Enhancing Access to NEXRAD Data--A Critical National Resource

Global Energy and Water Cycle Experiment (GEWEX) Panel, National Research Council

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A brief report from the
Global Energy and Water Cycle Experiment (GEWEX) Panel
Climate Research Committee
Board on Atmospheric Sciences and Climate
Commission on Geosciences, Environment, and Resources
National Research Council

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While the individuals listed above have provided constructive comments and suggestions, it must be emphasized that responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Enhancing Access to NEXRAD Data—A Critical National Resource

BACKGROUND

The Next Generation Weather Radar (NEXRAD) WSR-88D Doppler weather radar network was created to meet the weather surveillance radar needs of the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD). The network was installed as an integral part of a recent substantial upgrade of U.S. federal weather services. Its primary objective is to create nearly continuous radar coverage of the continental United States, making it possible to monitor the occurrence and development of severe weather events, including tornadoes, damaging winds, hail, heavy precipitation, flash floods, and hurricanes. The completed network of WSR-88D radars is shown in Figure 1. Note the virtually complete coverage east of the continental divide, as contrasted with the data voids in the western United States. A complete assessment of the NEXRAD radar coverage was prepared by the National Research Council's (NRC) National Weather Service Modernization Committee (NRC, 1995).

Doppler technology permits observation of the motion field of the air inside and around clouds. The addition of this capability to radars is especially crucial for the early identification and improved warning of severe weather. Frequent imagery showing horizontal distributions of radar reflectivity (related to precipitation intensity) and Doppler velocity (measured winds along the radar beam) is used in real time at local sites for weather surveillance and warning. Moreover, data from individual sites can be aggregated into more extensive regional views of severe weather systems, allowing them to be followed throughout their life cycle (OFCM, 1991a).

The upgrade to Doppler technology established a system for archiving data from the radar network to provide retrospective

assessments of weather situations that could be used to investigate events such as aircraft accidents, perform subsequent analyses, and conduct hydrometeorological research. Initially, the operational weather services judged that the primary research use of these data would be in understanding the behavior of severe weather events. Consequently, a limited number of high-density recording devices capable of recording Level II[1] radar data were provided that could, in principle, be moved around for special observing periods or for short-response events such as landfalling hurricanes. However, the research community identified many other uses of the NEXRAD data that should be pursued, including more extensive study of precipitating weather systems and cloud-precipitation processes that are crucial to advancing understanding of weather and climate. This capability was judged by NWS to have important postevent diagnostic value; consequently, in 1994 the NEXRAD agencies approved the installation of recorders on all WSR-88D systems. The agencies chose 8 mm tape technology, which they judged to be the best solution available at the time the decision was made (NEXRAD OSF, 1997).

PANEL'S CHARGE

The Global Energy and Water Cycle Experiment (GEWEX) Panel was asked to assess the value of the NEXRAD data for answering key atmospheric and hydrological science questions (see the tasking letter in the appendix). In response, the panel reviewed the status of WSR-88D data collection, processing, and archival, as well as the accessibility of archived data (with an emphasis on Level II). For this purpose, the panel examined reports by R. Carbone (panel member) and G. Mandt, Director, NWS/Office of Meteorology (OM). It should

[1] Level II contains the radar reflectivity, Doppler velocity, and spectrum width of the velocity estimate for all points along each radar beam. These data can be archived to 8 mm high-density tapes at the receiver site. One 8 mm tape contains 2 to 4 days of data. Because the antenna and receiver may be located several miles away from the associated weather office, there is often a jukebox device that cycles through ten 8 mm tapes before requiring a change. The 8 mm tapes are sent to the National Climatic Data Center (NCDC) in Asheville, North Carolina. For about $100 per day of data, copies can be obtained from NCDC. If more than 2 consecutive days of data is required, NCDC currently charges $25 for each additional day.

be noted that, because an emphasis of the present review was in identifying areas for improving the utility of the NEXRAD data, the conclusions and recommendations presented in this report could be taken out of context to suggest that the data in their present form have little utility. On the contrary, the panel concluded that the NEXRAD data are valuable for both their real-time applications in weather forecasting, and their utility for studying atmospheric dynamics in greater detail than was previously possible. At the same time, the panel identified strategies that could significantly improve the utility and value of the data.

PANEL'S OBSERVATIONS

The panel made the following observations.

1. Although the WSR-88D system has successfully improved forecasts and short-term warnings of severe weather events, the poor quality and limited accessibility of these data for research severely constrain their utility for studies of the evolution of weather systems over a long time period or a large spatial scale.
2. The operational weather services have as their highest priority real-time warning and forecasting of weather events. The use of NEXRAD data beyond this immediate application is of lower priority and receives a much lesser commitment from the operational agencies. For this reason, recording of Level II data is a requirement, but it is not enforced by the operational agencies (OFCM, 1991a, 1992). The general shortcoming that results when operational systems are used to provide climate (or research) data is described in detail in the recent Climate Research Committee report *Adequacy of Climate Observing Systems* (NRC, 1999).
3. WSR-88D data could provide an unprecedented view of the dynamics of precipitating storm systems because they cover a very large area with high space and time resolution. The data could make possible, for the first time, complete observation of the entire structure of large mesoscale convective systems over their full life cycle. However, the conditions under which the radars operate, how they operate, and whether the data are actually collected are unclear from

the actual archival performance. Only 65 percent of the NEXRAD data are currently archived (NEXRAD OSF, 1997).

4. Data processing is neither uniform nor done regularly. In particular, precipitation estimates derived from Level II data have been found to be highly uneven in quality from site to site and with time, often containing large and variable bias errors. As a consequence it is very difficult, if not impossible, to assemble an integrated view of precipitation across the entire network to study the evolution of mesoand synoptic-scale weather systems. Research using data from the whole network could lead to better analysis procedures that would mitigate many of these problems, thus producing a dataset that would be much more valuable than the sum of the datasets from the individual radar sites (NEXRAD OSF, 1998a).
5. Data archival is incomplete because some data are never recorded. Moreover, the accessibility of those data that are recorded is significantly reduced by the unreliable recording technology employed (NEXRAD OSF, 1997). There is a considerable effort under way by the NEXRAD Operational Support Facility (OSF) to improve the reliability of the Level II archival subsystems, but it is too early to judge the adequacy of that effort (NEXRAD OSF, 1999b).
6. The initial cost of the NEXRAD radar network was almost $1 billion. The research community should be in a position to capitalize on this major and valuable national resource, especially in view of the important national goal of improving the quantitative forecasting of precipitation events that lead to flooding, the understanding of seasonal and interannual variations in the North American water supply, and predictions of variation and change in regional climates.

The potential impact of the lack of reliability of the NEXRAD recording technology was illustrated during the major tornado outbreak in Oklahoma on May 3, 1999. The recorder on the central Oklahoma WSR-88D (KTLX) was not operating at the time of the storm. Fortunately, high-speed lines linked the radar to the National Severe Storms Laboratory and to the University of Oklahoma School of Meteorology. Both of these organizations thus recorded and preserved the data from this unprecedented severe storm event (McCarthy, 1999).

ISSUES

The panel identified the following issues that need to be resolved.

1. There are a number of intrinsic problems or limitations involved in estimating precipitation with conventional or Doppler radar, such as the effects of horizon obscuration, beam geometry, and anomalous propagation; contamination from migrating birds; and bright-band effects. Some of these deficiencies may be correctable, especially by exploiting the combining of observations from neighboring radars in the network. Some of the other deficiencies are not entirely correctable because of the limitations of single-frequency, single-polarized measurements. However, access to the data by researchers could produce significant improvements in the understanding of such problems. For example, the overlapping radar coverage allows for systematic estimation of the space-time distribution of quantities related to precipitation intensity. Understanding the causal relationship between the distribution of precipitation and ambient meteorological conditions would represent a significant advance, even if the absolute value of precipitation rates were to remain biased or uncertain. Exploitation of this possibility would require access to extensive amounts of continuously collected Level II data (NEXRAD OSF, 1998a; OFCM, 1991b; Zrnic and Ryzhkov, 1999).
2. Weaknesses in the actual radar operations make the data quality much poorer than it should be. Key problems include the following:

(1) Absolute calibrations are not performed on a regular schedule.
(2) Guidelines for the selection of volume scan modes are not clear.
(3) Tape recording of data is not done reliably.
(4) The 8 mm tapes used to record data are poorly maintained and often unusable (resulting in permanent and unpredictable data losses).

Revised operational policies and practices could mitigate these problems and provide a reliable flow of observational data with more uniform and predictable characteristics. However, such changes could occur only if the agencies were to give increased consideration to the value of the weather and climate research uses of WSR-88D Level II data for postevent analyses. Indeed, most of the research value of this dataset will come from retrospective analyses of data covering the entire United States for long time periods. Clearer operational guidelines would make it possible to conduct studies to characterize the role and behavior of convective precipitation systems in determining the climate of the United States.

3. Several other factors adversely affect the quality, cost, and accessibility of the Level II data that are being collected:

(1) The reliability (durability, longevity) of the storage medium (8 mm tapes)
(2) Failure to archive complete calibration information and other metadata[2]
(3) Data copy charges that make access to large data volumes prohibitively expensive

In the panel's judgment, 8 mm tape technology is not well suited to the task of Level II data storage. Insufficient attention has been paid to the routine and reliable execution of calibration procedures and recording of calibration information, suggesting an under-appreciation of the importance of quantitative data for both real-time and research applications. The failure to retain and provide calibration information seriously impedes the retrieval of useful data and degrades the value of the data that are archived. However, the panel was encouraged to learn that recent actions to improve calibration procedures, as recommended by the Technical Advisory Committee, s well as procedures for retaining calibration data as part of the archives, have been taken by the

[2] Since a new NEXRAD software implementation was carried out in November 1998, all metadata have been recorded on each 8 mm tape. Experience with the new software will show whether this concern has been eliminated (NEXRAD OSF, 1998b).

federal agencies. These actions should improve the quality and utility of the data.

The most favorable interpretation of the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) pricing structure yields a cost of $1.25 million for 1 year of data for the continental United States. Although climatological applications require data from large regions covering many years, the study of mesoscale convective processes in a weather context would also require extensive areal coverage (i.e., tens of radars). What makes the WSR-88D network a uniquely valuable data source is the potential to acquire nearly continuous and contiguous coverage of precipitating weather systems over the continental United States. However, the current pricing structure is prohibitive for research that would exploit these unique features. The panel recognizes that pricing is a policy issue based on decisions made within NOAA and the Office of Management and Budget. These policies should be examined in terms of their negative impact on research efforts requiring large amounts of NEXRAD data.

STRATEGIES

The panel concluded that the opportunity to address a number of critical national goals would be enhanced by the following promising strategies. These strategies include efforts to improve the quality of the data, while ensuring that the data are secured for future research applications and facilitating their use by the academic and research communities.

IMPROVING THE QUALITY OF THE DATA.

1. Operations and data archival plans should be reconsidered with an eye to exploiting the larger potential of the WSR-88D network to facilitate research beyond its immediate use for severe weather warnings. Representatives of the cognizant research groups, including those who study precipitating convective weather systems, regional hydrology, and climatic variations of the whole water cycle, should participate in these deliberations. Efforts to improve the quality of the data and enhance access should parallel and support an aggressive research program to investigate the current

problems with precipitation estimation algorithms and ground validation. If some compromise must be made on the amount and type of data to be archived, the research community should participate in determining which such compromise would be best. In all such deliberations, the research community would have to respect the primary mission of the WSR-88D systems in providing input for the weather and flood warnings necessary to protect life and property.

2. Operational policy should be changed to mandate regular and systematic recording of Level II data under all feasible circumstances, with a goal of increasing the capture rates. In this regard, the operational agencies should establish goals after considering the associated costs and research needs. Even more important, these data recordings must include metadata about operating conditions and calibration. A regular and routine schedule for calibration of the radar and maintenance of the recording equipment is also needed. Logs of the radar calibration and maintenance should be retained and made available as a critical part of the metadata. Site histories should be updated at reasonable intervals (5 years, for example) to account for changes in the operational environment that might affect the performance of the radars.

3. With regard to precipitation estimation for operational flood predictions and the water budget objectives of GEWEX science, the panel urges an accelerated pace in implementing polarimetric radar capabilities on WSR-88D platforms. Polarimetric radar techniques should mitigate many of the intrinsic limitations of the WSR-88D and significantly improve the quality of estimates of precipitation amount and type (Zrnic and Ryzhkov, 1999). This improvement, in conjunction with the other strategies proposed here, should enable the research necessary to improve precipitation rate algorithms. It should be noted, however, that the data stream from dual polarized radars will be even larger than that from the present WSR-88Ds, making it even more imperative to address the archival problems discussed earlier.

ENSURING THE AVAILABILITY OF THE DATA

4. NCDC should acquire, store, and provide quality-assured datasets on reliable, convenient, and affordable media. Information made available to the panel strongly suggests that NCDC's infrastructure is inadequate for this task. However, the potential benefits to be derived from a reliable and accessible NEXRAD database argue for a strengthened NCDC infrastructure to make this strategy work. Strong consideration should be given to developing quality assurance programs and using commercial archival formats such as digital versatile disc (DVD) technology.

ENHANCING ACCESS TO THE DATA

Implementation of the above strategies would improve access to the data, but an additional step should be considered.

5. Real-time dissemination of Level II data would add flexibility to the solution to the Level II access problem. It would also correct the current problem that results from the proprietary nature of the real-time data distribution. This inability to distribute the real-time data freely is an impediment to educational activities in this country that require these data. The feasibility of this strategy should be evaluated promptly after the 1999 warm season trial currently being conducted at the University of Oklahoma in conjunction with the UNIDATA[3] program. This project is using data compression technology that can enable cost-effective data communication and distribution and could increase the productivity of the existing WSR-88D and NCDC workforce (NEXRAD OSF, 1999a).

[3] UNIDATA-A community program established to help universities access real-time data and to acquire, share, and use the software needed to display and analyze those data; operated by University Corporation for Atmospheric Research (UCAR).

CONCLUDING REMARKS

The panel acknowledges that, based on the presentations received from NWS officials, the operational agencies recognize many of the problems cited in this report and are attempting to take appropriate actions. The panel believes, however, that the efforts to date have been 'fine-tuning' around the edges of a major deficiency and have not resulted in the improvements necessary to make effective use of a valuable national resource. The strategies recommended above could leverage a billion-dollar investment into a capability that could be used to significantly enhance understanding of the precipitation processes associated with flooding and flash flooding events, climate variations, and global change.

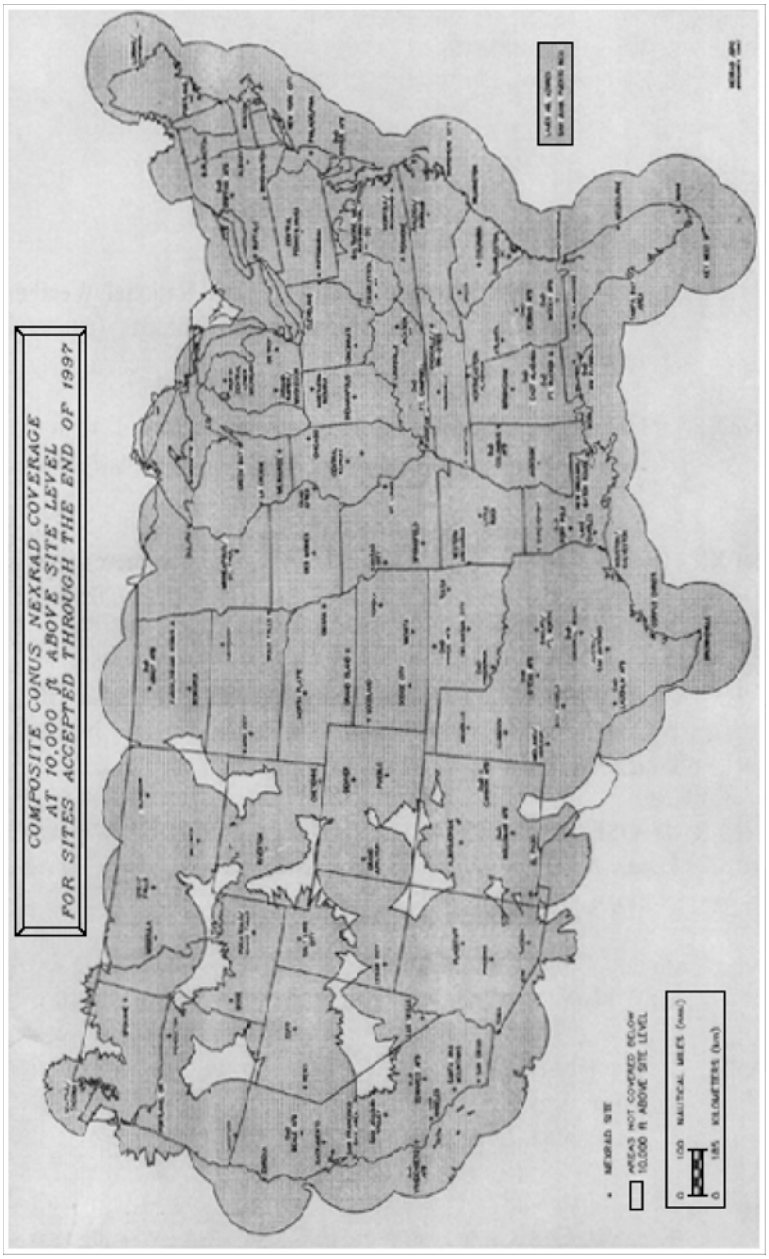

Figure 1.
The completed NEXRAD network in the contiguous states. The shaded areas indicate radar coverage above 10,000 feet. (Source: NEXRAD OSF)

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Appendix A

Tasking Letter from the USGCRP

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Dr. Soroosh Sorooshian
Chair, NRC GEWEX Panel
National Research Council HA 466
2001 Constitution Ave. Washington, DC 20418

Dear Soroosh,

As you know, the WSR-88D radar network is widely considered to be a success story in the context of the National Weather Service modernization. Many of the anticipated benefits related to the real-time depiction of weather and very short-term prediction of severe storms equal or exceed expectations. In spite of this success, there are considerable concerns pertaining to the utility of NEXRAD data for climate applications and quantitative research, as evidenced by the discussions at the March 18–19 NRC GEWEX panel meeting.

The issues of NEXRAD-assisted quantitative precipitation estimation and forecasting are central to the objectives of the

GEWEX Continental-Scale International Project (GCIP) to: (1) determine the variability of the Earth's hydrological cycle and energy exchange budget over a continental-scale; (2) develop and validate techniques for coupling atmospheric and surface hydrological processes in climate models; and (3) to provide a basis for translating the effects of future climate change to impacts on regional water resources.

As noted by Greg Mandt, the Acting Director of Meteorology of the NWS, at the recent NRC GEWEX panel meeting, the panel could provide valuable advice to the NWS in the post-modernization era, as the NWS assesses its options for increasing the utility and availability of NEXRAD data. We, therefore, request that the NRC GEWEX panel prepare a brief letter report to advise the relevant USGCRP agencies on promising strategies that might be pursued to most effectively realize the large potential of NEXRAD data for hydrometeorological and climate research and applications.

Sincerely,

David Goodrich Executive Director USGCRP Coordination Office

Appendix B

Acronyms

DOD	U.S. Department of Defense
DVD	digital versatile disc
FAA	Federal Aviation Administration
GCIP	GEWEX Continental-Scale International Project
GEWEX	Global Energy and Water Cycle Experiment
NCDC	National Climatic Data Center
NEXRAD	Next Generation Weather Radar
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NWS	National Weather Service
OFCM	Office of the Federal Coordinator for Meteorology
OM	Office of Meteorology
OSF	Operational Support Facility
UCAR	University Corporation for Atmospheric Research