thousands of people gather at a flat, arid site in the remote Nevada desert to celebrate life and self-expression in a one-of-a-kind event called Burning Man. Known among “Burners” as “the playa,” this ancient dry lake bed, population 0, transforms into an instant metropolis of 68,000 they call “Black Rock City.” Burners dress in elaborate homemade costumes, drive around in customized vehicles straight from a sci-fi fantasy, and set up their tents in orderly formations. Most outdoor festivals offer live music, food trucks, and beer gardens. Burning Man, however, bans most commercialism and instead encourages attendees to contribute something with a personal touch. The result is an event with humanistic and spiritual appeal. “It’s a very spiritual and selfless experience that you’ll never forget,” says Dan Chang, planning his ninth annual trip to Burning Man. “You can just let yourself go and feel a sense of community you just don’t feel anywhere else while being one with the environment.”
“Black Rock City is the perfect place to examine how [urbanization] can impact the atmosphere.”

The question is, one with what environment? Even though most Burners don’t notice at the time, the event’s rapid urbanization causes the atmosphere above the playa to change dramatically. Both before and after they arrive, turbulent eddies transport heat, water vapor and carbon dioxide between the surface and the atmosphere. When the playa is bare, its surface produces very small fluxes of CO₂ and water to the atmosphere because of a lack of water or living things at the surface. In addition, the flat and smooth playa surface cause the heat fluxes and turbulence to remain relatively simple. These fluxes, however, change quite noticeably when 68,000 people arrive and populate the formerly uninhabited area. The physical attributes of the sudden city, as well as the activities that take place there, change the availability of heat, carbon and water carried up from the surface by turbulent winds. This fact gives Burning Man a value and irresistible appeal to scientists who study urban climates.

Dr. Andrew Oliphant, an ambitious and well-liked micrometeorologist and professor of geography at SF State, saw Burning Man as a unique opportunity to collect data and study the atmosphere that Burners change so quickly and dramatically. A New Zealand native and SF State professor for 11 years, Oliphant attended Burning Man for the first time in August, 2013, along with a team of his students. “I was always interested in the processes that shape our natural environment and the environmental consequences of human actions,” he observes. In the New Zealand school system, geography is a common discipline taught to students starting at a young age. “By the time I went to university I knew I wanted to major in geography.”

The primary focus of micrometeorology is to study the interface between Earth’s surface and the atmosphere. Studying this interface in heavily populated urban environments, however, presents several challenges. “It’s very difficult to know what an urban area’s atmosphere would be like if the city itself wasn’t there,” Oliphant explains in his thick New Zealand accent. “Black Rock City is the perfect place to examine how [urbanization] can impact the atmosphere.” In part, this is because cities are usually complex mixes of vegetation, building materials, humans and machines. This makes it difficult to tease apart the relative effects of each on our climate system. A single mature tree can absorb 20 lbs. of CO₂ per year through photosynthesis. Cars collectively emit many tons of CO₂ into the atmosphere each day. Because the Nevada desert lacks trees, vehicles, permanent built structures, or bodies of water, Oliphant can discount such urban variables when he and his team analyze their data.

Oliphant’s team arrived at the future site of Black Rock City five days before the 2013 Burning Man event to take measurements while the playa remained vacant. In the middle of the future city, they hoisted state-of-the-art instruments on a 100-foot mobile tower. “I was terrified that we would have to constantly keep people from climbing the massive tower,” says Ryan Thorp, one of Oliphant’s dedicated undergraduate students. “Fortunately it wasn’t an issue.” They also used a sonic anemometer resembling a pair of three-fingered robotic claws to measure wind speed and temperature at various heights above the playa’s surface. They combined this data with high frequency measurements of CO₂ and water vapor concentrations to calculate the flux or exchange of these variables as they are carried aloft by turbulent winds. They were then able to compare these values with those taken as the Burners began to assemble. “The data we collected creates a representative picture of our impact on the world around us,” says Thorp.

Emitted CO₂ tends to remain trapped close to the cool surface at night, then slowly rise as the day progresses and the surface heats up. At Burning Man, Oliphant’s team observed a steady rise in the CO₂ flux as the city grew day by day and along with it, emissions from generators, propane tanks, and vehicles. This steady increase shows up as spikes on a graph of CO₂ fluxes over a week’s time. Burning Man’s climax occurs on the last night, when Burners gather around the center of Black Rock City, ignite a giant man built of wood and paper, and watch it go up in flames. “This is when we noticed a huge spike in CO₂ levels after analyzing the data,” says Oliphant. “At first glance, it may seem as though the actual burning of the man caused this dramatic spike. However, because Oliphant’s team strategically placed their instruments upwind from the pageant’s central site to avoid smoke, they are confident that the instruments picked up CO₂ from a different source: vehicles.

Each year, as the giant man smolders, Burners race back to their cars, trucks, vans, busses, and SUVs and start their engines, trying to get a good position for quickly exiting the playa. In 2013, approximately 20,000 vehicles turned over virtually at once for the mass exodus. Emissions levels increased significantly, showing up as a sharp spike on the graph of CO₂ levels in the atmosphere. Although this happens on a daily basis in large cities during rush hour, the Burning Man event is unique in that its urban environment is only one week old instead of hundreds of years old. Oliphant’s team was thus able to capture the effects of urban growth in a short period of time.
measuring the climate impacts of living roofs
by Dr. Andrew Oliphant

Research carried out in the Microclimate Lab in the Department of Geography & Environment focuses on biophysical interactions that occur at the interface between Earth’s surface and atmosphere. This includes the role of ecosystems as well as human activities, which provide sources and sinks of atmospheric constituents such as CO2, water vapor and heat energy at the surface. Until recently, the lab focused on observing natural ecosystems and their interaction with the atmosphere, especially exchanges of greenhouse gases. More recently, our focus has shifted toward urban ecosystems, which include both the biophysical processes of vegetation in cities and the role of the built environment and anthropogenic activities such as fossil fuel combustion. The mechanisms for transport of heat and trace gases between the surface and atmosphere is via vertical motions in turbulent winds that occur due to the frictional drag of the surface. In the Microclimate Lab, we use eddy transport theory and high frequency anemometers and gas analyzers mounted on towers above the surface to calculate the fluxes of heat and gases between the surface and atmosphere.

One of our current projects is to determine the climatic benefits of living roofs in urban areas. These roofs have the potential to mitigate carbon emissions through photosynthesis, reduce heat loading in buildings due to the thermal insulation of soil and to limit the urban heat island effect through enhanced evapotranspiration. An undergraduate student and Climate

Scholars grant recipient Ryan Thorp and a graduate student Siobhan Lavender are leading experimental work on the living roof of the California Academy of Sciences. There they have deployed an eddy flux monitoring station that is continuously measuring the rates of CO2, water vapor, radiation and heat energy exchanges between the rooftop ecosystem and the atmosphere. To date, this work has shown that the roof is a net sink of carbon, on the order of 1.5 grams per square meter per day. Although this is quite small compared with many natural ecosystems (~25%), it contrasts strongly with the large source of CO2 from most urban surfaces. For example, the daily CO2 emission from Black Rock City during the Burning Man event (see page 4) was 25 grams per square meter. The living roof also acts to increase the evaporative heat flux compared with traditional “dry” roofs. This amounts to the absorption of several million joules of heat energy from the atmosphere per day for every square meter of rooftop, helping to offset the enhancement of sensible heat fluxes over urban surfaces. In another project lead by graduate student Stephanie May we have found this evaporative cooling produces a 2-4 degree Celsius decrease in temperature in Golden Gate Park relative to the surrounding neighborhoods. It is hoped that improved understanding of unique urban climates and carbon cycles as well as the role of vegetation, can lead to urban planning and management decisions that will improve future climates from the local to global scale.

While the team works on analyzing the massive amount of data they obtained at Burning Man, Oliphant maintains a “living roofs” project in San Francisco. Green roofs, or living roofs, are a growing trend in the construction industry. Incorporating vegetation into the roof plans of inner city buildings can provide insulation, harvestable crops, and rainwater retention. “The idea is to cool an urban area which is already hotter than the surroundings due to the urban heat-island effect.” The California Academy of Sciences began construction of a 2.5 acre green roof in 2007, and Oliphant has set out to monitor how this and similar green roofs impact the air quality above. “The hope is that we see at least a slight decrease in CO2 levels as a result of these green roofs.” Of course, studying a green roof’s interaction with the climate in the middle of America’s largest inner city park is no easy task. It is very difficult to distinguish the effects of the roof from the effects of the surrounding forest. But “we’re working on it,” Oliphant says confidently.

Oliphant conducts another of his projects in the meadows of the Sierra Nevada. His goal there is to study how land-use changes affect many environmental factors, including climate change, on a very broad scale. This interdisciplinary project incorporates not just micrometeorology, but numerous other branches of science, as well. “One thing I love about this project is working with scientists from all sorts of disciplines,” says Oliphant. “I’ve gotten to know biologists, conservationists, and people from the whole spectrum of natural science.” Regardless of his return to Burning Man, one can rest assured that Andrew Oliphant will continue contributing to our understanding of climate change in innovative ways.

Photo top right
A thunderstorm approaching across the playa prior to the Burning Man event. Photo by Dr. Oliphant.

Photo above
This shows the team beginning to set up the experiment prior to the event. From left to right, Malori Redman (SF State undergrad), Craig Clements (SSLU Grad), Ryan Thorp (SF State undergrad) and Garrett Bradford (SF State grad).

Photo right
The main research tower in the middle of Black Rock City during the festival. Photo by Dr. Oliphant.

a labor-intensive chore. When asked if he will go back next year, Oliphant playfully closed his eyes, chuckled, and shook his head. “Depending on how well the research is received,” he answered hesitantly. “I may set some things up out there, but I’m not going to start a whole new project. I’ve got other things going on as well.”

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Top photo:
Micrometeorological station on the California Academy of Sciences (CAS) rooftop. Photo by Ryan Thorp.

Left:
Three dimensional sonic anemometer and high frequency gas analyzer deployer on the CAS rooftop. Photo by Dr. Oliphant.

Right:
Elevation view of the micrometeorological station on the CAS rooftop. Photo by Dr. Oliphant.