cross-agency collaboration and coordination should be encouraged, while various agencies also should leverage their strengths. The National Science Foundation should support advanced systems research, while also continuing to develop and support leading-edge computing and data management systems, he said. The Department of Energy should lead with advanced prototyping and deployment of next generation high-performance computing systems, he said. Reed and others also noted that the National Institutes of Health should assume a leadership role in computational science and high-performance computing.

—Randy Showstack, Staff Writer

MEETINGS

Linkages Between the Built Urban Environment and Earth's Climate System

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Although only 1.2% of the land area of the Earth is currently considered "urban," the spatial coverage and density of cities is expected to rapidly increase in the near future. The United Nations estimates that by the year 2025, 60% of the world's population will live in cities. Human activity in urban environments alters atmospheric composition; affects components of the water cycle; and modifies the carbon cycle and ecosystems.

However, our understanding of the effects of urbanization on the total Earth-climate system is incomplete. The U.S. Climate Change Science Program (CCSP) strategic plan states that "...in a world that is more populated, urban, and interconnected than ever...A more integrated understanding of the complex interactions of human societies and the Earth System is needed."

Several issues raised in the CCSP echo the aforementioned statement about the urban environment-climate system linkage:

1. How are land use and land cover linked to climate and weather?
2. What are the potential feedbacks of changes in land use and land cover to climate?
3. How do the primary and secondary pollutants from the world's mega-cities and large-scale, non-urban emissions contribute to global atmospheric composition?
4. How are estimates of atmospheric composition and related processes to be used in assessments of the vulnerability of ecosystems to urban growth and long-range chemical transport?
5. What are the climatic effects of temperature on air quality, particularly in urban heat islands and other regional settings, and the potential health consequences?

Also, a recent report of the U.S. Weather Research Program (USWRP) called for more observational and modeling work to improve basic understanding of weather and climate impacts in the urban zone.

To understand the urban-climate system linkage, an interdisciplinary effort combining in situ and remote sensing, modeling, and human dimension assessments is ultimately required. Yet modeling the Earth's climate system has been hampered for at least two reasons: (i) poor representation of the urban environment in global and regional climate models (GCMs and RCMs), and (ii) the difficulty obtaining detailed information on urban characteristics.

Observing and Modeling the Urban Climate System

A workshop on recent results of observing and modeling components of the urban environment was held at the 2003 AGU Fall Meeting in San Francisco last December. Over 50 scientists from various interdisciplinary backgrounds attended to discuss current data and scientific approaches.

At this workshop, A. Schneider emphasized the need for new urban representation methodologies because the use of common surrogate data sources for global cities in models, the Digital Chart of the World urban data, is outdated, while the satellite nighttime lights data overestimates urban extent due to "blooming." With the advance of satellite observations (http://earth.nasa.gov), as discussed by M. King, adding urban environmental factors into climate models becomes feasible and essential. Currently, an urban classification is not included in many of the major GCM/RCM land surface models. This exclusion renders the models inadequate for realistically simulating urban modifications to climate. R. Dickinson highlighted some of the benefits and challenges of including "urbanizing" climate models.

Modeling efforts at regional scales and smaller typically have poor urban classifications as well. Yet at these scales, the urban impact on weather and climate processes can be of first-order significance. Several participants discussed recent advances with the implementation and verification of new capabilities like the Town Energy Balance (TEB) model that uses local canyon geometry with surface and substrate radiative, thermal, moisture, and roughness properties to simulate the effects produced by urban canopy.

It is well known that urban areas modify the surface energy balance and coupled boundary layer processes through the creation of an urban heat island (UHI). Study of UHIs has primarily focused on mid-latitude cities like St. Louis or London. However, the workshop featured a presentation of one of the first comprehensive studies of temperature and humidity distributions of a tropical city: Singapore. Preliminary findings suggest that there are significant differences in the magnitude and timing of the peak UHI in Singapore compared to mid-latitude cities. In another study, satellite-derived skin temperature indicated that the largest urban impacts, in terms of skin temperature, are observed over the latitudinal band of 30–60°N, where most cities are located. The same study indicated that urban regions decrease surface albedo by 3–5% and decrease surface emissivity by 1–2%.

C. Milesi used satellite-derived temperatures and vegetation to illustrate that nighttime land surface temperatures consistently increased with the fractional impervious surface area. Others like L. Preshad discussed how such data revealed that neighborhoods with lower income, higher Hispanic populations, and lower educational levels were hotter than high-income, non-Hispanic areas. Urban core areas with high income also correlate strongly with high amounts of vegetation, and have significantly lower surface and air temperatures than model-projected UHIs. The suggestion is that neighborhoods with the means to alter their environments can produce amenable micro-climates. Researchers from Japan even suggested that urban surfaces perturb not only surface temperatures, but sub-surface temperatures as well.

The workshop was also a forum for summarizing the most significant findings from measurements of energy, mass, and momentum exchanges taken during field campaigns across North America, Europe, and Africa.

Surface thermal perturbations translate to atmospheric processes through fluxes in the boundary layer. Recent or planned campaigns like the Basel Urban Boundary Layer Experiment (BUBBLE), Joint Urban 2003, and the Houston Environmental Aerosol Thunderstorm project (HEAT) have and will develop new capabilities to observe, characterize, and understand critical flux processes. BUBBLE was the first deployment of a new, dual-channel infrared radiometer (DCIR) that measures the directional infrared radiation in two wavelength bands, and produces a direct measurement of longwave radiative flux divergence.

Urban Impacts on Key Earth Cycles

There was also renewed debate on how the urban environment affects the atmospheric water cycle. The literature has revealed evidence of precipitation processes affected by urbanized areas. A range of workshop participants discussed results corroborating and extending previous literature evidence of enhanced precipitation activity over and downwind of cities.

Several mechanisms have been proposed to explain rainfall affected by urbanization:

enhanced convergence, boundary layer destabilization, increased aerosols, or alteration of existing storms. D. Rosenfeld suggested that urban particulates act to delay conversion of cloud water into precipitation. Precipitation processes are delayed to greater heights in the clouds, respectively delaying the downdraft and allowing the clouds to invigorate further. In dry and unstable conditions, this causes reduced precipitation due to very low precipitation efficiency, and in tropical and moist subtropical conditions, enhanced storm vigor (increased updrafts, rainfall, lightning).

An important result of Rosenfeld's presentation is that it provides evidence of convergence between the UHI-dynamics and aerosol-microphysics arguments.

Human-related activities associated with transportation, energy production, and industrial processes are likely the sources of "urban" aerosols. A compelling body of evidence using ground and satellite data showed that aerosol optical thickness peaks during the middle of the week in New York City. This cycle was hypothesized to be related to increased transportation activity at the beginning of the business week. Emerging observational and modeling capabilities will help to clarify this finding and enable new discoveries. For example, it was demonstrated that satellite-derived columnar aerosol loading has shown good correlation (R=0.8–0.9) with Environmental Protection Agency (EPA) PM2.5 (particulate matter with particle size less than 2.5 mm) at the surface in urban areas like Houston, New York, and Chicago.

Even the carbon cycle is sensitive to the urban environment. Urban land transformation in the United States has reduced the amount of carbon fixed through photosynthesis by 1.6% of pre-urban values, according to M. Imhoff. This reduction nearly offsets the 1.8% gain made by the conversion of land to agricultural use. This is a striking fact given that urbanization covers less than 3% of the land in the U.S., while land under agricultural production approaches 29%. Using satellite data and a terrestrial carbon model, the impact of urbanization on net primary productivity (NPP) and its consequences for carbon balance and food production have been quantified. Urbanization is taking place on the most fertile lands and has a disproportionately large overall negative impact on regional- and even continental-scale NPP. In terms of biologically available energy, the loss of NPP due to urbanization alone is equivalent to the caloric requirement of about 6% of the U.S. population annually.

Urbanization will increase globally to reflect population migration to cities. The complexities of the Earth system are well known, but the relative influences and feedbacks of human-induced and natural forcings are not. The renewed focus on the urban environment is therefore timely and critical. Indeed, recent and upcoming international meetings in Lodz, Poland and Vancouver, British Columbia underscore the global interest in understanding the linkages between the urban environment and the climate system.

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Interdisciplinary Discussion of Volcanic Processes Beneath the Long Valley Caldera–Mono Craters Area

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Volcanism in the Long Valley Caldera–Mono Craters (LVCMC) volcanic field in eastern California over the past 4 Ma is dominated by the 0.76 Ma caldera-forming eruption of 600 km^3 of rhyolite to form the Bishop Tuff. Over the last 150 k.y., volcanism has concentrated along the Mono-Inyo chain, which extends 45 km north from Mammoth Mountain to Mono Lake (Figure 1, below). Recent eruptions along this chain have occurred from multiple vents 650 ± 50 yr B.P. and from a vent in the middle of Mono Lake ~300 yr B.P. An earthquake swarm in May 1980, including four M6 earthquakes accompanied by uplift of the resurgent dome in the center of the caldera, called attention to the restless nature of Long Valley caldera. Subsequent activity has included recurring swarms of earthquakes ($M \leq 5.8$), episodic uplift of the resurgent dome, diffuse outgassing of magmatic CO_2, and mid-crustal (10- to 25-km deep), long period (LP) volcanic earthquakes.

A 4-day workshop on volcanism of the LVCMC volcanic field was held recently on the southwest rim of the caldera. The workshop included over 65 participants from academia, government agencies, and the private sector, with participants from Italy, Japan, New Zealand, and Great Britain. A field trip led by Marcus Bursik, Wes Hildreth, and Gail Mahood visited deposits of the ~600 yr B.P. Inyo Domes eruptions, the Horseshoe Lake tree-kill area of high CO_2 flux, and outcrops of Bishop Tuff along Owens Gorge.

The goals of the workshop were to develop an interdisciplinary assessment of our current understanding of the LVMC volcanic system, and to identify outstanding questions that might be resolved with new observations or experiments, as a framework for guiding future proposals to both the U.S. National Science Foundation and the U.S. Geological Survey Volcano Hazards Program.

Wide-ranging discussions emphasized that, although we have learned a great deal about this complex magmatic system over the past 25 years, major questions have yet to be resolved. The most recent eruptions were localized along the Mono-Inyo chain, yet recent ground deformation has focused on the resurgent dome, and seismicity is concentrated beneath the south moat of the caldera, Mammoth Mountain, and the Sierra Nevada block south of the caldera (Figure 1).

Where is the next eruption most likely to occur? Could magma driving uplift beneath the resurgent dome erupt from vents along the Mono-Inyo chain? These questions highlight uncertainty in the size, distribution, and connectivity between magma bodies in the upper crust, as well as the deep roots of the magmatic system in the lower crust and upper mantle. Although magma intrusion seems a likely cause of uplift, available evidence does not preclude a role for magmatic brines or hydrothermal fluids. More broadly, the relationship between magmatism and basin-and-range extension remains unresolved.

Although viewpoints varied on many issues, the discussions revealed consensus on a number of points. While there is evidence for recent magmatic intrusion beneath the LVMC system, data do not support the existence of large (caldera-scale) magma bodies in the upper crust, as presumably existed prior to eruption of the Bishop Tuff. Seismic observations require fast, low attenuation wave-paths through the central caldera. Tomographic studies using local earthquake sources and magnetotelluric surveys show no evidence of a large magma body in the upper 10 km beneath the caldera. Furthermore, no volcanic activity has occurred in the eastern two-thirds of the caldera in the last 300,000 years (Figure 1). Eruption of basalts in the western third of the caldera in the last 150 k.y. limits the extent of any silicic melt pockets, which would prevent denser basaltic magmas from reaching the surface. However, the western structural boundary of the caldera, defined by the ring fracture system, is 2–4 km inboard of the topographic rim (Figure 1), such that most post-300 ka vents fall outside the structural caldera. Other evidence needing to be reconciled with any model of the LVMC system includes the lack of volcanic gas emission in the central caldera, and the decidedly cool temperatures (100°C at depths of 2–3 km) in the Long Valley Exploratory Well (LVEW) located near the center of uplift.

Considerable evidence supports recent emplacement of melt beneath both the resurgent dome and Mammoth Mountain. Evidence for intrusion in the central caldera includes uplift of as much as 80 cm during the past 2 decades. The uplift was accompanied by gravity changes that are interpreted to require intrusion of silicate melt. The deformation data constrain the shape (vertically elongate), the depth (6–10 km), and the volume change (~0.2 km^3 since the late 1970s), but not the total volume of the inflation source. Teleseismic tomography shows low P-wave velocities at mid-crustal depths (10–30 km) that are consistent with 10–20% partial melt. The fact that south-moat seismicity increases following the onset of accelerating uplift implies a causal link between the inflation source and south moat earthquakes.