A Dynamical Downscaling study in the Great Lakes Region Using WRF/Lake: Historical Simulation

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Introduction

The latest **WRF**v3.6.1 with an updated **1-D lake scheme** is employed to dynamically downscale the historical simulation produced by a CMIP5 model, **GFDL-CM3**, from 1970 to 2004. Our interests are focused on the lake-air interaction and associated surface processes in the **Great Lakes**, the largest group of fresh water bodies on Earth, trying to understand the climate and climate change in this region.

WRF/Lake Model

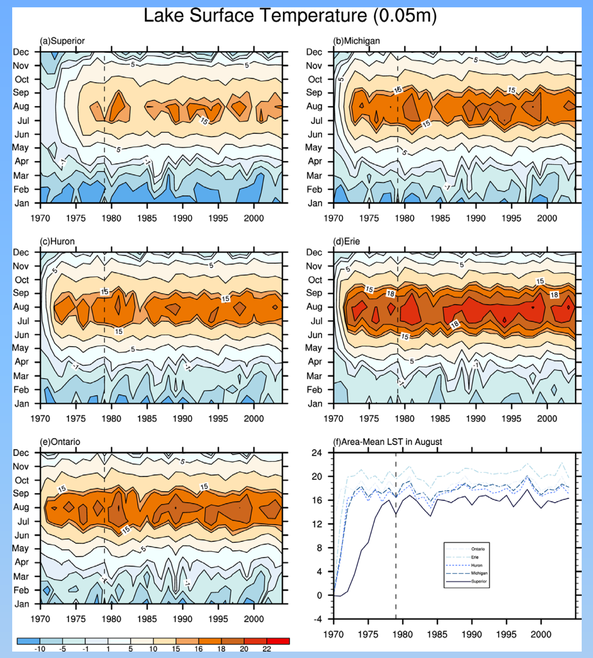
A 1-D lake Model originated from the CLM4.5 (Subin et al. 2012) is implemented in the latest WRF model (Gu et al. 2013). It is a mass and energy balance scheme with **20-25 model layers**, including up to **5 snow layers** on the lake ice, **10 water layers**, and **10 soil layers** on the lake bottom, based on the **actual lake points** and **lake depth**.

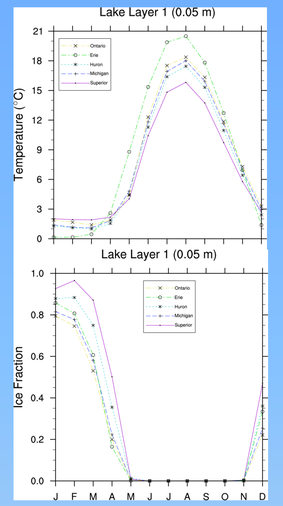
Downscaling Setup

GFDL-CM3	3D	Surface	Soil
6-hr Variables (~2° X 2.5°)	ta, ua, va, hus, zg	tas, uas, vas, huss, ps, psl	ts, tsl

WRF	
Domain Mesh	30 X 30 km (78 x 111)
Land Surface Model	**Noah LSM** with MODIS land use
Lateral Boundary	1-p specified and 9-p relaxation
Oceanic SST	ts

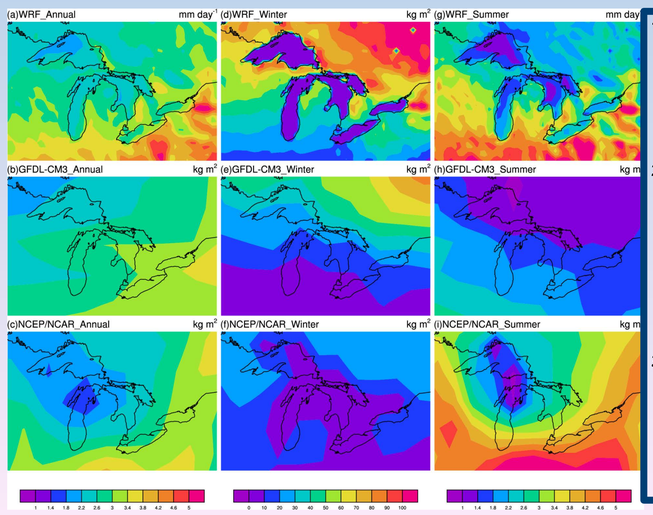
Lake Model





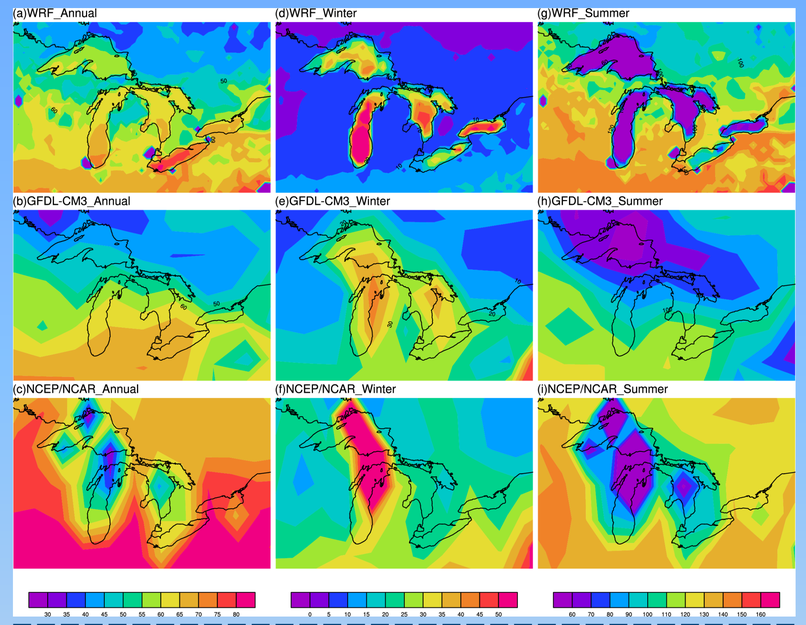
1) *Lake Superior* takes more time to **spin up**. The First 8 years are cut off.
2) Inter-lake comparison and seasonal-to-annual variability
3) Winter **ICE** overestimated; summer **LST** underestimated.

Precipitation



1) The the annual mean precipitation increases from **northwest to southeast**. The minimum is centralized on the GL.
2) The **meridional gradient** of snow water and the significant down-wind **lake-effect snow** are produced in WRF but overestimated (together with the cold surface bias).
3) Higher resolution in WRF has a better representation of **cumulus convective** processes. The GL and Appalachian topographic influence are explicit.

Evaporation



1) Strong land-lake and inter-lake evaporation **contrast**. (Some odd spots in large urban areas)
2) Warming (cooling) sources in winter (summer), corresponding to the maximum (minimum) evaporation centers.
3) The underestimated bias of land evaporation in GCM is **amplified** in WRF simulation.

Discussion and Future Work

(I) The preliminary results show that WRF/Lake model, with a realistic lake representation, provides **significantly improved** hydroclimates: lake surface temperature, annual cycle of precipitation, ice content, and lake-effect snowfall. **High resolution** and **comprehensive physics** are crucial to understanding the hydroclimatology in the GL region.

(II) **Unresolved 3D mixing** processes, WRF/Lake model is insufficient to represent the real thermal diffusivity in deep lakes. Future modeling effort should explore the importance of including a three-dimensional lake circulation in the GL region.

(III) Given that considerable uncertainties in GCM, the WRF downscaling from **multiple GCMs** is more proper in both historical simulations and future projections.

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