Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Lake Parameterization Scheme *FLake* in NWP Models COSMO and ICON: Status and Plans

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Outline

- Lake parameterization scheme FLake
- FLake within NWP models COSMO and ICON, first operational ICON results
- Critical issues
- Future work

The Lake Parameterization Scheme “FLake”

The scheme (Mironov 2008, Mironov et al. 2010, Kirillin et al. 2011) is based on the idea of self-similarity (assumed shape) of the evolving temperature profile. 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*** (variables) that specify the temperature profile. These are (optional modules)

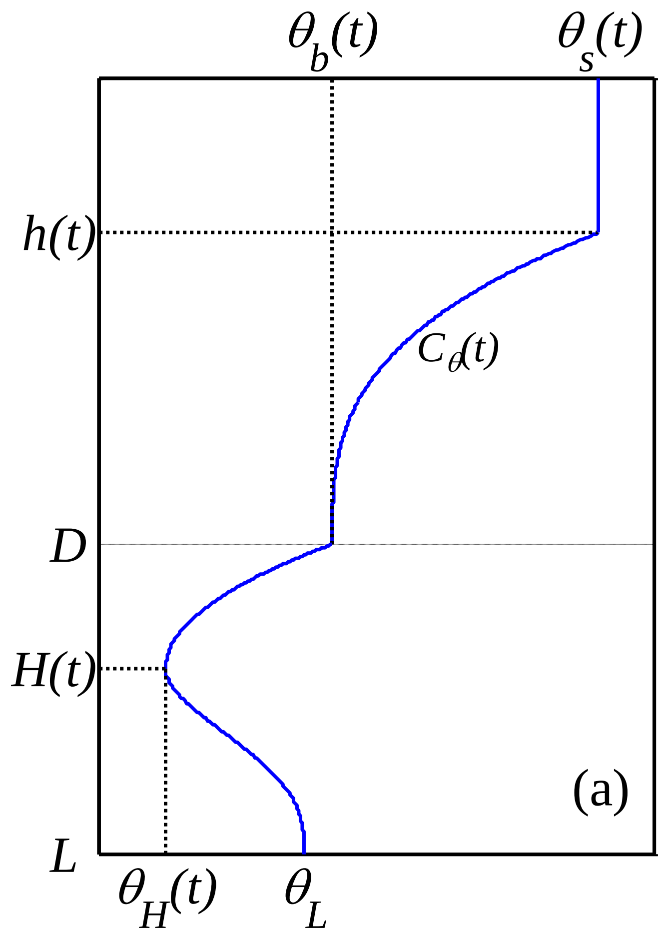
- the mean temperature of the water column,
- the surface temperature,
- the bottom temperature,
- the mixed-layer depth,
- the shape factor with respect to the temperature profile in the thermocline,
- the depth within bottom sediments penetrated by the thermal wave, and
- the temperature at that depth.

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

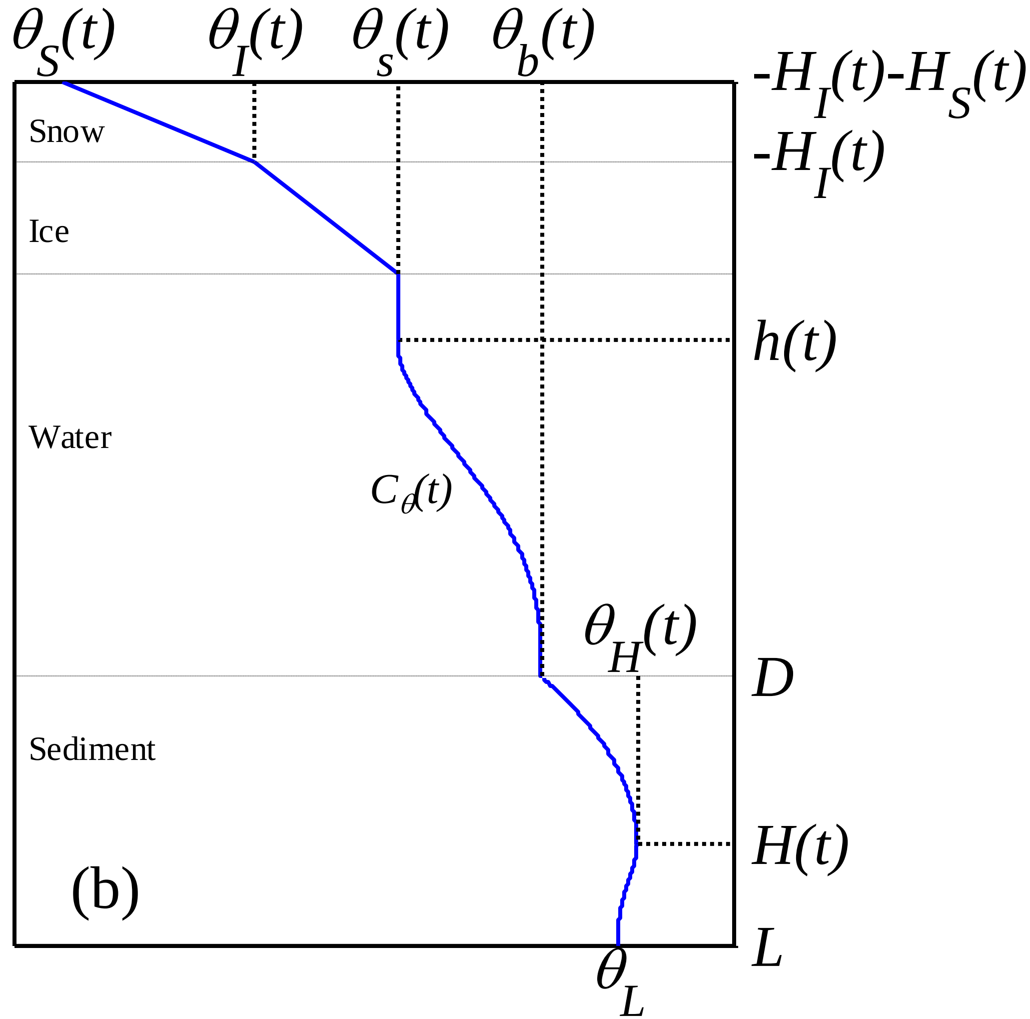
- the ice depth,
- the temperature at the ice upper surface,
- the snow depth, and the temperature at the snow upper surface.

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

Schematic representation of the evolving temperature profile



(a) The evolving temperature profile is characterised by several time-dependent variables, namely, the temperature $\theta_s(t)$ of the mixed layer, its depth $h(t)$, the bottom temperature $\theta_b(t)$, and the temperature-profile shape factor $C_\theta(t)$. Optionally, the depth $H(t)$ within bottom sediments penetrated by the thermal wave and the temperature $\theta_H(t)$ at that depth can be computed.



(b) For ice-covered lakes, additional variables are the temperature $\theta_I(t)$ at the ice upper surface and the ice thickness $H_I(t)$, and (optionally) the temperature $\theta_S(t)$ at the snow upper surface and the snow thickness $H_S(t)$.

FLake in NWP and Climate Models: External Parameters

- **lake fraction** (area fraction of an atmospheric model grid box covered by lake water)
- **lake depth**

Data set is developed by Kourzeneva (2010), Kourzeneva et al. (2012), and Choulga et al. (2014).

- Default values of wind fetch, optical characteristics of lake water (extinction coefficients with respect to solar radiation), depth of the thermally active layer of bottom sediments and temperature at that depth (not needed if bottoms sediment module is switched off)

FLake within COSMO and ICON

- Bottom sediment module is switched off (bottom heat flux is zero), maximum lake depth of 50 m
- Snow above the lake ice is not considered explicitly, the effect of snow is accounted for implicitly through the temperature dependence of the ice surface albedo (Mironov et al. 2012)
- Turbulent fluxes at the surface are computed with the current COSMO-model surface-layer scheme (Raschendorfer 2001)
- No tile approach in COSMO: lakes are the COSMO-model grid-boxes with FR_LAKE>0.5, otherwise land or sea water
- Tile approach in ICON: all lakes with FR_LAKE>0.03 are considered

FLake within COSMO and ICON (cont'd)

- No observational data are assimilated into FLake
- Freeze-up and break-up of lakes occurs freely
- No fractional ice cover over lakes

Cf. COSMO/ICON-NWP sea-ice scheme (Mironov et al. 2012):

- prognostic equations for $h_i(t)$ and $\theta_i(t)$ but no new ice is created (ocean is not allowed to freeze up itself),
- horizontal distribution of sea ice is subordinate to data assimilation scheme that delivers ice fraction f_i for each COSMO/ICON grid box,
- no ice if f_i is small (remove leftover as needed),
- h_i and θ_i are initialized with ad hoc values if there was no ice but data indicate it is present.

FLake within COSMO-EU/DE (DWD)

<u>Flake is used operationally</u> at DWD since 15 December 2010 within COSMO-EU (ca. 7 km horizontal mesh size), and since 18 April 2012 within COSMO-DE (ca. 2.8 km mesh size).

- Results of testing of COSMO-FLake are neutral to slightly positive.
- Verification against observational data indicate an improvement of some scores such as 2m-temperature in regions where many lakes are present (e.g. Scandinavia).
- The use of FLake allows to avoid some unwanted situations, e.g. an artificial cold air outbreak. This may occur in winter when a lake that is frozen in reality (low surface temperature) is treated as open water (high surface temperature) within COSMO due to the shortcomings of water surface temperature analysis scheme.

FLake within ICON-NWP (DWD)

Flake is used operationally at DWD since 20 January 2010 within ICON-NWP (ca. 13 km horizontal mesh size)

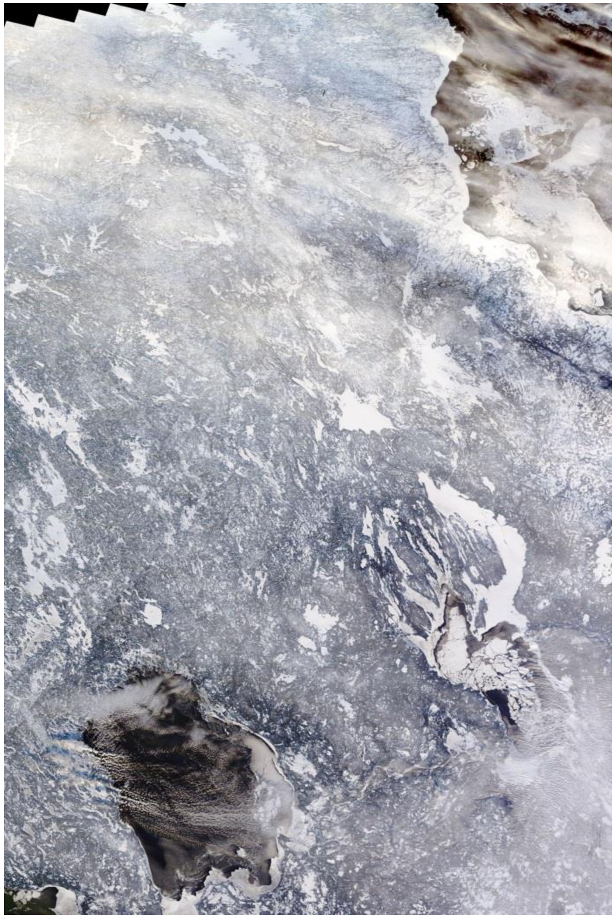
- Tiled surface scheme is currently used, effect of SGS lakes with FR_LAKE>0.03 is accounted for

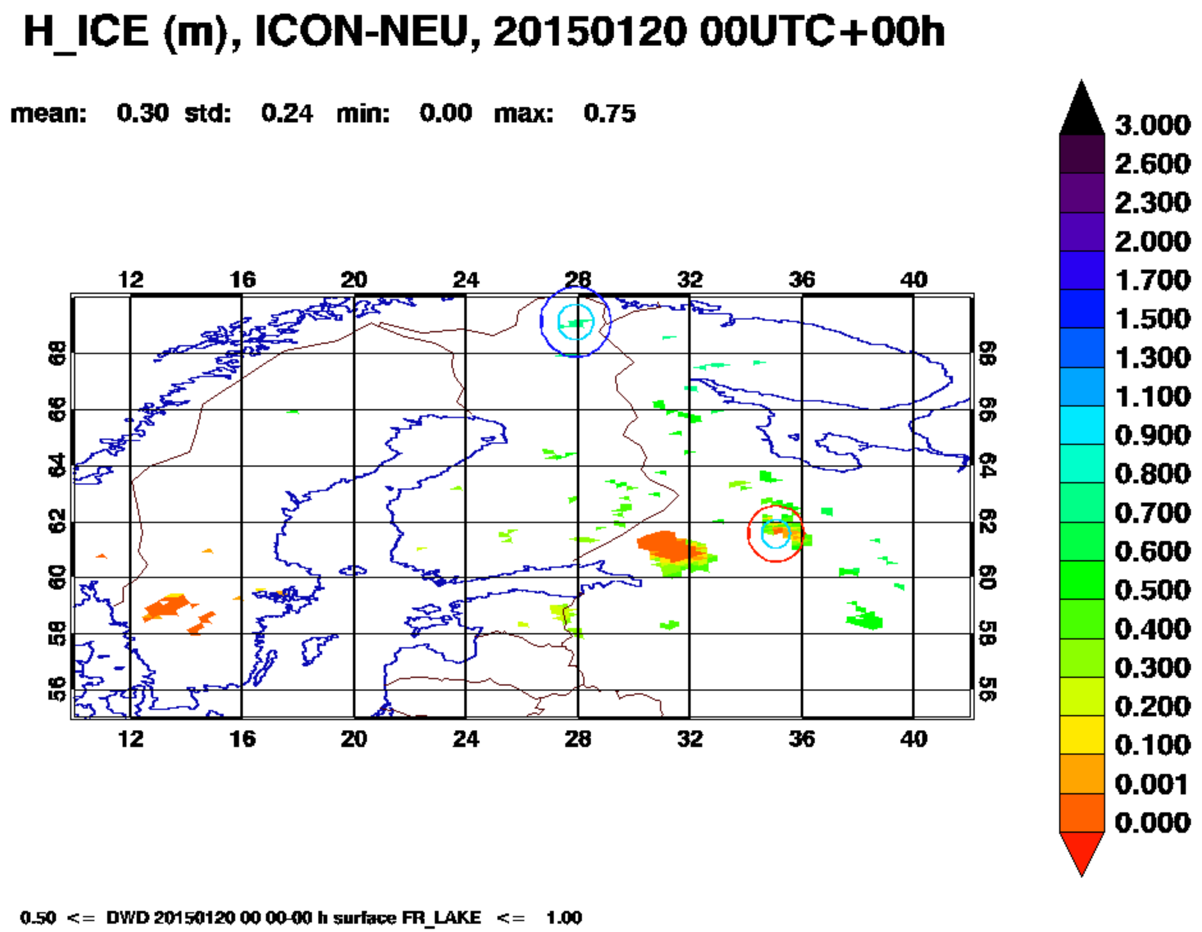
- The performance of FLake within ICON (and COSMO) is monitored

Monitoring of FLake Performance

- FLake prognostic variables (+ FR_ICE and surface fluxes) are retrieved from the DWD data bank (initial values form 00 UTC) and plotted
- Sanity check is performed and a warning e-mail message is sent if things go wrong (OK is sent if things look good)
- Monitoring results from the last week are available via DWD Intranet, results from the last months are stored in the archive

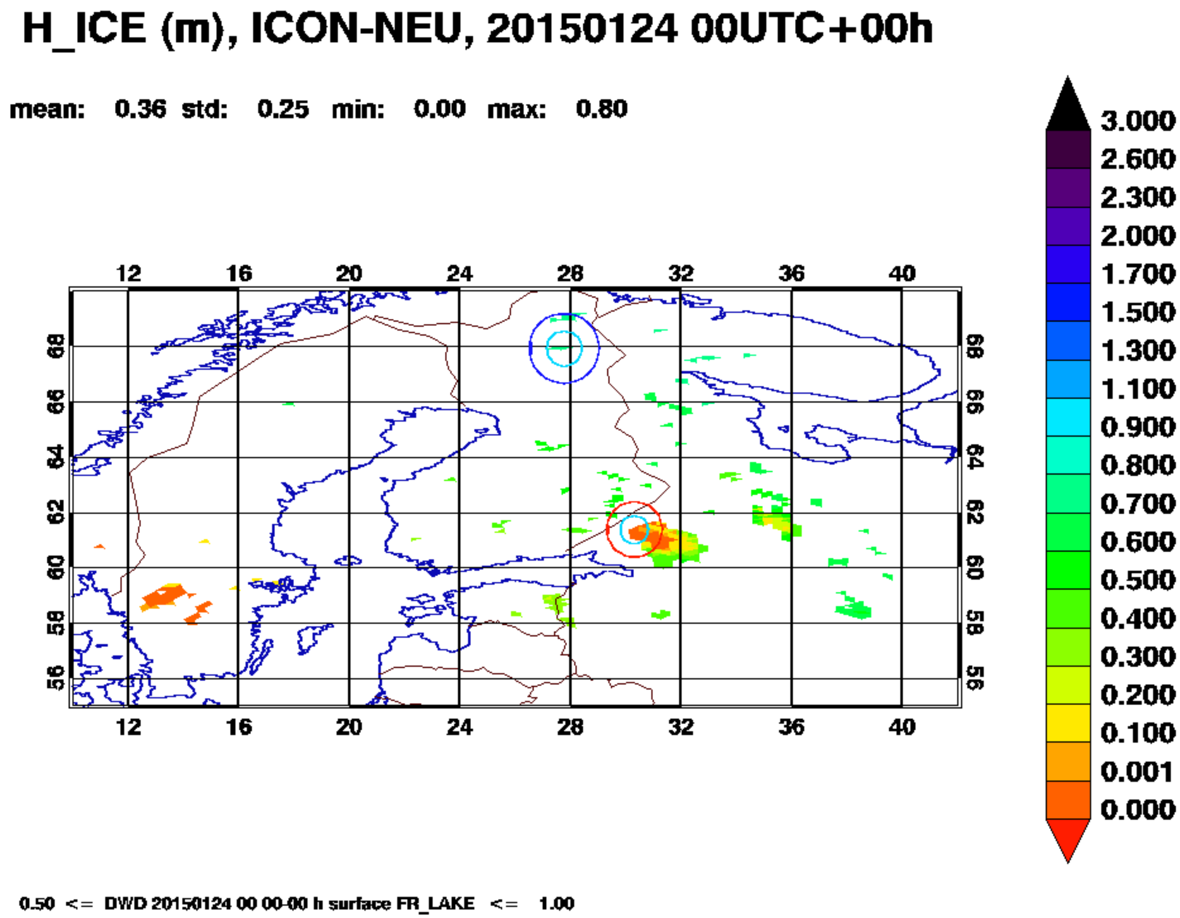
ICON-NWP Results vs. Observations





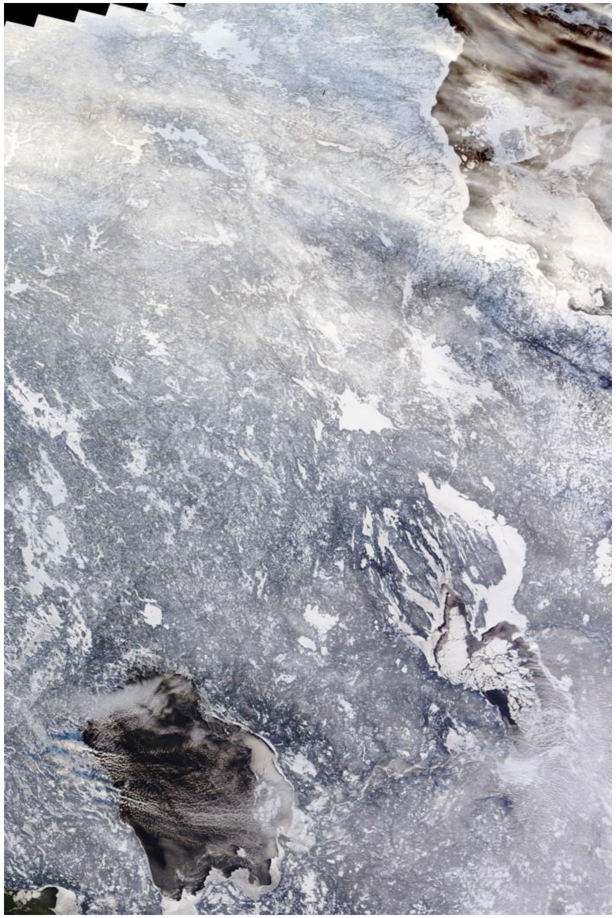
Lake Ladoga and Lake Onega ice cover, 20 January 2015. Satellite data (http://lance-modis.eosdis.nasa.gov/imagery/subsets/?subset=Karelia.2015020.terra.250m.jpg) vs. ICON forecast.

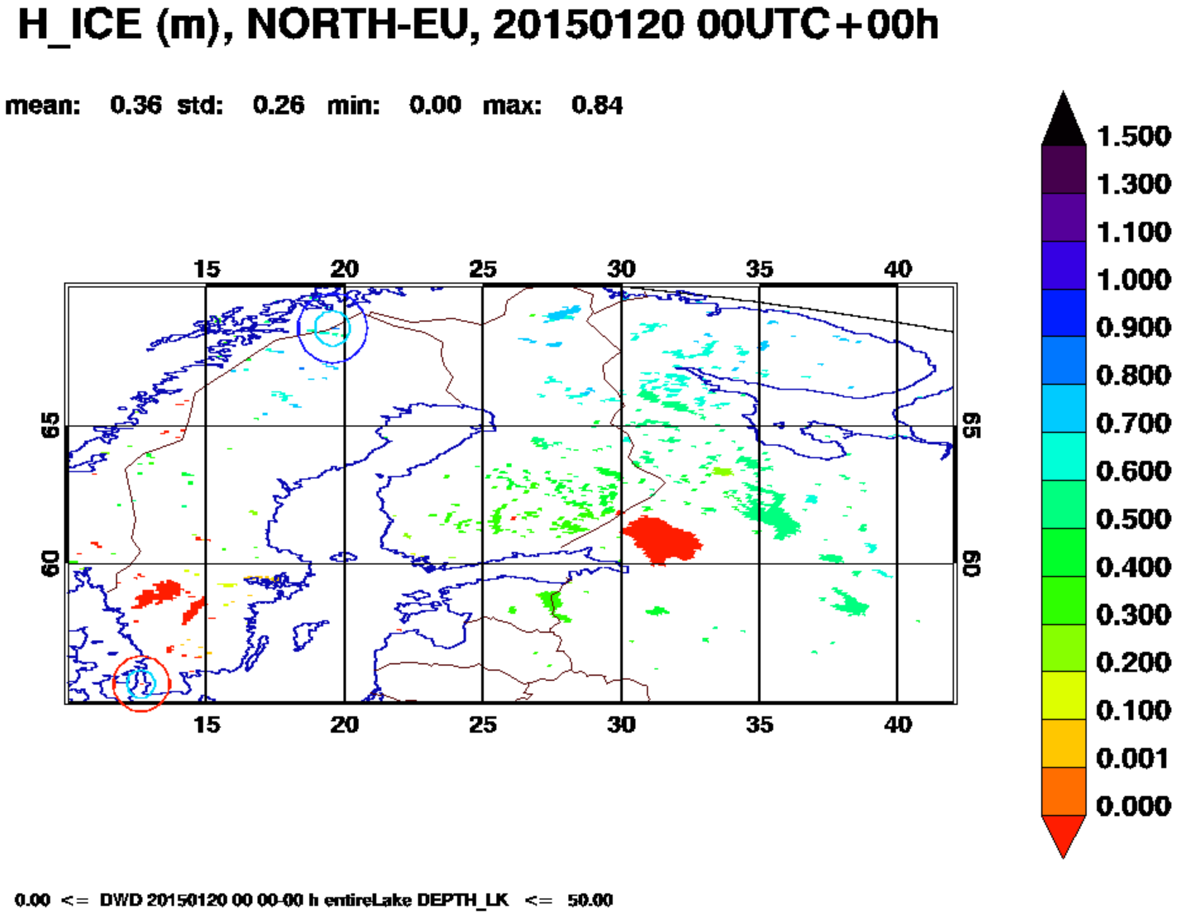
ICON-NWP Results vs. Observations



Lake Ladoga and Lake Onega ice cover, 24 January 2015. Satellite data (http://lance-modis.eosdis.nasa.gov/imagery/subsets/?subset=Karelia.2015024.terra.250m.jpg) vs. ICON forecast.

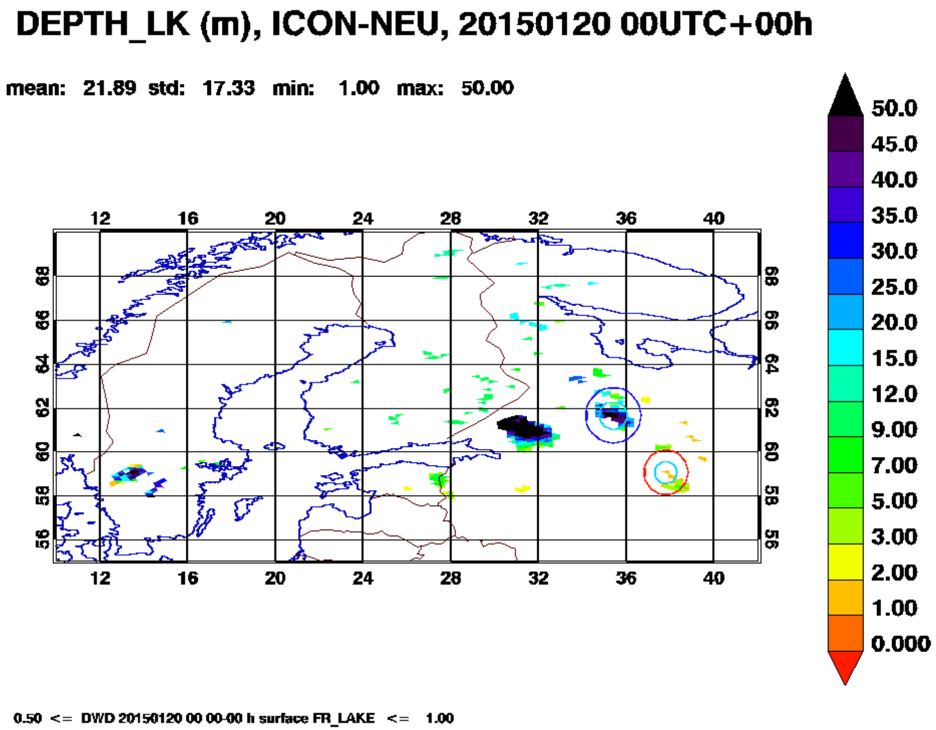
Importance of External Parameters

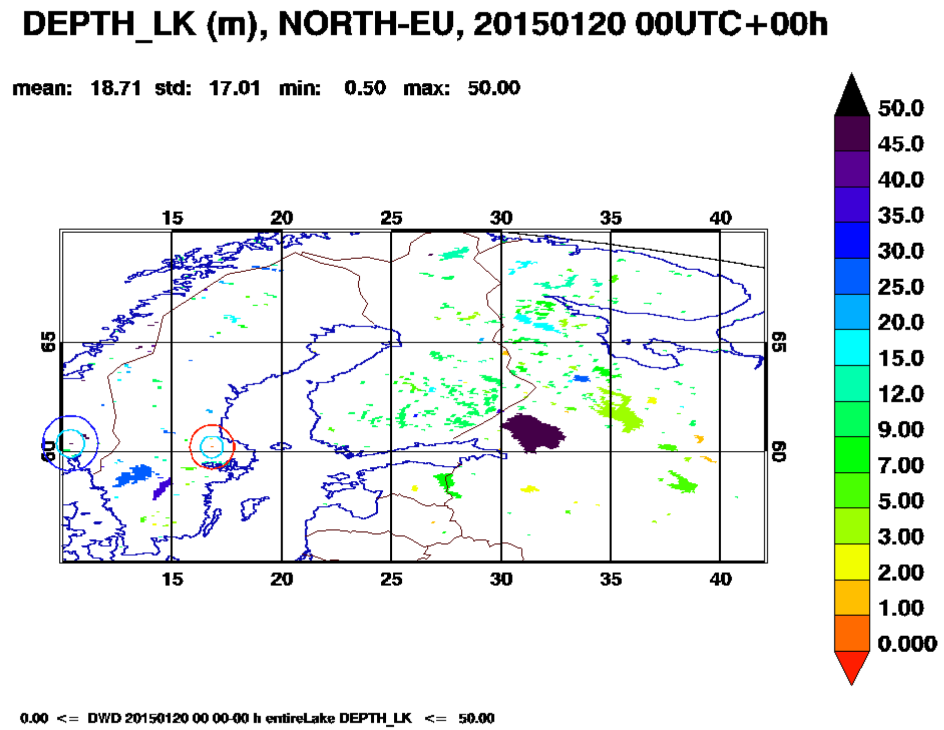




Lake Ladoga and Lake Onega ice cover, 20 January 2015. Satellite data (http://lance-modis.eosdis.nasa.gov/imagery/subsets/?subset=Karelia.2015020.terra.250m.jpg) vs. COSMO-EU forecast.

Importance of External Parameters (cont'd)



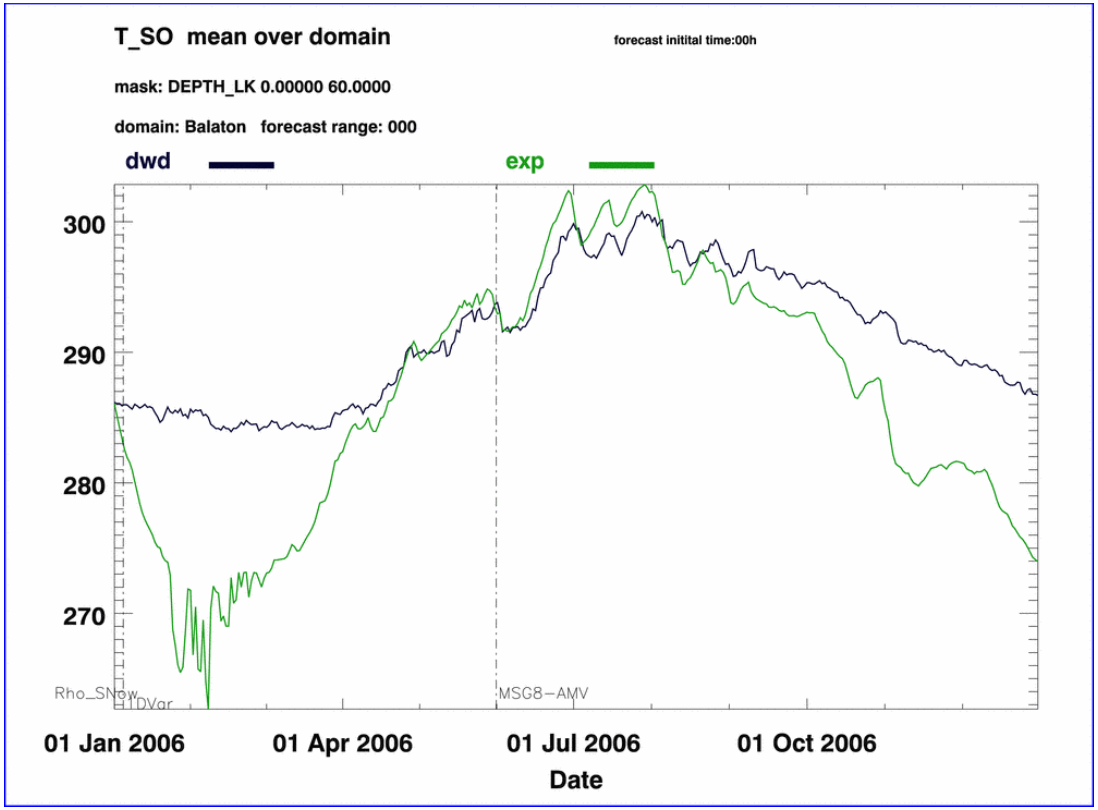


Lake-depth external-parameter field

in ICON – left left and COSMO-EU – right

(Kourzeneva 2010, Kourzeneva et al. 2012, Choulga et al. 2014).

Verification of Operational Results



Can we plot data from “operational-type” observations, at least for some lakes?

FLake in COSMO, results from parallel experiment, 1 January - 31 December 2006.
Lake Balaton, Hungary (mean depth = 3.3 m)

- Black – lake surface temperature from the COSMO SST analysis
- Green – lake surface temperature computed with FLake

Future Work: Explicit Treatment of Snow

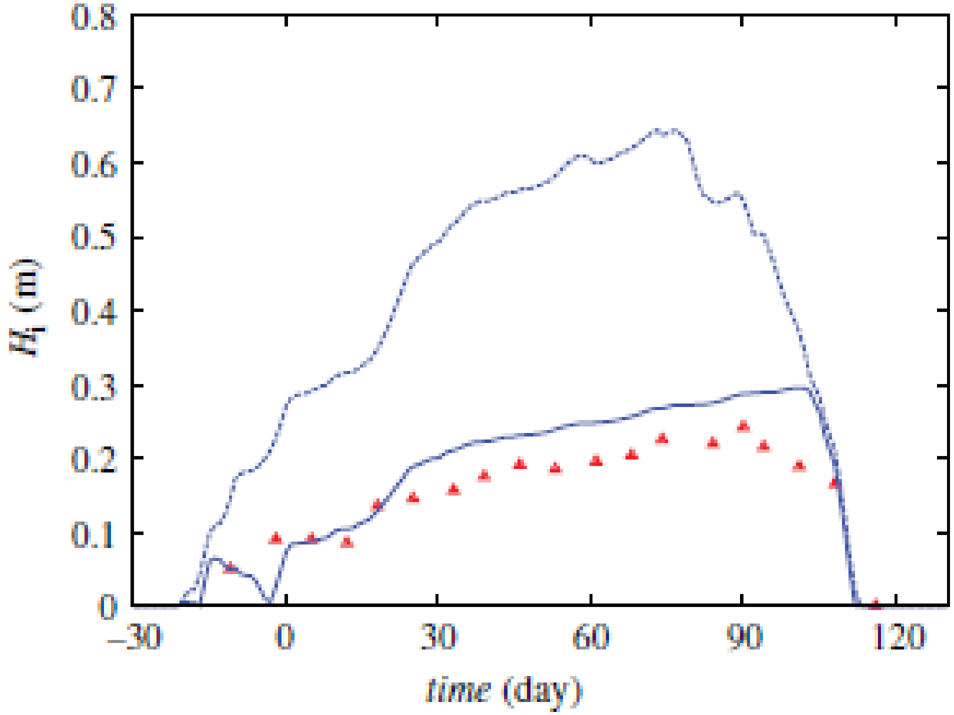


Fig. 9. Ice thickness in Lake Pääjärvi during winter 1999–2000, where day = 0 corresponds to 1 January 2000. Blue curves show results of simulations with FLake: solid curve – with a snow layer above the ice, and dashed curve – no snow above the ice. Red symbols show observational data.

Results of simulations with tuned snow density and snow heat conductivity (Mironov et al. 2012).

Future Work: Extension to Salt Water

Work started (c/o DM), however… there are issues that require research efforts

- Equation of state (cf. salinity in the ocean)
- Bottom boundary condition for salt concentration
- Initial conditions (e.g. total amount of salt in lake)
- Lake water budget

Conclusions

- Lake parameterization scheme FLake is implemented into COSMO and ICON-NWP and used operationally
- Results look satisfactory so far

- Monitor and verify operational results
- Update external-parameter fields

Medium-term prospects:

- explicit treatment of snow over sea and lake ice (a bulk snow model is advantageous for NWP)
- extension of FLake to salt water

Thank you for your attention!

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Info

FLake Web Page http://lakemodel.net (mirror http://nwpi.krc.karelia.ru/flake),

c/o Georgiy Kirillin and Arkady Terzhevik

Online FLake version at http://lakemodel.net (take a look and have fun!)

References

Kirillin, G., J. Hochschild, D.Mironov, A. Terzhevik, S.Golosov, and G. Nützmann, 2011: FLake-Global: Online lake model with worldwide coverage. *Environ. Modell. Softw.*, **26**, 683-684.

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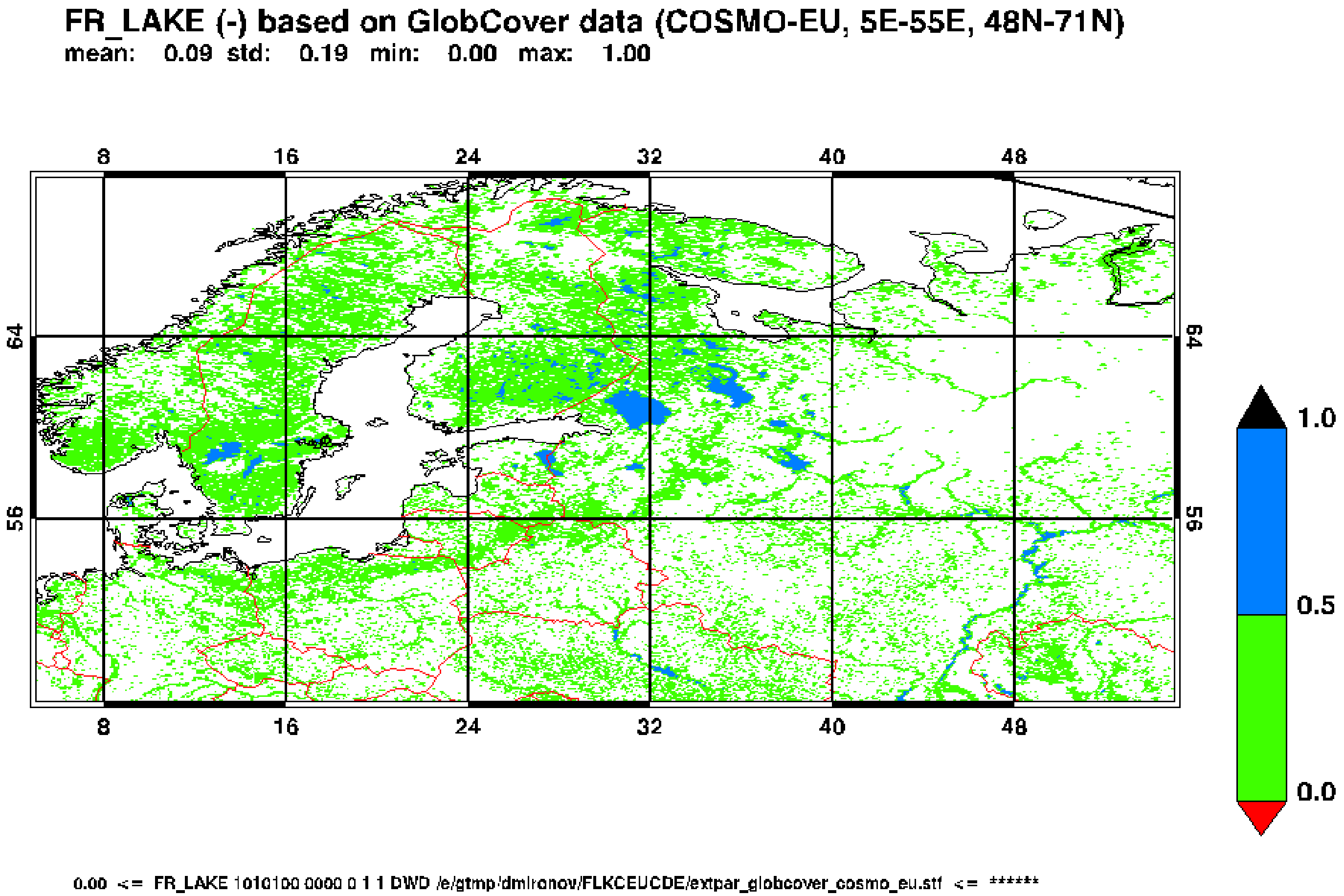
Mironov, D., B. Ritter, J.-P. Schulz, M. Buchhold, M. Lange, and E. Machulskaya, 2012: Parameterization of sea and lake ice in numerical weather prediction modelsof the German Weather Service. Accepted for publication in *Tellus A*.

Further references at http://lakemodel.net

External parameters and tiled surface scheme



The lake-fraction external-parameter field based on the lake-depth data from Kourzeneva (2010) and GlobCover physiographic data. The horizontal size of the COSMO-model grid is ca. 7 km.