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as of 01-Jul-2018

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Title: The Impact of Landscape Characteristics on Urban Surface Energy Balance (Research Area 11.1 STIR)
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Submitted By: Zhihua Wang
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STEM Degrees: 2 **STEM Participants:** 2

Major Goals: The following objectives was set as major goals for this project:
(1) Develop a mathematical model for the coupled heat and water transport, applicable to any urban environmental conditions. Specifically, this model will be used to (a) quantify the phase (and temporal) differences between all urban surface energy budgets and the LST, and (b) characterize the effect of different urban landscape materials (concrete, asphalt, soils, etc.) and vertical water advection (e.g. xeric versus mesic urban vegetation) on the urban SEB.
(2) Validate the model by comparisons to observational dataset from field measurements. In particular, the PI will obtain a wide range of dataset covering measurements under different weather conditions, geographic locations, and climatic zones, leveraged by his own urban monitoring campaign, sensor network affiliation, and collaborative research.
(3) Assess the impact of phase lags and SEB on building energy efficiency. We will apply the numerical model to assess the impact of different landscape planning strategies of urban mitigation/adaptation via surface energy transport, especially the improvement of building energy efficiency and enhancement of human thermal comfort.

Accomplishments: The accomplished goals and major findings, development, and conclusions generated from this project are summarized below:

We developed a mathematically tractable solution of heat diffusion-advection equation, based on the Green's function method. The method was validated against field measurements and capable of reconstructing the surface energy balance using single-point measurement, and applicable to water surface as well as urban pavements (as a reduced case).

We characterized the thermal behavior of different urban landscape materials (compact and porous concrete, compact and porous asphalt, artificial turf, and landscape gravel) and the impact of vertical advection. In particular, a peculiar 8-shaped hysteresis loop was identified by field observations over asphalt pavement.

The urban land surface energy balance (SEB) model was applied to assess the nocturnal cooling of urban areas, by correlating the cooling rate with size of cities, material thermal properties, as well as the relative contribution of vertical and horizontal advection.

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Training Opportunities: The project has provided financial support and mentorship of two graduate students at Ph.D. level: Jiachuan Yang (3 months) and Jiyun Song (3 months). Both Dr. Jiachuan Yang and Dr. Jiyun Song completed their Ph.D. dissertations in December 2016. Both students received dissertation awards: Dr. Jiachuan Yang the Dean's Dissertation Award from the Ira A. Fulton Schools of Engineering at ASU and now a post-doc researcher at Princeton University, and Dr. Jiyun Song the Dissertation Award from the Chinese-American Oceanic and Atmospheric Association and now a post-doc researcher at University of Cambridge. Support from this project contributes significantly to both PhD dissertation work.

Results Dissemination: The dissemination of results generated from this project were summarized below:

Peer-reviewed Journal publications

[1] Wang, Z. H., Li, Q. (2017). Thermodynamic characterisation of urban nocturnal cooling. Heliyon, 3, e00290. http://dx.doi.org/10.1016/j.heliyon.2017.e00290.

[2] Song, J., Wang, Z. H., Myint, S. W., Wang, C. (2017). The hysteresis effect on surface-air temperature relationship and its implications to urban planning: An examination in Phoenix, Arizona, USA. Landscape and Urban Planning, 167, 198-211. http://dx.doi.org/10.1016/j.landurbplan.2017.06.024.

[3] Yang, J., Wang, Z. H., Li, Q., Vercauteren, N., Bou-Zeid, E., Parlange, M. B. (2017). A novel approach for unraveling the energy balance of water surfaces with a single depth temperature measurement. Limnology and Oceanography, 62, 89-103. http://dx.doi.org/10.1002/lno.10378.

Ph.D. dissertation

[1] Yang, J. (2016). Urban Green Infrastructure: Modeling and Implications to Environmental Sustainability. Ph.D. dissertation, Arizona State University.

[2] Song, J. (2016 Urban Microclimate Response to Landscape Changes via Land-Atmosphere Interactions. Ph.D. dissertation, Arizona State University.

Honors and Awards: The students supported by this project received the following hours during the project period, with significant contribution from the support of the current project:

[1] Jiyun Song: Best Dissertation Award, Chinese-American Oceanic and Atmospheric Association (COAA), 2017

[2] Jiachuan Yang: Dean's Dissertation Award, Ira A. Fulton Schools of Engineering, ASU, 2016

[3] Jiyun Song: National Award for Outstanding Self-financed Chinese Students Study Abroad, China Scholarship Council, 2016

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: Graduate Student (research assistant)
Participant: Jiyun Song
Person Months Worked: 3.00 **Funding Support:**
Project Contribution:
International Collaboration:
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National Academy Member: N
Other Collaborators:

Participant Type: Graduate Student (research assistant)
Participant: Jia Yang
Person Months Worked: 3.00 **Funding Support:**

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Date Submitted: 6/20/18 12:00AM Date Published: 11/1/17 7:00AM
Publication Location:
Article Title: The hysteresis effect on surface-air temperature relationship and its implications to urban planning: An examination in Phoenix, Arizona, USA
Authors: Jiyun Song, Zhi-Hua Wang, Soe W. Myint, Chuyuan Wang
Keywords: Hysteresis effect; Remote sensing; Sensor network; Surface-air temperature relationship; Urban climate
Abstract: Urban areas, with massive built-up landscapes and manmade structures, have different patterns of local microclimate as compared to natural terrains. A better understanding of the surface-air temperature relationship in urban environments is of significant importance in interpreting urban climatic characteristics and solving related environmental problems via sustainable landscape planning strategies. In this study, we analyse the groundbased in-situ measurements as well as remotely sensed thermal dataset in Phoenix, AZ. Prominent hysteresis effect manifests in correlating diurnal cycles of surface and near-surface air temperatures. In particular, a peculiar pattern of “8-shaped” surface-air temperature hysteresis is observed over concrete pavement especially in winters. Pearson’s r values, measuring the strength of surface-air temperature coupling, show strong correlation with incoming solar radiation and wind speed, but are relatively insensitive to humidity.
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Article Title: Thermodynamic characterisation of urban nocturnal cooling
Authors: Zhi-Hua Wang, Qi Li
Keywords: Energy balance; Nocturnal cooling; Scaling; Urban heat island; Urban-rural breeze
Abstract: Nocturnal cooling of urban areas governs the evolution of thermal state and many thermal-driven environmental issues in cities, especially those suffer strong urban heat island (UHI) effect. Advances in the fundamental understanding of the underlying physics of nighttime UHI involve disentangling complex contributing effects and remains an open challenge. In this study, we develop new numerical algorithms to characterize the dynamics of urban nocturnal cooling based on solving the energy balance equations for both the landscape surface and the overlying atmosphere. Further, a scaling law is proposed to relate the UHI intensity to a range of governing mechanisms, including the vertical and horizontal transport of heat in the surface layer, the urban-rural breeze, and the possible urban expansion. The accuracy of proposed methods is evaluated against in-situ urban measurements collected in cities with different geographic and climatic conditions.
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Date Submitted: 6/20/18 12:00AM Date Published: 1/1/17 7:00AM
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Article Title: A novel approach for unraveling the energy balance of water surfaces with a single depth temperature measurement
Authors: Jiachuan Yang, Zhi-Hua Wang, Qi Li, Nikki Vercauteren, Elie Bou-Zeid, Marc B. Parlange
Keywords: Green's function approach; Surface energy partitioning; Water temperature; Water-atmosphere interactions
Abstract: The partitioning of solar energy over the Earth's surface drives the weather and climate of the coupled land-ocean-atmosphere system. Over water surfaces, the evolution of water temperatures at a given depth in the mixed layer implicitly contains the signature of surface energy partitioning, and as such it can be used to diagnose the surface energy balance. In this study, we develop a novel numerical scheme by combining the Green's function approach and linear stability analysis to estimate the water surface energy balance using water temperature measurement at a single depth. The proposed method is capable of predicting water temperature in the mixed layer, and solving for the components of the surface energy budgets with physically-based schemes. Evaluation against in-situ measurement and the maximum entropy production method demonstrates that this approach is robust and of good accuracy.
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The Impact of Landscape Characteristics on Urban Surface Energy Balance – Final Progress Report

Nothing to report in the uploaded pdf (see accomplishments)