LAKES AND GLOBAL MODELS

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Outline

- How are lakes represented in Global Climate Models?
  - History
  - CMIP5 models
- Lakes in the French CNRM-CM Global Climate Model
  - Description of the lake model
  - Impact of lakes in a GCM

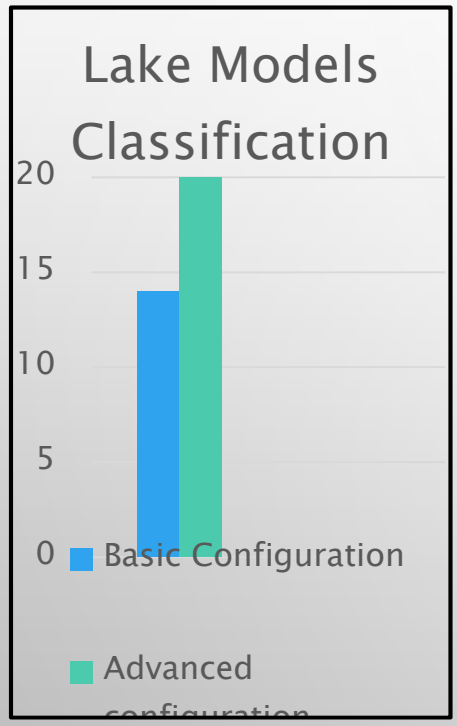
How Are Lakes Represented in Global Climate Models?

- In the past, surface models from GCMs mainly represented sea/ocean and land because these are the predominant surfaces interacting with the atmosphere
  - Lakes were not considered in the first climate simulations
- In the last decades, the increase in model resolution has allowed to distinguish and model other surfaces such as urban areas or humid areas like wetlands and lakes
  - Lakes were first treated in a simple way with characteristics (albedo) diagnosed from temperature (SST)
- More recently, modellers have developed parameterizations to represent processes governing these surfaces, to enhance the realism of simulations at the local, regional and global scale
  - Lake were treated as any other surface type coupled to the atmosphere (diurnal cycle)

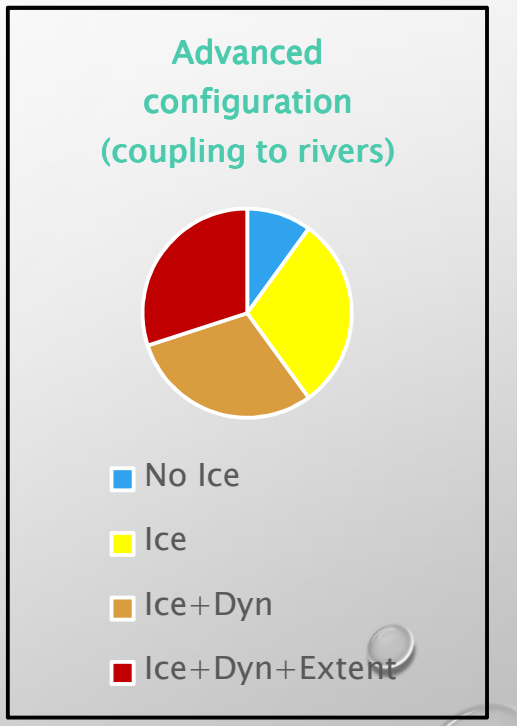
CMIP5 Project

- Promoted a standard set of model simulations in order to:
  - Evaluate how realistic the models were in simulating the recent past
  - Provide projections of future climate change for near term (up to 2035) and long term (up to 2100)
  - Understand some of the factors responsible for differences in model projections, including quantifying some key feedbacks such as those involving clouds and the carbon cycle
- 17 climate model groups and 40 models participated
  - Different ways of representing lakes in the climate simulations

Lakes characteristics in CMIP5 (2011)



- Advanced configuration (20)
  - Coupling to rivers (water and heat)
  - Specific ice treatment, prognostic albedo
  - Lake dynamics and Dynamic extent
- Basic configuration (14)
  - Diagnostic albedo, based on SST
    - ✓ CNRM-CM5 ARPEGE climate model



Lakes in CNRM-CM model

- CNRM-CM6 is the French global climate model used for CMIP6 inter-comparison exercise
- Uses a physical based model (FLake) to simulate Lake Surface Temperatures
  - Specific snow and ice treatment
  - Vertical lake dynamics
  - No dynamic extent representation
  - No coupling to rivers, no mass budget yet

Lake model FLake

- FLake is a two-layer bulk model (parameterization scheme) based
  - (i) on a self-similar parametric representation of the evolving temperature profile within lake water, ice and snow (the idea of "assumed shape" of the temperature-depth curve)
  - (ii) on the integral budgets of heat and kinetic energy for the layers in question. It is a computationally efficient lake model that incorporates much of the essential physics. Importantly, FLake does require (re-)tuning.
- FLake description in Mironov (2008) and Mironov et al. (2010)
- FLake web page http://lakemodel.net
- Online FLake version (Kirillin et al. 2011) at http://lakemodel.net (take a look and have fun!)

FLake Applications (more at http://lakemodel.net)

FLake is used as

- Lake parameterization scheme in numerical weather prediction (NWP) and climate models
- Single-column lake model in a stand-alone mode
- Physical module in models of lake ecosystems
- Educational tool

FLake Applications (more at http://lakemodel.net)

As a lake parameterization scheme, FLake is

- Used operationally within NWP models COSMO and ICON (German weather service), HIRLAM (Finnish meteorological institute, Helsinki, Finland), and ECMWF IFS (European centre for medium-range weather forecasts, Reading)
- Implemented into a number of NWP and climate models, incl. UK met office UM (pre-operational), model suite of Meteo-France, CLM, RCA, Canadian regional climate model, WRF
- Used as a lake parameterization module in the surface schemes TESSEL, SURFEX, and JULES

External parameter fields

Data sets used to generate external-parameter fields of lake fraction and lake depth were developed by Kourzeneva (2009, 2010) and Kourzeneva et al. (2012), Choulga et al. (2014)

Maintenance and further development

Of external-parameter data set is crucial!

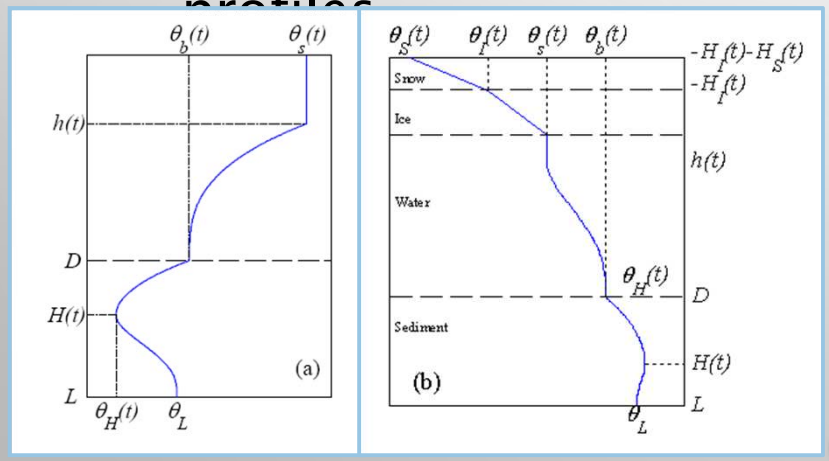
It is desirable to develop a (global) data set on optical characteristics of lake water (needed to specify the attenuation coefficient with respect to solar radiation).

Implementation of FLake into CNRM-CM

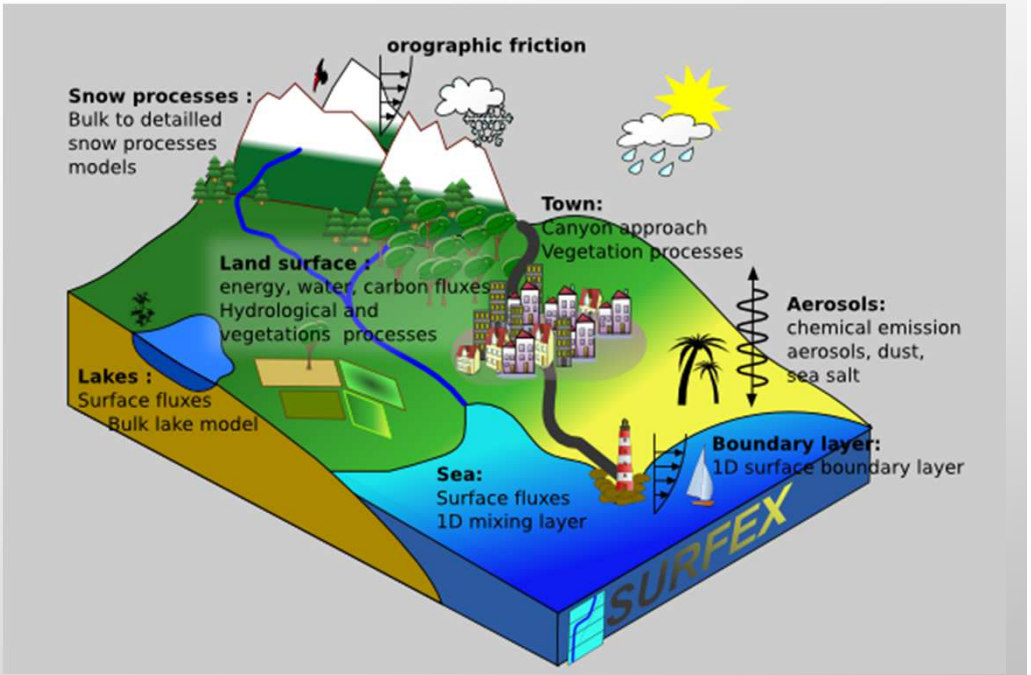
- Aggregation

S: total lake area
D: harmonic averaged depth

- Temperature profiles

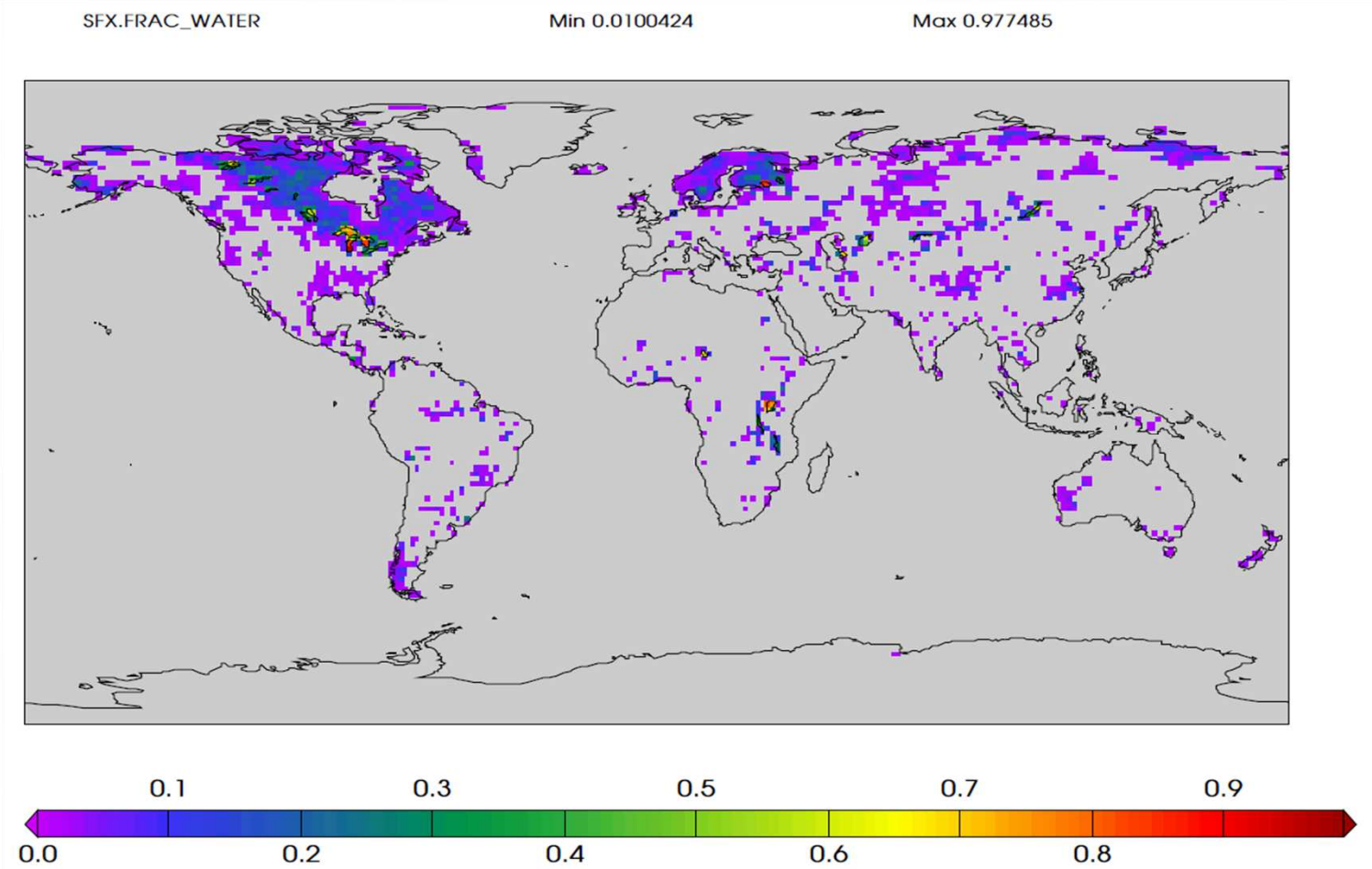


SURFEX



Model lake fraction

- Spectral truncature T127: 150km at the equator



SURFEX/FLake off-line calibration

- Driven by ERA-Interim atmospheric reanalyses 1979-2010
- Compared to ARC-Lake products (ESA project, ATSR1,2 radiometers) :
  - Surface temperature and ice cover 1991-2010, lakes area > 500km^2
- Settings of lake model consisted in adjusting lake depth, light extinction coefficient, ice albedo and develop a skin temperature model

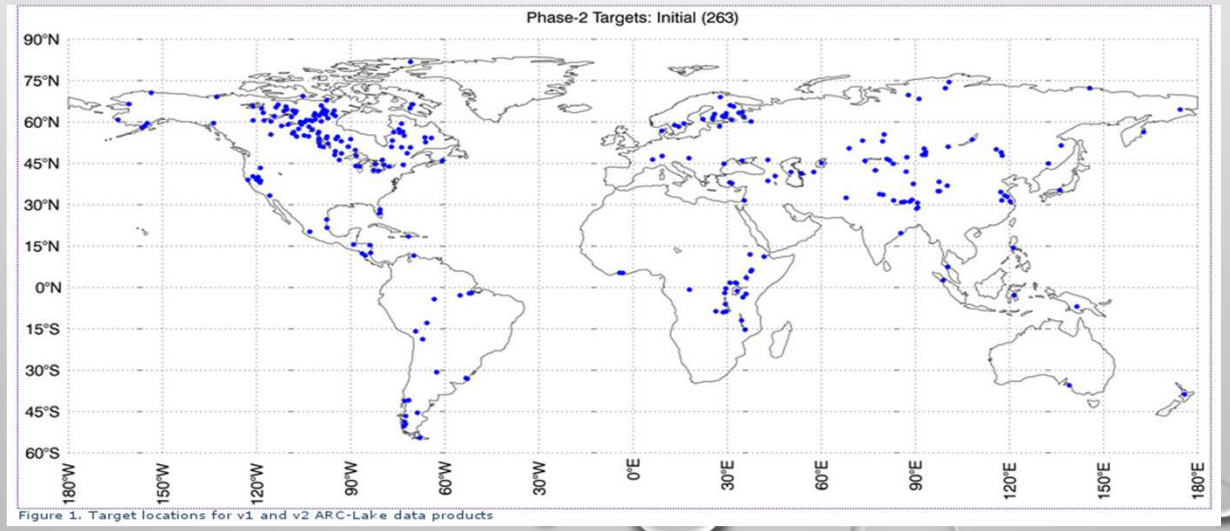
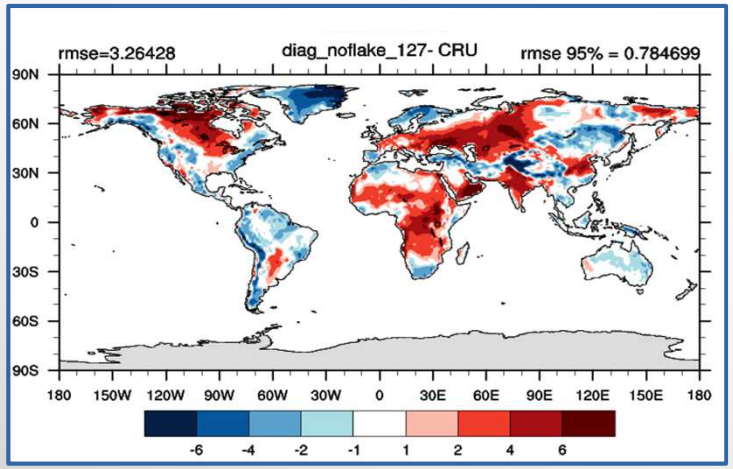


Figure 1. Target locations for v1 and v2 ARC-Lake data products

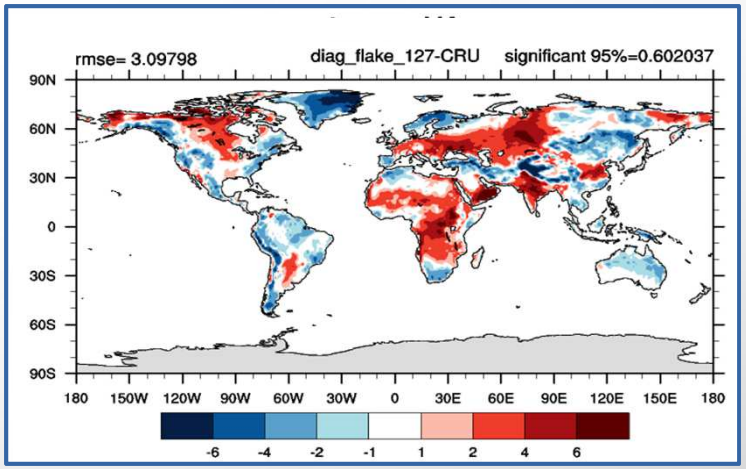
Air cooling effect

JJA maximum T2M

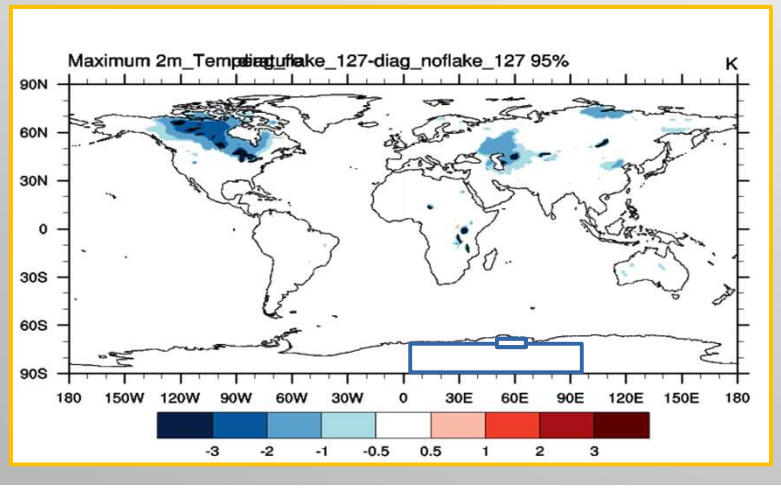
nolake - CRU



lake - CRU



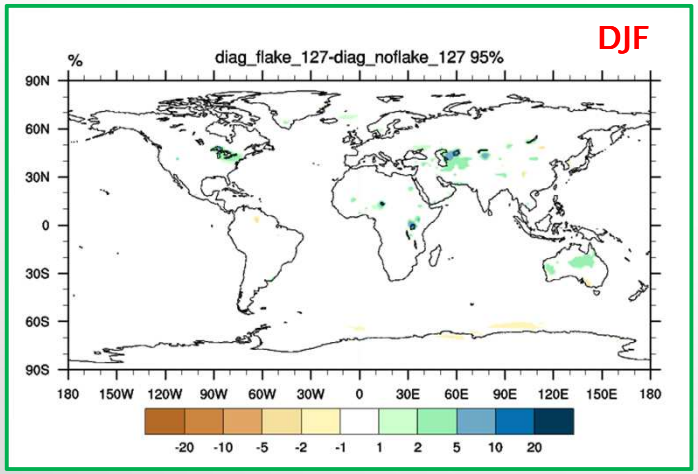
lake - nolake

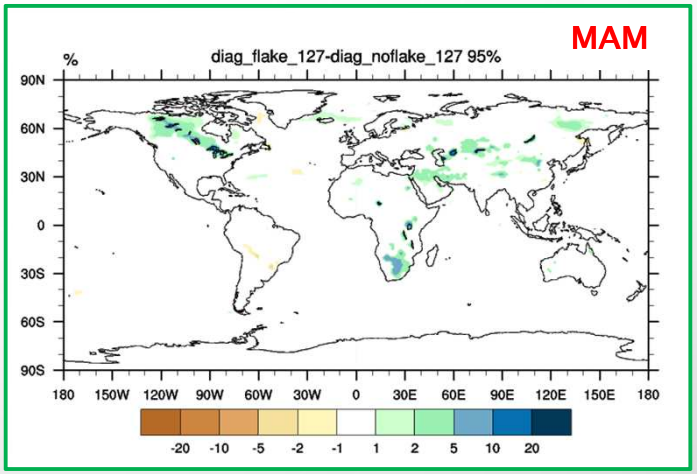


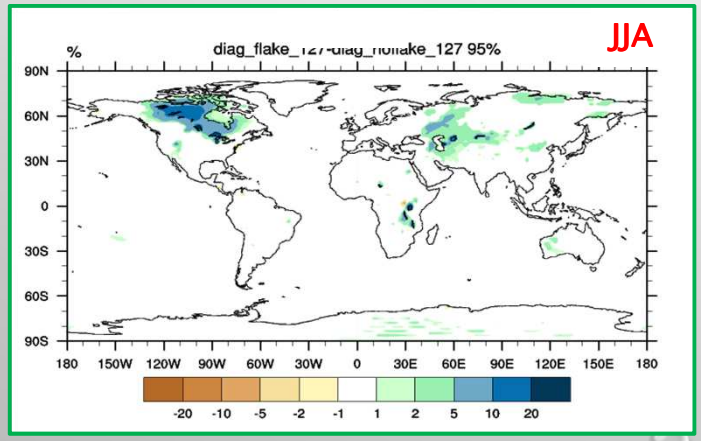
In JJA cooler water surfaces
tend to cool the air and reinforce breezes which affect the PBL

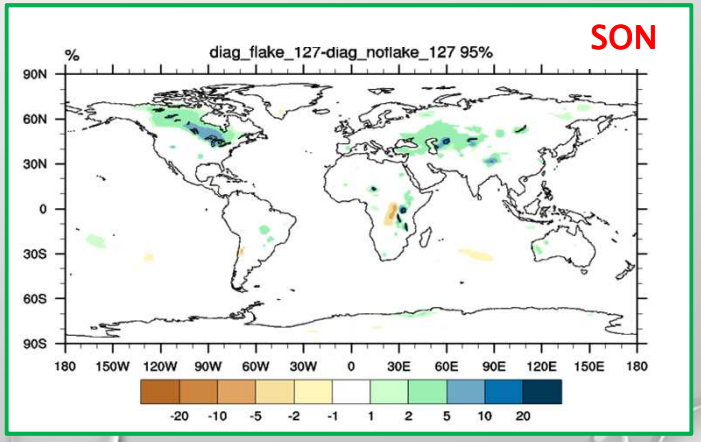
Air moistening effect

Seasonal RH2M









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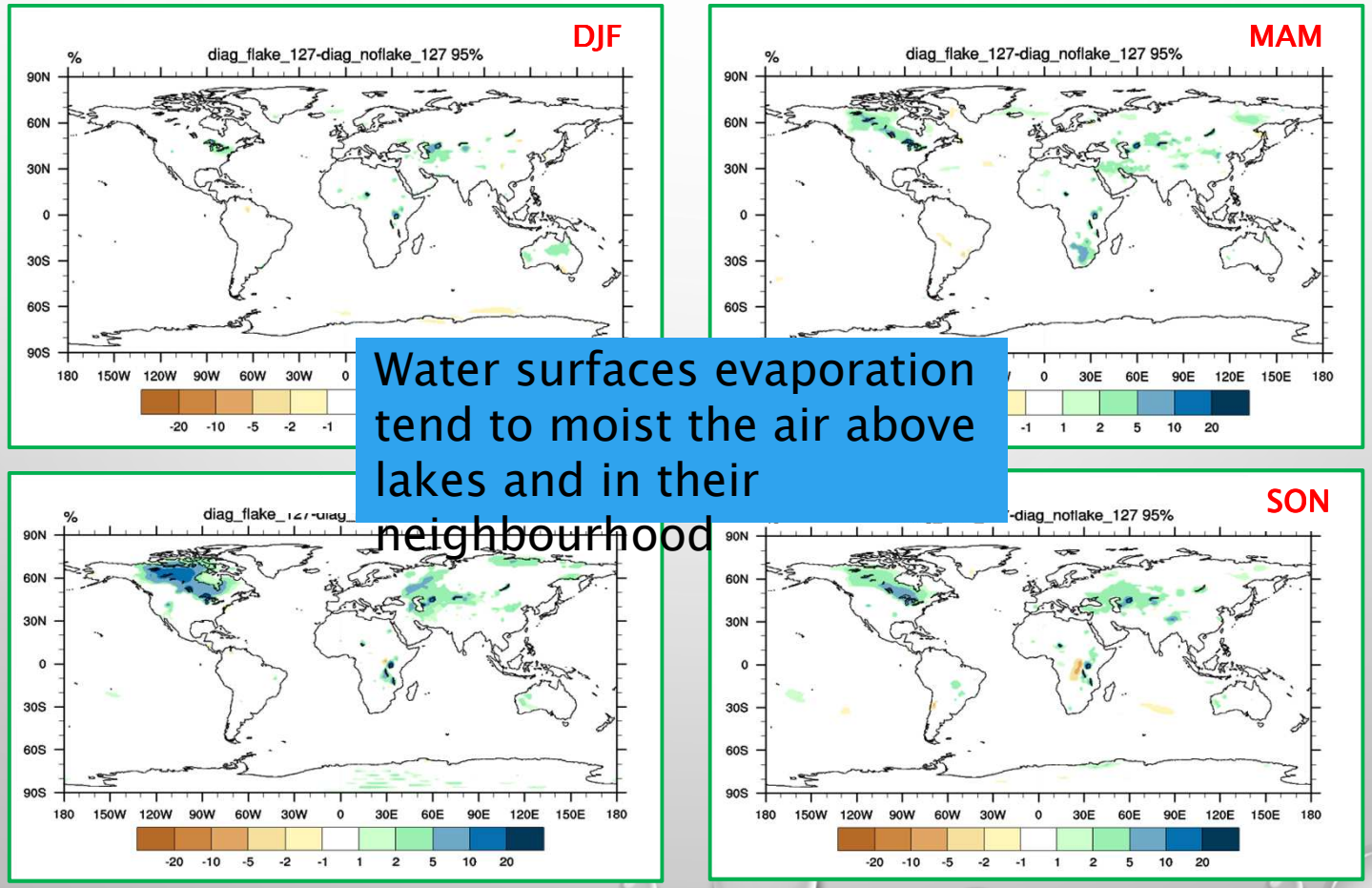
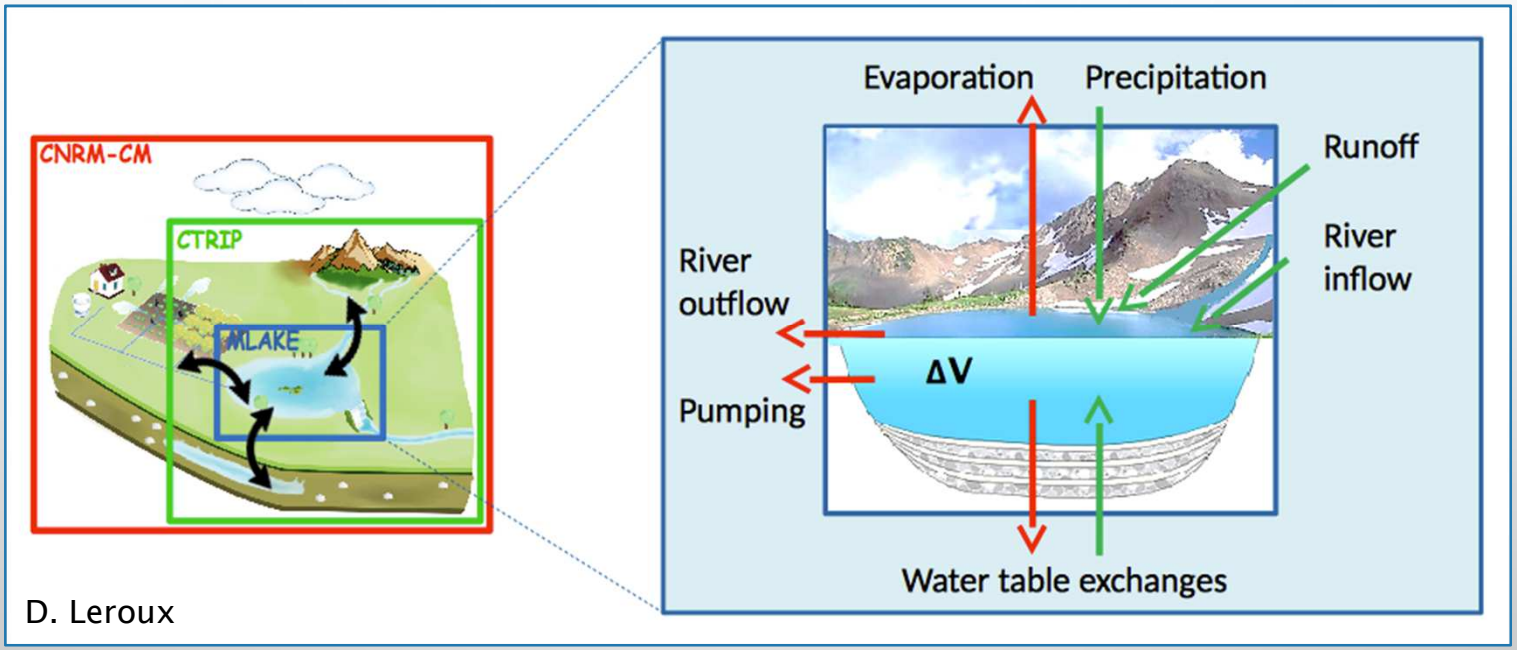


Water surfaces evaporation tend to moist the air above lakes and in their neighbourhood

Future developments: coupling lakes to rivers/aquifers



D. Leroux

- Implementation of a **mass budget** into the lake model FLake
- A step forward in representing **lake water storage**
- A prerequisite for using SWOT lake extent and height variations to represent lake water storage variations at the global scale

Conclusion

- The representation of lakes in global climate models was exhibiting 2 classes of various complexity (CMIP5)
- The French CNRM-CM improved lake representation by using physically-based lake model
- The tendency will be to improve lake model representation especially since new ECVs have been defined for lakes