Lake Processes Simulations with the Weather Research Forecasting Model for the Great Lakes

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Outline

• Bias in reanalyzed lake surface temperature
• Coupling of WRF and a lake model
• Calibration 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 of the NARR LST and MODIS LST

Lake region mean

LST: Lake surface temperature

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 3.2

• 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.
Surface Temperature Simulations at 10 km resolution for Lake Erie

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 Lake

Deep Water Forcing
## Calibration of Lake Physical Parameters

<table>
<thead>
<tr>
<th></th>
<th>Old</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eddy Diffusivity</strong></td>
<td>Too small</td>
<td>Enlarged</td>
</tr>
<tr>
<td><strong>Roughness length</strong></td>
<td>1 cm</td>
<td>0.5 cm</td>
</tr>
<tr>
<td><strong>Bathymetry</strong></td>
<td>50 m</td>
<td>Actual data</td>
</tr>
</tbody>
</table>
The air temperature was measured or simulated at a height of 4 m.
Lake Surface Temperature Bias

NARR minus MODIS
Mean Bias = 5.2 °C

WRF-Lake minus MODIS
Mean Bias = 2.2 °C

Winter (DJF), 2003-2008

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

Observation vs Simulation:

- **Dec**: Observation 0.55, Simulation 0.55
- **Jan**: Observation 0.82, Simulation 0.82
- **Feb**: Observation 0.82, Simulation 0.82

2003-2008
Winter Precipitation Simulations

OBS

Dec
Precip

Jan
OBS/Jan
Precip

Feb
OBS/Feb
Precip

WRF-Lake

Dec
Precip
WRF-Lake/Dec
Precip

Jan
WRF-Lake/Jan
Precip

Feb
WRF-Lake/Feb
Precip

WRF-NARR

Dec
Precip
WRF-NARR/Dec
Precip

Jan
WRF-NARR/Jan
Precip

Feb
WRF-NARR/Feb
Precip

2003-2008

mm

Legend:

- 250 mm
- 220 mm
- 190 mm
- 160 mm
- 130 mm
- 100 mm
- 70 mm
- 40 mm
- 10 mm
Precipitation Bias

**Simulated Precipitation Bias**

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

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

**Graph:**

- **Precipitation Bias (Domain Average)**
- **2003-2007**
- **Axis:** Precipitation mm/month
- **Legend:**
  - WRF-NARR minus OBS (blue)
  - WRF-Lake minus OBS (red)
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.
Acknowledgement

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