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- The Danish Meteorological Institute -

1. Summary of highlights

The numerical weather prediction system DMI-HIRLAM which is operational at the Danish Meteorological Institute (DMI) originates from the international HIRLAM project (Lynch et al., 2000). There has been operational changes at DMI during 2002 with regard to computer system, data assimilation and details of the forecast model. The main modifications are briefly mentioned below: A detailed description of the operational system used at DMI (Sass et al., 2002) is available at www.dmi.dk.

- A new supercomputer (NEC-SX6) has been installed (see section 2) . The DMI-HIRLAM forecasting system has become operational on the new computer system. The computer power has been increased substantially. A peak performance of 128 Gflops is available on the two 8 processor nodes.
- Locally retrieved ATOVS AMSU-A satellite data (NOAA 16 data) is now used in the 3D-VAR data assimilation system.
- The vertical resolution in DMI-HIRLAM has been increased from 31 to 40 model levels.
- The convection scheme used in DMI-HIRLAM has been upgraded (Sass, 2002). The convective cloud ascent model has been modified to describe better the vertical extent of convection and the diurnal cycle of convection. The frequency of erroneous small precipitation rates has been reduced, but heavy precipitation events tend to be intensified. Also cloud cover parameterization and microphysics have been modified in order to improve the model formulation at high resolution.
- The model's horizontal diffusion has been modified from explicit 4th order diffusion to implicit 4th order diffusion in order to improve numerical stability. This implicit scheme is described in the HIRLAM documentation (Undén et al., 2002).

2. Equipment in use

The operational HIRLAM system is run on an NEC-SX6 supercomputer with 16 processors (two nodes with each 8 processors) and a peak performance of 128 Gflops.

The memory amounts to 96 Gbyte. Currently the disc capacity amounts to 1 Tbyte. (see fig. 1). The front end consists of 2 AzusA systems with 4 cpu and 4 Gbyte each. The observation processing takes place on two 4 processor ORIGIN 200 computers. The GTS messages are processed and encoded to BUFR format. The lateral boundaries from ECMWF (European Centre for Medium-Range Weather Forecasts) are received four times a day, with origin time 00 UTC, 06 UTC, 12 UTC and 18 UTC respectively. The SGI ORIGIN computers also contain an operational database with results produced by the operational runs. The computationally most demanding operations take place on the NEC-SX6 supercomputer (analyses, forecasts and postprocessing). Some of the produced model level files are archived on a mass storage device.

3. Data from GTS in use

SYNOP, SHIP, DRIBU, PILOT, TEMP, AIREP, AMDAR/ACARS.
(ATOVS AMSU-A data is used, but is not retrieved via the GTS)

4. Data input system

Automated.

5. Quality control system

Non-controlled national observations as output on GTS.

6. Monitoring of observing system

Regional monitoring of observations implemented in order to assure high quality LAM products.

7. Forecasting system

The goal of the DMI-HIRLAM weather prediction system is to provide high accuracy meteorological forecast products, with a special priority on forecasts valid for the short range, up to about two days ahead. The system provides guidance to both meteorological staff (forecasters) and to numerous customers in general. Furthermore, the results are used as input (forcing) to specialized forecasts (e.g., a storm surge model , a road conditions model and an ozone forecasting system).

HIRLAM stands for HIgh Resolution Limited Area Model. The operational system consists of four nested models named DMI-HIRLAM-G, DMI-HIRLAM-N, DMI-HIRLAM-E and DMI-HIRLAM-D, respectively. In short, the models are

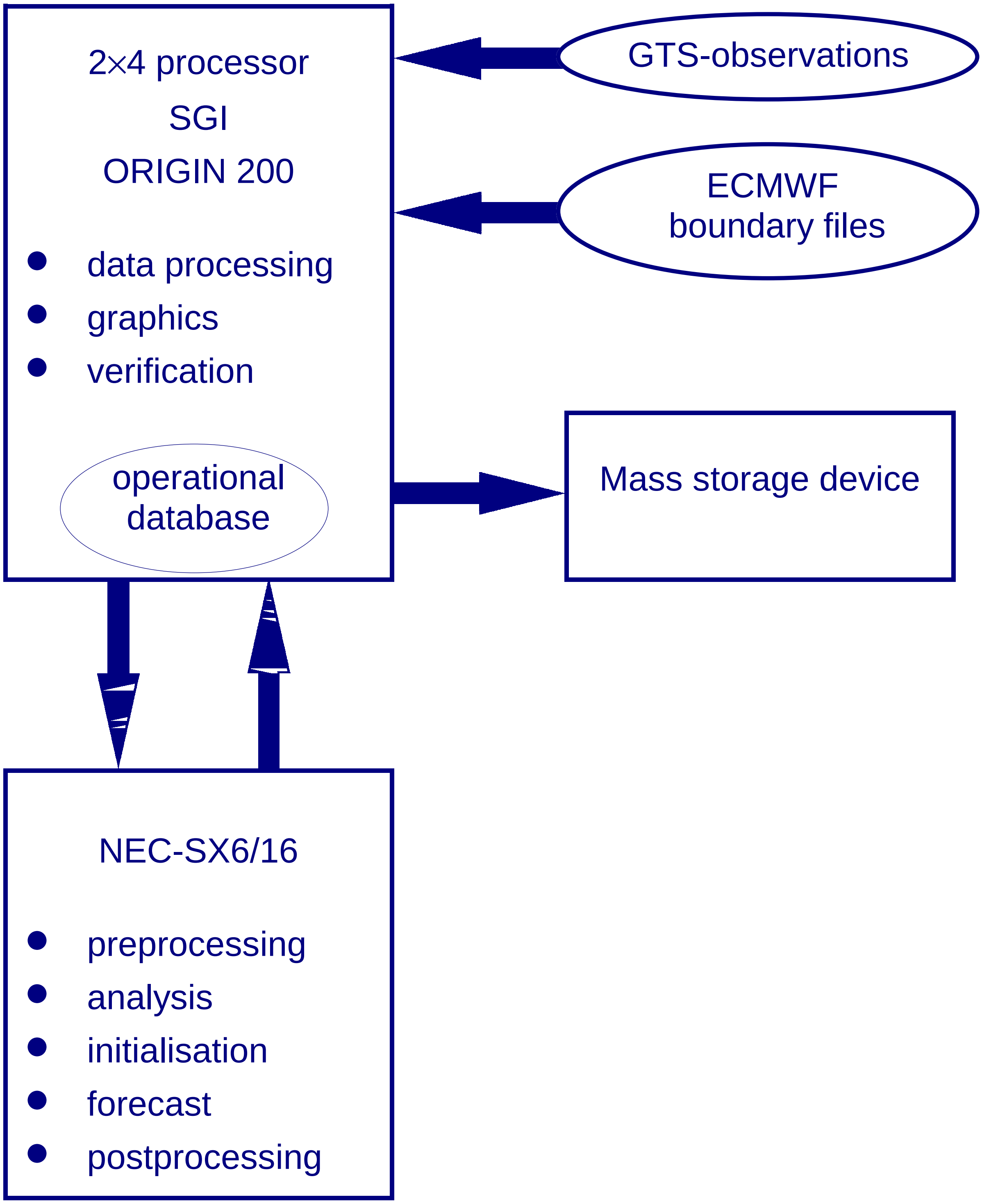

Figure 1: Computers and data flows.

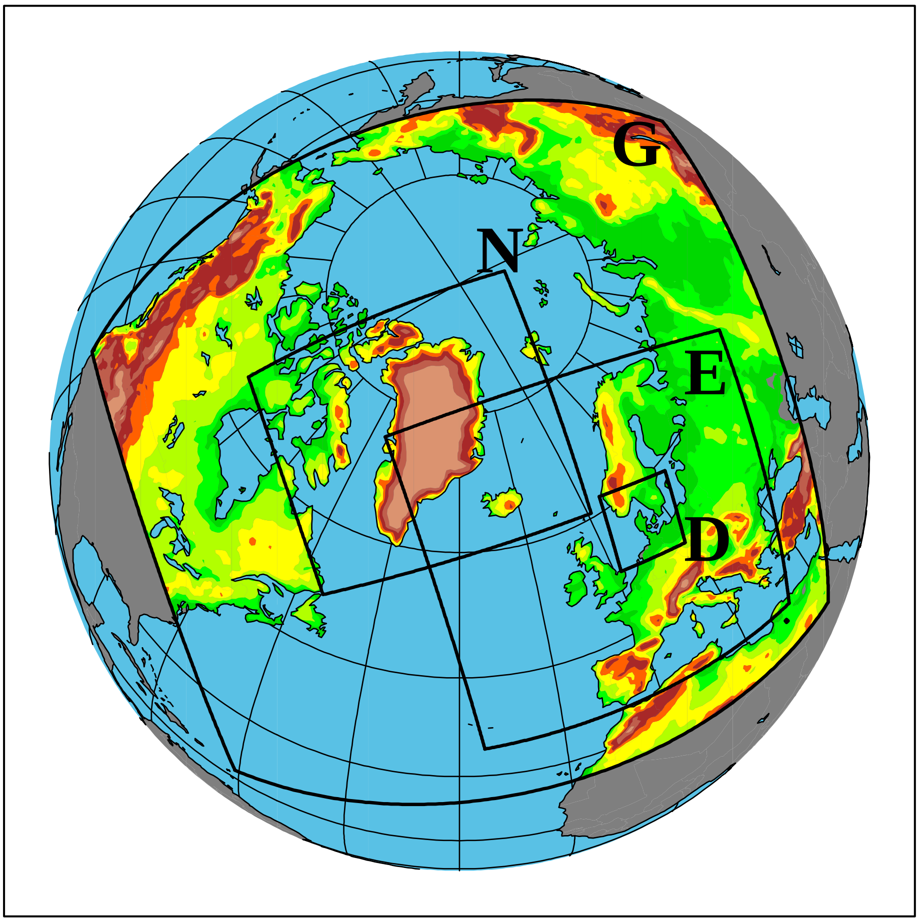

Figure 2: The DMI operational model integration areas.

abbreviated ‘G’, ‘N’, ‘E’, and ‘D’, respectively. The model integration areas are shown in figure 2.

The lateral boundary values of model ‘G’ are provided by the ECMWF global model. The ‘G’ model provides the lateral boundary values of the models ‘N’ and ‘E’. Finally, model ‘E’ supplies the boundaries for the very high resolution model ‘D’ around Denmark.

Table 1: Basic information related to model grid, resolution, time step, coupling strategy, forecast length and number of forecasts per day.

Model identification	G	N	E	D
grid points (mlon)	202	194	272	182
grid points (mlat)	190	210	282	170
number of vertical levels	40	40	40	40
horizontal resolution(deg)	0.45	0.15	0.15	0.05
time step (dynamics)	150 s	60 s	60 s	25 s
time step (physics)	450 s	360 s	360 s	500 s
host model	ECMWF	G	G	E
boundary age(forecast)	6 h	0 h	0 h	0 h
boundary age (assimilation)	0 h-6 h	−3 h - 0 h	−3 h - 0 h	−3 h - 0 h
boundary update cycle	3 h	1 h	1 h	1 h
data-assimilation cycle	3 h	3 h	3 h	3 h
forecast length (long)	60 h	36 h	54 h	36 h
long forecasts per day	4	2	4	2

Key parameters of the system setup with respect to resolution, time step, boundaries and data-assimilation are shown in table 1. Here ‘mlon’ is the number of longitude grid points and ‘mlat’ is the corresponding number of latitude points. Also the table shows the number of vertical levels in the models and the horizontal resolution (°) measured between neighbouring grid points. The time step used in the dynamics and in the physics are different. The boundary age means the age of the host model relative to the start time of the forecast. A distinction is made between boundary age during forecast and during data-assimilation. A negative value of the boundary age during data-assimilation means that analyses of the host model are available and will be used as lateral boundaries. The boundary update cycle is given as the number of hours between boundary files of the host model used for time interpolation in boundary zone between the models. The data assimilation cycle is the number of hours between new analysis states of the model. Finally, the table provides information about the forecast length in hours and the number of long forecasts per day for each model.

The data-assimilation procedure is shown in table 2 showing the operational time schedule.

The first column shows the model startup time in UTC. A given run is indicated by a letter followed by two digits describing model initial time and finally an indication of forecast length in hours. For example, ‘G00+60h’ means a 00 UTC analysis followed by a 60 hour forecast carried out for model ‘G’.

An analysis increment method is used for model ‘D’ (see below).

The initial states of the DMI forecasts are produced by analyses valid at 00 UTC, 06 UTC, 12 UTC and 18 UTC, respectively. The analysis states at 00 UTC and 12 UTC are achieved by retrospective analysis cycles (see below). The first guess of the analyses at 00 UTC and 12 UTC is a 3 hour forecast while a 6 hour forecast is used as input to the analyses valid at 06 UTC and 18 UTC. Forecasts with the models ‘N’ and ‘D’ are run only twice a day from the 00 UTC and 12 UTC analyses.

Assimilation runs with a cycling of 3 hours are managed as a sequence of retrospective analyses which are run twice a day in delayed mode. The first series of runs starts around 11.50 UTC. Model ‘G’ starts from the 00 UTC ECMWF analysis data prepared by an increment method where the available analysis for ‘G’ is interpolated to a coarse mesh data grid with ECMWF analysis data. The difference between this interpolated field and the new ECMWF analysis is an increment (‘large scale increment’) which is interpolated back to the DMI-HIRLAM field in normal resolution and added to get an updated HIRLAM analysis. Normal HIRLAM 3D-VAR cycles then follow immediately after (analyses valid at 03 UTC, 06 UTC, 09 UTC) to produce an ‘up-to-date’ state of the atmosphere. The second series of runs is made before midnight, using 12 UTC ECMWF analysis data in the processing. These runs produce 3D-VAR analyses valid at 15 UTC, 18 UTC and 21 UTC, respectively.

The analyses and forecasts produced in the assimilation cycles of model ‘G’ are used as boundaries for the corresponding 3-hourly cycles of the models ‘E’ and ‘N’. These are run as sequences around noon and midnight. The boundary age during data assimilation cycles for these models is either 0 hours, or −3 hours if an analysed boundary from the host model (‘G’) is available.

An analysis increment method is implemented for model ‘D’. In this case the first guess of model ‘D’ is corrected using analyses from model ‘E’. This method also applies to the 3-hourly cycles of model ‘D’.

Table 2: Operational time schedule used (G_E denotes restart from ECMWF analysis. See text for details)

UTC	G	N	E	D
1:40	G00+60 h			
1:43			E00+54 h	
2:30				D00+36 h
2:55		N00+36 h		
ECMWF 00 UTC				
7:37	G06+60 h			
7:43			E06+54 h	
ECMWF 06 UTC				
11:50	G_E00+03 h G03+03 h G06+03 h G09+03 h			
12:00			E03+03 h E06+03 h E09+03 h	
12:10				D03+03 h D06+03 h D09+03 h
12:20		N03+03 h N06+03 h N06+03 h		
13:40	G12+60 h			
13:43			E12+54 h	
14:30				D12+36 h
14:55		N12+36 h		
ECMWF 12 UTC				
19:37	G18+60 h			
19:43			E18+54 h	
ECMWF 18 UTC				
23:45	G_E12+03 h G15+03 h G18+03 h G21+03 h			
23:55			E15+03 h E18+03 h E21+03 h	
24:05				D15+03 h D18+03 h D21+03 h
24:15		N15+03 h N18+03 h N21+03 h		

8. Verification of prognostic products

Objective verification comprising both field verification and 'OBS-verification' has been implemented. The latter concerns comparison of forecast values with data from SYNOP- and radiosonde stations over the European area according to a station list originating from EWGLAM (European Working Group for Limited Area Models). Special efforts are devoted to forecast verification over Denmark.

9. Plans for the future

The NEC-SX6 computer system will be further upgraded in 2003 with respect to both speed, memory and disc space. In this context a revision of the forecast model areas of DMI-HIRLAM is planned, aiming at increased model resolution.

It is further planned to make more use of NOAA AMSU data. Also a version of 3D-VAR data assimilation using first guess at the appropriate time (FGAT) will be introduced.

Revised model components for parameterization of surface processes (ISBA), turbulence and convection will be tested and perhaps implemented operationally during 2003.

References

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