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The COSMO Priority Project VERSUS2 Final Report

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The COSMO Priority Project VERSUS2

Final Report

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Contents

1 Introduction

1.1 Overview

The development, implementation and operational use of the original VERSUS package (2006-2009 PP project) satisfied most of the needs for traditional verification, but the constant increasing model resolution as well as the current and planned ensemble systems asked for more suitable information from verification activities. At the same time users of model forecasts asked for more information about the real quality of their model: this means a step towards user-specific verification information.

The extension of the VERSUS package to VERSUS2 has covered these items and has provided the COSMO community with a "state of the art" verification tool. The "System Architecture Design" (SAD) specification document was released in May 2009 and updated in January 2010 (www.cosmo-model.org/content/tasks/pastProjects/versus2/docs/versus2-SAD.pdf).

1.2 Motivations

The aim of the VERSUS-1 Priority Project, started at the end of 2006 and concluded in February 2009, with the official delivery of the package, was the development of a common and unified verification 'library' including a Conditional Verification (CV) tool. This library has been included in the public COSMO Software along with the new software from Priority Project VERSUS2. The package and all its main features have been planned and realised with the intention to be a useful and friendly tool for the entire COSMO community for operational as well as research activities to perform traditional and conditional verification (CV), based on conventional methods. As the typical approach to CV consist of a selection of one or several forecast products and one or several mask variables or conditions, which is used to define thresholds for the product verification, the flexible way to perform such a selection is to use an 'ad hoc database', planned and designed for this purpose. In this case the masks or filters can be simple or complex SQL statements. After the selection of the desired conditions, a classical verification tool to turn out statistical indexes can be used, along with a graphics package to plot the scores. The general VERSUS architecture is basically composed of a set of integrated tools:

- **Relational Data Base Management System** (RDBMS), to store observations (OBS) and forecast (FCS) data, Station Data, Configuration data to perform verification, Verification results, Scores and plots, and User permissions; the chosen data base is MySQL in case of the initial VERSUS version;
- **Front End loader** (FE), a "daemon" process to load data from different sources into the RDBMS (File system or another DB); among FE functionalities, and very useful for CV, it is possible to use a loader dedicated to the SRNWP Data Exchange Programme observations, consisting in good quality operational data from a limited set of well instrumented and high quality observation sites in Europe, in particular providing soil, surface and boundary layer data;
- **A process performing verifications** through specific requests (Integration into the "R" statistics package);
- **A web-based user interface** (server-client architecture).

The VERSUS1 project was divided into 10 tasks and most of them has been completed. The delivery of the complete package occurred during a Workshop/Tutorial in February 2009. In the course of the first VERSUS project development, most of the COSMO members moved towards higher resolution models as well as ensemble forecasting systems. The increasing resolution has, in general, the impact that objective scores for weather parameters can be worse for high resolution models than for low resolution models. Increased resolution, in fact, generally produces better defined mesoscale structures, greater amplitude features, and larger gradients, and inevitably leads to space and time errors. This is known as the "double penalty" problem. Nevertheless such a model can provide very useful information. The need for verification techniques that allow for some tolerance to reasonably small space and time errors is then clear, retaining the main feature to be capable to test the real quality of information provided by the high-resolution model and the possible connections between forecast deficiencies and specific weaknesses in the model formulation. At the same time, as COSMO model future plans were in the probabilistic and ensemble forecast direction, suitable verification methods had to be applied. In general there are three methods to evaluate this kind of forecasts (Casati et al., 2008):

- Verification of an ensemble distribution: methods used to verify ensemble distributions are rank histograms (Talagrand histograms), Continuous rank probability score and its related skill score (a measure for the difference between the cumulative distribution function of the forecasts and observation), and minimum spanning tree (a sort of multidimensional rank histogram, not so widely used);
- Verification measures for the probability density function (pdf) of a generic probability forecast: methods used are "linear probability" and the "ignorance score". Both the methods are local, evaluating the pdf at the observation value, and both rewards sharp distributions which are also accurate;
- Verification of the probability of an event: methods used are Brier Score (BS) and its decomposition, Brier Skill Score (BSS), reliability diagrams, ROC and the Rank Probability Score (RPS). It is useful to add to these methods also bootstrap confidence intervals to generalize score estimates over different sample sizes.

All the above verification techniques, and others specialised for extreme events and user needs, had been analysed and then included in the VERSUS package to have a common "state-of-the-art" tool for verification for the entire COSMO community. VERSUS is routinely used for the calculation of seasonal statistics over a common area according to the guidelines (http://www.cosmo-model.org/content/tasks/verification.priv) derived on an annual basis from WG5 for each participating model of COSMO consortium (Common Plots). VERSUS is also used in the framework of the NWP Test Suite, which is the software environment to perform carefully-controlled and rigorous testing with calculation of verification statistics for any COSMO model test version. For this aim VERSUS software has been also installed at the ECMWF on a dedicated virtual machine (an innovative solution for that time). The NWP Test Suite has been used over the years as benchmark for the major changes of the new COSMO model versions. These activities have been important for the software debug and continuous COSMO model development.

2 Tasks and achievements

2.1 Project presentation

The PP VERSUS2 has been approved in September 2009 during the 24th STC Meeting (07-08/09/2009) that took place in Offenbach, Germany and has been declared closed in September 2016, during the 38th STC Meeting (05-06/09/2016), in Offenbach as well, with the release of VERSUS 5.1 and VAST 1.4 packages (June-July 2016), which form the COSMO Common Verification Software (CVS). Further developments on the system have been carried out from the end of the project up to October 2018 and then reported here for completeness. VERSUS maintenance has been assured by the Italian Air Force Meteorological Service up to December 2018.

In a first phase (COSMO year 2009), a "User Requirements Specification" had been compiled, and has been implemented during the following phases of the project itself (COSMO years 2010-2016). Most of the single phases has been concluded in one COSMO year. Every year, based on the real deliverables produced, the plan has been updated accordingly to a quick review of the requirements of the next phase, and the new phase to be developed has been fully described (see COSMO GM presentations for details).

A concise account of the tasks and achievements developed during the project is thus chronologically presented in the next section.

2.2 Project phases and tasks

2.2.1 Phase 1. COSMO year 2009

It has been completed as planned in Cosmo year 2009 , with the delivery of System Design Overview Document (SDO, updated in July 2009 as requested by the STC) and System Architecture Design (SAD, approved by the STC). During this phase of the project the main activity consisted in the implementation of VERSUS system at every service within COSMO consortium, in particular through the realization of a multi-platform RDBMS version of the software and consequently the installation of multi-platform DB version of VERSUS at every service.

2.2.2 Phase 2. COSMO year 2010

This phase was composed of many different tasks: at level 0 the main goal was to provide assistance to all VERSUS users inside the consortium, through the Help Desk service, bugs fixing activities and the following VERSUS update patch release. The implementation of COSI (global Score Cosmo Index) was then carried out, through both the initial preparation of the technical reference document and the factual index implementation. Another important step was to implement the software features concerning conditional verification: VERSUS software modules and related web GUI updates were developed for the implementation of weather type dependent verification and conditional verification (WDV, CV). During this phase a detailed documentation of Fuzzy verification toolbox, necessary in order to perform verification on high resolution models, was produced, with the implementation realised via the VAST software. Another important achievement was the introduction of Feedback Files (FF from now) as input for the system, with the realisation of new loader modules to be integrated in VERSUS_FE; this type of file was useful for the management of

new observation data such as Airep, Amdar, Windprofiler, TEMP (non standard pressure level) and Radar wind data.

2.2.3 Phase 3. COSMO year 2011

In this phase continued the activity of Help Desk, bug-fixing and release of VERSUS updates, and in parallel was carried out the improvement of VERSUS security and "plug&play" installation and web pages: in detail new installation/patch update procedures and back-up functionalities for the DB were developed, as well as a review of web GUI search pages for improved functionality. The work for the final implementation of the Feedback Files capability was carried on, with the implementation of a loader module, the creation of new web GUI, conditional verification for data from FF and a stand-alone tool for FF creation for all partners ,with the related documentation. A dedicated test phase for FF tool implementation and FF functionalities in VERSUS was then realised. The attention of the developers was also focused in the improving of the probabilistic scores, necessary to the EPS verification, with the implementation of "R" package in VERSUS with the creation of new web pages for GUI and the production of the related documentation.

2.2.4 Phase 4. COSMO year 2012

In this year the aim of developers was focused on software usability: an improvement of the batch execution functionality, even with the possibility of using it for cross verification, and of the suspect observation menu were realised, as well as the addition of a data permanence process, able to delete observation and forecast older than a configurable time presence. The work on the FF processing modules, started the former year, continued. The use of Feedback Files (FF) was important to improve upper air verification and Conditional Verification activities, where large amounts of data must be manipulated. A feasibility study on how to proceed with the implementation of FF was created by the Project Leader (PL) team, reviewed by DWD in July 2010, and the new Database Structure for FF was then created. At the same time the importance of updating the system, according with the evolution of the standard meteorological message formats, was taken into account by the implementation of new BUFR format, for observation, and GRIB2, for forecast. The adoption by WMO of a new template for BUFR was the main reason for this task as well as the foreseen use of GRIB2 as output of COSMO models. The process consisted in updating the system for the upload functionality of new BUFR template and merge (in space and time) with the old format. The use of the new template has made verification more flexible for the cumulated precipitation. A document describing the activity was delivered and approved. The updating of the system for the treatment of produced forecasts coded in GRIB2 format was then carried out with the related documentation. At the same time continued the user support activity, the implementation of the FF modules and probabilistic scores within the R package.

2.2.5 Phase 5. COSMO year 2013

The goal of the year was to complete the most crucial developments define by participants of the last VERSUS user meeting that took place in Rome in April 2012. Concerning the Help Desk/bug-fixing activities and release of VERSUS updates new practices were introduced: a forum web page dedicated to help desk activity for the users was created and was stated that any new development of the software was followed by a documentation update

(User Manual and Technical Manual). Regarding the release process for the new patches, each new patch assumed the creation of a packet instalment. The patches were delivered to the users through the Italian Air Force Meteorological Service ftp server. Moreover the test of each new VERSUS release was followed by the related test procedure. Automation of processes/GUI adjustment were also carried out. In this task some generic improvements on GUI and VERSUS functionalities were carried on in order to improve friendliness and the operational use of the system; among these are cronjobs for running php scripts to compile verifications, automatic storage of figures with reasonable names for unambiguous identification, replication function for similar verification activities and inclusion of performance diagrams in VERSUS plots: an activity not connected to the automation, but with the need to include more statistical indexes for precipitation verification, in one graph. Inside the Probabilistic Scores area during this year the PL team finished the calculation and visualization of the ensemble and probabilistic scores in VERSUS, using as a reference the EPS documents edited by F. Gofa and A. Bundel. In the same year continued the implementation of the WMO BUFR standard for observations, with the creation of test procedures and following test phase, as well as the implementation of 1 and 3 hours period for cumulated precipitation and wind gusts.

2.2.6 Phase 6. COSMO year 2013-4

The purpose of this year was to complete some of the existing requirements and ensure the stability of the system. Beside the normal help desk and support activity this year the first VERSUS Course for Developers took place in Pratica di Mare (May 2013) for 3 days, with the aim to familiarize potential developers with the software architecture. Regarding the refinement of the system was realized a code adjustment for DB Partitioning and a definition of standard coding for precipitation parameter was set, thanks to the TAG and SCA collaboration and specification of WG5 requirements on the measures and verification activities to be performed with such data. The activity for the use of FF in Versus continued through the implementation of a dedicated loader module, a new web GUI and a specific test phase for FF tool implementation and FF functionalities. In the EPS products verification sector was carried on and concluded the development of the statistical indexes CRPS/CRPSS (Continuous Ranked Probabilistic Score/Skill Score) and the realization of the Spread/Skill relation plots. This allowed the beginning of the pre-operational phase, consisting in a series of test over a period of 2-3 months with a following comparison of VERSUS results with current operational EPS verification.

2.2.7 Phase 7. COSMO year 2014-5

This year the help desk activity was divided in two different support levels: the first one being managed by Russian colleagues for the basic requests. They involved the PL team in case of more technical problems and bug fixing. In addition VERSUS User Seminar was organized: it took place in Turin (May 2015) for 3 days with the aim to introduce the new functionalities; among these the concurrent use of VERSUS by more than one user: the system could now be used by more than one user simultaneously. The implementation of Feedback Files use in VERSUS was completed, with the development of a new versus library to read the Feedback File in NETCDF, the definitive implementation of Loader module for FF, the new web GUI and the improvement of the graphics for upper air verification. Another important step was executed in the process of implementation of VERSUS functionality to ingest and manage GRIB2. This process involved multiple tasks as the analysis and creation of new DB area, adjustment and upgrade of the Phoenix code, creation of new FE

in VERSUS, code/GUI adjustment and following functionalities test phase. The same year, with the aim of introducing additional statistical techniques compatible with VERSUS, a new activity was stated. This activity dealt with the introduction of new statistical techniques for high resolution forecast and observation data (neighbourhood methods). The COSMO Verification Community considered the use and adaptation of external packages or libraries for pre-processing of data for verification as one of its main priorities. For this reason the main goal of the activity was the integration or adaptation of pre-existing packages (e.g. Beth Ebert Fuzzy Verification Toolbox). Moreover this work was extended to the use of gridded precipitation data from composite sources (e.g. radar, raingauges) while a pre-processing tool capable of reading GRIB files (for forecast and/or observation) and producing data in suitable format for the VERSUS system itself was developed. To this purpose the PL coordinated the execution of the Project VAST, project funded by COSMO, started in June 2014 and ended in May 2015. The software allowed to produce spatial verification of the precipitation field (main goal), wind speed and total cloud cover. The argument is treated in detail in the COSMO Technical Report 33 (Vela, 2017).

2.2.8 Phase 8 / Extension Phase COSMO year 2015-2016

The phase 8 (or Extension Phase) has brought the project VERSUS2 to the final refinements. In particular with the release of patch 5.0 Version (December 2015) and 5.1 Version (July 2016) was solved the problem of loading multisteps files and implemented the total cloud cover verification. Regarding the software functionalities, for the GRIB2 ingest new front end were created, with update of VERSUS code and GUI, as well as the implementation of the connection with existing GRIB1 tables and following tests. After these processes various refinements activities have been carried out, such as a control on EPS score accuracy, a test phase on the XML file format ingestion and a report of the loading performances. In the end final tests on all system functionalities have been performed.

3 Further developments

In addition to the achievements of the VERSUS2 Priority Project other improvements have been developed during the period September 2016 - October 2018. We will present in this section a brief overview of the main innovations.

Patch 5.1.1: implementation of correct precipitation Performance Diagrams for ECMWF and COSMO 12UTC run.

Patch 5.1.2: problems with graphs of cumulative 24h precipitation 12UTC run solved; problems in the creation of cron directory for new VERSUS installations solved; upgrade of GUI menu list (problems with the former patch, RH was not visualised any more); improvement of batch execution menu (verifications already performed now have the label execution $\rightarrow$ yes).

Patch 5.1.3: Improvement of upper air verifications (creation of values at all levels); adjustment of the progressive verification number.

Patch 5.1.4: Included in 5.1.5 .

Patch 5.1.5: Management of a new buoy BUFR template which introduces a new descriptor for the buoy identifier; correct visualization of cross verification graphics.

Patch 5.1.6: Management of the new synop messages BUFR template, concerning cumulated/averaged fields defined by the time period descriptor (windgust, precipitation, etc).

4 Conclusions

The VERSUS2 Priority Project, as is visible looking at the chronology reported here, has brought a constant improvement of the original VERSUS software, in order to keep the pace with the development of new technologies and verification methods. Many innovations has been carried out in multiple fields: for example, in the direction of having a valid tool to verify the Ensemble Probabilistic System (EPS), a set of new statistical scores has been implemented (R package for EPS verification) as well as the new interface functionalities to manage it (GUI improvement); the database performances have also been improved in order to decrease the verifications execution time. Another fundamental activity inside the project has been the help desk support for all the Cosmo consortium members, consisting in solving practical issues and fixing the reported bugs with the relative releases of VERSUS software upgrades (patch). The team has also realised the implementation of Weather Type Dependent Verification and the improvement of Conditional Verification, the introduction in the system of the possibility to ingest new kind of data both in terms of type (Airep, Amdar, Windprofiler, TEMP and many more through the use of Feedback Files (FF)) and format (GRIB1 to GRIB2 management, ingestion of XML files of post-processed forecasts) and has worked over time to refine every aspect of the over-mentioned tasks.

5 Meetings

- CVS Meeting, 20 November 2006, Pratica di Mare, Italy
- VERSUS2 meeting, 12 March 2009, Langen, Germany
- VERSUS tutorial, 16-18 February 2009, Pratica di Mare, Italy
- VERSUS2 meeting, 15-16 December 2009, Pratica di Mare, Italy
- VERSUS2 meeting, 4 March 2010, Langen, Germany
- WG5-VERSUS2 common meeting (minutes), 2-4 April 2012, Pratica di Mare, Italy
- WG5-VERSUS2 common meeting (minutes), 8-10 May 2013, Pratica di Mare, Italy
- WG5-VERSUS2 common meeting (minutes), 24-25 June 2014, Bologna, Italy
- WG5-VERSUS2 common meeting (minutes), 8 September 2014, Eretria, Greece
- WG5-VERSUS2 common meeting (minutes), 27-29 May 2015, Torino, Italy
- 11th COSMO General Meeting, 7-11 September 2009, Offenbach, Germany
- 12th COSMO General Meeting, 6-10 September 2010, Moscow, Russia
- 13th COSMO General Meeting, 5-9 September 2011, Rome, Italy
- 14th COSMO General Meeting, 10-14 September 2012, Lugano, Switzerland
- 15th COSMO General Meeting, 2-5 September 2013, Sibiu, Romania

- 16th COSMO General Meeting, 8-11 September 2014, Eretria, Greece
- 17th COSMO General Meeting, 7-10 September 2015, Wrocław, Poland
- 18th COSMO General Meeting, 5-8 September 2016, Offenbach, Germany
- COSMO/CLM User Seminar, 5-7 March 2013
- COSMO/CLM/ART User Seminar, 17-19 March 2014
- COSMO/CLM/ART User Seminar, 2-6 March 2015
- COSMO/CLM/ART User Seminar, 7-9 March 2016
- COSMO/CLM/ART User Seminar, 6-8 March 2017
- COSMO/CLM/ART User Seminar, 12-16 March 2018

6 User and technical Manual

The pdf version of the updated user manual is available at the following link:

http://www.cosmo-model.org/content/model/documentation/core/user_manual_5.1.6_05-10-2018.pdf

The pdf version of the updated technical manual is available at the following link:

www.cosmo-model.org/content/model/documentation/core/technical_manual.pdf

7 References

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Vela, N., 2017: V.A.S.T. (Versus Additional Statistical Techniques) User Manual (v2.0). www.cosmo-model.org/content/model/documentation/techReports/docs/techReport33.pdf

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.

No. 10: March 2010.

No. 11: April 2011.

No. 12: April 2012.

No. 13: April 2013.

No. 14: April 2014.

No. 15: July 2015.

No. 16: July 2016.

No. 17: July 2017.

No. 18: November 2018.

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):
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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.

No. 13: Chiara Marsigli (2009):
COSMO Priority Project "Short Range Ensemble Prediction System" (SREPS): Final Report.

No. 14: Michael Baldauf (2009):
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No. 15: Silke Dierer (2009):
COSMO Priority Project "Tackle deficiencies in quantitative precipitation forecast" (QPF): Final Report.

No. 16: Pierre Eckert (2009):
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Description of some convective indices implemented in the COSMO model.

No. 18: Daniel Leuenberger (2010):
Statistical analysis of high-resolution COSMO Ensemble forecasts in view of Data Assimilation.

No. 19: A. Montani, D. Cesari, C. Marsigli, T. Paccagnella (2010):
Seven years of activity in the field of mesoscale ensemble forecasting by the COSMO–LEPS system: main achievements and open challenges.

No. 20: A. Roches, O. Fuhrer (2012):
Tracer module in the COSMO model.

No. 21: Michael Baldauf (2013):
A new fast-waves solver for the Runge-Kutta dynamical core.

No. 22: C. Marsigli, T. Diomede, A. Montani, T. Paccagnella, P. Louka, F. Gofa, A. Corigliano (2013):
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No. 24: A. K. Miltenberger, A. Roches, S. Pfahl, H. Wernli (2014):
Online Trajectory Module in COSMO: a short user guide.

No. 25: P. Khain, I. Carmona, A. Voudouri, E. Avgoustoglou, J.-M. Bettems, F. Grazzini (2015):
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No. 26: D. Mironov, E. Machulskaya, B. Szintai, M. Raschendorfer, V. Perov, M. Chumakov, E. Avgoustoglou (2015):
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No. 27: J-M. Bettems (2015):
The COSMO Priority Project 'COLOBOC': Final Report.

No. 28: Ulrich Blahak (2016):
RADAR_MIE_LM and RADAR_MIELIB - Calculation of Radar Reflectivity from Model Output.

No. 29: M. Tsyrulnikov and D. Gayfulin (2016):
A Stochastic Pattern Generator for ensemble applications.

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A Turbulence Kinetic Energy – Scalar Variance Turbulence Parameterization Scheme.

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No. 35: G. Rivin, I. Rozinkina, E. Astakhova, A. Montani, D. Alferov, M. Arpagaus, D. Blinov, A. Bundel, M. Chumakov, P. Eckert, A. Euripides, J. Förstner, J. Helmert, E. Kazakova, A. Kirsanov, V. Kopeikin, E. Kukanova, D. Majewski, C. Marsigli, G. de Morsier, A. Muravev, T. Paccagnella, U. Schättler, C. Schraff, M. Shatunova, A. Shcherbakov, P. Steiner, M. Zaichenko (2018):
The COSMO Priority Project CORSO 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), Romania (NMA) and Russia (RHM). 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 editor:

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