Reconstructing the ENIAC Forecasts using the NCEP/NCAR Reanalysis

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Reconstrucing the ENIAC Forecasts using the NCEP/NCAR Reanalysis

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JMS020: Assessing and Exploiting Reanalysis Data Sets
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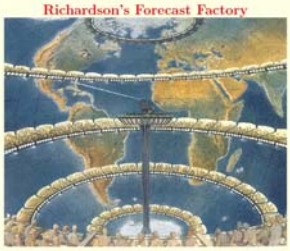
Pioneers of Scientific Forecasting

Cleveland Abbe, Vilhelm Bjerknes, Lewis Fry Richardson

Richardson's Forecast Factory



64,000 Computers: The first Massively Parallel Processor

Crucial Advances, 1920–1950

- *Dynamic Meteorology*
  - Quasi-geostrophic Theory
- *Numerical Analysis*
  - CFL Criterion
- *Atmopsheric Observations*
  - Radiosonde
- *Electronic Computing*
  - ENIAC

The Meteorology Project

Project estblished by John von Neumann in 1946.

Objective of the project:
To study the problem of predicting the weather using a digital electronic computer.

A Proposal for Funding listed three "possibilities":

- *New methods of weather prediction*
- *Rational basis for planning observations*
- *Step towards influencing the weather!*

The ENIAC

The ENIAC was the first multi-purpose programmable electronic digital computer.
It had:

- 18,000 vacuum tubes
- 70,000 resistors
- 10,000 capacitors
- 6,000 switches
- Power: 140 kWatts

Charney, et al., *Tellus*, 1950.

$$\begin{bmatrix}\text{Absolute}\\ \text{Vorticity}\end{bmatrix} = \begin{bmatrix}\text{Relative}\\ \text{Vorticity}\end{bmatrix} + \begin{bmatrix}\text{Planetary}\\ \text{Vorticity}\end{bmatrix} \qquad \eta = \zeta + f.$$

- The atmosphere is treated as a single layer.
- The flow is assumed to be nondivergent.
- Absolute vorticity is conserved.

$$\frac{d(\zeta+f)}{dt} = 0.$$

This equation looks deceptively simple. But it is nonlinear:

$$\frac{\partial}{\partial t}[\nabla^2\psi] + \left\{\frac{\partial\psi}{\partial x}\frac{\partial\nabla^2\psi}{\partial y} - \frac{\partial\psi}{\partial y}\frac{\partial\nabla^2\psi}{\partial x}\right\} + \beta\frac{\partial\psi}{\partial x} = 0,$$

Charney, Fjørtoft, von Neumann

Charney Fjørtoft von Neumann

Numerical integration of the barotropic vorticity equation
Tellus, 2, 237–254 (1950).

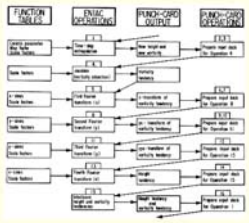
Solution method for BPVE

$$\frac{\partial\zeta}{\partial t} = \mathbf{J}(\psi, \zeta + f)$$

1. Compute the Jacobian
2. Step forward (Leapfrog scheme)
3. Solve Poisson equation $\nabla^2\psi = \zeta$ (Fourier expansion)
4. Go to (1).

- Timestep : $\Delta t = 1$ hour
- Gridstep : $\Delta x = 750$ km (at North Pole)
- Gridsize : $19 \times 16 \approx 300$ points
- Elapsed time for 24 hour forecast: About 24 hours.

Each forecast involved punching about 25,000 cards.
Most of the time was spent handling card-decks.



Flow-chart for the computations.

G. W. Platzman: The ENIAC Computations of 1950 — Gateway to Numerical Weather Prediction (BAMS, April, 1979).

Some key people in the ENIAC endeavour

Recreating the ENIAC Forecasts

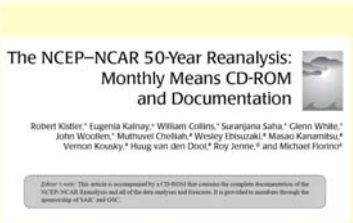
The ENIAC integrations have been recreated using:

- A MATLAB program to solve the BVE
- Data from the NCEP/NCAR reanalysis

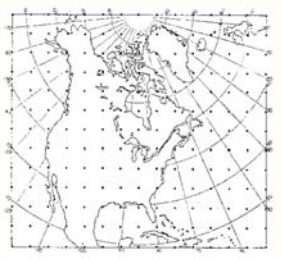
The initial dates for the four forecasts were:

- January 5, 1949
- January 30, 1949
- January 31, 1949
- February 13, 1949

The matlab code is available on the author's website
http://mathsci.ucd.ie/~plynch/eniac

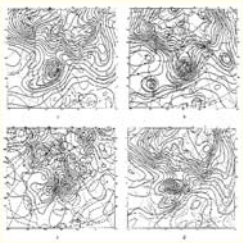


Bulletin of the American Meteorological Society, February, 2001

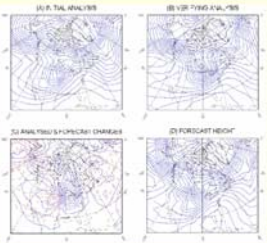


The computational grid for the integrations

ENIAC Forecast for Jan 5, 1949



Recreation of the Forecast



	Mean error		RMS error		S1 Score	
Case	Fcst.	Pers.	Fcst.	Pers.	Fcst.	Pers.
1	56.4	**−9.2**	113.4	**94.6**	**61.0**	62.2
2	31.1	**6.3**	**99.2**	114.6	**45.6**	62.9
3	−35.2	**20.4**	92.7	**89.2**	**46.4**	58.4
4	39.4	**1.1**	81.9	**80.7**	**39.5**	50.1

Mean error (bias), RMS error and S1 scores

Computing Time for ENIAC Runs

- *George Platzman, during his Starr Lecture, re-ran an ENIAC forecast*
- *The algorithm was coded on an IBM 5110, a desk-top machine*
- *The program execution was completed during the lecture (about one hour)*
- *The program* `eniac.m` *was run on a Sony Vaio (model VGN-TX2XP)*
- *The main loop of the 24-hour forecast ran in about 15 ms.*