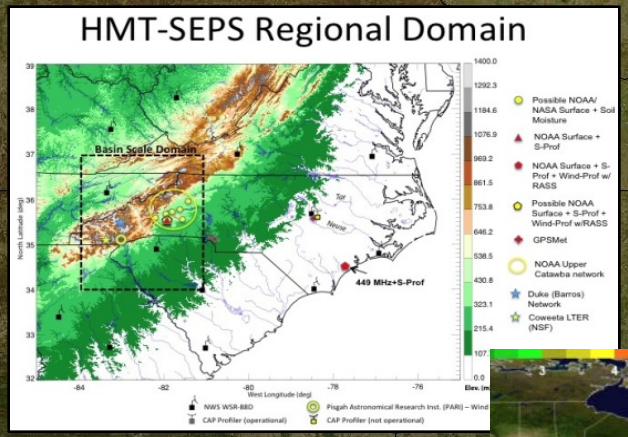
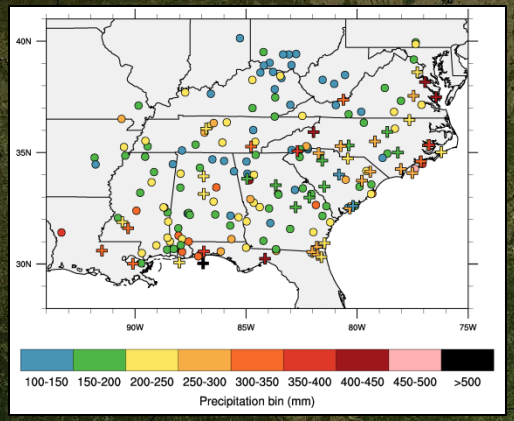
HMT-Southeast Pilot Study Data and Model Forecast Training Webinar





31 July 2013

Agenda

I. Quick intro: HMT-Southeast Pilot Study and webinar goals (Kelly Mahoney, Rob Cifelli)

II. HMT-SEPS Observational Data (Tim Coleman, Dan Gottas)

- GPS-Met precipitable water observations (Seth Gutman, Kirk Holub)

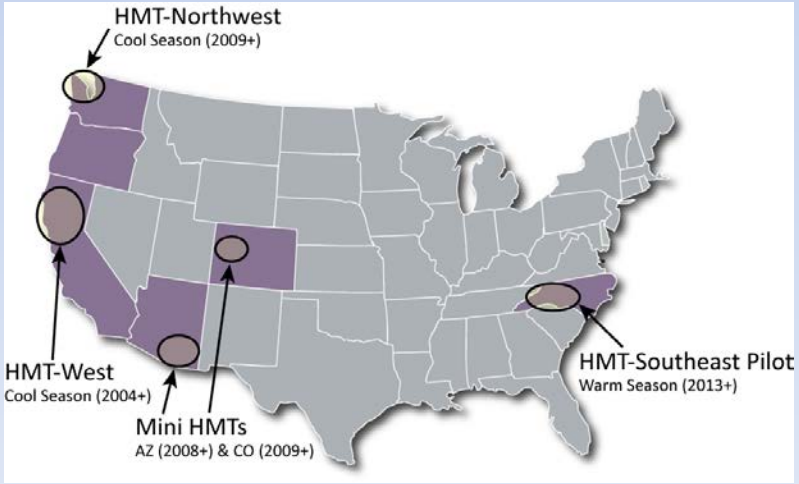
III. Model forecasts: ExREF (Ligia Bernadet)

IV. Questions, discussion

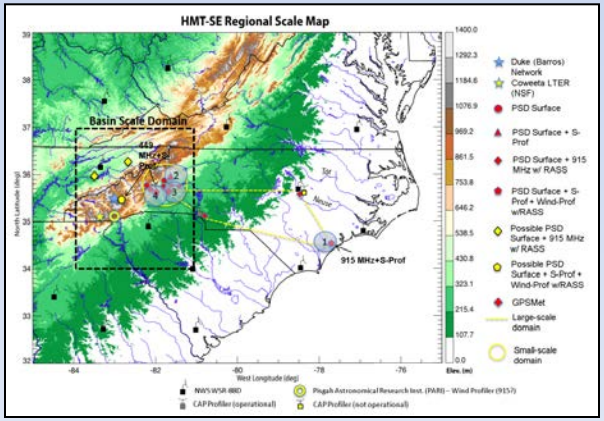
NOAA's Hydrometeorology Testbed (HMT)

- HMT conducts research on precipitation and weather conditions that can lead to flooding
- Aims to foster transition of scientific advances and new tools into forecasting operations
- Accelerates development , prototyping of advanced hydrometeorological observations, models, and physical process understanding
- HMT-Southeast: 2 parts
  1. Pilot Study in western North Carolina (Spring 2013 – Fall 2014)
  2. Operationally-oriented research on extreme precipitation and forecast challenge identification

Mobile atmospheric river observatory (as used in HMT-West and HMT-Northwest)



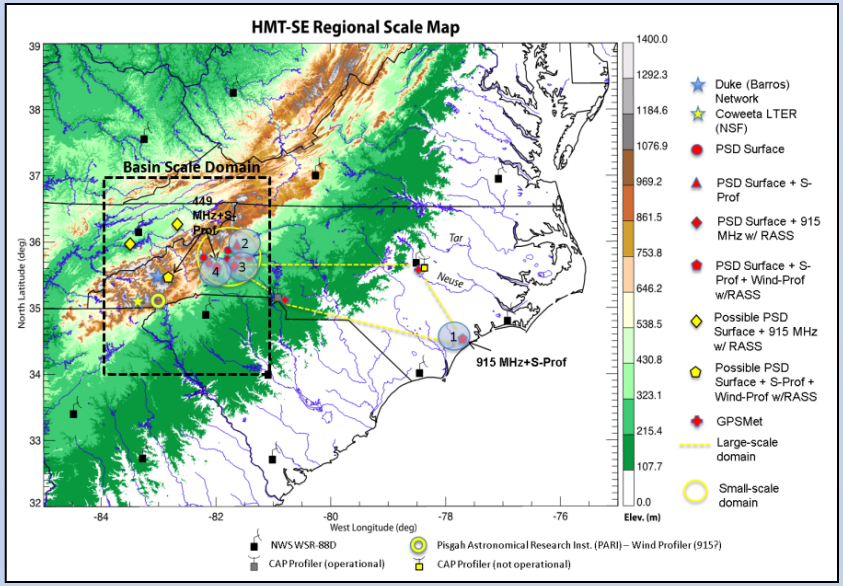
HMT-Southeast Pilot Study map



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

- Spring 2013 – Fall 2014 in western North Carolina (largest instrument focus in Upper Catawba watershed)
- QPE evaluations largely focused in western NC (but some instrumentation in central and eastern NC), QPF improvement goals region-wide.
- NOAA providing instrumentation and leveraging additional assets from NASA ground validation campaign, IPHEX
- Deployment began in June, will be completed in coming weeks.

- "Pilot study": Long-term plan, vision unclear at this time; *if* value is demonstrated, could consider expanding, prolonging (provided external support could be garnered)

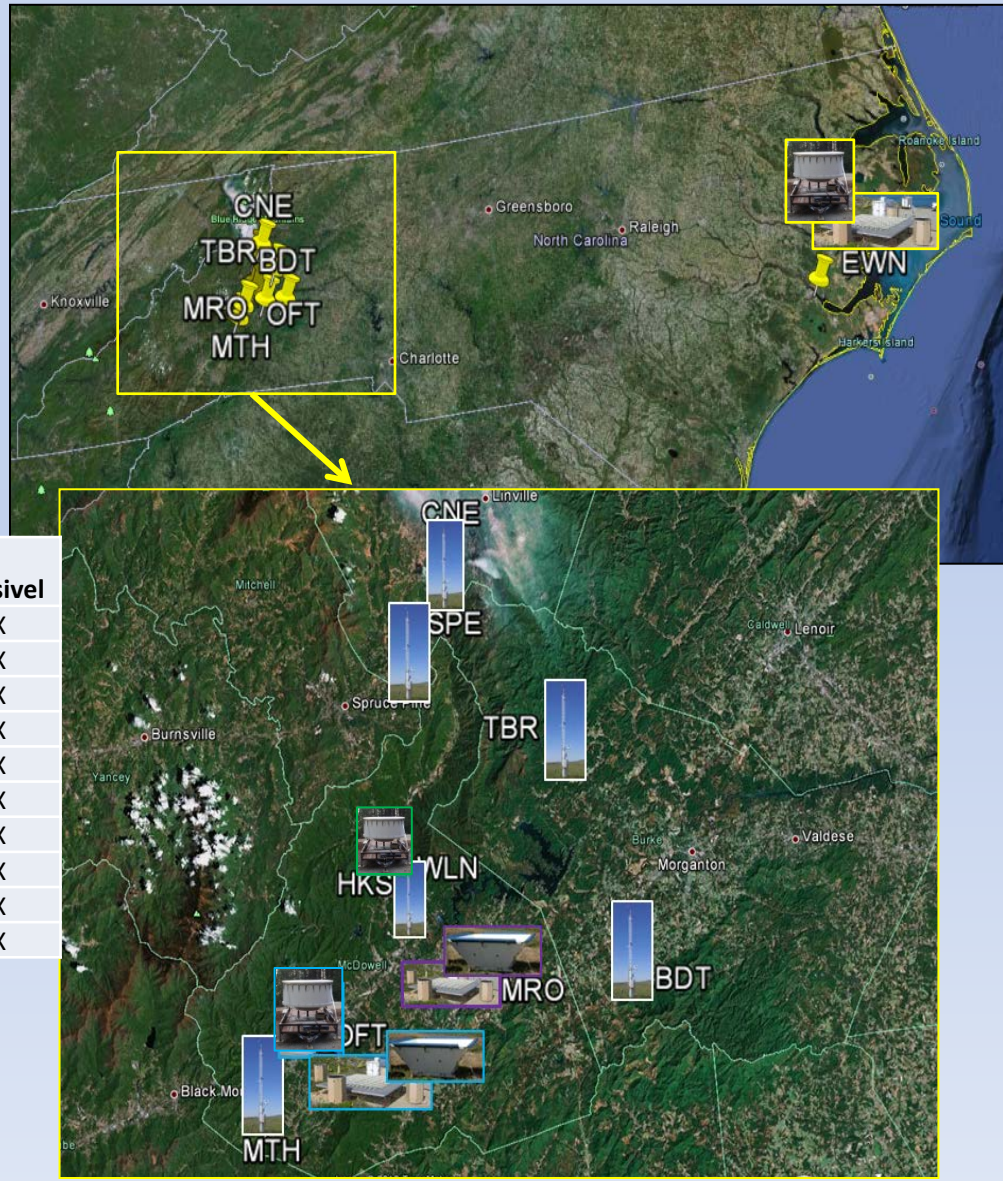


Asheville, NC Jan 2013

Newton, NC July 27 2013
Todd Sumlin, charlotteobserver.com

HMT-SEPS instrument deployment

- NOAA's HMT-SEPS deployment: 4 profiler sites and 6 surface meteorology sites
- Additional NASA precipitation gauge and disdrometer to be added to each of the surface sites in August/September
- Restoration of/upgrades to existing NC Div. of Air Quality Clayton, NC and Charlotte, NC wind profilers. Possible inclusion 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
Mount Hebron	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

Goals of Webinar

1. Inform user community of available HMT-SEPS observational and model forecast data
2. Demonstrate how information can be most easily accessed and used to address specific user needs
3. Answer community questions, address concerns, suggestions for improvement

- *The data collected is only useful if potential users know that it's there and how to use it*
- *We can only make the products better with feedback from users*
- *The funding for HMT-SEPS is limited, and we can make the most progress by working with users, collaborating and leveraging common interests and goals*

Agenda

I. Quick intro: HMT-Southeast Pilot Study and webinar goals (Kelly Mahoney, Rob Cifelli)

II. HMT-SEPS Observational Data (Tim Coleman, Dan Gottas)

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III. Model forecasts: ExREF (Ligia Bernadet)

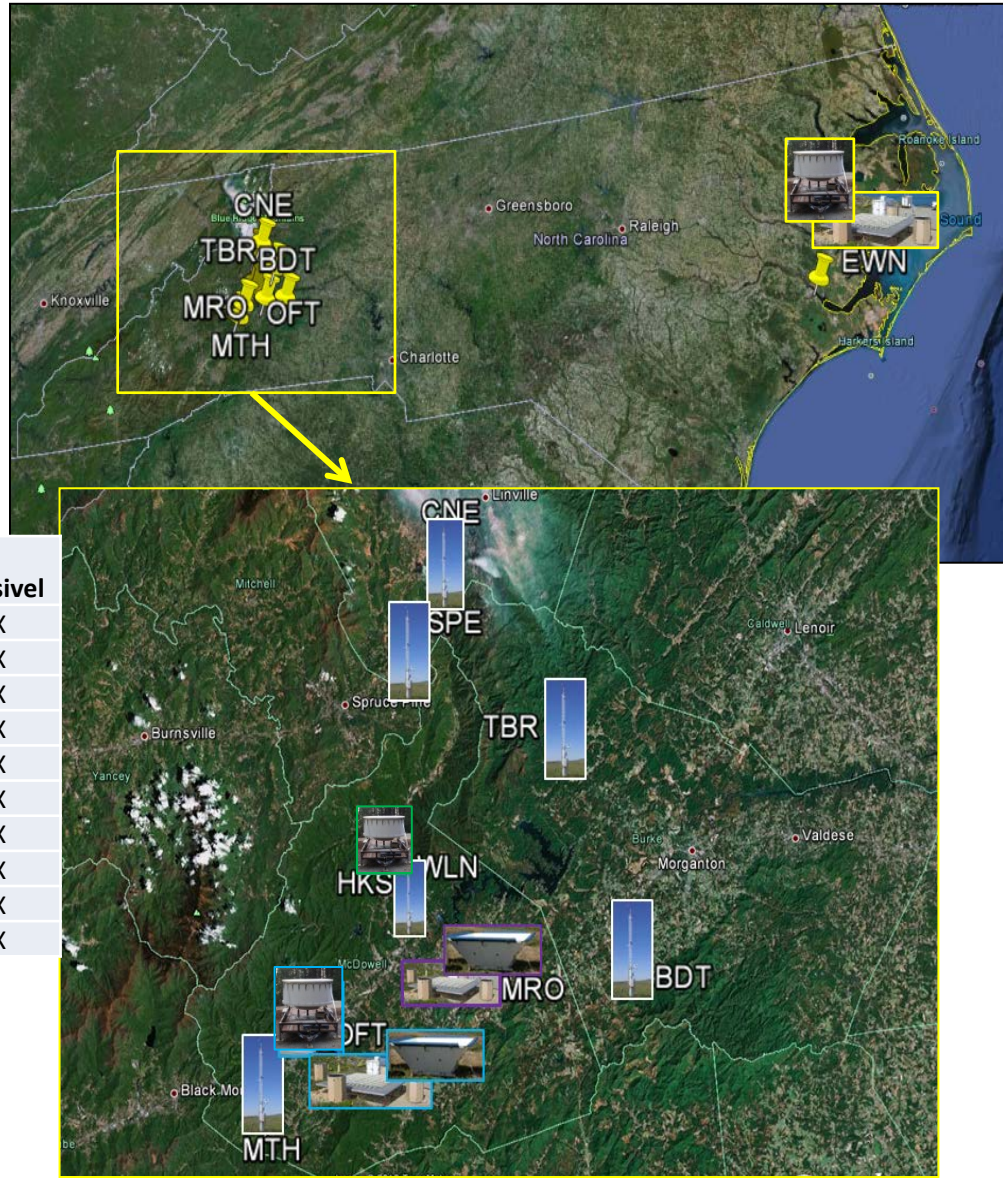
IV. Questions, discussion

Observations and Measurements in HMT-Southeast

- What instruments are deployed?
- What do they measure?
- Where are they located?
- Web tool demonstration
- Questions and Answers

HMT-SEPS instrument deployment

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



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Hankins	HKS	379				X	X		X
Marion	MRO	384		X	X		X		X
Mount Hebron	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

Wind Profilers

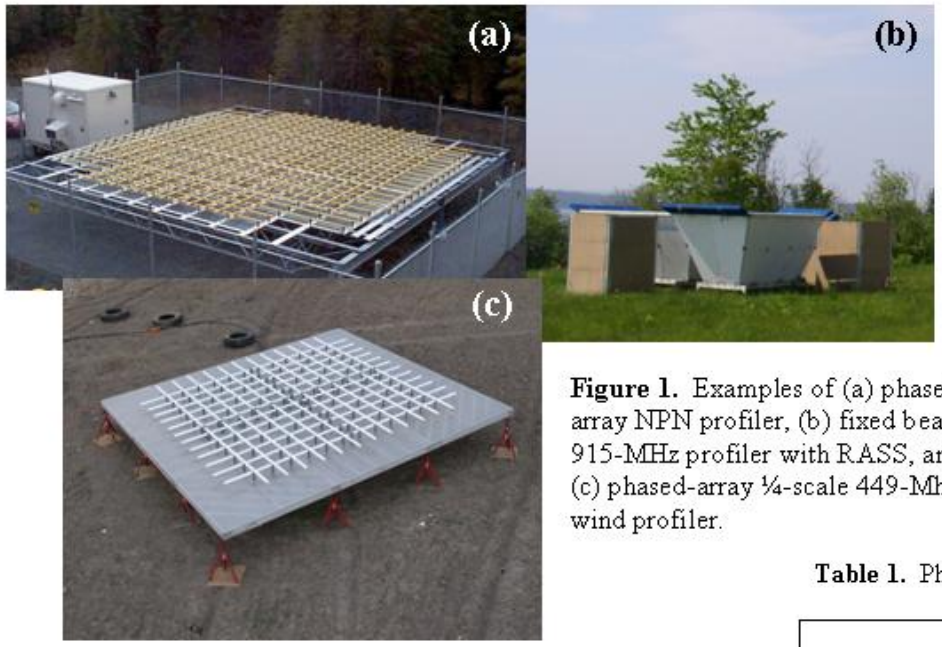


Figure 1. Examples of (a) phased-array NPN profiler, (b) fixed beam 915-MHz profiler with RASS, and (c) phased-array ¼-scale 449-Mhz wind profiler.

Table 1. Physical, operating, and sampling characteristics of wind profilers.

	404-MHz (NPN)	**915-MHz (boundary layer)**	**449-MHz (quarter- scale)**
Antenna type	Coaxial-colinear phased array	Flat rectangular microstrip patch	Coaxial-colinear phased array
Antenna diameter (m)	13	2	6
Beamwidth (deg.)	4	10	10
Peak transmit power (W)	6000	500	2000
Transmit pulse width (μs)	3.3[P], 20[P]	0.417*, 0.708*[,P]	0.708*, 2.833
Height coverage (m)	500** – 16,000	120 – 4,000	180[+] – 8,000
Vertical resolution (m)	320[✚], 900[✚]	63, 106*	106, 212*[,✚]
Temporal resolution (min)	60	60	60

* These settings reflect how the profilers were operated during typical deployments. Other degraded transmit and sampling resolutions are possible.

P Pulse-coding was used in selected operating modes to boost signal power and increase altitude coverage (for more information on pulse coding, see Ghebrebrhan, 1990).

\+ This minimum detectable range has been achieved with the ¼-scale 449-MHz profilers using a 0.7-μs pulse.

** Signal attenuators prevent accurate radar reflectivity data below 1 km.

✚ Increased vertical resolution as compared to the transmit pulse length was accomplished by oversampling.

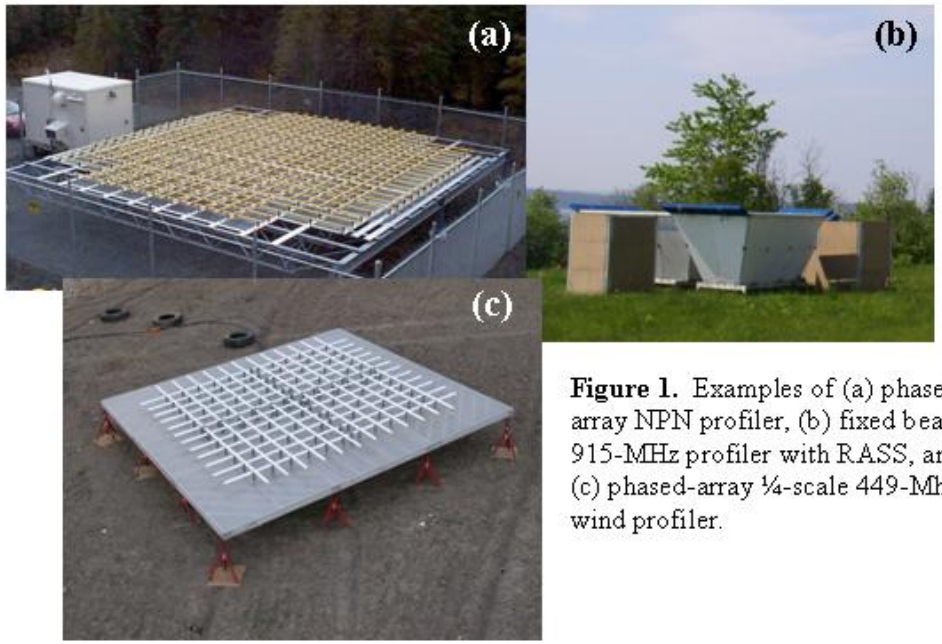


Figure 1. Examples of (a) phased-array NPN profiler, (b) fixed beam 915-MHz profiler with RASS, and (c) phased-array ¼-scale 449-Mhz wind profiler.

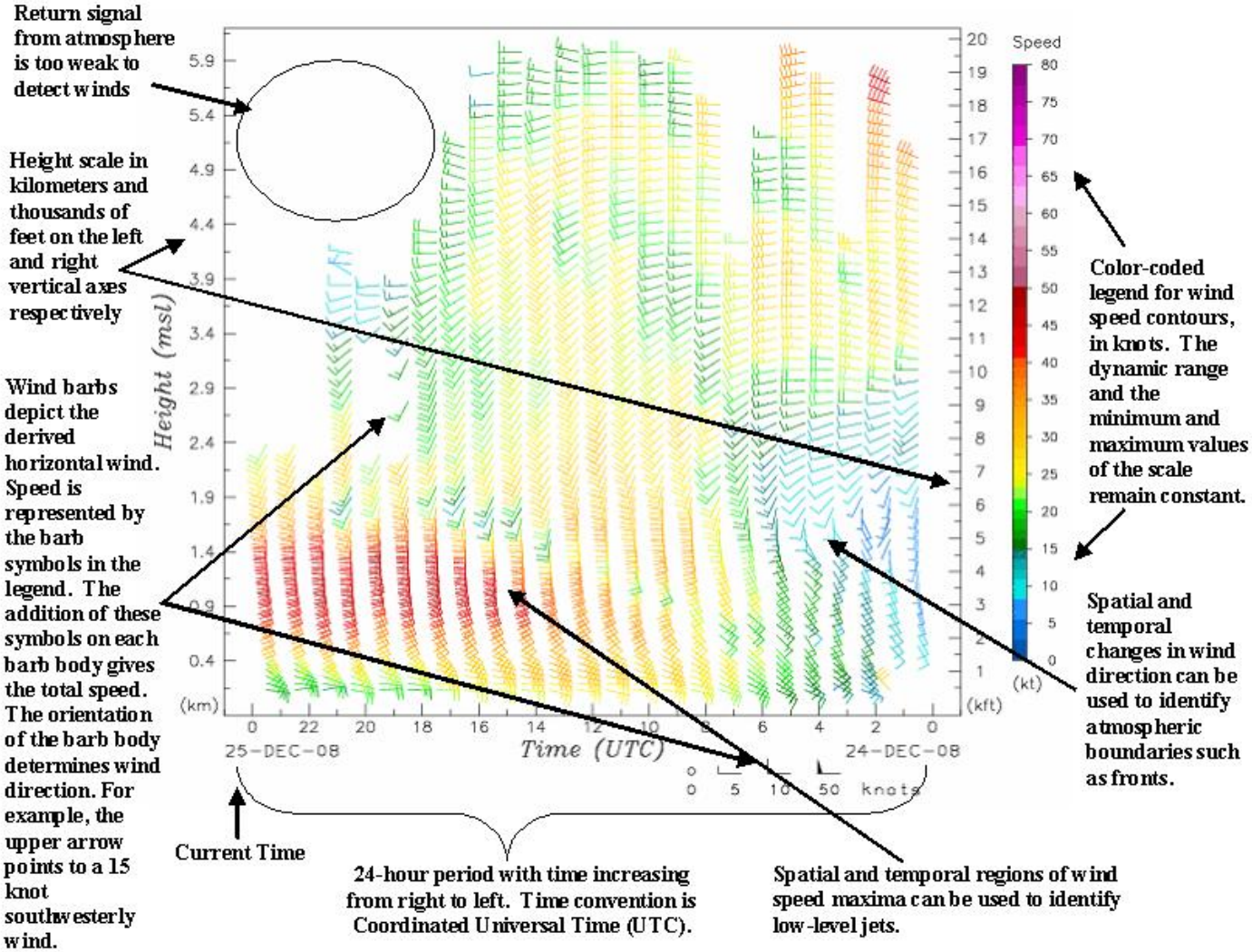
Wind Profilers

What they measure

- **Horizontal wind speed and direction**
- **SNR (reflectivity)**
- **RASS (virtual and potential temp)**
- **Vertical velocity**
- **Snow level**

Wind Profiler Winds

A radar wind profiler measures the Doppler shift of electromagnetic energy scattered back from atmospheric turbulence and hydrometeors along 3-5 vertical and off-vertical pointing beam directions. Backscattered signal strength and radial-component velocities are remotely sensed along all beam directions, and are combined to derive the horizontal wind field over the radar. Images include wind barbs, which depict the horizontal wind speed and direction, and color-coded wind speed. These data are typically sampled and averaged for each hour, and typically have 60 m and/or 100 m vertical resolution up to ~4 km and 8 km for the 915 MHz and 449 MHz systems respectively.



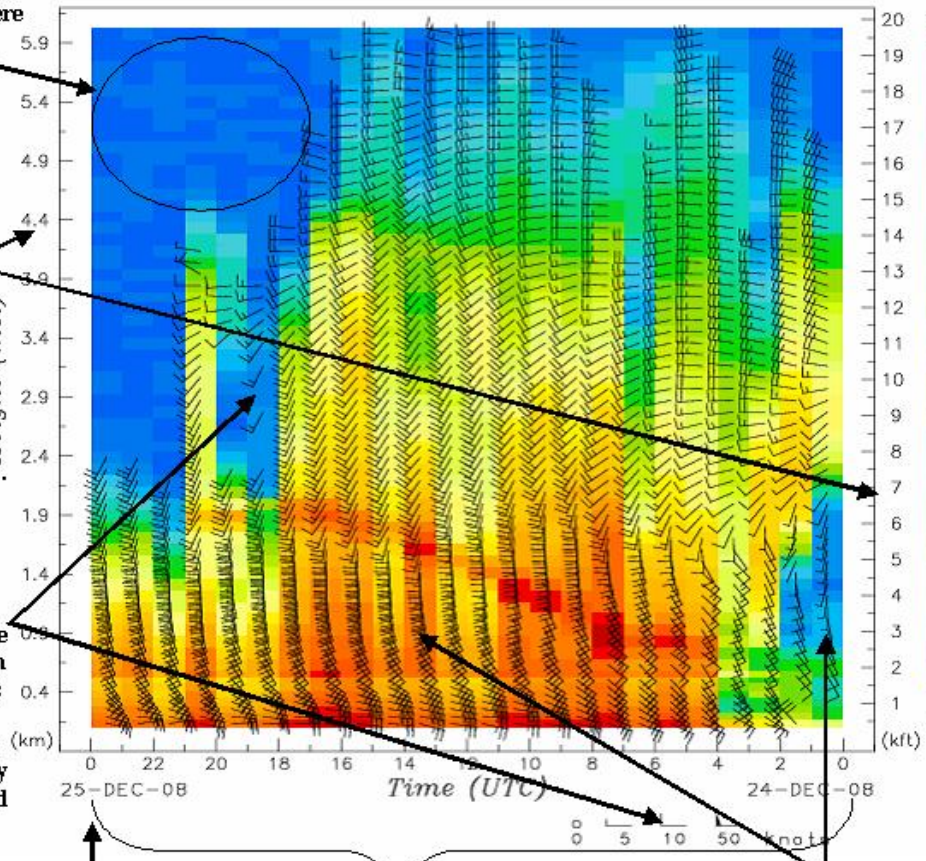
Wind Profiler Signal-to-Noise Ratio and Winds

A radar wind profiler measures the Doppler shift of electromagnetic energy scattered back from atmospheric turbulence and hydrometeors along 3-5 vertical and off-vertical pointing beam directions. Backscattered signal strength and radial-component velocities are remotely sensed along all beam directions, and are combined to derive the horizontal wind field over the radar. Images include color contours of signal-to-noise ratio and wind barbs, which depict the horizontal wind speed and direction. These data are typically sampled and averaged hourly, and typically have 60 m and/or 100 m vertical resolution up to ~4 km and ~8 km for the 915 MHz and 449 MHz systems respectively.

Return signal from atmosphere is too weak to detect winds

Height scale in kilometers and thousands of feet on the left and right vertical axes respectively

Wind barbs depict the derived horizontal wind. Speed is represented by the barb symbols in the legend. The addition of these symbols on each barb body gives the total speed. The orientation of the barb body determines wind direction. For example, the upper arrow points to a 15 knot southwesterly wind.



Color-coded legend for signal-to-noise ratio (SNR) contours, in decibels. The dynamic range and the minimum and maximum values of the scale remain constant. Higher (lower) values of SNR are associated with increased (decreased) backscattered energy.

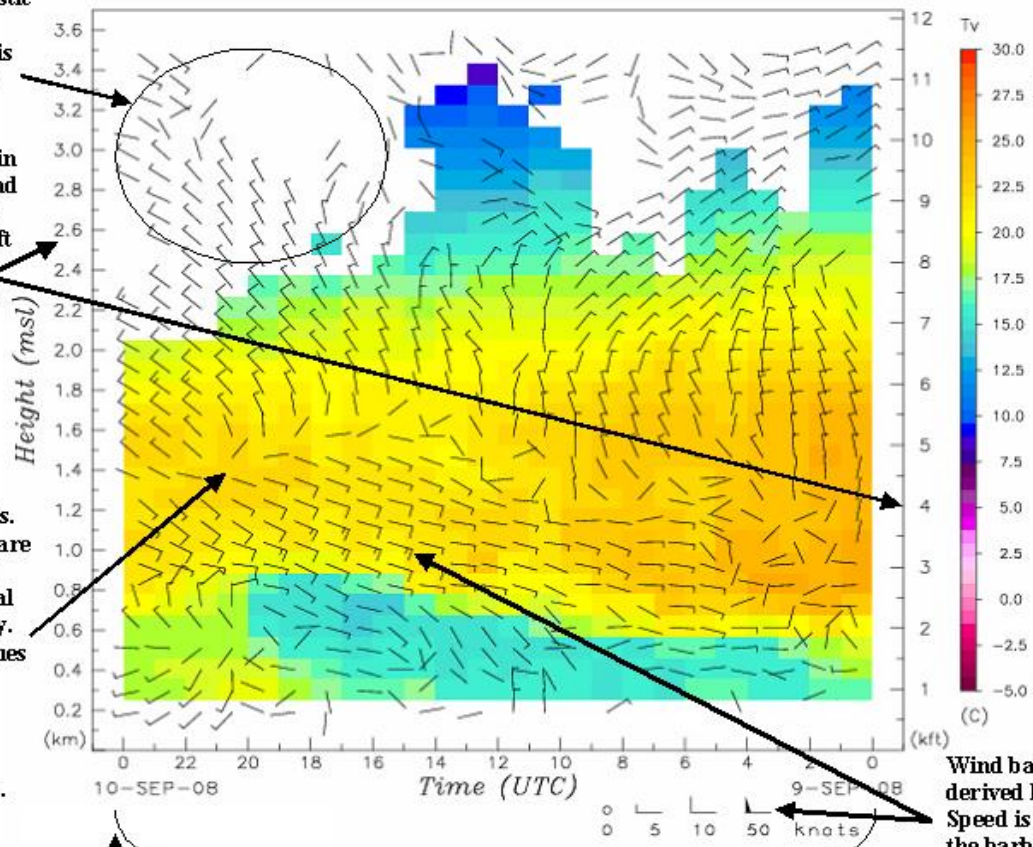
Current Time

24-hour period with time increasing from right to left. Time convention is Coordinated Universal Time (UTC).

Higher values of SNR correspond to backscatter from precipitation, and are correlated with precipitation rate. Lower values of SNR are associated with backscatter from clear-air turbulence.

Wind Profiler Temperature

A radio acoustic sounding system (RASS) is used in conjunction with the wind profiler to measure atmospheric virtual temperature. Images include contours of virtual temperature without the vertical radial velocity removed, and the derived horizontal winds depicted with wind barbs. These data are typically sampled and averaged for five minutes each hour, and typically have ~60 m vertical resolution up to ~1.5 km and 3.5 km for the 915 MHz and 449 MHz systems respectively.



Return acoustic signal from atmosphere is too weak to detect

Height scale in kilometers and thousands of feet on the left and right vertical axes respectively

Color fill represents virtual temperature measurements. These values are not corrected for the vertical radial velocity. Non-zero values of vertical velocity will produce an error in this measurement.

Color-coded legend for virtual temperature contours, in Celsius. The dynamic range of this scale remains constant, and the minimum and maximum values of the scale vary according to season and geographical location.

Wind barbs depict the derived horizontal wind. Speed is represented by the barb symbols in the legend. The addition of these symbols on each barb body gives the total speed. The orientation of the barb body determines wind direction. For example, the upper arrow points to a 15 knot east-southeasterly wind.

Current Time

24-hour period with time increasing from right to left. Time convention is Coordinated Universal Time (UTC).

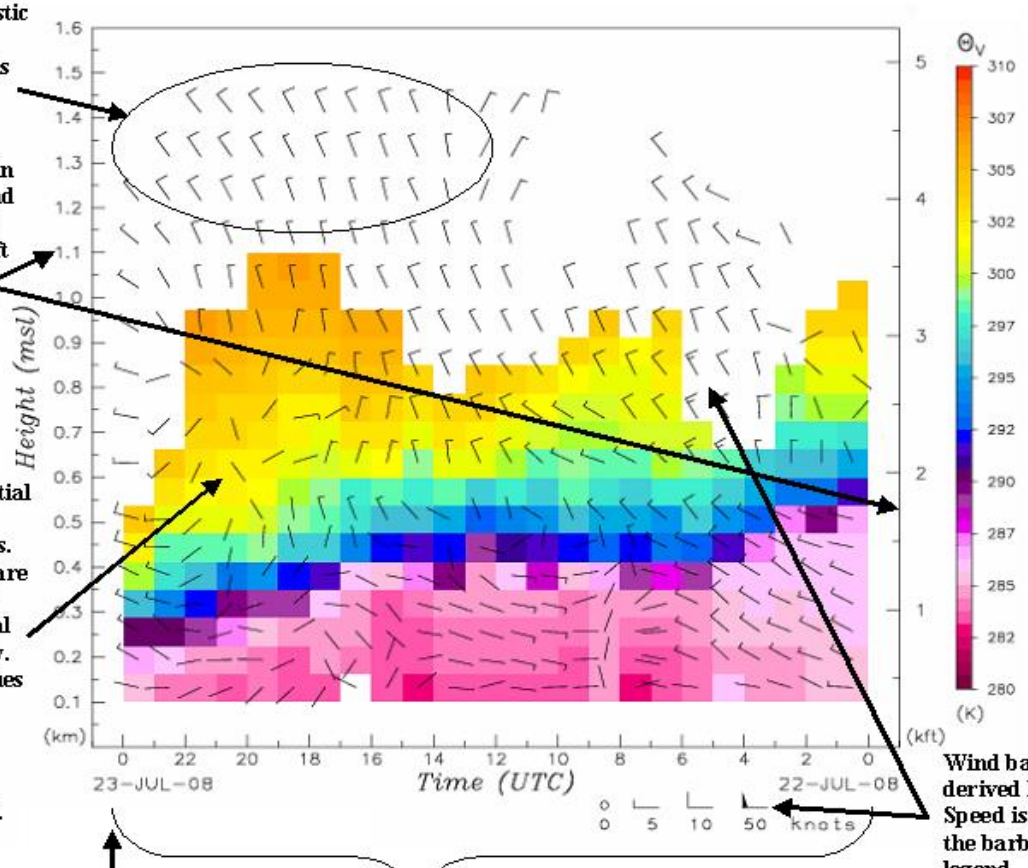
Wind Profiler Virtual Potential Temperature

A radio acoustic sounding system (RASS) is used in conjunction with the wind profiler to measure atmospheric virtual temperature. Using collocated near-surface measurements of temperature, relative humidity, and pressure, vertical profiles of virtual potential temperature are derived. Images include contours of virtual potential temperature without the vertical radial velocity removed, and the derived horizontal winds depicted with wind barbs. These data are typically sampled and averaged for five minutes each hour, and typically have ~60 m vertical resolution up to ~1.5 km and 3.5 km for the 915 MHz and 449 MHz systems respectively.

Return acoustic signal from atmosphere is too weak to detect

Height scale in kilometers and thousands of feet on the left and right vertical axes respectively

Color fill represents virtual potential temperature measurements. These values are not corrected for the vertical radial velocity. Non-zero values of vertical velocity will produce an error in this measurement.



Color-coded legend for virtual potential temperature contours, in Kelvin. The dynamic range of this scale remains constant, and the minimum and maximum values of the scale vary to accommodate the range of measured values over the period.

Wind barbs depict the derived horizontal wind. Speed is represented by the barb symbols in the legend. The addition of these symbols on each barb body gives the total speed. The orientation of the barb body determines wind direction. For example, the upper arrow points to a 15 knot northwesterly wind.

Current Time

24-hour period with time increasing from right to left. Time convention is Coordinated Universal Time (UTC).

Wind Profiler Snow Level

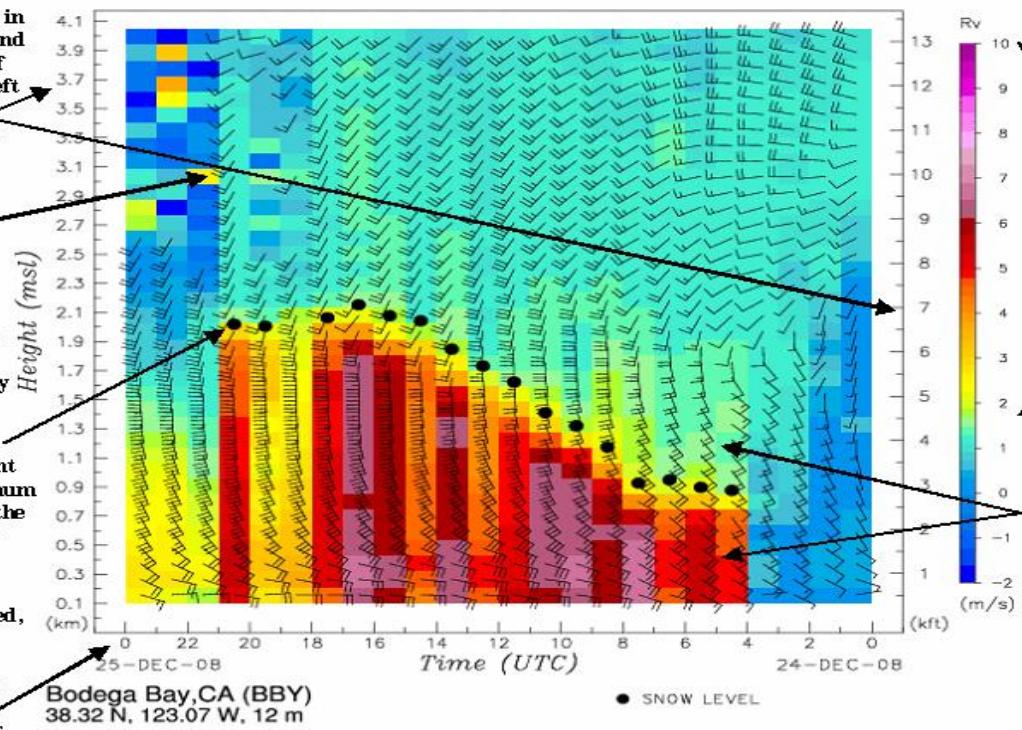
A radar wind profiler measures the Doppler shift of electromagnetic energy scattered back from atmospheric turbulence and hydrometeors along 3-5 vertical and off-vertical pointing beam directions. During ice-induced precipitation events, backscattered signal strength and radial-component velocities exhibit unique behaviors at the altitude where snow transitions to rain, which is referred to as the radar bright band. Images include color contours of vertical radial velocity and circular symbols to depict the height of the maximum SNR within the radar bright band, as derived from an automated bright-band detection algorithm. These data are typically sampled and averaged hourly, and typically have 60 m and/or 100 m vertical resolution up to ~4 km and ~8 km for the 915 MHz and 449 MHz systems respectively.

Height scale in kilometers and thousands of feet on the left and right vertical axes respectively

Wind barbs depict the derived horizontal wind. For example, the arrow points to a 20 knot southwesterly wind.

Algorithm – derived height of the maximum SNR within the radar bright band.

24 hours of data displayed, with time increasing from right to left. Time convention is Coordinated Universal Time (UTC).



Color-coded legend for vertical radial velocity contours, in meters per second. The dynamic range and the minimum and maximum values of the scale remain constant.

The vertical radial velocity during precipitation estimates the fall velocity of hydrometeors. Above the bright band, snow falls at slower speeds than rain below the bright band.

Time (UTC)	2330	2230	2130	2030	1930	1830	1730	1630	1530	1430	1330	1230
Snow Level (m)	none	none	none	2018	2005	none	2063	2152	2077	2042	1847	1731
Snow Level (ft)	none	none	none	6619	6576	none	6766	7058	6812	6697	6058	5677
Sfc Temp (C)	8.45	8.26	8.25	8.16	8.11	7.40	7.12	7.04	7.03	7.07	7.02	6.96

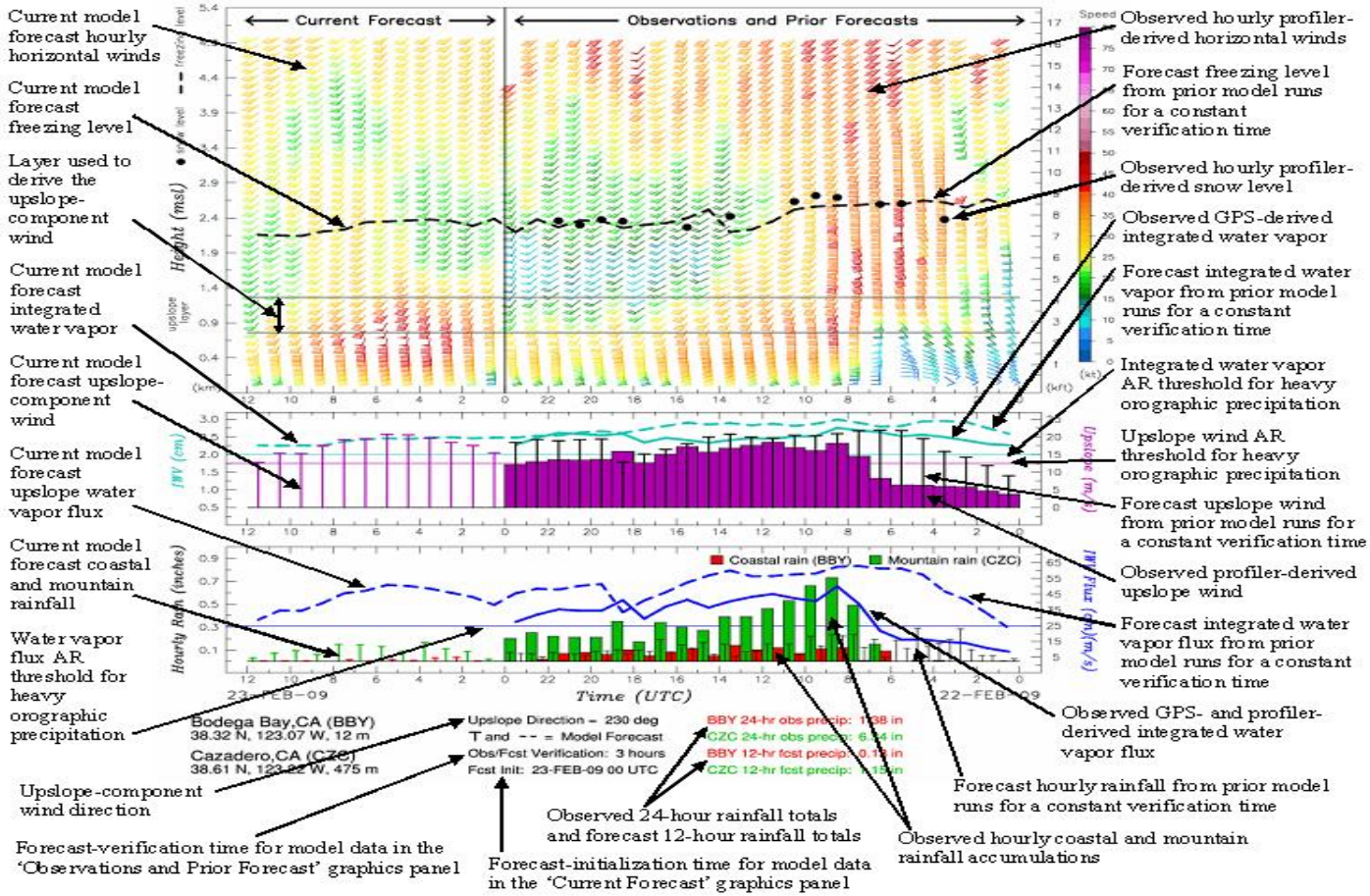
Time (UTC)	1130	1030	0930	0830	0730	0630	0530	0430	0330	0230	0130	0030
Snow Level (m)	1621	1411	1320	1174	927	949	898	877	none	none	none	none
Snow Level (ft)	5316	4628	4329	3850	3040	3112	2945	2876	none	none	none	none
Sfc Temp (C)	6.93	6.92	6.80	6.87	6.93	6.75	7.21	7.33	7.50	7.50	7.70	8.22

Table lists algorithm-derived snow level in meters and feet, and surface temperature in Celsius. Surface temperatures below freezing combined with elevated snow levels can indicate sleet or freezing rain.

White, A.B., D.J. Gottas, F.M. Ralph, and P.J. Neiman, 2002: An automated bright-band height detection algorithm for use with Doppler radar spectral moments. *J. Atmos. Oceanic Technol.*, **19**, 687–697.

Coastal Atmospheric River (AR) Monitoring and Early Warning System

Profiler and precipitation observations provided by the NOAA/ESRL Physical Sciences Division
GPS observations and model forecast provided by the NOAA/ESRL Global Systems Division



References

Jankov, I., J. Bao, P.J. Neiman, P.J. Schultz, H. Yuan, A.B. White, 2009: Evaluation and comparison of microphysical algorithms in WRF-ARW model simulations of atmospheric river events affecting the California coast. *J. of Hydrometeor.*, **10**, 847-870.

Neiman, P.J., A.B. White, F.M. Ralph, D.J. Gottas, and S.I. Gutman, 2009: A water vapor flux tool for precipitation forecasting. *Water Management*, **162**, WM2, doi: 10.1680/wama.2009.162.2.83.

Neiman, P.J., F.M. Ralph, A.B. White, D.E. Kingsmill, and P.O.G. Persson, 2002: The statistical relationship between upslope flow and rainfall in California's coastal mountains: Observations during CALJET. *Mon. Wea. Rev.*, **130**, 1468-1492.

Ralph, F.M., P.J. Neiman, G.A. Wick, S.I. Gutman, M.D. Dettinger, D.R. Cayan, and A.B. White, 2006: Flooding on California's Russian River: Role of atmospheric rivers. *Geophys. Res. Lett.*, **33**, L13801, doi:10.1029/2006GL026689.

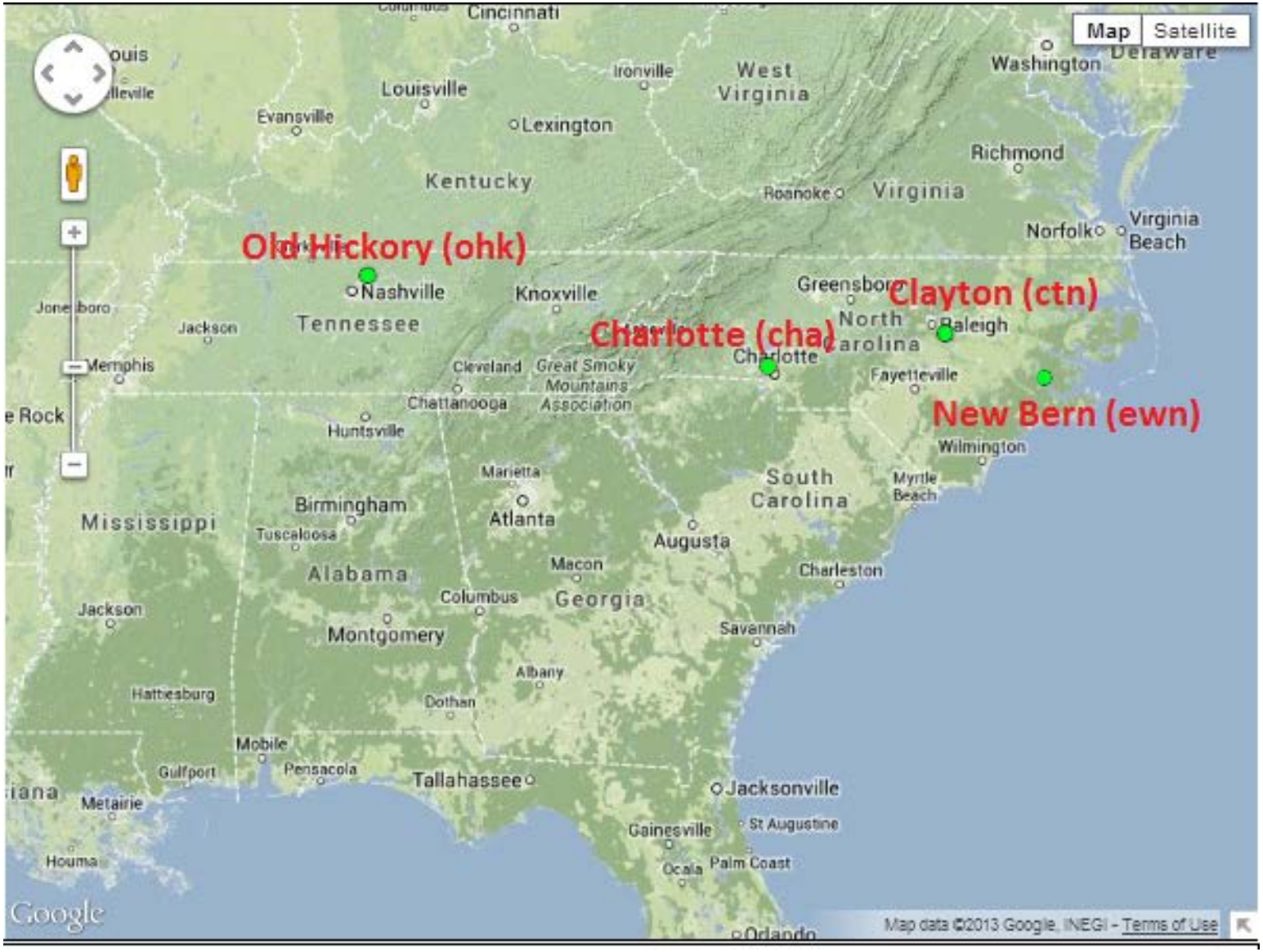
White, A.B., D.J. Gottas, E.T. Strem, F.M. Ralph, P.J. Neiman, 2002: An automated brightband height detection algorithm or use with Doppler radar spectral moments. *J. Atmos. Oceanic Technol.*, **19**, 687B697.

Yuan, H., J.A. McGinley, P.J. Schultz, C.J. Anderson, and C. Lu, 2008: Short-range precipitation forecasts from time-lagged multimodel ensembles during the HMT-West-2006 Campaign. *J. of Hydrometeor.*, **9**, 447-491.

Product Access: http://www.esrl.noaa.gov/psd/data/obs/

Contacts: Paul.J.Neiman@noaa.gov Daniel.Gottas@noaa.gov

HMT-SE Wind Profilers (as of 7/31/2013)



3 GHz and FMCW Precipitation Profilers

Table 1. S-band profiler characteristics

Frequency (GHz)	2.875
Antenna diameter (m)	2.4
Average transmit power (W)	20
Peak power (W)	360
Beamwidth (deg)	2.5
Range resolution (m)	45, 60, 105, 420
Time resolution, nominal (s)	30
Doppler technique	FFT
Estimated sensitivity (dBZ*e* at 10 km)	−14

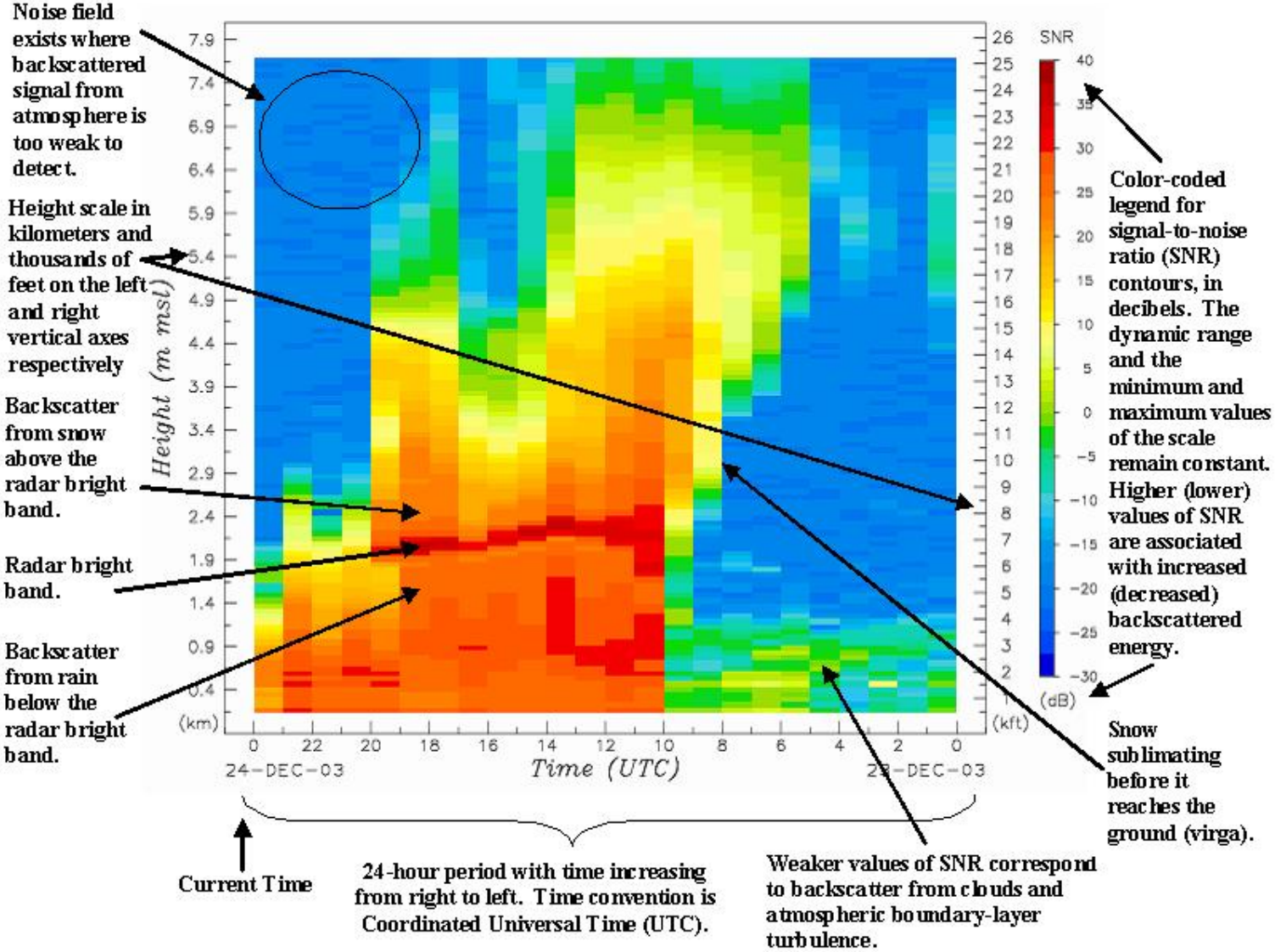
3 GHz and FMCW Precipitation Profilers

What they measure

- SNR (reflectivity)
- Vertical velocity
- Snow level

S-band Precipitation Profiler Reflectivity

An S-band precipitation profiler measures the magnitude and Doppler shift of electromagnetic energy scattered back from hydrometeors and clouds along a vertically pointing radar beam. Images include color contours of signal-to-noise ratio, which is related to precipitation distribution and intensity. These data are typically sampled and averaged hourly, and have a 60 m vertical resolution up to ~8 km.



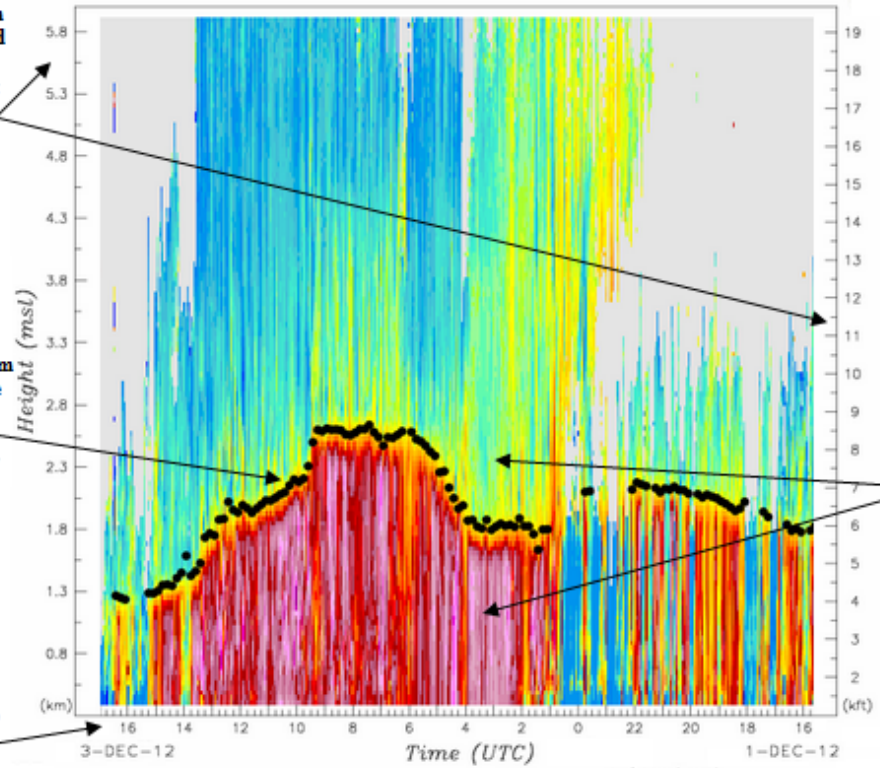
S-band Precipitation Profiler Snow Level

An S-band precipitation profiler measures the magnitude and Doppler shift of electromagnetic energy scattered back from hydrometeors and clouds along a vertically pointing radar beam. During ice-induced precipitation events, backscattered signal strength and radial-component velocities exhibit unique behaviors at the altitude where snow transitions to rain, which is referred to as the radar bright band. Images include color contours of vertical radial velocity and circular symbols to depict the height of the maximum SNR within the radar bright band (or snow level), as derived from an automated bright-band detection algorithm. The vertical radial velocity and SNR data are sampled every ~30 seconds, and typically have 40-60 m vertical resolution up to ~8 km. The bright-band detection algorithm produces averaged snow-level heights every 10-15 minutes, when bright-band precipitation is present.

Height scale in kilometers and thousands of feet on the left and right vertical axes respectively

Algorithm – derived height of the maximum SNR within the radar bright band (also known as snow level). Values are averaged and produced every 10-15 minutes.

24 hours of data displayed, with time increasing from right to left. Time convention is Coordinated Universal Time (UTC).



Color-coded legend for vertical radial velocity contours, in meters per second. The dynamic range and the minimum and maximum values of the scale remain constant.

The vertical radial velocity during precipitation estimates the fall velocity of hydrometeors. Above the bright band, snow falls at slower speeds than rain below the bright band.

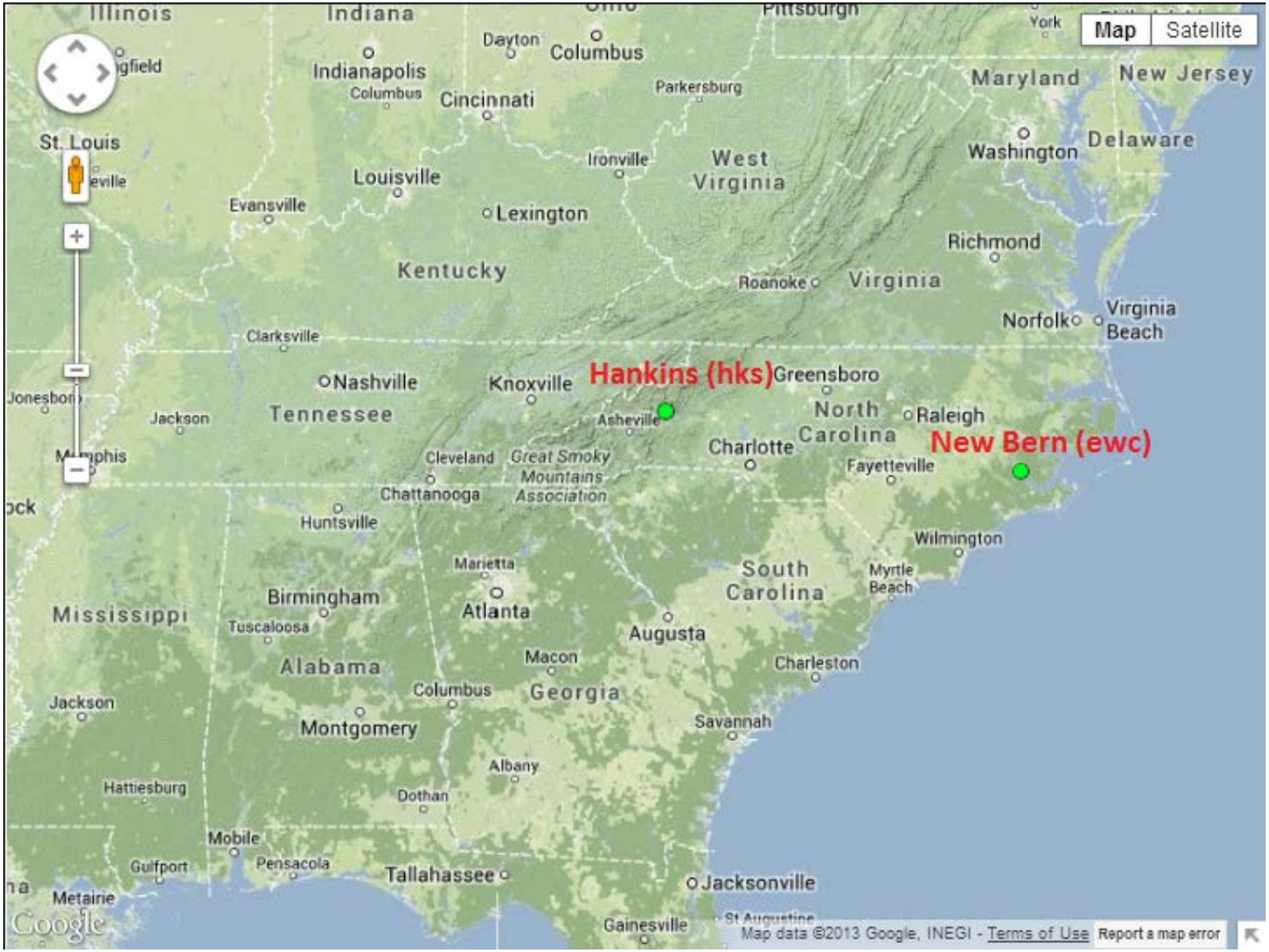
Time (UTC)	1630	1530	1430	1330	1230	1130	1030	0930	0830	0730	0630	0530	0430
Snow Level (m)	1249	1285	1352	1556	1908	1980	2087	2402	2596	2591	2538	2488	2091
Snow Level (ft)	4096	4214	4434	5103	6259	6494	6847	7878	8516	8500	8324	8160	6858

Time (UTC)	0330	0230	0130	0030	2330	2230	2130	2030	1930	1830	1730	1630	1530
Snow Level (m)	1845	1830	1797	none	2102	2118	2146	2116	2061	1989	1918	1794	1829
Snow Level (ft)	6053	6002	5895	none	6896	6947	7038	6940	6760	6525	6292	5885	6000

Table lists algorithm-derived snow level in meters and feet, and surface temperature (where available) in Celsius. Surface temperatures below freezing combined with elevated snow levels can indicate sleet or freezing rain.

White, A.B., D.J. Gottas, F.M. Ralph, and P.J. Neiman, 2002: An automated bright-band height detection algorithm for use with Doppler radar spectral moments. *J. Atmos. Oceanic Technol.*, 19, 687–697.

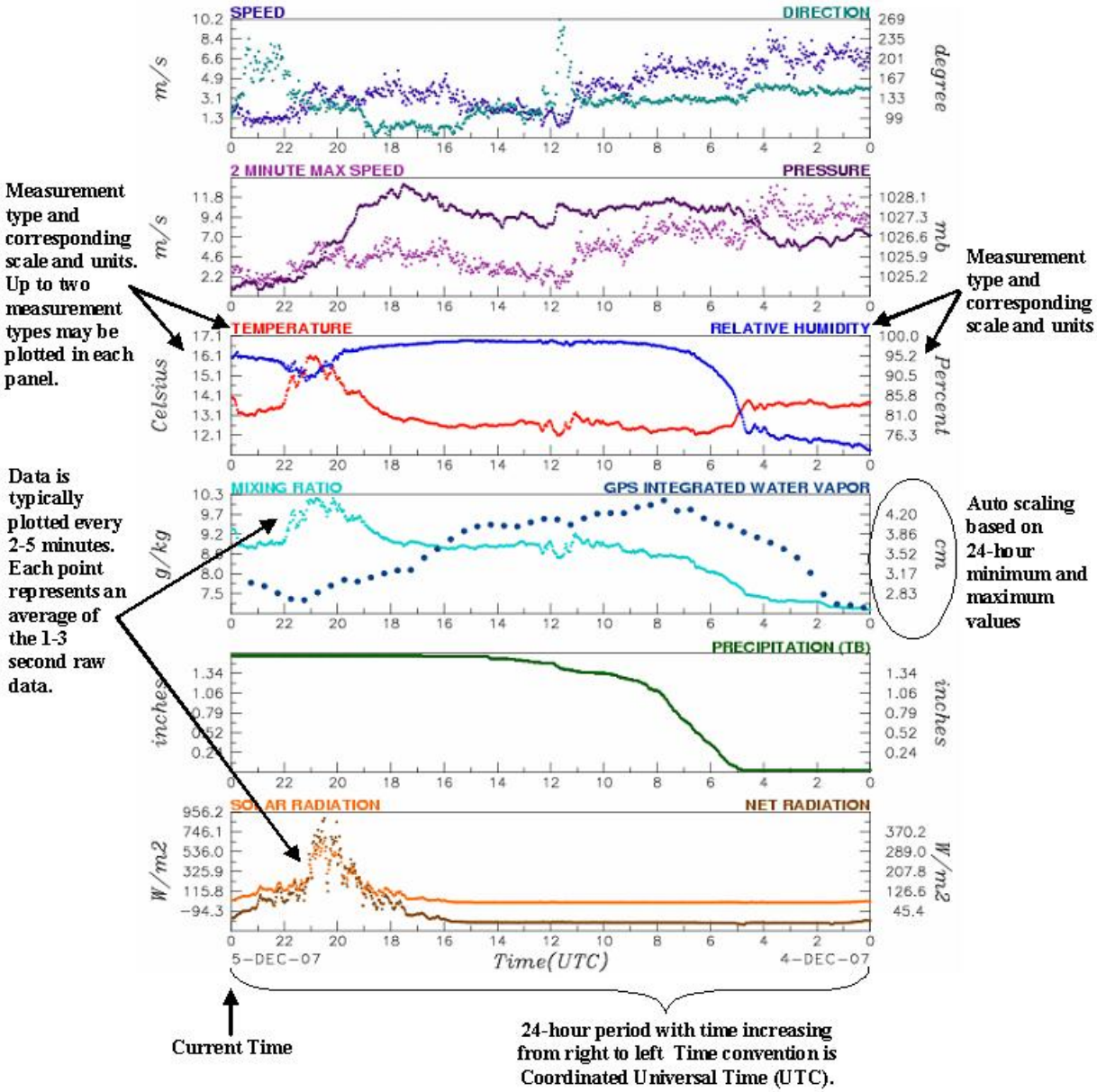
HMT-SE Precipitation Profilers: (as of 7/31/2013)



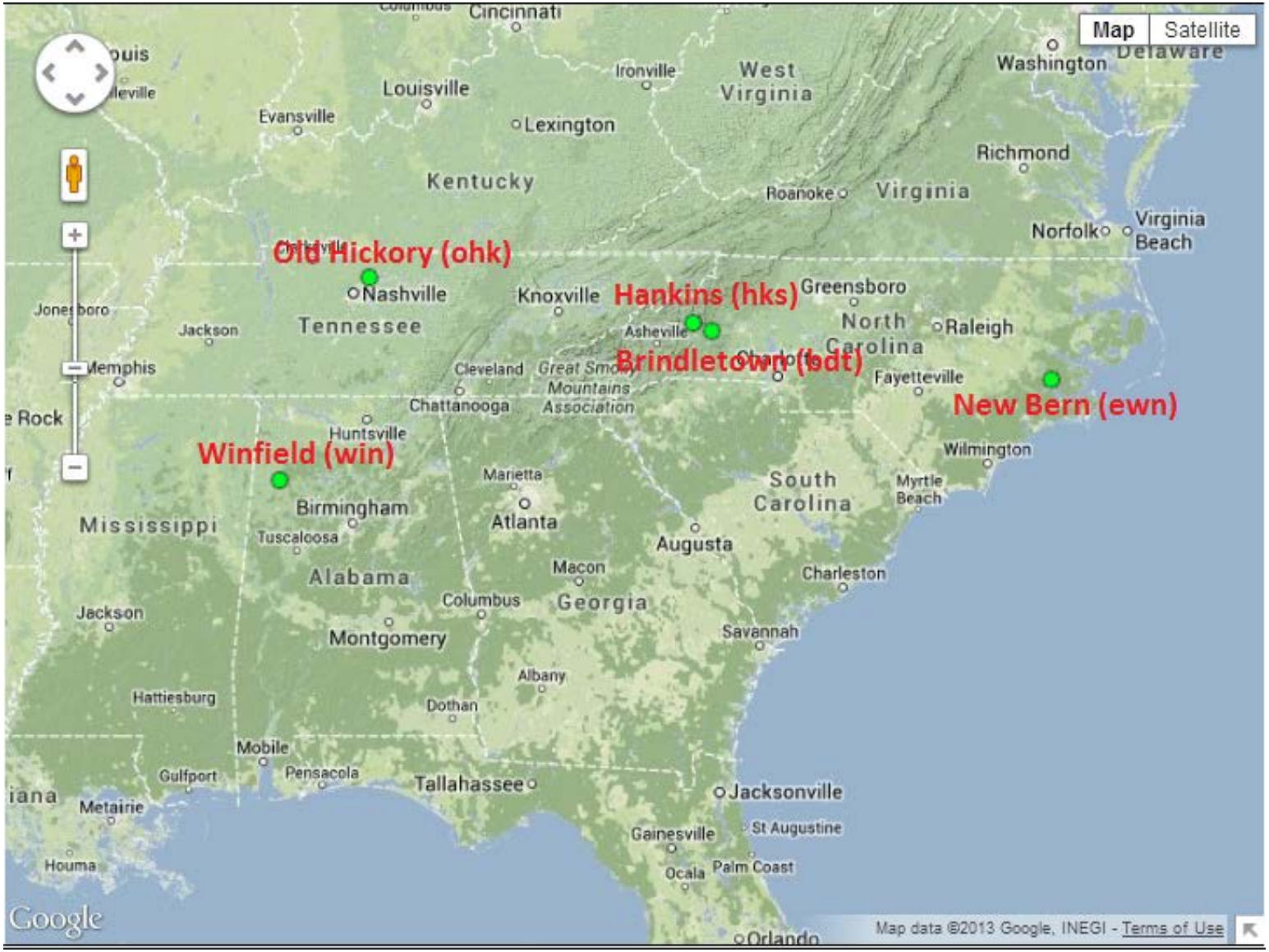
Surface Met Instrumentation

Surface Meteorology and Physics Product Description

A variety of instruments are used to measure various quantities related to meteorology, precipitation, radiation, soil, and atmospheric turbulence near the earth's surface. A standard suite of instruments are typically deployed at every site to monitor meteorological state variables. In addition, other instrumentation configurations are deployed to on a site-by-site basis to support hydrologic, surface-energy budget, and atmospheric turbulence applications.

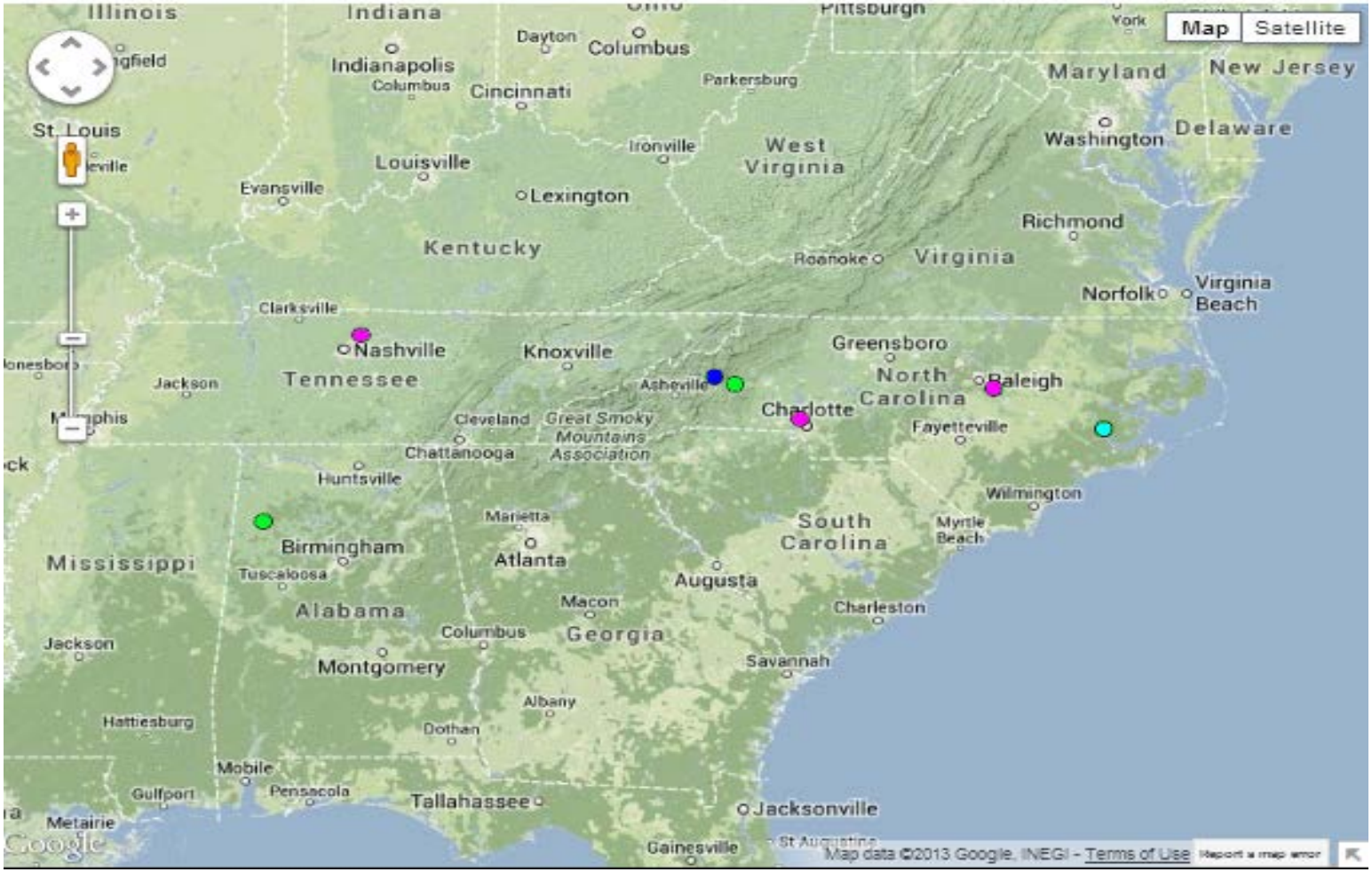


HMT-SE Surface Instrumentation (as of 7/31/2013)



All HMT-SE Instrumentation

- 449 MHz Wind Profiler + S-band
- 915 MHz Wind Profiler
- FMCW Precipitation Profiler
- Surface Met Only



Data Access and Visualization Demo

http://www.esrl.noaa.gov/psd/data/obs/datadisplay/

Agenda

I. Quick intro: HMT-Southeast Pilot Study and webinar goals (Kelly Mahoney, Rob Cifelli)

II. HMT-SEPS Observational Data (Tim Coleman, Dan Gottas)

- **GPS-Met precipitable water observations (Seth Gutman, Kirk Holub)**

III. Model forecasts: ExREF (Ligia Bernadet)

IV. Questions, discussion

Ground-Based GPS Water Vapor Observations Supporting HMT-SE

Seth I. Gutman & Kirk L. Holub
ESRL Global Systems Division

July 31, 2013

Overview Questions

1. The instruments we have in the field:
   a. What are they?
   b. Where are they? (or rather, where will they be?)
   c. What do they measure?

2. Where the observed data goes:
   a. What is on the webpage?
   b. How I can best use the webpage?
   c. How I can download the data? (real time and archived?)
   d. Does the data go anywhere besides the web?
      i. MADIS feeds -- as much as you want to say...we *don't* want to get into the nitty-gritty details like AWIPS importing, etc.
      ii. CAP/MADIS webpage for profiler data
      iii. Anywhere else?

3. Who can I contact if I have questions, comments, feedback, etc.?

Additional Information about GPS-Met

1. The instruments we have in the field:

   a. What are they?

   Commercial off-the-shelf geodetic (i.e. dual frequency carrier phase) GPS receivers. The same kind of receivers that are used by scientists, engineers and surveyors for high accuracy (mm-level) positioning.

   b. Where are they? (or rather, where will they be?)

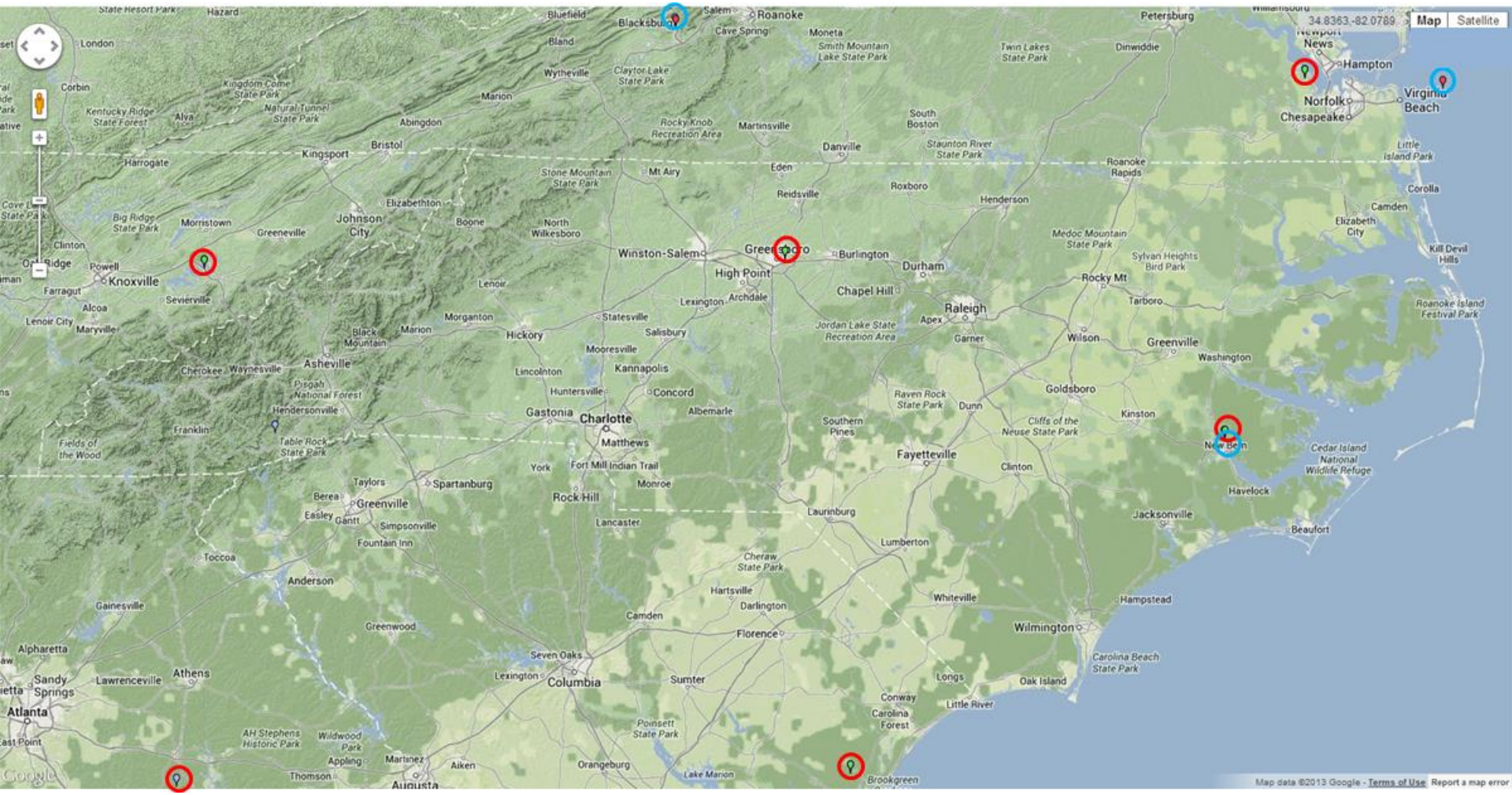
   See the next two slides.

   c. What do they measure?

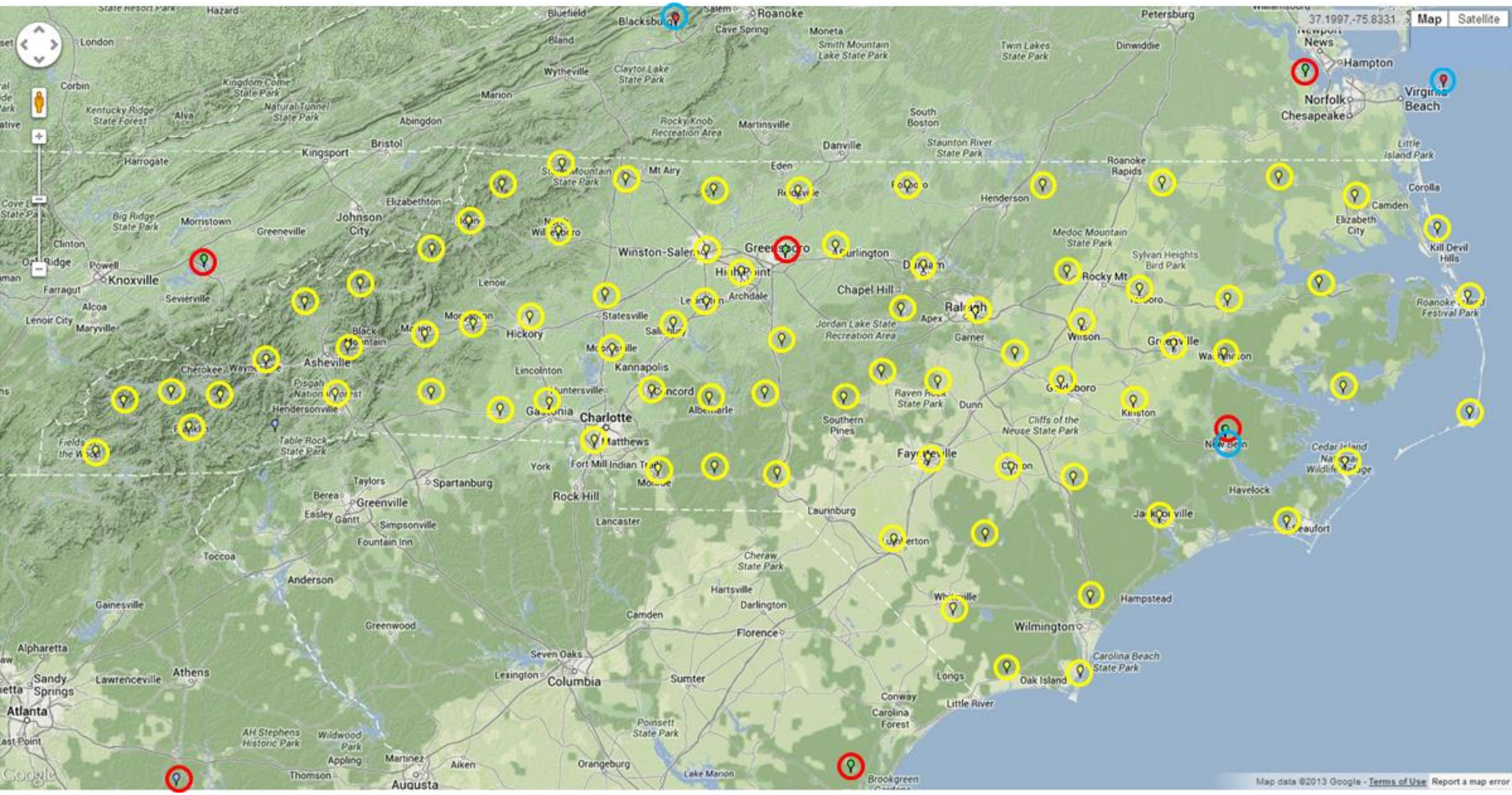
   Changes in the radio-refractivity of the neutral atmosphere caused by temperature, pressure and water vapor in the lower troposphere.

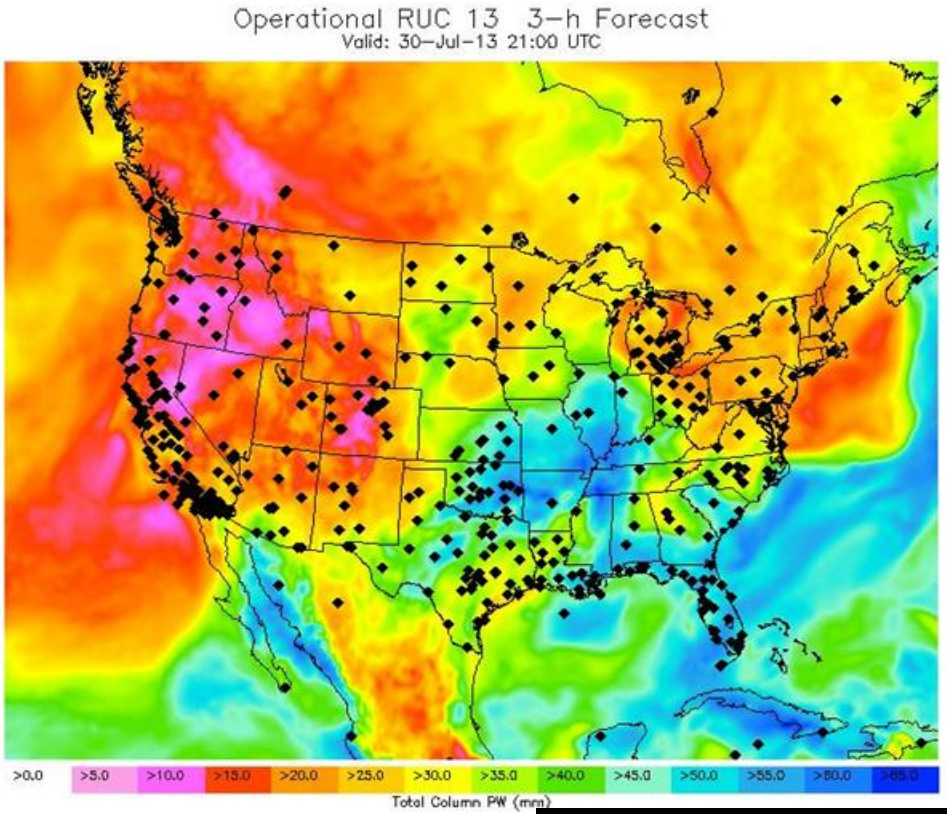
   If we make temperature and pressure readings in close proximity to the GPS antenna, then we can use this additional information to retrieve total column precipitable water vapor from the estimated signal delays with high accuracy and temporal resolution under all weather conditions..

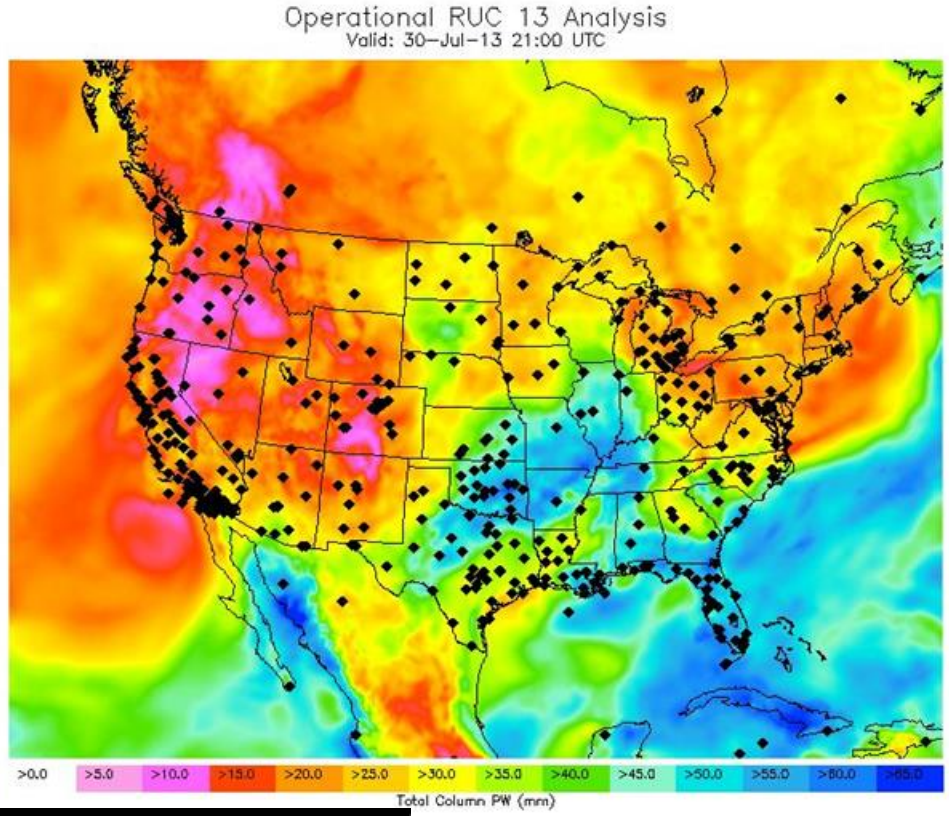
Existing Receivers used by ESRL/GSD for GPS Meteorology

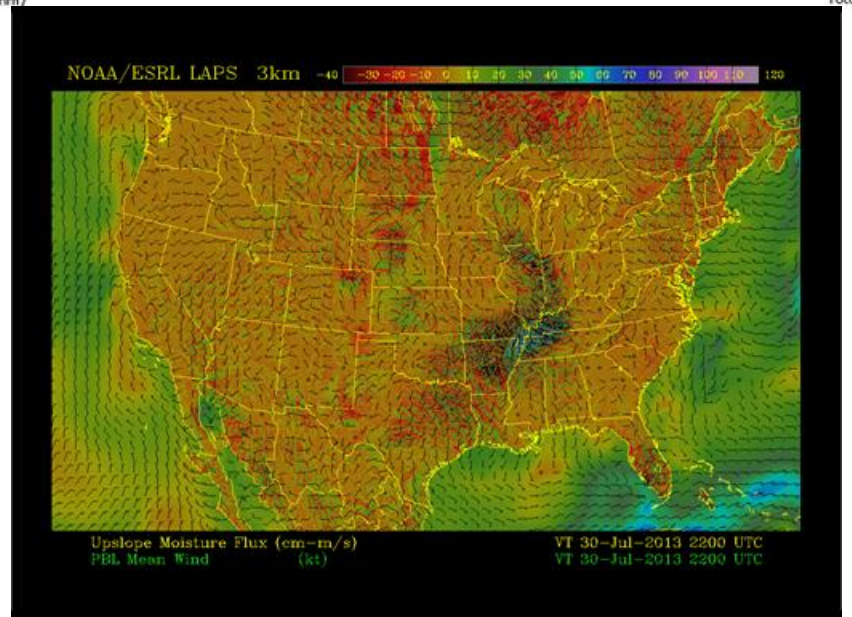


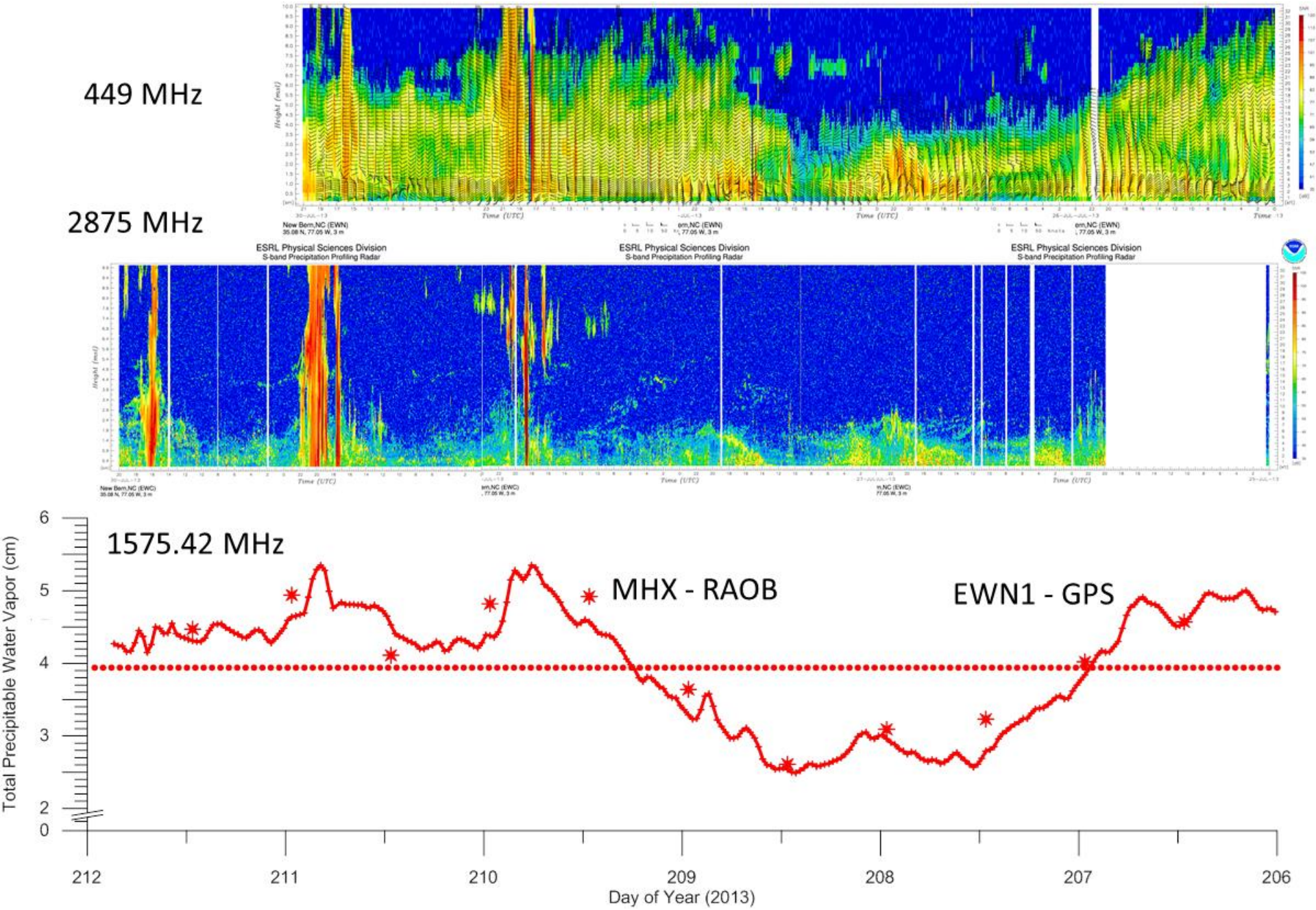
Existing & Available GPS Receivers in North Carolina




Operational RUC 13 3-h Forecast
Valid: 30-Jul-13 21:00 UTC
>0.0
>5.0
>10.0
>15.0
>20.0
>25.0
>30.0
>35.0
>40.0
>45.0
>50.0
>55.0
>60.0
>65.0
Total Column PW (mm)


Operational RUC 13 Analysis
Valid: 30-Jul-13 21:00 UTC
>0.0
>5.0
>10.0
>15.0
>20.0
>25.0
>30.0
>35.0
>40.0
>45.0
>50.0
>55.0
>60.0
>65.0
Total Column PW (mm)


NOAA/ESRL LAPS 3km
Upslope Moisture Flux (cm-m/s)
PBL Mean Wind (kt)
VT 30-Jul-2013 2200 UTC
VT 30-Jul-2013 2200 UTC


449 MHz
2875 MHz
ESRL Physical Sciences Division
S-band Precipitation Profiling Radar
1575.42 MHz
MHX - RAOB
EWN1 - GPS
Total Precipitable Water Vapor (cm)
Day of Year (2013)
212
211
210
209
208
207
206

Additional Information about GPS-Met

2. Where the observed data goes: http://gpsmet.noaa.gov
   a. What is on the webpage?
      i. Access to real-time and archived data and products (http://gpsmet.noaa.gov/cgi-bin/gnuplots/rti.cgi)
      ii. Comparisons with operational and research NWP Models
      iii. Comparisons with rawinsonde and satellite TPW.

   b. How I can best use the webpage?
      Practice.

   c. How I can download the data? (real time and archived?
      Instructions provided.

   d. Does the data go anywhere besides the web?
      NCEP, MADIS, GTS, UNIDATA, ARM.

2. Where the observed data goes: http://gpsmet.noaa.gov

a. What is on the webpage?

i. Access to real-time and archived data and products (http://gpsmet.noaa.gov/cgi-bin/gnuplots/rti.cgi)

ii. Comparisons with operational and research NWP Models

iii. Comparisons with rawinsonde and satellite TPW.

b. How I can best use the webpage?

It's easy to ues and pretty intuitive, but call us if you have any questions.

c. How I can download the data? (real time and archived?)

Instructions are provided in the download process/

d. Does the data go anywhere besides the web?

NCEP, MADIS, GTS, UNIDATA, ARM.

Points of Contact

Seth.I.Gutman@noaa.gov	303.497.7031
Kirk.L.Holub@noaa.gov	303.497.6642
Zoltan.Toth@noaa.gov	303.497.5042

Agenda

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IV. Questions, discussion

ExREF

Experimental Regional Ensemble Forecast System

Ligia Bernardet, Isidora Jankov, Steve Albers, Yuanfu Xie, Linda Wharton, Kirk Holub, Paula McCaslin, and and Zoltan Toth

Point of contact: ligia.bernardet@noaa.gov

NOAA/ESRL Global Systems Division

Forecast Applications Branch

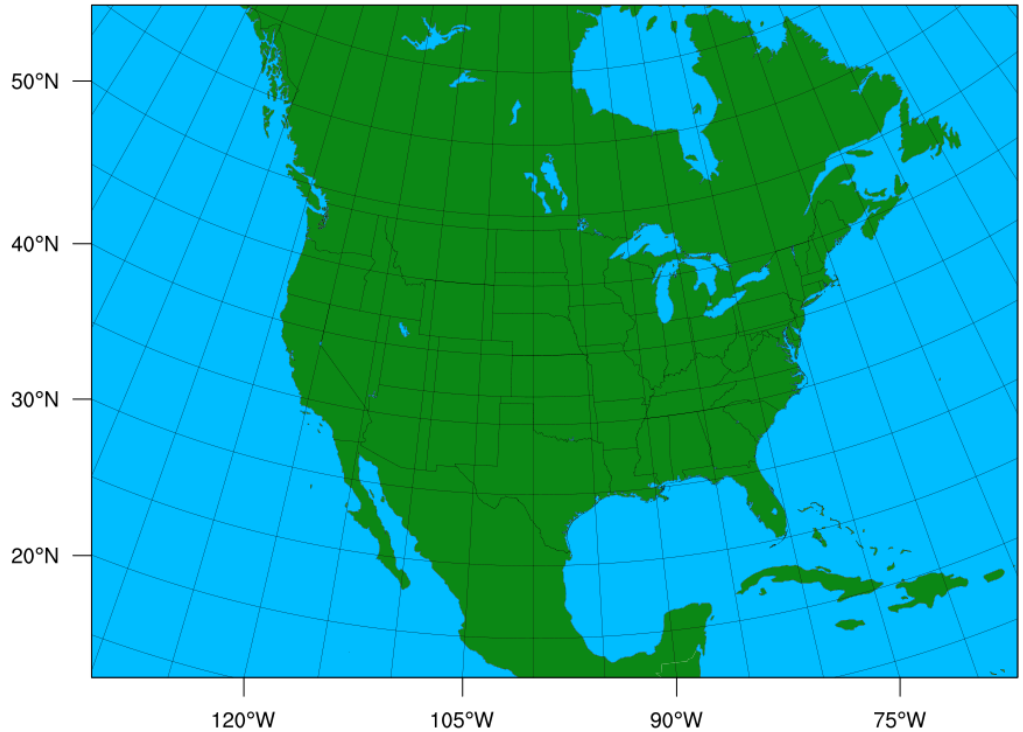
July 31, 2013

Contents

1. Overview of ExREF and the meaning of EXPERIMENTAL
2. Collaborations
3. Domain, model description
4. How ExREF complements existing models
5. Local Analysis and Prediction System
6. Distribution and fields available
7. Website
8. Verification scores
9. ExREF in the WPC Flash Flood and Intense Rainfall experiment
10. Timeliness
11. References
12. Future

Experimental Regional Ensemble Forecast

- NOAA ESRL/GSD has run an ensemble for HMT-W for various years
- Since the 2012-2013 winter, the domain became North American



Experimental

- ExREF is a community resource for development and testing of new ensemble techniques
- Configuration can change in response to partners needs
- Runs are conducted on NOAA R&D machines (non-operational)

ExREF Collaborations

NOAA ESRL Global Systems Division
Run ExREF in realtime Develop new initialization methods
NOAA Environmental Modeling Center
Use ExREF as a proving ground for SREF
Developmental Testbed Center
Conduct testing and evaluation of new ensemble techniques
NOAA Weather Prediction Center
Use ExREF as experimental guidance (Flash Flood experiment)
NOAA Hydrometeorology Testbed
Use ExREF for numerical guidance of high-precipitation events
National Weather Service WFOs
Use ExREF in AWIPS/GFE as experimental forecaster tool (CA STO now)

Current ExREF Model Description

Model	WRF ARW 3.4.1 (latest)
Members	8
Grid spacing	9 km
Vertical levels	35
Microphysics	Various
Cumulus	Kain Fritsh
PBL	YSU
Radiation	RRTM LW / Dudhia SW
Land surface model	Thermal diffusion
Forecast length	84 h
Frequency of run initialization	4 x day (00, 06, 12, 18 UTC)
Initial conditions	Various
Boundary conditions	Various

Member differentiation

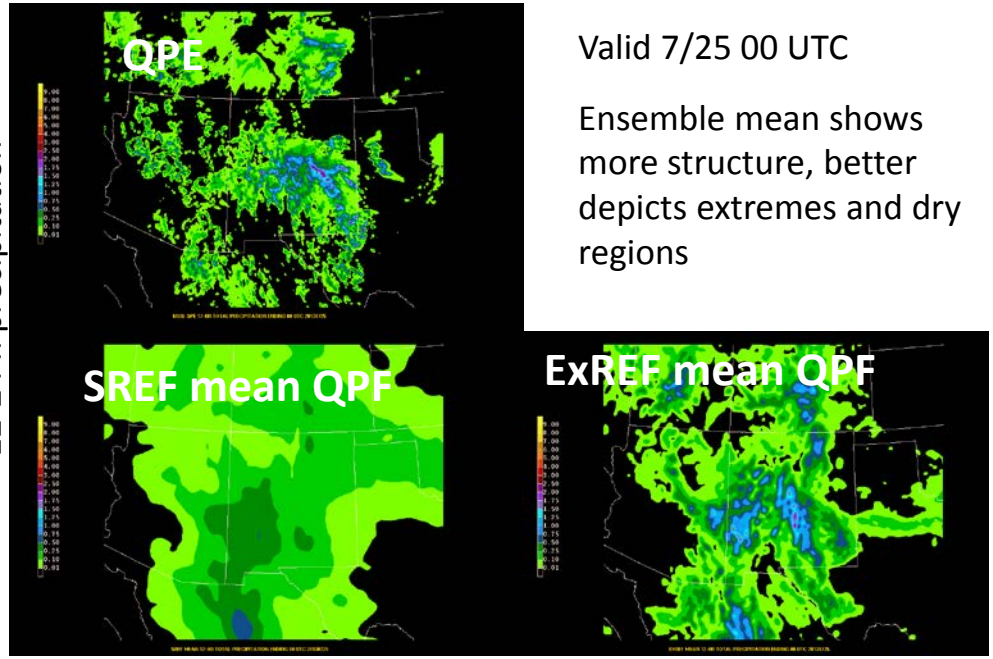
Member	Initial Conditions	Boundary Conditions	Microphysics	
m0	GFS	GFS	Thompson	
m1	**LAPS-t**	**GFS**	**Thompson**	**Control**
m2	LAPS-t	GEFS1	Ferrier	
m3	LAPS-t	GEFS2	WSM6	
m4	LAPS-t	GEFS3	Thompson	
m5	LAPS-t	GEFS4	Ferrier	
m6	LAPS-t	GEFS5	WSM6	
m7	LAPS-v	GFS	Thompson	

- Goal: representation of sources of uncertainty in NWP, both in model & IC/BC
- Members differ in initial and boundary conditions, as well as in microphysics
- Representing uncertainty well means solution enveloped by members

ExREF and SREF

	ExREF	SREF
Domain	North American (covers G212)	Twice as large (often distributed on G212)
Spacing	9 km (higher-resolution)	16 km
Members	8 ARW	21 ARW, NMM-E, NMM-B
Microphysics	Ferrier, Thompson, WSM6 (more sophisticated to represent precip)	Ferrier

12-24 h precipitation

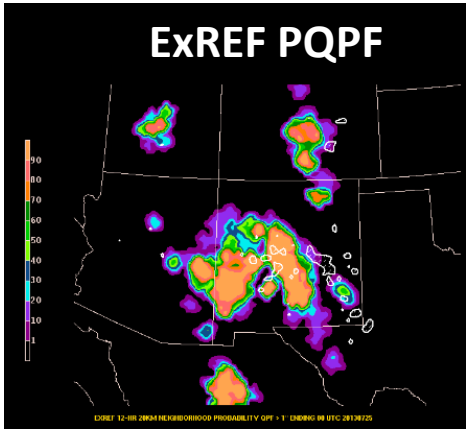


Valid 7/25 00 UTC

Ensemble mean shows more structure, better depicts extremes and dry regions

Best products from ensemble are probabilistic fields that help determine uncertainty

12-24 h PQPF 1 in



Figures courtesy F. Barthold (WPC)

ExREF m1 and NAM, RAP, HRRR

Member 1 is the control and can be used as a deterministic forecast

	ExREF m1	NAM and nest	RAP	HRRR
Domain	North American	North American/CONUS	North American	CONUS
Spacing	9 km	12 / 4 km	13 km	3 km
Dyn core	ARW	NMM-B	ARW	ARW
Microph	Thompson	Ferrier	Thompson	Thompson
Length	84 h	84 h	18 h	15 h

WPC Flash Flood Experiment

- ExREF was used to provide experimental guidance for QPF and FF
- ExREF compared to operational SREF

Very preliminary results on ExREF for QPF and FF guidance

- Was trusted and often used as a basis for the experimental forecasts
- Subjective model evaluation of QPF shows ExREF provided better guidance than SREF
- Underdispersive in the first 24 h (not evaluated for later lead times)
  - Several members starts from LAPS-t and differences from lateral boundaries and physics will have more effect later
- Forecasts are best when events are strongly forced
- Struggled with southern part of rain events

Local Analysis and Prediction System

LAPS has been developed by NOAA/ESRL/GSD

- Observation oriented analysis
- Efficient and fine resolution analysis, short latency
- Portability and ease of use
- Multiscale analysis
- Hot-start analysis
- Cloud analysis
- Good performance in verification of real time forecast

Traditional versus Variational LAPS

- LAPS-t uses Barnes analysis; LAPS-v uses variational analyses
- Those are methods to combine many observations onto a gridded analysis
- In the future, LAPS-t will be discontinued in favor of LAPS-v

More info: laps.noaa.gov

LAPS Motivation

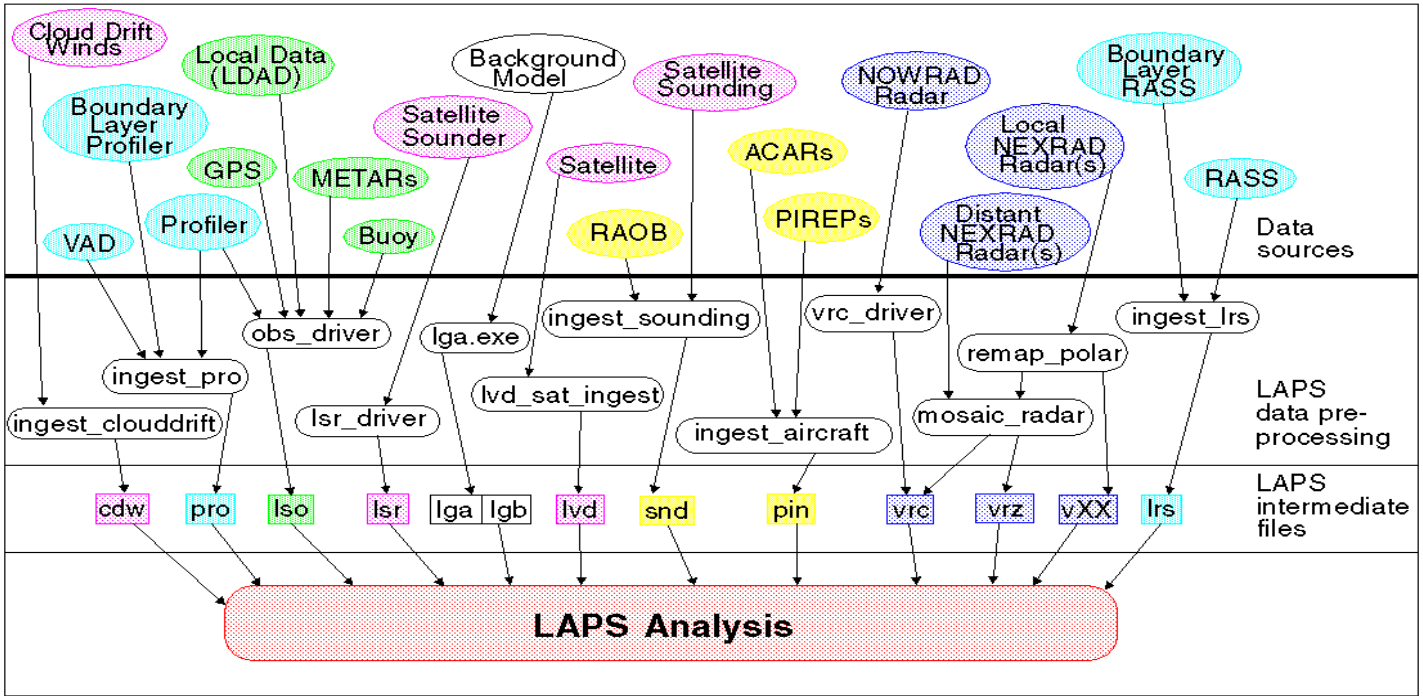
High resolution (0.5 – 20km), rapid update (10-60min), local to global

Highly portable system

Collaboration with user community - about 150 world wide

- Federal Gov't – NWS, RSA, PADS, FAA, DHS, SOS
- State Gov't – California Dept of Water Resoures
- International – Finnish Met. Inst., China Heavy Rain Inst.
- Private Sector – Toyota, WDT

Wide variety of data sources:



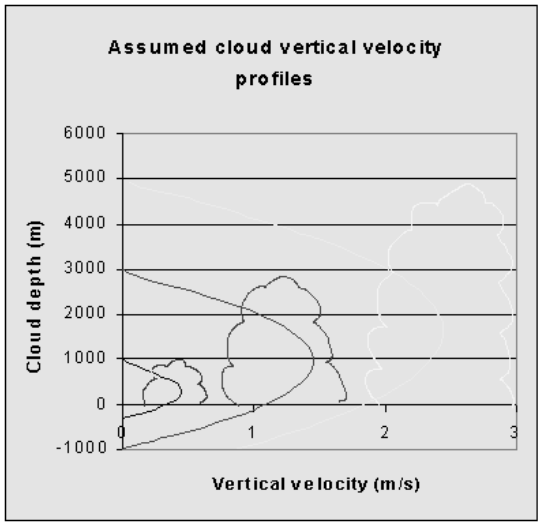
LAPS Hot Start

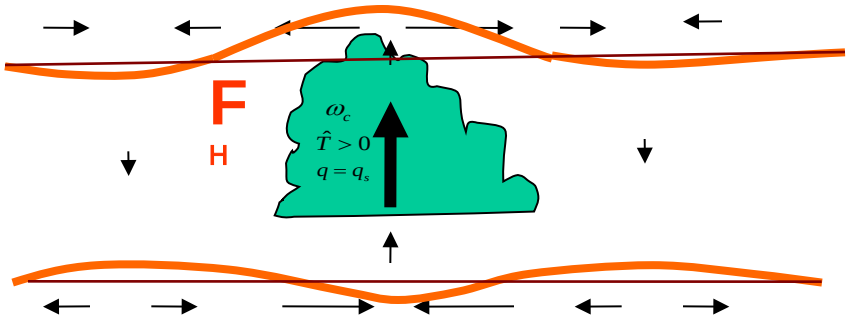
- Goal
  - Reduce model spinup time
- Method
  - Start the model file clouds and thermodynamic fields
- Process
  - Assimilate hydrometeors
  - Assure consistency with water vapor fields
  - Create balanced vertical velocity and divergence fields
  - Adjust temperature and height fields

LAPS Hot Start

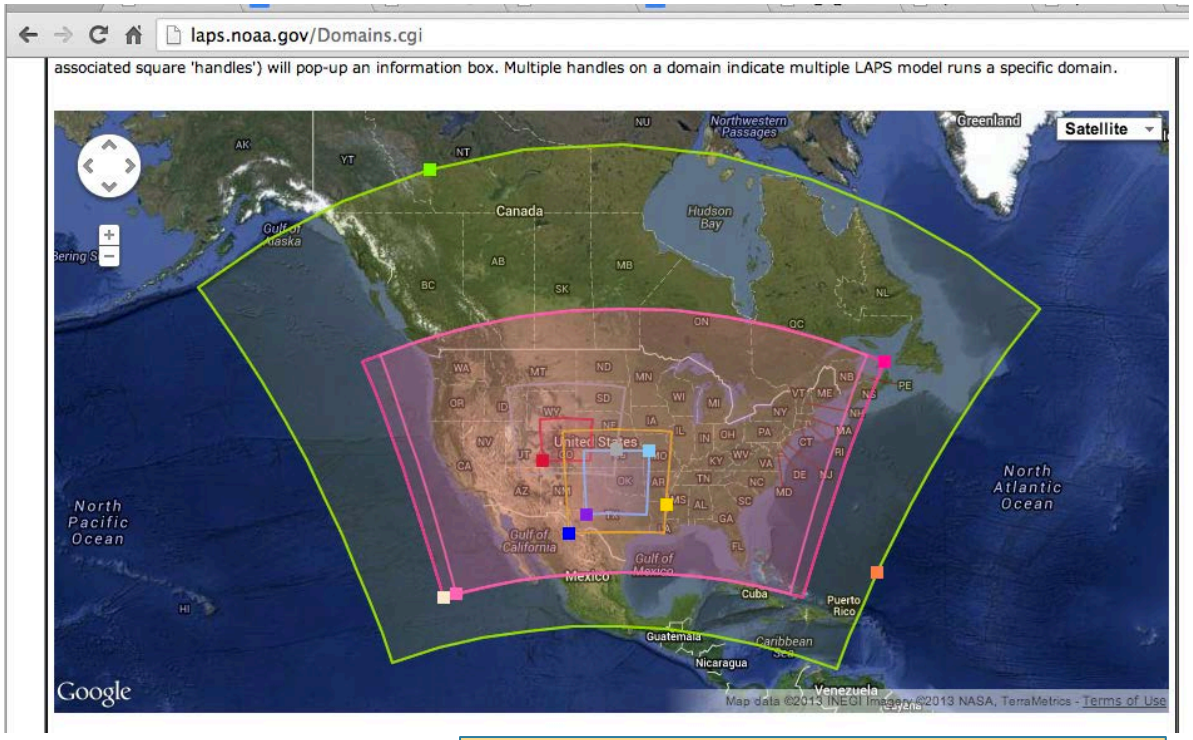
Three-Dimensional Cloud Analysis

METAR





LAPS domains and distribution

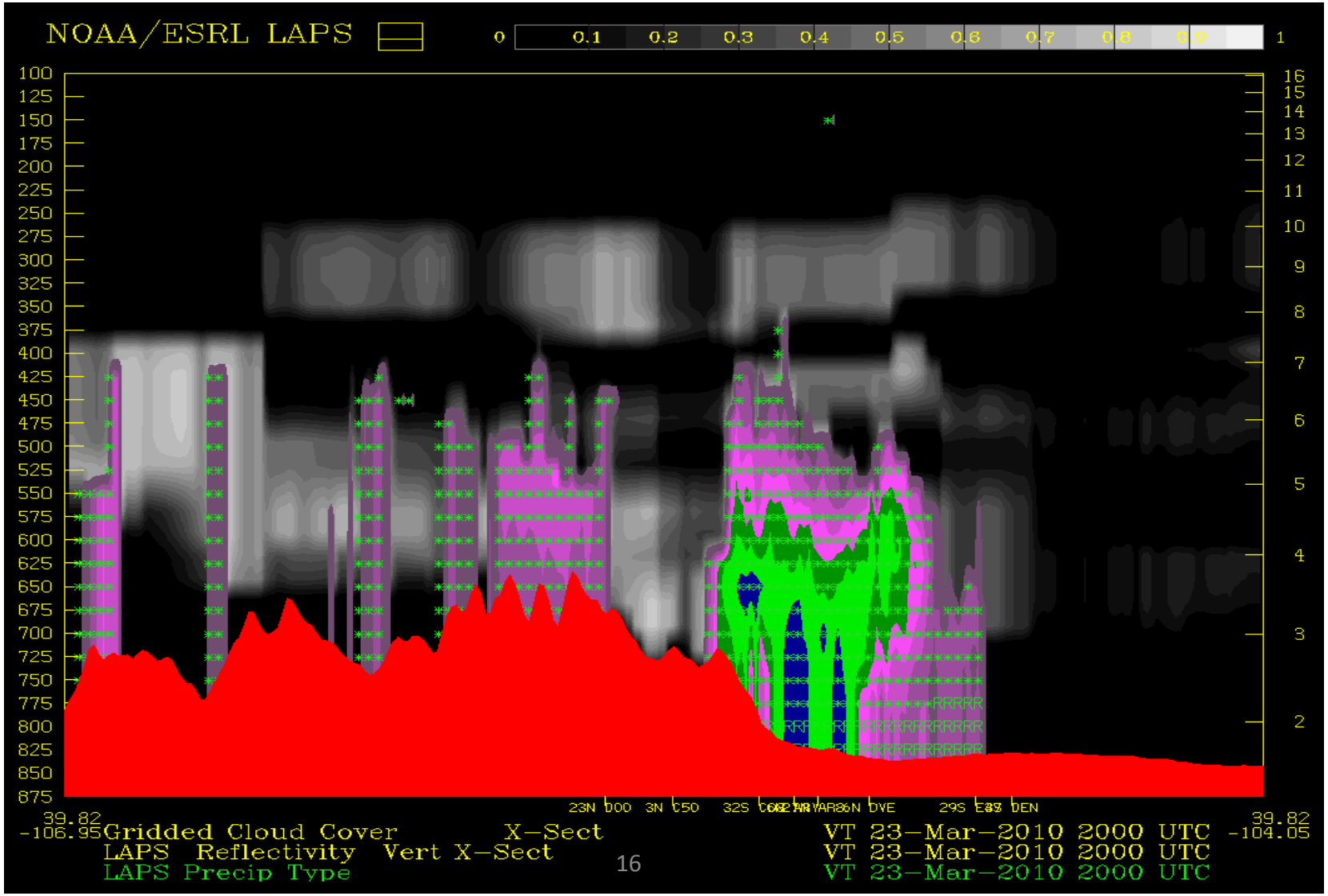


Domains of interest
laps.noaa.gov

- ExREF
  - NA LAPS-t: 9 km; hourly
  - NAV LAPS-v: 9 km; hourly
- CONUS: 3 km; 30 min
- ROC_HIRES: 1 km; 15 min over CO
- HWT
  - LAPS: 3 km; 15 min
  - VLAPS: 1 km; 15 min

Example of analyses available

Cloud, reflectivity, precipitation type 1-km, 15min update



Current ExREF distribution

- Sacramento WFO
  - Receives via LDM a geographical subset of ensemble mean over west coast
  - Used in AWIPS-I and GFE
- Weather Prediction Center
  - Receives all members and mean via ftp
  - Obtaining account on zeus for independent retrieval of data
- Other users
  - Images on web at http://laps.noaa.gov/hmt/hmt.html

ExREF Products

GRIB 2 (members and mean)

- 10-m U, V
- 2-m T, Td equivalent potential T
- CAPE, CIN
- MSLP
- Precipitable Water
- Precipitation
  - Runtotal
  - 3-h accumulations
- Snow
  - Runtotal
  - 3-h accumulations
- U, V, W, geop height, T, spec hum
  - 1000, 925, 850, 700, 500, 250

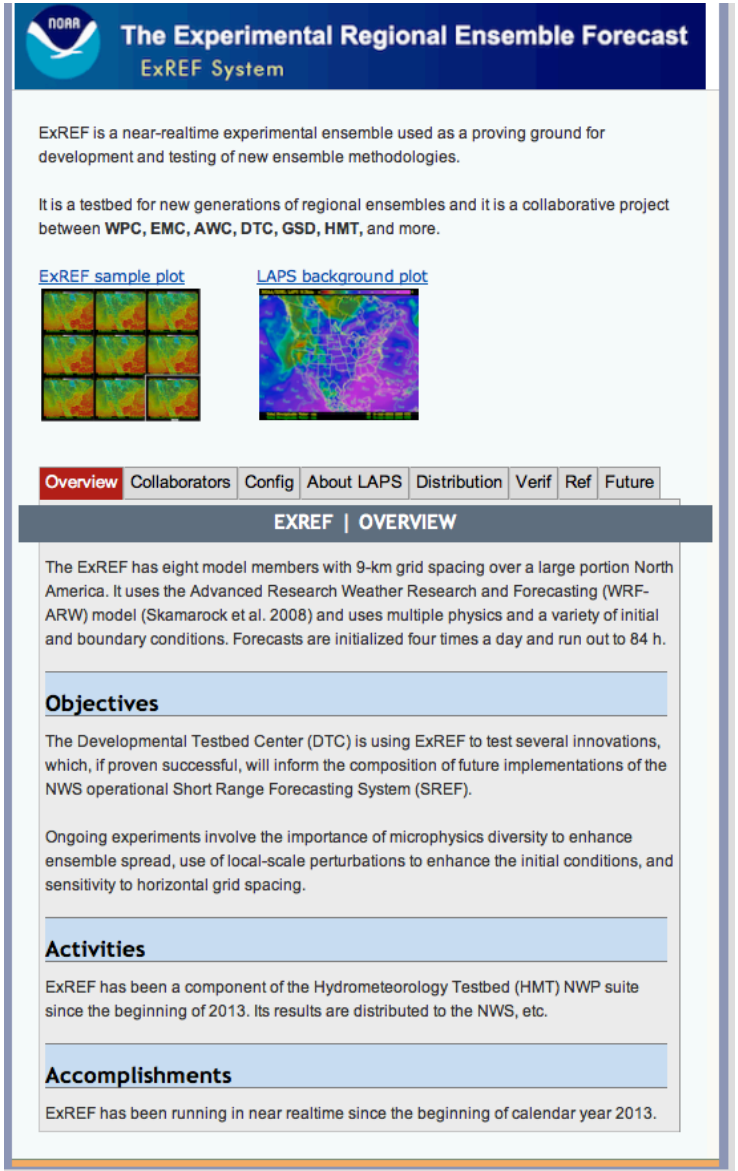
NetCDF members on Zeus

- Additional fields available

Requested fields

- Visibility (AWC and ER)
- Ceiling (AWC)
- BUFR soundings (ER)

ExREF website



The Experimental Regional Ensemble Forecast
ExREF System

ExREF is a near-realtime experimental ensemble used as a proving ground for development and testing of new ensemble methodologies.

It is a testbed for new generations of regional ensembles and it is a collaborative project between **WPC, EMC, AWC, DTC, GSD, HMT,** and more.

ExREF sample plot

LAPS background plot

Overview | Collaborators | Config | About LAPS | Distribution | Verif | Ref | Future

EXREF | OVERVIEW

The ExREF has eight model members with 9-km grid spacing over a large portion North America. It uses the Advanced Research Weather Research and Forecasting (WRF-ARW) model (Skamarock et al. 2008) and uses multiple physics and a variety of initial and boundary conditions. Forecasts are initialized four times a day and run out to 84 h.

Objectives

The Developmental Testbed Center (DTC) is using ExREF to test several innovations, which, if proven successful, will inform the composition of future implementations of the NWS operational Short Range Forecasting System (SREF).

Ongoing experiments involve the importance of microphysics diversity to enhance ensemble spread, use of local-scale perturbations to enhance the initial conditions, and sensitivity to horizontal grid spacing.

Activities

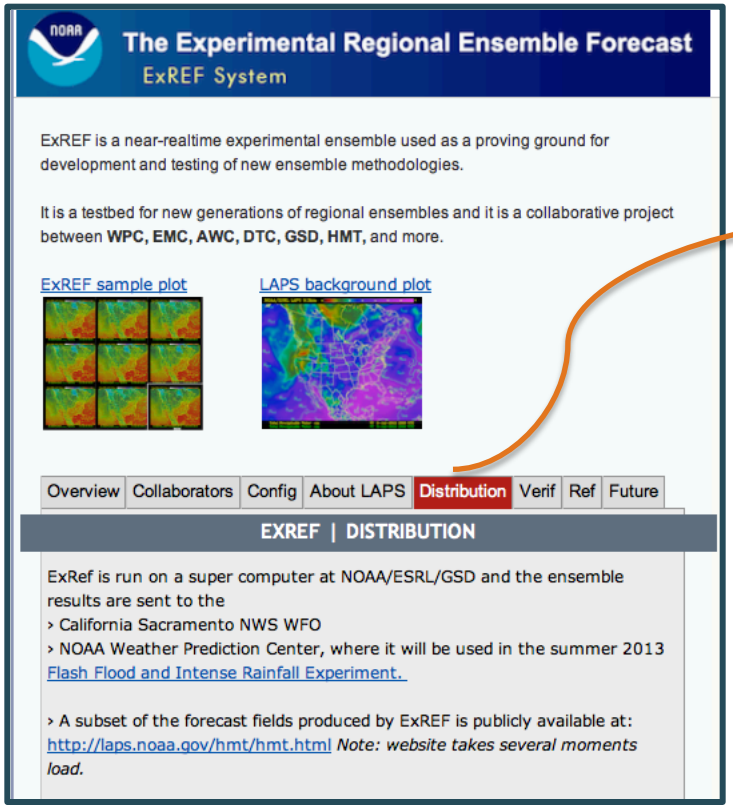
ExREF has been a component of the Hydrometeorology Testbed (HMT) NWP suite since the beginning of 2013. Its results are distributed to the NWS, etc.

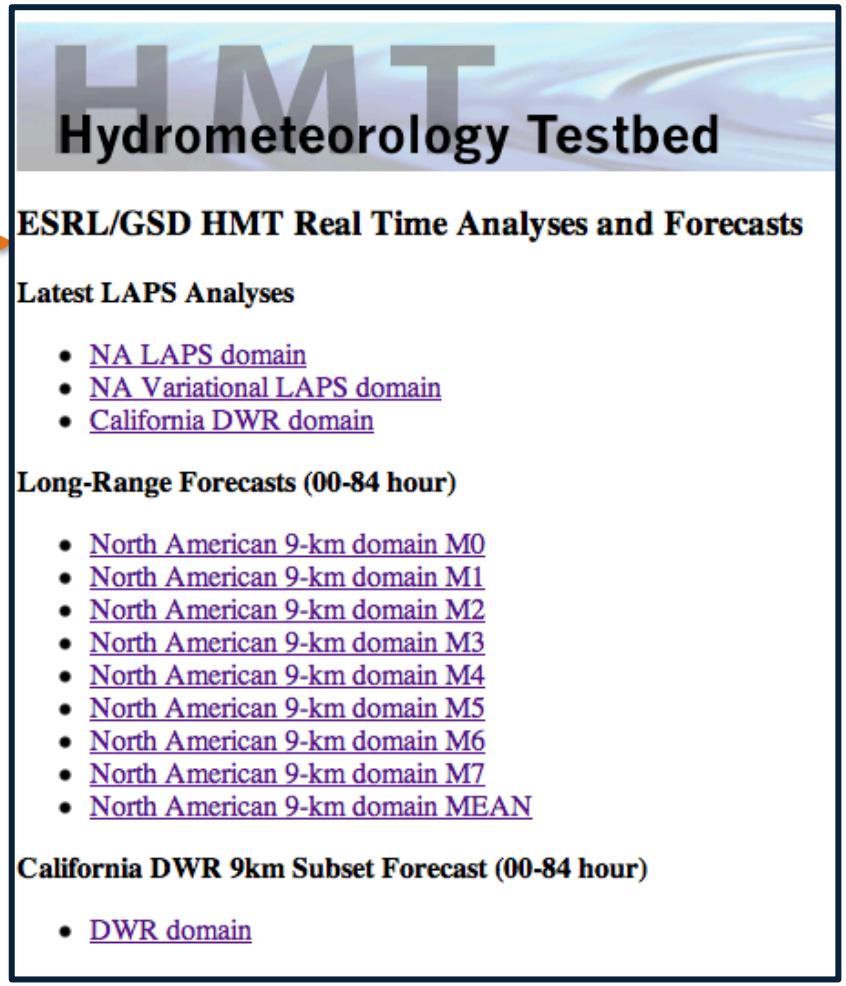
Accomplishments

ExREF has been running in near realtime since the beginning of calendar year 2013.

http://esrl.noaa.gov/exref/

Images on web





These images take a while to load

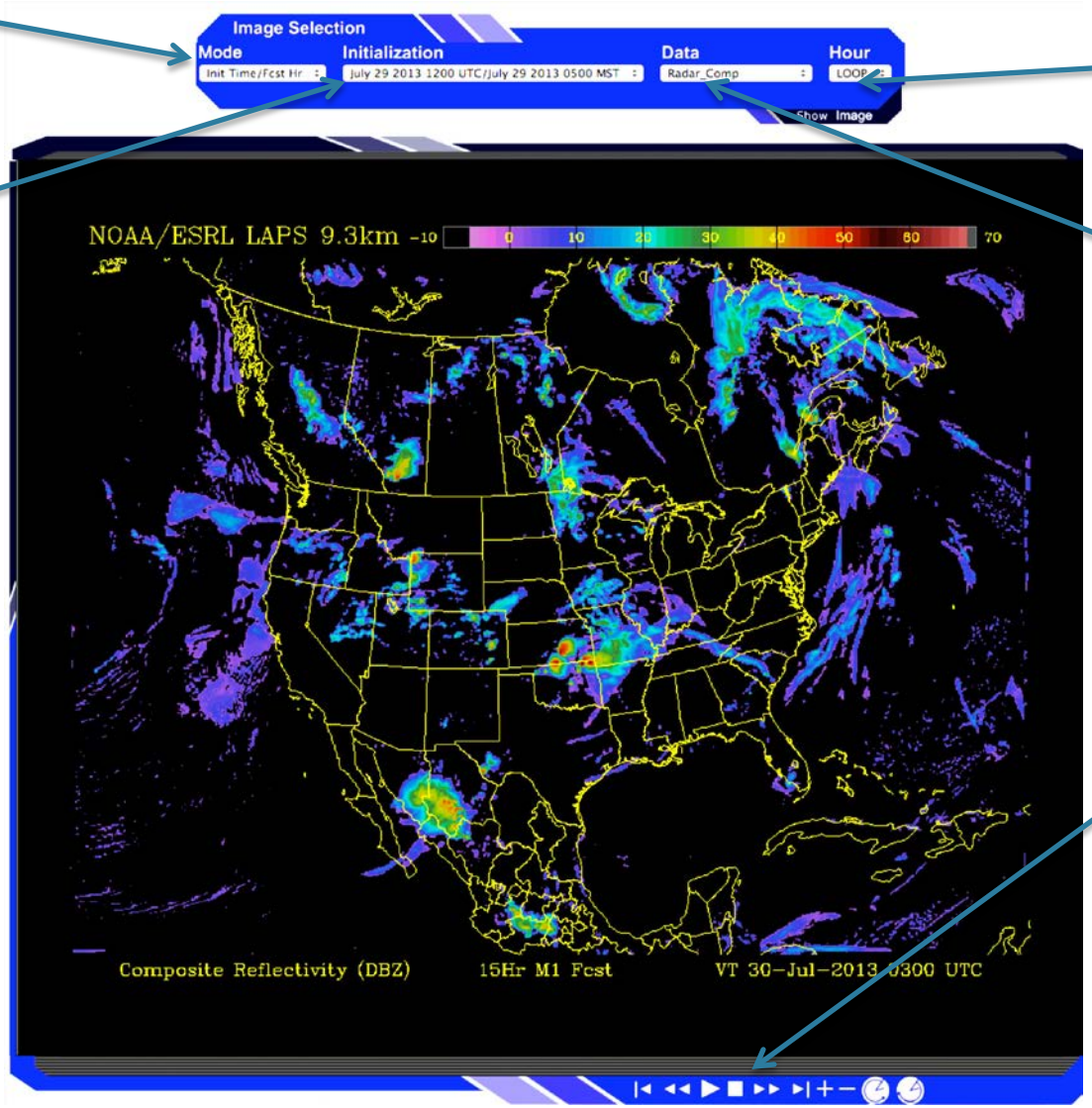
Image display

Leave as "Init Time"

Leave as "Loop"

Choose model initialization date

Choose variable



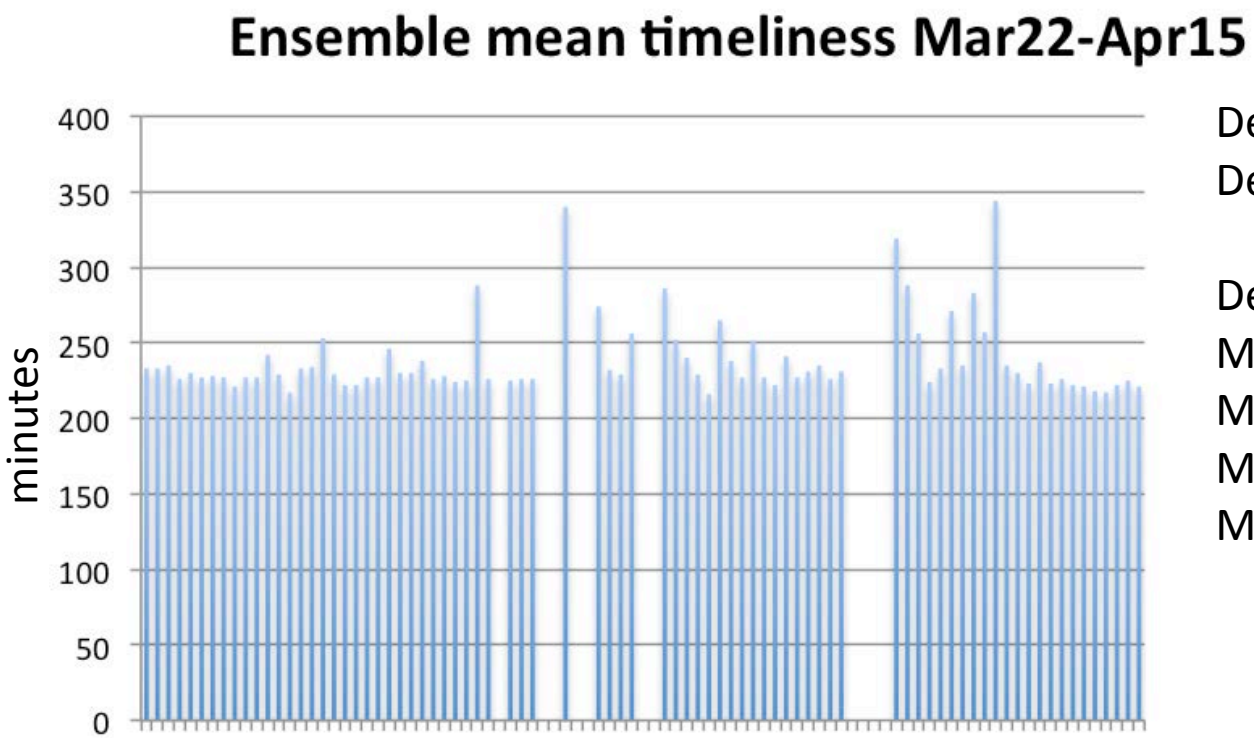
Animation controls

- To beginning
- Back one
- Loop
- Stop
- Forward one
- To end

Variables available on website

	0, 1, 3, 4, 6, 7	2,5 (Ferrier)	Mean
11 micron	✓	✓	✓
CAPE	✓	✓	✓
Cloud	✓	✓	
Fire danger	✓	✓	
IWV	✓	✓	✓
LiftedIndex_SfcDewPt	✓	✓	✓
Moist_flux	✓	✓	✓
Precip			✓
Radar_850	✓		✓
Radar_Comp	✓		✓
Radar_Sfc	✓		✓
Sfc_RelHum	✓	✓	✓
Snow	✓	✓	✓
Solar	✓	✓	✓
SfcTempWind	✓	✓	✓

ExREF Timeliness



Delivered 80 out of 90 forecasts
Delivery rate of 89%

Delivery timing stats in minutes
Mean: 239 minutes
Mode: 227
Max: 344
Min: 216

Primary issue is zeus unavailability
Zeus is not an operational machine; it is a R&D machine with downtimes
We cannot change zeus; we are improving all other aspects of reliability

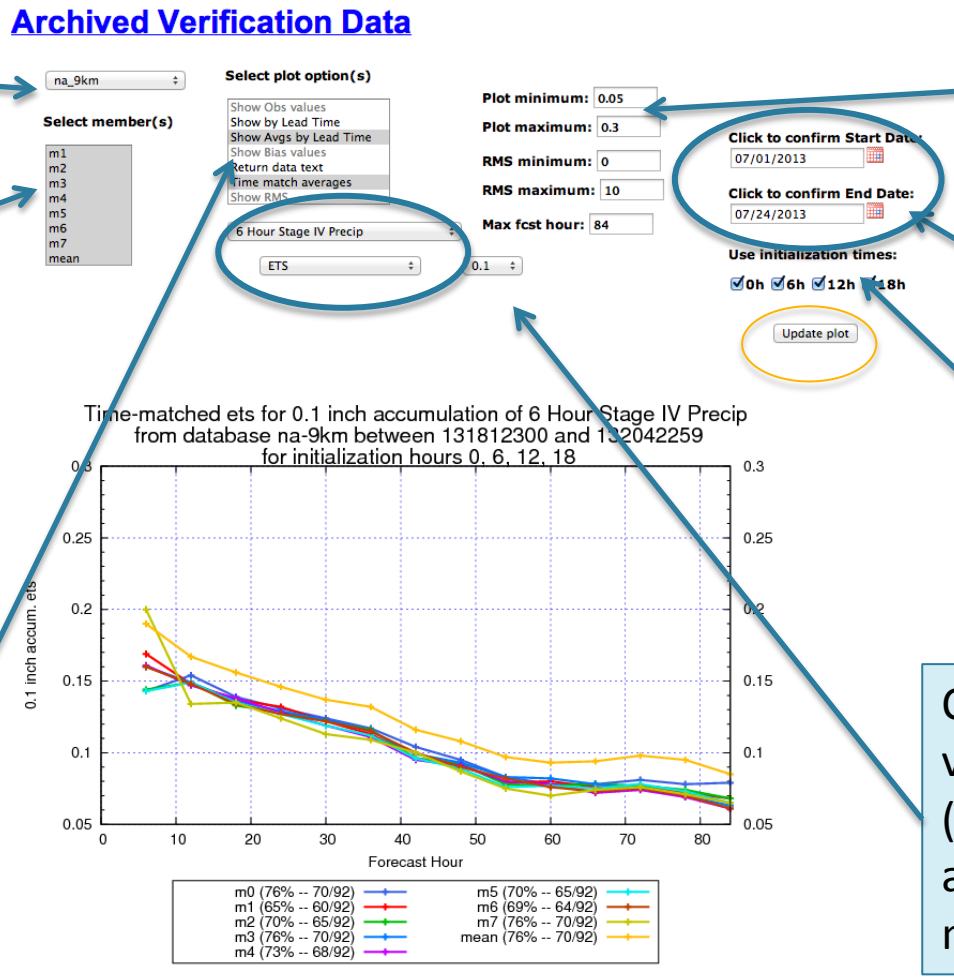
Verification database

http://laps.noaa.gov/verification/arc/

Choose "na_9km"

Choose members/ mean

Choose plot options
- Avs by lead time
- Time matches (homogeneous sample)
- Return data text (to download data)



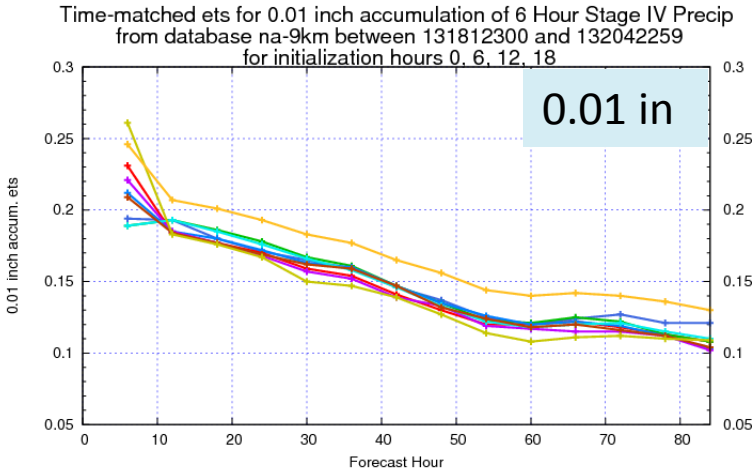
Choose axis max/min

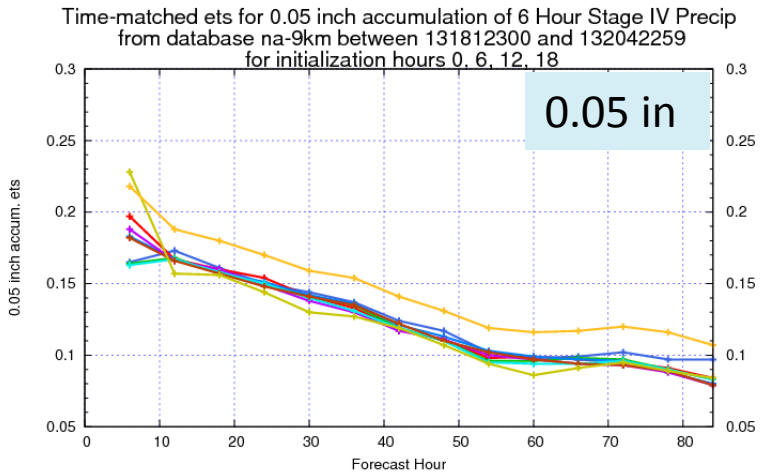
Choose period

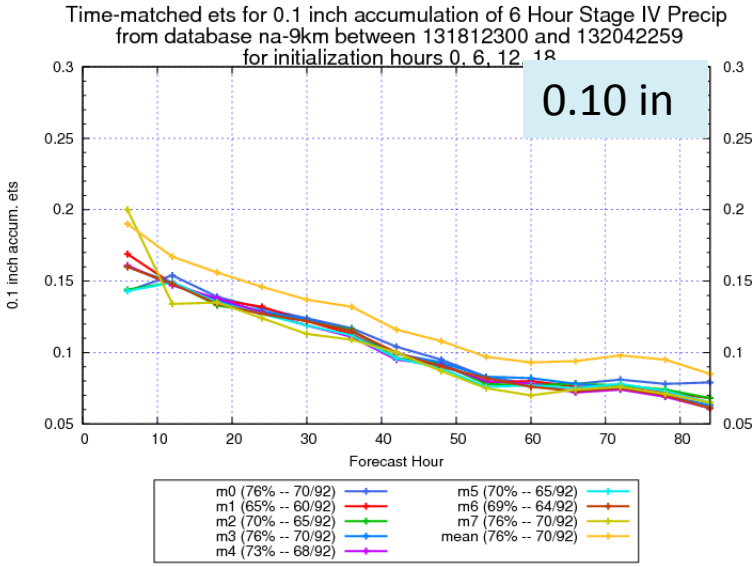
Choose init time

Choose variable to verify (threshold, if applicable), and metric

6-h QPF ETS July 1-24







ETS is higher

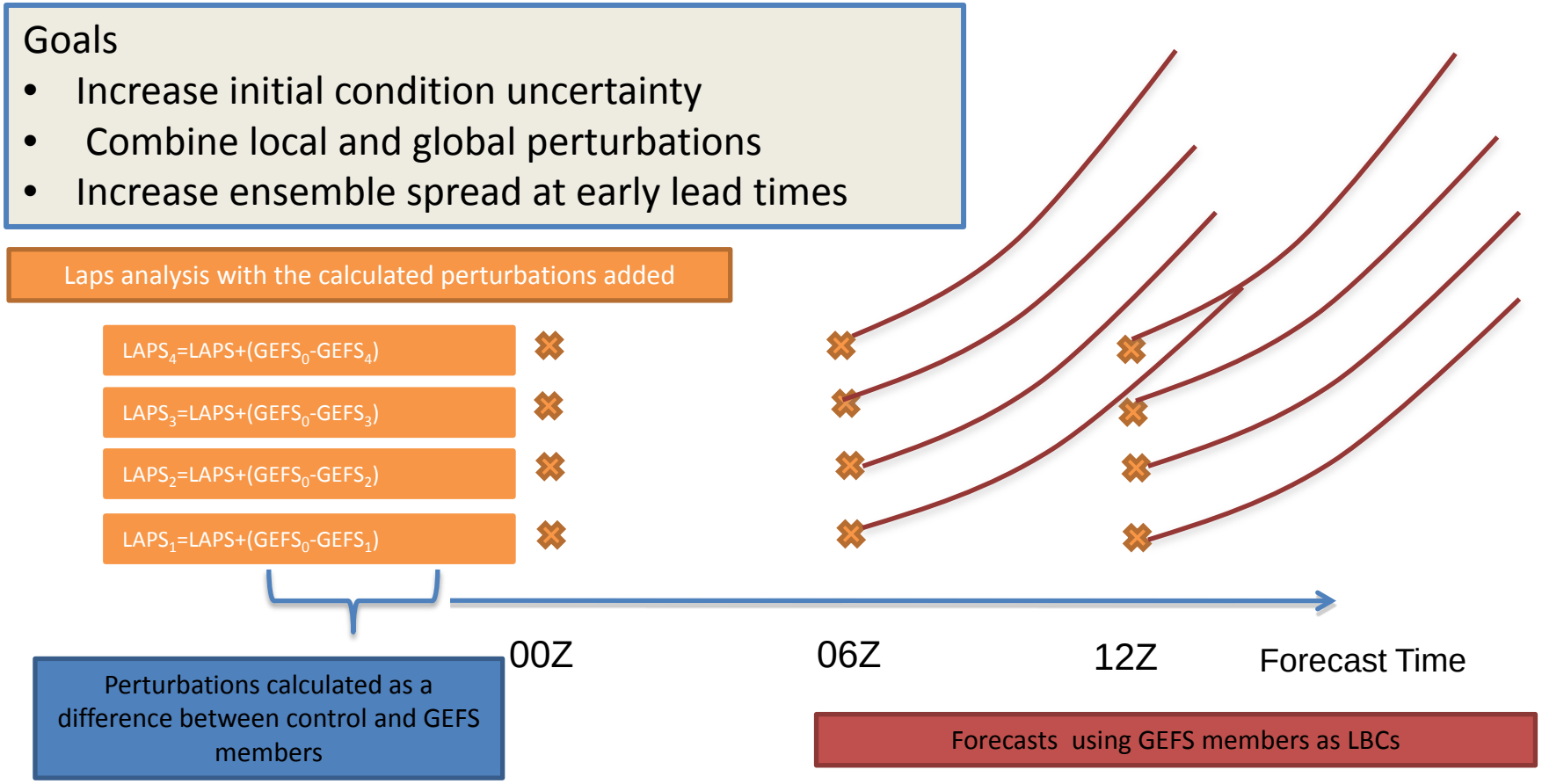
- at early lead times
- for lower thresholds

Member 7, LAPS-v, best at 6h

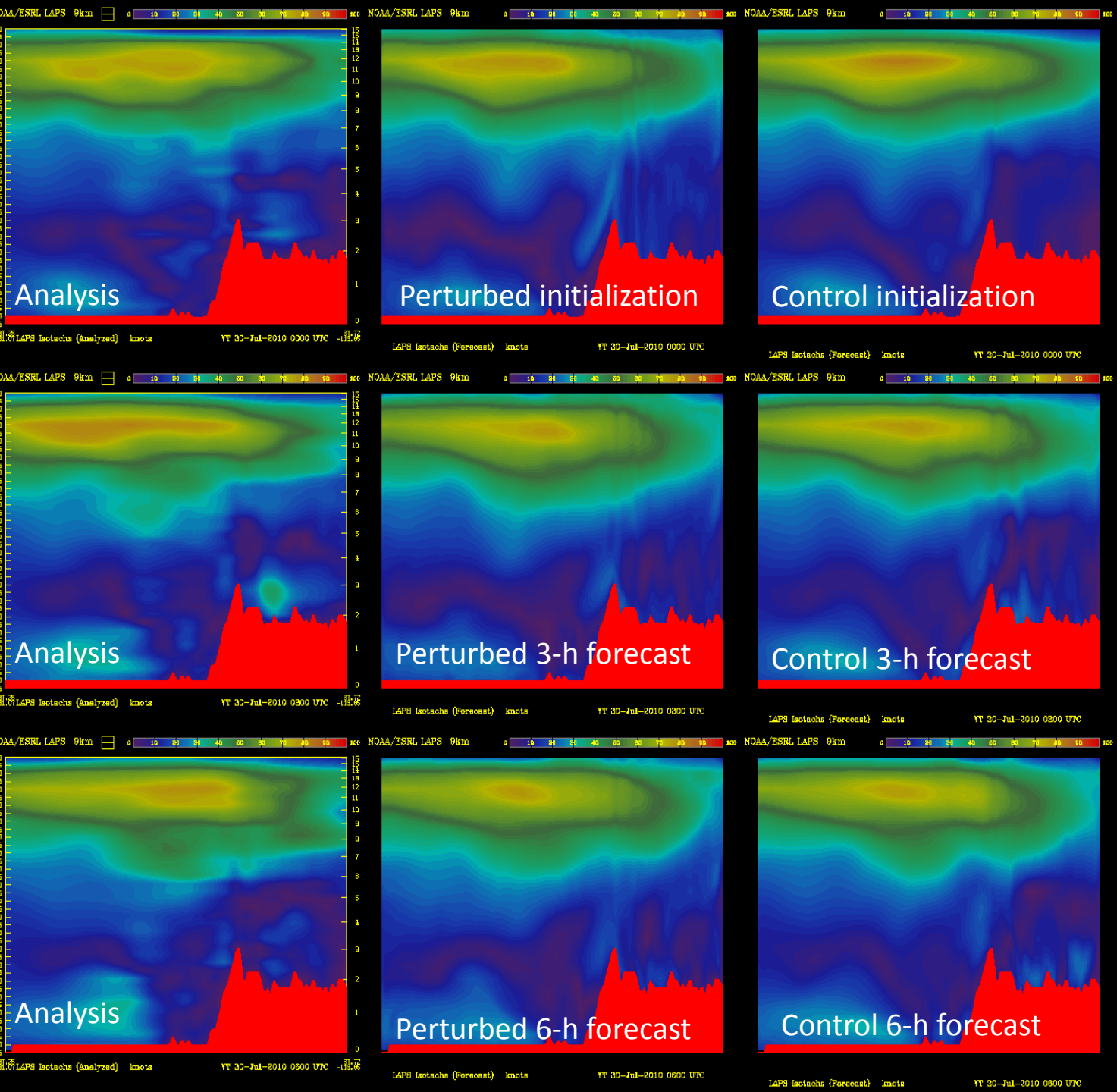
Ensemble mean distinctly higher

Under development: Initial Condition Perturbations

Goals
- Increase initial condition uncertainty
- Combine local and global perturbations
- Increase ensemble spread at early lead times



Similar work in dynamic downscaling of perturbations is being conducted at
- Austrian meteorological bureau
- University of Oklahoma

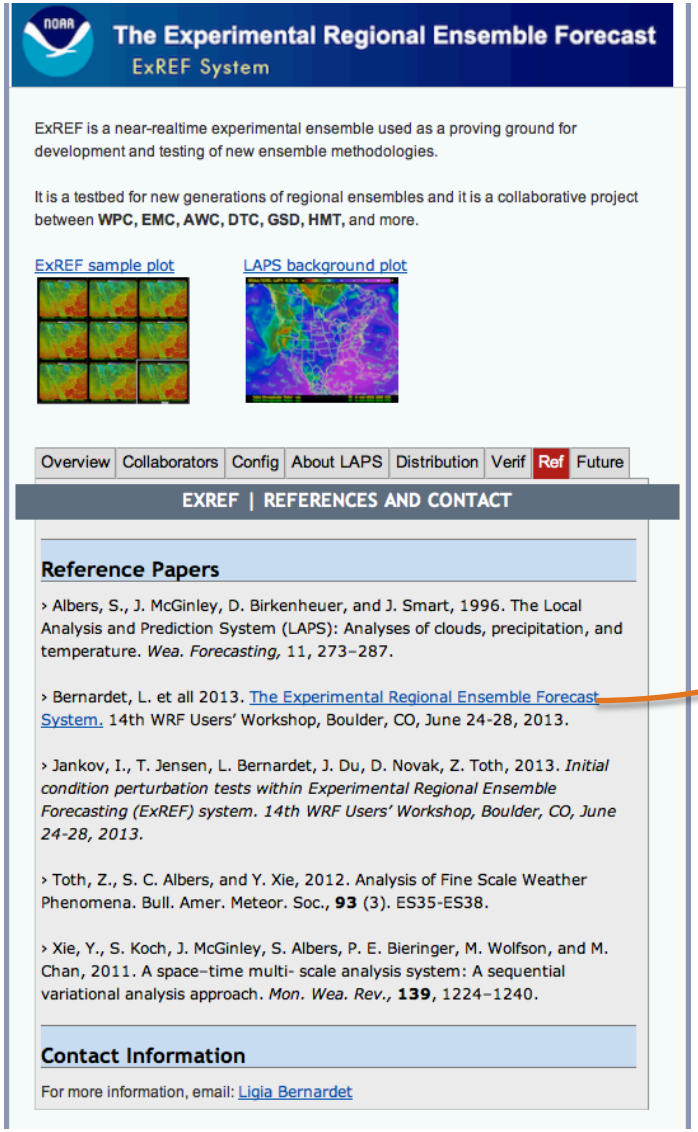


Previous work done at GSD for HMT-West in 2010, using a similar technique

Wind Speed Forecast initialized July 30 2010 00UTC

Note presence of more small scale features in initial model fields

References



The Experimental Regional Ensemble Forecast
ExREF System

ExREF is a near-realtime experimental ensemble used as a proving ground for development and testing of new ensemble methodologies.

It is a testbed for new generations of regional ensembles and it is a collaborative project between **WPC, EMC, AWC, DTC, GSD, HMT,** and more.

ExREF sample plot

LAPS background plot

Overview | Collaborators | Config | About LAPS | Distribution | Verif | Ref | Future

EXREF | REFERENCES AND CONTACT

Reference Papers

› Albers, S., J. McGinley, D. Birkenheuer, and J. Smart, 1996. The Local Analysis and Prediction System (LAPS): Analyses of clouds, precipitation, and temperature. *Wea. Forecasting,* 11, 273–287.

› Bernardet, L. et all 2013. The Experimental Regional Ensemble Forecast System. 14th WRF Users' Workshop, Boulder, CO, June 24-28, 2013.

› Jankov, I., T. Jensen, L. Bernardet, J. Du, D. Novak, Z. Toth, 2013. *Initial condition perturbation tests within Experimental Regional Ensemble Forecasting (ExREF) system. 14th WRF Users' Workshop, Boulder, CO, June 24-28, 2013.*

› Toth, Z., S. C. Albers, and Y. Xie, 2012. Analysis of Fine Scale Weather Phenomena. Bull. Amer. Meteor. Soc., **93** (3). ES35-ES38.

› Xie, Y., S. Koch, J. McGinley, S. Albers, P. E. Bieringer, M. Wolfson, and M. Chan, 2011. A space–time multi- scale analysis system: A sequential variational analysis approach. *Mon. Wea. Rev.,* **139**, 1224–1240.

Contact Information

For more information, email: Ligia Bernardet

Bernardet, L., S. Albers, L. Wharton, I. Jankov, D. Reynolds, K. Mahoney, E. Sukovich, W. Hogsett, D. Novak, and J. Du, 2013. The Experimental Regional Ensemble Forecast (ExREF) System.

14th WRF Users' Workshop, Boulder, CO, June 24-27. Available from http://www.mmm.ucar.edu/wrf/users/workshops/WS2013/extended_abstracts/p49.pdf.

The Experimental Regional Ensemble Forecast (ExREF) System

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[4] NOAA NCEP – Environmental Prediction Center, Silver Springs, MD
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[*]Cooperative Institute for Research in the Atmosphere – Colorado State University, Fort Collins, CO

1. Introduction

The Experimental Regional Ensemble Forecast (ExREF) system is a tool for the development of Numerical Weather Prediction (NWP) methodologies. ExREF is run in near-realtime by the Global Systems Division (GSD) of the National Oceanic and Administration (NOAA) Earth System Research Laboratory (ESRL), and its products are made available through a website, an ftp site, and via the Unidata Local Data Manager (LDM).

ExREF has been a component of the Hydrometeorology Testbed (HMT) NWP suite since the beginning of 2013. Its results are distributed to the National Weather Service Weather Forecast Office and the River Forecast Center in Sacramento, California, where they are ingested in the Advanced Weather Interactive Processing System (AWIPS) to provide guidance on the forecasting of extreme precipitation events. ExREF is also being supplied to the National Weather Service (NWS) Weather Prediction Center (WPC) where it will be tested in the upcoming Flash Flood and Intense Rainfall Experiment in July 2013. Finally, ExREF is being used as a proving ground for new methodologies in ensemble forecasting.

The Developmental Testbed Center (DTC) is using ExREF to test several innovations, which, if proven successful, will inform the composition of future implementations of the NWS operational Short Range Forecasting System (SREF). One innovation is an alternative initialization technique that uses dynamic downscaling of perturbations, as discussed in a companion poster by Jankov et al. (2013). Another is the use of multiple microphysical parameterizations as a way to generate ensemble diversity. And finally, ExREF will serve as a demonstration of the capabilities of a 9-km horizontal grid spacing ensemble, which SREF (currently run with 16-km grid spacing) will achieve in a few years, pending computational capability upgrades.

2. ExREF Overview

The ExREF has eight members with 9-km grid spacing over a large portion North America

Figure 1. ExREF domain.

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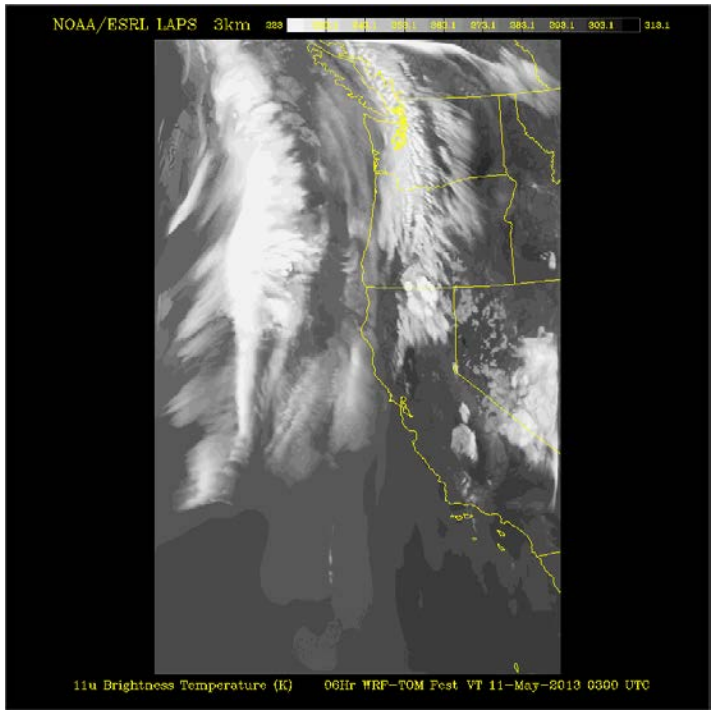
Preliminary work towards the High-Impact Relocatable Ensemble HIRES

- Next year, GSD is planning to run a relocatable 3-km ensemble
- Relocation on the fly as meteorology dictates
- Prototype: one 3-km member over the HMT-W in winter



Configuration

3-km grid spacing; 532x832 pts
Run hourly
Forecast length: 12 h
IC: LAPS using NAM as background
BC: NAM

Agenda

I. Quick intro: HMT-Southeast Pilot Study and webinar goals (Kelly Mahoney, Rob Cifelli)

II. HMT-SEPS Observational Data (Tim Coleman, Dan Gottas)

- GPS-Met precipitable water observations (Seth Gutman, Kirk Holub)

III. Model forecasts: ExREF (Ligia Bernadet)

IV. Questions, discussion

Concluding notes & time for questions, discussion

- Feedback is welcome and encouraged. Please tell us how we can make the data, displays, and products more useful to you.

- If you use the data and find it useful, please tell us that too
  - Important for quantifying/tracking utility, justifying potential extension/ expansion of project

- Our Facebook page is meant to be interactive - please share thoughts, questions, information with us (and the community) there!

https://www.facebook.com/NOAAHMTSoutheast

- Webinar is being recorded; we will send access information ASAP.

- Questions, comments, discussion?

Other news from HMT and HMT collaborators

- HMT WPC, HMT ESRL partners with NSSL/OU for Flash Flood and Intense Rainfall (FFaIR) experiment (July 2013)
- QPE validation planning underway: in collaboration OHD, NESDIS, NSSL, NCDC, CPC, others
- NC-Division of Air Quality and HMT repair and upgrade of Clayton, NC profiler; Charlotte, NC upgrade planned in coming months.
- NASA IPHEX planning underway
- NCSU graduate student to begin QPF error climatology work Fall 2013
- Additional potential projects and collaborations underway with specific WFOs, NASA SPoRT, other universities, NCAR

Contact information

- Facebook: https://www.facebook.com/NOAAHMTSoutheast (frequent updates, news interactive sharing between community members)
- Webpage: http://hmt.noaa.gov/field_programs/hmt-se/ (background information, science plan, documentation)

- Project manager: Rob Cifelli (rob.cifelli@noaa.gov)
- Lead Scientist: Kelly Mahoney (kelly.mahoney@noaa.gov)
- Data, observations, webpage:
  - Tim Coleman (timothy.coleman@noaa.gov)
  - Dan Gottas (daniel.gottas@noaa.gov)
- ExREF model forecasts: Ligia Bernadet (ligia.bernardet@noaa.gov)
  - GPS-met precipitable water obs: Seth Gutman (seth.i.gutman@noaa.gov)