WSR-88D AND WATER MANAGEMENT

Robert C. Shedd, Albert Peterlin, and Lucy E. Fox[1]

ABSTRACT: The National Weather Service has begun installing and using the first of over 100 new Doppler weather radars, referred to as WSR-88Ds. These new radars will allow far better spatial and temporal estimates of rainfall than has been possible in the past. This radar system will have a profound impact on the water management systems in the United States. This paper will describe the WSR-88D system and the products that will be available from the system.
KEY TERMS: precipitation; radar; water management

INTRODUCTION

Following over ten years of development activities, the NEXRAD (Next Generation Weather Radar) program has begun to deploy a new nationwide network of Doppler weather radars, referred to as WSR-88Ds. A significant portion of the development activity has focused on the capability of generating quantitative estimates of precipitation based on the radar information. For many years, the National Weather Service (NWS) has been able to use radar data as a qualitative estimate of rainfall, with a limited capability for quantitative estimation. By the end of 1996, the NWS will have for the first time a nearly nationwide real-time capability for routinely making quantitative, high-resolution estimates of precipitation based on radar data.

A large portion of the design of the precipitation algorithms will provide significant benefit to the water management community through improved precipitation estimates in both time and space. This paper will describe the WSR-88D system along with the processing used to generate the precipitation estimates. Some information will then be provided to describe potential benefits of the precipitation estimates for the water management community.

THE WSR-88D

The development of the WSR-88D has been a joint Department of Commerce, Department of Defense, and Department of Transportation effort to acquire, implement, and maintain a national, operational network of Doppler weather radars. The WSR-88D is meant to supercede the aging and rapidly deteriorating network that dates to the 1950s. The WSR-88D has been designed to meet hydrometeorological service

[1] Hydrologists, Office of Hydrology, NOAA National Weather Service, Silver Spring, MD 20910

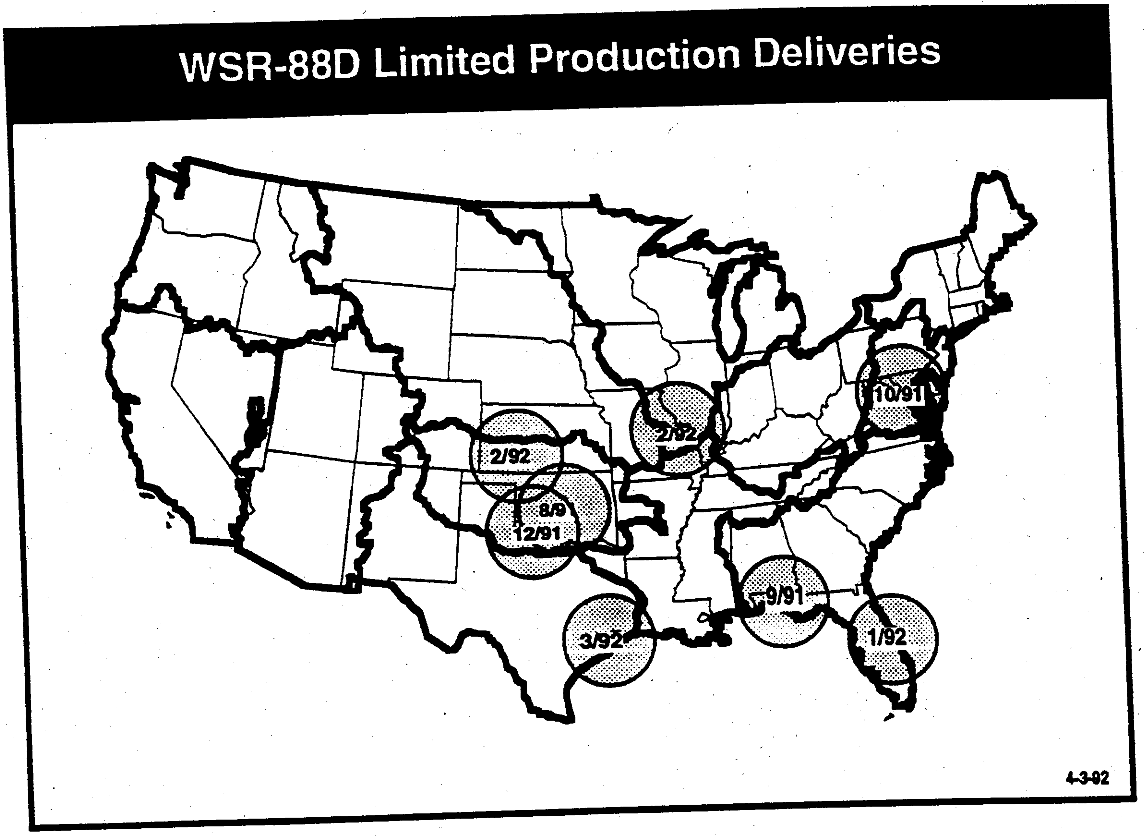

Figure 1 - Locations and Coverage of radars delivered as of July 1992

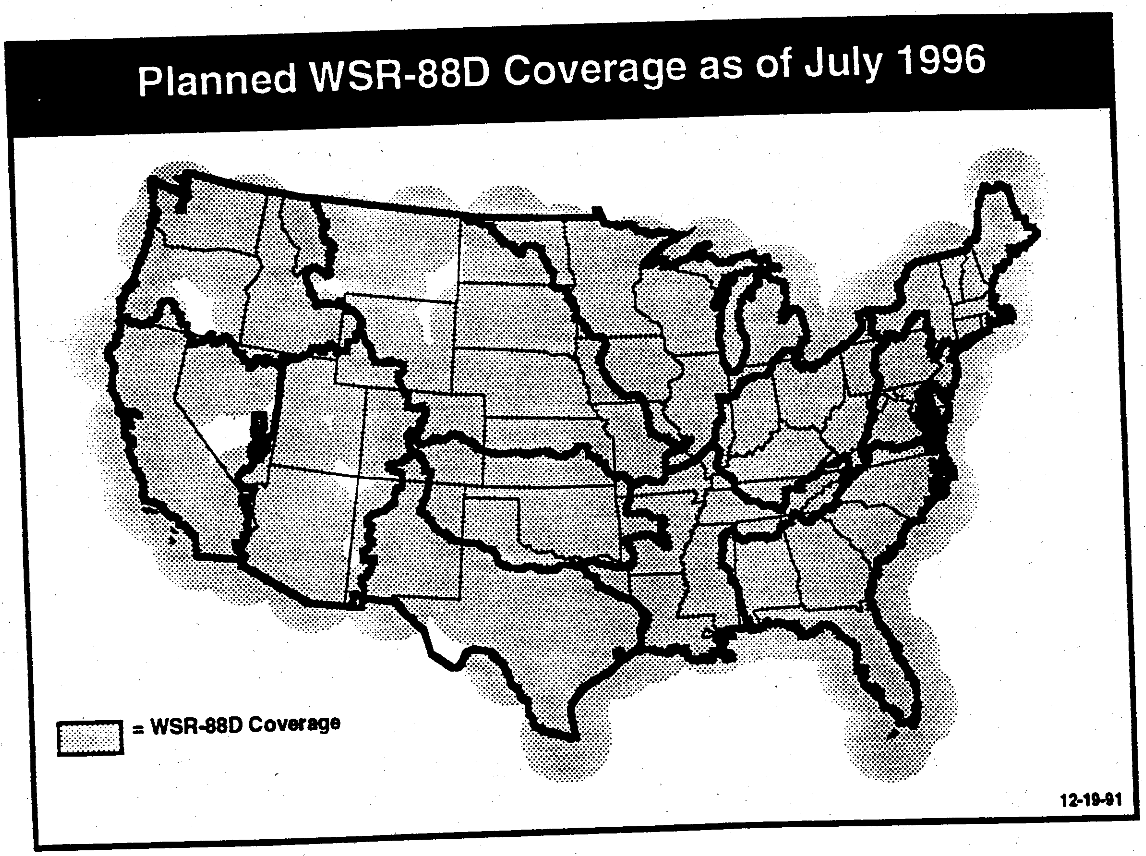

Figure 2 - Coverage from entire network of radars

needs of the United States into the 21st Century. The WSR-88D is a fully integrated system consisting of three major components:

(1) Radar Data Acquisition, RDA - an S-band Doppler radar;
(2) Radar Products Generator, RPG - the computer system capable of processing the reflectivity, velocity, and spectrum width data to generate products for use by the forecaster; and,
(3) Principal User Processor, PUP - the graphical user terminal used to display the high resolution products

Deployment of the WSR-88D began in 1991. The national network of over 120 radars is scheduled to be fully deployed in 1996. At that point, approximately 98% of the continental United States as well as Hawaii and portions of Alaska and Puerto Rico will have radar coverage (see Figures 1 and 2).

THREE STAGES OF PRECIPITATION PROCESSING

Precipitation processing using the WSR-88D will occur in three stages (see Figure 3). The first stage will occur in the WSR-88D RPG. Stage I precipitation processing includes a high level of automated quality control. Corrections will be made for reflectivity outliers, beam blockages, and isolated bins of reflectivity echoes. A composite reflectivity scan, referred to as a 'sectorized hybrid scan', is constructed using data from the four lowest tilts from the radar volume scan as described by Shedd et al.(1991). This hybrid scan of reflectivity is then converted to precipitation rates. The rates are accumulated over time to form hourly accumulations. Using a limited set of precipitation gages, a mean field adjustment of the accumulations takes place once per hour. The adjustment procedure employed makes use of a Kalman filter described in Ahnert and Krajewski(1986). More details on Stage I processing can be found in Ahnert et al.(1983).

Stage II processing occurs at the Weather Forecast Office associated with the particular WSR-88D. This process compares satellite sensed thermal infrared temperatures and ground surface temperatures comparisons for use in the identification of cloud-free areas to reduce errors caused by anomalous propagation and other spurious radar echoes. Stage II also incorporates a more comprehensive set of gage information than Stage I in order to generate an improved estimate of the mean field bias. Local adjustments in the precipitation field will also be made through the use of an objective analysis procedure and based on the proximity to a rain gage observation and the storm structure. The Stage II process, since it is not run coincident with the radar data flow, will be able to be updated as necessary to incorporate new precipitation gage observations.

Stage III processing is an interactive process run at each of the 13 NWS River Forecast Centers (RFC). This stage mosaics data from as many as 25 separate WSR-88Ds in order to generate a precipitation map over their area of hydrologic responsibility. Forecasters will have the ability to modify and edit both the radar and rain gage data based on their hydrometeorologic expertise in order to reduce any final errors not eliminated through the automated quality control procedures

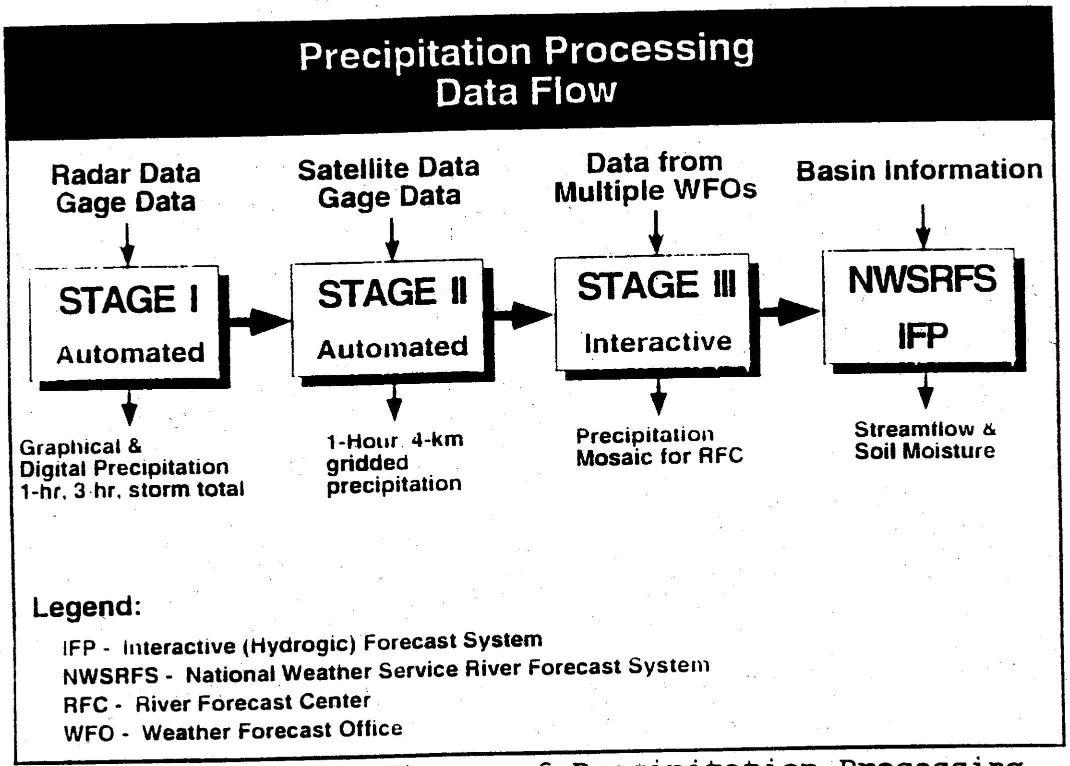

Figure 3 - Three Stages of Precipitation Processing

employed by Stages I and II. The RFC has the capability to re-run Stage II as necessary in order to incorporate the interactive adjustments made from Stage III. Included with the Stage III process is a capability to run 6 hour and daily accumulations to assimilate the vast amount of data that is recorded at these time scales. More description of Stage III processing can be found in Shedd and Smith(1991).

The ultimate objective of the three stages of processing is to provide the best possible quantitative estimates of precipitation. These estimates will be used as input to the hydrologic models running at the RFC.

PRECIPITATION PRODUCTS

Stage I processing will produce four basic products. The first three are graphical displays on a 2 km x 2km grid system using 16 data levels. These products display one-hour accumulations, three-hour accumulations, and storm total accumulations. The one-hour and storm total products are updated every radar volume scan, roughly six minutes. The three hour product is updated once per hour.

The fourth product generated by Stage I is a digital array product using 100 data levels on a logarithmic scale. The information contained in this product is the same as the one-hour graphical precipitation accumulation but at a different resolution. The grid system for this product is a polar stereographic projection with a grid size that varies between 3.5 and 4.5 km over the continental United States. This grid projection is referred to here as the HRAP grid. It is this product that is the basis of Stage II and III processing. Using this universal grid system, mosaicking and correlating information between multiple radars is more feasible than when local grid planes are used.

Stage II produces two separate products using an hourly time step. The first product is a gridded field of precipitation based on rain gage data. This field, referred to as the 'gage only' field, uses the radar to locate areas of precipitation; however, quantitatively the product is strictly based upon rain gage observations. The second product, referred to as a multi-sensor field, is a weighted average of the radar estimates and the gage field. An objective analysis procedure is used to develop the weights based on the storm variance and how close the given grid box is to an actual gage. Both of these products will be produced on the HRAP grid.

The Stage III process will also produce a product once per hour. This product will be a precipitation composite over a given River Forecast Center area. This product will be displayed on the HRAP grid and may be updated periodically as an increasing amount of rain gage data becomes available.

WATER MANAGEMENT BENEFITS

The immediate and obvious benefit of the WSR-88D system in terms of hydrometeorology is in the improvement of National Weather Service flood and flash-flood forecasting capabilities. However, it has long been recognized that a significant economic benefit would derive from improved water management capabilities (Hudlow et al., 1985). The WSR-88D Stage I precipitation estimates along with the Stage II and III capabilities will produce precipitation data on both space and time scales that have never before been possible using the current network of precipitation gages.

One example of water management benefits will be demonstrated as part of the Salt River Project in Arizona. The reconstruction of a major dam just upstream from Phoenix is a significant concern of this operation. The WSR-88D delivery schedule has been altered to allow for an early delivery of a WSR-88D to the Phoenix area in order to support the Salt River Project. It is anticipated that the WSR-88D data will be used to provide more accurate inflow estimates into the reservoir. These inflow estimates would be used to determine the best regulation of the dam during the construction procedures when the dam and the city of Phoenix are most vulnerable to a flash-flood threat.

Another area for water management benefits is for the Water Resources Forecasting Services (WARFS) a new project being undertaken by the NWS to improve long term streamflow forecasts (Fread et al., 1991; Day et al., 1992). The improved time and space definition of the precipitation will be used to better estimate the antecedent conditions used to initialize the forecasting model.

The hydrologic forecasting models require an extensive amount of calibration work to be performed based on historical time series of precipitation and streamflow data. This calibration is performed for each of the approximately 3000 forecast points for which the NWS provides daily forecasts. Improved space and time resolution of the precipitation should also enhance these necessary calibration procedures through improved definition of the time series.

There are over 20,000 locations across the country which have been identified as being flood risk areas. Only 3000 of these receive routine forecasts due to resource constraints and insufficient data to perform the necessary calibrations. Many of these unforecasted locations are in smaller watersheds with relatively short lead time on the flow peak. The use of the WSR-88D precipitation may provide the necessary information for calibration as well as allowing the hydrologic models to be run on shorter time and space scales than they currently run.

Water quality management may also be served through the use of improved precipitation estimates providing for improved streamflow estimates. Better information on the flow of water through a river should allow for better tracking of potential pollutants in the stream.

Improved precipitation estimates will also allow for enhanced reservoir operation in making decisions regarding flow releases, flood storage, recreation, and hydropower uses. Operations relying on accurate streamflow estimates, such as barge companies and power companies, will also benefit from WSR-88D precipitation estimates.

CONCLUSIONS

The WSR-88D systems have been providing routine data for about a year now. The initial response to the system, and the precipitation products in particular has been extremely positive. The precipitation estimates from the WSR-88D have been cited frequently as motivation for issuing or not issuing flood and flash-flood warnings.

In time, as the radar data become available over wider areas and are more routinely available to other water management agencies, the full benefit of the WSR-88D system will be achieved. Significant benefits should be seen in the area of reservoir operation, streamflow forecasting, and other areas related to water resources management.

REFERENCES

Ahnert, P.R., M.D. Hudlow, E.R. Johnson, D.R. Greene, and M.P.R. Dias, 1983. Proposed 'On-Site' Precipitation Processing for NEXRAD, Preprints, 21st Conference on Radar Meteorology, American Meteorological Society, Edmonton, Alberta, Canada, September 19-23, 1983, pp. 378-385.

Ahnert, P.R. and W.F. Krajewski and E.R. Johnson, 1986. Kalman Filter Estimation of Radar-Rainfall Field Bias. Preprints, 23rd Conference on Radar Meteorology, American Meteorological Society, Snowmass, Colorado, September 22-26, 1986, pp JP33-JP37.

Day, G.N., D.P. Laurine, and L.E. Brazil, 1992. Water Resources Forecasting for Improved Reservoir Operations. 4th Operations Management Workshop. American Society of Civil Engineers, Mobile, Alabama, March 16-18, 1992.

Fread, D.L., G.F. Smith, and G.N. Day, 1991. The Role of Real-Time Interactive Processing in Support of Water Resources Forecasting in the Modernized Weather Service. Preprints, 7th International Conference on Interactive Information and Processing Systems. American Meteorological Society, New Orleans, January 14-18, 1991, pp 294-298.

Hudlow, M.D., R.K. Farnsworth, and P.R. Ahnert, 1985. NEXRAD Technical Requirements for Precipitation Estimation and Accompanying Economic Benefits. Hydro Technical Note 4, Office of Hydrology, National Weather Service, NOAA, Silver Spring, MD. 49 pp.

Shedd, R.C. and J.A. Smith, 1991. Interactive Precipitation Processing for the Modernized National Weather Service. Preprints, 7th International Conference on Interactive Information and Processing Systems. American Meteorological Society, New Orleans, January 14-18, 1991, pp. 320-323.

Shedd, R.C., J.A. Smith, and M.L. Walton, 1991. 'Sectorized Hybrid Scan Strategy of the NEXRAD Precipitation Processing System' in *Hydrological Applications of Weather Radar*, I.D. Cluckie and C.G. Collier, eds. Ellis Horwood, Chichester, England, pp. 151-162.