CALMOMAX project – On the Meta Model

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COSMO General Meeting, Jerusalem, September 2017
Outline

1. Overview on the Convergence to the optimal parameters combination.
2. Results of Stage 2.
3. Results of Stage 3.
4. Results of Additional tests after stage 3 such as test for each month in 2013 and rainy days (only) in 2013.
5. Summary.
Convergence to the optimal parameters combination
Convergence to the optimal parameters combination

Figure 4: Example of convergence after first iteration. Each panel shows (in blue) the optimal 100 parameters values (in sorted order) among 1000 sampled combinations. The red lines represent the allowed ranges for each parameter, the green lines represent the uncertainty for each parameter after first iteration (following the optimal 100 values). Red crosses represent the best parameters combination after first iteration.
Convergence to the optimal parameters combination

Figure 5: Example of convergence after last (35th) iteration.
Stage 2 is the COSMO 2.2km for all year of 2013.

Validation of CALMO stage-2 Meta-Model using arbitrary test simulation

Figure 6: $T_{max}$ Meta-Model prediction for the tested parameter combination, vs COSMO simulation results during the year 2013. X axis presents the simulated $T_{max}$ minus the reference simulation. Y axis presents the Meta-Model $T_{max}$ minus the reference simulation.
Stage 2 is the COSMO 2.2km for all year of 2013.

Figure 7: Tmin Meta-Model prediction for the tested parameter combination, vs COSMO simulation results during the year 2013. X axis presents the simulated Tmin minus the reference simulation. Y axis presents the Meta-Model Tmin minus the reference simulation.
Stage 2 is the COSMO 2.2km for all year of 2013.

Figure 8: Pr Meta-Model prediction for the tested parameter combination, vs COSMO simulation results during the year 2013. X axis presents the simulated Pr minus the reference simulation. Y axis presents the Meta-Model Pr minus the reference simulation.
Stage 2 is the COSMO 2.2km for all year of 2013.

Figure 9: TCWC Meta-Model prediction for the tested parameter combination, vs COSMO simulation results during the year 2013. X axis presents the simulated TCWC minus the reference simulation. Y axis presents the Meta-Model TCWC minus the reference simulation.
Stage 2 is the COSMO 2.2km for all year of 2013.

Calibration results for entire year 2013

Figure 14: $S_p$ scores distributions after first iteration, together with the score of the reference (REF) simulation, for methods I-IV. For convenience, the distributions are presented as function of $\tilde{S}_p = 1 - S_p/S_{p,\text{REF}}$ for methods I, II and as function of $\tilde{S}_p = S_p/S_{p,\text{REF}} - 1$ for methods III, IV. Therefore higher $\tilde{S}_p > 0$ means better score with respect to the REF simulation.
Stage 2 is the COSMO 2.2km for all year of 2013.

The four methods

1. Averaging $T_{\text{max}}$ and $T_{\text{min}}$ over region, using RMSE-type score (Matlab parameter ‘pr_only’=0).

2. Not Averaging $T_{\text{max}}$ and $T_{\text{min}}$ over region, using RMSE-type score (Matlab parameter ‘pr_only’=1).

3. Averaging $T_{\text{max}}$ and $T_{\text{min}}$ over region, using COSI-type score (Matlab parameter ‘pr_only’=0).

4. Not Averaging $T_{\text{max}}$ and $T_{\text{min}}$ over region, using COSI-type score (Matlab parameter ‘pr_only’=1).
Stage 2 is the COSMO 2.2km for all year of 2013.

Figure 15: $S_p$ scores distributions after last iteration, together with the score of the reference (REF) simulation, for methods I-IV. For convenience, the distributions are presented as function of $\tilde{S}_p = 1 - S_p/S_{p,REF}$ for methods I, II and as function of $\tilde{S}_p = S_p/S_{p,REF} - 1$ for methods III, IV. Therefore higher $\tilde{S}_p > 0$ means better score with respect to the REF simulation.
Stage 2 is the COSMO 2.2km for all year of 2013.

Optimal parameters For Method IV.

Assuming method IV as the most reasonable, the final optimal parameters combination with its uncertainty is:

- rlam_heat=1.273 instead of the default 1.0. Uncertainty: [1.149 1.390];
- tkhmin=0.266 instead of the default 0.4; Uncertainty: [0.205 0.351];
- tur_len=346.5 instead of the default 150; Uncertainty: [294.6 409.9];
- entr_sc=0.0001607 instead of the default 0.003; Uncertainty: [0.0001261 0.0002104];
- c_soil=0.588 instead of the default 1.0; Uncertainty: [0.515 0.664];
- v0snow=12.3 instead of the default 20; Uncertainty: [11.6 13.3].
## Calibration results - seasonal dependence

<table>
<thead>
<tr>
<th>Cases</th>
<th>rlam_heat</th>
<th>Tkhmin</th>
<th>tur_len</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire 2013</td>
<td>1.149 1.273 1.390</td>
<td>0.205 0.266 0.351</td>
<td>294.6 346.5 409.9</td>
</tr>
<tr>
<td></td>
<td>[-6.5% +6.2%]</td>
<td>[-6.8% +9.4%]</td>
<td>[-5.8% +7.0%]</td>
</tr>
<tr>
<td>Summer 2013</td>
<td>0.954 1.071 1.164</td>
<td>0.186 0.221 0.270</td>
<td>352.2 357.5 398.9</td>
</tr>
<tr>
<td></td>
<td>[-6.2% +4.9%]</td>
<td>[-3.9% +5.4%]</td>
<td>[-0.6% +4.6%]</td>
</tr>
<tr>
<td>Winter 2013</td>
<td>0.982 1.112 1.232</td>
<td>0.791 0.891 0.929</td>
<td>109.8 117.2 127.9</td>
</tr>
<tr>
<td></td>
<td>[-6.8% +6.3%]</td>
<td>[-11.1% +4.2%]</td>
<td>[-0.8% +1.2%]</td>
</tr>
</tbody>
</table>

Table 5: CALMO stage-2 optimal parameters combinations, as well as their uncertainties for method IV for the following cases: all months in 2013, summer 2013 (Jul, Aug and Sep) and winter 2013 (Jan, Feb and Mar).

<table>
<thead>
<tr>
<th>Cases</th>
<th>entr_sc ((10^{-4}))</th>
<th>c_soil</th>
<th>v0snow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire 2013</td>
<td>1.261 1.607 2.104</td>
<td>0.515 0.588 0.664</td>
<td>11.6 12.3 13.3</td>
</tr>
<tr>
<td></td>
<td>[-1.8% +2.5%]</td>
<td>[-3.7% +3.8%]</td>
<td>[-3.5% +5.0%]</td>
</tr>
<tr>
<td>Summer 2013</td>
<td>4.439 4.890 5.495</td>
<td>1.090 1.150 1.205</td>
<td>20.2 21.2 22.3</td>
</tr>
<tr>
<td></td>
<td>[-2.3% +3.1%]</td>
<td>[-3.0% +2.8%]</td>
<td>[-5.5% +5.0%]</td>
</tr>
<tr>
<td>Winter 2013</td>
<td>1.387 1.714 2.076</td>
<td>0.0 0.041 0.134</td>
<td>29.2 30.0 30.0</td>
</tr>
<tr>
<td></td>
<td>[-1.7% +1.9%]</td>
<td>[-2.1% +4.7%]</td>
<td>[-4.0% +0.0%]</td>
</tr>
</tbody>
</table>

Table 6: CALMO stage-2 optimal parameters combinations, as well as their uncertainties for method IV for the following cases: all months in 2013, summer 2013 (Jul, Aug and Sep) and winter 2013 (Jan, Feb and Mar).
Calibration results for January 2013

Figure 22: $S_p$ scores distributions after first iteration (left) and last iteration (right), together with the scores of the reference (REF) simulation. For convenience, the distributions are presented as function of $\tilde{S}_p = S_p / S_{p,REF} - 1$. Higher $\tilde{S}_p > 0$ means better score with respect to the REF simulation.
Stage 3

Taking into account the uncertainties using also cases 1-5, the final optimal parameters combination (with its uncertainty) 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].
Summary of Stage 2 and Stage 3 where the values in tables are referred to method IV.

<table>
<thead>
<tr>
<th>CALMO Stage</th>
<th>rlam_heat</th>
<th>Tkhmin</th>
<th>tur_len</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage-2 Entire 2013</td>
<td>1.149 1.273 1.390</td>
<td>0.205 0.266 0.351</td>
<td>294.6 346.5 409.9</td>
</tr>
<tr>
<td></td>
<td>[-6.5% +6.2%]</td>
<td>[-6.8% +9.4%]</td>
<td>[-5.8% +7.0%]</td>
</tr>
<tr>
<td>Stage-2 Jan 2013</td>
<td>0.845 0.935 1.002</td>
<td>0.191 0.220 0.262</td>
<td>559.8 653.3 753.0</td>
</tr>
<tr>
<td></td>
<td>[-4.7% +3.5%]</td>
<td>[-3.2% +4.7%]</td>
<td>[-10.4% +11.1%]</td>
</tr>
<tr>
<td>Stage-3 Jan 2013</td>
<td>Default value*</td>
<td>0.983 1.000 1.000</td>
<td>104.3 109.3 117.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[-1.9% +0.0%]</td>
<td>[-0.6% +0.9%]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CALMO Stage</th>
<th>entr_sc (10^{-4})</th>
<th>c_soil</th>
<th>v0snow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage-2 Entire 2013</td>
<td>1.261 1.607 2.104</td>
<td>0.515 0.588 0.664</td>
<td>11.6 12.3 13.3</td>
</tr>
<tr>
<td></td>
<td>[-1.8% +2.5%]</td>
<td>[-3.7% +3.8%]</td>
<td>[-3.5% +5.0%]</td>
</tr>
<tr>
<td>Stage-2 Jan 2013</td>
<td>2.346 2.764 3.242</td>
<td>0.653 0.756 0.841</td>
<td>11.2 11.8 12.3</td>
</tr>
<tr>
<td></td>
<td>[-2.1% +2.5%]</td>
<td>[-5.2% +4.3%]</td>
<td>[-3.0% +2.5%]</td>
</tr>
<tr>
<td>Stage-3 Jan 2013</td>
<td>18.0 20.0 20.0</td>
<td>1.937 2.000 2.000</td>
<td>Default value*</td>
</tr>
<tr>
<td></td>
<td>[-10.3% +0.0%]</td>
<td>[-3.2% +0.0%]</td>
<td></td>
</tr>
</tbody>
</table>
New Results Beyond Stage 3:

The optimal parameters for Method 4 at COSMO 2.2km (Method 4 = Score by COSI method and pr_only=1 (only area average on rain, not on Daily Tmin and Tmax)

year 2013 Rlam_heat
New Results Beyond Stage 3:

year 2013 Tkhmin
New Results Beyond Stage 3:

year 2013 Entr_sc ($10^{-4}$)

- by month
- default
- entire 2013
New Results Beyond Stage 3:

year 2013 Turl_len

By month vs. default vs. entire 2013
New Results Beyond Stage 3:

year 2013 c_soil

month

by month

default

entire 2013
New Results Beyond Stage 3:
New Results Boyhood Stage 3:

The annual highest score
Rainy Day Optimal parameters for 2013

- The test of CALMO Rainy days is for Method 4 (COSI and pr_only=1) and COSMO 2.2km and year 2013.

- Only days with observed precipitation average area above or equal 0.05 mm/day.

- Approximately, 60% of the observed days in 2013 has above or equal 0.05 mm/days (for area average, there are 7 areas).

- We did not choose the threshold of rainy days to be 0.1mm because 0.01 mm is one of the five thresholds for calculating ETS of precipitation (see COSI method).
New Results Beyond Stage 3:

Planes Figure

CALMO with observed Rainy days compared to all days in 2013 (all available observation). The score is by COSI method

Only for daily Rain above or equal 0.05mm in 2013

All available observed days in 2013
Meanwhile, Matlab reached only integration 10 out of 40. Meanwhile there is no convergence. The goal is to reach iteration number 40 (or less if there is convergence before).

New Results Beyond Stage 3:

**COSI Score**
CALMO with observed Rainy days compared to all days in 2013 (all available observation). The score is by COSI method.

**CALMO Rainy days for iteration 10.**

Objective calibration

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**CALMO all days (for iteration 40)**

Score~ = 3.7
New Results Boyhood Stage 3:

The best optimal parameters:
CALMO with observed Rainy days compared to all days in 2013 (all available observation).
For iteration 10.
New Results Boyhood Stage 3:

The best optimal parameters 
CALMO with observed Rainy days compared to all days in 2013 (all available observation). For iteration 10.

<table>
<thead>
<tr>
<th>Optimal Parameter/test</th>
<th>Ralm_Heat</th>
<th>Tkhminn</th>
<th>Tur_len</th>
<th>Entr_c</th>
<th>C_soil</th>
<th>V0snow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainy days (iteration 10)</td>
<td>1.263</td>
<td>0.236</td>
<td>386.8</td>
<td>2.071</td>
<td>0.620</td>
<td>10.5</td>
</tr>
<tr>
<td>All days (iteration 40)</td>
<td>1.273</td>
<td>0.266</td>
<td>346.5</td>
<td>1.607</td>
<td>0.588</td>
<td>12.3</td>
</tr>
</tbody>
</table>
**Summary**

**Conclusions**

- There is a need to increase the number of iterations in order to be sure about the optimal parameters for Rainy days (precipitation area average of daily rain 0.05mm and above).

- It seems that the monthly behavior of the optimal parameters is not totally random.

- In the planes graph, there are some differences in the optimal parameters, especially, where the ‘Ralm_heat’ parameter is involved.
The End
1. Overview
2. Meta-Model
3. Performance score
4. Convergence to the optimal parameters combination
5. Stage 2
6. Stage 3
7. Summary
Back up Presentation
### Overview: stages of the CALMO project

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Stage-1</th>
<th>Stage-2</th>
<th>Stage-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7km</td>
<td>2.2km</td>
<td>1.1km</td>
</tr>
</tbody>
</table>

| Simulations domain | [17W-22E, 35N-57N] | [0E-17E, 42N-50N] | [0E-17E, 42N-50N] |

| Calibration area | Switzerland | Switzerland and north Italy | Switzerland and north Italy |

| Calibrated atmospheric fields | T2m-max; T2m-min; 24h-precipitation | T2m-max; T2m-min; 24h-precipitation; sounding profiles diagnostics: CAPE; CIN; total column water vapor; vector wind shears between the levels 500-700mb/700-850mb/850-1000mb; temperature, relative humidity and wind components at 850, 700 and 500mb | T2m-max; T2m-min; 24h-precipitation; sounding profiles diagnostics: CAPE; CIN; total column water vapor; vector wind shears between the levels 500-700mb/700-850mb/850-1000mb; temperature, relative humidity and wind components at 850, 700 and 500mb |


| Tuning parameters | rlam_heat, tkhmin, tur_len | rlam_heat, tkhmin, tur_len, entr_sc, c_soil, v0snow | tkhmin, tur_len, entr_sc, c_soil, crsmin |

Table 1: Overview: different stages of the CALMO project
Overview: tuned parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Used at stages</th>
<th>Brief physical meaning</th>
<th>Min</th>
<th>Default</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>rlam_heat</td>
<td>1,2</td>
<td>rlam_heat [no – units] is the parameter which linearly determines the heat resistance length of laminar layer; so that the higher is rlam_heat the higher is the resistance of laminar layer for heat transfer, and consequently, the lower is the heat transfer between the surface and the lower atmosphere.</td>
<td>0.1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>tkhmin</td>
<td>1,2,3</td>
<td>tkhmin [m²/s] and tkmin [m²/s] determine the minimum limits for the turbulence coefficients. tkhmin presence is evident when the turbulent diffusion coefficients (then the mixing) are small, which occurs in stable conditions, mainly at night near the surface.</td>
<td>0.1</td>
<td>0.4</td>
<td>1</td>
</tr>
<tr>
<td>tur_len</td>
<td>1,2,3</td>
<td>tur_len [m] is $l_{\infty}$ in Blackadar formula (Blackadar, 1962) for the turbulence length. The higher is tur_len, the higher are the turbulent coefficients (both vertical and horizontal) in the middle-upper atmospheric levels, and consequently the higher are the turbulent fluxes (mixing) for all the variables and tracers</td>
<td>100</td>
<td>150</td>
<td>1000</td>
</tr>
<tr>
<td>entr_sc</td>
<td>2,3</td>
<td>entr_sc [m⁻¹] is the mean entrainment rate of boundary layer humidity into the shallow convection clouds. The higher is entr_sc, the more effective is the shallow convection vertical mixing.</td>
<td>0.05e-3</td>
<td>0.3e-3</td>
<td>2e-3</td>
</tr>
<tr>
<td>c_soil</td>
<td>2,3</td>
<td>c_soil [no – units] is the surface-area index of the evaporating fraction of grid-points over land: c_soil ∈ [0, c_hnd=2]. The higher is c_soil, the higher is the surface evaporation.</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>v0snow</td>
<td>2</td>
<td>v0snow [no – units] is the factor in the terminal velocity for snow</td>
<td>10</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>crsmin</td>
<td>3</td>
<td>crsmin [s/m] is the minimum value of stomatal resistance used by the BATS approach for vegetation transpiration.</td>
<td>50</td>
<td>150</td>
<td>200</td>
</tr>
</tbody>
</table>

Table 2: COSMO parameters tuned at different stages of the CALMO project.
1. Overview
2. Meta-Model
3. Performance score
4. Convergence to the optimal parameters combination
5. Stage 2
6. Stage 3
7. Summary
Option not to average Tmax/Tmin over regions

Figure 1: Schematic example for the reason not to average Tmax/Tmin over regions.
Defining new regions for averaging the 24h accumulated precipitation (optional also for Tmax, Tmin)

Figure 2: Geographically unique regions for precipitation averaging: 1-green: Swiss plateau (300m<h<1500m); 2-red: Swiss Alps (1500m<h); 3-cyan: Italian Alps (1500m<h); 4-yellow: Italian hills and Ticino (300m<h<1500m); 5-blue: Po Valley (h<300m); 6-magenta: Italian north-west coast (mainly h<300m).
Figure 3: Available soundings inside CALMO-stages 2 and 3 domains.
Logarithmic transformation for some of the parameters

\[ x \rightarrow \hat{x} \equiv \log(\alpha \frac{x - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}} + \beta). \]

\[ \hat{x}_{\text{max}} - \hat{x}_d = \hat{x}_d - \hat{x}_{\text{min}} \] defines \( \alpha \) and \( \beta \).
1. Overview
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Performance score: COSI-type score

\[ S_p = \frac{1}{18} \left\{ \sum_{\Psi \neq 3} \omega_\Psi \sum_{\text{mon}=1}^{12} \left[ 1 - \frac{\sum_{\Psi_{\text{days}}} \sum_{\Psi_{\text{days}}} (F_{\Psi,p,d,r,\text{mon}} - O_{\Psi,d,r,\text{mon}})^2}{\sum_{\Psi_{\text{days}}} \sum_{\Psi_{\text{days}}} (O_{\Psi,d-1,r,\text{mon}} - O_{\Psi,d,r,\text{mon}})^2} \right] \right\} + \omega_3 \frac{\sum_{\text{mon}=1}^{12} \sum_{\Psi_{\text{ths}}} \sum_{\Psi_{\text{reg}}} ETS_{p,r,\text{mon},\text{thr}}}{N_{\Psi_{\text{days}},\text{mon}} N_{\Psi_{\text{reg}},\text{mon}}} \]

\[ ETS_{p,r,\text{mon},\text{thresh}} = \frac{H - \frac{(H+F)(H+M)}{N_{\Psi_{\text{reg}},\text{mon}}}}{H + M + F - \frac{(H+F)(H+M)}{N_{\Psi_{\text{reg}},\text{mon}}}} \]

\(-1/3 < ETS < 1\)