FLake and its use in HIRLAM and in SURFEX

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FLake – a bulk lake model for parameterization of lakes in NWP and climate modeling

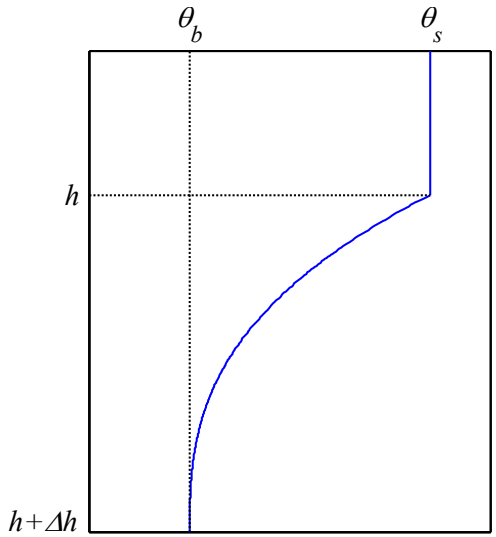
based on two-layer parametric representation of the temperature profile and self-simularity concept

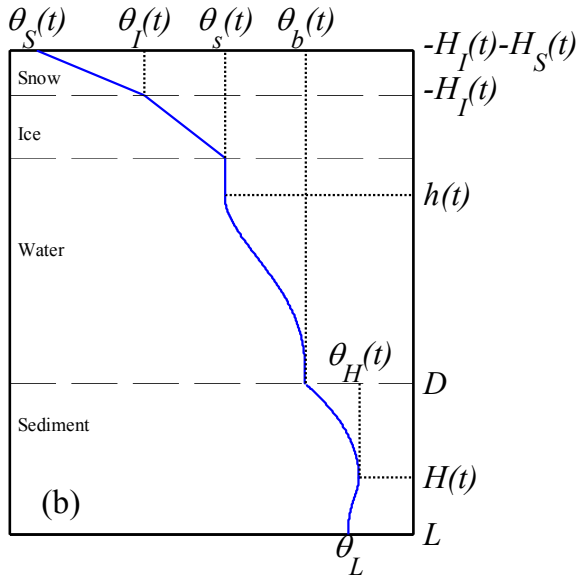
$\theta_s(t)$ – *mixed layer temperature*

h(t) – mixed layer depth

$\theta_b(t)$, *–bottom temperature*

D=h+Δh – lake depth.





FLake – a bulk lake model for parameterization of lakes in NWP and climate modeling

to represent temperature profile shape-function and shape-factor are used

$$\theta = \begin{cases} \theta_s , & 0 \le z \le h \\ \theta_s - (\theta_s - \theta_b)\Phi_\theta(\xi), & h \le z \le D \end{cases} \qquad \xi = (z-h)/(D-h)$$

$\Phi_\theta \equiv (\theta_s - \theta)/(\theta_s - \theta_b)$ – is approximated by polinom (ξ)

$$C_\theta = \int_0^1 \Phi_\theta(\xi)\, d\xi$$

FLake – a bulk lake model for parameterization of lakes in NWP and climate modeling

Prognostic equations

- for the **mean water** temperature
- for the bottom temperature
- for the mixed layer depth (in the cases of neutral stratification and convection)
- for the shape factor

Diagnostic equation

- for the **mixed layer (surface) temperature**

FLake – a bulk lake model for parameterization of lakes in NWP and climate modeling

Model blocks

- short-wave radiation transfer
- ice and snow (self-similarity, the linear temperature profile in ice and snow)
- bottom sediments

External parameters – Global Lake Database, model lake climatology

Global Lake Database

Parameters

- lake depth (mean or bathymetry)
- lake fraction

What is specific for the atmospheric modeling? *(e. g. in contrast to hydrological applications)*

- global coverage with all lakes included
- high accuracy is not critical

Sources of data

- direct measurements from regional databases: individual characteristics of lakes
- global map, ECOCLIMAP2

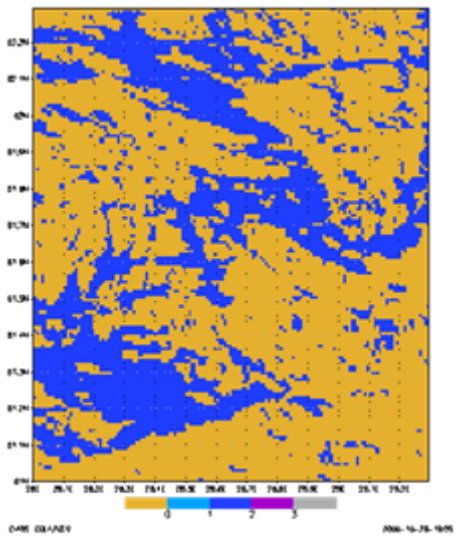
External parameters – Global Lake Database, model lake climatology

Global Lake Database

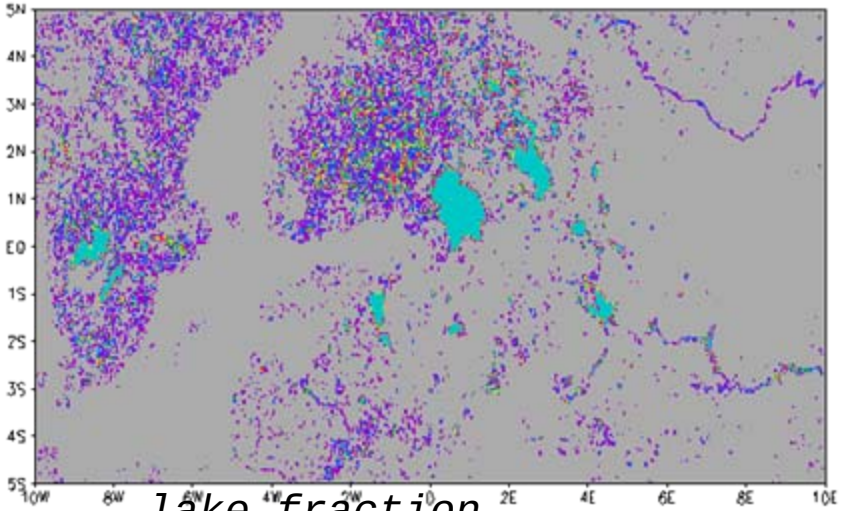
13 000 freshwater lakes

Bathymetry totally for 36 large lakes

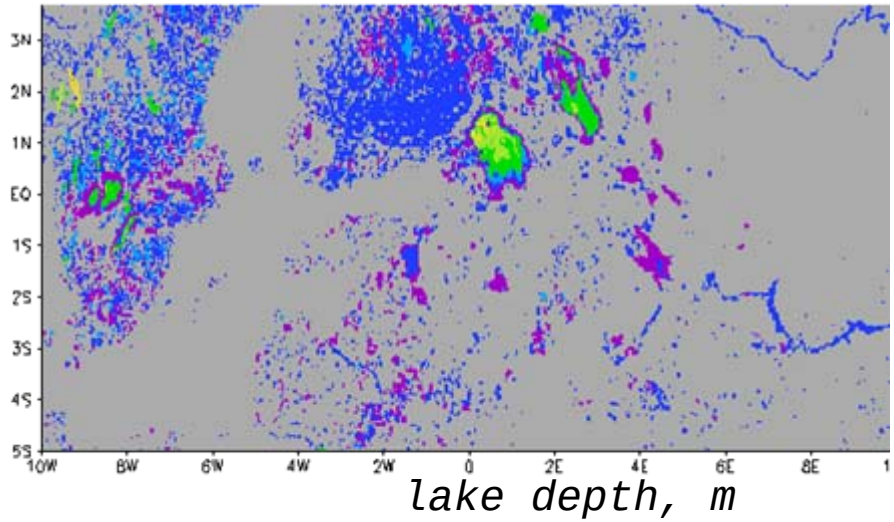
Lat, deg	Lon, deg	Mean Depth, m	Max Depth, m	Surface area, km**2	International name	Country
42.2	19.3	5	8.3	372.3	Scutari_(Skadar)	Albania
41	20.8	143	286	340	Ohrid	Albania
41	21	9999	9999	313.6	Big_Prespa	Albania
40.8	21.05	9999	9999	47.4	Small_Prespa	Albania
47.434	11.717	67.7	133	7.1	Achensee	Austria
47.755	13.959	2.5	5	0.9	Almsee	Austria
47.641	13.786	34.3	52.8	2.1	Altausseer_See	Austria
48.25	16.41	2.2	6.8	1.6	Alte_Donau	Austria
47.89	13.55	85.3	170.6	46.2	Attersee	Austria
47.511	9.679	89.9	254	539	Bodensee	Austria
48.592	15.4	14	40	1.5	Dobrastausee	Austria
47.542	15.058	24	38	0.5	Erlaufsee	Austria
46.578	13.924	14.9	29.5	2.2	Faaker_See	Austria
47.806	13.268	36	66.3	2.7	Fuschlsee	Austria
48.601	15.142	1.4	3.2	0.6	Gebhartsleich	Austria
46.932	10.739	53.8	112	2.6	Gepatsch_Stausee	Austria
47.992	13.095	9.7	14	1.3	Grabensee	Austria
47.636	13.881	41.1	63.8	4.1	Grundlsee	Austria
47.493	10.573	11	22	0.8	Haldensee	Austria
47.553	13.665	65.1	125.2	8.6	Hallstaatter_See	Austria
48.82	15.136	1.4	2.5	0.6	Haslauer_Teich	Austria
47.456	10.772	40.4	60	1.4	Heiterwanger_See	Austria
47.75	13.247	9.3	22	0.7	Hintersee	Austria
47.542	12.215	12.8	36	0.6	Hinterstoiner_See	Austria
47.924	13.305	14.9	32	3.5	Insee	Austria
48.588	14.182	10.4	15.6	1.4	Keutschacher_See	Austria



External parameters – Global Lake Database, model lake climatology



lake fraction



lake depth, m

the rotated spherical coordinates,
POLON= 30°, POLAT= -30°, d≈0.1°

Global Lake Database

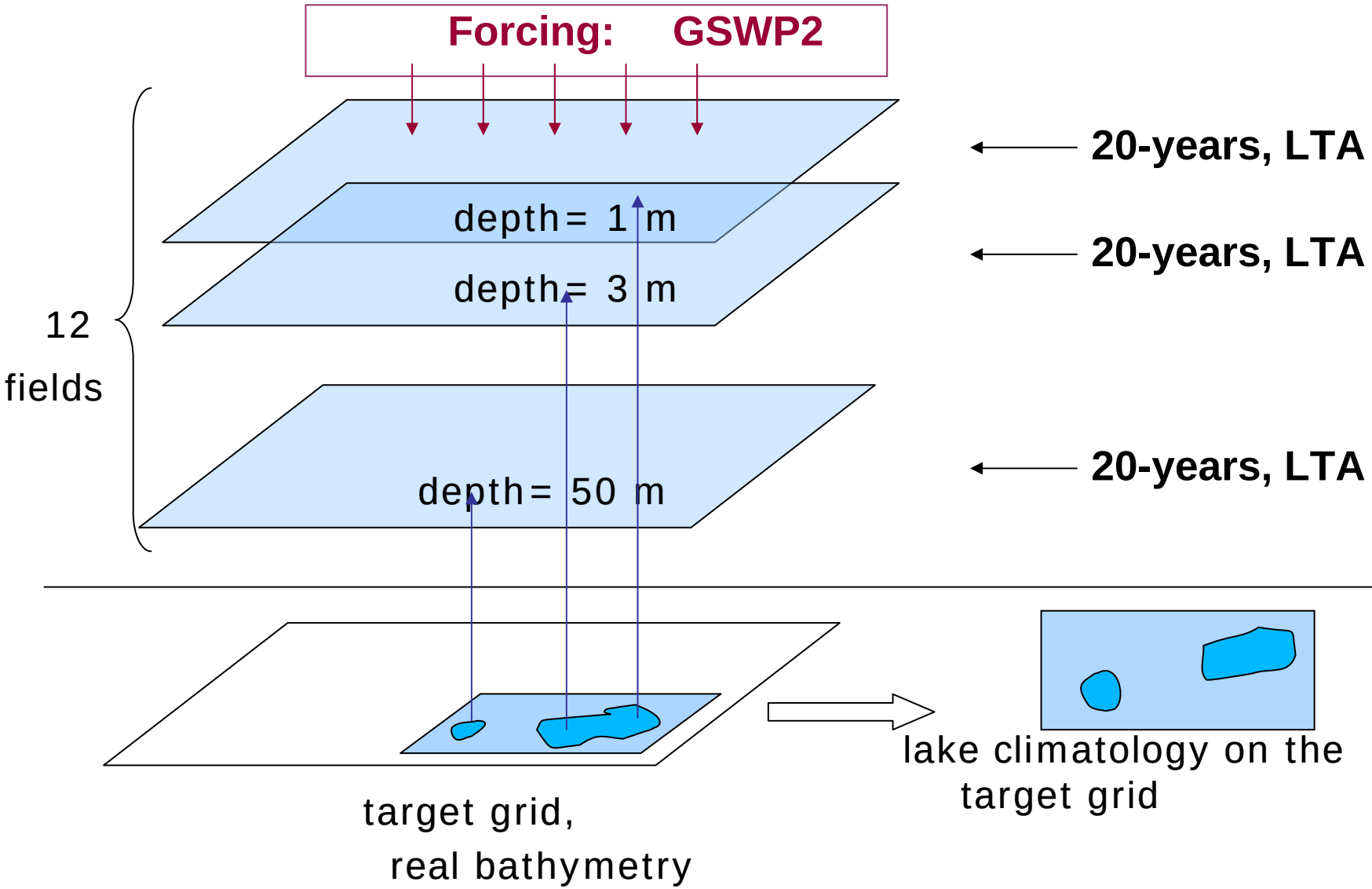
- **Mapping method is** fully automatic, uses probabilistic approach (optimization task)
- **To project** the information from 1 km initial map onto the target atmospheric grid, we make the histogram and use the most probable value of the lake depth

External parameters – Global Lake Database, model lake climatology

Model lake climatology

- climatological 20-year FLake run
- for the globe, resolution 1 deg.
- FLake offline with the forcing from GSWP2 (global soil wetness project)
- for the different classes of the lake depth
- 10-day representation of the annual cycle
  (to smooth the synoptic variability but to preserve the annual cycle with max. temporal resolution)

External parameters – Global Lake Database, model lake climatology

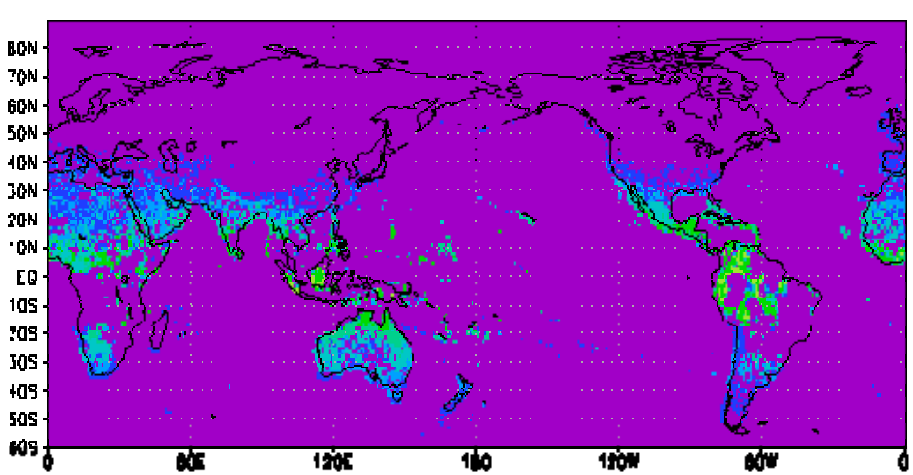


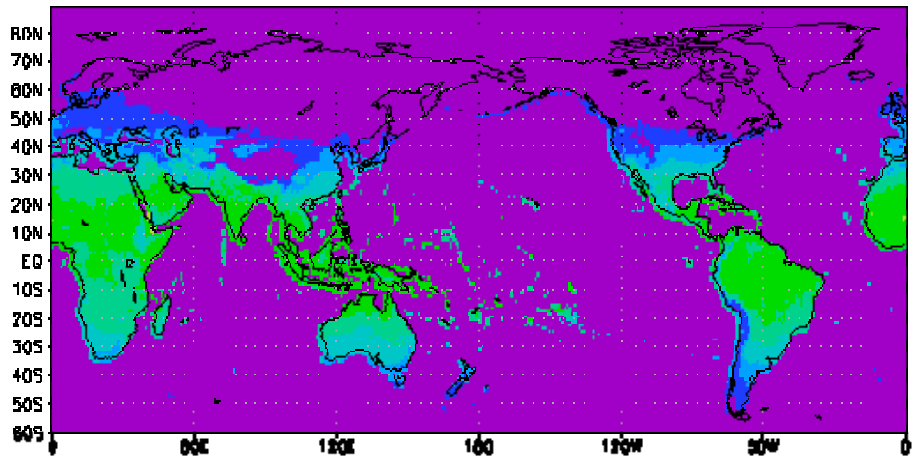
External parameters – Global Lake Database, model lake climatology

- for warm deep lakes, the bottom temperature was relaxed to t2m long term climatological mean

$$\frac{dT_b}{dt} = \frac{1}{\tau}\left(\overline{T2m} - T_b\right) \qquad \frac{1}{\tau} \approx \frac{k}{\rho c_p}\frac{1}{L^2}\left(\frac{\pi}{2}\right)^2 \qquad \tau \approx 10\text{days}$$

- consistency of the parameters, averaging the ice depth with PDFs



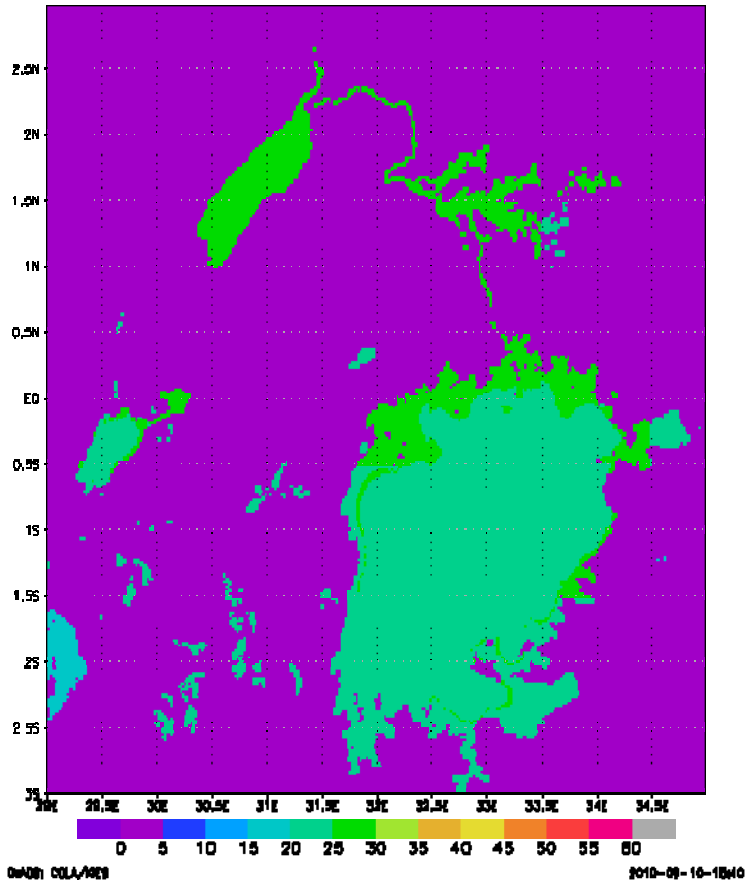


T bot, July, 1, depth = 50 m

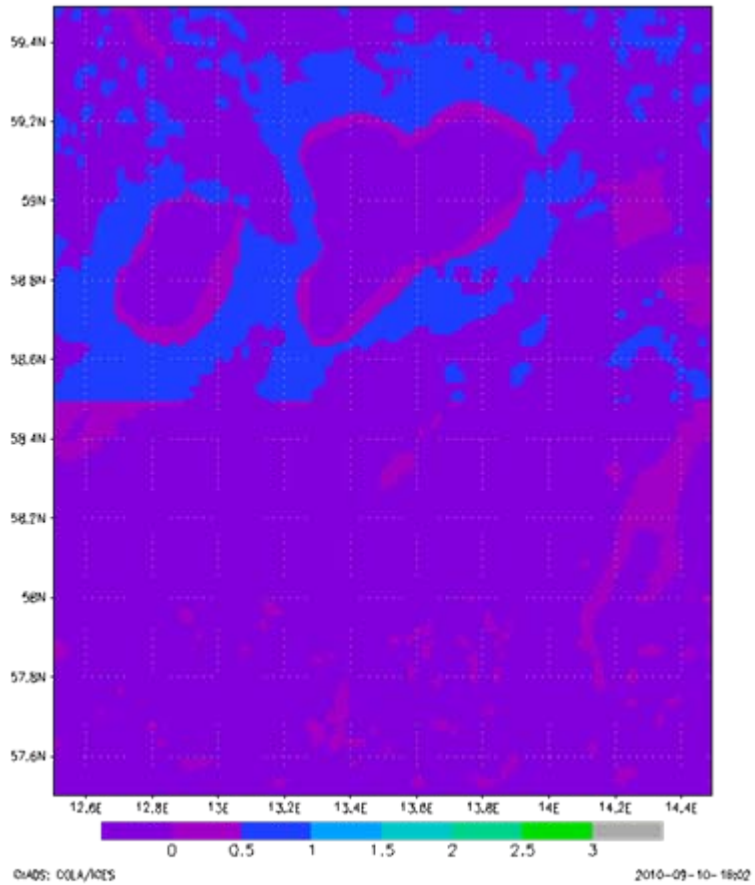
FLake

FLake with relaxation

External parameters – Global Lake Database, model lake climatology



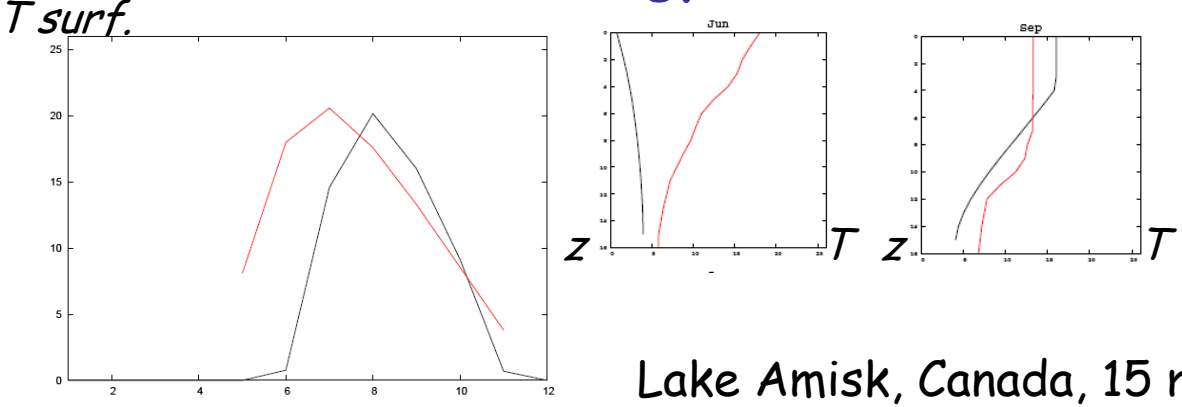
Mean water temperature, C, Lake Victoria, July, 1



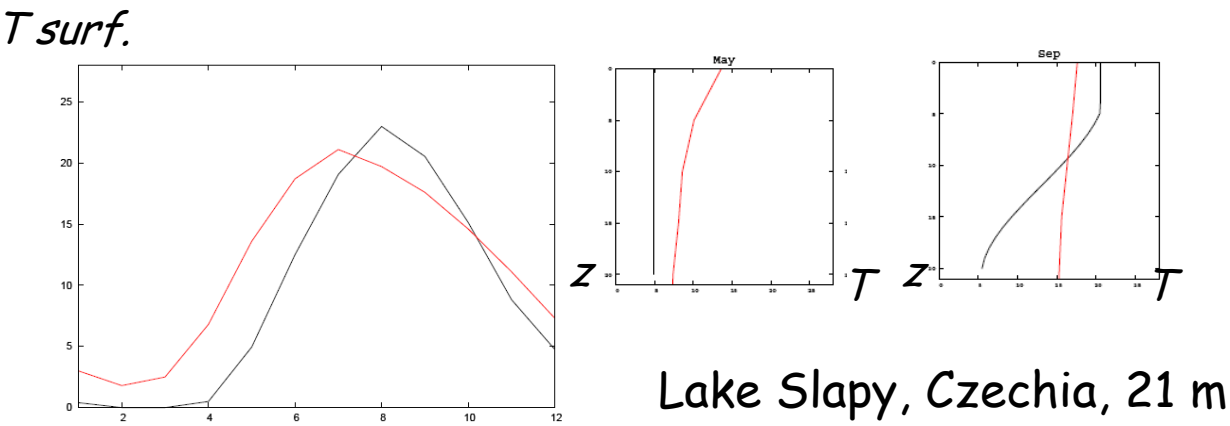
Ice depth, m, Lake Vanern and Lake Vattern, January, 1

External parameters – Global Lake Database, model lake climatology

- **Model lake climatology, verification**



Lake Amisk, Canada, 15 m



Lake Slapy, Czechia, 21 m

red – meas., black – sim.

Wrong atm. forcing or wrong lake model?

FLake seems to be very sensitive to forcing during the ice break-up period

FLake in HIRLAM

FLake is fully coupled
to HIRLAM,
at each time step, **tiling**
(newsnow, orosula, HIRLAM7.4)

HIRLAM provides:
Turbulent fluxes, SW↓, LW↓
(snow not used at the moment)

explicit

FLake provides:
lake surface temperature,
ice depth, albedo +
other prognostic & diagnostic lake variables

"Climatological" mode:
lake variables
are in history files, but
pass to the next cycle
without changes

FLake in SURFEX

- Scientifically similar with HIRLAM, but lot of technical details
- SURFEX provides lot of opportunities for the experiment design, mainly academic: different grids, interpolations, initialization methods, etc. Probably too many? Difficult to test.
- FLake-related program code: V. Masson.
  Only 1D test performed: R. Salgado
  (NUMLAB2009 playing with 2D).
  Very few technical runs of other configurations!

Will be included into coming version of SURFEX:

- Global Lake Database implementation (only for LON-LAT!)
- Corrections in initialization: the horizontal interpolation and the vertical shift of lake variables are forbidden or possible depending on the profile type. Global Lake Climatology is implemented.
- 2D testing with real lakes offline: works technically. But only for LON-LAT!

Ideas for DA of LST

For coupled system lake/atmosphere we need:

- To spread information in horizontal

  - OI?
  To adapt for discontinuous fields – to introduce into structure functions the dependency on depth

- To spread information in vertical (inside FLake)
  – EKF?
  Slow variables
  B-matrix modeling is difficult
  Nonlinearity sometimes may be strong

Ideas for DA of LST

Observed variables:

- Temperature
  - LST!
  - discontinuous in space, continuous in time – is it a correlation between LST of neighboring lakes?

- Ice cover
  - very important!
  - but discontinuous both in space and in time!
  - ice/no ice, ice depth, ice fraction (?), snow on ice (?)

Ideas for DA of LST

Observations

- In situ
  - SYKE

- Remote sensing
  - MODIS
  - coming ESA products - North Hydrology, probably gridded data for the region
    with 1 km resolution
    instead of data for particular lakes
    with 100m resolution
  - other, Laura will speak more

Ideas for DA of LST

To spread information in vertical (inside FLake)

State vector

$$\mathbf{x} = \begin{bmatrix} \overline{\theta} \\ \theta_b \\ h \\ C_\theta \end{bmatrix}$$

Obs vector

$$\mathbf{y} = \left| \theta_s \right|$$

Obs operator

$$\theta_s = \left(1 - C_\theta \left(1 - \frac{h}{D} \right) \right)^{-1} \left(\overline{\theta} - \left(1 - \frac{h}{D} \right) \theta_b \right)$$