Consortium

for

Small-Scale Modelling

Technical Report No. 12

COSMO Priority Project “VERification System Unified Survey (VERSUS)”: Final Report

June 2009

DOI: 10.5676/DWD_pub/nwv/cosmo-tr_12

Deutscher Wetterdienst

MeteoSwiss

ΕΘΝΙΚΗ ΜΕΤΕΩΡΟΛΟΓΙΚΗ ΥΠΗΡΕΣΙΑ

Ufficio Generale Spazio Aereo e Meteorologia

Instytucie Meteorogii i Gospodarki Wodnej

Administratia Nationala de Meteorologie

Agenzia Regionale per la Protezione Ambientale del Piemonte

Agenzia Regionale per la Protezione Ambientale dell’ Emilia-Romagna: Servizio Idro-Meteo-Clima

Centro Italiano Ricerche Aerospaziali

Amt für GeoInformationswesen der Bundeswehr

www.cosmo-model.org

Editor: Massimo Milelli, ARPA Piemonte
Printed at Deutscher Wetterdienst, P.O. Box 100465, 63004 Offenbach am Main

COSMO Priority Project

"VERification System Unified Survey (VERSUS)":

Final Report

Adriano Raspanti

Adriano Raspanti
Ufficio Generale Spazio Aereo e Meteorologia
Viale dell'Universitá 4
00185 Roma
Italia

Contents

Contents

1 Summary

The development of a complete Conditional Verification Tool has been the first priority and outcome of the VERSUS project. From a more general point of view the main purpose of VERSUS is the systematic evaluation of model performances in order to reveal, in a way different from the usual classical verification tools, model weaknesses. Once delivered and applied routinely, it should provide information to the all scientists and modelers, providing them hints which could be the causes of model deficiencies that can be seen in the operational verification. The typical approach to Conditional Verification consist of the selection of one or several forecast products and one or several mask variables or conditions, which would be used to define for example thresholds for the product verification (e.g. verification of T2M only for grid points with zero cloud cover in model and observations).

After the selection of the desired conditions, a classical verification tools is used to get statistical indexes. The more flexible way to perform a selection of forecasts and observations following a certain number of conditions, is to use an "ad hoc database", planned and designed for this purpose, where the mask or filter could be simple or complex SQL statements.

Through the development of VERSUS software we have achieved a unified tool able to perform operational standard verifications, operational conditional verifications along with experimental standard and conditional verifications, in batch and interactive mode.

The modularity of VERSUS easily allows updates and use of new verifications methods through the use and implementation of "R" language software package or even "ad hoc" algorithms (Fortran, C, PHP).

The verification software has been developed with an user friendly graphic interface, that makes easier the registration, modification and management of all the verification activities. The GUI is based on standard Web interface. This means also that the final architecture can be considered client-server kind.

2 Project report

The classical verification of forecast products is generally based on the evaluation of single elements (e.g. T2m, RR) over specific domains in space and time. The resulting numbers, tables and plots present measures of the overall performance of the model with regard to the product considered. Potential interdependencies between various products are a priori ignored (e.g. cloud cover & near surface temperature). The interpretation of classical verification results with regard to systematic deficiencies in the model simulation of specific processes is also far from trivial. Even though obvious failures of the model may be established, finding the reasons behind these failures is hampered by the integral properties of the classical approach, i.e. the averaging over spatial domains (and time) without consideration of specific details of the atmospheric and/or surface situation. However, a tool allowing a process or a situation dependent verification, e.g. the evaluation of the model forecast quality with regard to the diurnal cycle of near surface temperatures in the absence of clouds, would facilitate the task of finding the cause of model shortcomings and the model improvement. Formulating the verification of forecast products in conjunction with the existence of additional criteria, can be defined as Conditional Verification (CV).

The prime purpose of CV is the systematic evaluation of model performance in order to reveal typical shortcomings and the reasons behind them. Applied in a routine mode, it should also have the potential to provide information to the forecasters with regard to the situation and product dependent model reliability (e.g. typical clear sky forecast errors for T2M in contrast to cloudy sky condition errors). Then the typical approach to CV could consist of the selection of one or several forecast products and one or several mask variables, which would be used to define thresholds for the product verification (e.g. verification of T2M for grid points with zero cloud cover in model and observations only). However, the masking requirements may occasionally be rather complex as in the cases where the forecast product depends strongly on the history of the evolution rather than the current state of a certain variable. For this reason, one could define at least four classes of masks:

- time-independent masks;
- time dependent masks concurrent to the product;
- time dependent masks with possible time-lag to the verified product;
- masks depending on an atmospheric situation classification.

The first class is certainly the simplest to handle, but it carries nevertheless a certain potential with regard to the purpose of the exercise. Apart from obvious masks like the application of a land-sea filter or the stratification of verification results with regard to orographic height, one could envisage masks like the model soil type, plant cover, roughness length etc. The application of such masks might well reveal that certain deficiencies are more pronounced within certain ranges of a particular mask than outside of that range and thereby lead to the detection of a more specific model deficiency.

The second class concerns more the direct interaction between various model products. Typical examples would be the verification of T2M in the presence or absence of snow, but also the verification of products like surface radiative fluxes classified by the cloud cover.

The third class allows in addition to take into account the history of the model (or observation) evolution. E.g. the near surface temperature, as an instantaneous model product, depends among others on the cloud cover which was present in the period before the verification time. In order to obtain a meaningful CV for such a product/mask combination, one would evaluate the verified variable with respect to the previous evolution and the current state of the mask variable.

Finally, the fourth class may need a sophisticated algorithm or even manual intervention in the stratification of all cases with regard to the mask criteria. For example, if we are interested in the performance of the model in stable wintertime conditions, it may not be sufficient to check for a temperature inversion near the earth's surface or relatively high pressure over the domain considered.

Masking conditions may be formulated in model or observation space or both, depending on the application. E.g. in order to obtain a detailed insight in the models ability to simulate the diurnal cycle of near surface temperatures in cloud-free conditions, neither simulated nor observed cloud cover must exceed the specified threshold value.

Generally, several masks may be applied at once, e.g. simultaneous application of cloud cover, soil moisture and plant cover thresholds. Obviously the size of the ensemble will depend on the number of criteria applied. Even though this could be detrimental for the evaluation of a few case studies, in an operational environment this problem would be alleviated by the large number of forecasts generated.

One drawback of CV may be the multitude of verification products arising, if various mask criteria are applied to a set of forecasts.

A generalized CV tool, which can handle all the potential applications mentioned above would require development resources which exceed those available. Consequently, in a first step a tool which is able to handle at least the more basic applications mentioned above, has been created. The name of this tool, as well as the COSMO priority project, is VERSUS (VERification System Unified Survey).

However, VERSUS has been developed in a flexible, user configurable way in order to allow future extensions towards a fully flexible tool. Nevertheless it can be already applied both to operational and experimental forecast products.

In order to give a general idea, in the following table a first attempt was made to define a small set of products to be verified in conjunction with corresponding criteria. This set should only be considered as a starting point. No attempt has been made to order the following table with regard to the expected benefit.

Verified variable	Mask variable(s)	Criteria	Remarks
T2m	CLC(t); local time	lower & upper thresholds in CLC; local time slots	cloud cover thresholds should be applied over the time period preceding the verification time and both to model and observations
T2m	Wsoil	lower & upper thresholds in soil moisture (relative to field capacity)	soil moisture is a multi-layer variable and it may be useful to compute an effective soil moisture as average over several layers
T2m	SHF/LHF	thresholds in Bowen ratio	Bowen ratio as an indirect measure of soil wetness needs to be considered as an average over time
CLC(L)	vertical stability index	stable versus unstable situations	differences in temperatures at various pressure levels may be used as a stability index; the distinction with regard to stability may be considered as an example for situation dependent masking, e.g. to focus on low level stratus or convective regimes
RR	vertical stability index	stable versus unstable situations	regime dependent precipitation verification
U10m	z0	low, medium, large z0	correlation between wind speed errors and roughness length may point to problems in external parameters
T2m	U10m	upper threshold in wind speed	exclude advection dominated situations in temperature verification
Td2m	Wsoil	lower & upper thresholds in soil moisture (relative to field capacity)	determine the error of dew point temperatures in the case of dry soils versus wet soils
T2m	Wsnow	no snow, broken snow, snow	the temperature error is likely to depend on snow cover, hence a broken snow deck might be an indicator for melting snow

The project started in an experimental version using the already developed Common Verification Suite (Fortran package). A number of other Fortran applications were developed to implement some of the interdependencies of the table above. The results were encouraging because it was clear that applying a mask during the calculation of T2m standard verification, for example cloud/no-cloud, the model behaviour was really different and some clear indication arose from such a conditional verification.

On these basis it was decided to go further and to develop the VERSUS priority project and it was clear that the more flexible way to perform a selection of forecasts and observations following a certain number of conditions, is to design, build and use an "ad hoc database" where the mask or filter could be simple or complex SQL statements.

The project was planned on the development of ten tasks over a period of 3 years.

Of course not only conditional verifications, but also all the standards and common verification scores can be produced by VERSUS. For the comprehensive list of features of VERSUS package you can refer to the User Manual and Technical Manual, available in the installation package, on the VERSUS WEB GUI and soon on the COSMO website.

The following are only some of the most important features that can be found in VERSUS package:

- Verification (conditional or not) can be produced in batch or interactive mode;
- seasonal or monthly period can be produced in batch and interactive mode; any other time period can be produced in interactive way only;
- 3 different kind of users with different kind of privileges have been foreseen in VERSUS (see manuals for details);
- VERSUS can perform standard and conditional verification on continues and binary parameters for surface on-site observations;
- only standard verification is possible at the moment for upper-air observations;
- conditions can be imposed on both observation and forecasts spaces;
- VERSUS can be used not only for COSMO-models but also for, e.g., IFS and GME, provided the right information on the "model registration" module;
- VERSUS can calculate the usual standard statistical scores, both for continues and binary events. More scores can be introduced, through the GUI, using the "R" programming language;
- VERSUS can perform verification on different user-oriented stratifications, in time and/or space;
- all the scores, time series and daily cycles are produced in both text and graphical formats;
- graphic plots are highly configurable;
- all the possible activities are configurable through the web based GUI.

2.1 Open points

VERSUS has not been planned to cover all the existing verification methods, as well as all the possible products from a NWP. Moreover not all types of observation can be used at present, with VERSUS software, for example observation from satellite and radar. In more detail, the open points in the VERSUS project are:

- development of probabilistic and ensemble forecasts verification;
- development of object-based and fuzzy verification methods applied to precipitation;
- new scores for extreme events (e.g. extreme dependency score);
- more in general, development of User-oriented verification;
- statistical features like Confidence intervals and Bootstrap method;
- use of non conventional obs (e.g. radar, satellite, raingauges) and gridded observations (precipitation analysis).

In order to face and solve these open points, an extension of VERSUS project has been proposed: VERSUS 2.

2.2 Resources used

The development of VERSUS needed the use of resources with special skill in database project, design and management. Of course expertise in verification methods has been used to fulfil and clarify the general requirements coming from documents, discussions, meetings and "wishes" inside the COSMO community.

Resources with skill in PHP programming and implementation of PHP graphic (JPGRAPH) modules have been used to create graphic package inside VERSUS. Resources with some skill in "R" programming language and in statistical packages have been employed too.

Finally, resources with skill in software and DB installation and customization on different LINUX platforms have been employed (e.g. testing phase).

2.3 Lessons learned

The project started at the end of 2005 with no clear technical specification or requirements but only with a joint document coming from WG3-WG5 workshop and some "wishes" from WG3. The lack of a Reference Document made the development of Conditional Verification (CV) package, and later VERSUS, more difficult and the direction and the solutions adopted inside the COSMO community were not clear even inside WG5 itself.

For this reason, the extension of VERSUS (the new project named VERSUS2) will have, as TASK0, the redaction of such a Reference Document (System Architecture Design and Overview), reviewed and accepted by all the members of the COSMO community. This task can be seen as the most important of the whole project. People involved in the actual development of requirements will have a clear reference document to follow, as well as a detailed description of what, why and how they have to implement. This TASK0 should avoid mistakes and delays due to misunderstandings or no full comprehension of the project itself.

The project leader has to "stress" and push people to communicate among them and with the PL himself. Communication is important for the exchange of suggestions, ideas, clarifications, for the release of deliverables and so on. Just to give an example: some parts of VERSUS project were not really clear to everybody, almost until the end of the project itself, mainly due to poor communications.

3 Acknowledgements

This is the list of contributing scientists: Ulrich Damrath (DWD); Pirmin Kaufmann (MCH); Adriano Raspanti as PL (USAM); David Palella (USAM); Angela Celozzi (USAM); External Resources provided by USAM (ELSAG-DATAMAT); Flora Gofa (HNMS); Katarzyna Starosta (IMGW); Joanna Linkowksa (IMGW), Marek Lazanowicz (IMGW); Aurelia Lupascu (NMA); Rodica Dumitrache (NMA).

List of COSMO Newsletters and Technical Reports

(available for download from the COSMO Website: www.cosmo-model.org)

COSMO Newsletters

No. 1: February 2001.

No. 2: February 2002.

No. 3: February 2003.

No. 4: February 2004.

No. 5: April 2005.

No. 6: July 2006.

No. 7: April 2008; Proceedings from the 8th COSMO General Meeting in Bucharest, 2006.

No. 8: September 2008; Proceedings from the 9th COSMO General Meeting in Athens, 2007.

No. 9: December 2008.

COSMO Technical Reports

No. 1: Dmitrii Mironov and Matthias Raschendorfer (2001):
Evaluation of Empirical Parameters of the New LM Surface-Layer Parameterization Scheme. Results from Numerical Experiments Including the Soil Moisture Analysis.

No. 2: Reinhold Schrodin and Erdmann Heise (2001):
The Multi-Layer Version of the DWD Soil Model TERRA_LM.

No. 3: Günther Doms (2001):
A Scheme for Monotonic Numerical Diffusion in the LM.

No. 4: Hans-Joachim Herzog, Ursula Schubert, Gerd Vogel, Adelheid Fiedler and Roswitha Kirchner (2002):
LLM ¯ the High-Resolving Nonhydrostatic Simulation Model in the DWD-Project LITFASS.
Part I: Modelling Technique and Simulation Method.

No. 5: Jean-Marie Bettems (2002):
EUCOS Impact Study Using the Limited-Area Non-Hydrostatic NWP Model in Operational Use at MeteoSwiss.

No. 6: Heinz-Werner Bitzer and Jürgen Steppeler (2004):
Documentation of the Z-Coordinate Dynamical Core of LM.

No. 7: Hans-Joachim Herzog, Almut Gassmann (2005):
Lorenz- and Charney-Phillips vertical grid experimentation using a compressible non-hydrostatic toy-model relevant to the fast-mode part of the 'Lokal-Modell'

No. 8: Chiara Marsigli, Andrea Montani, Tiziana Paccagnella, Davide Sacchetti, André Walser, Marco Arpagaus, Thomas Schumann (2005):
Evaluation of the Performance of the COSMO-LEPS System

No. 9: Erdmann Heise, Bodo Ritter, Reinhold Schrodin (2006):
Operational Implementation of the Multilayer Soil Model

No. 10: M.D. Tsyrulnikov (2007):
Is the particle filtering approach appropriate for meso-scale data assimilation ?

No. 11: Dmitrii V. Mironov (2008):
Parameterization of Lakes in Numerical Weather Prediction. Description of a Lake Model.

No. 12: Adriano Raspanti (2009):
COSMO Priority Project "VERification System Unified Survey" (VERSUS): Final Report

COSMO Technical Reports

Issues of the COSMO Technical Reports series are published by the *COnsortium for Small-scale MOdelling* at non-regular intervals. COSMO is a European group for numerical weather prediction with participating meteorological services from Germany (DWD, AWGeophys), Greece (HNMS), Italy (USAM, ARPA-SIMC, ARPA Piemonte), Switzerland (MeteoSwiss), Poland (IMGW) and Romania (NMA). The general goal is to develop, improve and maintain a non-hydrostatic limited area modelling system to be used for both operational and research applications by the members of COSMO. This system is initially based on the COSMO-Model (previously known as LM) of DWD with its corresponding data assimilation system.

The Technical Reports are intended

- for scientific contributions and a documentation of research activities,
- to present and discuss results obtained from the model system,
- to present and discuss verification results and interpretation methods,
- for a documentation of technical changes to the model system,
- to give an overview of new components of the model system.

The purpose of these reports is to communicate results, changes and progress related to the LM model system relatively fast within the COSMO consortium, and also to inform other NWP groups on our current research activities. In this way the discussion on a specific topic can be stimulated at an early stage. In order to publish a report very soon after the completion of the manuscript, we have decided to omit a thorough reviewing procedure and only a rough check is done by the editors and a third reviewer. We apologize for typographical and other errors or inconsistencies which may still be present.

At present, the Technical Reports are available for download from the COSMO web site (www.cosmo-model.org). If required, the member meteorological centres can produce hard-copies by their own for distribution within their service. All members of the consortium will be informed about new issues by email.

For any comments and questions, please contact the editors:

Massimo Milelli
Massimo.Milelli@arpa.piemonte.it

Ulrich Schättler
Ulrich.Schaettler@dwd.de