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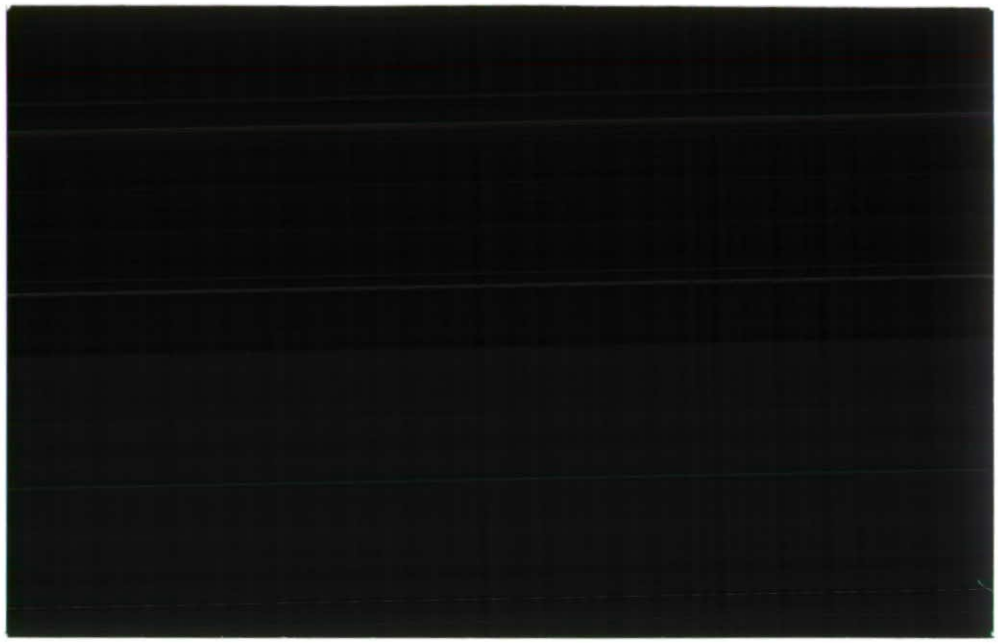

Natural Environment Research Council

HYREX Project T04072B

Design of Radar/Raingauge Networks for Hydrological Use

R. J Moore

HYREX PROJECT T04072B

DESIGN OF RADAR/RAINGAUGE NETWORKS FOR HYDROLOGICAL USE

Report up to 3 March 1995

PRINCIPAL INVESTIGATOR

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MAIN OBJECTIVES

The aim of the project is to review the requirements for rainfall field estimates in the hydrological sciences and to establish how these can be best met using networks of radars and raingauges.

METHODS AND/OR MATERIALS

A unique dataset collected from a dense network of raingauges and radars will be subject to statistical analysis and physical interpretation to better understand (i) the accuracy of different sensors to measure rainfall and (ii) the sensitivity of catchment flow models to rainfall uncertainty and variability.

The Project will develop and use the HYREX (HYdrological Radar EXperiment) infrastructure centred on the Brue catchment in Somerset, South-west England. This will comprise a network of some 50 recording raingauges over the 132 km^2 catchment gauged at Lovington and scanned by 3 radars: a new Doppler C-band radar at Cobbacombe Cross, a conventional C-band radar at Wardon Hill and an experimental Doppler dual-polarisation S-band radar at Chilbolton (Figure 1). A mobile vertical-pointing X-band radar will also be deployed by the University of Salford group within the catchment.

RESULTS TO DATE

Raingauge network

A design for a dense network of recording raingauges over the 132 km^2 Brue catchment was formulated by IH, the University of London/Nuffield College group and the NRA. This comprised 22 gauges at the centre of each 2 km radar grid square, two SW-NE lines of four squares each containing two gauges and two dense networks with 8 gauges per square in areas of low and high relief. The arrangement of the 8 gauge-within-a-square networks was chosen so that the mean of their values would provide the "best" estimate of the mean rainfall over the square: this resulted in a diamond-within-a-square configuration with sides .778 and 1.38 km respectively. This "design requirement" has been turned into an "operational design" following site visits and discussions with landowners. Installation began by Allwater Technology in September 1993 and in December was largely complete. The "as constructed" design, incorporating 49 gauges, is shown in Figure 2.

The main effort on the raingauge network aspect of the project has focussed on developing archiving and quality control procedures. The latter have included simple monthly tabulations of rainfall totals

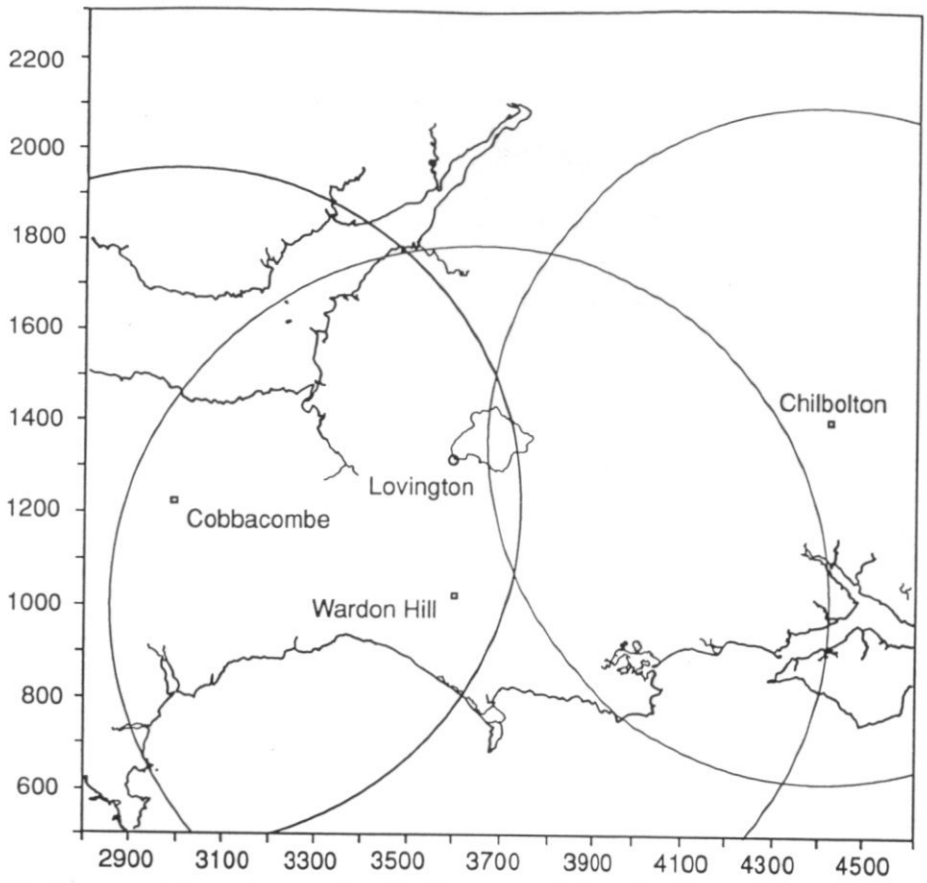
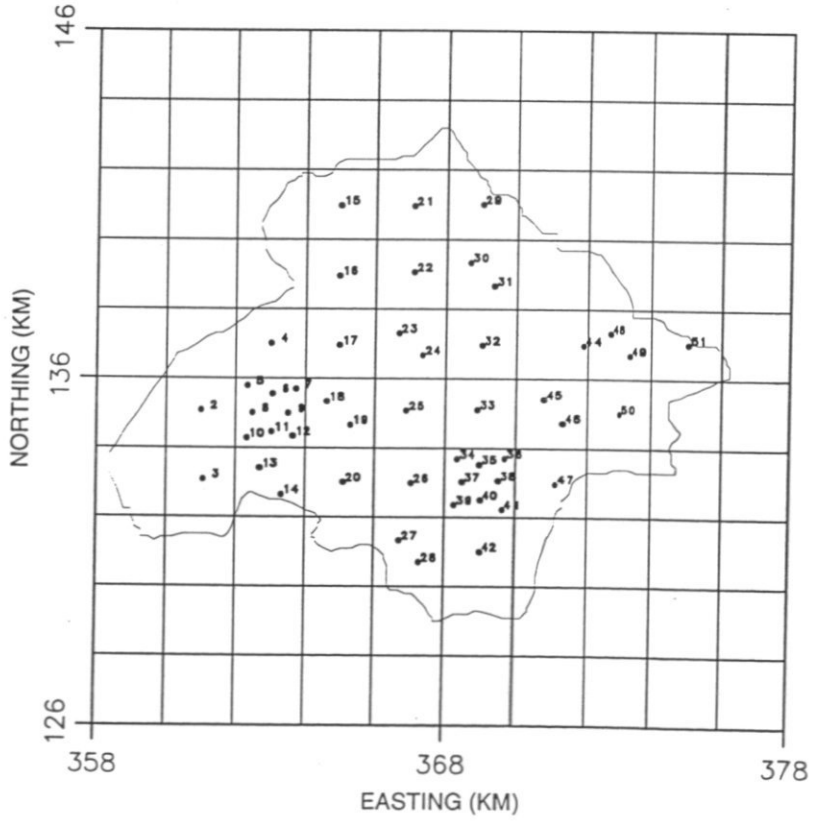


Figure 1 *The Brue catchment gauged at Lovington and the associated scanning radars (75 km radar circles indicated).*



2 KILKENNY FIELDS
3 ALFORD FIELDS
4 DITCHET HILL FARM
5 KITE LANE
6 MEADOW BUILDINGS
7 SNAGG FARM FIELDS
8 BRIDGE FARM ORCHARD
9 OPP SPRINGFIELD COTTS
10 MOOR LANE PADDOCK
11 JACOBS LANE FIELD
12 SHIELDSVILLE FARM
13 LOWER FARM SUTTON
14 INDUST PARK CC
15 SPRING STONY STRATTON
16 FIELDS IN EVERCREECH
17 RODMOOR FARM FIELDS
18 WADDON FARM ORCHARD
19 EAST HILL LANE FIELDS
20 KNAPP HOLLOW WYKE LANE
21 CHESTERBLADE BANKS FW
22 BADGER SET MANOR FW
23 MILTON WOOD CORN FIELD
24 GREENSCOWE FIELD
25 CRABTREE LANE FIELD
26 PITCOMBE FIELD
27 HADSPEN HOUSE FIELDS
28 FRANCOMBE LANE FIELDS
29 BATCOMBE HILL FIELDS
30 QUARRY FIELD BATCOMBE
31 SEAT LANE FIELD
32 WHADDONN FARM FIELDS
33 SEPTIC TANK COMPOUND
34 NEW HOUSE FARM FIELD
35 GODMINSTER WOODS
36 DROPPING LANE FARM
37 GODMINSTER FARM
38 REDLYNCH FARM STUMP
39 DODDS CORNER FIELD
40 TOWERS FIELD
41 POND FIELD BY TOWERS
42 KNOWLE FIELD BY STREAM
43 UPTON NOBLE FIELD
44 GOODEDGE FARM FIELDS
45 COGLY WOOD FIELDS
46 HORSLEY FARM FIELDS
47 MOOR WOOD FIELDS
48 WALTERS FARM FIELD
49 COOKS FARM FIELD
50 CRAWLY FARM FIELD
51 GLADWELL FARM FIELD

Figure 2 *The HYREX raingauge network within the Brue catchment*

for each gauge along with cumulative hyetographs (Figure 3). These have served to highlight the time of inception of new gauges, the malfunctioning of others and the broad range of rainfall variability experienced. Problems with gauges have included the following: loose funnel filter falling inside; flood water rising up side of collector; disconnected wiring; collector blocked with dung; mouse damage and nest; and failure to download. Allwater Technology, responsible for the day-to-day management of the gauges, have kept error logs which are updated during the course of monthly downloading. This information is being incorporated into the HYREX raingauge database to support automated recovery of reliable data. Monthly rainfall fields have been derived by multiquadric interpolation and used to identify gauge malfunction and to expose the influence of orography on rainfall amounts over the Brue catchment (Figure 4). Ratios of gauge to concident radar estimates of rainfall have been calculated and averaged over a month, using both 2 and 5 km grid square radar data from Wardon Hill and Cobbacombe. This has exposed that both radars are underestimating rainfall by a factor of between 1.5 and 2.5, with Cobbacombe being worst (Table 1).

Table 1 Mean raingauge/radar ratios for the Wardon Hill and Cobbacombe Cross radars, using 2 and 5 km data

Month	Cobbacombe		Wardon Hill	
	2 km	5 km	2 km	5 km
January	-	-	1.703	1.728
February	2.285	2.245	1.869	1.901
May	2.487	2.501	2.057	2.120

Automatic Weather Station

A NERC Equipment Pool Automatic Weather Station, sited in the 8-gauge low relief square at Bridge Farm Orchard, was installed on 2 September 1993. The basic station configuration has been modified to record at 15 minute intervals, to measure atmospheric pressure (in support of the rainfall forecasting project) and to record rainfall using 0.2 mm tipping buckets instead of .5 mm.

Soil Moisture Station

A Soil Moisture Station has been supplied to the HYREX project by IH under a Beta-test arrangement. Installation within the AWS compound occurred on 19 September 1994. The station is equipped with arrays of capacitance probes (Dean, 1994), tensiometers and soil thermometers which record at depths of 15, 25 and 50 cm; there is also a 0.5 mm tipping-bucket raingauge. Calibration of the capacitance probe is required using gravimetric samples and this is as yet only partially complete. Data have been quality controlled through the production of time series plots, exposing battery failure on 27 October 1994 (Figure 5). This was rectified on 18 January 1995.

Optical disdrometer

Problems with the optical disdrometer delayed its installation at the Bridge Farm site. These problems were resolved and the complete installation, including a shed to house the associated computer, was complete on 28 October 1994, unfortunately one week after the first IOP (Intense Observing Period) on 18 October. The instrument has been deployed once, from 14-15 February 1995. Details of the instrument are given by Illingworth and Stevens (1987). In a 10 second sampling interval it records

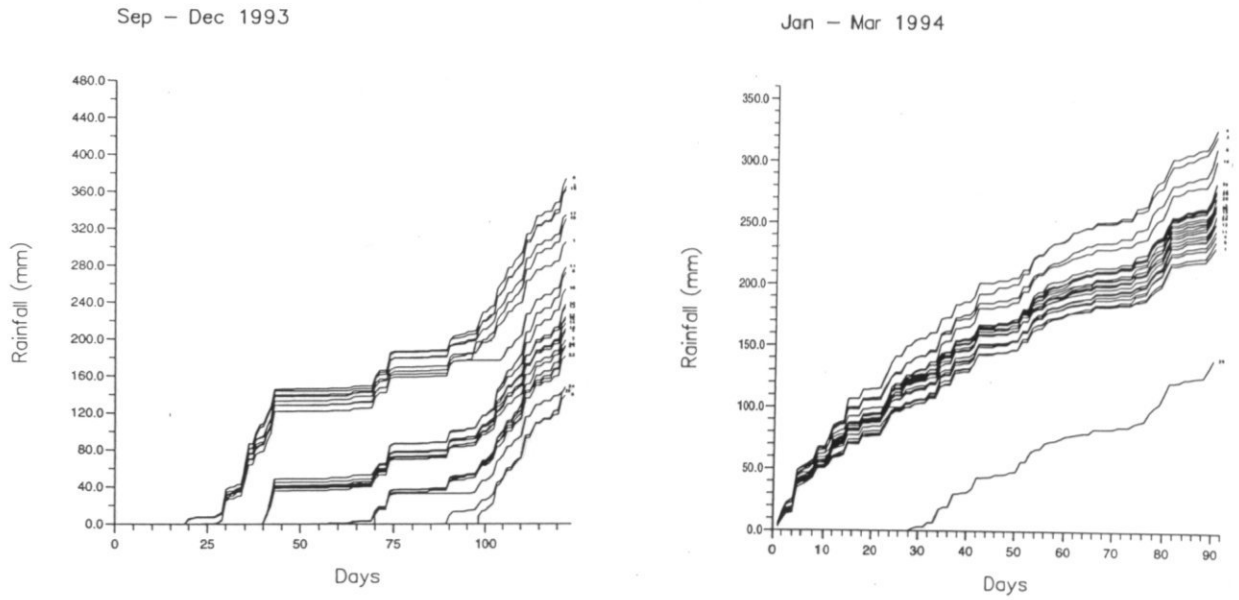


Figure 3 Cumulative hyetographs from the Brue raingauge network

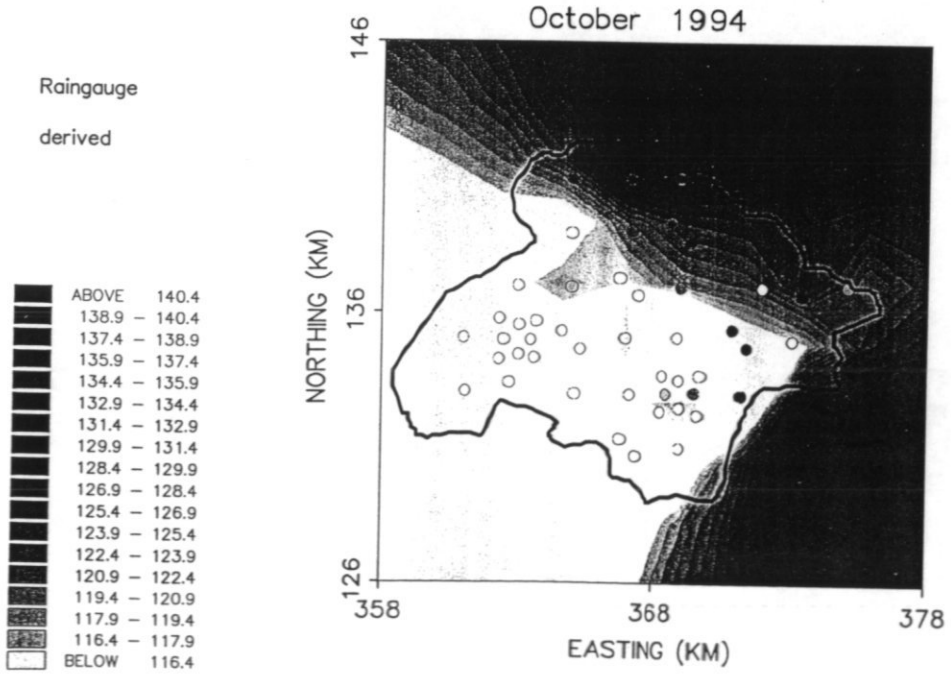


Figure 4 Rainfall field over the Brue catchment derived by multiquadric interpolation

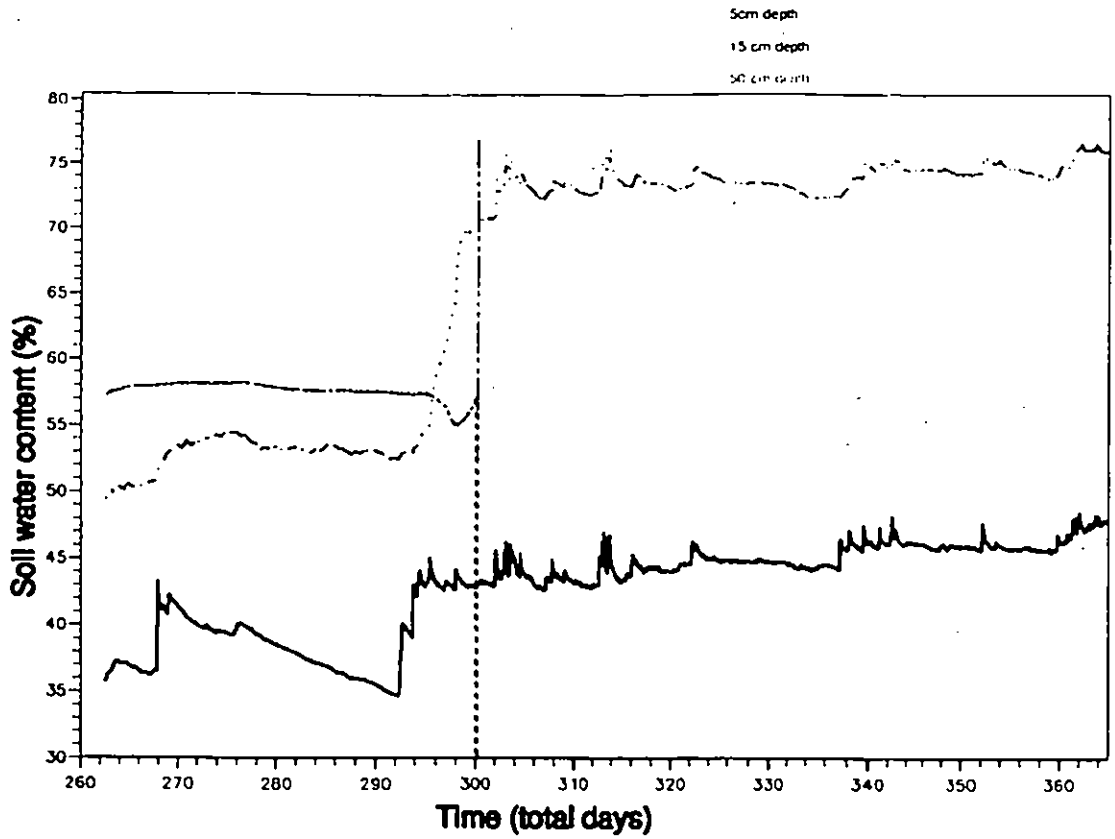


Figure 5 Capacitance probe measurements of soil moisture, indicating occurrence of battery failure on 27 October 1994.

the number of drops passing through the sampling volume and their duration of occupancy within the volume, both quantised into 16 range bins. These were averaged over a 15 minute period in order to reduce sampling effects to obtain 4 drop size histograms per hour. Since the lowest range bin (0 to 0.72 mm) suffers from loss of instrument resolution and the highest (3.65 mm and above) has no upper limit these have so far been omitted from analyses. The drop size distributions have been used to estimate radar reflectivity, Z, and rain rate, R, for each 15 minute period, assuming Rayleigh scattering theory applies and a C-band (5 cm) radar. These values have been used to estimate preliminary Z-R relationships of the usual form, $Z = aR^b$, where a and b are parameters.

Radar database management

IH received the first batch of HYREX radar data from the Met.Office in the second week of January 1994: data for September and October 1993 from Wardon Hill. Problems with access to Cobbacombe radar data, due to to the abscence of at-site archiving of data, were resolved in the first quarter of 1994 with NRA support in tape changing. Data are currently available for the two radars up to the end of December 1994, with Wardon Hill starting in September 1993 and Cobbacombe in February 1994.

Remote access to the volume-scan and Doppler products from the Cobbacombe radar has been problematical and required further software support by Lassen in the USA. This was resolved in the first quarter of 1995 with archived data now being able to be read by external (to the SunRise workstation) systems. A trial transfer to IH has not yet been tried, but is likely to involve the 18/19 October 1994 IOP event for which data were archived. Archiving is still restricted to manual mode, and a further visit by Lassen to the MO is planned to resolve the problems associated with the automatic mode.

River level data

River level data for the Brue at Lovington have been supplied by the NRA for the period 1 April 1985 to 1 January 1995 and incorporated in the HYREX database.

HYREX database

Dissemination of data held in the HYREX database to the wider HYREX community began on 21 March 1993. This is achieved using FTP access via the JANET network in a "guest" area of IH's UNIX computer network.

CONCLUSION AND ADDITIONAL REMARKS

(i) The first year of the project saw the design and implementation of the HYREX raingauge network over the Brue catchment and initiation of the data collection and database management phase.

(ii) A HYREX invited seminar on rainfall measurement using multiparameter radars, by Anthony Holt (University of Essex), was convened at IH in 1993.

(iii) In anticipation of the delay in the completion of the dense raingauge network, and the limited Special Topic funds available to the project, IH chose to defer recruitment of a HYREX researcher. Sean Wood started at IH in January 1995. Work relating to the planning, coordination, field instrumentation and database activities has been undertaken outside NERC HYREX funding by the Principal Investigator and colleagues (Dawn Carrington, Roger Austin and David Jones).

(iv) Future work will initially focus on issues concerning rainfall measurement accuracy using the HYREX raingauge network. Empirical measures of accuracy, not based on spatial correlation functions, will be used to explore the dependence of rainfall estimation accuracy on rainfall magnitude.

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