High-resolution Vegetation Proxy Modeling for Partial Shading Effects on BIPV Facades

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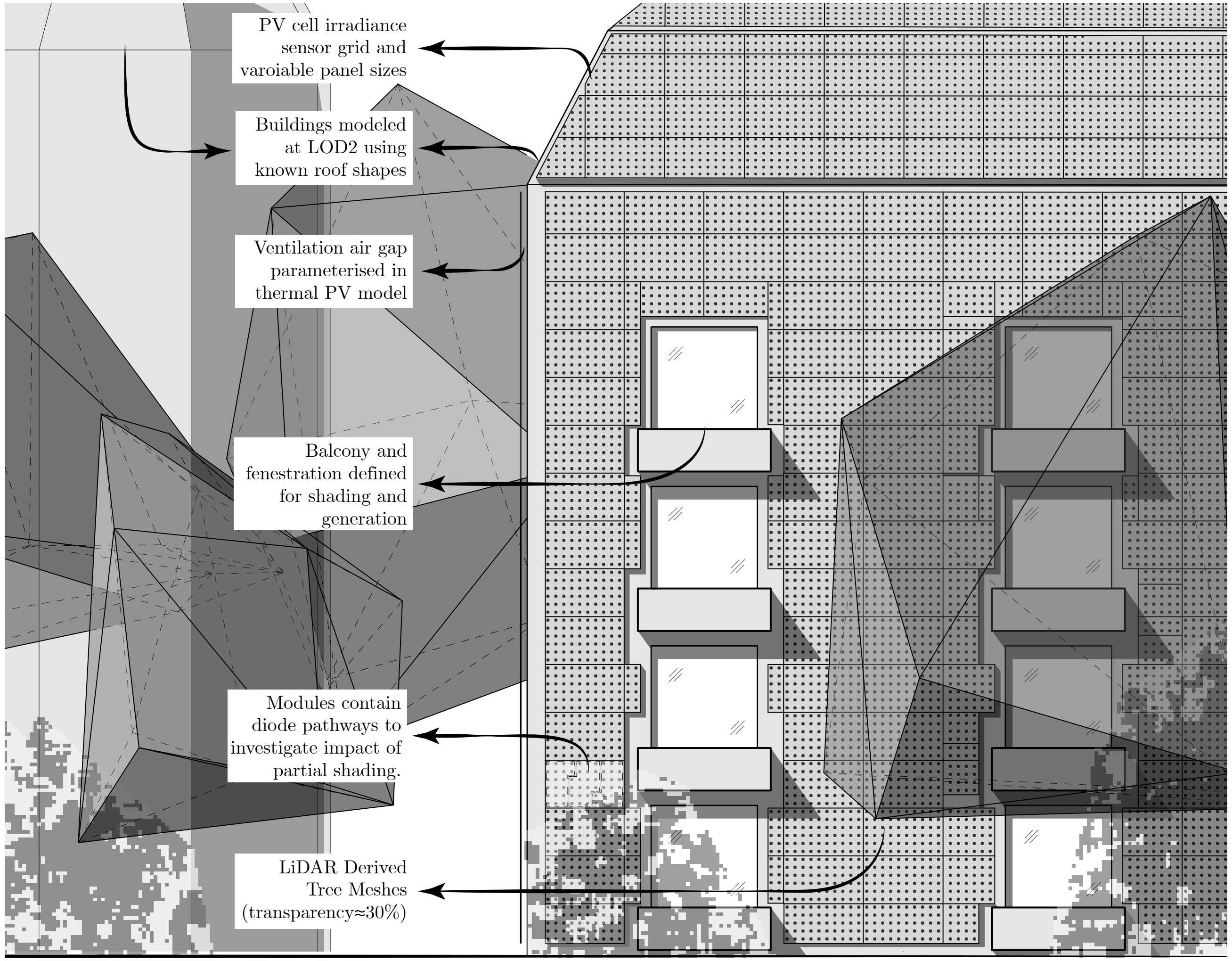
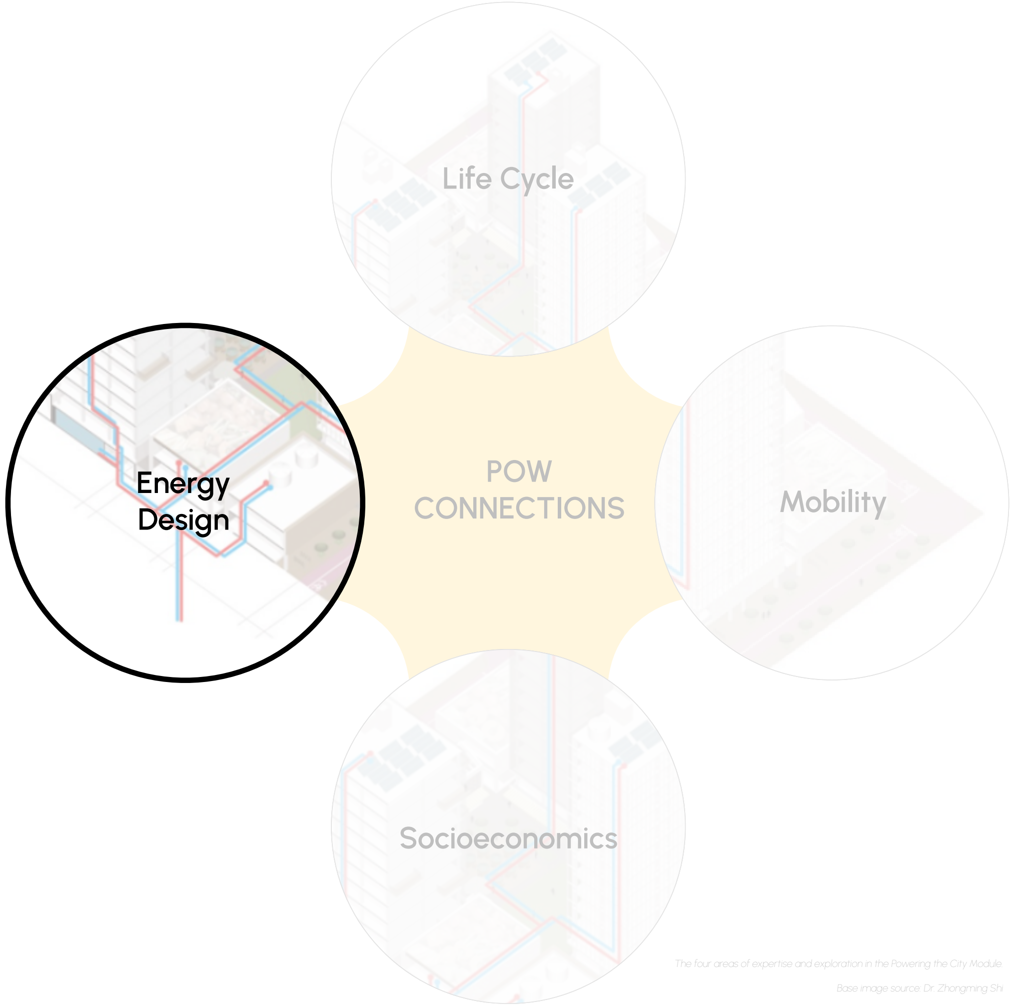
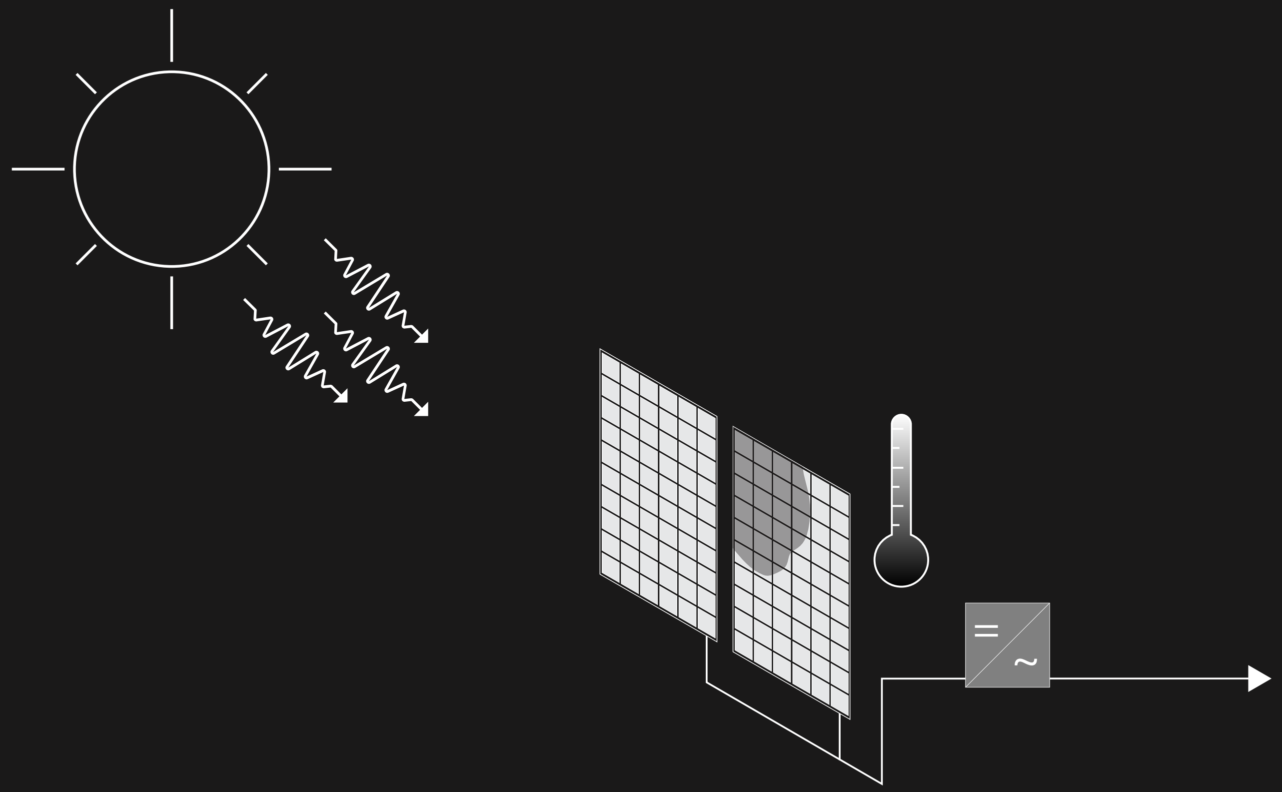




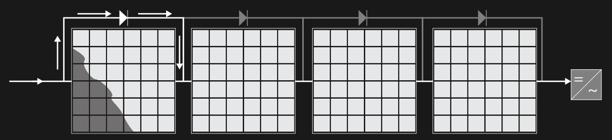
The four areas of expertise and exploration in the Powering the City Module.

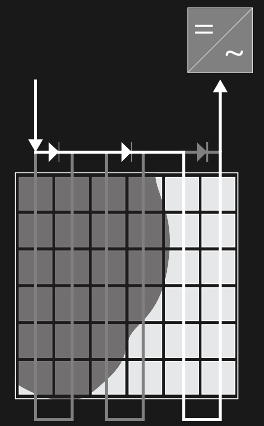
Base image source: Dr. Zhongming Shi

High-resolution



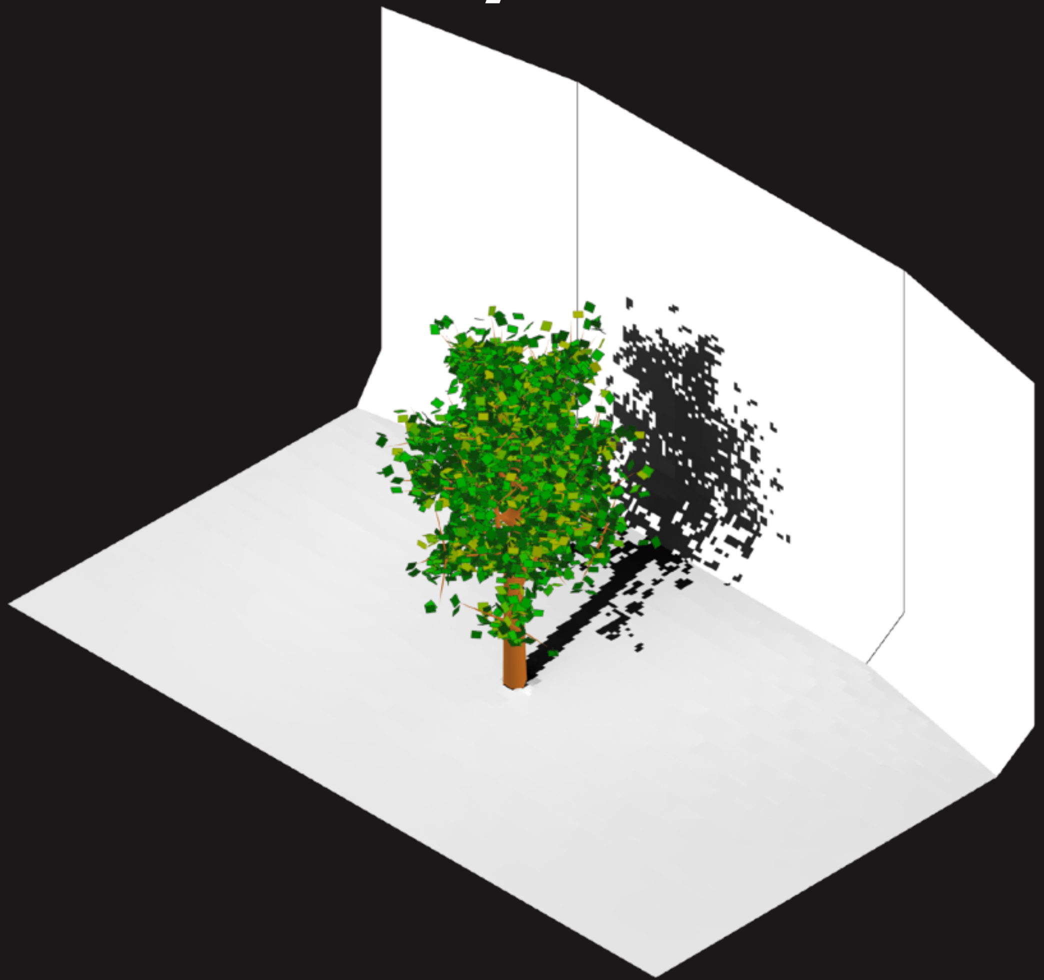
Partial Shading Effects on BIPV Facades





Vegetation Proxy

Modeling



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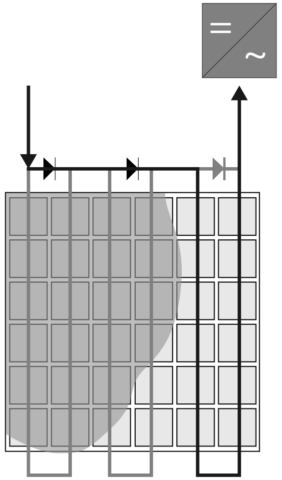
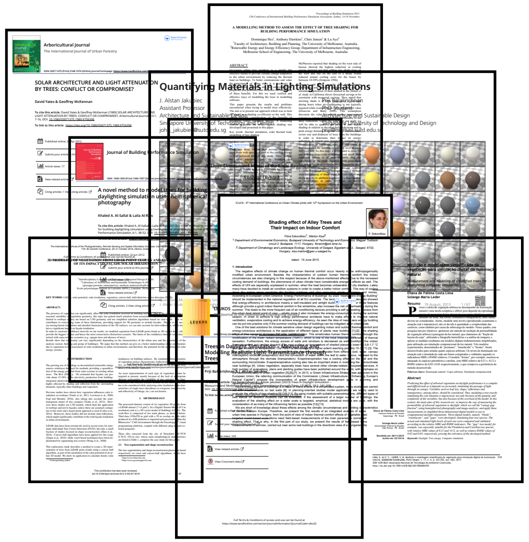
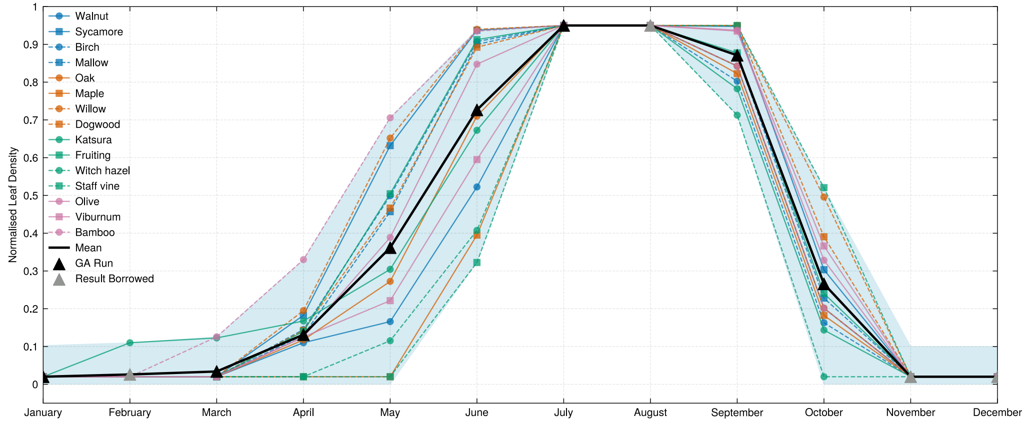
Overview

- Shadow patterns matter for photovoltaic performance.
- Who has done what and how can we apply it?
- Proxy trees from LiDAR and a genetic algorithm.
- Where to go from here?

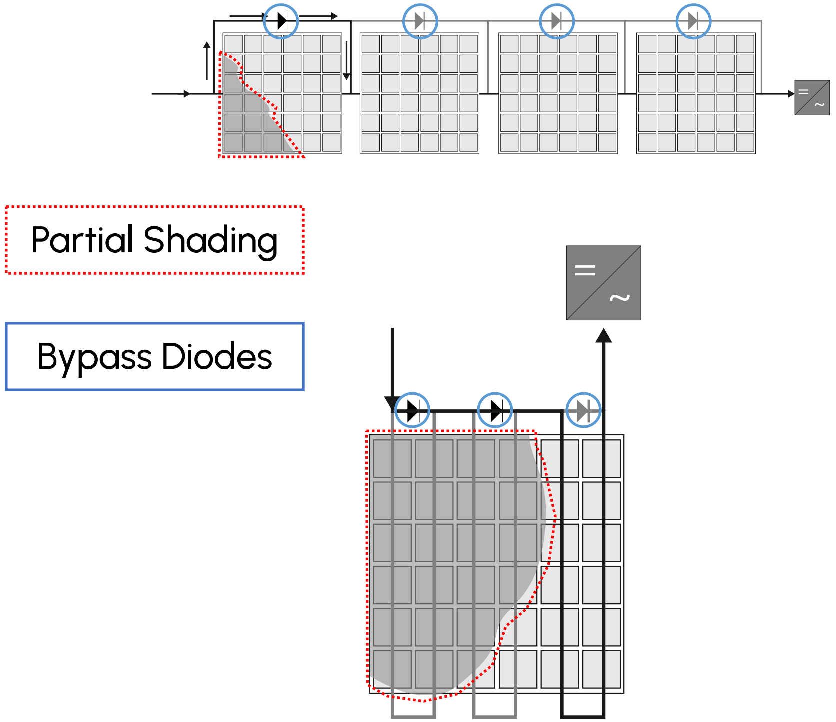






Partial Shading & Bypass Diodes

- Bypass diodes prevent damage in partially shaded strings (cells or modules).
- Their side-effect however is a reduced power output in the module.
- Modeling and simulating trees at larger scales is complex and computationally expensive.



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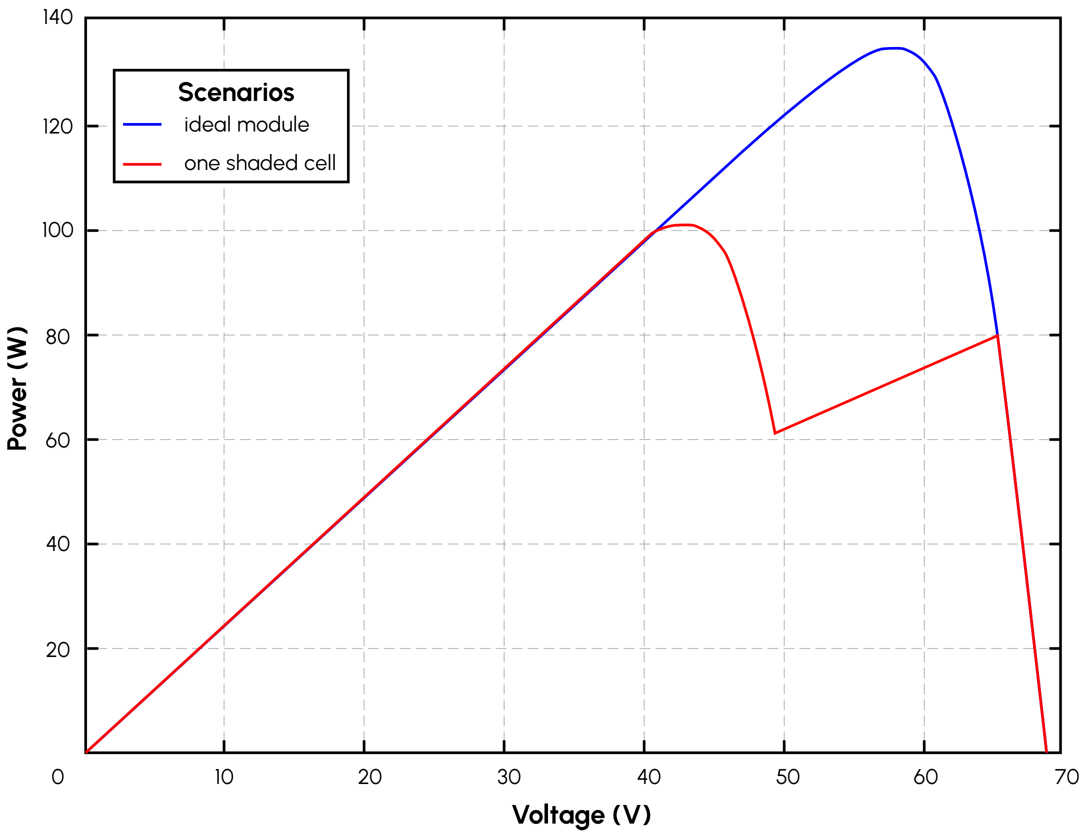

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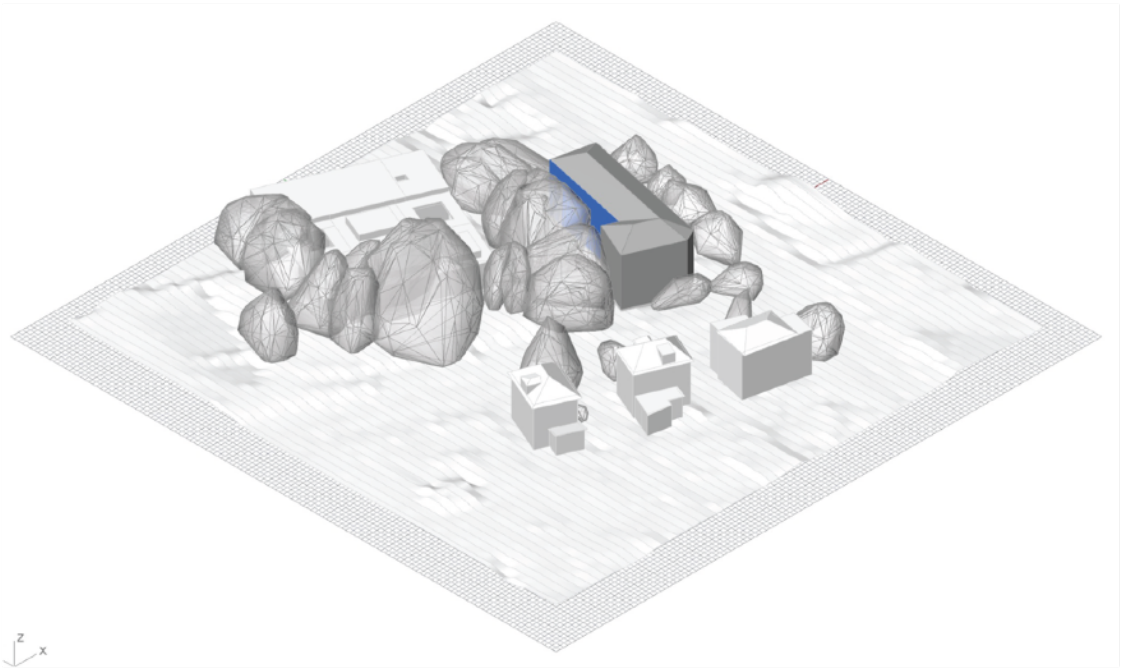
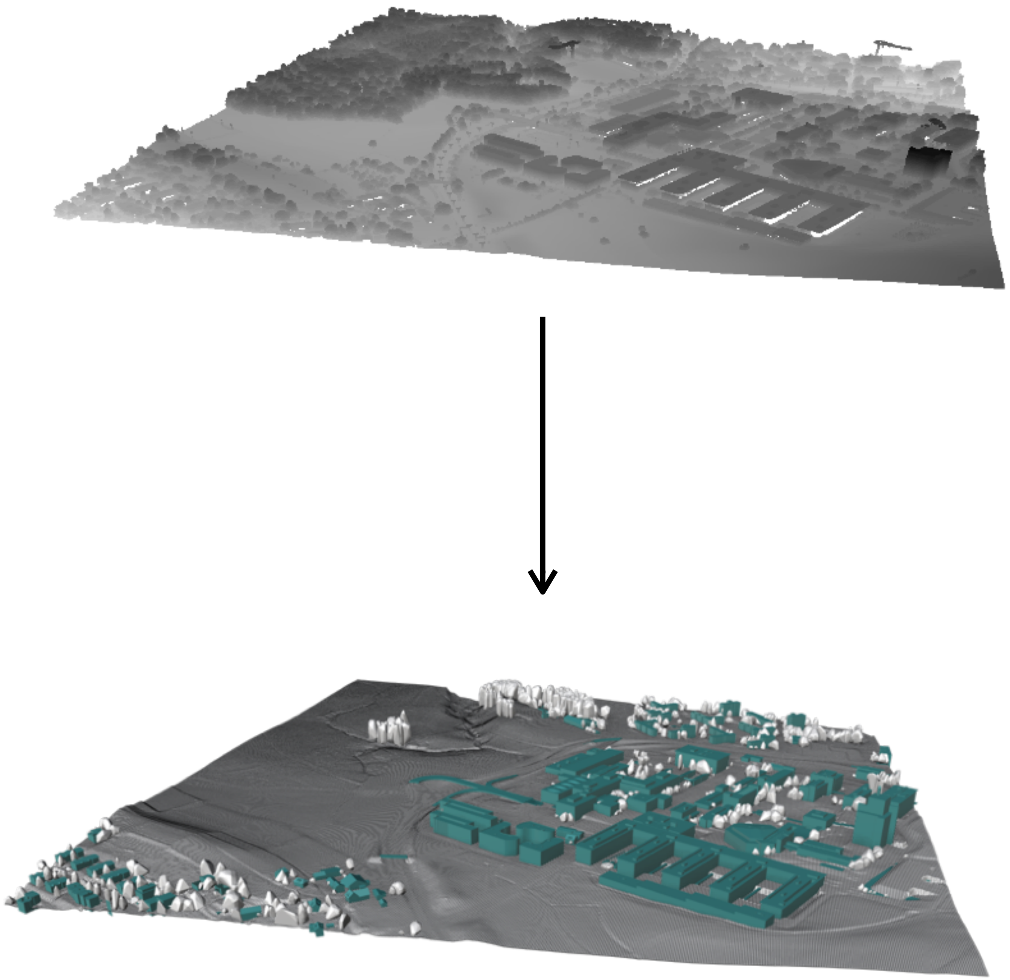


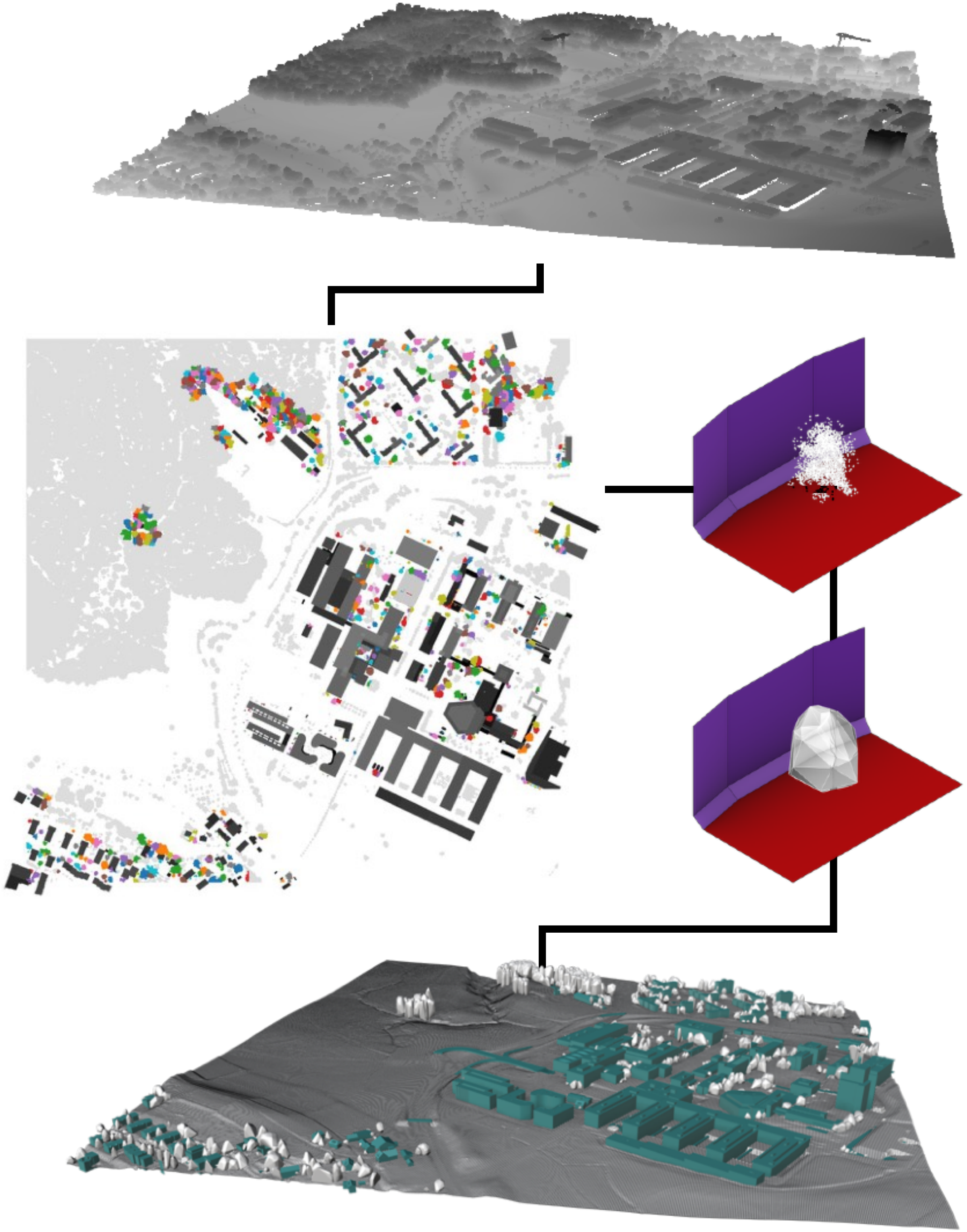
Existing Work

- From points in space to mesh representations of trees
- Crown models and perforation from gap percentage
- Extinction coefficients
- Fitting tree phenology curves



Existing Work

- From points in space to mesh representations of trees [1]
  - Point extraction [2]
  - Tree delineation through watershed algorithm [3]
  - Convex hull creation [4]



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Existing Work

- From points in space to mesh representations of trees
- Crown models and perforation from gap percentage [7]
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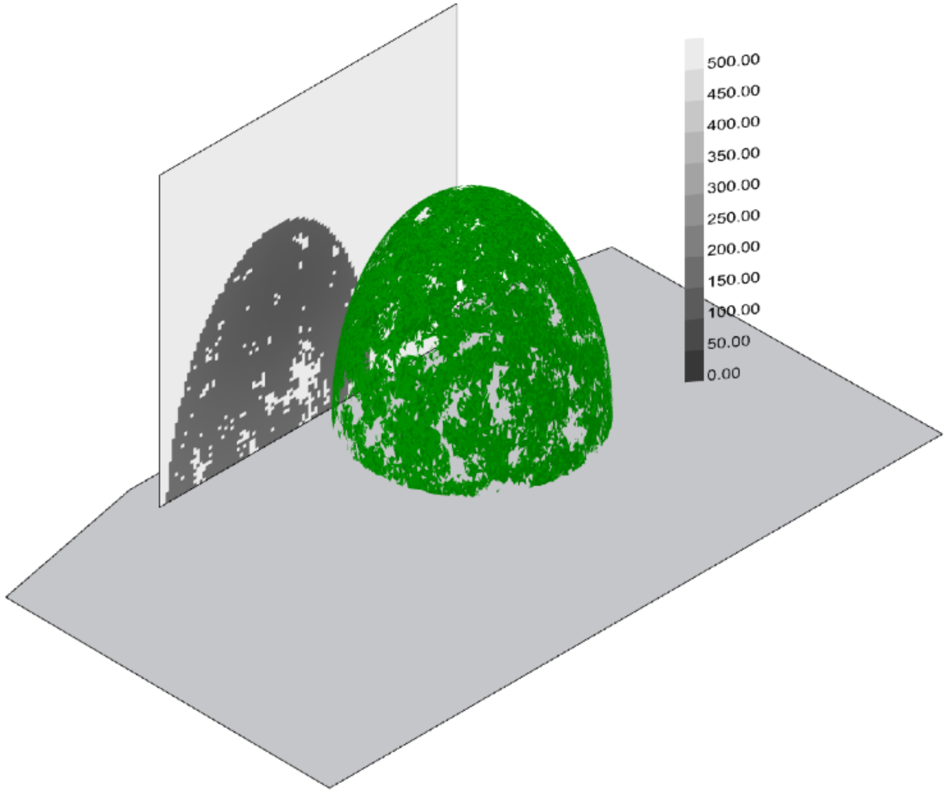
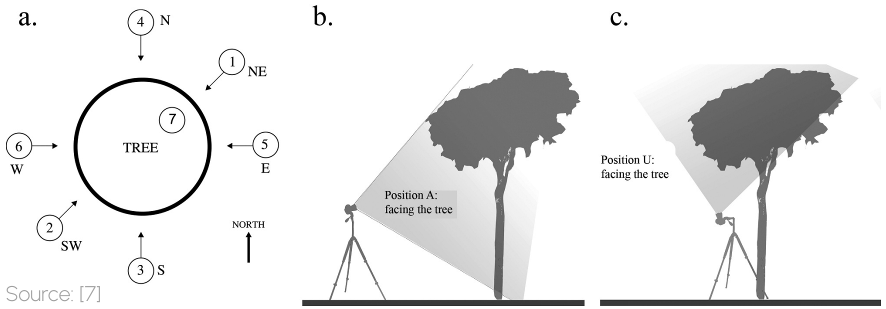
- Fitting tree phenology curves



Existing Work

- Crown models and perforation from gap percentage [7]
  - Transformation of field measurements into 3D models
  - Brings partial shading effect into simulation



Source: [7]

Fig. 1. (a) Camera positions, shown in plan, at seven locations around and under the crown. (b) Camera position, shown in section, to capture tree profile. (c) Camera position, shown in section, to capture tree undercanopy.

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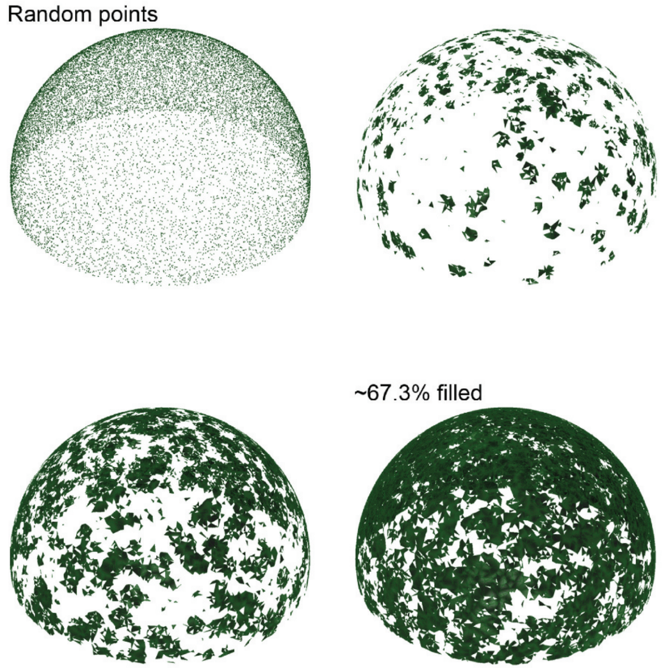
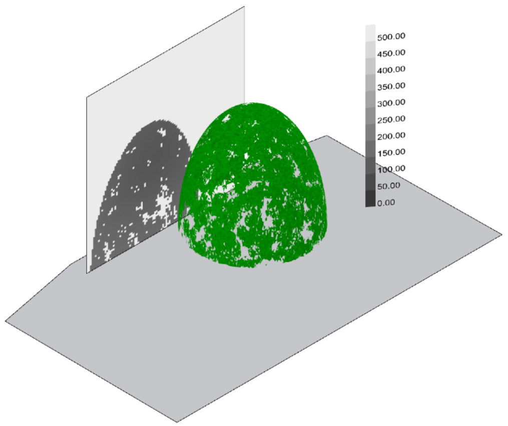
Source: [7]



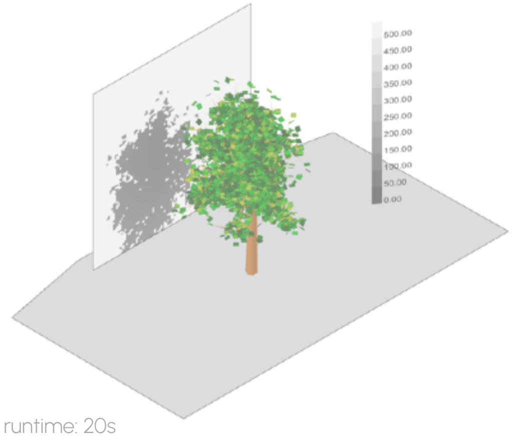
(a) Algorithmic process of generating a matched perforated tree crown model: From left to right: starting with 20,000 uniformly distributed random points on a hemisphere, triangle meshes are filled procedurally to cover 67.3% ($(1-\sqrt{0.107})*100$).

Existing Work

- Crown models and perforation from gap percentage [7]
  - Transformation of field measurements into 3D models
  - Brings partial shading effect into simulation



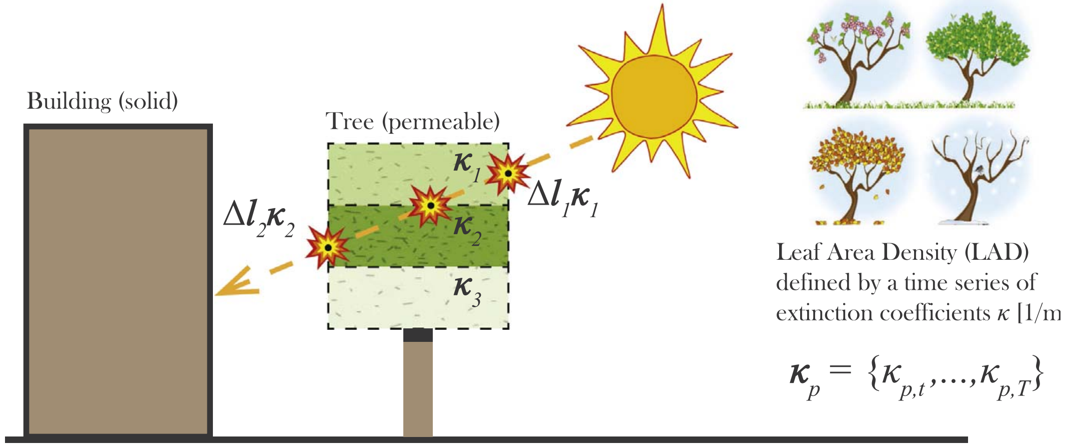
runtime: 36s



runtime: 20s

Existing Work

- From points in space to mesh representations of trees
- Crown models and perforation from gap percentage
- Extinction coefficients [8]
- Fitting tree phenology curves



Source: [8]

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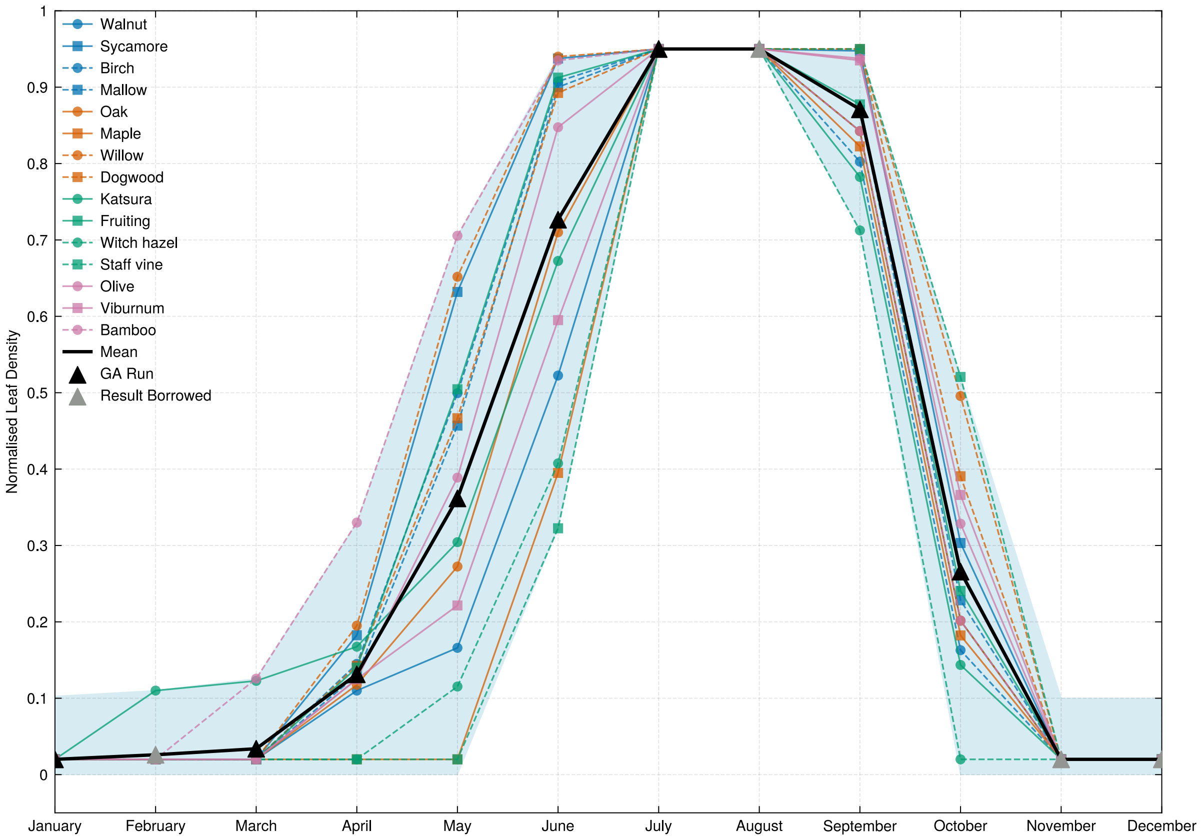
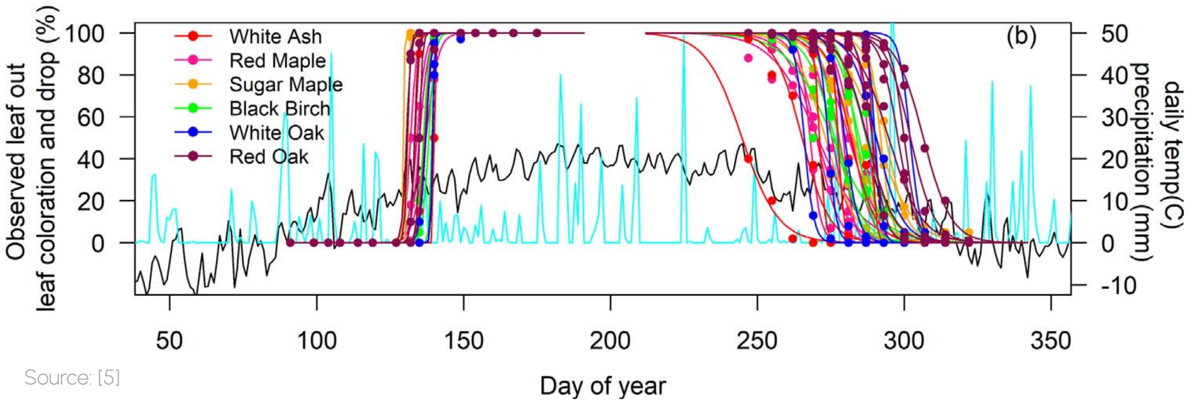


Motivation | Existing Work | Proxy Trees | Conclusion

Existing Work

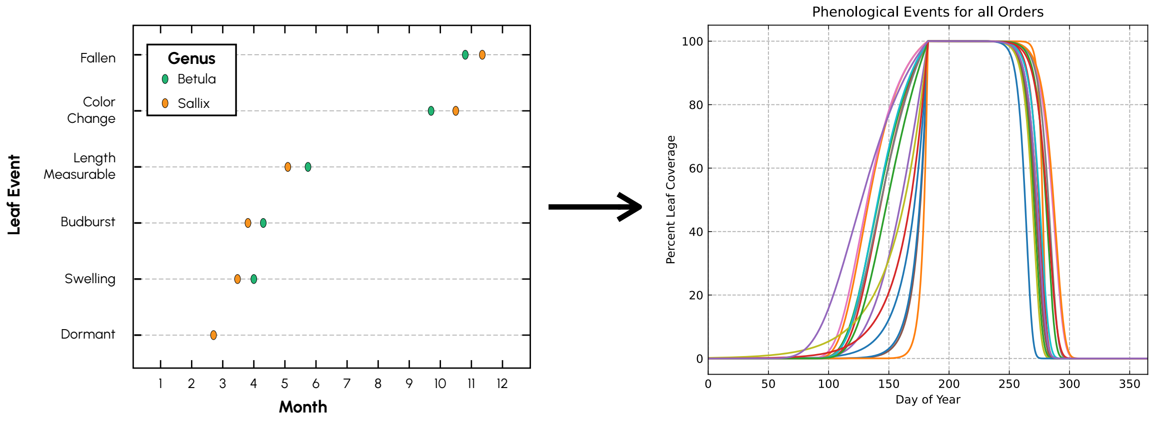
- Fitting tree phenology curves [5]
  - The GLOBE database of leaf events [6]
  - Interpolate points using sigmoid curves



Source: [5]

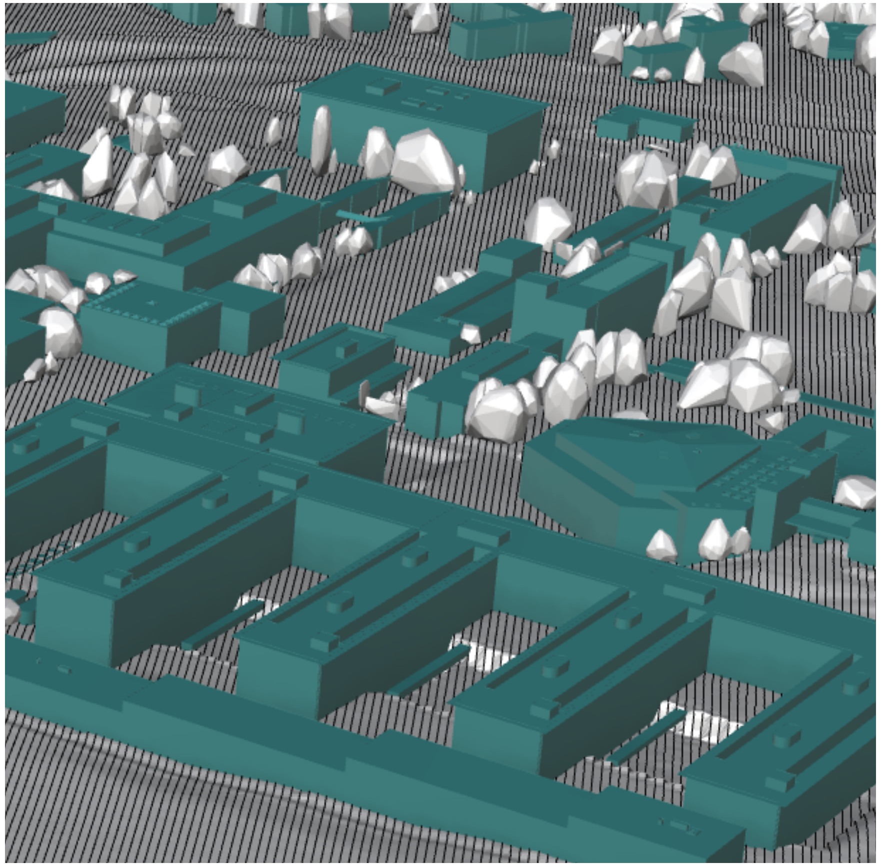
Group	Latitude	Longitude	Elevation	Date	Genus	Species	Phase
Alexander von Humboldt Gymnasium	47.449	8.593	386.8	15.03.12	Juglans	regia	swelling
	47.449	8.593	386.8	21.04.12	Juglans	regia	budburst
	...	...	...	...	...	...	...
	47.449	8.593	386.8	24.04.13	Juglans	regia	Swelling
	47.449	8.593	386.8	26.04.13	Juglans	regia	budburst

Source: [6]



New Proxy Trees

- Due to constraints of urban scale research objectives we need to work from LiDAR.
- Hypothesis:
    - The material properties of the convex hull model can be adjusted to mimic the partial shading effect of an actual tree.



Radiance Material Based Proxy

- Treat the convex hull as a type of black box.
- Fit the material parameters using a genetic algorithm where the fitness function evaluates the proxy model against a baseline tree model.

Source: [8]

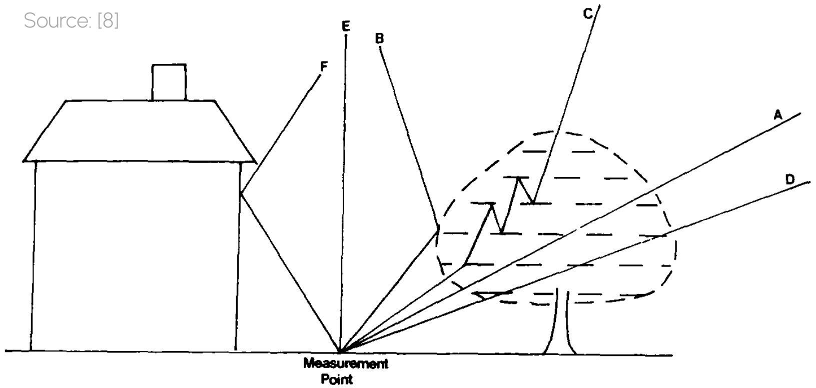
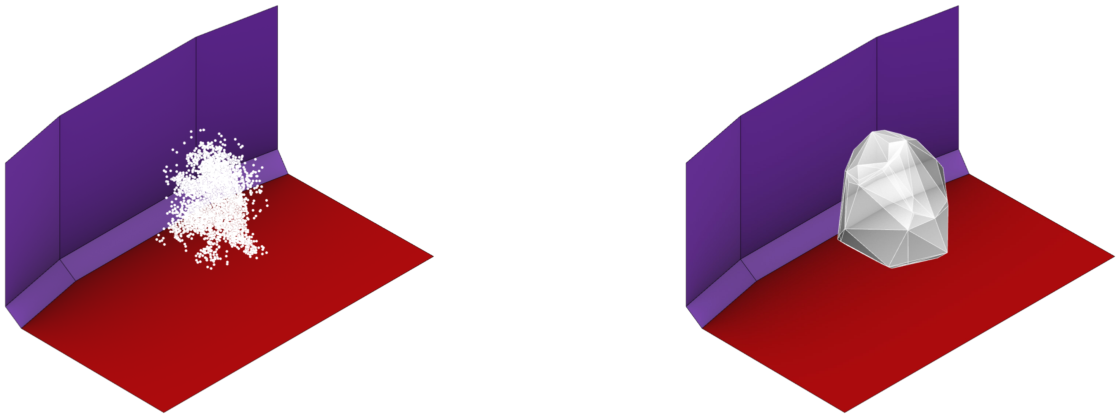
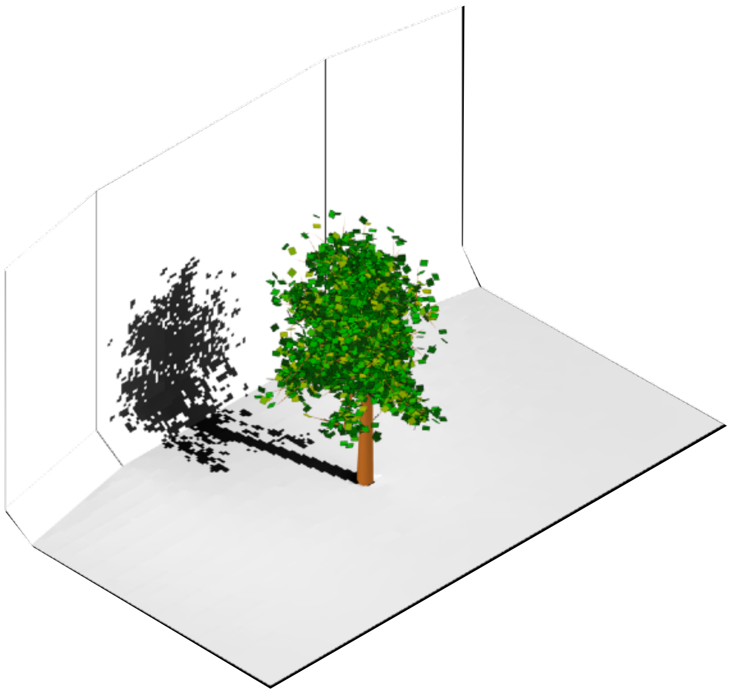


FIGURE 2. Possible pathways by which diffuse radiation might reach the measurement point.



Radiance Material Based Proxy

1. Simulate the baseline tree
2. Initialise the proxy simulations with random material parameters
3. Loop through simulations evaluating the difference between the two resulting arrays
4. Determine best parameters from the fitness evaluation
5. Repeat for every month



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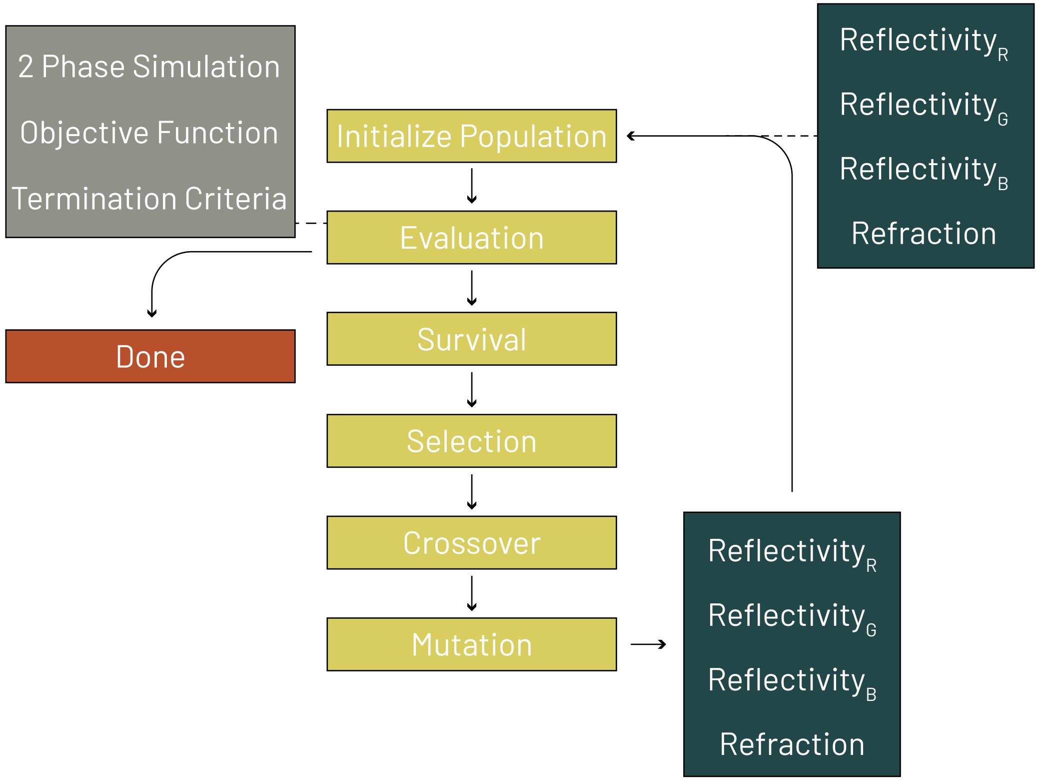

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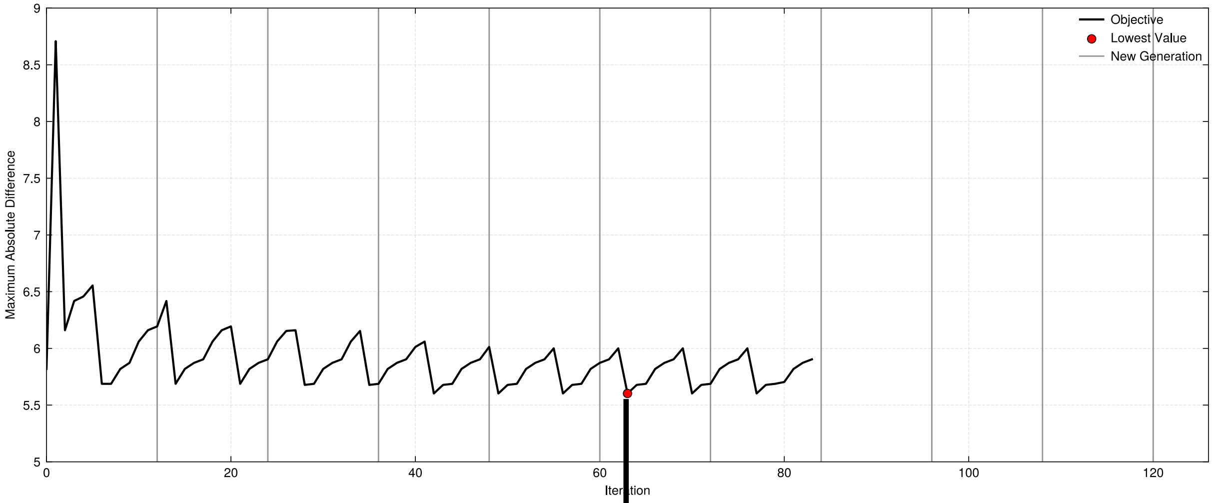

void glass tree_transparent_proxy_ga
0
0
4 0.23 0.14 0.88 1.15

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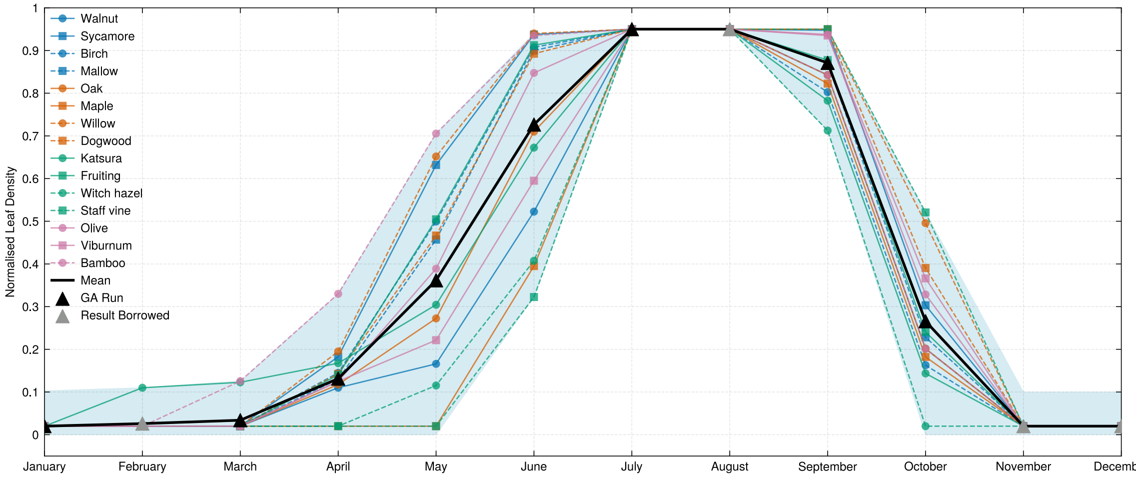
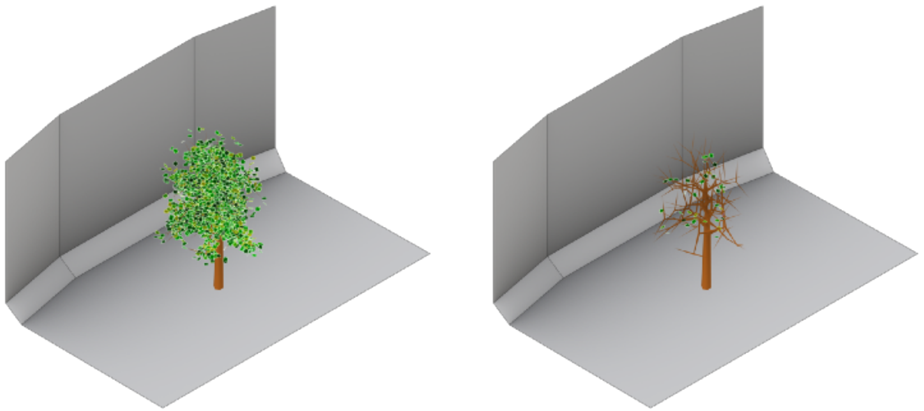
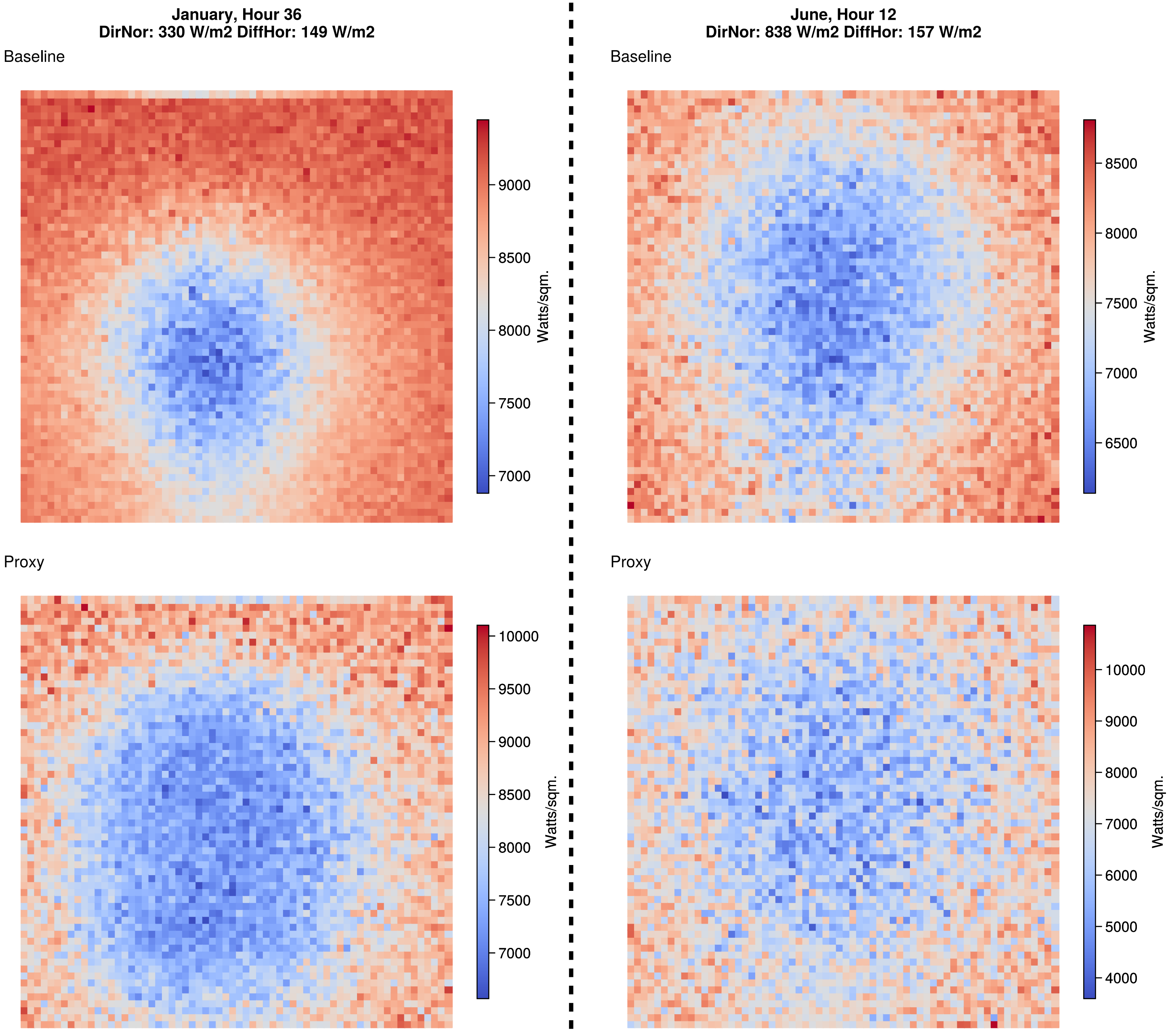




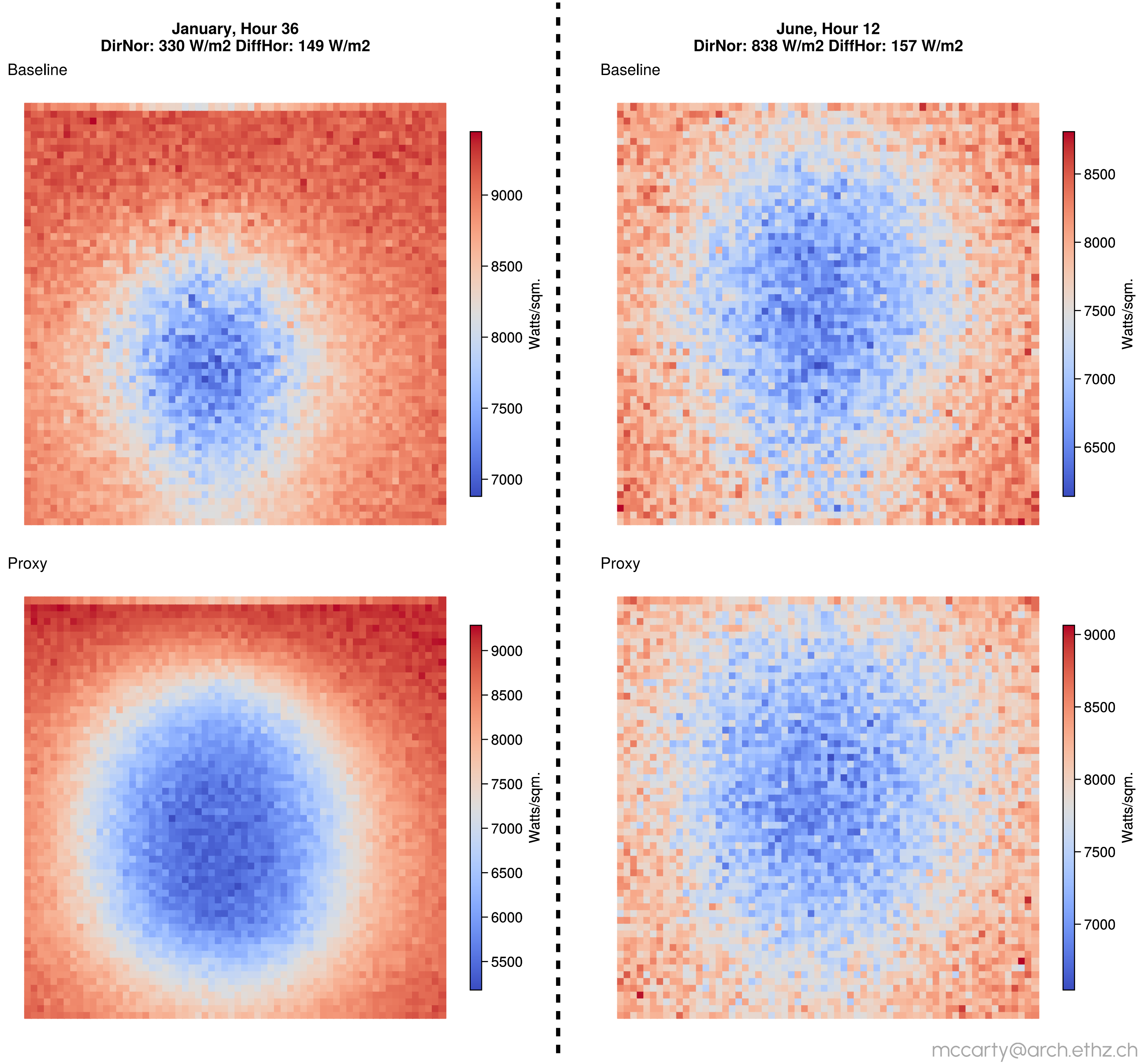
Results

- Glass based proxy
  - 1 month runtime: 38-42 seconds
- Translucent based proxy



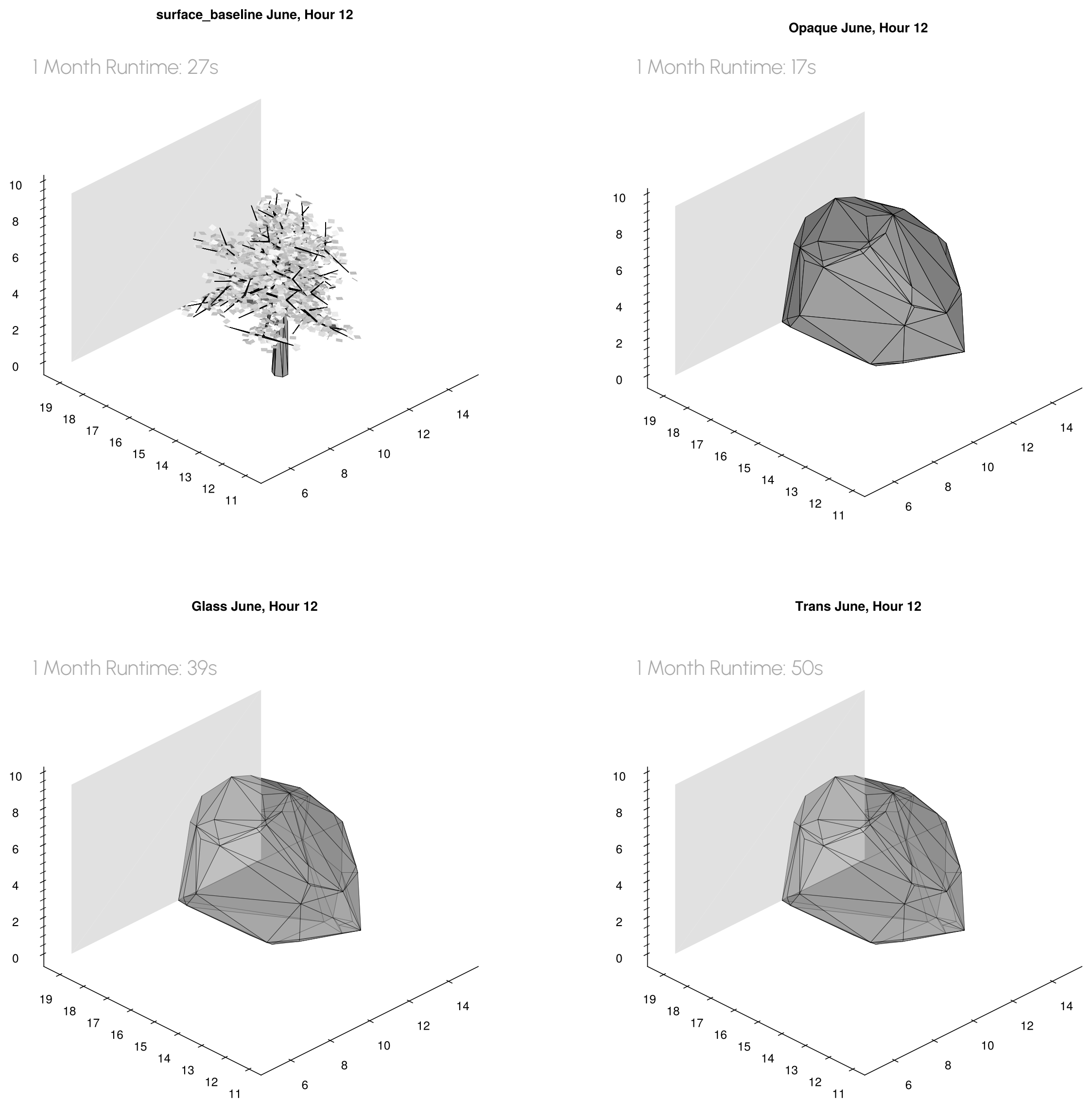
Results

- Glass based proxy
  - 1 month runtime: 38-42 seconds
- Translucent based proxy
  - 1 month runtime: 48-50 seconds



Conclusions

- Glass based tree proxies less capable of reproducing the partial shading phenomena seen in the baseline model.
- Translucent still not perfect in situations where diffuse/direct ratio is closer to 1.
- Unsure of runtime scaling.



References

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