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**NERC STEERING COMMITTEE
ON THE HYDROLOGICAL
APPLICATIONS OF
WEATHER RADAR**

**Second Report
August 1989**

Natural Environment Research Council

Institute of Hydrology

SECOND REPORT OF THE NERC STEERING COMMITTEE ON THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

1. INTRODUCTION

The period following the establishment of the Committee in March 1986 up to January 1988 was covered in the First Report of the NERC Steering Committee. During that period, under the chairmanship of Dr John Rodda, the Committee devoted considerable attention to the identification of research needs and their incorporation into a programme of potential research. The rationale underlying the formation of the group and the derivation of the research programme are both described in the earlier report. The terms of reference are given in Appendix A.

The period under review has seen an expansion of the UK network with the introduction of five new operational radars and progress in the planning of three installations in Scotland, with the establishment of a consortium comprising the Meteorological Office, the Scottish Development Department and a number of regional authorities. Figure 1 shows the network at 1 July 1989. Nine water authorities in England and Wales now receive weather radar information and use it as part of their flood forecasting and warning procedures. Many have plans (which will transfer with the flood defence responsibility to the National Rivers Authority) to enhance and extend their use of radar data by integrating it fully with regional telemetry systems and by feeding numerical radar data directly into operational flood forecasting models.

The last 18 months have seen a change in emphasis of the Committee's work. It has met regularly, at least once every six months, and given increasing attention to the identification, monitoring and publicising of ongoing research and development activities. A topic to which discussion has returned on many occasions has been how best to encourage commercial promotion of the UK Weather Radar System abroad. An important role for the Committee is to ensure that a sound scientific basis for this national operational system exists through a structured programme of research involving university departments and NERC's Institute of Hydrology.

2. OVERVIEW OF ACTIVITIES

The Committee has been conscious of the need to improve publicity and communication and has given considerable thought as to how these might be improved. It has introduced a brief presentation session at each of its meetings to allow one of the members to describe ongoing research activities and results. The Committee has introduced a simple six-monthly reporting system to monitor the content and progress of all research and development activities within its sphere of interest and of which it is aware. The latest reports form Appendix C and are reviewed in Section 4. It is also planned to produce a newsletter for general circulation.

The Committee arranged, with the support of the Institute of Hydrology, a one-day seminar in April 1989 on "Weather Radar and the Water Industry Opportunities for the 1990s". Many of the issues raised at the seminar overlap with those reviewed in other sections of this report. However, it is pertinent to note that the lead established by the United Kingdom in the development and application of weather radar has been significantly eroded over the last decade, the levels of fundamental research effort are extremely low and there has been little commercial exploitation of British expertise in this field.

To further publicise the considerable amounts of British research and development that have taken place, the Committee has embarked upon the preparation of a UK bibliography. (Any

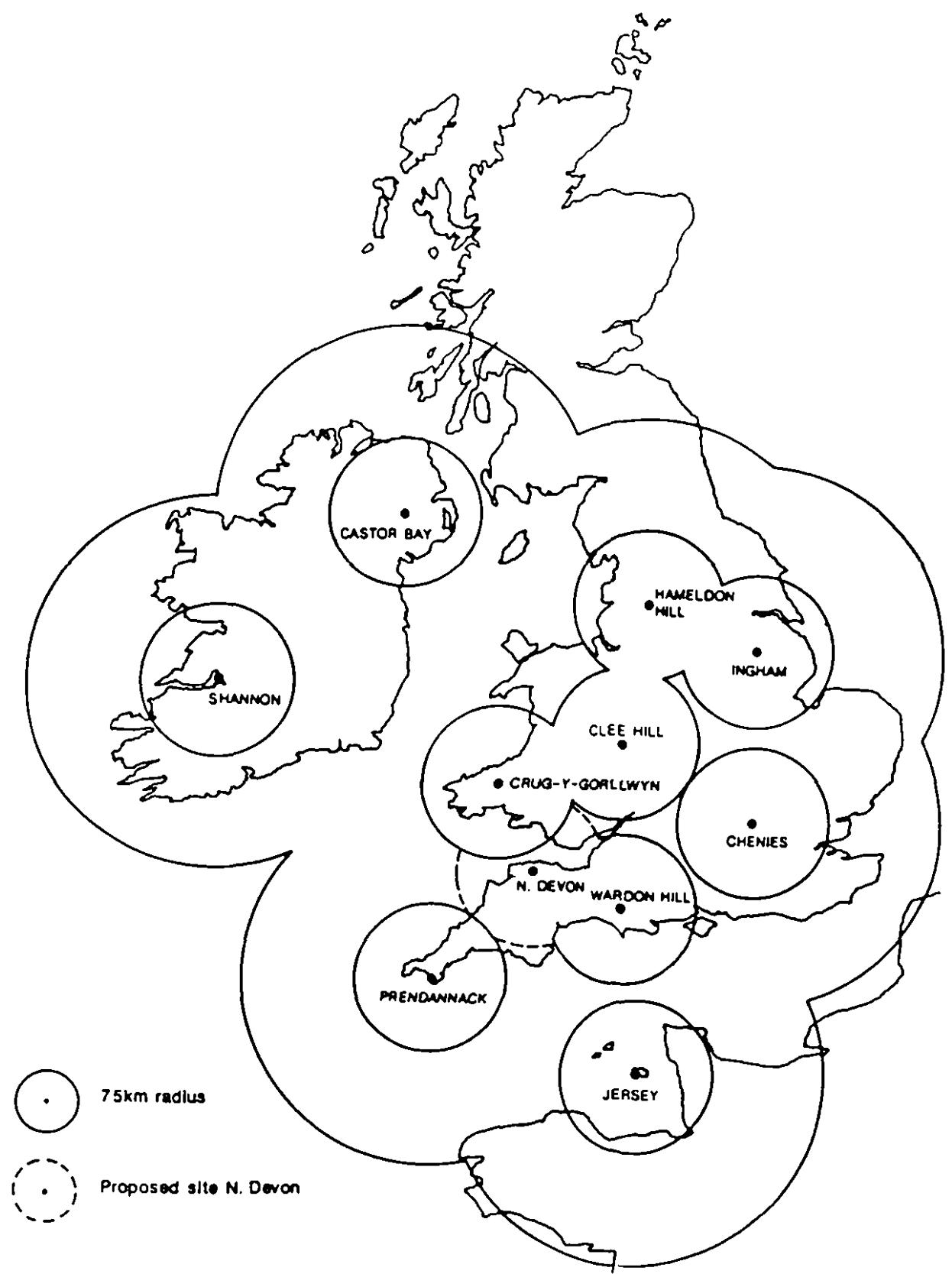


Figure 1 United Kingdom weather radar network 1989

readers of this report who can contribute material for inclusion should contact the Committee's Secretary at the Institute of Hydrology before the end of December 1989.)

The development of British applications has been an excellent example of co-operation between many public sector bodies, in particular water authorities, the Meteorological Office and research organisations such as those represented on the Committee, together with those firms that have developed hardware and software systems. However, this wide base fails to provide a focal point for any commercial initiative and fragments a potential source of research funding.

MEMBERSHIP

Following the appointment in January 1988 of Dr John Rodda as Director for Hydrology and Water Resources at the World Meteorological Organisation in Geneva, the Chairmanship of the Committee was taken by Dr Peter Walsh of North West Water. There have been two other changes to the membership of the Committee. Mr Bob Hatton (South West Water) has replaced Mr John Tinkler (Wessex Water), who has retired from the industry, as the representative from the South West Radar Consortium. Mr Roger Goodhew has replaced Dr Richard Bailey, both from Severn Trent Water, and represents the Lincoln Radar Consortium. All the water authority representatives are employed in the shadow National Rivers Authority units. There is currently no one on the Committee representing the utility water and sewerage business interests. A list of members and their affiliations is given in Appendix B.

The Committee has considered the scope of its present membership, which it considers to have provided a good balance of research and operational interest. However, with the imminent split of the water authorities, and, recognising the developing interests in Northern Ireland and Scotland, the Committee has invited nominations for membership from the water and sewage businesses of England and Wales and from the consortia in Northern Ireland and Scotland.

The Committee is particularly grateful for the work of John Rodda as its first Chairman and for the contributions made by Richard Bailey and John Tinkler. Members were also pleased to record their congratulations to Dr Ian Cluckie on his appointment as Professor of Water Resources at Salford University, where amongst his many interests he will be continuing work on the hydrological applications of weather radar.

4. RESEARCH ACTIVITIES

The original research programme was divided into 4 subject areas:-

CALIBRATION - the translation of the radar signal into rainfall amounts, taking into account the particular needs of hydrological applications.

FLOW FORECASTING - both for real-time events and for design flood estimation.

URBAN APPLICATIONS - to assess the issues involved and the opportunities for the design and management of storm water drainage systems.

COMMON DATA REQUIREMENTS establishment of a hydrologically orientated data archive for research and applications studies (since no central facility exists other than at the Meteorological Office, whose archives are primarily designed to meet meteorological needs).

Appendix C summarises the ongoing research in the first three subject areas that the Committee has identified and which is now the subject of its six-monthly review process. These tables show that the majority of funding support is coming from three sources. Those elements of the water authorities which will form the National Rivers Authority are supporting the development of applications and the improvement of calibration and flow forecasting procedures. The Meteorological Office is funding, mainly in-house, work devoted to meteorological aspects. The Ministry of Agriculture, Fisheries and Food and Department of the Environment finance specific projects being carried out at the Institute of Hydrology.

The Committee has had no success in procuring funds to support the establishment of a high resolution radar data facility in the form of an archive tailored to hydrological research or applications. The Committee believes that the formation of the National Rivers Authority, which will be the major operational user of radar data for hydrological purposes, provides an opportunity to take the lead and develop a consistent national archive system to meet hydrological needs.

Research activities with major combined hydrological and radar components are primarily based at three centres - the universities of Lancaster and Salford and the Institute of Hydrology. They have received limited funding from NERC and CEC sources. Consequently, the financial and human expertise form a potentially fragile base. It is a credit to this small and dedicated community that the British effort is held with such high regard in Europe and America. The Committee was particularly appreciative of the initiative by Professor W B Wilkinson, Director of the Institute of Hydrology, to make a fund available to support research of mutual interest to the Institute and universities.

In his paper to the seminar, Mr Vince Collinge demonstrated that there are potentially large benefits from several years of sustained investment and effort. The Committee operates without a budget either to finance its own meetings or to support research, and is unanimous in its view that the continuity of effort is jeopardised by the piecemeal and hand-to-mouth availability of support. The co-ordination and information exchange, which has taken place as a result of the Committee's activities, has ensured good use of those limited resources. There is little doubt that without the Steering Committee's influence there would have been a highly fragmented research effort, duplication would have been greater and opportunities for the cross-fertilisation of research ideas lost. The hard work and enthusiasm of Committee members have made a worthwhile impact and contribution to progress, but much more would have been possible with even a modest amount of funding. The Committee is now working to improve communication and publicity of its activities so that greater benefits can be generated through widening the participation to other centres of research whose work could interface with the research it has already identified and fostered.

3. SEMINAR ON WEATHER RADAR AND THE WATER INDUSTRY

The Steering Committee arranged the seminar for an invited audience which included representatives from water authorities, consulting engineers, shadow NRA units, universities, and commercial firms. Over 75 people attended and participated in a very full discussion of the eight papers presented. A primary theme of the seminar was to review current levels of investment and the benefits to be gained from further research. In his paper, Mr Collinge's assessment suggested a benefit/cost ratio of at least 3 for a network of eight radars covering England and Wales, and that to obtain the high potential benefits from FRONTIERS forecasts would require further and sustained research effort. Further objectives of the seminar were to initiate discussion on ways to exploit any commercial opportunities and to publicise fully recent developments and the direction of ongoing research. During the discussion, it became clear that many consulting engineers have had no direct involvement with weather radar. However, representatives present at the seminar expressed a keen interest in the potential of radar for use in overseas projects. Considerable interest was also shown in the Meteorological Office proposal to evaluate Doppler radar at one site on the south

coast.

The seminar is felt by the Committee members and those who attended to have been very successful in terms of dissemination of information, exchange of views and focussing attention on problems. The proceedings of the seminar are being prepared for publication in the British Hydrological Society's series of Occasional Papers.

INTERNATIONAL LINKS

CEC Project on the Use of Weather Radar for the Alleviation of Climatic Hazard

This three year project, part-funded by the Commission of the European Communities (CEC), began on 1 October 1987 and involves the Institute of Hydrology and the universities of Lancaster and Salford in the UK and partners in Portugal, Italy, France and the Netherlands. Emphasis in the past 18 months of the project has been placed on developing improved calibration procedures. A Special Interest Meeting on this topic was held at the Institut de Mécanique, Grenoble, France, from 24-25 March 1988. The first Annual Meeting of the project was held at Arabba, Italy from 27-29 November 1988, and Vince Collinge took the chair. Summaries of progress made over the year by each national group were complemented by discussion of a number of special topics introduced by a small number of invited international experts. A visit to a flood forecasting system serving the Veneto region of northern Italy, and incorporating an Ericsson Doppler radar, provided an impressive climax on the final day. A further meeting in Brussels was held in conjunction with the COST 73 group to discuss where the two groups' interests were common and where they differed. An Annual Report covering the first year of the project has been prepared. This covers the research progress made on calibration, flow forecasting and urban applications of weather radar by each partner country. An extension to a fourth year has been approved by the CEC.

International Contacts

Over the last 18 months, Committee members have continued to develop links with overseas organisations. Chris Collier, in his capacity as Chairman of the CEC COST-73 Management Committee for the Weather Radar Networking Project visited Sweden, Belgium, France and Italy. He has also made visits to a number of other countries including the USSR, China and Hungary.

Dr Peter Walsh gave presentations and held seminars on the use of weather radar for engineers and meteorologists working for various government agencies in Thailand and Malaysia. He also presented a paper to a technical conference on "Hydrology of disasters hydrological implications of natural disasters and those caused by man's activities" held during the 8th Session of the WMO Commission for Hydrology in Geneva in October 1988. The Radar and Flood Warning Office of North West Water NRA Unit hosted visitors from South Africa, Hong Kong and the University of Birmingham Overseas Graduate Course.

Robert Moore, IH, visited Japan for two weeks as a recipient of a fellowship Research Award for Foreign Specialists made available by the Japanese government and administered by the Director General of the Public Works Research Institute (PWRI). The visit included discussions with radar researchers at PWRI (located at Tsukuba Science City), Kyoto University, including its Disaster Prevention Research Institute (DPRI), and FRICS (Foundation of River and Basin Integrated Communications, Japan) in Tokyo. Seminars were presented at PWRI, Kyoto and Tokyo.

Robert Moore, Chris Haggett and Lisa Stewart attended the IAHS 3rd Scientific Assembly in Baltimore to present papers on weather radar calibration and on design storm estimation using weather radar data, respectively. Bryony Watson, a member of IH's Radar Calibration Group, visited the Dutch research group collaborating in the CEC project and located at Wageningen in February 1989.

Invited Seminars held at IH included presentations on radar calibration by Dr Yoshino, Head of Hydrology Dept, Public Works Research Institute, Japan, and on grid-square rainfall-runoff models for use with weather radar data by Professor Subhash Chander, Indian Institute of Technology, New Delhi (a contributor to the CEC Italian research group activities whilst on sabbatical leave).

Professor Cluckie visited the Federal Republic of Germany as a guest of the University of Hannover. He participated in a technical tour of Northern Germany with members of the French radar research group, which is based in Paris and carries out work on urban applications. Later, in a separate visit to Paris, he had discussions with radar researchers at the Grande Ecole des Ponts et Chaussees, the St Denis Drainage Authority and consulting engineers (BCEOM). Members of his group have visited Italy and Belgium. A formal co-operation and exchange agreement is at present being agreed with the University of Sao Paulo and the Institute of Water Resources and Meteorology at the University of Estadual Paulista. Similar arrangements are being formulated with Taiwan and the People's Republic of China. Taiwan, Brazil and Algeria have financed research studentships at the University of Salford.

COMMERCIAL OPPORTUNITIES

Although commercial initiatives are beyond the remit of the Committee, its members have become increasingly concerned that no single body, either in the public or commercial sectors, has all the expertise or a portfolio of products which could be actively marketed as a package for a complete weather radar system, capable of meeting the needs of "hydrological services agencies" in other countries. However, the Committee is satisfied that all the elements and supporting expertise is available from UK manufacturers and the organisations represented on the Steering Committee.

Members' concern has been raised by two considerations. The reduction in the UK lead in radar expertise applied to hydrology over the last five years is consequent upon the low levels of research funding during that period and a perceived increase in the level of activities by many other countries, most probably in Europe, America and Japan. Members of the Committee are fully convinced that the current state of development of weather radar in the UK is sufficiently advanced to be marketed successfully. The high level of reliable operational use by shadow NRA Units and the Meteorological Office demonstrates this unequivocably. However, the failure to promote the UK system as a whole means that there is no income and therefore no incentive for manufacturers to support research activities which would undoubtedly lead to improvement in an already excellent system. The improvements would extend the capability and quality of existing systems.

APPENDIX A

TERMS OF REFERENCE OF THE NERC STEERING COMMITTEE ON HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

- To identify, in association with users, the main features of a prospective research programme for the application and development of weather radar data for hydrological purposes and to co-ordinate its implementation.
- To seek funding for research on hydrological applications of weather radar and to use this to increase support.
- To provide a forum for the exchange of ideas and information and to foster closer links between research on weather radar, its application for hydrological purposes and its commercial exploitation.
- To review the existing system for the collection and archiving of weather radar and other data for hydrological uses and to advise on developments to meet research purposes.
- To promote and establish international contacts with other organisations concerned with the hydrological application of weather radar.
- To report on its work annually to NERC, MAFF, DOE and the Met. Office and the Water Industry generally.

APPENDIX B

LIST OF MEMBERS

Dr P D Walsh	North West Water (Chairman)
Mr R Buckingham	Ministry of Agriculture, Fisheries and Food
Prof I D Cluckie	University of Salford
Mr C G Collier	Meteorological Office
Mr V K Collinge	University of Lancaster
Mr R C Goodhew (Dr R A Bailey)	Severn Trent Water Severn Trent Water)
Mr C M Haggett	Thames Water
Mr R W Hatton (Mr J A Tinkler)	South West Water Wessex Water)
Mr R J Moore	Institute of Hydrology
Mr C E Wright	Department of the Environment
Mrs E J Stewart	Institute of Hydrology (Secretary)

APPENDIX C

LIST OF ONGOING ACTIVITIES AND PROJECT PROGRESS REPORTS

ABBREVIATIONS

AWA	Anglian Water Authority
CEC	Commission of the European Communities
DoE	Department of the Environment
HR	Hydraulics Research Ltd
IH	Institute of Hydrology
MAFF	Ministry of Agriculture Fisheries and Food
MO	Meteorological Office
NERC	Natural Environment Research Council
NRA	National Rivers Authority
NWWA	North West Water Authority
SERC	Science and Engineering Research Council
STWA	Severn Trent Water Authority
TWA	Thames Water Authority
UL	University of Lancaster
US	University of Salford
WA's	Water Authorities
WRc	Water Research Centre
WxWA	Wessex Water Authority
YWA	Yorkshire Water Authority

Research Project	Investigating Body	Commissioning Body	Report Dates
A.1. Assessment of accuracy of rainfall measurement and diagnosis of errors	MO	MO	Quarterly (Met03) Case study investigations: end 1988
A.2. Improvement of accuracy of radar measurements (taking into account orographic aspects)	MO, STWA UL UL	MO, STWA NWWA NERC	Interim reports: September 1988, April 1989, thereafter yearly May 1989 Interim report: September 1989
A.3. Improvement of accuracy of radar measurements (taking into account non-orographic factors)	MO, STWA, AWA, YWA US UL IH	MO, STWA, YWA AWA NWWA TWA	Interim reports: September 1988, April 1989, thereafter yearly May 1989
A.4. Investigation of the man-machine interface	MO	MO	Interim reports: July 1988, thereafter yearly
A.5. Assessment of accuracy of snowfall measurement and optimisation of radar calibration gauges during snowfall	STWA, MO, (IH)		← ? No date ? IH
A.6. Blending of radar data with data from existing dense telemetering raingauge networks within the user's environment	IH US UL IH	TWA AWA/WxWA NWWA DOE	October 1989 Final reports: 1989, 1990 (UB) May 1989 reported in A2 March 1989, September 1990

TABLE A Research projects on calibration of weather radar 1988/1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: A1

Project Title: Assessment of accuracy of rainfall measurements and diagnosis of errors.

Report Period: to July 1989

Introduction:

The Advisory Services Branch (Met 0 3) of the Met Office produce quarterly a report entitled 'Radar Data Assessment'. The latest version covers the period 1 October to 31 December 1987. Within the FRONTIERS Project case studies of observed measurement problems are carried out.

Progress:

The quarterly reports continue to be produced following a standard format. In addition to the quarterly report, the facility has been established to map comparisons of 'unadjusted' and 'adjusted' radar rainfall data from the PARAGON system, with climatological daily gauge data. Various statistics on the distribution of radar/gauge ratios are produced. These maps were developed in connection with the work of the Lincoln Long Range Calibration group.

A few more cases of anomalously intense bright bands at long range have been noted but available effort has been concentrated on writing up the previous cases.

Problems:

(NB) The explanation of the bright-band effect has not yet been found. Investigations are continuing.

The Data Assessment reports are rather late in being produced. Late arrival of gauge and other data cause this, but there are no easy solutions.

Financial Aspects:

Costs are included in the FRONTIERS Project and the Met 0 3 budget.

Reports Prepared or Due:

A report describing the bright-band phenomenon has been prepared.

Progress report submitted by: C. G. Collier (MO)

Date: July 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: A2

Project Title: Improvement of accuracy of radar measurements (taking into account orographic aspects)

Report Period: to July 1989

Introduction:

Objectives:

(1) Devise improved ways of determining rain type; (2) Assess the applicability of existing domain boundaries and redefine as necessary; (3) Assess the applicability of, and update/redefine as necessary, the detailed orographic scaling factor due to variations of wind speed and humidity; (4) Determine optimal sites for orographic raingauges (with regard to areas of maximum orography and taking into account variable wind drift) and derive ways of using such gauges (whether in or upwind of the areas of interest) to determine in real time the appropriate orographic scaling factor.

Progress:

A technique of deriving rain type using correction around a point has been specified. Initial case studies are encouraging but further analysis is needed to confirm, or otherwise, the validity of the approach (Objective 1).

Work has continued on the production of orographic enhancement correction fields for Ireland, to replace the first-guess fields inserted in 1987. Eleven case studies using Irish daily gauge data have been completed but the orographic signal does not appear so strong as in earlier case studies over England and Wales. For wind directions not represented in the case studies, following the discovery of a more detailed and recent annual average rainfall field for Ireland, a final version of the annual average enhancement field has been produced in machineable form at 5 km resolution. The case studies do not appear suitable to produce enhancement fields by averaging, as done for England and Wales. Therefore over small geographically coherent areas, statistical correlations have been sought between the observed enhancement and height or the mean annual average enhancement. If a stable and high correlation can be found, then the final tables can be produced by machine. Analysis of the results continues (Objective 3).

The new radar analysis step introduced to the FRONTIERS system (Project A4) has been designed to ensure that raingauge adjustment applied to the radar network images is done in such a way that any orographic corrections applied to the data are consistent with the adjustment technique employed. Work is in progress to assess the procedure (Objective 4).

Reports prepared or due:

Brown, R., Sargent, G.P. and Blackall, R.M. 1989. "Range and orographic corrections for use in real-time radar data analysis". Preprint Vol., Int Symp on Hydrological Applications of Weather Radar, U. of Salford, 14-17 Aug.

Shepherd, G.W., Cluckie, I.D., Collier, C.G., Yu, S. and James, P.K. 1988. "The identification of rainfall type from weather radar data". Met. Mag., 117, pp. 180-186.

Warner, C. 1989. "The new FRONTIERS radar analysis", Met O 24 Internal Report No. 5.

Progress report submitted by: C.G. Collier (MO)

Date: July 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR.

Project
No: A2

Project Title: Orographic rainfall enhancement in North West England from surface and radar data.

Reporting period: October 1988 to July 1989

Introduction:

This is a project being undertaken by a postgraduate research student, Mr K R Brown, working for a PhD. It is funded by NERC. Duration October 1988 to September 1991 (3 years).

Progress:

During the initial phase Kelvin Brown has been developing his computing skills both on a PC and on the University mainframe. He has also carried out a literature review, which of course is on-going, and a listing of references is available. From an initial list of 20 rainfall events he has selected those with good orographic enhancement for more detailed study, and has carried out a range of analyses of the ground truth and radar data (Hamelton Hill). We also now have available a digital terrain map of the Bowland Fells, which will be refined in the coming year.

Problems:

A major difficulty we have found is establishing a satisfactory base rainfall level upwind of the high ground under study.

Financial Aspects:

Research studentship fully funded by NERC. Some additional support (equipment, computing facilities) from the University.

Reports Prepared or due:

None.

Progress Report submitted by: V. K. Collinge

Date July 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: A3

Project Title: Improvement of accuracy of radar measurements (taking into account non-orographic factors)

Reporting period: Until July 1989.

Introduction:

Objectives:

(1) Derive ways of increasing accuracy at long range using (a) estimates of the type and vertical extent of the rain system, and (b) long-range gauge measurements, to derive range normalization law appropriate to each occasion; (2) Derive procedures for ensuring that radar calibrations are biased in favour of the hydrologically more important areas of heavier rain.

Progress:

Within the FRONTIERS Project some work has been carried out relevant to Objective 1. Detailed range corrections have been evaluated for each radar site using appropriate radar beam profiles and various depths of precipitation. The theoretical results agree very well with the actual ranges to which precipitation can be detected at each radar site.

Studies contrasting expected bright-band intensities with those actually observed for a number of anomalously intense cases have been completed. Dr Zrnic of the Severe Storms Laboratory, USA has been consulted as to whether the three body scattering mechanism could account for the anomalous bright-band intensities, but this proved unlikely. A further possibility based upon the production of large hydrometeors within convective elements triggered by orography is being considered.

Reports Prepared or Due:

Brown, R., Sargent, G. P. and Blackall, R. M., 1989 "Range and orographic corrections for use in real-time radar data and analysis" Preprint Vol., Int Symp on Hydrological Applications of Weather Radar, 14-17 August, U. of Salford.

Progress report submitted by: C. G. Collier (MO)

Date: July 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: A3

Project Title: Improvement of Accuracy of Radar Measurements (taking into account Non-Orographic Factors).

Reporting period: Six months July to December 1988.

Introduction:

Three meetings were held. John East extended his brief to the Welland & Nene following Nigel Fawthrop's move to Peterborough. Brian Hems joined Maureen Mylne from the Met Office team at Bracknell. Richard Cross joined Roger Goodhew from Severn-Trent's group. Activity has focussed on preliminary data assessment trials and confirmation of radar performance and data acceptability criteria. Completion of radar setting-up adjustments and the official opening of Ingham aerial took place during September 1988.

Progress:

Data handling has been standardized on 3.5 in discs using SMART or ASCII textfiles. Radar performance has been assessed using limited June and October 1988 data. Initial results indicate little loss in radar data performance out to well beyond 100 km radius. Data from adjacent aerials have been mapped for 1986/7 to provide a geographical perspective for viewing Ingham data. A casebook of radar reference material including catchment scale maps is being assembled to aid in data diagnostics.

Problems:

Fully calibrated data was not available during the period. This unexpected delay limited the effectiveness of analytical effort. Comparative Assessments of radar performance from adjacent aerials in overlap areas are handicapped by the lack of an anaprop algorithm deletion technique for Chenies and Ingham data. Both these constraints need to be removed.

Financial Aspects:

Staff time costs continue at < £5000 per half-year.

Reports prepared or due:

Lincoln Calibration Investigation, June 1988, Met Office, 10/88.

LORCS - Third Report to the Steering Group, LiWRP, 10/88.

Summary of Performance Assessment of Lincoln Weather Radar for October 1988, 12/88.

Progress report submitted by: R.C. Goodhew

Date: April 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: A3

Project Title: Improvements in accuracy of radar measurements

Reporting period: until July 1989

Introduction:

This work has been undertaken by the support of Wessex and Anglian Water Authorities. Previous efforts of a visiting research fellow from China were being directed into the general area of accuracy and its improvement by real-time calibration, a particular feature being a concentrated focus on the impact of bright-band on the presently adopted real-time calibration procedures.

Progress:

Studies are in progress using Hameldon Hill and Upavon Weather radars. This study has been extended to include Chenies and Lincoln radars. A considerable amount of software has been developed for this purpose and is presently being employed on both Upavon and Chenies radars. From May onwards data from Lincoln and Dorset radars will also be employed. The effort is being concentrated on procedures that will be incorporated directly into real-time monitoring/forecasting systems that will be triggered on an event basis. These procedures will also have the feature of being dynamic in a spatial sense with parts of a regional telemetry system being activated as a result of incoming storms and their particular spatial distribution.

Financial Aspects:

Total budget of approx £170k from WWA and AWA with indirect support from the Chinese Government and SCEL (Salford Civil Engineering Ltd)

Reports Prepared or Due:

Various internal reports have been produced.
Wessex Radar Information Project Report No.5 due shortly.
Some papers are in the process of being published.
A University of Salford Ph.d. will be submitted in 1990

Progress report submitted by: I. D. Cluckie

Date: July 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: A2, A3
A6

Project Title: The use of meteorological data for calibrating a weather radar used for rainfall measurement and forecasting

Report period: Up to July 1989

Introduction:

Research at the University of Lancaster has been in progress since January 1988 under the following funding:

<u>Funding agency</u>	<u>Duration</u>	<u>Principal Investigator</u>	<u>Research staff</u>
NERC (research grant)	April 1986- March 1988		James Buxton (up to April 1988) Ewan Archibald (from October 1988)
NERC/EEC	October 1987- September 1990	V K Collinge Prof P C Young	plus technician (part-time)
North west Water	May 1988- March 1989		

Progress:

- (1) Systems have been set up for handling decalibrated radar data from Hameldon Hill supplied by the Met. Office. Extensive software has been written for plotting radar data, ground truth data assessment factors and other data in form of maps (colour).
- (2) Anomalies in Hameldon Hill data have been identified from three sources, and software to correct these has been written.
- (3) Investigation into the affects of physical and meteorological parameters on the Assessment Factor have been carried out and are still in progress.
- (4) Time series analysis techniques have been developed and successfully applied as an alternative calibration system.
- (5) Study area extended from 80 x 60 km rectangle to full 75 km radius and software modified accordingly.

Problems:

The biggest problems we face are funding and continuity. The NERC grant was really a pump-priming operation, and the scale of funding was very limited. The nature of this work involves handling large data sets and requires substantial software development. Adequate supporting staff and continuity are therefore vital.

Financial Aspects:

NERC	£26,000 (over 2 years)	(plus University support for equipment = £10,000 approx)
NERC/EEC	£17,000 (over 3 years)	
NWW	£20,000 (over 1 year)	

Academic staff costs are not included in the above figures.

Reports prepared or due:

Progress report to NERC	- April 1987
Final report to NERC	- September 1988
Interim progress report to NWW	- September 1988
Annual report to EEC	- October 1988
Final report to NWW	- May 1989

Progress report submitted by: V.K. Collinge

Date: July 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: A3, A6, B1

Project Title: Local calibration of weather radar

Report period: January 1988 June 1989

Introduction:

This project forms a contract with Thames Water and also includes strategic research commissioned by MAFF and will also be reported to the CEC. The aim is to develop techniques for combining telemetering raingauge data with radar data to obtain a better estimate of the rainfall field at the current time.

Progress:

Software to decalibrate the at-site radar data was installed on TW's VAX computer in December 1988, a total prototype system for recalibration delivered on 1 March 1989, and following system integration by TW staff became operational on 14 March 1989. The recalibration procedure is based on fitting an extended form of multiquadric surface to calibration factors defined at each 15 minute time-frame, and then applying this calibration surface to the decalibrated radar field to obtain a recalibrated rainfall field. Analysis of historical data for 19 storm events indicate that the product is 22% more accurate than the at-site calibrated product, on average. Operational constraints suggest that the actual average accuracy will improve by between 22 and 13%. The use of a continuous surface rather than domains and the procedure's independence of rainfall type also mean that the new product is free of spatial and temporal discontinuities. A procedure to estimate the rainfall field from raingauge data alone was delivered to Thames Water in June 1989; this is to be used operationally to complement the recalibrated radar product and to substitute for it when radar data are unavailable.

Problems:

Timing errors in the archived raingauge data have required extensive quality control of data prior to analysis (these errors are not present in more recent data).

Financial Aspects:

The Thames Water contract is for £30K per annum over two years ending 1 October 1989.

Reports prepared or due:

- (1) Local Calibration of Weather Radar : Annual Report, 46pp, December 1988.
- (2) Progress Reports for Steering Committee Meeting on Local Calibration of Weather Radar, 1st , 2nd , 3rd , 5th , 6th
- (3) CEC Weather Radar and Climate Hazard Annual Report, Chap. 2, 2-18, November 1988.
- (4) Annual report to MAFF, February 1989.
- (5) Radar measurement of precipitation for hydrological application, NERC Seminar, March 1988, 12pp.
- (6) Towards an improved system for weather radar calibration and forecasting using raingauge data from a regional telemetry system, IAHS 3rd Scientific Assembly, Baltimore, May 1989, 9pp.

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: A4

Project Title: Investigation of the man-machine interface

Reporting period: to July 1989

Introduction:

Objectives:

(1) Develop methods of manual intervention leading to improved accuracy of rainfall analyses and forecasts, develop automated procedures to supersede these where and when practicable, and keep under review the optimal balance between the two types of approaches; (2) Undertake a user survey to identify the relative importance of timeliness and accuracy with regard to both actual and forecast (1, 3 and 6 hours) rainfall.

Progress:

The achievement of the first objective is being sought within the framework of the FRONTIERS Project in the Meteorological Office. Progress over the last 12-18 months is outlined.

The FRONTIERS software which performs a correlation between radar and satellite data has been rewritten to remove several errors discovered over the previous year. One of the more serious was the use of visible data after the time when normalisation fails because part of the image is black. Thus rainfall counts were placed spuriously in the darkest visible classes and these persisted because the table is built up over many cycles. By examining visible data from each month, a diagram has been produced showing when normalisation fails. A long-standing error in the coastline has also been corrected. Previously, registering the satellite picture using the coastline of mainland Europe caused it to be misregistered by about two pixels over the UK.

A fundamental study of the Austin Lovejoy satellite/radar correlation technique used in FRONTIERS has commenced, in collaboration with Mr Minghu Cheng from the Academia Sinica, Beijing. Software has been written to apply the technique to our archived data and results obtained from ten frontal cases. Average statistics from these cases confirm ones impression that the two-dimensional correlation tables give the best results, followed by the visible then the IR tables. A very noteworthy result is that whilst the probability of rain increases slowly with decreasing cloud-top temperature, there is almost a step change of probability in the visible. In order to define a critical probability above which a satellite class is defined as precipitating, it is necessary to maximise some statistical measure by comparison of the radar observed and satellite predicted precipitation. Several statistics have been examined including the Hansen and Kuipers skill score used a Malvern prior to 1985. The current method of minimising the percentage difference between the area of the observed and predicted precipitation proved best, whilst Hansen and Kuipers score overpredicted the area of precipitation. Some correlation tables have been produced as a function of rainfall rate and these show that although the heavier rain is confined to the colder, brighter cloud, the percentage of such cloud associated with heavy rain is small.

The new radar analysis has been completed and was introduced. The new analysis simplifies the reintroduction of gauge calibration and ensures that such calibration is reconciled with any orographic corrections applied. Quality control has been added to ensure that only sensible calibration data are used. A simple method of dealing with bright-band errors, by imposing a specified limit on the maximum rainfall rate in a designated area, has been introduced. The menu structure has been changed so that instead of applying corrections for different phenomenon sequentially over the whole radar area, individual regions of the radar area are analysed in turn.

Thus one can return to the start of the radar analysis and change any correction if desired. Any regions not analysed default to the remote site corrections, ensuring consistency from one image to the next. The choice of corrections applied to each region and the consequent radar boundary have been added to the tape archive to aid evaluation. To try and speed up the radar analysis, the replay system has been rewritten to hold the replays in core rather than read them continually from disc and the display system has also been rewritten.

An off-line evaluation of 56 frontal forecast cases from the winter of 1987/88 was completed and presented to the Steering Committee for Work on Short Period Forecasting. Increased skill was shown compared to previous evaluations. The satellite-derived rainfall was found to enhance forecast accuracy. Although the forecasts were mainly evaluated on a rain/no rain basis, they were found to be at least as successful when evaluated quantitatively.

Information to address the relative importance of forecast timeliness and accuracy has been collected, but analysis has not yet been undertaken (Objective 2).

Reports Prepared or Due:

- | | | |
|---|------|---|
| Brown, R. and Cheng, M. | 1989 | "Real-time combination of radar and satellite data for very-short-short-period precipitation forecasting," Preprint Vol. COST-73 Seminar, 5-8 Sept., Brussels, CEC. |
| Browning, K.A. and Collier, C.G. | 1989 | "Nowcasting of precipitating systems" to appear in <u>Reviews of Geophysics</u> , September. |
| Collier, C.G. | 1988 | "Use of weather radar and satellite data" in Weather Sensitivity and Services in Scotland, edited by S.J. Harrison and K. Smith, publ. by Scottish Academic Press. |
| Collier, C.G. | 1989 | Applications of Weather Radar Systems. A guide to uses of radar data in meteorology and hydrology, publ. by Ellis Horwood Ltd., Chichester, 294 pp. |
| Collier, C.G., Brown, R. and Conway, B.J. | 1989 | "On the future of very short period rainfall forecasting using radar data", Preprint Vol. 5th Int. Conf. on Interactive Info. and Processing Systems for Met., Ocean. and Hydrology, 29 Jan-3 Feb., Anaheim, California, Am. Met. Soc., Boston. |

Progress report submitted by: C.G. Collier

Date: July 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: A6

Project Title: Blending of radar data with data from existing dense raingauge telemetry networks.

Reporting period: until July 1989

Introduction:

This forms a major element of both the Wessex and Anglian Radar Information Projects. The ARIP project will focus on the exploitation of both the Chenies and the Lincoln weather radars. The WRIP project will initially use Upavon before absorbing information from the new MoD radar to be sited in Dorset and the Exmoor radar. The topographic differences of the two regions when combined with the radar individual site characteristics will allow a detailed study of a wide range of problems.

Progress:

This research has recently commenced on the ARIP project and should start on the WRIP project early in 1990. Some preliminary work has already been carried out by members of the group using Hameldon Hill data in general and Manchester area data in particular.

Financial Aspects:

See A3

Reports Prepared or Due:

Ph.D. Thesis by G.W. Shepherd (1987), University of Birmingham
Detailed ARIP and WRIP reports to follow.
A University of Salford Ph.D. will be submitted in 1990.

Progress report submitted by: I. D. Cluckie

Date: July 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: A6

Project Title: Variation of extreme rainfall events in upland areas

Reporting period: April 1987 - July 1989

Introduction:

The project is being undertaken at the Institute of Hydrology, commissioned by the Department of the Environment Water Directorate. The study of spatial and temporal variations in rainfall has particular implications for the structuring of design storms for reservoir flood estimation. This project explores the combined use of radar and gauge rainfall data to develop improved representations of areal and temporal profiles. The 10,000 km² study area is centred on the Hameldon Hill radar station. The first phase of the project was concerned with spatial variations of extreme rainfalls, focussing particularly on the re-assessment of the areal reduction factors given in the Flood Studies Report. The second phase commenced in April 1989 and aims to use raingauge and radar data to develop more realistic storm profiles for upland areas.

Progress:

Statistical areal reduction factors (ARFs) for durations of between 1 and 8 days have been calculated for a range of return periods using daily raingauge data. A technique has been developed to derive areal reduction factors for durations shorter than 1 day by combined analysis of daily rainfall data and hourly PARAGON radar data, together with a model of rainfall depth-duration frequency at a point. Innovative aspects of the research have been presented internationally in a scientific paper (Stewart, 1989).

Problems:

Problems have been encountered concerning the fact that the hourly radar data from the PARAGON system are unadjusted by gauge data (other than the calibration gauges) and only about half of the rain days have 24 complete hourly totals. Also, the radar dataset under analysis is not continuous, consisting only of selected heavy rainfall events. This makes the return period effect difficult to assess.

Financial aspects:

The project is funded by the DoE Reservoir Safety Commission
Total budget for Phase I £60K
Total budget for Phase II £70.5K

Reports prepared or due:

Stewart, E. J. (1989) Areal reduction factors for design storm construction: joint use of raingauge and radar data. IAHS Publ. no. 181 (Proc. Third Scientific Assembly, Baltimore) May 1989.

Stewart, E. J. (draft) Variation of extreme rainfall events in upland areas. Phase I Report, DoE Contract PECD7/7/190

Final Report due September 1990

Progress report submitted by: E. J. Stewart (IH)

Date: July 1989

Research Project	Investigating Body	Commissioning Body	Report Dates
B.1. Calibration procedures for flow forecasting	IH IH IH, UL, US US	MAFF TWA CEC AWA	Annually (IH/MAFF) October 1989 (IH, TWA) October 1990 (NERC, CEC) Pilot study: December 1987(UB/AWA) Main project:December 1990(UB/AWA) Interim report on Bright Band: October 1988 (UB)
B.2. Assessment of FRONTIERS data for flow forecasting	US/NWWA/MO	NWWA/MO	Interim report: March 1989(MO/NWWA) Final report: March 1990(MO/NWWA) October 1991 (UB)
B.3. Real-time rainfall forecasting at small time and space resolution for flood forecasting	IH IH	TWA TWA	October 1989 (IH/TWA) October 1989
B.4. Snow measurement and snowmelt forecasting using weather radar	(IH)(US)		
B.5. Distributed models for flow forecasting using weather radar data	IH US US	MAFF WxWA AWA	Annually (IH/MAFF) October 1988 (UB) Pilot study: December 1987 Main project: December 1990
B.6. Weather radar and simple alarm procedures for flood warning	(TWA)	(TWA)	
B.7. Weather radar for real-time river basin management	US US IH, US STWA (UL)	WxWA AWA CEC STWA -	December 1989 (UB/WxWA) December 1990 (UB/AWA) October 1990 (NERC, CEC) December 1989 -
B.8. Data provision for research on hydrological applications of weather radar	MO (MO)(UB)	-	Interim report: September 1989 In abeyance

TABLE B Research projects on flow forecasting applications of weather radar data 1988/1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: B1

Project Title: Calibration Procedures for Flow Forecasting

Reporting period: until July 1989

Introduction:

This work is currently being progressed by two research students and an external collaborator but will in the fullness of time also form an element of both the WRIP, ARIP and CEC projects.

Progress:

A Ph.d. is in the process of being finalised (submission - April 1989) and a second Ph.d. which also addresses this area will be completed in September 1989.

Financial Aspects:

Partial support through the CEC grant (totals some £10k and Taiwanese and Brazilian Government Studentships).

Reports Prepared or Due:

A University of Birmingham Ph.d. thesis by Pao-shan Yu 1989.
Paper presented to 5th International Symp. Stochastic Hydraulics and Hydrology special edition to be published in May 1989 (Cluckie and Yu).

Progress report submitted by: I. D. Cluckie

Date: July 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: B2

Project Title: Assessment of FRONTIERS Data for Flow Forecasting

Reporting period: First meeting of project steering group in April 1989

Introduction:

This project is a fully funded CASE Studentship funded by the North West Water Authority, the North West Radar Consortium and the Meteorological Office.

Progress:

The project has now been started and work on the development of a new range of models which utilise fuzzy set theory are being evolved within an expert systems framework for the maximum utilisation of FRONTIERS data. A detailed program of work was agreed at the first progress meeting. A range of software has now been written and tested for the decoding and reading and graphical display of the FRONTIERS archive radar tapes. Work is in progress on the effect of the calibration process on real-time forecasting models and the information content of the numerical data from a hydrological modelling point of view. A separate report has been provided by NWW.

Financial Aspects:

Approximately £27K

Reports Prepared or Due:

A University of Salford Ph.d. in 1991

Progress report submitted by: I. D. Cluckie

Date: July 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: B2

Project Title: Assessment of FRONTIERS Data for Flow Forecasting

Reporting period: To June 1989

Introduction:

This project is being undertaken by the research group at Salford University led by Professor I D Cluckie, as a fully funded CASE Studentship. The aim is to further the fundamental hydrological understanding of FRONTIERS precipitation forecast data in real-time hydrological forecasting models and includes detailed studies of storms in the North West Water area.

Progress:

Work has concentrated on setting up programs for reading, decoding and analysing FRONTIERS forecast and actual data and incorporating UNIRAS (standard graphics system) into the forecasting and model parameter estimating programs. These are now complete. Initial FRONTIERS data have just been received, and decoding programs and graphics programs for display and analysis of these data produced. Complete analysis of all previous NW flood events where models have previously been produced (previous studies) has been carried out, with a view to understanding flood producing characteristics and identifying fast/medium/slow response events.

The next step is to order FRONTIERS data to match previously identified events, and carry out analysis and forecast comparisons using these data.

Financial aspects:

3 year project with total budget £27,000, jointly funded by North West Water, North West Radar Consortium and the Meteorological Office.

Reports prepared or due:

Interim Reports Oct. 89, 80 Final Report and University of Salford PhD in 1991. Formal progress meeting due in September 1989.

Progress Report submitted by: J. M. Knowles (NRA-NW)

Date: June 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: B2, B3

Project Title: Regional and national radar rainfall forecasting systems

Report period: January 1988 June 1989

Introduction:

This project forms a contract with Thames Water and also includes strategic research commissioned by MAFF and will also be reported to the CEC. The aim is to develop techniques for short period, high resolution, rainfall forecasting. New techniques will be compared with the Met. Office FRONTIERS product.

Progress:

Techniques based on correlation-matching have been developed to identify both regional and local storm speed and direction from radar data. This is seen as a first step in developing a short-term rainfall forecasting procedure.

Problems:

A project to specifically address this research area is to begin in October 1989.

Financial Aspects:

Preliminary work has been undertaken as part of the Thames Water Local Calibration of Weather Radar Study. A new contract with Thames Water specifically on this topic is to begin 1 October 1989 and will be worth £35K over one year.

Reports prepared or due:

Reports prepared so far are referenced in the Local Calibration of Weather Radar Study. (A3, A6, B1).

Progress report submitted by: R. J. Moore (IH)

Date: June 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: B5, B7,
A5, B4

Project Title: Real-time forecasting of river flows

Reporting period: January 1988 June 1989

Introduction:

This project form IH's strategic research programme on real-time flow forecasting commissioned by MAFF and includes the flow forecasting component of the CEC project. Research focusses on developing improved modelling, updating and input specification techniques. That which relates specifically to radar includes radar calibration (reported elsewhere), the development of grid-square models for use with radar data, the use of GIS techniques with radar data for model input specification, the evaluation of radar data for flow forecasting, and gauge/radar network design implications.

Progress:

Data preparation and preliminary modelling has been undertaken on the Wyre case study as part of the CEC contract in collaboration with NWWA. The aim is to develop forecasting and control procedures to assist in the operation of two flood storage basins along the Wyre. Transfer function models have been employed to gain a quick appreciation of the catchment and channel dynamics and of data reliability. More detailed modelling has used a probability-distributed/nonlinear storage conceptual catchment model and a simple finite difference flow routing model. The use of channel geometry to define wave speed-discharge relations has been investigated as part of the channel flow routing model development.

An assessment of snowmelt models for use in the Severn Trent Flood Forecasting System has been carried out under contract to STWA. This included consideration of how forecast improvement could be achieved through better measurement. The potential of radar to measure snowfall when calibrated using heated raingauges was reviewed along with satellite-mounted active microwave imagery which will become available in 1990.

Problems:

Lack of financial support.

Financial Aspects:

MAFF commission funding assigned to radar related research (including radar calibration) is £30K pa. CEC funding is £10K pa for 3 years which includes urban applications and calibration components, project management, travel, etc. The STWA contract has a value of £8K.

Reports prepared or due:

- (1) CEC Weather Radar and Climatic Hazard Annual Report, Chap. 4, 36-40, November 1988.
- (2) Annual Report to MAFF, February 1989.
- (3) Assessment of snowmelt models for use in the Severn Trent Flood Forecasting System, 41 pp, December 1988.

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: BS

Project Title: Distributed Models for Flow Forecasting using Weather Radar Data.

Reporting period: until July 1989

Introduction:

There is a research studentship specifically on this topic and a University of Birmingham Ph.d. thesis will be submitted in April 1989. A second research studentship partially covers this area though is primarily concerned with storm maximisation and extreme flood estimation in connection with reservoir safety.

Progress:

Doctoral thesis submitted by Pao-shan Yu on Grid-square Based Distributed Modelling approach. This model, known as the GBDM, has also been applied and extensively modified for utilisation in PMP/storm maximisation work. A computer program known as RADMAX has been constructed for this purpose and will be described in a thesis to be submitted by Pessoa in September 1989.

Financial Aspects:

Research Student from Government of Taiwan.
Research Student from Government of Brazil

Reports Prepared or Due:

A University of Birmingham Ph.d. April 1989.
A University of Birmingham Ph.d. September 1989.
A paper was presented to the Anglo/Polish hydrology colloquium held at the Univ. B'ham in July 1988 by Pessoa and Cluckie.
A number of papers are in the process of publication at this time by Cluckie, Yu and Pessoa.

Progress report submitted by: I. D. Cluckie

Date: July 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: B6

Project Title: Weather radar and alarm procedures for flood warning

Report period: June - December 1989

Introduction:

The project is being undertaken by Thames Water, NRA unit with the aim of improving the detection of heavy rainfall, in particular convective storms, in and around London. A two stage alarm procedure is envisaged making use of 2 km radar data from the Chenies installation received by the Authority's VAX 11/750 telemetry computer. A stage 1 alarm will initiate automatic interrogation of the telemetry network every 15 minutes bringing on-line data archives up-to-date. The regional radar recalibration system will be activated (as described in project A6) as will the operation of flood forecasting models. A stage 2 alarm, based on locally calibrated radar data, will warn flood duty staff of heavy rainfall approaching subcatchments in and around London. The feasibility of passing warnings to outside agencies will be evaluated.

Progress:

Work on the project commenced in June 1989. The procedure operating on the VAX 11/750 which handles alarms from telemetry outstations has been modified to receive and process alerts generated from other sources e.g. radar data. Formulation of the procedure, including the setting of criteria for the generation of stage 1 and 2 alarms, is currently under review.

Problems: Nil

Financial Aspects:

The project will be funded by Thames Water, NRA unit making use of a software consultant.

Reports prepared or due:

A report will be prepared at the end of the project.

Progress report submitted by: C. M. Haggett, Thames Water NRA Unit Date: June 1989

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: B7

Project Title: Weather Radar for Real-time River Basin Management

Reporting period: until July 1989

Introduction:

This project has attracted limited funds from NWW

Progress:

A number of real-time flood forecasting models are in the progress of being constructed throughout the North West region. These complement the previous work carried out in this area since 1979. This work has been completed on a range of about nine rainfall-runoff cases and four cases involving a tidal influence are being finalised at this time.

Financial Aspects:

This project is financed by NWW through SCEL (Salford Civil Engineering Ltd).

Reports Prepared or Due:

Interim reports in the form of technical appendices are being prepared on 13 river basins at this time. A final report will be produced during October/November of 1989.

Progress report submitted by: I. D. Cluckie

Date: July 1989

Research Project	Investigating Body	Commissioning Body	Report Dates
C.1. Urban drainage network studies using WASSP and weather radar	US, IH (US)	CEC (NWWA)	October 1990 Interim report: March 1990 (US/NWWA) Final report: September 1991 (US/NWWA)
C.2. Real-time control of an urban balancing pond	IH		
C.3. Use of weather radar in modelling rainfall-runoff in mixed urban/rural catchments	IH, US		
C.4. Reduction of pollution from urban drainage networks by active control procedures	US, NWWA, WRC HR, IH		(See C1)

TABLE C Research Projects on urban applications of weather radar

PROGRESS REPORT TO NERC STEERING COMMITTEE ON
THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

Project
No: C1

Project Title: Urban Drainage Network Studies using WASSP and Weather Radar.

Reporting period: Until July 1989.

Introduction:

This project has derived its initial funding from the CEC and has continued the work of Shepherd into the use of radar data in WASSP models. The project has now significantly expanded with the advent of the North West Urban Radar Project (NWURP). The group now consists of four researchers.

Progress:

A considerable amount of progress has been made on the calibration/storm recognition issue with two presentations being given at the Grenoble CEC meeting, and a presentation at the Salford BHS meeting on 22 September 1988. The allied research presently underway involves a project on the development of real-time control procedures for large urban drainage networks and the development of a river quality impact model. Two new research posts have been filled and one is being advertised at this time. Preliminary work on the sensitivity of WASSP models to various types of radar input data has been completed. Work is continuing on aspects associated with the calibration and validation of existing 'WASSP' areas in Bolton.

Financial Aspects:

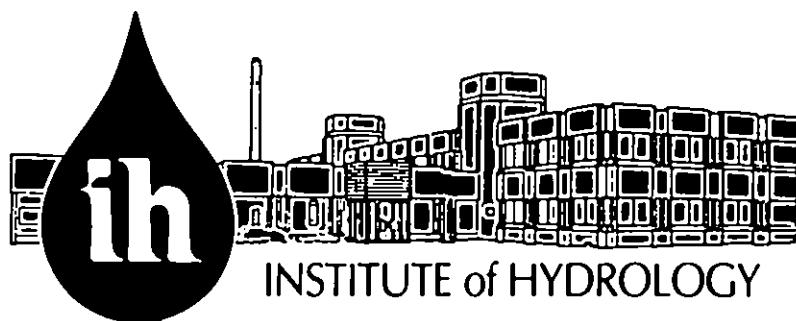
In excess of £100k from North West Water, SERC and WRC. The major portion of this funding is directed through SCEL (Salford Civil Engineering Ltd).

Reports Prepared or Due:

Shepherd, Birmingham Ph.d. 1987, and partially CEC annual report.
Also Meteorological Magazine in May 1988 (See Shepherd, Cluckie, Collier, Yu and James).

Progress report submitted by: I. D. Cluckie

Date: July 1989



The **Institute of Hydrology** is a component establishment of the UK Natural Environment Research Council, grant-aided from Government by the Department of Education and Science. For over 20 years the Institute has been at the forefront of research exploration of hydrological systems within complete catchment areas and into the physical processes by which rain or snow is transformed into flow in rivers. Applied studies, undertaken both in the UK and overseas, ensures that research activities are closely related to practical needs and that newly developed methods and instruments are tested for a wide range of environmental conditions.

The Institute, based at Wallingford, employs 140 staff, some 100 of whom are graduates. Staff structure is multidisciplinary involving physicists, geographers, geologists, computer scientists, mathematicians, chemists, environmental scientists, soil scientists and botanists. Research departments include catchment research, remote sensing, instrumentation, data processing, mathematical modelling, hydrogeology, hydrochemistry, soil hydrology, evaporation flux studies, vegetation-atmospheric interactions, flood and low-flow predictions, catchment response and engineering hydrology.

The budget of the Institute comprises £4.5 million per year. About 50 percent relates to research programmes funded directly by the Natural Environment Research Council. Extensive commissioned research is also carried out on behalf of government departments (both UK and overseas), various international agencies, environmental organisations and private sector clients. The Institute is also responsible for nationally archived hydrological data and for publishing annually HYDROLOGICAL DATA: UNITED KINGDOM.