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WSR-88D PRECIPITATION PROCESSING AND ITS USE IN NATIONAL WEATHER SERVICE HYDROLOGIC FORECASTING

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Abstract

The National Weather Service (NWS), along with the Department of Defense and Transportation, have begun deployment of a new national network of weather radars referred to as the WSR-88D. This new radar will have a significant impact on the hydrologic services provided by the NWS. A three stage process has been developed to provide the highest quality of quantitative precipitation estimates on a 4-km grid across the United States. This process, using both automated and interactive techniques, will incorporate precipitation gages and satellite information to minimize the effects of the numerous sources of error possible when processing radar data. In addition to the new data flow, the NWS is restructuring some of their operations, including new hydrometeorologist positions, to support the use of this high resolution precipitation data in the hydrologic forecasting operations of the NWS.

Introduction

The National Weather Service (NWS), along with the Departments of Defense and Transportation, is in the process of deploying a new nationwide network of WSR-88D (Weather Surveillance Radar-1988 Doppler) weather radars under the NEXRAD (Next Generation Weather Radar) program. The WSR-88D represents a significant milestone for hydrologic modelling as the new radar will allow for gridded, real-time, quantitative estimates of precipitation to be input into operational NWS hydrologic models.

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This paper discusses the WSR-88D system components and provides an overview of the precipitation processing techniques employed to generate reliable precipitation estimates from radar measurements. Also, some discussion is provided on changes being made to incorporate the new data stream into the hydrologic forecasts.

The WSR-88D System

The new WSR-88D radar system has two major components: state-of-the-art microwave radar, computer, and communication hardware and high performance software which combine to produce a system which is second to none in the world in terms of performance, versatility, and information processing. The network of over 100 radars, each of which will operate 24 hours per day in an automatic scanning mode, will serve as a replacement and upgrade to the aging WSR-57 and WSR-74 radar systems currently in operational use by the NWS.

Never before has the U.S. had the capability to produce quantitative radar-derived rainfall estimates over the U.S., much less rainfall estimates at the fine spatial (2 km) and temporal scales (6 min) possible with the WSR-88D. This is possible because of digital data processing of the backscattered radar signals by computers (unlike the current radar system) and the generation of a diverse array of value-added products. These products include both rainfall products as well as Doppler velocity-derived products to aid the forecasters in identifying adverse weather situations which may develop rapidly and to serve as numerical input into existing computer models which forecast rainfall and streamflow.

In order to accomplish this task, the WSR-88D system has been designed around four major pieces of hardware: 1) the pedestal and antenna which transmit and receive microwave signals with a high resolution 0.95 degree beamwidth, 2) the Radar Data Acquisition (RDA) unit which generates the transmitted microwave signal and converts the raw returned signal into reflectivity, radial velocity, and spectrum width data, 3) the Radar Product Generator (RPG) computer which runs quality control and scientific algorithms to generate a myriad of derived meteorological and hydrological products from these three measurements, and 4) the Principal User Processor (PUP) which allows the forecaster to visualize the products and aid him in the automatic identification of potentially hazardous weather situations (Klazura et al, 1992). Within about five years the PUP will be replaced by the Advanced Weather Interactive Processing System, a workstation which will allow WSR-88D products to be combined with other data sources such as satellite and automated surface weather observations.

The reflectivity data which is collected by the radar is used to generate a number of value-added products. The Precipitation Processing System (PPS), to be described in more detail in the next section, produces rainfall accumulations over various time periods and is the focus of this paper. In addition to these hydrologic applications, the reflectivity data are also used for meteorological applications. Storm track algorithms keep track of storm motions and forecast future positions. The vertical reflectivity structure is used to determine the likelihood of hail production. Also the probability of severe weather is computed using reflectivity tops and the vertically integrated liquid water content (OFCM, 1991).

Radial velocity data are used to produce a variety of products used to automatically detect severe-weather-producing mesocyclones. Vertical wind profiles are computed, and wind shear and turbulence are produced for aviation applications. Despite the computer automation of the radar scanning and product generation, the human forecaster remains a key element in the hydrological and meteorological interpretation of the products and the issuance of watches and warnings based on the output.

Three Stages of Precipitation Processing

The NWS has defined three stages of precipitation processing for operational use (figure 1). These different stages are designed to meet the various needs of the hydrometeorologist, ranging from flash-flood warnings, to river stage forecasting, and water management activities. The overall objective is to provide the best quantitative estimates of precipitation possible given the various time constraints imposed on the operational forecaster.

The first stage of processing is performed in the WSR-88D RPG. It will perform a high level of automated quality control, incorporating radar reflectivity data from the four lowest elevation angles of the WSR-88D volume scan, along with a limited sample of precipitation gage data in order to generate precipitation accumulations. The quality control attempts to minimize the impacts resulting from isolated reflectivity points, excessively high reflectivity values, anomalous propagation, abrupt time rates of change of precipitation volume, and range effects resulting from a height varying vertical profile of reflectivity. Precipitation products are updated every 5-10 minutes. Graphical products are produced on a 2-km rectilinear grid with 16 data levels. These products depict 1-hour, 3-hour, and storm total accumulations. The timeliness and spatial resolution of these products are designed to meet the needs of the flash-flood warning program (Ahnert et al. 1983).

Stage II processing is performed on an hourly time step and produces products on a polar stereographic grid projection, approximately 4-km on a side. Since the time constraints on Stage II are not as great as for Stage I, a more comprehensive set of precipitation gage data is available in order to

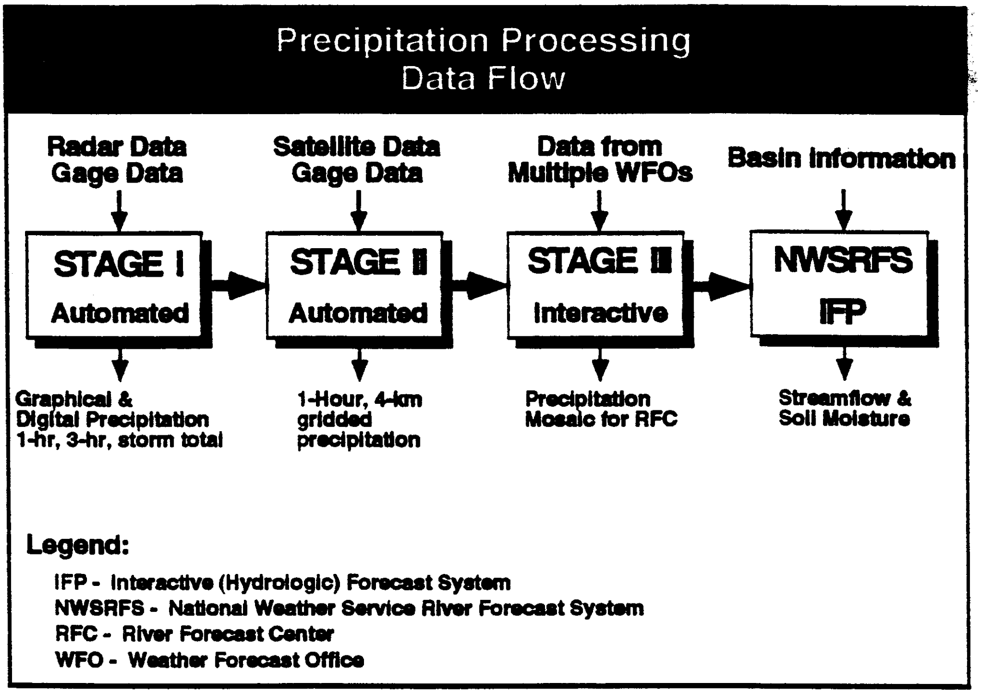

Figure 1 Illustration of the processing stream associated with the multistages of processing employed to prepare the rainfall estimates for input to the NWSRFS.

compute a mean bias of the precipitation field as well as performing local adjustments of the radar estimated precipitation. Satellite and surface temperature data are also incorporated into Stage II processing in order to detect and remove anomalous radar echoes occurring in clear air. Stage II creates a gage-only rainfall accumulation field which uses radar information to locate areas of precipitation; however, quantitatively, this field is based strictly upon gage data. This gage-only field is then merged with the radar field to produce a multi-sensor field. The merging is an objective analysis based on the nearness of any gages and the spatial uniformity of the precipitation field.

In order to produce river flow forecasts, precipitation estimates must be available over the entire river basin in question. NWS river forecasts are generated at 13 River Forecast Centers (RFC), each with a responsibility for a major river basin. An RFC region of responsibility may encompass up to 25 radars. Stage III processing runs at the River Forecast Center to incorporate and mosaic data from each radar in the RFC area of responsibility onto a common grid system. Stage III has been designed as an interactive process to allow the forecaster some control over the precipitation estimates being input to the hydrologic models. In order to accomplish this task, each RFC will be staffed with three hydrometeorologists whose responsibility it will be to ensure that the highest quality data is input to the models and that appropriate coordination with various Weather Forecast Offices is achieved. Stage III operates with the same spatial and temporal resolution as defined by Stage II, i.e, hourly data on roughly a 4-km grid spacing. Stage III allows the forecaster the capability to assess the quality of both the radar estimated precipitation as well as the precipitation gage data and to make modifications to the data as appropriate. (Shedd and Smith, 1991).

<u>Interface to Hydrologic Model</u>

Most of the NWS River Forecast Centers use the National Weather Service River Forecast System (NWSRFS) to generate hydrologic forecasts. The NWSRFS system is described by Anderson (1986). Presently, precipitation input to NWSRFS is through basin-average precipitation time series derived from available precipitation gage observations. Typically, these mean areal precipitation (MAP) time series are in 6-hour increments over areas ranging in size from hundred to a few thousand square miles.

With the arrival of gridded quantitative precipitation estimates from the WSR-88D, changes are being made to NWSRFS to accommodate this high resolution data source. The existing MAP preprocessor will be replaced with a new version. Basin average estimates will still be generated; however, rather than averaging from a sparse rain gage network, radar estimated precipitation from Stage III will be averaged over the basin in question to generate the precipitation time series.

The new MAP time series will be produced in one-hour increments rather than six-hour. This should also allow for a corresponding decrease in the size of many of the areas over which precipitation estimates will be generated. The result of this process should be an increase in the number of locations for which streamflow forecasts may be generated.

In addition to these steps to increase the temporal and spatial resolution of existing lumped hydrologic models, the NWS will investigate the possibility of incorporation of a more distributed modelling approach in which computations are performed over gridded regions as opposed to basin areas within NWSRFS. Further information on this process is provided in a companion paper by Lindsey(1993).

<u>Conclusions</u>

By the end of 1996, when the entire network of over 120 radars is in place across the United States, real-time quantitative precipitation estimates will be available from over 96% of the country. The steps being taken now represent major steps in the hydrometeorologic services of the NWS. The improved temporal and spatial resolution of the precipitation estimates provides opportunities for improved streamflow forecasts, increased number of river forecast points, improved operations of reservoirs, and other water management activities.

Appendix I. References

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