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Including Upper Air Measurements in Operational Weather Observing Networks: Example of the New York State MesoNet

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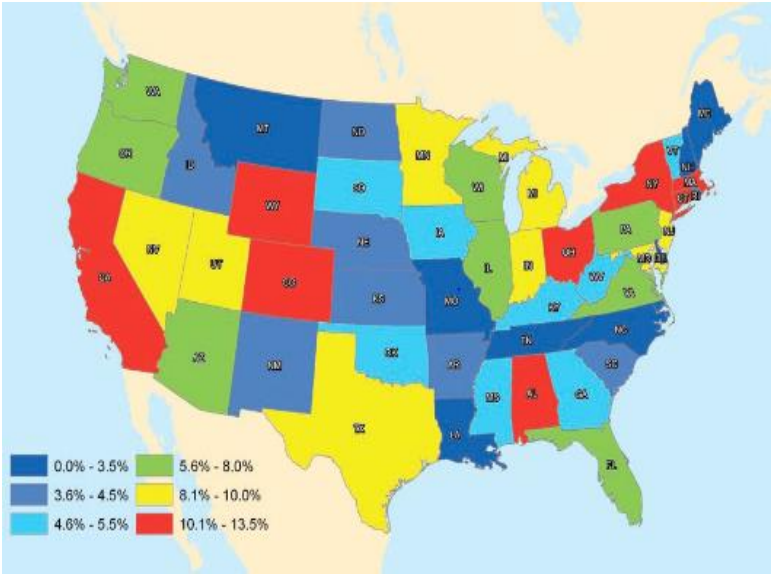
Motivation for the NYS MesoNet

- MesoNet: “MESO-scale NET-work”
- Why in NYS ?
  - Several states recognize the economic value
  - NYS economic sensitivity very high
  - 7 major severe weather events (Hurricane, Storm, Flooding, etc) between 2006 and 2012 for a total of $92billion

➔**Decision of Gov. Cuomo and VP Biden**

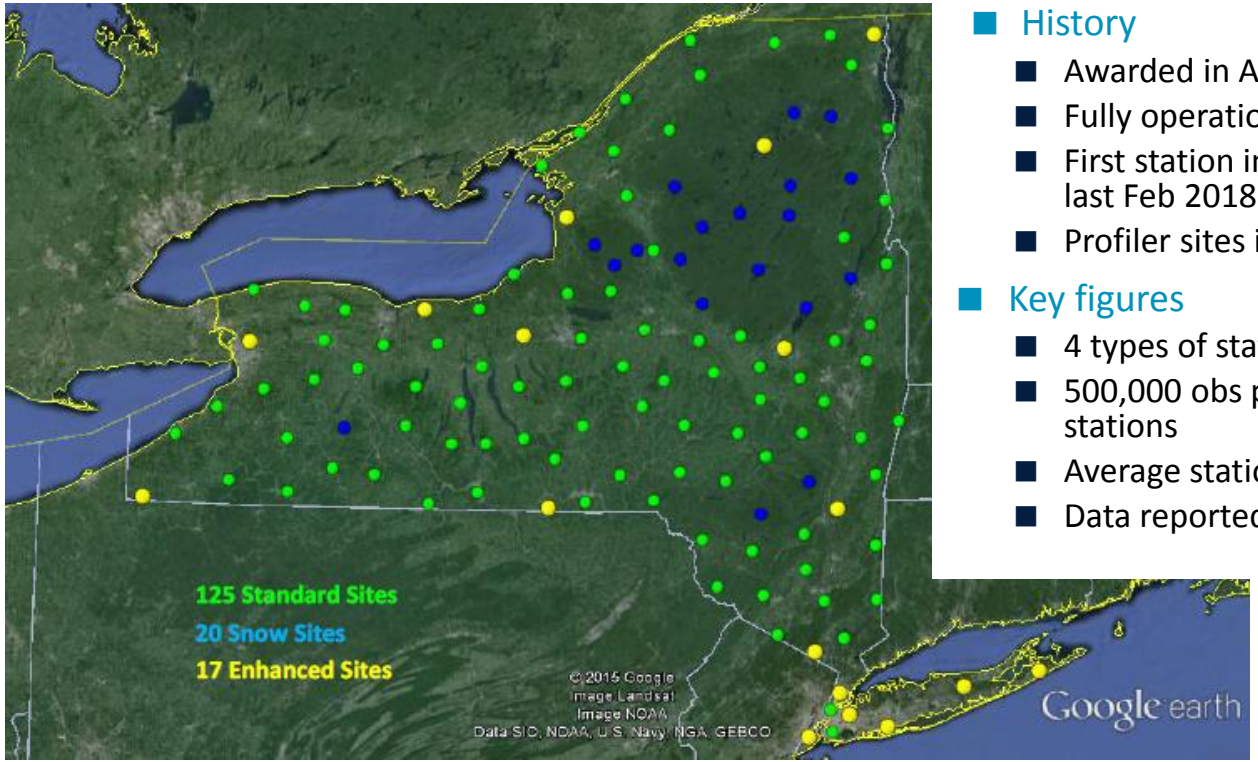
- Main Goals
  - To build the NYS Early Warning Weather Detection System
  - To improve high impact weather observations and forecasts

➔**To establish a dense weather observation network**



Source Lazo et al., BAMS, 2011

Overview of the NY State Mesonet

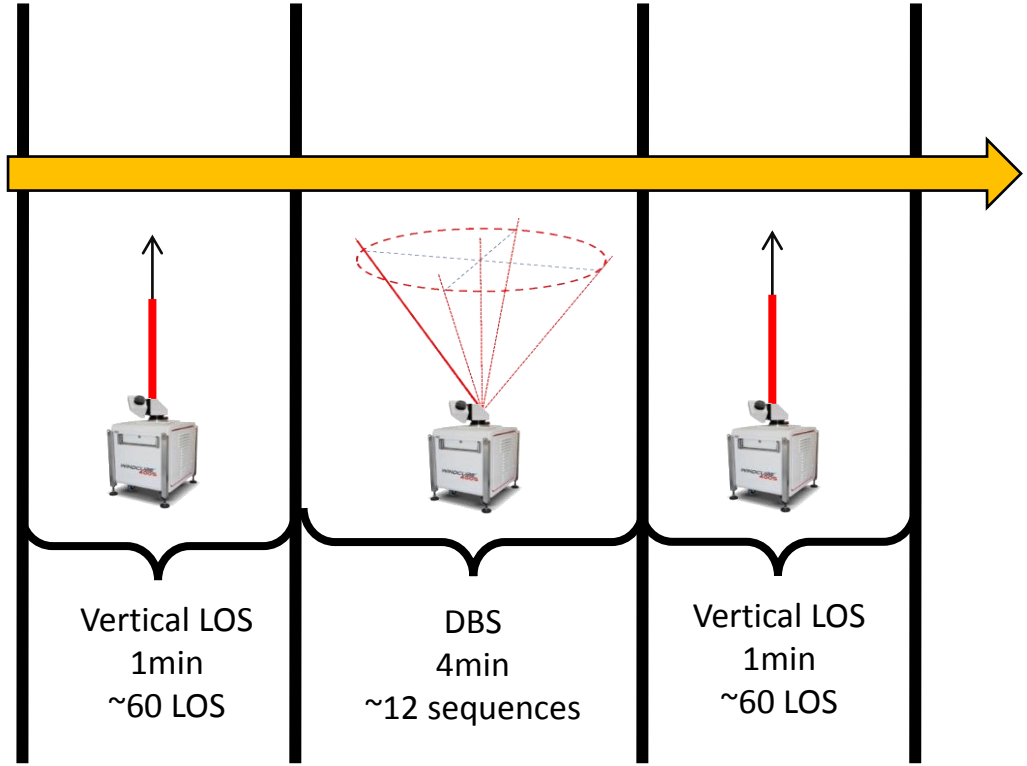


- History
  - Awarded in April 2014
  - Fully operationnal in March 2018
  - First station installed in Fall 2015 and last Feb 2018
  - Profiler sites installed in 2017
- Key figures
  - 4 types of station
  - 500,000 obs per day from the surface stations
  - Average station spacing ~ 30km
  - Data reported every 5 min.

“Enhanced” sites : Example of Belleville

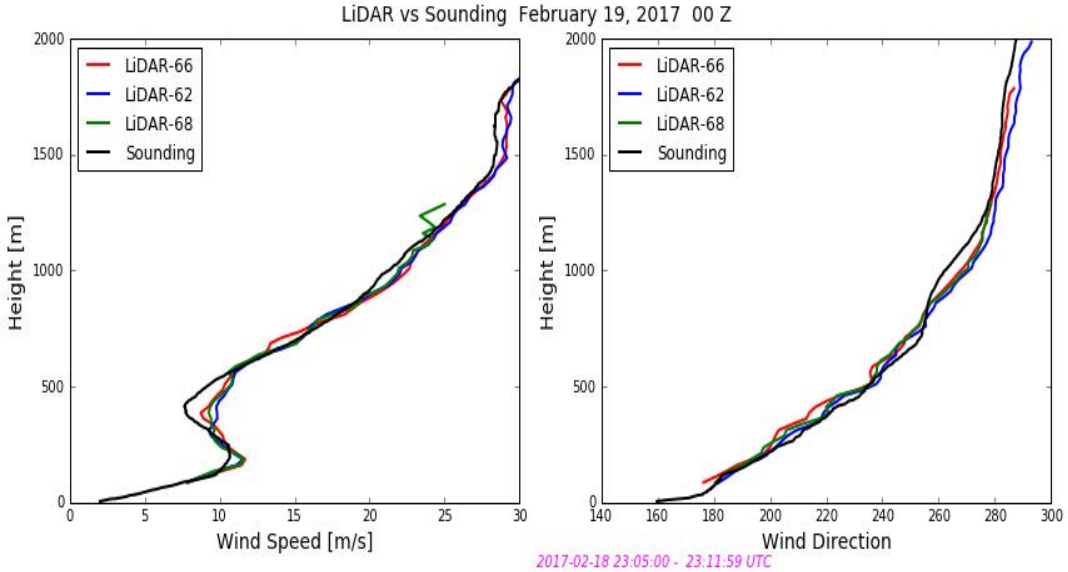
- Three remote sensors
  - Coherent Doppler Lidar (LEOSPHERE)
  - Microwave Radiometers (RADIOMETRICS)
  - Sun Photometer (MMR/SSI) / Multiscan Multichannel Radiometer + Sky imager
- Outputs
  - Profiles of Temperature, Relative Humidity, Winds, and Aerosols in Lower Troposphere
  - PBL Height, Cloud Base Height, Cloud coverage
  - Cloud classification
  - Radiation (spectral, direct/diffuse)
  - Convective Available Potential Energy (CAPE), Kinetic energy,..

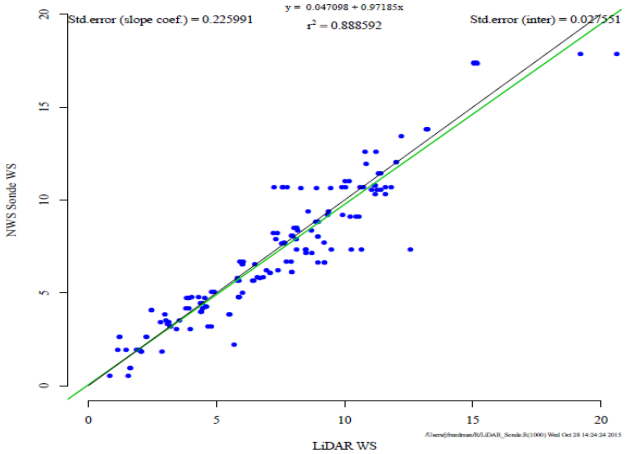
Configuration & Scenarios of Doppler LIDAR



- Adapted configuration: High resolution and long distance
  - Range Resolution of 75m
  - Display resolution of 30m
  - Measurement up to 10 km
  - 1s of Acc Time per LOS
- Sequence of 5min
  - 1min Vertical LOS
  - 4min DBS

Validation of wind measurements at Albany site





- Mean differences on wind speed with radiosounde = 0.23m/s

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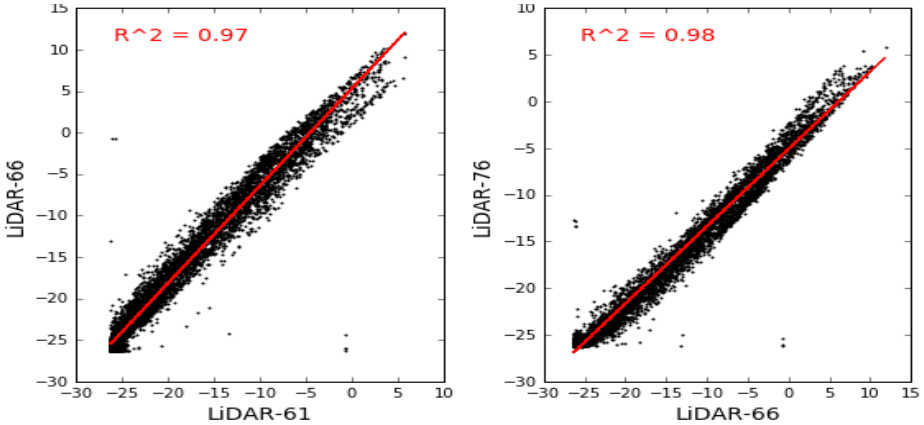
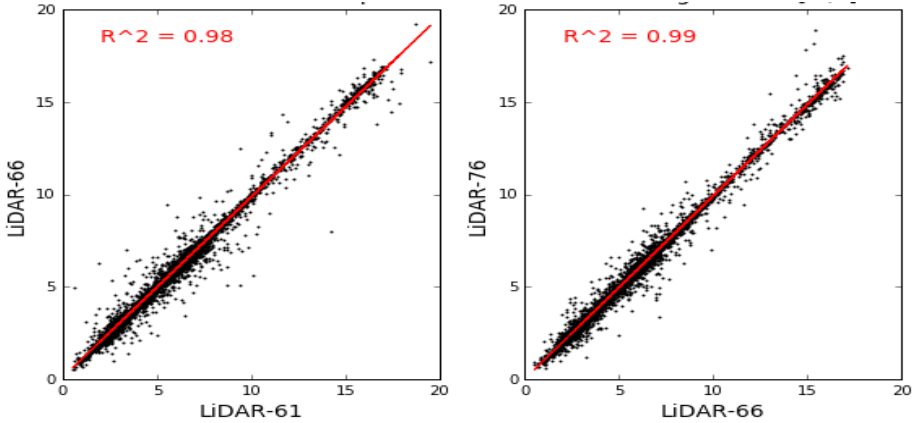
Intercomparison between Doppler Lidars at Albany site

Lidar Signal (Carrier To Noise Ratio) in dB



Wind measurements in m/s



- Mean differences between Doppler Lidars
  - CNR ~1 dB
  - Wind speed = 0.0275m/s

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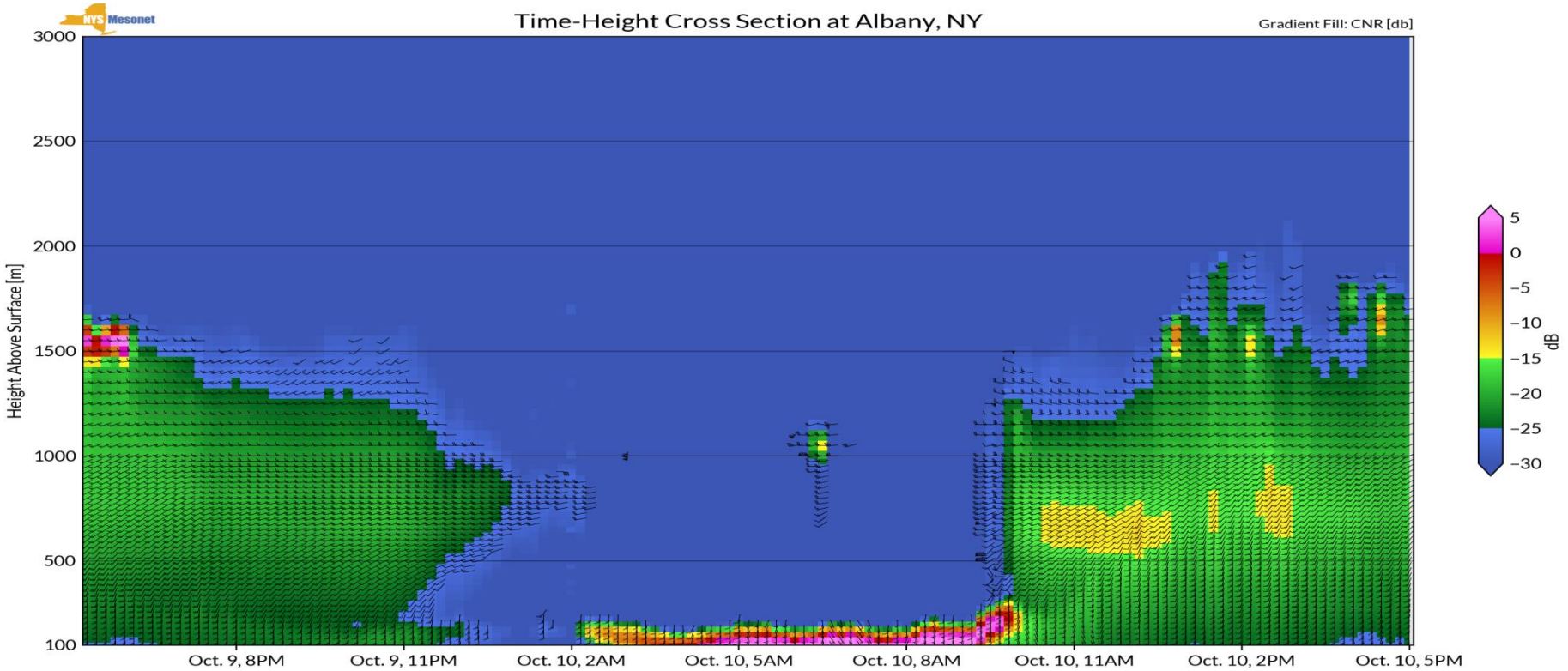
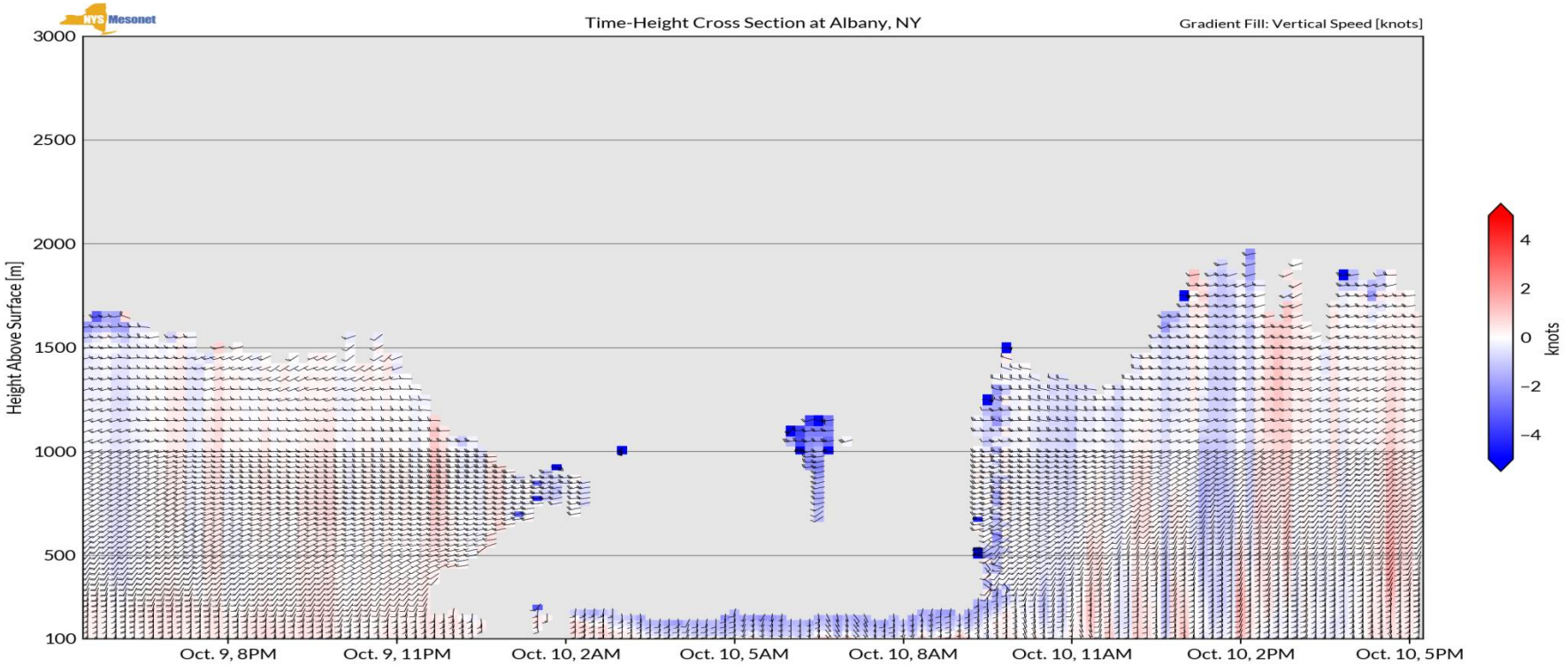
WEATHER & CLIMATE

Example of a fog event the 9th of October at Albany site

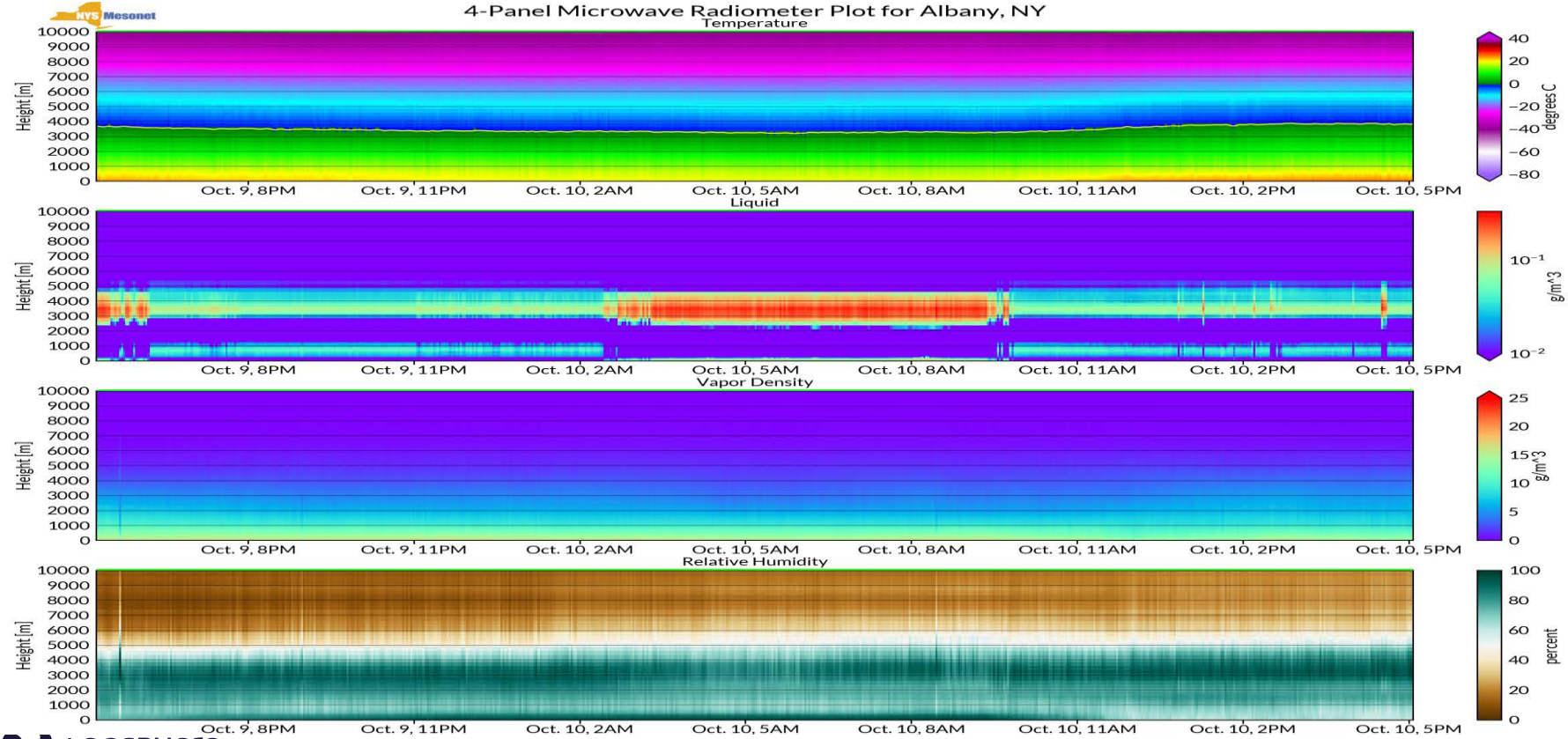
Fog layer observed by the Doppler Lidar



Fog layer observed by the Doppler Lidar



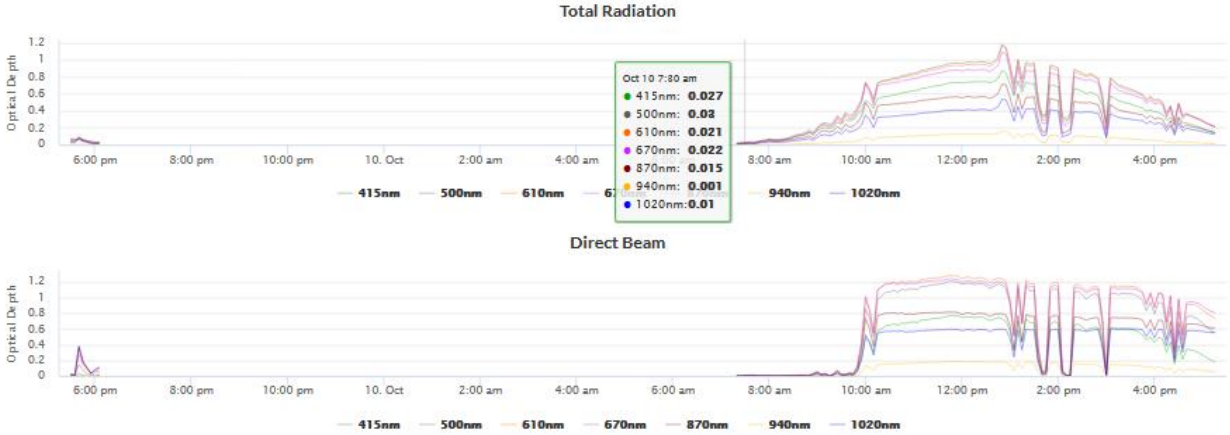
Fog layer observed by the MW Radiometer



Fog layer observed by Sun Photometer and sky imager

Photometer Image

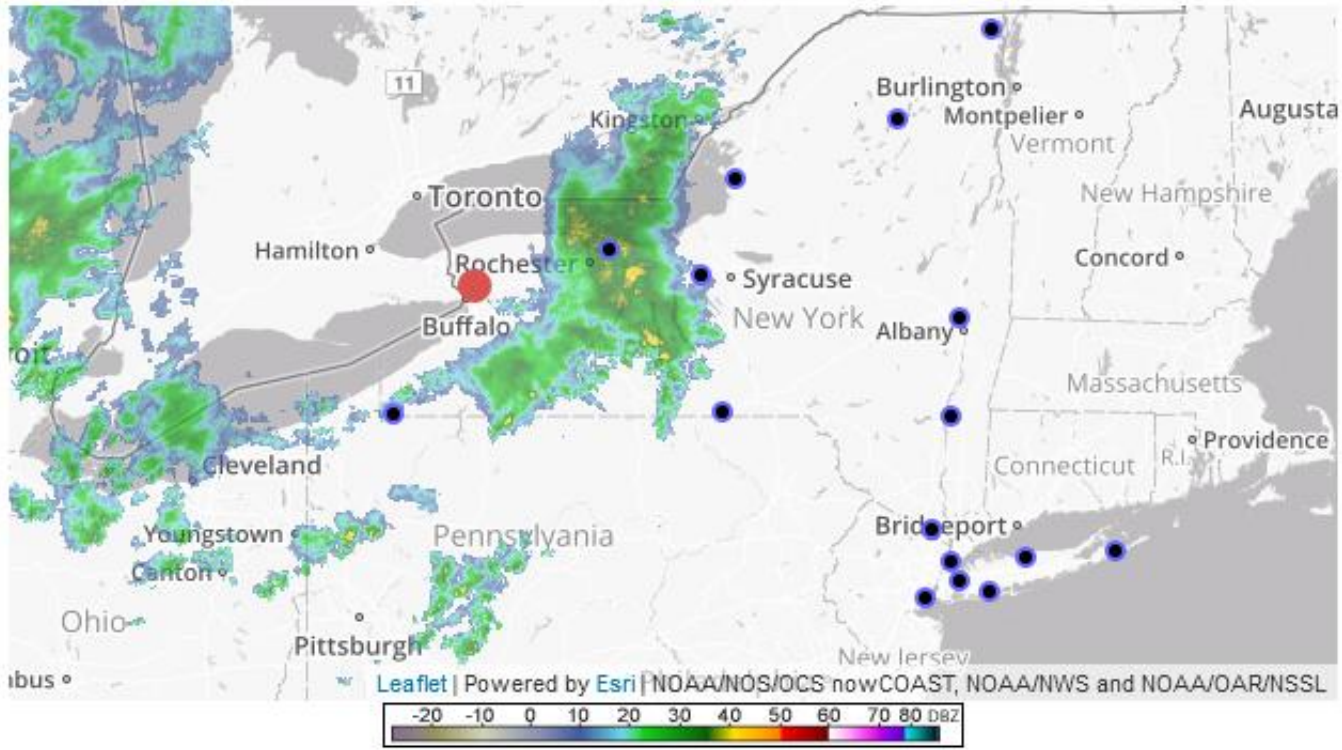
Oct 10, 2018 7:25 AM EDT



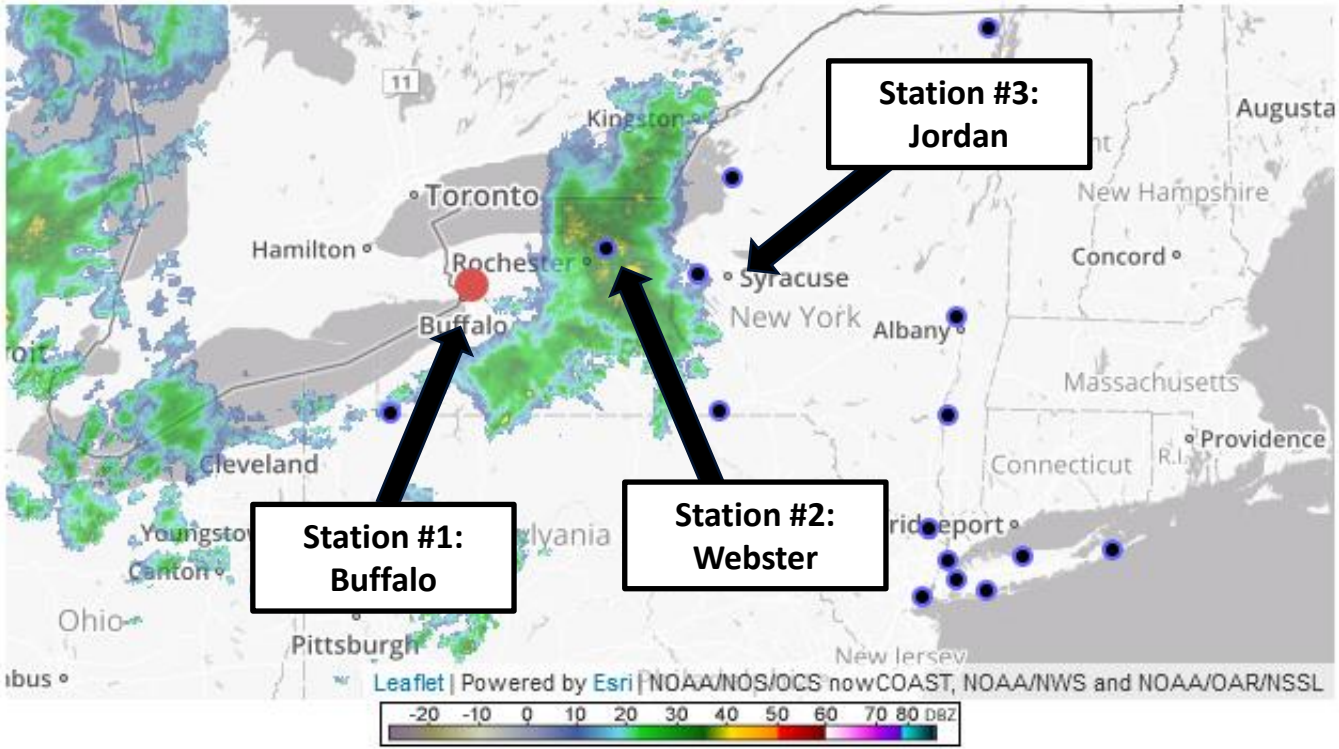
WEATHER & CLIMATE

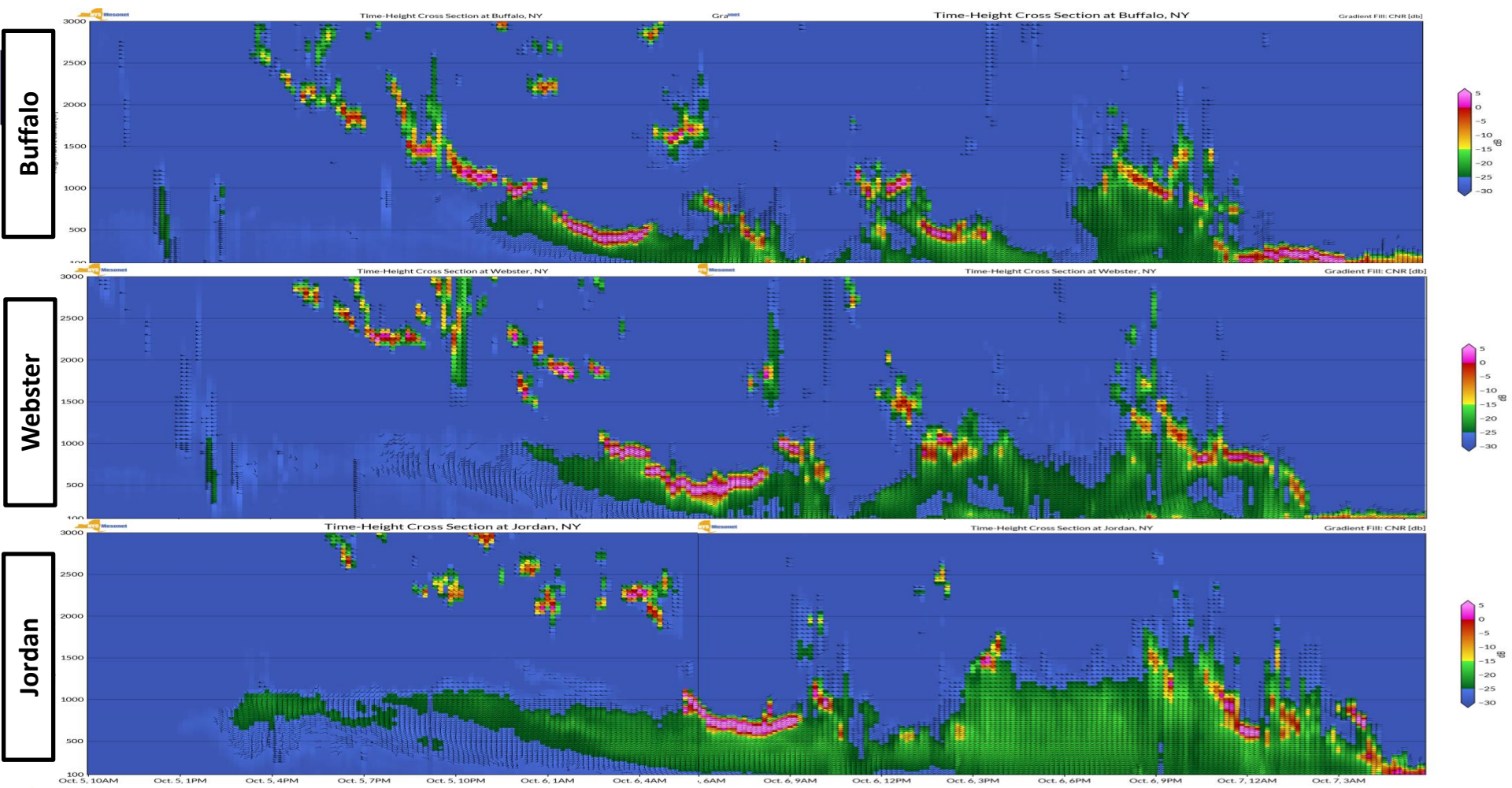
Example of a convective storm the 5th of October at three different sites

Convective storm the 5th of October

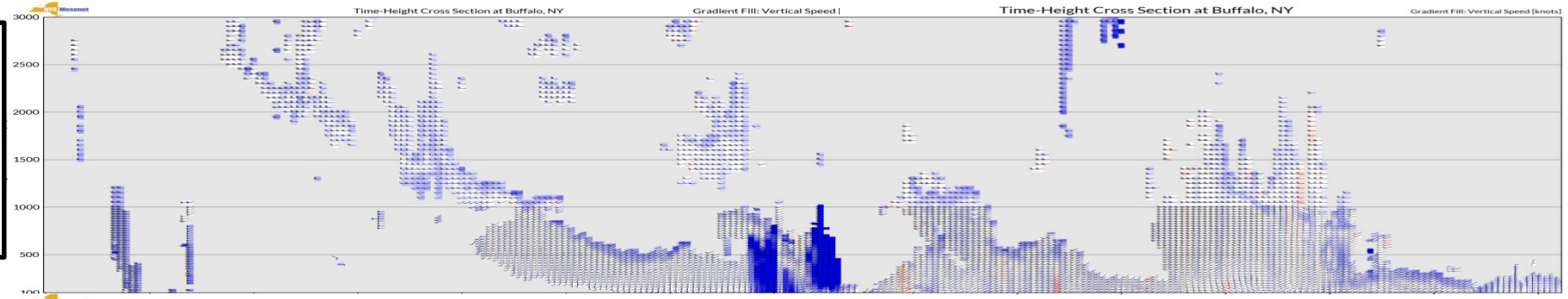


Convective storm the 5th of October

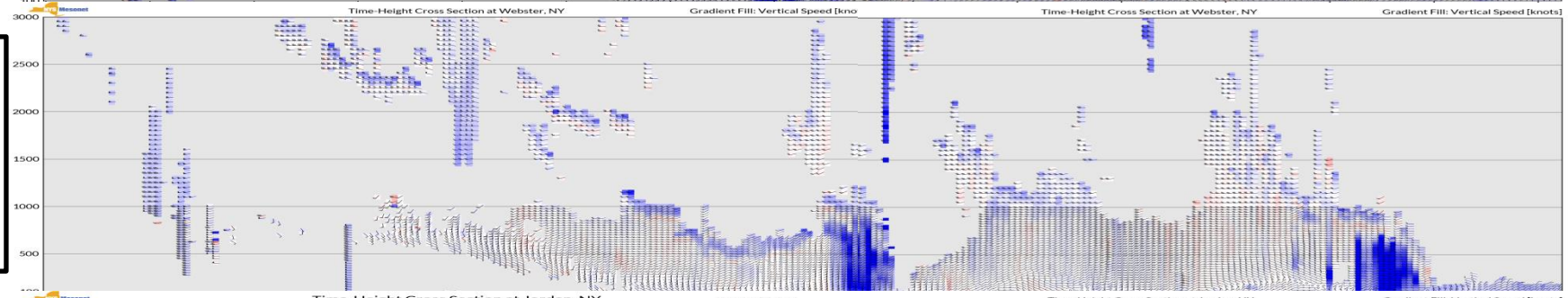



Buffalo
Time-Height Cross Section at Buffalo, NY
Gradient Fill: CNR [db]
Webster
Time-Height Cross Section at Webster, NY
Gradient Fill: CNR [db]
Jordan
Time-Height Cross Section at Jordan, NY
Gradient Fill: CNR [db]
Oct. 5, 10AM
Oct. 5, 1PM
Oct. 5, 4PM
Oct. 5, 7PM
Oct. 5, 10PM
Oct. 6, 1AM
Oct. 6, 4AM
Oct. 6, 9AM
Oct. 6, 12PM
Oct. 6, 3PM
Oct. 6, 6PM
Oct. 6, 9PM
Oct. 7, 12AM
Oct. 7, 3AM

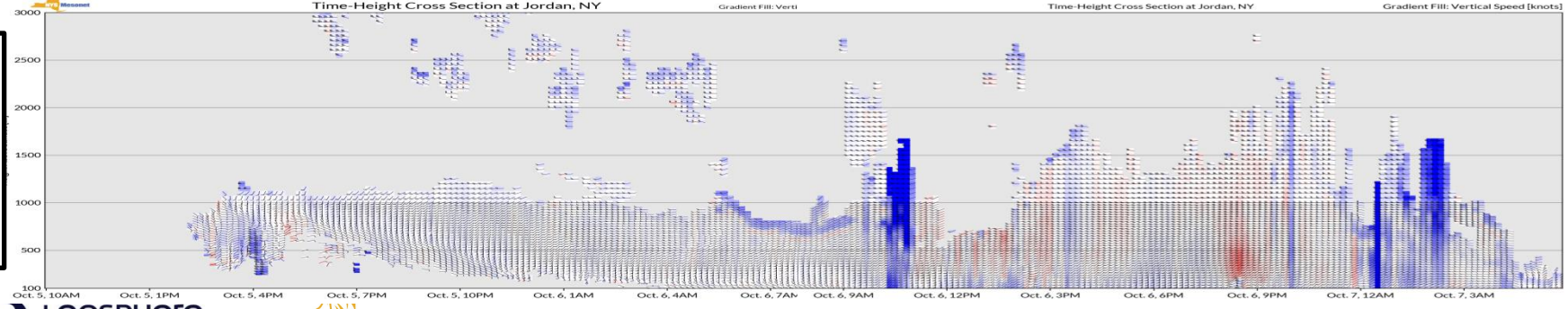
Buffalo

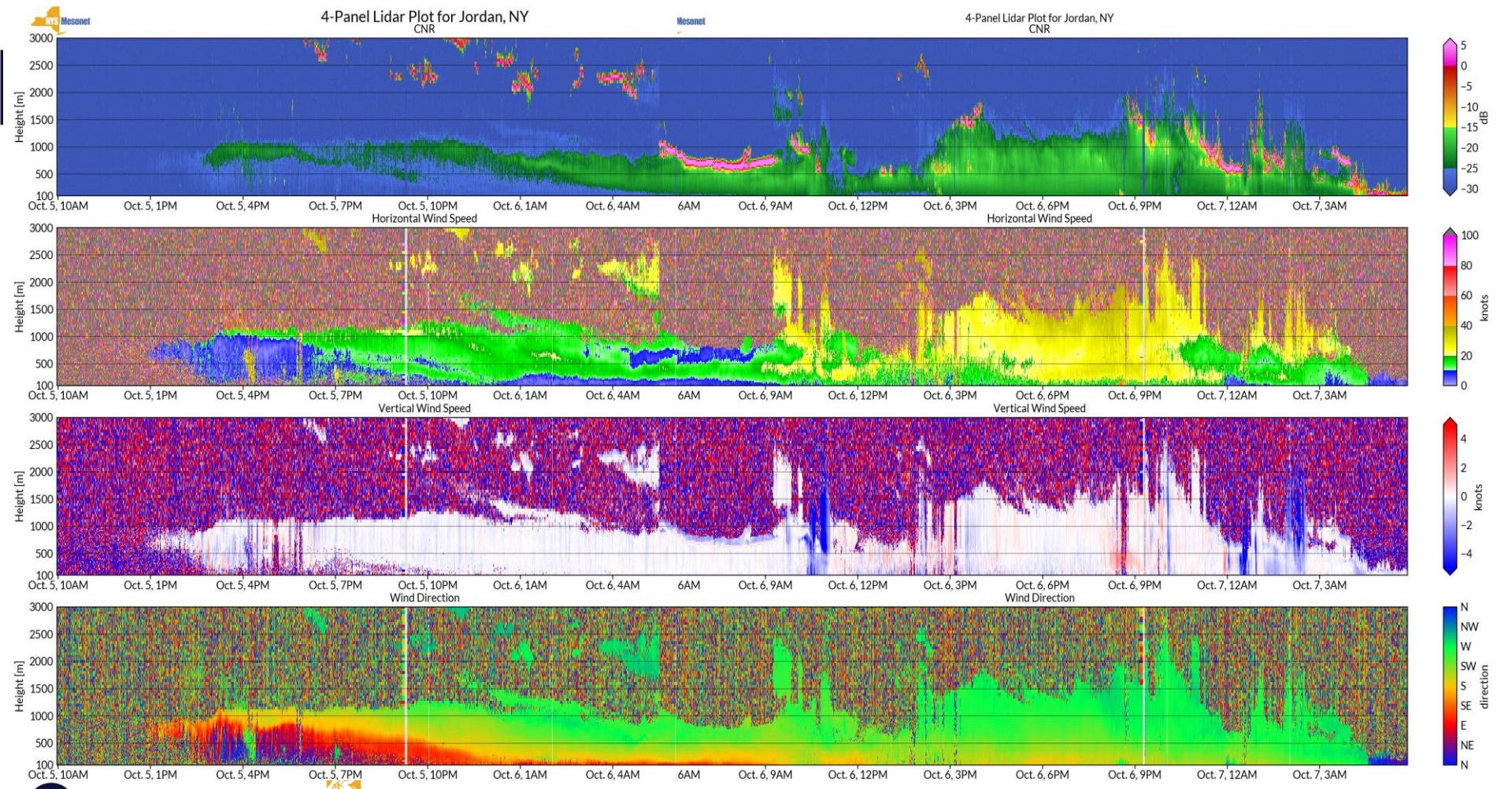


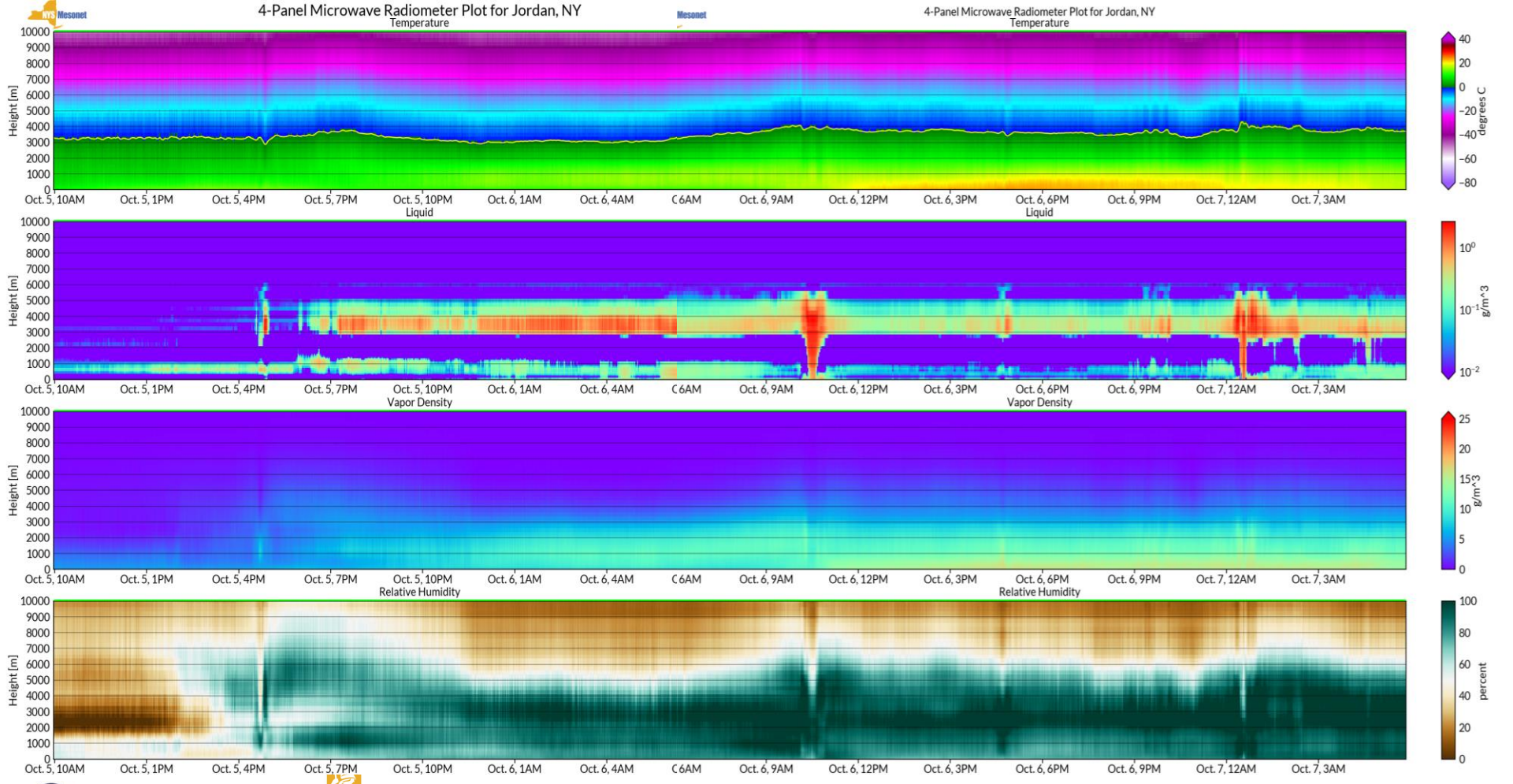
Webster



Jordan




4-Panel Lidar Plot for Jordan, NY
CNR
Mesonet
4-Panel Lidar Plot for Jordan, NY
CNR
Mesonet
Height [m]
3000
2500
2000
1500
1000
500
100
Oct. 5, 10AM
Oct. 5, 1PM
Oct. 5, 4PM
Oct. 5, 7PM
Oct. 5, 10PM
Oct. 6, 1AM
Oct. 6, 4AM
6AM
Oct. 6, 9AM
Oct. 6, 12PM
Oct. 6, 3PM
Oct. 6, 6PM
Oct. 6, 9PM
Oct. 7, 12AM
Oct. 7, 3AM
5
0
−5
−10
−15
−20
−25
−30
dB
Horizontal Wind Speed
Horizontal Wind Speed
100
80
60
40
20
0
knots
Vertical Wind Speed
Vertical Wind Speed
4
2
0
−2
−4
knots
Wind Direction
Wind Direction
N
NW
W
SW
S
SE
E
NE
N
direction


4-Panel Microwave Radiometer Plot for Jordan, NY
Temperature
Liquid
Vapor Density
Relative Humidity
Height [m]
degrees C
g/m^3
percent
Oct. 5, 10AM
Oct. 5, 1PM
Oct. 5, 4PM
Oct. 5, 7PM
Oct. 5, 10PM
Oct. 6, 1AM
Oct. 6, 4AM
Oct. 6, 9AM
Oct. 6, 12PM
Oct. 6, 3PM
Oct. 6, 6PM
Oct. 6, 9PM
Oct. 7, 12AM
Oct. 7, 3AM

Conclusions

- NYS Mesonet the world first high density surface/remote sensing network
- Deployment of the network in 4 years
- High repeatability between Doppler Lidars (0.027ms/s) and high accuracy (0.23m/s)
- Next steps
  - Implement the retrievals of aerosol / Cloud, backscatter and mass concentration
  - Data assimilation into NWP with NCEP
- Open questions:
  - Return on Investment
  - Improvement of forecasting score
- Similar projects launched worldwide to initiate dense networks with remote sensors
  - In Europe, emerging network with 25 Doppler Lidars

Questions ?

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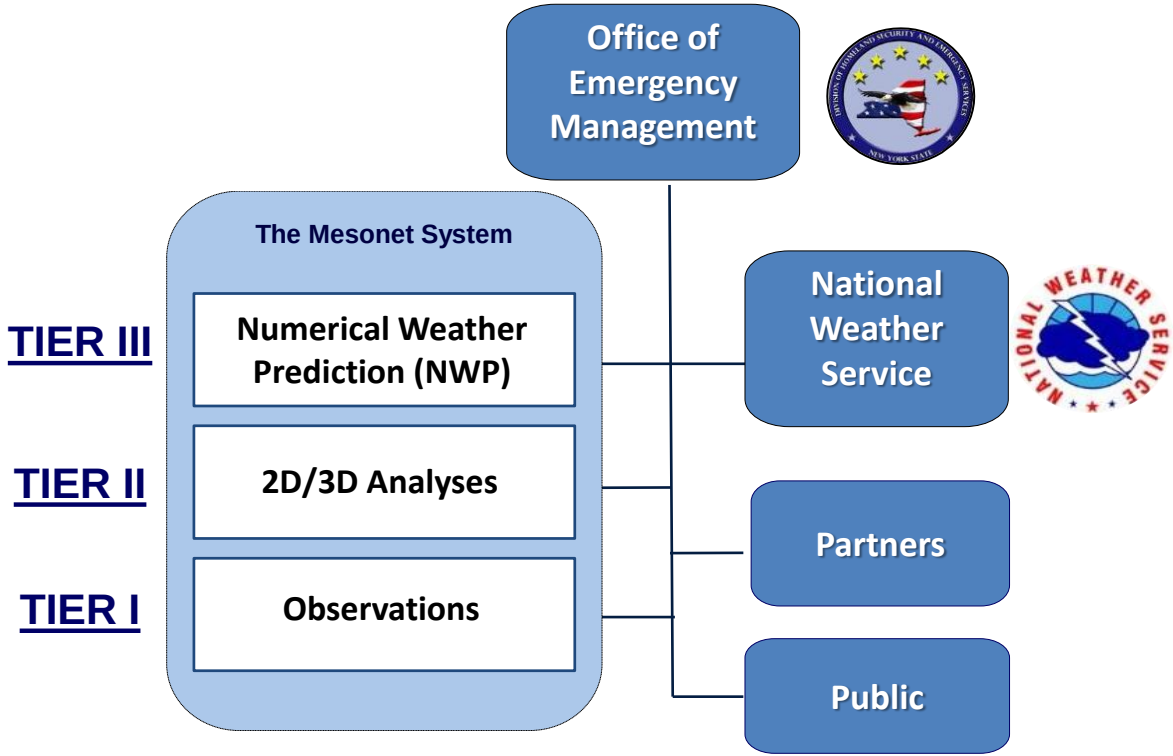
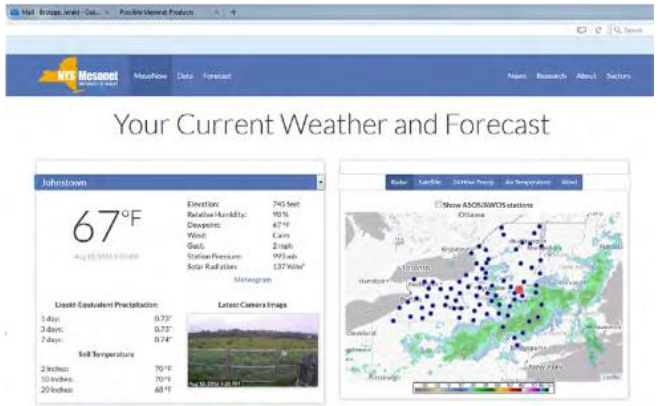
Data Dissemination / Policy

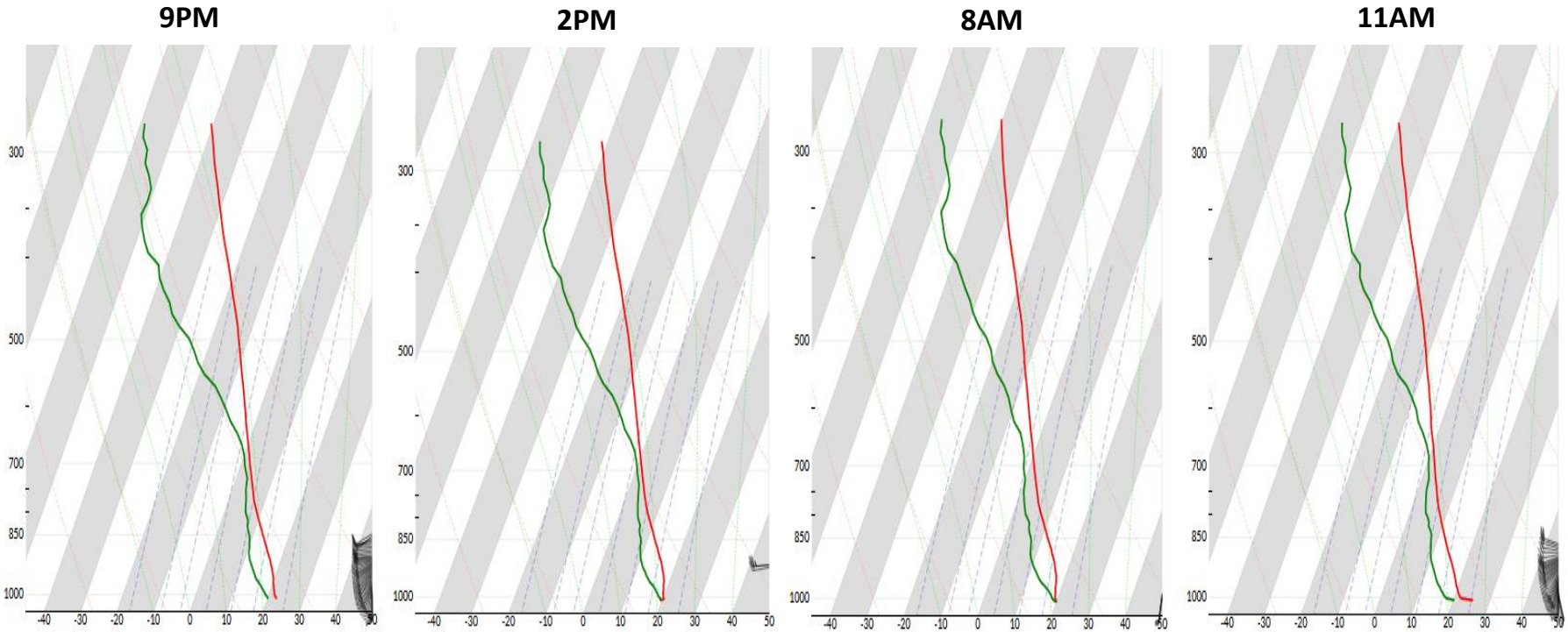


http://nysmesonet.org



- 6 categories of partners
  - Public agencies
  - Media users
  - Academic and Not for Profit Research Users
  - Weather station hosts
  - Individuals
  - Others

Fog layer observed on T-skew



Standard sites: Example of Belleville

- Standard Observations
  - Surface Pressure
  - Relative Humidity @2m
  - Air Temperature @ 2 and 9 m
  - Precipitation
  - Wind Speed and direction @10m
- Additional Observations
  - Soil Moisture & Temperature at 3 levels (5, 25 and 50 cm)
  - Solar Radiation
  - Snow Depth
  - Camera!
- Site selection constraints: 30km spacing, representativeness, WMO and FEMA guidelines

Meteorological Products

Wind	Vertical wind speed Horizontal wind speed Wind direction	**In DBS Mode, 1s data averaged over 5min**
Turbulence	TKE	**Can be easily calculated as the standard deviation of the three components of the wind vector**
Aerosol/ Clouds	Top / Bottom of layers Discrimination of layers Backscatter profile	**Provided in FixedforPBL every 4min**
PBL	Height of residual and mixing layers	**Provided in FixedforPBL only after 2 min**

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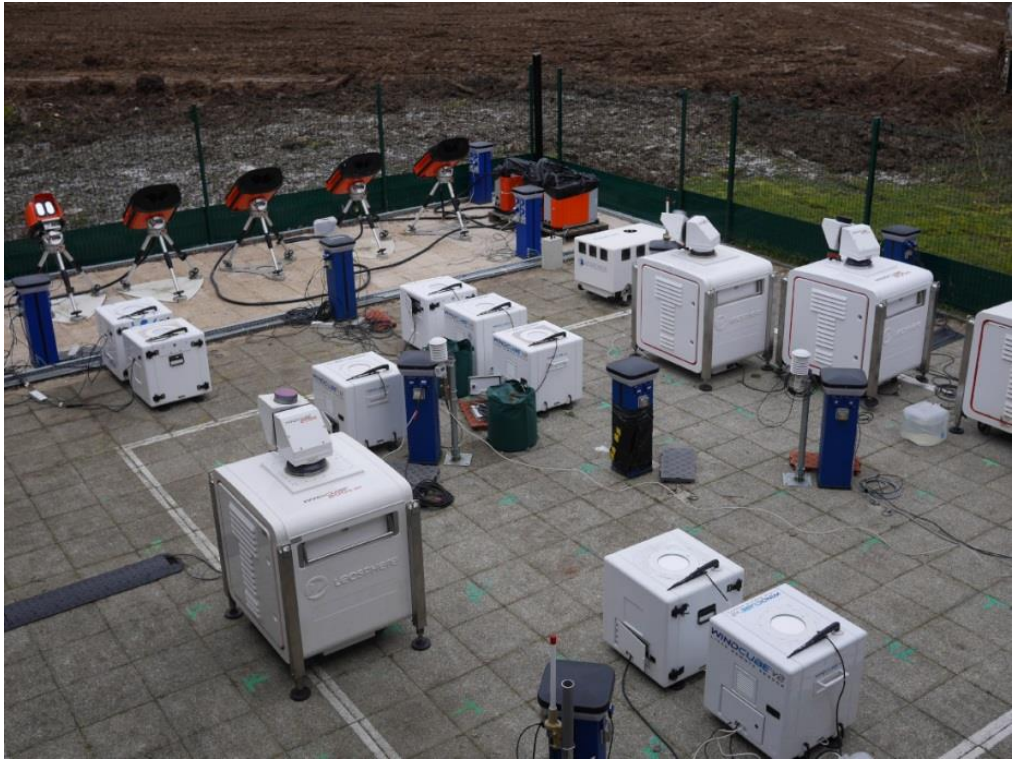
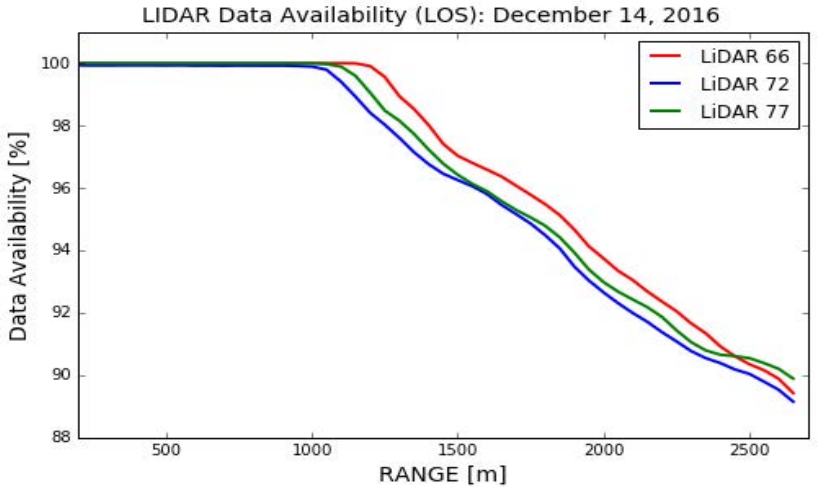
Tracability and Repeatability of WINDCUBE data

- Strict calibration and validation process for each manufactured or serviced unit
- Calibration of few parameters like range gate positions in dedicated benches
- Demanding verification process to ensure data consistency between all LIDARs
  - Accuracy and precision of wind speed againts a certified reference Lidar
  - Slope between 0.985 and 1.015
  - Bias on wind direction <2°

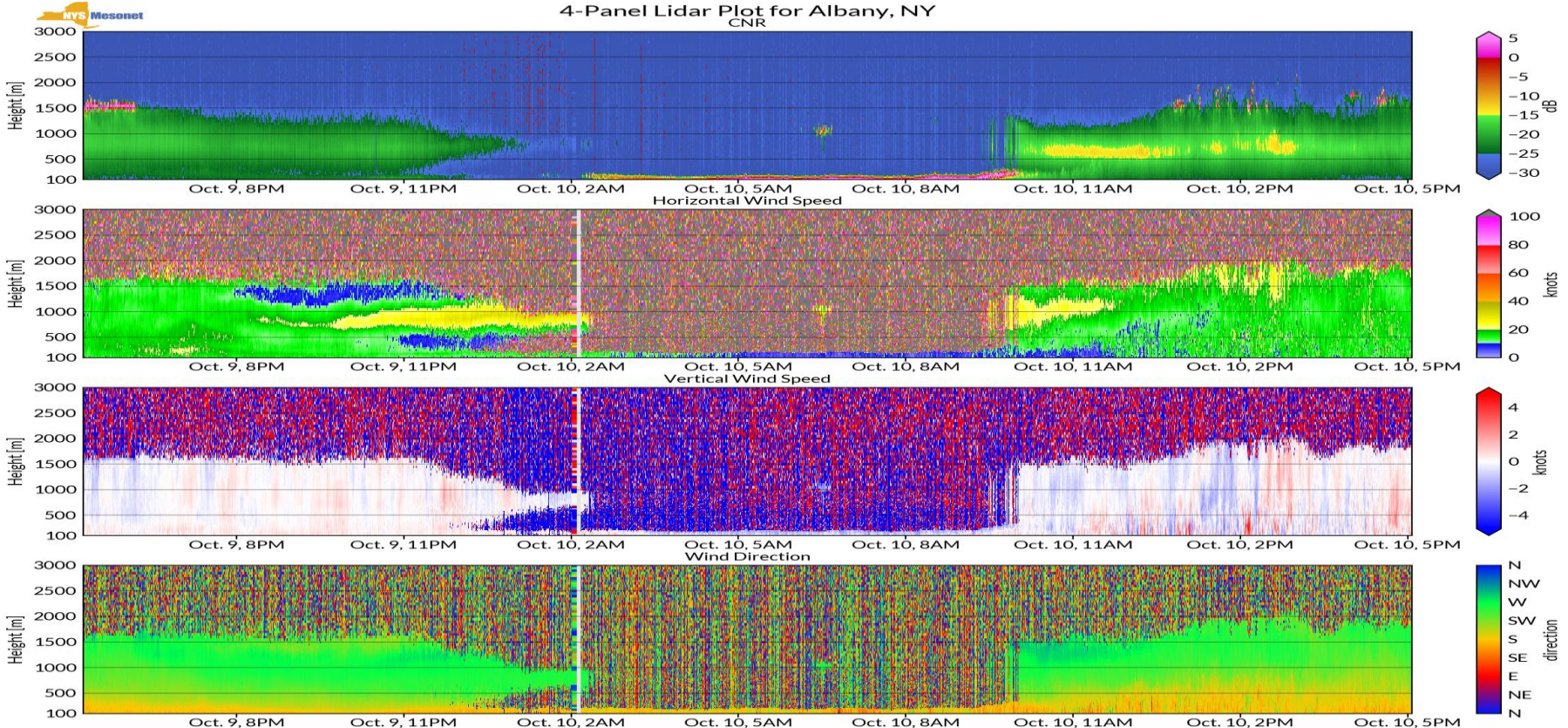


Intercomparison between Doppler Lidars at SUNY site

- Comparison of Data availability (ie. maximum range) for three WINDCUBEs
- Very high availability within boundary layer
- Mean Difference: less than 100m at 90%

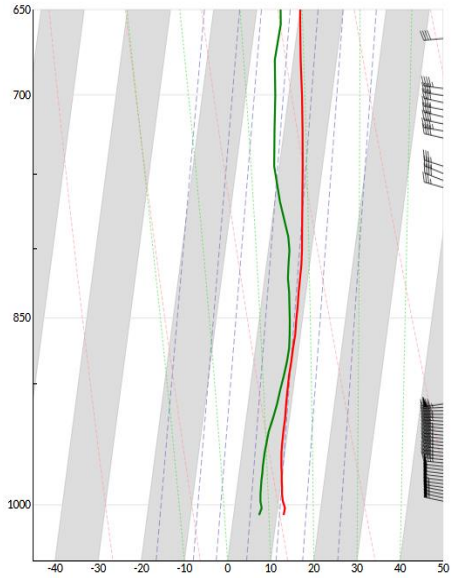


Fog layer observed by the Doppler Lidar

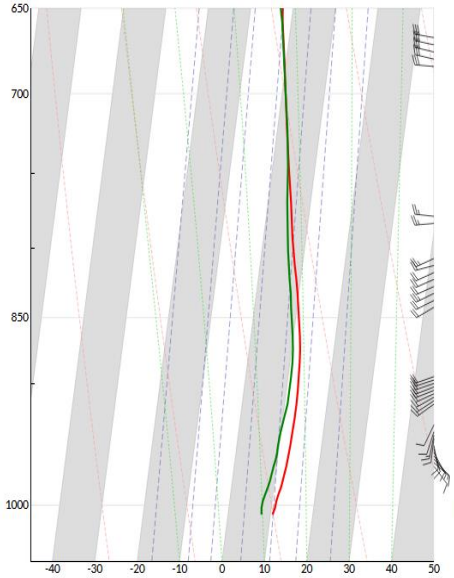


Combinaison of MW radiometer and Doppler Lidar

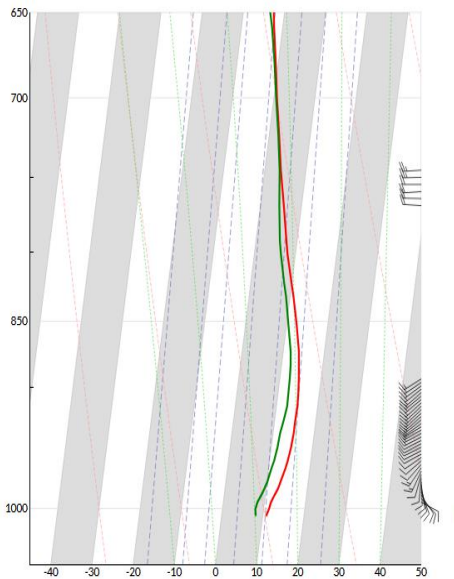
October 5th 6:50PM EDT



October 6th 12:30PM EDT



October 6th 03:30AM EDT



October 6th 09:40AM EDT