Enhancing total water prediction for the Great Lakes through calibration of the National Water Model in Canadian watersheds

H43I-2136

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Background

Recent widespread flooding and erosion across the Great Lakes resulting from record and near record high lake levels underscores the need for total water prediction in the Great Lakes. Nearly half of the basin is in Canada **(Figure 1a)**, requiring NWM development for the Canadian portion of the Great Lakes basin. Recent expansion of the NWM hydrofabric into the Canadian portion of the Great Lakes basin, described by Mason et al (2019), has set the stage for expanding modeling into Canada for NWM version 2.1.

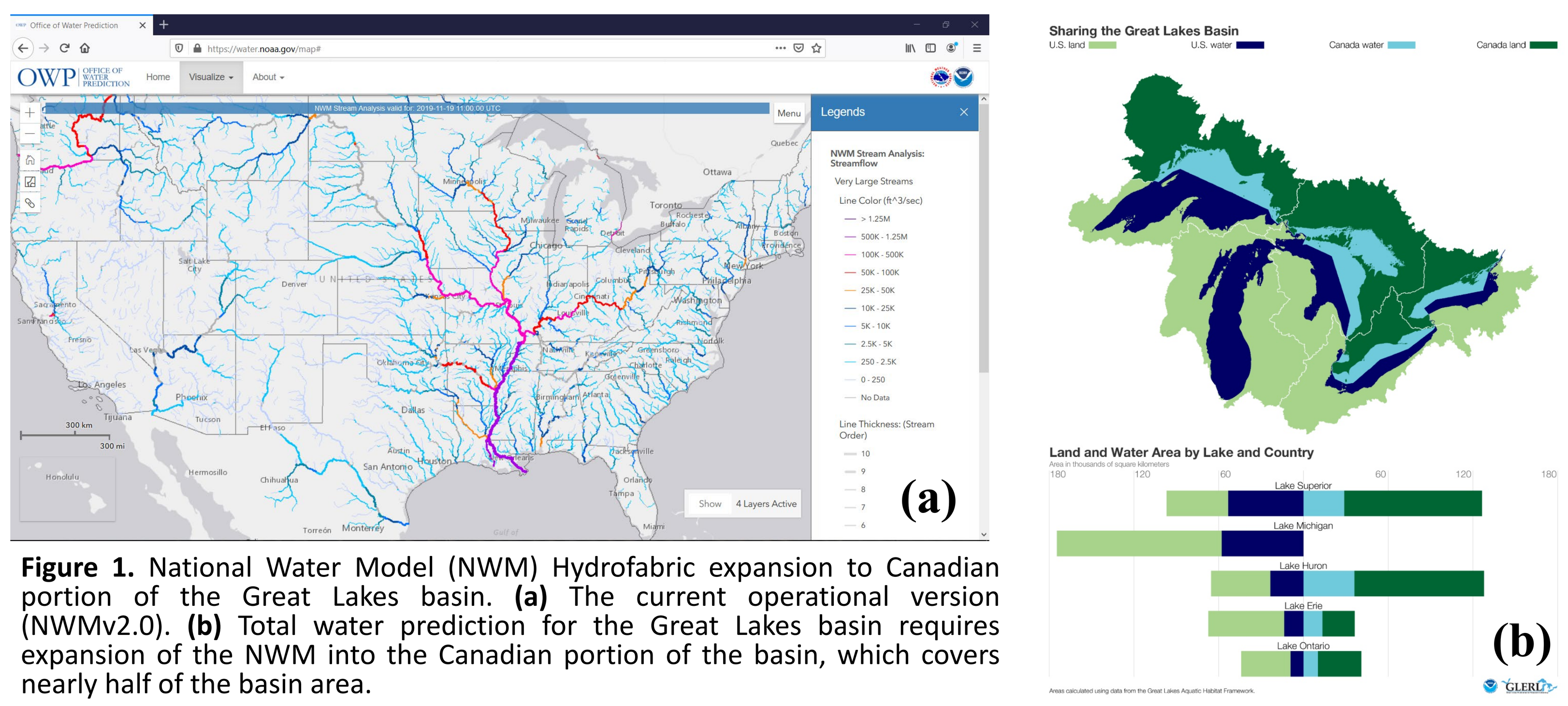

Figure 1. National Water Model (NWM) Hydrofabric expansion to Canadian portion of the Great Lakes basin. **(a)** The current operational version (NWMv2.0). **(b)** Total water prediction for the Great Lakes basin requires expansion of the NWM into the Canadian portion of the basin, which covers nearly half of the basin area.

Methods

- Calibrated at 27 gages that were identified based on size, period of record (2007-2017), and lack of regulation.
- Spin-up was conducted using 2007-2016 data to provide initial conditions.
- A dynamically dimensioned search (DDS) algorithm was employed for each gage, using 150 to 300 iterations starting in 2007. Calibration was based on maximizing the weighted NSE for the 2008-2013 period.
- DDS calibration results were evaluated to identify "donor" catchments with which to expand the parameterization to the ungaged portion of the Canadian land surface.

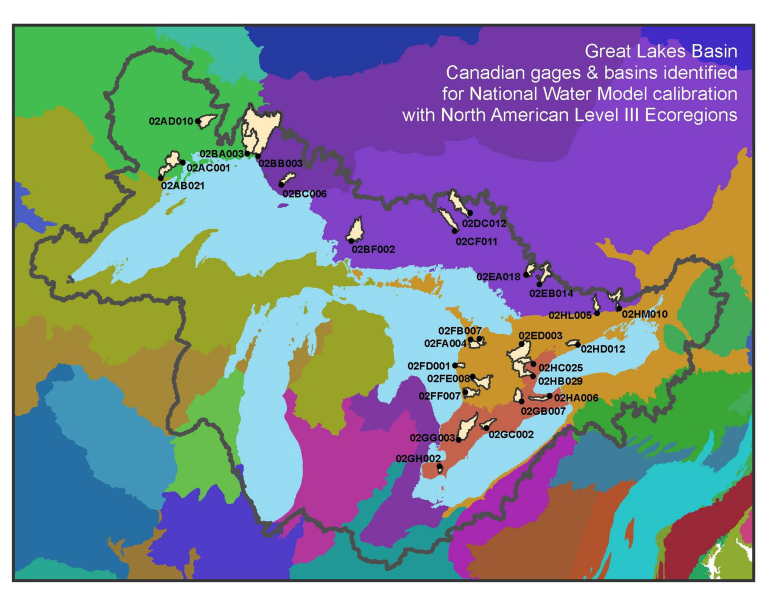

Figure 2. Locations of calibration catchments in Canada

- Parameter donors for each HUC8 (Canada) and HUC10 (U.S.) were identified by finding the donor catchment with the minimum distance from the HUC based on the Gower's distance metric.

Table 1. Calibration Parameters

Name	Description
bexp	beta parameter
smcmax	maximum soil moisture content for each soil type
dksat	saturated soil hydraulic conductivity (m/s)
refkdt	parameter in the surface runoff parameterization
slope	slope index
retdeprtfac	multiplier on maximum retention depth before flow is routed as overland flow
lksatfac	multiplier on saturated hydraulic conductivity in lateral flow direction.
zmax	conceptual maximum depth of bucket
expon	bucket model exponent
cwpvt	canopy wind parameter
vcmx25	maximum rate of carboxylation at 25°C (μmol CO_2/m^2/s)
mp	slope of conductance to photosynthesis relationship
mfsno	Snowmelt parameter
rsurfexp	soil shape function exponent parameter

Data

Geophysical

The expansion of the NWM into the Canadian portion of the Great Lakes employs the new spatially consistent hydrofabric spanning the international border, described by Mason et al. (2019), shown in **Figure 3.**

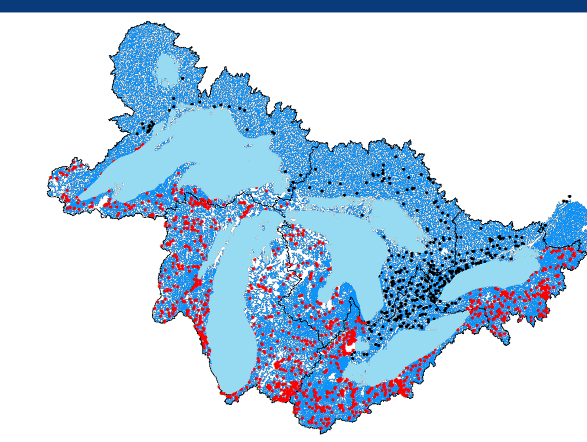

Figure 3. Great Lakes Hydrofabric for the NWM

Meteorological Forcings

The Analysis of Record for Calibration (AORC), the dataset currently used for calibration of the NWM, is a high-resolution dataset of near-surface weather based on surface, radar, and satellite observations.

Precipitation fields from the AORC are shown in **Figure 4** for 2010 to 2018. From 2012 to 2018, significant biases were present in southern Ontario, resulting in the need to adjust calibration and validation periods for 18 catchments.

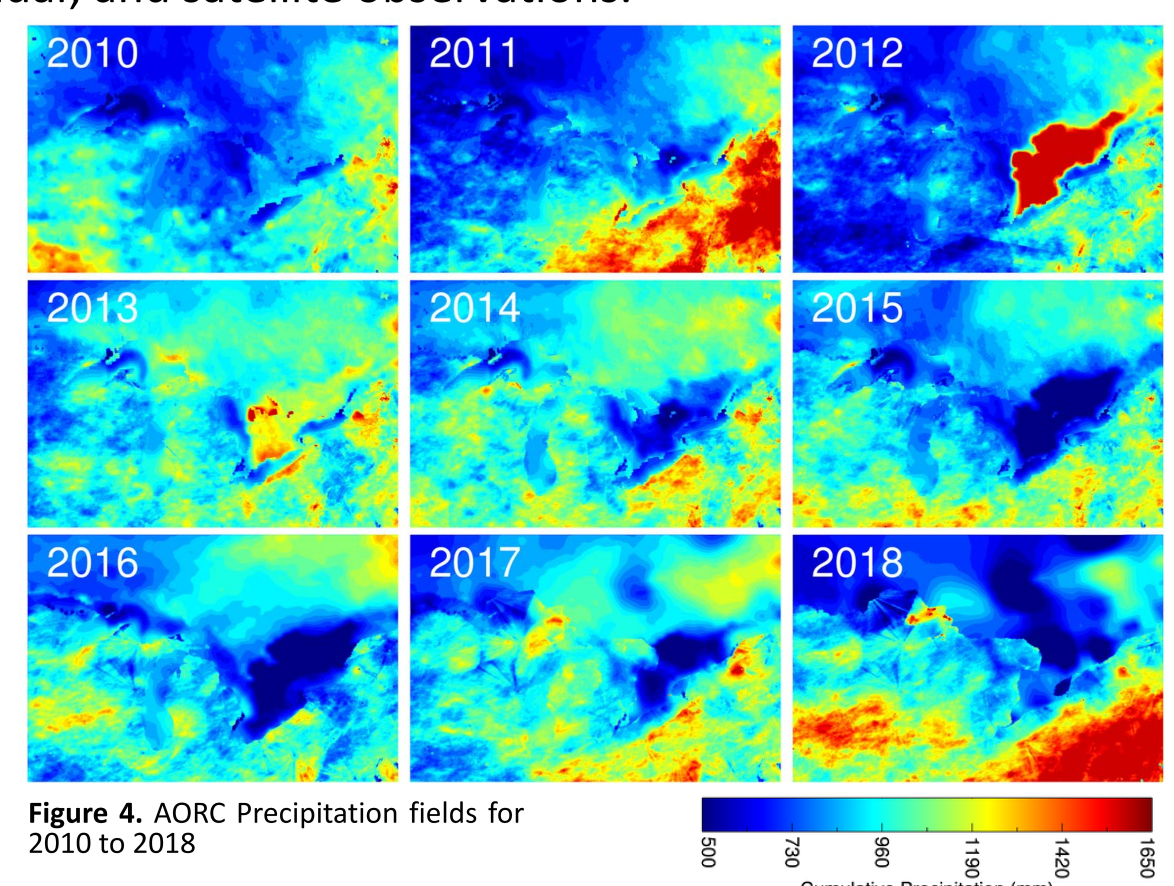

Figure 4. AORC Precipitation fields for 2010 to 2018

Calibration Results

Example hydrographs are shown in **Figure 5** for one catchment where the AORC appropriately represented precipitation **(a)**, and one catchment in southern Ontario where the AORC did not adequately reflect precipitation **(b)**. The 2012-2013 data were subsequently removed for calibration in gages that were impacted by the problematic AORC data during that period.

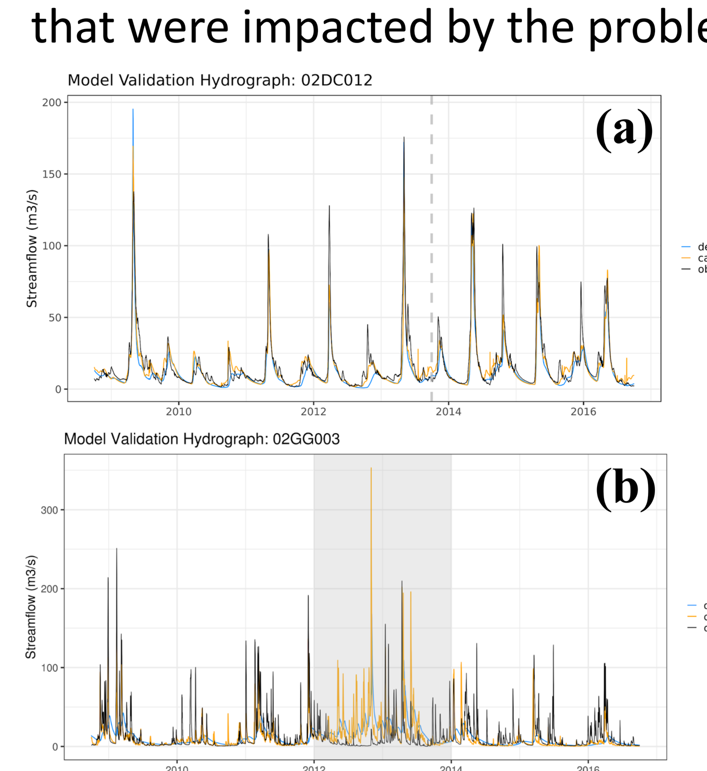

Figure 5. Example hydrographs resulting from calibration.

Figure 6 and **Table 2** summarize calibration results for all 27 watersheds. The weighted NSE from the best calibration run for each watershed ranged from 0.19 to 0.65 (NSE ranged from 0.37 to 0.86).

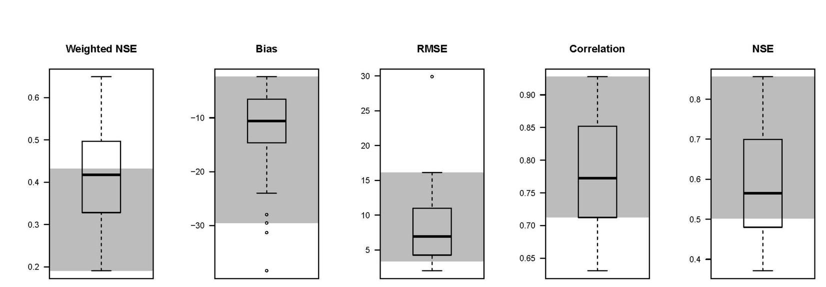

Figure 6. Calibration metrics for all catchments (boxplots) and donor catchments (shaded gray range)

Table 2. Calibration results. Donor catchments are highlighted in green and outlined in red.

Gage ID	02AB021	02AC001	02AD010	02BA003	02BB003	02BC006	02BF002	02CF011	02DC012	02EA018	02EB014	02ED003	02FA004
Weighted NSE	0.42	0.42	0.39	0.39	0.33	0.33	0.31	0.22	0.19	0.51	0.57	0.56	0.32
% Biase	-11	-11	-2	-2	-6	-6	-13	-11	-7	-8	-15	-8	-13
RMSE	7.0	7.0	11.0	11.0	29.9	29.9	12.4	4.3	7.3	4.2	7.0	10.1	4.5
Correlation	0.71	0.71	0.80	0.80	0.85	0.85	0.87	0.90	0.93	0.70	0.65	0.72	0.86
NSE	0.50	0.50	0.63	0.63	0.72	0.72	0.69	0.80	0.86	0.48	0.39	0.49	0.72

Gage ID	02FB007	02FD001	02FE008	02FF007	02GB007	02GC002	02GG003	02GH002	02HA006	02HB029	02HC025	02HD012	02HL005	02HM010
Weighted NSE	0.32	0.43	0.43	0.49	0.42	0.45	0.33	0.56	0.45	0.54	0.65	0.53	0.38	0.26
% Biase	-10	-38	-28	-24	-6	-14	-30	-5	-31	-5	-11	-7	-10	-22
RMSE	2.0	5.2	12.5	13.9	4.9	9.2	16.1	2.9	6.7	7.5	2.4	2.9	3.4	3.8
Correlation	0.85	0.77	0.81	0.70	0.76	0.73	0.86	0.76	0.77	0.65	0.63	0.68	0.82	0.88
NSE	0.71	0.47	0.60	0.42	0.56	0.51	0.64	0.56	0.48	0.42	0.37	0.46	0.66	0.72

Regionalization

From the 27 calibrated basins, 9 were determined to have good enough skill to be used as "donor" gages for regionalization, highlighted in **Figure 7.** For each HUC8, parameters were taken from the donor catchment based on the Gower's distance metric. **Figure 8** shows example results from regionalization of the snowmelt parameter, mfsno.

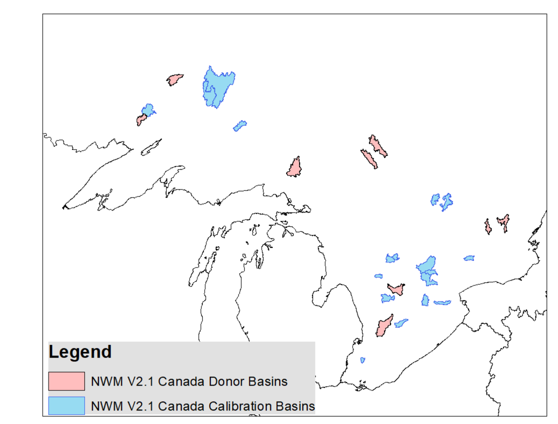

Figure 7. Locations of the calibrated catchments. Donor catchments selected for regionalization of calibrated parameters are shown in red.

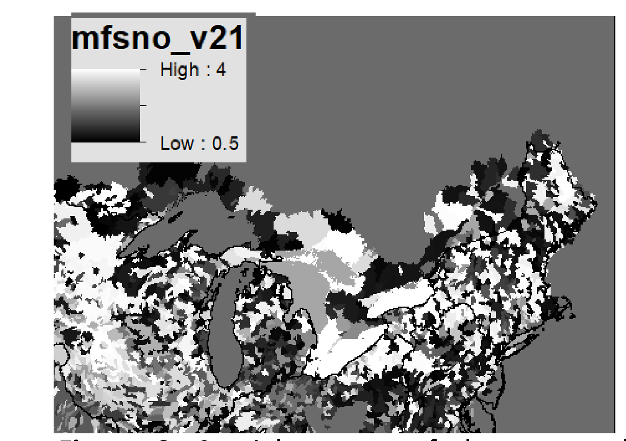

Figure 8. Spatial pattern of the snowmelt parameter after regionalization.

Discussion and Conclusions

- The National Water Model version 2.1 will be the first version to operate across the entire (U.S. and Canada) portion of the Great Lakes basin, enabling future developments in total water prediction for the largest surface freshwater body in the world.
- Calibration of the National Water Model configuration of WRF-Hydro was conducted across 27 gaged watersheds in the Canadian portion of the Great Lakes basin with varying degree of success.
- Calibration success was limited by the biases found in the precipitation field of the Analysis of Record for Calibration (AORC) in southern Ontario, underscoring the need to evaluate alternative precipitation data for use in NWM development in the Great Lakes region. Similar problems with representing precipitation in southern Ontario and, more generally, across the U.S.-Canadian border have been identified in the North American Land Data Assimilation dataset by Gronewold et al. (2018).
- Future work will investigate potential improvements to calibration, for example:
  - Improving the precipitation data for the AORC, starting with evaluation of the Canadian Precipitation Analysis (CaPA) dataset (see poster #H43I-2139 for more details)
  - Calibration to alternative or multiple objectives, for example snow water equivalent.

Acknowledgements & References

Acknowledgements

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References

- Gronewold, A. D. et al. (2018). Resolving Hydrometeorological Data Discontinuities along an International Border. *Bulletin of the American Meteorological Society*, 99 (5), 899–910.
- Mason, L. A. et al. (2019). New Transboundary Hydrographic Data Set for Advancing Regional Hydrological Modeling and Water Resources Management. *Journal of Water Resources Planning and Management,* 145 (6), 06019004.