip and temp across the NCRB
  - Significant increases in discharge for all basins except Sask & Red R.
- Invested in knowledge mobilisation through C3S Interactive Atlas
  - We want your feedback on what you’d like to see!
Food for Thought…

Based on the past year of interactions, we’d like to see more:

• Concrete cross-linkages between themes (models)
  – Innovation in IMPC lies at the intersection of our individual expertise

• Regular interaction with “satellite” GWF project groups
  – More frequent and defined meetings would be welcomed
  – Consider mobility of HQP to be truly pan-Canadian in our training?

• Engagement of stakeholders willing to guide process (not just outcome)
  – We would welcome the opportunity to have stakeholders at the table from the
    outset of the process, and leverage their resources/expertise

• Focus on explicitly defining our deliverables/outcomes
  – Identify our over-arching goals and how we address stakeholder needs
  – Ensure individual theme projects link up with integrated system outcomes

• Knowledge influencing, not just knowledge mobilisation
  – Collectively I believe we can set a new standard for research and user engagement