SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	**COSMO NWP meteorological test suite**
Computer Project Account:	spitrasp
Start Year - End Year :	2016 - 2017
Principal Investigator(s)	Amalia Iriza (NMA,Romania)[1] Antonio Vocino (USAM, Italy)[2] Andrea Montani (Arpae-SIMC, Italy)[3]
Affiliation/Address:	National Meteorological Administration (NMA)[1] Centro Nazionale di Meteorologia e Climatologia Aeronautica (CNMCA)[2] Environmental Agency of Emilia-Romagna – Hydro-Meteo-Climate Service (Arpae-SIMC)[3]
Other Researchers (Name/Affiliation):	Flora Gofa (HNMS, Greece) Rodica Dumitrache (NMA, Romania) Philippe Steiner (MCH, Switzerland)

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

The aim of the COSMO NWP Meteorological Test Suite Special Project is to employ the software environment built on the ECMWF platform during the SPITRASP project (2013-2015) for carefully-controlled and rigorous testing (including calculation of verification statistics) for any COSMO model test-version. NWP COSMO benefits from the evaluation of new model versions prior to consideration for operational implementation (official version) according to source code management procedure. This procedure facilitates the decision whether the upgrade of a model test version to a new release is possible and gives the possibility to evaluate the impact that all implemented numerical or physical processes advances bring to convection permitting model resolutions. This type of designated testing also provides the research community with baselines against which the impacts of new techniques can be evaluated on a larger spatial and temporal domain.

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

- With regards to the running and maintaining of the test suite, we encountered problems with access permission for stop/start pending jobs (always to be performed through communication with ECMWF personnel).
- Problems with permissions read/write resulted since the installation of VERSUS patch 4.2 (August 2015).
- Due to slightly larger costs of the suite on the new Cray platform and the introduction of the COSMO-2.8km runs, additional computing resources were requested from ECMWF in August.
- Due to the new requirements of storing also data from two additional COSMO-2.8km model versions, the disk space of the VERSUS virtual machine was increased from 400 GB to 2 TB.

Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

The collaboration with the administrative and support team from ECMWF was very good. In our opinion, the procedures used for the progress report are clear. Periodic reminders of resource and data usage and reporting deadlines are very helpful.

Summary of results

(This section should comprise up to 10 pages and can be replaced by a short summary plus an existing scientific report on the project.)

The platform previously developed as part of the NWP Meteorological Test Suite project represents a well-defined framework to test present and future versions of the COSMO model for their forecasting performance. This tool was employed to perform tests that upgrade a model test-version to a new release. The statistical measures are defined within the task itself. The verification task concerns both the type of scores to be used as well as the array of parameters (850 hPa relative humidity, precipitation, 2m temperature and so on). The comparison of the model versions for validation was carried out on a common domain. The new version of the model was considered validated or accepted if the set of verification results show a positive impact on the common domain or if the results are neutral.

1. Model Set-up

In the frame of the present Special Project, 4 model versions were employed for testing, either as operational or new releases (5.01, 5.03, 5.04a and 5.04e).

Version 5.01 was previously implemented on the older IBM HPC for evaluation against COSMO version 5.0, during the previous NWP Meteorological Test Suite special project (2013-2015). Starting with version 5.03 of the COSMO model, tests were performed on the Cray HPC available, using ECMWF computer resources both for numerical simulations and for archiving procedures. As a consequence, versions 5.03, 5.04a and 5.04e of the COSMO model (7km horizontal resolution) were implemented on the Cray HPC following the procedure presented in the Final Report of the respective priority task. Billing units were provided by the members as part of the SPITRASP special project previously registered.

Previous tests (up to version 5.03 of the model) had only been performed for the 7 km horizontal resolution of the COSMO model. Starting from version 5.04a of the COSMO model, the 2.8km horizontal resolution of the model was also tested using the NWP Suite. For this purpose, the operational 5.03 version of the model was also integrated at both resolutions in order to be used for the verification.

Versions 5.04a and subsequent version 5.04e of the COSMO model (7km and 2.8km horizontal resolution), as well as version 5.03 (2.8km resolution) were implemented according to the procedure presented in the Final Report of the respective priority task.

For all model versions, the int2lm 2.0 version was used for the interpolation of initial and lateral boundary conditions provided by the ECMWF IFS system.

The directory structure and the archiving procedures for version 5.03 (5.3) of the COSMO model (new) followed the ones used for the previous versions. On completion of the testing procedure, model outputs were transferred to the machine with the installed VERSUS software for the statistical analysis. The model output obtained from the numerical experiments is locally stored in the ECFS system.

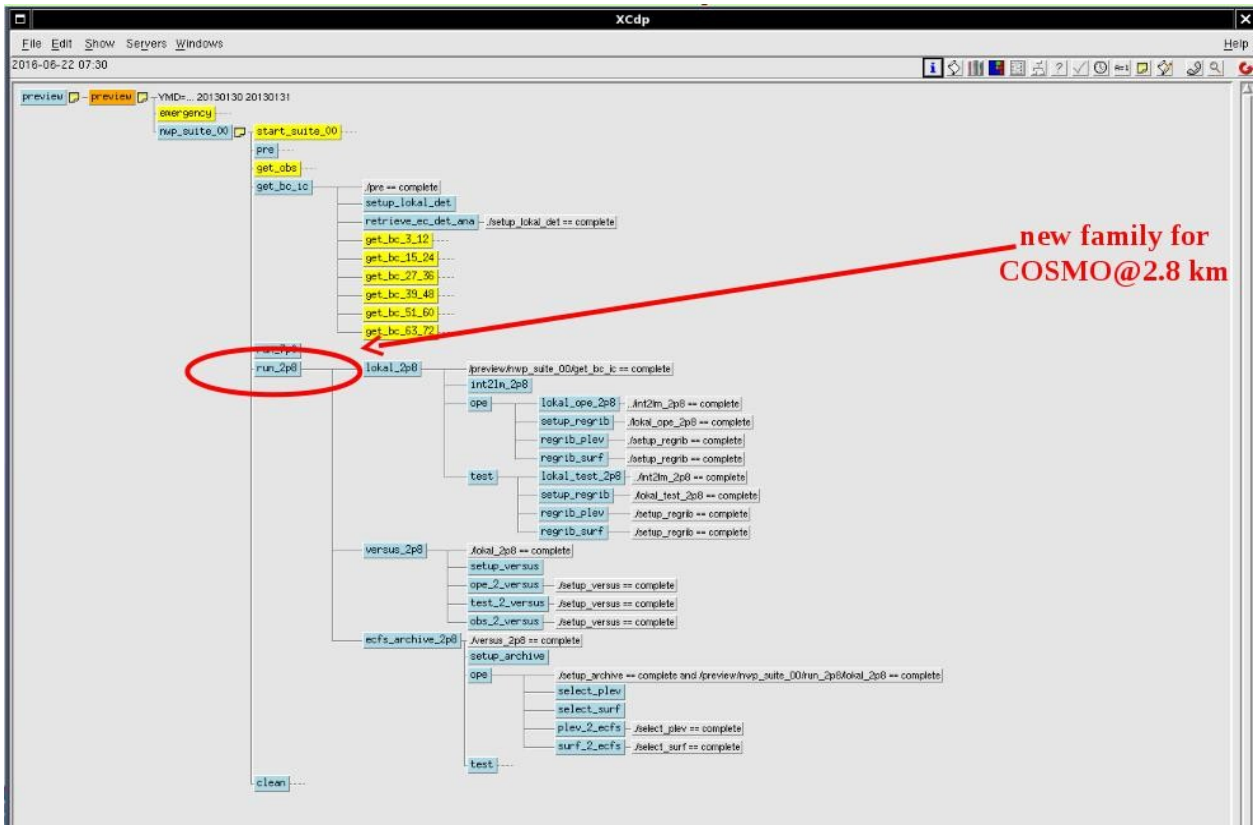


Figure 1. NWP test suite family and tasks, including new tasks for the 2.8km resolution.

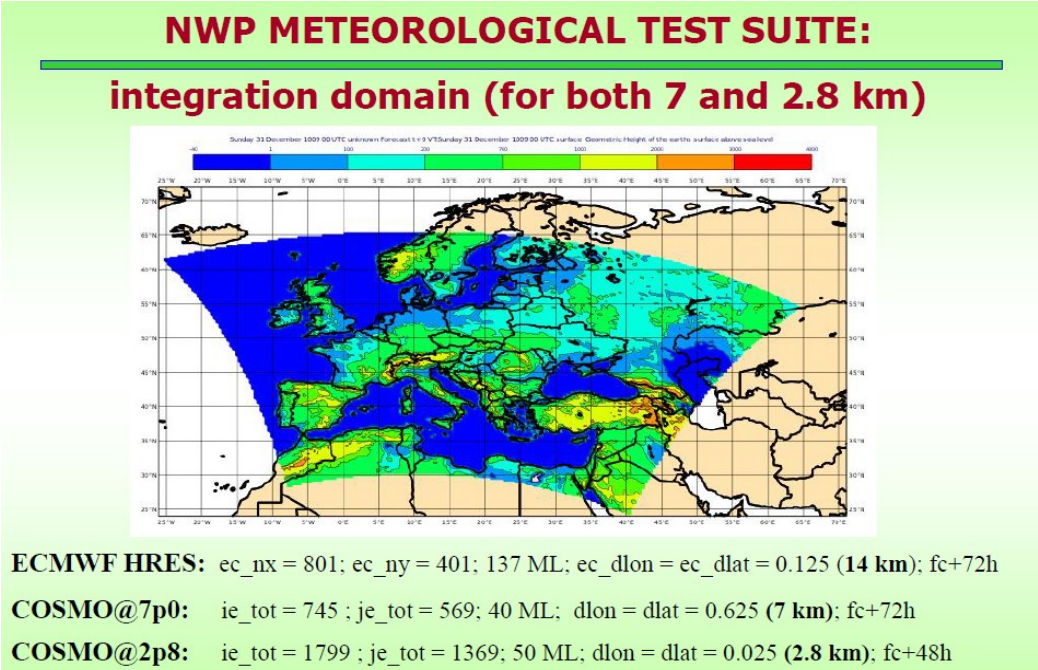


Figure 2. Integration domain and domain characteristics for the COSMO model used for all tests.

For all model versions, both horizontal resolutions, the integration domain used for calculation covers the COSMO countries and a good part of European Russia (in figure 2).

The ***cost of the suite*** in the present configurations is specified in tables 1, 2 and 3. Note that the last version run on the IBM HPC was COSMO-5.01 (during the previous special project), while all subsequent versions were run on Cray, with the same queuing systems and processors.

Table 1 Cost of the suite in the previous configuration on the IBM system.

INT2LM for COSMO-5.01 (5.1) on IBM
about 81.5 BU per run (takes ~ 8 min)
total_tasks = 64 and nodes = 1
COSMO-5.01 (5.1) on IBM
about ~ 2284 BU per run (takes ~ 28 min)
total_tasks = 512 and nodes = 8

Table 2 Cost of the suite in the present configurations for the 7km resolution on Cray.

COSMO-7km		
INT2LM COSMO-5.03 (5.3)	*INT2LM COSMO-5.04a*	*INT2LM COSMO-5.04e*
about 40 BU per run (~ 6min)	about 43 BU per run (~ 5min 30sec)	about 40 BU per run (~ 6min)
EC_total_tasks=24, EC_nodes=1	**EC_total_tasks=36, EC_nodes=1**	**EC_total_tasks=24, EC_nodes=1**
COSMO-5.03 (5.3)	*COSMO-5.04a*	*COSMO-5.04e*
about 3600 BU per run (~ 28min)	about 2993 BU per run (~ 15min 28sec)	about 4100 BU per run (~ 21min)
EC_total_tasks=480, EC_nodes=20	**EC_total_tasks=720, EC_nodes=20**	**EC_total_tasks=720, EC_nodes=20**

Table 3 Cost of the suite in the present configurations for the 2.8km resolution on Cray.

COSMO-2.8km		
INT2LM for COSMO-7km to COSMO-2.8km		
about 278 BU per run (~ 864 sec)		
COSMO-5.03 (5.3)	*COSMO-5.04a*	*COSMO-5.04e*
about 38417 BU per run (~ 6616 sec)	about 35682 BU per run (~ 6145 sec)	about 37000 BU per run (~ 6300 sec)
EC_total_tasks=1296, EC_nodes=36	**EC_total_tasks=1296, EC_nodes=36**	**EC_total_tasks=1296, EC_nodes=36**

Due to slightly larger costs of the suite on the new Cray platform and the introduction of the COSMO-2.8km runs, additional computing resources on the ECMWF platform were requested during 2016.

The forecast period of each daily run is 72 hours for the 7km resolution and 48 hours for the 2.8km resolution, on one daily cycle based on the 00UTC initializing data. Simulations were performed for one month in summer (July 2013) and one month in the winter season (January 2013), 2 months in total for each model version. The initial and lateral boundary data are provided by the ECMWF IFS system.

2. MODEL OUTPUT VERIFICATION

The verification was performed with grid-to-point comparisons. This technique allows to compare gridded surface and upper-air model data to point observations. 3600 selected stations situated in an area covering -25/24/65/65 (W/S/E/N) were used for the data the stratification. Previously registered suspect observation values for each parameter (forecast-observation greater than a specific limit were excluded) and included in the verification test in order to eliminate errors that are connected with observations. For version 5.04e of the model, verifications were also carried out for a smaller stratification, which contained only **198** German stations.

The new model versions were registered with the version number (COSMO-5.03, COSMO-5.04a and COSMO-5.04e) and resolution for the 2.8km model (COSMO-5.03-2p8, COSMO-5.04a-2p8 and COSMO-5.04e-2p8), in order to follow the evolution of model versions/tests. Four models were taken into account during the entire duration of the special project: 5.01 and 5.03 respectively - operational and 5.03, 5.04a and 5.04e respectively - new test versions, as follows:

- new test version 5.03 against operational 5.01
- new test version (5.04a) against operational 5.03
- new test version (5.04e) against operational 5.03

All models have the same grid characteristics but they were each assigned a different model id: 102 (COSMO-5.01-7km), 103 (COSMO 5.03–7km), 104 (COSMO 5.03–2.8km), 105 (COSMO 5.04a–7km), 106 (COSMO 5.04a–2.8km), 107 (COSMO 5.04e–7km), 108 (COSMO 5.04e–2.8km).

4 front-ends (FE) are also registered separately for each new test versions and each resolution (in total 28 Fes for 4 model versions, 2 horizontal resolution). These were created separately due to the different interpolation methods used in each case: three separate FEs for precipitation, cloud cover and other parameters and a separate FE for the upper air data, for each model version and resolution. The large size of the files containing the forecast data (especially for the 2.8km model) would slow down the VERSUS system. Due to this problem, original grib model outputs were split in hourly smaller files before the uploading phase, using the **wgrib** facility, in order to speed up the latter.

The verification modules for the tests were the following:

- **surface continuous parameters** (2mT, Dew Point T, WindSp, TCC, MSLP): BIAS, RMSE – up to 72 hours anticipation for COSMO-7km, up to 48 hours anticipation for COSMO-2.8km;
- **precipitation verification** (6h, 12h, 24h) for selected thresholds (greater than 0.2, 0.4, 0.6, 0.8, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 25, 30): ETS, FBI, Performance diagrams – up to 72 hours anticipation for COSMO-7km, up to 48 hours anticipation for COSMO-2.8km;
- **upper air verification** - T, RH, WindSp for selected pressure levels (250., 500., 700., 850., 925., 1000.): BIAS, MAE, RMSE – up to 72 hours anticipation for COSMO-7km, up to 30 hours anticipation for COSMO-2.8km.

For the model output verification, the following steps were performed:

- Registration of the models
- Configuration of FEs and data ingestion
- Configuration of all standard surface and upper air verification tests
- Execution of the verifications in a batch mode
- Configuration of Cross model verification: interactively and batch mode
- Configuration of related graphics
- Analysis of scores in numerical format

3. VERIFICATION RESULTS

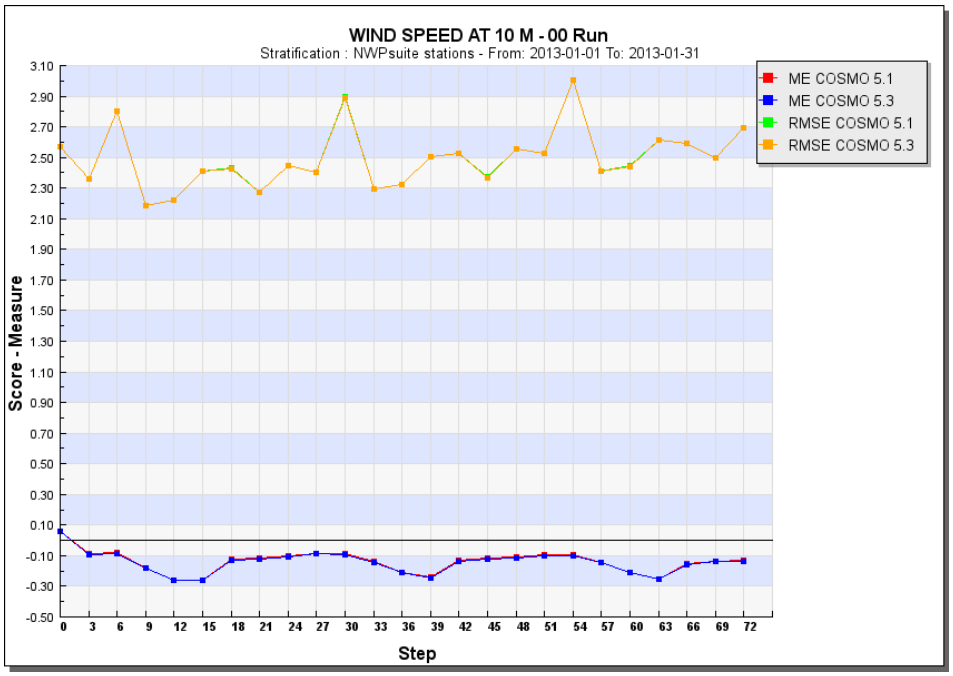
As previously mentioned, the verifications for all model versions were performed for the months of January and July 2013. Some of the statistical results that were obtained through the VERSUS system (surface and upper air) are presented in figures 3 – 6 for the 7km model version and the 2.8km version.

With respect to 10 meter wind speed, mean error values for the winter period are worsened in version 5.03 (7 km resolution) but this is not noticeable in the summer period. Overall the comparison of scores shows neutral impact resulting from the introduction of this version (figure 3).

The scores for the forecast of upper air parameters (relative humidity, temperature and wind speed) for version 5.04a against version 5.03 show similar behavior for both models. Note that only a few main instances are given in this report indicatively.

Temperature comparison of ME and RMSE for version 5.04a against version 5.03 gave insignificant differences (figures 4 - 5). Temperature is underestimated during winter periods for almost all levels and hours, while for the summer there is a small overestimation mainly in the middle atmospheric levels. No significant changes also were demonstrated from the two various resolutions.

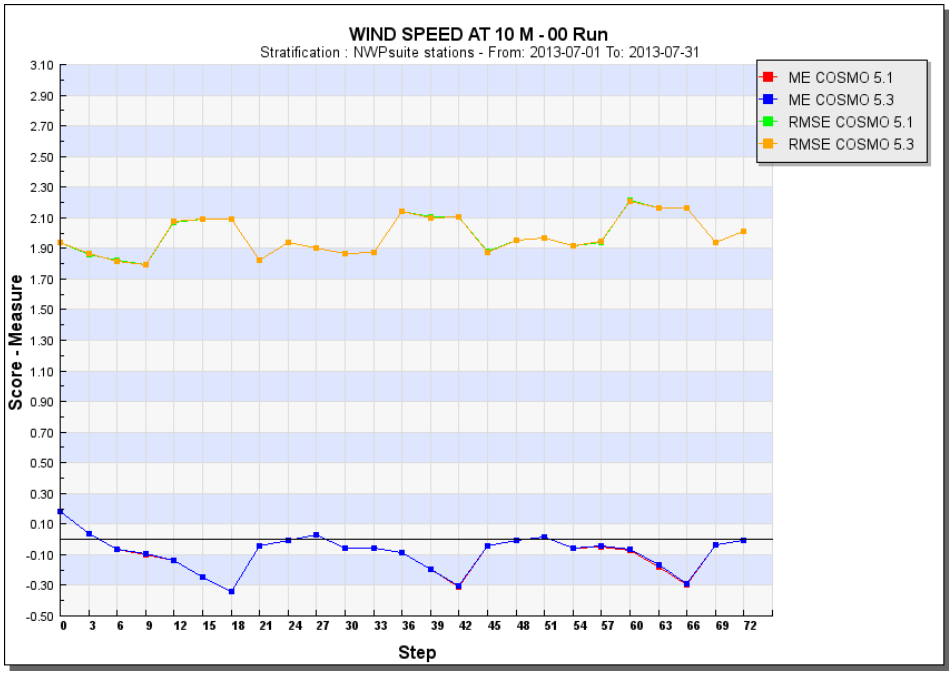
For the forecast of precipitation (6h and 24h accumulation periods but only the 24h are presented here), the statistics of versions 5.04e and 5.03 of the model are similar (overestimation in small thresholds [>0.2mm] but underestimation of precipitation amounts for higher thresholds [<5mm], higher FAR and lower POD with increasing threshold) with some differences mainly associated with False Alarm Rate score (figure 6). It is noted however that there is an increased overestimation for the small thresholds with version 5.04e during the afternoon hours of the day for both resolutions while for the winter the statistical indices are almost identical. For higher thresholds, POD and FAR are slightly worsen with new version and the statistical significance is increased (smaller “crosses”). The overall performance of the higher resolution version is better that the coarser one for both versions (5.03, 5.04e).



WindSp winter

ME	5.3	5.1	
0	0.062	0.062	0.000
3	-0.090	-0.087	-0.003
6	-0.087	-0.082	-0.005
9	-0.181	-0.178	-0.003
12	-0.263	-0.260	-0.003
15	-0.260	-0.258	-0.002
18	-0.130	-0.125	-0.004
21	-0.120	-0.117	-0.003
24	-0.105	-0.101	-0.004
27	-0.089	-0.086	-0.003
30	-0.094	-0.089	-0.005
33	-0.142	-0.139	-0.003
36	-0.212	-0.209	-0.003
39	-0.243	-0.239	-0.004
42	-0.134	-0.130	-0.004
45	-0.122	-0.116	-0.006
48	-0.114	-0.110	-0.004
51	-0.097	-0.094	-0.003
54	-0.102	-0.096	-0.006
57	-0.144	-0.141	-0.003
60	-0.213	-0.209	-0.004
63	-0.255	-0.251	-0.004
66	-0.155	-0.149	-0.006
69	-0.141	-0.136	-0.004
72	-0.135	-0.130	-0.004
RMSE	**5.3**	**5.1**	
0	2.571	2.571	0.000
3	2.358	2.358	0.000
6	2.799	2.801	0.002
9	2.188	2.189	0.001
12	2.222	2.224	0.002
15	2.411	2.411	0.000
18	2.426	2.429	0.002
21	2.275	2.274	0.000
24	2.445	2.446	0.000
27	2.403	2.404	0.001
30	2.891	2.893	0.003
33	2.295	2.294	0.000
36	2.326	2.327	0.001
39	2.503	2.504	0.001
42	2.523	2.524	0.001
45	2.370	2.374	0.003
48	2.553	2.555	0.001
51	2.525	2.526	0.001
54	3.006	3.006	0.001
57	2.411	2.411	0.001
60	2.441	2.445	0.004
63	2.616	2.615	-0.001
66	2.589	2.590	0.001
69	2.498	2.497	-0.001
72	2.694	2.695	0.000

(a)



WindSp summer

ME	5.3	5.1	
0	0.182	0.182	0.000
3	0.036	0.036	0.000
6	-0.063	-0.063	0.000
9	-0.096	-0.099	0.002
12	-0.135	-0.137	0.003
15	-0.245	-0.247	0.002
18	-0.344	-0.343	0.000
21	-0.044	-0.046	0.002
24	-0.004	-0.006	0.002
27	0.030	0.029	-0.001
30	-0.055	-0.056	0.000
33	-0.057	-0.060	0.003
36	-0.086	-0.087	0.001
39	-0.192	-0.195	0.003
42	-0.307	-0.309	0.002
45	-0.040	-0.041	0.001
48	-0.006	-0.007	0.001
51	0.015	0.015	0.000
54	-0.058	-0.057	-0.001
57	-0.046	-0.050	0.004
60	-0.067	-0.070	0.002
63	-0.169	-0.178	0.008
66	-0.292	-0.295	0.003
69	-0.039	-0.036	-0.002
72	-0.006	-0.003	-0.003
RMSE	**5.3**	**5.1**	
0	1.938	1.938	0.000
3	1.863	1.862	0.000
6	1.819	1.819	0.001
9	1.796	1.797	0.000
12	2.074	2.073	-0.001
15	2.092	2.093	0.000
18	2.090	2.089	-0.001
21	1.824	1.825	0.001
24	1.938	1.938	0.000
27	1.900	1.899	-0.001
30	1.869	1.869	0.000
33	1.877	1.875	-0.002
36	2.140	2.141	0.000
39	2.099	2.103	0.004
42	2.105	2.106	0.001
45	1.877	1.879	0.002
48	1.952	1.956	0.004
51	1.965	1.965	0.001
54	1.914	1.914	0.001
57	1.945	1.942	-0.003
60	2.211	2.211	0.001
63	2.160	2.161	0.001
66	2.167	2.166	-0.001
69	1.935	1.938	0.002
72	2.009	2.010	0.001

(b)

Fig. 3 Wind Speed at 10 m verification results (00UTC run) – COSMO-5.01 (5.1) and COSMO-5.03 (5.3) ME and RMSE for: (a) January 2013 (b) July 2013, Numerical scores and differences on the right pane. Colors indicate: **red** - worsening, **green** - improvement, **yellow** - neutral.

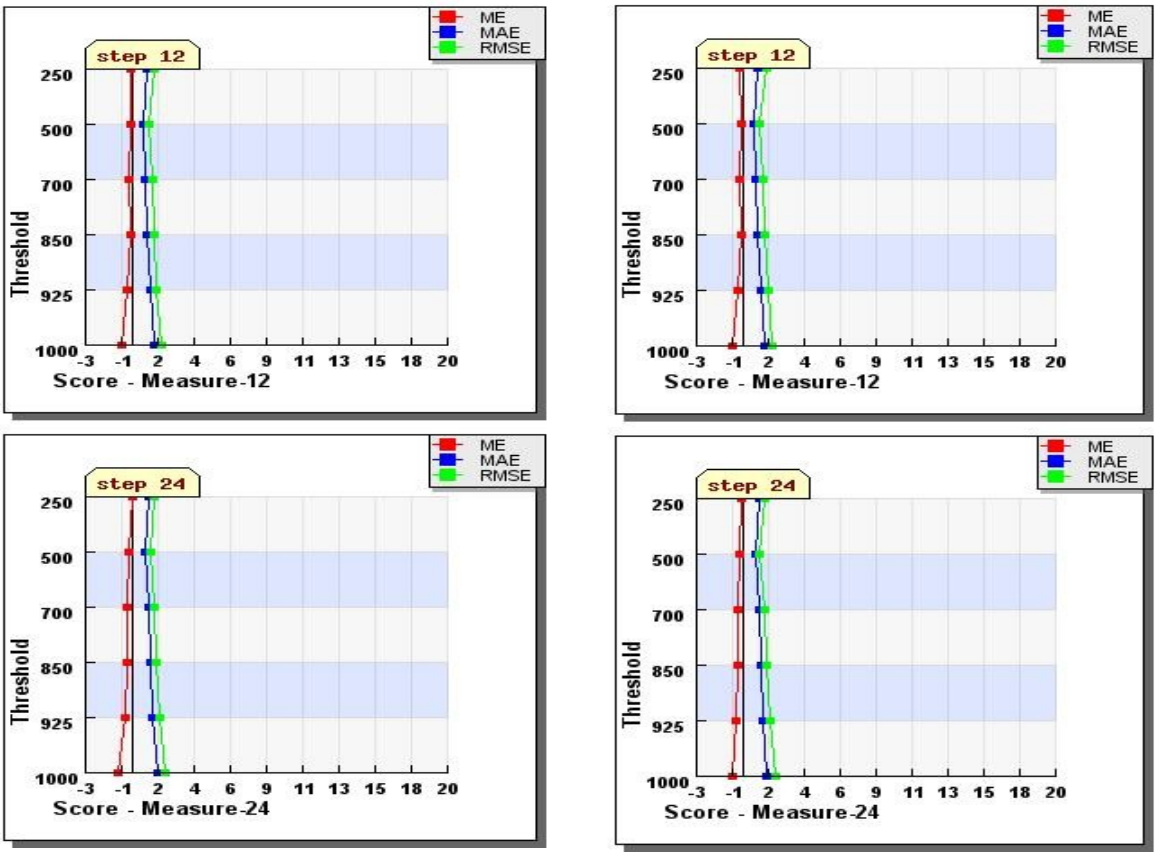


Fig. 4 COSMO-2.8km Upper air verification for January 2013: Temperature
COSMO 5.03 (left) / COSMO 5.04a (right)

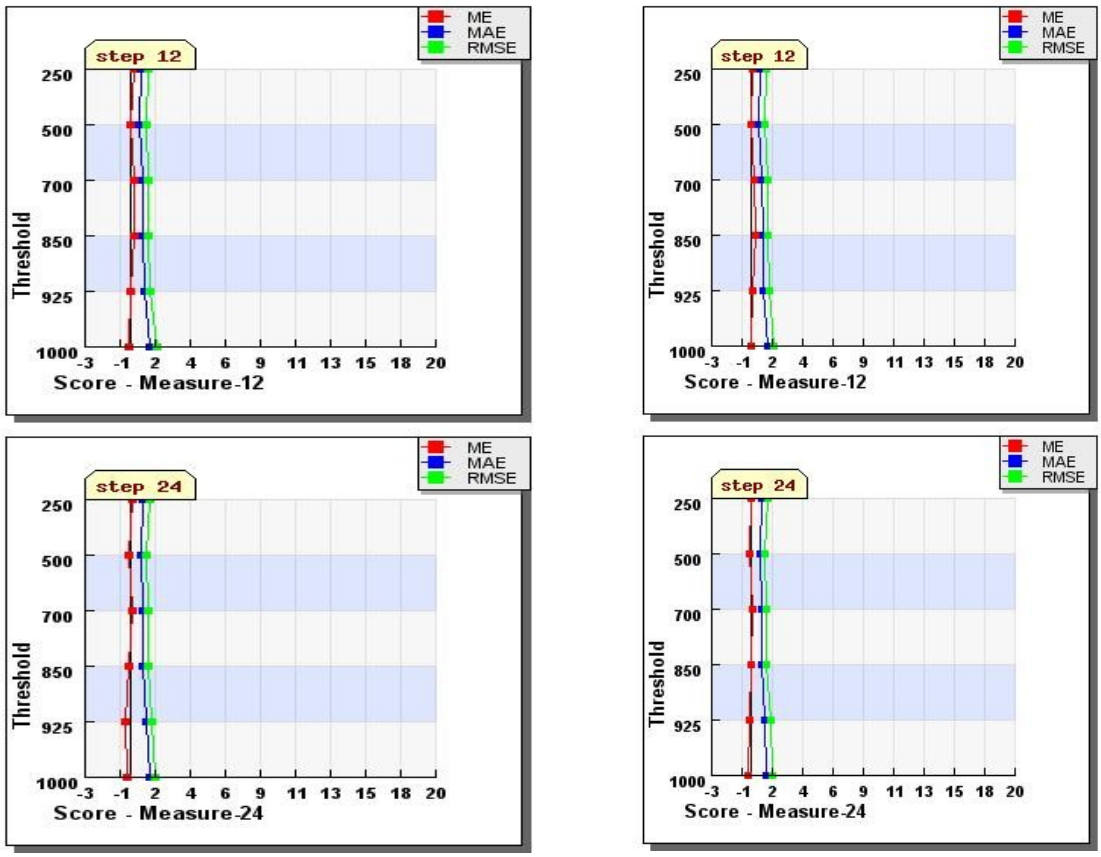
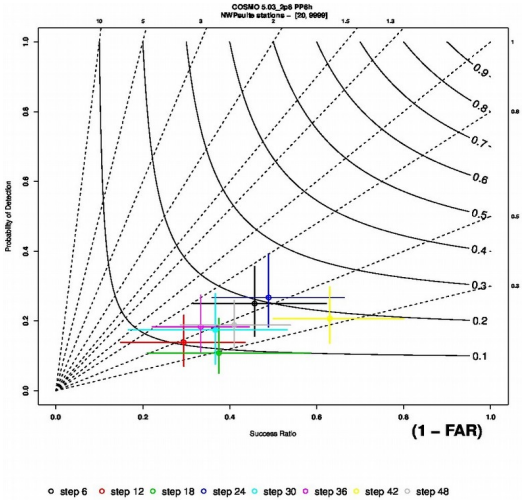
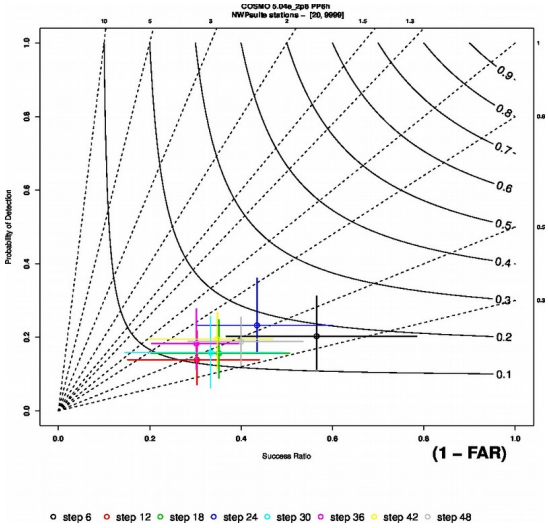


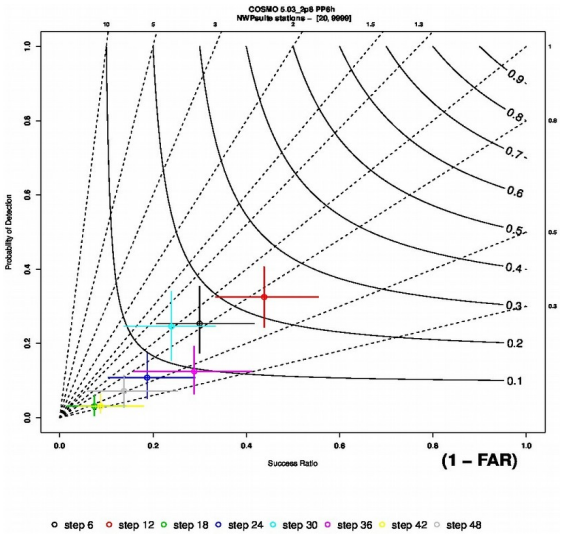
Fig. 5 COSMO-2.8km Upper air verification for July 2013: Temperature
COSMO 5.03 (left) / COSMO 5.04a (right)



a)



b)



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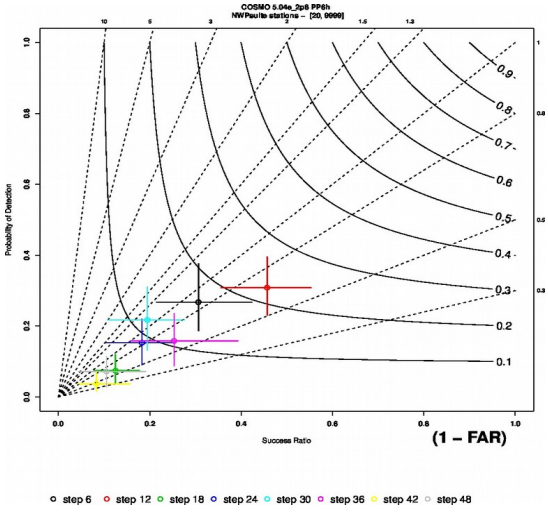

d)

Fig. 6 COSMO-2.8km 6h precipitation > 20mm verification results (00UTC run), (1-FAR) for: (a) COSMO 5.03 January 2013 (b) COSMO 5.04e January 2013 c) COSMO 5.03 July 2013 d) COSMO 5.04e July 2013

List of publications/reports from the project with complete references

1. A. MONTANI, A. IRIZA, M. BOGDAN, A. CELOZZI, R. DUMITRACHE, F. GOFA - "Numerical Weather Prediction Meteorological Test Suite": COSMO 5.3 vs. 5.1, COSMO-Model Report, December 2015
2. A. MONTANI, **A. IRIZA,** M. BOGDAN, R. BOVE, R. DUMITRACHE, F. GOFA (contributors) - *"Numerical Weather Prediction Meteorological Test Suite": COSMO 5.04a vs. 5.03 (7km and 2.8km)*, COSMO-Model Report, August 2016
3. A. MONTANI - "COSMO NWP meteorological test suite: present status", The 18th COSMO General Meeting, Offenbach, Germany, Parallel Session: WG5, NWP Test Suite, WG6, 5 - 9 September 2016
4. F. GOFA - "NWP Test suite: Verification reports", The 18th COSMO General Meeting, Offenbach, Germany, Parallel Session: WG5, NWP Test Suite, WG6, 5 - 9 September 2016
5. M. MILELLI - "WG6 overview", The 18th COSMO General Meeting, Offenbach, Germany, 5 - 9 September 2016
5. A. MONTANI, **A. IRIZA,** M. BOGDAN, R. DUMITRACHE, F. GOFA, R. BOVE (contributors) - *"Numerical Weather Prediction Meteorological Test Suite": COSMO 5.04e vs. 5.03 (7km and 2.8km)*, COSMO-Model Report, March 2017

The detailed report regarding the comparisons of the operational and test versions for the COSMO model using this platform were submitted to the COSMO Steering Committee and are also avilable on the official web-site of the Consortium for authorized users.

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

The current research activity which includes the evaluation of each new COSMO version through a defined procedure (the NWP test suite) will be continued for new model versions (and added configurations) in the frame of the „**Testbed for the Evaluation of COSMO Model Versions**" special project approved for 2018-2020.