CONSORTIUM FOR SMALL SCALE MODELING COSMO

CALMO Project: The proof of the Parameters Calibration Method

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Abstract

Parameterization schemes applied in NWP and climate models include many poorly confined parameters. In order to eliminate the resulting uncertainties, "expert tuning" is usually performed for a certain target area and model configuration. However, such calibration is not optimal for different target regions or model configurations. A practicable objective calibration method has been developed by Bellprat et al. (2012) [1] using the climate model CCLM-4.8, which has shown to be better than expert tuning.

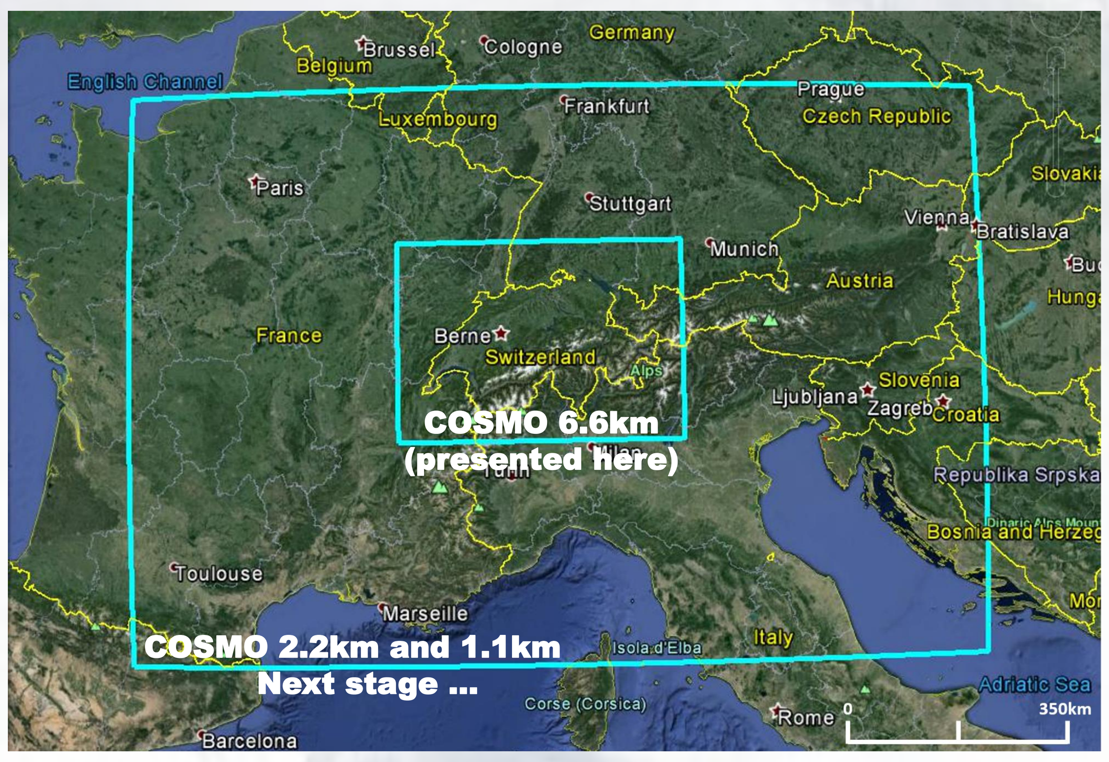
Goal

Apply the calibration method for NWP applications

Method

1. Choose parameters to calibrate depending on the fields to be verified, model domain, season of verification. Understand expected influence.
2. Construct the Meta-Model to "guess" the COSMO forecasts for different parameters values
3. Define the forecast performance function (score) to estimate the forecasts quality
4. Run the Meta-Model for MANY (10,000) parameters values combinations, and give a score for each combination. Choose parameters values combination which got the best score. This parameters combination can then be used in order to produce better quality forecasts

Calibration Domains



Up to now:

- *COSMO **6.6 km** over Switzerland (verification vs. Swiss observations)*
- *Driven by: analyses of the operational COSMO 6.6 km at MeteoSwiss*
- *Series of 36h runs for January and June 2008*
- *Calibrating: 3 parameters $rlam_{heat}$, tkh_{min}, tur_{len}*

Next stage:

- *COSMO **2.2 and 1.1 km** over bigger domain (verification vs. Swiss and Italian obs.)*
- *Driven by same analyses, but initialized at soil by **"Terra Stand-Alone"***
- *Series of 36h runs for typical+extremal periods during 2013*
- *Calibrating: several most sensitive parameters (to be defined)*
- ***Won CSCS proposal for 1,000,000 node-hours!***

Meta Model

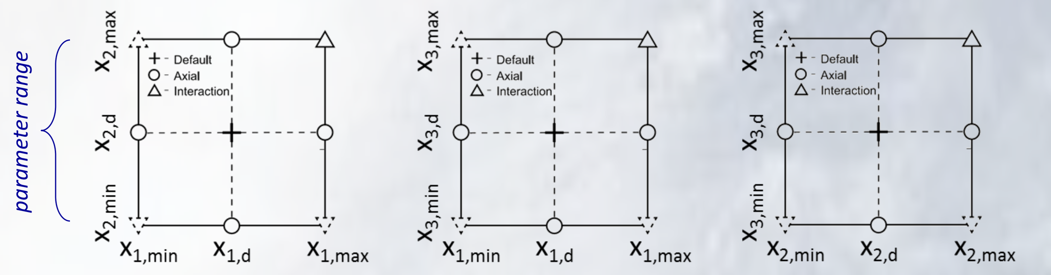
- *Choose parameters values ($rlam_{heat}$, tkh_{min}, tur_{len})*

  Ranges: $rlam_{heat} \in [0.1\ 1\ 10]$, $tkh_{min} \in [0\ 1\ 2]$, $tur_{len} \in [100\ 500\ 10^4]$
- *Choose day "i" at region "r"*
- *The COSMO field **F** (ex: **Tmax**, **Tmin** or **Precip.**) is approximated by:*

$$F_{i,r} \cong F_{i,r}^{d} + c_{i,r} + a_{i,r}^{(1)}x_1 + B_{i,r}^{(1,1)}x_1^2 + a_{i,r}^{(2)}x_2 + B_{i,r}^{(2,2)}x_2^2 + a_{i,r}^{(3)}x_3 + B_{i,r}^{(3,3)}x_3^2 + B_{i,r}^{(1,2)}x_1x_2 + B_{i,r}^{(1,3)}x_1x_3 + B_{i,r}^{(2,3)}x_2x_3$$

$$x_1 = \frac{rlam_{heat} - rlam_{heat,d}}{rlam_{heat,max} - rlam_{heat,min}} \quad x_2 = \frac{tkh_{min} - tkh_{min,d}}{tkh_{min,max} - tkh_{min,min}} \quad x_3 = \frac{tur_{len} - tur_{len,d}}{tur_{len,max} - tur_{len,min}}$$

- *How to construct such approximation?*
- *One has to perform several (at least $2N + \frac{1}{2}N(N-1)+1$) COSMO simulations with specific parameters values:*



- *Each simulation (with given x_1, x_2, x_3) yields forecasted $F_{i,r}$*
- ***Interpolation** (quadratic fit) of $F_{i,r}$ in parameters space yields $F_{i,r}$ for **any** parameters values, according the formula above*

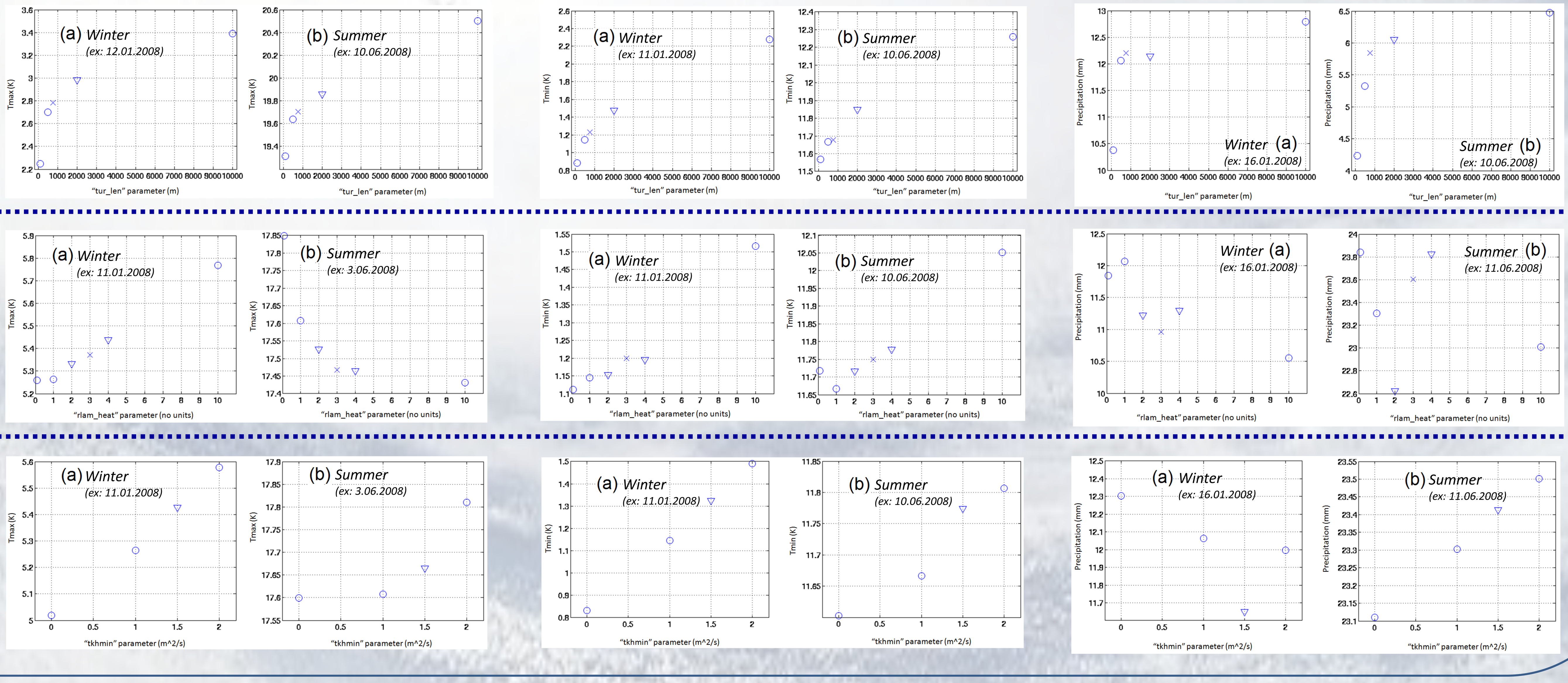
[1] Bellprat, O., Kotlarski, S., Lüthi, D. and Schär, C. (2012), Objective calibration of regional climate models, J. Geophys. Res., 117, D23115

$rlam_{heat}$, tkh_{min}, tur_{len} influence on COSMO forecasts

tur_{len} is the asymptotic (with z) turbulent length. The higher is tur_{len}, the higher are the turbulent fluxes (mixing) for all the variables and tracers. The result is increasing 2m-Temperature and Precipitation mainly in stable conditions (which are suppressed)

$rlam_{heat}$ is the laminar resistance factor for heat and moisture transfer between soil and atmosphere. Higher $rlam_{heat}$ leads to increase of 2m Temperature in stable conditions (with cold soil), and to decrease of 2m Temperature in unstable conditions (with warm soil). The influence on Precipitation is not obvious

tkh_{min} is the lower limit of the turbulence coefficient for heat and moisture. Higher tkh_{min} "keeps alive" turbulence at stable conditions (which are suppressed) leading to the increase of 2m Temperature. The influence on Precipitation is not obvious



Forecast Performance Function

*For given parameters values combination "**p**", the RMSE type score for comparing the forecasts $F_{Tmax,p,i,r}$, $F_{Tmin,p,i,r}$, $F_{Pr,p,i,r}$ with observations $O_{Tmax,i,r}$, $O_{Tmin,i,r}$, $O_{Pr,i,r}$ is:*

$$S_p = \sqrt{\frac{1}{N_{regs} \times N_{days}} \sum_{regions} \sum_{days} \left\{ \frac{\left(F_{Tmax,p,i,r} - O_{Tmax,i,r}\right)^2}{W_{Tmax} \times \left(\sigma_{Tmax,r}\right)^2} + \frac{\left(F_{Tmin,p,i,r} - O_{Tmin,i,r}\right)^2}{W_{Tmin} \times \left(\sigma_{Tmin,r}\right)^2} + \frac{\left(F_{Pr,p,i,r} - O_{Pr,i,r}\right)^2}{W_{Pr} \times \left(\sigma_{Pr,r}\right)^2} \right\}}$$

$\sigma_{Tmax,r}$, $\sigma_{Tmin,r}$, $\sigma_{Pr,r}$ - observations standard deviations at a given region "r" (to normalize the forecast errors)

W_{Tmax}, W_{Tmin}, W_{Pr} - normalization weights for combining Tmax, Tmin and Precipitation scores

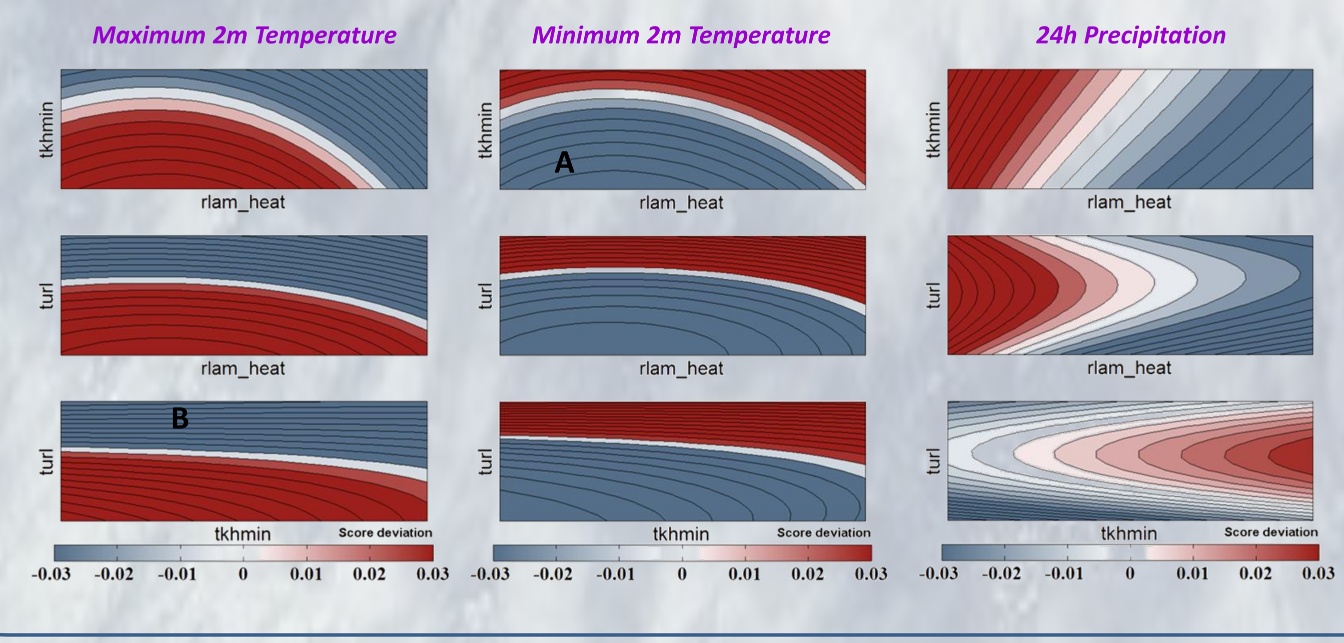
Meta-Model forecasts scores ($S_p - \overline{S_p}$) for pair-wise parameters combinations (ex: January 2008)

Best combination   Worst combination

ex: A

Tmin usually too high. Low tkh_{min} and $rlam_{heat}$ decrease Tmin (at SBL)

better score!



ex: B

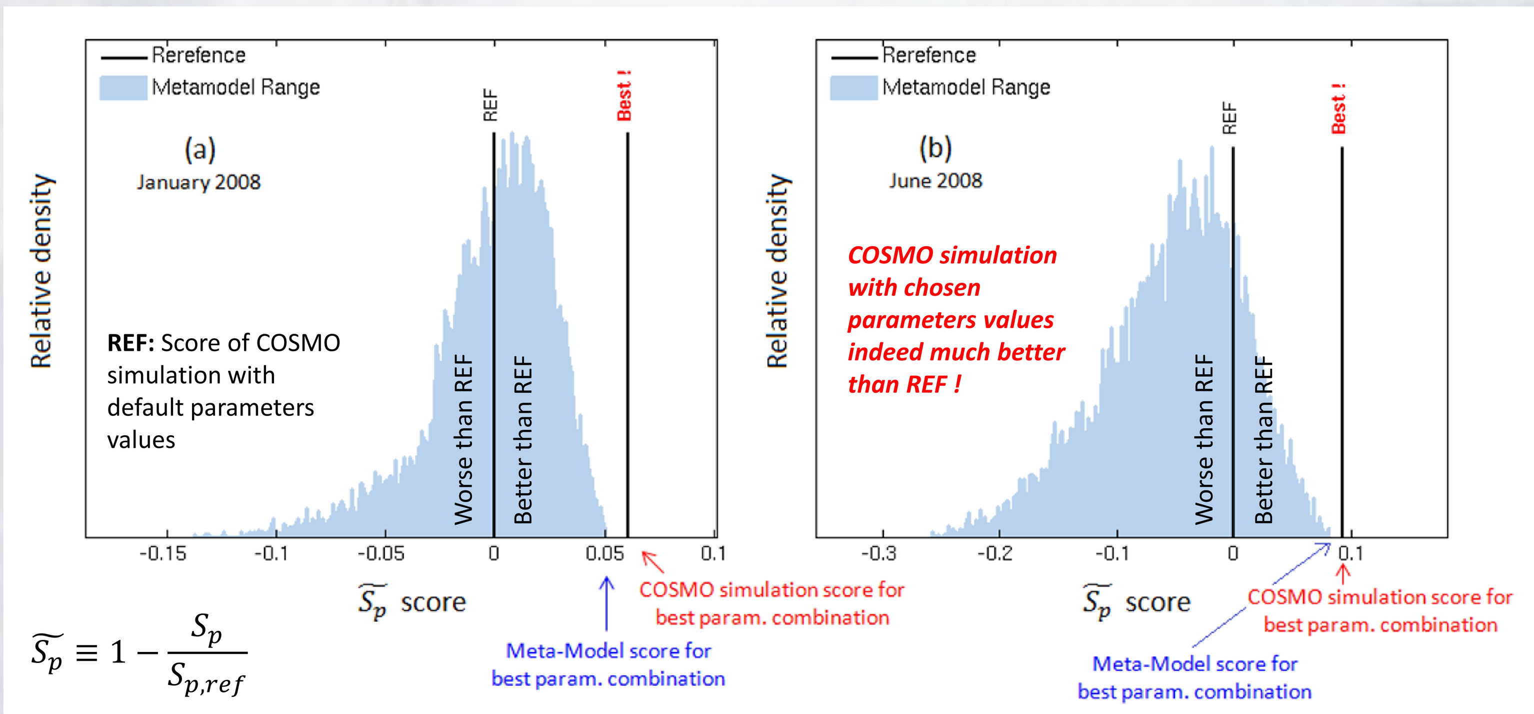
Tmax usually too low. Small sensitivity to tkh_{min}. High tur_{len} increases Tmax

better score!

Best Parameters Values Combination

Scores calculated for the Meta-Model "forecasts" for 10,000 parameters values combinations

Scores distributions



Best parameters:

	"rlam_heat" [0.1 1 10]	"tkhmin" [0 1 2]	"tur_len" [100 500 10000]
January 2008	8.22	0.02	1037
June 2008	0.17	0.02	102

Calibration results with COSMO-7
(based on 3 parameters, Switzerland area and 40-days validation period)
indicate that objective calibration method applied for COSMO-CLM is also valid for NWP applications