Lake Process Simulations with the Weather Research Forecasting Model

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Radar Precipitation: 04/21/2011 18:42:08 GMT

Radar Precipitation: 04/21/2011 18:54:59 GMT

Radar Precipitation: 04/21/2011 19:13:10 GMT

Radar Precipitation: 04/21/2011 19:43:08 GMT

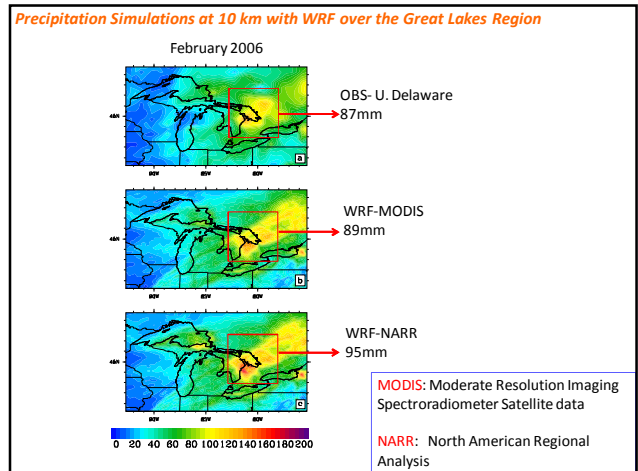Radar Precipitation: 04/21/2011 20:00:59 GMT

Regional Climate Model

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.

Precipitation Simulations at 10 km with WRF over the Great Lakes Region

February 2006

OBS- U. Delaware
87mm

WRF-MODIS
89mm

WRF-NARR
95mm

MODIS: Moderate Resolution Imaging Spectroradiometer Satellite data

NARR: North American Regional Analysis

A Physically-based Lake Model

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

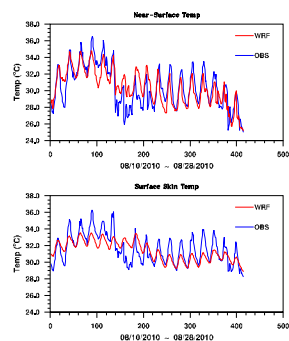- **The lake in the model is divided into 10 vertical layers.**

Coupling of the WRF-Lake Model

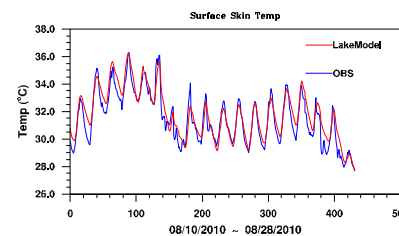**We have recently coupled the lake model into the WRF model.**

WRF-lake Simulations

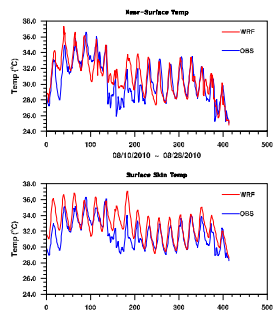**Lake depth = 1.9m**
Beta   = 0.4

Station :
Taihu(31.4ºN, 120.2ºE)
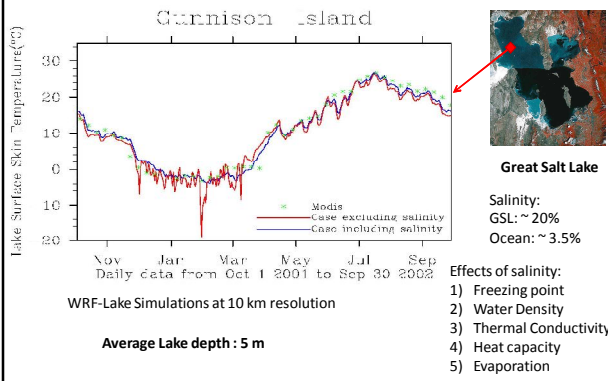

Lake model offline run

Lake depth = 1m
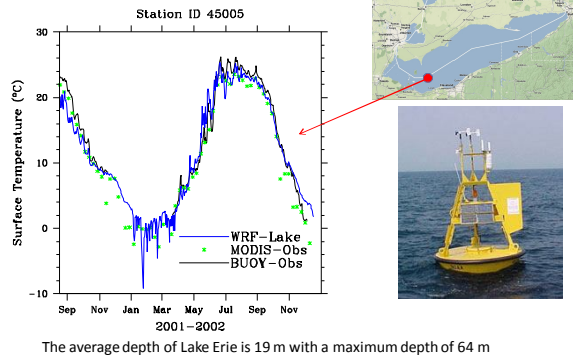Beta   = 0.6

WRF-lake Simulations

Lake depth = 1m
Beta   = 0.6

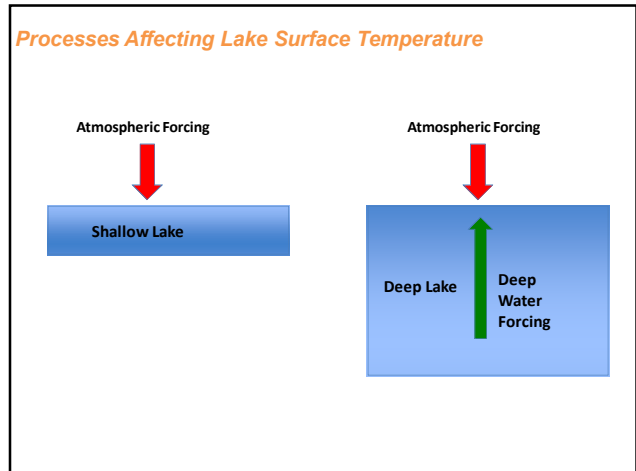*Lake Surface Temperature Simulations over Great Salt Lake*
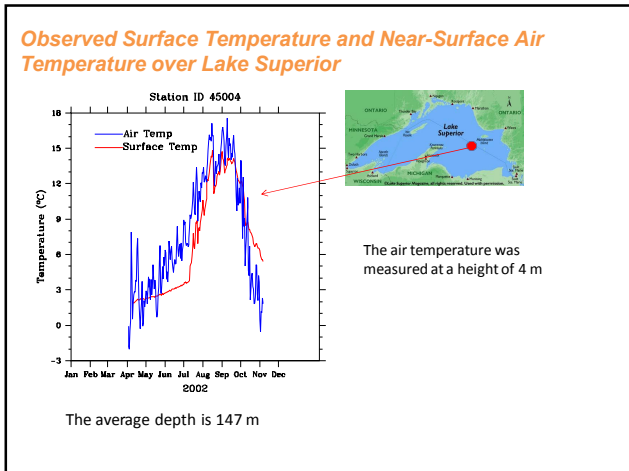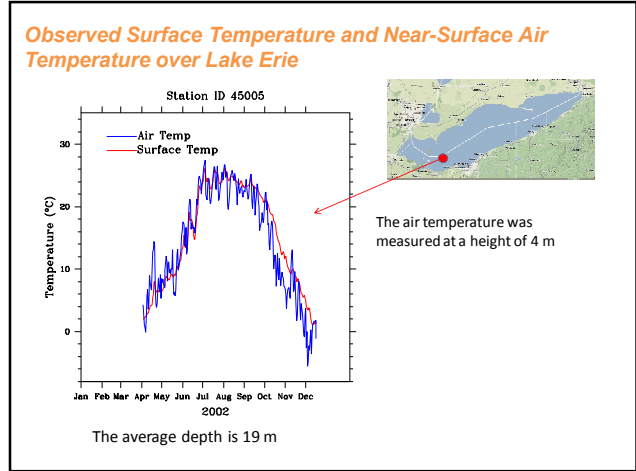

WRF-Lake Simulations at 10 km resolution

Average Lake depth : 5 m

Great Salt Lake

Salinity:
GSL: ~ 20%
Ocean: ~ 3.5%

Effects of salinity:
1) Freezing point
2) Water Density
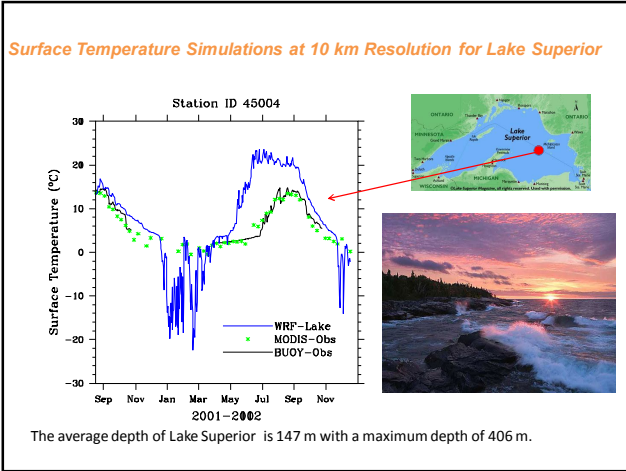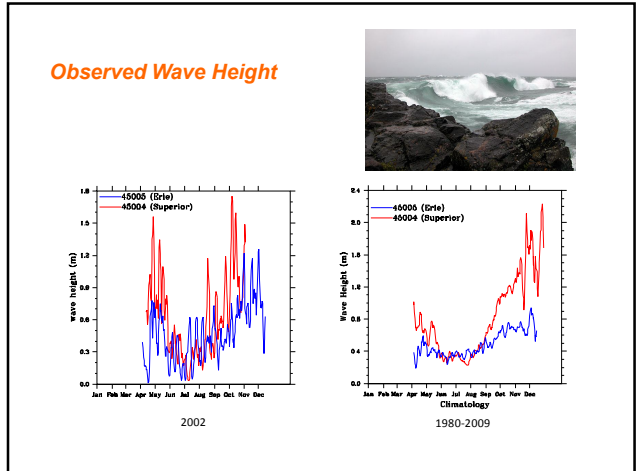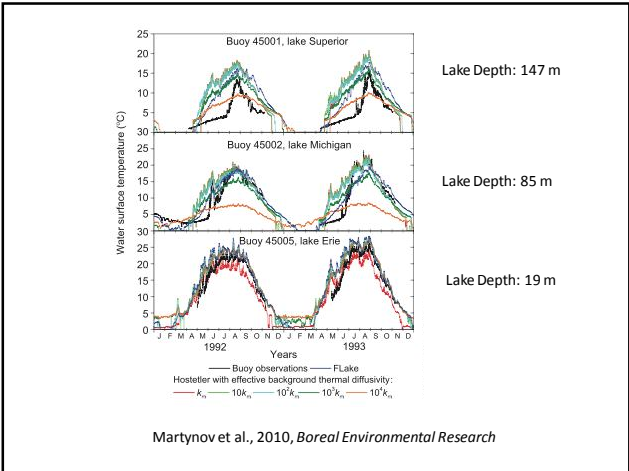3) Thermal Conductivity
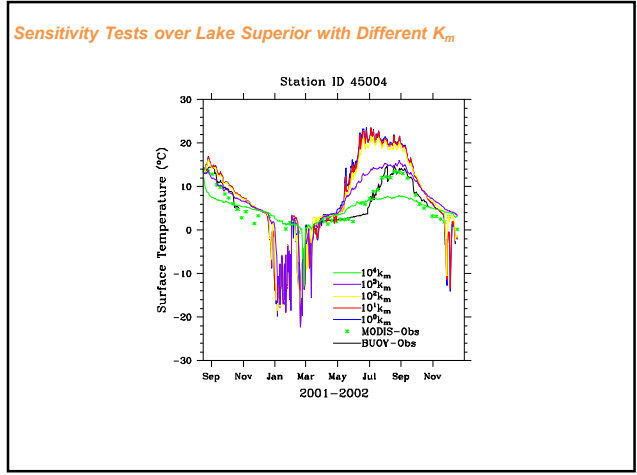4) Heat capacity
5) Evaporation

Great Lakes

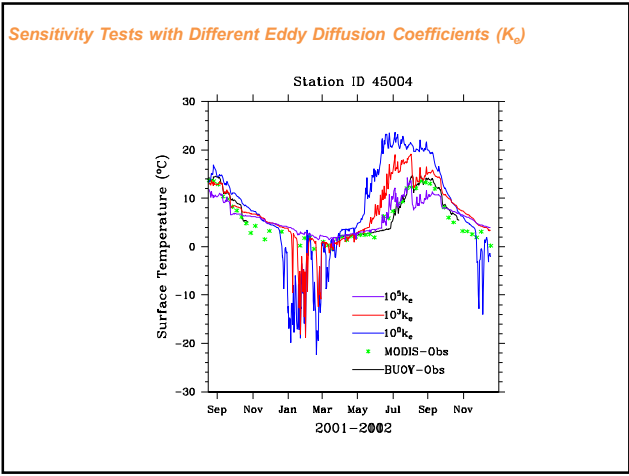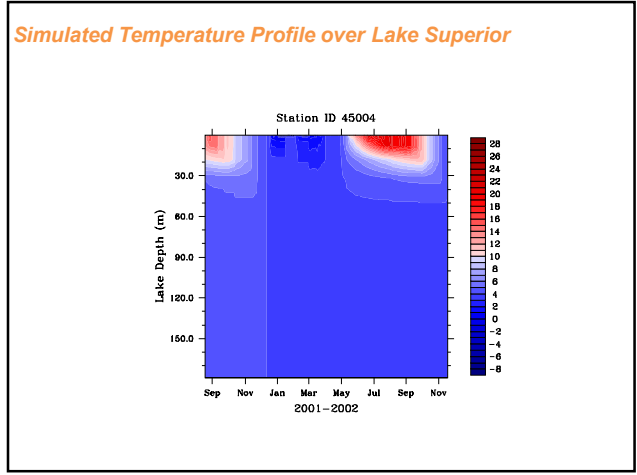*Surface Temperature Simulations at 10 km resolution for Lake Erie*

The average depth of Lake Erie is 19 m with a maximum depth of 64 m

Surface Temperature Simulations at 10 km Resolution for Lake Superior

The average depth of Lake Superior is 147 m with a maximum depth of 406 m.

Observed Surface Temperature and Near-Surface Air Temperature over Lake Erie

The air temperature was measured at a height of 4 m

The average depth is 19 m

Observed Surface Temperature and Near-Surface Air Temperature over Lake Superior

The air temperature was measured at a height of 4 m

The average depth is 147 m

Processes Affecting Lake Surface Temperature

Atmospheric Forcing
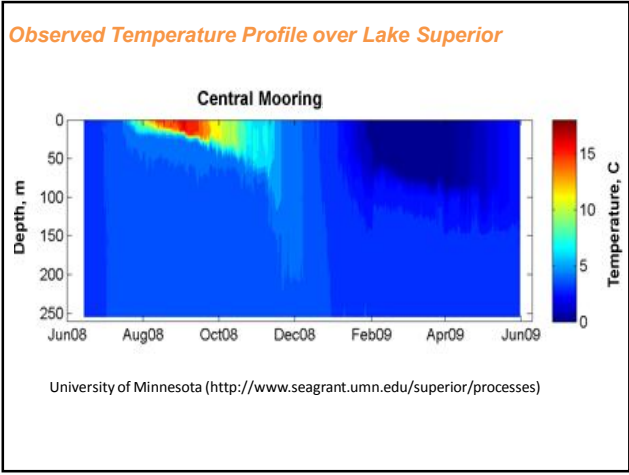
Shallow Lake

Atmospheric Forcing

Deep Lake

Deep Water Forcing

Vertical Energy Transfer within the Lake Water

1) **Molecular Diffusion Coefficient (K_m) (1.433×10^{-7} (m^2/s))**

2) **Eddy Diffusion Coefficient (K_e) (Unit: m^2/s)**

*Sensitivity Tests over Lake Superior with Different K_m*

Lake Depth: 147 m

Lake Depth: 85 m

Lake Depth: 19 m

Martynov et al., 2010, *Boreal Environmental Research*

Observed Wave Height

2002

1980-2009

Observed Temperature Profile over Lake Superior

University of Minnesota (http://www.seagrant.umn.edu/superior/processes)

Simulated Temperature Profile over Lake Superior

Sensitivity Tests with Different Eddy Diffusion Coefficients (K_e)

Eddy Diffusion Coefficients (K_e)

Lake Depth	T>4 °C	0°C ≤T≤4°C	T<0°C
>150m	$10^2 K_e$	$10^5 K_e$	0
50~150m	$10^2 K_e$	$10^4 K_e$	0
<50m	K_e	K_e	0

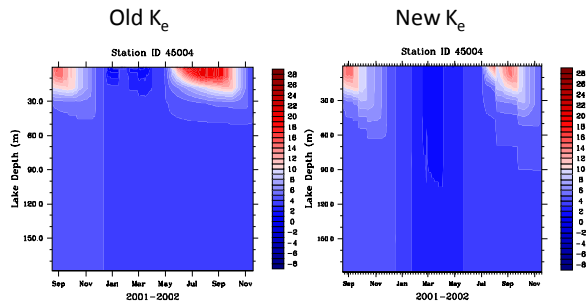Surface Temperature Simulations for Lake Superior
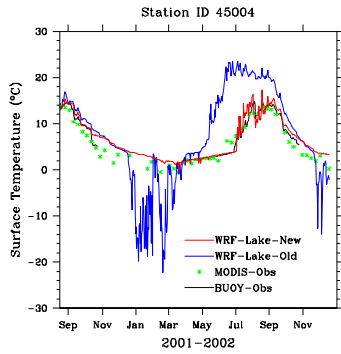
Near-Surface Air Temperature Simulations for Lake Superior
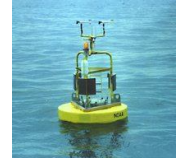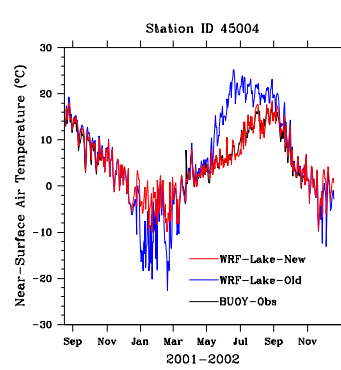
The air temperature was measured or simulated at a height of 4 m

Simulated Temperature Profiles over Lake Superior

Old K_e   New K_e

Summary

1) Surface temperature over the shallow lake (e.g. Lake Erie) is dominantly controlled by atmospheric forcing, while over the deep lake (e.g. Lake Superior), it is affected by the forcing from both the atmosphere and the deep lake processes.

2) The poor surface temperature simulations over the deep lake result from the unrealistic parameterization of eddy diffusion, which weakens the energy exchanges between the lower and upper parts of the lake.

3) Adjustments of the eddy diffusion coefficient have markedly improved the surface temperature simulations over the deep lake.

Thanks!!!