COSMO Priority Project CALMO : Calibration of COSMO Model

Version 1.0, 23.01.2013

Project leader : **A.Voudouri / HNMS**

Project duration : **01.2013 – 12.2014**

Project resources : **2.35 FTE**

Contributing scientists :

O.Bellprat / ETHZ [1]	**2013*: 0.46 FTE 2014: 0.2 FTE**
A.Voudouri / HNMS	**2013: 0.63 FTE 2014: 0.7 FTE 2015: 0.2 FTE**
F. Grazzini / ARPA-SIMC	**2013: 0.1 FTE**
J.-M. Bettems / MeteoSwiss	**2013: 0.02 FTE 2014: 0.02 FTE 2015: 0.02 FTE**

*(2013 refers to COSMO year 01.2013-09.2013, 2014 refers to COSMO year 09.2013-09.2014 and 2015 refers to COSMO year 09.2014-12.2014)

This priority project is assigned to Working Group 3b

Summary

Many unconfined parameters exist in COSMO, but the 'expert tuning' done within the development process is for a certain target area and for a certain model configuration; and it is questionable if this calibration is still optimal for different target regions or other model configurations. Therefore an automatic, multivariate, 'objective' calibration of those parameters could be beneficial to the quality of the model configurations used by the different COSMO members and could accelerate the further development of the model, in particular when introducing significant new developments (e.g. EULAG). Furthermore a better understanding of the sensitivity of the model quality in the parameter space could also benefit the perturbation of an EPS when using stochastic physics.

Such an objective calibration method has been developed by O.Bellprat at ETHZ for the COSMO-CLM [1, 2] and has shown to be at least as good as an expert tuning. The optimal was also found to be close to the COSMO-EU configuration, hinting to a low dependency of the calibration results with respect to the computation mode (climate or weather).

[1] O.Bellprat is a PhD student of Prof. Ch. Schär who has developed the calibration method for the COSMO-CLM.

It is the goal of this project to adapt the method developed at ETHZ – with the contribution of the involved scientist – and to assess the impact of such a calibration on the forecast quality when using different target areas.

Motivation

The Institute of Atmospheric and Climate Science (ETHZ) has applied an objective calibration method for regional climate models using a quadratic meta model presented in Neelin et al. (2010) [3] on the COSMO-CLM. After having recognized key model parameters, and defined a representative performance score, a cost effective meta-model describing a measure of the model quality in the space spanned by these model parameters can be defined. The calibrated parameters are then obtained by finding the maxima of the meta-model in the parameters space with standard mathematical methods. The definition of the meta model requires relatively few COSMO model runs and makes this approach practicable (e.g. for 5 unknown parameters about 20 model runs are necessary which means about 100 years of COSMO simulation time).

The calibration allowed the reduction of model error of an expert tuned COSMO-CLM model by about 10% using at the same time much less human resources. The optimal was also found to be close to the COSMO-EU configuration, hinting at a low dependency of the calibration results with respect to the computation mode (climate or weather). The use of such an objective method is attractive due to the high efficiency, wide calibration range and transparency of the method. Moreover the expert knowledge required for an expert tuning is not always readily available, which can hinder the development process.

This Priority Project will assess the practicability of the calibration framework developed at ETHZ for NWP applications, and then implement the necessary adaptations. The adapted method will then be used to evaluate the sensitivity of the optimal parameters to the choice of the target region (e.g. N. Europe, Alps, and Mediterranean) and to assess a possible model quality gain with respect to the default configuration. A software package and a complete documentation will be made available to the whole COSMO community at the end of the project.

The developed tools and methodology could be used later on by each COSMO member to define an optimal calibration over the target area of interest, for re-calibration after core model changes (e.g. EULAG, higher resolution), as well as for a fair assessment of different modules (e.g. TERRA and CLM), and for optimal perturbation of parameters in EPS.

Actions proposed

- Preliminary work (e.g. acquire computing resources) (Task 1)
- Adaptation of the existing method for NWP applications (Task 2)
- Sensitivity of optimal parameters to the choice of the target region (Task 3)
- Define optimal methodology in terms of computing time and quality gain (Task 4)
- Documentation, including scientific paper (Task 5)

Main deliverable:

1. Answer to the question: “How practicable is the calibration framework developed at ETHZ for NWP applications? Which adaptations are necessary?”
2. Answer to the question: “How sensitive is the optimal parameters set with respect to the model domain? Any gain in model quality observed?”
3. Tools and documentation for applying the developed methodology.
4. Peer reviewed scientific paper.

Description of individual tasks

Task 0: Administration and support

Due to the distributed nature of the project team, a particular effort will be necessary to keep a good information flow between all participants (e.g. by organizing regular phone or web conferences).

Deliverables:

(1) Project coordination, meeting and web conference organization

Estimated resources:

J.-M. Bettems / MeteoSwiss 2013: 0.02 FTE, 2014: 0.02 FTE, 2015: 0.02 FTE

A.Voudouri / HNMS : 2013: 0.06 FTE, 2014: 0.05 FTE, 2015: 0.05

Task 1: Preliminary work

Literature survey and knowledge transfer between contributing scientists belongs to this task. The computing resources for tasks 2 and 3 should also be guaranteed during this phase of the project.

This task is divided into the following sub-tasks:

1.1: Literature Survey
Literature survey of relevant scientific papers, in particular with respect to the choice of the statistical measure (performance score). In order to proceed with the selection of related NWP variables, discussions with/or relevant references obtained from scientists responsible for the parameterization schemes is required.

1.2: Knowledge transfer
This task includes interaction among the contributing scientists regarding the implementation of the CCLM method in COSMO for NWP. A meeting will be organized early on in the project.

1.3: Technical Infrastructure
Estimate and acquire necessary computing resources for model simulation. Installation of COSMO model, Neelin meta-model, statistical package, and any other required tools on the available machines.

Deliverables:

(1) A list of papers related to key model parameters, variable selection and quantification of model performance.
(2) A working technical framework for performing objective model calibration.

Estimated resources:

A.Voudouri / HNMS : 2013 0.12 FTE, 2014 0.10

O.Bellprat / ETHZ: 2013 0.12 FTE

Task 2: Adaptation of the method

This task touches the scientific aspects of the project, and aims to answer the following questions: “How practicable is the calibration framework developed at ETHZ for NWP applications?” and “Which adaptations are necessary?”

A (non exhaustive) list of aspects to consider are:

- Which performance function (verification score)? How robust is the performance ranking with respect to this choice?
- Parameters subspace to consider (convection resolving scale and convection parameterization scale)?
- Which base configuration (initial condition of the soil, data assimilation or none, simulation length)?

This task is divided into the following sub-tasks:

2.1: Documentation of tuning parameters and choice of parameters subspace
Compile a document listing all tuning parameters in the model, with a short documentation of the meaning, the default value, the allowed range, the model sensitivity, and any other useful information. The choice of the parameter subspace to consider for the optimization process will be made on the basis of this document.

2.2: Selection of performance function(s)
Standard statistical measures such as the RMSE, BIAS or frequency BIAS, linear correlation coefficient, Brier Score will be evaluated. Additional multivariate skill scores, such as those used in different weather services for monitoring the quality of the model, will also be envisaged. Support of WG5 is expected.
A couple of alternatives will be proposed to measure the robustness of the optimum with respect to the choice of the performance function.

2.3: Identification of key-variables for NWP
Implementation of the CCLM method in COSMO for NWP requires identification of the key variables on small scale physical processes, such as 2m Temperature, MSL

pressure etc for which performance functions will be applied. Following results of task 2.1, parameters mainly affecting these variables will be considered for calibration.

2.4: Experimental set-up.
The configuration of a single model run has to be defined: base model configuration, domain size and location, initial condition of the soil, data assimilation or free run, simulation length.
The type of experiments to compute will then be defined, with regard to the scientific questions to answer, taking into account the limitations due to the computing resources. A trade-off has to be found between the domain size, the length of a simulation, the number of simulations used to define the meta-model, the size of the parameter subspace.

2.5: Collection of data
Lateral boundary conditions and observations will be collected.

2.6: Compute experiments and analyse results
Compute N COSMO model integrations to specify the meta-model and use the meta-model to find the optimum, according to the specifications made in 2.4.
Because these integrations will take a lot of elapsed time, it is important to well coordinate the different experiments and the other tasks.

Deliverables:

(1) A documentation of the tuning parameters in the COSMO model.

(2) The definition of a performance function applicable on NWP.

(3) The documentation of the experimental set-up.

(4) A scientific discussion of the results obtained.

(5) A scientific paper based on (3) and (4).

Estimated resources:

A.Voudouri / HNMS : 2013: 0.25 FTE, 2014 0.10

O.Bellprat / ETHZ: 2013: 0.29 FTE, 2014 0.05

F.Grazzini / ARPA-SIMC 2013: 0.1FTE

Task 3: Sensitivity with respect to target region

The goal here is to apply the results of task 2 to answer the following questions: “How sensitive is the optimal parameters set with respect to the model domain?” and “Is any gain in model quality observed in comparison with the standard configuration?” This task could also be used as a test bed to refine the developments of task 2. Depending on the computing resources, one or two target areas could be used (e.g. Alps, Mediteranean).

It will start after the end of Task 2 and will be divided into:

3.1: Application of the method over different regions
COSMO re-calibration over one (or two) target areas will be performed in order to evaluate the sensitivity of the optimal set of coefficients with respect to the target domain.

3.2: Analyse results

Model results will be analysed and gain of meteorological quality when using the optimal configuration against the standard configuration will be examined.

Deliverables:

(1) Definition of an optimal model configuration in terms of simulation length/period, initial conditions (soil) and data assimilation.

(2) Dissemination of analysis results to be discussed among scientific groups responsible on model development.

Estimated resources:

A.Voudouri / HNMS : 2013 0.20 FTE 2014 0.15

O.Bellprat / ETHZ: 2013 0.05 FTE

Task 4: Practicability of the method

This task aimed at finding a compromise between the forecast quality gain and the computing cost of the method. Amongst the aspects to consider are the length of each single simulation, the possibility to use a standalone SVAT to reduce the soil spin-up, the effect of the resolution.

Start after the end of tasks 2 and 3, in 2014.

Deliverables:

(12.2014) Practicable methodology in terms of computing resources, associated tools.

Estimated resources:

A.Voudouri / HNMS : 0.25 FTE (2014)

Task 5: Documentation

Publish scientific results of the project in a peer reviewed journal on the basis of the task 2 (and 3 if the associated results are available soon enough).

A complete description of the methodology, including a ‘cookbook’ to facilitate the usage of this method by other COSMO members, will be made available in a COSMO Technical Report.

Deliverables:

(01.2014) Peer reviewed scientific paper

(12.2014) Technical description of the method, including ‘cookbook’, final report

Estimated resources:

A.Voudouri / HNMS: 2014: 0.20 FTE,

O.Bellprat / ETHZ: 2014 0.15 FTE

Risks

One goal of the project is to show that the method which has been successfully applied to the COSMO-CLM can be adapted for NWP applications. There is the risk that either the benefit on the forecast quality is not significant in this case, or that the method is prohibitively expensive in terms of computing time.

Links to other projects or work packages

WG5 for the choice of the performance function.

WG2 and WG3a for the documentation of the model parameters.

References

[1] Bellprat, Omar, Sven Kotlarski, Daniel Lüthi, Christoph Schär: Objective calibration of regional climate models. J. Geophysical Research (*submitted*)

[2] Bellprat, Omar, Sven Kotlarski, Daniel Lüthi, Christoph Schär, 2012: Exploring Perturbed Physics Ensembles in a Regional Climate Model. J. Climate, 25, 4582-4599

[3] Neelin J. D., Bracco A. ,Hao Luo, McWilliams J. C., and Meyerson J.E. 2010, Considerations for parameter optimization and sensitivity in climate models. Proceedings of the National Academy of Sciences of USA, 107 (50), 21349 21354

Task	Contributing scientist(s)	FTE- years	Start	Deliverables	Date of delivery	Preceding tasks
0	Antigoni Voudouri (HNMS) Jean-Marie Bettems (MeteoSwiss)	0.06-2013 0.05-2014 0.05-2015 (**0.16 HNMS**) 0.02-2013 0.02-2014 0.02-2015 (**0.06 Meteoswiss**)	01.2013	(1) Project coordination, meeting and web conference organization, support	12.2014	
1	Antigoni Voudouri (HNMS) Omar Bellprat (ETHZ)	0.12-2013 0.10-2014 (**0.22 HNMS**) **0.12** (ETHZ)		(1) A list of papers related to key model parameters, variable selection and quantification of model performance. (2) A working technical framework for performing objective model calibration.	09.2014	
2	Antigoni Voudouri (HNMS) Omar Bellprat (ETHZ) Frederico Grazzini (ARPA)	0.25-2013 0.10-2014 **(0.35 HNMS)** 0.29-2013 0.05-2014 **(0.34 ETHZ)** **0.10 (ARPA)**	01.2013	(1) A documentation of the tuning parameters in the COSMO model. (2) The definition of a performance function applicable on NWP. (3) The documentation of the experimental set-up. (4) A scientific discussion of the results obtained. (5) A scientific paper based on 3 and 4.	01.2014	1
3	Antigoni Voudouri (HNMS) Omar Bellprat	0.20-2013 0.15-2014 **(0.35 HNMS)**	02.2014	(3) Definition of an optimal model configuration in terms of simulation length/period, initial conditions (soil) and data assimilation.	11.2014	2

	(ETHZ)	**0.05 (ETHZ)**		(4) Dissemination of analysis results to be discussed among scientific groups responsible on model development.		
4	Antigoni Voudouri (HNMS)	0.20-2014 0.05 2015 (**0.25 HNMS**)	09.2013	Practicable methodology in terms of computing resources, associated tools.	12.2014	2(, 3)
5	Antigoni Voudouri (HNMS) Omar Bellprat (ETHZ)	**0.20 (HNMS)** **0.15 (ETHZ)**	09.2014 09.2013	Technical description of the method. Peer reviewed scientific paper.	12.2014 01.2014	4 2(, 3)