U51B-0020 0830h POSTER

### Origin and Evolution of a Thermally Stratified Layer at the Top of the Core

Bruce A Buffett[1] (773-702-8107; buffett@geosci.uchicago.edu)

Hans-Peter Bunge[2] (+49-89-2180-4226; bunge@lmu.de)

[1]Department of Geophysical Sciences, The University of Chicago, 5734 S. Ellis Avenue, Chicago, IL 60637, United States

[2]Department of Geo and Environmental Sciences, Ludwig Maximilians University, Theresienstrasse 41, Munich D-80333, Germany

A substantial amount of heat is transported through the Earth's core by conduction down the adiabatic temperature gradient. Typical estimates for the conductive heat flow near the core-mantle boundary (CMB) are 5 to 6 TW. These values are within a factor of two of the values commonly cited for the heat flow into the base of the mantle. If the heat flow into the base of the mantle exceeds the heat flow conducted doewn the adiabat, then cold, dense fluid at the CMB helps to drive vigorous convection in the core. However, if the heat flow into the mantle is less than the conductive heat flow (e.g. subadiabatic), then a warm stratified layer can develop at the top of the core. Under these circumstances convection in the core is sustained by compositional buoyancy from the inner-core boundary. Light elements gradually accumulate in the convecting region of the core, whereas warm fluid accumulates at the top of the core because heat is conducted toward the CMB faster than it can be removed by mantle convection. A competition between the density deficits in the convecting and stratified regions govern the growth or disappearance of the stratified layer. We investigate the evolution of the stratified layer using estimates of the CMB heat flow from a three-dimensional numerical model of mantle convection in a spherical shell. Geological estimates of plate motions over the past 120 Ma are imposed as boundary conditions in the numerical calculations to quantify the resulting changes in CMB heat flow. The calculations are extended to earlier times by cyclically repeating the plate motion record. Averaging the predictions over several cycles reduces the effect of initial conditions. The results indicate that minima in CMB heat flow occur 40 to 50 Ma after minima in the surface heat flow. An additional time delay is incurred by the time required to develop the stratified layer once the heat flow becomes subadiabatic. The net time delay is sufficient to cause the stratified layer to reach its maximum thickness during or shortly after the peak surface heat flow. The predicted growth of the layer in our simulation reaches a maximum thickness of approximately 50 km about 100 Ma ago. We expect the occurrence of a stratified layer to suppress variability in the magnetic field at the surface due to magnetic screening, and may even promote a stable polarity. The temporal correlation between the maximum layer thickness and the occurrence of the Cretaceous superchron suggests a caustive relationship.

## U51C MCC: 3001-3003 Friday 1020h

## Human-Induced Climate Variations Linked to Urbanization: From Observations to Modeling II

*Presiding:* **J Shepherd,** NASA Goddard Space Flight Center**; M Jin,** University of Maryland, College Park

U51C-01 1020h INVITED

### Framework for Inclusion of Urbanized Landscapes in a Climate Model.

Robert E Dickinson (404-385-1509; robted@eas.gatech.edu)

Georgia Institute of Technology, 311 Ferst Drive, Atlanta, Ga 30332-0340, United States

Because of concentrated human populations, it becomes necessary to examine the consequences of urban areas for global climate. Urbanization changes the landscape by modifying the natural energy and water cycling processes and may introduce significant additional energy sources. Urban areas can either be considered from the viewpoint as to how their local climates are modified by their specifiic micrometeorological characteristics, or how there effects can be scaled up to the scales addressed by global regional climate models. We address the latter question. The land surfaces under a single atmospheric column of the model is partitioned into tiles with distinct micrometerological properties. However, the model resolution may restrict them to all interacting with the same atmospheric properties. The urban properities that cover the widest areas need to be considered first. These are evidently forests, grass, and pavements. Of these, the forests and grass might be combined with those outside the urban area to populatethe model's gridsquare forest and grass tile. However, urban/suburban lawns may be are sufficiently different from natural grasslands to merit a separte tile, and posibly be represented as irrigated where lawn watering prevails. Pavements are drastically different in their physical properties than natural surfaces, and typicaly cover a few tens of percent of an urban area (road densities of order of 10 km/km2). Largely asphalt, they have very low albedo,and are imperious to infiltration of precipitation. Hence, their characterization may be the most important issue for inclusion of urban effects in a global model. The minimum requirements for their inclusion are : a) global data sets of their relative areas, and b) average properties (e.g. albedo. emissivity, capacity for water storage, roughness, ...) How might these be obtained or what these might be are discussed.

U51C-02 1045h

### Surface-Atmosphere exchanges in urban areas: Observations and models

Sue Grimmond[1] (812 855 7971; grimmon@indiana.edu)

Tim R Oke[2] (toke@ubc.ca)

[1]Sue Grimmond, Indiana University, Bloomington, IN 47405, United States

[2]T.R. OKe, University of British Columbia, Vancouver, BC V6T 1W5, Canada

Increasing attention is being directed to the climates of urban areas given a large and increasing proportion of the worlds population live in cities, and urban settings are the locations of some of the most profound human impacts on the natural environment. Although understanding of urban effects on climate is incomplete, over the last decade much has been learnt about how urbanization modifies the climate system at micro, local and meso-scales, and the variability both within and between cities. This paper will attempt to summarize the most significant findings of this research. Data on the fundamental energy, mass and momentum exchanges will be presented from measurements campaigns from cities across North America (Vancouver, Mexico City, Los Angeles, Chicago, Sacramento, Tucson, Oklahoma City, Baltimore); Europe (Lodz, Marseille); and Africa (Ouagadougou), along with results of evaluations of simple (LUMPS-NARP and UK Met-Office) to more complex (TEB) surface-atmosphere exchange schemes, appropriate for use in global circulation, numerical weather prediction, and regional land-atmosphere models.

U51C-03 1100h

### Detecting and Simulating Urban-induced Climate Changes via EOS observations and NCAR Community Land Model

Menglin Jin[1] (201-405-8833; mjin@atmos.umd.edu)

Christa Peters-Lidard[2] (cpeters@hsb.gsfc.nasa.gov)

[1]Department of Meteorology, University of Maryland, College Park, MD 20742, United States

[2]Hydrological Sciences Branch, NASA-GSFC Code 974 Greenbelt, Greenbelt, MD 20771, United States

Advanced EOS observations provide us an unique opportunity to detect and simulate urban induced climate changes. Using 5km EOS MODIS-observed skin temperature, land cover, albedo, emissivity, LAI, aerosol optical depth, and cloud properties, we examine the surface-atmosphere interactions and urban heat island effects from selected big cities (New York, Beijing, Phoenix, and Houston) to global coverage. These analyses address physical processes modified by urban constructions as well as the general features of urban climate. We find the largest urban impacts in terms of temperature are observed over 30-60N, where most cities are located. In addition, urban regions overall decrease surface albedo by 3-5% and decrease surface emissivity by 1-2%. Focusing on Houston, we develop an urban scheme and couple it into NCAR Community Land Model (CLM-urban) to simulate urban climate. CLM-urban can improve the simulation of water and energy cycles over Houston with the use of observed LAI, albedo and emissivity, as well as urban thermal properties.

U51C-04 1115h

### How Has Urbanization Altered the Carbon Cycle in the United States?

Marc L Imhoff[1] (301-614-6628; marc.l.imhoff@nasa.gov)

Lahouari Bounoua[2] (301-614-6631; bounoua@dounia.gsfc.nasa.gov)

Ruth DeFries[3] (rdefries@geog.umd.edu)

William Lawrence[4] (blawrenc@bowiestate.edu)

Taylor Ricketts[5] (taylor.ricketts@wwfus.org)

[1]Biospheric Sciences Branch, NASA's Goddard Space Flight Center, Greenbelt, MD 20771, United States

[2]Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD 20742, United States

[3]Department of Geography, University of Maryland, College Park, MD 20742, United States

[4]Department of Natural Sciences, Bowie State University, Bowie, MD 20715

[5]World Wildlife Fund, 1250 Twenty-fourth St. NW, Washington, DC 20037, United States

Data from two satellites and a terrestrial carbon model were used to quantify the impact of urbanization on net primary productivity (NPP) and its consequences on carbon balance and food production. We found that different classes of urbanization have a recognizable satellite-based NDVI signal at a spatial resolution of 1 km. Our results show that urbanization is taking place on the most fertile lands and hence has a disproportionately large overall negative impact on regional and even continental scale NPP. Urban land transformation in the U.S. has reduced the amount of carbon fixed through photosynthesis by 1.6 percent of the pre-urban value. The reduction nearly offsets the 1.8 percent gain made by the conversion of land to agricultural use, a striking fact given that urbanization covers less than 3 percent of the land in the U.S. while agricultural lands approach 29 percent. At local and regional scales, urbanization increases NPP in resource-limited regions, and through localized warming "urban heat" contributes to the extension of the growing season in cold regions. In terms of biologically available energy, the loss of NPP due to urbanization of agricultural lands alone is equivalent to the caloric requirement of about 6 percent of the US population annually.

U51C-05 1130h

### Modeling Urban Surface-Atmosphere Sensible Heat Exchanges

Sarah M. Roberts[1] (604.822.2663; sroberts@geog.ubc.ca)

T. R. Oke[1] (604.822.2900; toke@geog.ubc.ca)

Aude Lemonsu[2] (aude.lemonsu@cnrm.meteo.fr)

C. S. B. Grimmond[3] (grimmon@indiana.edu)

Phoebe Jackson[1] (pjackson@geog.ubc.ca)

[1]Department of Geography, University of British Columbia, 217 - 1984 West Mall, Vancouver, BC V6T 1Z2, Canada

[2]Centre National de Recherches Météorologiques, Météo-France, 42 av Coriolis, Toulouse 31057, France

[3]Atmospheric Science Program, Department of Geography, Indiana University, Student Building 120, Bloomington, IN 47405, United States

Understanding the nature of energy partitioning at the surface of cities is prerequisite to gaining proper insight and ability to model their climatic environment and impacts. Of particular relevance in the urban setting is the surface-atmosphere exchange of sensible heat. The combined conductive-convective exchange of turbulent sensible heat flux ($Q_H$) and net storage heat flux ($\Delta Q_S$) has been shown to account for over 90% of the daytime net radiation at highly urbanized sites. This relation depends on surface structure, materials and the degree of surface-atmosphere coupling and its understanding is required in many applications; for example, to assess building climates, and to model evapo-transpiration, the urban heat island, and boundary layer growth. Observational studies, while allowing for general awareness of urban surface-atmosphere energetic interactions, are often limited in their applicability to other urban sites and/or processes. To overcome this, numerical models which aim to simulate urban climates have been developed. The Town Energy Balance (TEB) model of Masson (2000) couples the micro- and meso- scales and accurately represents the urban energy budget in meso-scale atmospheric models. TEB uses local canyon geometry together with surface and substrate radiative, thermal, moisture and roughness properties to simulate the effects produced by the presence of buildings. The urban system is simulated by calculating individual energy balances for walls, roads, and roofs, which are then integrated to resolve the local-scale surface energy balance. The model has been independently evaluated using measured fluxes from three dry sites - central Mexico City, a light industrial site in Vancouver (Masson *et al.*, 2002) and the city center of Marseille, France

(Lemonsu *et al.*, 2003). At these sites, TEB simulated net radiation to within less than 10 W $m^{-2}$ and its partitioning into turbulent and storage heat fluxes to within a few tens of W $^{-2}$. TEB's good performance points towards its promise in conducting further analyses to better understand the primary criteria affecting local-scale urban surface-atmosphere energy exchanges. Such an analysis is performed for a site in Marseille and the results reveal that the wind regime plays the dominant role in energy partitioning in this environment. Varying urban geometry and surface radiative properties also result in appreciable changes whereas alterations to surface thermal parameters do little to impact the relative degree of surface-atmosphere sensible heat sharing.

### U51C-06 1145h

## Measuring Longwave Radiative Flux Divergence in an Urban Canyon

Andres Soux[1] (604 764 0496; asoux@geog.ubc.ca)

Tim R Oke[1] (toke@geog.ubc.ca)

Manuel Nunez[2] (nunez@utas.edu.au)

Matthew Wilson[2] (matthew.wilson@utas.edu.au)

[1]Department of Geography, University of British Columbia, 1984 West Mall, Vancouver, BC V6T 1Z2, Canada

[2]School of Geography and Environmental Studies, University of Tasmania, Private Bag 78, Hobart, TAS 7001, Australia

There has been very little measurement of longwave radiation divergence since the urban studies of Fuggle, Oke and Nunez in the mid 1970's or the rural work of Funk in the early 1960's. Although radiative divergence has been widely ignored for sometime there is the belief that it may play an important role in balancing nocturnal energy budgets in a range of environments. For example, in urban environments surface temperature relates well to the energy balance whereas air temperature does not, even in non-turbulent conditions. This is probably due at least in part to the effects of longwave divergence. To help answer issues related to longwave divergence a new dual-channel infrared radiometer (DCIR) has been developed. The DCIR, as the name implies, measures the directional infrared radiation in two wavebands and can, through differencing of the signals and further signal processing, give a direct measurement of longwave radiative flux divergence. The DCIR was deployed for the first time as part of a larger study (BUBBLE) of the urban boundary layer of Basel, Switzerland. The objective is to further study the thermal regime of a city at the canyon scale. To this end, a street canyon was carefully selected, in the city of Basel. The canyon surface and air volume were instrumented, including turbulent and conductive fluxes, and standard meteorological variables in addition to radiation. A unique data set was obtained to allow the complete energy balance of the canyon system to be evaluated without the need to resort to using residuals to quantify the magnitude of the longwave radiative flux divergence. Measured values of longwave flux-divergence are converted to cooling rates to compare with measured air temperature cooling. Preliminary results show that at the onset of canyon air-volume cooling, measured cooling rates are slightly lower than radiative cooling rates. The differences are less than 0.5° C. This contrasts sharply with previously measured above roof level and rural differences of greater than 5° C. The difference between the rural and above-canyon case and the in-canyon case is most likely a result of differences in radiative environments and wind and temperature fields. The differences illustrate the strong role of urbanization on the surface energy budget.

# U52A MCC: Level 1 Friday 1330h

## Human-Induced Climate Variations Linked to Urbanization: From Observations to Modeling III Posters

***Presiding:*** **J Shepherd,** NASA Goddard Space Flight Center**; M Jin,** University of Maryland, College Park

### U52A-0021 1330h POSTER

## Synergistic use of MODIS and Nighttime DMSP/OLS Data for the Assessment of the Climatic Effects of Urbanization

Cristina Milesi[1] (milesi@ntsg.umt.edu)

Christopher D Elvidge[2] (chris.elvidge@noaa.gov)

Ramakrishna R Nemani[1] (nemani@ntsg.umt.edu)

Steven W Running[1] (swr@ntsg.umt.edu)

[1]Numerical Terradynamic Simulation Group, School of Forestry, University of Montana, Missoula, MT 59812, United States

[2]NOAA/National Geophysical Data Center, 325 Broadway, Boulder, CO 80305, United States

As urban areas are continuing to expand globally, there is an increasing need for exploring methods for monitoring the environmental effects of urbanization. In this paper we explore the synergistic use of the fractional Impervious Surface Area (ISA), a measure of urban development density estimated from the Defense Meteorological Satellite Program/Operational Linear Scanner (DMSP/OLS), and the normalized difference vegetation index (NDVI), a surrogate for vegetation biomass, and the land surface temperature (LST) data from the MODerate resolution Imaging Spectroradiometer to understand how land cover changes due to urbanization influence the local climate. We performed our analysis over the metropolitan areas of Chicago, Atlanta and Phoenix, U.S.A., representing different climatic regimes and urban development densities. The results indicate that NDVI does not necessarily decrease linearly as the fractional ISA increases, and may eventually increase with the density of development due to vegetation management practices, as in the case of Phoenix. In contrast, the nighttime LST consistently increases with the fractional ISA in the three urban environments. The urban-rural differences in nighttime LST for the three metropolitan areas are similar for equal values of imperviousness, indicating that the fractional ISA from the DMSP/OLS and standard products from MODIS could provide a continental physically based characterization of the surface that could be used to track the effects of urbanization on the local and regional climate.

### U52A-0022 1330h POSTER

## Urban Growth as a Component of Global Change

Annemarie Schneider[1] (617.353.8033; anmarie@bu.edu)

Mark A Friedl[1]

Curtis E Woodcock[1]

[1]Boston University Department of Geography and Center for Remote Sensing, 675 Commonwealth Avenue, Boston, MA 02215, United States

Urban populations have exploded in the last three decades, with nearly 50 percent (3 billion) of the Earth's inhabitants currently living in cities (UN 2000). Further, while urban land cover accounts for less than two percent of the Earth's land area, this proportion is growing rapidly as more cities expand into natural ecosystems and agricultural areas. The amount and rate of this land conversion affects local and regional ecosystems, climate, biogeochemistry, as well as food production. While monitoring and understanding of land use/cover change has improved dramatically in the arenas of forests, grasslands, and agriculture, more attention must be paid to the form and extent of urbanization as a key land transformation process. To address this issue, this research involves two objectives: 1) to map and monitor urban areas globally using coarse resolution data, and 2) to understand urban growth and its drivers during the last decade at regional to local scales, in a cross section of global cities. The first objective is to improve understanding of the methodological requirements for mapping urban land cover over large areas from coarse resolution remotely sensed data. Circulation models will soon include urban information in their parameterization of global land cover (G. Bonan, pers. comm.), however, no complete, updated map of global cities exists. Of the commonly used surrogate data sources, the Digital Chart of the World urban data (Danko 1992) is outdated, while the nighttime lights data (Elvidge et al. 1999) overestimates cities due to "blooming" effects. To meet this need, a technique called boosting is used to improve supervised classification accuracy and provides a means to integrate Moderate Resolution Imaging Spectroradiometer (MODIS) data with prior information derived from ancillary sources. Results indicate that fusion of data types improves urban classification results by resolving confusion between urban and other classes that occurs when any of the data sets are used by themselves. The second objective is to understand the rates, patterns, and drivers of urban expansion in cities around the globe. Urban areas have typically been studied at the local scale on a case by case basis, with little or no comparison performed among studies. A global comparison of cities is critical if we are to understand and mitigate the effects of rapid urban growth, as well as determine efficient use and sustainability of land and resources. The approach involves change detection in a sample of cities using Landsat imagery, and statistical analysis combining land cover data with socioeconomic data. Preliminary results reveal the emergence of several city "types," based on commonalities in spatial patterns, rates and mechanisms of growth.

**References:**

Danko, D. M., 1992. The Digital Chart of the World project. *Photogrammetric Engineering and Remote Sensing 58*, 1125–1128.

Elvidge, C. D., Baugh, K. E, Dietz, J. B., Sutton, P. C., and Kroehl, H. W., 1999. Radiance calibration of DMSP-OLS low light imaging data of human settlements. *Remote Sensing of Environment 68*, 77–88.

United Nations, 2000. *Demographic Yearbook, Department of Economic and Social Affairs, Statistical Office*, United Nations, New York, New York, 674 p.

URL: http://cers28.bu.edu/urban

### U52A-0023 1330h POSTER

## Urban Heat Island Connections to Neighborhood Microclimates in Phoenix, Arizona: Defining the Influences of Land Use and Social Variables on Temperature

Lela C Prashad[1] (lela.prashad@asu.edu)

William L Stefanov[1] (will.stefanov@asu.edu)

Anthony Brazel[1] (abrazel@asu.edu)

Sharon Harlan[1] (Sharon.Harlan@asu.edu)

[1]Arizona State University, PO Box 873211, Tempe, AZ 85287-3211

Phoenix, AZ is known to have an urban heat island that significantly increases minimum and maximum temperatures, which continue to climb as the city grows and becomes denser. We present a study that investigates "neighborhood" scale (1 square km) microclimate and its potential connections to the regional heat island. The purpose of our study is to: 1) identify social factors/ behaviors that influence temperature on a neighborhood scale and relate fluctuations to the overall heat island; 2) determine the effect of land use on temperature at the neighborhood and regional scales; 3) evaluate a range of thermal infrared (TIR) remotely sensed (RS) data and compare the RS surface temperatures to air temperature. Neighborhoods in both the urban core and fringe were delineated within Phoenix for our study. The neighborhoods represent a range of income levels and ethnicities. Daytime TIR data from Landsat sensors (TM, ETM+) and the airborne MASTER sensor were used to obtain surface temperatures for the neighborhoods. Nighttime surface temperature data were obtained from the ASTER sensor. Vegetation indices (SAVI) were created from Landsat and MASTER imagery. Climate monitors installed in each neighborhood recorded air temperature and dew point readings every 5 minutes. Land use was obtained from an expert systems classification of Landsat imagery and from aerial photos. Our results indicate surface temperatures correlate strongly with air temperatures. The 12.5m/pixel MASTER and 30m/pixel Landsat thermal data can highlight surface temperature gradients within a neighborhood while nighttime ASTER data provides better mean surface temperature discrimination between neighborhoods, and allows for quantification of local diurnal temperature variation. Neighborhoods with a low mean income, high percentage of Hispanics, and low educational attainment are significantly hotter than their high-income, non-Hispanic, highly educated counterparts. Urban core neighborhoods with high income also correlate strongly with high amounts of vegetation (R= -.637) and have significantly lower surface and air temperatures than regional heat island models predict. This suggests that neighborhoods with the means to alter their environments with vegetation can also produce more amenable microclimates. Conversely, neighborhoods with a high area percentage of concrete, asphalt roadways, and built materials exhibit a strong positive correlation with increased surface and air temperature.

### U52A-0024 1330h POSTER

## Instantaneous Rain Rates in Satellite Observations and a General Circulation Model

Eric M Wilcox ((609)452-6500 x6995; ewilcox@princeton.edu)

Princeton University, NOAA Geophysical Fluid Dynamics Laboratory, P.O. Box 308, Princeton, NJ 08542-0308

The frequency distribution of instantaneous rain rates is explored as a diagnostic tool for assessing the representation of precipitation in global atmospheric general circulation models (GCMs). A growing number of predictions are now being made about future changes in the frequency of extreme precipitation events in response to anthropogenic greenhouse gas loading. However, it is not yet clear that modern GCMs represent the process of precipitation sufficiently to capture present-day or future variability of precipitation