2nd Workshop on Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling
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Interactive Lakes in the Canadian Regional Climate Model, versions 4 and 5

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2 years ago, in Zelenogorsk…

This were our plans:

“… *The works on interactive 1D lake model coupling with CRCM are actually in progress.*

As a first step, several lake models were tested off-line in conditions, reflecting different lake configurations (subgrid and resolved, deep and shallow lakes).

The lake database and surface scheme / lake model interface are being developed.

A flexible interface configuration is considered, allowing for use of different lake models.”

What has been done since Zelenogorsk?

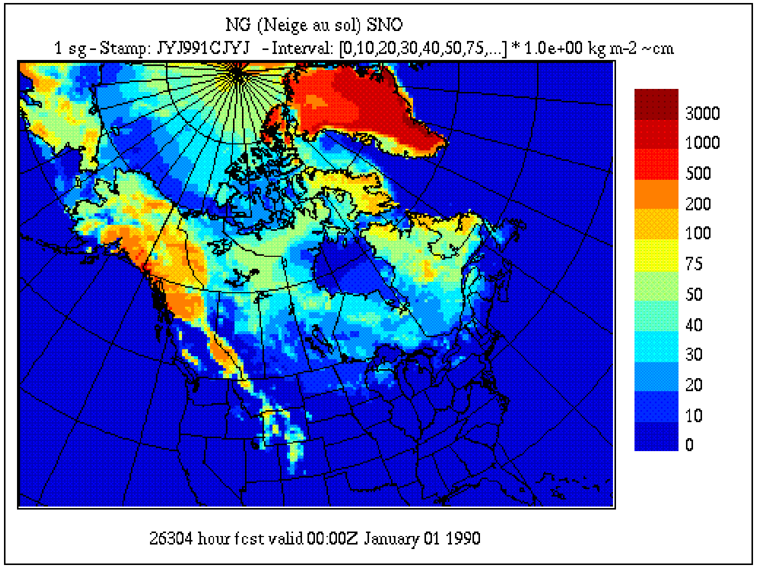
• Publication of off-line tests in the special issue of Boreal Environment Research
Martynov A., L. Sushama, R. Laprise: "Simulation of temperate freezing lakes by one-dimensional lake models: performance assessment for interactive coupling with regional climate models" Boreal Env. Res. 15: 143–164

• Active participation in the Lake Model Imtercomparison Project: see presentation tomorrow

• Coupling of lake models with the Canadian Regional Climate Model, versions 4 and 5 (ongoing work)

Canadian Regional Climate Model (CRCM)

➢*Reference: Laprise R., “Regional Climate Modelling”, J. Comp. Phys., 227(2008) 3641-3666*



• Current version: CRCM 4.

- Surface scheme: CLASS 2.7, no mosaic.

- Horizontal resolution:: 45 km, non-parallelized.

• Used by Consortium Ouranos and Environment Canada for climate change simulations.

• In development: CRCM 5, highly parallelized high resolution regional model.

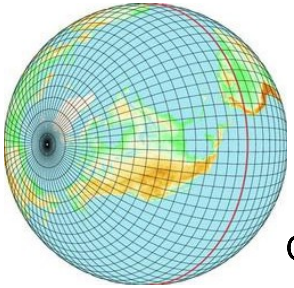
- Horizontal resolution: 10-20 km.

- Based on Global Environment Multi-scale (GEM), the global NWP model of Environment Canada in configuration GEM-LAM.

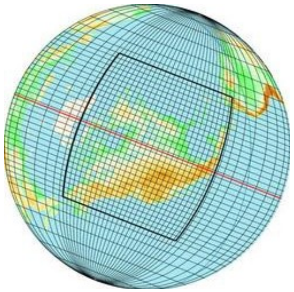
-Surface schema : CLASS 3.4 with mosaic.

New surface elements in development:: lakes, coupled hydrology, dynamic vegetation, oceans, permafrost, thermokarst, ice sheets, glaciers.

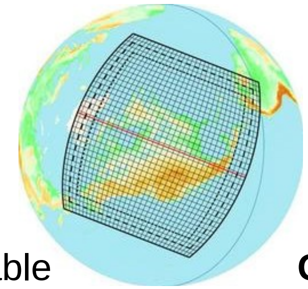
GEM Configurations



Global regular



Global variable



GEM-LAM

CRCM: coupling with 1D lakes

- Two different lake model coupling schemes were developed:

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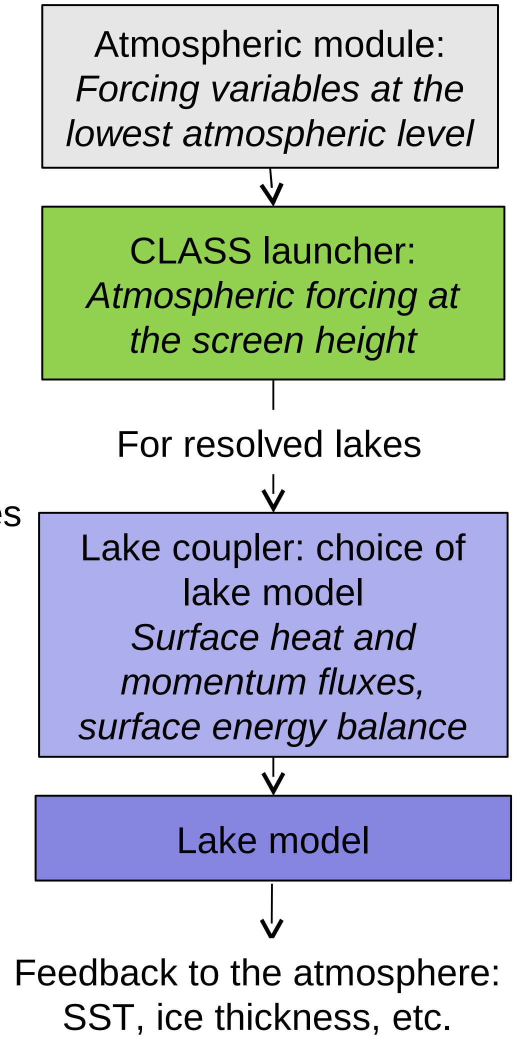
1. CRCM4 + CLASS 2.7)

Lake models are called by the surface scheme launcher

Only resolved lakes can be treated by CLASS 2.7 → lake models are applied only to resolved lakes (the mosaic approach is possible In newer CLASS versions)



CRCM: coupling with 1D lakes

- Two different lake model coupling schemes were developed:

1. CRCM4 + CLASS 2.7

Atmospheric module:
Forcing variables at the lowest atmospheric level

↓

CLASS launcher:
Atmospheric forcing at the screen height

For resolved lakes

↓

Lake coupler: choice of lake model
Surface heat and momentum fluxes, surface energy balance

↓

Lake model

↓

Feedback to the atmosphere: SST, ice thickness, etc.

Lake models are called by the surface scheme launcher

Only resolved lakes can be treated by CLASS 2.7 → lake models are applied only to resolved lakes (the mosaic approach is possible In newer CLASS versions)

2. CRCM5 (GEM)

Atmospheric module:
Forcing variables at the lowest atmospheric level

↓

GEM SURFACE module
Mosaic approach
Lake fractions are calculated for grid tiles

For tiles with lake fractions

↓

Lake coupler: choice of lake model
Surface heat and momentum fluxes, surface energy balance

↓

Lake model

↓

Aggregation of calculated surface parameters for different surface types

Lake model launcher Is independent from surface schemes. The mosaic approach is realised before the surface couplers are called

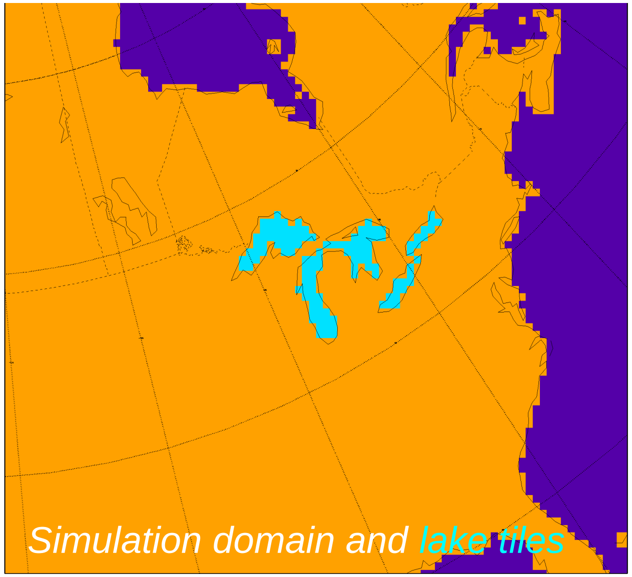
The resulting surface variables are aggregated, based on their fractions on the grid tiles.

Coupled CRCM4 simulations: resolved lakes

- First coupled simulations : 26 year-long period, 1979-2005.

- Five different CRCM4 model configurations were compared
- Simulation domain: 80x90 grid, centered on the Great Lakes
- Boundary forcing: NCEP/NCAR reanalysis.

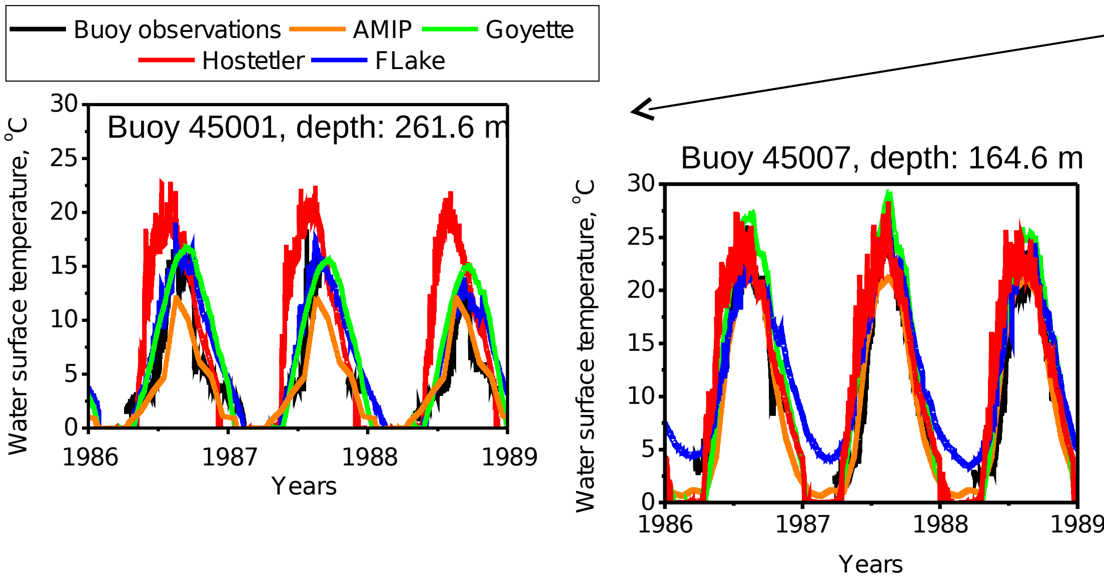
- Observation data: NDBC buoy water surface temperature

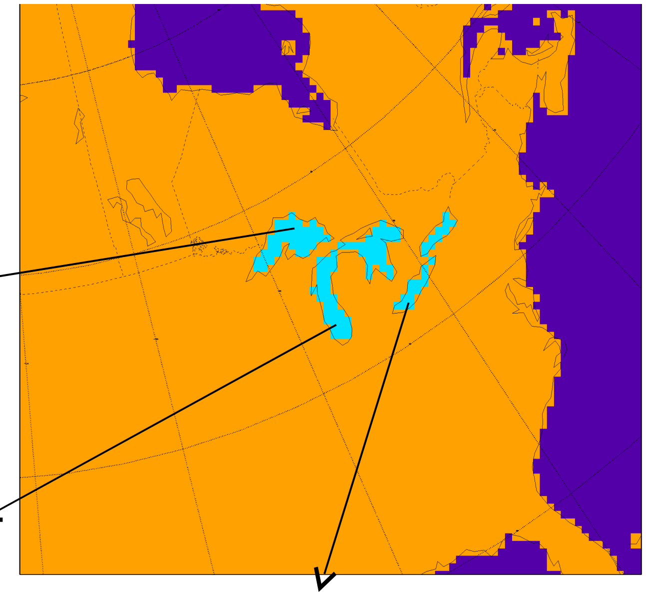


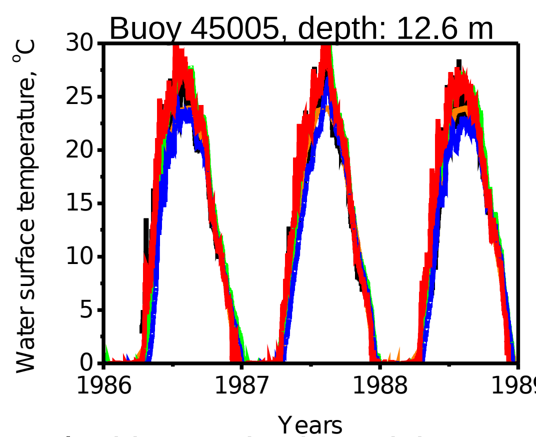
Coupled CRCM4 simulations: resolved lakes

Comparison of coupled and uncoupled simulations:

- AMIP II SST
- Goyette model
- Hostetler model (native surface fluxes)
- Flake model (native surface fluxes), 60 m max. depth





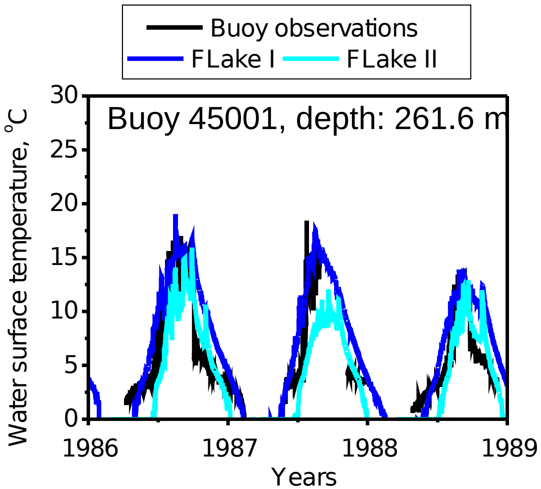


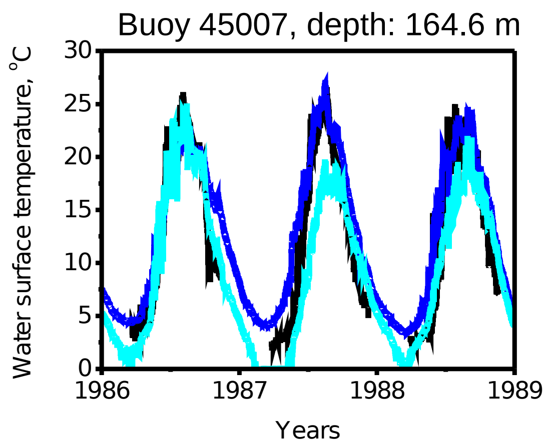
- As in off-line tests, best results are obtained in shallow lakes (Erie)
- Problems arise in deeper lakes (Michigan, Superior).
- Hostetler model provides too rapid and too strong spring heating, due to lacking under-ice mixing.
- FLake produces too few ice in southern lake Michigan.
- Both lake models have difficulties in describing the spring temperature patterns in deep lakes.

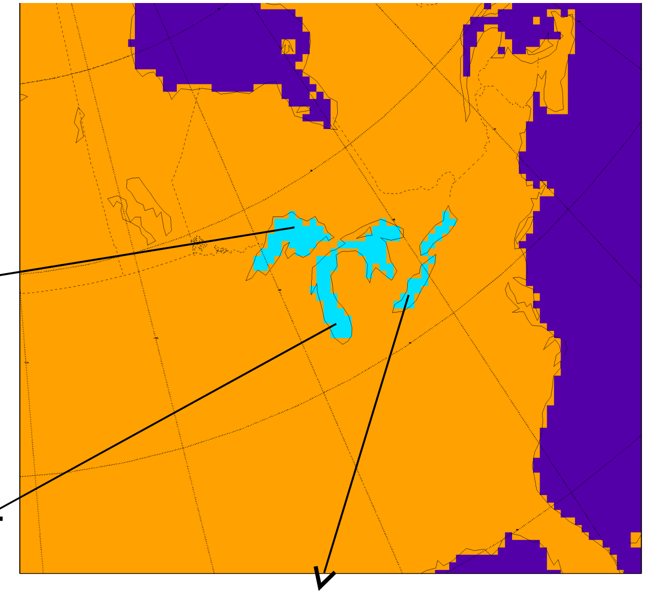
Coupled CRCM4 simulations: resolved lakes

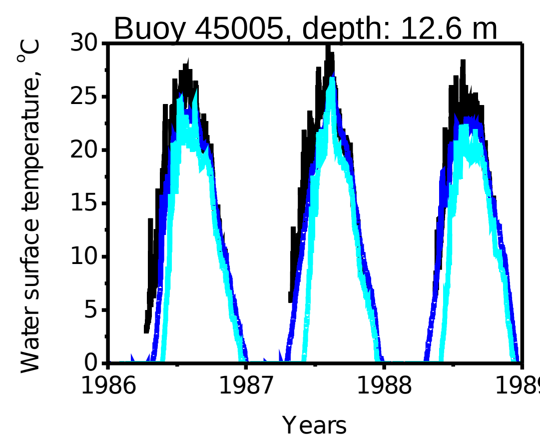
The importance of surface heat flux parameterization.

- Flake model (native surface fluxes): Flake I
- Flake model (Hostetler model surface fluxes, BATS-based) : Flake II









- FLake II with BATS-based surface fluxes is generally too cold, compared with FLake II and buoy observations .
- Not only the correct lake model, but also correct surface heat flux parameterizations have to be used: a task for LakeMIP?

Coupled CRCM4 simulations: resolved lakes

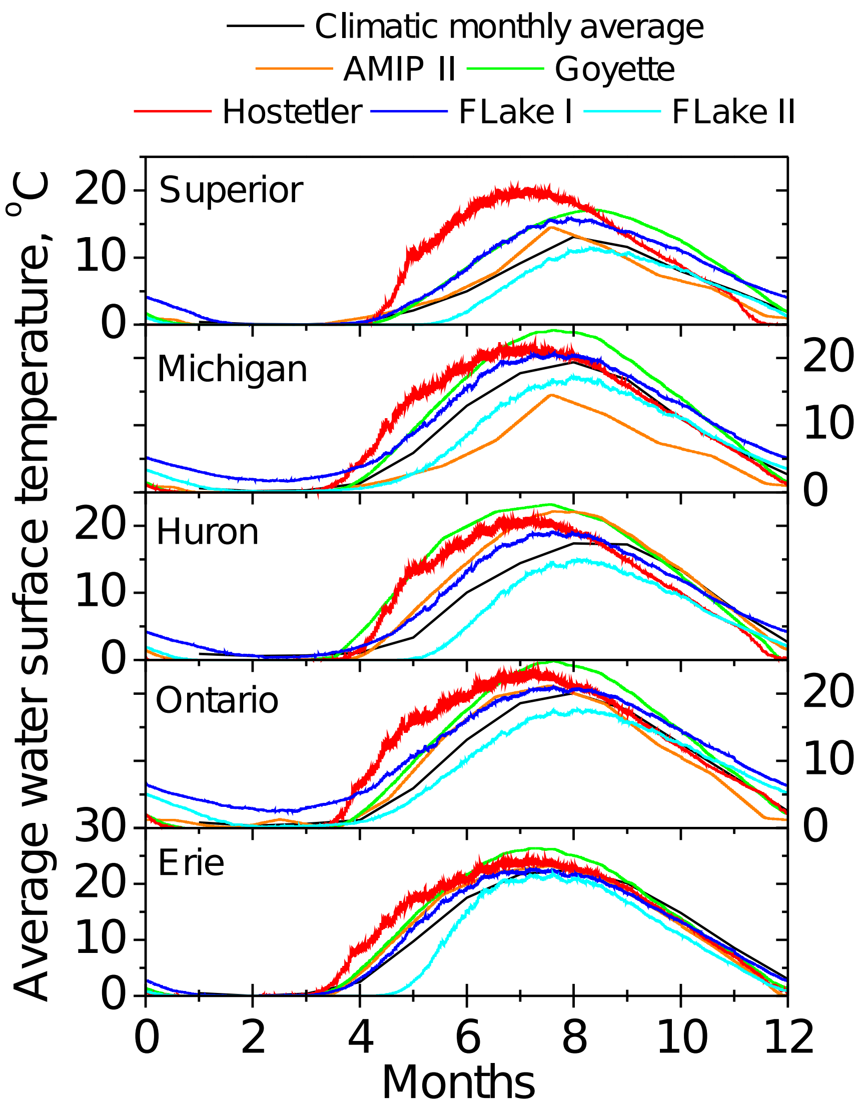
Simulation averages and climatological means

Simulation: 26-year-long averaged SST values
Climatology: from Irbe 1992, Goyette *et al*. 2000

- Among all tested CRCM versions, best results are obtained by the FLake I configuration.

- FLake I is comparable with the Goyette model, which is the standard lake model in CRCM4, but is simpler in use, than the Goyette model.

- In the shallow lake Erie, most CRCM versions are close to climatological means (except Flake II) - good hint for shallow subgrid lakes.

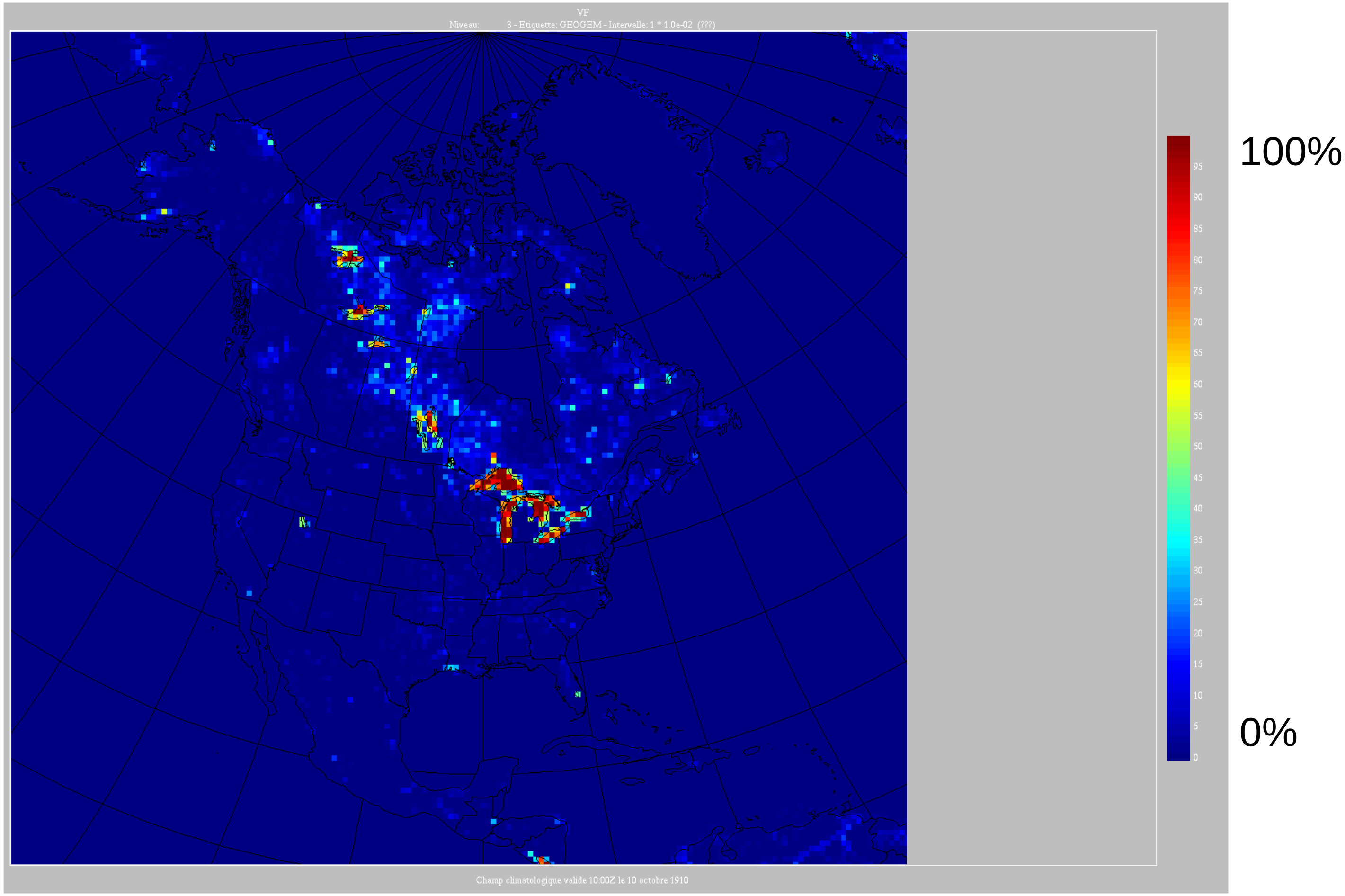


Coupled CRCM5 simulations: subgrid lakes

- First coupled simulation (Hostetler lake model)

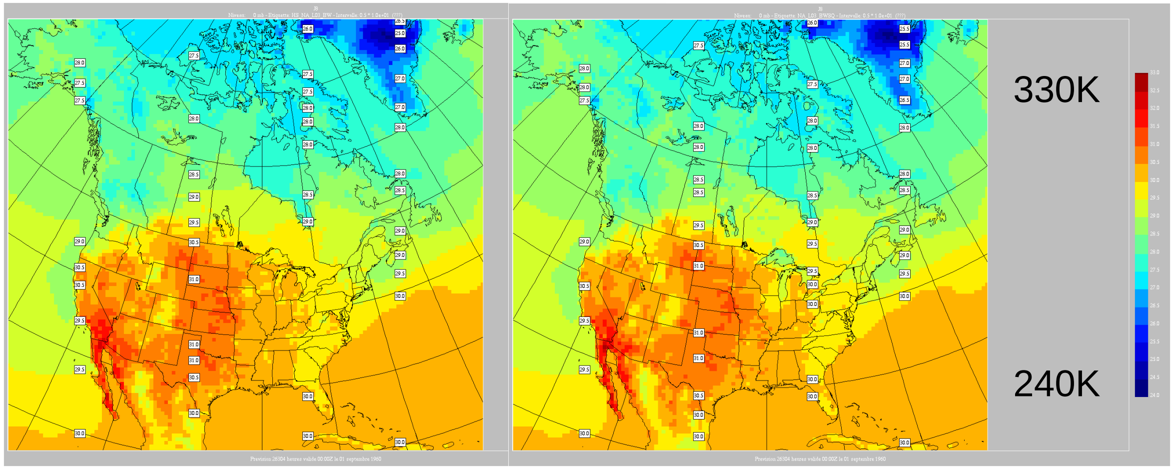
- Simulation domain: North America, 170×158, rezolution 0.5°
- Subgrid lakes are simulated
- Depth parameterization: 10 meters if lake fraction ≤ 0.5, 60 meters otherwise (large lakes)

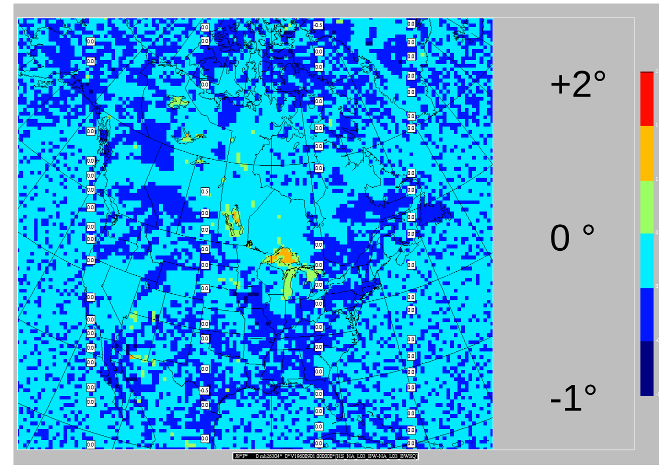
Simulation domain and lake fraction map



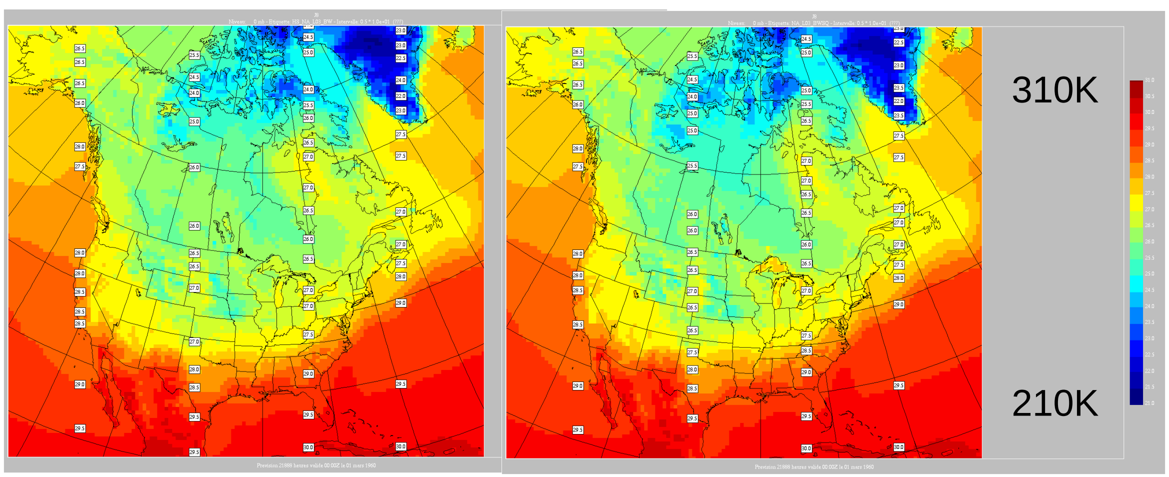
Coupled CRCM5 simulations: subgrid lakes

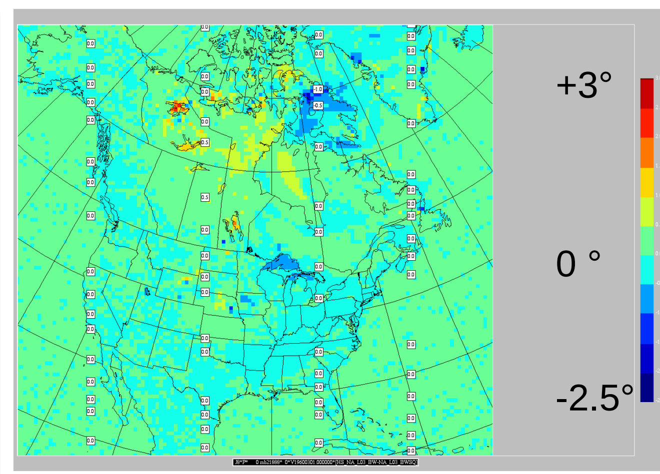
Surface temperature: summer





Hostetler AMIP Hostetler – AMIP





Winter

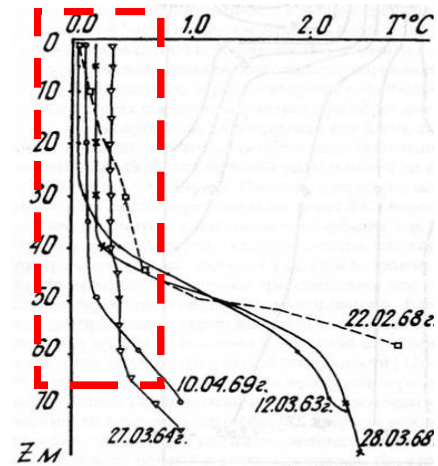
Subgrid lakes: no substantial difference with AMIP
Large lakes: warmer than AMIP in summer

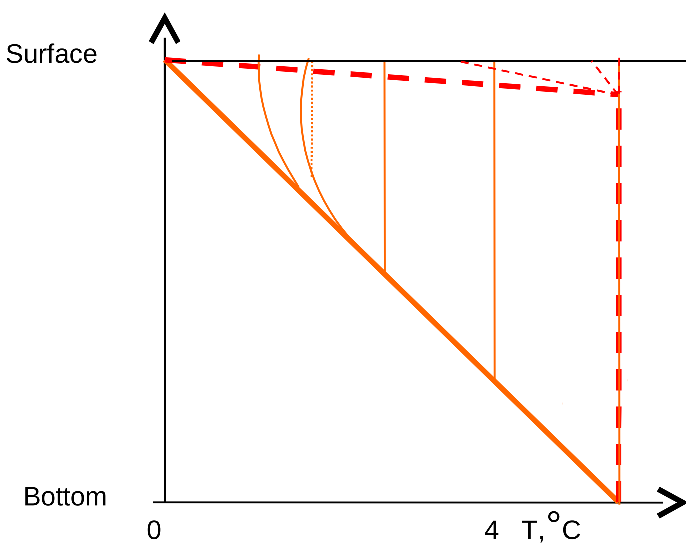
Adaptation of lake models to large lakes

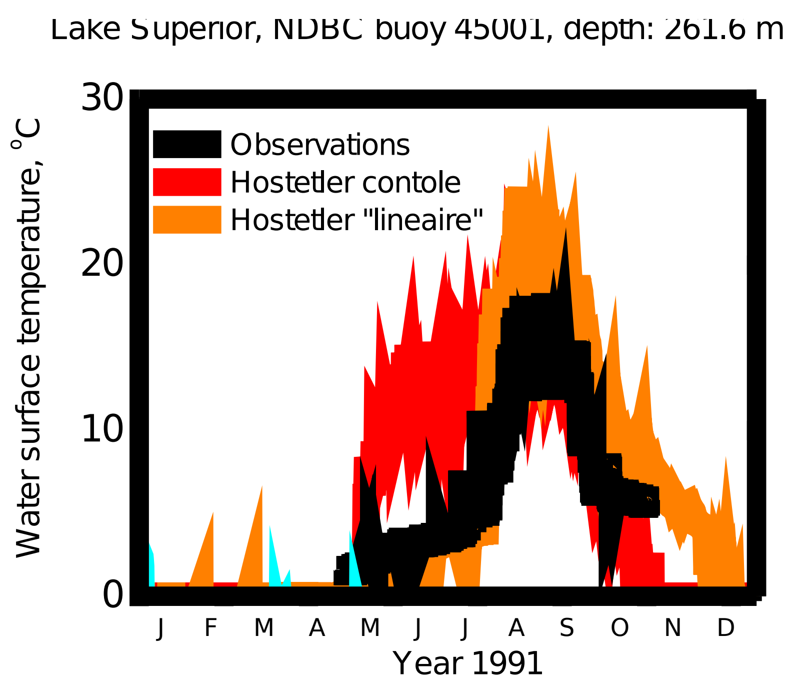
- Models of Hostetler, FLake: evident problems with large lakes
- FLake: strongly parameterized, difficult to modify
- Hostetler model: simple and flexible

Possible solution in Hostetler: forced mixing under the lake ice

Test: initialisation of CRCM4/Hostetler with linear water temperature profile → evident correspondence with observations.







Adaptation of lake models to large lakes

• Better description of large and deep lakes: 3D models

3D simulations → vertical profiles of water temperature, effective diffusion, especially in winter conditions → base for modification of diffusivity parameterization in Hostetler model.

Agreement with researchers from Great Lakes Environmental Research Laboratory (GLERL), Ann Arbor, Michigan for dat aof 3D simulations of lakes Michigan and Erie.

Future work

- Validation runs for CRCM5, coupled with Hostetler model.

- Adding other lake models to CRCM5: FLake and, possibly, other models.

- Modification of the Hostetler model in order to improve the performance in large deep lakes, possibly using 3D lake simulations as a base for the enhanced mixing parameterization.

- Comparison of coupled CRCM5 model with other lake-coupled climate models (RCA, etc.)

- Adding realistic lake depth and water transparency data to the coupled CRCM5 model. Surface heat flux parameterization tuning.

- Climate change simulations, using lake-coupled climate models.

Acknowledgement

We are very thankful to

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LakeMIP participants: Stéphane Goyette, Victor Stepanenko, Marjorie Perroud, Xing Fang, Klaus Jöhnk, and Dmitrii Mironov

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Thank you!

Questions?