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COSMO WG3b: Highlights

Jean-Marie Bettems / MeteoSwiss

Jerusalem, COSMO GM, September 2017

WG3b highlights

Summary of WG3b activities and links to related documents

http://www.cosmo-model.org/content/tasks/workGroups/wg3b/default.htm

→ Help maintain the information up-to-date by (actively!) sending feedback and corrections to the WG3b coordinator
jean-marie.bettems@meteoswiss.ch

WG3b – TERRA news (1/3)

- **New unified COSMO / ICON TERRA with COSMO v5.05**
  → *delay due to unexpected bad results from NWP test suite*
  → *bad scores due to soil drying in summer in some regions*
  → *hidden effect in ICON-EU due to active soil moisture analysis*
  → *requires new minimal stomatal resistance map… but issue not fully solved*
  → *more details in Uli S. talk*

- **Effect of canopy layer**
  → *very significant impact on T2m daily cycle amplitude*
  → *multiple approaches, coordinated by AG TERRA @ DWD*

- **Usage of Harmonized World Soil Database**
  → *improved information on soil texture, incl. vertical structure*
  → *work in progress*

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WG3b – TERRA news (2/3)

- **Phenology**
  → *phenology model to capture inter-annual variability of vegetation cycle*
  → *significant impact on T2m on large region in spring and summer*
  → *more details later*

- **Urban parameterization**
  → *see PT AEVUS*

- **Snow model**
  → *see PT SAINT*

- **Mire parameterization**
  → *a parameterization of mire effects developed at RHM*
  → *will be integrated in ICON*
  → *planned for COSMO v5.06*

WG3b – TERRA news (3/3)

- **PhD project to improve TERRA for NWP**
  → *in group of Prof. Ch. Schaer / ETHZ*
  → *start in January 2018*
  → *start with Linda work on new formulation of soil water lower BC*
  (allow ground water build up, consider slope dependent runoff)
  (significantly reduces warm biases in climate simulations)
  → *more developments will be included…*

- **Coupling with surface layer**
  → *many numerical inconsistencies recently corrected in ICON test*
  → *see PT ConSAT (WG3a)*

WG3b – Priority tasks and projects

- **PP CALMO-MAX**, 06.2017-09.2019, A. Voudouri / HNMS
  → *calibration of unconfined model parameters made practicable*
  → *more details later*

- **PT TERRA Nova**, 09.2016-06.2018, Y. Ziv / IMS
  MsC Verena, 10.2017-04.2018, V. Bessenbacher / ETHZ
  → *document TERRA performance, compare with CLM performance*
  → *compare v5.0 / v5.05 conservative / v5.05 aggresive (/ CLM)*
  → *work on-going, waiting for COSMO v5.05*

- **PT AEVUS**, 09.2017-09.2018, P. Mercogliano / CIRA
  → *urban parameterization for operational forecast*
  → *based on Hendrik Wouters bulk model (TERRA-URB)*

- **PT SAINT**, 07.2017-06.2019, S. Bellaire / SLF **(proposal!)**
  → *multi-layers snow model for operational forecast*
  → *new development, using also Ekaterina multi-model*
  → *full support of SLF / Davos*

WG3b – Software

- **EXTPAR**
  → ***COSMO software*** *for generation of external parameters*
  → *more details later*
- **TERRA standalone**
  → *standalone TERRA module, based on COSMO v5.03*
  → *maintained by IMS (best effort)*
  → *code and documentation available on COSMO site*
- **CALMO meta-model**
  → *MatLab software to fit and apply the meta-model*
  → *further developments expected in PP CALMO-MAX*
  → *code and documentation available on COSMO site*
- **SNOWE**
  → *full featured snow analysis package, incl. snow density*
  → *developed and maintained at RHM*
  → *code and documentation available on COSMO site*

WG3b – Some important or critical issues

- **Status of common COSMO / ICON library (soil & surface)**
  → *also tiles*
  → *also external parameters*
  → *also tuning / calibration*
  → *in which code do we start new developments?*

- **Status of TERRA code**
  → *clean code help streamline development and avoid bugs*
  → *clean code is a pre-requisite for sharing development effort*
  → *time for a re-write?*

- **Status of human resources for soil & surface layer**
  → *COSMO SP: further develop TERRA, do not use a community model*
  → *growing importance of soil & surface for high resolution applications*
  → *how many educated resources do we currently have?*

- **New PP combining PhD @ C.Schaer / phenology / canopy …**
  → *possible interest of Prof. S. Seneviratne (maybe another PhD)*
  → *including CALMO calibration*
  → *meaningful?*

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EXTPAR

EXTPAR

- The **official source code** is available in a private repository in the C2SM organization on GitHub
https://github.com/C2SM-RCM/extpar
- In its March 2017 meeting the COSMO StC has nominated **Katie Osterried**, working at ETHZ for C2SM, as **Source Code Administrator**
- Currently **different versions of the code** exist at DWD and at MPI
- Currently **GRIB output is not working correctly** (but NetCDF is ok)
- A **meeting** was organized **at Offenbach** on 2017 June 27 to discuss the current situation (draft minutes on COSMO web)
http://www.cosmo-model.org/content/tasks/workGroups/wg3b/docs/EXTPAR%20meeting%20201706.pdf

EXTPAR

Latest COSMO release (version 4.0, 29.09.2016, on GitHub)

- Support for the **MACv2 aerosol climatology** split into spectral bands, as developed by RosHyMet
- Optional creation of subgrid-scale slope parameters needed for the new **runoff formulation** developed by Linda Schlemmer
- **Corrects** a sign bug in the calculation of the THETA parameter used in **SSO** parameterization as reported by R. Zentek and J. Helmert
- Includes changes suggested By B. Rockel regarding the correct raw data set declaration for AHF and ISA fields used in **TERRA_URB**

EXTPAR

Next milestones (end 2017)

- Code synchronization with DWD and CLM community, **unified version** on GitHub
- **Test installation** at CSCS, incl. all raw data
- Improve **documentation** on COSMO web, incl. software access
- Review support of **GRIB output** (remove GRIB 1 support? correct or remove GRIB 2 support?)

→ **Probable delay due to illness of Katie**

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CONSORTIUM FOR SMALL SCALE MODELING
COSMO

Phenology model

The topic

- **Currently, LAI climatology is used in COSMO**
  (based on sine-curve)
- In European spring, LAI can vary substantially depending on the weather
- LAI influences transpiration and latent heat flux and thus temperature and many more variables

- Main research questions to be answered :

  What is the sensitivity of COSMO to LAI?
  Does the performance improve if actual LAI is used?

The experimental design

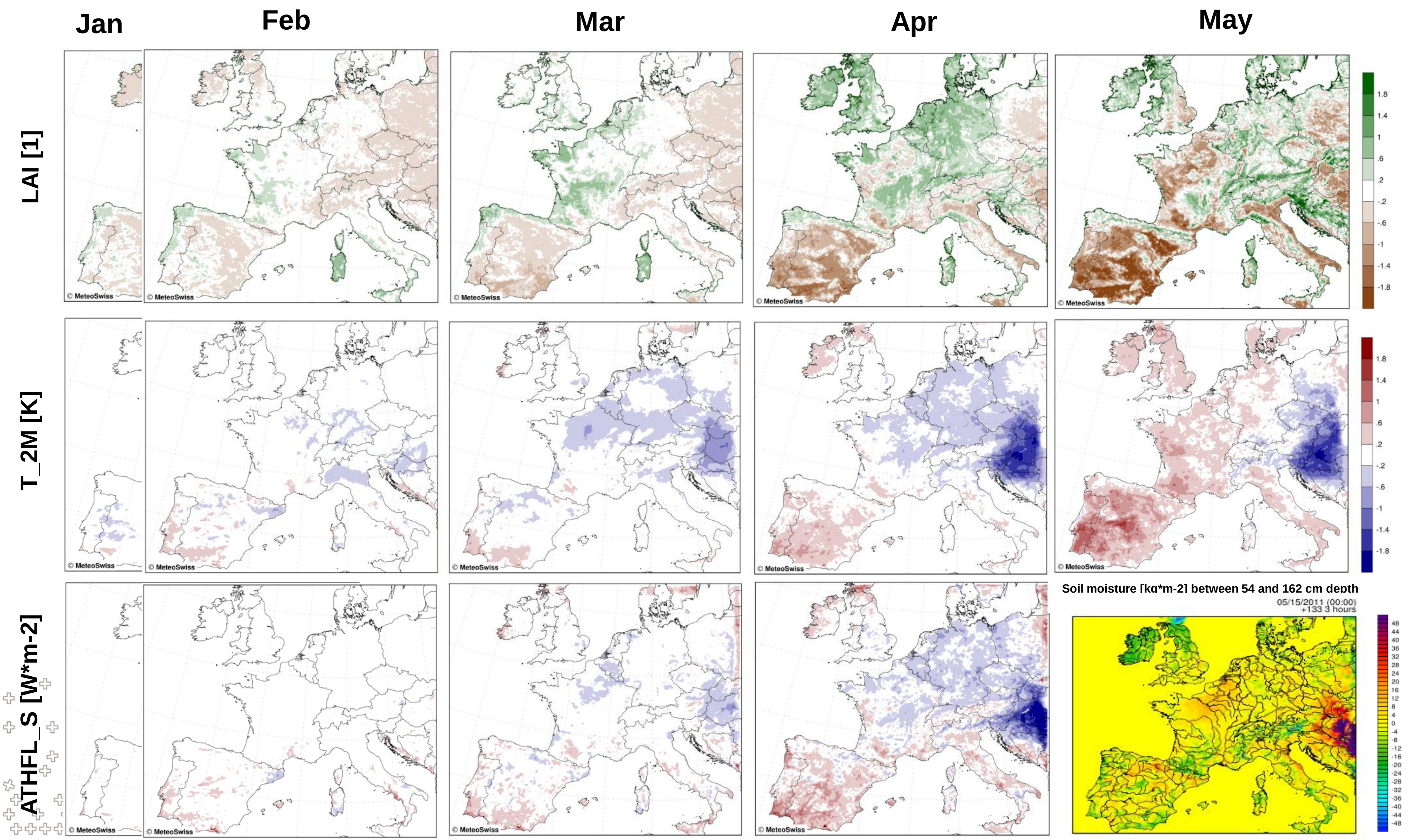
- **phenology model by Stöckli et al**. (2011)* provides daily LAI maps (based on MODIS data with Ensemble Kalman Filter)

- **2 parallel runs** with COSMO-7 restarted every 24 hours with fresh start field from the archive over the period 15 Jan 2011 – 31 October 2011 (very warm and early spring)
  - 1 reference run with **operational (climatological) LAI**
  - 1 experimental run with **actual LAI** merged every 24 hours; soil moisture and soil temperature run freely

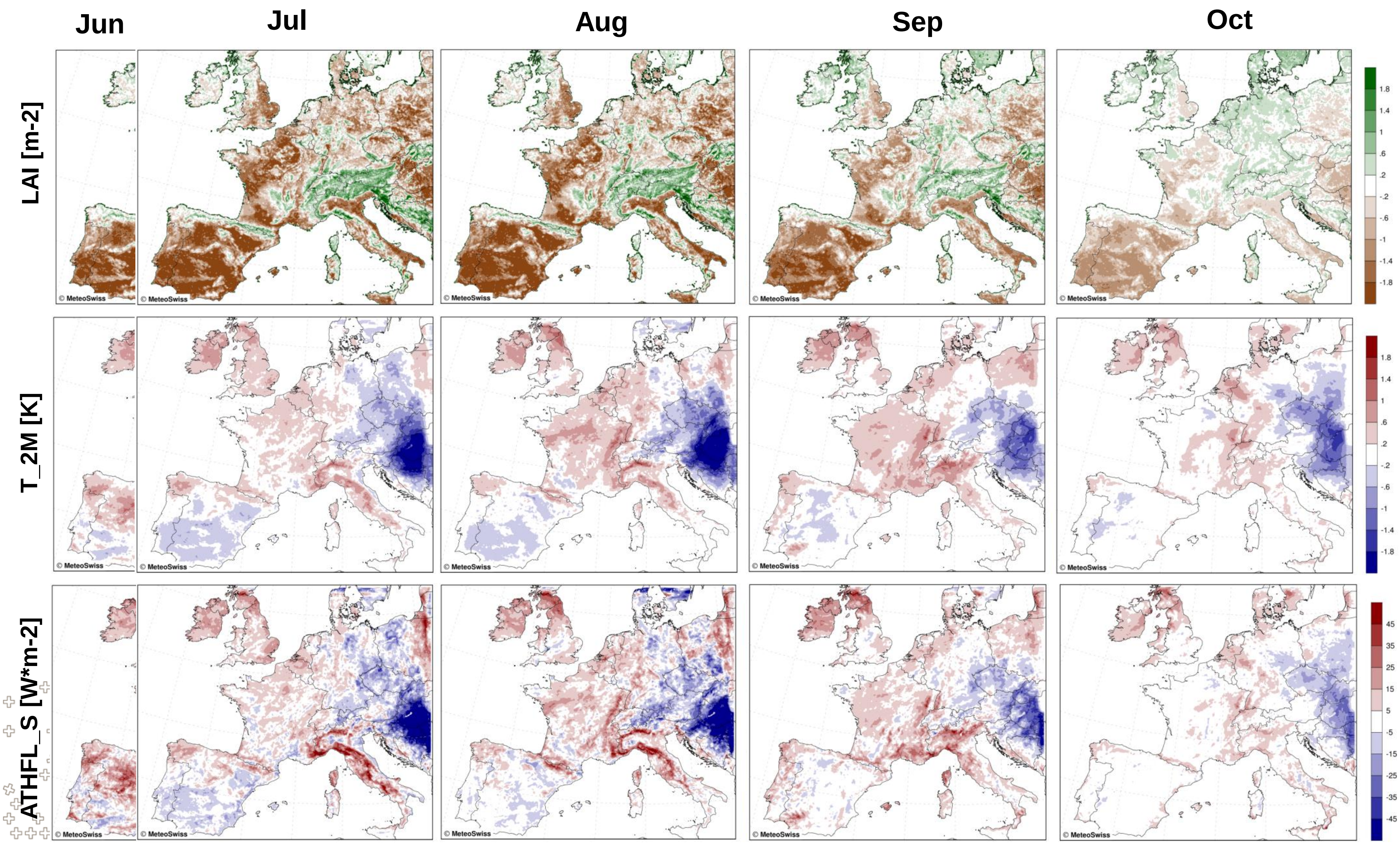
⇒ 2 parallel runs with only difference LAI (plus soil feedback!)
look at impact on T_2M and ATHFL_S

* Stöckli, R., T. Rutishauser, I. Baker, M. A. Liniger, and A. S. Denning (2011), A global reanalysis of vegetation phenology, J. Geophys. Res., 116, G03020, doi:10.1029/2010JG001545

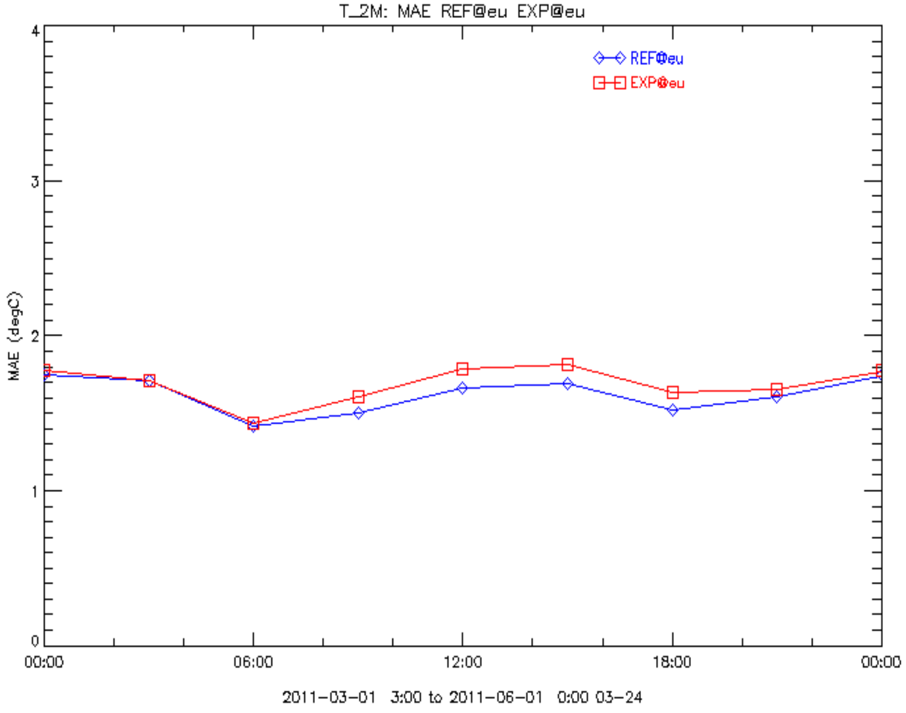
monthly means of daily 15h UTC values year 2011. exp minus ref

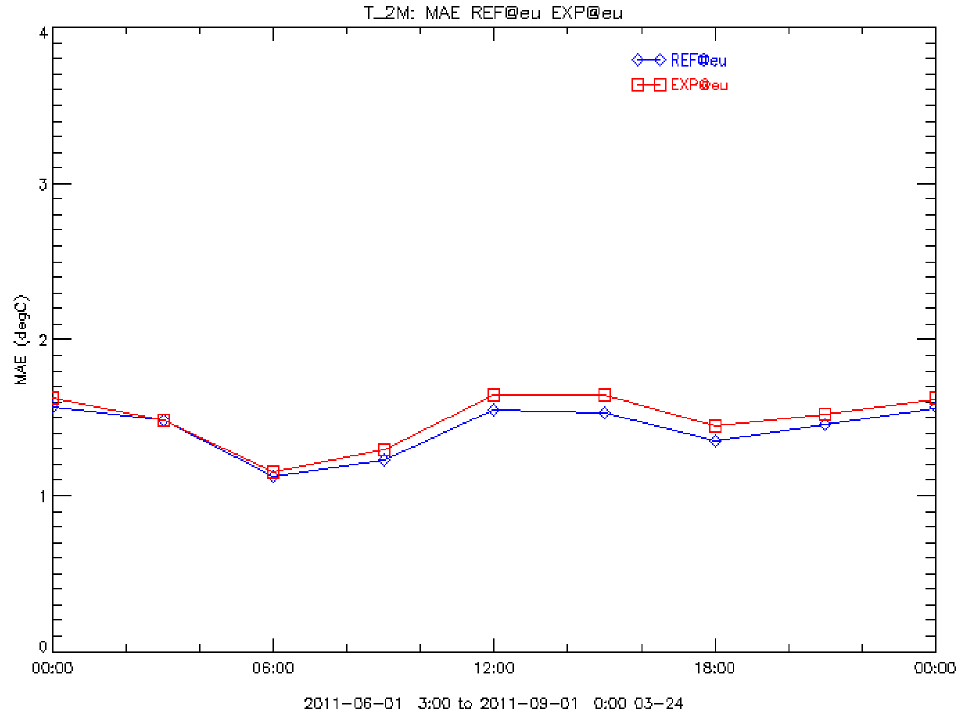


monthly means of daily 15h UTC values year 2011. exp minus ref



Verification of T_2M (MAM and JJA)





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Conclusions and Outlook (1)

- What is the sensitivity of LAI changes in COSMO?

=> T_2M: spatially variable, roughly 1 K / 2 LAI (April 2011). 2 LAI is what we can expect in extreme years.

=> ATHFL_S: 40 Wm^{-2} / 3 LAI.

- Does the performance improve if actual LAI is used?

=> No and Yes … BUT: COSMO tuned for ref and need more years (e.g. also a year with late phenology)

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CONSORTIUM FOR SMALL SCALE MODELING
COSMO

PP CALMO & CALMO-MAX

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.

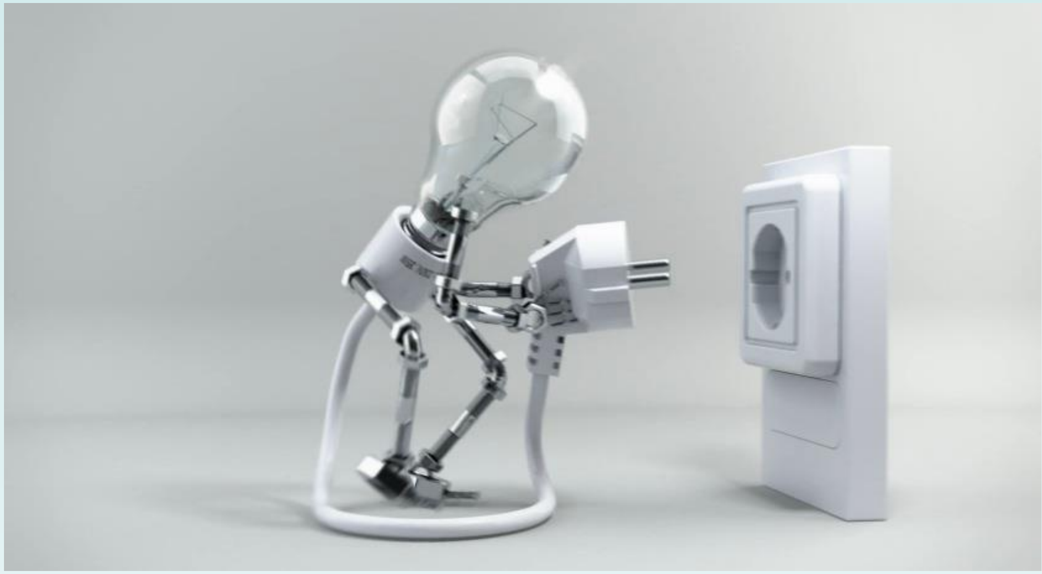
- Project status: Finished (Work completed in 3 phases 01.2013 – 12.2016)

- 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

- free or poorly confined parameters included in parameterization schemes
- expert tuning used by model developers is done subjectively by trying to improve the agreement of forecasts with available observations
- expert tuning **lacks objectivity** and is hard to **replicate**



CALMO – The idea

- 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 MM is used to reproduce model results and provides an objective method to replace 'expert tuning' and reduce computational costs by constructing a statistical surrogate model
- The methodology was applied by Bellprat to objectively calibrate COSMO-CLM and reduced the model error of an expert tuned model by about 10%

Selection of important model parameters for the calibration

(in terms of sensitivity with respect to model variables)

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

$$<P> \text{ stands for } <SNOWGSP> or <TOTPREC> or <CLCL> or <CLCM> or <CLCH> or <CLCT>$$

$$S_{\begin{bmatrix} TMIN\,2m \\ TMAX\,2m \end{bmatrix}} = \begin{bmatrix} <TMIN\,2m> \\ <TMAX\,2m> \end{bmatrix}_{TEST} - \begin{bmatrix} <TMIN\,2m> \\ <TMAX\,2m> \end{bmatrix}_{DEFAULT}$$

DESCRIPTION OF PARAMETER LIST with sensitivities tested

PARAMETER	INTERPRETATION	RANGE	TEST VALUES (default)
a_stab	factor for stability correction of horizontal length scale	0.0 – 1.0	0.0 , 0.5, 1.0
crsmin	minimum stomatal resistance	50-300	50, 150, 300
c_soil	surface area index of evaporative soil surfaces (dependent on surface area density of the roughness elements over land , c_lnd)	0-c_lnd(2.0)*	0, 1, 2
entr_sc	mean entrainment rate for shallow convection	5.0E-5 – 2.0E-3	5.0E-5, 3.0E-4, 2.0E-3
mu_rain	shape parameter of the rain drop size distribution (max value set equal to 2 for COSMO.V5.0	0 – 2	0,1,2
q_crit	critical value for normalized oversaturation	1.0 – 4.0	1.6, 2.8, 4.0
qi0 **	cloud ice threshold for autoconversion (tentative validity if different than 0)	0-0.01	0, 0.005, 0.01
rain_n0_factor	factor to reduce the evaporation of raindrops	0.02 - 5.0	0.02, 1.0, 5.0
rat_sea	ratio of laminar scaling factors for heat over sea	1-100	10, 20, 100
rlam_heat	scaling factor of the laminar boundary layer for heat	0.1 – 2.0	0.1, 1.0, 2.0
tkhmin tkmmin	minimal value of diffusion coefficient for heat and momentum (kept equal)	0.1-1.0	0.1, 0.4, 1.0
tur_len	asymptotic maximal turbulent length scale (m)	100 – 1000	100, 150, 1000
v0snow	factor in the terminal velocity for snow	10.0 – 30.0	10, 20, 30

* c_lnd: Surface-area index of gridpoints over land (excluding leaf-area index).

** The «gray» variable **qi0**, although its sensitivity will be shown, it is not accounted at this stage of our work due to caution regarding its use if different than its default value (communication with Axel Seifert).

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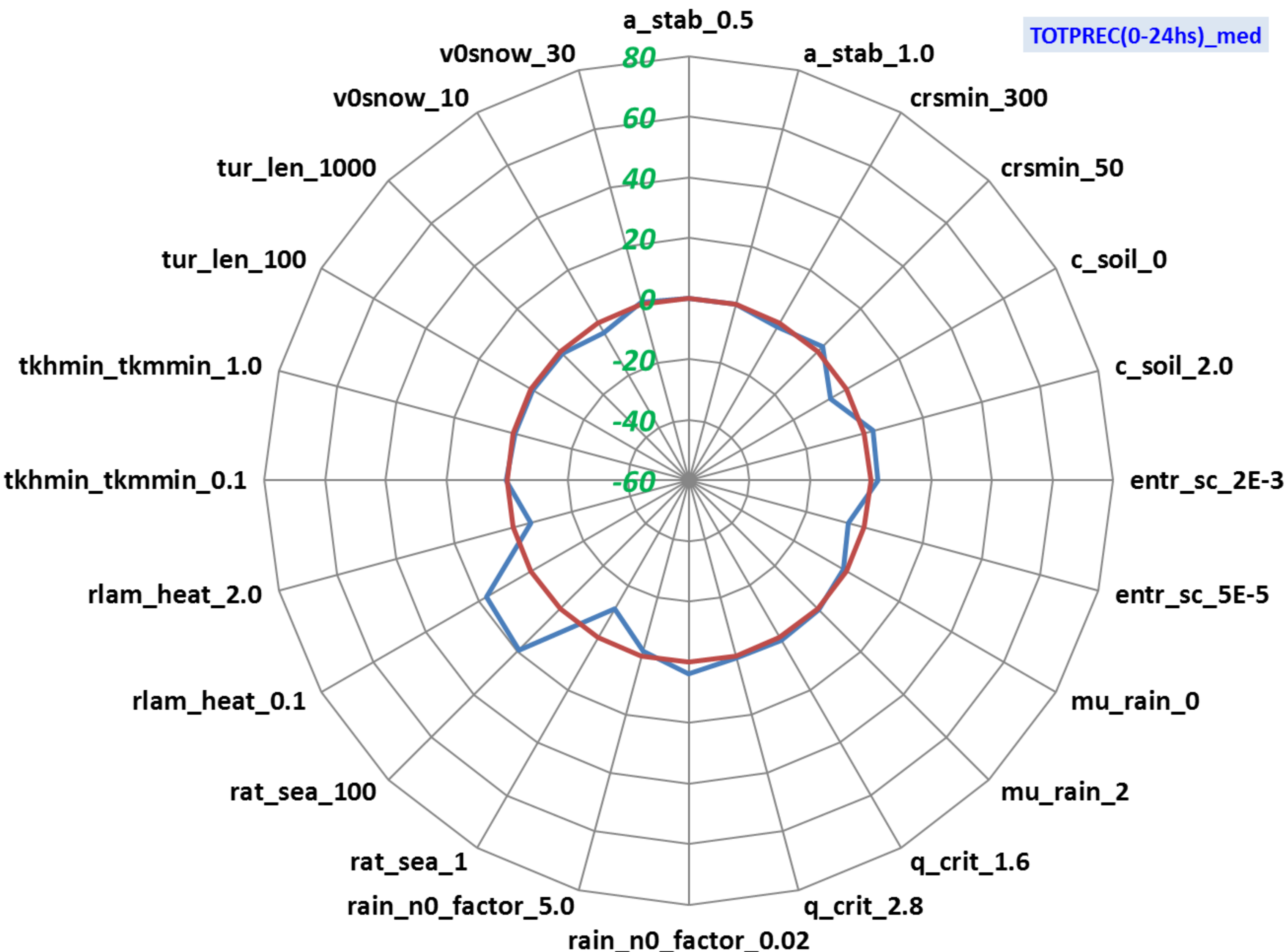

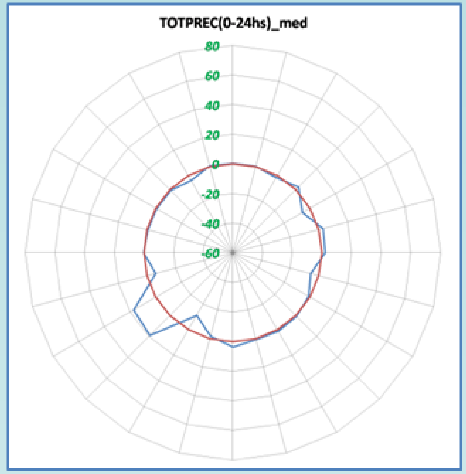
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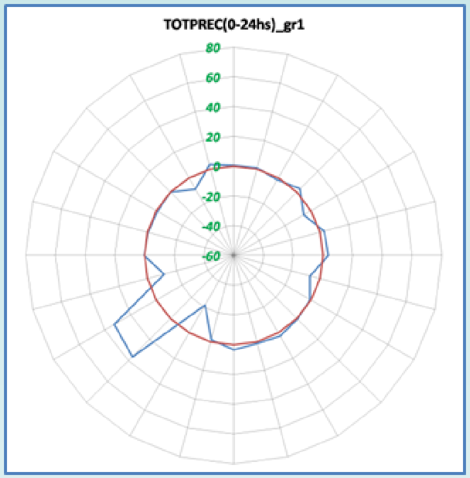
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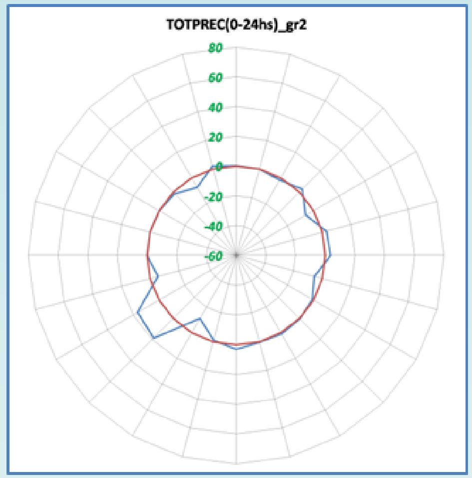
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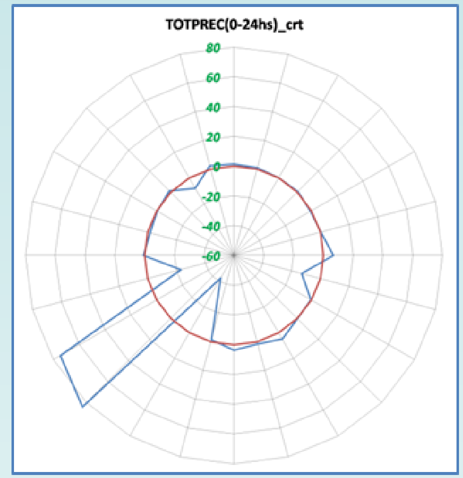
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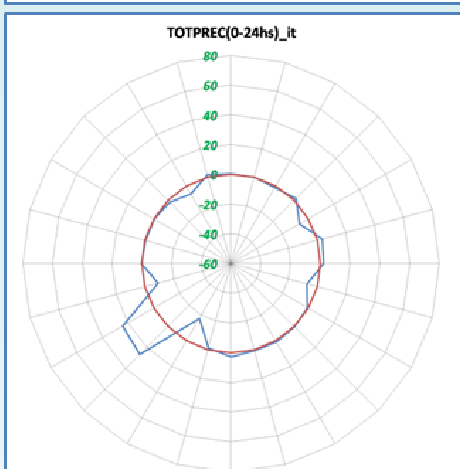
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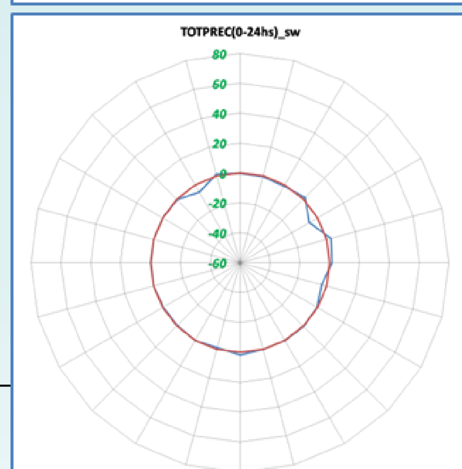
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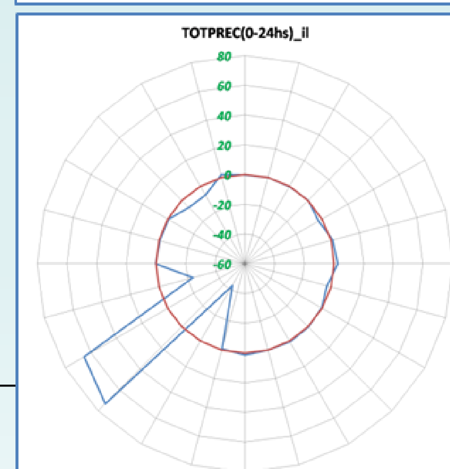
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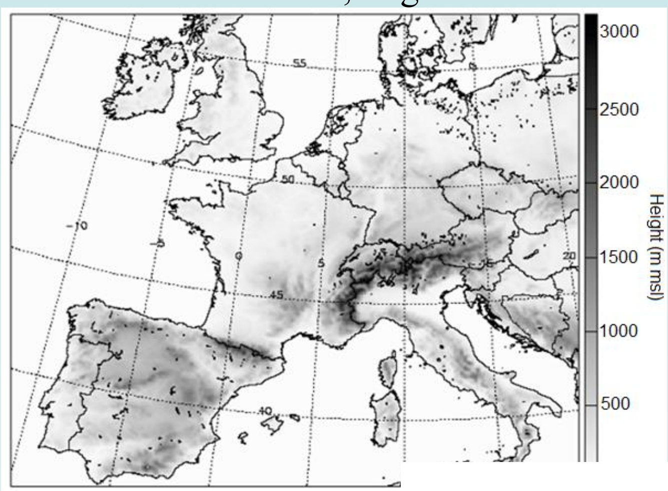
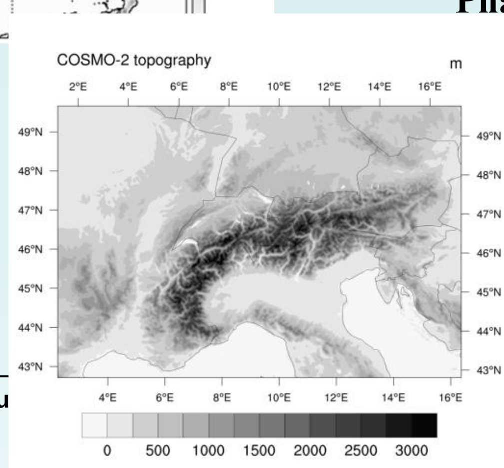
Perform at least 2N + 0.5N(N − 1) + 1 real model simulations were N is the number of parameters used for the calibration

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





Phase-2 finished within COSMO year 2015-16

- Simulations using COSMO with a 2.2 km mesh size
- The simulation period the **entire year** of 2013 using Piz Daint resources
- **6 parameters** rlam_heat, tkhmin, tur_len, entr_sc, v0snow, and c_soil
- The history of the soil was not used
- 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)

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**
- **5 parameters** 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

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

Define an objective performance function

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

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*

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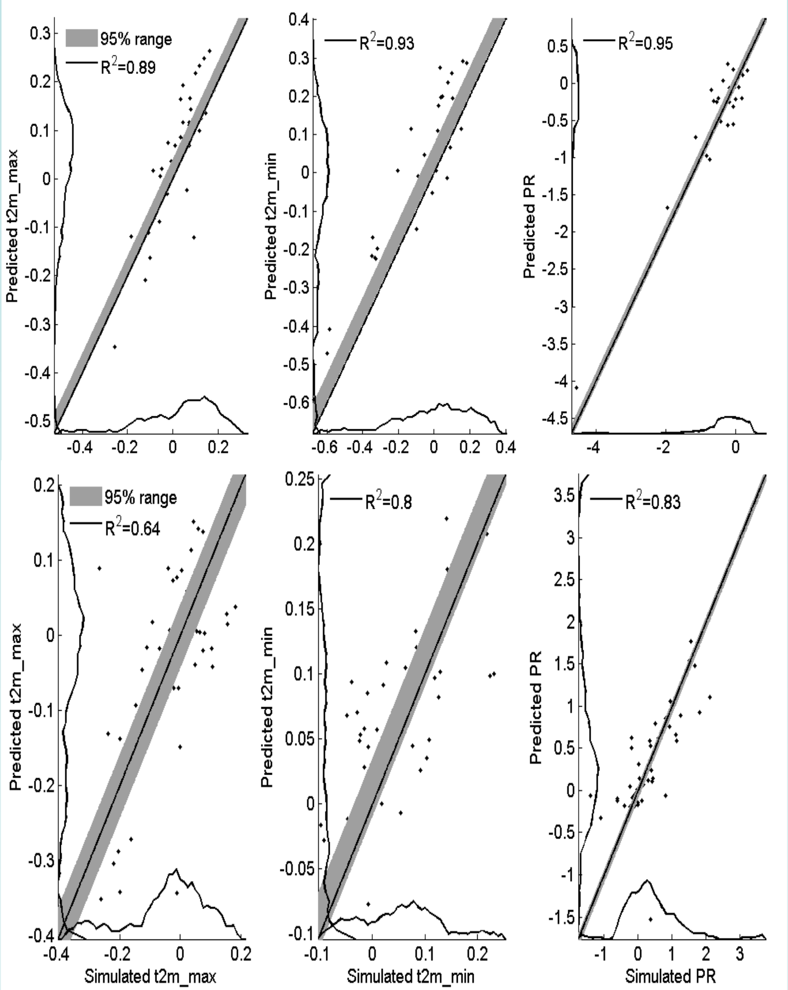
Check the MM accuracy
CALMO- Phase 1 results

Phase-1 results

- The MM is capable in reproducing COSMO-NWP, thus the objective methodology can be transferred from RCM to NWP

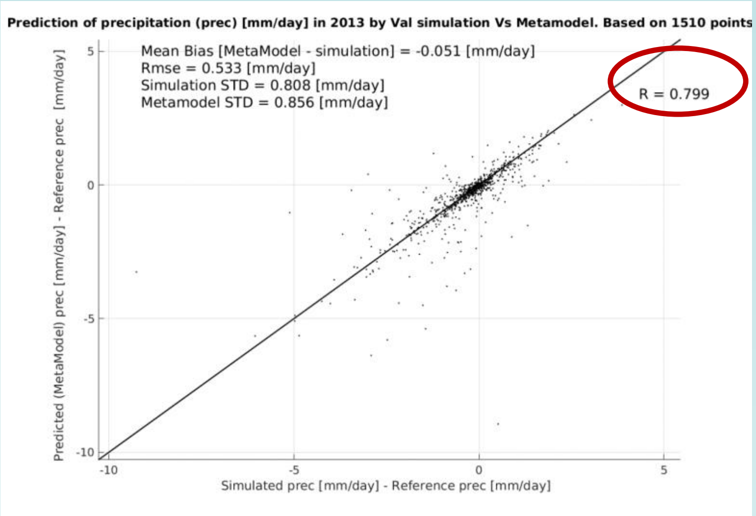
- The best correlations 95% and 93% are calculated during winter period for 24 hours accumulated precipitation and minimum 2m temperature respectively, while also for maximum temperature correlation is better 89% during winter against 64% for summer

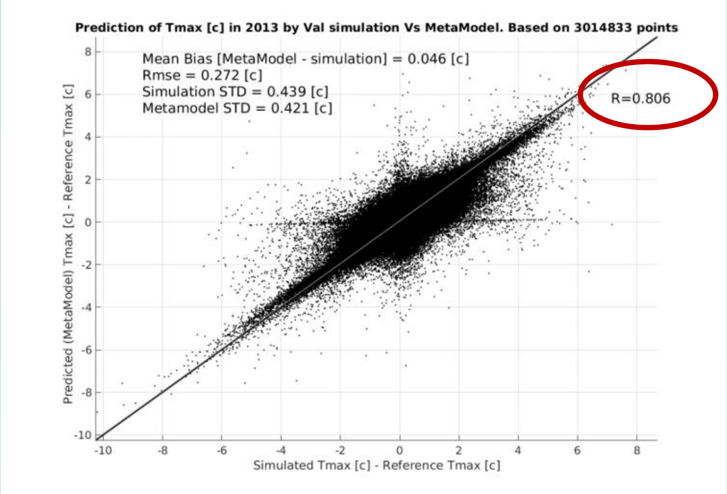
- A different set of optimum parameter values for each season was extracted

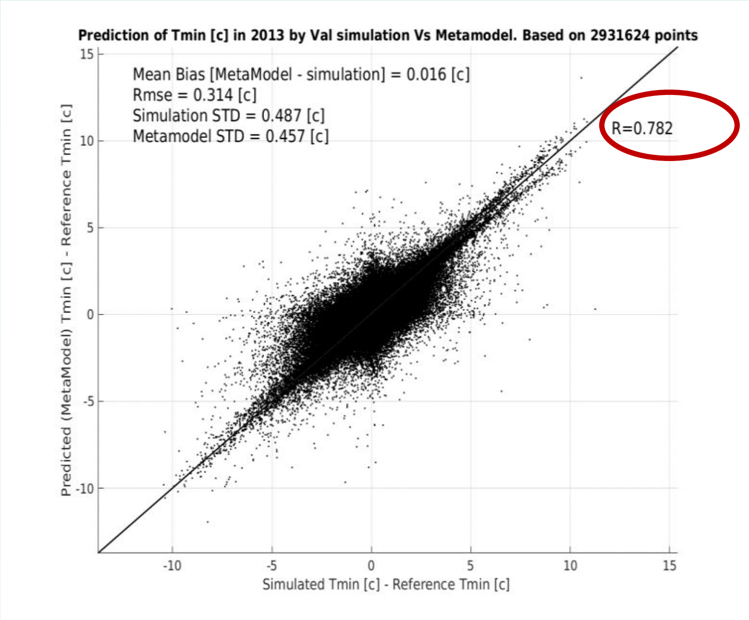


Tmax (left panel), Tmin (centered panel) and precipitation (right panel) for the period 3-20.1.2008 (upper) and 2-20.6.2008 (lower panel)

Check the MM accuracy
CALMO- Phase 2 results

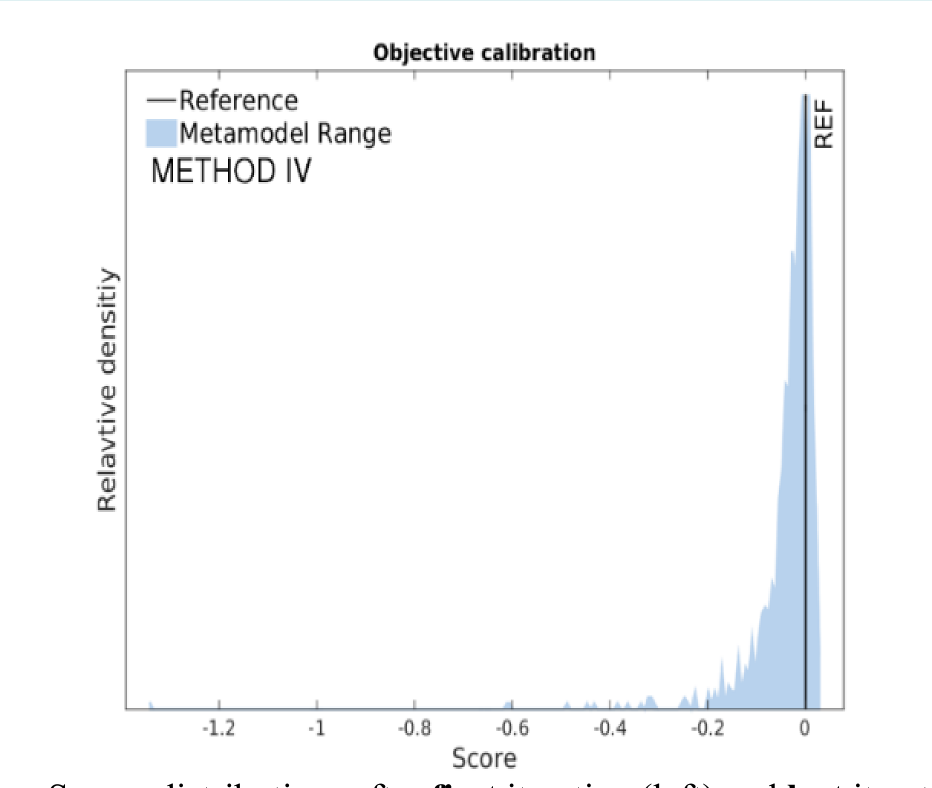


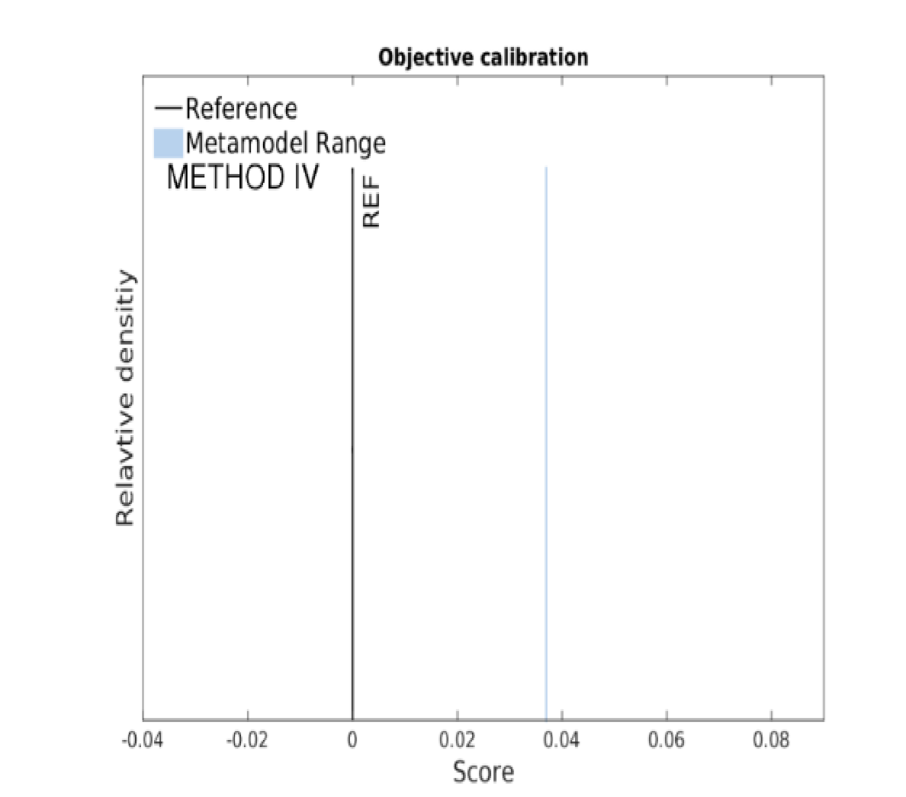




- The MM is capable in accurately reproducing COSMO-2km over an entire year
- The correlations calculated during simulation period for 24 hours accumulated precipitation maximum and minimum 2m temperature are 79.9%, 80.6% and 78.2% respectively (figure on the right)

Sample the parameter space by MM
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

- rlam_heat=**1.273** default ***1.0***. Uncertainty: [1.149 1.390];
- tkhmin=**0.266** default ***0.4***; Uncertainty: [0.205 0.351];
- tur_len=**346.5** default ***150***; Uncertainty: [294.6 409.9];
- entr_sc=**0.1607e-3** default ***0.003***; Uncertainty: [0.1261e-3 0.21043-3];
- c_soil=**0.588** default ***1.0***; Uncertainty: [0.515 0.664];
- v0snow=**12.3** default ***20***; Uncertainty: [11.6 13.3].

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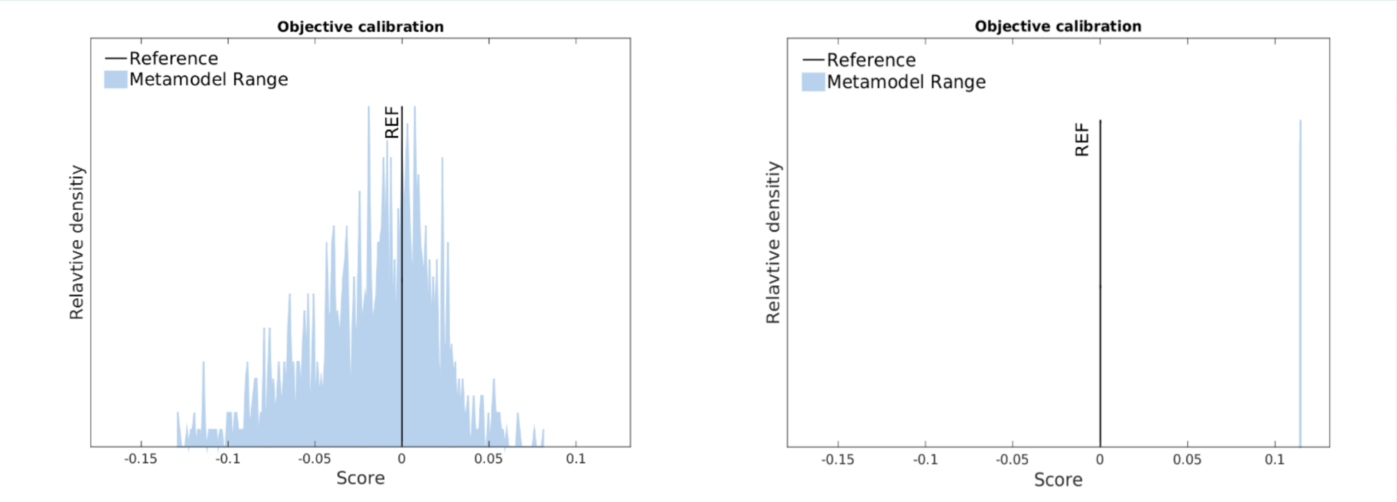
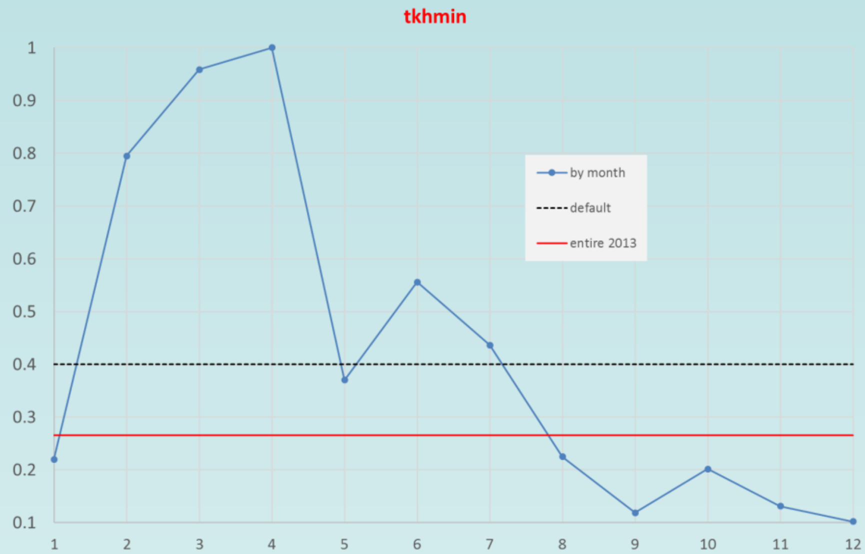
Check the MM accuracy
CALMO- Phase 3 results

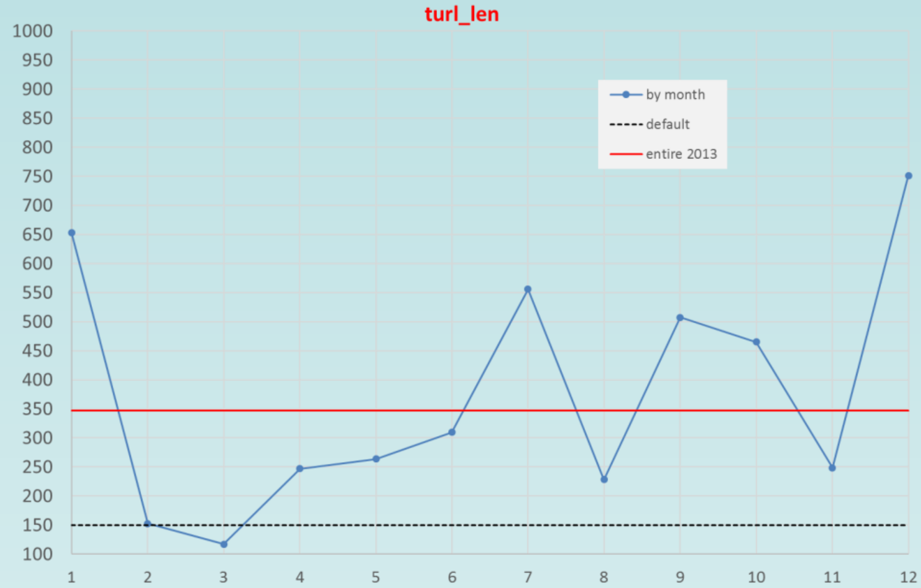


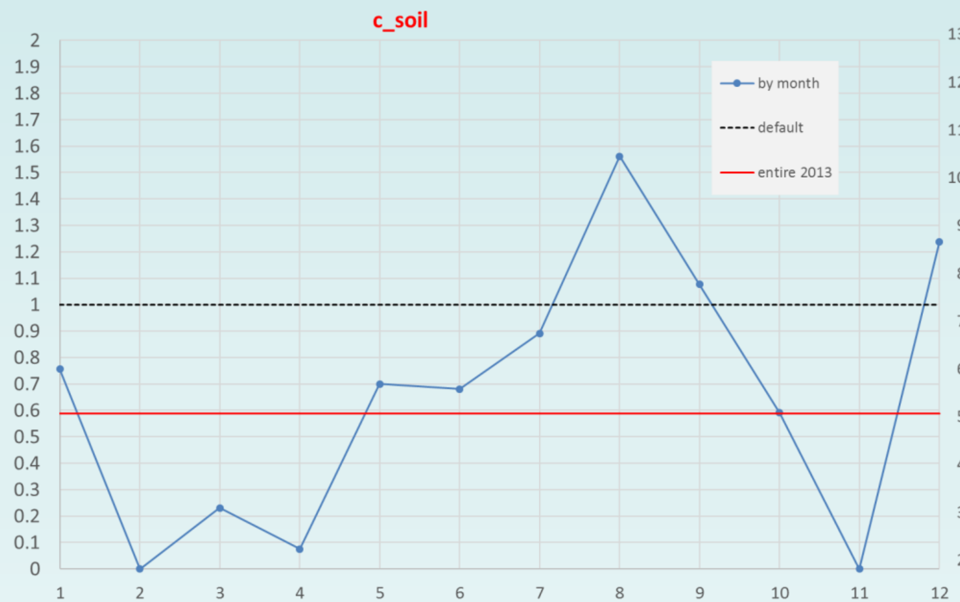
Scores distributions after **first** iteration (left) and **last** iteration (right), together with the scores of the reference (REF) simulation.

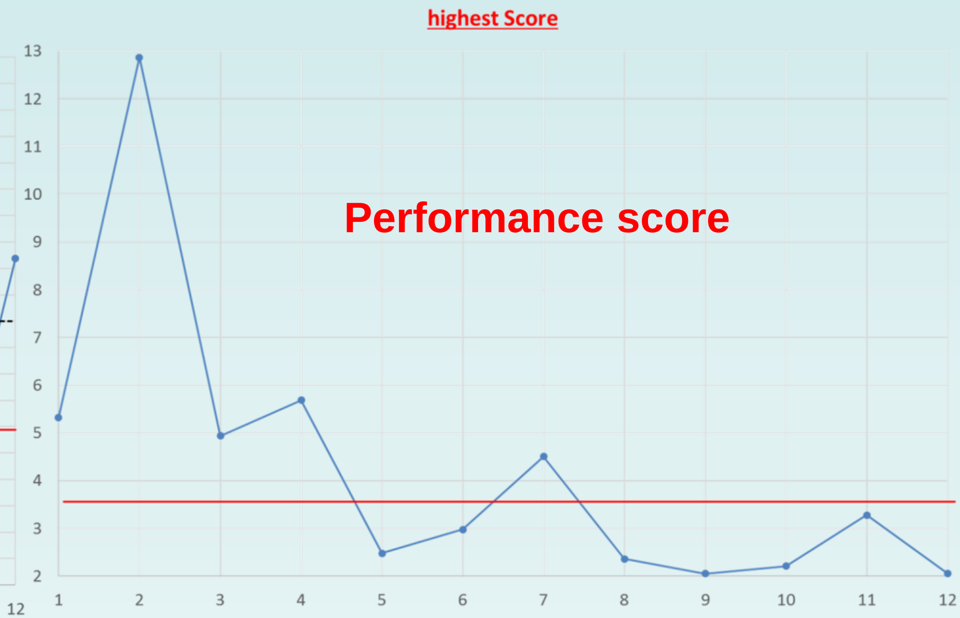
- Obtain the final optimal parameters combination
  - tkhmin=**1** default ***0.4***; Uncertainty: [0.983 1];
  - tur_len=**109.3** default ***150***; Uncertainty: [104.3 117.2];
  - entr_sc=**0.002** default ***0.003***; Uncertainty: [0.0018 0.002];
  - c_soil=**2** default ***1.0***; Uncertainty: [1.937 2];
  - crsmin=**200** default ***150***; Uncertainty: [186.3 200]

Yearly optimum cycle



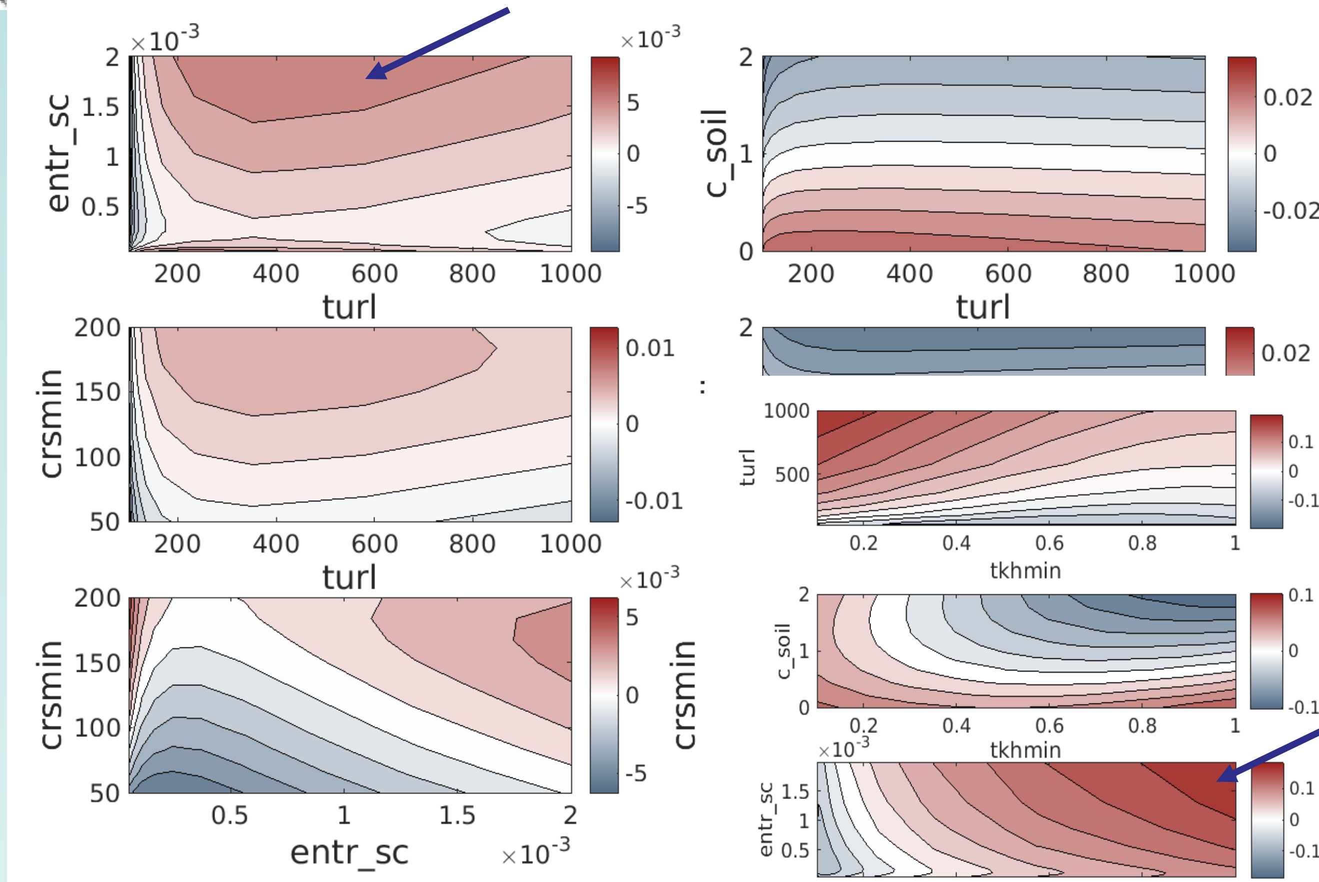


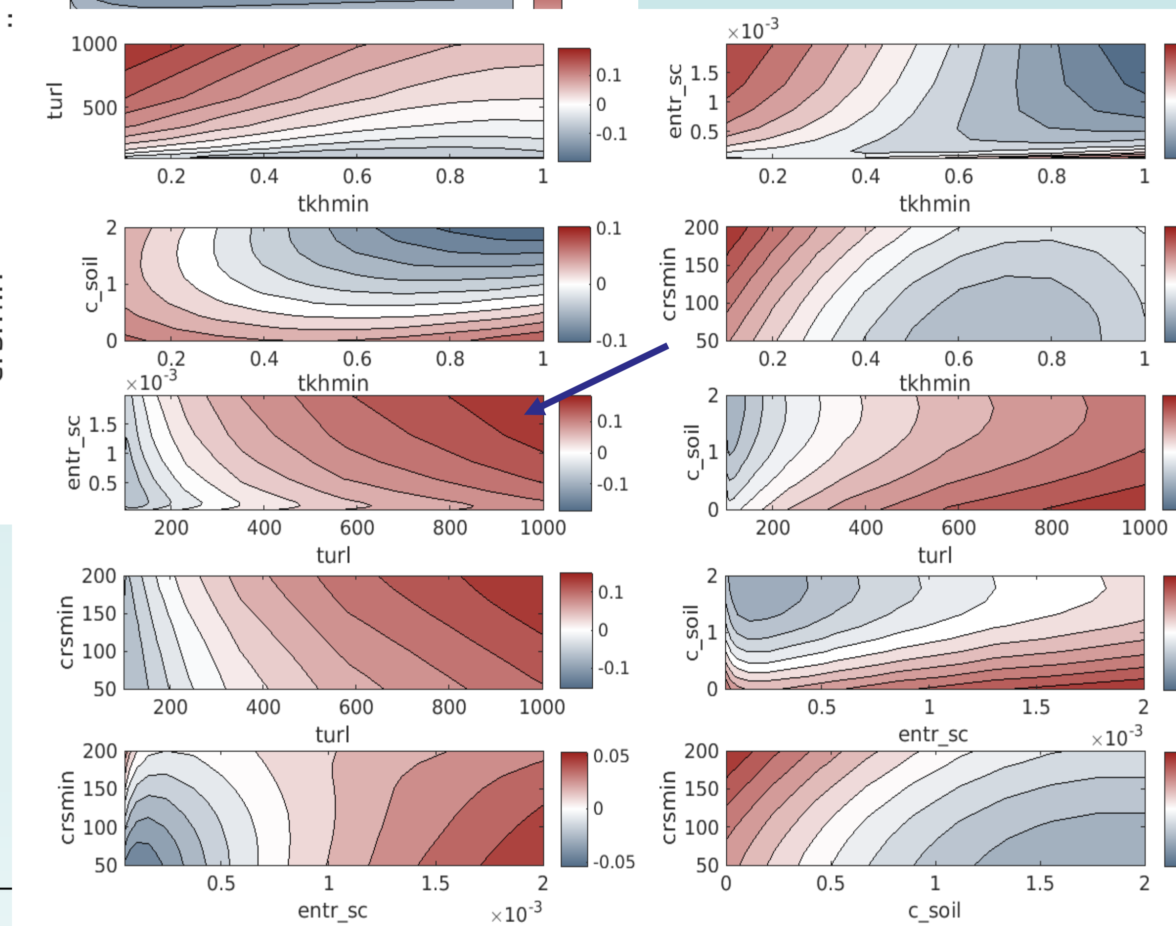




ΕΘΝΙΚΗ ΜΕΤΕΩΡΟΛΟΓΙΚΗ ΥΠΗΡΕΣΙΑ

Contours of score deviation for pairwise parameters combinations





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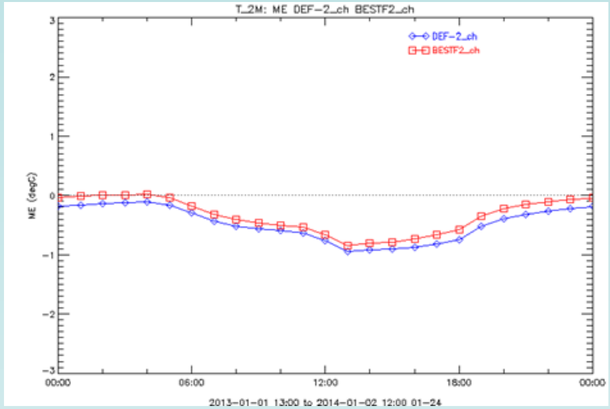
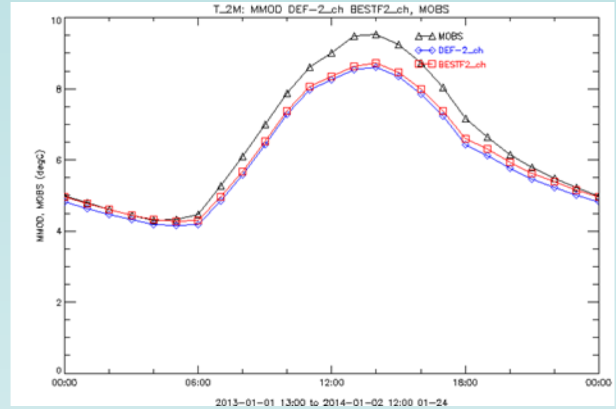
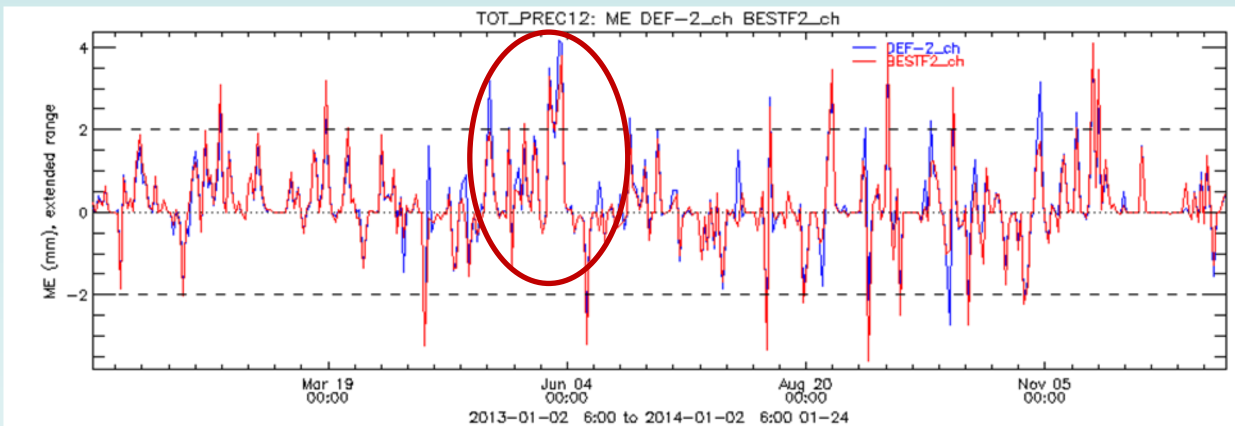
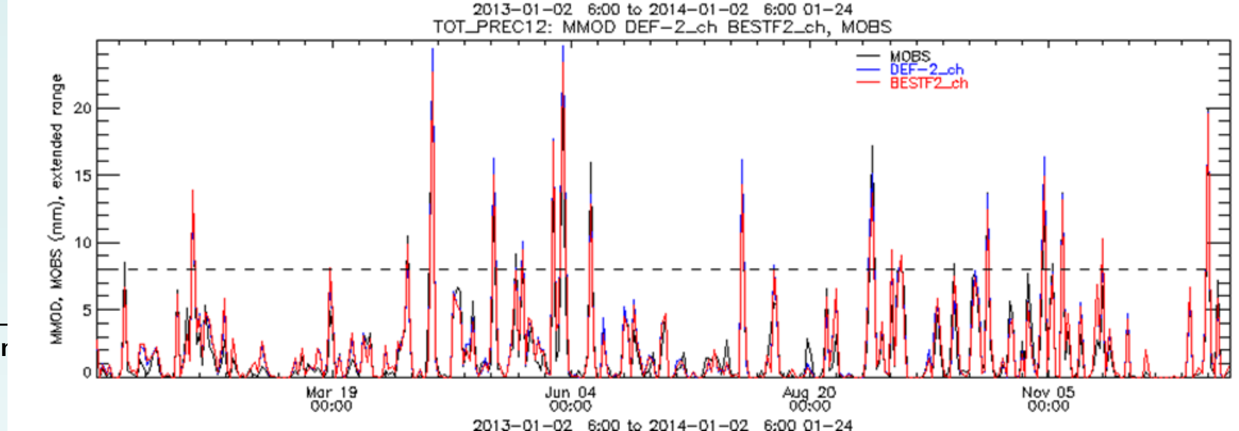
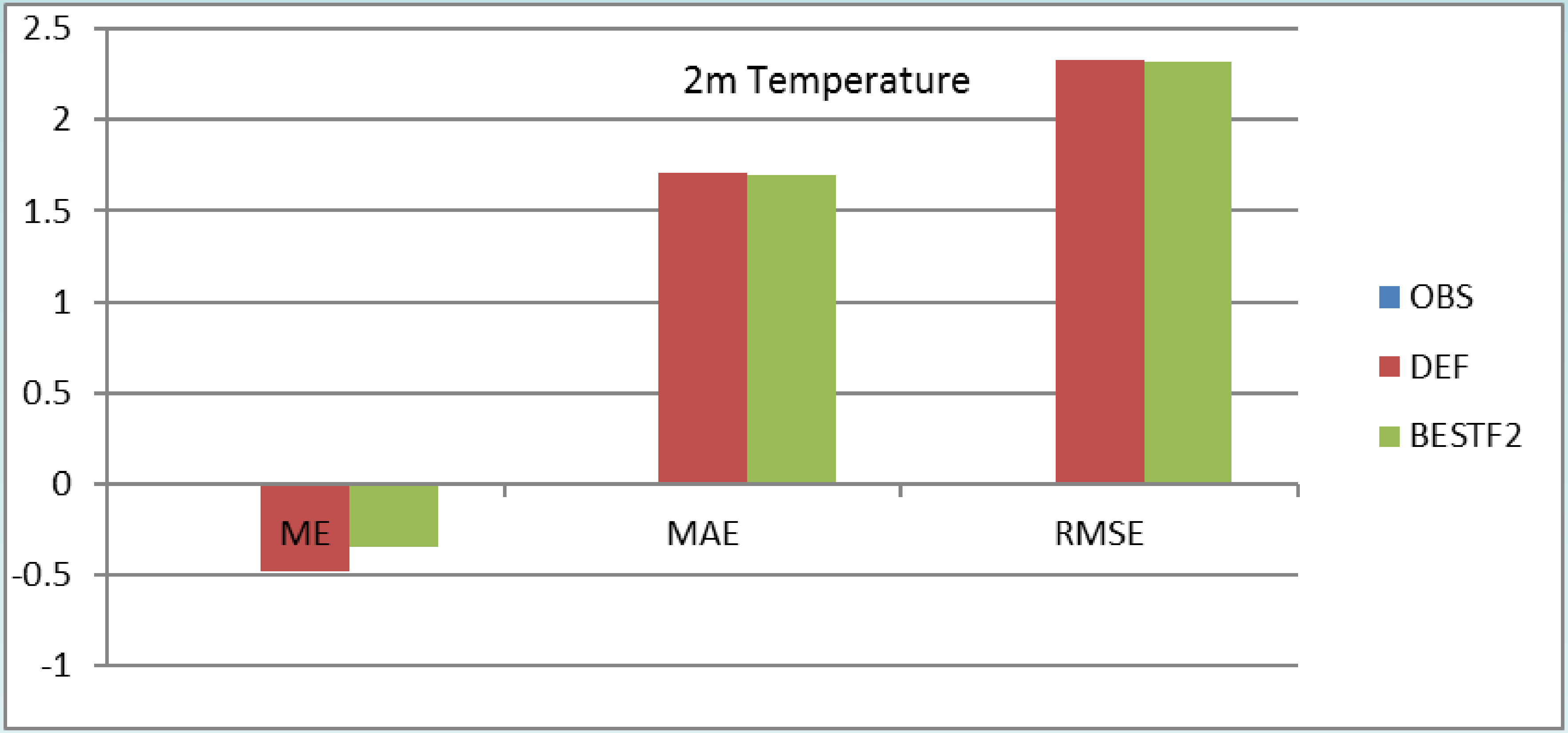
Perform a real COSMO simulation with the selected parameters combination to verify results










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

ΕΘΝΙΚΗ ΜΕΤΕΩΡΟΛΟΓΙΚΗ ΥΠΗΡΕΣΙΑ
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Further validation

- Test performed by E. Bucchignani, P. Mercogliano, M. Milelli
- 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°

Results: Time series of T2m

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

	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**

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
  - Start a configuration for the COSMO-1 calibration over an entire year to use as a benchmark (a CSCS proposal for computer resources is pending for approval)
  - 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

DESCRIPTION OF PARAMETER LIST
with sensitivities tested

PARAMETER	INTERPRETATION	RANGE	TEST VALUES (default)
a_stab	factor for stability correction of horizontal length scale	0.0 – 1.0	0.0 , 0.5, 1.0
crsmin	minimum stomatal resistance	50-300	50, 150, 300
c_soil	surface area index of evaporative soil surfaces (dependent on surface area density of the roughness elements over land , c_lnd)	0-c_lnd(2.0)*	0, 1, 2
entr_sc	mean entrainment rate for shallow convection	5.0E-5 – 2.0E-3	5.0E-5, 3.0E-4, 2.0E-3
mu_rain	shape parameter of the rain drop size distribution (max value set equal to 2 for COSMO.V5.0	0 – 2	0,1,2
q_crit	critical value for normalized oversaturation	1.0 – 4.0	1.6, 2.8, 4.0
qi0 **	cloud ice threshold for autoconversion (tentative validity if different than 0)	0-0.01	0, 0.005, 0.01
rain_n0_factor	factor to reduce the evaporation of raindrops	0.02 - 5.0	0.02, 1.0, 5.0
rat_sea	ratio of laminar scaling factors for heat over sea	1-100	10, 20, 100
rlam_heat	scaling factor of the laminar boundary layer for heat	0.1 – 2.0	0.1, 1.0, 2.0
tkhmin tkmmin	minimal value of diffusion coefficient for heat and momentum (kept equal)	0.1-1.0	0.1, 0.4, 1.0
tur_len	asymptotic maximal turbulent length scale (m)	100 – 1000	100, 150, 1000
v0snow	factor in the terminal velocity for snow	10.0 – 30.0	10, 20, 30

* c_lnd: Surface-area index of gridpoints over land (excluding leaf-area index).

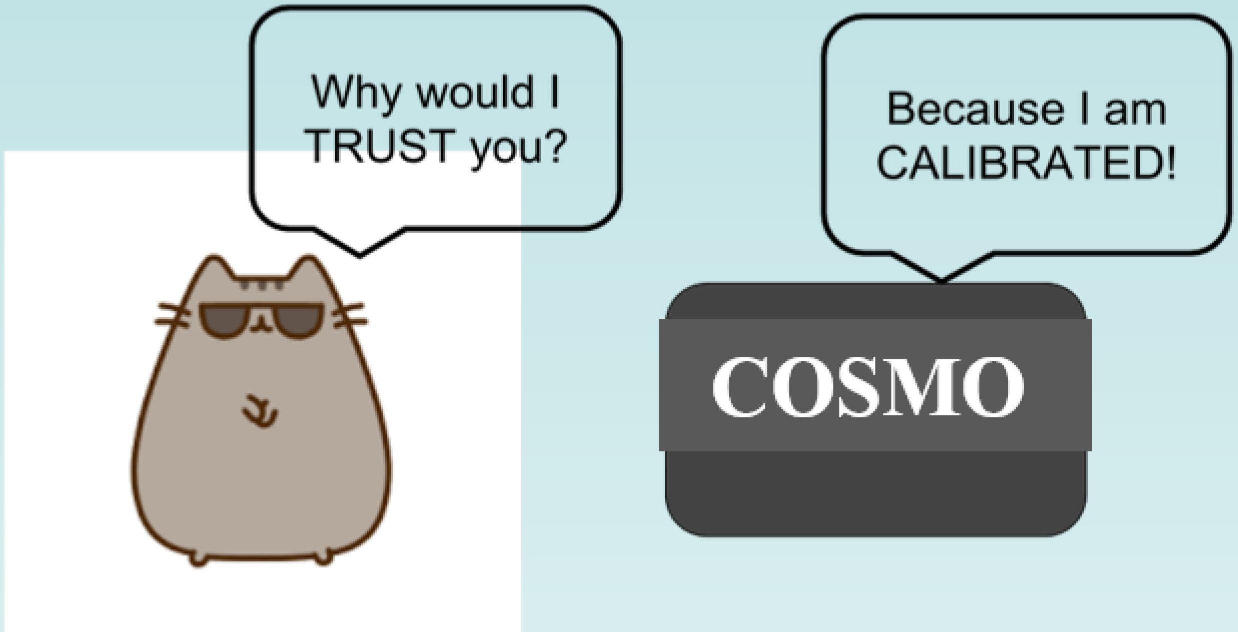
** The «gray» variable **qi0**, although its sensitivity will be shown, it is not accounted at this stage of our work due to caution regarding its use if different than its default value (communication with Axel Seifert).

Proposed parameter list

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] **[0,0.3,0.6] proposed by ETHZ**
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	**soilhyd**** Replace with gamma	[**1**, 6] ** 0.4

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
- 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
- A **peer reviewed paper** has been published in Atm. Res. vol. 190; a second peer reviewed paper is in the review process.



THANK YOU FOR YOUR ATTENTION

QUESTIONS???

Proposed ways to minimize computational cost

- Compute hindcasts instead of assimilation cycle and regular forecast
- Use a limited domain (e.g. half of COSMO-1 in both directions)?
- Use a coarser resolution (e.g. 2.2 instead of 1.1 km)
- Use a set of limited time periods (e.g. 1 month in each season), bind these periods with TERRA standalone runs to keep soil memory on-going
- Consider an iterative method to fit the MM (in line which Euripides’s proposal), to obtain a specified level of MM accuracy
- Partition set of unconfined model parameters in different subsets (if weak dependency between the subsets can be assumed), calibrate first subset, then next subset
- Only consider the unconfined parameters that effect the meteorological variable of ‘interest’
- ……….