Simulations of Lake Processes and Their Effects on Precipitation Using a Coupled WRF-Lake Model

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Outline

• Biases in reanalyzed lake surface temperature

• Coupling of WRF and a lake model

• Calibration and validation of the coupled WRF-lake model

• Lake-effect precipitation simulations

• Summary
Objective

Quantifying lake processes and their effects on local and regional weather and climate using the Weather Research and Forecasting (WRF) model coupled with a physically-based lake model.

Lake-Effect Snow
Difference Between the NARR LST and MODIS LST

Lake region mean

NARR: North American Regional Analysis

MODIS: Moderate Resolution Imaging Spectroradiometer Satellite data
Precipitation Simulations at 10 km resolution with WRF over the Great Lakes Region

February 2006

OBS- U. Delaware
87mm

WRF-MODIS
89mm

WRF-NARR
95mm
All the release versions of the WRF model do not include a lake scheme.

The lake surface temperature is provided by the forcing data for the WRF model.
A Physically-based Lake Model

- We have coupled a lake model into WRF

- This lake model is a one-dimensional water and energy balance model (Hostetler et al., 1993; 1994).

- The lake in the model is divided into 10 vertical layers.

- Ice fraction and snow on the ice are also considered in the lake model.
The average depth of Lake Erie is 19 m with a maximum depth of 64 m.
The average depth of Lake Superior is 147 m with a maximum depth of 406 m.
Processes Affecting Lake Surface Temperature

Atmospheric Forcing

Shallow Lake

Deep Water Forcing

Deep Lake
# Calibration of Lake Physical Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Old</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eddy Diffusivity</td>
<td>Ke</td>
<td>Ke increased by a factor of $10^2$-$10^5$</td>
</tr>
<tr>
<td>Roughness length</td>
<td>1 cm</td>
<td>0.5 cm</td>
</tr>
<tr>
<td>Bathymetry</td>
<td>50 m</td>
<td>Actual data</td>
</tr>
</tbody>
</table>
Surface Temperature Simulations for Lake Superior

Station ID 45004

Surface Temperature (°C)

2001–2002

Sep Nov Jan Mar May Jul Sep Nov

Different lines represent various data sources:
- Red: WRF–Lake–New
- Blue: WRF–Lake–Old
- Green asterisks: MODIS–Obs
- Black: BUOY–Obs
Lake Surface Temperature Bias

NARR minus MODIS

Mean Bias = 4.0 °C

Winter (DJF), 2003-2008

WRF-Lake minus MODIS

Mean Bias = 0.2 °C

Winter (DJF), 2003-2008
Lake Ice Fraction Simulations

Observation

Dec

Jan

Feb

Simulation

Dec

Jan

Feb

Spatial Correlation

0.55

0.82

0.82

2003-2008
Winter Precipitation Simulations

2003-2008

OBS

WRF-Lake

WRF-NARR
Simulated Precipitation Bias

**Precipitation Bias**

(Domain Average)

- **Bias = 7.2 mm/month**
- **WRF-NARR minus OBS**

- **Bias = 4.3 mm/month**
- **WRF-Lake minus OBS**
Summary

- The coupled WRF-Lake model realistically simulates the lake surface temperature and lake ice fraction for the Great Lakes.

- This coupled model also reduces the biases in the lake-effect precipitation simulations and has a capability of dynamic simulations of lake-atmosphere interactions.
Acknowledgement

This project was supported by the NOAA Modeling, Analysis, Predictions, and Projections Program. Grant Number: NA090AR4310195.