THE MODEL CHAIN OF THE DEUTSCHER WETTERDIENST AND ITS USE IN OPERATIONAL WEATHER FORECASTING

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Introduction

According to law the Deutscher Wetterdienst (DWD) has to guarantee the meteorological safety of air and sea navigation. The DWD has also to provide forecast information for a wide variety of users including the public, private enterprises and media. These tasks are carried out in the business area «Forecast customers and media» of the new organizational structure of the DWD.

Within the international collaboration of the National Meteorological and Hydrological Services (NMHS's) organized by the World Meteorological Organization (WMO), the DWD runs one of the Regional Specialized Meteorological Centres (RSMC's) of the Global Data Processing System (GDPS) of the World Weather Watch (WWW). In this function the DWD has to provide basic weather analyses and forecasts for Europe and the North Atlantic.

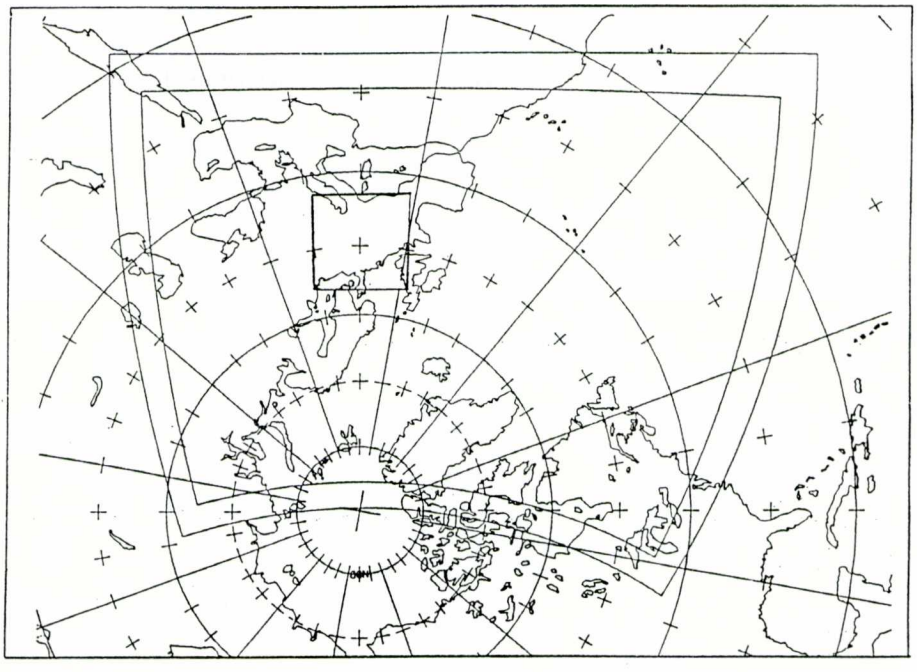
The backbone of all activities of the DWD in weather forecasting is a chain of Numerical Weather Prediction (NWP)-models providing analyses as well as forecasts up to seven days ahead. In this paper this model chain and its use in operational forecasting is described.

The model chain

The model chain of the DWD consists of three NWP models, namely

- a global model (GM),
- a limited area model covering Europe and the North Atlantic (called «Europa-Modell», EM), and
- a high resolution model covering Germany and the neighbouring countries (called «Deutschland-Modell», DM).

The global model (GM) has been derived from a similar model of the European Centre for Medium Range Weather Forecasting (ECMWF). It is a spectral model with triangular truncation at wavenumber 106. That roughly corresponds to a horizontal grid size of 200 km in mid latitudes. In the vertical the GM has 19 levels. It runs twice a day up to 168 h starting from the analyses for 00 and 12 UTC. Its main purpose is to provide boundary values for the EM. The forecasts beyond 78 hours are calculated in order to support medium-range forecasting.



Domain of the «Europa-Modell» (EM) including the boundary zone and the domain of the «Deutschland-Modell» (DM)

The «Europa-Modell» (EM) is the main weather forecast model of the DWD. It is a grid point model with a mesh of 181 x 129 grid points (mesh size 0.5°) in rotated spherical coordinates(see fig.). The rotated north pole has the geographical coordinates λ = 170° W and φ = 32.5° N. In this coordinate system, the domain extends from φ' = 32° S to 32° N where the convergence of the meridians is still small. Thus, the true distance between grid points in W-E-direction varies only between 55.6 km in the center of the domain and 47.1 km at the edges; in N-S-direction, the distance is 55.6 km.

In the vertical, the model atmosphere is resolved by 20 layers of upward increasing thickness. Eight layers are used in the lowest 2 km of the atmosphere to reproduce the structure of the boundary layer sufficiently well; four layers are placed in the stratosphere.

EM is based on the primitive equations in a terrain-following hybrid coordinate system. The prognostic variables are

- surface pressure p_s
- horizontal wind components (u, v)
- total heat $h = c_p T + Lq_v$, defined as the sum of enthalpy and latent heat of condensation,
- total water content $q_w = q_v + q_c$, which is the sum of the specific contents of water vapour q_v and cloud water q_c.

Assuming water saturation in clouds, the three variables temperature T, water vapor content qv and cloud water content qc can be determined diagnostically from the prognostic variables h and qw distinguishing between cloud and no-cloud-areas. The vertical velocity in the pressure system ω is used as further diagnostic quantity. The geopotential (ϕ) of the pressure surfaces is derived with aid of the hydrostatic equation.

The processes of horizontal diffusion, grid-scale precipitation, moist convection, cloudiness and radiation, and the vertical turbulent fluxes are physically parameterized by using appropriate numerical schemes. A soil model predicts the temporal revolution of temperature and water content at the surface for land points whereas for sea points the sea surface temperature is kept constant during the forecast.

The «Deutschland-Modell» (DM) has the same physical design and the same vertical grid structure as the EM, but with a mesh size of $0.125^o \sim 14$ km it has a much higher horizontal resolution. It has its own analysis scheme for which the EM provides the boundary values.

78 h-EM forecasts are produced twice a day for 00 and 12 UTC with a cut-off time of 3 h 30 min and a time step of 5 min. The boundary data for these forecasts are provided at 3 h intervals by a GM run from the same initial data. GM and EM share the four processors of a CRAY Y-MP-Supercomputer during the operational suite, each model using 2 CPUs nominally.

The DM runs up to 48 h with the boundary data from an early run of the EM (cut-off time 2 h 14 min). The DM forecasts are available 3 h 20 min, the EM forecasts 5 h 35 min, and the GM forecasts 6 h 25 min after observation time.

According to the different horizontal resolution, there are differences in the ability of the models to simulate typical features of the weather in the mid latitudes. The GM is able to reproduce all features of the Macro- (or Synoptic-) Scale, i.e. features with a typical horizontal dimension greater than 2000 km like the moving lows and highs near surface and the baroclinic waves connected with them in upper levels. The EM additionally resolves the hyper-baroclinic frontal zones at which the depressions originate and which belong to the meso-α-Scale (200 - 2000 km). The main precipitation activity takes place at these frontal zones. The DM finally is able to reproduce some of the phenomena of the meso-β-Scale (20 - 200 km) like frontal-substructures (e.g. rain bands) and the weather features originated by the orography (foehn, enhanced precipitation, formation of lee cyclones).

For the latter the different representation of the mountains is crucial. Whereas the maximum height of the Alps is only around 1500 m in the GM, the barrier extends to a height of up to 2300 m in the EM and up to 3130 m in the DM.

Operational use of the model products

The output of the model chain is distributed to the Central Forecasting Unit of the DWD in Offenbach and to the Regional Offices in Essen, Hamburg, Leipzig, Munich, Offenbach, Potsdam und Stuttgart. These offices are responsible for producing weather forecasts for all time scales tailored to the needs of the different users and for issuing warnings of hazardous weather. The provision of special products for the media is carried out by the Media Service Centre in Offenbach.

A subject of the output is provided via the Global Telecommunication System (GTS) of the WWW for use by the NMHS's in Europe. The main tool for the provision is at present a long-wave facsimile transmission, but it will be replaced by a satellite distribution system very soon.

The model output is used in different form. The EM provides the basic analyses and forecasts of geopotential, temperature, humidity and wind of the standard pressure levels 850, 700, 500, 300 and 200 hPa in the form of maps. The analysis of the surface maps with the isobars of the surface pressure and the fronts is still carried out manually, but model fields are used as a supporting tool. The forecast maps for surface are interactively produced at workstations, whereby the meteorologist has to insert the fronts and can change the numerically forecasted pressure field if necessary.

Other EM products are predictions of precipitation sums and of the 10 m wind. From the DM forecasts of the low cloudiness, amount and type of precipitation, type of convection and also of the 10 m winds are derived and distributed.

Another way to present the output is the production of so-called meteograms, in which the course of the meteorological parameters is indicated for grid points near special places. They can be used as a basis for local forecasts.

As an important tool in the case of nuclear or chemical accidents, analyses and forecasts of air trajectories can be produced by the EM as well as the DM.

Some special products for use in the media have been developed during the past year with aid of the EM and DM output. These are loops showing the cloud development as seen from a satellite, animations of the temperature distribution and pictograms containing weather information.

From the description of the different forms of the output, one could possibly infer that all weather forecasts could be derived directly and more or less automatically from the model products. That is, of course, not true. Although the quality of the numerical forecasts is quite high, the prognoses are not perfect and the well-trained meteorologist is needed to monitor the weather, to compare it with the numerical forecast run, to derive alternative forecasts if an error of the model becomes obvious and, finally, to produce the tailored forecasts for the different end users.