SECTION 1

HYDROMETEOROLOGY PRODUCTS AND SERVICES: A PARTNERSHIP IN PUBLIC SAFETY

INTRODUCTION

Hydrometeorology is the branch of meteorology that focuses on the "ups and downs" of water in the atmosphere, with particular interest in the where, when, how, and how much, regarding precipitating water. Hydrometeorology is the science of how atmospheric water in all its forms-water vapor, liquid, or solid-interacts with the land and with energy fluxes to deliver precipitation (or not deliver it) onto the land below. Whereas traditional hydrology studies what happens to water after it falls out of the sky, hydrometeorology wants to understand and predict the details of this initial "down side" in the global hydrologic cycle. The boundaries of hydrometeorology are not clear-cut, and the problems of the hydrometeorologist overlap with those of the climatologist, the hydrologist, the cloud physicist, and the operational meteorologist. But with its focus on atmospheric water becoming water on or in the ground, hydrometeorology and the products and services it provides are particularly important to managing water resources, including managing the growing risks to our water supply, water quality, healthy stream flows, agriculture, and ecosystems. These products and services are needed to design roads, dams, and waterway systems; manage flood plains; plan and conduct emergency management operations when flooding threatens; and ensure the safety and preparedness of activities ranging from recreation to aviation, construction, and surface transportation system use and management.

The purposes of this article are to: (a) explain what hydrometeorological products and services are and why they and the research that supports them are important; (b) highlight the hydrometeorological products and services available and the collaborating agencies responsible for the collection, maintenance, and operation of the meteorological and hydrological data collection network; and (c) engage the users of this information to ensure we understand their needs. Even though the Federal government is committed to improving the quality and accuracy of hydrometeorology warnings that the public receives, the Federal agencies implementing this commitment will have to work with many public and private organizations to expand existing capabilities and to develop new and innovative ways to further improve public safety.

THE VALUE OF HYDROMETEOROLOGY

The natural processes studied by hydrometeorology influence our economic and social lives in many ways. These processes and the "weather events" that result from them affect the revenues and profits of businesses, large and small. They can disrupt and disorganize communities. As our Nation's population grows and infrastructure costs increase, natural disasters stemming from precipitation patterns can undermine social and economic infrastructures at local and even regional levels.

Our ecosystems are subject to many pressures (e.g., land-use change, resource demands, and population changes); their extent and pattern of distribution is changing; and landscapes are becoming more fragmented. Climate change constitutes an additional factor reflected in hydrometeorological processes - a factor that could change ecosystems and endanger the many benefits they provide to populations and economic activities that depend on them.

Water quality is a critical environmental factor, partly due to the tremendous growth of the Nation's demand for clean water in the context of continuing urban expansion and development. Hydrometeorological processes affect the water resources of the Earth, which makes those processes of interest to both the meteorologist and the hydrologist. Measurements of rainfall, stream flow, and water loss as a result of evaporation-all of which are observations used by hydrometeorologists to issue precipitation rates, stream flow, flood predictions, and drought outlooks-are essential for various applications in connection with water resources planning, drainage design, water quality control, reservoir design and operation, and flood control.

The single hydrometeorological event that has resulted in the largest loss of life is storm surge: rapid rises of sea water and flooding associated with landfalling hurricanes. Storm-surge height can exceed 20 ft (6 m) when strong hurricanes strike a coastline with shallow water offshore. In recent decades, large losses of life due to storm surge have become less frequent. However, the rapid growth of U. S. coastal populations and related infrastructure and the increasing complexity of evacuation have increased the vulnerability of coastal communities. Improved building codes in hurricane-

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prone regions have greatly reduced fatalities from wind damage, but many fatalities continue to result from tropical cyclone-induced inland flooding. To provide reliable scientific information, the hydrometeorologist measures tide levels, wind direction and speed, barometric pressure, and rainfall rates to describe and forecast inland flooding events.

Figure 1-1. Landslide in La Conchita, California, 2005. (USGS photo)

Landslides (debris flows and debris avalanches) triggered by heavy rain occur in all 50 states and are widespread in the U.S. island territories of Puerto Rico and the U.S. Virgin Islands (Figure 1-1). In the conterminous United States, the areas most seriously affected are the Pacific Coast, the Rocky Mountains, and the Appalachian Mountains. Areas where wildfires or human modification of the land have destroyed vegetation on slopes are particularly vulnerable to landslides and debris flow during and after heavy rains. Flash flood-producing rains falling on steep terrain can weaken soil and trigger catastrophic mud slides that damage homes, roads, and property. Monitoring landslide-producing conditions typically requires extensive networks of ground-based rain gauges and hydrometeorological instruments.

Soil moisture has many possible applications in hydrometeorology, but the primary areas are in runoff and evaporation modeling. Moist ground can have an effect similar to open water in that it can easily absorb solar radiation, with some of the absorbed energy taken up in evaporating water. As a result, neither the ground nor the air above it heats up as much as it would if the ground were dry. However, the evaporated water now becomes part of the atmospheric water content that can feed into subsequent hydrometeorological processes. Runoff and evaporation modeling simulates water infiltration and movement in soils, evaluating precipitation and runoff, drainage, evaporation from the soil surface, and transpiration by vegetation.

Flash floods occur very quickly after the precipitation event that causes them (Figure 1-2). Flash-flood damage and most fatalities tend to occur in areas immediately adjacent to a stream or arroyo. Flash floods are very strong - they can roll boulders, tear out trees, destroy buildings and bridges, and scour out new channels. Rapidly rising water can reach heights of 30 feet or more.

Excessive rainfall that causes rivers and streams to swell rapidly and overflow their banks is frequently associated with hurricanes and tropical storms, large clusters of thunderstorms, supercells, or squall lines. Other types of flash floods can occur from dam or levee failures, or a sudden release of water held by an ice jam (Figure 1-3). Heavy rainfall in the mountains can cause downstream canyon flooding. A deep snowpack increases runoff produced by melting snow. Heavy spring rains falling on melting snowpack can produce disastrous flash flooding. Densely populated areas, in particular, are at a high risk for flash floods. The construction of buildings, highways, driveways, and parking lots increases runoff by reducing the amount of rain absorbed by the ground, increasing the flash-flood potential. *Flash Flood Guidance* is used to predict the occurrence of flash flooding in a specific area based on specified rainfall amounts within a given duration of time. *Flash Flood Warnings* are issued as needed and focus on specific communities, streams, or areas where flooding is imminent or already in progress.

Some examples of hydrometeorolog-

Figure 1-2. Flash flood in Las Vegas, NV, August 19, 2003. (Photo courtesy of Las Vegas Review Journal.)

Figure 1-3. Ice jam around Big Island in Richford, Vermont, March 15, 2007. (Photo courtesy of Richard Heurtley, http://www.richfordvt.net/icejam/index.html)

ical products and services that provide a vital foundation for numerous applications and users, including transportation, agriculture, water supply and flood control, are flood watches and warnings, drought outlook, water supply outlook, ice forecasts, and quantitative precipitation forecasts (QPF). Federal, state, and local agencies are working together to improve these products and services which help mitigate the socioeconomic impacts of hydrometeorological events. Understanding the importance of these products and services requires understanding of how the information is created, communicated, and used. The different perspectives of the hydrometeorological community and its stakeholders, regarding the use of these products and services, are a key consideration as well.

COLLABORATORS AND PARTNERS

Many Federal, state, and local agencies collaborate (in many ways) in providing accurate and updated information to produce these hydrometeorological products and services while avoiding duplication of efforts.

Collaboration enables the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), an agency under the U.S. Department of Commerce, to fulfill its mission objectives of providing forecasts and warnings for the protection of life and property and of enhancing the national economy. The NWS data and products form a national information database and infrastructure that can be used by other governmental agencies, the private sector, the public, and the global community.

The United States Geological Survey (USGS) is an agency within the Department of the Interior. The USGS Water Resources Division collects and publishes stream flow data. It also provides other hydrologic information to enable better use and management of water resources. The USGS owns and maintains many of the river gages that provide the data needed for the NWS to accomplish its mission. The NWS often installs telemetry devices on USGS river gages to access data remotely which is then shared by the two agencies.

The United States Bureau of Reclamation (USBR) in the Department of the Interior primarily operates dams, power plants, and canals in the 17 western states of the country. The Bureau's mission is to assist in meeting the increasing demand for water in the West while protecting the environment and public investment. The USBR provides the NWS with rainfall and river data along with information about daily outflow from reservoirs. It uses NWS river forecasts and water supply forecasts in operating dams and plants.

The United States Army Corps of Engineers (USACE) provides engineering, management, and technical services to the Department of Defense and other Federal agencies. It is engaged in planning, designing, and operating water control structures (river and harbor navigation, flood control, water supply, hydroelectric power, etc.), and other civil works projects (environmental restoration, wildlife protection, recreation, disaster response, etc.). The USACE provides the NWS with current and forecast reservoir outflows. The NWS also exchanges river stage and precipitation data with the USACE.

The Natural Resources Conservation Service (NRCS), a Federal agency within the U.S. Department of Agriculture, works with local, state, and Federal agencies and with private groups to conserve, improve, and sustain natural resources and the environment. The NWS and the NRCS share and coordinate water-supply forecasting responsibility. The NWS provides hydrometeorological and snow cover data and receives data from the SNOTEL network operated by the NRCS. This network, consisting of 732 automated and 935 manual stations, provides valuable snow depth, snow-water equivalent, and temperature data for high-elevation sites. Many of these remote stations are inaccessible during winter time, but are essential to forecasting snow-melt runoff, which is the largest contributor to river flows in the western United States.

The National Park Service (NPS) of the U.S. Department of the Interior is entrusted to preserve the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations. The NPS cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout the Nation. The park system consists of 378 areas covering more than 83 million acres in 49 states. Many national parks are part of the Cooperative Observer Network. Cooperative Observer data includes 24-hour precipitation totals, snowfall, soil temperature, evaporation and other parameters important for hydrometeorological products and services. There are many gages located in the parks, and these data are exchanged with the NWS. The NPS use hydrometeorological forecasts for park safety and planning.

The mission of the Bureau of Indian Affairs (BIA) is to enhance the quality of life, to promote economic opportunity, and to carry out the responsibility to protect and improve the trust assets of American Indians, Indian tribes, and Alaska natives. BIA is part of the Department of the Interior. Native American lands are spread across the United States. Cooperation with various tribes is important when dealing with hydrometeorological issues such as flooding, rainfall, and water quality in areas under tribal jurisdiction. Often special consideration will be required to obtain data and disseminate hydrometeorological forecasts or products for these areas.

The Tennessee Valley Authority (TVA) operates the Tennessee River system to provide a wide range of public benefits that depend on accurate and timely hydrometeorological products and services. Among these benefits are year-round navigation, flood damage reduction, affordable electricity, improved water quality and water supply, recreation, and economic growth. TVA operates the dams, locks, and reservoirs of the Tennessee River and its tributaries as one integrated system in order to provide these multiple benefits to the region.

The Joint Agricultural Weather Facility (JAWF), which was created in 1978, is a cooperative effort between U.S. Department of Agriculture (USDA) World Agricultural Outlook Board and NOAA to collect, on an ongoing basis, global hydrometeorological data and agricultural information to determine the impact of atmospheric conditions on crop and livestock production. JAWF reports are followed closely not only by producers, but also by commodity traders.

The International Boundary & Water Commission (IBWC), established by a 1944 Treaty, is responsible for the distribution, regulation, and conservation of the Rio Grande between Mexico and the United States. As a bi-national commission, the commission is also responsible for the joint construction, maintenance, and operations of international storage dams, reservoirs, and hydroelectric plants on the Rio Grande. In addition, the IBWC uses hydrometeorological products and services to regulate the water allocated to Mexico from the Colorado River, protect the lands surrounded by the two rivers by maintaining river and levee projects, and strive to preserve the international boundary between the two countries in a sensitive, timely, and fiscally responsible manner.

The hydrometeorology community's strengths are derived from strong collaborative ties among its programs and with its partners and customers. By working together, the members of this community can reach more people more effectively and achieve the core results of their collective missions: *to save lives and protect property*.

HYDROMETEOROLOGICAL OBSERVATIONS

The NWS owns and operates important components of the Nation's environmental observing capability-radars, data buoys, upper air observing systems, surface observing systems, data collection and distribution systems - which provide real-time hydrometeorological data and contribute to the Nation's climate record. The NWS approach to observing systems explicitly recognizes the multiparty, multidisciplinary, multiplatform, and multipurpose nature of environmental observations and seeks to maximize the effectiveness of all participants through the Global Earth Observing System of Systems (GEOSS). GEOSS will help all involved produce and manage their hydrometeorological information in a way that benefits the environment as well as humanity by taking a pulse of the planet.

Historical stream flow data are essential for the NWS River Forecast Centers (RFC) to calibrate the rainfall-runoff models in the National Weather Service River Forecast System (NWSRFS). Output from NWSRFS is the basis for NWS river forecasts and flood warnings. A long-term historical record that includes extreme wet and dry periods allows forecasters to define rate-dependent watershed parameters that govern the watershed response to the full range of possible hydrologic conditions. Hydrometeorological monitoring, communications, and computer technology used in stream flow forecast systems have advanced rapidly over the last few years. For operational forecasting, real-time stream flow data allows river forecasters to adjust model states or the projected hydrographs to match observed flows. Projected hydrographs at headwater points are routed downstream along with reservoir releases and intervening local flows. The routed flows must be converted to a stage at each forecast point. Stage-discharge relationships developed and maintained by the USGS and other partners are based on periodic on-site stream flow measurements and are essential to NWS hydrologic forecast and warning operations.

Figure 1-4. Stream gage at the Suwannee River above the Gopher River near Suwannee, Florida (7.6 miles upstream from the mouth of the Suwannee) (USGS photo)

The USGS operates and maintains a nationwide streamgaging network of about 7,000 gages (Figure 1-4). These gages help produce accurate and timely identification of floods and flash floods and their impacts on the ecosystem. The network is supported by funding through the USGS' Cooperative Water Program, the USGS National Streamflow Information Program, other Federal water and environmental agencies, and approximately 800 state and local funding partners. Data from this network are used by a large number of public and private users, including government agencies responsible for water management and emergency response, utilities, environmental agencies, universities, colleges, consulting firms, and recreational interests. Likewise, these users access the data for a wide variety of uses, including decision making related to water supply, hydropower, flood control, forecasting floods and droughts, water quality, environmental and watershed management, research, navigation, fishing, and water-based recreation.

Flood mapping studies are extremely important since the Federal Emergency Management Agency (FEMA) uses floodplain maps to establish flood risk zones and require flood insurance, through the National Flood Insurance Program (NFIP), for properties within the 100-year floodplain. Many areas subject to development in the near future are unmapped or have outdated maps. Preventing new development in floodplains, which reduces future flood damage, is the cornerstone of floodplain management.

The Global Precipitation Measurement (GPM) mission (Figure 1-5) is one of the next generations of satellite-based Earth science missions that will study global precipitation (rain, snow, and ice). The Tropical Rainfall Measuring Mission (TRMM) was the first satellite dedicated to rainfall measurement and is the only satellite that carries a weather radar. GPM can improve climate prediction through better understanding of surface water fluxes, soil moisture storage, cloud/precipitation microphysics, and latent heat release in the Earth's atmosphere. It will advance precipitation measurement capability from space through combined use of active and passive remote-sensing techniques. These measurements will be used to calibrate dedicated and operational passive microwave sensors with the goal of achieving global sampling. GPM will advance numerical weather prediction (NWP) skills through more accurate and frequent measurements of instantaneous rain rates with better error characterizations and improved assimilation methods. It will advance knowledge about the global water/energy cycle and fresh water availability. Improved measurements of the space-time variability of global precipitation will close the water/energy budget and elucidate the interactions between precipitation and other climate parameters. GPM will improve flood-hazard and fresh-water-resource prediction capabilities through better temporal sampling and spatial coverage of high-resolution

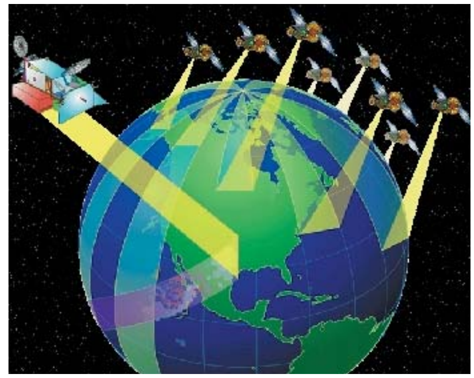


Figure 1-5. GPM is a cooperative mission between NASA, the National Space Development Agency (NASDA) of Japan, and other international partners. Building on the success of the Tropical Rainfall Measuring Mission (TRMM), GPM, via a constellation of small satellites, will continue measurement of global precipitation, a key climate factor. (NASA Goddard Earth Sciences Data and Information Services Center web site)

precipitation measurements and innovative designs in hydrometeorological modeling.

HYDROMETEOROLOGICAL MODELS AND PREDICTIONS

The National Weather Service River Forecast System (NWSRFS), designed for use in an operational environment, provides stream flow forecasts under a variety of hydrometeorological conditions in river basins, ranging from small systems to large and complex basins. The NWSRFS is used operationally at all thirteen NWS RFCs in the United States and has been implemented in many countries. Some of these implementations consist of more than a thousand data collection stations and hundreds of forecast points. Providing both deterministic and probabilistic forecast capabilities for short-term and long-term forecasting, the NWSRFS offers flexibility in the hydrologic and hydraulic models that can be used to model a basin.

Predicting the precise location, severity, and timing of flash-flooding events from predictions of precipitation or direct observation of rainfall rates is a key goal of hydrometeorology. The Flash Flood Monitoring and Prediction (FFMP) system is an integrated suite of multi-sensor applications which detects, analyzes, and monitors precipitation and generates short-term warning guidance for flash flooding automatically within Advanced Weather Interactive Information Processing System (AWIPS). FFMP will provide forecasters with accurate, timely, and consistent guidance and will supplement forecaster event monitoring with multi-sensor, automated event monitoring. The intended benefits are: longer lead times on warned events, fewer missed events, increased forecaster situational awareness, and reduced forecaster fatigue during warning situations. FFMP is a collaborative effort involving the NWS, the National Severe Storms Laboratory (NSSL), and the National Center for Atmospheric Research (NCAR). The focus of FFMP is on improving the accuracy and timeliness of warnings (severe thunderstorm, tornado, flash flood, etc) issued by NWS forecasters, through the development of automated warning guidance.

The Hydrometeorology Testbed (HMT) is a concept aimed at accelerating the infusion of new technologies, models, and scientific results from the research community into daily NWS and RFC hydrometeorological forecasting operations. Unlike typical research field projects, the HMT will operate as a demonstration with forecasters and researchers joining forces in an operational setting. An HMT plan now being formulated, under the auspices of NOAA's Weather and Water mission goal, targets California's flood-vulnerable American River Basin for the first full-scale deployment of this highly instrumented facility, (starting in the second half of this decade). Following the California demonstration, HMT facilities will be sequentially deployed to other regions of the Nation to address additional serious hydrometeorology problems that are unique to those locations. Hydrometeorological products and services are improving predictions of California's heavy winter rains, monitoring air, water and soil; to help water resource managers prevent catastrophic flooding in the Sacramento region.

INFORMATION DISSEMINATION

Hydrometeorological products, such as Quantitative Precipitation Forecasts (QPF), heavy snow forecast, soil moisture, and snow-water equivalent just to name a few, reach a broad spectrum of customers, including emergency and water resource managers. Emergency managers use this information for both strategic, long-term planning and tactical, short-term planning. RFCs also provide river forecasts to water resource managers, who make critical decisions that affect flood control, water supply, water quality, river and lake transportation, irrigation, hydropower, and recreation, as well as maintain the ecological health of the rivers.

The NWS' Advanced Hydrologic Prediction Services (AHPS) suite is a new and essential component of climate, water, and weather services. AHPS is a web-based suite of accurate and information-rich forecast products. They display the magnitude and uncertainty of occurrence of floods or droughts from hours, to days and months in advance. These new products will enable government agencies, private institutions, and individuals to make more informed decisions about risk-based policies and actions to mitigate the dangers posed by floods and droughts. AHPS provides better hydrometeorological information to water managers and city officials, helping them make water-allocation and economic-related decisions, such as when and where to evacuate, how to use reservoir storage capacity and releases, and when to reinforce levees and to what level.

The Hydrometeorological Automated Data System (HADS), is a real-time data acquisition and data distribution system operated by the NWS Office of Hydrologic Development. HADS exists in support of NWS activities of national scope, specifically the Flood and Flash Flood Warning programs administered by the weather service forecast offices and the operations performed at RFCs throughout the United States. The hydrometeorological data acquisition aspect of HADS involves the receipt of raw hydrological and meteorological observation messages from Geostationary Operational Environmental Satellites (GOES) Data Collection Platforms (DCPs). Raw DCP messages are received in a nearly continuous flow from Wallops Island. Every 3 minutes (beginning on the hour) the HADS processor program translates raw information into Standard Hydrometeorological Exchange Format (SHEF) products.

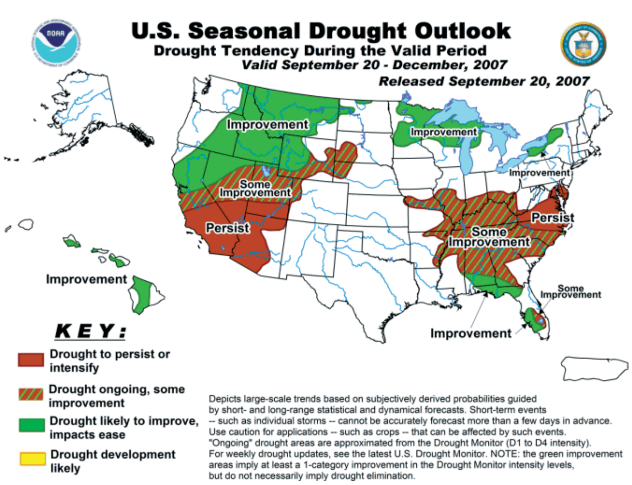
ALERT (Automated Local Evaluation in Real-Time) and IFLOWS (Integrated Flood Observing and Warning System) are automated flood warning systems which provide real-time precipitation data in many parts of the country. Basically, both systems use line-of-sight radio communications to transmit data via networks of transmitters, repeaters, and base stations. Both ALERT and IFLOWS use tipping-bucket gages which measure rainfall in 1 mm (about 0.04 inch) increments. The higher capacity tipping bucket performs better during heavy rainfall events than smaller mechanisms. The purpose of these systems are to reduce the annual loss of life from flash floods, reduce property damage, and reduce disruption of commerce and human activities.

The National Integrated Drought Information System (NIDIS) is a Drought Early Warning System. The system provides water users across the board - farmers, ranchers, utilities, tribes, land managers, business owners, recreationalists, wildlife managers, and decision-makers at all levels of government - with the ability to assess their drought risk in real time and before the onset of drought, in order to make informed decisions that may mitigate a drought's impacts. Recognition of droughts in a timely manner is dependent on our ability to monitor and forecast the diverse physical indicators of drought, as well as the relevant economic, social, and environmental impacts. NIDIS will coordinate and integrate a variety of observations, analysis techniques and forecasting methods in a system that supports drought assessment and decision-making at the lowest geopolitical level possible. The tools allow users to access, transform and display basic data and forecasts across a range of spatial and temporal scales most suited to their individual needs.

IMPROVING HYDROMETEOROLOGY: CURRENT AND PLANNED RESEARCH

The National Oceanic and Atmospheric Administration's National Severe Storms Laboratory (NSSL) continues to be a pioneer in the area of research and development. NSSL research serves society's needs for weather and water information by developing methods to monitor and predict floods and flash floods. For many years, the lab has researched the use of dual polarization radar to improve precipitation measurements. The more precise measurements of the spatial distribution of precipitation rates made possible by this technique will help forecasters provide more accurate and timely warnings for flash floods--the number one severe weather threat to human life. NSSL researchers are also adapting phased array radar, a state-of-the-art radar technology used by the military, to perform multiple observing tasks simultaneously and to detect the types of severe weather of interest to hydrometeorologist. For example, a phased array radar can do a full-volume scan in less than one minute, compared with 4-5 minutes for the current generation of weather radars. At the same time, this new radar can focus in on local storm conditions that may produce the heavy precipitation likely to cause a flash flood or landslide in a small part of the radar's search area. The next-generation quantitative precipitation estimates (QPE) (Q2) continues NSSL's departure from radar-centric precipitation estimation and moves toward a multi-sensor approach focused on high-resolution integration of radar, satellite, model, and surface observations to produce very high-resolution precipitation estimates. NSSL manages and maintains a national flash-flood-scale hydrologic geographic information system (GIS) dataset in support of the NWS AWIPS Flash Flood Monitoring and Prediction (FFMP) system for assisting forecasters in flash-flood warning decisions.

In support of the mission of the U.S. Geological Survey (USGS), its National Research Program (NRP) conducts basic and problem-oriented hydrologic research. The program has grown to encompass a broad spectrum of scientific investigations. The sciences of hydrology, mathematics, chemistry, physics, ecology, biology, geology, and engineering are used to gain a fundamental understanding of the processes that affect the availability, movement, and quality of the Nation's water resources. The NRP encompasses a broad spectrum of scientific investigations and focuses on long-term integrated studies related to water resource and environmental problems. The NRP provides an infrastructure within which the USGS can develop new information, theories, and techniques to understand, anticipate, and solve water-resource problems, facing managers of Federal lands and the Nation.



The Coastal and Inland Flooding Observation and Warning (CI-FLOW) Project consortium is focused on the Tar-Pamlico River Basin in North Carolina. CI-FLOW is working with North Carolina State University (NCSU) to couple its existing estuary model, a watershed water quality model, and an estuary water quality model to the NSSL multi-sensor precipitation estimation system and the NWS distributed hydrologic model. The resulting CI-FLOW demonstration program will facilitate the evaluation and testing of new technologies and techniques to produce accurate and timely identification of coastal, estuary and inland floods; flash floods; and their impacts on coastal ecosystems.

NOAA's Community Hydrologic Prediction System (CHPS) will enable NOAA's water research and development enterprise and operational service delivery infrastructure to be integrated and leveraged with other Federal water agency activities, academia, and the private sector. CHPS provides a new business model in which members of the hydrometeorological community operate more collaboratively through the sharing and infusion of advances in science and new data, without each member having to build or take ownership of the entire system.

EDUCATION AND OUTREACH

Hydrometeorological training at the University Corporation for Atmospheric Research (UCAR) Cooperative Program for Operational Meteorology, Education and Training (COMET®) covers a wide range of topics related to precipitation, atmospheric moisture, and watershed processes. COMET's mission is to serve as a premier resource that supports, enhances, and stimulates the communication and application of scientific knowledge of the atmospheric and related sciences for the operational and educational communities. The working professional in hydrometeorology can enter at a very basic level to learn about the hydrologic cycle and the rainfall runoff process. More advanced topics include hydrologic models, stream flow routing, flash flood processes, unit hydrograph theory, and more specialized topics, such as snow hydrology and river ice. To assist the learner in moving through the material in a logical and effective order, case scenarios are used to tie the various topics together. Case scenarios are structured around real events for long-term floods, short-term flash floods, warm and cool season concerns, and impacts in both urban and non-urban watersheds.

There is an opportunity to strengthen the connection between the weather enterprise and the larger science community through scientific education and outreach programs. To encourage the type of interdisciplinary interaction necessary for successful large-scale experiments, scientists entering into hydrometeorology from the universities and other institutions must grasp the complexity of the issues linked with regional water and energy cycles. Little of this knowledge is disseminated through traditional work/study approaches.

Public education and outreach programs can also play a role in strengthening the links between the providers and users of weather and hydrologic services so that individuals, communities, and organizations can make effective use of the available products and services. Education and outreach activities must be undertaken together with partners, such as educational institutions, emergency management agencies, and the media (Figure 1-6). An informed and educated public will have a better appreciation for the information provided as science and technology advance, and they will be better equipped to make decisions related to their life needs. A broad range of people use hydrometeorological products and services, and education and outreach programs must be carefully tailored to meet the needs of these various groups.

It's easy to underestimate the depth and force of floodwaters, especially at night and in unfamiliar areas.

Floodwaters often conceal damage to the roadbed.

Figure 1-6. NOAA weather hazard public awareness education on the web. Would you stop, or go on through this flooded roadway? **Turn Around...Don't Drown!** (NOAA web site)

SUMMARY

Integrated, improved, and an increased number of observations are key to improving our understanding, analysis, and prediction of the Earth's environment - from space to the atmosphere to water. Gaps in the observing architecture must be addressed to ensure continuity of observations and establish cost-effective approaches to establishing a truly integrated observing capability-the key to improving our hydrometeorological forecasting capability.

Clearly, the public is best served when the governmental, academic, and private sectors work together to take advantage of their different capabilities and to avoid duplication of effort. Together, the participating entities in all three sectors can reach more people, more effectively, and achieve the core results of our collective missions: to save lives and protect property. Internal and external partnerships allow these sectors to leverage resources to get the job done.

Public education is vital in preparing citizens to respond properly to hydrometeorological threats. Only an educated public will know how to respond to hydrometeorological warnings, how to recognize potentially threatening situations, and how to act appropriately. Through improved outreach and communications, the partners in providing hydrometeorological products and services can improve awareness and delivery of these services and develop products designed to best serve the needs of all users.

To that end, the OFCM plans to conduct, in coordination with the OFCM-sponsored Committee for Environmental Services, Operations, and Research Needs, a crosscut assessment of hydrometeorological products, services, and supporting research across the Federal meteorological community. While the approach focuses on the roles and contributions of Federal entities, effective coordination also requires attention to the roles of state and local governments, the private sector, the academic community, and public-private partnerships. The assessment, which will consider the end-to-end system from observations to modeling and data assimilation for analysis and prediction, to end-user education, has the following objectives:

- Define the needs and requirements for hydrometeorological products, services, and supporting research for the Federal agencies and the customers they support.
- Investigate agency plans and alternatives for satisfying new requirements.
- Create more efficient and effective partnerships among the agencies to better leverage subject-matter expertise and resources to meet the growing needs for better hydrometeorological products and services.

Decision makers need to receive hydrometeorological-related information any time, without delay. To better support stakeholders and decision makers, we must have a well-developed information system, allowing free exchange of data among the various agencies and avoiding duplication in data collection. We must increase the Nation's environmental observing capability and undertake joint activities with operational hydrometeorological services. We must collaborate at all levels (Federal, state, and local) and produce research of consistently high quality. Finally, we need to improve our products and services to help clarify the uncertainty of events such as floods and flash floods, resulting in short-term forecast and warning improvements and improved public response to the decisions of the emergency management and water resource communities.

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