

An urban energy balance-guided machine learning approach for synthetic nocturnal surface Urban Heat Island prediction: A heatwave event in Naples

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INTERNATIONAL WORKSHOP ON HIGH-RESOLUTION THERMAL EO | S8 | ID109

11 May 2023



+ MOTIVATION



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+ WHAT?



Computational Efficiency

Empirical/ML Approach to map the Hazard



Scalability to other European Functional Urban Areas

Southern-European Coverage Input Data



Low-cost to Local Authorities

Open-Science Approach

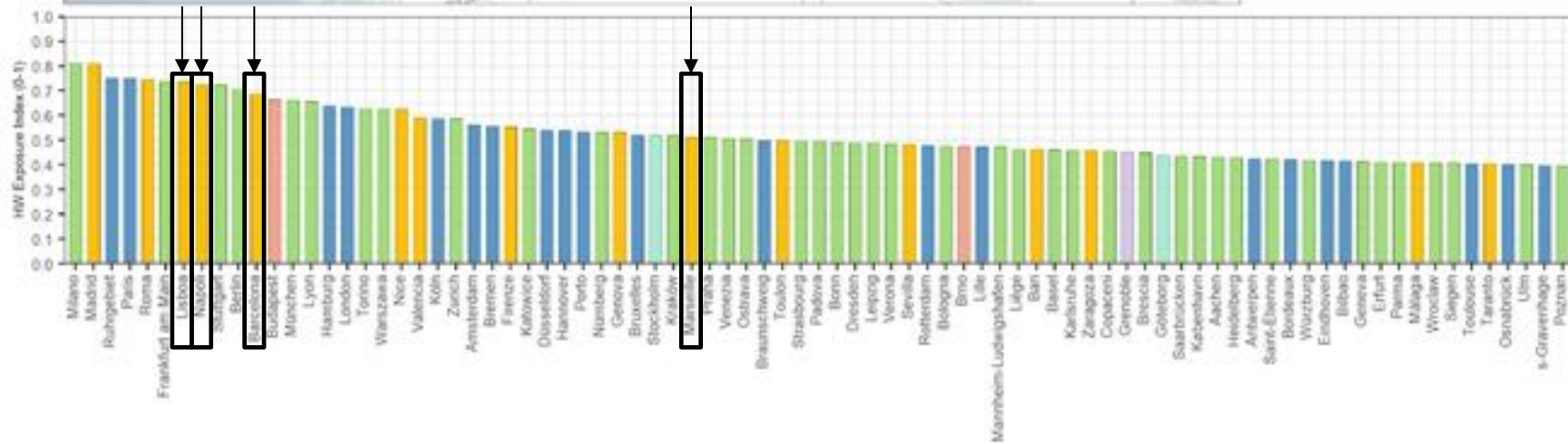
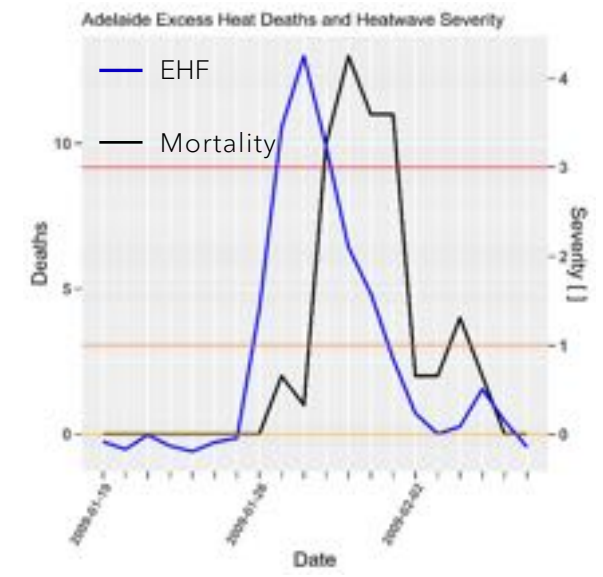
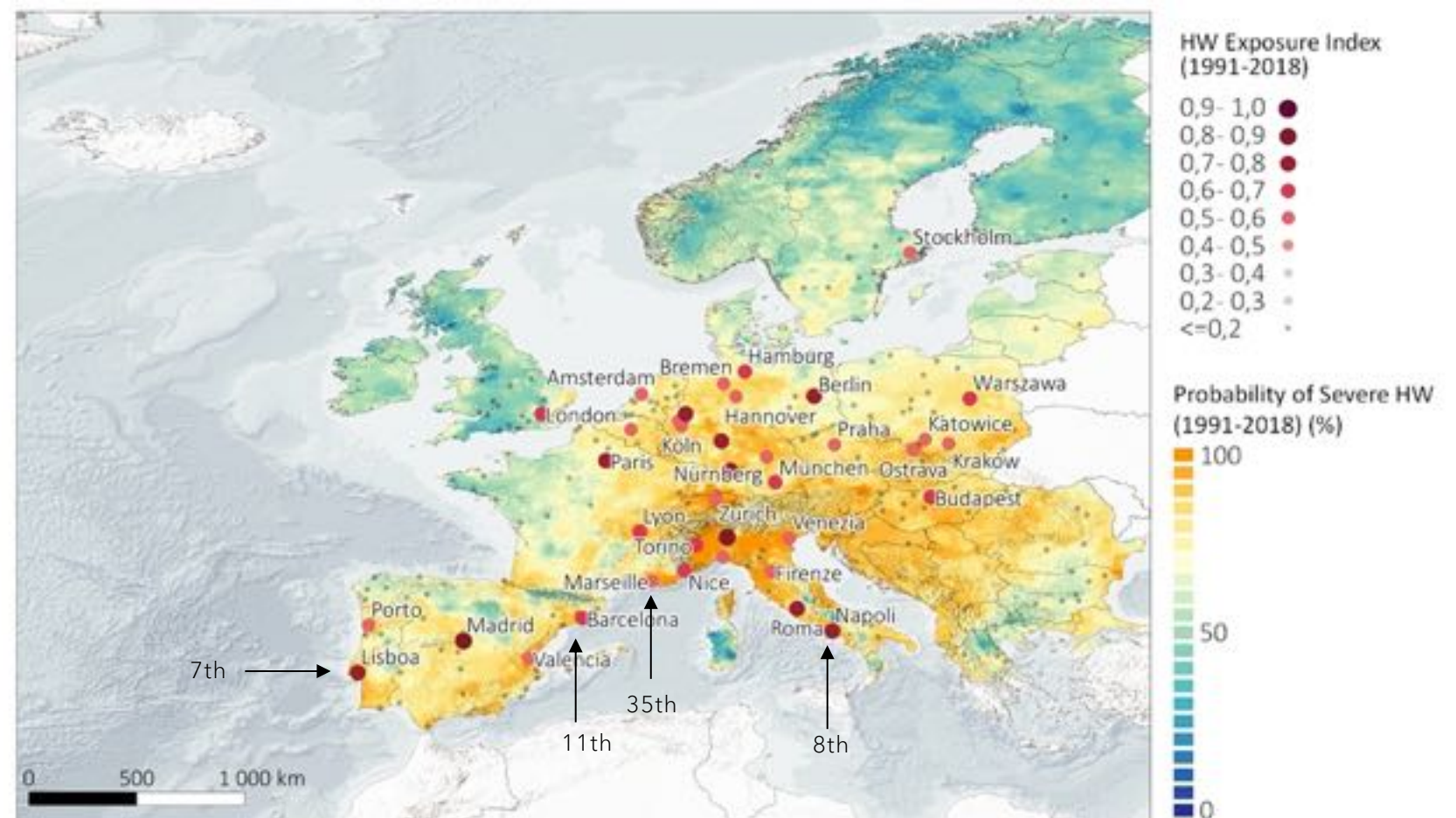


THE AIM: To Acknowledge the Urban Planning Role in Heatwave Exposure and Contribute Towards Local Climate Change Adaptation Strategies

+ WHERE?

Defining the Aol

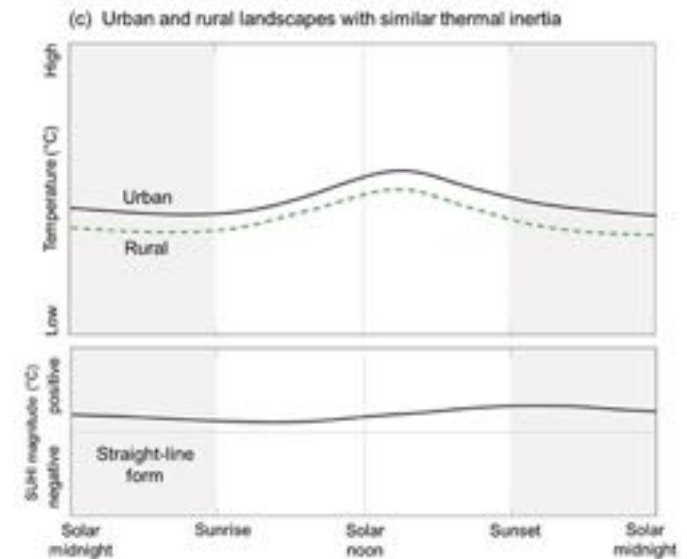
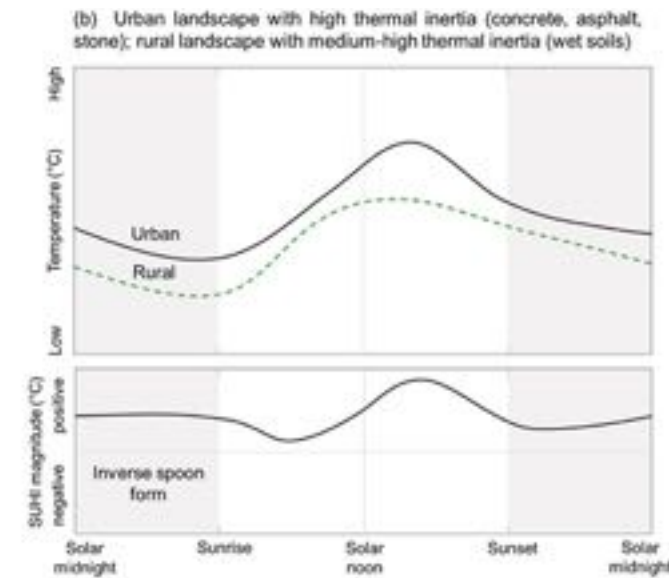
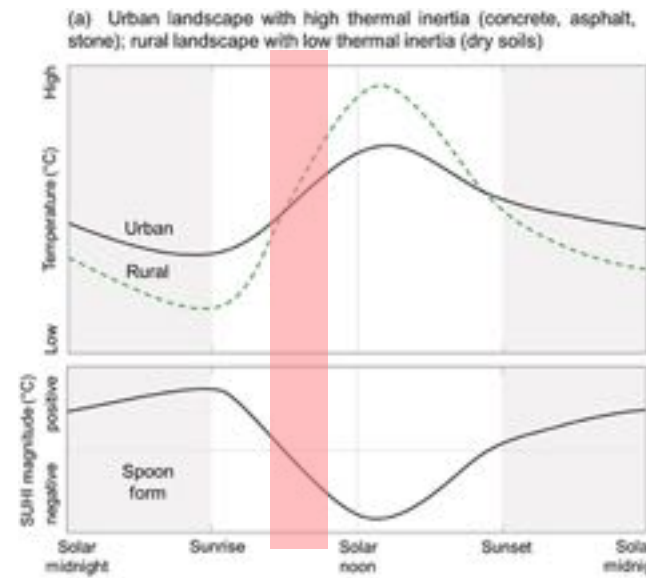
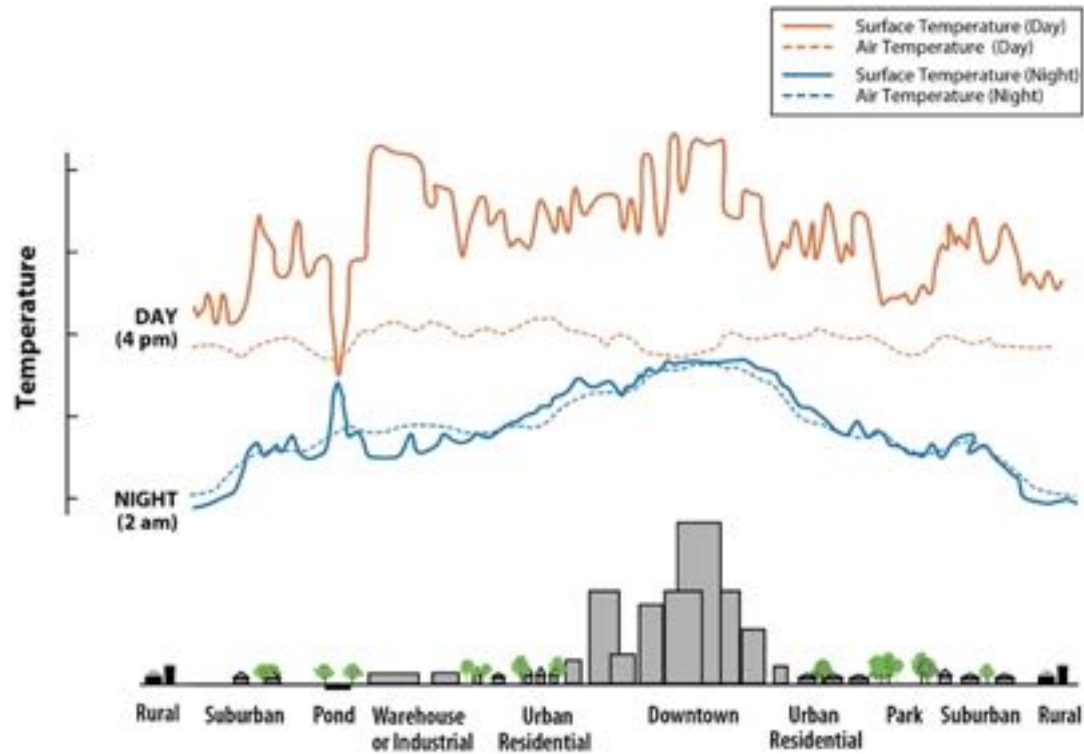
Equation 1	$EHF = EHI_{sig} \times MAX(1, EHI_{accl})$
Where	<p>EHF is the Excess Heat Factor, in $^{\circ}C^2$</p> <p>EHI_{sig} is the long-term 3-days daily mean temperature anomaly (compared to the 30-years 90th percentile)</p> <p>EHI_{accl} is the short-term 3-days daily mean temperature anomaly, compared to the previous 30 days</p>



Source: Nair et al. (2018)

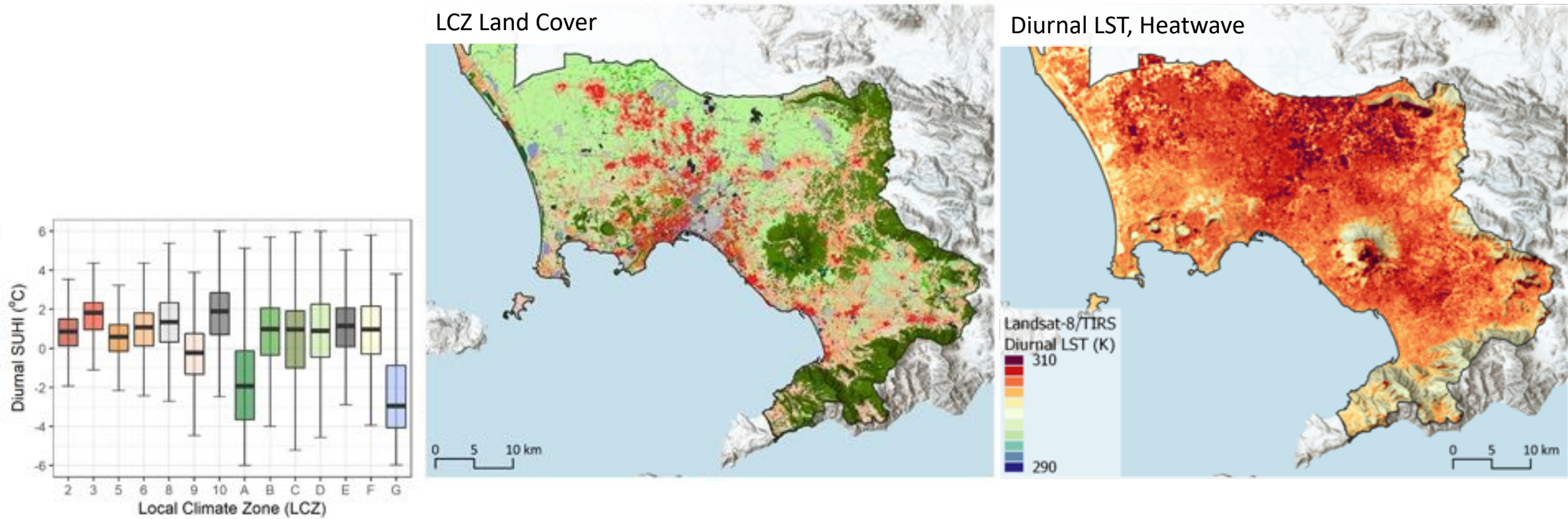
+ WHAT?

Targeting the UHI during HW events



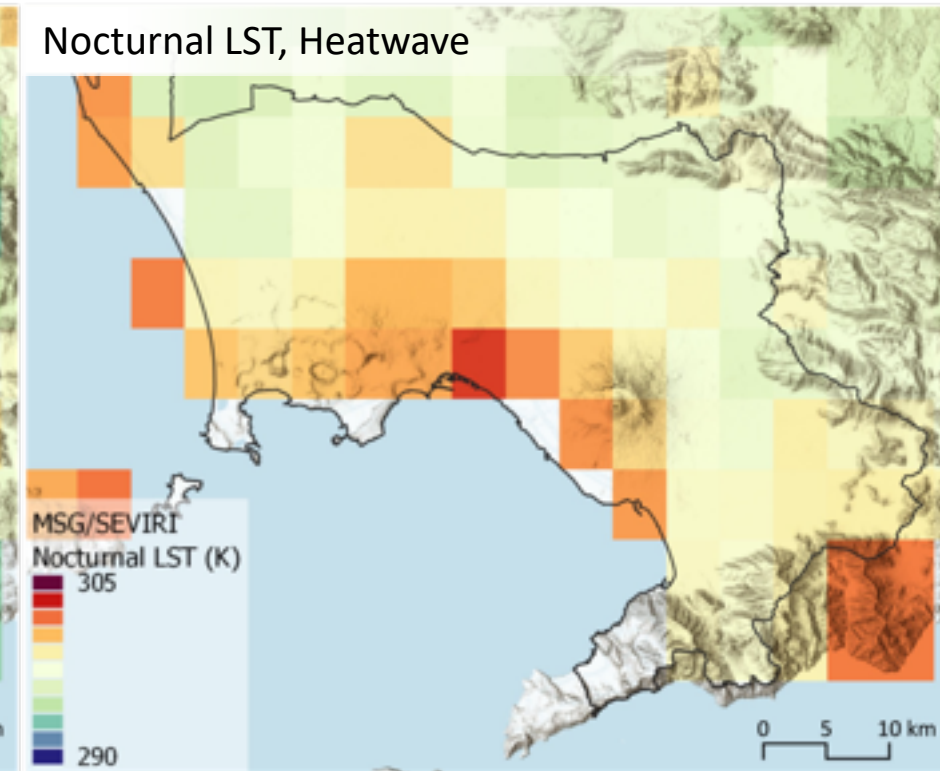
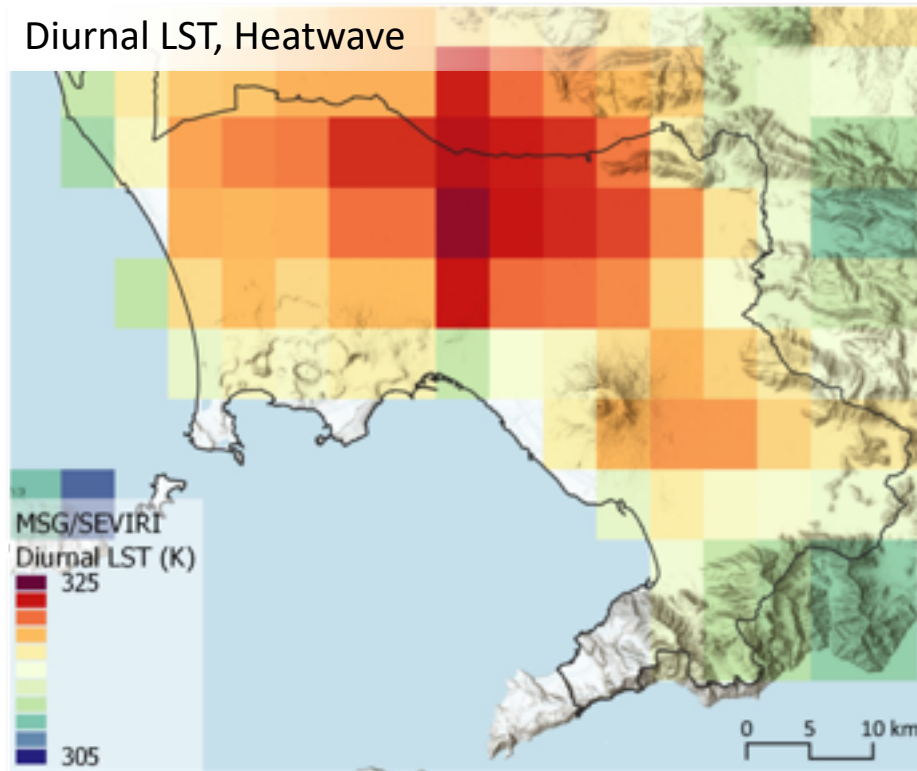
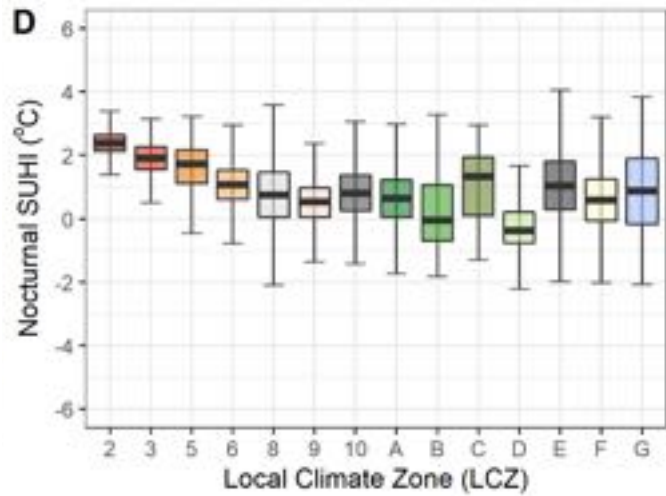
Source: Stewart, I. D., Krayenhoff, E. S., Voogt, J. A., Lachapelle, J. A., Allen, M. A., & Broadbent, A. M. (2021). Time evolution of the surface urban heat island. *Earth's Future*, 9, e2021EF002178. <https://doi.org/10.1029/2021EF002178>

+ HOW?



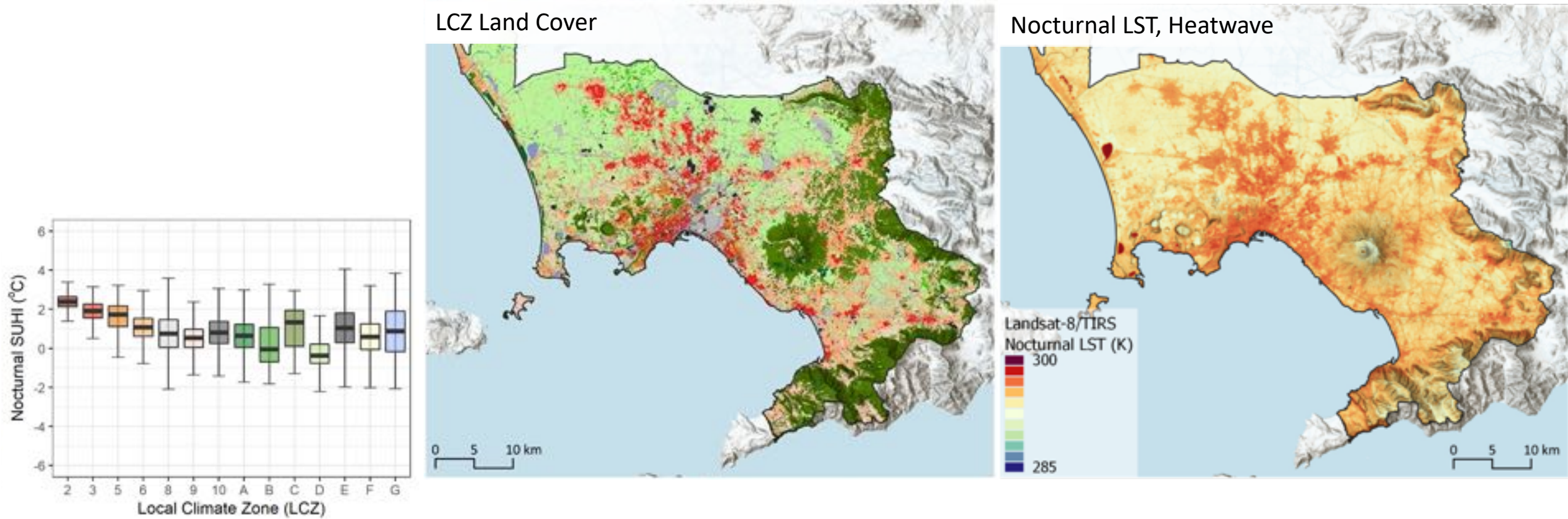
No SUHI in NAPLES during the Day!

+ HOW?



But SUHI in NAPLES during the Night!

+ HOW?



But SUHI in NAPLES during the Night!

+ HOW?

$$Q_{net} (+ Q_F) = Q_E + Q_H + \delta Q_G (+ \delta Q_A)$$

$$Q_{net} = SW \downarrow + SW \uparrow + LW \downarrow + LW \uparrow$$

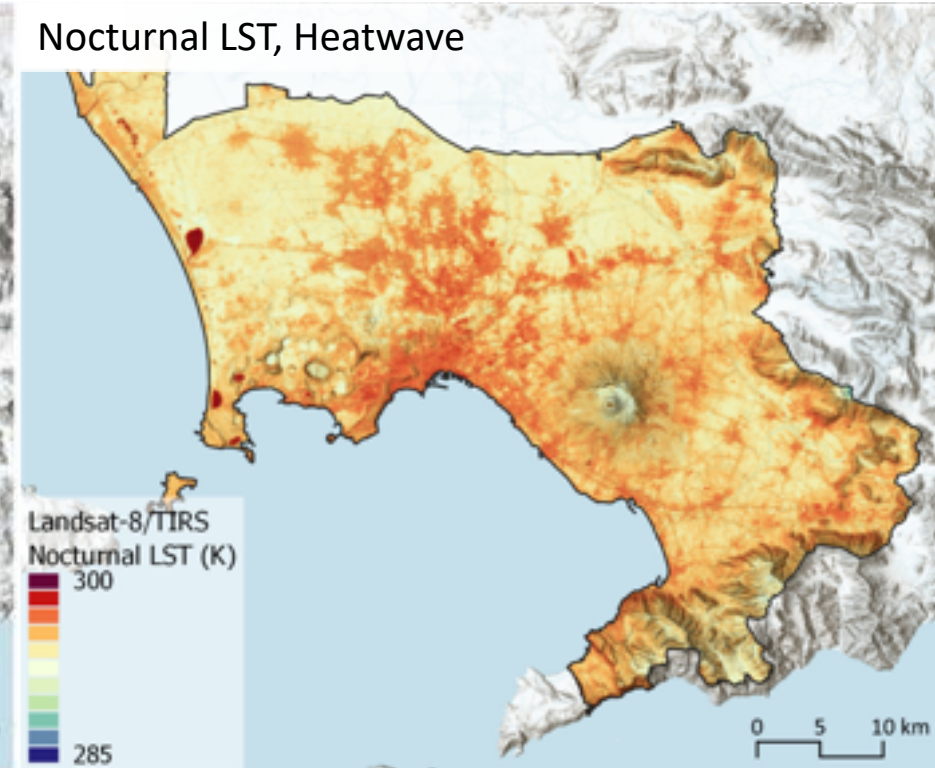
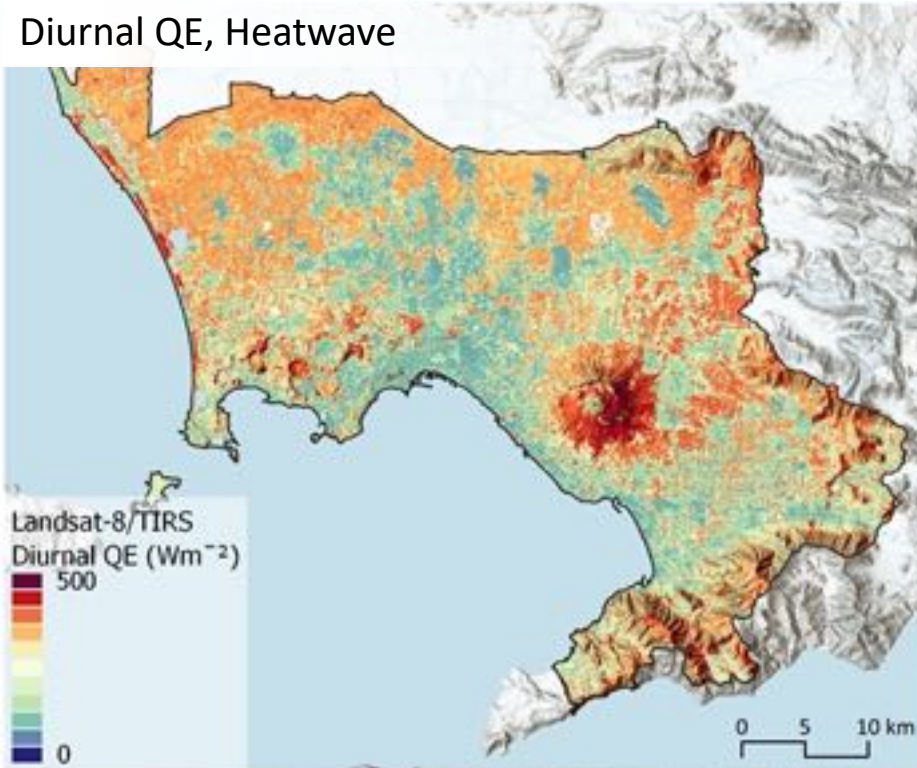
$$SW \uparrow = \alpha SW \downarrow$$

$$LW \uparrow = \varepsilon \sigma LST^4 + (1 - \varepsilon) LW \downarrow$$

$$\delta Q_G = a_1 Q_{net} + a_2 \frac{\partial Q_{net}}{\partial t} + a_3$$

$$Q_H = \frac{BR (Q_{net} - \delta Q_G)}{(1 + BR)}$$

$$Q_E = \frac{(Q_{net} - \delta Q_G)}{(1 + BR)}$$



LST correlates negatively with latent heat (QE)!

+ HOW?

$$Q_{net} (+ Q_F) = Q_E + Q_H + \delta Q_G (+ \delta Q_A)$$

$$Q_{net} = SW \downarrow + SW \uparrow + LW \downarrow + LW \uparrow$$

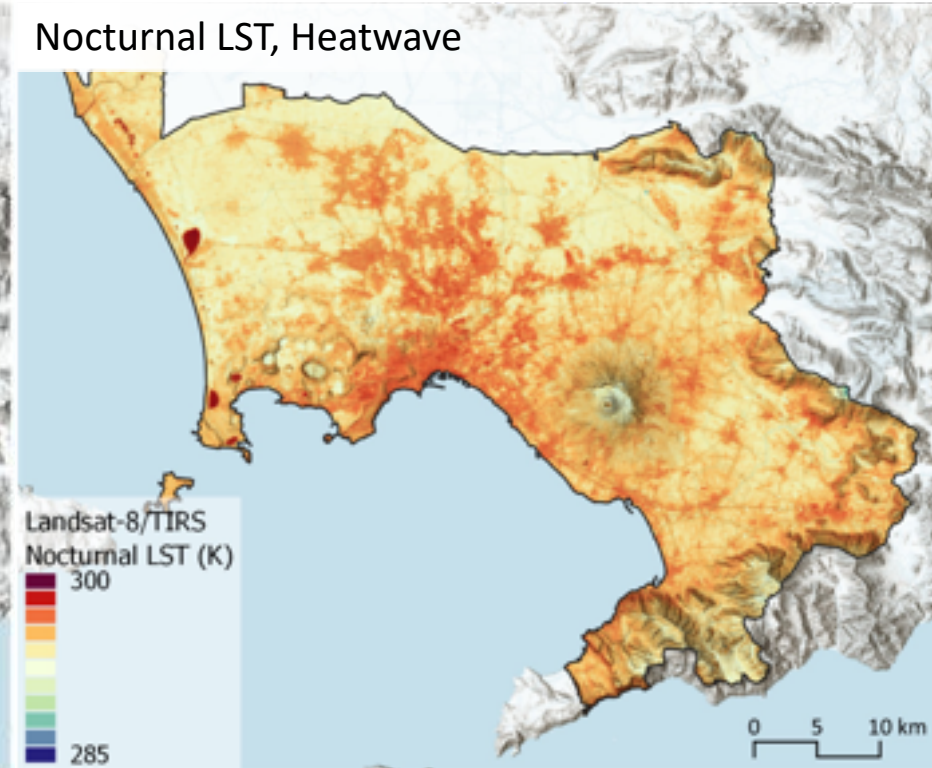
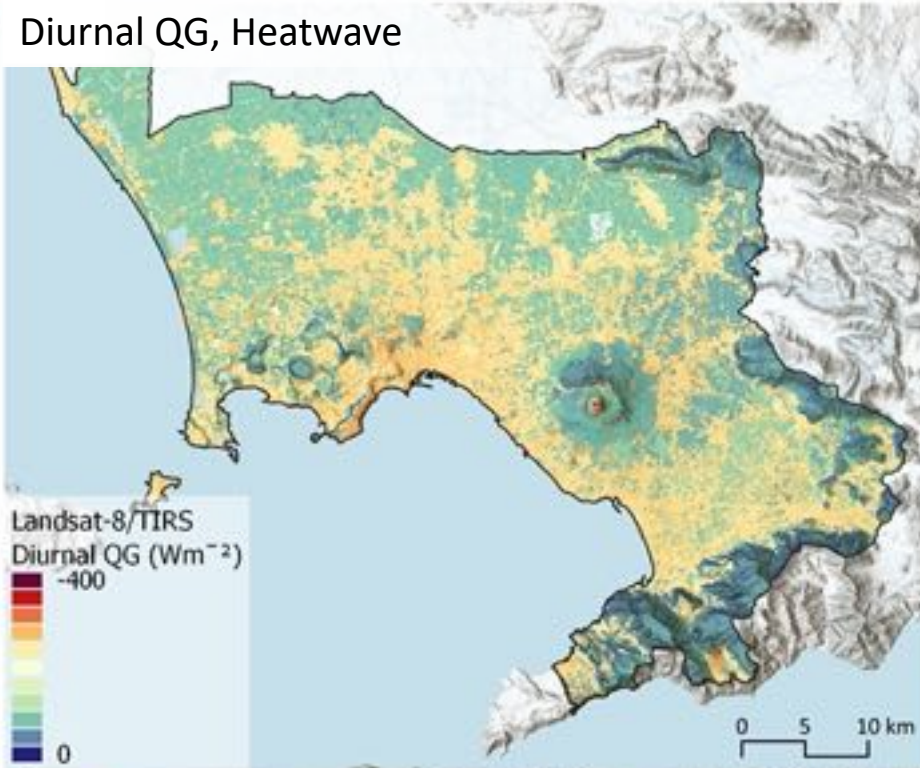
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$$Q_E = \frac{(Q_{net} - \delta Q_G)}{(1 + BR)}$$



LST correlates positively with absolute storage heat (QG)!

+ HOW?

$$Q_{net} (+ Q_F) = Q_E + Q_H + \delta Q_G (+ \delta Q_A)$$

$$Q_{net} = SW \downarrow + SW \uparrow + LW \downarrow + LW \uparrow$$

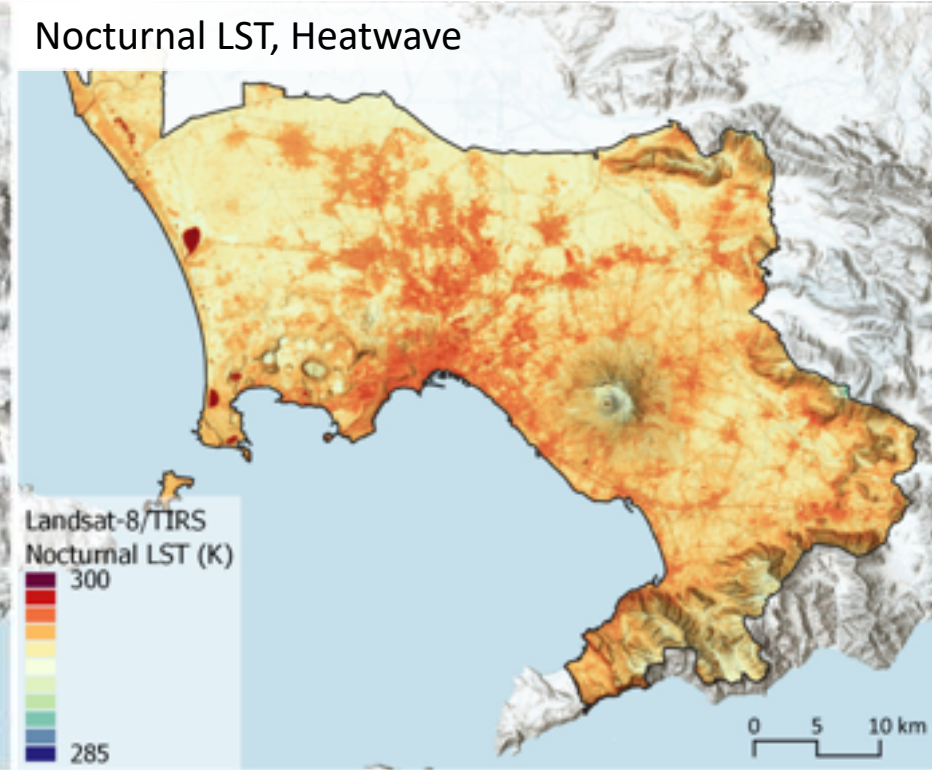
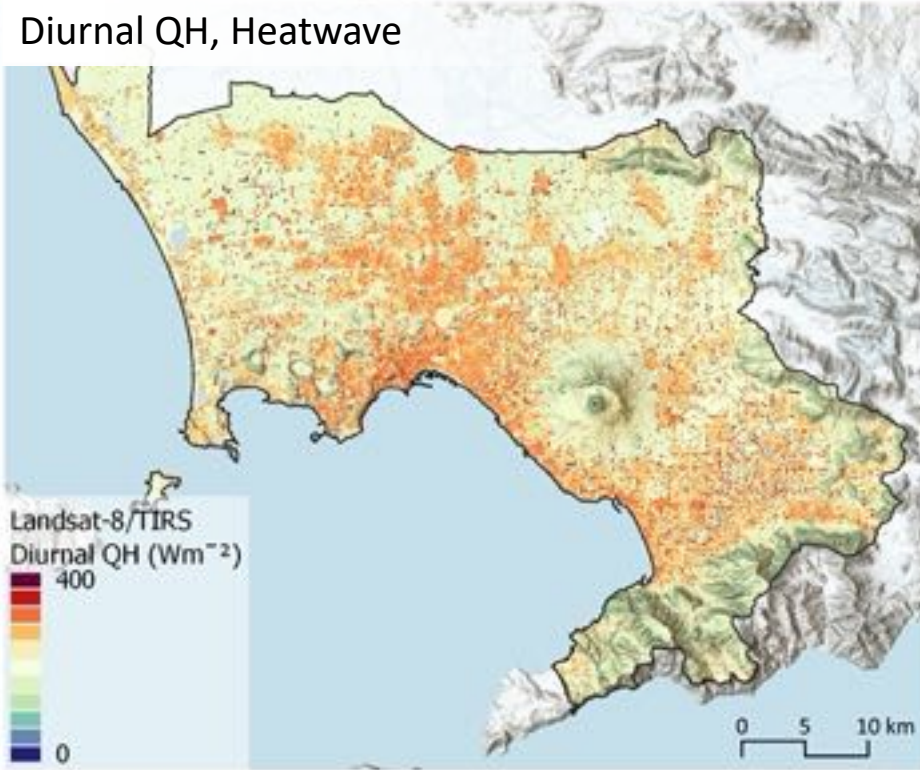
$$SW \uparrow = \alpha SW \downarrow$$

$$LW \uparrow = \varepsilon \sigma LST^4 + (1 - \varepsilon) LW \downarrow$$

$$\delta Q_G = a_1 Q_{net} + a_2 \frac{\partial Q_{net}}{\partial t} + a_3$$

$$Q_H = \frac{BR (Q_{net} - \delta Q_G)}{(1 + BR)}$$

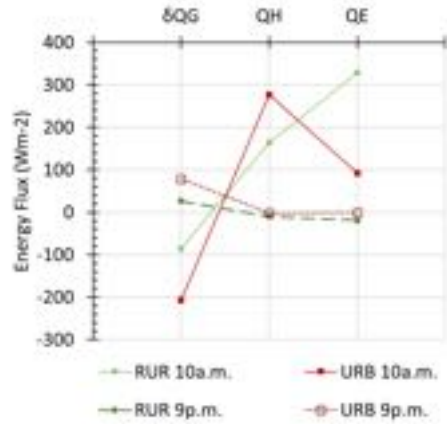
$$Q_E = \frac{(Q_{net} - \delta Q_G)}{(1 + BR)}$$



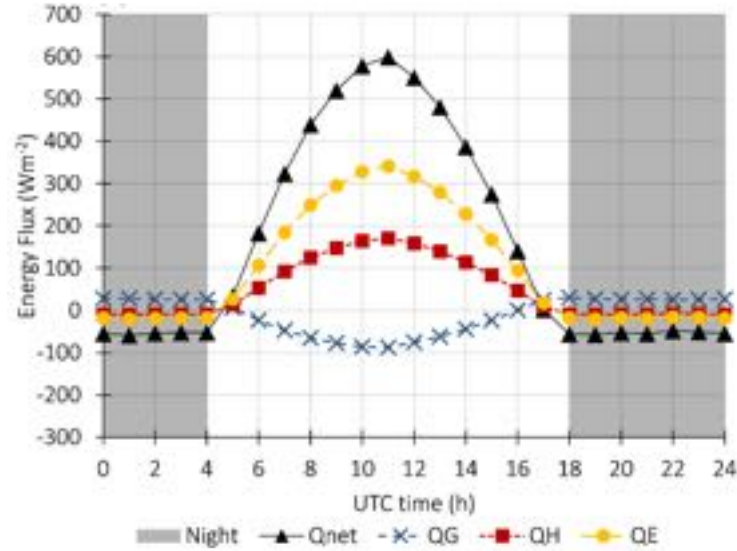
LST correlates positively with absolute sensible heat (QH)!

+ HOW?

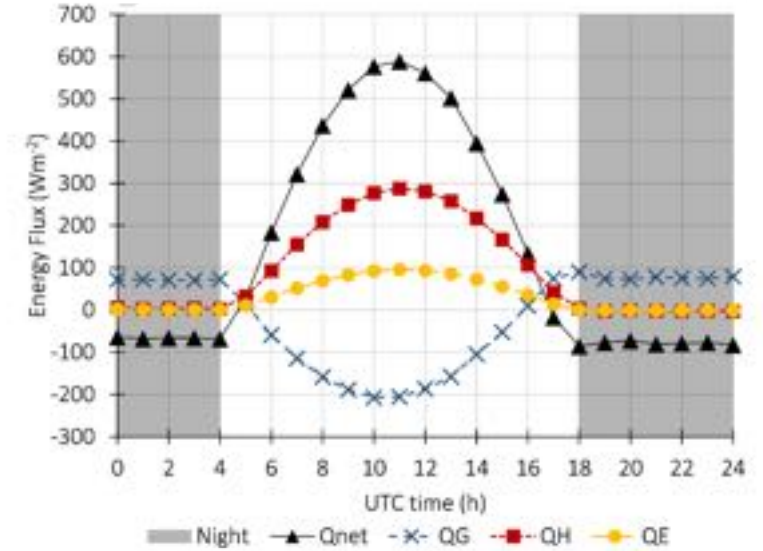
Landsat-8



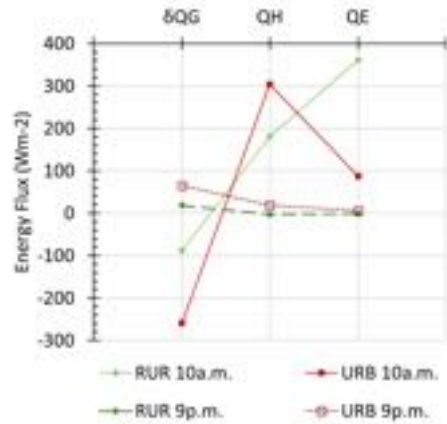
Rural Site Energy Balance Cycle



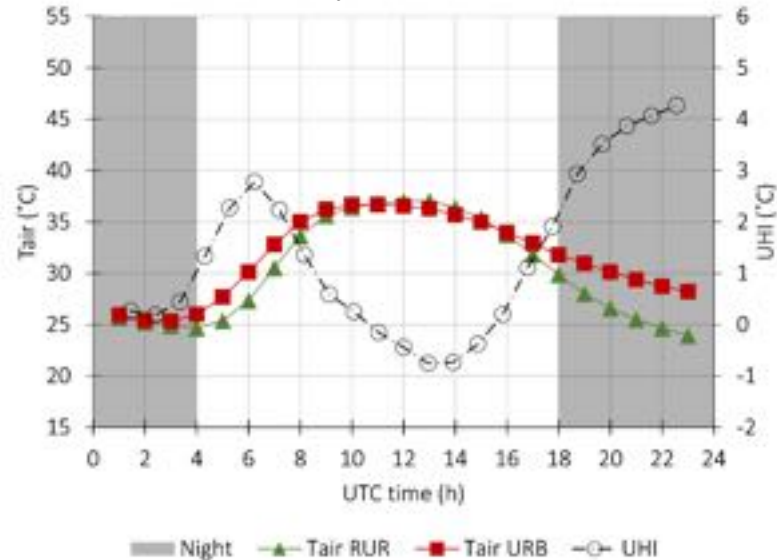
Urban Site Energy Balance Cycle



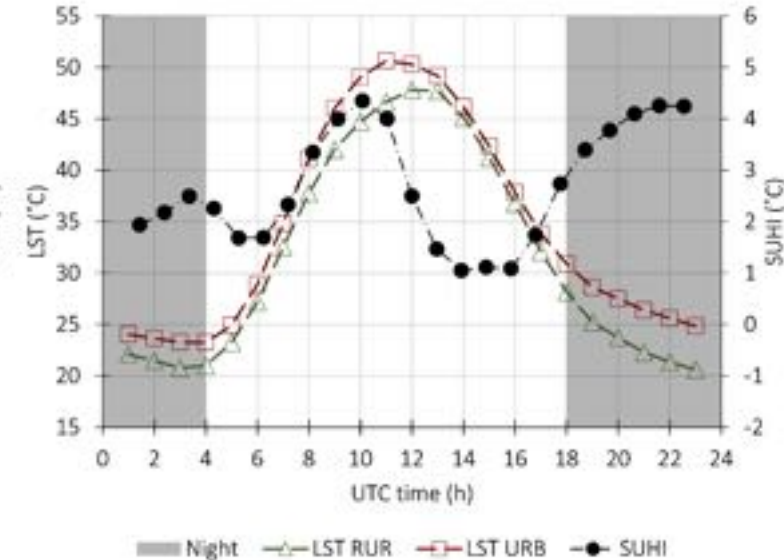
MSG/SEVIRI



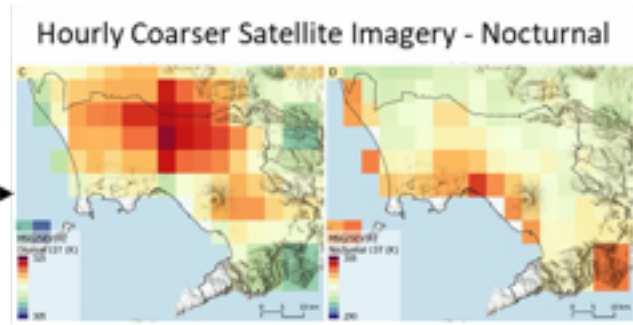
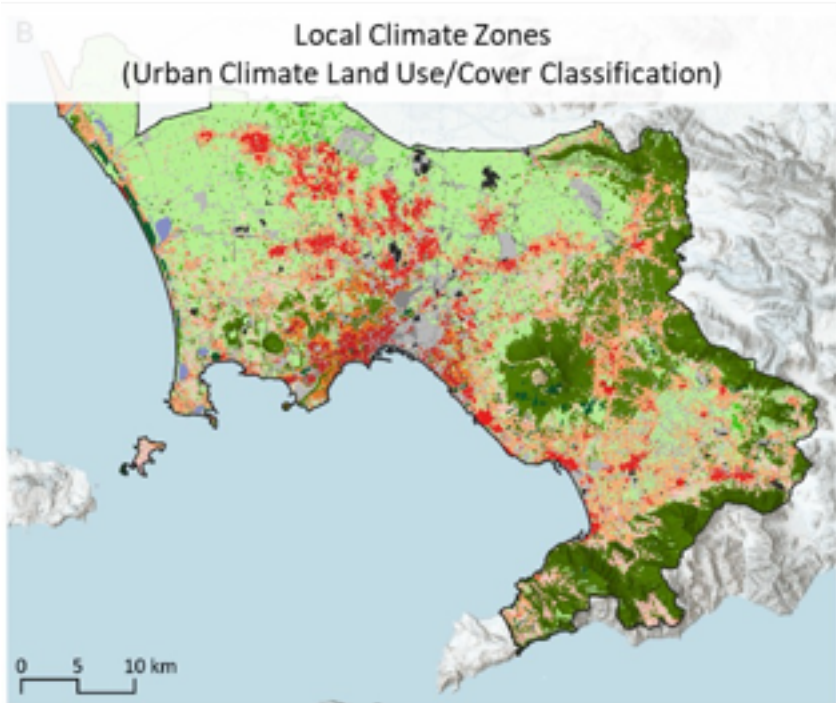
T_{air} and UHI



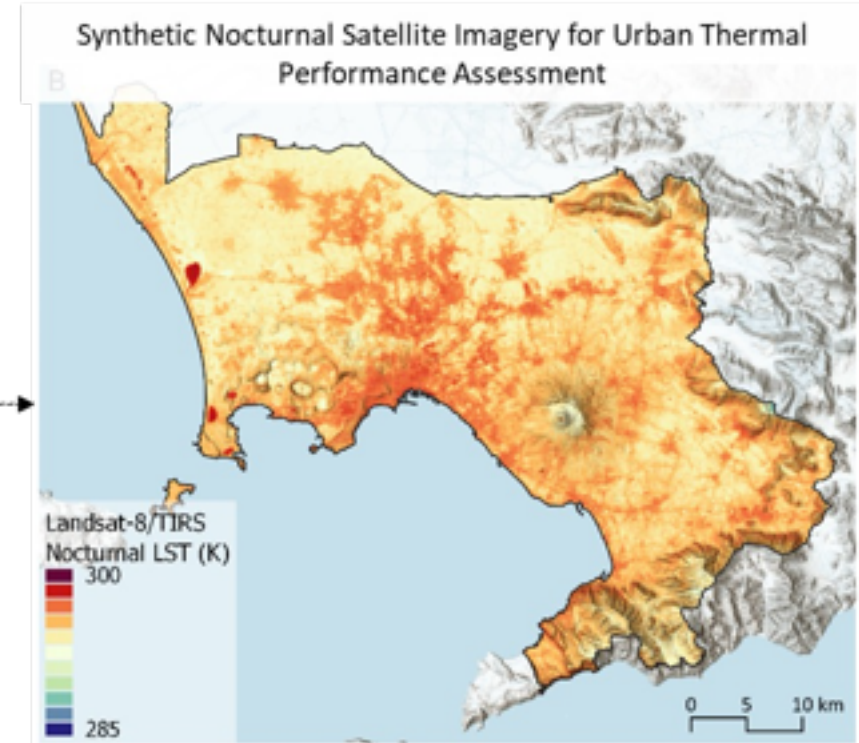
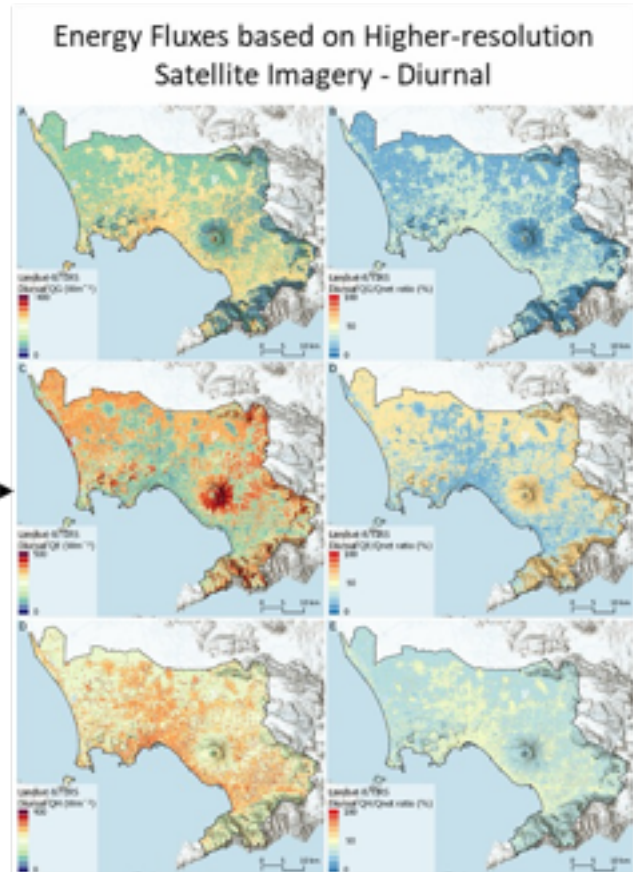
LST and SUHI



+ HOW?



+

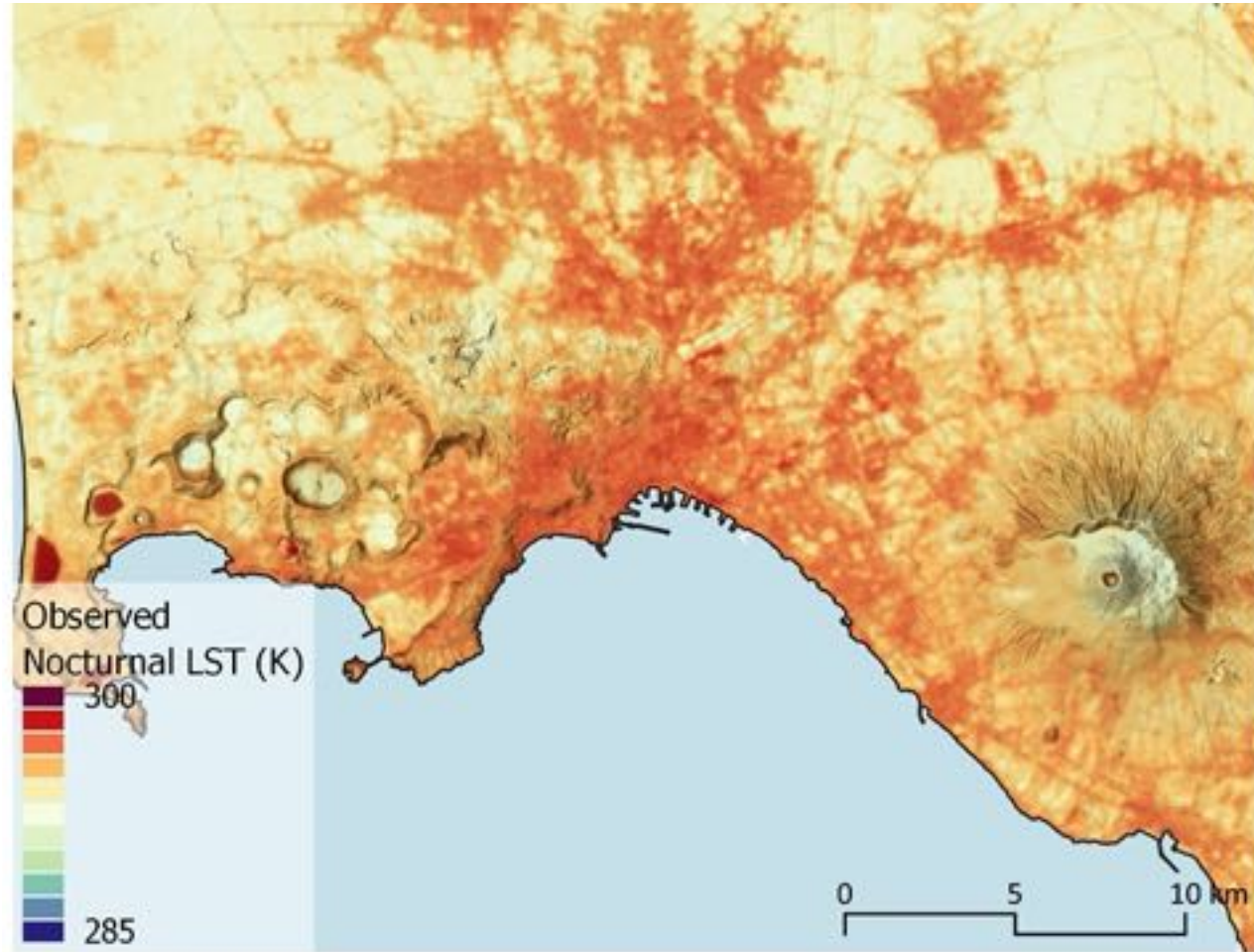


Machine Learning Model:

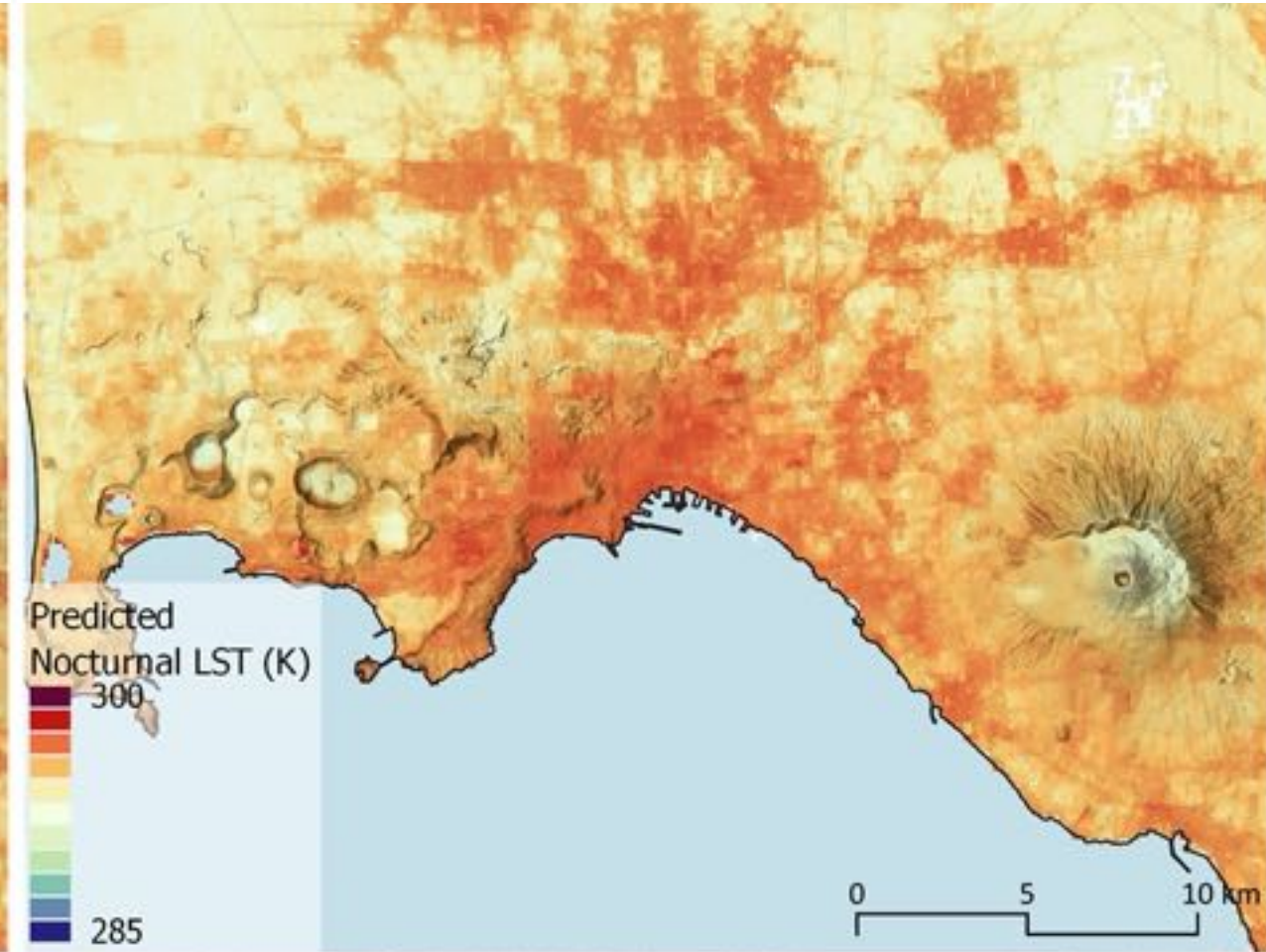
Random Forest

+ RESULTS

Observed LST



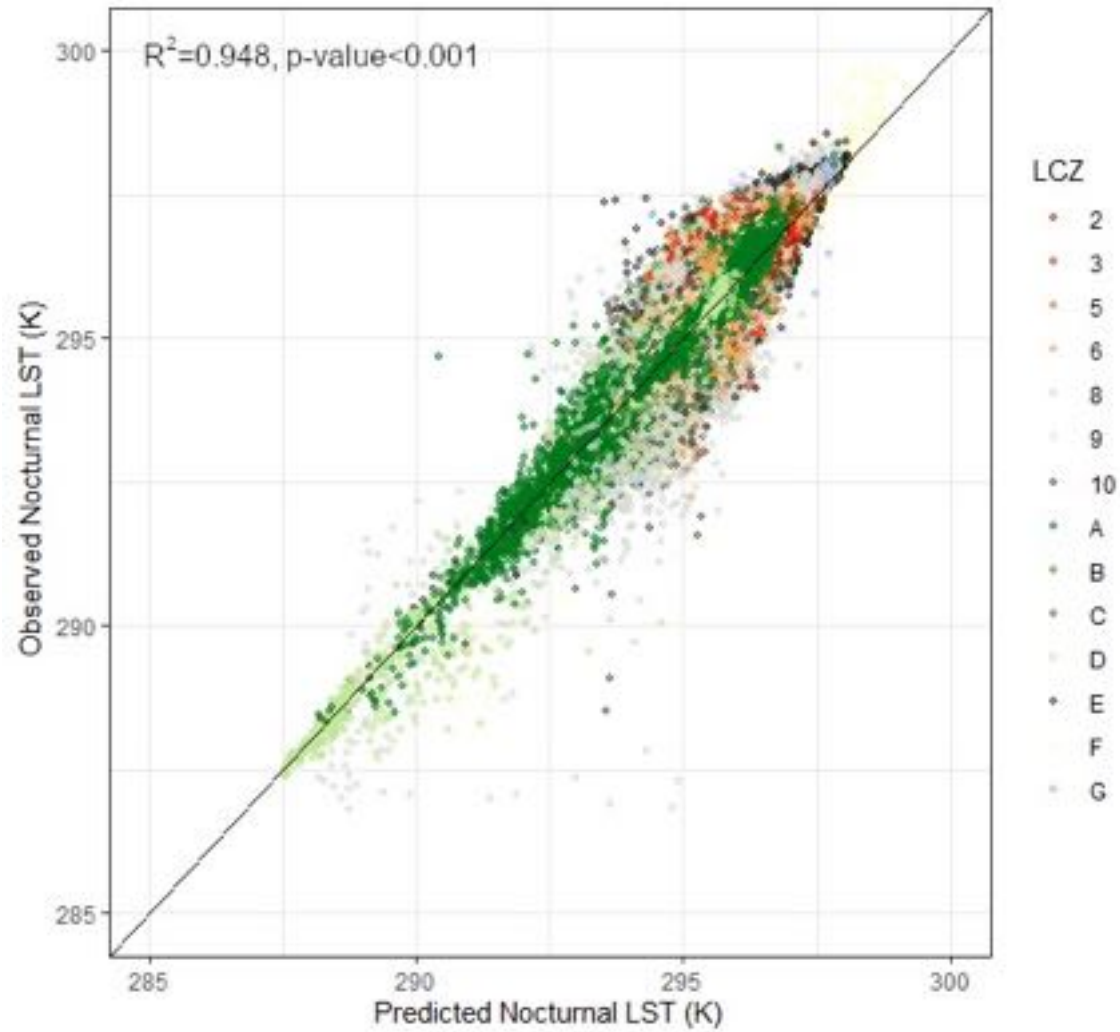
Predicted LST



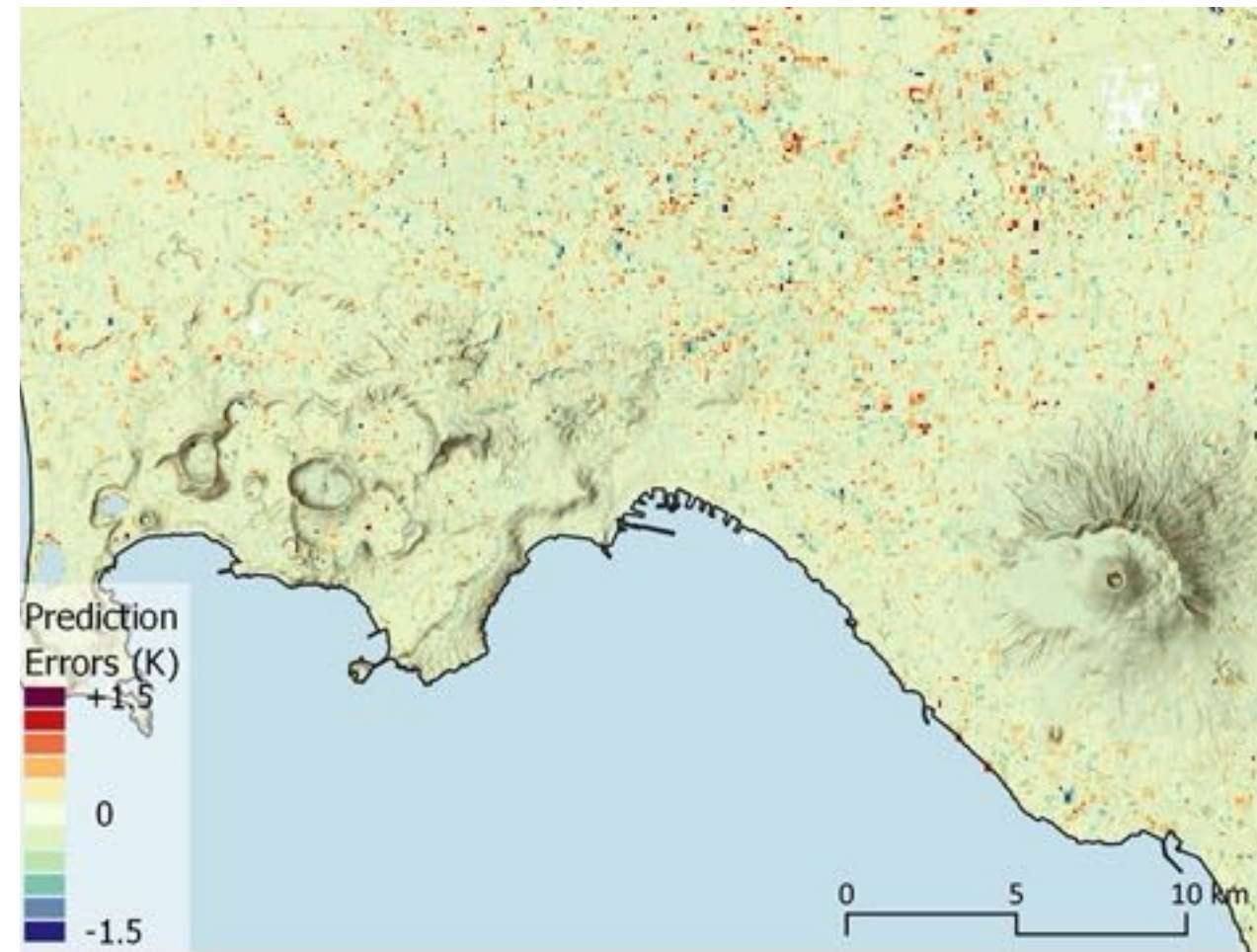
Random Forest Model Predictions match observations!

+ RESULTS

Predicted versus Observed LST



Predicted LST Errors



With low and spatially random residuals.

+NOW WHAT?

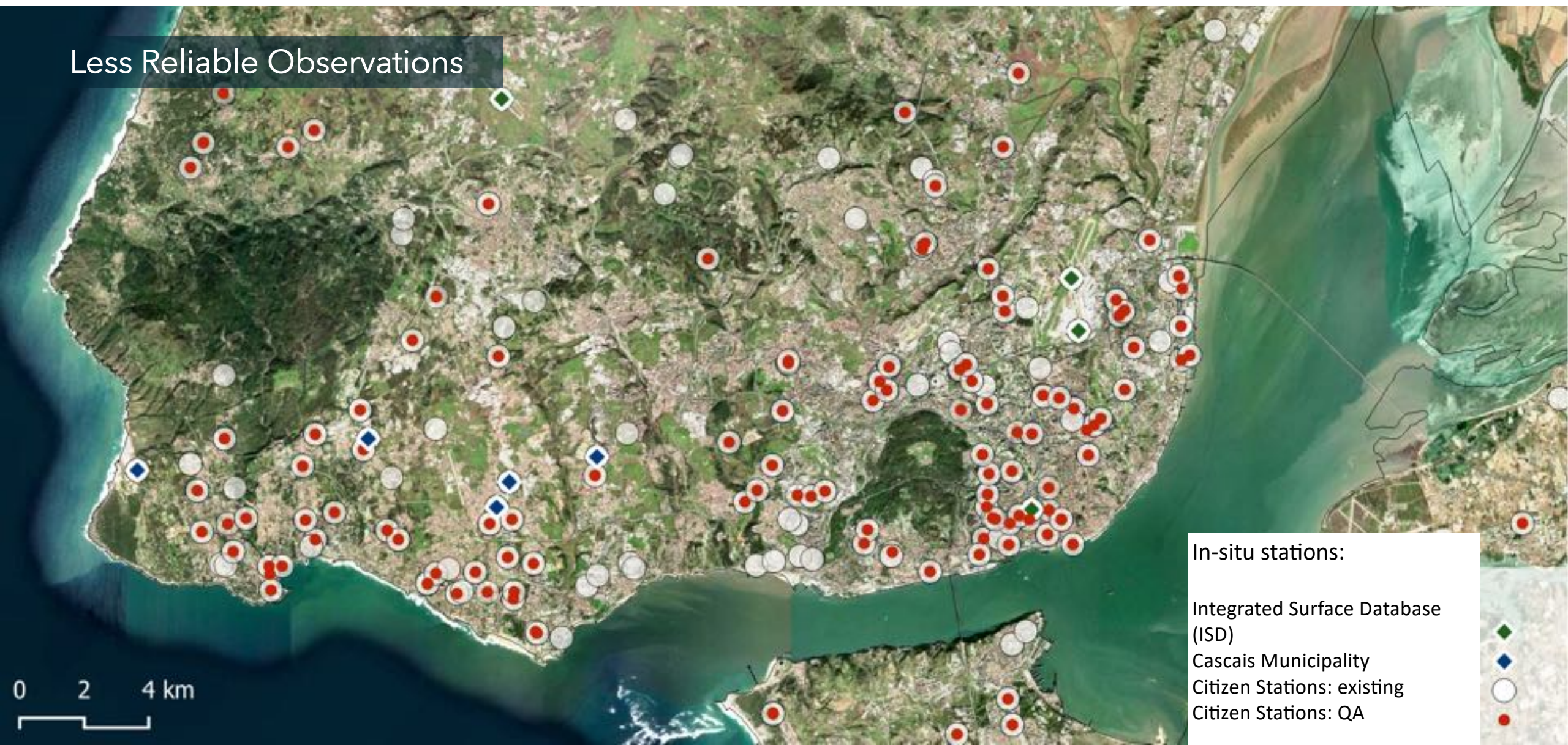
Case in Point: Contributions Towards Digital Twins?



+NOW WHAT?

Case in Point: Contributions Towards Digital Twins?

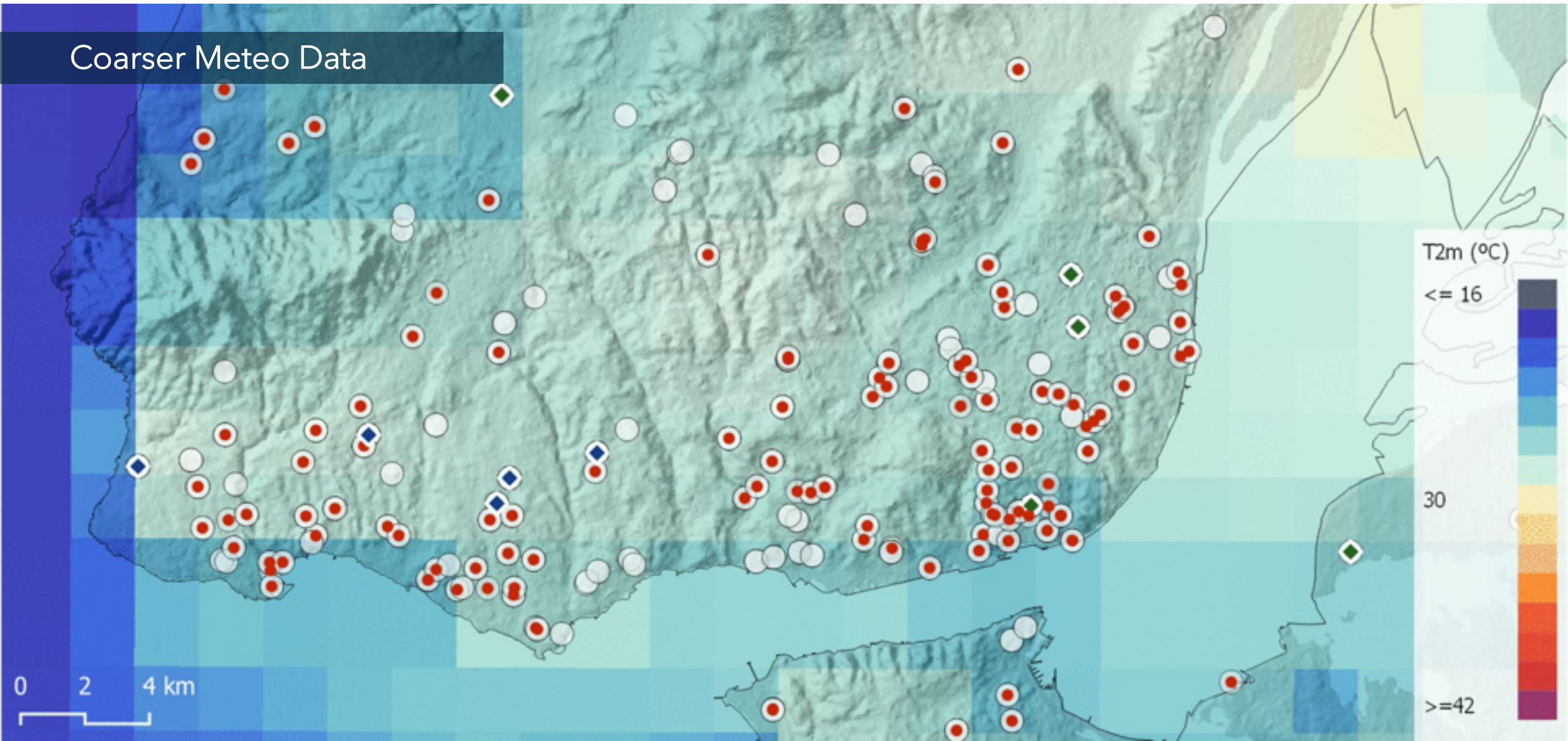
Less Reliable Observations



+NOW WHAT?

Case in Point: Contributions Towards Digital Twins?

Coarser Meteo Data

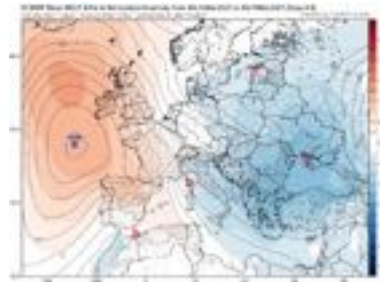


+NOW WHAT?

Case in Point: Contributions Towards Digital Twins?

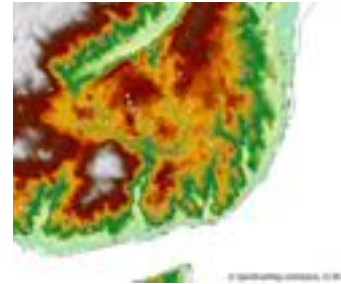
THE SOLUTION!

Citizens Data + EO + NWP + AI = Data Fusion
Data Fusion = WHERE!



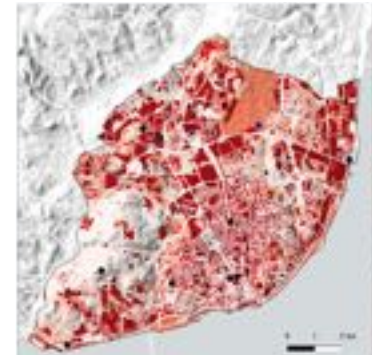
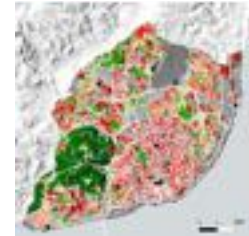
BACKGROUND CONDITIONS:

- AROME T2m
- MSLP
- RH
- Wind U/V



LANDSCAPE EFFECTS:

- Elevation
- TOPEX (per wind U/V)
- Lat/Lon
- Coast/river distance



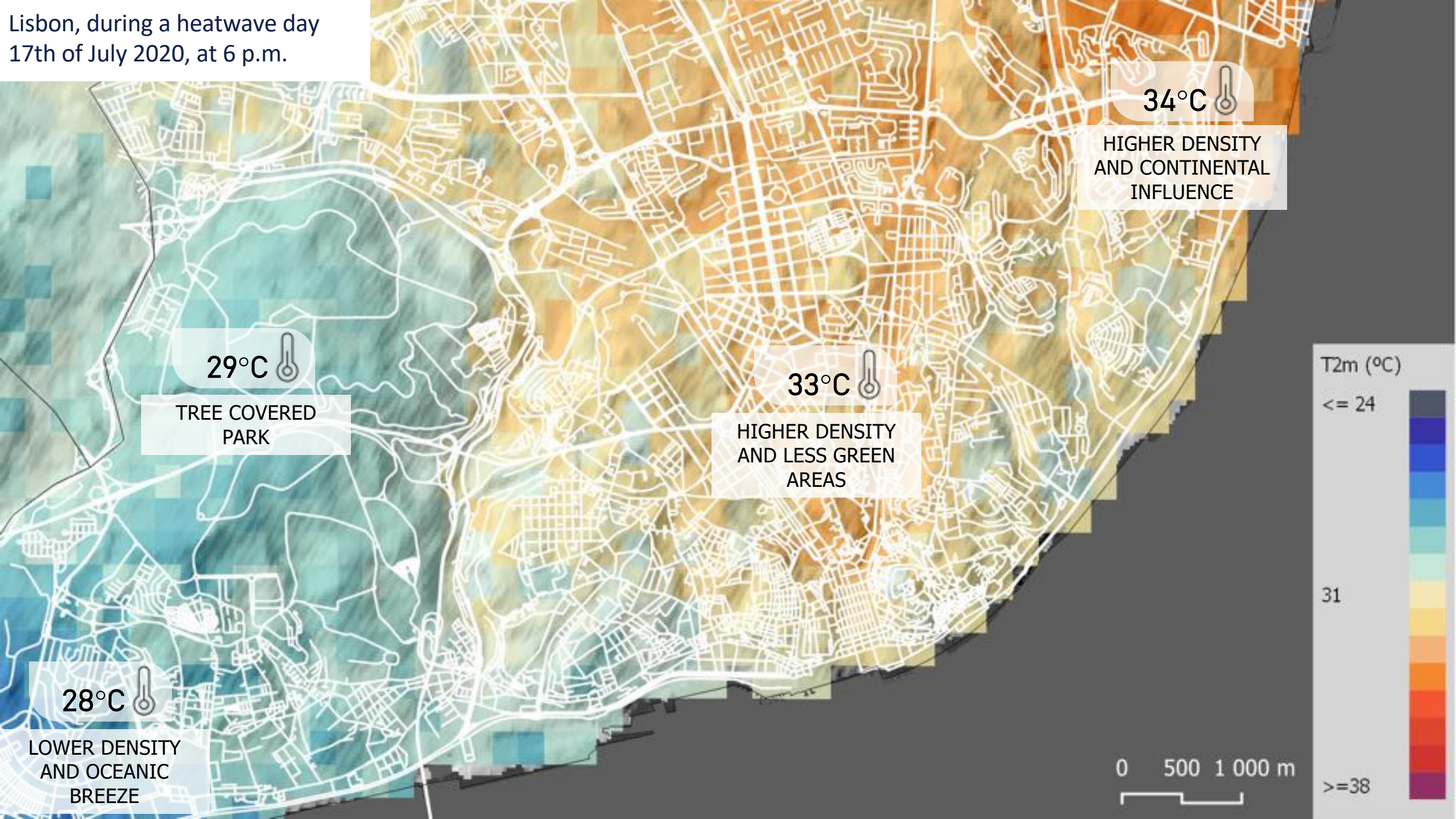
URBAN EFFECTS:

- Satellite-based Energy Fluxes and Bowen Ratio (QH/QE)
- Imperviousness
- Tree-cover percentage

Lisbon, during a heatwave day
17th of July 2020, at 6 p.m.



Lisbon, during a heatwave day
17th of July 2020, at 6 p.m.



Present-day Forecast

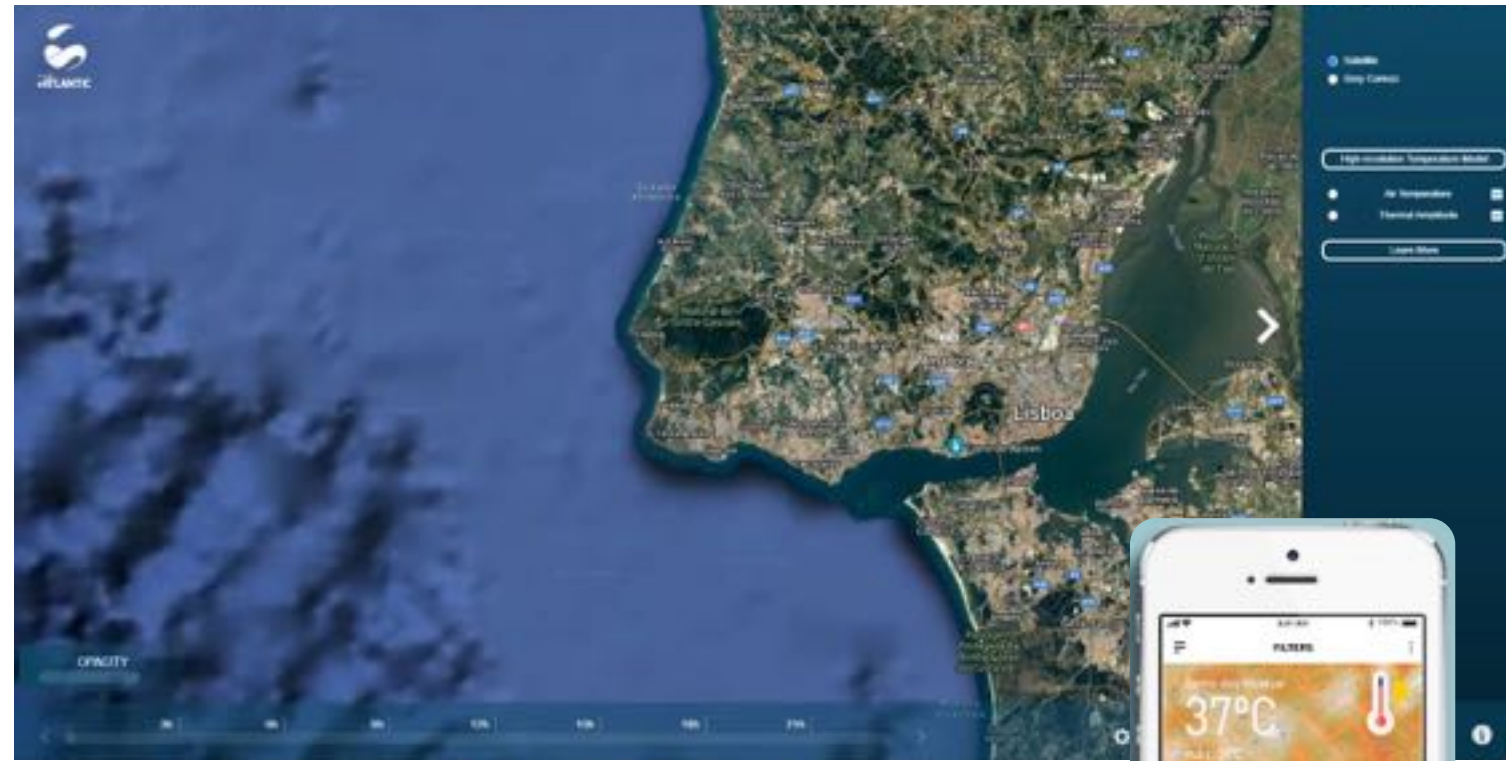
➔ How much cooler/warmer a neighbourhood is, compared to the long-term average climate?



➔ How extreme is the heat (cold) in a given neighbourhood, compared to the local temperature range?



➔ Which are the cooling (heating) acclimatization needs, in each neighbourhood?



Future Scenarios

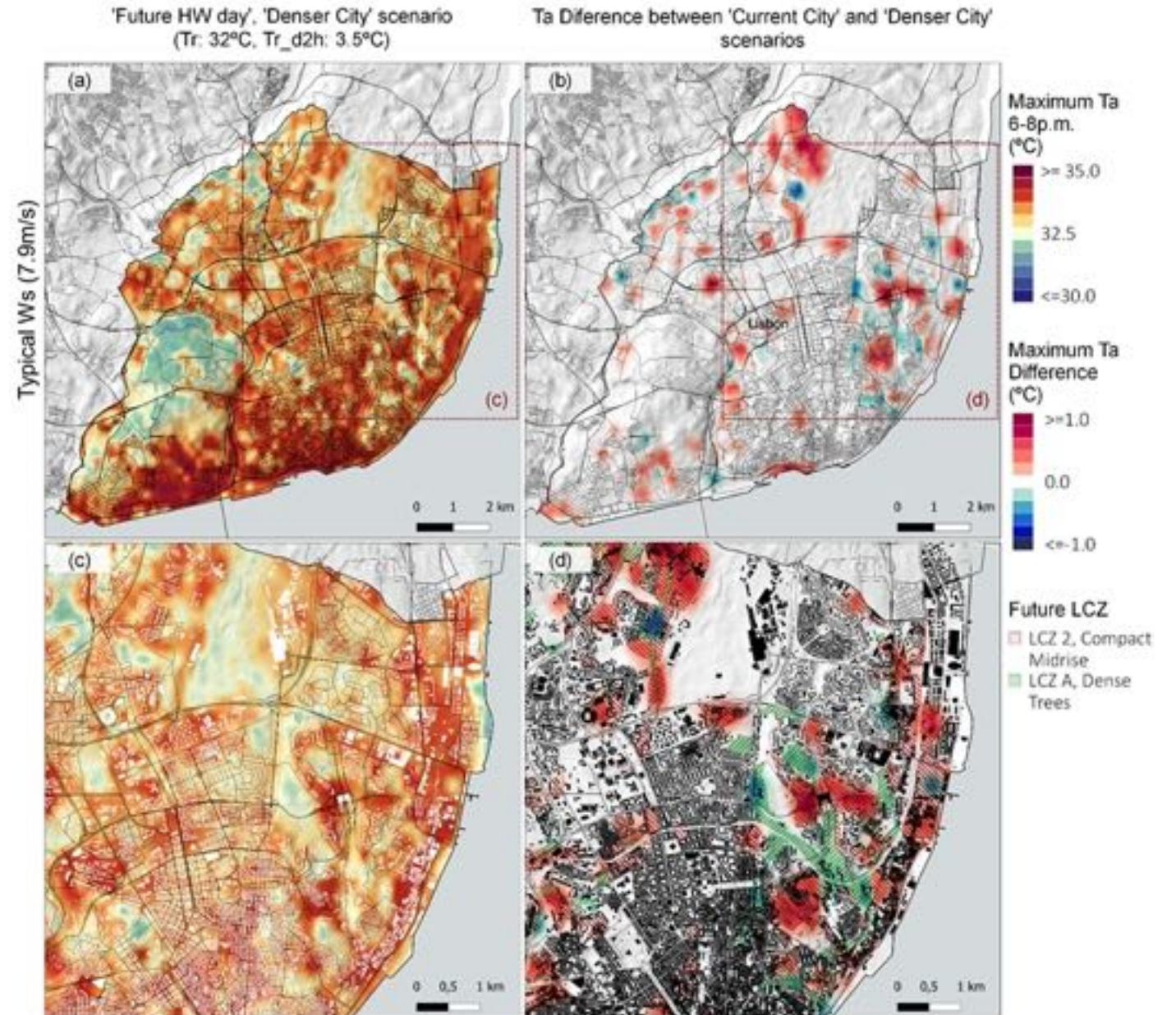
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