The new DWD forecast system

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Abstract

Recently, in spring 2007, the new high resolution short range forecast model COSMO-DE has been operationally implemented within the NWP model suite at DWD to improve the short range weather prediction and the prediction of severe weather in Germany. Now the model suite consists of three models with different resolutions: GME (40 km), COSMO-EU (7 km) and COSMO-DE (2.8 km). All models are running with their own data assimilation suite. The COSMO-DE model is started every three hours. High resolution radar data are assimilated. The 21-h forecasts are available one hour after observation.

This paper describes the configuration of the NWP model system at DWD. Due to the rapid update cycle of the COSMO-DE model (8 times a day), the operational timetable had to be completely reorganised, to provide this model with the best possible boundary data. The design of this new operational timetable and the data flow between the different NWP models is discussed.

The operational forecast models are producing more than 500 GByte of data a day. Numerical experiments using the NUMEX system are producing an amount of data in the same order. With the planned development of a regional ensemble prediction system on the new computer system, based on the COSMO-DE model, this amount will increase dramatically. The use of the DWD data handling system for operational and research purposes is briefly reviewed. Finally an short outlook to the further model developments at the DWD is given.

Operational NWP-model suite

Since spring 2007, the operational NWP-model suite of DWD consists of three different NWP-models, the global model GME and the regional models COSMO-EU and COSMO-DE. Fig. 1 is showing all three models with their forecast areas. In addition to the NWP-models there are three wave models - the global wave model (GSM), the local wave model covering the Baltic Sea and parts of North Sea (LSM) and the Mediterranean wave model (MSM).

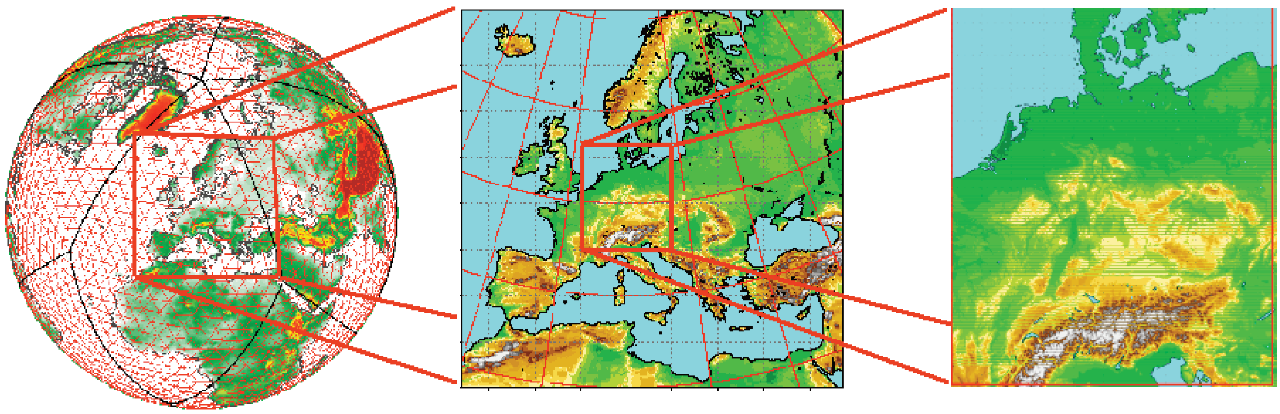

Fig. 1 GME, COSMO-EU and COSMO-DE with data dependencies

The GME [1] is a global hydrostatic forecast model based on a horizontal triangular grid. One of the large advantages of this grid is the absence of singular points at the North and South Pole. The horizontal resolution is about 40 km and the grid cell area has a size of about 1384 km_. The number of vertical levels is 40. This model version is running since 27. September 2004. Some additional features of the GME model are:

- 7-layer soil model including freezing/melting of soil water
- sea ice model
- seasonal variation of plant cover based on NDVI data.

The data assimilation cycle of the GME is running eight times a day. A separate analysis of atmospheric fields (optimal interpolation), sea surface temperature (only 00 UTC) and of snow (density, depth, temperature) is executed. During the analysis of atmospheric fields ATOVS data of NOAA-15, -16, 18 and AQUA are included using a 1DVAR approach. The use of METOP-A data will be implemented soon, because of the better data coverage in the Atlantic and Pacific Oceans, the analysis of atmospheric fields will be improved. Due to the lack of conventional observations over the sea and Antarctica the global assimilation analysis at 00 UTC is using so called “pseudo temps” above these regions. These “pseudo temps” are derived from the ECMWF 00 UTC analysis and cover the oceans and Antarctica with a minimal distance of 180 km between points. They are used like TEMPS within the analysis scheme.

The regional model COSMO-EU is used operationally since 28. September 2005 and is covering Europe with a grid distance of about 7 km. This model has 40 vertical levels (like GME), but with a different vertical distribution. Important properties of the COSMO-EU are [2]:

- non-hydrostatic, fully compressible Euler equations
- parametrized convection
- 7-layer soil model including freezing / melting of soil water
- prognostic variables are p, u, v, w, T, qv, qc, qi, qr, qs, TKE.

Boundary data are interpolated from the GME at hourly intervals. The COSMO-EU has an own data assimilation suite. It is performing a continuous data assimilation (nudging scheme) which is started eight times a day for three hour assimilation periods. At 00 UTC an analysis of sea surface temperature and of the surface moisture is done. The surface moisture is determined with an variational approach. At 00, 06, 12 and 18 UTC a separate analysis of snow (density, depth, temperature) is executed.

The new high resolution model COSMO-DE is used operationally since 16. April 2007. The goals of developing this model were to provide a model-based NWP-system for very short range forecasts (until 21 hours) of severe weather events on the meso-_ scale, especially those related to

- deep moist convection (super- and multi-cell thunderstorms, squall-lines, MCCs, rainbands,...)
- interactions with fine-scale topography (severe downslope winds, Föhn-storms, flash floodings, fog, ...)

The COSMO-DE model has a horizontal resolution of about 2.8 km and 50 vertical layers. The main properties of COSMO-DE are [5,6,9,10]:

- non-hydrostatic, fully compressible Euler equations
- resolved deep convection
- 7-layer soil model including freezing / melting of soil water
- prognostic variables are p, u, v, w, T, qv, qc, qi, qr, qs, qg (graupel), TKE
- radar data assimilation based on Latent Heat Nudging [3,7,8]

Boundary data are interpolated from the COSMO-EU model hourly. Radar data are available as a 2 dimensional composite every 5 minutes and are derived from a radar composite (reflectivity) of 16 stations with a spatial resolution of 1 x 1 km. The use of these data gives a better precipitation forecast until forecast hours 4 to 5.

The COSMO-DE is running eight times a day for an 21 hour forecast. This rapid update cycle gives the forecasters the possibility to use several consecutive forecasts as an LAF-ensemble. The very short observation cut off time of about 40 minutes allows it to provide the complete forecast 1 hour after analysis time within the database. The model output frequency of several meteorological fields is 15 minutes. So it is possible to evaluate the development of high resolution meteorological phenomena with a life cycle up to 2 hours. The data assimilation cycle is similar to that of the COSMO-EU, but without surface moisture analysis. The assimilation of radar data with the Latent Heat Nudging is executed during data assimilation.

With the implementation of the COSMO-DE as an additional forecast model with a rapid update cycle, it was necessary to reorganize the schedule of the complete NWP-model suite. Figure 2 shows the old and new operational schedule. The new schedule is mainly based on the requirement to provide the COSMO-DE forecasts eight times a day one hour after analysis time within the database.

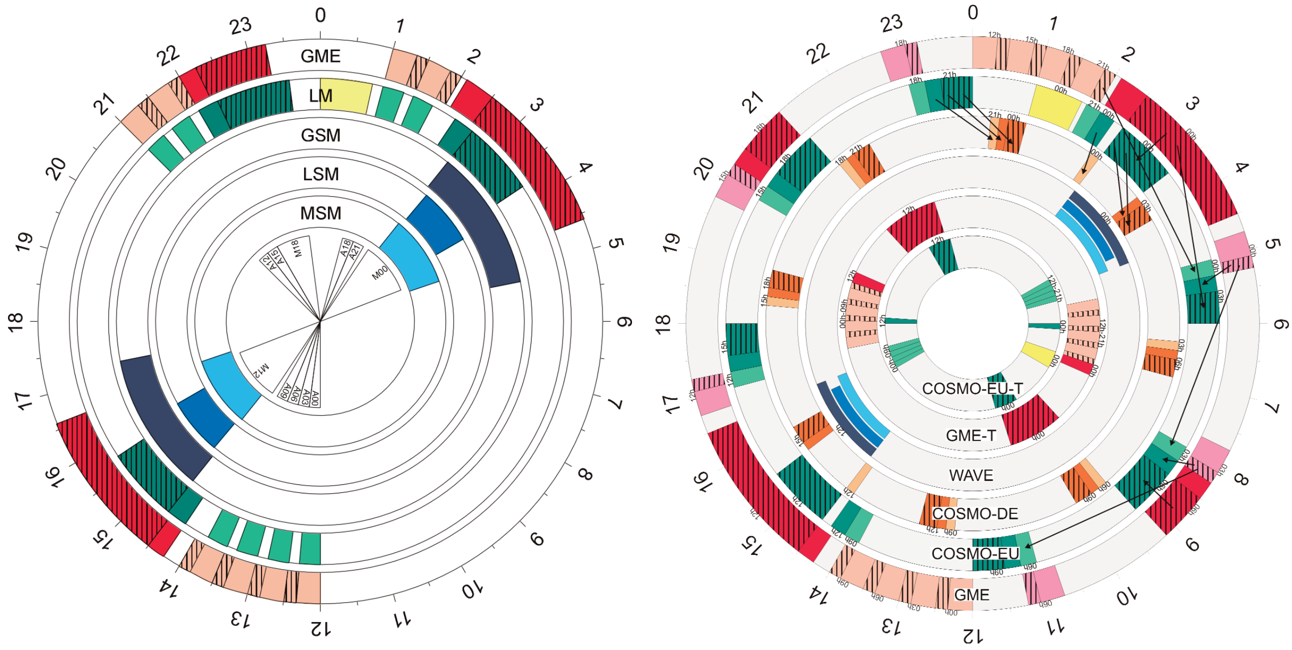

Fig. 2 Operational schedule without (left) and with (right) COSMO-DE forecasts (LM has been renamed to COSMO recently)

Both pictures show an 24 hour clock, every circle corresponds to one NWP-model. The dark areas characterize the production runs, the brighter areas of a model circle the data assimilation. Each model run consists of an analysis and a forecast run (dashed area). To prepare boundary data of COSMO-DE some additional COSMO-EU runs had to be implemented. So every running COSMO-DE gets boundary fields of a COSMO-EU run with an analysis time of X-3 hours. To provide the additional COSMO-EU runs with proper boundary data a GME run at 06 UTC was implemented and the analysis time of the 18 UTC run was adapted. The data assimilation of COSMO-EU was reorganized and, to provide this data assimilation with boundary data, a so called GME-pre-assimilation was implemented. The arrows at the right picture show the boundary data transfer between the different NWP-models; the two inner circles indicate the schedule of the pre-operational test suites of GME and COSMO-EU.

model	time [UTC]	forecast range [h]	data cut off [UTC]	ready [UTC]
GME	00, 12 06, 18	174 48	02:14 / 14:14 08:15 / 20:15	04:30 / 16:30 09:00 / 21:00
COSMO-EU	00, 12 06, 18 03, 09, 15, 21	78 48 24	02:14 / 14:14 08:15 / 20:15 05:15 / 11:15 / 17:15 / 23:15	03:30 / 15:30 09:15 / 21:15 06:00 / 12:00 / 18:00 / 24:00
COSMO-DE	00, 03, 06, 09 .. 21	18 (21)	00:30 / 03:30 / 06:30 .. 21:30	01:00 / 04:00 / 07:00 .. 22:00

Table 1 NWP-model with forecast time, observation cut off- and ready-times

Table 1 shows the forecast time and the observational cut off- and the ready-times of all production runs of the three NWP-models. Ready-time means that the forecast has finished and all data are available for further use. All forecast data are stored already during the model run into the field database. So every post-processing application has immediately access to these data.

Databases

The very complex structure of the DWD NWP-system described above requires the use of an effective data handling system. So all observation and model data are stored within a commercial RDBMS (ORACLE). All metadata are stored within the tablespaces of the database system, the real GRIB- and BUFR- data are stored as so called bfiles within the filesystem of the dataserver.

The access to the database is performed by socket communication with a DWD-written user interface. This user interface consists of a client part "csobank", running on several hosts, and a server part "oserver", running on the dataserver. The server part organises a uniform access to all data stored, no matter whether they are stored online or are archived on a tape silo. Some special features of this DWD-written user interface make it possible to use the tape archive like a large disk cache of some Petabyte.

Users can create an own set of database tables. With the help of the DWD experiment system called NUMEX they can simulate the run of the complete operational model suite including archiving of data, without thinking about disk space on compute servers and archiving of data. Due to these features the database system is heavily used by research people from DWD and several universities for the model development.

Operational data handling

The data transfer between all operational NWP-models is always done via the described databases. Applications on all clients have the same user interface. Figure 3 show the data transfer between GME and COSMO-EU and post-processing respectively between COSMO-EU and COSMO-DE. It is possible that different parts of the model suite are running on different hosts.

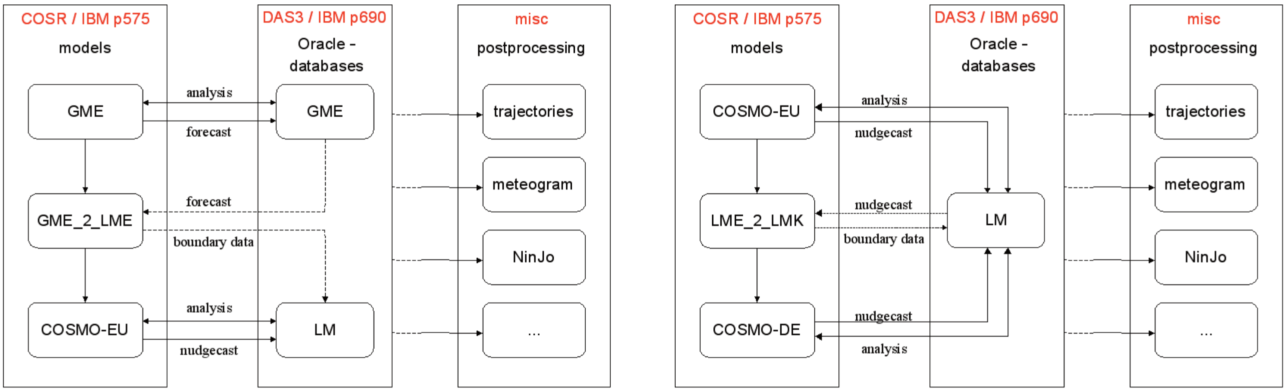

Fig. 3 data transfer GME _ COSMO-EU (formerly called LME) and COSMO-EU _ COSMO-DE (formerly called LMK)

DWD cooperates with several weather services and research institutes worldwide, running the COSMO- or the HRM-model (a hydrostatic regional NWP-system, see http://www.met.gov.om/hrm/) as an operational regional model. These partners receive boundary data of the GME. The data delivery of GME data via internet starts immediately with the first model output. So many regional NWP models worldwide, driven by GME data, can run in parallel (Fig. 4).

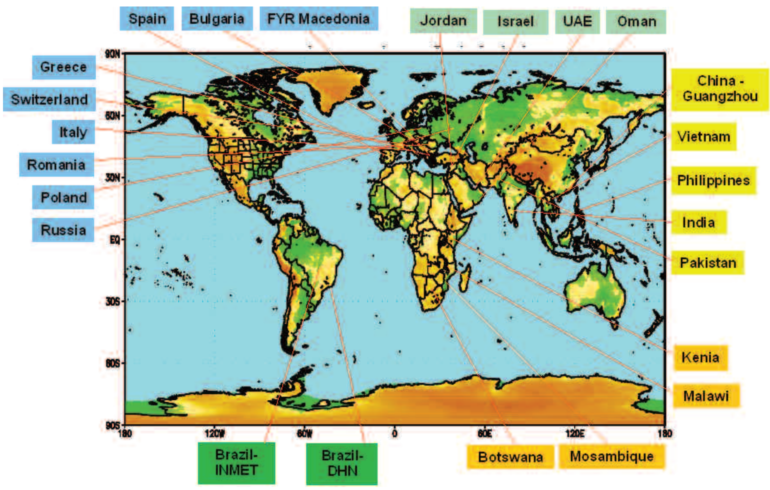

Fig. 4 Worldwide provision of GME boundary data

Data distribution

There is a great demand from research users (universities, scientific institutes, special projects, ..) to get data from the NWP models of DWD for their projects. These data are used to drive their own models or to validate the DWD model data against new observation systems. To fulfil these requirements the DWD has several advantages:

- universities and institutes are running the COSMO model for their own purposes, feedback is given back to DWD (extensions, bugs, ..)
- operationally produced analysis and forecast data are evaluated against different types of observations (quality feedback)
- the COSMO model is used as a climate model within the CLM community (http://www.clm-community.eu/)

To make use of all these advantages the DWD decided to provide an easy to use web-interface for scientific users to order NWP data of GME and COSMO. This web-interface, developed in the framework of the DFG-funded project SPP1167 (http://www.meteo.uni-bonn.de/projekte/SPPMeteo/) is working for about three years and has has the following properties:

- free use for research purposes
- no need to have DWD internal use IDs
- no direct access to DWD internal infrastructure like databases and archive (prevention of security problems)
- definition of detailed data requests via the web-interface
- execution of data requests via NUMEX infrastructure (illegal requests are rejected)
- GRIB data are made available on a special FTP-server (avoid problems with external network administrators, ..) and are retained for about 7 days
- limitations: only GRIB data older than 2 days, no observation data
- three access modes of forecast data are available (Fig. 5):
    - several forecast times of one model forecast
    - one defined forecast time of several model forecasts
    - all forecast times valid at a defined target date

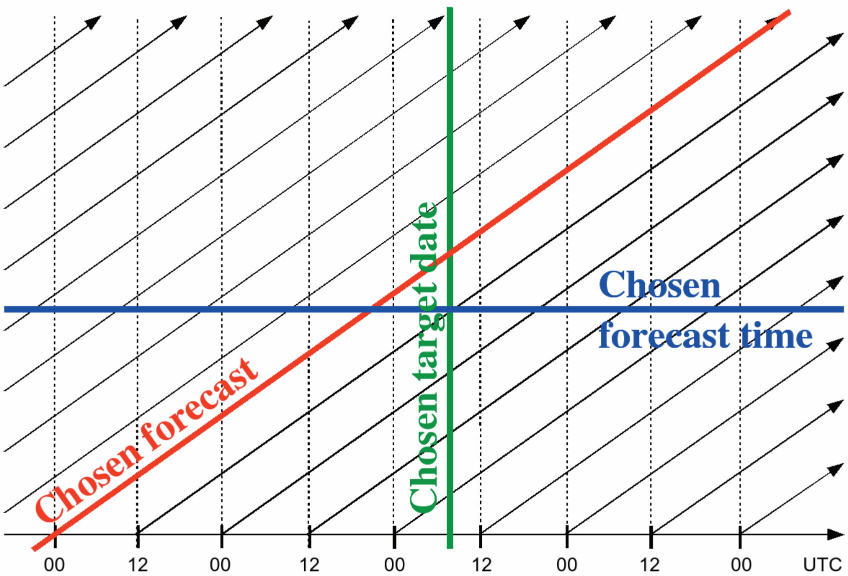

Fig. 5 Access modes to forecast data in the web-interface

Outlook

The DWD is going on to improve the forecast models on global and regional scale. The further developments within global forecasting are:

- 2008 replacement of the Optimal Interpolation by a 3D-Var scheme (for better exploitation of satellite data)
- 2008 introduction of a surface moisture analysis
- 2009 increase the resolution of the GME to 20 km (horizontal) and 60 levels (vertical)
- 2011 replacement of GME by ICON (ICOsahedral Nonhydrostatic Global Circulation Model [4]

The next milestones within regional forecasting are:

- 2008 introduction of a LAKE model within COSMO-EU
- 2009 pre-operational run of a local COSMO-DE ensemble (20 members)
- 2011 operational run of a local COSMO-DE ensemble (40 members)
- 2011 replacement of the COSMO-EU by ICON

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