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

The bathymetry of the Great Lakes (m)

Lake Superior
Lake Michigan
Lake Huron
Lake Ontario
Lake Erie
Lake surface temperature simulations
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

(a): FLake-old

(b): FLake-new
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

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 1\textsuperscript{st}, 6\textsuperscript{th}, 11\textsuperscript{th}, 16\textsuperscript{th}, 21\textsuperscript{st}, and 26\textsuperscript{th}

- 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

Summer: CFS_Flake - CFS

Winter: CFS_Flake - CFS

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

Summer:
- CFS_Flake - CFS
- Unit: mm
- 0.60mm

Winter:
- CFS_Flake - CFS
- Unit: mm
- -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

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.