NCAR Hydrometeorology Prediction System

Description
The NCAR Hydrometeorology Prediction System is a real-time system designed to advance the prediction of heavy rainfall, flash floods and streamflow prediction through the integration of state-of-the-art rainfall estimation, precipitation forecasting, and hydrology modeling techniques into one seamless system. This system provides 0-12 hour forecasts and 0-1 hour nowcasts of rainfall accumulations on very high resolution spatial grids (from 100 m to 3 km in resolution) and identifies location-specific regions of heavy rainfall and potential flash floods. The Hydrometeorology Prediction System was run in real time from 7 July - 31 August 2014 to test its predictive skill along the Colorado Front Range and to advance short term prediction of high-impact weather.

The fully-integrated components of this prediction system are described below.

Quantitative Precipitation Estimation
Timely and accurate Quantitative Precipitation Estimates (QPE) are essential for forecasting streamflow, flash floods and localized urban flooding. Radar and rain gauge based QPE are being used in this prediction system for determining: "How hard it is raining? How much rain has fallen in the intermediate past?" Quality-controlled QPE fields, produced from dual-polarization radar data, are being used in this prediction system as input for precipitation nowcasts (QPN), as input into the hydrology model (WRF-Hydro), for evaluation of radar-based QPE compared to rain gauge measurements of precipitation, and for verification of precipitation forecasts (QPF).

The impact of the Colorado flood of 2013 is one of the motivations for developing this integrated prediction system.

Quantitative Precipitation Forecast
Quantitative Precipitation Forecast (QPF) is a critical input for hydrological models in order to produce accurate streamflow prediction. Current operational NWP weather models are useful in providing guidance for precipitation forecast, but not adequate in providing QPF with timing and location precision that is required by the hydrological models. One of the key aspects in improving the accuracy of short-term QPF is to initialize the NWP models with high density and high frequency data. At NCAR, data assimilation systems have been developed that have the capability to assimilate conventional data as well as radar observations. The WRFDA 3DVar, a 3-dimensional, variational data assimilation system assimilating conventional observations and radar radial velocity and reflectivity with 1-3 hourly rapid update cycles, is being run this summer in the NCAR Hydrometeorology Prediction System. Additional state-of-the-art NWP models are also being run and tested in real-time.

Quantitative Precipitation Nowcast
The skill of Quantitative Precipitation Nowcasting (QPN) decreases very rapidly in the first hour using basic storm extrapolation techniques. In addition, NWP techniques have insufficient skill to provide suitable, accurate warnings of heavy precipitation on the scale needed for flash flood forecasting. Thus, a heuristic nowcast system called Autonowcaster/Trident (ANC), that blends observations with numerical model analyses, is used to improve upon simple precipitation extrapolation techniques. This is a unique state-of-the-art real-time system that provides explicit prediction of precipitation and warnings of heavy rainfall. The ANC system automatically assesses the instability of the atmospheric using numerical model analyses and combines this information with observational data sets (radar,
satellite, surface stations, soundings, and high-resolution 4-D boundary layer winds from FINECAST) to predict the location and timing of new storm initiation, storm growth and dissipation. This system provides 0-1 hour precipitation accumulation nowcasts and warning products, updated every minute, with a spatial resolution of 1 km.

**FINECAST**
Rapidly updated, high resolution meteorological analysis is one of the key requirements for improvement of forecasting various hazardous weather events. The Fine-Scale Analysis and Nowcast System (FINECAST) assimilates high density and frequency observations from the NEXRAD radars into a convection-permitting model to produce high resolution wind fields and buoyancy fields. By optimally fitting model trajectories to observations using the 4DVar technique, dynamically consistent meteorological fields are retrieved that include convergence, vertical velocity, buoyancy, vertical wind shear, CAPE and relative humidity.

**WRF-Hydro Flood Forecasts**
Flood forecasts depend on knowledge of the state of atmospheric features that trigger heavy rain as well as the state of surface and subsurface water, including the heights of rivers and reservoirs and the amount of soil saturation. Although both meteorological and hydrological models have improved in detail and accuracy over recent years, they can be difficult to operate in a simultaneous and integrated fashion. The hydrological extension of the Weather Research and Forecasting model (WRF-Hydro) is a community-based framework designed to link models of the atmosphere and terrestrial hydrology. The configuration of WRF-Hydro running in the Hydromet Prediction System ingests WRF-3DVar atmospheric model output and ANC nowcasts with selected WRF-Hydro hydrology physics options to produce analyses and forecasts of water cycle processes and streamflow prediction over a range of spatial and temporal scales. A spatially-continuous 100m resolution grid is being used for streamflow prediction along the Colorado Front Range.

**Performance Evaluation**
Timely verification of the Hydromet Prediction System components can pinpoint strengths of the system, areas for improvement, and aid in interpretation of the forecasts. Verification statistics are being computed in near-realtime to evaluate the precipitation forecasts from the WRF-3DVar with radar data assimilation, the WRF-3DVar without radar data assimilation, and performance of the radar-based QPE compared to rain gauge precipitation measurements. The NCAR Model Evaluation Tools (MET) software package is being used to produce statistics based on the comparison of an input forecast (QPF, QPN, Streamflow) and an input verification data set (QPE, rain gauges, NSSL Multi-Radar/Multi-Sensor QPE product, stream gauges). For evaluation of the QPE, the QPE field is treated as a forecast and evaluated using rain gauge observations. Streamflow forecast evaluation will also be included in the system at a later time.

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