

A satellite image of Earth showing a large river system, likely the Mississippi River, winding through a green and brown landscape. The curvature of the Earth is visible at the top of the frame.

Improving lake process prediction within the Climate Forecast System for North America

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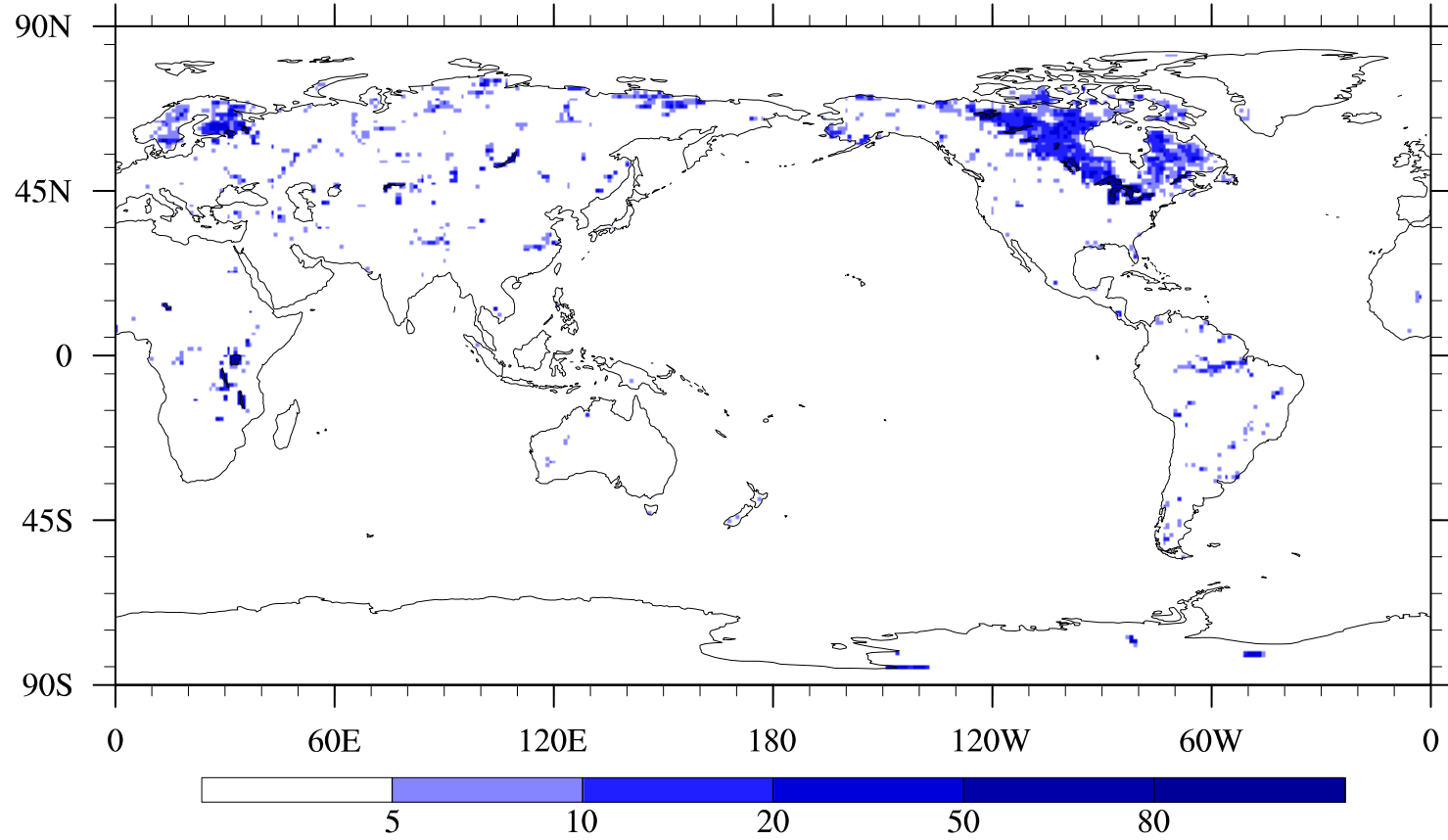
Project Motivations

- **The Climate Forecast System (CFS) version 2 does not include a lake scheme.**
- **For resolved lakes (i.e. the Great Lakes), the CFS model treats them as ocean; and unresolved small lakes are treated as land.**
- **Lake processes and their interactions with the atmosphere are neglected.**
 - Potentially degrading CFS climate forecasting skill.

Project Objectives

- 1) To incorporate a physically based lake model into CFS**
- 2) To evaluate and improve the prediction skill of CFS**

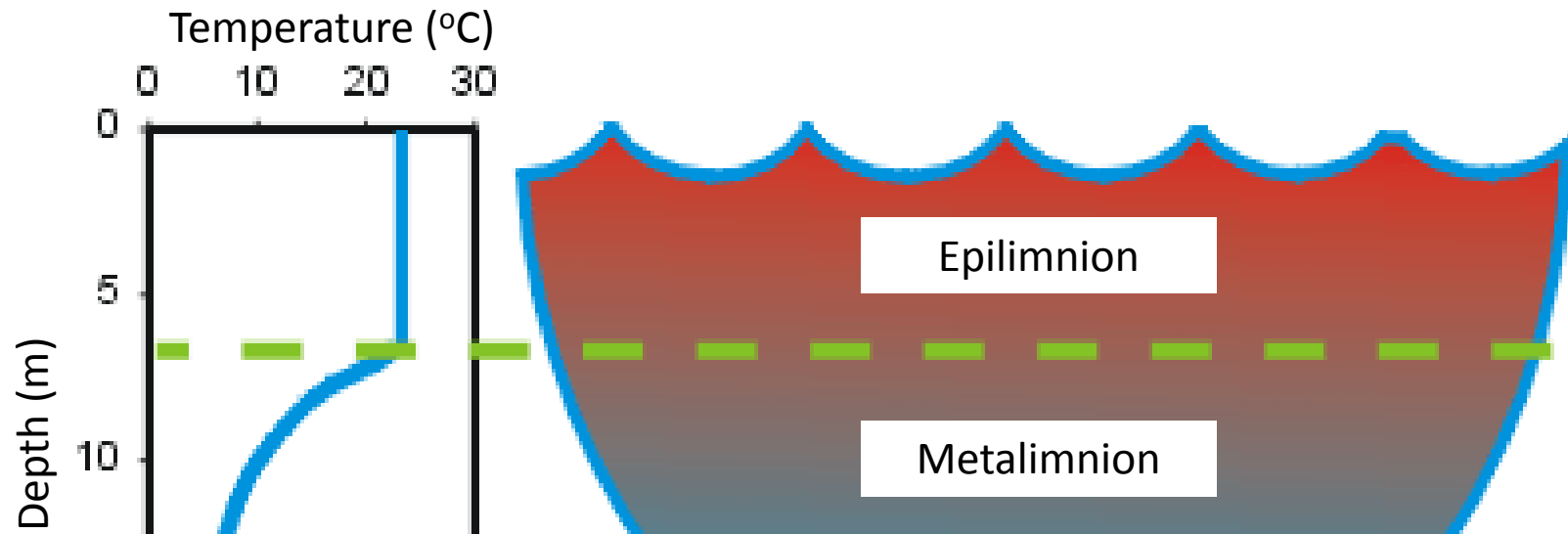
The lake fractions for the CFS model grids at a 100 km resolution



The FLake Model

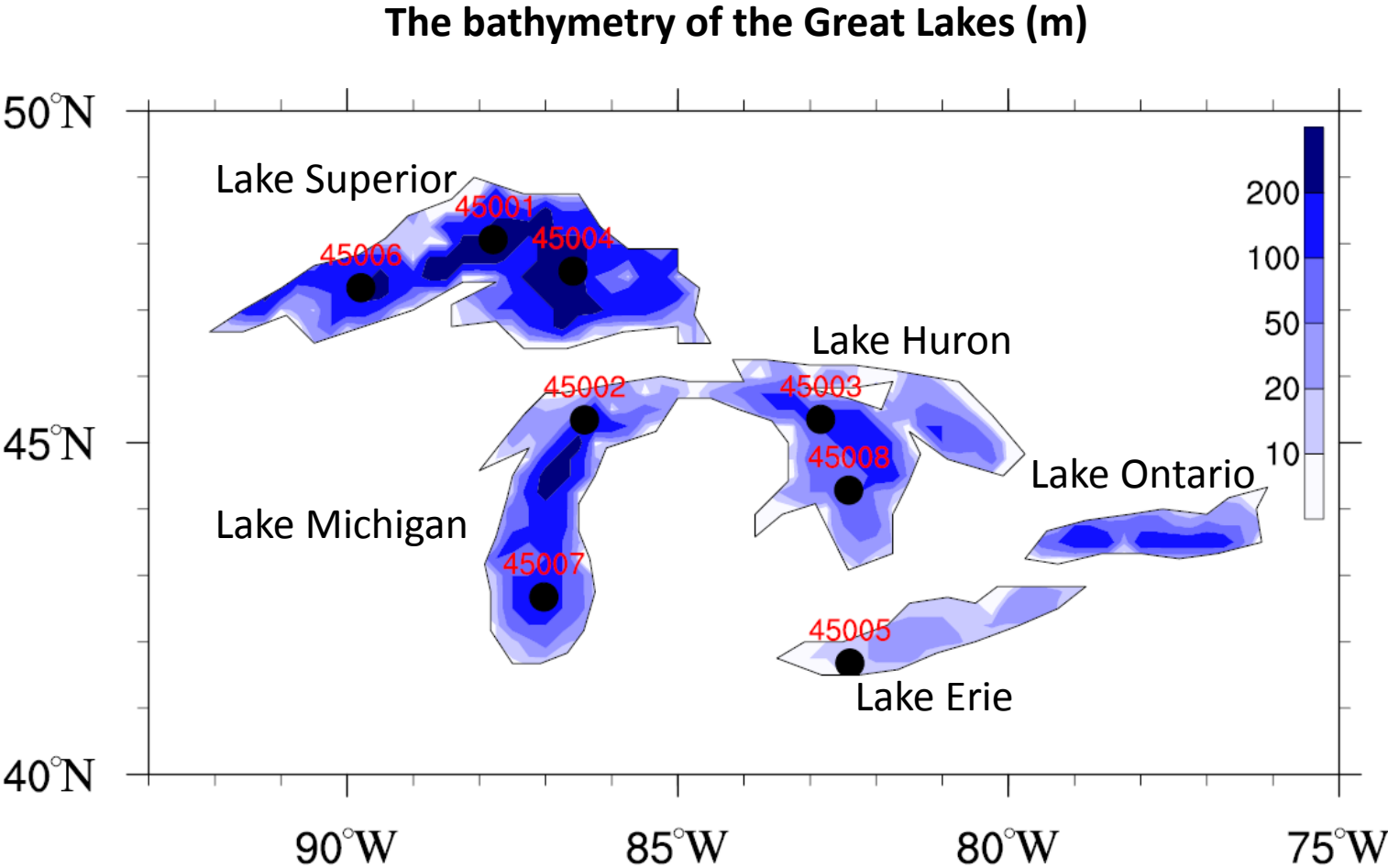
- **The Freshwater Lake (Flake) model developed by Mironov (2008):**
<http://www.flake.igb-berlin.de>
- **FLake is a one dimensional, two-layer physically based lake model that simulates:**
 - lake temperature
 - surface fluxes
 - lake ice thickness
- **It is currently operational in climate system models in Europe and Canada.**

Lake Thermal Stratification

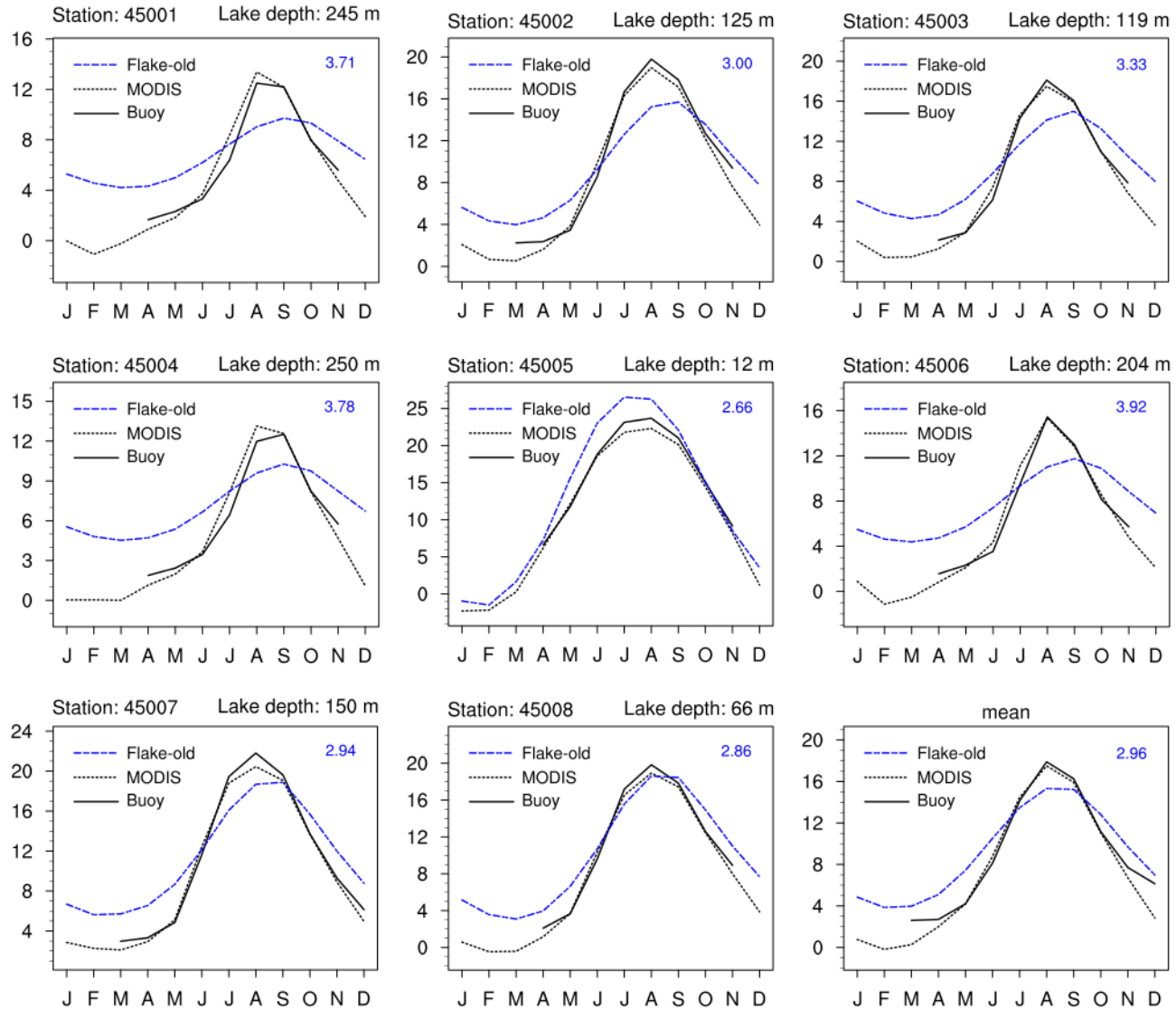


The FLake model

The bathymetry of the Great Lakes

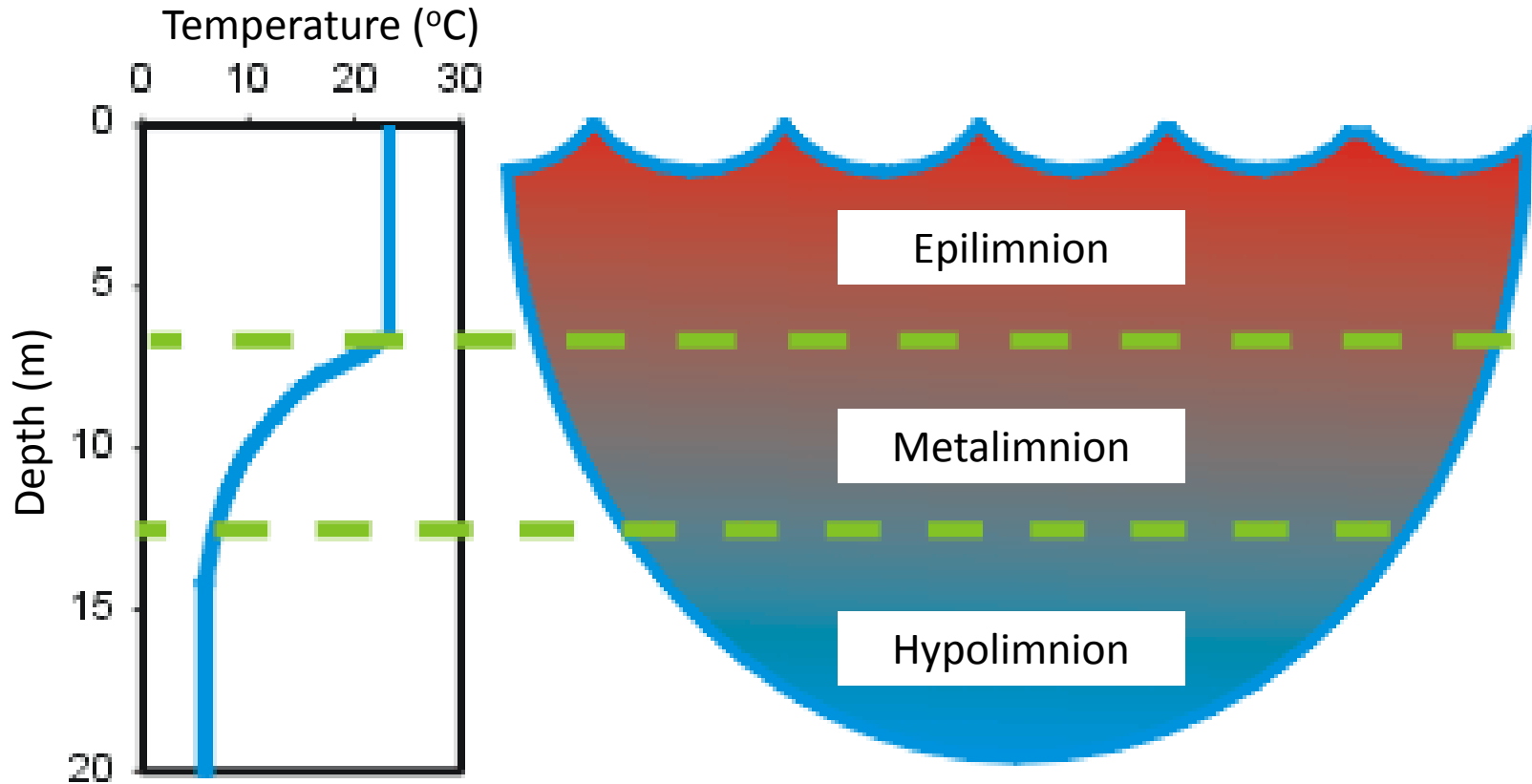


Lake surface temperature simulations



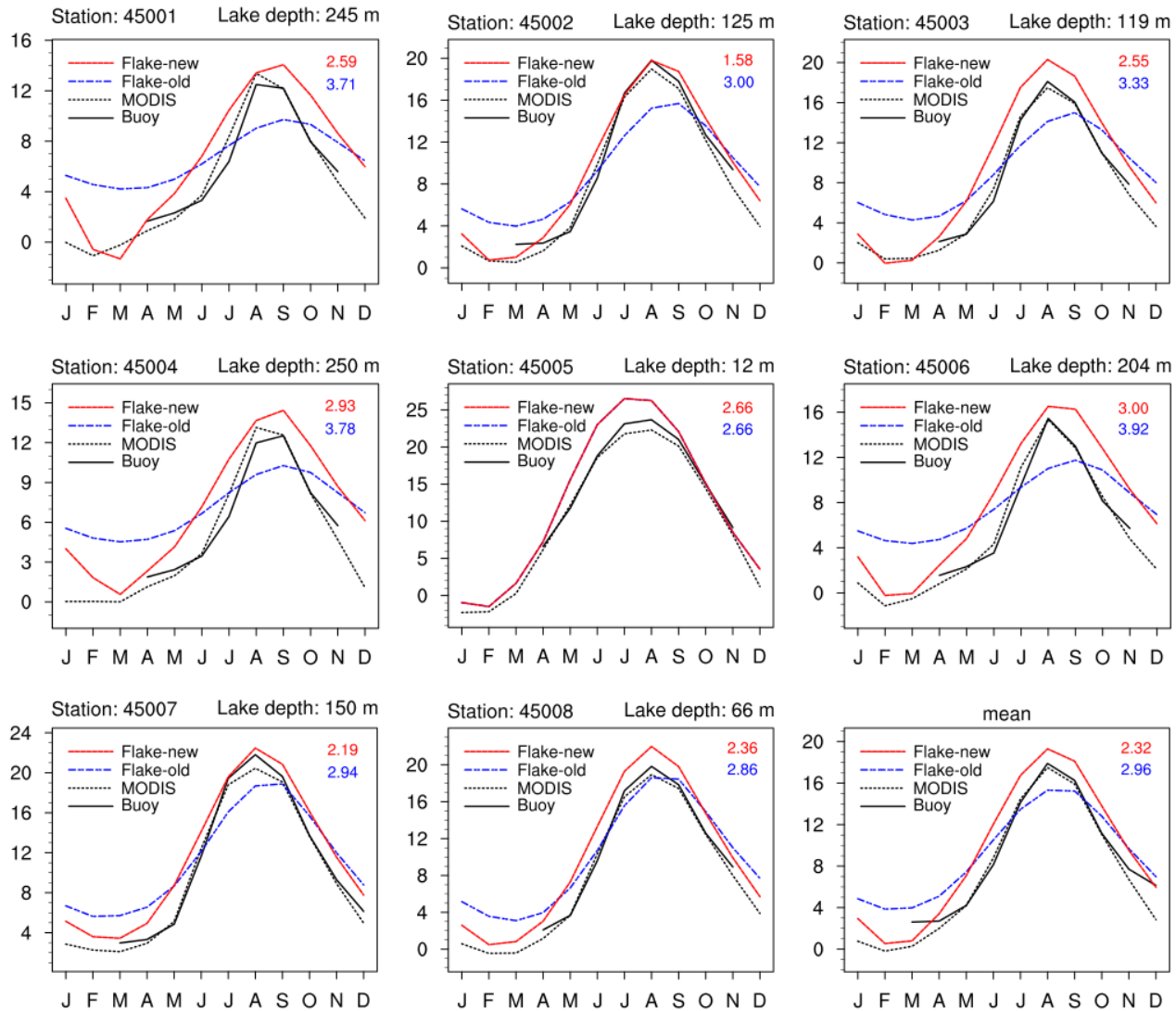
1984-2010

The Improved FLake model



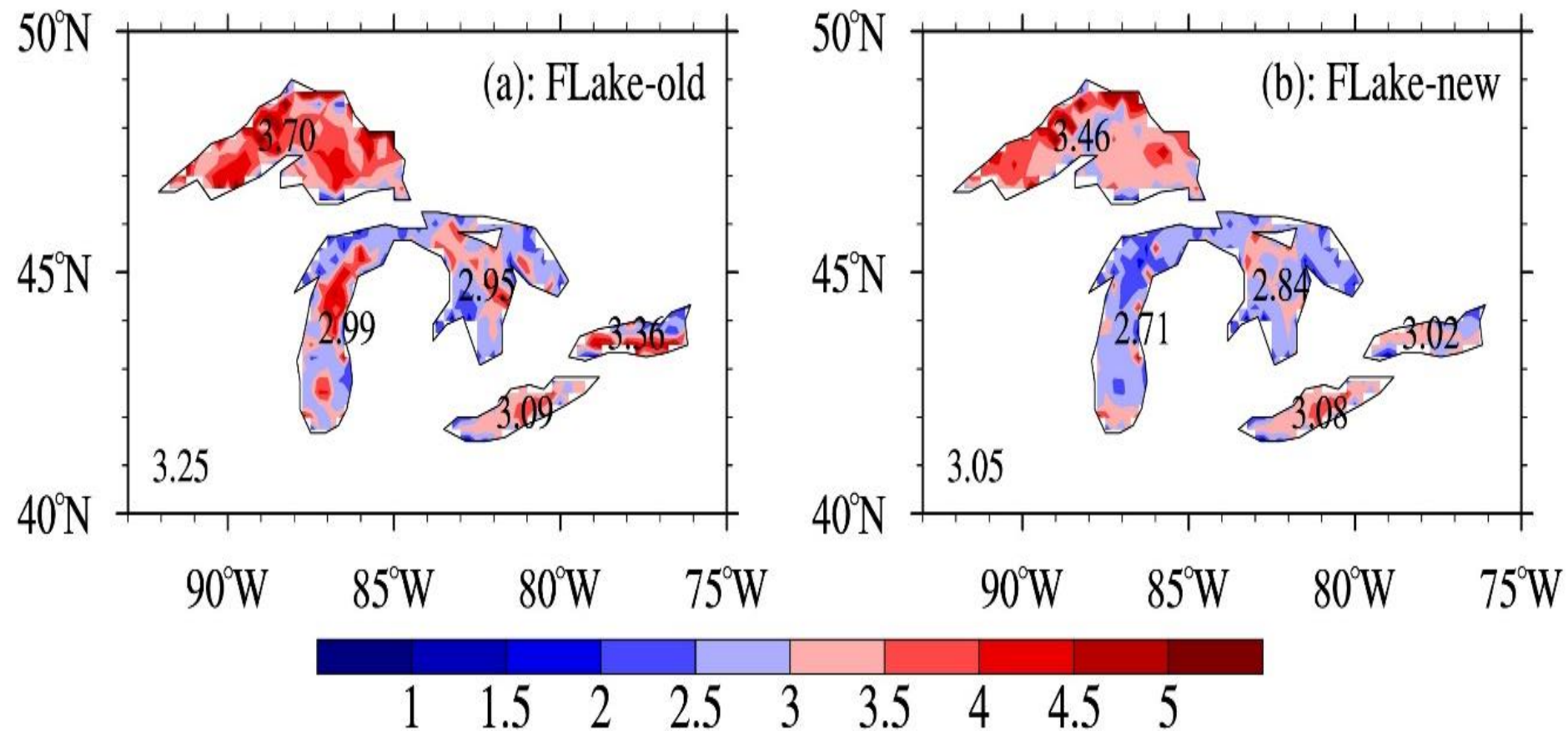
One additional layer is added to the Flake model to describe the hypolimnion

Lake surface temperature simulations

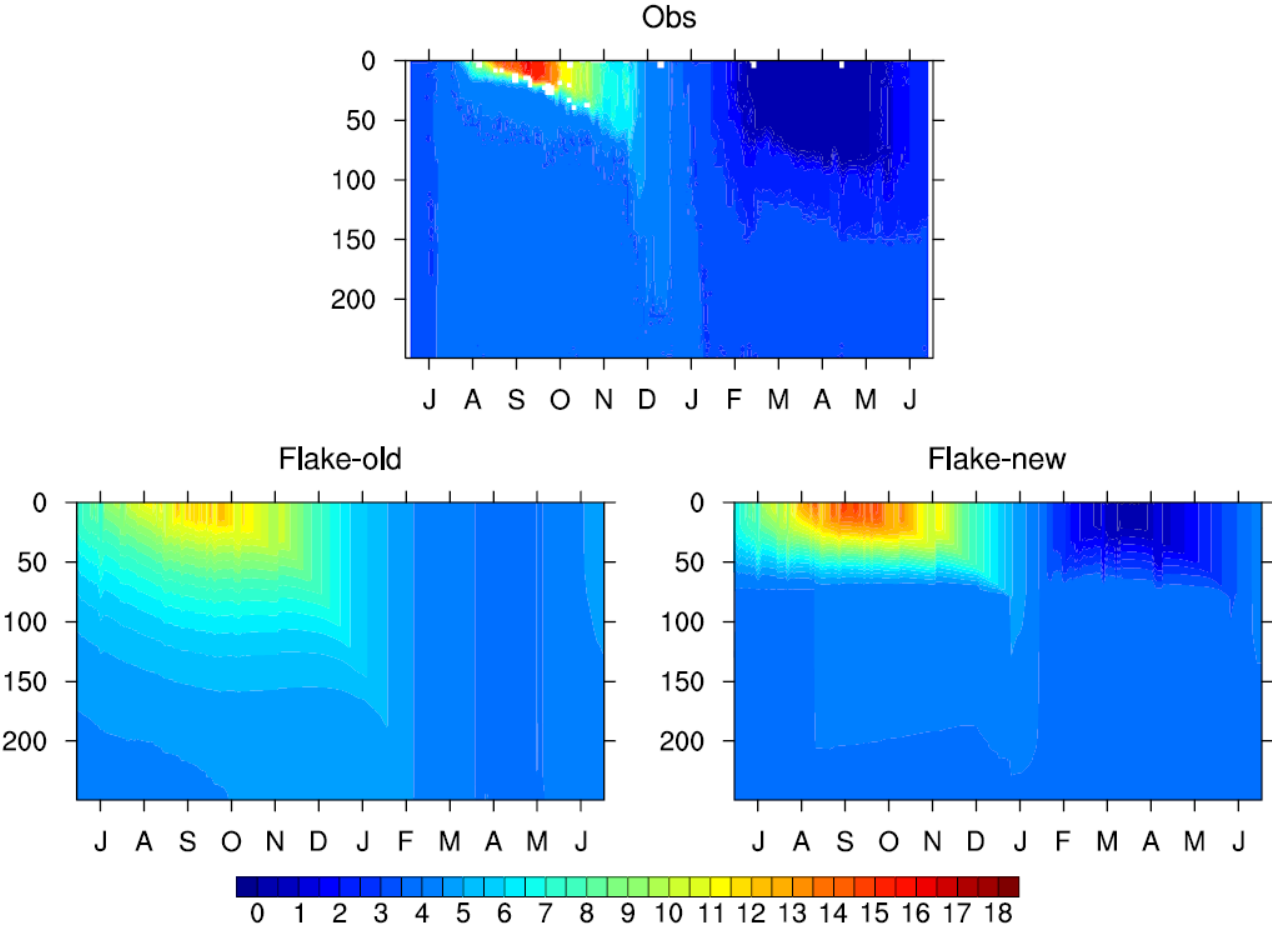


1984-2010

Lake surface temperature simulations



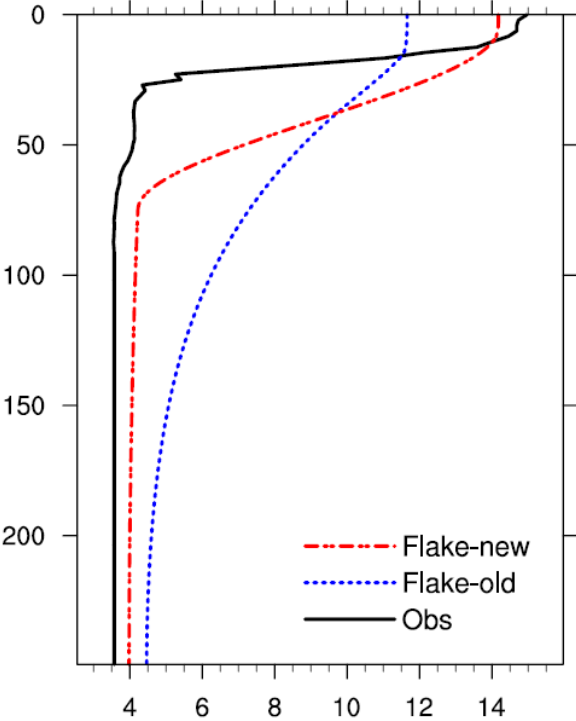
Lake temperature profile simulations for Lake Superior



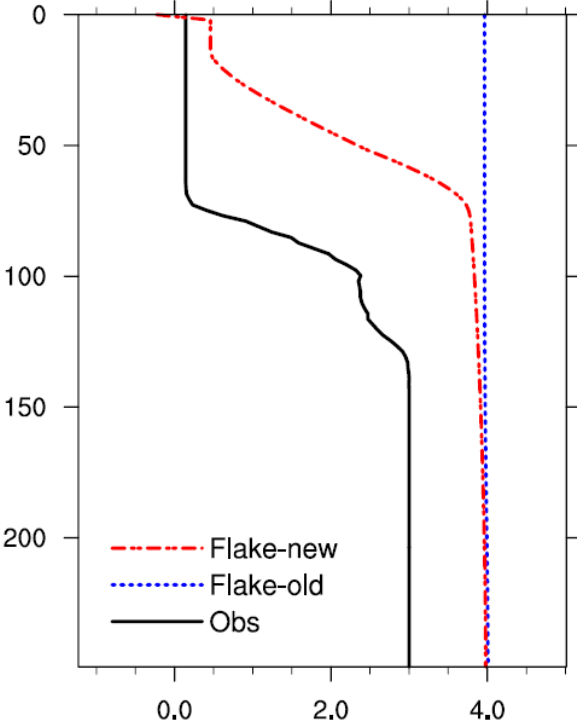
2008-2009

Lake temperature profile simulations for Lake Superior

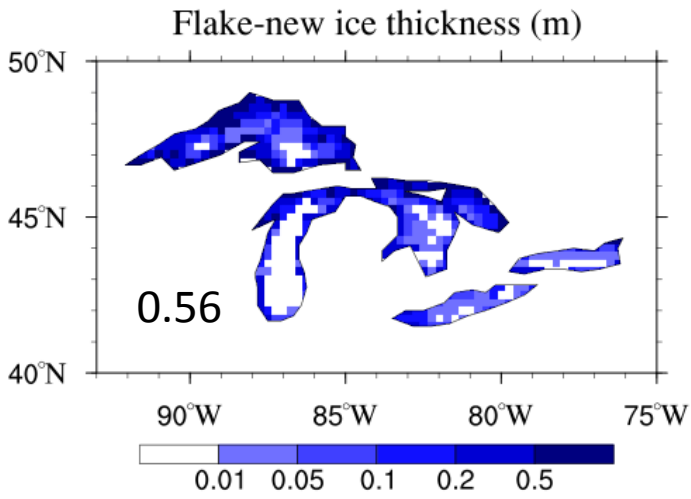
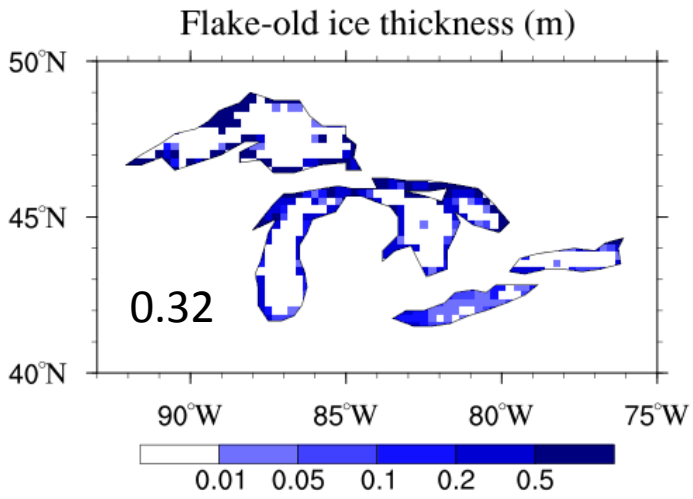
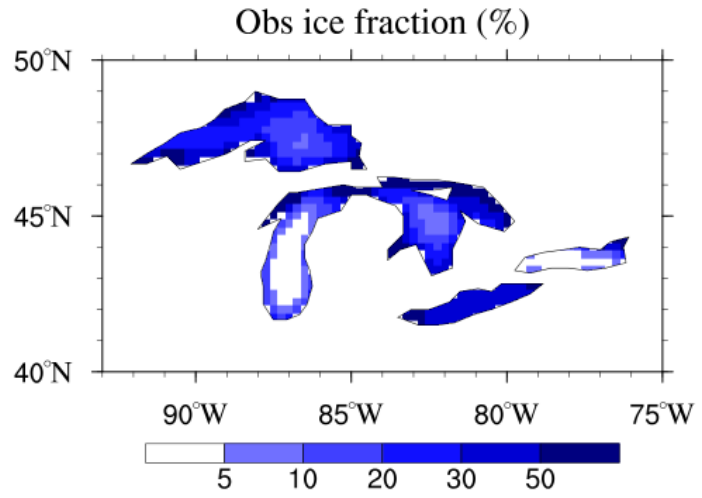
September 2008



March 2009



Lake ice simulations



1984-2002

Coupling between CFS and FLake

CFS subroutines

ghphys.f

sfc_drv.f

Flake subroutine

sfc_drv_Flake.f

```
if (flag_lake == 0) then      ! Noah
    call sfc_drv (...)
else if (flag_lake == 1) then ! Noah with FLake
    call sfc_drv_Flake(...)
end if
```

```
subroutine sfc_drv_Flake(...)
...
if ( RFrLake (iix,iiy) .ge. lake_pct_min ) then
! RFrLake > lake_pct_min, FLake is activated
    call sfc_drv(...)
    call flake(...)
    ! Do flux average
End if
end subroutine sfc_drv_Flake
```

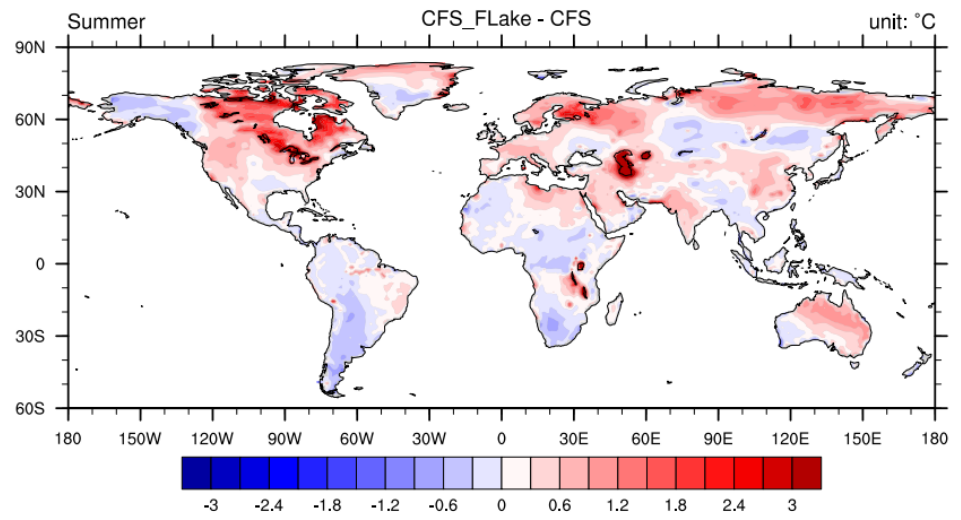
Currently, lake_pct_min is set to 10%

Lake fraction and lake depth from the
Global Lake Database version 2
(Kourzeneva, 2009)

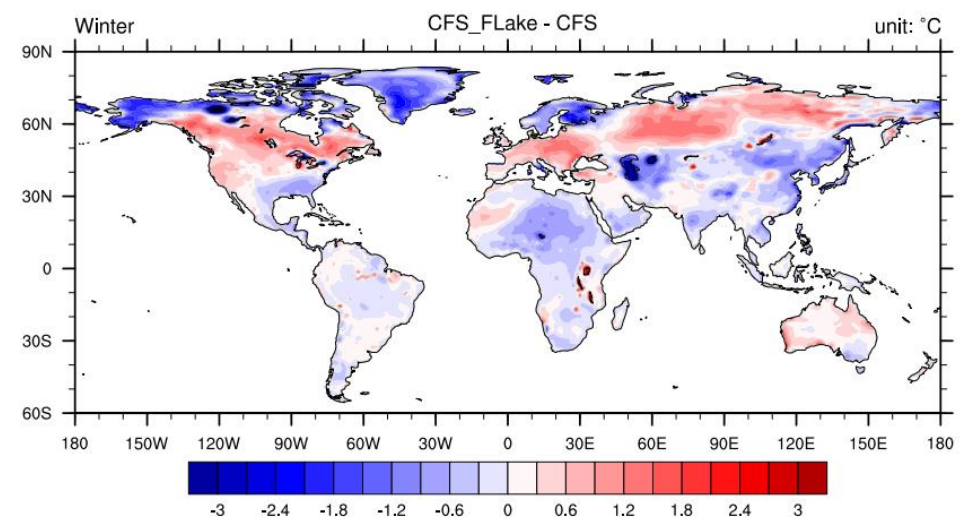
Ensemble simulations with CFS and CFS_FLake for 2014

- Initial times: Z00 on 1st, 6th, 11th, 16th, 21st, and 26th
- Run time: 9 months
- Hindcasts: Starting from April 2013 through December 2014 to produce 9 leads for each simulation month for 2014.
- There are total 6 ensemble members for each simulation month from January through December 2014 .

Temperature hindcasts with CFS and CFS_Flake for 2014

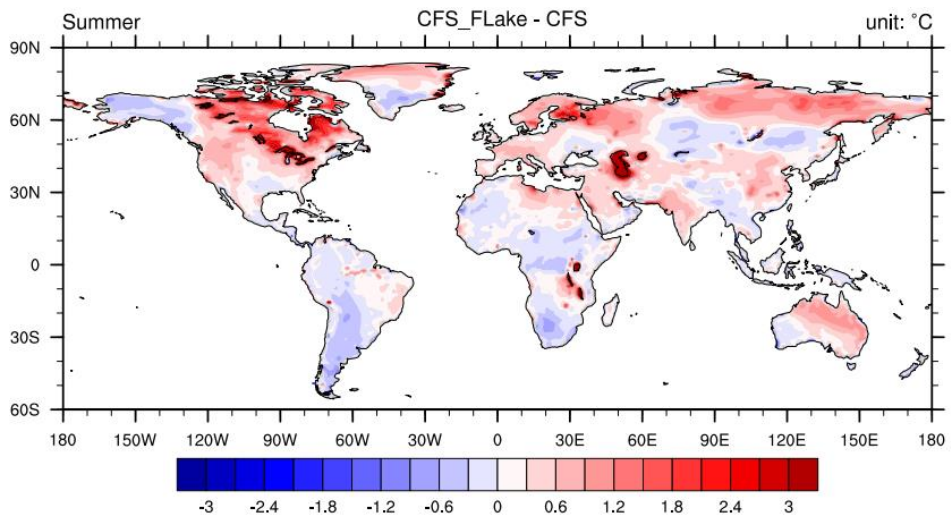


0.46°C

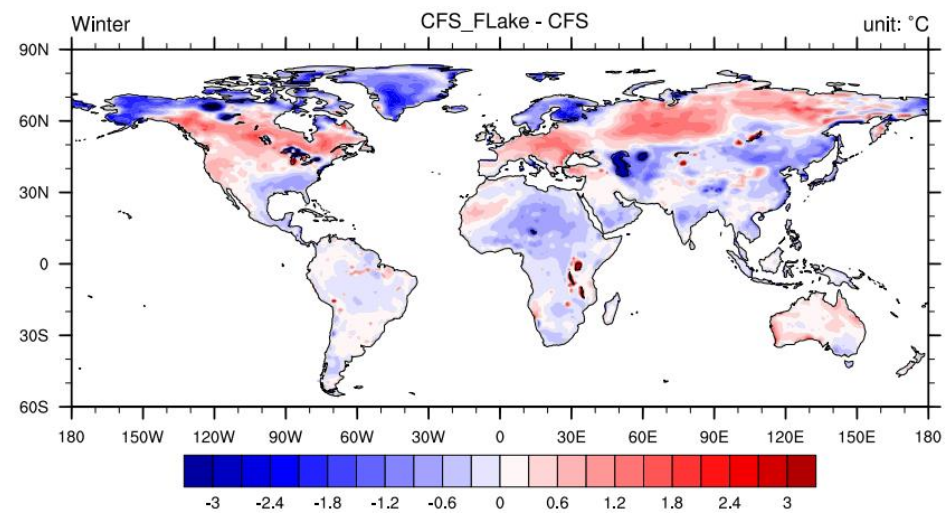


-0.17°C

Surface skin temperature hindcasts with CFS and CFS_FLake for 2014

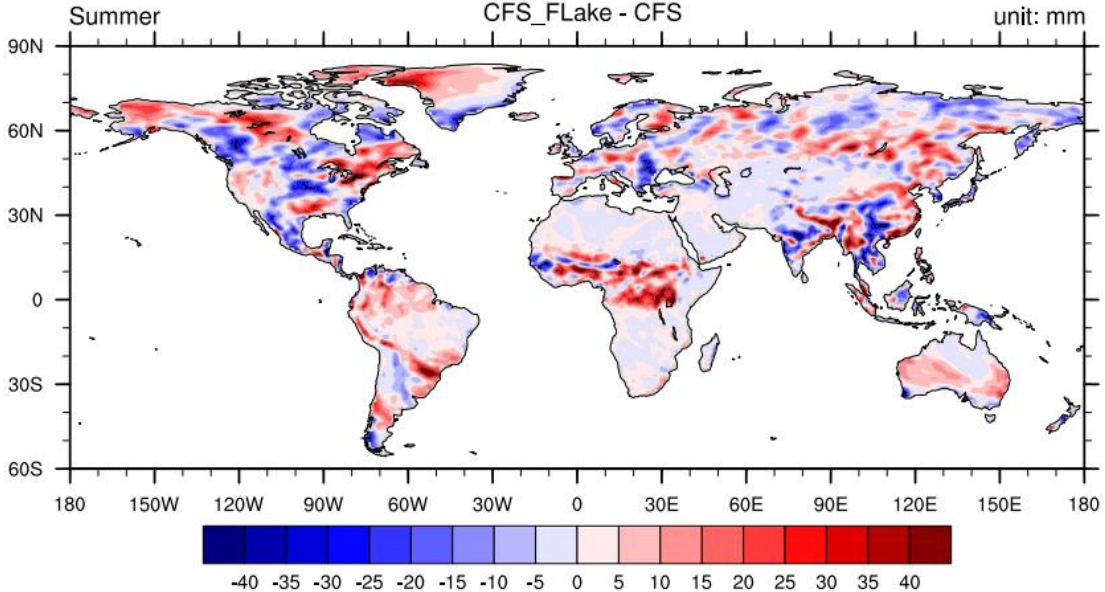


0.51°C

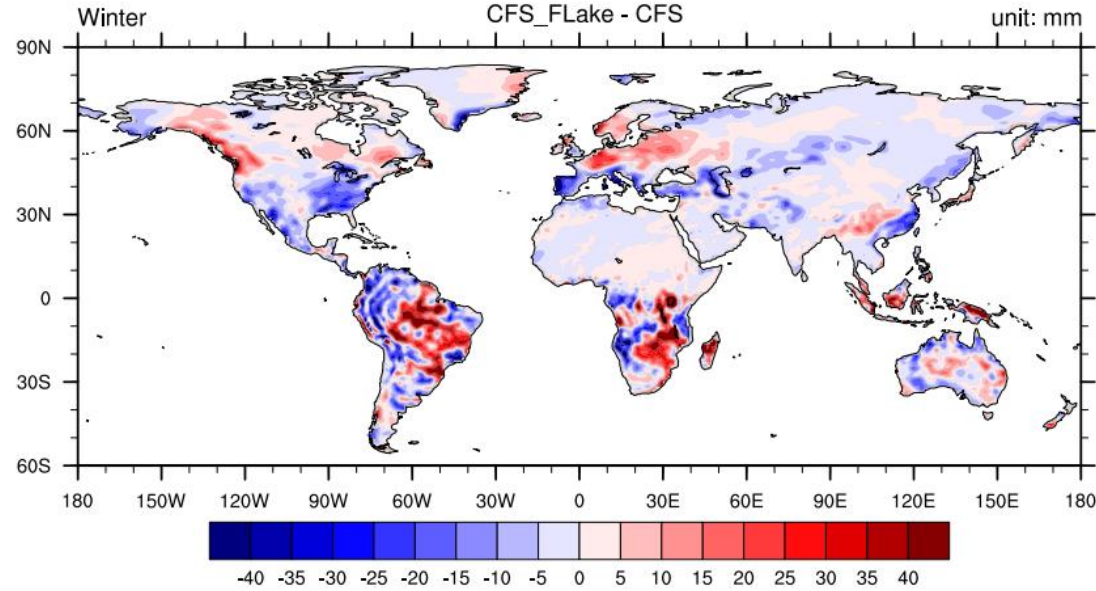


-0.29°C

Precipitation hindcasts with CFS and CFS_Flake for 2014

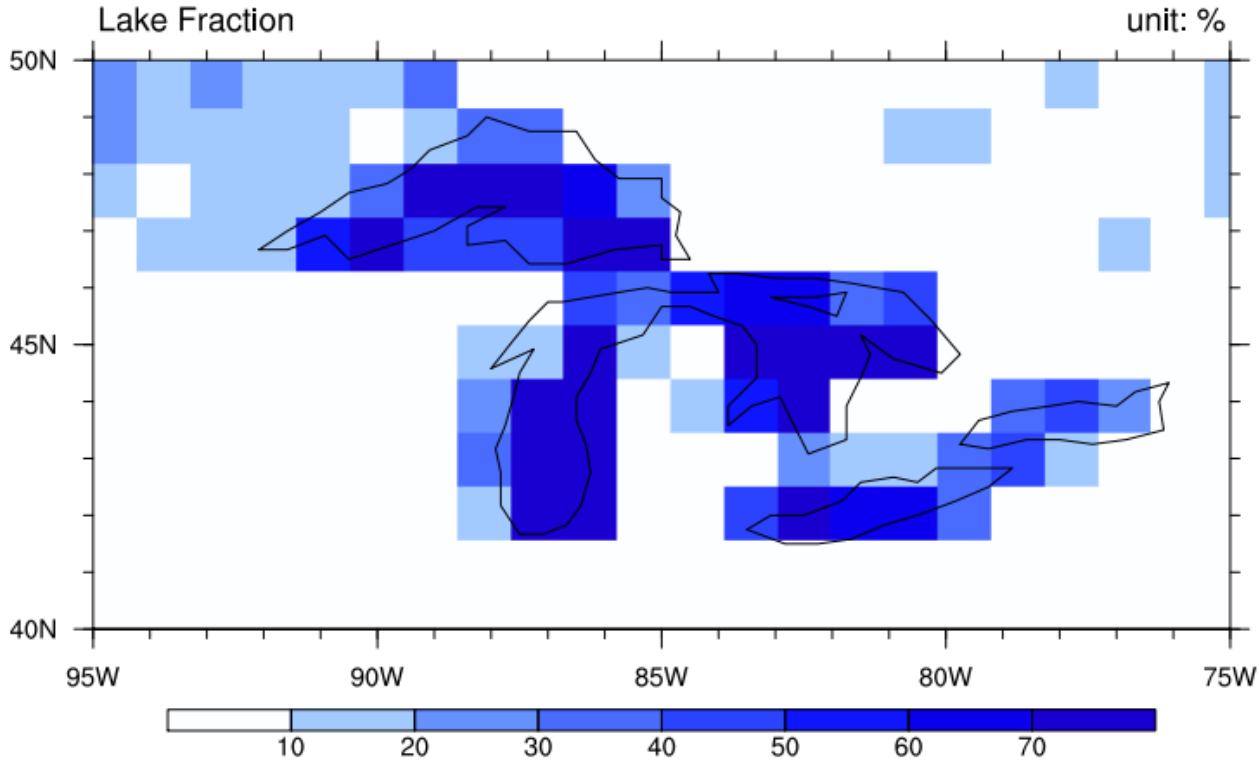


0.60mm



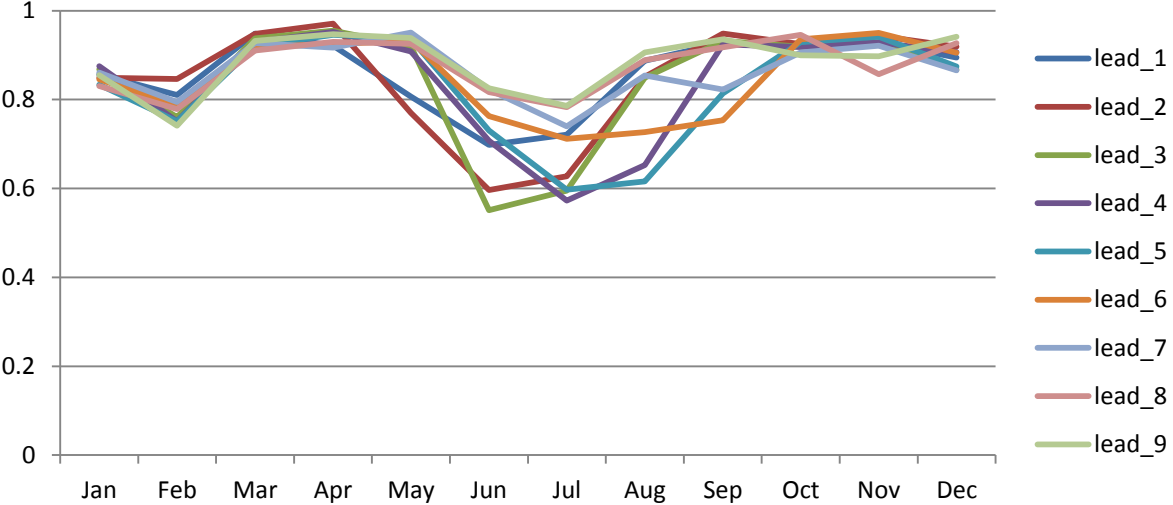
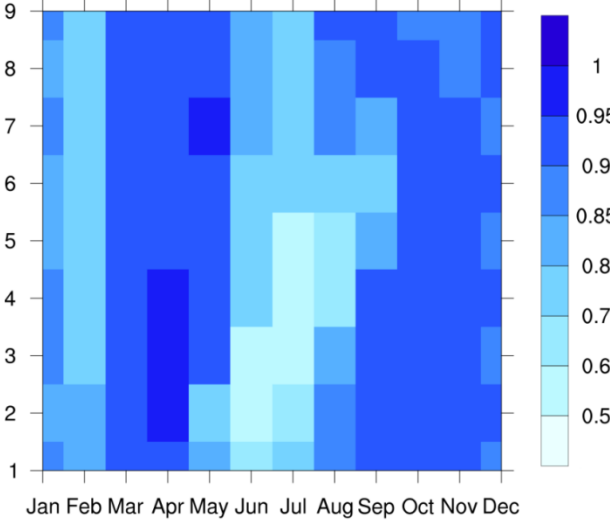
-0.66mm

Lake Fraction distribution in the Great Lakes region in CFS_FLake

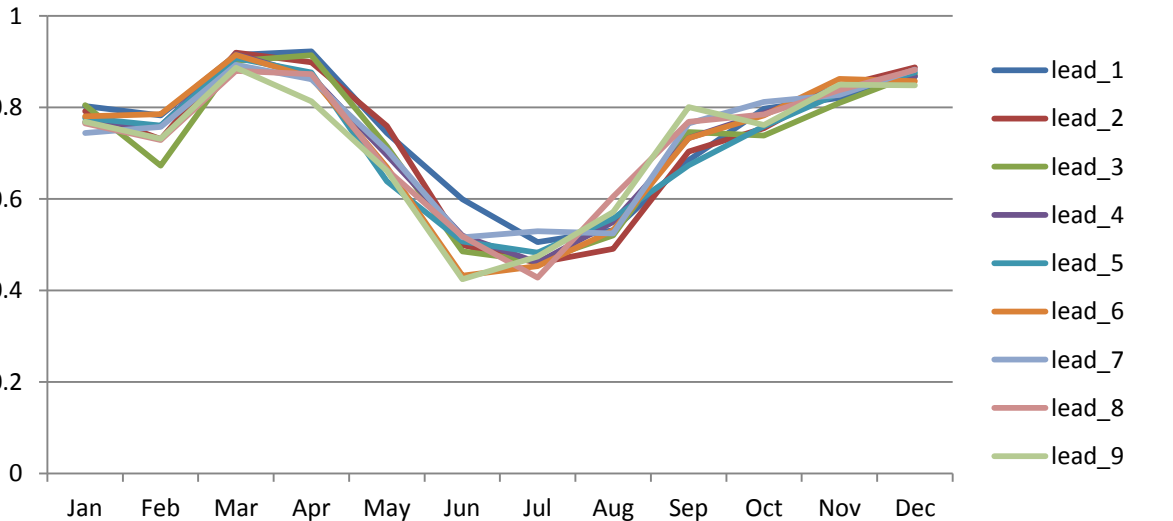
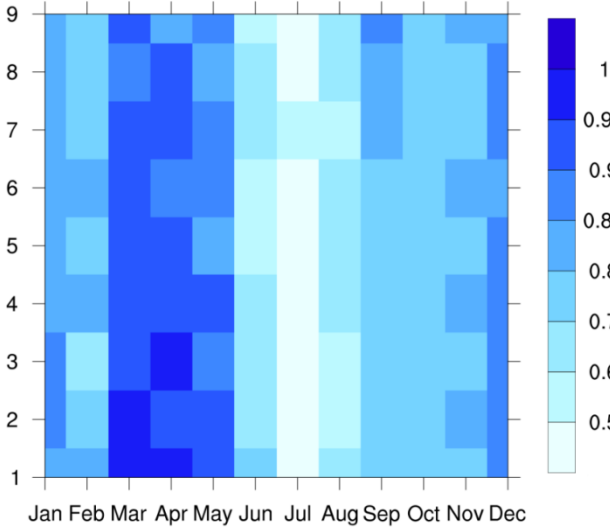


Correlation between hindcasts and observations for the Great Lakes region

CFS temperature hindcasts

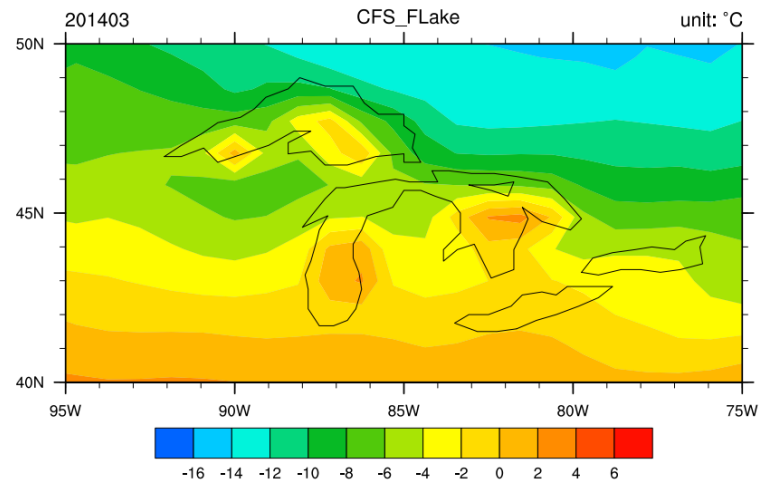
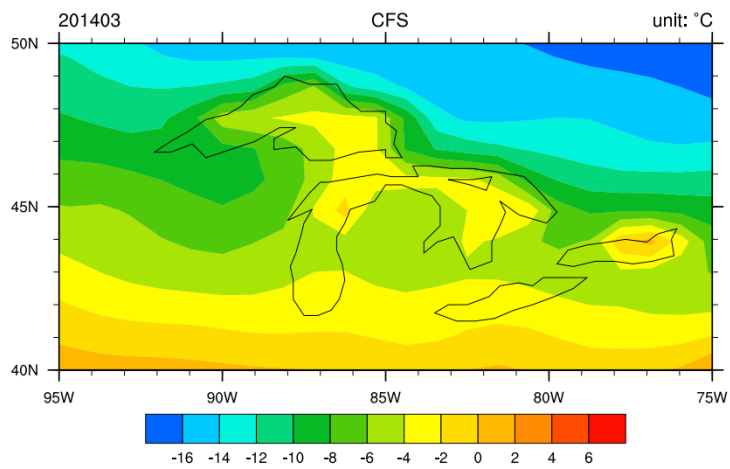
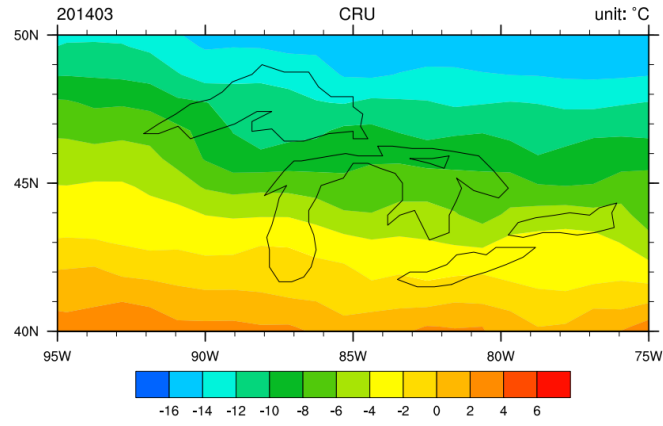


CFS FLake temperature hindcasts



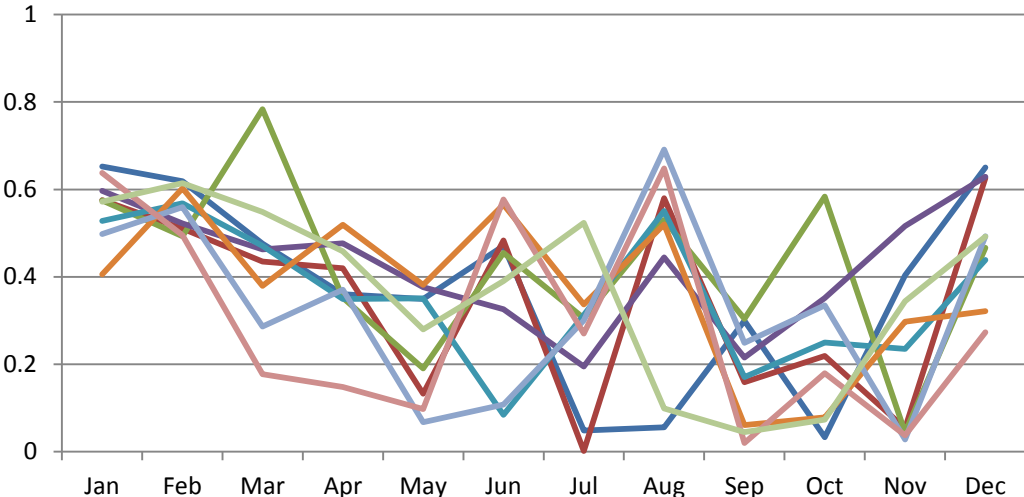
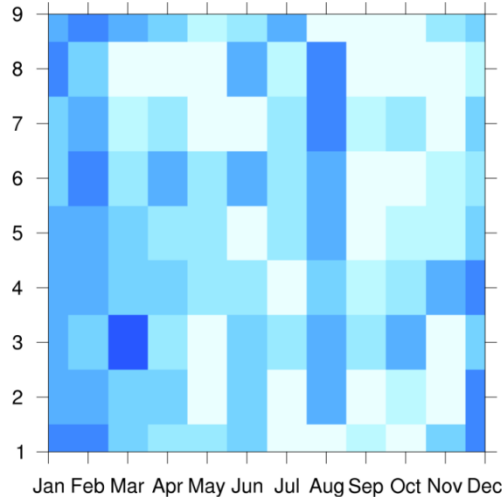
Observation: the Climate Research Unit (CRU) data

Temperature observations and hindcasts for the Great Lakes region

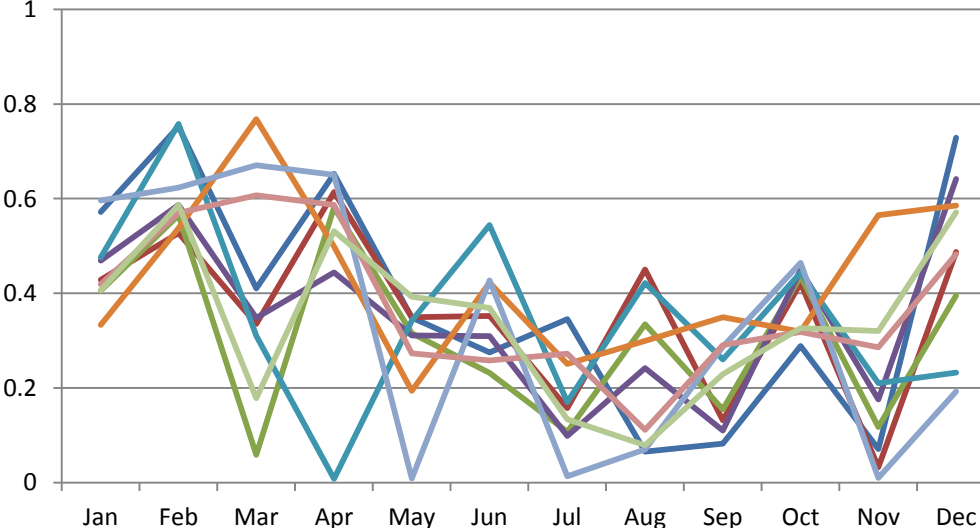
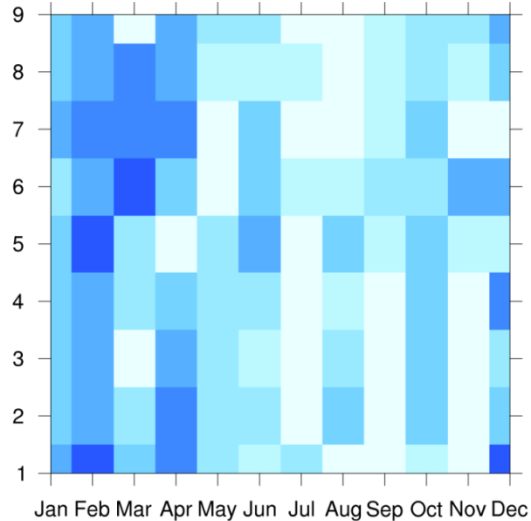


Correlation between hindcasts and observations for the Great Lakes region

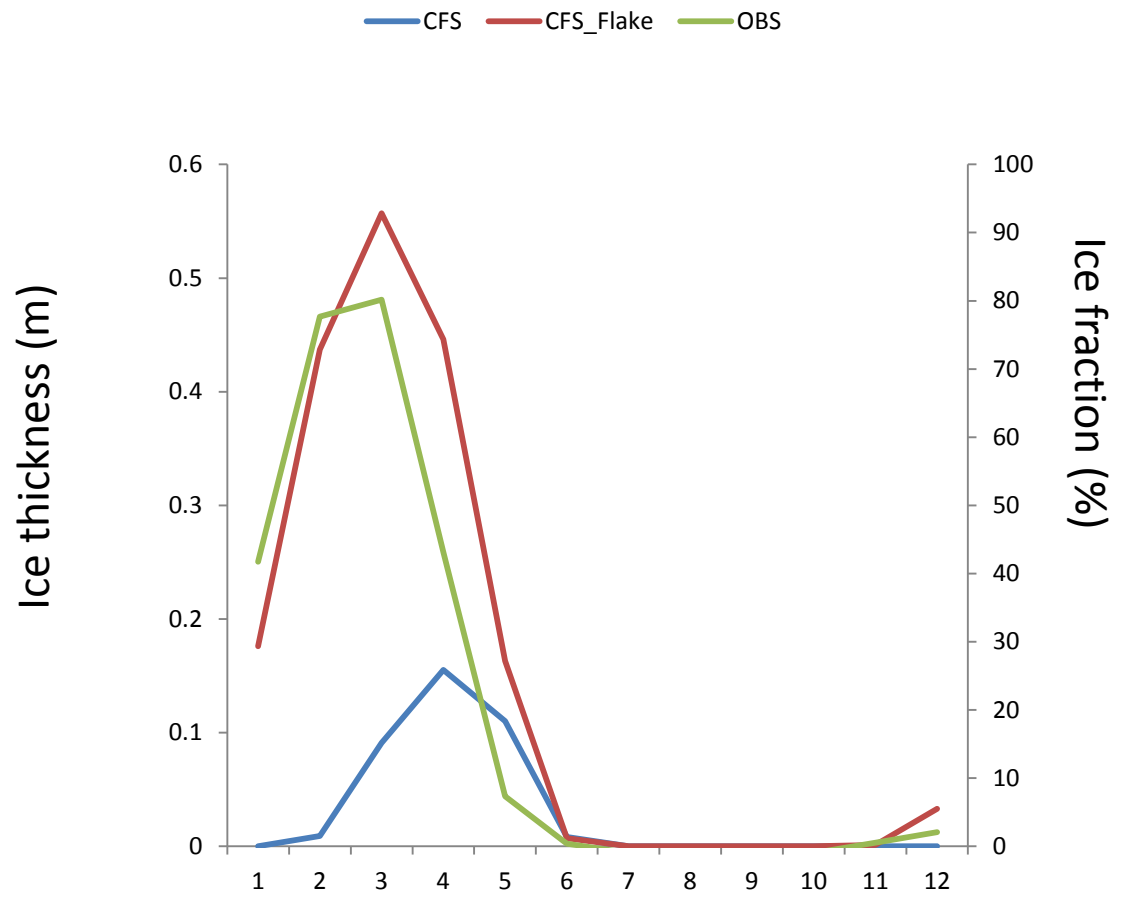
CFS precipitation hindcasts



CFS_FLake precipitation hindcasts

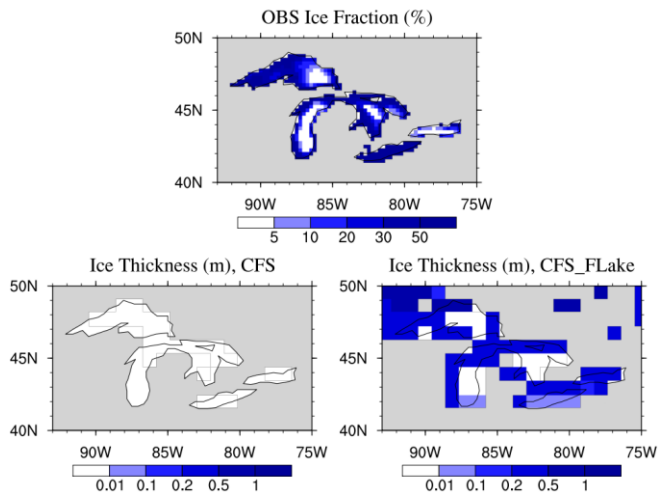


Lake ice hindcasts for the Great Lakes for 2014

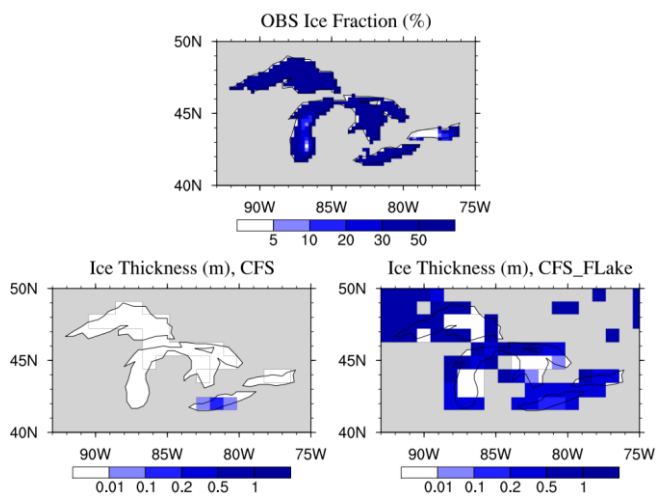


Lake ice hindcasts for the Great Lakes for 2014

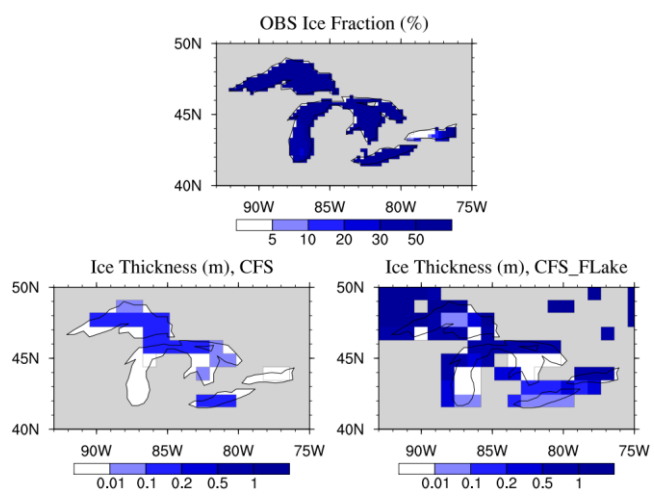
Jan. 2014



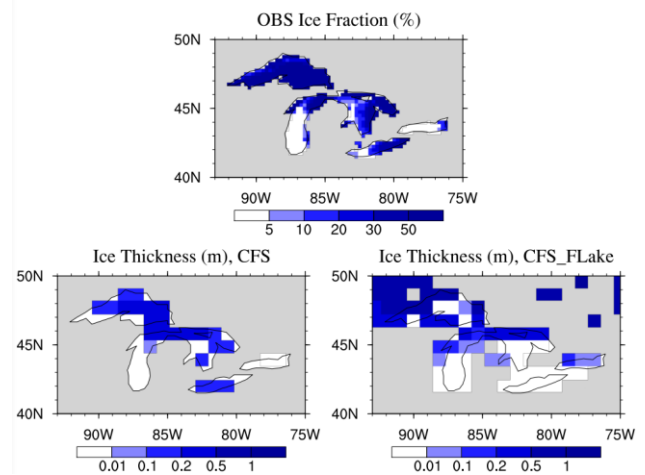
Feb. 2014



Mar. 2014



Apr. 2014



Summary

- 1) We added one additional layer to the FLake model for deep lakes (>50 m) to improve the simulations of lake stratifications.**
- 2) The improved FLake model produces better simulations for lake surface temperature, temperature profile and lake ice.**
- 3) The coupled CFS_FLake model changes precipitation and temperature forecasts at both global and regional scales when compared to the original CFS.**
- 4) The coupled model produces a better spatial distribution of lake ice than the original CFS for the Great Lakes region.**
- 5) Longer term ensemble simulations with the coupled CFS-FLake model are needed to more objectively evaluate its performance in climate forecasts.**