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State-of-the-Art in Short Range Forecasting.
HIRLAM Activities.

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Preface

Short-range forecasts are constructed using a variety of sources of guidance. The emphasis in this presentation will be on the role of NWP model output, but other sources of guidance will also be briefly considered. It is the current experience that greatest value is obtained by a systematic combination of NWP products with conventional observations, radar imagery, satellite imagery and other data. This is especially true for nowcasting (less than six hours). But the focus of attention here is on the short range, from six to 48 hours.

The development of forecasting models requires a substantial investment of resources. To ensure maximum effctiveness and efficiency, eight European countries currently combine their efforts in the HIRLAM (High Resoluton Limited Area Modelling) Project. They are Denmark, Finland, Iceland, Ireland, Netherlands, Norway, Spain and Sweden. The HIRLAM analysis and forecasting system is the basis for operational short-range forecasting in these countries.

The current state of short-range forecasting will be summarised. An outline of the structure of the HIRLAM model will be given, but the primary emphasis will be on how the output guidance provided by this model is used in practical applications.

HIRLAM

The HIRLAM System is a complete suite of programs for assimilation and analysis of observational data, and production of numerical predictions. The current analysis is an Optimal Interpolation (OI) system. A variational assimilation system is at an advanced stage of development. The forecast model is a hydrostatic primitive equation grid-point model. It includes a comprehensive package of physical processes. Several major model upgrades have been made or are expected to be made this year:

- A parallel (MPP recoded) version of model code
- A two time-level semi-lagrangian advection scheme
- A digital filtering initialization scheme
- A higher-order turbulence scheme
- A new climate field generation package
- A new surface parameterisation scheme (ISBA)
- A new condensation and mass-flux convection scheme
- A more comprehensive diagnostics and postprocessing package

The operational implementations of HIRLAM differ in horizontal and vertical resolution, and in details of the physical parameterisations. However, the typical resolution used is 20km, with about 30 vertical levels.

Why Limited Area Models?

In Europe we are fortunate to have regular weather guidance for the medium range provided by ECMWF. Predictions out to ten days are disseminated daily, and a large range of other forecast products are also made available. However, short-range forecasting requires more detailed guidance. The cut-off for the ECMWF forecast is about eight hours, too long for many purposes, and a single model integration per day is inadequate for rapid updating of forecasts.

Virtually all European NMSs run a limited-area model (LAM) to provide short-range forecast guidance.

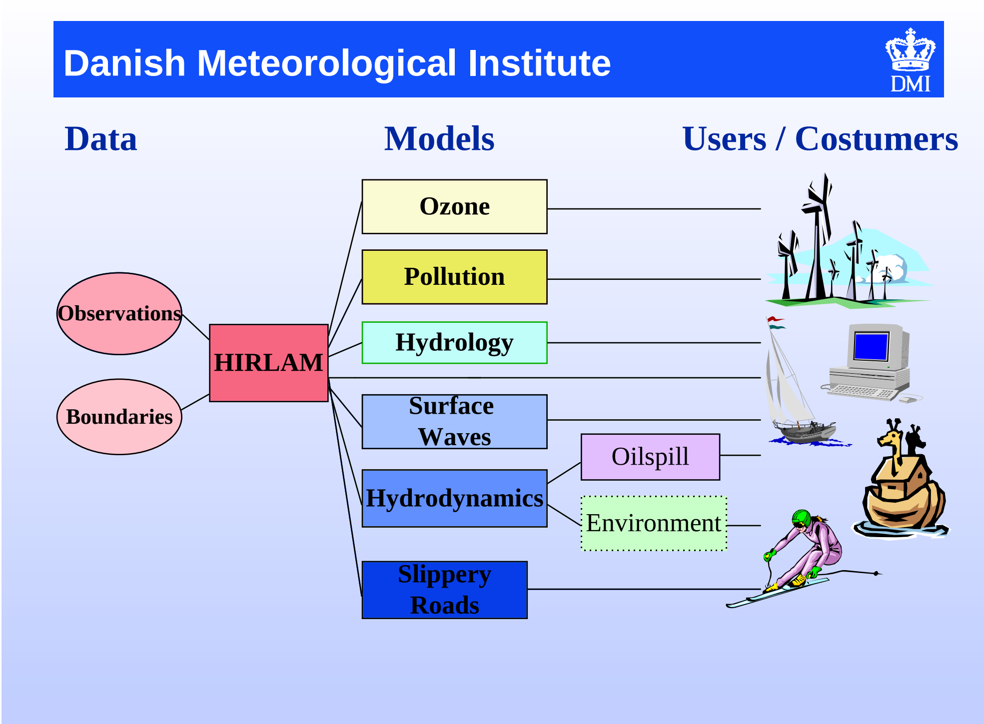

Figure 1: Schematic diagram of model interdependency at the Danish Meteorological Institute, showing the central role played by the HIRLAM model (thanks to Leif Laursen, DMI, for the diagram).

These systems provide local control and a degree of autonomy not otherwise available, and have many other attractions:

- Choice of geographical area and model resolution
- Freedom to run forecasts more frequently
- Nested systems with higher resolution
- Availability of more comprehensive range of outputs
- Outputs at a high time resolution
- Freedom to modify model to local requirements
- Maintenance of local modelling expertise

It is no accident that LAMs are ubiquitous. Not only can they provide vital guidance which is beyond the capability of medium-range models, but they produce the high time and space resolution required to drive a large range of other application models essential for serving customer needs.

Applications

The value of the guidance provided by LAMs is potentially very great. This is demonstrated by the remarkable range of actual and potential applications of this information. Only a selection from a rapidly growing list of applications can be mentioned here. Figure 1 shows the model interdependency at DMI, indicating the central role of the limited area model HIRLAM as a driver for other application models. It is representative of the situation at other NMSs.

Perhaps the most important application of LAM guidance is to provide timely warning of weather extremes. Huge financial losses can be caused by gales, floods and other anomalous weather events. Medium range guidance generally signals large-scale events well in advance. But LAMs can give better timing and localization of events predicted by medium-range models. Moreover, the higher spatial resolution and use of more recent observational data enables LAMs to catch the development of small-scale, localized events which have slipped through the net of medium-range models. The warnings which result from this additional guidance can enable great saving of both life and property.

Transportation, energy consumption, construction, tourism and agriculture are all sensitive to weather conditions. There are expectations from all these sectors of increasing accuracy and detail of short range forecasts, as decisions with heavy financial implications must continually be made.

Agriculture is becoming more precise in planning and operations. LAMs can provide valuable guidance on ground conditions for work-planning, on drying conditions for harvesting, on frost-risk for crop damage, on wind conditions for disease dispersal, on rain amounts for a whole range of reasons. Decisions on when to spray crops, when to protect against frost, when to spread fertilizer can be based on objective criteria using short-range forecasts as input.

Using the output from limited area models, special guidance is generated for the marine community. Winds (or surface stresses) predicted by the LAM are used to drive wave models, which predict sea and swell heights and periods. Forecast charts of the sea-state, and other specialised products can be automatically produced and distributed to users.

Prediction of road ice is performed by specially designed models which use forecasts of temperature, humidity, precipitation, cloudiness and other parameters to estimate the conditions on the road surface. In practice it is found that road conditions are highly sensitive to small errors in inputs, and manual intervention by a forecaster is generally required to ensure predictions of satisfactory quality. Snowfall is a direct model output, but this can be usefully suplemented by a range of objective indicators of snowfall probability also calculated from LAM output, enhancing the value and usefulness of the NWP guidance.

Limited-area guidance is a crucial component of the input to models for prediction of low-level ozone, pollen levels and other pollution phenomena. Sunburn warnings depend on total ozone levels, and prediction is possible either by treating ozone as a prognostic or passive model variable or, more usually, by using regression techniques to relate stratospheric ozone levels to predictions of atmospheric structure. Trajectories are easily derived from limited area models, either during the course of a forecast or using output fields. These are vital for modelling pollution drift, for nuclear fallout, smoke from forest fires and so on.

Aviation benefits significantly from LAM output. Only the key areas can be mentioned: prediction of hazards (lightning risk, icing risk, CAT, mountain waves), forecast of freezing levels, of cumulonimbus tops. Very high resolution column models, using input from LAMs, are also used to model the boundary layer for applications such as fog prediction at airports. Automatic generation of terminal aerodrome forecasts (TAFs) from LAM and column model outputs enables servicing of a large number of airports from a central forecasting facility.

Postprocessing

As stated above, it has been found that best results are obtained by using NWP products in conjunction with radar output, satellite imagery and other data. Systematic methods of combining a variety of data types are available; SatRep is one such system. Model output can be superimposed on satellite imagery enabling assessment of very short range forecasts and thereby giving a measure of forecast quality. Model accumulated rainfall predictions can be compared with corresponding accumulations detected by radar. Combined data enable the forecaster to fine-tune guidance for users.

The quality and range of direct model output (DMO) is constantly increasing. However, some specific parameters can be significantly enhanced in value by post-processing. Kalman filtering is commonly used for surface temperature forecasts, to remove systematic bias and other model errors. Model output statistics (MOS) are still popular for some applications. Neural networks are found to be flexible and powerful for a range of applications.

Presentation of Results

The forecaster has always been faced with the difficulty of analysing large volumes of data of diverse types, of synthesising this into a coherent form and of synopsizing the results for the users of the forecasts. With technological advances, this problem has grown to the point where it is utterly impractical to proceed without sophisticated computer-based systems for processing and display of observational and forecast data. Powerful and versatile Graphical User Interface (GUI) systems are now available for management of the vast quantities of data which must be exploited in the production of a forecast. These GUIs have a large range of options for manipulation of digital data, for combination of data from different sources, and for presentation in a form directly useful for applications.

Many GUIs are currently in use. I will base my remarks on the Metacast System with which I am familiar, but these remarks are quite general. This system allows:

- Display of observations
- Display of NWP products
- Display of radar and satellite imagery
- Computation of derived fields
- Mixing products from different models
- Combination/overlay of different data types
- Output of both stratiform and convective precipitation
- Objective prediction of hail, thunderstorms, etc.
- Animation of sequences of forecasts
- Production of time-series
- Manual modification of forecasts

GRIB files containing forecast fields are input to the GUI and used as first guess fields for generation of symbolic displays. Schematic symbols depicting sunshine, rain, snow, gales, etc. are chosen and located automatically on the basis of the model output. These can then be fine-tuned by a forecaster.

Conclusion

Results will be shown which demonstrate that limited area model guidance has consistently improved in both accuracy and detail over recent years. This guidance is now vital not only for direct use by forecasters, but as driving data for a large range of application models. Future plans for the HIRLAM Project will be described, and the expected benefits for users will be outlined.

YOK THINK YOU HAVE PROBLEMS!

From Petrus Licentious Maximus, HIRLAM *Special Correspondent, Rome*

Current concern about the millennium bug pales to insignificance compared to the plight of the hapless Romans during the reign of Augustus. As the year 1BC began, unease grew rapidly to frenzy in the Forum, panic on the Palatine, chaos on the Capitoline. How would the calendar cope with the following year? Zero would be convenient, but would not be invented for another six centuries. 1CC or 1BD might do, but each would lead to numbers increasing with time, which seemed almost bizarre. In any case, the jump in time was bound to cause difficulties, perhaps fatal for the Empire.

Rumours were rife: the central heating systems would fail; the Public Baths would have to close; interruption of the operation of the city aqueducts would bring great hardship; the Colosseum gates might malfunction, leading the lions into the crowds instead of the arena, to the delight of the slaves (there being no Christians available yet). Chariot salesmen announced new models described as *tempamicable* or time-friendly, guaranteed immune to all Y0K difficulties.

The imperial Horologist, Casio, was adamant that all sun-dials must be scrapped and replaced. It later transpired that his personal fortune was much enhanced by this decision, and he was stripped of his honours and banished in disgrace. The City Engineer demanded double salt-rations for his men, insisting that the Senate decree that no new projects be undertaken for a year. To allay growing public anxiety and find a solution, Augustus established a Tribunal, piloted by Pontius Pilatus. Pilate botched this job so badly that he was made governor of an obscure colony in Judaea, never to be heard of again.
