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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 two upgrades of the operational forecasting system during 2001. The first one took place on 1 June and the second on 14 December. The system upgrades of the limited area models are partly related to the boundary data received from the ECMWF global model. Also the variational data-assimilation (3D-VAR) is now run at higher resolution, and the forecast model has been updated. A detailed description of the operational system used at DMI is available at www.dmi.dk. A brief summary of the main components of the upgrades is given below:

- The improved availability of boundary data from ECMWF has been utilized in the DMI operational system. Fresh boundary values are available 4 times pr. day. These have been introduced in the form of frames defined for the coarse mesh model DMI-HIRLAM-G. This implies that the age of the boundary values in the long forecasts is approximately 6 hours. Also the time resolution resolved by the boundary files has been doubled from every 6 hours to every 3 hours. The horizontal resolution of the boundary fields has been increased, first from 1.5° to 1.0°. After the introduction of frames the horizontal resolution has been further increased to the resolution of the DMI-HIRLAM-G model. In the vertical direction data are received from every second level of the ECMWF global model. In addition, the ECMWF SST-fields and fractional ice cover is received at a resolution of 1.0° instead of 1.5° used previously. These fields are used to update the corresponding surface fields in DMI-HIRLAM. The improved resolution of data from ECMWF has a positive impact on the forecast quality of DMI-HIRLAM.

- Until December 2001 the Optimum Interpolation (OI) data assimilation system has been operational for the higher resolution models DMI-HIRLAM-E and DMI-HIRLAM-N run at a horizontal resolution of 0.15°. On 14 December the HIRLAM 3D-VAR system was introduced operationally for these models. Prior to the operational implementation it has been demonstrated that almost all traditional parameters verify better with the 3D-VAR system compared to the results of the OI system. The introduction of 3D-VAR has been facilitated by code optimisations making the execution faster. The very high resolution model

DMI-HIRLAM-D operating at a resolution of 0.05° for an area around Denmark is still utilizing analysis increments from DMI-HIRLAM-E.

- The convection scheme has been modified to describe better the heat- and moisture transports across the intersection between the moist convective layer and the stable overlying layer. The modification, accounting for the effects of 'shallow convection', has been documented (Sass, 2001). It has been shown that the modification leads to some reduction of the frequency of small precipitation intensities in the model, in better agreement with observations. In addition, the relative humidity (and cloud cover) in the low troposphere has been shown to agree better with observations.

2. Equipment in use

The operational HIRLAM system is run on an NEC-SX4 supercomputer with 16 processors and a peak performance of 32 Gflops (see fig. 1). 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-SX4 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.

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.

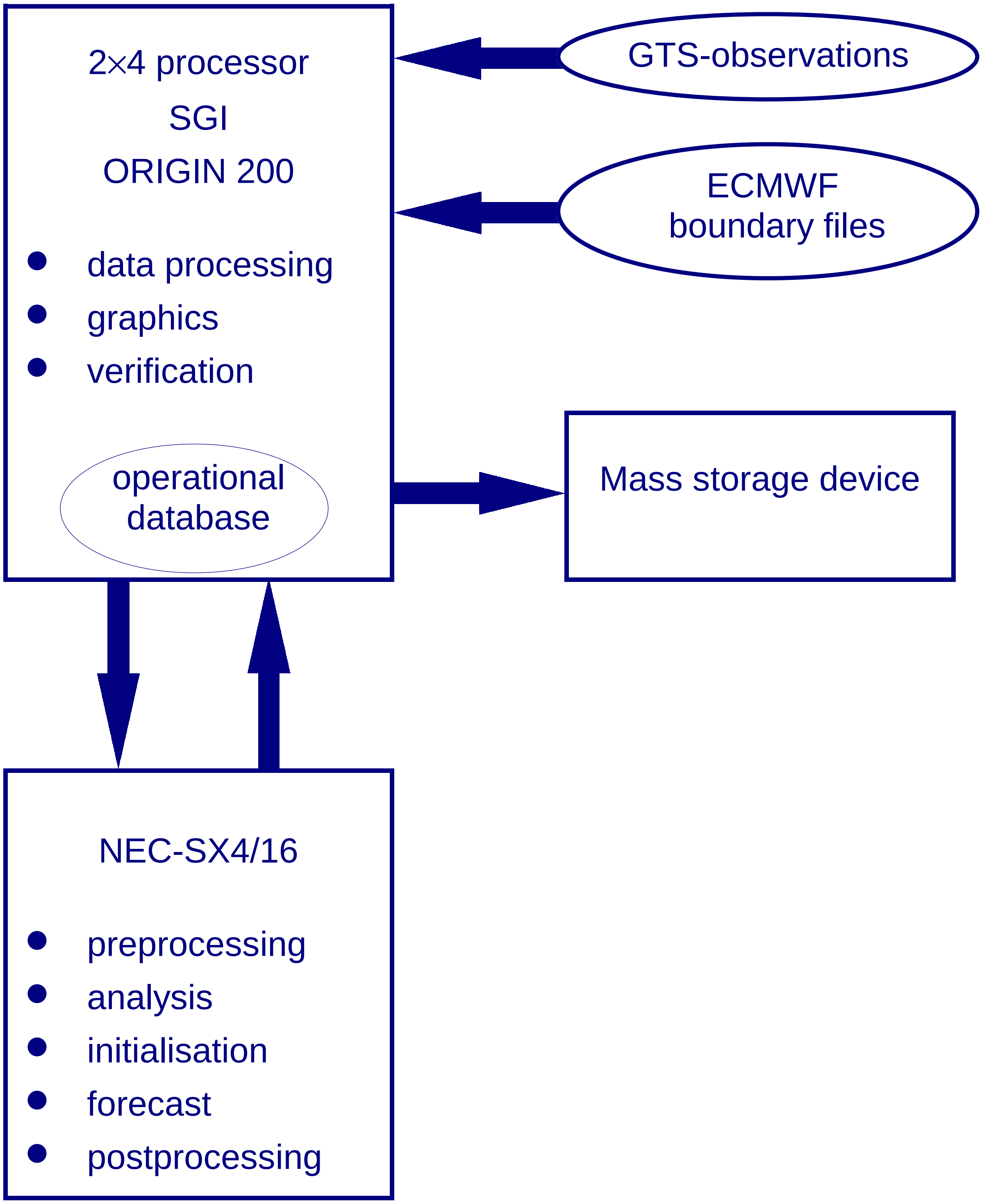

Figure 1: Computers and data flows.

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 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	31	31	31	31
horizontal resolution(deg)	0.45	0.15	0.15	0.05
time step (dynamics)	240 s	100 s	100 s	36 s
time step (physics)	720 s	600 s	600 s	216 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

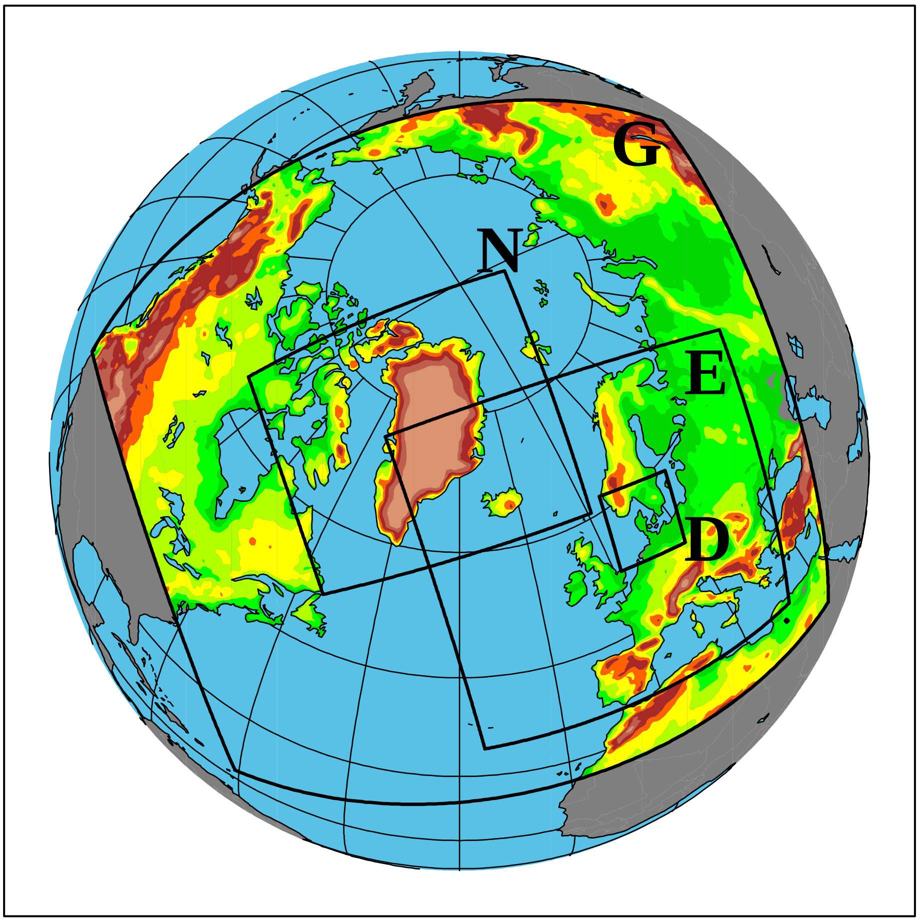

Figure 2: The DMI operational model integration areas.

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 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 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 in the evening, 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 also run as sequences in the late morning and in the evening. 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 also 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
ECMWF 18 UTC				
1:40	G00+60 h			
1:42			E00+54 h	
2:30				D00+36 h
2:55		N00+36 h		
ECMWF 00 UTC				
7:40	G06+60 h			
7:42			E06+54 h	
11:00	G_E00+03 h G03+03 h G06+03 h G09+03 h			
11:20			E03+03 h E06+03 h E09+03 h	
11:35				D03+03 h D06+03 h D09+03 h
11:40		N03+03 h N06+03 h N06+03 h		
ECMWF 06 UTC				
13:40	G12+60 h			
13:42			E12+54 h	
14:30				D12+36 h
14:55		N12+36 h		
ECMWF 12 UTC				
19:40	G18+60 h			
19:42			E18+54 h	
22:45	G_E12+03 h G15+03 h G18+03 h G21+03 h			
23:05			E15+03 h E18+03 h E21+03 h	
23:20				D15+03 h D18+03 h D21+03 h
23:25		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

It is planned to implement the operational DMI-HIRLAM system on a more powerfull computer system (NEC-SX6). The details concerning the operational upgrade will be decided in spring 2002. A new model setup is expected to become operational in autumn 2002. Recent model developments, e.g. associated with advection of moisture variables and in connection with condensation processes may be included in the operational setup already in 2002. Other promising developments concerning data-assimilation and model will most likely take place in 2003.

References

Lynch, P., Gustafsson, N., Sass, B., and Cats, G. (2000). Final report of the hirlam 4 project, 1997-1999. *HIRLAM 4 Project Report, 59 pp.*

Sass, B. (2001). Modelling of the time evolution of low tropospheric clouds capped by a stable layer. *HIRLAM Tech. Report*, 50:1–43.