MMA-3

Forecasting Lake Levels Under Climate Change: Implications of Bias Correction

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Overview

- Numerical climate models serve as a basis for projecting future lake levels for the Great Lakes under climate change
- Water supplies were generated with hydrological components from the WRF/GFDL-CM3 climate model, then used to drive a routing model to produce lake levels for the 21st century
- Adjustments to the method of bias correcting water supplies yielded varying projections of 21st century lake levels
- **Results indicate that lake level forecasts are highly influenced by the bias correction method used**

Methods

Step	Description	Details		
1	Extract modeled components	Downscaled climate model components for water supply: overlake precipitation (P), overlake evaporation (E), overland runoff (R)		
2	Calculate net basin supply (NBS)	$NBS = P_{lake} - E_{lake} + R_{land}$		
3	Bias correct net basin supply with observational data	1) Normalize NBS by removing mean and standard deviation	$NBS^* = \frac{NBS_{raw} - \mu_M}{\sigma_M}$	$^*\mu_M = \mu_F - M_H$ (for future)
		2) Apply observed NBS mean/standard deviation to normalized model NBS	$NBS_{debias} = NBS^* (\sigma_O) + \mu_O$	
4	Run NBS through routing model	Coordinated Great Lakes Regulation Routing Model (CGLRRM) produces lake level forecasts using NBS inputs		

GCM-RCM Generation

The hydrological components in this study were extracted from a dynamically downscaled climate model

- Global climate model
  - GFDL-CM3
    - CMIP5 model
    - Coarse resolution: 200km
    - Does not resolve the lakes
- Regional Climate model
  - WRF
    - High resolution: 30km
    - Lake model included

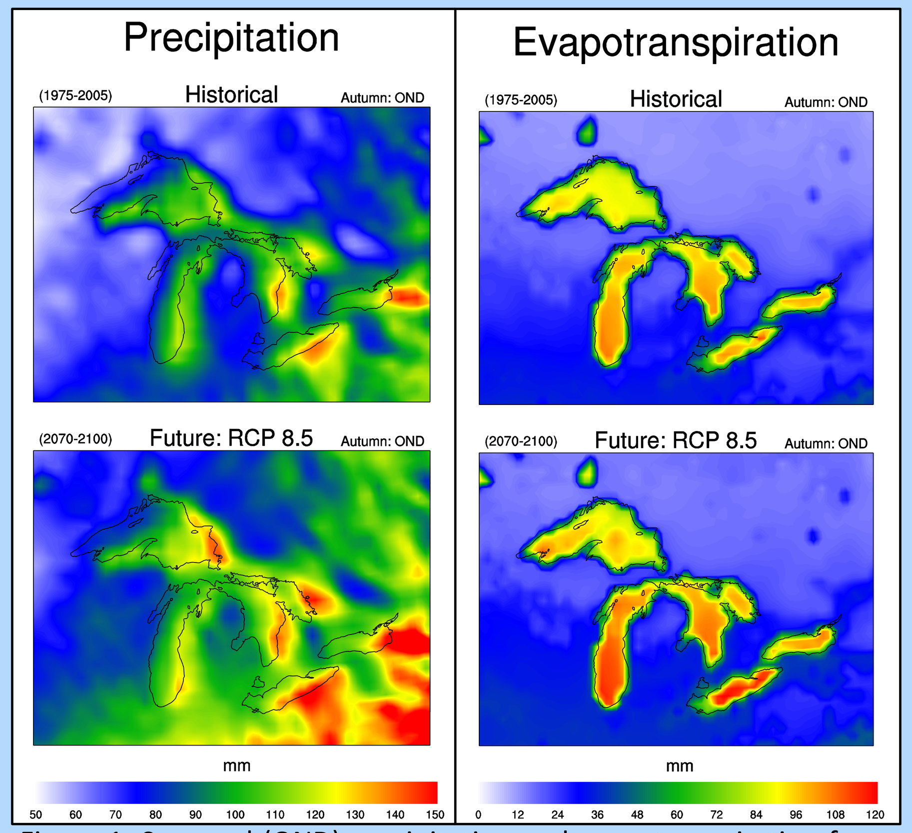

Figure 1: Seasonal (OND) precipitation and evapotranspiration from the GFDL-CM3/WRF downscaled climate model

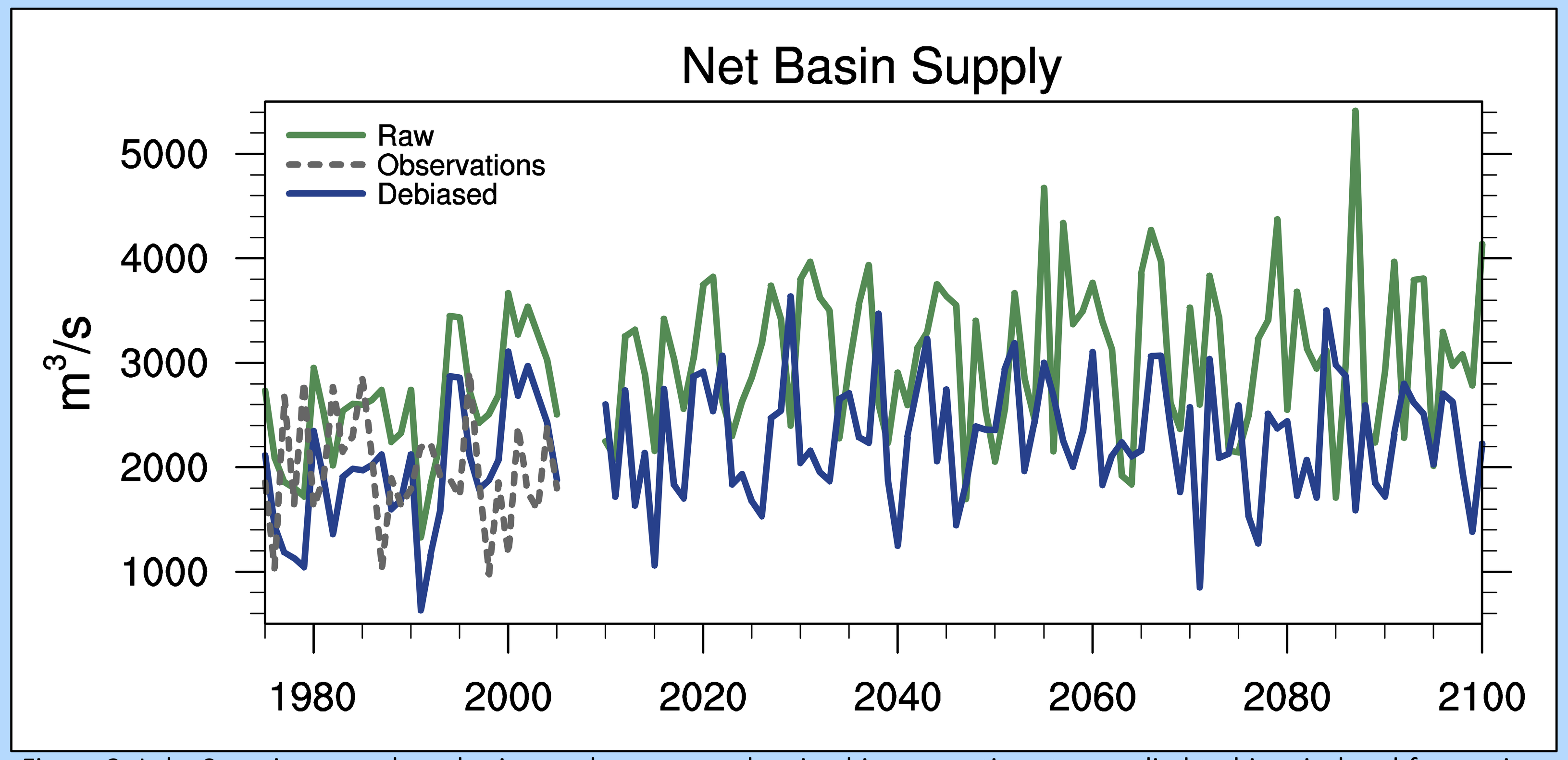

Figure 2: Lake Superior annual net basin supply averages showing bias correction step applied to historical and future time periods. Results in this figure are based on the conventional debiasing method (Method 1)

Bias Correction of Net Basin Supply

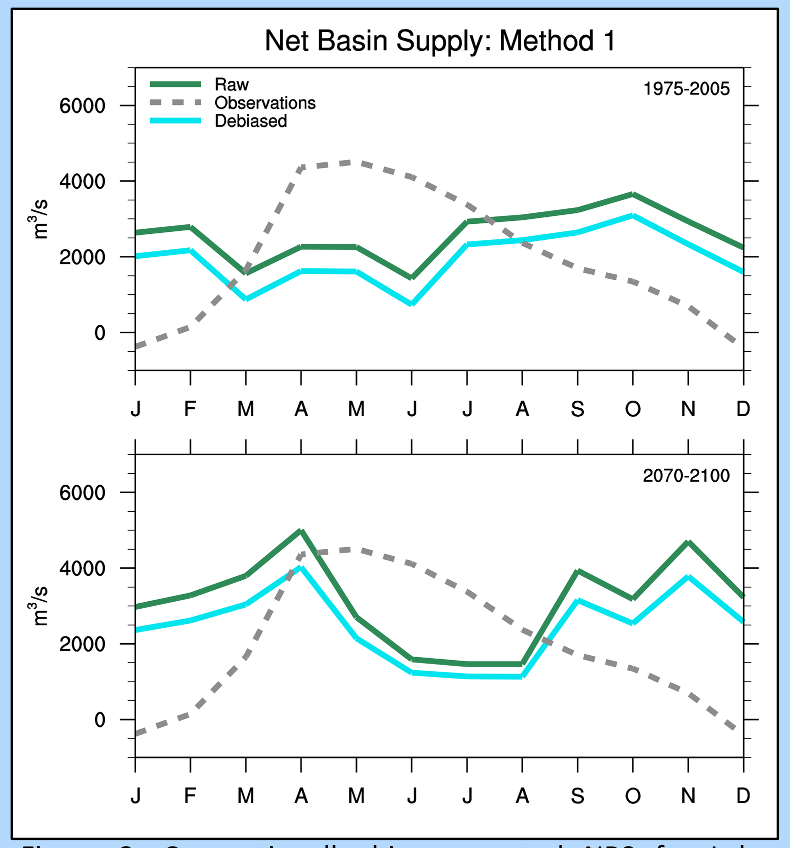

Figure 3: Conventionally bias corrected NBS for Lake Superior compared to observational data and raw model output

Method 1: Conventional

- Bias corrects NBS mean and standard deviations spanning the entire multi-decadal historical and future time periods
- Does not realistically reconstruct the historical NBS seasonal cycle when compared to observed data

Method 2: Monthly

- Bias corrects NBS mean and standard deviations on a monthly scale rather than the multi-decadal scale in method 1
- More realistically reconstructs the historical NBS seasonal cycle

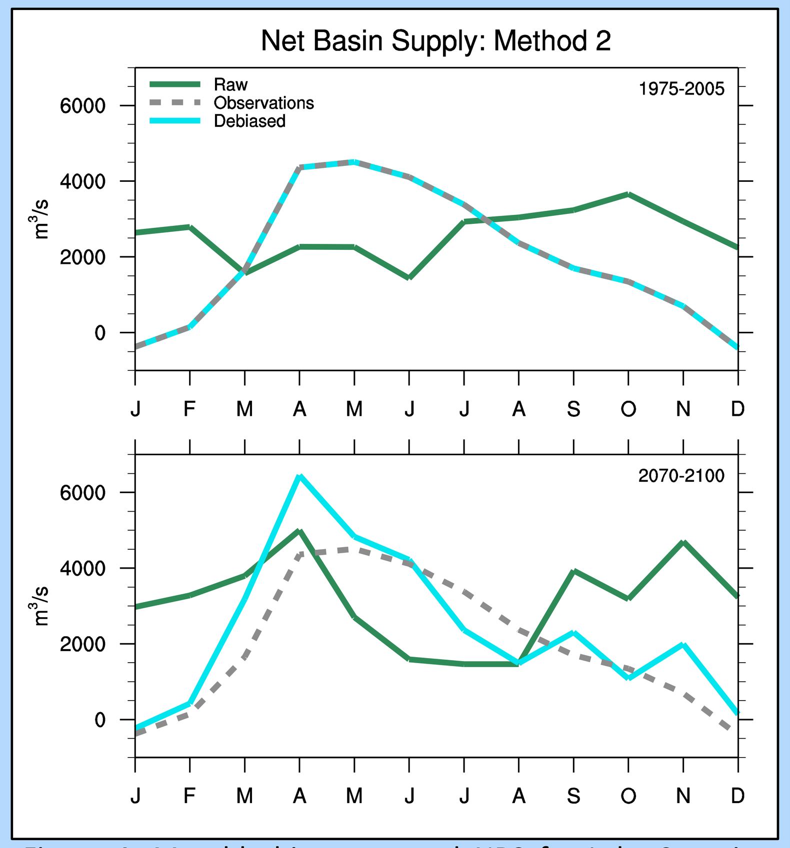

Figure 4: Monthly bias corrected NBS for Lake Superior compared to observational data and raw model output

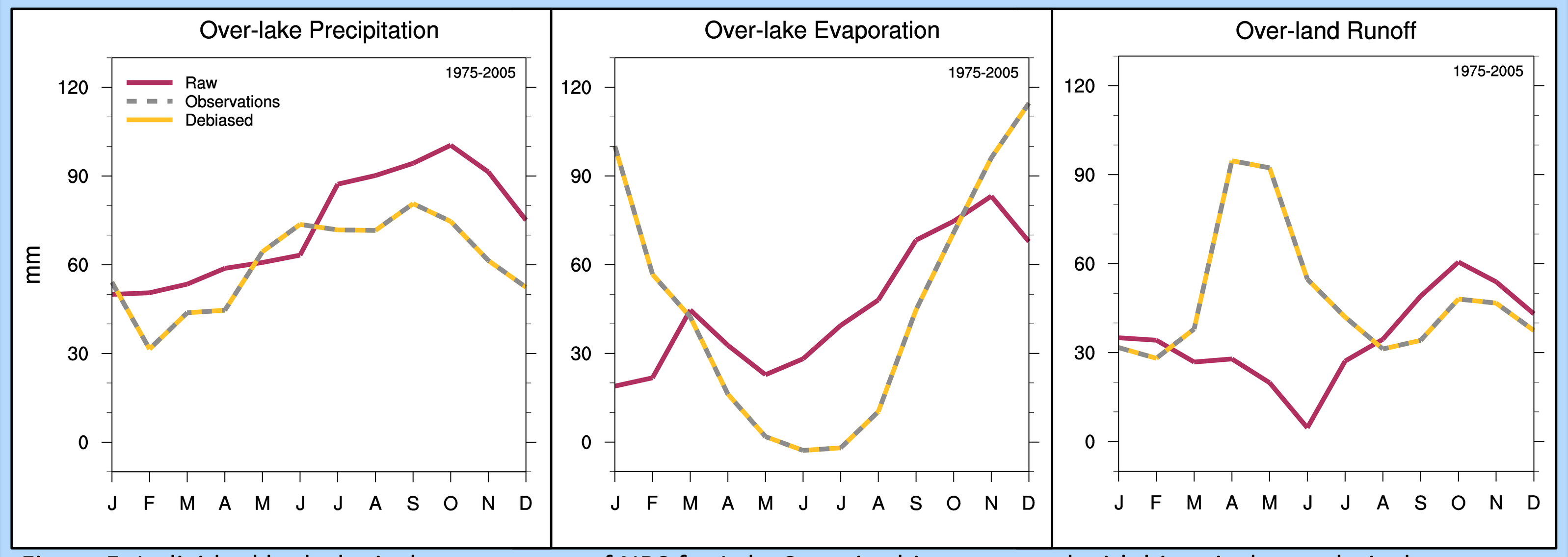

Figure 5: Individual hydrological components of NBS for Lake Superior bias corrected with historical reanalysis data

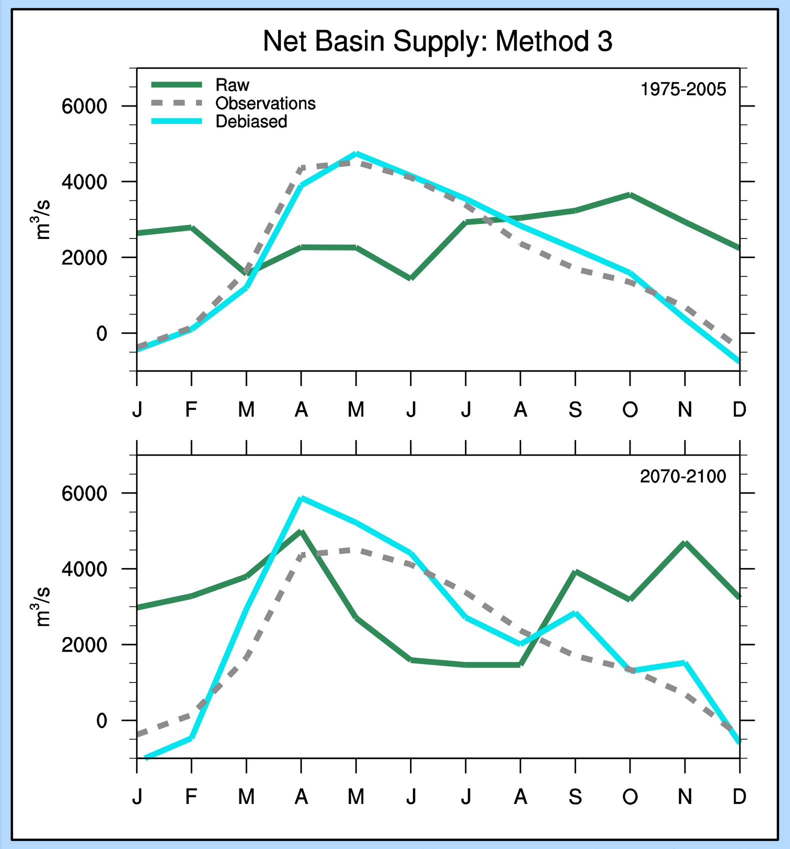

Figure 6: Monthly component bias corrected NBS for Lake Superior compared to observational data and raw model output

Method 3: Component

- Bias corrects mean and standard deviation on a monthly scale
- Bias corrects the individual hydrological components instead of entire NBS based on historical reanalysis data
- Produced similar results as Method 2 because both methods used bias correction on a monthly scale to reconstruct historical seasonality
  - Accurately reconstructed historical NBS observations without using NBS data in bias correction

Results

- Small changes in bias correction have large corresponding influence on lake level projections
- Conventional method (1) shows end of century water levels well below the historical average
- Monthly and component methods (2 & 3) show lake levels remaining around the historical average

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- Results of this study fall within range of results from other prominent lake level forecasting studies that utilized different methods

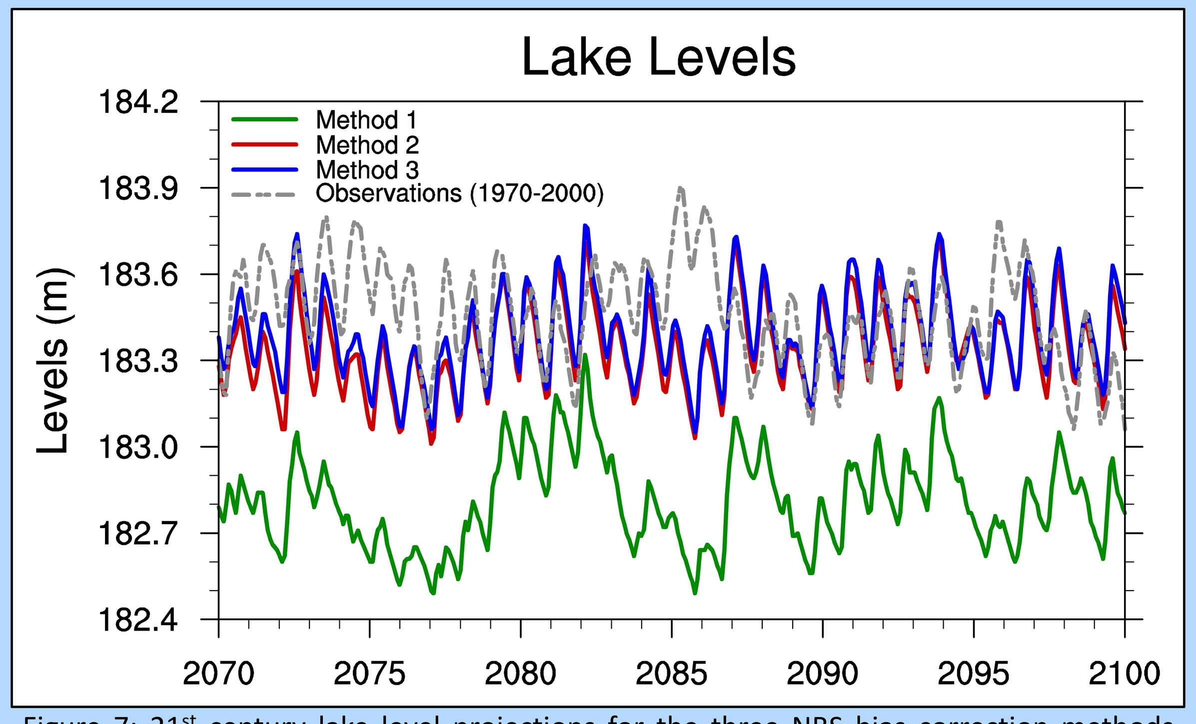

Figure 7: 21st century lake level projections for the three NBS bias correction methods shown with observational data from the 20th century for Lake Superior

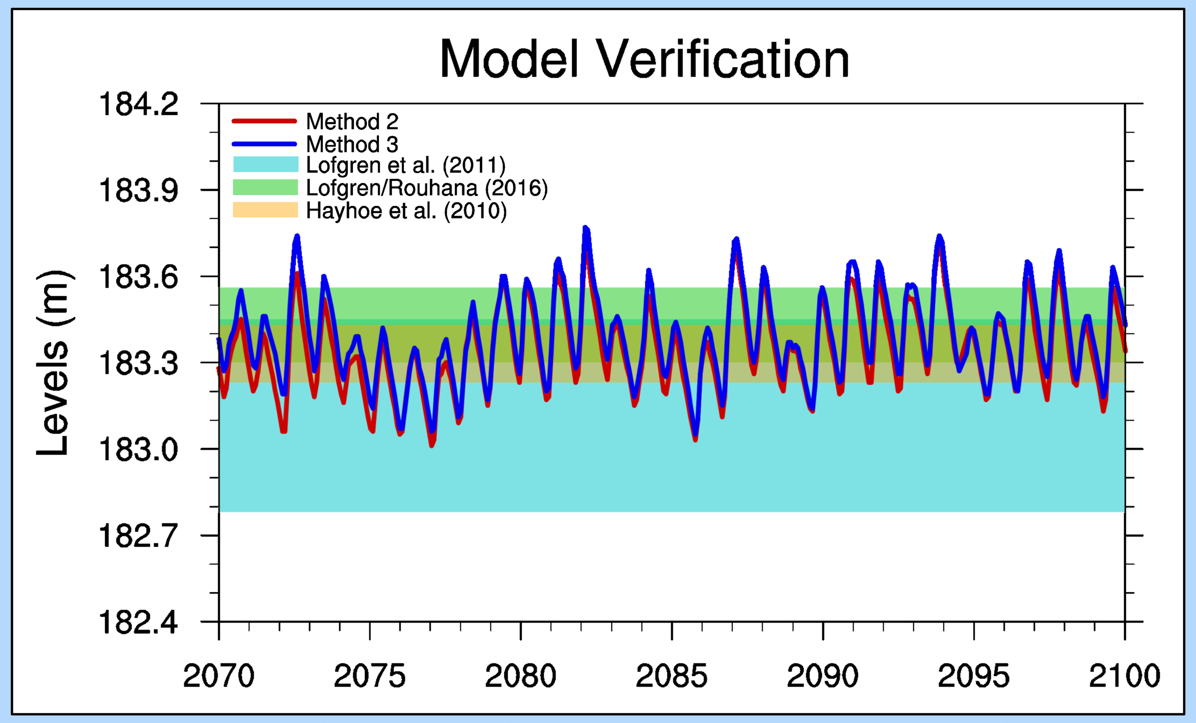

Figure 8: Projections of water levels from this study compared to ranges of other water level model projections using different techniques for Lake Superior

Conclusions and Future Work

Takeaways:

- Lake level forecasts are heavily influenced by bias correction
- Inherent biases in the climate model cannot be ignored
  - Underlying model uncertainty and physical representation not solved

Recommendations for future work:

- Apply to climate models other than GFDL-CM3/WRF
  - Set performance threshold for models used
- Further comparison with other lake level forecasting studies
- Analysis of the nature of the climate model's component bias

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