J5.3 NATIONAL WEATHER SERVICE HYDROLOGIC SCIENCE AND DEVELOPMENT: COUPLING THE ATMOSPHERE TO THE OCEANS

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1. INTRODUCTION

A water molecule gently rises and falls with the ocean's movements. It has circulated with like molecules and with the chloride ions and other constituents of this salt water environment. The sun warms, the waves break, and the water molecule rises into the atmosphere as water vapor. So continues the hydrologic cycle. This cycle moves water in its various phases from the oceans to the atmosphere to the land and rivers, and back to the sea.

As the water molecule moves more freely in the atmosphere, it travels with the air currents, and rises and falls with the heating and cooling of air particles through which it passes. This molecule meets other water molecules which coalesce on dust and pollen particles to form water droplets. These droplets combine to form clouds.

Conceptually, this journey is tracked by monitoring water movement and the storage throughout the system. The motion and resting places of the water molecule are modeled. A complicating factor is the wide range of time and space scales over which these hydrologic processes occur. At the minute by minute and meter by meter level, water percolates into the soil mantle. At scales of months and tens of kilometers, snow packs accumulate and melt, and water moves through the groundwater aquifers.

2. RIVER FORECAST SYSTEM

From the time the water molecule forms clouds until it returns to the oceans, scientists model the physics of motion and phase changes that occur as water moves through this portion of the hydrologic cycle (Figure 1). Science and development activities within the National Weather Service (NWS) Office of Hydrologic Development (OHD) span the wide range of forces which affect water through the transition from airborne water droplets, to its fall to the land as snow or rain, to its passage through the soil mantle and down minor streams and major rivers as well as lakes and reservoirs on its path to the sea.

These processes are modeled by the NWS River Forecast System (NWSRFS). The NWSRFS includes a wide range of techniques which account for myriad transitions water experiences in this part of the hydrologic

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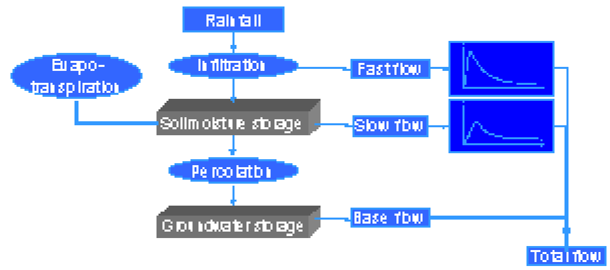

Figure 1. Conceptual Catchment Representation.

cycle, such as: multi-sensor precipitation estimation; snow accumulation, ablation, and melt; passage over and through the soil mantle; and streamflow through rivers, lakes, and reservoirs. One of the key components of NWSRFS is a model of soil moisture accounting. This accounting considers the movement of water through the soil as a series of conceptual reservoirs which represent the water retained in near surface, intermediate, and deep layers of the soil. Movement of water among these reservoirs mimics percolation, evaporation, withdrawal of water by plant roots, and the passage of water on and within the ground into nearby streams (Figure 2). The

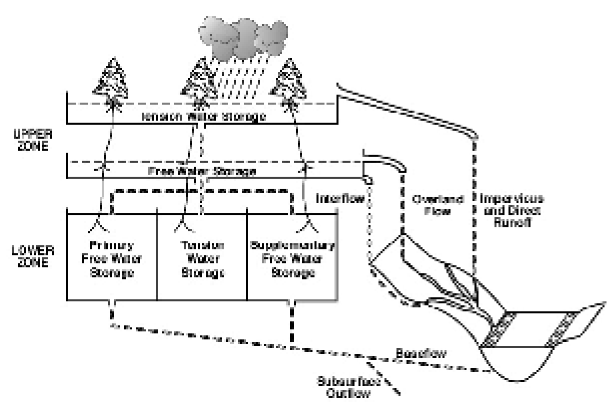

Figure 2. Soil Moisture Model Schematic.

conceptual soil moisture accounting model can be applied to a wide range of climatic conditions by adjusting the capacity of the conceptual reservoirs and modifying the rate of water movement among the reservoirs. This process of model calibration is done by using historical observed data of model inputs (precipitation, temperature, evaporation) and outputs (streamflow) to tune the reservoir sizes and flow rates. The calibration process ensures the model simulated output most closely matches observed streamflow. The NWSRFS soil moisture accounting model has successfully been applied throughout the wide variability of climate regimes across the United States and around the world.

NWS Hydrologic Services are delivered at locations along the Nation's rivers. The U.S. is served by 13 River Forecast Centers (RFC), each of which is responsible for a major hydrologic drainage area. Within each RFC's area of responsibility, river basins are defined and the soil moisture accounting model is calibrated. Forecasts of stream conditions can then be generated for locations of interest to the public, and for use by water and emergency managers.

A system is no better than the data which drive it, and the NWSRFS is fortunate to have the vast array of NOAA's observational systems to provide accurate and consistent inputs. Satellite, radar, and rain gauge measurements are combined to produce a multi-sensor precipitation estimate. The NWS cooperative weather observing system provides temperature, snow cover, and streamflow information, and the NWS National Centers for Environmental Prediction provide short- and long-term climatic forecasts. These data allow the NWSRFS to produce accurate and reliable forecasts of our Nation's rivers from several hours to several months into the future.

3. WATER PREDICTIONS FOR LIFE DECISIONS

Producing river forecasts is not the only goal of the NWS Hydrologic Services Program. These forecasts must be turned into useful information, which can be interpreted and applied by the public, and water and emergency managers to make decisions affecting their lives, property, and businesses. One form of useful information the NWS produces is River Forecast Inundation Maps. These map displays (Figure 3), available for selected areas in the U.S., show river forecast conditions on geophysical features and a photo background so NWS

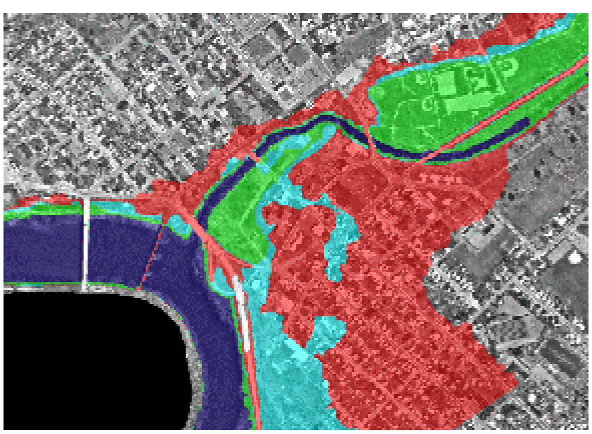

Figure 3. Sample Flood Forecast Inundation Map.

customers can determine how future river conditions will affect their lives and property. River forecast inundation maps are being Implemented as a part of the NWS Advanced Hydrologic Prediction Service (AHPS). Initial AHPS capabilities should be available throughout the U.S. during the next few years.

Since forecasts are never certain, another component of AHPS capabilities being developed by the OHD is the specification of confidence for any forecast river value (Figure 4). The degree of certainty will change over time, with river conditions, and with the length of a forecast. Confidence is typically higher for forecasts of the near future than of the far, and for low flow/dry weather conditions than of high flow forecasts. The level of certainty or confidence a customer should put in a forecast will affect their response. The more the user of an NWS river forecast knows, the more enlightened decisions affecting their lives and property can be.

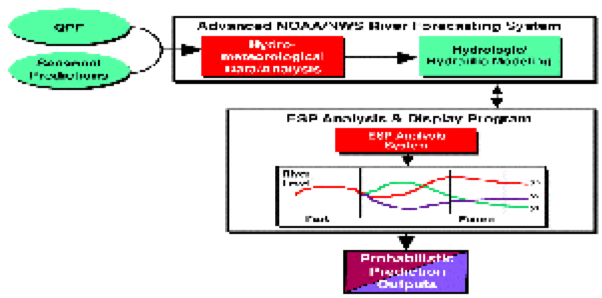

Figure 4. Ensemble Streamflow Forecasting.

4. HIGHER RESOLUTION MODELS

Another enhancement to NWS river services is being developed to produce forecasts at many locations within a river basin, not just at the basin outlet (Figure 5). Models which account for the movement of water throughout the basin, or distributed models, allow NWS customers who live away from the river outlet location to have information for their local, internal basin, location. Distributed models can also produce additional information, such as soil moisture conditions, throughout a river basin. This can allow resource management decisions to be adjusted based on finer spatial resolution, maximizing the benefits of distributed NWS river forecasts.

A project designed to bring the best scientific researchers together to assess performance of distributed hydrologic models is the Distributed Model Intercomparison Project (DMIP), sponsored by the NWS OHD. A broad spectrum

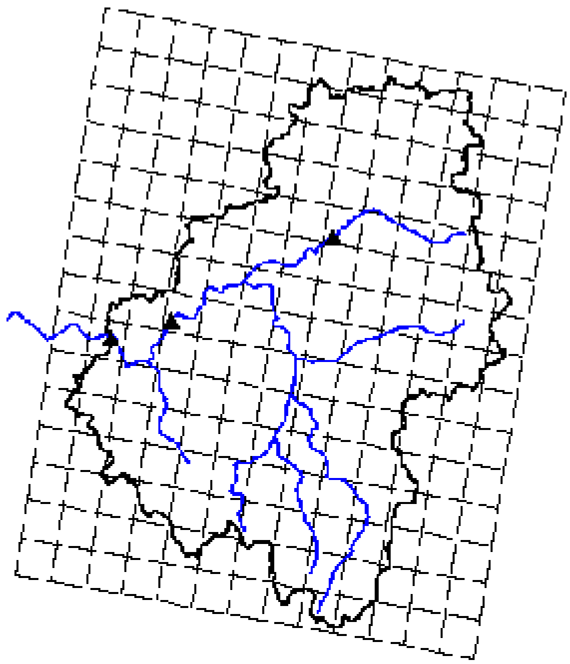

Figure 5. High Resolution Hydrologic Modeling.

of Governmental, private sector, and university researchers applied their models to several river basins by using NWS data. A recent workshop where participants presented and discussed their results showed that distributed models produced accurate streamflow predictions for specific basins and events and predicted hydrographs at interior basin locations. The DMIP project also has demonstrated a new approach to infuse science from the research community into NWS operations.

5. EPILOGUE

From the time it leaves the sea until it returns again, NWS freshwater research is coupling other core NOAA components to predict the movement of water from the atmosphere to the oceans. A water molecule is well tracked by precipitation, snow, soil, distributed, and river models all developed and continually improved by the NWS Hydrology Program. It's future location, and the degree of certainty a user should have in that forecast, can be displayed graphically and mapped to provide valuable, understandable information for NWS customers to make decisions concerning their safety and property.