Annual WWW Technical Progress Report on the GDPS 2006

Country: Germany Centre: NMC Offenbach

1. Summary of highlights

The modelling suite of DWD now consists of three models, namely the global icosahedral-hexagonal grid point model **GME** (grid spacing 40 km, i.e. 368642 grid points/layer, 40 layers), the non-hydrostatic regional **COSME-E** (COSMO model Europe, formerly known as *LME*, grid spacing 7 km, 665x657 grid points/layer, 40 layers), and finally the convection-resolving **COSMO-K**, covering Germany and its surroundings with a grid spacing of 2.8 km, 421x461 grid points/layer and 50 layers.

The COSMO model (http://cosmo-model.cscs.ch/) is used operationally at the national meteorological services of Greece, Italy, 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 the COSMO model for worldwide applications.

The high-resolution regional model **HRM** (http://www.met.gov.om/hrm/index.html) of DWD is being used as operational model with a grid spacing between 7 and 30 km and 25 to 40 layers at nineteen national/regional meteorological services, namely Bosnia-Herzegovina, Brazil-INMET, Brazil-Navy, Bulgaria, China, Israel, Italy, Jordan, Kenya, Libya, Mozambique, 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 COSMO model users.

The main improvement of DWD's modelling suite was the introduction of the convection-resolving model **COSMO-K** for short range predictions with a rapid update cycle, i.e. 21-h forecasts eight times per day with a 30-min data cut-off. This new model explicitly resolves deep convection including its life cycle and possible organization into cloud clusters or squall lines. For the determination of the initial state of COSMO-K the observations of DWD's radar network, consisting of 16 C-band radars, are being used, too. The latent heat nudging (LHN) method makes use of the precipitation scans which are available at 5-minutes intervals at a resolution of about 1x1 km^2.

2. Equipment in use

2.1 Main computers

2.1.1 Two identical IBM p575 POWER5 Clusters

Operating System AIX 5.3
52 p575 nodes (8 POWER5 processors per node, 1.9GHz)
7.6 GFlops/s peak processor speed
3.1 TFlops peak system performance
32 GB physical memory per node
HPS switch (dual plane (2 x 2.5 GB/s bidirect.)
16.6 TB (6 DS 4300 Turbo) usable disk space, FC SAN attached

One compute server is used to run the operational forecasts while the second systems hosts the research workload and serves as

2.1.2 IBM p690 Server / p615 Server

Operating System AIX 5.3
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
22.7 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 48 FC-tape drives
16 x 9840 A (20 GB, 10 MB/s)
8 x 9940 A (60 GB, 10 MB/s)
22 x 9940 B (200 GB, 30 MB/s)
2 x T10000 (500 GB, 120 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 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.

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. Forecasting system

4.1 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 COSMO-E. 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 COSMO-E, a continuous data assimilation system based on the nudging approach provides analyses at hourly intervals.
Forecast runs of GME and COSMO-E 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 06 and 18 UTC) forecasts for COSMO-E and 174-h fore-

casts (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 COSMO-E.

4.2 Medium range forecasting system (4-10 days)

4.2.1 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 4.3

4.2.2 Model

Medium range forecasts at the DWD are mainly based on the ECMWF system (deterministic model and EPS). Additionally, GME (see 4.3) forecasts up to 7 days augment the model guidance available.

4.2.3 Operationally available 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.

4.2.4 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.

4.3 Short-range forecasting system (0-72 hrs)

Operational short-range forecasting is based on the products available from the global model GME (grid spacing of 40 km, 40 layers) and the non-hydrostatic limited area model COSMO-E (grid spacing of 7 km, 665x657 grid points/layer, 40 layers), where COSMO-E covers the time period up to 78 hours from 00 and 12 UTC (48 hours from 06 and 18 UTC). COSMO-E is nested in the GME with an updating of the lateral boundary values at hourly intervals.

For nowcasting and very short range forecasts (up to 21 hours) the convection-resolving meso-gamma scale model COSMO-K (grid spacing of 2.8 km, 421x461 grid points/layer and 50 layers) provides numerical guidance eight times per day with a very short data cut-off of 30 minutes. Lateral boundary conditions of COSMO-K are derived from COSMO-E forecasts.

Fig. 1 shows the domains and topographies of the three operational models of DWD, namely the global model GME and the regional models COSMO-E and COSMO-K.

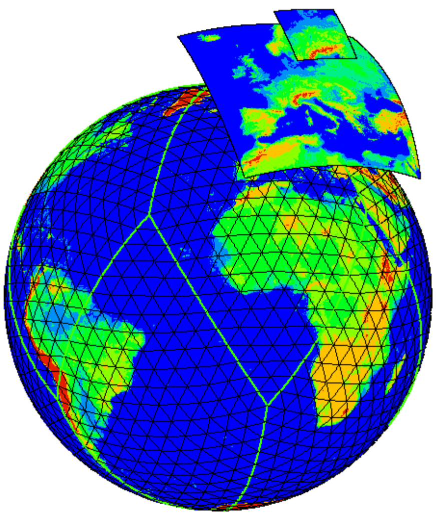

Figure 1 Model domains and topographies of the three operational models of DWD, namely the global model GME (grid spacing 40 km) and the regional models COSMO-E (grid spacing 7 km) and COSMO-K (grid spacing 2.8 km).

4.3.1 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.

Limited area model ***COSMO-E***

a) Limited-area analysis of atmospheric fields

The data assimilation system for the COSMO-E 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 40 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 COSMO-E 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	665 x 657 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, temperature and relative humidity at 2 m
Horizontal anal. grid	665 x 657 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). 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).

Convection-resolving model ***COSMO-K***

d) Limited-area analysis of atmospheric fields

The data assimilation system for the COSMO-K 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 conventional data of type TEMP, PILOT, SYNOP, BUOY, AIRCRAFT and AMDAR. Additionally, radar observations (5-min precipitation scan) are included via the latent heat nudging method.

Analysis method	Observation nudging technique and latent heat nudging method
Analysed variables	p, T, u, v, Rel. Hum.
Horizontal anal. grid	421x461 points (0.025° x 0.025°) on a rotated latitude/longitude grid
Vertical resolution	50 hybrid layers
Products	All analysis products are given on the 421x461 grid and available at hourly intervals. a) On the 50 layers Variables: p, T, u, v, w, q_v, q_c, q_i, q_{rain}, q_{snow}, $q_{graupel}$, 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 30 min for COSMO-K runs.
Initialization	None

e) 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	421 x 461points (0.025° x 0.025°) 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). 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).

4.3.2 Model

a) Schematic summary of the Global Model

Domain	Global
Initial data time	00, 06, 12, 18 UTC
Forecast range	174 h (from 00 and 12 UTC), 48 h (from 06 and 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	3-time-level, leapfrog, split semi-implicit scheme, Δt = 133.33 s, time filter. 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 (Bosnia-Herzegovina, Brazil, Bulgaria, China, Greece, Israel, Italy, Kenya, Libya, Mozambique, Oman, Pakistan, Philippines, Poland, Romania, Senegal, Serbia, Spain, Switzerland, United Arab Emirates, Vietnam). 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.*

b) Schematic summary of the limited area model COSMO-E

Domain	Europe
Initial data time	00, 06, 12, 18 UTC
Forecast range	78 h (48 h for 06 and 18 UTC)
Prognostic variables	p, T, u, v, w, q_v, q_c, q_i, q_{rain}, q_{snow}, TKE
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

c) Schematic summary of the convection-resolving model COSMO-K

Domain	Germany and surrounding
Initial data time	00, 03. 06, 09, 12, 15, 18, 21 UTC
Forecast range	21 h
Prognostic variables	p, T, u, v, w, q_v, q_c, q_i, q_{rain}, q_{snow}, $q_{graupel}$, TKE
Vertical coordinate	Generalized terrain-following, 50 layers
Vertical discretization	Finite-difference, second order
Horizontal grid	421 x 461 points (0.025° x 0.025°) on a rotated latitude/longitude grid, mesh size 2.8 km; Arakawa-C grid, see Fig. 1.
Horiz. discretization	Finite-difference, fifth order
Time integration	Two-time-level, 3^{rd} order Runge-Kutta, split explicit (*Wicker and Skamarock, 1998*), $\Delta t = 25$ s.
Horizontal diffusion	implicit
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*) only for shallow convection
	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

4.3.3 Operationally available numerical weather prediction products

Short-range forecasts are based on direct model output (DMO) of the COSMO-E 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 COSMO-E is given in annex 2.

4.3.4 Operational techniques for application of NWP products

Forecast are produced partly automatically, based on the data listed in 4.3. 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.

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 COSMO-E (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 COSMO-E. UV Index is forecasted within COSMO-E derived from the large scale UV Index forecasts by GME and adapted to COSMO-E 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 specific forecasts, which are offered as *Direct Model Output*.
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 COSMO-E is used as data input for the TOPTHERM model. TOPTHERM calculations are visualised by the selfbriefing software pc_met.

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 COSMO-E 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 COSMO-E data.

Further the COSMO-E model output is the data base for the visualisation software SkyView and the icing forecast model ADWICE.

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 model ADWICE forecasts the atmospheric icing between surface and FL 300 for a forecast period of 48 hours. 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 except of the model ADWICE 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 by automatic e-mail.

4.5 Specialized numerical predictions

4.5.2 Models

4.5.2.1.1 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 (COSMO-E) order in space

a) Daily routine (ca. 1500 trajectories)

Trajectories based on COSMO-E forecasts:

Domain	Domain of COSMO-E (see Fig. 1)
Resolution	0.0625° (as COSMO-E)
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	COSMO-E or GME trajectory models
Domain	COSMO-E or global
Data supply	u, v, w, p_s from COSMO-E 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 (COSMO-E) or 168-h (GME)
Mode	Interactive menu to be executed by forecasters

4.5.2.1.2 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		COSMO-E: 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		48 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		

4.5.3 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 .

4.5.3.1 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 COSMO models

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 its server ftp.dwd.de. For more information see http://www.uv-index.de.

5. Verification of prognostic products

GEOPOTENTIAL 500 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	10	9	9	9	8	7	7	7	7	8	9	9	8.2
36.h	18	18	17	15	15	14	14	12	14	15	17	18	15.5
60.h	29	29	28	25	24	22	21	20	23	24	27	29	25.1
84.h	42	44	42	34	34	31	31	28	33	35	40	42	36.3
108.h	57	61	58	45	46	42	41	38	45	48	55	56	49.3
132.h	70	80	72	58	59	53	51	48	60	62	70	71	62.7
156.h	83	93	85	71	69	62	60	59	73	77	85	85	75.3
p156.h	134	152	138	115	120	94	89	79	102	123	129	131	117.2
climate	114	129	112	96	99	80	67	67	83	99	110	107	97.0

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	.99	.99	.99	1.00	1.00	1.00	1.00	.996
36.h	.99	.99	.99	.99	.99	.98	.98	.98	.99	.99	.99	.99	.985
60.h	.97	.97	.97	.96	.97	.95	.95	.95	.96	.96	.97	.96	.962
84.h	.93	.94	.93	.93	.93	.90	.89	.90	.92	.92	.93	.93	.920
108.h	.87	.88	.85	.87	.88	.83	.80	.82	.84	.86	.87	.87	.853
132.h	.80	.80	.77	.79	.80	.73	.69	.71	.72	.78	.79	.78	.764
156.h	.71	.72	.68	.68	.71	.62	.58	.59	.58	.68	.69	.69	.662

PRESSURE MSL RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	1.3	1.2	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.2	1.08
36.h	2.2	2.2	2.0	1.8	1.7	1.6	1.6	1.5	1.7	1.8	2.0	2.2	1.84
60.h	3.1	3.2	2.9	2.6	2.4	2.2	2.2	2.2	2.4	2.7	3.0	3.2	2.69
84.h	4.3	4.5	4.2	3.3	3.3	3.0	3.0	2.9	3.3	3.8	4.1	4.4	3.68
108.h	5.6	6.0	5.6	4.3	4.2	3.9	3.8	3.7	4.4	4.9	5.5	5.8	4.81
132.h	7.0	7.5	6.8	5.4	5.2	4.7	4.5	4.6	5.5	6.1	6.9	7.2	5.95
156.h	8.2	8.6	8.1	6.4	6.0	5.4	5.1	5.4	6.6	7.3	8.3	8.3	6.97
p156.h	12.1	13.4	12.3	10.3	9.6	7.8	7.5	6.9	8.7	11.2	11.2	12.4	10.29
climate	10.0	10.7	9.6	8.0	7.0	5.9	5.3	5.5	6.6	8.6	9.2	10.2	8.05

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	.98	.98	.99	.99	.99	.99	.990
36.h	.98	.98	.98	.98	.97	.96	.96	.95	.97	.98	.98	.98	.971
60.h	.95	.95	.95	.95	.94	.93	.91	.91	.93	.94	.95	.95	.939
84.h	.90	.91	.90	.92	.89	.87	.84	.84	.87	.89	.89	.90	.886
108.h	.83	.84	.82	.86	.81	.79	.74	.75	.77	.82	.81	.83	.807
132.h	.74	.76	.74	.77	.72	.70	.63	.63	.64	.73	.70	.75	.710
156.h	.63	.68	.64	.67	.62	.61	.53	.51	.51	.63	.57	.67	.605

TEMPERATURE 850 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	1.0	1.0	.9	1.0	.9	.9	.9	.9	.9	.9	.9	1.0	.94
36.h	1.6	1.6	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.5	1.6	1.48
60.h	2.1	2.1	1.9	1.9	1.8	1.9	1.8	1.7	1.7	1.8	1.9	2.1	1.89
84.h	2.6	2.7	2.5	2.3	2.3	2.2	2.2	2.0	2.1	2.2	2.4	2.5	2.32
108.h	3.3	3.3	3.0	2.7	2.7	2.7	2.6	2.4	2.4	2.6	2.9	3.0	2.80
132.h	3.9	3.9	3.6	3.2	3.2	3.1	2.9	2.8	2.9	3.1	3.4	3.6	3.29
156.h	4.4	4.5	4.2	3.7	3.6	3.5	3.3	3.1	3.4	3.6	4.0	4.1	3.77
p156.h	6.4	6.7	6.4	5.8	5.6	5.0	4.7	4.3	5.0	5.4	6.1	5.9	5.60
climate	5.4	5.3	4.9	4.9	4.7	3.9	3.5	3.5	3.9	4.3	5.0	4.9	4.52

TEMPERATURE 850 hPa ANOMALY CORRELATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	.98	.98	.98	.98	.98	.97	.96	.96	.97	.97	.98	.98	.974
36.h	.95	.96	.95	.95	.94	.92	.91	.91	.93	.94	.95	.94	.938
60.h	.92	.92	.92	.92	.91	.88	.87	.86	.90	.90	.92	.91	.901
84.h	.88	.88	.87	.88	.86	.82	.81	.81	.85	.85	.88	.86	.853
108.h	.81	.81	.80	.83	.80	.74	.73	.75	.78	.78	.82	.80	.788
132.h	.74	.72	.72	.76	.73	.66	.65	.68	.69	.70	.75	.73	.710
156.h	.66	.63	.63	.68	.66	.58	.56	.60	.58	.60	.66	.65	.624

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), 2006.**

GEOPOTENTIAL 500 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	8	7	8	9	9	9	10	10	10	9	9	8	8.8
36.h	16	16	17	19	21	21	22	21	20	20	18	16	18.9
60.h	26	25	27	30	33	33	36	35	33	31	28	26	30.2
84.h	37	36	38	43	50	48	52	51	48	44	38	36	43.5
108.h	51	48	52	58	68	61	69	69	63	58	50	50	58.0
132.h	62	62	66	73	83	77	85	84	79	70	61	64	72.0
156.h	74	75	79	88	97	91	98	98	92	83	72	77	85.3
p156.h	116	119	117	139	139	160	155	144	154	137	134	116	135.9
climate	82	94	91	108	116	118	121	119	119	107	98	92	105.5

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	.996
36.h	.98	.98	.98	.98	.99	.98	.98	.98	.99	.98	.98	.98	.984
60.h	.95	.96	.96	.96	.96	.96	.95	.96	.96	.96	.96	.96	.958
84.h	.90	.92	.91	.92	.91	.92	.90	.91	.92	.91	.92	.92	.912
108.h	.80	.86	.83	.85	.84	.87	.83	.84	.85	.84	.87	.85	.843
132.h	.70	.77	.72	.75	.75	.79	.74	.76	.76	.77	.80	.75	.755
156.h	.57	.67	.59	.64	.65	.70	.66	.67	.68	.68	.72	.64	.656

PRESSURE MSL RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	1.0	1.0	1.0	1.0	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.12
36.h	1.8	1.8	1.9	2.1	2.2	2.4	2.4	2.5	2.3	2.2	2.1	2.0	2.15
60.h	2.6	2.7	2.8	3.2	3.5	3.6	3.8	3.9	3.6	3.3	2.9	2.8	3.22
84.h	3.8	3.8	3.9	4.3	4.9	4.9	5.4	5.5	5.0	4.5	3.9	3.7	4.47
108.h	5.0	4.8	5.2	5.6	6.6	6.2	7.0	7.1	6.4	5.8	4.9	4.9	5.78
132.h	5.9	5.8	6.5	6.9	7.9	7.5	8.5	8.5	7.7	6.9	5.9	6.0	7.01
156.h	6.9	6.9	7.6	8.2	9.1	8.8	9.6	9.8	8.9	8.1	6.8	7.0	8.13
p156.h	10.1	10.6	10.5	12.6	12.3	14.3	14.9	13.0	14.8	12.5	11.6	9.8	12.25
climate	7.0	8.1	8.4	10.0	10.3	10.8	11.5	11.2	11.6	9.6	8.1	7.7	9.53

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	.993
36.h	.97	.97	.97	.98	.98	.98	.97	.98	.98	.97	.97	.97	.973
60.h	.93	.94	.94	.95	.94	.94	.94	.94	.95	.94	.94	.93	.940
84.h	.86	.88	.88	.90	.88	.90	.87	.88	.90	.89	.89	.88	.885
108.h	.75	.82	.79	.83	.80	.84	.79	.80	.83	.82	.81	.80	.805
132.h	.63	.73	.67	.74	.70	.75	.70	.71	.75	.74	.73	.71	.713
156.h	.51	.63	.55	.64	.60	.67	.62	.61	.67	.64	.64	.61	.615

TEMPERATURE 850 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	.8	.8	.8	.8	.8	.9	.9	.9	.9	.9	.9	.9	.87
36.h	1.4	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.6	1.6	1.5	1.4	1.51
60.h	1.8	1.7	1.8	1.9	2.1	2.1	2.2	2.3	2.2	2.1	2.0	1.9	2.00
84.h	2.1	2.1	2.2	2.4	2.7	2.6	2.8	2.8	2.7	2.5	2.3	2.3	2.46
108.h	2.5	2.5	2.6	2.9	3.2	3.0	3.3	3.4	3.2	2.9	2.7	2.7	2.92
132.h	2.9	2.9	3.1	3.3	3.7	3.5	3.8	3.9	3.7	3.3	3.0	3.0	3.33
156.h	3.2	3.2	3.5	3.7	4.0	3.8	4.2	4.3	4.1	3.7	3.3	3.4	3.70
p156.h	4.5	4.5	4.6	4.9	5.2	5.4	5.4	5.4	5.7	5.2	5.0	4.7	5.03
climate	3.5	4.1	4.8	5.2	5.6	5.1	5.2	5.2	5.0	4.3	3.9	3.6	4.62

TEMPERATURE 850 hPa ANOMALY CORRELATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	.97	.98	.98	.99	.99	.99	.98	.98	.98	.98	.97	.97	.980
36.h	.92	.93	.95	.96	.96	.95	.95	.95	.95	.94	.92	.92	.943
60.h	.87	.89	.92	.93	.93	.91	.91	.91	.91	.89	.88	.87	.901
84.h	.81	.84	.88	.89	.88	.87	.85	.86	.86	.83	.83	.81	.851
108.h	.73	.78	.82	.83	.83	.82	.79	.79	.80	.78	.78	.74	.790
132.h	.65	.72	.77	.77	.77	.76	.72	.73	.72	.71	.73	.67	.727
156.h	.57	.65	.70	.71	.72	.71	.67	.66	.66	.63	.67	.59	.662

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), 2006.**

GEOPOTENTIAL 500 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	10	8	8	8	7	7	6	6	6	7	9	10	7.7
36.h	18	15	16	15	13	13	11	12	12	14	16	19	14.6
60.h	32	26	31	26	23	23	18	20	22	24	27	29	25.0
84.h	47	42	50	38	34	33	30	30	36	38	40	42	38.3
108.h	69	67	67	52	47	45	42	41	51	53	57	59	54.2
132.h	91	90	80	68	62	58	52	53	68	68	75	85	70.8
156.h	109	108	95	78	71	70	59	61	81	84	98	110	85.2
p156.h	153	177	169	111	144	97	94	99	111	155	148	169	135.7
climate	153	137	111	116	119	94	84	83	90	125	119	139	114.2

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	1.00	1.00	1.00	1.00	1.00	1.00	.997
36.h	.99	.99	.99	.99	.99	.98	.99	.99	.99	.99	.99	.99	.989
60.h	.97	.97	.96	.96	.98	.94	.97	.97	.96	.96	.97	.98	.967
84.h	.93	.93	.89	.92	.96	.89	.93	.93	.90	.91	.94	.94	.922
108.h	.84	.83	.82	.86	.92	.81	.85	.86	.80	.84	.87	.88	.848
132.h	.74	.70	.74	.73	.87	.71	.74	.77	.65	.74	.78	.75	.742
156.h	.65	.58	.65	.69	.82	.59	.66	.67	.51	.69	.61	.63	.645

PRESSURE MSL RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	1.1	1.0	1.0	.9	.8	.8	.8	.8	.8	.9	1.0	1.0	.90
36.h	1.9	1.8	2.0	1.6	1.5	1.4	1.2	1.3	1.3	1.6	2.0	2.0	1.62
60.h	3.0	2.7	3.3	2.5	2.5	2.2	1.8	2.2	2.2	2.7	3.1	3.0	2.59
84.h	4.5	4.2	5.0	3.5	3.5	3.2	2.7	3.0	3.2	3.9	4.4	4.2	3.76

108.h	6.2	6.5	6.7	4.4	4.5	4.2	3.7	3.7	4.6	5.1	6.2	5.7	5.13
132.h	8.7	8.7	7.8	5.7	5.5	5.0	4.3	4.5	5.9	6.4	7.7	7.9	6.52
156.h	10.3	10.0	9.0	6.6	6.3	5.7	4.8	5.2	6.9	7.6	9.6	9.5	7.63
p156.h	14.7	14.9	14.0	9.4	11.3	7.5	7.5	7.0	9.5	13.8	13.4	15.0	11.51
climate	13.0	10.8	9.8	9.0	8.1	5.7	5.8	6.2	7.0	10.2	11.2	13.3	9.17

PRESSURE MSL ANOMALY CORRELATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	1.00	.99	.99	.99	.99	.99	.99	.99	.99	.99	1.00	1.00	.993
36.h	.99	.98	.98	.98	.98	.96	.97	.97	.98	.98	.98	.99	.978
60.h	.97	.95	.94	.95	.95	.90	.95	.94	.95	.94	.95	.97	.946
84.h	.92	.89	.87	.91	.89	.82	.89	.88	.89	.88	.90	.94	.890
108.h	.85	.77	.77	.86	.81	.72	.78	.79	.77	.81	.82	.88	.802
132.h	.70	.62	.65	.74	.74	.65	.68	.69	.63	.72	.74	.76	.692
156.h	.59	.52	.55	.69	.65	.56	.64	.55	.51	.65	.54	.70	.598

TEMPERATURE 850 hPa RMSE

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	.9	.9	.9	.8	.9	.9	.9	.9	.8	.9	.9	.9	.87
36.h	1.4	1.4	1.4	1.3	1.3	1.3	1.2	1.3	1.2	1.3	1.3	1.4	1.31
60.h	2.0	1.7	1.9	1.6	1.6	1.7	1.5	1.6	1.5	1.7	1.7	1.7	1.69
84.h	2.5	2.2	2.5	2.0	2.0	2.1	1.9	1.9	2.0	2.1	2.0	2.1	2.12
108.h	3.3	3.0	3.1	2.4	2.5	2.6	2.3	2.3	2.6	2.5	2.5	2.5	2.64
132.h	4.1	3.7	3.6	2.8	3.1	3.0	2.8	2.7	3.1	3.1	2.9	3.2	3.17
156.h	4.9	4.3	4.2	3.3	3.6	3.5	3.2	3.0	3.6	3.8	3.5	3.9	3.74
p156.h	6.6	5.7	5.9	4.4	5.8	5.6	4.7	4.6	4.7	6.2	4.7	5.3	5.34
climate	5.6	4.4	4.6	3.9	4.8	4.6	3.9	3.6	4.0	4.9	3.7	4.5	4.37

TEMPERATURE 850 hPa ANOMALY CORRELATION

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
12.h	.98	.98	.98	.97	.98	.98	.97	.96	.98	.97	.97	.97	.974
36.h	.96	.94	.94	.92	.96	.94	.94	.93	.95	.94	.93	.94	.941
60.h	.92	.91	.91	.88	.93	.89	.90	.89	.91	.91	.89	.90	.904
84.h	.88	.85	.83	.82	.90	.83	.85	.84	.84	.86	.83	.87	.851
108.h	.80	.74	.74	.74	.85	.75	.78	.77	.75	.79	.72	.80	.770
132.h	.70	.61	.68	.63	.78	.67	.68	.67	.62	.71	.66	.69	.675
156.h	.57	.48	.57	.50	.71	.58	.58	.58	.51	.59	.56	.55	.564

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), 2006.**

6. Plans for the future

6.1 Development of the GDPFS

Development of the GDPFS

Direct use of satellite radiances
Since eearly 2006, AMSU-A data are used operationally with a 1D-Var scheme for the global model GME. The 1D-Var retrievals are assimilated additionally to the pseudo-temps (profiles over sea, derived from ECMWF analyses) until the amount of usable satellite data is improved especially in the southern hemisphere and direct assimilation is available with 3D-Var.
The 1D-Var scheme is currently enhanced for data of NOAA-18, while AMSU data of METOP is being monitored.
Other activities are the use of radiances for the regional model COSMO-LME with 1D-Var and its nudging analysis.

(Hess)

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. These modifications have been used operationally in LME since April 2006.

(Schraff)

Revision of plant properties in the global model GME

In the context of sensitivity studies of the global model GME with regard to the introduction of seasonal variability in plant properties a problem in the evolution of the simulated soil moisture in the summer season was revealed in the operational models evolution of soil moisture. In the absence of a soil moisture assimilation scheme an unrealistic local minimum in the volumetric soil moisture profile develops well below the earths surface as a consequence of excessive transpiration by plants which access lower soil layers directly through their roots. The experimental introduction of seasonally variable plant cover alleviates this problem to some extent. However, the assumption of a constant root density profile whithin the soil needs to be removed in order to reduce the problem further. As the overall drying out of the soil in the operational model is also felt to be too excessive an investigation concerning the role of soil hydrological properties and the formulation of surface runoff has been instigated. Pending the outcome of these investigations these changes will be introduced into the operational model in the near future.

(Ritter, Helmert)

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, Anlauf, Pingel, Cress, 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 COSMO-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.

In general, LMK has better scores for wind speed and gusts in 10 m above ground. The RMSE of the wind speed is reduced by about 5 to 10% compared to LME. The RMSE of 2m temperature is mostly smaller in LMK, too, although no soil moisture analysis is used. The precipitation forecast had better true skill statistics (TSS) in the months September to November 2006. But in December, LMK had drawbacks compared to LME. This is partly due to the fact, that LHN is switched off in winter months due to bright bands in the radar data, which are up to now not corrected. The stratification of LMK is often slightly too unstable, which gives the hint, that convection is not efficiently enough resolved by the model. In contrary, LME produces too stable stratifications, an artefact of the parameterization.

In general LMK improves precipitation forecasts in situations, where convection is connected with a synoptic forcing, whereas it does not perform as well in free convection situations. Here, only the latent heat nudging can trigger precipitation events a few hours in advance.

LMK has clear advantages in more dynamically driven phenomena due to its better spatial resolution. Lee waves are often correctly forecasted, which gives an increased skill for aviation, especially for gliders. Strong downslope winds in stably stratified atmosphere are better forecasted too, an example was found at 05.11.2006 in the lee of the Erzgebirge, where a hydraulic jump like flow field could be simulated by LMK.

The operational usage is planned for April 2007.

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

6.2 Planned 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 are performed investigating several grid optimization strategies and properties of the used operators, as well as the temporal and spatial discretization schemes.

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

GME at ECMWF

GME is running daily at ECMWF based on the 12 UTC analysis of ECMWF's IFS model since 2002.
A version like the operational model at DWD with 40 levels and 40 km mesh size was running all year 2006. In addition a version with 30 km mesh size is running since November 2006. It yields slightly better scores.
The 40 km model provides initial and boundary conditions for daily runs with different versions of the limited area model COSMO-LME at ECMWF.

(Frank)

Parameterization of cloud microphysics:

For the 7-km COSMO-LME at DWD a revised prognostic microphysical parameterization has been developed. The modified scheme includes a new parameterization of warm rain processes and a more detailed description of the snow microphysics. For the snow size distribution a diagnostic relation for the intercept parameter as a function of temperature and mixing ratio has been introduced, which results in larger values for low temperatures, i.e. smaller snowflakes. The new scheme leads to a better representation of orographic precipitation, e.g. reducing the overestimation of precipitation over mountains, and to a reduction of spurious drizzle events. Both results in an improved QPF skill during wintertime and demonstrates the importance of cloud microphysics on the mesoscale.

(Seifert)

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