3rd Workshop on Lakes in NWP and Climate Modelling
Helsinki, 18 September 2012

Lakes in the Canadian Regional Climate Model, version 5: current state and future plans

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Outline

- Canadian Regional Climate Model, version 5
- 1D lakes in CRCM5
  - Validation runs
  - CORDEX project contribution
- Lakes and climate change in North America
- Remaining issues
- Future plans:
  - 3D oceans and lakes
  - MODIS-based validation study
- Summary

Canadian Regional Climate Model, version 5

- Based on LAM configuration of GEM used for NWP

  - Combination of Meso-Global and Regional (15 km) Physics
  - Libraries: Dynamics GEM_3.3.3 & Physics_5.0.4
  - Kain-Fritsch deep & Kuo – transient shallow convection
  - Sundqvist large-scale condensation
  - Correlated-K solar and terrestrial radiations
  - Subgrid-scale mountain gravity-wave drag & Low-level orographic blocking
  - TKE planetary boundary layer and vertical diffusion

- Recent modifications:
  - Land-Surface Scheme: CLASS_3.5
  - ECOCLIMAP: distribution of sand and clay and formulation of bare soil albedo
  - Elements of CLASS_3.6:
    - Sturm et al. snow thermal conductivity
    - Snow albedo refreshment threshold
  - Peatlands
  - Interactive thermodynamical 1D lakes (Flake, Hostetler) with realistic lake depth (Kourzeneva et al. 2012)

CRCM5/lakes: validation run

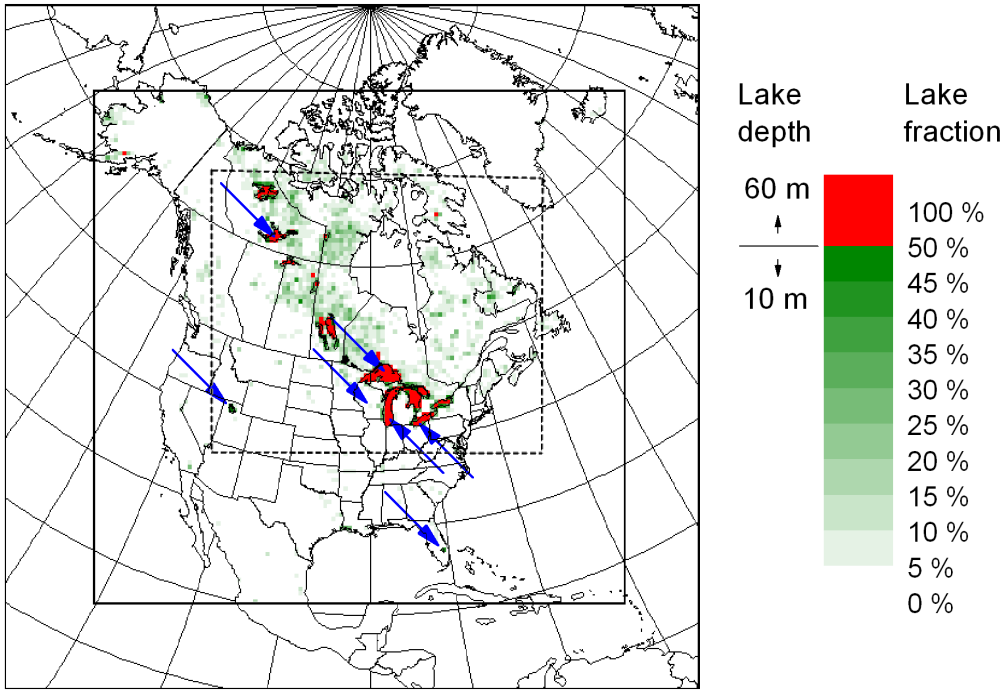
- Simulation period: 1958-2007. Boundary forcing: ERA40 (1958-2002), ERA-Interim (2002-2007)

- Simulation domain: 170 × 158 grid (130 × 118 free), horizontal resolution : 0.5°.

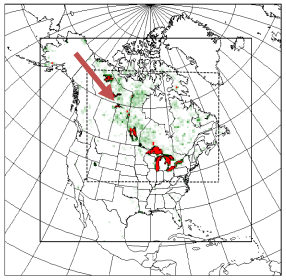
- Four simulations:
  NL: no lakes
  AM: AMIP II
  HL: Hostetler model
  FL: Flake model

- Lake depth parameterization:
  60 m if lake fraction > 50%
  10 m elsewhere

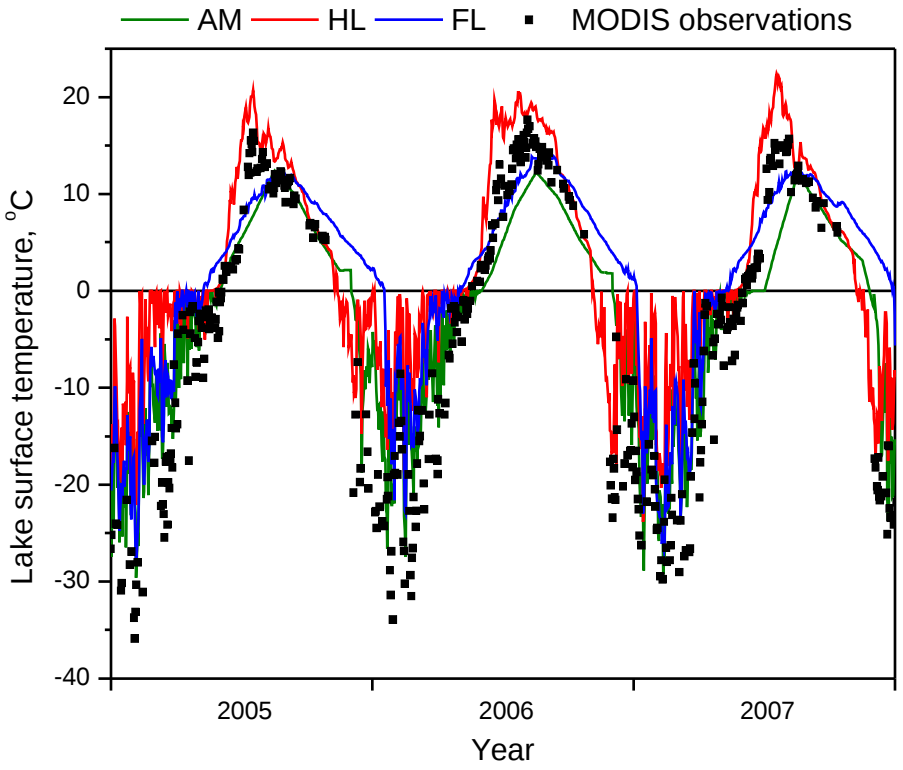
- Seven lake sites for performance evaluation (blue arrows):
  - Great Slave Lake - Lake Superior
  - Lake Michigan - Lake Erie
  - Sparkling Lake - Great Salt Lake
  - Lake Okeechobee



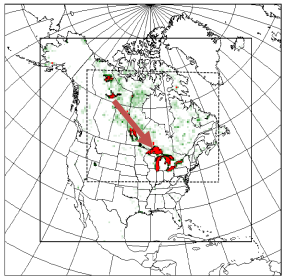
Performance evaluation: Great Slave Lake



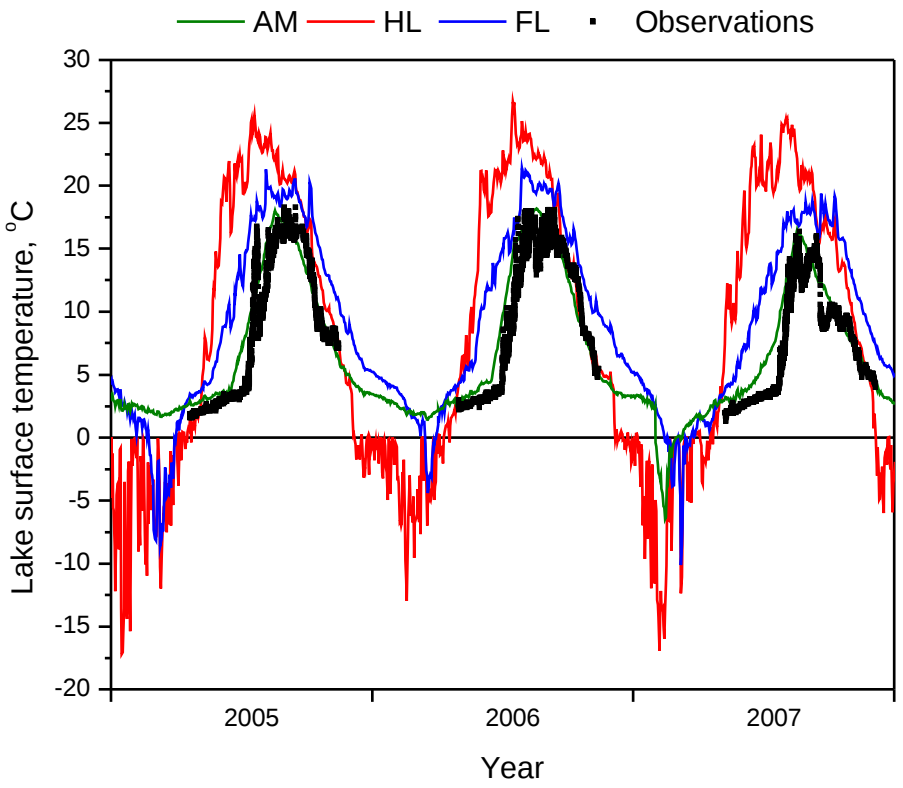
- Great Slave Lake, Northwest Territories (central basin).
- Large and deep northern freshwater lake.
- MODIS – derived data
  (courtesy of Homa Kheyrollah Pour,
  University of Waterloo)
- AMIP II: good shape, low values
  in summer.
- Hostetler: too rapid warming in spring,
  high maximum temperatures
- FLake: generally good, late autumn



Performance evaluation: Lake Superior

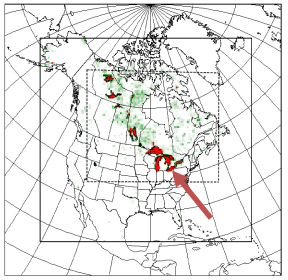


- Lake Superior
- Large and deep temperate freshwater lake.
- NDBC buoy 45001



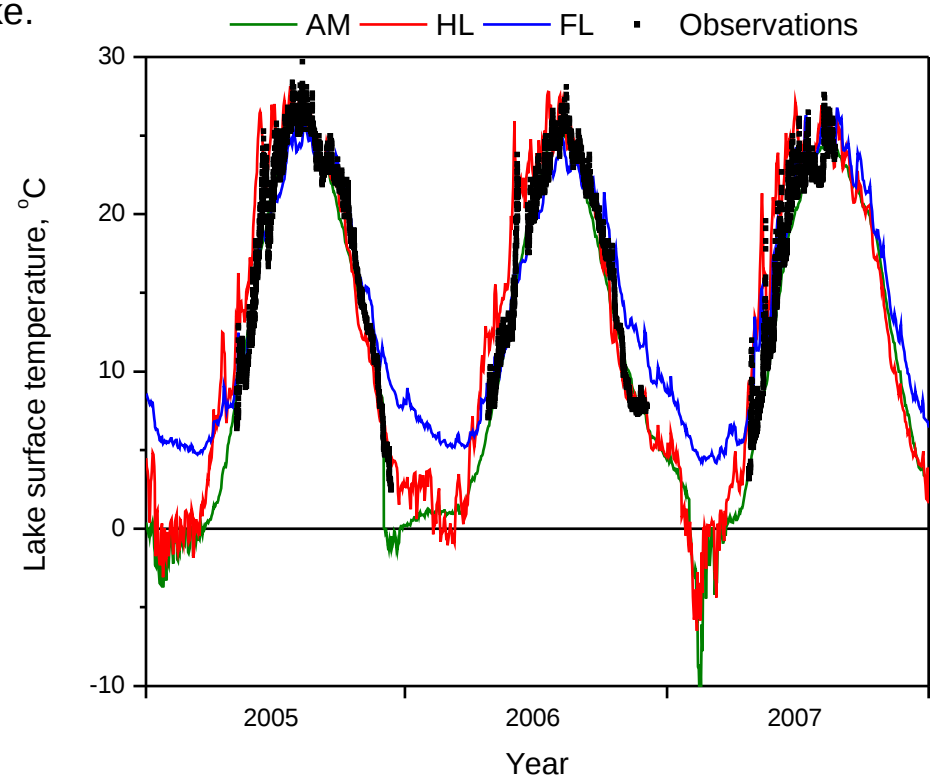
- AMIP II: good agreement with observations!
- Hostetler: too rapid warming in spring, very high maximum temperatures, too much ice.
- FLake: too high temperatures in summer

Performance evaluation: Lake Erie

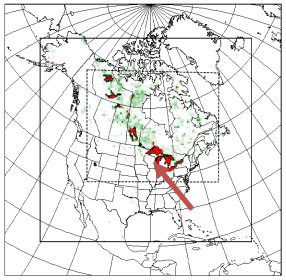


- Lake Erie
- Large and shallow temperate freshwater lake.
- NDBC buoy 45005.

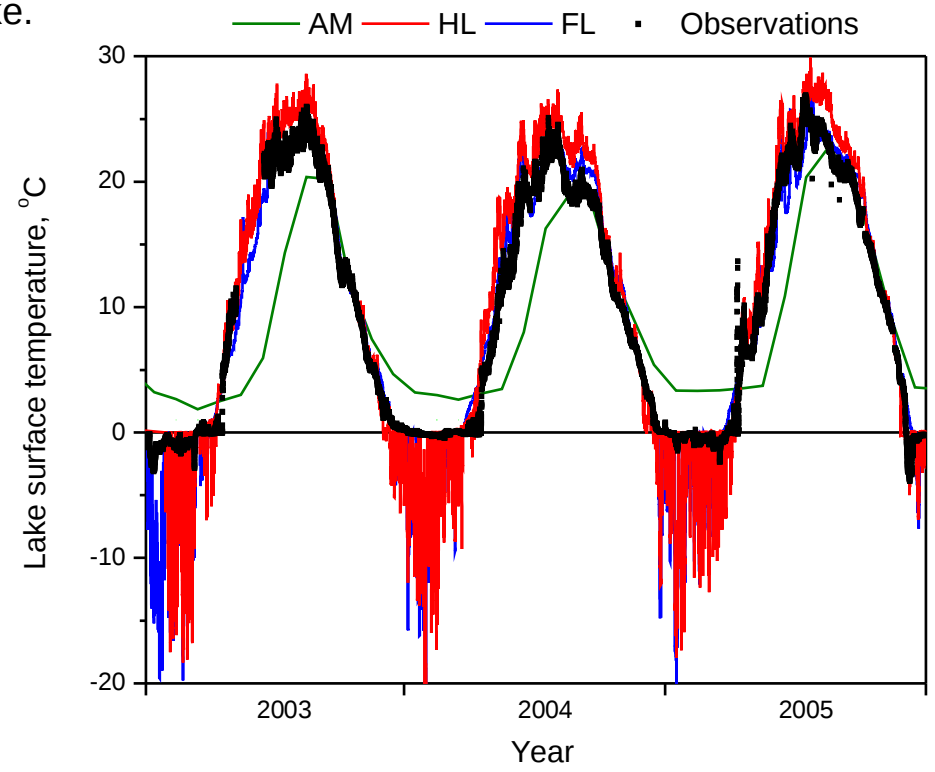
- AMIP II: good agreement with observations.
- Hostetler: good agreement with observations.
- FLake: good agreement with observations in summer, too warm in wintertime



Performance evaluation: Sparkling Lake

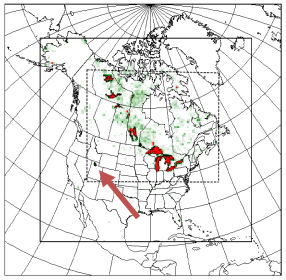


- Sparkling Lake, Wisconsin.
- Small and shallow temperate freshwater lake.
- NTL LTER project
  University of Wisconsin, Madison.



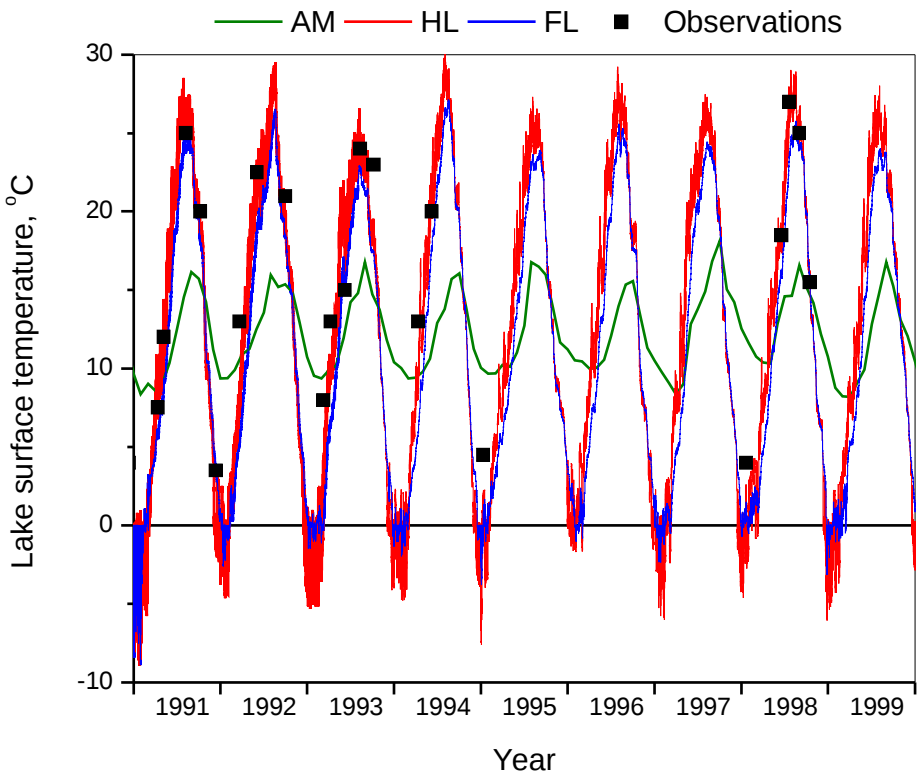
- AMIP II: substantially differs
  from observations.
- Hostetler: good agreement
  with observations, a bit too warm.
- FLake: good agreement with observations.

Performance evaluation: Great Salt Lake

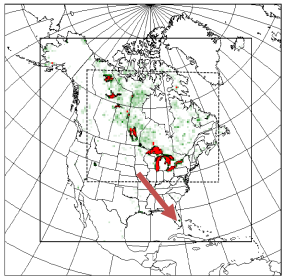


- Great Salt Lake, Utah.
- Large and shallow salty lake, arid climate.
- USGS water level stations.

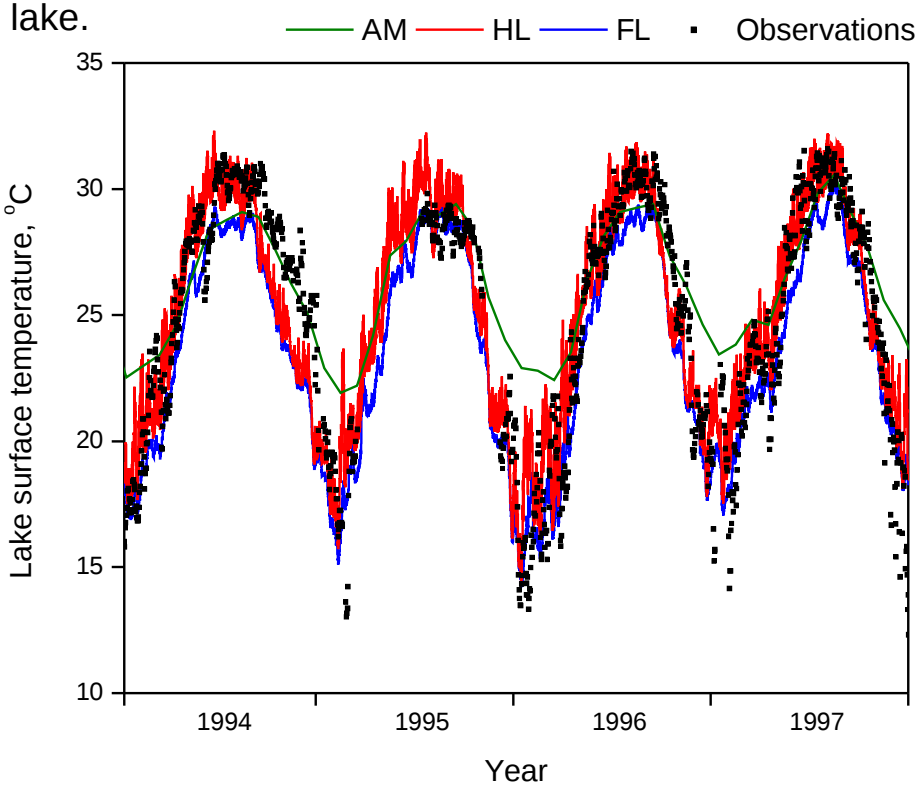
- AMIP II: very different from observations.
- Hostetler: generally good agreement with observations, winter freezing.
- FLake: generally good agreement with observations, winter freezing.



Performance evaluation: Lake Okeechobee



- Lake Okeechobee, Florida
- Medium-sized shallow freshwater subtropical lake.
- South Florida Water Management District buoy LZ40



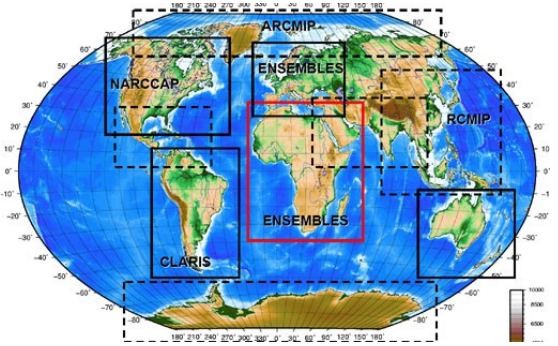
- AMIP II: very different from observations.
- Hostetler: generally good agreement with observations.
- FLake: generally good agreement with observations.

Martynov A., L. Sushama, R. Laprise, K. Winger and B.Dugas (2012) "Interactive Lakes in the Canadian Regional Climate Model, version 5: The Role of Lakes in the Regional Climate of North America" Tellus A 2012, 64, 16226, DOI: 10.3402/tellusa.v64i0.16226

As a result of this validation study, the FLake model was chosen as a main lake treatment option in CRCM5.

The CORDEX project

- The COordinated Regional climate Downscaling Experiment (CORDEX)
- In this project a number of GCM climate scenarios/predictions derived from the CMIP5 set of integrations are downscaled over a range of limited-area regions (Jones 2009).
- The project is based on numerous regional Model Intercomparison Projects (MIPs)
- The results are supposed to be available for the 5th IPCC Assessment Report - i.e. in summer 2012.



- CRCM5 contribution:

- Two simulation domains: North America and Africa

- For each domain:

  - ER40 / ERA-Interim driven runs (1958-2008)

  - 2 GCM-driven runs: CanESM2-CCCma and MPI-ESM-LR (1951-2100)

  - 1 member for each domain/GCM forcing pair

4 principal articles: 1 published, 3 submitted

CORDEX/North America: climate change and

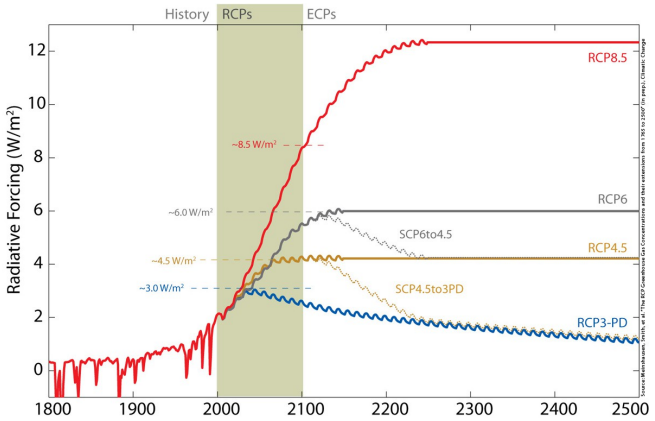
- North American CORDEX domain
- MPI-ESM-LR - driven CRCM5 run (1951-2100
- Emission scenario: RCP4.5 (medium-low)
- Comparison of 30-year-long periods:

  1981-2010 (present climate) and

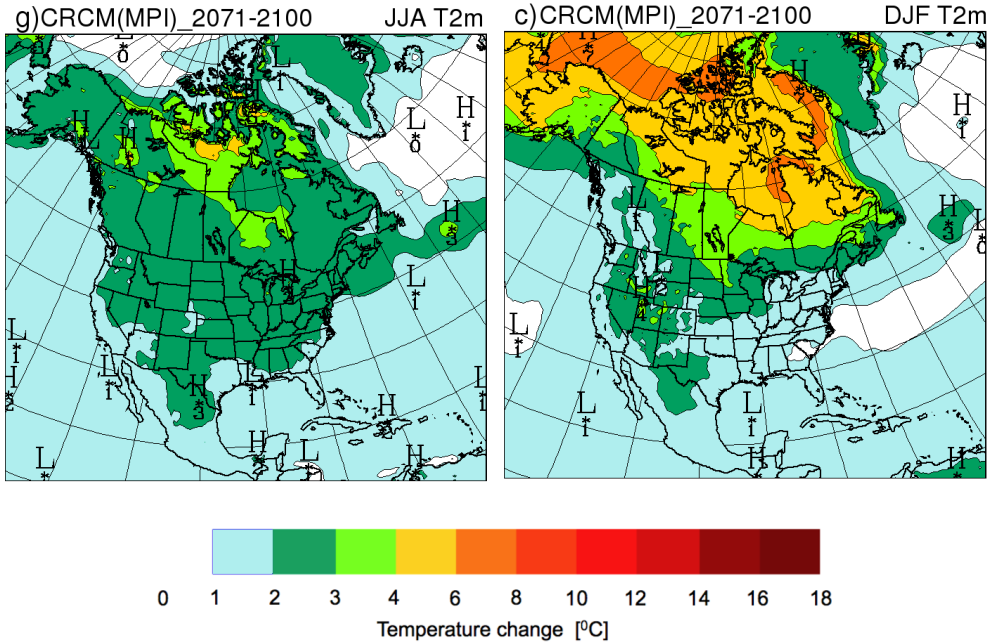
  2071-2100 (future climate)
- Climate change:

  Average : 2.5-3 °C both in JJA and

  Up to 8 °C in some regions in DJF



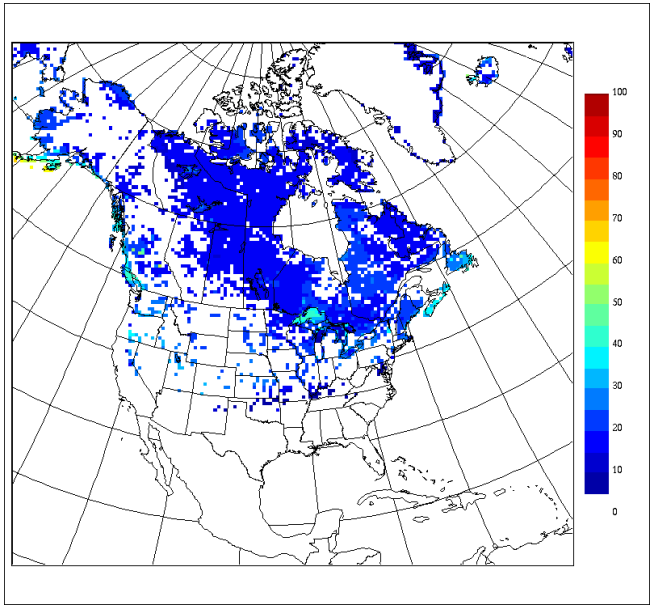
http://www.pik-potsdam.de/~mmalte/rcps/



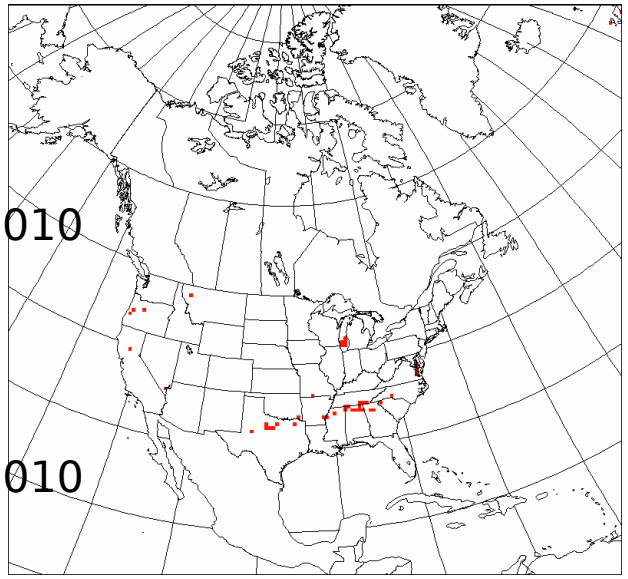
Šeparović L, et al. (2012) Present climate and climate change over North America as simulated by the fifth-generation Canadian Regional Climate Model (CRCM5 Clim Dyn (submitted).

CORDEX/North America: climate change and

Lakes in climate change conditions (preliminary results of an ongoing study)

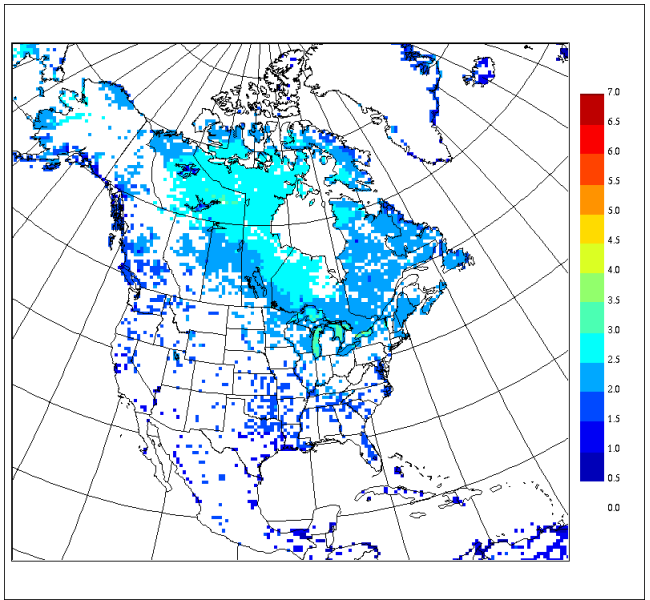


Reduction of ice cover duration (days) in 2071-2100 , compared with 1981-2010



No more ice cover in 2071-2100 , compared with 1981-2010

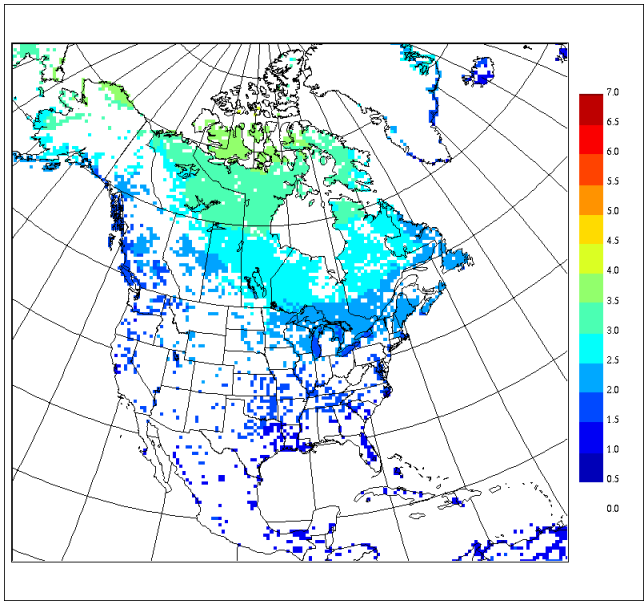
Average summer (JJA) lake surface temperature in 2071-2100 , compared with 1981-2010



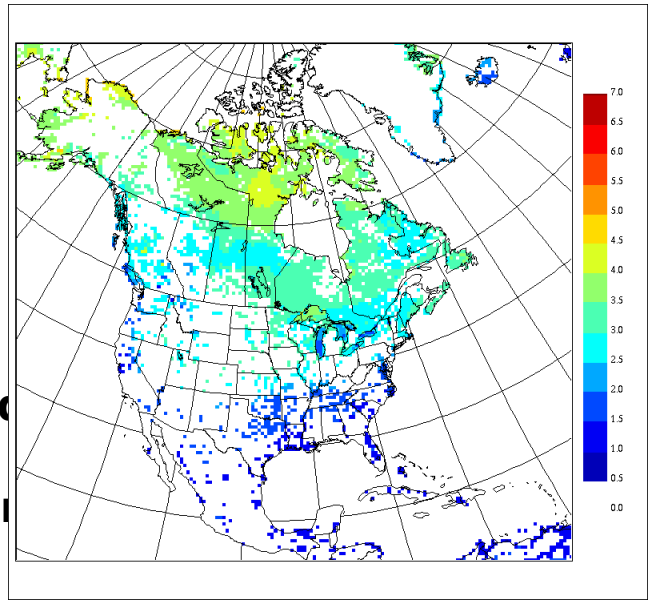
CORDEX/North America: climate change and

Lakes in climate change conditions
(preliminary results of ongoing study)

Average annual lake surface temperature
in 2071-2100 , compared with 1981-2010



Minimum annual lake surface temperature
in 2071-2100 , compared with 1981-2010



→Lakes respond to the climate change:

- **Shorter ice cover duration**
- **Thermal regime change: ice -free lakes extend**
- **The ice cover temperature strongly increases**
- **Strongest changes occur in winter (DJF) in nor**

Remaining issues

- Large and deep lakes, especially the Laurentian Great lakes
  - FLake and Hostetler both have problems over such lakes

- Northern lakes: no lake model validation yet
  - lack of good quality in-situ measurements, especially during winter periods

- Other types of lakes? Equatorial lakes, mountain lakes, etc. The lake model validation has been performed as for now for a narrow range of lake types.

Problem solving: 3D lakes

- Large and deep lakes, especially the Laurentian Great lakes
  - FLake and Hostetler both have problems over such lakes

→ **3D lakes. Coupling with the NEMO model of oceans is the next step in development of the CRCM model. Oceans, coastal seas and large lakes will be treated by NEMO. The coupling has already been developed for NWP applications by Environment Canada and will be adapted to climate simulations.**

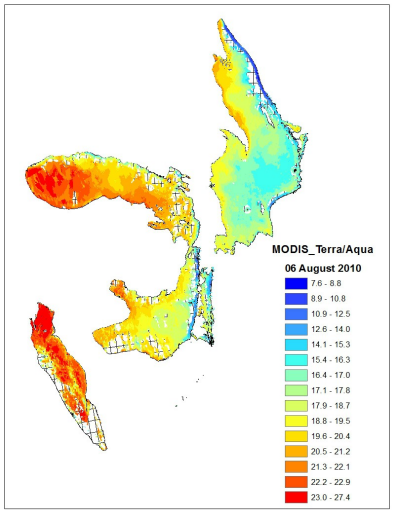
Problem solving: satellite-based LST

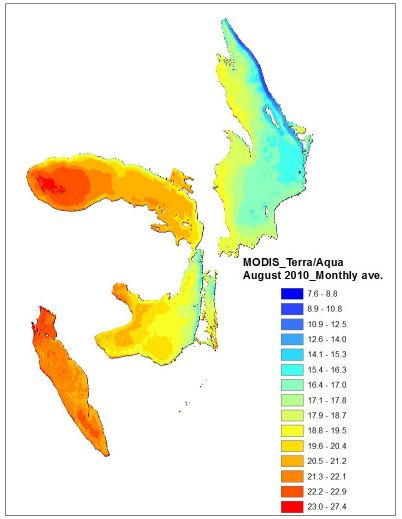
- Northern lakes: no lake model validation yet
  - lack of good quality in-situ measurements, especially during winter periods

- Other types of lakes? Equatorial lakes, mountain lakes, etc. The lake model validation has been performed as for now for a narrow range of lake types.

→ **Extended program of comparison of satellite-derived lake temperature data with simulations has been proposed in collaboration between Centre ESCER and University of Waterloo (C. Duguay, H. Kheyrollah Pour). MODIS-derived LST data at high spatial resolution will be collected and treated for many regions of the globe and compared with in-situ measurements, where available and with results of coupled and offline model simulations. Northern lakes, Great Lakes, equatorial lakes, etc. are supposed to be treated.**

Limitations:
- excellent spatial, poor temporal resolution
- clouds





Courtesy of Homa Kheyrollah Po

Summary

- Interactive lakes are operational with CRCM5. FLake: the default option.
- Future climate simulations show adequate reaction of lakes to climate change.
- Validation issues: good performance in temperate and shallow subtropical lakes; problems in deep Great lakes; nothing can be said about northern lakes, except large and deep ones
- A solution for Great Lakes: coupling with the 3D ocean model (NEMO)
- For other lakes: satellite data-based validation program - on a preliminary phase
- Many thanks to

Rene Laprise
Laxmi Sushama
Bernard Dugas
Claude Duguay
Homa Kheyrollah Pour
Leo Separovic
Kossivi Tete
Michel Valin
Katia Winger

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

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