FRESHWATER CENTRE

Lakes
Watershed Simulation and Forecasting System
WSFS
www.environment.fi/waterforecast

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SYKE

Third Workshop on Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling

Finnish Meteorological Institute, Helsinki, September 18-20 2012

S Y K E

Lake surface temperature

- Lake surface temperature to improve lake evaporation simulation
- Simple equation by Lindström et.al. (*):

$$T(t) = (1-k) \cdot T(t-1) + k \cdot T_{air}(t)$$

k is a parameter, calibrated using observations of lake surface temperature

*) Lindström, G., Gardelin, M. and Persson, M. 1994. *Conceptual modeling of evapotranspiration for simulations of climate change effects*. SMHI RH No. 10, 25 p

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Improved model

- Simple model poor in midsummer:
  too low temperatures
- Supposed to be mainly due to radiation energy from the sun, and was added as follows:

$$T(t) = (1-k)\cdot T(t-1) + k\cdot (T_{air}(t) + r(t)\cdot l)$$

r(t) = intensity of the short-wave radiation

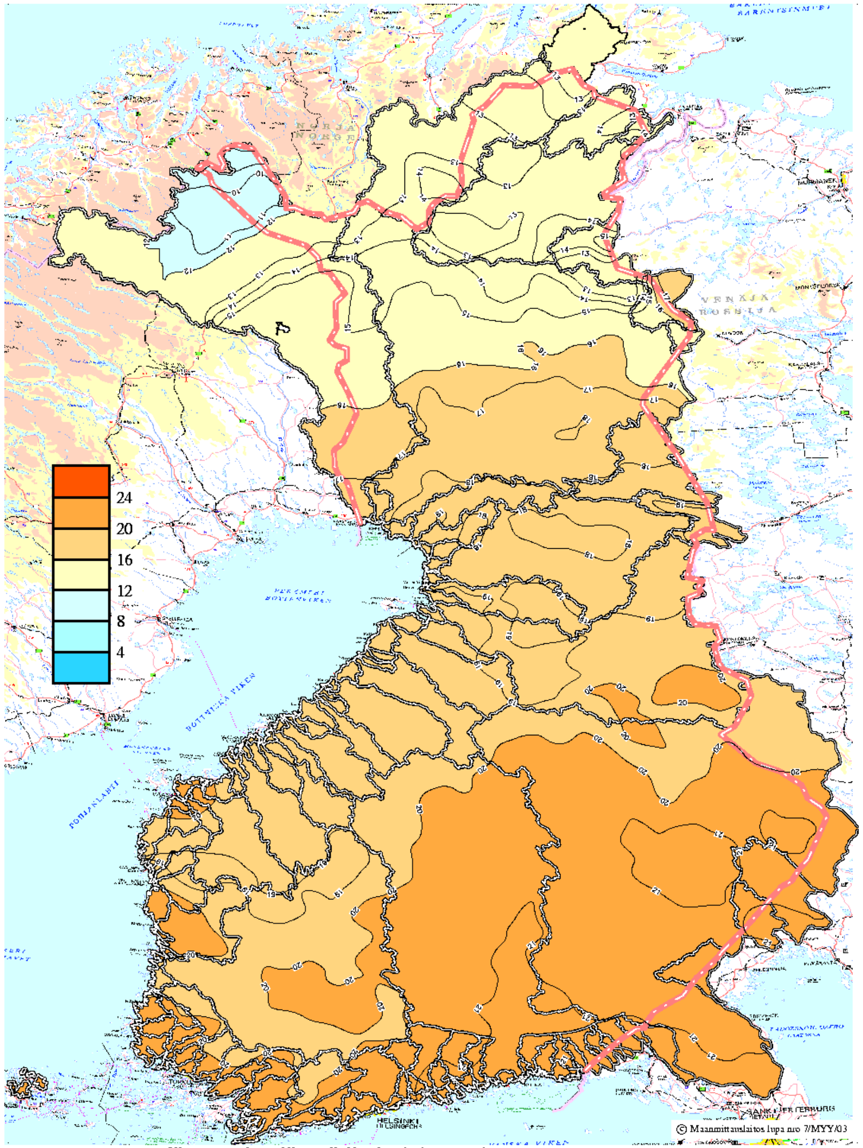
l = influence of the short-wave radiation on lake surface warming

Implementation

- Parameters calibrated using lake surface observations over a long (30-40 y) period for 30 lakes.
- Additionally there is a large number of observation points in rivers for some of which the same model is calibrated and used operationally
- The lake and river temperature results are presented as graphs and as maps.

Simulated lake surface temperature 1.8.2012

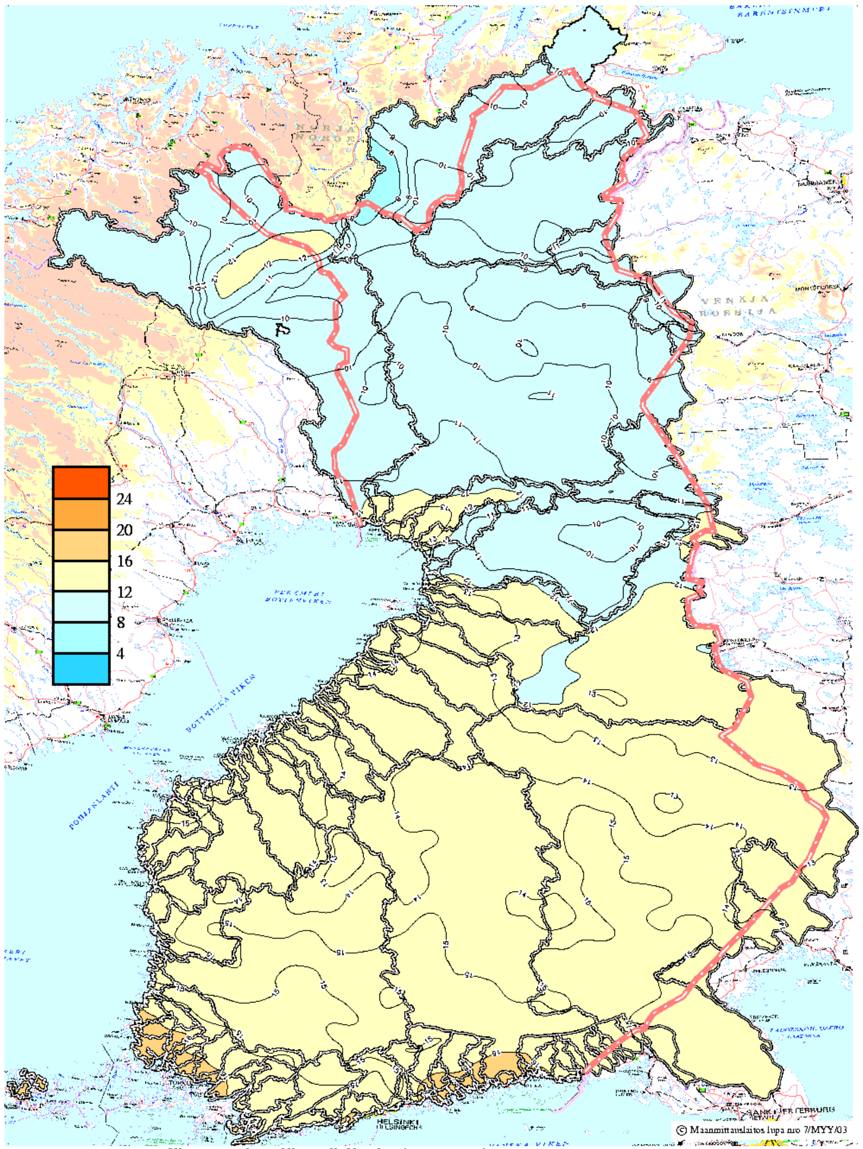
Vesistömallijärjestelmä - SYKE-WSFS Watershed models



Järven pintalämpötila (°C) 1. 8.2012
Forecast day 1. 8.
Lake surface temperature (°C) 1. 8.2012

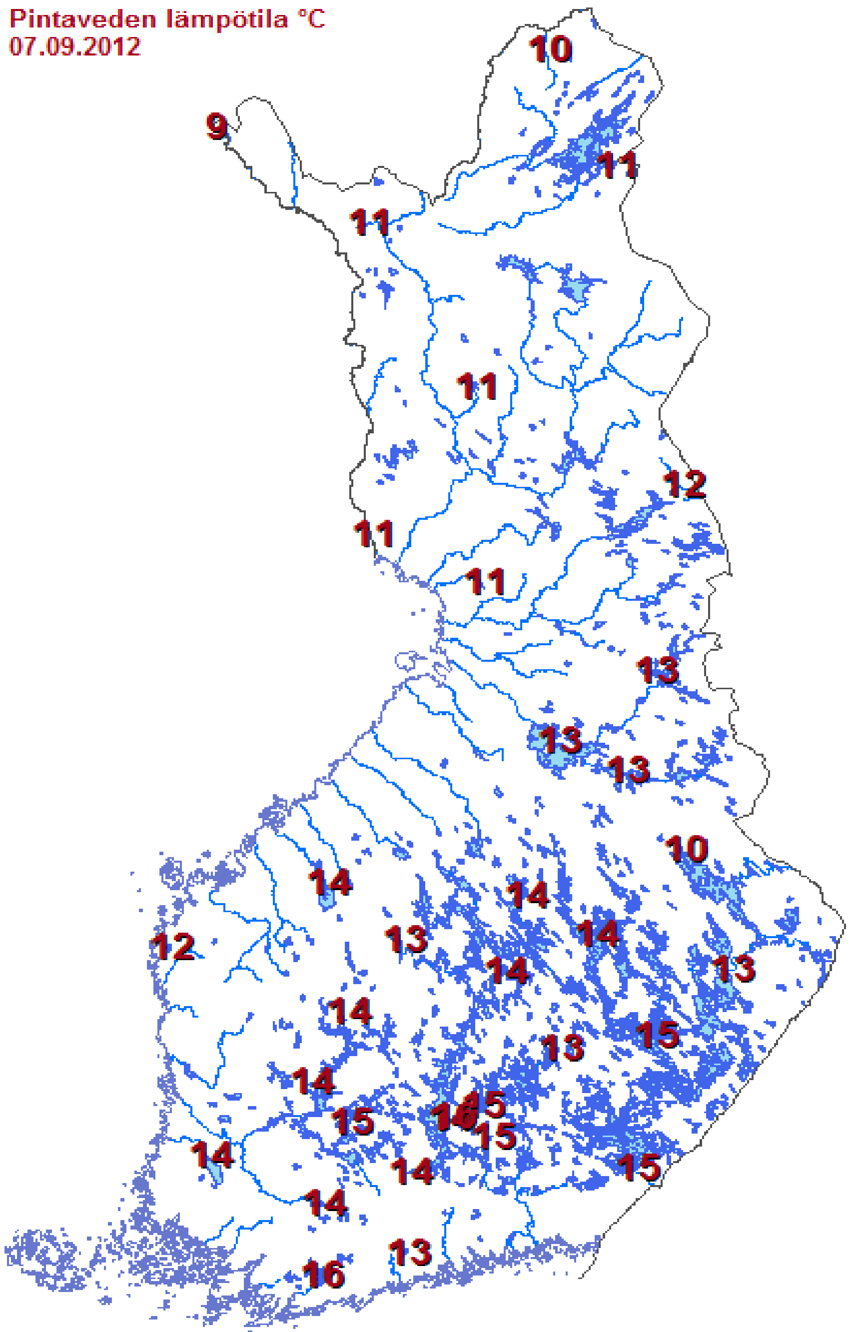
Simulated lake surface temperature 7.9.2012

Vesistömallijärjestelmä - SYKE-WSFS Watershed models



Järven pintalämpötila (°C) 7. 9.2012
Forecast day 7. 9.
Lake surface temperature (°C) 7. 9.2012

Observations and observation sites 7.9.2012



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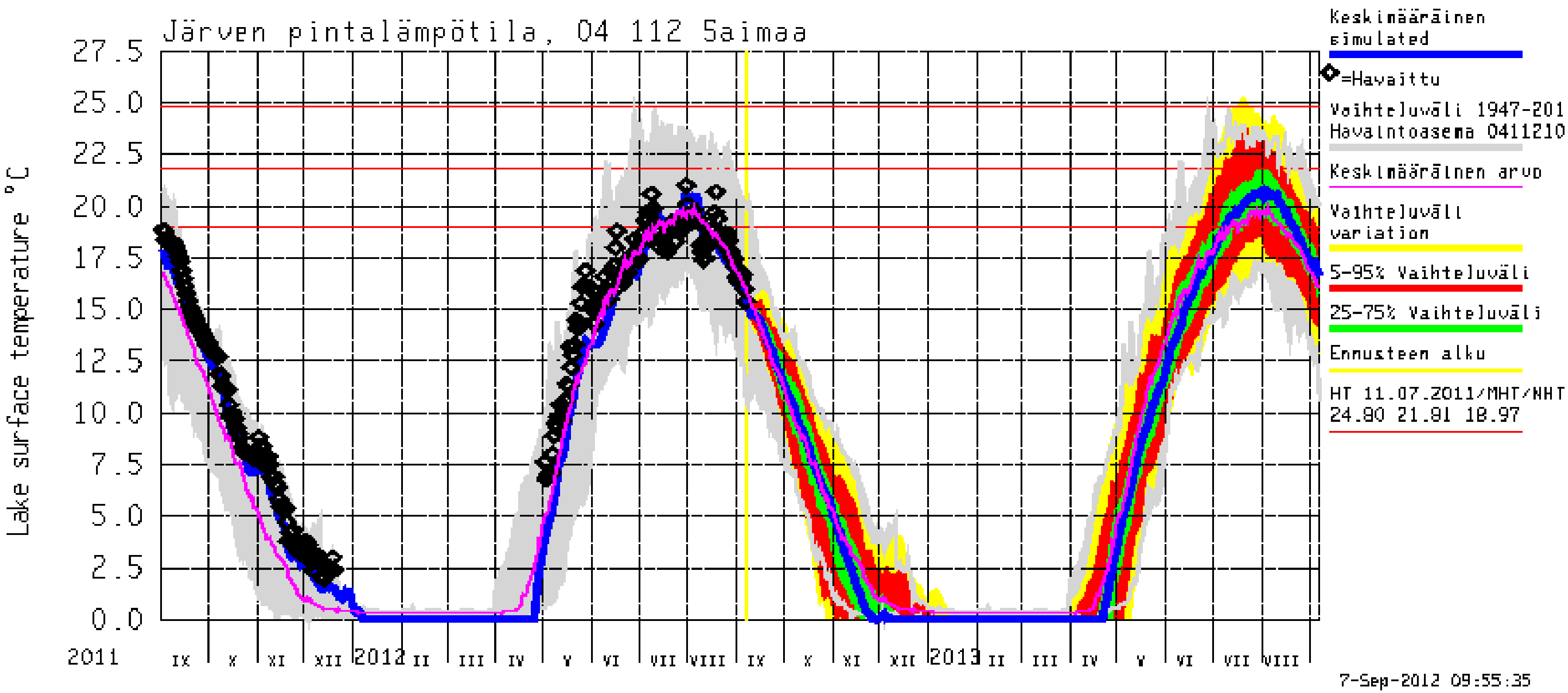
Lake Saimaa, surface temperature



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Lake evaporation

- Input: lake surface temperature , short - wave radiation index and precipitation
- Short-wave radiation by latitude and date
- Precipitation included to indicate cloudiness and high relative humidity
- Approach is more statistical than physical.

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- Method was used to simulate potential evaporation measured by Class A –pans.
- Class A evaporation calculated by air temperature, short-wave radiation and precipitation; calibrated against long -time observation series
- Same dependencies were applied to lake evaporation, replacing air temperature by lake surface temperature.

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Physical lake evaporation model

- Dalton's equation (Aerodynamic formula)

$$Q_e = \rho_a C_e (q_s - q_a) U_a$$

  - q_s and q_a are specific humidities at lake surface and air 2m level
  - U_a is wind speed
  - C_e is bulk transfer coefficient
  - P_a is air density
- Affecting factors
  - Air temperature
  - Lake surface temperature
  - Wind speed
  - Relative humidity
  - Near surface (atmospheric) stratification
    - Difference between air and lake surface temperature
    - Wind speed
    - Surface roughness

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Bulk transfer coefficient (C_e)

Near surface atmospheric stratification according to Launiainen (1995, fig 4.)

- Richardson number (R_z)

$$R_Z = \frac{g}{\theta_s} z_a \frac{\theta_{va} - \theta_{vs}}{{U_a}^2},$$

- Θ_s, Θ_{va} and Θ_{vs} are potentia temperature at surface and virtual potential temperatures at surface and in air
- Surface roughness at lake surface z_a $4*10^{-4}$ (Neutral case $1.56*10^{-3}$)

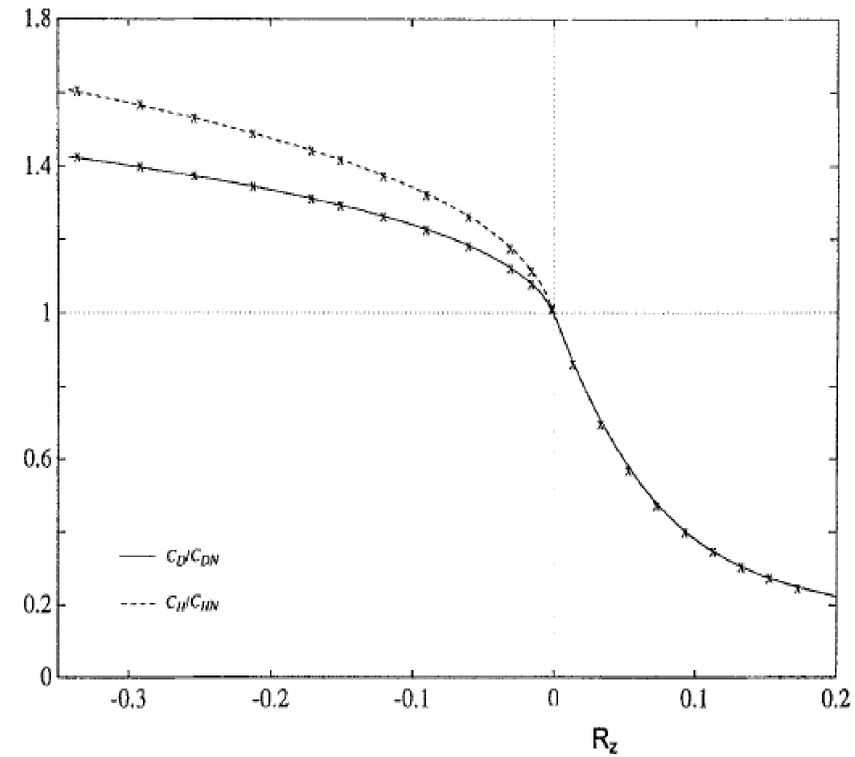

Fig. 4. Drag coefficient and bulk heat transfer coefficient (referred to 10 m) for diabatic cases. The continuous and dashed lines depict the C_D/C_{DN} and C_H/C_{HN} dependences based on iteration, while the crosses are those calculated according to (A5)–(A7) using the ζ from Equations (9) and (11). The roughness lengths used, $z_0 = 10^{-4}$ m and $z_0/z_T = 1$, correspond to the neutral case ($C_{DN} = C_{HN} = 1.2 \times 10^{-3}$).

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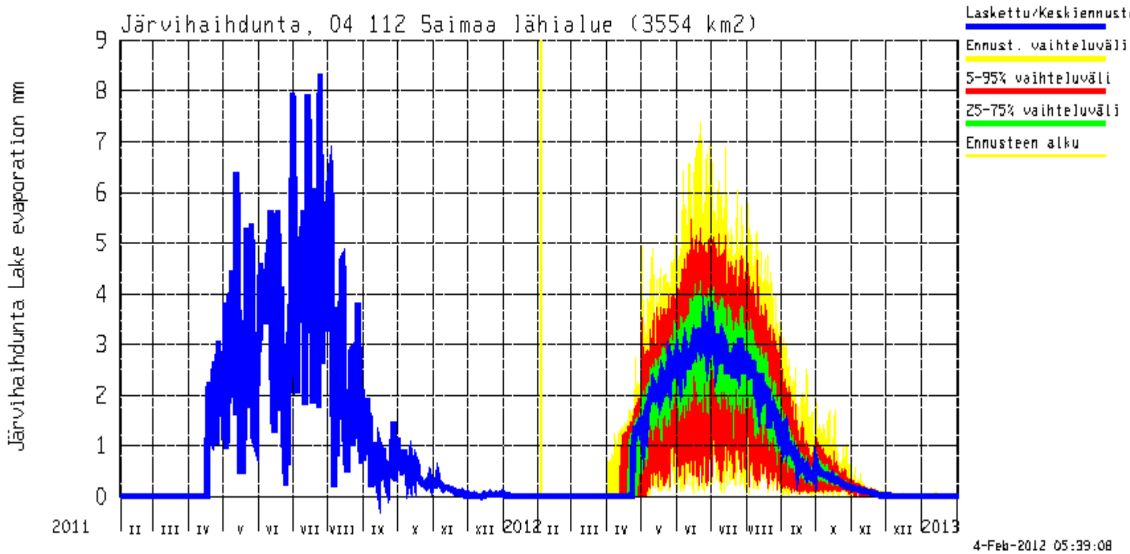
Saimaa lake evaporation



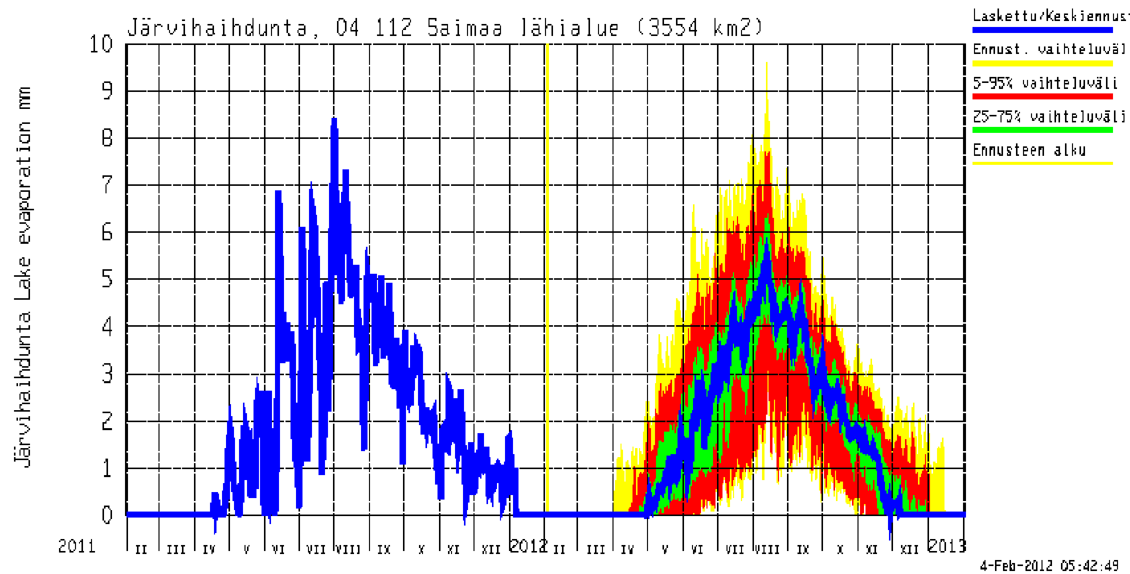
Old method

- Large evaporation in Spring
  ~ 1-3 mm/d in May
- Small evaporation in Autumn
  < 1.5 mm/d in September and October

New method

- Summer and Autumn:
  Evaporation increases
  ~ 2-3 mm/d
- Spring:
  Decreases ~ 2 mm/d

NOTE! Preliminary results , limited amount of wind speed and humidity observations



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Comparison of lake evaporation equations

Evaporation equations

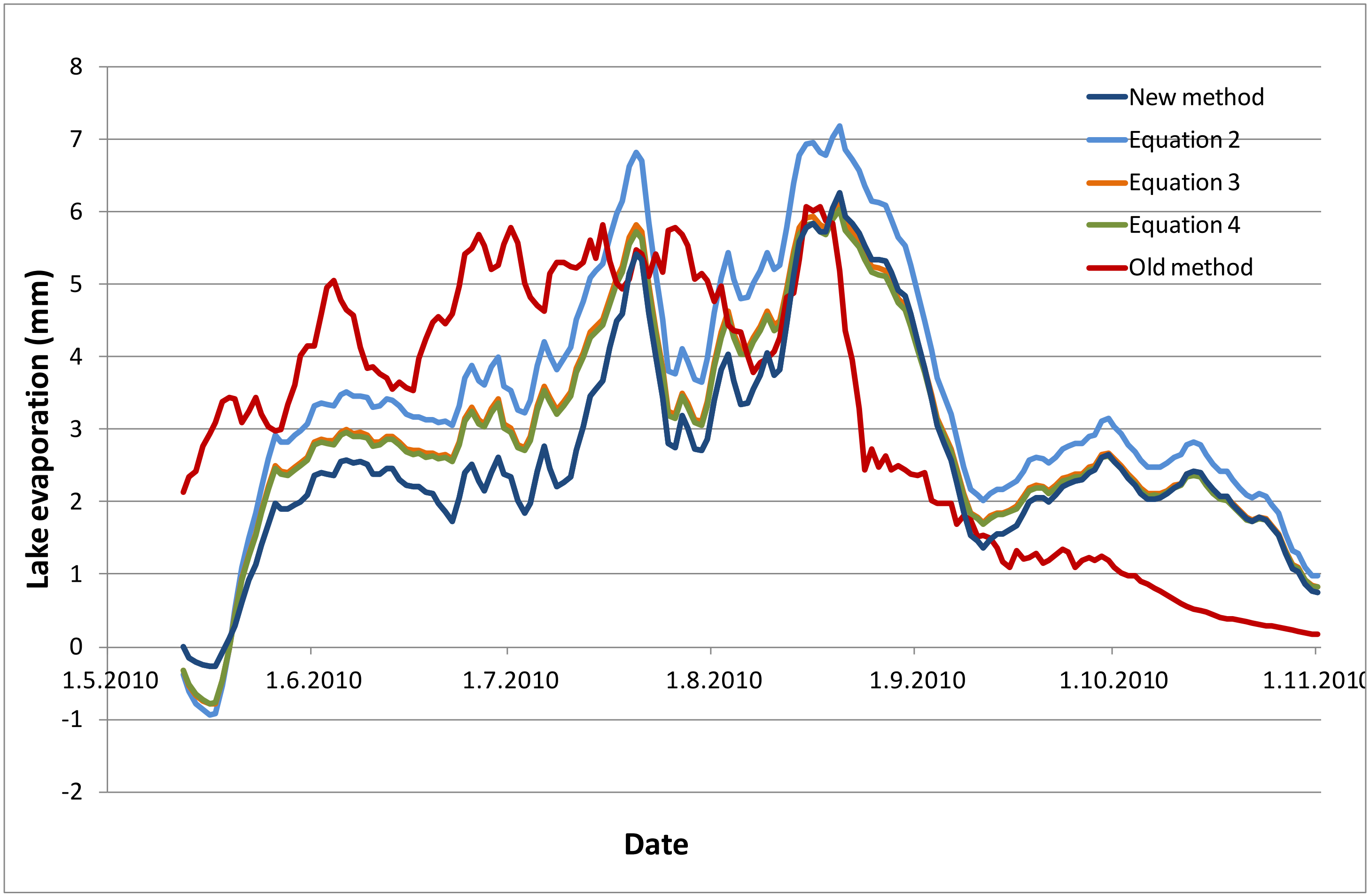
New method = $\rho_a * C_e * (q_0 - q_2) * U_{10}$

Equation 2 = $(0.15+0.108*U_2)(e_0-e_2)$

Equation 3 = $(0.236+0.068*U_2)(e_0-e_2)$

Equation 4 = $(0.127+0.16*U_2^{0.62})(e_0-e_2)$

*Equations 2-4 from Järvinen and Huttula, 1982



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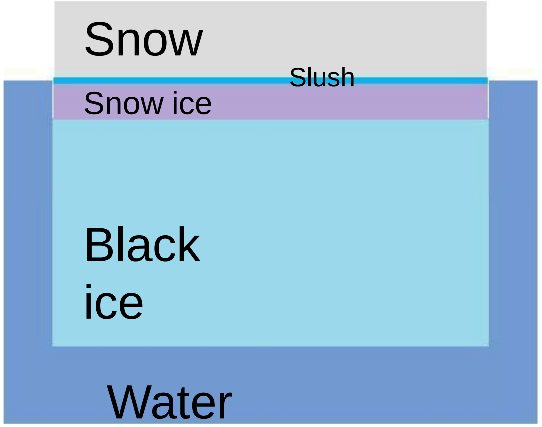
Ice thickness model

- Calculates ice thickness at observation points
  - All lake and river points in Finland
  - Simulates black ice, snow ice, slush and snow on ice
- Ice growth is driven by
  - Air temperature
  - Water temperature (beginning of freezing)
  - Thickness of snow and slush
  - Thickness of snow ice and black ice
- Melting of ice
  - Air temperature, snow



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Ice thickness model

- Ice growth calculated using heat transfer
  - Stefan's equations
  - Snow ice and black ice separately
  - T_a =Air temperature, L =latent heat of water,
  - $h_{i,}$, h_s and h_{si} = thickness of black ice, snow ice and slush
  - ρ_{si} and ρ_i =densitiy of snow ice and ice
  - $k_{i,}$, k_s and k_{si} =heat transfer capacity
  - Indices *i*, *s* and*si* refer to (black) ice, snow and snow ice.
- Melting calculated using degree-day factor

$$\frac{dh_{si}}{dt} = \frac{-k_s T_a}{(h_s + \frac{k_s}{k_{si}} h_{sl})\rho_{si} L}$$

$$\frac{dh_i}{dt} = \frac{-k_i T_a}{(h_i + \frac{k_i}{k_s} h_s + \frac{k_i}{k_{si}} h_{si})\rho_i L}$$

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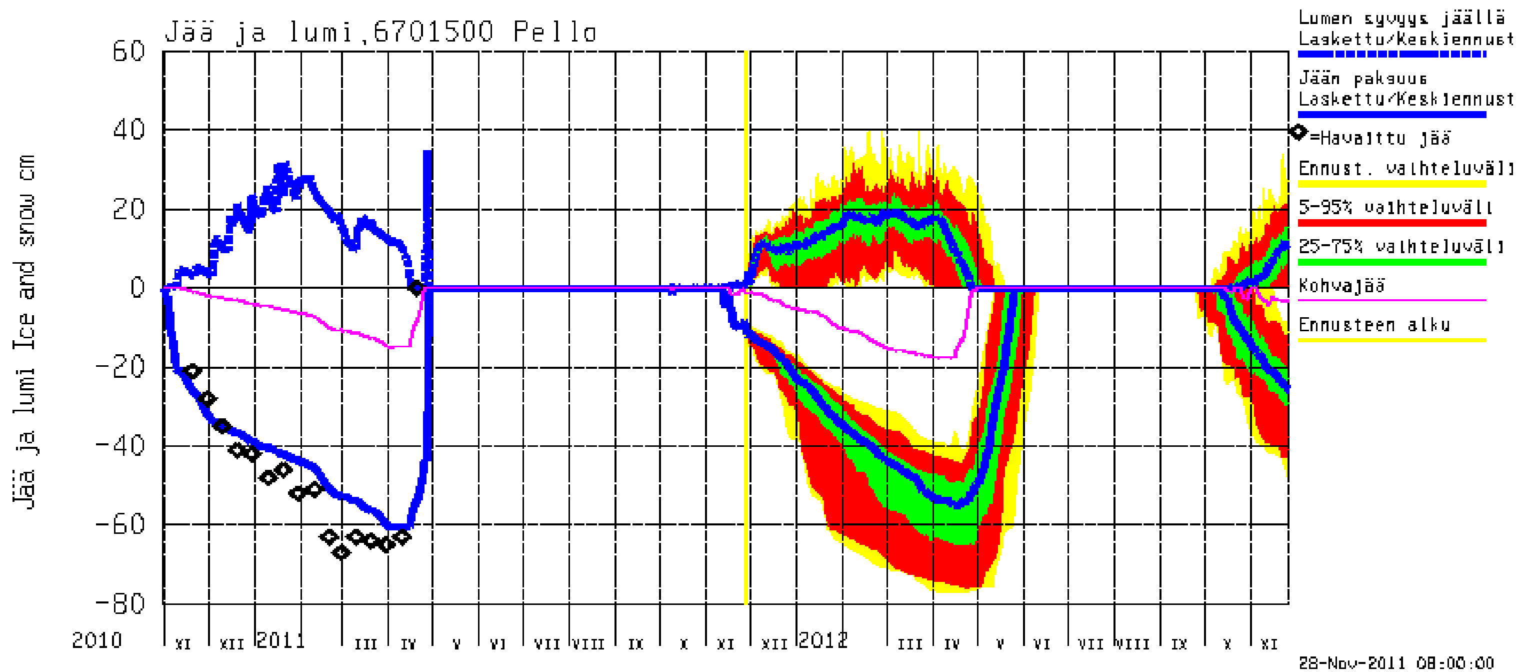
Ice thickness model: results at Tornionjoki river Pello 28.11.2011



Observed (black diamond) and simulated total ice (solid blue line), snow ice (solid cyan line) and snow (dashed blue line above zero level)

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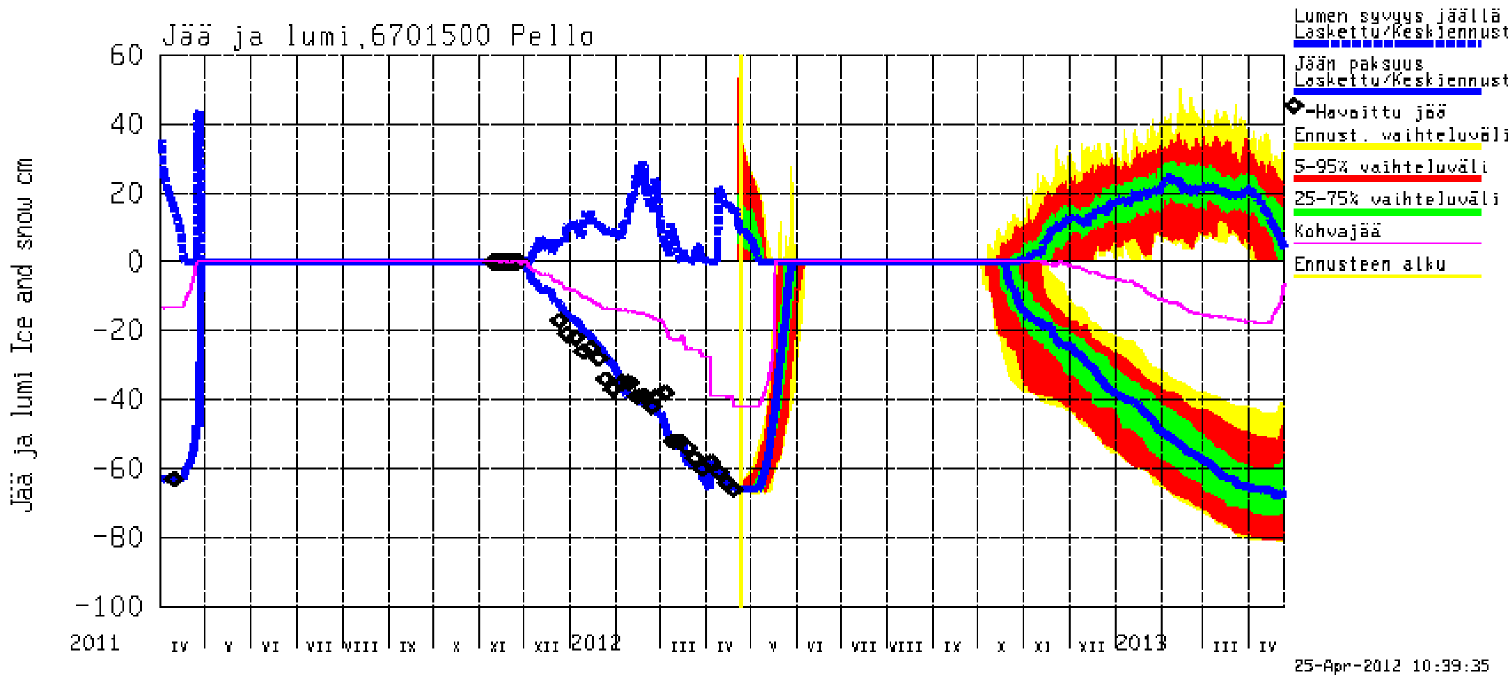
Ice thickness model: results at Tornionjoki river Pello 25.4.2012



Observed (black diamond) and simulated total ice (solid blue line), snow ice (solid cyan line) and snow (dashed blue line above zero level)

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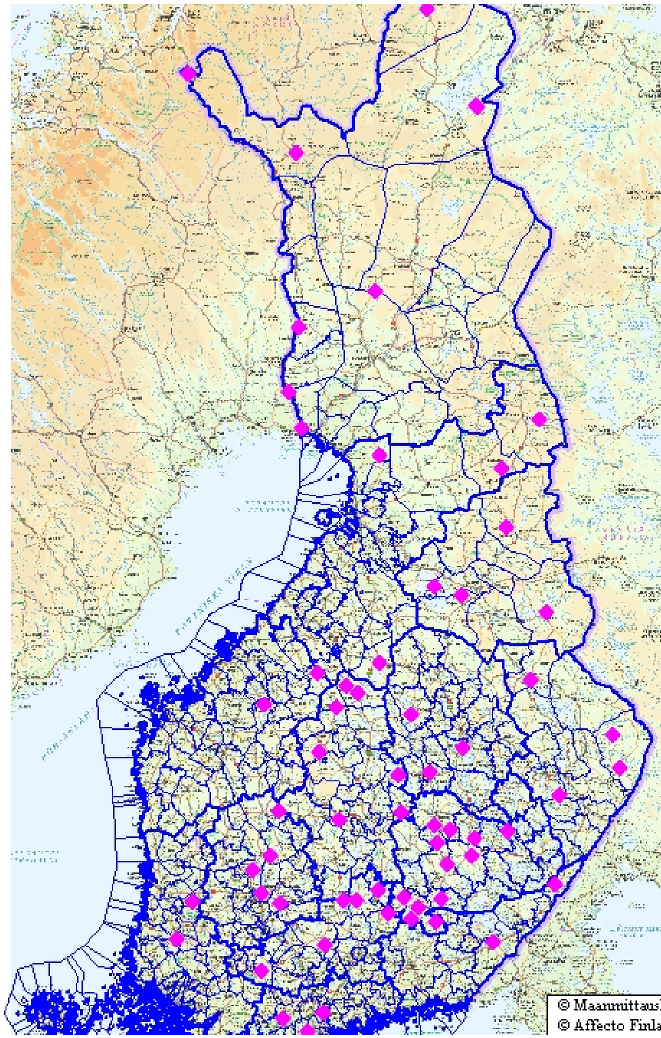
Ice observation points 2006-2010

63 points total, ice thickness calculated and calibrated



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Ice thickness map

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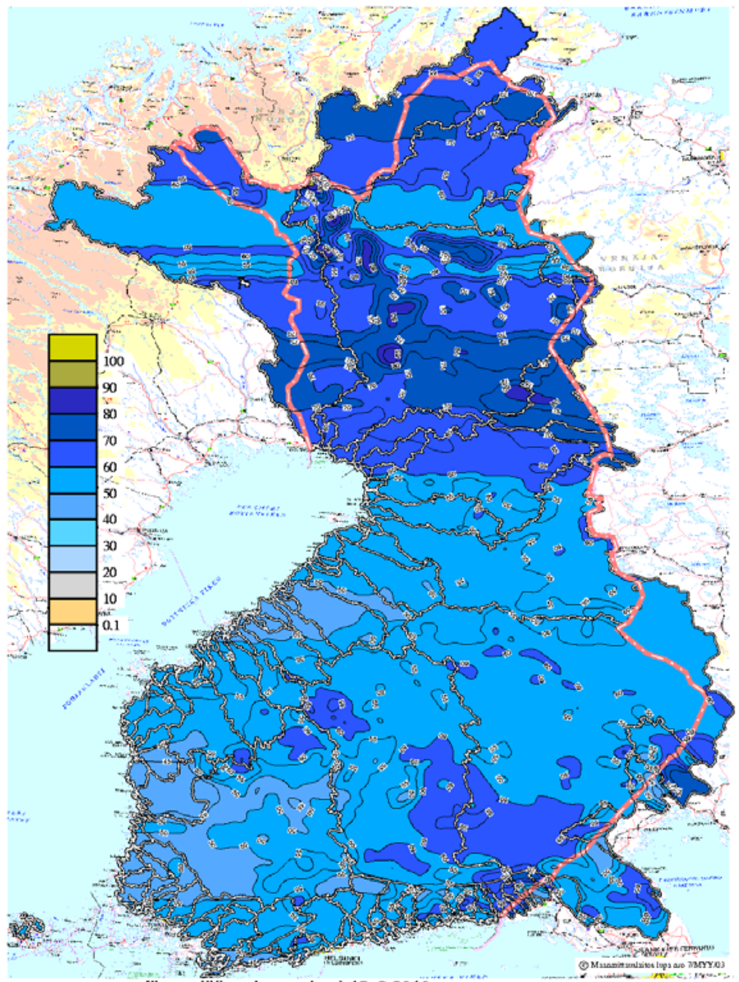

Järven jäänpaksuus (cm) 15. 3.2010
Forecast day 15. 3.
Lake ice thickness (cm) 15. 3.2010

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