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

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Session 5: Urban Environmental And Health Impacts I

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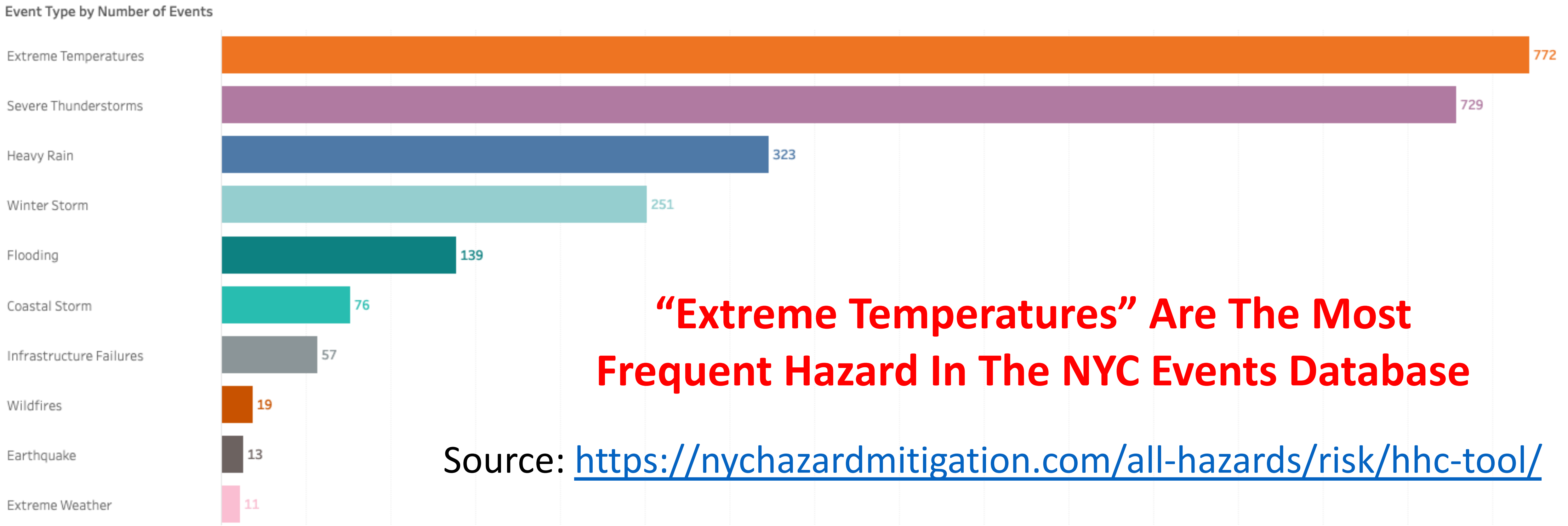
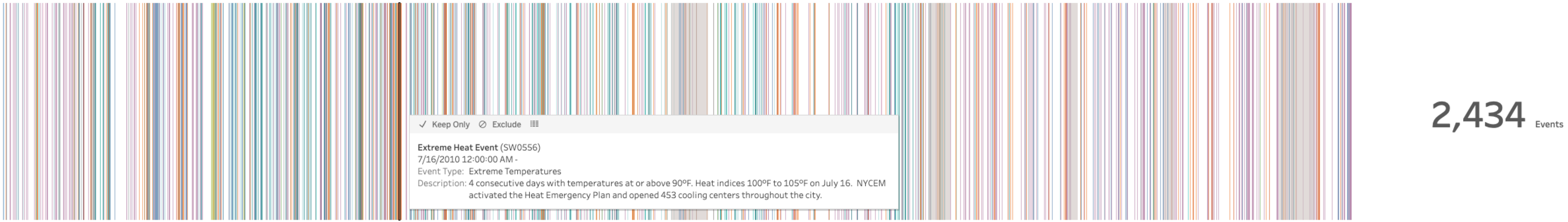
Motivation: Extreme Temperatures In NYC



"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

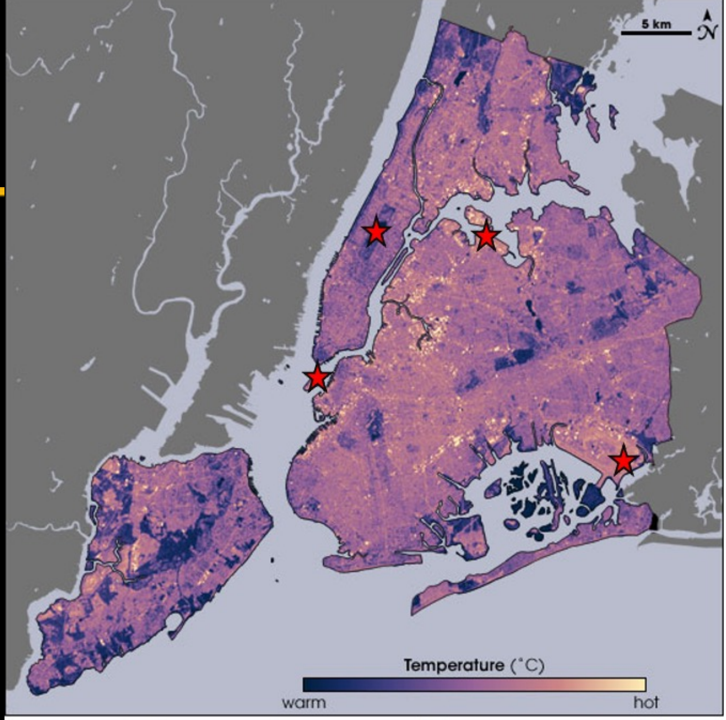
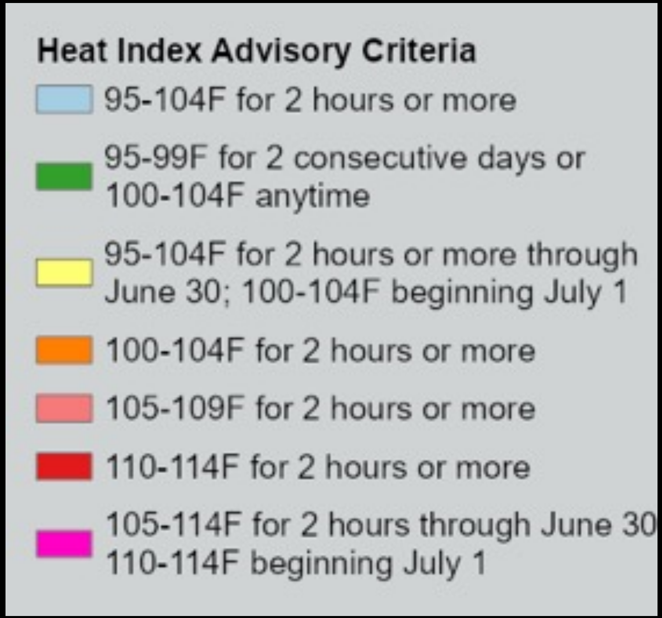


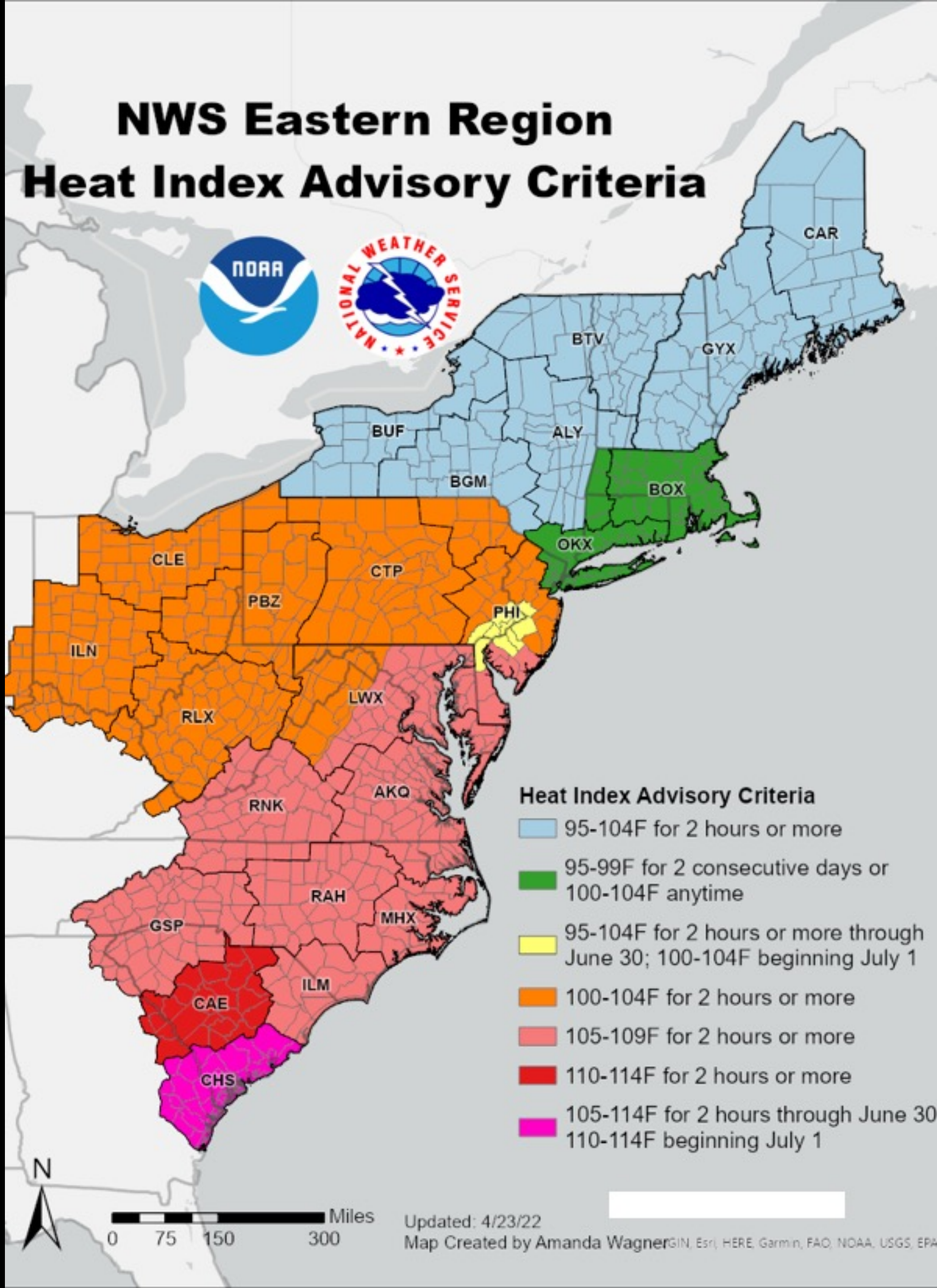
Image source: Landsat image from August 14th, 2002, with ASOS locations annotated

The National Weather Service Issues Two Primary Heat Products

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



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



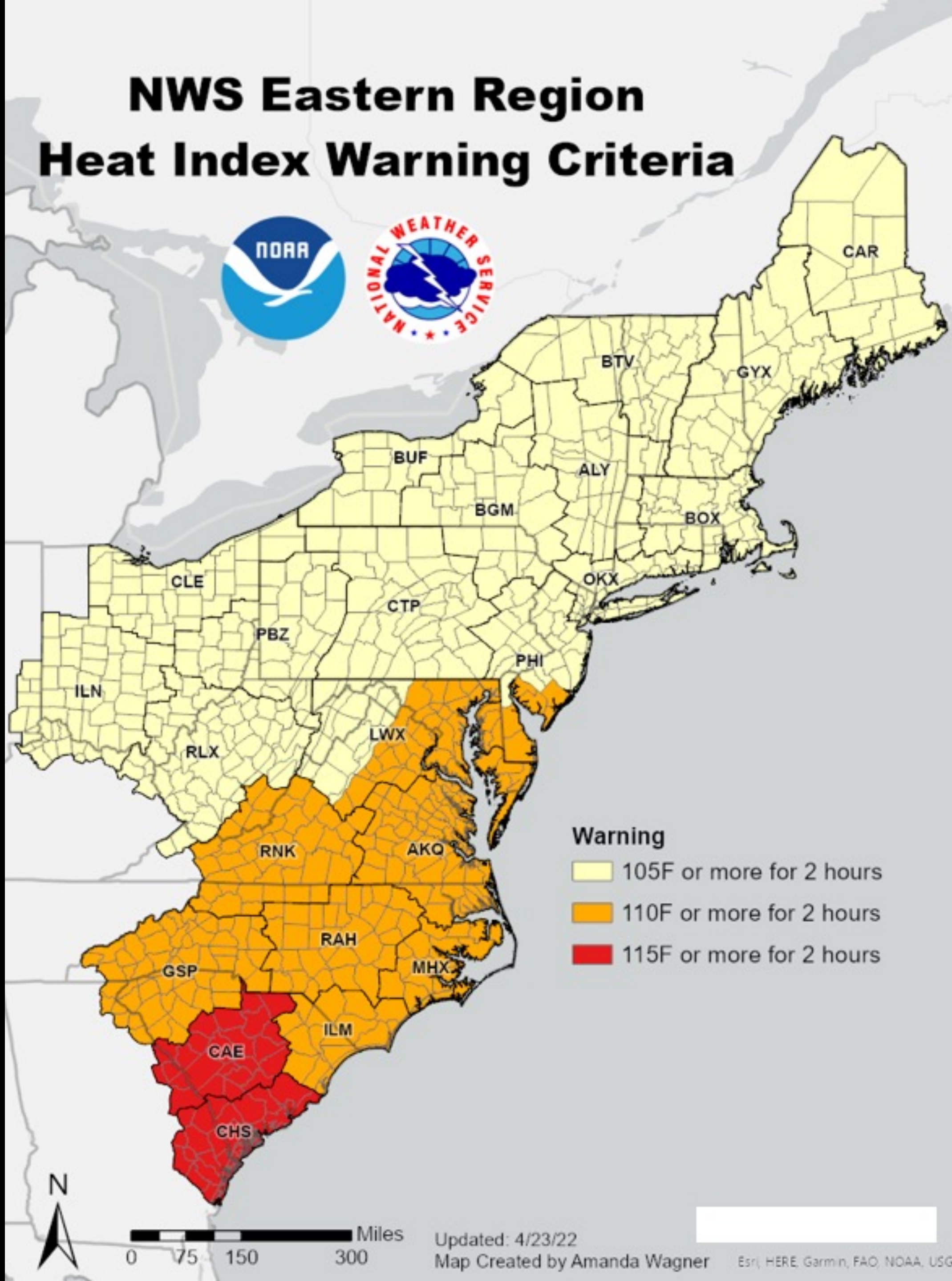
The National Weather Service Issues Two Primary Heat Products

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

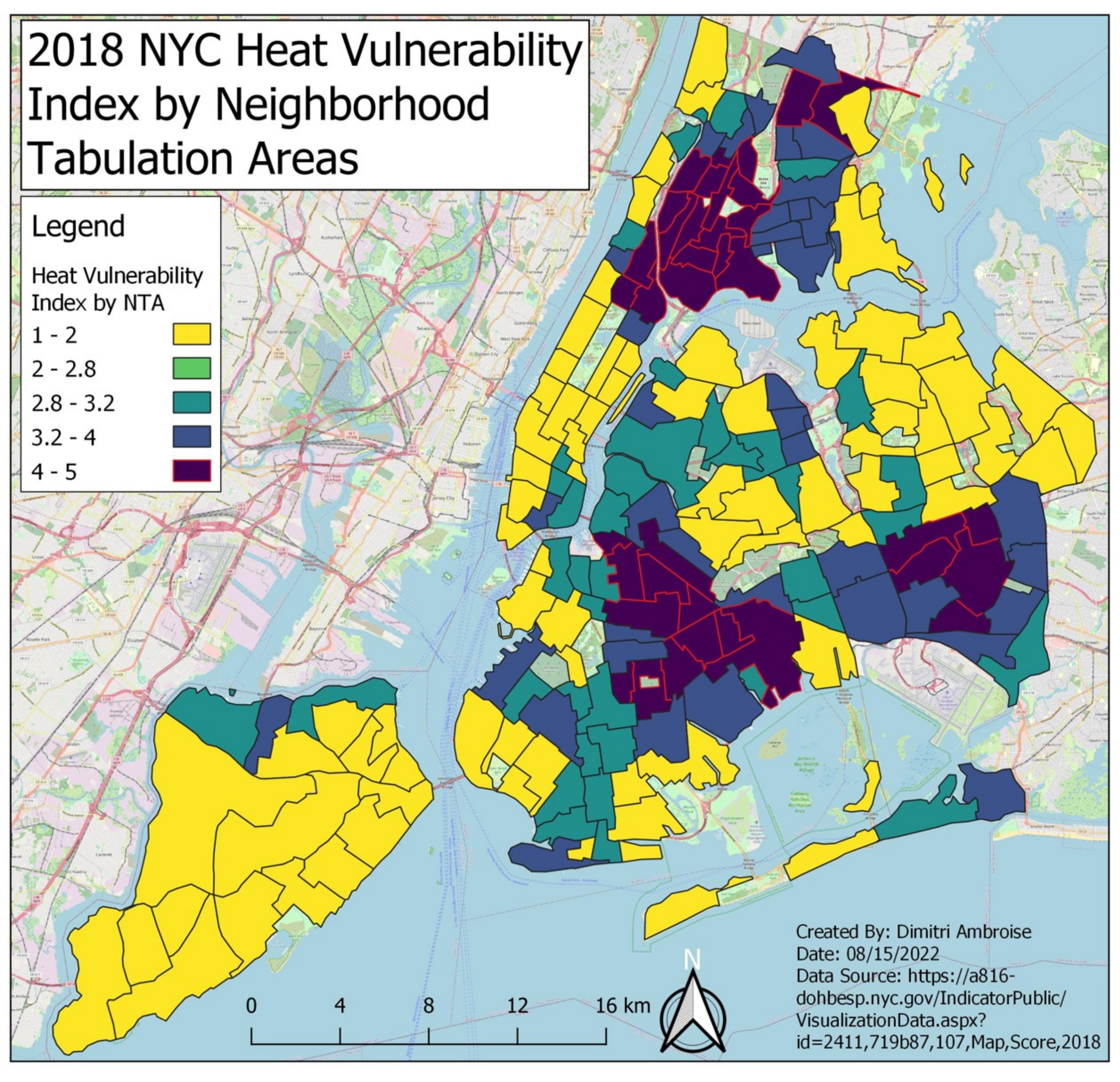
Warning

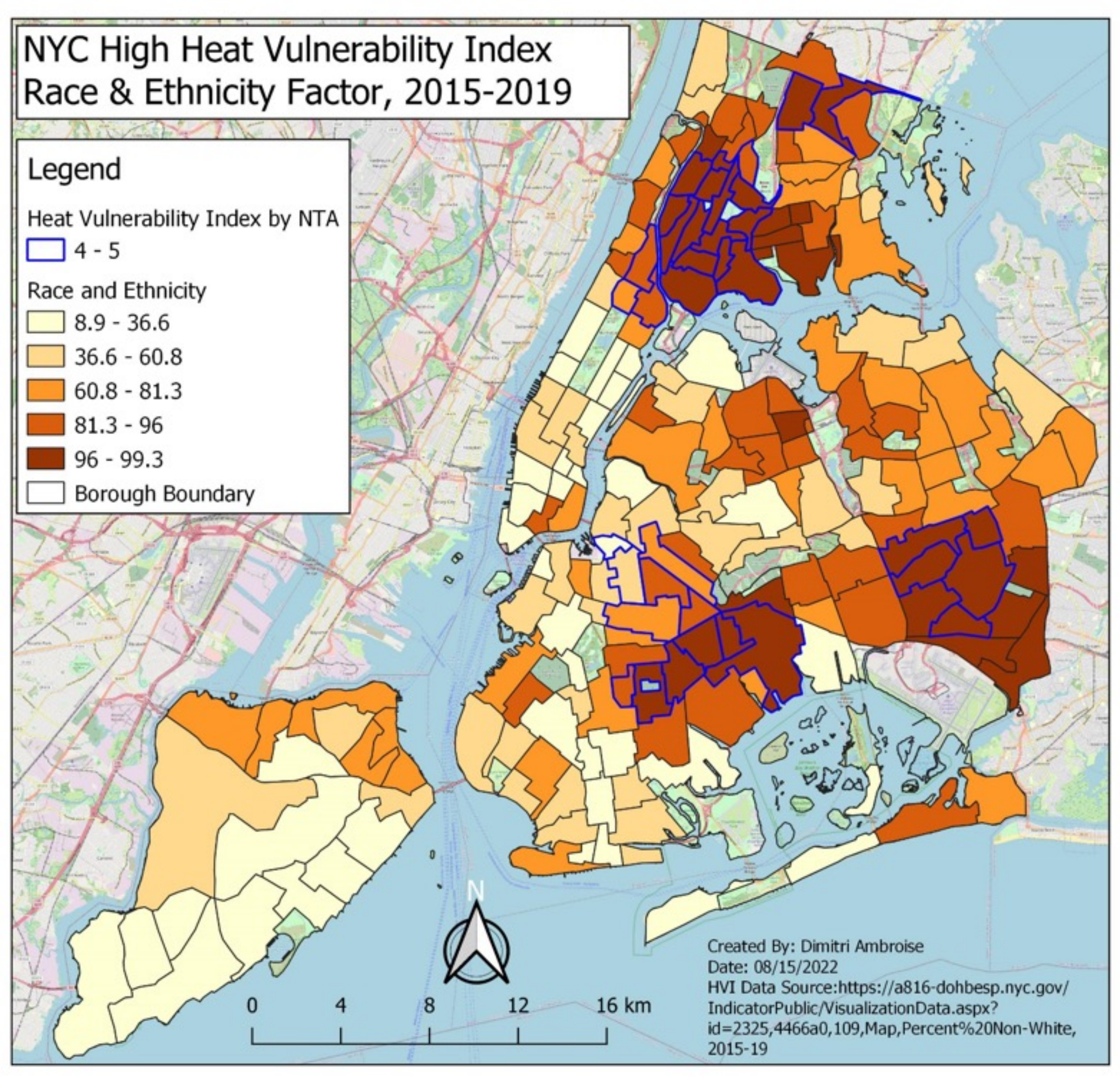
- 105F or more for 2 hours
- 110F or more for 2 hours
- 115F or more for 2 hours

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



NYC Neighborhoods: Maps By NERTO Student Dimitri Ambroise





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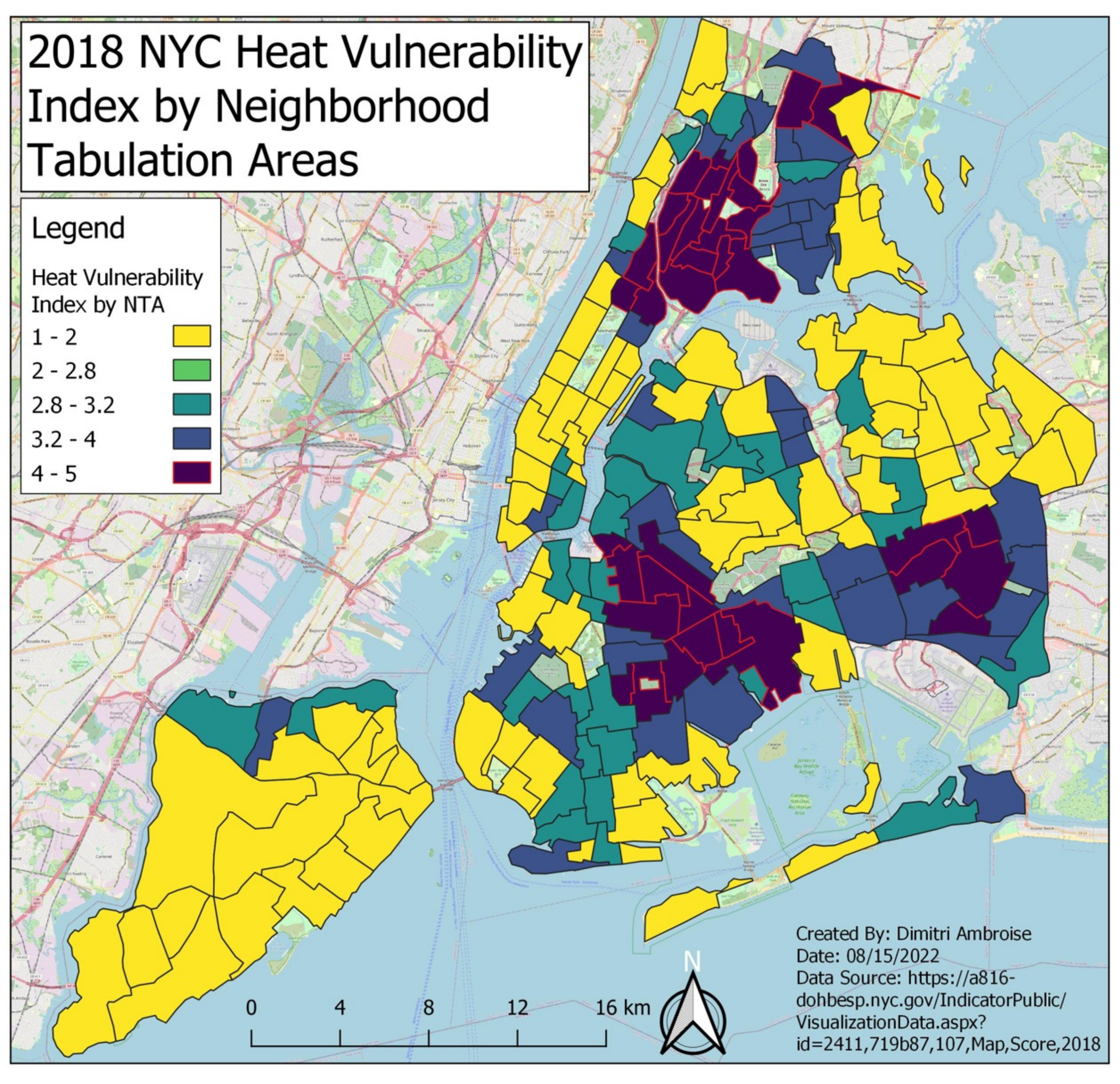

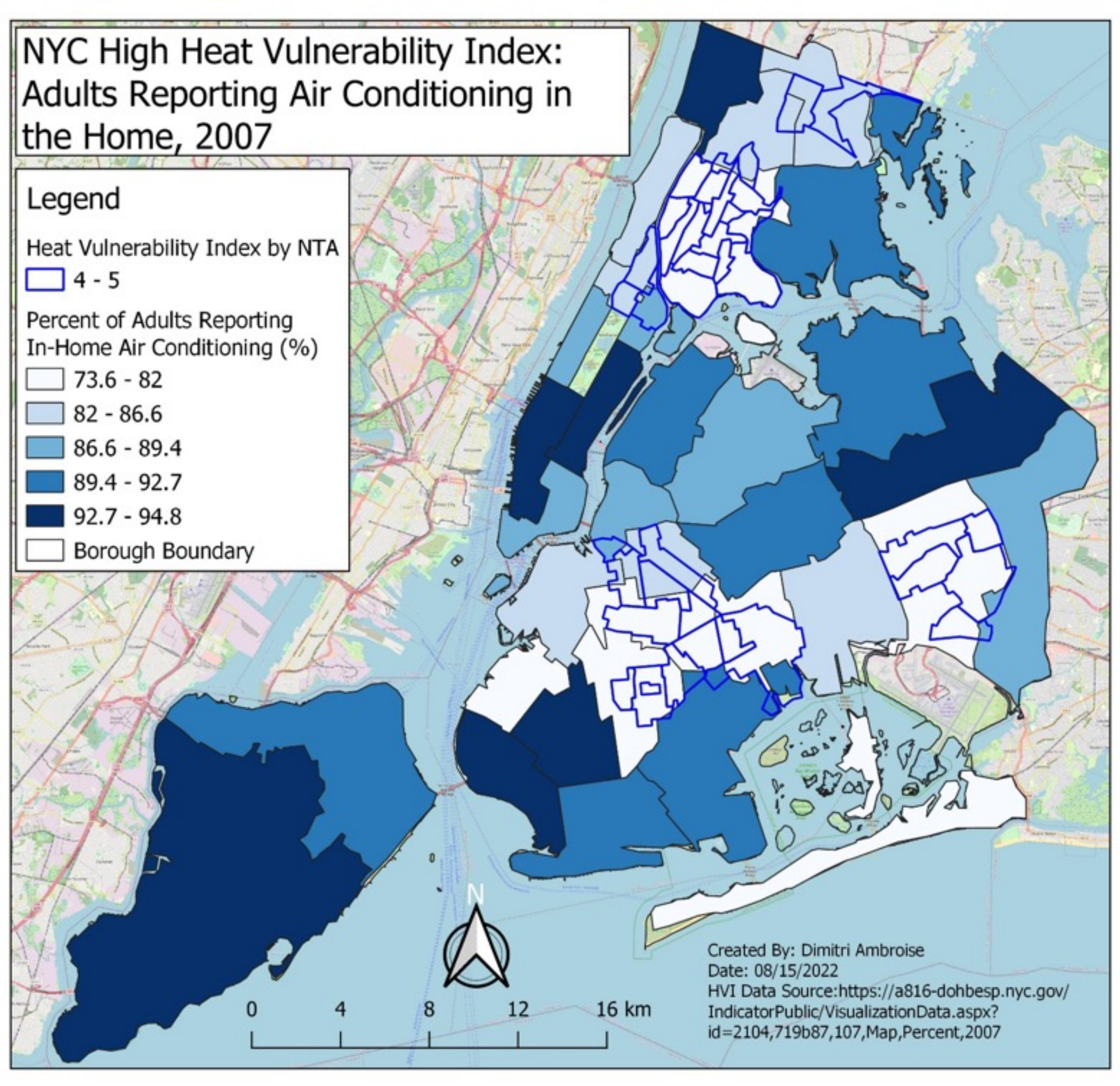

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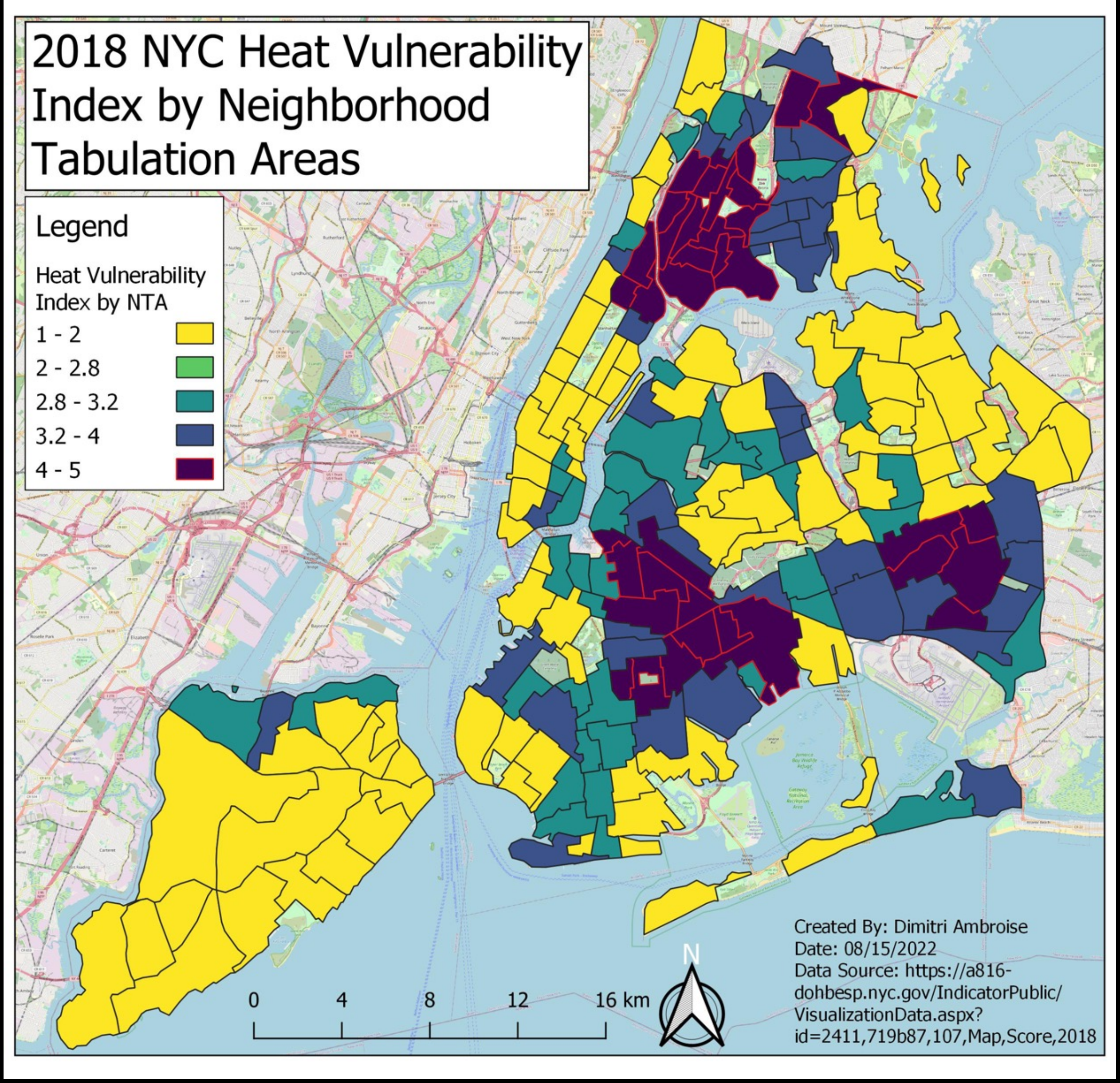
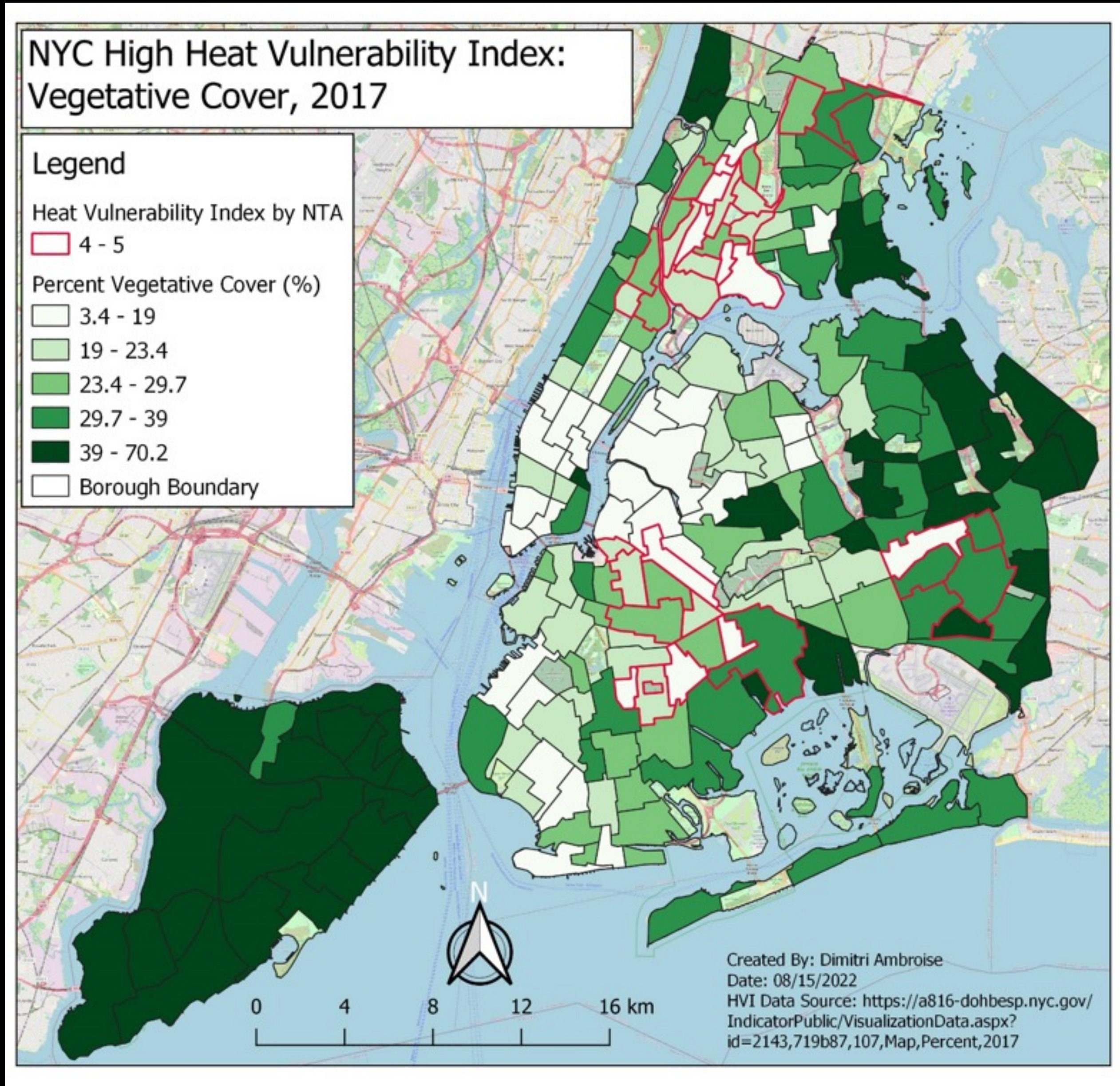
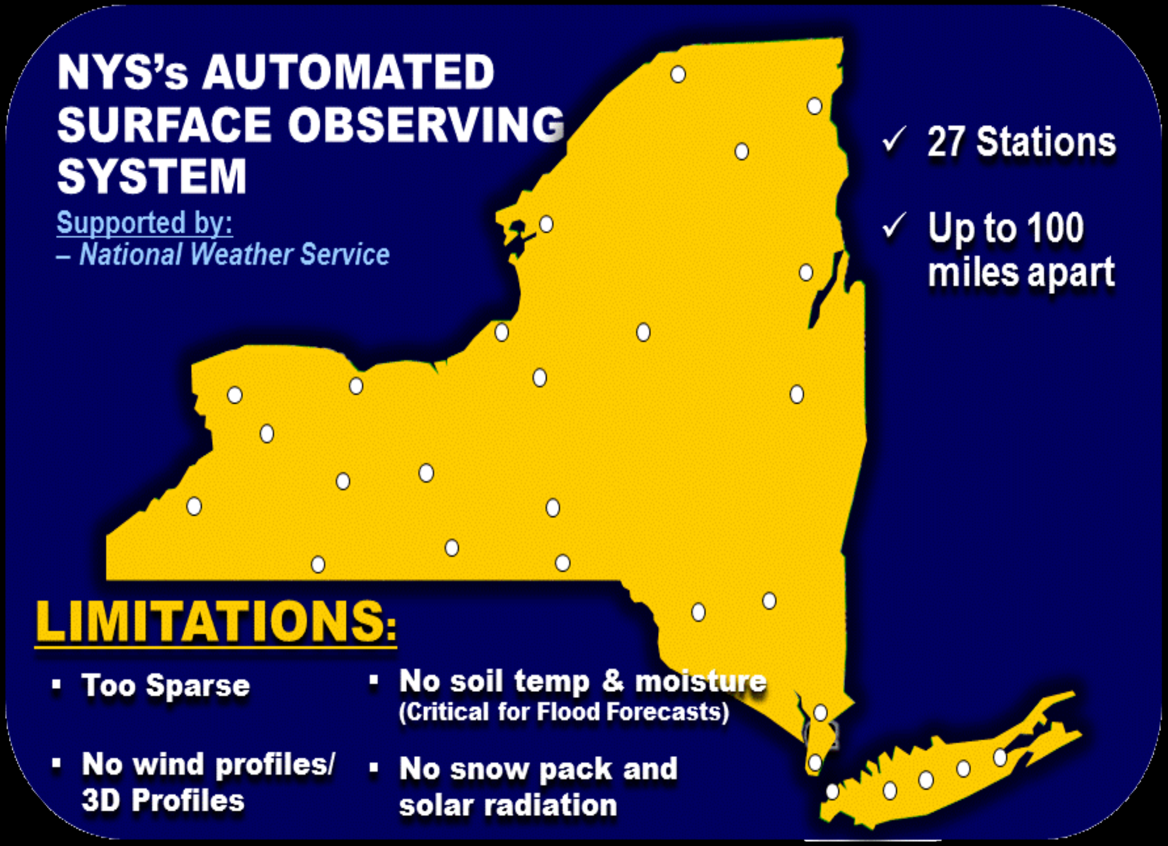




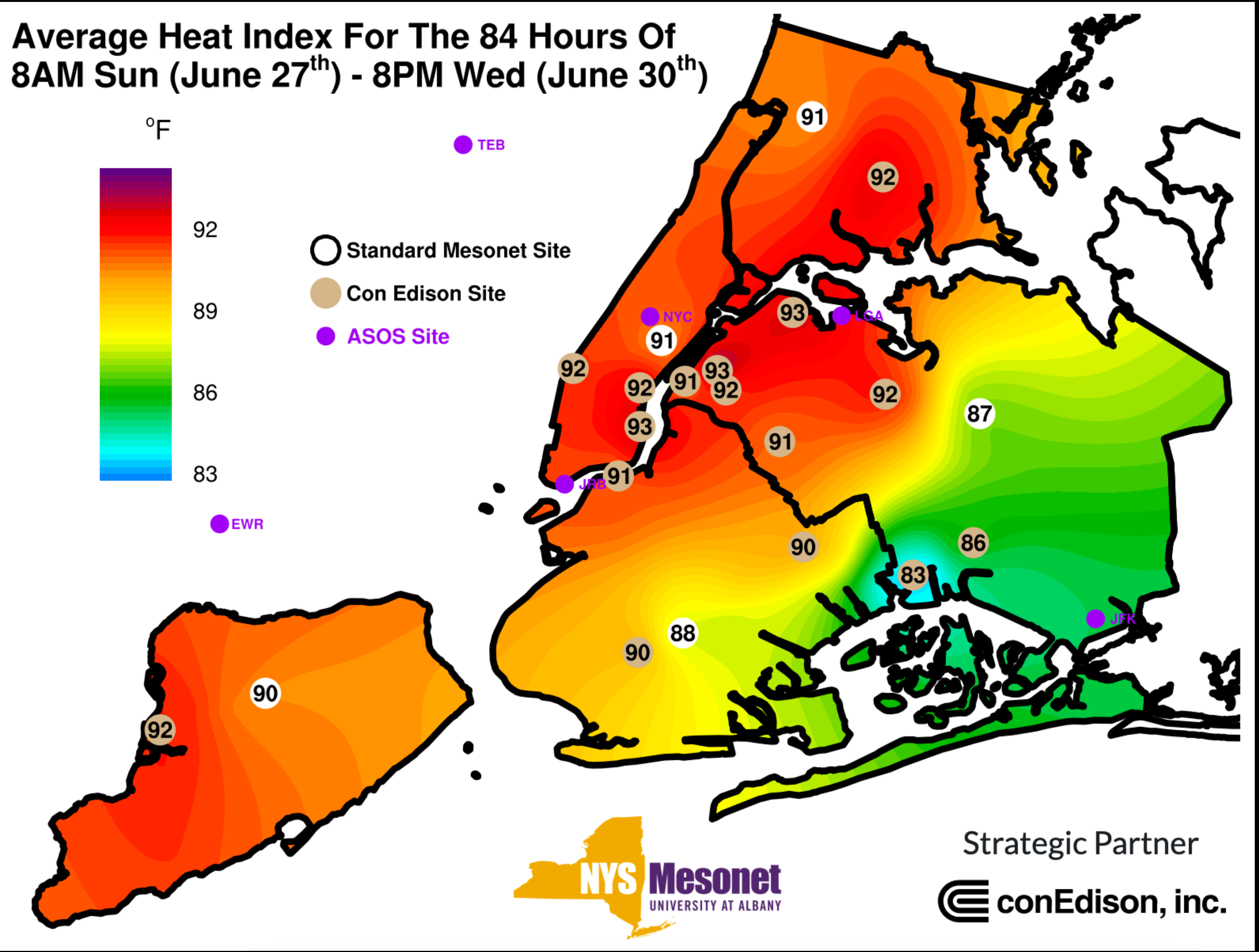
New York State Mesonet Overview

- $30M network conceived after Hurricane Irene (2011) and funded after Hurricane Sandy (2012)
- All standard 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



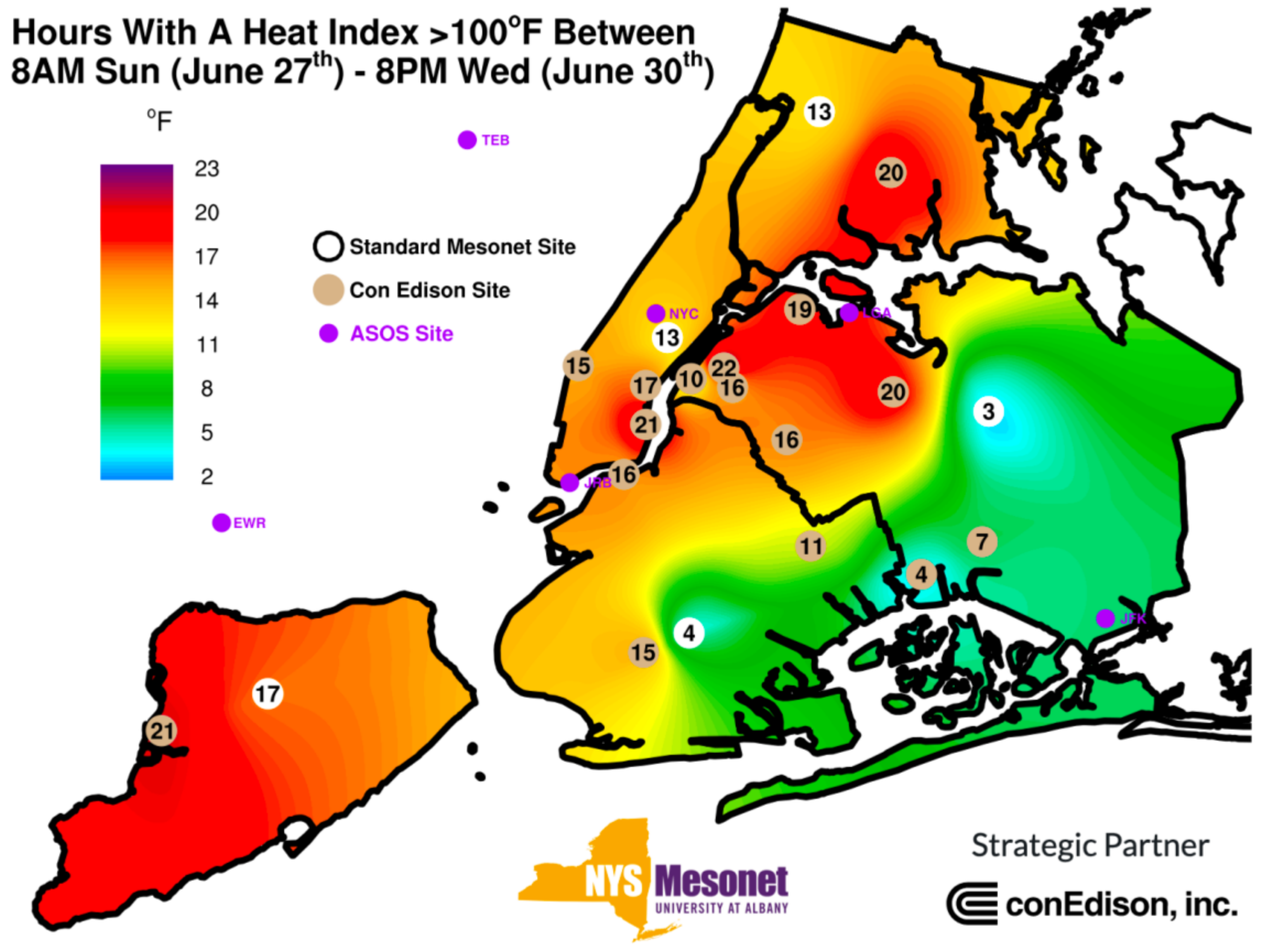
The First Big Project Heatwave: 84 Hours

- June 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!



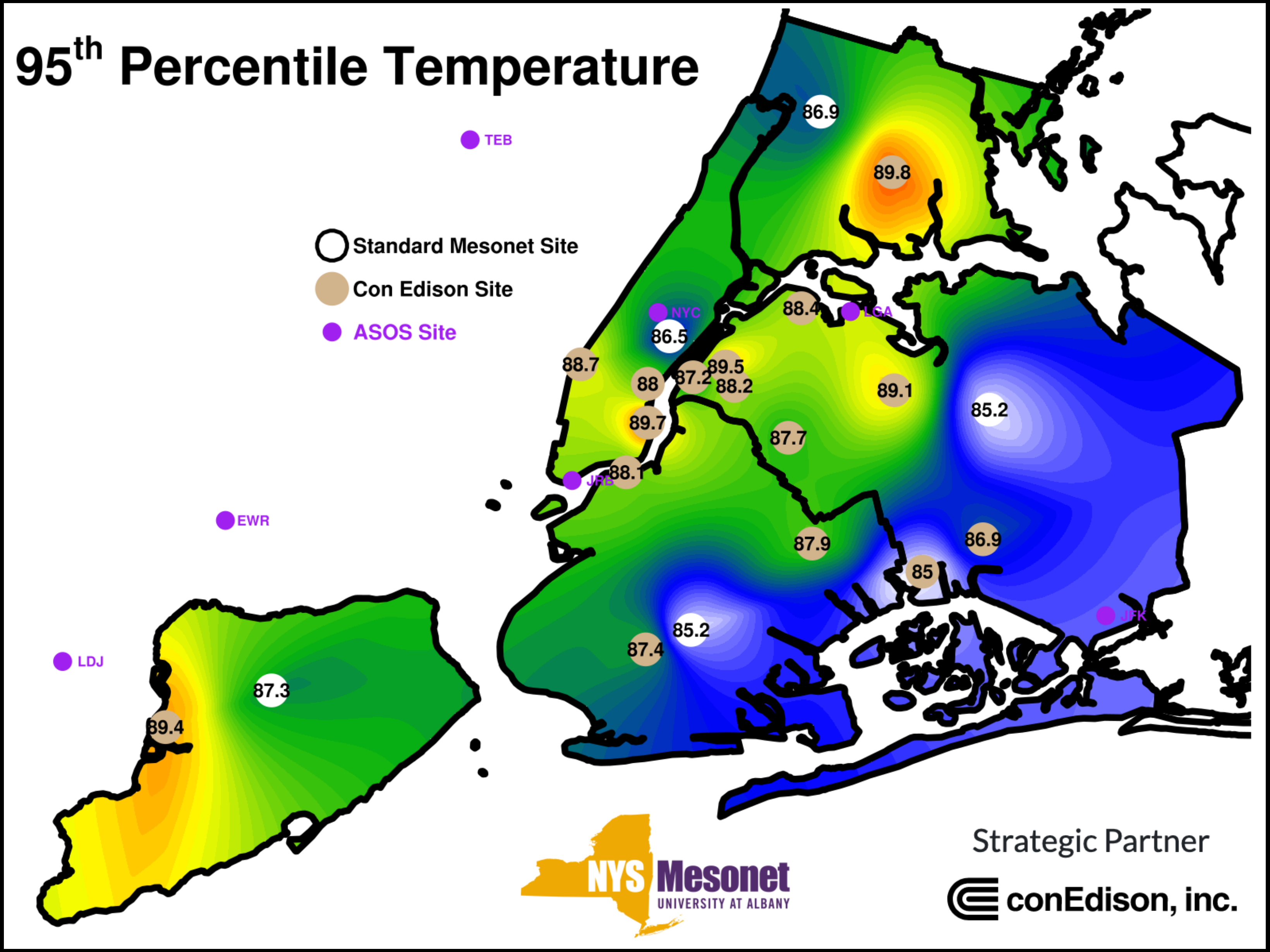
The First Big Project Heatwave: 84 Hours

- June of 2021 saw a significant heat event in NYC
- Using an arbitrary 100F cutoff, the total hours of heat indices >100F also varies 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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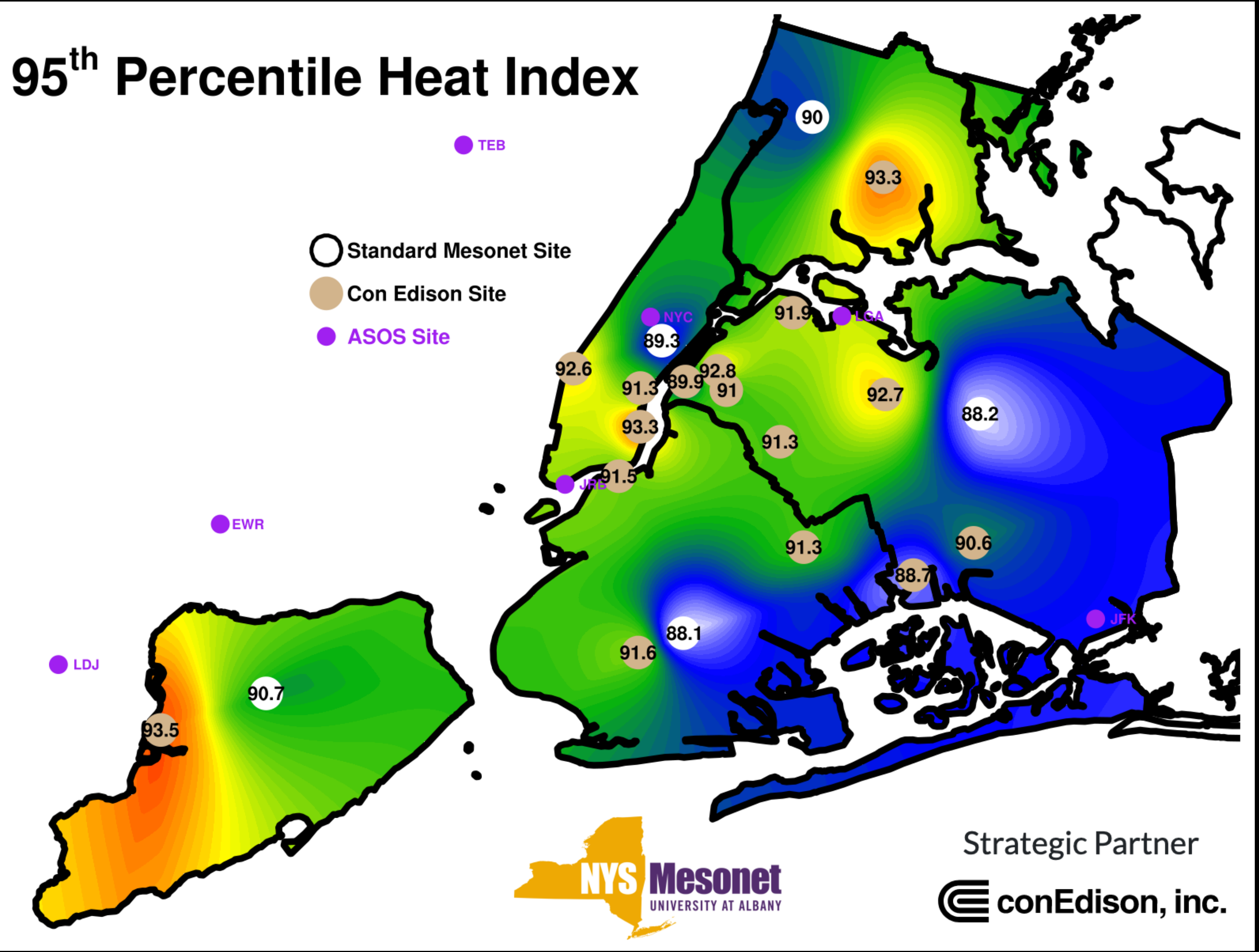
- Use May-September of both 2021 and 2022 to calculate the 95th percentile
- Heat Index displays a similar pattern



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.

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

Wet Bulb Globe Temperature

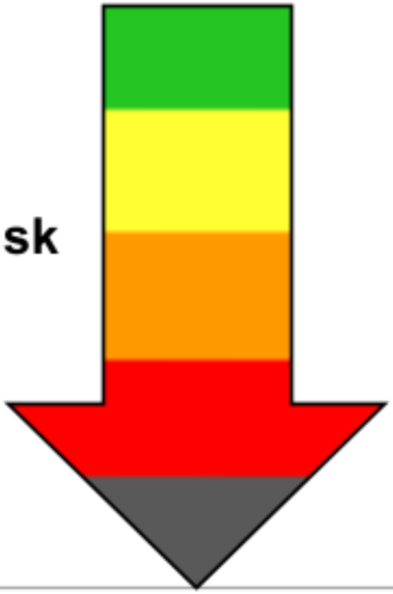
Disclaimer: Always check with local officials for appropriate actions and activity levels. Experienced heat stress will depend upon duration and intensity of activity and personal health and vulnerability.

WBGT by Region (°F)			**Threat Level** WBGT at these values increasing heat stress.
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

Risk of heat illness

https://www.weather.gov/rah/WBGT

Increased risk for heat illness



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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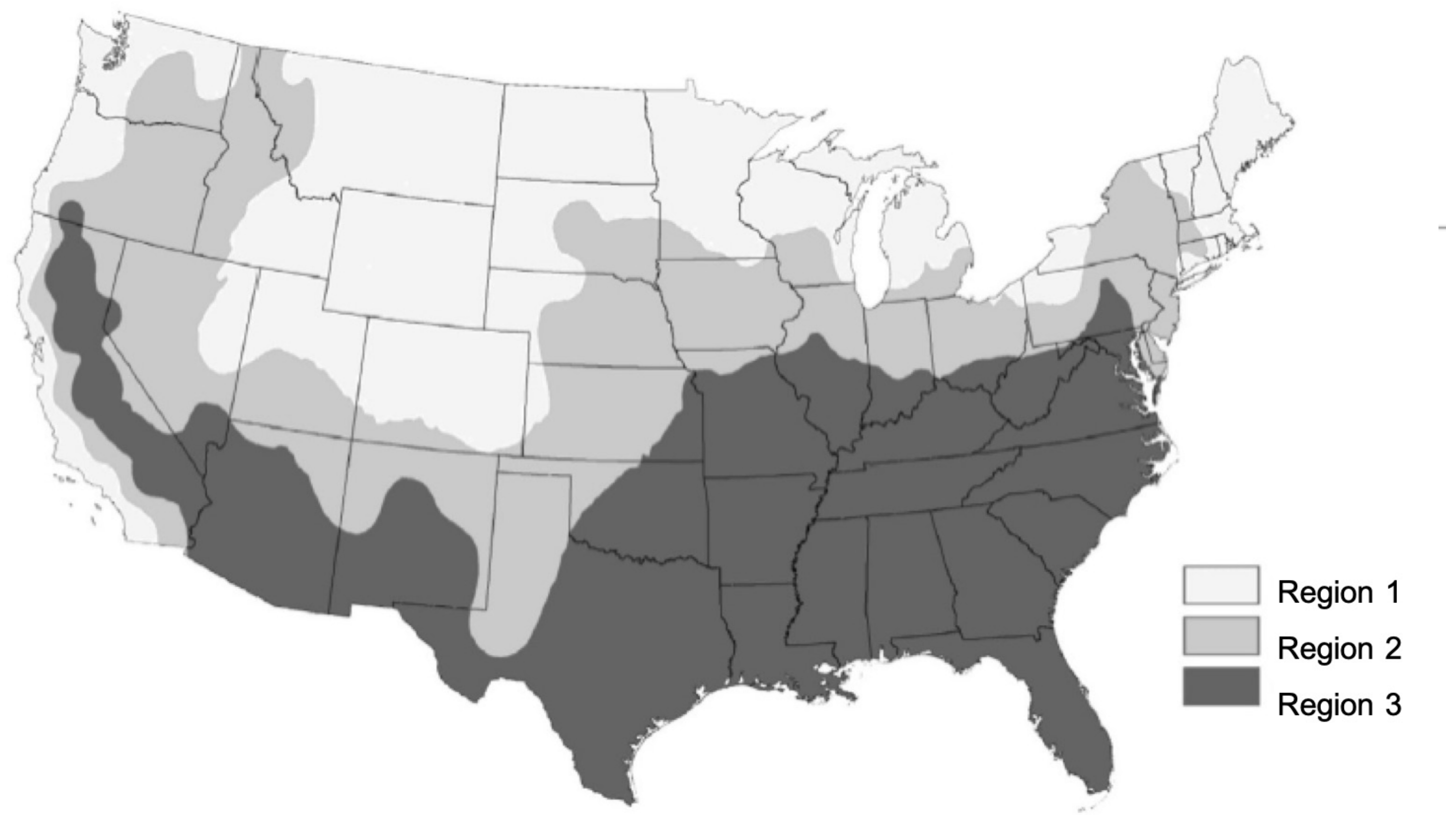

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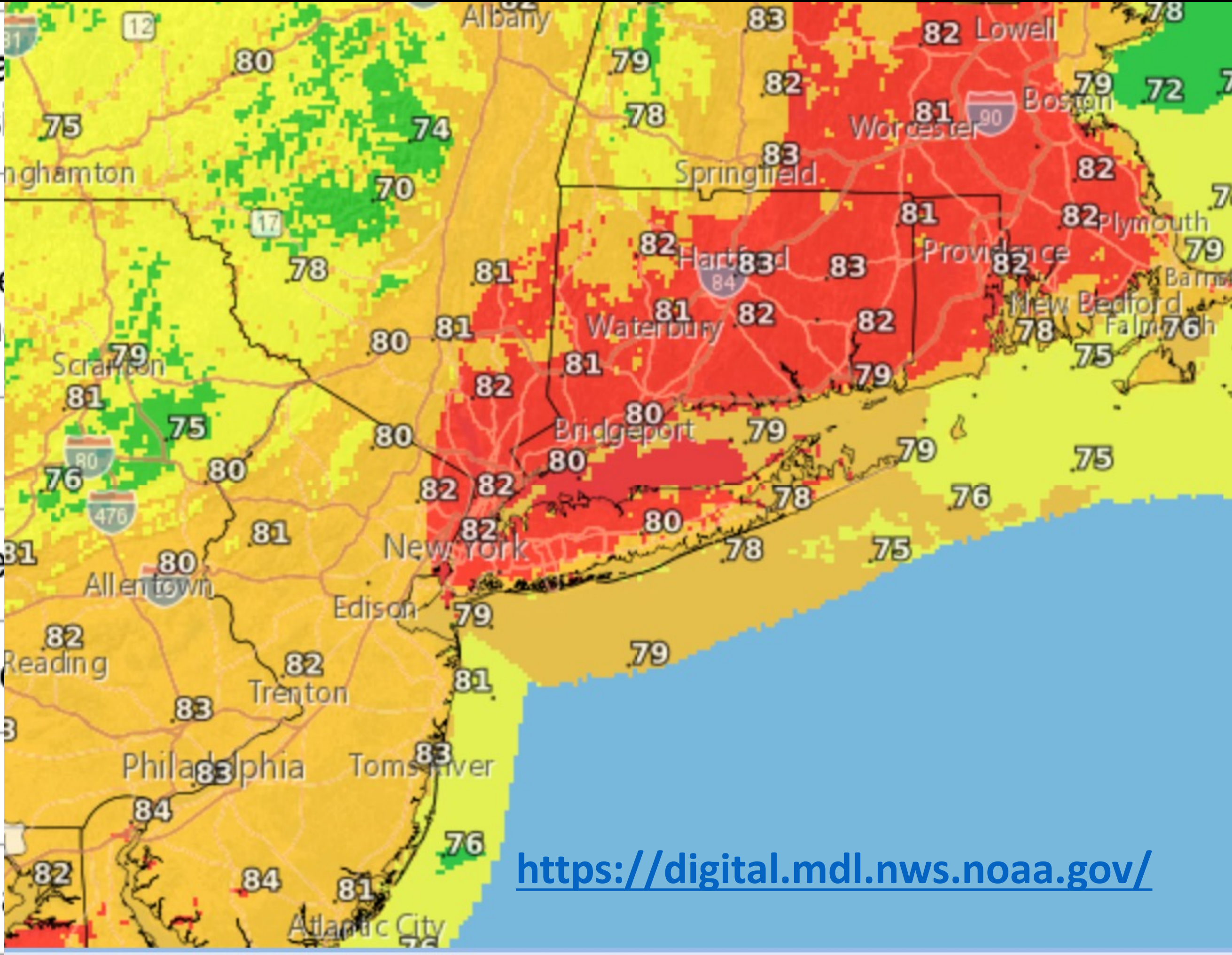

https://digital.mdl.nws.noaa.gov/

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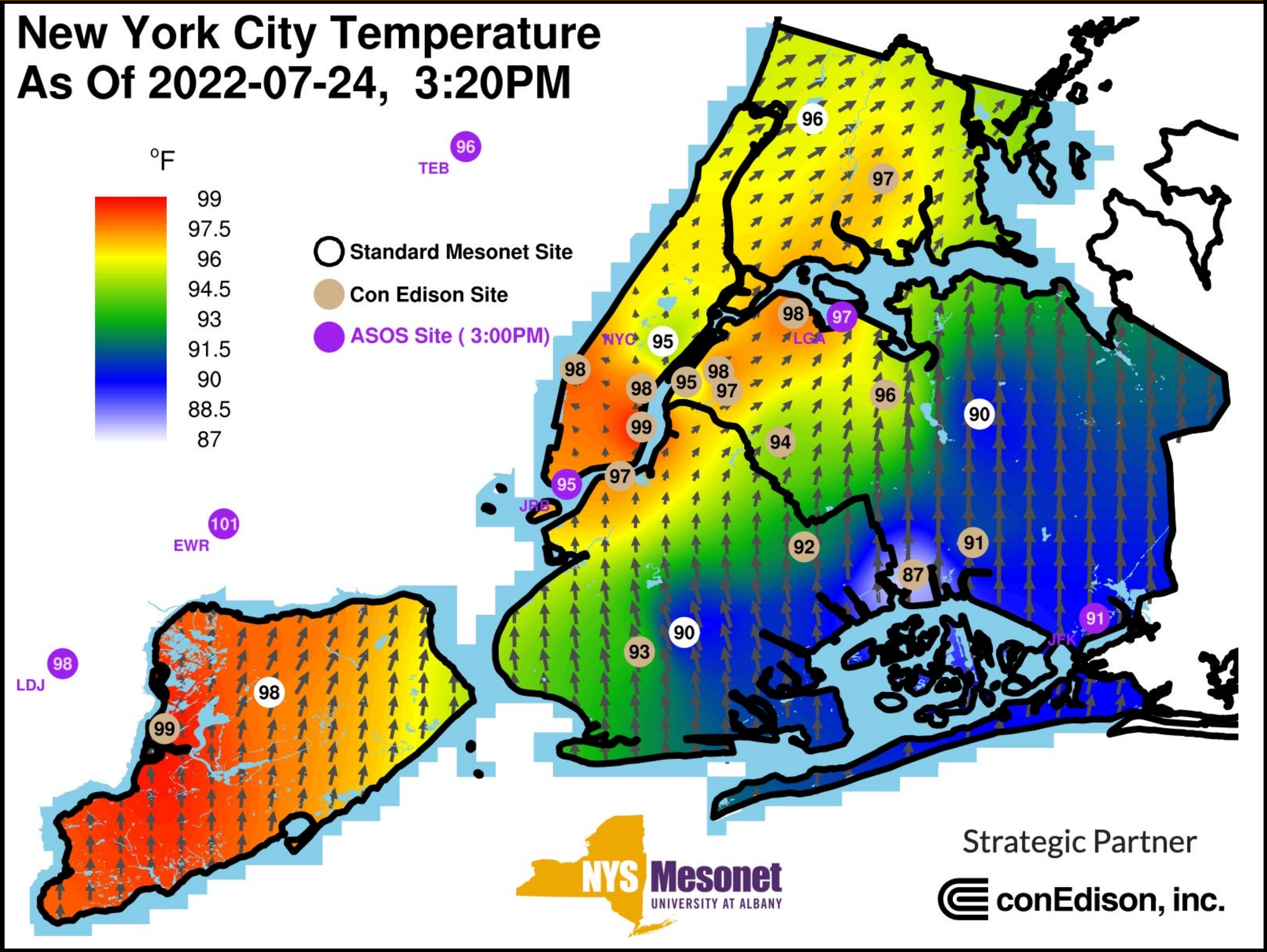
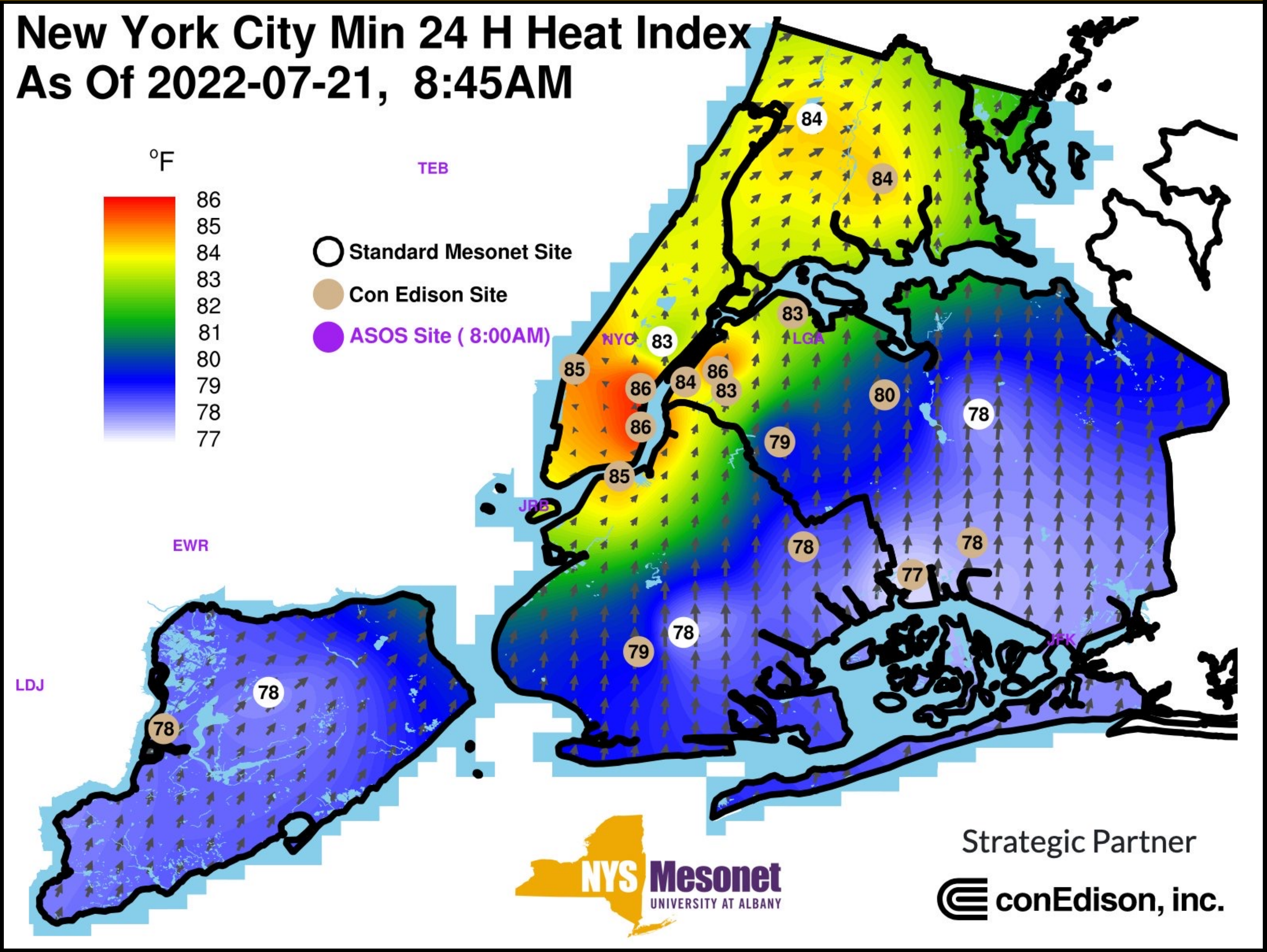
Latest Realtime Test Products

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



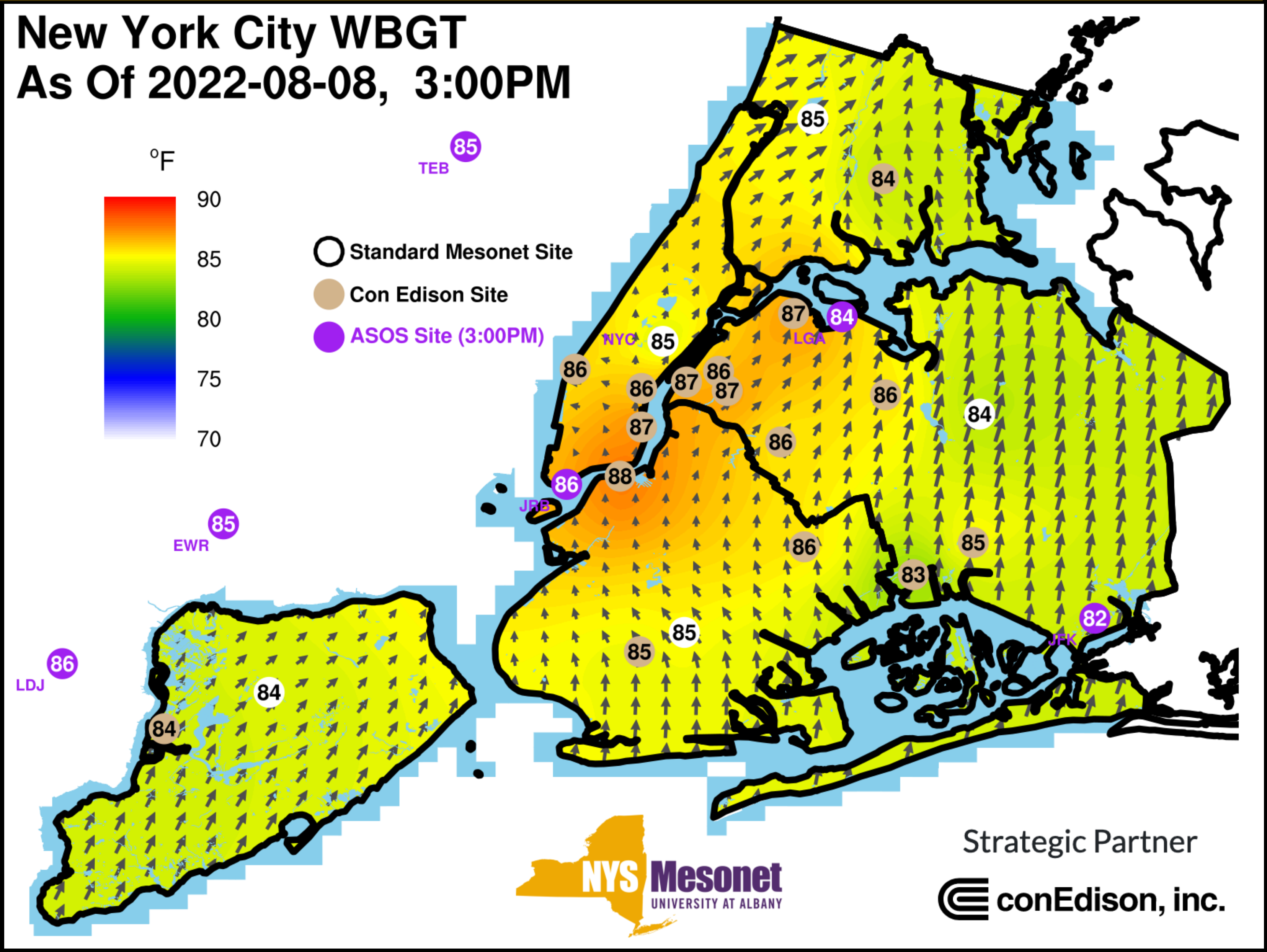
Latest Realtime Test Products

… and added a few extra heat products …

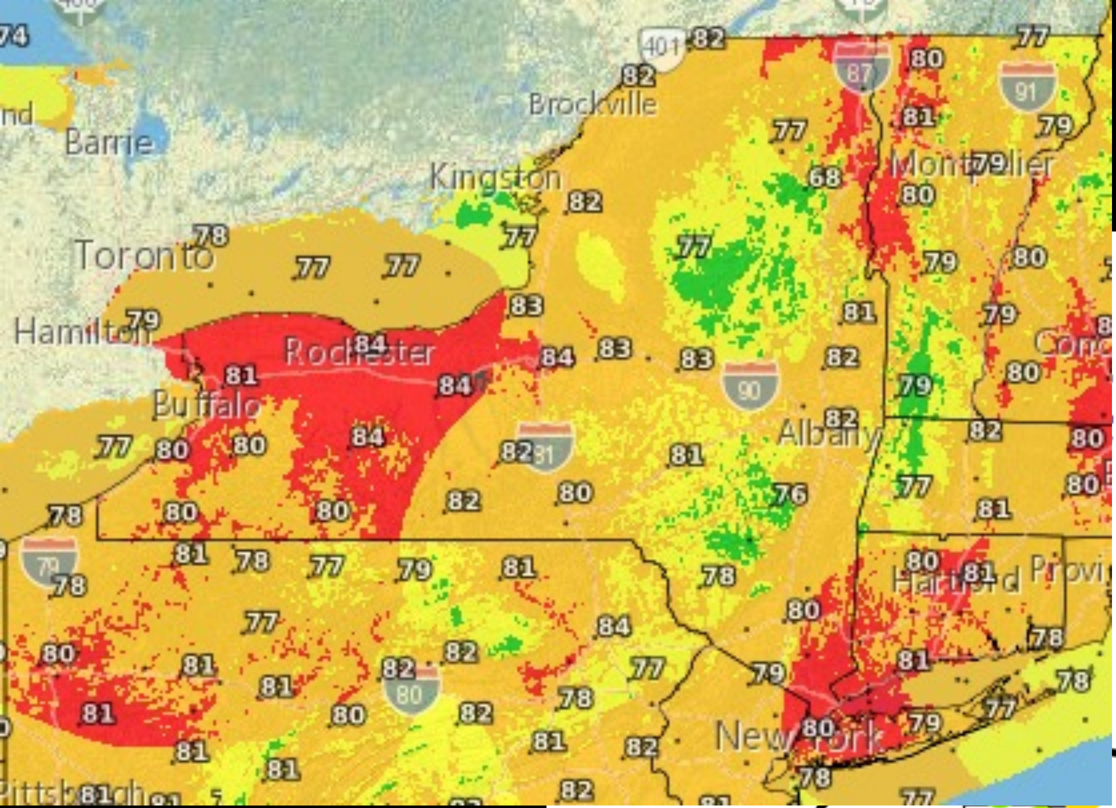


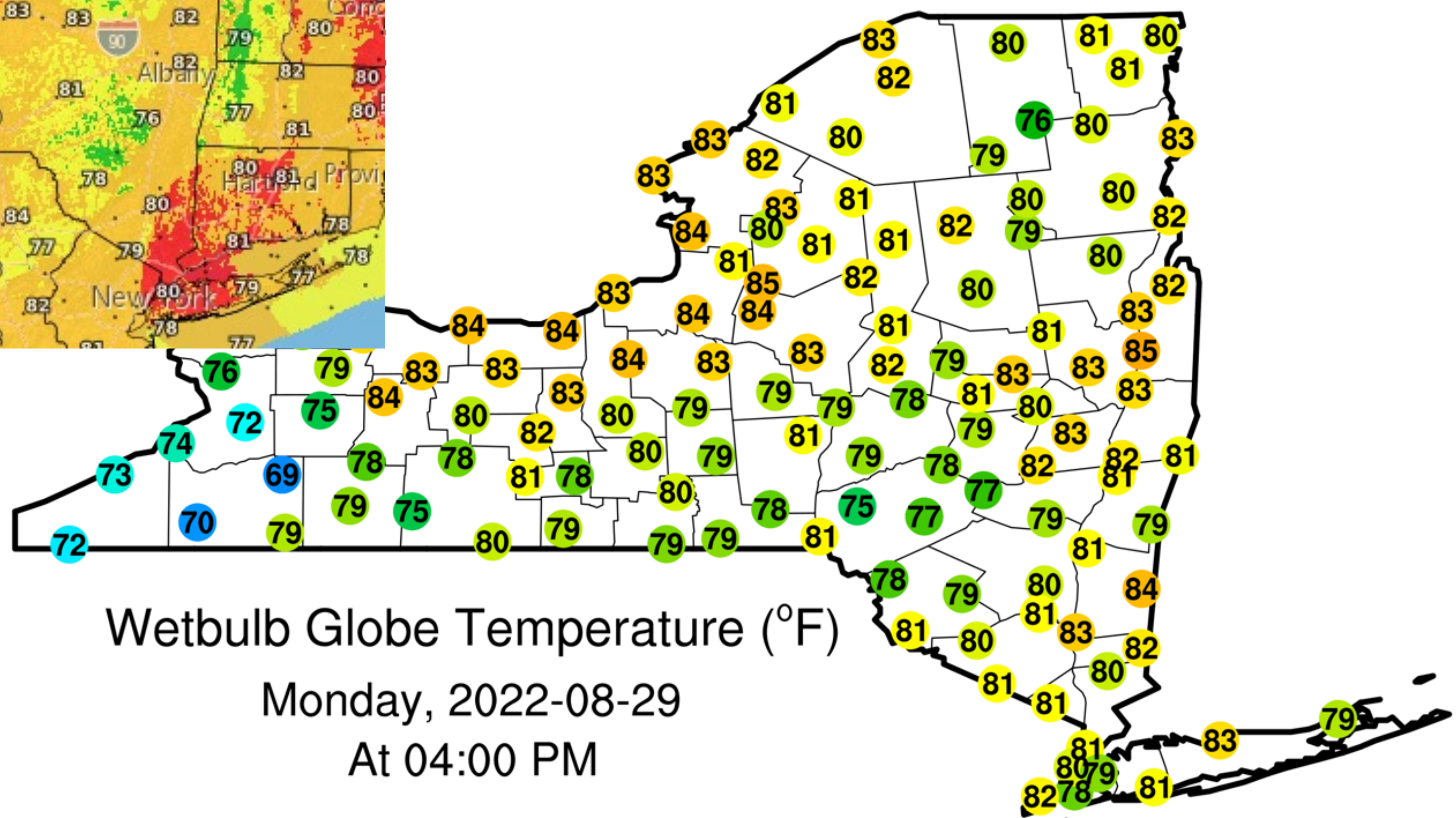
Latest Realtime Test Products

… including WBGT



Statewide WBGT





Wetbulb Globe Temperature (°F)

Monday, 2022-08-29

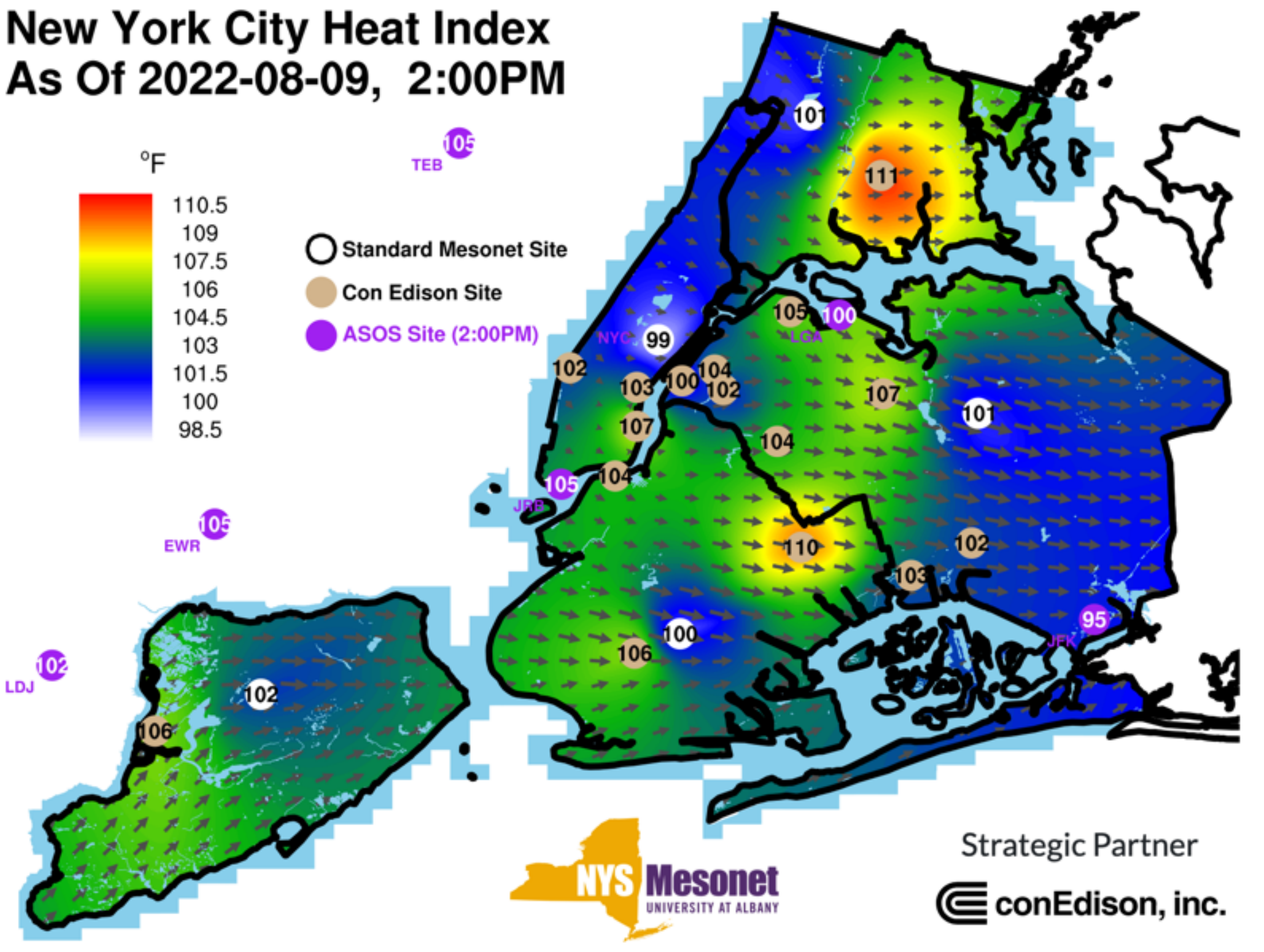
At 04:00 PM

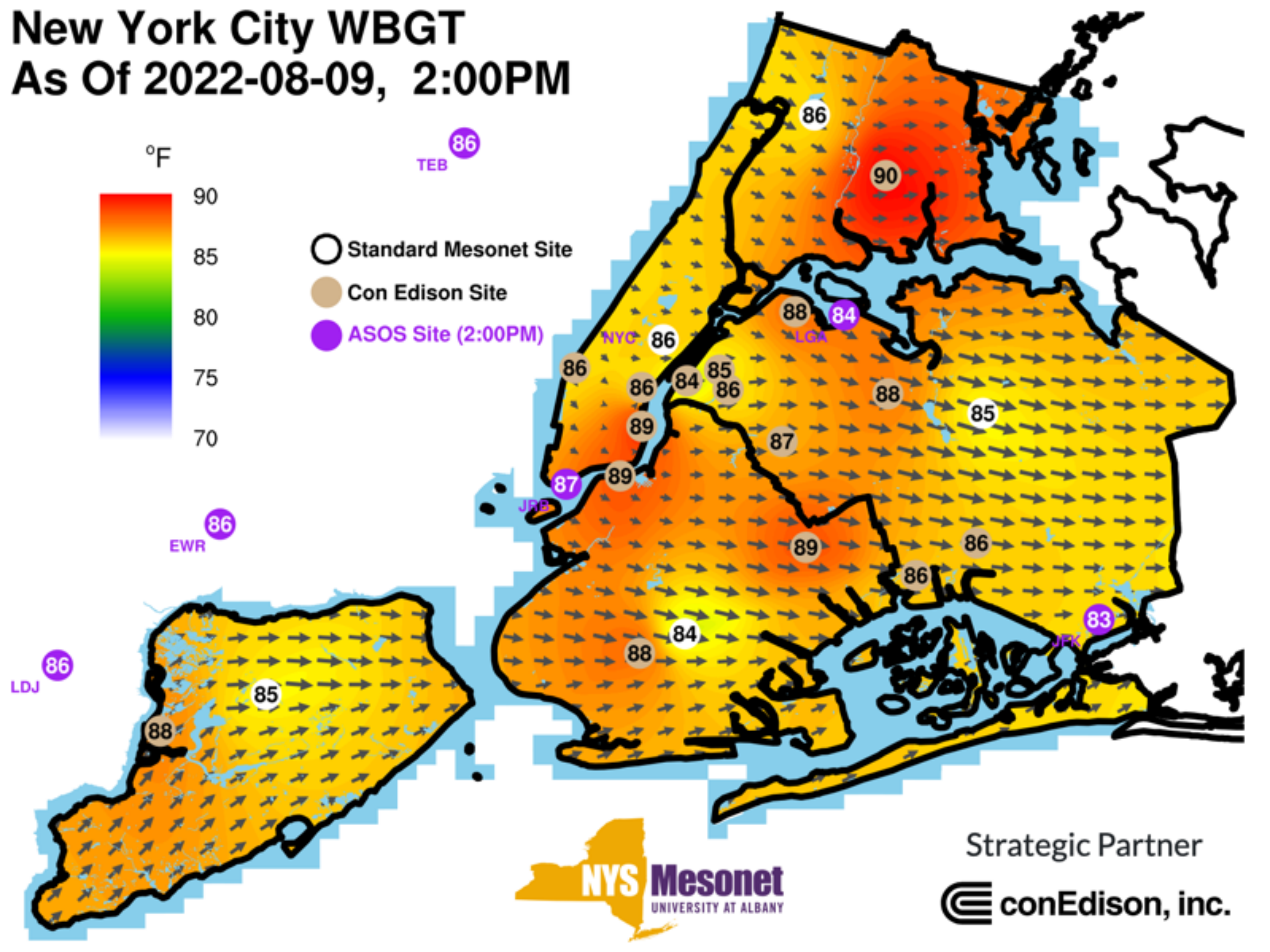
Thanks!

Photo courtesy of Dave Radell

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

Comparing Heat Index to WBGT





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

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

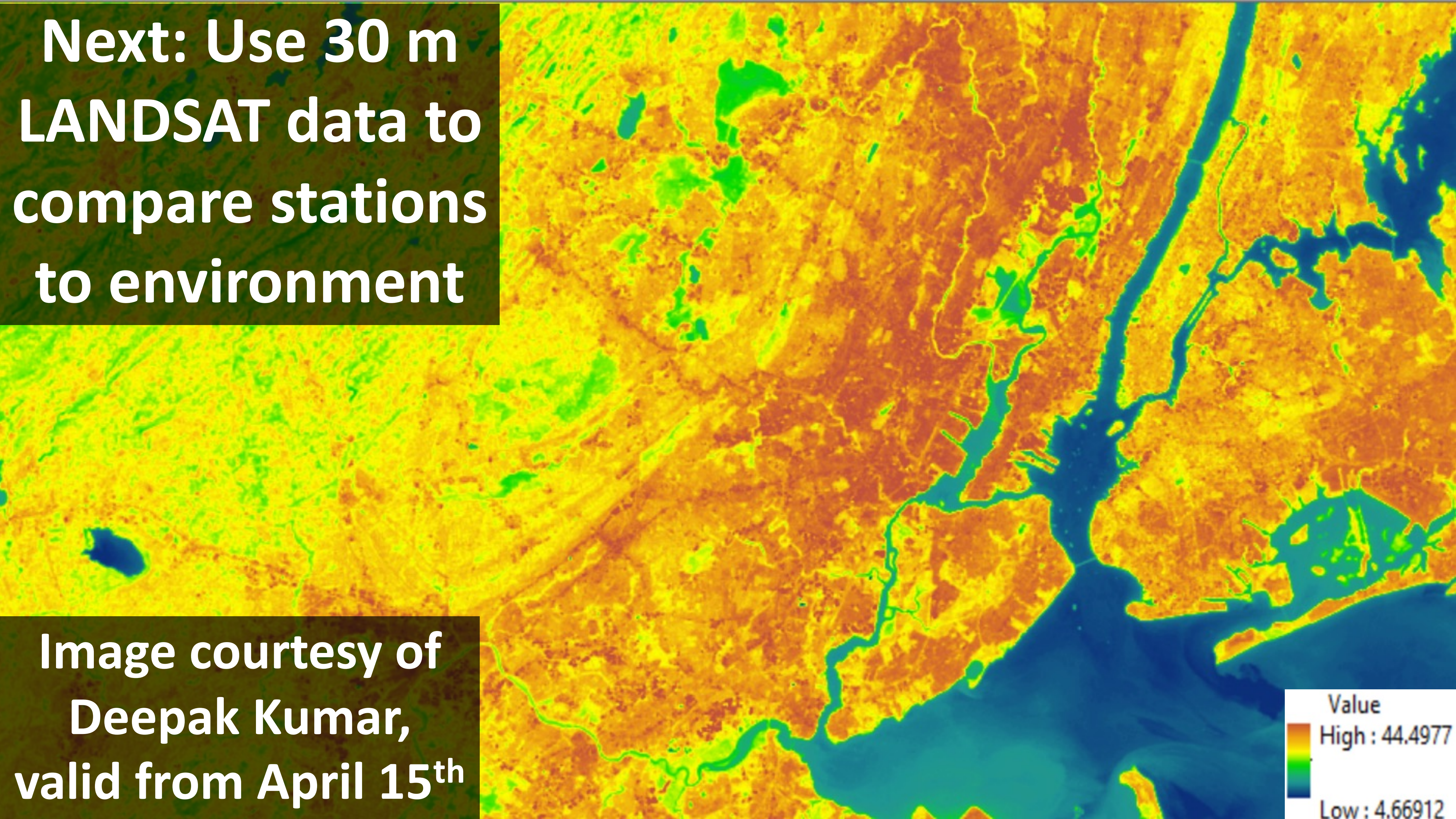
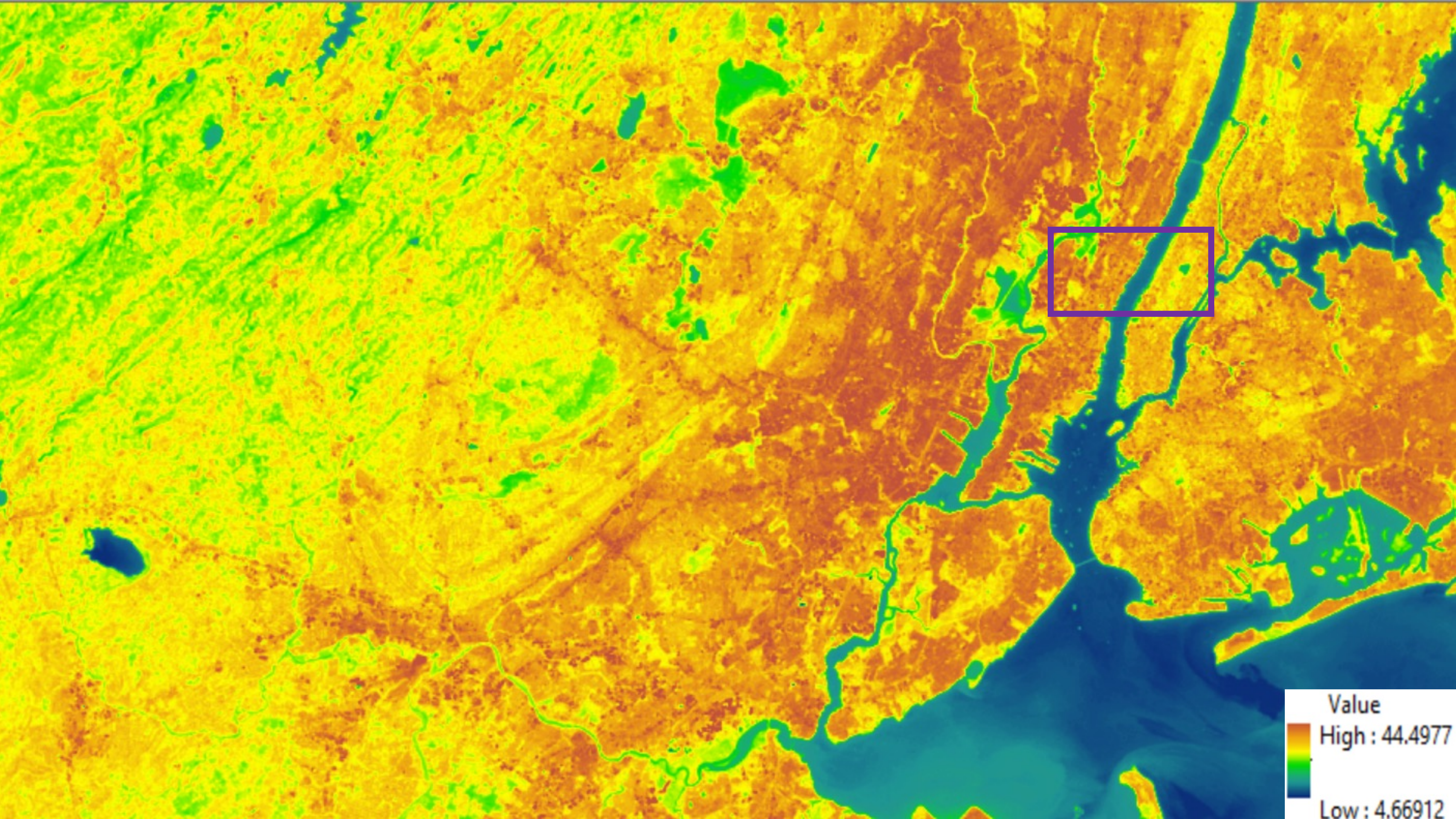
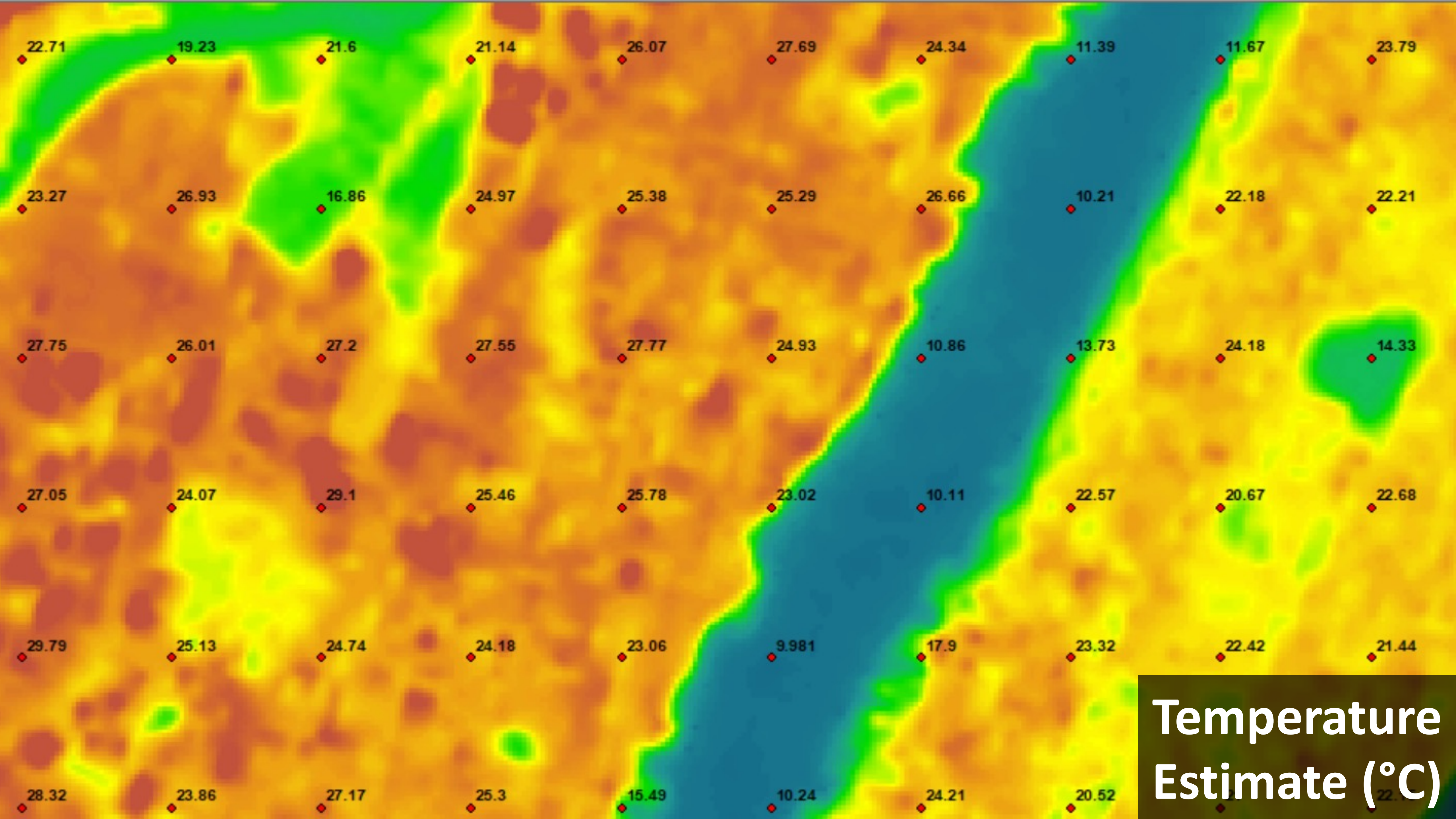


Image courtesy of Deepak Kumar, valid from April 15th


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)

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: σ=5.67x10^{-8} is used.

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

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

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