The NYS Early Warning Weather Detection System

The New York State Mesonet

Everette Joseph[3], Jerry Brotzge[1], Chris Thorncroft[2]

[1]Program Manager, New York State Mesonet
[2]Chair, Department of Atmospheric and Environmental Science
[3]Director, Atmospheric Sciences Research Center (ASRC)
SUNY, University at Albany

The New York State Mesonet

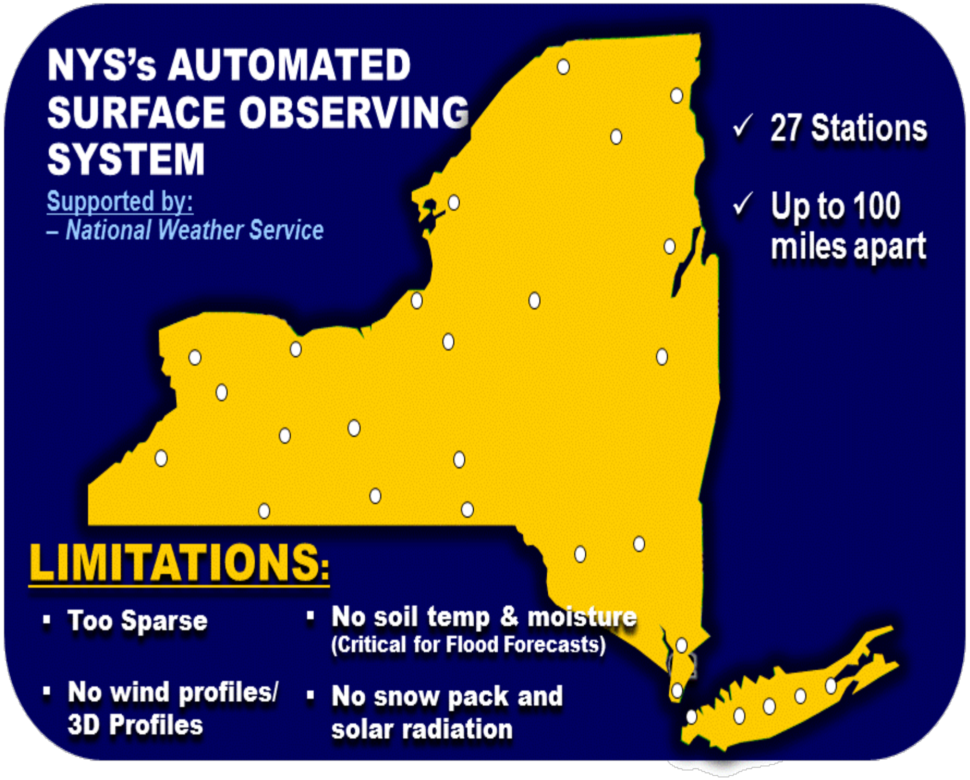
Outline

- Background
- System description and progress
- Enhanced sites
- PBL Pilot with NCEP
- NWP

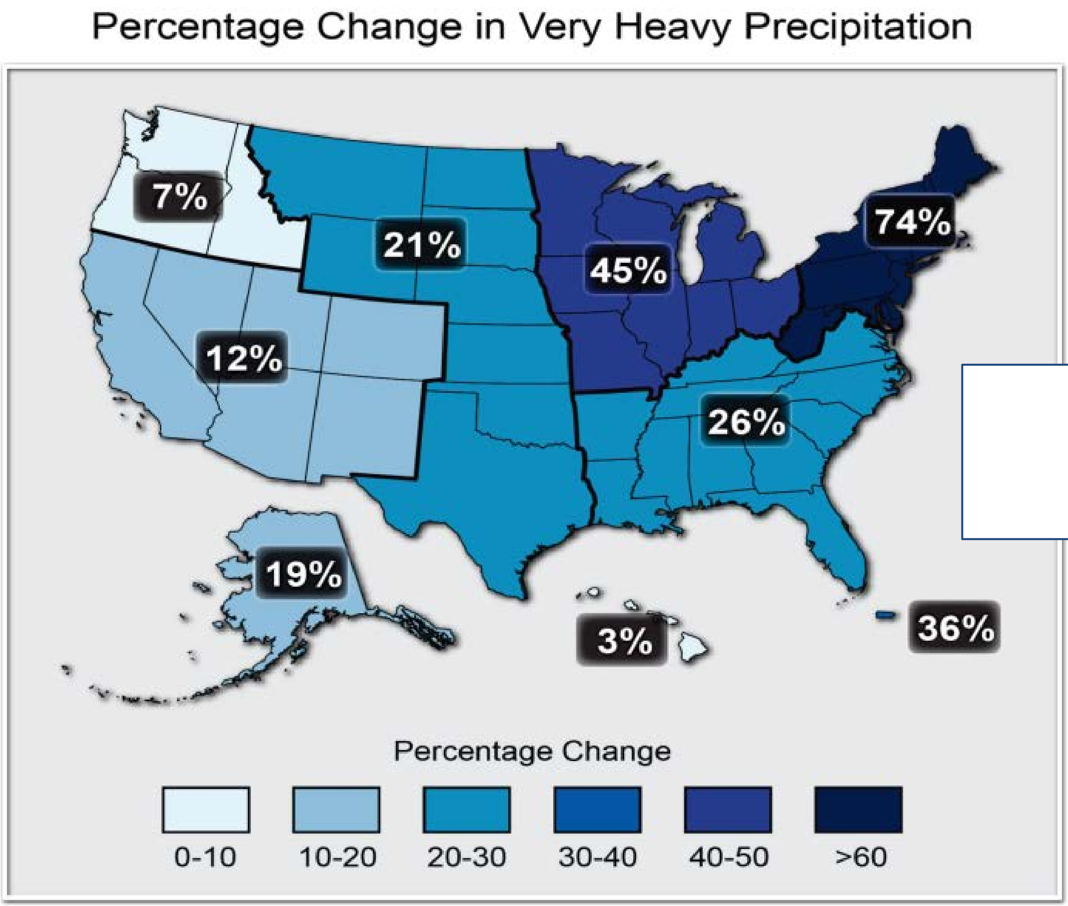
Why a Mesonet in New York?

Scarcity of weather observations in NY

- 27 Automated Surface Observing Stations (ASOS)
- Some Gaps in Radar Coverage
- NWS & Emergency Managers are Often Blind



Why a Mesonet in New York?



1958-2011 trend in Very Heavy Precipitation

Why a Mesonet in New York?

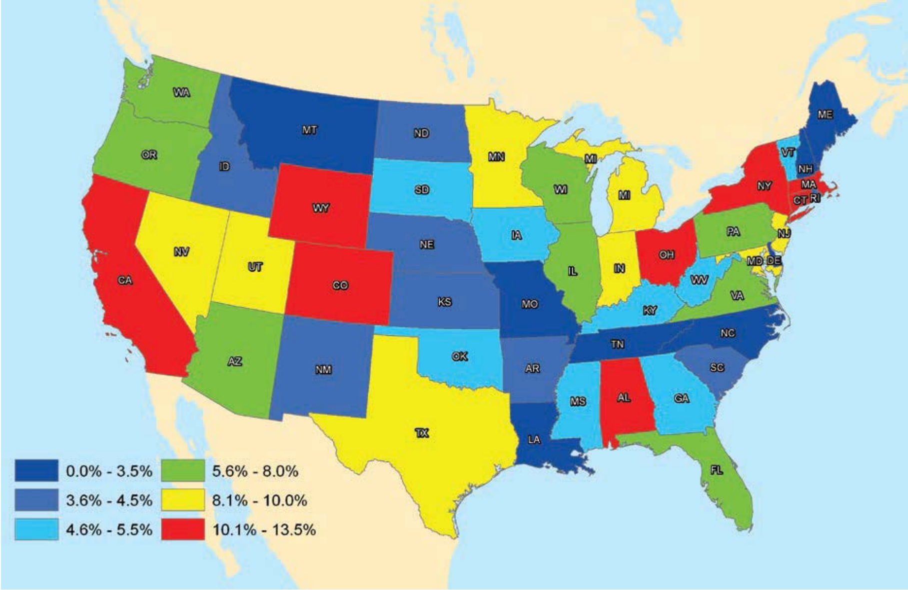
Recent history of very costly high-impact events

- **2012 – Hurricane Sandy - $66B**
- **2011 – Tropical Storm Lee - $3B**
- **2011 – Hurricane Irene - $14B**
- **2010 – Northeast Flooding - $2B**
- **2008 – Ice Storm - $2B**
- **2007 – Heat/Drought - $3B**
- **2006 – Flooding - $2B**

Why a Mesonet in New York?

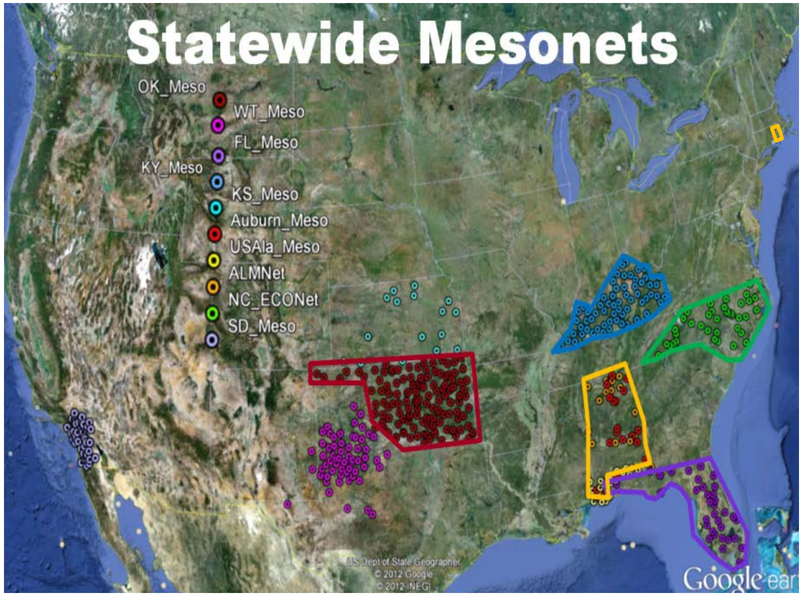
State economy is especially sensitive to weather

State Economic Sensitivity to Weather by GSP



* Lazo et al., 2011 (BAMS)

Other states have realized the economic value



Brief Overview

- NYS Mesonet awarded 1 April 2014
- Comprised of 125 stations, including:
  - Soil moisture/temperature at 3 depths
  - Camera (still images)
  - 20 snow sites
  - 17 profiler ("enhanced") sites
  - 17 flux sites
- Data collected, quality-controlled, and disseminated every 5 min
- Have 50+ sites now operational
- All 125 sites operational by 31 December 2016

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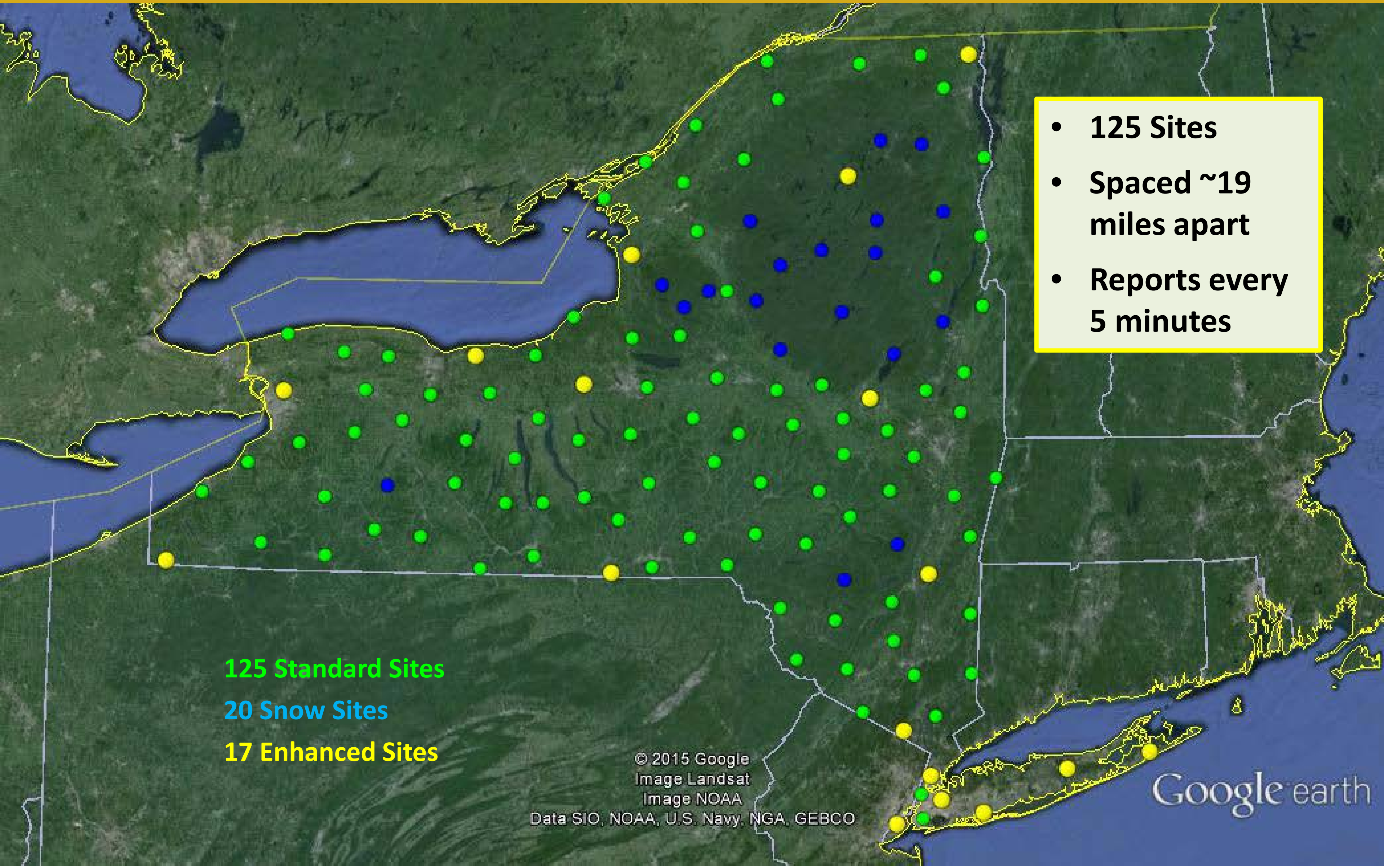

- 125 Sites
- Spaced ~19 miles apart
- Reports every 5 minutes

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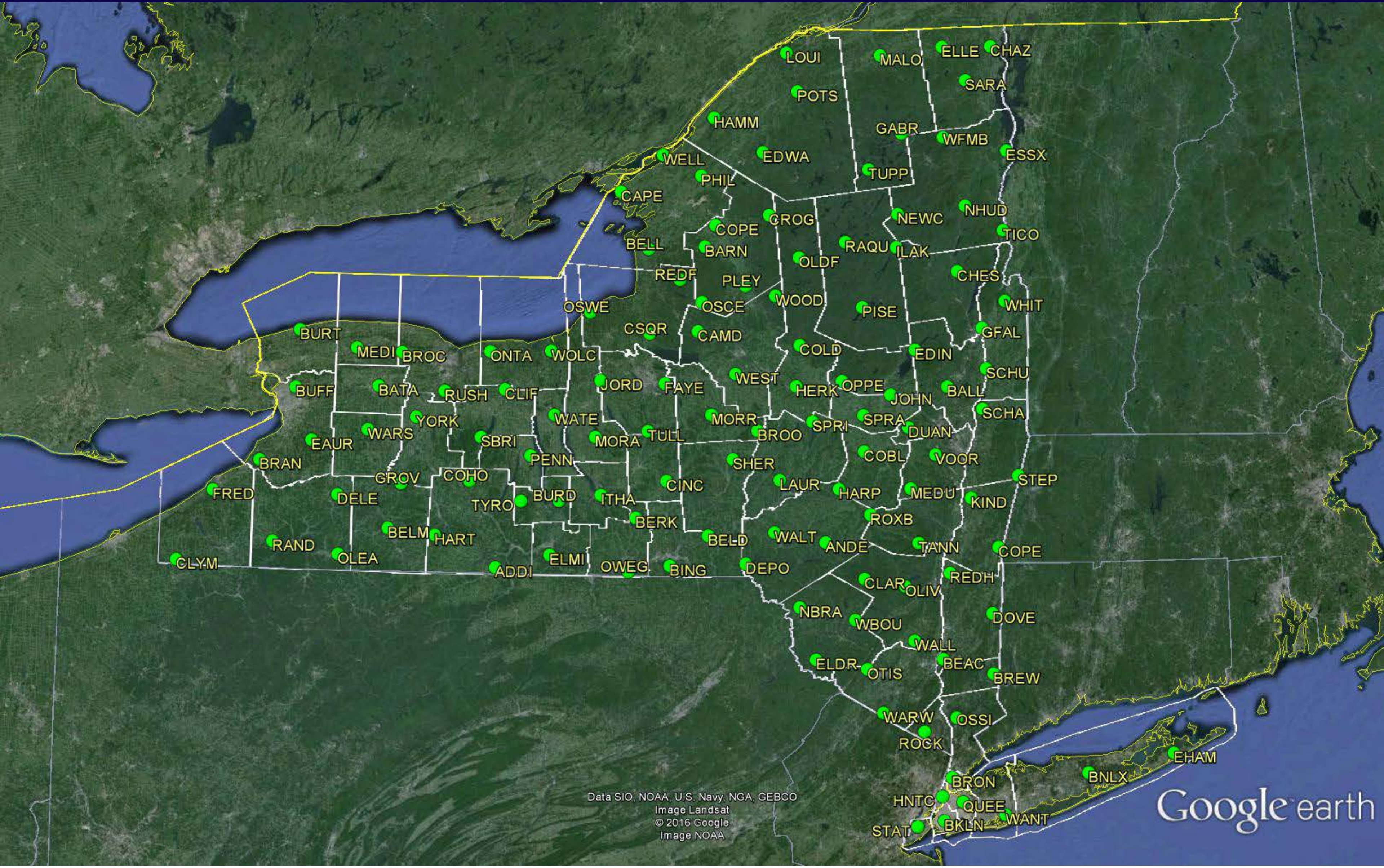

May 2016

NYS MESONET

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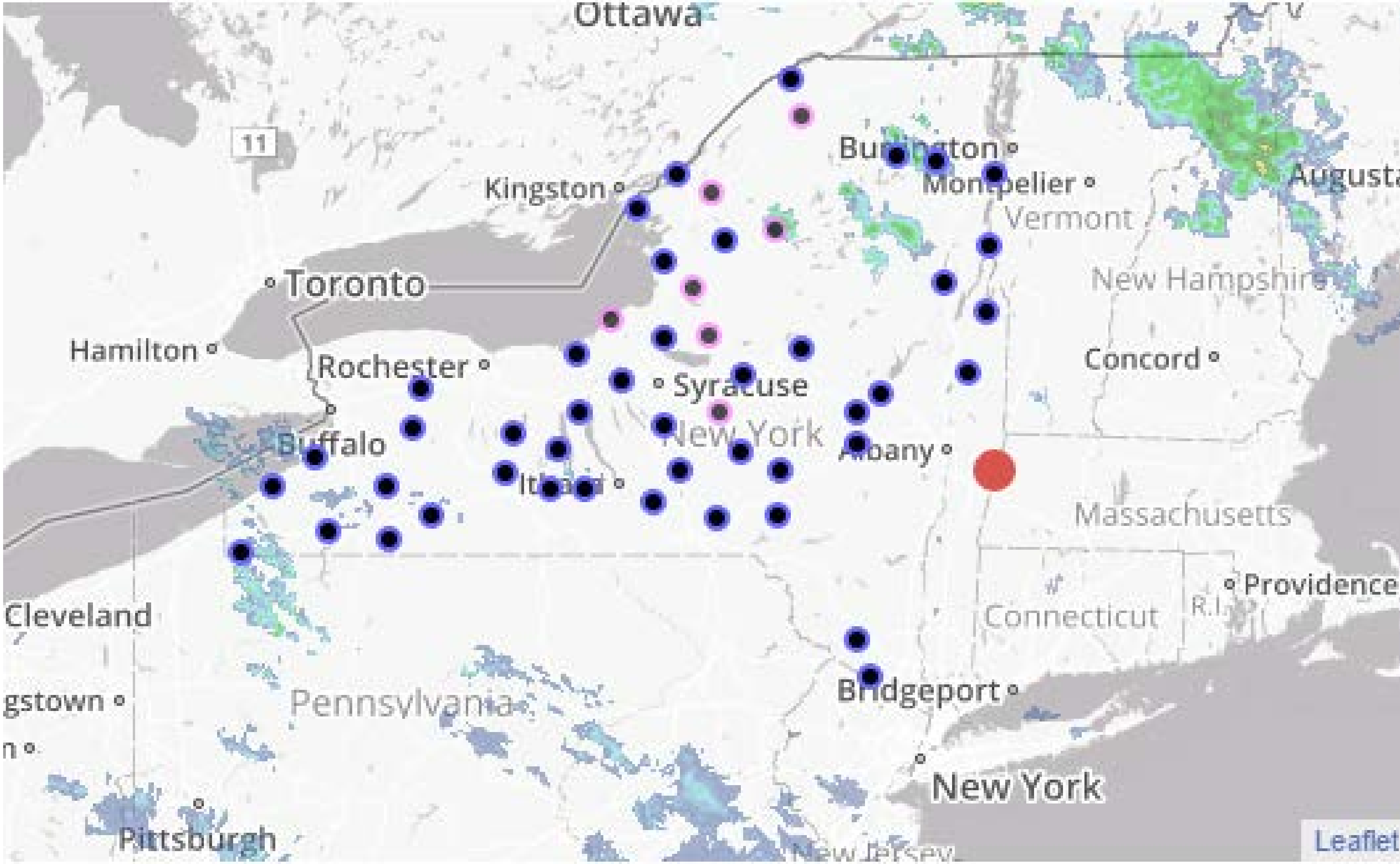

Some Site Selection Considerations

- General network configuration with 19 mile spacing
- Area representativeness – valley, high terrain, crops, forests
- NWS input – areas prone to flooding; gaps in observations
- WMO standards:
  – Generally flat terrain
  – No obstructions (no trees, pavement) within 300 ft
- FEMA guidelines:
  – No flood zones, no wetlands
  – No historical property
  – No archaeologically sensitive areas
- Require a 33’ x 33’ area

Best Sites

Adirondack Sites

NYC Sites

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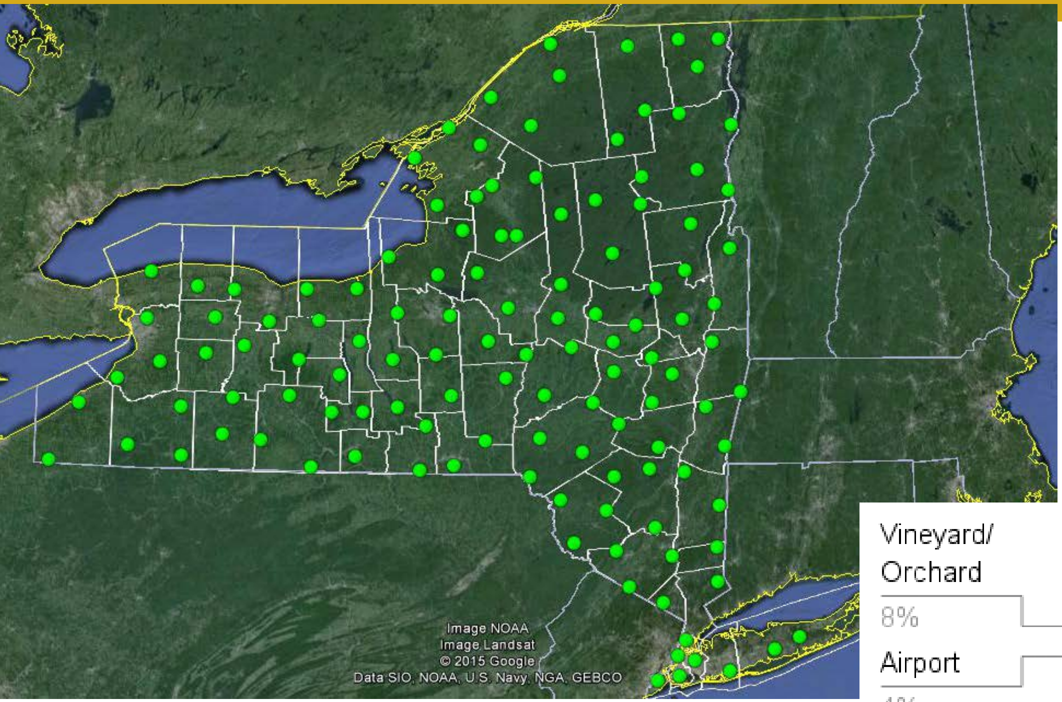
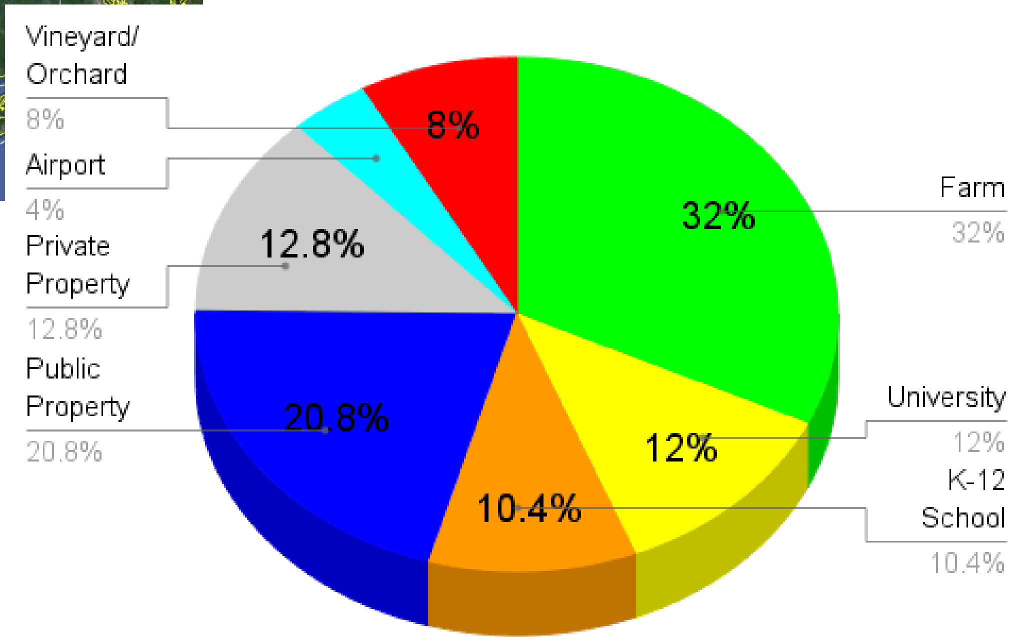
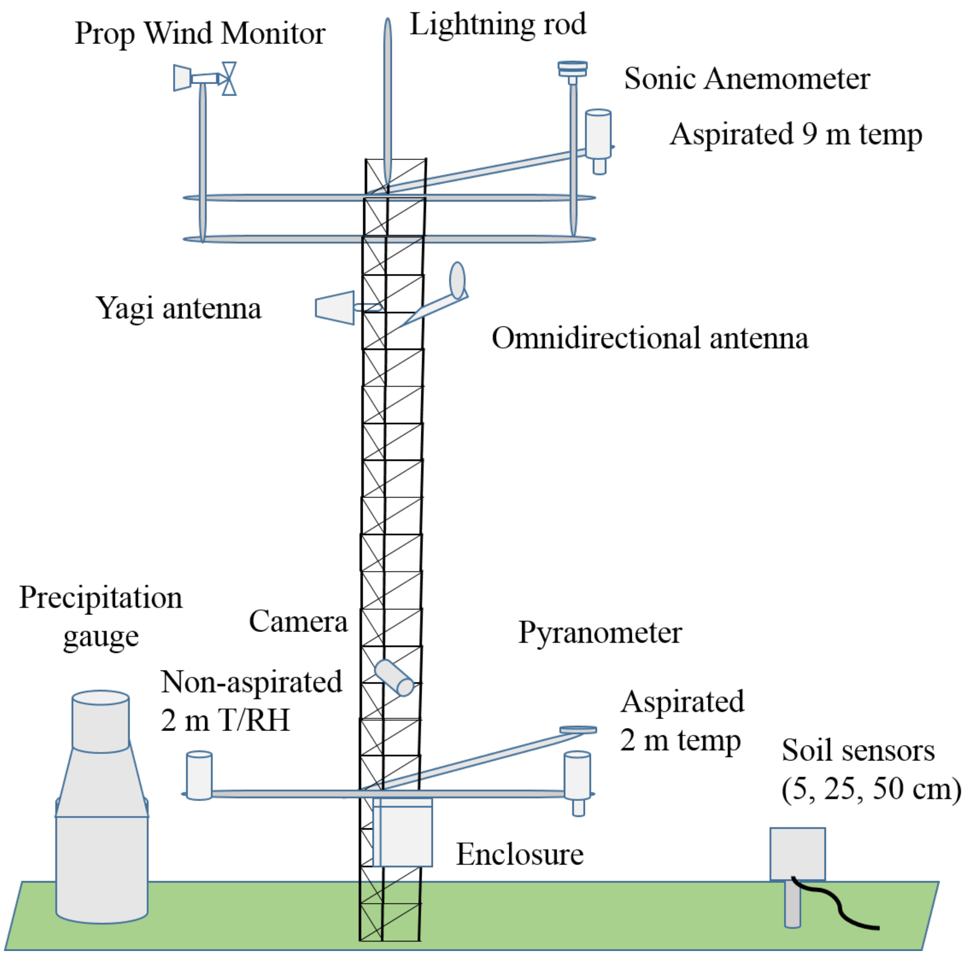




Standard Site

Standard Observations

- Precipitation
- Temperature
- Humidity
- Wind Speed and Direction
- Solar Radiation
- Barometric Pressure
- Soil Temperature (5, 25, 50 cm)
- Soil Moisture (5, 25, 50 cm)
- Site Photos



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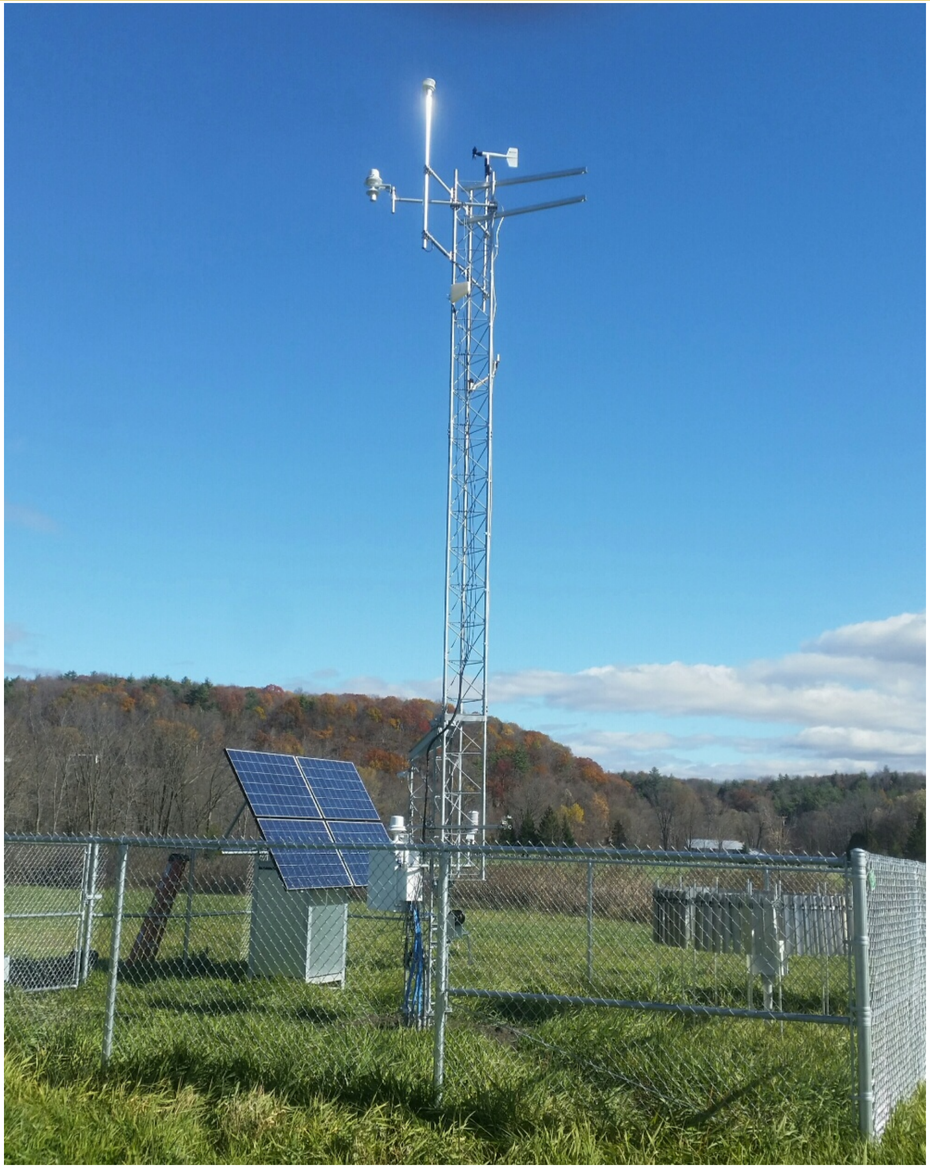

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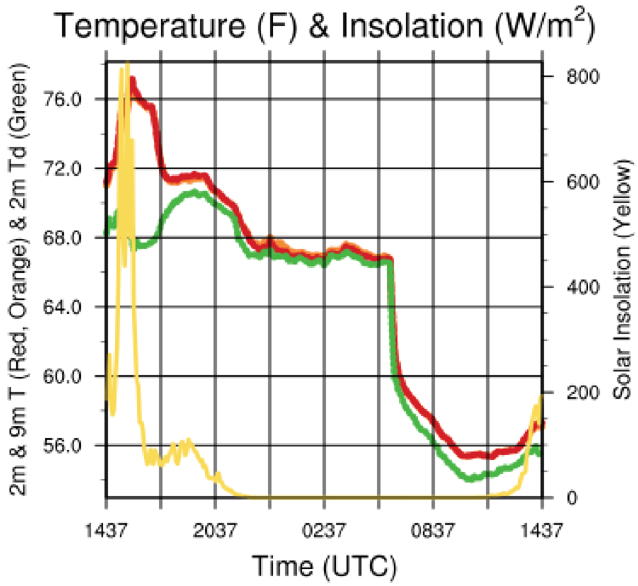
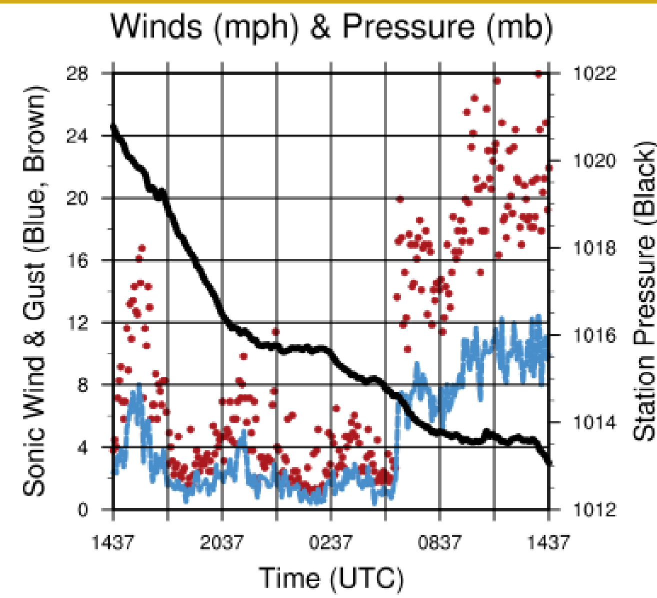
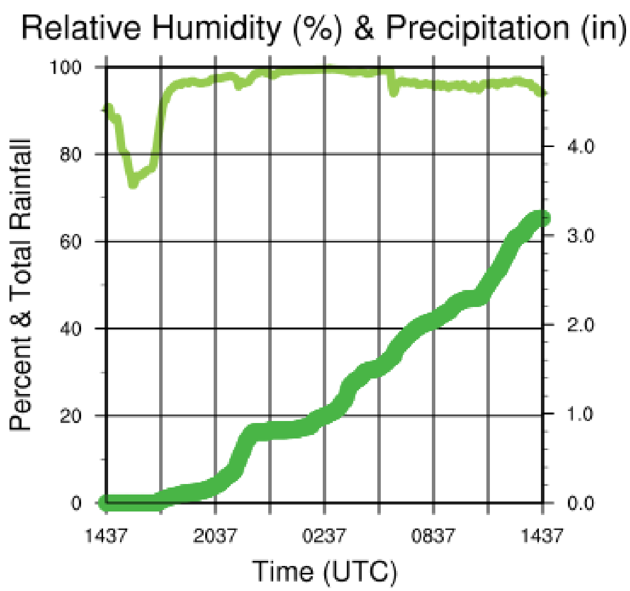
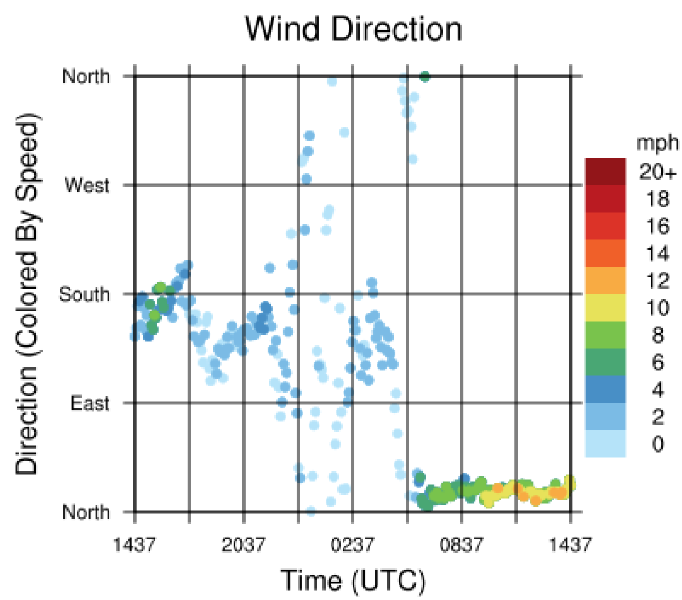
Data and Products



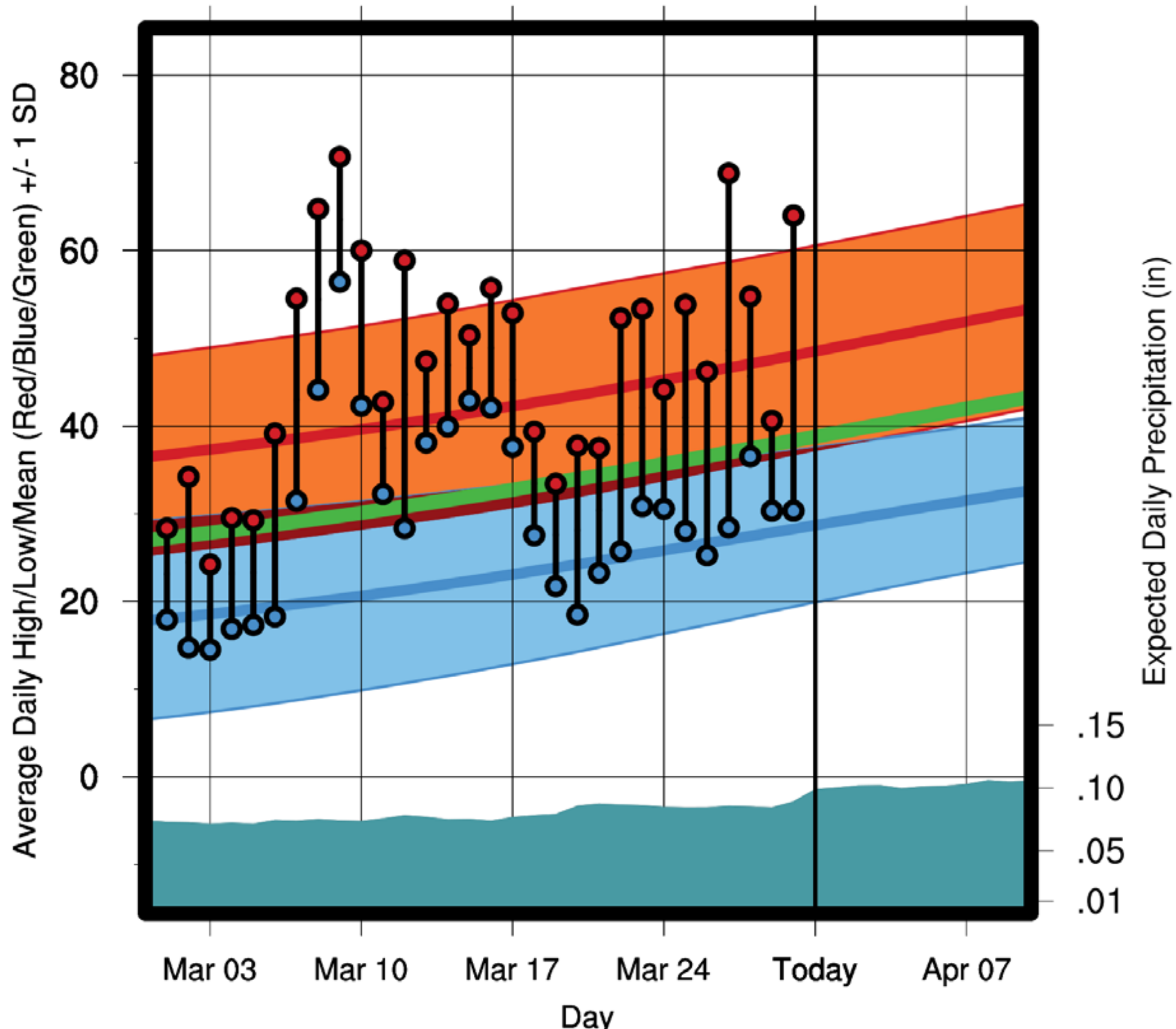






Data and Products

Recent Climate Values For Batavia



Location: Batavia
Station elevation: 276.12 m
Station lat/lon: 43.02; -78.14
Figure created on Thu, 2016-03-31, at 15:47 UTC

Summary Of Past 30 Days
Warmest/Coldest: **70.7/14.5**
Versus Expected: **+10.2/?**
(Mean Temperature/Precipitation)

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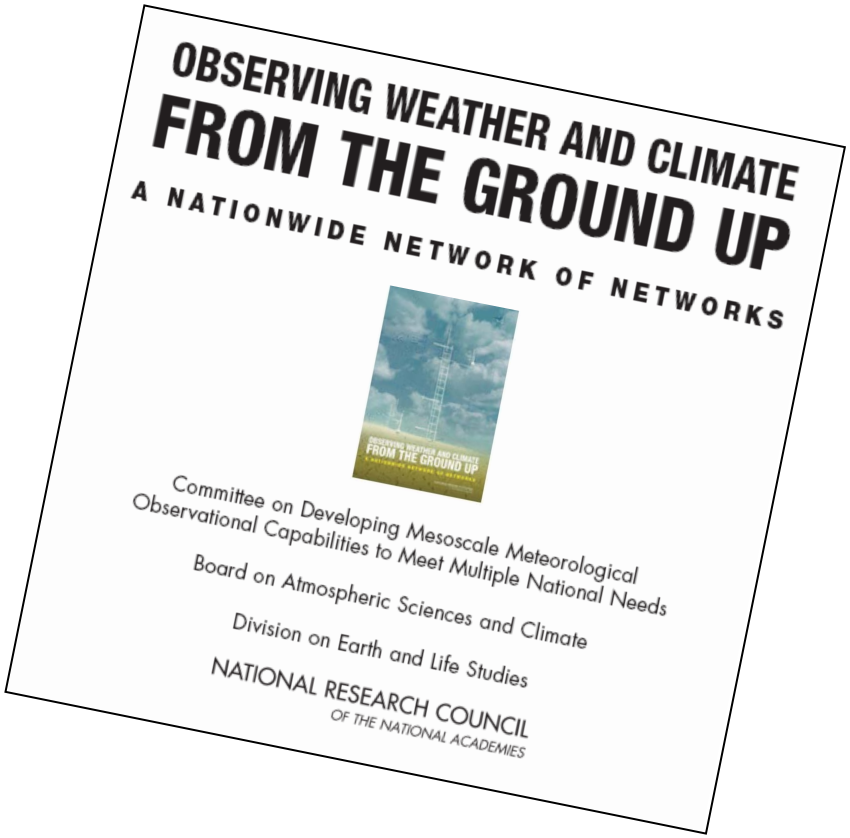

The most **critical observing needs to accurately nowcast severe local storms are measurements of moisture and wind in the lower troposphere**

Federal agencies and their partners <u>should deploy lidars and radio frequency profilers nationwide at approximately 400 sites to continually monitor conditions to 3 km AGL</u>

Humidity, wind, and <u>diurnal boundary layer structure profiles are the highest priority for a network</u>, the sites for which should have a <u>characteristic spacing of ~50–200 km and vertical resolution of ~100 m.</u>

17 Enhanced Station

Located within 500 m of Standard Site

LIDARs

- Vertical wind profiles up to 3 km AGL
- Selected RNRG/Leosphere 100S

Microwave Radiometers

- Vertical temperature and moisture profiles up to 10 km AGL
- Selected Radiometrics MP-3000A

Sun Photometer (MMR/SSI)

- Multi-scan Multi-channel Radiometer
- Shadowband Sky Imager
- Designed/built by Mesonet/ASRC

Enhanced (Profiler) Sites

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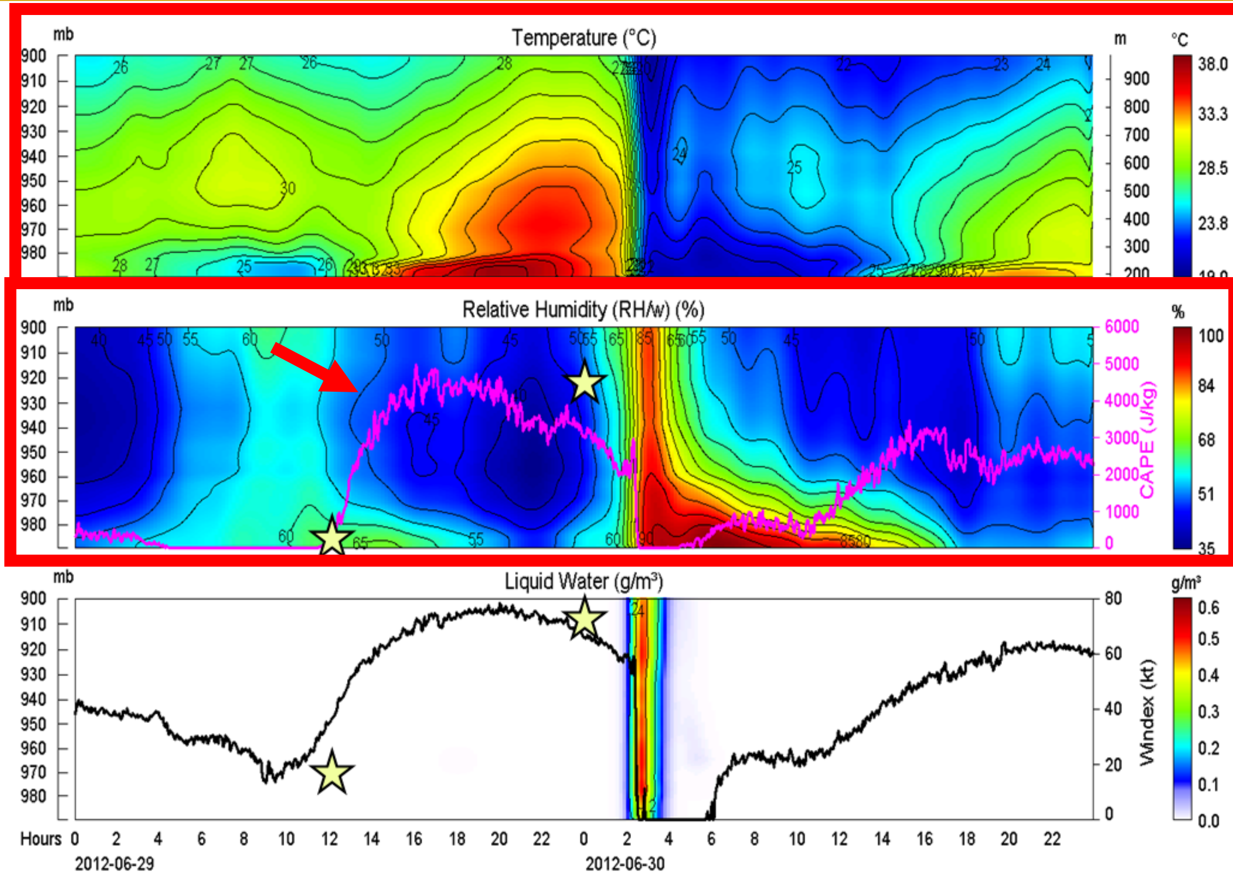
Profiler data of atmospheric temperature and stability

Weather balloon derived CAPE value from 12Z on June 29th evolved from near zero to 3,000 J/kg in just a couple of hours demonstrating the advantage of continuous profiling



Novakovskaia et al 2013

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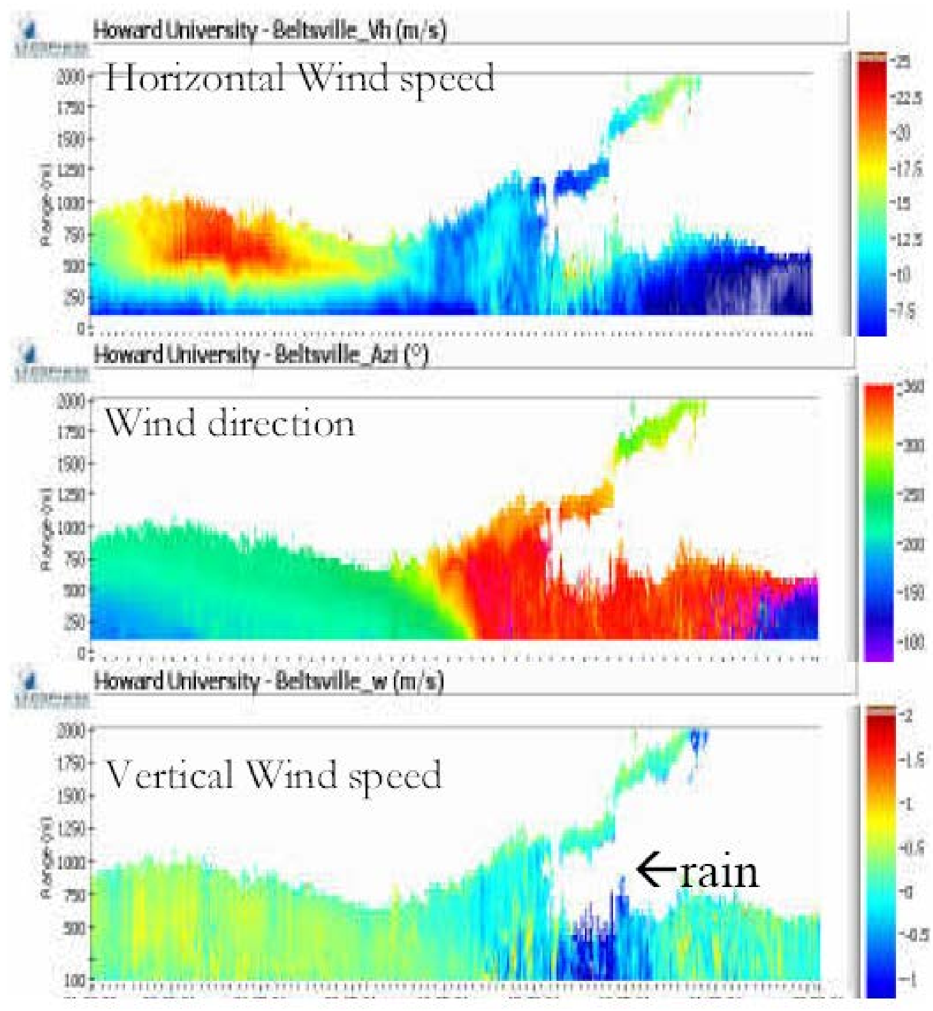
- Frontal passage preceded by a low-level jet was captured and the wind evolution revealed by the wind lidar
- Reversal of the wind speed from southerly to northerly and the front proceeding jet are well captured

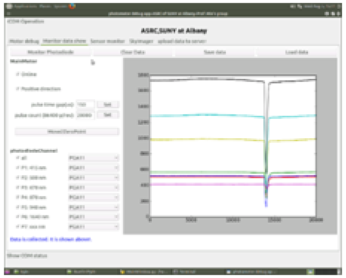


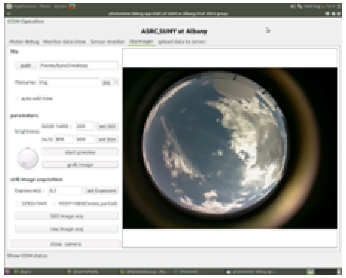
Demoz et al 2013

Multi-scan Multi-channel Radiometer and Shadowband Sky Imager (MMR/SSI)

New design ➔ Accurate spectral radiation measurements with angular distribution & sky condition

- ✓ Better diffusor
- ✓ Narrow shadowband
- ✓ New wavelength selection/sensor
- ✓ Robust data system
- ✓ Retrieval algorithm package





	MMR/SSI (MFRSR)	Retrievals
Radiation	Direct	Langley Calibration [Harrison and Michalsky, 1994]
	Direct, Diffuse, and total	Synthesis PAR [Min, 2005]
Aerosols	Direct	Aerosol optical depth and Angstrom Coefficient [Min et al., 2004]
	Diffuse/Direct	Single Scattering Albedo [Yin et al, 2014]
Clouds	Diffuse/Total+MWR	Cloud optical depth and effective radius [Min and Harrison, 1996]
	Spectral Total	Fractional sky cover (Cloud cover) [Min et al, 2008]
	Direct	Cloud optical depth for optically thin clouds [Min et al, 2004a]
	Direct and Total	Cloud phase partition for optically thin clouds [Wang and Min, 2008]
Cloud Cover	Sky imager	Yang, Min, at al. [2015]
Cloud Motion	Sky imager	Du and Min …

Enhanced Station

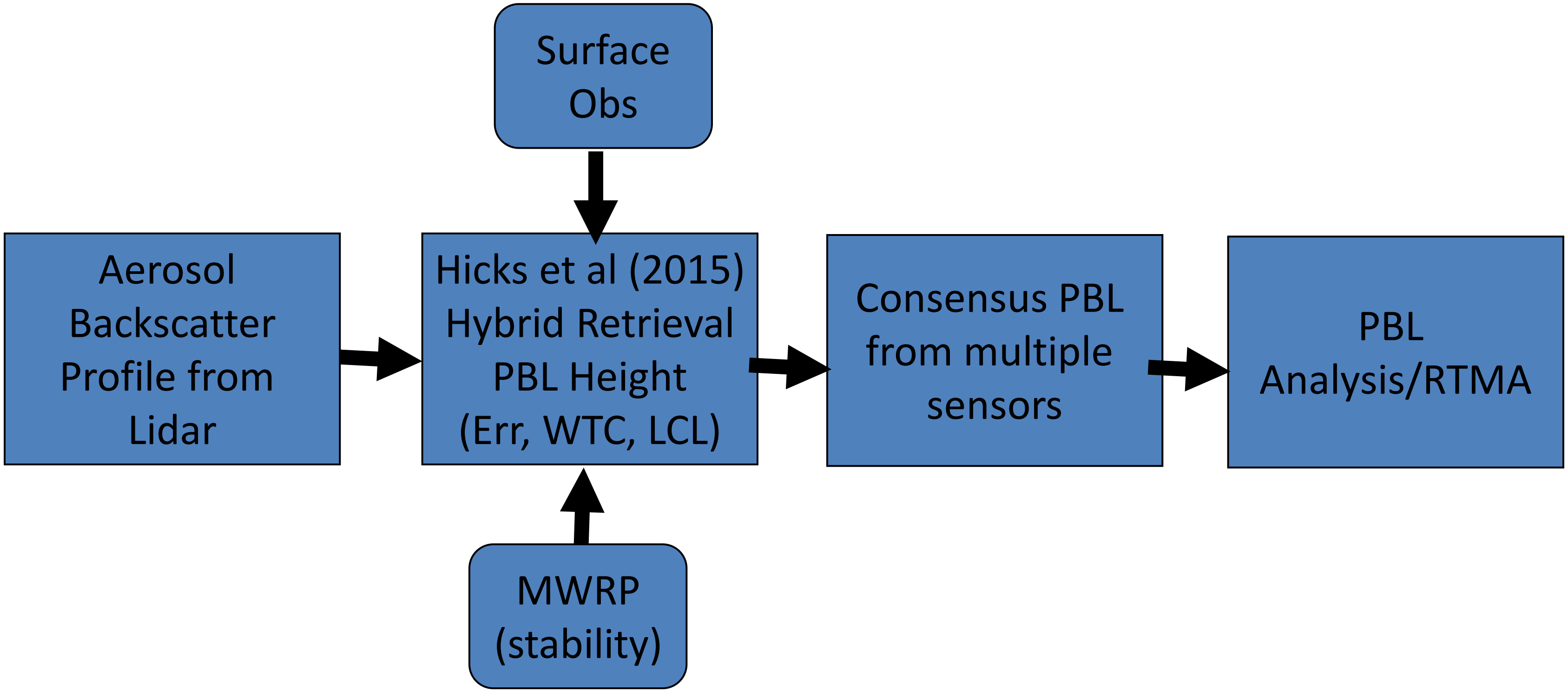
Output from Enhanced/Standard data:

- Clear sky/cloud classification --- sky condition
- Accurate radiation (spectral, direct/diffuse)
- Profiles: Temp., RH, Wind, and aerosols
- PBL height, cloud base height, LCL
- Aerosols: AOD & profile, SSA, Angstrom Coefficient
- Clouds: cloud fraction, COD, Effective radius
- Forecast indices (CAPE, k, etc)

Complex process:

- Characterize measurement, retrieval uncertainties
- Develop robust retrieval algorithms
- Products developed from synergistic retrieval/analysis approach (multiple sensors)

Example of product (PBL) developed from multiple sensors and algorithms



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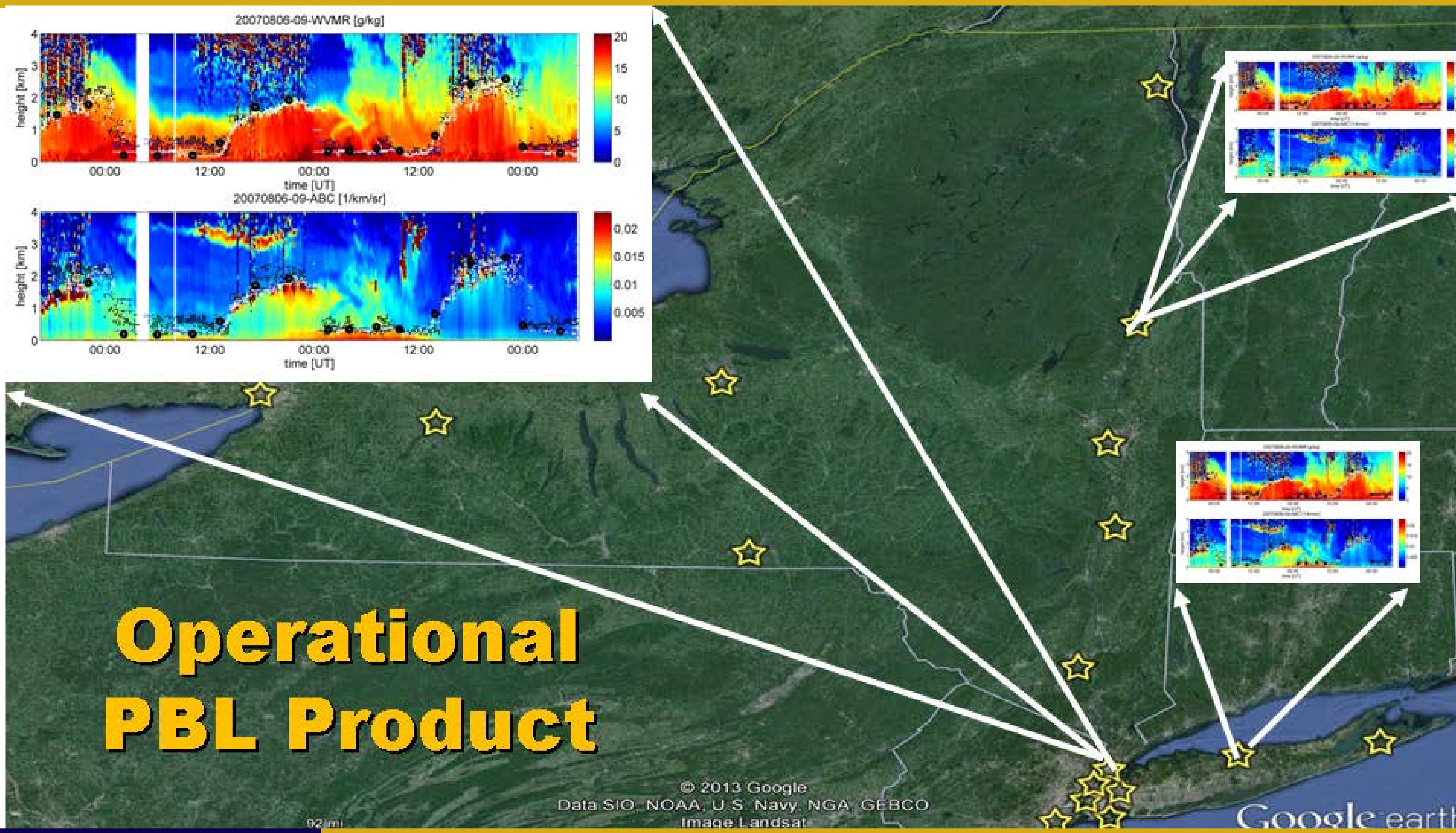
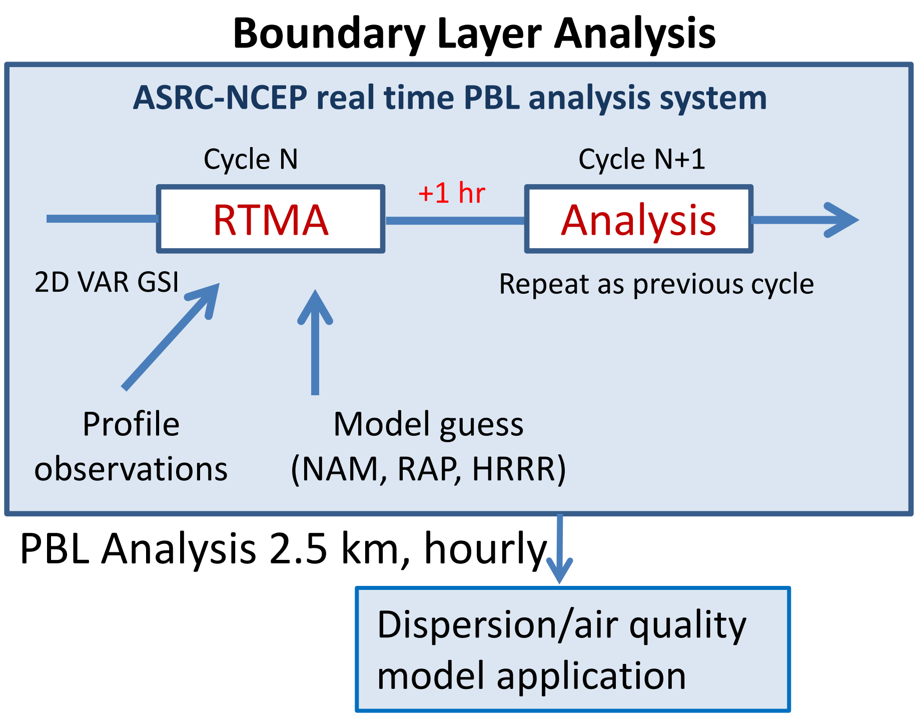


UAlbany/ASRC-NCEP Collaboration on Real-Time PBL Analysis Study

- Developing unified PBL operational analysis system -- ASRC for NYS and NCEP CONUS
- Leverage prototype PBL analysis established by NOAA-NASA-Howard ROSES project in 2007 (McQueen)
- **Objective:**
  - Develop near real time PBL products by blending model estimates and multi-platform profile observations (aircrafts, radiosonde, and NYS mesonet).
  - Demonstrate use of NYS mesonet vertical profiles for real-time PBL analysis.
  - Demonstrate the impact of PBL analysis on air quality/dispersion modeling.

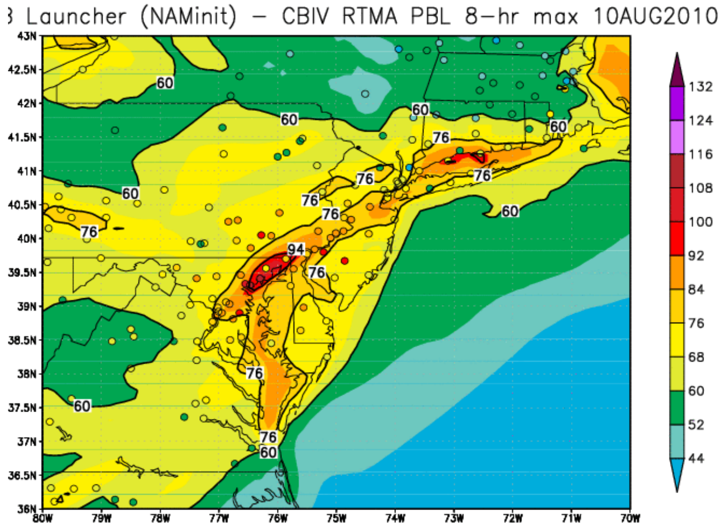
Real-time PBL analysis system using multi-platform profile observations



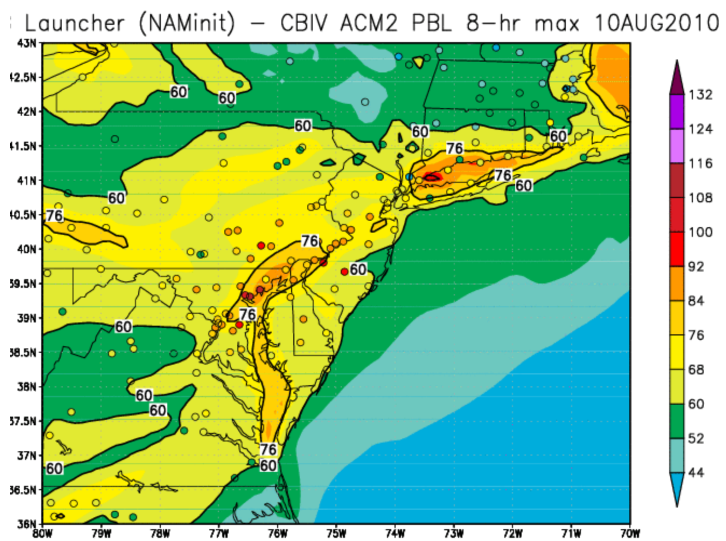
- Ualbany/ASRC – NCEP Pilot study
- Derivation of PBL heights from the following observation data:
  - Radiosondes, aircraft profiles, and NYS mesonet lidar profiles
  - optional data: MPLNET lidars, ceilometer, and CALIPSO, if resource is available
- Evaluation of model 1st guess used for RTMA (NCEP's weather model output):
  - NAM
  - RAP
  - HRRR
- Assimilation of PBL heights into Real-Time Mesoscale Analysis (RTMA), which is 2D VAR Gridpoint Statistical Interpolation (GSI) analysis system
- Final product will be PBL height analysis (2.5 km resolution, hourly)
- Application to air quality/dispersion models with RTMA PBL analyses

The impact of improved boundary layer on CMAQ ozone forecasts from the study by NOAA/NWS/NCEP EMC (Jeff McQueen)

a)

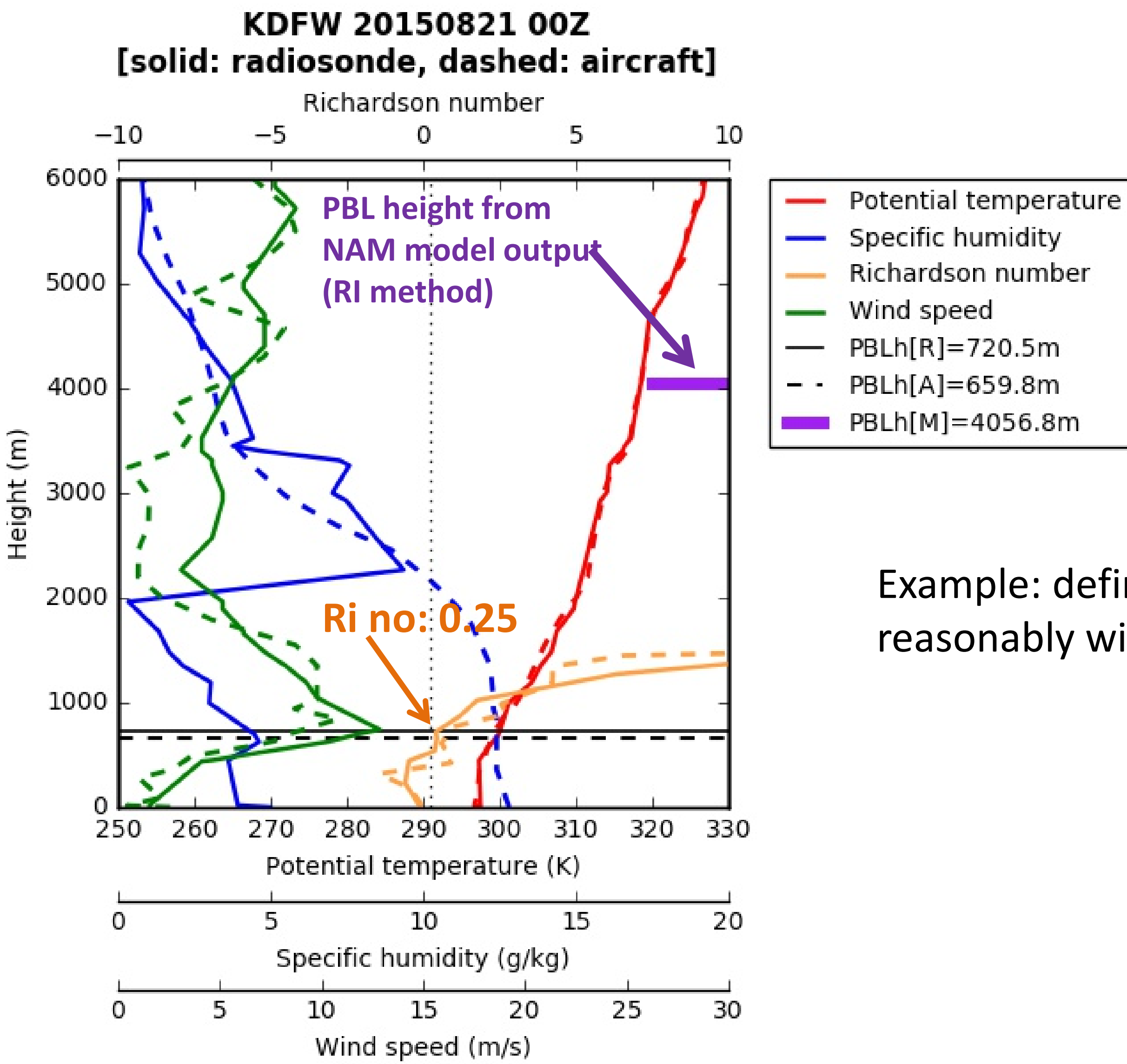


b)



- Comparison of daily 8hr max ozone prediction from the NAM-CMAQ with the operational CB-IV chemical mechanism to observations from the monitoring networks (e.g., EPA AIRNow, colored circles, ppb) using
  - a) the CMAQ default derived PBL height
  - b) the RTMA PBL height valid August 10, 2010
- The ozone simulation shows improvement over the Baltimore-Washington urban corridor when using the PBL analysis.

PBL height defined using radiosonde and aircraft (Dallas-Fort Worth airport)

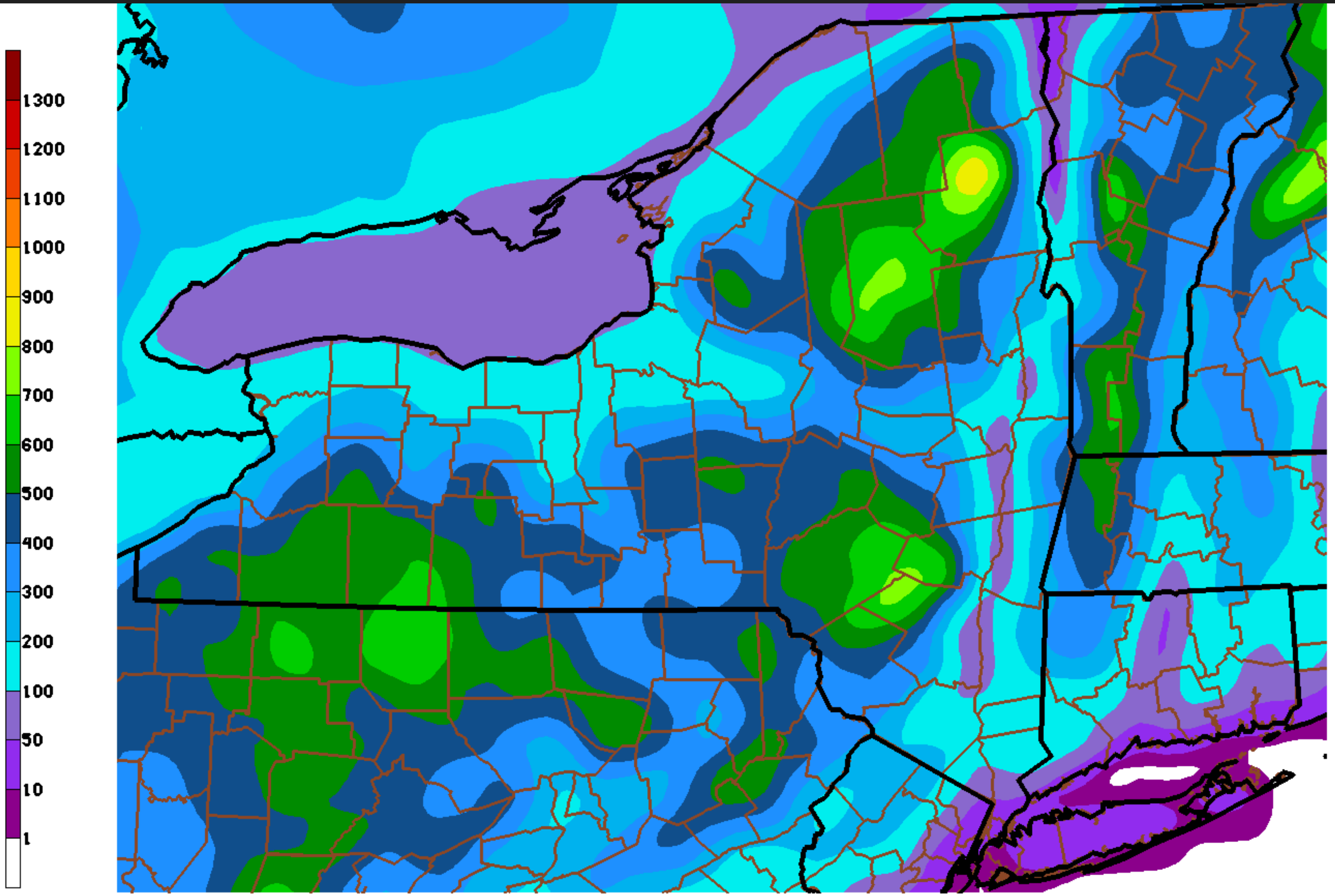


Example: defined PBL height reasonably with Ri no.

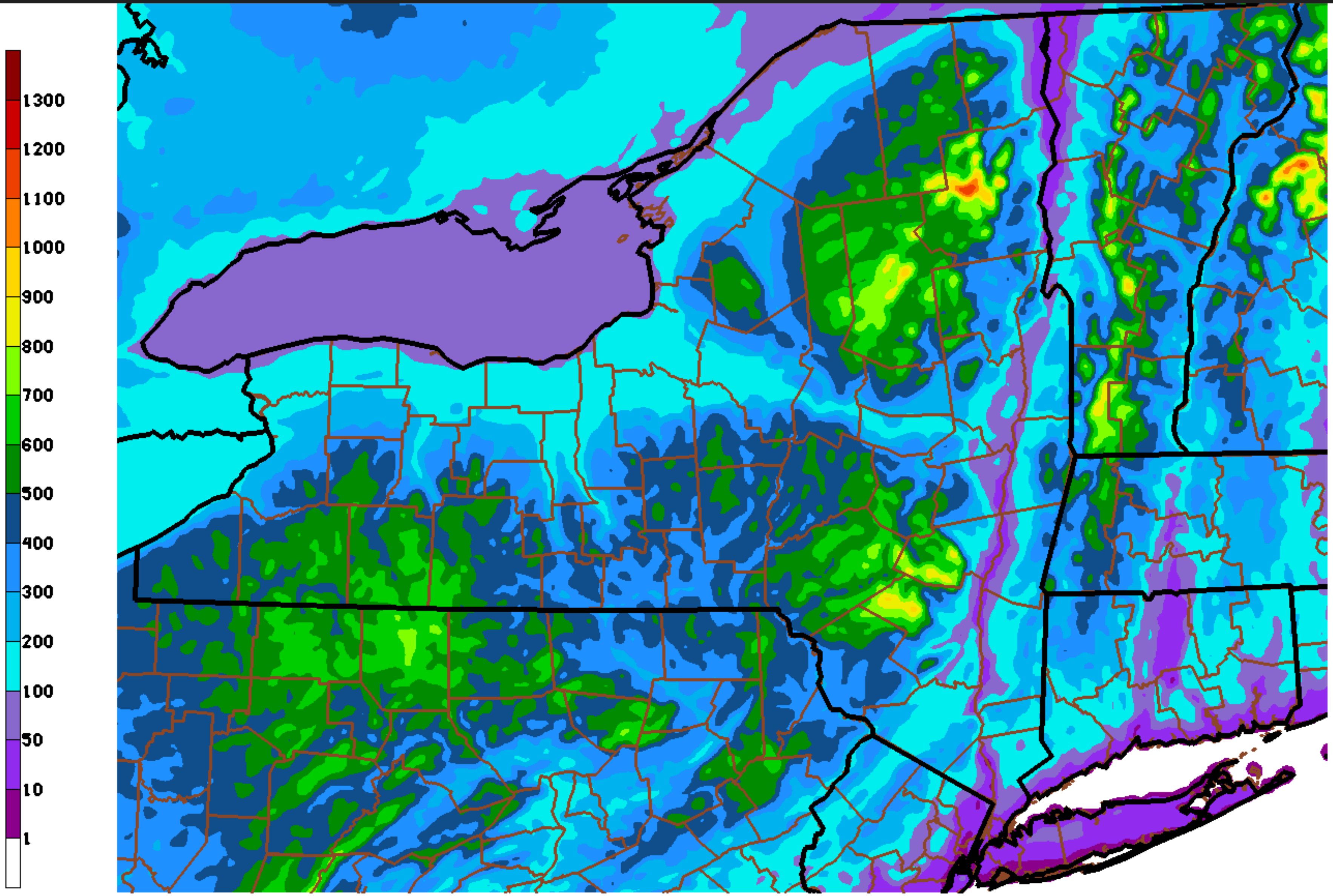
NWP Activities

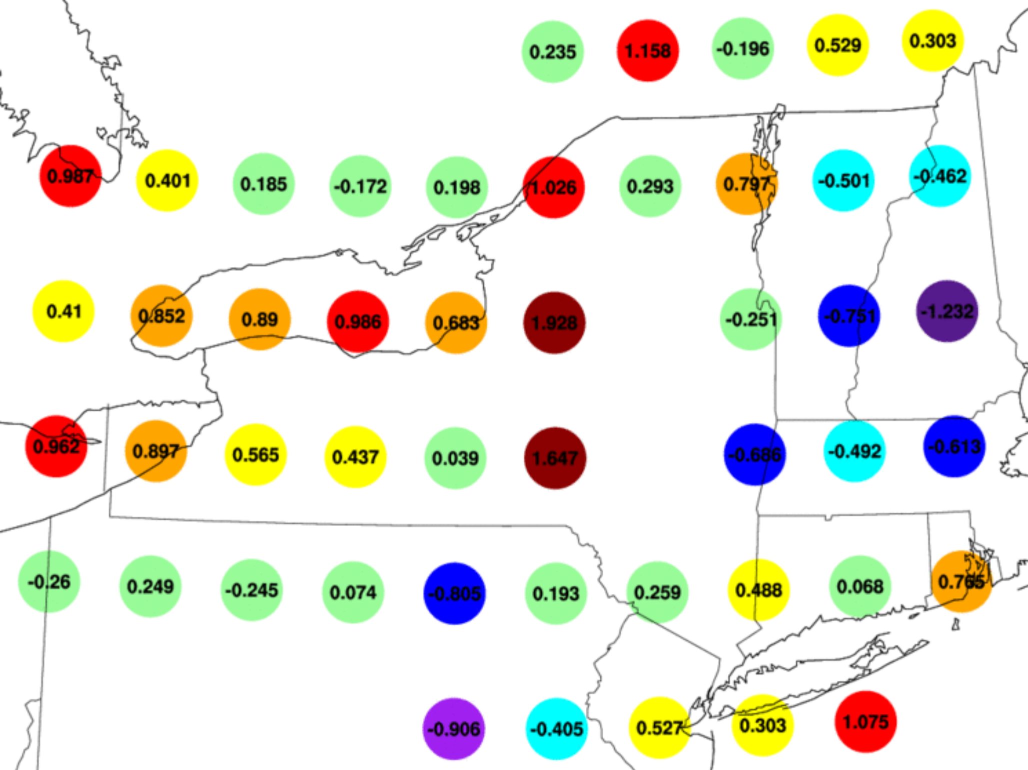
- Just beginning to study impact of NYM observations on NWP
- WRF/DART ensemble system
- Inner domain of ~ 3km grid (New York)
- Outer domain only (15 km) – 56 members
- Perturbed GFS initial conditions and boundary conditions unique to each member and each cycle
- Perform 3 hourly assimilation cycles
  - Adaptive Anderson Inflation
  - Gaspari Cohn localization, .05 (~600 km) horizontal localization
- Inputs for Experiment 1:
  - ACARS, METAR Altimeter, Radiosonde, SSEC Sat Winds, Marine
  - Evaluate Only: NYS Mesonet, METAR wind/temp
- Inputs for Experiment 2:
  - Experiment 1 + NYS Mesonet winds/temp
- Using METAR obs as "truth" assess the impact of adding NYS Mesonet data

Outer Domain NY Topography



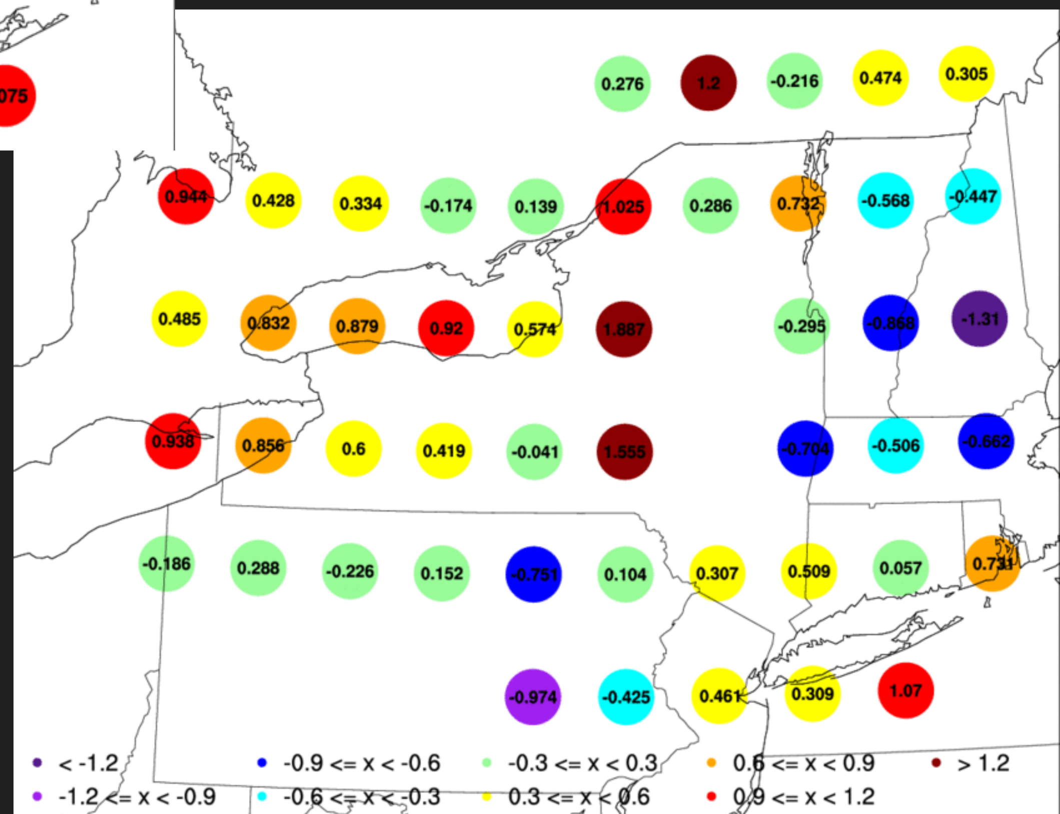
Inner Domain NY Topography

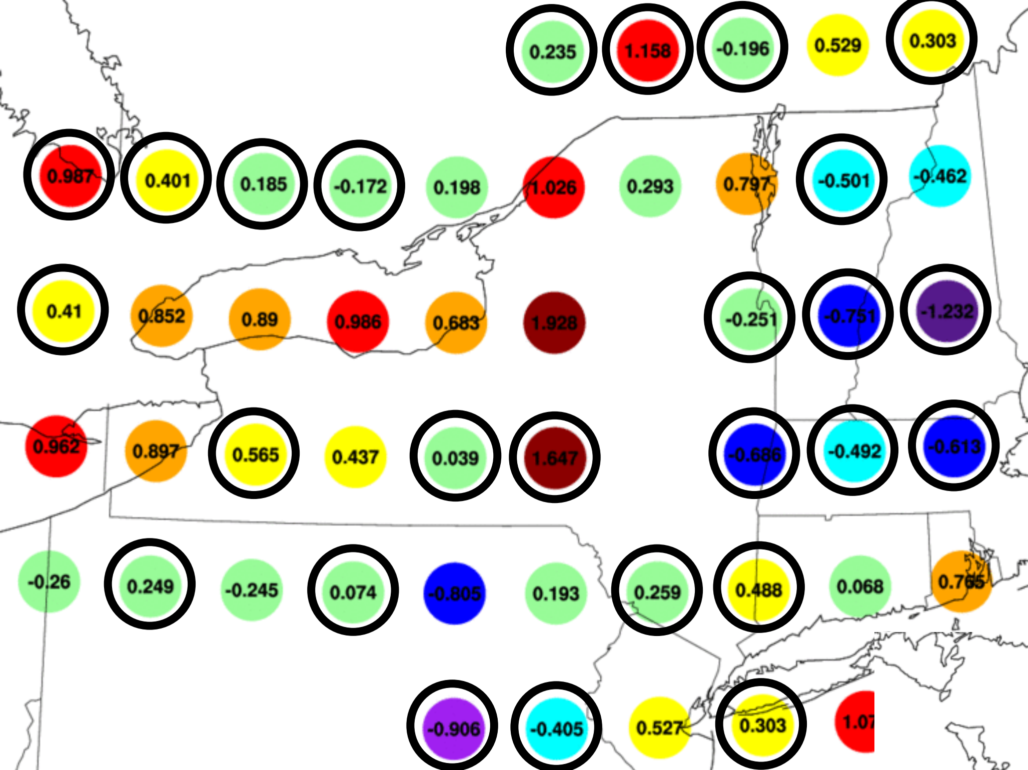




Experiment 1 (left)
Experiment 2 (below)

1°x1° Binned
METAR Biases

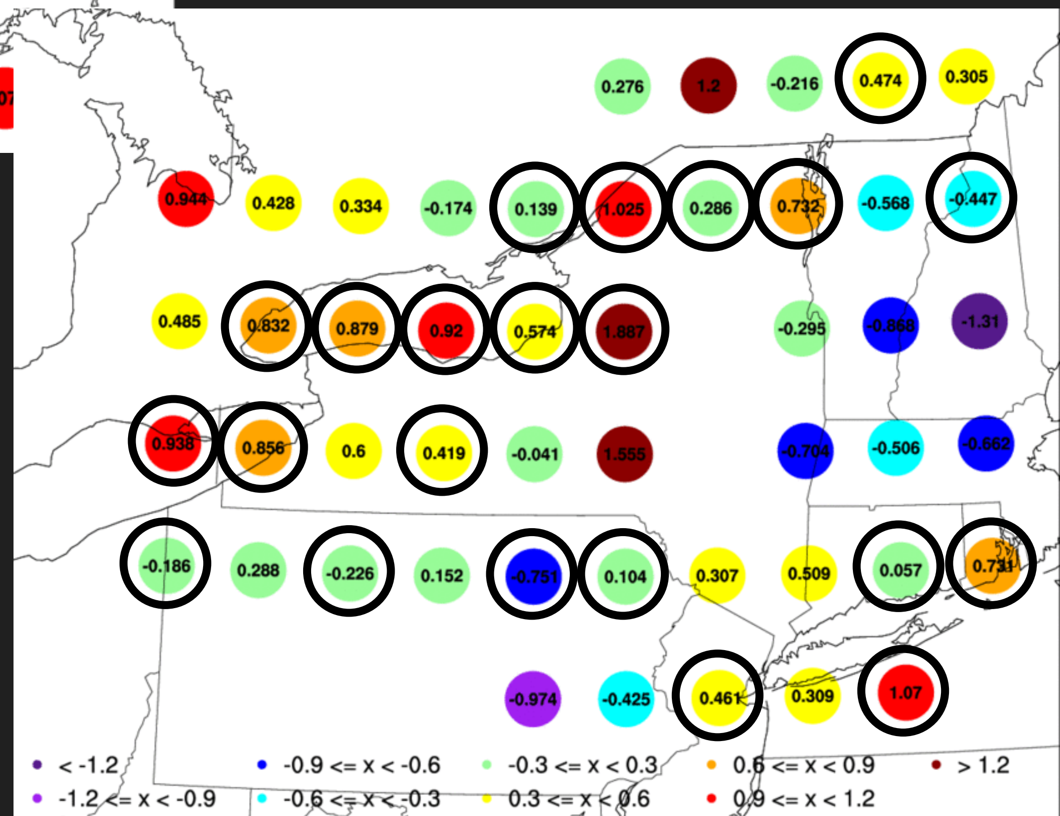




NY Area Biases (a-o):

Exp. 1 -> Exp. 2

0.1131° C -> 0.0983° C



HIGH QUALITY NETWORK

- **Highest Priority**
- **Rigorous Program including:**
  - Site Selection Process
  - Calibration / Testing Program
  - Routine Field Maintenance
  - Quality Assurance Program
  - Automated Systems
  - Software from OK Mesonet
  - Manual Inspection Program
  - **And High Quality Staff & Expertise!**

QUALITY ASSURANCE

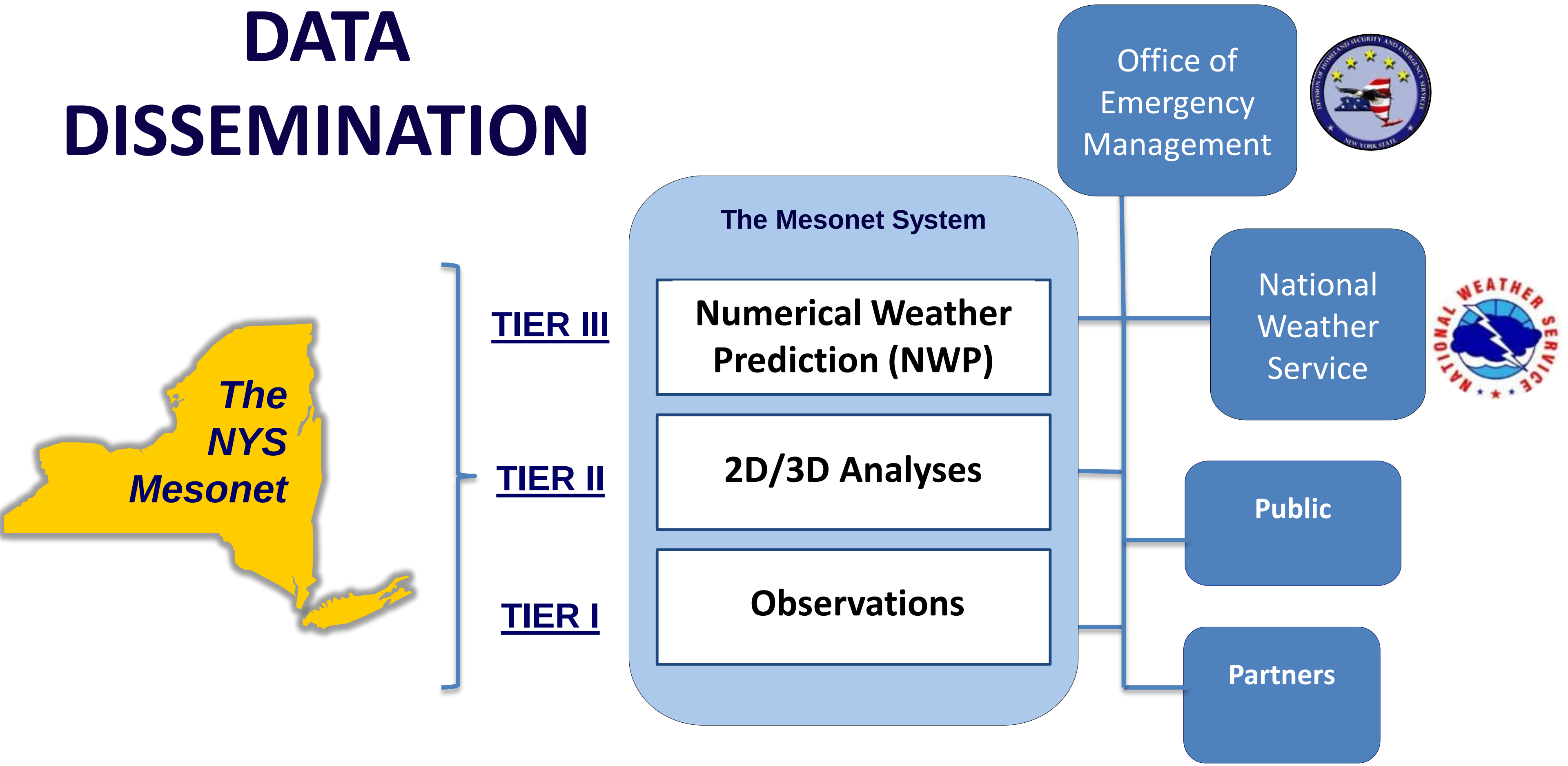
Automated QA routines

- Missing data filter
- Tech visit flag
- Range filter
- Step tests
- Persistent tests
- Spatial tests
- Like sensor comparisons
- Climate persistent tests
- Wind speed profile tests
- Etc., etc.

Manual QA routines

- Review of all meteograms
- Reviews all flagged data
- Monthly QA data
- Radar vs Station data
- Spatial maps
- Temporal maps
- Annual data reviews
- Customer inquiries
- And more!

DATA DISSEMINATION

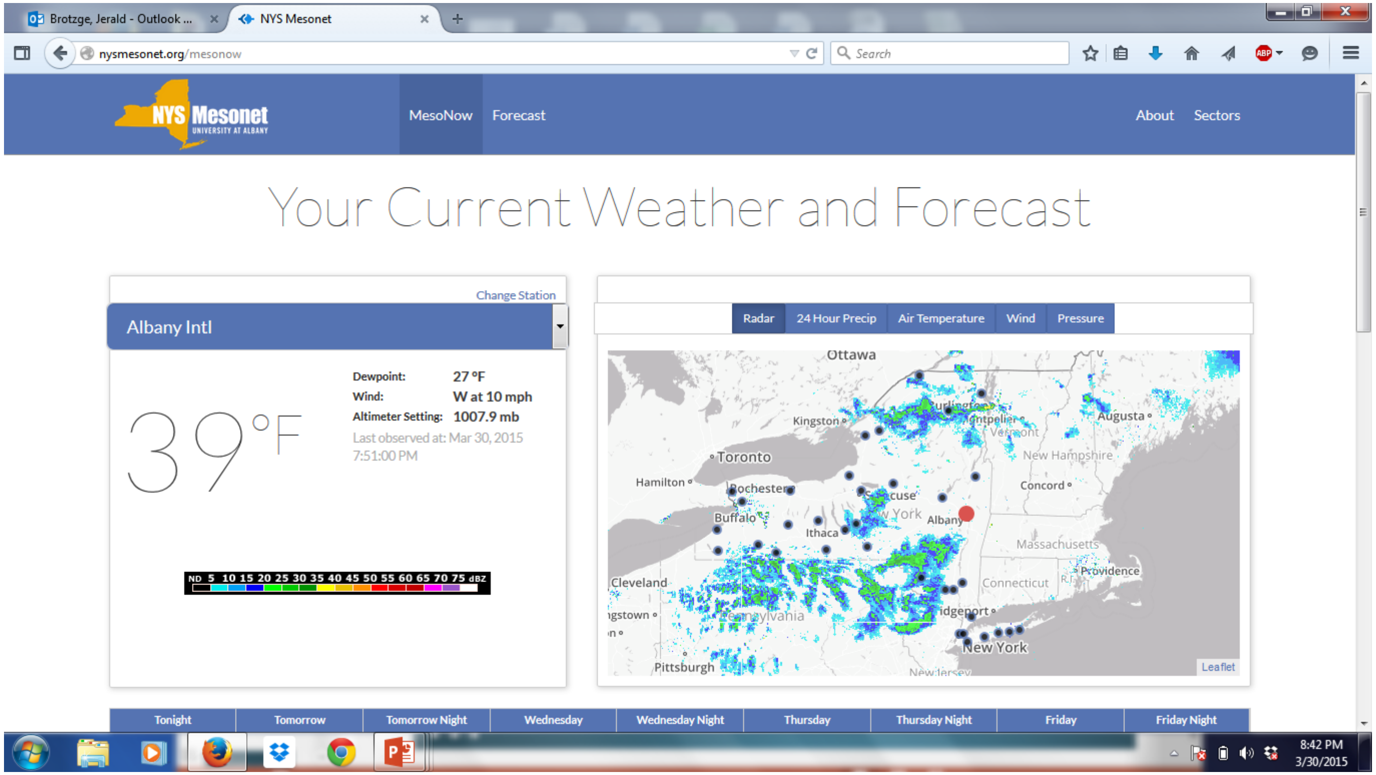


Webpages and Social Media – Operational

http://nysmesonet.org

Facebook.com/nysmesonet

Twitter.com/nysmesonet



QUESTIONS, THOUGHTS, COMMENTS

Jerry Brotzge, PhD
Program Manager
jbrotzge@albany.edu

Chris Thorncroft, PhD
Chair, UAlbany DAES
cthorncroft@albany.edu

Everette Joseph, PhD
Director of ASRC
ejoseph@albany.edu

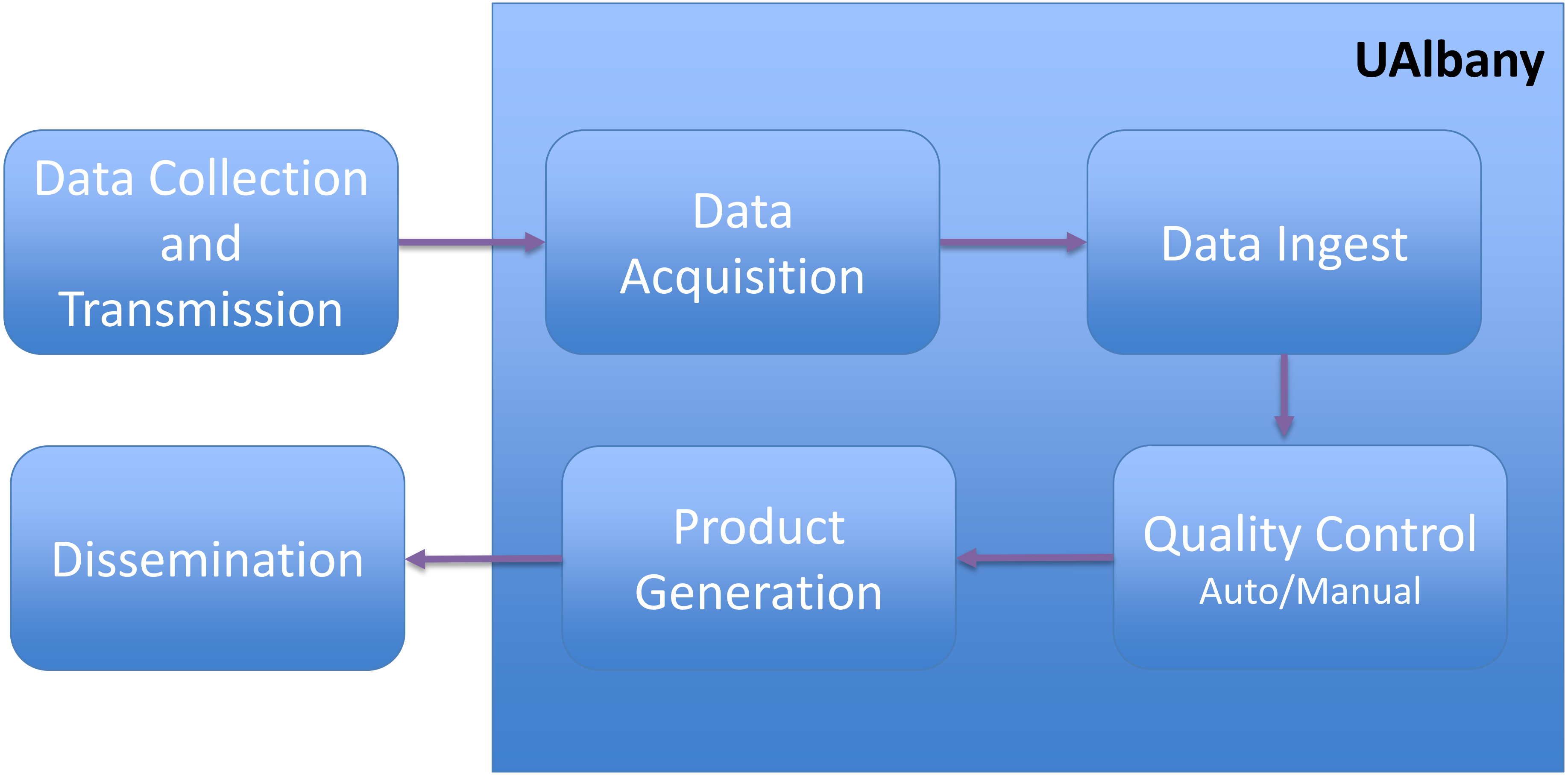
Snow Stations – 20 sites

- **Snow Water Equivalent**
  - CS725 SWE

- **Snow Depth**
  - CS SR50A

- **Expands state network**
  - NYCDEP snow network in Catskills

Data Flow


UAlbany
Data Collection and Transmission
Data Acquisition
Data Ingest
Quality Control
Auto/Manual
Product Generation
Dissemination

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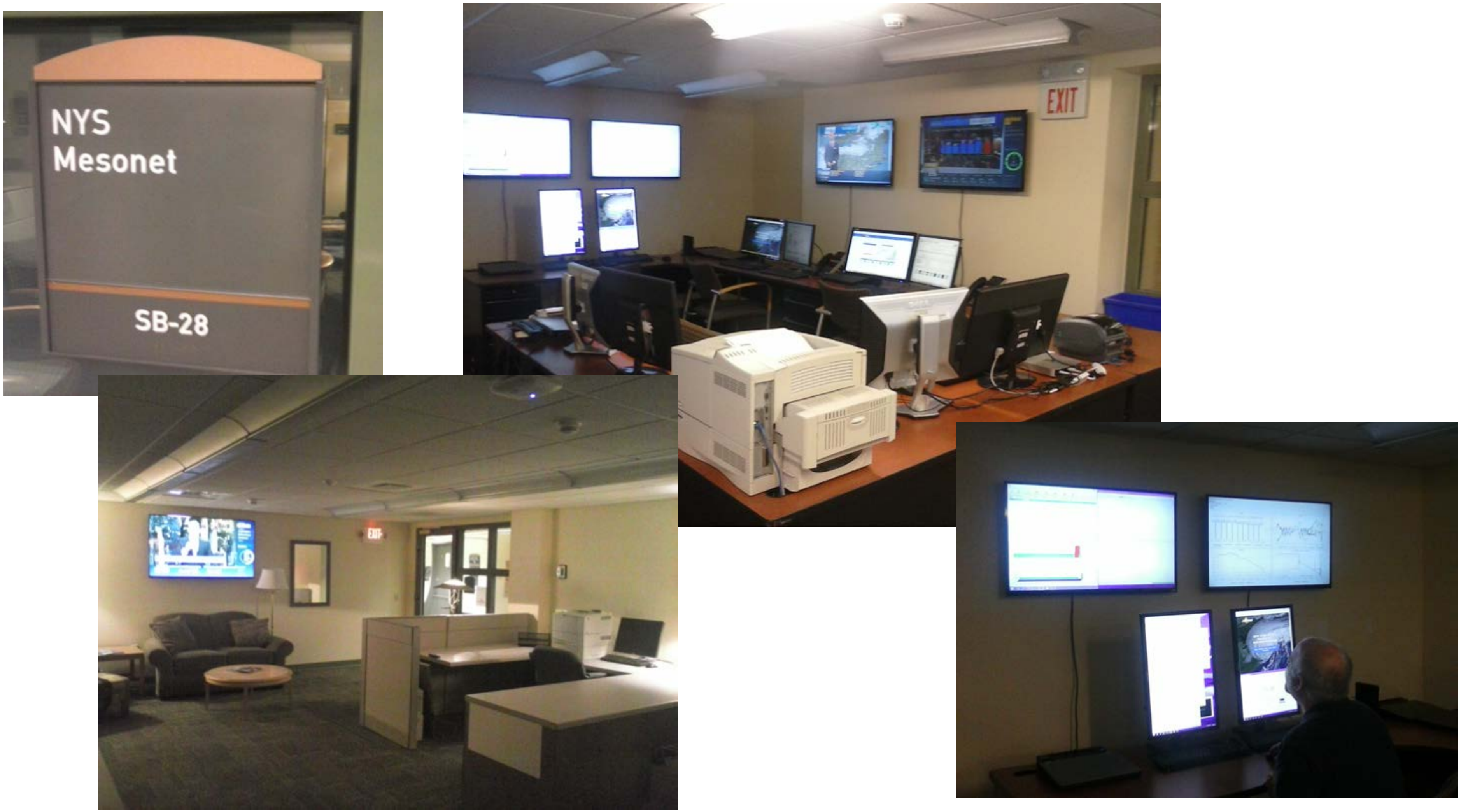

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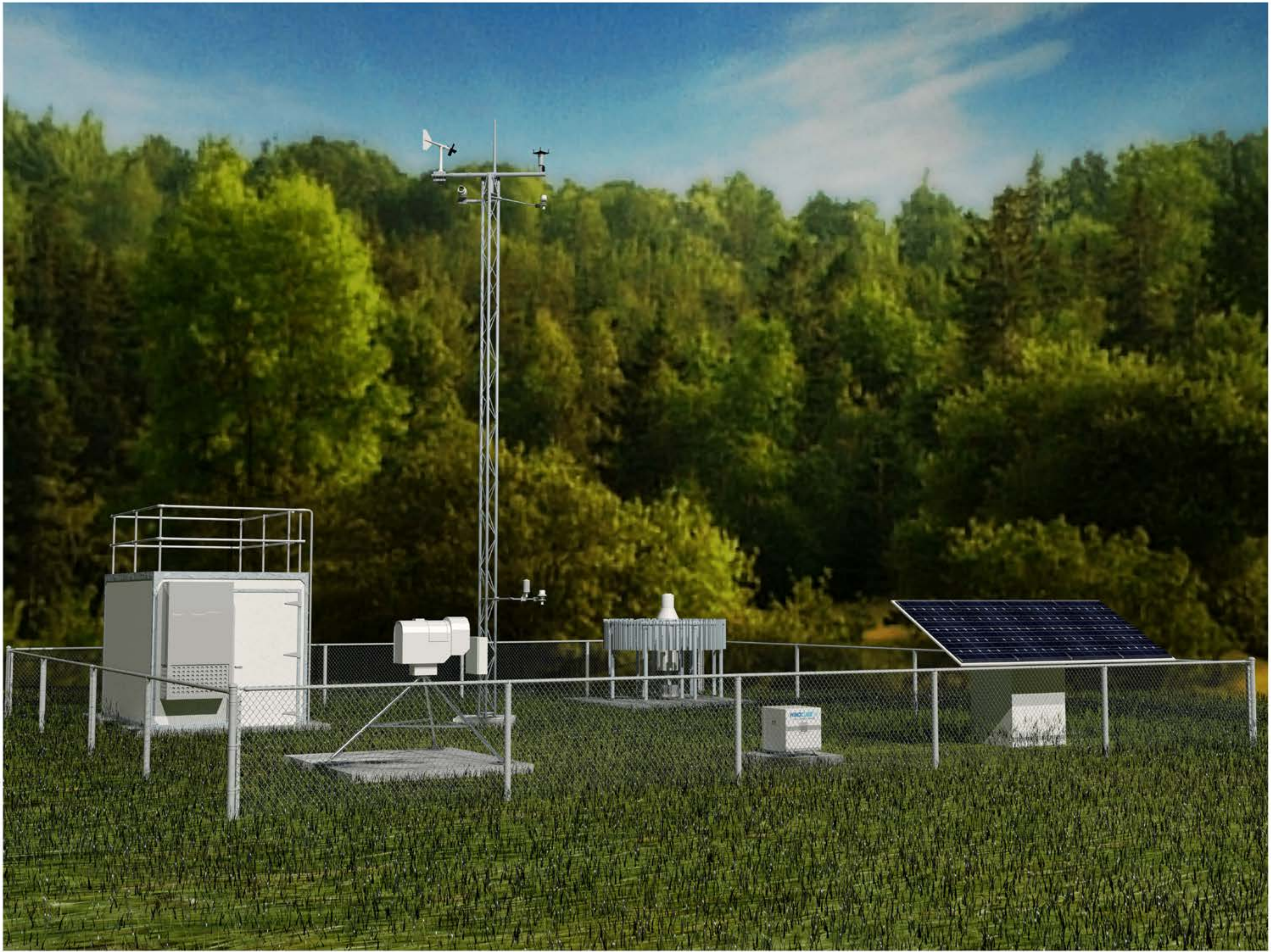
May 2016

Fun Facts

- Miles driven: 45,305 miles
- Tickets: 0
- Highest elevation: 2,404 ft
- Lowest elevation: 36 ft
- Sites in ADK: 17
- Closest to Atlantic: 2.29 miles
- Closest to Canada: 2.27 miles
- Closest to Lake Ontario: 0.52 miles
- Farthest distance apart: 389 miles



Site Selection: General Network Topology

- There were two primary stages of site selection:
  1. General network topology
  2. Specific site selection

- For the general network topology, a number of criteria were used:
  - All sites had to reside within the state of NY
  - At least one site in every county and borough across the state (62 total)
  - Desired ~ 20 mile spacing between sites ("meso"-scale network)
  - Desire to represent full range of landscapes and topographies across the state
  - Solicited NWS feedback (e.g., flood-prone areas, data gaps)
  - Targeted publicly-owned land as easier for permitting

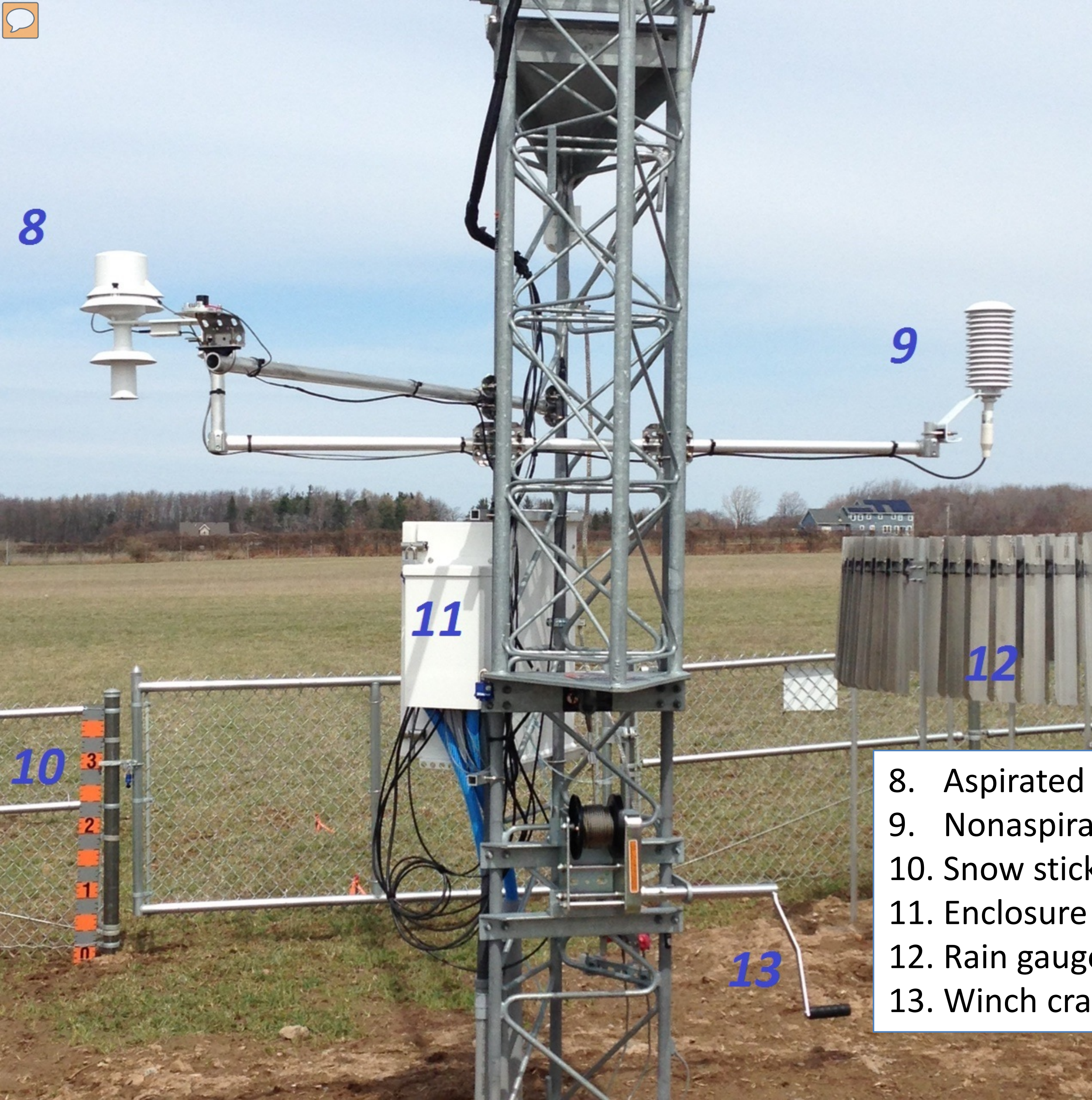
Why a Mesonet in New York?

- Scarcity of weather observations in NY
- Long-term trends of heavier rainfall
- Recent history of very expensive high-impact events
- State economy is especially sensitive to weather
- Valuable for emergency management, utilities, ground transportation (roads, rail), aviation, agriculture, etc.

History of Project

- Idea began in 2011 following Hurricane Irene and TS Lee
- Discussions began with DHSES in summer 2012
- Superstorm Sandy in fall 2012
- Gov. Cuomo and VP Biden announced Mesonet award Jan 7, 2014
- NYS Mesonet award began April 1, 2014
- Network fully operational by Dec 31, 2016

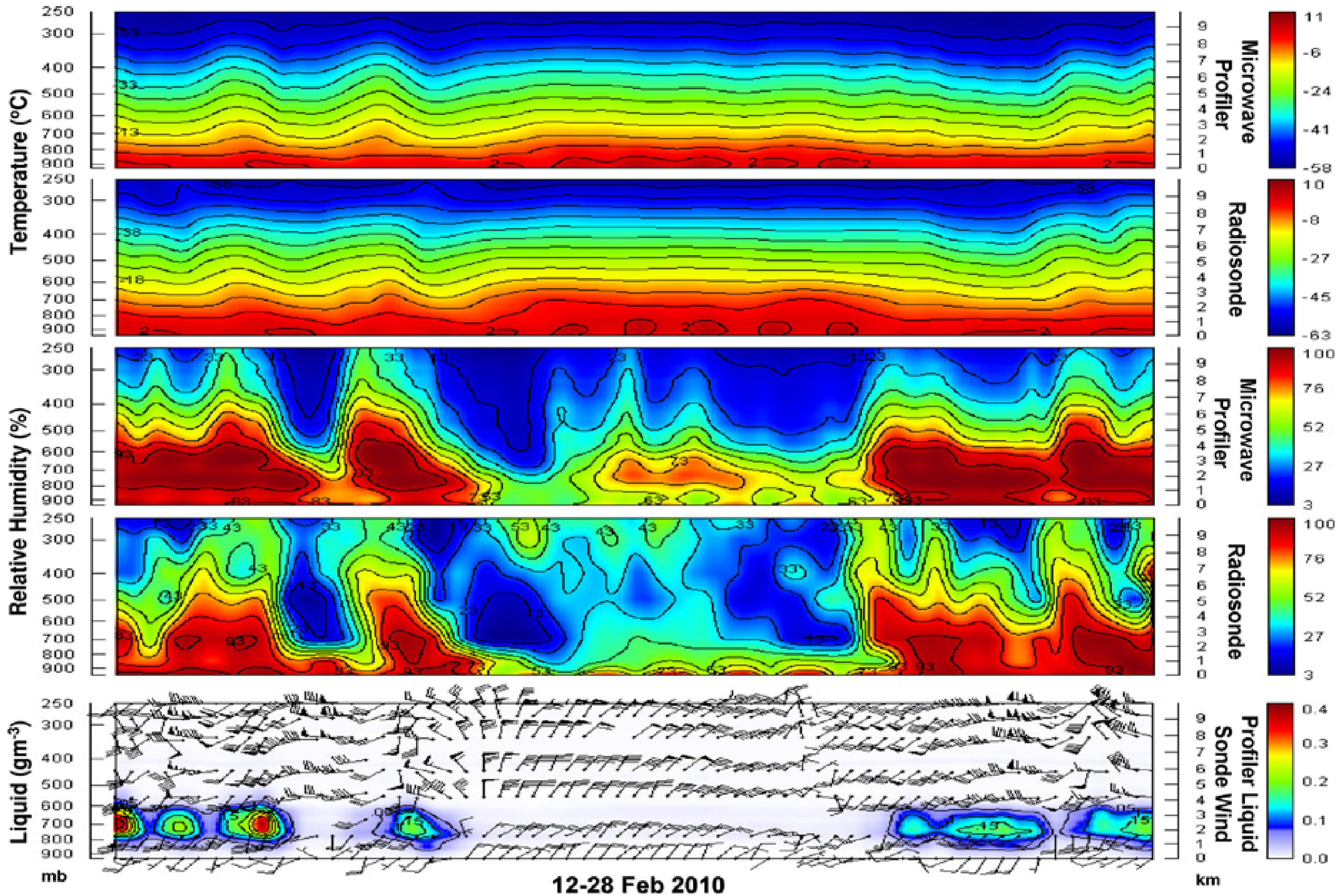
1. Sonic anemometer, 10 m
2. Lightning rod
3. Wind vane, 10 m
4. Aspirated air temperature, 9m
5. Horizontal crossbars
6. Omnidirectional antenna
7. Yagi antenna



8. Aspirated temperature, 2m
9. Nonaspirated T/RH
10. Snow stick
11. Enclosure (barometer)
12. Rain gauge/shields
13. Winch crank for tower

The NYS Early Warning Weather Detection System

16-day time series
6-hrly radiosonde data



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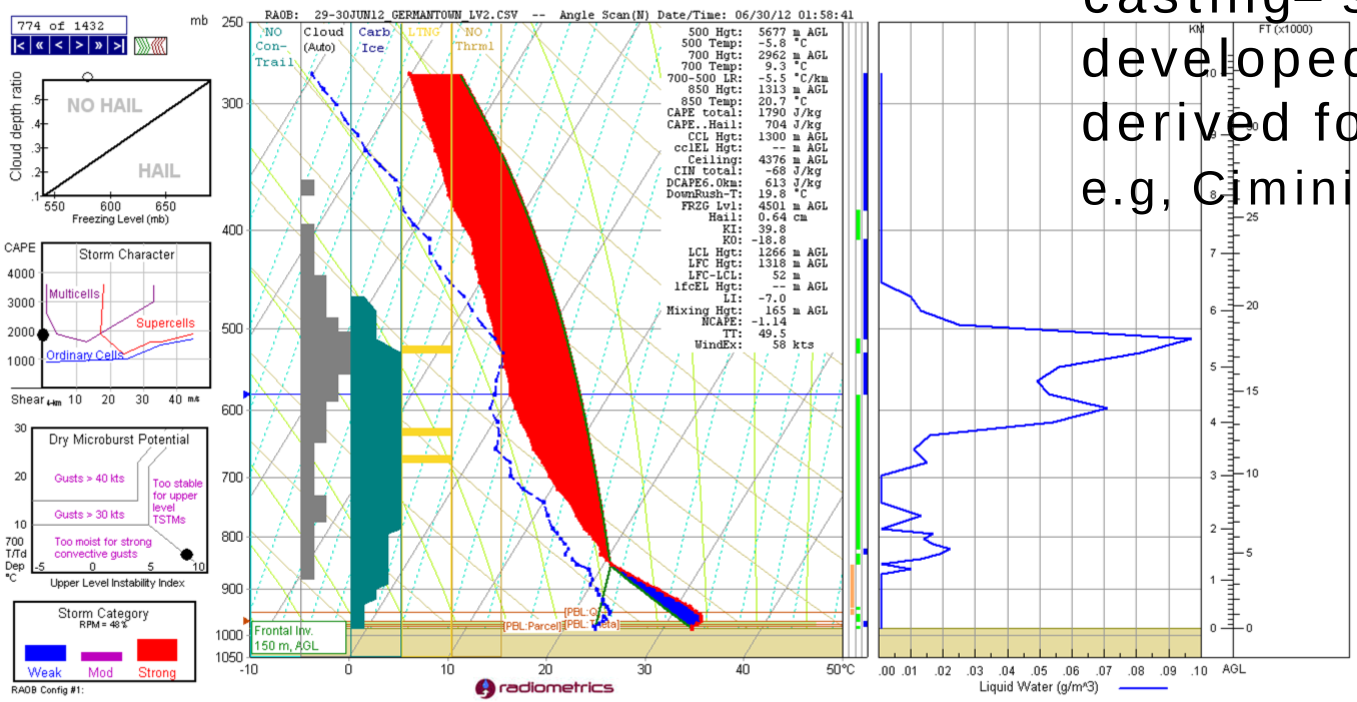


For application -- now casting– several studies developed and tested derived forecast indices: e.g, Cimini et al 2014

Wind Lidar –Doppler Lidar

- Wind - The Doppler frequency shift from the spectra signal
- Aerosol backscatter/cloud base - The energy content of the Doppler spectra
  - Lidar equation:

$$P(\mathrm{r}) = CE\frac{\beta(r)}{r^2}\exp[-2\int_0^r ext(z)\,dz]$$

Time domain:

- Time gating
- Spatial resolution

Spectral domain:

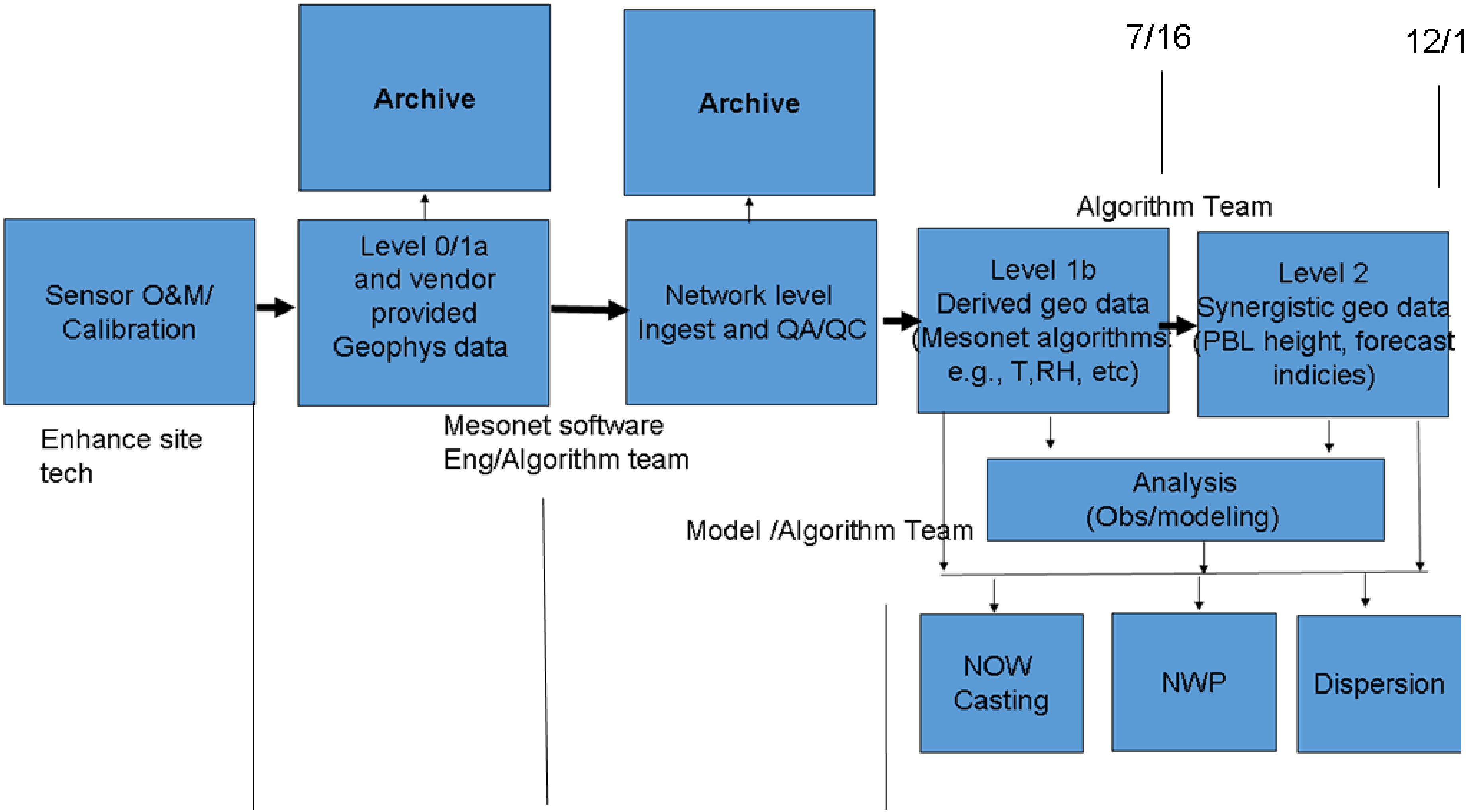
- FFT of each gated time domain
- Averaging of gated spectral (reduce noise)
- Estimating Doppler frequency

- Radial wind speed
- Spectral dispersion
- Carrier-to-Noise Ratio

- 3D wind speed
- Turbulence?
- Aerosol backscatter coefficient
- Cloud base
- PBL height

Issues:

- Radiometric calibration & calibration accuracy? --- scaling
- Gate binning and complex autocorrelation function vs. FFT to enhance SNR
- Aerosol profile vs wind/turbulence profile for PBL height


7/16
12/16
Archive
Archive
Algorithm Team
Sensor O&M/ Calibration
Level 0/1a and vendor provided Geophys data
Network level Ingest and QA/QC
Level 1b Derived geo data (Mesonet algorithms: e.g., T,RH, etc)
Level 2 Synergistic geo data (PBL height, forecast indicies)
Enhance site tech
Mesonet software Eng/Algorithm team
Analysis (Obs/modeling)
Model /Algorithm Team
NOW Casting
NWP
Dispersion