WWW TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA-PROCESSING AND FORECASTING SYSTEM (GDPFS), AND THE ANNUAL NUMERICAL WEATHER PREDICTION (NWP) PROGRESS REPORT FOR THE YEAR 2005

GERMANY

Centre: NMC Offenbach

1. Summary of highlights

The modelling suite at DWD consists of the global icosahedral-hexagonal grid-point model GME (average mesh size ~ 40 km, i.e. 368642 grid points/layer, 40 layers) and the nonhydrostatic limited-area “Lokal-Modell” LM-Europe (LME, mesh size ~ 7 km, 665x657 grid points/layer, 40 layers). LM is used operationally at the national meteorological services of Greece, Poland, Romania 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 worldwide applications.
The hydrostatic high-resolution regional model HRM of the DWD is being used as operational model at fifteen national/regional meteorological services, namely Brazil-INMET, Brazil-Navy, Bulgaria, China, Israel, Italy, Kenya, Oman, Pakistan, Philippines, Romania, Senegal, Spain, United Arab Emirates and Vietnam. For lateral boundary conditions, GME data are sent via the Internet to the HRM and LM users.
During 2005 the main improvements of the NWP suite included:
17/02/05: Usage of AMV winds in BUFR format in the global data assimilation.
July 05: The main high performance computer IBM RS/6000 SP with 120 nodes equipped with 16 Power3 processors each is replaced by an IBM p575 system with 48 nodes equipped with 8 Power5 processors each. Both systems have a similar peak performance but the sustained performance of GME and LME is higher on the p575 system due to a faster interconnect.
28/09/05: The model domain of the regional model LM is extended from 325x325 to 665x657 grid points, and the number of layers is increased from 35 to 40. Moreover, a new 7-layer soil model including the thermal effects of freezing and thawing of soil moisture is introduced.

2. Equipment in use

2.1 Main computers

2.1.1 IBM p575 POWER5 Cluster

Operating System AIX 5.2
48 p575 nodes (8 POWER5 processors per node, 1.9GHz)
7.6 GFlops/s peak processor speed
2.9 TFlops peak system performance
32 GB physical memory per node
HPS switch (dual plane (2 x 2.5 GB/s bidirect.)
14.4 TB (6 DS 4300 Turbo) usable disk space, FC SAN attached

Compute server used to run the operational forecasts and research workload

2.1.2 IBM p690 Server / p615 Server

Operating System AIX 5.2
2 p690 nodes (32 POWER4 processors, per node, 1.7 GHz)
128 GB physical memory per node
3 p615 nodes (2 POWER4 processors per node, 1.7 GHz, 2 GB memory)
40.5 TB (3 Enterprise Storage Server) usable disk space (SAN attached)

This logically partitioned (LPAR) high availability cluster hosts
data management server (Oracle database) LPAR (20 processors, 90 GB memory)
operational pre-/post processing and user research server LPAR (8 processors, 20 GB)
test system LPAR (2 processors, 8 GB memory)

2.1.3 Sun Fire 4900 Server

Operating System Solaris 9
2 Sun Fire 4900 Server (8 processors, 1.2 GHz
32 GB of physical memory
18,7 TB of disk space for SAM-QFS filesystems
50 Archives (currently 750 TB)
connected to 3 StorageTek Silos via SAN

This failover cluster is used for HSM based archiving of meteorological data and forecasts:

2.1.4 Storage Tek ACS Silo (3 components)

Attached are 46 FC-tape drives
16 x 9840 A (20 GB, 10 MB/s)
10 x 9940 A (60 GB, 10 MB/s)
20 x 9940 B (200 GB, 30 MB/s)

2.2 Networks

The main computers are interconnected via Gigabit Ethernet (Etherchannel) and connected to the LAN via Fast Ethernet:

2.3 Special systems

2.3.1 Satellite data system

Windows 2000 Server
Used for preparation of satellite pictures (from METEOSAT and NOAA and FEN-GYUN),
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.

SYNOP (AUTO)	47.000
SYNOP (manned)	39.000
BUOY	15.000
SHIP	13.000
TEMP A	1.400
METAR	215.000
PILOT A	400
AIREP	21.000
AMDAR	23.000
SATEM A	11.000
SATOB, section 2	6.700
SATOB, section 3	600
SATOB, section 4	800
SATOB, section 5	1.100
SATOB, section 7	1.000
GRIB	14.000
BUFR	26.000

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 IBM p690/p615.
Independent 4-dim. data assimilation suites are performed for both models, GME and LME. 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 LME, a continuous data assimilation system based on the nudging approach provides analyses at hourly intervals.
Forecast runs of GME and LME with a data cut-off of 2h 14 min after the main synoptic hours 00, 12 and 18 UTC consist of 78-h (48-h for 18 UTC) forecasts for LME 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 LME.

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

ECMWF-EPS-data and MOS applied to the GME and ECMWF model are in use to produce medium-range forecasts up to day 7. A statistical PPM-based interpretation scheme applied to both ECMWF and GME forecasts is still in use also. 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 thunderstorm, probability of fog.

Medium-range forecast activity has moved to the Central Forecast Office in Offenbach in 2004. Forecasts in plain language for the public are created by a particular software developed by DWD. It produces texts automatically from MOS data. At present texts are produced for 7 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 LME, where LME covers the time period up to 78 h from 00 and 12 UTC (48 hours from 18 UTC) only.
The short-range forecasts for Central Europe up to 78 hours are derived from the limited-area "Lokal-Modell" LME. Fig. 1 shows the model domain of the LME. The model 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, LME is nested in the GME.

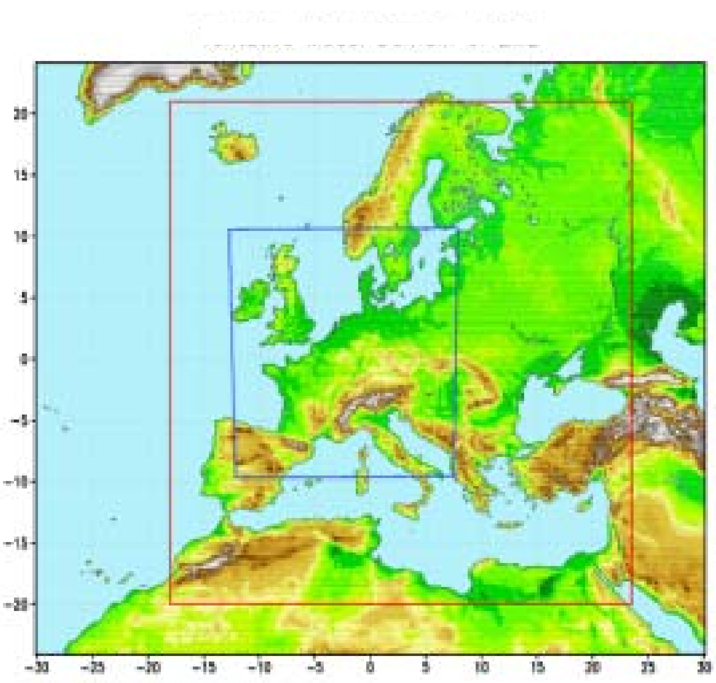

Figure 1 Model domain of the “Lokal-Modell” LME (outer frame), mesh size of 7 km, 665 x 657 gridpoints.

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; 1D-Var for ATOVS retrievals.

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 40 km)
Vertical resolution	40 hybrid layers (see GME)
Products	a) On icosahedral-hexagonal grid of the GME (368642 gridpoints/layer, 40 layers) Variables: p_s, T, u, v, q_v, q_c, q_i, o_3 b) On a regular geographical grid, 720 x 361 points (0.5° 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), sea ice and snow cover

Horizontal anal. grid On icosahedral-hexagonal grid of the GME (average mesh size of 40 km)

Data used SST, sea ice: Synop-Ship, NCEP-SST analysis as background, NCEP analysis of sea ice distribution.
Snow cover: Snow depth, present and past weather, precipitation amount,
temperature analysis. History taken into account.
NCEP analysis of snow cover.

Local Model (LME)

a) Limited-area analysis of atmospheric fields

The data assimilation system for the LME 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 665 x 657 points (0.0625° x 0.0625°) on a rotated latitude/longitude grid

Vertical resolution 40 hybrid layers

Products All analysis products are given on the 665 x 657 grid and available at hourly intervals.

a) On the 35 LM layers
Variables: p, T, u, v, w, q_v, q_c, q_i, TKE

b) On 10 pressure levels (1000, 950, 850, 700, 500, ..., 200 hPa)
Variables: p_{msl}, Φ, T, u, v, ω, Rel. Hum.

c) On 4 constant height levels (1000, 2000, 3000, 5000 m)
Variables: p, T, u, v, w, Rel. Hum.

Assimilation scheme	Continuous data assimilation. Insertion of data in 3-h cycles. Cut-off time 2 h 14 min for LME 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 grid	665 x 657 points (0.0625° x 0.0625°) on a rotated latitude/longitude
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, temperature and relative humidity at 2 m
Horizontal anal. grid grid	665 x 657 points (0.0625° x 0.0625°) on a rotated latitude/longitude
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). 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*), 40 layers

Vertical discretization	Finite-difference, energy and angular-momentum conserving
Horizontal grid	Icosahedral-hexagonal (*Sadourny et al., 1968*), mesh size between 37 and 43 km, average mesh size 40 km; Arakawa-A grid
Horiz. discretization	Finite-difference, second order
Time integration time filter.	3-time-level, leapfrog, split semi-implicit scheme, Δt = 133.33 s, For moisture variables (water vapour, cloud water, cloud ice): 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*) Free-atmosphere turbulent fluxes based on a level-two scheme (*Mellor and Yamada, 1974*) Sub-grid scale orographic effects (blocking and gravity wave drag) based on *Lott and Miller, 1997* 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 7-layer soil model *(Heise and Schrodin, 2002)* including simple vegetation and snow cover; prescribed climatological value for temperature at about 14 m depth. Over water: Fixed SST from SST analysis over open water; for ice-covered ocean areas a sea ice model provides ice thickness and temperature; roughness length according to Charnock´s formula in ice-free areas.

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, Philippines, 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" LME

Domain Central Europe

Initial data time 00, 12, 18 UTC

Forecast range 78 h (48 h for 18 UTC)

Prognostic variables p, T, u, v, w, q_v, q_c, q_i, TKE, rain, snow

Vertical coordinate Generalized terrain-following, 40 layers

Vertical discretization Finite-difference, second order

Horizontal grid 665 x 657 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*), Δt = 40 s, time filter.
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

7-layer soil model *(Heise and Schrodin, 2002)* including simple vegetation and snow cover; prescribed climatological value for temperature at about 14 m depth.

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 LME and on statistically corrected values (simple Kalman filtering). MOS-Mix guidance based on GME and ECMWF data is provided, too.
The ECOMET catalogue of the LME is given in annex 2.

7.3.4 Operational techniques for application of NWP products

Forecast are produced partly automatically, based on the data listed in 7.3.3. Forecasts in plain language and warnings for the public and for aviation are produced by meteorologists. Any kinds of fields, DMO and MOS-date are available and used in combination with nowcasting techniques. Forecasts of significant weather (SWC) for Middle Europe are produced on the base of LME and special techniques. 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.

In the beginning of 2005 SRNWP-PEPS (Short Range Numerical Weather Prediction – "Poor man's" Ensemble Prediction System) was introduced in DWD as an additional technique for short range forecasting. PEPS makes use of four different main operational limited area models (LAM) developed by different consortia which are availabe in Europe (COSMO, Aladin, HIRLAM and UK Met Office). These four models are all representatives of today's state of the art in the Short-Range Numerical Weather Prediction field (see EUMETNET SRNWP program) and are used by 26 national weather services to produce their operational forecasts. Using most of these deterministic products the SRNWP-PEPS generates probability forecasts for Europe. This is done by interpreting the overlapping areas of the single forecasts as members of a local ensemble. The results of PEPS are used both for general forecasts and for warnings especially concerning precipitation rates, fresh snow, gusts and minimum and maximum temperatures.

Short range forecasts of weather and temperature in pictorial form are automatically produced for online presentation on the Internet using MOS forecasts of GME (worldwide and national) and Kalman filtered LME (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 LME. UV Index is forecasted within LME derived from the large scale UV Index forecasts by GME and adapted to LME predicted cloudiness and snow cover.

The aviation needs for its planning and safe management of flights beside the wind and temperature forecasts of different flight levels and specific forecasts, which are offered as *Direct Model Output*. These data are visualised in form of charts, images, time series and piktograph (see below). Cross sections are vertical sections along defined flight routes.

The cross sections contain the distribution of cloudiness, temperature and wind between the surface and FL 240 at different time steps until H+30.
For the planning of gliding flights in Germany, the Alpine area and the eastern part of France the software package TOPTHERM is used. TOPTHERM is able to calculate the development of thermal lift for small scaled areas. The output of LME is used as data input for the TOPTHERM model. TOPTHERM calculations are visualised by the selfbriefing software pc_met.

Significant weather charts 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.
Further the LME model output is the data base for the visualisation software SkyView and the icing system ADWICE (Advanced Diagnosis and Warning system for aircraft ICing Environments).
SkyView presents for variable sections of areas in Middle Europe precipitation, convection cloudiness and wind of different levels on grid points. The results are presented every two hours. The flash viewer allows overlapping of several parameters. Therewith a common analysis of the requested parameters is possible.
The icing system ADWICE provides diagnostic and prognostic products of inflight icing hazards between surface and FL 300. The system uses model data of the LME as well as observational data (SYNOP, METAR, RADAR) in order to classify the weather/cloud situation into four different icing scenarios called freezing, stratiform, convective and general. Furthermore, ADWICE estimates an universal icing intensity based on an estimation of liquid water content. New methods concerning the estimation of icing intensities are under development.
Currently ADWICE runs operational at the DWD. The maximum icing forecast time depends on the forecast model which is used and is currently limited to 78 hours using LME data. At the moment results are visualised in the DWD-Intranet. With the adoption of the visualisation system NinJo ADWICE icing maps will be visualised by NinJo.

All aviation meteorological products with the exception of ADWICE maps are offered to a closed user group over the web site: www.flugwetter.de.

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

In the maritime department programs are run to extract globally direct model grid point information from the weather and seastate models for German research vessels and other ships or yachts. The data is distributed automatically by e-mail.

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 (LME) order in space

a) Daily routine (ca. 1500 trajectories)

Trajectories based on LME forecasts:

Domain	Domain of LME (see Fig. 1)
Resolution	0.0625° (as LME)
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	72-h trajectories, optional start/arrival levels

Trajectories based on GME forecasts:

Domain	Global
Resolution	~ 40 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. 96-h backward trajectories for the GAW mountain stations Zugspitze, Jungfraujoch, Sonnblick and Hohenpeißenberg, and to the German meteorological observatories. 72-h backward trajectories for 5 African cities in the framework of the METEOSAT-MDD program, disseminated daily via satellite from Bracknell. 120-h backward trajectories for the German polar stations Neumayer (Spitzbergen) and Koldewey (Antarctica) and the research ships Polarstern and Meteor, disseminated daily. 168-h forward trajectories for 14 Eastern European nuclear power plants. Mainly backward trajectories for various scientific investigations.
Forecast range	168-h forward and backward trajectories, optional start/arrival levels

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

Models	LME or GME trajectory models
Domain	LME or global
Data supply	u, v, w, p_s from LME 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	72-h (LME) or 168-h (GME)
Mode	Interactive menu to be execu7.4.2.2 Sea wave models

Domain	Global	Mediterranean	North, Baltic and Adriatic Sea Areas
Numerical scheme	Shallow water, 3rd generation WAM		
Wind data supply	GME: u, v at 10 m		LME: u, v at 10 m
Grid	geographical (regular lat/lon)		
Resolution	0.75° x 0.75°	0.25° x 0.25°	0.10° x 0.167°
Initial data time	00 and 12 UTC		
Forecast range	174 h		78 h
Model output	significant wave height, peak period, direction		
Initial state	sea state adapted to predicted 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 area 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 and 6-hour interval sum of precipitation totals
- global radiation/duration of sunshine 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 LME

The model output contains

- current values of the snow cover (reference point 06.00 UTC)
- snow depth (in cm)
- water equivalent (in mm)
- precipitation supply, defined as the sum of melt water release and rain in mm) of the last 24 h (analysis period)forecast values of snow cover development (forecast interval maximum 72 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 SNOW 3 was developed for Baden-Württemberg, Rhineland-Palatinate, Saxony, Saarland, Parts of North-Rhine-Westphalia and Hesse, Luxembourg, the French region of the Moselle and Bavaria together with parts of Vorarlberg (Austria), will be extended to Thuringia. This model is similar to SNOW-D but it runs every 6 hours and has a higher temporal (1 hour) and spatial (1km*1km) resolution. 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 its server ftp.dwd.de. For more information see http://www.uv-index.de.

8. Verifications

GEOPOTENTIAL 500 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	10	10	10	9	8	8	8	8	8	8	9	10	8.8
36. h	18	17	17	17	15	14	13	13	14	16	17	18	15.7
60. h	29	26	27	26	24	22	21	21	23	26	27	28	25.0

84. h	41	38	39	37	34	32	29	31	34	39	40	41	36.3
108. h	56	50	53	49	46	42	39	41	45	53	55	55	48.9
132. h	72	65	67	62	58	51	49	51	57	67	72	71	61.9
156. h	87	80	80	75	71	60	58	60	69	81	88	85	74.3
p156. h	146	135	141	133	107	92	87	88	97	123	144	142	119.5
Climate	118	114	117	104	92	75	66	69	78	99	118	115	97.1

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	0.99	0.99	0.99	0.99	1.00	1.00	1.00	0.995
36. h	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.985
60. h	0.97	0.97	0.97	0.96	0.96	0.95	0.95	0.95	0.95	0.96	0.97	0.97	0.962
84. h	0.94	0.94	0.95	0.93	0.92	0.89	0.89	0.89	0.90	0.92	0.93	0.94	0.919
108. h	0.88	0.90	0.90	0.87	0.85	0.82	0.81	0.80	0.81	0.84	0.88	0.89	0.854
132. h	0.81	0.83	0.83	0.80	0.77	0.74	0.70	0.70	0.71	0.75	0.80	0.81	0.769
156. h	0.72	0.76	0.76	0.70	0.66	0.64	0.58	0.59	0.59	0.65	0.70	0.73	0.672

PRESSURE MSL RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	1.3	1.3	1.2	1.2	1.1	1.0	1.0	1.0	1.0	1.1	1.2	1.3	1.14
36. h	2.2	2.1	2.0	1.9	1.7	1.7	1.6	1.6	1.7	1.8	2.0	2.2	1.88
60. h	3.2	3.0	2.9	2.6	2.5	2.3	2.2	2.2	2.6	2.8	2.9	3.1	2.69
84. h	4.2	4.1	4.0	3.6	3.3	3.0	2.9	3.0	3.6	3.9	4.1	4.2	3.66
108. h	5.6	5.2	5.2	4.7	4.3	3.8	3.6	3.9	4.7	5.2	5.4	5.5	4.75
132. h	7.1	6.5	6.5	5.8	5.2	4.6	4.5	4.7	5.7	6.3	6.8	6.9	5.88
156. h	8.4	7.9	7.5	6.8	6.1	5.2	5.1	5.2	6.5	7.5	8.2	8.1	6.88
p156. h	13.2	12.4	11.9	11.2	9.0	7.4	7.3	7.7	8.7	10.4	12.8	13.6	10.46
Climate	10.1	9.9	9.6	8.0	6.4	5.6	5.2	5.7	6.9	8.4	10.1	10.8	8.06

PRESSURE MSL ANOMALY CORRELATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.989
36. h	0.98	0.98	0.98	0.97	0.97	0.96	0.95	0.96	0.97	0.98	0.98	0.98	0.969
60. h	0.95	0.95	0.96	0.94	0.93	0.91	0.91	0.92	0.93	0.95	0.95	0.96	0.938
84. h	0.91	0.91	0.92	0.90	0.86	0.85	0.84	0.85	0.85	0.89	0.90	0.93	0.885
108. h	0.84	0.85	0.86	0.83	0.77	0.77	0.75	0.75	0.75	0.81	0.84	0.87	0.808

132. h	0.74	0.78	0.77	0.73	0.64	0.66	0.62	0.66	0.64	0.72	0.75	0.79	0.709
156. h	0.64	0.68	0.69	0.62	0.51	0.56	0.51	0.58	0.55	0.61	0.63	0.70	0.607

TEMPERATURE 850 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	1.0	1.0	1.0	0.99
36. h	1.6	1.5	1.6	1.6	1.5	1.5	1.5	1.4	1.4	1.4	1.5	1.6	1.53
60. h	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.8	1.8	1.8	2.0	2.0	1.92
84. h	2.5	2.4	2.5	2.4	2.4	2.3	2.2	2.1	2.2	2.2	2.5	2.5	2.34
108. h	3.0	3.0	3.1	2.8	2.8	2.6	2.5	2.5	2.6	2.7	3.0	3.0	2.80
132. h	3.6	3.5	3.6	3.2	3.2	3.0	2.8	2.8	3.0	3.2	3.5	3.6	3.26
156. h	4.2	4.1	4.2	3.8	3.7	3.3	3.2	3.1	3.4	3.7	4.1	4.1	3.73
p156. h	6.4	6.1	6.5	6.2	5.6	4.8	4.5	4.5	4.7	5.6	6.1	6.0	5.59
climate	5.2	5.1	5.2	4.7	4.6	3.8	3.3	3.4	3.7	4.4	4.8	4.9	4.43

TEMPERATURE 850 hPa ANOMALY CORRELATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	0.98	0.98	0.98	0.97	0.97	0.96	0.96	0.96	0.96	0.97	0.98	0.98	0.971
36. h	0.95	0.95	0.95	0.94	0.93	0.91	0.90	0.90	0.91	0.94	0.94	0.95	0.931
60. h	0.92	0.92	0.92	0.91	0.89	0.86	0.85	0.85	0.86	0.90	0.91	0.91	0.892
84. h	0.88	0.88	0.87	0.87	0.84	0.80	0.79	0.79	0.80	0.85	0.86	0.87	0.842
108. h	0.83	0.82	0.82	0.81	0.78	0.73	0.72	0.72	0.72	0.78	0.80	0.81	0.777
132. h	0.75	0.76	0.75	0.74	0.70	0.66	0.64	0.64	0.62	0.68	0.72	0.73	0.700
156. h	0.68	0.68	0.67	0.65	0.62	0.59	0.56	0.56	0.52	0.58	0.63	0.65	0.615

Table 3: Verification results of the GM for the extratropical northern hemisphere for different forecast times (p156.h stands for the rmse-values of persistence and climate for the rmse-values of climate), 2005.

GEOPOTENTIAL 500 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	8	9	9	10	11	11	12	12	11	10	9	9	10.1
36. h	17	18	20	23	23	24	25	26	23	20	19	18	21.3
60. h	27	28	32	37	36	36	38	39	37	32	30	29	33.4
84. h	38	41	45	52	51	51	55	54	51	44	42	39	46.9
108. h	50	53	60	69	67	66	72	70	66	58	55	49	61.2
132. h	61	66	75	84	83	82	88	86	83	69	69	59	75.5
156.	70	76	87	98	96	97	102	100	100	82	80	69	88.0

h													
p156. h	116	120	137	140	154	154	151	152	148	150	125	129	139.7
climate	92	91	98	105	115	127	112	118	114	106	103	101	106.8

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	1.00	1.00	1.00	1.00	1.00	1.00	0.996
36. h	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.980
60. h	0.95	0.95	0.95	0.94	0.95	0.96	0.94	0.94	0.95	0.96	0.96	0.96	0.950
84. h	0.91	0.89	0.89	0.88	0.90	0.92	0.88	0.89	0.89	0.91	0.91	0.93	0.900
108. h	0.84	0.81	0.81	0.78	0.83	0.86	0.80	0.81	0.82	0.85	0.84	0.88	0.827
132. h	0.76	0.71	0.69	0.68	0.74	0.78	0.69	0.71	0.72	0.77	0.75	0.82	0.736
156. h	0.69	0.62	0.58	0.56	0.64	0.69	0.59	0.63	0.59	0.68	0.67	0.75	0.641

PRESSURE MSL RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.4	1.4	1.3	1.2	1.2	1.27
36. h	1.9	2.0	2.3	2.6	2.6	2.6	2.6	2.8	2.6	2.3	2.2	2.1	2.37
60. h	2.9	2.9	3.4	3.9	3.8	3.8	4.1	4.1	3.9	3.4	3.2	3.0	3.53
84. h	3.9	4.1	4.7	5.2	5.3	5.2	5.7	5.6	5.3	4.5	4.4	4.0	4.80
108. h	5.0	5.2	5.9	6.6	6.7	6.7	7.1	7.1	6.6	5.7	5.6	4.9	6.10
132. h	5.8	6.2	7.1	8.0	8.0	8.2	8.5	8.5	8.3	6.8	6.8	5.9	7.34
156. h	6.5	7.1	8.1	9.1	9.0	9.5	9.6	9.7	9.6	7.9	7.7	6.6	8.37
p156. h	10.3	10.7	11.4	12.0	13.1	14.0	14.2	14.3	13.2	13.5	11.3	10.8	12.40
climate	7.9	8.0	8.6	9.3	10.4	12.0	10.7	10.6	9.9	9.5	9.2	8.3	9.52

PRESSURE MSL ANOMALY CORRELATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.991
36. h	0.97	0.97	0.96	0.96	0.97	0.98	0.97	0.96	0.96	0.97	0.97	0.97	0.968
60. h	0.93	0.92	0.92	0.91	0.93	0.95	0.92	0.92	0.92	0.94	0.94	0.94	0.928
84. h	0.87	0.86	0.85	0.84	0.86	0.90	0.85	0.85	0.85	0.89	0.88	0.89	0.866
108. h	0.79	0.77	0.76	0.74	0.78	0.83	0.76	0.75	0.77	0.82	0.80	0.82	0.782
132. h	0.70	0.67	0.65	0.64	0.69	0.74	0.66	0.66	0.65	0.73	0.70	0.74	0.686
156. h	0.63	0.58	0.54	0.54	0.61	0.66	0.56	0.58	0.52	0.63	0.61	0.65	0.594

TEMPERATURE 850 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.1	1.1	1.0	1.09
36. h	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.0	2.0	1.8	1.7	1.7	1.80
60. h	1.9	2.1	2.2	2.4	2.4	2.5	2.5	2.6	2.5	2.2	2.2	2.1	2.30
84. h	2.3	2.4	2.6	2.8	2.8	2.9	3.0	3.1	3.0	2.7	2.5	2.4	2.71
108. h	2.6	2.8	3.0	3.3	3.3	3.3	3.5	3.6	3.4	3.1	2.9	2.7	3.12
132. h	3.0	3.1	3.4	3.7	3.7	3.8	4.0	4.0	3.9	3.4	3.3	3.0	3.52
156. h	3.2	3.4	3.8	4.2	4.1	4.3	4.3	4.4	4.3	3.7	3.6	3.2	3.88
p156. h	4.5	4.6	5.0	5.1	5.4	5.3	5.1	5.4	5.7	5.4	4.7	4.7	5.08
climate	3.6	4.1	4.8	5.3	5.3	4.8	5.0	5.2	5.0	4.2	3.6	3.6	4.54

TEMPERATURE 850 hPa ANOMALY CORRELATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	0.96	0.96	0.97	0.98	0.98	0.98	0.97	0.98	0.97	0.97	0.96	0.96	0.971
36. h	0.91	0.91	0.93	0.94	0.95	0.93	0.93	0.93	0.93	0.92	0.89	0.91	0.923
60. h	0.86	0.85	0.88	0.90	0.91	0.89	0.88	0.88	0.89	0.88	0.83	0.86	0.876
84. h	0.80	0.79	0.83	0.85	0.87	0.84	0.83	0.83	0.84	0.82	0.76	0.81	0.824
108. h	0.73	0.73	0.78	0.79	0.82	0.78	0.77	0.76	0.78	0.76	0.68	0.77	0.763
132. h	0.65	0.66	0.71	0.73	0.76	0.71	0.70	0.70	0.71	0.69	0.60	0.72	0.696
156. h	0.59	0.60	0.64	0.66	0.71	0.62	0.65	0.65	0.63	0.62	0.53	0.67	0.632

Table 4: Verification results of the GM for the extratropical southern hemisphere for different forecast times (p156.h stands for the rmse-values of persistence and climate for the rmse-values of climate), 2005.

GEOPOTENTIAL 500 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	11	11	9	10	8	7	7	7	7	8	10	11	8.8
36. h	22	17	15	17	13	13	12	13	15	15	18	19	15.7
60. h	36	28	26	29	23	24	20	22	25	25	30	30	26.5
84. h	50	44	38	42	34	37	30	31	40	43	44	45	39.8
108. h	70	61	54	54	47	50	41	43	57	64	56	67	55.3
132. h	94	86	71	66	59	61	51	61	72	89	79	93	73.4
156. h	113	108	85	81	72	72	63	74	89	107	101	118	90.3
p156. h	183	182	163	137	117	126	108	113	115	163	185	192	148.4
climate	147	149	142	102	100	92	73	81	92	122	143	150	116.0

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	1.00	1.00	1.00	1.00	1.00	1.00	0.997
36. h	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.99	0.99	0.99	0.99	0.988
60. h	0.97	0.98	0.98	0.96	0.97	0.96	0.95	0.96	0.96	0.97	0.96	0.98	0.965
84. h	0.94	0.94	0.95	0.91	0.93	0.89	0.89	0.90	0.89	0.92	0.91	0.94	0.919
108. h	0.87	0.87	0.90	0.84	0.88	0.80	0.81	0.80	0.78	0.82	0.87	0.87	0.841
132. h	0.78	0.78	0.82	0.75	0.78	0.71	0.69	0.62	0.63	0.69	0.76	0.75	0.729
156. h	0.70	0.67	0.75	0.63	0.63	0.59	0.56	0.46	0.49	0.57	0.64	0.62	0.608

PRESSURE MSL RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	1.4	1.2	1.1	1.0	0.9	0.8	0.8	0.8	0.9	0.9	1.1	1.2	1.01
36 .0	2.5	1.9	1.8	1.8	1.5	1.4	1.3	1.4	1.6	1.7	1.9	2.0	1.74
60. h	3.9	2.9	2.6	2.8	2.3	2.2	2.0	2.1	2.5	2.6	2.8	2.9	2.64
84. h	4.9	4.1	3.5	3.7	3.2	3.0	2.7	3.0	3.8	4.0	4.1	4.0	3.67
108. h	6.6	5.3	5.0	4.7	4.3	3.9	3.5	3.8	5.1	5.7	5.1	5.7	4.88
132. h	8.7	7.5	6.4	5.6	5.3	4.7	4.0	4.8	6.2	7.7	7.0	7.9	6.33
156. h	10.1	9.5	7.7	6.9	6.1	5.5	5.0	5.6	7.6	9.3	9.0	9.9	7.68
p156. h	16.2	15.5	12.8	11.1	8.3	8.6	8.0	8.7	9.4	12.1	15.6	17.1	11.94
climate	12.8	11.9	9.9	7.7	6.1	5.8	5.4	6.4	7.7	9.5	11.0	12.9	8.91

PRESSURE MSL ANOMALY CORRELATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	0.99	1.00	0.993
36. h	0.98	0.99	0.98	0.98	0.97	0.97	0.96	0.97	0.97	0.98	0.98	0.98	0.976
60. h	0.96	0.97	0.96	0.94	0.93	0.93	0.92	0.94	0.94	0.96	0.94	0.96	0.944
84. h	0.92	0.93	0.92	0.89	0.88	0.84	0.84	0.87	0.85	0.89	0.88	0.92	0.885
108. h	0.86	0.86	0.85	0.81	0.76	0.73	0.75	0.76	0.75	0.77	0.84	0.84	0.798
132. h	0.75	0.76	0.78	0.70	0.60	0.61	0.65	0.62	0.60	0.64	0.71	0.70	0.676
156. h	0.64	0.65	0.66	0.58	0.43	0.49	0.50	0.48	0.47	0.50	0.59	0.54	0.546

TEMPERATURE 850 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	1.0	0.9	0.8	0.9	0.9	0.8	0.9	0.8	0.8	0.9	0.9	0.9	0.88
36. h	1.5	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.3	1.4	1.4	1.33
60. h	2.0	1.7	1.7	1.7	1.6	1.6	1.6	1.5	1.7	1.7	1.7	1.7	1.70
84. h	2.4	2.1	2.2	2.1	2.0	2.0	1.9	1.9	2.1	2.2	2.1	2.2	2.10

108. h	2.9	2.6	2.8	2.6	2.5	2.5	2.4	2.3	2.7	2.9	2.5	2.9	2.64
132. h	3.3	3.3	3.4	3.1	3.0	3.0	2.8	2.9	3.3	3.6	3.0	3.7	3.19
156. h	3.9	4.2	4.0	3.8	3.6	3.4	3.3	3.4	3.8	4.3	3.5	4.2	3.77
p156. h	5.8	5.6	6.8	6.0	5.4	5.4	5.0	4.7	4.7	6.3	5.6	5.5	5.56
climate	4.6	5.0	5.6	4.4	4.6	4.2	3.5	3.4	3.6	4.6	4.4	4.4	4.35

TEMPERATURE 850 hPa ANOMALY CORRELATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12. h	0.96	0.97	0.98	0.98	0.98	0.98	0.96	0.97	0.97	0.98	0.98	0.97	0.972
36. h	0.92	0.94	0.96	0.94	0.95	0.94	0.92	0.92	0.93	0.95	0.94	0.93	0.937
60. h	0.87	0.91	0.94	0.91	0.92	0.90	0.88	0.89	0.87	0.92	0.90	0.89	0.899
84. h	0.81	0.87	0.90	0.86	0.88	0.85	0.82	0.84	0.79	0.86	0.85	0.83	0.846
108. h	0.72	0.79	0.83	0.79	0.81	0.76	0.71	0.75	0.64	0.76	0.78	0.70	0.755
132. h	0.64	0.68	0.77	0.70	0.74	0.68	0.62	0.60	0.50	0.65	0.69	0.54	0.650
156. h	0.52	0.52	0.67	0.55	0.63	0.57	0.51	0.42	0.36	0.50	0.58	0.47	0.524

Table 5: Verification results of the GM for the european region 36° - 72°N, 12°W - 42°E for different forecast times
(p156.h stands for the rmse-values of persistence and climate for the rmse-values of climate), 2005.

9. Plans for the future

9.1 Development of the GDPFS

Direct use of radiances

A 1D-Var scheme for ATOVS radiances has been put into operation on 4 January 2006. Only 1D-Var analysis increments are further assimilated for GME, which essentially reduces spurious biases generated from vertical interpolation errors. Currently only AMSU-A channels are used, their observation errors have been reduced for tuning which essentially improved forecast quality. Further tuning addresses the horizontal observation coverage and weights to assimilate the 1D-Var retrievals. The 1D-Var retrievals are used additionally to the pseudo-temps until the amount of usable satellite data is improved especially in the southern hemisphere. Work on AIRS data is progressing as well and experimental runs are being started.

(Hess, Gebhardt, Graesle, Koepken)

Radar-derived precipitation

The Latent Heat Nudging (LHN) algorithm for the assimilation of 2D radar-derived near-surface precipitation into the experimental convective-scale version of LM (LMK, resolution: 2.8 km) has been revised completely. This has been motivated by the introduction of a prognostic precipitation scheme in the operational LME. The new prognostic treatment of precipitation generates fields of the 3D latent heat release and surface precipitation, which differ significantly from those produced by the previous diagnostic precipitation scheme, and which cause some problems in the context of conventional LHN.

The most important modification introduced to the LHN algorithm to mitigate these problems is the use of a vertically averaged precipitation flux as a ‘reference precipitation’ which is deployed instead of the real model precipitation to compare to the observed precipitation. The revised LHN of radar-derived precipitation data leads to continuously improved analysed precipitation fields during the assimilation, and in the subsequent forecasts, the positive impact decreases less rapidly than in the simulations with diagnostic precipitation. On average, the positive impact of LHN remains large for 4 hours and lasts for about 6 hours into the free forecasts

(Klink, Stephan, Schraff)

Quality control of radiosonde humidity

A significant reduction of the general threshold in the ‘first guess’ check for radiosonde humidity has been tested to allow for a more strict quality control of these data. However, a new stability-dependent enhancement factor to the threshold still accounts for large model errors and allows for large observation increments near inversions. In addition, a spatial consistency check for integrated water vapour (IWV) derived from radiosonde humidity and optionally from GPS-derived zenith path delay has been developed. This check uses model-derived IWV as background information and is equivalent to a first guess check of IWV in the absence of neighbouring observations. The modifications are planned to become operational in LME by the end of 2005.

(Schraff)

Soil moisture analysis

The soil moisture analysis scheme (SMA) has been adapted for the multilayer soil model. It has been implemented in LME and runs operationally. Extensive tests of the SMA were performed for a 8 month period in 2000. Inclusion of relative humidity in the cost function led to better screen level humidity forecasts. Replacing the forecast prcecipitation by anylsed values had the biggest overall impact. The tests also revealed that improving the model physics effecting the soil moisture is at least as important as improving the initial state.

(Lange, Wergen)

Introduction of a prognostic snow density

The evaluation of the GME performance in spring time conditions revealed problems in the simulation of the near surface temperature in the presence of aged snow at the ground. Under these circumstances the operationally assumed constant snow density leads to an overestimation of the snow thickness in conjunction with an underestimation of the heat conductivity through the snow. This causes an exaggerated decoupling of the snow surface temperatures from the soil itself and an associated underestimation of the heat flux through the snow layer, leading to a serious underestimation of the night-time minimum of the near surface temperatures. This problem can be alleviated through the introduction of a prognostic snow density in conjunction with a revision of the density dependence of the snow heat conductivity. Even though the simulation of the snow density accounts for the metamorphosis of existing snow and the impact of freshly falling snow only in a very crude way, the formulation captures important aspects of the temporal evolution of the snow density such as compaction due to processes like gravitational sedimentation and the reduction of the mean density, if fresh snow fall occurs.

(Ritter)

Introduction of seasonally variable plant properties

In the currently operational GME plant properties, which are derived from landuse data, are considered constant throughout the year. In reality plant cover and related properties exhibit both periodic and non-periodic temporal variability due to the controlling mechanisms of seasonally varying availability of sufficient solar radiation and soil moisture and human interference through agricultural exploitation of land surfaces. In order to introduce a first order approximation to the variability of plant related properties a multi-year monthly mean NDVI climatology has been projected to the GME grid. For any given actual forecast time the ratio of the climatological value of the NDVI to the annual maximum value for the same grid point is used as a scaling factor for plant properties. First test with this approach indicate a distinct impact on the simulated evapo-transpiration. This has to be expected, as any variation of the plant cover implies a change with regard to the direct availability of moisture from deeper soil layer reservoirs for the evapo-transpiration process. In the absence of plants, evaporation over land is controlled by the availability of moisture in the immediate vicinity of the surface and thereby much more dependent on precipitation events within the last few days.
The new approach will undergo further testing and validation efforts before it will be implemented in the operational model version.

(Ritter, Heise, Liermann, Schrodin)

Global modelling

A global 3D-Var observation space data assimilation scheme is under development. Main aim is the improved assimilation of satellite data (esp. ATOVS) and a flexible specification of background error covariances. For the latter a specification of the B-Matrix in Wavelet transformed representation is investigated.

(Rhodin, Pingel, Schmid, Anlauf, Tomassini, Buchhold, Hess, Paul, Wergen)

LM-Kürzestfrist (LMK)

In the area of mesoscale modelling at DWD, a very high resolution model for short-term numerical weather prediction (NWP) based on the existing nonhydrostatic limited-area model Lokal-Modell (LM) is under development. One of the main purposes of this new model, called LMK (LM Kürzestfrist - LM for very short term prediction), is to provide the hydrological models of flood forecasting systems with input data at a high update rate. Especially to improve the quantitative precipitation forecasting (QPF), work has to be done in the area of data assimilation. In addition to the use of conventional data, such as surface, radiosonde, aircraft and wind profiler measurements, high-resolution precipitation data derived from radar networks are introduced in the nudging-type assimilation of the LMK. Using the “Latent Heat Nudging” (LHN) technique the thermodynamic quantities of the atmospheric model are adjusted locally in such a way that the modelled precipitation rates resemble the observed precipitation rates. In the framework of a project funded by hydrological authorities of the German federal states the use of the radar data in LMK will be made operational.
Basic investigations of the LHN algorithm have been carried out in a case study of a convective situation which caused flooding events in different river catchments. The evaluation of the experiments performed is based on subjective assessment of the precipitation fields as well as on objective skill scores. The results show that precipitation patterns are introduced in the analysis in good agreement, both in position and amplitude, with those observed by radar. Increasing the horizontal model resolution shows a potential for further improvements of the quantitative precipitation forecast. An additional adjustment of specific humidity (corresponding to the temperature increments) during the LHN leads to a better assimilation of developing thunderstorms and to a more realistic free forecast afterwards. However, the positive impact of the radar data decreases rapidly during

the forecast. In order to understand this, more investigations of the 3D model state are carried out. The main focus is on the interactions between the process of LHN and the model dynamics.
Besides making use of radar observations for the data assimilation these data can also be used for verification purposes. Radar composite pictures will be statistically compared with radar pictures generated from LMK output using the Radar Simulation Model by G. Haase (1998). Furthermore, it is being planned to compare measured and model-derived radar data with pattern recognition methods.

(Baldauf, Förstner, Helmert, Klink, Lenz, Reinhardt, Schraff, Stephan)

9.2 Research Activities in NWP

Global modelling

In collaboration with the Max Planck Institute for Meteorology in Hamburg a new general circulation model ICON (acronym for ICOsahedral Nonhydrostatic) is under development. The project target is a unified model for global and regional climate simulation and weather forecasting. The new model will discretize the fully elastic, nonhydrostatic Navier Stokes equations on geodesic, icosahedral, locally refined grids combining finite volumes techniques with a staggered C-grid approach on regular Delaunay triangulations. Currently extensive tests with its shallow water version are performed.

(Frank, Heinze, Liermann, Majewski, Rípodas, Ritter, Steppeler)

GME at ECMWF

GME is running daily at ECMWF based on the 12 UTC analysis of ECMWF's IFS model since 2002. Until September 2004 two version of GME with 40 km and 60 km mesh size were running to compare different resolutions of the model, and to compare the operational model at DWD with forecasts starting from the IFS analysis. Since October 2004 only one version with the same 40 km resolution and 40 levels as the operational model at DWD is running at ECMWF. These forecasts provide initial and boundary conditions for daily runs with different versions of the limited area model LM at ECMWF.

Medium range forecasts of GME initialized with the IFS analysis are similar to the forecasts of the T511L60 model of ECMWF, and standard verification scores of these GME forecasts are close to ECMWF ones.

(Frank)

Prognostic graupel

For LM, an additional optional microphysical parameterization scheme which takes into account also graupel has been developed. This scheme considers cloud water, cloud ice, rain, snow, and graupel as prognostic condensate categories. The purpose of this scheme is to represent in a better way the cloud microphysical processes in explicitly resolved deep convection. It is intended to be used in the 2.8-km version of LM (LMK). The scheme was tested in a three-months testsuite in LMK; only little impact on forecast quality was found. Further sensitivity tests regarding the assumptions about the graupel particle properties are ongoing.

(Reinhardt, Seifert)

LM: Very-high resolution simulations and first urbanisation steps

In the framework of the 2002-2005 EU FP5 project FUMAPEX (Integrated systems for forecasting urban meteorology, air pollution and population exposure), very high-resolution simulations with the Lokalmodell LM were performed for 6 air pollution episodes in Helsinki, Oslo and Valencia. The LM was one-way interactively nested using 3 nests with 7km, 2.8 and 1.1km horizontal resolution and 35,45 and 45 vertical layers, respectively, but without changes in parameterisations. Results were compared to surface measurements and radiosoundings in the urban areas showing some improvement with increasing resolution especially in coastal and mountainous areas. The largest deficits are found for extreme winter inversion episodes in Oslo and Helsinki were inversion strength and stability are underestimated and surface temperatures overpredicted to a large extent (Fay and Neunhäuserer, 2005b). Similar results are found in the model intercomparison with HIRLAM and MM5 versions of the Danish, Norwegian and Finnish Meteorological Institutes, a Spanish RAMS version, and ARPA-SMR LAMI, where episode results are also evaluated in the context of 1-year statistical model scores (Fay et al., 2004b and 2005a).

First urbanisation measures were applied to LM by introducing urbanised physiographic parameters and adding an anthropogenic heat source. Sensitivity studies for a Helsinki spring episode case show improved surface fluxes and BL parameters leading to the successful simulation of a comprehensive heat island effect in LM parameters (Neunhäuserer and Fay, 2005).

(Neunhäuserer, Fay)

Development of a z-coordinate version of the nonhydrostatic model LM

The Z-coordinate version of LM replaces the terrain following model layers by levels defined by constant height. Such model layers cut into mountains. In this way the violation of an approximation condition is avoided and a better representation of vertical velocities and as a consequence a better prediction of precipitation is expected. The model can now run with realistic initial values and a total of 9 cases have been done. The impact on precipitation is substantial. The threat score is about doubled. The RMS of winds and temperatures is significantly improved for the 24 hr forecasts.

(Steppeler, Bitzer, Prohl)

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