# Annual WWW Technical Progress Report on the GDPS 2003

Country: Germany                                                                 Centre: NMC Offenbach

## 1. Summary of highlights

*The modelling suite at DWD consists of the global icosahedral-hexagonal gridpoint model GME (average mesh size ~ 60 km, i.e. 163842 gridpoints/layer, 31 layers) and the nonhydrostatic limited-area "Lokal-Modell" LM (mesh size ~ 7 km, 325 x 325 gridpoints/layer, 35 layers). LM is used operationally at the national meteorological services of Greece, Poland and Switzerland and at the regional meteorological service in Bologna (Italy), too. The military weather service of Germany operates a relocatable version of LM, called RLM, for world-wide applications.*
*The hydrostatic high-resolution regional model HRM of the DWD is being used as operational model at twelve national/regional meteorological services, namely Brazil-INMET, Brazil-Navy, Bulgaria, China, Israel, Italy, Kenya, Oman, Romania, Spain, United Arab Emirates and Vietnam. For lateral boundary conditions, GME data are sent via the Internet to the HRM and LM users.*
*During the year 2003 the main improvements of the NWP suite included:*

- *July 03: Upgrade of the main high performance computer IBM RS/6000 SP from 80 to 120 nodes equipped with 16 Power III processors each.*
- *Improved quality check of SATEM humidity data.*
- *16/09/03: Cloud ice is introduced as a prognostic variable in GME, LM and HRM resulting in a better description of ice and mixed phase clouds and an improved radiation balance at the surface and the top of the atmosphere.*
- *02/12/03: Polar wind vectors (MODIS data) derived from the polar-orbiting satellites Terra and Aqua are used in the global data assimilation. The overall impact on forecast quality depends on the season but is always neutral or slightly positive.*
- *17/12/03: Pseudo-TEMPs (~ 9600 profiles over the oceans and Antarctica) based on the 00 UTC analysis of the ECMWF are used in the final global assimilation analysis for 00 UTC which is computed at 12.30 UTC each day. The gain in forecast quality at day 3 due to these data is between 14 to 17 hours in the southern hemisphere and up to 6 hours in the northern hemisphere and Europe.*

## 2. Equipment in use

### 2.1 Main computers

#### 2.1.1 IBM RS6000 SP

Operating System AIX 5.1

120 Power3-II Nodes (1920 Processors, 375 MHz)
Peak performance 1.5 Gflops per processor
8 or 16 GB Memory per processor
SP Switch 2
7,6 TB disk space

Used for operational forecasts and research

#### 2.1.2 ORIGIN 2000 (Operating System IRIX)

SGI ORIGIN 2000
Operating System IRIX 6.5
System of 4 O2000 servers
70 processors, 250 MHz
62 GB Memory

Access to StorageTek ACS Silo

The total system consists of servers for code development, pre- and postprocessing, Hierarchical Storage Management and Oracle databases.

#### 2.1.3 Storage Tek Silo (3 components)

Attached are
9840 drives: 16
9940 drives: 10

### 2.2 Networks

#### 2.2.1 Ethernet

Workstations, X-Terminals and PC's are connected to the main computers via routers to the Ethernet.

#### 2.2.2 HIPPI and Gigabit Ethernet

The IBM and the SGI servers are connected by HIPPI via two HIPPI switches. During 2004 HIPPI will be replaced by Gigabit Ethernet with Etherchannel.

#### 2.2.3 ATM

Access from the LAN to some of the O2000 servers is provided via routers to the ATM-connected systems

### 2.3 Special systems

#### 2.3.1 Satellite data system

Windows 2000 Server
Used for preparation of satellite pictures (from METEOSAT and NOAA and FENGYUN), vertical profiles of temperature and humidity (from NOAA).

#### 2.3.2 Interactive graphical system

A number of SGI workstations and colour plotters are used for presentation of satellite- and radar data as well as model output, surface forecast charts significant weather charts, and other interactive graphics,
The MAP (Meteorological Application and Presentation System) Workstation is used to display and animate all available meteorological data sources.

#### 2.3.3 Telecommunication system

The Meteorological Telecommunications System Offenbach (MTSO) is realized on a High-Availability-Primecluster with two Primepower 400 Computers (Fujitsu Siemens Computers) running on Sun-Solaris systemsoftware and RMS clustersoftware.

The belonging MSS and AFD Applications are communicating in real time via the GTS (RMDCN and leased lines), national and international PTT networks and the Internet with WMO-Partners and global customers like ESOC, EUMETSAT, ECMWF and DFS.

## 3. Data and products from GTS in use

At present nearly all observational data from the GTS are used. GRIB data from France and GRIB data from the UK, the US and the ECMWF are used. In addition most of the OPMET data are used.

Typical figures for 24 hours are:

| | |
|---|---|
| SYNOP | 70.000 reports, |
| SHIP | 12.000 reports, |
| TEMP, part A | 1.300 reports, |
| METAR | 175.000 reports, |
| PILOT, part A | 600 reports, |
| AIREP | 20.000 reports, |
| AMDAR | 18.000 reports, |
| SATEM, part A | 11.000 reports, |
| SATOB, section 2 | 5.300 reports, |
| SATOB, section 3 | 600 reports, |
| SATOB, section 4 | 800 reports, |
| SATOB, section 5 | 1.100 reports, |
| SATOB, section 7 | 1.100 reports, |
| GRIB | 13.000 bulletins, |
| BUFR | 20.000 bulletins |

## 4. Data input system

Fully automated system. Incoming reports in character oriented code forms are converted into BUFR before storing them into a data base.

## 5. Quality control system

There is no quality control system in use regarding outgoing data to the GTS except for formal structure.

### 5.1 Quality control of incoming data

The formats of all coded reports are checked and if necessary and possible corrected. Surface and upper air reports are checked for internal consistency before storing them into a data base.

## 6. Monitoring of the observing system

Surface observations and upper air observations are monitored quantitatively only on the national level. DWD acts as a lead centre for monitoring the surface observations in Region VI. At present, only the surface pressure observational data are checked.

## 7. Forecasting systems

### 7.1 System run schedule and forecast ranges

Preprocessing of GTS-data runs on a quasi-real-time basis about every 6 minutes on the ORIGIN 2000.
Independent 4-dim. data assimilation suites are performed for both models, GME and LM. For GME, analyses are derived for the eight analysis times 00, 03, 06, 09, 12, 15, 18 and 21 UTC based on an intermittent optimum interpolation scheme. For LM, a continuous data assimilation system based on the nudging approach provides analyses at hourly intervals.
Forecast runs of GME and LM with a data cut-off of 2h 14 min after the main synoptic hours 00, 12 and 18 UTC consist of 48-h forecasts for LM and 174-h forecasts (48-h for 18 UTC) of the GME. Additionally, three ocean wave models (3rd generation WAM), the global GSM, Mediterranean MSM and local wave model (North, Baltic and Adriatic Sea areas) LSM provide guidance about wind sea and swell based on 00 and 12 UTC wind forecasts of GME and LM.

### 7.2 Medium range forecasting system (4-10 days)

#### 7.2.1 Data assimilation, objective analysis and initialization

As far as GME is in use for medium range forecasting, the same procedures are applied as for short range forecasting described in item 7.3.1.

#### 7.2.2 Model

Medium range forecasts at the DWD are mainly based on the ECMWF system (deterministic model and EPS). Additionally, GME (see 7.3) forecasts up to 7 days augment the model guidance available.

#### 7.2.3 Numerical weather prediction products

ECMWF and GME global forecasts are available up to day 7. The ECOMET catalogue of the DWD global model products is given in annex 1.

#### 7.2.4 Operational techniques for application of NWP products

Using ECMWF-EPS-data, MOS applied to the GME and a statistical PPM-based interpretation scheme applied to both ECMWF and GME forecasts medium-range forecasts are produced up to day 7. Forecasts are provided for the public both in tabular form and in plain language. The forecasts in tabular form comprise the parameters daily maximum and minimum temperatures, relative sunshine duration, daily precipitation amount and probability, wind speed and direction, probability of thunder-storm, probability of fog.

A new method to produce medium range forecasts in plain language for the public has been introduced in 2003. It allows for a centralized medium-range forecast activity. For this purpose a particular soft-ware was developed by DWD which produces texts automatically from the data bases described above. At present texts are produced for 8 Areas in Germany according to user requirements. Every day in the beginning of the forecast business the meteorologist examines and – where necessary – modifies the texts taking into account additional model results (for example external models which are not part of the initial data base. The automatically produced texts comprise all significant weather parameters like cloud cover, precipitation, wind and extreme temperatures. In addition to this the automatic text production is in use for worldwide forecasts, which are available by dialling a premium

rate number on a fax machine, on a telephone answering device or on mobile telephones using short message system (SMS). The latter ones are produced however without forecasters' intervention.
Progress was made in medium range forecasting concerning the risk assessment of extreme weather for the forecast interval 120 hours down to 36 hours by synoptic interpretation of model results in combination with the evaluation of the COSMO-LEPS and EFI- (extreme forecast index) charts, provided by ECMWF. LEPS means Limited Area Ensemble Prediction System and was developed by the COSMO-Consortium (Members are Germany, Greece, Italy, Poland and Switzerland). LEPS is a combination of the EPS with the Limited Area Model LM and allows for utilising the benefits of EPS for the regional Scale. The Risk-Assessment is made available as a bulletin called "5 day forecast of weather risks". There will be given statements on the probability of certain weather events like storm, heavy precipitation, severe thunderstorm-situations, widespread snowfall or freezing precipitation, heat and cold waves. The bulletin is produced once a day in the late morning with actualisation according to new model results in the evening or night hours if necessary. It is available for the regional offices within DWD and for the public via the internet.

Agrometeorological forecasts cover a wide span of applications aiming at a reduction of the use of insecticides and fungicides or at an optimization of the water supply to plants. NWP results are combined with additional models which calculate the drying of leaves or the temperature and water balance in the ground.

### 7.3 Short-range forecasting system (0-72 hrs)

Operational short-range forecasting is based on the products available from GME and LM, where LM covers the time period up to 48 h only.
The short-range forecasts for Central Europe up to 48 hours are derived from the limited-area "Lokal-Modell" LM. Fig. 1 shows the model domain of LM and Fig. 2 the model levels. The 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 numerical weather prediction, LM is nested in the GME.

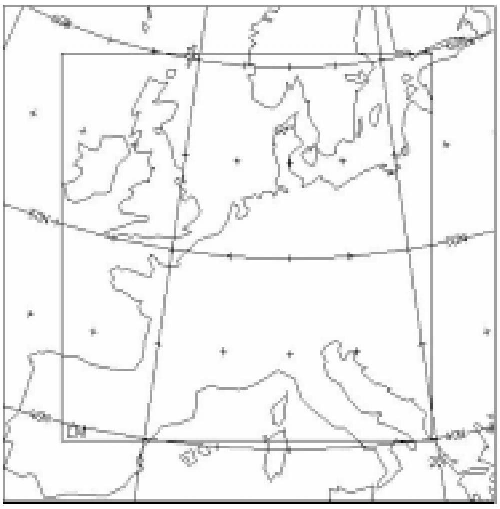

Figure 1 Model domain of the "Lokal-Modell" LM mesh size ~ 7 km, 325 x 325 gridpoints.

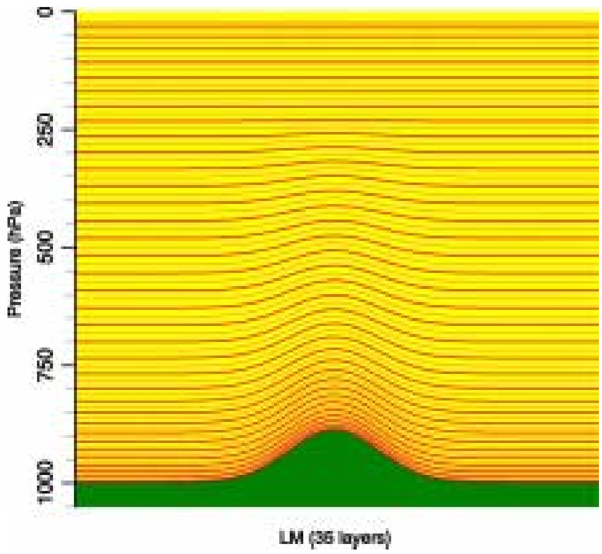


Figure 2 Model layers of LM.

### 7.3.1 Data assimilation, objective analysis and initialization

*Global Model (GME)*

**a) Global analysis of mass, wind field and humidity**

The program for the global analysis of mass and wind field, formerly developed by ECMWF, was ported to MPP systems by DWD with the support of the PALLAS software house.

| | |
|---|---|
| Analysis method | 3-dimensional multivariate optimal interpolation (humidity 2-dimensional). Direct use of thickness data. Box method. |
| Analysed variables | Φ, u, v, Rel. Hum.; Ozone from ECMWF analysis (12 UTC) |
| Horizontal anal. grid | Icosahedral grid of the GME ( average mesh size of 60 km ) |
| Vertical resolution | 31 hybrid layers (see GME) |
| Products | a) On icosahedral-hexagonal grid of the GME (163842 gridpoints/layer, 31 layers) Variables: $p_s$, T, u, v, $q_v$, $q_c$, $q_i$, $o_3$<br><br>b) On a regular geographical grid, 480 x 361 points (0.75° x 0.5°) 12 pressure levels 1000, 950, 850, 700, 500, ..., 50 hPa Variables: $p_{msl}$, T, Φ, u, v, Rel. Hum. |
| Assimilation scheme | Intermittent data assimilation. Insertion of data every 3 hours. 3-h forecast used as first guess. All observations within a ± 1.5-h window used as synoptic. Cut-off time 2 h 14 min. |
| Initialization | Incremental digital filtering initialization (*Lynch, 1997*) consisting of a 3-h adiabatic backward run and a 3-h diabatic forward run centered at the initial time. The filtering is performed in vertical mode space; only the external mode plus the first nine internal ones are filtered. |

**b) Global analysis of surface parameters**

| | | |
|---|---|---|
| Analysis method | Correction method | |
| Analysed variables | Sea surface temperature (SST) and snow cover | |
| Horizontal anal. grid | On icosahedral-hexagonal grid of the GME (average mesh size of 60 km) | |
| Data used | SST: | Synop-Ship, NCEP-SST analysis as background, NCEP-data of ice border. |
| | Snow cover: | Snow depth, present and past weather, precipitation amount, temperature analysis. History taken into account. NCEP-data of ice border. |

*Local Model (LM)*

**a) Limited-area analysis of atmospheric fields**

The data assimilation system for the LM is based on the observation nudging technique (*Schraff, 1997)*. The variables nudged are the horizontal wind, temperature, and humidity at all model layers, and pressure at the lowest model level. The lateral spreading of the observational information is horizontal, or optionally along model layers or isentropic surfaces. At present, the scheme uses only conventional data of type TEMP, PILOT, SYNOP, BUOY, AIRCRAFT and AMDAR.

| | |
|---|---|
| Analysis method | Observation nudging technique |
| Analysed variables | p, T, u, v, Rel. Hum. |
| Horizontal anal. grid | 325 x 325 points (0.0625° x 0.0625°) on a rotated latitude/longitude grid |
| Vertical resolution | 35 hybrid layers (see LM) |
| Products | All analysis products are given on the 325 x 325 grid and available at hourly intervals.<br><br>a) On the 35 LM layers<br>Variables: p, T, u, v, w, $q_v$, $q_c$, $q_i$, TKE<br><br>b) On 10 pressure levels (1000, 950, 850, 700, 500, ..., 200 hPa)<br>Variables: $p_{msl}$, $\Phi$, T, u, v, $\omega$, Rel. Hum.<br><br>c) On 4 constant height levels (1000, 2000, 3000, 5000 m)<br>Variables: p, T, u, v, w, Rel. Hum. |
| Assimilation scheme | Continuous data assimilation. Insertion of data in 3-h cycles.<br>Cut-off time 2 h 14 min for LM runs. |
| Initialization | None |

**b) Limited-area analysis of soil moisture**

| | |
|---|---|
| Analysis method | 2-dimensional (vertical and temporal) variational technique |
| Analysed variables | Soil moisture of two soil layers at 00 UTC |
| Horizontal anal. grid | 325 x 325 points (0.0625° x 0.0625°) on a rotated latitude/longitude grid |
| Data used | 2-m temperature analyses at 12 and 15 UTC |

**c) Limited-area analysis of other surface parameters**

| | |
|---|---|
| Analysis method | Correction methods |
| Analysed variables | Sea surface temperature (SST) and sea ice cover, snow cover |

| | |
|---|---|
| Horizontal anal. grid | 325 x 325 points (0.0625° x 0.0625°) on a rotated latitude/longitude grid |
| Data used | SST: Synop-Ship, US-data of ice border, sea ice cover analysis from BSH (German Institute for shipping and hydrology) for the Baltic Sea and indirectly satellite data (via NCEP-SST and GME_SST analyses).<br>Snow cover: Snow depth, present and past weather, precipitation amount, 2-m temperature analysis (plus model prediction). |

Additionally, the plant cover is derived on a weekly basis by evaluation of satellite data (NDVI index).

### 7.3.2 Model

#### 7.3.2.1 Schematic summary of the global model GME

| | |
|---|---|
| Domain | Global |
| Initial data time | 00, 12, 18 UTC |
| Forecast range | 174 h (from 00 and 12 UTC), 48 h (from 18 UTC) |
| Prognostic variables | $p_s$, T, u, v, $q_v$, $q_c$, $q_i$, $o_3$ |
| Vertical coordinate | hybrid sigma/pressure (*Simmons and Burridge*, *1981*), 31 layers |
| Vertical discretization | Finite-difference, energy and angular-momentum conserving |
| Horizontal grid | Icosahedral-hexagonal (*Sadourny et al., 1968*), mesh size between 55 and 65 km, average mesh size 60 km; Arakawa-A grid |
| Horiz. discretization | Finite-difference, second order |
| Time integration | 3-time-level, leapfrog, split semi-implicit scheme, $\Delta t$ = 4 min, time filter.<br>For moisture variables (water vapour, cloud water, cloud ice):<br>Positive-definite, shape-preserving horizontal advection (SL-scheme). |
| Horizontal diffusion | Linear, fourth order |
| Orography | Grid-scale average based on a 1-km data set |
| Parameterizations | Surface fluxes based on local roughness length and stability (*Louis*, *1979*)<br><br>Free-atmosphere turbulent fluxes based on a level-two scheme (*Mellor and Yamada, 1974*)<br><br>Sub-grid scale orographic effects (blocking and gravity wave drag) based on *Lott and Miller, 1997*<br><br>Radiation scheme (two-stream with two solar and five longwave intervals) after *Ritter and Geleyn (1992)*, full cloud-radiation feedback based on predicted clouds |

| | |
|---|---|
| | Mass flux convection scheme after *Tiedtke (1989)* |
| | Kessler-type grid-scale precipitation scheme with parameterized cloud microphysics |
| | Two-layer soil model *(Jacobsen and Heise, 1982)* including simple vegetation and snow cover; prescribed climatological values at about 40 cm depth for temperature and at 100 cm depth for soil moisture. |
| | Over water: Fixed SST from SST analysis; roughness length according to Charnock´s formula |

Analyses and forecasts (up to 78 h) data of GME are sent twice daily (for 00 and 12 UTC) via the Internet to several other national weather services (Brazil, Bulgaria, China, Greece, Israel, Italy, Kenya, Oman, Poland, Romania, Spain, Switzerland, United Arab Emirates, Vietnam, Yugoslavia). These data serve as initial and lateral boundary data for regional modelling. For a detailed description of GME, see *Majewski, 1998* and *Majewski et al., 2002*.

#### 7.2.3.2 Schematic summary of the "Lokal-Modell" LM

| | |
|---|---|
| Domain | Central Europe |
| Initial data time | 00, 12, 18 UTC |
| Forecast range | 48 h |
| Prognostic variables | p, T, u, v, w, $q_v$, $q_c$, $q_i$, TKE |
| Vertical coordinate | Generalized terrain-following, 35 layers (see Fig. 2) |
| Vertical discretization | Finite-difference, second order |
| Horizontal grid | 325 x 325 points (0.0625° x 0.0625°) on a rotated latitude/longitude grid, mesh size 7 km; Arakawa-C grid, see Fig. 1. |
| Horiz. discretization | Finite-difference, second order |
| Time integration | Three-time-level, leapfrog, split explicit scheme (*Klemp and Wilhelmson, 1978*) with the extensions proposed by *Skamarock and Klemp* (*1992*), $\Delta t$ = 40 s, time filter.<br>Optionally, a two-time-level split-explicit scheme (*Wicker and Skamarock, 1998*) and a 3-d semi-implicit scheme (*Skamarock et al., 1997*) are available. |
| Horizontal diffusion | Linear, fourth order |
| Orography | Grid-scale average based on a 1-km data set. Topography has been filtered to remove grid-scale structures |
| Parameterizations | Surface fluxes based on local roughness length and stability (*Louis, 1979*) |

Free-atmosphere turbulent fluxes based on a level-2.5 scheme with prognostic TKE (*Mellor and Yamada, 1974*)

Radiation scheme (two-stream with two solar and five longwave intervals) after *Ritter and Geleyn (1992)*, full cloud-radiation feedback based on predicted clouds

Mass flux convection scheme after *Tiedtke (1989)*

Kessler-type grid-scale precipitation scheme with parameterized cloud microphysics

Two-layer soil model *(Jacobsen and Heise, 1982)* including simple vegetation and snow cover; prescribed climatological values at about 40 cm depth for temperature and at 100 cm depth for soil moisture.

Over water: Fixed SST from SST analysis; roughness length according to Charnock´s formula

### 7.3.3 Numerical weather prediction products

Short-range forecasts are based on direct model output (DMO) of the LM and on statistically corrected values (simple Kalman filtering). MOS guidance based on GME data is provided, too.
The ECOMET catalogue of the LM is given in annex 2.

### 7.3.4 Operational techniques for application of NWP products

NWP results are used for a variety of further applications. Some of these applications are briefly described below.
DMO is used for the production of any weather situation imaginable in 2-D or 3-D modules as still picture, dynamic graphics, or as a complete film. A graphics system developed for the visualization of meteorological data supports the interactive or automatic presentation of DMO in single images or image sequences.

Short range forecasts of weather and temperature in pictorial form are automatically produced for on-line presentation on the Internet using MOS forecasts of GME (worldwide and national) and Kalman filtered LM (national).
The state of road surfaces is predicted by a road weather forecast system (SWIS – Strassenzustands- und Wetter-Informations-System) using MOS data based on GME and an energy balance model of the road surface.
The influence of weather on human health is forecasted using a bio-synoptical weather classification scheme and the predicted vorticity, temperature and humidity in the surfaces 900, 850, 700 and 500 hPa. The thermal strain on a prototype human being is calculated by a physiologically relevant energy balance model which employs forecasted temperature, humidity, wind and short- and long-range irradiances derived from predicted cloudiness. Both weather classification and thermal strain data are calculated for all pixels of the Local Model LM of DWD. UV Index is forecasted within LM derived from the large scale UV Index forecasts by GME and adapted to LM predicted cloudiness and snow cover.

Agrometeorological forecasts cover a wide span of applications aiming at a reduction of the use of insecticides and fungicides or at an optimization of the water supply to plants. NWP results are combined with additional models which calculate the drying of leaves or the temperature and water balance in the ground. These forecasts are presented in www. Agrowetter.de

Significant weather charts which are in use as general guidance for the aeronautical consulting business in the regional forecasting offices and which are issued as products for general aviation cover the middle european area in a layer from surface up to 24 500 ft. As additional information jet-axes and cat areas are included if within the layer. Icing conditions and turbulence areas are described. The charts are produced interactively on work stations using LM results in combination with conventional synoptic methods.

During the season an advice for gliding pilots is prepared which may be received via facsimile. It presents charts of the lowest cloud base or the height of thermal activity, precipitation, wind direction and wind speed for several times during the day. It is based on LM data.

## 7.4 Specialized forecasts

### 7.4.2 Models

#### 7.4.2.1 Trajectory Models

Trajectory model:

| | |
|---|---|
| Forecast variables | r (λ, φ, p or z, t) |
| Data supply | u, v, w, $p_s$ from NWP forecasts (or analyses) |
| Numerical scheme | 1st order Euler-Cauchy with iteration (2nd order accuracy) |
| Interpolation | 1st order in time, 2nd (GME) or 3rd (LM) order in space |

a) Daily routine (ca. 1500 trajectories)

Trajectories based on LM forecasts:

| | |
|---|---|
| Domain | Domain of LM (see Fig. 1) |
| Resolution | 0.0625° (as LM) |
| Initial data time | 00, 12 UTC |
| Trajectory type | Forward trajectories for 36 German, Czech, Swiss, and French nuclear and chemical installations, backward trajectories for scientific investigations |
| Forecast range | 48-h trajectories, optional start/arrival levels |

Trajectories based on GME forecasts:

| | |
|---|---|
| Domain | Global |
| Resolution | ~ 60 km (as GME) |
| Initial data time | 00, 12 UTC |
| Trajectory type | 72-h forward trajectories for ca. 60 European nuclear sites and 8 German regional forecast centers, backward trajectories for 37 German radioactivity measuring sites and 8 forecast centers using consecutive +6h to +18h forecast segments.<br>96-h backward trajectories for the GAW mountain stations Zugspitze, Jungfraujoch, Sonnblick and Hohenpeißenberg, and to the German meteorological observatories.<br>72-h backward trajectories for 5 African cities in the framework of the METEOSAT-MDD program, disseminated daily via satellite from Bracknell.<br>120-h backward trajectories for the German polar stations Neumayer (Spitzbergen) and Koldewey (Antarctica) and the research ships |

| | |
|---|---|
| | Polarstern and Meteor, disseminated daily.<br>168-h forward trajectories for 14 Eastern European nuclear power plants.<br>Mainly backward trajectories for various scientific investigations. |
| Forecast range | 168h forward and backward trajectories, optional start/arrival levels |

b) Operational emergency trajectory system, trajectory system for scientific investigations:

| | |
|---|---|
| Models | LM or GME trajectory models |
| Domain | LM or global |
| Data supply | u, v, w, $p_s$ from LM or GME forecasts or analyses, from current data base or archives |
| Trajectory type | Forward and backward trajectories for a choice of offered or freely eligible stations at optional heights and times in the current period of 7 to 14 days. |
| Forecast range | 48-h (LM) or 168-h (GME) |
| Mode | Interactive menu to be executed by forecasters |

### 7.4.2.2 Sea wave models

| Domain | Global | Mediterranean | North, Baltic and Adriatic Sea Areas |
|---|---|---|---|
| **Numerical scheme** | Deep water, 3rd generation WAM | | |
| **Wind data supply** | GME: u, v at 10 m | | LM/GME:<br>u, v at 10 m |
| **Grid** | geographical (regular lat/lon) | | |
| **Resolution** | 0.75° x 0.75° | 0.25° x 0.25° | 0.167° x 0.10° |
| **Initial data time** | 00 and 12 UTC | | |
| **Forecast range** | 174 h | | 48 h |
| **Model output** | significant wave height, frequency, direction | | |
| **Initial state** | sea state adapted to analysed wind field over last 12 h | | |
| **Verification** | Available on request | | |

## 7.4.3. Numerical Weather Prediction Products

The forward and backward trajectories are an important tool for emergency response activities. In addition to these forecasts for concentration and deposition of radionuclides are produced using a Lagrangian Particle Dispersion Model.
Based on the Sea wave models charts are produced for swell and significant wave height, frequency and direction .

## 7.4.4 Operational techniques for applications of NWP results

Forecasts of the optimal (shortest and/or safest) route of ships are evaluated using the results of the global sea wave model and of NWP in the ship routing modelling system of the DWD. The system calculates isochrones taking into account the impact of wave and wind on different types of ships.

A very special application of the NWP result is a hydrological one. A model-system called SNOW-D allows for estimating and forecasting snow-cover development and areal melt water release. The

model enables a daily calculation and forecast of grid-point values of the water equivalent of the snow cover and meltingwater release. The snow cover development is computed with the help of physically-based model components which describe accumulation (build-up, increase), metamorphosis (conversion, change) and ablation (decrease, melting).
The model input data are

- 6-hour interval averages of air temperature and vapour pressure
- global radiation/duration of sunshine and precipitation totals of the last 24 h
- three times a week additional data from a part-time network (depth of snow cover, water equivalent of snow cover)
- output data of the „Lokal-Modell“

The model output contains

- current values of the snow cover (reference point 06.00 UTC)
  - snow depth (in cm)
  - water equivalent (in mm)
- specific water equivalent (in mm/cm)

- forecast values of snow cover development (forecast interval maximum 48 hours, forecasting for 6-h-intervals)
  - water equivalent (in mm)
  - precipitation supply, defined as the sum of meltwater release and rain (in mm)

The results are provided grid-oriented and with a blanket coverage for Germany. A summary of the grid values can be made for any area required.

In addition to SNOW-D, a new model-system called SNOW2 was developed for Baden-Württemberg and Rhineland-Palatinate and will be extended to Bavaria. This model is similar to SNOW-D but it runs every 6 hours and has a higher temporal resolution (1 hour). Not only DWD measurements but also data from regional networks are integrated in the data sampling procedure. Universal Kriging is used for regionalization of measured values to the computational grid.

The strongly improved physics uses wind speed (which is neglected in SNOW-D) for computation of turbulent transfer of heat and moisture taking into account the atmospheric static stability.
The model output contains the quantities of SNOW-D but in addition forecast values of snow depth, snow temperature, ice content and so on can be derived.

The operational UV Index forecast has been upgraded to a physically based fully deterministic global system. It is based on the dynamic prediction of ozone within DWD's global model GME and uses ECMW forecasts +12 h for initialisation. The model comprises modifications for clouds, snow albedo, and since the end of 2003 seasonal variations of aerosol optical depth derived from NASA MODIS MOD08_M3 data. The “large-scale UV-Index” forecasts are suited to interpolation to the grids of national higher resolution models (HRM). They can then be adjusted to the HRM topography and HRM forecasts of snow cover and cloudiness. All forecasts are supplied to the interested WMO member states by the RSMC Offenbach via ist server ftp.dwd.de. For more information see http://www.uv-index.de.

## 8. Verifications

Tables 1 up to 6 show verification results of GME for the European region (36° - 72° N, 12°W – 42 °E), tables 7 up to 12 for the extratropical northern hemisphere and tables 13 up to 18 for the extratropical southern hemisphere. In all tables forecast times vary from 12 h up to 156 h in intervals of 24 hours. p156.h stands for the RSME-values of persistence and climate for the rsme-values of climate.

## 8.1 European Region

**Table 1 : GEOPOTENTIAL 500 hPa RMSE**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | 11 | 11 | 9 | 9 | 8 | 8 | 8 | 7 | 8 | 10 | 9 | 12 | 9.3 |
| 36.h | 23 | 21 | 18 | 18 | 17 | 14 | 14 | 14 | 18 | 19 | 17 | 22 | 17.9 |
| 60.h | 39 | 35 | 33 | 28 | 27 | 23 | 25 | 25 | 31 | 31 | 29 | 36 | 30.2 |
| 84.h | 56 | 52 | 50 | 40 | 37 | 33 | 35 | 36 | 44 | 46 | 44 | 50 | 43.5 |
| 108.h | 70 | 72 | 70 | 52 | 49 | 45 | 48 | 46 | 56 | 65 | 65 | 71 | 59.2 |
| 132.h | 86 | 89 | 91 | 65 | 61 | 58 | 60 | 58 | 69 | 86 | 82 | 89 | 74.6 |
| 156.h | 99 | 106 | 109 | 85 | 74 | 71 | 70 | 68 | 79 | 104 | 97 | 101 | 88.5 |
| p156.h | 182 | 142 | 161 | 181 | 106 | 97 | 95 | 104 | 125 | 190 | 190 | 162 | 144.6 |
| climate | 129 | 118 | 140 | 135 | 98 | 83 | 87 | 84 | 98 | 144 | 141 | 115 | 114.3 |

**Table 2: GEOPOTENTIAL 500 hPa ANOMALY CORRELATION**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | .99 | .99 | 1.00 | 1.00 | 1.00 | 1.00 | .996 |
| 36.h | .98 | .98 | .99 | .99 | .98 | .99 | .98 | .98 | .98 | .99 | .99 | .99 | .983 |
| 60.h | .94 | .95 | .95 | .97 | .95 | .97 | .93 | .94 | .93 | .96 | .96 | .96 | .951 |
| 84.h | .87 | .88 | .89 | .94 | .90 | .93 | .86 | .87 | .88 | .91 | .92 | .92 | .897 |
| 108.h | .79 | .76 | .79 | .90 | .84 | .85 | .73 | .76 | .81 | .82 | .85 | .80 | .809 |
| 132.h | .70 | .64 | .71 | .83 | .74 | .75 | .62 | .63 | .69 | .71 | .77 | .68 | .704 |
| 156.h | .60 | .54 | .62 | .72 | .62 | .61 | .54 | .52 | .60 | .58 | .68 | .56 | .597 |

**Table 3: PRESSURE MSL RMSE**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | 1.2 | 1.3 | 1.2 | 1.1 | 1.0 | 1.0 | .9 | .8 | .9 | 1.0 | 1.1 | 1.4 | 1.09 |
| 36.h | 2.5 | 2.0 | 2.0 | 1.9 | 1.7 | 1.5 | 1.6 | 1.4 | 1.8 | 2.0 | 1.9 | 2.6 | 1.90 |
| 60.h | 4.0 | 3.3 | 3.1 | 2.7 | 2.6 | 2.3 | 2.6 | 2.3 | 3.0 | 3.4 | 2.9 | 4.0 | 3.02 |
| 84.h | 5.7 | 4.6 | 4.4 | 3.6 | 3.4 | 3.2 | 3.4 | 3.2 | 4.2 | 4.7 | 4.1 | 5.4 | 4.18 |
| 108.h | 7.4 | 6.4 | 6.3 | 4.3 | 4.2 | 4.1 | 4.2 | 4.2 | 5.3 | 6.4 | 5.7 | 7.5 | 5.50 |
| 132.h | 9.0 | 8.0 | 7.8 | 5.6 | 5.0 | 5.0 | 5.1 | 5.0 | 6.6 | 7.9 | 7.0 | 8.9 | 6.74 |
| 156.h | 10.0 | 9.6 | 8.9 | 7.2 | 6.2 | 6.0 | 6.0 | 5.8 | 7.3 | 9.0 | 8.1 | 9.9 | 7.83 |
| p156.h | 17.1 | 12.1 | 13.5 | 12.2 | 7.3 | 7.5 | 6.7 | 8.0 | 10.4 | 16.3 | 14.2 | 14.4 | 11.63 |
| climate | 11.4 | 9.2 | 11.2 | 9.1 | 5.5 | 5.5 | 5.5 | 6.0 | 7.7 | 11.9 | 10.1 | 10.3 | 8.62 |

**Table 4: PRESSURE MSL ANOMALY CORRELATION**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .991 |
| 36.h | .97 | .97 | .97 | .98 | .95 | .96 | .96 | .96 | .96 | .98 | .97 | .97 | .966 |
| 60.h | .92 | .90 | .93 | .95 | .89 | .92 | .91 | .92 | .89 | .94 | .92 | .93 | .918 |
| 84.h | .84 | .81 | .87 | .91 | .81 | .83 | .84 | .83 | .82 | .88 | .85 | .85 | .846 |
| 108.h | .74 | .66 | .76 | .88 | .74 | .73 | .75 | .69 | .73 | .77 | .74 | .72 | .742 |
| 132.h | .63 | .50 | .68 | .79 | .64 | .63 | .66 | .53 | .58 | .66 | .64 | .59 | .629 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 156.h | .53 | .38 | .55 | .66 | .47 | .48 | .54 | .39 | .51 | .54 | .56 | .48 | .508 |

**Table 5: TEMPERATURE 850 hPa RMSE**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | 1.0 | 1.0 | .9 | .9 | .9 | .9 | .9 | .9 | .8 | .9 | .9 | 1.0 | .93 |
| 36.h | 1.7 | 1.5 | 1.5 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 | 1.4 | 1.7 | 1.44 |
| 60.h | 2.4 | 2.1 | 2.0 | 1.8 | 1.8 | 1.7 | 1.6 | 1.7 | 1.8 | 1.9 | 1.9 | 2.2 | 1.90 |
| 84.h | 3.0 | 2.6 | 2.7 | 2.4 | 2.3 | 2.1 | 2.0 | 2.1 | 2.2 | 2.5 | 2.3 | 2.8 | 2.40 |
| 108.h | 3.6 | 3.1 | 3.3 | 2.9 | 2.8 | 2.5 | 2.3 | 2.4 | 2.6 | 3.1 | 2.8 | 3.4 | 2.91 |
| 132.h | 4.0 | 3.6 | 4.0 | 3.2 | 3.3 | 2.9 | 2.8 | 2.7 | 3.1 | 3.7 | 3.3 | 4.1 | 3.40 |
| 156.h | 4.3 | 4.1 | 4.5 | 3.8 | 3.6 | 3.4 | 3.1 | 3.1 | 3.5 | 4.2 | 3.9 | 4.5 | 3.83 |
| p156.h | 5.8 | 5.0 | 5.9 | 6.8 | 5.2 | 4.7 | 4.6 | 5.0 | 5.2 | 6.6 | 5.8 | 6.0 | 5.56 |
| climate | 4.4 | 4.3 | 4.9 | 5.4 | 4.4 | 4.2 | 3.6 | 4.1 | 4.0 | 4.8 | 4.4 | 4.4 | 4.41 |

**Table 6: TEMPERATURE 850 hPa ANOMALY CORRELATION**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | .97 | .97 | .98 | .98 | .98 | .97 | .96 | .96 | .97 | .97 | .97 | .97 | .971 |
| 36.h | .91 | .93 | .94 | .96 | .94 | .94 | .92 | .91 | .93 | .94 | .93 | .93 | .930 |
| 60.h | .84 | .86 | .89 | .93 | .89 | .89 | .87 | .86 | .87 | .89 | .88 | .87 | .878 |
| 84.h | .73 | .79 | .81 | .87 | .83 | .83 | .79 | .78 | .79 | .82 | .83 | .80 | .807 |
| 108.h | .60 | .71 | .70 | .82 | .76 | .76 | .70 | .70 | .71 | .71 | .76 | .69 | .718 |
| 132.h | .52 | .59 | .60 | .77 | .67 | .68 | .58 | .63 | .60 | .56 | .69 | .55 | .620 |
| 156.h | .43 | .48 | .53 | .69 | .57 | .54 | .49 | .54 | .50 | .46 | .58 | .43 | .521 |

## 8.2 Extratropical northern hemisphere

**Table 7: GEOPOTENTIAL 500 hPa RMSE**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | 11 | 11 | 10 | 10 | 9 | 9 | 9 | 8 | 9 | 10 | 10 | 11 | 9.8 |
| 36.h | 21 | 20 | 19 | 19 | 19 | 17 | 19 | 15 | 18 | 19 | 19 | 21 | 19.0 |
| 60.h | 34 | 32 | 31 | 29 | 29 | 27 | 29 | 25 | 29 | 31 | 31 | 33 | 30.0 |
| 84.h | 48 | 46 | 45 | 41 | 41 | 38 | 39 | 35 | 40 | 44 | 45 | 46 | 42.3 |
| 108.h | 63 | 60 | 59 | 53 | 53 | 48 | 50 | 45 | 52 | 57 | 59 | 61 | 55.0 |
| 132.h | 75 | 73 | 73 | 66 | 64 | 58 | 59 | 54 | 64 | 69 | 73 | 74 | 66.9 |
| 156.h | 87 | 85 | 86 | 81 | 76 | 65 | 67 | 62 | 74 | 81 | 86 | 86 | 77.9 |
| p156.h | 141 | 129 | 142 | 134 | 110 | 92 | 82 | 91 | 105 | 141 | 141 | 131 | 119.8 |
| climate | 106 | 107 | 111 | 107 | 84 | 73 | 69 | 70 | 87 | 108 | 108 | 101 | 94.3 |

**Table 8: GEOPOTENTIAL 500 hPa ANOMALY CORRELATION**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | 1.00 | .99 | 1.00 | 1.00 | .99 | .99 | .99 | .99 | .99 | 1.00 | 1.00 | .99 | .994 |
| 36.h | .98 | .98 | .98 | .98 | .97 | .97 | .96 | .97 | .97 | .98 | .98 | .98 | .977 |
| 60.h | .95 | .95 | .96 | .96 | .93 | .92 | .89 | .93 | .93 | .96 | .96 | .95 | .941 |
| 84.h | .89 | .90 | .91 | .92 | .87 | .86 | .81 | .86 | .87 | .91 | .91 | .90 | .884 |
| 108.h | .81 | .83 | .85 | .86 | .78 | .76 | .70 | .76 | .79 | .84 | .84 | .82 | .804 |
| 132.h | .73 | .75 | .77 | .78 | .67 | .66 | .57 | .66 | .69 | .77 | .76 | .72 | .711 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 156.h | .63 | .67 | .67 | .67 | .56 | .56 | .45 | .56 | .59 | .69 | .66 | .63 | .613 |

**Table 9: PRESSURE MSL RMSE**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | 1.4 | 1.5 | 1.4 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.2 | 1.2 | 1.3 | 1.4 | 1.29 |
| 36.h | 2.6 | 2.4 | 2.3 | 2.1 | 2.0 | 2.0 | 2.2 | 1.8 | 2.2 | 2.3 | 2.3 | 2.4 | 2.22 |
| 60.h | 3.7 | 3.5 | 3.4 | 2.9 | 2.9 | 2.7 | 3.0 | 2.6 | 3.2 | 3.4 | 3.3 | 3.5 | 3.17 |
| 84.h | 5.0 | 4.7 | 4.7 | 3.9 | 3.8 | 3.5 | 3.7 | 3.4 | 4.3 | 4.6 | 4.5 | 4.7 | 4.22 |
| 108.h | 6.4 | 6.0 | 6.0 | 5.1 | 4.7 | 4.3 | 4.4 | 4.2 | 5.3 | 5.8 | 5.8 | 6.0 | 5.33 |
| 132.h | 7.5 | 7.2 | 7.0 | 6.1 | 5.7 | 5.1 | 5.1 | 5.0 | 6.3 | 6.8 | 7.0 | 7.3 | 6.34 |
| 156.h | 8.3 | 8.3 | 7.9 | 7.1 | 6.5 | 5.6 | 5.6 | 5.6 | 7.0 | 7.7 | 8.0 | 8.4 | 7.17 |
| p156.h | 13.2 | 11.4 | 12.7 | 11.1 | 9.2 | 7.3 | 6.8 | 7.8 | 9.3 | 11.7 | 12.4 | 12.0 | 10.41 |
| climate | 9.5 | 8.6 | 9.9 | 8.2 | 6.6 | 5.4 | 5.3 | 5.6 | 7.1 | 8.7 | 9.4 | 9.2 | 7.77 |

**Table 10: PRESSURE MSL ANOMALY CORRELATION**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | .99 | .99 | .99 | .99 | .98 | .98 | .97 | .98 | .98 | .99 | .99 | .99 | .985 |
| 36.h | .96 | .96 | .97 | .97 | .95 | .93 | .91 | .94 | .94 | .96 | .97 | .96 | .952 |
| 60.h | .92 | .91 | .94 | .94 | .90 | .87 | .84 | .88 | .88 | .92 | .93 | .92 | .904 |
| 84.h | .85 | .84 | .88 | .88 | .82 | .78 | .74 | .80 | .79 | .85 | .88 | .86 | .832 |
| 108.h | .75 | .75 | .80 | .80 | .72 | .67 | .63 | .69 | .69 | .75 | .79 | .77 | .735 |
| 132.h | .65 | .64 | .72 | .70 | .59 | .54 | .51 | .58 | .59 | .66 | .71 | .66 | .630 |
| 156.h | .57 | .52 | .64 | .59 | .47 | .46 | .40 | .48 | .49 | .58 | .62 | .56 | .532 |

**Table 11: TEMPERATURE 850 hPa RMSE**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | 1.1 | 1.1 | 1.1 | 1.0 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 1.04 |
| 36.h | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.5 | 1.6 | 1.6 | 1.7 | 1.7 | 1.67 |
| 60.h | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 | 2.1 | 2.1 | 1.9 | 2.0 | 2.0 | 2.2 | 2.2 | 2.17 |
| 84.h | 3.0 | 2.9 | 2.8 | 2.7 | 2.7 | 2.5 | 2.5 | 2.3 | 2.5 | 2.5 | 2.7 | 2.7 | 2.65 |
| 108.h | 3.7 | 3.4 | 3.4 | 3.1 | 3.1 | 2.9 | 2.9 | 2.7 | 2.9 | 3.0 | 3.3 | 3.3 | 3.13 |
| 132.h | 4.1 | 3.9 | 4.0 | 3.7 | 3.6 | 3.2 | 3.2 | 3.0 | 3.3 | 3.4 | 3.8 | 3.8 | 3.58 |
| 156.h | 4.5 | 4.5 | 4.4 | 4.2 | 3.9 | 3.5 | 3.5 | 3.3 | 3.7 | 3.9 | 4.3 | 4.3 | 4.00 |
| p156.h | 6.4 | 6.2 | 6.7 | 6.5 | 5.3 | 4.8 | 4.4 | 4.3 | 5.3 | 6.1 | 6.2 | 6.1 | 5.70 |
| climate | 4.8 | 4.9 | 5.1 | 4.9 | 4.3 | 3.8 | 3.5 | 3.3 | 4.2 | 4.8 | 4.7 | 4.7 | 4.41 |

**Table 12: TEMPERATURE 850 hPa ANOMALY CORRELATION**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | .97 | .97 | .98 | .98 | .97 | .96 | .96 | .96 | .97 | .97 | .97 | .97 | .969 |
| 36.h | .93 | .93 | .94 | .94 | .91 | .89 | .88 | .89 | .91 | .94 | .93 | .93 | .918 |
| 60.h | .88 | .88 | .90 | .90 | .84 | .83 | .81 | .83 | .86 | .89 | .88 | .88 | .865 |
| 84.h | .81 | .82 | .84 | .84 | .77 | .76 | .73 | .76 | .79 | .83 | .82 | .82 | .800 |
| 108.h | .71 | .75 | .76 | .78 | .70 | .68 | .66 | .68 | .72 | .77 | .74 | .75 | .723 |
| 132.h | .63 | .68 | .67 | .70 | .61 | .60 | .58 | .60 | .63 | .70 | .64 | .66 | .642 |
| 156.h | .56 | .59 | .58 | .60 | .53 | .51 | .50 | .50 | .53 | .62 | .54 | .56 | .553 |

### 8.3 Extratropical southern hemisphere

**Table 13: GEOPOTENTIAL 500 hPa RMSE**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | 11 | 11 | 11 | 13 | 13 | 14 | 15 | 15 | 15 | 13 | 12 | 10 | 12.8 |
| 36.h | 25 | 25 | 26 | 30 | 31 | 32 | 35 | 33 | 32 | 29 | 28 | 21 | 28.8 |
| 60.h | 37 | 37 | 39 | 46 | 47 | 48 | 53 | 49 | 46 | 45 | 41 | 32 | 43.4 |
| 84.h | 50 | 50 | 53 | 62 | 64 | 64 | 69 | 64 | 59 | 61 | 55 | 42 | 57.8 |
| 108.h | 62 | 63 | 67 | 78 | 80 | 79 | 84 | 80 | 73 | 76 | 68 | 54 | 72.0 |
| 132.h | 72 | 77 | 83 | 93 | 93 | 92 | 100 | 94 | 87 | 90 | 79 | 67 | 85.6 |
| 156.h | 81 | 89 | 96 | 104 | 105 | 105 | 113 | 106 | 100 | 104 | 89 | 79 | 97.5 |
| p156.h | 110 | 127 | 134 | 144 | 149 | 137 | 151 | 151 | 145 | 139 | 125 | 114 | 135.5 |
| climate | 81 | 93 | 93 | 108 | 103 | 123 | 104 | 112 | 116 | 102 | 95 | 90 | 101.7 |

**Table 14: GEOPOTENTIAL 500 hPa ANOMALY CORRELATION**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .99 | .992 |
| 36.h | .95 | .96 | .96 | .96 | .96 | .97 | .95 | .96 | .96 | .96 | .96 | .96 | .959 |
| 60.h | .89 | .90 | .92 | .90 | .90 | .92 | .88 | .91 | .92 | .90 | .90 | .92 | .905 |
| 84.h | .81 | .83 | .84 | .82 | .81 | .86 | .80 | .84 | .86 | .82 | .82 | .86 | .830 |
| 108.h | .70 | .74 | .73 | .72 | .71 | .80 | .70 | .75 | .79 | .72 | .72 | .79 | .738 |
| 132.h | .60 | .63 | .60 | .62 | .61 | .72 | .57 | .65 | .71 | .61 | .63 | .69 | .636 |
| 156.h | .50 | .51 | .48 | .52 | .50 | .65 | .45 | .57 | .61 | .48 | .54 | .57 | .534 |

**Table 15: PRESSURE MSL RMSE**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | 1.4 | 1.5 | 1.5 | 1.7 | 1.7 | 1.7 | 1.9 | 1.8 | 1.8 | 1.7 | 1.6 | 1.3 | 1.65 |
| 36.h | 2.7 | 2.8 | 2.9 | 3.3 | 3.4 | 3.4 | 3.9 | 3.5 | 3.5 | 3.3 | 3.1 | 2.3 | 3.18 |
| 60.h | 3.8 | 3.9 | 4.1 | 4.9 | 4.8 | 5.1 | 5.5 | 5.0 | 4.9 | 4.7 | 4.4 | 3.3 | 4.52 |
| 84.h | 5.0 | 5.0 | 5.3 | 6.3 | 6.3 | 6.5 | 7.0 | 6.4 | 6.1 | 6.1 | 5.7 | 4.2 | 5.83 |
| 108.h | 6.0 | 6.1 | 6.5 | 7.4 | 7.8 | 7.8 | 8.4 | 7.8 | 7.3 | 7.4 | 6.9 | 5.2 | 7.07 |
| 132.h | 6.9 | 7.3 | 7.7 | 8.5 | 9.0 | 9.0 | 9.7 | 9.1 | 8.5 | 8.6 | 7.8 | 6.4 | 8.21 |
| 156.h | 7.6 | 8.1 | 8.6 | 9.4 | 10.1 | 10.2 | 10.9 | 10.1 | 9.5 | 9.6 | 8.3 | 7.4 | 9.15 |
| p156.h | 9.6 | 10.5 | 11.3 | 12.2 | 13.7 | 13.2 | 14.1 | 13.7 | 13.5 | 13.0 | 10.9 | 10.4 | 12.16 |
| climate | 7.2 | 8.3 | 8.5 | 9.6 | 10.1 | 12.1 | 10.0 | 10.1 | 10.9 | 9.5 | 8.2 | 8.3 | 9.38 |

**Table 16: PRESSURE MSL ANOMALY CORRELATION**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | .98 | .98 | .99 | .98 | .99 | .99 | .98 | .98 | .99 | .98 | .98 | .99 | .984 |
| 36.h | .92 | .93 | .94 | .93 | .94 | .95 | .93 | .94 | .94 | .94 | .92 | .95 | .937 |
| 60.h | .85 | .86 | .88 | .85 | .88 | .90 | .86 | .88 | .89 | .87 | .84 | .90 | .873 |
| 84.h | .74 | .78 | .80 | .76 | .79 | .84 | .77 | .79 | .83 | .79 | .74 | .85 | .789 |
| 108.h | .64 | .69 | .69 | .67 | .68 | .77 | .66 | .69 | .75 | .69 | .62 | .78 | .693 |
| 132.h | .55 | .59 | .57 | .59 | .58 | .69 | .53 | .59 | .66 | .57 | .52 | .67 | .593 |
| 156.h | .45 | .50 | .47 | .50 | .47 | .62 | .42 | .50 | .58 | .46 | .46 | .56 | .500 |

**Table 17: TEMPERATURE 850 hPa RMSE**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | 1.1 | 1.2 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.2 | 1.3 | 1.2 | 1.2 | 1.0 | 1.18 |
| 36.h | 1.8 | 2.0 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.3 | 2.2 | 2.1 | 2.0 | 1.7 | 2.09 |
| 60.h | 2.3 | 2.5 | 2.6 | 2.7 | 2.9 | 2.9 | 3.1 | 3.0 | 2.9 | 2.8 | 2.6 | 2.1 | 2.69 |
| 84.h | 2.7 | 2.9 | 3.0 | 3.3 | 3.4 | 3.4 | 3.6 | 3.5 | 3.4 | 3.3 | 3.0 | 2.4 | 3.14 |
| 108.h | 3.1 | 3.2 | 3.5 | 3.7 | 3.7 | 3.9 | 4.0 | 3.9 | 3.8 | 3.8 | 3.3 | 2.8 | 3.55 |
| 132.h | 3.4 | 3.6 | 3.9 | 4.0 | 4.1 | 4.2 | 4.4 | 4.3 | 4.2 | 4.1 | 3.5 | 3.1 | 3.89 |
| 156.h | 3.6 | 3.9 | 4.2 | 4.2 | 4.3 | 4.4 | 4.7 | 4.6 | 4.5 | 4.5 | 3.8 | 3.4 | 4.18 |
| p156.h | 4.4 | 4.8 | 5.0 | 5.2 | 5.0 | 5.0 | 5.3 | 5.5 | 5.4 | 5.3 | 4.9 | 4.5 | 5.02 |
| climate | 3.3 | 3.7 | 4.4 | 4.8 | 4.7 | 4.8 | 4.4 | 4.8 | 4.5 | 4.3 | 3.6 | 3.4 | 4.23 |

**Table 18: TEMPERATURE 850 hPa ANOMALY CORRELATION**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.h | .95 | .94 | .96 | .96 | .97 | .97 | .96 | .97 | .96 | .96 | .95 | .95 | .958 |
| 36.h | .85 | .84 | .88 | .89 | .89 | .89 | .87 | .90 | .89 | .88 | .85 | .87 | .875 |
| 60.h | .76 | .76 | .80 | .81 | .81 | .82 | .79 | .82 | .82 | .80 | .77 | .79 | .797 |
| 84.h | .68 | .69 | .72 | .74 | .73 | .75 | .71 | .76 | .76 | .73 | .69 | .72 | .724 |
| 108.h | .58 | .60 | .64 | .68 | .67 | .68 | .63 | .69 | .68 | .65 | .62 | .64 | .646 |
| 132.h | .48 | .50 | .57 | .61 | .61 | .62 | .55 | .63 | .61 | .58 | .55 | .56 | .572 |
| 156.h | .40 | .41 | .50 | .56 | .55 | .58 | .48 | .57 | .56 | .50 | .48 | .47 | .506 |

## 9. Plans for the future

A seven-layer soil model which includes freezing of soil moisture and a better representation of vegetation and snow will be made operational in spring 2004.
In April 2004, the mesh size of GME will be reduced from 60 to 40 km, and the number of layers increased from 31 to 40 with the lowest model layer placed at 10 m above the model topography. In the same month, the 3-D advection of the precipitation phases rain and snow will be introduced in the LM. This improves the spatial distribution of precipitation in mountainous regions like the Black Forest for the winter season dramatically.
In September 2004, the model domain of LM will be increased from 325 x 325 to about 650 x 650 gridpoints with a mesh size of 7 km to cover whole of Europe, the number of layers will be increased from 35 to 40, and the forecast range extended from 48 to 78 hours.
A nowcasting and very short range (up to 18 hours, initialised every three hours) forecast version of LM is under development with a mesh size of 2.8 km and 50 layers. This high a resolution aims mainly at the explicit prediction of deep convection which is a major forecasting problem in Germany during the warm season. The further development of LM is co-ordinated in the Consortium for Small-Scale Modelling (COSMO). Current members of COSMO are the weather services of Germany, Greece, Italy, Poland and Switzerland.
Concerning applications of NWP results it is planned to make a more systematic approach to severe weather forecasting by making use of objective methods based on the EPS provided by the ECMWF. For any kind of postprocessed specialized forecasts of the parameters temperature, wind and significant weather MOS will be used instead of Kalman Filtering.

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