Implementation of the Lake Model in LM. Present Status.

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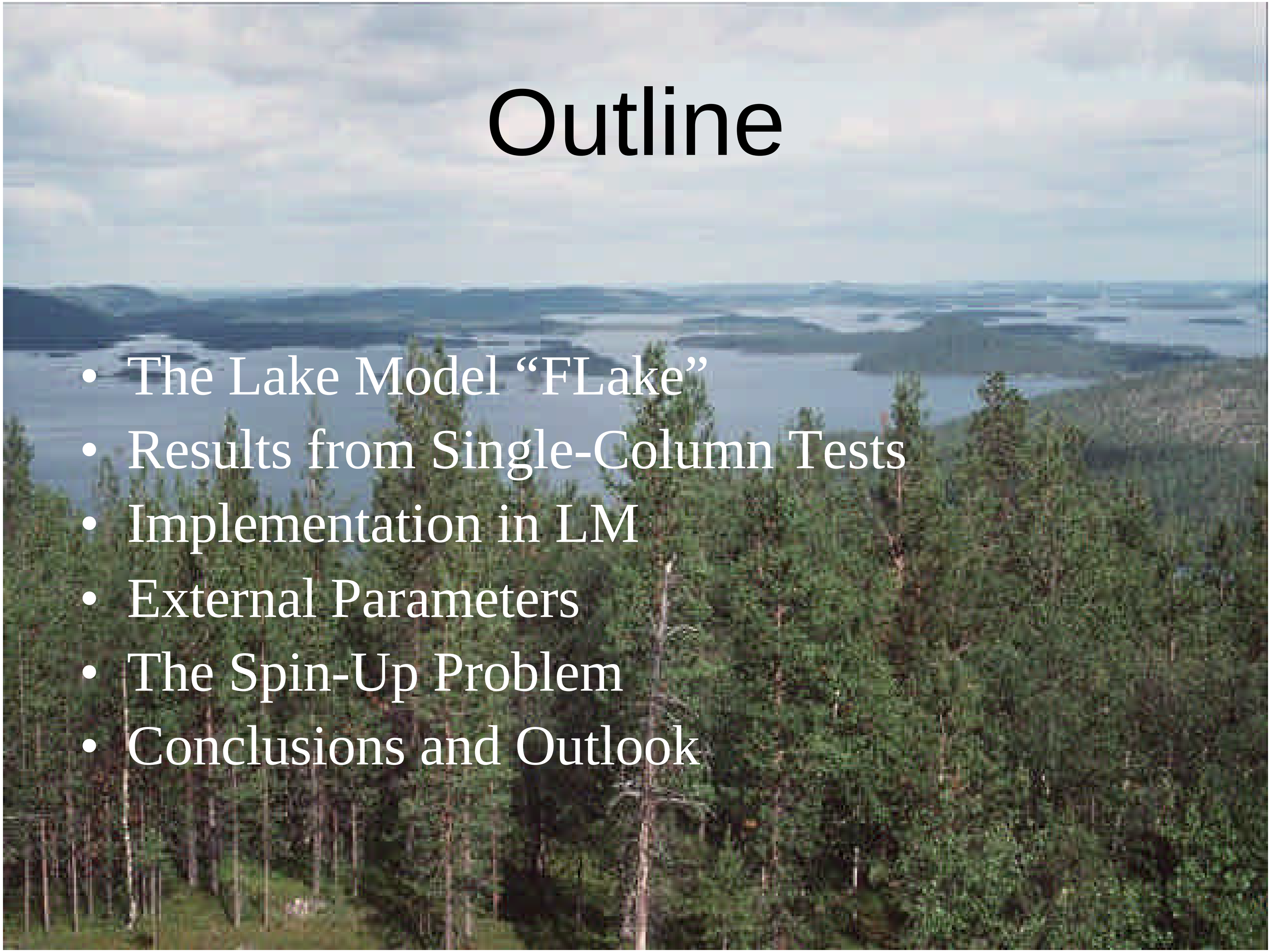


Outline

- The Lake Model “FLake”
- Results from Single-Column Tests
- Implementation in LM
- External Parameters
- The Spin-Up Problem
- Conclusions and Outlook

The Lake Model "FLake"

The model is based on the idea of self-similarity (assumed shape) of the evolving temperature profile. That is, instead of solving partial differential equations (in *z*, *t*) for the temperature and turbulence quantities (e.g. TKE), the problems is reduced to solving ordinary differential equations for time-dependent ***parameters*** that specify the temperature profile. These are

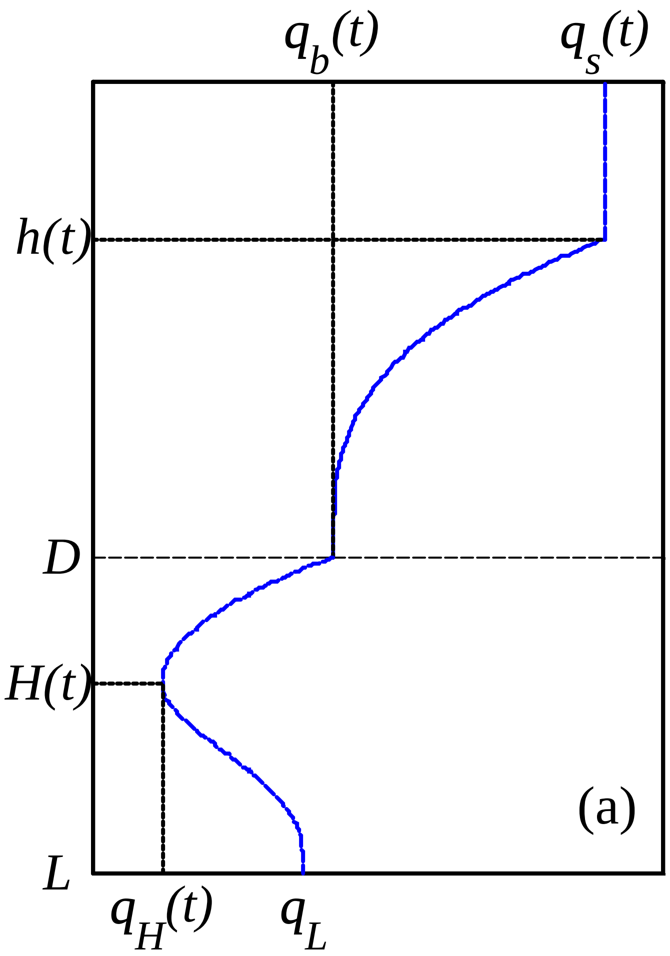
- the surface temperature,
- the bottom temperature,
- the mixed-layer depth,
- the depth within bottom sediments penetrated by the thermal wave, and
- the temperature at that depth.

In case of ice-covered lake, additional prognostic variables are

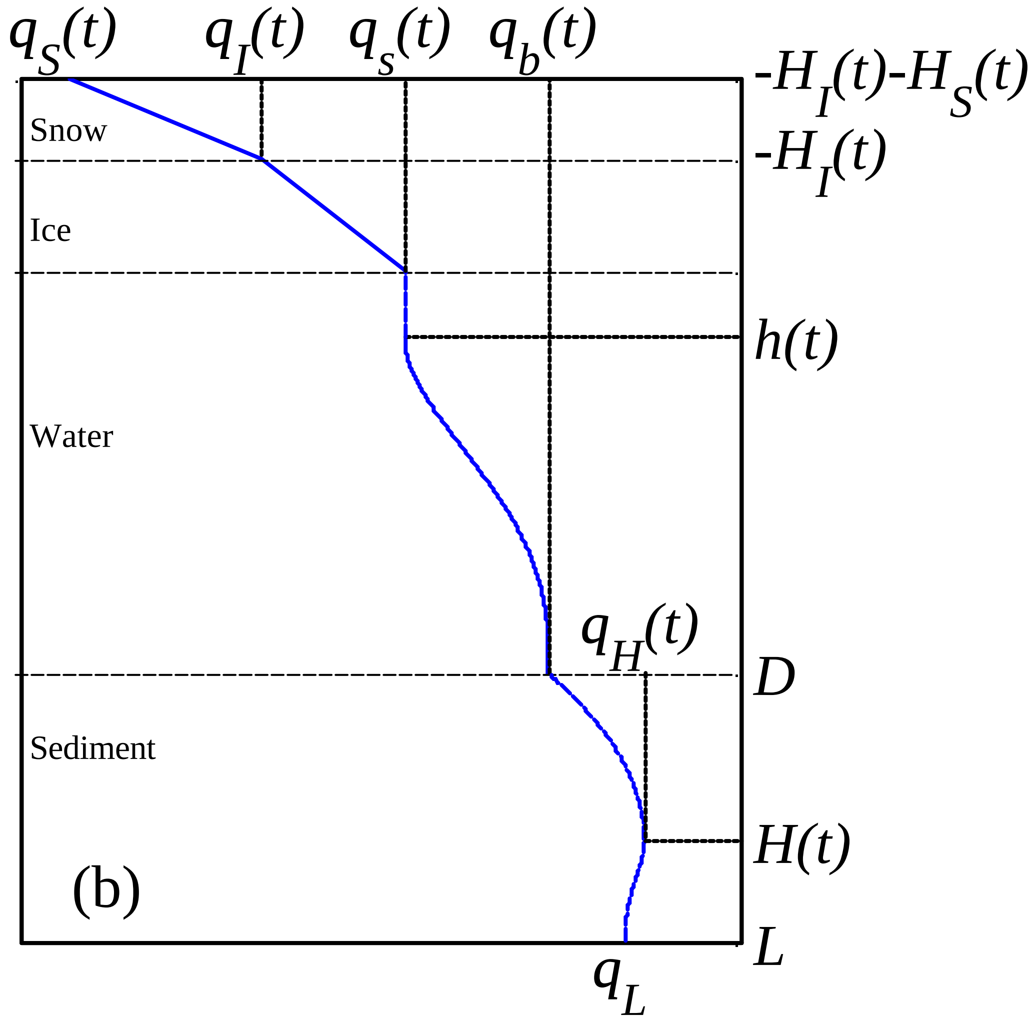
- the ice depth,
- the temperature at the ice upper surface,
- the snow depth, and the temperature at the snow upper surface.

Important! The model does not require (re-)tuning.

Schematic representation of the temperature profile



(a) The evolving temperature profile is characterised by five time-dependent parameters, namely, the temperature $?_s(t)$ and the depth *h(t)* of the mixed layer, the bottom temperature $?_b(t)$, the depth *H(t)* within bottom sediments penetrated by the thermal wave and the temperature $?_H(t)$ at that depth.



(b) In winter, four more variables are computed, namely, the temperature $?_S(t)$ at the air-snow interface, the temperature $?_I(t)$ at the snow-ice interface, the snow thickness $H_S(t)$ and the ice thickness $H_I(t)$.

Single-Column Tests

- Kossenblatter See, Germany (52 N, mean depth = 2 m)
- Lake Krasnoye, Russia (60 N, mean depth = 8 m)
- Lake Pääjärvi, Finland (61 N, mean depth = 15 m)

Forcing in 1D Mode

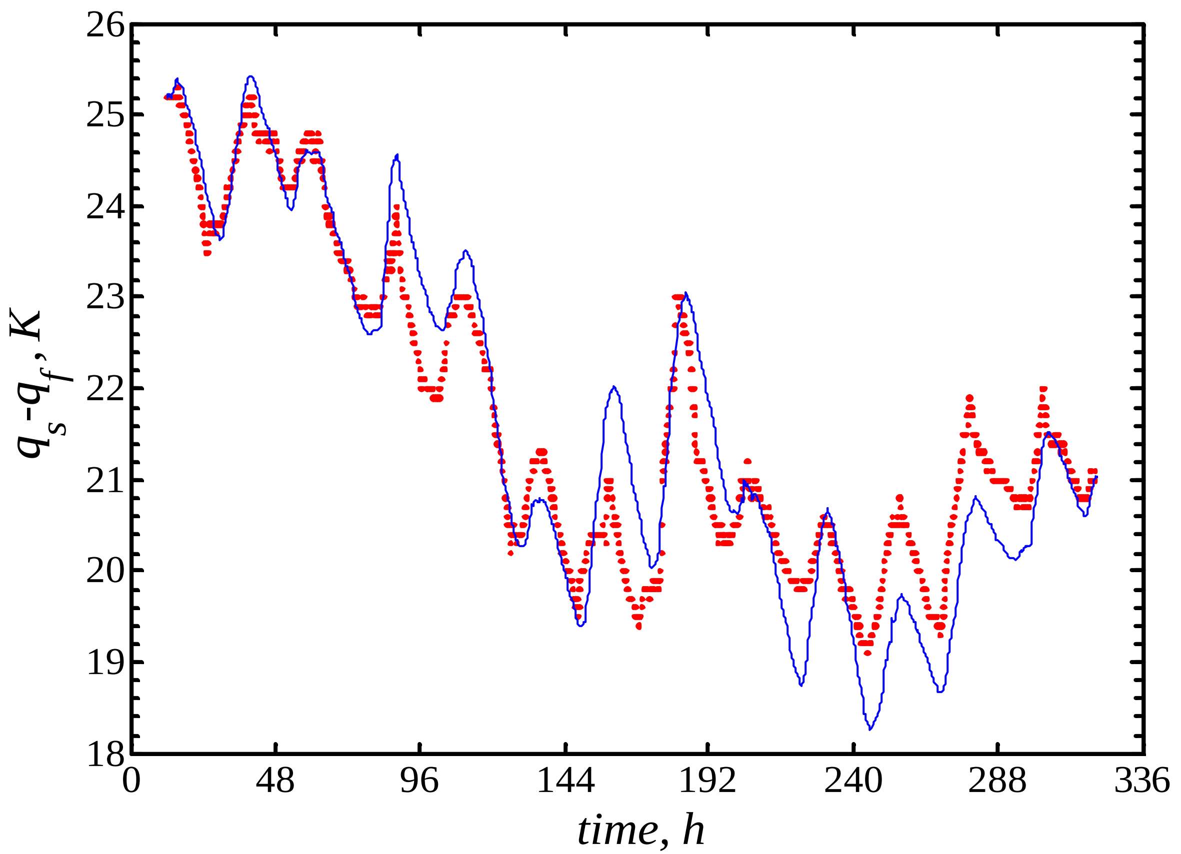
Known from observations:

- short-wave radiation flux,
- long-wave radiation flux from the atmosphere.

Computed as part of the solution (depend on lake surface temperature):

- long-wave downward radiation flux from the surface,
- fluxes of momentum and of sensible and latent heat,
- for ice-covered lakes, surface albedo.

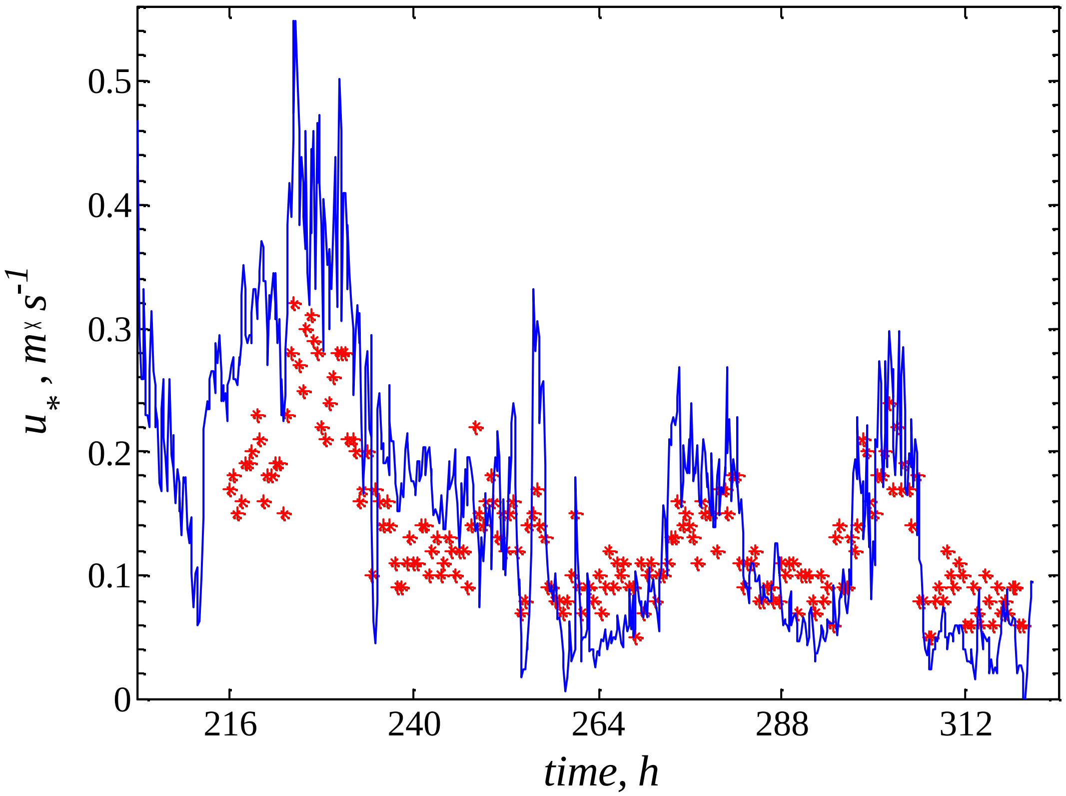
Kossenblatter See. 8-21 June 1998.



Water surface temperature

- Dots - measured
- Line - computed

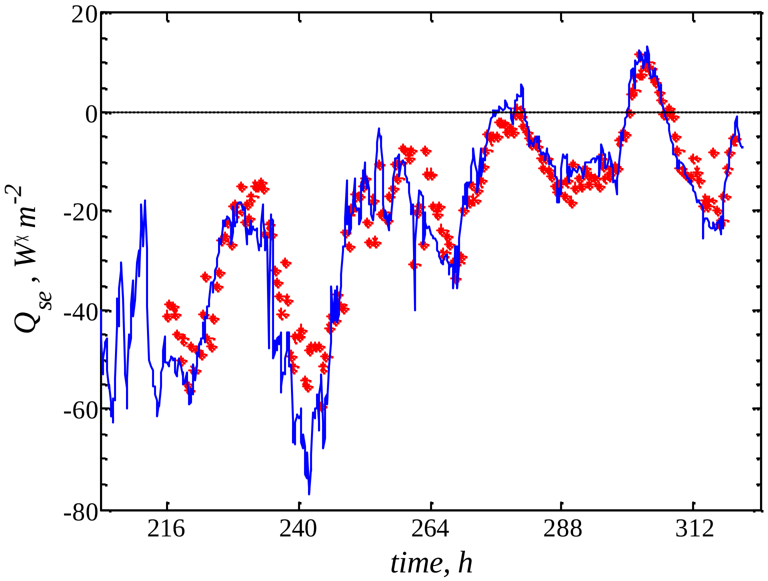
Kossenblatter See. 8-21 June 1998.

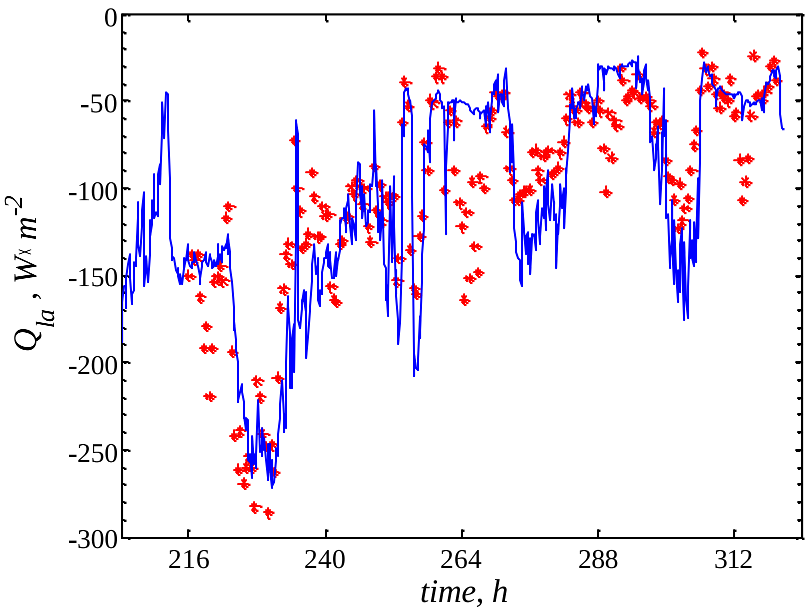


Friction velocity in the surface air layer

- Symbols - measured
- Line - computed

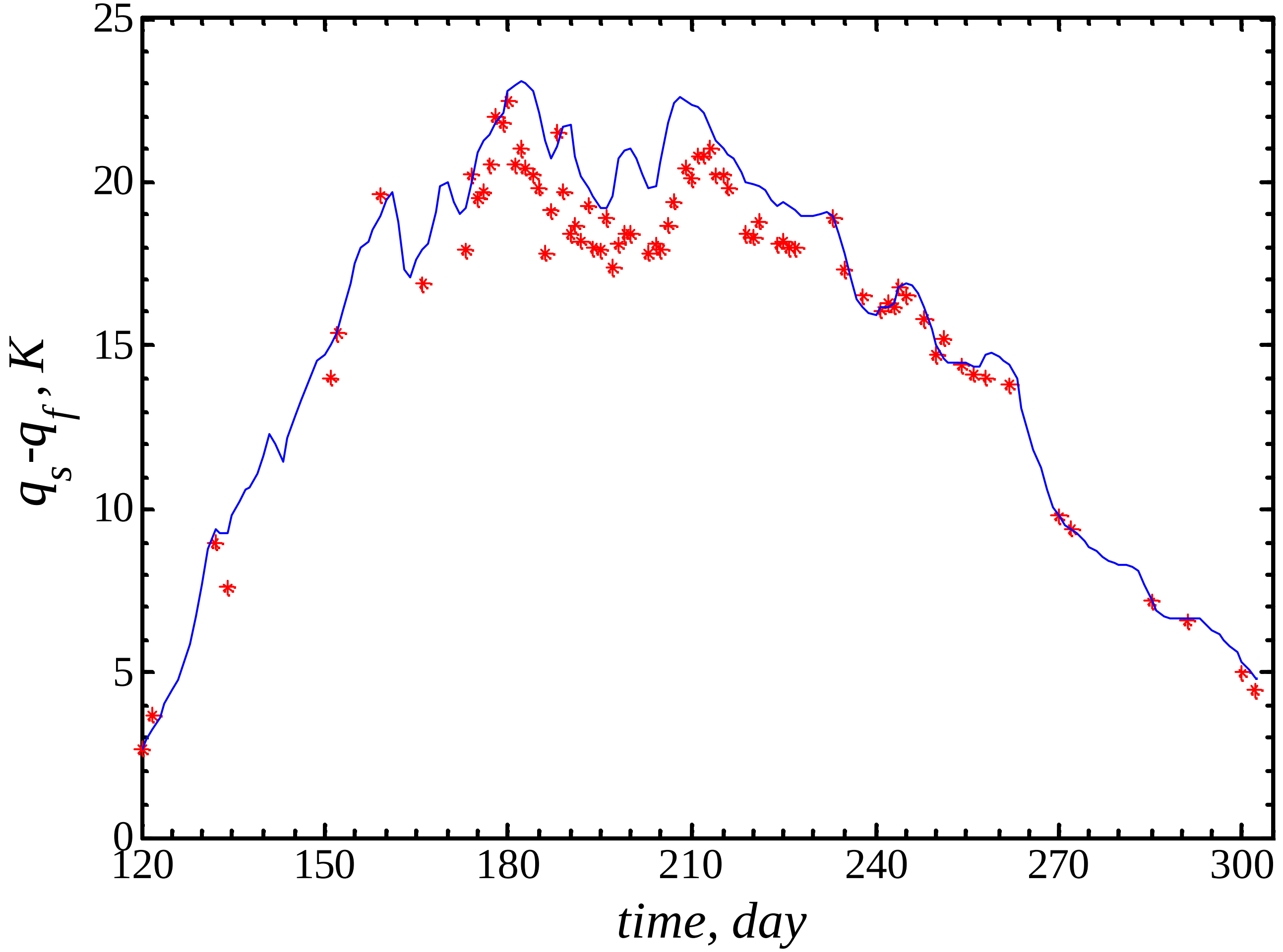
Kossenblatter See. 8-21 June 1998.





- Sensible heat flux
- Latent heat flux
- Symbols – measured
- Lines– computed

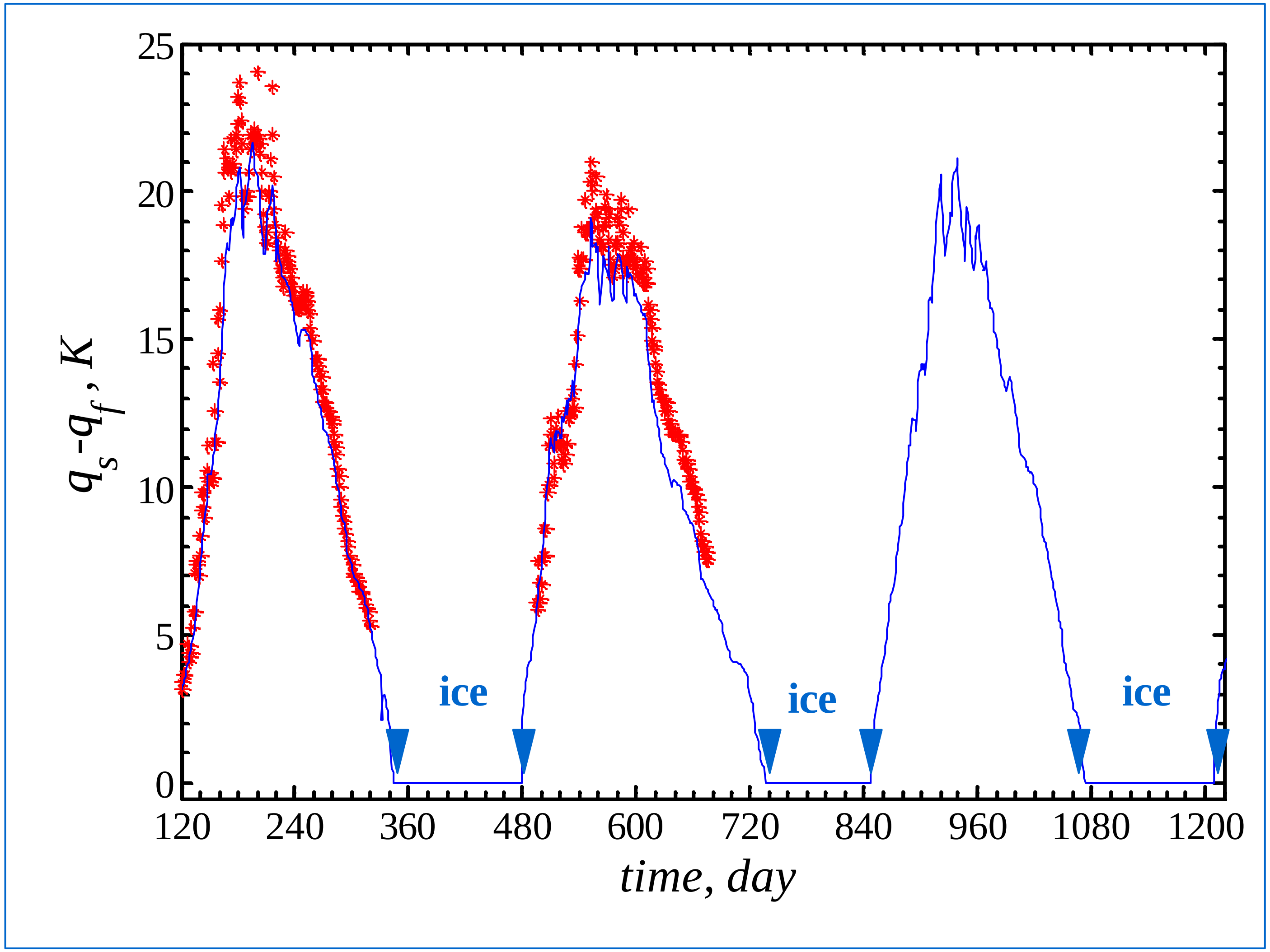
Lake Krasnoye, 1 May - 31 October 1970.



Water surface temperature *?*$_s$ (*?*$_f$ is the fresh-water freezing point)

Dots – measured, Line - computed

Lake Pääjärvi, 1 May 1999 - 31 August 2002.



Water surface temperature ?$_s$ (?$_f$ is the fresh-water freezing point)

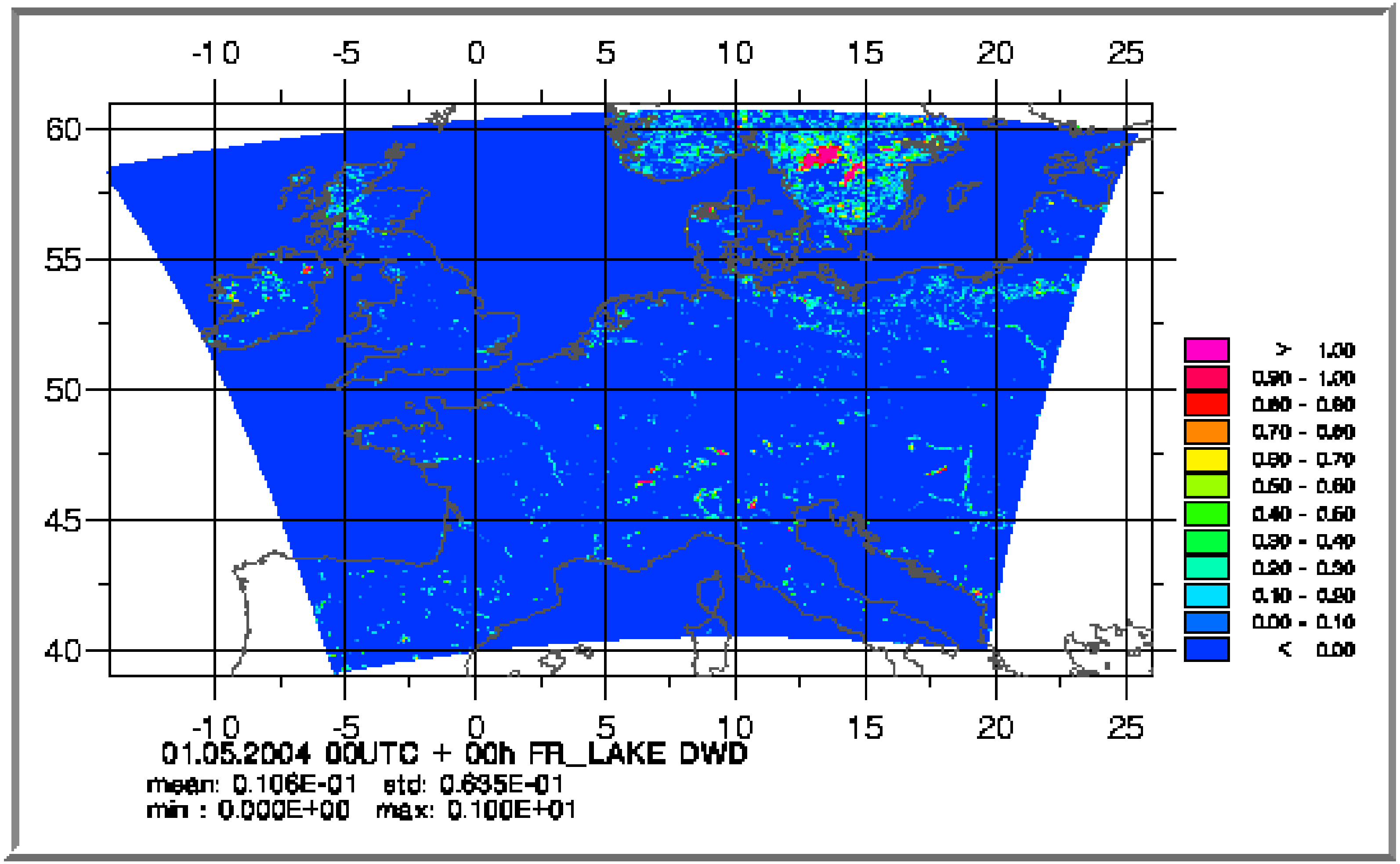
- Dots – measured, Line - computed

FLake in LM: External Parameters

- geographical latitude (easy)
- lake fraction in LM grid-box (not so easy)
- lake depth (not easy at all, e.g. should the mean depth for the entire lake be taken, or different depths for different LM grid-boxes?)
- typical wind fetch
- optical characteristics of lake water (extinction coefficients with respect to short-wave radiation)
- depth of the thermally active layer of bottom sediments, temperature at that depth (cf. soil model parameters)

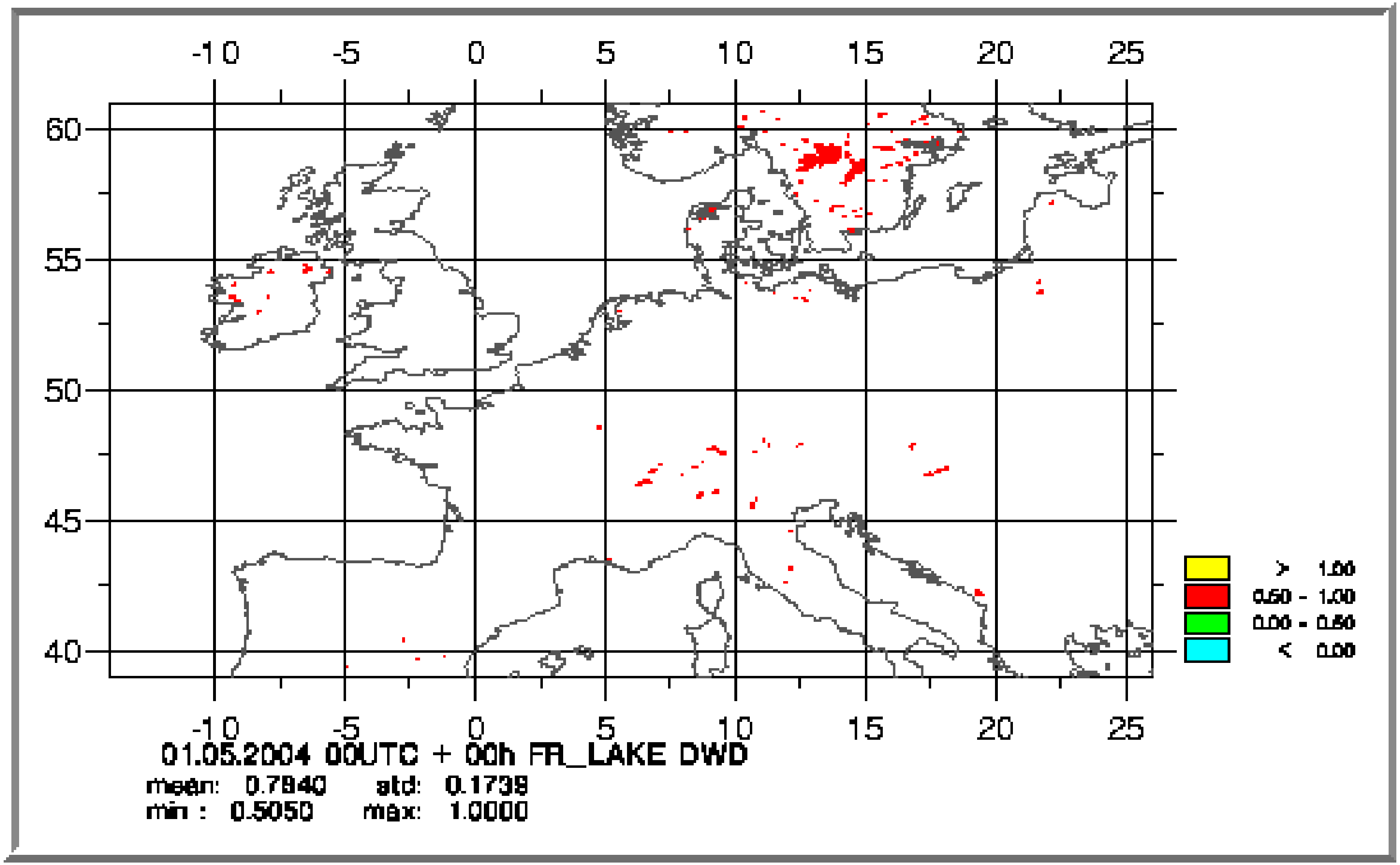
Default values of the last three parameters can be used.

Lake Fraction



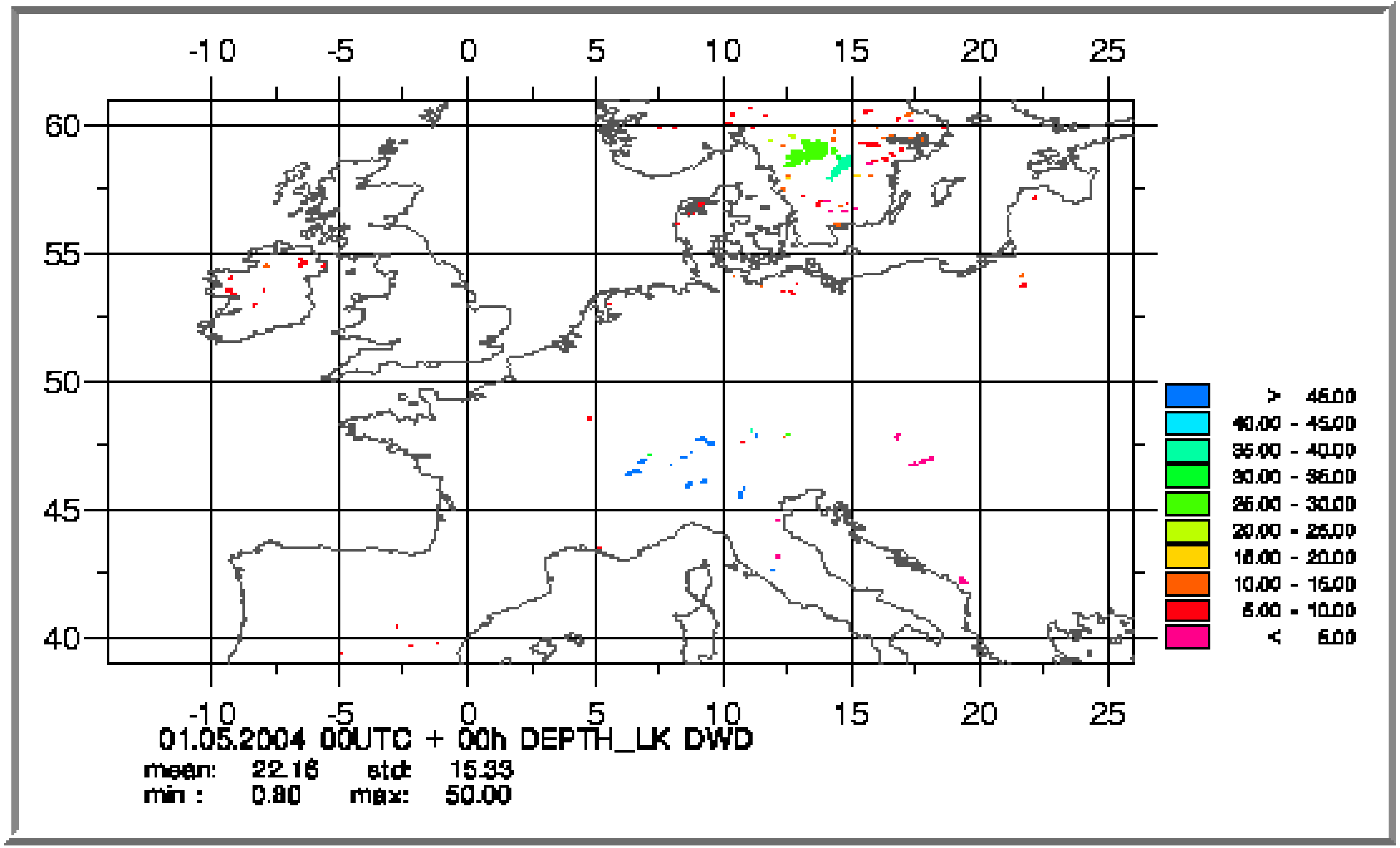
Lake fraction for the DWD LM domain (Natalia Schneider, Bodo Ritter) based on the GLCC global data set (http://edcdaac.usgs.gov/glcc) with 30 arc sec resolution, that is ca. 1 km at the equator.

Lake Fraction



Lake fraction for the DWD LM domain based on the GLCC global data set.
Red - LM grid boxes with FR_LAKE >0.5.

Lake Depth

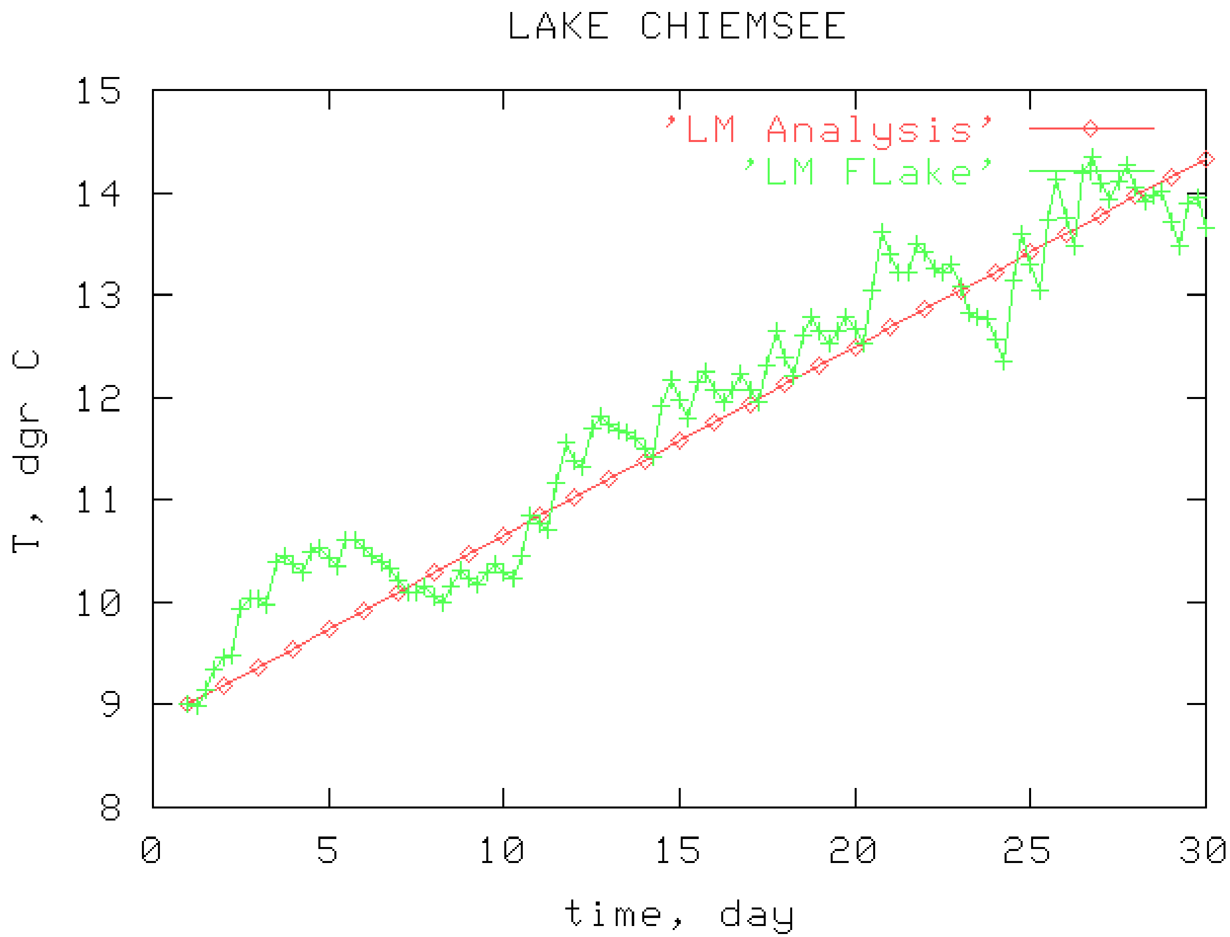


Lake depths for the DWD LM domain. The field is developed (Natalia Schneider) using various data sets. Each lake is characterised by its <u>mean depth</u>.

FLake in LM: Test Runs

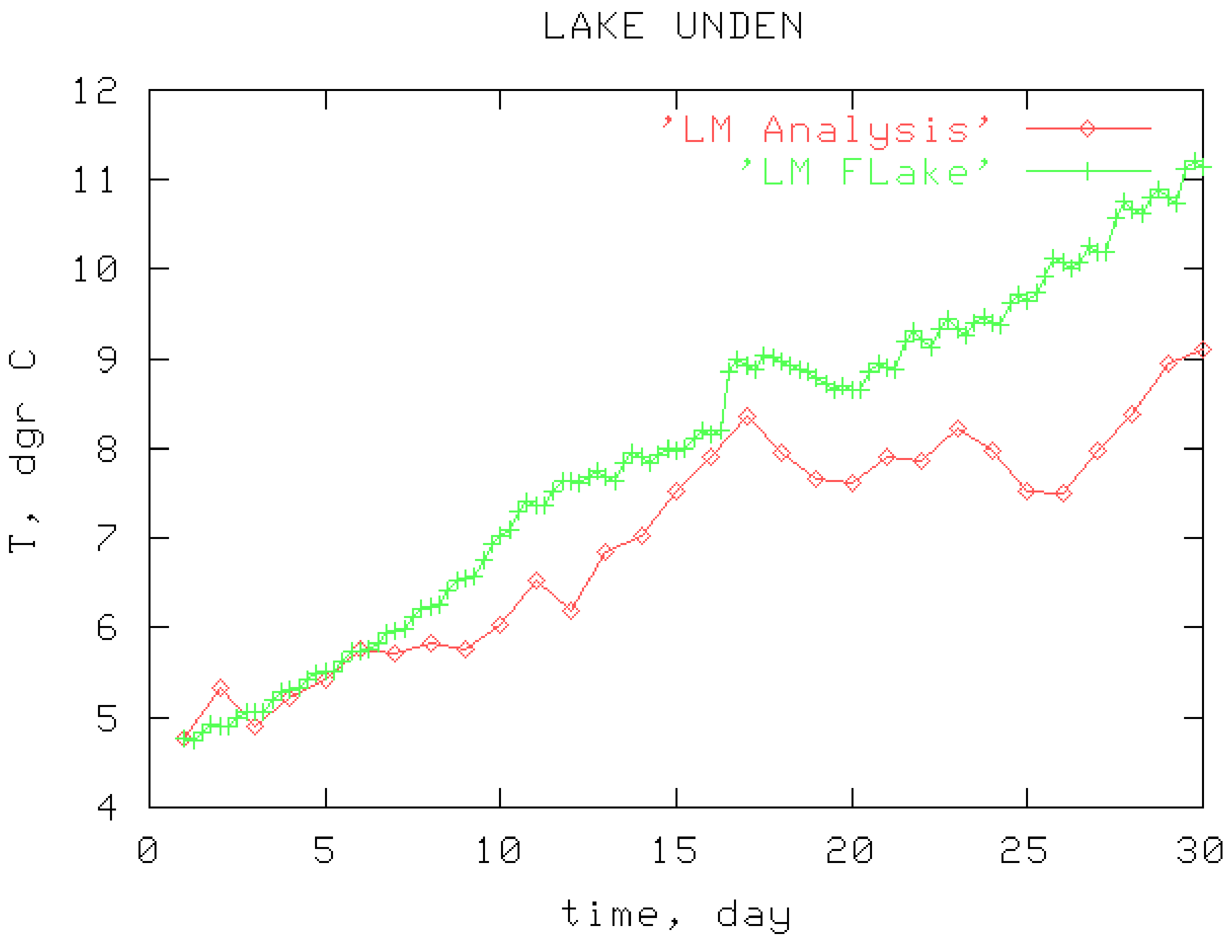
- no tile approach: lakes are the LM grid-boxes with FR_LAKE>0.5, otherwise land or sea water
- all lakes are 25 m deep
- default values for other lake-specific parameters
- LM parallel experiment (including the entire data assimilation cycle) over 1 month, 1 through 30 May 2004
- “artificial” initial conditions, where the lake surface temperature is equal to the LM SST from the assimilation
- turbulent fluxes are computed with the LM surface-layer scheme (Raschendorfer 2001); optionally, the new surface-layer scheme (Mironov 2004) can be used
- the effect of snow is accounted for through the surface albedo

FLake in LM: Results from Parallel Experiment
1 – 30 May 2004



- Chiemsee, Germany (mean depth = 25.6 m)
- Red – lake surface temperature from LM SST analysis
- Green – lake surface temperature computed with FLake

FLake in LM: Results from Parallel Experiment
1 – 30 May 2004



- Lake Unden, Sweden (mean depth = 30.7 m)
- Red – lake surface temperature from LM SST analysis
- Green – lake surface temperature computed with FLake

FLake in LM: Results from Parallel Experiment
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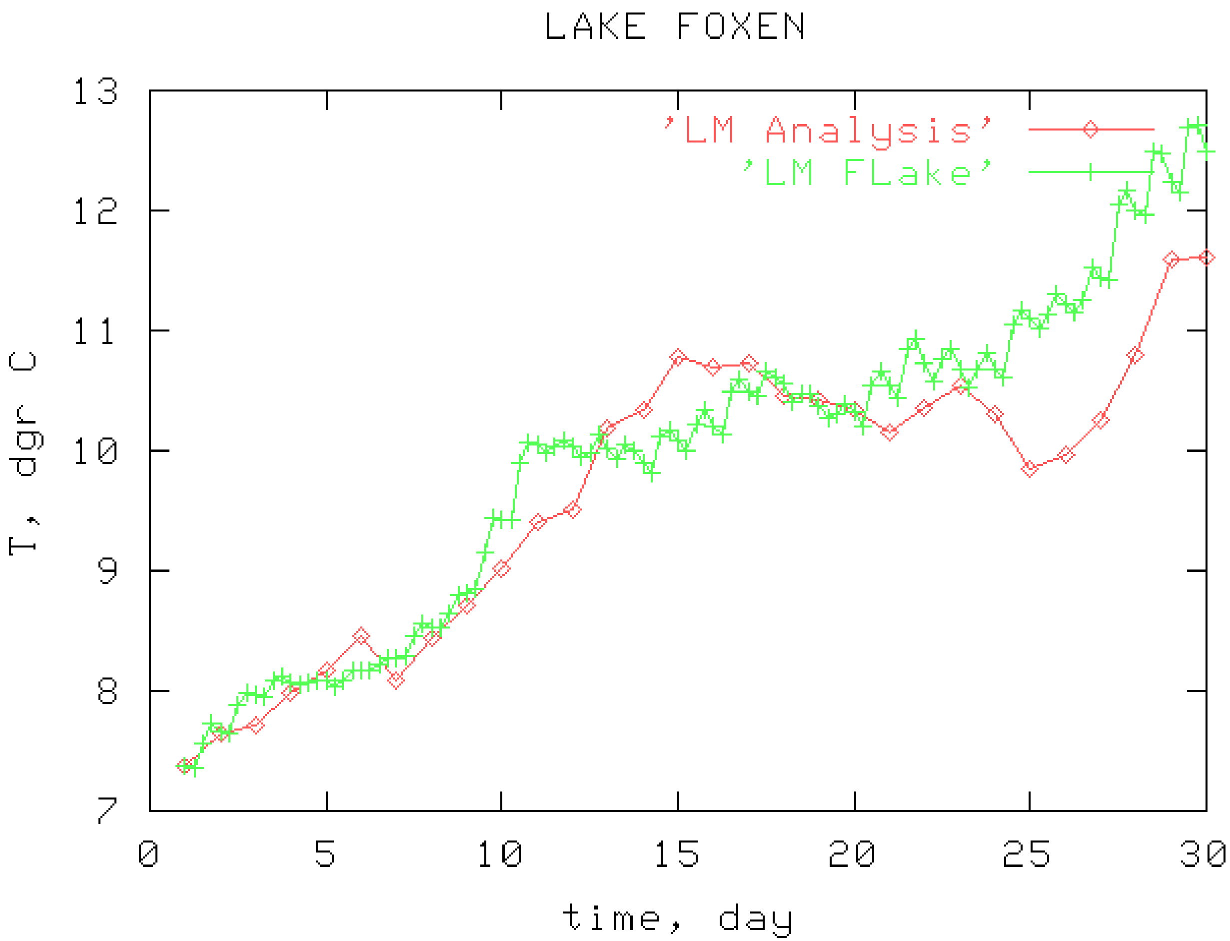
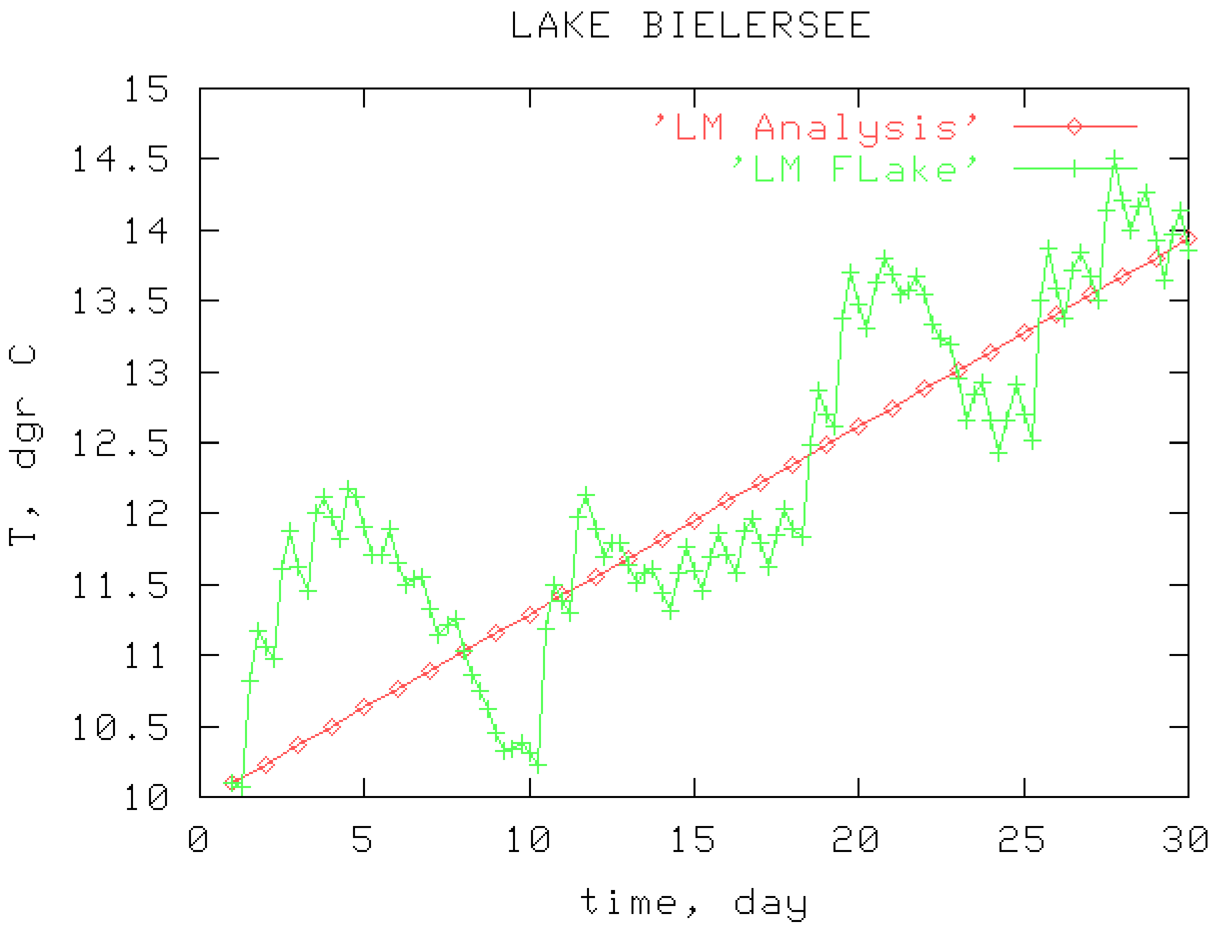


- Lake Foxen, Sweden (mean depth = 21.0 m)
- Red – lake surface temperature from LM SST analysis
- Green – lake surface temperature computed with FLake

FLake in LM: Results from Parallel Experiment
1 – 30 May 2004



- Bielersee, Switzerland (mean depth = 32.0 m)
- Red – lake surface temperature from LM SST analysis
- Green – lake surface temperature computed with FLake

FLake in LM: the Spin-Up Problem

- Lakes have a long memory: wrong initial conditions result in wrong heat content and in wrong water-surface temperature until the memory is faded. This may last up to a year.
- Observations offer water-surface temperature, whereas the vertical temperature structure (mean temperature of the water column, bottom temperature, mixed-layer depth) is unknown.

A Way Out

- generate forcing for the entire yearly cycle, e.g. using monthly-mean data from the GME data bank
- set-up a single-column run (computationally cheap!) with arbitrary (!) initial conditions
- repeat a year-long integration cyclically until a perpetual-year periodic solution is obtained; such solution corresponds the climatological-mean state of a given lake
- take initial conditions for the LM cold start from that perpetual-year solution

Conclusions

- The lake model FLake shows a satisfactory performance in single-column experiments
- The 2D external-parameter fraction-lake field consistent with the LM land-sea mask is developed using the global GLCC data set with 30 arc sec horizontal resolution
- FLake is implemeted in LM, results from test runs look reasonable
- The 2D external-parameter lake-depth field is developed for the current DWD LM configuration

Outlook

- Comprehensive data set (global, or at least European), containing lake depths - this seems to be a serious problem
- Initial data for the LM-FLake cold start

Acknowledgements: EU Commissions, Project INTAS-01-2132.

Acknowledgements

Michael Buchhold, Thomas Hanisch, Peter Meyring, Van Tan Nguyen, Ulrich Schättler, Christoph Schraff (DWD), Sergey Golosov (IL, St. Petersburg), Ekaterina Kourzeneva (RSHU, St. Petersburg), Arkady Terzhevizk (NWPI, Petrozavodsk), Anders Ullerstig (SMHI, Norrköping), Burkhardt Rockel (GKSS, Geesthacht), and

Günther Doms