Surface heat fluxes over an artificial lake in South Portugal: Simulations with SURFEX / Meso-NH linked to FLake and observations

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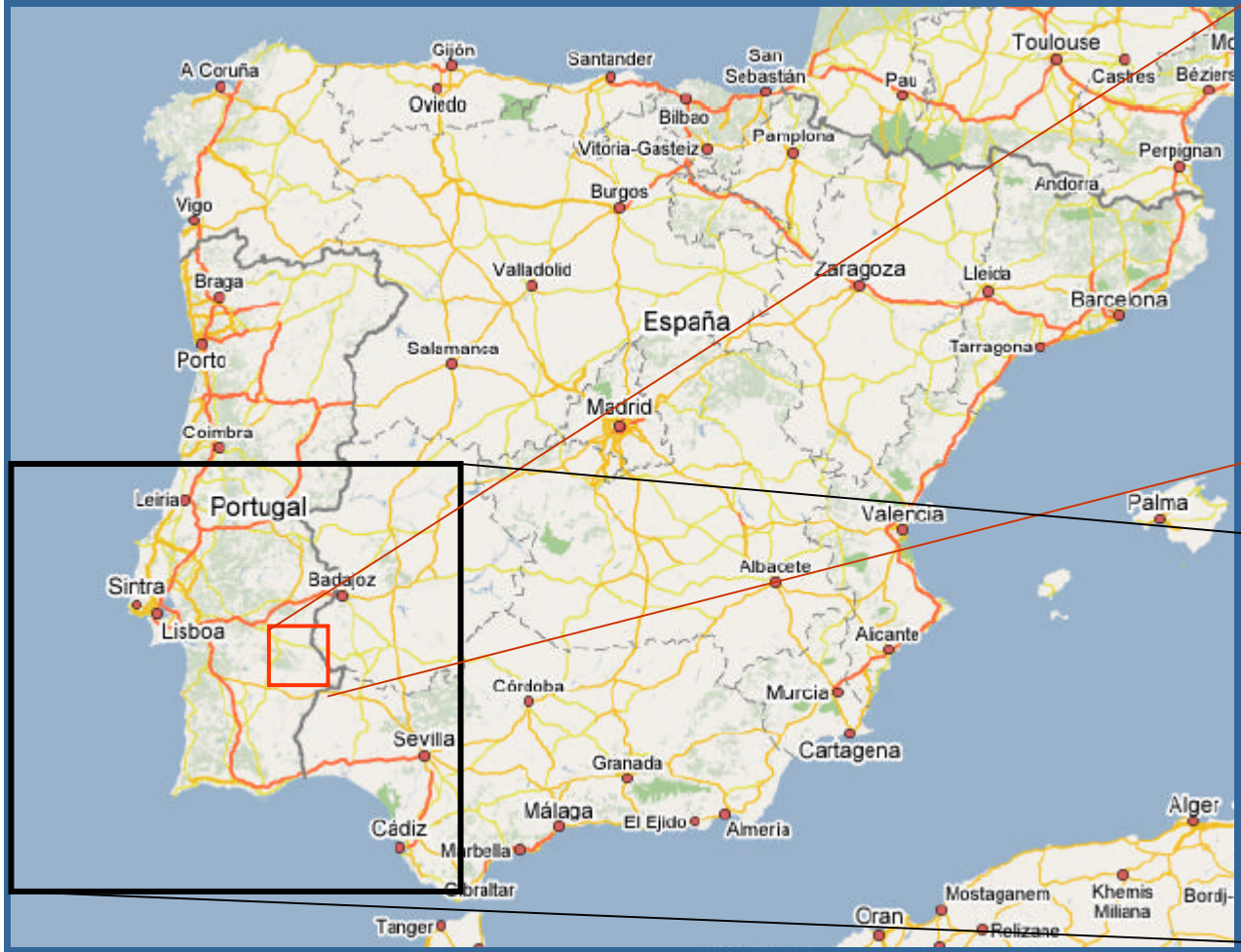
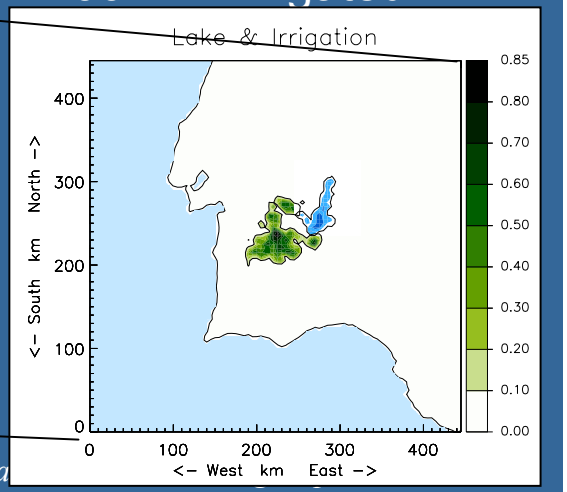
Motivation

- Study of the impact of an artificial lake and irrigation on climate
  - Based on Meso-NH simulations
  - Mediterranean, Semi-arid conditions



Alqueva dam:
250 km² water surface
1700 km² irrigated



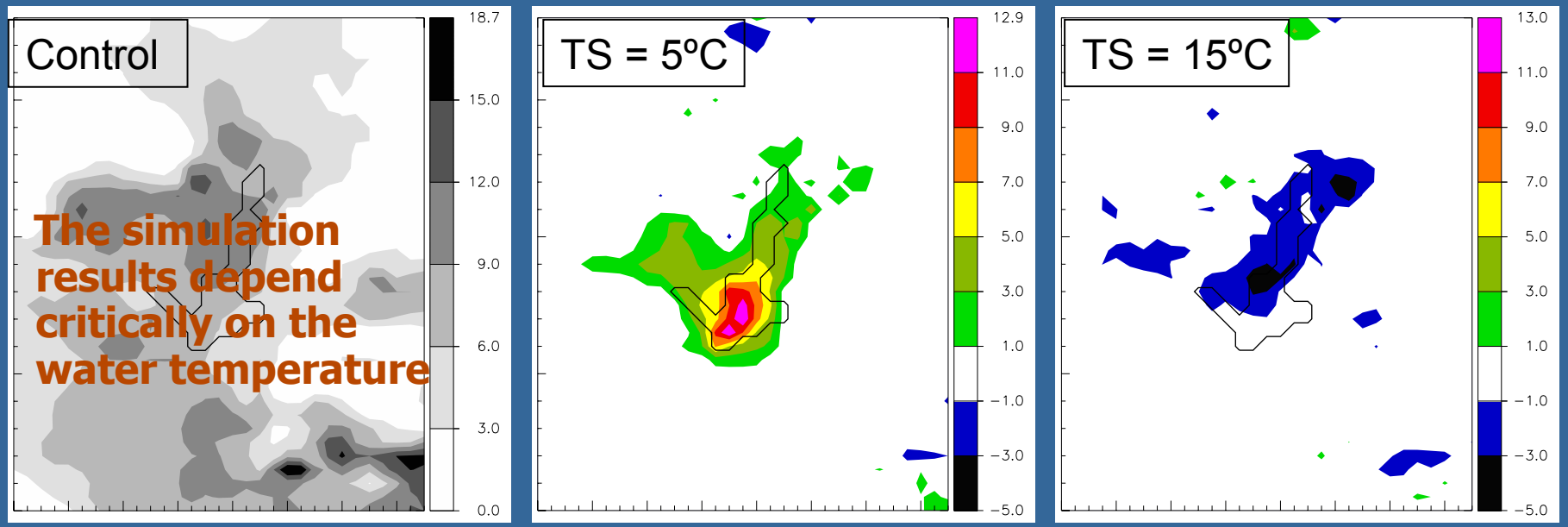
Impact on fog (example)

Example:

1 case study (4/1/2003)

different water temperature

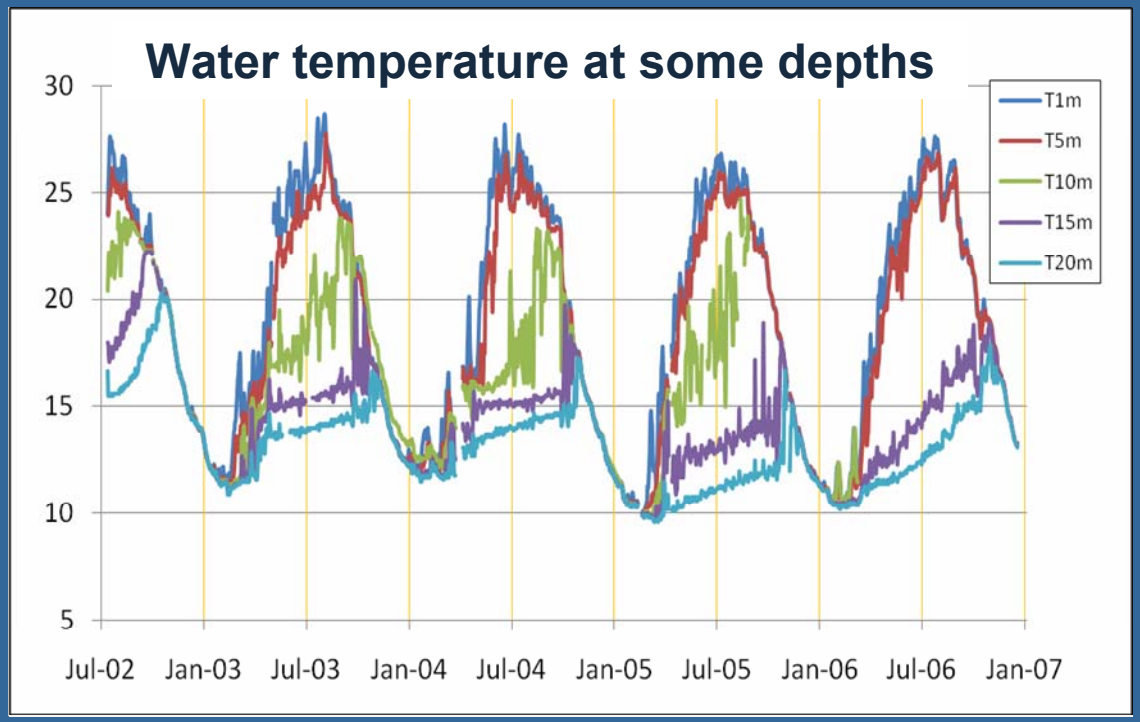
- The impact of the lake on fog depends strongly on the difference between the surface water temperature and the daily minimum air temperature :
  - When the water is warmer relatively to air, the impact is negative on fog;
  - When the water is colder, the lake induces more fog
  - The effect of cooling the air is more important than the injection of water vapor in the atmosphere.



Total number of hours with fog and associated anomalies

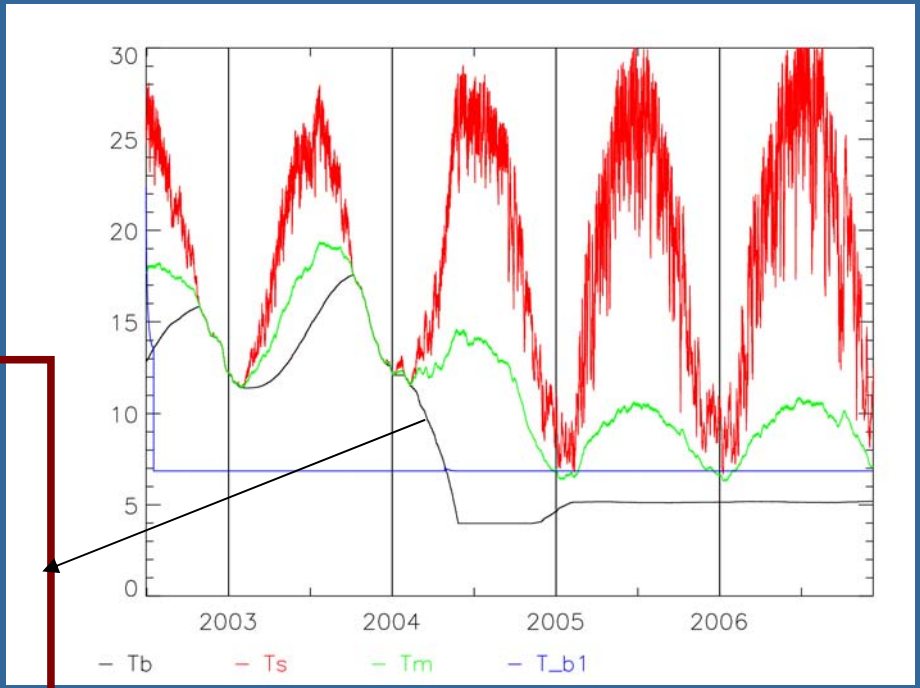
Long period Observations in Alqueva

- Permanent station in a raft over the water (after July 2002) - INAG
- Water temperature at 5 levels
- Air temperature and moisture, wind
- Precipitation
- Solar radiation



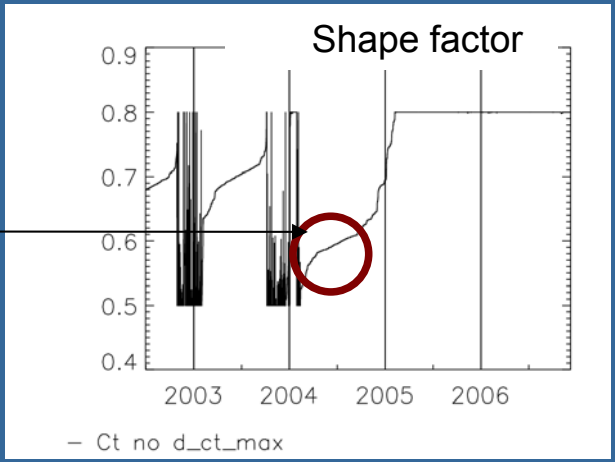
5 years simulation with Flake off line (1st test)

- Parameters:
  - Extinction Coefficient: 5 m^{-1}
  - Depth: 25 m
  - With Sediments



Not realist:
Bottom temperature decrease in spring, reaching the temperature of maximum density

Wy?:
C_θ < 0.6 after no stratified period.
=> ΔT_b <0



1st attempt
! C_T_n_flk = C_T_min
C_T_n_flk = 0.65
(when T = Cst > 4°C)
2nd attempt
constrain the variation of C_θ:
ΔC_θ < 0.1/Δt

5 years simulation with Flake off line (1st test)

- Parameters:
  - Extinction Coefficient: 5 m^{-1}
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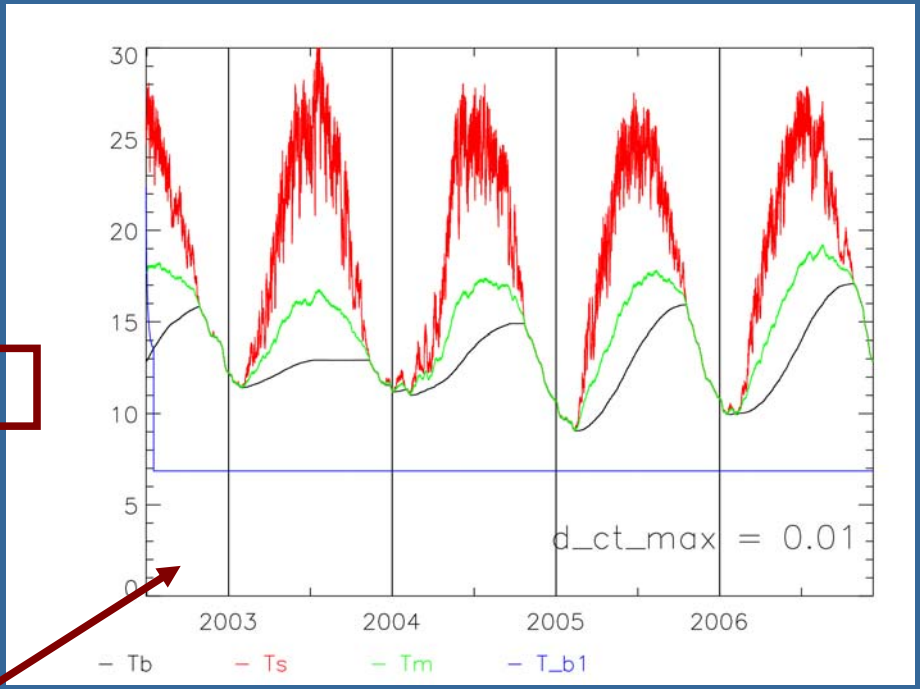
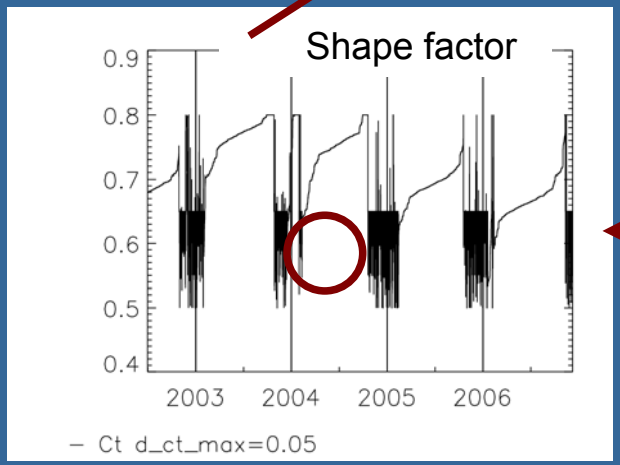


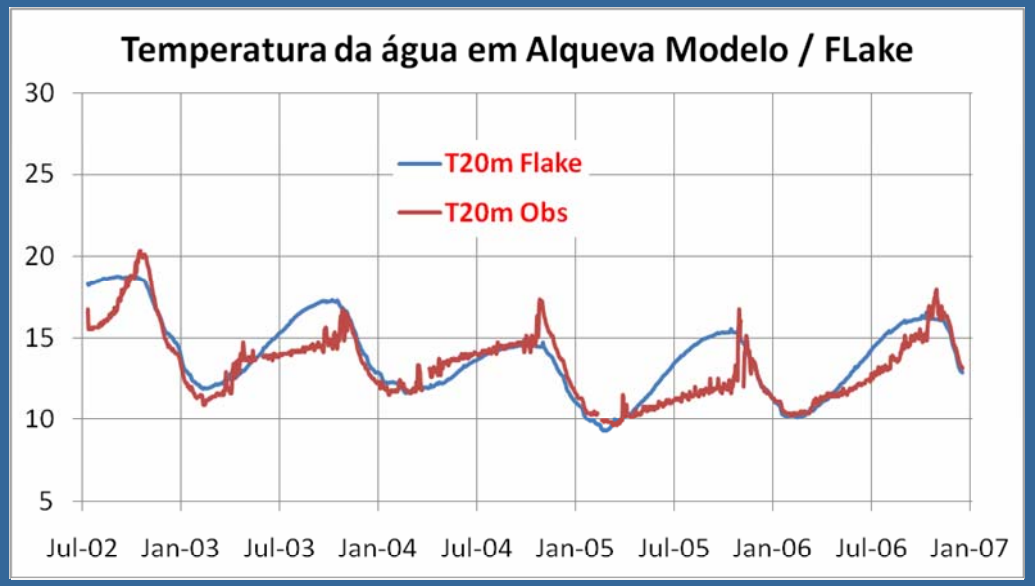
Realist



1st attempt
! C_T_n_flk = C_T_min
C_T_n_flk = 0.65
(when T = Cst > 4°C)
2nd attempt
constrain the variation of C_θ:
$\Delta C_\theta < 0.1/\Delta t$

5 years simulation with Flake off line

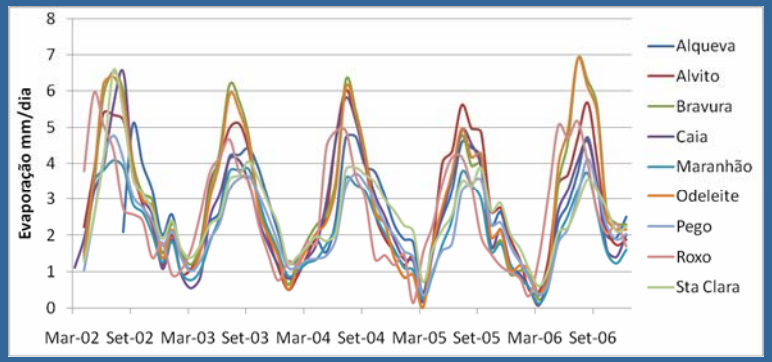
- Parameters:
  - Extinction Coefficient: 4 m^{-1}
  - Depth: 30 m
  - With Sediments
- FLake results accord with data
  - High correlations
  - Negative bias in near surface temperatures
  - Positive bias in deep water

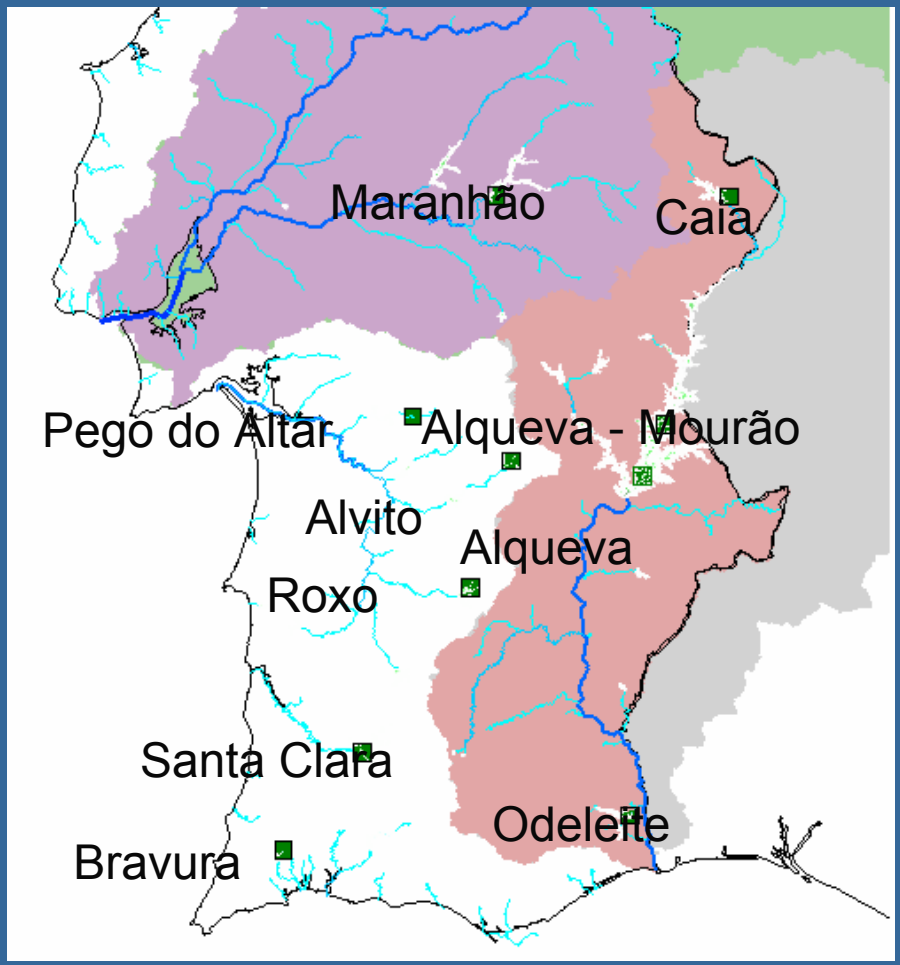


Statistics	T1m	T5m	T10m	T15m	T20m
Bias	**-1.28**	**-1.61**	**-1.24**	**0.08**	**0.62**
EAM – Absolute mean error	**1.40**	**1.75**	**1.51**	**0.96**	**1.04**
RQEM – Root Mean square error	**1.73**	**2.18**	**2.05**	**1.23**	**1.40**
IOA - index of agreement	**0.97**	**0.94**	**0.91**	**0.94**	**0.90**
R^2	**0.96**	**0.96**	**0.84**	**0.77**	**0.71**
Correlation	**0.98**	**0.98**	**0.91**	**0.88**	**0.84**

More simulations with Flake off line

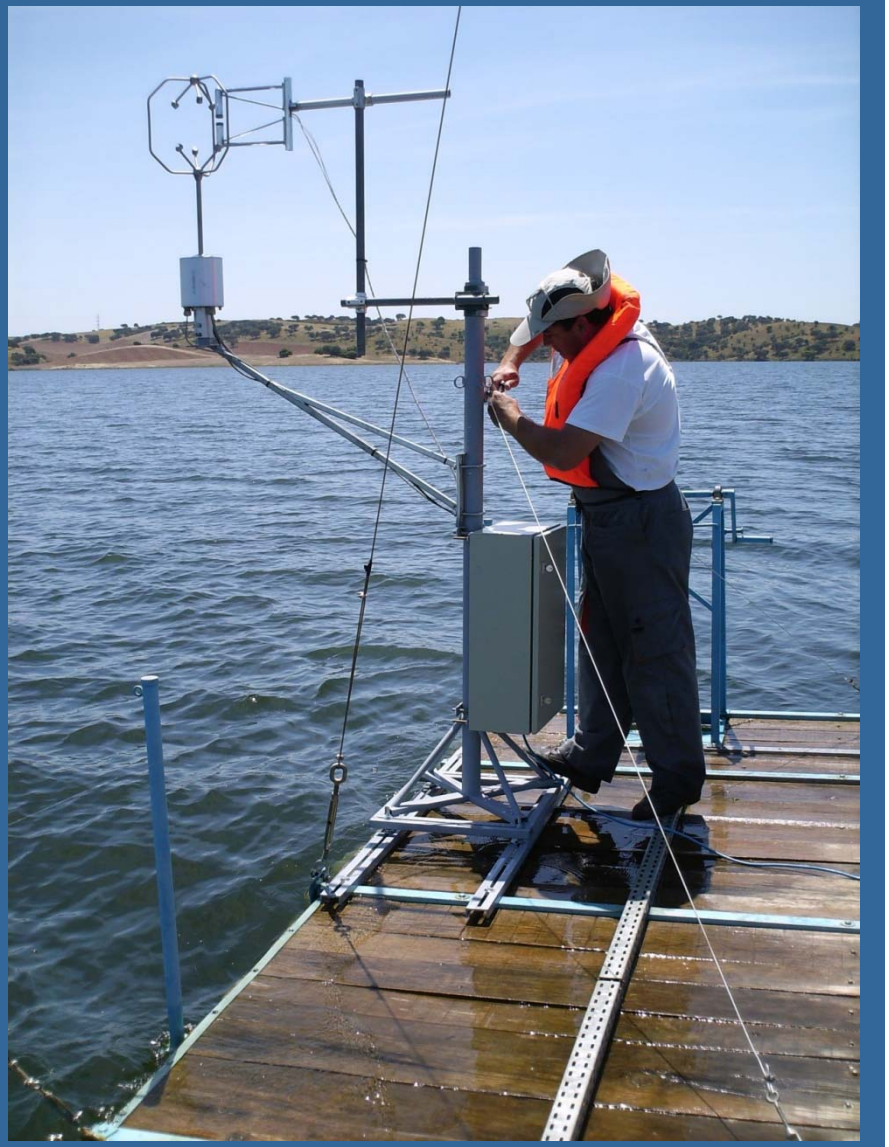
- Over other dams in South Portugal with floating meteorological stations
  - Results compare well with observations.
  - Objective: to estimate evaporation from reservoirs





Alqueva: Field experiment

- 10 July – 5 September 2007
- Collaboration: U. Lisboa, INAG and EDIA (Lake management)
- Sensible and latent heat fluxes with an eddy correlation system
  - Sonic Anemometer(metek)
  - Krypton Hygrometer (Campbell)
- Radiation:
  - Solar (up and down)
  - Long wave (up and down)



Lake08, St. Petersburg, September 2008

Alqueva: Field experiment

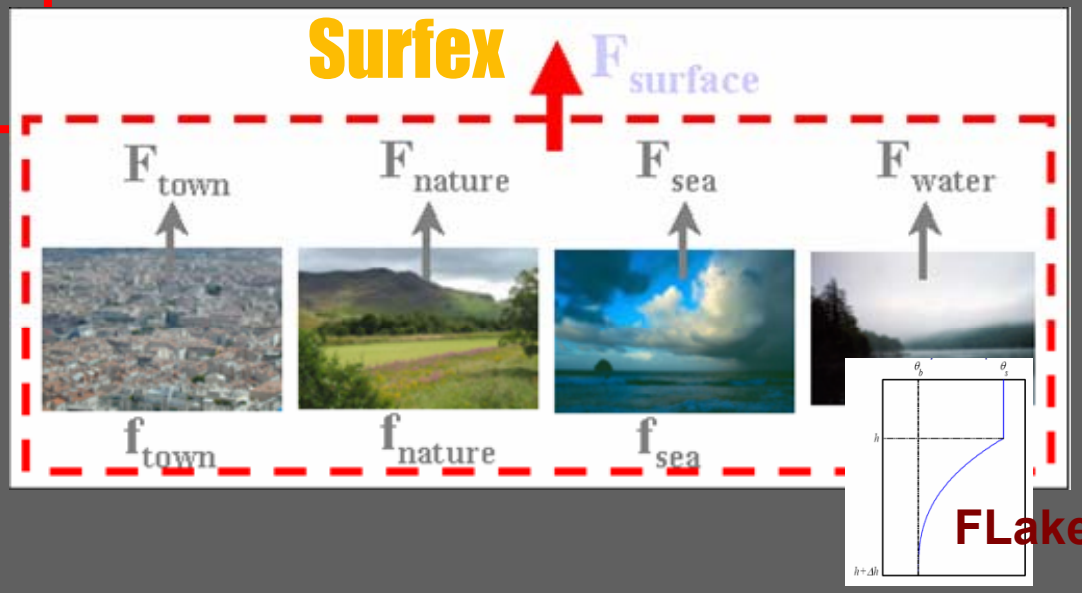
- Time series used in the tests:
  - Forcing (56 days):
    - T2m, q2m, v2m, Rs, Ratm
  - Data for validation
    - Tw_1m, Tw_15m, Tw_20m, Tw_deep
    - H (53 days)
    - LE (18 days)

Méso-NH
AROME
Arpège / Aladin

albedo
emissivity
radiative temperature

momentum flux
sensible heat
latent heat
CO2 flux
Chemical fluxes

Atmospheric forcing
Sun position
Downward radiative fluxes



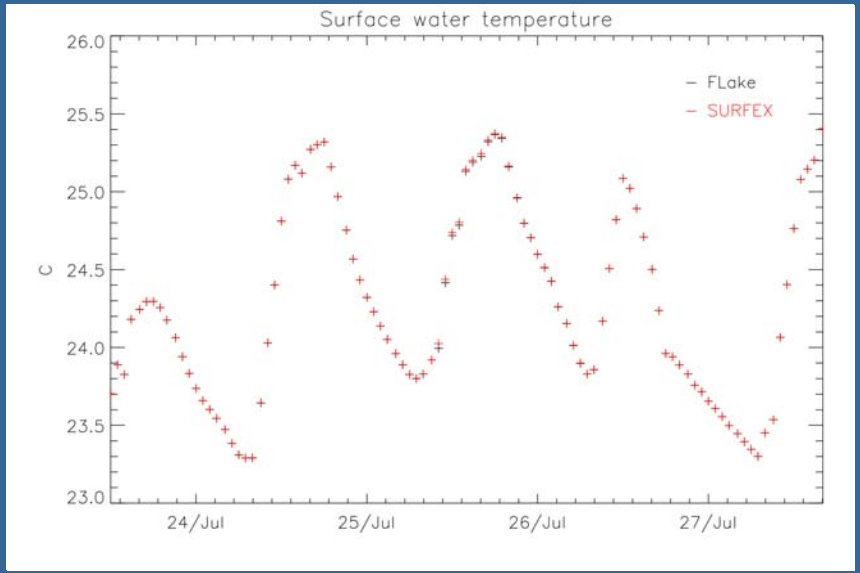
Flake inside SURFEX (technical aspects)

- Although not in Meso-NH norms, the original FLake code was remained as it is in http://nwpi.krc.karelia.ru/flake/ (for future compatibility)
- An interface (flake_interface.f90) to communicate with SURFEX is used.
- FLake code is prepared for single-column applications. So, The flake_interface calls the flake routines inside a DO loop over the horizontal grid points where lakes are present.
- The coupling is explicit.
- The fluxes are computed before the advance of flake variables, namely of the Surface Temperature.
- The fluxes of momentum and of sensible and latent heat may be computed using the routines provided by FLake (SfcFlx routines) or by the SURFEX WATER_FLUX routine.
- All the routines for the pre and pos processing have been modified in accordance.

Test 1. SURFEX_Flake versus Flake alone

The results of SURFEX_FLake Flake alone coincide, with only small differences due to numerical approximations.

Flake is correctly implemented in SURFEX



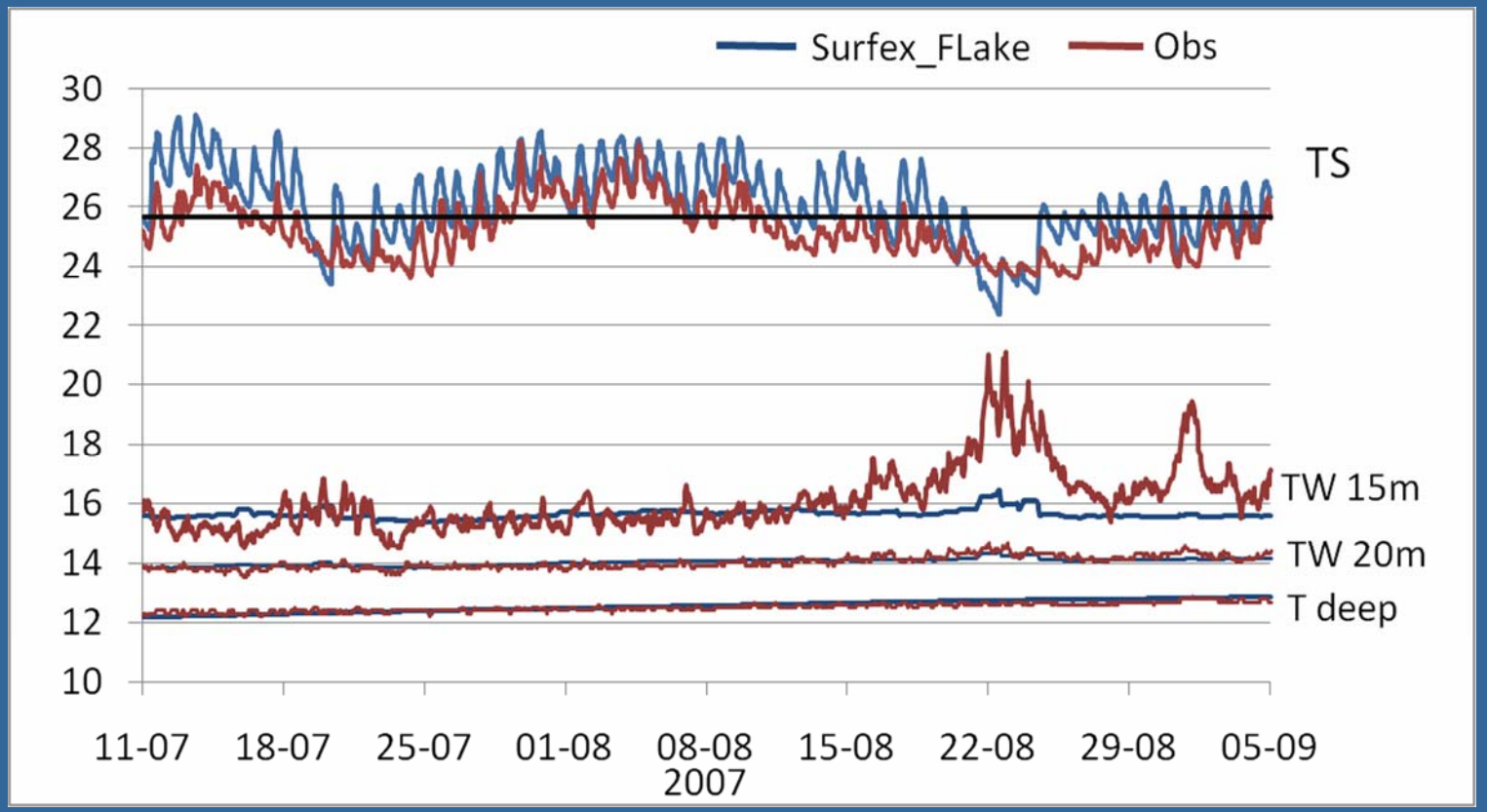
Water surface temperature simulated by FLake alone (black) and inside SURFEX (red) for the period where the differences are greater

Test2. SURFEX_FLake versus WATFLUX and Observations

- Experiments:
  - Flake (fluxes computed by SfcFlx / FLake)
  - FLake_WFLX (fluxes computed by WATFLUX / SURFEX)
  - WATFLX with C^{te} water temperature
- Parameters and initial conditions
  - Observations
  - Tuning

Parameters		Initial Values	
WATER_DEPTH	40.	TS=T_ml	298.8
WATER_FETCH	1000.	C_t	0.77
T_BS	282.	T_bot	285.4
DEPTH_BS	0.8	T_b1	283.2
EXTCOEF_WATER	3.5	h_ml	3.3
		h_b1	0.4

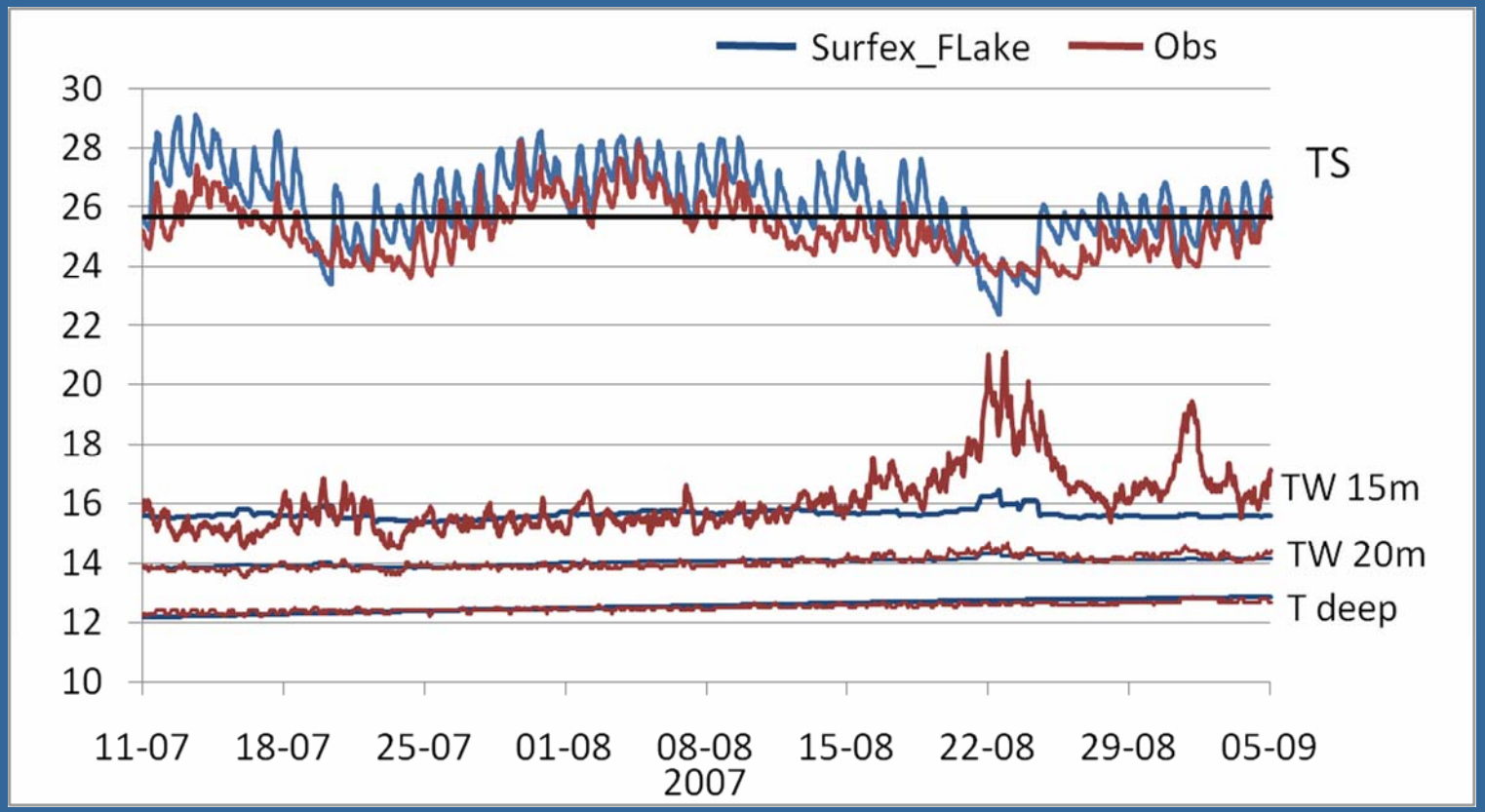
Test2. Water Temperature



- TS_FLK_WFLX > TS_Obs
- Good correlation
- Bias de TS_FLK_WFLX > TS constant (for this period Ts_WATFLX ~ mean(Ts_obs))

	correlation	Bias	RMSE
FLK_WFLX	0.85	0.9	1.1
WATFLUX	0.0	0.2	1.2

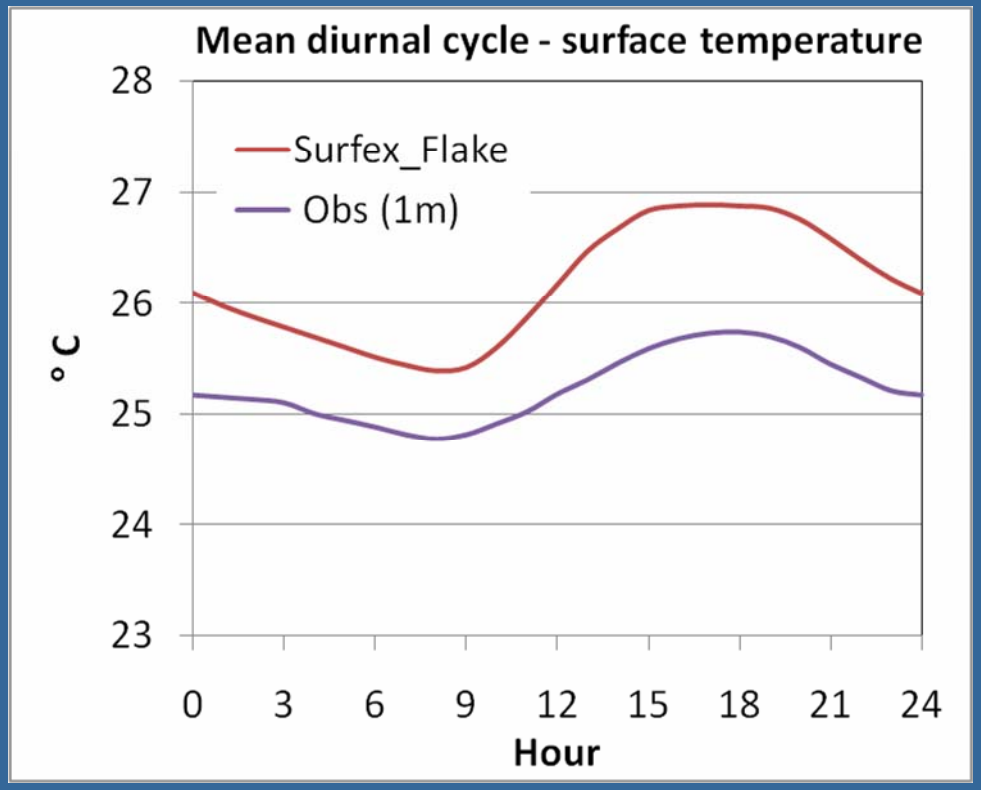
Test2. Water Temperature



- Good representation of deep temperature
- Bad representation of an late august episode of mixing layer deepening (3D process?)

Statistics	Correlation	**Bias**	**RMSE**
T_15m	0.56	-0.4	1.1
T_20m	0.76	0.01	0.13
T_bot	0.91	0.05	0.10

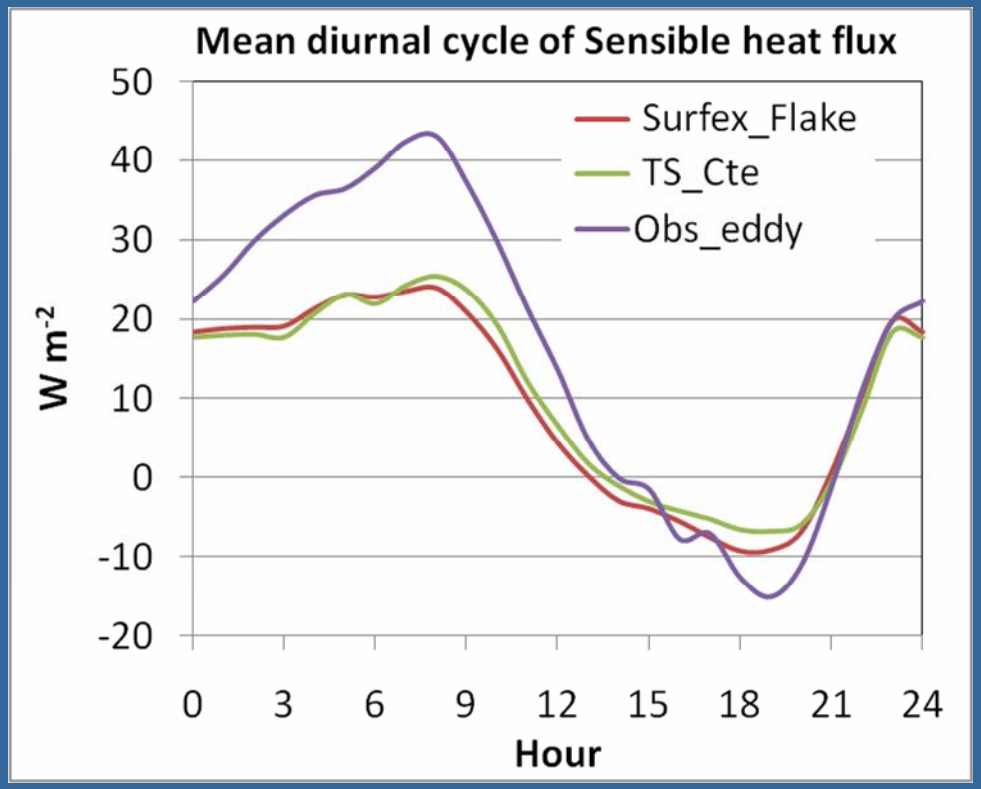
Test2. Water Temperature



	correlation	Bias	RMSE
FLK_WFLX	0.85	0.9	1.1
WATFLUX	0.0	0.2	1.2

Teste 2. Sensible Heat Flux

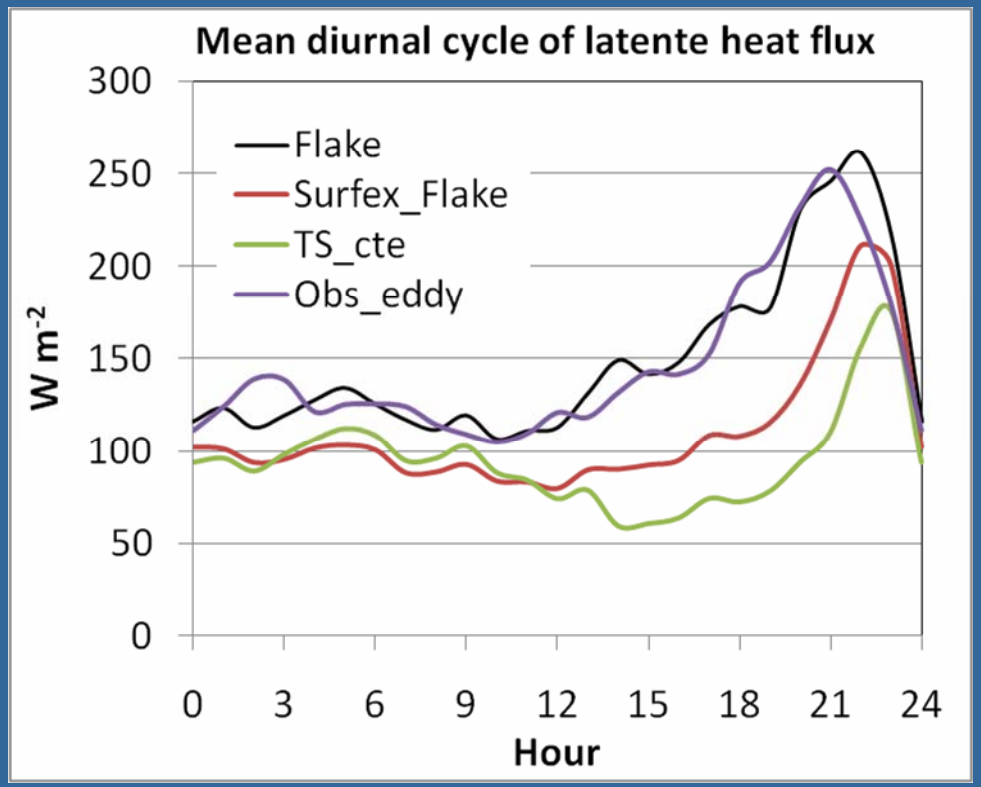
- Sensible heat Flux (53 days in the mean computation)
  - Simulated < Observed (night time and morning)
  - Same pattern
  - In the afternoon H is negative
  - Maximum positive at 9 a.m.
  - Impact of lake model is weak
  - Note: Ts in TS_Cte ~ mean T



H	Correlation	Bias	RMSE
Surfex_flake	0.87	-6.2	18.4
TS_Cte	0.80	-6.5	19.8

Teste 2. Latent Heat Flux

- Latent heat flux (only 18 day – good days)
  - (Less accurate data)
  - Simulated << Observed
  - Impact of the lake model is more visible and positive (late afternoon)
  - Maximum of evaporation in the beginning of night (21 – 22 H)
  - Flux Scheme of Flake accord better with the observations.



H	Correlation	Bias	RMSE
Surfex_flake	0.62	-47.	81.
TS_Cte	0.42	-61.	113.
Flake	0.68	2.2	69.

Conclusions

- Flake is available on SURFEX
- The implementation was tested for no ice conditions.
- With a minor change in the code, FLake reproduced well the evolution of water thermal profiles of south Portugal (Mediterranean) lakes on a scale of several years
- For one summer period, the use of the lake model has a positive, although weak, impact on computed surface fluxes, namely in evaporation. In certain critical situations (ex: Fog), it can make the difference.

Future work:

- 3D Simulations with Meso-NH
- Test the flux schemes over water bodies used in Meso-NH.
- Test the implementation on ice conditions.
- Test the snow schemes of Surfex with FLake.
- Collaborate in the construction of global maps of FLake parameters (depth, extinction coefficient, etc.)