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INTERACTIVE HYDROMET INFORMATION SYSTEM FOR REAL-TIME FLOOD FORECASTING AND WARNING

Abstract: Research and development work is being conducted for the National Weather Service on a new-generation flash flood monitoring and forecasting computer workstation. The workstation represents an integration of national data sources, regional networks of real-time rain gages, radar-rainfall and satellite remote sensing, and geographic information system and relational database management software. The HYDROMET system provides for hydrologic forecast analyses and (semi)automatic warning message dissemination.

INTRODUCTION

Floods are the number one natural disaster in the United States in terms of loss of life and property[1]. Since 1970 the average flood-related fatality rate has increased to 200 per year and flood damages continue to increase; in 1983 they were almost $5 billion. The goal of flood warning is to reduce losses by increasing the length of time in which a community can take protective actions. Advance warnings can ideally provide information on the likely location, timing and extent of flooding; and enable activation of alerting, evacuation and rescue teams, and other counter-disaster procedures.

Technical advances in hydrologic data collection, communications, computer processing and modeling, and message dissemination hold promise for increasing lead time during which flood danger and damage reduction actions can be taken. A prototype next-generation hydrometeorological (hydromet) forecasting system for the local scale is being developed as part of the

Denver AWIPS-90 Risk Reduction and Requirements Evaluation (DARRRE) project at NOAA's Program for Regional Observing and Forecasting Services (PROFS) in Boulder, Colorado[2]. The DARRRE-HYDRO system is intended to provide experience with real-time hydromet data ingest and processing functions in preparation for National Weather Service modernization activities schedules for the 1990's.

The NWS modernization program involves integration of new data sources and types, including Doppler radar, new products and display concepts, and new forecaster decision support workstations. Prototyping experience provides lessons on the many aspects of forecaster interaction, system reliability, and training requirements. The overall objective is to provide the field forecaster with local capabilities for automatic data collection and processing of hydrologic data for the more timely and accurate solution to the flash flood and flood problems. This experience will provide valuable insights into the service requirements of the hydrologic program.

In this paper, we will describe the developed modules of the DARRE-HYDRO forecasting system and how it is operated to obtain flash flood warning messages.

DARRRE-HYDRO FORECASTING SYSTEM

The DARRRE computing system consists of a large array of networked computers forming a distributed computing system capable of processing the voluminous amounts of data in real time. The DARRRE-HYDRO system is comprised of various computer software and hardware modules listed as follows:

- o Data collection network,
- o Database management,
- o DARRRE interactive workstation,
- o Forecasting applications, and
- o Warning message formulation and dissemination.

Hydromet Data Collection Network

Hydromet data include relatively static spatial and temporal numerics on drainage patterns and areas, and dynamic measurements of rainfall, streamflows and soil moisture. Data collected in the field are transmitted to the forecast station where they are reviewed and input to a hydrologic forecast procedure. Five basic data sources include:

1. Network of automatic, computer-controlled surface hydromet stations (e.g. precipitation, river stage);

2. Doppler radar reflectivity and velocity data;
3. Surface-based remote probes (i.e. profilers) for temperature, humidity and wind profiles;
4. Satellite visible and infrared image data; and
5. NWS surface and upper air observations and NMC (National Meteorologic Center) diagnostic and prognostic products;

One important new data source are the local community ALERT (Automated Local Evaluation in Real Time) systems. Many communities across the country are installing networks of automated gages (data collection platforms or DCPs) which remotely monitor precipitation and stream stage (i.e. water level) and report the data by radio transmission to the central station computer. The data from the local ALERT DCPs is collected in real-time, as the event is occurring, and is idle the remaining time. The central receiving computer automatically monitors, records, and analyzes the incoming data and signals the operators when rapid changes exceed preset threshold values[3]. Figure 1 illustrates the ALERT data capture operation.

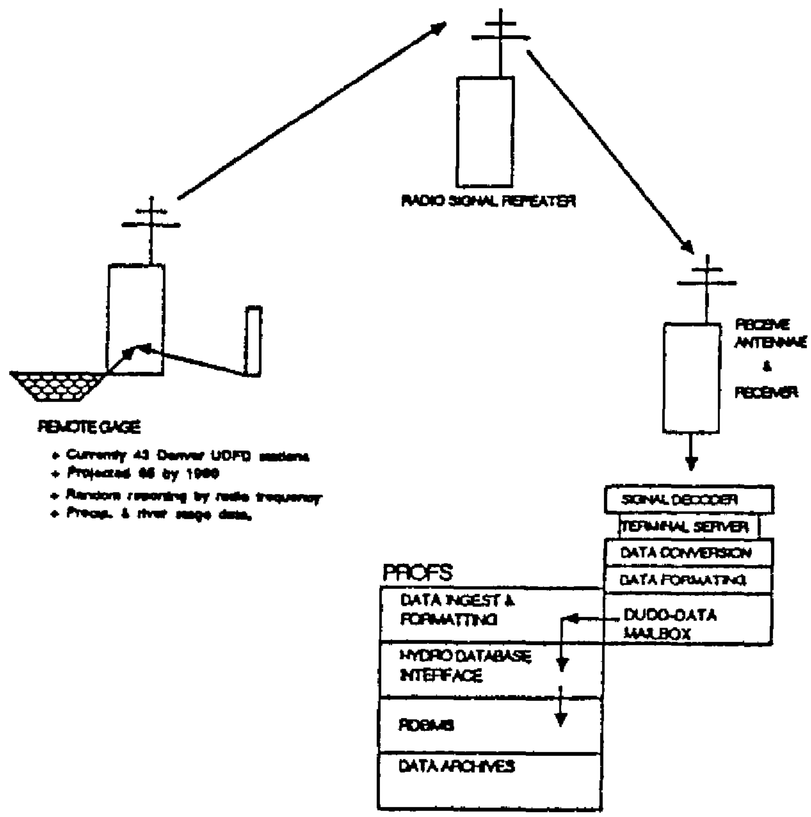

Figure 1. Local data collection platforms transmit rainfall and river stage data to the central computer in real time.

Another important hydromet data source is the Colorado State Engineer's Office system which monitors a statewide network of remote DCPs for precipitation and stream or reservoir stage. These gages report through a GOES satellite data channel on a timely basis to the State Engineer's Office minicomputer. This data is used to manage the state's water resources in an efficient manner. The state network collects real-time samples every fifteen minutes and transmits the data to the base station every four hours. When rate-of-change thresholds are exceeded at a DCP, the platform initiates an exception report to the state computer. Exception reports are communicated directly by voice synthesis to the National Weather Service (NWS) office where verification procedures are begun.

The NWS uses Doppler radar for a variety of purposes, such as identifying the location and intensity of micro-bursts, the intense very localized down drafts located near thunderstorms. The radar data is also used to determine the location and intensity of precipitation. Radar scans of the atmospheric reflectivity are recorded ar several azimuth angles and processed into a composite reflectivity image. Rain droplets reflect the radar beam in proportion to their size and density, in a logarithmic functional relationship; the processing takes advantage of this, and converts the reflectivity data into a distributed precipitation map, encompassing 150 kilometer radius about the radar site. The computed radar rainfall intensity distribution is verified and corrected automatically by the real-time precipitation gage sensors.

The NWS its own network of regional surface air observation (SAO) data collection platforms, and regular national data products, such as the national satellite imagery. Some of these national data provide regional forecasts for precipitation and river stage, as well as daily updated indicators of rainfall depths required to create a flood. The national data is provided and shared by a high speed data communication network between the NWS offices. These data provide the weather forecaster with an overall perspective of potential flooding hazards.

Hydromet Database Management System

The database management system consists of a relational database collecting and organizing for rapid retrieval the real-time and regular transmissions from the sources listed earlier. The relational database integrates the real-time data with gage specific static data. A gage has a large number of static attributes associated with it, such as gage identification, location, type, and archived data including rainfall amount and a time stamp.

The relational database provides an automated organization to the data which allows development of standardized data retrieval operations, efficient storage use, and rapid insertion and extraction of data. This data management architecture, once established, reduces the data maintenance requirements of system. Automated procedures can be installed to generate summary reports before periodic data backup and purging. As additional gages are added to the network, or new data sources are added, the appropriate tables are changed to incorporate the addition and integrate the new data into the database.

Hydromet Data Display and Interactive Workstation

An important element of the DARRRE system is computer graphics workstations which aid forecasters in understanding the data. User-friendly, menu-driven user interaction modes permit rapid and flexible acces to data, display of data in colors overlaid on maps of selectable scales, and time sequence animation of images. Interactive workstations for display of data, control of analysis and database management operations improve the performance of the forecaster operator in making judgments about the state of the atmosphere.

The DARRRE Hydromet workstation is designed to be a powerful, easy-to-use tool for accessing and manipulating large quantities of hydromet data[4]. The DARRRE workstation system is made up of two independent subsystems: the Graphics and Image Display subsystem (Figure 2) and the Text subsystem. The Graphics and Image Display subsystem has two user input devices for each display: a mouse and a keypad. The user displays the hydromet information products or enables a forecast analysis procedure by selecting from a menu (Figure 3) using the mouse or the keypad. The Text subsystem is a text retrieval and editing system which used to call up textual forecast information as part of warning message preparation (see below, Hydromet Warning Message Formulation and Dissemination).

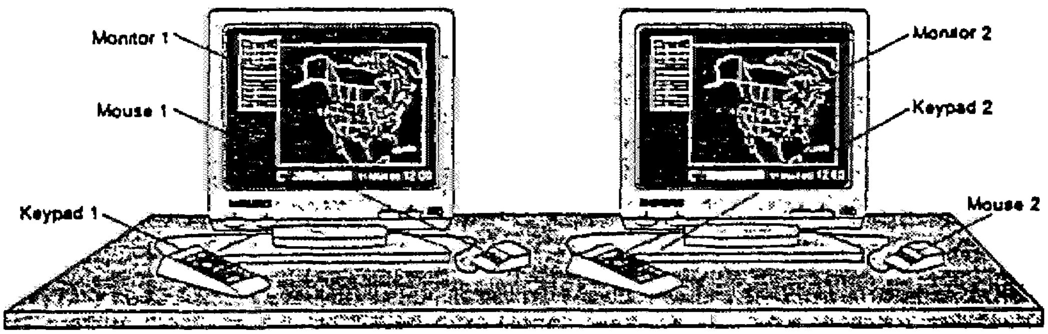

Figure 2. DARRRE graphics system displays information products retrieved from the database[4].

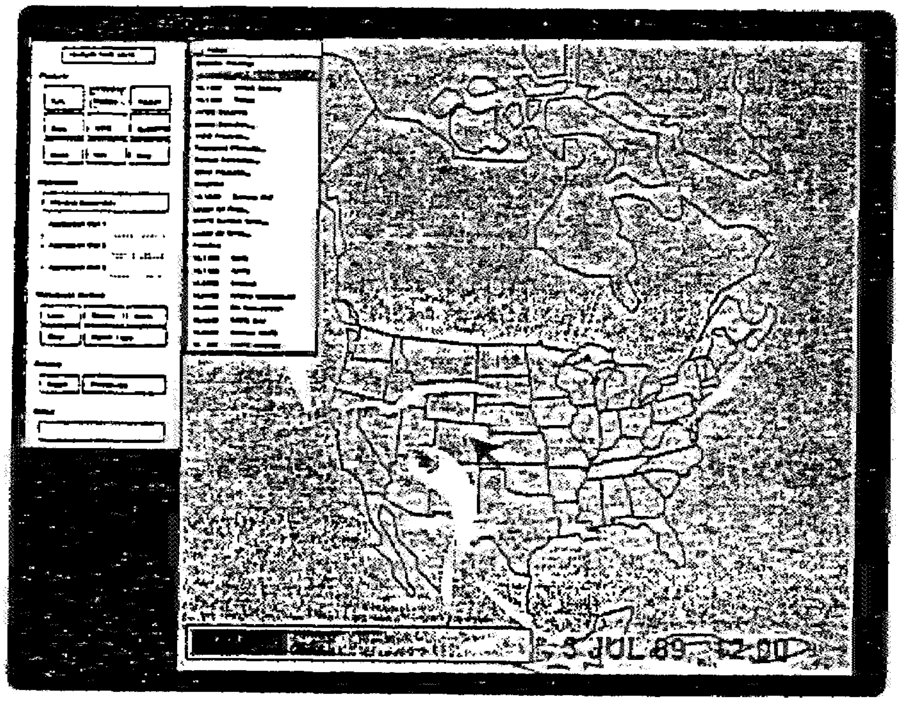

Figure 3. Interactive workstation provides access to the many hydromet information products using graphical displays and menu command selection options[4].

Static data displays include graphical representations of river and stream basins, stream paths, gage locations, and political boundaries. Current status displays include gage point data displays of the previous hour rainfall and river stage. These displays include the appropriate NWS guidance values, and warning stage data in the stage displays. The river stage can be displayed as a time series for a user selected time period. The location of a severe storm cell can be inferred from these point gage displays, but they should be compared with the radar imagery for corroboration. From these data displays it is possible to anticipate the location of potential flooding. The forecaster can then notify the appropriate response agencies to take mitigating measures.

Hydromet Forecasting Applications Programs

Various data processing and hydromet forecasting algorithms have been developed and integrated into the workstation functionality. Hydromet applications programs reduce the amount of information a forecaster must process and analyze in order to issue a flood forecast. These programs, while maintaining a high degree of flexibility, provide fast, efficient, accurate procedures for estimating runoff. A listing of these functions includes:

1. Next Generation Weather Radar (NEXRAD) Hydrology Precipitation Sequence (PPS),
2. Precipitation Gridded Field (PGF), and
3. Flood Monitoring and Prediction (FMP).

The NEXRAD algorithms are particularly important for determining precipitation amounts in space and time. The NEXRAD PPS sequence consists of five algorithms that use the Doppler radar data and rain gage reports to produce high resolution rainfall accumulation products. Also coded for operational use are Flash Flood Potential (FFP) algorithms which incorporate flash flood guidance indices provided by the NWS River Forecast Centers. The FFP predicts the probability of flash flood occurrences up to one hour in the future.

Determination of the areal distribution of rainfall based on rain gage reports has always been problematic. Thiessen polygon methods and isohyetal methods have been used to standardize the solution to this problem. Computerized methods can take advantage of the changes in the system, i.e. out-of-service or non-reporting gages, quickly without a deterioration to rainfall estimate probability. Stochastic methods, such as kriging for stationary fields, provide a statistical approach to the precipitation distribution problem, providing a varying probability to a location's precipitation estimate as a function of its distance from the other reporting gages within the entire network, not only its nearest neighbors.

Flood monitoring and prediction functions provide detailed site-specific information on the flood conditions occurring or likely to occur. Interactive computer graphics displays in color formats are provided in the DARRRE HYDRO workstation to enable selection of data sets and applications procedures.

Basin maps of Colorado's river drainage system and basin divides provide a visual key to the data - its selection and display. Rain gage and river flow data can be selected and plotted on the basin maps. Vector data formats can be overlaid on the image data (e.g. radar). Hydrographs of river flows can be retrieved from the database and displayed along with site-specific flood impact information (e.g. E-19 data).

The rivers and headwaters applications provide the forecaster with an easy to understand and use computer graphics environment that uses exclusively a mouse for all menu selections and data input. This application uses provides large area maps to define the primary area of interest, such as a river basin selected from a state-scale map. Then, further focus on more detail can occur as the user selects additional scale refinements until the degree of detail is obtained necessary to evaluate a risk or hazard. Each graphics image is geographically registered, so locational information is accurately represented.

After the state-scale basin has been selected, the particular stream basin or sub-basin is selected for analysis from a menu dynamically created by querying the database to return the names of the stream basins within a particular state-scale river basin. Then the data to be displayed is selected from a menu of possibilities. Currently they are:

- o Time series of river stage at a gage;
- o Point gage rainfall,
- o Point stream stage measurements,
- o Analyze rainfall,
- o Estimate rainfall runoff,
- o Display flood advisory.
- o Display NEXRAD accumulation image;
- o Stochastic precipitation analysis.

Hydrologic rainfall-runoff procedures include the unit hydrograph and the NWS's headwater guidance method. These are procedures with which many NWS forecasters are familiar and their computerization provides a flexible and rapid means to obtain a site-specific forecast of potential flood events. Runoff hydrographs are generated using several rainfall sources. These sources may be extracted from the real-time data available and distributed using one of several algorithms, to model current runoff conditions for ungaged streams. The forecaster may enter a rainfall distribution to use in the runoff model. The computed runoff hydrograph is displayed with both stage and discharge labeled ordinate axes. The hydrograph estimates are base on unit hydrograph procedures. Time to peak and peak flow can be extracted directly from the summed storm unitgraphs.

Historic flooding data is retrieved from the static database as E-19 flood depth-damage information. This text information is provided to allow the forecaster to immediately evaluate the degree of hazard based on previous historic information available.

Hydromet Warning Message Formulation

Textual information is obtained in a "windows" environment with which the user can retrieve text information and prepare word forecasts and warning messages. Figure 4 illustrates a text window display. The user selects commands using the pull down menu options available. Upon completion of a text message the user can select a menu command which transmits the message to the standard NWS communications ports (Figure 5). Depending upon the message class (i.e. Public, Aviation, Hydrology) type and priority of the message it can be directed to the appropriate channel for dissemination.

CONCLUSIONS

The prototype interactive hydromet information system for real-time flood forecasting and warning represents a realization of the new technology for hydromet data collection, processing and analysis, and warning message generation using a user-friendly interactive workstation. The system is representative of an advanced state-of-the-art for flood warning[5] which will be available across the U.S. during the 1990's.

Operational testing of the system is scheduled for the coming flood season. Initial testing indicates that improved hydromet services can be obtained, and that NWS forecasting personnel are receptive to use of these hydromet functions in concert with the other meteorological functions installed on the workstation.

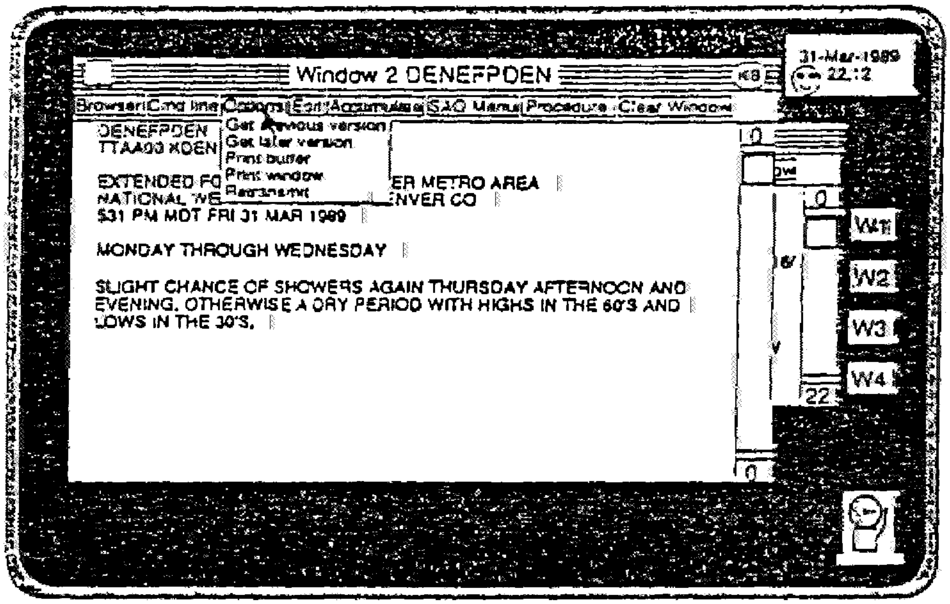

Figure 4. Text windowing capabilities permit editing of flood warning messages[4].

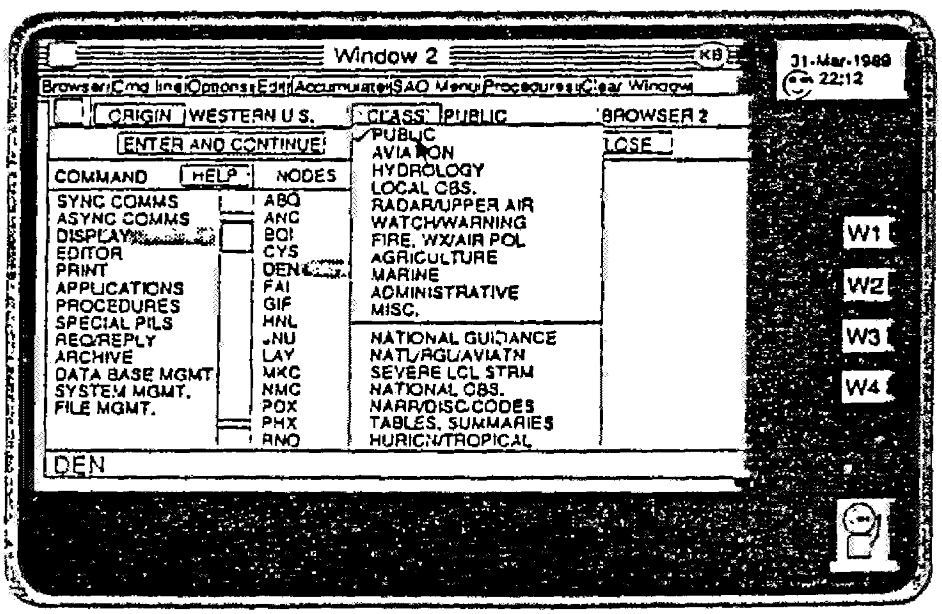

Figure 5. Dissemination of flood and other warning messages can be (semi)automatically obtained using the menu command options[4].

REFERENCES

1. National Weather Service. 1985. "Guidelines on Community Local Flood Warning and Response Systems." Hydrology Subcommittee of the Federal Interagency Advisory Committee on Water Data. Silver Spring, MD. August.

2. Walts, D., P. Schultz, R. Tibi. 1989. National Weather Service Modernization - Advanced Weather Information Processing System, in Computerized Decision Support Systems for Water Managers, Proceedings of the 3rd Water Resources Operations Management Workshop, Colorado State University, June 27-30 1988. Published by the American Society of Civil Engineers, N.Y.,N.Y.

3. Johnson, L.E., S. O'Donnell, S.R. Durrans, C. Andrews-Jones. 1989. DARRRE-HYDRO Progress Report. University Colorado at Denver, Dept. Civil Engineering. May.

4. PROFS (Program for Regional Observing and Forecasting Services). 1989. DARE-II User Guide. Document No.: PR 5.7 U (2.0). Environmental Research Laboratories, National Oceanic and Atmospheric Administration. Boulder, CO. November.

5. Johnson, L.E. 1989. Flood Warning Systems, in Computerized Decision Support Systems for Water Managers, Proceedings of the 3rd Water Resources Operations Management Workshop, Colorado State University, June 27-30 1988. Published by the American Society of Civil Engineers, N.Y.,N.Y.

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