Current status of the PP CELO - tuning of COSMO-EULAG, migration to COSMO V5.04h and verification

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INTRODUCTION

The compressible dynamical core of the fluid solver EULAG has been recently implemented into the COSMO framework. The new prototype model COSMO-EULAG (CE) employs the standard set of physical parameterizations adapted to the Runge-Kutta dynamical core. To date, a number of tests both idealized and realistic have been performed to validate the new CE model. Preliminary simulations were carried out using default values of the model parameters. The tests confirmed suitability of CE for modeling processes characteristic for mesoscale weather forecasts. The current efforts are focused on further optimization, testing and tuning of the CE model. As a starting point, we make use of the deliverables from the CALMO project. Within the project, model COSMO was calibrated and several key parameters were optimized. The new realistic simulations with CE are performed taking into account these tuned parameters. The new simulations are oriented towards modeling of mesoscale weather over complex Alpine topography.

CALMO – TUNED PARAMETERS

The calibration of the COSMO model was performed based on the daily (24 hours) forecasts for the entire year 2013. Two additional optimizations were done for the summer (Jul, Aug, Sep) and winter (Jan, Feb, Mar) seasons. The tuning was performed using mesh of horizontal resolution of 2.2 km and involves only six independent parameters. The parameters are highly sensitive to the verified fields. Their optimal combinations for each time period are given in the Table below. In the first column are default values.

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

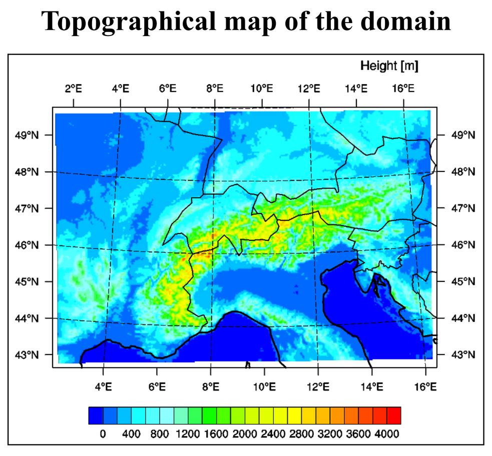
Brief definitions of the parameters. More details in [1,2]

rlam_heat – scaling factor for the thickness of the laminar boundary layer for heat.
tkhmin – [m^2/s] minimal diffusion coefficient for heat. Active in stable BL conditions.
tur_len – [m] maximal turbulent length scale
entr_sc – [m^{-1}] mean entrainment rate for shallow convection.
c_soil – surface-area index of the evaporating fraction of grid-points over land.
v0snow – factor in the terminal velocity for snow

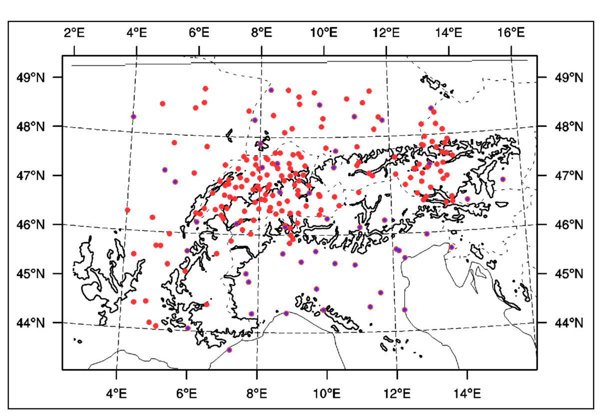
CE - FORCAST VERIFICATION

- Verification of the CE forecast was performed for the whole month - November 2013
- Simulations were carried out for each day separately (i.e. 24h forecast)
- 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.
- Horizontal step of the computational mesh is 2.2 km
- Computational domain - the standard operational COSMO-2 domain used by Meteo-Swiss with 60 vertical levels
- The simulations were performed using both CE and RK – for comparison
- Numerical forecasts were verified by comparing with observational data
- The verification was performed 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 2m) and precipitation
- As of the dynamical fields, we compare average (over the whole month) values of mean error - ME and root mean square error - RMSE

Topographical map of the domain



Station network for surface verification



EXPERIMENT SETTINGS

Dynamics:

- Numerical and Smagorinsky diffusion are *turned off* for Cosmo-Eulag and *turned on* for Cosmo Runge-Kutta
- 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
- 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)

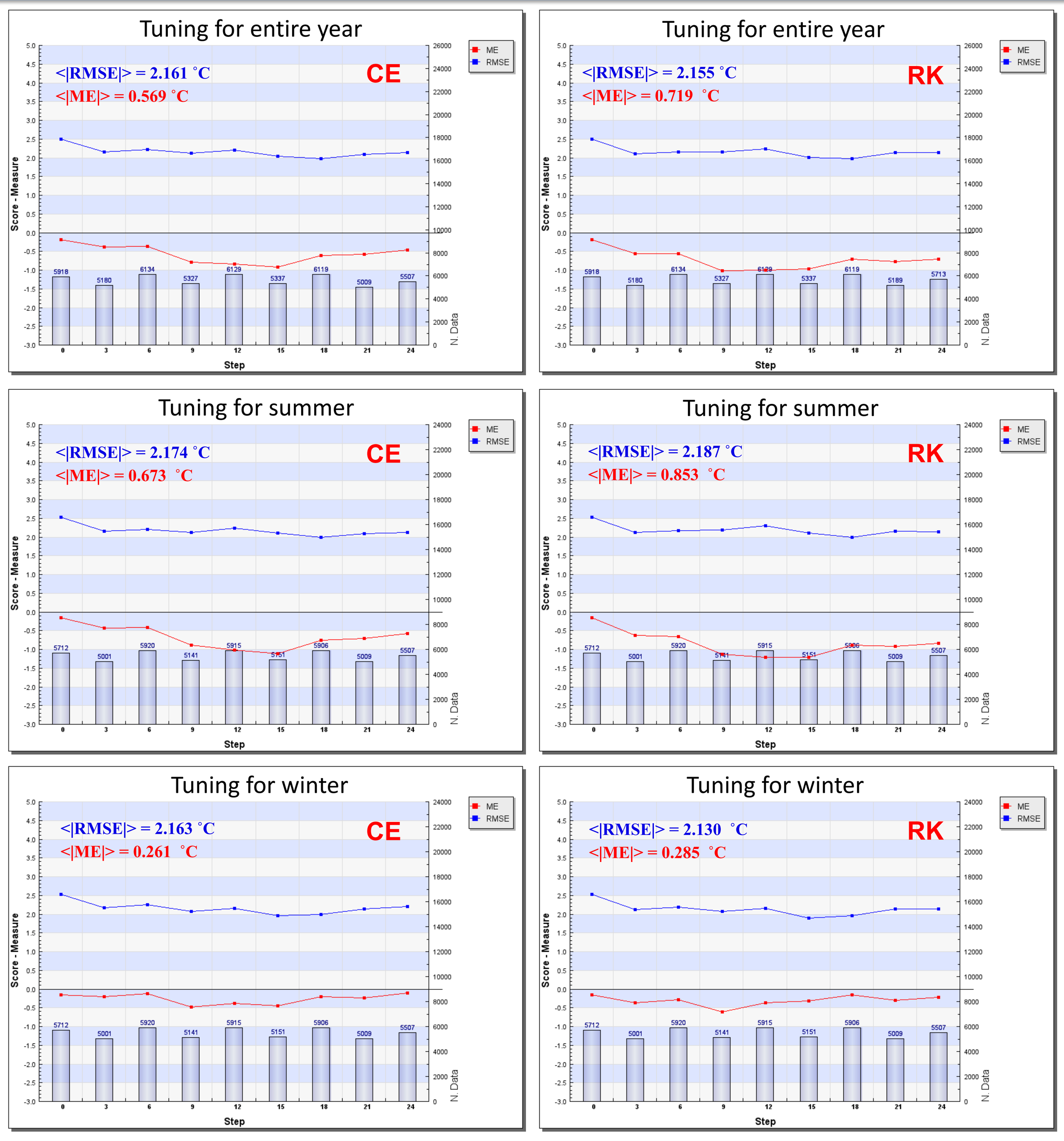
Turbulence and convection scheme:

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

Soil model:

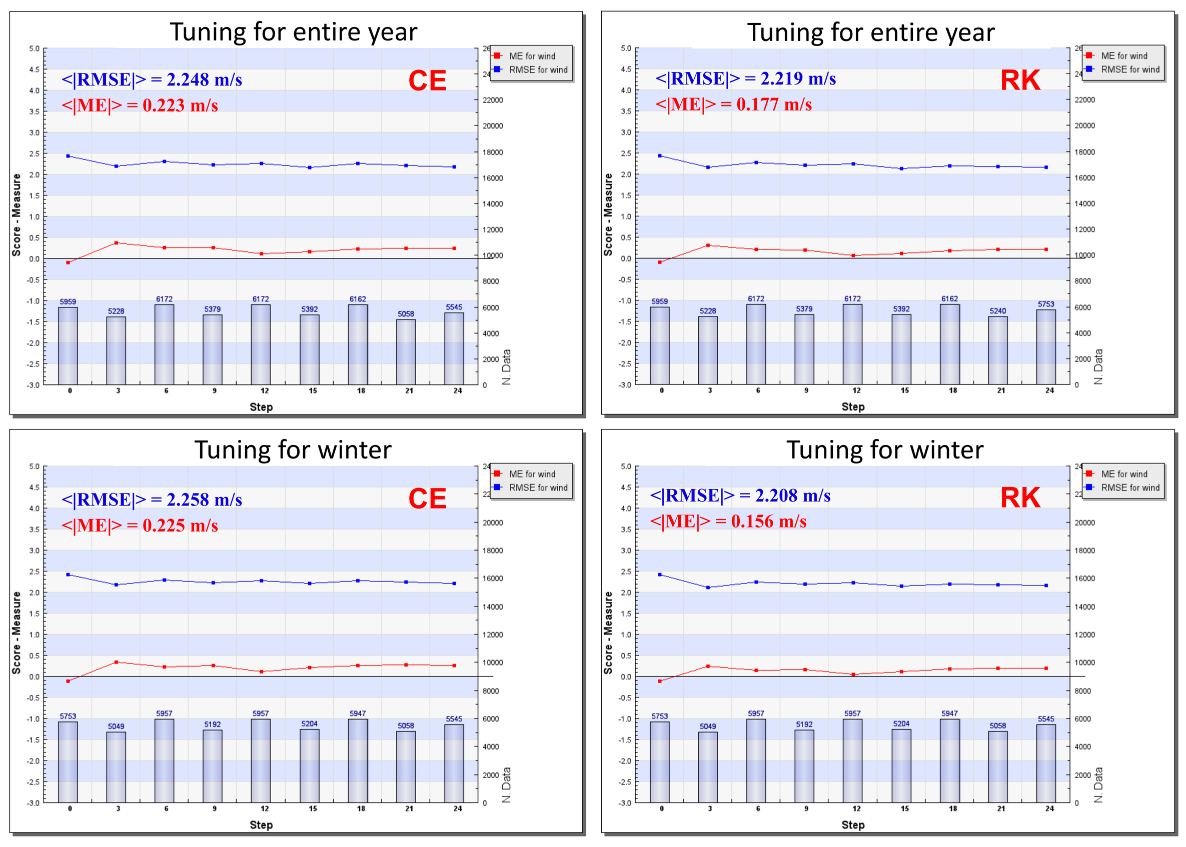
- Multi-layer soil model is used (*lsoil* = T, *lmulti_layer* = T, *lforest* = T)

TEMPERATURE AT 2m - FORECAST VERIFICATION



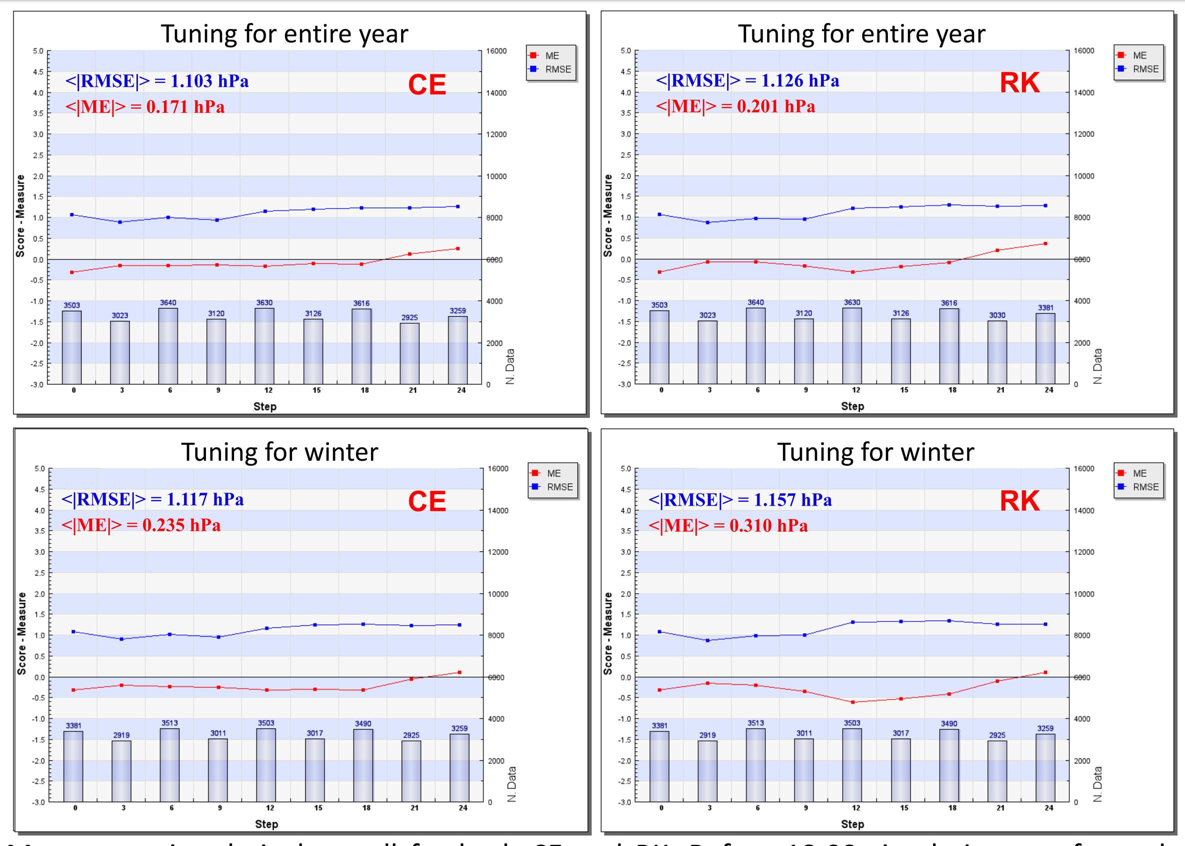
Results computed using CE are closer to observations than those computed with RK. The best scores (small ME) have been obtained using combination of parameters optimized for the winter season. Differences in RMSE are almost negligible.

WIND AT 10m



Numerical forecasts computed using both CE and RK are in close agreement with observations. The mean error (ME) is smaller for simulations performed with RK. CALMO tuning has little effect on the average statistics.

PRESSURE



Mean error is relatively small for both CE and RK. Before 18:00 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.

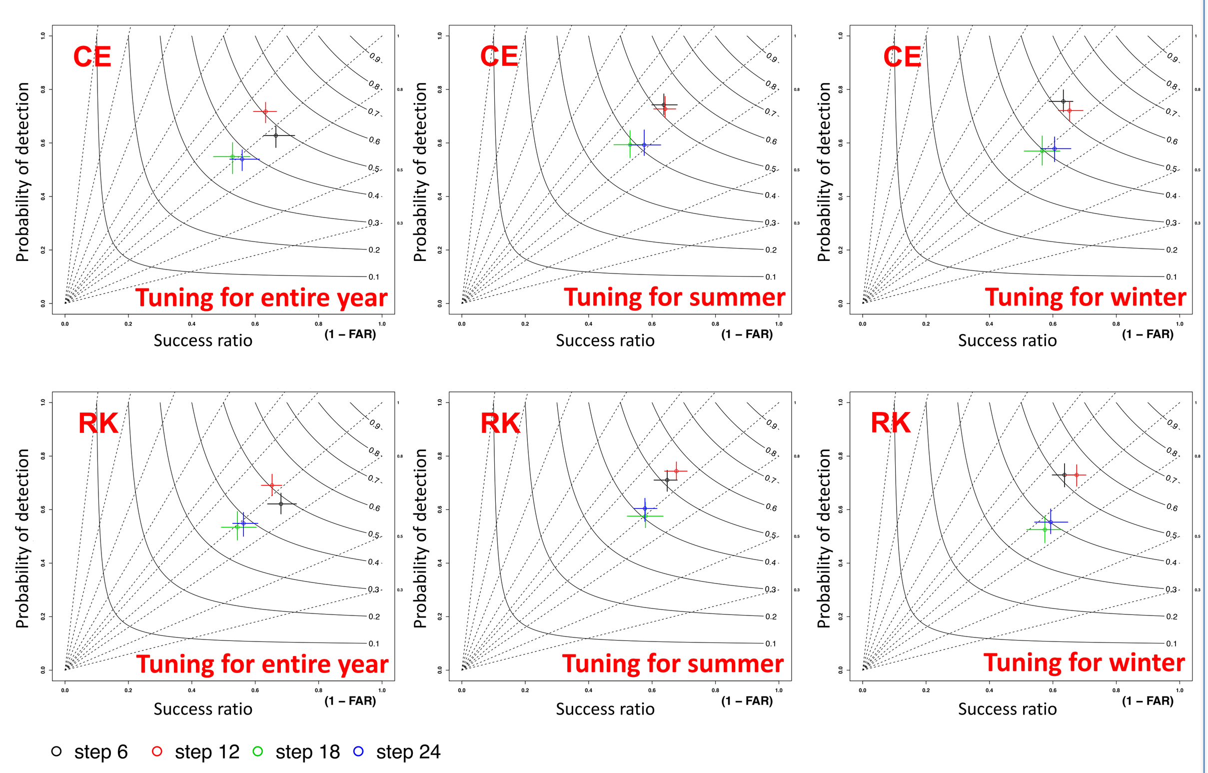
SUMMARY OF QUANTITATIVE COMPARISON

Mean error	Tuning for entire year		Tuning for summer		Tuning for winter	
	CE	RK	CE	RK	CE	RK
Pressure [hPa]	0.171	0.201	0.151	0.170	0.235	0.310
Wind [m/s]	0.223	0.177	0.204	0.164	0.225	0.156
Temperature [°C]	0.569	0.719	0.673	0.853	0.261	0.285
Dew point Temperature [°C]	1.140	1.122	0.772	0.774	1.925	1.909

RMSE	Tuning for entire year		Tuning for summer		Tuning for winter	
	CE	RK	CE	RK	CE	RK
Pressure [hPa]	1.103	1.126	1.121	1.146	1.117	1.157
Wind [m/s]	2.248	2.219	2.224	2.192	2.258	2.208
Temperature [°C]	2.161	2.155	2.174	2.187	2.163	2.130
Dew point Temperature [°C]	2.783	2.731	2.624	2.578	3.406	3.353

PRECIPITATION

Precipitation 5mm and more - forecast verification



Numerical results computed using CE and RK are in good quantitative agreement. The differences are in the range of statistical uncertainty. The results are weakly sensitivity to different sets of parameters.

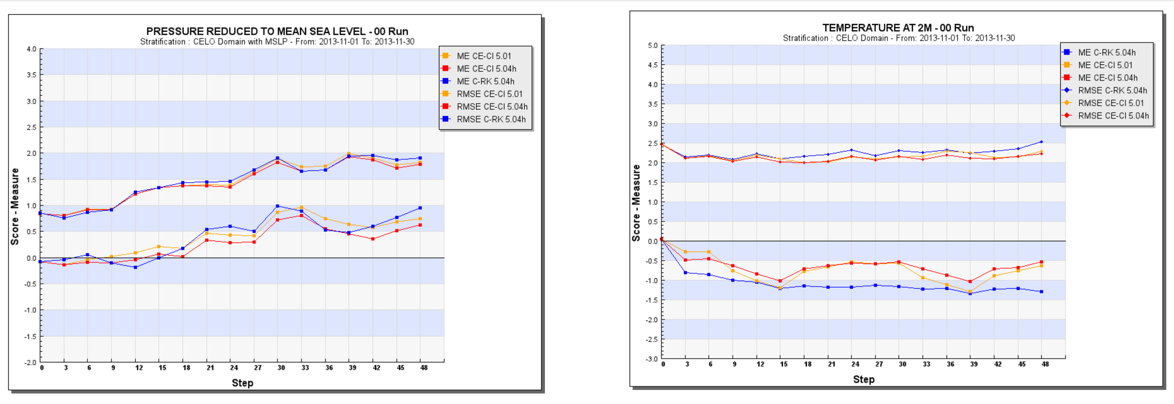
MIGRATION WITH EULAG DYNAMICAL CORE TO THE RECENT COSMO FRAMEWORK ver. 5.04h

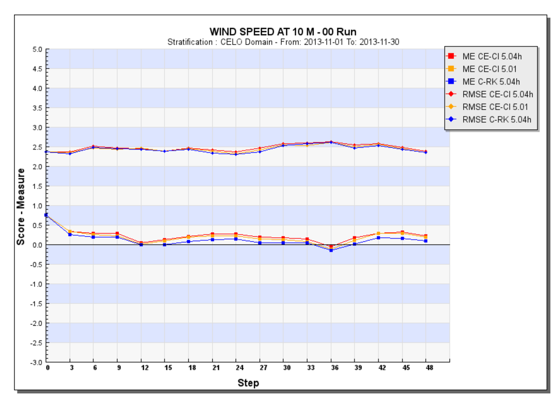
The original implementation of CE (compressible) has been developed based on the COSMO framework ver. 5.01 released in November 2014. The updated COSMO code (ver. 5.04h), released this year, contains number of structural changes and improvements. Therefore, a logical step is to couple the EULAG dynamical core with the most recent COSMO framework. It is expected that COSMO-EULAG will be officially released with COSMO ver. 5.06.

Migration to COSMO ver. 5.04h enforces several modification in the EULAG code. With respect to [3] some missing properties need to be introduced. These include:
- strict checking of return codes from system and MPI functions
- introducing of the INTENT attribute across the code
- employing of COSMO templates for the subroutines and modules
- introducing of the working precision parameter for the EULAG modules

For the final checking of memory consistency within EULAG modules the Valgrind toolkit will be utilized.
Handling of block-data structure is carried out by the COSMO framework only.

COMPARISON OF NUMERICAL FORECASTS BEFORE AND AFTER MIGRATION





Figures present verification scores (bias and RMSE) for 48 hour forecast of CE implemented into COSMO V5.01 and V5.04h and compare them with native COSMO V5.04h.

Both mean sea level pressure and temperature (at 2m) computed using CE, based on the most recent version of COSMO 5.04h, are closest to observations.

There is some overestimation of surface wind velocity (at 10 m) in CE.

RESTART FUNCTION

Ongoing technical developments carried out within the CELO project include implementation of the restart package for the CE code. The default routines of COSMO are not sufficient since EULAG uses different dynamical fields than the standard Runge-Kutta dynamical core. These additional fields, as well other parameters and extra variables need to be stored. New tools for I/O operations will be synchronized with original COSMO modules [3]. All additional data will be saved in the same binary file. The simulation results should be the same regardless of the number of sub-runs.

The restart package is necessary for performing long time climate simulations, and complex weather forecasting using high-resolution grids.

CONCLUSIONS

The EULAG model has been successfully coupled to the COSMO framework. The aim of current study was tuning of the prototype model.

- In most considered cases we noticed very little difference between CE and RK results.
- Optimized parameters derived within the CALMO PP (especially for winter) allows to obtain accurate forecast of temperature at 2m.
- The best agreement with observations but not for the dew point temperature was obtained in simulations with optimized parameters for the winter season.
- There is little effect of CALMO tuning on surface pressure and wind at 2m.
- Precipitation statistics evolve (in time) in a similar manner.
- Parameters tuned for winter season results in larger probability of detection.
- Numerical forecasts computed using the most recent version of CE (based on COSMO 5.04h) are closer to observation than those computed using former model.

REFERENCES

[1] CALMO – progress report at www.cosmo-model.org. Bookmark: COSMO Tech Reports
[2] http://www.cosmo-model.org/content/model/documentation/core/cosmoUserGuide.pdf
[3] COSMO Standards for Source Code Development Ver. 1.4, Ulrich Schaettler, August 2017[4]