QUANTIFYING THE EFFECT OF VEGETATION IN THE RADIATIVE BUDGET OF A TROPICAL CITY.

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Abstract

The increased urbanization and climate change have resulted in the intensification of the urban heat island (UHI) effect, particularly in tropical cities. Urban surfaces interact with radiation; absorbing, reflecting, or emitting radiative energy at various wavelengths. The radiative budget of a city is directly influenced by the urban geometry, surface materials, solar incident angle, and atmospheric diffuse radiation. Vegetation intercepts radiation and therefore, plays a role influencing the radiative budget of a city.

This study proposes a consideration of the 3-D structure of both vegetation and built environment to analyse the effects of vegetation in the radiative budget of the city of Singapore at different scales. 3-D models of the urban environment, including buildings, infrastructures, and vegetation were created using a combination of earth observation data. Then, the 3-D Discrete Anisotropic Radiative Transfer (DART) model will be used to estimate the radiation intercepted by the urban surfaces counting for the presence of vegetation cover at city and neigborhood scale.

Introduction

Examining the effect of urban vegetation on the radiative budget of a city helps to guide the development of thermally comfortable urban spaces and to mitigate the UHI effect. To do so, we require a detailed understanding of the influence of the complex interactions between the built environment and vegetation; accounting for the 3D nature of the urban scenes.

The city of Singapore is one of the greenest cities in the world, which makes it an interesting study area to assess the benefits urban vegetation, in terms of urban microclimate, outdoor thermal confort and UHI.

Objective

The objective of this study is to quantify the influence of vegetation in the radiative budget of a city, considering the full 3-D nature of the urban scenes. The study consists of a city-scale analysis of Singapore and a neigborhood-scale anaysis of Tanjong Pagar district.

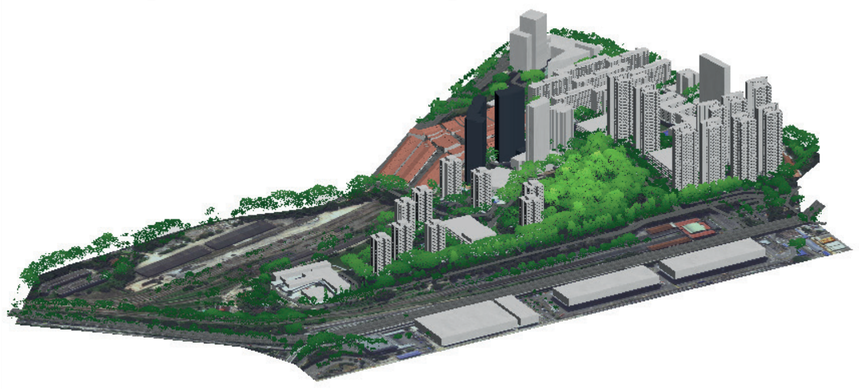
Methods

City scale: WorldView2 satellite imagery was used to map the land cover and vegetation types across Singapore. These data were analysed using image segmentation and rule-based classification. Three-dimensional data was extracted from a digital surface model coming from photogrammetric reconstruction of Digital Globe stereo satellite images. Slope filters were applied on the DSM to identify ground points and to create the digital terrain model (DTM). Building and vegetation heights were extracted by cross-referencing the DSM and DTM with the building footprints and the vegetation classes from the land cover map.

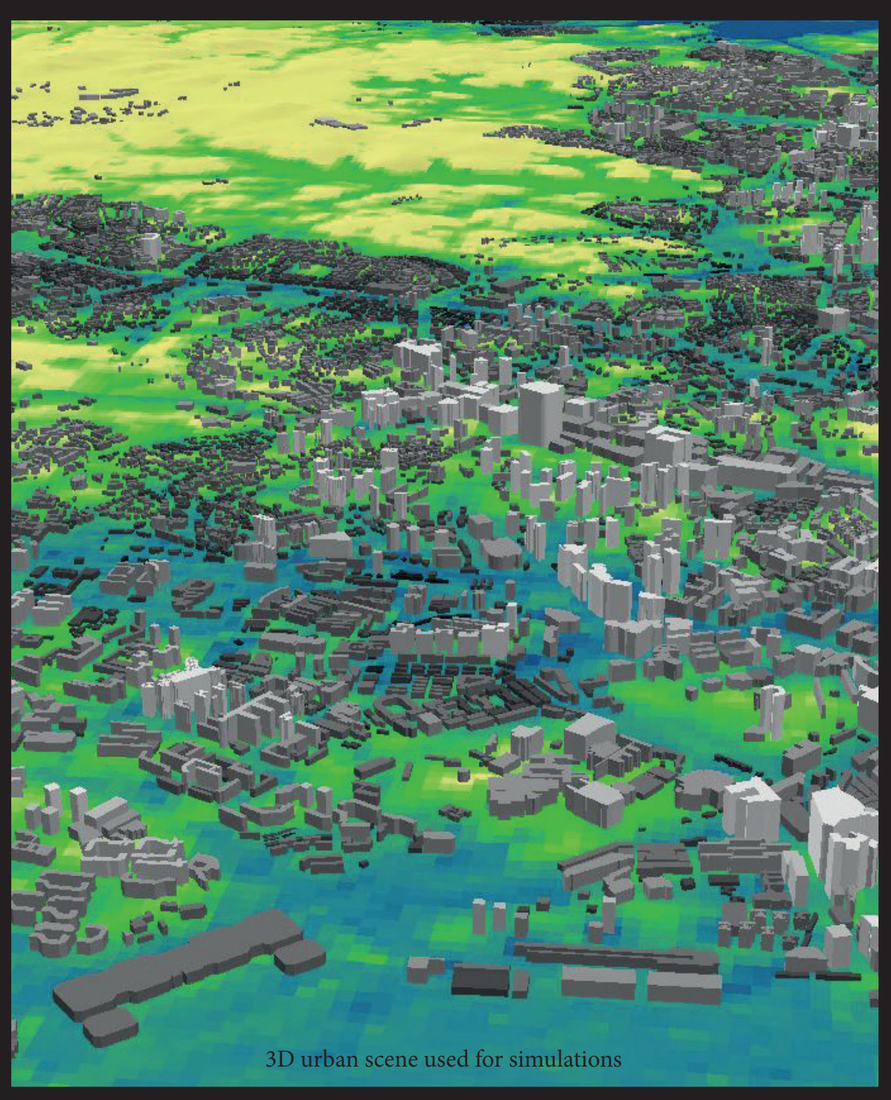
A 3-D model of the city was reconstructed with the elements of the scene grouped by land cover type.

Neigborhood scale: a 3D model of Tanjong Pagar South was created to carry out simulations at neighbourhood scale. The components of the scene are grouped according to building material type and a gradient of leaf area index is distributed over the vegetation areas.

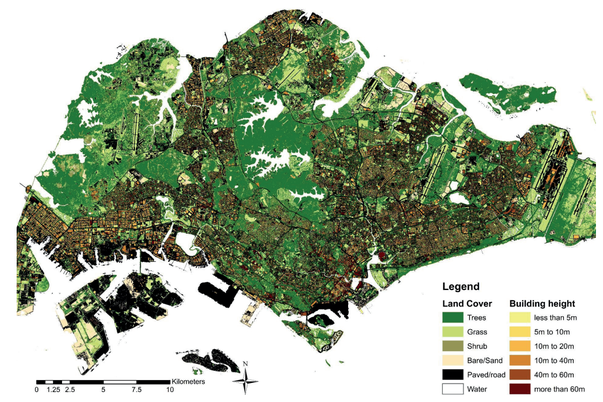
Finally, the 3-D Discrete Anisotropic Radiative Transfer (DART) model will be used to simulate the radiative budget of the scenes; and to estimate the radiation intercepted by the urban surfaces accounting for the presence of vegetation cover.



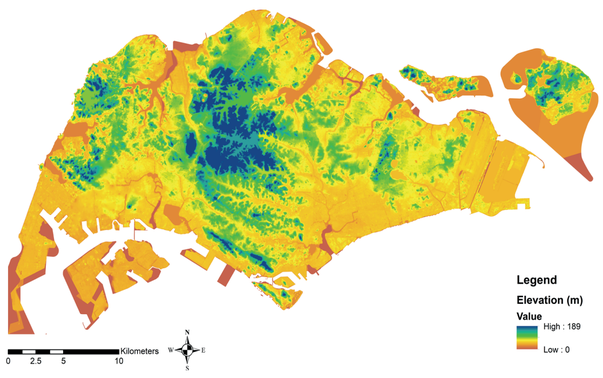
3D model of Tanjong Pagar South used for simulations at neighbourhood scale.



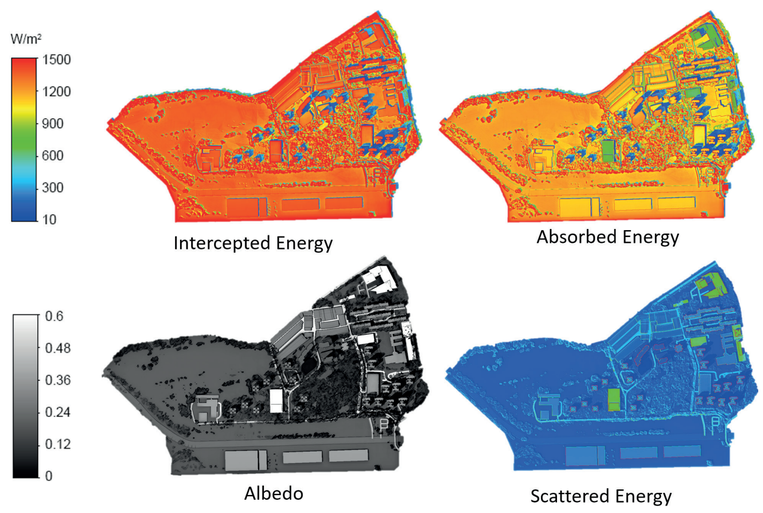
3D urban scene used for simulations



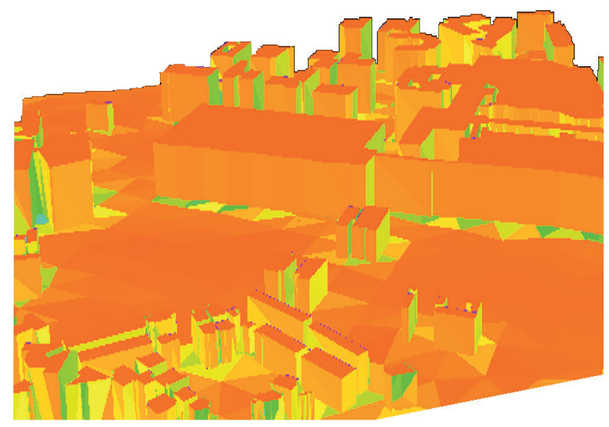
Land Cover map of Singapore



DTM of Singapore



Radiative budget simulation at neigbourhood scale. Units in W/m2.



Subset of radiative budget simulation at city scale, not incuding vegetation.

Discussion

This work-in-progess uses commercially available optical data to generate a 3D model of the city of Singapore. The same approach can be replicated elsewhere. However, the accuracy for deriving vegetation heights from optical data remains low. Ideally, ALS would be the best data source for this purpose, but access to such data at city scale is still restricted in Singapore. The main advantage of using DART is the capability to simulate spatially explicit 3D radiation budget for any urban or natural landscape. Biophysical indicators such as leaf area index and canopy spread are required to obtain realistic radiative transfer simulations, especially at finer scales. In this study, a constant LAI value will be assumed for trees and for the shrub for the city scale simulations. Once accurate LAI estimations become available at city scale, more realistic simulations could be performed.

Conclusion

Studies of the UHI effect are gaining more attention in the recent years and the demand for mitigation strategies is also on the rise. This research will contributes to a quantitative understanding of the influence of vegetation in the radiative budget of a city . Additionally, this study will demonstrate the potential of using DART for full 3D urban analysis at different scales, oppening oportunities for more detailed analysis in the field of urban outdoor thermal confort and UHI.

References

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