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

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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 (1970-2005) and future projection (2006-2100) from **GFDL-CM3**, which is also compared with 25 other CMIP5 models. 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

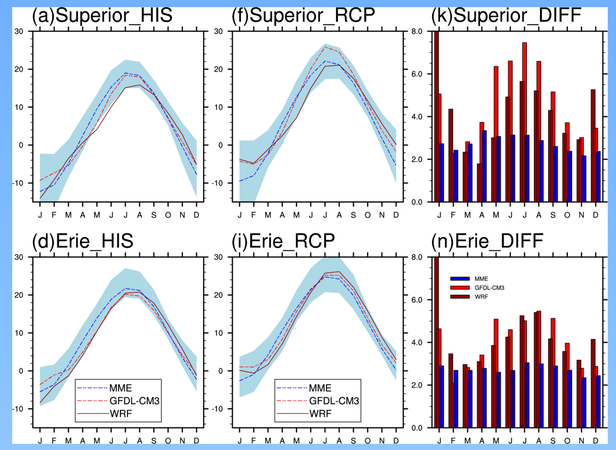
A 1-D lake Model originated from the CLM4.5 (*Subin et al. 2012*) is implemented in the latest WRF model (*Gu et al.* 2013). It is a mass and energy balance scheme with **25 model layers**, including up to **5 snow layers** on the lake ice, **10 water layers**, and **10 soil layers** on the lake bottom,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

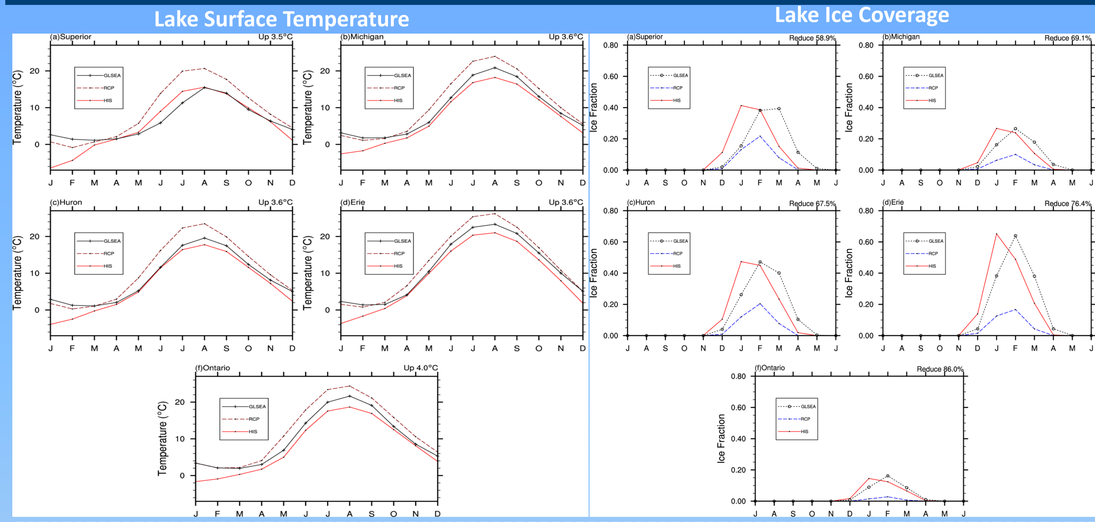
WRF	
Domain Mesh	30 X 30 km (78 x 111)
Land Surface Model	**CLM4** with MODIS land coverages
Lateral Boundary	1-p specified and 9-p relaxation
Oceanic SST	Updated by skin temp (ts)

Great Lakes' Climate Effects



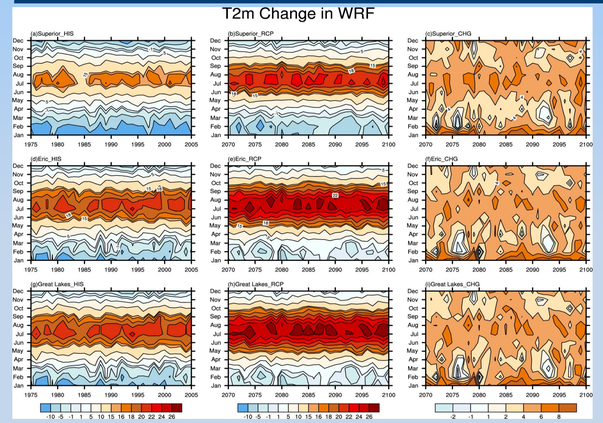
Downscaling:
◆**Warming** (<**Cooling**) **in winter (Summer)**
◆**Deep lake > shallow lake**

Lake Projection

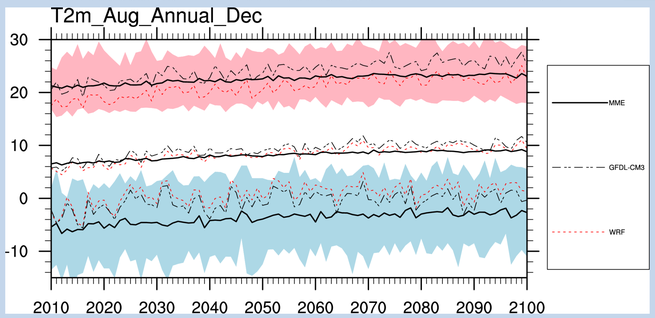


(1) **HIS**: Historical climatology (1975-2005); **RCP**: Future climatology (2070-2100); (2)**GLSEA**: Great Lakes Surface Environmental Analysis, http://coastwatch.glerl.noaa.gov/glsea/ ; (3)**De-biasing**: The lake ice coverage has been scaled on the GLSEA time series.

Air Temperature



		Trends (°C /100yr)		
		1st half	2nd half	Cent.
WRF	Feb.	8.8	0.3	4.1
	Aug.	6.5	1.8	5.7
	Annual	6.7	1.2	4.5
CM3	Feb.	6.7	-0.2	3.1
	Aug.	8.0	3.4	6.0
	Annual	6.8	0.9	4.5
MME	Feb.	4.9	1.6	3.5
	Aug.	3.8	0.8	2.8
	Annual	4.0	1.2	2.8



- Colder (than 20th C) winters would still happen in an overall warming climate in later 21st C.
- Trend: Summer > Annual > Winter
- Trend: GFDL-CM3 > WRF> MME in summer

Conclusion and Future Work

- **GFDL-CM3**
  - Ranks in the median among CMIP5 models,
  - Suitable for downscaling in the Great Lakes region.
- **WRF/Lake** is able to reproduce the air-lake interactions.
- The Great Lakes' **climate effects**
  - warming (<cooling) in winter (summer), Cooling in annual mean
  - Deep Lake > Shallow Lake
- RCP4.5 Scenario
  - **Temperature**: warming
    - ◆4-6 °C/100yr in T2m (summer > winter)
    - ◆3-4 °C/100 in LST (small inter-season and inter-lake contrast)
  - **Precipitation**: spatially heterogeneous
    - ◆weak and uncertain
    - ◆Overland > Overlake; WRF>CM3>MME
  - **Ice**: diminishing
    - ◆59% (Superior) to 86% (Ontario)
    - ◆Future Change > Current Bias

- **Comprehensive validation of WRF/Lake's historical simulation**
- **Improve the Lake scheme to a better ice simulation**
- **Compare different emission scenarios (e.g. RCP4.5 vs RCP8.5)**
- **Multiple model downscaling**

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