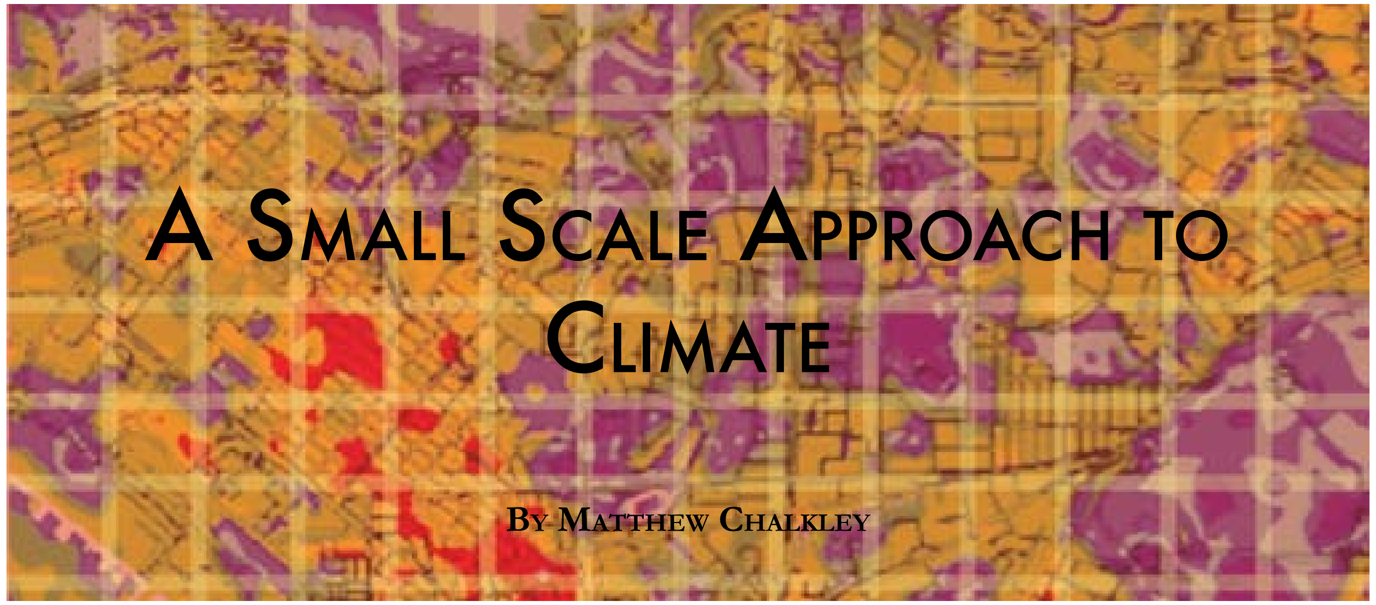


A Small Scale Approach to Climate

By Matthew Chalkley

Interest in global climate change has increased tremendously in recent years. The mounting evidence about anthropogenic causes of global warming and the ever present dissent has increasingly led to climate becoming part of the popular discourse. Lost in much of this popular debate is consideration of local climate. Rather than looking at climate on a global or continental scale, local climate analyzes much smaller units of area such as cities or states.

The study of local climate looks to understand how local environmental feedback loops affect local climate. This microscale approach to climate allows for an investigation of how certain factors, particularly ground cover, cause a deviation from the climatic conditions that one would anticipate for the region.

The Yale Surface Heat Budget Project is a collaboration that investigates questions unified by this central theme of local climate exploration. The collaboration, which began in 2010, is guided by three Yale University faculty members, Professor Xuhui Lee and Professor Karen Seto of the Yale School of Forestry and Environmental Science, and Professor Ronald Smith of the Department of Geology and Geophysics. The collaboration meets weekly to analyze the current literature as well as to discuss the professors' own research in order to share expertise.

An area of particular interest to the local climate community and the research collaboration is urban heat islands. Urban heat islands are a clear example of how the local environment can influence local climate. Traditional thinking holds that temperatures in cities are increased by the modification of land use from vegetation to materials that effectively retain heat (for example, asphalt); a secondary warming effect also arises from the amount of waste heat generated by energy use in cities.

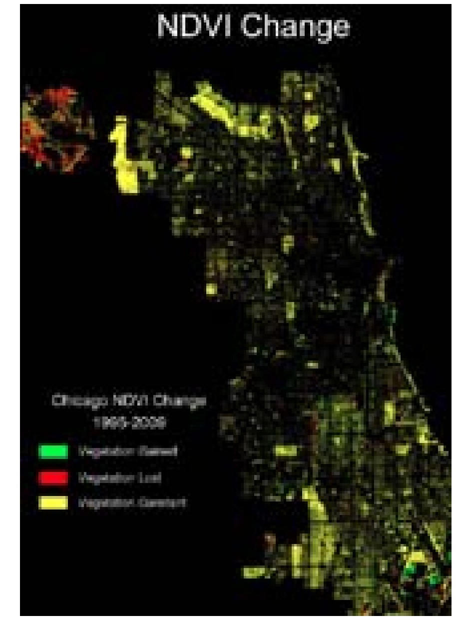
A recent effort by Chicago mandated increased material reflectivity to combat the increased temperatures typically associated with cities. This policy was to be applied to newly constructed roofs and laid pavement. There was a simultaneous effort to green the city. The relevant policies introduced included the expedition of green roof permits, the increase in planting street-side trees, and the mandate that new developments devote a proportional amount to green space.

"a recent effort by Chicago mandated increased material reflectivitiy to combat the increased temperatures typically associated with cities."

The reflectivity policies were motivated by the belief that increased reflectivity of the surfaces would increase the overall reflection coefficient, or albedo, of the city area. Formally, albedo is defined as a fraction ranging from 0 to 1 indicating the ratio of reflected radiation to total incident radiation. Less reflective regions (such as cities) have lower albedos; Chicago, for example, has an albedo of about 0.1, although measurement techniques make it likely that this is an underestimate. In comparison, the albedo of freshly laid asphalt is 0.05, grass's is 0.25, and fresh snow's is 0.90.

Increasing albedo via the reflectivity policies would cause more heat to be dissipated by the city, thereby reducing the temperature. Likewise, increasing vegetation should reduce the temperature because evapotranspiration converts solar radiation into latent heat absorbed by the water molecules. Such absorption of heat by water molecules occurs without an increase in temperature, as compared to sensible heat. Greater vegetation also serves to increase land surface roughness, which in turn increases convection helping to disperse heat.

The Yale Surface Heat Budget Project is currently analyzing this policy by looking at satellite data that precisely measures the albedo. Using data collected by LANDSAT since 1995, researchers were able to determine that there had been an increase in albedo of 0.016 using algorithms to determine the reflectance of the surface. Over the same time period, NDVI (Normalized Difference Vegetation Index) was shown to have changed by 0.07. NDVI ranges from -1 to 1 and indicates the difference in absorption at the near infrared



The change in vegetation over fifteen years after policies were passed that required greening of the city. The data is compiled by comparison of LANDSAT images compiled in the two years noted. Image courtesy of Christopher Mackey.

spectrum and the absorption in the visible spectra. This difference is a good measure of vegetation coverage because chlorophyll strongly absorbs in the visible range and foliage strongly reflects in the near infrared. Healthy vegetation will tend to have a high NDVI while most other materials will tend to be around 0 as they do not preferentially absorb or reflect these particular wavelengths. The temperature could also be measured through LANDSAT data by use of Planck's law, which relates radiance to the temperature of a black body emitter, which the earth can be approximated as.

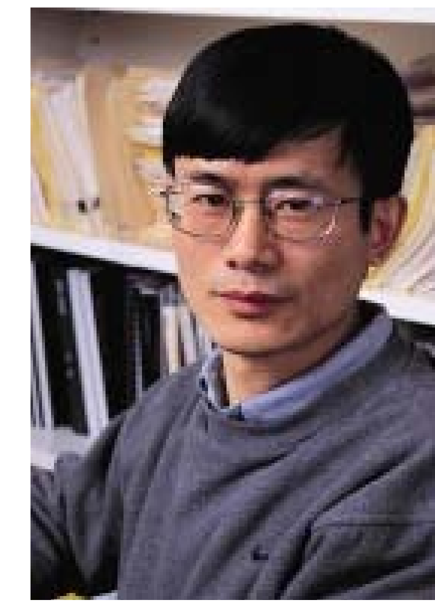
This analysis showed that policies to reduce reflectivity were more effective in reducing temperature because of the relative ease of implementation in the city. To generate significant temperature reduction through vegetation, the amount of vegetation needs to be increased to levels practically unattainable in cities in any setting other than a park. The study only considered sites with NDVIs greater than 0.35, which is already higher than many lawns.

Building on these results, the Yale Surface Heat Budget project is looking to tackle the question of urban heat islands on a larger scale. They have recently selected sites throughout the country for an investigation into what factors influence degree of warming. However, sites had to be selected carefully. Firstly, all sites had to have an urban core of at least four pixels on a MODIS image corresponding to at least one square mile in size. In contrast, the study of Chicago selected 29 pixels of the city center after eliminating many for different problems associated with processing. Furthermore, ideal sites have limited elevation change outside the city, as that adds a confounding variable to measuring temperature change. In total, 40 sites were selected for the study.

Preliminary results indicate that contrary to popular belief, which holds that the relative severity of the urban heat island effect was due to anthropogenic factors such as increased energy waste, decreased vegetation, or decreased albedo, it is actually environmental factors that determine the size of the effect. Once the potential for an urban heat island has been established by the generation of a population center, local environmental factors such as rainfall, latitude, and climate determine how much warmer the city will be than the surrounding areas. The next step in the project is to find an accurate computer model of the phenomenon to be able to demonstrate how modulating these environmental factors affect the temperature.

If the topic of local climate interests you, then look out for the upcoming article in *Nature* by Lee. The paper addresses the latitudinal control of local climate response, primarily measured by temperature change, to deforestation. Professor Lee predicts that "people will be surprised to see how much [climatic response] is dependent upon latitude."

"people will be surprised to see how much [climate response] is dependent on latitude."



Professor Xuhui Lee of the Yale School of Forestry and Environmental Science and a co-head of the Yale Surface Heat Budget Project. Photo courtesy of Xuhui Lee.

About the Author

MATTHEW CHALKLEY is a junior in Davenport. He is majoring in chemistry and currently does research into the insertion of carbon dioxide into organometallic species in Professor Hazari's lab.

Acknowledgements

The author would like to thank Professor Lee for his enthusiastic help in writing this article.

Further Reading

- Remotely sensing the cooling effects of city-scale efforts to reduce urban heat island. Building and Environment-Available in preprint on Professor Lee's website under publications.
- Lee, X. 2010. Forests and climate: a warming paradox. *Science* 328: 1479.
- Seto, KC and Shepherd, JM. 2009. Global Urban Land-Use Trends and Climate Impacts. *Current Opinion in Environmental Sustainability* 1: 89-95.
- Zaitchik, BF; Macalady, AK; Bonneau, LR; Smith, RB. 2006. Europe's 2003 heat wave: a satellite view of impacts and land-atmosphere feedbacks. *International Journal of Climatology* 26: 743-769.