A CITYWIDE UNDERSTANDING OF THE URBAN HEAT ISLAND EFFECT

The urban heat island (UHI) effect is the phenomenon by which cities experience higher temperatures than their less urban surroundings **(see Figure 1).** Since this temperature difference is linked to increased heat waves and greenhouse gas emissions, a need has arisen to mitigate the effects of UHI in the world's rapidly expanding cities.

To better understand UHIs, researchers at CSHub have developed an approach that quantifies a city's texture, or a city's geometrical layout, to predict the severity of the UHI effect. The approach, inspired by materials science, harnesses the resemblance between the texture of urban environments and molecular structures.

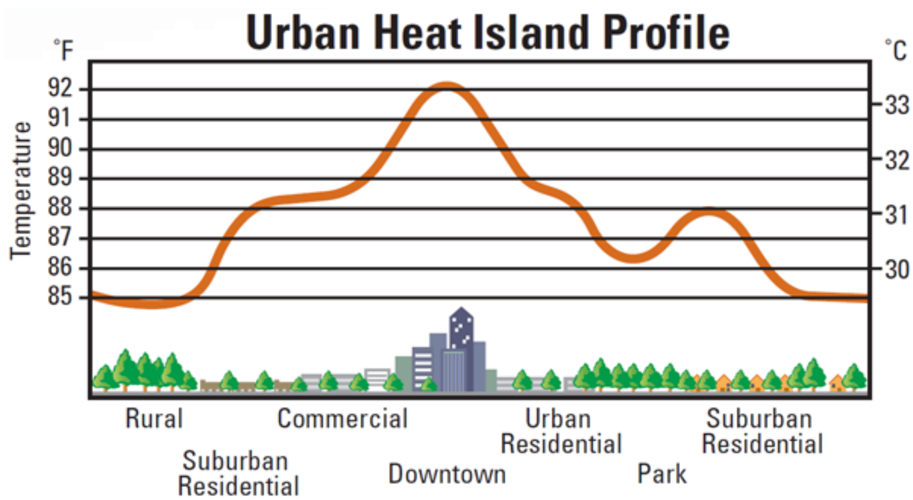

Figure 1. Building density impacts the severity of urban heat islands. (FHWA/EPA, 2003)

MATERIAL SCIENCE PROVIDES INSIGHTS INTO CITY TEXTURE

- To measure the UHI effect, researchers gathered 10 years of hourly climate data from over 22 urban weather stations and then collected building data from within a 3-mile radius of each station.
  - Since solar radiation and human activities complicate daytime UHI data, nighttime climate data was used to isolate the effects of city texture on UHIs.
  - Though changes to city texture occurred over the 10 years that data was gathered, these changes were too insignificant to affect the average values for the hundreds of thousands of measurements taken.

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- Researchers then analyzed this data using a statistical physics tool from material science called the radial distribution function—also known as *g(r)*.
- This tool traditionally describes the difference between the local and average densities of atoms.
- However, in this instance, it conceives of buildings as atoms to capture variations in building density.
- Variations in building density allowed researchers to quantify the orderliness of a city's texture: ordered city textures display regular variations in building density (indicating the regular intervals of streets and buildings), while the opposite is true for less ordered city textures (**see Figure 2**).
- Depending on their orderliness, city textures were then grouped by their resemblance to the atomic structure of a **crystal**, **liquid**, or **gas.**
    - **Crystals** are highly ordered with regular patterns.
    - **Liquids** are more sporadic and possess chaotic dimensions.
    - **Gases** have a local density almost the same as the average, suggesting almost no order.

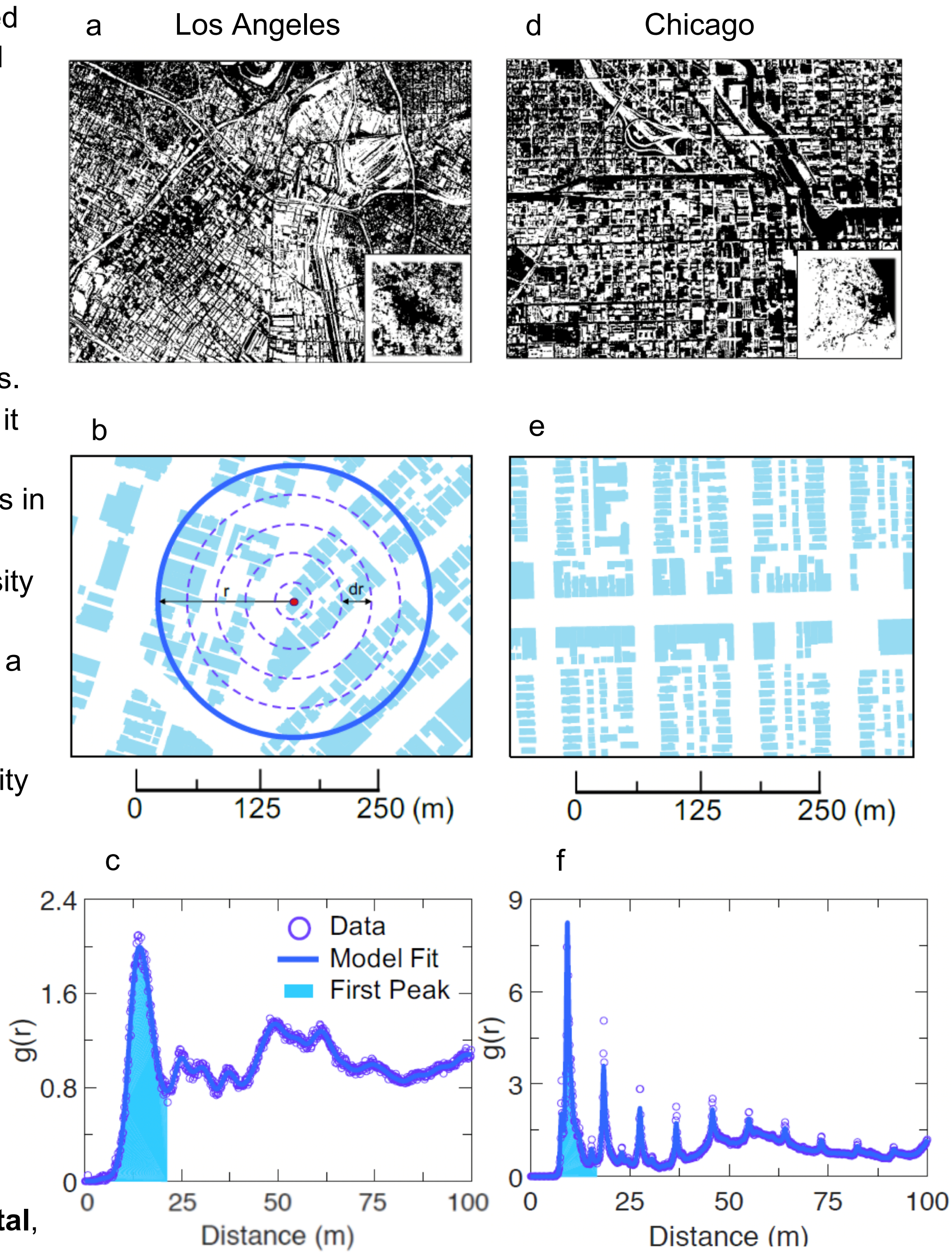

Figure 2. This figure compares the city textures, in this instance of LA (**a, b, & c**) to that of Chicago (**d, e, & f**). The irregular spikes in L.A.'s *g(r)* (**c**) indicate that it is a disordered, liquid city. Chicago's *g(r)* (**f**), on the other hand, shows more regularity and displays crystal characteristics.

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CITY TEXTURE PREDICTS THE SEVERITY OF URBAN HEAT ISLANDS

- **Researchers found a correlation between city texture and UHI data.**
  - Cities characterized as **crystals**, with their highly ordered textures, **can magnify the effects of UHIs.**
  - On the other hand, less ordered, **liquid cities displayed lower UHI effects.**
  - **Gas** cities, the most disordered, **experienced the least severe UHI effects**. However, these are not found in the American cities we studied. Rather, they tend to exist in Europe where cities have developed over many centuries.
- **A highly ordered city experiences UHIs twice as severe as a city with a disordered structure of local buildings** (see **Figure. 3**)
  - For example, Chicago (point 4) displays more than twice the UHI effect as Dallas (point 6).

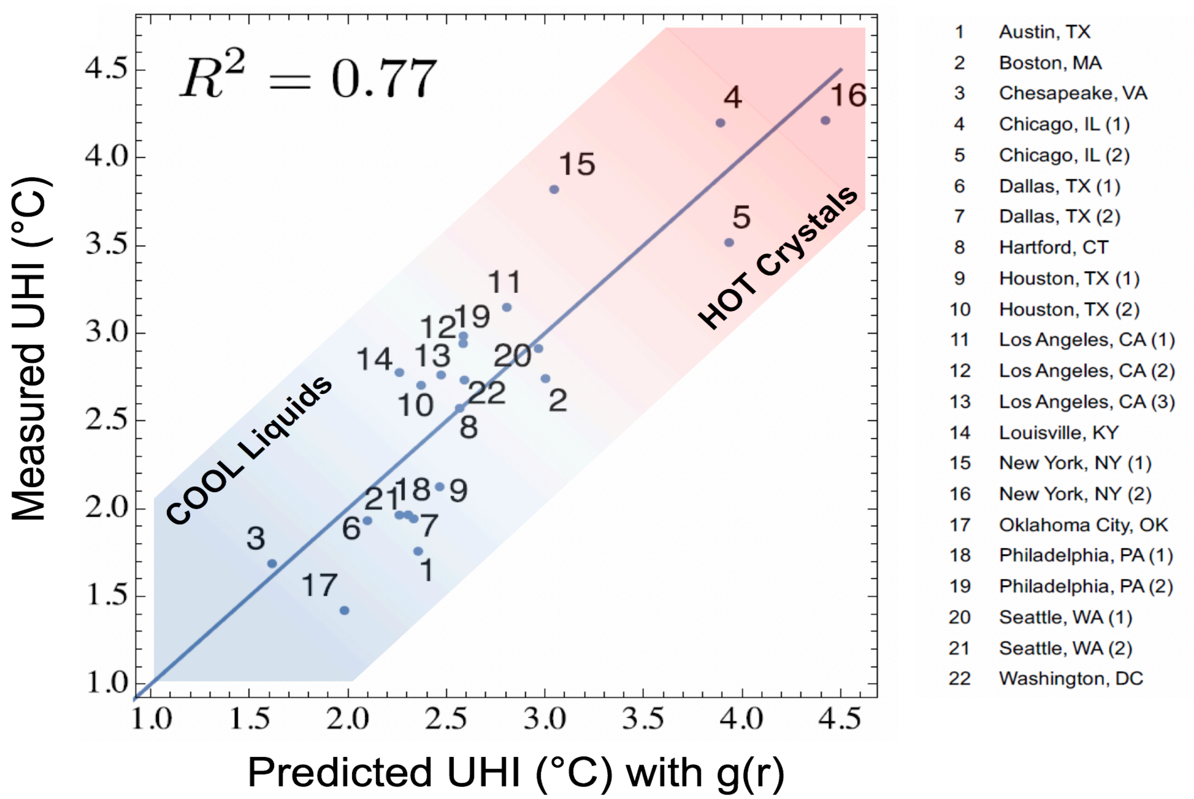

Figure 3. A strong correlation was found between measured UHI data and UHI predictions based on our city texture model. Liquid cities experienced less severe UHI effect while the opposite was the case for crystal cities.

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CITY TEXTURE MAY INFORM UHI MITIGATION

- While traditional approaches to UHI either investigate single street canyons or entire cities, the MIT approach is more localized. This effectively bridges the gap between the two traditional approaches.
- For existing urban spaces, this model may mitigate the impacts of UHIs by identifying particularly vulnerable areas for retrofit.
- Models such as these can predict severity of UHIs without the need for detailed surface or air temperature data. This will allow planners to account for the UHI effect regardless of climate change's impact on future temperature levels.
- Mitigation of the urban heat island effect will lessen heat waves, which will lower emissions and improve quality of life.
- Since decreasing UHIs will also lower energy demand, this model may allow developers and city planners to plan more energy efficient cities.

References:

Sobstyl, J.M., Emig, T., Abdolhosseini Qomi, M.J., Ulm, F.-J., and Pellenq R. J.-M., "Role of City Texture in Urban Heat Islands at Night Time." *Physical Review Letters,* February 2018.

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