# Evaluating the Impact of Urban Trees on the Thermal Comfort in Imola, Italy and Tempe, USA

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[2]School of Arts, Media, and Engineering, Arizona State University, United States of America

UNIVERSITY OF BOLOGNA
Ph.D. Program of Health, Safety, and Green systems
ARIZONA STATE UNIVERSITY

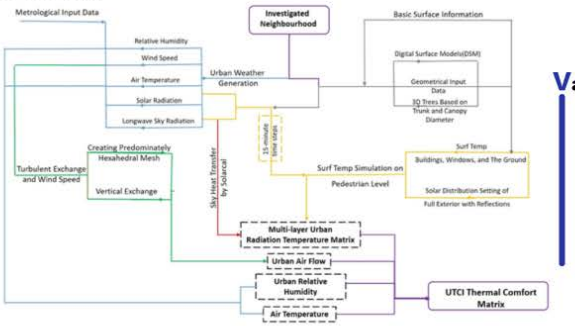
## Introduction

- As tree planting has become a priority for many cities around the globe to combat urban heat, **the need to optimize tree placement** for **maximum cooling benefits** has increased due to limited resources.
- Yet, modeling neighborhood micro-climate at high spatial resolution models that simulate air temperature, wind flow, and radiant fluxes in complex urban settings is **time-consuming and requires extensive computing power**.

## Objectives

- Introducing a **Python-enhanced** hybrid approach for simulating the **diurnal impact** of street trees on **Mean Radiant Temperature** (MRT) and **thermal comfort** (Universal Thermal Comfort Index, UTCI) based on a 3D model in **Rhino**, **EnergyPlus**, and **Ladybug** components in grasshopper.
- Mapping spatial variations of the MRT by the presented model to assess the effects of trees in **different climates** and **urban forms** in the cities of **Imola, Italy** and **Tempe, USA**.

## Methodology



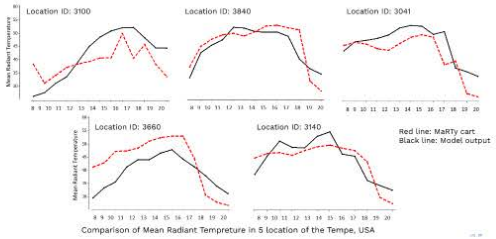

## Case study

Imola, Italy

Tempe, USA

## Validation

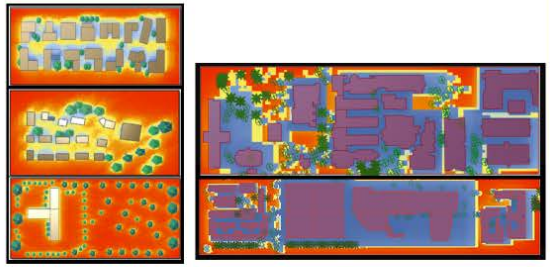
Model output for Tempe **was validated** for hot summer days in June 2018 through human bio-meteorological observations at select locations on Arizona State University's Tempe campus using the **MaRTy cart**.




Comparison of Mean Radiant Tempreture in 5 location of the Tempe, USA

## Results

The model was tested in two contrasting climates: **hot and humid** Imola, Italy, and **hot and dry** Tempe, Arizona, USA.
Results show that building shade has impressively helped the Tempe to decrease the MRT, while in Imola, low building density creates less shaded area and it impacted the MRT in most of the area.



Spatial variations in MRT on the June 9th, at 3PM at the micro-scale in the cities of Imola, Italy (left) and Tempe, USA (right)

MaRTy cart

## Conclusion

This model is a cohesive approach that minimizes miscalculation by employing **various engines** and using the output of one step as input for the next step in an integrated fashion.

It uses an accurate **3D model of geometric** properties of buildings and trees.

The **hierarchical structure** of the proposed model not only enables it to overcome the issues of previous models regarding modeling thermally comfortable urban environments, but also makes it **faster**, more accurate, and higher in quality by combining various, highly efficient engines into an integrated set of **3D visualization** and **mapping methods**.

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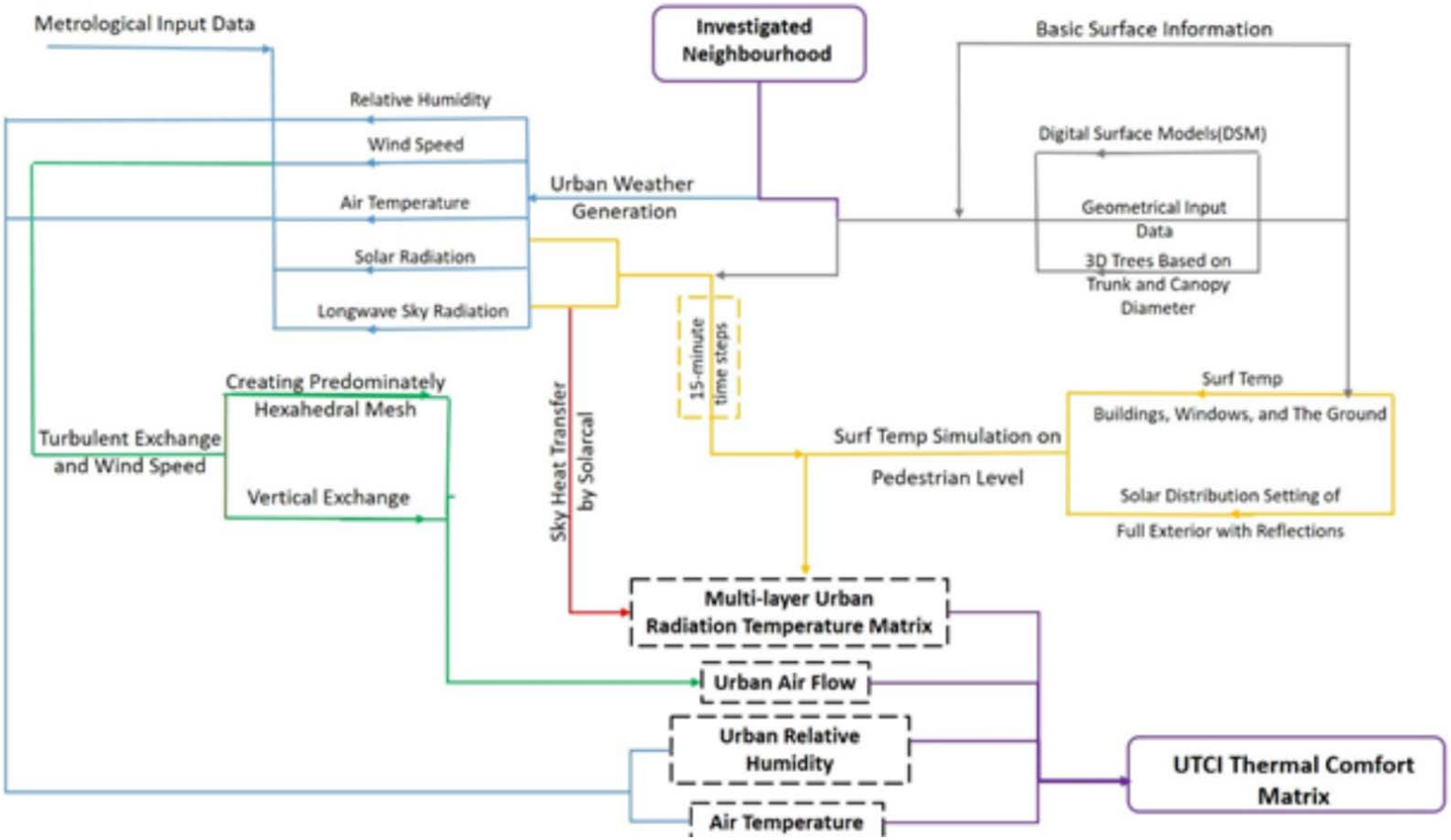


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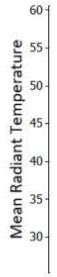

:es of America

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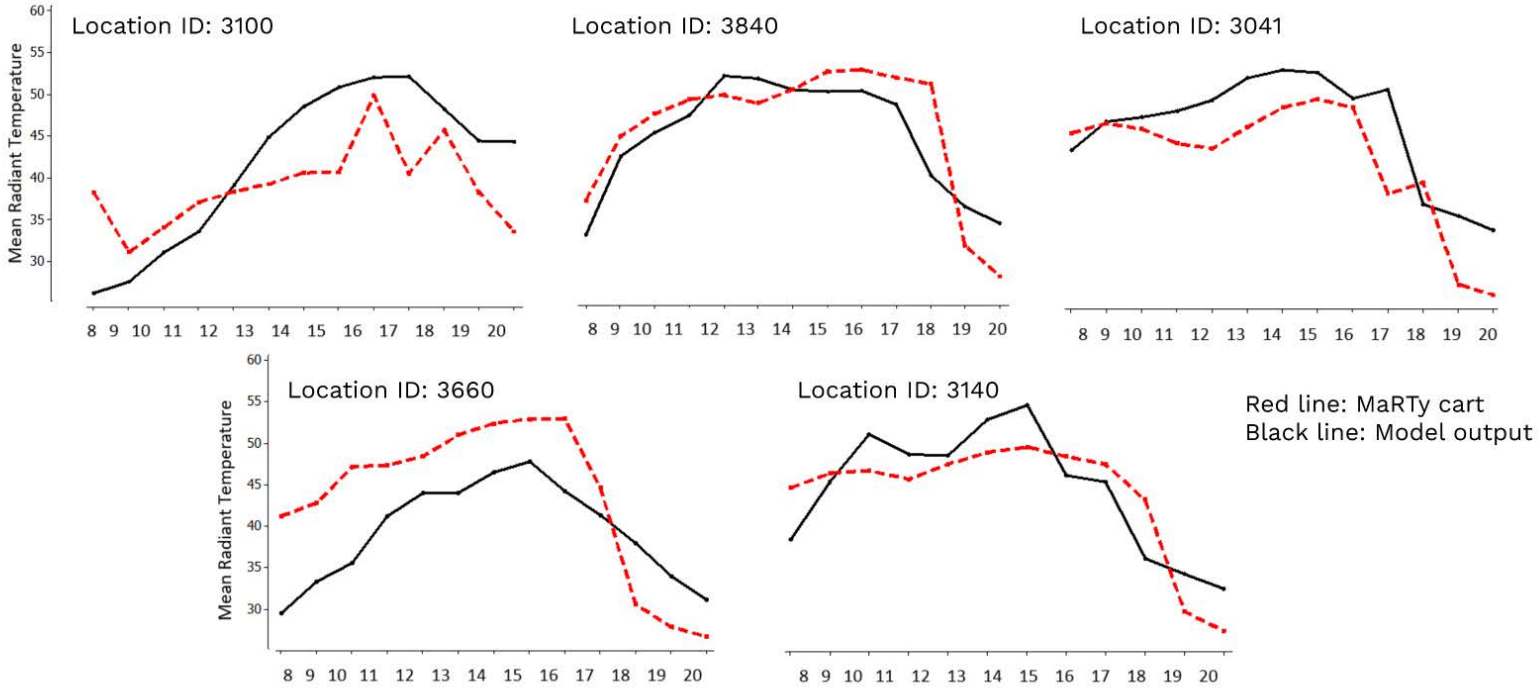
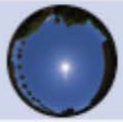
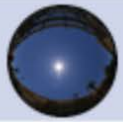
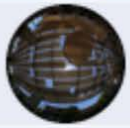



Comparison of Mean Radiant Tempreture in 5 location of the Tempe, USA

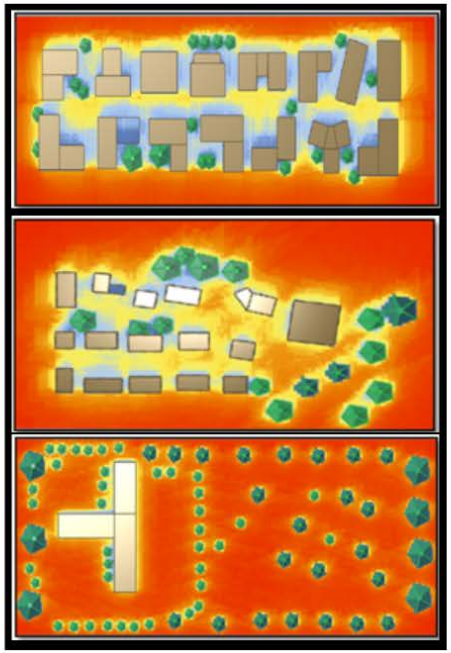
| ID | Fisheye Photo | Shade Type | Tree Species | Ground Surface | Albedo (12:30 LST) | SVF | 360° sky fraction | 360° tree fraction | 360° building fraction | 360° imperv. fraction | 360° perv. fraction |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3100 |  | exposed | - | imperv. | 0.20 | 0.8393 | 0.2182 | 0.0988 | 0.1498 | 0.1905 | 0.3410 |
| 3840 |  | building canyon | - | imperv. | - | 0.5138 | 0.0866 | 0.1681 | 0.2788 | 0.4534 | 0.0009 |
| 3041 |  | exposed | - | imperv. | 0.21 | 0.7681 | 0.1796 | 0.1343 | 0.2281 | 0.3876 | 0.0608 |
| 3660 |  | PV canopy | - | imperv. | - | 0.0415 | 0.0208 | 0.0585 | 0.4072 | 0.4714 | 0.0001 |
| 3140 |  | exposed | - | imperv. | 0.17 | 0.8653 | 0.2587 | 0.2669 | 0.0438 | 0.3788 | 0.0389 |

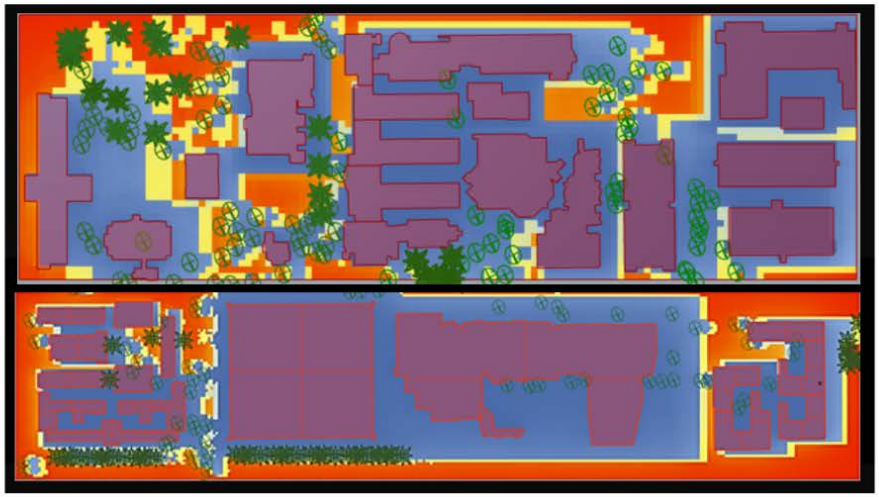
| Time | 3660 | | 3140 | | 3100 | | 3840 | | 3041 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 Jun 2018 | EP | MaRTy | EP | MaRTy | EP | MaRTy | EP | MaRTy | EP | MaRTy |
| 8 AM | 27.10 | 41.43 | 41.17 | 46.94 | 60.37 | 64.13 | 39.64 | 55.76 | - | - |
| 9 AM | 28.80 | 32.95 | 54.37 | 57.63 | 66.64 | 66.22 | 44.81 | 57.93 | 52.48 | 63.46 |
| 10 AM | 32.87 | 36.49 | 58.29 | 61.45 | 67.51 | 64.97 | 47.95 | 64.00 | 64.71 | 66.54 |
| 11 AM | 35.86 | 40.05 | 61.23 | 63.85 | 69.02 | 61.80 | 55.64 | 64.22 | 74.73 | 67.10 |
| 12 PM | 42.55 | 41.55 | 67.76 | 64.57 | 71.37 | 60.63 | 59.57 | 65.70 | 70.47 | 65.26 |
| 13 PM | 49.27 | 42.60 | 67.36 | 63.22 | 76.23 | 65.40 | 59.56 | 69.24 | 70.26 | 68.46 |
| 14 PM | 53.57 | 44.21 | 65.44 | 65.54 | 77.95 | 69.69 | 63.10 | 71.15 | 77.81 | 70.90 |
| 15 PM | 56.31 | 44.36 | 65.23 | 68.50 | 77.40 | 71.61 | 64.88 | 71.89 | 80.94 | 72.05 |
| 16 PM | 57.78 | 55.14 | 65.26 | 68.80 | 71.78 | 69.79 | 59.95 | 71.94 | 66.13 | 70.07 |
| 17 PM | 57.81 | 44.10 | 62.93 | 67.52 | 73.72 | 50.60 | 55.93 | 60.45 | 64.70 | 68.42 |
| 18 PM | 53.28 | 50.23 | 51.15 | 66.46 | 48.26 | 53.19 | 51.20 | 41.04 | 48.45 | 60.96 |
| 19 PM | 48.71 | 41.43 | 45.92 | 39.21 | 45.82 | 30.69 | 45.67 | 37.29 | 45.19 | 37.34 |
| 20 PM | 48.61 | 35.82 | 43.06 | 34.20 | 42.66 | 28.26 | 41.85 | 35.64 | 42.19 | 33.31 |
| RMSE | 8.54829 | | 6.141 | | 10.40103 | | 10.32038 | | 7.44776 | |

# Results

The model was tested in two contrasting climates: **hot and humid** Imola, Italy, and **hot and dry** Tempe, Arizona, USA.

Results show that building shade has impressively helped the Tempe to decrease the MRT, while in Imola, low building density creates less shaded area and it impacted the MRT in most of the area.





MaRTy cart

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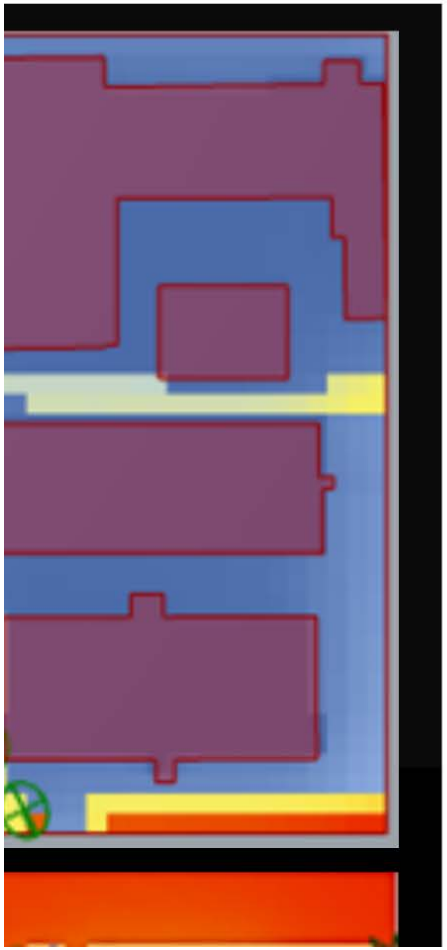


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(left) and Tempe, USA (right)

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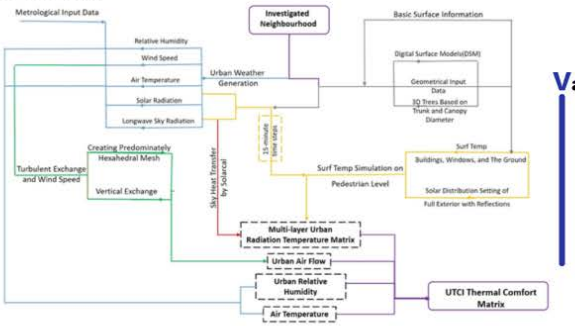


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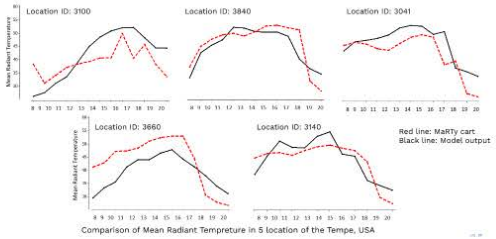


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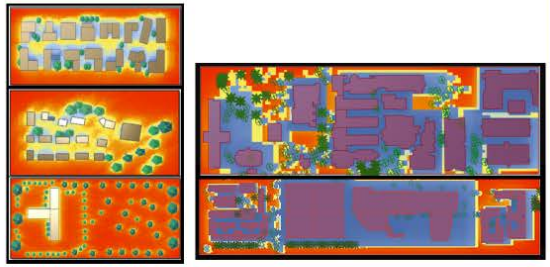

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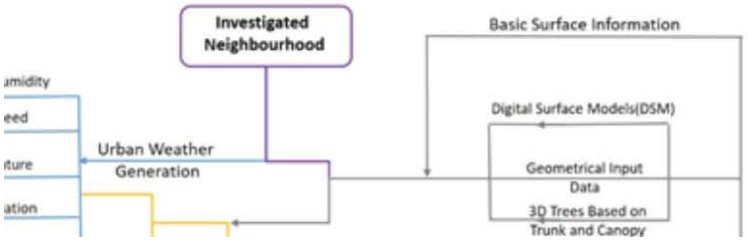


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