# Impacts on model performance score from CALMO and CALMO-MAX

Voudouri A.1 *, Carmona I.2, Avgoustoglou E.1, Levi Y.2,Bettems J.M.3and E.Bucchignani4

*1.Hellenic National Meteorological Service 2.Israel Meteorological Service 3.MeteoSwiss 4.Italian Aerospace Research Center (CIRA)*
*∗corresponding author e-mail: antigoni.voudouri@hnms.gr*

## 1 Introduction

The priority project CALMO of COSMO (years 2013-2016) induced an objective multivariate calibration method aiming on substituting expert tuning. Expert tuning is a procedure by which free or poorly confined parameters existing in the parameterization schemes of RCM and NWP models are mainly tuned using expert knowledge (Duan et al., 2006; Skamarock, 2004;Bayler et al., 2000).This procedure, performed for specific parameterization schemes addressed by model developers, usually underestimates parameter interactions, follows a non-objective procedure, and is difficult to replicate without a direct involvement of the model developers.
Several studies, over the last years, have been conducted towards substituting expert tuning by objective and automatic methodologies to calibrate unconfined model parameters existing in both NWP and RCM model (Bellprat et al., 2012a and 2012b, Gong et al.,2015, Duan et al., 2016, Gong et al., 2016, Voudouri et al., 2017, 2018).

At the framework of CALMO, the implementation of the calibration method that has been developed by Bellprat et al. (2012a) and implemented for a regional climate model has been applied on COSMO-NWP model using a horizontal resolution of 0.0625o and then tested for a horizontal resolution of 0.02o (approximately 2km) over a mainly continental domain covering the Alpine Arc.
In the priority project CALMO-MAX (years 2017—in progress) additional tests on the advantages ofthe calibration method for COSMO model, using a finer resolution of 0.01o are studied. The steps followed, namely model setup, parameter selection as well as basic differences between the two priority projects are briefly described in Section 2. Results from CALMO to be considered in CALMO-MAX are presented in Section 3. A summary and conclusions are given in Section 4.

## 2 Data and Methodology

### 2.1 Model setup

The code used is the refactored version of the COSMO model (Lapillonne and Fuhrer,2014) based on the official version 5.00 of the model, capable of running on GPU-based hardware architectures, operationally used by MeteoSwiss. In CALMO, simulations were performed with COSMO model over the whole year 2013 and operated with horizontal resolution of 0.02o (approximately 2km) for a domain including the wider area of Switzerland and Northern Italy (Fig. 1), while in CALMO-MAX a finer resolution of 0.01° (about 1 km) is used. The vertical extension reaches 23.5 km ( 30hPa) with 60 model levels for CALMO and 80 for CALMO-MAX. Initial and boundary fields for all tests are derived from the MeteoSwiss operational forecasting archive system at 0.02o horizontal resolution ( 2km).

In addition, the history of the soil, not used in the configuration of CALMO, is considered in the CALMO-MAX simulations (hindcast mode). Finally, for CALMO-MAX, the soil has been initialized by a 3 years spin-up using TERRA Standalone (TSA).

---

doi:10.5676/dwd_pub/nwv/cosmo-nl_19_05

## 2.2. Data and selected parameters

The unconfined parameters existing in COSMO model are related to sub-grid scale turbulence, surface layer parameterization, grid-scale clouds, precipitation, moist and shallow convection, radiation, soil scheme etc. (Doms et al., 2011, Gebhardt et al., 2011). Thus, sensitivity experiments using twelve parameters associated with turbulence (tur_len, tkhmin, tkmmin), surface layer parameterization (rat_sea, rlam_heat, crsmin), grid-scale precipitation (v0snow), moist and shallow convection (entr_sc), radiation (rad_fac, uc1) and the soil scheme (c_soil) have been performed and the most sensitive ones have been selected. Figure 2 illustrates the sensitivity of minimum 2m temperature with respect to 7 (left panel) and 5 parameters (right panel) respectively. The red polygon refers to the zero sensitivity "axis" while sensitivities close to zero are depicted with blue bullets. In left panel of figure 2, negative sensitivities, well below the red polygon are depicted with orange bullets while positive sensitivities well above the red polygon are depicted with green bullets. In right panel of figure 2, all negative and positive sensitivities are depicted with green bullets. The dashed polygon line that connects the dots denotes optically the overall sensitivity for the considered meteorological variable especially to the degree that it is convex/concave and mainly in reference to the zero sensitivity red polygon. In CALMO, the six model parameters selected were: asymptotic turbulence length scale, tur_len [m]; minimal diffusion coefficients for heat, tkhmin[m2/s]; scalar resistance for the latent and sensible heat fluxes in the laminar surface layer, rlam_heat [no units]; the surface-area index of the evaporating fraction of grid points over land, c_soil[no units]; the factor in the terminal velocity for snow, v0snow[no units]; and the mean entrainment rate of boundary layer humidity into the shallow convection clouds, entr_sc [m-1]. In CALMO-MAX five parameters were selected: tkhmin, rlam_heat, v0snow(already used in CALMO), and additionally the fraction of cloud water/ice considered for radiation, radfac[no units] and the parameter for computing the amount of cloud cover in saturated conditions, uc1[no units].

The parameters are calibrated against daily minimum and maximum 2m temperature values (Tmax and Tmin respectively) as well as 24h accumulated precipitation (prec). For temperature, available measurements of daily mean surface air temperature selected at the station network of MeteoSwiss were used. More specifically the interpolated values of all available 2m-temperature maximum and minimum observations over Switzerland to a 2km-grid are provided by Frei (2014).

For precipitation observations over Switzerland, the gridded MeteoSwiss radar composites were used, corrected by rain gauges and interpolated to the model grid. Over Northern Italy, observations interpolated to the model grid were used only where the grid points in the vicinity of the stations get a value. In addition to Tmin, Tmax and prec, radio soundings data and the associated model profiles at grid points near the soundings locations were used. Sunshine duration and 2m dew point temperature are also considered in CALMO-MAX with observational data provided by MeteoSwiss.

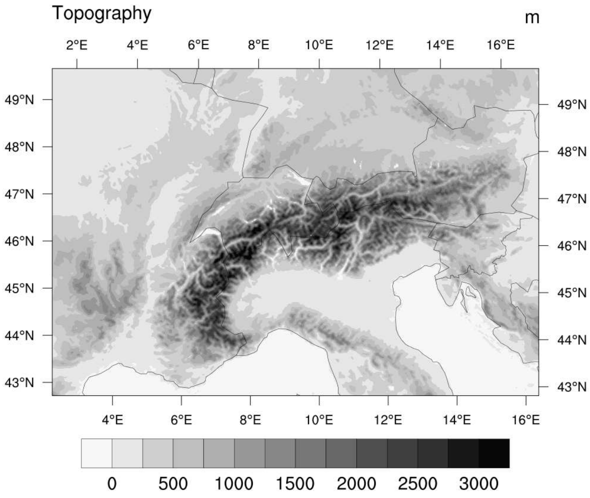

Figure 1: Topography of the simulation area

## 2.3. Methodology

The calibration methodology is presented in detail in Voudouri et al. 2017 and 2018. It relies on a Meta-Model (MM) that approximates the parameter space, using a multi-variate quadratic regression in an n-dimensional model (Neelin et al., 2010 and 2010a). The specific MM is based on the assumption that changes of the simulated model quantity, due to a parameter perturbation, are smooth and thus can be approximated by a 2nd order polynomial regression.

As a quadratic fit is determined by only three points, this assumption allows fitting the MM by performing a low number of simulations, namely 2N+0.5N(N-1)+1, for N parameters, which is crucial for computationally expensive NWP and RCM models.The use of a quadratic regression further inhibits over-fitting and allows for analytical solutions of the parameter space. Once the MM has been constructed, it can be used as a surrogate to perform a large number of simulations, testing several parameter values in order to find theoptimal combination of values.

In CALMO, the MM adapted for COSMO-CLM by Bellprat et al., 2012a, has been consolidated and extended by adding the option not to average Tmax/Tmin over regions, the prediction of multiple vertical profile characteristics, and the possibility of supporting new geographical regions. The quality score to account for model performance was a RMSE-type performance score initially tested in CALMO preliminary phase.Successively, an advanced performance score was introduced based on the COSMO Index (COSI) developed by Damrath (2009). The COSI score combines the RMSE-type for continuous variables and the ETS (Equitable Threshold Score) for categorical fields. The COSI score in CALMO-MAX is updated to include sunshine duration, mean, maximum and minimum dew point temperature, while for precipitation ETS is replaced with the FSS (Fraction Skill Score).

## 3 Results

During the preliminary phase of CALMO, it has been shown (Voudouri et al., 2017 and 2018) that the MM developed for climate models (Bellprat 2012a, 2012b) can be adapted to COSMO-NWP. Therefore, the objective methodology can be transferred from RCM to NWP. During the second phase of CALMO, an optimal set of six parameters over the entire year has been extracted, as well as monthly optimal values illustrating model parameters sensitivity on different weather types. Figure 3 shows the 24 hour accumulated precipitation (prec), Tmax and Tmin values provided by MM against COSMO simulation results during the year 2013. The related correlation values are 79.9%, 80.6% and 78.2% respectively.

Monthly and yearly improvement of the model performance associated with daily minimum and maximum 2m temperature, as well as 24h accumulated precipitation when using the set of optimum parameter values, against the values recommended in the default model setup have been investigated. More specifically the annual cycle of the performance score using the optimum set of six parameters is presented in Figure 4. The annual cycle of the improved performance score when the optimum parameter sets is used is presented in the blue dotted line in Figure 4, while the red line stands for the improvement of the score over the entire year, when the optimum set of parameters is used replacing the default ones.

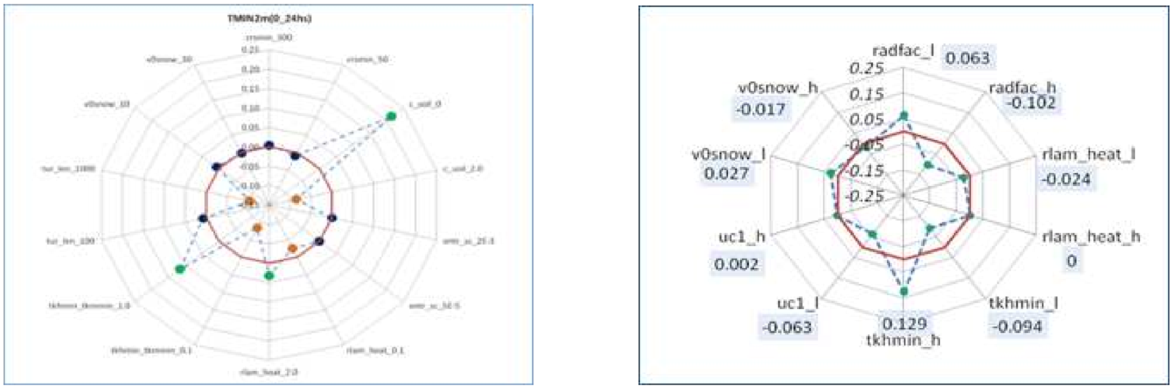

Figure 2: Spider graphs of minimum 2m temperature sensitivity with respect to 7 (left panel) and 5 parameters (right panel)

The monthly variability of the performance score with respect to the overall improvement (over the entire year) indicates that the model performance is sensitive to different weather patterns. This feature is pronounced during winter (and specifically for February) with the overall improvement reaching up to 12%. The effects of calibration methodology on yearly and monthly performance score, using finer model resolution, is now investigated at the framework of CALMO-MAX

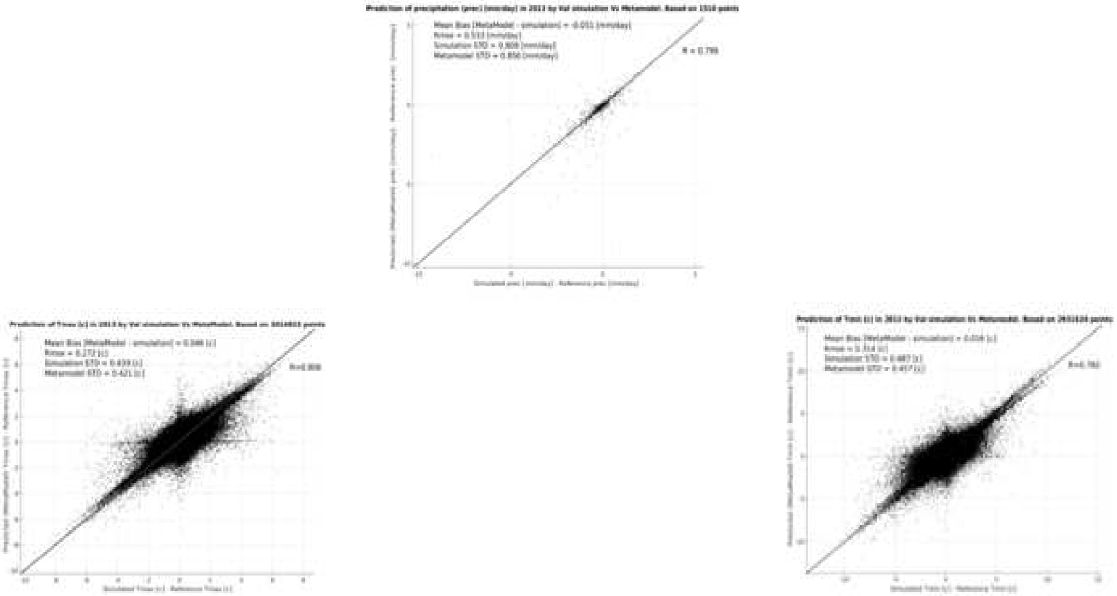

Figure 3: 24h accumulated precipitation (upper panel), Tmax (left panel), Tmin (right panel) Meta-Model prediction for the tested parameter combination, vs. COSMO simulation results during the year 2013. X axis presents the simulated field minus the reference simulation. Y axis presents the Meta-Model field minus the reference simulation.

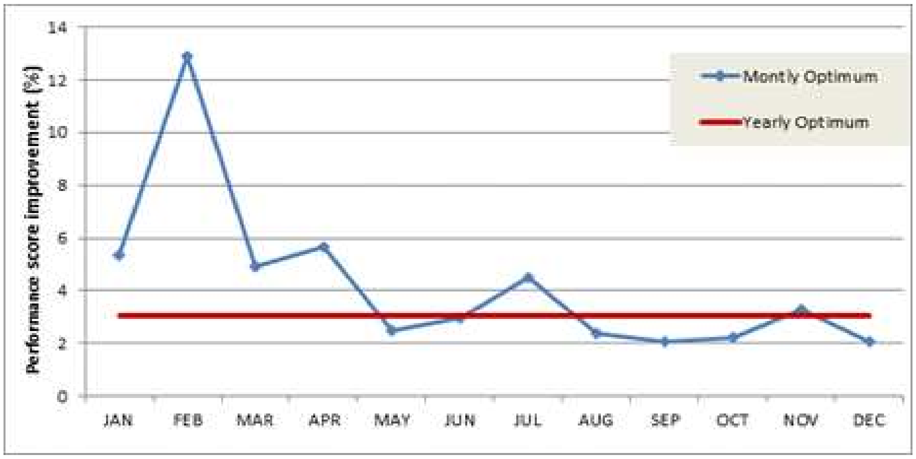

Figure 4: cycle of the performance score improvement using the optimum set for six parameters used in CALMO

## 4 Conclusions

The methodology used in CALMO and CALMO-MAX priority projects showed that the calibration of the unconfined model parameters using the MM is feasible. Model performance can be improved on monthly and yearly basis. However, the methodology remains computationally expensive. Towards this direction, it will be examined within CALMO-MAX whether the computational cost could be reduced by e.g. applying CALMO methodology on10-20 days set, representing most of the synoptic situation, instead of an entire year. Once the computational cost is reduced, the developed methodology could be used by each COSMO member, to define an optimal parameter set over the target area of interest, for re-calibration after major model changes (e.g. higher horizontal and / or vertical resolution), for an unbiased assessment of different modules (e.g.parameterization schemes), as well as for optimal perturbation of parameters when run in ensemble mode.

**Acknowledgments** The present work is part of CALMO priority project of COSMO. CSCS is acknowledged for providing the computer resources.

# References

[1] Albergel, C., de Rosnay, P., G. Balsamo, G., Isaksen, L., Munoz-Sabater, J., 2012: Soil Moisture Analyses at ECMWF: Evaluation Using Global Ground-Based In Situ Observations. *J. Hydrometeor*, 13, **1442-1460**.

[2] Aligo, E. A., Gallus, W. A. and Segal, M., 2007: Summer Rainfall Forecast Spread in an Ensemble Initialized with Different Soil Moisture Analyses. *Wea. Forecasting*, 22, **299-314**.