The Development of Computer Weather Forecasting in Ireland

Peter Lynch

Meteorology & Climate Centre

School of Mathematical Sciences

University College Dublin

The Development of Computer Weather Forecasting in Ireland

Irish Meteorological Society Meeting
Botanic Gardens, 10 November 2011

Peter Lynch

Meteorology & Climate Centre
School of Mathematical Sciences
University College Dublin

Outline

- The beginning: ENIAC & JNWPU
- NWP products from NMC Washington
- Our first NWP activities
- Early computers: PDP 11/40s, DEC-2050
- LAPEM
- Semi-Lagrangian Scheme
- Establishment of ECMWF
- Joining the HIRLAM Project
- Climate Modelling (C4I)
- HARMONIE

More information in Article in Special Issue of *Splanc* commemorating 75 years of Met Éireann

The Development of Computer Weather Forecasting in Ireland

Peter Lynch,
Meteorology & Climate Centre, School of Mathematical Sciences
University College Dublin

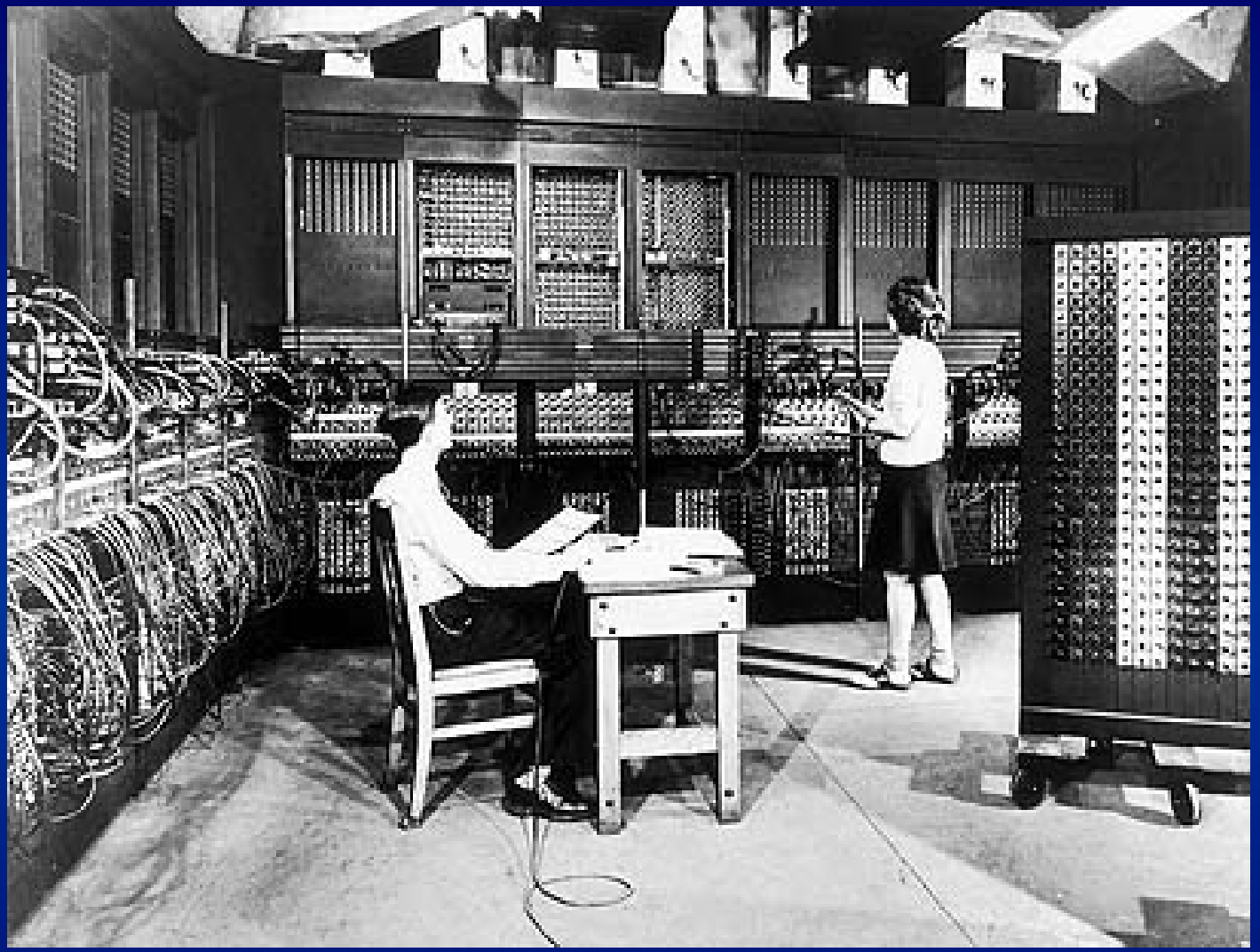
The Beginning of Numerical Weather Prediction

"The Meteorology Project"

Established by John von Neumann in 1946

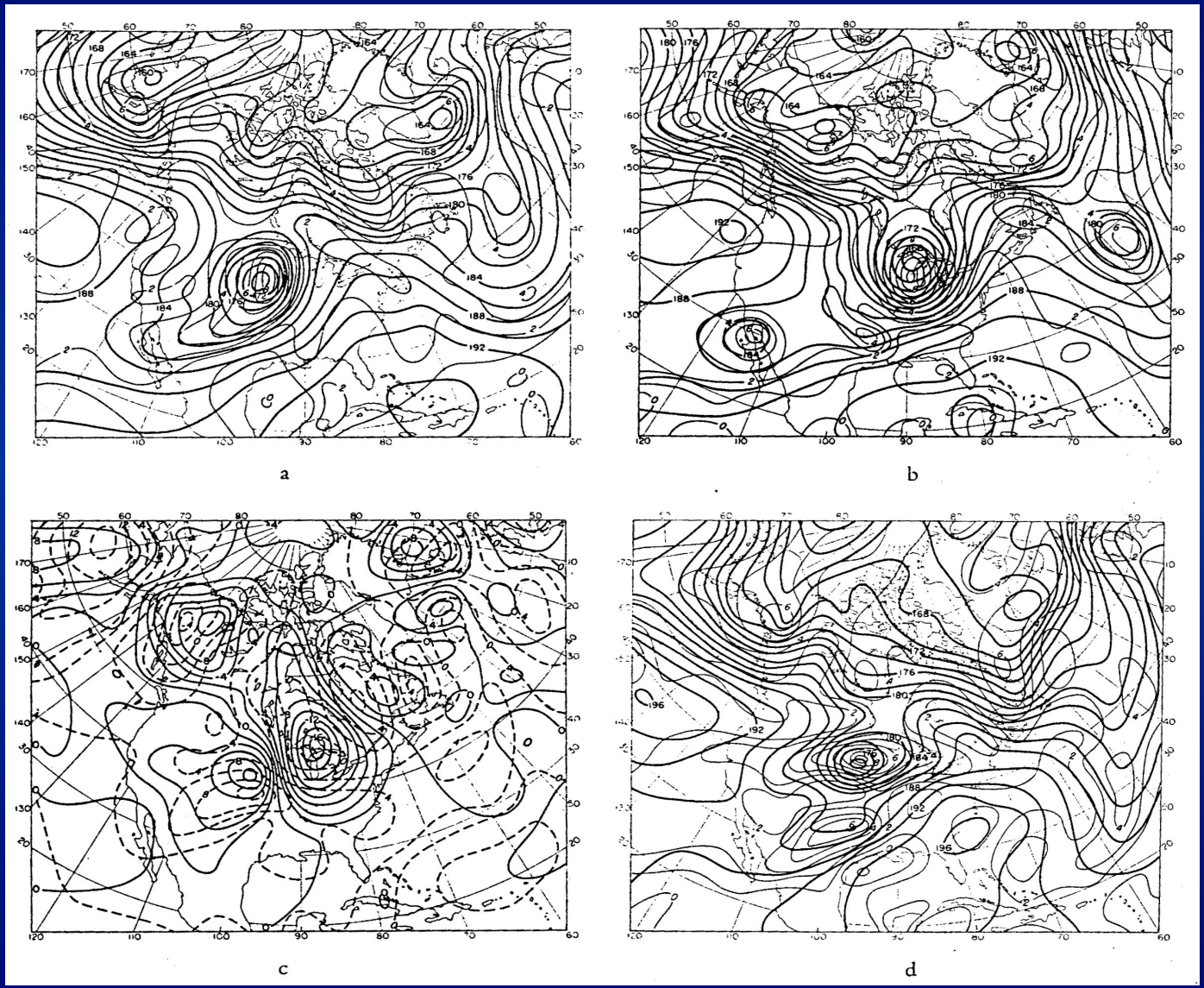
Objective of the project:

To study the problem of predicting the weather using a digital electronic computer

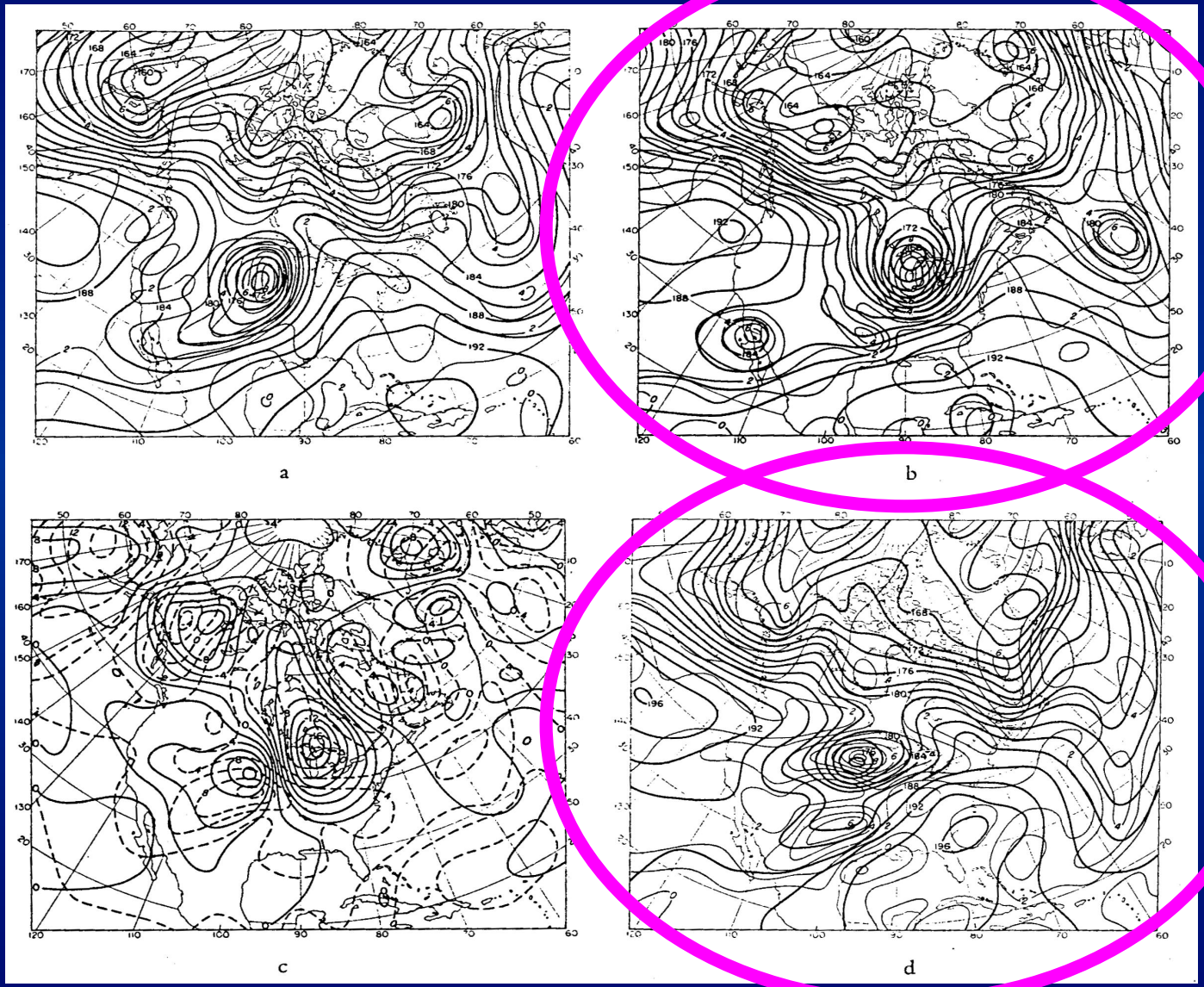


The ENIAC was the first multi-purpose programmable electronic digital computer

First ENIAC Forecast: for Jan 5, 1949



First ENIAC Forecast: for Jan 5, 1949



NWP Operations (JNWPU)

Joint Numerical Weather Prediction Unit established in Washington in July 1954

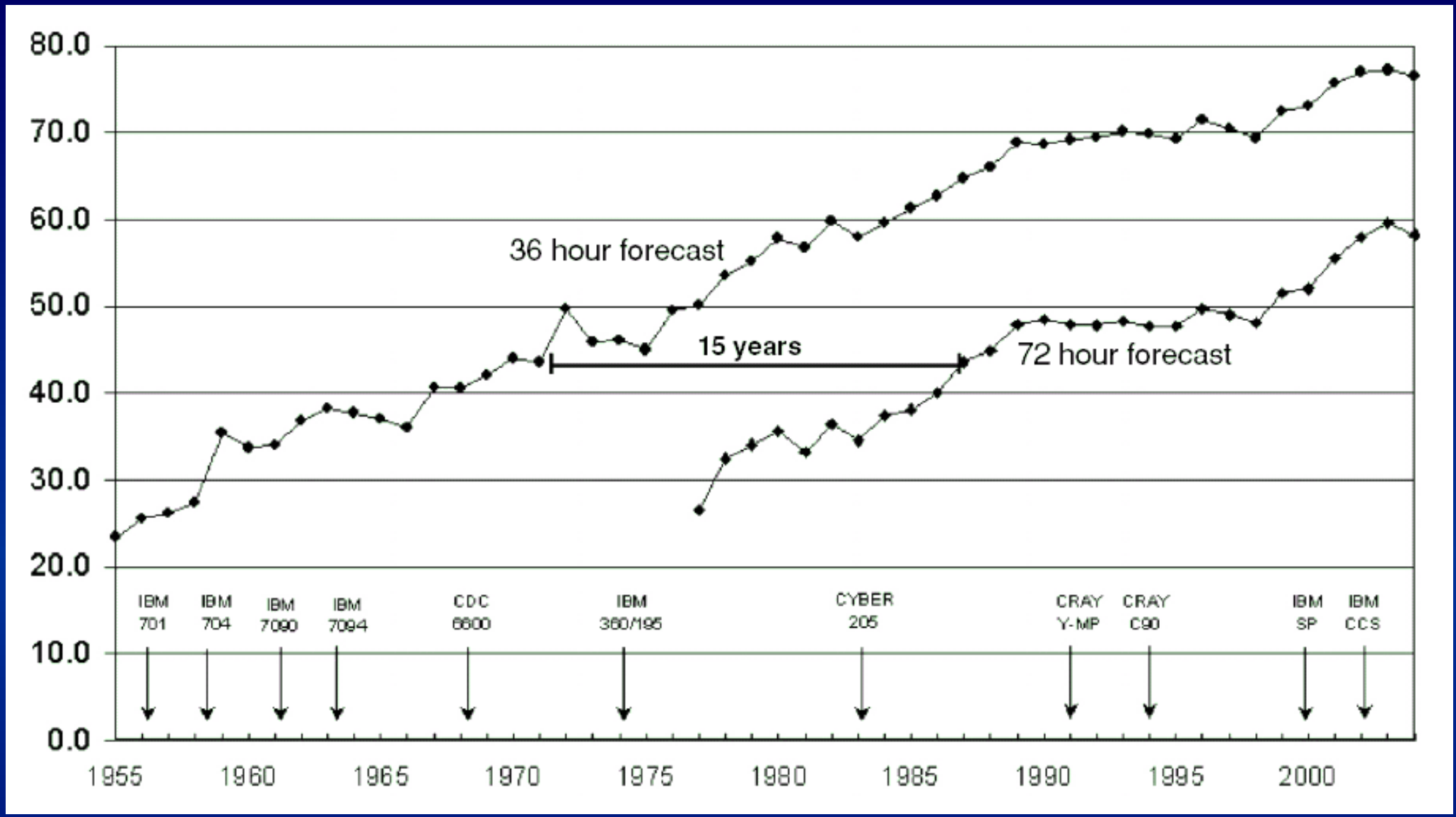
- Air Weather Service of US Air Force
- The US Weather Bureau
- The Naval Weather Service

Operational numerical weather forecasting began in May 1955, using a 3-level quasi-geostrophic model.

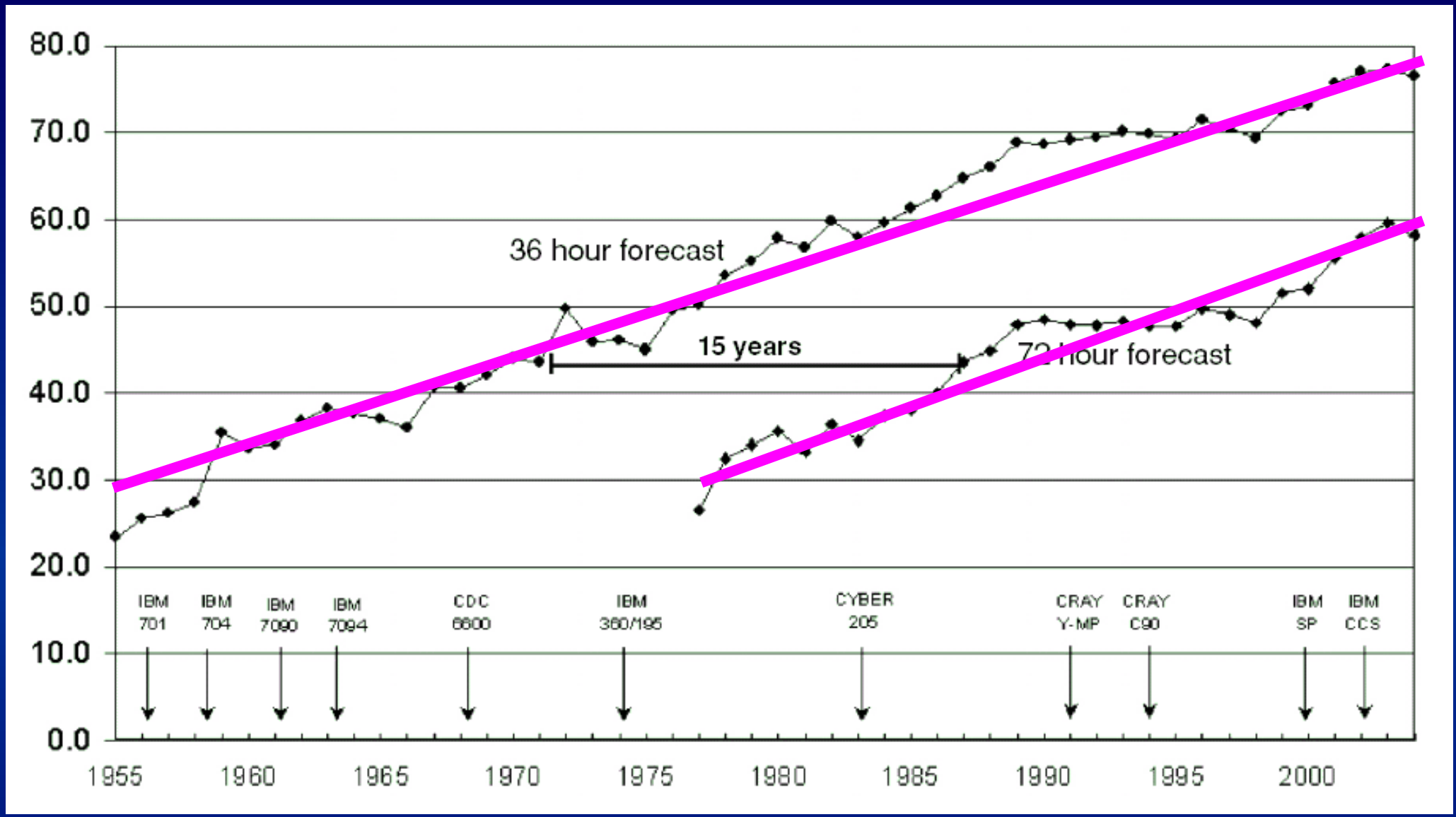
D649/K649 MuFAX Chart Recorder

Transceiver
Pye Electronics

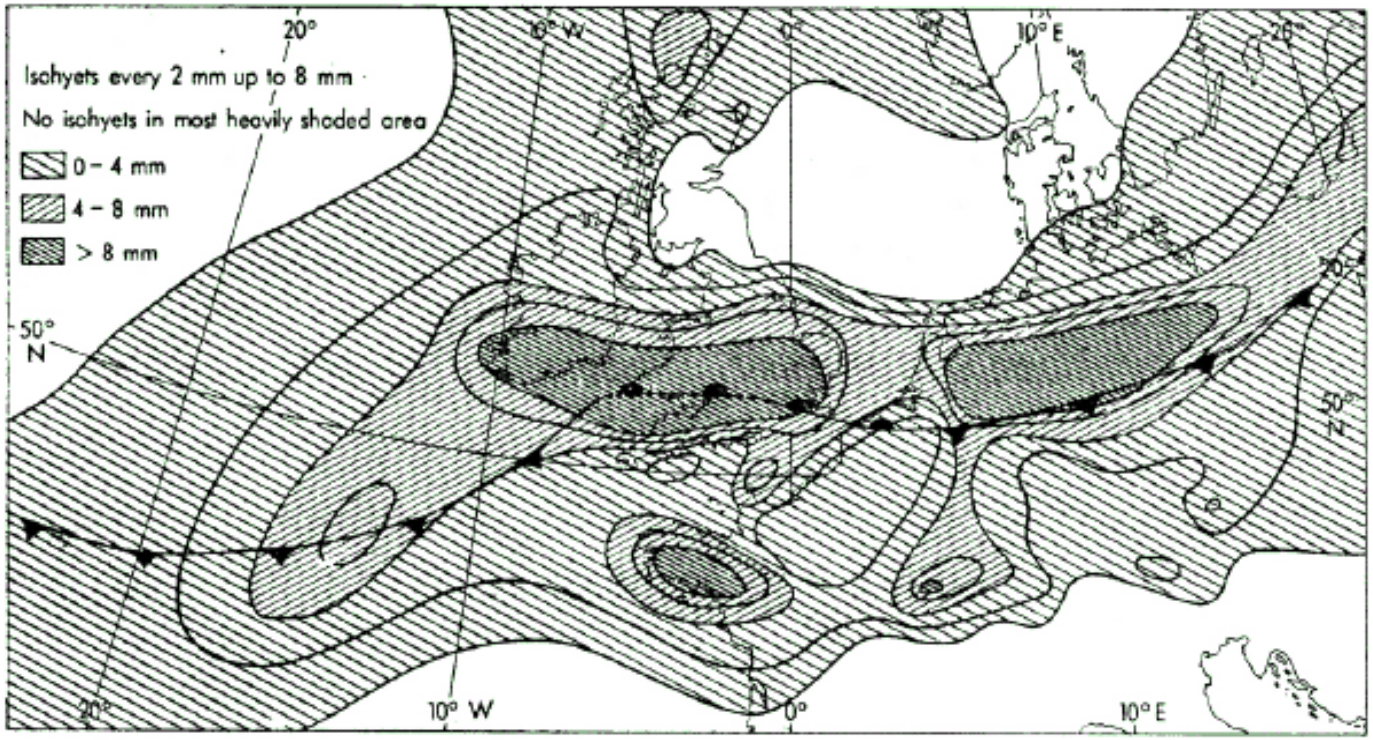
NMC forecasts were used in CAFO and Airports

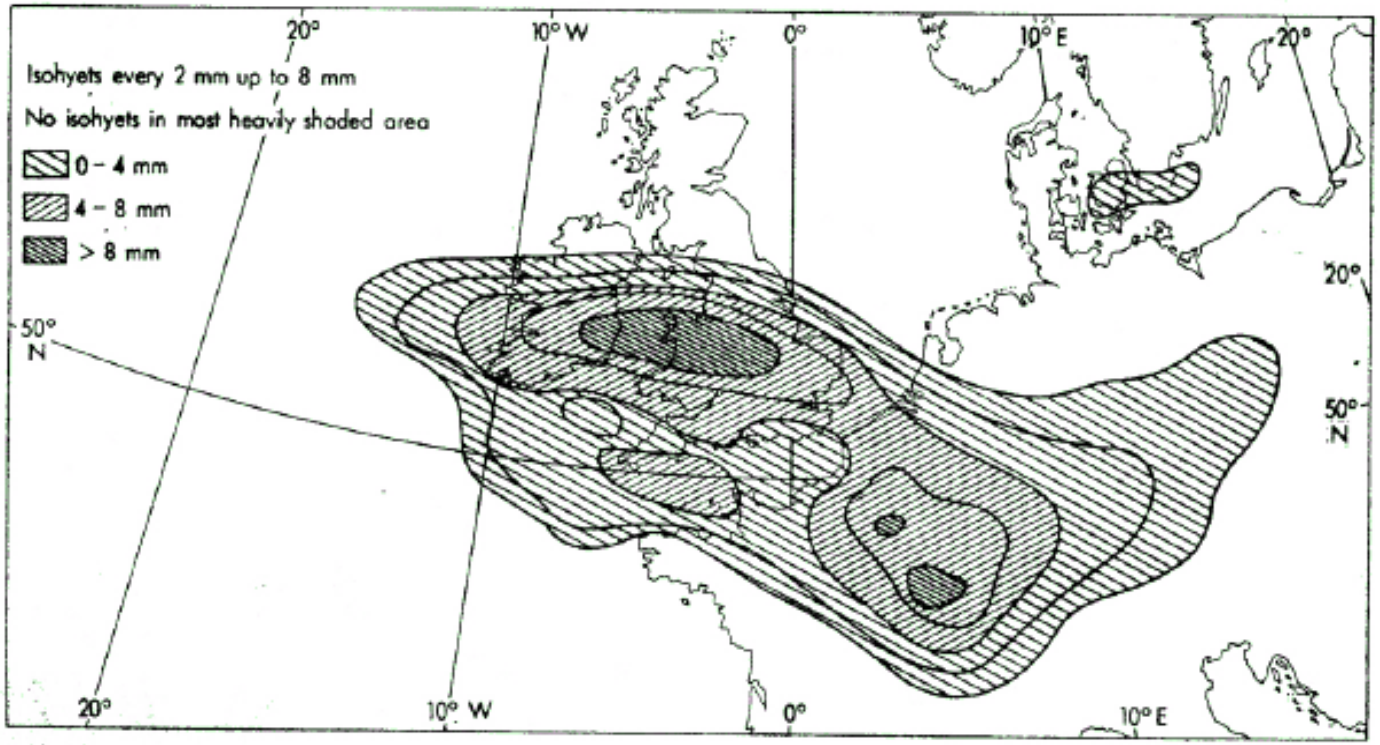


Skill of 36 hr and 72 hr NMC/NCEP forecasts of 500 hPa height from 1955 to 2004.



Skill of 36 hr and 72 hr NMC/NCEP forecasts of 500 hPa height from 1955 to 2004.





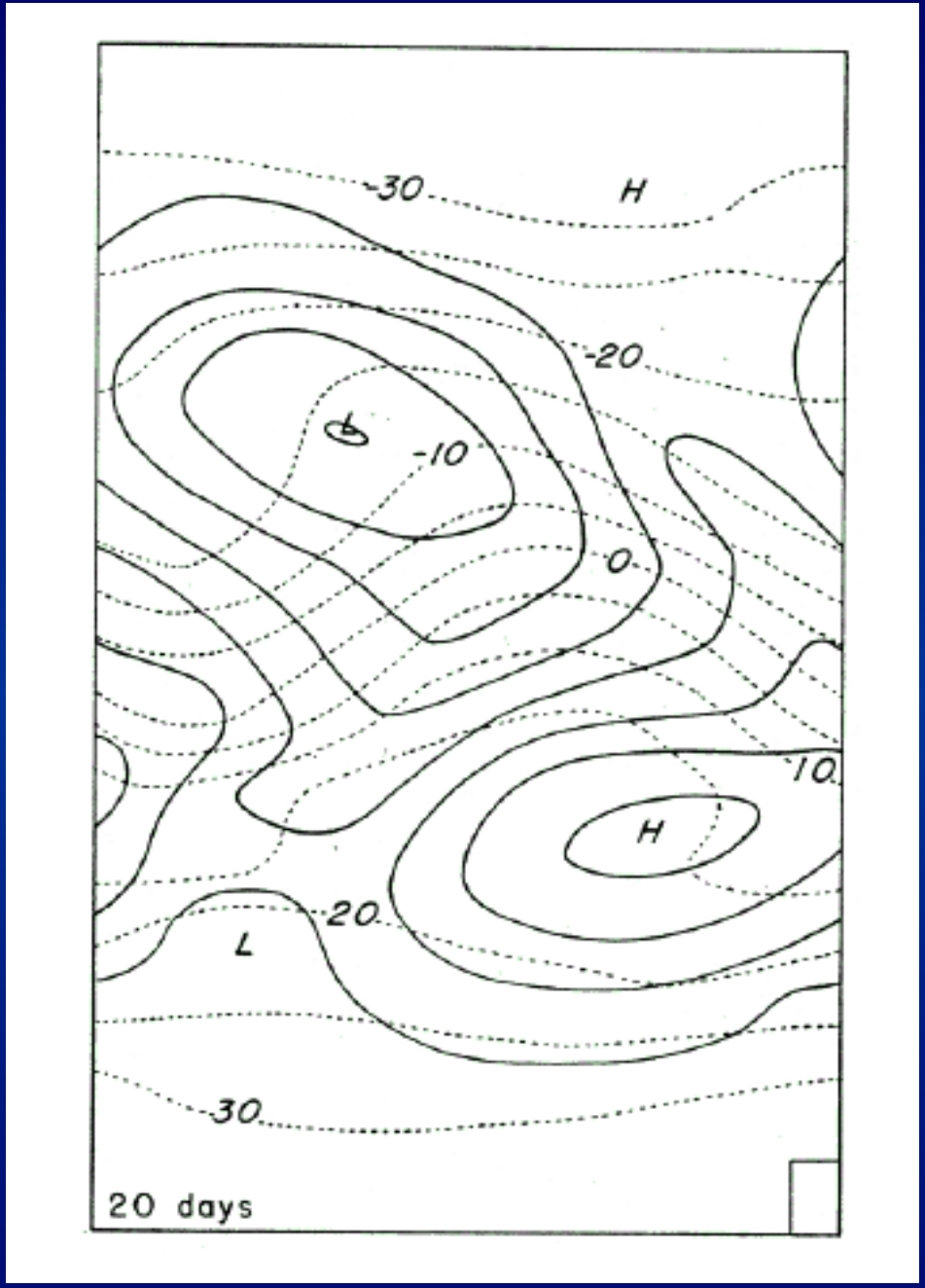
Early Rainfall Forecast

Top Panel:

Total rainfall for 06–18 UTC on 1 December 1961,

Bottom panel:

Forecast of total rainfall with the Bushby-Timpson model



The first GCM (climate model) [1956]

Norman Phillips' simulation of the general circulation of the atmosphere.

European Centre for Medium-Range Weather Forecasts (ECMWF)

An intergovernmental organisation supported by 34 States, based in Reading, UK.

Originally a COST (European Co-operation in Science and Technology) project, the Centre was established in 1975 when its Convention entered into force.

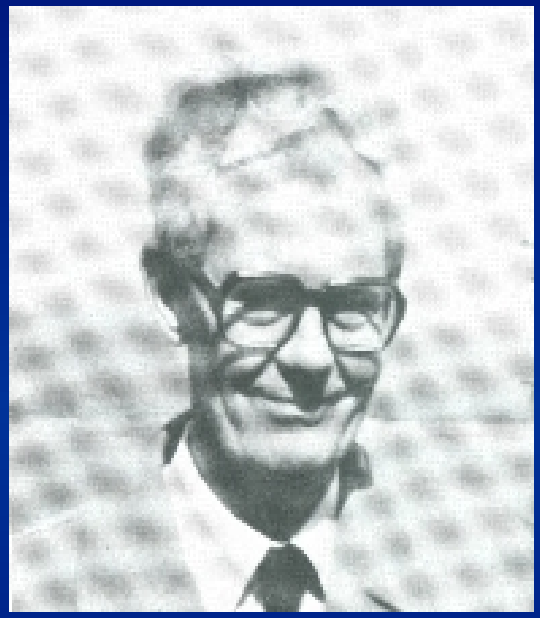
The first real-time medium-range forecasts were made in June 1979.

Has been producing operational medium-range weather forecasts since 1 Aug. 1979.

Three Directors of the Irish Met Service

Austin Bourke

Kilian Rohan



Donal Linehan

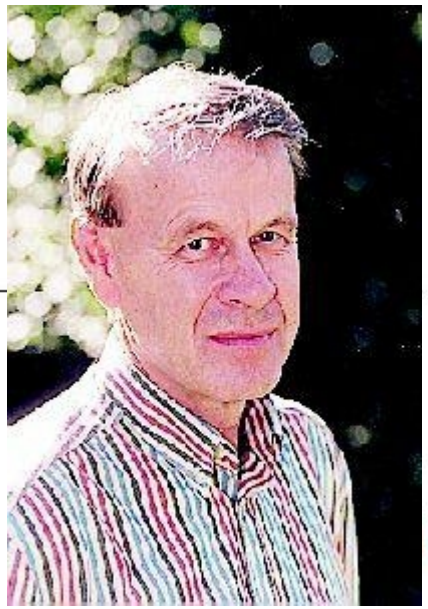
SMHI in Norrköping

Lars Moen, author of the NP model

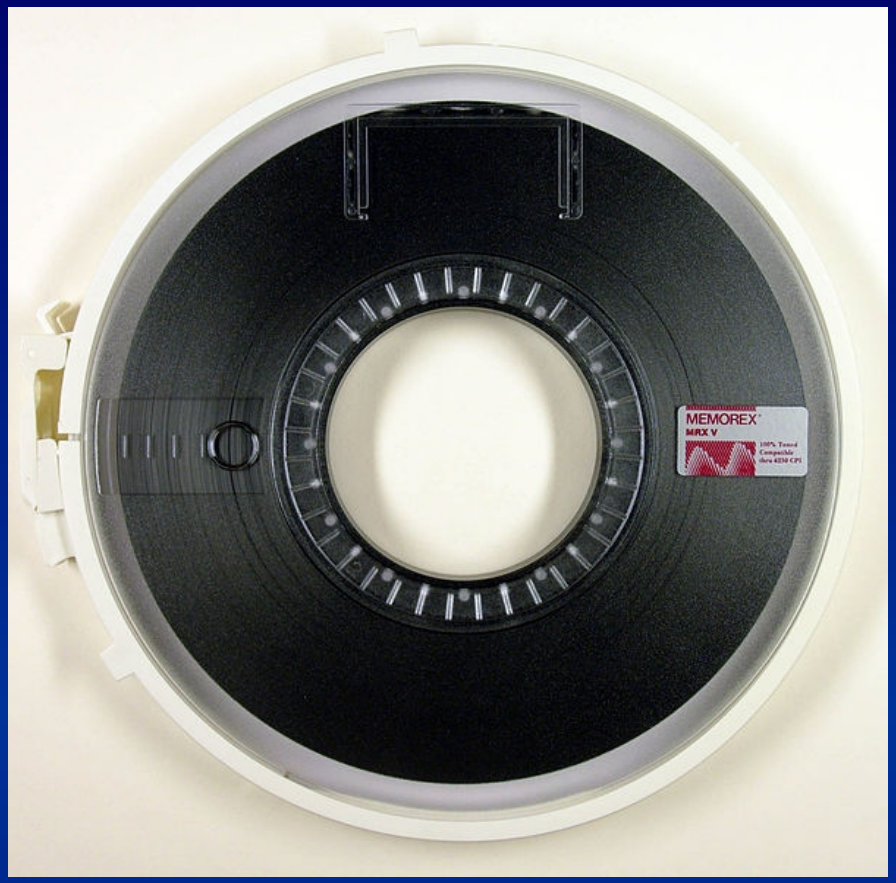
SMHI Weather Services Research About SMHI Contact

A multi-level quasi-geostrophic model for short range weather predictions.

Type: Reports, Series: RMK, Meteorology
Report series RMK, 3
Published: 1975
Author: Moen, L.



Responsible for this page Customer service
Send e-mail to Customer service
Last updated 02 September 1975


MEMOREX
MRX V


MEMOREX
MRX V

CDPS
Central Data Processing Service

Public Service Computer Bureau,
managed by the CDPS at Kilmainham,
operational from January 1973.

CDPS
Central Data Processing Service

Public Service Computer Bureau,
managed by the CDPS at Kilmainham,
operational from January 1973.

Google for:

“Central Data Processing Service”

Result: NOTHING! AS IF IT NEVER EXISTED.

IBM System/360

IBM 7330
Magnetic Tape Unit

1402 Card Reader

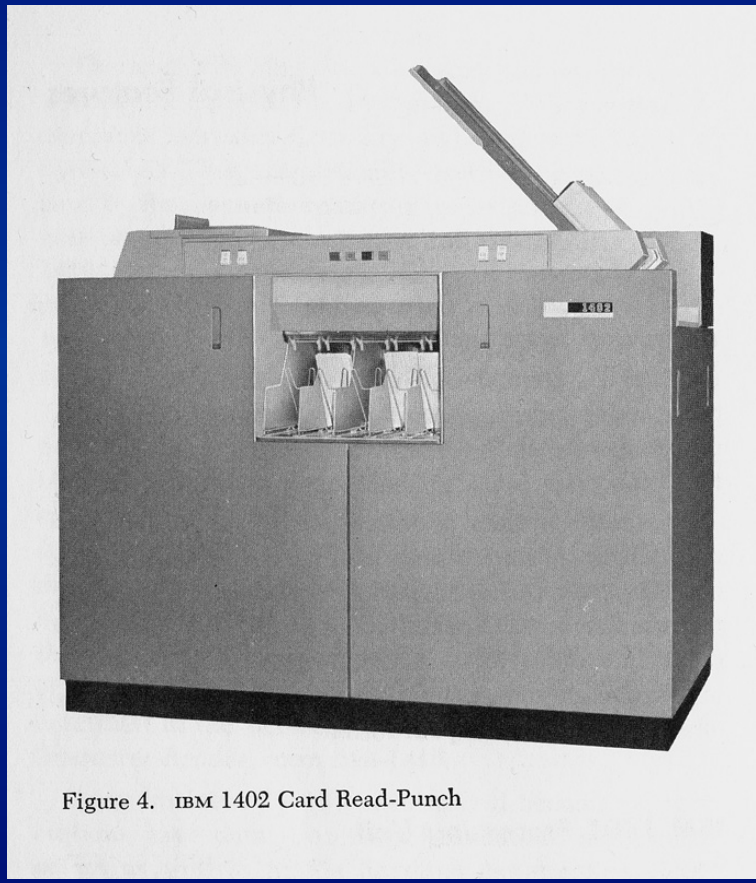
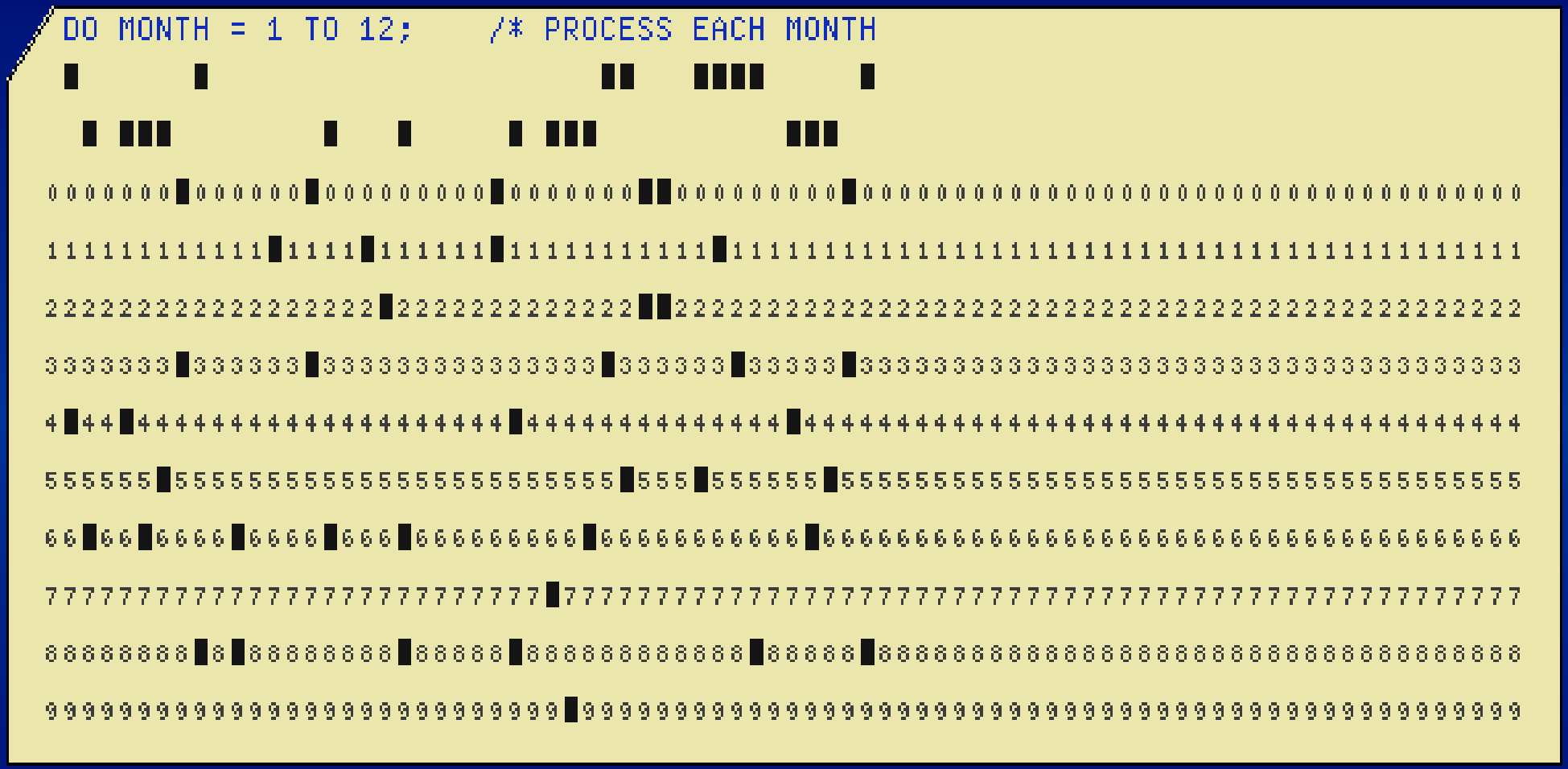
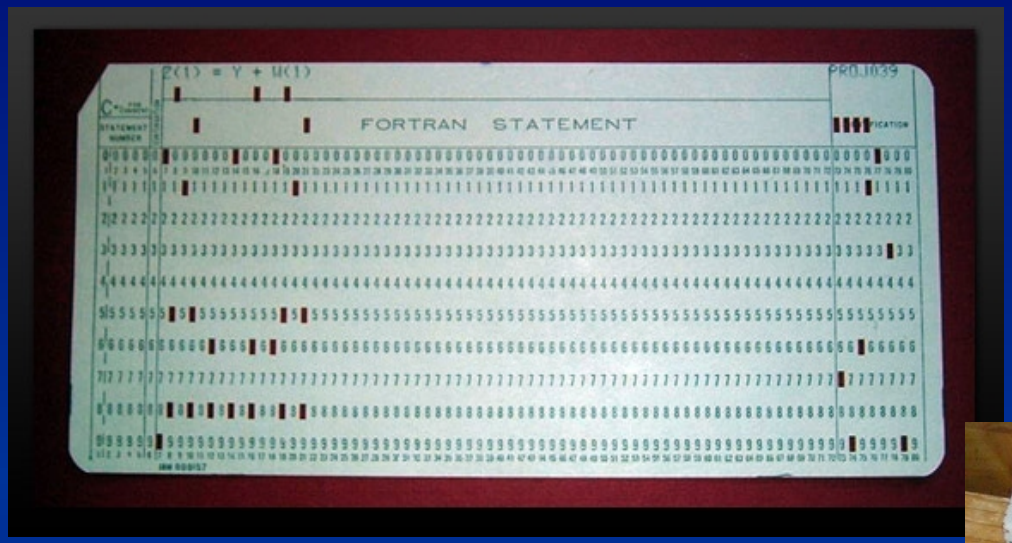


Figure 4. IBM 1402 Card Read-Punch

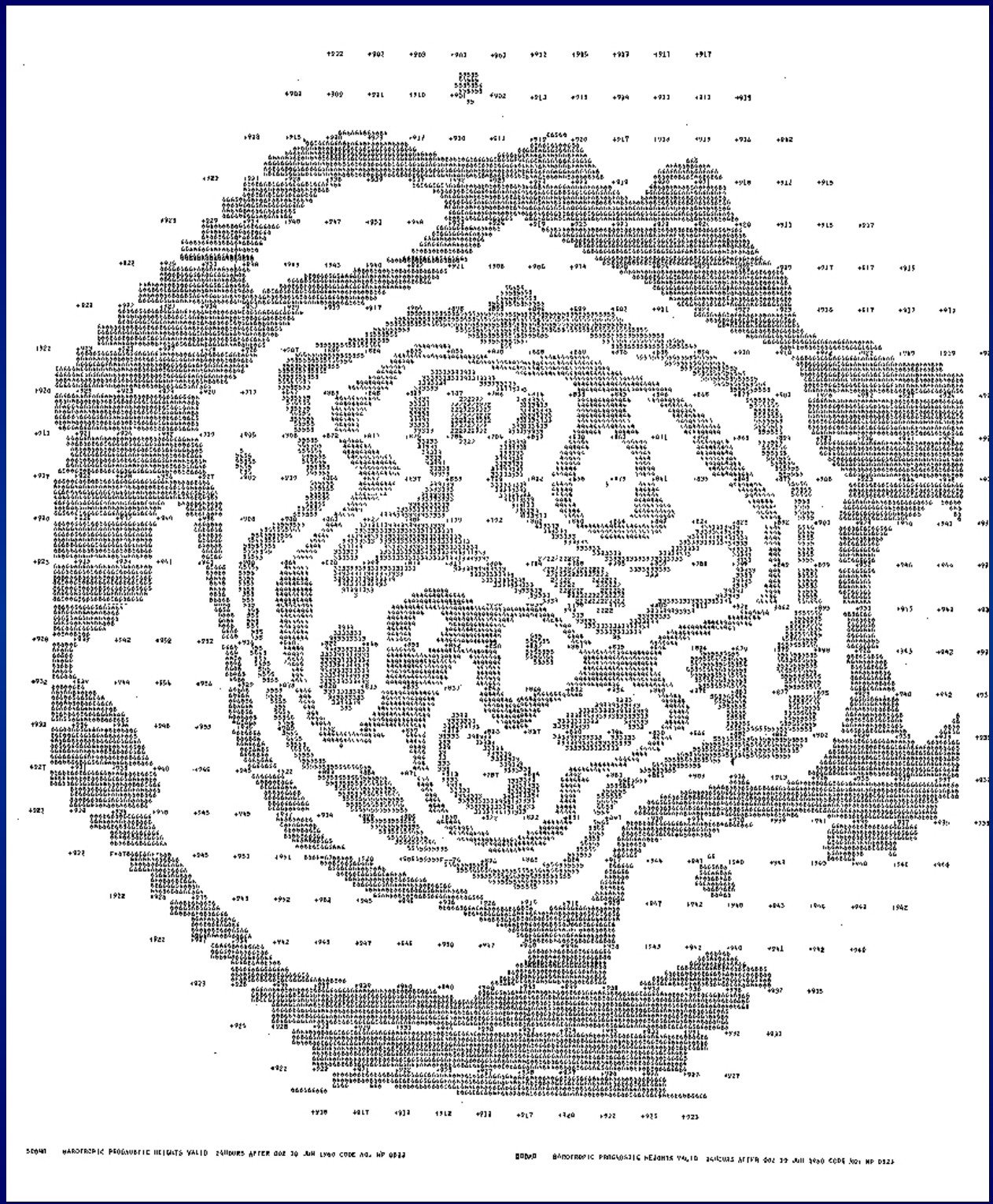

DO MONTH = 1 TO 12; /* PROCESS EACH MONTH

More Primitive means of punching cards.



Weather-Forecast coming off a Line-Printer

Met Office, Bracknell (c. 1965)

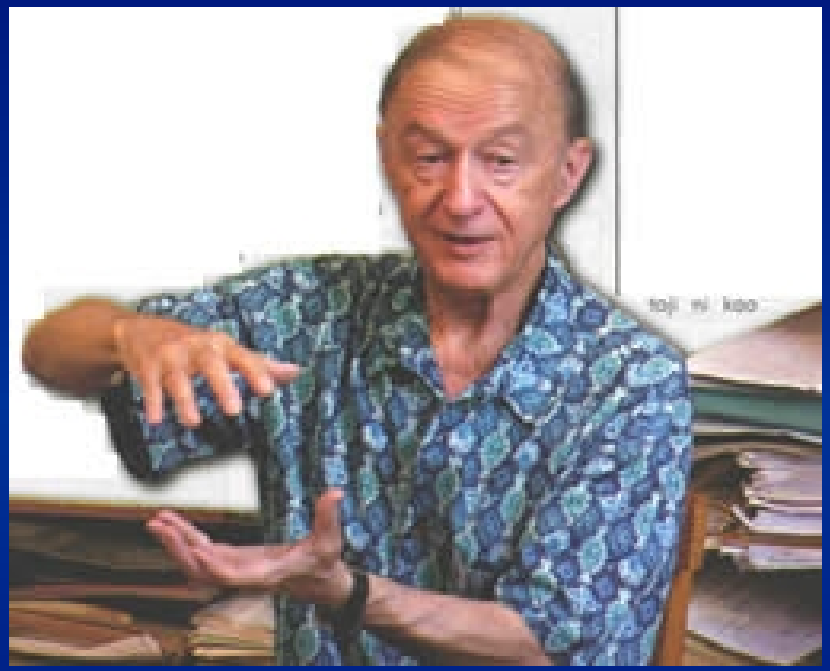


Line printer graphic output:

"Zebra Chart"

Fedor Mesinger

Author of the HIBU / LAPEM Model



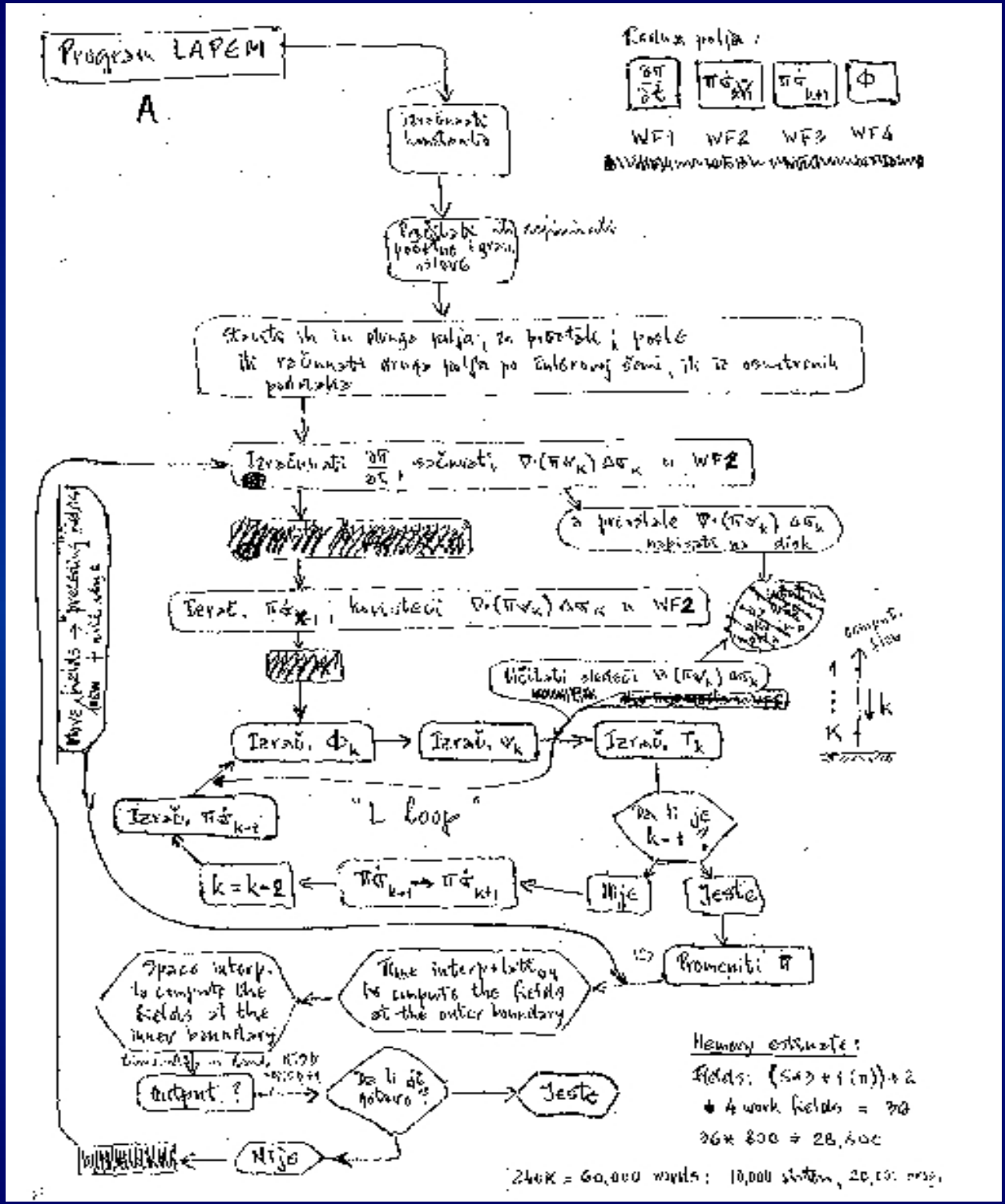
LAPEM: Limited Area Primitive Equation Model

Ray Bates worked with the HIBU model while he was in Egypt (1976)

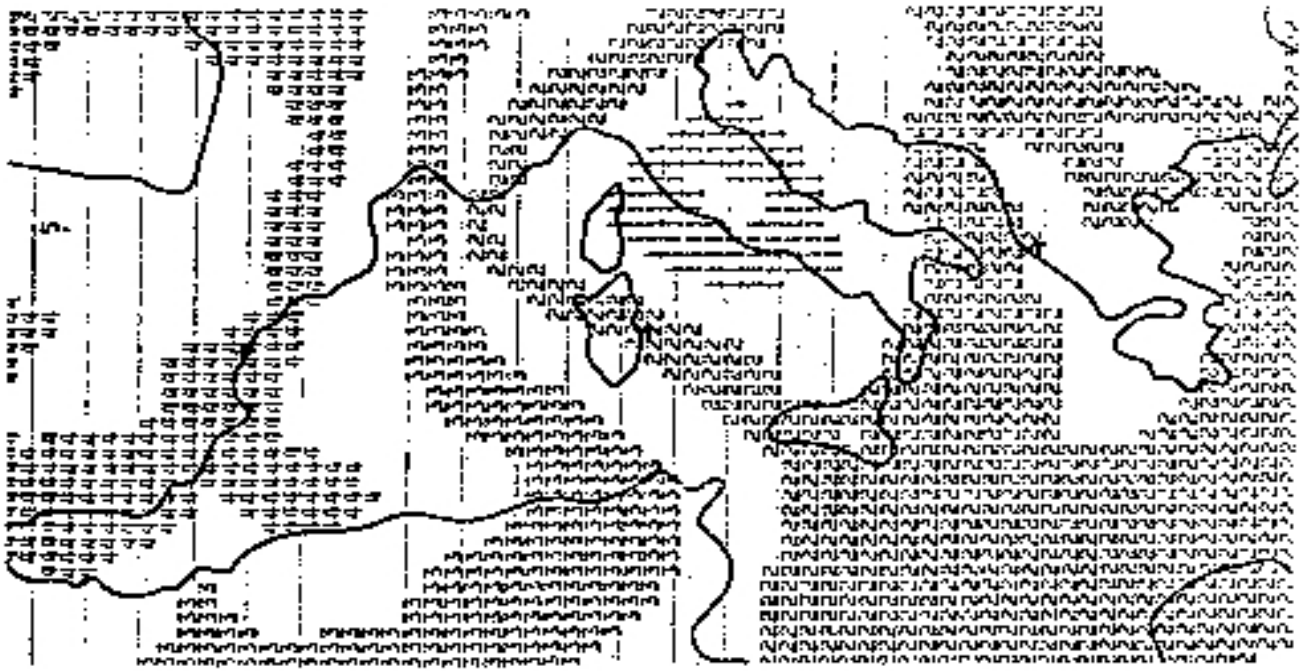
Ray in 1976

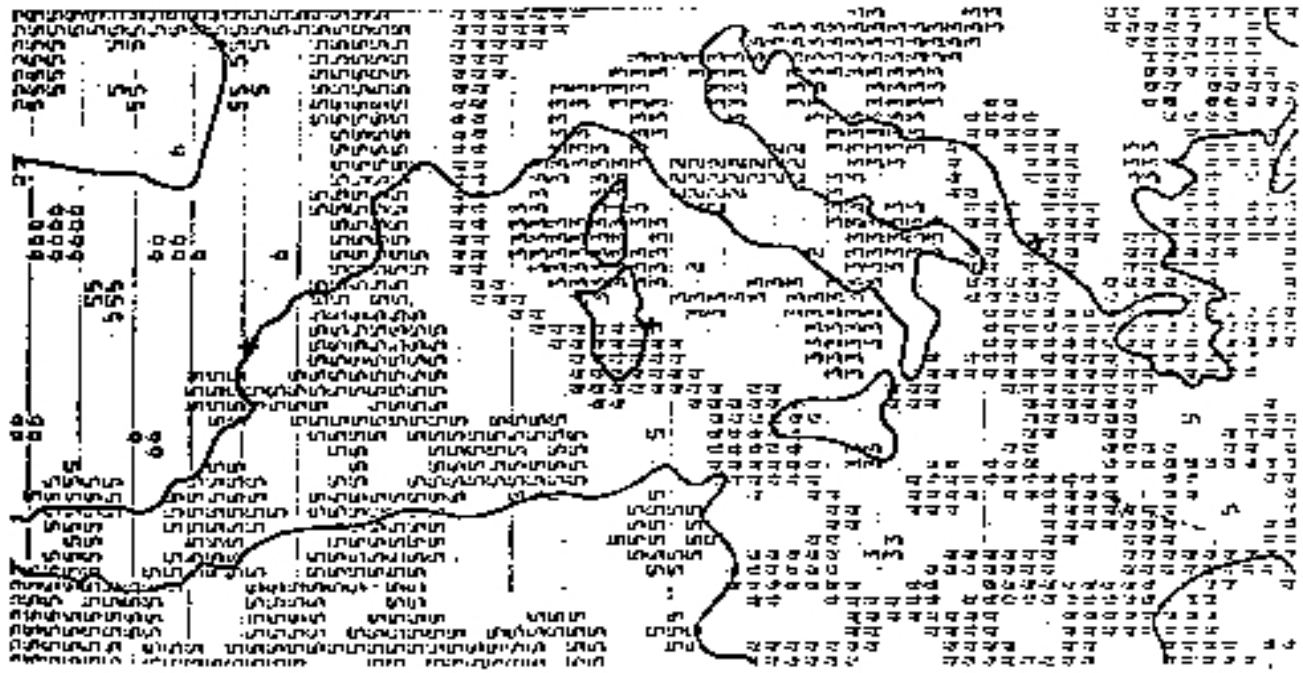
Ray today

Original Flowchart for LAPEM



Zebra-charts for LAPEM





Nils Gustafsson

Author of the Optimal Interpolation (OI) Objective Analysis scheme.

Later: Chief innovator in development of Variational Assimilation for Limited-Area Models and Inspirational figure in the HIRLAM Project.

1976 – 1978

PL and Austin Woods visit SMHI in Norrköping.

Swedish balanced model (NP model) running on IBM 360 at CDPS Kilmainham.

Nils Gustafsson visits IMS (1978). Objective Analysis run.

Declan Murphy develops Automatic Data Extraction (ADE).

Jim Hamilton develops plotting and graphics packages.

Fedor Mesinger visits IMS (1978).

LAPEM implemented (on DEC 20-40 at TCD).

Acoustic Coupler

Our gateway to the DEC 20-40 at TCD

1979 - 1981

June 1979: DEC 20-50 Installed at IMS.

November 1979: Move to new HQ in Glasnevin.

June 1980: First Operational Numerical Forecasts.

March 1981: Data link to ECMWF established.

July 1981: ECMWF data used for First-Guess fields and Lateral Boundary Conditions.

September 1981: NORWAV: Sea and swell model.

PDP 11/40

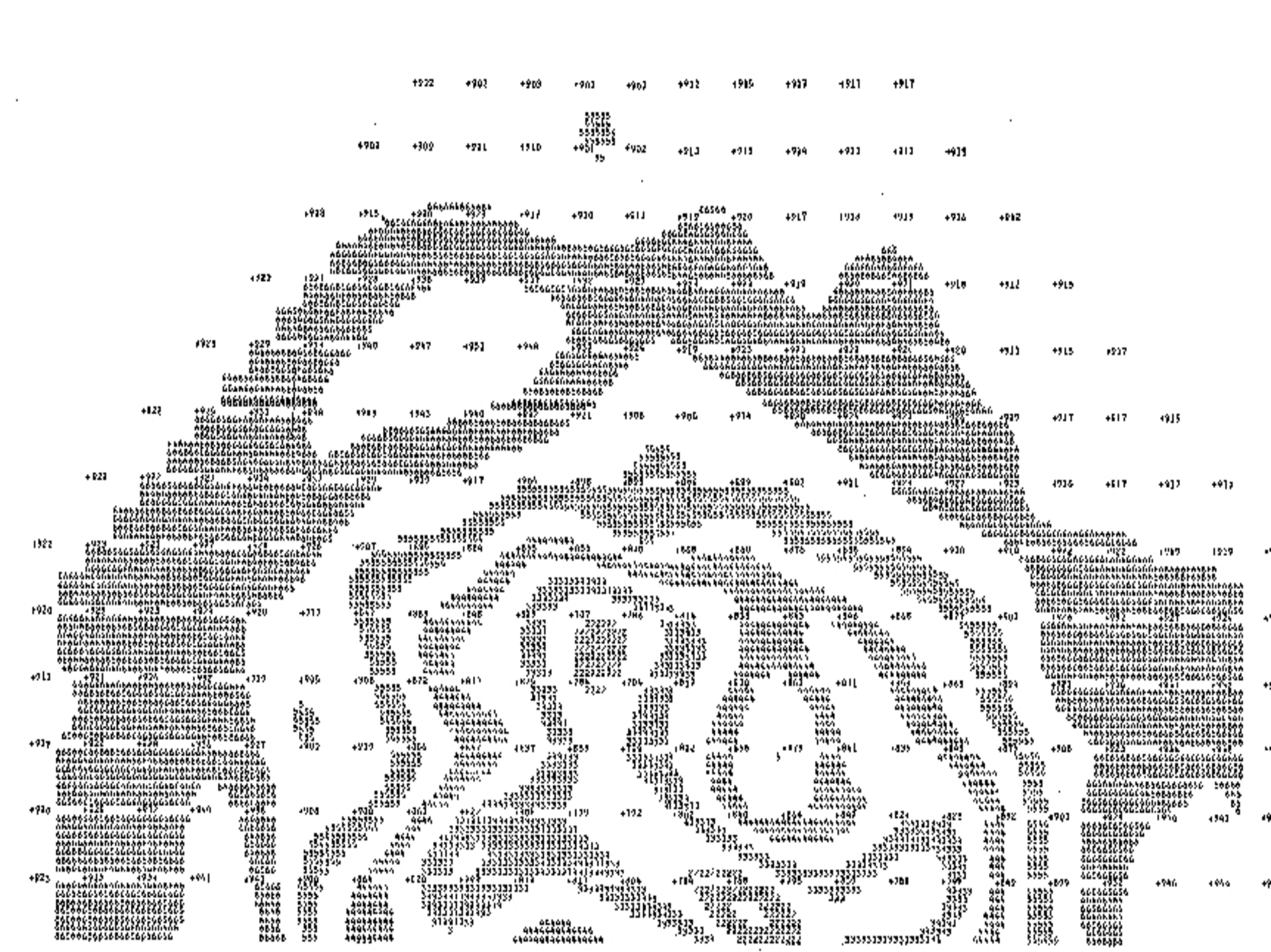
Bill Wann
(1925-2011)

(See an Appreciation
by Declan Murphy
in *Splanc*, Summer 2011)

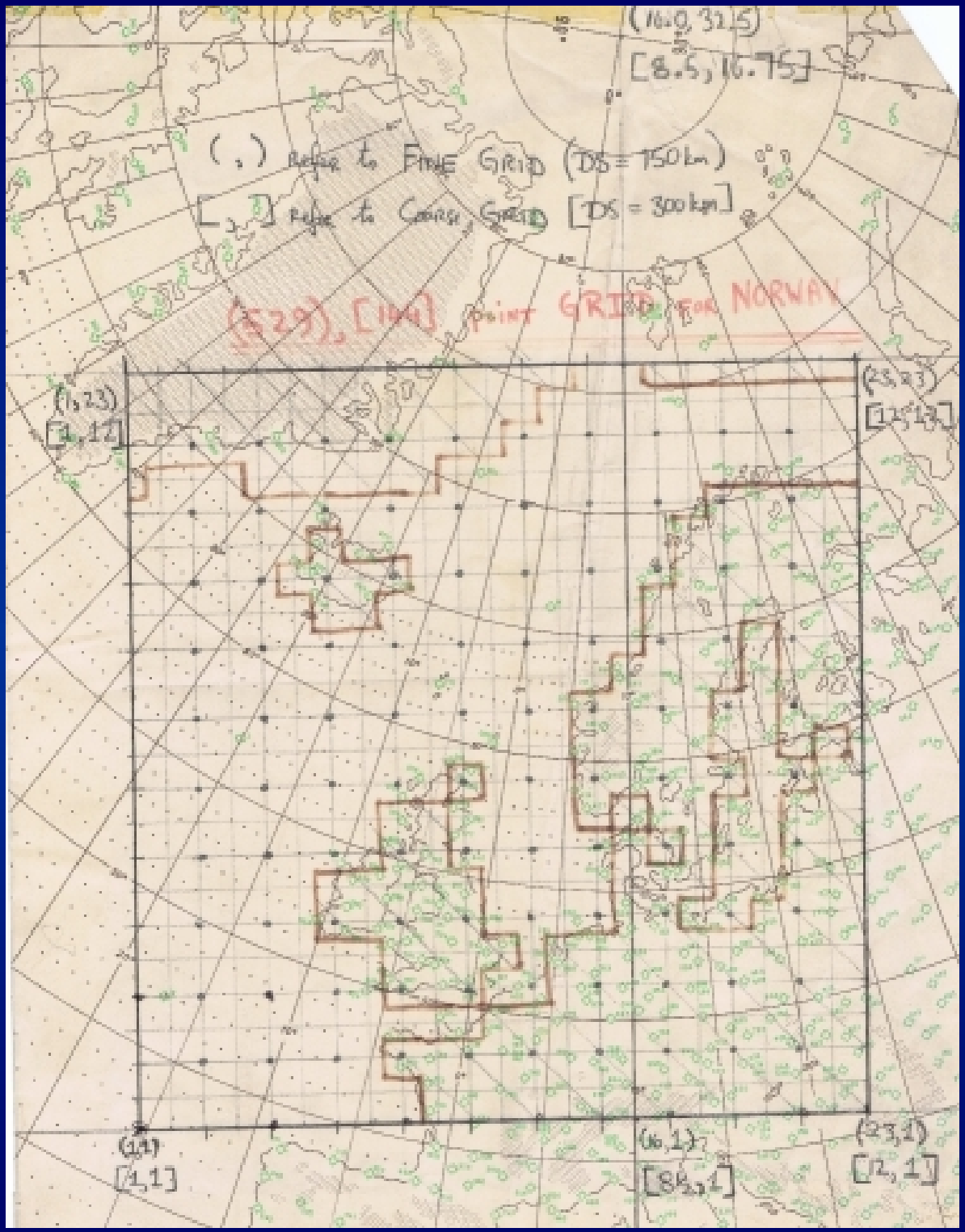

DECSYSTEM-2050: ECL processor
2K words of cache. 256 kwords of RAM
DECSYSTEM 20

DEC 20-50

- ECL Processor
- 2K words of cache
- 256 kilo-words of RAM
- Word-length of 36 bits !
- TOPS-20 Operating System



Calcomp Graphical Plotter



Grid for NorWav model

1982 – 1986

1982: Semi-Lagrangian scheme implemented.

1983: Variational Initialization scheme introduced.

1984: Laplace Transform Initialization developed.

1985: New methods (ADI and SI) for adjustment.

1986: Semi-Implicit, semi-Lagrangian model (SLSI).

1986: Refined analysis scheme introduced.

Paper by Ray Bates and Aidan McDonald on semi-Lagrangian scheme

Multiply-Upstream, Semi-Lagrangian Advective Schemes: Analysis and Application to a Multi-Level Primitive Equation Model

J. R. BATES AND A. McDONALD

Irish Meteorological Service, Dublin, Ireland

(Manuscript received 12 April 1982, in final form 16 September 1982)

ABSTRACT

The stability properties of some simple semi-Lagrangian advective schemes, based on a multiply-upstream interpolation, are examined. In these schemes, the interpolation points are chosen to surround the departure points of the fluid particles at the beginning of a time step. It is shown that the schemes, though explicit, are unconditionally stable for a constant wind field.

Application of the schemes to a multi-level split explicit model shows that they enable full advantage to be taken of the splitting method by allowing a long time step for advection. It is shown that they can thus lead to a considerable saving of computer time compared to Eulerian schemes, while giving comparable accuracy.

Over 100 citations on Google Scholar (6 Nov 2011)

1985 – 1990

1985: PL (in KNMI) attended HIRLAM planning meeting in DMI, Copenhagen.

1989: IMS joins the HIRLAM Project.

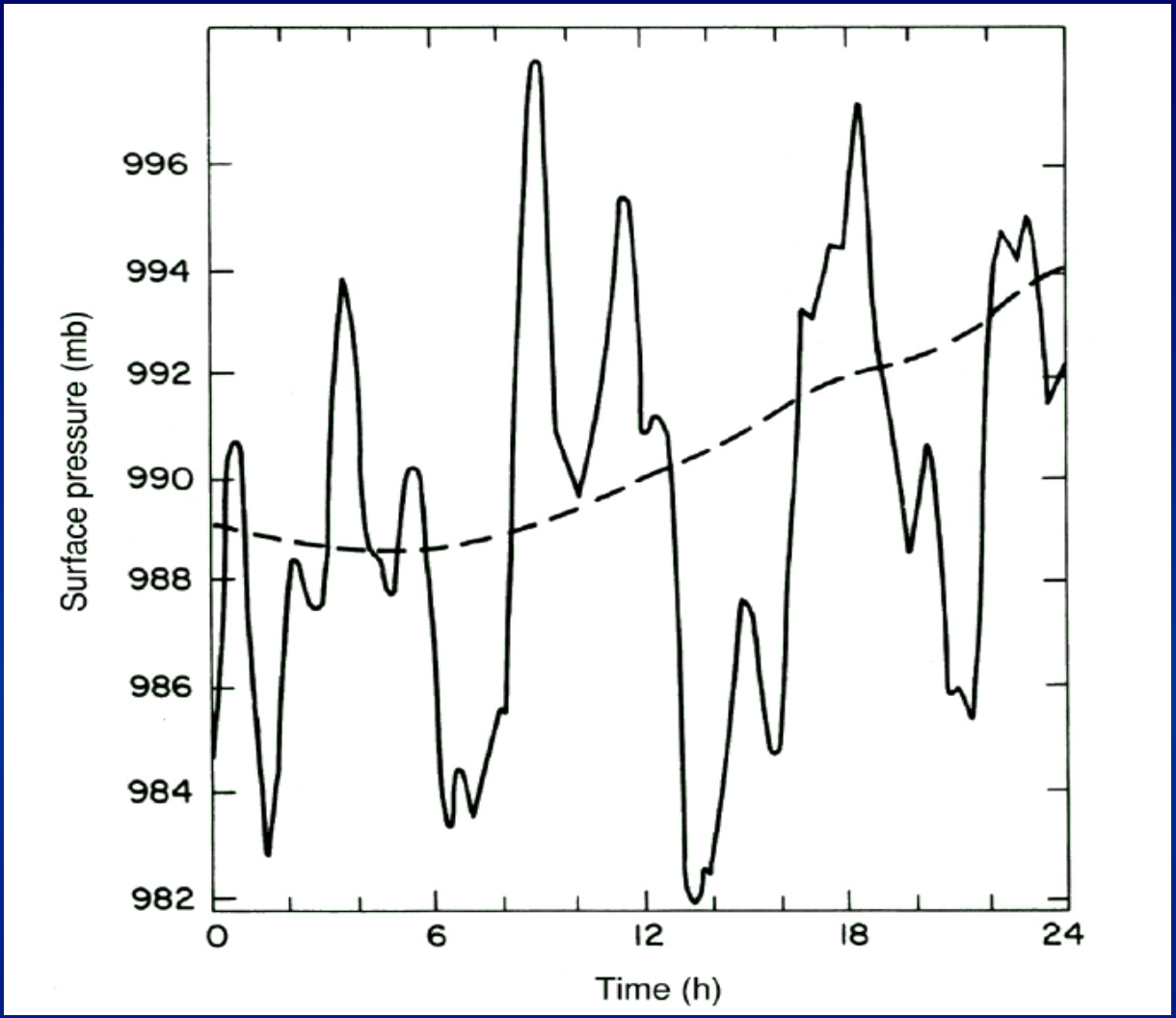
1990: DFI developed, first in MISU (Stockholm) and later in Met Éireann.

HIRLAM (HIgh Resolution Limited Area Model):
A research cooperation between several European National Meteorological Institutes.

The aim of HIRLAM is to develop and maintain a numerical short-range weather forecasting system for operational use.

Our main contributions:

- Semi-Lagrangian Scheme
- Digital Filtering Initialization



Surface pressure as a function of time for two 24-hour integrations of a primitive equation model

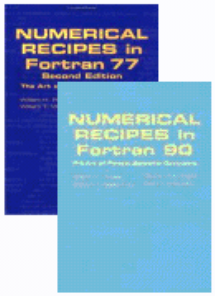


Table of Contents
Index

page: Next
page: Previous
go to page:

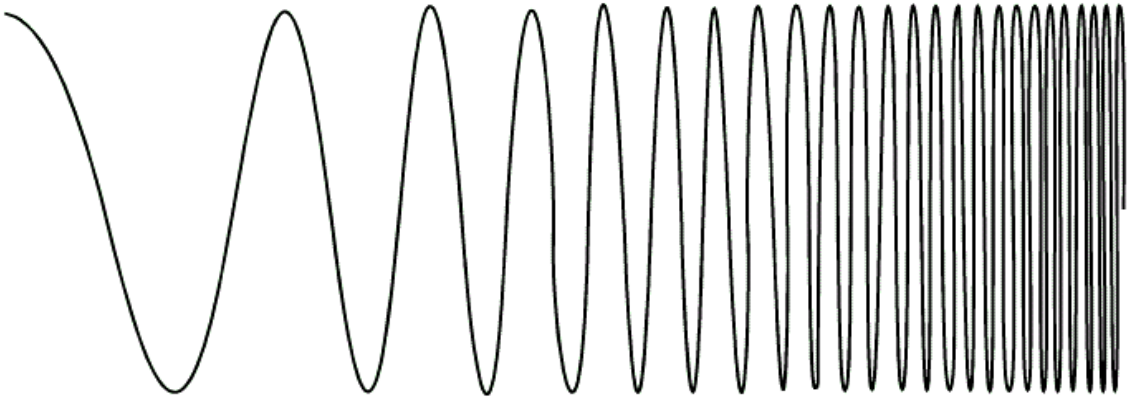
section: Next
section: Previous

chapter: Next
chapter: Previous

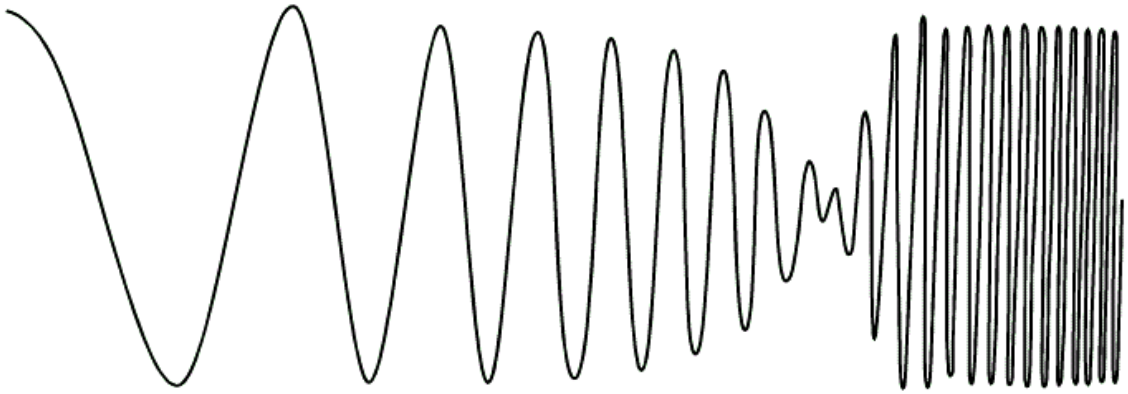
page: Bigger
page: Smaller
page: Fit

Print Page
Subscribe

Quick links...
About...



(a)



(b)

Figure 13.5.1. (a) A "chirp," or signal whose frequency increases continuously with time. (b) Same signal after it has passed through the notch filter (13.5.15). The parameter ϵ is here 0.2.

541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556

13.5 Digital Filtering in the Time Domain

Suppose that you have a signal that you want to filter digitally. For example, perhaps you want to apply *high pass* or *low pass* filtering, to eliminate noise at low or high frequencies respectively; or perhaps the interesting part of your signal lies only in a certain frequency band, so that you need a *bandpass* filter. Or, if your measurements are contaminated by 60 Hz power-line interference, you may need a *notch filter* to remove only a narrow band around that frequency. This section speaks particularly about the case in which you have chosen to do such filtering in the time domain.

Before continuing, we hope you will reconsider this choice. Remember how convenient it is to filter in the Fourier domain. You just take your whole data record, FFT it, multiply the FFT output by a filter function $\mathcal{H}(f)$, and then do an inverse FFT to get back a filtered data set in time domain. Here is some additional background on the Fourier technique that you will want to take into account.

- Remember that you must define your filter function $\mathcal{H}(f)$ for both positive and negative frequencies, and that the magnitude of the frequency extremes is always the Nyquist frequency $1/(2\Delta)$, where Δ is the sampling interval. The magnitude of the smallest nonzero frequencies in the FFT is $\pm 1/(N\Delta)$, where N is the number of (complex) points in the FFT. The positive and negative frequencies to which this filter are applied are arranged in wrap-around order.
- If the measured data are real, and you want the filtered output also to be real, then your arbitrary filter function should obey $\mathcal{H}(-f) = \mathcal{H}(f)^*$. You can arrange this most easily by picking an $\mathcal{H}$ that is real and even in f.

13.5 Digital Filtering in the Time Domain

Suppose that you have a signal that you want to filter digitally. For example, perhaps you want to apply *high pass* or *low pass* filtering, to eliminate noise at low or high frequencies respectively; or perhaps the interesting part of your signal lies only in a certain frequency band, so that you need a *bandpass* filter. Or, if your measurements are contaminated by 60 Hz power-line interference, you may need a *notch filter* to remove only a narrow band around that frequency. This section speaks particularly about the case in which you have chosen to do such filtering in the time domain.

Before continuing, we hope you will reconsider this choice. Remember how convenient it is to filter in the Fourier domain. You just take your whole data record, FFT it, multiply the FFT output by a filter function $\mathcal{H}(f)$, and then do an inverse FFT to get back a filtered data set in time domain. Here is some additional background on the Fourier technique that you will want to take into account.

- Remember that you must define your filter function $\mathcal{H}(f)$ for both positive and negative frequencies, and that the magnitude of the frequency extremes is always the Nyquist frequency $1/(2\Delta)$, where Δ is the sampling interval. The magnitude of the smallest nonzero frequencies in the FFT is $\pm 1/(N\Delta)$, where N is the number of (complex) points in the FFT. The positive and negative frequencies to which this filter are applied are arranged in wrap-around order.
- If the measured data are real, and you want the filtered output also to be real, then your arbitrary filter function should obey $\mathcal{H}(-f) = \mathcal{H}(f)^*$. You can arrange this most easily by picking an $\mathcal{H}$ that is real and even in f.

Silicon Graphics SGI Challenge-L

HIRLAM operational at Met Éireann in 1994

1989 - 2011

1989: IMS joins the HIRLAM Project.

1990: DFI developed, first in MISU (Stockholm) and later in Met Eireann.

1997: FASTEX. HQ @ EINN

1997-1999: PL Project Leader of HIRLAM

2005(?): *Visual Weather* graphics package.

2011: HARMONIE goes operational.

HIRLAM Launch

Minister for Energy Noel Treacy launched the HIRLAM Model on 23 November 1994

Meteorological Service

WELCOME

The Director of the Meteorological Service

Mr D J Murphy

welcomes you to the Official Launch of the new computer weather forecasting system

HIRLAM

High Resolution Limited Area Model

by the Minister for Energy

Mr Noel Treacy, T.D.

Meteorological Service Headquarters,
Glasnevin Hill, Dublin 9
4:00pm, Wednesday 23rd November, 1994.

HIRLAM
what is it?

Ireland

Denmark

Netherlands

HIRLAM is a **HI**gh **R**esolution **L**imited **A**rea **M**odel, a state-of-the-art weather prediction system, the result of an international research project involving several European countries.

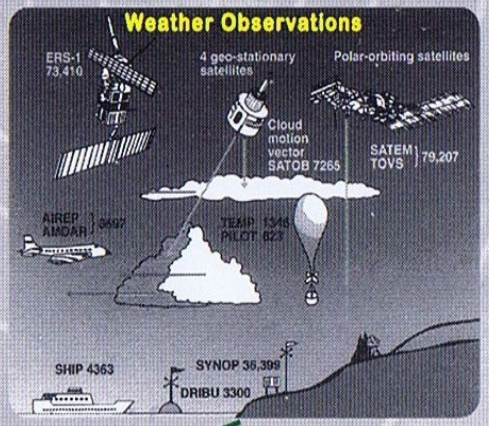
Finland

Norway

Iceland

Sweden

HIRLAM
how it works



Basic Predictive Equations for the Atmosphere

$$\frac{du}{dt} - \left(f + u\frac{\tan\phi}{a}\right)v = -\frac{1}{a\cos\phi}\frac{1}{\rho}\frac{\partial p}{\partial\lambda} + F_\lambda$$

$$\frac{dv}{dt} + \left(f + u\frac{\tan\phi}{a}\right)u = -\frac{1}{\rho a}\frac{\partial p}{\partial\phi} + F_\phi$$

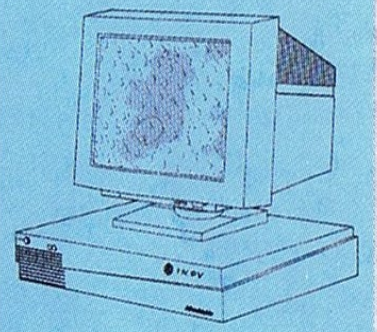
$$g = -\frac{1}{\rho}\frac{\partial p}{\partial z}$$

$$\frac{\partial\rho}{\partial t} = -\frac{1}{a\cos\phi}\left[\frac{\partial}{\partial\lambda}(\rho u) + \frac{\partial}{\partial\phi}(\rho v\cos\phi)\right] - \frac{\partial}{\partial z}(\rho w)$$

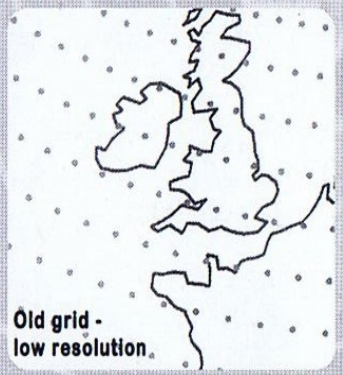
$$C_p\frac{dT}{dt} - \frac{1}{\rho}\frac{dp}{dt} = Q$$

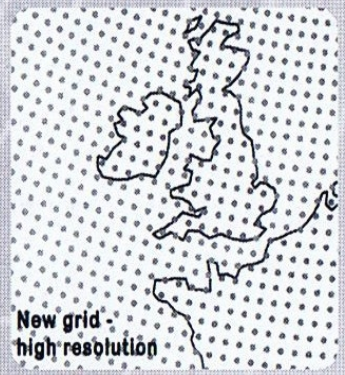
$$p = \rho RT$$

Forecast

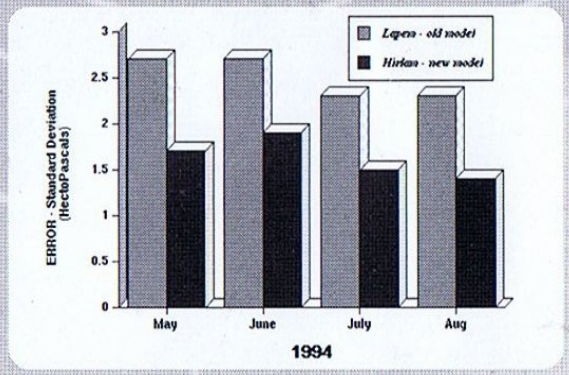


HIRLAM means better forecasts





HIRLAM - the first part of the name stands for '**HI**gh **R**esolution'. **HIRLAM** calculates forecast values for a denser grid of points than before, leading to greater forecast accuracy, as shown in the error graphs below.



HIRLAM who benefits

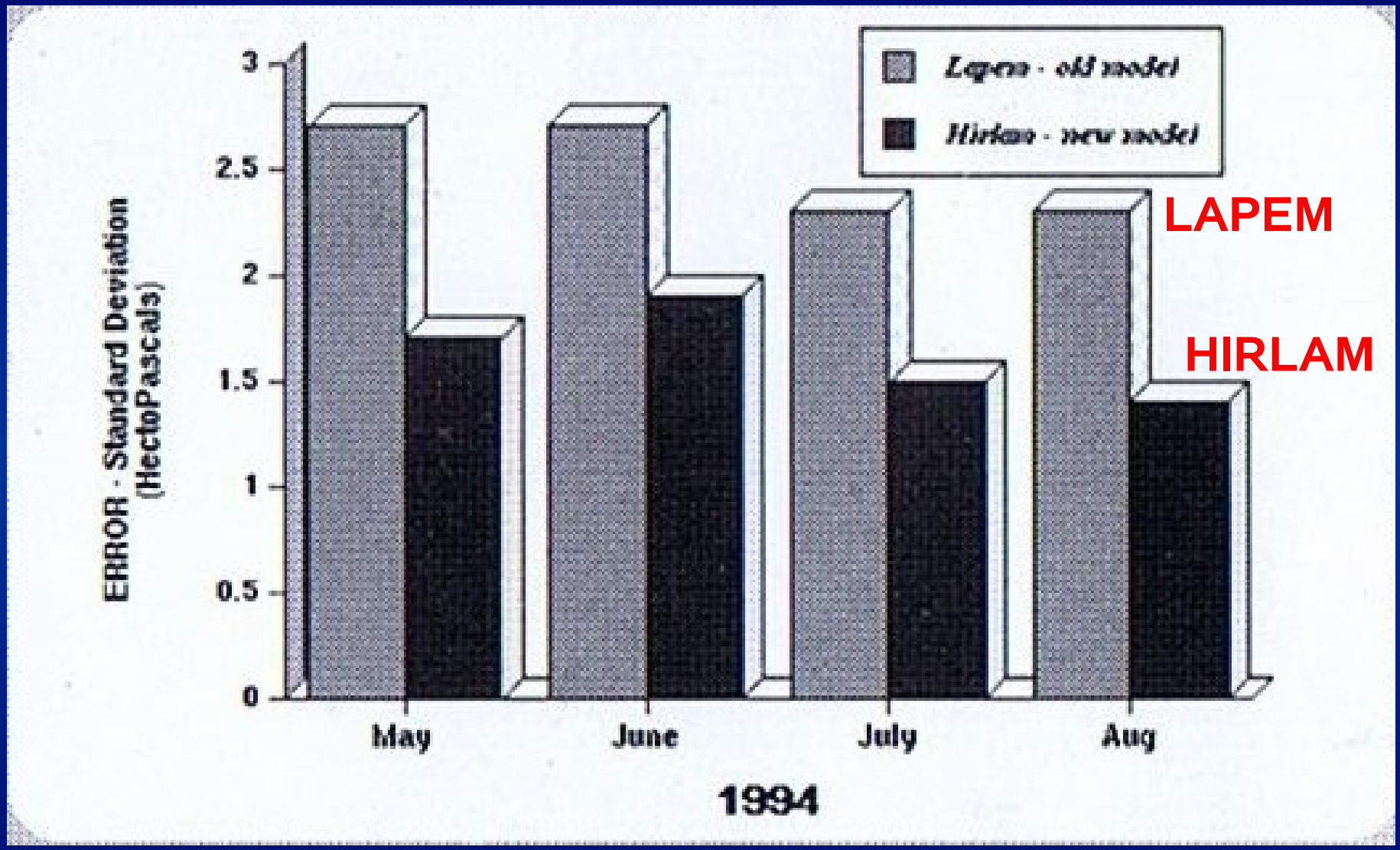
- ⇨ Marine
- ⇨ Fisheries
- ⇨ Agriculture

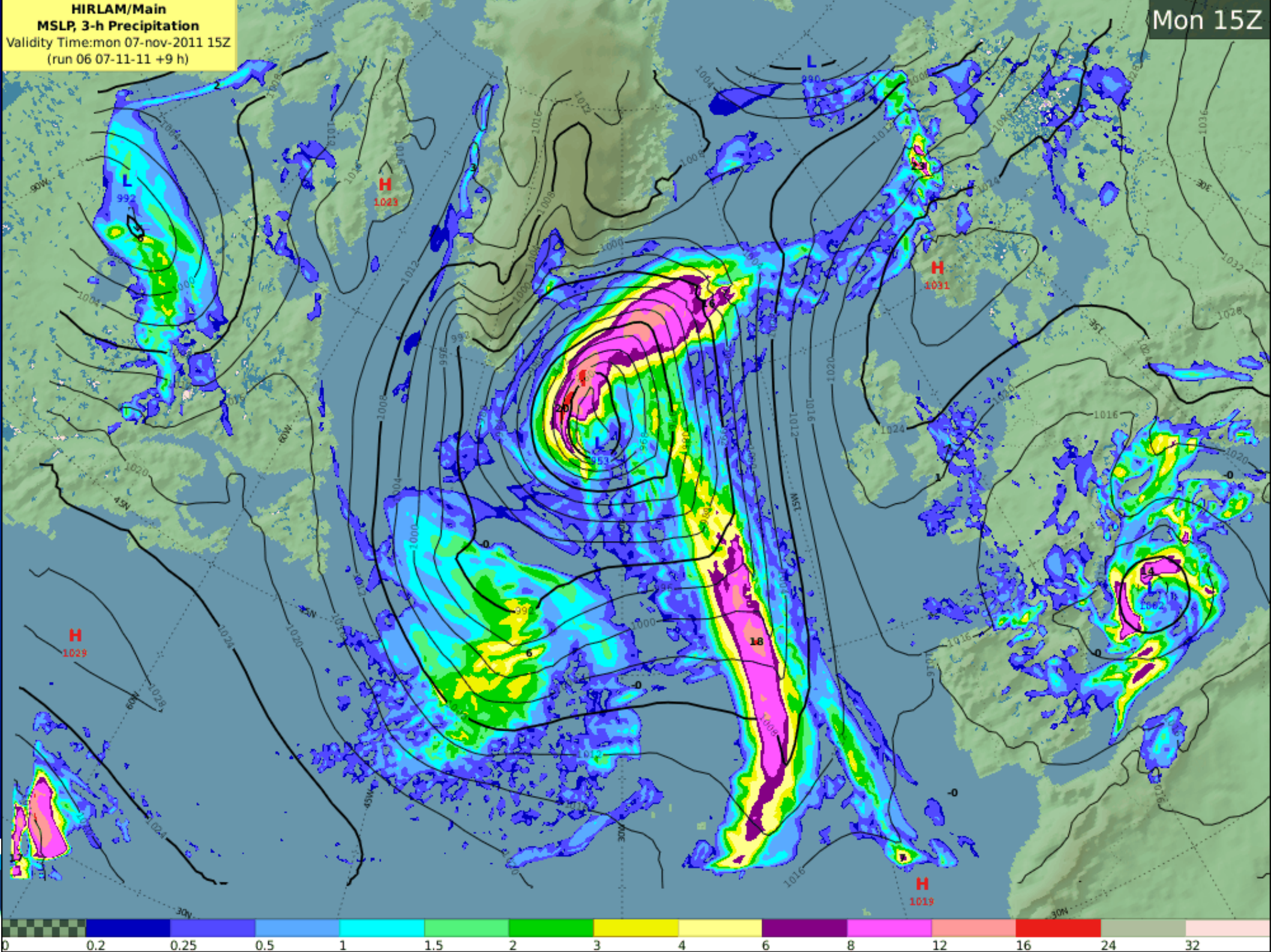
- ⇨ General Public
- ⇨ Local Authorities
- ⇨ Environmental Agencies

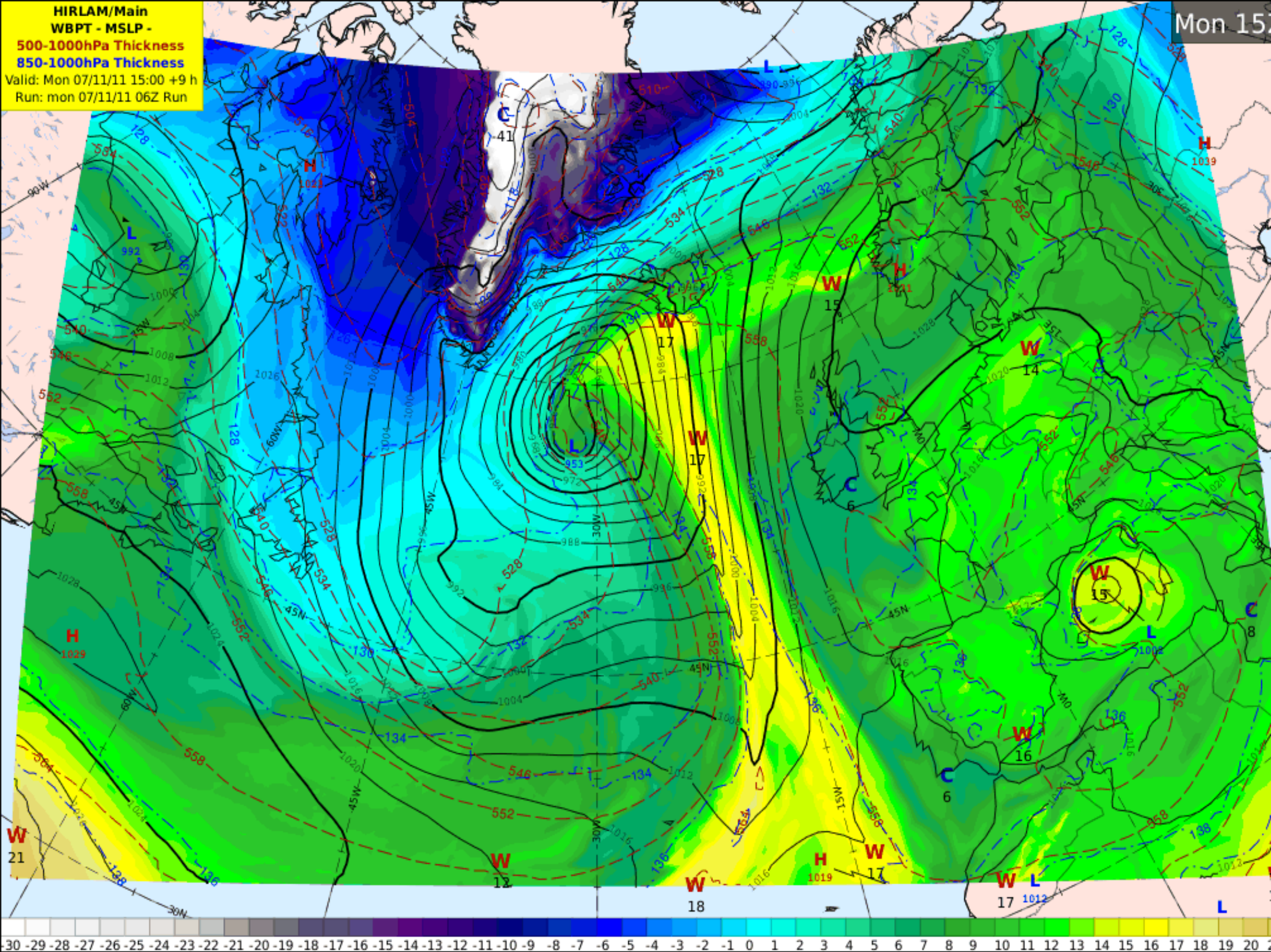
- ⇨ Energy
- ⇨ Industry
- ⇨ Construction

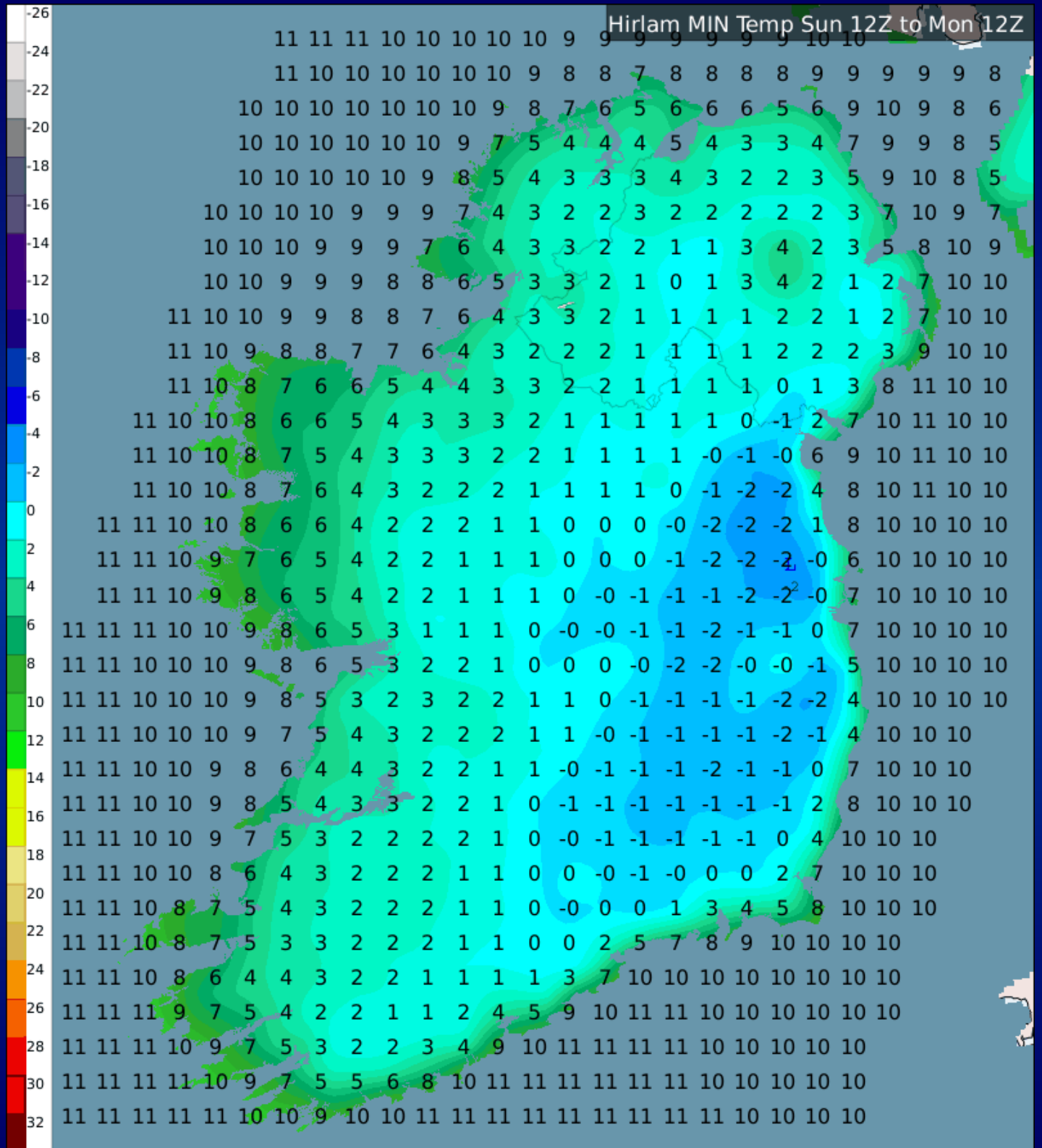
- ⇨ Tourism
- ⇨ Transport
- ⇨ Aviation

Forecast Errors much smaller for HIRLAM




HIRLAM/Main
MSLP, 3-h Precipitation
Validity Time:mon 07-nov-2011 15Z
(run 06 07-11-11 +9 h)
Mon 15Z
0
0.2
0.25
0.5
1
1.5
2
3
4
6
8
12
16
24
32


HIRLAM/Main
WBPT - MSLP -
500-1000hPa Thickness
850-1000hPa Thickness
Valid: Mon 07/11/11 15:00 +9 h
Run: mon 07/11/11 06Z Run
Mon 15
-30 -29 -28 -27 -26 -25 -24 -23 -22 -21 -20 -19 -18 -17 -16 -15 -14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20


Hirlam MIN Temp Sun 12Z to Mon 12Z
-26
-24
-22
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32

HARMONIE

HIRLAM

ALADIN

RESEARCH on

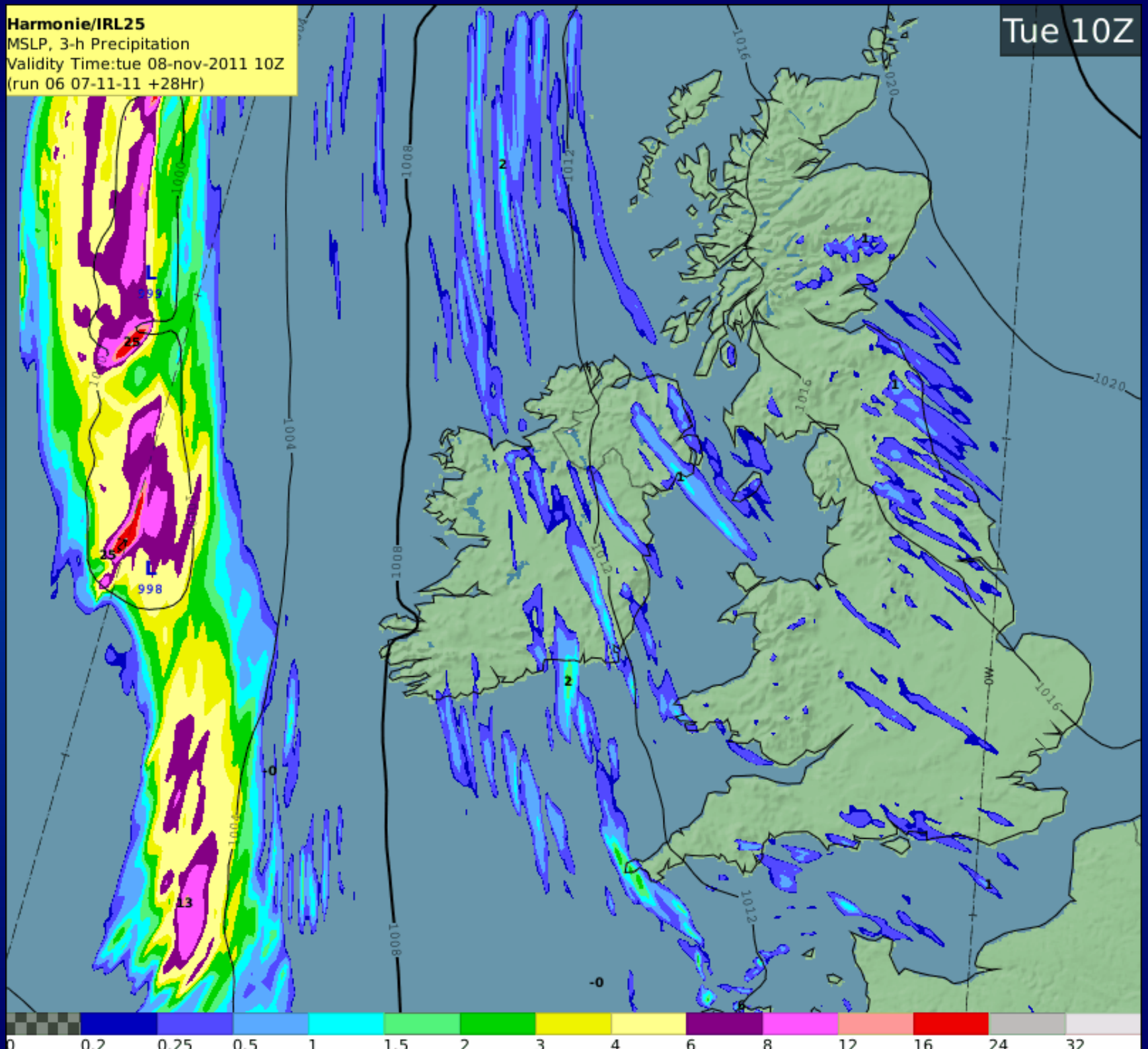
MESOSCALE

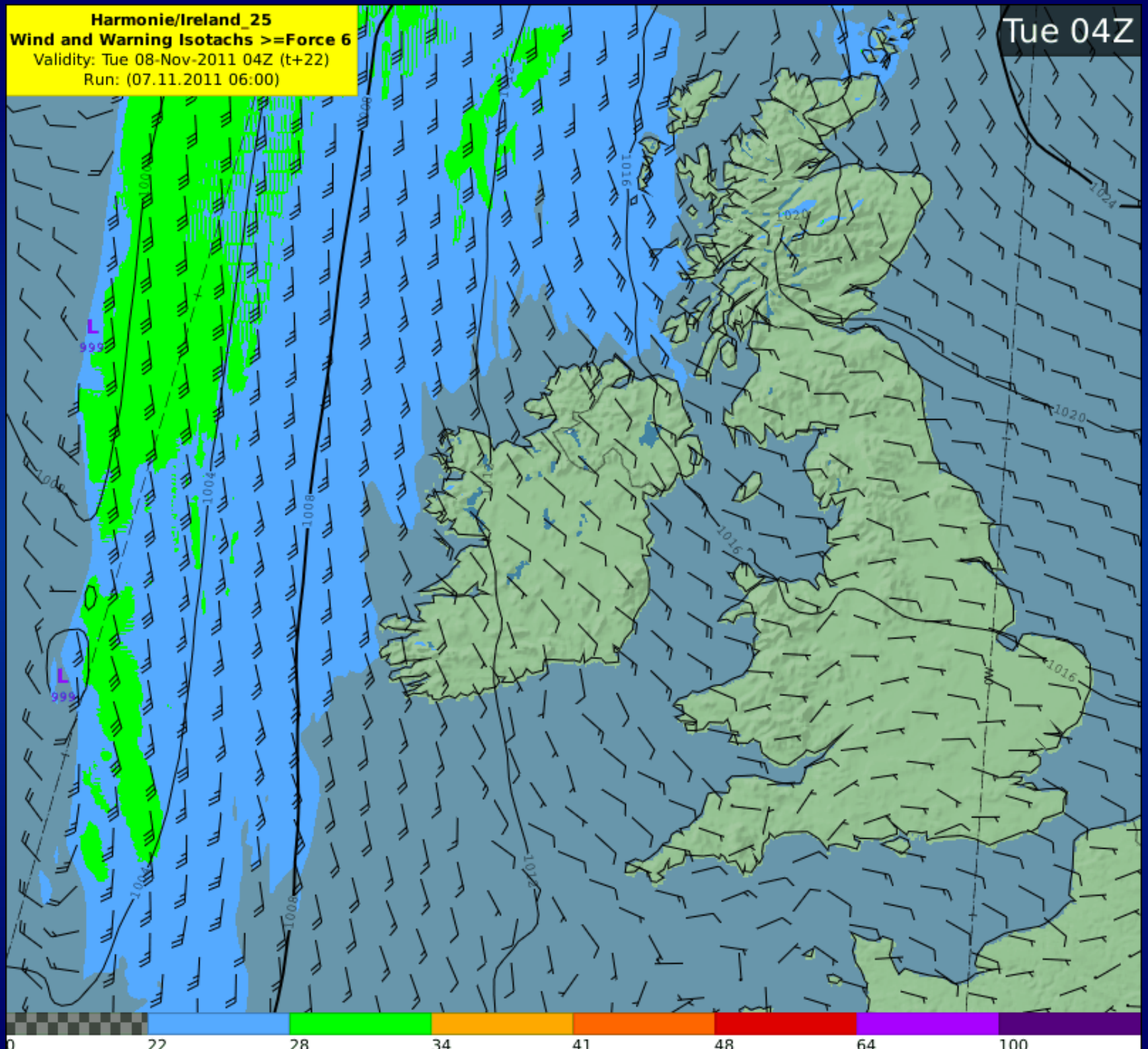
OPERATIONAL

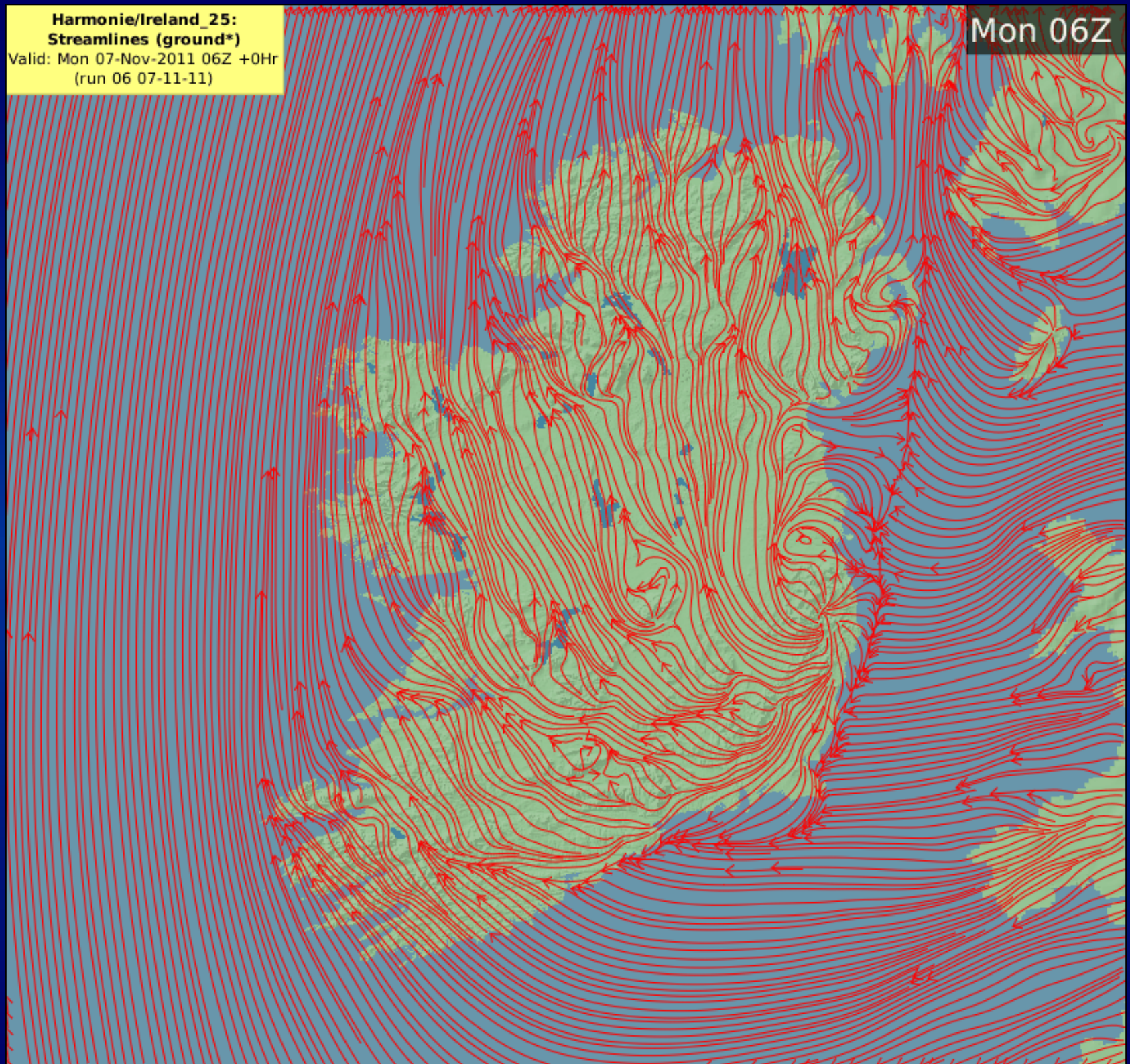
NUMERICAL WEATHER PREDICTION

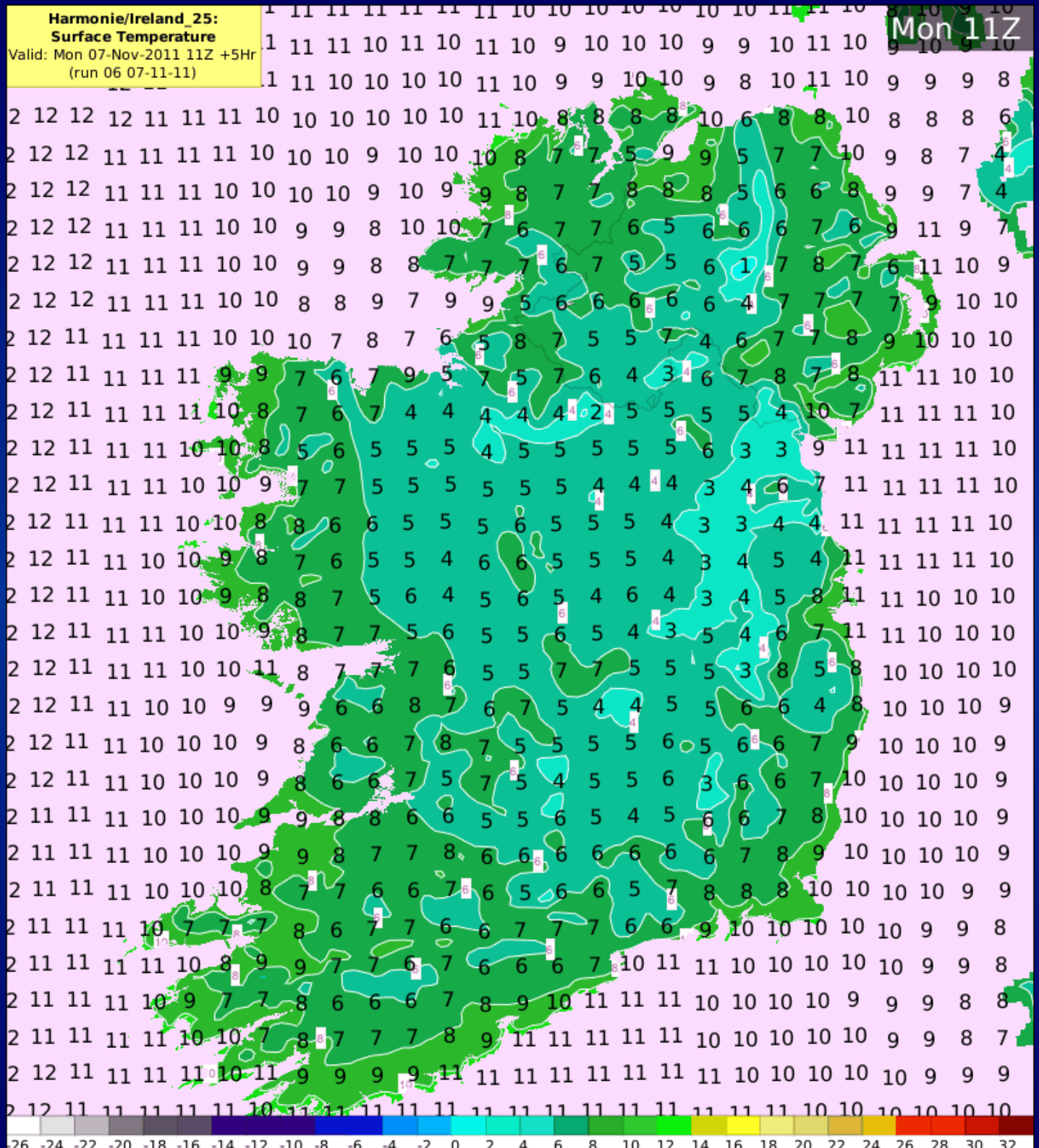
IN

EUROPE


Harmonie/IRL25
MSLP, 3-h Precipitation
Validity Time:tue 08-nov-2011 10Z
(run 06 07-11-11 +28Hr)
Tue 10Z
0
0.2
0.25
0.5
1
1.5
2
3
4
6
8
12
16
24
32


Harmonie/Ireland_25
Wind and Warning Isotachs >=Force 6
Validity: Tue 08-Nov-2011 04Z (t+22)
Run: (07.11.2011 06:00)
Tue 04Z
0
22
28
34
41
48
64
100


Harmonie/Ireland_25:
Streamlines (ground*)
Valid: Mon 07-Nov-2011 06Z +0Hr
(run 06 07-11-11)
Mon 06Z


Harmonie/Ireland_25:
Surface Temperature
Valid: Mon 07-Nov-2011 11Z +5Hr
(run 06 07-11-11)
Mon 11Z

OTHER MODELLING ACTIVITIES

F&M (virus) models

Trajectory (TDD) models

Post-Processing

Slow Equations

WAM: Wave Models

Satellite Data

Probabilistic (Ensemble) Forecasting

Regional Climate Modelling (C4I)

Regional Climate Modelling and the Community Climate Change Consortium for Ireland (C4I) Project

http://www.c4i.ie/

Peter Lynch's UCD Web Page | plus.maths.org | The Robert Boyle Science Festi... | c4i: Community Climate Con...

c4i Community Climate Change Consortium for Ireland

Community Climate Change Consortium for Ireland

Home | News | Links | Our Team | Contact Us

- Home
- Verification
- Projections
- Publications

The C4I Project

The Community Climate Change Consortium for Ireland (C4I) Project was established in 2003. Based in the headquarters of Met Éireann, the Irish National Meteorological Service, in Dublin, its main objective is to consolidate and intensify the national effort in climate change research by building a capability for carrying out regional climate modelling in Ireland and to provide assistance to Irish scientists utilizing climate model output for their analyses.

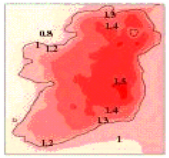
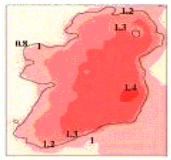
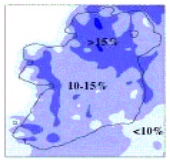
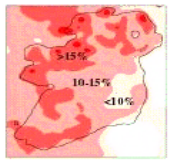
A summary of recent work is available in this leaflet (PDF file, 883K). The full final report can be downloaded from here (PDF file, 6.0 MB).

Climate Projections

The scientific evidence is growing that man-made greenhouse gas emissions are having a significant effect on the earth's climate.

Computer driven mathematical models can evaluate the response of the climate system to predicted greenhouse gas concentration.

Click here to read the whole article.

Temperature		Rainfall	
			
January: 1 to 1.5°C warmer	July: 1 to 1.5°C warmer	January: 10 to 20% wetter	July: 10 to 20% drier

Future Climate Change in Ireland

We can expect the average temperature to rise in the future. The average temperature in the years 2021 to 2060 will be 1 to 1.5°C higher compared to the years 1961 to 2000. For the same years, C4I is predicting wetter winters and drier summers.

Depending on assumptions on the emission scenario, the changes can be either weaker or stronger.

Please look also at our synopsis of the February's 2007 IPCC report.

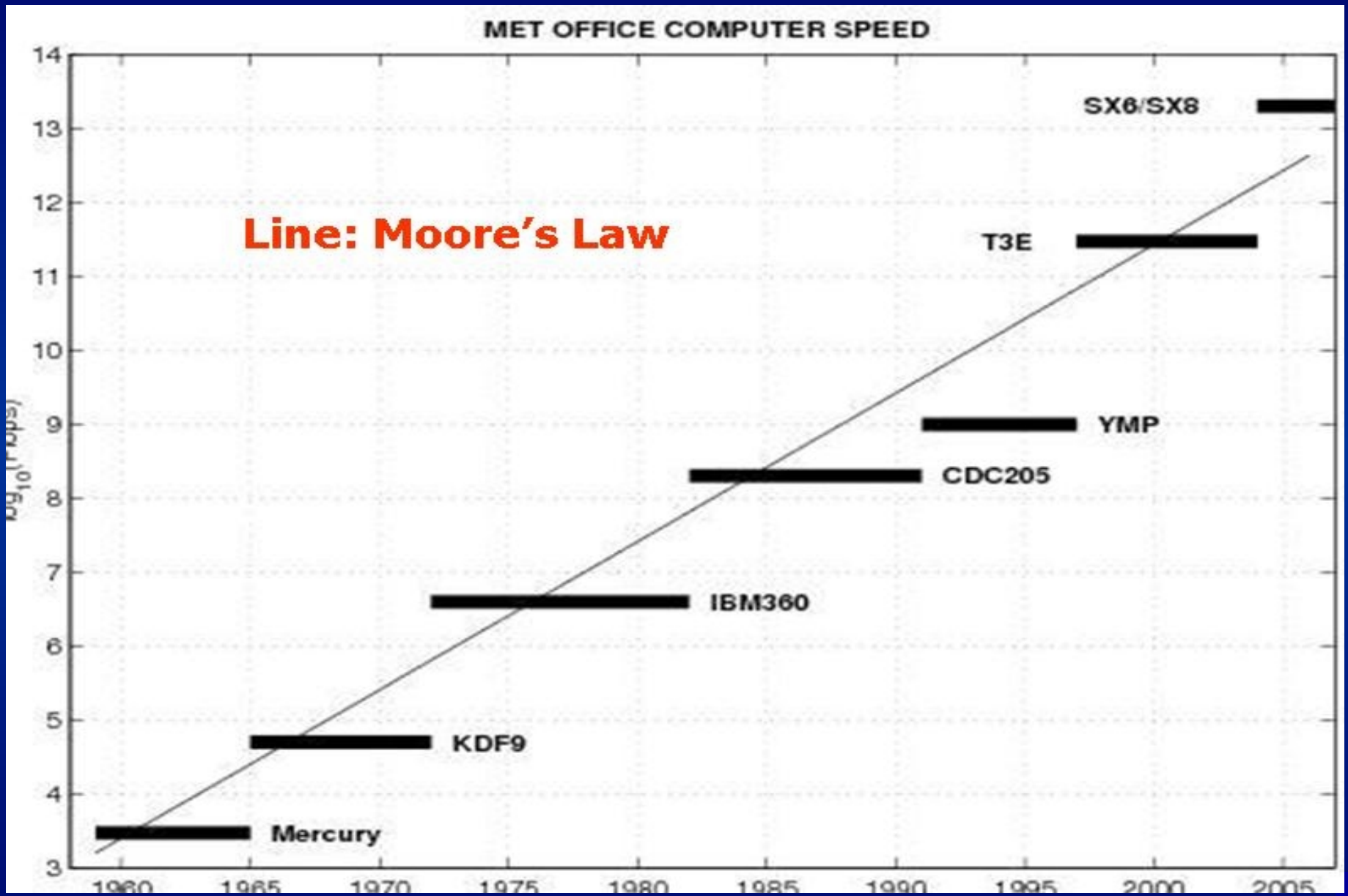
www.c4i.ie

C4I Project Description	Current Status	Funding
Download the C4I Project	A flavour of	The C4I Project is funded by the following Irish agencies:

Find: WMO | Match case

UCD DUBLIN

Growth in Computing Power, 1960 - 2005



Growth in Computing Power

IBM System/360 (circa 1976)

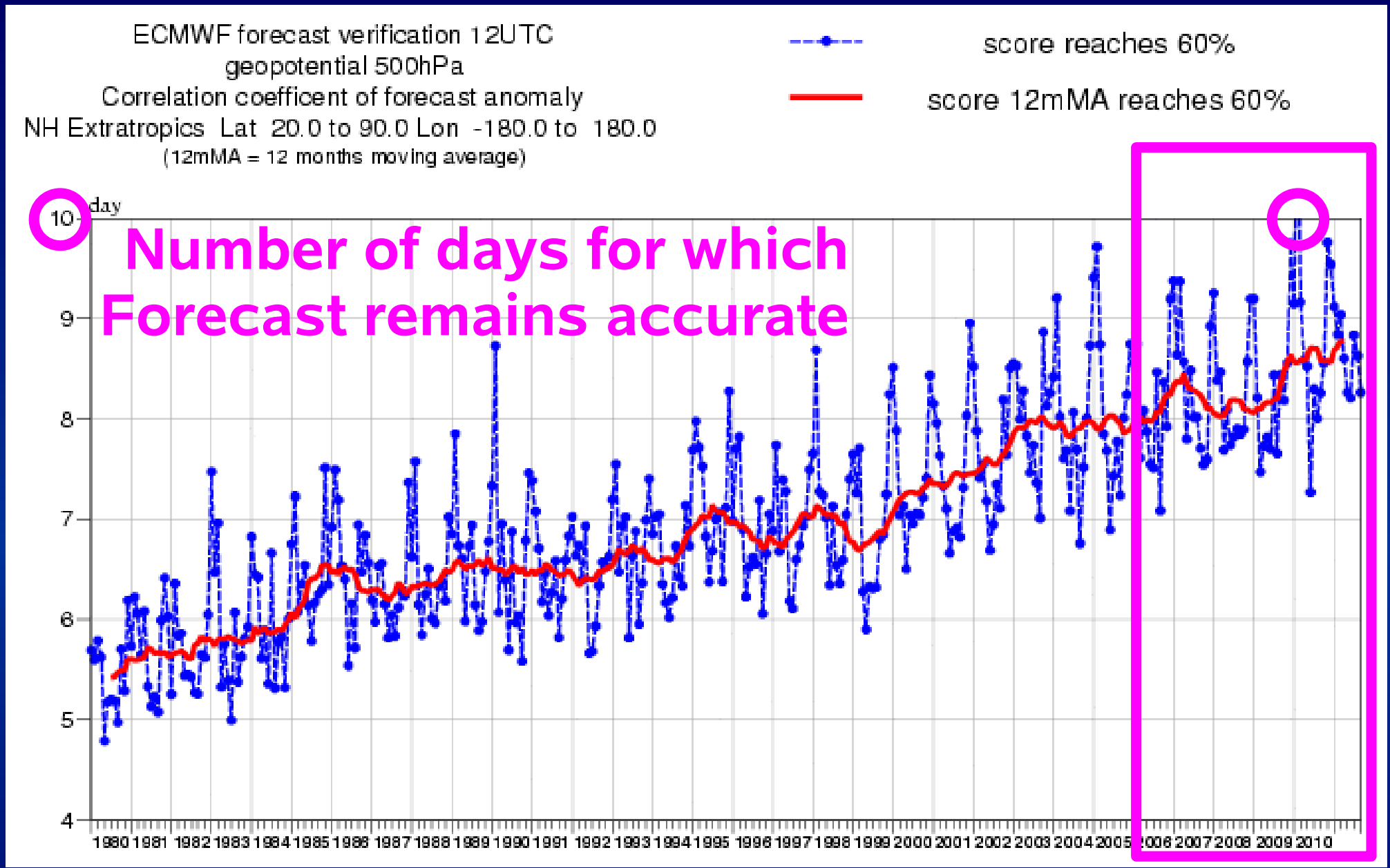
<<

Smart Phone (Today)

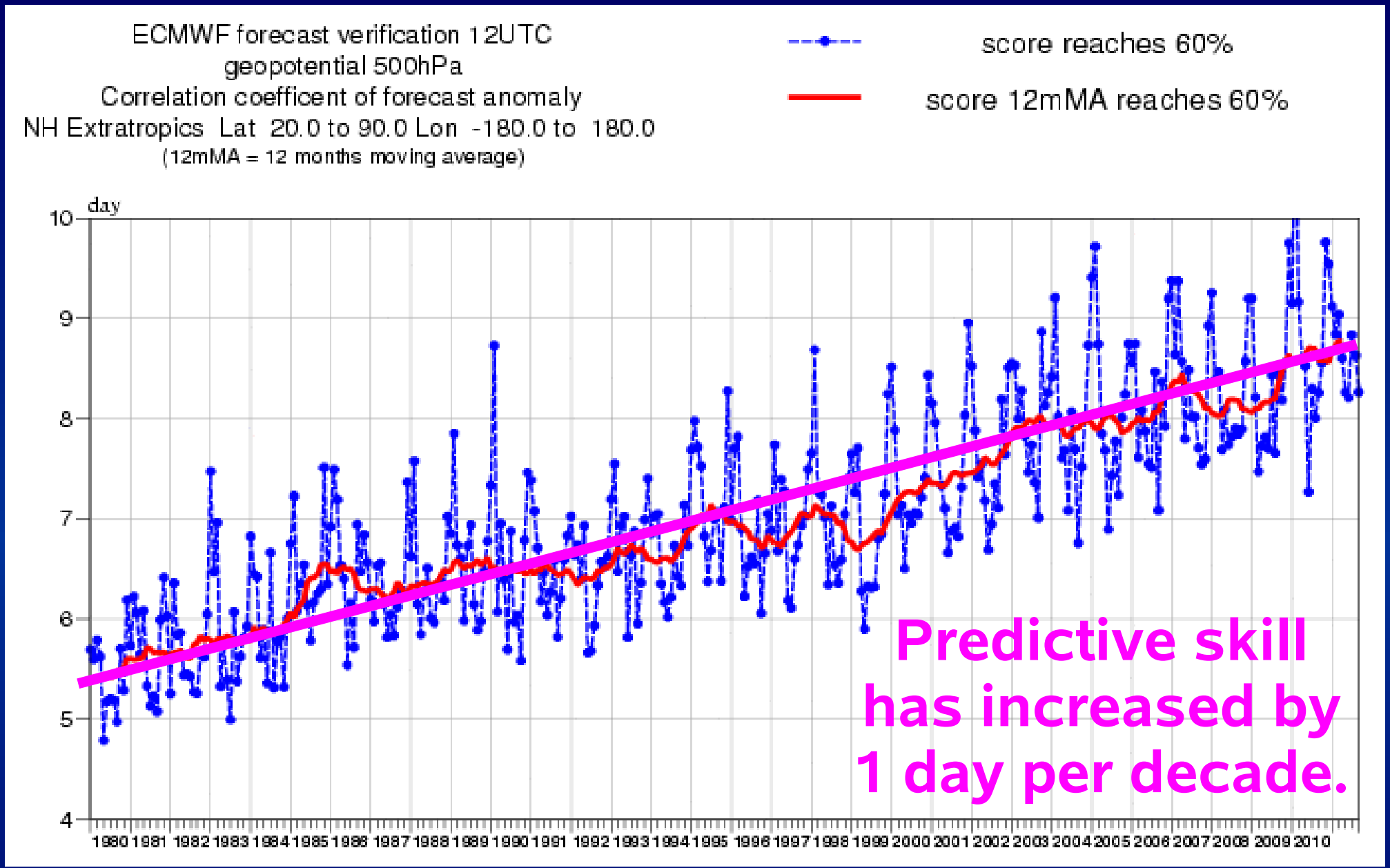
European Centre for Medium-Range Weather Forecasts (ECMWF)

Leading NWP centre

An intergovernmental organisation supported by 34 States, based in Reading, UK.



ECMWF broke the "10-day Barrier" in February 2010.



ECMWF broke the "10-day Barrier" in February 2010.

Thank you