On the use of FLAKE in SURFEX coupled to Meso-NH

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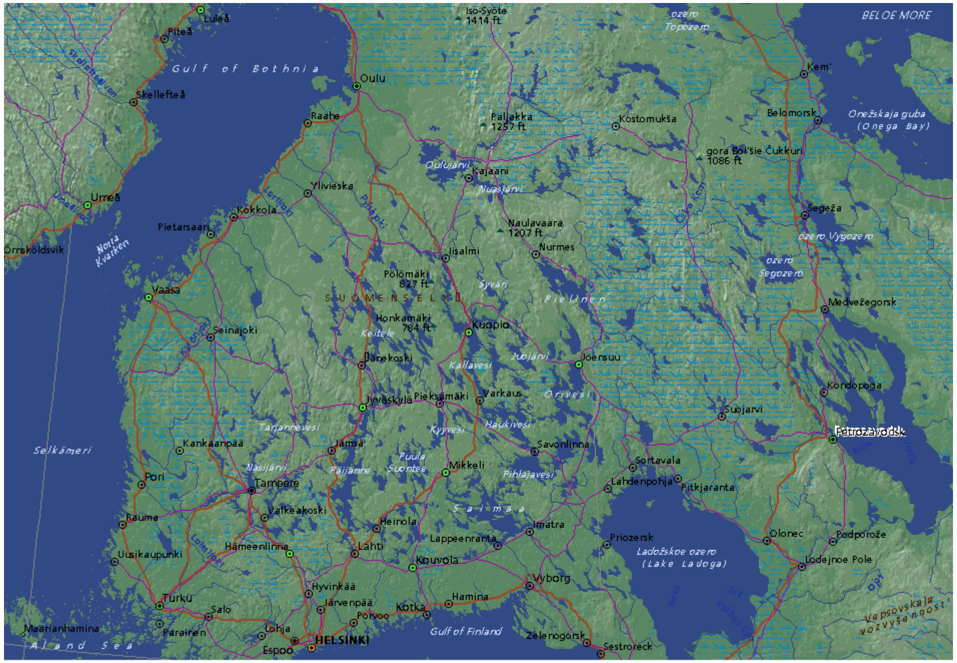
Motivation

- Return to FLake, almost 10 years after the coupling with SURFEX
  - *Salgado & Le Moigne (2010)*
- Availability of a set of data: exploitation of ALEX 2014
  - A field experience conducted around tha Alqueva reservoir
- A new running field campaign ALOP
- Return to the question of the impact of ALqueva on local climate
  - 15 years after the close of the gates *(Salgado, 2016, Policarpo et al., 2017)*
- Collaborate with the IPMA (Portuguese met office) in improving the local AROME physiography and activate FLake
  - improve weather forecast for the region
- Use FLake in studies about surface carbon fluxes and algal blooms
- Test the possibility of using FLake approach and results to forecast:
  - water temperature
  - Evaporation from the reservoir
  - water quality parameters

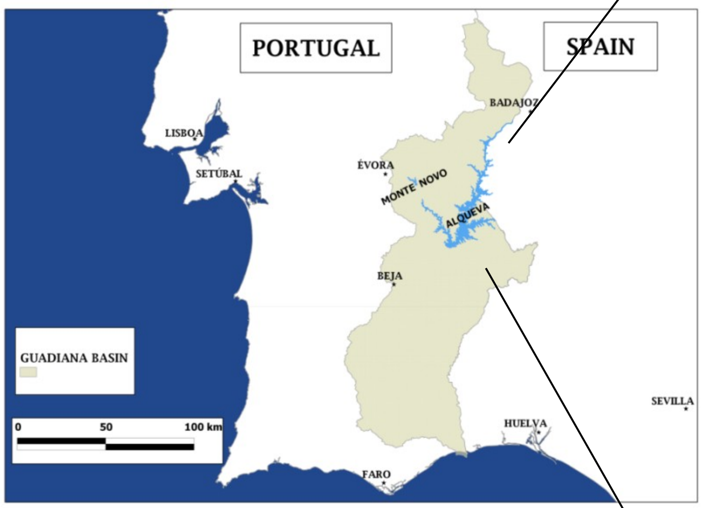
Why lake schemes in atmospheric models?

- Some regions can be highly influenced by the presence of lakes
  - The boreal zone (9.2% of the area of Sweden and 10% of the area of Finland are covered by lakes)
  - Eastern Africa and of the American Great Lakes region
  - In the Mediterranean region, dams and reservoirs have been constructed.
- An accurate prescription of lake surface temperatures becomes more important as the horizontal resolution of the models increases.

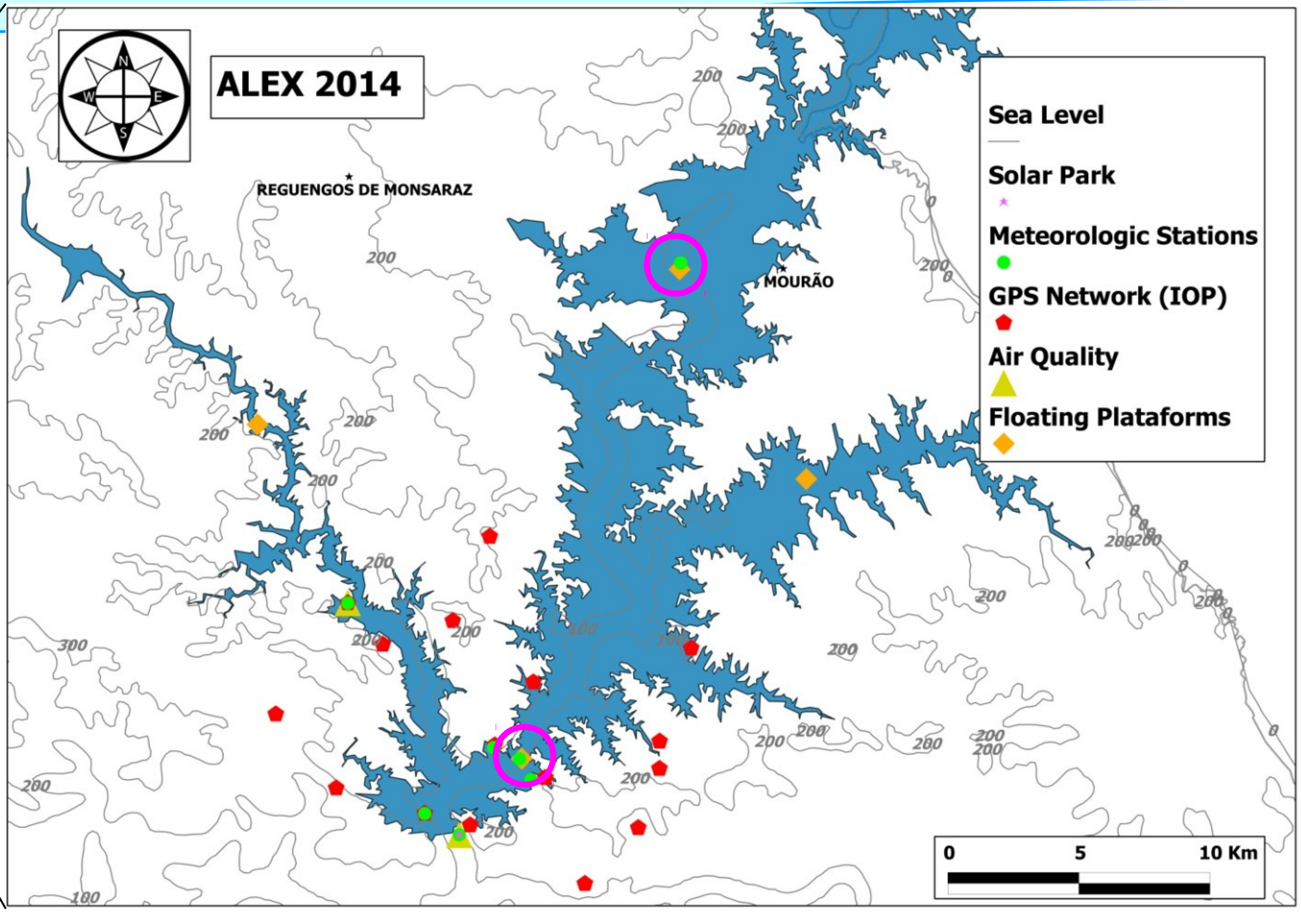


Lake Regions: Finland, Karelia

ALEX2014 field campaign



www.alex2014.cge.pt



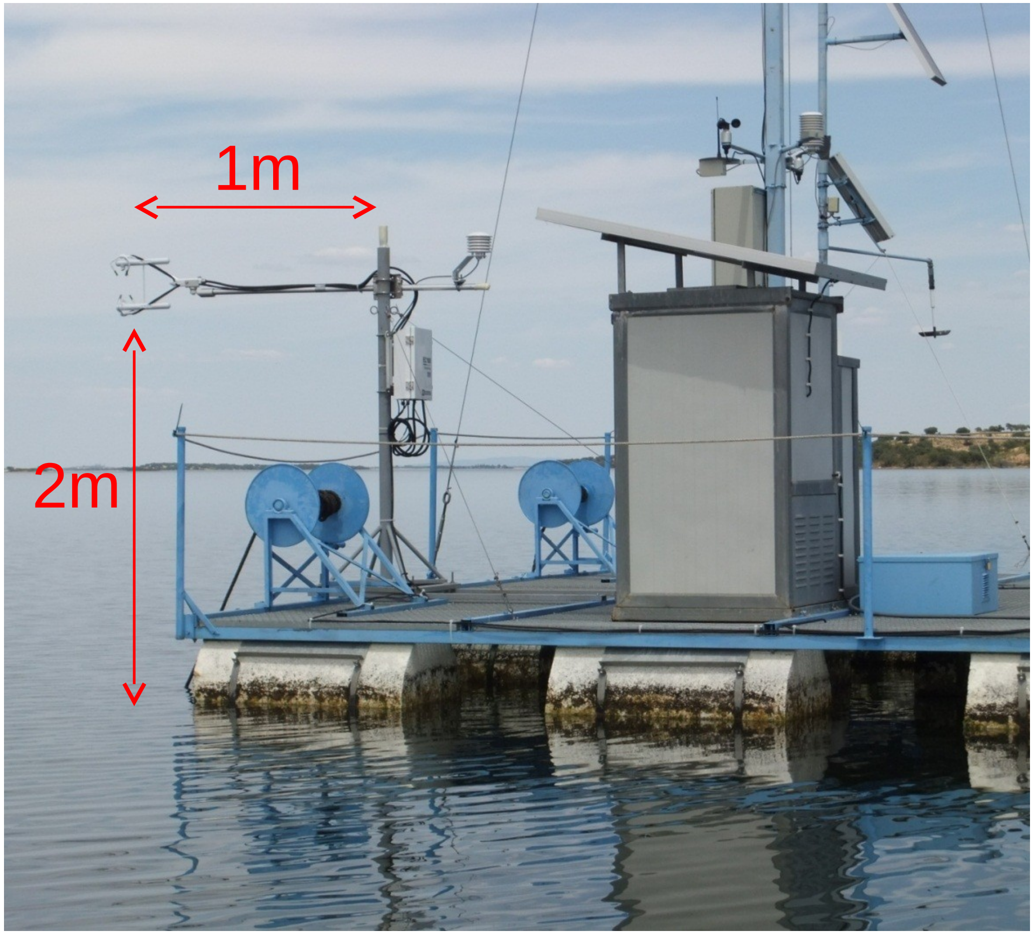
The **ALqueva hydro-meteorological EXperiment**, ALEX 2014

- An integrated field campaign with measurements of chemical, physical and biological parameters around the Alqueva reservoir;
- With the purpose of studding the lake-atmosphere interactions
- From June to September and comprised a three days Intensive Observation Period (IOP) from 22 to 24 July.

ALEX2014 field campaign (2)

Central Site: Floating Platform

- Energy fluxes (radiative and sensible and latent heat), CO_2 and H_2O
- Under water measurements



Intensive Observation Period: 22, 23 and 24 of July 2014, :

- 18 meteorological balloons with meteorological radiosondes were launched.

The FLake model: Water temperature profile

ALOP

- Water temperature profile:
- two layers:
- Mixed Layer

$$\theta(z,t) = \theta_s \quad at\, 0 \leq z \leq h$$

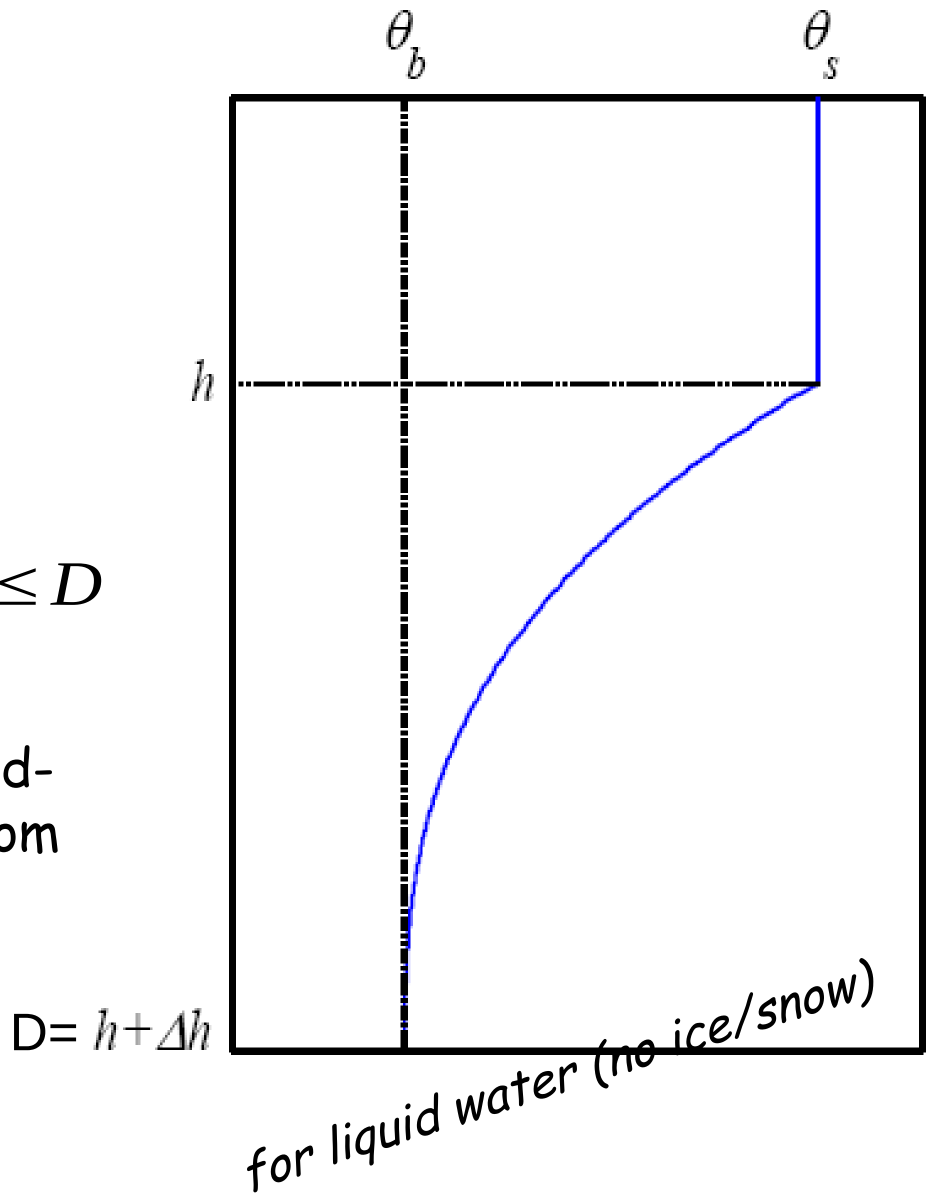
thermocline

$$\theta(z,t) = \theta_s - (\theta_s - \theta_b) * \Phi(\varsigma) \quad at\, h \leq z \leq D$$

The thermocline extends from the mixed-layer outer edge z = h to the basin bottom z = D.
And can be defined by a shape factor:

$$C_T = \int_0^1 \Phi(\varsigma)\, d\varsigma$$

Mironov (2008), Mironov et al. (2010)

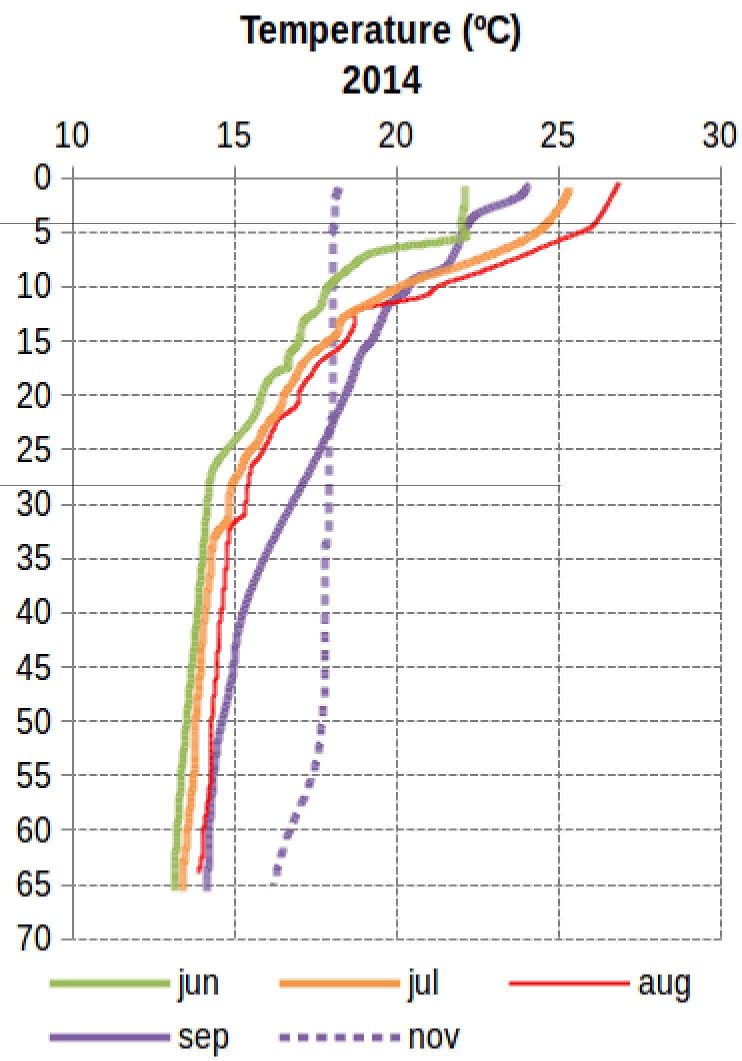


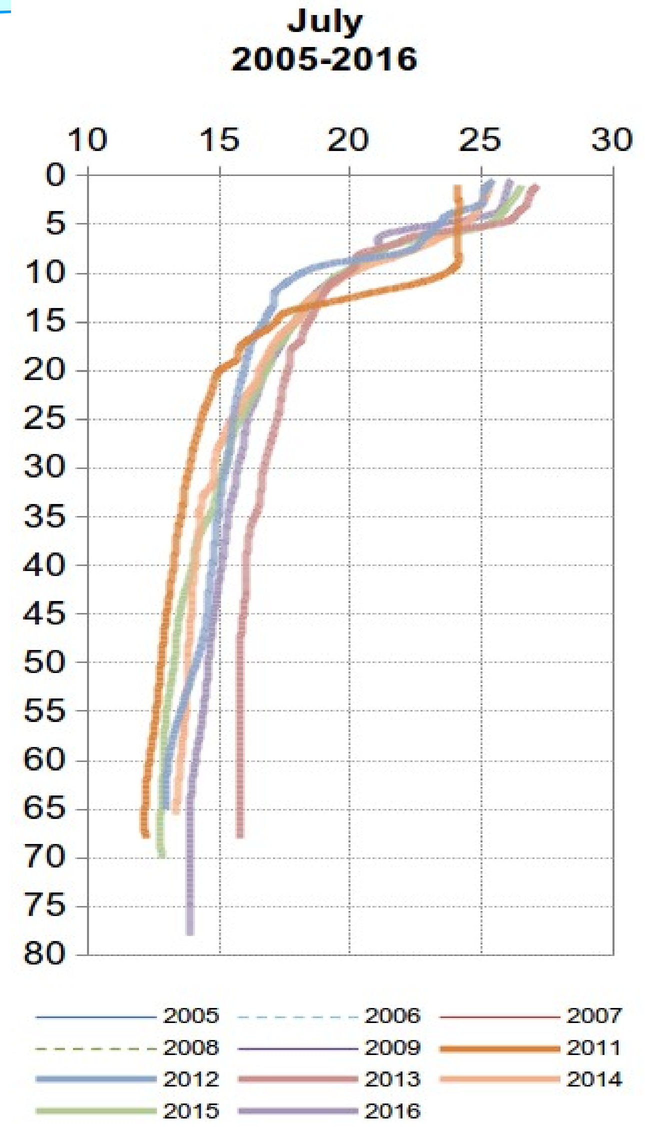
Real profiles (examples)

Measurements in Alqueva
Floating platform

Mixed Layer thickness:
normally less than 5m
frequently less than 3m
sometimes not well defined

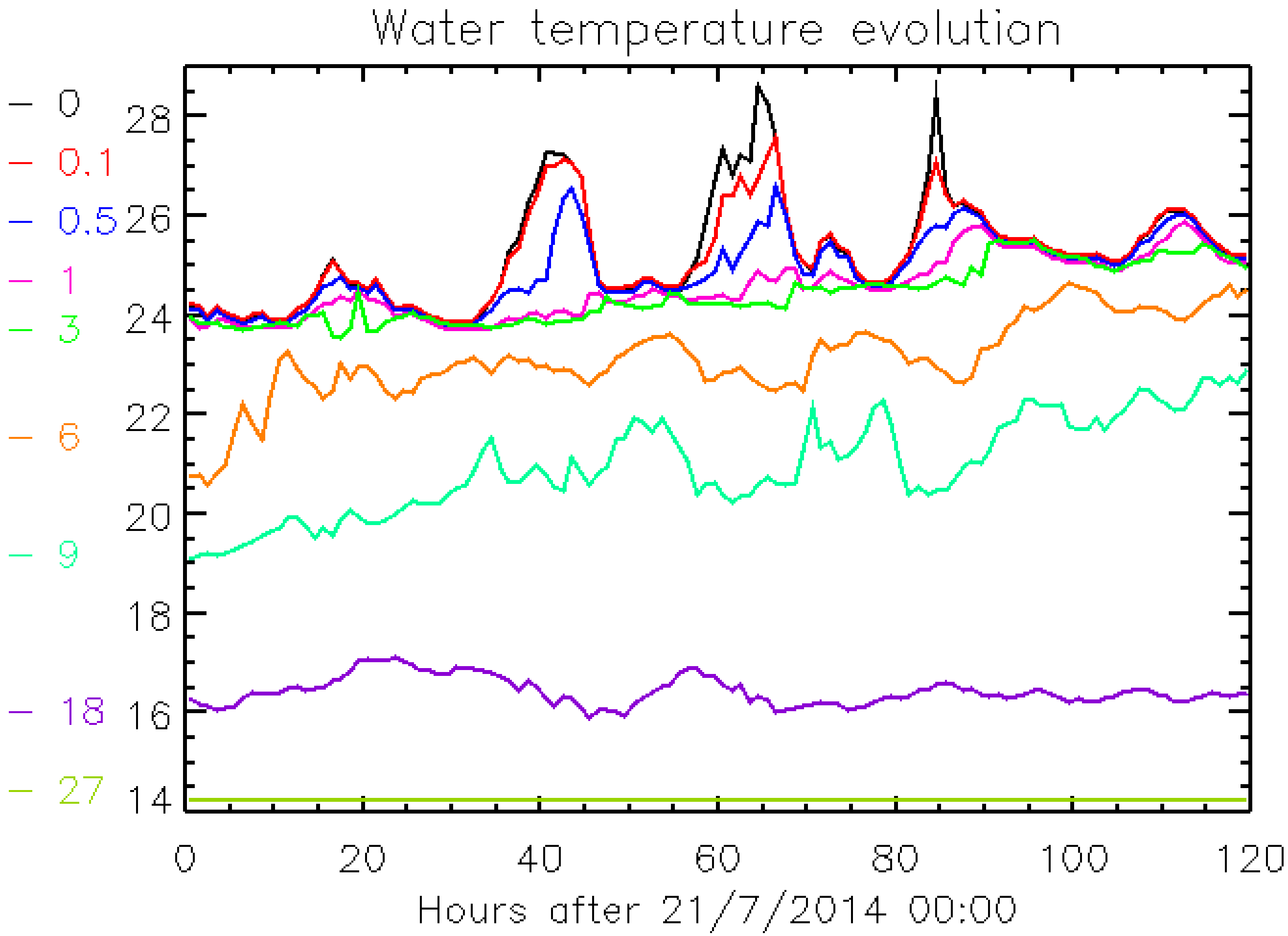
Bottom of the thermocline
= Bottom of lake (in FLake)?





Real profile (another example)

- Mixed Layer is not always well defined
- ΔT between Surface and 1 m can be greater ~4°!
- Warm period, very stratified lake
- An argument to develop a skin temperature computation?



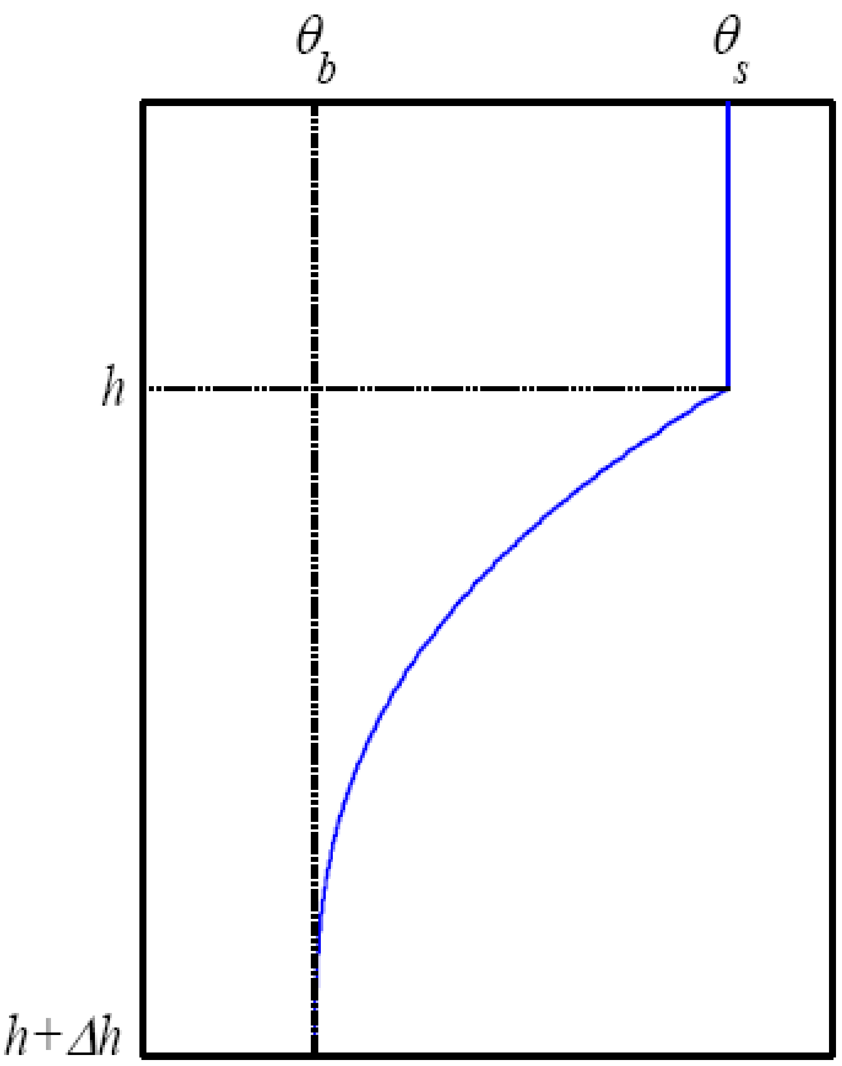
ALEX 2014 observations: continuous temperature observations. Hourly mean temperature at different depths, from 21 to 25 July 2014

The FLake model: Water prognostic variables

- Surface or mixed layer temperature, θ_s
- Bottom temperature, θ_b
- Mixed layer depth, h
- Shape factor , C_T

The evolution are based on 4 equations:

- 2 Equations for conservation of energy
- Evolution of h
- Evolution of C_T

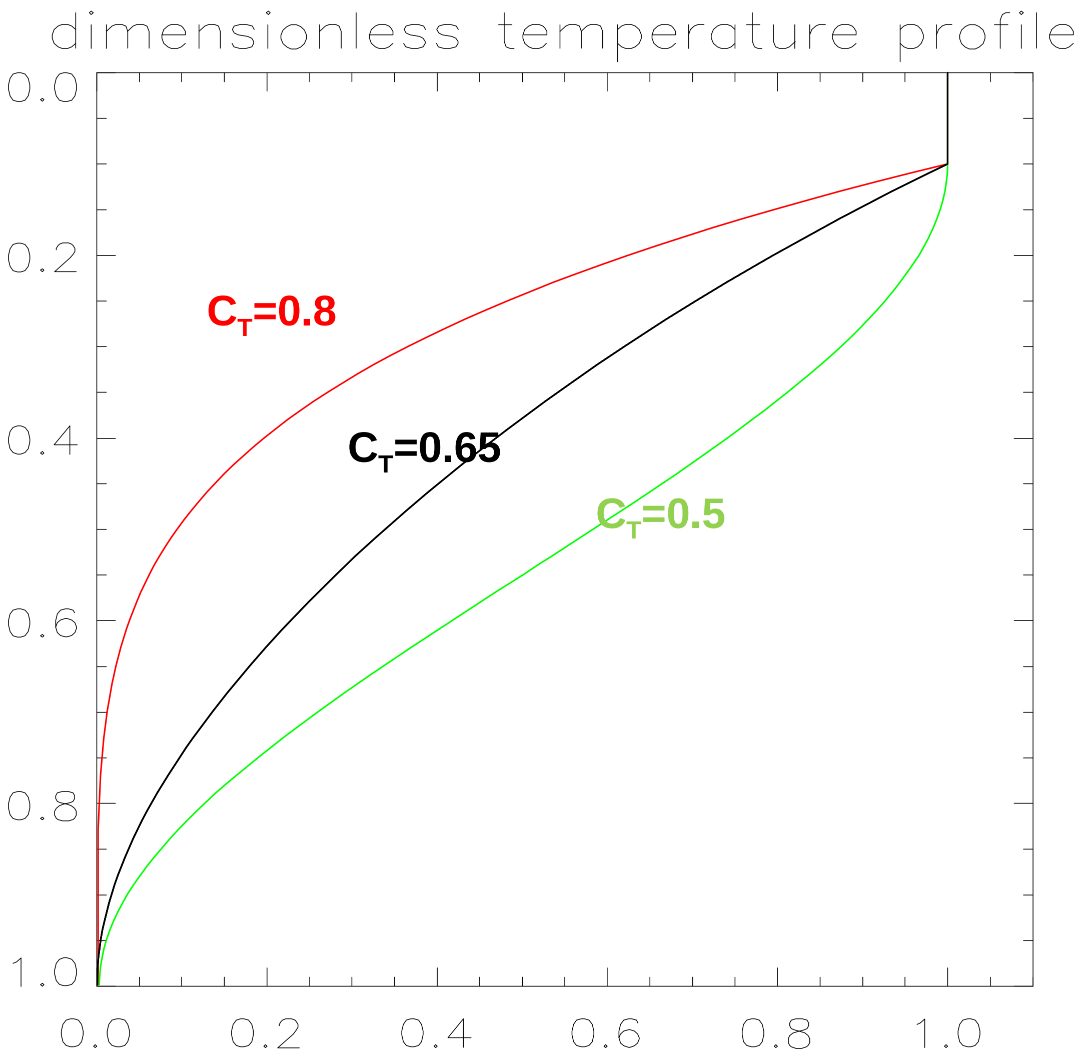


Key parameters

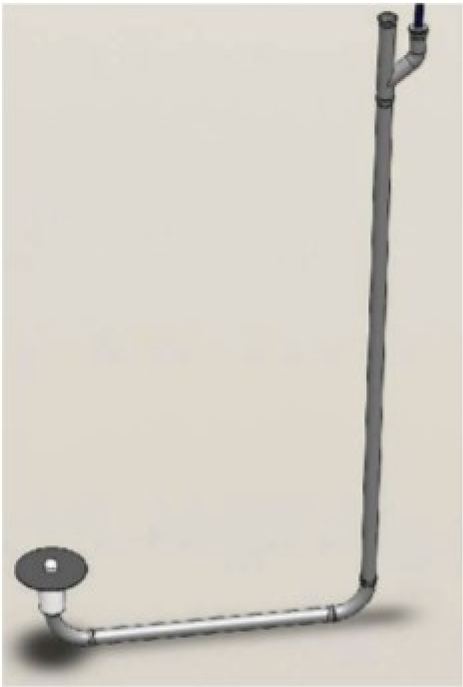
- Lake fraction (ecolcimap)
- Lake depth (Lake Database)
- **Extinction coefficient of light**
- Albedo and emissivity

Comments on the shape factor

- The dimensionless temperature profiles lie in the area bounded by the green and the red curves.
- During the mixed-layer deepening, dh/dt > 0, the temperature profile evolves towards the limiting curve, where $C_T = C_{max} = 0.8$
- During the mixed-layer stationary state or retreat, dh/dt ≤0, the temperature profile evolves towards the green curve, where Cmin= 0.5
- Cmin = 0.5 is consistent with a linear temperature profile that is assumed to occur under the ice



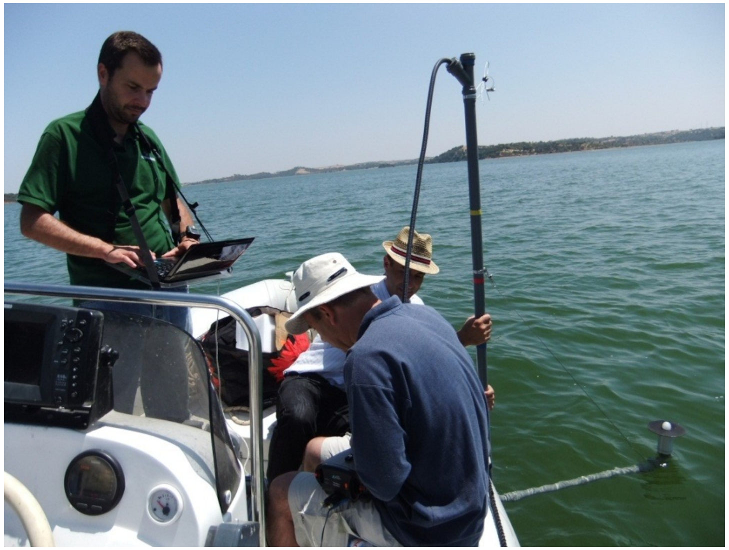
Extinction Coefficient: measurement apparatus



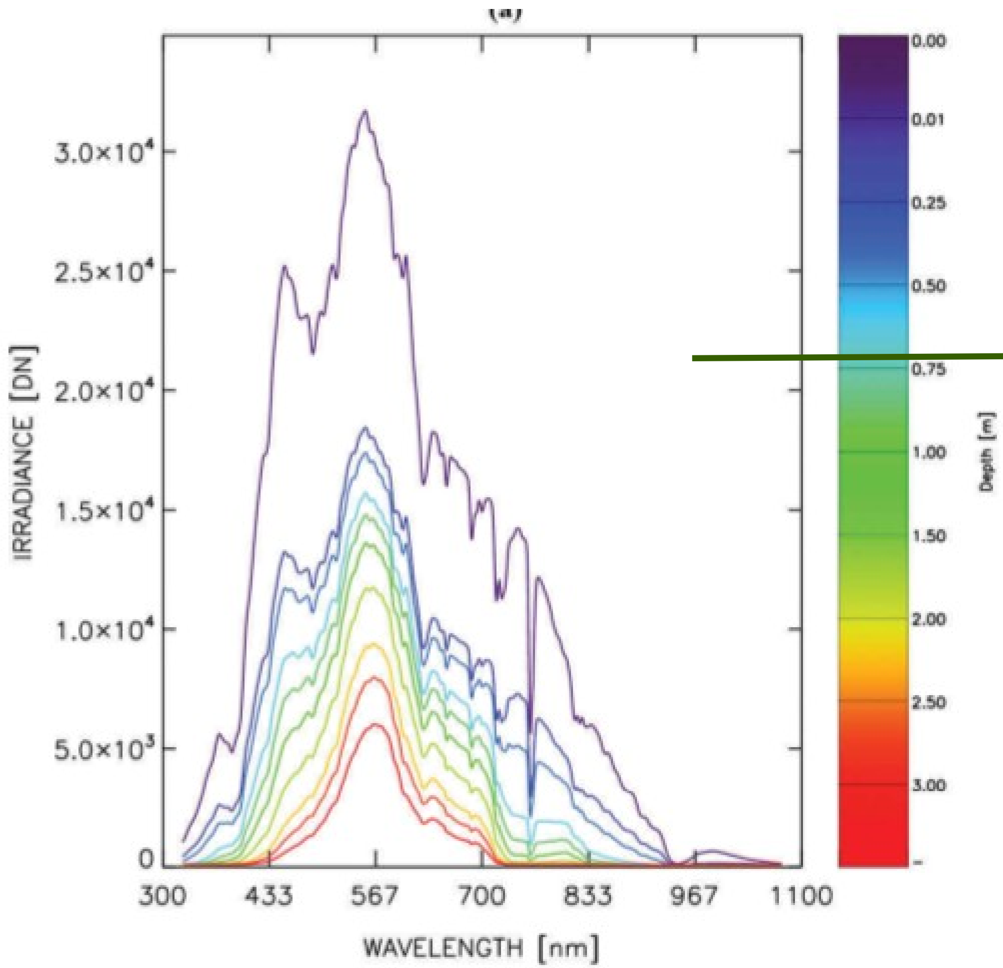
Underwater irradiance measurements at
Alqueva reservoir (Potes et al., 2013, 2017)
Thau lagoon (Thaumex, LeMoigne et al., 2013)
other water bodies

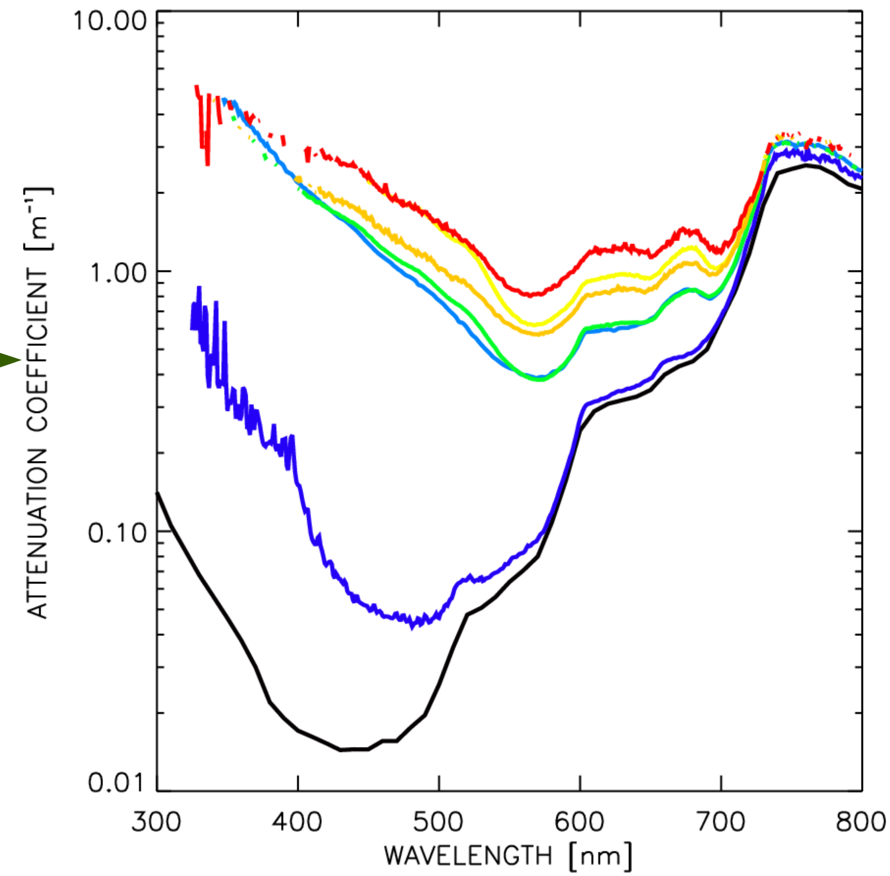
FieldSpec UV/VNIR da ASD coupled to an optical cable and a cosine receptor

- Wavelengths between 325 – 1075 nm
- Spectral resolution of 3 nm
- 180° of FOV
- Maximum depth of 3 m



Extinction Coefficient: estimation





Spectral Irradiance measurements at different depths between surface and 3 m (example - Alqueva)

Spectral Extinction Coefficient for different water bodies: Pure water (Black); Pool (Blue) Alqueva 2014 (other colours) Depends on wavelength

Extinction Coefficient: Observed Values

Extinction coefficient in the PAR band

Table 1. Measurement details

Date	Time (UTC)	Measurement location	PAR attenuation coefficient[a] (m^{-1})
Smith and Baker (1981)	–	Pure water	0.166
10 July 2014	10:24	Alqueva-Montante	0.709 ± 0.006
14 July 2014	10:32	Swimming complex	0.191 ± 0.002
30 July 2014	11:19	Alqueva-Montante	0.849 ± 0.025
27 August 2014	10:25	Alqueva-Montante	0.875 ± 0.023
27 August 2014	14:30	Alqueva-Mourão	1.112 ± 0.019
25 September 2014	15:31	Alqueva-Montante	1.055 ± 0.004
25 September 2014	10:39	Alqueva-Mourão	1.459 ± 0.007

[a]Photosynthetically active radiation attenuation coefficient for the layer 0–3 m.

from Potes et al. (2017)

The extinction coefficients change in space (depends on lake) and also in time
The integral (for all solar spectrum) extinction coefficient should be slightly larger

Initialization for mesoscale simulations

We need initial conditions for:

- Surface or mixed layer temperature, θ_s
- Bottom temperature, θ_b
- Mixed layer depth, h
- Shape factor ,C_T

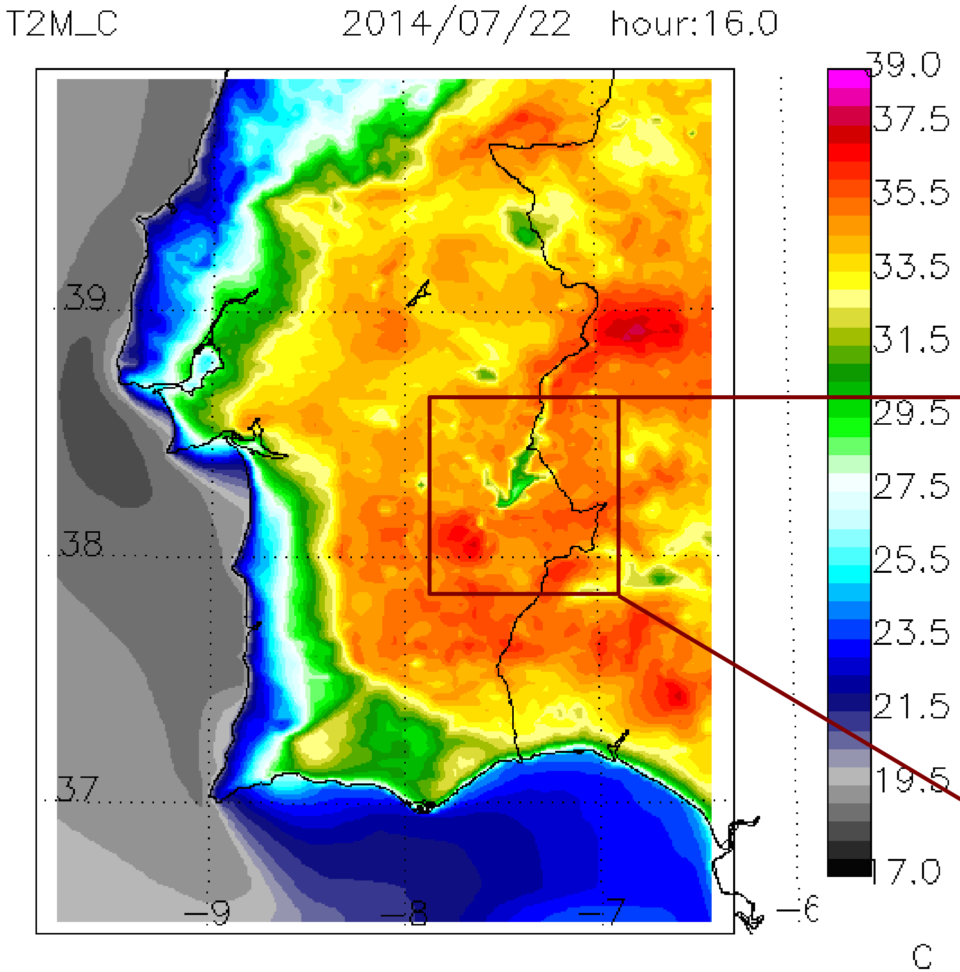
  - For climate simulations it is not important: FLake is not to much sensitive and we can start in winter (non stratified period)
  - For operational forecast on may use an optimal assimilation process (against observed lake surface temperature)
  - For short range mesoscale simulations namely with meso-NH, we may **adjust the parameters if we have measurements**
  - If not we should have climatological values

The estimation has been done iteratively, minimizing mean square errors (For bottom temperature the observed temperature at 27m was used)

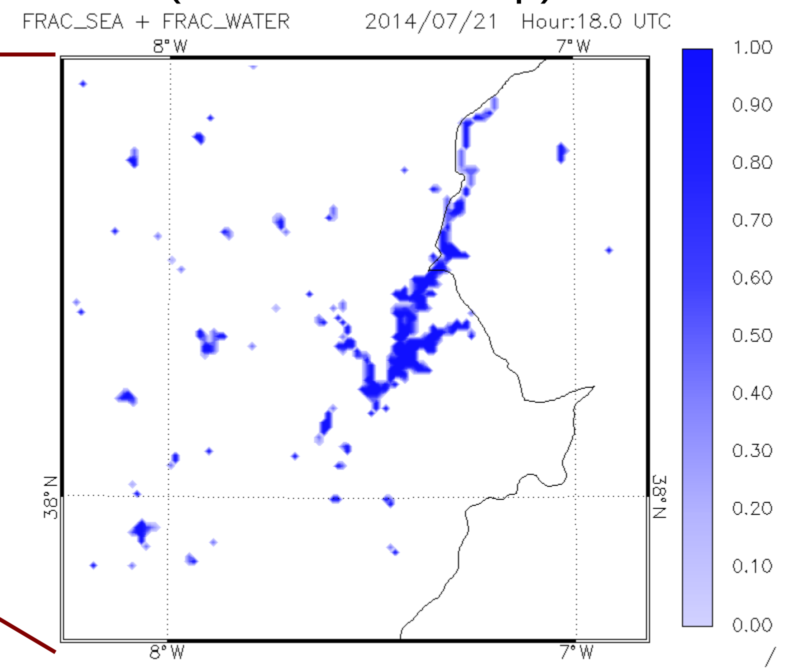
Impact of initial conditions - example

Meso-NH – SURFEX – FLake Simulation
3km resolution over South Portugal
100 x 128 grid points

- ALEX IOP case: 22-24 July 2014
- Initialization and forcing: ECMWF
- 78 hours of simulation
- 64 vertical levels, concentrated in the BL



Alqueva water surface area: 250 km^2
(Not in Ecoclimap)



Sensitivity to initial conditions - example

Temperature of the water mixed layer on a Alqueva lake point

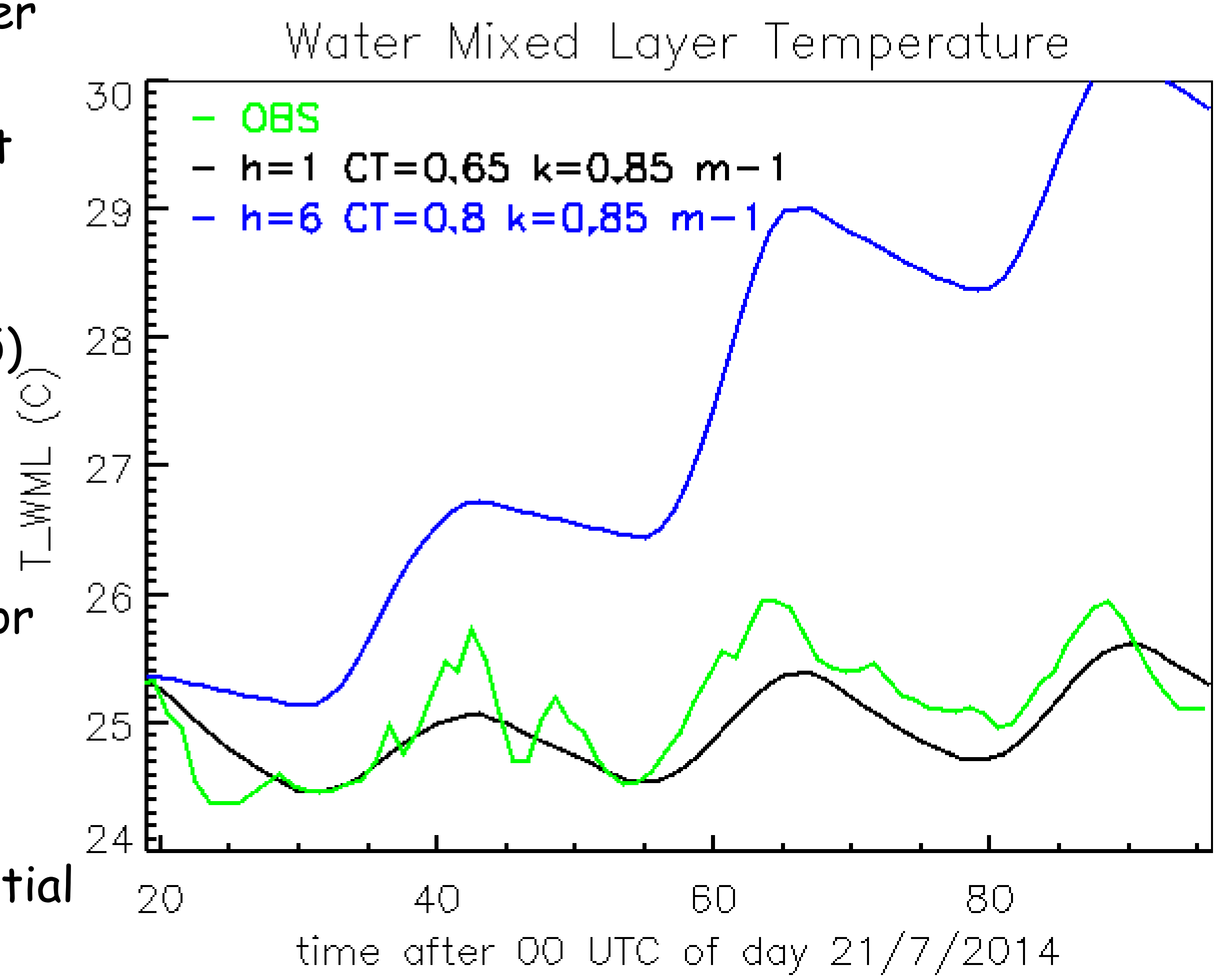
OBS = mean temperature of the first levels (up to 3 m)

Two cases:

- adjusted parameters (h=1, CT=0.65)
- a different set of initial conditions

For both cases:

- lake depth = 27 m botom
- extinction coefficient estimated for July 30, K = 0.85 m^{-1}
- No sediments

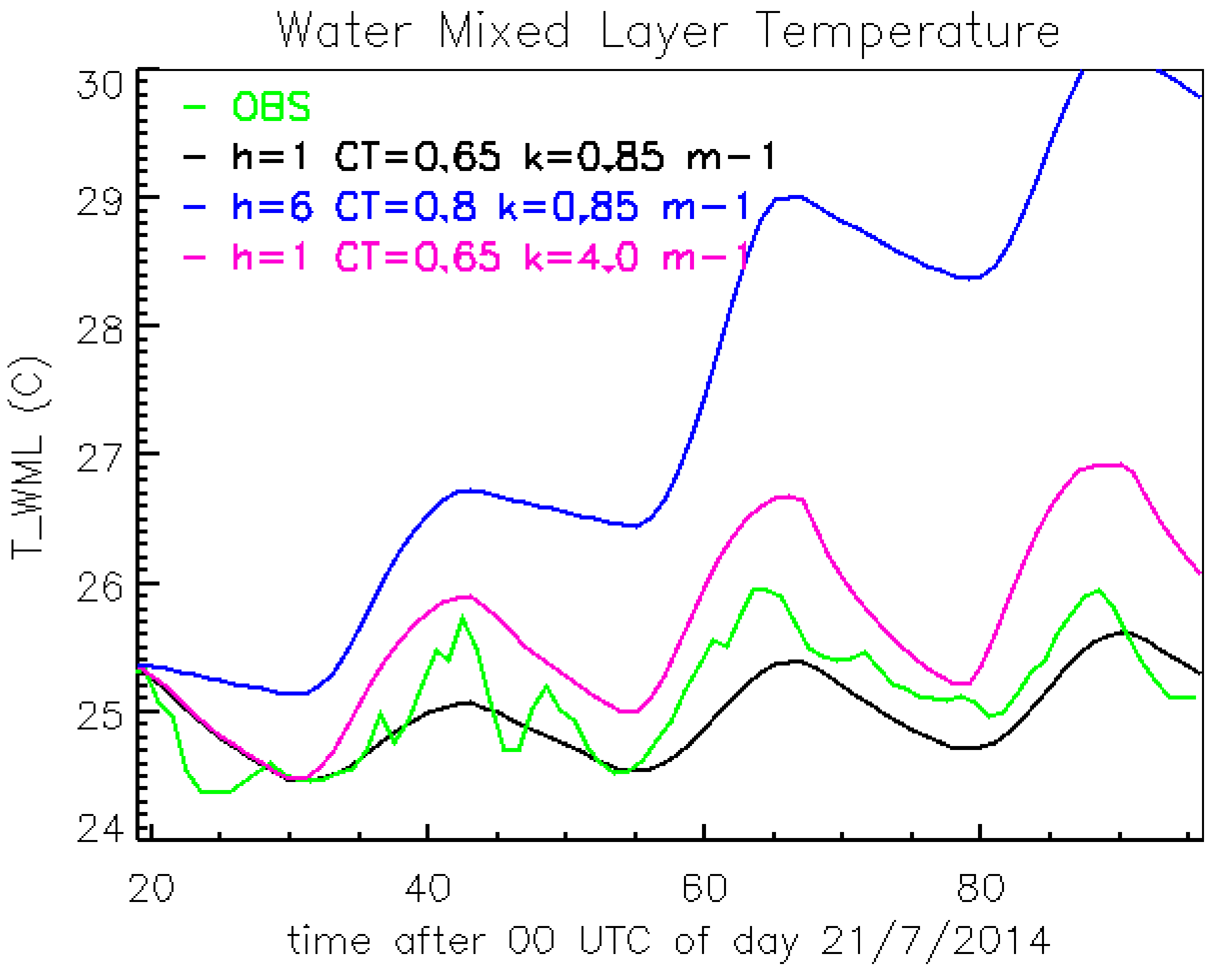


The simulated temperature for an initial shape factor of 0.8 is unrealistic.

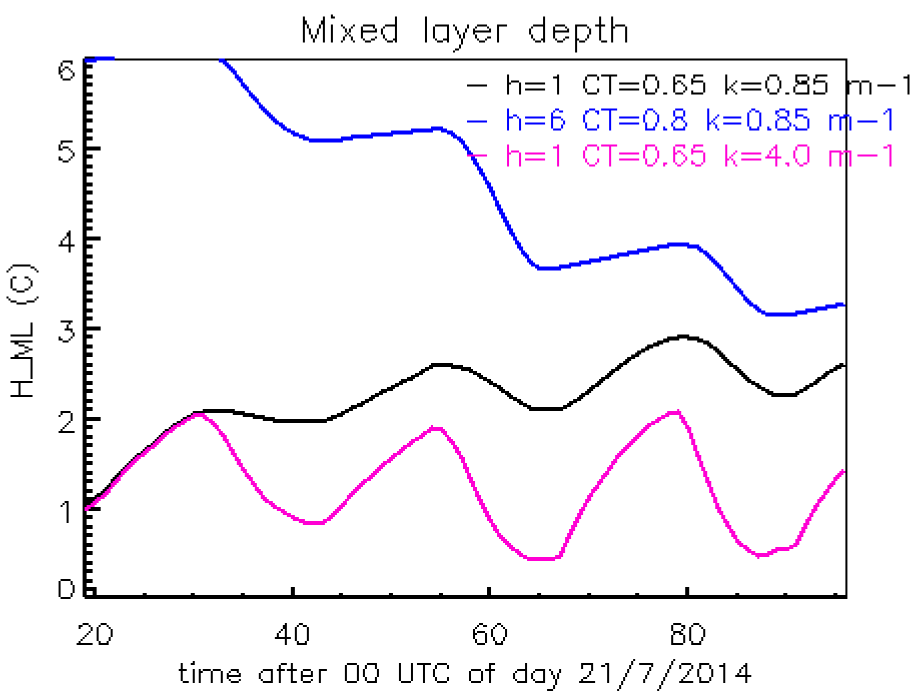
Errors can be of 5°C

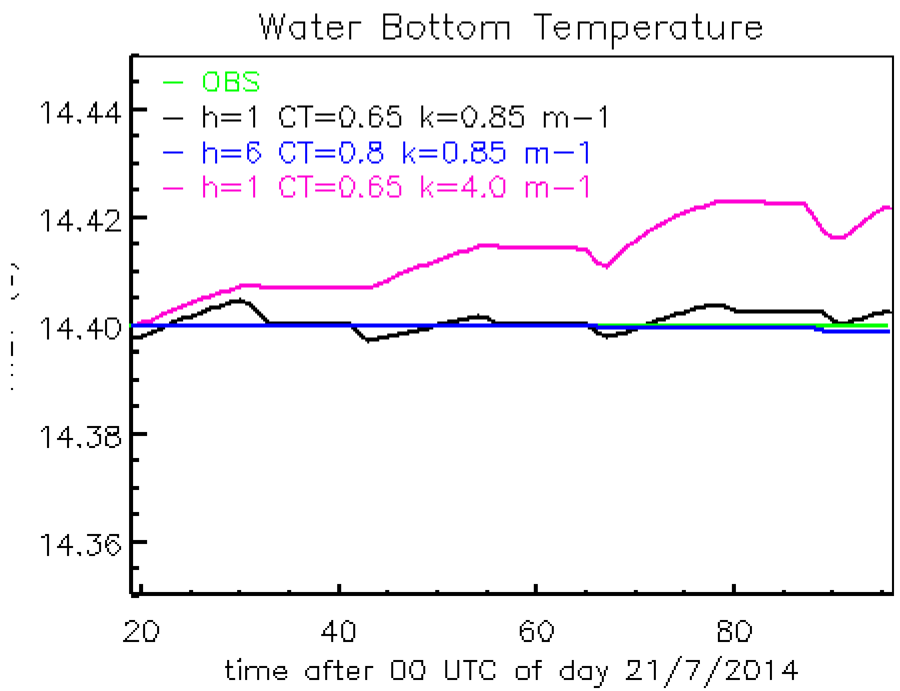
+ Sensitivity to Extinction coefficient

- Increasing K (to 4 m^{-1})→ increase the temperature and the daily amplitude of lake mixed layer temperature
- In the example, the difference between the two simulations is more 1°C
- Probably, the optimal value should be between 0.85 and 4 m^{-1})



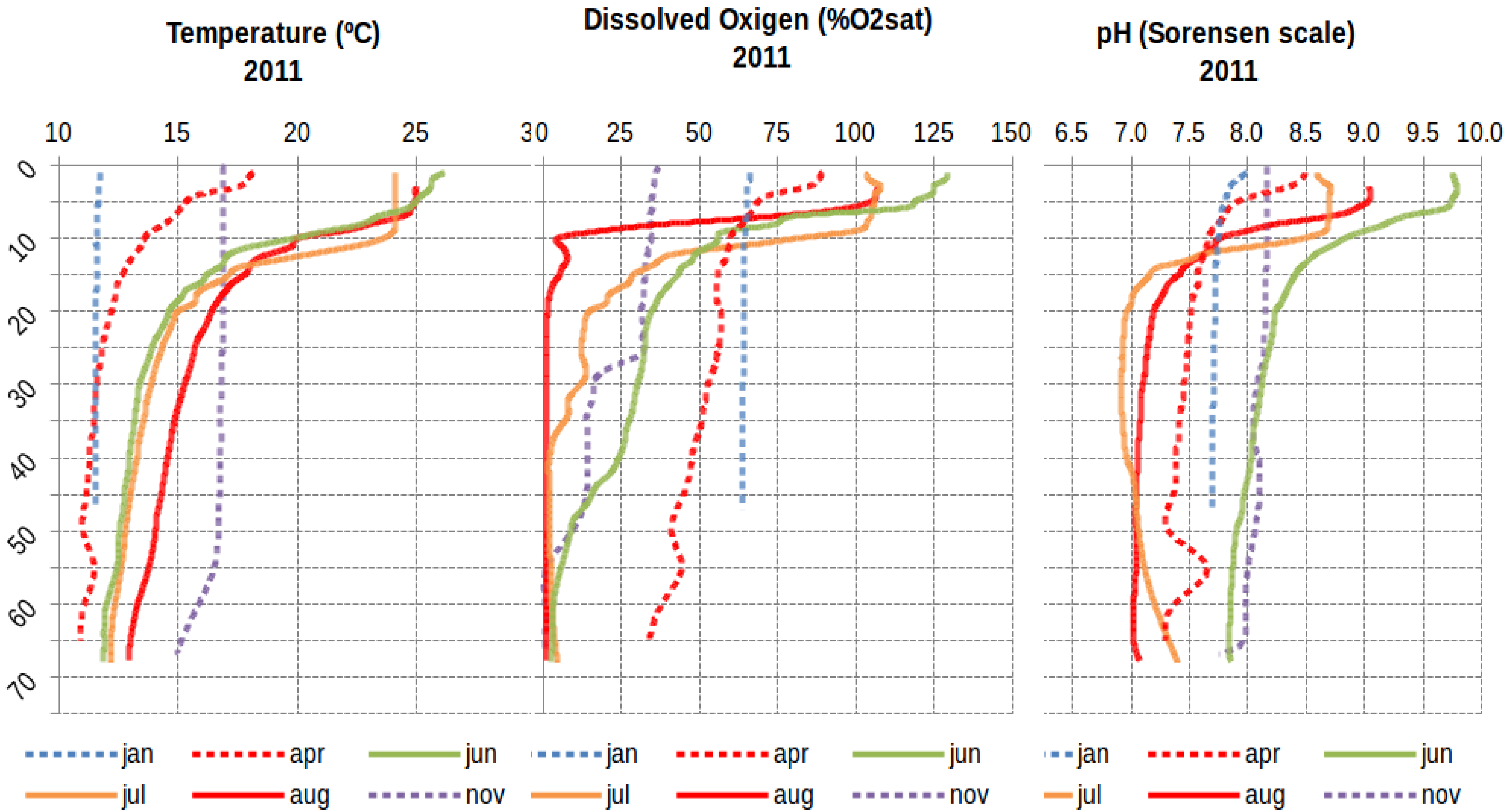
FLake in Meso-NH – impact on results





- With the same k, h tends to an "equilibrium" value: ~3 m
- (coherent with observations)
- However, the shape factor has more inertia (not shown)
- So the impact of an error in initial conditions lasts in time

Application of the same concept for biol-chemical quantities



The profiles are similar. It should be possible to model the profiles of other chemical parameters using the same similarity approach → EcoFLake

Conclusions / notes

- In short range simulations, FLake is sensitive to initial conditions, namely to the shape factor
- When observations are available, the shape factor should be adjusted
- Simulations confirm that the importance of extinction coefficient
- In reservoirs, FLake depth should not be the maximum depth.
- The Surface skin temperature should be computed explicitly
- Lake database should include the depth of the reservoirs (namely in Iberia)
- Ecoclimap should also include the reservoirs
- The similarity approach of FLake may be extended to model other quantities related to water quality
- It should be important if more people try FLake inside SURFEX
- It is time to improve the FLake interface to surfex
  - example: k should not be in prep_pgd

New ALOP Project

ALOP

ALentejo **O**bservation and **P**rediction systems

Observations

New field campaign: - 2 years of continuum measurements (beginning in Mars/April 2017)

Modeling

Meso-NH Tutorial in Évora (by Christine Lac)

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