Objective Calibration of COSMO-crCLIM

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Outline

- New model version to calibrate
- Calibration framework
- Calibration results
- Open questions from the calibration results
- Ongoing work with the calibration - method

New model version to calibrate

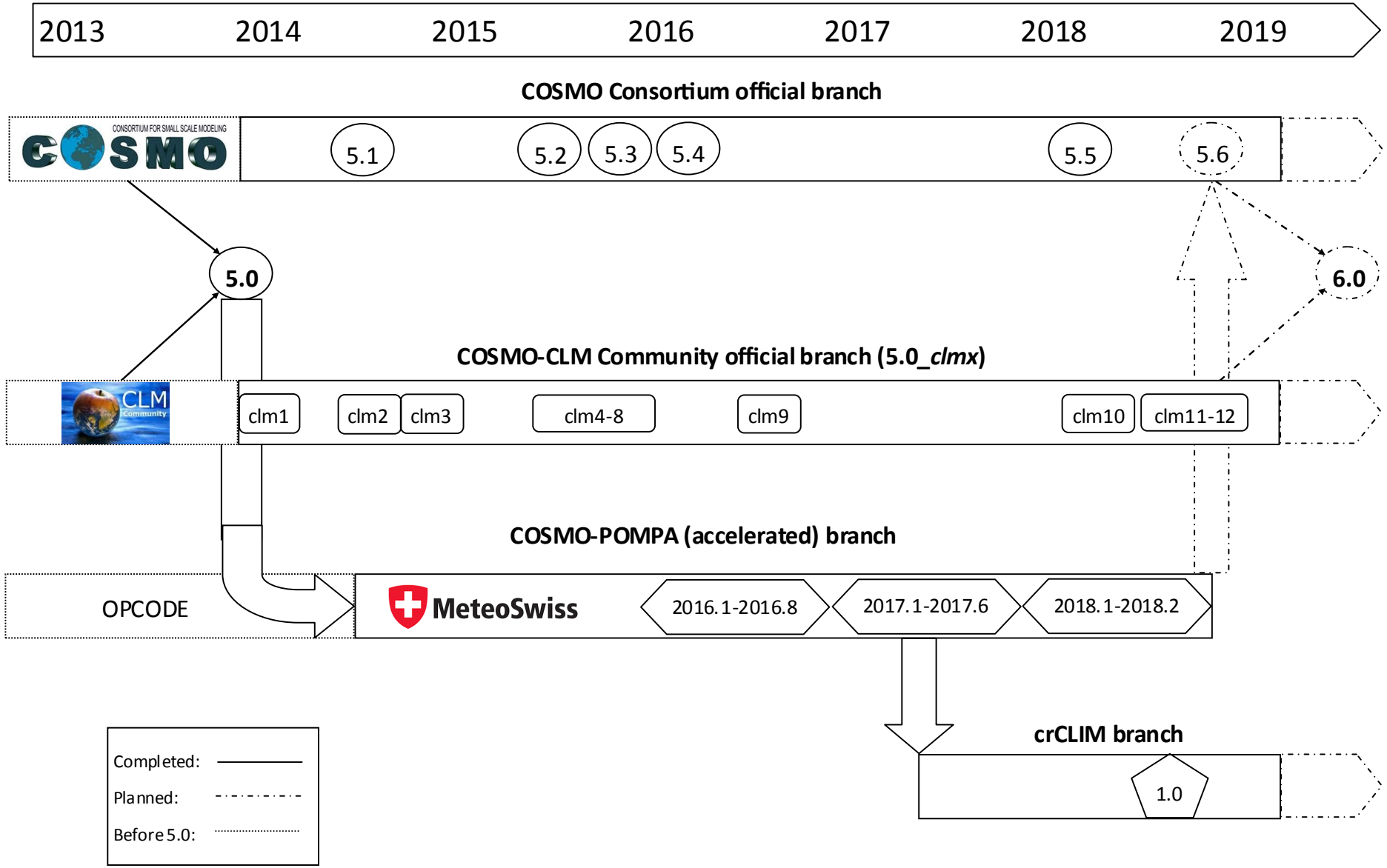
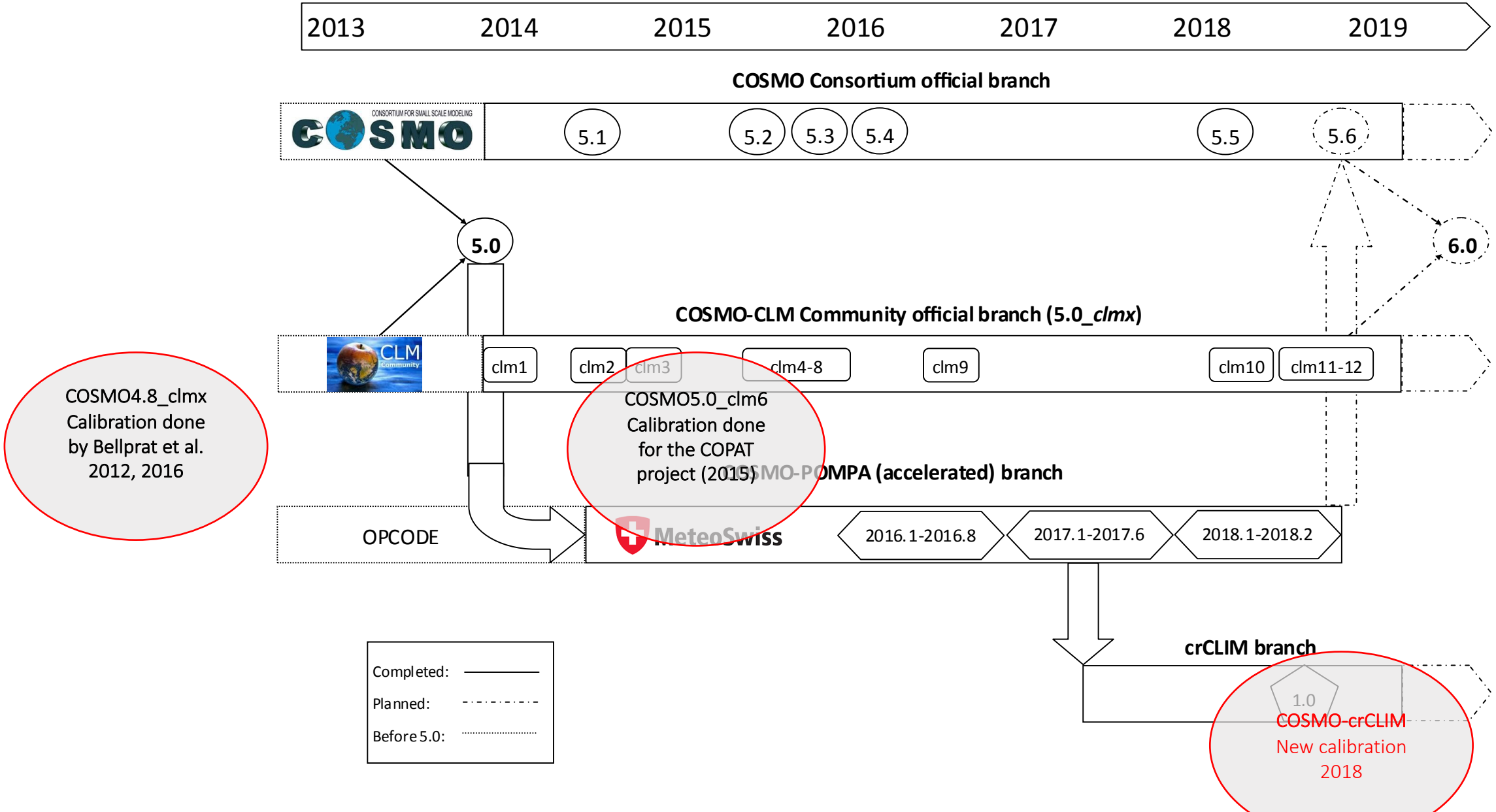
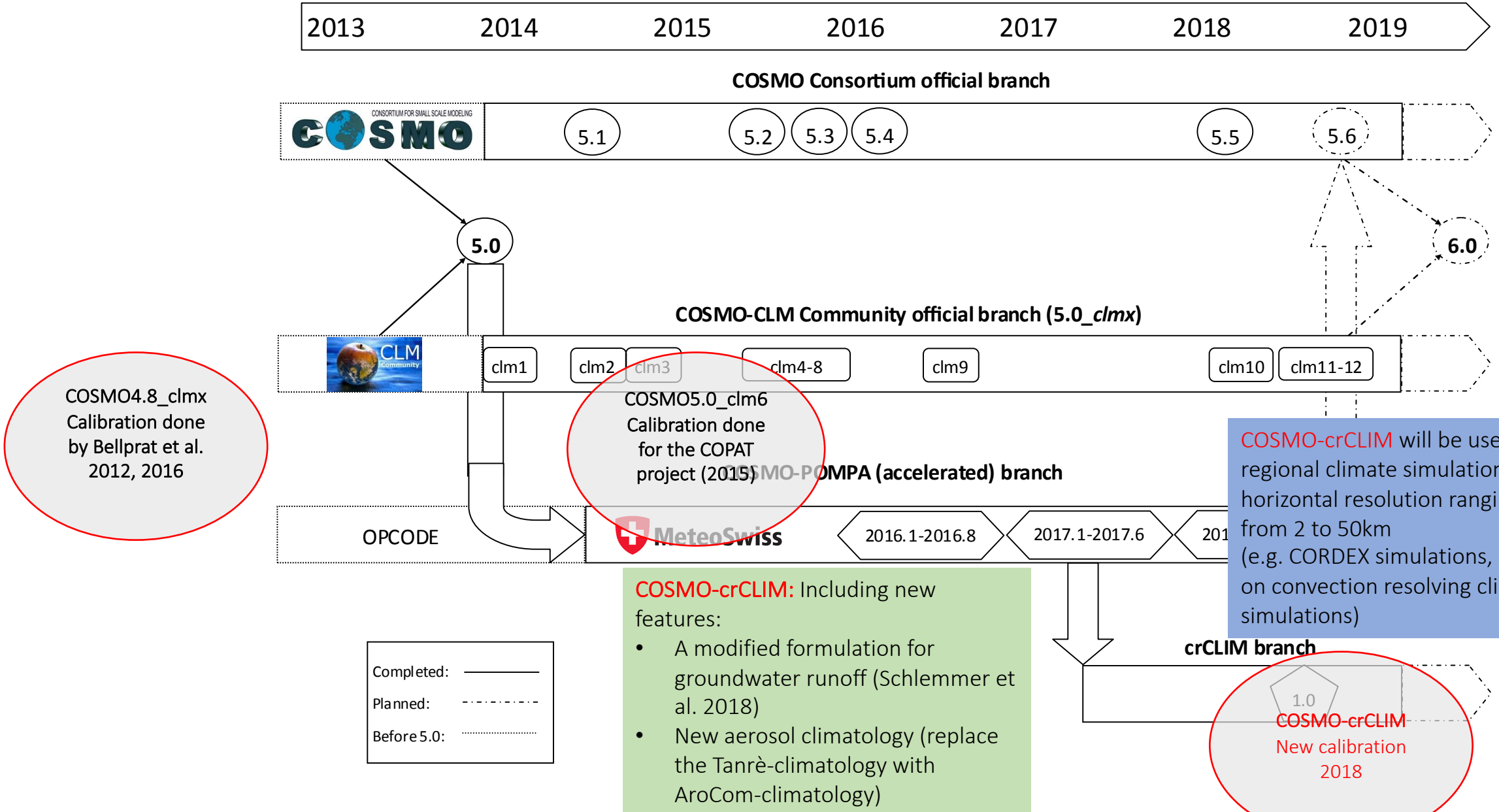


Figure: Katherine Osterried, C2SM.

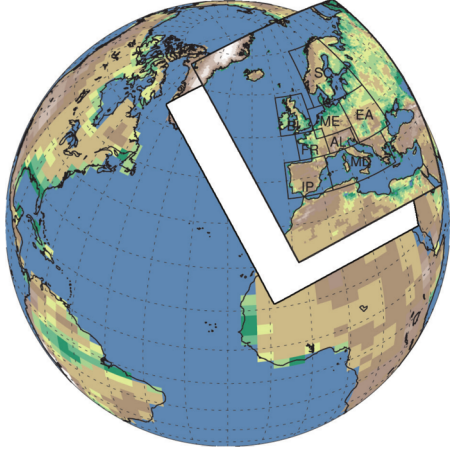
New model version to calibrate



New model version to calibrate



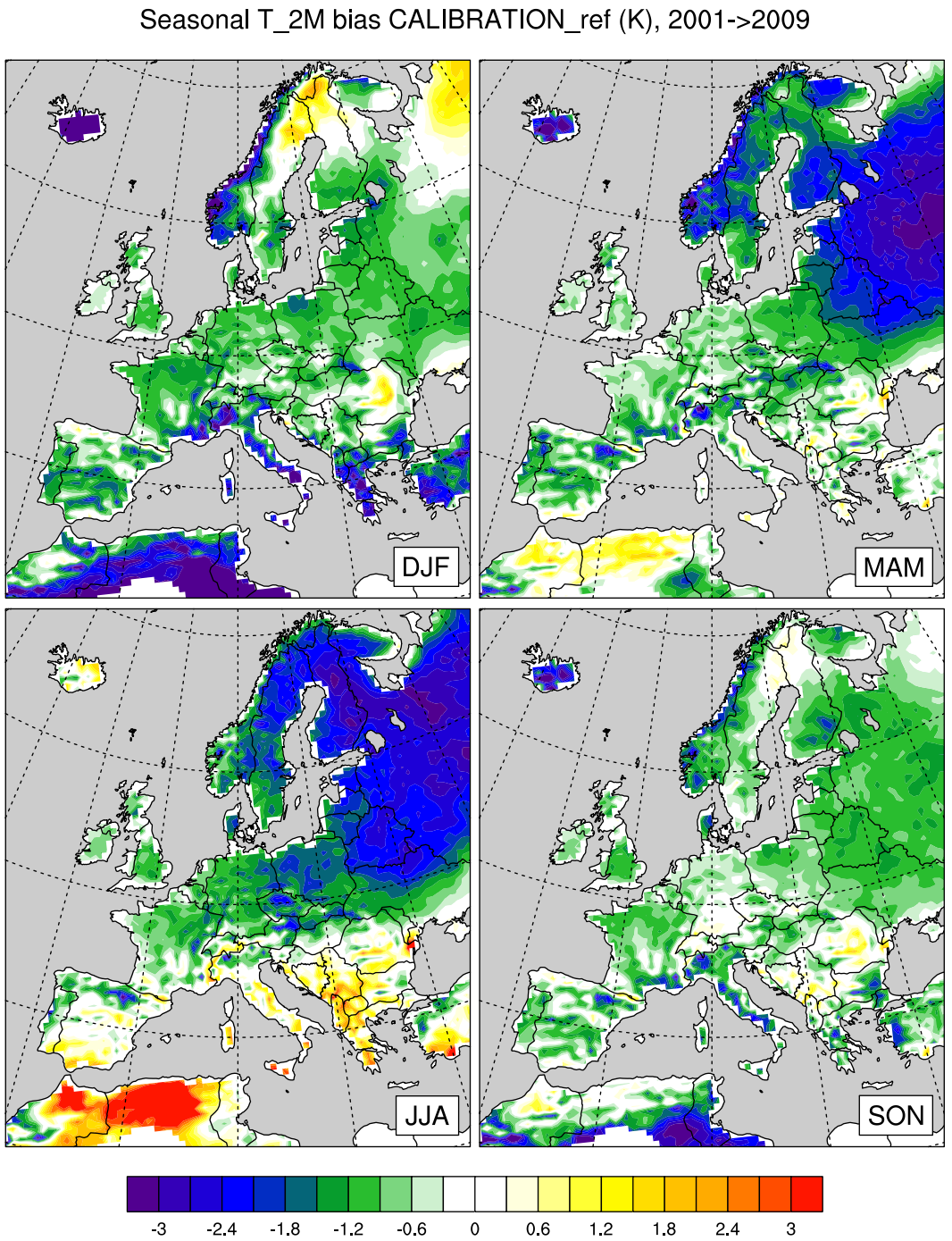
Calibration framework



Calibration method:	Bellprat et al. (2012, 2016). The meta-model is build by using a parametric regression model.
Model version	COSMO-crCLIM (the GPU version of the COSMO-model).
Model domain/resolution	EURO-CORDEX domain with the 50km horizontal resolution.
Calibration time	The simulations are from 2000-2009, where only the last 5 years (2005-2009) is used for the calibration.
Tuning parameters	8 tuning parameters (decided based on previous calibration done by Lüthi et al. and Bellprat et al. Coordinated with CALMO-MAX.)
Number of simulations	8 different tuning parameters, this gives in total 128 simulations + 1 reference simulations. Additional independent runs are also performed.
Performance score (PS)	Same as in Bellprat et al. E-OBS for t2m and pr. CRU for cloud-cover data.

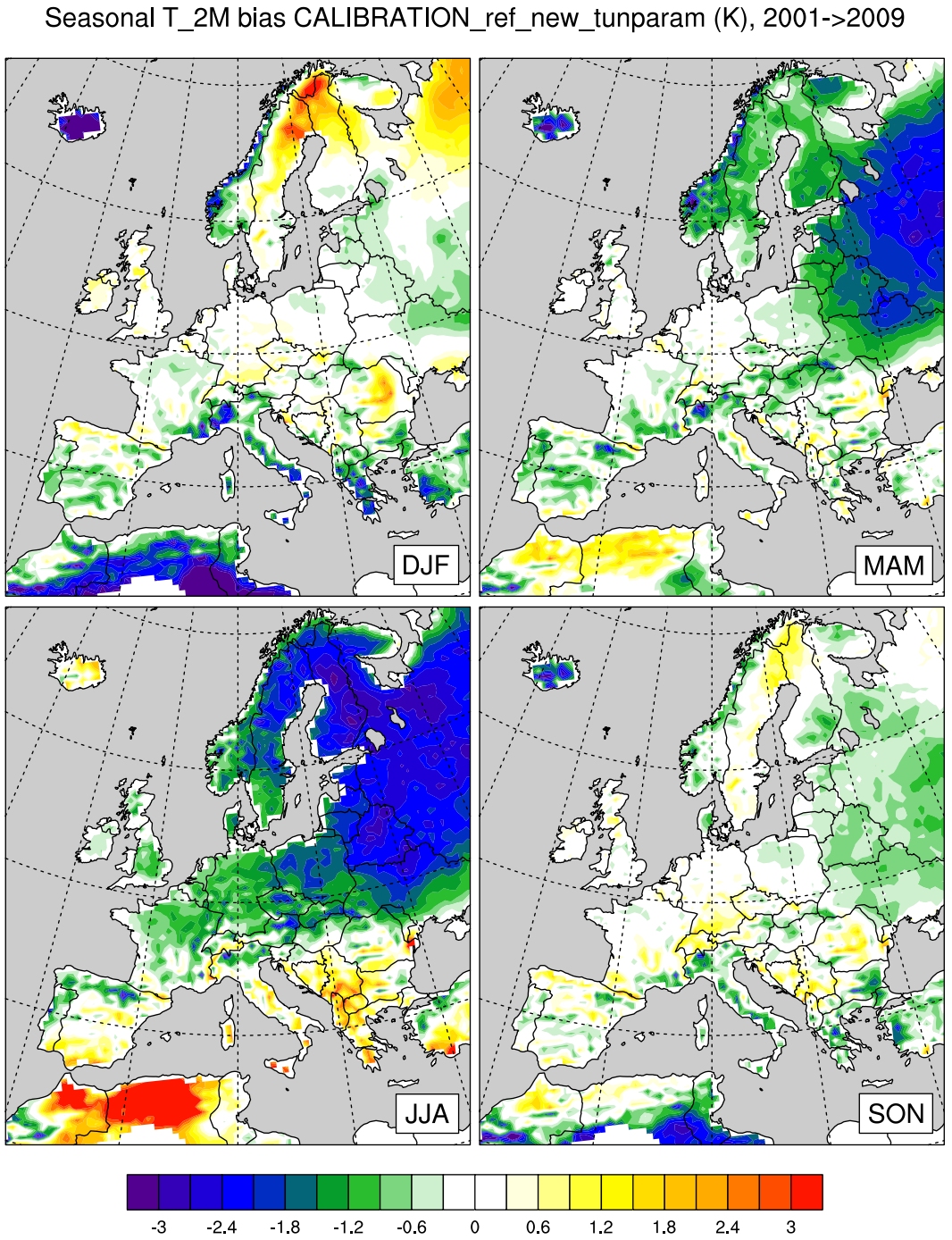
We started with..

Acronym	Description of the parameter	Old range
rlam_heat	Scalar resistance for sensible and latent heat fluxes in the laminar surface layer (Land-surface)	[0.1;1; 2]
v0snow	Factor in the terminal velocity for snow (Microphysics)	[10;20;30]
tkhmin (and tkmmin)	Minimal vertical turbulent diffusion rate [m^2s^{-1}] (Turbulence)	[0.1;0.4; 1]
tur_len	Maximal turbulent length scale (m) (Turbulence)	[60;500; 1000]
uc1	Parameter controlling the vertical variation of critical relative humidity for sub-grid cloud formation (radiation)	[0;0.3; 0.6]
radfac	Fraction of cloud water and ice considered by radiation scheme (radiation)	[0.3;0.6; 0.9]
fac_rootdp2	Uniform factor for root depth field (Soil and vegetation)	[0.5;1; 1.5]
l_g	tuning parameter for ground-water runoff (soil and vegetation)	[0.25; 1.59; 10]

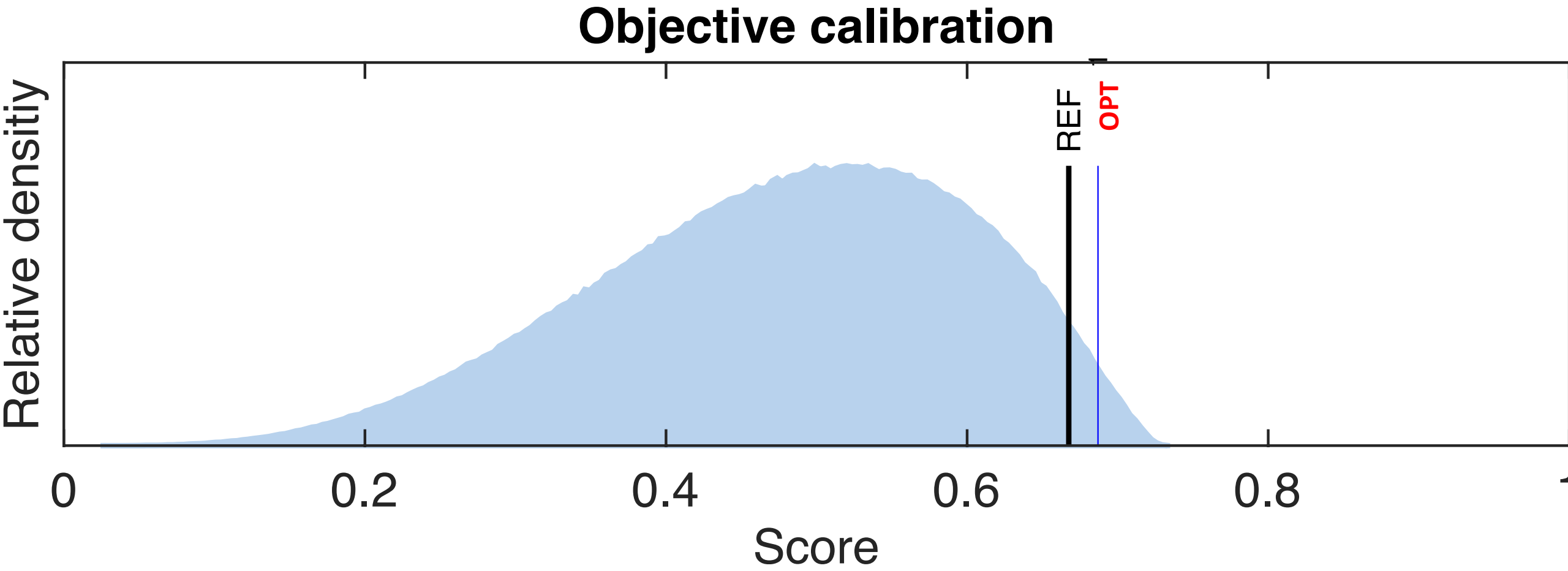


But it didn’t help so much..

Acronym	Description of the parameter	Old range	Old OPT
rlam_heat	Scalar resistance for sensible and latent heat fluxes in the laminar surface layer (Land-surface)	[0.1;1; 2]	0.45
v0snow	Factor in the terminal velocity for snow (Microphysics)	[10;20;30]	20
tkhmin (and tkmmin)	Minimal vertical turbulent diffusion rate [m^2s^{-1}] (Turbulence)	[0.1;0.4; 1]	0.4
tur_len	Maximal turbulent length scale (m) (Turbulence)	[60;500; 1000]	750
uc1	Parameter controlling the vertical variation of critical relative humidity for sub-grid cloud formation (radiation)	[0;0.3; 0.6]	0.25
radfac	Fraction of cloud water and ice considered by radiation scheme (radiation)	[0.3;0.6; 0.9]	0.55
fac_rootdp2	Uniform factor for root depth field (Soil and vegetation)	[0.5;1; 1.5]	0.9
l_g	tuning parameter for ground-water runoff (soil and vegetation)	[0.25; 1.59; 10]	1.33

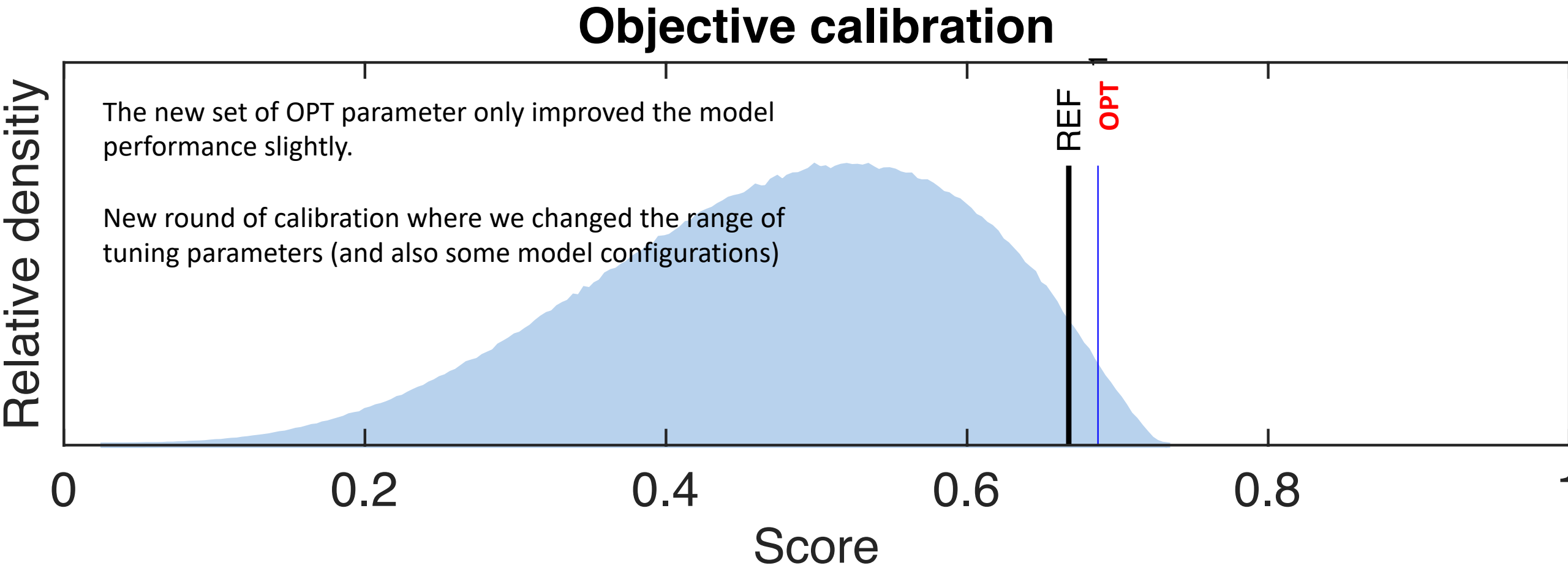


The distribution of the model performance



Calibration range estimated with the metamodel (MM) when computing three million parameter combinations from a Latin hypercube experiment.

The distribution of the model performance



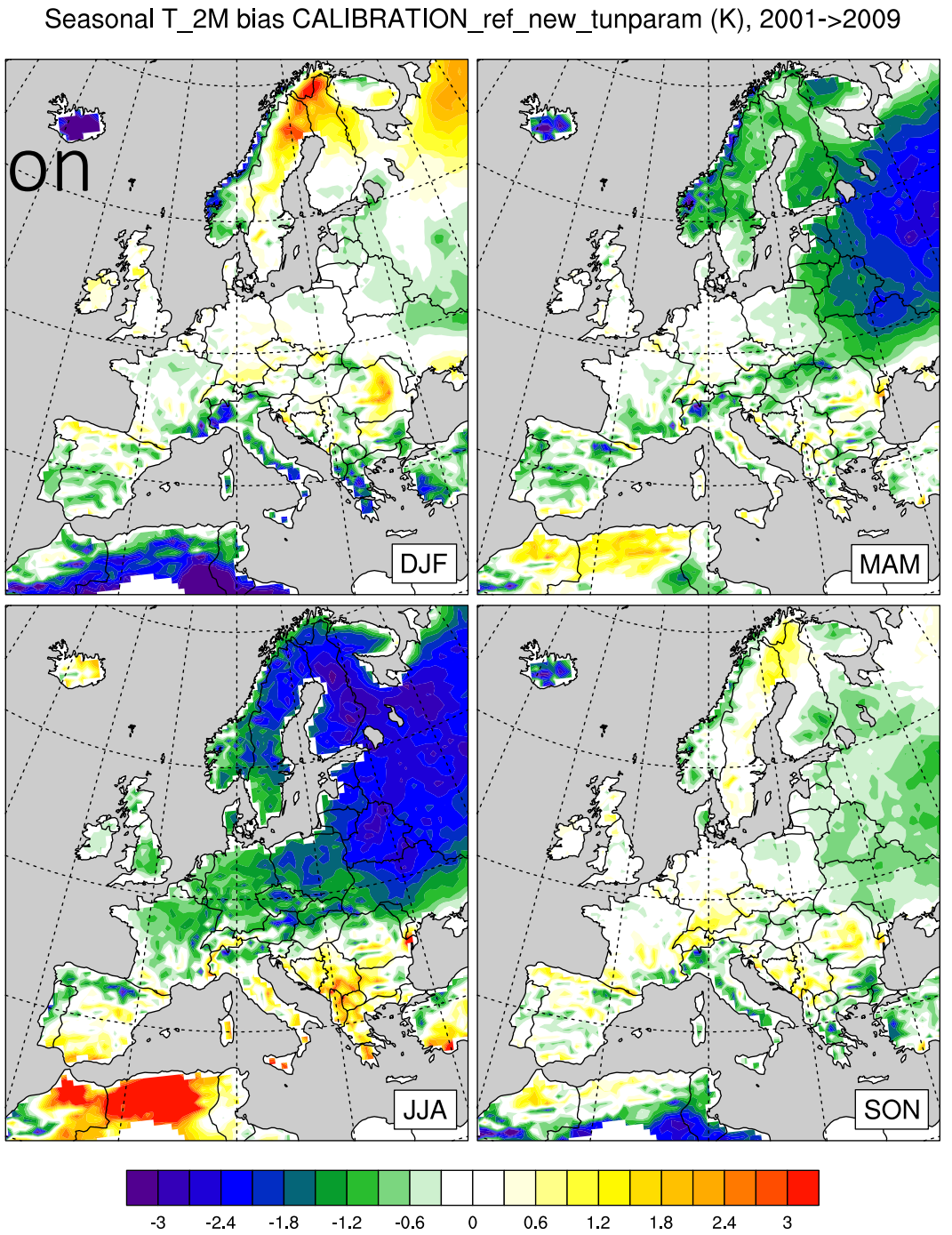
Calibration range estimated with the metamodel (MM) when computing three million parameter combinations from a Latin hypercube experiment.

Second round of the calibration…

Acronym	Description of the parameter	Old range	Old OPT	New range
rlam_heat	Scalar resistance for sensible and latent heat fluxes in the laminar surface layer (Land-surface)	[0.1;1; 2]	0.45	[0.1;1; 2]
v0snow	Factor in the terminal velocity for snow (Microphysics)	[10;20;30]	20	[10;20;30]
tkhmin (and tkmmin)	Minimal vertical turbulent diffusion rate [m^2s^{-1}] (Turbulence)	[0.1;0.4; 1]	0.4	[0.1;1; 2]
tur_len	Maximal turbulent length scale (m) (Turbulence)	[60;500; 1000]	750	[60;500; 1000]
uc1	Parameter controlling the vertical variation of critical relative humidity for sub-grid cloud formation (radiation)	[0;0.3; 0.6]	0.25	[0;0.8; 1.6]
radfac	Fraction of cloud water and ice considered by radiation scheme (radiation)	[0.3;0.6; 0.9]	0.55	[0.3;0.6; 0.9]
fac_rootdp2	Uniform factor for root depth field (Soil and vegetation)	[0.5;1; 1.5]	0.9	[0.5;1; 1.5]
l_g	tuning parameter for ground-water runoff (soil and vegetation)	[0.25; 1.59; 10]	1.33	[0.25; 1.59; 10]

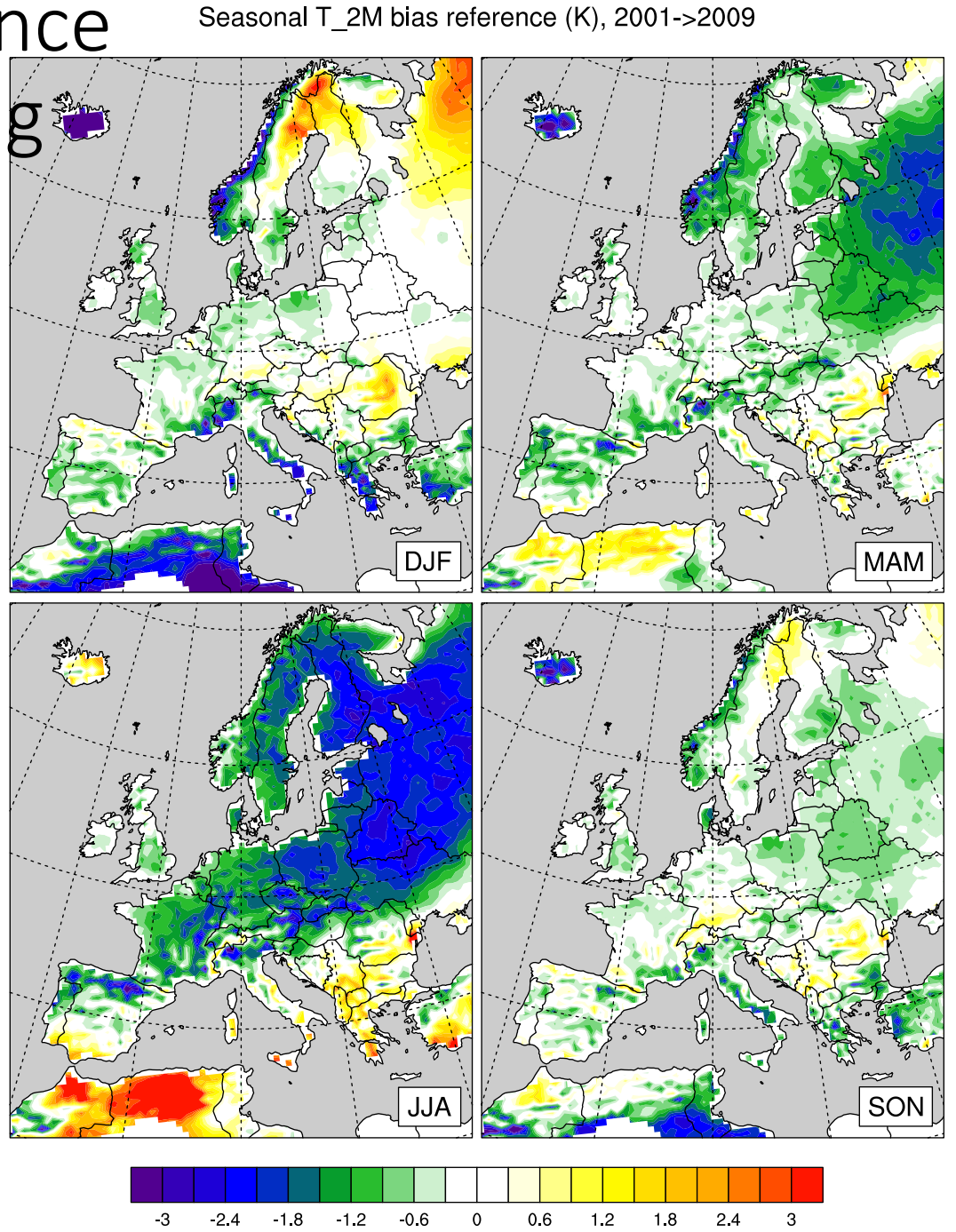
Temperature bias with OPT parameters from the old calibration

Acronym	Description of the parameter	Old range	Old OPT	New range
rlam_heat	Scalar resistance for sensible and latent heat fluxes in the laminar surface layer (Land-surface)	[0.1;1; 2]	0.45	[0.1;1; 2]
v0snow	Factor in the terminal velocity for snow (Microphysics)	[10;20;30]	20	[10;20;30]
tkhmin (and tkmmin)	Minimal vertical turbulent diffusion rate [m^2s^{-1}] (Turbulence)	[0.1;0.4; 1]	0.4	[0.1;1; 2]
tur_len	Maximal turbulent length scale (m) (Turbulence)	[60;500; 1000]	750	[60;500; 1000]
uc1	Parameter controlling the vertical variation of critical relative humidity for sub-grid cloud formation (radiation)	[0;0.3; 0.6]	0.25	[0;0.8; 1.6]
radfac	Fraction of cloud water and ice considered by radiation scheme (radiation)	[0.3;0.6; 0.9]	0.55	[0.3;0.6; 0.9]
fac_rootdp2	Uniform factor for root depth field (Soil and vegetation)	[0.5;1; 1.5]	0.9	[0.5;1; 1.5]
l_g	tuning parameter for ground-water runoff (soil and vegetation)	[0.25; 1.59; 10]	1.33	[0.25; 1.59; 10]



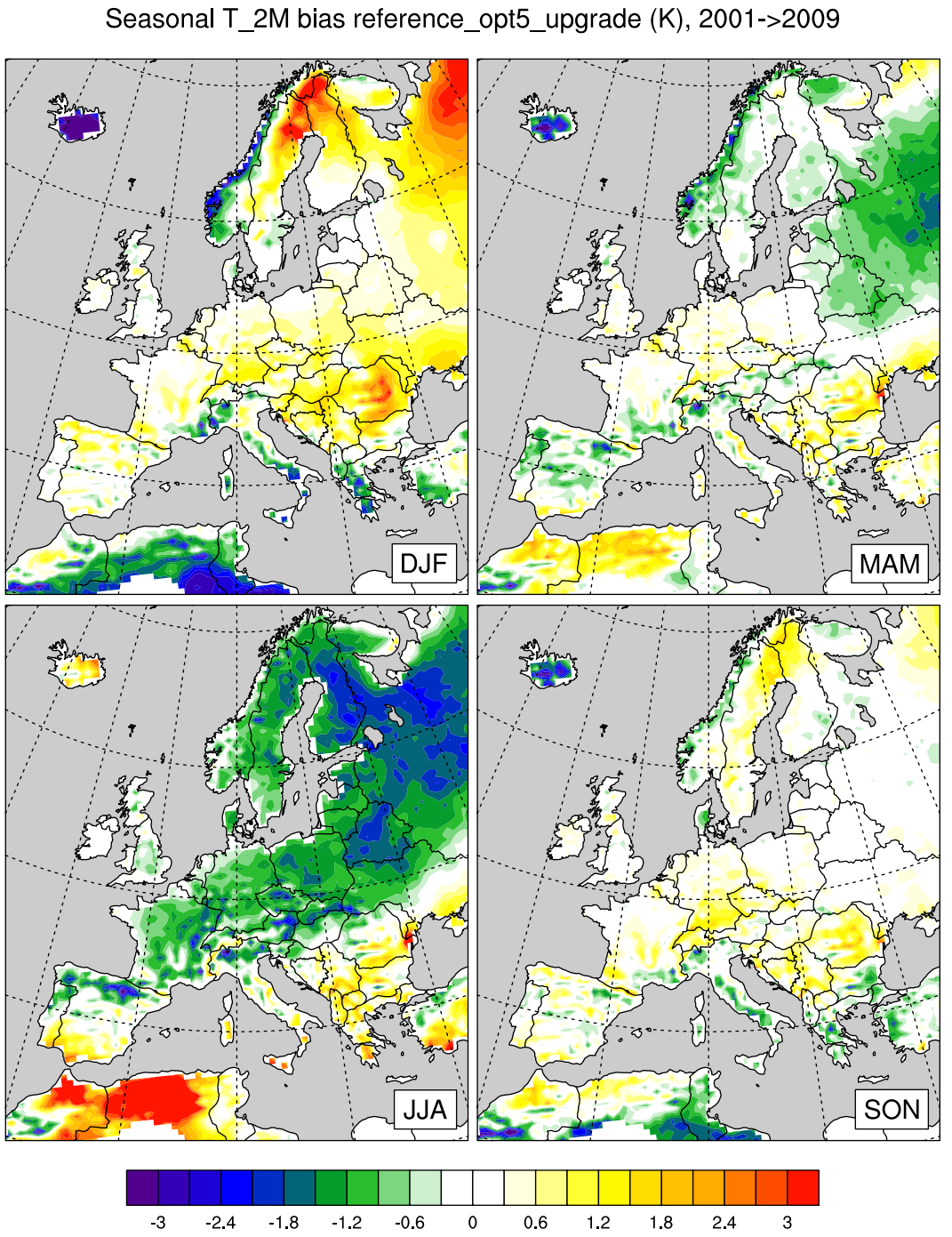
Temperature bias with the reference tuning parameters (before starting the second round of calibration)

Acronym	Description of the parameter	Old range	Old OPT	New range
rlam_heat	Scalar resistance for sensible and latent heat fluxes in the laminar surface layer (Land-surface)	[0.1;1; 2]	0.45	[0.1;1; 2]
v0snow	Factor in the terminal velocity for snow (Microphysics)	[10;20;30]	20	[10;20;30]
tkhmin (and tkmmin)	Minimal vertical turbulent diffusion rate [m^2s^{-1}] (Turbulence)	[0.1;0.4; 1]	0.4	[0.1;1; 2]
tur_len	Maximal turbulent length scale (m) (Turbulence)	[60;500; 1000]	750	[60;500; 1000]
uc1	Parameter controlling the vertical variation of critical relative humidity for sub-grid cloud formation (radiation)	[0;0.3; 0.6]	0.25	[0;0.8; 1.6]
radfac	Fraction of cloud water and ice considered by radiation scheme (radiation)	[0.3;0.6; 0.9]	0.55	[0.3;0.6; 0.9]
fac_rootdp2	Uniform factor for root depth field (Soil and vegetation)	[0.5;1; 1.5]	0.9	[0.5;1; 1.5]
l_g	tuning parameter for ground-water runoff (soil and vegetation)	[0.25; 1.59; 10]	1.33	[0.25; 1.59; 10]

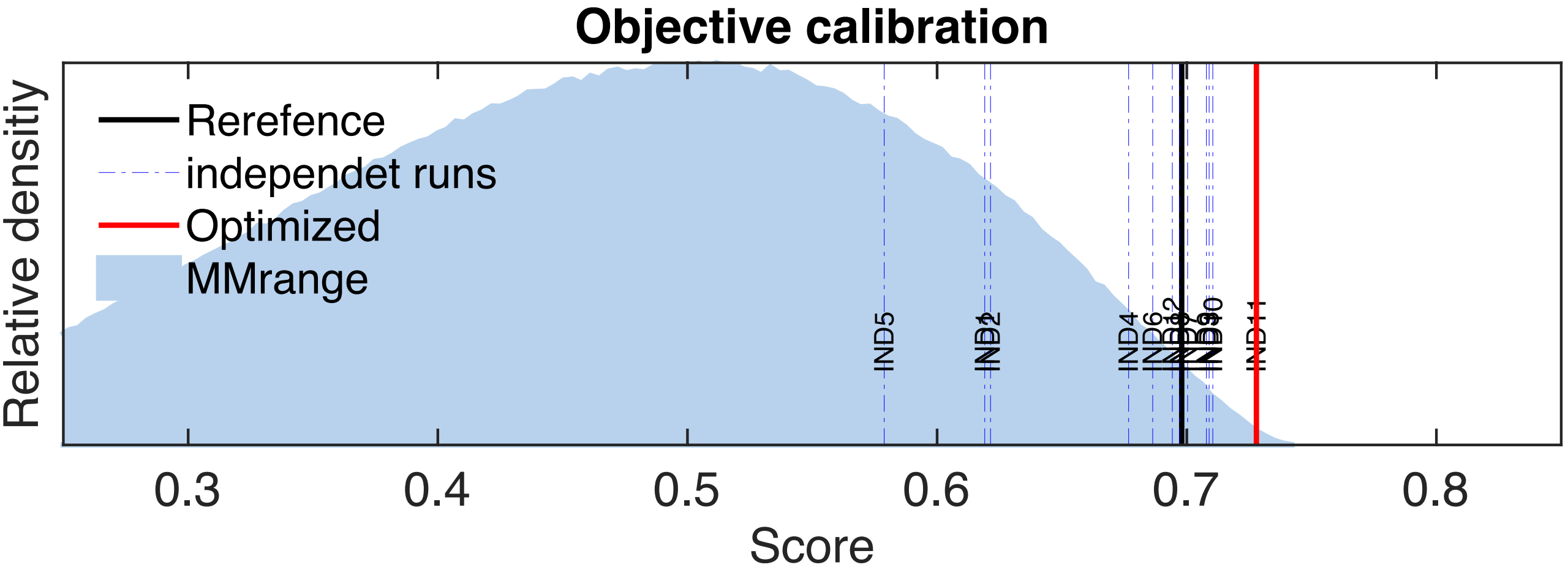


Temperature bias with the new set of OPT parameters

Acronym	Description of the parameter	Old range	Old OPT	New range	OPT
rlam_heat	Scalar resistance for sensible and latent heat fluxes in the laminar surface layer (Land-surface)	[0.1;1; 2]	0.45	[0.1;1; 2]	0.72
v0snow	Factor in the terminal velocity for snow (Microphysics)	[10;20;30]	20	[10;20;30]	25.6
tkhmin (and tkmmin)	Minimal vertical turbulent diffusion rate [m^2s^{-1}] (Turbulence)	[0.1;0.4; 1]	0.4	[0.1;1; 2]	1.37
tur_len	Maximal turbulent length scale (m) (Turbulence)	[60;500; 1000]	750	[60;500; 1000]	563
uc1	Parameter controlling the vertical variation of critical relative humidity for sub-grid cloud formation (radiation)	[0;0.3; 0.6]	0.25	[0;0.8; 1.6]	0.75
radfac	Fraction of cloud water and ice considered by radiation scheme (radiation)	[0.3;0.6; 0.9]	0.55	[0.3;0.6; 0.9]	0.59
fac_rootdp2	Uniform factor for root depth field (Soil and vegetation)	[0.5;1; 1.5]	0.9	[0.5;1; 1.5]	0.96
l_g	tuning parameter for ground-water runoff (soil and vegetation)	[0.25; 1.59; 10]	1.33	[0.25; 1.59; 10]	3.57

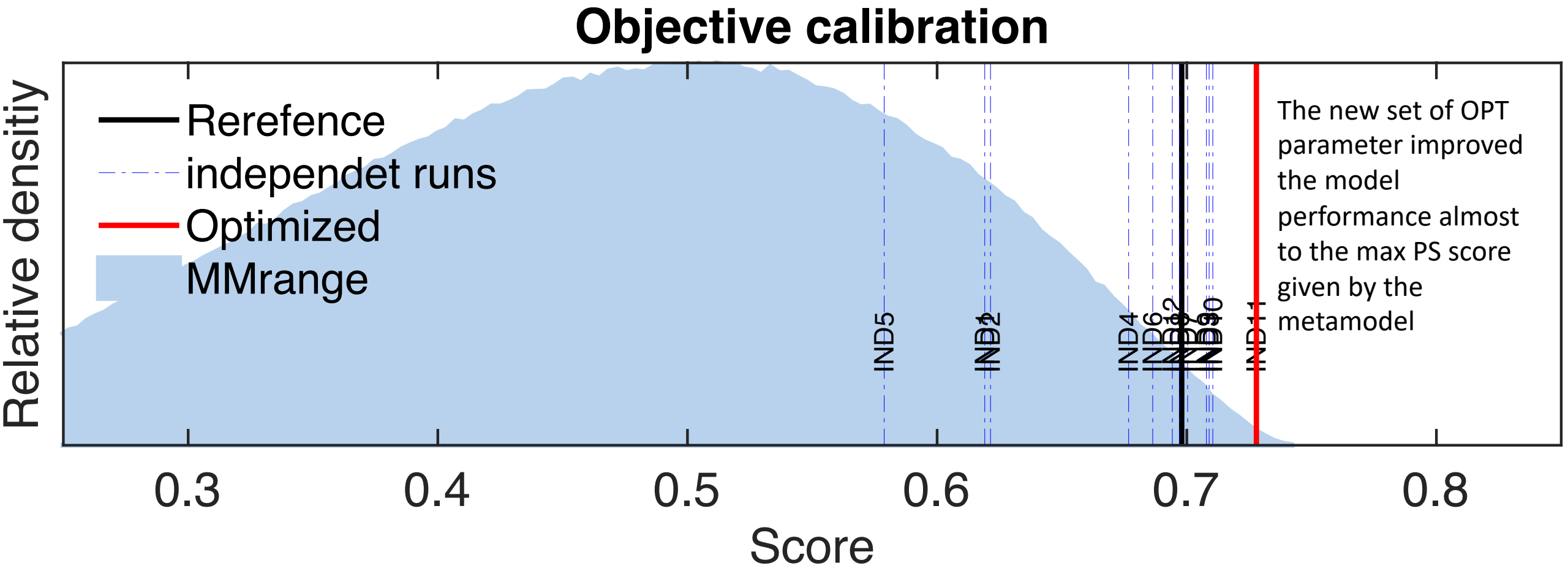


The distribution of the model performance



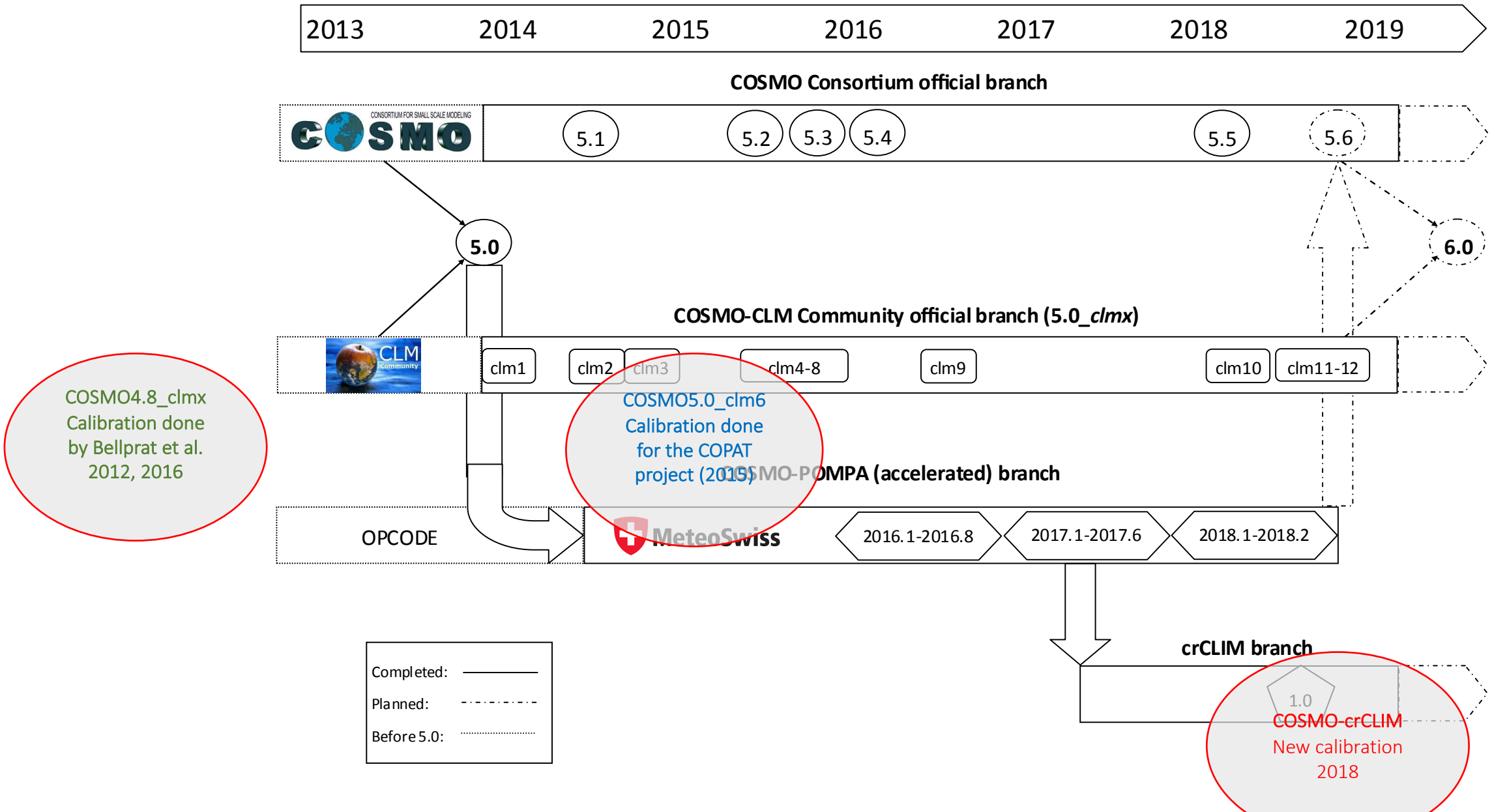
Calibration range estimated with the metamodel (MM) when computing three million parameter combinations from a Latin hypercube experiment.

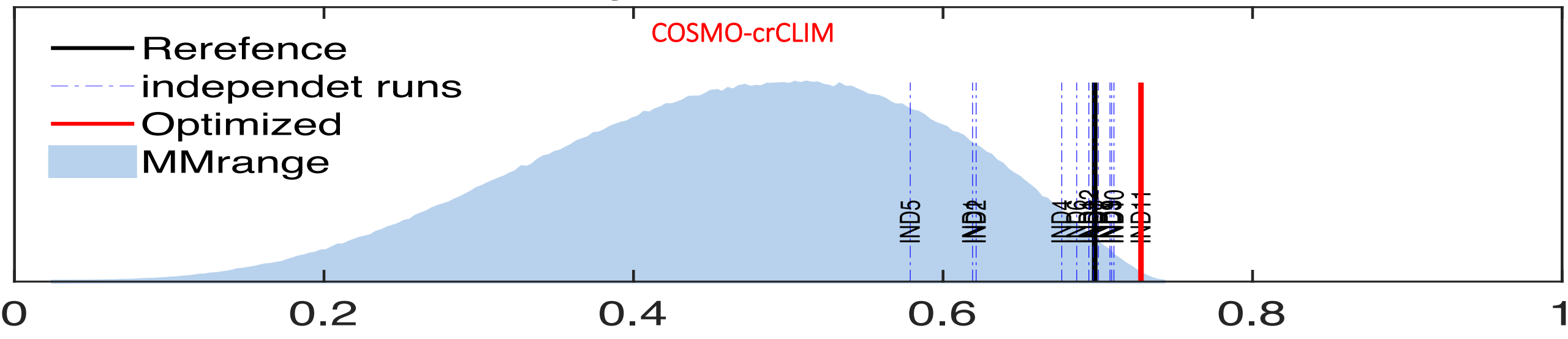
The distribution of the model performance

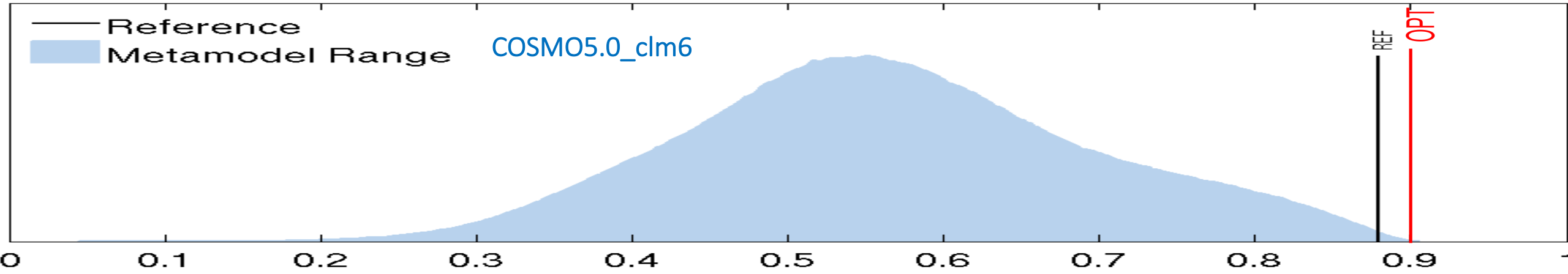


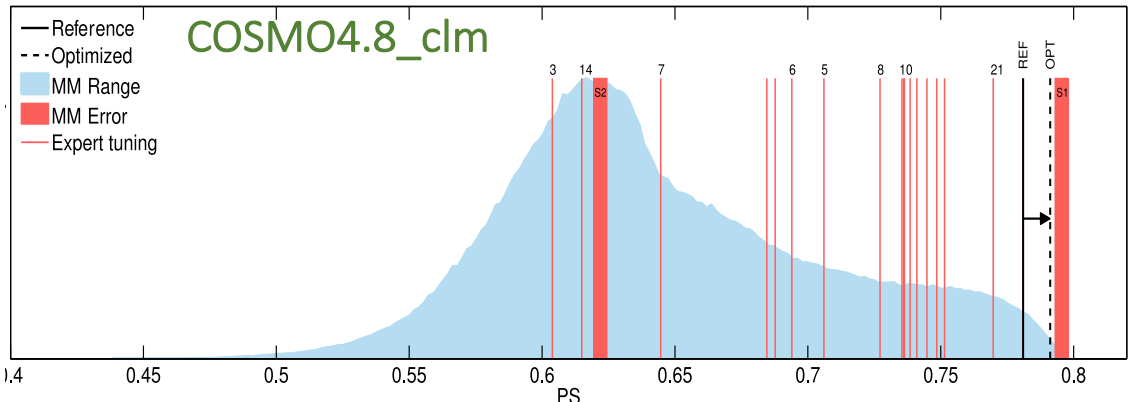
Calibration range estimated with the metamodel (MM) when computing three million parameter combinations from a Latin hypercube experiment.

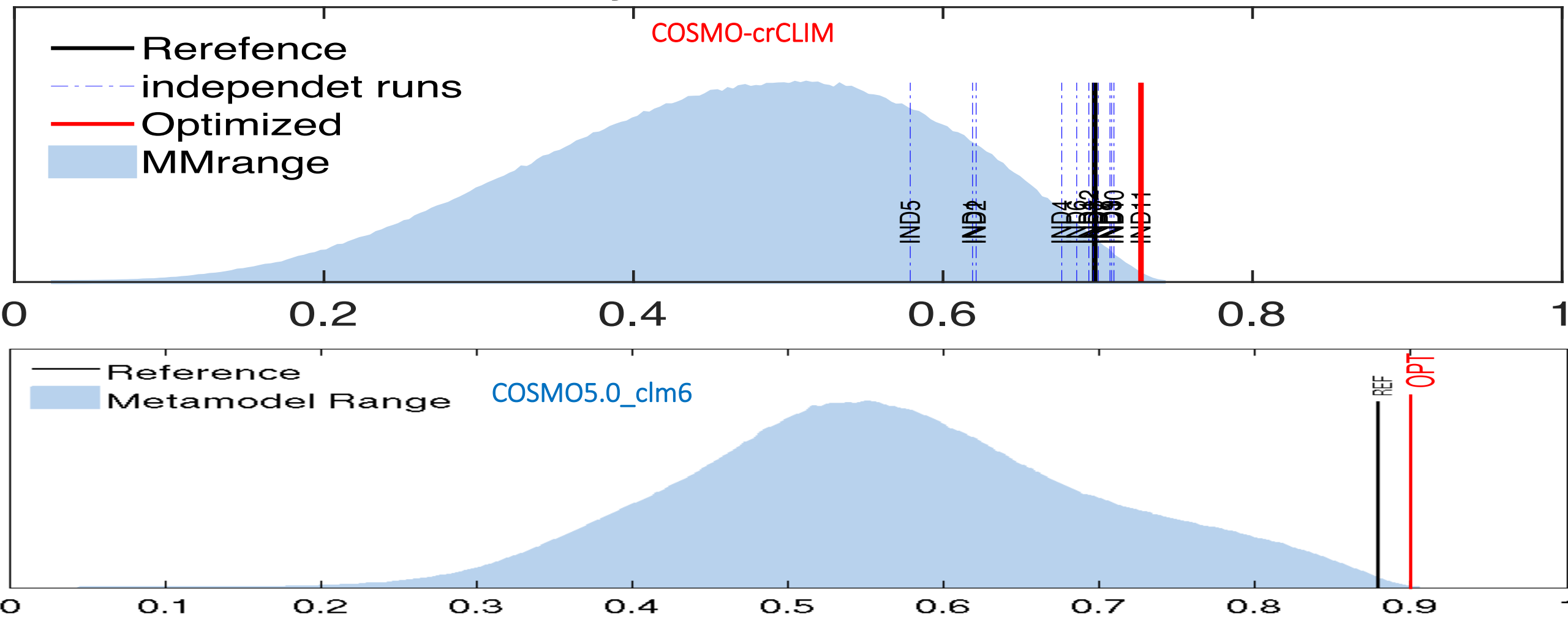
Comparing with the results from older calibration



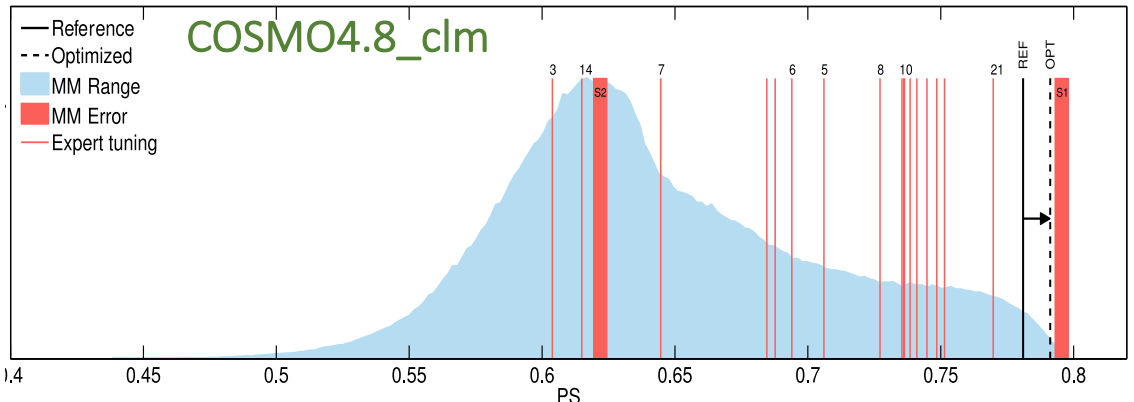

COSMO-crCLIM
Rerefence
independet runs
Optimized
MMrange
IND5
IND11
0
0.2
0.4
0.6
0.8
1


Reference
Metamodel Range
COSMO5.0_clm6
REF
OPT
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9


Reference
Optimized
MM Range
MM Error
Expert tuning
COSMO4.8_clm
3
14
7
6
5
8
10
21
REF
OPT
S2
S1
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
0.8
PS



The maximum PS-score estimated from the metamodel was much higher from the two past calibration experiments.



Open questions

- The objective calibration on EUR44 with the COSMO-crCLIM version gave a set of OPT parameters that had a performance almost as good as the best estimate from the metamodel.
- However, the skill of the metamodel is not as good as previously (the maximum PS score has been up to 0.9 previously from the meta model, compared to 0.75 now).
- Why is the metamodel not so good as previously?
  - the set of tuning parameters not the best choice
  - the range too wide/narrow
  - using different observations to calibrate the model with
  - the time period when the calibration is done affecting the results?

Ongoing activities with the calibration method

- Ongoing work: objective calibration on the Central Asia domain (done by Emmanuele Russo at Uni Bern/Freie Universität Berlin)
- Goal:
  - Find the most sensitive parameters for the region
  - Compare the most sensitive parameters with the ones of other regions: is the model sensitivity similar for different regions?

Indicating the different tuning parameters in the model and doing sensitivity runs for one year.

TURBULENCE	
tkhmin	(0,**0.4**,1,2)
tkmmin	(0,**0.4**,1,2)
tur_len	(100,**500**,1000)
d_heat	(12,**10.1**,15)
d_mom	(12,15,**16.6**)
c_diff	(0.01,**0.2**,10)

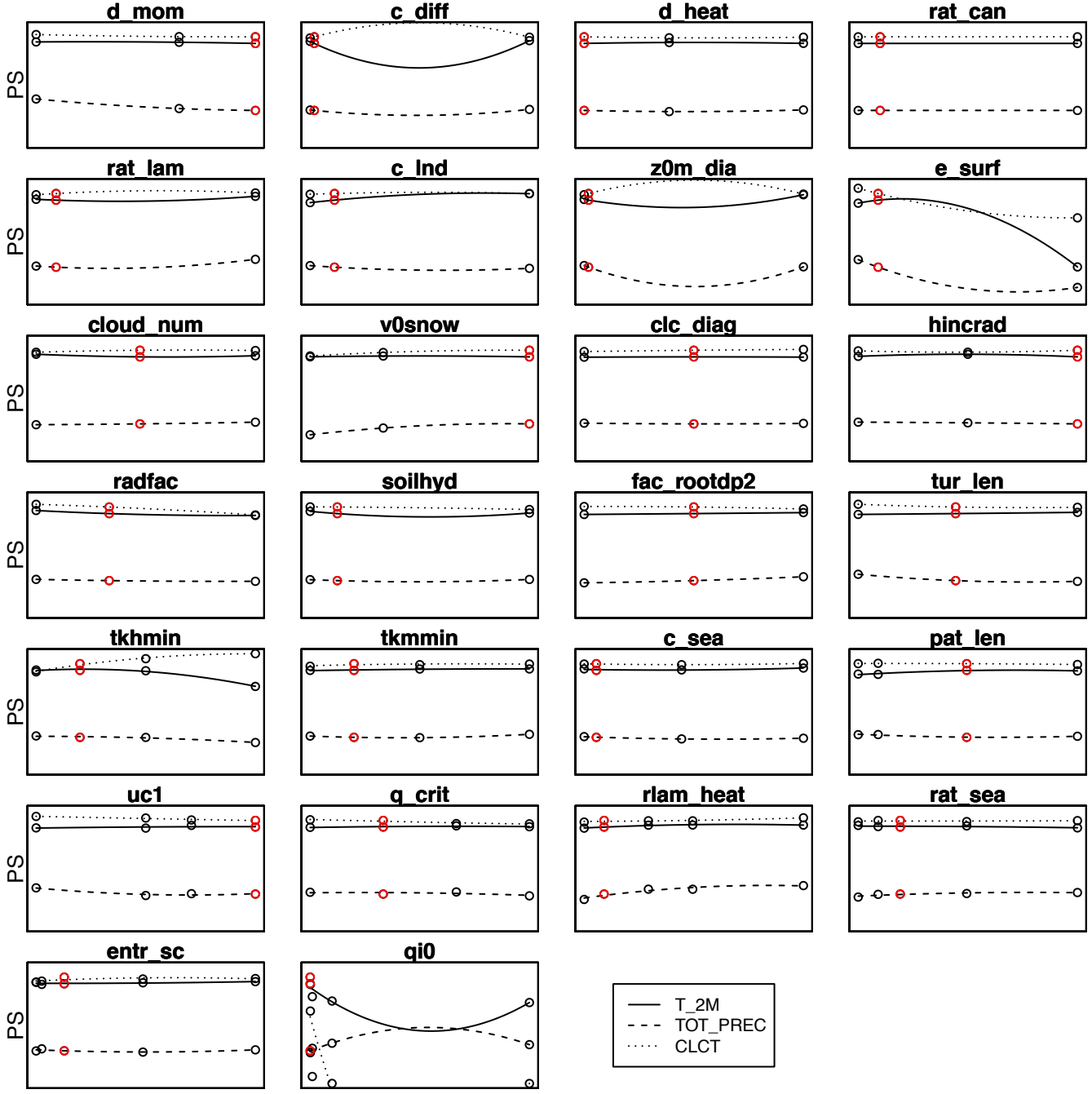
Soil-model	
soilhyd	(**1**,1.62,6)
fac_rootdp2	(0.5,**1**,1.5)

Radiation	
uc1	(0.2,0.5,0.625,**0.8**)
q_crit	(1,**4**,7,10)
clc_diag	0.2,**0.5**,0.8)
hincrad	(0.5,0.75,**1**)
radfac	(0.3,**0.5**,0.9)

Land-surface	
rlam_heat	(0.1,**1**,3,5,10)
rat_sea	(1,10,**20**,50,100)
rat_can	(0,**1**,10)
rat_lam	(0.1,**1**,10)
c_sea	(1,**1.5**,5,10)
c_lnd	(1,**2**,10)
z0m_dia	(0.001,**0.2**,10)
pat_len	(10,100,**500**,1000)
e_surf	(0.1,**1**,10)

Microphysics	
cloud_num	(5e+7,**5e+8,**1e+9)
qi0	(**0**,0.00001,0.0001, 0.001,0.01)
v0snow	(10,15,**25**)

Convection	
entr_sc	(5e-5, 1e-4, **3e-4**, 1e-3, 2e-3)



Sensitivity of the different parameters when simulating the reference (red) and perturbed runs for one year over the central Asian domain.

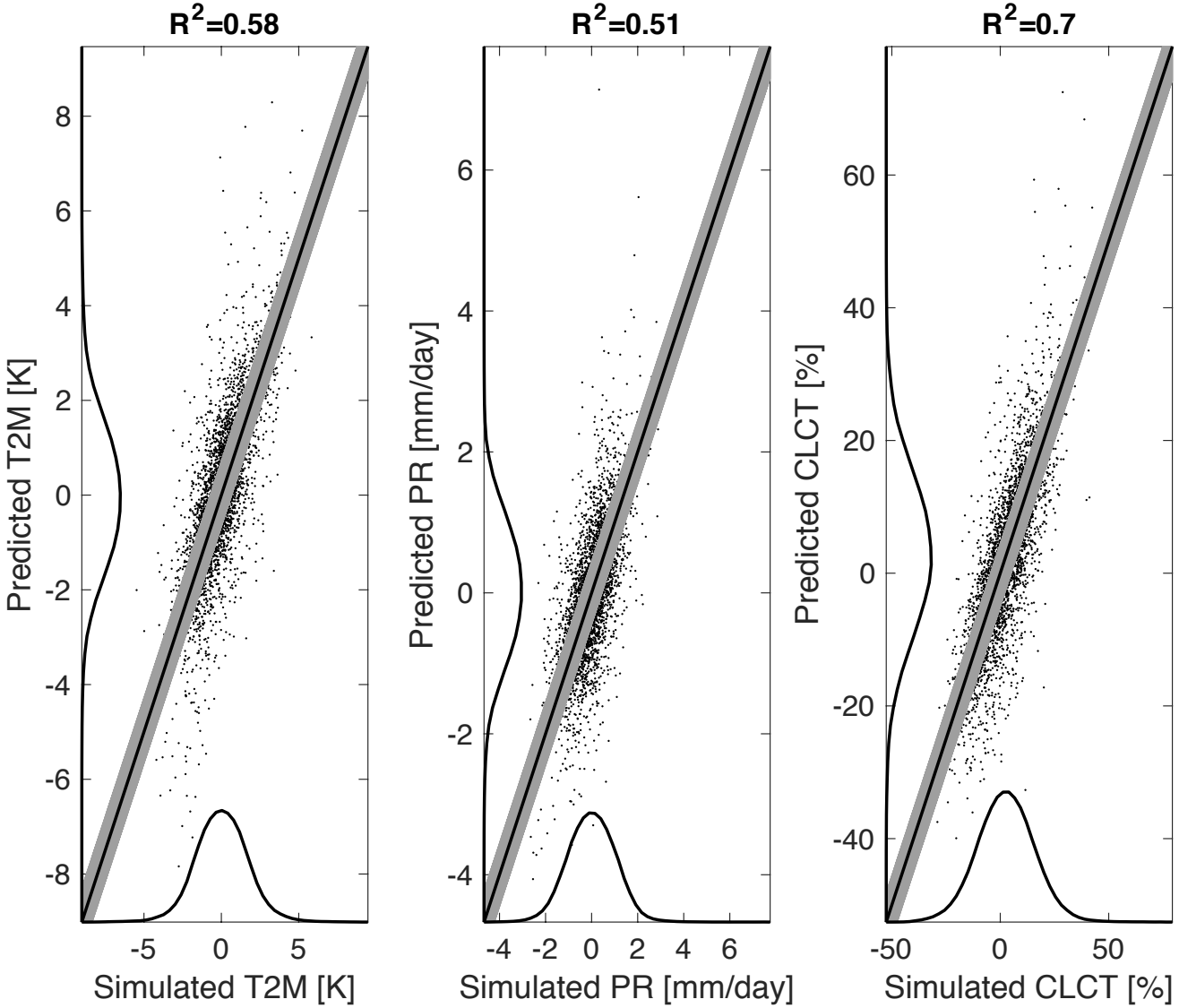
Next step: perform the calibration over Central Asia with a set of selected parameters (based on the sensitivity runs)

Summary

- Objective calibration on the EURO-CORDEX domain (50km resolution) with the COSMO-crCLIM:
  - With the OPT set of parameters, the PS score was improved from ~0.7 to ~0.74 (max PS score estimated by the metamodel is ~0.75)
  - The metamodel is not as good as previously (the maximum PS score has been up to 0.9 previously from the meta model, compared to 0.75 now).
- There is a large interest in using the objective calibration method from the CLM-Community.
- Now the code is on github (C2SM-RCM), will move the code to the COSMO-ORG repository (need to be coordinated with Katherine Osterried)

Extra slides

Performance of the metamodel to predict the independent simulations

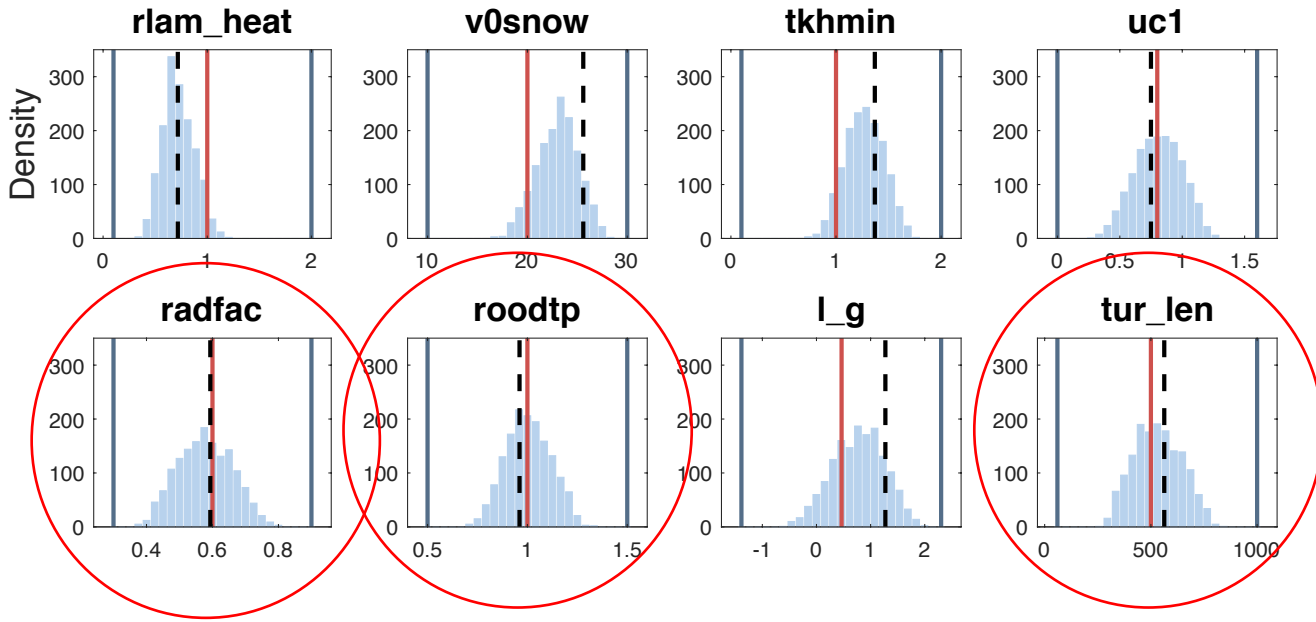


Selecting the tuning parameters and the range

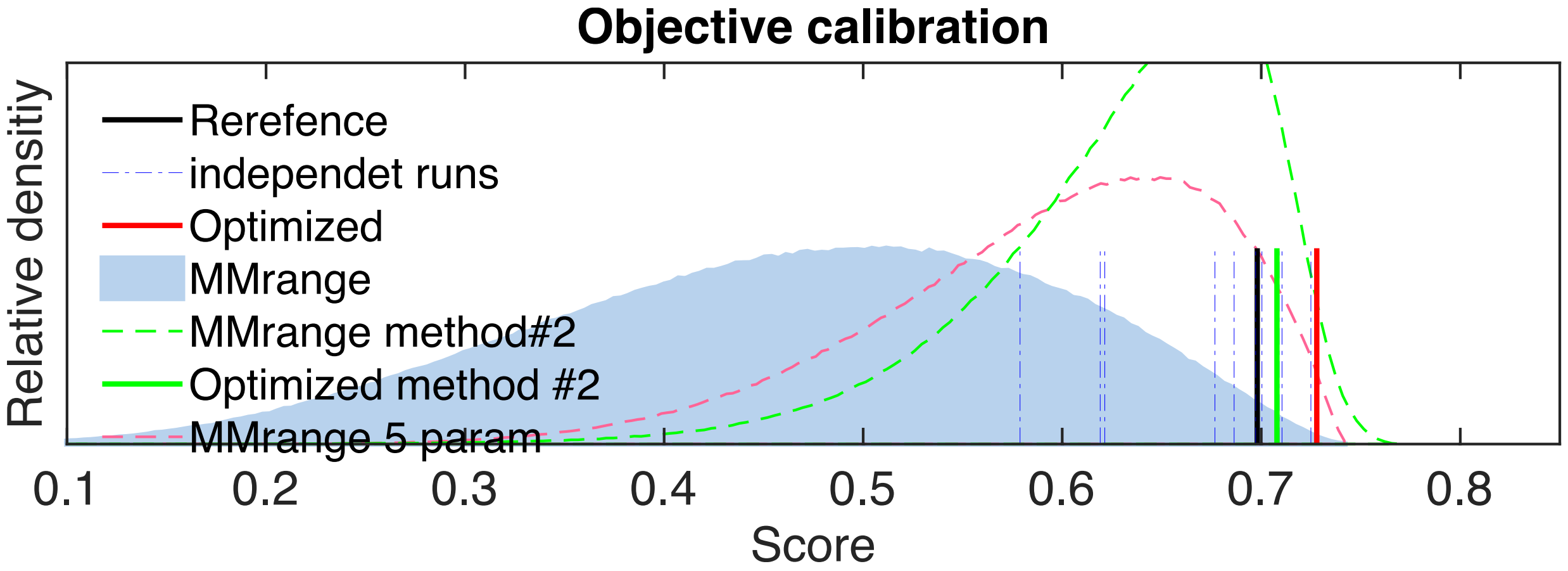
- The first round of calibration was not giving the best results probably due to not starting from a very good model state (we had to make some changes in the dynamic namelist settings) and also due too a too narrow range for some of the tuning parameters.
- The second round of the calibration gave better results, but some of the tuning parameters didn’t change so much, suggesting that we could only have done the calibration on 5 tuning parameters.

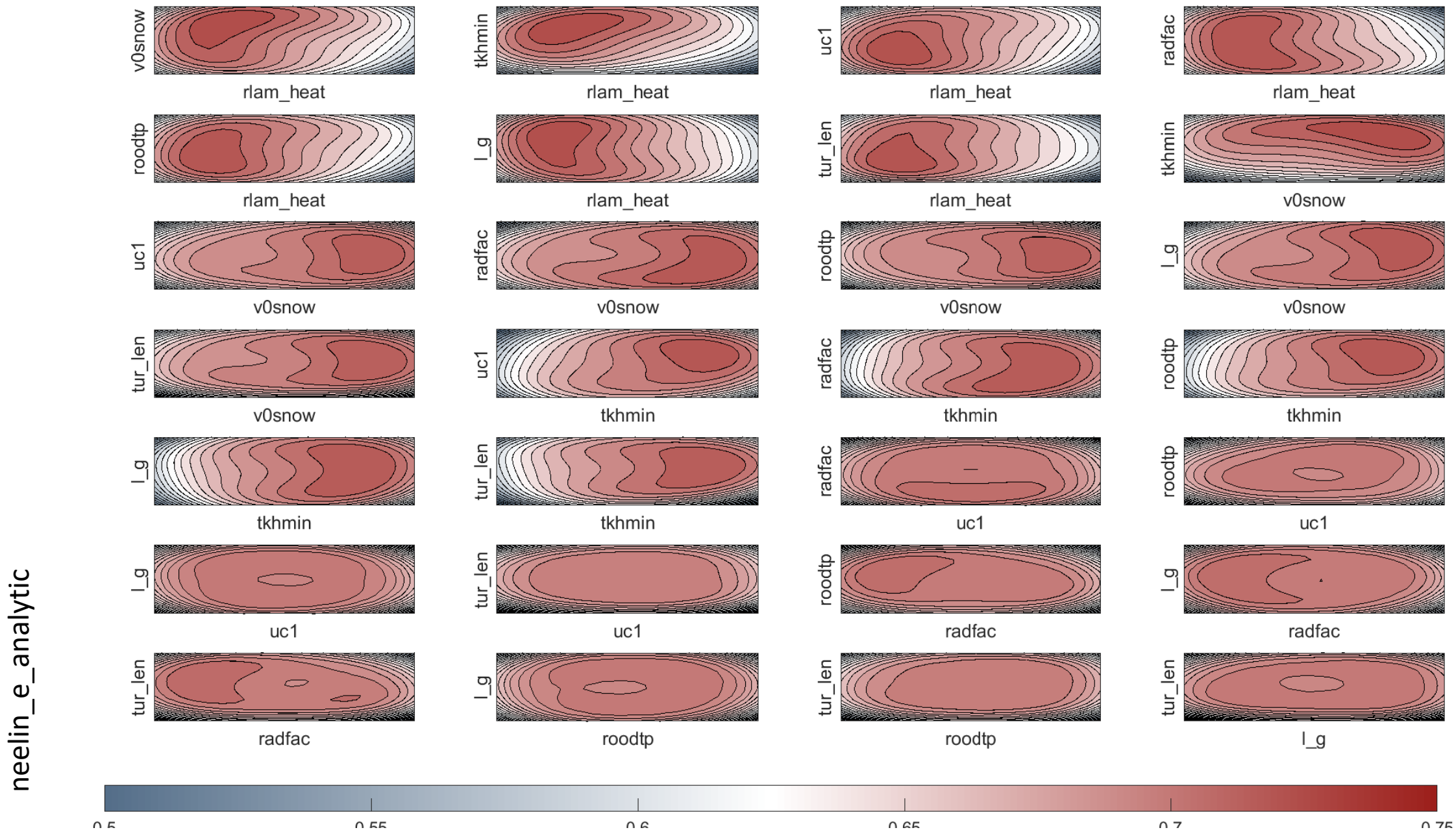
Selecting the tuning parameters and the range

Acronym	Description of the parameter	Old range	Old OPT	New range	OPT
rlam_heat	Scalar resistance for sensible and latent heat fluxes in the laminar surface layer (TURBULENCE - scheme)	[0.1;1; 2]	0.45	[0.1;1; 2]	0.72
v0snow	Factor in the terminal velocity for snow. Microphysics - scheme	[10;20;30]	20	[10;20;30]	25.6
tkhmin (and tkmmin)	Minimal vertical turbulent diffusion rate [m^2s^{-1}] (TURBULENCE – scheme)	[0.1;0.4; 1]	0.4	[0.1;1; 2]	1.37
tur_len	Maximal turbulent length scale (m) (TURBULENCE - scheme)	[60;500; 1000]	750	[60;500; 1000]	563
uc1	Parameter controlling the vertical variation of critical relative humidity for sub-grid cloud formation (RADIATION - scheme)	[0;0.3; 0.6]	0.25	[0;0.8; 1.6]	0.75
radfac	Fraction of cloud water and ice considered by radiation scheme (RADIATION - scheme)	[0.3;0.6; 0.9]	0.55	[0.3;0.6; 0.9]	0.59
fac_rootdp2	Uniform factor for root depth field (Soil-model)	[0.5;1; 1.5]	0.9	[0.5;1; 1.5]	0.96
l_g	tuning parameter for ground-water runoff (Soil-model)	[0.25; 1.59; 10]	1.33	[0.25; 1.59; 10]	3.57



Comparing the different ways to build the meta model




neelin_e_analytic
v0snow
rlam_heat
tkhmin
rlam_heat
uc1
rlam_heat
radfac
rlam_heat
roodtp
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rlam_heat
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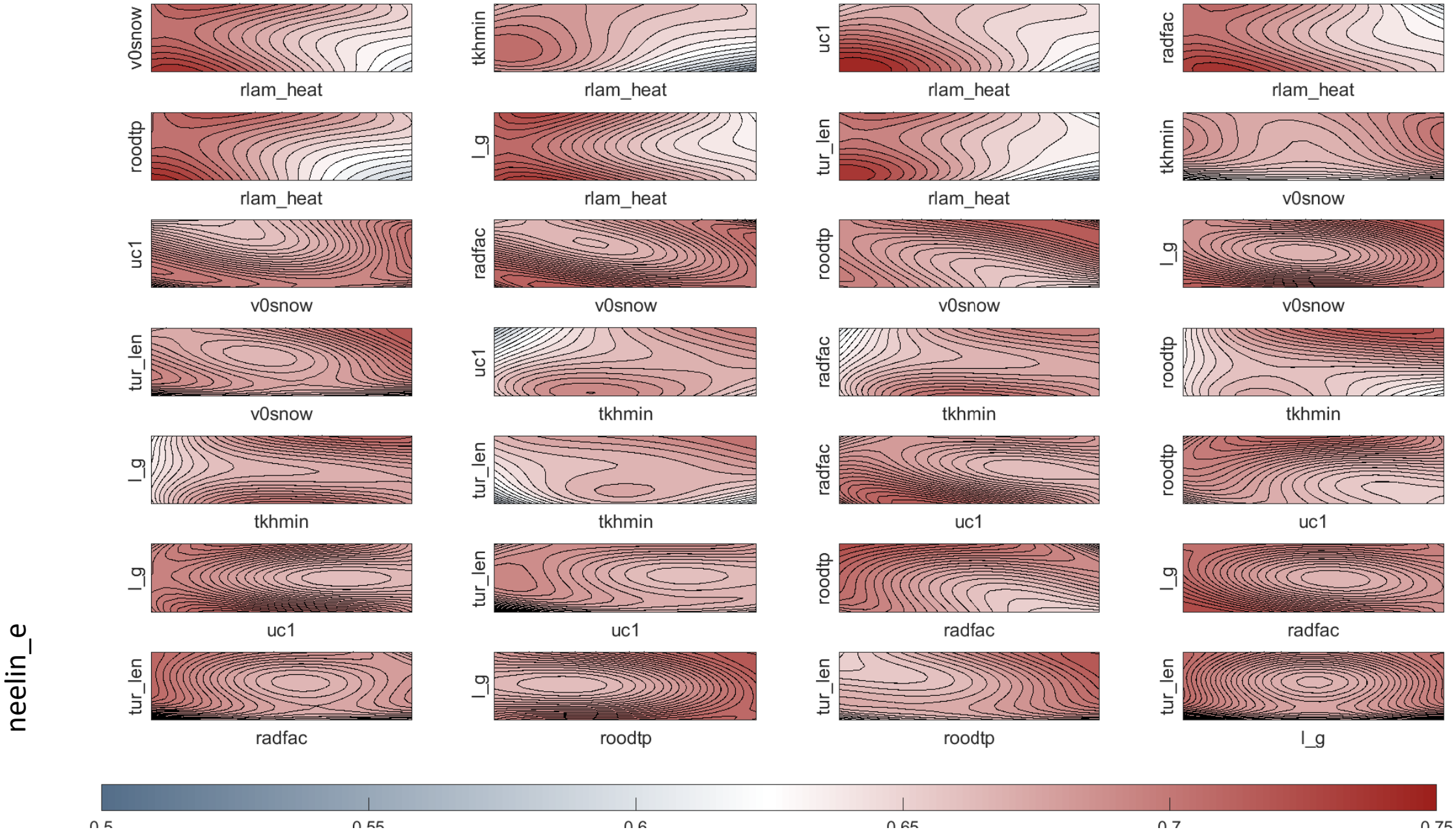
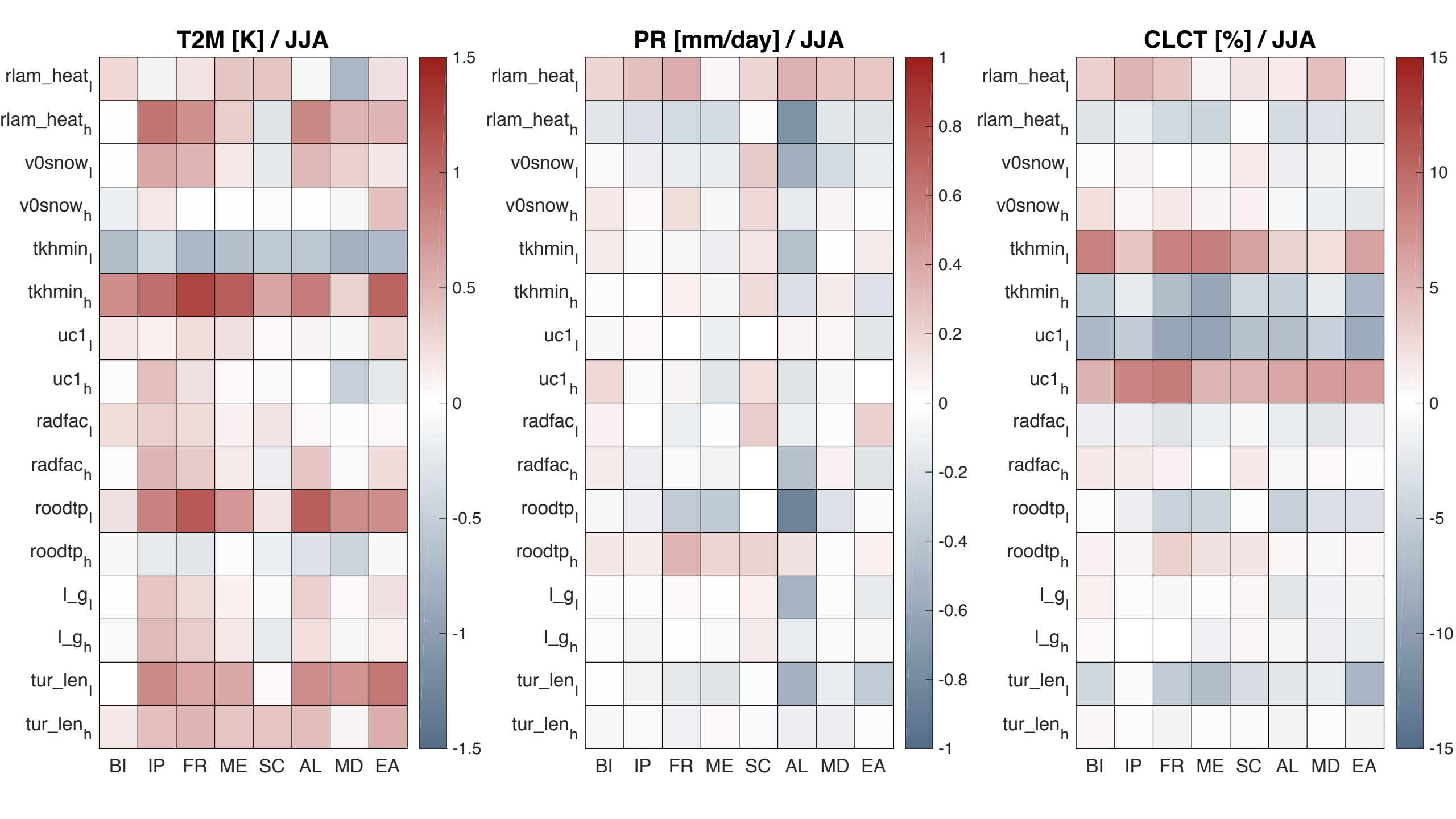
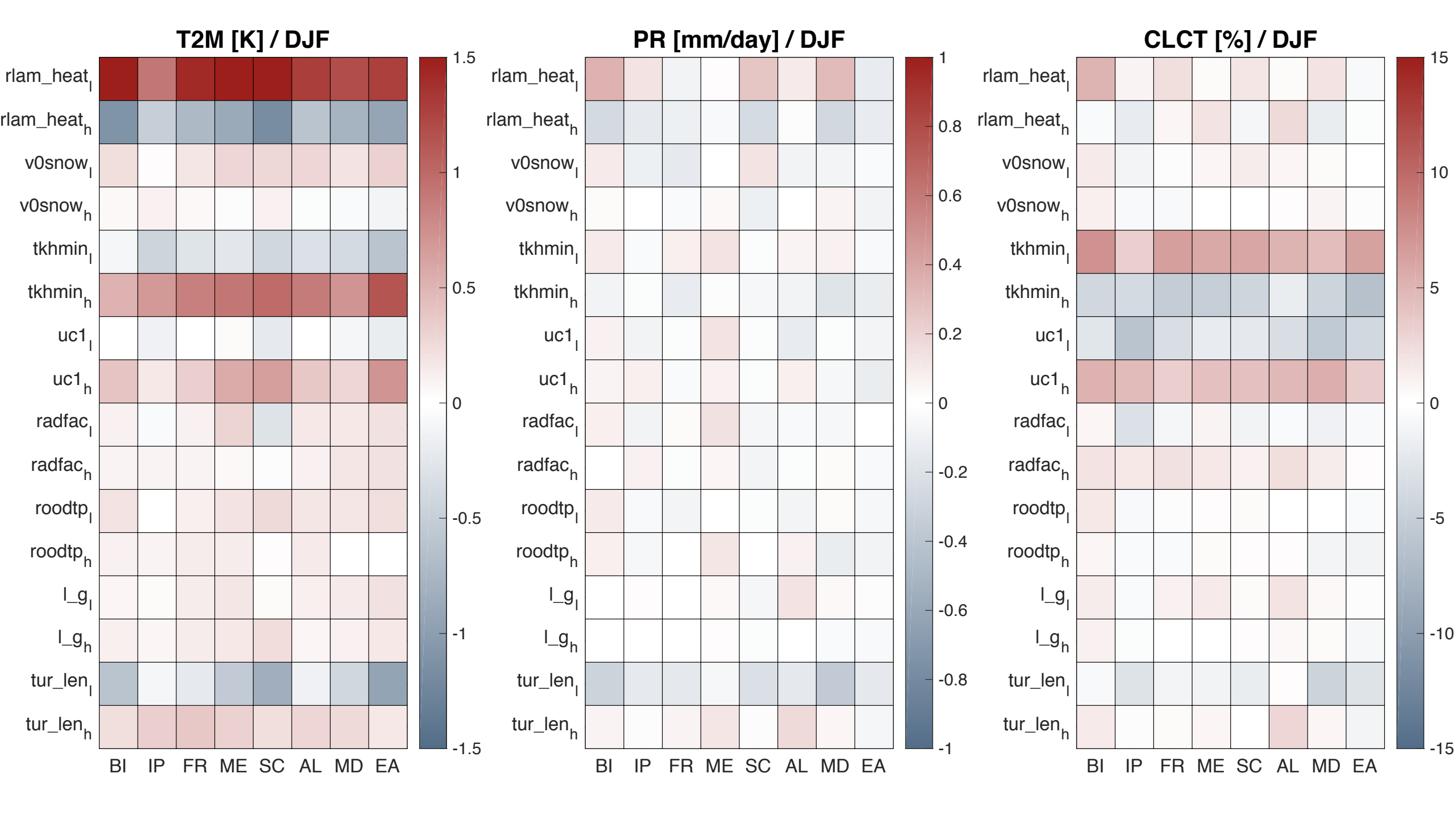
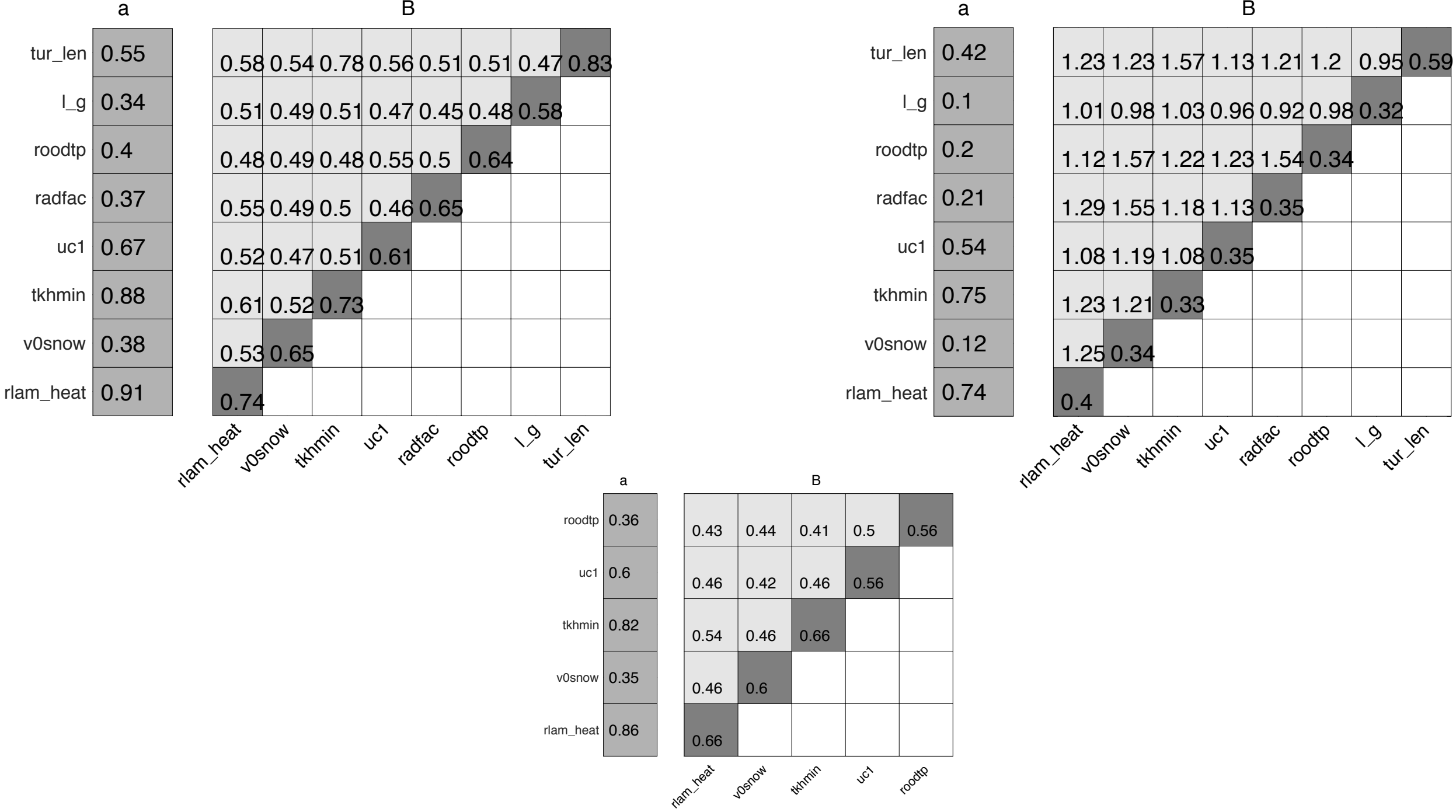
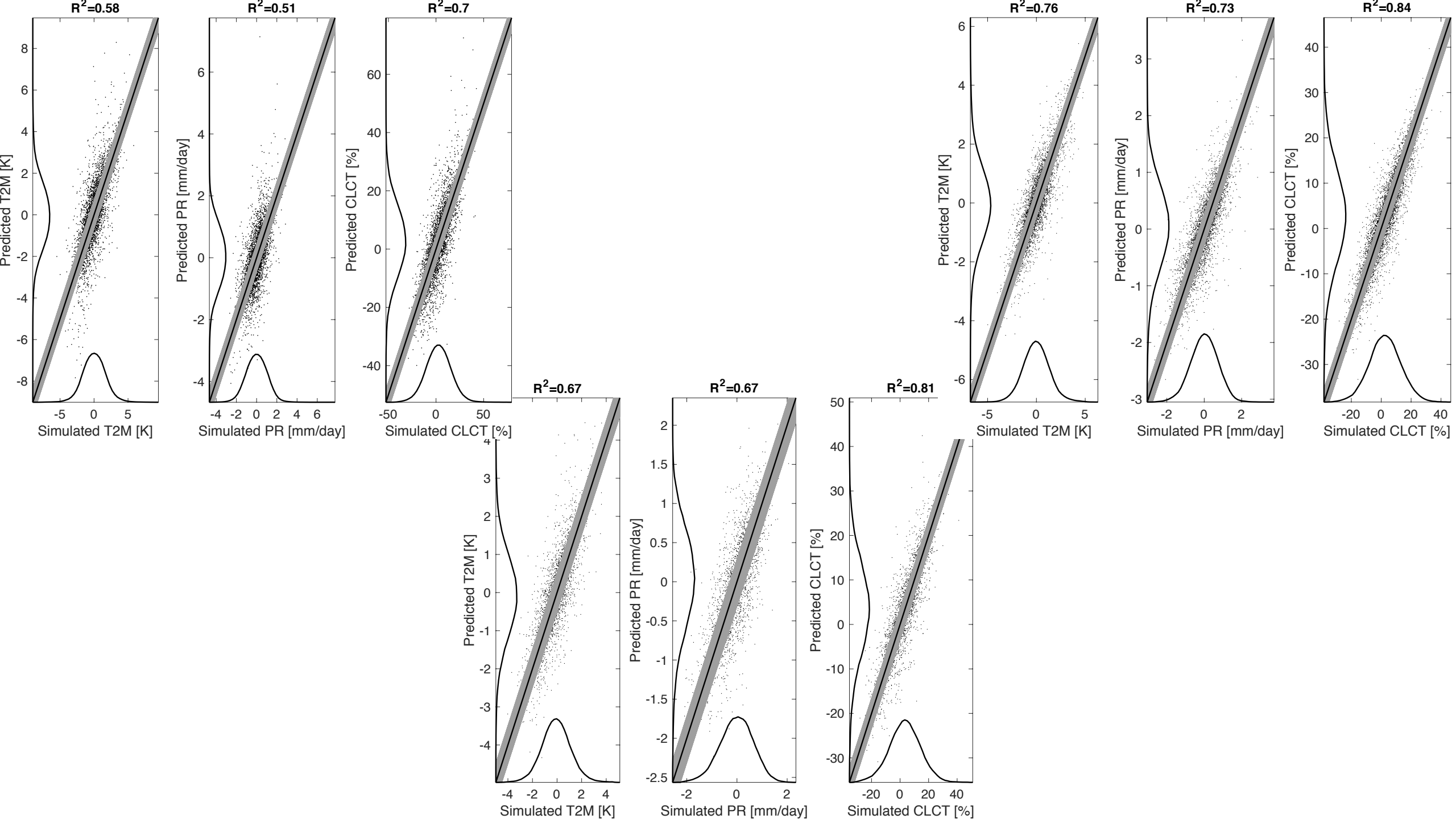
0.7
0.75

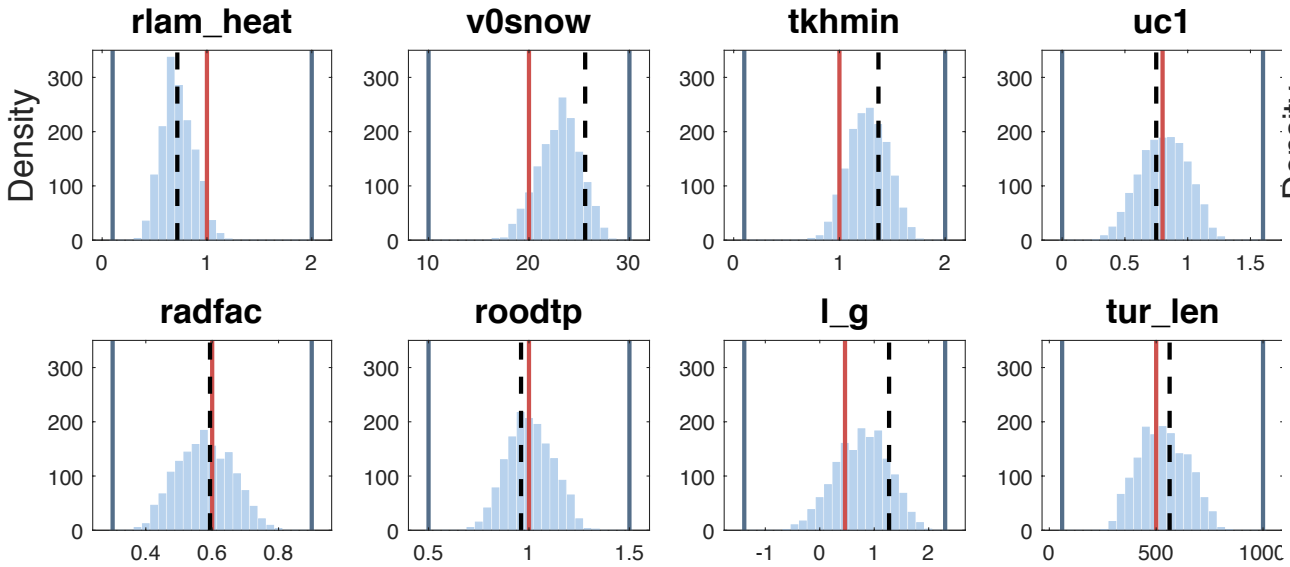

neelin_e
v0snow
rlam_heat
tkhmin
rlam_heat
uc1
rlam_heat
radfac
rlam_heat
roodtp
rlam_heat
l_g
rlam_heat
tur_len
rlam_heat
tkhmin
v0snow
uc1
v0snow
radfac
v0snow
roodtp
v0snow
l_g
v0snow
tur_len
v0snow
uc1
tkhmin
radfac
tkhmin
roodtp
tkhmin
l_g
tkhmin
tur_len
tkhmin
radfac
uc1
roodtp
uc1
l_g
uc1
tur_len
uc1
roodtp
radfac
l_g
radfac
tur_len
radfac
l_g
roodtp
tur_len
roodtp
tur_len
l_g
0.5
0.55
0.6
0.65
0.7
0.75

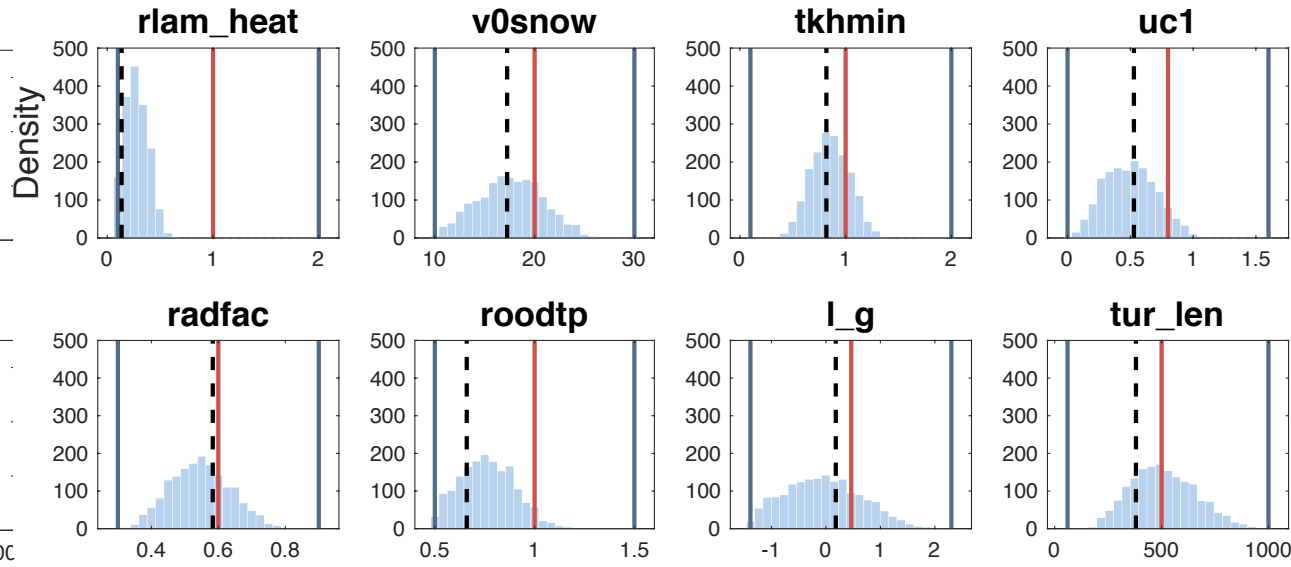

T2M [K] / JJA
PR [mm/day] / JJA
CLCT [%] / JJA
rlam_heat_l
rlam_heat_h
v0snow_l
v0snow_h
tkhmin_l
tkhmin_h
uc1_l
uc1_h
radfac_l
radfac_h
roodtp_l
roodtp_h
l_g_l
l_g_h
tur_len_l
tur_len_h
BI IP FR ME SC AL MD EA
1.5 1 0.5 0 -0.5 -1 -1.5
1 0.8 0.6 0.4 0.2 0 -0.2 -0.4 -0.6 -0.8 -1
15 10 5 0 -5 -10 -15

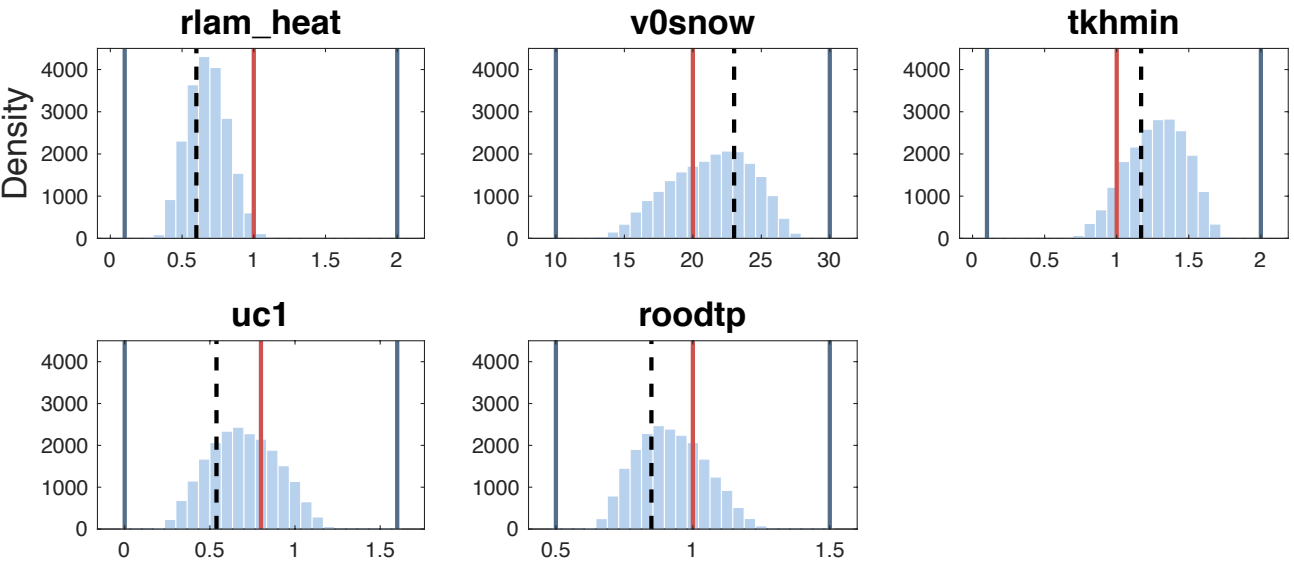

T2M [K] / DJF
PR [mm/day] / DJF
CLCT [%] / DJF
rlam_heat_l
rlam_heat_h
v0snow_l
v0snow_h
tkhmin_l
tkhmin_h
uc1_l
uc1_h
radfac_l
radfac_h
roodtp_l
roodtp_h
l_g_l
l_g_h
tur_len_l
tur_len_h
BI IP FR ME SC AL MD EA
1.5 1 0.5 0 -0.5 -1 -1.5
1 0.8 0.6 0.4 0.2 0 -0.2 -0.4 -0.6 -0.8 -1
15 10 5 0 -5 -10 -15


a
B
tur_len 0.55
l_g 0.34
roodtp 0.4
radfac 0.37
uc1 0.67
tkhmin 0.88
v0snow 0.38
rlam_heat 0.91
0.58 0.54 0.78 0.56 0.51 0.51 0.47 0.83
0.51 0.49 0.51 0.47 0.45 0.48 0.58
0.48 0.49 0.48 0.55 0.5 0.64
0.55 0.49 0.5 0.46 0.65
0.52 0.47 0.51 0.61
0.61 0.52 0.73
0.53 0.65
0.74
rlam_heat v0snow tkhmin uc1 radfac roodtp l_g tur_len
a
B
tur_len 0.42
l_g 0.1
roodtp 0.2
radfac 0.21
uc1 0.54
tkhmin 0.75
v0snow 0.12
rlam_heat 0.74
1.23 1.23 1.57 1.13 1.21 1.2 0.95 0.59
1.01 0.98 1.03 0.96 0.92 0.98 0.32
1.12 1.57 1.22 1.23 1.54 0.34
1.29 1.55 1.18 1.13 0.35
1.08 1.19 1.08 0.35
1.23 1.21 0.33
1.25 0.34
0.4
rlam_heat v0snow tkhmin uc1 radfac roodtp l_g tur_len
a
B
roodtp 0.36
uc1 0.6
tkhmin 0.82
v0snow 0.35
rlam_heat 0.86
0.43 0.44 0.41 0.5 0.56
0.46 0.42 0.46 0.56
0.54 0.46 0.66
0.46 0.6
0.66
rlam_heat v0snow tkhmin uc1 roodtp


R2=0.58
Predicted T2M [K]
Simulated T2M [K]
R2=0.51
Predicted PR [mm/day]
Simulated PR [mm/day]
R2=0.7
Predicted CLCT [%]
Simulated CLCT [%]
R2=0.67
Predicted T2M [K]
Simulated T2M [K]
R2=0.67
Predicted PR [mm/day]
Simulated PR [mm/day]
R2=0.81
Predicted CLCT [%]
Simulated CLCT [%]
R2=0.76
Predicted T2M [K]
Simulated T2M [K]
R2=0.73
Predicted PR [mm/day]
Simulated PR [mm/day]
R2=0.84
Predicted CLCT [%]
Simulated CLCT [%]


rlam_heat
v0snow
tkhmin
uc1
Density
radfac
roodtp
l_g
tur_len


rlam_heat
v0snow
tkhmin
uc1
Density
radfac
roodtp
l_g
tur_len


rlam_heat
v0snow
tkhmin
Density
uc1
roodtp