Agenda

Monday morning (9h00-10h30, CALMO-MAX session, chair Antigoni Voudouri)

- 09:00-09:30 Final review of CALMO project (A. Voudouri)
- 09:30-10:00 On the Domain Sensitivity of COSMO Model over the Mediterranean Area (E. Avgoustoglou)
- 10:00-10:30 On the Meta-Model (I. Carmona)
- 10:30-11:00 Coffee break
- 11:00-12:30 Open discussion: review of CALMO-MAX plan, resources, future workshop, list of scientific questions (All)

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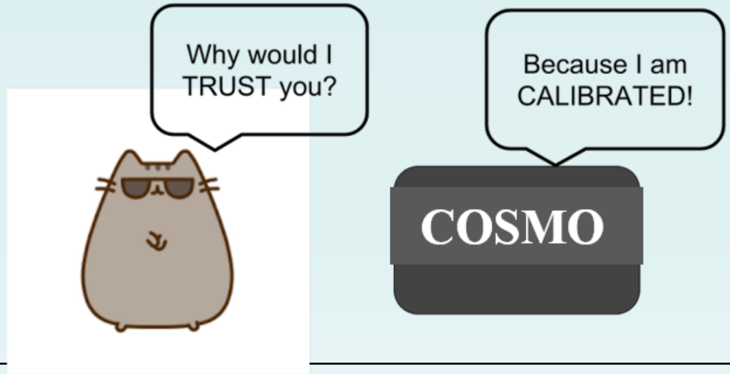
CALMO
Calibration of COSMO model

- Aim of the project
  - Provide an objective methodology for COSMO to substitute expert tuning and
  - Establish a standard procedure (tool) that objectively improves model performance by determining optimum values of the unconfined parameters.

- Project status: Finished (Work completed in 3 phases 01.2013 – 12.2016)

- FTEs invested: 6.5

- Project Team : A. Voudouri, P. Khain, I. Carmona, E. Avgoustoglou, J.-M. Bettems, F. Grazzini, and O. Bellprat



CALMO – The problem

- NWP and climate models use parameterization schemes for physical processes which often include free or poorly confined parameters.
- Model developers normally calibrate the values of these parameters subjectively to improve the agreement of forecasts with available observations, a procedure referred as expert tuning.
- Expert tuning sometimes referred to as *bad empiricism* **lacks objectivity** and requires **significant computer resources.**

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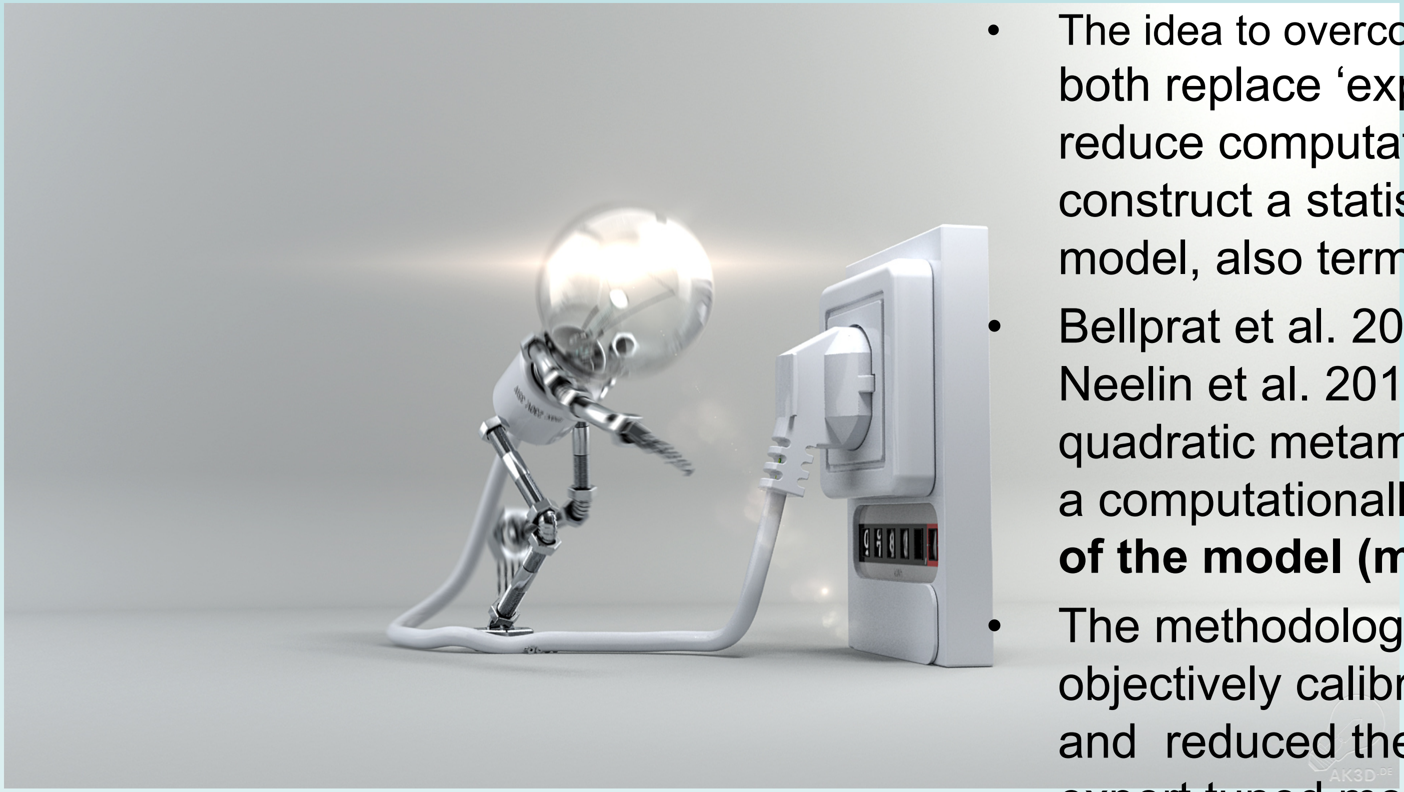
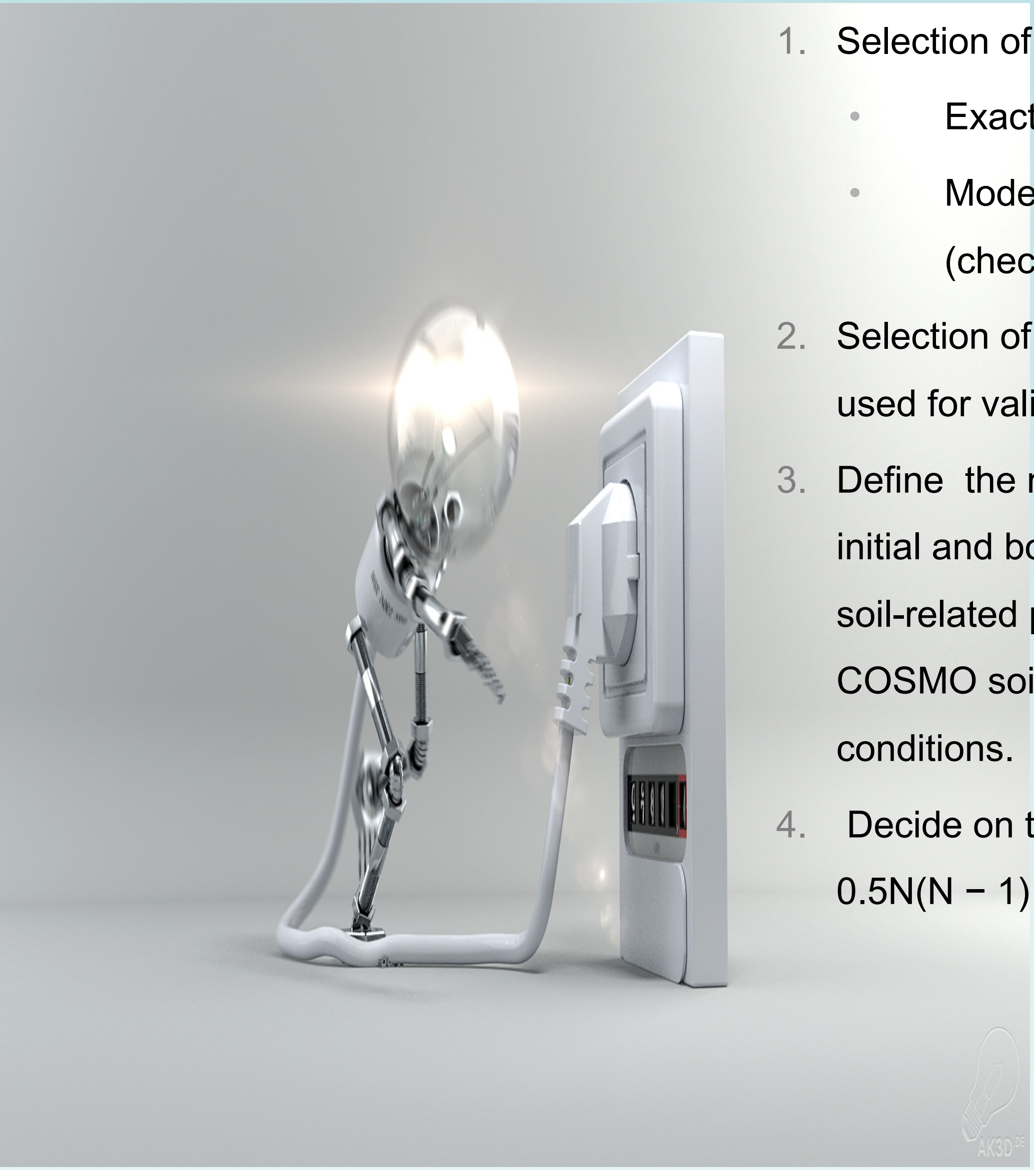
CALMO – The idea



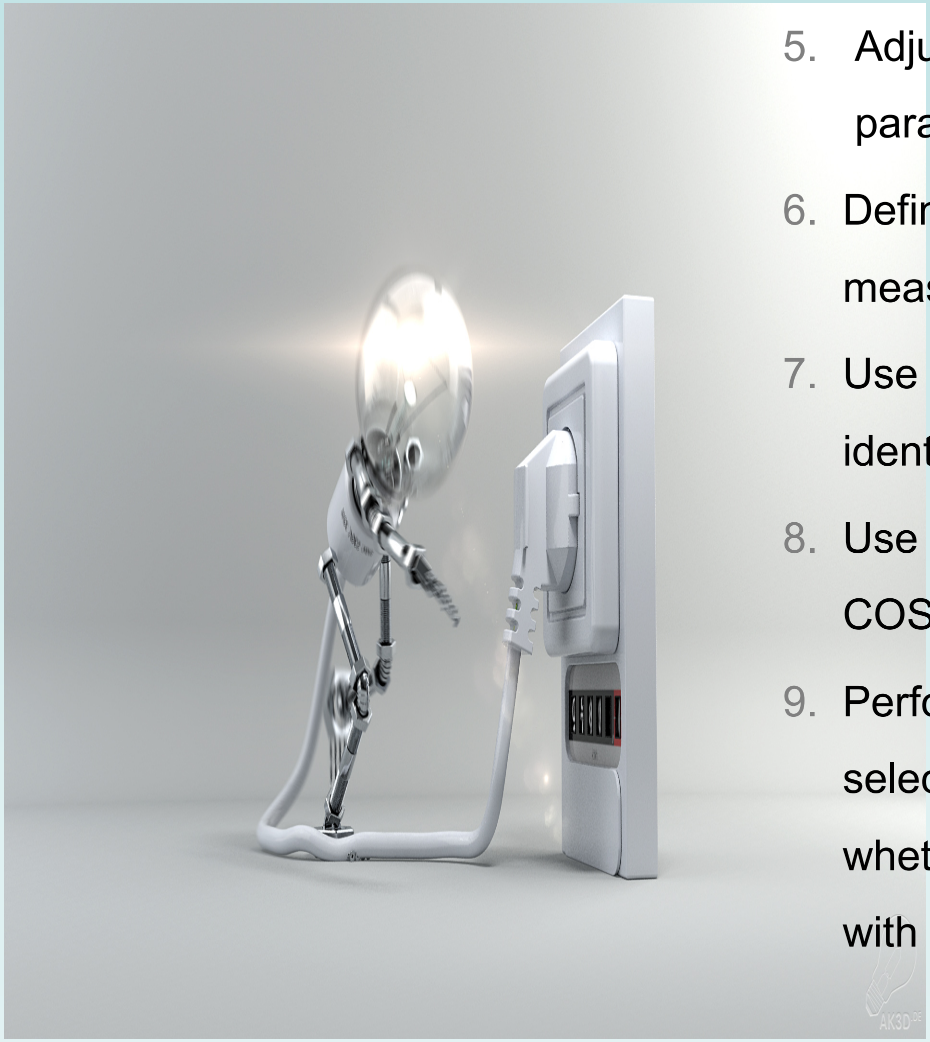
- The idea to overcome the problem of both replace ‘expert tuning’ and reduce computational costs is to construct a statistical surrogate model, also termed model emulator
- Bellprat et al. 2012 used the work of Neelin et al. 2010 on building a quadratic metamodel that serves as a computationally **cheap emulator of the model (meta-model MM)**
- The methodology was applied to objectively calibrate COSMO-CLM and reduced the model error of an expert tuned model by about 10%

CALMO methodology-How to….. (1)



1. Selection of important **model parameters** for calibration
   - Exact value is not well known
   - Model performance is sensitive to the choice of the value (check)
2. Selection of model variables with appropriate observations to be used for validation .
3. Define the method to perform the COSMO simulations time, i.e. initial and boundary conditions and the forecasts time ranges. For soil-related parameters, long term "spin-up" simulations of the COSMO soil scheme are needed for preparing proper initial conditions.
4. Decide on the number of parameters (N) and perform $2N + 0.5N(N - 1) + 1$ simulations of calibrated parameters.

CALMO methodology-How to….. (2)



5. Adjust the **meta-model** applicable to parameter variations
6. Define an objective **performance function** to measure model quality
7. Use MM to sample the parameter space to identify **optimal parameter configurations**.
8. Use optimal parameters configuration to run COSMO model.
9. Perform a real COSMO simulation with the selected parameters combination to verify whether the forecasts are indeed better (than with the default parameters combination).

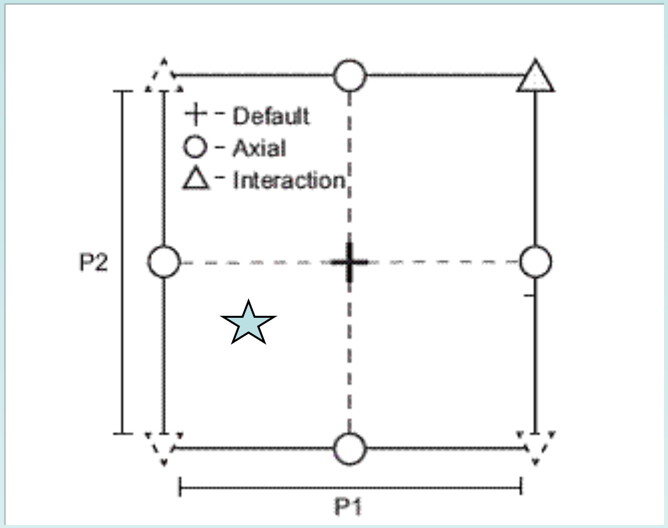
Define sensitivities

$$S_{<P>}(\%) = \frac{<P>_{TEST} - <P>_{DEFAULT}}{<P>_{DEFAULT}} \bullet 100$$

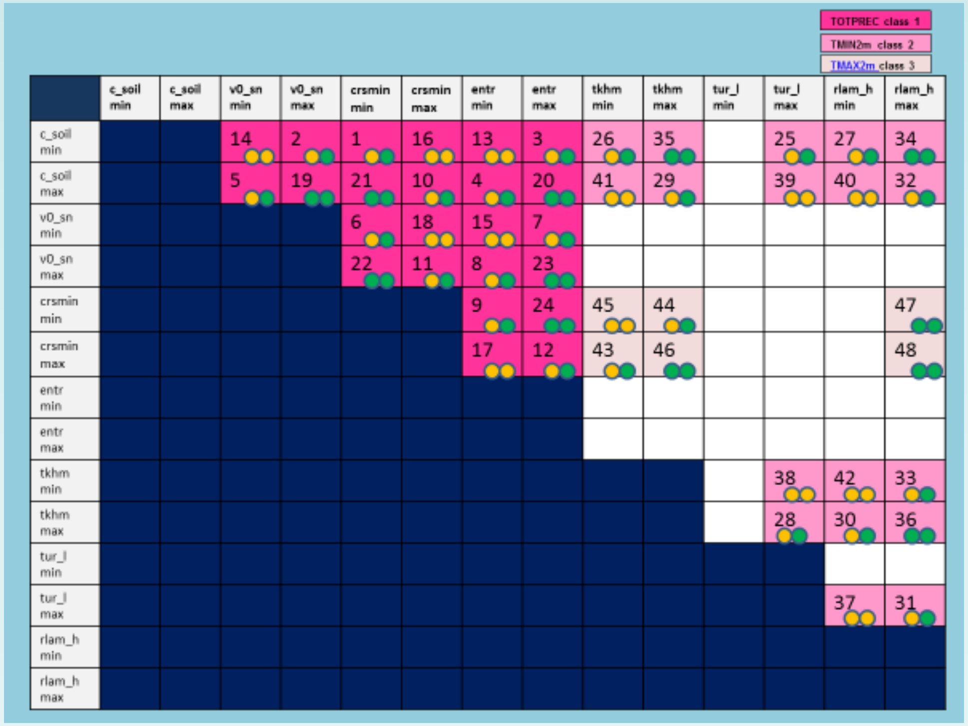
$<P>$ stands for $<SNOWGSP>$ *or* $<TOTPREC>$ *or* $<CLCL>$ *or* $<CLCM>$ *or* $<CLCH>$ *or* $<CLCT>$

$$S_{\begin{bmatrix} TMIN2m \\ TMAX2m \end{bmatrix}} = \begin{bmatrix} <TMIN2m> \\ <TMAX2m> \end{bmatrix}_{TEST} - \begin{bmatrix} <TMIN2m> \\ <TMAX2m> \end{bmatrix}_{DEFAULT}$$

Number of simulations required
Experimental design



2N+N(N-1)/2 +1default



	c_soil min	c_soil max	v0_sn min	v0_sn max	crsmin min	crsmin max	entr min	entr max	tkhm min	tkhm max	tur_l min	tur_l max	rlam_h min	rlam_h max
c_soil min			14	2	1	16	13	3	26	35		25	27	34
c_soil max			5	19	21	10	4	20	41	29		39	40	32
v0_sn min					6	18	15	7						
v0_sn max					22	11	8	23						
crsmin min							9	24	45	44				47
crsmin max							17	12	43	46				48
entr min														
entr max														
tkhm min												38	42	33
tkhm max												28	30	36
tur_l min														
tur_l max													37	31
rlam_h min														
rlam_h max														

Construction of the MM

COSMO forecasted field $F_{i,r}$ for a specific region *r* and day *i* may be approximated by N-dimensional polynomial

$$F_{i,r} \cong F_{i,r}^{d} + c_{i,r} + \sum_{n=1}^{N} a_{i,r}^{(n)} x_n + \sum_{n=1}^{N} \sum_{m=1}^{N} B_{i,r}^{(n,m)} x_n x_m$$

where N the number or parameters $p_1, p_2, p_3 \ldots p_N$ used

$$x_m = \frac{p_m - p_{def}}{p_{max} - p_{min}} \quad \text{and} \quad x_n = \frac{p_n - p_{def}}{p_{max} - p_{min}}$$

and x_m, x_n the normalized parameters

Description of the performance score

$$S_{COSI-p} = \frac{1}{N_m \sum_{\Psi=1}^{N_\Psi} \omega_\Psi} \left\{ \sum_{\substack{\Psi=1 \\ \Psi \neq 3}}^{N_\Psi} \omega_\Psi \sum_{m=1}^{N_m} \left[1 - \frac{\sum_{r=1}^{N_r} \sum_{d_m=1}^{N_{d_m}} \left(F_{p,\Psi,\Psi,m,d_m} - O_{\Psi,r,m,d_m} \right)^2}{\sum_{r=1}^{N_r} \sum_{d_m=1}^{N_{d_m}} \left(O_{\Psi,r,m,d_m-1} - O_{\Psi,r,m,d_m} \right)^2} \right] + \omega_3 \frac{\sum_{m=1}^{N_m} \sum_{r=1}^{N_r} \sum_{t=1}^{N_t} ETS_{p,r,m,t}}{N_m N_r} \right\}$$

Ψ, r, m, d_m refer to field, region, month and day of month m while N_Ψ, N_r, N_m, refer to their upper limit numbers of 21, 6, 12, respectively, and N_{dm} takes the values 31,30 and 28 depending on the month. Index p denotes the values of the corresponding specific parameter combination.

ω_ψ

$ETS_{p,r,m,t}$ for a particular parameter combination p, region r, month m and threshold index t

$$ETS_{p,r,m,t} = \frac{H - \frac{(H+F)(H+M)}{N_r N_m}}{H + M + F - \frac{(H+F)(H+M)}{N_r N_m}}$$

H refers to the number of *hits*

F to the number of “*false alarms*”

M to the number of *misses*

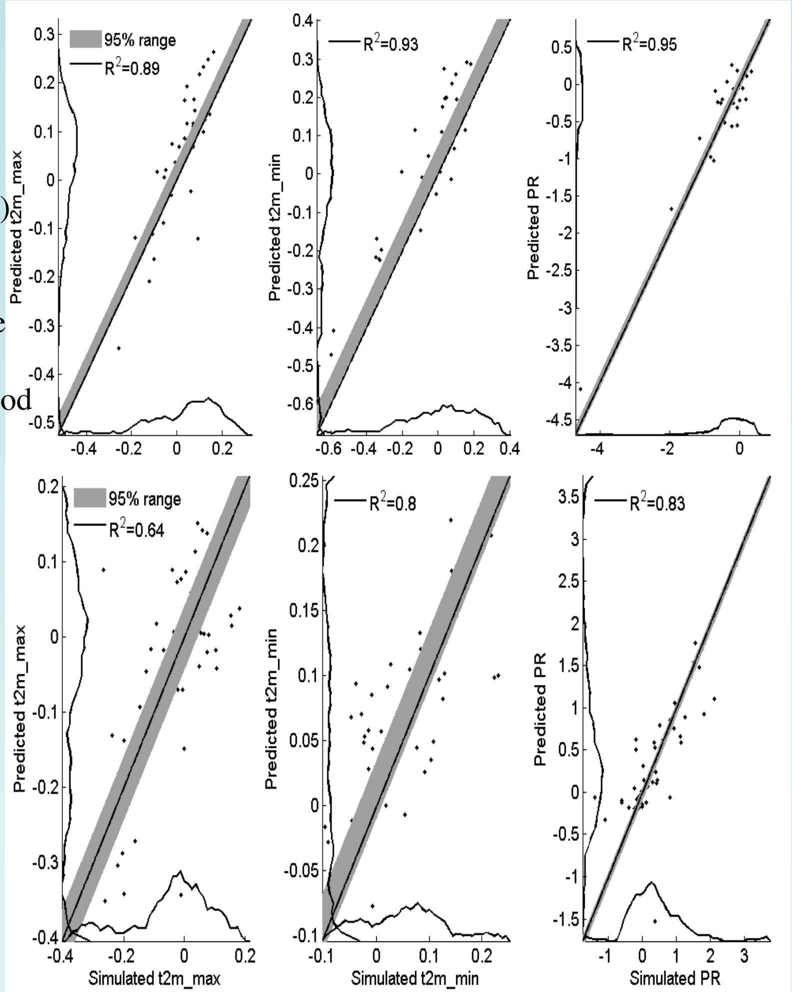
PP CALMO –Phase 1 results

Phase-1 finished within COSMO year 2014-15

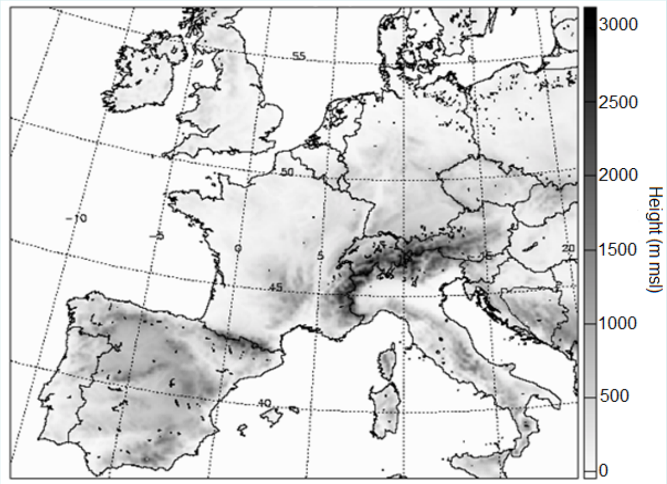
- 3 parameters (tur_len, tkhmin and rlam_heat)
- 3 variables : maximum daily temperature (Tmax), minimum daily temperature (Tmin) and 24 hours accumulated precipitation (Pr)
- two 3-weeks periods winter (3-20/1/2008) and summer (2-20/6/2008)
- COSMO-7km, large domain (figure below)

Phase-1 results

- The MM is capable in reproducing COSMO-NWP, thus the objective methodology can be transferred from RCM to NWP
- The best correlations 95% and 93% are calculated during winter period for 24 hours accumulated precipitation and minimum 2m temperature respectively, while also for maximum temperature correlation is better 89% during winter against 64% for summer (figure on the right)
- A different set of optimum parameter values for each season was extracted



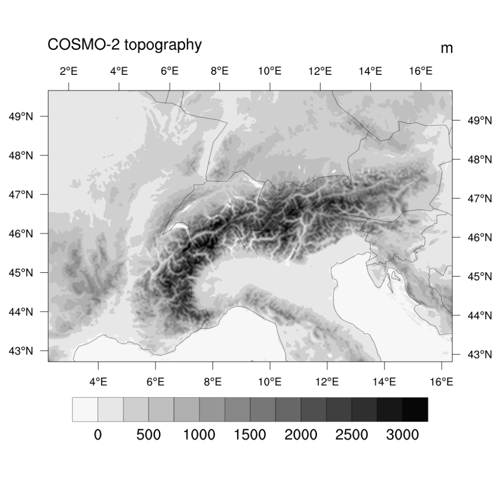
Tmax (left panel), Tmin (centered panel) and precipitation (right panel) for the period 3-20.1.2008 (upper) and 2-20.6.2008 (lower panel)



PP CALMO – Phase 2

Phase-2 finished within COSMO year 2015-16

- Simulations using COSMO with a 2.2 km mesh size
- The simulation period was significantly increased from 40 days of 2008 to the entire year of 2013 using Piz Daint resources
- The number of calibrated parameters has been increased from 3 to 6 , namely rlam_heat, tkhmin, tur_len, entr_sc, v0snow, and c_soil
- The history of the soil was not used the configuration of this calibration experiment
- Set of **model fields** used in quality score:
  - Daily min and max of **T2m** (grid points, CH and Northern Italy)
  - Daily accumulated **precipitation** (regions, CH and Northern Italy)
  - Total column **water vapor** (11 sounding)
  - **Wind shear** 500-700 / 700-850 / 850-1000 hPa (11 soundings)
  - **U, V, T** and **RH** at 500, 700 and 850 hPa (11 soundings)



- MM has been consolidated and extended by
  - adding the option not to average Tmax/Tmin over regions
  - adding the prediction of multiple vertical profile characteristics, and
  - supporting new geographical regions.
  - include a a COSMO standard performance score, a new COSI performance score
  - develop a new method for logarithmic transformation of selected parameters

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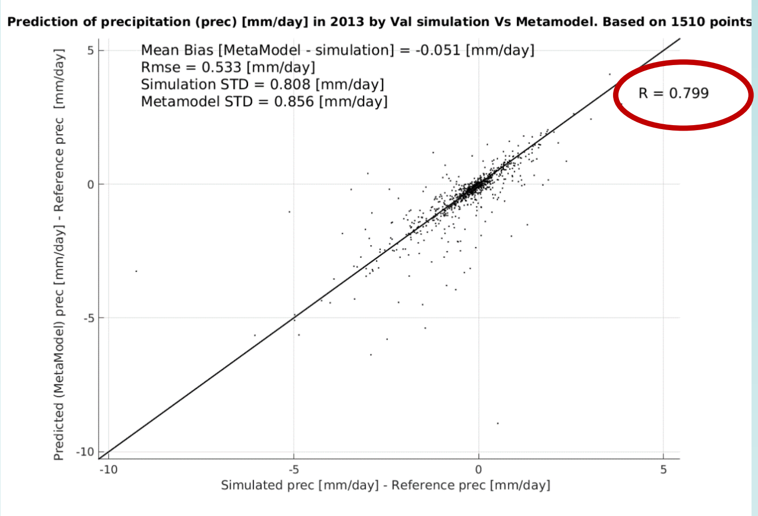
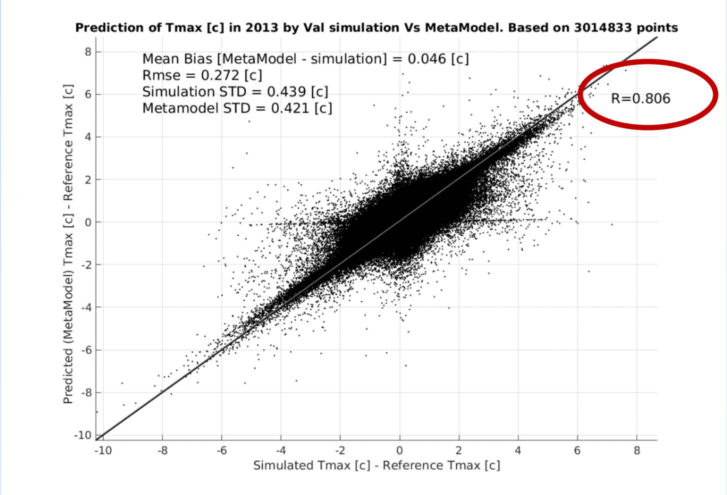
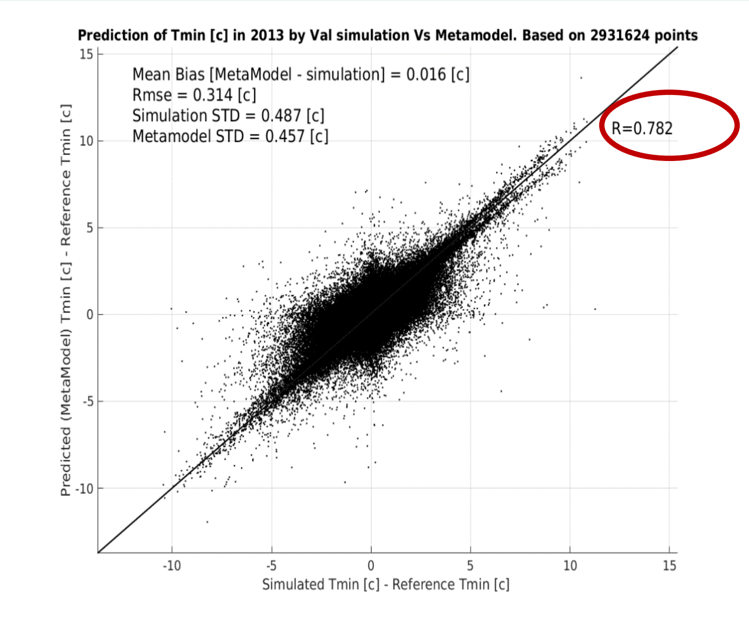
PP CALMO – Phase 2 results

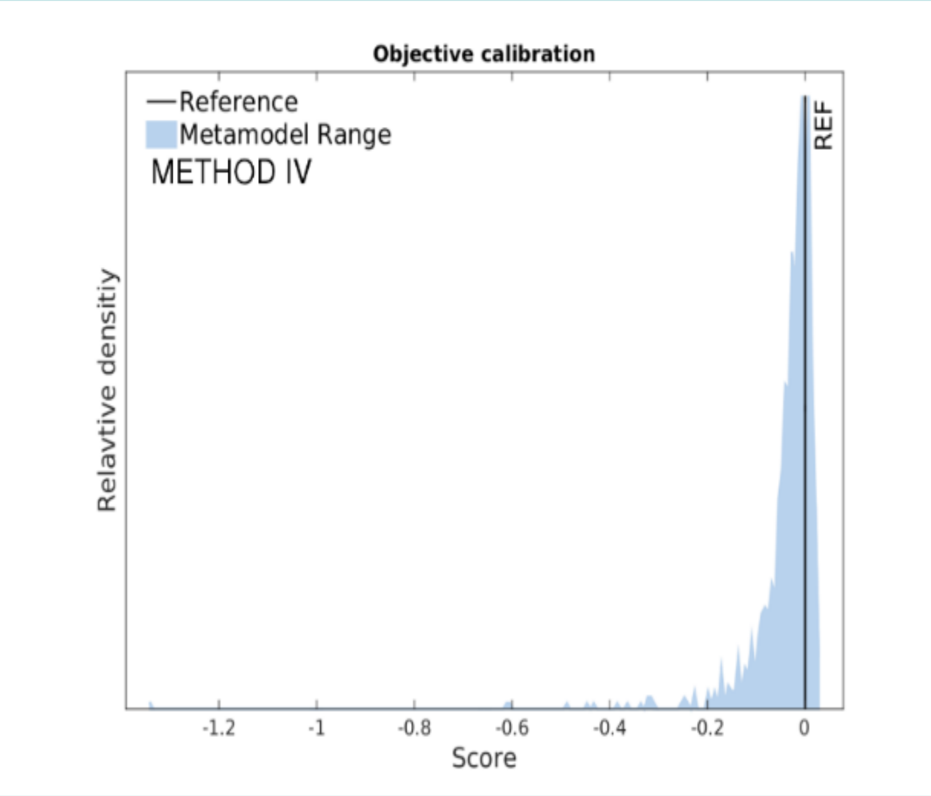


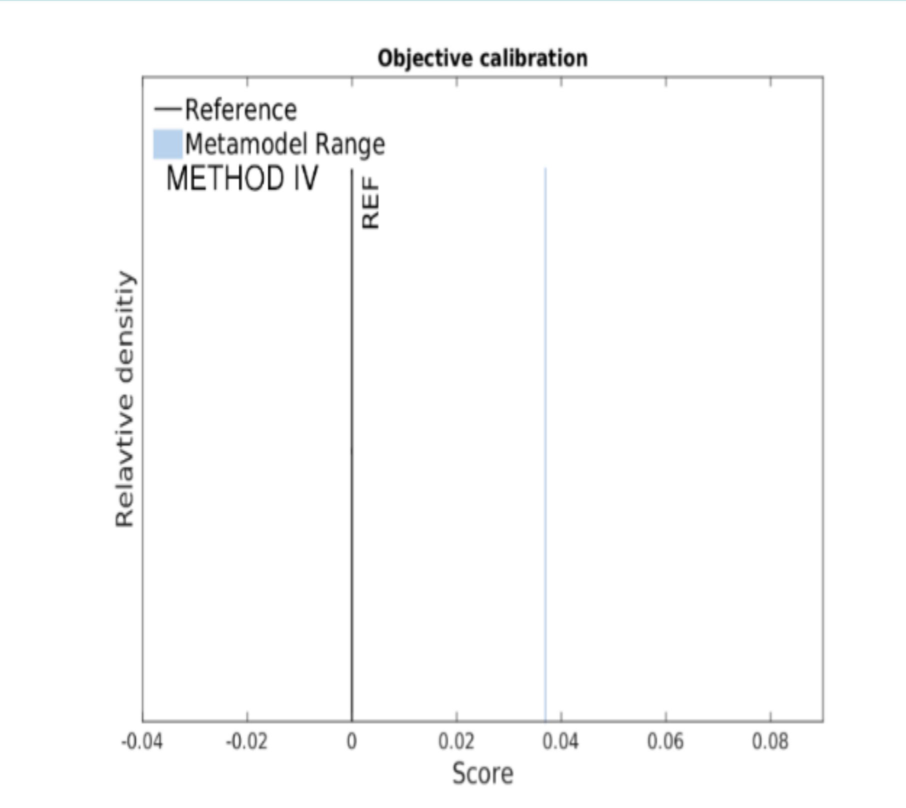




- ➢An optimal parameters combination was obtained and the verification showed an overall improvement of the COSMO model, although the model had already undergone expert tuning over a period of almost one decade.
- ➢The MM is capable in accurately reproducing COSMO-NWP over an entire year
- ➢The correlations calculated during simulation period for 24 hours accumulated precipitation maximum and minimum 2m temperature are 79.9%, 80.6% and 78.2% respectively (figure on the right)

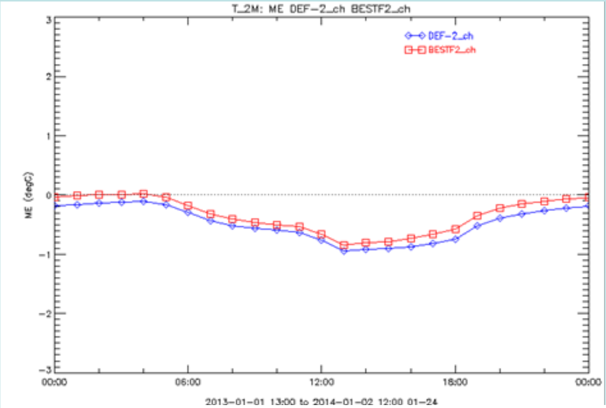
PP CALMO – Phase 2 results

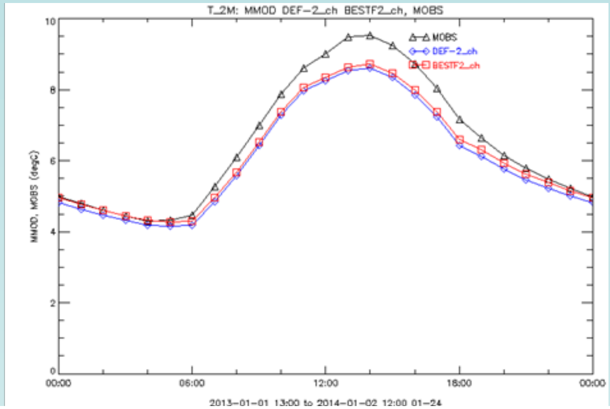


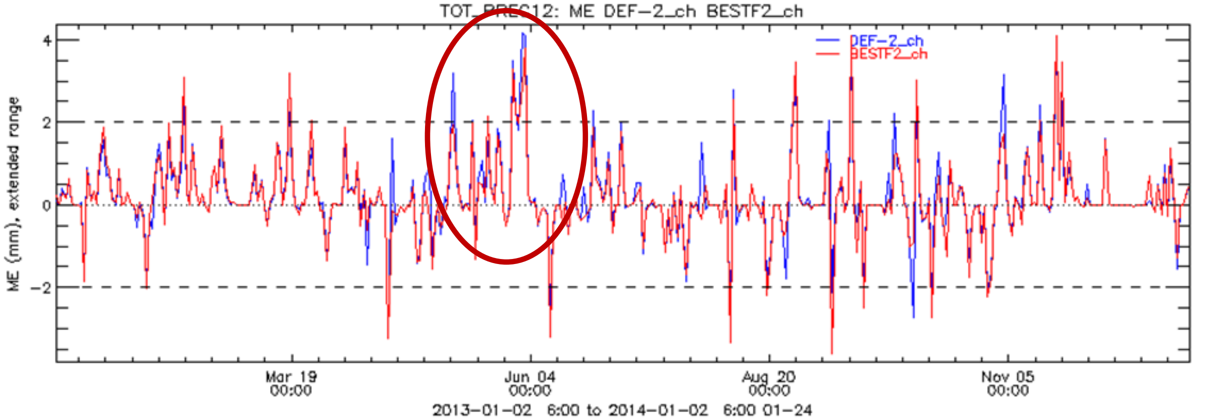


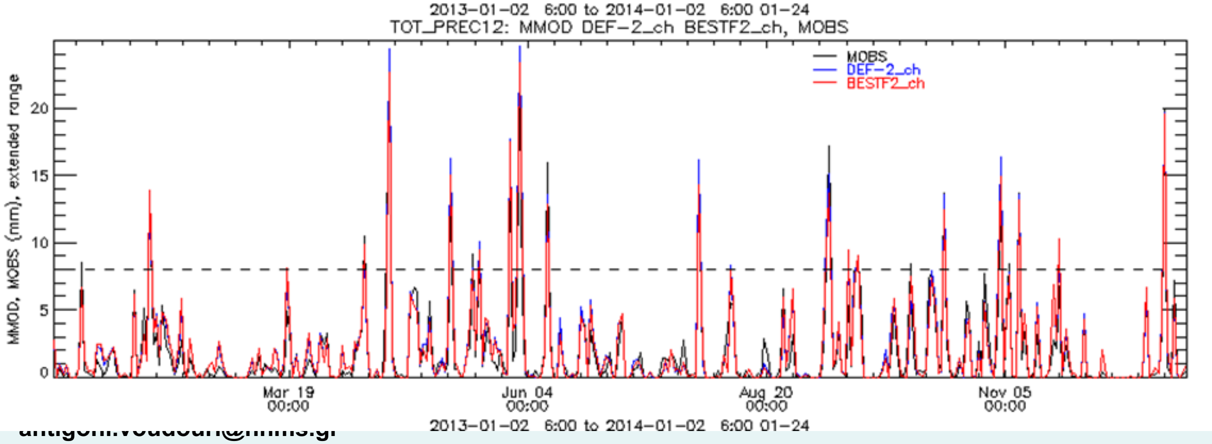
Scores distributions after **first** iteration (left) and **last** iteration (right), together with the scores of the reference (REF) simulation for COSMO 2.2km

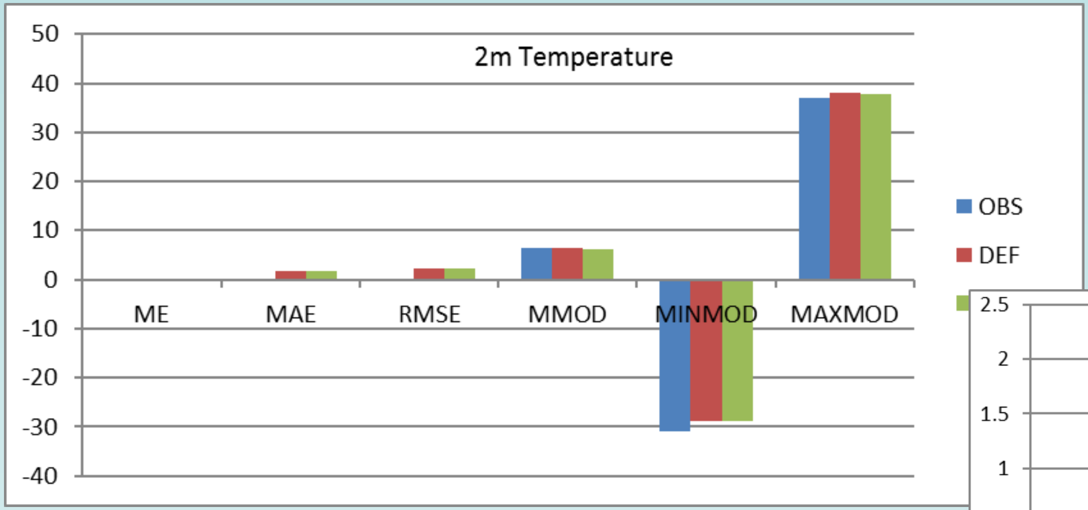
Parameter	Acronym	Default values	Optimum value (after method 4)
Factor for laminar resistance for heat	rlam_heat	1 (20 rat_sea) (0.1-2)	1.273 (15.71092) Uncertainty: [1.149 1.390]
Minimal diffusion coefficient for heat	tkhmin	0.4 (0.1-1)	0.266 Uncertainty: [0.205 0.351]
Maximal turbulent length scale (m)	tur_len	150 (100-1000)	346.5 Uncertainty: [294.6 409.9];
Entrainment rate for shallow convection	entr_sc	0.3e-3 (0.05e-3, 2e-3)	0.1607e-3 Uncertainty: [0.1261e-3 0.2104e-3];
Surface-area index of the evaporating fraction of grid points over land.	csoil	1 (0-2)	0.588 Uncertainty: [0.515 0.664];
Factor for vertical velocity of snow	v0snow	20 (10-30)	12.3 Uncertainty: [11.6 13.3]

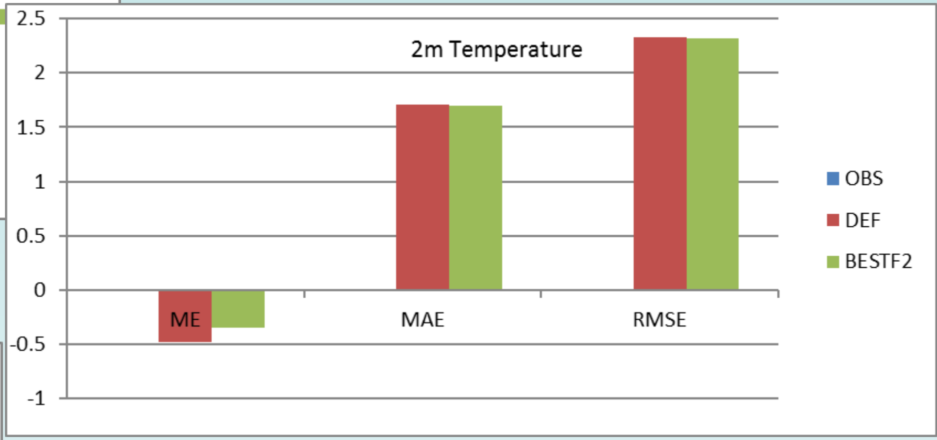

T_2M: ME DEF-2_ch BESTF2_ch
DEF-2_ch
BESTF2_ch
ME (degC)
00:00 06:00 12:00 18:00 00:00
2013-01-01 13:00 to 2014-01-02 12:00 01-24

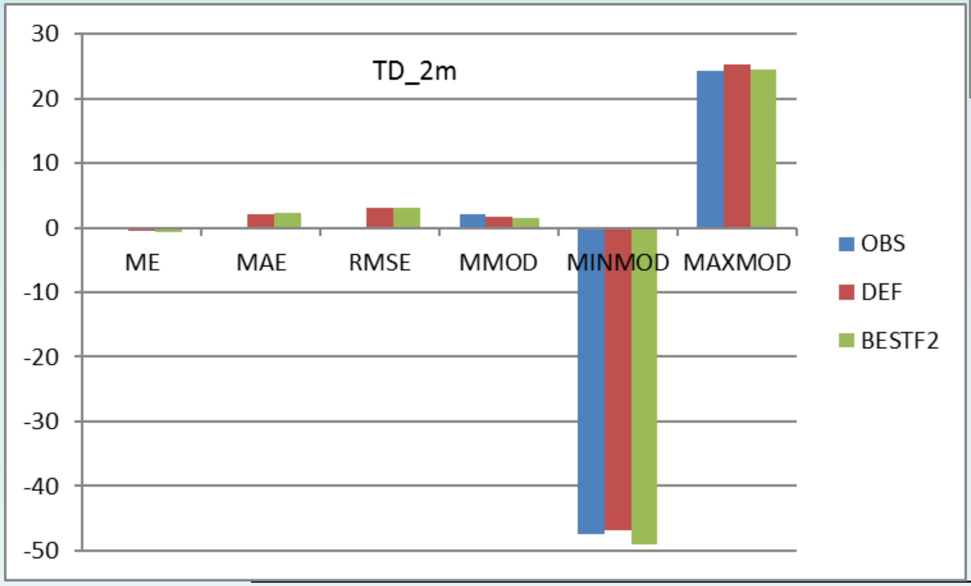

T_2M: MMOD DEF-2_ch BESTF2_ch, MOBS
MOBS
DEF-2_ch
BESTF2_ch
MMOD, MOBS (degC)
00:00 06:00 12:00 18:00 00:00
2013-01-01 13:00 to 2014-01-02 12:00 01-24


TOT_PREC12: ME DEF-2_ch BESTF2_ch
DEF-2_ch
BESTF2_ch
ME (mm), extended range
Mar 19 00:00
Jun 04 00:00
Aug 20 00:00
Nov 05 00:00
2013-01-02 6:00 to 2014-01-02 6:00 01-24


TOT_PREC12: MMOD DEF-2_ch BESTF2_ch, MOBS
MOBS
DEF-2_ch
BESTF2_ch
MMOD, MOBS (mm), extended range
Mar 19 00:00
Jun 04 00:00
Aug 20 00:00
Nov 05 00:00
2013-01-02 6:00 to 2014-01-02 6:00 01-24


2m Temperature
50
40
30
20
10
0
-10
-20
-30
-40
ME
MAE
RMSE
MMOD
MINMOD
MAXMOD
OBS
DEF


2m Temperature
2.5
2
1.5
1
0.5
0
-0.5
-1
ME
MAE
RMSE
OBS
DEF
BESTF2


TD_2m
30
20
10
0
-10
-20
-30
-40
-50
ME
MAE
RMSE
MMOD
MINMOD
MAXMOD
OBS
DEF
BESTF2

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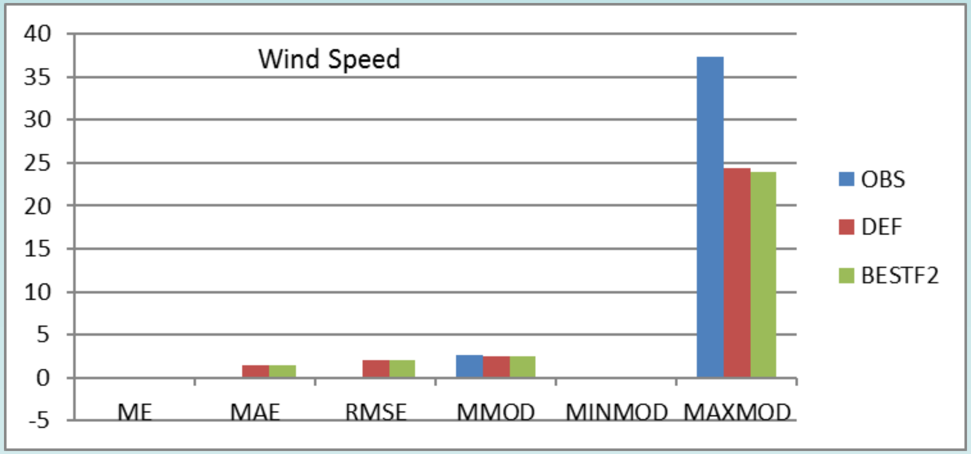

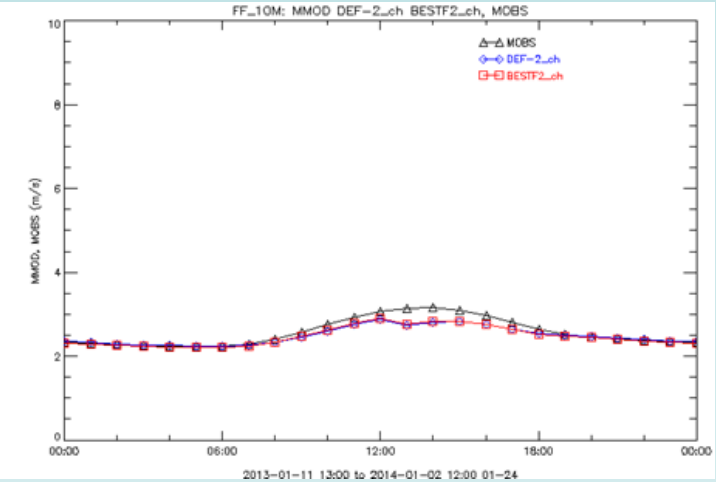

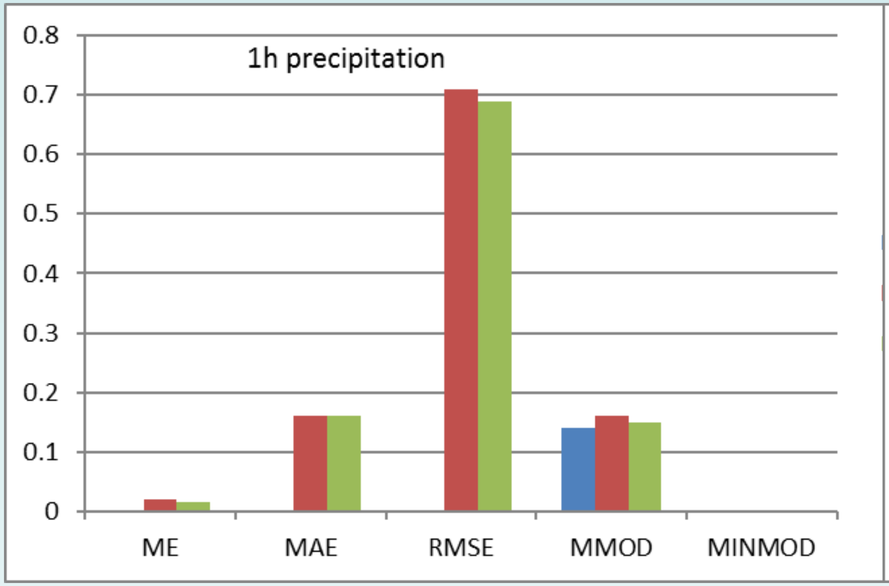

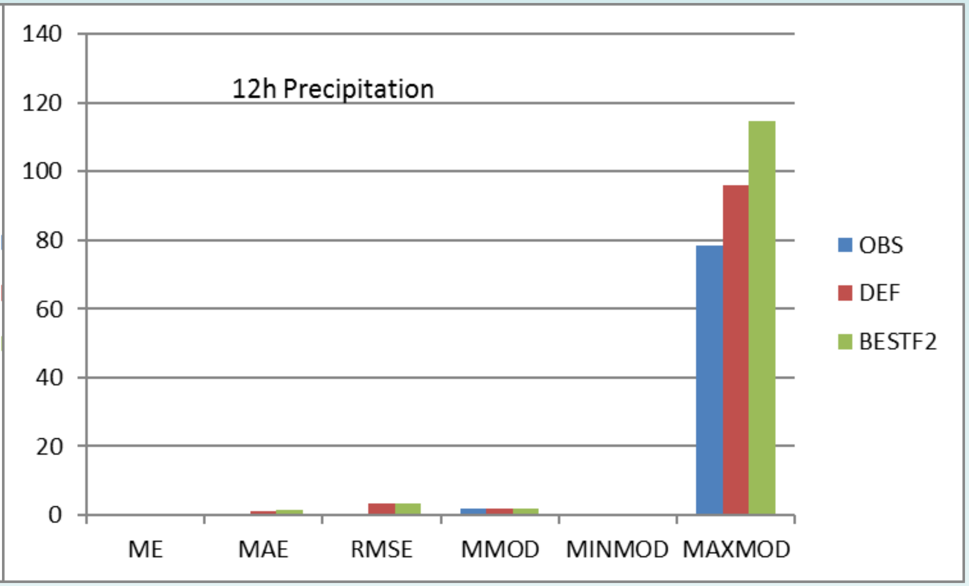

COSMO-1
5 free parameters used for calibration

Surface layer		
Name	range	comment
c_soil	[0,1*, c_lnd]	c_lnd=2
rlam_heat (and rat_sea)	[0.1, 1*,2] *([1,20*,100]*	*changes in rlam_heat must be compensated by an inverse change of rat_sea in order to maintain (at least approximately) rlam_heat*rat_sea. [0,20*, 200)* *This in principle also applies to COSMO model unless we intend to change the evaporation over water.*

Shallow convection		
Name	range	comment
entr_sc	[0.5 ,3, 20]E-04	

turbulence		
Name	range	comment
tur_len	[100,150*, 1000]	L_scal=MIN(0.5*l_hori, tur_len
tkhmin (and tkmmin)	[0.1, 0.4*, 1]	*Should be equal!* *Increasing values does not keep low clouds, decreasing values better scores*

Vegetation and soil		
Name	range	comment
crsmin	[50,150*,200]	

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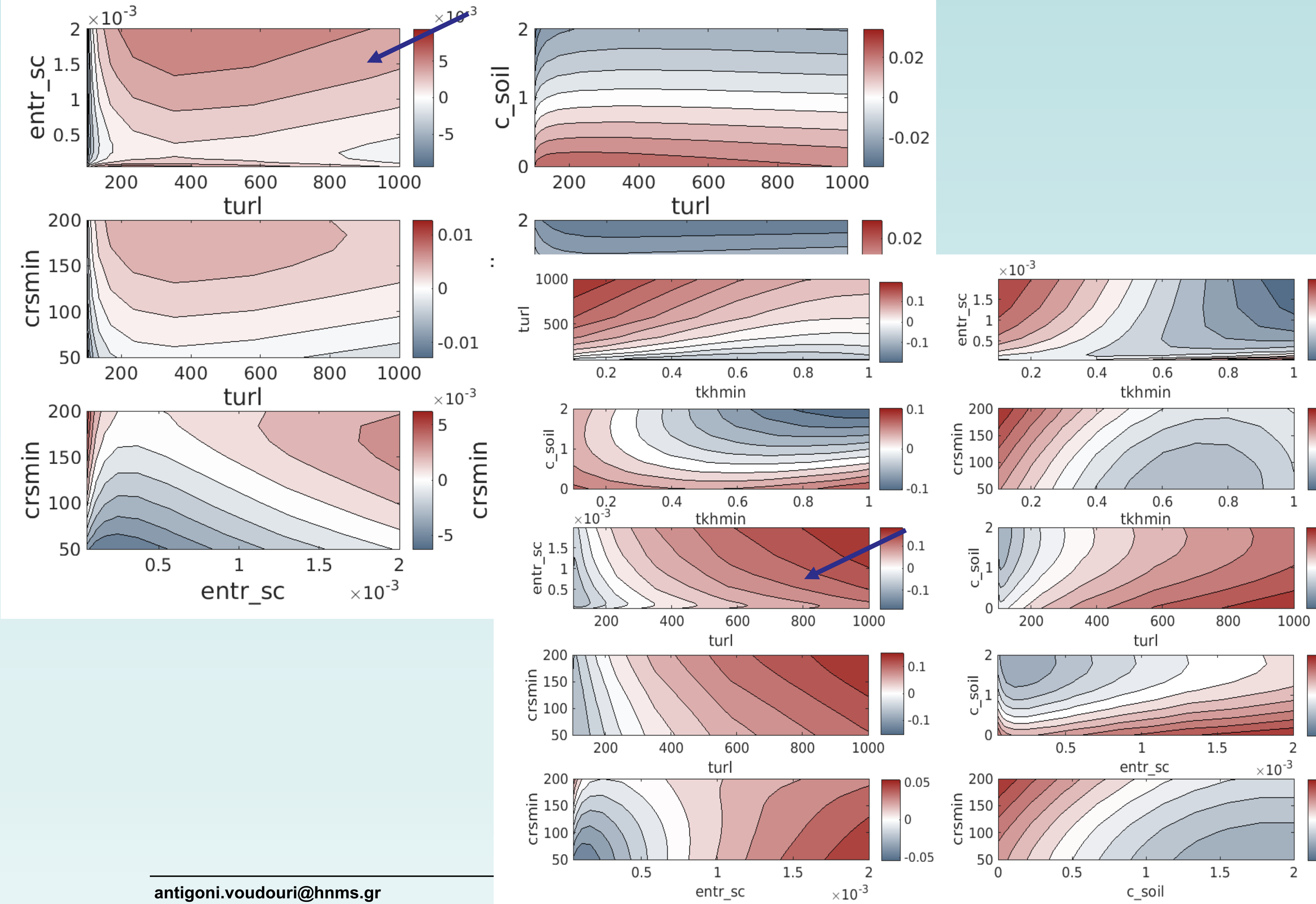
Contours of score deviation for pairwise parameters combinations



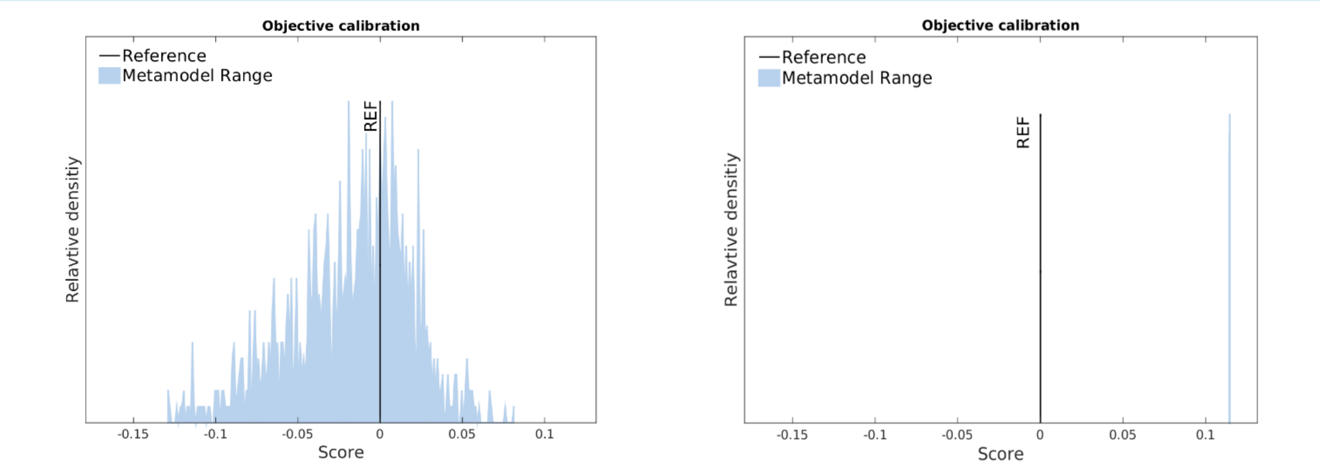
antigoni.voudouri@hnms.gr

PP CALMO – Phase 3 results

Phase-3 finished within COSMO year 2016-17

- Simulations using COSMO with a 1.1 km mesh size (same domain as in stage 2)
- The simulation period was deteriorated to one month, namely January 2013
- The number of calibrated parameters has been 5, namely tkhmin, tur_len, entr_sc, crsmin and c_soil
- The soil memory and the prior 3 years soil spin up has been considered using TERRA
- Better performance scores can be extracted once the MM is fitted (see figure below)
- The final optimal parameters combination obtained (with its uncertainty) once the calibration methodology is applied is:

  tkhmin=**1** instead of the default 0.4; Uncertainty: [0.983 1];
  tur_len=**109.3** instead of the default 150; Uncertainty: [104.3 117.2];
  entr_sc=**0.002** instead of the default 0.003; Uncertainty: [0.0018 0.002];
  c_soil=**2** instead of the default 1.0; Uncertainty: [1.937 2];
  crsmin=**200** instead of the default 150; Uncertainty: [186.3 200]



Scores distributions after **first** iteration (left) and **last** iteration (right), together with the scores of the reference (REF) simulation.

CALMO Stage	rlam_heat (0.1,2)	tkhmin	tur_len	entr_sc (10^{-4})	c_soil	v0snow
Stage-2 Entire 2013	1.149 1.273 1.390 [-6.5% +6.2%]	0.205 0.266 0.351 [-6.8% +9.4%]	294.6 346.5 409.9 [-5.8% +7.0%]	1.261 1.607 2.104 [-1.8% +2.5%]	0.515 0.588 0.664 [-3.7% +3.8%]	**11.6 12.3 13.3 [-3.5% +5.0%]**
Stage-2 Jan 2013	0.845 0.935 1.002 [-4.7% +3.5%]	0.191 0.220 0.262 [-3.2% +4.7%]	559.8 653.3 753.0 [-10.4% +11.1%]	2.346 2.764 3.242 [-2.1% +2.5%]	0.653 0.756 0.841 [-5.2% +4.3%]	**11.2 11.8 12.3 [-3.0% +2.5%]**
Stage-3 Jan 2013	Default value*	0.983 1.000 1.000 [-1.9% +0.0%]	104.3 109.3 117.2 [-0.6% +0.9%]	18.0 20.0 20.0 [-10.3% +0.0%]	1.937 2.000 2.000 [-3.2% +0.0%]	**Default value***

Preliminary activity with COSMO-1 over Turin including TERRA-URB parameterisation

Edoardo Bucchignani[1,2], Paola Mercogliano[1,2], Massimo Milelli[3],

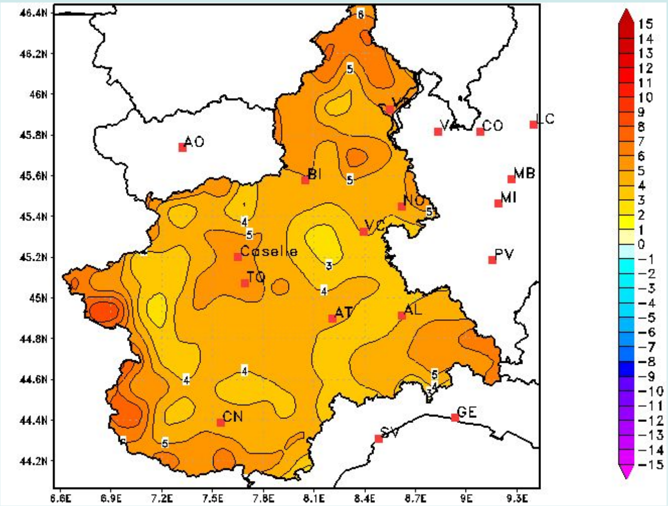
1 CIRA Centro Italiano Ricerche Aerospaziali – Capua (Italy)

2 CMCC Centro Euromediterraneo sui Cambiamenti Climatici – Capua (Italy)

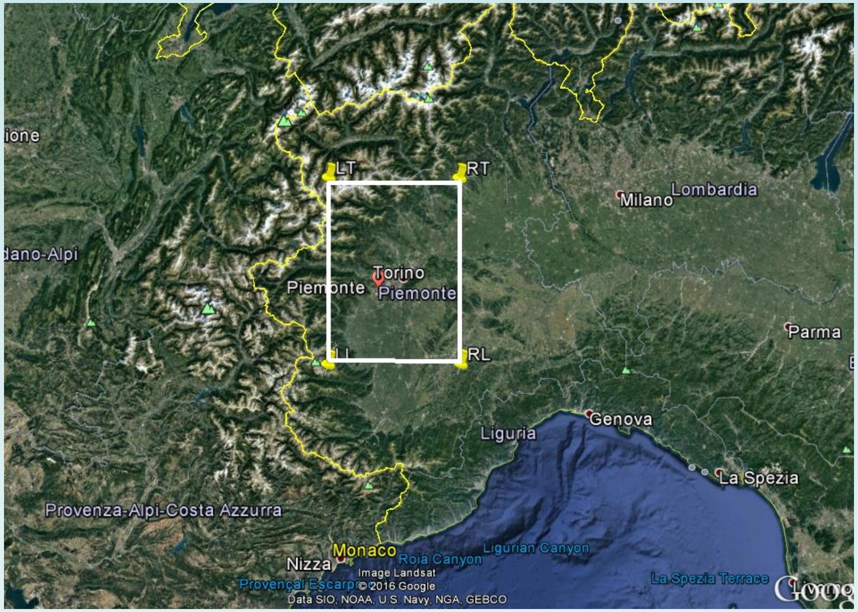
3 ARPA Piemonte – Torino (Italy)

The Test Case considered

In the period 1-16 July 2015, Piedmont region and Turin in particular experienced extreme temperature values and uncomfortable conditions for the population.
In Turin, the maximum temperature since 1990 (38.5°) has been recorded in July 2015.
Ground stations data highlighted the presence of a UHI effect over Turin.



Anomaly of Maximum temperature of the period 1-16 July 2015 with respect to the reference period 1971-2000.
Source: ARPA Piemonte



Domain: 7.15 – 8.05 E ; 44.6 – 45.5 N

Rotated North Pole: 8 (-172)° ; 45°

Model version and set-up

- Model versions:
  - int2lm_2.0_clm4
  - cosmo_5.0_clm8 including TERRA_URB
- COSMO-CLM resolution: 0.009° (about 1 km)
- Computational domain: 100 x 100 points; 60 vertical levels, time step 3 s.
- Deep-convection resolving set-up, also including tuning settings regarding soil heat conductivity
- Time period: From 1 to 7 July 2015
- Forcing data: ECMWF IFS analysis (resolution of 0.075°)
- Validation dataset provided by ARPA Piemonte for the stations:

Moncalieri/Bauducchi	44.961111°	7.709227°
Giardini Reali	45.073699°	7.688576°
Consolata	45.076667°	7.679444°

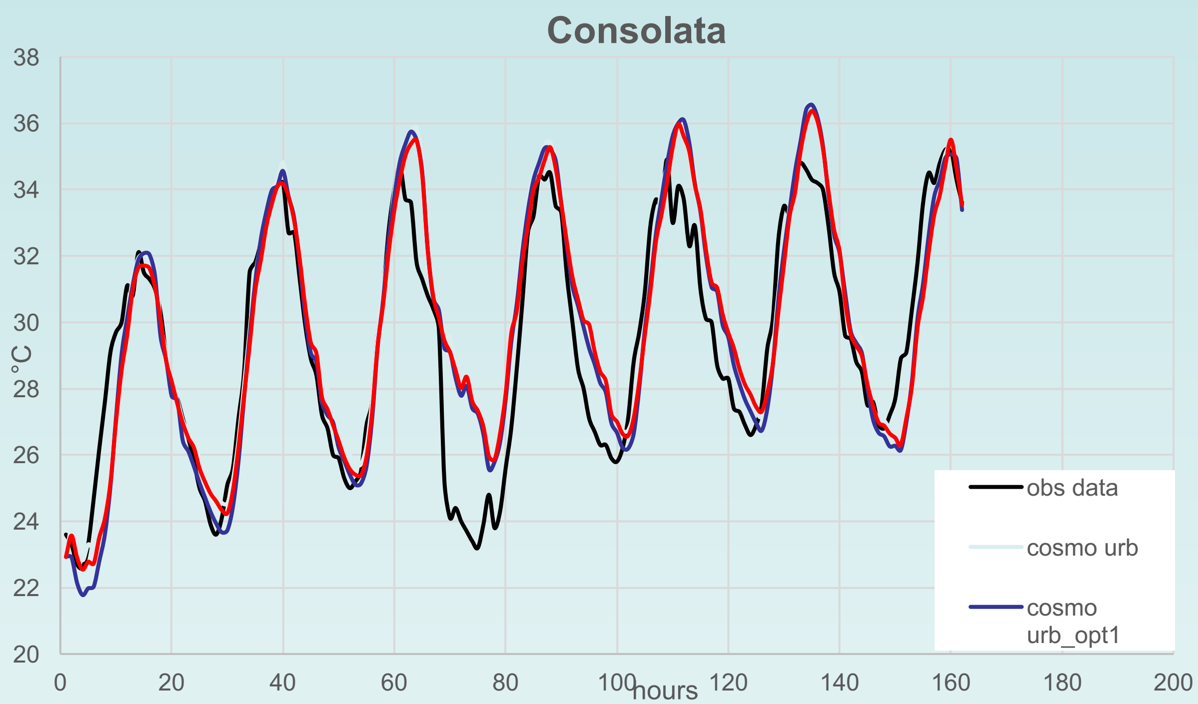
Model configuration and sensitivity

Three different model configurations have been tested:

	Default	OPT1	OPT2
rlam_heat	1.0	0.74	1.24
tkhmin	0.4	0.176	0.233
tkmmin	0.4	0.4	0.233
tur_len	150	368.8	363.9
entr_sc	0.003	0.00014	0.000267
c_soil	1.0	0.663	0.492
v0snow	20	17.8	12.1
rat_sea	20.0	20.0	16.12903

Results: Time series of T2m

Time series of T2m for Consolata station (urban cell) with the different configurations and observational data.



URB: Simulation with default control parameters
URB_OPT1: Simulation with first set of modified control parameters
URB_OPT2: Simulation with second set of modified control parameters

T2m (°C) observed value and bias over the period 1-7 July

	OBS	BIAS URB	BIAS URB_OPT1	BIAS URB_OPT2
Average bias	**29.4**	**0.68**	**0.36**	**0.43**
Maximum bias	**29.4**	**5.5**	**5.0**	**4.9**

This table shows the average observed T2m value, the average bias (model minus observation) over the simulated period and the maximum bias, obtained with the different configurations.

Comments

- Both optimized configurations allow a significant reduction of the average bias.
- OPT2 allows also a reduction of the maximum bias.

Supporting material

- The **final report is available in** the COSMO Technical Reports **No 32**
- A **detailed description of different phases** of the project is available in the COSMO Technical Reports **No 25 and No 31.**
- The **code of the meta-model**, including the associated documentation is available in
  http://www.cosmo-model.org/content/support/software/default.htm#calmo
- A **peer reviewed paper** has been published in Atm. Res. vol. 190; a second peer reviewed paper is in the review process.
- More information and documentation on CALMO and CALMO–MAX at the following
  http://www.cosmo-model.org/content/tasks/priorityProjects/calmoMax/default.htm
  http://www.cosmo-model.org/content/tasks/priorityProjects/calmo/default.htm

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References

- Avgoustoglou E., A. Voudouri, P. Khain, F. Grazzini and J.M. Bettems, 2017: Design and Evaluation of Sensitivity Tests of COSMO Model Over the Mediterranean Area. Perspectives on Atmospheric Sciences, Vol.1, Springer, pp 49-55
- Khain P., I. Carmona, A. Voudouri, E. Avgoustoglou, J.-M. Bettems, F. Grazzini, 2015: The Proof of the Parameters Calibration Method: CALMO Progress Report. COSMO Technical Report, 25.
- Khain P., I. Carmona, A. Voudouri, E. Avgoustoglou, J.-M. Bettems, F. Grazzini, P. Kaufman, 2017: The Success of the Parameters Calibration Method: CALMO Progress Report 2. COSMO Technical Report (under preparation).
- Voudouri A., E. Avgoustoglou and P. Kaufmann, 2017: Impacts of Observational Data Assimilation on Operational Forecasts. Perspectives on Atmospheric Sciences, Vol.1, Springer, pp 143-150
- Voudouri A., Khain P., Carmona I., Bellprat O., Grazzini F., Avgoustoglou E. , Bettems J.M and Kaufmann P., 2017: Objective calibration of numerical weather prediction models. Atm. Res.190, pp 128-140
- Voudouri A., Khain P., Carmona I., Avgoustoglou E., Kaufmann P Grazzini F.cand Bettems J.M., : Optimization of high resolution COSMO model performance over Switzerland and Northern Italy (submitted)

CALMO-MAX

- No definitive answer on the possibility to **improve the model performance**
- No full assessment of the effect of the **soil memory**
- Optimization of the method in terms of **computing resources** is pending

- Need to
  - ✓ define the model configuration for the COSMO-1 calibration, incl. the code, the namelist, prepare the initial conditions with TSA,test the chosen model configuration
  - ✓ define the set of model parameters to calibrate and collect the observations for the MM
  - ✓ define the calibration strategy to reduce computational cost,
  - ✓ define the performance score to use and accordingly adapt the MM

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ETHZ parameter list

Calibration of the 50km COSMO-gpu model (the POMPA version)

New features: Implementation of the revised TERRA_ML scheme (Schlemmer et al. 2017, in prep). With the new formulation the conductivity and diffusivity parameter is replaced with a new parameter (gamma) that regulates how much runoff is produced.

Table of the parameters that was used to calibrate the CCLM5.0-6 version.

The following table lists the parameters are used for the calibration, the values given in the Values column are [minimum value; default value; maximum value]:

Parameter name	Description of the parameter	Values	Suggested new parameters, changes:
rlam_heat	Scalar resistance for sensible and latent heat fluxes in the laminar surface layer	[0.1;**1**;5]	
entr_sc	Entrainment rate for shallow convection [m^{-3}]	[$3*10^{-5}$;$\mathbf{3*10^{-4}}$;$3*10^{-3}$]	
tkhmin	Minimal vertical turbulent diffusion rate [m^2s^{-1}]	[0.1; **1**; 2]	
qi0	Threshold for conversion cloud ice to snow	[**0** ;$5*10^{-5}$;10^{-4}]	→ Use the default value (0)
uc1	Parameter controlling the vertical variation of critical relative humidity for sub-grid cloud formation	[0; **0.8**; 1.6]	→ Decrease the range [0;**0.3**;0.6]
radfac	Fraction of cloud water and ice considered by radiation scheme	[0.3; **0.5**; 0.9]	
fac_rootdp2	Uniform factor for root depth field	[0.5; **1**; 1.5]	
soilhyd	Factor for the hydraulic conductivity and diffusivity	[0.1;**1**;10]	→ Replace with the gamma. Now it is set to 0.4. Need to decide the range

Work of O. Bellprat

Acronym	**Parameter**	**Value**
Minimal diffusion coefficient for heat	tkhmin	[0. 1 ,**0.4**,2] COSMO-CLM 1
Factor for laminar resistance for heat	rlam_heat	[0.1,**1**,10]
Threshold for the conversion from ice to snow	qi0	[**0**,5e-5, 1e-4]
Entrainment rate for shallow convection	entr_sc	[3e-5,3e-4,3e-3]
Parameter controlling the vertical variation of critical relative humidity for sub-grid cloud formation	uc1	[0,0.8,1.6]
Uniform factor for root depth field	root_dp (fac_root_dp)	[0.5,**1**,1.5] [0.1 ….in src_soil.f90)
Factor for vertical velocity of snow	*v0snow*	*[5,20,35]*
Fraction of cloud water and ice considered by the radiation scheme	radfac	[0.3,**0.5**,0.9]
Factor for hydraulic conductivity	oilhyd (kexpdec)	[**1**, 6]

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