ARD to DRI - Safe Software D118

Supplementary Report

Dean Hintz, August 2024

Safe Software explored key aspects and challenges related to building data value chains from raw data to ARD and DRI in order to support disaster response and climate resilience applications, both in this and previous OGC disaster and climate pilots. As discussed in prior pilots, while ARD - Analysis Ready Data - was initially developed for EO (earth observation) applications; it can also be useful to apply ARD approaches to analytic model results to make these results more widely accessible.

In order to evaluate and validate the approaches discussed in this section, Safe Software has included an ARD component to test against. Our ARD / DRI component supports ARD and DRI generation related to disaster and climate resilience indicators such as urban heat island effects for NYC. By participating in DP21, DP23 and CRP23 Safe gained experience building flood impact, drought severity and heat risk indicators.

In this pilot, Safe Software supplied an D121 Weather Event component which integrates real time data observations from a publicly accessible weather service (such as the National Weather Service API) with data related to urban heat effect factors from the D118 ARD urban heat service component. The FME platform, which supports data integration and automation, is used to aggregate relevant data from a range of data sources relevant to the chosen climate resilience scenario, namely extreme urban heat. Some of the source data incorporated included surface type, impervious surfaces, and buildings data.

The goal is to construct a limited urban digital twin that is focussed on providing extreme heat warnings for urban areas, including evaluation of effects related to urban heat islands. Ultimately it is hoped this will help develop a standardized ARD service that can be used by a variety of components to drive decision ready indicators in order to support timely decision making.

Note that a number of open and OGC standards are utilized in these components. The results are stored in an OGC Geopackage spatial database and made available via OGC API services such as OGC API Features. Datasets are also made available via a variety of OGC and other open standards (Geopackage, geojson, GeoTIFF, GML and GeoRSS) as messaging data streams and for extraction and download. Finally, data is published in cloud native formats such as COG, Geoparquet and Flatgeobuff as needed.

Urban Extreme Heat ARD Service and Workflow

Safe Software was a participant in the Extreme Heat Team for NYC. The primary goal of this effort was to develop approaches for monitoring and modeling urban heat island (UHI) effects in order to better support heat risk mitigation and planning. Urban Heat Island Effect (UHIE): Heat islands are urbanized areas that experience higher temperatures than outlying areas when exposed to the same sunlight. Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies. Urban areas and artificial landscapes, where these structures are highly concentrated and greenery is limited, become "islands" of higher temperatures relative to outlying areas. Heat Island Effect | US EPA It is worth noting that while flood impacts may constitute the natural hazard with the greatest monetary impact, many observations have been made that support extreme heat as the greatest natural hazard impact in terms of human lives lost each year. For more information see these WHO and CBC and Climate Central reports.

One of the central challenges when addressing climate and disaster impacts is downscaling effects and impacts to the local level. For example, temperature forecasts either from weather or climate models are often only available in a kilometer level resolution. NOAA's HRR forecast models are considered High Resolution: https://rapidrefresh.noaa.gov/hrrr/ at 3km grid size. The difficulty is that urban heat island effects vary significantly within these kilometer squares.

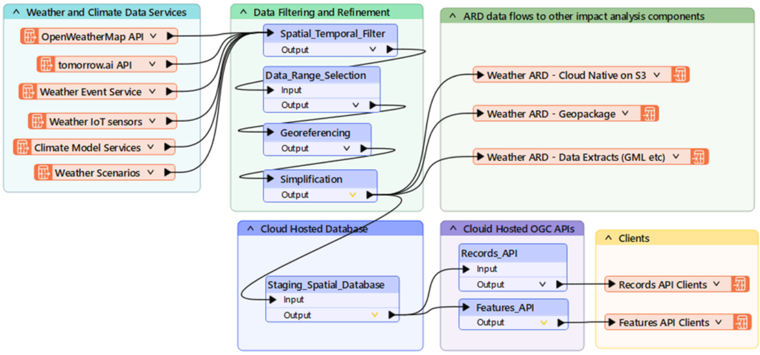
Surface material is one of the most important factors in analyzing urban heat island (UHI) effects. UHI mitigation and urban cooling mechanisms consistently highlight the crucial role of green, gray, and blue infrastructure in regulating urban temperatures. Surface type data is often available in a much higher resolution (~ 1m) such as in the case of NYC. This allows analysis to utilize a pan sharpening approach whereby a low resolution dataset is perturbed by a much higher resolution grid to provide a better estimate of local conditions. Thus, the spatial distribution of the local landscape and built environments can be incorporated into UHI analyses to capture their localized impacts more accurately.

To effectively account for the influence of surface material on UHI, a promising strategy is to integrate surface type and surface material data into a comprehensive analysis. The spatial distribution of different surface materials is used to generate an albedo surface. This approach enables a more granular understanding of how specific surface characteristics affect the UHI effect across the city.

The surface type and material information is combined with weighted contributions from albedo, emissivity, and thermal conductivity, to develop a more robust model of UHI intensity. This integrated approach allows for a holistic assessment of how different surface properties interact and contribute to the overall UHI effect. By assigning appropriate weights to each factor based on their relative importance, we create a composite UHI contribution grid that captures the spatial variability of UHI intensity across the city. This information drives the model which produces a grid showing where there is a greater probability or risk of Urban heat island effects. The purpose of this model is to help estimate what areas are most at risk due to urban heat island effects, especially in regards to health. These areas can then be used to generate extreme heat alert warnings, both as a city wide warning as well as to subscribers by specific location. This data can also help plan mitigation measures such as tree planting, green roofing etc to reduce urban heat island effects.

Approach

- Generate urban heat island effect grid for study area in NYC.
- An alternative grid can be generated from an external model such as the results from the Climate Central urban heat study.
- Platform administrator selects the default urban heat index model
- Accept weather data service messages from D121 for locations or cities of interest
- Extract environmental variable values from weather data service messages
- Add urban heat island effect to forecast temperature from weather service message.
- Generate appropriate heat risk result based on threshold values for urban heat island effects: green, yellow, red
- Expose this location or area request / response service via an OGC Features API



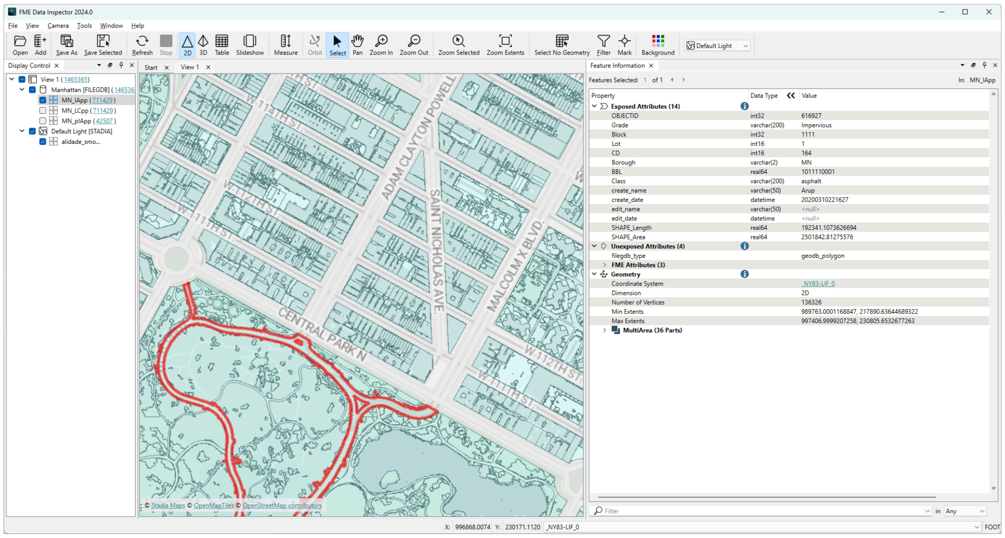
Weather Data Service Real Time Data Streams to ARD & DRI

Urban Heat Island Index Workflow

Modeling goal: Multiply normalized absorption surface by the observed UHI temperature range for the city to get estimated, interpolated UHI temp delta values per location.

1. Read the ESRI geodatabase for impervious surfaces and surface types from NYC Open Data (asphalt, grass etc).
2. Map surface types to albedo values using a lookup table
3. Generate an albedo surface model by setting height (z) = albedo.
4. Convert these vector albedo surface to a smoothed, interpolated albedo raster grid, normalized to between 0 to 1.
5. Invert this to generate an absorption surface
6. Generate a cooling surface based on green and blue area types

7. Sum the urban heating and cooling grids to get an overall normalized estimated urban heat index grid
8. Use a published parameter for observed temperature range due to urban effects to scale the normalized heat index by multiplying it by the observed temperature range to generate an estimated UHI effect grid
9. Add forecast or observed temperature projections from the weather event feed to the estimated UHI effect grid to derive estimated temperatures throughout the urban landscape



Features Selected: 1 of 1 In: MN_IApp

Property	Data Type	Value
Exposed Attributes (14)		
OBJECTID	int32	616927
Grade	varchar(200)	Impervious
Block	int32	1111
Lot	int16	1
CD	int16	164
Borough	varchar(2)	MN
BBL	real64	1011110001
Class	varchar(200)	asphalt
create_name	varchar(50)	Arup
create_date	datetime	20200310221627
edit_name	varchar(50)	<null>
edit_date	datetime	<null>
SHAPE_Length	real64	192341.1073626694
SHAPE_Area	real64	2501842.81275576
Unexposed Attributes (4)		
filegdb_type		geodb_polygon
FME Attributes (3)		
Geometry		
Coordinate System		_NY83-LIF_0
Dimension		2D
Number of Vertices		136326
Min Extents		989763.0001168847, 217890.63644689322
Max Extents		997406.9999207258, 230805.6532677263
MultiArea (36 Parts)		

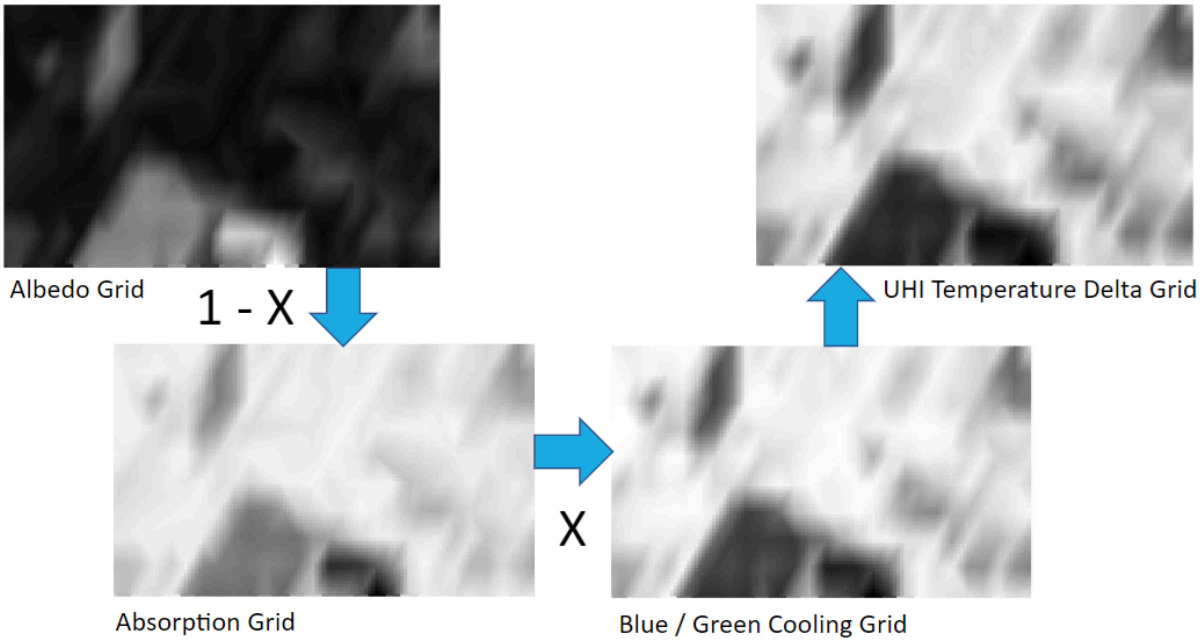
NYC impervious surface and surface type database from NYC Open Data

Surface albedo grid

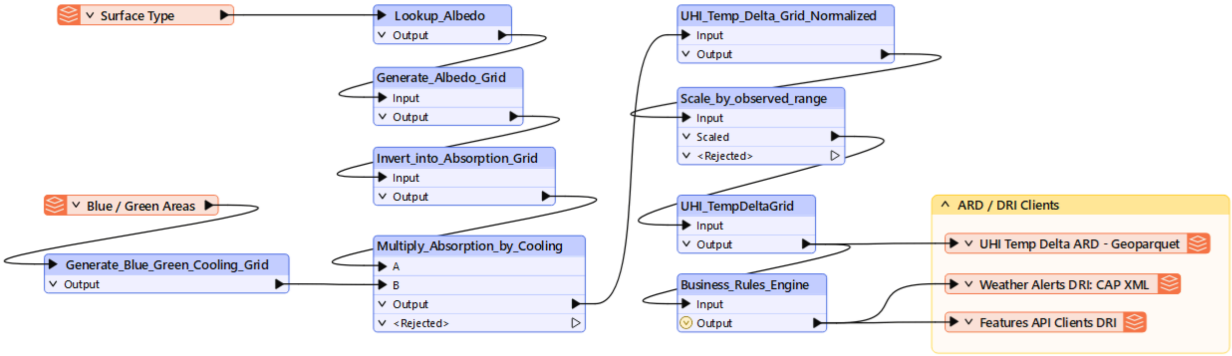
Green and blue surface types and resulting urban cooling grid

Urban Extreme Heat ARD Service Workflow

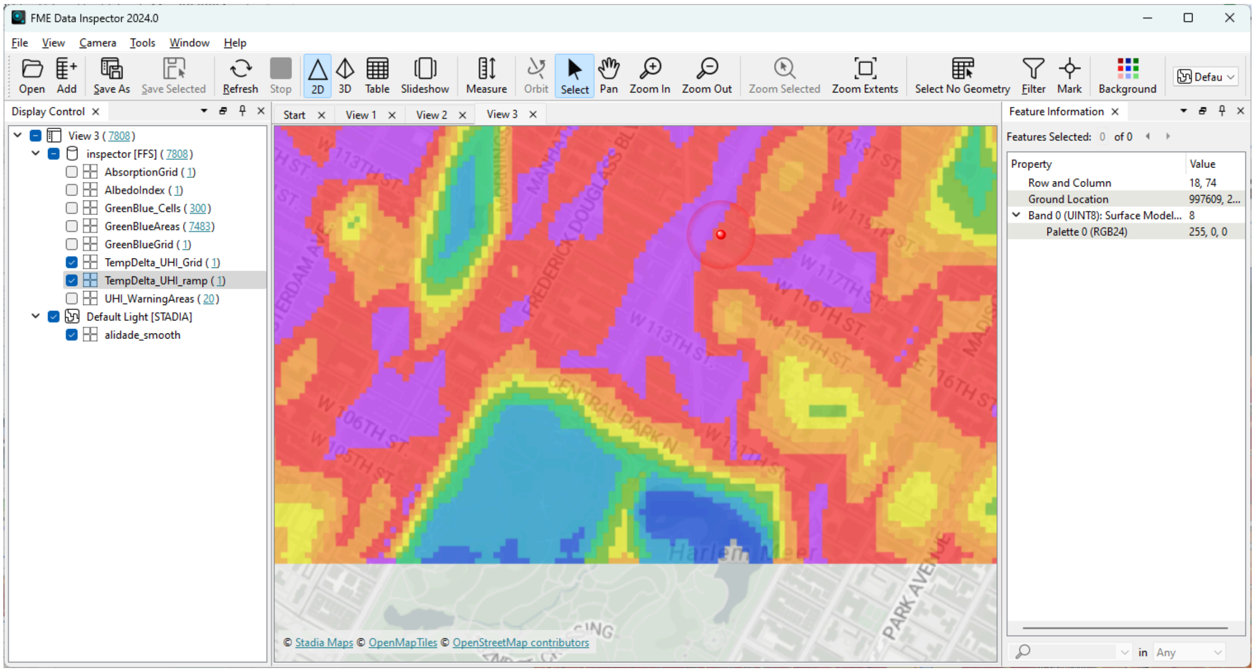
1. Accept OGC API Feature requests for locations and areas of interest.
2. Combine observed or forecast temperature observations with expected temperature deltas from the urban heat index grid generated above.
3. Evaluate modified urban heat values against warning thresholds.
4. Determine whether and what type of urban heat warnings to produce
5. Generate heat warning messages with the appropriate warning levels and transmit this back to the requester as an OGC API Feature response.



UHI model raster algebra analytic workflow



Urban Heat Island Delta Grid FME Workflow

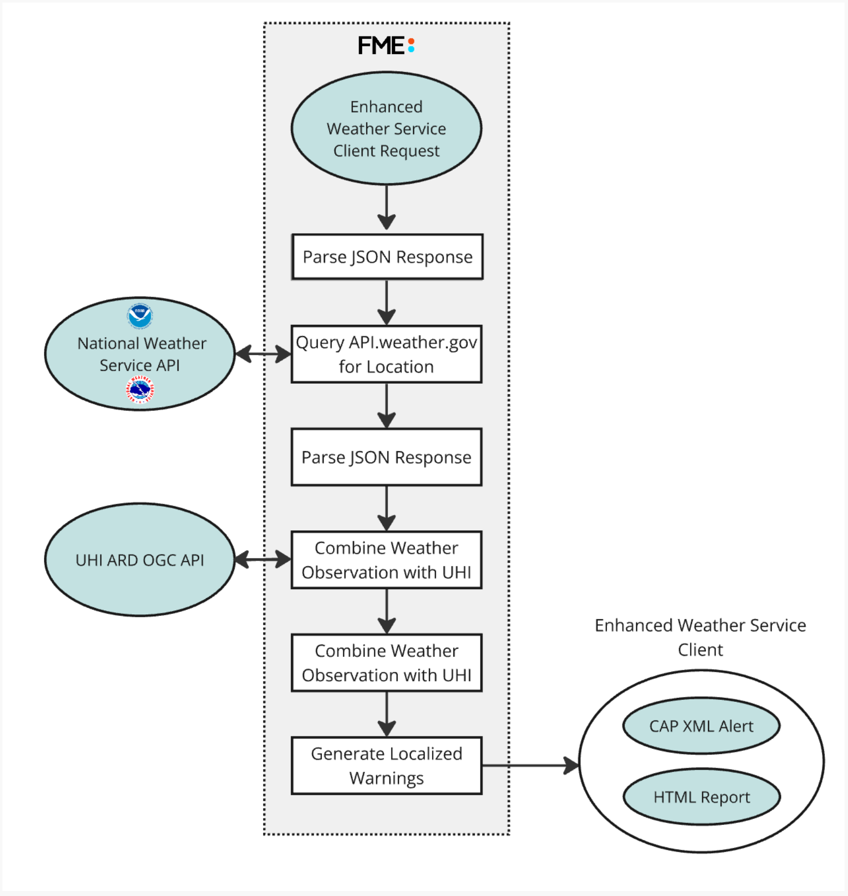


Features Selected: 0 of 0

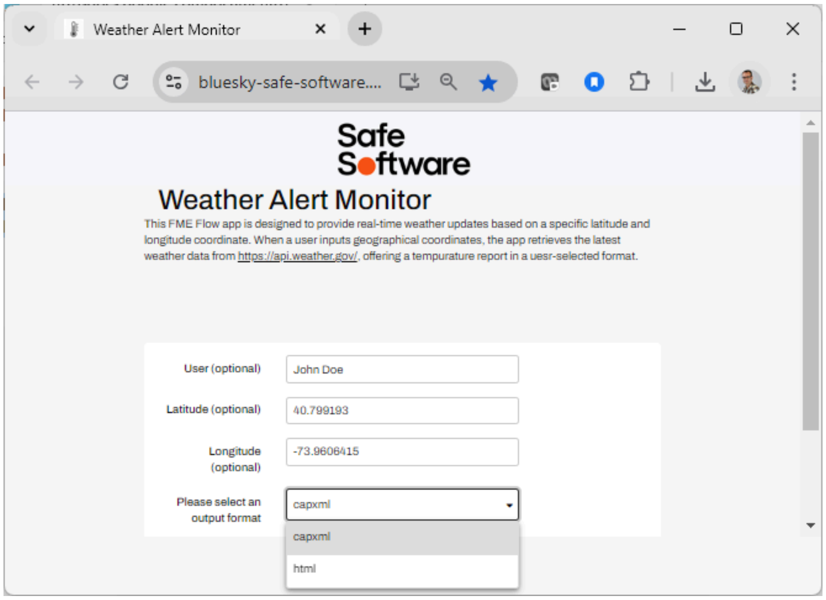
Property	Value
Row and Column	18, 74
Ground Location	997609, 2...
Band 0 (UINT8): Surface Model...	8
Palette 0 (RGB24)	255, 0, 0

Estimated UHI temperature delta grid (with color ramp from cool (blue) to hot (purple)

Note that the OGC API is used to connect this urban heat island effect ARD analysis back to the D121 Weather Event Component. The Weather Event component tracks NWS events, queries this ARD service, accepts the response and then generates warnings and subscription responses based on client location and area of interest.



Weather Service Real Time Data Feeds: FME Approach

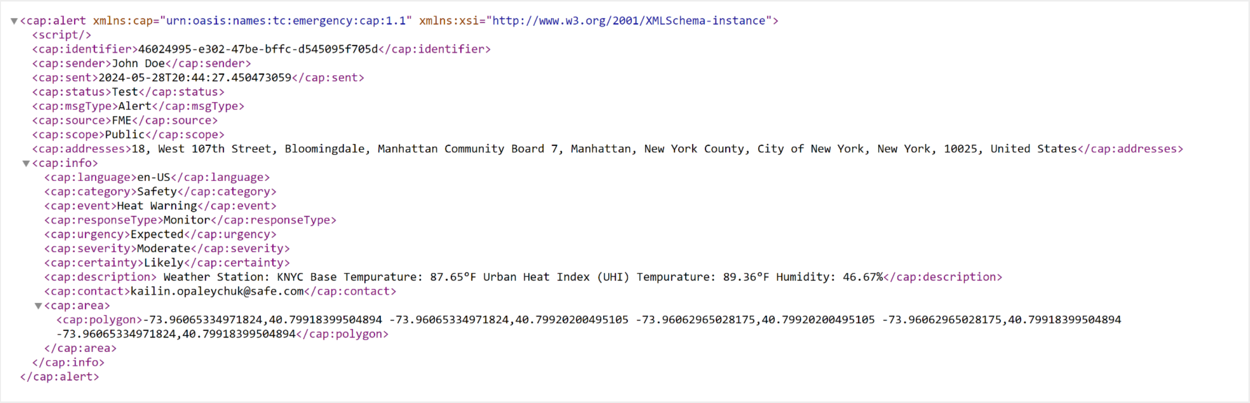


Weather Alert Monitor

This FME Flow app is designed to provide real-time weather updates based on a specific latitude and longitude coordinate. When a user inputs geographical coordinates, the app retrieves the latest weather data from https://api.weather.gov/, offering a tempurature report in a uesr-selected format.

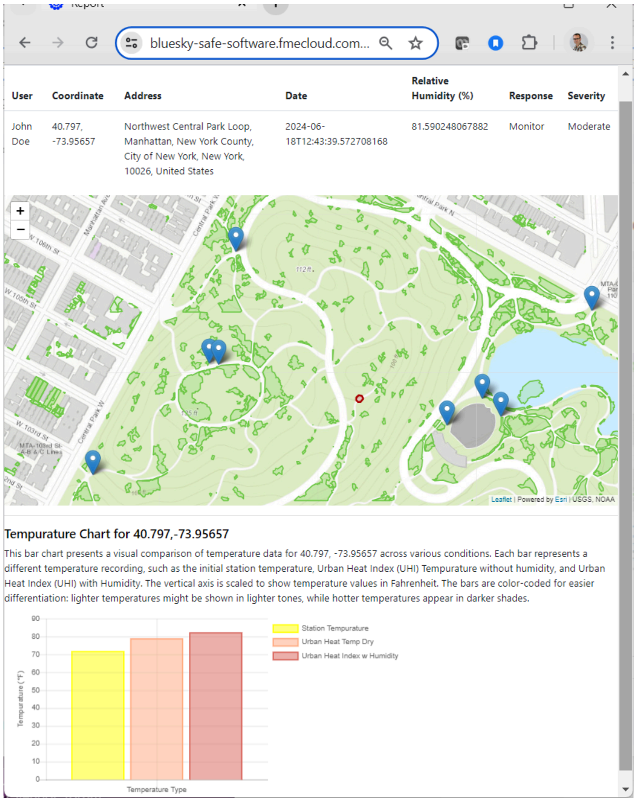
User (optional): John Doe
Latitude (optional): 40.799193
Longitude (optional): -73.9606415
Please select an output format: capxml

Weather Alert Monitor: [FME Flow App]



```
▼<cap:alert xmlns:cap="urn:oasis:names:tc:emergency:cap:1.1" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
   <script/>
   <cap:identifier>46024995-e302-47be-bffc-d545095f705d</cap:identifier>
   <cap:sender>John Doe</cap:sender>
   <cap:sent>2024-05-28T20:44:27.450473059</cap:sent>
   <cap:status>Test</cap:status>
   <cap:msgType>Alert</cap:msgType>
   <cap:source>FME</cap:source>
   <cap:scope>Public</cap:scope>
   <cap:addresses>18, West 107th Street, Bloomingdale, Manhattan Community Board 7, Manhattan, New York County, City of New York, New York, 10025, United States</cap:addresses>
  ▼<cap:info>
     <cap:language>en-US</cap:language>
     <cap:category>Safety</cap:category>
     <cap:event>Heat Warning</cap:event>
     <cap:responseType>Monitor</cap:responseType>
     <cap:urgency>Expected</cap:urgency>
     <cap:severity>Moderate</cap:severity>
     <cap:certainty>Likely</cap:certainty>
     <cap:description> Weather Station: KNYC Base Tempurature: 87.65°F Urban Heat Index (UHI) Tempurature: 89.36°F Humidity: 46.67%</cap:description>
     <cap:contact>kailin.opaleychuk@safe.com</cap:contact>
    ▼<cap:area>
       <cap:polygon>-73.96065334971824,40.79918399504894 -73.96065334971824,40.79920200495105 -73.96062965028175,40.79920200495105 -73.96062965028175,40.79918399504894
       -73.96065334971824,40.79918399504894</cap:polygon>
     </cap:area>
   </cap:info>
</cap:alert>
```

DRI Example: CAP XML - Common Alerting Protocol

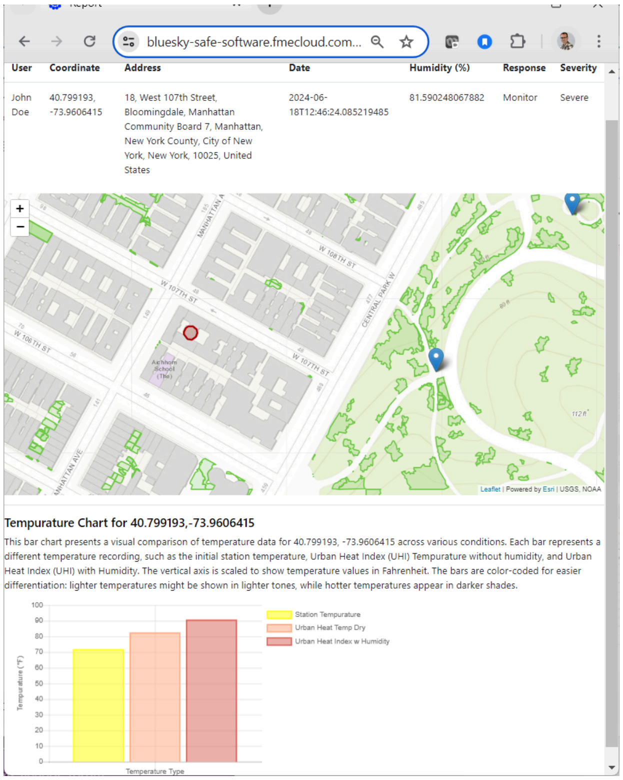


User	Coordinate	Address	Date	Relative Humidity (%)	Response	Severity
John Doe	40.797, -73.95657	Northwest Central Park Loop, Manhattan, New York County, City of New York, New York, 10026, United States	2024-06-18T12:43:39.572708168	81.590248067882	Monitor	Moderate

Tempurature Chart for 40.797,-73.95657

This bar chart presents a visual comparison of temperature data for 40.797, -73.95657 across various conditions. Each bar represents a different temperature recording, such as the initial station temperature, Urban Heat Index (UHI) Tempurature without humidity, and Urban Heat Index (UHI) with Humidity. The vertical axis is scaled to show temperature values in Fahrenheit. The bars are color-coded for easier differentiation: lighter temperatures might be shown in lighter tones, while hotter temperatures appear in darker shades.

Urban Temperature HTML Report: NYC Central Park



User	Coordinate	Address	Date	Humidity (%)	Response	Severity
John Doe	40.799193, -73.9606415	18, West 107th Street, Bloomingdale, Manhattan Community Board 7, Manhattan, New York County, City of New York, New York, 10025, United States	2024-06-18T12:46:24.085219485	81.590248067882	Monitor	Severe

Tempurature Chart for 40.799193,-73.9606415

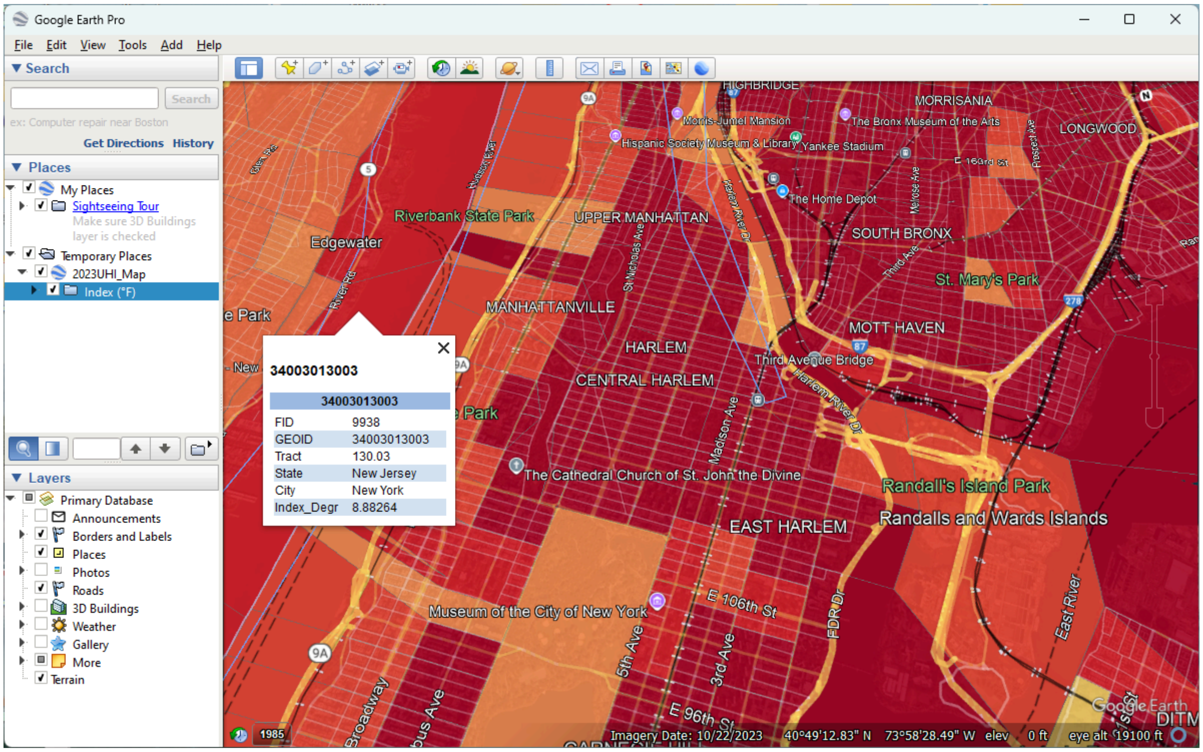
This bar chart presents a visual comparison of temperature data for 40.799193, -73.9606415 across various conditions. Each bar represents a different temperature recording, such as the initial station temperature, Urban Heat Index (UHI) Tempurature without humidity, and Urban Heat Index (UHI) with Humidity. The vertical axis is scaled to show temperature values in Fahrenheit. The bars are color-coded for easier differentiation: lighter temperatures might be shown in lighter tones, while hotter temperatures appear in darker shades.

Urban Temperature HTML Report: NYC high density residential

Discussion

The iterative development of the weather event service and underlying urban heat effect component yielded some interesting observations. First of all, the data model and resolution used for ARD outputs is perhaps more important than the specific format or standard used. During the research for this report, a number of urban heat effect data products were encountered. It is noteworthy that a number of these products were vector based. This could be because the urban heat island analytics is in the early stages of development. Some of these products are national in scope and so thematic vector polygons require a relatively small amount of data to cover selected urban areas across the country.

However, upon closer examination, the limitations of the vector data model can be clearly seen. Consider the estimated temperature gradations in the figure below from Climate Central. One can observe that the UHI temperature delta changes from 7.0 in central park to 10.6 immediately north of the park. One would expect a more gradual increase in temperature, and for the park or the Hudson river to have a cooling influence on nearby areas. In Safe Software’s component, a continuous interpolated raster surface was employed. As seen in the Estimated UHI temperature delta grid shown above, there is a gradual warming from central park and hudson river into built up areas.



34003013003

34003013003	
FID	9938
GEOID	34003013003
Tract	130.03
State	New Jersey
City	New York
Index_Degr	8.88264

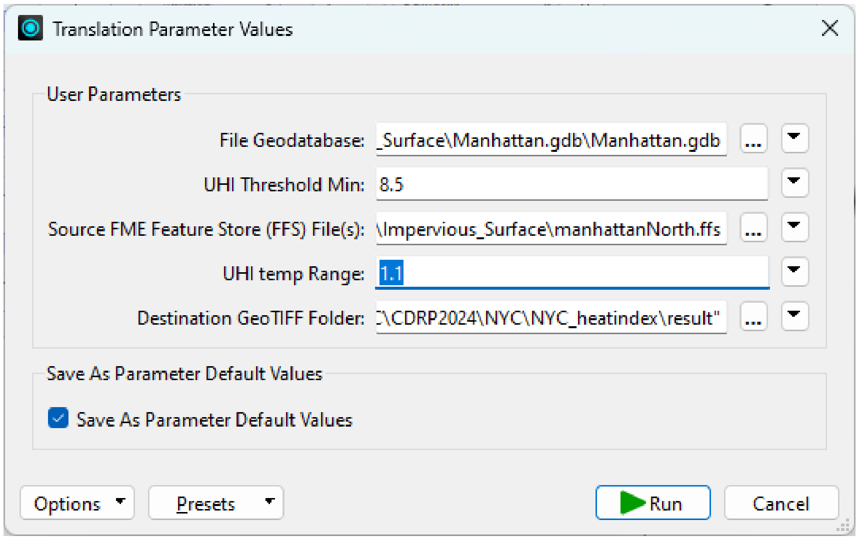
Climate Central urban heat effect map in OGC KML

For many model results, often a raster or gridded result seems to be a more flexible data product than a thematic vector interpretation. Another example of this was from the 2021 Disaster Pilot. In that case, initially the flood model was used to generate a flood polygon. However, these polygons were of limited use since they did not contain flood depth information. It was later determined that a flood depth of 20cm was the limit for civilian traffic and flood depth of 40cm for first responders. These business rule thresholds were then used in combination with the flood time series grids to produce flood polygons relevant for the evaluation of road closures and mitigated flood routing.

A similar example was encountered when generating a drought model for the 2023 Climate Pilot. At first the model was used to generate heat polygons from climate forecasts. However, much of the localized info from the climate estimates were lost in this classification process. In this case it was found that a more efficient method for storing heat and rainfall data was as point data in the geopackage. Further, by combining heat and rainfall estimates at the same spatial temporal point in the time series, it was possible to construct SQL queries to query millions of grid cells and in seconds get an answer to the question: “Where and when will we see monthly min temp > 23C and precipitation < 70% of historical norms from 1960 - 1990?”

In each case the data model used to store the ARD results had to be carefully designed in consultation with the stakeholders planning to utilize the data. Use cases needed to be clearly documented and understood. Also, minimal business rule pre-evaluation meant that the resulting ARD could be applied to a wider array of applications.

Another observation was the usefulness of automation. Specifically, the FME UHI ARD service (D118) was constructed in such a way that key calibration variables were exposed as parameters. One of these parameters was temperature range. The usefulness of this became apparent during the OGC member meeting leading up to the final pilot presentation workshop. Navteca and Safe Software decided to collaborate on a 3D animation showing urban heat island effects in central Manhattan. Navteca initially simply took the urban heat index above and overlaid it on their 24 hour shade model. The problem was this did not appear at all realistic. The urban heat ranges and areas did not change over time. In order to develop a more realistic rendition, the Safe UHI ARD component was run at 10% increments to simulate the effects of a warming day, Navteca then used these UHI grids to interpolate from morning to the the hottest part of the day in late afternoon (100% UHI grid) followed by descending grids back down to 0% for late at night. The result was a much more intuitive rendering that dramatically illustrated the potential effects of UHI in the context of a 3D building and landscape model of NYC. The ARD needed to support this rendering was generated in less than 30 minutes due to the automated nature and suitable parameterization of the ARD service.



Translation Parameter Values

User Parameters

File Geodatabase: _Surface\Manhattan.gdb\Manhattan.gdb

UHI Threshold Min: 8.5

Source FME Feature Store (FFS) File(s): \Impervious_Surface\manhattanNorth.ffs

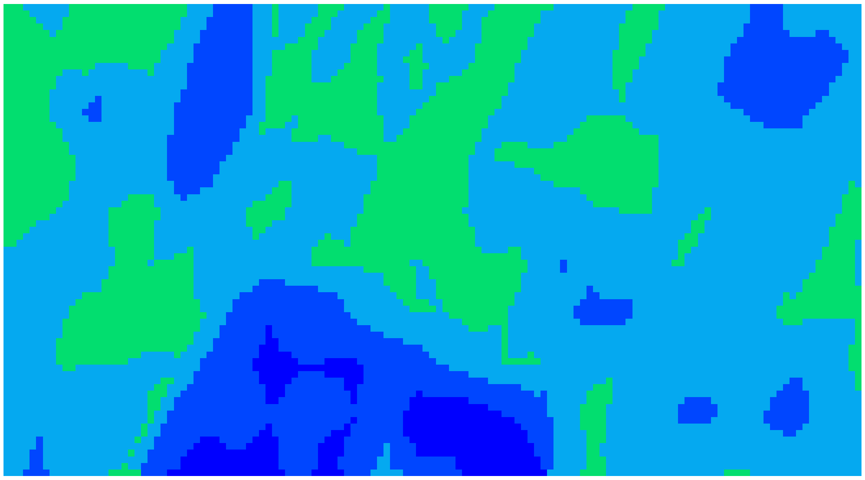
UHI temp Range: 1.1

Destination GeoTIFF Folder: \CDRP2024\NYC\NYC_heatindex\result"

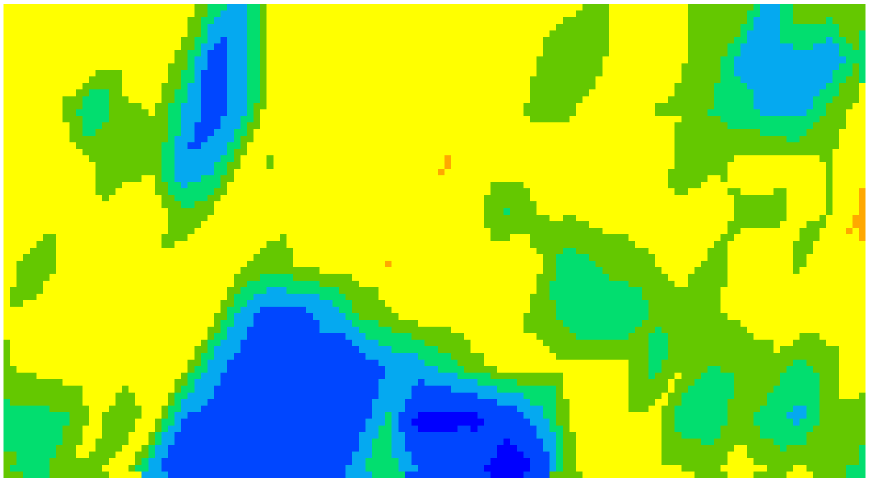
Save As Parameter Default Values

☑ Save As Parameter Default Values

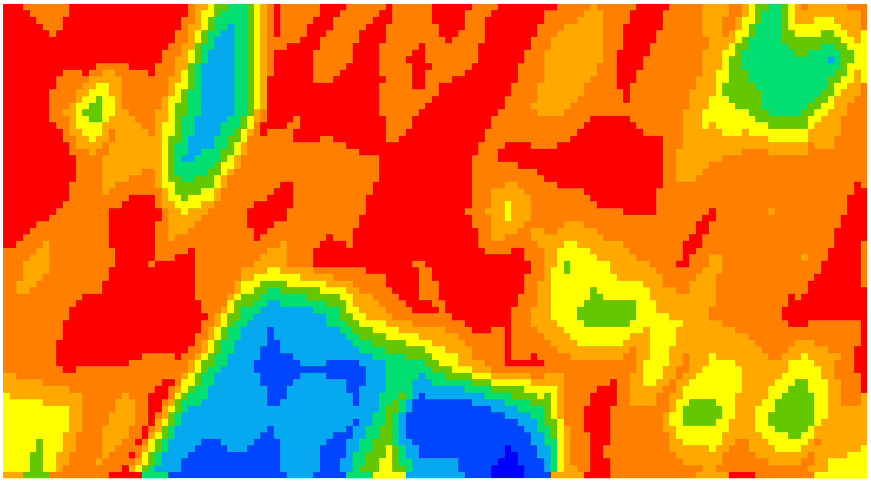
Parameterized UHI ARD Service set to interpolate the UHI grid using a 1.1 F spread



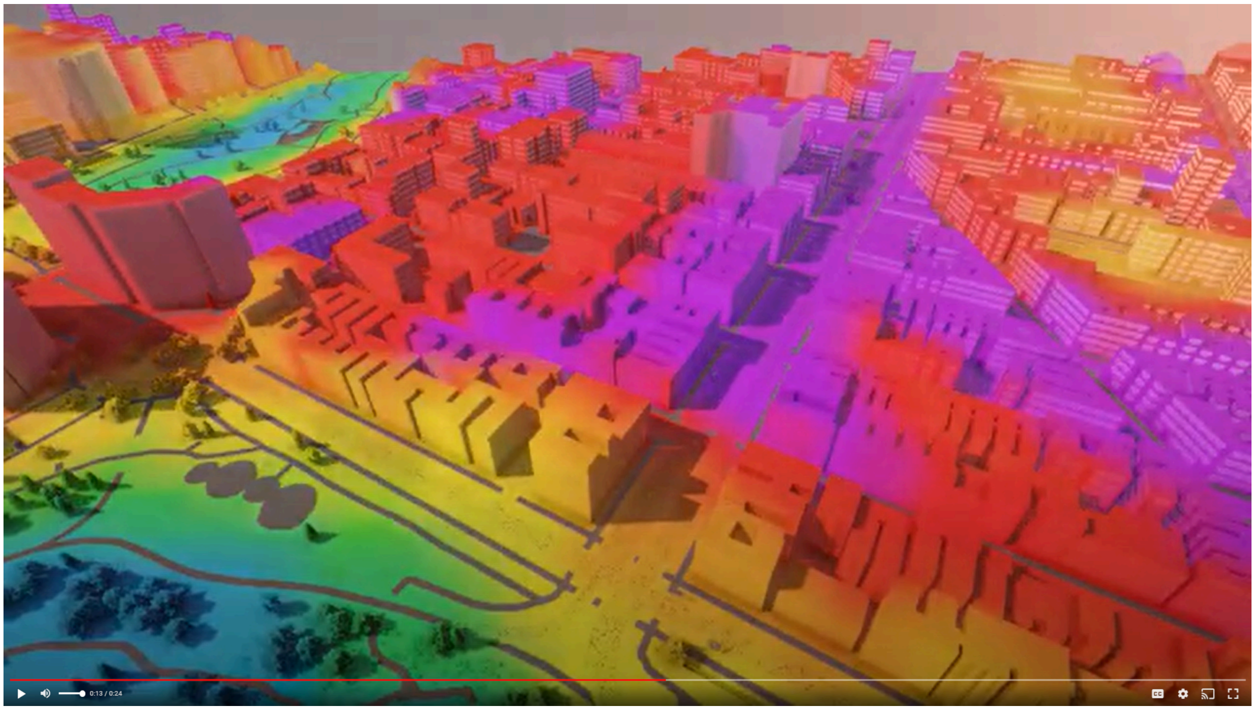
estimated UHI heat index: 10 am



12pm - estimated UHI heat index: 1pm



estimated UHI heat index: 4pm



**Navteca [3D landscape visualization](#) using data from FME UHI ARD Service:
Estimated UHI delta for Manhattan N of Central Park over 12 hours**

Open Standards - Next Steps

Many OGC standards exist related to the definition of data formats and APIs. However, to date few OGC standards relate to domain specific standards. At present, there is a lack of well defined data standards related to emergency response, disaster management and climate change impacts. One of the few examples is the OASIS CAP XML standard https://docs.oasis-open.org/emergency/cap/v1.2/CAP-v1.2-os.html which can be used to provide data feeds for emergency incidents.

There are also emerging standards related to Next Gen 911 with NENA providing much of the leadership and coordination. One of the key standards for this is CLDFX XML Civic Location Data Exchange Format https://cdn.ymaws.com/www.nena.org/resource/resmgr/standards/NENA-STA-004.2-2024_CLDXFUS_.pdf thought this is specifically designed to support NG 911 services and not for general application to emergency reponse.

The majority of disaster application systems are proprietary in nature and there are limited options for integrating between vendor environments or between vendor applications and open source.

Summary

At the time of writing, most weather services did not yet provide weather warnings based on urban heat island effects. Thus there are currently gaps in the availability of both ARD (Analysis Ready Data) and DRI (decision ready indicators) related to urban heat effects. In the context of a warming climate, this is becoming an increasingly severe risk to human health and life. This risk is particularly stark in urban environments, which typically are characterized by high heat absorption and low emissivity typical of artificial landscapes.

Urban heat models and their derivatives have been published such as Climate Central's national UHI model. Climate Central makes their data available in the form of OGC KML thematic vector data. The model's ARD results are useful for gaining a general understanding of probable urban heat effects at the national and regional scales. However, given the data model chosen and the statistical summary per census area, localized interpretations of urban heat effects are somewhat limited.

Experimental urban heat models based on surface type, green / blue spaces show promise for high resolution localized estimates. Urban heat island models can support more accurate and localized heat hazard warnings & feed impact estimates. Higher resolution local data can provide more granular impact estimates, better accounting for cooling effects, and improved support for targeted response & mitigation planning. Grided or raster ARD outputs from these models tend to be more flexible in application as they avoid the data loss that comes with classification or statistical summarization by census area.

In the context of this pilot, FME was found to be a useful platform for building value-added real time services by integrating existing weather services with higher resolution models for local areas.

Key to supporting integration across climate and disaster resilience components are automated, parameterized models that produce readily accessible ARD data and services using open standards.

While standards have been developed for emergency response (NENA NG911) and critical incidents (OASIS CAP), there remains a significant gap in the availability of open common data standards for the disaster management and climate resilience domain. It is hoped that open standards agencies such as the OGC can serve as facilitators for development of new data sharing and ARD standards. Such standards would go a long way to making climate impact hazard model integration and automation much easier across multiple cumulative impacts over time and across scenarios. This type of data sharing and interoperable flexibility will be essential to help mitigate the increasing severity and degree of climate impacts that we are experiencing.

Links

Climate Central Urban Heat Islands:
https://www.climatecentral.org/climate-matters/urban-heat-islands-2023

Heat Watch: Bronx-Manhattan Report https://osf.io/pvd9f

NOAA National Weather Service API: https://www.weather.gov/documentation/services-web-api

CBC News: Extreme Heat is a Global Killer:
https://www.cbc.ca/news/health/heat-second-opinion-1.7241714

WHO: Heat and Health:
https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health

OGC Climate and Disasters: https://www.ogc.org/initiatives/climate-and-disasters/

Navteca Landscape visualization:
https://github.com/opengeospatial/climate-resilience-dwg/raw/master/2024-07_Pilot-ER/Navteca_Safe_NYC_UHI_Movie_011.mp4

Navteca: https://navteca.com/index.html

Safe Software Disaster and Climate Resilience OGC Pilots:
https://support.safe.com/hc/en-us/articles/25407418223245-OGC-Disaster-and-Climate-Resilience-Pilots

FME and Open Standards:
https://fme.safe.com/blog/2021/03/importance-ogc-open-standards/
Safe Software: Public Safety: https://fme.safe.com/fme-in-action/industries/public-safety/