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FGGE—THE GLOBAL WEATHER EXPERIMENT

FGGE is the acronym for First GARP (Global Atmospheric Research Program) Global Experiment. The following account is a slightly shortened version of a WMO Press release. We hope to publish an article before the end of 1978 describing the contribution of the Meteorological Office to FGGE.

The World Meteorological Organization (WMO) has launched one of the largest and most complex scientific undertakings ever attempted. Thousands of scientists from virtually every country in the world will be using the most sophisticated tools such as earth satellites, instrumented aircraft, ships, balloons, free-floating ocean buoys, and gigantic high-speed computers to subject the entire atmosphere of the earth and the sea surface to the most intensive surveillance and study ever made. The experiment will last for one full year with two separate periods of two months for special observations in the tropics and southern hemisphere. The purpose of this highly co-ordinated international effort is to ascertain the attainable limits of weather forecasting and to investigate the mechanisms underlying climatic change. The extension of the range of accurate weather forecasts and better understanding of climate variations both have enormous economic value.

Meteorology—both public service and science

The research side of meteorology has so far not caught the public eye. Governments and the citizens at large have tended to see meteorology exclusively as a public service. There is, however, an increasing recognition that the science of meteorology must develop further to meet the ever-increasing national needs for extended weather forecasts and warnings to protect life and property and to meet the many daily requirements for weather information. On the international level this recognition was evidenced by United Nations General Assembly resolutions adopted as far back as 1961 and 1962. These resolutions are the immediate origin of the World Meteorological Organization's major operational activity, the World Weather Watch, and the important research activity, the Global Atmospheric Research Program (GARP). The success of both of these programs has made possible the Global Weather Experiment.

The fundamental problem of meteorology

What then is this gigantic research project involving so many thousands of scientists and their ingenious technological equipment? In order to find out how far ahead the weather can be forecast, meteorologists must obtain a better understanding of the behaviour of the global atmosphere and the physical processes underlying that behaviour. This will enable them to develop improved mathematical–physical models of the atmosphere which will be used in the effort to make weather forecasts more reliable and of longer validity. Successful accomplishment of these two formidable tasks will also make it possible to work towards designing a cost-effective global observing and forecasting system for routine use by the nations of the world, that is to say, an even more effective World Weather Watch.

The nub of the problem—and it has not changed significantly in the more than one hundred years of the existence of WMO and its predecessor organization IMO—is how to improve weather forecasts. The fundamental problem of accurately forecasting the weather presents two basic difficulties. The first is to obtain rapidly enormous quantities of precisely observed data covering such elements as atmospheric pressure, temperature, humidity, and wind speed and direction at the earth's surface and at different heights from an adequate global network of observing platforms using different techniques. At the present time there is still a lack of weather observing stations, especially over the oceans and in the southern hemisphere. The second difficulty is to process these enormous quantities of data equally rapidly (otherwise the weather forecast might well be out of date before it appeared).

Until recent times practical day-to-day forecasting was done mainly by plotting the weather observations on maps and analysing the major weather systems, that is to say, areas of low pressure and high pressure. Partly on the basis of theoretical considerations, but also and very largely on the basis of his own experience, the forecaster would determine the future speed and direction of these systems and the extent to which they would intensify or diminish. This would lead him in turn to a forecast of the weather which would be associated with the systems.

The mathematical revolution in meteorology

About 60 years ago a British meteorologist, L. F. Richardson, devised a procedure whereby the weather could be predicted by mathematical equations based on well-known physical laws. At the time his procedure smacked of science fiction. It would have required 64 000 mathematicians working with calculating machines day and night throughout the year, processing surface and upper-air data received from 2000 weather stations scattered over the globe. But Richardson was no idle dreamer. He originated what we now call numerical weather prediction. This technique became practicable 25 years later. The American mathematician John von Neumann was the first to use an electronic computer operated by a team of meteorologists and mathematicians to analyse and predict weather by mathematics and machines.

The technological revolution: satellites and computers

The technological revolution which produced high-speed electronic computers also produced artificial earth satellites in the 1950s which opened a new dimension in weather observational capacity. Today in the words of a great Norwegian meteorologist, the late Sverre Petterssen, 'the principal technological barriers have yielded. . . . . It has now become possible to keep the whole atmosphere under constant surveillance and to process vast volumes of data on a "real-time" (instantaneous) basis'. Without this technological revolution we should not have today's global weather observation scheme known as the World Weather Watch. Nor would it be possible to launch the present Global Weather Experiment.

A major problem facing research meteorologists trying to improve atmospheric prediction models—and hence to obtain better forecasts—is that they do not have a really satisfactory world-wide set of observations with which to test their models. Scientists specify that an ideal data network would be observation stations spaced 500 km apart collecting pressure, temperature, humidity and wind data at different heights up to 30 km. Without such a data set it is not easy to distinguish between those forecast errors which are due to inadequacies of the models and those caused by the lack of good observations. A good global data set for the whole year and thus covering all the seasons would be invaluable. This is the task of the Global Weather Experiment.

The Experiment and the need for more data

One thing is clear. In order to improve atmospheric models, the Global Weather Experiment must collect a more complete set of data on the condition of the atmosphere globally than is now available from existing observational stations.

The Build-up Year for the Global Experiment began on 1 December 1977. Some of the scientific tools needed for the Experiment such as satellites and the communications and data-processing system will be brought into operation. The preliminary data-collection period started on 1 January 1978. Observations from World Weather Watch stations and satellites in operation will be collected and analysed to enable the data transmission and processing system to be tested. The Operational Year begins on 1 December 1978 when the basic observing and data processing system goes into full operation. This phase of intense global coverage will last for 12 consecutive months. During that year there will be two special observing periods: 5 January–5 March, and 1 May–30 June 1979.

The basic observation system

The basic observation system during the whole 12 month period of experiment will be WMO's global weather system, the World Weather Watch (WWW). In any 24 hour period WWW collects, and transmits to processing centres, standard meteorological observations from more than 9200 land stations making surface observations, nearly a thousand stations making upper-air observations, 9 fixed ocean weather ships and some 7400 merchant ships making surface observations only, and reconnaissance and commercial aircraft providing more than 3000 reports daily. The Global Experiment will be the first occasion where a truly integrated system of satellites is used to observe the earth's atmosphere. Five geostationary satellites will continuously monitor the equatorial and subtropical belts the world round, and a series of polar-orbiting satellites will be used to determine the temperature structure of the atmosphere as well as to provide information on cloudiness and the temperature of the sea.

Inadequacy of the basic observation system

The enormous masses of observational data collected are nevertheless inadequate for a valid global experiment. The ideal requirements of research meteorologists are for a data set consisting of intensive meteorological observations from the entire globe for a full year. This is impossible for financial reasons alone. As a measure of how expensive this kind of research is, the annual cost of operating one fixed ocean weather ship is about $2 million. An ideal project would call for 200 ships just to cover upper-air observations in the tropics alone. A compromise is necessary between what is scientifically desirable, what is technologically feasible and what is economically attainable.

Additional special observation systems to attain global coverage

The scientists managing the experiment have therefore gone ahead with a less perfect but reasonably satisfactory scheme. They will fill the gaps by means of Special Observing Systems. The observational plan includes two specially chosen periods mentioned above (5 January–5 March, and 1 May–30 June 1979). During each of these periods there will be concentrated observational coverage for 30 days.

The gaps to be filled by data collection during the Special Observation Periods relate largely to upper-air information needed from the equatorial tropics, and surface pressure and temperature from the vast ocean areas of the southern hemisphere. To collect this information a formidable assortment of highly sophisticated scientific and technological tools will be used.

Data collection in the tropics especially over the oceans

First, to obtain upper-air information from the tropics, rawinsonde balloons released from land stations and from some 50 ships will be used. The development of a special rawinsonde system for deployment on ships has been undertaken by WMO.

To supplement these activities over the tropical oceans not adequately covered by ships, instruments called dropwindsondes will be used. These are to be released from about 12 aircraft flying each day at an altitude of about 9–12 km over carefully planned courses in the Indian, eastern and central Pacific, and Atlantic Oceans. As the instruments descend they will transmit back to the aircraft information on pressure, temperature and humidity as well as their true locations which they pick up from an Omega Navigation System. These data are then to be fed into the main data-processing system.

Additional data will be collected by commercial jet aircraft equipped with apparatus which automatically records on magnetic-tape cassettes. These data can have special value when the aircraft is flying over areas from which other reliable observations are sparse. This will increase the information gathering resources by some 80 commercial airline aircraft. A number of other commercial aircraft will install equipment for automatic transmission of meteorological data to ground stations via satellite (ASDAR).

To obtain data above the level at which the aircraft fly, use will be made of a series of about 300 constant-level balloons. These will drift along at an altitude of about 14 km and will provide certain required data. The balloons will be launched from Ascension and Canton Islands. The signals from the balloons and their corresponding locations are picked up by one of the polar-orbiting satellites and then incorporated into the data-processing system.

Drifting buoys in the southern oceans

From the southern oceans, that other great and normally silent area, information will be collected by drifting buoys. Three hundred of these buoys will measure atmospheric pressure near the sea surface and the temperature of the sea water within the upper one or two metres. Some buoys will also measure air and water temperature and wind speed. All these data are to be picked up in the same way as those from the constant-level balloons (namely by polar-orbiting satellite) and then transmitted to the data-processing centres.

Special research satellites

Another supplementary observing facility will be provided by two research satellites. They will provide radiation data making possible estimates of sea-surface temperature, atmospheric temperature profiles and moisture content, and information on the sea-ice coverage. One will also yield data on atmospheric ozone content and distribution, and the other on wind speed and direction at the ocean surface. This is, of course, in addition to the polar-orbiting and geo-stationary satellites.

Regional experiments in association with the Global Weather Experiment

Several specialized experiments having to do with significant regional phenomena (Asian monsoon, west African monsoon, and the weather of the polar regions) which are important elements of the global atmospheric circulation will be carried out in conjunction with the Global Weather Experiment. These include projects which collect important oceanographic information that will permit more definitive studies of oceanic responses to atmospheric influences and vice versa. The principal regional experiments have their own scientific aims, but will provide detailed data for the Global Experiment and will benefit, in turn, from the improved global data set provided by the Global Experiment, since the regional phenomena are inextricably linked with the global circulation. These have relevance not only for the task of improving weather forecasts and extending their useful range, but also for studying the physical processes in the atmosphere leading to a better understanding of climate.

The Asian Monsoon Experiment (MONEX)

In order to understand the physical phenomena that bring life-giving rains and cause devastating droughts in Asia, research projects are under way to obtain the data required for a better analysis and evaluation as the basis for improved forecasting and other applications to human activities in the region. Because of the natural division of the monsoon into a winter and summer phase, and because of the regional distinctions in the monsoon between the eastern region and western regions of Asia, two separate efforts are required, namely a winter MONEX and a summer MONEX. Both of these are designed to observe and obtain a more comprehensive understanding of the regional and seasonal fluctuations of the Asia monsoon and its effects on the global atmospheric circulation. The experiments will cover the area of the west Arabian Sea, the north of the Bay of Bengal, and the South China Sea.

The West African Monsoon Experiment (WAMEX)

The west African region, like Asia, is subject to wide interannual variations in rainfall, and is subject therefore to prolonged and severe periods of drought.

WAMEX is an experiment mounted by the countries of the region to take advantage of the enhanced global data coverage during the observational phase of the Global Weather Experiment. It will also contribute significantly by providing increased detail in the tropical observing network required by the Global Experiment. Its principal aim, however, is to attempt to clarify the three-dimensional structure of the monsoon and to understand the physical mechanism which generates and maintains the monsoon. Ultimately it is expected that the improved understanding of the phenomenon in its planetary, regional and subregional aspects will provide the basis for improved forecasting and other practical applications to regional planning.

The Polar Experiment (POLEX)

The polar regions, both North and South, are the major heat sinks in the global atmospheric–oceanic system, and as such constitute a significant element that has to be taken into account in the Global Weather Experiment. The Polar Experiment (POLEX) is designed to be carried out during the Global Experiment in order to provide an improved data set in the polar regions, provide calibration and 'ground truth'* for the satellite observations, and to assist in modelling high-latitude processes that are of importance in the global circulation. These data will also be especially important for assessing the role of snow and ice cover in climate dynamics. Much of this work will be carried out as part of ongoing national and international studies in the polar regions, but within the context of the Global Weather Experiment and the World Climate Program of WMO.

The value of the earlier tropical experiment (GATE)

The Global Weather Experiment will benefit considerably from the GARP Atlantic Tropical Experiment (GATE) which made extensive meteorological and oceanographical observations of one-third of the earth's tropical belt from 15 June to 30 September 1974. The purpose of that activity—until the Global Experiment, the largest scientific experiment ever undertaken—was to collect data which would enable meteorologists to have a clearer picture of the behaviour of the tropical weather systems and their ultimate effect on global weather. GATE was an outstanding success and it will contribute greatly to the planning and implementation of the Global Weather Experiment.

The management of the Experiment

The number of scientists managing the vast global weather experiment is surprisingly small. The management consists of a small group of meteorologists, oceanographers and technical specialists who form a centralized FGGE Operations Centre within the Secretariat of WMO in Geneva. Following the practice of the World Weather Watch, each country participating in the Experiment will look after its own contribution to the gigantic experiment. The total of such contributions is enormous. In addition to the normal contribution of the 147 Members of WMO, all of whom participate actively in the World Weather Watch, 75 of these Members plus five intergovernmental organizations are making special or additional contributions to the Global Experiment and the regional projects related to it. These contributions include funds for such things as special instrumentation, 4 polar-orbiting and 5 geostationary satellites, 43

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* e.g. surface pressure to act as a datum for absolute values of geopotential.

research ships, 12 special research aircraft, 300 constant-level balloons, 300 floating buoys, masses of observational and communications equipment, the time of thousands of scientists and the use of the world's largest computers.

A decade of planning

The role of the Operations Centre is to complete the extensive planning in time for the observational year. The initial planning of the Experiment actually started at a meeting of 50 prominent scientists in Stockholm in 1967. Since then, the detailed planning of every aspect of the gigantic experiment has engaged the efforts of hundreds of meteorologists and technologists in many meetings all over the globe.

The monitoring and co-ordination of the Experiment

Once the observational year begins, the Operations Centre will monitor the performance of the observing system as a whole and initiate corrective actions when necessary on the basis of reports on how the various systems are working. It will also co-ordinate activities with the special and regional programs mentioned earlier. The Operations Centre has available at all times the full resources of the WMO Secretariat, and policy guidance from WMO's Intergovernmental Panel and from a small scientific advisory board, both established especially for the Global Experiment. Finally the Operations Centre will arrange for international assessment of the experiment and prepare a report on the conduct of the experiment and on the experience gained.

Data management and processing

The wide range of observing systems already described will produce an enormous amount of data. The management of these data presents a formidable task far beyond the capacity of any single country or organization. These data will in fact be organized and processed into a complete and consistent set for use in the ensuing research work in many countries. The countries and organizations which will play the major role in this important but arduous task are: Australia, Finland, France, Federal Republic of Germany, Japan, The Netherlands, Sweden, United Kingdom, USA, USSR, the European Space Agency and the European Centre for Medium-range Weather Forecasts.

What happens to the fantastic masses of data collected? The global data sets are used in two quite different ways. First, the meteorological centres of the World Weather Watch in all parts of the world will receive a large increase in the amount of information that normally comes into them. They will receive this in real time, that is to say, almost as it happens. This will enable them to improve the quality of their routine operational services and any research and analytical work that they are undertaking.

Research to start during operational year

Of greater significance, a wide variety of research based on the data sets produced by the Experiment will be carried out by national services, academies and universities. The intensive period of research will begin during the operational year. It will continue for several years thereafter. Areas of study will include prediction and predictability experiments, diagnostic studies, sensitivity experiments, and investigations of seasonal variations. Arrangements are being made for international co-ordination of much of the subsequent research and evaluation and for wide dissemination among scientists of the results of the Experiment.

The possible results of the Global Experiment

At this stage it would be foolhardy to venture a guess as to the specific results of such a gigantic scientific undertaking as the Global Weather Experiment. It may well be that by the middle 1980s the consolidated results will make it possible to extend the useful range of weather forecasts to 10 days or more. But at the moment we cannot be sure. However, we can be optimistic that all this effort on the part of thousands of scientists and technologists and the expenditure by most of the governments of the world of considerable resources will lead to a better understanding of atmospheric motion so that meteorologists can develop better models for weather prediction. We can be equally optimistic that the Experiment will result in a substantial strengthening in the operation and effectiveness of the present World Weather Watch. This could have economic benefits far outweighing the cost of the Global Weather Experiment. Finally the data sets and their study and analysis will make possible a clearer understanding of the mechanisms underlying climate variations, a subject of increasing interest and importance for the whole of mankind.

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A TEST OF DATA ACQUISITION AND PROCESSING FOR FGGE

By M. V. JONES and J. BALLENTINE
(Meteorological Office, Bracknell)

SUMMARY

A Data Acquisition and Processing Test was carried out by the UK Area Sub-centre for Surface-based Data in July 1977 in preparation for FGGE. Statistics of the data collection are presented, together with some suggestions for improved data capture in the future.

INTRODUCTION

The First GARP (Global Atmospheric Research Program) Global Experiment (FGGE) is an attempt to improve meteorological telecommunications and computing resources over the whole world and to use them to attack the problem of the medium-to-long-range predictability of the atmosphere. An unprecedented collection of observations is planned, involving both conventional techniques and specially deployed observing equipment. The Operational Year of FGGE will begin on 1 December 1978, and will be preceded by a Build-up Year.

There are detailed plans for assembling these data, involving many collecting centres in nine countries. The Meteorological Office acts as an 'Area Sub-centre', with responsibility for collecting surface, radiosonde and pilot-balloon observations from Europe (WMO Region VI excluding USSR), Africa (including the Atlantic and Indian Ocean islands in WMO Region I), and the Middle East (WMO Block 40, namely Syria, Lebanon, Israel and Jordan in Region VI, and Iraq, Iran and the Arabian peninsula in Region II). Two other categories of observations are to be included in the collection, namely all aircraft and surface ship reports received in real time via telecommunication channels from anywhere in the world. Similar observations from the rest of the world are to be collected by three other Area Sub-centres.

Such data are described as 'surface-based'. The observations are assembled into ten-day periods and sent to the 'Surface-based Data Centre' in Moscow. This centre in turn merges the collections from the four Area Sub-centres and the 'Space-based and Special Observing Systems Data Centre' (in Sweden) for retention at one of the two World Data Centres, also in Moscow. The flow of data is depicted in Figure 1.

THE DATA PROCESSING AND ACQUISITION TEST

As part of these plans the UK Area Sub-centre undertook to execute a test in respect of observations for 1–20 July 1977, that is to say two ten-day periods.

Details are given below, together with some results of the test, and some suggestions for a more effective collecting system. The principal tool available was the 'Synoptic Data Bank' (SDB) which is normally used in real time in support of forecasting and archiving of data.

Data arriving at Bracknell through the Global Telecommunication System (GTS) and domestic channels are checked for correctly formatted bulletin headings, before being submitted to the SDB. The SDB software inspects the bulletin headings in order to sort the observations into types (SYNOP, TEMP,

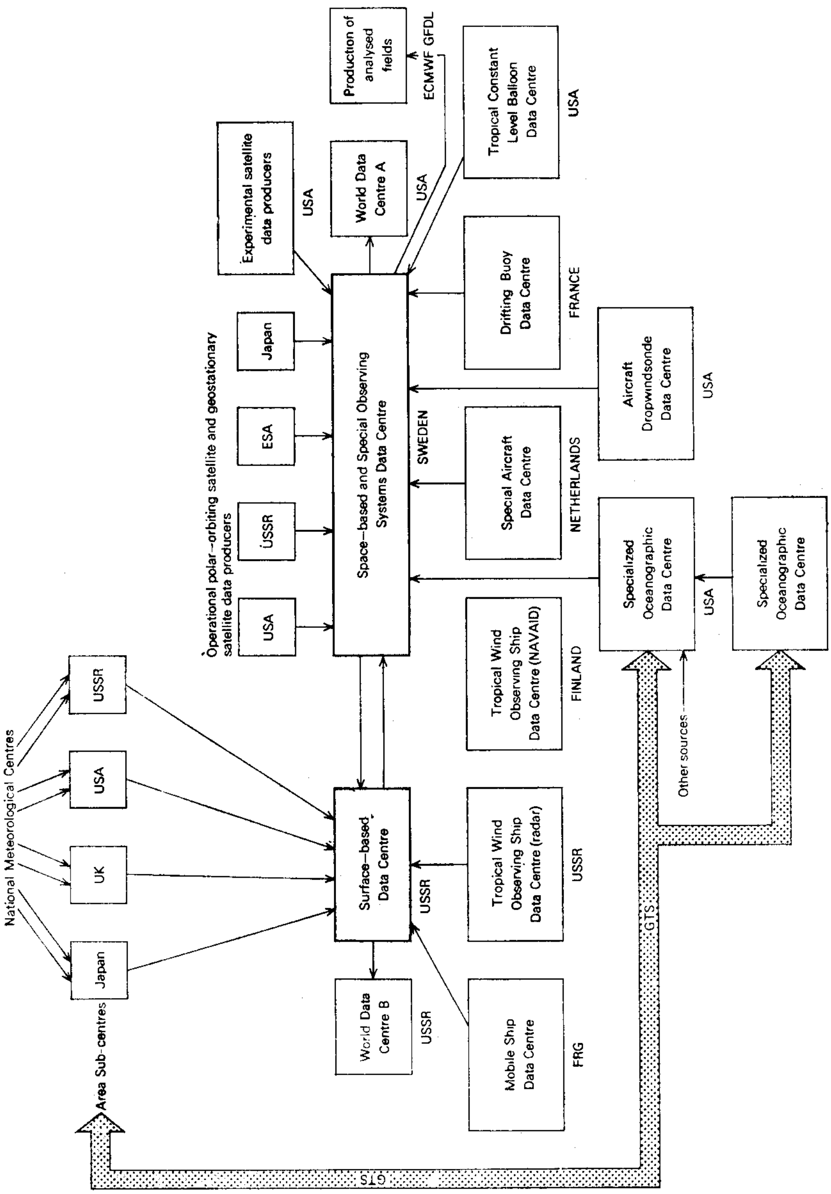

FIGURE 1—THE SCHEME FOR COLLECTION OF DELAYED DATA

ECMWF = European Centre for Medium-range Weather Forecasts
GFDL = Geophysical Fluid Dynamics Laboratory (USA)

AIREP etc.) and, after applying quality-control procedures, stores them in data sets. One data set (a 'bank') contains 12 hours of reports, and in normal operation reports may be stored if they arrive within 36 hours.

Software has been written to inspect the banks, so that their contents may be monitored at any time in terms of observation type and geographical area. An extension of this technique enables a bank to be analysed by time of storage. These two facilities will be referred to below as 'Data Monitoring' and 'Time of Receipt' respectively. After 60 hours of immediate accessibility by computer programs and enquiry terminals each bank is copied to magnetic tape for five years' retention.

COLLECTION FROM REGION VI AND OCEAN WEATHER SHIPS

Bracknell receives almost all the available reports from Europe and Ocean Weather Ships (OWS) and also from Syria, Lebanon, Israel and Jordan, so that the real-time SDB in this case almost meets the requirements of FGGE. However, during this test period the Data Monitoring program was run after 36 hours to identify any missing or corrupt observations, from any of the 32 National Meteorological Centres (NMCs), so that we might request a repeat of those reports from the appropriate NMC. OWS observations were not monitored.

It is interesting to note that most observations identified by the program were missing rather than corrupt. From the correspondence received from the NMCs it appeared that many of the requests referred to observations which were no longer made, that is to say that the station lists used were out of date, even though a great effort had been made to keep up with notified changes.

The NMCs were asked to send their late observations on 5-hole paper tape within 60 days, so that they could be read into the computer alongside the observations from Africa and the Middle East.

COLLECTION FROM REGION I AND THE MIDDLE EAST

Experiences gained a few years ago with the GARP Atlantic Tropical Experiment (GATE) indicated that the collection of observations from Africa on 5-hole paper tape (as used in telecommunications) was practicable.

Firstly it was necessary to request (through WMO) the participation of 53 NMCs and ask for a contact in each NMC. On receiving a formal agreement, three fibre boxes and some detailed instructions were to be sent to each NMC. The boxes were to be used to post observations back to the Area Sub-centre, with seven days' data in each box.

Careful instructions were sent with the boxes. Again, experience with GATE was helpful, as was conversation with the occasional African visitor to the Meteorological Office at Bracknell.

DATA PROCESSING

During the test period itself the only data processing was that involved in the normal operational Synoptic Data Bank activity, together with Data Monitoring of European observations as described above.

The plans allowed a period of 73 days after the last observation for each box to return to the United Kingdom, so that reading paper tapes for 1–7 July was begun on 18 September.

This phase of processing was in three parts: firstly to copy the contents of paper tape into a disc data set, secondly to add those observations to the appropriate bank (previously copied back to disc from an archive magnetic tape), and finally to extract the required observations for arrangement into the format necessary for dispatch on magnetic tape to Moscow.

The first phase took place during the day, when staff were available to operate the paper-tape reader and the visual display unit (VDU) used for control. By means of the VDU it was possible to display the first few characters from each tape, as a check that the tape had been mounted correctly. This facility also proved invaluable for deciding how to process some of the tapes which arrived with formats bearing little resemblance to those we had requested.

The second and third phases took place overnight, since no special operator action was required other than to ensure that the jobs were run in the correct order. During these phases the extra observations were incorporated into our own archives.

Each magnetic tape was dispatched (on time) to the Surface-based Data Centre via the Foreign and Commonwealth Office.

QUANTITY OF DATA RECEIVED

Region VI

The exact numbers of observations collected in response to Data Monitoring messages were not measured. However, it is true to say that every European NMC received notification of at least one missing observation during the 20 days. Some of the missing observations were in fact reported as NIL, but could not be recognized as such by the SDB software.

In reply to the messages 192 paper tapes were received. Some of these tapes contained all the observations for the particular day rather than just the missing or corrupt observations that were requested. Such tapes could be used, but some tape-reading time and disc space were unnecessarily occupied. Tapes from two NMCs were received too late to be of use.

These results are summarized in Table I(a).

Africa and the Middle East

Table I(b) presents an analysis of the extent of participation in the collection of delayed data by African and Middle Eastern countries.

The principal question to be asked about the collection of delayed data is: 'How many more data have been collected than were available in real time?'. So as background information, Tables II and III present statistics of the collection of data in real time from Africa and the Middle East.

Table II is extracted from the results of a survey carried out at Bracknell in connection with World Weather Watch (WWW). Observations from Region I (Africa) were monitored in real time from 1 to 15 September 1977 as they arrived in the Synoptic Data Bank. The table shows that in general less than half the expected data are received within six hours.

Table III gives for each time and type of report and each WMO block number the maximum and minimum numbers of reports for any one day (out of the 20 days of the test period) arriving through the GTS within 36 hours. There is an alarmingly large number of zeros in this table, particularly in the upper-air columns. Elsewhere there are indications of a wide variation from day to day, especially in the southern blocks.

TABLE I—PARTICIPATION 1–20 JULY 1977

(a) *Region VI excluding USSR*
All 32 NMCs had at least one missing or corrupt observation.
192 paper tapes were received in time.
Two NMCs sent data too late.

(b) *Africa and the Middle East*

	No. of NMCs	No. of NMCs who had formally agreed to participate
All data received in time to be incorporated	33	15
Some data received in time, some too late	2	2
All data received too late	4	3
No data received	14	2
Totals	53	22

TABLE II—WWW MONITORING OF REGION I FROM 1 TO 15 SEPTEMBER 1977 AT RTH BRACKNELL

	Surface Percentage received*	
	00 GMT	12 GMT
Cut-off (hours)		
HH + 1	14	16
HH + 3	22	40
HH + 6	29	47
Missing at HH + 6	71	53

	Upper Air Percentage received*	
	00 GMT	12 GMT
Cut-off (hours)		
HH + 3	19	23
HH + 6	32	38
Missing at HH + 6	68	62

* The number of reports received is expressed as a percentage of the number expected (according to WMO documents).

TABLE III—MAXIMUM AND MINIMUM NUMBER OF REPORTS THROUGH GTS (PER DAY)

	Time of report (GMT)							
	SYNOP				UPPER AIR			
WMO Block Nos.	00	06	12	18	00	06	12	18
40	57	131	95	101	11	13	15	6
	34	82	88	52	6	0	11	0
60	44	57	59	74	7	30	6	36
	36	49	52	36	4	24	3	26
61	44	66	65	56	2	37	9	40
	13	49	39	15	0	12	3	10
62	24	38	40	25	6	23	4	3
	0	13	20	16	1	2	1	0
63	31	59	53	25	4	12	5	0
	12	7	0	0	0	1	0	0
64	19	52	47	54	0	13	3	7
	0	0	0	0	0	0	0	0
65	20	47	39	30	0	7	2	13
	12	17	16	3	0	1	0	0
66	1	14	15	11	0	0	1	0
	0	0	0	0	0	0	0	0
67	24	94	63	41	6	24	3	0
	0	2	0	0	0	0	0	0
68	42	86	89	95	12	2	10	0
	16	24	0	3	0	0	0	0

The postal data were added to the data banks at some time during the last few hours before midnight GMT, so that they could be distinguished by their 'time-of-receipt'. There were a few occasions where real-time data, particularly for 1800 GMT, had also been stored during those hours, so that the delayed data were indistinguishable—such occasions have been ignored in the following statistics. Figure 2 shows a typical analysis by time-of-receipt of one data bank for a particular block, a particular type of data and a particular datum time. The addition of delayed data can be clearly seen at approximately 820 minutes after 0600 GMT (i.e. 1940 GMT), so that the numbers of reports before and after may be measured. Note that the time of day at which the observation is received is stored, but the 'date-of-receipt' is not, and that in this case the 'delayed' observations were stored at 1940 GMT some 70 days after the observation time.

Table IV is a summary of all the suitable time-of-receipt analyses, expressed in terms of the overall percentage increase of data due to delayed collection for the period. The very high percentages of course reflect the small numbers of such observations arriving over telecommunication channels. The sparsity of the upper-air network accentuates the effect on figures of any data losses due to omission of observations or excessive postal delay—hence several zeros in the table.

Nevertheless the increase of 32 per cent for the whole of Africa and the Middle East over the 20 days is encouraging and justifies the continued effort. This figure is expected to be improved in the future (see 'Suggestions for improved Data Capture' starting on page 241); continued co-operation by the participating countries, especially those acting as Regional Telecommunication Hubs (RTHs), will be very much appreciated.

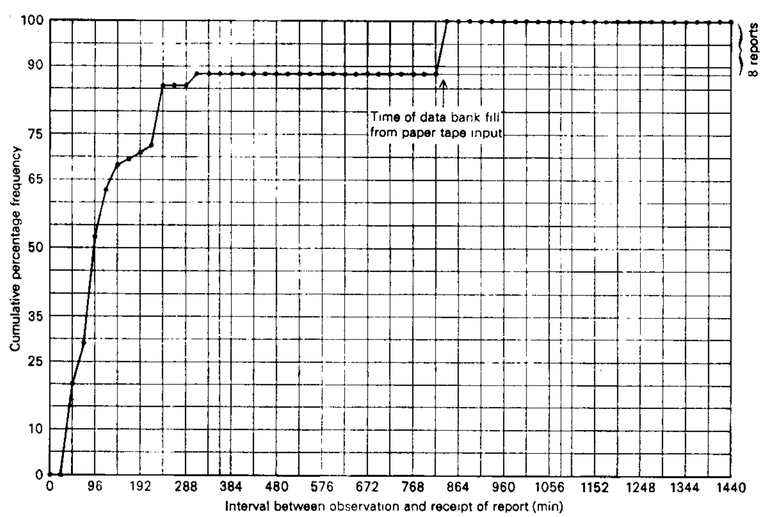

FIGURE 2—TIME OF RECEIPT/FREQUENCY CURVE

Observations at 0600 GMT, 8 July 1977. Surface reports 'SYNOP' for Block 61. Total number of reports = 69. No reports received outside time interval.

TABLE IV—NUMBER OF EXTRA REPORTS RECEIVED BY POST EXPRESSED AS A PERCENTAGE OF THE NUMBER RECEIVED THROUGH THE GLOBAL TELECOMMUNICATION SYSTEM

	Time of report (GMT)								
	SYNOP				UPPER AIR				
WMO Block Nos.	00	06	12	18	00	06	12	18	All times
40	11	4	9	17	7	21	15	10	10
60	7	19	19	23	6	7	0	1	14
61	24	3	8	33	100	8	4	9	14
62	62	62	25	77	10	90	125	60	56
63	25	29	37	68	36	3	105	0	36
64	785	75	90	65	0	85	58	123	98
65	21	8	27	54	0	21	0	27	26
66	700	132	138	224	0	0	0	0	161
67	99	21	50	63	115	148	117	0	50
68	18	8	7	19	0	0	4	0	11
All Blocks	46	22	31	43	22	36	28	22	32

Average percentage increase = 32% for the period.

Table V gives an indication of the variability of numbers of delayed reports from day to day. Again there are many zeros and a wide daily variation.

TABLE V—MAXIMUM AND MINIMUM OF REPORTS ADDED FROM PAPER TAPE (PER DAY)

	Time of report (GMT)							
	SYNOP				UPPER AIR			
WMO Block Nos.	00	06	12	18	00	06	12	18
40	13	7	22	25	2	3	3	1
	0	0	0	4	0	0	0	0
60	4	19	15	17	1	6	0	1
	0	0	0	7	0	0	0	0
61	14	6	9	34	1	4	1	7
	1	0	0	2	0	0	0	0
62	13	31	23	34	1	15	5	3
	0	0	0	2	0	0	2	0
63	8	16	15	24	1	1	4	0
	0	0	0	0	0	0	0	0
64	37	42	58	51	0	8	2	8
	3	9	4	0	0	1	0	0
65	7	8	17	27	0	1	0	4
	0	0	0	0	0	0	0	0
66	1	10	10	11	0	1	0	0
	0	0	0	0	0	0	0	0
67	18	29	45	33	4	16	2	0
	0	0	0	0	0	0	0	0
68	7	8	7	33	0	0	1	0
	1	1	2	0	0	0	0	0

Table VI shows the total numbers of observations of various types and times included on the magnetic tapes sent to the Surface-based Data Centre. There are no great surprises in the table, but it is interesting to note the variation with time of day, particularly with regard to SYNOPs. It should be remembered in this context that the local time corresponding to 0000 GMT ranges between 2300 and 0400.

TABLE VI—TOTAL NUMBER OF OBSERVATIONS SENT TO SURFACE-BASED DATA CENTRE FOR PERIOD 1–20 JULY 1977

Time (GMT)	SYNOP	SHIP	AIREP	UPPER AIR*	TOTAL
00	8 510	11 764	6 438	4 359	31 071
06	13 660	11 014	9 974	3 797	38 445
12	13 320	11 773	7 387	5 633	38 113
18	12 010	11 308	9 250	3 235	35 803
Totals	47 500	45 859	33 049	17 024	143 432
Daily mean	2 375	2 293	1 652	851	7 171

* The upper air reports include all available parts A, B, C and D for PILOT and TEMP reports.

DIFFICULTIES WITH POSTAL COLLECTION

Timing

Some of the boxes intended for return postage of paper tapes were not received by the departments which prepare the data. This was partly because half the containers were posted to addresses supplied from within the Meteorological Office and not to official addresses, since these NMCs had not (at the time of posting) agreed formally to participate in the test.

Even though the containers were posted from the Meteorological Office at Bracknell by air mail on 3 June, some of them did not reach their destination in time. This is probably why 6 sets of data arrived late, and why no data arrived from 14 other NMCs.

Difficulties did occur when data were posted by surface mail from distant countries in the Middle East and South-east Africa as they take 8–12 weeks to arrive at Bracknell.

Content

After the GATE experiment, a report was produced on difficulties found with the collection of data arising from the use of paper tapes. Many of the problems found during GATE recurred with the paper tapes collected during the July test:

Only two-thirds of the tapes had the correct WMO bulletin heading—the other one-third were unacceptable for reading into the computer.

Some tapes were unsuitable for use on optical paper-tape readers, because of incomplete perforation, or because of a non-standard 5-hole configuration on 7-hole width paper.

Some NMCs had compiled several days' observations, not in chronological order, on to one paper tape. These tapes had to be read on a viewer and where possible split into separate days before being used with the other delayed data for the same day. Two NMCs were unable to supply data on paper tape and instead sent them in manuscript form which had to be punched on to 5-hole paper tape at Bracknell.

A few tapes had unwound during transit and were slightly damaged, whilst some were securely held with heavily gummed cellulose tape. Unfortunately the gum from the cellulose tape came off on to the edges of the paper tape and caused sticking on the paper-tape reader head.

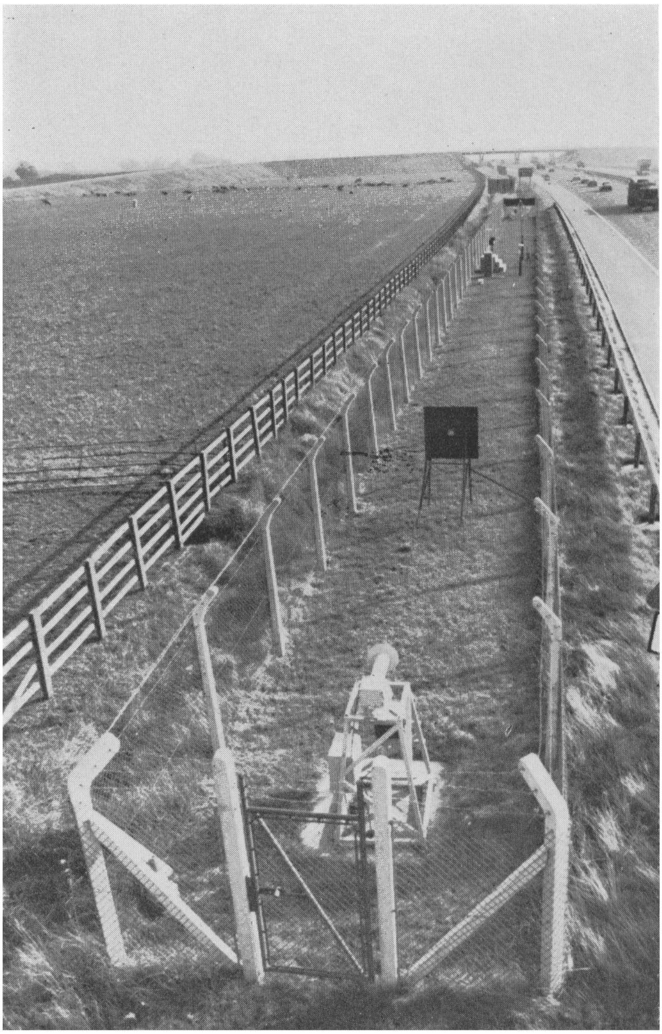

PLATE I—A GENERAL VIEW OF THE CENTRAL COMPOUND LOOKING EASTWARDS

The transmitter unit of the Meteorological Office Transmissometer (MOT) is in the foreground with the other visibility and meteorological instruments midway along the length of the compound. The black screens at the far end and in the foreground were used to prevent drivers being distracted by the light.
(See page 243.)

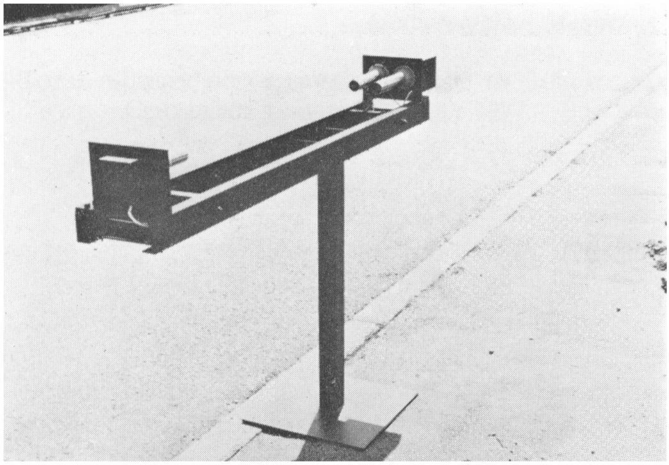

PLATE II—A CLOSE VIEW OF THE INSTRUMENT DESIGNED BY THE TRANSPORT AND ROAD RESEARCH LABORATORY SHOWING THE TWIN TRANSMITTING AND RECEIVING ELEMENTS AT THE FAR END OF THE INSTRUMENT

(See page 244.)

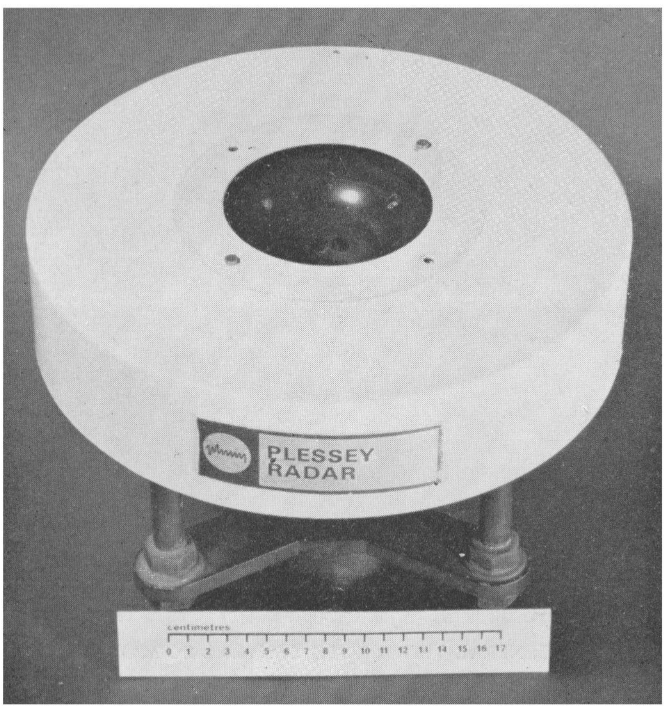

PLATE III—A VIEW OF THE POINT VISIBILITY METER DEVELOPED BY PLESSEY RADAR LTD FOR THE HOME OFFICE

The rule gives an indication of its small size—the unit shown here is mounted on a pole for operational use. (See page 244.)

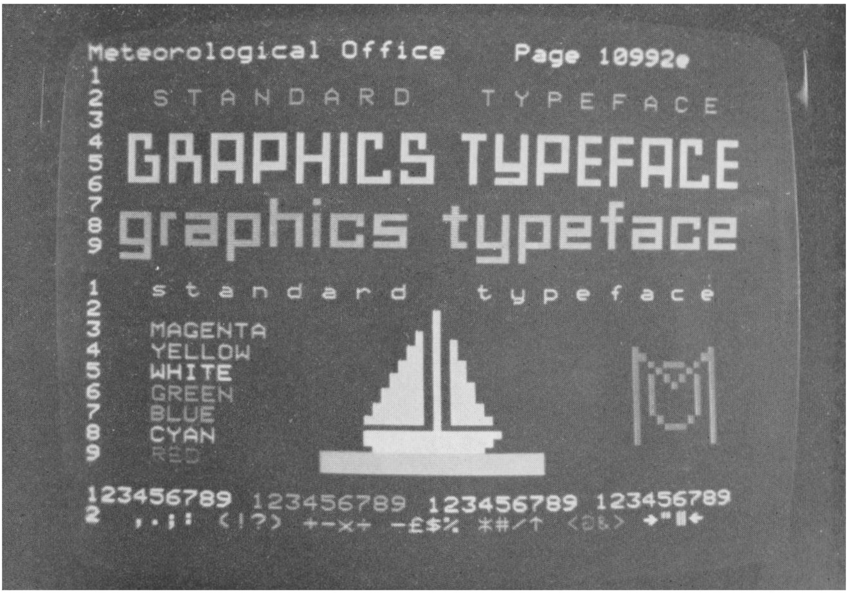

PLATE IV—PRESTEL DISPLAY FORMAT, SHOWING CAPABILITIES OF SYSTEM AND RANGE OF COLOURS AVAILABLE

(See page 252.)

PLATE V—SAMPLE FORECAST FOR A REGION

(See page 253.)

PLATE VI—PRESTEL EDITING TERMINAL SHOWING TELEVISION RECEIVER, EDITING KEYBOARD FOR INPUT AND HAND-HELD KEYPAD FOR SELECTING FRAMES FOR DISPLAY

(See page 250.)

Group collectives

Early in 1976, five RTHs were requested to help during the July trial period by collecting the data for all NMCs in their area of responsibility and sending one tape per day to the Area Sub-centre. Out of the five, four agreed to co-operate, but in the event no collectives were received. Two of them sent their national data, but in both cases they arrived too late to be included.

SUGGESTIONS FOR IMPROVED DATA CAPTURE

Timing

A better list of addresses has been built up with the help of the GARP Activities Office and by direct correspondence with the NMCs. This will help to get the containers to the correct addresses. A supply of six 10-day containers was posted in October to the NMCs who had provided data for the July test. They will receive a steady supply of boxes during the Build-up Year and the Operational Year.

Help has been offered by a commercial company with contacts in the meteorological services of two countries, and this has already proved effective (at the time of writing the Build-up Year has just begun).

Countries which could not meet the 60-day deadline for getting data to Bracknell will be requested to air-mail the data.

Content

To try to reduce the number of observations lost owing to incorrect bulletin headings, a sample paper tape with print-out will be sent to every NMC, showing the layout of bulletin headings and observations requested for input to the computer.

Officers preparing the tapes will be requested not to use adhesive tape but to use special wire-strengthened plastic ties, which will be provided, to hold the data tapes in transit.

A short report on the difficulties found during the July test and suggestions on how they might help to overcome them has been sent to every NMC whether or not they sent data during the tests. Each supply of containers will have precise instructions in English or French for collecting the data.

For the three NMCs that cannot provide paper tapes, data in manuscript form will be punched on to paper tapes. Provision will also be made for a limited number of non-standard paper tapes to be re-cut to 5-hole paper tapes.

Monitoring of missing reports from Region VI will continue. Data sets of station numbers administered by each NMC will be kept up to date to ensure the maximum efficiency of the monitoring program.

Monitoring of the area covered by the postal collection of data will take place after the paper tapes have been added to the GTS data sets, and information about continuing deficiencies in any particular area, such as can be seen from the figures in Tables IV and V, will be forwarded to the GARP Activities Office for possible rectification in the future.

It is unlikely that much manual inspection and correction of meteorological data or bulletin headings will be undertaken as was done for GATE, because this would involve too many staff to keep pace with daily processing of the data. However, it may be possible to amend computer programs to accommodate some of the types of incorrect bulletin headings which were received during the trial period, hence capturing a number of observations which would otherwise have been lost.

A further nine NMCs in Africa and the Middle East have been requested by WMO to participate in FGGE during the Build-up Year and the Operational Year, and although only a few observations are expected from each NMC, any data sent to Bracknell will help increase the amount of delayed data collected.

One RTH has begun to send a collective on magnetic tape at monthly intervals. Although many extra observations are obtained in this way, the collective does not include all observations for the area which have been received on paper tape.

Acknowledgements

The authors wish to thank the following for their valuable assistance in planning and carrying out this project:

GARP Activities Office, WMO, especially Dr Boldirev; contributing NMCs in Europe, Africa and the Middle East; Foreign and Commonwealth Office.

The assistance of several branches of the UK Meteorological Office, in particular the team who performed similar work for GATE is also gratefully acknowledged. The special computer programs were mostly written by C. Long. The following cheerfully assisted with the bulky and sometimes tedious work of dispatching postal boxes and reading in paper tapes: D. Green, Mrs A. Saunders, and Mrs A. Jackson.

551.508.92:656.1

THE MEASUREMENT OF FOG ON MOTORWAYS

By H. A. DOUGLAS (Meteorological Office, Bracknell*), D. J. JEFFREY (Transport and Road Research Laboratory, Crowthorne) and F. JEZZARD (Police Scientific Development Branch, Home Office, London)

Summary

The Meteorological Office, the Transport and Road Research Laboratory and the Home Office have combined in a trial to evaluate potential low-cost visibility instruments as possible aids in motorway traffic control. The results of the trial show that the two instruments under test came close to the performance criteria laid down before the trial but that each had limitations. The short-baseline transmissometer showed a temperature drift which was sufficient to give an apparent visibility change of 7 m $°C^{-1}$ (at 200 m), and the forward-scatter instrument gave poor results when obscuration was caused by factors other than fog (for example precipitation or spray).

Introduction

A series of multiple crashes on motorways, in fog conditions, during the late sixties and early seventies, led to the appropriate authorities considering the use of instrumentation to help reduce the incidence and costs of such accidents (a single multiple accident has been estimated to cost £0·5 million, excluding the cost of suffering and bereavement (Transport and Road Research Laboratory (TRRL), 1972a)). The Home Office originally considered the use of an

* Now at Meteorological Office, RAF Strike Command, High Wycombe.

instrument which would assist the police in cases of prosecution for driving dangerously fast for the prevailing visibility conditions. This was soon shown to be impracticable, and the emphasis shifted to providing relatively low-cost instrumentation to give advance warning of the visibility ahead. The Transport and Road Research Laboratory were interested in the effects of fog on driver behaviour and traffic flow parameters. Also the appropriate authorities wished for detailed forecasts, on a time-scale of one to two hours, of the visibility to an accuracy better than 20 per cent over the entire length of a motorway and for estimates of how the visibility would change with time. The Meteorological Office became involved in 1972 when it advised both groups that it was not realistic, even with the aid of instruments, to expect such accurate forecasts of the distribution or density of fog.

The three organizations then agreed to co-operate in a trial which had the aims of identifying and establishing some of the relevant details of instrument performance, traffic flow parameters and police control procedure. The trial, using a length of the M4 motorway near Reading, took place between February 1974 and June 1976. Each organization sought different information, and this paper summarizes the results from the trial of two relatively low-cost instruments designed to measure the visibility.

A description of the site and the instruments is followed by a discussion of the results.

Experimental details and description of the instruments

The particular aims of the experiment, described in this paper, were: (1) the evaluation of the accuracy of different visibility-measuring techniques, and (2) to determine whether instruments will continue to operate successfully over long periods when left unattended at the roadside.

To provide the necessary data for these aims to be achieved, three compounds were erected alongside the eastbound lane of the M4 motorway, between Theale and Reading. This site was chosen since TRRL had already started to instrument the site and it was known to be a fog-prone area, being low-lying and adjacent to gravel pits. All the compounds housed one of each type of visibility instrument on trial, whilst the central compound also contained a modified Meteorological Office Transmissometer (MOT), for use as a reference instrument, and various other meteorological instruments (see Plate I). The MOT (Meteorological Office, 1971) measures the optical transmission (T) of a horizontal beam (d km long) of light through the atmosphere. The transmission is related to the extinction coefficient (σ) and thence to the visibility (V) by Koschmieder's equation

$$V = 2{\cdot}9957/\sigma \text{ km},$$

where $\sigma = d^{-1} \ln T^{-1}$. For this trial, the support structure was modified to allow the beam to be at a standard height of 1·3 m above the road surface, and the baseline was reduced from 200 m to 100 m. The effect of reducing the baseline was to change the operating range of the instrument from 100 m–20 km to 50 m–10 km. The output from the transmissometer was exponentially smoothed with a time-constant of 40 seconds. Before installation on the motorway, the instrument was compared with a standard transmissometer and it was confirmed that the alterations had not affected the response.

Two measuring techniques were under trial; the first, similar to that employed by the MOT, measured the ratio of received light to transmitted light. The difference was that the instrument in the trial used a folded-path technique with an effective path length of 4 m. This allowed for measurements of visibility down to 10 m but with an effective upper limit of 200 m. An instrument (TRRLT) designed at the Transport and Road Research Laboratory (TRRL, 1972b and 1974) was used to represent this technique (see Plate II). In this particular instrument, the initial beam is split—one path passing through the atmosphere and the second being totally enclosed. This allows the compensation circuit for lamp fluctuations to be self-contained. The outputs from the two matched detectors are compared, the difference in their values being a measure of the atmospheric attenuation or extinction coefficient (σ). The output was again exponentially smoothed with a time-constant of 40 seconds.

The second technique was that of forward scatter. A Point Visibility Meter (PVM), (Winstanley and Adams, 1975), developed by Plessey Radar Ltd under a Home Office contract, was the instrument used to represent this technique. The instrument (see Plate III) measures the light scattered at a specific angle ($\approx 34°$) in the forward direction of the beam. The angle was selected so that dependence on particle size was minimized and thus it can be assumed that the intensity of the received light was proportional to the extinction coefficient (σ). An exponential smoothing circuit was applied to the output. This had a time-constant of 120 seconds, the longer time being intended to compensate in part for the much smaller sampling volume of this instrument.

During the trial, the MOT was regularly serviced, cleaned and calibrated, whilst the other visibility instruments were left untouched. Data from all the instruments were telemetered every 15 minutes to TRRL where they were recorded in a computer-compatible form. When the visibility, as indicated by the MOT, dropped below 800 m, data from the instruments were recorded on punched paper tape, every 2 minutes, at the motorway site. The analysis described in this paper was carried out by the Meteorological Office, after copying the original data both from the magnetic tapes and from the paper tapes, and principally covers the period of the first full winter, November 1974 to May 1975.

Results

(1) *General*

Clearly an important feature of any instrument which is intended to operate in a roadside environment over a long period of time is the stability of its calibration. The changes in calibration could arise from many causes, but one of the principal problem areas is the cleanliness of the optical surfaces. To identify any such shift, two periods were chosen (one near the beginning and one near the end of the trial period) for which the MOT gave similar values, and where the temperatures were the same (see later). The mean values of the outputs of the TRRLT and the PVM were calculated and Table I lists the results. The changes in calibration—equivalent to a zero shift—are given in terms of a change in recorded visibility for a true visibility of 200 m. The changes of 123 mV (TRRLT) and 111 mV (PVM)—obtained from the values in column (c) of Table I by subtracting the 2 mV change in the mean output of the MOT—would give an apparent visibility change of 46 m and 9 m respectively. To identify any drift in calibration related to temperature, all occasions for which the MOT (which

TABLE I—COMPARISON OF MEAN VALUES OF OBSERVATIONS TO CONSIDER CALIBRATION DRIFT (TEMPERATURE LIMITS 3 °C TO 6 °C)

	a 17 Nov. 1974	b 11 May 1975	c Difference (a—b)	Visibility*
	Mean voltage output of instrument			
MOT	9·475	9·473	0·002	0·1 m
TRRLT	0·188	0·063	0·125	46 m
PVM	0·176	0·063	0·113	9 m
No. of readings	6	8		

* The value in column (c) expressed in terms of visibility for a true visibility of 200 m.

has a negligible temperature coefficient) indicated a visibility of between 6·5 km and 7·0 km were extracted, and regressions of the temperature and the outputs of the TRRLT and PVM were calculated. This range was selected so that within the range there should be no measurable change of output in either the PVM or the TRRLT. The correlation coefficient ($r = 0{\cdot}094$, $N = 73$) in the case of the PVM showed the effect to be negligible. In the case of the TRRLT there was a significant relationship which would give a temperature coefficient of 7 m $°C^{-1}$, at 200 m.

The well-known variability of fog restricted these instrumental comparisons to data recorded from the central compound. The Meteorological Office is also using the data recorded from all three sites, with a view to establishing the spatial and temporal variations which do occur. This investigation will be reported elsewhere.

To aid comparisons, made difficult by differences in path length, time-constants, and physical principles, the rate of change of visibility (defined in terms of the MOT value) was calculated for each data point and the comparisons were made both for the whole data set and for the 'reduced set' in which the visibility was changing only slowly (less than 20 m min^{-1}). The usual form of comparison was a scatter diagram with the associated regression equation and correlation coefficient. Two such diagrams are presented as Figures 1 and 2.

Figure 1 illustrates the 'reduced set' of data for the PVM, within the limited range of 50 m to 1 km, whilst Figure 2 gives the corresponding scatter plot for the TRRLT over the range of 50 m to 200 m.

The TRRLT and PVM comparisons are now considered separately.

(2) *Point Visibility Meter* (*PVM*)

This instrument functions by using the forward scatter of light, and the scattering function, and hence the indicated visibility, is dependent on the particle size, although the forward angle has been selected to minimize such an effect. Thus, unlike the MOT, the PVM would give a different signal level for, say, snow and fog even when the optical attenuation in the atmosphere was the same. The calibration equation provided by the manufacturer is designed to measure fog. Unfortunately it was not possible to separate completely the data relating to fog from those relating to other obscurants although it could be seen that many of the points exhibiting large deviations from the expected value came into the latter category. A parallel investigation by the Meteorological Office has confirmed this dependence on the actual conditions causing the atmospheric attenuation, and this work will be reported more fully at a later date.

The PVM has a very small sampling volume (roughly a cube of sides 10 mm) and the increased time-constant compared to that of the transmissometers is only a partial compensation for this feature. The comparison of instrument performance between the MOT and the PVM should thus be under as uniform conditions as possible to limit effects due to spatial variations of visibility and thus the 'reduced set' of data was used (Figure 1). The resulting regression was

$$Y = 0{\cdot}802M + 19{\cdot}52 \quad (r = 0{\cdot}92,\ N = 840),$$

where Y and M are the visibilities as measured by the PVM and MOT respectively, r is the correlation coefficient and N the number of relevant points. This

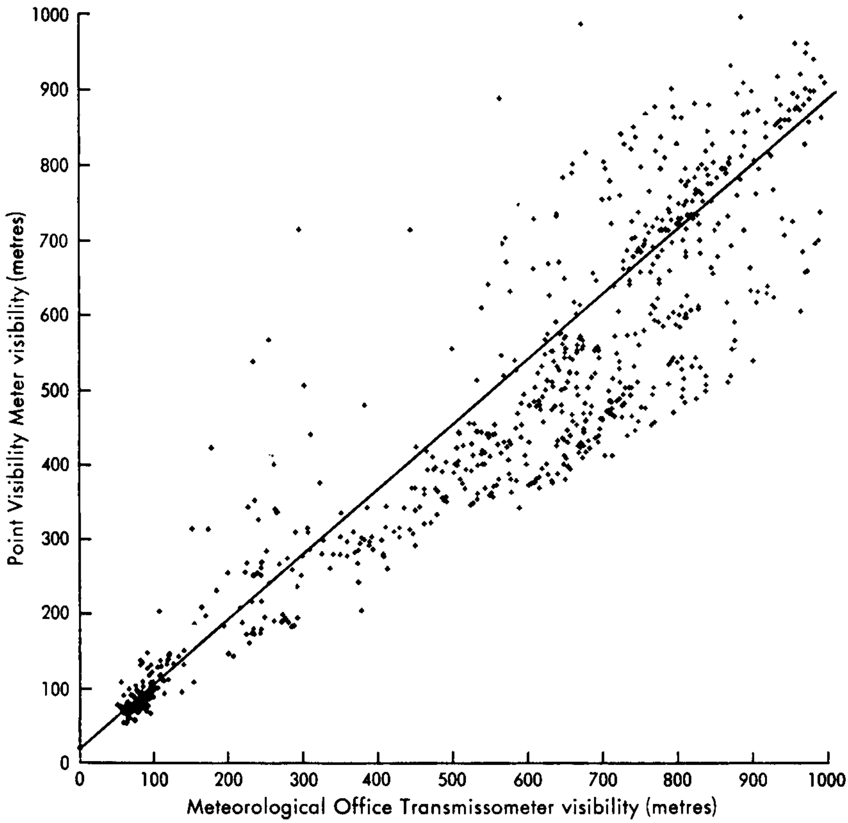

FIGURE 1—SCATTER PLOT, WITH ASSOCIATED REGRESSIONS, SHOWING THE COMPARISON BETWEEN VISIBILITIES AS INDICATED BY THE POINT VISIBILITY METER (Y) AND THE METEOROLOGICAL OFFICE TRANSMISSOMETER (M), IN STEADY CONDITIONS (RATE OF CHANGE $\leqslant$20 m/min) AND WITHIN THE RANGE 50–1000 m

Equation of regression line $Y = 0{\cdot}802M + 19{\cdot}52$
Correlation coefficient $r = 0{\cdot}916$
Number of observations $N = 840$

regression should be considered as the best estimate in fog conditions over the range 50 m to 1 km. Using this regression to give the value of Predicted (PVM) visibility in the formula

$$\text{Error} = \frac{(\text{Observed (PVM)} - \text{Predicted (PVM)})}{\text{Actual (MOT)}} \times 100 \text{ per cent}$$

gives a mean error of 1·5 per cent and a standard error of 20 per cent over the above range. Over the limited range of 50 m to 200 m, the corresponding figures are 0·3 per cent and 20 per cent.

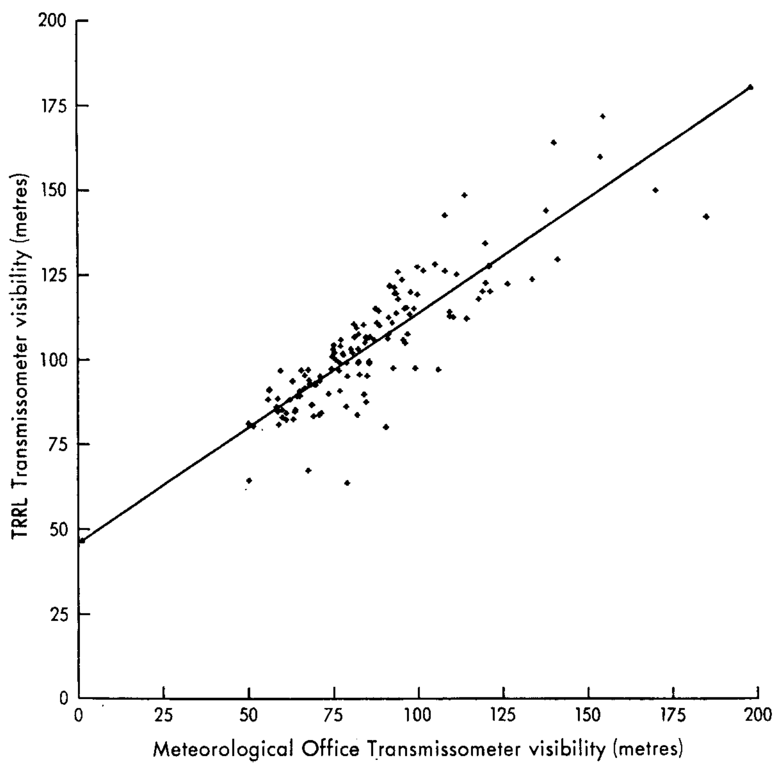

FIGURE 2—SCATTER PLOT, WITH ASSOCIATED REGRESSIONS, SHOWING THE COMPARISON BETWEEN VISIBILITIES AS INDICATED BY THE TRANSPORT AND ROAD RESEARCH LABORATORY TRANSMISSOMETER (Z) AND THE METEOROLOGICAL OFFICE TRANSMISSOMETER (M), IN STEADY CONDITIONS (RATE OF CHANGE $\leqslant$20 m/min) AND WITHIN THE RANGE 50–200 m

Equation of regression line $Z = 0{\cdot}670M + 47{\cdot}36$
Correlation coefficient $r = 0{\cdot}860$
Number of observations $N = 142$

(3) *Transport and Road Research Laboratory Transmissometer* (*TRRLT*)
The physical principle utilized by this instrument is independent of the particle size problem encountered with the PVM. The main difference between the TRRLT and the MOT is the difference in path length, and thus its representativeness of the general visibility. For the data shown in Figure 2, the regression over the range 50 m to 200 m was

$$Z = 0{\cdot}670M + 47{\cdot}36 \quad (r = 0{\cdot}86,\ N = 142),$$

where Z is the visibility as measured by the TRRLT, the other symbols having the same meaning as for the PVM case. The associated mean and standard errors, within the range 50 m to 200 m, were 0 per cent and 11 per cent respectively, and these should be compared with the second set of figures given for the PVM. The lower error figures for the TRRLT, compared with the PVM, are due to the relative independence of particle size of the transmissometer principle, but it should be remembered that 200 m is the effective upper limit to the range of this instrument.

(4) *The 1975/76 winter*
The trial again took place throughout this period, but technical problems, combined with a very low incidence of fogs, meant that few additional data were obtained. These data have not been fully processed, but the initial calculations indicate a similar result to that for the first winter. Table II lists the corresponding full data regressions for each instrument for each winter.

TABLE II—COMPARISON OF REGRESSION EQUATIONS OVER THE TWO WINTERS

	Winter 1974/75	Winter 1975/76
TRRLT for range 50 m–400 m	$Z = 0{\cdot}636M + 59{\cdot}91$ ($r = 0{\cdot}787$, $N = 385$)	$Z = 0{\cdot}627M + 75{\cdot}27$ ($r = 0{\cdot}804$, $N = 28$)
PVM for range 50 m–1 km	$Y = 0{\cdot}670M + 68{\cdot}61$ ($r = 0{\cdot}838$, $N = 1442$)	$Y = 0{\cdot}532M + 152{\cdot}27$ ($r = 0{\cdot}670$, $N = 66$)

CONCLUDING REMARKS

The trial has indicated the potentials and limitations of two types of instrument. Both are able to withstand exposure to a roadside environment. One, based on transmission, illustrates the disadvantage of a range limited by its effective baseline whilst the second, based on forward scatter, gives different responses under different conditions. Standard errors of 11 per cent and 20 per cent respectively over the range 50 m to 200 m, common to all instruments, have been established, and with this knowledge the two user authorities are continuing their own investigations into the most appropriate low-cost visibility instrument. The Home Office have established a prototype network on part of the M1 motorway to provide real-time data to the Police and to evaluate the benefits of such a scheme. TRRL are continuing to use the M4 site to establish relationships between traffic parameters, driver behaviour and visibility. The trial has given the Meteorological Office further experience of two instruments which could be considered as visibility instruments for sites where a 200 m baseline is impracticable.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the help and advice of colleagues associated with this project and thank the Thames Valley Police for their assistance with the running of the trial.

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551.5:621.391

METEOROLOGICAL OFFICE PARTICIPATION IN PRESTEL—THE POST OFFICE VIEWDATA SYSTEM

By J. PARKER

(Meteorological Office, Bracknell)

SUMMARY

Prestel and teletext are discussed. These new information media use domestic television receivers as visual display units. In this review particular reference is made to their relative merits and their importance to the Meteorological Office.

INTRODUCTION

June 1978 saw the start of the test service of the Post Office viewdata system known as Prestel. Since the Meteorological Office is participating in the test this is an appropriate time to review the system, together with the complementary information medium, teletext. Both are important new developments in the communications field providing relatively cheap visual displays of information from data banks which are accessed by very simple techniques. The visual presentation allows efficient assimilation and the ease with which the data can be accessed makes the potential size of the body of users very large.

COMPARISON BETWEEN TELETEXT AND VIEWDATA

Since both systems are relatively new communications media it is worth while spending some time looking at their similarities and differences. At first sight they may seem to be alike and essentially competing, but in fact this is not so. The basic similarity is that they both use a suitably modified domestic television receiver to display, on demand, information stored in a computer. The electronic modifications to the television set, and the display format, are essentially the same for both systems so that each can be displayed on the same receiver. However, the methods used to transfer the information from computer to television set are fundamentally different.

Teletext is the system developed by the broadcasting authorities, the BBC version being better known as Ceefax and that of the IBA as Oracle. Although they were developed independently, a single standard was agreed upon and has been in use since 1974. Teletext is made possible by the need for some blank lines in the normal television signal to allow time for the scanning beam in the receiver to return to the top of the screen. These blank lines are used to transmit digital representations of information as part of the broadcast signal. The modified electronics of the receiver then extract the teletext portion, decode the signal and display the information on the screen instead of the normal picture. Viewdata has been designed by the Post Office, who have adopted the trade name of Prestel. It achieves the same display by means of a simple conversion to a domestic telephone. In this way data can be sent between computer and television receiver along ordinary telephone lines. This means that instead of information being broadcast for anyone to use, the data bank is interrogated at the initiative (and usually at the expense) of the user. Not only does this give a new means of communicating information, but it also allows for more efficient use of the existing public telephone network.

This one basic difference has many consequences. For example, teletext is available only during broadcasting hours, whereas Prestel provides a 24 hour service. Perhaps of more importance is the fact that the information disseminated by teletext is under the ultimate control of the appropriate broadcasting authority. With Prestel the responsibility for the content of the information remains with the 'Information Provider', the Post Office merely supplying the means of communication. This is a significant point with regard to the Meteorological Office participation. As a contributor we have an editing facility and information can be updated immediately, as and when required (see Plate VI). There is also an important financial comparison. Access to teletext information is free because of its broadcast nature, but Prestel will cost the user the price of a local telephone call at least, and the Information Provider has the option of adding a charge for the information on display. On this basis teletext is the more attractive system for the user. However, the virtually unlimited capacity of Prestel gives it an overwhelming advantage. The capacity of the teletext system is limited by the number of spare lines available within the television signal. At present Ceefax and Oracle each make use of only two lines. This provides for display an absolute maximum of 800 frames, one frame being effectively the amount of information that can be displayed on the screen at one time. In practice the capacity is reduced as a result of the method of transmission. The entire content of the data bank is broadcast in a cyclic manner, which means that there is a significant time-lag between frame selection and frame display, its length depending on the total number of frames in the sequence. It takes roughly 24 seconds to transmit 100 frames, so that on selecting a frame from a 100 frame sequence there will be an average delay of 12 seconds before display. To keep this delay to a tolerable minimum considerably less than the maximum number of frames are in fact used. Since Prestel is accessed directly, any frame can be selected and displayed in about 2 seconds, and the capacity of the data bank is limited solely by the amount of storage available to the computer. After using Prestel, information seekers are likely to find the delay inherent in teletext trying. For the test service Prestel will have in the region of 100 000 frames available for use. This allows for a fairly comprehensive coverage of information to be provided. Ideally a user should be able to gather from various parts of the data bank all the information he needs on a particular subject. For example, as well as the average weather conditions for a holiday destination he should be able to find out the times of the best form of transport, hotel facilities, package tour operators and sources of entertainment.

The relative sizes of the data banks, and the different access methods, result in a fairly well-defined distinction between the type of information held on each system, which in turn explains their complementary nature. A broadcast system has the advantage that all users are able to select the same item of information simultaneously from the relatively small data bank. Prestel's much larger data bank, however, can only be used by a fraction of the population at one time because there must be a finite number of access points to the computer. Thus teletext is better qualified to transmit the sort of information that many people want to see simultaneously, such as the latest news. Prestel on the other hand is best suited to hold large quantities of long-period reference data and information tailored to specialized interests. Naturally there is a certain amount of overlap between the two systems, but clearly, they both have a place in the field of mass communication.

The final and perhaps most crucial difference, however, is that Prestel is an interactive system. Since there is a two-way link between user and computer, each can respond to the requirements of the other, and the user can make fuller use not only of the data bank but also of the capabilities of the computer itself. This has many implications for the future which will be discussed later, but it also means that there is a difference in the way that teletext and Prestel are used.

How to use teletext and Prestel

Both systems work on the principle of identifying frames by number. A particular frame can be displayed by entering its number on a hand-held keypad (see Plate VI). Teletext uses three-figure numbers which are listed on several known index frames. Selecting a number causes the frame to be displayed when it is next broadcast in the sequence, and it is held on the screen until another frame is chosen. Prestel frames can be selected in a similar manner, but since the data bank is so much larger, up to nine digits are used for frame identification. This method of access is perfectly acceptable to someone knowing the reference to a required frame since the display is almost instantaneous. However, it was realized from the beginning that for Prestel to succeed it would have to appeal to all types of user, from the domestic level with no experience of dealing with computers to someone in the business world with little time to cope with elaborate access procedures, and therefore it had to be simple to use. To achieve this Prestel is structured on the basis of a selection tree, each branch giving access to a different classification of information. In essence, a user is presented with up to ten options on early frames in the structure, and progresses by keying a single digit on the keypad according to his choice. This procedure is followed until the required information is displayed. Equally simple instructions allow a user to retrace his path over the previous three frames he has viewed, and also to correct keying errors. As a further aid the Post Office recommends to all Information Providers the practice of including 'prompts' on all frames, that is to say, advice on what needs to be done as the next step.

DISPLAY FORMAT

Plate IV illustrates the Prestel display format and the facilities available as design aids so that information can be presented in an attractive fashion. As explained earlier the teletext format is essentially the same. The screen has 24 lines, 22 of which are available to the Information Provider, the top line being reserved for Post Office information and the bottom line for messages from the computer. Each line has 40 character positions. All standard keyboard characters are available, but in addition each character position can be divided into six squares, any combination of which can be displayed at that position. This gives the facility of building simple illustrations, and has enabled the Post Office to provide a bold graphics typeface, which can be used for the automatic construction of headlines, for example (see Figure 1). They have also provided a choice of colours which they describe as red, yellow, green, blue, magenta, cyan (pale blue) and white, plus a facility that enables any group of characters to flash on and off at regular intervals. The display format has been designed to present the maximum information that can comfortably be read on a television screen, and thus underlines a fundamental editing problem that faces the Information Provider. To keep the cost to the user down to an acceptable minimum, as much information as possible should be displayed on one frame. At the same time the overall appearance of the frame should be attractive, clear, and easy to read.

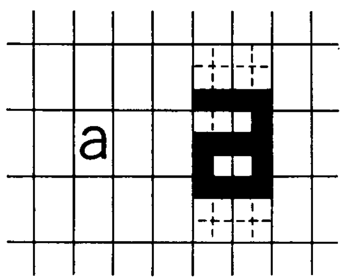

FIGURE 1—ILLUSTRATION OF STANDARD TYPEFACE AND GRAPHICS TYPEFACE

The constraint of 40 characters per line, however, means that an average line of text from this page of the *Meteorological Magazine* would occupy two lines on a Prestel screen. Furthermore, a heading using the graphics typeface takes three lines. Consequently a certain style of presentation has to be adopted to give the maximum amount of information with the minimum number of words. Not only that, but consideration must also be given to the appearance and readability of the information in terms of layout and colour.

THE TEST SERVICE

A test service is at present being jointly run by the Post Office, television manufacturers and numerous Information Providers, all of whom are interested in the potential of a full public service. For the trial about 1500 Prestel user terminals are being made available to a selection of people in London, Norwich and

Birmingham. As an Information Provider the Meteorological Office has an editing terminal located in the Central Forecasting Office under the control of the Public Services Branch, which is used for entering, and updating as necessary, a selection of meteorological information (see Plate V). At present this terminal consists of a television receiver and an editing keyboard (see Plate VI). It is envisaged that in the future there will be a need for an 'intelligent' terminal with a microprocessor and its own local storage. In this way a batch of editing can be carried out locally without being connected to the Prestel computer, the telephone link only being used to send the completed frames. It will also be possible for some of the updating to be done directly using a computer-to-computer link.

For the purpose of the test service the Meteorological Office is providing a wide range of meteorological information. Forecasts are naturally of prime importance, and range in scope from a broad forecast for the United Kingdom as a whole to forecasts tailored for particular activities and localities. However, actual weather conditions and climatological averages are also of great interest and importance to a wide variety of people, and a selection of each is included within the section of the data bank allocated to the Meteorological Office. Prestel also affords the opportunity to advertise the full range of the consultancy services of the Office. By contrast, the range of meteorological information that can be displayed by teletext is severely limited and must be of a much more general nature. Since the contribution of the Meteorological Office to Prestel is fully under its editorial control the test service will be used to experiment with the proportion of space allocated to each type of information, and also the layout and content of the various frames. In this way it is hoped to ensure that the service is as suitable as possible for the user.

FUTURE APPLICATIONS OF PRESTEL

To demonstrate further the importance of the interactive aspect of Prestel it is perhaps worth while listing some of the potential applications. Primarily of course it provides a centralized information service, not only in terms of actual stored information but also by acting as a first reference point in a wider search for information. Teletext can also fulfil this function to some extent, although the volume and content of information differ considerably. However, Prestel can go one step further and act as an intelligent interface with specialist data banks on remote computers belonging to other organizations. It can translate the requirements of the user according to the protocol and language of the appropriate computer, locate the information and then transmit it to the user's terminal. The Prestel computer can also be used by individuals to store their own information, whether it be facts and figures or favourite recipes. Furthermore, since messages are no more than units of information, Prestel can act as a communication device, storing and sending messages to individual terminals. This of course extends the use of the telephone to the deaf. Some of the information stored in the system could well be in the form of advertisements—jobs, property, services, rentals, wanted and for sale—which could be responded to immediately via Prestel. Programmed learning is a natural application of such an interactive system, not only in terms of formal education in schools using prerecorded video cassettes but also in the home. Prestel can also provide a calculator service which can bridge the gap between pocket calculator and powerful computer. In the same way that goods could be bought and sold in response to advertisements, so reservations could be made for hotels or holidays. Prestel can even contribute to the field of entertainment in the form of jokes, quizzes and games.

In the future the communications aspect of Prestel could be of great importance to the Meteorological Office, with the advent of compatible hard-copy printers and video cassettes. Given the facility of forming 'closed user groups' where only members of the group can access a certain part of the data bank, private messages can be sent within a group. Outstations with editing terminals will then have an alternative means of communication, not only within the Meteorological Office, but also with any known subscriber to Prestel. The message switching capability of the Prestel computer can then be used, for example, to deliver warnings to customers on a semi-automatic basis.

Conclusion

Prestel is an example of a new concept in information media with an immense information capability and potentially far-reaching impact on telecommunications and society. It is the result of bringing together the best features of several technologies—large-scale integration in the receivers, optimized software in modern, fast, real-time computers, simplified data structures and computer access protocols—each aspect designed to ensure that the general public will be as much at home in using this new medium as it is now in using the telephone. As such it is ideally suited to provide a valuable aid in the dissemination of meteorological information, as well as being a potential source of substantial revenue for the Meteorological Office.

Acknowledgement

I am indebted to colleagues in the Public Services Branch of the Meteorological Office for helpful suggestions and encouragement in producing this article.

REVIEW

Environmental Aerodynamics, by R. S. Scorer. 240 mm × 155 mm, pp. 490, *illus*. Ellis Horwood Limited, Publishers, Chichester, 1978. Price: £20.00.

On the dust cover we are told that this book is an entirely rewritten successor to *Natural Aerodynamics*. The readership is intended to be wide, ranging from civil and mechanical engineers through applied mathematicians and physicists to aerobiologists and ecologists. The fact that the subject matter has largely been drawn from the content of two lecture courses which Professor Scorer has given to students at Imperial College contributes to both the strengths and the weaknesses of the book.

A glance at the first two chapters, on fundamental equations and the phenomena of fluid flow, will warn the reader that this book is pitched at a very different level from that of its predecessor. Right from the start there is a no-nonsense assumption of postgraduate mathematical fluency, although this is tempered by a liberal supply of examples of applications of the theory in nature. This distinguishes it from most texts on dynamical meteorology, which rarely delve into the subject in detail and leave the student with a wide gap to traverse before reaching the level of current research, but it may discourage the non-mathematician. In the third chapter the subject of secondary vorticity (a favourite one of Professor Scorer) is examined in depth, but the chapter on the effects of the rotating earth is a disappointing contrast. It is difficult to accept that our understanding of baroclinic systems has not progressed from Sutcliffe's development theory, and in view of the role of fronts in controlling the level of environmental pollution it would have seemed appropriate in a book with this title to extend the discussion of frontal dynamics beyond that of Margules. A reference to rotating annulus laboratory experiments and to modern studies of frontal structure might not have been out of place, but evidently these topics do not figure prominently in the author's lecture courses. On the subject of waves in stratified fluids, however, he is back in his element and gives an extensive up-to-date review, though personal opinion has a tendency to supplant objective discussion in some places (the sizeable literature on critical layer absorption is dismissed in a single paragraph as being speculative and based on incomplete mathematics).

The second part of the book, on turbulent phenomena, clouds and dispersion, is necessarily more descriptive. The chapter on partly turbulent flow is largely concerned with buoyant convection and jets as determined by laboratory experiments, while in the subsequent chapter the author considers examples of similar effects in the atmosphere. The subject of dispersal of pollution really requires a book to itself, but Professor Scorer manages to compress it into a single chapter by concentrating attention on dispersion from point sources near the ground. The chapter on clouds and fallout is concerned with the principal dynamical processes leading to different cloud forms. This is a topic on which the author has written several books and papers and here he has given a concise account linking theory and observations, but the inclusion of a section on the dynamics of atmospheric tides seems out of place. The book tails off a bit towards the end with a chapter which attempts to cover the aerodynamics of aphids, swallows, cuckoos, vultures, buzzards, albatrosses, locusts and pest swarms, but does so in such an insubstantial way that it seems barely worth including. The same can be said for the epilogue entitled 'Making peace with nature'. The examples for discussion at the end are mostly reworded versions of those in the earlier book, but they are as thought-provoking now as they were 20 years ago.

Professor Scorer is an acknowledged master of the art of attractive presentation and this book is an excellent example of his skills. The theoretical arguments are illustrated by clear uncluttered diagrams and by a large number of superb photographs, all of which are relevant to the text and not just included for their pictorial quality. The enthusiasm of the author is communicated to the reader throughout the book but the style resembles that of a verbally delivered lecture, and ideas, assumptions and approximations are introduced so thick and fast that at times one wishes it were possible to stop the author and ask a question. Sometimes there is some confusion so that a prior knowledge is really required in order to appreciate the argument (such as on page 219 where the symbol beta is used for two totally different physical quantities within the same sentence), while at other times the author's novel viewpoint gives new insight into the subject.

This book is not a comprehensive text on dynamical meteorology but an account covering the broad interests of a leading scientist. Those who browse through it will find a great deal to attract their attention, but I doubt if the genuine readership will be as widespread as that of its classic predecessor *Natural Aerodynamics*.

P. W. WHITE

Note added in proof: A paperback edition of this publication is also available at £7.50.

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