IT'S GETTING HOT IN HERE!

Exploring the Local Effects of New York City Heat Waves with In-situ and Satellite Observations

NERTO Report

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<u>**NERTO Report Fields**</u>

PROJECT INFORMATION:

NERTO or Professional Development Report Title: It's Getting Hot in Here! Exploring the local effects of New York City heat waves with in-situ and satellite observations

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Home Institution and Major: The City College of New York; M.S. Sustainability in the Urban Environment

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1. Dr. Tarendra Lakhankar, Civil Engineering Department at the City College of New York

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1. Dr. Jordan Gerth, NOAA Physical Scientist with the National Weather Service Office of Observation in Silver Springs, Maryland, USA
2. Dr. David B. Radell, Science and Operations Officer with the National Weather Service Forecasting Office in New York/Upton, New York, USA
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Report Category (Please choose only ONE):

☐ Healthy oceans

☒ Weather Ready Nation

☐ Resilient Coastal Communities and Economies

☐ Climate Adaptation and Mitigation

☐ Engagement Enterprise

☐ Science and Technology Enterprise

Outputs: (Please choose only ONE)

☐ Intern created new system(s) for enhancing functions at host office;

☐ Intern generated new data for models or products for host office;

☒ Intern delivered oral or poster presentation of internship project results;

☒ Intern created new NOAA mission-aligned professional networks;

☐ Intern demonstrated new NOAA mission-aligned core competencies.

Outcomes: (Please choose only ONE)

☐ Intern has new NOAA-mission knowledge and skills

☐ Intern published peer reviewed article(s) and citation index validated

☒ Intern demonstrated new/expanded competencies to conduct research and engage in NOAA mission-aligned activities;

☐ Intern contributes to a diverse and highly skilled candidate pool for future workforce of pursues careers in disciplines that support NOAA mission enterprise;

☐ Intern is offered NOAA mission workforce employment at completion of internship.

NERTO Value to The Line Office: Work with your NERTO Mentor and write a short description to complete this section

The National Weather Service (NWS) currently issues heat advisories and warnings at the county level despite threats and impacts that are more localized. In addition, the NWS mission has recently expanded to include impact-based decision support services (IDSS). A central aspect of IDSS is working with NWS stakeholders, such as emergency managers, to understand forecasts of adverse weather and assist in any preparation or response efforts. For this project, the NWS is thus interested in understanding the local, neighborhood-level effects of heat waves and improving its messaging of heat threats in New York City (NYC), particularly for vulnerable populations. This project extends the outcomes of an Office of Oceanic and Atmospheric Research (OAR) Weather Program Office grant awarded to the University of

Albany to aggregate nearly 50 weather stations around NYC and evaluate more actionable temperature products such as wet bulb temperature.

The NERTO program adds value to the line office by allowing for a Win-Win-Win situation, where the office wishes to expand its capacity or support services, but it may not have the personnel to do so. The NERTO program trains students who are actively seeking an opportunity to conduct research that aligns with NOAA missions. Thus, the first win-win is fulfilled by accepting the students as temporary researchers on the line office expansion project. The second win-win is fulfilled when the students go on their NERTOs and may then decide to join the NOAA line office, which satisfies the need to address the aging workforce of many line offices.

REPORT WORD COUNT: [Minimum: 1,500 and Maximum count: 2,500]

Abstract:

Heat waves are silent, slow and invisible killers,

> *MALE, AGE 65, BLACK, JULY 16, 1995*
>
> *R/Os [responding officers] discovered the door to apt. locked from the inside by means of door chain. No response to any knocks or calls. R/Os . . . gained entry by cutting chain. R/Os discovered victim lying on his back in rear bedroom on the floor. [Neighbor] last spoke with victim on 13 July 95. Residents had not seen victim recently. Victim was in full rigor mortis. R/Os unable to locate the whereabouts of victim's relatives.*

This excerpt is from *Heat Waves: A Social Autopsy of Disaster in Chicago* by Eric Klinenberg, and it briefly illustrates the better conditions that hundreds of people were found in after a 1995 Chicago heat wave (Kilnenberg 2015). In an effort to reduce the impacts of heat waves, the National Oceanic Atmospheric Administration (NOAA) National Weather Service (NWS) has an interest in expanding its understanding of the local, neighborhood-level effects of heat waves and improving its messaging of heat threats in New York City (NYC), particularly for and to vulnerable populations. As an extension of the outcomes of an Office of Oceanic and Atmospheric Research (OAR) Weather Program Office grant awarded to the University of Albany to aggregate nearly 50 weather stations around New York City, the NYC Mesonet will be used to evaluate more actionable temperature products such as wet bulb globe temperature (WBGT), more specifically the archived 2018-2021 stations data that is available for NYC (Bassill 2020). Coupled with satellite datasets, like the satellite data products from 2018-2021 acquired from a virtual Advanced Weather Interactive Processing System (AWIPS) via the Common AWIPS Visualization Environment (CAVE) application and from the Real-Time Mesoscale Analysis (RTMA) 2.5km Products, publically, available from NOAA National Centers for Environmental Prediction (NCEP) (NOAA NWS NCEP and NCO Web Team n.d.). The two information sets, weather station and satellite, with be overlaid with the highest at-risk neighborhoods identified as at risk of heat-vulnerability or heat-related illness or death, and various social indicators, according to the NYC Environmental Public Health Tracking Program, a program of the NYC Department of Health and Mental Hygiene. The results show that the highest at risk neighborhoods are in roughly 3 clusters, (i) North most cluster: Harlem, Spanish-East Harlem, West Concourse, Hunts Point (ii) South most cluster: East New York, Brownsville, Williamsburg, Bedford-Stuyvesant (iii) East most cluster: Jamaica, St. Albans, Hollis, Springfield Gardens North. In these

areas there are generally a higher number and percentages of: (1) hotter surface temperatures, (2) individuals without A/C (3) a lack of vegetative cover (4) individuals with in-home medical equipment (5) non-white identifying individuals. These results supports the social science field and illustrates that invisible connections between an urban environment and the natural environment around it.

Summary of Research: Using Python, programs were written to accomplish various data science tasks related to Heat Waves in NYC : (1) Clean raw CSV data from weather stations throughout NYC (2) Calculate Wet Bulb Globe Temperature and Heat Index from the cleaned datasets (3) Interact with and visualize satellite datasets (4) Overlay weather station and satellite datasets with socioeconomic impact factors.

Methodology:

A Jupyter Notebook Python environment was created using Microsoft Visual Studio Code to work with the NYS Mesonet data that was stored as CSV files (Bassill 2020). These files contained environmental information like the station name, the date and time of the observations in Z time (a standard time nomenclature used in reference to Greenwich Mean Time (UTC)), the stations latitude (degrees north) and longitude (degrees east) coordinates, station elevation in meters, wind direction in degrees, wind speed in meters per second (m/s), the max wind speed observed meters per second (m/s), the air-temperature in °C, the percent of relative humidity, precipitation in millimeters (mm), solar radiation in watts per meters squared (W/m^2), and pressure in pascals.

The Pandas Python library allows for the reading and writing of tabular (Excel / spreadsheet) data and Numpy is a Python library for multi-dimensional array mathematics (Harris 2020) (The Pandas Development Team n.d.). With these functionalities the raw CSV data for the Queens Long Island City (QNLICI) station was used as a test case to create a general universal Jupyter Notebook data cleaning program. This station was selected because it had the most values present that could be used to calculate Heat Index and Wet Bulb Globe Temperature.

The program is set to: (1) assign the corresponding column, or Pandas series, names to allow for an ease in data processing, since series names were not initially present, (2) set the data time column as date time objects variables and not simple string or integer variable and set it as the identifying row index, or pandas index, (3) sort the values in chronological order, (4) remove air temperature observation that are below 26.388 °C or 79.49 °F, since the threshold for heat wave identification is 80°C, (5) calculate Heat Index using various formulas (National Weather Service n.d.) (Wikipedia n.d.) (6) create a new air-temperature in °F column, as it is the US standard unit of measure for temperature (7) calculate the Heat Index percentiles for the air-temperature in °F, prompt the user to input a desired percentiles and output the corresponding temperature observation, generate a graphic depicting heat index curve and show where on the curve the user's input resides (J. D. Hunter 2007) (8) convert the original wind speed value from meters per second to miles per hour and barometric pressure, mm, to inches of mercury, as these values are what is used in the OSHA WBGT calculator used for validation (Occupational Safety and Health Administration n.d.) (9) calculate the natural (static) wet bulb temp, Tn or NWB and Tg or GT read the air-temperature °C as Ta or dry-bulb temperature, DB.

In 1999 Charles H. Hunter and Olivia Minyard published a report titled “Estimating Wet Bulb Globe Temperature Using Standard Meteorological Measurements” where they determined $WBGT = 0.7Tn + 0.2Tg + 0.1Ta$ and concluded that the average difference between the observed and their calculated WBGT was less than 0.5 °C with a maximum difference of 1.3°C (C. H. Hunter 1999). Dr. Vincent E. Dimiceli & Steven F. Piltz built on Hunter and Minyard’s report and presented an algorithm that was ported under this project into Python Jupyter notebook software to calculate WBGT (Dimiceli n.d.). As some errors came along an alternative document, by Sean Heuser presented an substitute method for calculating wet bulb temperature and with some manual zenith angle tweaking, the newly translated program appears to be functioning as intended as seen in Figure 1 (Heuser n.d.). The resulting WBGT, calculated during this study for the first time stamp at the QNLICI station, was approximately 27°C. This is understood to be correct for this specific station case and was verified against the wet bulb globe temperature calculator offered by OSHA (Occupational Safety and Health Administration n.d.). The calculated WBGT value may be correct for this case however further solar angle tweaking or automating the zenith angle calculations will be needed on a station by station basis as well as validating the WBGT across all available timestamps at the QNLICI station, then across all the other stations in the Mesonet system (William F. Holmgren et al. 2018).

Originally the GOES 16 ECONUS Annual Satellite Land Surface Temperature data products from 2018-2021 acquired from Advanced Weather Interactive Processing System (AWIPS) via the Common AWIPS Visualization Environment (CAVE) application (Lee Byerle, Kashaud Bowman NOAA NWS TOWER-S Team 2022). However this dataset could not functionally be used, as a large number of temperatures value pixels are not present on a frequent basis due to cloud cover. Figure 2. As a substitute the US Conus 2.5 km Real-Time Mesoscale Analysis (RTMA) Products temperature band was used as it accounts for cloud cover corrections (NOAA NWS NCEP and NCO Web Team n.d.). This data is stored a Grib2 raster files, a geospatial data file type, to access and view this data, the Pygrib Python library, which reads and writes GRIB files, and matplotlib Python library, which plots charts and other graphics, Figure 3, depicts a visual of the RTMA surface temperature band that was extracted and saved as a GDAL Numpy array (J. D. Hunter 2007) (Whitaker 2020).

Using the Geospatial Data Abstraction Library or GDAL in Python, the RTMA data was re-projected to the coordinate reference system of ESPG: 4326 and clipped to the extent of a NYC borough boundary shapefile found on NYC’s OpenData database (NYC Department of City Planning 2013) (GDAL/OGR Contributors, 2022). However the resulting image was extremely coarse and the color needed to be smoothed out. GDAL provides some resampling and resolution adjustment options. In this case a bilinear resampling was chosen. Bilinear resampling utilizes the weighted average values of the four nearest neighboring raster cells and assigns the output cell a value based on its distance from one the four nearest cell centers smoothing the output raster grid, Figure 5 - Figure 7, depict the observed RTMA temperature band in a red gradient.

With working geospatial map, the Social and Socioeconomic Indicators that correlate to heat waves can begin to be analyzed. During this portion of the analysis WBGT is not used as a reference due to the created program not yet being verified as accurate across all time stamps and then across all the stations on the Mesonet system, so the surface temperature or ambient temperature band from the newly resamples and smoothed RTMA 2.5 km product is used instead. Depicted in Figure 4, are the neighborhoods identified as at risk of heat-vulnerability or heat-related illness or death, according to the NYC Environmental Public Health Tracking Program, a program of the NYC Department of Health and Mental Hygiene (New York City Department of Health and Mental Hygiene 2018). Risk factors that increase heat- vulnerability in NYC are (1) hotter surface temperatures (2) less home air conditioning (3) less green space (4) residents who are low-income or non-Latinx Black. Differences in these risk factors across neighborhoods are rooted in systemic racism and disproportionally effect minority, non-white and non-white passing, individuals then white individuals.

The highest at-risk neighborhoods are in roughly 3 cluster, (i) North most cluster: Harlem, Spanish-East Harlem, West Concourse, Hunts Point (ii) South most cluster: East New York, Brownsville, Williamsburg, Bedford-Stuyvesant (iii) East most cluster: Jamaica, St. Albans, Hollis, Springfield Gardens North. Figure 5 - Figure 7, depict the observed RTMA temperature band in a red gradient and highlights the highest at-risk neighborhoods on August 7, 2022 at 1500z, 1700z and 2100z or 11am, 1pm, 5pm EST, respectively. Throughout this day, it can be seen that the Queens cluster is cooler than the Bronx and Brooklyn clusters and that the Bronx cluster is cooler than the Brooklyn cluster, meaning that residents in Brooklyn would be the most at risk, though this needs to be checked by looking at heat index and WBGT as well as temperature. Figure 8 - Figure 11, shows that (1) there is a high concentration of non-white identifying individuals in the highest at neighborhoods (2) there is a high percentage of individuals without air conditioning units (3) the lowest percentages of vegetative cover, which can contribute to the high temperatures seen in in the Brooklyn cluster at 2100z verses the Queens cluster at the same time due to heat absorption in the morning and radiations in the evening by surfaces like asphalt, sidewalks and building facades (4) that the highest number of individuals with in-home medical equipment, like breathing apparatus, insulin coolers/refrigerator, motorized beds and chairs, surveillance/emergency warning systems, are in the highest risk neighborhoods.

Results and Conclusions:

The current data processing and created visualization supported the following preliminary conclusions: (1) Heat Waves have the capacity to increase in frequency and intensity (2) the individuals most likely to be affected: (I) Young / Elderly (II) Non-White or White-Passing Minority Individuals (III) The Medically Disabled (IV) Low Income Individuals (3) the individuals least likely to be affected: (I) Working Age (II) White / White-Passing Individuals (III) Able Bodied (IV) Wealthy/ Affluent (4) more vegetative cover in the high risk neighborhoods has the capacity to lead to reduce observed surface temperatures and (5) local infrastructure can play a supporting role in observed radiative heat from sidewalks, asphalt and other such surfaces.

Future Work:

If more time was available here are a few of the tasks that would be expanded upon or added:

- Complete data cleaning for all the available Mesonet stations, verify WBGT Accuracy across all timestamps then across all stations and automate zenith angle calculation for WBGT
- Explore the effects of marine water body and wind on possible cooling and or heat transfer/transplant
- More extensive social impact research across New York City
  - Income/ Wealth/ Population Density/ Spoken Language distribution across NYC
  - Identify the concentration of NYCHA buildings
  - Local hospital locations
  - Electrical Substation Service Map
  - NYC 311 reports regarding open fire hydrants
  - Media reports regarding severity of the heat events
- Individuals can partner with local heat wave mapping /monitoring efforts to help increase the density of in-situ observations by placing observational instruments on their cars, in front of their homes, around parks.

References

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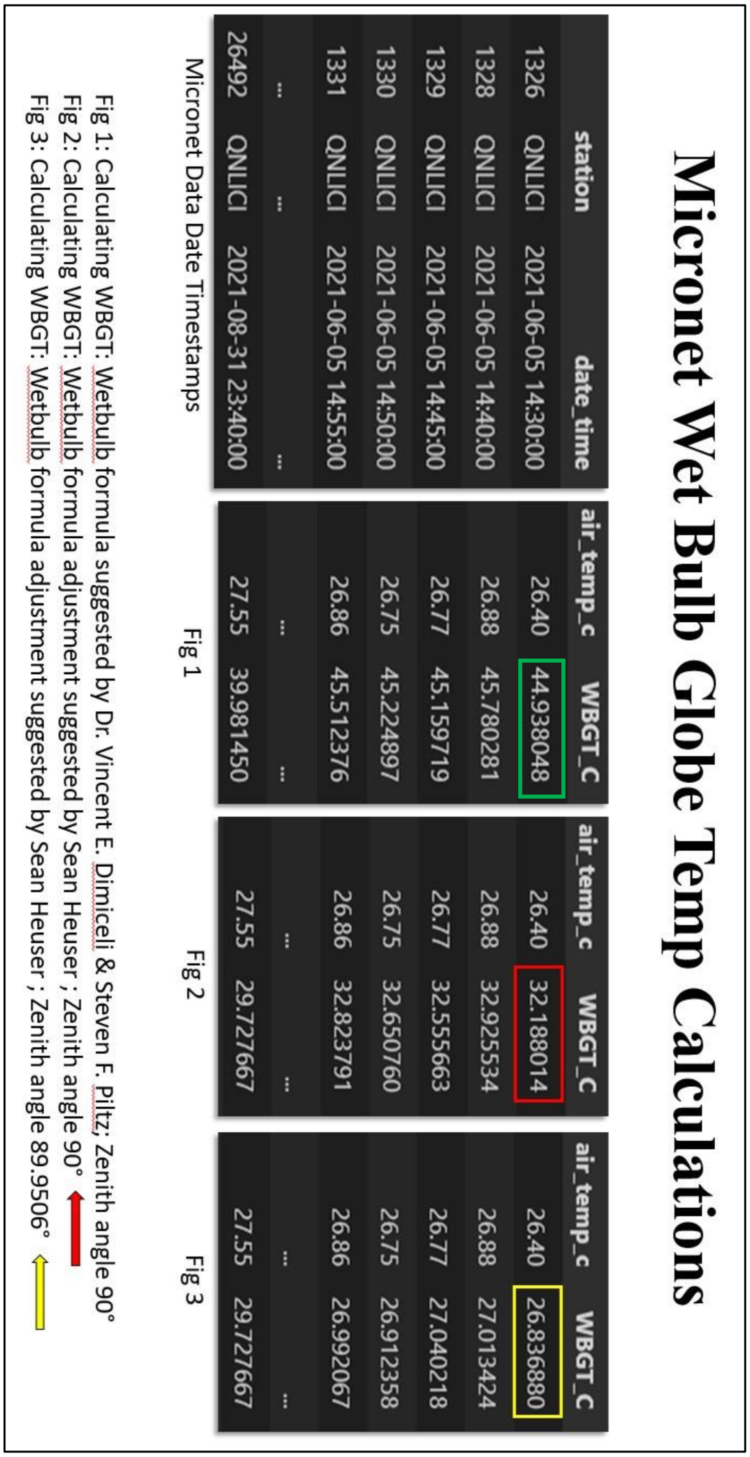
Figures:



Micronet Wet Bulb Globe Temp Calculations

Micronet Data Date Timestamps

	station	date_time
1326	QNLICI	2021-06-05 14:30:00
1328	QNLICI	2021-06-05 14:40:00
1329	QNLICI	2021-06-05 14:45:00
1330	QNLICI	2021-06-05 14:50:00
1331	QNLICI	2021-06-05 14:55:00
...	...	...
26492	QNLICI	2021-08-31 23:40:00

Fig 1

air_temp_c	WBGT_C
26.40	44.938048
26.88	45.780281
26.77	45.159719
26.75	45.224897
26.86	45.512376
...	...
27.55	39.981450

Fig 2

air_temp_c	WBGT_C
26.40	32.188014
26.88	32.925534
26.77	32.555663
26.75	32.650760
26.86	32.823791
...	...
27.55	29.727667

Fig 3

air_temp_c	WBGT_C
26.40	26.836880
26.88	27.013424
26.77	27.040218
26.75	26.912358
26.86	26.992067
...	...
27.55	29.727667

Fig 1: Calculating WBGT: Wetbulb formula suggested by Dr. Vincent E. Dimiceli & Steven F. Piltz; Zenith angle 90°
Fig 2: Calculating WBGT: Wetbulb formula adjustment suggested by Sean Heuser ; Zenith angle 90°
Fig 3: Calculating WBGT: Wetbulb formula adjustment suggested by Sean Heuser ; Zenith angle 89.9506°

Figure 1: Results of the WBGT formula translation and calculations, note the reduction of the WBGT from 45°C (green box) to 32°C (red box) then to an approximate 27deg C or 80°F (yellow box). There is a difference of about 5°C be a Zenith angle of 90° and 89.9506°

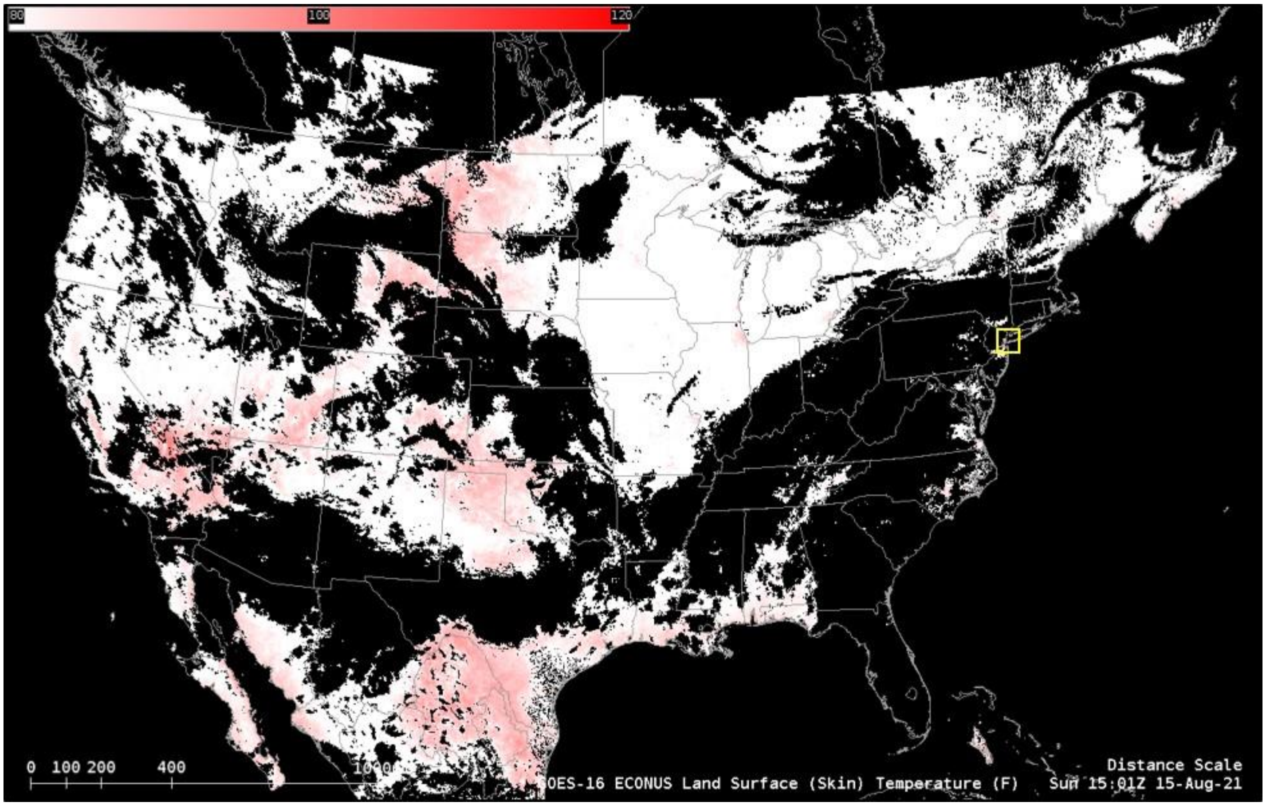


Figure 2: Archived US CONUS Land Surface Temperature observations for August 15, 2021, via the Advanced Weather Interactive Processing System (AWIPS). The red color gradient denotes temperature. However, note the yellow square over NYC, which falls in a large black zone where there is little observed change in the LST. This is due to the black coloring representing cloud cover, when the clouds are thick enough as seen here they can cause inaccuracies in an analysis.

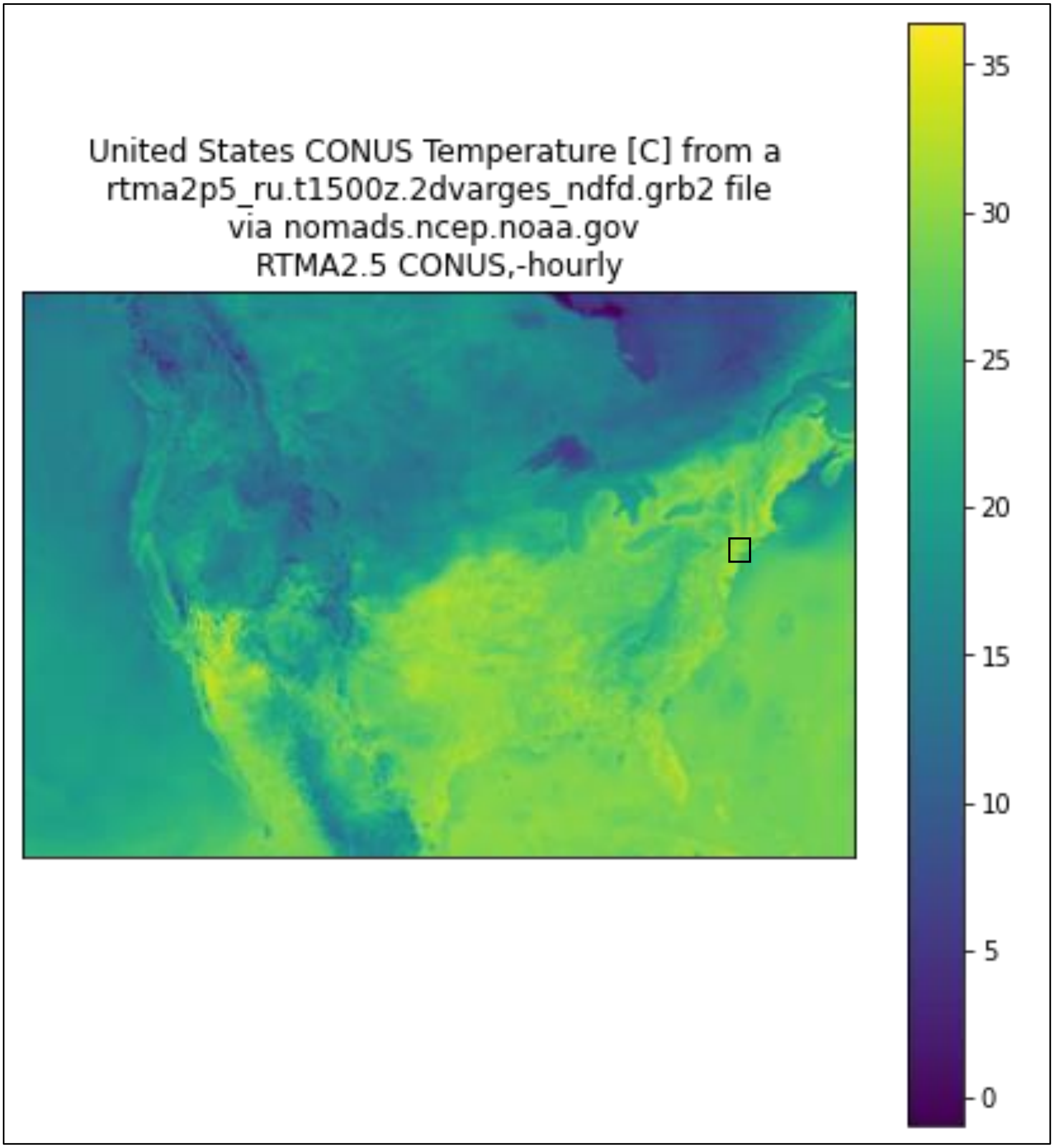


Figure 3: US Conus 2.5 km Real-Time Mesoscale Analysis (RTMA) Products Temperature Band in °C at Aug 7th 2022, 1500z (11am EST). The black square represents where NYC is generally located, also note the pixel presence uniformity across the US

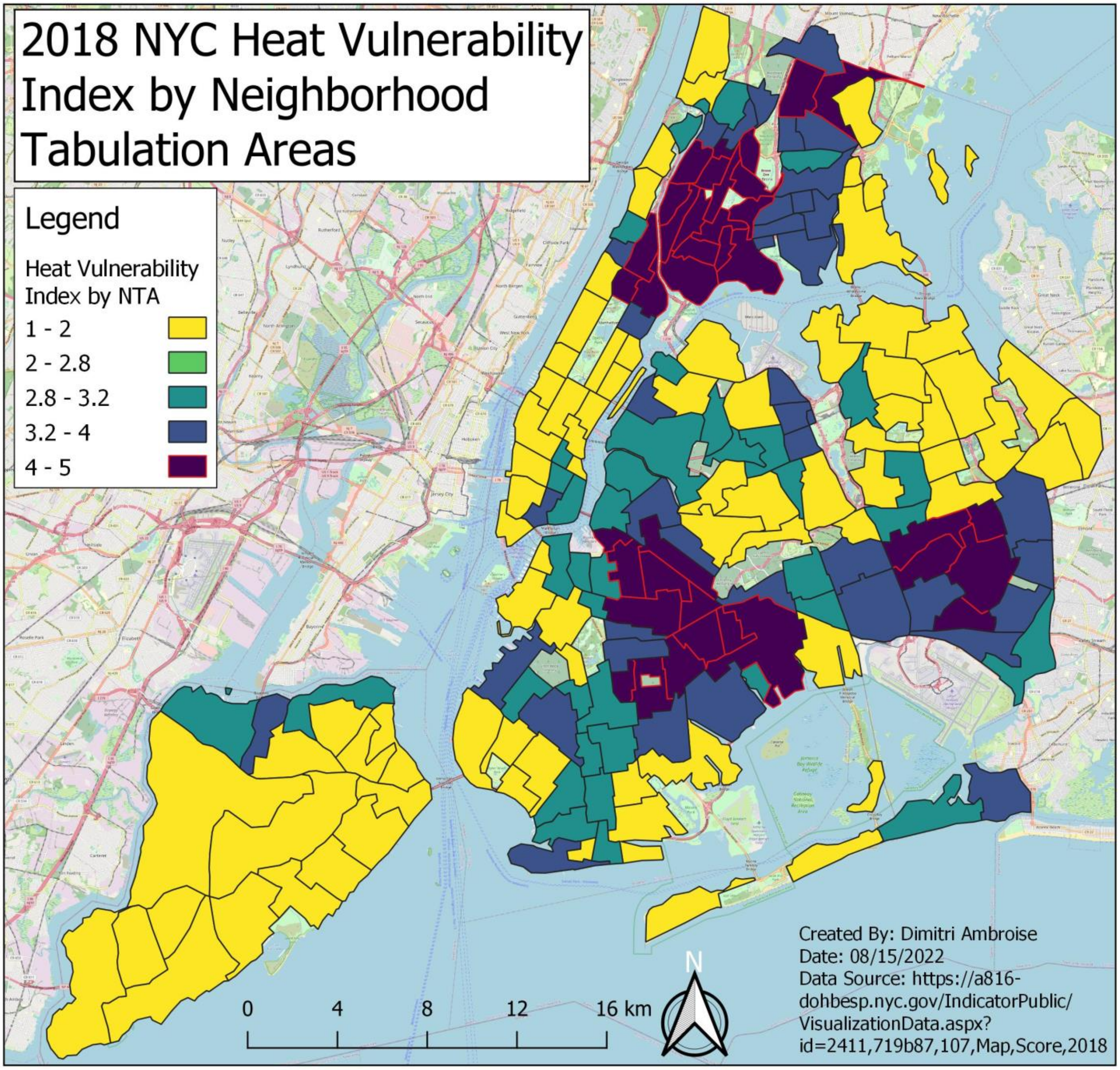


Figure 4: 2018 NYC Heat Vulnerability Index by Neighborhood. Some of the highest at risk neighborhoods are depicted in purple with red outlines. (i) North most cluster: Harlem, Spanish-East Harlem, West Concourse, Hunts Point (ii) South most cluster: East New York, Brownsville, Williamsburg, Bedford-Stuyvesant (iii) East most cluster: Jamaica, St. Albans, Hollis, Springfield Gardens North

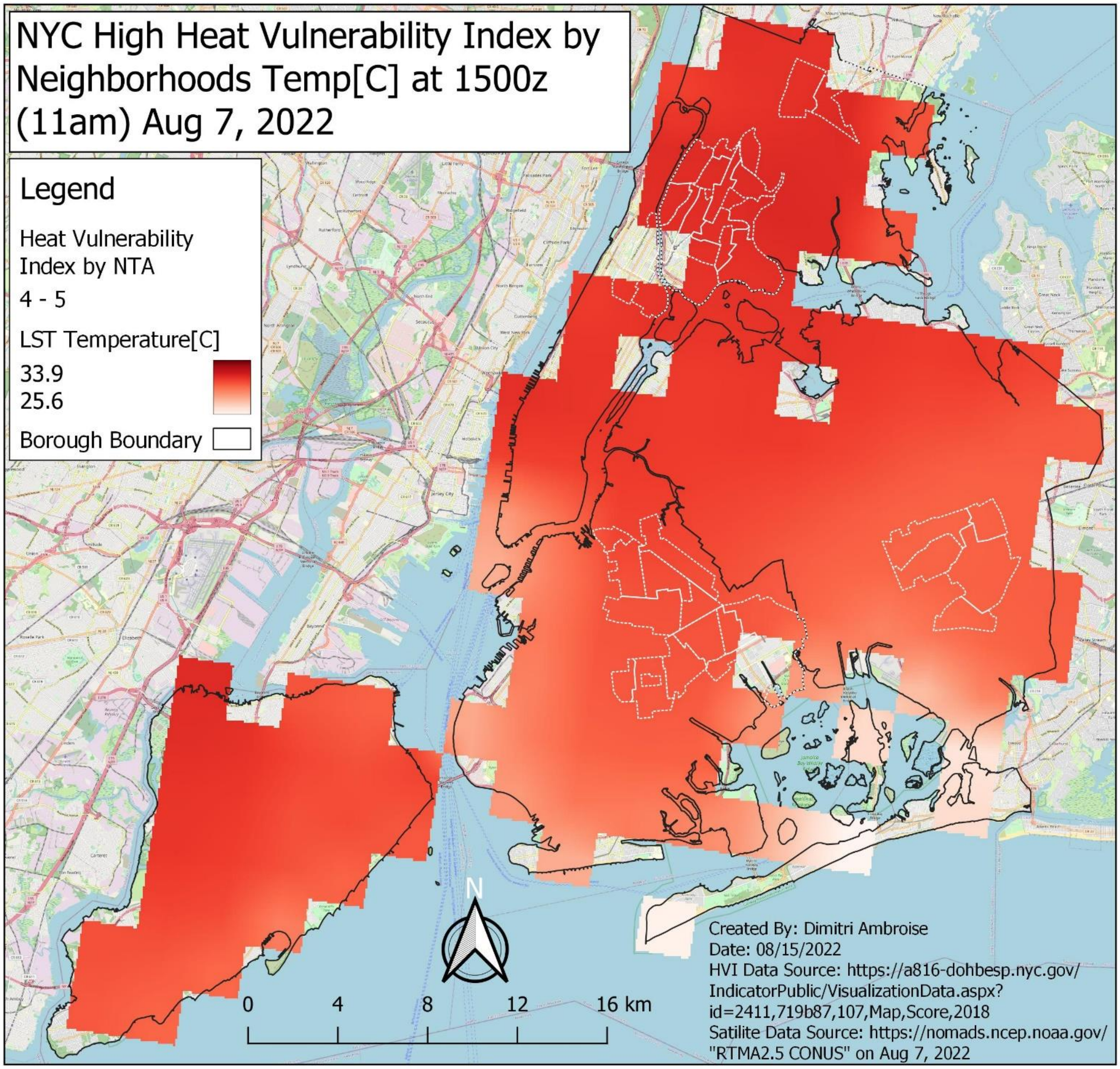


Figure 5: August 07, 2022 1500z (11am EST.) Land Surface Temperature (red gradient) Map of NYC's Highest Heat Vulnerability Index at Risk Neighborhoods. Note the temperature difference in the clusters at 5pm EST. Temperature Scale Reference: 25°C ≈ 77°F and 33°C ≈ 91.4°F

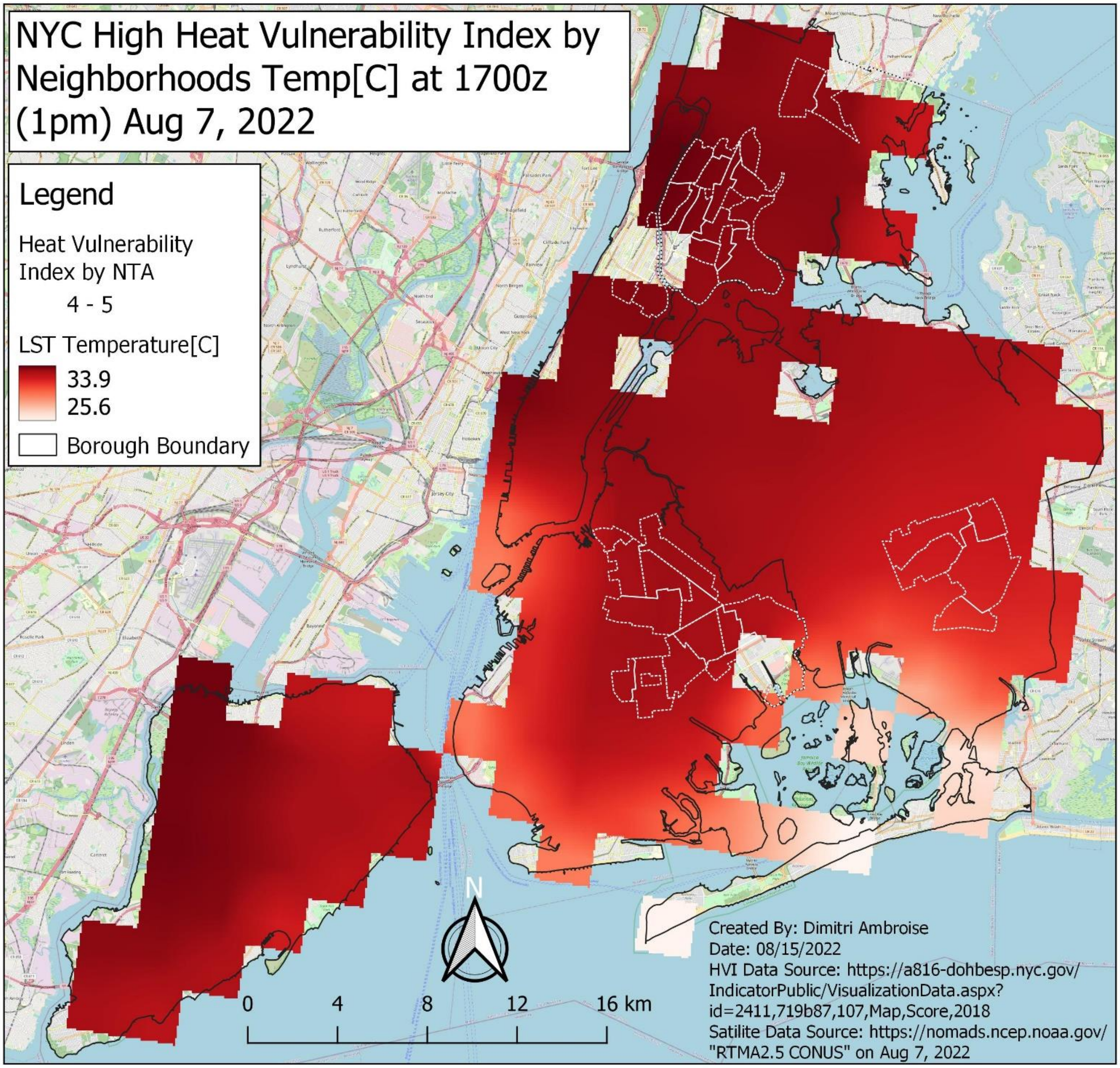


Figure 6: August 07, 2022 1700z (1pm EST.) Temperature Map of NYC's Highest Heat Vulnerability Index at Risk Neighborhoods. Note the temperature difference in the clusters at 5pm EST. Temperature Scale Reference: 25°C ≈ 77°F and 33°C ≈ 91.4°F

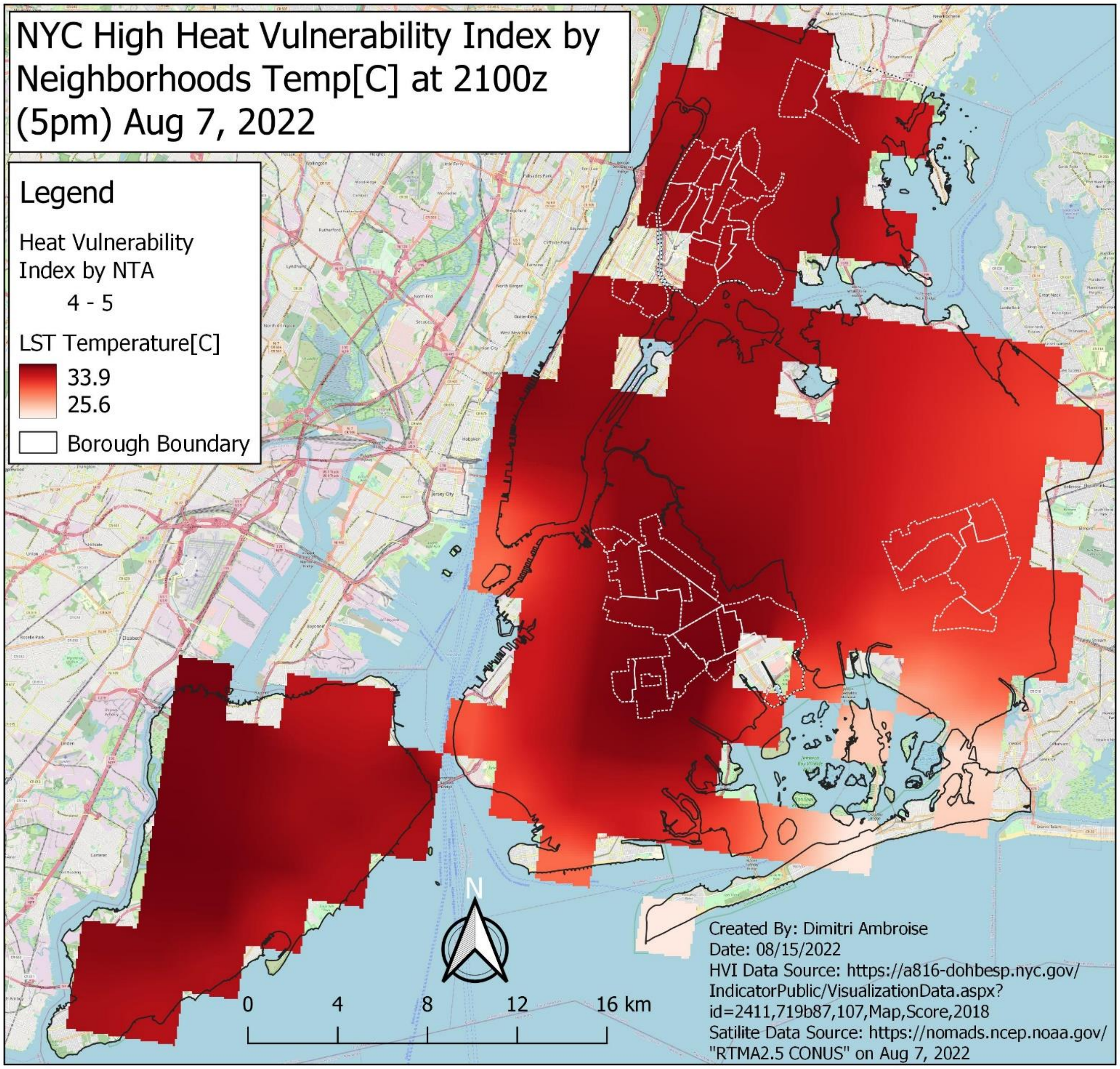


Figure 7: August 07, 2022 2100z (5pm EST.) Temperature Map of NYC's Highest Heat Vulnerability Index at Risk Neighborhoods. Note the temperature difference in the clusters at 5pm EST. Temperature Scale Reference: 25°C ≈ 77°F and 33°C ≈ 91.4°F

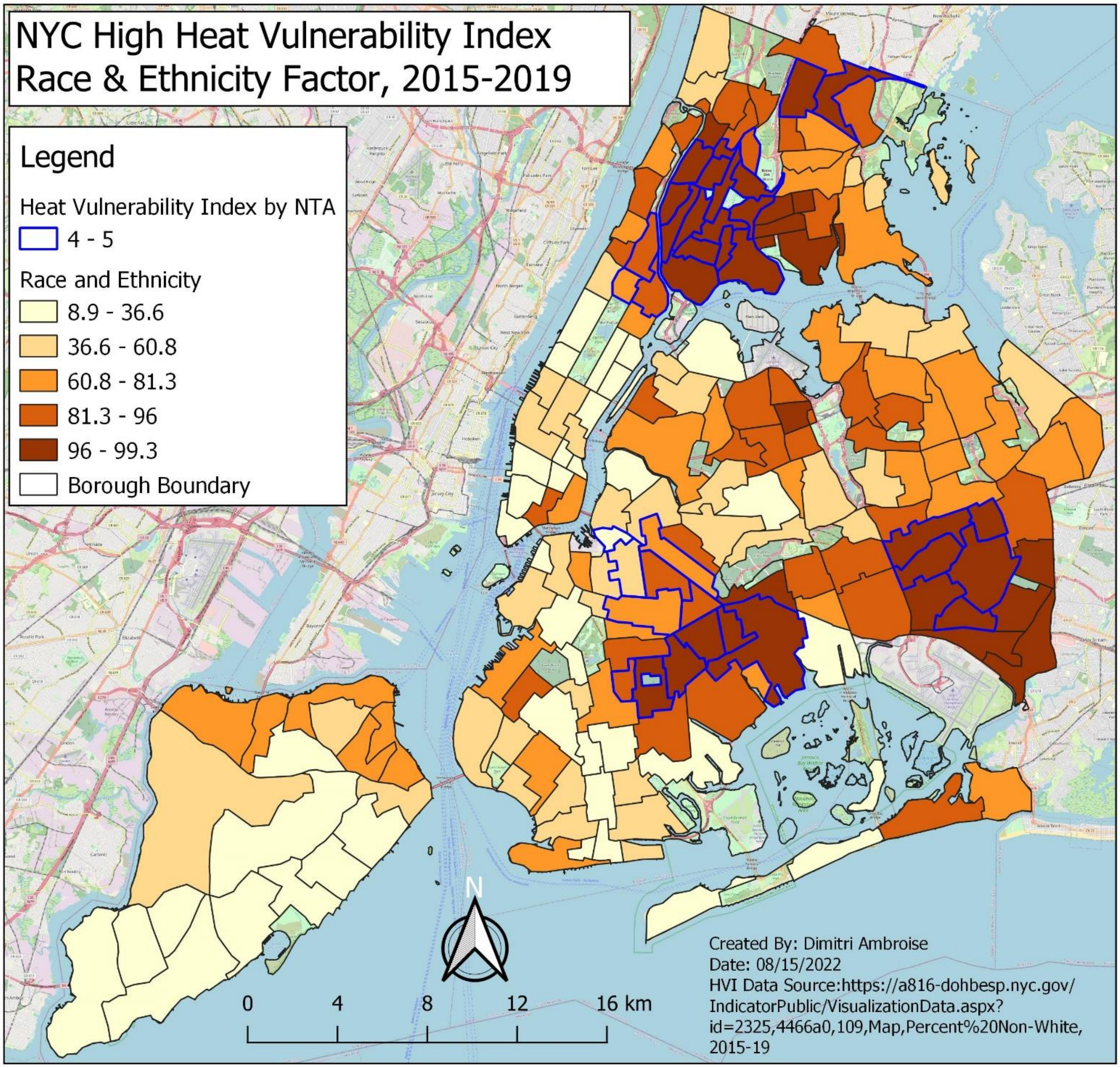


Figure 8: NYC's Heat Vulnerability Index Highest at Risk Neighborhoods Racial-Ethnic Profile map denotes the highest percentages of non-white individuals, the dark brown color, overlapping with the with outlines of the at risk neighborhoods

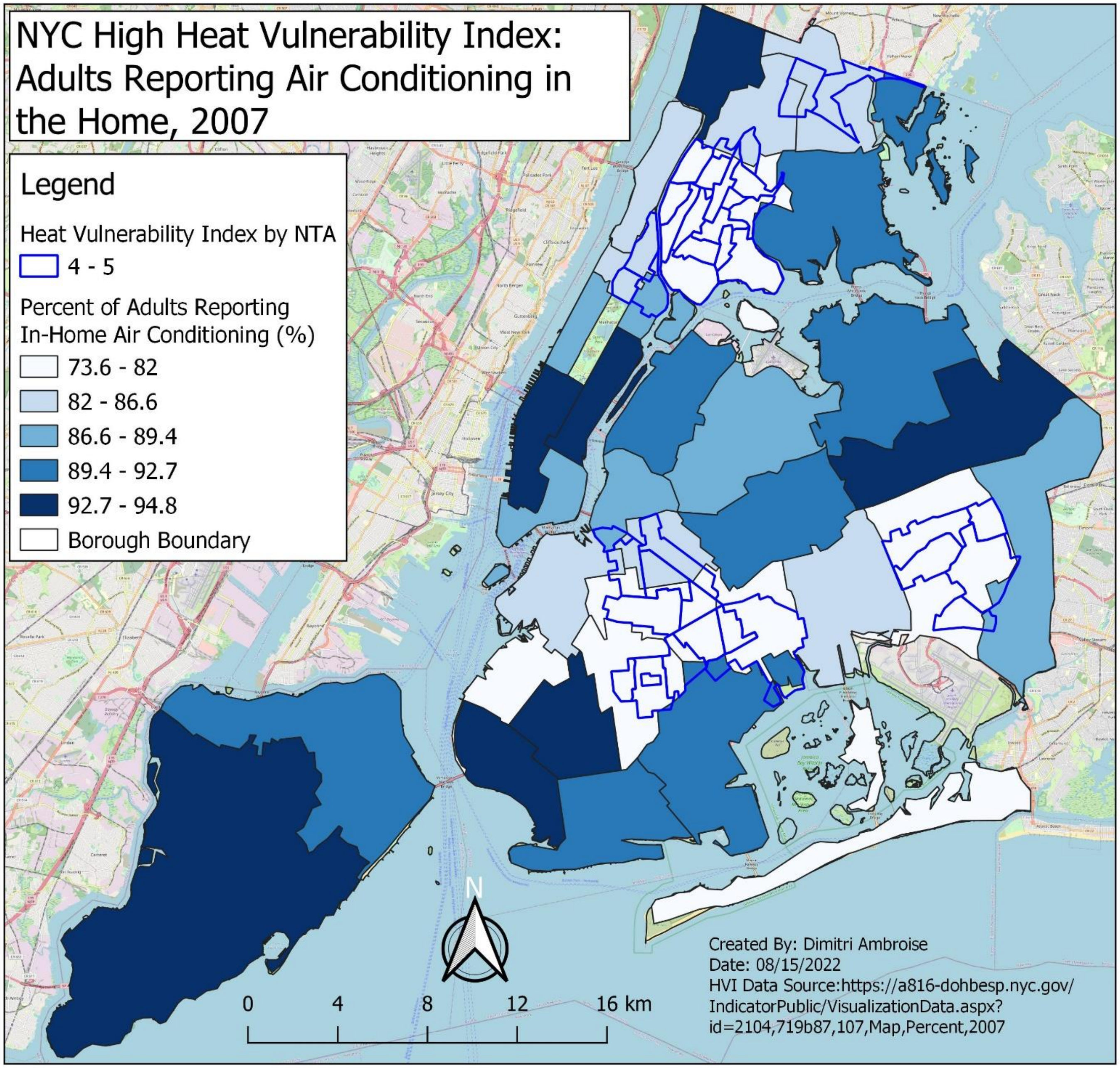


Figure 9: NYC's Heat Vulnerability Index Highest at Risk Neighborhoods map depicted by lowest percentages of individuals reporting having AC units in the home, the dark blue color, overlaps with the outlines of the at risk neighborhoods. It should be noted that an individual may have an AC unit, however it may not be operable nor installable in a given window, depending on its design.

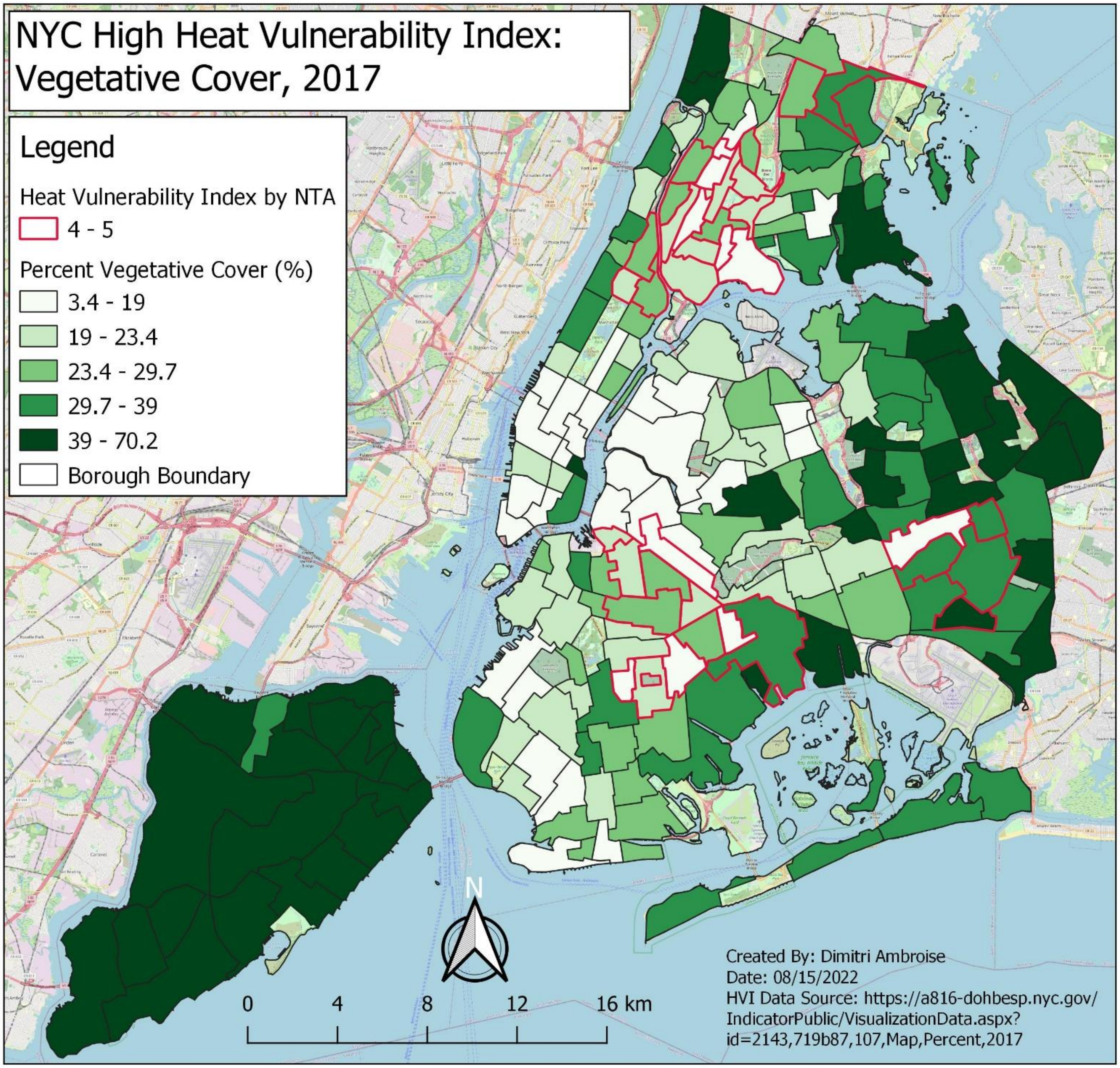


Figure 10: NYC's Heat Vulnerability Index Highest at Risk Neighborhoods Map showing the percent of vegetative cover, this could include, trees on streets and sidewalks, grass, shrubbery, and parks. The at risk neighborhoods, outlined in red, show that in the Bronx and Brooklyn there is a lack of vegetation cove between 3.4% -30%. Comparatively most of the at-risk neighborhoods in Queens have 30% - 39% coverage.

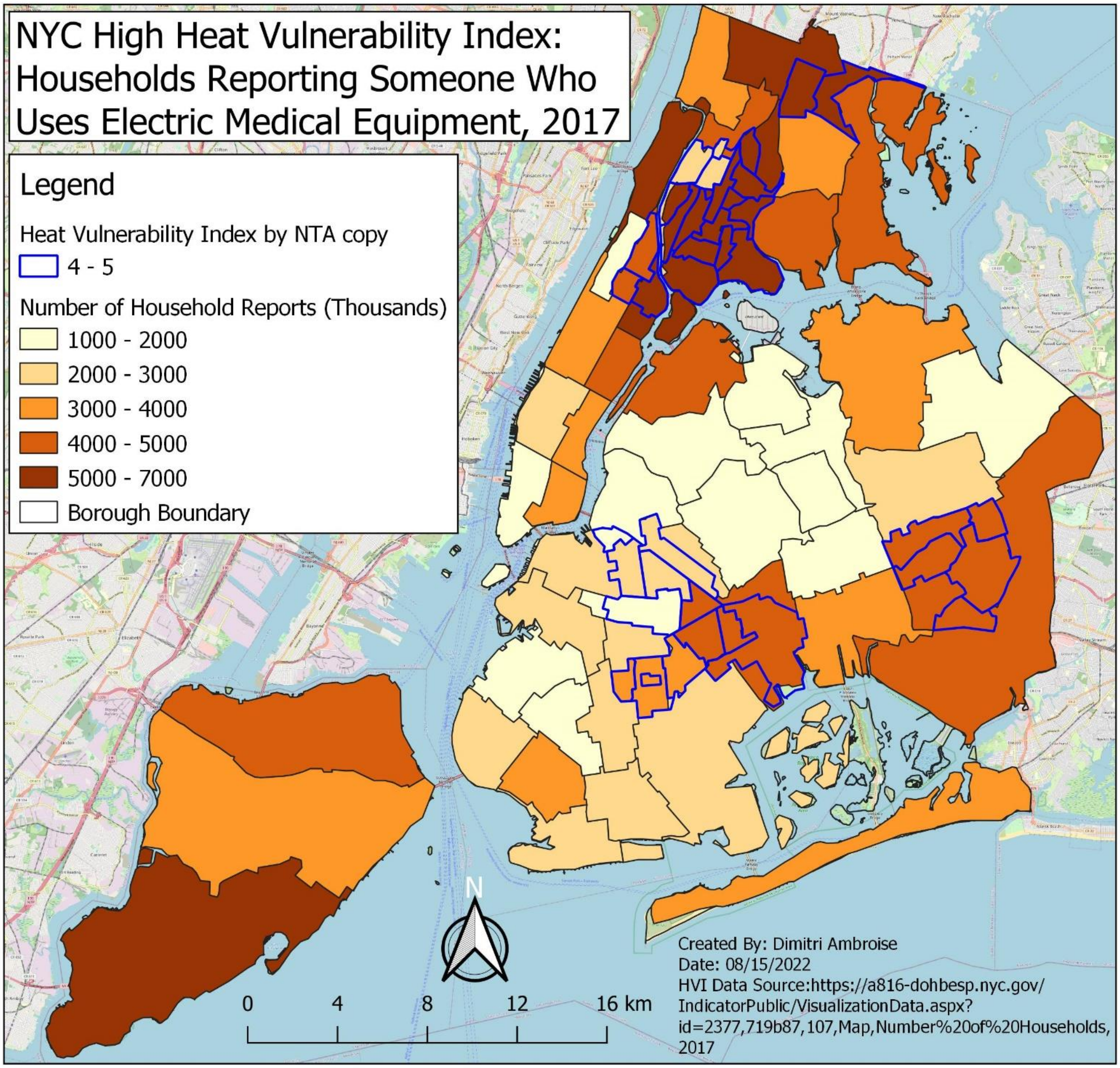


Figure 11: NYC's Heat Vulnerability Index Highest at Risk Neighborhoods Map showing the number of households reporting someone uses electrical medical equipment. That equipment can include but is not limited to: breathing apparatus, insulin coolers/refrigerator, motorized beds and chairs, surveillance/emergency warning systems.

Photos:

Photo 1: Dr. Jordan Gerth, NWS Office of Operations (Left) and Dimitri T. Ambroise, NOAA EPP/MSI Graduate Fellow (right) inside the National Weather Service Operations Center national monitoring room in Silver Spring, Maryland

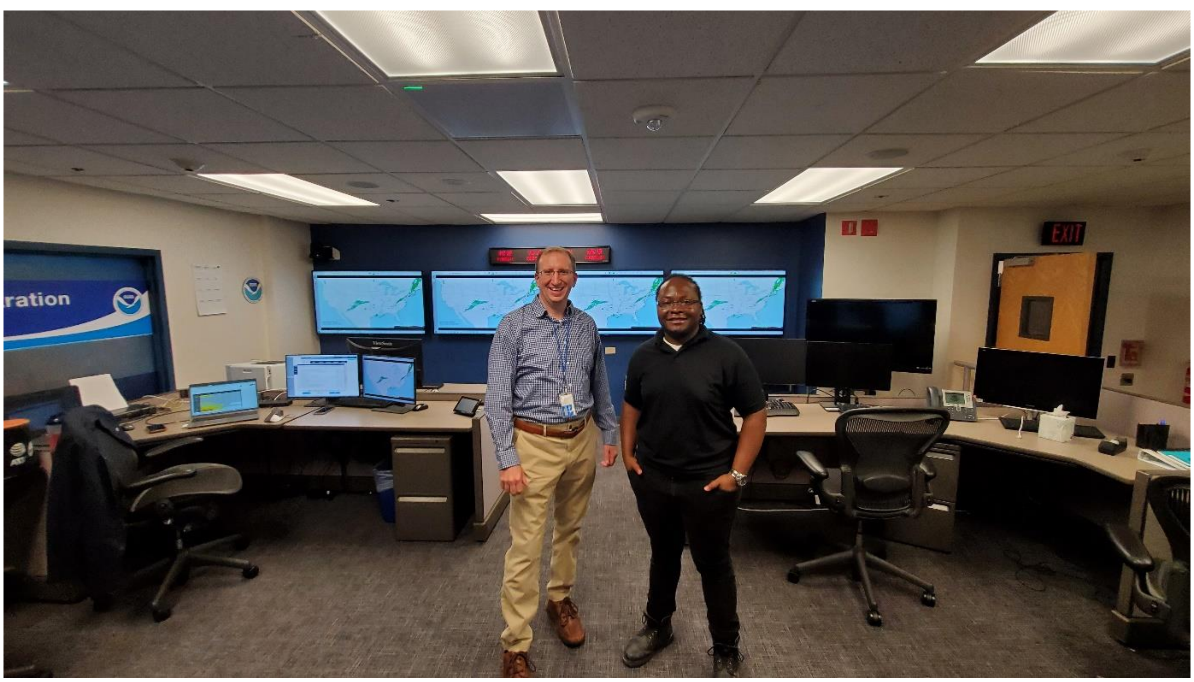


Photo 2: Brian Montgomery, NWS Operations Center Team Lead(Left) and Dimitri T. Ambroise, NOAA EPP/MSI Graduate Fellow (right) inside the National Weather Service Operations Center monitoring room in Silver Spring, Maryland

Photo 3: Alex Lamers, Warning Coordination Meteorologist for NOAA/NWS National Centers for Environmental Prediction (Left) and Dimitri T. Ambroise, NOAA EPP/MSI Graduate Fellow (right) in the atrium of the Weather Prediction Center (WPC) in College, Park

Photo 4: Attendees present at my NERTO exit presentation; Shakila Merchant- NOAA CESSRST Affiliate (Top Left) Dr. David Radell – NWS WFO Affiliate (Top Right) Brian Montgomery - NWSOC Affiliate (Bottom Left) Dimitri T. Ambroise – NERTO Intern (Bottom Right)

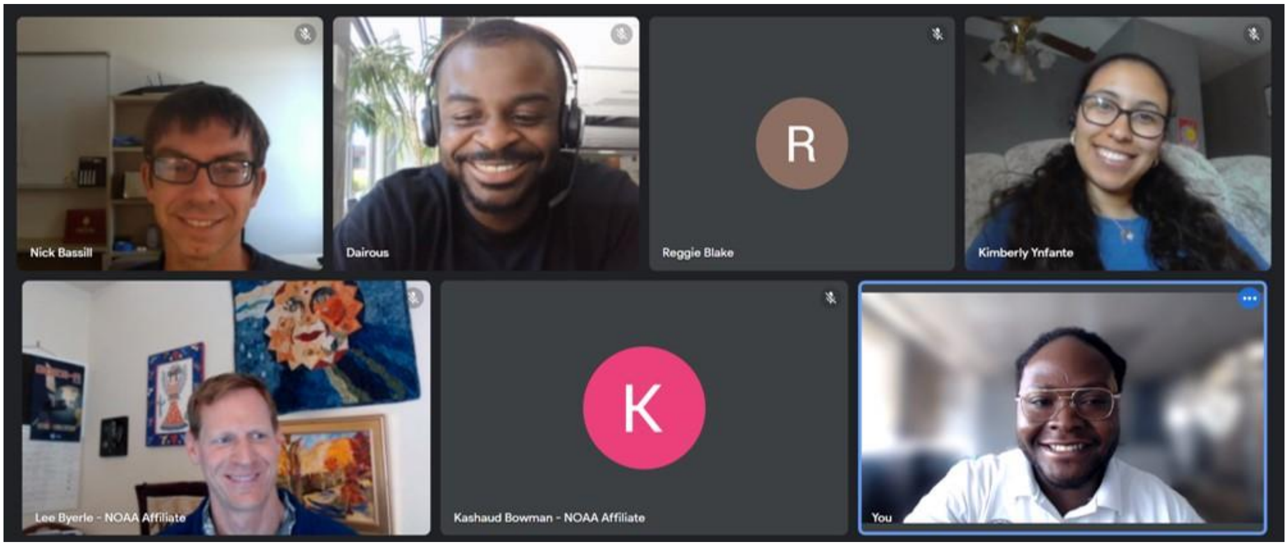


Photo 5: Attendees present at my NERTO exit presentation; Top Left to Right: Dr. Nicholas Bassill - NYS Mesonet SUNY/University at Albany Affiliate, Dairous Bonsu – Schneider Electric Affiliate, Dr. Reginald Blake – CUNY CityTech Affiliate, Kimberly Ynfante de Sanfilippo – Center for Humanistic Change Affiliate Bottom Left to Right: Lee A. Byerle - NOAA Affiliate /TOWR-S Team, Kashaud Bowman - NOAA Affiliate /TOWR-S Team, Dimitri T. Ambroise – NERTO Intern (Bottom Right)

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