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PRECIPITATION PROCESSING WITH THE WSR-88D

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ABSTRACT

The National Weather Service (NWS) has been deploying the new WSR-88D weather radars since late 1991. A significant portion of the WSR-88D algorithm set is in support of precipitation processing. The integrated system of the WSR-88D with high resolution radar data along with significant computing capabilities will allow the use of radar for wide scale generation of quantitative precipitation estimates from radar for the first time. Precipitation processing will be performed in three stages to support both the flood and flash-flood forecasting requirements of NWS. The three stage processing will also take advantage of other supporting information -- rain gage and satellite infrared imagery -- in order to improve and quality control the radar precipitation estimates. The final stage of processing is an interactive process to perform final quality control of the precipitation field while mosaicking data from multiple radars over NWS River Forecast Center areas of responsibility. The radar estimated precipitation will then be used as input to the hydrologic models run by the River Forecast Center. It is anticipated by 1996, when the complete network of WSR-88Ds is deployed, that approximately 98% of the continental United States will be provided with radar coverage.

INTRODUCTION

Since 1979, a significant amount of work has taken place within the NEXRAD (Next Generation Weather Radar) program in the development of the WSR-88D (Weather Surveillance Radar - 1988, Doppler). NEXRAD is a joint program of the Departments of Commerce, Defense and Transportation for the development, deployment, and operation of a new nationwide network of weather radars. The first commissioning of a WSR-88D system is scheduled to take place in 1993.

A major portion of the WSR-88D software is in support of precipitation processing. In addition to the processing within the WSR-88D, the NWS Office of Hydrology has developed a three stage process for developing high quality quantitative estimates of precipitation for use as input into existing hydrologic models. These radar derived precipitation products will have a number of uses both in NWS forecasting and other water management applications.

Availability to the data stream will be provided through a variety of mechanisms for both real-time and non-real-time products. The appropriate path for a given organization depends on whether or not they are a NEXRAD program agency, the time requirements of their data needs, and the resolution of the data required.

THE WSR-88D SYSTEM

The new WSR-88D radar system has two major components: state-of-the-art

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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, 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. 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 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 anomalous radar echoes occurring in clear air. Stage II creates a gage-only 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 uniformity of the precipitation field.

In order to produce river flow forecasts, precipitation estimates must be available over the entire river basin in question. In some cases for the NWS, this requires incorporating data from up to 25 radars within a single office in order to generate a precipitation time series. Stage III processing runs at the River Forecast Center to incorporate data from each radar in the RFC area of responsibility. 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. 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).

The output of Stage III processing will be used as precipitation input to the hydrologic models running at the RFC. Currently, these models rely almost completely upon data from precipitation gages to generate the necessary precipitation input for the streamflow and stage forecasts. The increased time and space resolution available from the radar estimated precipitation should allow for consideration of decreasing the areas for which the models are currently applied, and eventually allow for the possibility of more distributed approach to NWS hydrologic modelling.

DATA DISTRIBUTION

Stage I WSR-88D data output is available at several levels, which we will appropriately call Level I, Level II and Level III. Level I data consists of analog WSR-88D echo signals obtained directly from the receiver on the Radar Data Acquisition (RDA) portion of the 88D. This signal is digitized within the RDA before it is sent to the Radar Product Generator (RPG) portion of the WSR-88D for immediate, real-time generation of base and derived products. Level I signal can be archived (called Archive Level I) for use by technical staff doing maintenance or during training. There are now no developed plans to collect, archive, or distribute Level I data.

Level II data consists of digitized base data (reflectivity, radial velocity and spectrum width) from the RDA prior to further processing. Level II data is then ported to the hydrometeorological algorithms resident in the RPG for development of the 39 types of derived products. Access to real-time Level II data will generally be restricted to the three WSR-88D member agencies. It is anticipated that some selected university access to real-time Level II data may be needed, and it is likely it will be limited to universities having specific contractual agreements for WSR-88D algorithm analysis, evaluation or development through an on-going formal Memorandum of Agreement with the member agencies. Level II data will be archived (Archive Level II) on a significant number of WSR-88D sites. Archive Level II data will be used in support of non-realtime operations, maintenance, and development of WSR-88D products within the NWS. It will also be useful for a wide range of radar hydrology and radar meteorology research and development activities. Archive Level II data will be stored and distributed to the governmental agencies, universities, private corporations, individuals and the public by the National Climatic Data Center at Asheville, North Carolina.

Level III data consists of the processed base products and the output of the hydrometeorological algorithms. Level III data will be available to the three member agencies and to many additional users (called external users) via a wide range of delivery options, several to be highlighted.

The NEXRAD Information Dissemination Service (NIDS) has been established to allow real-time dissemination of selected WSR-88D base and derived products to external users, in fact, anyone entering into contractual arrangements with one of the NIDS providers. Four private sector data providers selected by the NWS will access each WSR-88D in the United States and make them available to subscribers. The basic set of eleven WSR-88D base and derived products will be available in real-time from each NIDS vendor. These vendors may also provide value added products derived from the base unaltered products. The contractual agreement between the NIDS vendors and the NWS specifies that all real-time access to the WSR-88D products available to the NIDS vendors will be through a NIDS vendor. (Baer, 1991) The NIDS contract pertains only to the Stage I products.

As a means of insuring low cost access to NIDS output by selected agencies (governmental, public and private), a Special Subscriber program has been developed by the NWS. State Emergency Management Agencies and other agencies with established, shared and contractual arrangements with the NWS will be eligible to become NIDS Special Subscribers. The Special Subscriber program will be limited to 100 participants when the full WSR-88D network is in place. Approval of all Special Subscriber applications rests jointly with the Office of Hydrology and the Office of Meteorology. The University Corporation of Atmospheric Research (UCAR) has been encouraged to negotiate a contract with one or more of the NIDS providers. If this type of contract arrangement can be accomplished to serve university interests, there may be no need to consider university requests within the Special Subscriber context.

Level III data will also be available in non-realtime through several archival mechanisms. The first of these is referred to as archive Level III data, and is prescribed within the Federal Meteorological Handbook Number 11 (FMH-11). Archive Level III will be routinely collected at all NWS sites. The mandated set of WSR-88D base and derived products will be archived at each site and then delivered to the National Climatic Data Center at Asheville, North Carolina for distribution to the nation for non-operational and non-real-time use. Selected Level III data will also be archive at NWS operational sites for use in internal post analysis, training, and development activities on the site. This selected data archive is referred to as Archive Level IV.

While the RFCs have not fully developed plans to archive or distribute the value added Stage II or regional Stage III precipitation products, the NWS has every intention of continuing to share it's data with those water agencies with which it has ongoing relationships of mutual cooperation. The actual means and methods for sharing this data with water resource agencies is now being studied, and within the next several months, a formal mechanism should be developed within the NWS to insure water agencies across the country that access to the Stage II and Stage III precipitation products will be available to them.

It is also anticipated that one answer to national water resource and climatological resource data needs for a national real-time or near real-time precipitation product (called Stage IV precipitation) could be a product developed by collecting and mosaicking the basin wide mosaicked product prepared at each of the 12 RFCs in the conterminous United States. In the future, invitations will be extended to a wide range of water resource interests to meet and help map out requirements for collection, compilation, archiving, and disseminating this product.

STATUS AND EXPERIENCE

As of January 1993, approximately 15 radars have been deployed across the United States. When the full network across the United States of 135 radars is completely available, approximately 98% of the area of the country will be provided with radar estimated precipitation estimates. Although some problems with both hardware and software have been discovered over the past year, overall the experience with the new radars has been extremely positive. In the past, many or most flash-flood warnings have been issued after the onset of the flood event. In regions where the WSR-88D has been deployed, there have been a number of cases with a significant lead time on the issuance of the flash-flood warnings. Similar improvements in the area of severe weather prediction have also been noted.

Although precipitation estimates from the WSR-88D have not yet been directly and routinely input to the RFC hydrologic models, in a number of cases, the radar estimated precipitation has been manually input by the forecaster to update the model on a more timely basis than had they had to wait for precipitation gage reports.

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