A Presentation On All Things Heat

Dr. Nick Bassill

January 18th, 2023

A Brief Introduction

- I work at the UAlbany Center of Excellence, which is a state funded organization tasked with assisting with NY's weather problems
- I have a PhD in meteorology from the University of Wisconsin
- I arrived at UAlbany as a Post-Doc with the NYS Mesonet in 2014

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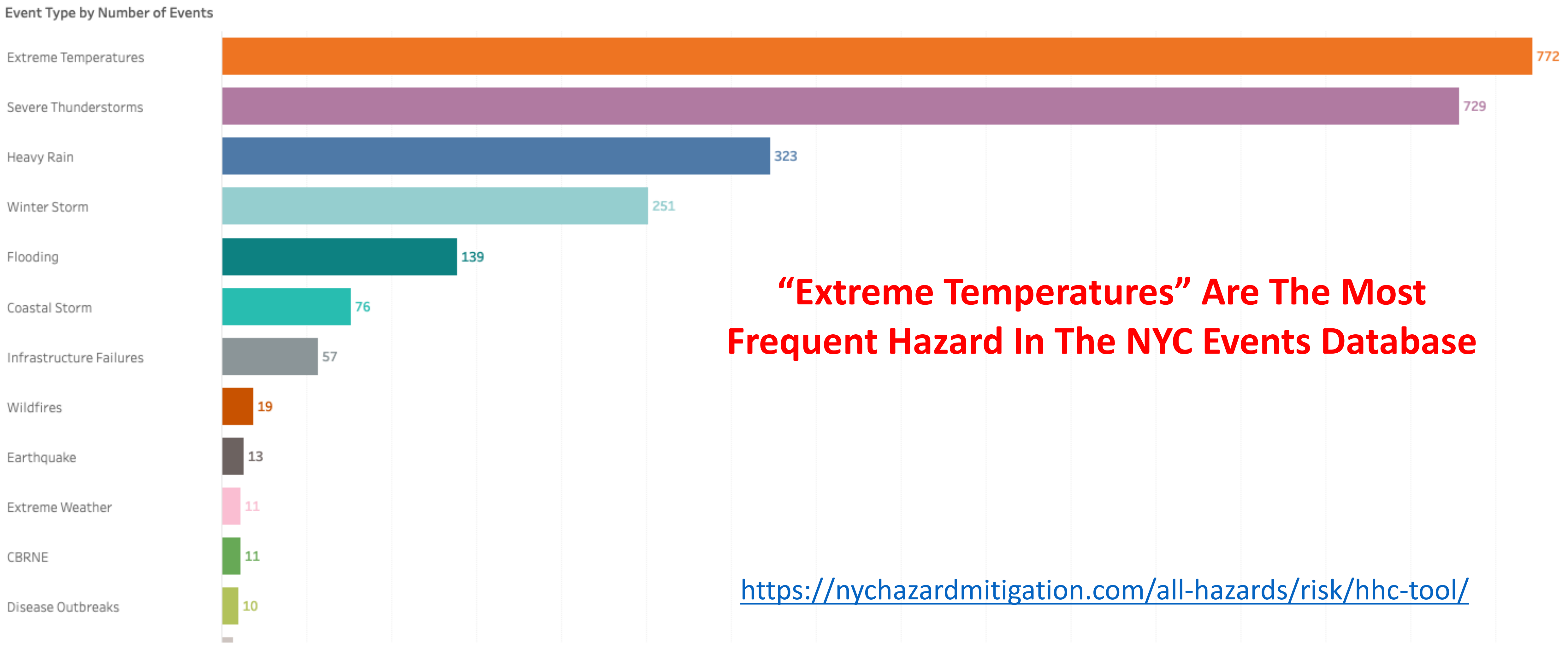
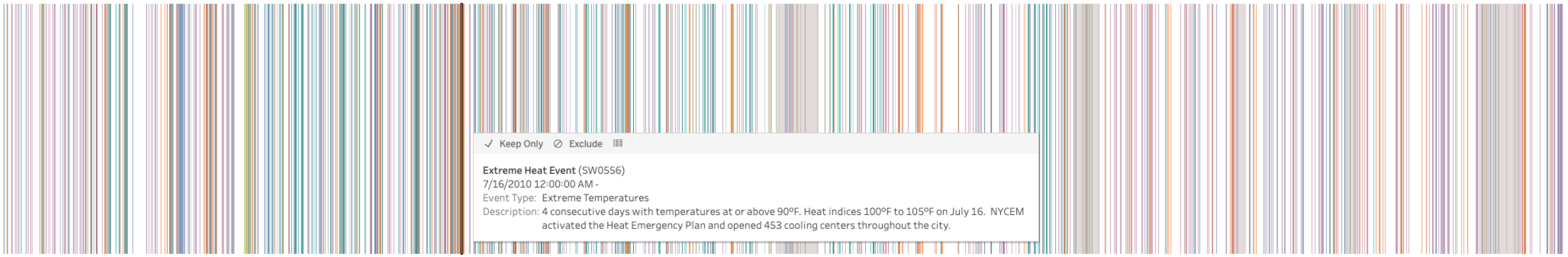
State University of New York

Weather and
Climate Analytics
Center of
Excellence (COE)



"Extreme Temperatures" Are The Most Frequent Hazard In The NYC Events Database

https://nychazardmitigation.com/all-hazards/risk/hhc-tool/



2,434 Events

What is heat?

How would you explain it?

What factors change what might be considered hot?

Variable	Temperature	Moisture	Sunshine	Wind	Time	Observed
Temperature	✓					✓
Dewpoint or Relative Humidity		✓				✓
Heat Index (or “Feels Like” or “Apparent”)	✓	✓				
Wet Bulb Temperature	✓	✓				
Weighted Temperature Humidity Index	✓	✓			✓	
Wet Bulb Globe Temperature	✓	✓	✓	✓		

NYS Mesonet
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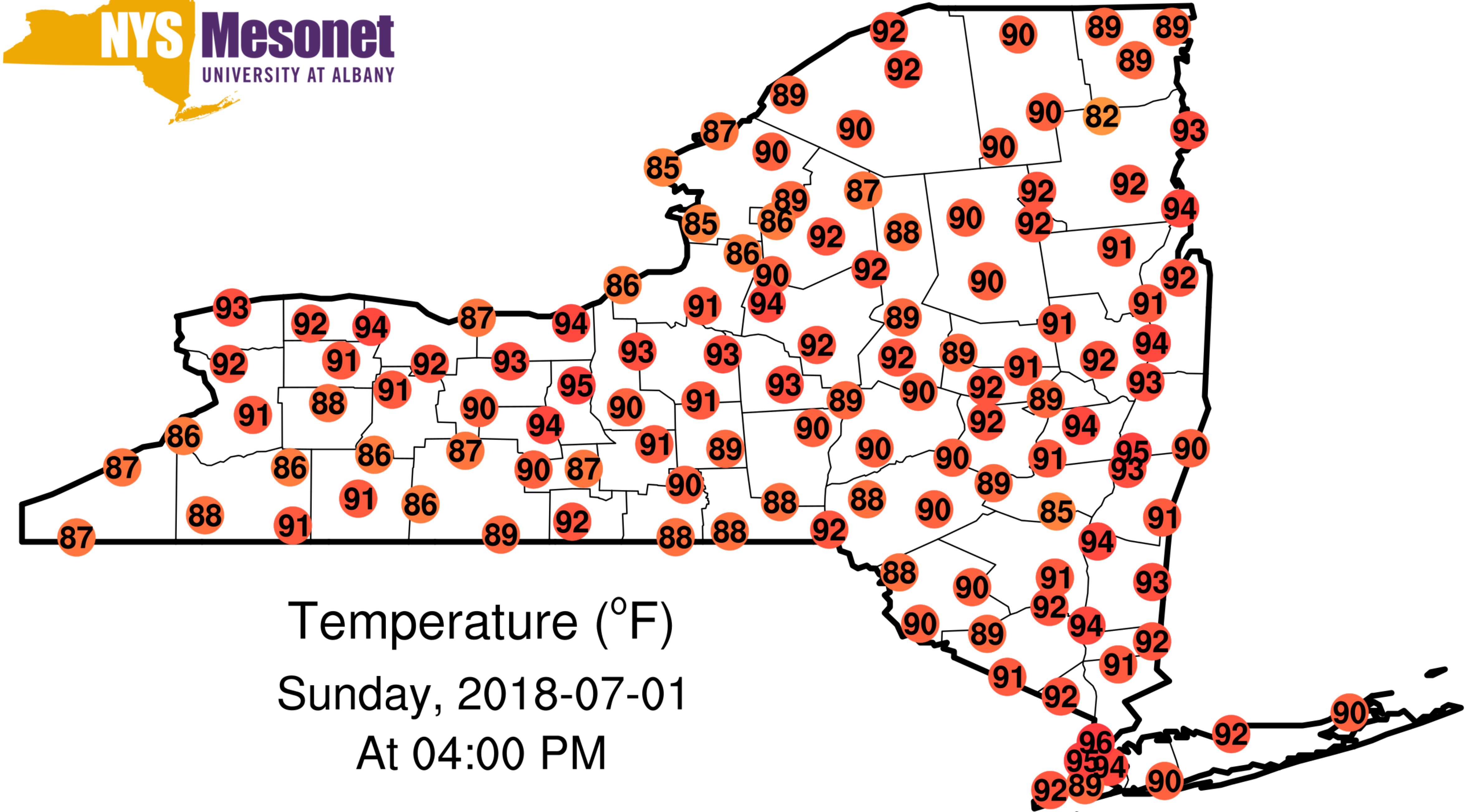

Temperature (°F)
Sunday, 2018-07-01
At 04:00 PM

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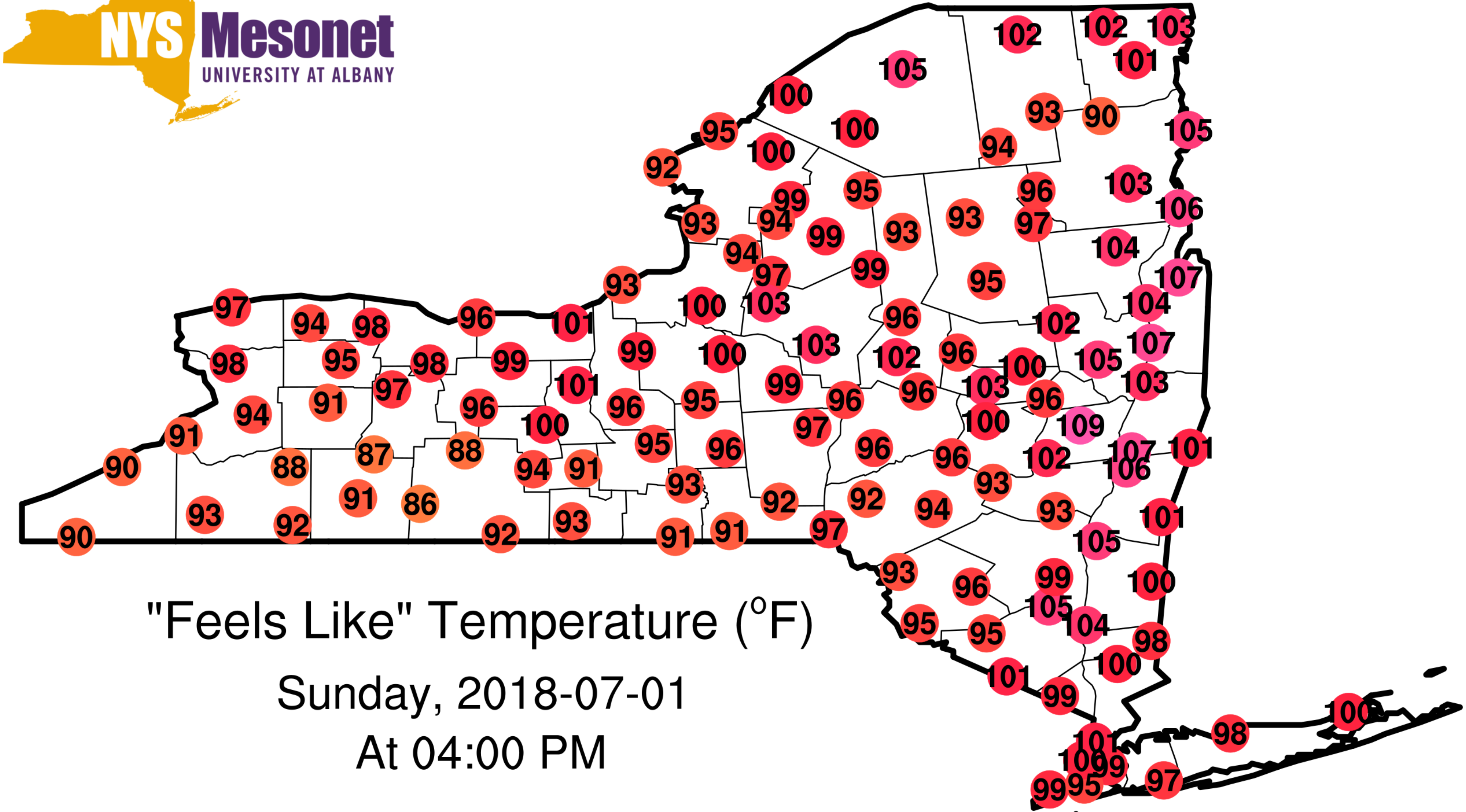

"Feels Like" Temperature (^{o}F)

Sunday, 2018-07-01

At 04:00 PM

NWS Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution   Extreme Caution   Danger   Extreme Danger

New York State Mesonet!

NYS Mesonet
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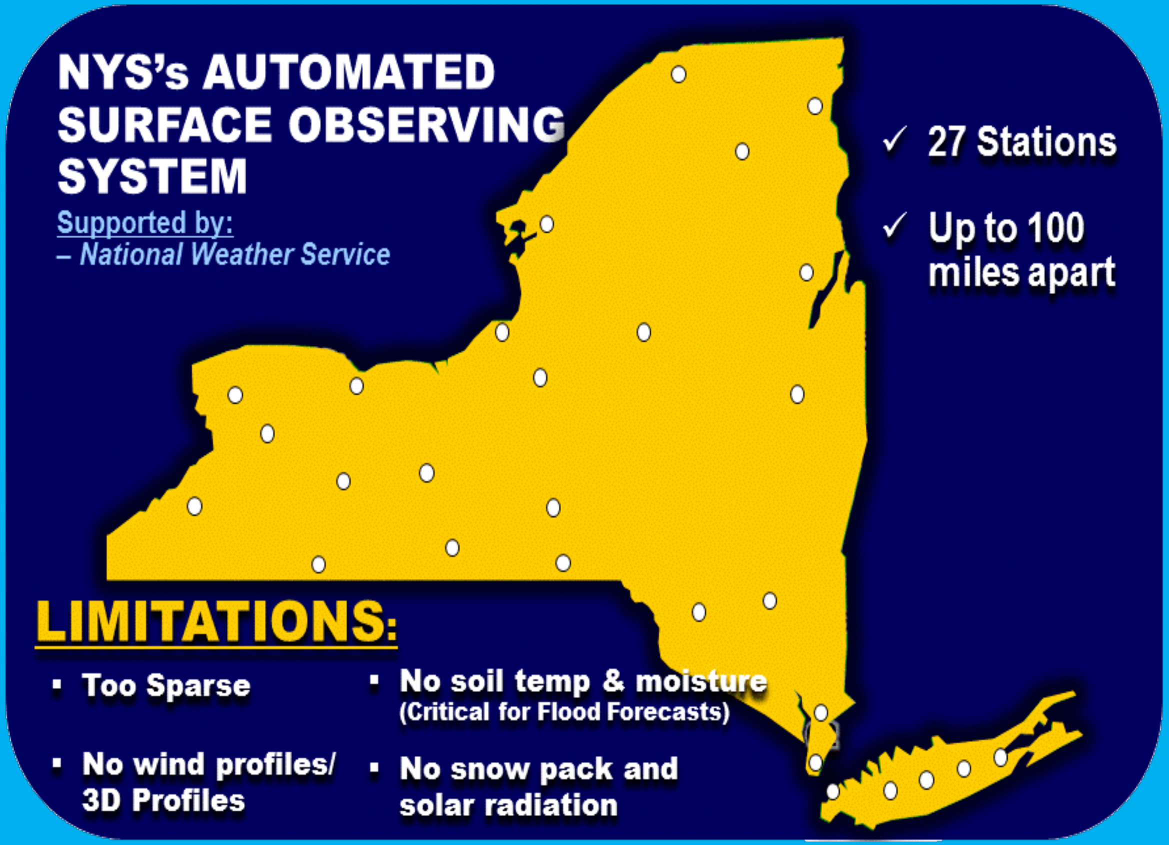
29 April 2021

New York State Mesonet Overview

- $30M network conceived after Hurricane Irene (2011) and funded after Hurricane Sandy (2012)
- All sites installed between August 2015 and April 2018
- Network includes various sub-networks
  - **126 Standard sites**
  - **20 Snow sites**
  - **17 Profiler sites**
  - **18 Flux sites**
  - ***12 Thruway sites***
  - ***17 ConEd micronet sites***
  - ***DOT Skyway sensor***
  - ***12 NYSERDA Irradiance sites***
- Data is collected every 5 minutes
- This network fills in various gaps in existing ASOS network



NYS Mesonet
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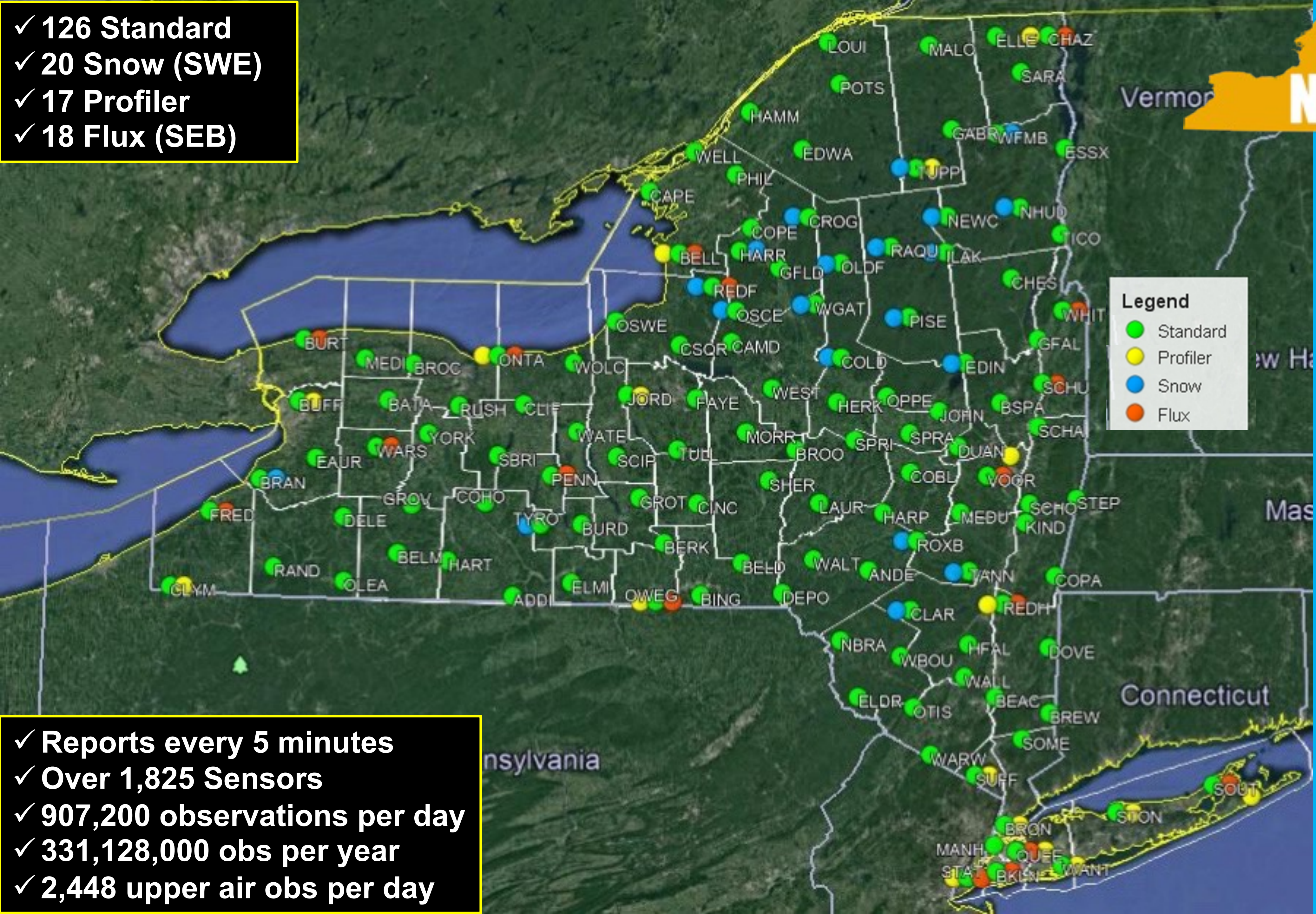
Map

- ✓ 126 Standard
- ✓ 20 Snow (SWE)
- ✓ 17 Profiler
- ✓ 18 Flux (SEB)



- ✓ Reports every 5 minutes
- ✓ Over 1,825 Sensors
- ✓ 907,200 observations per day
- ✓ 331,128,000 obs per year
- ✓ 2,448 upper air obs per day

Station Near Philadelphia, NY

NYS Mesonet
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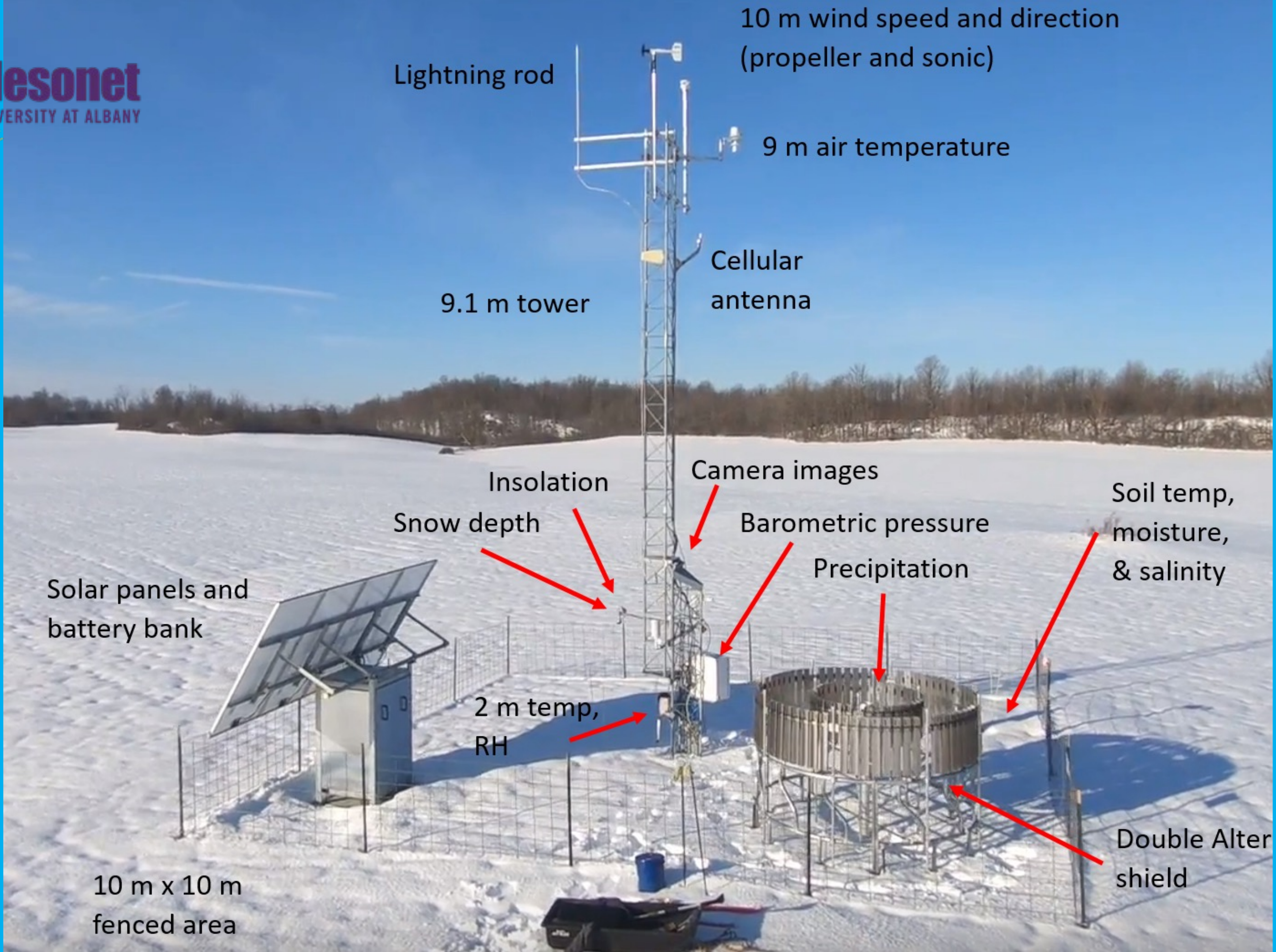


Operations

Over 1,000,000 observations collected and archived daily
126 stations covering New York's 54,556 square miles
Over 1,000,000 lines of code for data ingest and processing

- Field Operations
  - Over 4,000 sensors and support equipment
  - Drive 2,000 miles per week repairing sensors, maintaining site vegetation
  - Maintain site power and communications

- UAlbany Operations
  - Data, networking, and quality control
  - Design and maintain datalogger code, ingest, quality control, firmware, security, and products
  - Employ 4-6 students per semester to staff Ops Center

Who would say it's hotter, on a 1-10 scale?

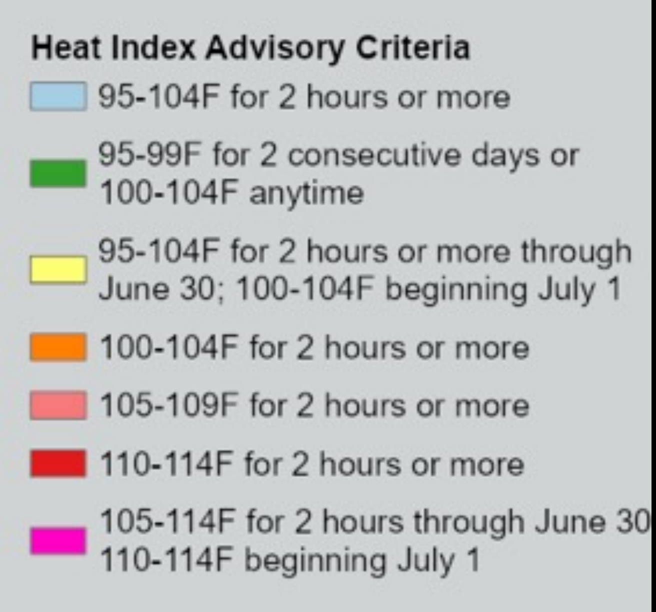
1) A Death Valley resident on a 105F day after a week of 125F days?

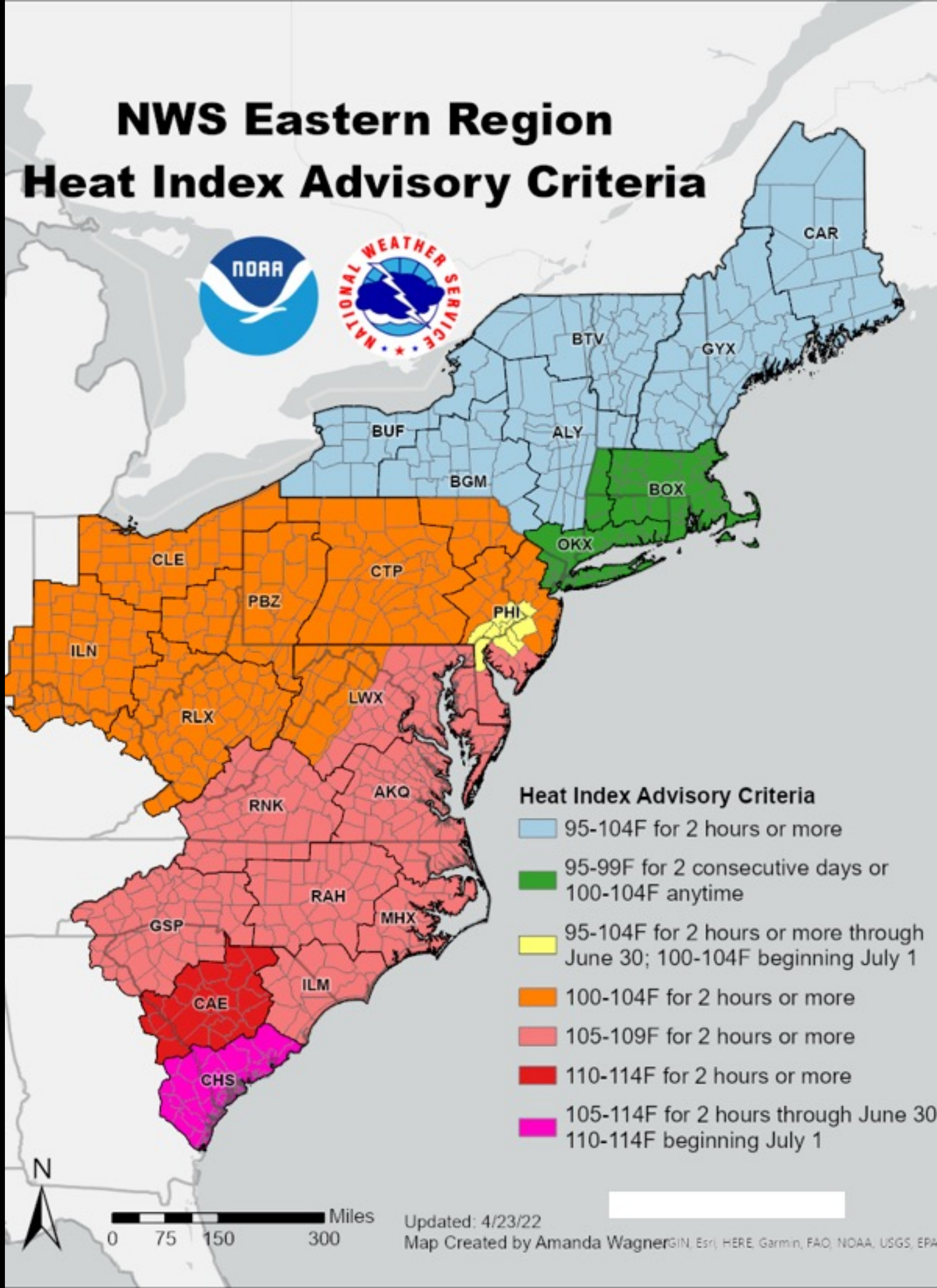
Or

2) A transplanted Inuit experiencing a 95F day for the first time?

The National Weather Service Issues Two Primary Heat Products

(1) A heat advisory: you may be surprised to learn there is no single definition!

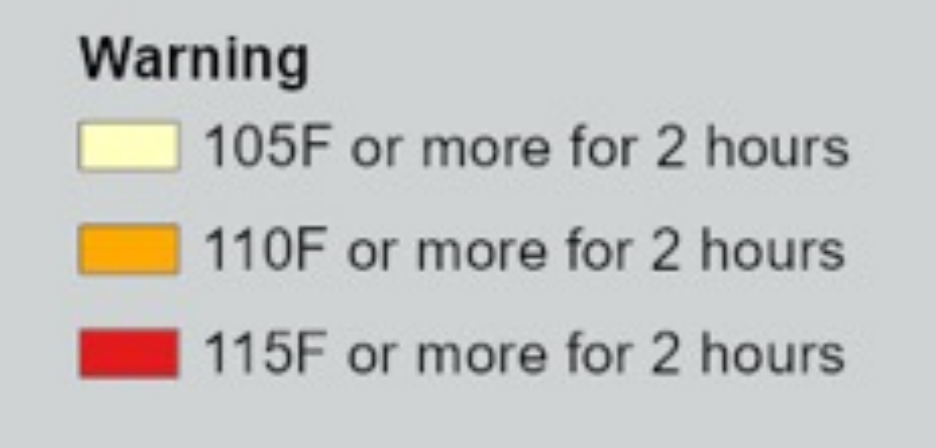




via https://www.weather.gov/aly/preparedness →

The National Weather Service Issues Two Primary Heat Products

(2) A heat watch/warning: there's likewise not a single definition



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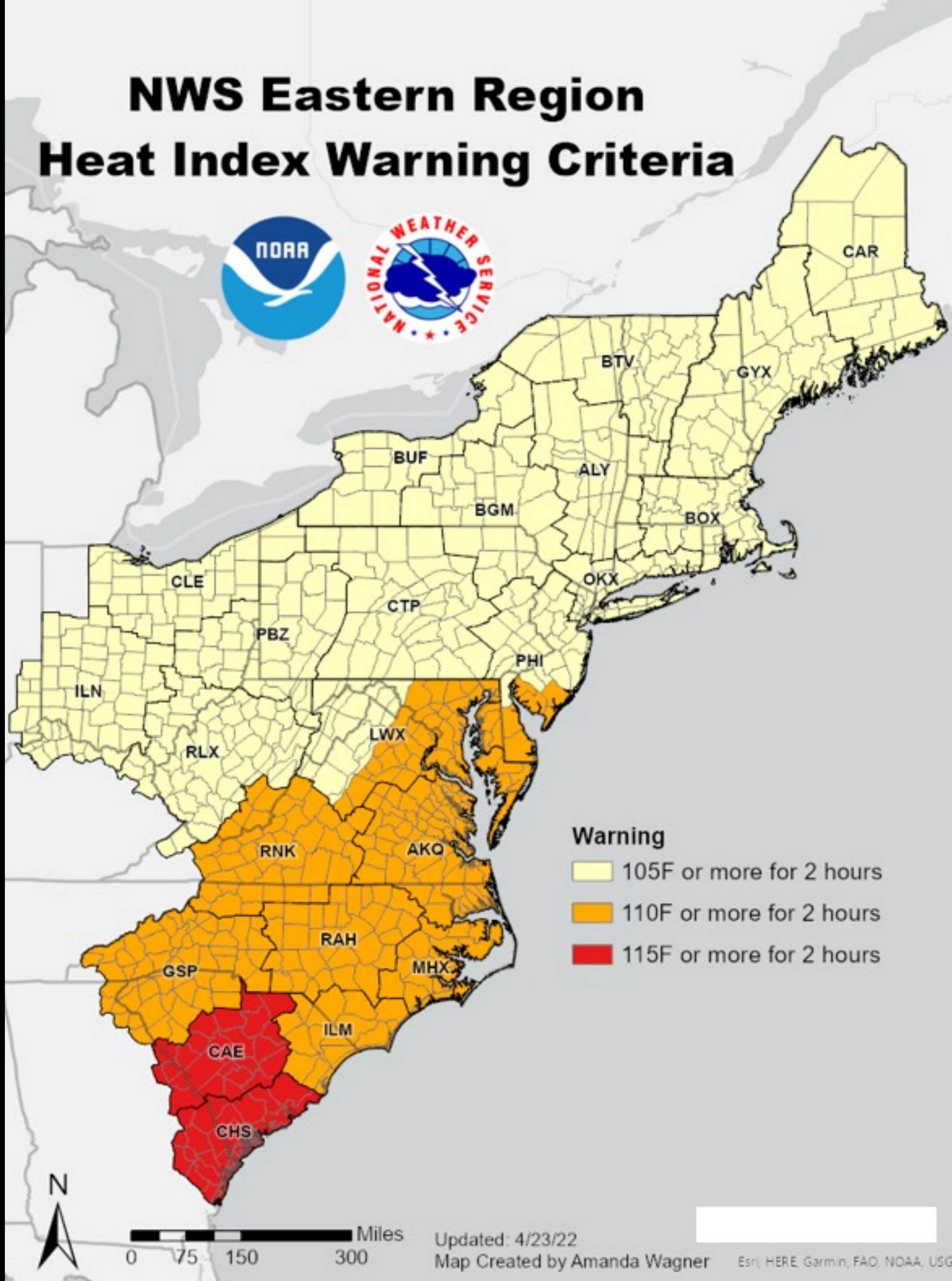

Variable	Temperature	Moisture	Sunshine	Wind	Time	Observed
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Wet Bulb Temperature	✓	✓				
Weighted Temperature Humidity Index	✓	✓			✓	
Wet Bulb Globe Temperature	✓	✓	✓	✓		

How do we calculate Heat Index?

It’s “just” a few simple equations with several “if” checks

Heat Index is only valid at temperatures above ~80F

The Heat Index Equation

The computation of the heat index is a refinement of a result obtained by multiple regression analysis carried out by Lans P. Rothfusz and described in a 1990 National Weather Service (NWS) Technical Attachment (SR 90-23). The regression equation of Rothfusz is

$$HI = -42.379 + 2.04901523*T + 10.14333127*RH - .22475541*T*RH - .00683783*T*T - .05481717*RH*RH + .00122874*T*T*RH + .00085282*T*RH*RH - .00000199*T*T*RH*RH$$

where **T** is temperature in degrees F and **RH** is relative humidity in percent. **HI** is the heat index expressed as an apparent temperature in degrees F. If the **RH** is less than 13% and the temperature is between 80 and 112 degrees F, then the following adjustment is subtracted from **HI**:

$$ADJUSTMENT = [(13-RH)/4]*SQRT\{[17-ABS(T-95.)]/17\}$$

where **ABS** and **SQRT** are the absolute value and square root functions, respectively. On the other hand, if the **RH** is greater than 85% and the temperature is between 80 and 87 degrees F, then the following adjustment is added to **HI**:

$$ADJUSTMENT = [(RH-85)/10] * [(87-T)/5]$$

The Rothfusz regression is not appropriate when conditions of temperature and humidity warrant a heat index value below about 80 degrees F. In those cases, a simpler formula is applied to calculate values consistent with Steadman's results:

$$HI = 0.5 * \{T + 61.0 + [(T-68.0)*1.2] + (RH*0.094)\}$$

In practice, the simple formula is computed first and the result averaged with the temperature. If this heat index value is 80 degrees F or higher, the full regression equation along with any adjustment as described above is applied.

The Rothfusz regression is not valid for extreme temperature and relative humidity conditions beyond the range of data considered by Steadman.

https://www.wpc.ncep.noaa.gov/html/heatindex_equation.shtml

Wet Bulb Globe Temperature

"The Wet Bulb Globe Temperature (WBGT) is a measure of heat stress in direct sunlight, which is based on temperature, humidity, wind speed, sun angle, and cloud cover (solar radiation). This differs from the heat index, also called the apparent temperature, which is based only on temperature and humidity and is calculated for shady areas. If you work or exercise in direct sunlight, the WBGT is a good element to monitor."

This is not currently something widely used by the public, and most meteorologists wouldn't be able to explain it. However, it's something NWS wants to use more.

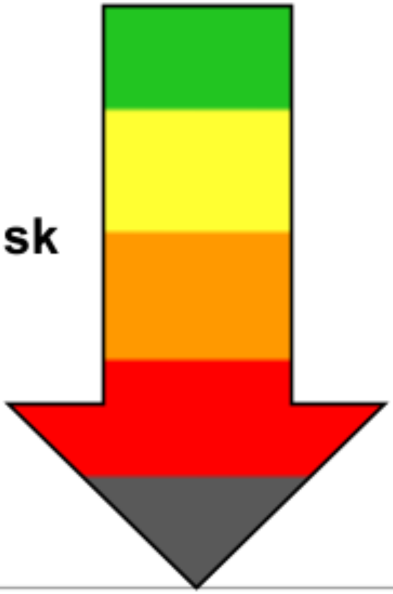
WBGT Index and Athletic Activity Chart

WBGT Index (F)	Athletic Activity Guidelines
Less than 80	Unlimited activity with primary cautions for new or unconditioned athletes or extreme exertion; schedule mandatory rest/water breaks (5 min water/rest break every 30 min)
80 - 84.9	Normal practice for athletes; closely monitor new or unconditioned athletes and all athletes during extreme exertion. Schedule mandatory rest /water breaks. (5 min water/rest break every 25 min)
85 - 87.9	New or unconditioned athletes should have reduced intensity practice and modifications in clothing. Well-conditioned athletes should have more frequent rest breaks and hydration as well as cautious monitoring for symptoms of heat illness. Schedule frequent mandatory rest/water breaks. (5 min water/rest break every 20 min) Have cold or ice immersion pool on site for practice.
88 - 89.9	All athletes must be under constant observation and supervision. Remove pads and equipment. Schedule frequent mandatory rest/water breaks. (5 min water/rest break every 15 min) Have cold or ice immersion pool on site for practice.
90 or Above	**SUSPEND PRACTICE/MUST INCLUDE MANDATORY BREAKS AS DIRECTED BY GAMEDAY ADMINISTRATOR DURING CONTEST.**

Wet Bulb Globe Temperature

Disclaimer: Always check with local officials for appropriate actions and activity levels. Experienced heat stress will depend upon duration and intensity of activity and personal health and vulnerability.

WBGT by Region (°F)			**Threat Level** WBGT at these values increasing heat stress.	**Risk of heat illness** https://www.weather.gov/rah/WBGT
Region 1	Region 2	Region 3		
< 72.3	< 75.9	< 78.3	Low Threat	
72.3 - 76.1	75.9 - 78.7	78.3 - 82.0	Elevated Threat	
76.2 - 80.1	78.8 - 83.7	82.1 - 86.0	Moderate Threat	**Increased risk for heat illness**
80.1 - 84.0	83.8 - 87.6	86.1 - 90.0	High Threat	
>84.0	>87.6	>90.0	Extreme Threat	

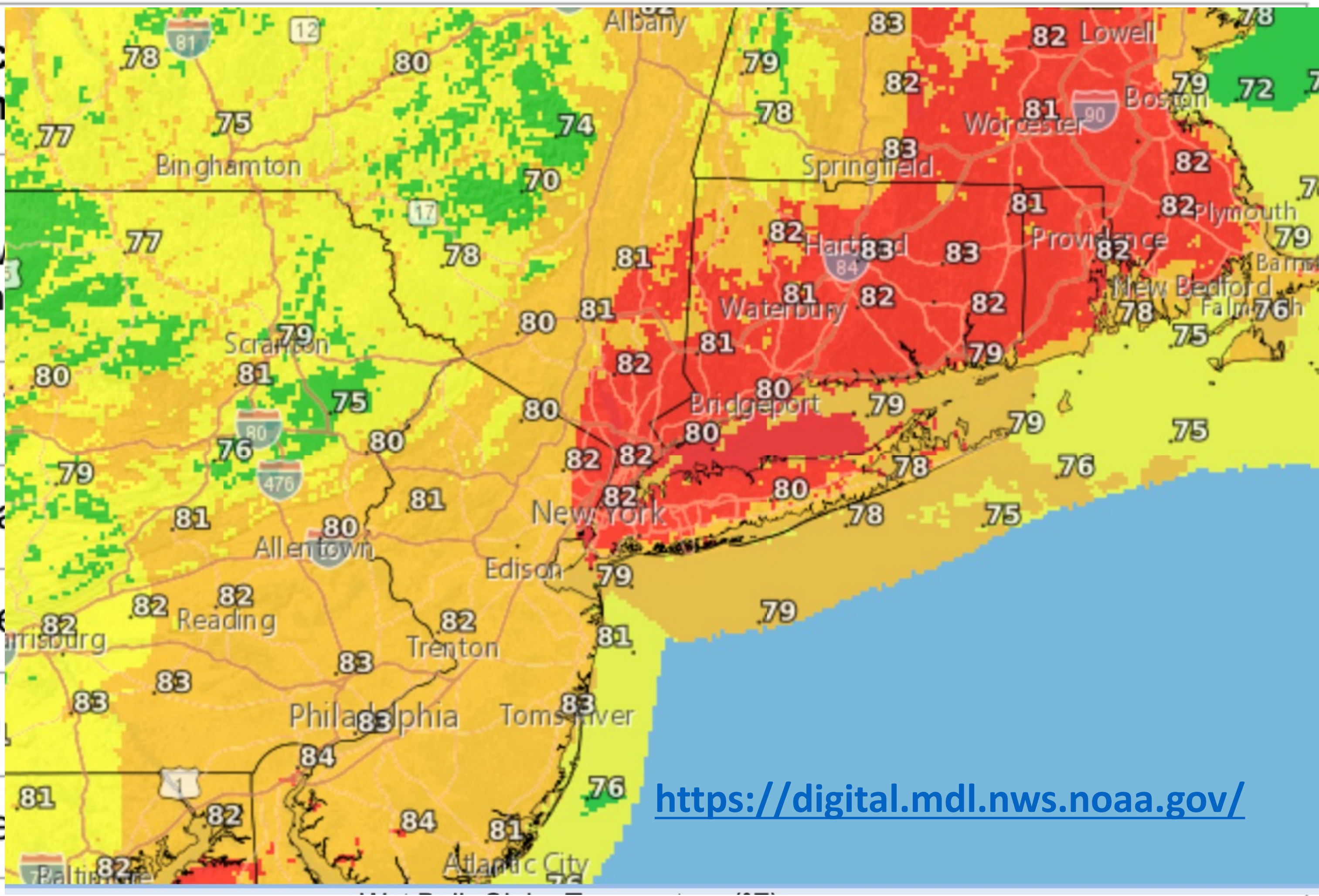


Regions are from Grundstein, A., Williams, C., Phan, M and Cooper, E., 2015. Regional heat safety thresholds for athletics in the contiguous United States. *Applied Geography*, 56, pp.55-60. 10.1016/j.apgeog.2014.10.014.

Wet Bulb Globe Temperature

Disclaimer: Always check with local offic
heat stress will depend upon duration an

WBGT by Region (°F)			
Region 1	Region 2	Region 3	W in
< 72.3	< 75.9	< 78.3	Low
72.3 - 76.1	75.9 - 78.7	78.3 - 82.0	Eleva
76.2 - 80.1	78.8 - 83.7	82.1 - 86.0	Mode
80.1 - 84.0	83.8 - 87.6	86.1 - 90.0	High
>84.0	>87.6	>90.0	Extre



https://digital.mdl.nws.noaa.gov/

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How Is Wet Bulb Globe Temperature Calculated?

WBGT = $0.7T_w + 0.2T_g + 0.1T_a$

Derivation https://www.weather.gov/media/tsa/pdf/WBGTpaper2.pdf

The following heat equation was taken from a paper by Hunter and Minyard (1999), with the exception of the constant in the second term on the right:

$$(1-\alpha_{sps})S(f_{db}s_{sp} + (1+\alpha_{es})f_{dif}) + (1-\alpha_{spl})\sigma\varepsilon_a T_a^4 = \varepsilon\sigma T_g^4 + 0.115u^{0.58}(T_g - T_a) \qquad (1)$$

The coefficient in the second term on the right side of equation (0.115) is from the convective heat flow coefficient. It was determined during testing that setting this coefficient equal to 0.437 gives a more accurate estimation of the globe temperature. This value may need to be adjusted for different spheres.

Now, putting all T_g terms on the left of the equation, replacing 0.115 with 0.315 and dividing by $\varepsilon\sigma$ we get:

$$T_g^4 + \frac{0.315u^{0.58}}{\varepsilon\sigma}T_g = \frac{(1-\alpha_{sps})S(f_{db}s_{sp}+(1+\alpha_{es})f_{dif})+(1-\alpha_{spl})\sigma\varepsilon_a T_a^4}{\varepsilon\sigma} + \frac{0.315u^{0.58}}{\varepsilon\sigma}T_a \qquad (2)$$

The values of all variables except T_g are either given or can be calculated from available data from the NWS. The following values are provided.

Globe albedo for short and long wave radiation: $\alpha_{sps} = \alpha_{spl} = 0.05$ so $1-\alpha_{sps} = 1-\alpha_{spl} = 0.95$.

Black globe emissivity: ε=0.95

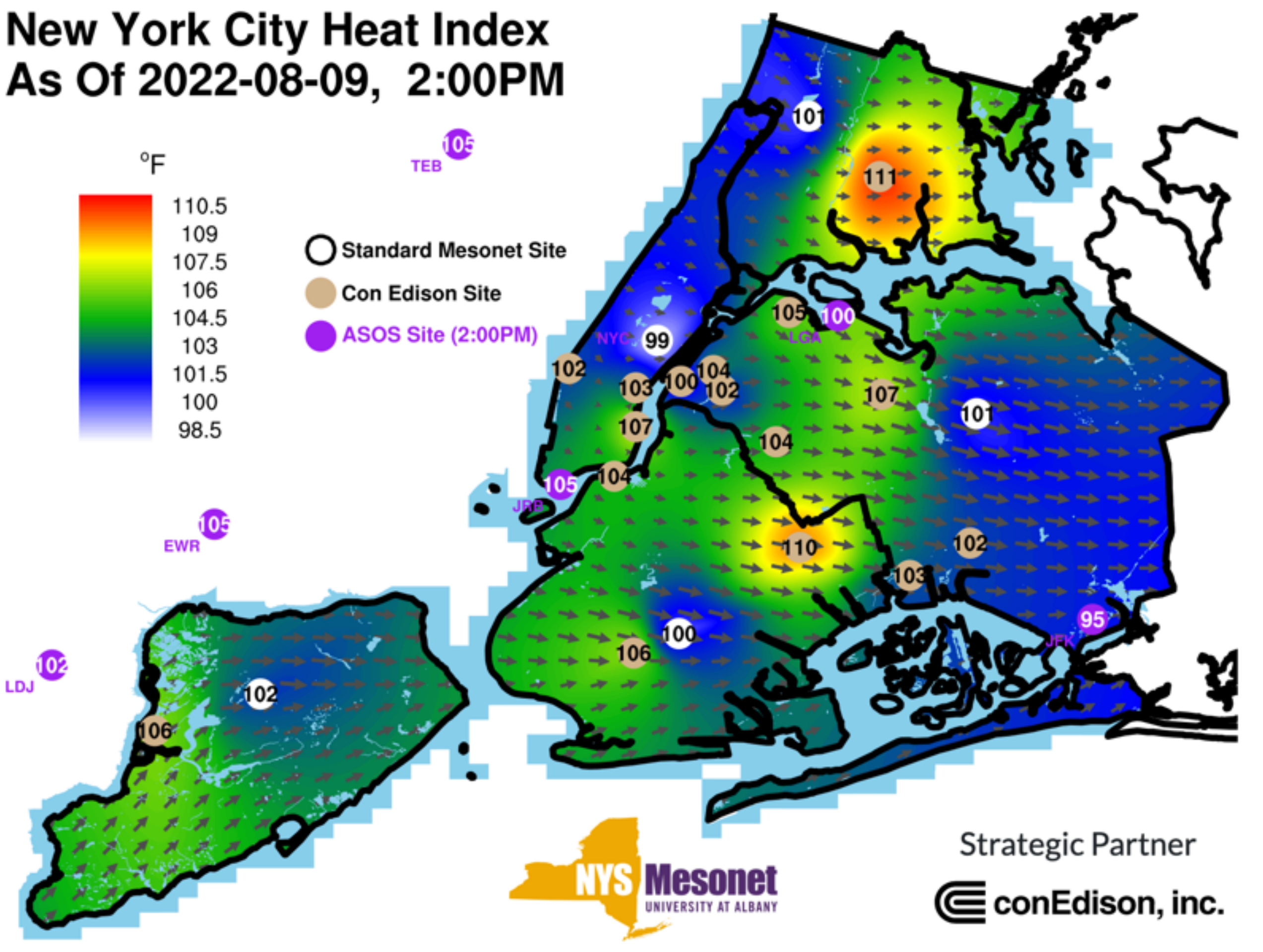
Stephan-Boltzman constant:σ=5.67x10^{-8} is used.

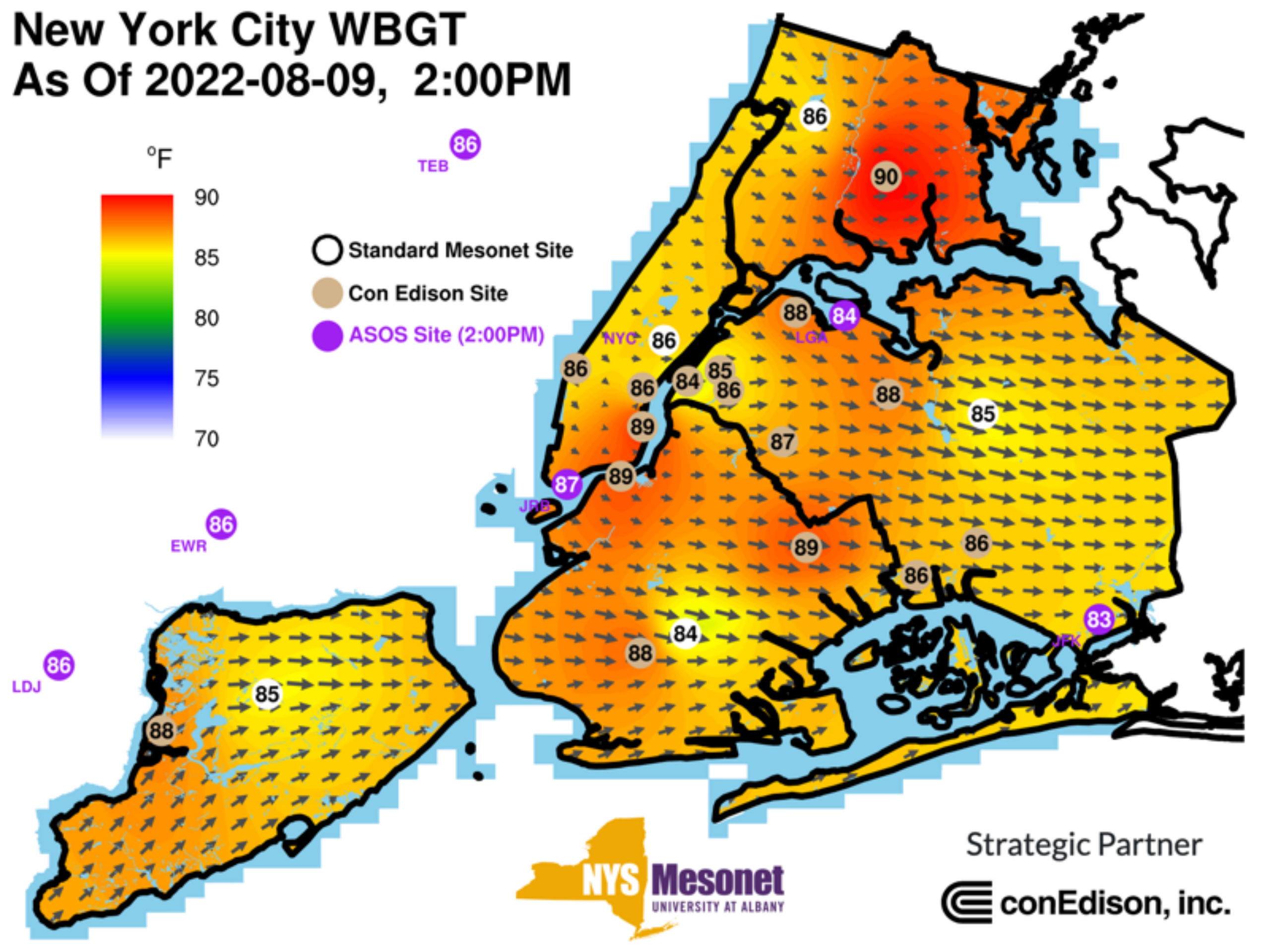
Albedo for grassy surfaces: α_{es}= 0.2.

When these values are entered into equation (2) we get:

$$T_g^4 + \frac{0.315u^{0.58}}{0.95(5.67\times10^{-8})}T_g = \frac{0.95S(f_{db}s_{sp}+(1.2)f_{dif})+0.95(\varepsilon_a)\sigma T_a^4}{0.95(5.67\times10^{-8})} + \frac{0.315u^{0.58}}{0.95(5.67\times10^{-8})}T_a \qquad (3)$$

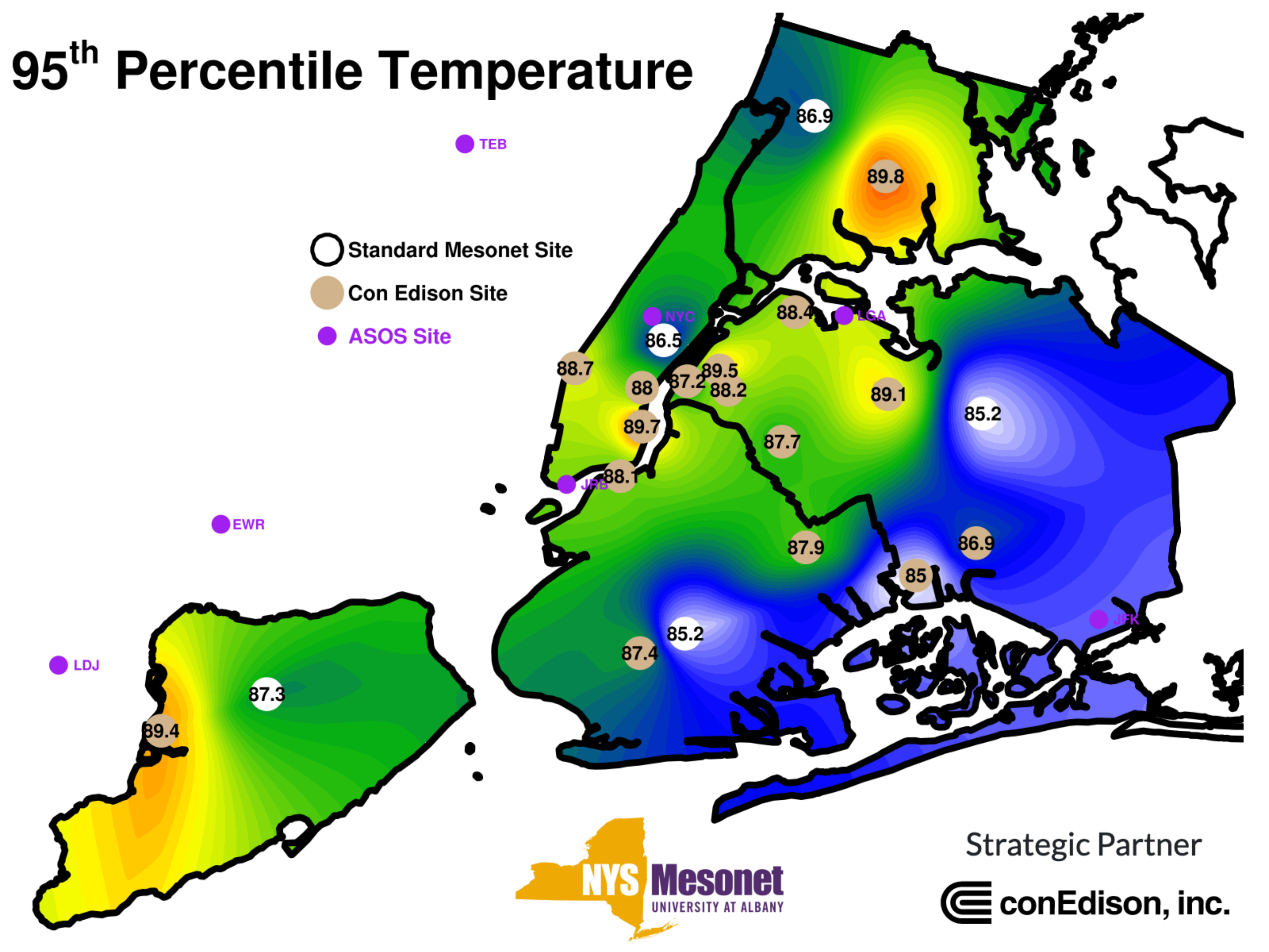
Comparing Heat Index to WBGT



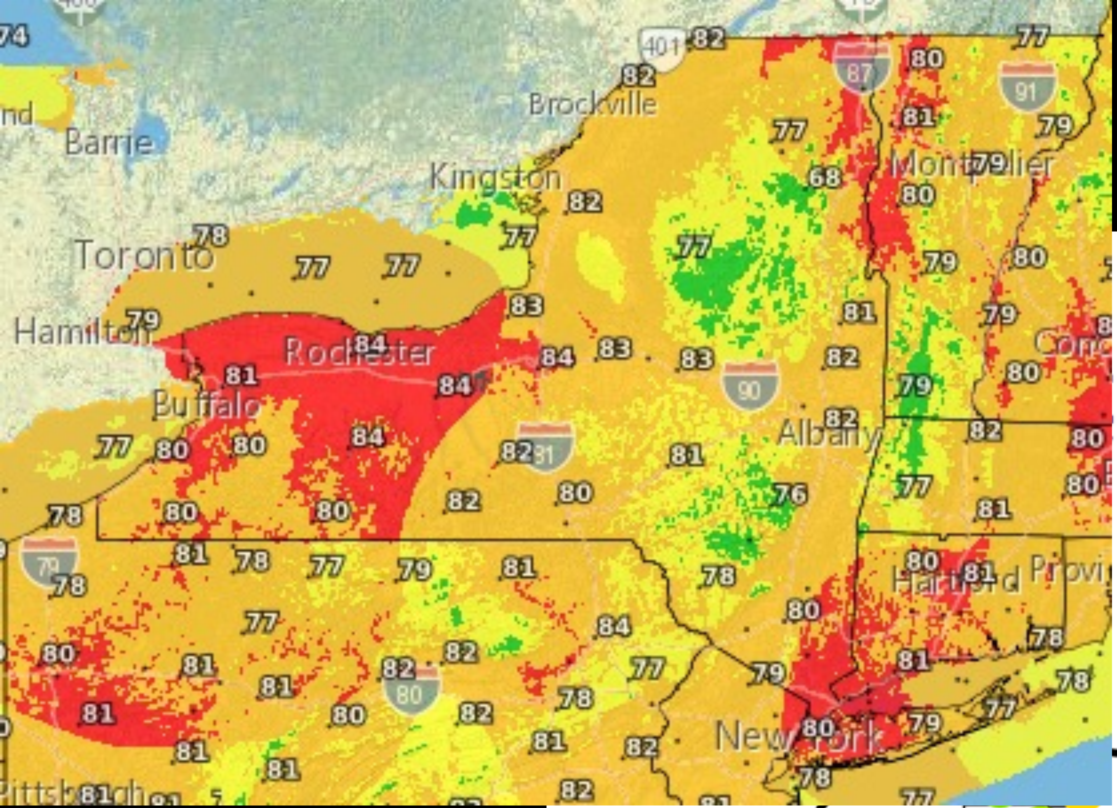


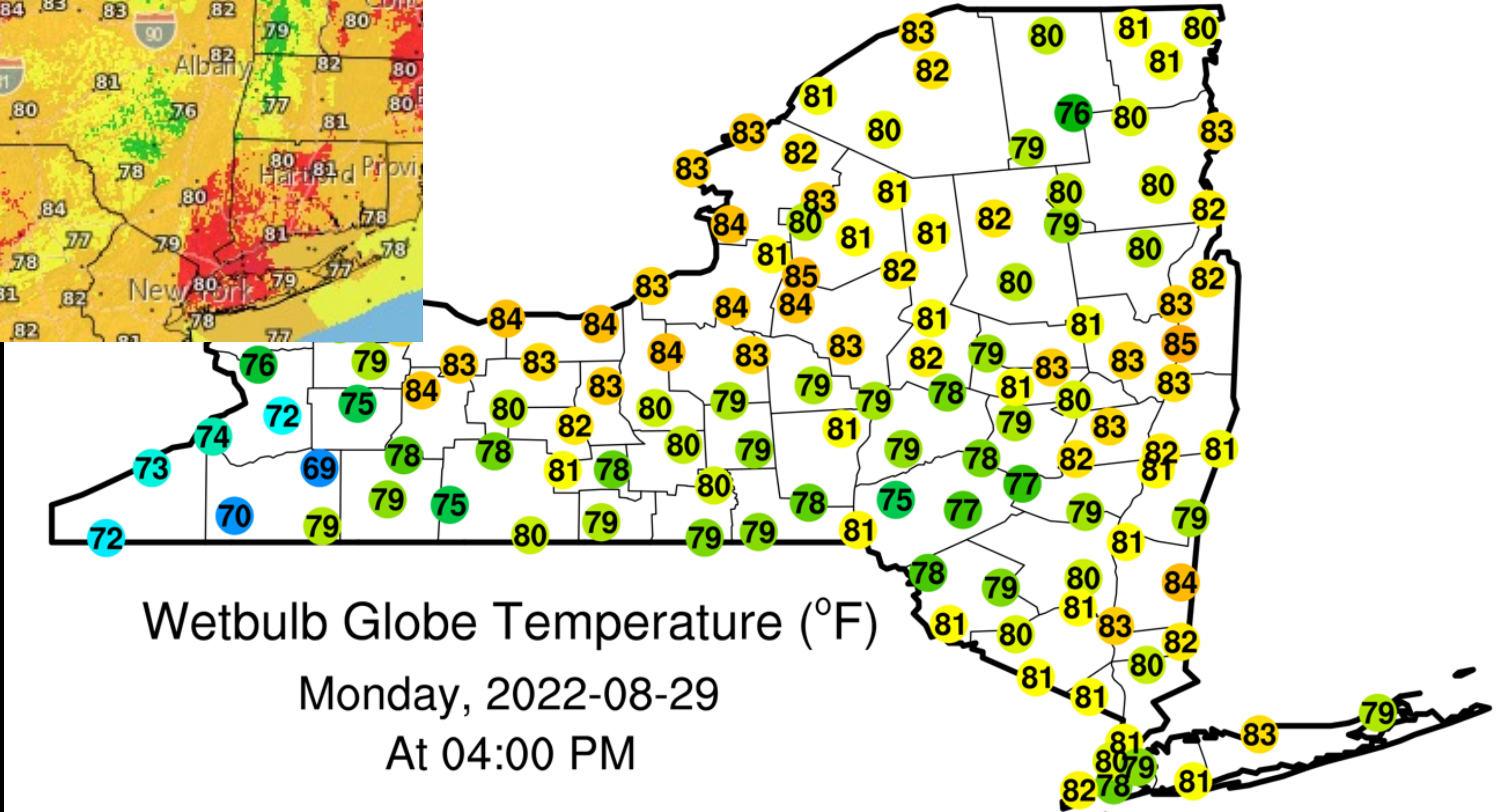
https://operations.nysmesonet.org/~nbassill/NOAA/

Siting Quality Matters



Statewide WBGT





Next: Use 30 m LANDSAT data to compare stations to environment

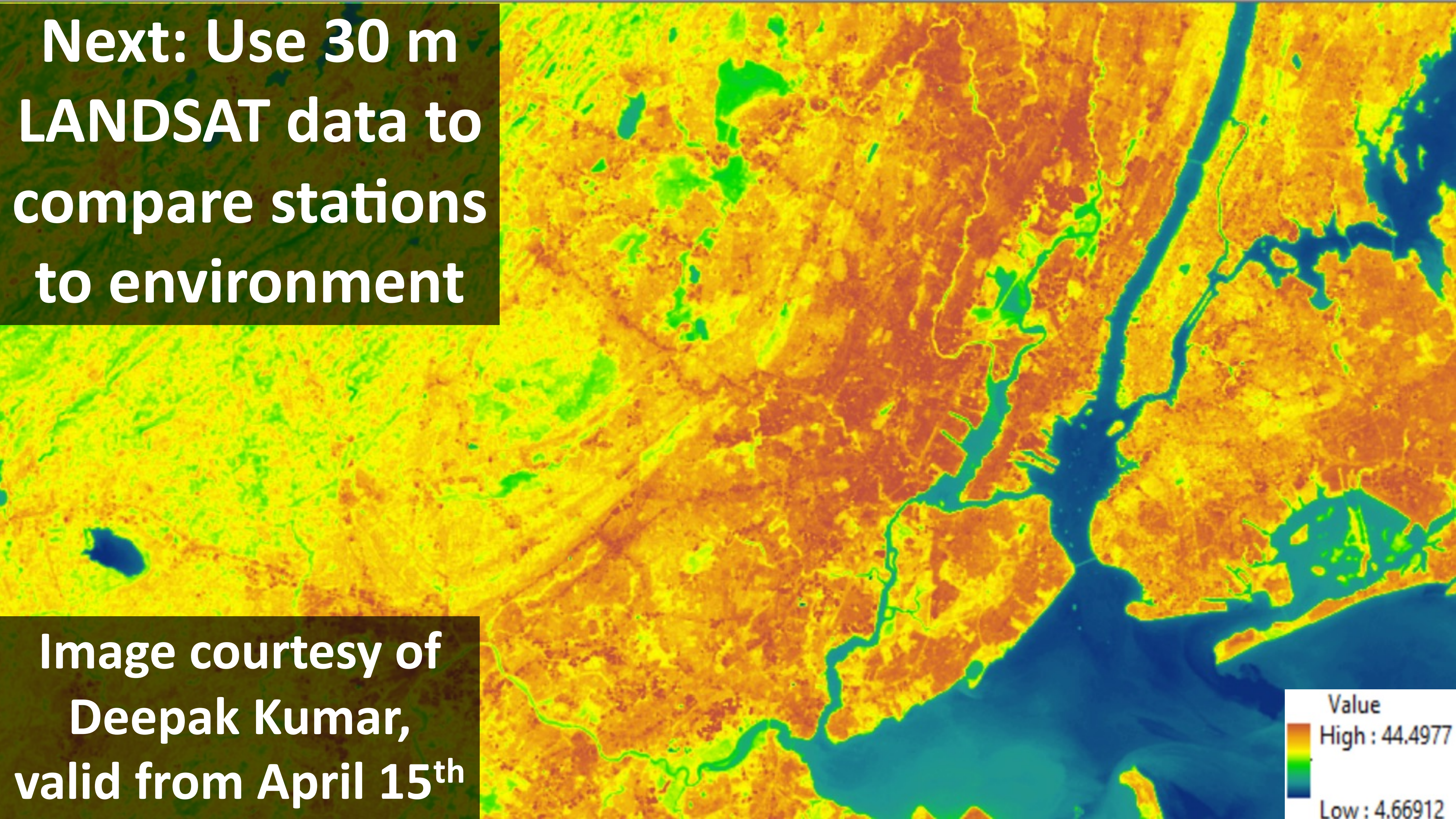
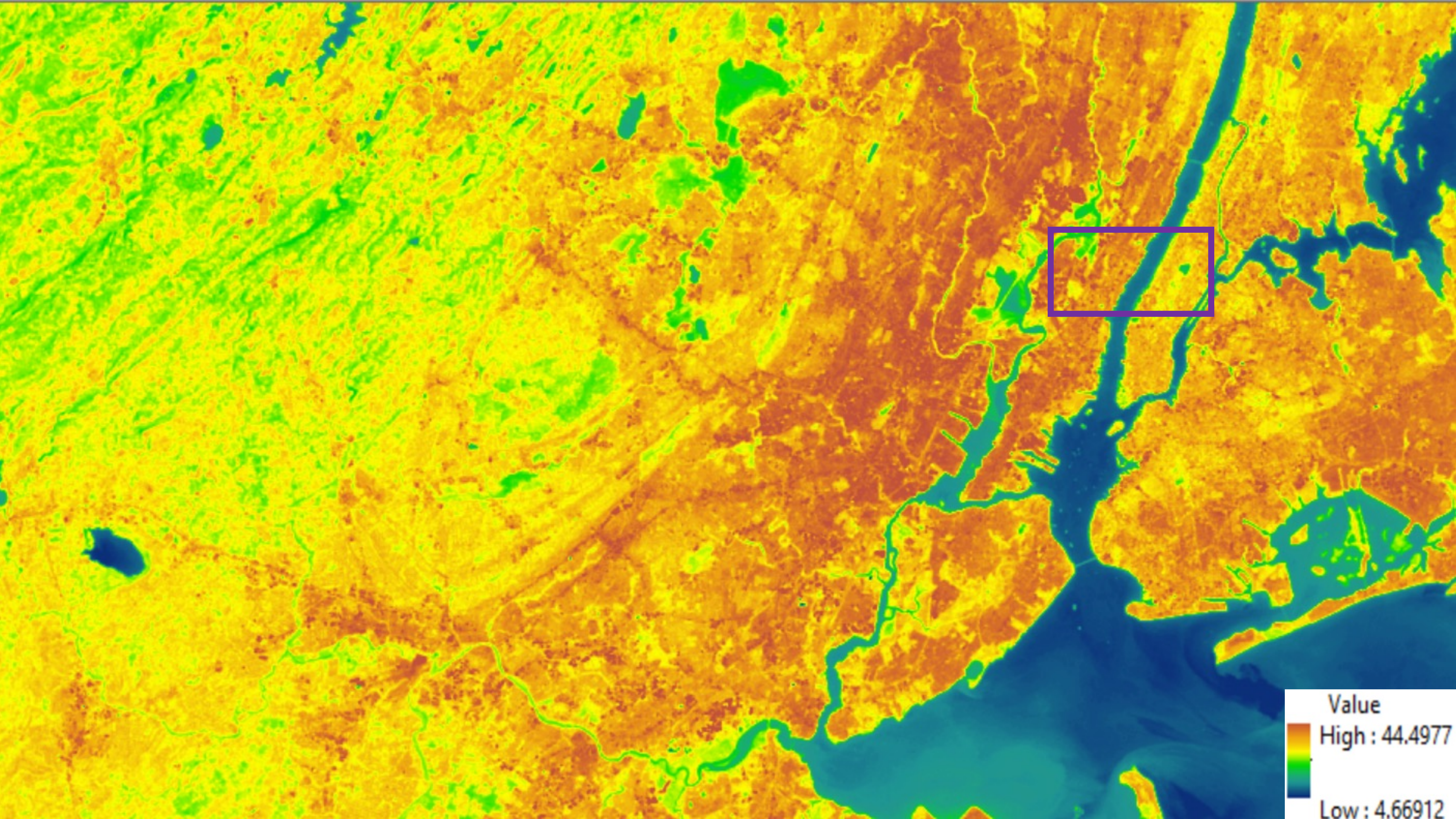
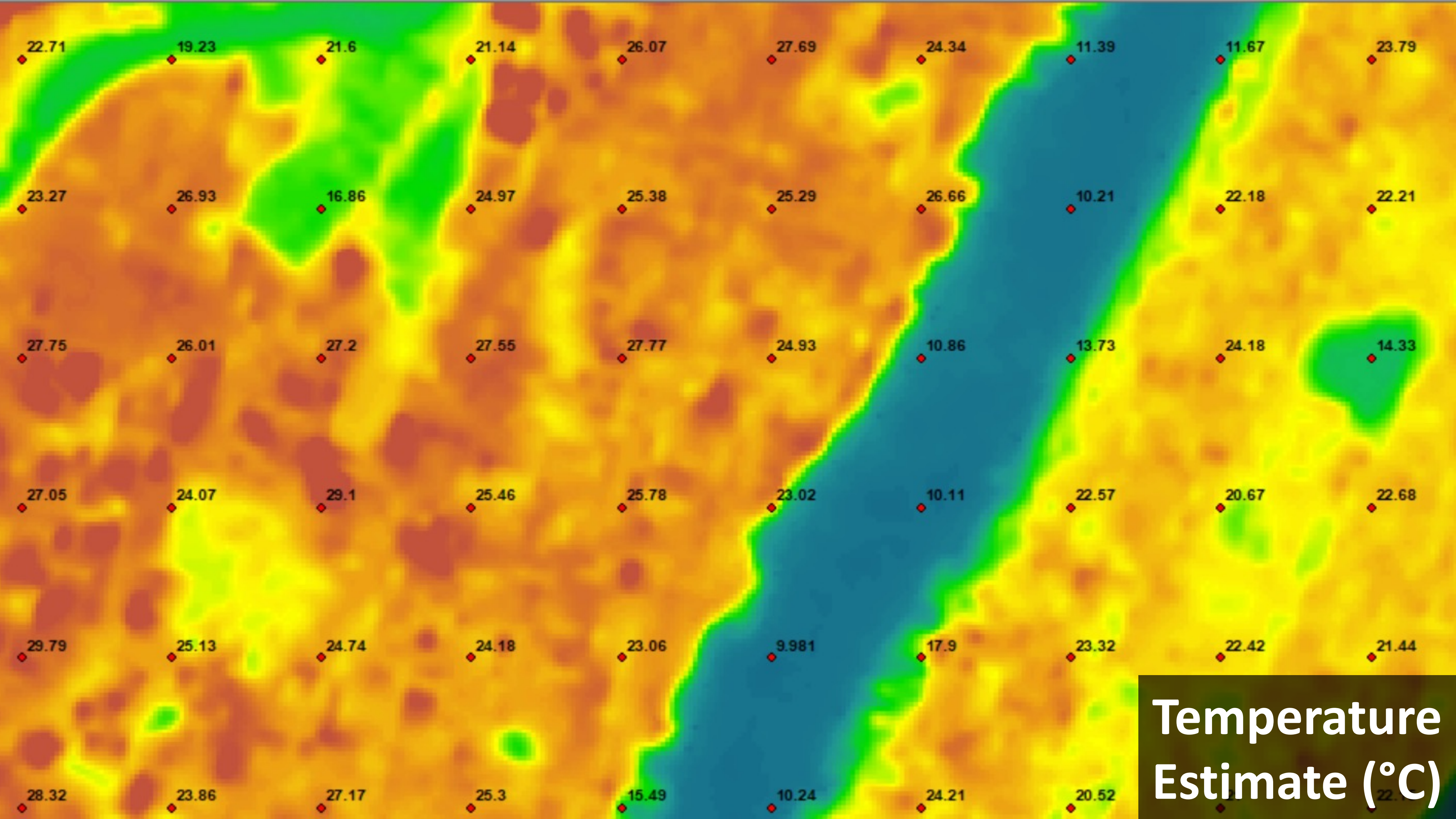


Image courtesy of Deepak Kumar, valid from April 15th


Value
High : 44.4977
Low : 4.66912


22.71
19.23
21.6
21.14
26.07
27.69
24.34
11.39
11.67
23.79
23.27
26.93
16.86
24.97
25.38
25.29
26.66
10.21
22.18
22.21
27.75
26.01
27.2
27.55
27.77
24.93
10.86
13.73
24.18
14.33
27.05
24.07
29.1
25.46
25.78
23.02
10.11
22.57
20.67
22.68
29.79
25.13
24.74
24.18
23.06
9.981
17.9
23.32
22.42
21.44
28.32
23.86
27.17
25.3
15.49
10.24
24.21
20.52
Temperature Estimate (°C)

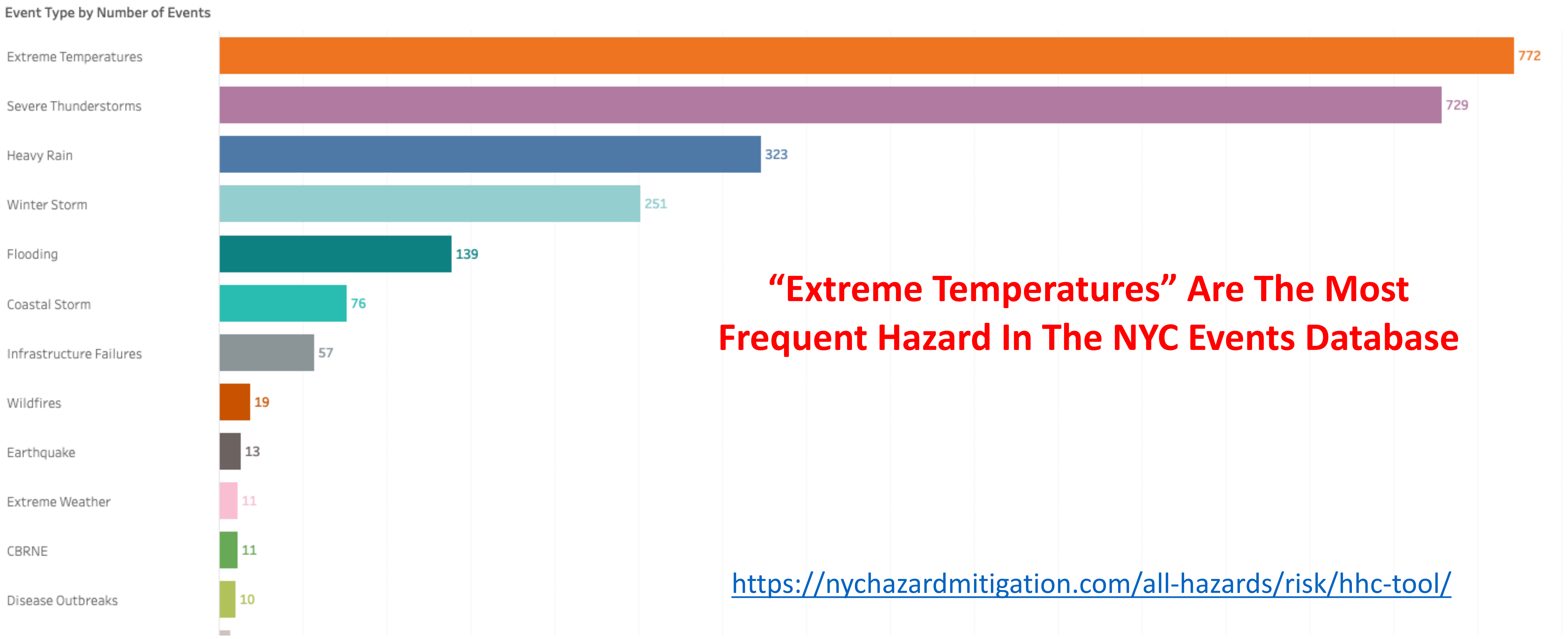
End

“Improving analysis and communication of extreme temperatures across the New York City metropolis using a dense network of in situ observations”

Or, “Urban Heat Island Project”

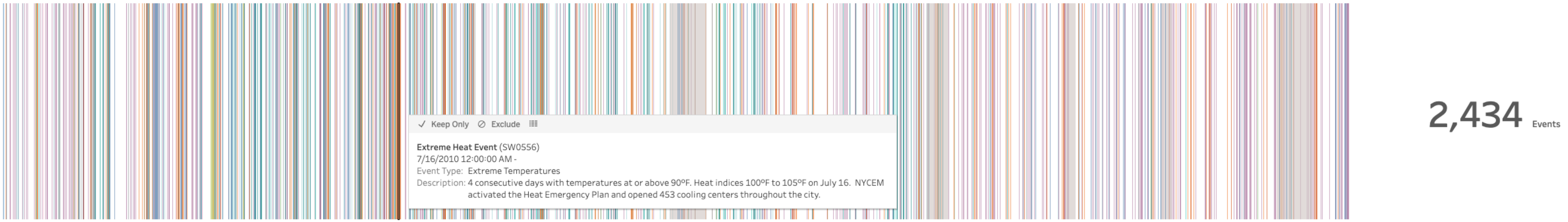
Nick Bassill, Jeannette Sutton, Eric Stern, Chris Thorncroft

https://operations.nysmesonet.org/~nbassill/NOAA/



"Extreme Temperatures" Are The Most Frequent Hazard In The NYC Events Database

https://nychazardmitigation.com/all-hazards/risk/hhc-tool/



Key Questions:

- How is information disseminated from NWS, NYC EM, etc. to other stakeholders and the public?
- How does NWS currently issue heat products?
- What are some of the limiting factors preventing better products?
- What went right - or wrong - in prior heat waves?
- What ancillary factors are important? Green space, cooling centers, etc?

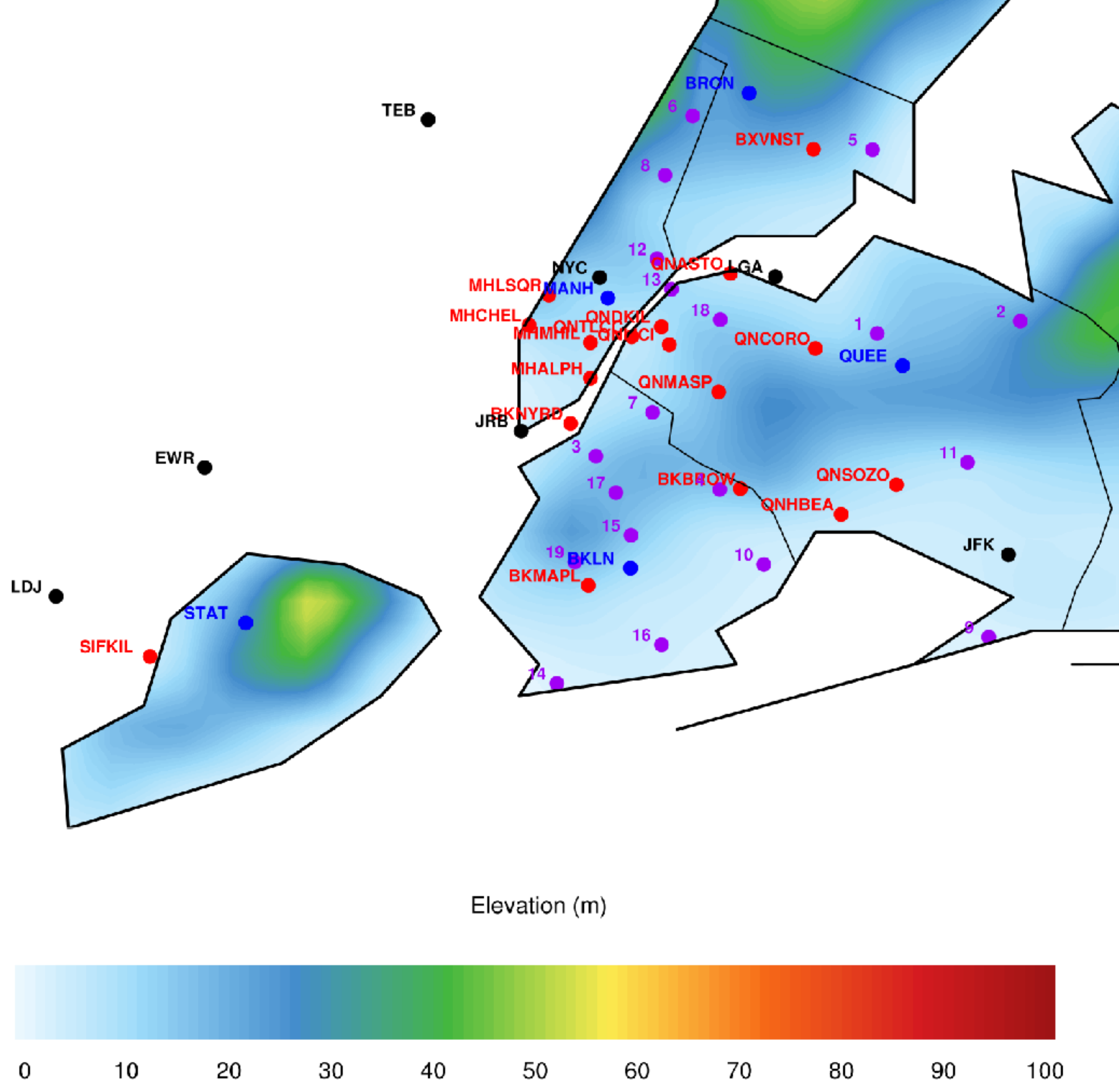
Proposed Network Of Opportunity

-ASOS (Black)

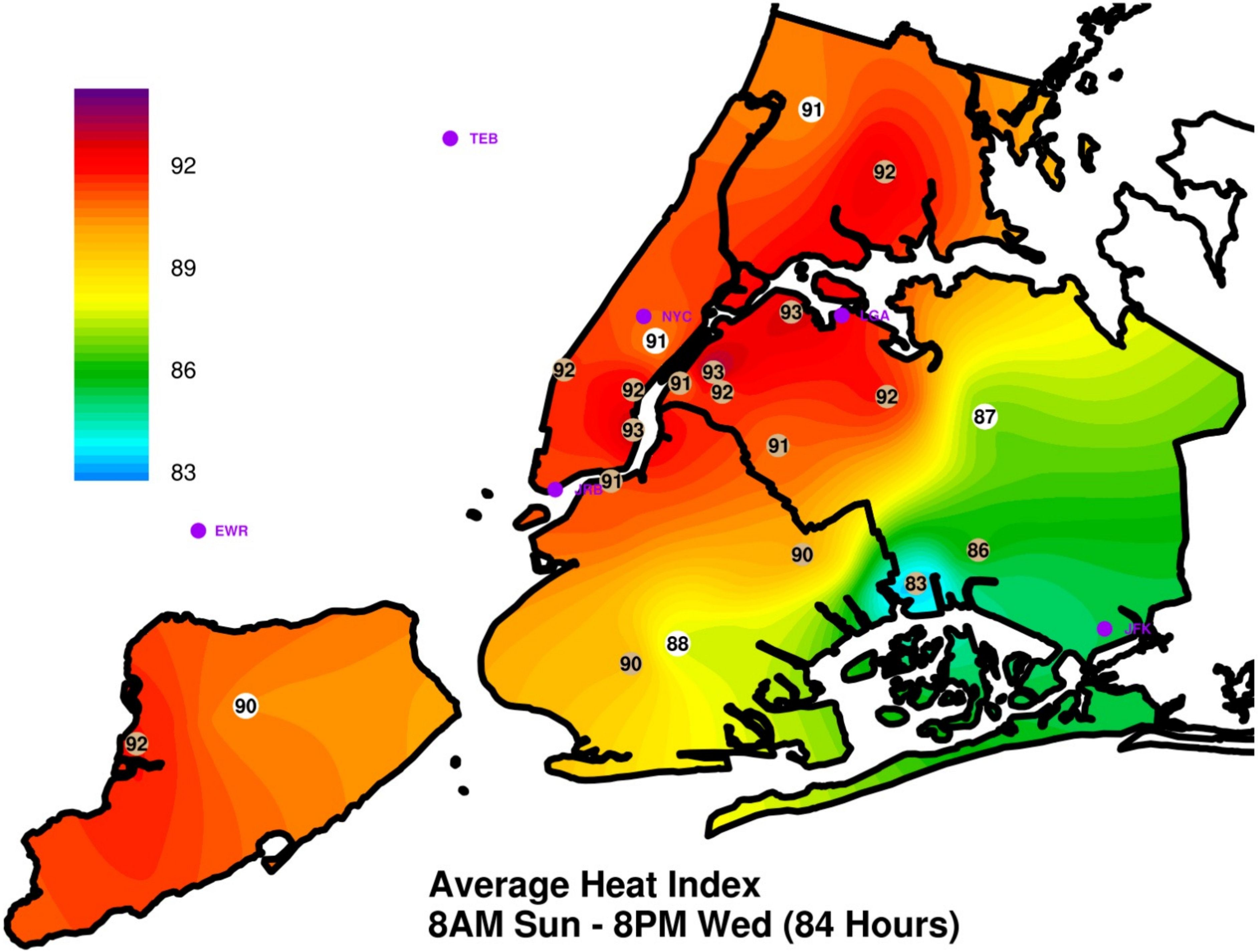
-NYS Mesonet (Blue)

-ConEd Micronet (Red)

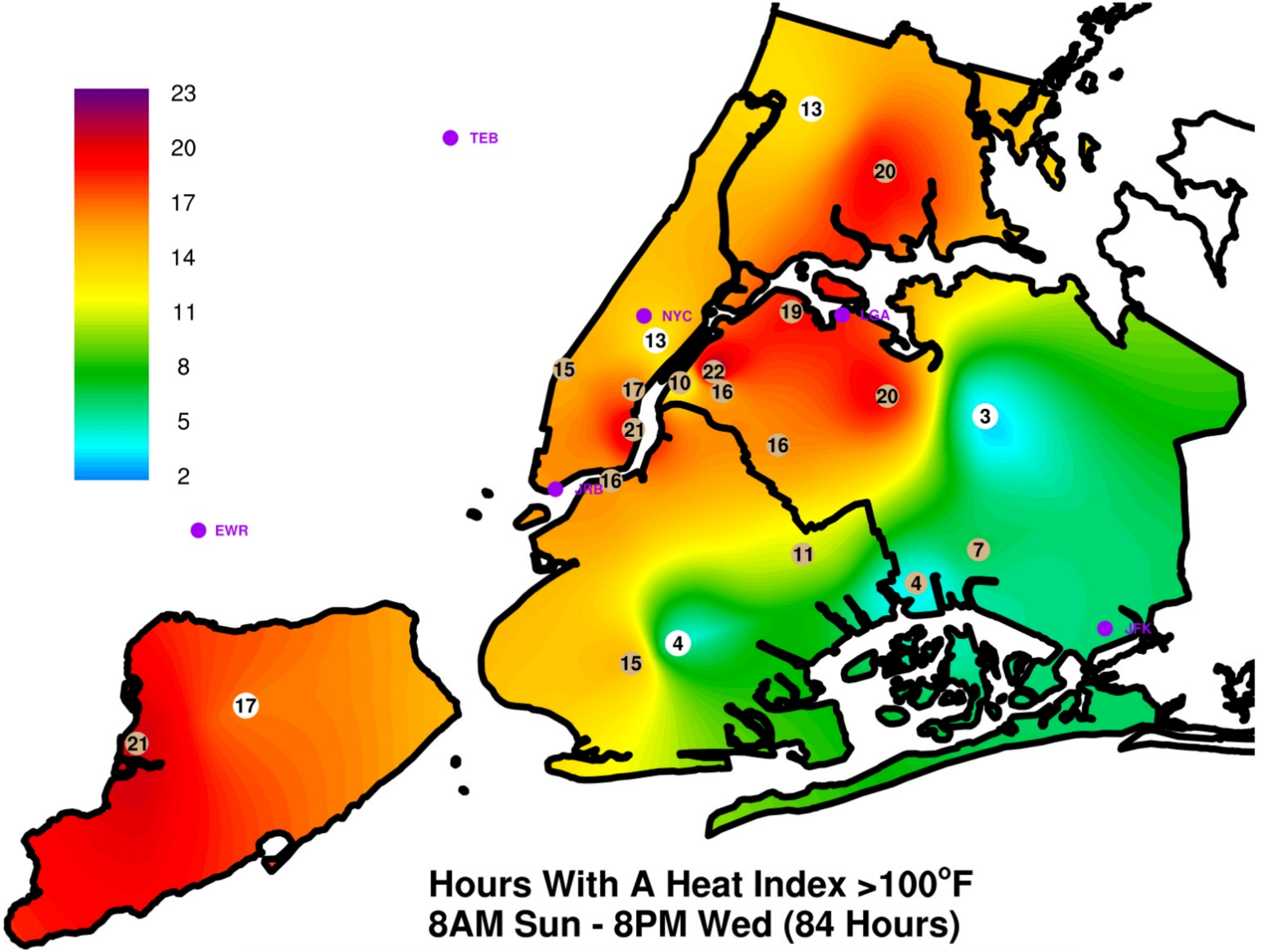
-CUNY (Purple)



June 27th-30th Heat Wave



June 27th-30th Heat Wave



June 27th-30th Heat Wave