(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

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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

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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

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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

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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

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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

on short time scales. This study is a first step toward making such an assessment. Observations of instantaneous rain rate from TRMM and SSM/I polar-orbiting satellites are averaged over model grid cells with horizontal spacing of approximately 200km, which is consistent with global scale atmospheric simulations used for climate change prediction. The grid cells are grouped by geographic region (such as tropical, extra-tropical, land and ocean) and sufficient satellite overpasses are collected to construct distribution functions for each region of the frequency of occurrence of rain rates ranging from less than 0.1 mm/hr to greater than 10 mm/hr. The observed frequency distributions are compared with output from a coincident simulation of the GFDL atmospheric general circulation model. Corresponding simulated frequency distribution functions are constructed from snapshots of rain rate from individual time steps of the model, which are sufficiently sampled to capture the full diurnal variability of precipitation. Excessive drizzle associated with difficulty parameterizing cumulus convection is commonly observed in modern GCMs. The extent of this problem is examined quantitatively in this study and the sensitivity of such problems to the formulation of cumulus convection is discussed.

U52B MCC: 3001-3003 Friday 1340h

Evolution of Biogeochemical Cycles I

Presiding: **P Falkowski,** Institute of Marine and Coastal Sciences, Rutgers University**; M New,** NASA Headquarters

U52B-01 1340h

Carbon Dioxide Cycling and a Methane Greenhouse on Ancient Earth

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The continental cycle of silicate weathering and metamorphism dynamically buffers atmospheric CO_2 and climate. Feedback is provided by the strong temperature dependence of silicate weathering. Hydrothermal alteration of oceanic basalts can also dynamically buffer CO_2. The oceanic cycle links the surface to the mantle. Feedback is provided by the dependence of carbonatization on dissolved carbonates in sea-water. The oceanic cycle has no thermostat. Currently the continental cycle is more important, but early in Earth's history, especially if heat flow were higher than it is now, more vigorous plate tectonics would have made the oceanic cycle dominant. We find that CO_2 greenhouses thick enough to defeat the faint early Sun are implausible and that, if no other greenhouse gases are invoked, very cold climates are expected for much of the Proterozoic and the Archaean. This prediction for the most part flies in the face of evidence that early Earth was warm. We favor biogenic methane as the chief sup-plement to CO_2. High methane abundances (hundred to thousands of ppm) are expected given methane's current biological source and an anoxic atmosphere. Methane is a likely primary product of the advent of oxygenic photosynthesis. To first approximation methane and oxygen enter the atmosphere in stochiometric proportions. Mostly the methane and oxygen react with each other, but a small fraction of the oxygen reacts with rocks or with volcanic or metamorphic gases. This it is methane that accumulates first. High methane abundances in turn affect the oxidation state of the Earth because they facilitate hydrogen escape. Possible consequences of the irreversible oxidation of the Earth include the oxygenation of the atmosphere.

U52B-02 1355h

The use of mass-independent and mass-dependent isotope fractionations to study the sulfur cycle

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The inclusion of δ^{33}S and δ^{36}S data with δ^{34}S data is providing a new perspective on the evolution of Earth's sulfur cycle. Two types of sulfur isotope fractionations have been observed in the geologic record, mass-independent isotope fractionations and mass-dependent isotope fractionations. Mass-independent isotope effects have been reported in some of Earth's oldest rocks, present-day atmospheric aerosol samples, and in some volcanic ash layers in ice cores (c.f., Savarino et al. year, 2002 AGU Fall meeting). These mass-independent isotope signatures have been used both to provide insight into the atmospheric sub-cycle and also as a tool to trace the movement of sulfur through other parts of the global sulfur cycle. Mass-dependent isotope effects are responsible for most of the very large range of δ^{34}S fractionations that are observed in the geologic record. The ability to identify different types of mass-dependent isotopic fractionations by using δ^{33}S and δ^{36}S data can provide a means of differentiating between different types of biological and abiological signatures in the geologic record. We will discuss the developing framework for evaluating these mass-dependent isotopic fractionations and their range of potential applications (see also Johnston et al. 2003 AGU Fall meeting).

U52B-03 1410h

Implications of Multiple Sulfur Isotopes for Biological Systems

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The major isotopes of sulfur (δ^{34}S) provide a valuable tool to study the evolution and dynamics of ancient biological systems. We recently described the additional information that evidence from δ^{33}S and (δ^{36}S can provide for our understanding of metabolic pathways in geological environments (Farquhar et al., 2003). The application of the minor isotope system of sulfur arises because recent advances in analytical techniques allow us to measure different mass-dependent fractionation relationships that are predicted for different types of sulfur metabolisms (disproportionation vs. dissimilatory reduction). Here we report on the progress of experiments to measure the mass-dependent fractionation relationships for a variety of sulfur metabolisms and also the implications of our findings for study of the sulfur cycle. Our results may provide a test for a hypothesis that an apparent change in (δ^{34}S values during the Neoproterozoic reflected a shift in dominant metabolic process from sulfate reduction to sulfur disproportionation (Canfield and Teske, 1996; Canfield, 2000). This shift in dominant metabolic process has been interpreted as providing evidence for the oxidation state of the ocean and atmosphere at this time.

U52B-04 1425h

Oxygen Isotopes in Marine Sulfate: Reassessing the Sulfur Cycle Over the Past 10 Million Years

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Sulfate plays an important role in the modern ocean, serving as the primary oxidant for much of the organic matter and nearly all the methane produced in ocean sediments, yet the biogeochemical cycle of marine sulfate is assumed to be relatively stable with a long residence time of over 10 million years. Nearly all investigations into the long term dynamics of the marine sulfate cycle have focused on the sulfur isotopes of reduced sulfate deposits, primarily pyrite, and most have concluded that marine sulfate concentrations were low in the Archean, increased in the Proterozoic to modern values, and have remained more or less unchanged through much of the Phanerozoic. Because of the widely varying oxygen isotopic composition of the various sources and sinks of sulfate to the ocean, we suggest that temporal variations in the oxygen isotopes of marine sulfate may provide a closer look at the dynamics of the biogeochemical sulfate cycle. We present a continuous record of oxygen isotopes in marine sulfate measured in marine barite over the last 10 million years. Large shifts in the oxygen isotopic composition of marine sulfate, including a decrease of 6 per mil over the past 2.5 million years, indicate that the marine sulfate cycle is far more dynamic than previously thought. We use these measurements with a numerical model to explore changes in marine sulfate over the past 10 million years. Although many parameters in the sulfate budget are not well constrained, we identify several scenarios which can explain the observed pattern of oxygen isotopic variations. We suggest that changes in the sulfate cycle are linked closely to changes in sulfate reduction and sulfide reoxidation on continental shelves, which were affected by the periodic glaciations of the Plio-Pleistocene.

U52B-05 1440h

Biomarkers Indigenous to Late Archean Rocks

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Two new lines of evidence support the authenticity of molecular fossils in late Archean rocks of the Hamersley Province, Western Australia. Specifically, they support 1) a syngenetic relationship between the kerogen and extractable biomarkers, and 2) a indigenous relationship between extractable compounds and the host rocks. Carbon skeletons released from kerogen via high-pressure hydropyrolysis match those found in associated extracted bitumen. Biomarker ratios indicate less mature steranes and terpanes (i.e. hopanes and tricyclic terpanes) are embedded in the kerogen matrix as compared to the highly mature steranes and terpanes in the extracts, which is similar to findings in other hydropyrolysis experiments. Lithology-associated variations in biomarker distributions are noteworthy and suggest environmental settings are associated with differing biotic ecosystems. The evidence reported here confirms the 2.7 Ga antiquity of diverse biosynthetic pathways. Molecular data, together with isotopic data, indicate aerobic and anaerobic respiration pathways were fundamental to the complex microbial biogeochemistry of the late Archean. The biomarkers in these rocks support an early radiation of the three domains of life and radiation within the bacteria, such that clades of cyanobacteria, green sulfur bacteria, and proteobacteria had been established.

U52B-06 1455h

The Origin of Sterol Biosynthesis: A Time-Point for the Evolution of Eukaryotes and the Presence of O2

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The evolution of sterol biosynthesis is of critical interest to geoscientists as well as to evolutionary biologists. The first enzyme in the pathway, squalene monooxygenase (Sqmo), requires molecular oxygen (O2), suggesting that this process post-dates the evolution of Cyanobacteria. Additionally, the presence of steranes in ancient rocks marks the suggested time-point of eukaryogenesis(1). Sterol biosynthesis is viewed primarily as a eukaryotic process, and the frequency of its occurrence in bacteria long has been a subject of controversy. In this work, 19 protein gene sequences for Sqmo from eukaryotes were compared to all available complete and partial prokaryotic genomes. Twelve protein gene sequences representing oxidosqualene cyclase (Osc), the second enzyme of the sterol biosynthetic pathway, also were examined. The only unequivocal matches among the bacteria were the alpha-proteobacterium, Methylococcus capsulatus, in which sterol biosynthesis already is known, and the planctomycete, Gemmata obscuriglobus. The latter