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DATA PROCESSING IN THE METEOROLOGICAL OFFICE SHORT-PERIOD WEATHER FORECASTING PILOT PROJECT

by C G Collier

Meteorological Office Radar Research Laboratory, RSRE, Malvern.

SUMMARY

The Meteorological Office Short-Period Weather Forecasting Pilot Project, which began in 1978, required the development of techniques for processing radar and satellite imagery. In this paper we describe the data processing system which enables data from several radars to be composited in real-time, as well as being combined with data from Meteosat to give the mesoscale pattern of precipitation. The resulting data are presented within a minicomputer environment to small teams of research meteorologists and forecasters. The primary aims of the Pilot Project are to use these data to improve understanding of mesoscale weather systems, and to devise methods for preparing detailed forecasts of precipitation for 0-6 h ahead.

The system we describe is structured as a distributed processing minicomputer network mostly using dedicated communications lines rented from the Post Office. Instantaneous fields of precipitation, and rainfall totals integrated for short time periods over areas defined by users, are distributed from each radar site to a number of Meteorological Office and Water Authority users, who are presently assessing the usefulness of the data for real-time operations. Data from each radar are also transmitted to Malvern for compositing in real-time to produce an instantaneous precipitation field over a substantial portion of England and Wales. We discuss the software modules which are used in this system, and describe the data archives which are being created.

1. INTRODUCTION

The aims of the Meteorological Office Short-Period Weather Forecasting Pilot Project, which began in 1978, have been listed by Browning (1977) as:

(i) To establish and operate facilities to provide mesoscale observational fields of cloud and precipitation (albeit at first over only a part of the country in the case of some of the data); and, in the light of practical experience, to optimise the accuracy, reliability, and the clarity and timeliness of presentation, of the data.

(ii) To exploit these data to improve our understanding of the structure, mechanism, evolution, and predictability of precipitation and associated wind systems.

(iii) To develop simple analytical procedures to optimise the use of these data for the provision of improved forecasts of precipitation and wind (initially over a period of a few hours but with a view to extending the period of improved forecasts up to 6 to 12 h).

(iv) To assess from practical experience the utility of the actual and forecast fields of precipitation to users.

(v) To assess the desireability, and most cost-effective way, of extending the mesoscale observational network and forecasting techniques.

The Project is expected to take 5 to 8 years to complete, and is primarily concerned with the measurement and forecasting of surface precipitation, although data from several levels in the atmosphere will be collected to improve the estimates of the precipitation reaching the ground.

Mesoscale observations of precipitation and cloud have been greatly improved by recent advances in real-time radar data processing and satellite imagery. Work on quantitative rainfall measurement by radar over the previous decade in the United Kingdom. (Central Water Planning Unit, Reading, 1977), and in many other countries, particularly the USA (for example Wilson, 1970, Woodley et al, 1975, Saffle, 1976), together with the considerable work reported in the literature on the use of radar for general weather surveillance and analysis (for a review see, Browning, 1978), provided the impetus for the use of radar as a key element in the mesoscale observational system. At the same time, work had been in progress for several years at Malvern (Taylor and Browning, 1974), which had led to the development of digital methods whereby data from several radars, equipped with on-site minicomputers, can be transmitted to a central location and composited automatically to give a map of the precipitation distribution over a large area. Finally, the advent of the geostationary weather satellite, Meteosat, providing half-hourly cloud imagery over an area including the UK., made the use of satellite cloud data for very short-period weather forecasting a realistic proposition.

These advances have made it feasible to bring together digital radar and satellite data in near real-time, so that methods can be developed for using them with more conventional synoptic data. Browning (1979) has discussed this total system concept, in which most of the meteorological analysis and forecasting is carried out by forecasters using an interactive video display computer system. This concept, known as the FRONTIERS plan (Forecasting Rain Optimized using New Techniques of Interactively Enhanced Radar and Satellite), will be investigated as part of the Pilot Project.

Most of the work to date in the Pilot Project has been aimed at achieving objective (i) above. This has involved establishing an extensive data communications system linking a number of minicomputers providing data from a number of radars and from Meteosat. Software systems have been prepared in order to accomplish both real-time and off-line data processing. Detailed descriptions of these systems will appear elsewhere. The purpose of this paper is to describe briefly the data processing system as a whole, emphasizing how data will be provided to accomplish the other aims of the Project specified above.

2. THE PILOT PROJECT DATA NETWORK

2.1 Sources of data

The radar network presently being used consists of four radars (Figure 1). Details of the actual radar hardware are given by Ball et al (1979b) and in several internal Met. O.RRL reports. The radars at Camborne (Cornwall) and Upavon (Wiltshire) are old Plessey 43S radars

(10 cm wavelength, 2^{o} beamwidth) sited in a non-optimum manner, and therefore give somewhat limited coverage compared with the other two radars. The radar at Clee Hill (Shropshire) is a Plessey 43C radar (5.6 cm wavelength, 1^{o} beamwidth), which has a horizon at or below 0^{o} in virtually all directions. The 43C is the radar that was operated until recently at Llandegla as part of the Dee Weather Radar Project. The radar at Hameldon Hill, near Burnley (Lancashire), is a new Plessey 45C radar (5.6 cm wavelength, 1^{o}beamwidth). Although the Hameldon Hill radar forms part of a separate project, known as the North West Radar Project* (Collier et al, 1980), data from this radar will be used in the Pilot Project. The Camborne, Upavon and Clee Hill sites are manned (in the case of Clee Hill, Civil Aviation Authority personnel are close by, but no Meteorological Office staff are on-site). The Hameldon Hill radar is completely unmanned, and represents the first such quantitative weather radar in the British Isles. These radars are capable of producing precipitation data at one-minute intervals with a minimum resolution of about 1 Km, although resolutions of 5 min and 2 or 5 Km are used in the Pilot Project.

The satellite, Meteosat, is in a geostationary orbit over the Equator, and is capable of providing IR and visible cloud imagery at 30 min intervals with a resolution in the IR at 50^{o}N of 6 Km E-W and 12 Km N-S (plus some over-estimation of the northward extent of cloud because of the oblique angle of view). These data are received at a central ground station in Darmstadt (Federal Republic of Germany) for processing, archiving and re-distribution to real-time users via Meteosat itself (Morgan, 1978). There are two types of user receiving station: primary and secondary. The Primary Data User Station (PDUS) receives high resolution digital data, and the Secondary Data User Station (SDUS) receives data in analogue format (WEFAX). The United Kingdom Meteorological Office has established a SDUS at Lasham (Hampshire), and we are presently making the best possible use of data obtained via Lasham after having been digitized at the Met. Office, Bracknell.

The Pilot Project radar network is not regarded as a fully operational system. However, technical staff of the Met. Office Radar Research Lab.

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*The North West Radar Project is a cooperative venture supported by the Meteorological Office, the North West Water Authority, the Water Research Centre, the Central Water Planning Unit, and the Ministry of Agriculture, Fisheries and Food.

(Met. O.RRL), Malvern, and local technical staff of the Met. Office Maintenance Organisation (Met. O.M.O.) are endeavouring to keep the radars at Camborne, Upavon, and Clee Hill running 24 hours per day. The Hameldon Hill radar system, on the other hand, will be regarded as operational from the beginning of 1980, and its maintenance will be undertaken jointly by local (Aughton) Met. O.MO.staff, and staff of the North West Water Authority.

2.2 The computer network

Each radar in the network shown in Figure 1 has its own on-site minicomputer, which is used to accept the raw radar data, apply various corrections and output the data in a number of formats to a variety of locations, including a compositing centre in the Met. O.RRL at Malvern. The software in use at the radar sites is based on work carried out at Malvern by the Royal Signals and Radar Establishment over several years. Further developments and additions are likely to be made to it for several years to come. This software has been developed for use with Digital Equipment Co. (DEC) PDP-11 series minicomputers (Ball et al, 1976, 1979b). The initial choice of computer in the early 1970s was based upon the availability of extensive software and hardware servicing support provided by that company. These advantages remain, and as the task of rewriting software for another system would in any case have required considerable work, DEC PDP-11 series computers are being used throughout the Pilot Project data processing system.

The software has reached a degree of complexity which requires special test facilities within the Met. O.RRL, similar to those used by the Atmospheric Environment Service in Canada (Aldcroft, 1976). In order to aid the speedy identification of faults in the radar site system, specialized diagnostic software has been developed in the Met. O.RRL (James, 1979) for use at the radar sites. This software provides tests for the various computer interfaces used on-site, the radar-computer interface unit, and the display system.

The computer network, shown in Figure 2, is a distributed computer network having a radial communications system centred on Malvern. This differs from the larger American National Weather Service AFOS (Automation Field Operations and Services) computer network described by Klein (1976), in which communications are effected using a ring system known as a 'multidrop' system. All the communication lines used in the Pilot Project, with the exception of the links from the Hameldon Hill radar[1], are private wires leased from the Post Office.

In order to provide data of sufficient intensity resolution for compositing and analysis at Malvern, 8-bit (208 intensity levels only are used) radar data are sent to Malvern via a synchronous line network, operating at 2412 baud[2] (Figure 3). A field of surface precipitation is transmitted from each radar site every 15 minutes. Satellite data are received at Malvern from Lasham via Bracknell every 30 minutes via a 600/1200 baud private line (Figure 2). Private Post Office lines have error rates in the region of one bit in 10^6 bits, although errors often occur in bursts. It was considered that simple error checking methods would suffice, and the techniques employed are described in Appendix A.

Data from individual radars are supplied in a 3-bit format to a number of other Meteorological Office locations and Water Authority users. These data are transmitted via 600/1200 baud private wires leased from the Post Office. The location of these outlets, and the radars supplying them, are shown in Figure 4.

Several of the computers in the Pilot Project system are located within the Met. O.RRL at Malvern (Figure 2). Data from the individual radar sites are fed at 15 minute intervals[3] into the PDP11/40 computer at Malvern, in which the radar composite picture is generated and recorded on magnetic tape. Satellite data are also received into this computer and archived on magnetic tape. The radar composite data are passed in near real-time to a further PDP11/34 computer known as the Display Computer (Figure 2).

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1. Communication between Hameldon Hill, Warrington and Franklaw (Figure 2) is accomplished by the use of the North West Water Authority microwave communications system (Collier et al, 1980).
2. One baud corresponds to a rate of one signal element per second in an equal length code; it is usually taken as approximately one bit of data per second.
3. Data from the N.W.Radar Project computer at Hameldon Hill are continuously transmitted to Malvern where they are recorded using a dedicated PDP11/34 computer which passes one picture every 15 minutes to the Network PDP11/40 computer.

This computer is employed to reformat and display the radar composite and satellite data for flexible use by a team of forecasters. The display computer software, although relatively simple at present, is being enhanced in line with the FRONTIERS program described by Browning (1979).

Development of the radar site software is carried out at Malvern on a PDP11/34 computer. Radar video data and azimuth interrupts may be simulated on this computer with a version of the electronic radar-computer interface used at the radar sites (Ball et al, 1979a), and an analogue-to-digital unit provided with data from a simple clocked electronic signal generator. This facility allows the radar-site software to be developed and tested at Malvern before being passed to the radar sites. Routine off-line data processing, such as the provision of hardcopy, is also carried out on this computer, and on a further (PDP11/20) computer. All the computers at Malvern have magnetic tape drives and a removable disc capability (with the exception of the N.W. Radar Project data recording computer, and the network computer which has a 'fixed head' disc). This enables software* to be developed on one computer and easily used on another computer.

3. REAL-TIME DATA PROCESSING

3.1 Data processing at the radar sites

Ball et al (1979b) have described the software system which forms the basis of that used at the radar sites. No commercial operating system is used at the sites, as the intention is to keep the on-site computer hardware configurations as small and as simple as possible. Nevertheless, the software is still complex, involving several nested interrupt routines whose priorities are a function of time. The primary tasks carried out in real-time within the main radar data processing software modules may be summarized, in the order they are carried out, as follows. Some of these tasks remain to be fully implemented, and some differ from those described by Ball et al (1979b).

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*All the software developed in the Met. O.RRL has been written using PDP MACRO-11 assembly language, althougha variety of subroutines (MACROs) have been developed to provide programmers with certain facilities usually only found in high level languages (Davy, 1974, DeJonckheere and Pezzey, 1979 (internal Met. O.RRL reports). These facilities have aided rapid software development, and given a degree of program self-documentation. The operating system used has been DEC DOS-11, but this is soon to be upgraded to RT-11 Version 3.

- Control of the radar aerial elevation. Data are collected during azimuth scans at four basic elevations (nominally at 1.5°, 0.5°, 2.5° and 4°) every 5 minutes. During the lowest scan the elevation may be changed a little as a function of azimuth in order to lift the beam clear of minor obstructions.

- Input of digital amplitude data previously derived by range integration of analogue radar signals (resolution of input data is 750 m, 0.1°).

- Amplitude data averaged in azimuth (resolution 750 m, 1.0°).

- Correction for occultation of the beam by intervening hills and obstacles.

- Elimination of ground clutter by comparison with a stored clutter map followed by interpolation to derive weather signals in the cluttered areas.

- Correction for attenuation through rain for the 5.6 cm radars (attenuation is negligible for the 10 cm radars)

- Conversion of radar reflectivity factor, Z, to rainfall rate, R, using the standard relationship $Z = 200\ R^{1.6}$ (Marshall and Palmer, 1948).

- Averaging in range (resolution 1.5 Km, 1.0°)

- $(1/\text{range})^2$ attenuation correction for ranges beyond 50 Km (for ranges less than 50 Km the correction is applied via hardware).

- Conversion from a large number of polar cells to a relatively small number of Cartesian cells on both 2 Km and 5 Km grids (2 km grid for the 0.5° elevation scan only out to a maximum range of 50 Km for the Camborne, Upavon and Clee Hill radars and 75 Km for the Hameldon Hill radar; 5 Km grid out to 210 Km maximum range at each elevation scan except 4° for which the maximum range is 105 Km).

- Insertion of data from higher elevation scans into badly cluttered parts of the lowest elevation data grid (referred to as the 'multi-beam' task); this is a way of overcoming the problem of extensive areas of ground clutter close to a radar site.

- Calibration of the radar using data telemetered from several rainguage sites at different ranges from the radar.

- Convert to 8-bit float notation in order to reduce the amount of storage space (magnetic tape, computer core etc.) needed for the data grids.

- Write data to 9 track, 800 bpi magnetic tape (7" diameter spools, 600 ft tape), the data being zero packed, and areas with no data in the corner of the Cartesian grid being removed. Data integrated over subcatchments are also written to tape. These tapes are sent to Malvern by rail or post about ten days after recording for archiving.

- Output to local users of 3-bit picture data and rainfall totals for subcatchment areas integrated over a specified period (eg 15 minutes, 1 hour, 24 hours).

- Output of 8-bit data to the Met. O.RRL at Malvern including a repeat transmission which is used in an error checking routine at Malvern (Appendix A).

3.2 Compositing data from several radars at Malvern

Ball et al (1979b) describe software developed by the Royal Signals and Radar Establishment (RSRE) to produce, in near real-time, a composite picture of surface rainfall based on data from three radar sites. A form of packet switching communications system was developed initially to enable control of the network as a whole being passed from one radar site to another if necessary (Taylor, 1975). However, the need for any radar site to be able to control total network operation is not great. Moreover, it is accepted that radars which are part of separate projects (eg the Hameldon Hill radar) must not be interfered with by other sites. Thus, following the suggestion by Ball et al (1979b) that the network communications could be simplified, we have developed new software for use in the network computer at Malvern, and in the computers at the radar sites, which uses the error checking techniques described in Appendix A. Essentially, the network computer software, developed by Mr P R Larke of the Met. O.RRL, adopts a passive role, 'listening' for data from the radars within a pre-set temporal window every 15 minutes.

At Malvern the data from several radar sites are processed simultaneously every 15 minutes on an interrupt basis. At present four radars are involved, but the software has been written to cope with data from at least eight radar sites. The main tasks, in the order in which they are carried out, are summarized as follows:-

- Simultaneous input of data from radar sites using a 'dual buffer' technique for each site. Two buffers are allocated to each site so that data may be received in one, whilst data are being transferred to the computer disc from the other. This avoids any possible loss of data during disc transfers.

- Error checking routines to assess whether data from the repeat transmissions are required (Appendix A).

- Empty buffers for each site alternately to the computer disc as the data are received, so that a complete data set for each site in 8-bit format is built up on the disc ready for further processing after data transmissions have ceased.

- Wait for about five minutes to ensure that none of the data is missed by late arrival, and that the software is not blocked from progress by the non-arrival of data from any of the sites.

- Read the data on disc (in 8-bit format) into the computer core, placing the data from each site in a composite 128 x 128, 5 km grid. A stored map gives the boundaries between radar sites. The particular set of boundaries used depends upon which radar sites are available on a given occasion.

- Write the composite data (in a 128 x 128, 5 km grid) to 9 track, 800 bpi magnetic tape (do the same for the data from each individual site on 84 x 84, 5 Km grids, as back-up for the on-site tape recordings).

- Output the composite picture in 3-bit format to a local display at Malvern, and to other users elsewhere. An example of this output is shown in Figure 5.

- Output the composite picture in 8-bit format to the Malvern Display computer; 8-bit data are transmitted in order that the data from the individual radars within the composite picture may be re-calibrated in the Display computer if necessary. This procedure requires the data to possess its maximum possible resolution.

- Receive satellite data from Bracknell on a 256 x 256 5 Km grid in a 3-bit packed format (radiance values on each line are packed according to a run-length coding scheme). This task may be activated at any time regardless of the receipt of the radar data.

- Write satellite data to a 9 track, 800 bpi magnetic tape separate from the radar data using a second tape drive unit.

3.3 Satellite data processing

The need in the Pilot Project is for infra-red (IR) and visible (VIS) satellite data(and combination thereof) in digital format covering part of the British Isles and surrounding areas. Therefore the SDUS Meteosat data received at Lasham are transmitted to the Systems Development Branch (Met.O.22) of the Meteorological Office at Bracknell, where the data are digitized on a PDP11/70 computer, the area required being extracted and projected on to an extended National Grid (for compatibility with the radar data), and transmitted to the Met. O.RRL at Malvern, where it arrives about 5 minutes after being received at Lasham. These data can be sent, either on a 128 x 128, 10 Km grid formatted in the same way as the radar data transmitted from radar sites, or on a 256 x 256, 5 Km grid in a packed format. The 128 x 128 grid format enables the data to be displayed on a colour monitor using an electronic store for radar data as described by Ball et al (1979a) (see section 3.5). The 256 x 256 grid format, the normal mode of transmission to Malvern, enables the data to be input into the Network and Display computers (Figure 2) for further processing. Data are transmitted from Darmstadt every half-an-hour. Following on improvement in the schedule in June 1979, each picture is received at Malvern about 15 minutes after the observation time. The satellite data may be used by the Forecasting Techniques Group of the Met. O.RRL as soon as they are received in the Display oomputer (section 3.4) by using a series of simple teletype commands. An example is given in Figure 6.

3.4 The Malvern computer-driven radar-cum-satellite display

The total system of processing, analysing and forecasting using radar and satellite data has been discussed by Browning (1979). A computer-driven display is being developed for this purpose at Malvern (Figure 2). The main tasks carried out by forecasters which require an interactive display are:-

- Meteorological analysis: ie the generation of quality controlled radar composite pictures and analysed radar-cum-satellite actuals.

- Very-short-range forecasting of precipitation using the radar-satellite combination as the basic data, and both objective and subjective forecasting techniques.

- Tailoring and dissemination of actual and forecast precipitation information using video displays, computer-to-computer links etc. (Because the data are analysed in a digital format, dissemination via digital communications can be accomplished with a minimum delay between the production of a product and its reception by a user.)

It will take a considerable time to develop in full the required software and to optimize the way in which forecasters implement the various tasks. At present only simple software techniques exist, which enable radar and satellite data to be stored on a computer disc, combined, and displayed separately or in combination. The techniques now in use for combining the radar and satellite data require further development before they can enable the FRONTIERS strategy, outlined by Browning (1979), to be fully implemented.

The radar and satellite data are displayed using an electronic store developed by the RSRE, known as the Fast Update Store (Ball, 1979). Data are passed to this store very rapidly by a Direct Memory Access (DMA) transfer from the computer core, and may be displayed on either a 256 x 256 grid or a 128 x 128 grid. Sequences of in excess of 50 radar or satellite pictures or the combination may be replayed at variable speed. An example of the combination is shown in Figure 7. Forecasters may select pictures using a variety of software facilities. The details of the analysis and forecasting procedudes will be the subject of future reports.

3.5 Data formats and types of terminal

In the Pilot Project, data are distributed to selected Meteorological Offices and Water Authorities direct from individual radars (section 2.2). Data will also be distributed to some users after further processing (ie the compositing of data from individual sites, and analysis by a forecaster using the Display computer) at Malvern.

The data are formatted as a stream of 3-bit (7 intensity levels) numbers framed by various sequences of control characters, and may be displayed by the user on a colour monitor using a commercially available electronic store designed, initially, by the RSRE (Ball et al, 1976). This store, in the form currently available from JASMIN Electronics Ltd, may hold up to nine pictures from individual radars or four pictures of the radar composite which may be replayed in time lapse sequence. Subcatchment data transmitted from the individual radars may be displayed on a simple strip printer (Ball et al, 1979b). Data may also be recorded and replayed by users using an audio cassette recorder and a modem. Figure 8 shows the maximum hardware configuration that a user could have.

4. OFF-LINE DATA PROCESSING

The aims of the Pilot Project include research into methods of producing short-period precipitation forecasts, and fundamental research into the structure, mechanism and behaviour of meteorological systems. In order to achieve these aims, it is necessary to establish an extensive meteorological data base. A requirement exists (Browning, 1977) for an archive comprising radar, satellite and more conventional meteorological data. Such an archive is being established at Malvern, Table 1, and includes raingauge data, facsimile satellite IR and VIS data, occasional serial radiosonde data (from a Mk III radiosonde system at Malvern), and data from a vertically pointing radar situated at Malvern, as well as instantaneous and time integrated digital radar and satellite data.

In order to ensure that the radar data received at Malvern are of acceptable quality, a significant amount of effort has been put into the development of quality control procedures. These procedures involve the comparison, both off-line and in near real-time, of the radar data with raingauge data, and the early identification of the effects of hardware faults by the Met. O.RRL team of forecasters.

In order to achieve easy reference to data, one radar composite picture and one satellite picture per hour are selected from the archives for routine

TABLE 1: Summary of the principal data archives being established in the Pilot Project.

Data source	Archives on 9 track magnetic tape held at Malvern	Archives on media other than magnetic tape held at Malvern
1. Data from individual radars - instantaneous rainfall rates	Data from 4 elevation angles (0.5^o nominal, 1.5^o, 2.5^o, 4^o) out to a range of 210 Km (at Clee Hill the elevations are 0^o nominal, 0.5^o, 1.5^o, 2.5^o) on a 5 Km grid (84 x 84 matrix) except at the highest* elevation for which the max. range is 105 Km. There are 208 intensity levels. Data from the lowest elevation are composited from data at several elevations in order to produce the 'optimum' surface precipitation field. Data from this precipitation field are also available on a 2 Km grid out to 50 Km range for the Camborne, Upavon and Clee Hill radars, and to 75 Km range for the Hameldon Hill radar. Data from each elevation are recorded on a 5 minute cycle.	
2. Data from individual radars -hourly rainfall totals	Data from the 'optimum' surface precipitation field on both the 2 Km and 5 Km grids integrated over clock hours.	
3. Radar network data composited at Malvern - instantaneous rainfall rates	Data from the 'optimum' surface precipitation field on the 5 Km grid for each radar being used to form the composite. One picture from each site is received every 15 minutes. The radar composite pictures on a 128 x 128 grid are also recorded.	
4. Radar compatible satellite IR data (small area)	Data are recorded on a 256 x 256 matrix of 5 Km squares with 8 levels of intensity; data interval 30 minutes.	
5. Raingauge data	Hourly totals from some 40 raingauges, and daily totals from about 4000 raingauges covering the project area (obtained from the Systems Development Branch of the Met. Office at Bracknell).	
6. Facsimile satellite and VIS data (large area)		Facsimile displays on TR4/S receiver; data interval 30 minutes for Meteosat, 6 hours for TIROS-N.
7. Serial radiosonde data from Malvern area		Radiosonde data on hardcopy nominally at hourly intervals during the passage of some precipitation systems.
8. Vertical precipitation profiles from Malvern area (not yet available)		Height-time print-outs of precipitation echo intensity.

* The maximum range of the second highest elevation is 140km.

reproduction as hardcopy (lineprinter output). These hardcopy files, known as the 'condensed data set', provide the means of easily and quickly identifying cases of particular interest. An example of a printout is given in Figure 9. The condensed data set can be updated, daily if the users demand it, within one hour of the radar composite and satellite magnetic tapes being removed from the Network computer. On request, other data, including hourly integrations of the radar site data, may be made available as hardcopy or as a magnetic tape copy. The area integrations(subcatchments) recorded on the magnetic tapes at the radar sites are also available to users.

Interest in these archived data has been expressed by several Water Authorities who hope to carry out off-line case studies of hydrologically interesting events. Arrangements have also been made to supply hourly integrations of the surface precipitation field for each radar, based on the data acquired at five minute intervals,to the Hydrometeorological Branch (Met.O.8) of the Meteorological Office at Bracknell. These data will be combined with available autographic and daily raingauge data to produce a database which should enable practical hydrometeorological research to be carried out.

5. FUTURE DEVELOPMENTS

The data processing system described in this paper has been producing data for only a few months, although data, of variable quality, from one or two individual radar sites have been available for much longer than this (since May 1978 in the case of the Camborne radar, and since February 1979 for the Upavon radar). The basic software package at the radar sites has now operated for over 12 months, although several improvements have been made to it during this period. Satellite data have been received at Malvern (although not continuously recorded) since May 1978. The network software, and the first version of the software to combine radar and satellite data, have been extensively tested off-line, and have been in continuous use since June 1979.

In excess of 5.10^6 bits of information are processed each hour in the total system. At present this includes data from only four radars and analogue and digital IR and analogue VIS images from Meteosat. A further radar site in the London area is already in the planning stage, and the FRONTIERS strategy calls for the future use of data (cloud texture information) from the TIROS-N polar orbiter satellites and conventional synoptic data. Clearly the data processing system will expand throughout the next few years of the Pilot Project.

The new generation of mesoscale numerical weather prediction (NWP) models (Carpenter et al, 1978), being developed in parallel with the Pilot Project, is likely to require new sources of data for model initialization. Browning (1979) has pointed out how the FRONTIERS strategy relates to these NWP models, and has stressed the need to investigate how radar and satellite data together might be used to define the humidity field over a wide area, in a timely and more accurate fashion than using more conventional data. The data archives being established in the Pilot Project provide the necessary database and the opportunity to investigate how this can be achieved.

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METEOROLOGICAL OFFICE RADAR RESEARCH LABORATORY - MET O RRL

Research Reports

No 1 The Short Period Weather Forecasting Pilot Project
K A Browning

No 2 Observation of Strong Wind Shear using Pulse Compression Radar.
K A Browning, P K James (Met O RRL). D M Parkes, C Rowley A J Whyman (RSRE)

No 3 Assessment of a Real-Time Method for Reducing the Errors in Radar Rainfall Measurements due to Bright-Band
J L Clarke, RSRE, C G Collier, Met O RRL

No 4 Meteorological Applications of Radar
K A Browning

No 5 Structure of the Lower Atmosphere Associated with Heavy Falls of Orographic Rain in South Wales.
J Nash, K A Browning

No 6 On the Benefits of Improved Short Period Forecasts of Precipitation to the United Kingdom - Non Military Applications Only
C G Collier

No 7 Persistence and Orographic Modulation of Mesoscale Precipitation Areas in a Potentially Unstable Warm Sector.
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No 9 Objective Forecasting Using Radar Data: A Review
C G Collier

No 10 Structure, Mechanism and Prediction of Orographically Enhanced Rain in Britain: A Review
K A Browning

No 11 A Strategy for Using Radar & Satellite Imagery for Very-Short-Range Precipitation Forecasting.
K A Browning, C G Collier, P Menmuir.

No 12 Radar as part of an Integrated System for Measuring and Forecasting Rain in the UK: Progress and Plans.
K A Browning

No 13 Data Processing in the Meteorological Office Short-Period Weather Forecasting Pilot Project.
C G Collier.

APPENDIX A: Error Checking

Since the error rates on leased Post Office lines are low (usually less than one bit in 10^6 bits), no special error checking is carried out within the user terminal equipment used in conjunction with data transmissions from the radar sites. The data transmissions are continuously repeated for the 15 minute period between the data updates. Errors observed by the users in one transmission may be overwritten by display of the data in the next transmission. However, there is not time in the radar site software for more than two transmissions per 15 minutes of the 8-bit synchronous data to the Met. O.RRL at Malvern. Further transmissions within a period of 15 minutes would delay the production of the radar composite for greater than 5 minutes. For these data an error checking procedure based upon use of the automatic repeat transmission sequence has been adopted.

If an error is detected in the first transmission by the network software at Malvern which examines special block check characters generated at the radar sites, then the error may be corrected by receipt of the appropriate data blocks in the second transmission within one minute. Errors in the actual precipitation intensity values, rather than the block check characters, will not be detected until the data are displayed. No special checking code (such as the Hamming code) is used, and the procedure is a simple form of the Forward Error Correction(FEC) technique with a high degree of data redundancy, and a low ($\sim$ 10%) usage of the communications line. For the Hameldon Hill radar system this procedure is modified as all data processed are continually transmitted to Malvern for recording, and there is no time for repeat transmissions. In this case errors detected by examination of the block check characters are flagged but cannot be corrected.

FIGURE 1 Approximate area within which precipitation can be observed using radars located at Camborne (Cornwall), Upavon (Wiltshire), Clee Hill (Shropshire), and Hameldon Hill (Lancashire). Areas with quantitative coverage are shaded, and the areas of qualitative coverage are enclosed by a broken line.

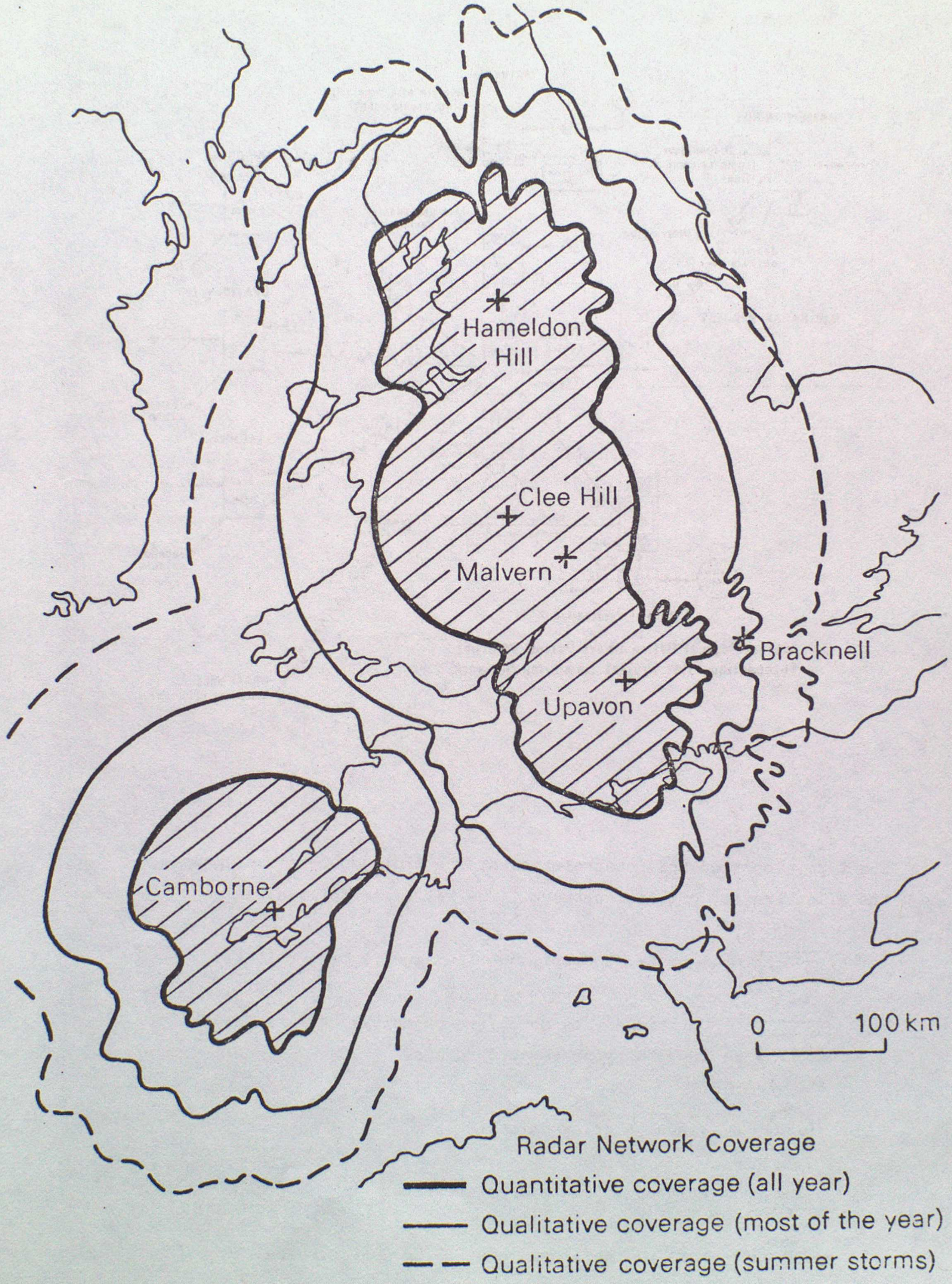
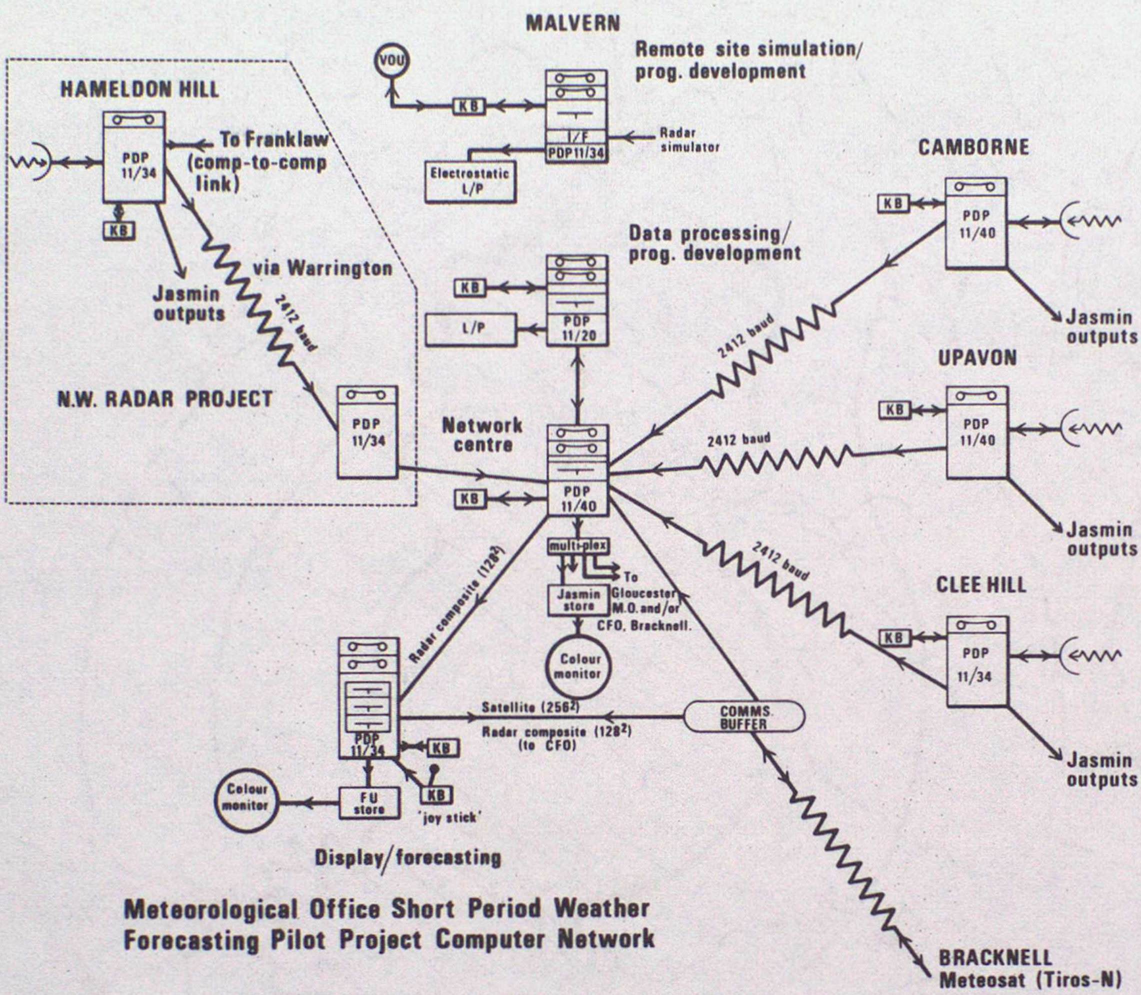


FIGURE 2



Meteorological Office Short Period Weather Forecasting Pilot Project Computer Network

The type, location and interrelation of the minicomputers making up the Pilot Project computer network. The key is as follows:

- 9 track, 800 bpi, 600 ft magnetic tape unit
- Cartridge (2.4 megabytes capacity) or fixed head (~130K bytes capacity)discs.
- VDU — Visual display unit
- KB — Keyboard: teletype or decwriter
- 2412 — Post Office leased line DATEL 2412 service.

FIGURE 3

The communications network connecting the radars to the Met. O.RRL at Malvern. All the lines (except the microwave link used in the N.W. Radar Project) are land lines leased from the Post Office and operated at a data rate of 2412 baud.

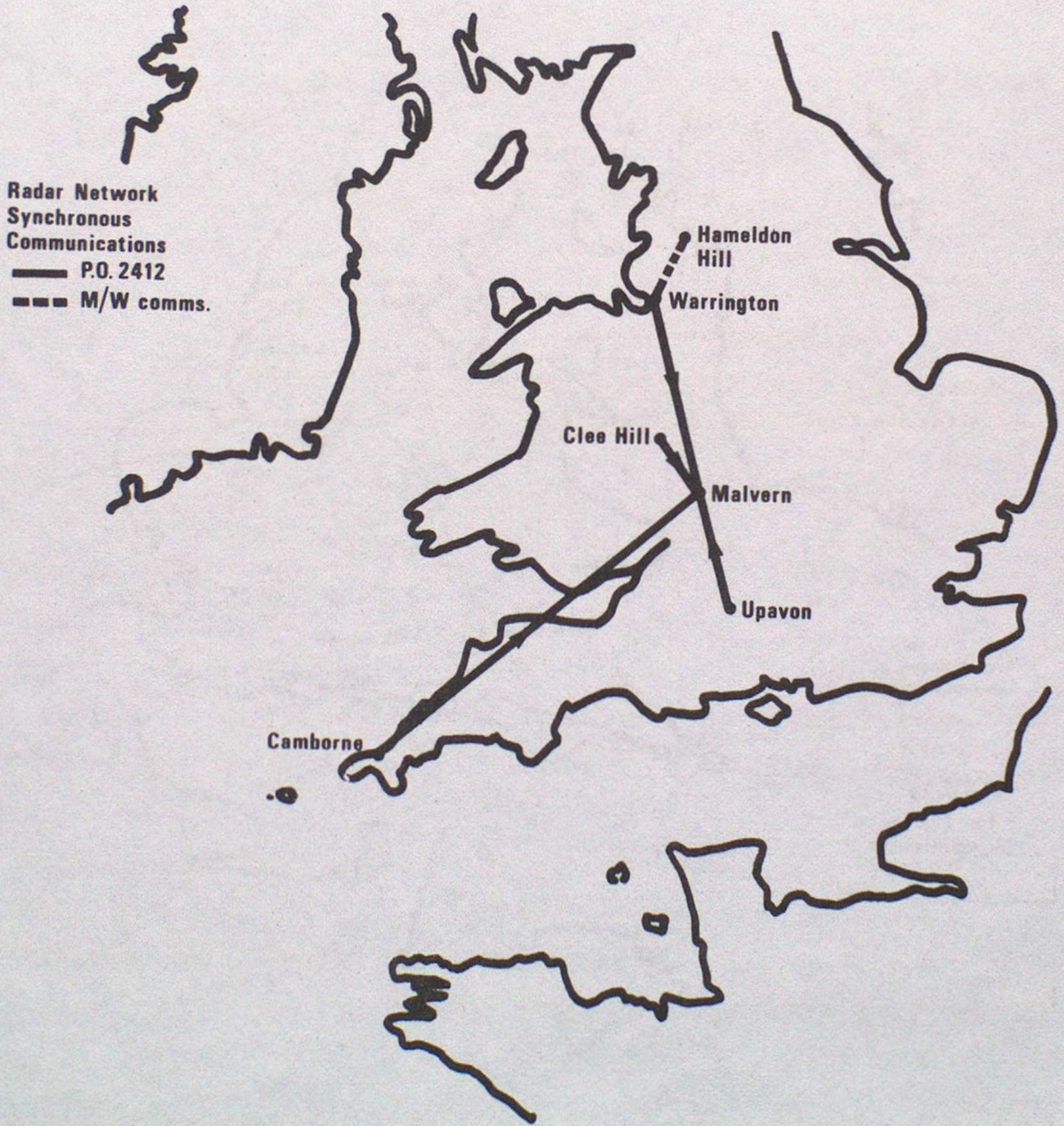


FIGURE 4

Illustrating the communication line network connecting various existing (solid line) and planned (dashed lines) users to the radars. All the lines shown carry 3-bit data and are land lines leased from the Post Office and operated at a data rate of 600 baud.

FIGURE 5

Colour photograph of the colour television display showing the rainfall distribution at 1600 GMT on 21st June 1979 as it was seen in real-time at Malvern using data from the Camborne, Upavon and Clee Hill radars. Rainfall cells are 5 x 5 Km and correspond to the National Grid. The rainfall intensity code is shown in the bottom right hand corner of the photograph: L < 1.0 mmhr^{-1} and S ≥ 64 mmhr^{-1}.

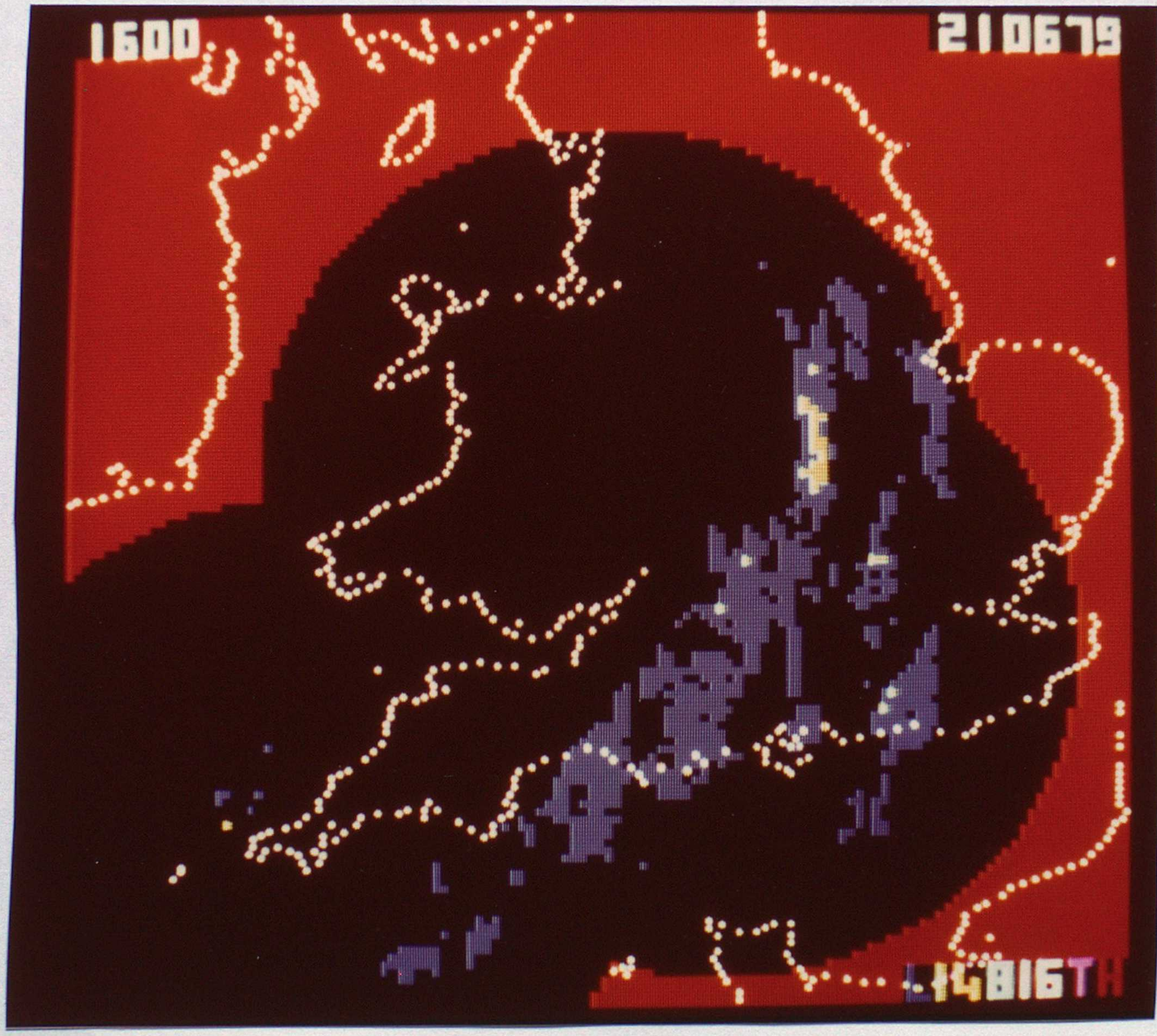


FIGURE 6

An example of the Meteosat data received at Malvern and displayed on a colour television monitor. The data shown in colour are for 0400 BST on the 1st August 1978, Purple (light grey) represents cold high cloud tops and green (dark grey) represents low cloud or the land/sea surface.

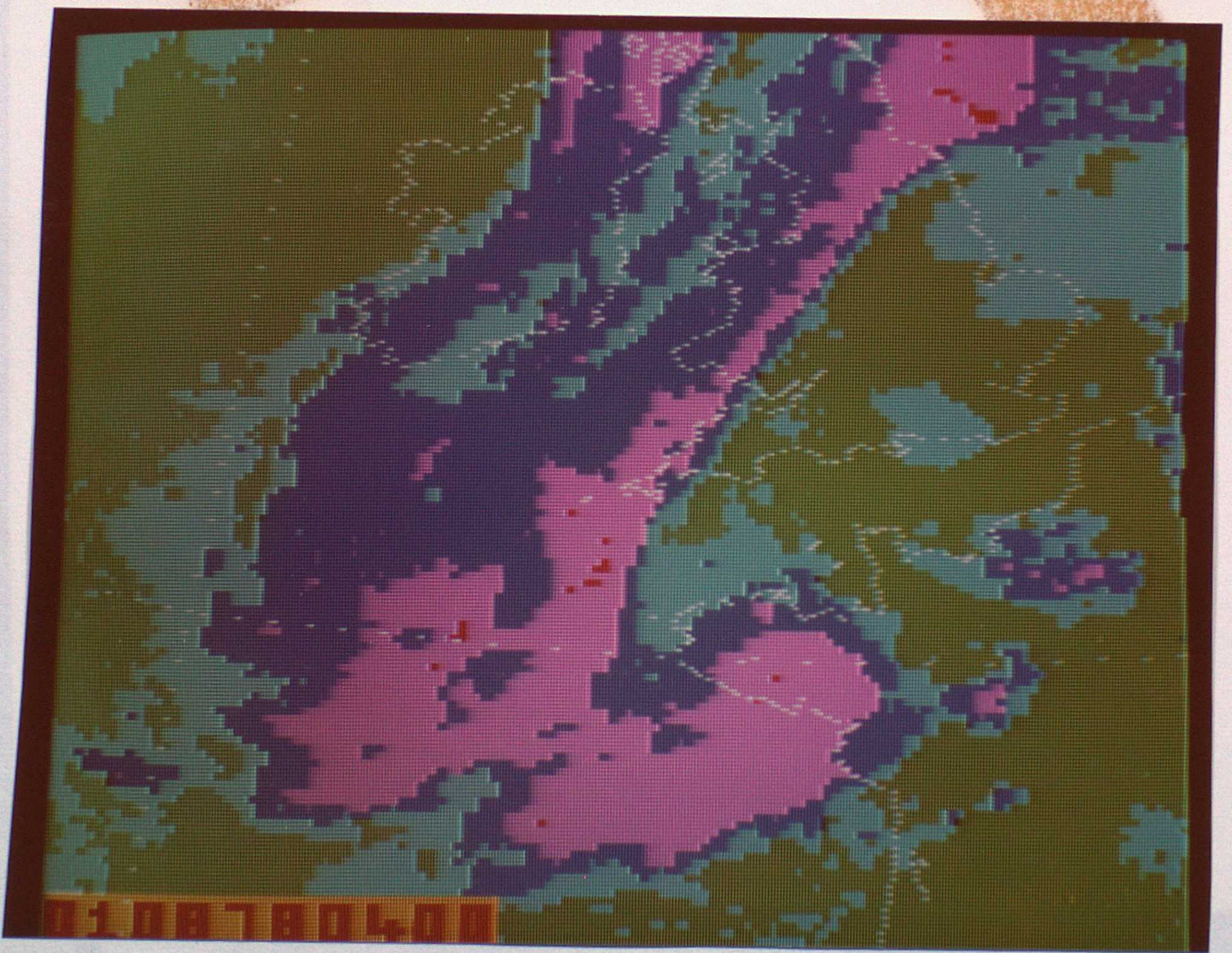


FIGURE 7

Colour photograph of the colour television display showing a picture derived from the combination of the radar and satellite data. The example was derived for 0900 GMT on 21st June 1979. Only the areas of cold high cloud are shown outside the area of the radar network. The satellite image has been re-registered, and, within the area delineated by a red line, radar data are displayed. For a more detailed explanation of the technique see the text.

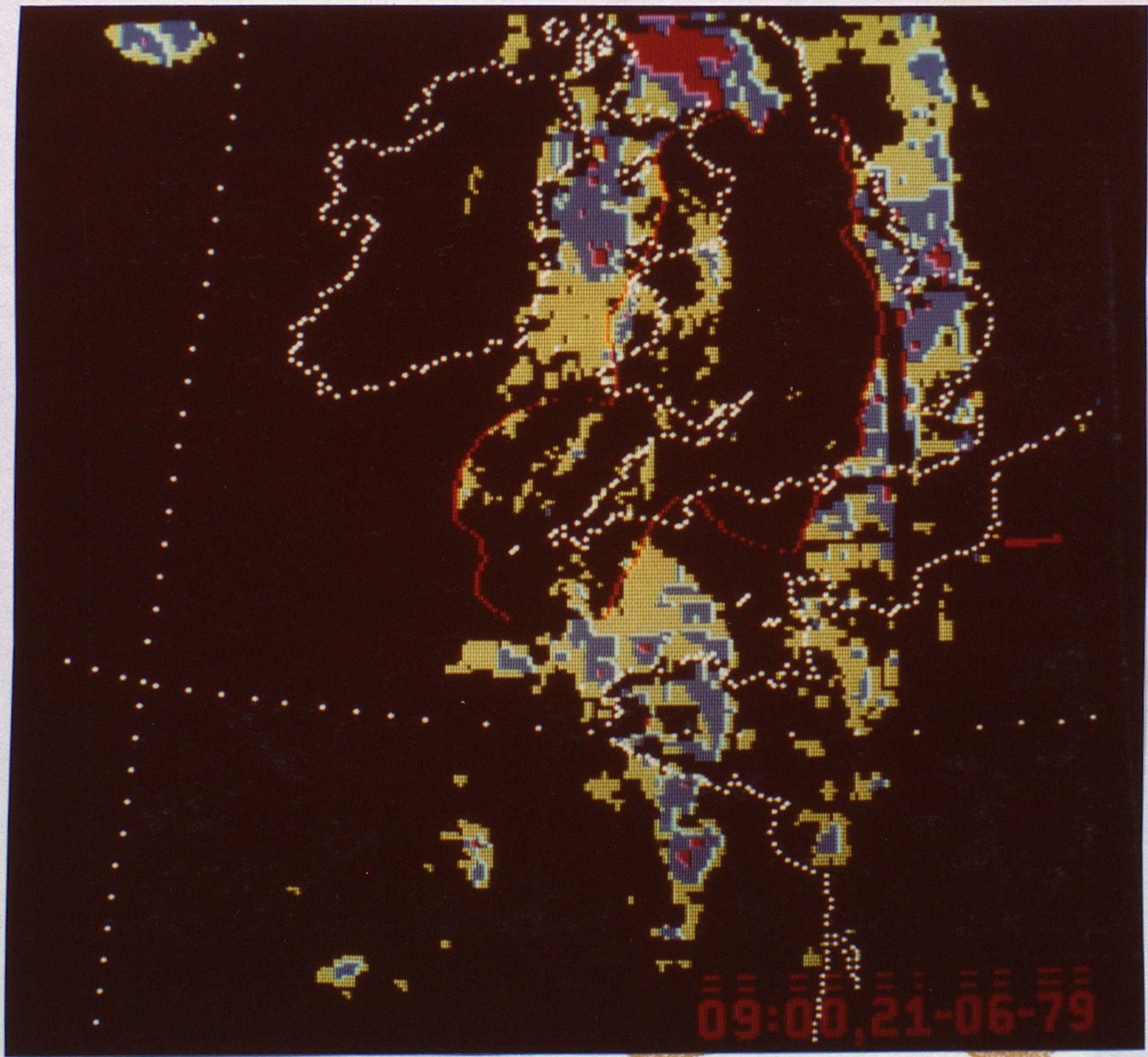
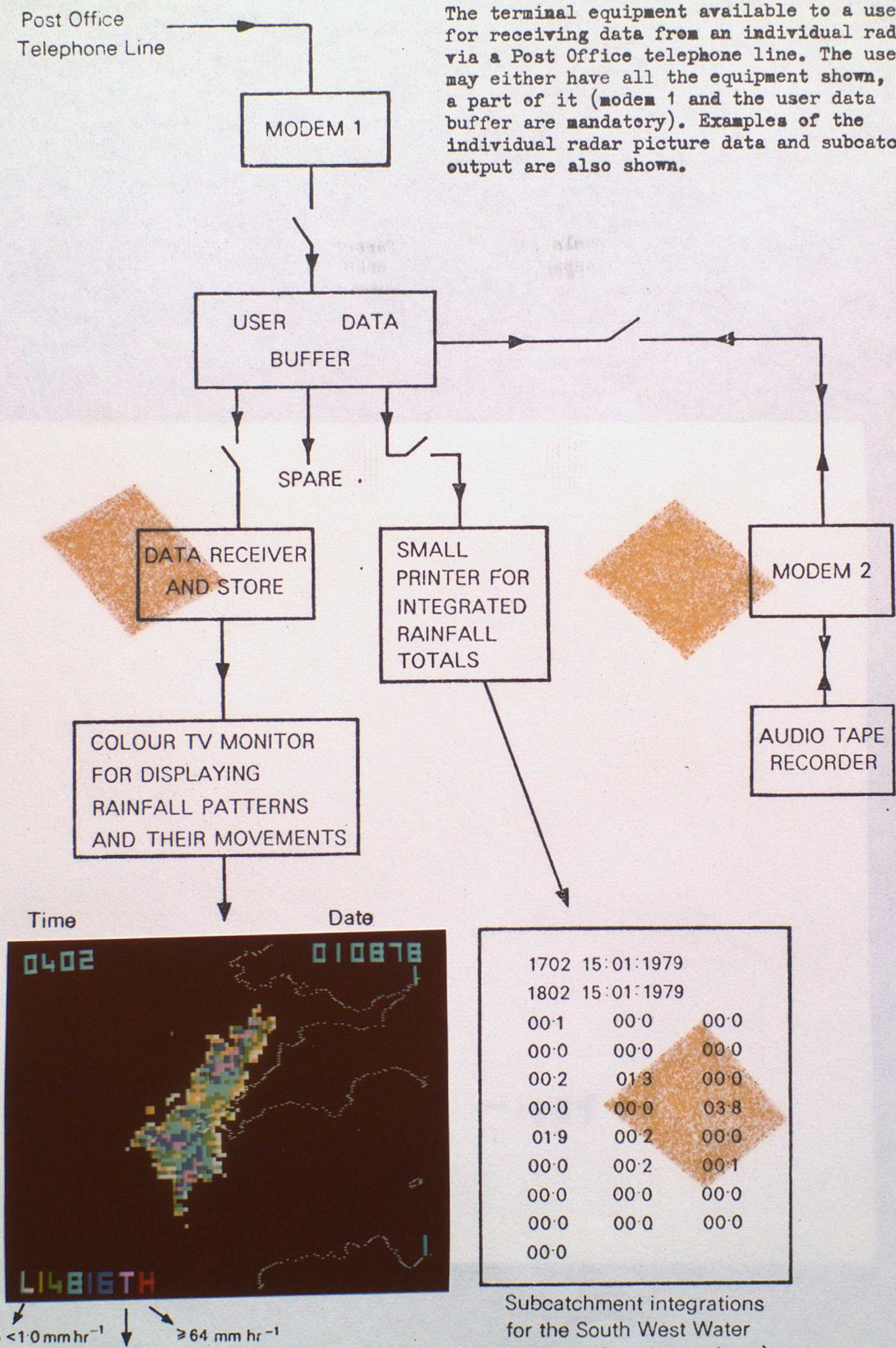


FIGURE 8

The terminal equipment available to a user for receiving data from an individual radar via a Post Office telephone line. The user may either have all the equipment shown, or a part of it (modem 1 and the user data buffer are mandatory). Examples of the individual radar picture data and subcatchment output are also shown.



Subcatchment integrations for the South West Water Authority (mm in one hour)

FIGURE 9

An example of the hardcopy product forming the 'condensed data set'. The example is a radar composite picture made up of data from the Camborne, Upavon and Clee Hill radars at 1600 GMT on 21st June 1979. Different symbols represent different rainfall rates as shown. The coastline is shown dotted. The area not observed with the radars is shown by a pattern of '7's.