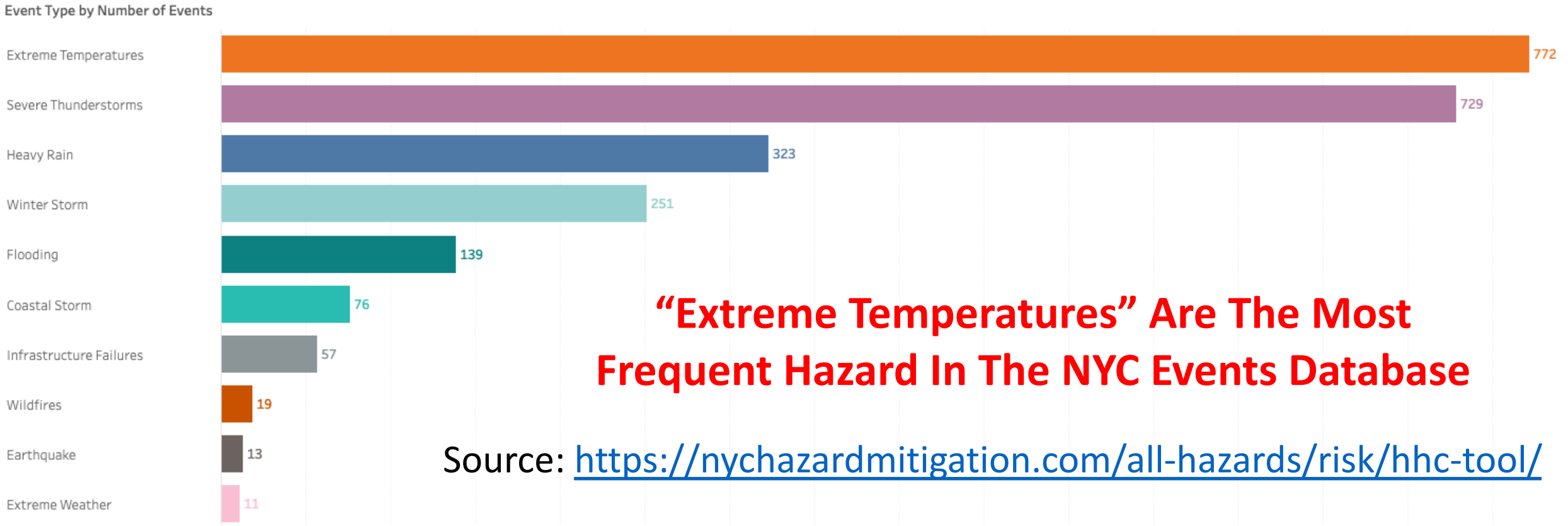
Analyzing Extreme Temperature Variables Across the New York City Metropolis Using a Dense Network of in situ Observations

Nick Bassill
UAlbany Center of Excellence
November 2nd, 2022

Contact: nbassill@albany.edu or @NickPBassill

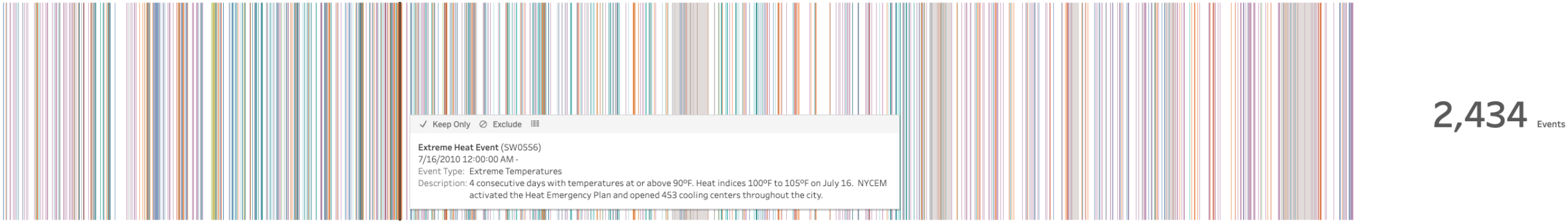
Northeast Regional Operational Workshop XXIII
Supported by NOAA Award NA21OAR4590360

Motivation: Extreme Temperatures In NYC



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

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



Motivation Continued

- Matte and coauthors (2016) estimated median annual excess deaths due to heat at **121** in New York City (NYC)
- NYC's geography significantly modulates temperature and moisture, due to proximity to water bodies large and small, amount of vegetation and infrastructure, etc.
- NYC is extremely diverse socioeconomically, which can present communication challenges
- NWS products for NYC are a one-size-fits-all approach
- New wealth of high-quality surface observations
- NWS would like to test new tools, such as Wet-bulb Globe Temperature

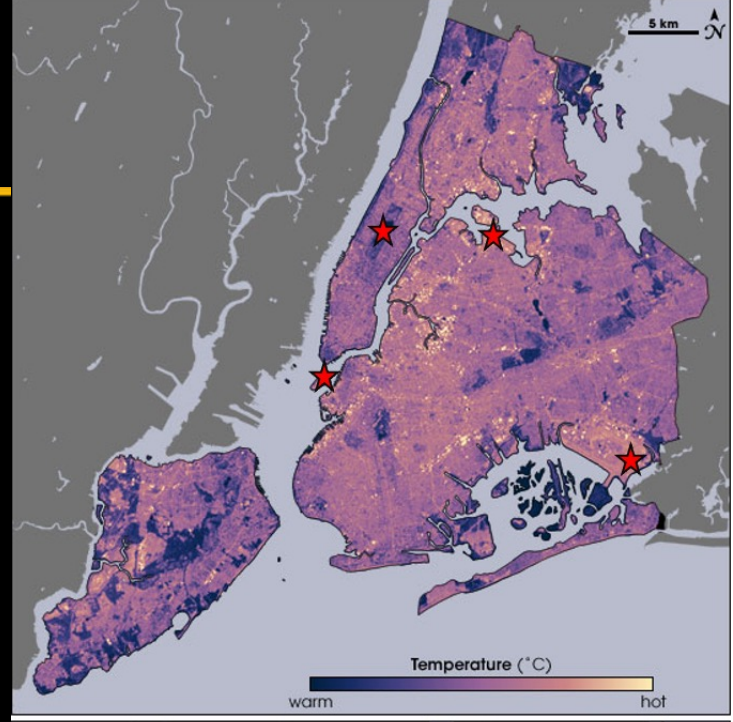


Image source: Landsat image from August 14th, 2002, with ASOS locations annotated

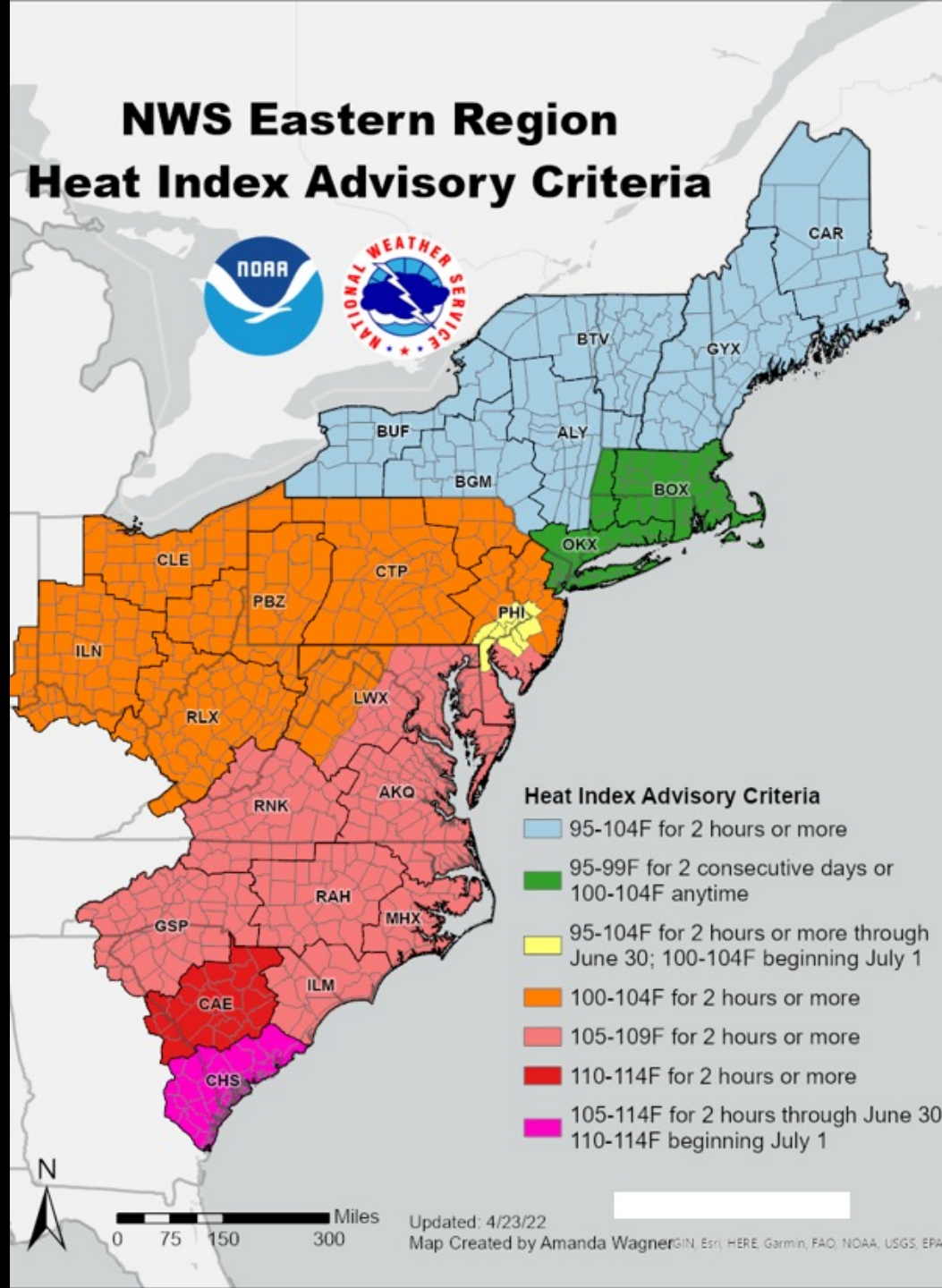
The National Weather Service Issues Two Primary Heat Products

(1) A heat advisory: there are several definitions across the northeast

Heat Index Advisory Criteria

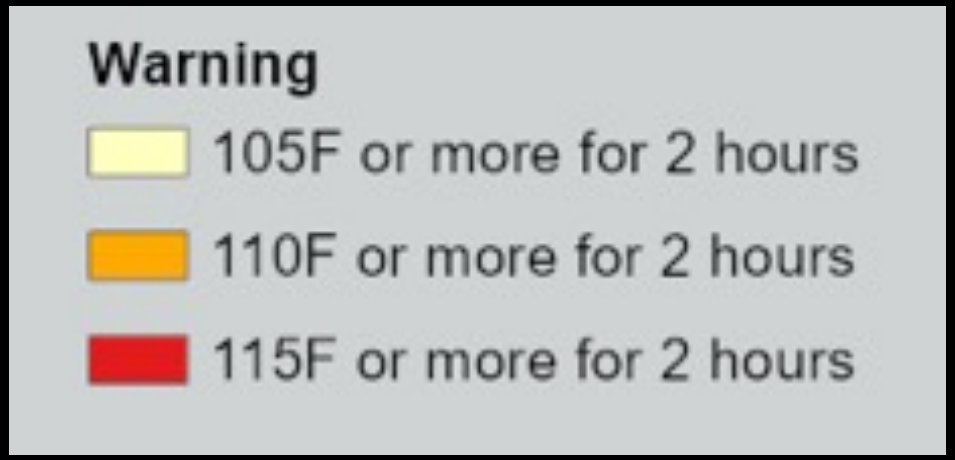
- 95-104F for 2 hours or more
- 95-99F for 2 consecutive days or 100-104F anytime
- 95-104F for 2 hours or more through June 30; 100-104F beginning July 1
- 100-104F for 2 hours or more
- 105-109F for 2 hours or more
- 110-114F for 2 hours or more
- 105-114F for 2 hours through June 30 110-114F beginning July 1

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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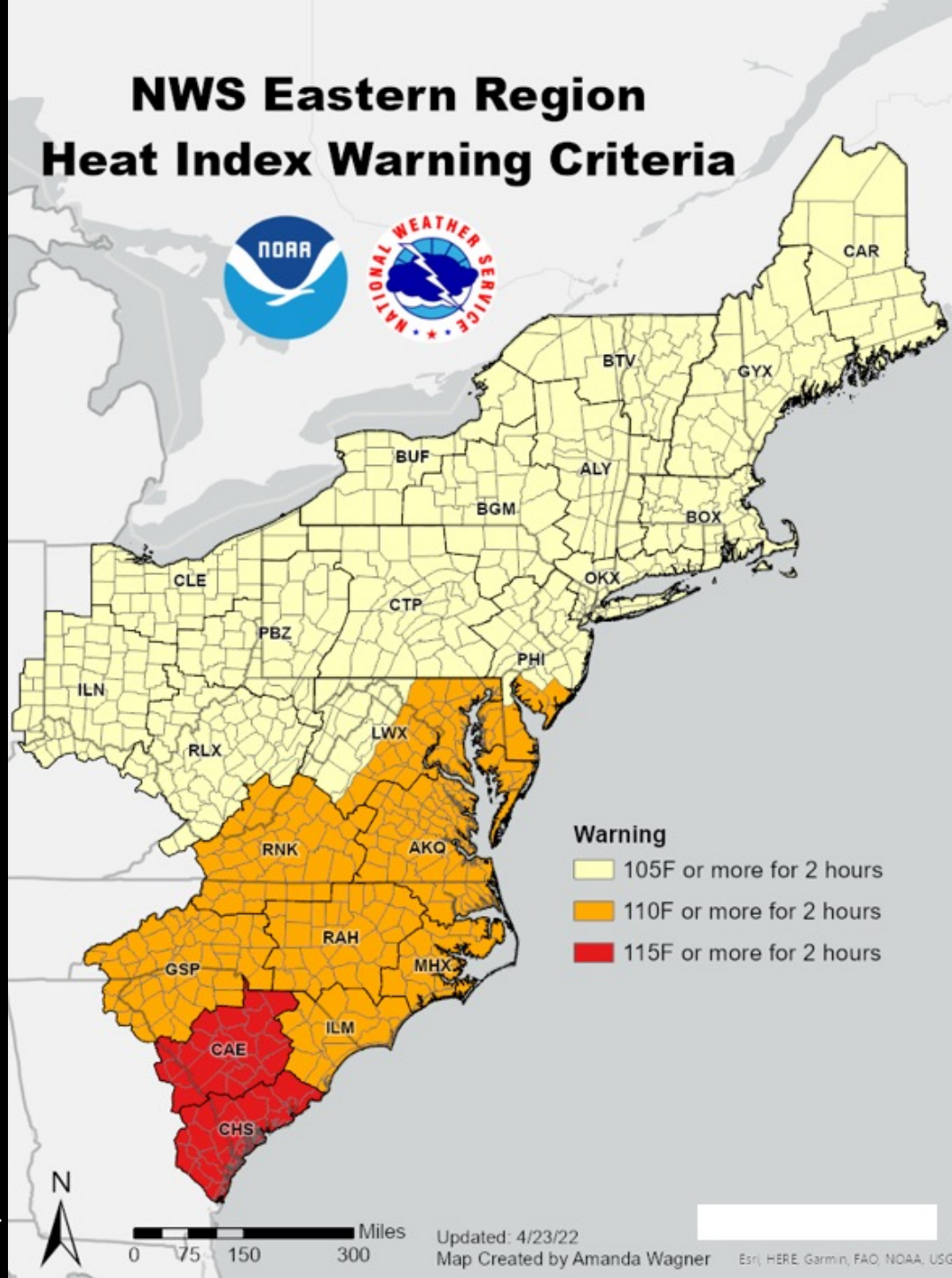
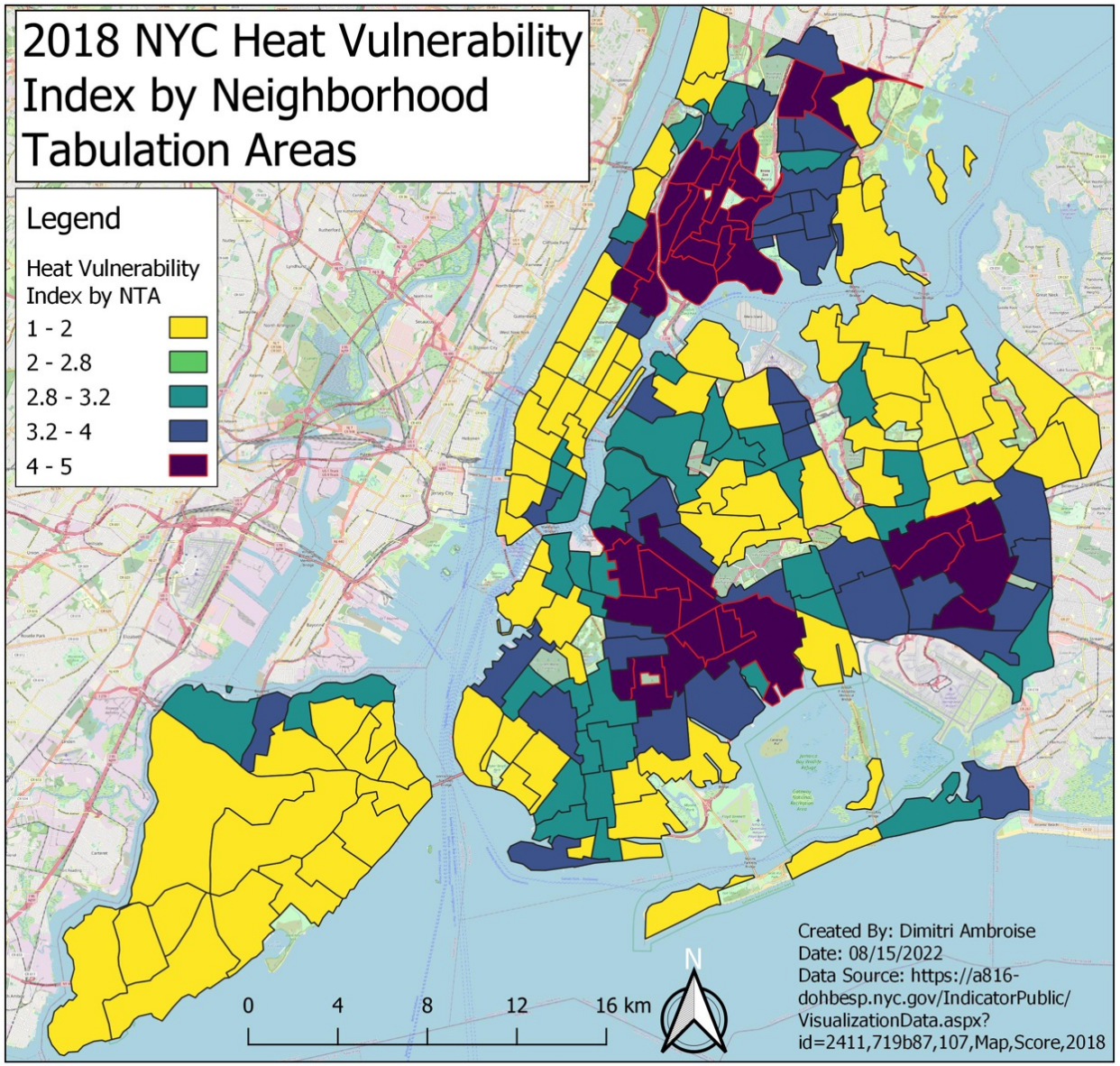
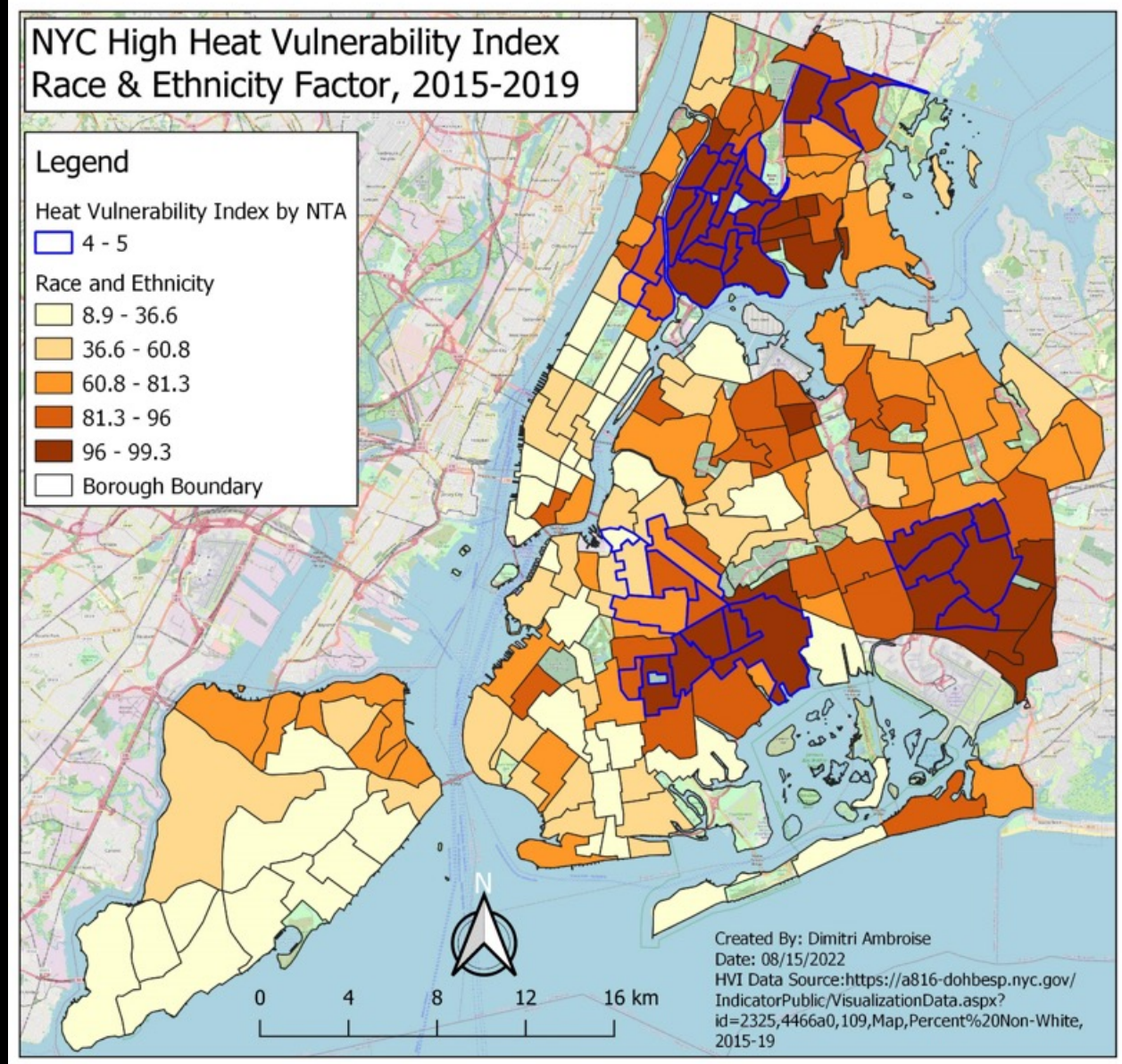


NYC Neighborhoods: Maps By NERTO Student Dimitri Ambroise





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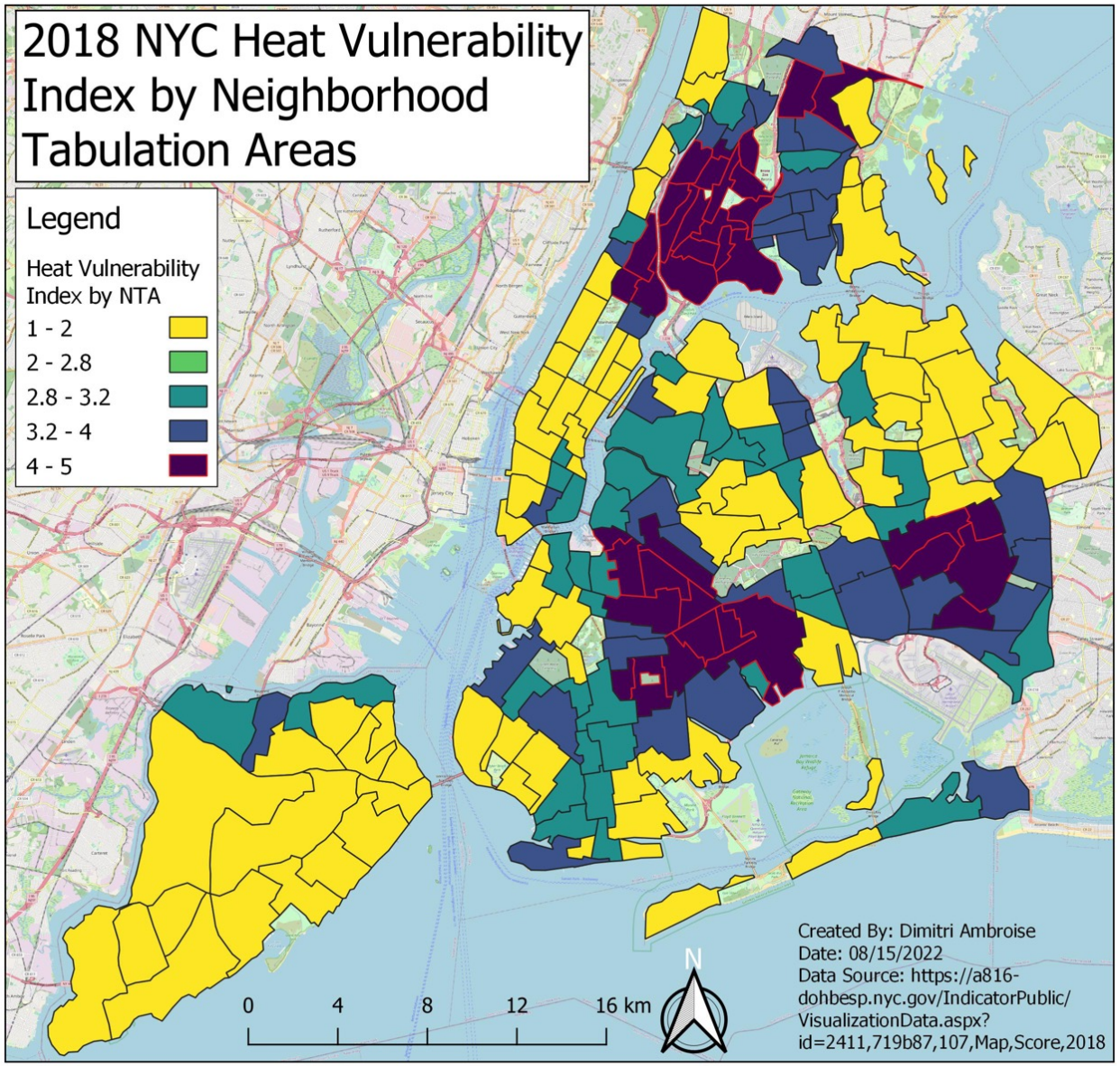

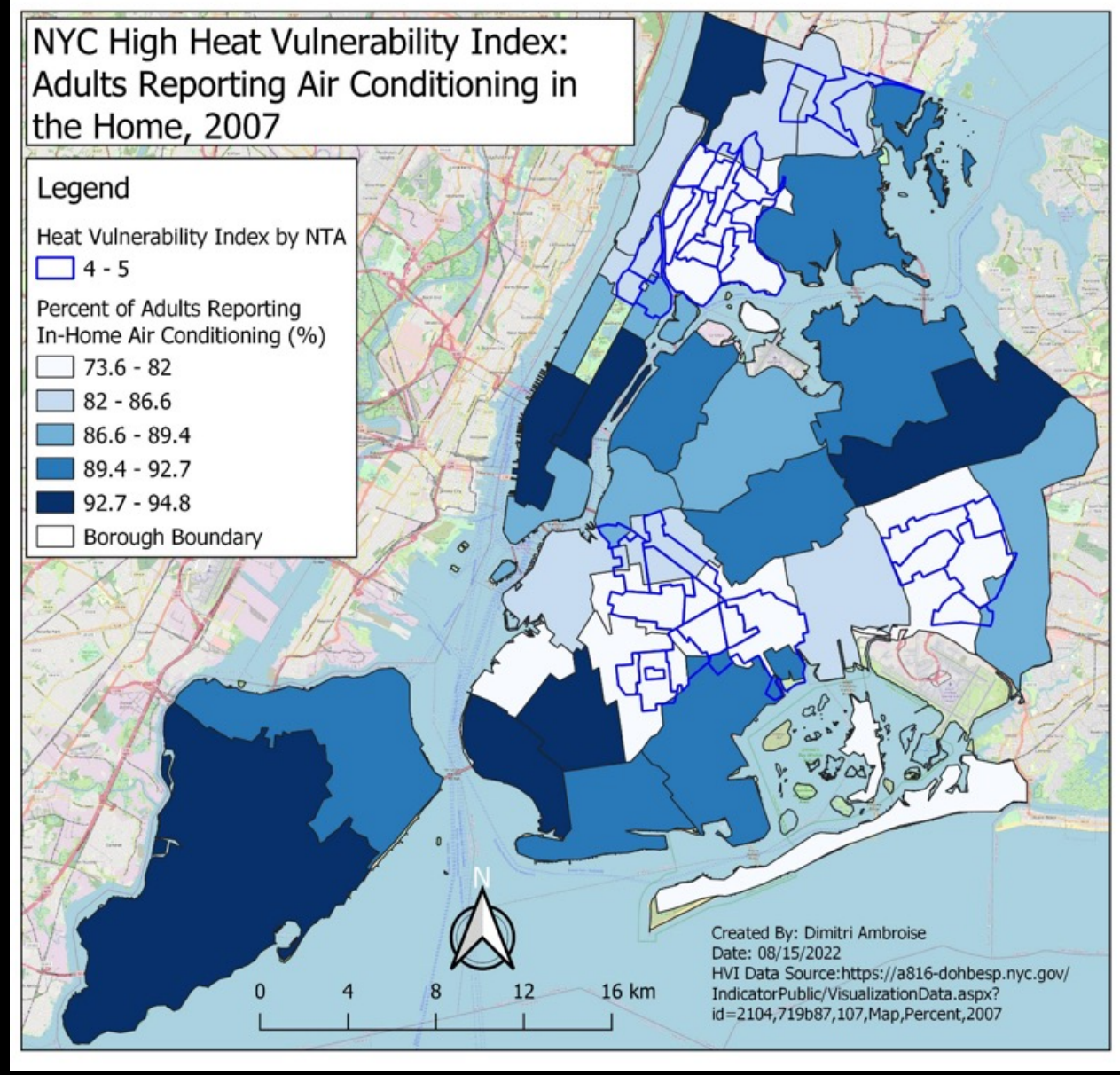

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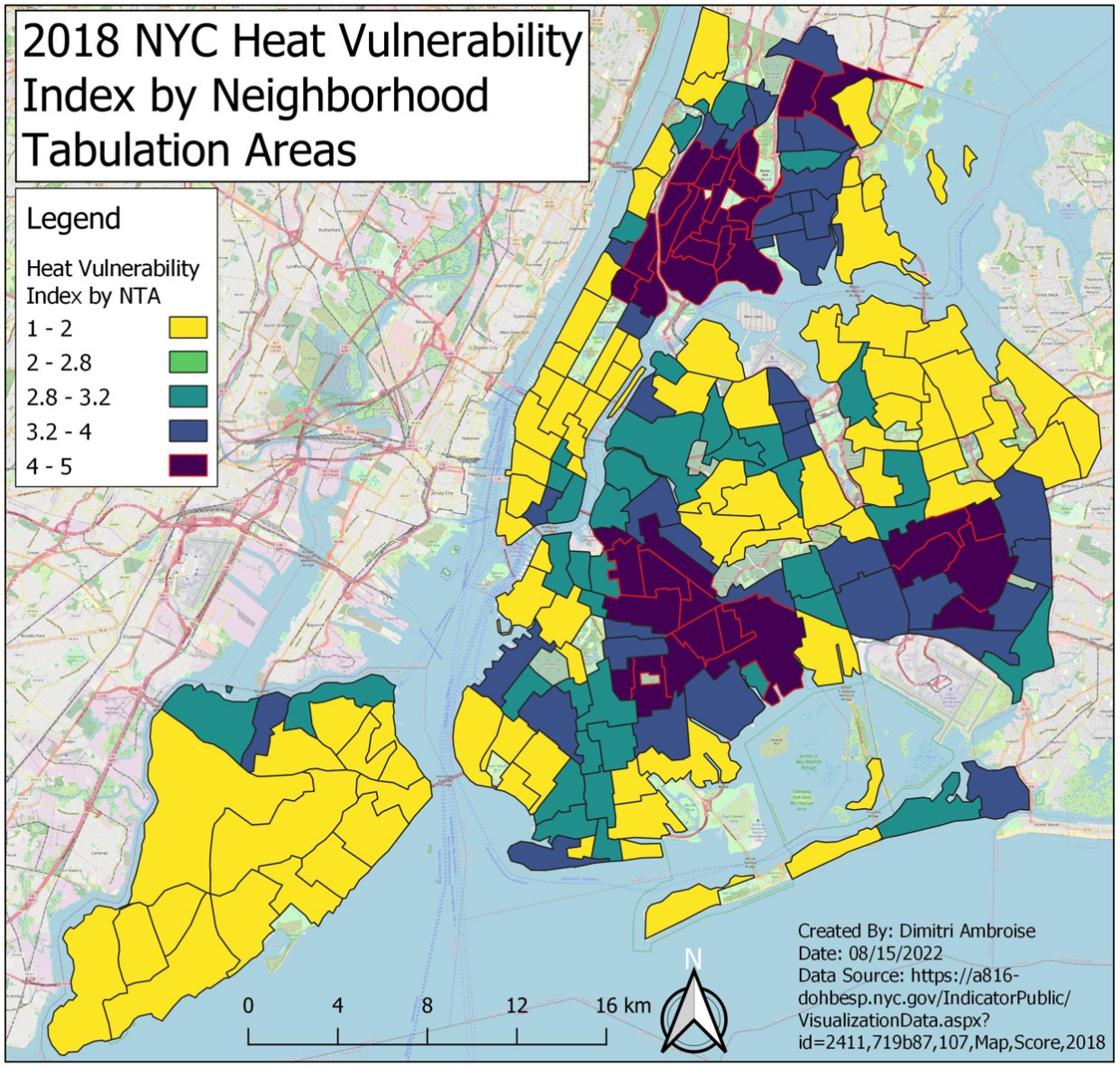
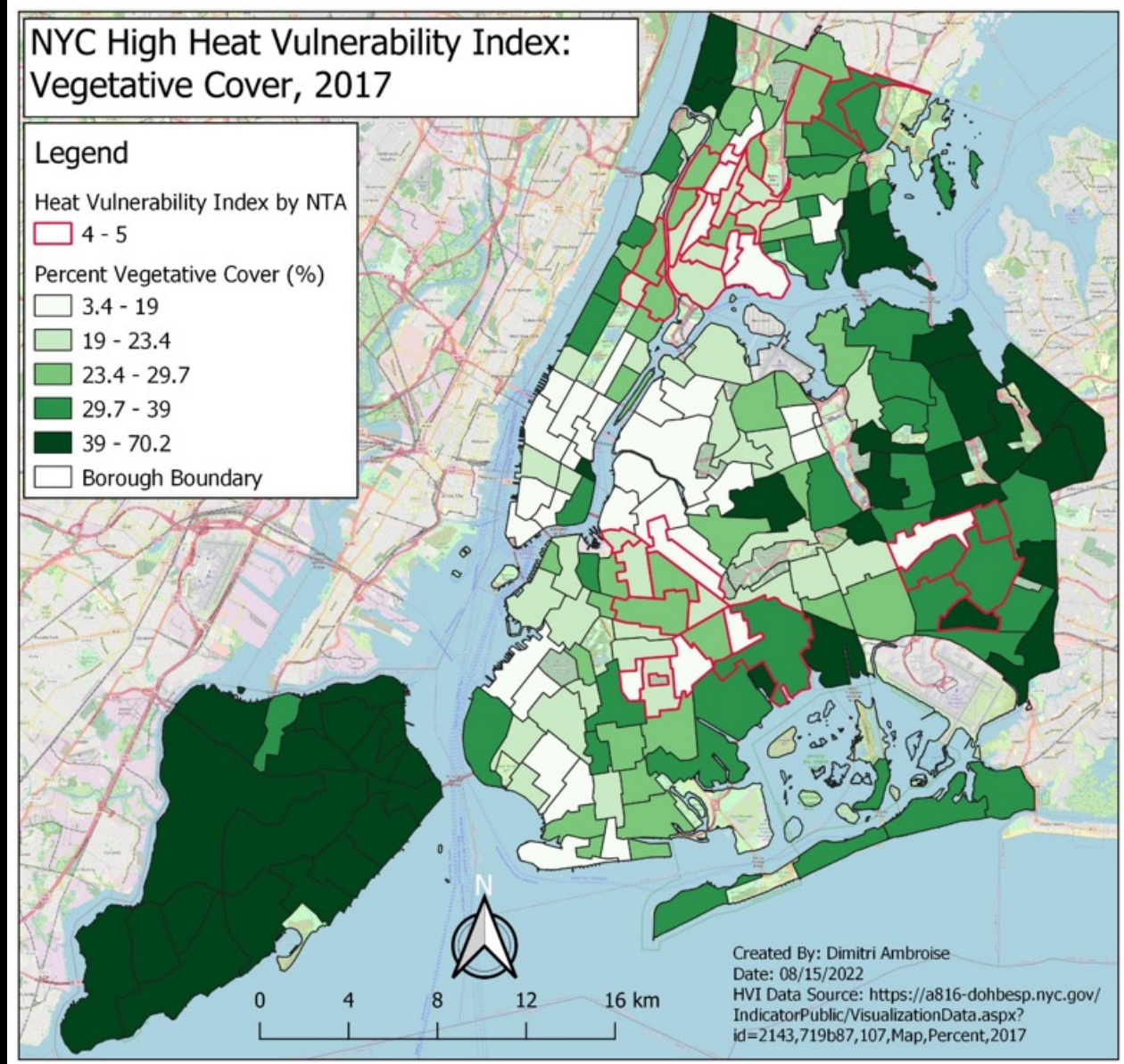
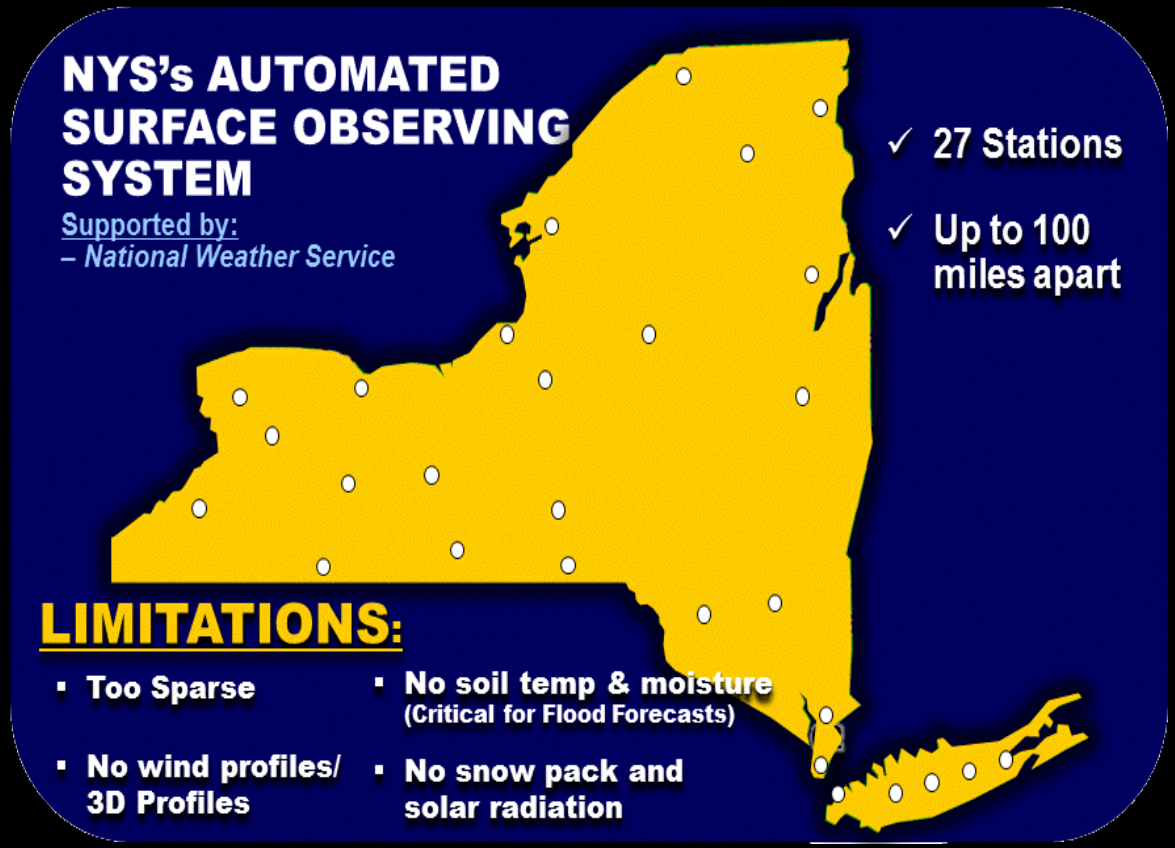




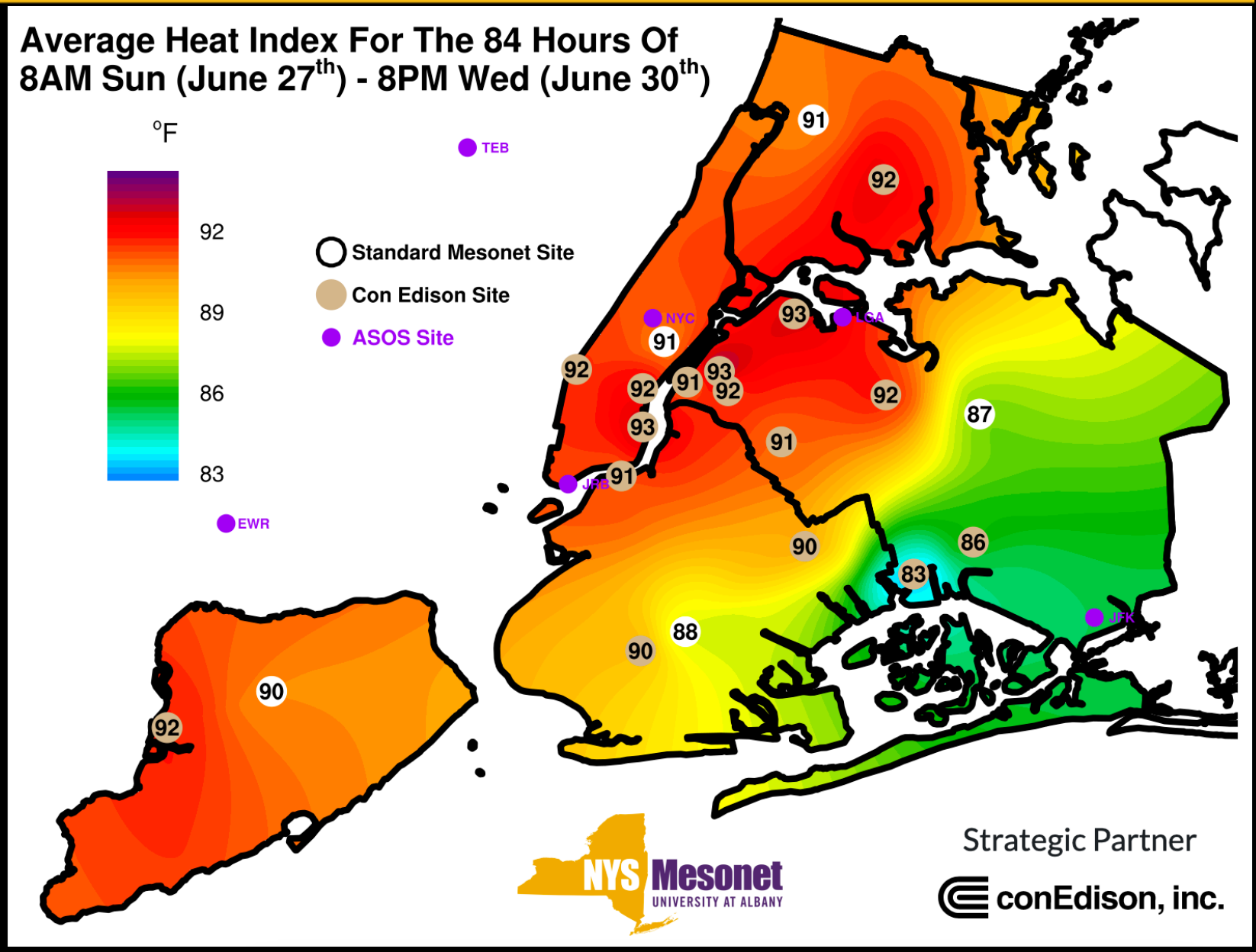
New York State Mesonet Overview

- $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 <- 5 in NYC**
  - 20 Snow sites
  - 17 Profiler sites
  - 18 Flux sites
  - *12 Thruway sites*
  - ***17 ConEd micronet sites <- All in NYC***
  - *DOT Skyway sensor*
  - *12 NYSERDA Irradiance sites*
- Data is collected every 5 minutes
- This network fills in various gaps in the pre-existing ASOS network



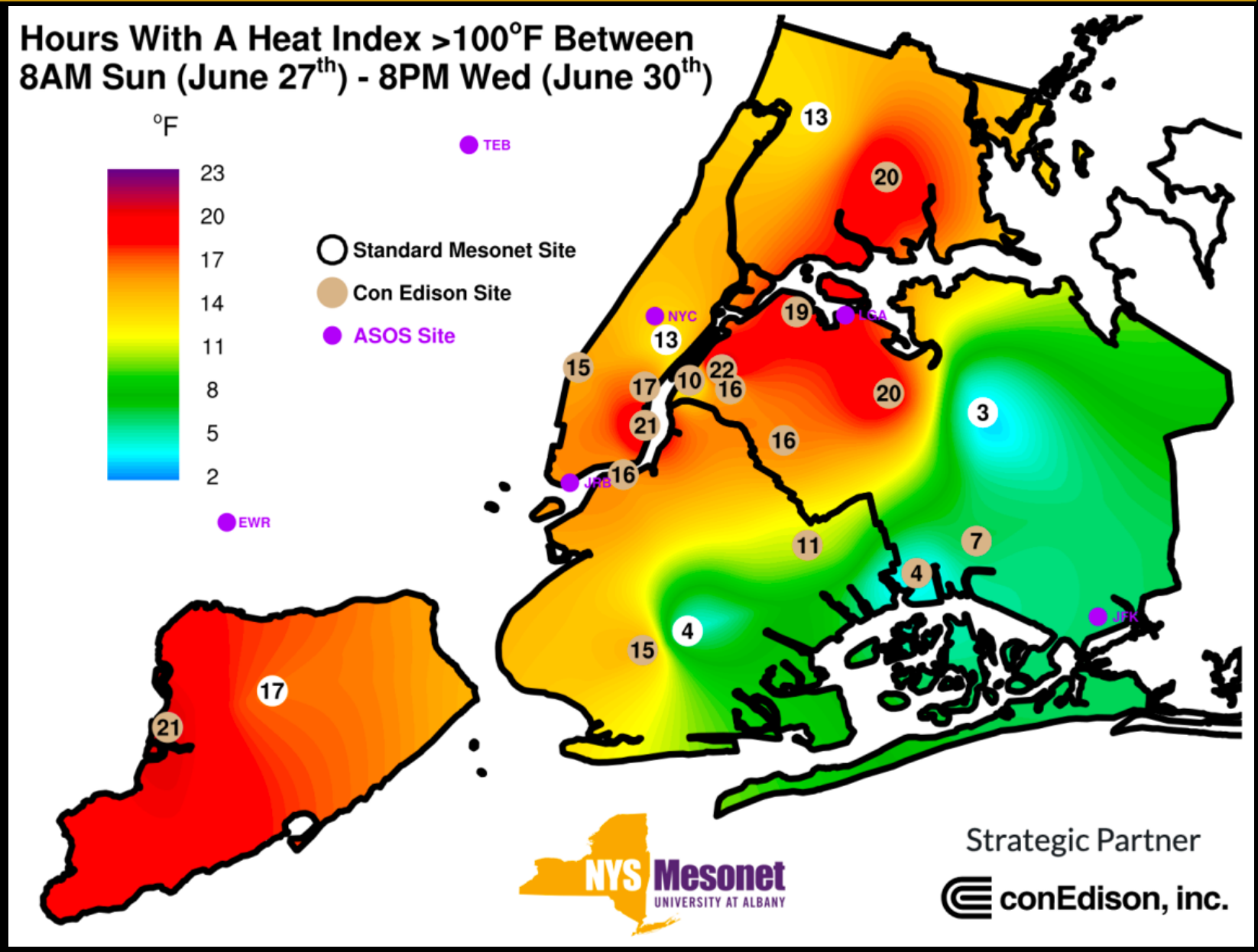
The First Big Project Heatwave

- June of 2021 saw a significant heat event in NYC
- Average area heat indices were above 90F in most places
- The average 84-hour heat index varies by 10F across Queens alone!



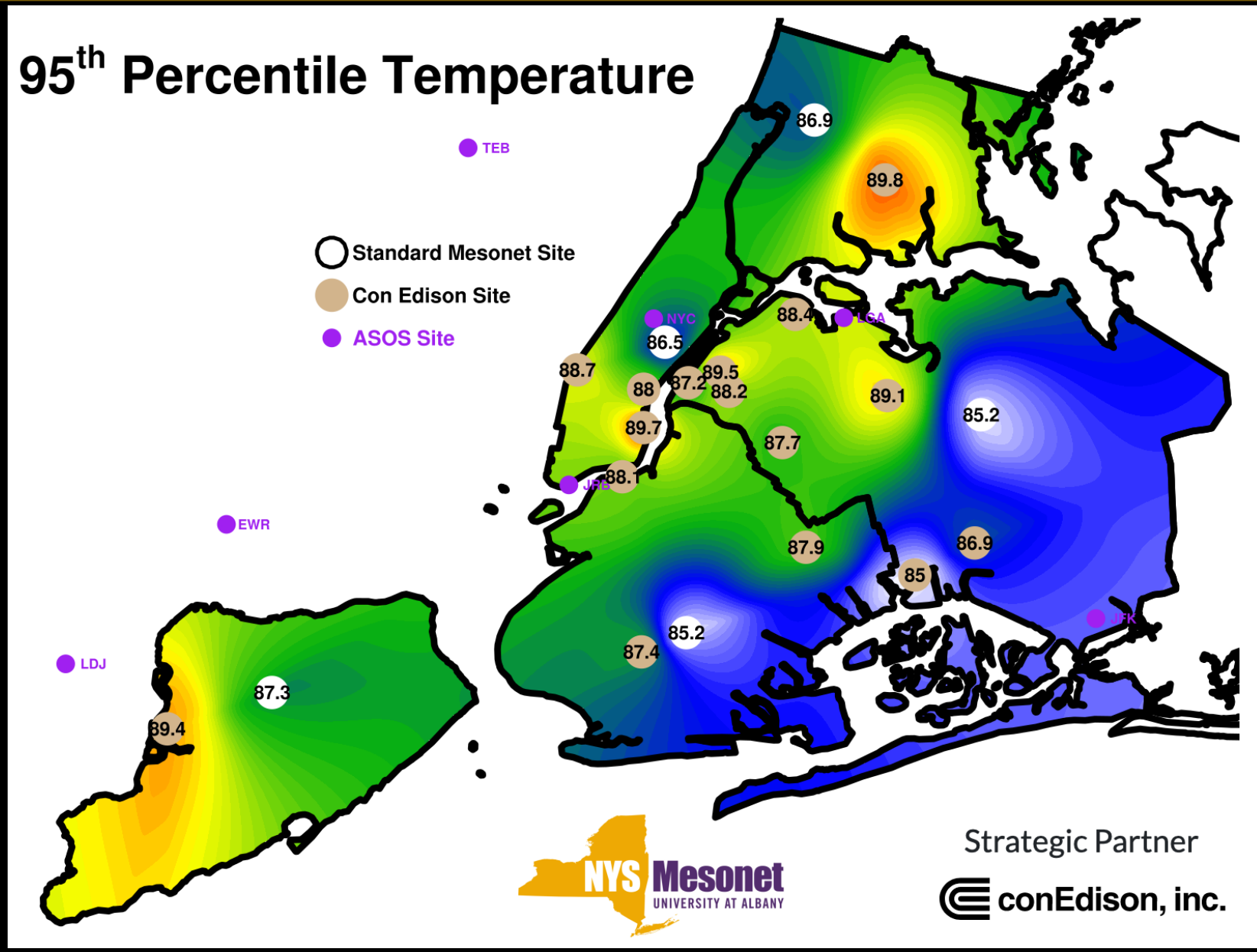
The First Big Project Heatwave

- June of 2021 saw a significant heat event in NYC
- Using an arbitrary 100F cutoff, the total hours of heat indices >100F also various quite a bit across the city
- What differences are due to weather, and what are due to siting?



A Brief Climatology

- The ConEd sites were installed in fall of 2020, so there are 2 years of data
- Use May-September of both 2021 and 2022 to calculate the 95th percentile
- Temperature takeaway: standard sites are lower than ConEd sites



A Brief Climatology

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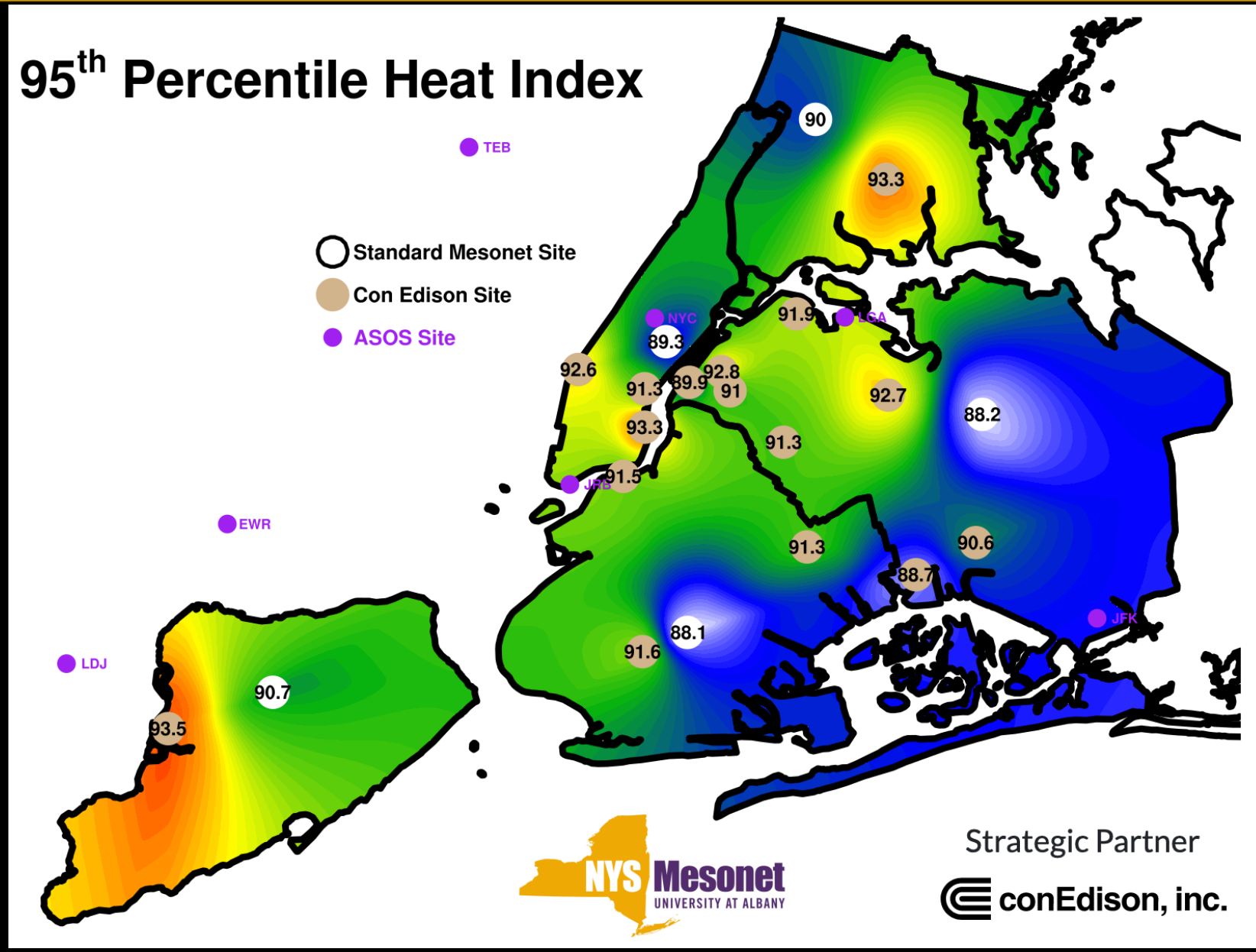
- Use May-September of both 2021 and 2022 to calculate the 95th percentile
- Heat Index displays a similar pattern



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."
- NWS definition

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

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	
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.

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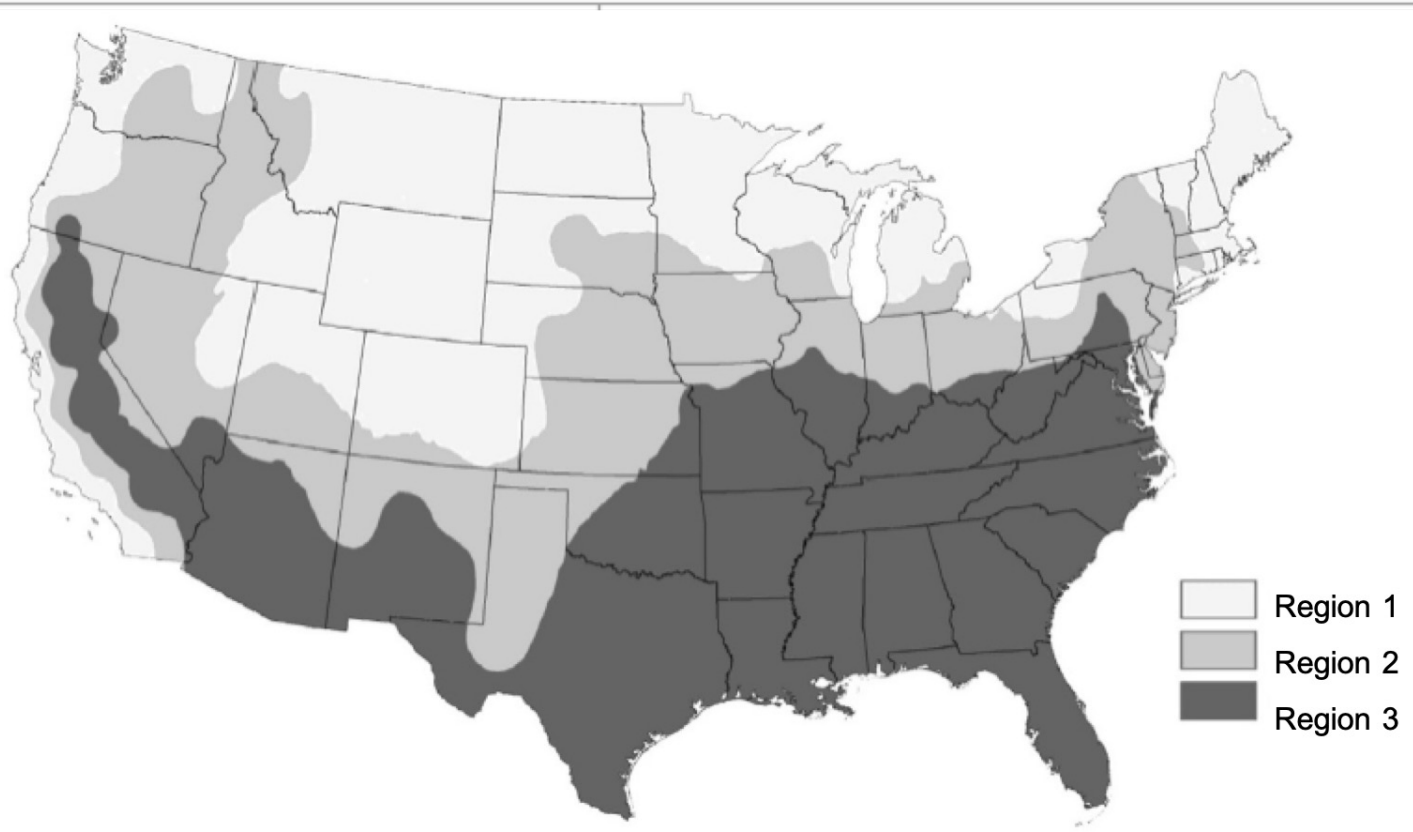

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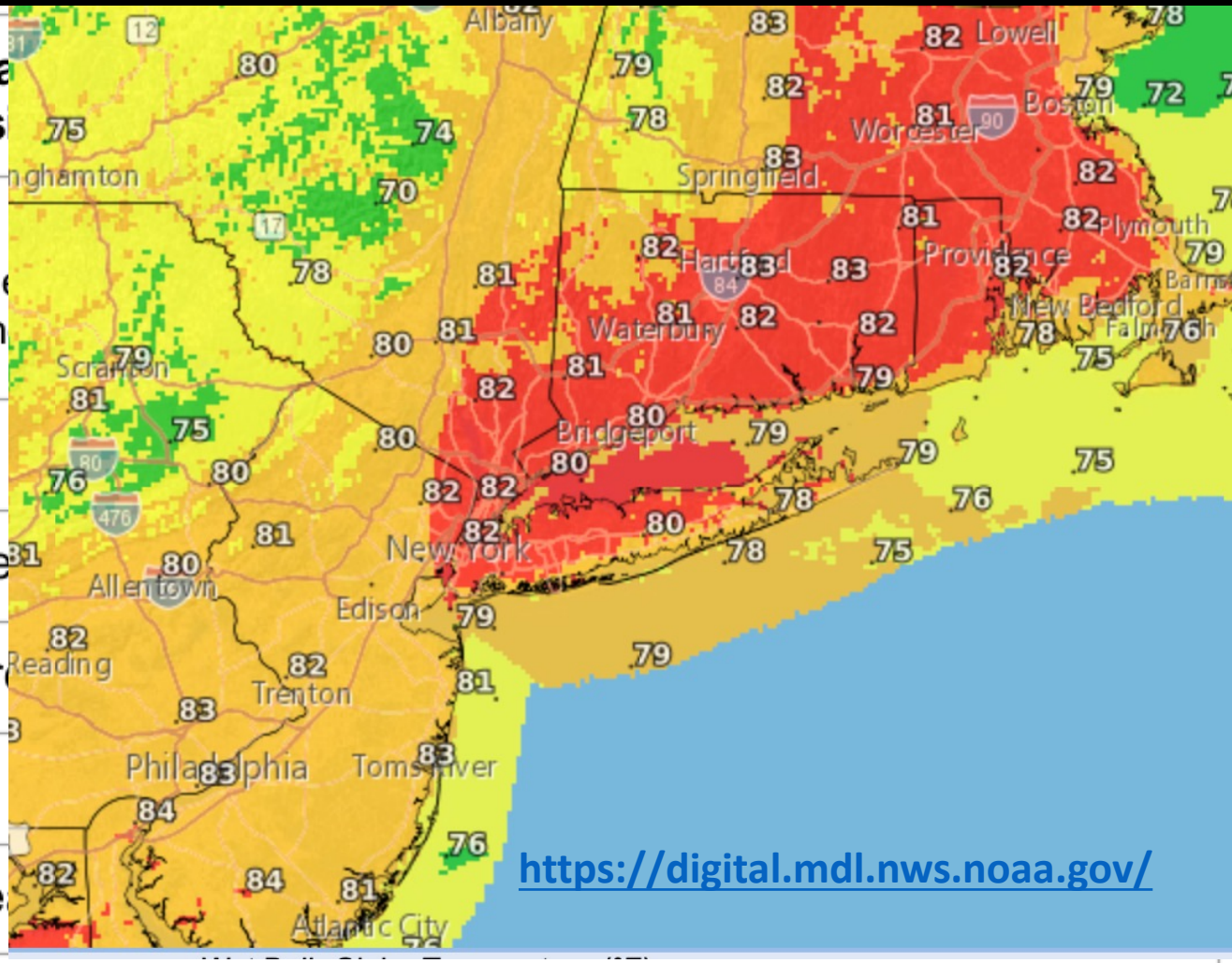

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How Is Wet Bulb Globe Temperature Calculated?

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:

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

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:

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

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:$\sigma=5.67\times10^{-8}$ is used.

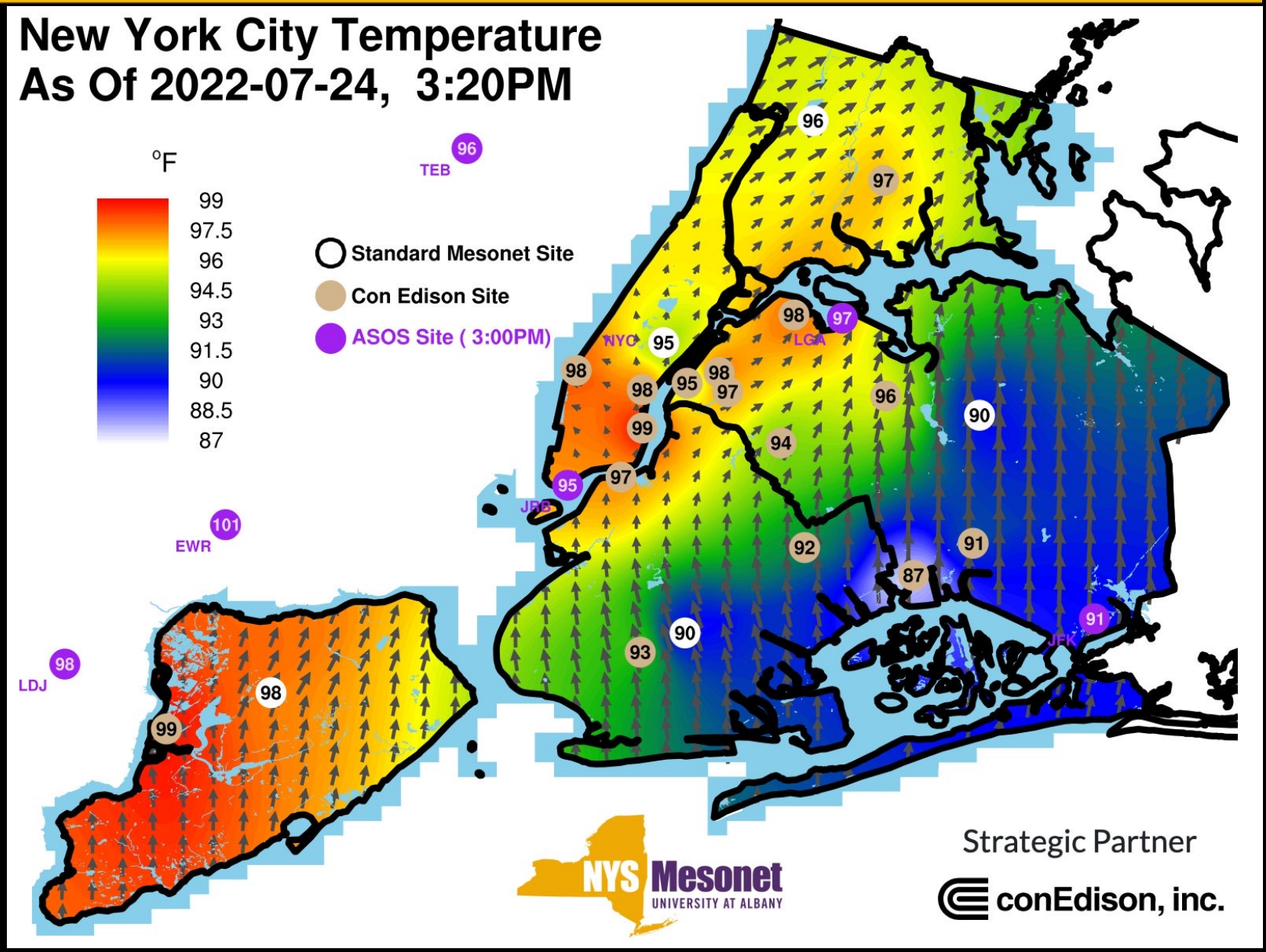
Albedo for grassy surfaces: α_{es}= 0.2.

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

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

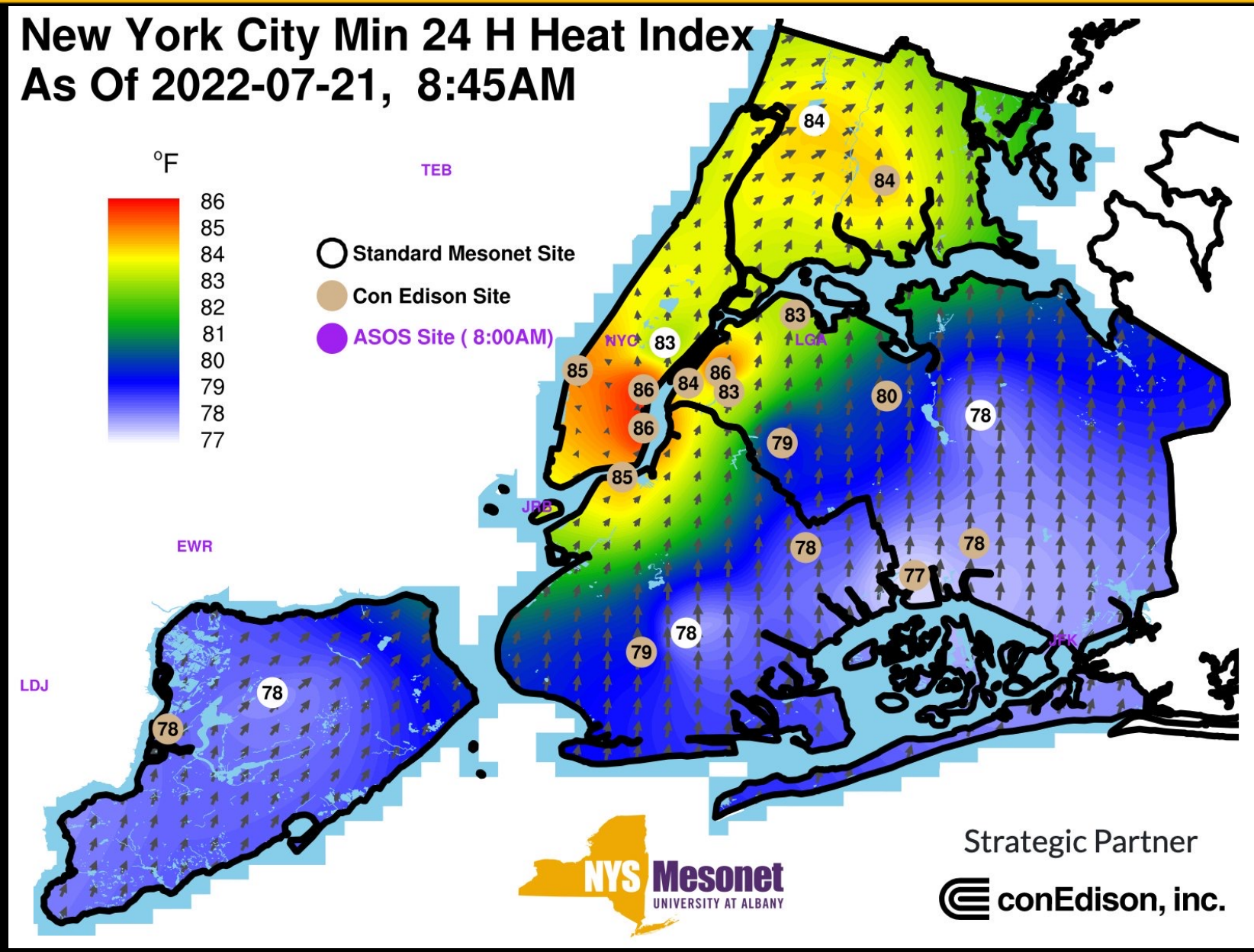
Latest Realtime Test Products

Near the end of year 1 (of 3) of this project, we have combined NYS Mesonet and ASOS data



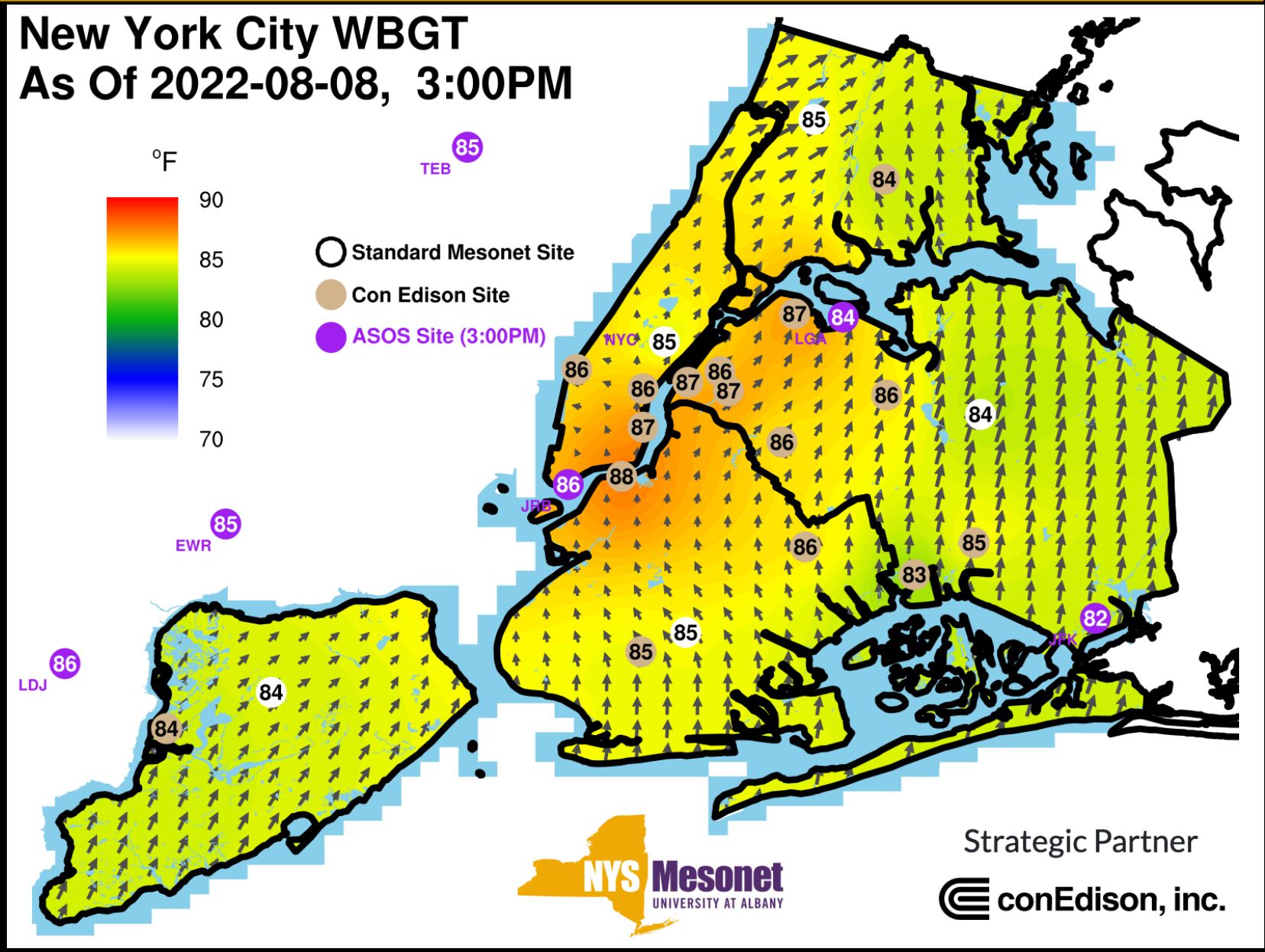
Latest Realtime Test Products

… and added a few extra heat products …

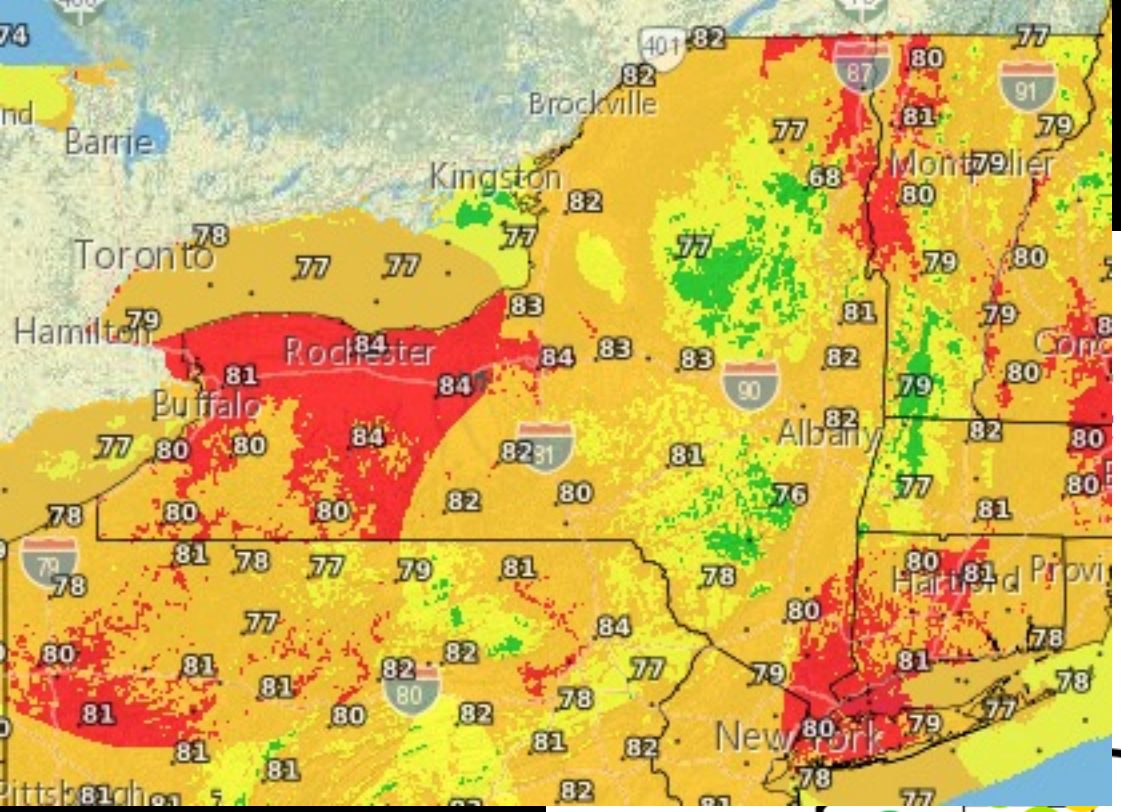


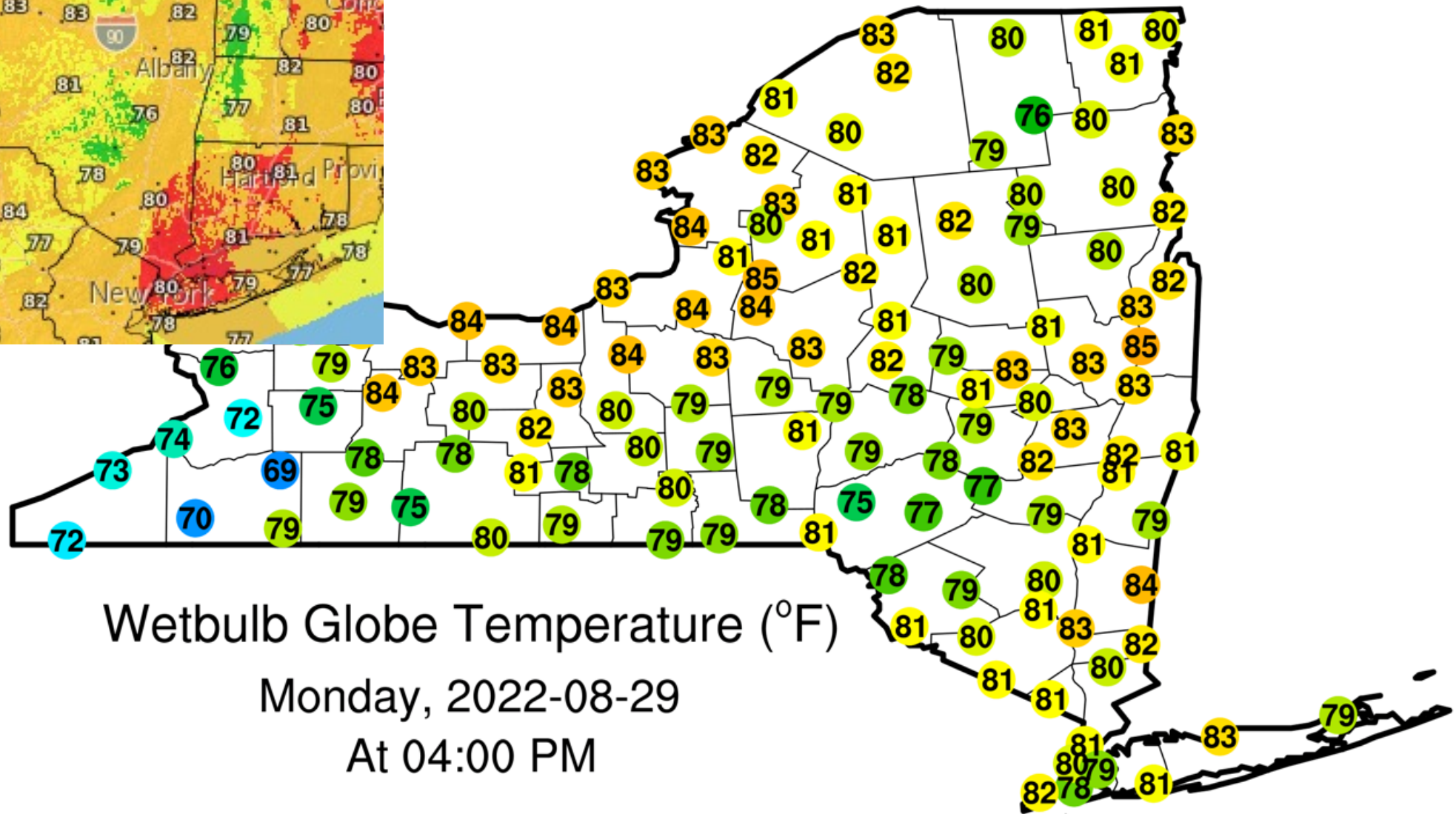
Latest Realtime Test Products

… including WBGT



Statewide WBGT





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

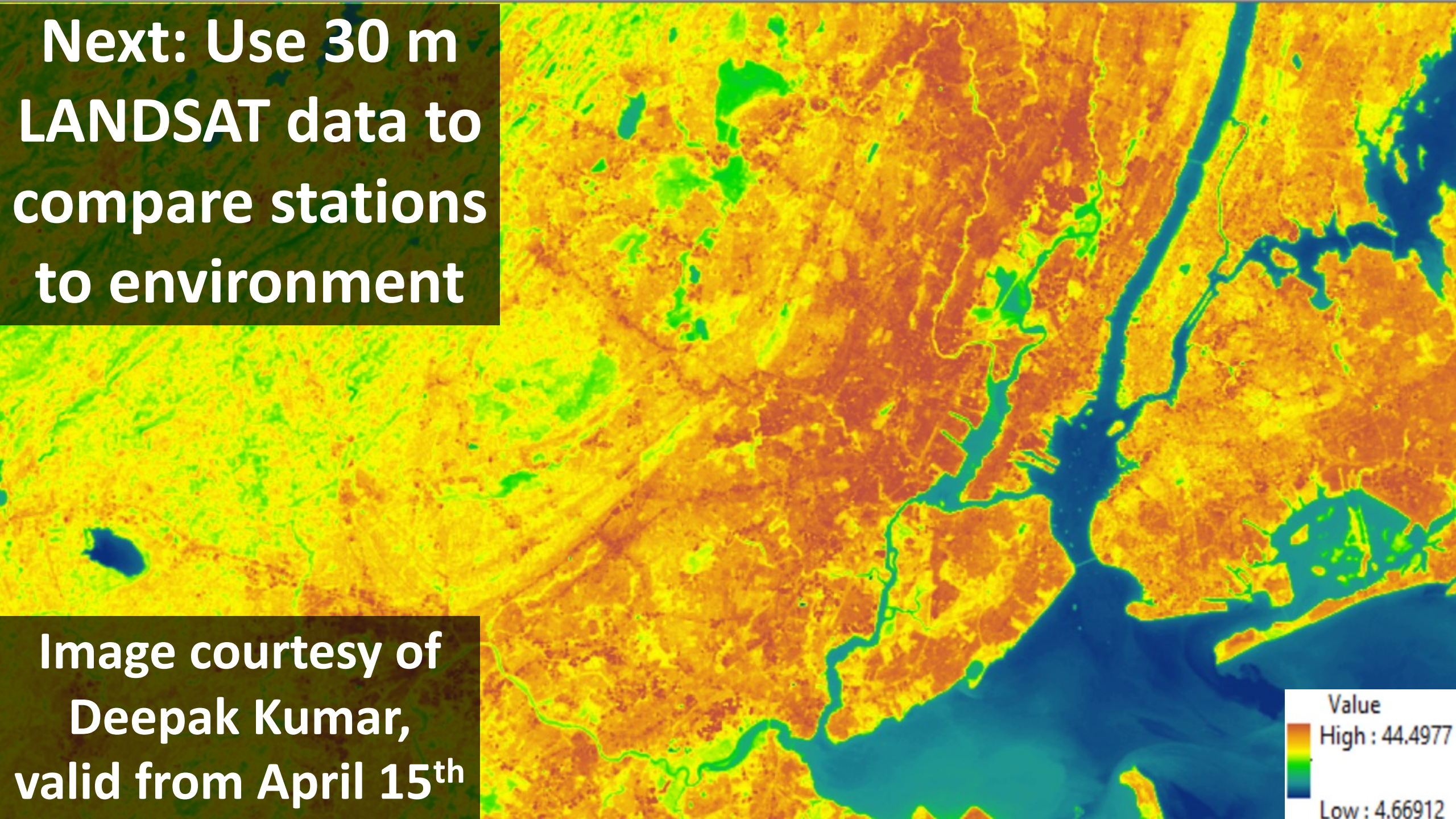
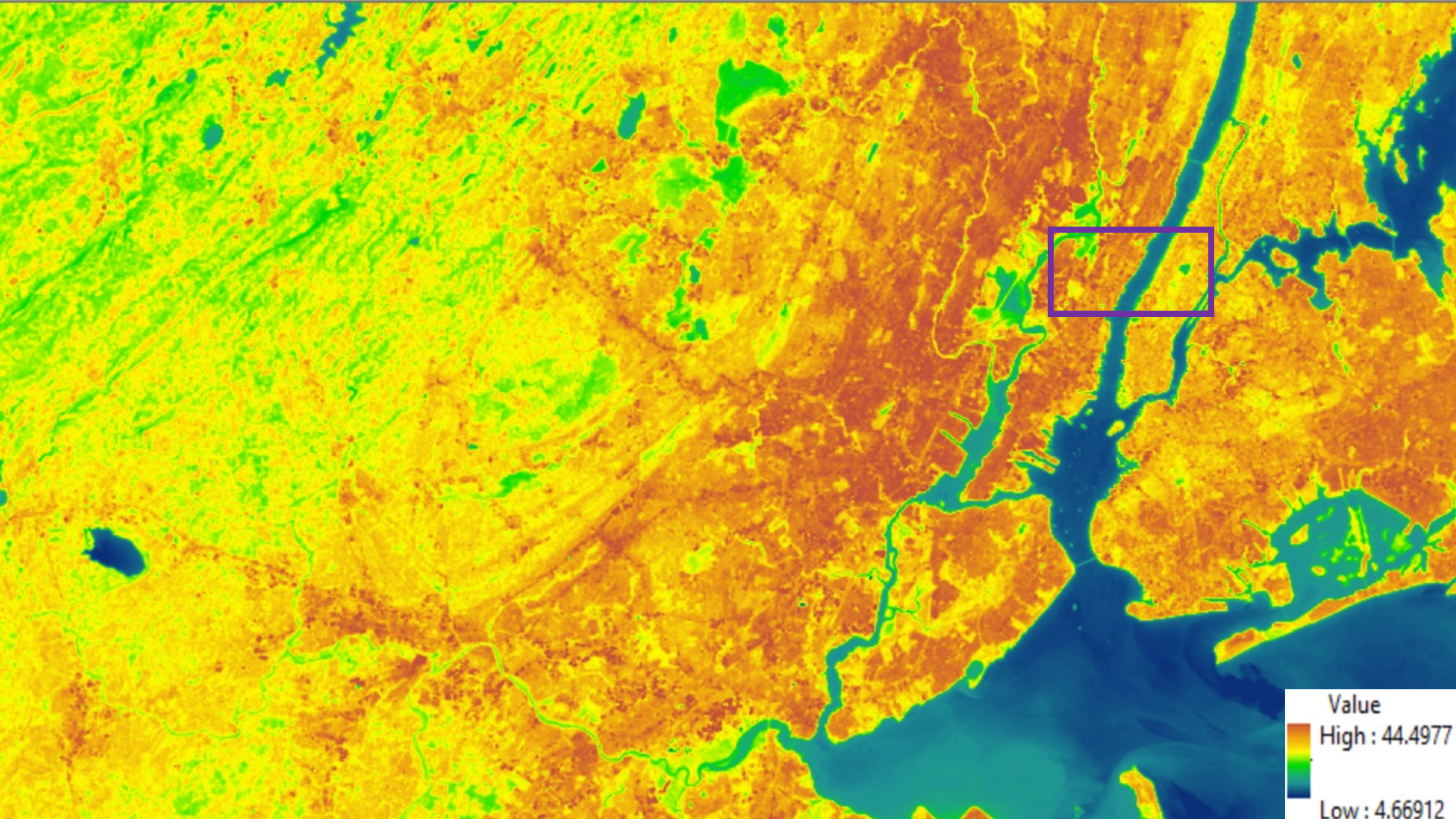
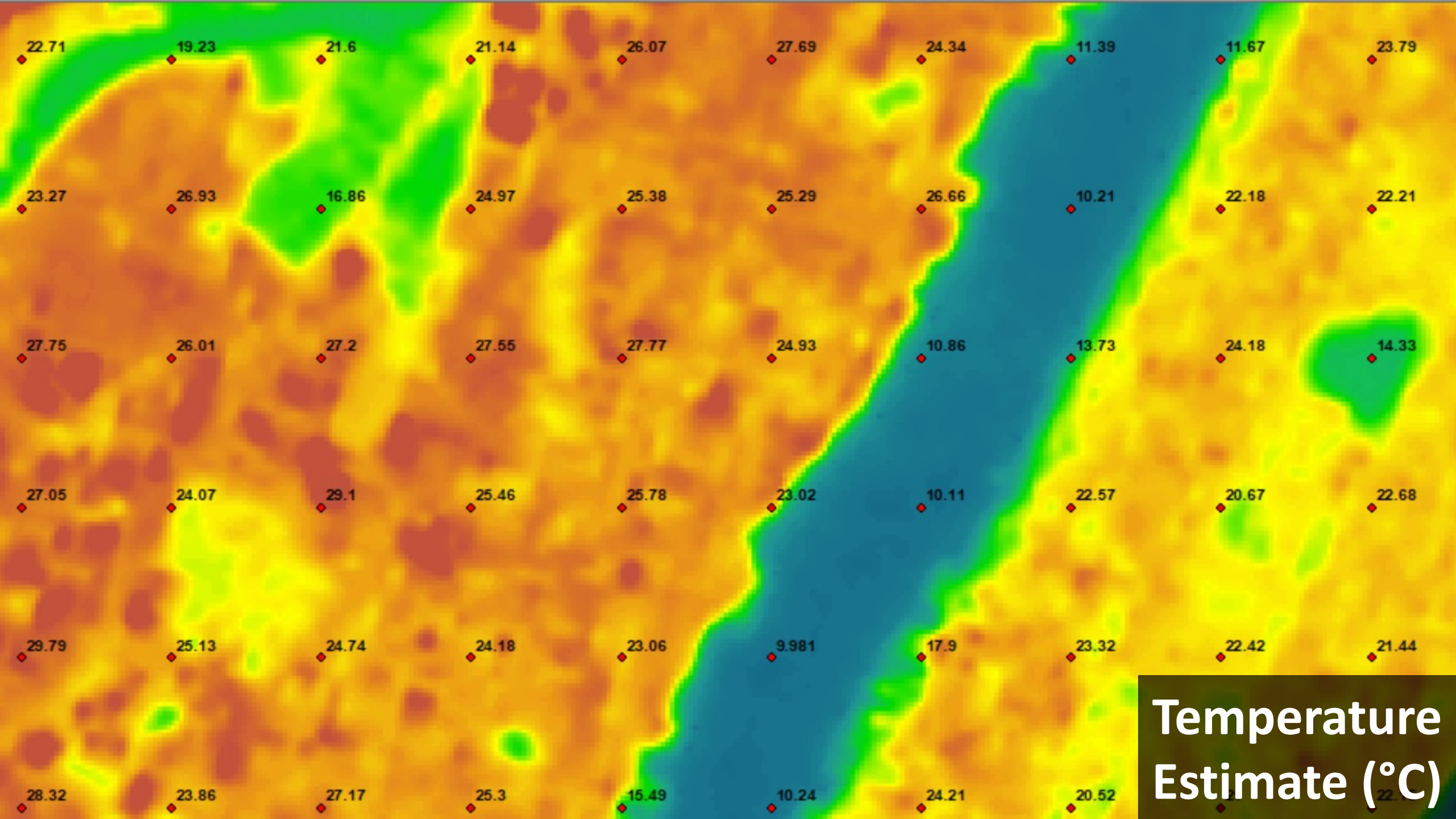


Image courtesy of Deepak Kumar, valid from April 15th


Value
High : 44.4977
Low : 4.66912

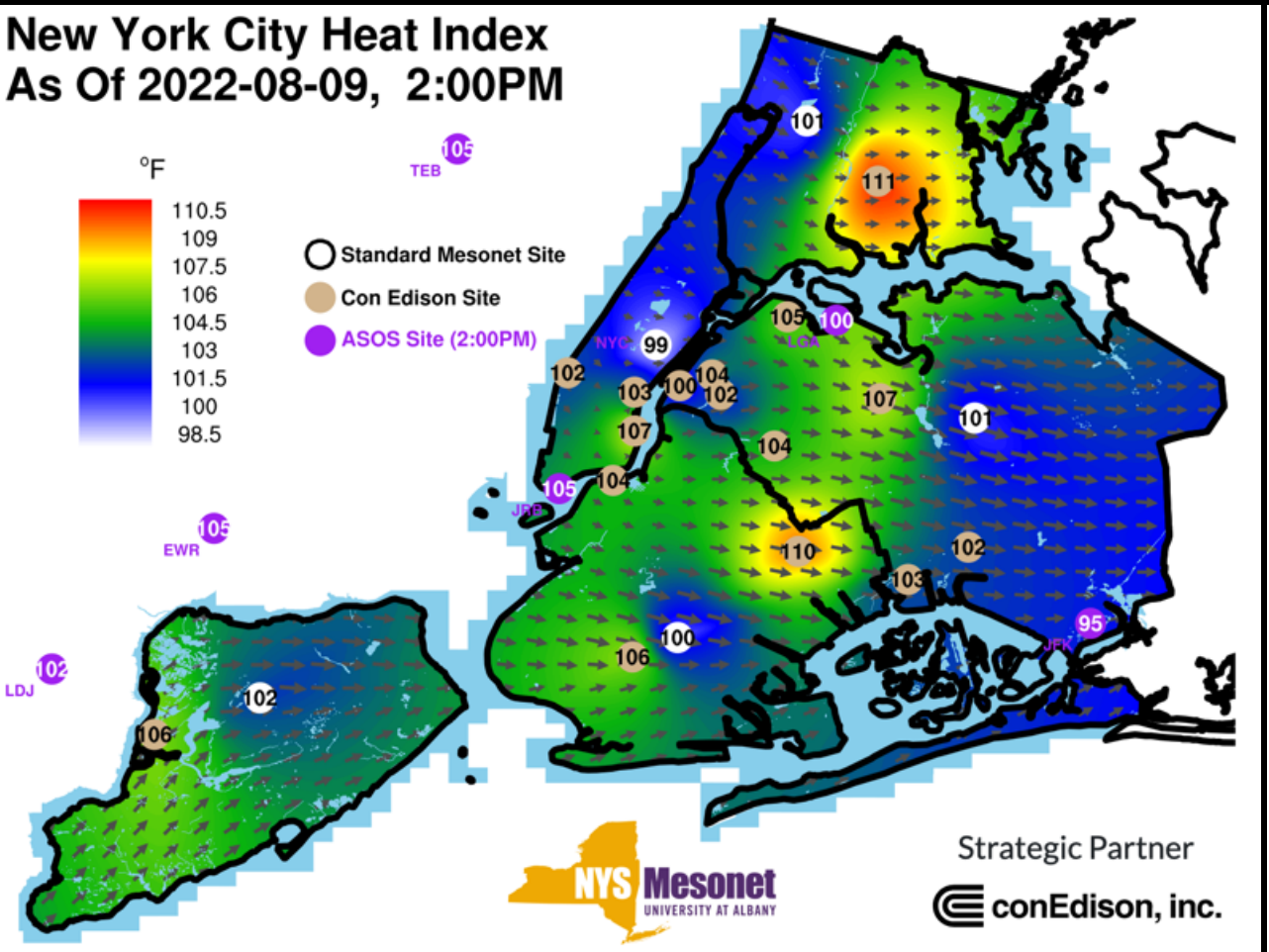

22.71
19.23
21.6
21.14
26.07
27.69
24.34
11.39
11.67
23.79
23.27
26.93
16.86
24.97
25.38
25.29
26.66
10.21
22.18
22.21
27.75
26.01
27.2
27.55
27.77
24.93
10.86
13.73
24.18
14.33
27.05
24.07
29.1
25.46
25.78
23.02
10.11
22.57
20.67
22.68
29.79
25.13
24.74
24.18
23.06
9.981
17.9
23.32
22.42
21.44
28.32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

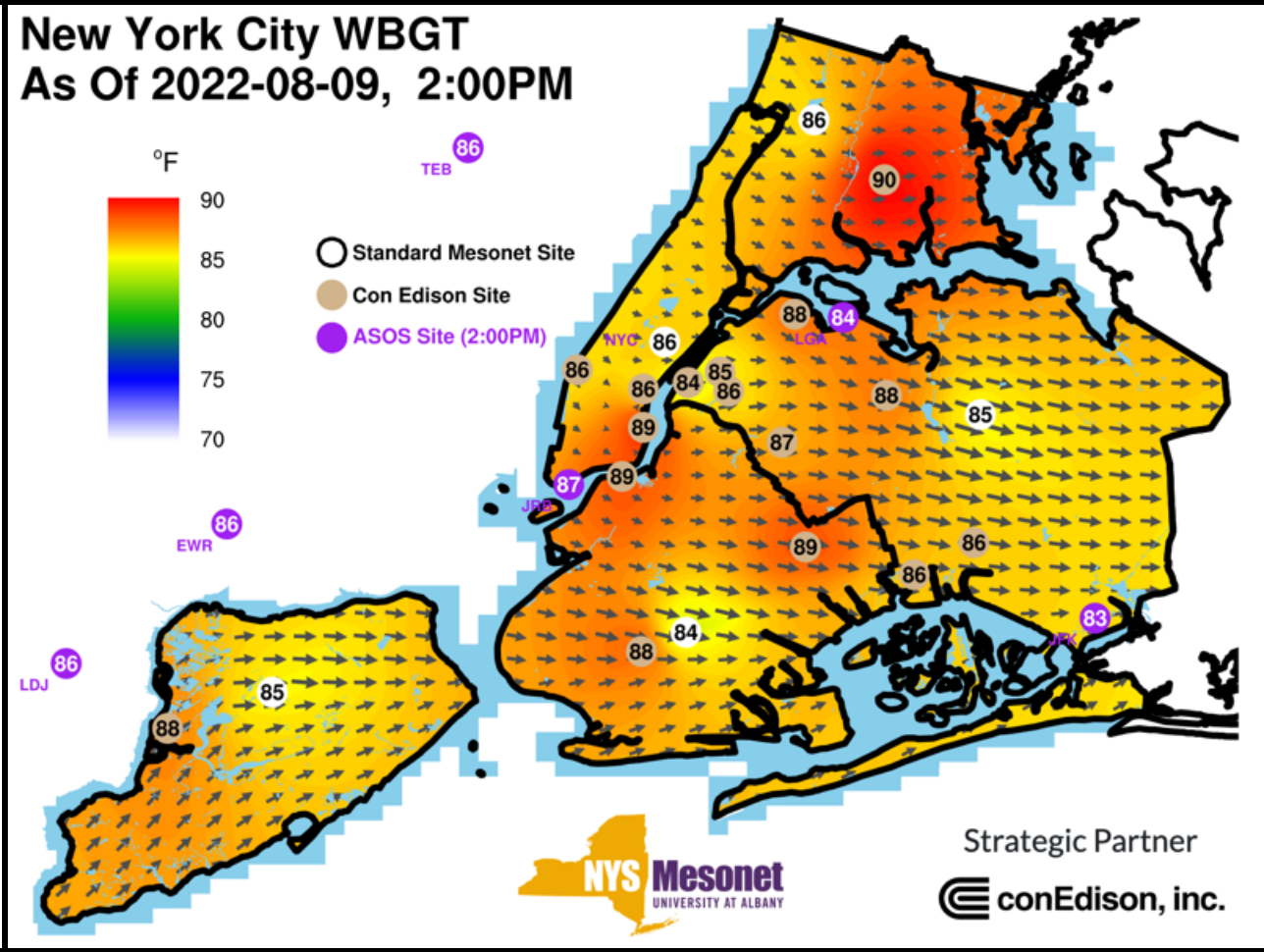
Thanks!

Photo courtesy of Dave Radell

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

Comparing Heat Index to WBGT





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

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.**

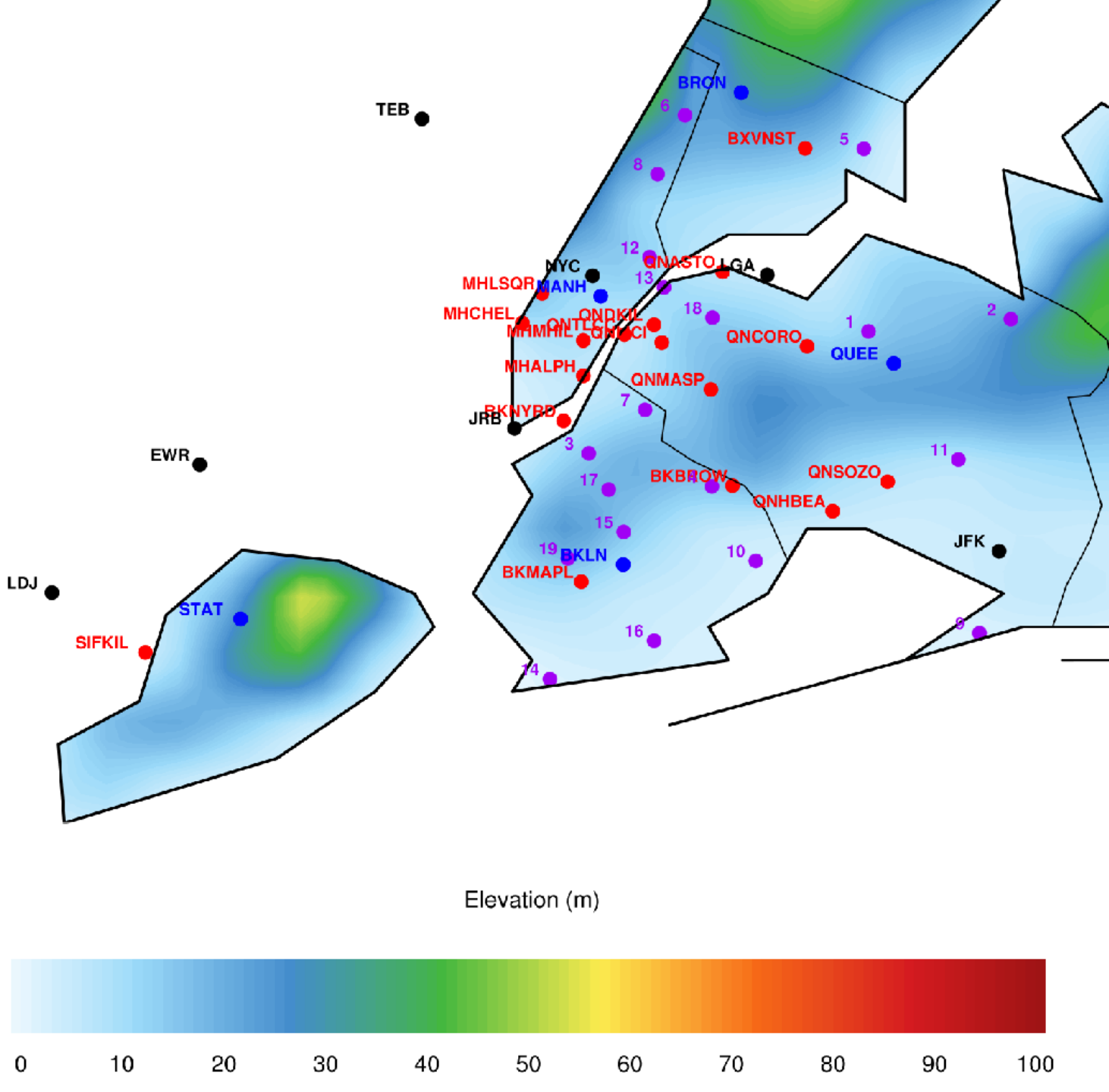
Proposed Network Of Opportunity

-ASOS (Black)

-NYS Mesonet (Blue)

-ConEd Micronet (Red)

-CUNY (Purple)



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?