Questions & Answers Part 2

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Kathryn Conlon (kcconlon@ucdavis.edu), Evan Mallen (emallen3@gatech.edu), or Sean McCartney (sean.mccartney@nasa.gov).

Question 1: I saw in the material that one of the examples of exposure is homes without AC, but air conditioning access is also one of the examples of adaptive capacity. So, homes without AC (lack of access to AC) is an indicator of exposure or adaptive capacity?

Answer 1: You're right, AC is a difficult one to characterize. Sometimes it can be classified as exposure since it directly impacts levels of heat exposure while at home. Research has shown that AC access is one of the most important factors determining magnitude and frequency of extreme heat exposure. But it can also be classified as adaptive capacity when framed as AC ACCESS, or the ability to own and operate AC. This is often more related to wealth, or the ability to afford the costs of regular air conditioning.

Question 2: How is the relative risk of mortality compared to or related to surface temperature?

Answer 2: We can model the relationship between a health outcome (e.g., hospitalizations, mortality) with an exposure (e.g., surface temperature). This allows us to look at how an increase in surface temperature is associated with (or related to) relative risks of mortality. We do this by taking health data, like deaths due to diabetes (we know that diabetes can make it difficult for a person to cool themselves off), and looking at the temperature (like surface temperature) on a given day and estimate the risk of a person with diabetes dying on that day. Often, we think about temperature thresholds that can make people sick. So, rather than modeling the relationship of the risk of dying on a day with a specific temperature, you can model the risk of dying on a day with x temperature, RELATIVE to the risk of dying on a day with a lower temperature. Or, you could compare the risk of a person with diabetes dying on a hot day to the risk of a person without diabetes dying on a hot day – both give you a relative risk or mortality.

Question 3: What is a good resource to best not drown out Heat Vulnerability Index (HVI) weightings?
Answer 3:
Bao, J., Li, X., & Yu, C. (2015). The Construction and Validation of the Heat Vulnerability Index, a Review. *International journal of environmental research and public health*, *12*(7), 7220–7234. https://doi.org/10.3390/ijerph120707220

Wolf, T., Chuang, W., Mcgregor, G. (2015). On the Science-Policy Bridge : Do Spatial Heat Vulnerability Assessment Studies Influence Policy? *International Journal of Environmental Research and Public Health*, 12, 13321–13349. http://doi.org/10.3390/ijerph121013321

Question 4: Can we use HVI to compare two cities' conditions?
Answer 4: Yes, you can use an HVI to compare two cities to each other. I would recommend that to make this comparison, you use the exact same HVI indicators and construction methods so there are no confounding variables. I would also recommend pooling your data across the two cities such that the mean and z-scores include all data within each indicator, not just within each city. This would allow you to highlight the relative differences between cities. However, I would not recommend comparing two cities in very different climates because the local physiological acclimatization, or the local population's unique relationship with heat, may be very different. Comparing a very warm city to a very cool city will naturally bias the HVI toward the warm city, especially if your HVI has high weighting or reliance on exposure indicators.

Question 5: What would you recommend we do for an HVI if there is not data for all subdivisions of a geography? For example if some census tracts had data, and some do not?
Answer 5: This is a great question. It's not uncommon that there will be missing data, especially in geographies where people don't live (e.g., large industrial complexes can be their own geographies, but won't have data assigned to them). In my opinion, it comes down to how much data you're missing. In my experience, I've had data unavailable in, some 5% of tracts, and these areas had missing data across the board (i.e., not just one variable). In this case, I present those tracts as 'missing' or indicated with blank information. However, if you're finding that a good number (a personal rule of thumb: 20%) of your tracts (or study area) have missing data, you don't reliably have information about that location, so it's best not to use that indicator.

Question 6: Is it possible to evaluate the effects of measures taken to reduce the UHI? Is it possible to measure what measure is the most effective for which place?
Answer 6: Yes, though it can be a difficult exercise. In the Urban Climate Lab, we regularly test heat mitigation policies through our modeling. That is, we build a model under baseline conditions and heat mitigation scenarios like albedo enhancement, or reflective roofing and pavements, or tree planting initiatives. This helps us to evaluate both the cooling effects and the public health impacts of such infrastructural strategies. However, social and behavioral interventions are more difficult to evaluate without pilot projects. The strategies Dr. Conlon mentioned such as phone trees and cooling centers can only be evaluated once implemented.

Question 7: Is there a method for adequately blending data from different scales, such as MODIS/LANDSAT with administrative bounds?
Answer 7: Yes, we will discuss this more in detail in Part 3 of the webinar series.

Question 8: Mitigation strategies and interventions are in essence area-specific. Is there a list of conventional interventions which can be the basis for suggesting these?
Answer 8: Yes, I'd recommend the US EPA Heat Island Compendium as a first place to start. This resource has a great set of recommendations and studies to support them. You're right that it will be very important to design your interventions with local context in mind. For example, in a very hot and dry climate, it may not be most appropriate to recommend water-intensive tree planting campaigns when the climate will not support it. We are still in the beginning stages of research within this topic in relation to health and intervention.

Question 9: For the exposure component, most of the models are considering LST that is essentially SUHI as an exposure component, however CUHI (canopy layer UHI) determines heat stress. How can CUHI be estimated? Are there any models to estimate mean radiant temperature in urban areas?
Answer 9: Yes, but these models are substantially more complex and often unavailable publicly. The types of climate models that can generate air temperature are much more computationally intensive to run, often expensive, and need to be run on more of a city-by-city basis. These models are becoming more accessible over time, but for now, most cities are still using land surface temperature given the global scale and

accessibility. We know that LST does not perfectly correlate with air temperature, but it can still be helpful in determining relative priority.

Question 10: With regard to reducing urban heat island effects, are the existing Nature-Based Solutions capable of coping with existing and future anticipated heatwaves? (As per World Meteorological Organization [WMO] predictions for 2021–2025 at least one year out of it would witness a year we cross 1.5°C.)
Answer 10: We specialize in local climate change and we find that UHI and microclimates are far greater in magnitude than on a global scale. We also have more control in regards to mitigating and regulating local areas. The strategies mentioned in the presentation can help to mitigate warming on a local scale.

Question 11: What are examples of construction methods that create differences in outcomes?
Answer 11: We presented an increasing complexity of HVI construction methods. Depending on the inputs being used, there can be differences in outcomes that are created. We are not sure of an exact method of comparing these differences. It is also dependent on how you use your HVI and on your particular area of research.

Question 12: Assuming there are about 1,000 different census tracts, do authors have to separately conduct PCA for each census tract having its own exposure (e.g., heatwave) sensitivity and adaptive capacity data?
Answer 12: PCA is a statistical, data-reduction method. PCA's goal is to take a lot of variables and identify those that are statistically alike. If you were to use a PCA to create your index, you would be creating one dataset that includes your geographic identifier (e.g., census tract code) and the normalized estimates for each indicator for each geographic unit. This dataset would then be used in your PCA. The PCA will group variables together that it finds to be 'similar'. Essentially, you run one PCA for the entire dataset, which would include indicators for exposure, sensitivity, and adaptive capacity.

Question 13: After PCA analysis, how were the vulnerability index scores calculated? The authors mentioned normalization, how is it done? Did the authors use any equation?
Answer 13: By 'normalize' we are saying that you want your variables to be on the same scale. One of the most efficient ways to do this is to calculate the proportion of that variable for that geographic area. We demonstrate this in more detail in Part 3.

Question 14: Can the authors share the codes of the PCA and vulnerability score calculation? Was the heatwave data applied together with the demographic data when doing the PCA analysis?
Answer 14: Please see Part 3 of this training series and associated materials for more details on the HVI scoring mechanisms. In short, yes, we do apply the heat and demographic indicators together when conducting our HVI analyses, including for PCA. https://appliedsciences.nasa.gov/join-mission/training/english/arset-satellite-remote-sensing-measuring-urban-heat-islands-and

Question 15: How could, or should, the considerations going into selecting components to include in the HVI also inform monitoring and evaluation efforts?
Answer 15: This depends on what you would like to monitor or evaluate. If you have heat-related health impact data, such as heat hospitalizations or deaths, then you can evaluate your HVI's performance based on this data. You can also create a supervised HVI, as demonstrated in Conlon et al., 2020 (see slides for full reference). However, this data can be difficult to obtain on a spatially comprehensive scale and may only be possible for large-scale HVIs, such as at the state or national level. It may also be useful to monitor health outcomes pre and post intervention to determine effectiveness of the intervention in a given location. You can also use individual HVI indicators to track progress of interventions like tree planting by monitoring tree canopy each year. Census-derived indicators may change too slowly to adequately monitor changes.

Question 16: How can we use HVI to understand the relationship between land surface temperature and armed conflict?
Answer 16: Interesting question. There is some research that indicates higher crime rates during periods of high temperatures, but I have seen no research connecting heat and armed conflict on a larger scale. If you are concerned with only LST, I would recommend correlating LST with locations of armed combat rather than creating an entire HVI. However, you could consider a multiple regression with other factors relevant to combat as controls to determine the contribution of heat with all else held constant.

Question 17: What other exposure parameters can be considered and available in spatial data format through remote sensing data?
Answer 17: The three most common exposure parameters available as remote sensing data are land surface temperature (LST), impervious surfaces, and vegetation or lack of

vegetation. Some HVIs will use indicators such as distance to water where the thermal impacts of large bodies of water may influence local temperatures. Please see Part 3 of this training for more details on acquiring and using these types of datasets.

Question 18: Where can you find statistics on AC units in the household? I haven't been able to find that data from the census yet.
Answer 18: AC data can be challenging to find. It is currently unavailable as a census variable. You may be able to find this data on a city's GIS data portal. You can also find it on a larger scale using the American Housing Survey. The data used in Part 3 of this training includes estimates based on AHS data applied by housing type. New models are emerging to predict AC data using housing characteristics, such as the following paper:

Gronlund, C.J., Berrocal, V.J. Modeling and comparing central and room air conditioning ownership and cold-season in-home thermal comfort using the American Housing Survey. *J Expo Sci Environ Epidemiol* 30, 814–823 (2020). https://doi.org/10.1038/s41370-020-0220-8

Question 19: In the absence of threshold how are the bi-directional Indicators handled? How is "Risk" (probabilistic) calculated?
Answer 19: HVIs typically do not handle probabilistic indicators of risk. Instead, they usually highlight relevant factors that could exacerbate the impact of given hazards should they occur. In this way, they are inferential or "a-priori" vulnerability to identify areas where it may be most effective to intervene. As for bi-directionality, you should select only indicators that are relevant to your chosen intervention and ensure that it is oriented such that an increase in the indicator means an increase in vulnerability. Please see Part 3 for more examples on how to accomplish this in practice.

Question 20: Heat-related mortality is not available for most of the developing regions, so in that case how heat related mortality can be assessed?
Answer 20: It is difficult to get heat-related mortality for most regions at the scale we are discussing in this training (mostly urban-scale). This is why we can use HVIs as tools to help us indicate areas of relative risk given underlying vulnerabilities as represented by the indicators. Estimating heat-related mortality itself can be a complicated epidemiological exercise, and is outside of the scope of this training.

Question 21: Have you seen applications of the vulnerability formula (exposure + sensitivity +/- adaptive capacity) to assess the vulnerability of infrastructure to fail in extreme heat? What sorts of factors could be used in lieu of health/income indicators, particularly for sensitivity?
Answer 21: This formula is most often used as a conceptual framework for population-based vulnerability, not for infrastructure. However, several principles could still apply to an infrastructure-based analysis. For example, you could still use heat as an exposure indicator combined with a measure of infrastructure priority, such as important evacuation routes, bridges, or other infrastructure that will be needed in an emergency. A "sensitivity" could be something like the material type and its resilience to heat exposure. For example, asphalt that may melt, or concrete that may buckle during an extreme heat event.

Question 22: In order to reduce the influence of the administrative areas chosen would it not be more effective switching from a vector model (Admin polygons as you are using now) to a completely raster model (per pixel values no aggregation)?
Answer 22: This is always a possibility as well, though you may need to then rasterize your data as well. You can do so using a vector to raster conversion in a GIS platform, or you can create your own grid using the Fishnet function if you would like to avoid administrative boundaries. However, in much of my own experience, data will often come already in these boundaries, so they are a natural place to start. Cities will also often use these boundaries in their planning efforts, so it can be useful to keep everything in these geographies throughout. If you'd like to keep your analysis at the gridded scale, you may be interested in this earlier ARSET training on gridded population datasets:
https://appliedsciences.nasa.gov/join-mission/training/english/arset-introduction-population-grids-and-their-integration-remote

Question 23: You just mentioned (while answering a question) about defining/characterizing the HVI with the intervention you have in mind. What are the advantages and disadvantages of selecting the intervention first, versus developing the HVI (or perhaps several to compare varying characteristics) first and using it to inform the choice of intervention?
Answer 23: Great question, the way you design and use your HVI is up to you. We have found in our work that generic HVIs including many indicators can be too complex to inform specific strategies. For example, a PCA HVI with 10 indicators can tell you which

areas to prioritize, but not necessarily what intervention may be most appropriate to help reduce vulnerability in that area. Choosing an intervention first can help you limit your indicators to only those which are most relevant to the intervention, which can more efficiently and effectively locate areas for deployment.

Of course, you should take broader local context into account for your intervention design as well. Consider what impacts your community has faced in prior heat events and discuss with community members what would have helped them through this event. Consider also your local climate. If your city is too hot and dry to sustain a robust tree canopy, then you may want to consider albedo enhancement instead. If heat is a rare event, say for a region with a cool climate, then you may consider interventions designed more toward a short-term emergency response than a long-term heat mitigation campaign. We encourage you to consider all of these questions before you begin your heat risk assessments of any kind, but especially when designing an HVI.

Question 24: Do we have to normalize all shapes to get SVI, including indicators of adaptive capacity?
Answer 24: Yes, we recommend that you normalize all indicators used in your index to better highlight relative priority within your selected geography.

Question 25: Is there a generalized threshold HVI value that must not be exceeded irrespective of your geographical location?
Answer 25: Not to our knowledge. We recommend you interpret HVIs only for relative prioritization within your selected geography. All HVIs are unitless scales that simply show which areas are higher or lower than others depending on your chosen indicators. That is, your HVI may have a different range or scale than others depending on what you choose to include, how you score your HVI, and how many indicators you choose to include. We do not recommend comparing HVI scores directly across different HVI designs, as they may inherently differ in range and scale. However, you can compare two different HVIs if you normalize them once again. Please see Conlon et al. (2020) (full reference in the slides) for more information on comparing HVIs.

Question 26: My research field is demography. Beside health risk related to HVI, is there any other relationship between HVI and population indicators? e.g. fertility or migration

Answer 26: To our knowledge, there haven't been studies that explore the relationship between HVIs (heat vulnerability indices) and population indicators like fertility and migration. However, there is a growing literature that is finding a relationship between temperatures (i.e., extreme heat, heat waves) and birth outcomes (e.g., preterm birth, small for gestational age). The evidence is limited that fertility is impacted, however, one study (https://www.nature.com/articles/s41598-021-81496-x) suggests that extreme heat following conception may be associated with reduced fertility. Similarly, there may be a relationship between population movement and climate-driven drought, of which extreme heat is related (https://journals.ametsoc.org/view/journals/wcas/6/3/wcas-d-13-00059_1.xml?tab_body=fulltext-display) . Thus, the mechanisms for how heat influences movement need additional exploration.

Question 27: Can ambulance calls, emergency department visits, and hospital admissions data be used as sensitivity data?
Answer 27: Absolutely, if this data is available, then you can incorporate it into your HVI. However, be careful when selecting your scale. If this data is only available at a county scale, but you'd like to make a city-scale HVI, then your data will not vary across your selected geography. You may need to conduct a broader scale analysis, such as a state-level HVI across counties.

Question 28: Besides temperature, is humidity also one of the Independent Factors for Exposures? For example, in tropical areas humidity is higher than in subtropical areas.
Answer 28: Yes, you can include humidity in your HVI if it is available at the appropriate scale. This can be difficult to obtain on a high-resolution and spatially comprehensive scale without computational modeling or using gridded reanalysis data from weather stations. It is generally not as broadly available as a direct measurement compared to a remotely sensed product like LST.

Question 29: As we know, the energy of storm clouds comes from heat, and the heat island effect would raise the temperature of a city. Does that mean if they have enough water supply from suburbs, the city would possibly be a perfect place to generate thunderstorms?
Answer 29: There has been some research on the interaction between the urban heat island and precipitation (example below), however this is not nearly as thoroughly researched as the relationship between urbanization and heat.

Wu, Luo, Y., Chen, F., & Wong, W. K. (2019). Observed Link of Extreme Hourly Precipitation Changes to Urbanization over Coastal South China. Journal of Applied Meteorology and Climatology, 58(8), 1799–1819. https://doi.org/10.1175/JAMC-D-18-0284.1

Question 30: In the presentation, one of the variables used to measure sensitivity was the proportion of the population over 65. What is the goal of using the proportion of x demographic instead of (normalized) population of x demographic? For an index that would be used to allocate resources might it be more (or additionally) useful to use or add a normalized population value since proportion can be high but population low?

Answer 30: Excellent point. In this training we simply present the conventional methods of HVI creation. But you are correct that it may be misleading to include only proportions of the population rather than absolute values if it runs the risk of highlighting low-population areas. You do not need to convert to proportions first, but we do recommend that you do still normalize all indicators so they use the same scale. Both are valid methods, but it will be important to consider how you frame your findings based on which method you choose.

Question 31: How do we project UHI for future periods, can climate projections be used for the same?

Answer 31: This is difficult to accomplish on the same scale as most HVIs without computationally intensive climate modeling. General Circulation Models (GCMs, often used for global climate change studies) are too coarse for many HVI applications, particularly at the urban scale. However, the UHI is much more sensitive to the drivers of urban heat described at the beginning of this training, including loss of vegetation, impervious materials, waste heat, and urban morphology. If you can project these trends forward for your city, then you will have a good sense of directionality for your UHI intensity as well. For example, is your city growing? How quickly? Is it planting or losing trees, and in which areas of the city? What types of building materials are being used or considered? These types of questions can help you understand how your microclimates may change even without computationally-derived air temperatures.

Question 32: I constructed a UHI time series over Ghana, West Africa and observed negative temperatures at some periods. What might be the cause of these results?

Answer 32: If by negative temperatures, you mean the city showed lower temperatures than surrounding rural areas, then that may indeed be the case at times, particularly in drier climates. The concept of the urban heat island often assumes the surrounding rural areas to be more heavily vegetated, but in dry climates it tends to be urban areas that have the most vegetation because there is a population to plant and maintain this vegetation. While we are not familiar with the specific climate of Ghana, we can say that the urban heat island, if defined as urban minus rural temperatures, is not universally positive in all contexts at all times.

Question 33: Different methods to construct HVI could lead to substantially different results, as you have shown on the map. But which one(s) is more reliable? All methods are reasonable, but how can I evaluate their validity? The validation doesn't help too much because it's method-dependent.
Answer 33: We don't have the "best" method at the moment, but it is dependent on how you are going to use your HVI. Even though we used PCA in the Detroit example, that may not be the best example for your specific area and there were still gaps in the data. Using an overlay in addition to your HVI and having supplemental health data will help as well. It is also encouraged to co-develop your HVI with members of your local/regional community who know it best.

Question 34: Is there any modified areal unit problem (MAUP) issues in using HVI? In other words, would the area size that researchers choose to use influence HVI?
Answer 34: Yes! Using the Detroit example, we used two different geographies of census blocks and census tracts and found the data to vary significantly. Characteristics of your data will also vary based on its specificity which can also lead to extremes within the data as well. Your use case will influence this as well.

Question 35: What other measures could be implemented in areas built with pavement and that are highly vulnerable to surface heat?
Answer 35: I'd recommend the US EPA Heat Island Compendium as a first place to start for more information on heat mitigation measures. This resource has a great set of recommendations and studies to support them. But it will be very important to design your interventions with local context in mind. For example, in a very hot and dry climate, it may not be most appropriate to recommend water-intensive tree planting campaigns when the climate will not support it. We are still in the beginning stages of research within this topic in relation to health and intervention. Trees have been found to cool surfaces between 2 - 9 degrees Fahrenheit.

Question 36: For those of us living in cold(er) regions of the world, are there equivalent Cold Vulnerability Indices and are the methods discussed for HVIs relevant/appropriate?
Answer 36: We are not familiar with any CVIs that have been created but we can see the need for them in colder areas of the world. As with HVIs, you want to think about exposure, availability of heating, sensitivity, and literature among other variables. Health indicators also play a role within analysis as will. A social vulnerability index is more closely related to this and viewing cold as a hazard varies significantly from heat and HVIs. Much of what applies to HVI will apply to CVI as well.

Question 37: If you use a certain parameter to compute HVI, would it be possible to identify the relationship between that specific factor and HVI? For example, can I generate a regression analysis between HVI and land surface temperature?
Answer 37: You can, but autocorrelation will be an issue. Using other types of exposure such as social vulnerability indices, they will give you more insight into these parameters.

Question 38: I was wondering if there is a recommendation on high resolution temperature data to replicate a similar study presented? I have used PRISM products but always want to keep up with the updated solutions.
Answer 38: You can, but some of the data products that capture temperature are broad and do not work well with city level data. Those data products work well on larger scales, as cities have wide variations in regards to microclimates.

Question 39: In the case of lack of data, what could be basic HVI indicators for vulnerability?
Answer 39: It depends on the location of where the HVI is being built. Tolerance for heat also depends on where the city is located. Refer to the topics covered in the presentation and go from there.

Question 40: Classification of socioeconomic data could be very challenging because of different aggregation levels. What is the best way to integrate different methods in the analysis of HVI to achieve best fit at the local scale (provinces, municipal cities, etc.)?

Answer 40: The data issue is substantial in HVI construction. In the next part of this webinar, we will go into more detail about the types of data available dependent on your area of study.

Question 41: Many HVIs in the literature use income as a sensitivity parameter, but I see you classify income as adaptive capacity. Given there are quite a few published works in this space, how do you justify differences between your classification and some of the conflicting HVI indicator classifications? (E.g., seeking expert advice, commenting on the wordy specifics of the index components.)
Answer 41: We have seen this before. Exposure, sensitivity and adaptive capacity help us to essentially compose our thoughts. We like to think of sensitivity as a person's tolerance of heat based on income. Adaptive capacity for income is in relation to access, as in what resources a person can access based on their income. There is another overlap in regards to access (or lack thereof) of air conditioning as well, which can reduce sensitivity.

Question 42: We have seen in case studies HVIs are sensitive to scale, and land surface temperature is found to be a key variable across the studies discussed today. My question is, if I am interested in a study over densely populated tropical South Asian cities, can I use MODIS LST data (MOD11A1 or MOD11A2) for HVI studies, or is Landsat data the only sensitive data for HVI studies, because of the higher spatial resolution of Landsat LST than the MODIS 1km LST product?
Answer 42: You can use either with Landsat having the higher spatial resolution. We personally use the MODIS 8 day LST to get a compilation of multiple images. You can resample a MODIS image to have a higher resolution as well. We will demonstrate this in more technical detail during Part 3 of this webinar series.

Question 43: Are there any other techniques like Weighted Overlay but more precise for this model?
Answer 43: It depends on how you define precision. Weighted Overlay is useful if you are using an HVI as a communication tool, such as talking to members of a community or to the public.

Question 44: How do you suggest addressing discrepancies between community-identified priority metrics and metrics identified through health outcome data? If HVI drawn from community priorities suggests one heat

reduction strategy and health outcome-derived HVI suggests another, how do you reconcile this?

Answer 44: Often, we use science to design interventions but without assessing whether a community is in a position to receive, implement or maintain the intervention. In a scenario where two discrepant HVIs indicate different locations or types of interventions, it is important to connect with the community. The community, often, has knowledge of what type of intervention will or won't work. Negotiation in this case is useful as you want input from the community but also want to make sure it is scientifically accurate as well. Again this is dependent on your community and area of study. We don't advise using an HVI as an absolute truth; rather, HVIs can be useful in jump starting conversations about hazards and help with prioritizing interventions.