ROYAL METEOROLOGICAL SOCIETY : AUSTRALIAN BRANCH MEETING

3 September 1974

Automation in Meteorology

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Mr Maine, Assistant Director Computing, of the Bureau of Meteorology, opened his address by posing the question: 'Why is it necessary to use very powerful computers for meteorological processing?' The answer lies in the complexity of the non-linear equations of atmospheric motion, which cannot be adequately solved analytically, and also in the enormous number of arithmetic and logical operations necessary for mathematically integrating numerical physical models of the real atmosphere. He then defined a number of important terms which recurred throughout the discussion. 'Hardware' and 'software' are by now standard, but 'skinware' is something of an Orwellian newcomer and is defined as the group of programmers and operators entrusted to develop the software and maintain it, and run the hardware. 'System' embraces the application of 'hardware', 'software' and 'skinware' and procedures for particular applications, *eg*, communications, analysis and prognosis (also included in the list of defined terms), or data handling and storage.

Mr Maine then surveyed some relevant background to automation in meteorology. Much of this is already part of universal meteorological folklore, but it is interesting to note that the genesis of the digital computer is now attributed to Atanasoff, who reputedly conceived the idea over a drink in a bar in 1937; a working model, using binary arithmetic, was built in 1939. The earliest Australian computer applications were undertaken in the University of Melbourne School of Meteorology, which in 1956-57 experimented with a barotropic prediction model. The Bureau of Meteorology undertook preliminary research into numerical analysis and prediction during 1963-64 on the CSIRO CDC 3600 machine in Canberra, then in 1968 took delivery of the first of its two IBM 360/65 computers.

Routine numerical Australian Region analyses and prognoses commenced in 1969, and at about the same time a data bank was created. During the same year the Commonwealth Meteorology Research Centre, now Australian Numerical Meteorology Research Centre (ANMRC) was also formed and multilevel primitive equation models were later developed. Since 1970 an operational broad scale hemispheric numerical analysis/prognosis system has commenced and intensive work has taken place on improved numerical methods in conjunction with ANMRC. Approximately thirty man years have been expended so far in automated analysis and prognosis research.

The aim of the Bureau's ADP organisation is to provide continuous support for the conduct of operational numerical analysis and prognosis and modelling research and to maintain an efficient data bank. For the system to evolve, there is a need to develop objective assessment criteria so as to allow sound progress in operational model development. In automation it is also necessary to avoid expensive relearning as staff changes.

The main elements of an automated numerical analysis, prognosis and communication system were then outlined; apart from the computer itself and the sequence of application jobs, the resident computer tasks to maintain facilities control, automatic

job sequence control, and the communications 'subtasks' form major components. However, man-machine interaction was singled out for particular attention. Human judgment, through interaction, is required to compensate for inadequacies in data, in meteorological science and in computing. There is also the requirement for human command and control of the ADP system. The problems in introducing such a system are basically twofold, technical and human. Technical problems may trap the unwary by causing breakdown when certain constraints are violated, for example those caused by the application of finite difference methods. An example was given of stable and unstable solutions to the heat transfer equation by examining the relationship between grid spacing and allowable timestep. Computational economy may be achieved by invoking implicit difference schemes, although time truncation may cause errors for sufficiently large timesteps. Human or personnel problems may arise if staff are unprepared industrially or technically for changes in work patterns caused by automation. These may be solved by management studying and adjusting work patterns in planning for the field use of numerical products, and by staff gaining adequate training and familiarisation in the ADP system and the development of procedures for field use of computer products.

Benefit cost ratios have become a new deity and must be considered. Mr Maine said the major costs included hardware and other facilities, and systems development and running. Benefits accrue from gains in the efficient and economic handling of operational tasks, an increase in the scope for scientific attention to meteorological problems, avoidance of staff increases that would otherwise be required to effect improvements in routine tasks and improved skill from man-machine products. Mr Maine considered that the monitoring of ADP benefits must match the scale of the product, *eg*, we should not look for direct improvement in thunderstorm or maximum temperature forecasts if the system has been geared to broader numerical products and if there have been no objective procedures established to link such forecasts with the numerical product. In planning for future requirements, it is necessary to consider developments and trends in meteorological and numerical modelling, and developments in computing itself. Although the Bureau is still using filtered models operationally, and the ANMRC grid P.E. model is still not operationally economic for use on the IBM 360/65 machine, great promise for reducing the heavy computational requirements necessary to extend the effective range of prediction is shown by the ANMRC spectral P.E. model. Operational long range forecasting, weeks or months ahead, using global, stochastic or general circulation models also does not appear to be feasible with the current machine. Mesoscale modelling requirements handling severe weather systems such as thunderstorms also appear to exceed the Bureau machine's capacity.

On the ADP front, developments in electronics, *eg*, micro-integrated circuits, are leading to miniaturisation of computers and decreased costs of storage elements. These developments are in turn leading to increased emphasis on special processors for special applications, distributed or decentralised computing, connection of linked computer systems, and different computer architecture, *eg*, hybrid computers, and larger, faster memories. An interesting and relevant example of new architecture is provided by a parallel processor which has N elements or parallel CPU's and memories that are able to act on their own data streams or interact with each other's. Control is exerted from a central processor and central memory. Mr Maine indicated how such a computer could drastically reduce the computing time for predictions from present numerical models. He said he believed that since parallel operations are characteristic of the way the atmosphere functions, as the physical complexity of atmospheric models increases there will be an increasing appeal to parallel processors to produce timely operational results.

Future planning of the Bureau could envisage the development of a national computer system network comprising the Head Office large computer system, Regional Forecast Centre (RFC) medium computers in Sydney and Brisbane and smaller though compatible computers in the other Regional Offices. These could be connected to the Bureau's private wire network, Central Telegraph Offices (PMG), TELEX, and Department of Transport AFTN network. In addition to its current functions of broad-scale modelling, research and development, data handling and storage, such a central computer would become heavily involved in finer scale predictions, tropical modelling,

time averaged weather predictions and communications control. With the development of a Bureau network, the regional computers could carry out functions of operational finer scale analysis, routine data processing and communication, development of objective forecasting aids, plotting and data array, hydrometeorological and atmospheric dispersion monitoring and warning, weather forecasting and warning message composition and editing, teleprocessing and facsimile picture compression and decompression. In addition the regional computers could be coupled with the STD telephone network, enabling direct keying in by field observers of observational messages, whose input could be automatically controlled.

Summarising, Mr Maine emphasised that automation in the Bureau of Meteorology is still in its early stages and a number of challenges lie ahead with the application of further scientific developments and automation. Re-orientation or retraining in new skills will be required of meteorologists, and management recognition of the need to match personnel attributes to jobs associated with automation will be required. A most suitable development for automation in meteorology would be the use of fast parallel central processors and a network of regional processors balanced largely by aspects of efficiency of operation and economy. The aim would be to provide improved meteorological service, based on a better scientific insight to atmospheric processes in general.

In opening the discussion following the talk, Dr J. Garratt inquired about the role of visual satellite data in the evolving system. Mr Maine replied that picture recognition of satellite data has not yet been automated, and manual interpretation of cloud pictures is used to modify the numerical analyses by generation of pseudo observations. However, the computer can be and is already of assistance in increasing the efficiency of picture production and processing and tracking of the satellite. In answer to a question by Mr T. Hayles about the proposed replacement for the IBM 360/65 duplex system, Mr Maine replied that it would be premature to answer directly but gave examples of recent British and American acquisitions of IBM 370/195, CDC 7600 and ILLIAC IV machines. Professor T. Asai enquired about the analysis techniques applied over the data sparse areas south and west of Australia. Mr Maine stated that a variety of techniques are employed, including use of model forecast fields as first guess analyses, interpretation of satellite pictures, and manual methods based on continuity and conceptual models. Mr J. Brown in commenting on Mr Maine's vision of adequate scientific understanding, data, and computing power as necessary factors for progress in automation asked which of these should come first. Mr Maine considered that none of them could be considered in isolation but that development should be on all fronts.

Dr W. Gibbs challenged Mr Maine's comments concerning matching the scale of evaluation and by implication confining it to the broad-scale numerical models. He considered this to be an academic exercise, symptomatic of too much concentration on pure scientific application, rather than systems application. The benefits in terms of improved weather forecasting for the customer must also be assessed. He cited the developing US AFOS (Automation of Field Operations and Services) system as an example of customer oriented priorities. Mr Maine replied that although quantitative benefit cost ratios in ADP are not easily obtained, he agreed that benefits must be determined. He indicated that the developments he envisaged dealt with such regional aspects as planned automation of 'clerical' type meteorological functions, and forecast construction editing and transmission, facsimile and visual display. The system in fact also facilitates an AFOS type concept. In reply to a question from Mr I. Bell concerning benefit/cost ratios, Mr Maine replied that, in certain areas, model prognoses are already clearly superior to those produced manually. In addition requests for meteorological data have been greatly speeded up and the function of quality control has been facilitated. The system also has the potential, if peripheral equipment is acquired, to vastly reduce the amount of paper used. The Bureau's present data bank information services could not be carried out without the computer. While agreeing with Mr K. Morley that there is a compelling need for adequate scientific understanding, Mr Maine offered his opinion that this would be closely linked to developments in computing power because of the complexity of adequate numerical atmospheric models.

Mr D. Reid suggested that automation of observations could lead to their increased frequency. Mr Maine indicated that four dimensional assimilation was one way of handling increased frequency but stated that there may also be greatly increased hardware costs which impinge upon the economies, and that there was a need to determine the most important quantities to observe. The meeting ended on a whimsical note when Mr I. Bell asked if the computer will spell the end of fronts. Mr Maine replied that the atmosphere will remain despite automation.

P.F.N.