Improving Prediction of Extreme Precipitation Events in the Southeast US: Moisture Sources and Transport Mechanisms

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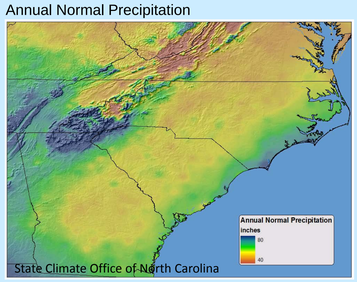
Motivation

Extreme precipitation in the southeast U.S.:

- Southeast U.S. experiences extreme rainfall during all seasons
- Large variability in types of weather systems capable of producing flooding; region comprised of both coastal and mountainous terrain
- Known regional challenges exist for quantitative precipitation forecasting (QPF) and estimation (QPE) – especially for extreme precipitation

Annual Normal Precipitation



NOAA's Hydrometeorological Testbeds:

Advancing and improving extreme precipitation forecasts

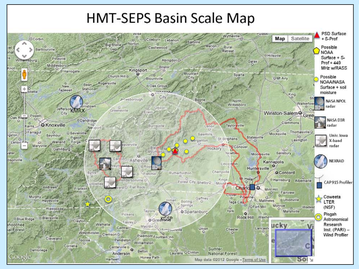
- HMT conducts research on precipitation and weather conditions that can lead to flooding
- Fosters transition of scientific advances and new tools into forecasting operations
- Accelerates development and prototyping of advanced hydrometeorological observations, models, and physical process understanding

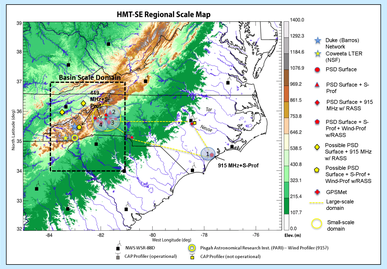
Flooding in Asheville, NC from Hurricane Frances (2004)

HMT-Southeast Pilot Study (HMT-SEPS)

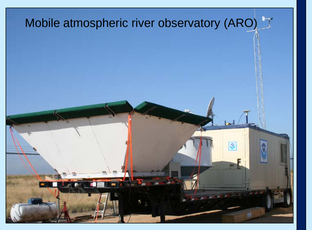
- An HMT-Southeast Pilot Study (HMT-SEPS) is planned for May 2013 – September 2014 in western North Carolina
- Largely focused on QPE in western portions of North Carolina (but some instrumentation in central and eastern NC)
- NOAA will bring instrument assets to region and leverage additional assets from NASA ground validation campaign
- Exact deployment plan still in development; likely components include:

HMT-SEPS Basin Scale Map





Mobile atmospheric river observatory (ARO)



- NOAA HMT instrumentation many include:
  - 3 profiling radars (including 449 MHz for wind profiling with RASS and S-band for precipitation vertical structure). Each site will measure surface temperature, relative humidity, pressure, wind, and precipitation, as well as use a NOAA parsival disdrometer for drop size distribution measurements
  - An upgrade to the Charlotte CAP 915 MHz profiler to provide improved clutter and melting level detection. A nearby GPS receiver will provide integrated water vapor measurements.
- The NASA GPM program will deploy instrumentation as part of COPrHEX. NASA may also support deployment of additional NOAA resources for HMT-SEPS, including:
  - a 449 MHz wind profiler to supplement the existing NOAA profiler site in the Upper Catawba basin; and
  - 6 surface sites in the Upper Catawba basin with standard meteorology sensors (temperature, relative humidity, pressure, wind, redundant precipitation measurements using a combination of NOAA and NASA gauges, and one or more NASA disdrometers) as well as soil moisture and temperature (5-levels)

HMT-SEPS QPE objectives:

- Support NWS adaptation to polarimetric radar algorithms
- Evaluate and improve QPE systems (e.g., MPE, MRMS, Stage IV), focusing on:
  - intelligent integration of multi-sensor QPE information for gauges, radars, and satellite;
  - infrared (IR) and microwave satellite QPE products (CMORPH, SCaMPR, Hydro-Estimator, TRMM 2A25 and 3B42) with ground-based QPE;
  - 4-D structure of precipitation and variability of the drop size distribution (DSD) with resulting impact on QPE systems (e.g., appropriate Z-R (selection);
  - impact of gap-filling radars on QPE systems

QPF objectives

- Improve understanding of region-specific physical processes impacting extreme event QPF
- Analyze climatology and event classifications toward improving understanding of large-scale and mesoscale dynamics associated with extreme precipitation;
- Facilitate researcher and forecaster collaboration to
  - (i) clarify processes/environmental parameters affecting extreme precipitation;
  - (ii) identify human and model QPF challenges; and
  - (iii) identify new or improved tools, definitions and classifications to connect relevant research findings to benefit operational forecasting;
- Evaluate impact of HMT-SEPS observations on data assimilation and resulting QPF [pending collaboration with larger modeling efforts]

Preliminary research: Extreme precipitation

What is the climatology of extreme precipitation events in the southeast U.S.?

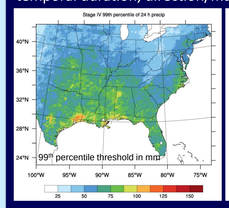
How do QPF errors relate to the largest observed precipitation events?

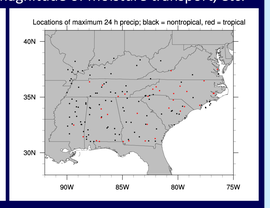
What are the primary moisture sources and moisture transport mechanisms for extreme rainfall in the southeast U.S.?

Extreme Precipitation Climatology

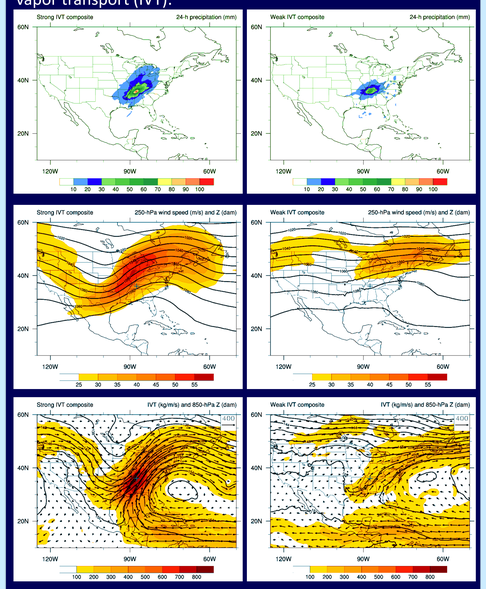
Data source:
4-km NCEP Stage-IV radar and multi-sensor precipitation analysis

Methodology:
Analyze the 99th percentile of "non-tropical" wet days (per individual gridpoint) by characteristics such as season, spatial size, temporal duration, direction/magnitude of moisture transport, etc.





One example of a preliminary climatological analysis strategy: Composite events according to strength of integrated water vapor transport (IVT):



Additional analyses by sub-regions, moisture sources, event size and duration, and more are underway.

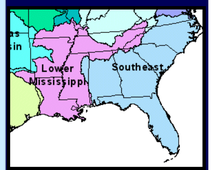
QPF verification

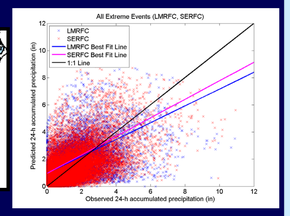
Data:
32-km HPC (24-h lead time) QPFs and 32-km Stage IV data (upscaled from 4-km) QPEs

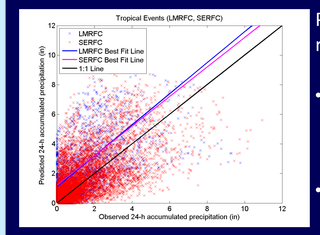
Methodology:
1. Compare QPFs and QPEs for all "tropical" extreme events*
2. Compare QPFs and QPEs for all "non-tropical" extreme events*

* as designated by the extreme precipitation climatology.

Region:
Previous QPF verification research (Ralph et al. 2010) focused on regional verification; thus, this analysis started by looking at forecasts in the Lower Mississippi River Forecast Center (LMRFC) and Southeast River Forecast Center (SERFC) regions.

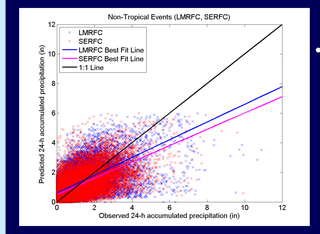






Preliminary results suggest:

- Tropical events in these regions may be more generally over-forecasted;
- Non-tropical events may tend to be under-forecasted

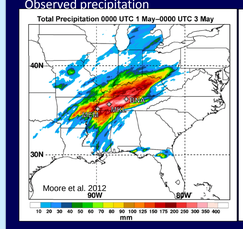


- Additional research is underway to focus definitions, use different regions, etc.

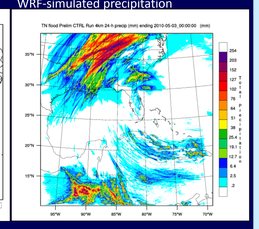
Case study analysis and model-based experiments

Nashville, TN floods: May 2010

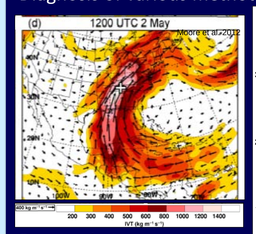
Observed precipitation

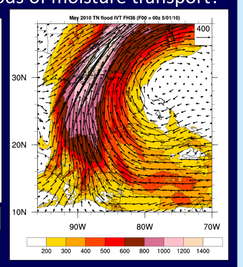


WRF-simulated precipitation



Role of Pacific vs. Caribbean as moisture source? Diagnosis of various methods of moisture transport?





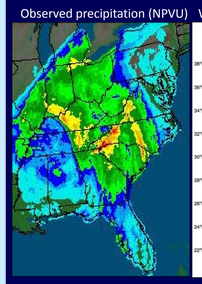
Currently investigating:

- Decreasing moisture in various parts of model domain
- Altering terrain to investigate orographic impact
- Budget calculations

NC heavy rainfall: November 2011

Role of southerly vs. easterly moisture source, transport methods?

Observed precipitation (NPVU)



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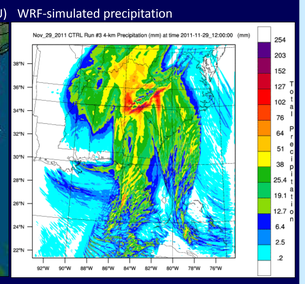

Next steps

- Develop research on extreme precipitation climatology, QPF verification of human and model forecasts, and case studies and model experiments
- Prepare for HMT-SEPS Pilot Study and deployment activities in spring 2013
- Establish collaborative projects in areas of regional partner interest

Acknowledgements

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