2003 NASA Academy Poster Session

Modeling Urban Land-Atmosphere Interactions

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INTRODUCTION:

[1] Accompanying with rapid land cover and land use changes, urbanization presents extreme human impacts on nature's atmosphere Earth surface climate system. Hence, it is essential to simulate urban climate and the reciprocal interactions between the earth and the atmosphere.

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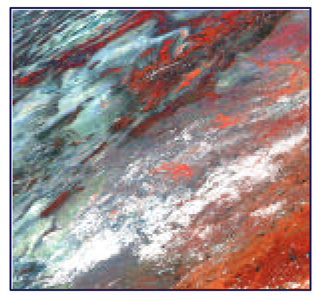
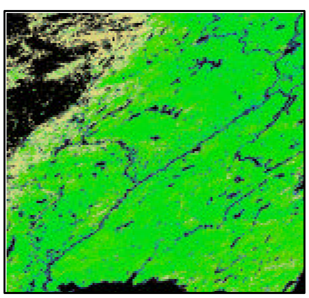


Recent projections of urbanization rates suggest that more than 60% of the world's population will live in cities by the year 2030. In the United States, much of Europe, and Japan, more than 80% of the population lives in urbanized areas. As cities grow, natural land covers are removed and replaced by buildings, roads, parking lots, sidewalks, and other impervious surfaces.



[3] Various observational and modeling results have highlighted the unique characteristics of urban land-atmosphere interactions caused by the modification of the climate interface. Recent NASA Earth Observing Systems (EOS) mechanisms such as the MODerate Resolution Imaging Spectroradiometer (MODIS) on board the Terra (EOS AM) and Aqua (EOS PM) have provided an open gateway to measure and monitor multiple land-atmosphere components at high resolutions.

Our research analyzes MODIS surface albedo data as well as emissivity, land cover clouds, land surface temperature and leaf area index levels over the Houston, Texas region to quantitatively examine human-induced disturbances on climate system.

Investigation over the city discloses the ranges and extremes of human impacts on climate system, and identifies the critical parameters that determine these impacts. This work will lead to the expansion of a coupled modeling study to explain the mechanisms for precipitation enhancement observed by Shepherd et al. (2002.)

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[1] Land Surface Temperature mosaic product of the Houston area for September 15, 2001
[2] July 2001 averaged Albedo-Surface Reflectance for the Houston, TX area.
[3] July 2001 averaged Leaf Area Index for the Southeast US Region

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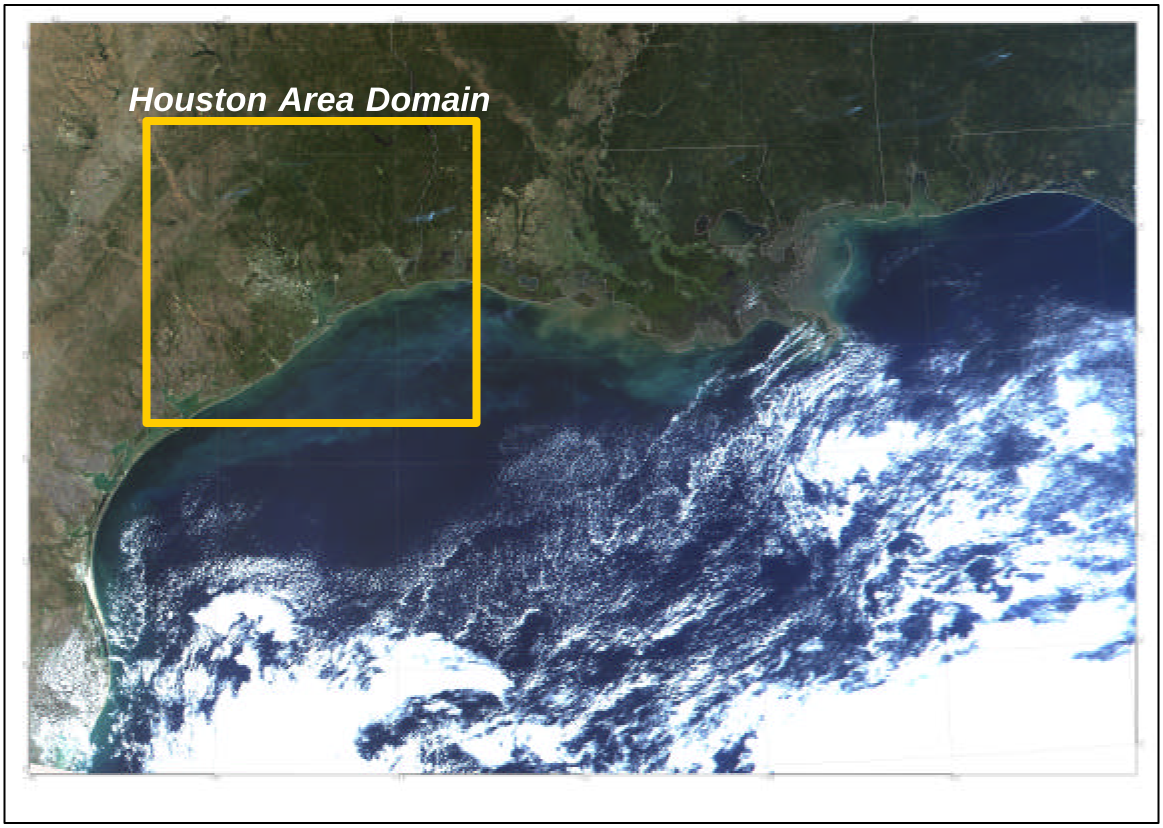
PROJECT GOALS

To develop a capability that models observed impacts of urban areas, such as precipitation and aerosols.

To evaluate a model of urban land-atmosphere interactions based on remote estimation of surface properties for the Houston, Texas region; using advanced urban canopy parameterization, including internal boundary layer models capable of resolving the unique water, energy and momentum dynamics in an urban setting.



True-color image of the Texas Gulf Coast acquired on September 29, 2000 by the Moderate Resolution Imaging Spectroradiometer (MODIS.)

BACKGROUND

Recent projections of urbanization rates suggest that more than 60% of the world's population will live in cities by the year 2030. In the United States, much of Europe, and Japan, more than 80% of the population lives in urbanized areas. As cities grow, natural land covers are removed and replaced by buildings, roads, parking lots, sidewalks, and other impervious surfaces.

Current NASA EOS mechanisms such as MODIS can simultaneously monitor global surface, biosphere, and atmosphere at high resolutions. Consequently, various observational and modeling results have highlighted the unique characteristics of urban land-atmosphere interactions caused by the modification of the climate interface. Most recently, NASA-GSFC investigators have provided the first spaceborne evidence of these impacts on precipitation patterns downwind of the urbanized area.

In this project we evaluated a subgrid urban water, energy and momentum balance model based on remote estimation of urban land-surface properties. We analyzed MODIS LST, surface white-sky broad band albedo, land surface emissivity, land cover, and atmospheric optical depth for global urban areas to generalize the urban effects. These parameters where estimated using a combination of current NASA satellite sensors (e.g., Terra (EOS AM)) and more traditional platforms (e.g. NOAA-14 (AVHRR) and Landsat.)

METHODS AND SIMULATIONS

Land surface skin temperature (LST), retrieved from upward long wave radiation, is closely related to surface energy budget and may be more suitable in studies of climate change. We can estimate LST by acquiring the emitted spectral radiance L at a wavelength l from a surface at thermodynamic temperature T_S. This factor is given by multiplying the Planck function by spectral emissivity $e(l)$. We can then present a fundamental theoretical description for the LST algorithm, based on *Z. Wan et al.* (1989):

$$L(l,T) = e(l)B(l,T_S).$$

We determined internal source radiation levels by separating direct from diffuse radiation. Hence, we used a generalized Split-Window LST algorithm based on *Z. Wan and J. Dozier* (1996) to study multilayer atmospheres at vertically heterogeneous conditions. The thermal infrared spectral signature measured from MODIS is expressed by adding surface thermal emittance (1), the atmospheric downward thermal irradiance reflected by the surface (2), and the atmospheric upward thermal radiance (3):

$$L(j) =$$

$$t_1(j)e(j)B(j,T_S) \qquad (1)$$

$$+\frac{1-e(j)}{p}t_2(j)E_a(j) \qquad (2)$$

$$+ L_a(j). \qquad (3)$$

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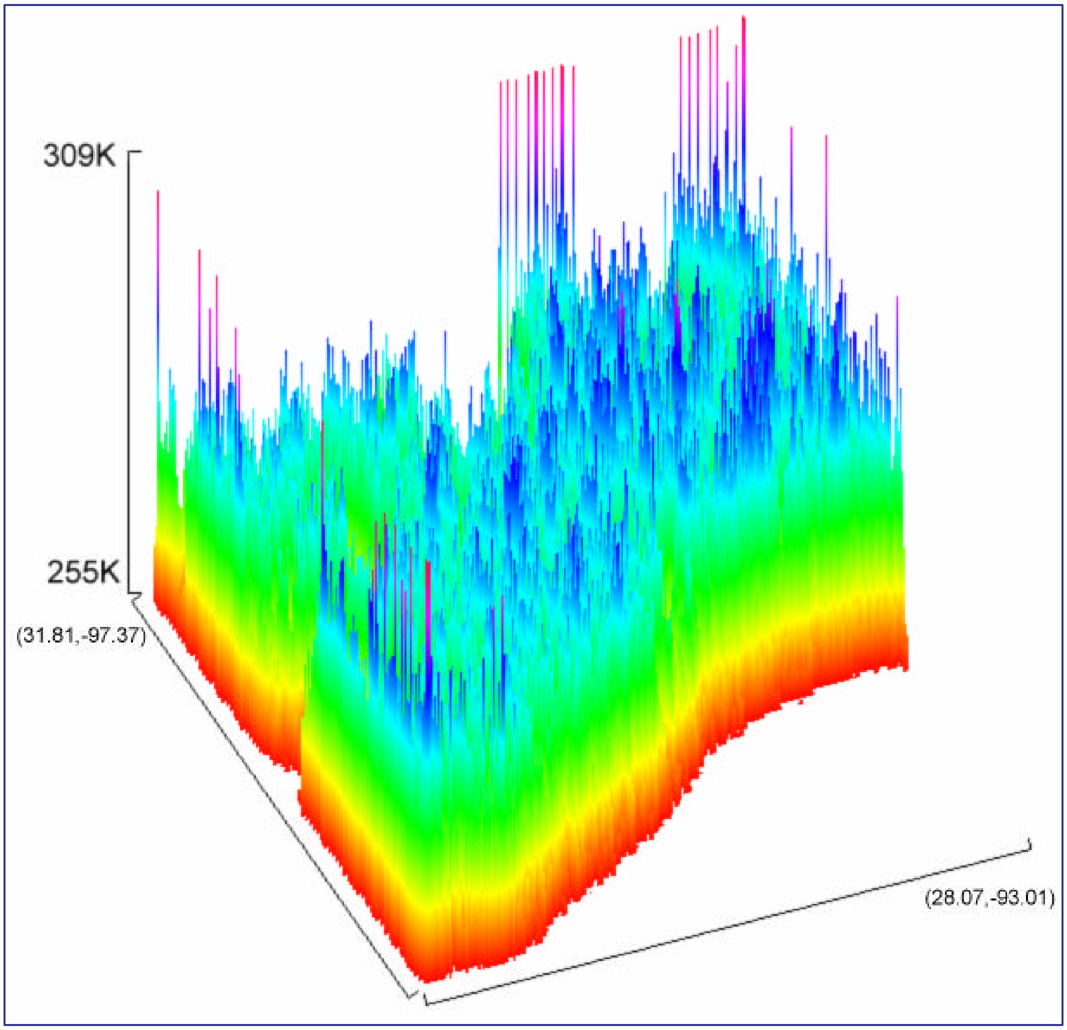

The Land Surface Temperature mosaic product of the domain area for September 15, 2001 is presented here. Land surface skin temperature (LST), retrieved from upward long wave radiation, is closely related to surface energy budget and may be more suitable in studies of climate change. On land, soil and canopy temperature are among the main determinants of the rate of growth of vegetation and they govern seasonal starting and termination of growth. Hydrologic processes such as evapotranspiration and snow and ice melt are highly sensitive to surface temperature fluctuation, which is also an important discriminating factor in classification of land surface types.

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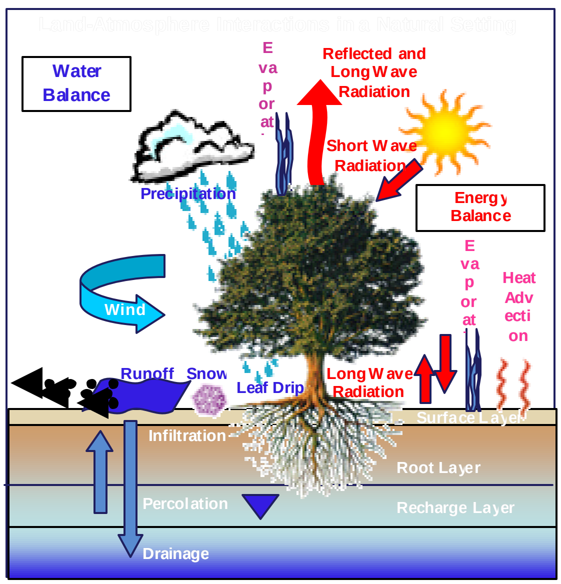
URBAN MODEL APPLICATION:

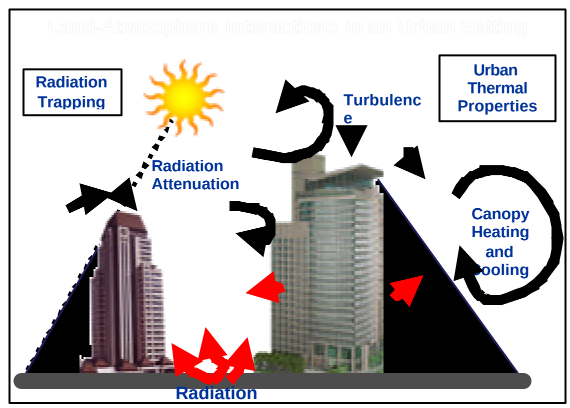
The results of this project provide the tools to develop and evaluate models of Urban Land Surface-Atmosphere Processes: Water, Energy, Mass, Momentum.

Modeling urban land-atmosphere interactions at 1km or finer resolutions also enables:

1. Coupled prediction of urbanization effects on water, energy, carbon cycles

2. Information reconnaissance for future sensor/mission needs (e.g. Urban Observing Mission)





FUTURE WORK

Additional models estimating Urban Aerodynamic Roughness using frontal area density determined from satellite imagery will enhance the modeled products discussed here.

ACKNOWLEDGEMENTS

Our most sincere appreciation for the people who have been directly involved in the development and advancement of this project by means of practical and technical recommendations; especially to Ms. Ruiming Chen, the 2003 NASA-GSFC Academy staff members Mr. Johnny Erickson, Ms. Sarah MacLellan and, Mr. Paul Gosling, as well as the people from the Puerto Rico Space Grant Consortium and the NASA-PaSCoR program; without your assistance this initiative could have never broken ground.

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