Hydrometeorology Testbed West (HMT-West) Overview

Allen White[1], Rob Cifelli[1], Dave Reynolds[1,2], Lynn Johnson[1,3], Ligia Bernardet[1,2], Kelly Mahoney[1,2], Dave Novak[4], Kirk Holub[1],and Rich Lataitis[1]

[1]NOAA Earth System Research Laboratory, Boulder, CO
[2]Cooperative Institute for Research in Environmental Sciences, U. of Colorado, Boulder, CO
[3]Cooperative Institute for Research in the Atmosphere, Colorado State U., Ft. Collins, CO
[4]NOAA National Weather Service Weather Prediction Center, College Park, MD

VLab Forum, 20 May 2015

Water is One of NOAA's Five Grand Science Challenges

http://nrc.noaa.gov/CouncilProducts/WhitePapers.aspx

Understanding the Water Cycle

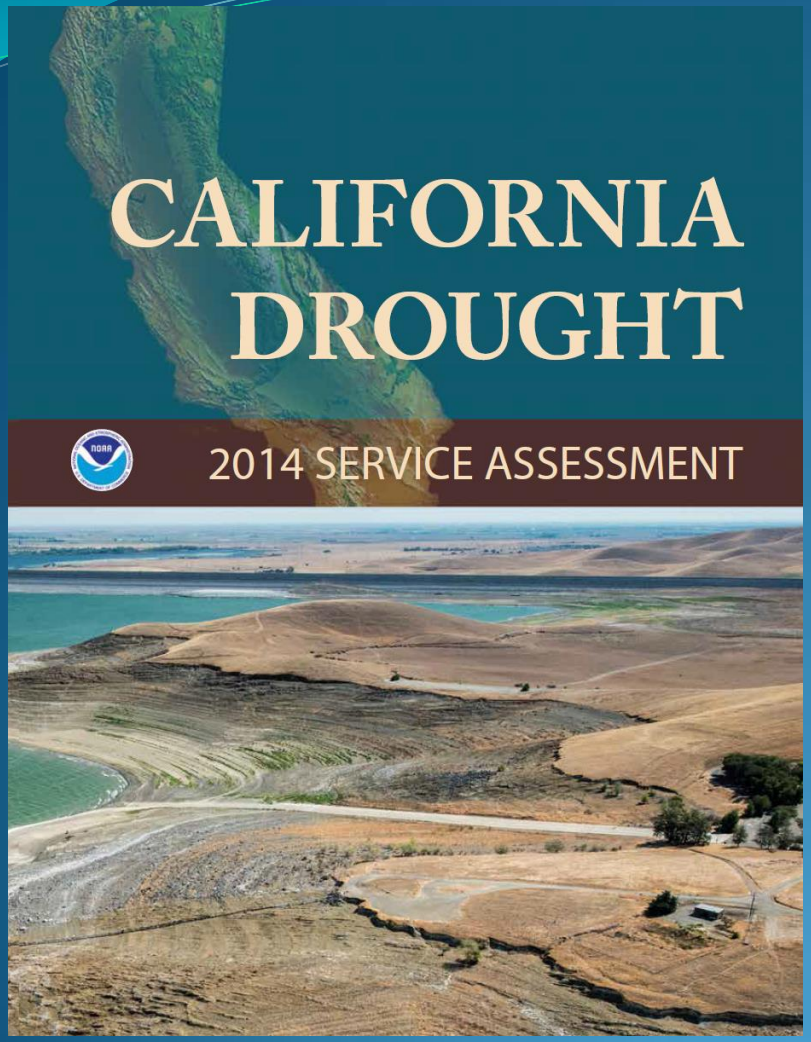
Findings from NOAA's Water Cycle Science Challenge Workshop

28 August – 1 September 2011, NOAA Earth System Research Laboratory, Boulder, Colorado

28 September 2012

An Interagency Planning Workshop on **Water Cycle Science** for NOAA recommended several goals that HMT addresses and called for increased support and for coordination with other agencies.

Examples of several key drivers for improved understanding and prediction of the water cycle. (Courtesy Don Cline)



High level finding and recommendation from CA's Drought Service Assessment:

HLF 3: NOAA's Habitat Blueprint and Hydrometeorological Testbed (HMT) are examples of successful NOAA models for intra-agency and interagency collaboration, and for engaging with the research community.

Recommendation HLF 3a: NOAA should expand the scope of the Hydrometeorological Testbed (HMT) in partnership with water resources agencies and other science organizations to promote "forecast-based reservoir operations," scope and develop the needed forecast methods, and develop relevant decision support models in order to enhance California's ability to mitigate potential drought impacts.

Hydrometeorology Testbed

hmt.noaa.gov

New!

Home | About | Field Programs | Data | Meetings | Publications | News | Resources | Transitions

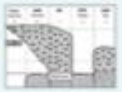
Tools for Water in a Changing Climate

NOAA's Hydrometeorology Testbed (HMT) conducts research on precipitation and weather conditions that can lead to flooding, and fosters transition of scientific advances and new tools into forecasting operations. HMT's outputs support efforts to balance water resource demands and flood control in a changing climate. (Read more...)

New items posted 2-4 times per month

What's New...

April 1, 2014
Evaluating rainfall measurements over Sonoma County



March 17, 2014
New tool evaluates how well forecast models are predicting precipitation

February 28, 2014
Russian River Hydrologic Modeling Meeting

Major Activity Areas

Developing and prototyping 21st Century methods for observing precipitation

Addressing the challenge of extreme precipitation forecasting; from identifying gaps to developing new tools

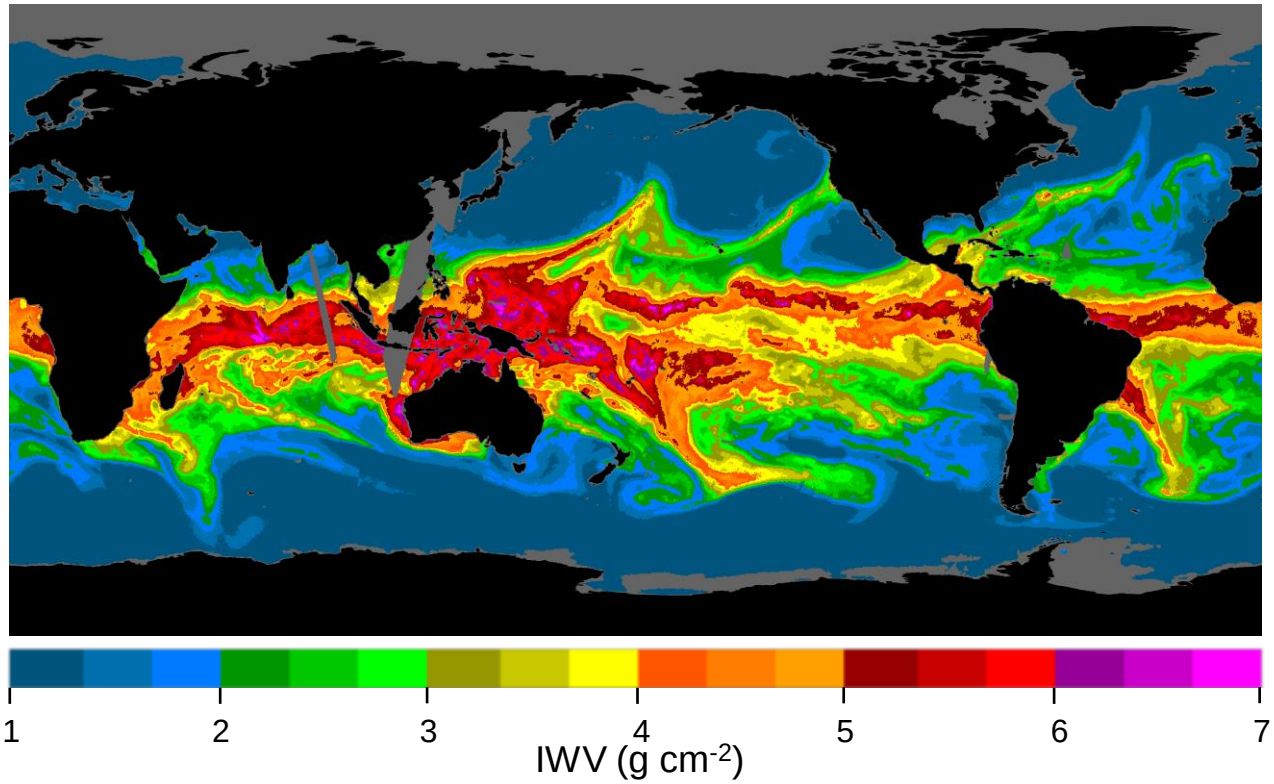
Characterizing snow to address uncertainty in forecasting, flood control, and water management

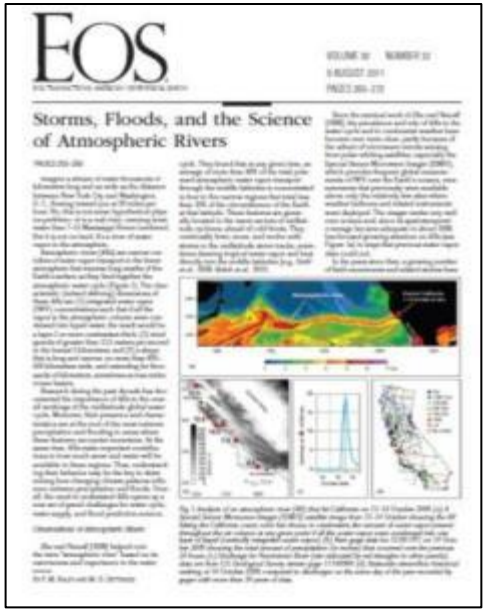
Evaluating advanced observations of rain and snow, temperature, and soil moisture to provide best possible "forcings" for river prediction

Developing tools for forecasters and users of extreme precipitation forecasts

HMT is led by the ESRL Physical Sciences Division
with partners across NOAA, other agencies, and universities.

HMT-West Research has Identified Atmospheric Rivers (ARs) as the Primary Meteorological Cause of Extreme Precipitation & Flooding on U.S. West Coast




EOS

Storms, Floods, and the Science of Atmospheric Rivers

Ralph, F.M., and M.D. Dettinger, 2011: Storms, Floods and the Science of Atmospheric Rivers. *EOS, Transactions, Amer. Geophys. Union.*, **92**, 265-266.

Atmospheric River Information Page: http://www.esrl.noaa.gov/psd/atmrivers/

"On average, about 30-50% of annual precipitation in the west coast states occurs in just a few AR events."

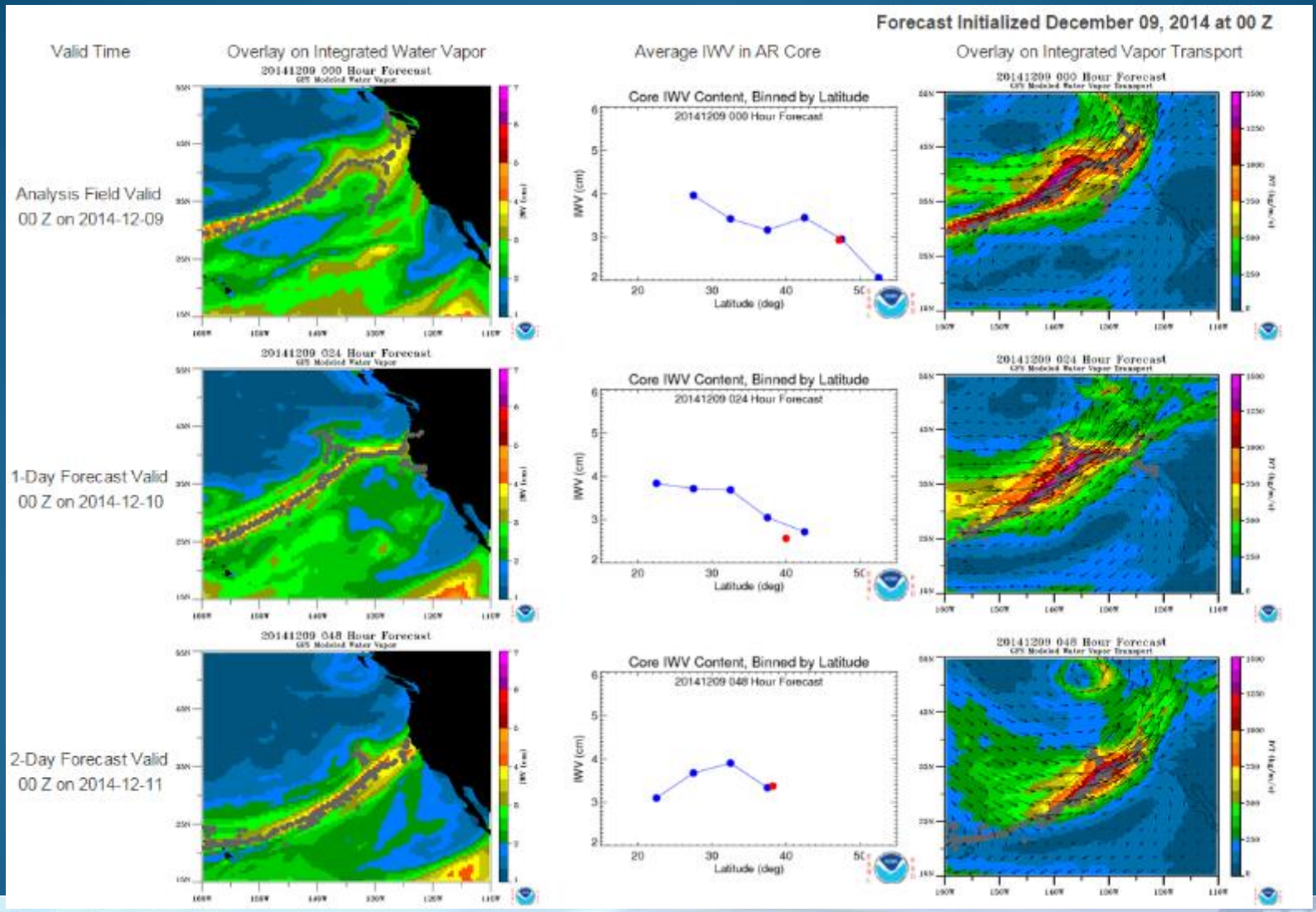
"A strong AR transports an amount of water vapor roughly equivalent to 7.5–15 times the average flow of liquid water at the mouth of the Mississippi River."

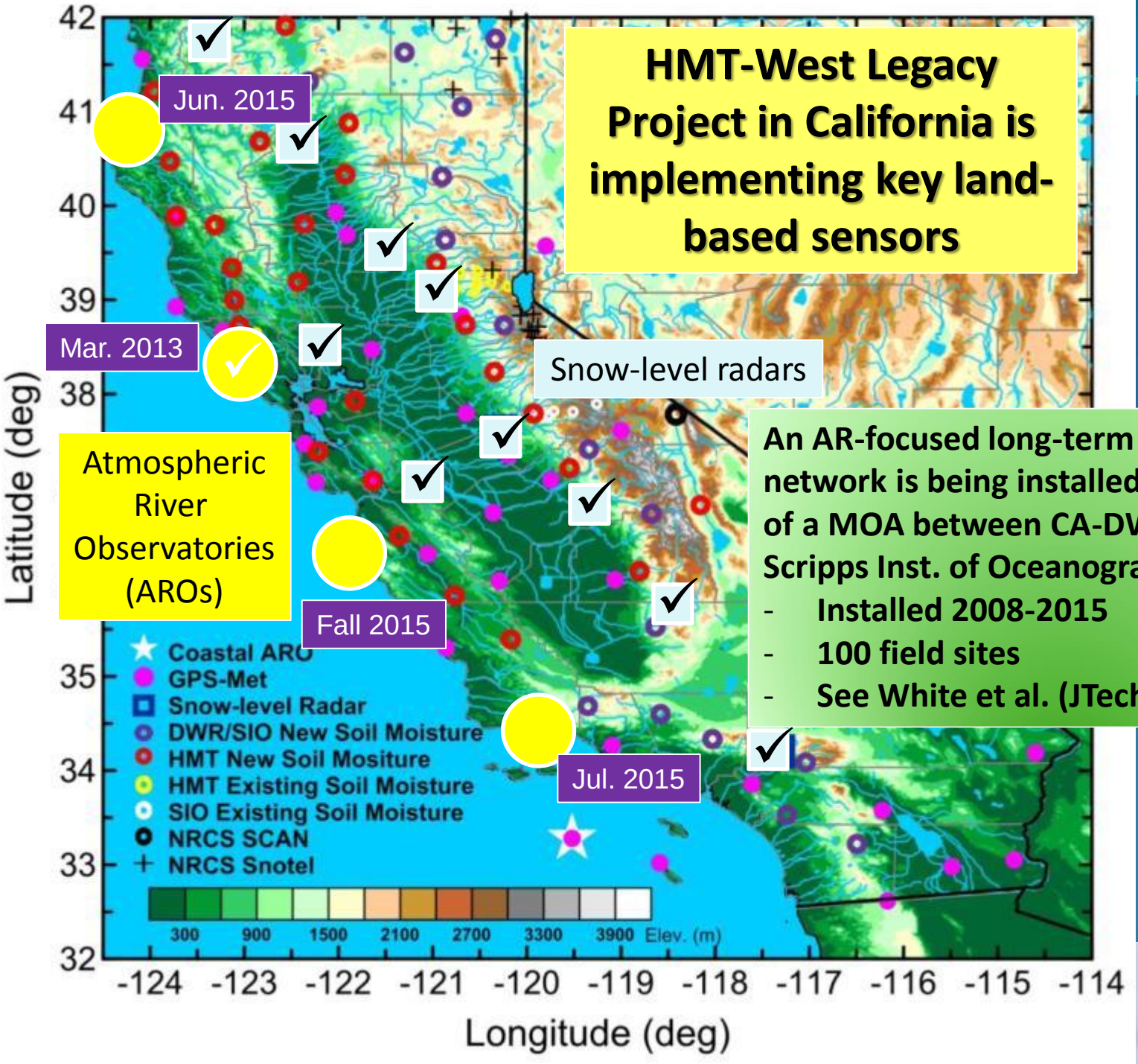
GFS analysis time out to 7-day forecast

HMT AR Detection Tool

http://www.esrl.noaa.gov/psd/psd2/coastal/satres/data/html/ar_detect_gfs.php

IWV (left)
IVT (right)




HMT-West Legacy Project in California is implementing key land-based sensors
Jun. 2015
Mar. 2013
Snow-level radars
Atmospheric River Observatories (AROs)
Fall 2015
Jul. 2015
An AR-focused long-term observing network is being installed in CA as part of a MOA between CA-DWR, NOAA and Scripps Inst. of Oceanography
- Installed 2008-2015
- 100 field sites
- See White et al. (JTech, 2013)
Coastal ARO
GPS-Met
Snow-level Radar
DWR/SIO New Soil Moisture
HMT New Soil Mositure
HMT Existing Soil Moisture
SIO Existing Soil Moisture
NRCS SCAN
NRCS Snotel
300 900 1500 2100 2700 3300 3900 Elev. (m)
Latitude (deg)
Longitude (deg)
42 41 40 39 38 37 36 35 34 33 32
-124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114

HMT-Legacy Network Instrument Function

- **Land-based GPS Sensor –** measure the fuel (water vapor content) carried by the winds as the storm makes landfall.
- **Wind Profilers –** measure the rate at which the fuel is being supplied to generate heavy rain (fuel rate)
- **Snow-level Radar (S-band profilers) –** measure the depth of the atmosphere warmer than freezing. Deeper this layer more moisture is available and the higher the elevation snow will fall in the mtns. Higher snow level more runoff will occur.
- **Soil Moisture Sensor –** measure the moisture content of the soil and calibrate that to field capacity to determine runoff potential.

Atmospheric River Observatories Fill Largest Single Monitoring Gap

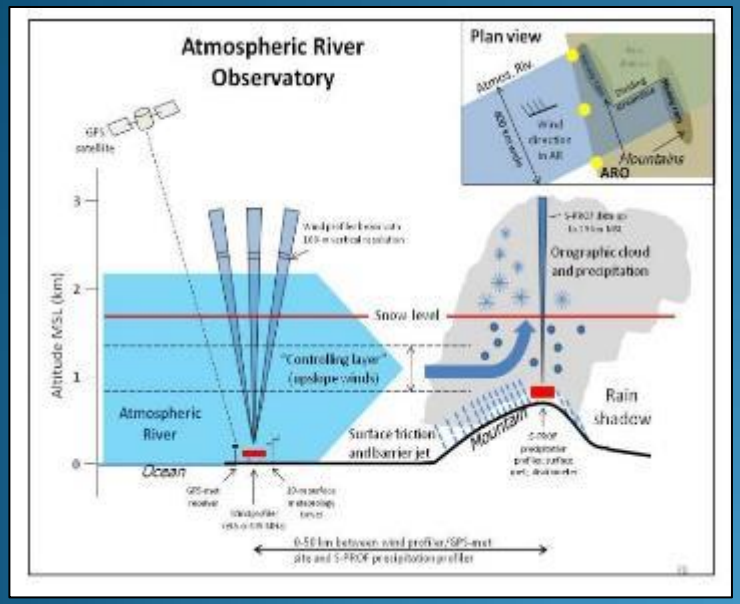
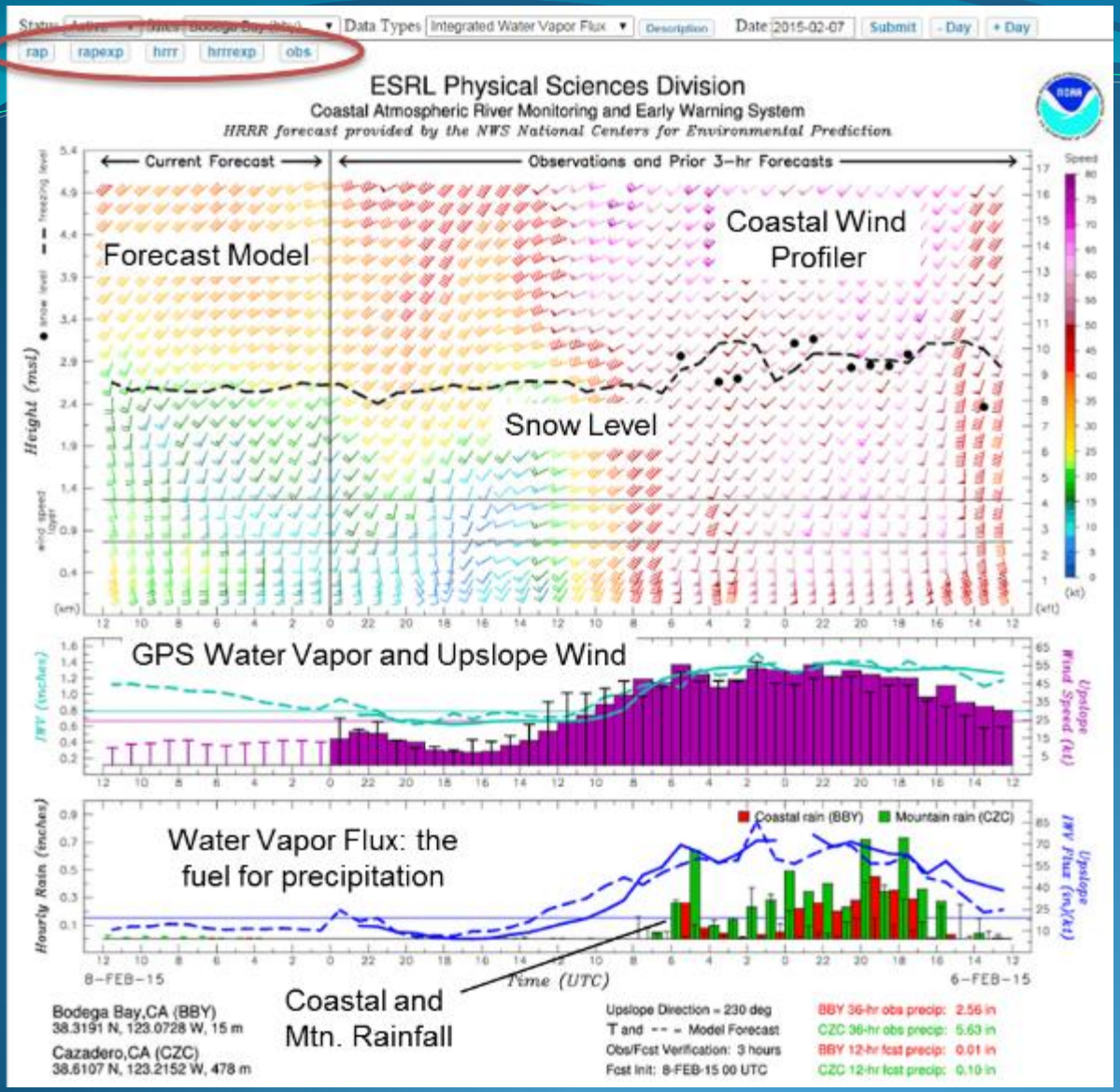


Photo by Clark King, PSD

¼-scale 449-MHz wind profiler
Radio acoustic sounding system
10-m surface met. tower
GPS receiver

Photos by Florence Low, CA-DWR

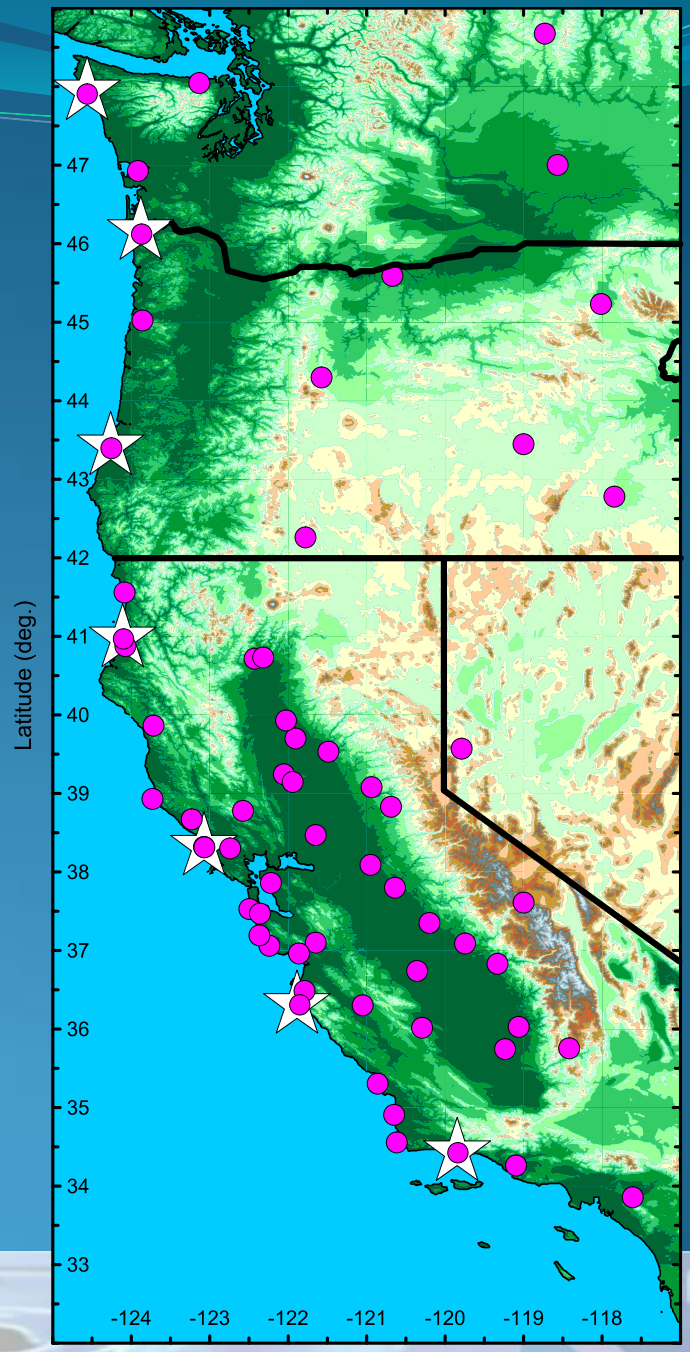


HMT Real-time Upslope Water Vapor Flux Tool Display

Now uses HRRR and RAP forecast models

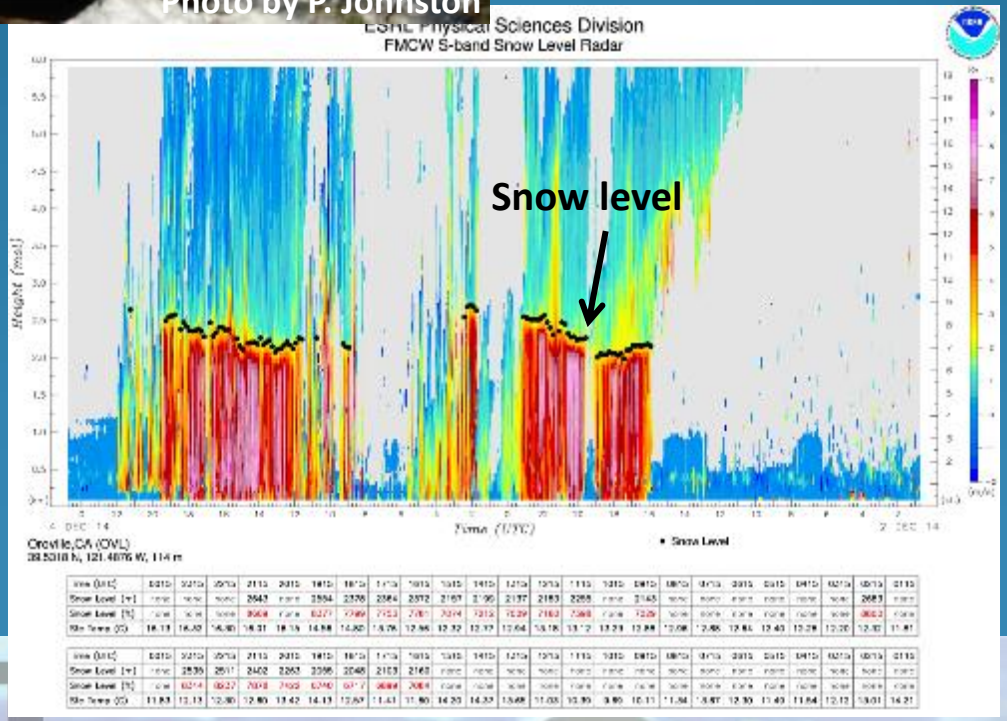
Providing forecasters with the critical observations to determine how ARs are impacting the area and how model forecasts are portraying the AR conditions and orographic precipitation enhancement.

CA-DWR and U.S. DOE are jointly supporting a coastal network of seven atmospheric river observatories. This "picket fence" will provide the first line of defense for winter storms that pound the West Coast each year. This network will be completed this year. UNAVCO/NOAA-GSD is providing real-time GPS-Met data across these West Coast States.



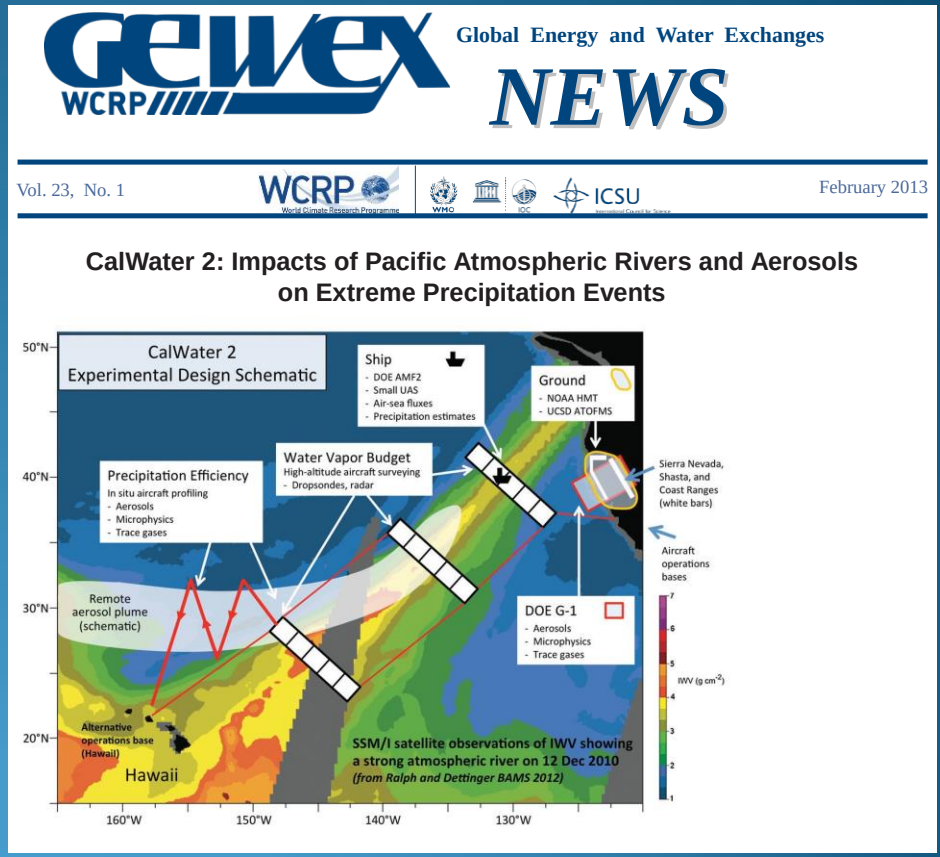
Snow-level Radar

- Provides proxy snow-level height during precipitation events
- Utilizes proven FMCW technology to substantially lower cost
- **Uses the patented ESRL automated snow-level detection algorithm proven in nationwide field experiments**
- Less than 8’ diameter footprint
- Low-power requiring minimal infrastructure



HMT Future Work (FY15)

- Finish HMT-Legacy observing system deployments in CA, OR, WA
- Continue 2nd MOU with CA-DWR
  - Observing network O&M funding
  - Network optimization studies
  - SF Bay modeling project
- Publish research on HMT-SEPS in North Carolina
  - Role of ARs in the East vs West
  - Precipitation microphysics
- Carry out MOU with SCWA
  - Forecast Informed Reservoir Operations
  - Improved QPE for the Russian River Basin
  - Additional rain gauge/soil moisture sites
  - Benefits analysis
- Analyze CalWater 2 data (Jan-Feb 2015)
- Coordinate with NMFS on Russian River Habitat Blueprint projects
- Implement AWIPS-2 in house



Backup slides

Why Improve QPF?

Improving the amount, type, location and timing of quantitative precipitation forecasts (QPF) and probabilistic quantitative precipitation forecasts (PQPF) are key elements to enhance the information content and reliability of these forecasts.

Water Resource Managers

Emergency Management

Who needs accurate and reliable QPFs?

Public

Transportation

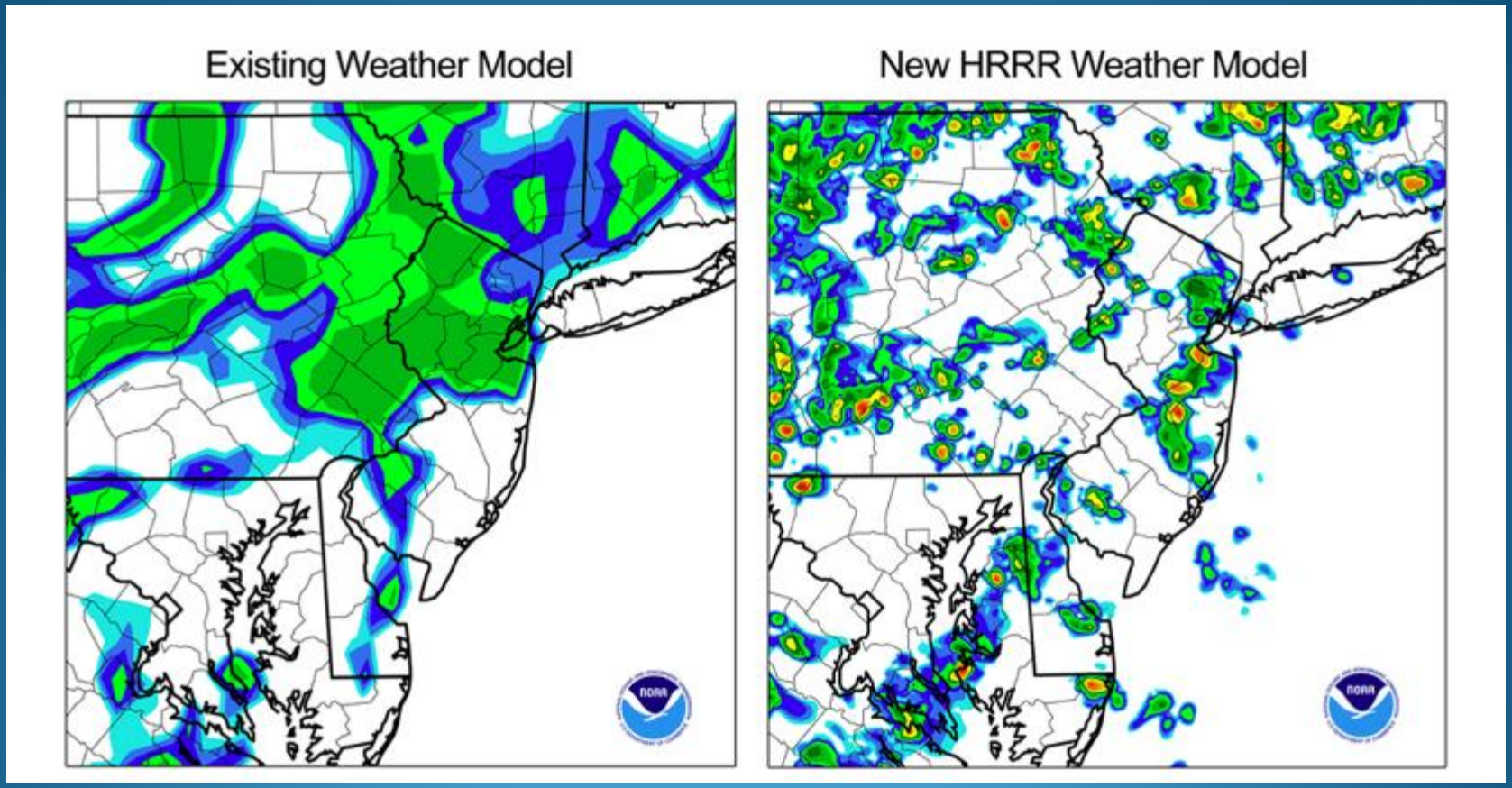
Agriculture

Benefit of Expanded Observation Networks Recent Past and Near Future

- Allowed us to begin a climate record of land-falling AR magnitude, duration, relationship to flooding, seasonality.
- Allowed us to define the spatial and temporal resolution needed to monitor extreme rainfall events
- Allowed us to define the critical observations that we need to properly model extreme events - gaps
- Test beds have provided the scientific credibility needed to bridge the research to operations gap - Sustainability – not just a research project…
- Expand capability to all areas in the west.

HRRR is Operational

NOAA ESRL/GSD's High Resolution Rapid Refresh model now at NCEP



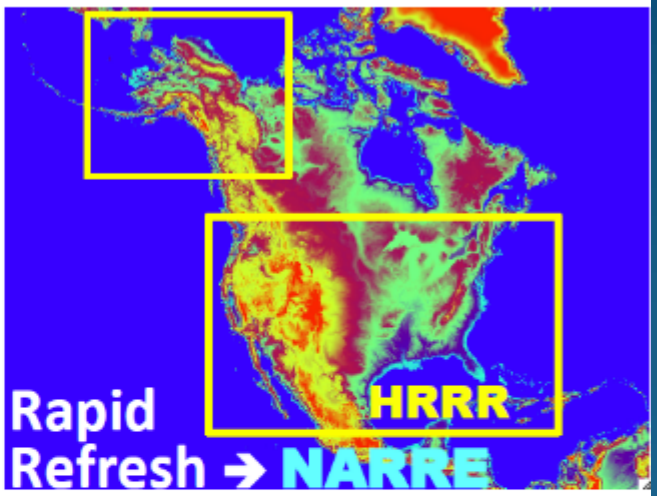
Evolution of hourly updated NOAA modeling

Feb 2014 Rapid Refresh v2 – NCEP oper

- PBL/soil/radar assimilation enhancements
  - ➔ **Improved surface forecasts, convective environment fields**
- Hybrid ensemble-variational GSI assimilation
- Model – improved cloud / PBL / LSM, numerics improvements, updated WRF

Aug 2014 – HRRR (3km) - planned NCEP oper with 3km/15min radar refl. assimilation

2015 – RAPv3 / HRRRv2



North American Rapid Refresh Ensemble (NARRE) ~2017

- NMM, ARW cores
- Hourly updating with GSI-hybrid EnKF
- Initially 6 members, 3 each core, physics diversity (stochastic only or with RAP/ NAM/NCAR suites)
- Hourly forecasts to 24-h
- NMMB (+ARW?) members to 84-h 4x/day

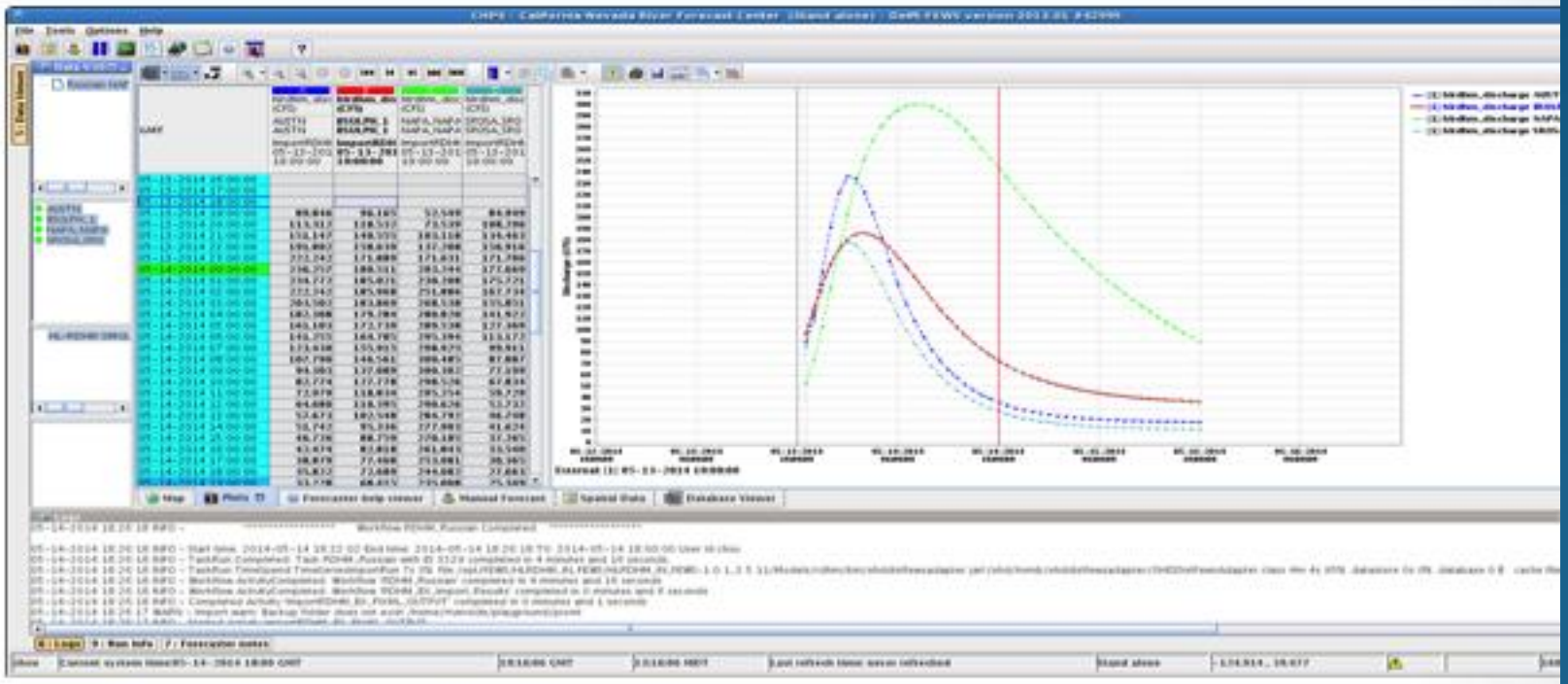
NARRE / HRRRE at NCEP

2017 – Ensemble Rapid Refresh/NAM – NARRE (w/ hybrid 4d-ens/var DA)

2019? – Ensemble HRRR – HRRRE – (ultimately with hourly ~3km ensemble DA)

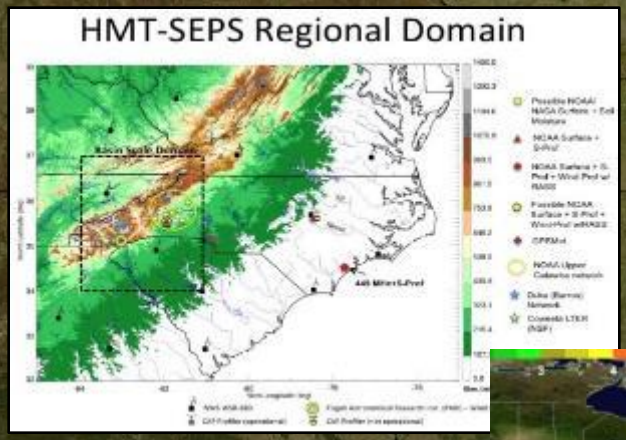
HMT/Riverside Technology implemented the NOAA RDHM into CHPS to demonstrate flash flood potential for NWS WFO-Monterey

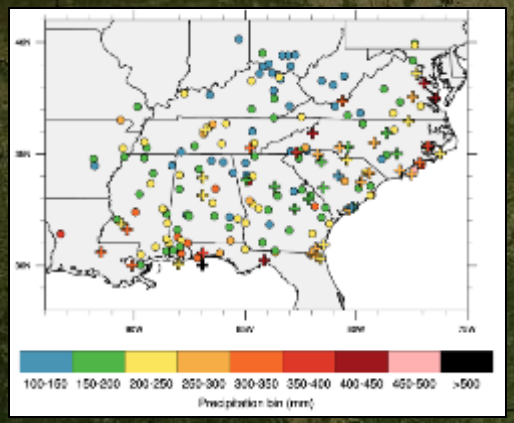
Plot of Streamflow to May 16 0600z, 2014 (cfs)



- Discharge at the Napa River near the Napa City Station
- Discharge near the Mouth of the Big Sulfur Creek Intersecting the Russian River
- Discharge at the Austin Creek Cazadero Station
- Discharge at the Santa Rosa Creek near Santa Rosa station

HMT-Southeast Pilot Study

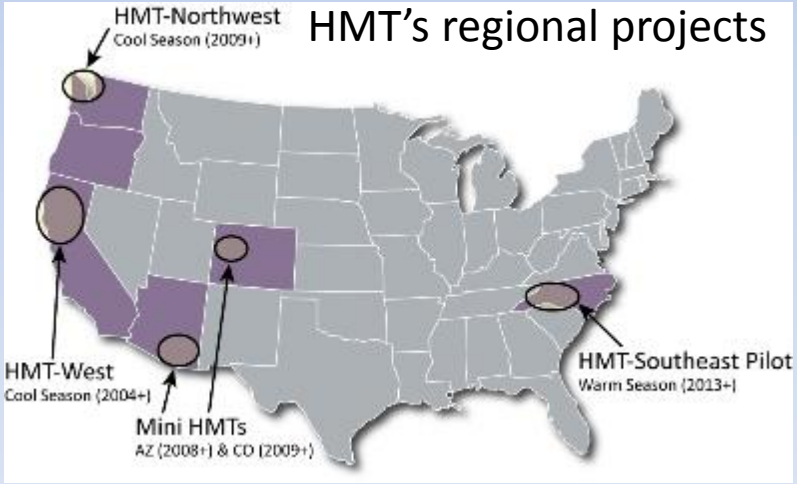




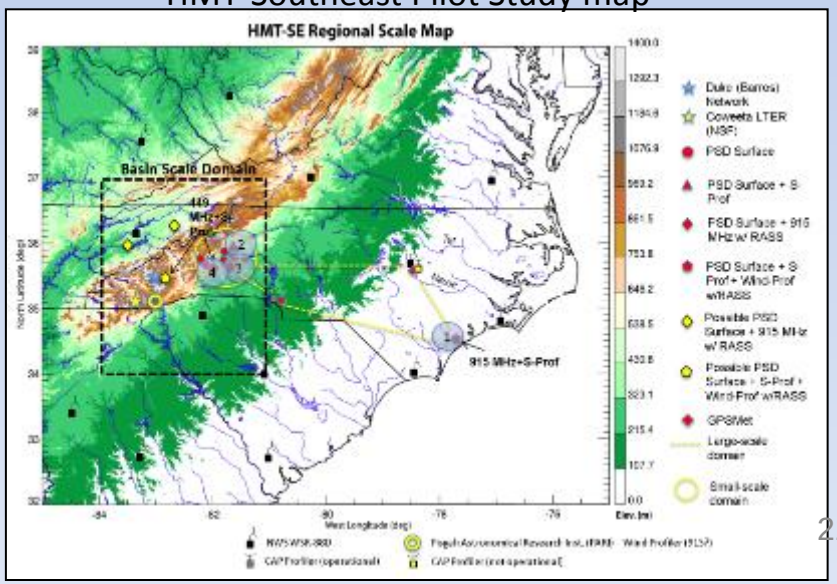
NOAA Vlab Webinar
20 May 2015

NOAA's Hydrometeorology Testbed – Southeast

- HMT-Southeast: Two parts
  1. Pilot study (deployment) in western North Carolina (Spring 2013 – Fall 2014)
  2. Operationally-oriented research on extreme precipitation and forecast challenge identification

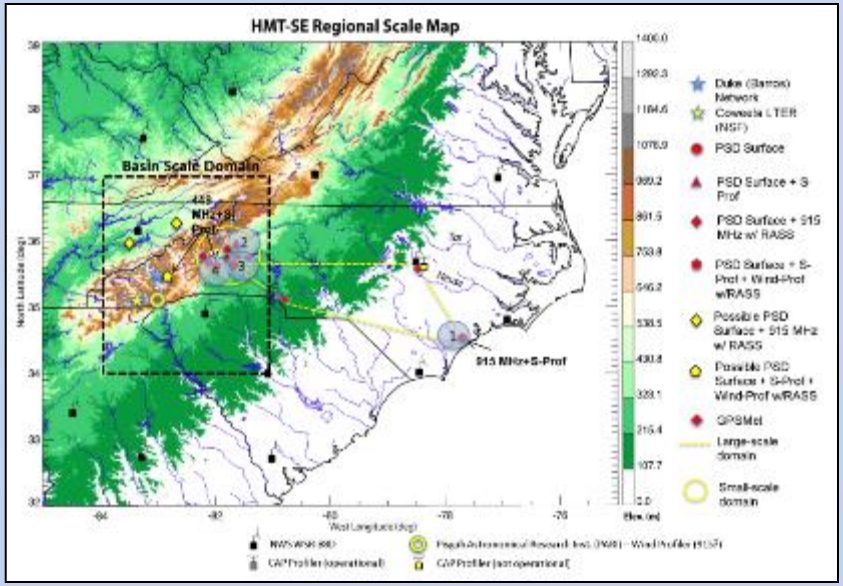


HMT-Southeast Pilot Study map



HMT-Southeast Pilot Study ("HMT-SEPS")

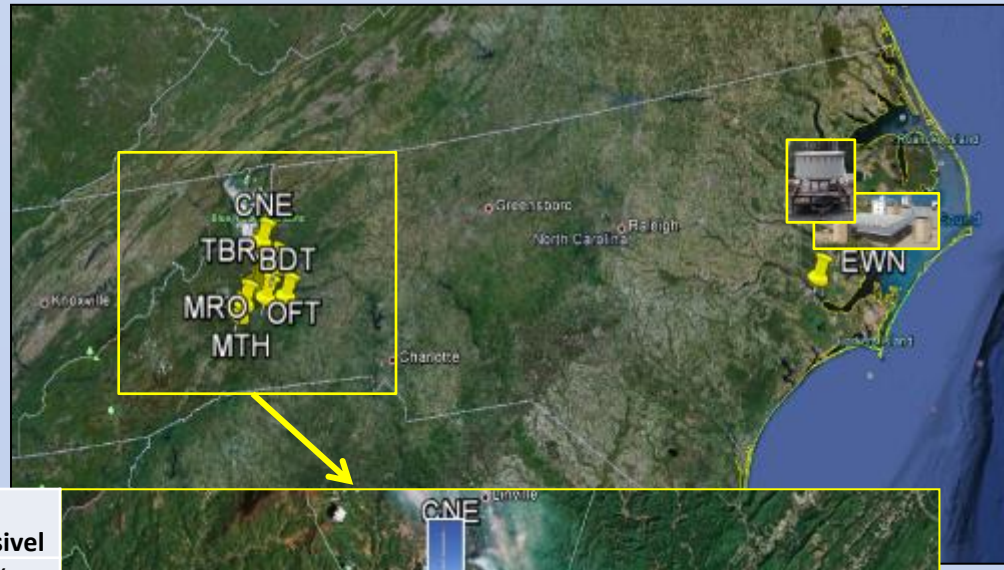
- Spring 2013 – Fall 2014 in western NC
- QPE evaluations largely focused in western NC (but some instrumentation in central and eastern NC), QPF improvement goals region-wide
- NOAA provided instrumentation and leveraged additional assets from NASA ground validation campaign, IPHEx
- PSD team:
  - Rob Cifelli: Project lead
  - Kelly Mahoney: Lead Scientist
  - Ellen Sukovich: QPF lead
  - Ben Moore: Research associate
- "Pilot study": Long-term plan, vision was never solidified; *if* value is demonstrated, we allowed that we could consider expanding, prolonging (provided external support could be garnered)



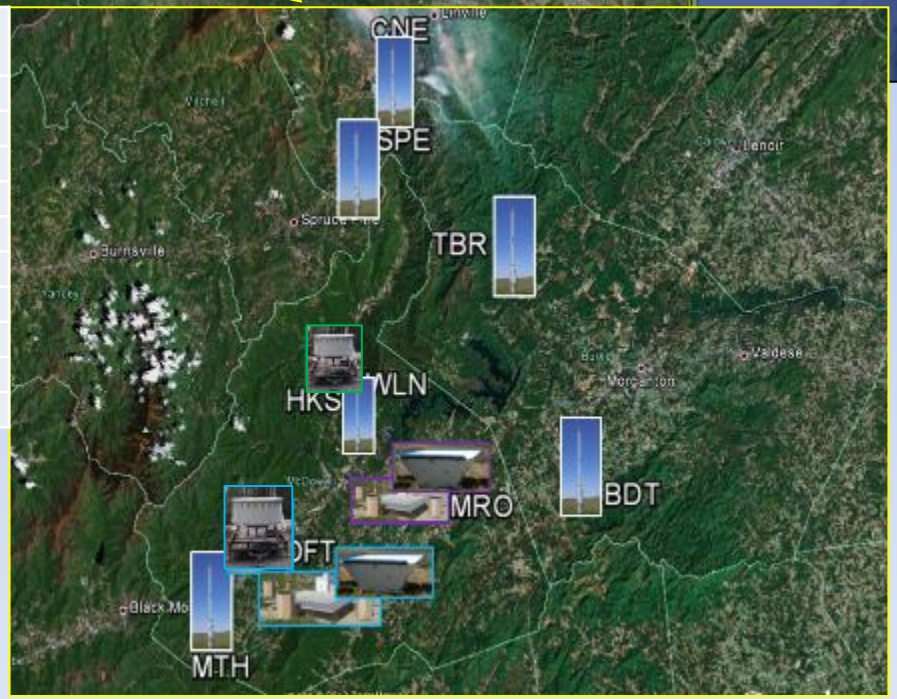

Old Fort, NC instrument installation (Aug 2013)

HMT-SEPS instrument deployment

- NOAA's HMT-SEPS deployment: 4 profiler sites and 6 surface meteorology sites
- Additional NASA precipitation gauge and disdrometer at each surface site
- Restoration of/upgrades to existing NC Div. of Air Quality Clayton, NC and Charlotte, NC wind profilers.
- Incorporation of new profiler in RTP at US EPA's campus.



Site Name	Site ID	Elev (m)	449	915	RASS	S-band	Met	Soil Moisture	Parsivel
Brindletown	BDT	355					X	X	X
Crossnore	CNE	1008					X	X	X
Hankins	HKS	379				X	X		X
Marion	MRO	384		X	X		X		X
Crooked Creek	(MTH)	519					X	X	X
New Bern	EWN	3	X			X	X		X
Old Fort	OFT	421	X		X	X	X		X
Spruce Pine	SPE	833					X	X	X
Table Rock	TBR	356					X	X	X
Woodlawn	WLN	523					X	X	X

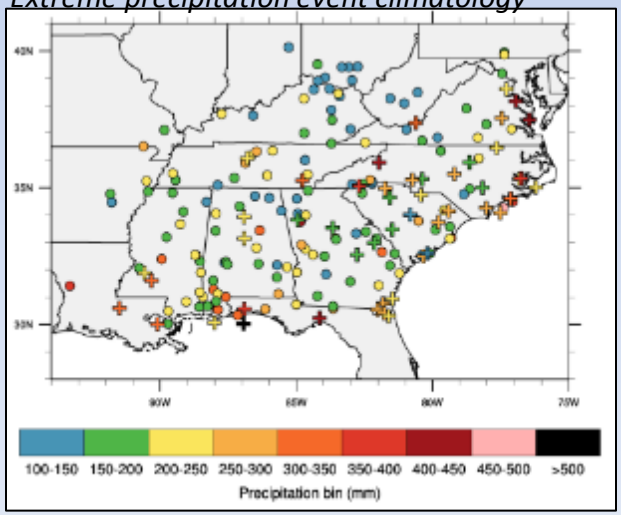


All data and observations were available in real-time (as well as for archived download) at: http://www.esrl.noaa.gov/psd/data/obs/datadisplay/index.php?ProjectID=7

HMT-SE Research Themes

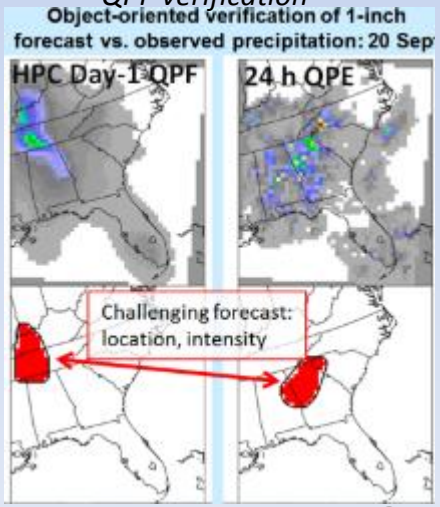
- Research topics not regionally-bound to western NC
- Major research projects/themes:
  1. **The Climatology of Southeast US Extreme Precipitation Events** (Lead by ESRL PSD, B. Moore et al. 2015, MWR)
  2. **Southeast US QPF error climatology** (Efforts ongoing at ESRL PSD, North Carolina State University; Baxter et al. 2014)
  3. **Case studies of heavy precipitation events** (e.g., July 2013 western NC flash flood - Efforts ongoing at ESRL PSD and NCAR)
  4. **Heavy precipitation processes and the relevance of "atmospheric rivers" to heavy SE precipitation** (Efforts ongoing at ESRL PSD)
  5. **Bulk microphysical characteristics of NC precipitation observed with disdrometers and vertically pointing precipitation profilers; assess performance of default NEXRAD rainfall algorithms**. (Efforts ongoing at ESRL PSD)
  6. **Performance assessment of radar, gauge, and multi-sensor QPE in the upper Catawba river basin** (ESRL PSD, OHD - ongoing)

Extreme precipitation event climatology



Extreme precipitation event case studies

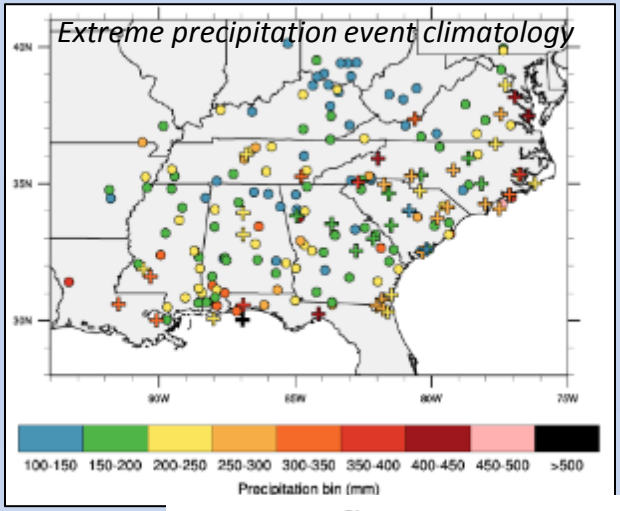
QPF verification

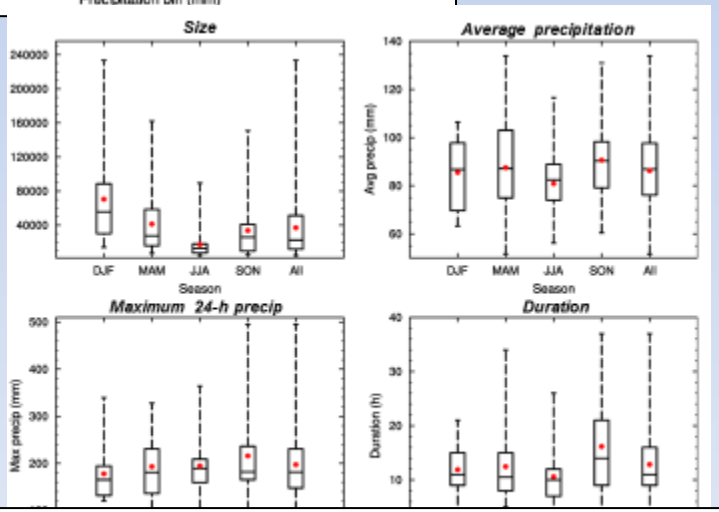


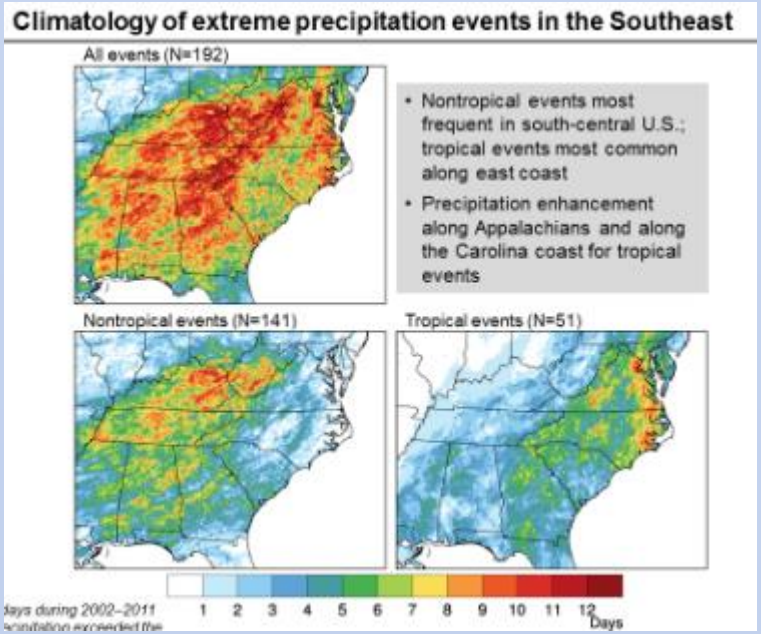
HMT-SE Research Themes: Extreme event climatology example

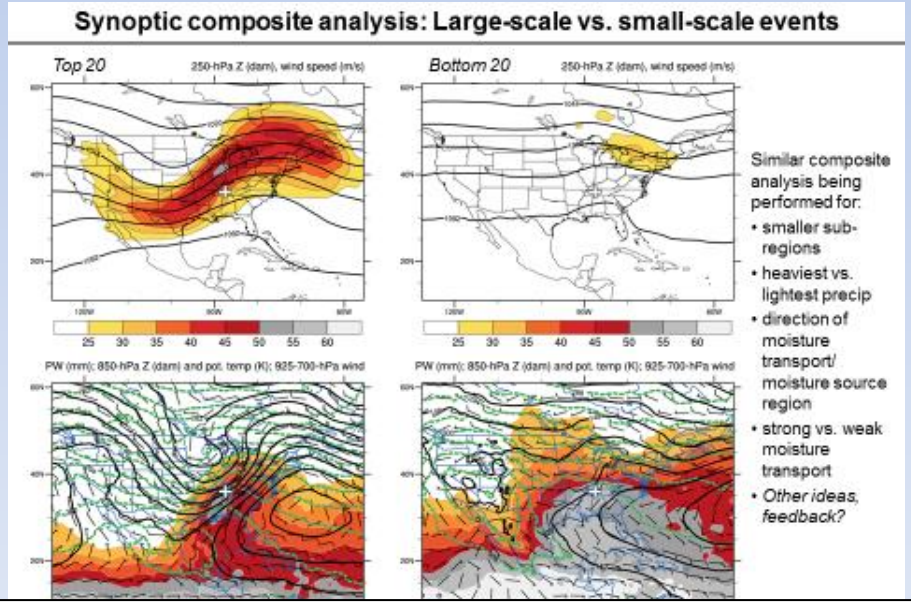
Motivation:

- Large regional variability in event types, seasonality, environmental characteristics, and forecast skill
- How well do we understand specific event types, associated forecast errors?
- Construct an "extreme precipitation climatology"





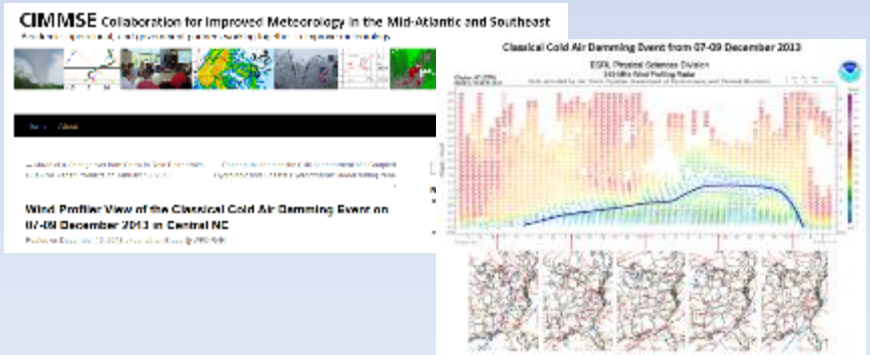




Moore, B. J., K. Mahoney, E. Sukovich, R. Cifelli, and T. Hamill, 2015: **Climatology and environmental characteristics of extreme precipitation events in the Southeastern United States**. *Mon. Wea. Rev.*

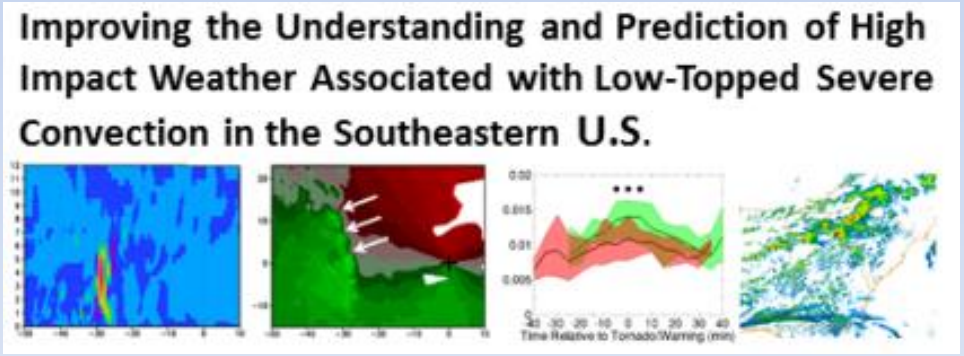
HMT-SEPS achievements: Research to Operations/Applications

- Periodic large-audience community webinars provided forecaster training, community updates:
  - June 2012; July 2013; November 2013; July 2014
- National Weather Service Area Forecast Discussions mention HMT observations 75+ times in 15 months
- Forecast experiment participation: NCEP Weather Prediction Center (WPC) Flash Flood and Intense Rainfall experiments, Winter Weather Experiment
- NWS office visits, meetings, presentations: Raleigh, NC; Greenville-Spartanburg, SC
- Informal, event-based dialogues between NWS forecasters and HMT-PSD staff to help with interpretation of HMT observations, collaborate on HMT research topics using real-time cases



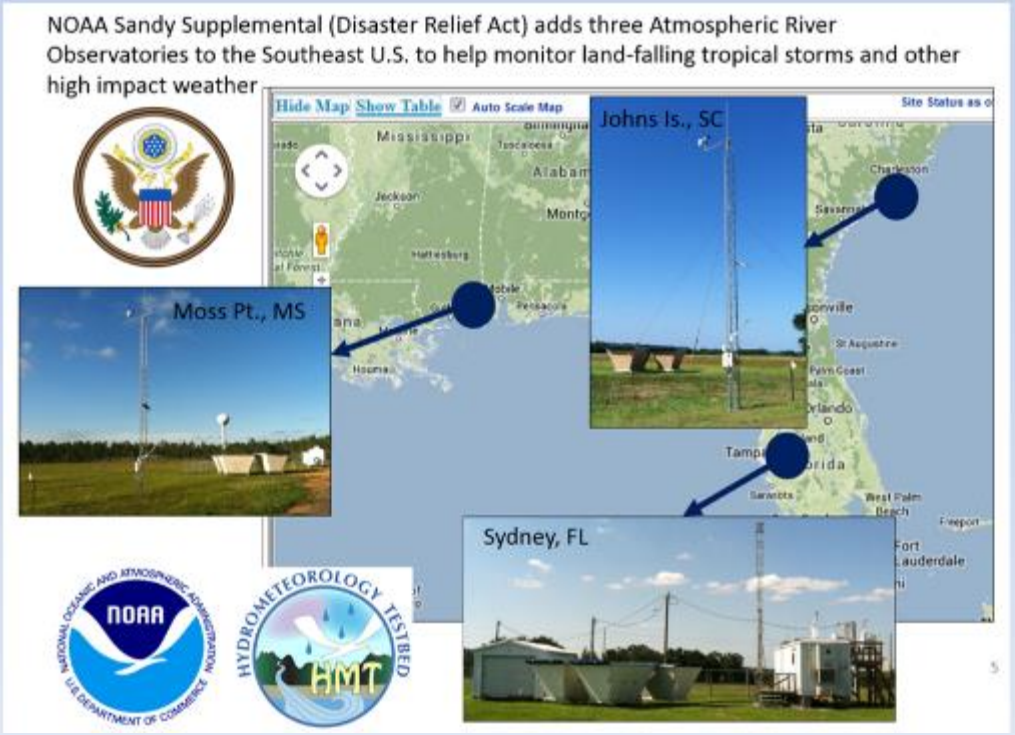
HMT-SEPS leveraged projects

- NASA Integrated Precipitation and Hydrology Experiment (IPHEx)
- Verification of quantitative precipitation reforecasts over the Southeast United States (Baxter et al. 2014)
- USWRP CSTAR project with NC State: “Improving Understanding and Prediction of High Impact Weather Associated with Low-Topped Severe Convection in the Southeastern U.S.”
- QPE validation: in collaboration OHD, NESDIS, NSSL, NCDC, CPC, CSU-CIRA
  - “CMORPH and GPM Level3 Algorithms Development” (P.I. Xie; NESDIS GOES-R support)
  - “Data Fusion and Applications” (P.I. Zhang; NESDIS GOES-R support)
  - “Development of a regional system for QPE” (CSU-CIRA Ph.D. thesis)



HMT-Southeast Now

- HMT-SEPS deployment officially concluded in November 2014 (instruments were removed)
- Sandy Supplemental funding supporting some new and ongoing Atmospheric River Observatories (AROs) through 2015
- Sandy Supplemental funding (+ NOAA PSD support) allowing for continued research
- Plans for several more manuscripts; presentations; forecast experiment participation

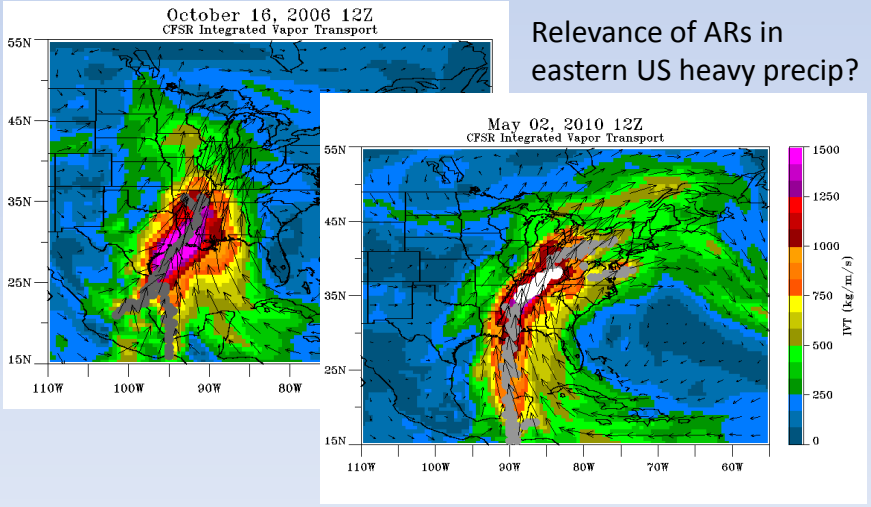


New Bern, NC HMT-SEPS coastal site also to remain active through 2015

HMT-Southeast Now

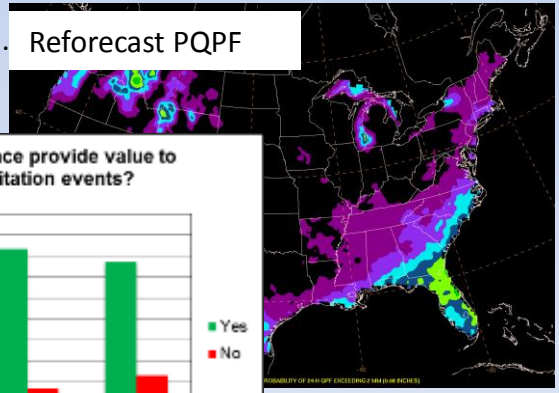
- Sandy Supplemental funding (+ PSD support) is allowing for continued research focused on:
  - Identify contribution of ARs to extreme precipitation in SE
  - Case study analysis on extreme precipitation events, flood risk
  - Evaluation of GEFS reforecasts for extreme precipitation event types

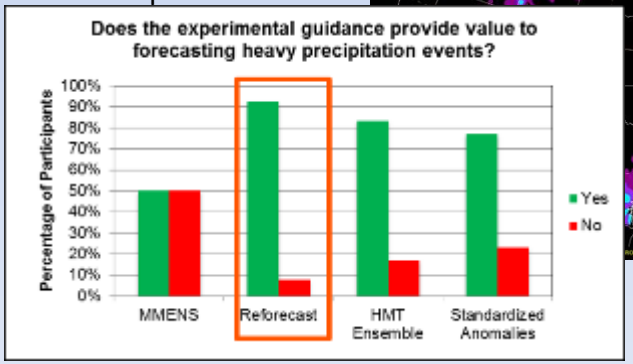
- Future of HMT-SE?
  - Despite successful pilot study, interesting science challenges, and an engaged and enthusiastic operations/applications community, current funding and staffing realities dictate project spin-down



Relevance of ARs in eastern US heavy precip?

HMT-WPC uses Hamill et al. reforecast dataset in forecast experiments

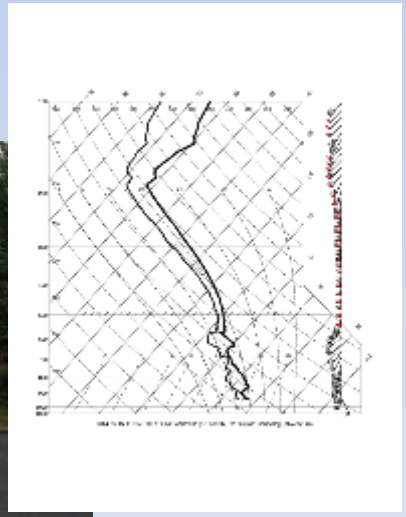




Backup slides

HMT-SE collaborations and external partnerships

- HMT WPC (Weather Prediction Center), NSSL/OU, NOAA Hazardous Weather Testbed (HWT) for Flash Flood and Intense Rainfall (FFaIR) experiment
- QPE validation: in collaboration OHD, NESDIS, NSSL, NCDC, CPC, others
- NC-Division of Air Quality and HMT repair and upgrade of Clayton, NC and Charlotte, NC profilers
- US EPA: Profiler assistance, data
- North Carolina State University: NCSU graduate and undergraduate student support for QPF error research
- UNCA – IOP soundings
- NASA, Duke University, NCSU, CSTAR/USWRP, UNCA, NCAR, WPC, NSSL, NWS Eastern and Southern Region Headquarters, NWS WFOs, RFCs, …



The R2O Spectrum

RESEARCH TO OPERATIONS

EXTERNALLY FUNDED PARTNERS
-NGGPS
-OAR R2O
-HMT/HWT
-Others

HMT-PSD Development Group

Interactive Experiments

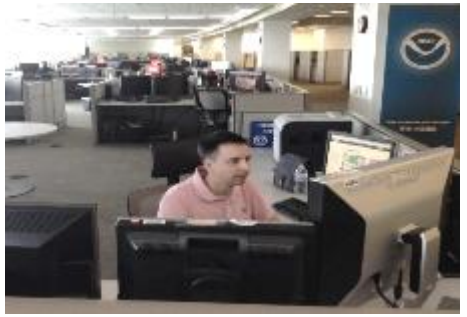
HMT-WPC

NGGPS Liaison

Vice Workoff

Sarah Perfater

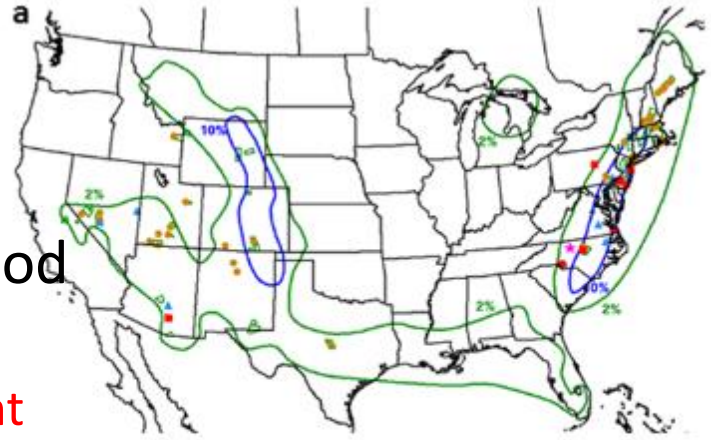
WPC Development and Training Branch



Flash Flood and Intense Rainfall Experiment

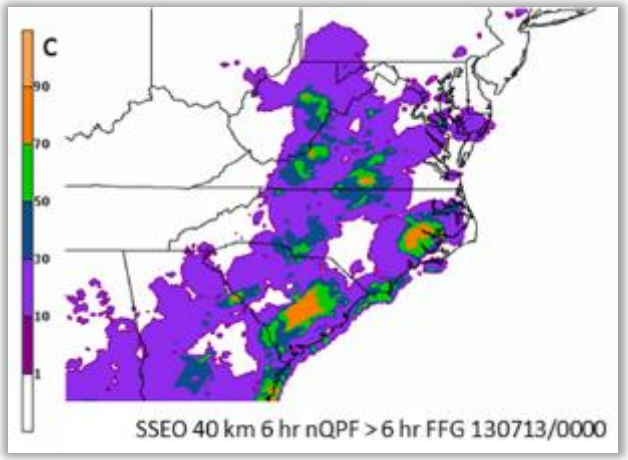
July 7-25, 2014

- 23 participants: operations, research, and academia
- Daily Activities
  - 18 hr CONUS probabilistic flash flood outlook (18-12 UTC)
  - 6 hr event-driven probabilistic flash flood forecasts (18-00 UTC and 00-06 UTC)
    - Collaboration with HWT-Hydro experiment
  - Subjective evaluation exercises



FFaIR 18 hr Flash Flood Outlook valid 140716/1200
and flash flood warnings (green), flash flood LSRs (brown), flood LSRs (blue), mPING reports (red), USGS stream gage exceedance (pink)

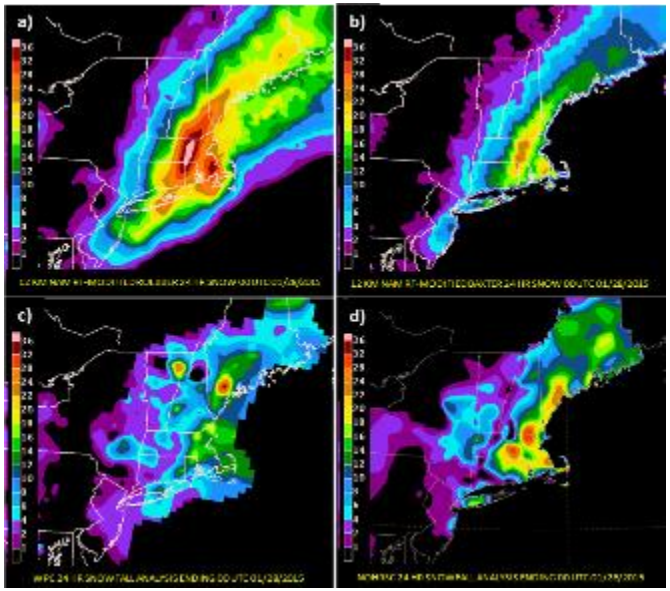
- Key datasets and findings:
  - Flash Flood Observation Database
  - Effective probabilistic guidance
    - (hi-res ensembles paired with FFG)



2015 Winter Weather Experiment

12 January – 13 February 2015

- 28 participants: operations, research, and academia
- Daily Activities
  - 24 hr deterministic snowfall forecast
  - Day 4-7 probabilistic winter precipitation, heavy snow and freezing rain forecasts
    - Daily webinar to interested NWSFOs
  - Subjective evaluation exercises



- Key datasets and findings:
  - Microphysics-based parameters (rime factor, percent of frozen precipitation) provide value to the forecaster.
  - Day 4-7 winter weather products effective; well received

Upcoming Activities

2015 FFaIR: July 6-25 at WPC

Focus: 1) Use of additional hydrologic parameters
2) Expanding probabilistic Flash Flood forecasts to Day 2
3) Communication of uncertainty

NGGPS Funded Partner Projects

- Bosart and Keyser, SUNY Albany, "An Investigation of the Skill of Week Two Extreme Temperature and Precipitation Forecasts at the NCEP-WPC“
- Colle and Chang, Stony Brook University, "Validation of Significant Weather Features and Processes in Operational Models Using a Cyclone Relative Approach."

HMT Competition

- Tentative decisions made. To be announced soon.

Key FY16 R2O Thrust

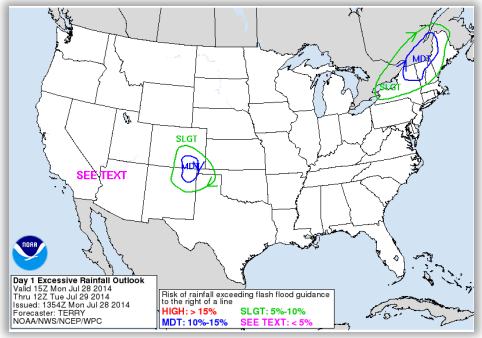
RESEARCH TO OPERATIONS

Establishing and Improving Probabilistic Services

-Particular focus on the forecaster and tools

Flash Flood and Intense Rainfall Experiment

NWS Hydrology Program



Winter Weather Experiment

NWS Winter Wx Program

Medium Range Experiment?

NWS Public Program

Day 8, 9, and 10 forecasts?

Challenges and Opportunities

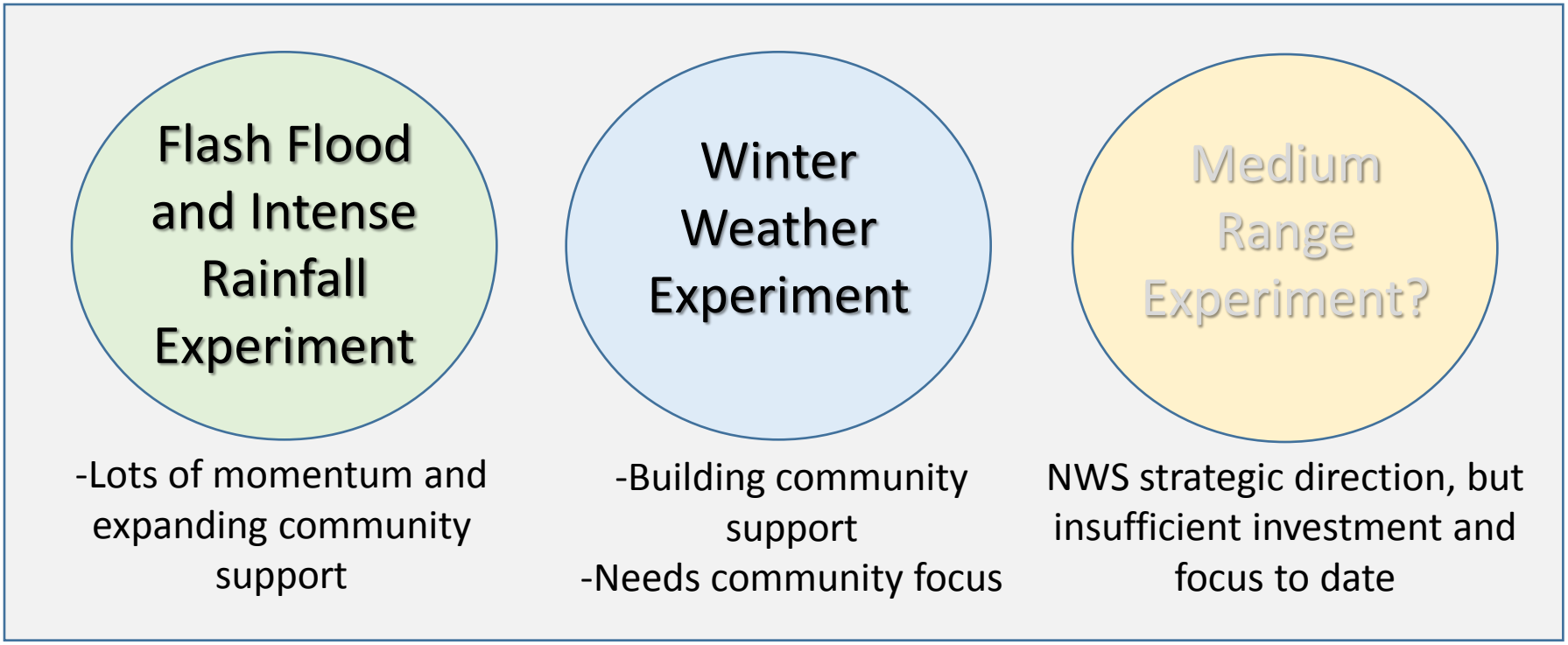
Explosion of competitive funding avenues

-New experience for HMT-WPC.

Sustaining sufficient infrastructure

-Increasing project management, IT, and data management complexity

-Need to acquire/develop these skillsets




Thank you!
HMT
Hydrometeorology Testbed
NOAA