Development of land component in climate model of INM RAS-MSU

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The contribution climate system components in the weather predictability *(Dirmeyer et al., 2015)*

(particularly the tropical oceans) can have global impacts. Thus, the land surface holds promise as a source of predictability and prediction skill in the gap between traditional weather and climate time scales.

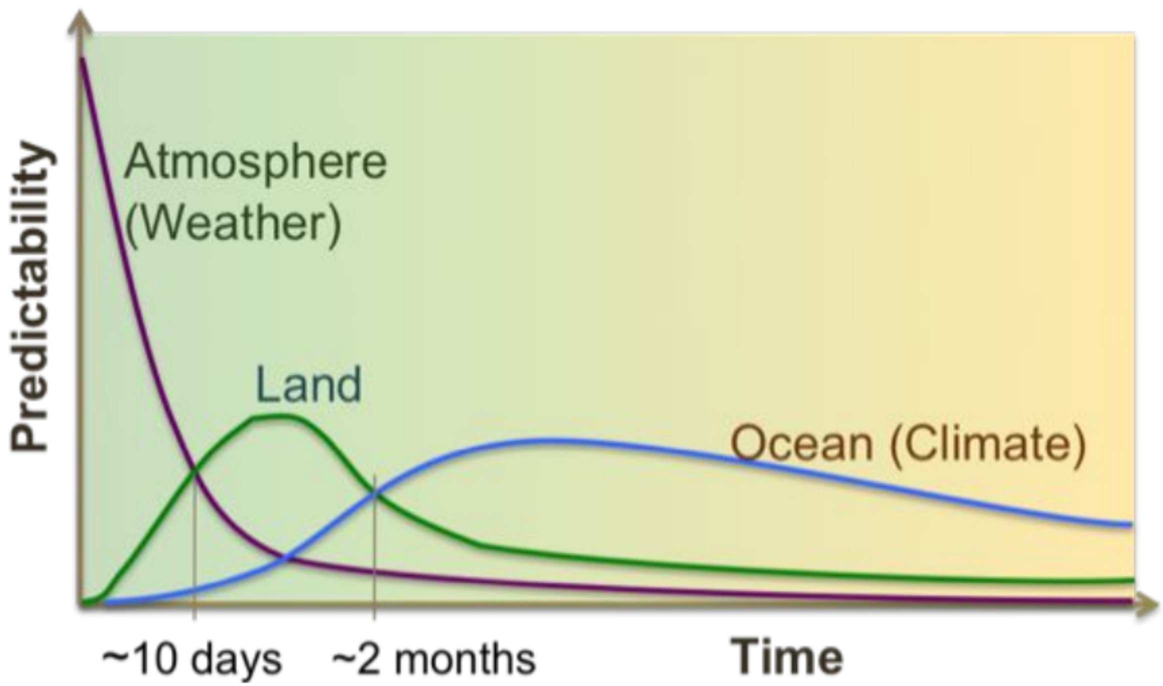
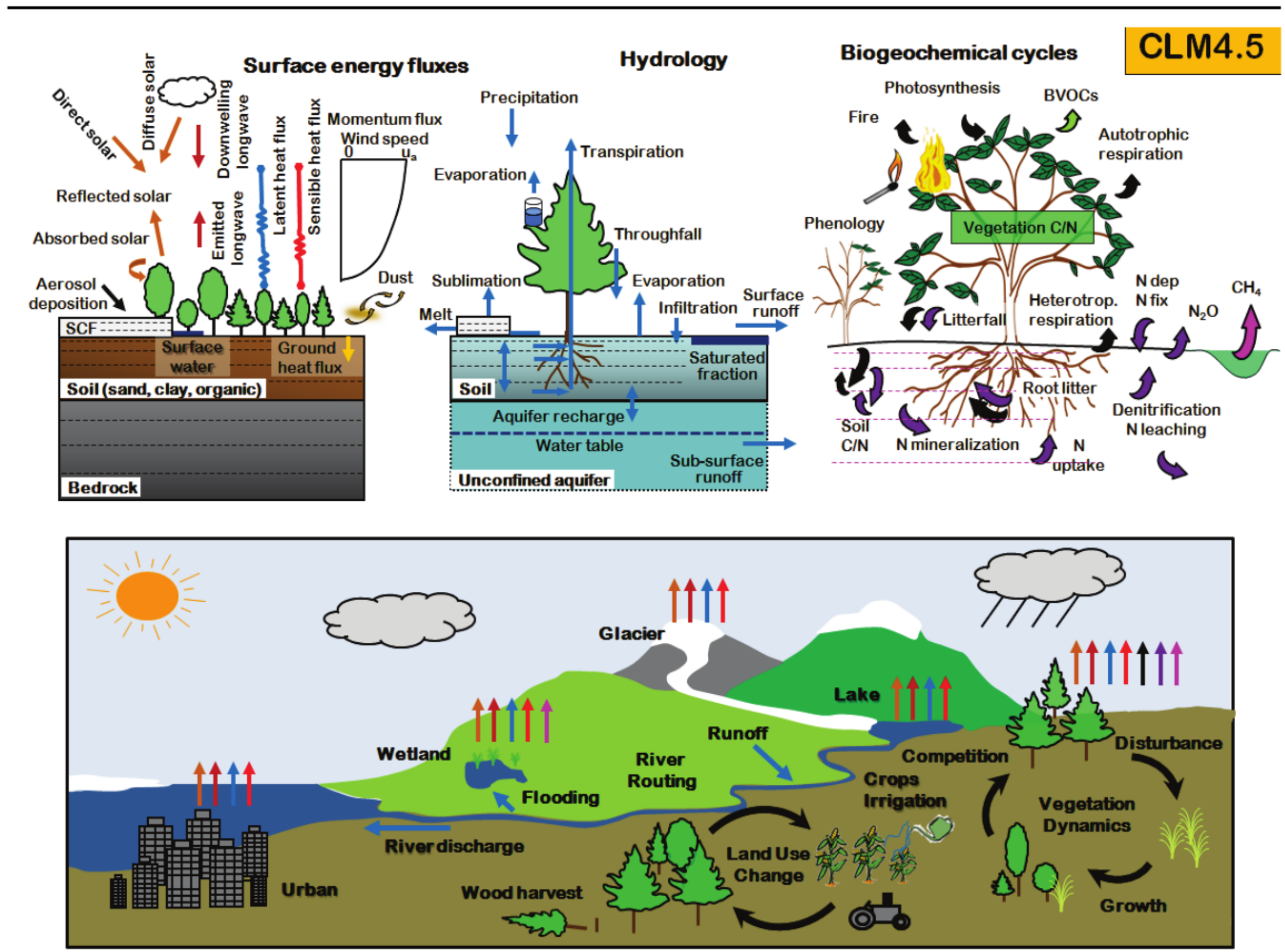


Figure 2. Schematic of the time scales associated with predictability originating from the initial states of atmosphere, land and ocean

It should be evident that this feedback is a coupled process between land and atmosphere. Thus

Example state of the arte land surface model CLM4.5



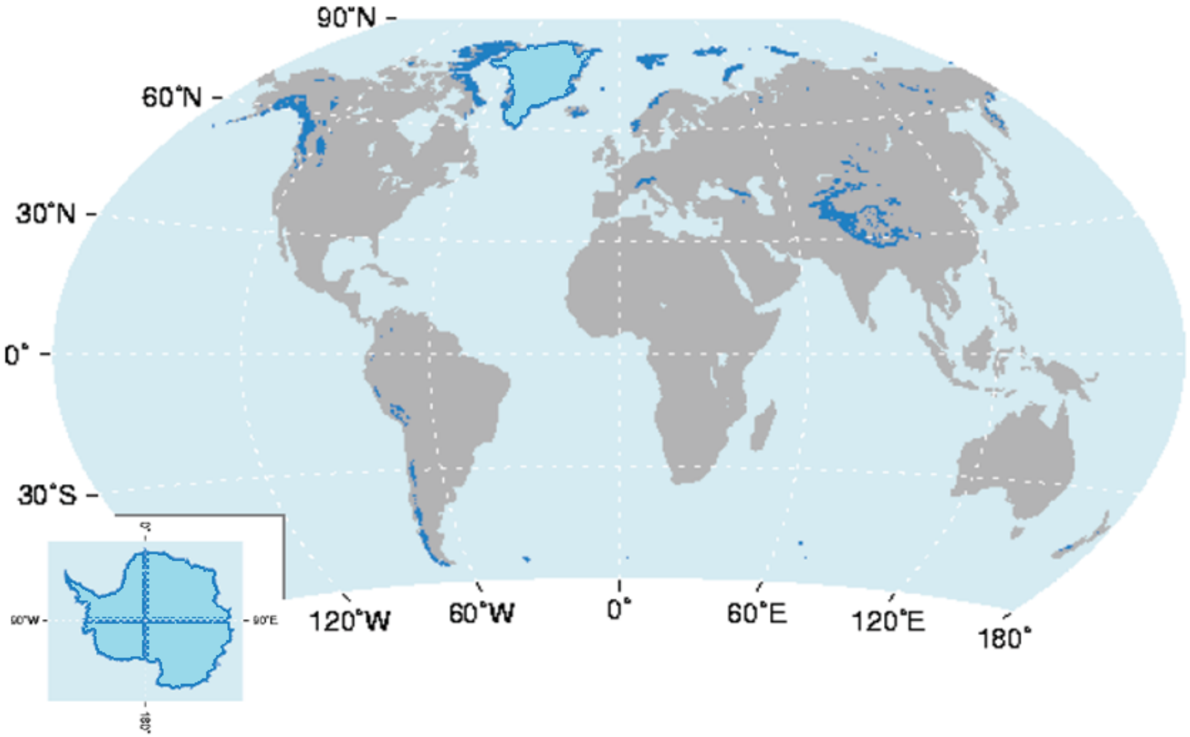
Параметризация	CLM (2013)	H-TESSEL (2015)	TERRA (2011)	ИВМ (1998-2015)
Почва	15 слоев	есть	7 слоев	23 слоя
Снег	До 5 слоев	1 слой	1 слой (?)	многослойная
Агрегирование потоков	мозаика	мозаика	мозаика	мозаика
Схема приземных потоков	М-О	М-О	М-Я	М-О
Влагоперенос в почве	есть	есть	есть	есть
Модель грунтовых вод	есть	нет	нет	нет
Ледники	есть	нет	нет	Гренландия
Фотосинтез	есть	есть	нет	есть
Модель речной сети сети	есть	нет	нет	нет
Городская модель	есть	нет	нет/есть	нет
Углеродный цикл	есть	нет	нет	есть
Азотный цикл	есть	нет	нет	нет
Динамика растительности	есть	нет	нет	нет

Параметризация	CLM (2013)	H-TESSEL (2015)	TERRA (2011)	ИВМ (1998-2014)
Модель внутренних водоемов	есть	есть	есть	нет
Модель метана	есть	нет	нет	есть
Модель пожаров	есть	нет	нет	нет
Модель с/х земель	есть	нет	нет	нет

Plans

- Development of a active layer model as part of INMCM, with the ability to launch under other atmospheric forcing (e.g. reanalis)
- Option to be run in both global parallel code (MPI) and single-column modes
  - development of a model interface
  - version control system (git)
  - technical documentation (doxygen)
- Our plans on model components development:
  - lakes model (Bogomolov)
  - glaciers model (Toropov)
  - rivers network model
  - land use Map (?)
  - permafrost and wetlands (?)
  - terrestrial carbon cycle
  - dynamic vegetation
  - towns model

Model of the dynamics of glaciers

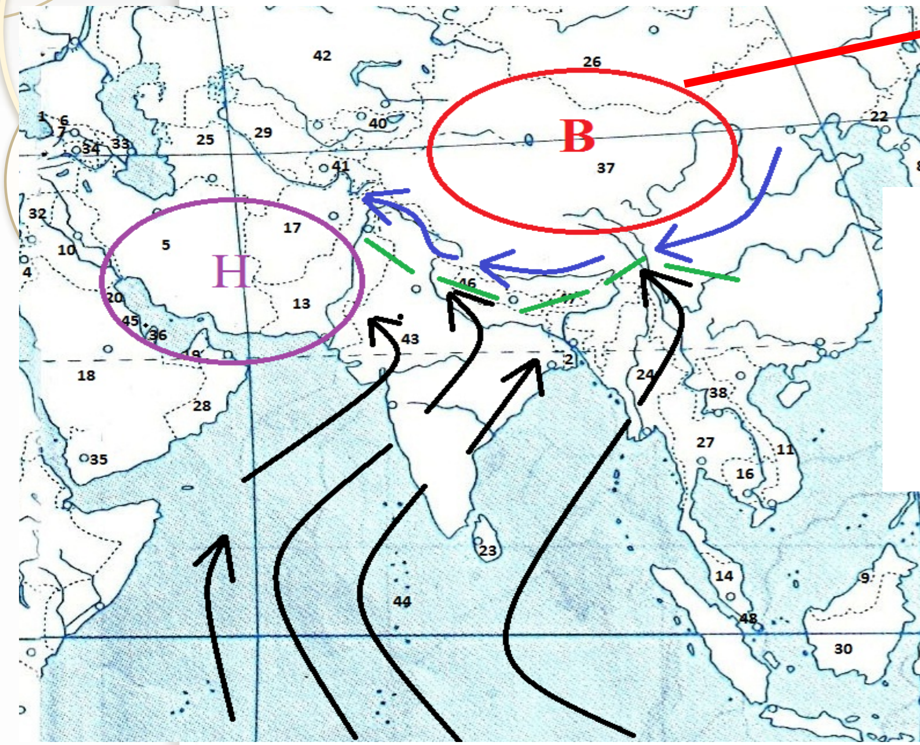


1. Regional effect: contribute to runoff major rivers (the upper Ob - 25%, Kuban, Terek - 30%, all the major rivers of Europe ...)

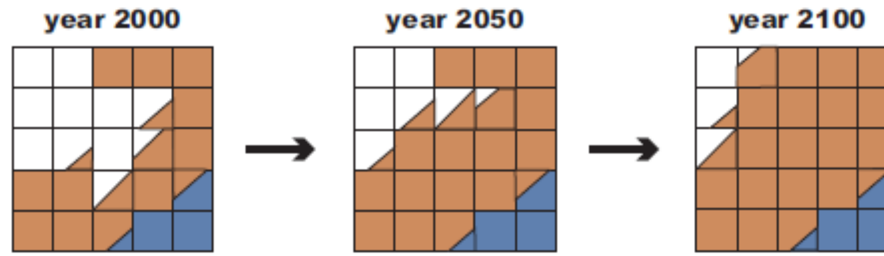
2. The costs of heat melting in the summer half of the year

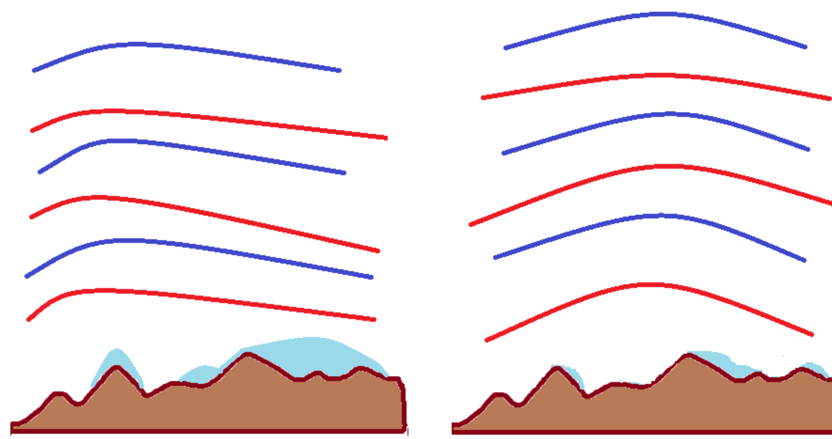
3. Effect on the large-scale dynamics through the "albedo effect"

"Albedo effect" and the Indian monsoon (K. Taylor, 2005; A. Kislov, 2001)



Tibetan anticyclone





Mountain glaciers melt

Decreases albedo and increases the radiation balance

Increased temperature

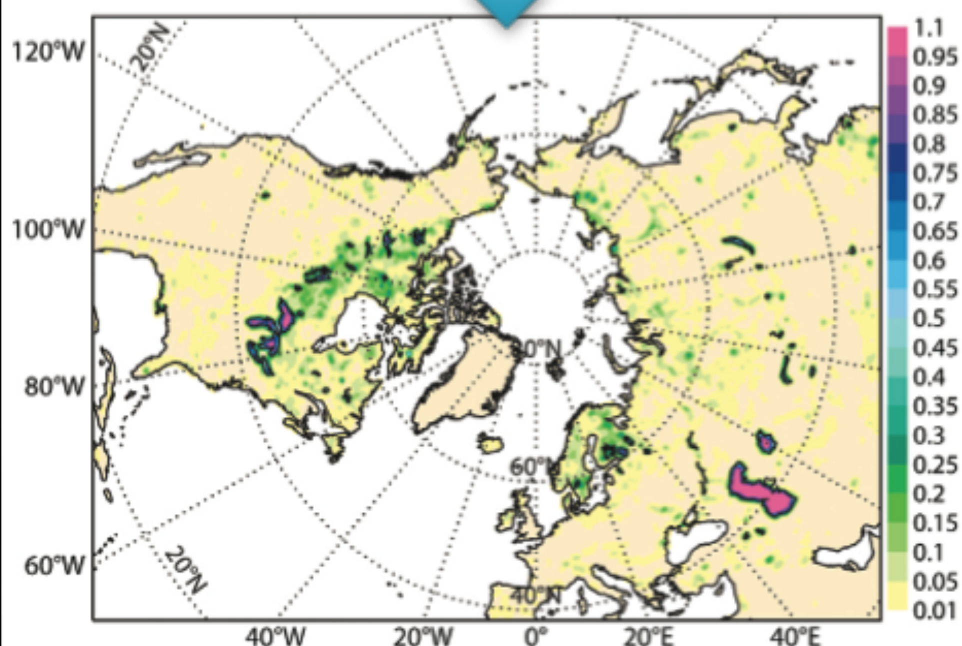
Growing pressure, strengthening Tibetan anticyclone

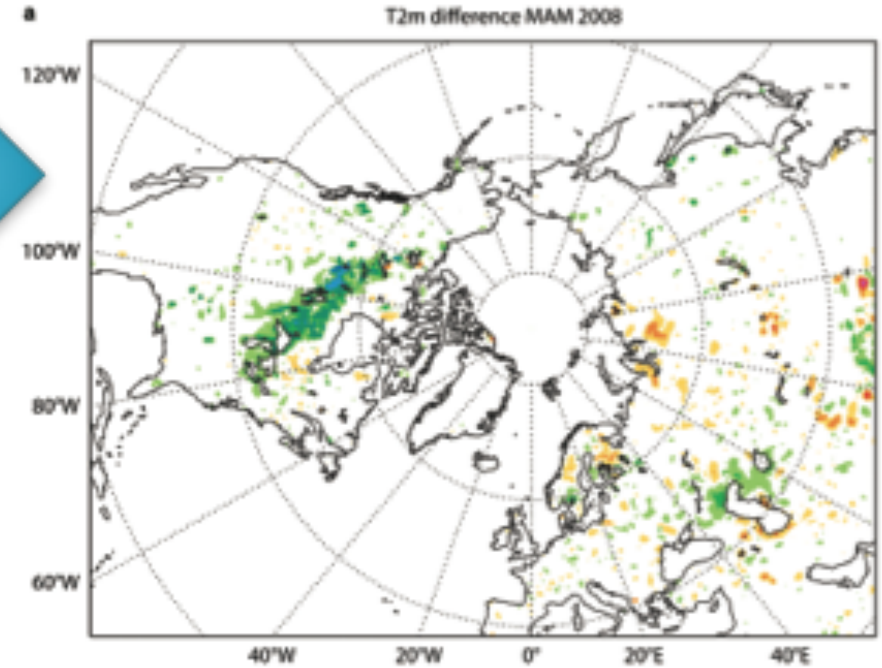
Lake models in climate models and weather forecasting systems

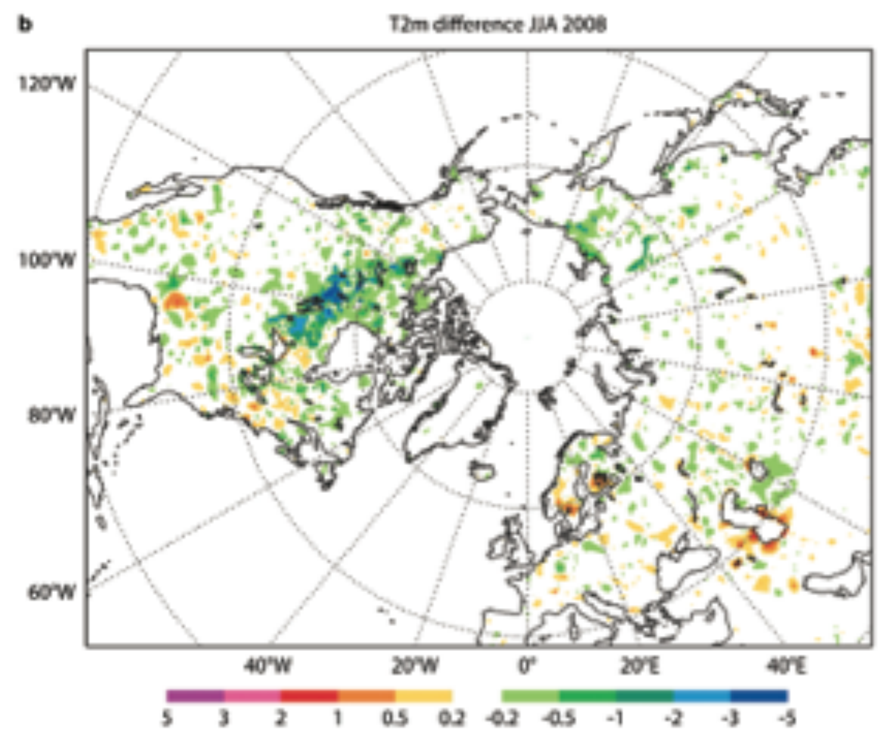
Climate/NWP model	Lake model
IFS (ECMWF)	FLake
UKMO (MetOffice)	FLake
COSMO (European Consortium)	FLake
HIRLAM (European Consortium)	FLake
CESM (US consortium)	CLM-LISSS4
CRCM (Canada)	Flake/Hostetler
WRF (Penn SU)	FLake
…	…

Effect of lakes on T_{2M} in IFS model *(Balsamo et al. 2012)*

The fraction of area occupied by lakes in IFS







Lakes in INMCM4

- Climate model participates in CMIP 5 (http://cmip-pcmdi.llnl.gov/cmip5/)
- Resolution of atmospheric block: 2° x1.5° (lat., lon.), 21 vertical levels.
- The cell of land surface contains 4 types: vegetation, snow, bare ground, inland waters
- The share of snowless surface occupied with vegetation, inland waters and the bare ground is defined according to the (Wilson and Henderson-Sellers, 1985). Resolution of data: 1° x 1°
- Humidity of air above the inland water surface is equal to the saturated, but water does not have its own additional heat content
- Soil located under different types of surfaces within the model grid cell has the same vertical profiles of temperature, humidity, ice concentration.

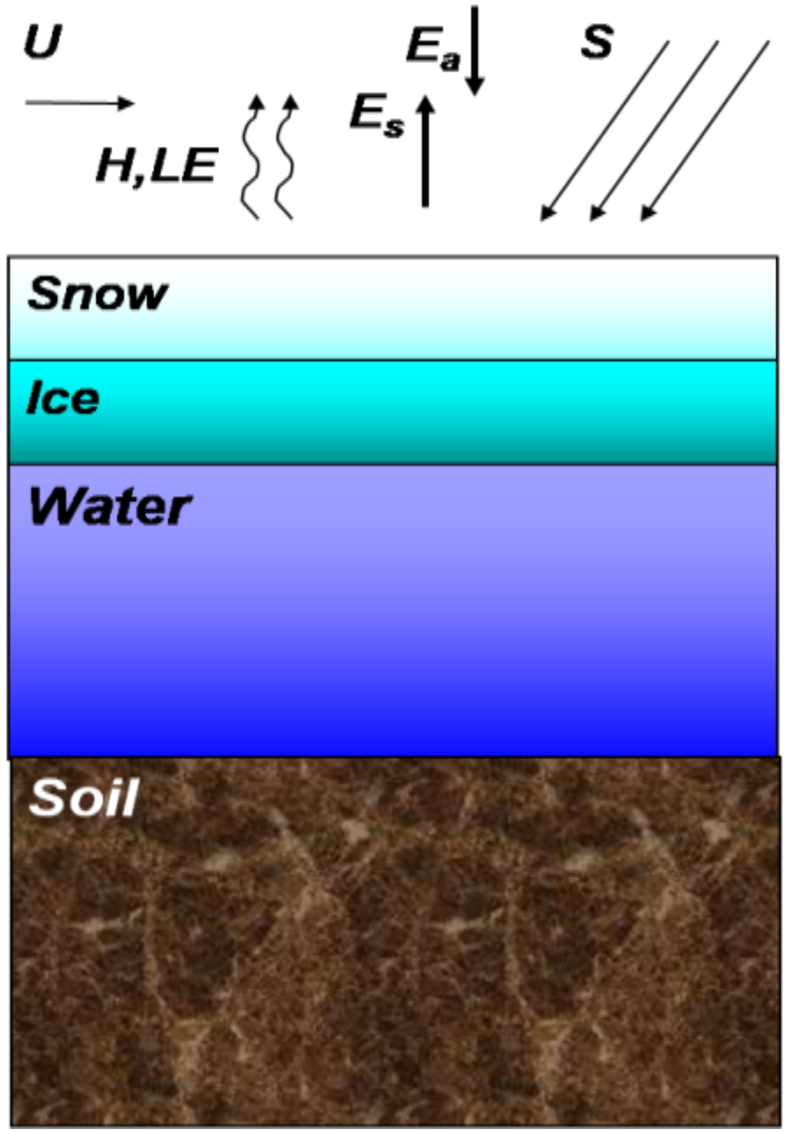
The components of lake parameterization in climate models

- Lake model
- Global lake depth and lake distribution maps
- Surface layer scheme (turbulent fluxes over the lake, the aggregation of fluxes in the land cell)

LAKE model

(Stepanenko & Lykossov 2005, Stepanenko et al. 2011)

- Multilayer (~10) snow model with liquid moisture treatment
- Multilayer ice model (~10)
- Thermo- and hydrodynamics in water column (k-epsilon)
- Heat and moisture transfer in soil including permafrost
- Methane, carbon dioxide and oxygen production, diffusion and ebullition



K-ε turbulence closure in LAKE model

$$\overline{w'\phi'} = -k_\phi \frac{\partial \overline{\phi}}{\partial z}$$

- counter-gradient effects missing

Kolmogorov formula (1942)

$$k_M = C_e \frac{E^2}{\varepsilon}, \qquad C_e = C_e(M,N)$$

$$k_T = k_S = C_{eT} \frac{E^2}{\varepsilon}, \quad C_{eT} = C_{eT}(M,N)$$

M – friction frequency,
N – Brunt-Vaisala frequency

stability functions

k-ε parameterization

$$\frac{\partial E}{\partial t} = \frac{\partial}{\partial z}\left(\nu + \frac{k_M}{\sigma_E}\right)\frac{\partial E}{\partial z} + P + B - \varepsilon$$

$$\frac{\partial \varepsilon}{\partial t} = \frac{\partial}{\partial z}\left(\nu + \frac{k_M}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial z} + \frac{\varepsilon}{E}\left(c_{1\varepsilon}P + c_{3\varepsilon}B - c_{2\varepsilon}\varepsilon\right)$$

Boundary conditions

$$-\frac{k_M}{\sigma_E}\frac{\partial E}{\partial z} = c_{we}\left(\frac{\tau_s}{\rho_w}\right)^{3/2}, \quad c_{we} \approx 100$$

$$-\frac{k_M}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial z} = \left(C_e^0\right)^{3/4}\frac{k_M}{\sigma_\varepsilon}\frac{E^{3/2}}{\kappa\left(z'+z_0\right)^2}$$

Ri-based diffusivity

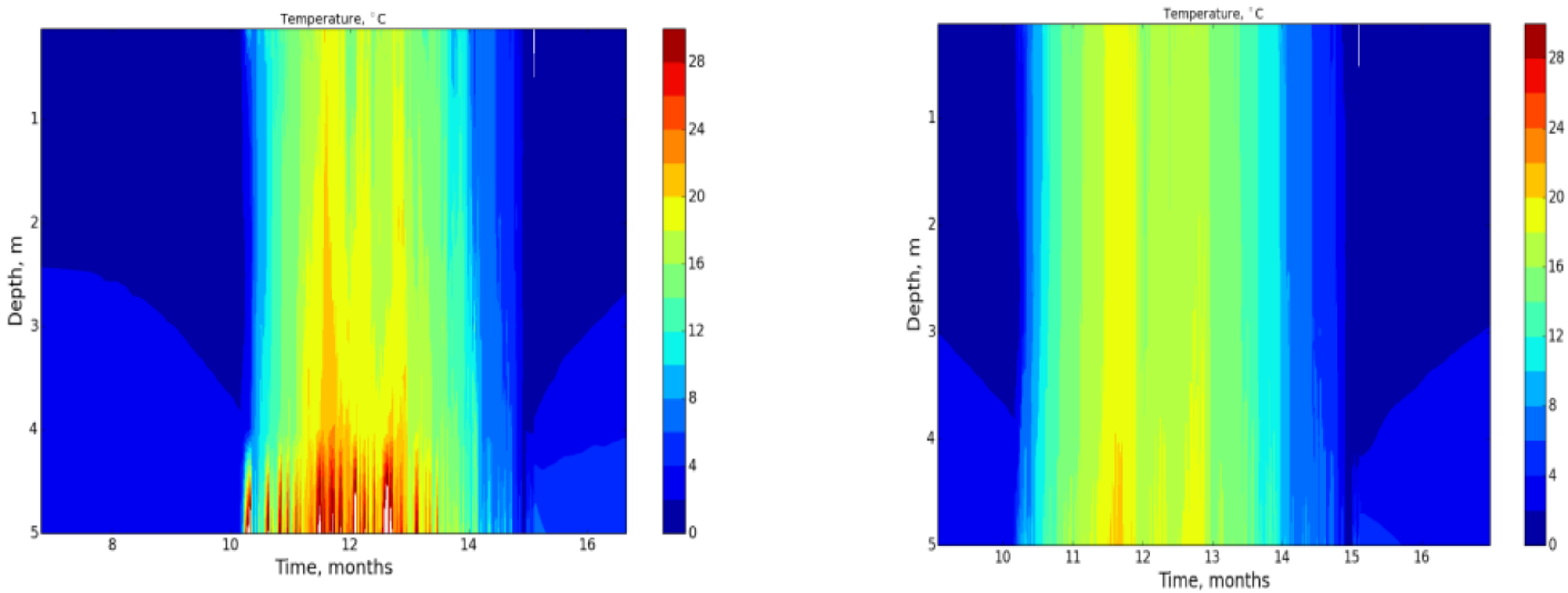
- Parameterized velocity profile in the lake leads to *(Hendersson-Sellers, 1985)*

$$k_T = \frac{k w_s^* z}{Pr_0} \exp(-k^* z)(1 + Ri^2)^{-1}$$

$$Ri = \frac{-1 + \left[1 + 40 N^2 k^2 z^2 / (w_s^{*2} \exp(-2k^* z))\right]}{20}$$

- Good correspondence to many measurements in lakes
- No need for velocity profile calculation
- Allows for large time steps

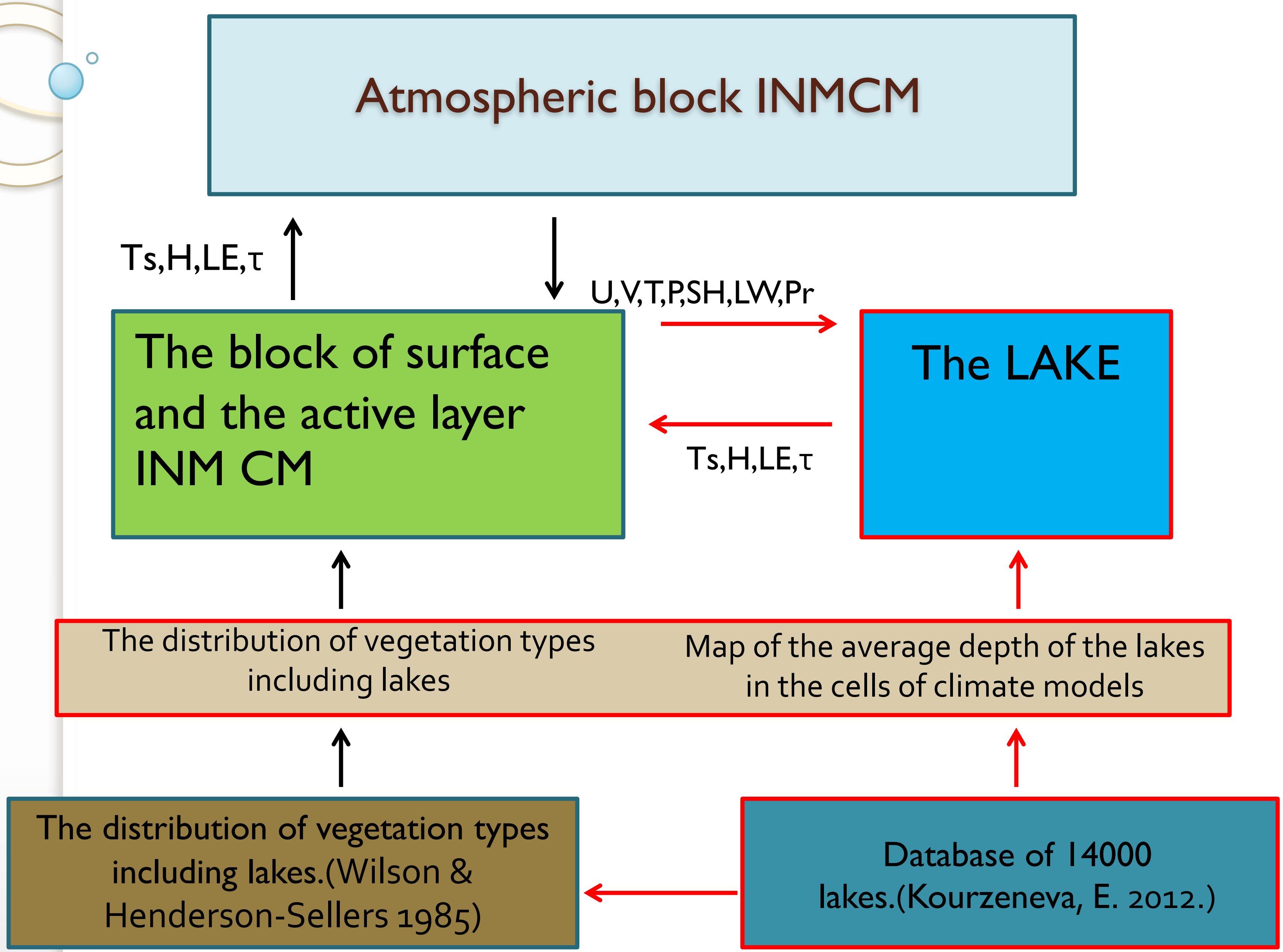
Convective adjustment scheme in the case of unstable stratification



a) б)

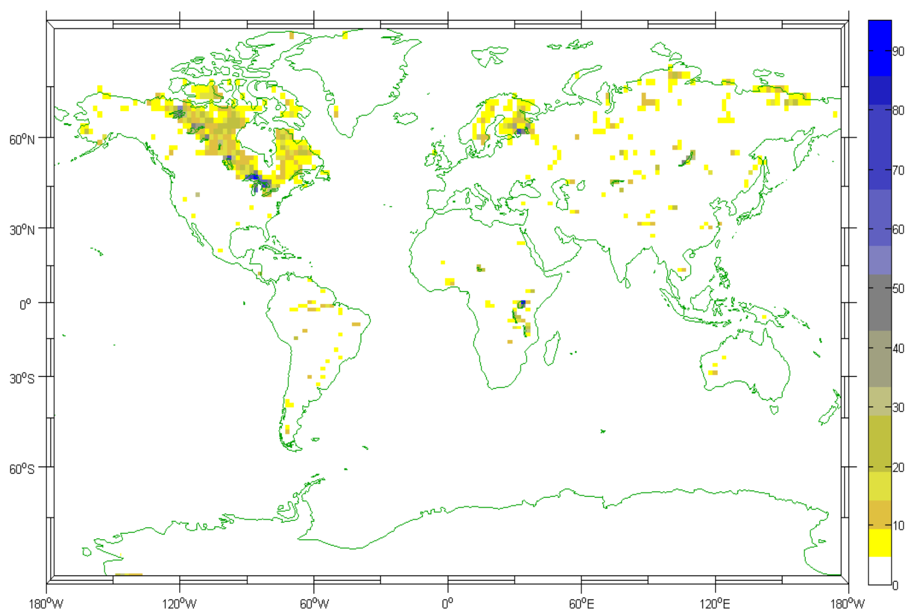
The distribution of the temperature field on the reservoir depth of 5 meters depth to the annual cycle: a) without mixing scheme, b) with mixing scheme.

Coupling schemes LAKE and INMCM



Lake depth, lake map (global data)

- A digital map of lakes is created: fraction of cells occupied by lakes and the average depth of the lakes in the cell.
- Map is based on the database, consisting of order 14000 freshwater lakes (Kourzeneva, et al. 2012).
- Old mask INMCM4 contains 13 types (1018 cells with lakes)
- New mask 14 types (2422 cells with lakes)

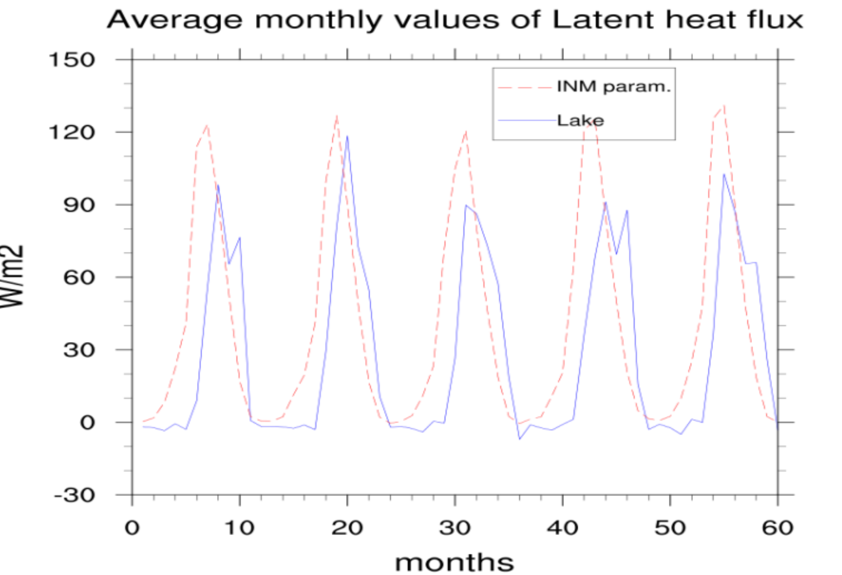


Validation lake surface temperature from INMCM with measurements date

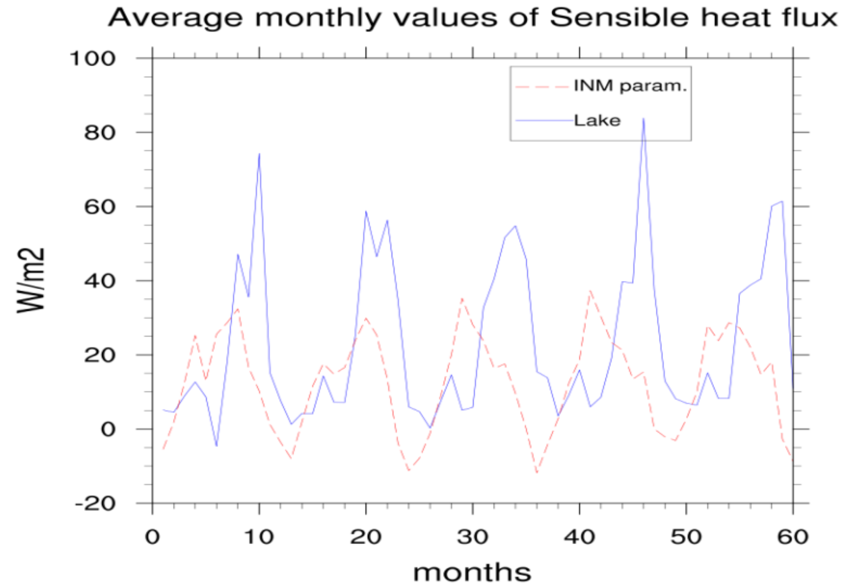
lake name, the geographical position	Averaged over the 5 years, average summer temperature on the lakes surface from LAKE/INMCM model (1980-1985), °C.	Averaged over 15 years, the average summer temperature of the lakes surface, based on satellite data(1986-2000), °C.
Huron, Canada	19,2	18,52
Victoria, Tanzaniya- Kenya-Uganda	25,25	23,84
Baikal, Russia	14,83	12,74
Ladoga, Russia	15,49	14,61

Global measurements Lakes Database

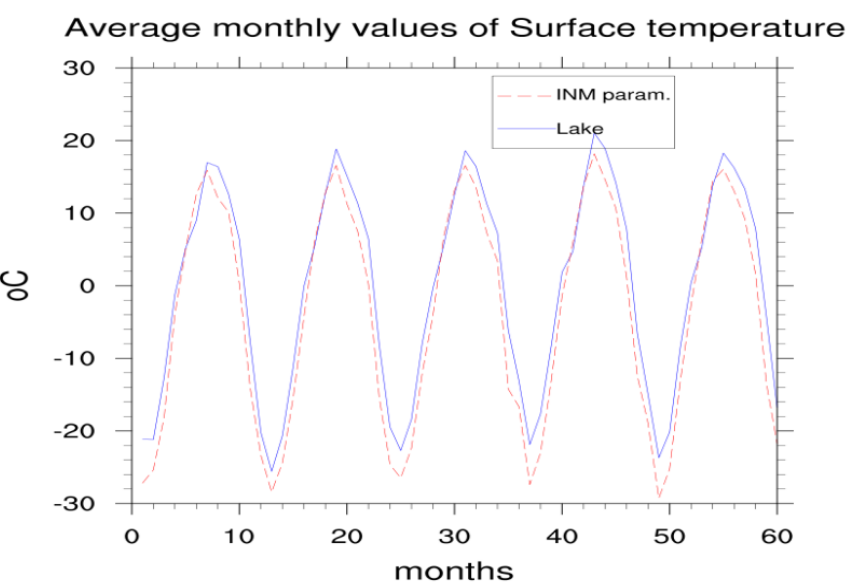
https://portal.lternet.edu/nis/mapbrowse?packageid=knb-lter-ntl.10001.3



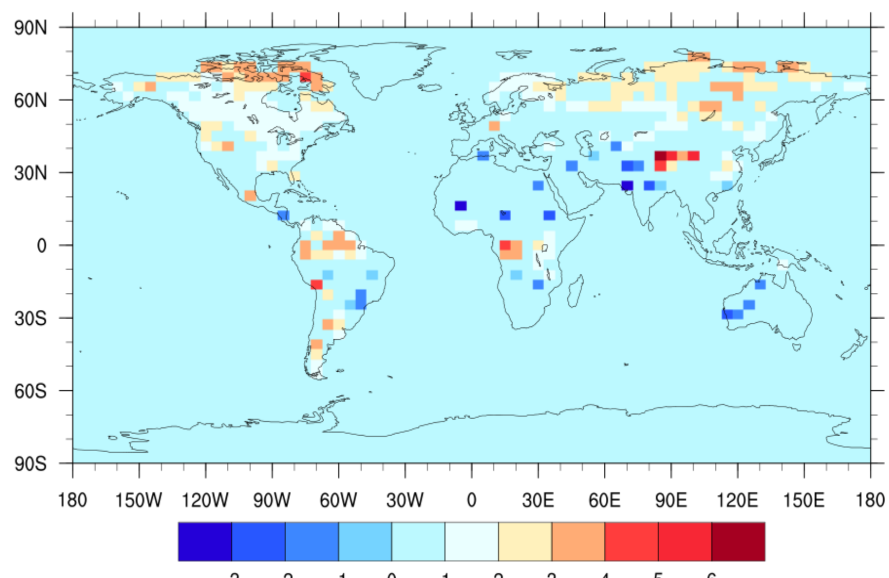
Average values of latent heat fluxes to the Lake Baikal in 5 years



Average values of sensible heat fluxes to the Lake Baikal in 5 years



Average values of the surface temperature of Lake Baikal in 5 years



The difference between average annual temperatures of the surface waters of the LAKE model and INMCM

conclusions

Существенная разница сохраняется и при осреднении температуры потоков тепла, причиной этому может являться то, что накопление тепла в модели LAKE происходит более интенсивно, нежели в старой параметризации, где у водоема нет собственной дополнительной теплоемкости, а профиль температуры, как и для других типов, рассчитывается с молекулярной теплопроводностью. В реальности же, так же как и в модели Lake, у воды альбедо и коэффициент шероховатости значительно ниже, чем у большинства типов суши, т. е. больше солнечной радиации накапливается в виде тепла в водоемах. Особенно этот эффект значителен в низких широтах, где суммарная солнечная радиация наиболее велика.

Thank you for your attention!

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