Report of HIRLAM Management Group Visit to DMI, Monday 17 September 2001.

Introduction and Opening

The meeting was opened by Leif Laursen, head of meteorological research at DMI. He quoted the goals in the HIRLAM MoU, of being of superior quality, which is very important. He reviewed the different model configurations that are run at DMI. The large area system "G" uses 3D- VAR and ECMWF analysis for large scales twice a day. The two nested analyses are still with OI but planned to be 3D-VAR (but in one area). The HIRLAM system is used as an engine providing a large number of data and products to customers. It is particularly important for severe weather and the Denmark storm in December 1999 was well simulated when using a big area and high spatial resolution. They want to extend the highest resolution area for even better forecasts of severe weather. Furthermore, even higher resolutions down to 1.4 km have been run and have many details which are on scales that are hard to verify.
DMI puts a lot of effort on verification and Leif showed examples for 5 coastal stations' 10 m winds, and HIRLAM was of higher quality than other models, both in HR/FAR and distributions. Targets of hit rates +- 2m/s of 65 % were fulfilled. Plans are for 3D-VAR in the "E" system in October and the STRACO shallow convection. In December the frames will be used and the E and N areas joined. In 2002 the new computer will be used and ATOVS usage and IDFI implemented.

The need for high resolution forecasts, Peter Aakjaer.

Peter Aakjaer is Director of Forecasting Services Department and gave an overview of the DMI forecasting activities. There are a large numbers of products disseminated in media, to customers and on the Internet. It was PAA's opinion that the vision for the HIRLAM co-operation should be to be better than the best, i.e. better than ECMWF. Whereas D+5 performance has improved over the years, there is very little improvement seen in the D+0 forecasts. The cost of running HIRLAM is high, higher than the contribution to ECMWF. There are of course a lot of details and parameters that are not available from ECMWF and HIRLAM is of higher resolution. One should make more use of the many more locally available data sources for HIRLAM. Many applications run on the direct model output. The extremes are important to represent realistically (e.g. min pressure). The forecasters expect a lot of detailed information. The cloud height and amount, visibility, gustiness, precipitation type and amount as well as convection and lightning are important forecast parameters. A particular problem was the convergence in time, i.e. the latest forecast being best. The spin-up of precipitation is such a well-known feature. Another one is the case of fast developing cyclones, where problems have been seen.
The forecasts should be trustworthy, of very high availability, realistic and easy to use. For extreme weather the deterministic forecasts are used 99% of the time and EPS is only of marginal interest at present.

Recent progress in HIRLAM-5, Per Undén.

The Project Leader pointed out that HIRLAM also was open to European cooperation in the SRNWP context. Some of the targets in the HIRLAM MoU had been achieved or intensively worked on, whereas others of mesoscale model, new verification methods and predictability have been started and will require ongoing effort. A lot of effort has gone into data assimilation and 3D-VAR has consistently been shown to give forecast improvements compared with OI. Still, there are further developments needed and ongoing for the background quality control of observations, unifying the background fields for minimisation and qc as well as introducing an observation density dependency in the qc. The Météo-France simplified and regularised physics has been implemented in 4D-VAR and experiments run (see separate talk). Particular efforts have been put on the use of ATOVS data in 3D-VAR, both of directly received and ECMWF archived data. Positive impacts of the data have been shown. The correct use of channels and bias correction is vital. For operational usage it is necessary to obtain a wider coverage with minimum delay and EUMETSAT has very quickly put together a detailed plan for an TOVS re-distribution service from 5 local stations. Then there has been work on use of scatterometer data and most recently of Quikscat data. Radar radial winds or VAD winds are available from the Nordic Radar network and assimilation experiments of the Swedish data show a positive impact on forecasts for both VAD and radial winds. The VAD winds have the advantage that they will be interchanged on a European basis. Then the ZTD GPS data have been interfaced and assimilated with 3D-VAR. A bias correction is necessary. The impact is neutral but some situations show nice impact on precipitation.

Then the model developments were reviewed. Most of the effort is on the physical parameterisation, where there are a number of problem areas that required developments. The CBR turbulence scheme has shown a clear bias of wind speed in strong wind situations in that there was too much mixing and too little wind shear. Revisions to CBR have been developed and shown to rectify most of the problems and the KNMI revision will soon be implemented in the next release. Other work in turbulence is for stable ABL, where an extended MO theory increases mixing in the very shallow and stable BL. It showed to reduce 2m temperature and particularly humidity biases.

The ISBA surface scheme has been developed for a long time and in HIRLAM-5 a concentrated effort has gone into implementing the scheme. The surface analysis has been completely re-written and includes the ISBA related parameters. Ernesto Rodriguez gave an overview of the scheme and recent results. It has been tested extensively for all four seasons and different years, at INM as well at FMI in their setup. There has been tuning of some parameters and particularly important was the observation operator/postprocessing operator for 2m values. The most representative fraction should be used, and an average of the surface temperature of the land fractions has been used. This showed very good results for the Scandinavian area.

Another priority area is the convection and condensation scheme. The Kain-Fritsch and Rasch-Kristjánsson schemes have been used in HIRLAM versions, e.g. at the Rossby centre and in the BALTEX re-analyses, where verification against the BALTEX radar centre data showed a much more realistic distribution of precipitation amounts than the Reference. It is being worked on for implementation in the Reference system. The MF GWD parameterisation has been interfaced and tested in data assimilation in HIRLAM. It needed development of climate fields for this purpose. The results are reasonable but the effects are fairly small, so more tuning will be done.

The HIRLAM system has undergone a big development in that the mini-SMS has been implemented for a significant efficiency improvement, particularly at ECMWF. The verification system is being developed and there has been a HIRLAM/SRNWP workshop at KNMI.

Limited area climate modelling at DMI, Ole Bøssing Christensen.

Ole Bøssing is a member of a regional climate modelling group at DMI. They use a version of HIRLAM with ECHAM physics, HIRHAM4. It is a downscaling from global models in two steps, first nested in 50 km and then at 20 km resolution. They are particularly looking at precipitation and have tested the simulation with perfect boundaries from ERA15. There is too much precipitation in N Norway, otherwise it is OK. In the climate scenarios they see an increase in the number of days of heavy precipitation. It is particularly in summer and with the higher resolution simulation. In the winter it is too wet even with current climate due to much zonalisation.

Very short range forecasts of precipitation, Bent Hansen Sass.

Bent is working on the problem of the spin-up and lack of realism in the precipitation forecasts in the very short range. For this he has designed a nudging scheme that uses a 3D cloud analysis and nudges through cloud amounts and liquid water in the moisture and temperature model equations. He has tested it in 1D with weak forcing and showed that he could create clouds and retain skill for quite a few hours. The purpose is to have much more realistic clouds in the first hours of the forecast to support better road temperature modelling.

Towards use of ground based GPS data in NWP, Henrik Vedel.

Henrik gave a background to the use of Zenith Total Delay GPS data. The dry delay is mainly pressure related and is the biggest term. The second is smaller and mainly moisture related. Co-location statistics between GPS and radiosondes shows a standard deviation of 12 mm whilst against the model it is 17 and between RS and model it is 14. Thus the model can be improved from GPS data. A period has been assimilated with 3D-VAR and shows neutral forecast results. It should however be remembered that the number of GPS data is still very small compared with conventional data, which dominate very much in the assimilation. One can find a case in the period which looks more realistic but is hard to verify.

Gustiness in DMI-HIRLAM, Niels Woetmann Nielsen.

Niels has developed a parameterisation of gustiness due to shear production in the stable BL and both shear and buoyancy in the convective BL. The gustiness over friction velocity is modelled with a universal function of height and height of BL and of convective velocity scale in the convective case. A quite realistic gustiness factor of 1.2 - 1.5 is achieved in the unstable case. He showed that there is much less land-sea contrast of gustiness than for the mean wind. A report is available on the DMI web.

Visibility and Lightning in DMI-HIRLAM, Claus Petersen.

Visibility is modelled in an exponential decay manner. There are different parameters depending on cloud, aerosols, precipitation rate and type etc. The scheme works reasonably well with 29% in the correct of 5 classes but 72% if +- 1 class allowed. This is for February, whereas for summer is is much better. Also a lightning index is calculated from convection calculations of the HIRLAM profile.

Use background at correct observation time in the HIRLAM 3D-VAR system, Xiang-Yu Huang.

Hans discussed the errors made in OI and 3D-VAR when off-time data are used at the central analysis time. The innovation value may be of the wrong sign due to the use of the background at the central time rather than the correct time. 4D-VAR calculates innovation (observation departures) at the correct time during its model integration. The same mechanism can be applied for 3D-VAR for computing the initial innovations. This option has been implemented. By using the background at the correct time in 3D-VAR one assumes that the increments are constant in time and space (within the time window and the advection scale). The space assumptions is probably the more questionable one. Assimilation was done for the December 1999 period but at low resolution and a positive impact noticed. Then a bug was found and the results are now rather neutral, but another clean run is needed before any conclusions can be drawn. The results will be documented at the end.

Advection experiments with DMI-HIRLAM, Jérôme Chenevez.

Jérôme is working with air pollution applications. Dispersion and transport of the ETEX release has been simulated with HIRLAM. There is also an off-line tracer model based on HIRLAM fields, but the current research has been done with a transport equation inside HIRLAM. The semi-Lagrangian advection scheme was shown to produce far too high a maximum. The Bott's scheme was then used, following work at MISU and then the accuracy was very good and an almost perfect simulation was achieved. These schemes are also relevant for advection of cloud water. The Bott's scheme makes the semi-Lagrangian model 10-15% more expensive, but it is still some 41% less expensive than the Eulerian scheme.

High resolution experiments with the HIRLAM 3D-VAR system, Kristian Mogensen.

Kristian has been working on the use of 3D-VAR for the DMI "E" 0.15 degree model. He has run from 19991020 until 1231, encompassing the EUCOS SOP and the December storms. 3D-VAR has been used with OpenMP due to too much memory usage with MPI on the NEC. Full resolution minimisation has been compared with low resolution minimisation and with OI. Both full and low resolution are significantly better than OI, particularly at upper levels. The full and low resolution versions are very close, so there does not seem to be so necessary to use the full resolution one, for which the statistics have not been computed but merely extrapolated down the scales.
He also compared with using the analysis from the DMI-HIRLAM "G". This was slightly inferior compared with 3D-VAR in "E", but still somewhat better than OI. Another project is to merge the "E" and "N" areas and this has been tested and seems to be a bit worse than "E" over EWGLAM stations than 3D-VAR in "E" (performance of 3D-VAR over Greenland?). Yet another idea is to double the resolution in "G" to 0.225 degrees. This leads to improvement of the scores.

HIRLAM 4D-VAR using MF simplified physics, Xiaohua Yang.

Xiaohua has worked with the Météo-France simplified physics in HIRLAM and for 4D-VAR. The non-linear version compares reasonably well with HIRLAM in some tests (although it is the tangent linear and adjoint which is used in 4D-VAR). For the non-linear outer loop HIRLAM physics is used in 4D-VAR. The Météo-France GWD vertical diffusion and moist physics were employed. Experiments were first done at very low resolution, then at a higher one. The runs so far have been very expensive due to a large number of iterations in some of the cycles and maybe lack of convergence. The forecast scores have not showed any improvement yet.

Structure function characteristics for 2m temperature and relative humidity in different horizontal resolutions, Kai Sattler.

Kai has compared different ways of deriving structure functions of forecast errors and at different resolutions. The first method, the NMC method, makes use of forecast differences at different lead times. It shows that the length scale varies with time of year, shortest in the summer. Furthermore the correlations are quite anisotrophic even ove sea, due to the dominant flow direction. Over land, as well as over sea near to land, there is a strong land sea contrast. Land points or sea points are much more correlated than land with sea points.
Also the Hollingsworth-Lönnberg method has been used to extrapolate a Gaussian function to 0 and estimate observation errors. It is much higher in "G" than in the highest resolution "D". This is due to the representativeness error which is included in the "observation error" and which is much higher at 0.45 than 0.05 degrees.

Use of ATOVS AMSU-A brightness temperatures with the DMI-HIRLAM 3D-VAR system, Bjarne Amstrup.

Bjarne has assimilated NOAA16 data from the local receiving stations in Smidsbjerg and Søndre Strømfjord, thus obtaining a rather complete data coverage over 24 hours. First the RMS and biases were computed and channels selected based on this plus that the bias correction was used. Channels 1-3 have very high RMS since they see the surface temperature. No data over land, ice or cloud contaminated areas were used. Convergence criteria in the analysis had to be changed. The impact was only neutral in this experiment. It could be due to the summer period. Bjarne thought that the cloud information in level-1d processed data could be beneficial. Furthermore is a first guess check needed. Kristian Mogensen pointed out that this will soon be done.

Improving moisture spin-up with incremental digital filtering initialization, Xiaohua Yang.

Xiaohua presented results of from the use of incremental DFI that Xiang-Yu Huang and Xiaohua have developed. The IDFI does not suffer from any noise problem, even though only the increments are filtered (or rather the difference between filtered analysis and filtered first guess are added to unfiltered first guess. This is also what is in the blending in ALADIN implementations.)
In the "health tests" of DFI Xoahua found that the DFI had a significant dampening effect on

the forecast rain rate if applied on a forecast field. NMI does not have that effect, rather some overshoot after a few time steps. With IDFI the rate is very smooth from the beginning of forecasts. Tests show that the forecast impact is small, although there is an improvement of the small rain amount classes.

Coding structure and efficiency of the DMI forecast model, Jess U. Jørgensen.

Jess gave a background to the development of the structure of the DMI-HIRLAM forecast model. It dates back to 1997 when a detailed proposal for recoding and parallelising the forecast model was agreed on. This turned out not to be adhered to and later on the parallel HIRLAM code followed another route, based on PARLAM and the FMI/SMHI parallel code. Jess recoded according to the original proposal and implemented it at DMI. Recently the distributed memory parallel version was coded.
The DMI version of the Hirlam forecast model is build up around the PPF kernel (Plug and Play Fortran). This kernel is designed similar to operating systems, but written in Fortran 77 and a few C routines. In addition to the kernel, the PPF runtime library include a memory manager and a shell. Together these provide an environment similar to an operating system without a graphical interface similar to the raw linux kernel. The Hirlam forecast model, the wave model WAM, the road prediction model and Megraf etc. are modules in the PPF kernel. The full forecast model consist of a number of modules each representing different physical and dynamical process'. The Hirlam physics is split into 7 different modules:

time stepping and task handling
ocean surface diagnostics
vertical diffusion
radiation
codensation
surface fluxes

The hart of a module is the API (Application Interface routines) which bind each scheme belonging to the module to the kernel. The API is a partly static environment. Tunables in namelists are static, but data arrays are assigned via the PPF kernel. Modules can decide to keep variables private or public, but dynamic array information is always kept in the memory manager. Thus any module can access any data array and the array attributes by asking the memory manager. The array attributes defined in the API in the array assignment call, provide an array classification. Examples of array class' are:

input fields
output fields
prognostic multilevel fields
climatic fields
boundary fields

There are currently 25 different attributes in use. An array can belong to different class'. A class can be processed by a general routine, which inquire the memory for the fields belonging to the specific class. This feature allows as an example the vertical diffusion module to define the TKE field and also decide how the dynamics should advect and diffuse the field trough the array attributes.

There is no dependency between modules except that shared scalars and arrays must be initialized with meaningful variables. There are no cross references between modules, which means that they are selfcontained, but they contain normally calls to the PPF kernel. The use of a kernel prevent generation of call trees from the source code, but the kernel is doing this step in runtime if requested including profiling information.
The model is kept backward compatible by keeping old versions. The overheads of using the kernel are small and the forecast model runs very efficiently. Also the parallel version has run well by the most benchmarkers in the current computer procurement.

Discussions with DMI management

The Management Group met with Anne Mette Jørgensen, Director of Research and Development Department, Leif Laursen, Bent Hansen Sass and Xiang-Yu Huang. We discussed the DMI staff contributions, where Leif planned for continuing HIRLAM staff contribution from Xiaohua Yang, as Core group member on full time, Xiang-Yu Huang and Kristian Mogensen on half time. Bent Hansen Sass, Kai Sattler and Niels Woetmann Nielsen will contribute on small percentages. It is important to also allow time for the scientific development and publications for Xiaohua. DMI would like clear definitions of what is priority in the project. The Project Leader has such priorities, but there are far too many sub-projects in the plan. The somewhat fragmented contributions from a large number of people were also discussed. Leif encouraged the Project Leader to be tough on staff contributions, if the commitments were not adhered to. DMI is procuring a 10 times more powerful computer for the next 6 to 8 years and will have the capacity to serve in some form of common production.
In another discussion with Leif and Maryanne Kmit and Kristian Mogensen, the efficiency of the reference system was discussed. The DMI system is more efficient on the VPP at ECMWF, although the low vector performance for the reference include the I/O idle which the DMI way of doing it avoids. The Management Group stressed that it was a major problem in the project that DMI was not running the reference and it was particularly unfortunate since a lot of important work is done at DMI. Leif would be prepared to use the reference system if it was only marginally less efficient than the DMI one on the ECMWF and DMI computers.

Conclusions

The Project Leader thanked Leif Laursen and all the staff who had worked with the presentations. They were very interesting and very well presented. It showed that a lot of work was done in HIRLAM and with the HIRLAM system. There were many positive and promising results presented. The Management Group would like to thank the hosts, Leif Laursen and his staff, for the visit and the meetings that took place.

Per Undén
20 September 2001