Dew Point Bombs:

Large Model Errors Provide An Obvious Target of Opportunity for Fire Weather Forecasters

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AMS 14th Fire and Forest Meteorology Symposium | May 3, 2023

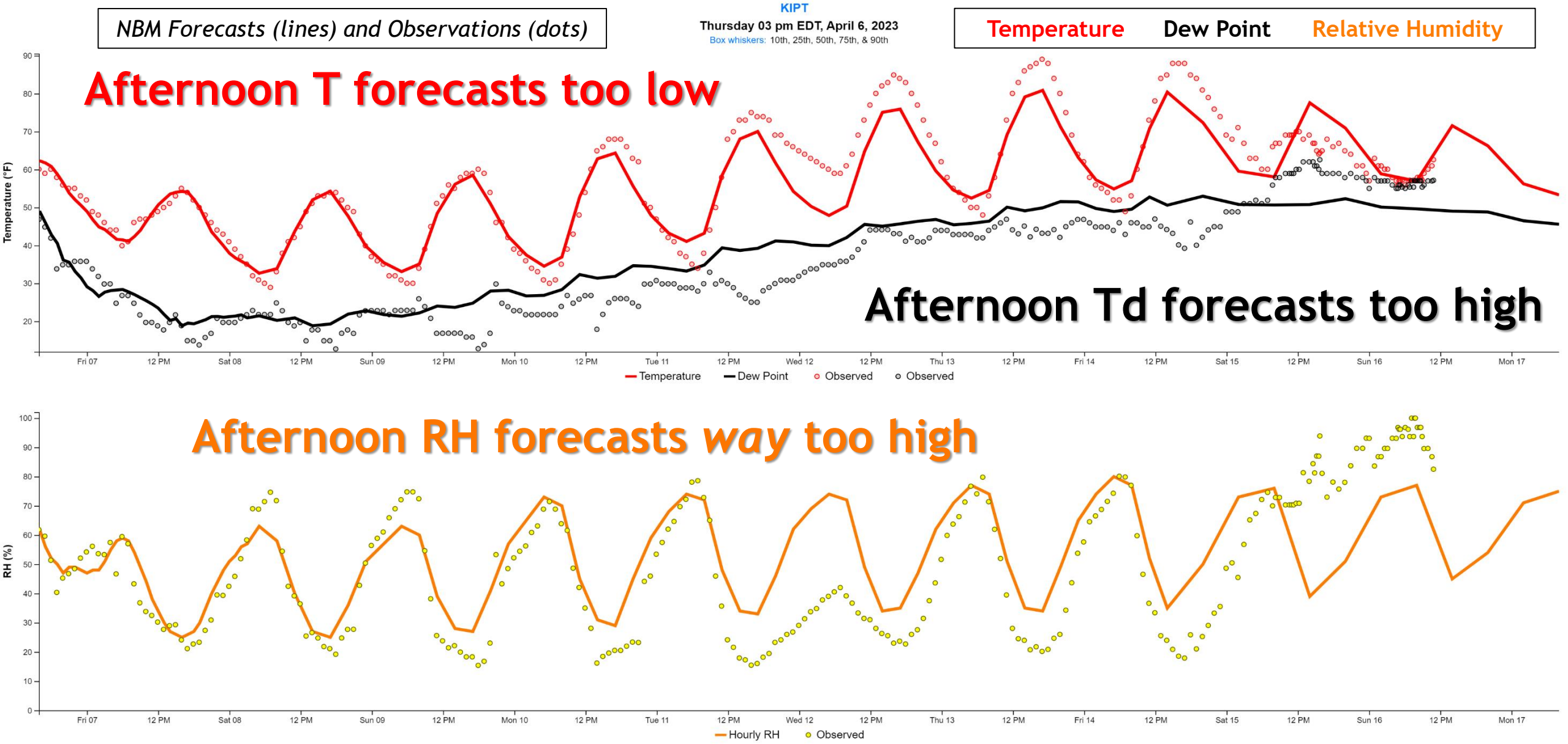
Motivation/Problem/Opportunity

- There are specific spring days where models/our official forecasts badly overestimate minimum relative humidity (forecast RH significantly too high).

- PA Fire Weather Partners (Bureau of Forestry, Allegheny National Forest) told us they often divide our minimum RH forecasts by 2 in order to be adequately prepared for fire weather potential.

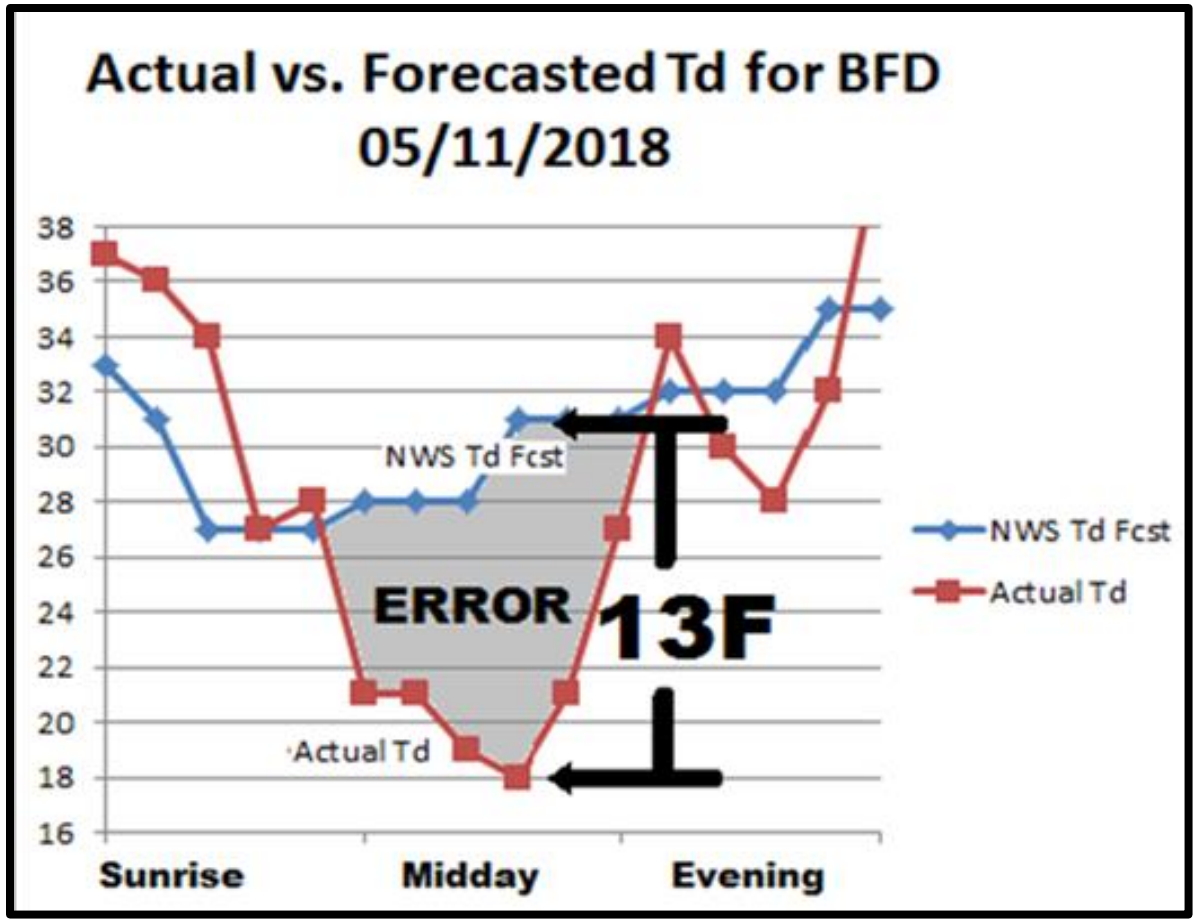
Motivation/Problem/Opportunity

NBM Forecasts (lines) and Observations (dots)



Dew Point Bombs

Td drop of 10°F followed by a rise of 5°F



- NWS Dew Point Forecast:

31°F

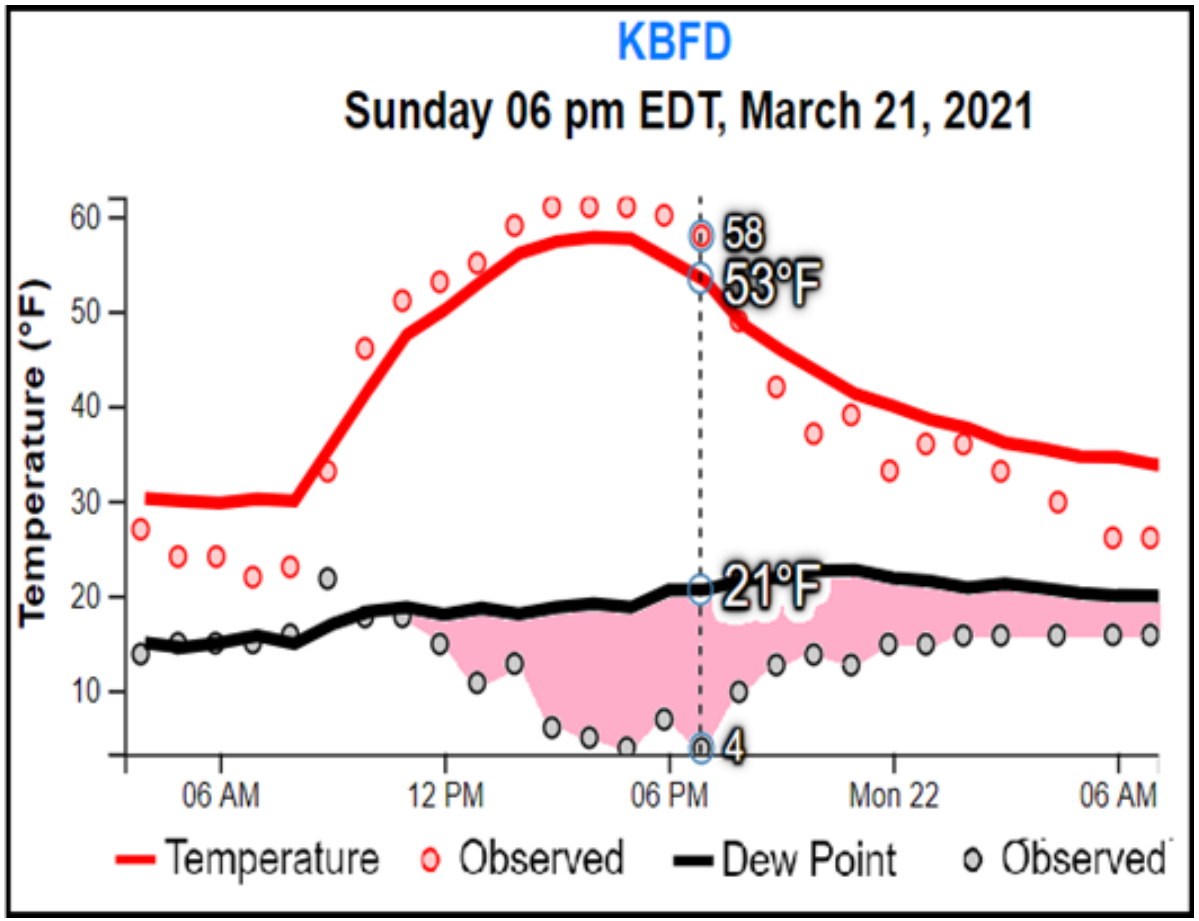
- Actual Dew Point Reported:

18°F

- Forecast Error:

+13°F

Dew Point Bombs



- NBM Dew Point Forecast:

21°F

- Actual Dew Point Reported:

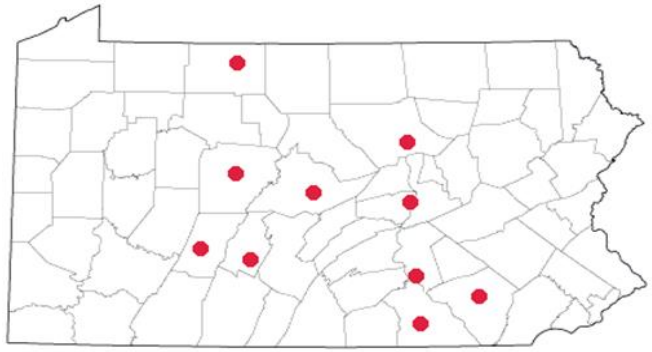
4°F

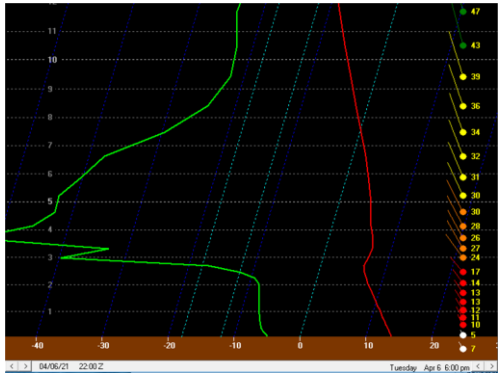
- Forecast Error:

+17°F

Diving into the Data

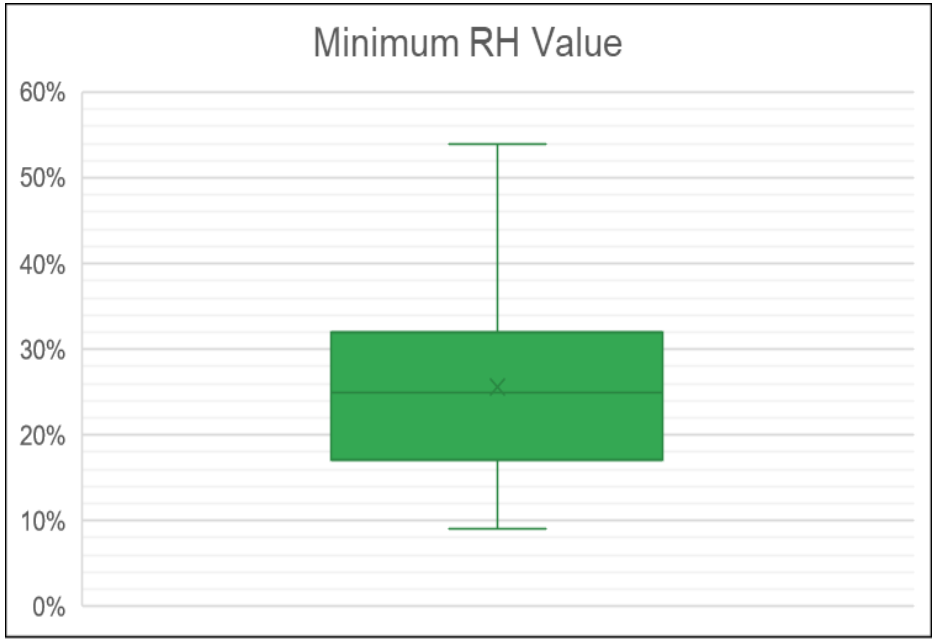
- 110 dew point bomb cases from 2013-2021
- ASOS sites in central PA
- Forecast guidance from NAM sounding profiles
- Observed data from Weather Underground

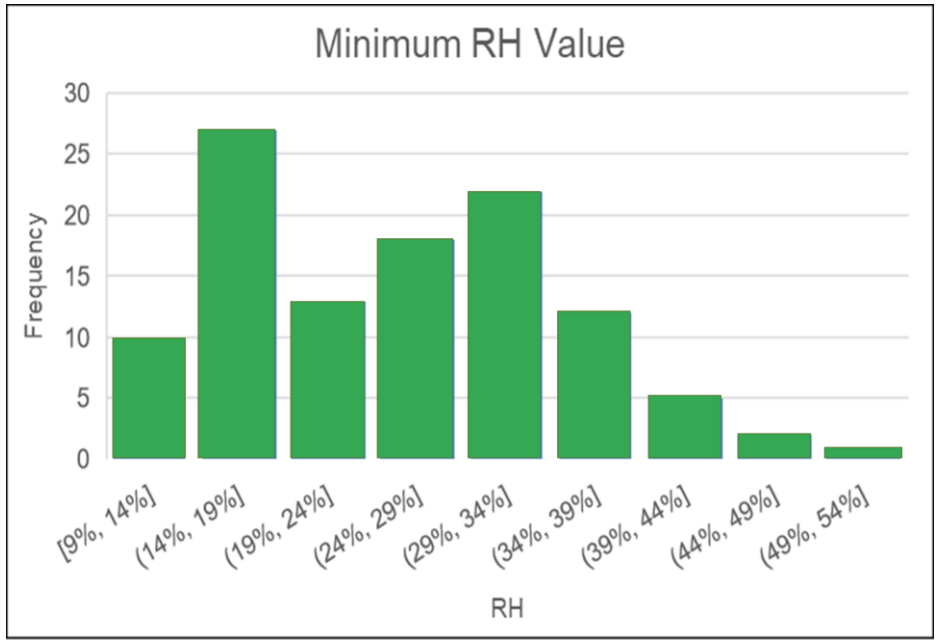




WEATHER UNDERGROUND

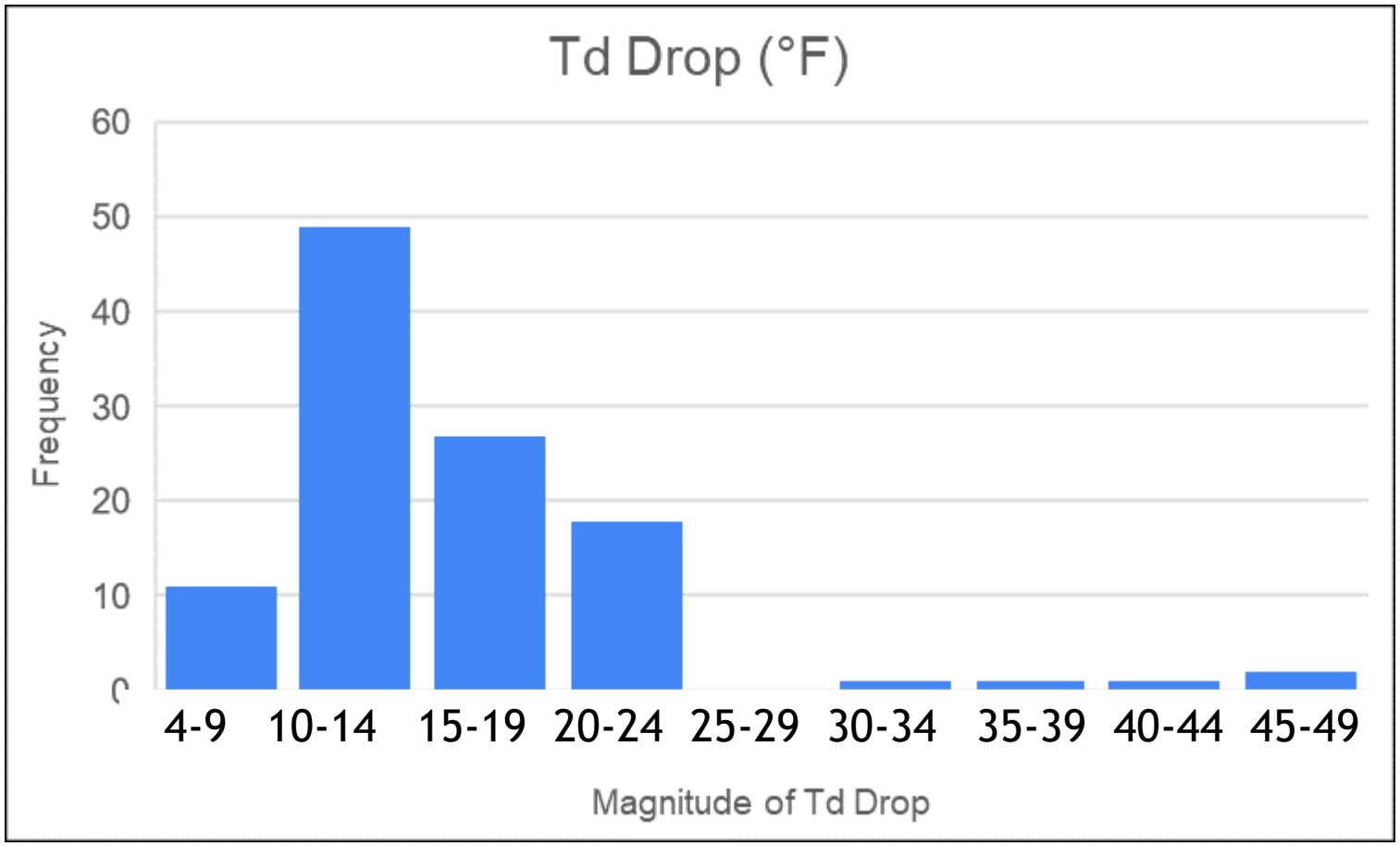
Minimum Observed RH values





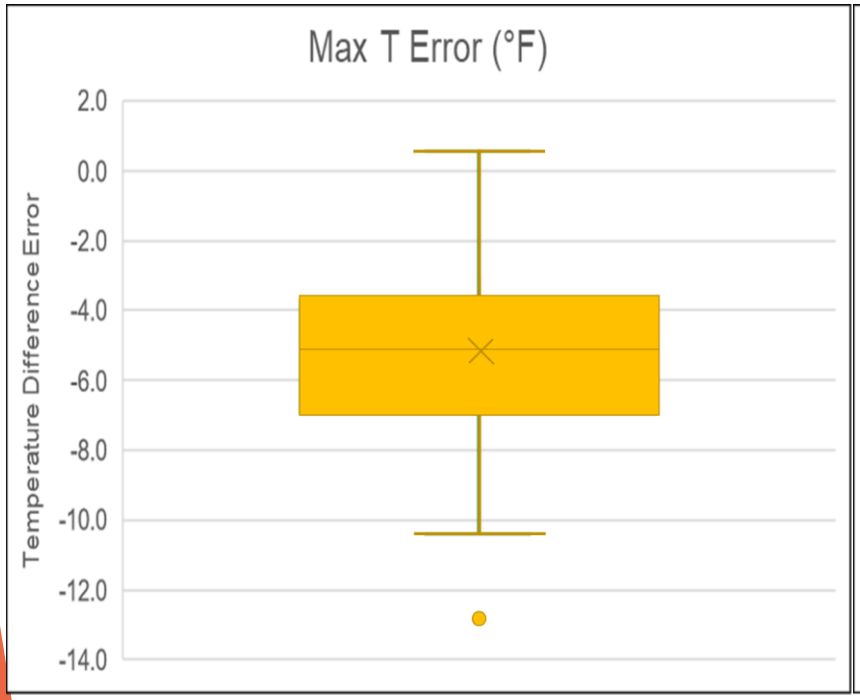
Many cases fall in 20-30% range, which is critical for Red Flag Warning criteria in Central PA.

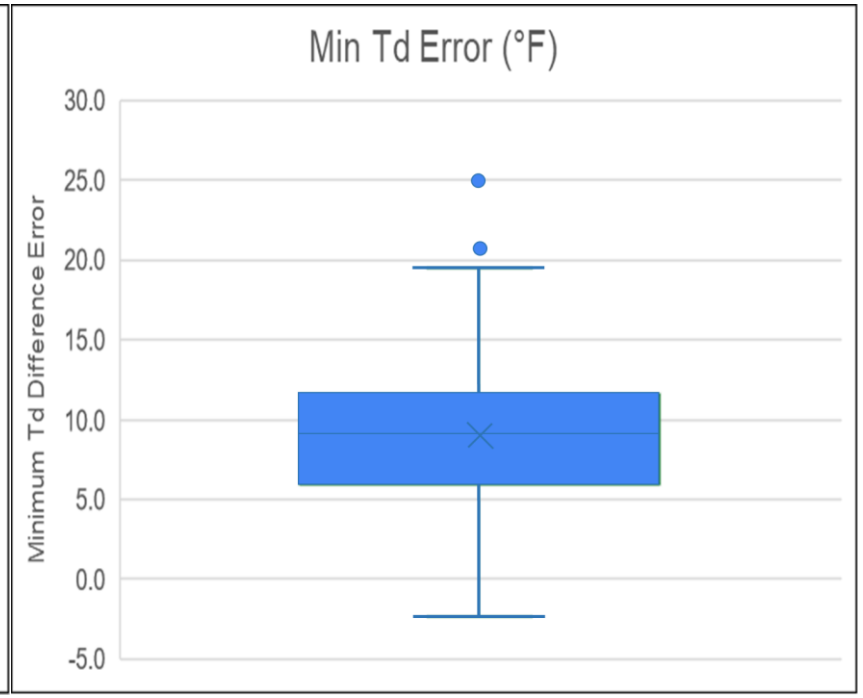
How far does the dew point drop?

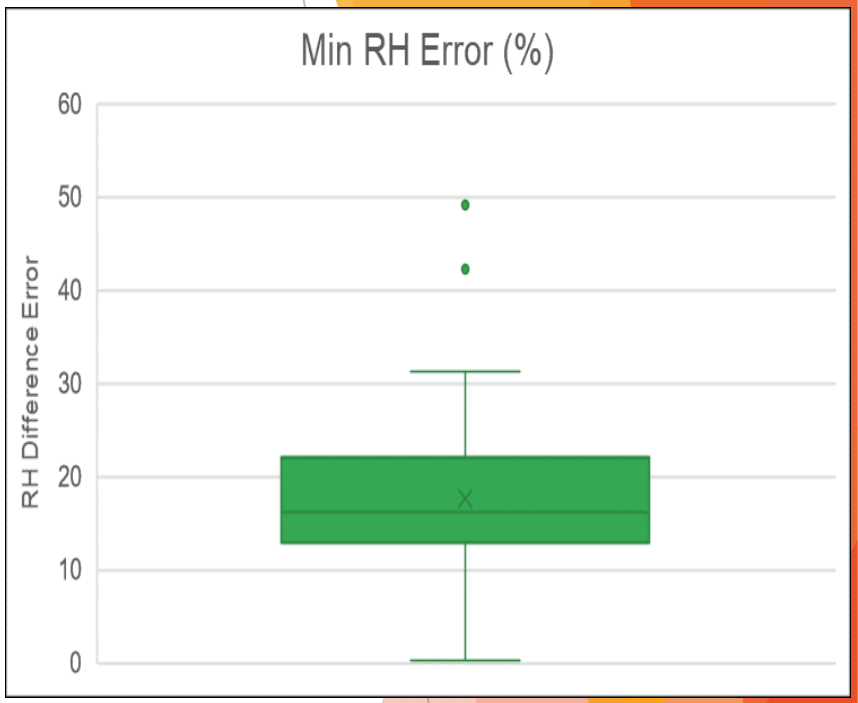


Magnitude of the drop is most often in the 10-20°F range.

T, T_d, and RH Errors



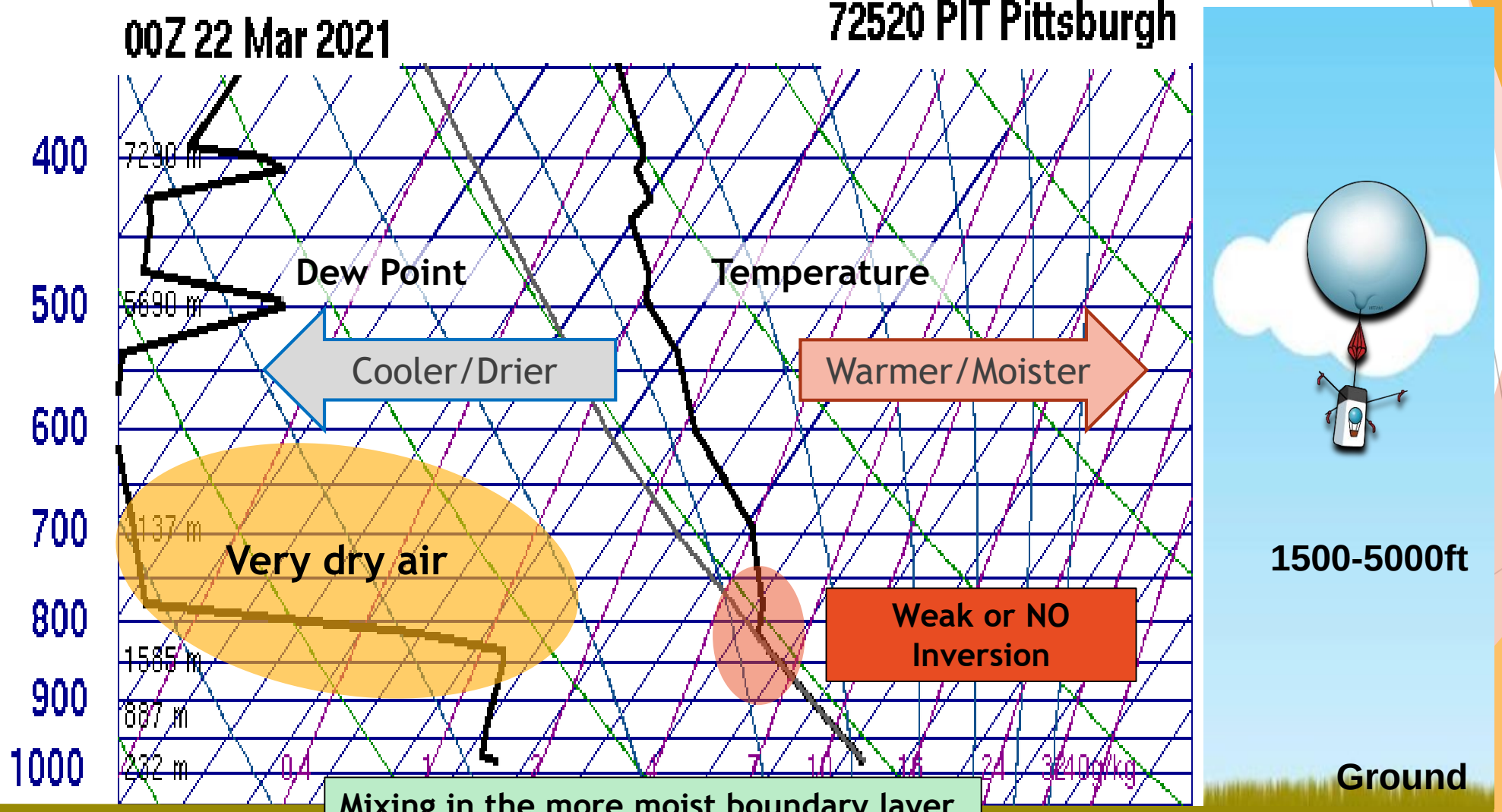




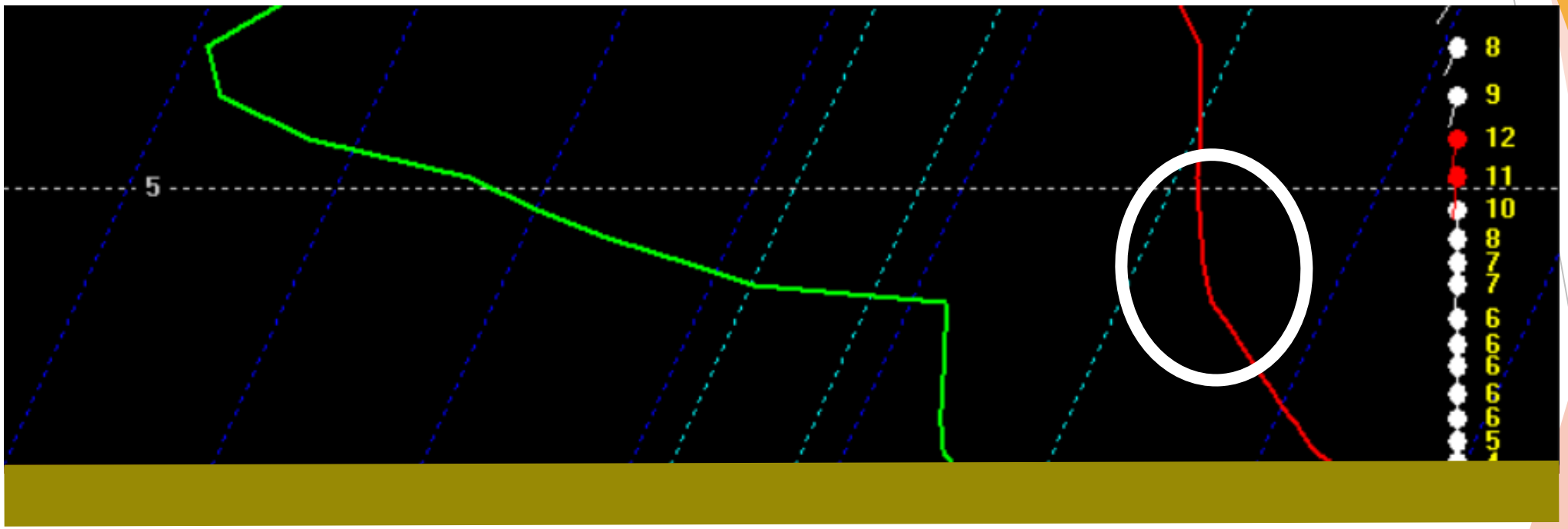
Dew point error is the biggest contributor, but **temperature errors** contribute, too.

We believe these errors are fixable,
but we need to build more confidence to drop dew points
by 10 or 15°F from guidance.

Sounding Analysis:
Dew Point Bomb Ingredients

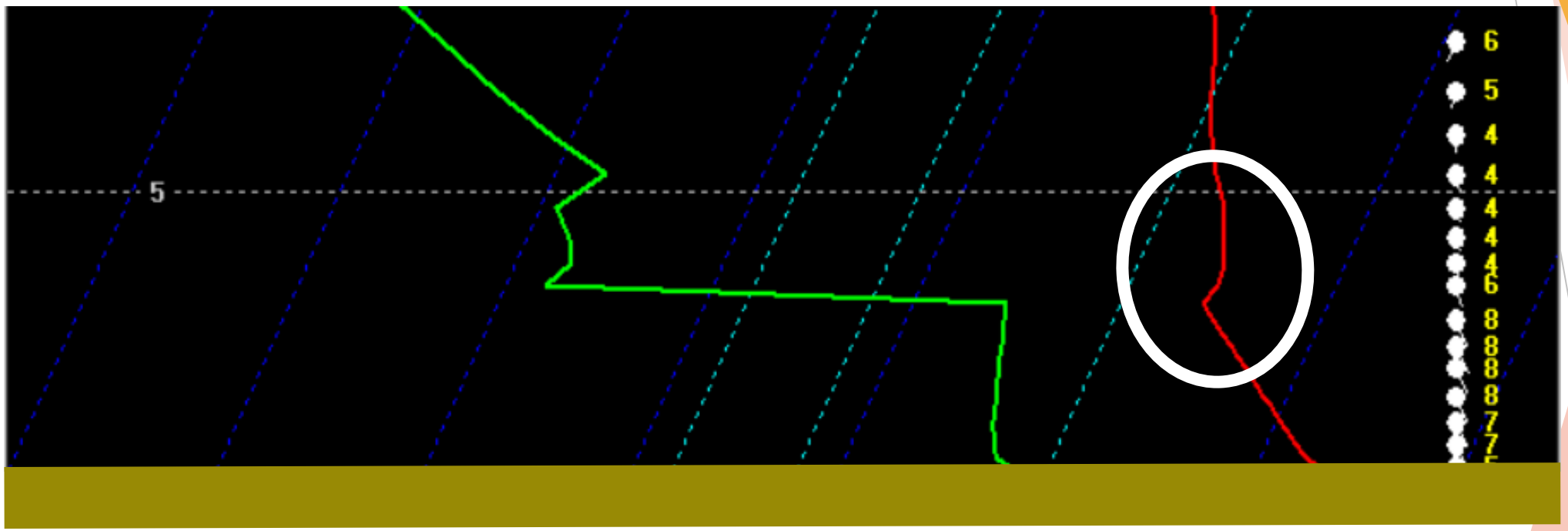


The **inversion strength** plays a major role in dew point bomb potential.



This Skew-T * DID * produce a 10°F T_d Bomb.

The **inversion strength** plays a major role in dew point bomb potential.



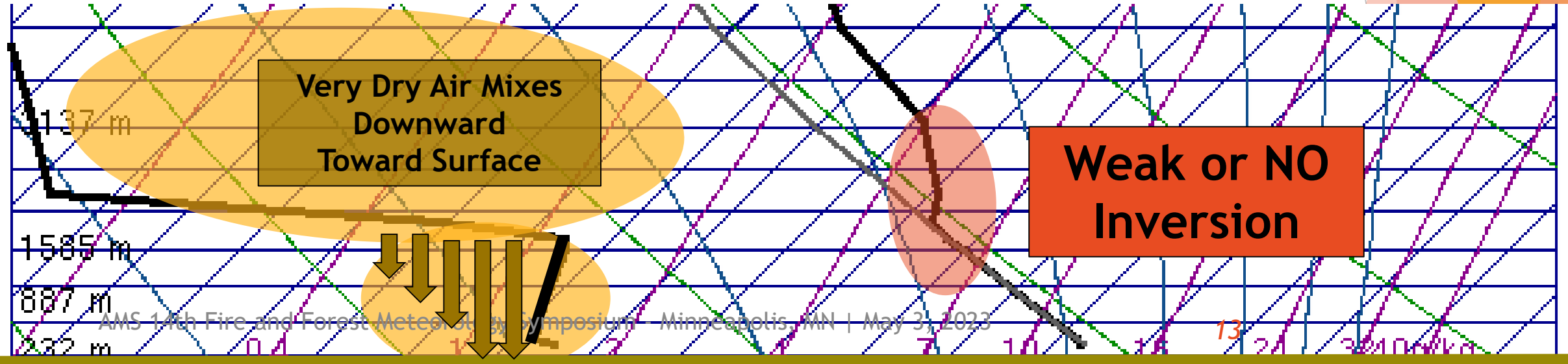
This Skew-T * DID NOT * produce a T_d Bomb

(But did mix and drop the dew point 5°F)

Once mixing begins and dry air gets pulled down, **the dew point begins to drop.**

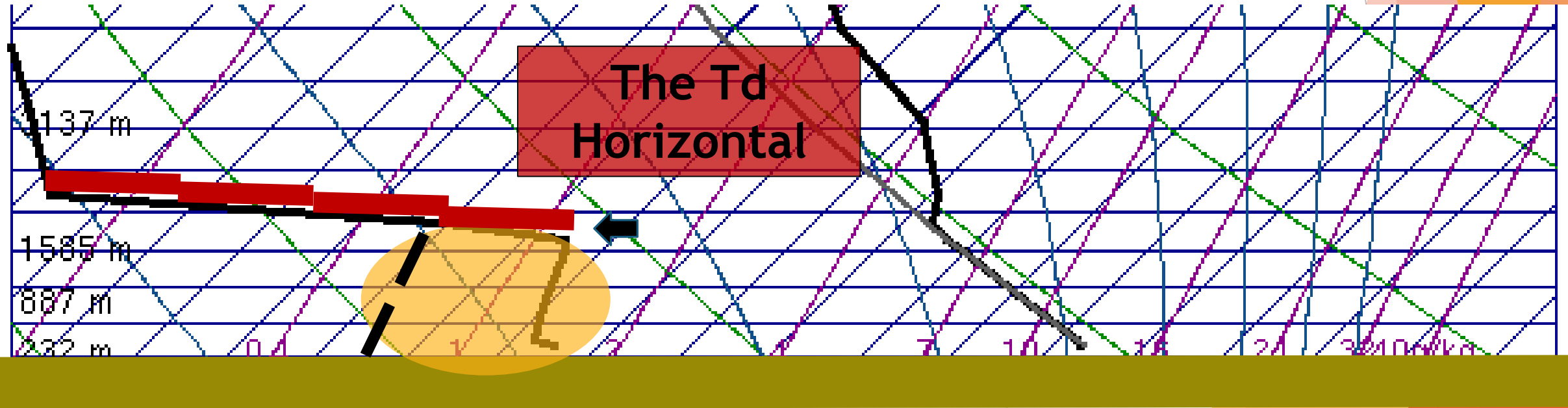
BURNING QUESTION:

HOW FAR WILL THE DEW POINT DROP??



Qualitative Rule-Of-Thumb

- Our preliminary findings show that the magnitude of the **MAX dew point drop** under ideal conditions is about **"1/4 to 1/3" the length of the horizontal portion** of the dew point plot line on the sounding.

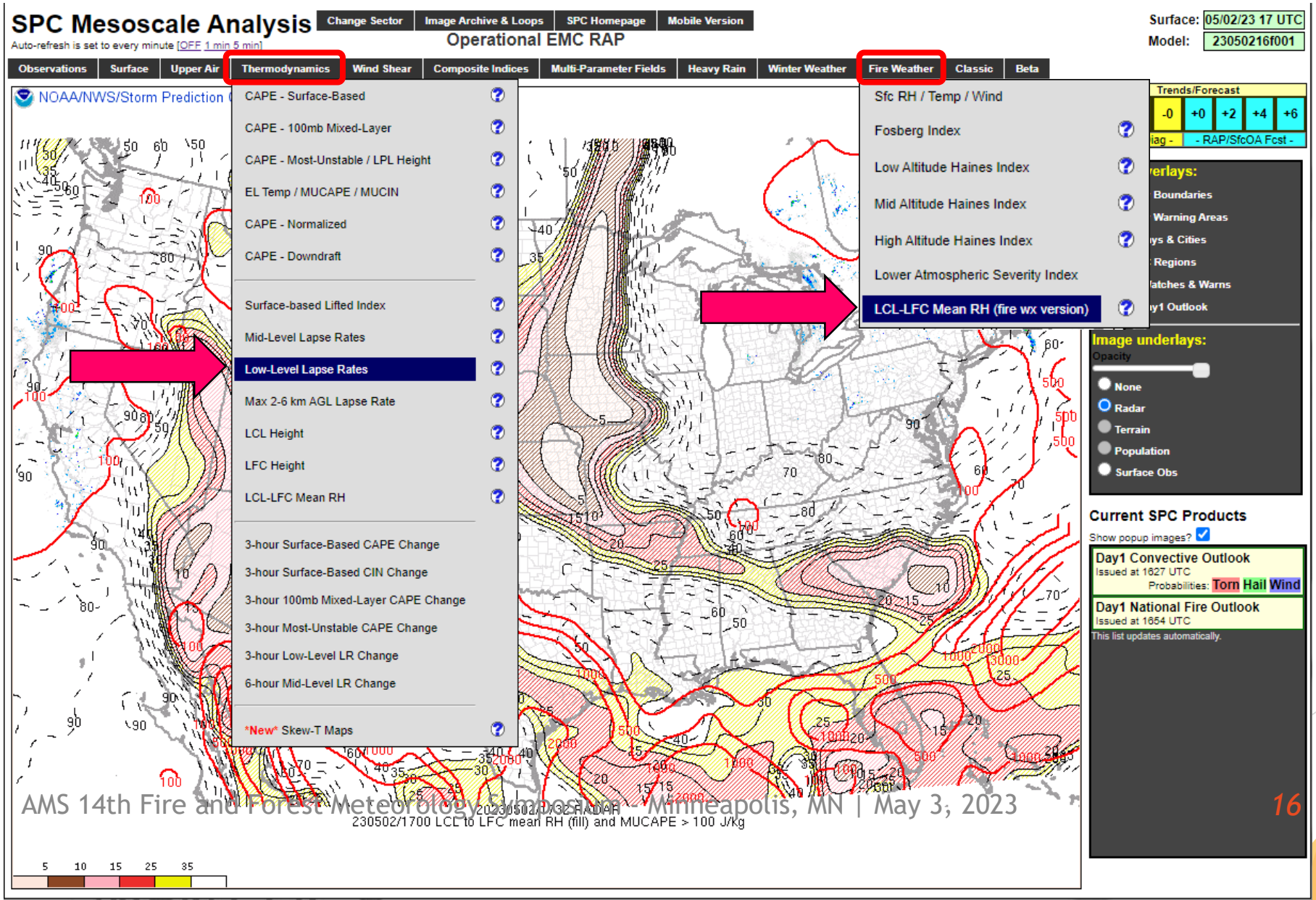


Identifying Dew Point Bomb Potential

- Very inefficient to click through a bunch of soundings…can we look at broader geographic areas?

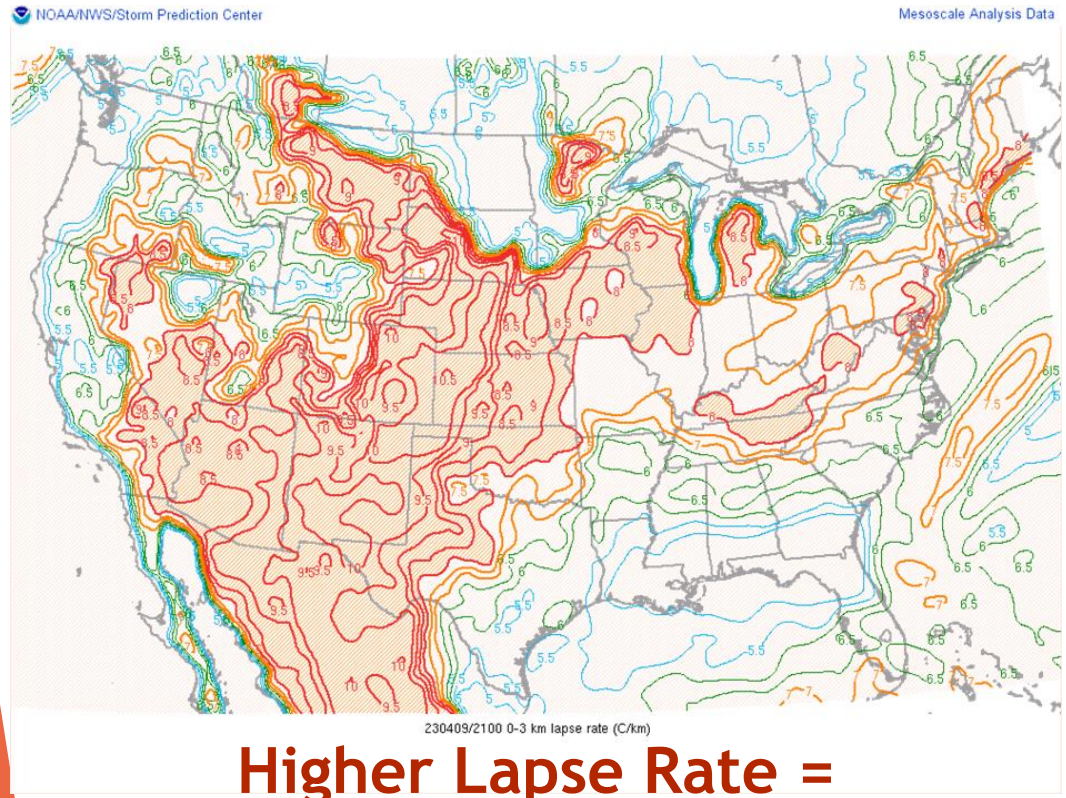
- INGREDIENTS FROM SPC MESOANALYSIS:
  - Weak or No Inversion
    - Low-level (0-3km) Lapse Rates > 7°C/km
  - Dry air above the boundary layer
    - LCL-LFC Mean RH <30%

SPC Mesoscale Analysis Page



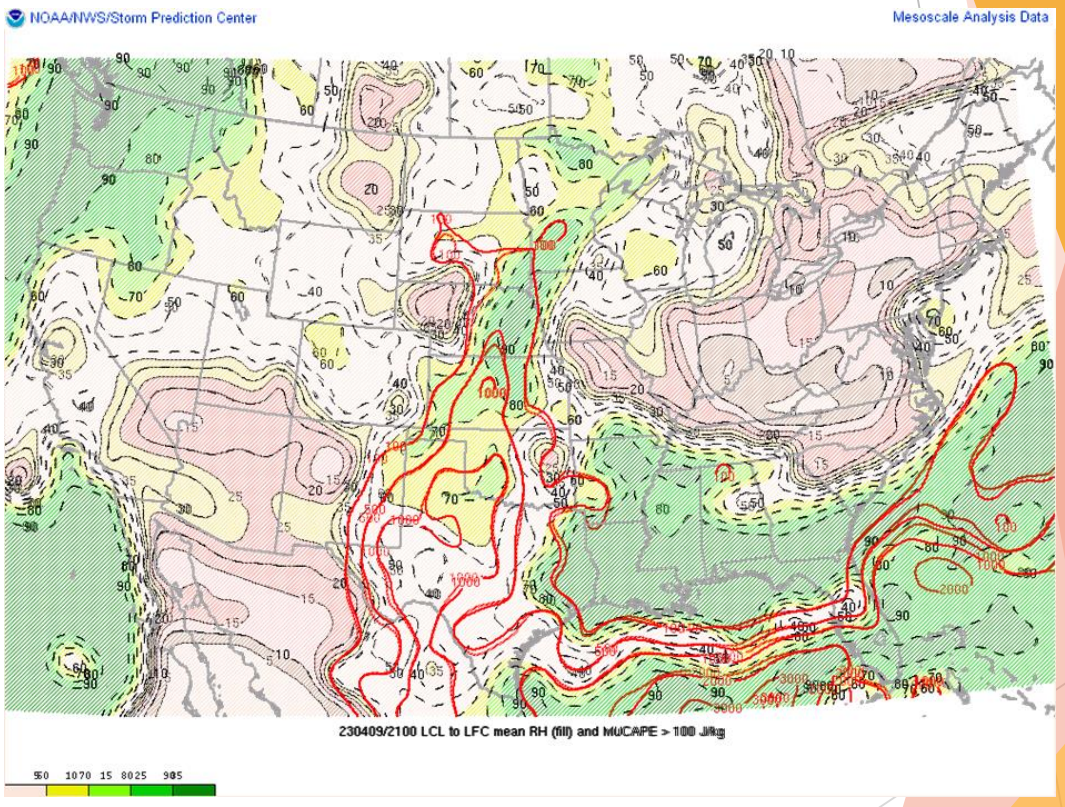
SPC Mesoscale Analysis Page

Low Level Lapse Rates (0-3km)



Higher Lapse Rate = Weaker Inversion

LCL-LFC Mean RH



Lower value = drier air

www.spc.noaa.gov/exper/mesoanalysis/

Dew Point Bomb Case Study

April 6, 2021

Enter new date! <-- Start Here!
(Default hour is 21z)

"Dewpoint Bomb" Research Project Viewer

April 06, 2021 at 21z

www.weather.gov/ctp/TdB_Viewer

WPC Surface Analysis

Low-Level Lapse Rates (0-3km)

LCL to LFC Mean RH

Precipitable Water & Transport Vector

WPC Surface Analysis

Low-Level Lapse Rates (0-3km)

LCL to LCFC Mean RH & muCAPE

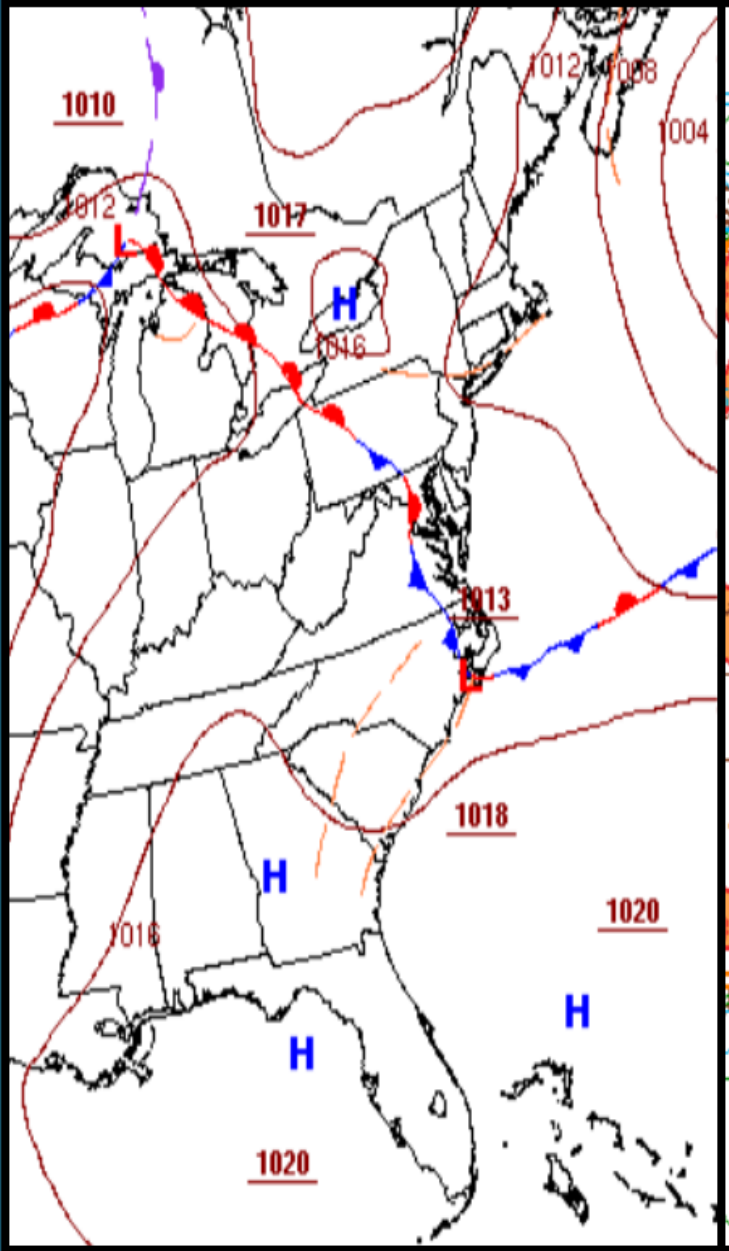
100mb mean parcel LCL Hgt + PWat (lowest 400mb)
+ 925-850mb Layer Moisture Transport Vectors

Enter new date! <-- Start Here!
(Default hour is 21z)

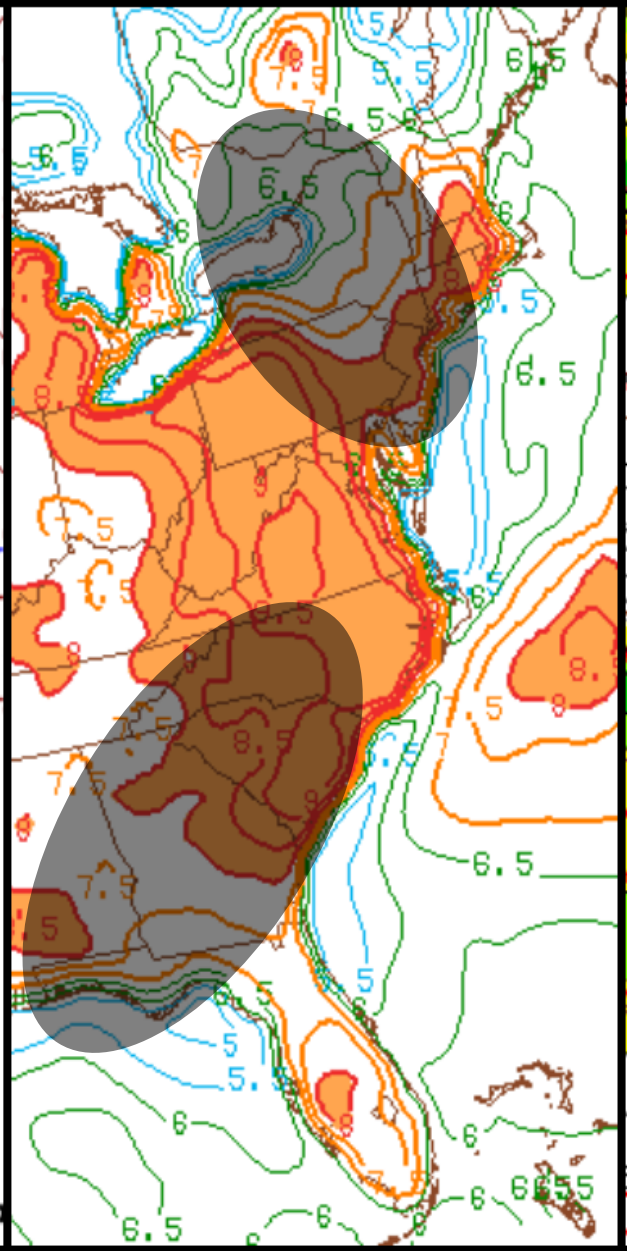
"Dewpoint Bomb" Research Project Viewer

April 06, 2021 at 21z

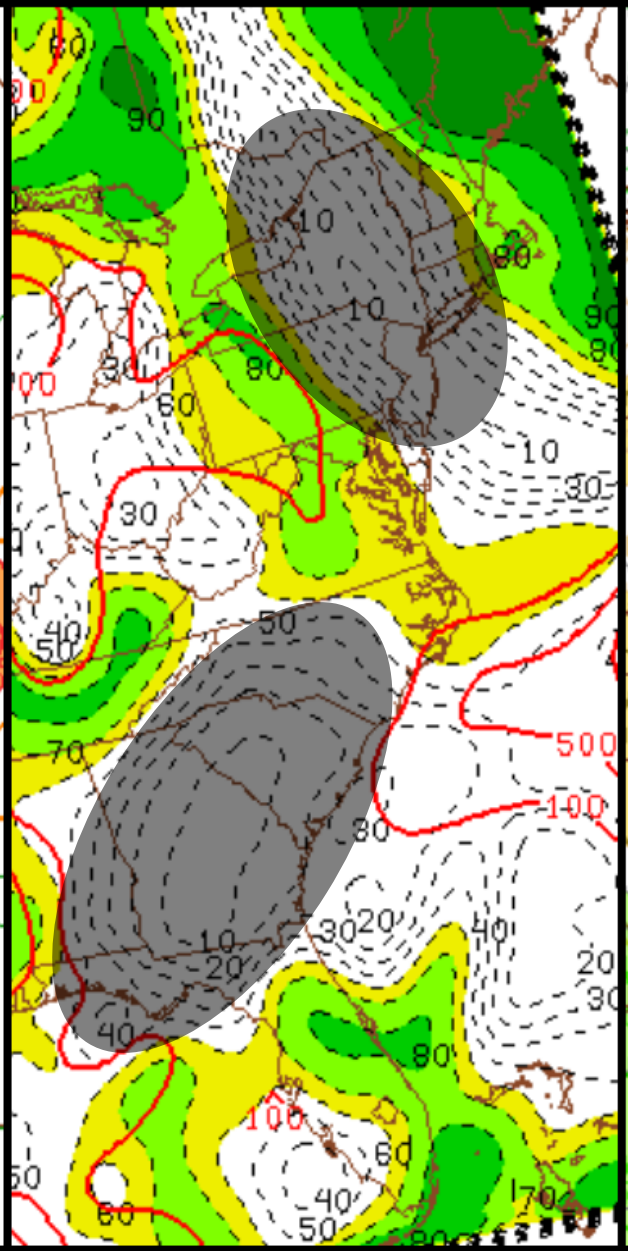
www.weather.gov/ctp/TdB_Viewer



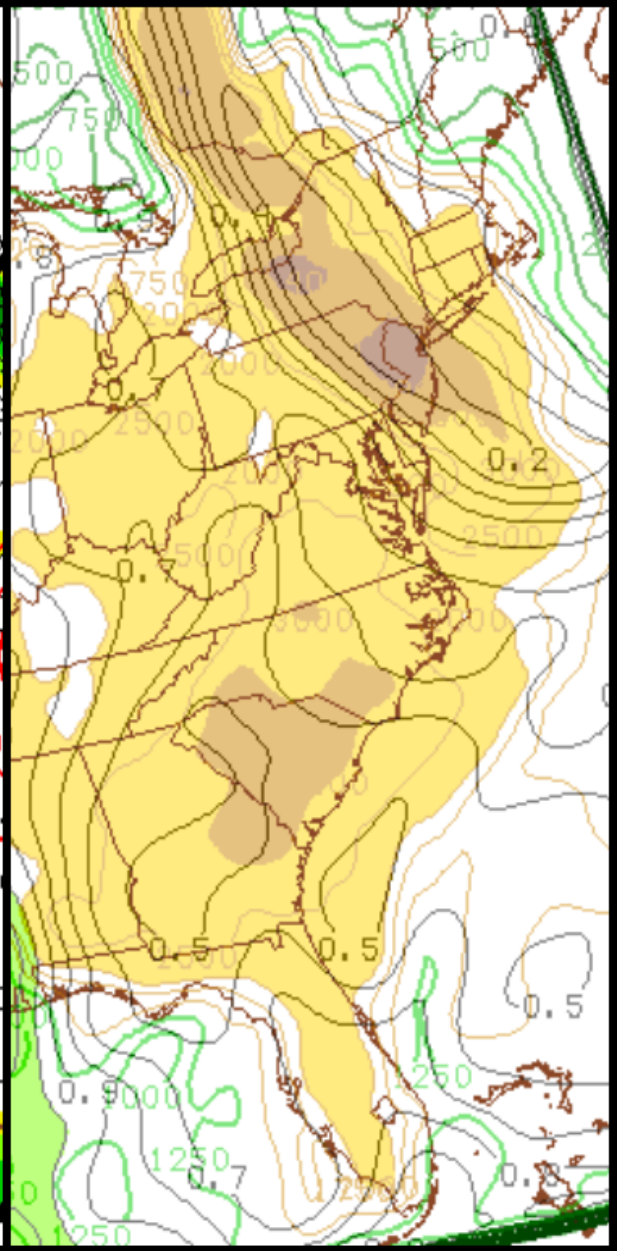
WPC Surface Analysis



Low-Level Lapse Rates (0-3km)

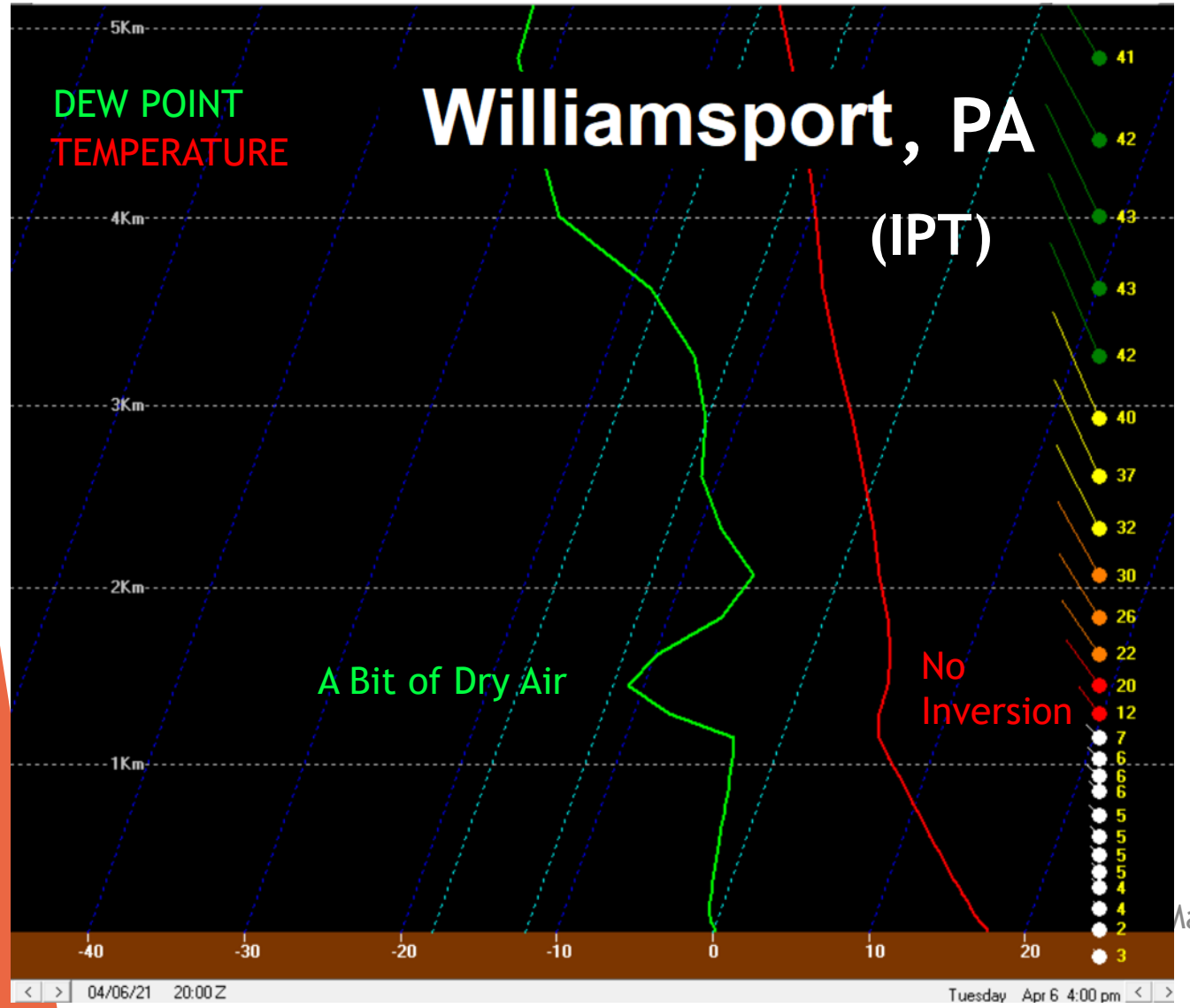


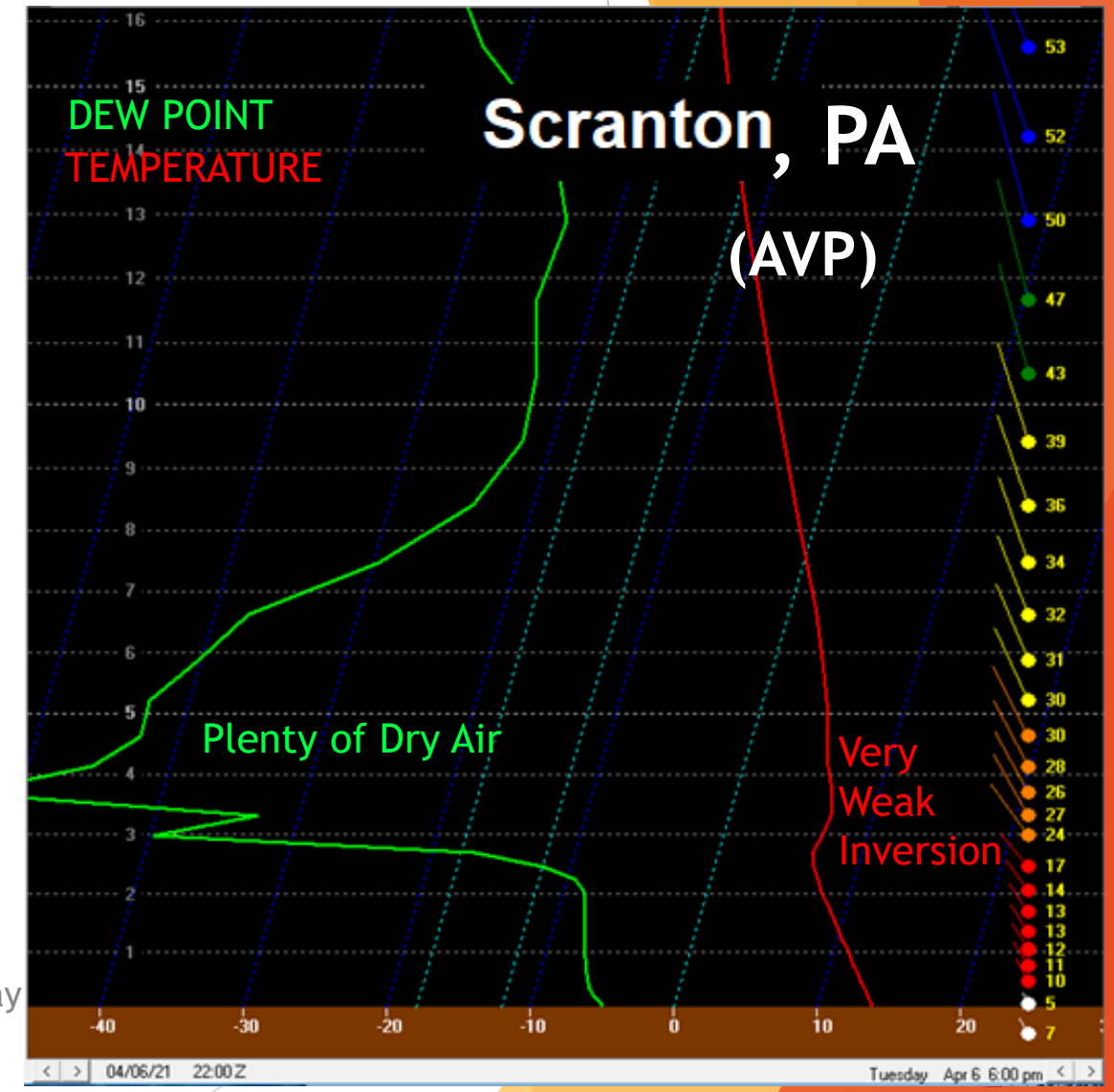
LCL to LCFC Mean RH & muCAPE



100mb mean parcel LCL Hgt + PWat (lowest 400mb)
+ 925-850mb Layer Moisture Transport Vectors

Sounding Examples: 4/6/21 at ~5PM





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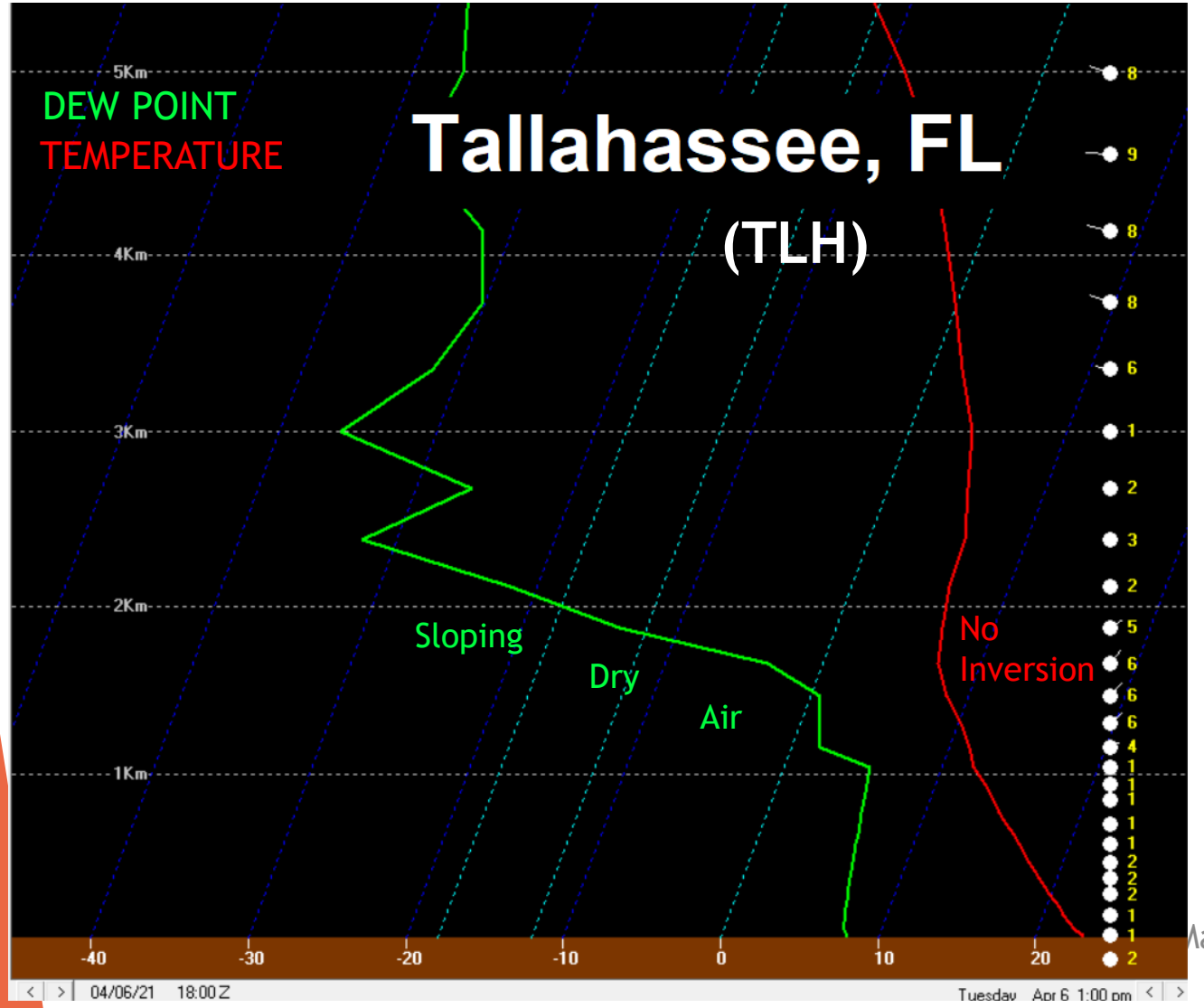
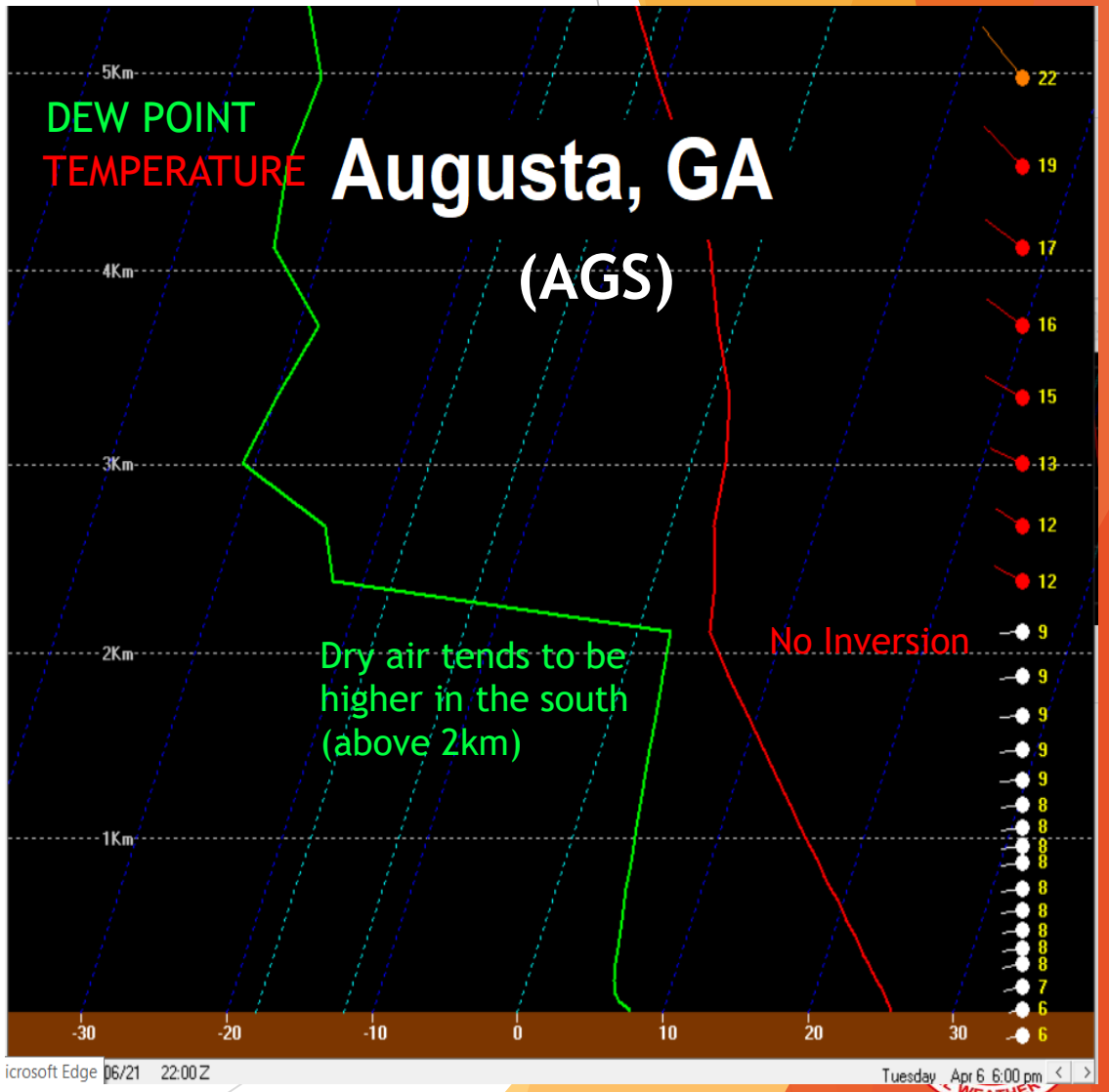




What Happened?

Dew point bombs occurred in BOTH areas!

In the Northeast…

Highlights:

- AVP went from 24°F to -3°F!
- HZL went from 21°F to -4°F!

Overview:

- At least 12 Sites had dew point bombs, many in the 15-20°F range.
- AVP / HZL / ABE / BGM / ELM / ALB / SYR / RME / ITH / MSV / EWR / JFK

In the Southeast…

Highlights:

- Occurred across a large area, from NC-SC-GA into FL.

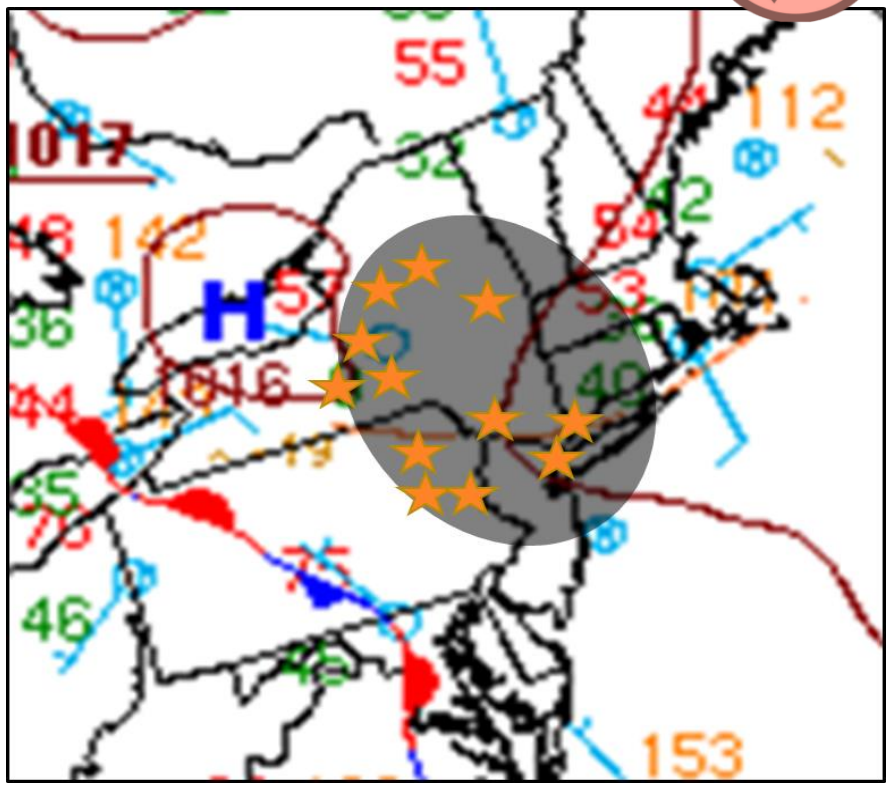
Overview:

- At least 12 Sites had dew point bombs, but many other sites did not fall 10°F.
- AGS / GSP / FAY / HKY / CHS / SAV / VLD / VDI / ABY / CSG / ECG / TLH

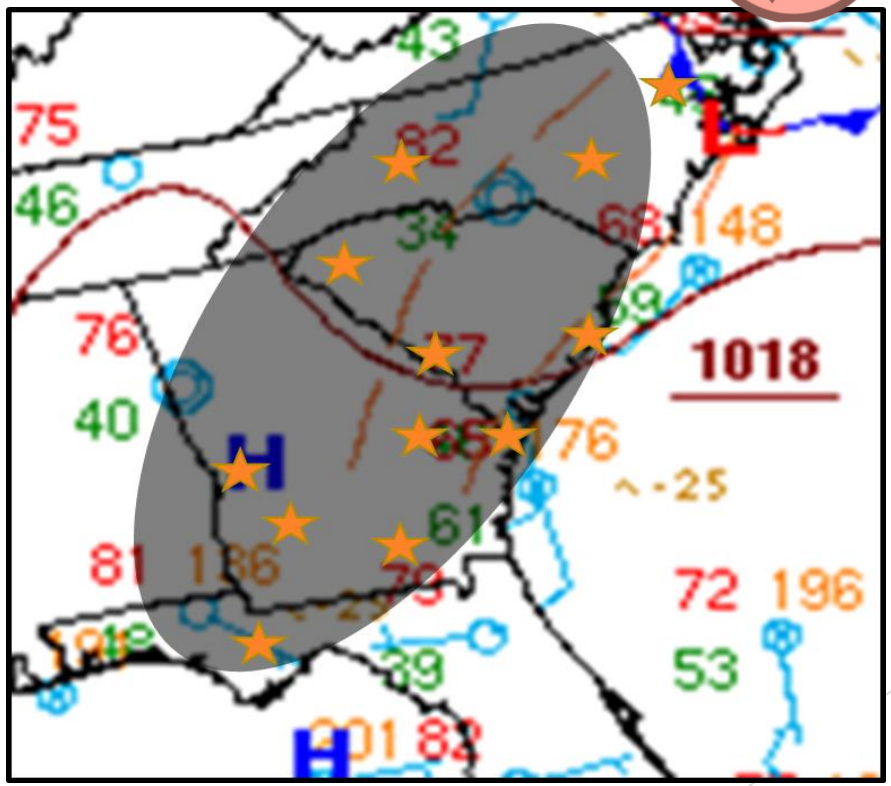
What Happened?

Dew point bombs occurred in BOTH areas!

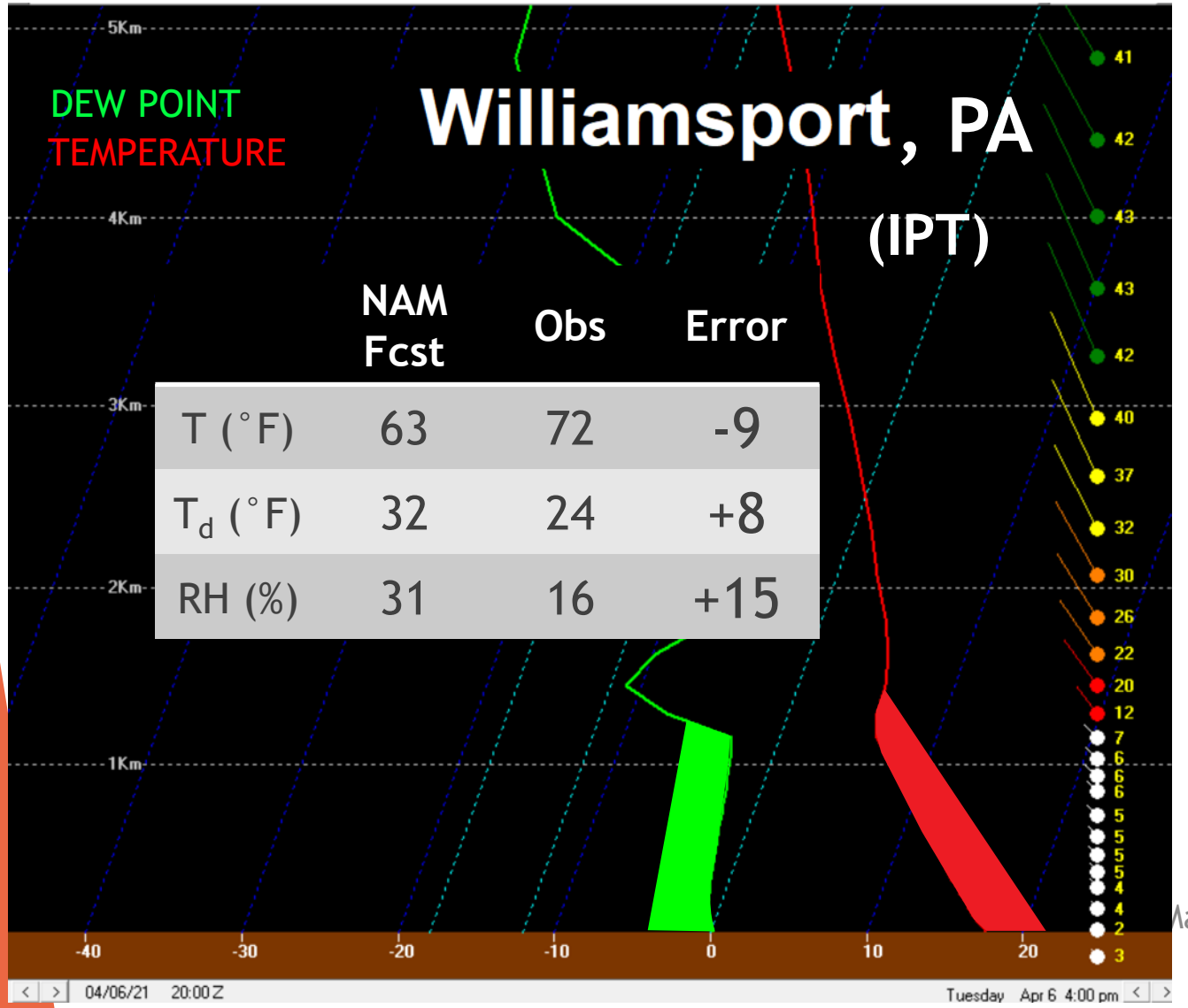
In the Northeast…

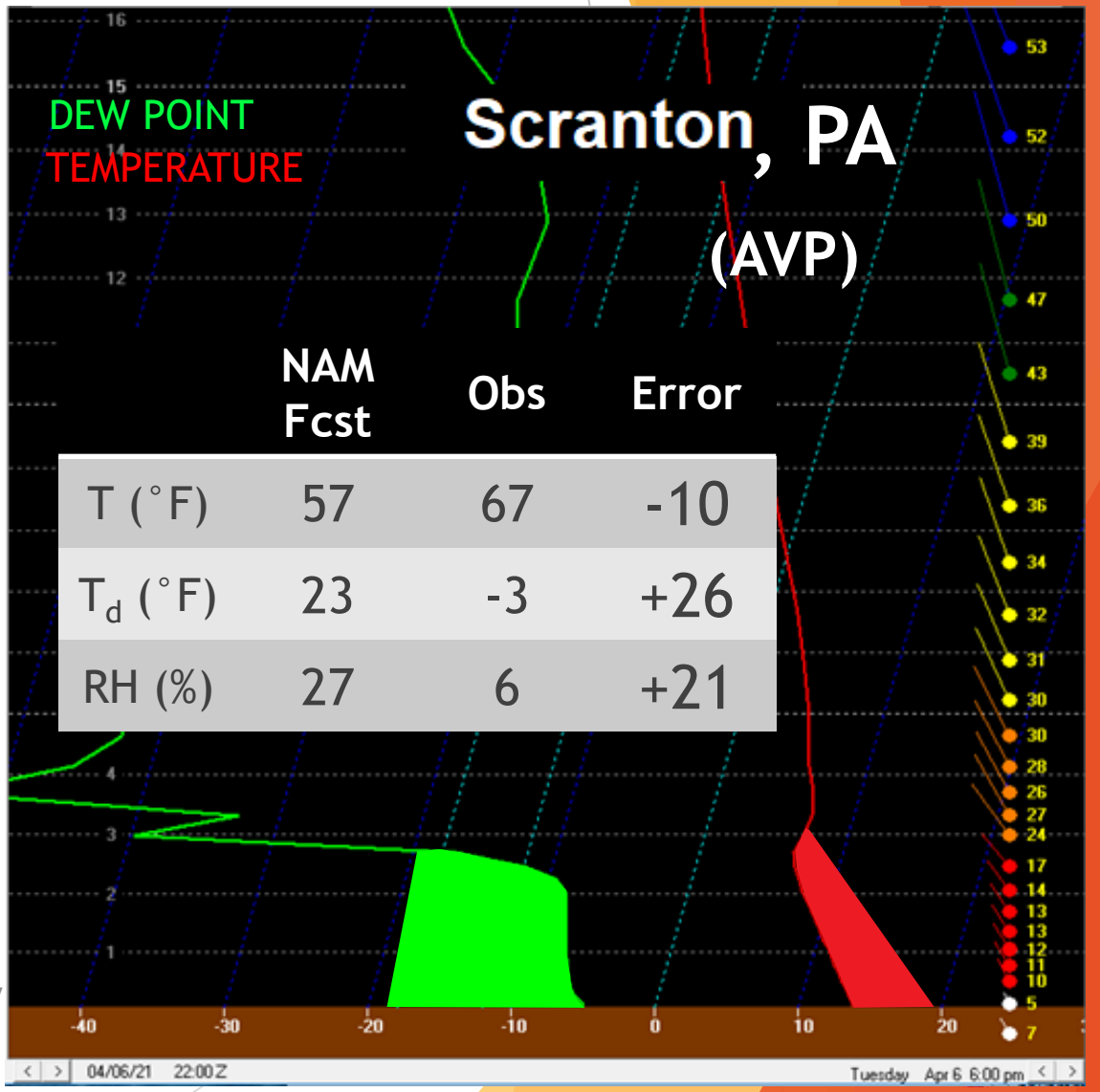


In the Southeast…

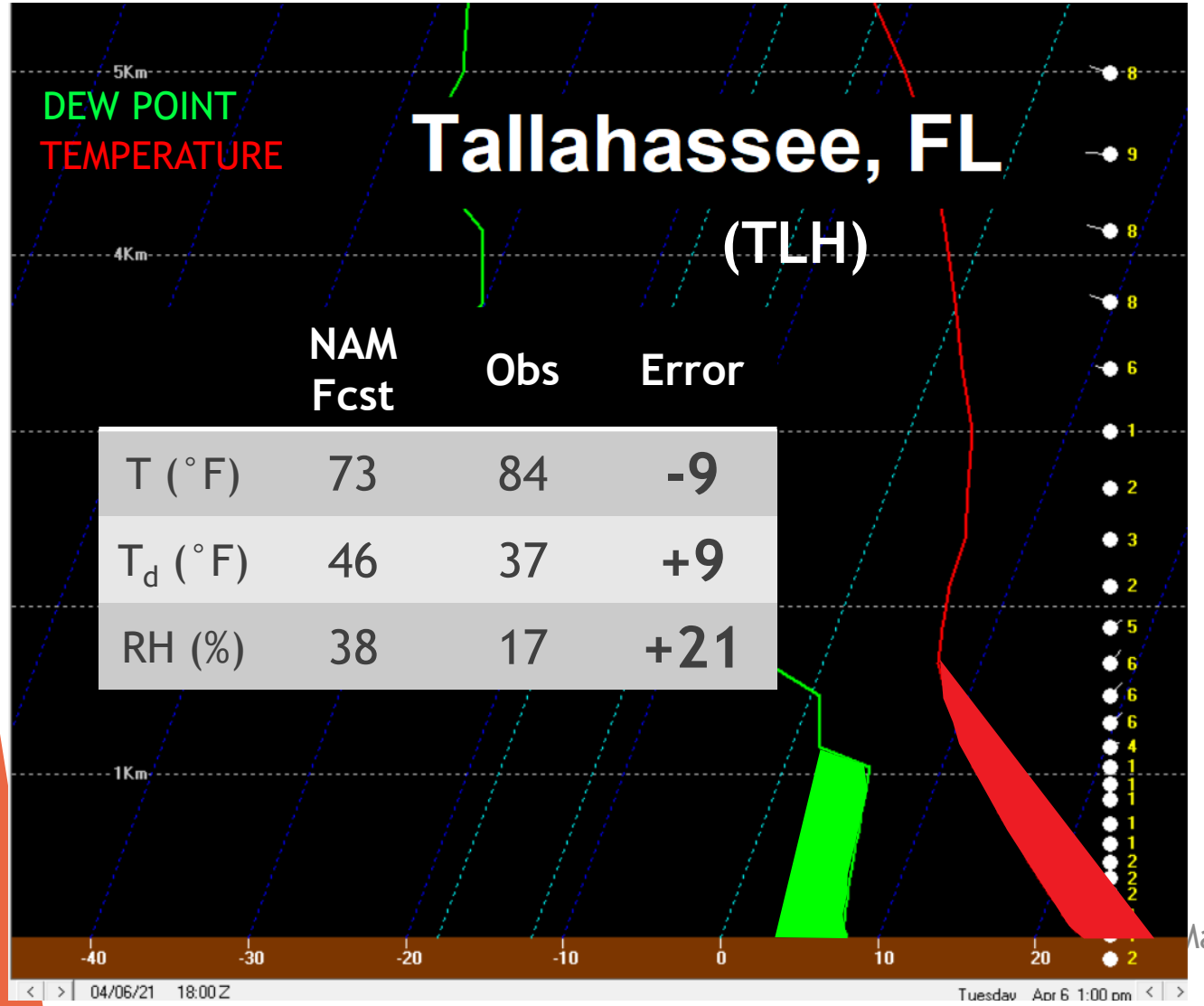


Sounding Examples: 4/6/21 at ~5PM

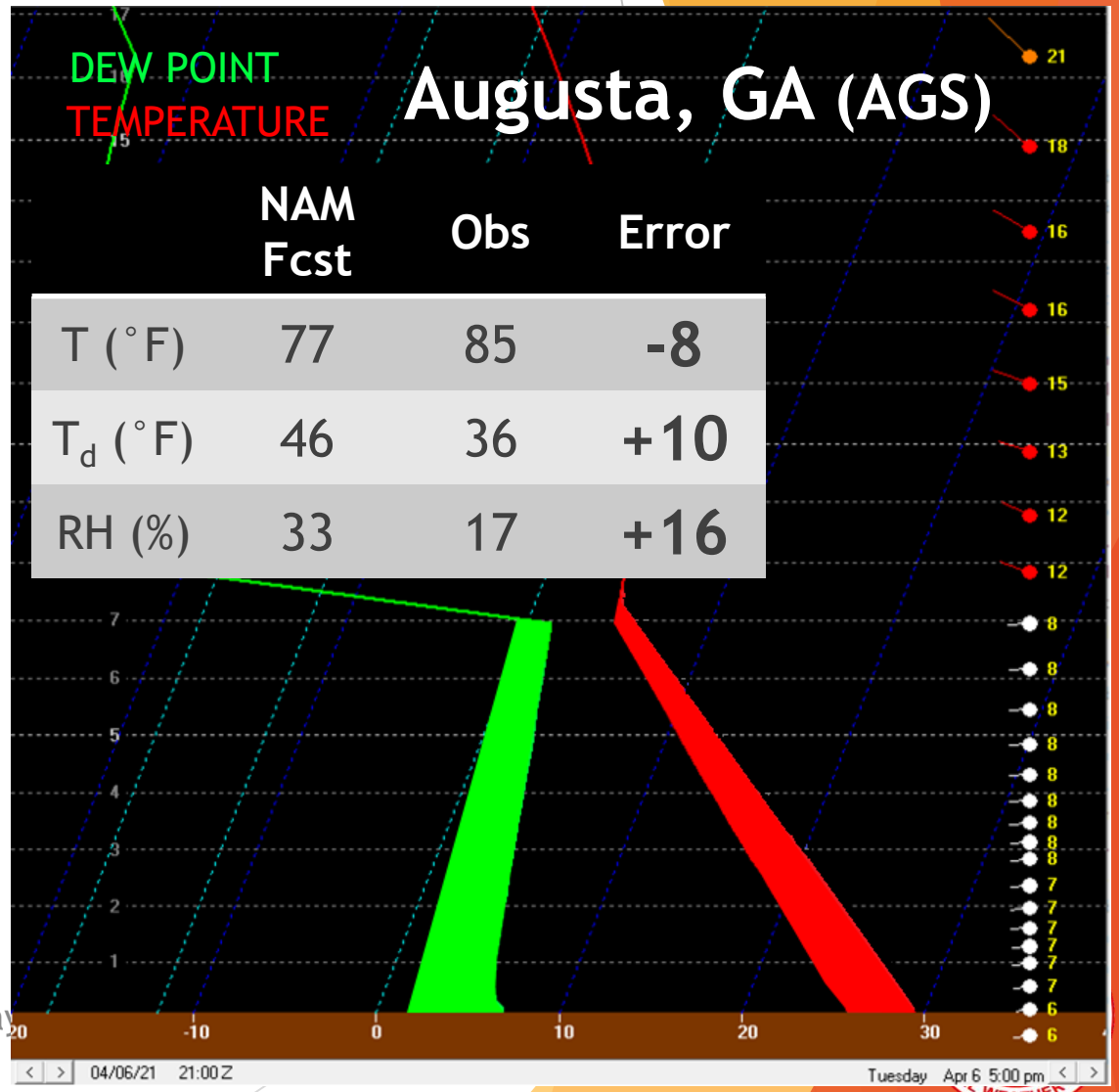




Sounding Examples: 4/6/21 at ~5PM



	NAM Fcst	Obs	Error
T (°F)	73	84	-9
T_d (°F)	46	37	+9
RH (%)	38	17	+21



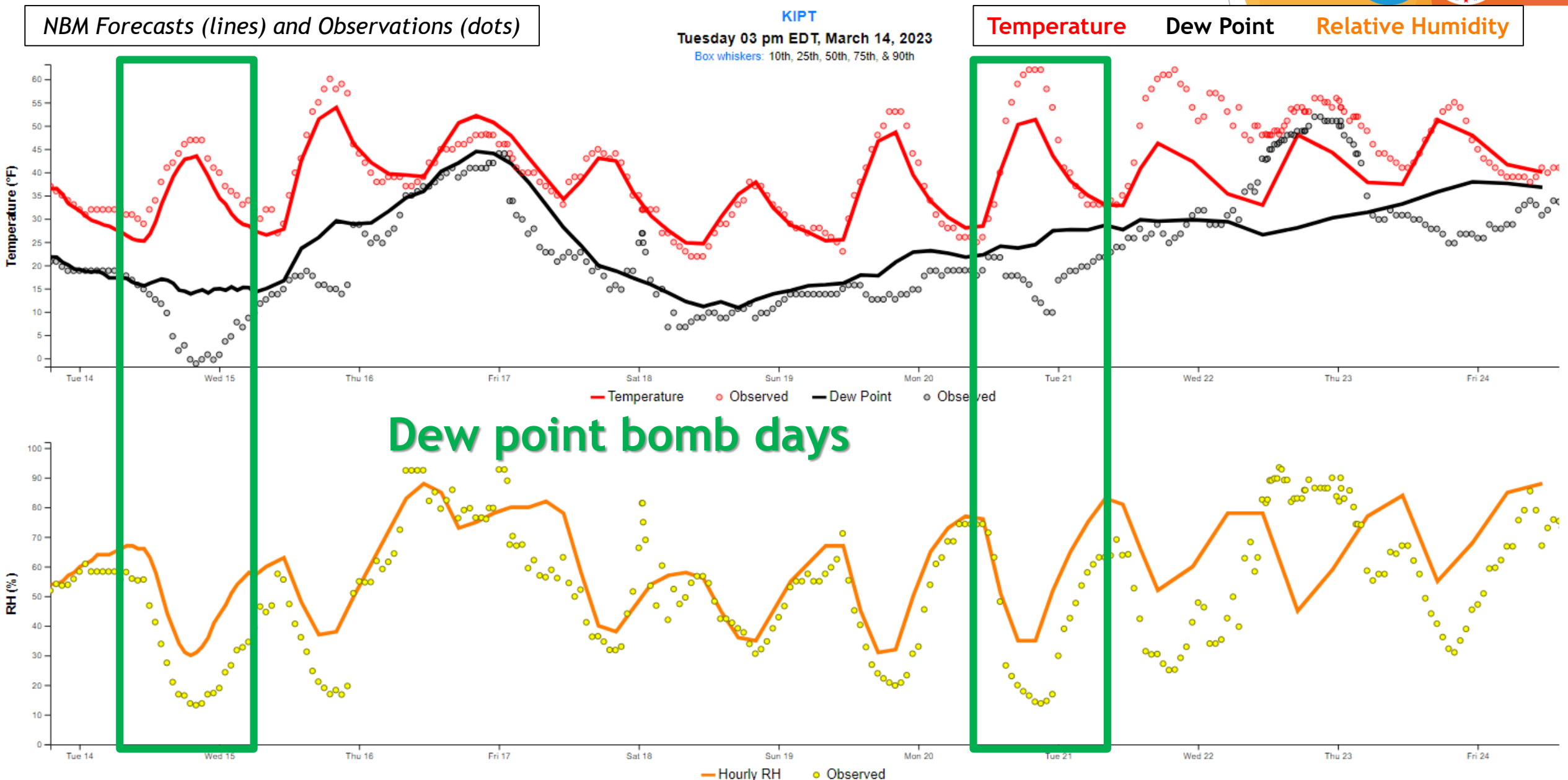
	NAM Fcst	Obs	Error
T (°F)	77	85	-8
T_d (°F)	46	36	+10
RH (%)	33	17	+16

A Look at Model Performance

March 2023

National Blend of Models (NBM)

NBM Forecasts (lines) and Observations (dots)



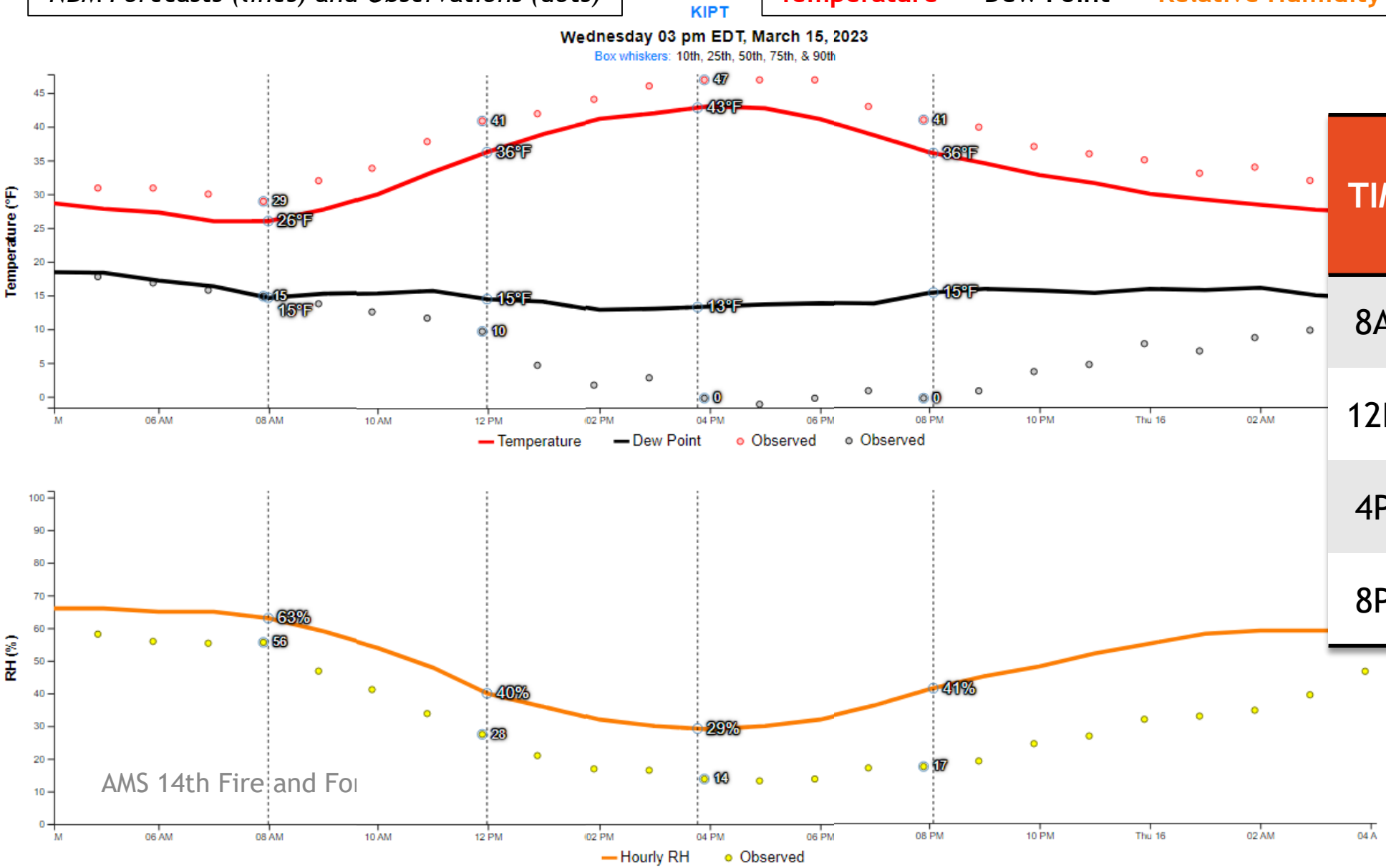
National Weather Service Forecast Process

- National Blend of Models is the “starting point”
- Identify “Targets of Opportunity”
- Make improvements to the forecast
- Tools that have shown some potential:
  - NBM 10th percentile dew point (reasonable “floor”)
  - NBM 90th percentile temperature (reasonable “ceiling”)
  - High Resolution Ensemble Forecast (HREF) ensemble minimum relative humidity
  - Individual high-resolution guidance (Regional Canadian, HRRR, etc.)

NBM Performance: March 15, 2023 – KIPT

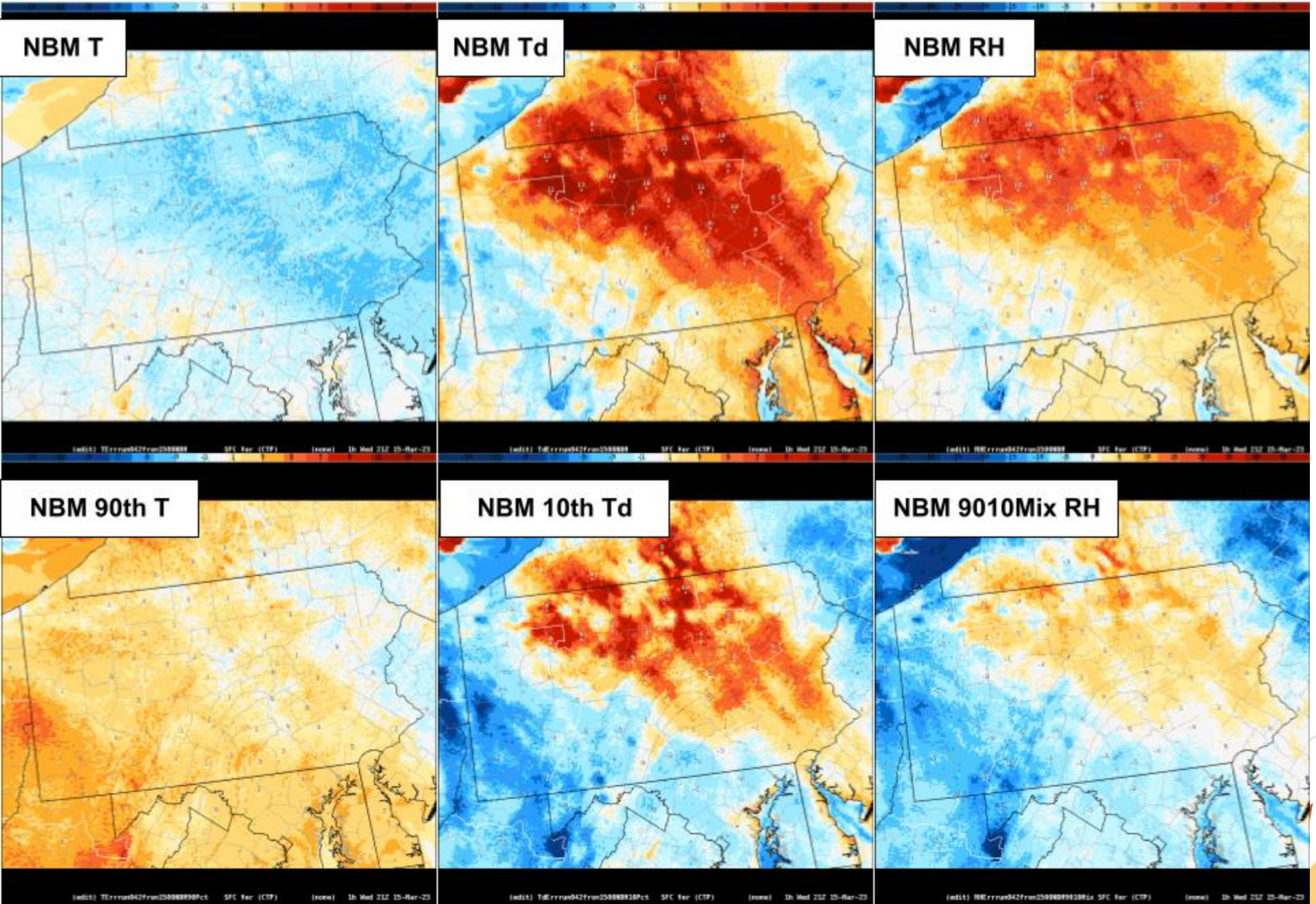
NBM Forecasts (lines) and Observations (dots)

Temperature **Dew Point** **Relative Humidity**



TIME	T Error (°F)	Td Error (°F)	RH Error (%)
8AM	-3	0	+7
12PM	-5	+5	+14
4PM	-4	+13	+15
8PM	-5	+15	+24

NBM & NBM Percentile Performance: March 15, 2023



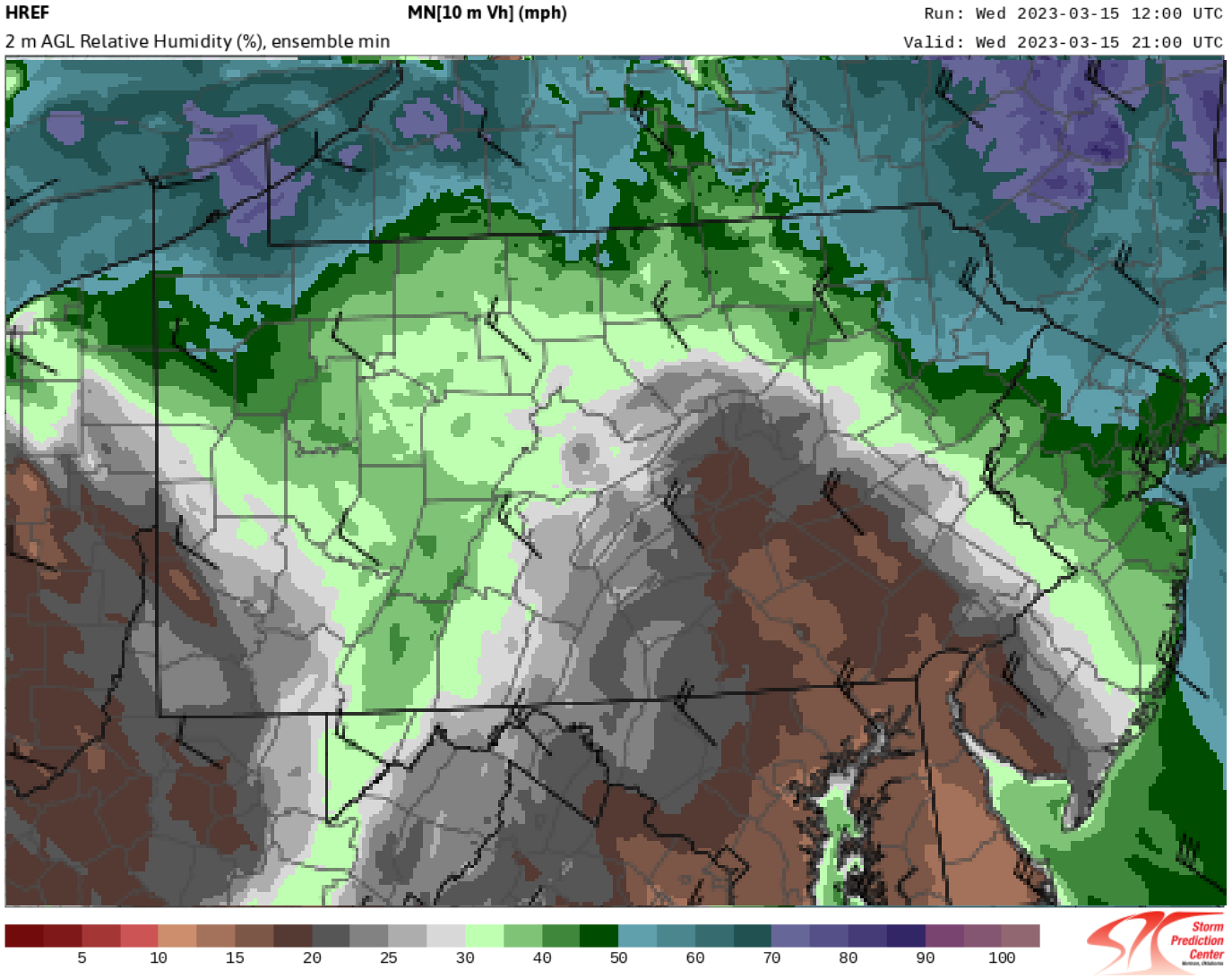
NBM Forecast Too High

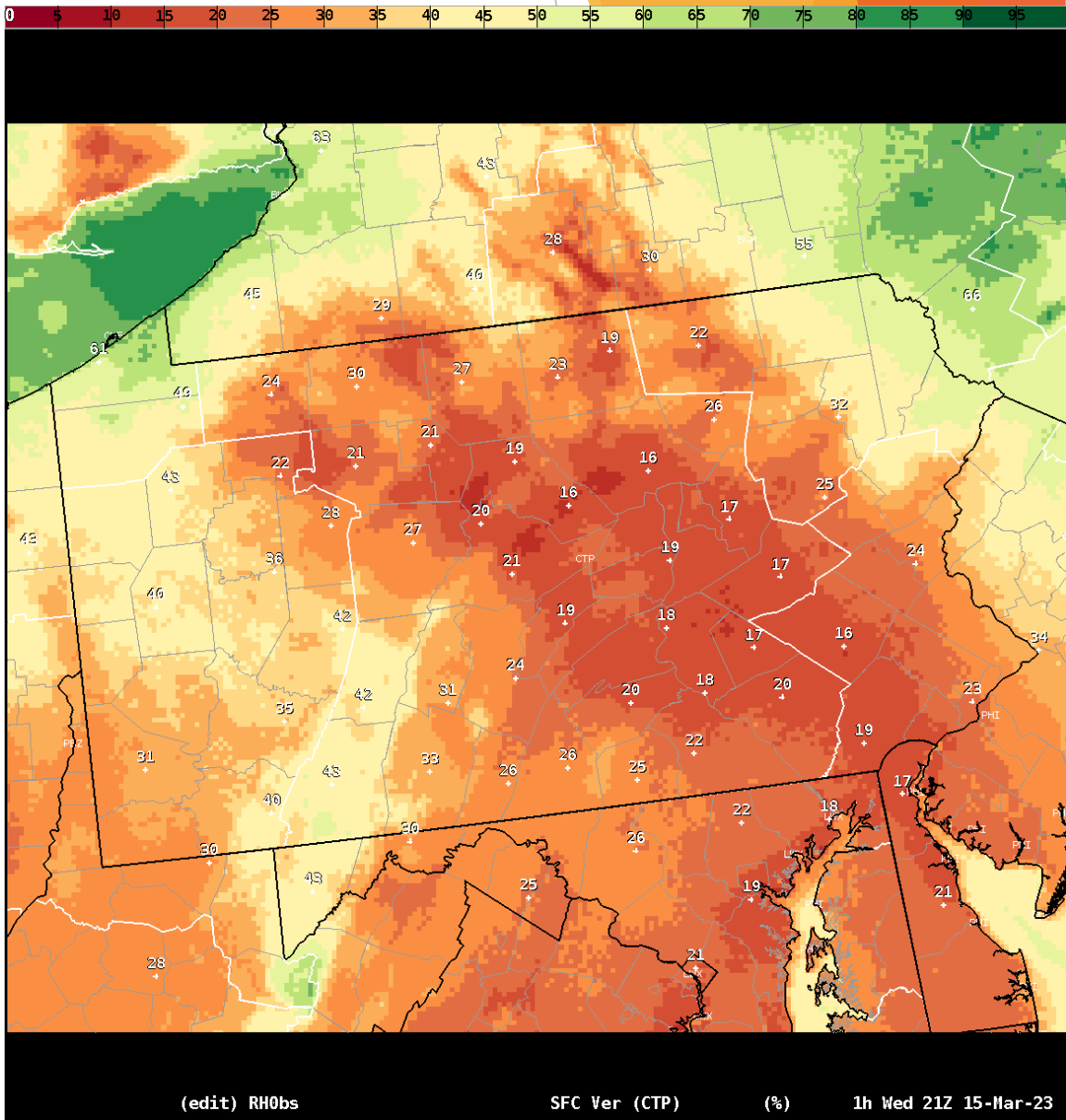
NBM Forecast Too Low

90th T is a bit too high & 10th Td isn't low enough:

Combination is pretty close!

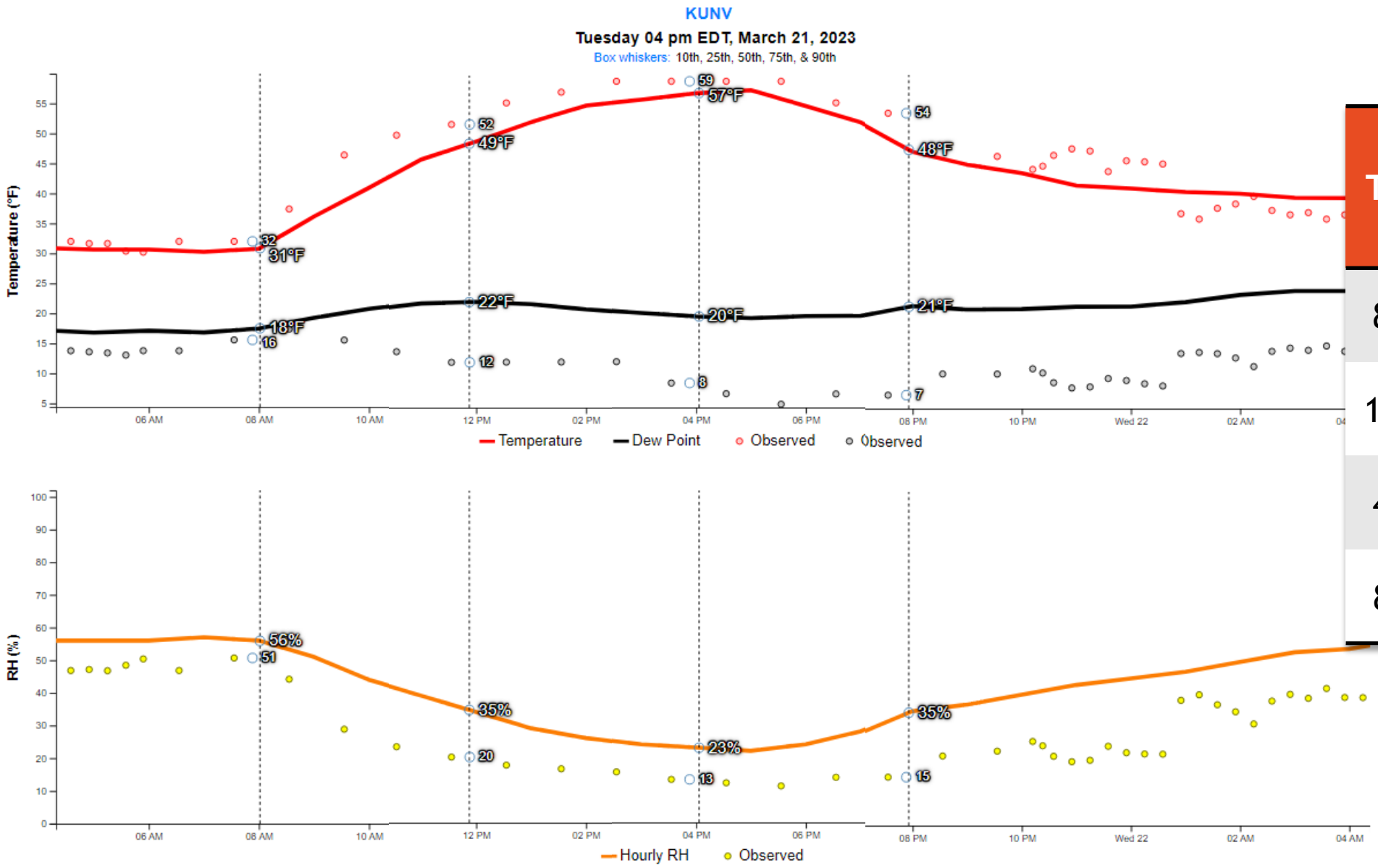
HREF Performance: March 15, 2023





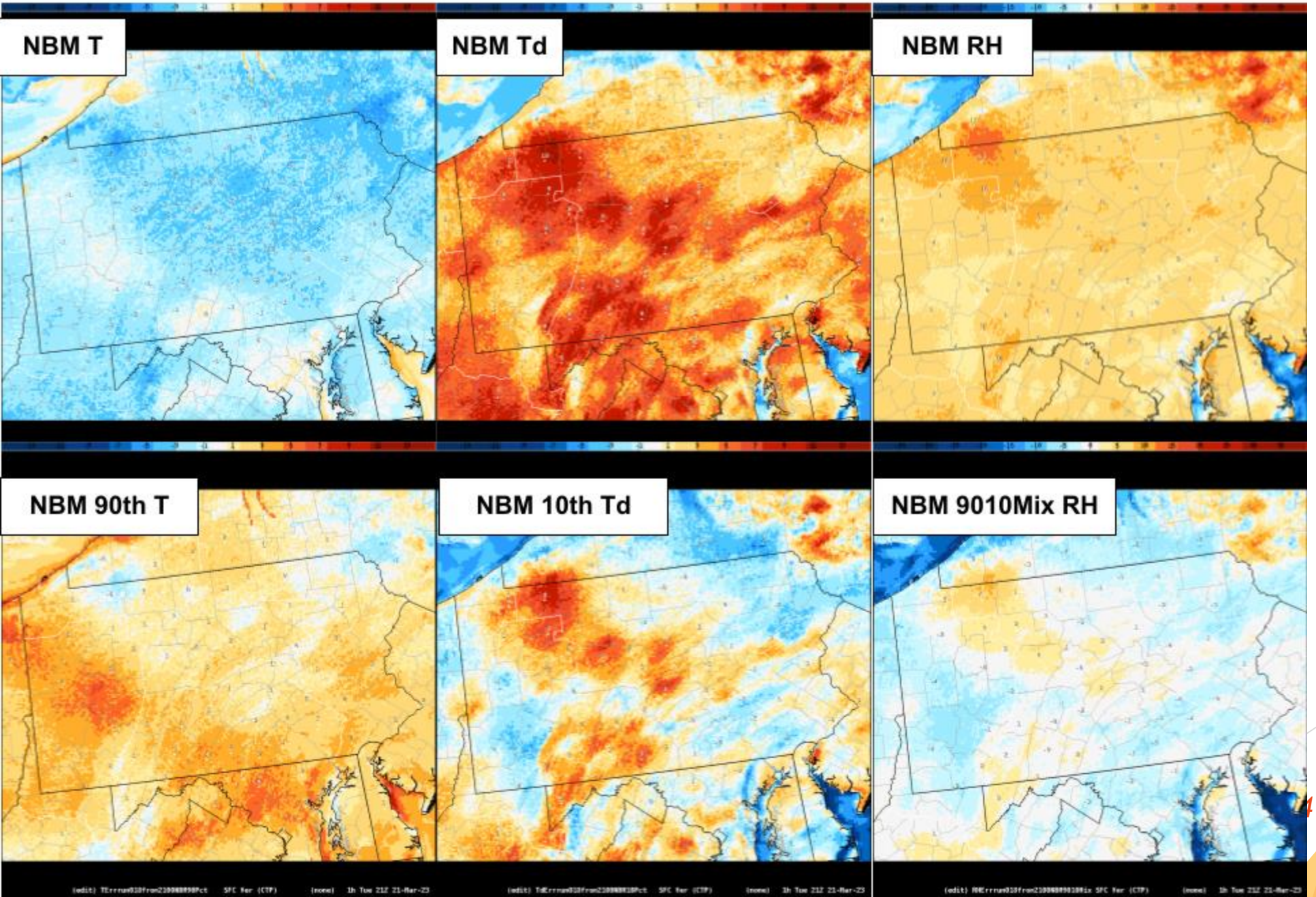
Min RH values **below 20%** possible in SE PA

NBM Performance: March 21, 2023 - KUNV



TIME	T Error (°F)	Td Error (°F)	RH Error (%)
8AM	-1	+2	+5
12PM	-3	+10	+15
4PM	-2	+12	+10
8PM	-6	+14	+20

NBM & NBM Percentile Performance: March 21, 2023



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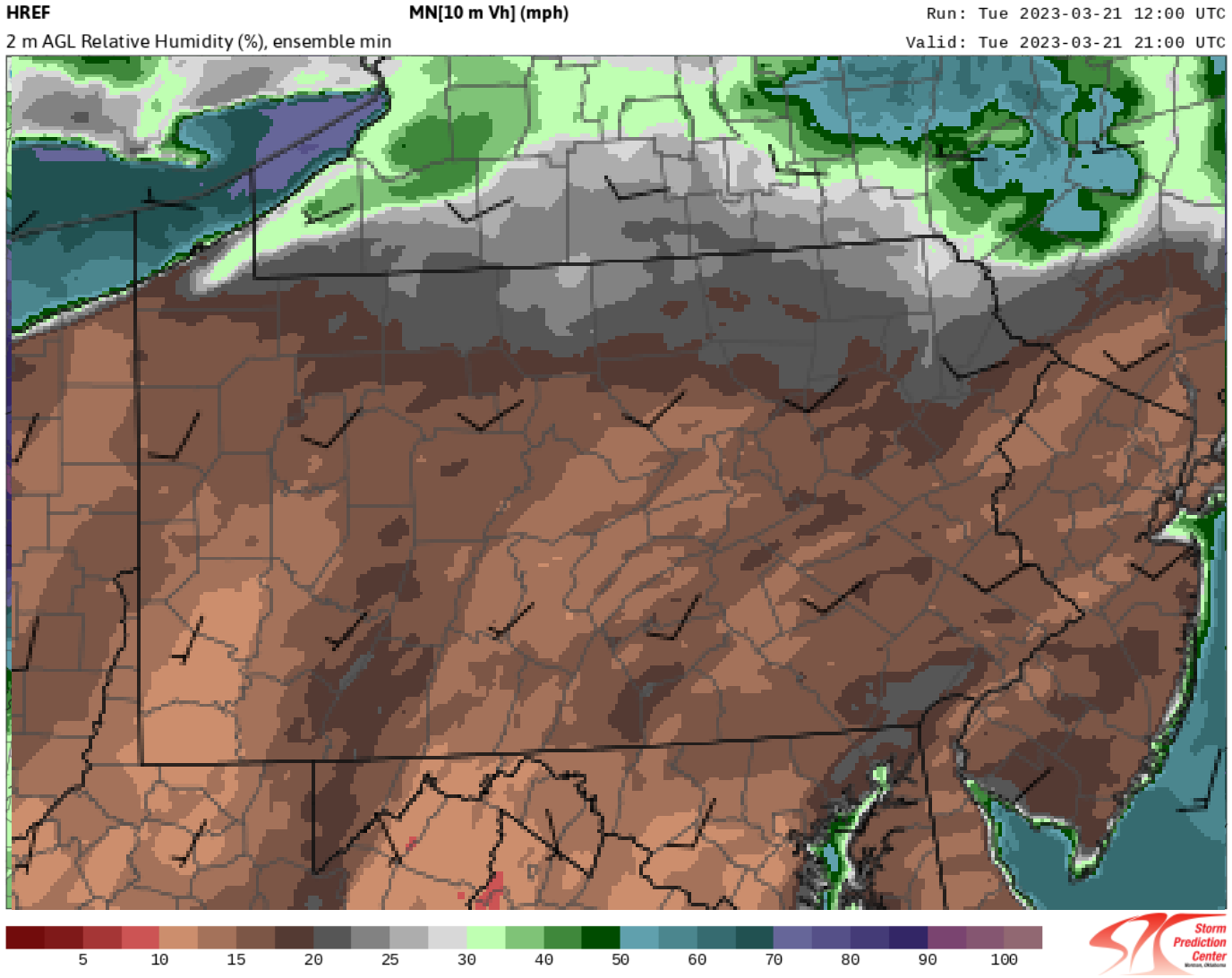
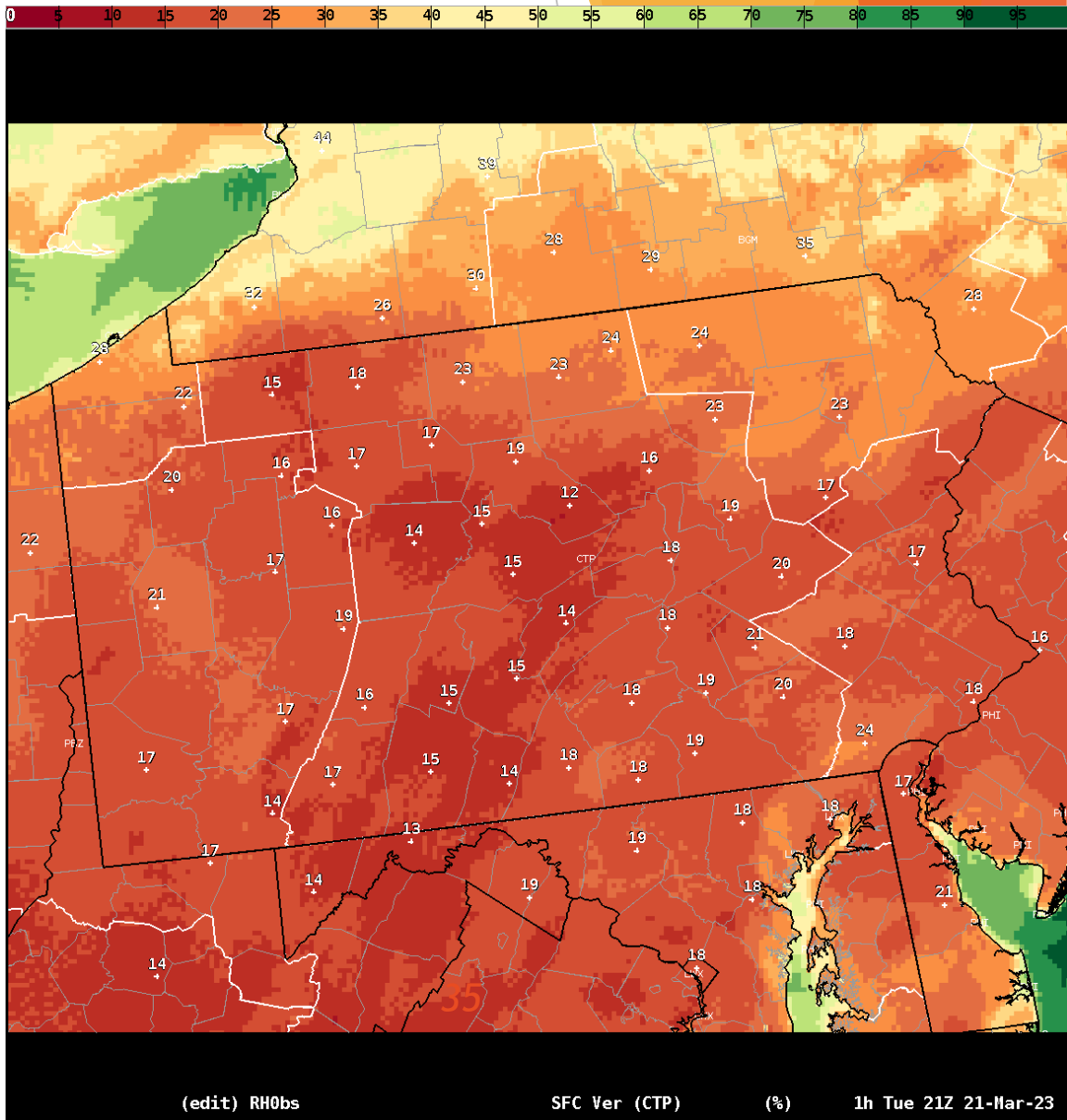




Min RH values of 10% to 20% possible across PA

Model Performance Wrap-Up

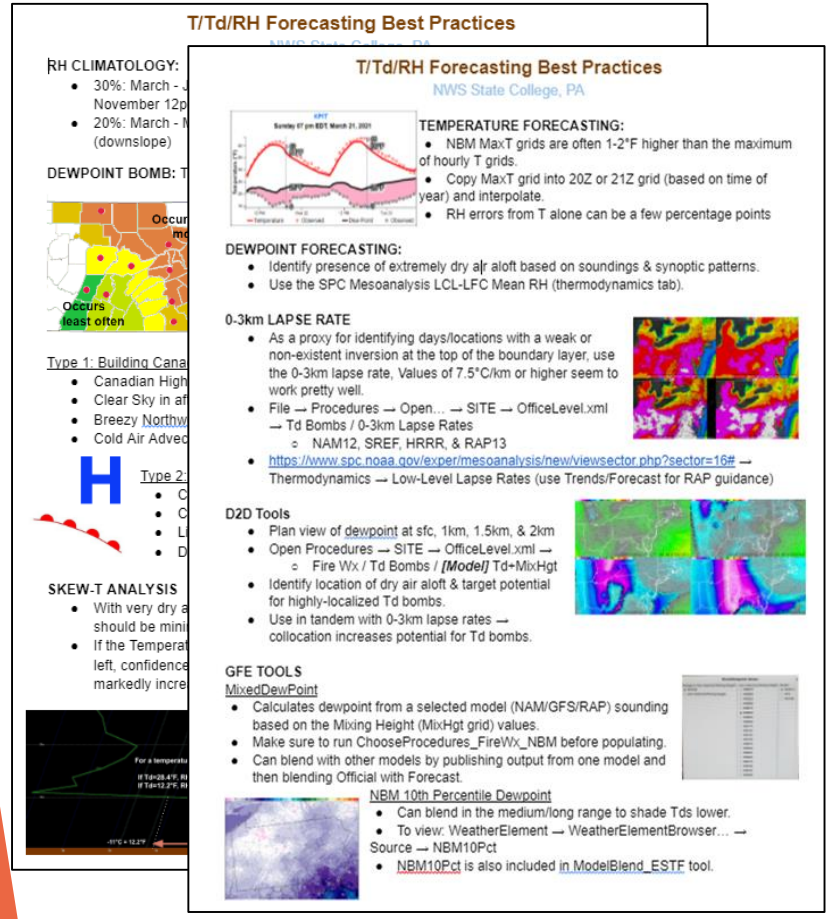
- Some models have a clue, but the “Blend” falls short.
- We have shown that these dew point bombs are a sure-fire Target of Opportunity and forecasters can significantly improve model forecasts.

FUTURE MODEL VERIFICATION ACTIVITES:

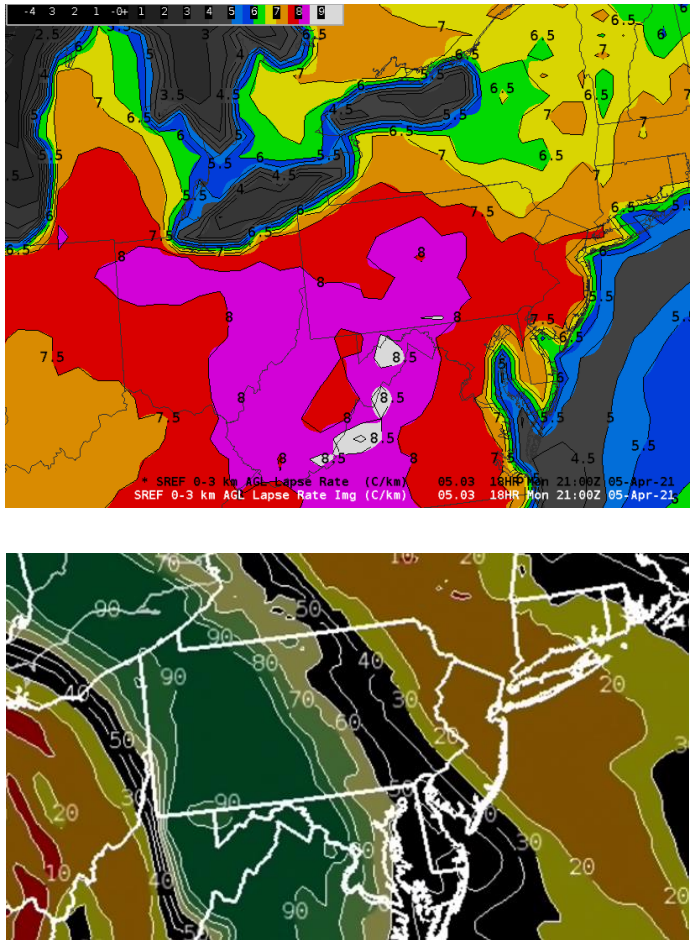
- Daily tabulation of T/Td/RH forecasts and observations since April 2021 yet to be analyzed.
- Bulk analysis of sounding data planned for this summer with a Hollings Scholar from Penn State.

Other Operational Efforts

Dew Point Bomb Guide for Forecasters



NWS AWIPS Procedures



Spot Forecast Monitor

*** TEST TEST TEST * Fire Weather Monitor (for Td & RH)**
March 10, 2021 * TEST TEST TEST *

METAR		15z 10am	16z 11am	17z 12pm	18z 1pm	19z 2pm	20z 3pm	21z 4pm	22z 5pm	23z 6pm	00z 7pm
		Observed Difference from 5am Official NWS Forecast									
BFD 5 am	Td	5°F	6°F	6°F	7°F	5°F	3°F	4°F	6°F	6°F	8°F
	RH	14%	14%	13%	5%	9%	7%	8%	11%	12%	13%
FIG 5 am	Td	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	RH	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
JST 5 am	Td	7°F	7°F	5°F	8°F	10°F	12°F	12°F	11°F	11°F	11°F
	RH	2%	19%	12%	14%	15%	16%	17%	18%	20%	21%
AOO 5 am	Td	1°F	0°F	1°F	3°F	6°F	6°F	4°F	4°F	5°F	5°F
	RH	6%	14%	9%	9%	9%	10%	8%	10%	12%	14%
UNV 5 am	Td	0°F	3°F	3°F	1°F	3°F	3°F	4°F	5°F	5°F	7°F
	RH	0%	9%	7%	5%	8%	9%	9%	12%	13%	16%
IPT 5 am	Td	0°F	4°F	3°F	3°F	3°F	2°F	2°F	4°F	5°F	6°F
	RH	2%	12%	9%	8%	8%	9%	8%	12%	16%	16%
SEG 5 am	Td	1°F	3°F	3°F	2°F	1°F	1°F	1°F	2°F	3°F	4°F
	RH	2%	13%	10%	7%	6%	7%	5%	9%	9%	15%
MDT 5 am	Td	3°F	3°F	3°F	2°F	2°F	2°F	3°F	5°F	4°F	5°F
	RH	8%	9%	8%	3%	6%	7%	8%	12%	11%	13%
LNS 5 am	Td	4°F	5°F	3°F	3°F	2°F	2°F	0°F	1°F	0°F	1°F
	RH	13%	11%	8%	6%	6%	8%	4%	8%	3%	1%

In Summary

- Model (and human) forecasts of **minimum relative humidity** are often **far too high** on well-mixed dry days.
- Dew point bombs pose a **significant operational impact** because they often result in RH values unexpectedly dipping below Red Flag Warning criteria.
- There are **identifiable environmental parameters** that give us hints when they'll occur.
- Now we need to work on **accurately forecasting dew point bomb magnitude AND improving models!**

THANK YOU!

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Dew Point Bomb Guide

Presentation Slides and Additional Content

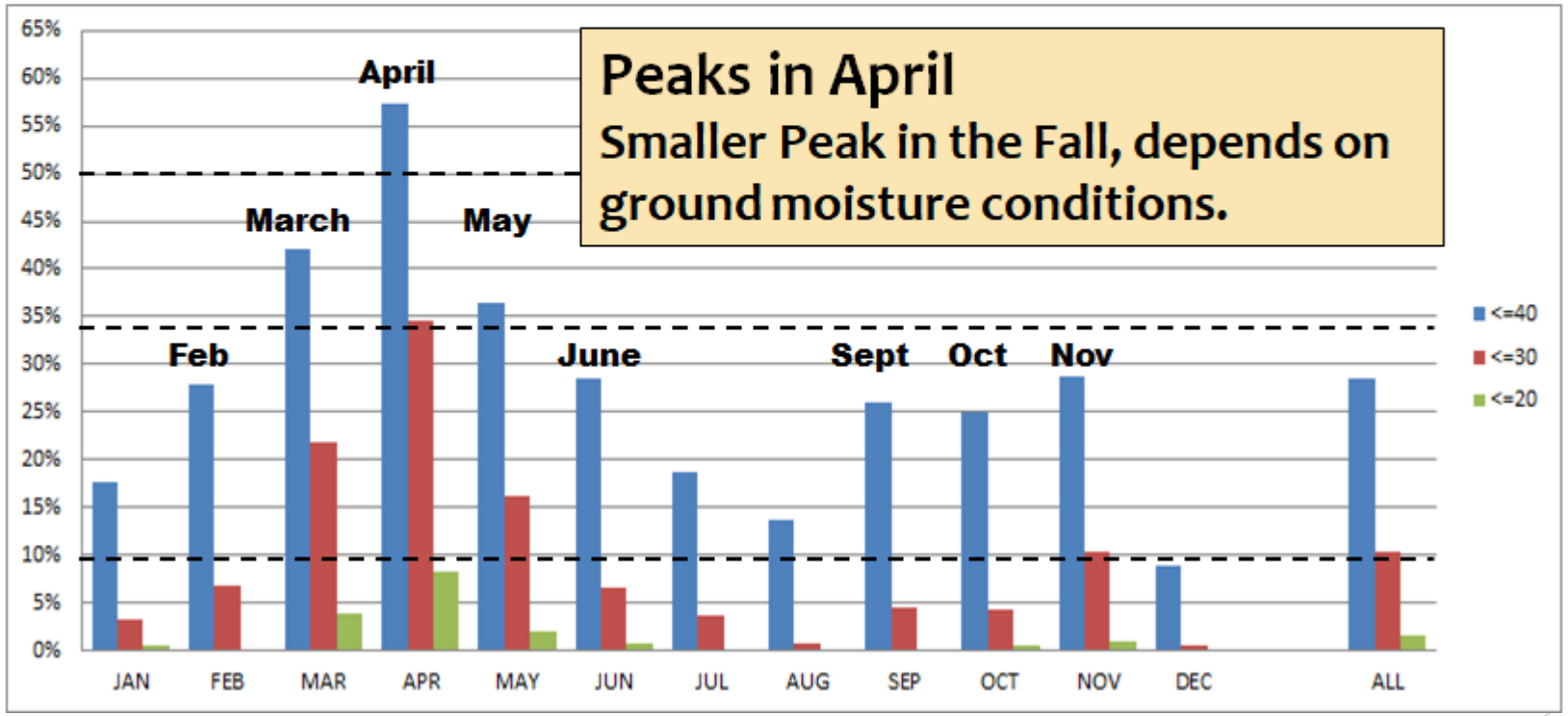
Additional Content

Questions can be directed to
John.Banghoff@noaa.gov

Minimum RH Climatology

ALL SITES

Frequency of <=40%/30%/20% Minimum RH



“Dew Point Bombs”

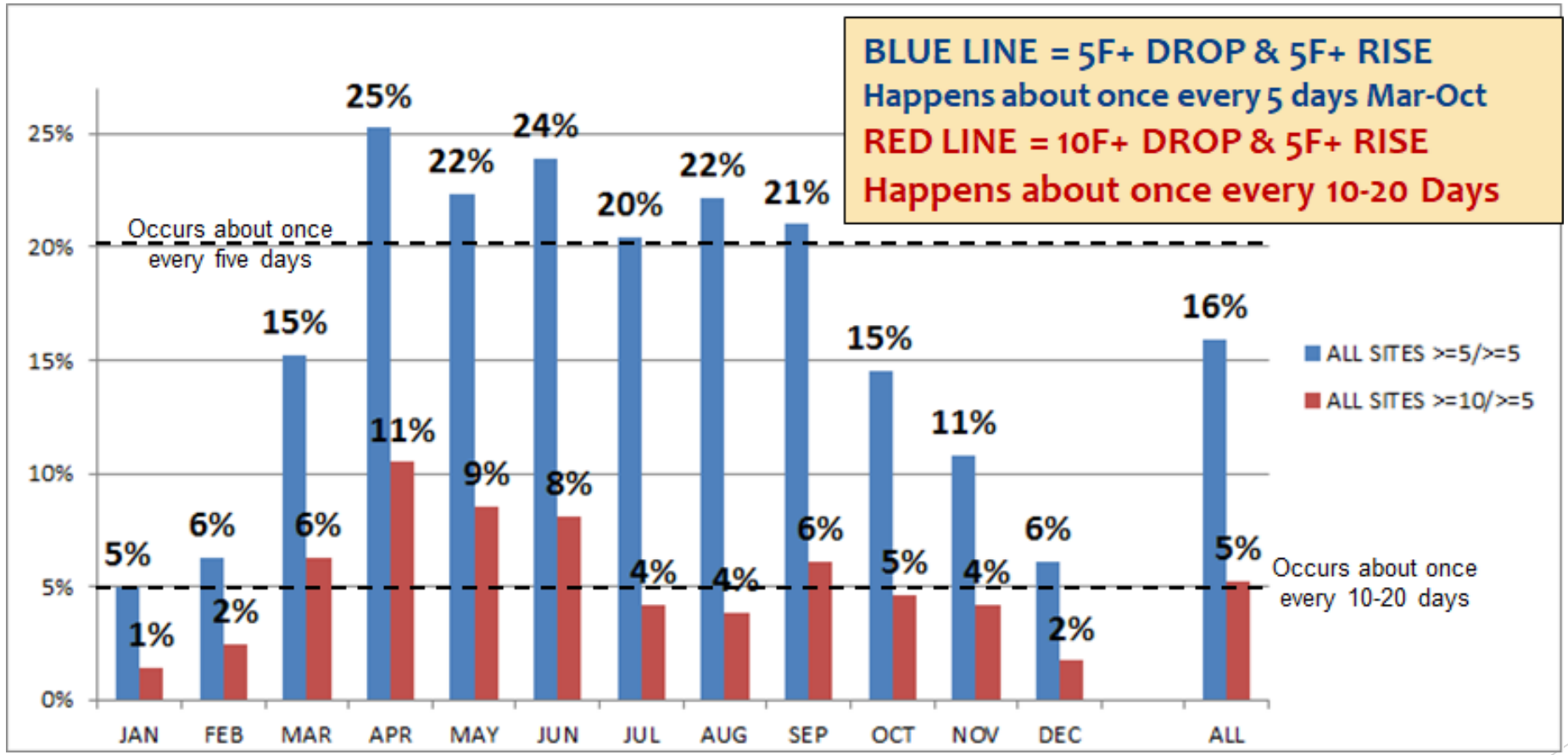
- Significant dew point drop during the day followed by a rise by mid evening.

  T_d: Drop of ≥ 10°F / Then a rise of ≥ 5°F *

- Not necessarily associated with specific RH thresholds, but almost always push RHs down into critical Fire Weather categories.

- Often equate to RHs falling 10-20% lower than expectations

Dew Point Bomb Climatology

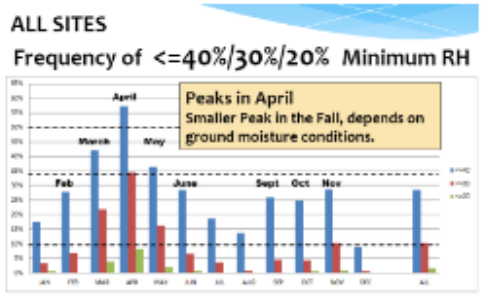


T/Td/RH Forecasting Best Practices

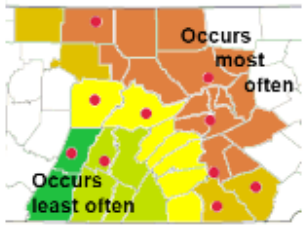
NWS State College, PA

RH CLIMATOLOGY:

- 30%: March - June Noon-9p, October - November 12p-10p
- 20%: March - May 1p-8p, Mid Summer in SE (downslope)



DEWPOINT BOMB: Td drop of >= 10°F followed by a rise of >= 5°F



DEWPOINT BOMB CLIMATOLOGY

- "Dewpoint Bombs" occur most frequently at Williamsport (THE MOST), Bradford, Harrisburg, and Selinsgrove
  - Least frequent at Johnstown & Altoona.

SYNOPTIC PATTERNS

Type 1: Building Canadian High/Breezy Winds

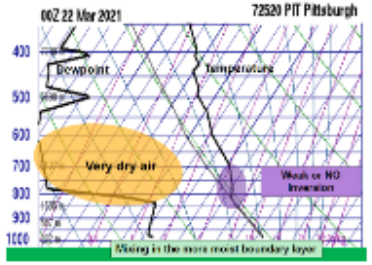
- Canadian High building into area (generally 1-2 Days behind a Cold Front)
- Clear Sky in afternoon
- Breezy Northwester or North Flow (10-15 mph, G 20-25 mph)
- Cold Air Advection in lowest 5000ft

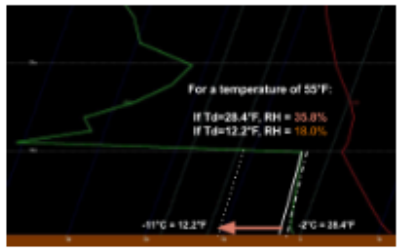
Type 2: Retreating High Pressure and/or Approaching Warm Front/Light Winds

- Canadian High retreating as a Warm Front approaches from the SW
- Clear Sky or thin Mid/High Clouds
- Light Winds generally less than 6 mph
- Deep Mixing Layer

SKEW-T ANALYSIS

- With very dry air within the lowest 2km, the inversion should be minimal or non-existent.
- If the Temperature line goes vertical or slopes back to the left, confidence in mixing down drier air to the surface markedly increases.





- Models tend to have too much moisture flux from the surface, resulting in Skew-Ts overestimating Tds in mixing situations.
- Realistic upper bound for surface Td will be mean boundary layer mixing ratio (dash dot line)
- Expected surface Td min with isothermal or inversion at top of BL will be mixing ratio at inversion height. (solid line).
- Minimum bound of Td minimum will be mixing ratio ¼ to ⅓ of the way up the nearly-horizontal Td line (dotted line).

T/Td/RH Forecasting Best Practices

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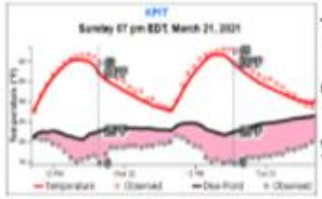


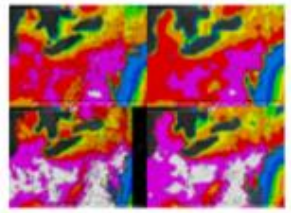
TEMPERATURE FORECASTING:

- NBM MaxT grids are often 1-2°F higher than the maximum of hourly T grids.
- Copy MaxT grid into 20Z or 21Z grid (based on time of year) and interpolate.
- RH errors from T alone can be a few percentage points

DEWPOINT FORECASTING:

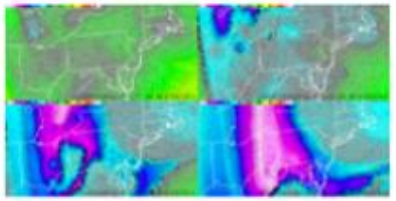
- Identify presence of extremely dry air aloft based on soundings & synoptic patterns.
- Use the SPC Mesoanalysis LCL-LFC Mean RH (thermodynamics tab).

0-3km LAPSE RATE



- As a proxy for identifying days/locations with a weak or non-existent inversion at the top of the boundary layer, use the 0-3km lapse rate, Values of 7.5°C/km or higher seem to work pretty well.
- File → Procedures → Open… → SITE → OfficeLevel.xml → Td Bombs / 0-3km Lapse Rates
  - NAM12, SREF, HRRR, & RAP13
- https://www.spc.noaa.gov/exper/mesoanalysis/new/viewsector.php?sector=16# → Thermodynamics → Low-Level Lapse Rates (use Trends/Forecast for RAP guidance)

D2D Tools

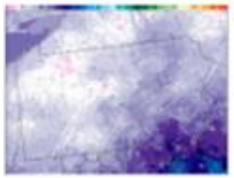


- Plan view of dewpoint at sfc, 1km, 1.5km, & 2km
- Open Procedures → SITE → OfficeLevel.xml →
  - Fire Wx / Td Bombs / ***[Model]*** Td+MixHgt
- Identify location of dry air aloft & target potential for highly-localized Td bombs.
- Use in tandem with 0-3km lapse rates → collocation increases potential for Td bombs.

GFE TOOLS

MixedDewPoint

- Calculates dewpoint from a selected model (NAM/GFS/RAP) sounding based on the Mixing Height (MixHgt grid) values.
- Make sure to run ChooseProcedures_FireWx_NBM before populating.
- Can blend with other models by publishing output from one model and then blending Official with Forecast.



NBM 10th Percentile Dewpoint

- Can blend in the medium/long range to shade Tds lower.
- To view: WeatherElement → WeatherElementBrowser… → Source → NBM10Pct
- NBM10Pct is also included in ModelBlend_ESTF tool.

Messaging Fire Weather Days

- Worked with PA Fire Agencies to identify best practices:
  - *Use "wildfire" in place of "brush fire"*
  - *Don't use "Fire Danger"*
  - *Be sure to include "spread" after the phrase "increased risk of wildfire"*
- Designed social media templates to message days with an elevated risk of wildfire spread → 99% of wildfires in PA are caused by humans!