Status Report of the Deutscher Wetterdienst DWD
2001 - 2002

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1. Operational Numerical Weather Prediction System GME and LM

Tab. 1 gives an overview of the operational numerical weather prediction system at the Deutscher Wetterdienst.

Table 1 The numerical weather prediction system at DWD

Model	Domain	D (km)	Layers	GP/layer	Flop/24 h (10^{12})	Initial date (UTC)	Forecast range (h)
GME	global	~ 60	31	~ 164000	7.2	00 12 18	174 174 48
LM	Germany/ surrounding	~ 7	35	~ 106000	25.0	00 12 18	48 48 48

The **Global Model (GME)** uses an icosahedral-hexagonal grid which allows a nearly uniform resolution with less than 20% variation of mesh size over the globe.
The key features of the GME include

- icosahedral-hexagonal grid (**Sadourny et al., 1968**), mesh size between 55 and 65 km, average mesh size ~ 60 km,
- Arakawa A grid, all variables are placed at triangle vertices,
- tangential plane with local spherical coordinate system at each node,
- hybrid vertical coordinate (**Simmons and Burridge, 1981**), 31 layers,
- second order accurate gradient and Laplace operators based on local coordinates and using the 6 (5) surrounding nodes,
- bilinear interpolation using the 3 surrounding nodes,
- biquadratic interpolation using the 12 surrounding nodes,
- prognostic variables: surface pressure, temperature, horizontal wind components, specific water vapour and cloud water contents,
- Eulerian, split semi-implicit (first 5 modes) treatment of surface pressure, temperature, horizontal wind components,
- semi-Lagrangian, positive-definite, monotone advection of water substances,
- three time level, Asselin filtering,
- physical package: adapted from the former operational regional model EM/DM plus the parameterization of sub-grid scale orographic drag by **Lott and Miller, 1997**,
- incremental Digital-Filtering-Initialization by **Lynch, 1997**,
- intermittent 4-d data assimilation based on OI scheme, 6-h cycle.

Detailed descriptions of GME are available in **Majewski (1998)** and **Majewski et al. (2002)**.

The current users of GME data are listed in Tab. 2.

The limited area **Lokal-Modell (LM)** is designed as a flexible tool for forecasts on the meso-ß and on the meso-γ scale as well as for various scientific applications down to grid spacings of about 100 m. For operational NWP, LM is nested within GME on a 325 x 325 grid with 35 layers. The mesh size is 7 km. The LM is based on the primitive hydro-thermodynamical equations describing compressible nonhydrostatic flow in a moist atmosphere without any scale approximations. The continuity equation is replaced by an equation for the perturbation pressure (respective a height dependent base state) which becomes a prognostic variable besides the three velocity components, temperature, water vapour and cloud water. The set of model equations is formulated in rotated geographical coordinates and a generalized terrain-following vertical coordinate. Spatial discretization is by second order finite differences on a staggered Arakawa-C/Lorenz-grid. For the time integration, three different methods have been implemented:

- a Leapfrog scheme using the Klemp and Wilhelmson time splitting method including extensions proposed by **Skamarock and Klemp (1992)** to solve for the fast modes,
- a two-time level split-explicit scheme proposed by **Wicker and Skamarock (1998)**, and
- a fully 3D implicit scheme treating all pressure and divergence terms implicitly **(Thomas et al., 2000)**.

For more information about LM and its data assimilation system, see separate report on the COSMO-group in this volume.

2. High Performance Computer at DWD

The high performance computer system at DWD is an IBM RS/6000 SP (80 nodes with 16 processors each). The processors (PE: processing elements) are equipped with a 375 MHz CPU (Power3-II). Most of the nodes possess 8 GByte of shared memory, some possess 16 GByte. The peak performance of the total 80-node system (1280 PEs) will be around 2 Teraflop/s. The sustained performance for typical NWP codes on the full system is about 150 Gflops/s.

The operational NWP system, i.e. the

- global icosahedral-hexagonal grid point model GME and its data assimilation suite,
- nonhydrostatic local model LM and its data assimilation suite,
- global sea state model GSM,
- local sea state model LSM,
- Mediterranean sea state model MSM,
- trajectory model TM,
- Lagrangian particle dispersion model LPDM, and
- objective weather interpretation scheme for GME and LM,

is running on 28 nodes, for development 52 nodes are reserved. In the first quarter of 2003, all 80 nodes will be available for operational model runs.

3. International Usage of the HRM and Distributed Regional NWP

A portable version of the former hydrostatic regional model EM/DM of the DWD, called HRM (**H**igh resolution **R**egional **M**odel) is being used by a number of National Meteorological Services (NMS), namely Brazil (NMS in Brasilia and Military Naval Service in Rio de Janeiro), Bulgaria, China (Regional Service of Guangzhou), Israel, Italy, Oman, Poland, Romania, Spain, Switzerland and Vietnam, for regional NWP. HRM is designed for shared memory computers, is written in Fortran90 and uses OpenMP for parallelization. Via the Internet, GME initial and lateral boundary data are sent to the users of the HRM. This enables distributed computation of regional NWP. The DWD starts sending the GME data 2h 55min past 00 and 12 UTC; only the sub-domain covering the region of interest is sent to the NMS in question. Depending on the speed of the Internet, the transmission of the 48-h (78-h) forecast data at 3-hourly intervals (i.e. 17 (27) GRIB1 code files each with a size between 0.3 to 3 MByte depending on the area of the regional domain) takes between 30 minutes to 2 (3) hours. Thus at the receiving NMS the HRM can run in parallel to the GME at DWD using the interpolated GME analysis as initial state and GME forecasts from the same initial analysis as lateral boundary conditions. This is a considerable step forward because up to now most regional NMS have to use 12h “old” lateral boundary data which degrade the regional forecast quality by more than 10%.

Table 2: Current Users of GME Data (September 2001)

Country	Service	Main Application
Brasilia	National Meteorological Service Navy Weather Service	**HRM** **HRM**
Bulgaria	National Meteorological Service	**HRM**
China	Regional Service of Guangzhou	**HRM**
Germany	National Meteorological Service	**LM**
Greece	National Meteorological Service	**LM**
Israel	National Meteorological Service	**HRM**
Italy	Regional Service SMR-ARPA	**LM**
Oman	National Meteorological Service	**HRM**
Poland	National Meteorological Service	**LM**
Romania	National Meteorological Service	**HRM**
Spain	National Meteorological Service	**HRM for LEPS**
Switzerland	National Meteorological Service	**LM**
United Kingdom	National Meteorological Service	**PEPS**
Yugoslavia	National Meteorological Service	**ETA**
Vietnam	National Meteorological Service	**HRM**

4. Planned future developments

The pre-operational trial of the new NWP system consisting of GME with a mesh size of 40 km and 40 layers and LM covering whole of Europe with a mesh size of 7 km and 40 layers will start in December 2002. The operational production of the new NWP system is scheduled for end of 2003.

After a planned upgrade of the IBM RS/6000 SP in 2003, research work will concentrate on a nowcasting version of LM, called LMN, for Germany with a mesh size of 2.8 km and 50 layers. LMN will produce 18-h forecasts eight times a day (00, 03, ..., 18, 21 UTC) with a very short data cut-off. The main goal will be the explicit prediction of deep convection by LMN without the need to parameterize this complex process. This step will help to improve detailed local weather forecasts because for the first time an operational NWP model will handle explicitly convective processes and the interaction between the convective scale and larger scales. First case studies performed with LM at such high a resolution proved that the model is able to simulate properly the formation of convective cloud clusters and squall lines.

Of course, the development of this very high-resolution LM requires the solution of many scientific and technical problems in modelling, data assimilation (e.g. usage of radar data) and model interpretation. The COSMO group (Consortium for Small Scale Modelling) with the members Germany, Greece, Italy, Poland and Switzerland is concentrating all its efforts on this difficult task.

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