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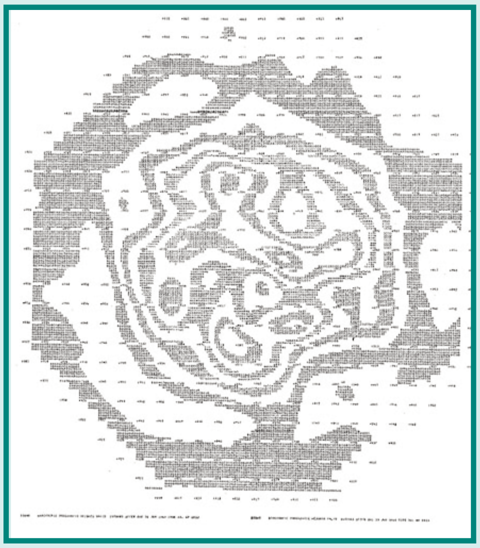
The Development of Computer Weather Forecasting in Ireland

The experimental weather forecasts carried out on the ENIAC computer in 1950 heralded a new era in operational weather forecasting. Within five years, the Joint Numerical Weather Prediction Unit, involving the United States Air Force, Navy and National Weather Service, was making computer forecasts on a daily basis. It was to be another ten years before computer forecasts were consistently superior to manually prepared ones but, from the mid-sixties, the automatic forecasts (Numerical Weather Predictions or NWP) have been essential in forecasting practice. The more advanced countries - United States, Britain, Germany, France and Russia - were first in the game but soon a number of smaller countries were able to join in and make contributions.



Curiously, it was in Sweden that the first real-time forecasts were made. This work was inspired by Carl-Gustaf Rossby, who had returned to Stockholm from America. Sweden has remained an important player, and had an important part in the development of NWP in Ireland. However, the first generally available NWP guidance came from Washington. Products from the National Meteorological Center (NMC) were distributed freely by fax to forecast offices around the world. They were used by CAFO and in the Irish airports for the preparation of general and aviation forecasts. But, by the mid-seventies, computer equipment capable of generating weather forecasts was becoming affordable and the Irish Met Service began to explore avenues for entering the fray. The Director at that time, Austin Bourke, had many international contacts. In particular, he was friendly with Alf Nyberg, Director of the Swedish service, and Nyberg agreed to assist us in building up expertise in NWP.

So, in April 1976, Austin Woods and I visited SMHI in Norrköping, to work with the scientists there and to study their latest forecasting model, then nearing readiness for operations. This was the (quasi-geostrophic) *NP-model*, developed mainly by Lars Moen. We returned to Dublin with tape reels, print-outs and boxes of punched cards (in case we could not read the tapes; and this turned out to be the case). The plan was for Austin to work on preparation of the initial data (the process called objective analysis) and for me to implement the NP model. After a few months of effort, I managed to generate a trial forecast from the sample data. We had no plotters, so the output was used to concoct *zebra charts*, using a line printer, which showed the patterns of high and low pressure. The results were realistic but unspectacular: the forecast fields tended to be over-smooth, missing many essential small-scale details.

While Ray Bates was in Egypt in 1976, he worked with a forecasting model originally developed by the Yugoslavian Hydrological Institute and Belgrade University (the HIBU model). This was Fedor Mesinger's model, later called LAPEM (Limited Area Primitive Equation Model; the American ETA model is a grand-child of LAPEM). Fedor kindly offered to make this model available to us if we wished to engage in NWP. Ray was appointed Head of Research in 1978, and coordinated the computer forecasting activities. After a short spell in WMO in 1981, Ray returned as Assistant Director with responsibility for research, including NWP. Since Austin Woods had departed for ECMWF, Ray worked on the objective analysis system.

ECMWF

The European Centre for Medium-Range Weather Forecasts (ECMWF) was established in 1976, Ireland being a founder member. *The Centre*, as it is known, has been of enormous benefit to the member states, and to meteorology in Europe. The initial idea was that the Centre would produce forecasts in the range four to ten days ahead, with the shorter-range forecasts being produced locally. This task-sharing made much sense. It was always felt that, if a central agency were to take over all responsibilities for NWP, vital expertise would be lost in the member states and the science would ultimately suffer. The arrangements that were agreed have resulted in a productive synergy between the Centre and the member states. Ireland has derived significant benefit from involvement in ECMWF, and has also made major contributions through exchange of staff and activity on the Centre's committees.
To perform the analysis, we needed observational data, and this was prepared using an Automatic Data Extraction (ADE)

scheme. The upper air part of the ADE was based on the Swedish scheme; the surface part was developed in-house. It was Declan Murphy who was responsible for this work. In addition, Jim Hamilton was working on software to drive plotters so that real weather charts could be produced, not just the rough zebra charts. In the ensuing years, Jim was to develop graphics systems that were used in many different countries.

A pair of Digital PDP 11/40 computers, installed in HQ and linked to the Global Telecommunications System, acquired observational data in real time. These machines, manufactured by Digital in Galway, ran in tandem to ensure backup in the event of failure. The NP model was first run on the IBM System/360 in CDPS (Central Data Processing Services), the Public Service Computer Bureau at Kilmainham, which had been operational from January. Job input was via a card-reader, which was the size of a large deep-freeze, held in the Department of Education in Marlborough Street. I had to deliver the card deck before 4pm for an overnight job; before the flexi-days, it was a good excuse to slip away early from 55 O'Connell Street. It took a little longer to get the objective analysis running. We were given considerable help from Nils Gustafsson, who had designed the system. Nils visited us in Dublin in 1978. Aidan McDonald was transferred from Shannon Airport to join the group around then. He was to work on the NWP system for the following thirty years or so.

The Swedish NP model was a filtered model; that is, it used an approximated system of equations designed to eliminate noise from the solution. However, the approximations also distort the “weather waves”. LAPEM was based on the more fundamental primitive equations. Fedor Mesinger visited Dublin in 1978 and provided much advice on implementation of this model. We were then able to run the ADE, the objective analysis and both forecast models on the Digital DEC 20-40 computer in Trinity College, using a dial-up link, which now seems like a Heath-Robinson device: a number was dialled and, when a piercing screech was heard, the handset was inserted in a cradle, with subsequent communication via an acoustic link.

DEC 20

The following year, a faster computer, a DEC 20-50 was installed in our new HQ in Glasnevin, where we moved in November 1979. The GTS data was transferred regularly from the PDPs to the 20-50. For computer buffs, the DEC 20-50 had an ECL processor, 2K words of cache, a ludicrously small 256 kilo-words of RAM and a bizarre word-length of 36 bits. Its TOPS-20 operating system was intuitive and “user-friendly”. Tears were shed when the 20-50 was craned out of HQ some years later.

Comparing the filtered and primitive equation models, it was soon apparent that the PE model was consistently superior, giving a much more realistic flow, with sharp frontal boundaries and more active baroclinic developments. So, we decided to cease work on the NP model and go for LAPEM. The first operational numerical forecasts were delivered in July 1980. We were in the game at last.

Among the first people I met upon joining the Irish Met Service in 1971 were Bill Wann, Andy McManus and Jim Logue. All three were highly computer-literate, and were busy developing advanced systems for processing climatological data. In 1976, Bill was appointed Head of a new division of the service, the Computer Division. He managed the acquisition of the first computers purchased by the Service, the twin PDP 11/40s for communications and, later, the mainframe DEC 20-50 for NWP. In a recent appreciation in *Splanc* (Issue 31) Declan Murphy has written about the many other contributions, in computing and elsewhere, that Bill made to the Service.

In October 1980, the second meeting of the European Working Group on Limited Area Modelling was hosted by us in Glasnevin. This annual meeting served as a valuable means of sharing information and learning of the latest developments in other forecasting centres. Membership of ECMWF was also critical for our activities. The data link to Reading was established in March 1981, so that we had data to specify initial fields for the analysis and lateral boundary values for the model. Later in the year, a sea and swell model originating in Norway (called NORWAV) was implemented.

The initial support from our colleagues in Sweden and Yugoslavia was of great help to us in making a good start. But now it was time to fly solo. With Ray Bates at the helm, we began NWP research in earnest. We learned of a novel method for treating the advection process, conceived by André Robert in Canada, and called the semi-Lagrangian scheme. We worked hard to implement this scheme, introducing an important modification: the Robert scheme used three time levels, whereas the scheme developed in Dublin was a two time level scheme, which was more efficient and which later became the international standard. Ray also analysed the properties of the scheme and published the first demonstration of its unconditional stability. The model we implemented in 1982 was the first-in-the-world operational application of a semi-Lagrangian advection scheme.

We introduced a variational initialization scheme the following year. And a new method for eliminating high frequency noise, Laplace transform initialization, was developed in 1984. In addition, new implicit methods, including an alternating direction implicit or ADI scheme, were developed for adjustment. We also constructed a much more efficient version of the forecasting model, which went into action in 1986. The re-formulated model, which used a semi-implicit, semi-Lagrangian (SLSI) scheme, allowed us to speed up the forecasts substantially.

For several years we continued to develop the forecasting system. Other developments included a Digital Filtering Initialization (DFI) scheme, which was later used in many operational centres; a new filtered system of equations, the *slow equations*; a model for dispersion of Foot & Mouth virus; other transport, dispersion and deposition (TDD) models; various schemes for post-processing of model output; and so on. However, the task of NWP is large and complex, and a small research group can undertake only a limited set of tasks. If we were to survive in the business, we would have to pool our resources.

I spent from September 1984 to August 1985 working as a visiting scientist at KNMI, the Dutch National Meteorological Service. Before returning, I was invited to participate in a meeting in Copenhagen to plan the HIRLAM (High-Resolution Limited Area Model) Project. At that meeting, we were encouraged to participate in the new project. HIRLAM got under way in 1986. Ireland was not initially a member, but we joined in 1989. This meant that we were part of a large community of model developers, with access to the latest developments and an opportunity to contribute to cutting-edge research. Amongst our major contributions to HIRLAM were the semi-Lagrangian scheme and the digital filtering initialization scheme.

The HIRLAM model was made operational in 1994, when we acquired a Silicon Graphics Challenge-L machine, largely on the initiative of Ray McGrath. The HIRLAM model was officially launched in November of that year by the Minister for Energy, Noel Treacy. Verification results over the ensuing years have shown a steady improvement as further refinements have been introduced. That the HIRLAM model is comparable to the best available elsewhere has been shown in many comparative evaluations. It is the basis of operational forecasting in all the participating countries, and is the corner-stone of our operational forecasting system at Met Éireann. Of course, such models are still inherently limited in their capacity to predict changes, and the forecaster plays a vital and indispensable role in interpreting and augmenting the information churned out by the computer. Prediction of pressure and wind patterns is generally excellent, but forecasts of temperature and humidity near ground-level still need improvement. Rainfall is notoriously difficult to predict, but progress here has been impressive, too.

HIRLAM

HIRLAM has been the backbone of the NWP suite in the Irish Met Service for over twenty years. We have gained the advantage of having access to an advanced forecasting system, and have also made significant contributions to its development. I served as Project Leader of HIRLAM for the fourth phase of the project: HIRLAM-IV ran from 1997 to 1999. The development of a variational data assimilation system was a major focus of research in the Project. Forecasts based on 3D-Var assimilation were consistently better than the forecasts based on the older OI assimilation. Development work in 4-dimensional variational data assimilation (4D-Var) continued with increased emphasis. Significant improvements to the forecast model were also made, including an improved semi-Lagrangian scheme. As a result, substantial improvements were achieved in operational forecasts produced by the HIRLAM System.

An additional benefit of our activities in numerical weather prediction has been that much of the expertise built up in developing NWP has been directly applicable to the challenge of predicting climate change. Thus, in 2003, we were able to establish a project called the Community Climate Change Consortium for Ireland (C4I). The primary goal of C4I was the application of regional climate models (RCMs) to simulate the future climate of Ireland at high spatial resolution. The RCMs are structurally very similar to the models used for NWP. This project, led by Ray McGrath, would require another article to do it justice.

Around 2004, the HIRLAM community joined forces with another European group, ALADIN, to develop a new model called HARMONIE. This non-hydrostatic model is now running operationally in Met Éireann. It has been a prolonged effort, but the result is that we now have an NWP system that ranks among the best in the world. The practical result is that the quality of weather forecasts has improved to the point where the rare forecast failures evoke surprise rather than resignation. We have come a long way.