Tuning of compressible COSMO-EULAG model for regional numerical weather prediction

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Introduction

- The compressible dynamical core of the fluid solver EULAG has been implemented into the COSMO framework (ver. 5.01)
- To date, a number of tests both idealized and realistic have been performed using CE
- The tests confirmed suitability of CE for modeling processes characteristic for mesoscale weather
- The current efforts are focused on further optimization, testing and tuning of the CE model (with parameterizations of COSMO ver. 5.01)
- **The new realistic simulations are performed using a set of parameters optimized within the CALMO project.**

CE – forecast verification

Verification of the CE numerical forecasts was performed based on the comparison of the simulation results with observations

•The simulations were developed for 2 entire months **2013** featured by different weather phenomena i.e. **July** - vigorous convective processes and **November** - strong wind gusts

•Simulations were carried out for each day separately (i.e. 24h forecast)

•For each month we run **3 sets of simulations** using parameters evaluated within the CALMO project. Subsequent runs correspond to optimal combinations of parameters tuned for different time periods, namely, **entire year, summer and winter 2013**.

•The quantitative statistics were computed using dedicated software – **Versus**

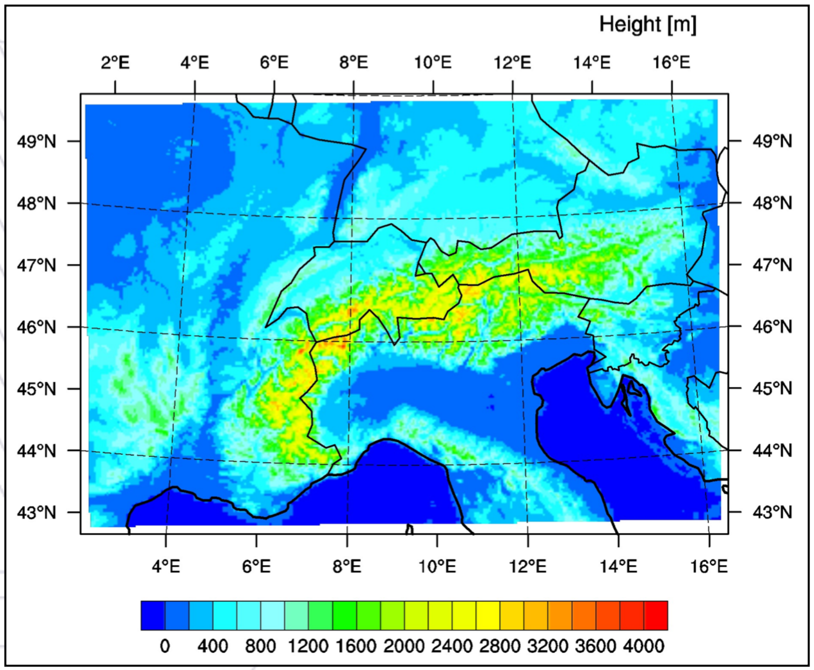
•The analysis is restricted to 4 dynamical fields (**temperature at 2 m, wind at 10 m, sea level pressure and dew point temperature also at 2 m**) and **precipitation**

•As for the dynamical fields, we compare average (over the whole month) values of mean error - ME and root mean square error - RMSE

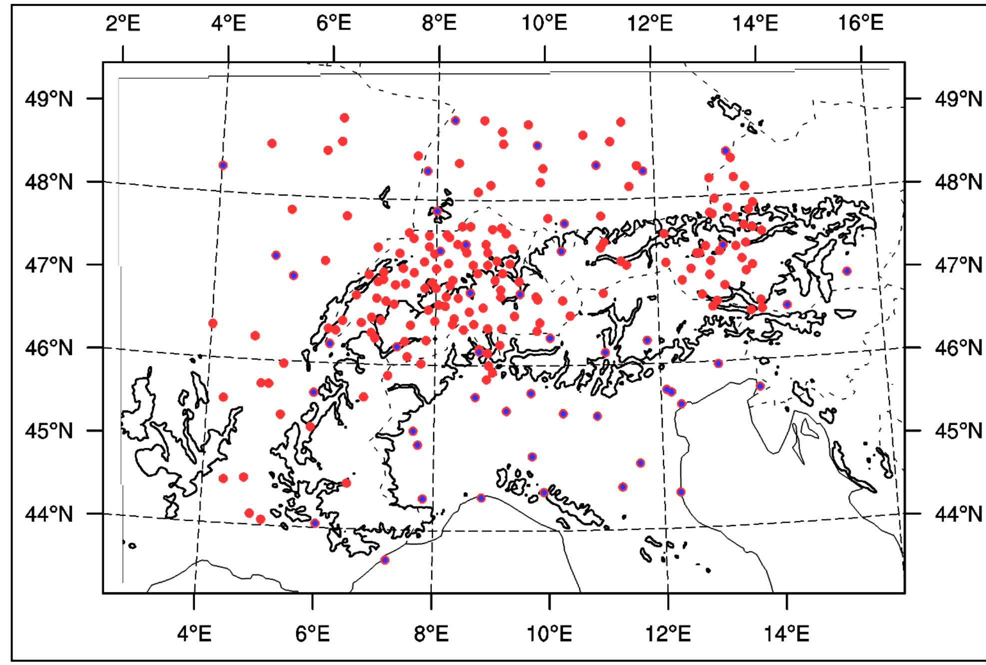
Computational domain

Computational domain - the standard operational COSMO-2 domain used by Meteo-Swiss.

Topographical map of the domain



Station network for surface verification



- Horizontal step of the computational mesh is 2.2 km
- Mesh has 60 vertical levels
- The simulations were performed using both CE and RK – for comparison

CALMO – tuned parameters and calibrated fields

Parameter	Default value	Tuning for		
		entire year	summer	winter
rlam_heat	1.0	1.273	1.071	1.112
tkhmin	0.4	0.266	0.221	0.891
tur_len	150	346.5	357.5	117.2
entr_sc	0.003	0.0001607	0.000489	0.0001714
c_soil	1.0	0.588	1.150	0.041
v0snow	20.0	12.3	21.2	30

Tuned parameters
rlam_heat – determines (linearly) the heat resistance length.
tkhmin – [m^2/s] minimal diffusion coefficient for heat. Active in stable BL.
tur_len – [m] maximal turbulent length scale
entr_sc – [m^{-1}] mean entrainment rate of humidity for shallow convection clouds.
c_soil – surface-area index of the evaporating fraction of grid-points over land.
v0snow – factor in the terminal velocity for snow

Calibrated atmospheric fields
T_{max} and T_{min} at 2m; 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

Experiment settings

Dynamics:
- In Cosmo Runge-Kutta setup moist quantities are advected using the „Bott2Strang” scheme
- In Cosmo-Eulag setup moist quantities are advected using the MPDATA A scheme
- For Cosmo Runge-Kutta *irunge_kutta*=1 and *itype_fast_waves*=2
- Numerical and Smagorinsky diffusion are *turned off* for Cosmo-Eulag and *on* for Cosmo Runge-Kutta
- dt = 10 s (RK), dt = 10 s (CE)

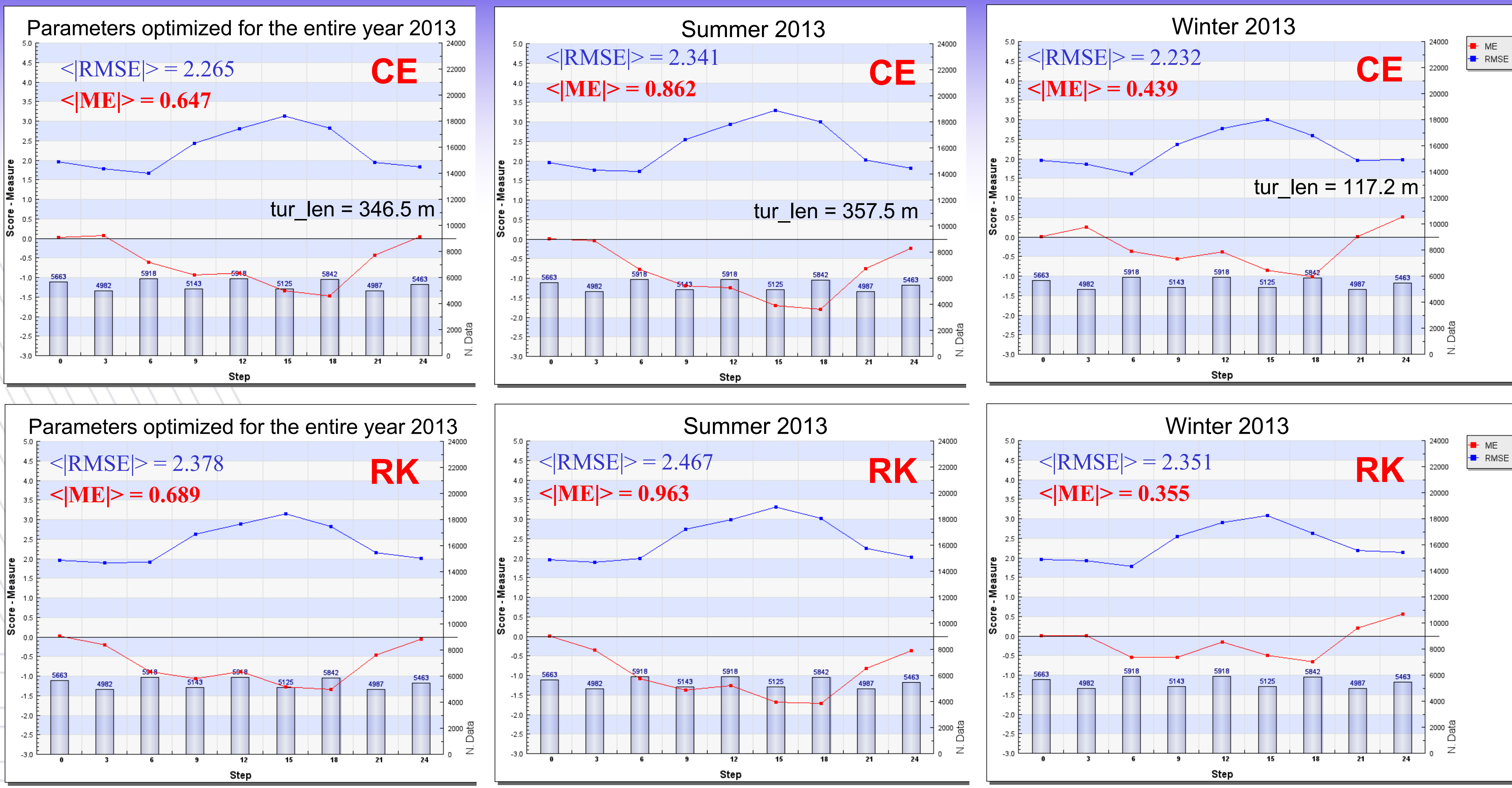
Microphysics:
- Standard one-moment COSMO microphysics parameterization including ice, rain, snow and graupel precipitation (*igsp*=4)

Radiation:
- Calculated every 6 minutes
- Topographical corrections to radiation are *turned off* (*lradtopo*=F)

Turbulence and convection scheme:
- Default turbulence setup for high-resolution NWP (*itype_turb* = 3, *limpltkediff* = T)
- Shallow convection parameterization is *turned off* (*lconv* = F)

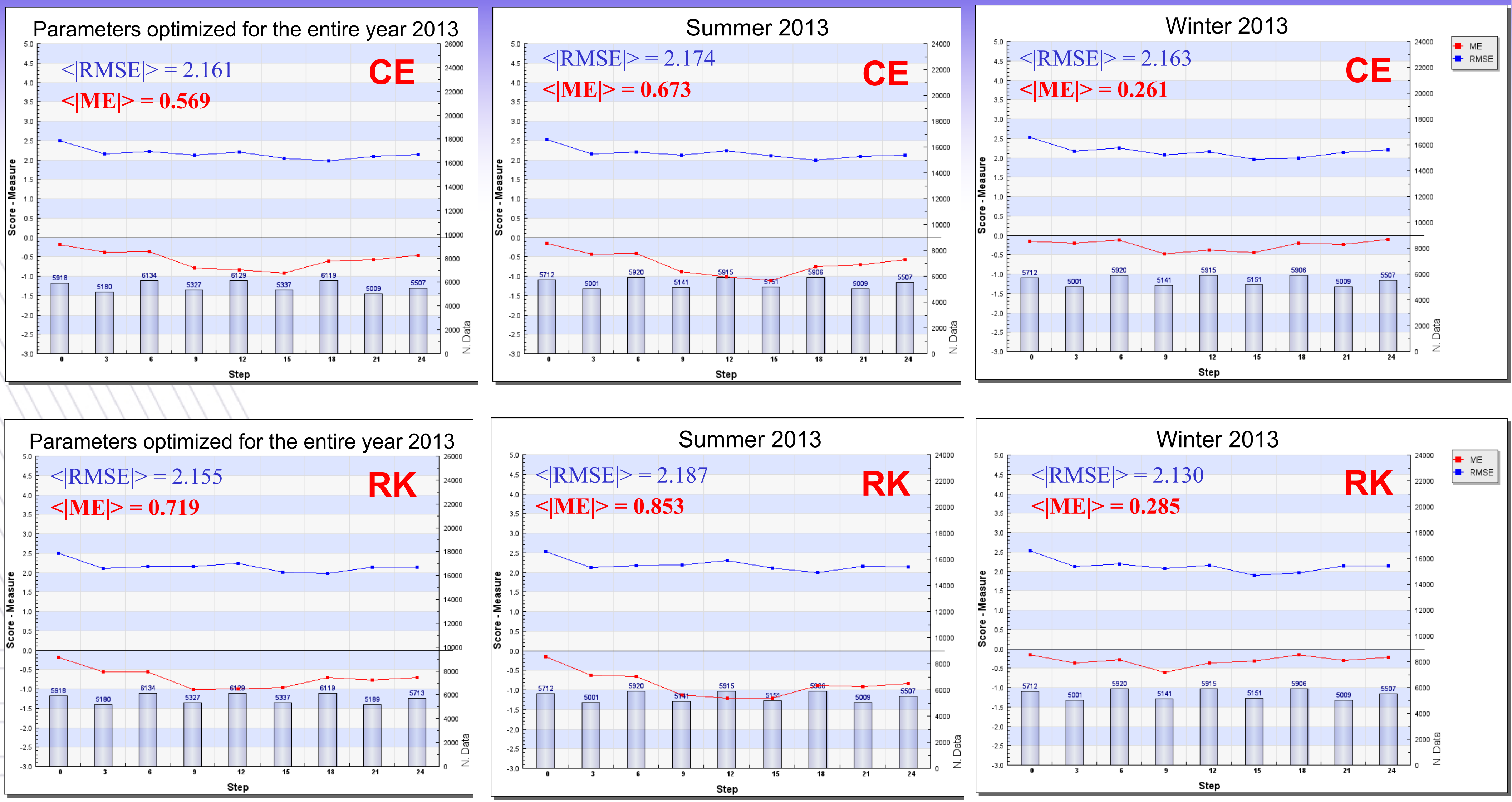
Soil model:
- Multi-layer soil model is used (*lsoil* = T, *lmulti_layer* = T, *lforest* = T)

Temperature (ºC) at 2 m – forecast verification for JUNE



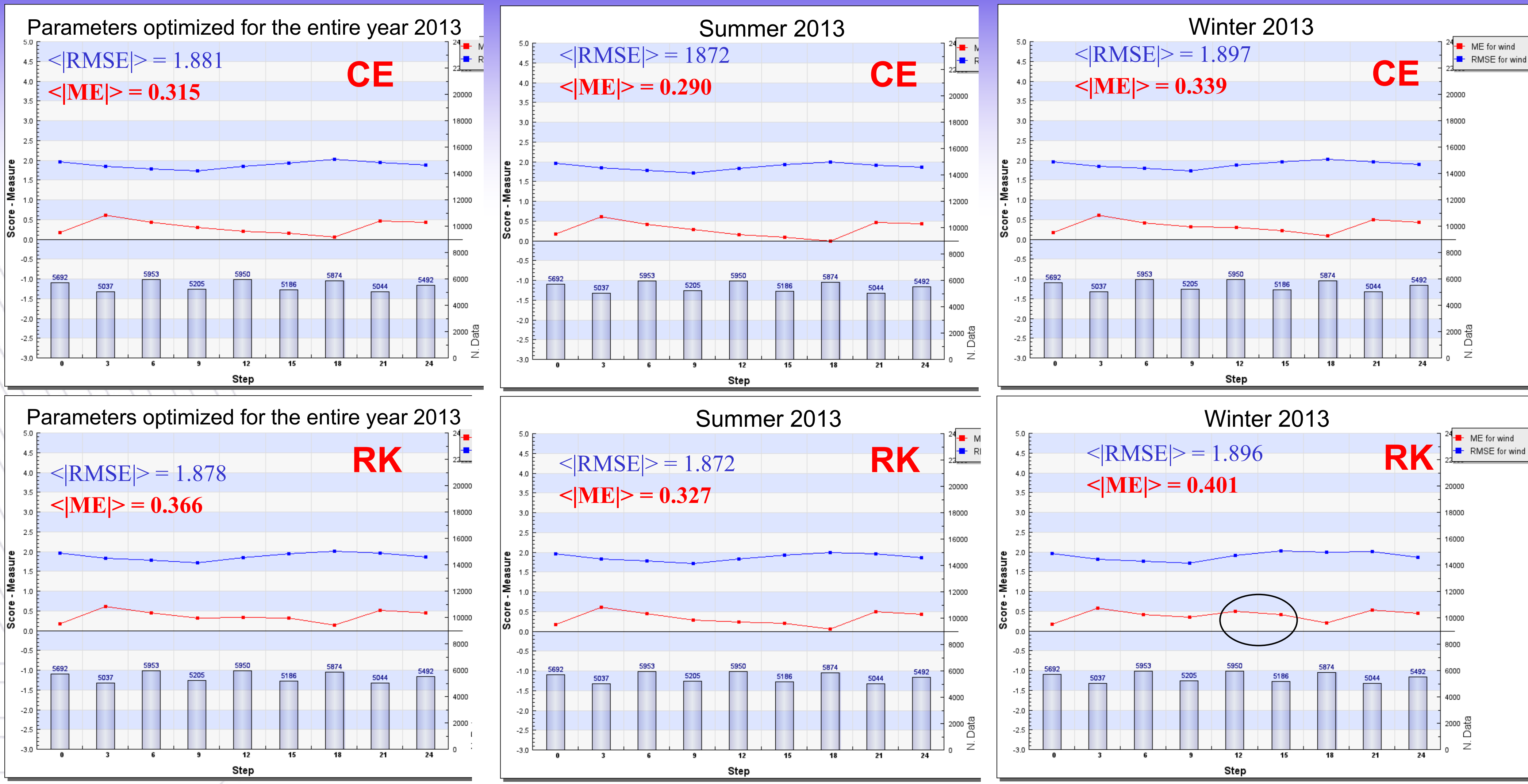
- Results computed using CE with parameters optimized for the entire year and summer season are closer to observations than those computed with RK.
- Surprisingly the best scores (small ME) have been obtained with RK and using combination of parameters optimized for the winter season. Likely due to shorter mixing length.
- The largest deviation is observed in the early afternoon hours. This is due to strong heat surface fluxes.

Temperature (°C) at 2 m – forecast verification for NOVEMBER



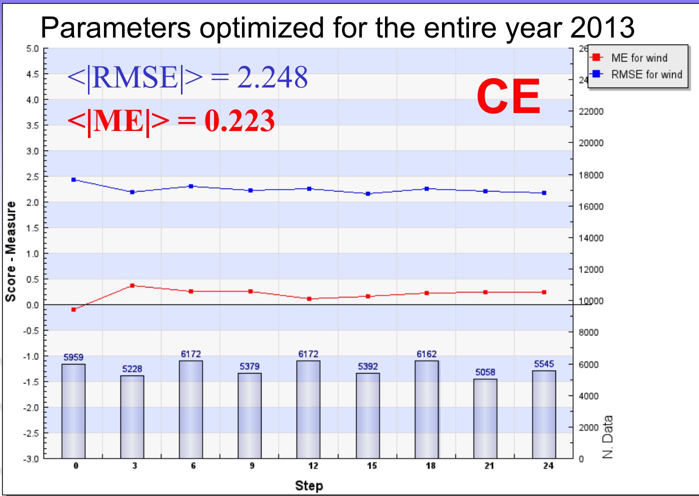
- Results computed using CE are closer to observations than those computed with RK.
- Differences in RMSE are practically negligible.
- Heat surface fluxes are not as strong as for July. Therefore, the time dependence is weaker.

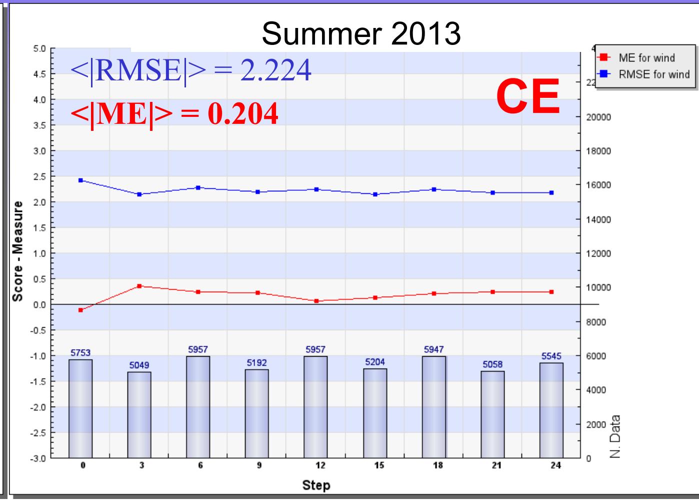
Wind (m/s) at 10 m – forecast verification for JUNE

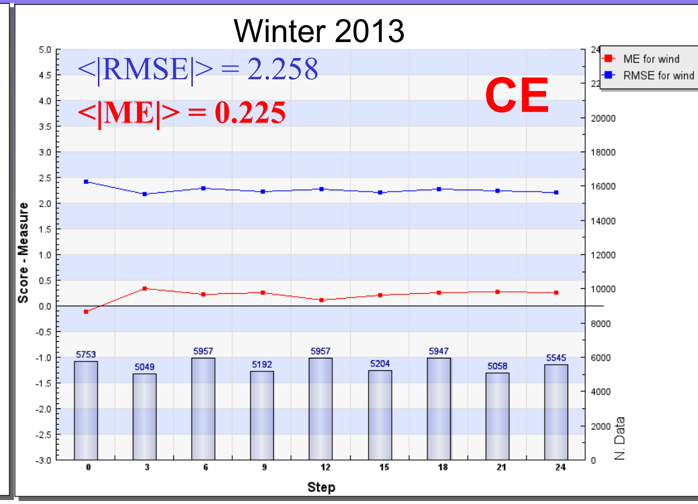


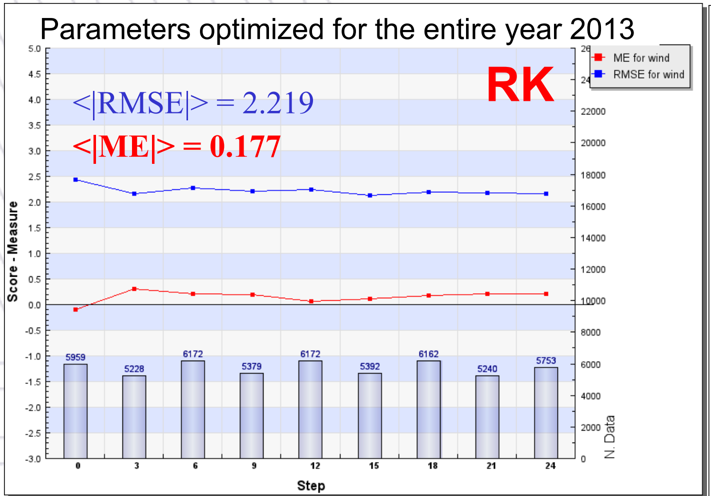
- The mean error (ME) is smaller for simulations performed with CE. RMSE is similar for both CE and RK results.
- Parameters optimized for winter seasons result in visibly larger ME in RK simulations

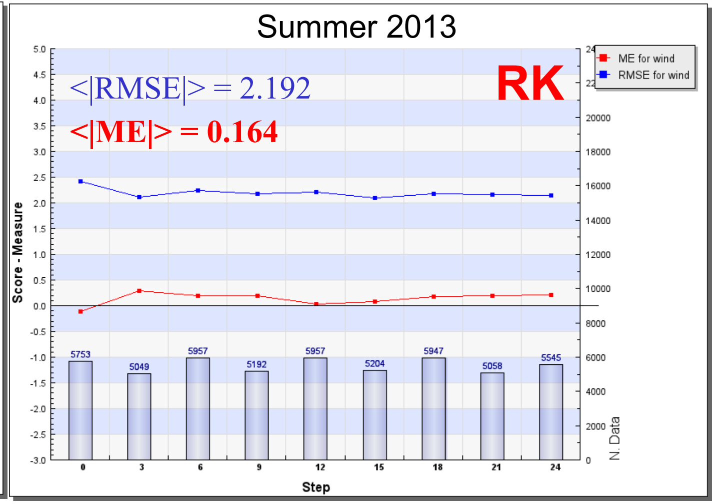
Wind (m/s) at 10 m – forecast verification for NOVEMBER

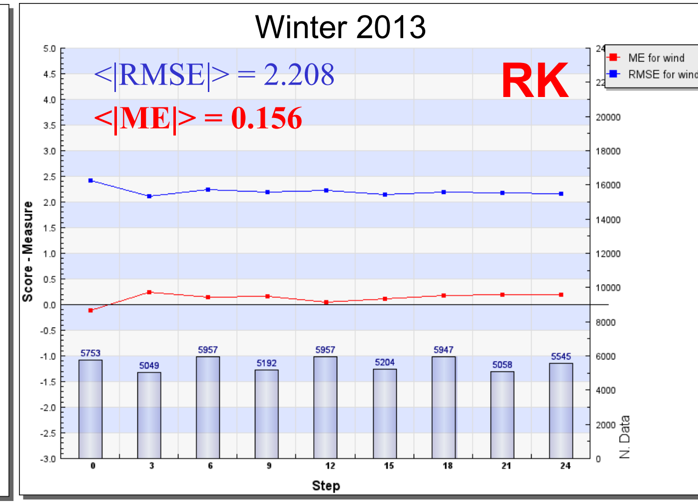






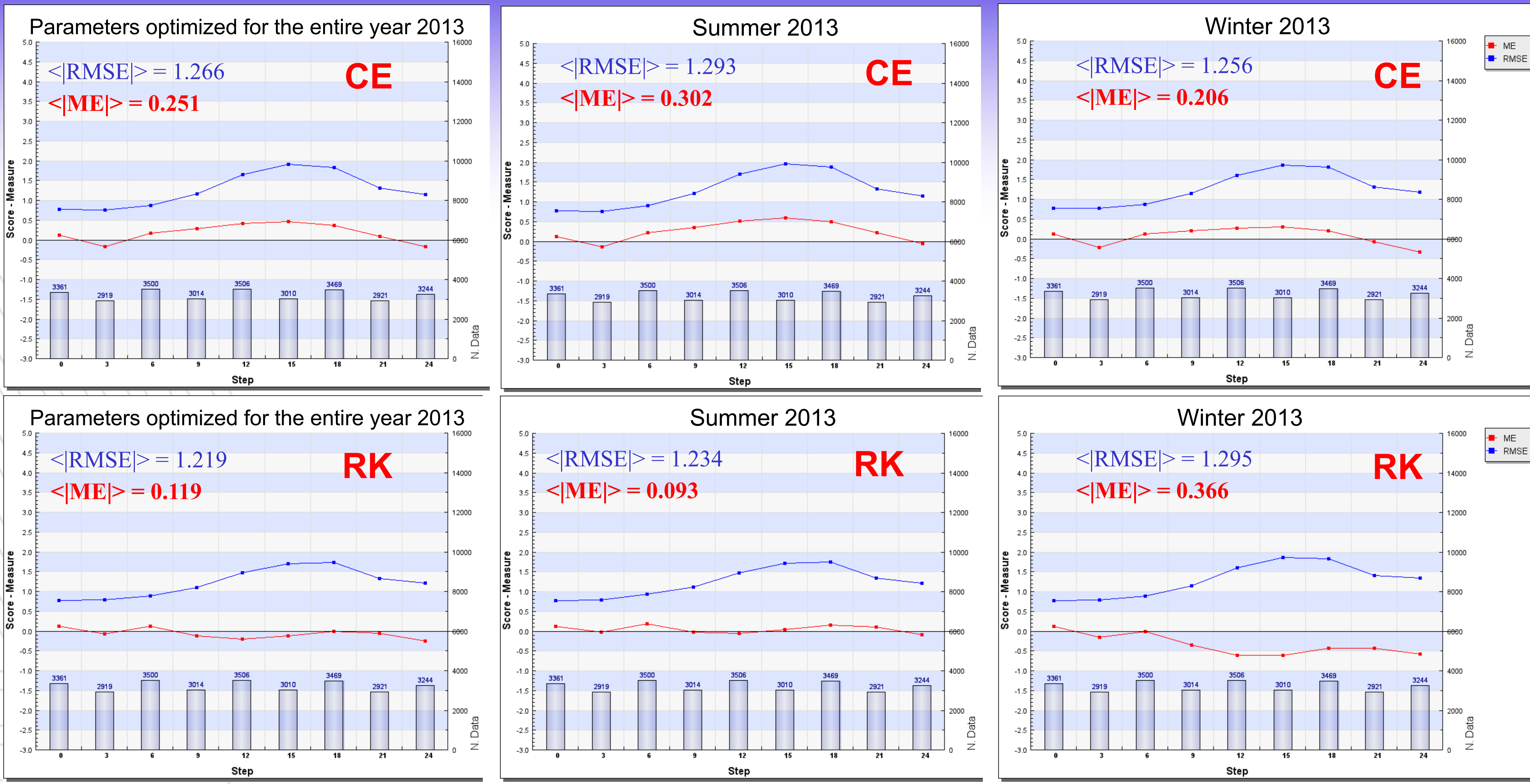






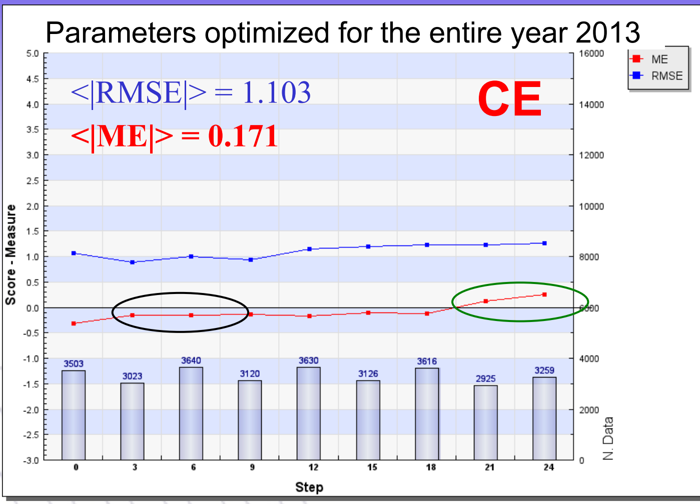
- Numerical forecasts of wind computed using both CE and RK are in close agreement with observations. (Better agreement than for July)
- In contrast to July, the mean error (ME) is smaller for simulations performed with RK.
- CALMO tuning has little effect on the average statistics.

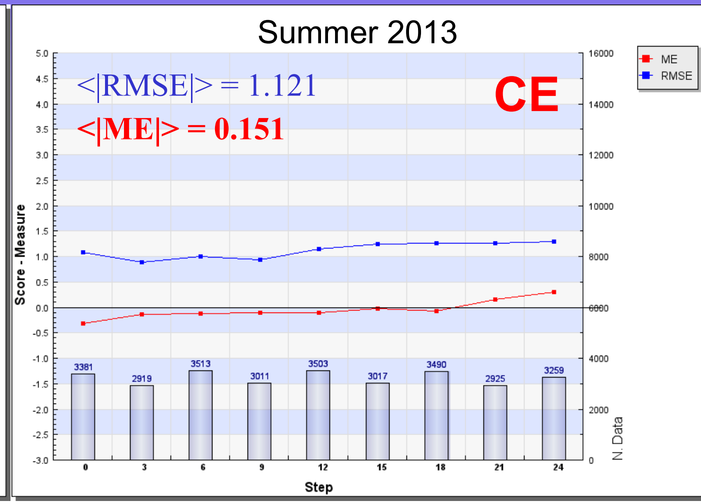
Pressure (hPa) – forecast verification for JUNE

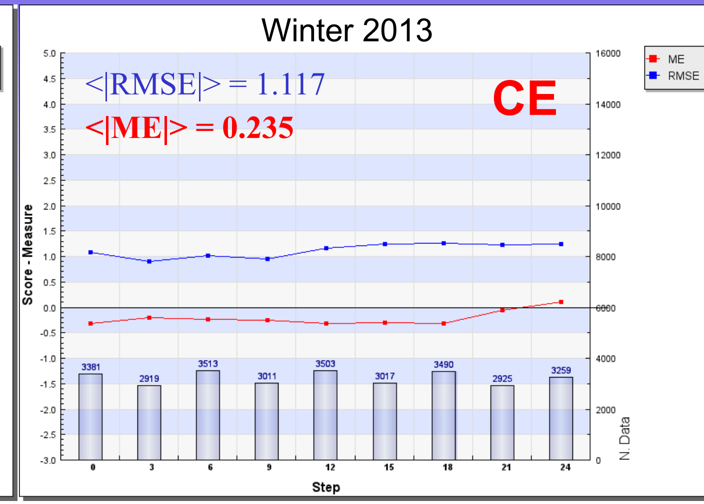


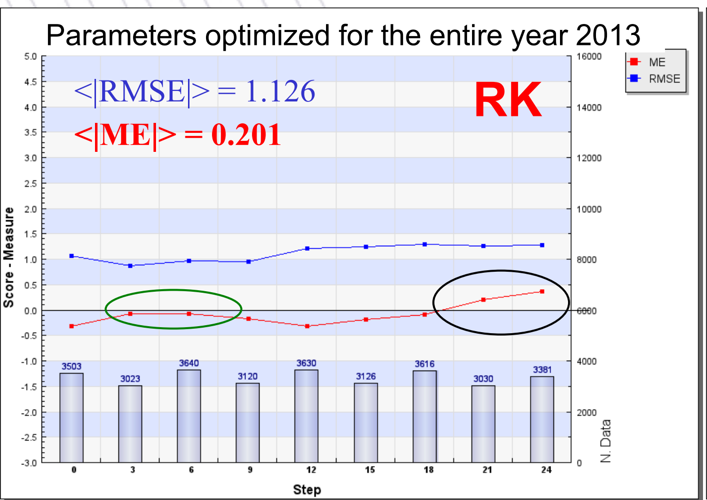
- Mean error is close to 0 in simulation performed with RK and parameters tuned for summer
- On the other hand, RMSE is similar for both RK and CE
- Mean errors of CE results have characteristic diurnal cycle. More attention to coupling with the soil model is needed.
- ME of the RK simulations is larger for “winter tuning”. Possibly due to too short mixing length ?

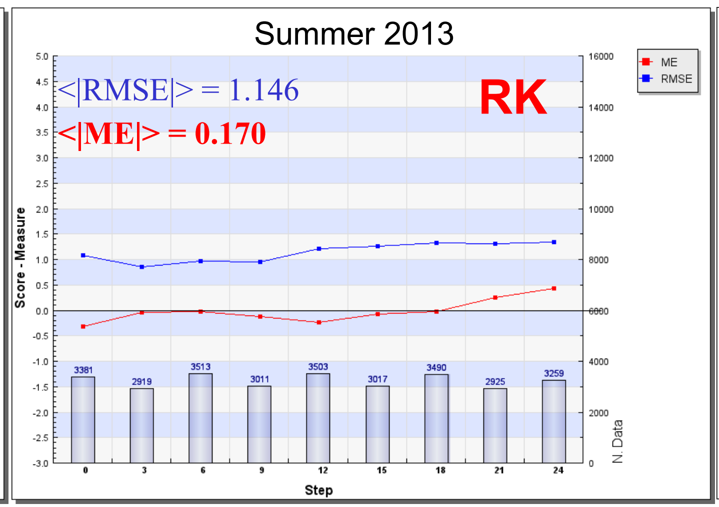
Pressure (hPa) – forecast verification for NOVEMBER

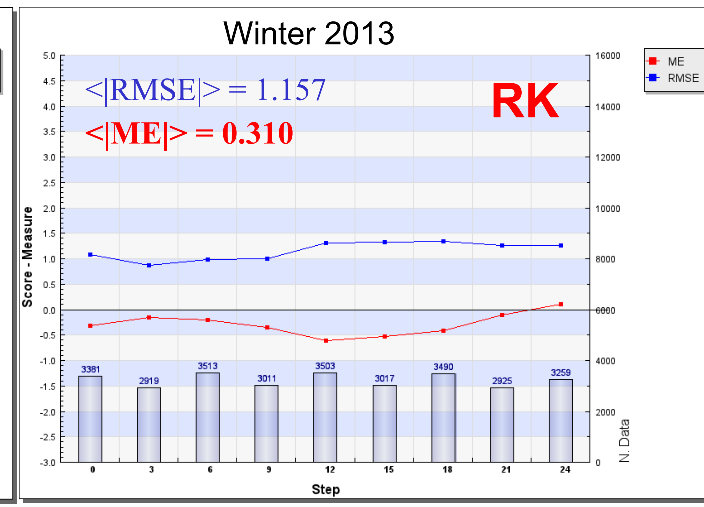






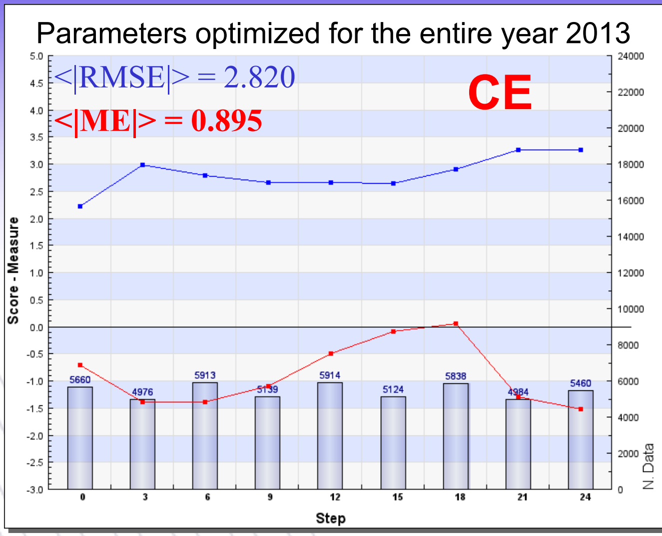


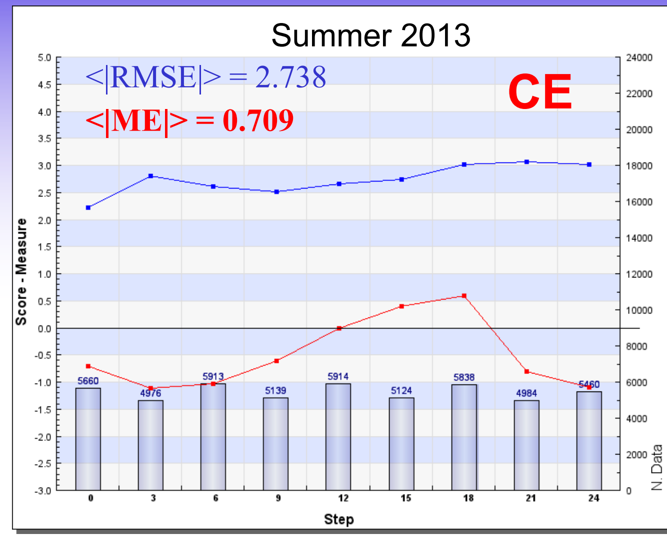


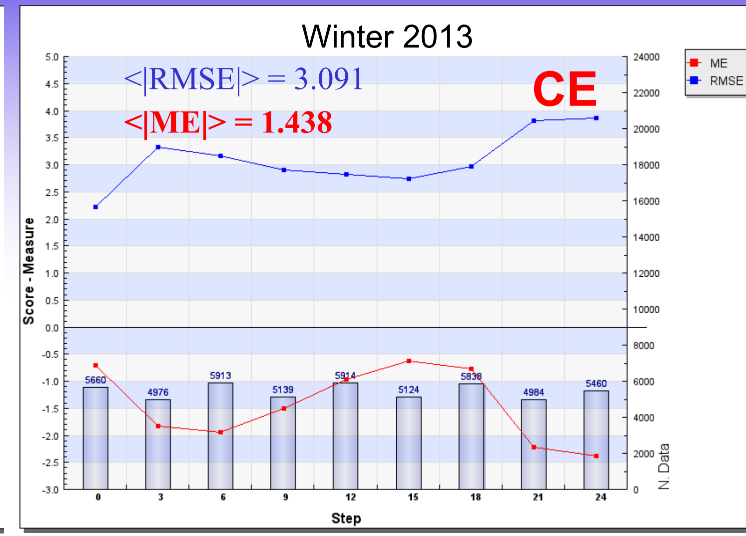


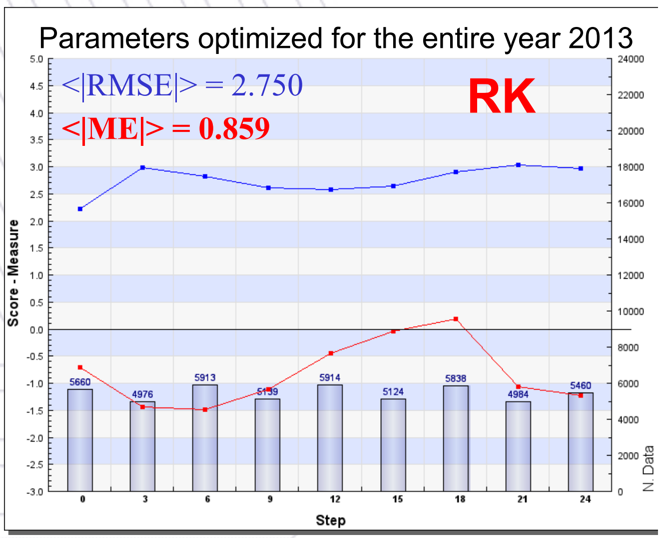
Mean error is relatively small for both CE and RK. Before 18:00, ME in simulations performed with RK are slightly more in line with observations than those performed with CE. After 18:00, the forecast computed using CE is in better agreement with observations (lower ME). Surprisingly, tuning of parameters for the summer season results in lower mean error than tuning for the winter season. This may be due shorter mixing length.

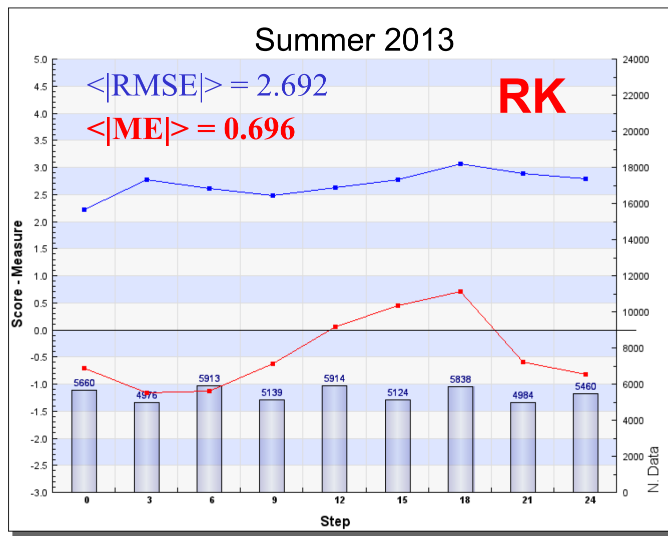
Dew Point Temperature (ºC) at 2 m – JUNE

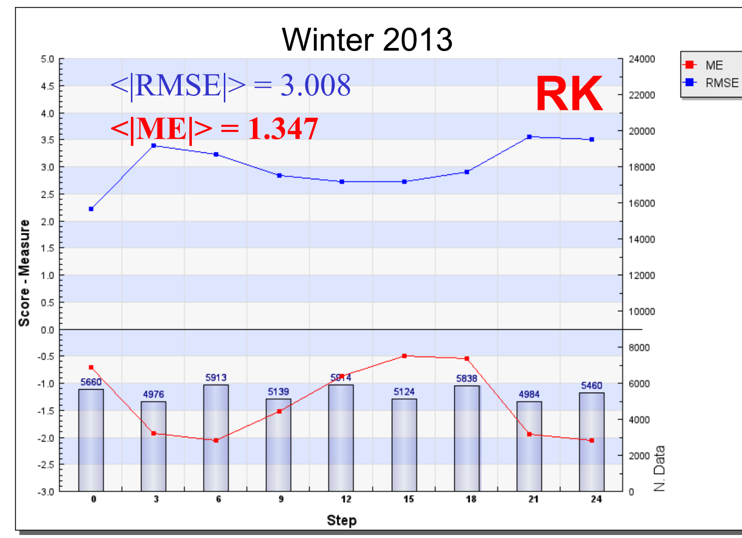






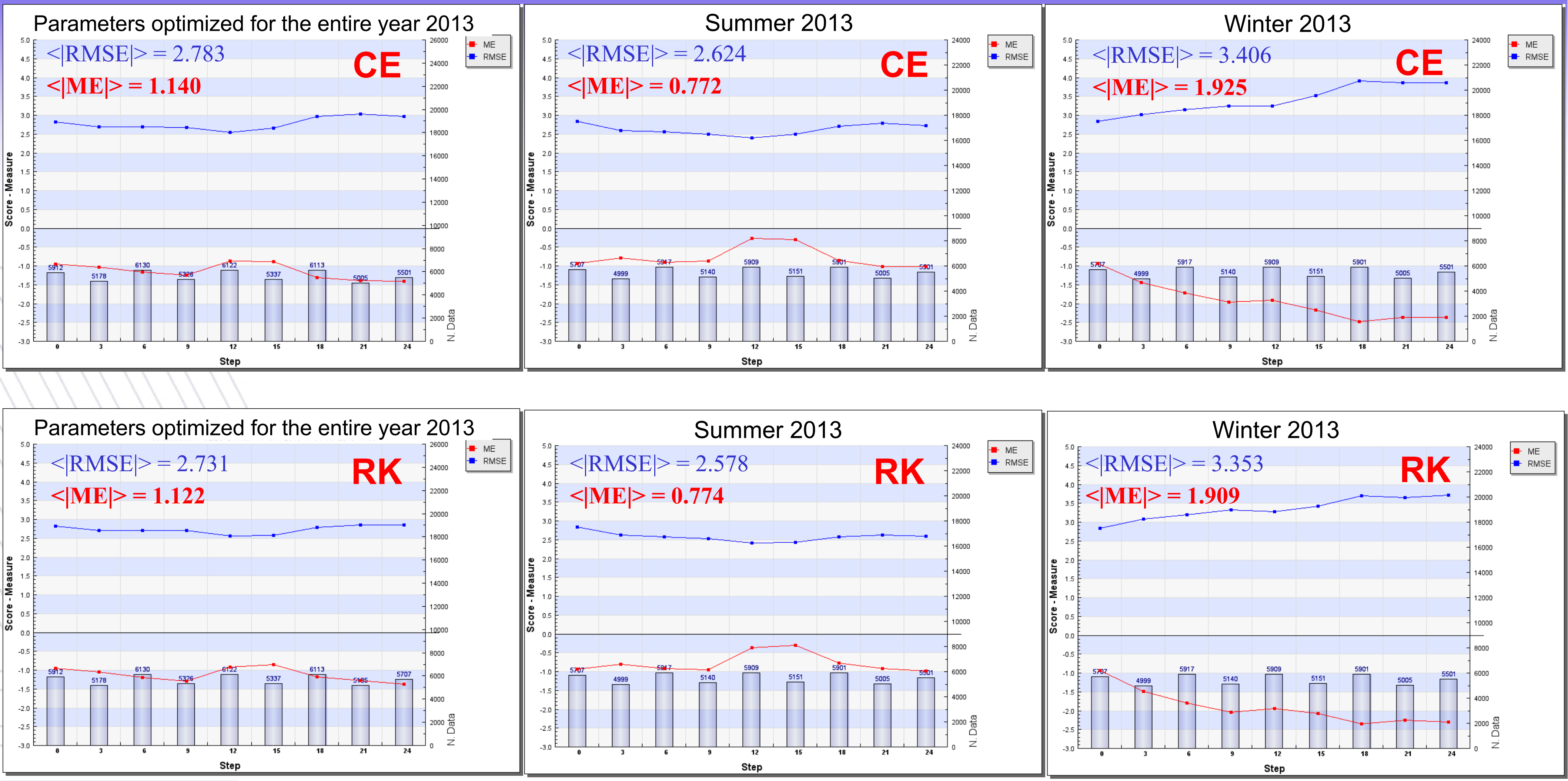






- Relatively low differences between results computed using RK and CE
- Strong sensitivity to the time of the day. Again, this may be related to the weather diurnal cycle.

Dew Point Temperature (ºC) at 2 m – NOVEMBER



The parameters tuned for the winter season result in much worse results in the dew point temperature. Some explanation of the discrepancy is in the methodology used for the CALMO optimization. Both temperature and relative humidity were used for the calibration but only at 850, 700 and 500 hPa. On the other hand, better agreement with observation was obtain for the temperature at 2m. This also can be explained because T_{max} and T_{min} at 2 m were used in the CALMO calibration procedure.

Summary of quantitative comparison - July

Mean error	Entire year		Summer		Winter	
	CE	RK	CE	RK	CE	RK
Pressure	0,251	0,119	0,302	0,093	0,206	0,366
Wind	0,315	0,366	0,290	0,327	0,339	0,401
Temperature	0,647	0,689	0,862	0,963	0,439	0,355
Dew point temperature	0,895	0,859	0,709	0,696	1,438	1,347

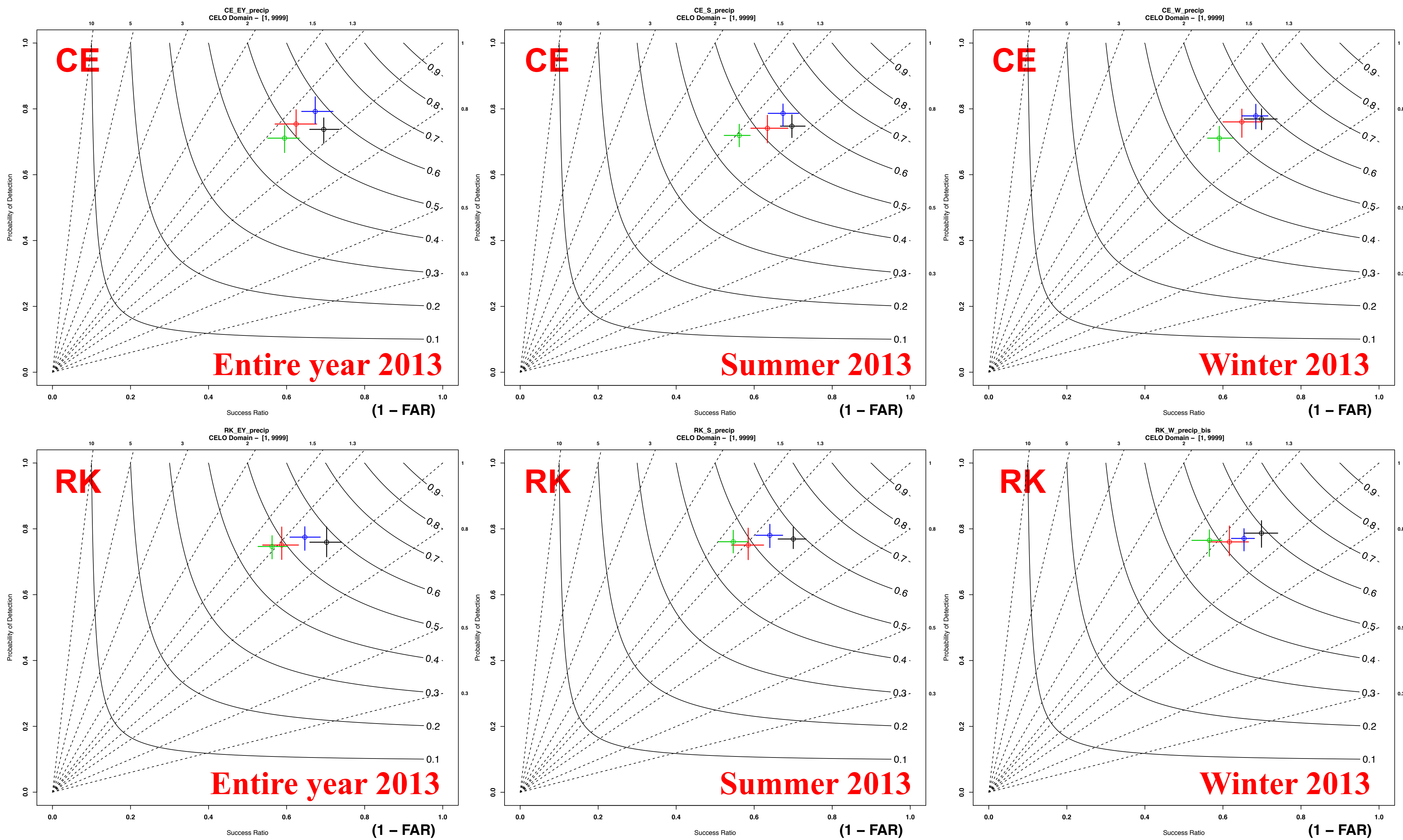
RMSE	Entire year		Summer		Winter	
	CE	RK	CE	RK	CE	RK
Pressure	1,266	1,219	1,293	1,234	1,256	1,295
Wind	1,881	1,878	1,872	1,872	1,897	1,896
Temperature	2,265	2,378	2,341	2,467	2,232	2,351
Dew point temperature	2,820	2,750	2,738	2,692	3,091	3,008

Summary of quantitative comparison - November

Mean error	Entire year		Summer		Winter	
	CE	RK	CE	RK	CE	RK
Pressure	0.171	0.201	0.151	0.170	0.235	0.310
Wind	0.223	0.177	0.204	0.164	0.225	0.156
Temperature	0.569	0.719	0.673	0.853	0.261	0.285
Dew point temperature	1.140	1.122	0.772	0.774	1.925	1.909

RMSE	Entire year		Summer		Winter	
	CE	RK	CE	RK	CE	RK
Pressure	1.103	1.126	1.121	1.146	1.117	1.157
Wind	2.248	2.219	2.224	2.192	2.258	2.208
Temperature	2.161	2.155	2.174	2.187	2.163	2.130
Dew point temperature	2.783	2.731	2.624	2.578	3.406	3.353

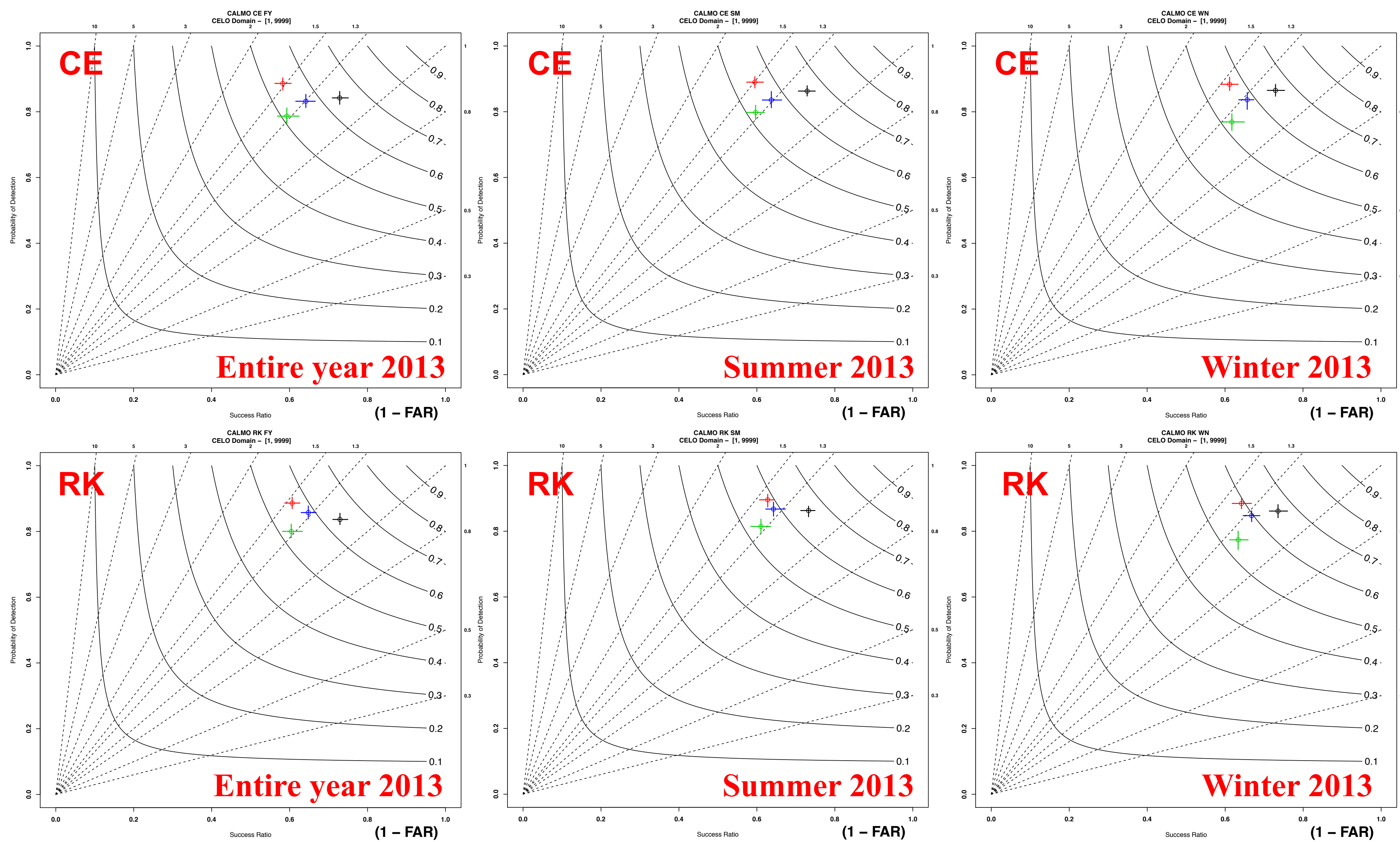
Precipitation - 1mm and more JUNE



○ step 6 ○ step 12 ○ step 18 ○ step 24

Results computed using CE and RK are in good quantitative agreement. Effect of tuning is practically negligible.

Precipitation - 1mm and more NOVEMBER

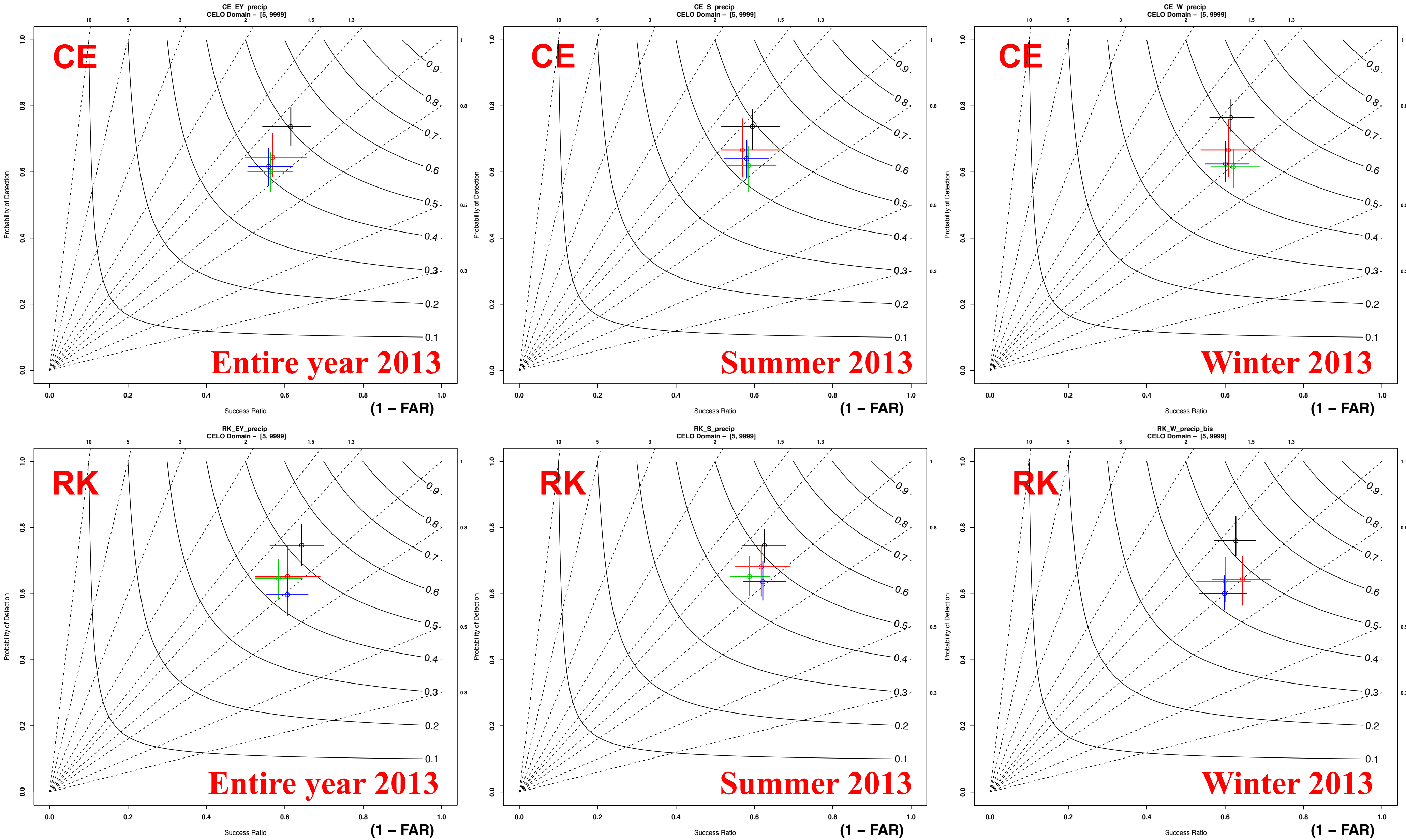


○ step 6 ○ step 12 ○ step 18 ○ step 24

Lower uncertainty and larger probability of detection than for July.

Value of uncertainty strictly depends on the amount of precipitation.

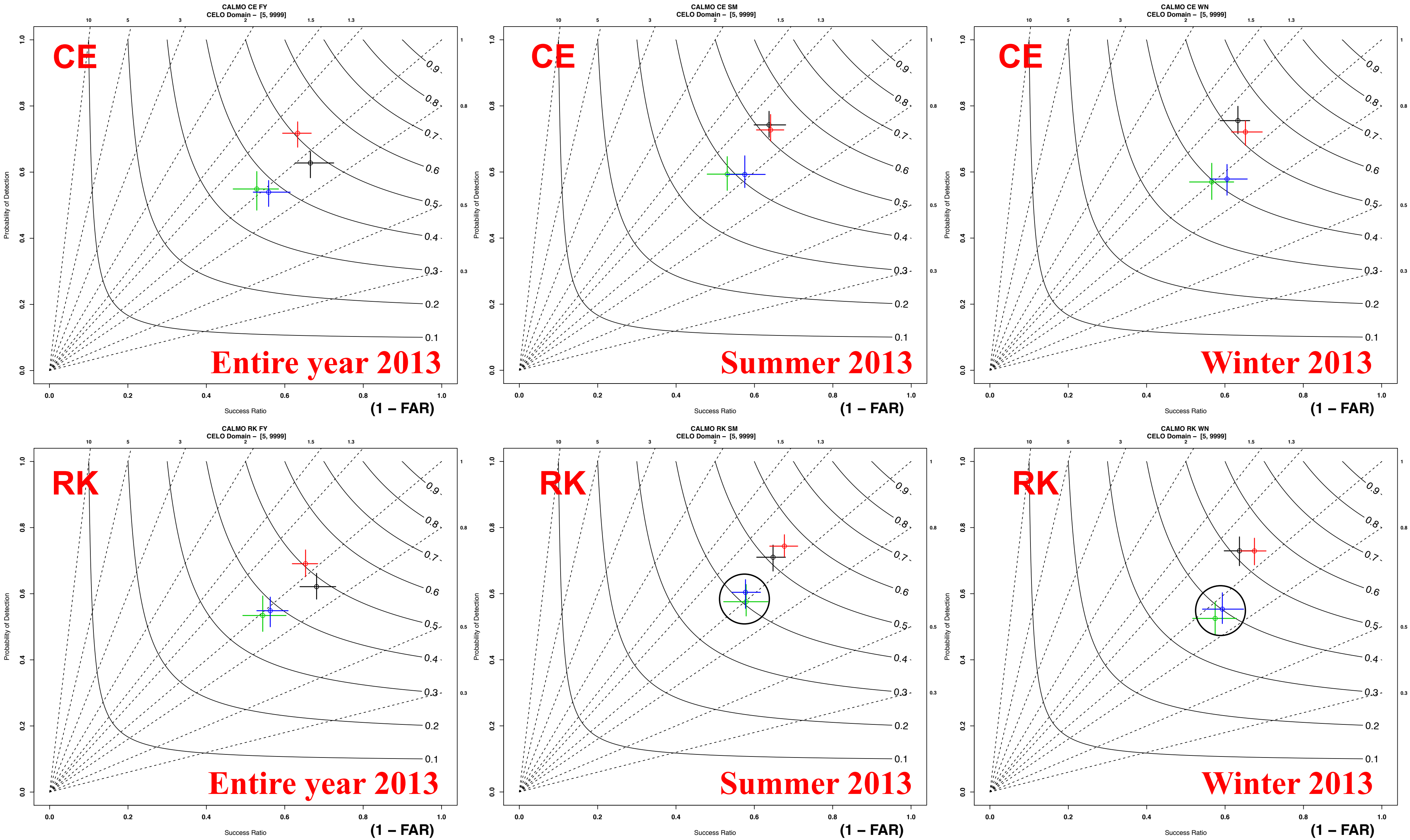
Precipitation - 5mm and more JUNE



○ step 6 ○ step 12 ○ step 18 ○ step 24

Observed differences between RK and CE are within statistical uncertainty.
Negligible effect of tuning.

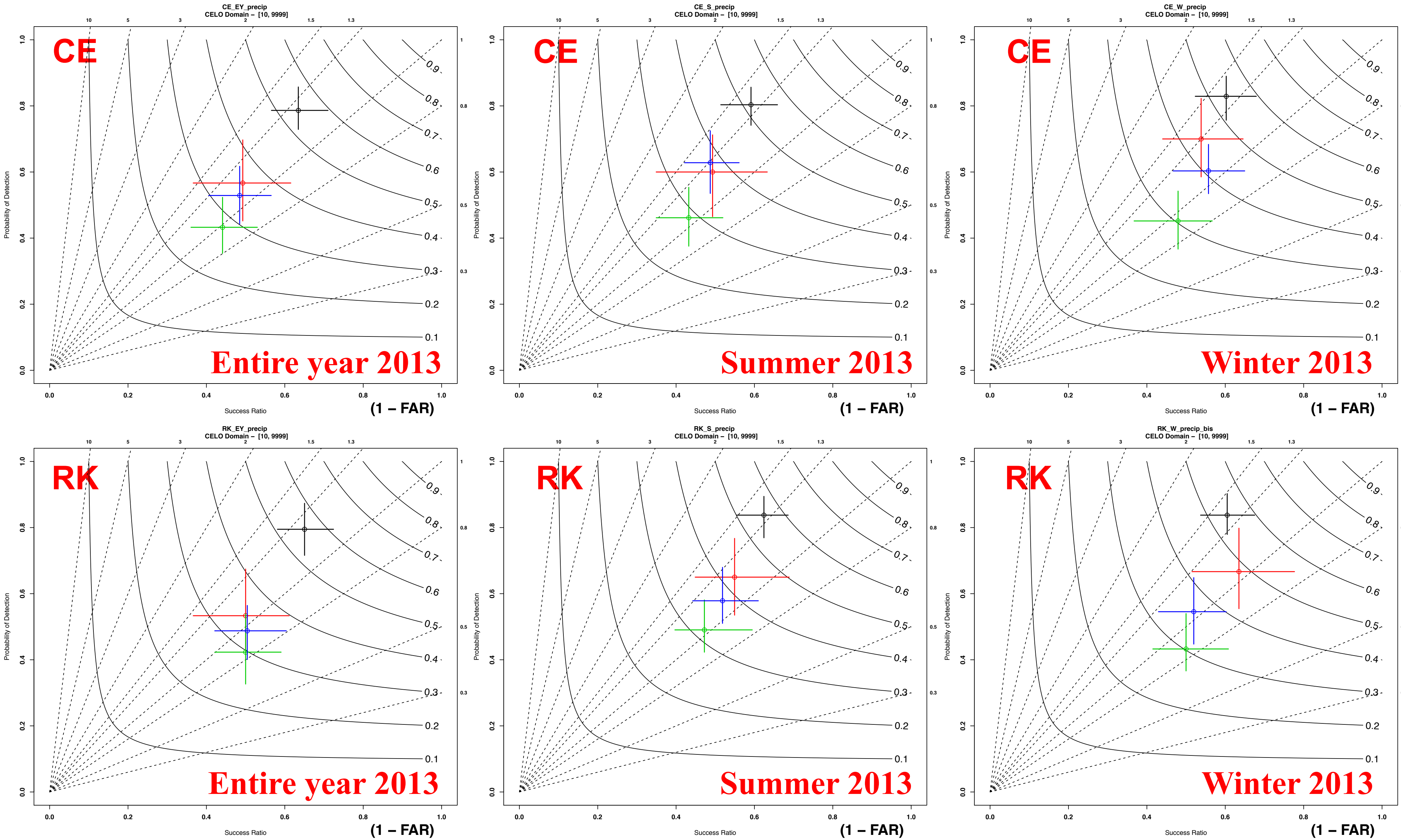
Precipitation - 5mm and more NOVEMBER



○ step 6 ○ step 12 ○ step 18 ○ step 24

Slightly larger Probability of Detection for Steps 12 and 18 in simulations with parameters optimized for the summer season.

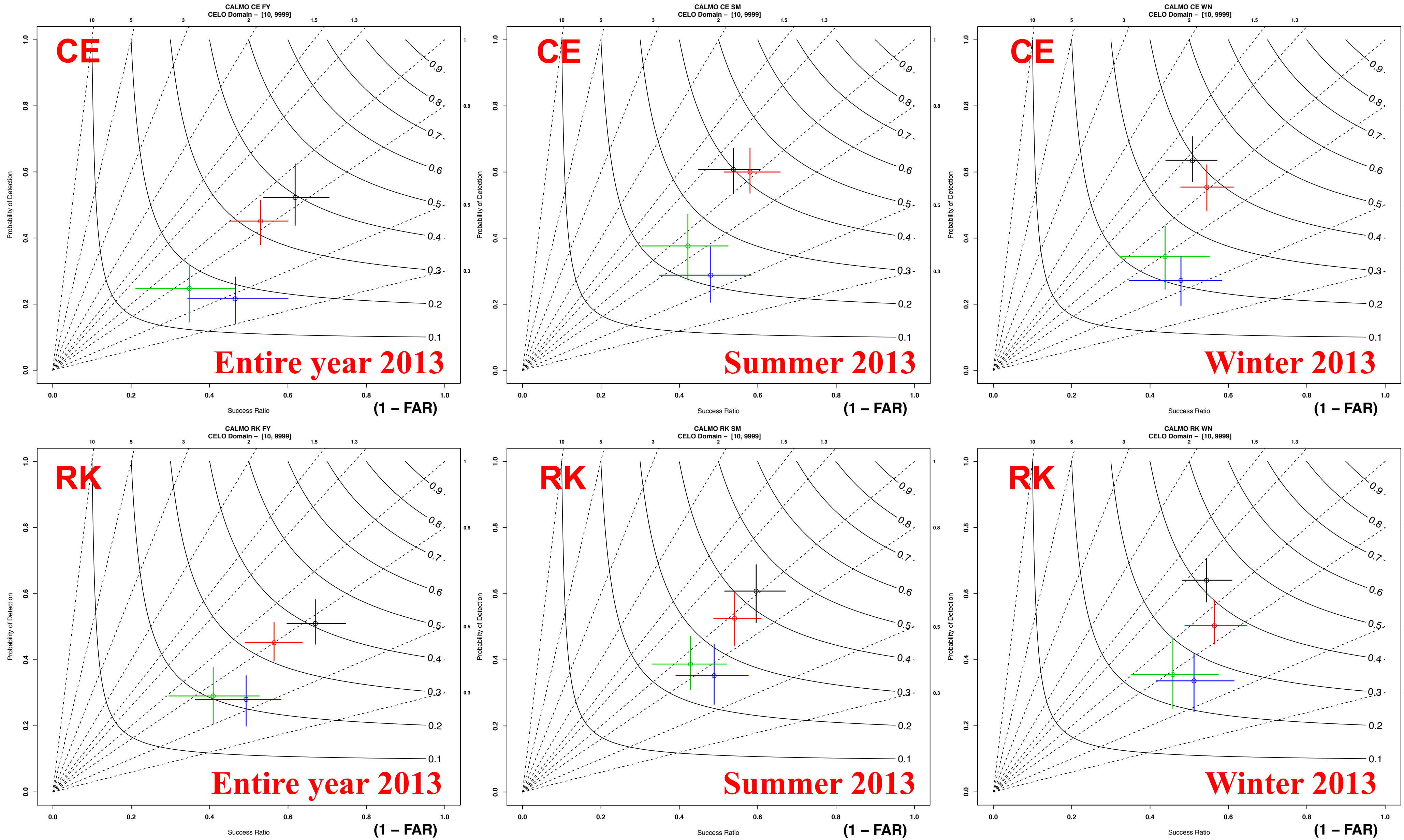
Precipitation - 10mm and more JUNE



○ step 6 ○ step 12 ○ step 18 ○ step 24

Precipitation statistics evolve (in time) in a similar manner both in RK and CE.
Larger uncertainty results from the rarity of stronger precipitation events.

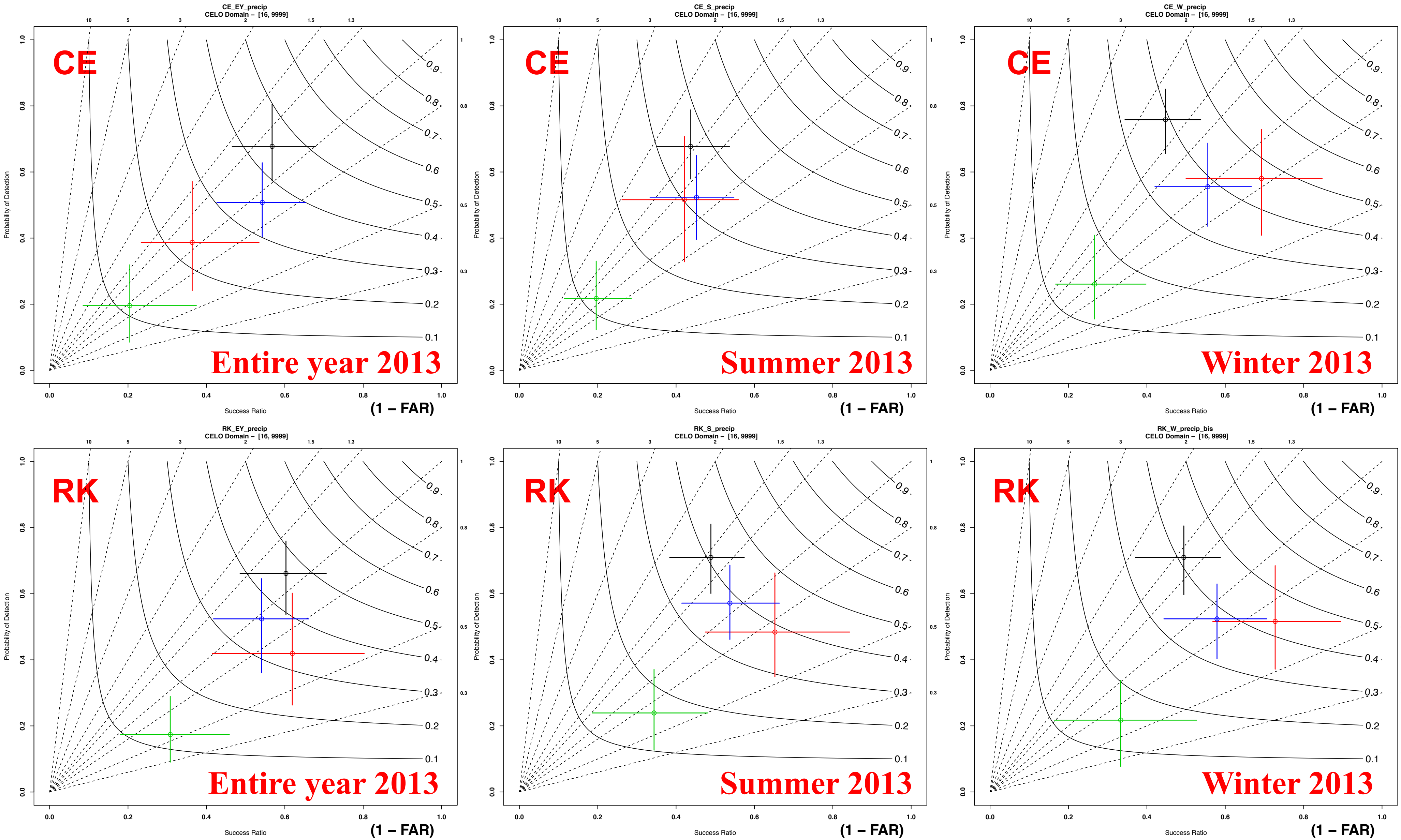
Precipitation - 10mm and more NOVEMBER



○ step 6 ○ step 12 ○ step 18 ○ step 24

Tuning for winter and summer results in slightly larger probability of detection.

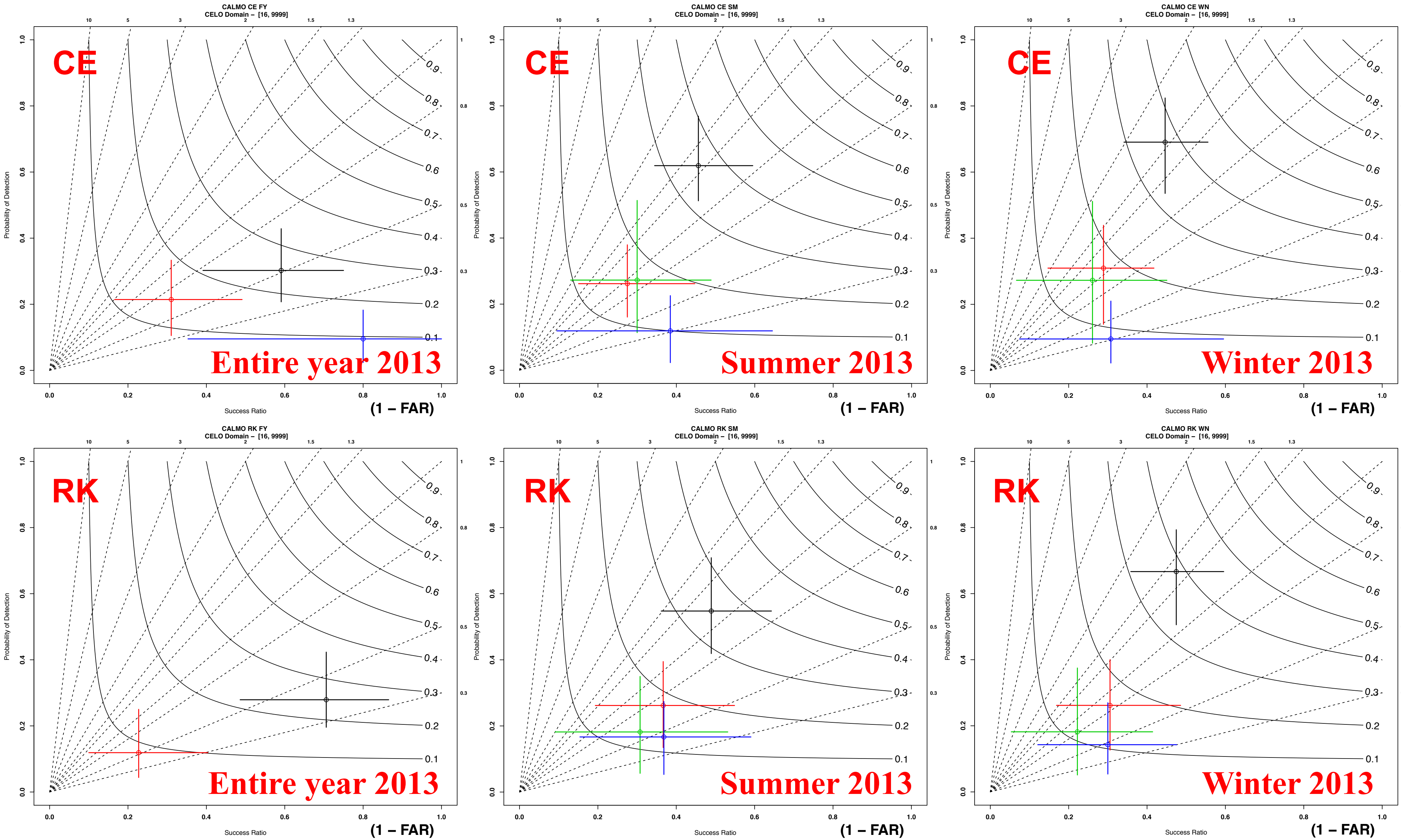
Precipitation – 16 mm and more JUNE



○ step 6 ○ step 12 ○ step 18 ○ step 24

Larger Success Ratio is observed in RK simulations with parameters tuned for winter and summer seasons

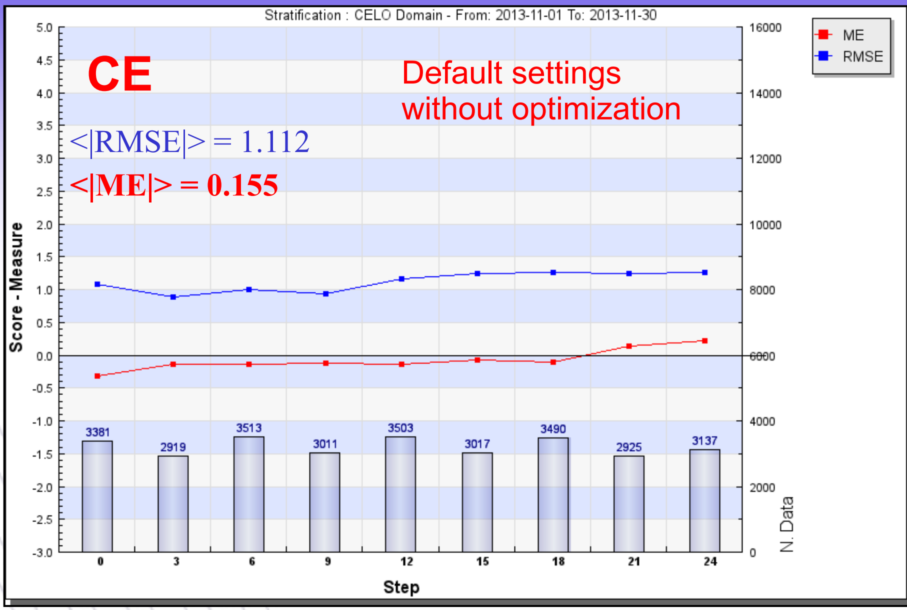
Precipitation – 16 mm and more NOVEMBER

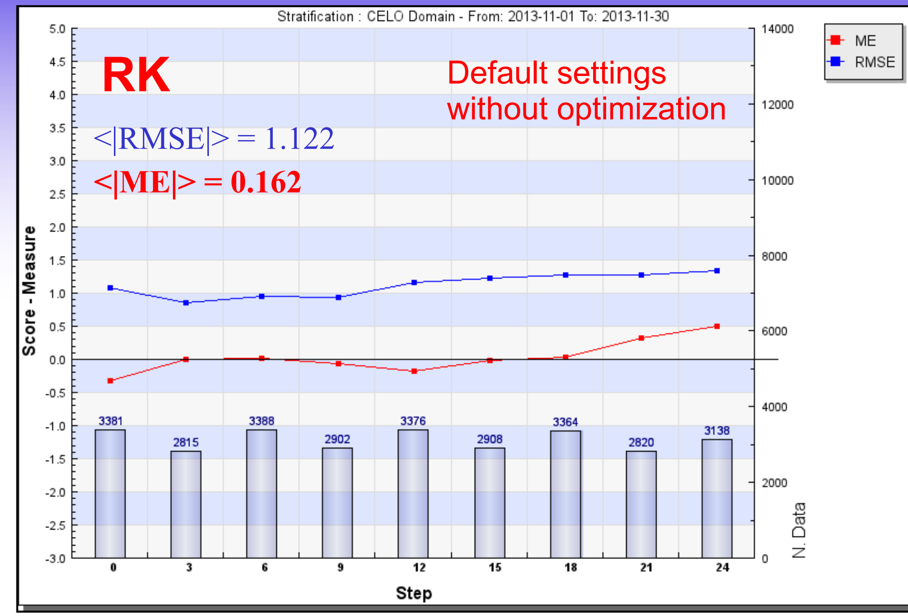


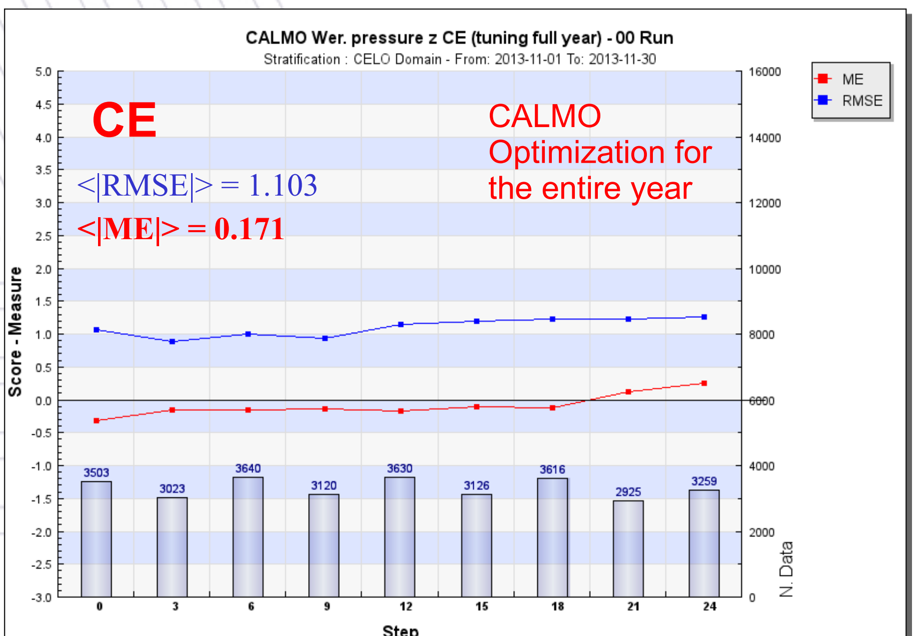
○ step 6 ○ step 12 ○ step 18 ○ step 24

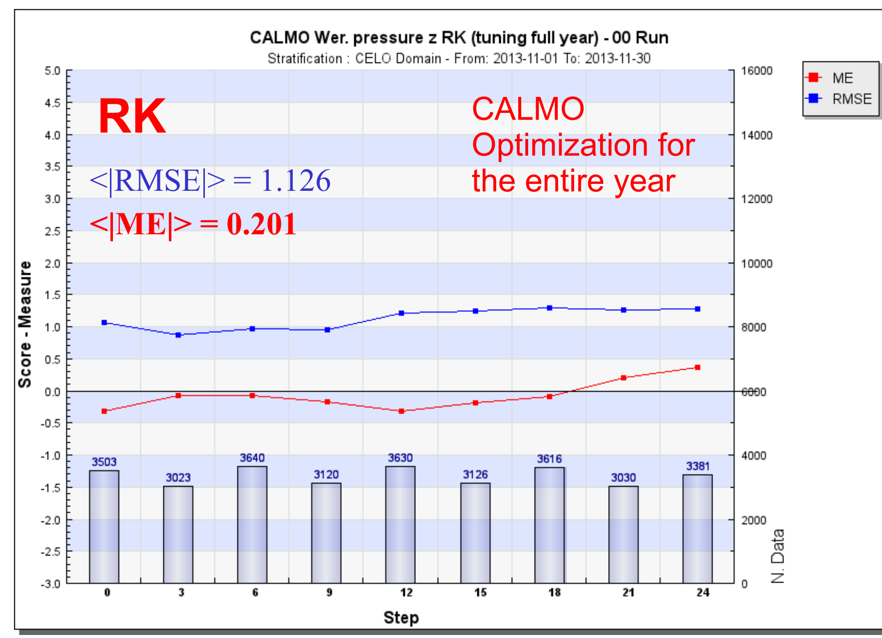
Results computed using parameters calibrated for winter and summer have smaller uncertainty and are closer in line with observations.

Pressure (hPa) – before and after tuning (November 2013)



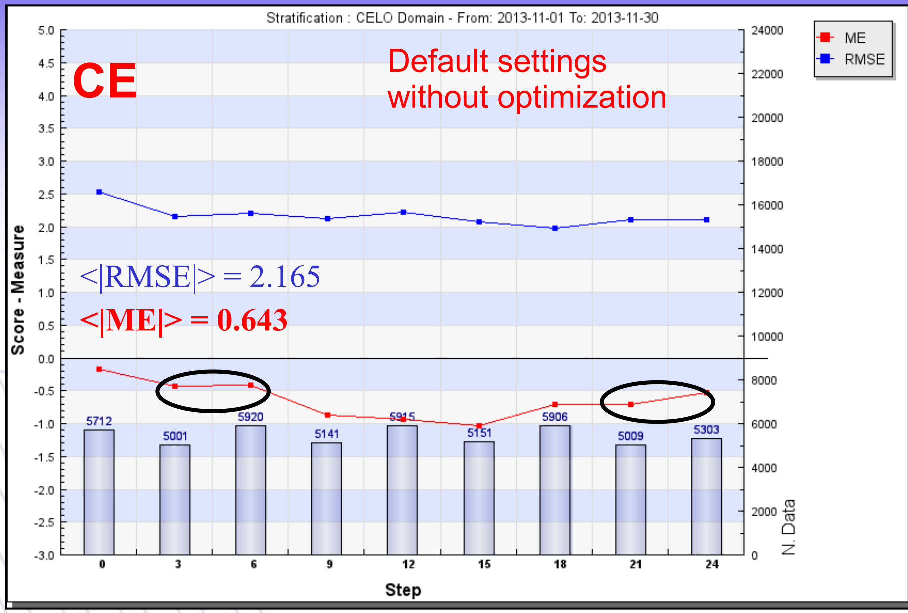


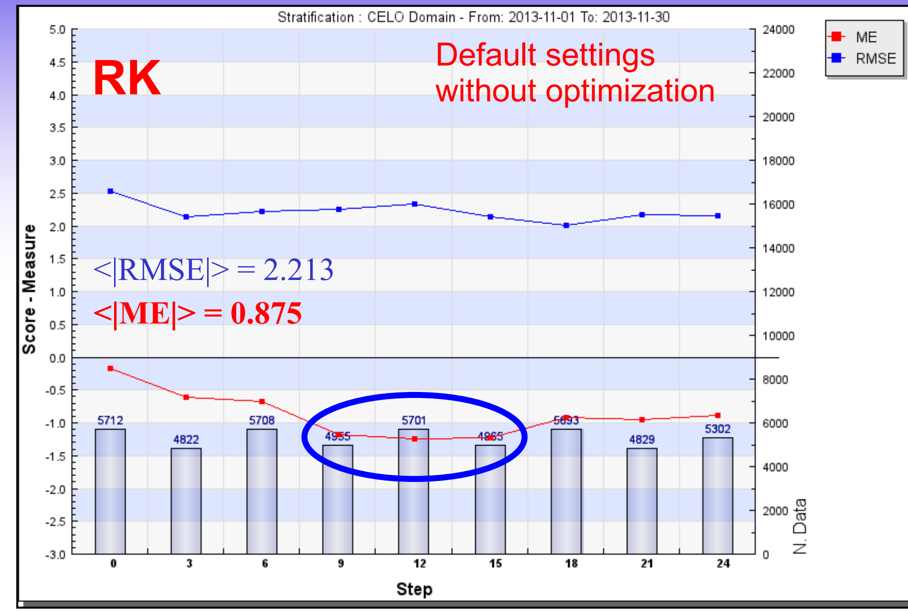


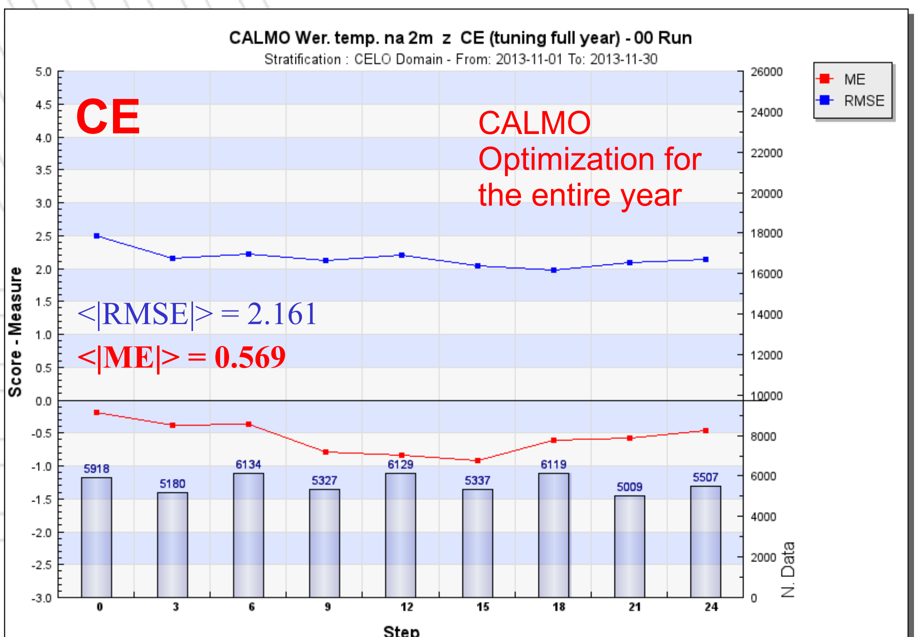


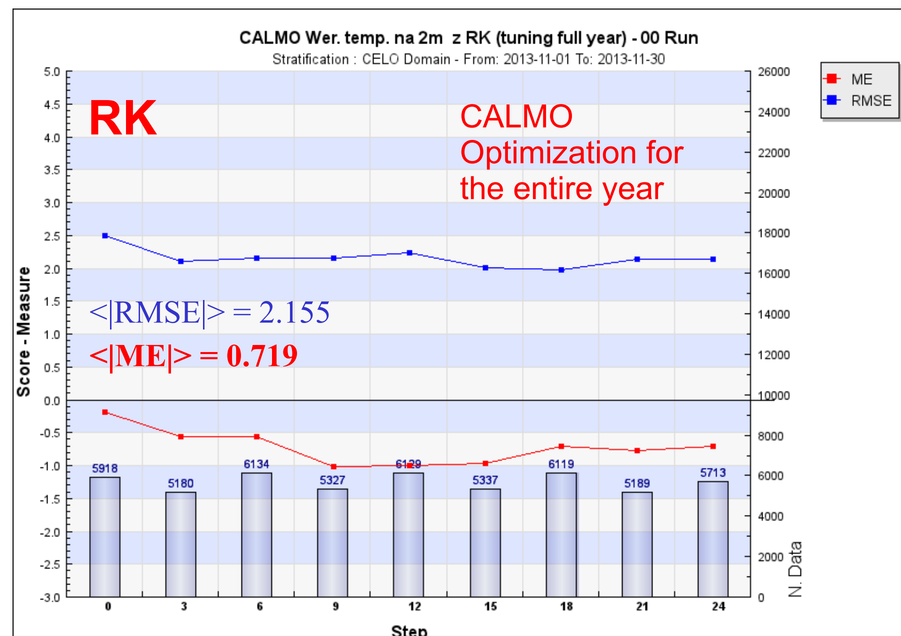
CALMO tuning (for the entire year) slightly deteriorates the simulation results both CE and RK. Namely, ME is larger while cumulative RMSE is on similar level.

Temperature (ºC) at 2 m – before and after tuning (November 2013)



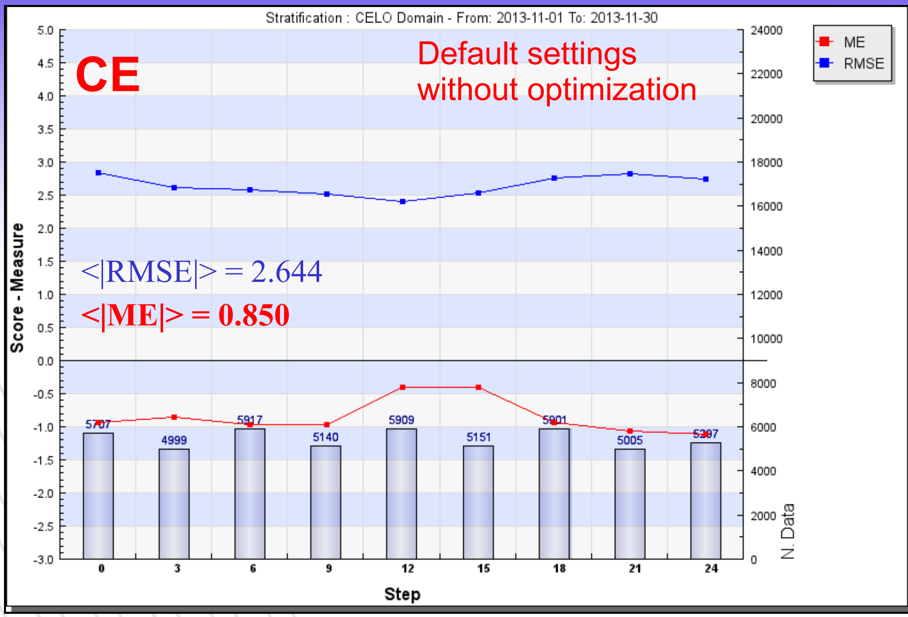


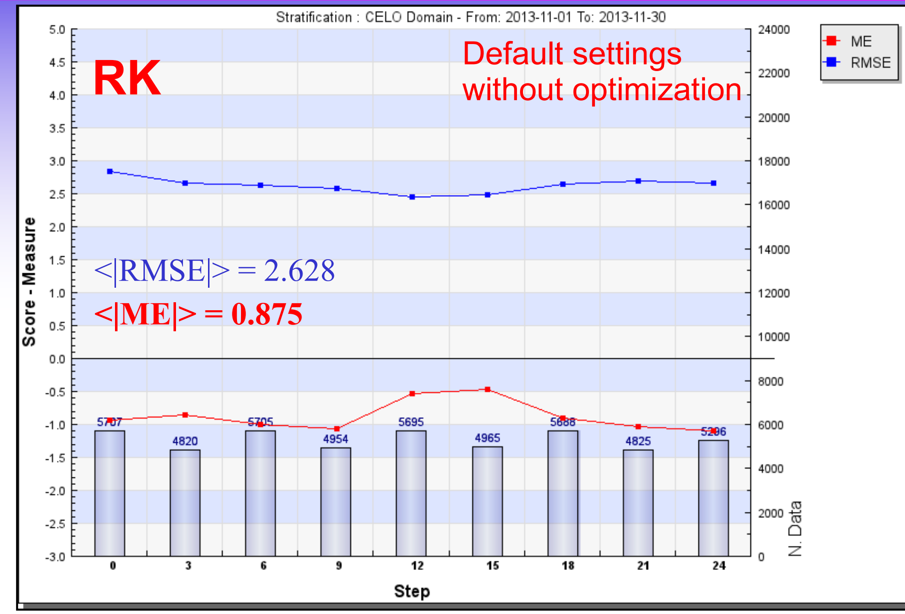


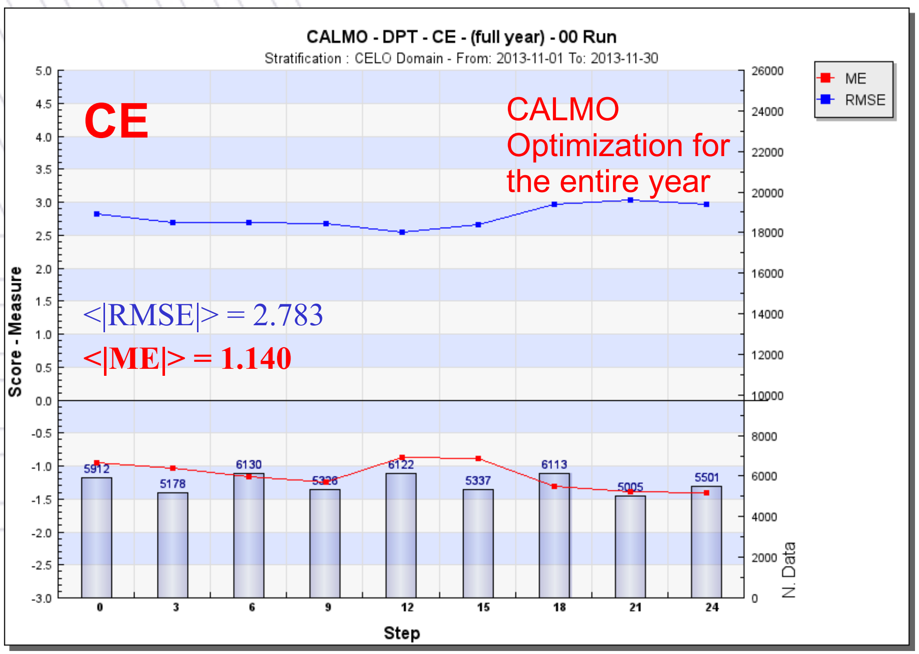


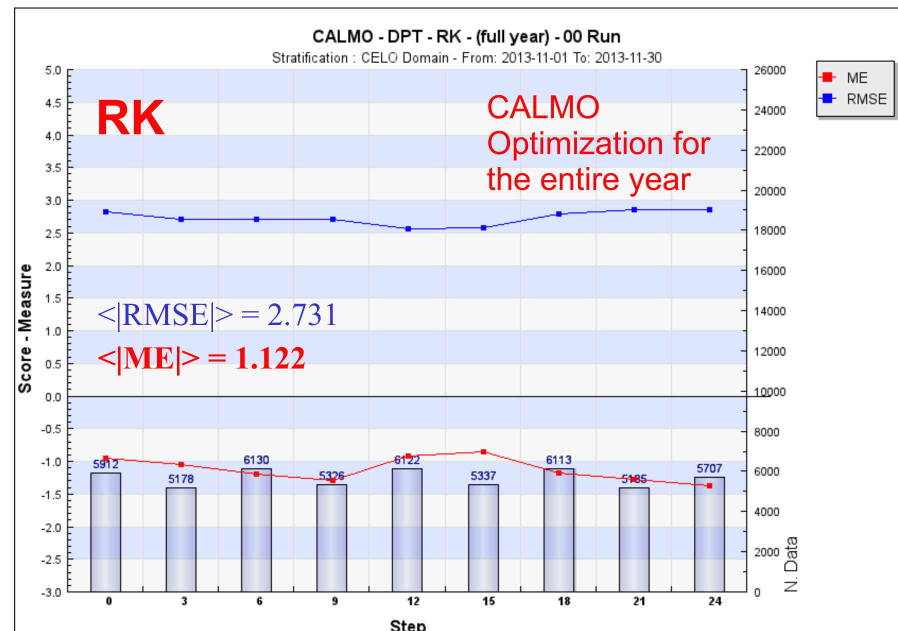
There is significant improvement of the temperature (at 2 m) forecast in simulations with optimized CALMO parameters – significantly smaller ME

Dew point temperature (ºC) at 2 m – before and after tuning (November)



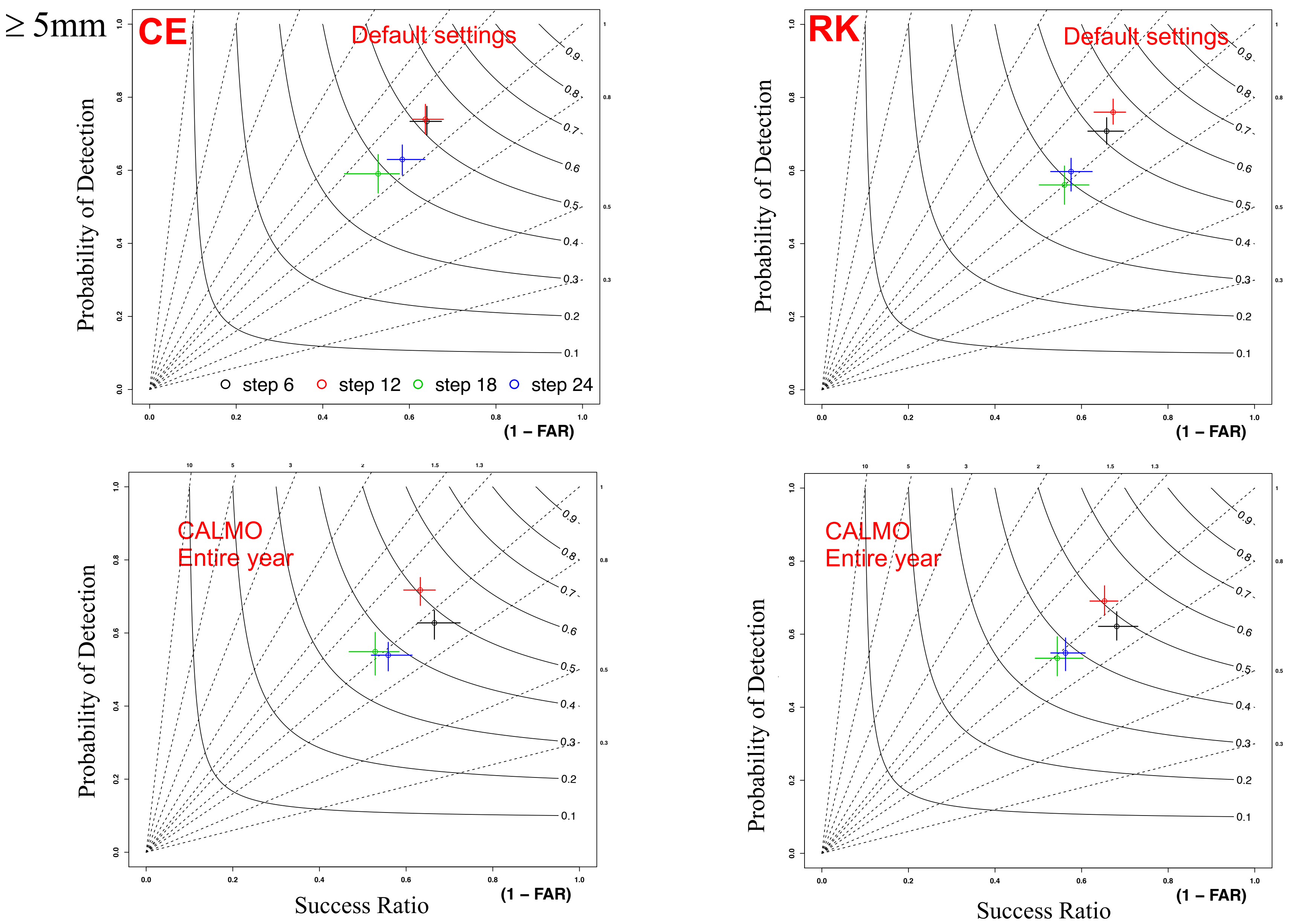






However, for the dew point temperature (2m), CALMO tuning deteriorates numerical results.

Precipitation – forecast verification before and after tuning



Probability of detection is slightly lower in simulations with tuned parameters. Nevertheless, the sensitivity of the statistics to the CALMO tuning is relatively low.

Conclusions

- **The EULAG model has been successfully coupled to the COSMO framework.**
- The aim of current study was tuning of the prototype model CE with parameterizations of COSMO ver. 5.01.
- In most considered cases we noticed very little difference between CE and RK results.
- Quantitative statistics of dynamical fields revealed stronger dependence of the numerical forecast to diurnal cycle – especially for June
- Coupling of the EULAG dynamical core with the soil model needs further investigation and optimization

Conclusions

- Optimized parameters derived within the CALMO PP allows to obtain more accurate forecast of temperature at 2 m for both June and November.
- CE numerical forecasts of wind at 10 m computed for June is closer to observation then the RK forecast. In turn, RK forecasts are closer to observation for November.
- Mean level surface pressure in CE numerical results is weakly sensitive to tuning and strongly dependent on diurnal cycle.
- Dew point temperature at 2 m is sensitive to mixing length. Best CE and RK forecasts have been obtained using parameters optimized for the summer season (both for June and November)
- Precipitation statistics evolve (in time) in a similar manner.
- Parameters tuned for the entire year results in lower probability of detection than default parameters. Better agreement with observations has been obtained for winter tuning.

THANK YOU FOR YOUR ATTENTION