weather by computer

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A Report from





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ANALYSIS



Ancient Brahman law decreed that a weather forecaster who predicted badly should have his tongue removed, cutting off the source of the poor weather report. This did nothing to improve the weather forecast, gave pause to would-be applicants for the job, and did little to advance the science.

Methods have improved since and the sanctions imposed for failure reduced to civilized grumbling. There even may come a day when the citizen's irritation with the weatherman is rare. The meteorologist's own initiative in improving his chances with more refined forecasting tools will be the cause. Most recent of these is the digital computer, complex, extremely fast, highly versatile. Still only in its initial use stages by weathermen, it is already helping produce more accurate and detailed analyses and forecasts with a wider range of form - upper air charts, surface pressure, wave height, sea and swell.

A case in point is described in the following pages . . .

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Cmdr. Paul M. Wolff, Officer-in-Charge, FNWF, explains operation of the 1604 computer to Capt. S. W. Betts, Director of Naval Weather Service.



The 1604, heart of the computer system at Monterey, will perform two billion computations during one weather analysis and forecast cycle. The Fleet Numerical Weather Facility was established at Monterey in February, 1961. At that time, computer produced weather and oceanographic forecasts were being routinely transmitted to one user, the Pacific Missile Range Meteorology Department, Point Mugu. By December, 1961, analyses and forecasts of the air/ocean environment which involves naval operations were being routinely produced to more than one hundred operating Navy units.

The mission of FNWF is to provide weather and oceanographic information required in support of world-wide naval activities. At the same time, the Facility is expected to develop new computer methods in data handling, analyses, forecasting, and in the rapid transmission of this information to users. The effort is basically an engineering application of computer technology. Most of the forecasting techniques used were developed by practicing meteorologists; computer programs have been developed which imitate these time-tested hand techniques. Much of it involves enormous computation volume - detailed sea and swell analyses and forecasts, mixed layer depth computations, large-scale atmospheric flow patterns on a hemispheric scale, and detailed predictions of weather conditions at a particular time and a particular place for a specific type of naval operation. By conventional hand methods, the task is impossible, for the computations necessary for one day's operation at FNWF exceed six billion.



Hemispheric weather is predicted from this building on the Naval Postgraduate School campus. A second 1604 computer system is used here for training naval officers.



The numerical print-out of a "depth of mixed layer" forecast by the FNWF computer system. Translated, this contoured forecast will show Fleet commanders temperature for both sea surface and mixed layer (F.), the mixed layer depth in 10's of feet, and the sea state based on wind code. These computer predictions determine equipment settings for submarine detection.

how it's done...

Incoming weather reports are received by land-line and radio teletype circuits from several thousand reporting stations around the world as well as more than one thousand ships at sea. This data is automatically collected and placed on magnetic tapes by Control Data 160-A computers. The program in the larger Control Data 1604 computer then edits the data and produces charts of individual environmental parameters, both subsurface, on the ocean, surface, and in the air above it for a particular time. Each one of these analyses covering the northern hemisphere contains information at 4,000 geographic points. Forecasts are then produced extending forward for two days in time with forecast fields showing temperature, pressure, and so on for each hour. Analyses and forecast fields in the form of contoured charts are then transmitted to other Navy weather centrals where they are translated to naval operation forecasts by hand and by small computers. The number of specific naval activities now receiving weather information in the form of computer produced forecasts is increasing. These are tailored to the place, time, and form of weather information required for the particular operation in progress. This pin-point service really exploits the computer capability in environmental prediction to an advanced

degree. For example, one complete analysis and forecast cycle involves over two billion individual computations at present and is being continually expanded. This is possible for the first time with the present generation of large computers like the Control Data 1604, in which previously required re-computations and error checking have been eliminated from operational programming.

The computer programs are designed to run entirely without human intervention. Stopping the computer while the operator made decisions was tried and rejected as being too slow and inefficient. With highly refined computer programming, it is possible to forecast the weather surrounding a particular ship, plane, or missile. For example, a ship en route from Hawaii to California will find of little interest an area forecast describing conditions over several thousand square miles of ocean. When this forecast is derived from the hourly fields of wind, sea swell, cloud cover, and precipitation in the memory of the Control Data 1604 at Monterey, it can show the captain hourly conditions he can expect along the ship's route. To implement this technique, hourly observations are received at Monterey from many land stations and selected ships. The computer, with its ability to utilize many thou-



The solid-state electronics of the 1604 computer are housed in eight bays. In the center (under glass) is one of eight magnetic core memory "stacks" which store and issue the mass of weather data.



Computer-drawn weather maps are compared to transmitted hand-drawn maps. Plotted contours by the 160-A are accurate to 1/100th of an inch.



Cmdr. Ted Hesse points out the circular pattern of an East Coast hurricane on a "surface analysis" chart.

Control Data computers predict hourly positions, central pressures of all "lows" including fast-moving deepening cyclones. A storm forecast of such magnitude uses 8000 instructions, six minutes computing time for a 48-hour forecast.



sand observations in a single analysis, can produce information on the small time and space scales necessary for a specific time and place.

As an example of a detailed operational forecast, FNWF has been providing predictions for points on a grid less than 10 miles apart of sea height, sea temperature, wave height, and depth of mixed layer. These predictions are then used in determining equipment settings and tactics for submarine detection exercises in a given area.

Commander Paul Wolff, officer-in-charge at FNWF, explains the difference between this service and a conventional weather forecast with a hypothetical case over land. "A businessman schedules a round of golf with a client one afternoon. His newspaper forecast reads: 'Increasing cloudiness with showers today.' Since the client is an important prospect, the host does not want the activities dampened by significant amounts of rain. From a fully modernized computer forecasting system, it would be entirely feasible to produce a forecast for the 10-mile square area containing the golf course which might read as follows: 'Fair skies 12:00 to 2:00, increasing cloudiness 2:00 to 4:00 with showers between 4:00 and 6:00.' Using this forecast, businessman and client could obtain a tee-off time in the late morning and make some intelligent use of weather prediction."

the future...

In line with the mission handed to Wolff and the FNWF, the plans center around three words: develop, improve, disseminate.

Among programs already designed and under test are:

- ... Steering computations for the Navy's hurricane forecasters;
- . . . Charts to aid in forecasting precipitation and areas of clear sky;
- . . . Charts of all conditions for areas from grids 200 miles on a side down to 10 mile squares;
- ... Combined forecasts for the troposphere and any level in it;
- ... Routine radio and radar refraction computations;
- ... Refining by computer the type and kind of weather observations needed for improved accuracy;
- ... Salinity, sediment content, and temperature analyses at fixed ocean depths;
- ... Extent and size of surf at points on a particular beach;
- ... Ship routing, employing the computer's sea height forecasts.

These are only a few of the ambitious projects now underway at FNWF. At the same time, improvements are in motion to optimize such techniques as RF transmission of weather forecasts to distant places, direct reception of teletype data on magnetic tape in the computer's format, multiple data transmission, and ultra-high frequency data transmission using weather satellites.

When you consider that FNWF was once two naval officers in a cramped, windowless office in Washington in 1958, the advance in meteorological knowledge and scope of forecasting ability in little more than two years is unprecedented.

Although the FNWF complex is not alone in the field of computer weather prediction, its technique of using the computer to imitate successful hand methods is a unique combination of theory and empiricism particularly suited to a new science. The continued research and development there holds much promise for success in man's age-old contention with weather. Among some of the side-effects to be expected may even be a new stature for the weatherman in the eyes of the citizenry. Instead of being the focus of ridicule and annoyance, he could become a hero.

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Diagram of Control Data computer system at Navy's FNWF, Monterey, California.



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