ENVIRONMENTAL

A Shifting Landscape

The Earth's warming climate presents unprecedented challenges to scientists who study the environment. Species they've tracked in the field one year are hard to find the next. Models that they used to predict atmospheric conditions don't work with current measurements. Field observation and data render obsolete long-held assumptions about glaciers and forests. No longer able to rely on yesterday's maps and models, today's environmental scientists are creating new ones to describe the world as it is—and may be in the future.


ISTOCKPHOTO

BIOLOGY

Amphibians face a double threat from climate change.

by Sarah McMenamin, Ph.D.

When I started graduate school five years ago, I didn't set out to study climate change. I wanted to examine developmental variability in a population of salamanders: How did the pond where a salamander larva hatched influence its growth, development, and process of metamorphosis? During three summers in Yellowstone National Park, in a valley with dozens of small ponds where salamanders came to breed and larval populations would develop, I caught, measured, weighed, and took DNA samples from more than 600 larval and adult tiger salamanders.

I found that the characteristics of ponds strongly influenced the development of the larval salamanders. In more permanent ponds, salamanders spent a long time in larval form and metamorphosed very late in development, while salamanders living in ponds that dried early in the year metamorphosed at very small sizes to escape the drying pond.

But there was something wrong. Maps and amphibian surveys from the 1990s showed ponds with amphibian populations in places that I found to be completely dry. Ponds characterized as permanently filled with water in the 1990s now dried before the end of the summer. Several ponds dried so rapidly that I would return to a pond after only a few days and find hundreds of dried amphibian bodies where the water used to be.

Analyzing records of Yellowstone's climate conditions from the past hundred years, I found that Yellowstone's climate had warmed considerably over the last century, with the maximum summer temperature increasing several degrees. Furthermore, the annual rain and snow precipitation that filled local ponds had declined dramatically. I worked with a geologist to analyze satellite images going back 20 years. Like my observations on the ground, these images showed a drying landscape.

As ponds were disappearing, so were amphibian populations. I looked for populations of the four native amphibian species—the tiger salamander, two species of frog, and a rare toad—and found that the three most common species had disappeared since the 1990s. And ponds that still contained water now supported less amphibian biodiversity.

I showed that changing climate conditions in this area have made the environment lethal to amphibians. But these populations have experienced a lot of climate variation in recent millennia, so why are modern changes any more threatening?

TAL SCIENCE

Climate is now changing very rapidly, possibly faster than at any time in recent evolutionary history, and populations may not be able to adapt. Moreover, amphibians around the globe are in rapid decline for many reasons, including loss of habitat, as well as pollution, runoff, and pesticides, which amphibians absorb through their thin skins. Most frighteningly, a fungal disease called chytridiomycosis is killing amphibians everywhere.

Climate change makes populations more susceptible to diseases like the chytrid fungus, and it can dry out remaining amphibian habitats. Even in a protected place like Yellowstone, it is difficult to protect against threats like climate change and disease.

Doing this research is exciting and challenging and sometimes scary. I hope that as more people learn about the dangers of climate change and the threats to amphibians everywhere, we will be able to protect our fascinating amphibious friends.

Sarah McMenamin earned her Ph.D. from Stanford in May and is now a post-doctoral fellow at the University of Washington. In addition to her abiding love for salamanders, Sarah enjoys reading science fiction, hiking, and fencing.

FOREST ECOLOGY

Why more trees might not mean less carbon dioxide.

by Matthew Hurteau, Ph.D.

Forested ecosystems cover close to a third of the Earth's surface and range from highly diverse tropical forests to those dominated by a single species, such as Ponderosa pine forests. Forests are both influenced by and have the capacity to influence the climate system. As trees grow, they absorb carbon dioxide from the atmosphere and produce biomass through photosynthesis. This process has garnered a lot of attention as people have recognized the need to reduce greenhouse gases (such as CO_2) in the atmosphere to combat global climate change. At the same time, the climate has been changing, increasing temperatures in some regions. In the western U.S., warming temperatures have been associated with larger wildfires, which burn biomass and kill trees, releasing carbon dioxide back into the atmosphere.

As recently as the turn of the 20th century, ecosystems such as Ponderosa pine forests experienced frequent surface fires ignited by lightning and by the activities of Native Americans. Unlike the fires we see today, which kill trees and burn houses, these fires typically burned only the forest understory. In the process, they consumed fallen branches and needles and other dead plant material on the forest floor. This process cycled nutrients back into the soil and provided bare ground for trees and understory plants to regenerate.

In the mid-1900s, policymakers decided that this natural process was "bad" because it meant fewer trees and therefore less lumber. But suppressing fire and increasing the number of trees has actually led to an increase in the occurrence of severe wildfires. In the past, when there were fewer trees, the fires were less severe. So how can we balance the need to mitigate climate change by sequestering carbon in trees while maintaining processes such as fire that are integral to the health of these forests?

In my research, I use field data and computer models to determine how best to structure the forest to sequester carbon, while allowing for natural processes such as fire. In a modeling environment, I create forest stands with varying numbers and sizes of trees—and then set them on fire. I track how much carbon is lost and how much remains in the system. I found that in these dry, fire-prone forests, having fewer, larger trees provides the best insurance against carbon loss due to wildfire.

This work presents numerous challenges. A forest model is a simplification of reality, and the scientific body of knowledge is constantly growing. As we obtain more information, we need to decide what components are necessary to include in the models to better approximate reality. However, I find this research extremely rewarding because I get to help develop strategies that ensure we have ecologically functioning forests that have a lower risk of burning up in a wildfire, while providing a climate mitigation benefit.

Matthew Hurteau earned his Ph.D. in ecology from the University of California, Davis, and is now a post-doctoral researcher at Northern Arizona University. When not working on his research, Matthew enjoys backcountry skiing, cycling, and backpacking.

ATMOSPHERIC CHEMISTRY

The air up there, and why it matters to us down here.

by John Crounse

Growing up, I was very interested in chemical reactions—especially the explosive kind. Fortunately, during my high school and college years, these interests were channeled into more beneficial (and less dangerous) pursuits. In the graduate program in physical chemistry at Caltech, I was drawn to atmospheric chemistry, seeing it as a field with enormous potential to benefit life on Earth.

The study of atmospheric chemistry has led to several important changes in how we interact with the environment. The most famous example was the discovery that chlorofluorocarbon (CFC) compounds were leading to substantial ozone destruction in the polar stratosphere. This eventually led to the Montreal Protocol, an international treaty that phased out production of the chemicals believed to cause the ozone loss. Today, many atmospheric chemists focus on two problems that affect people around the world: global warming and air pollution. These problems have a major common cause: Burning fossil fuels releases both carbon dioxide and pollutants into the atmosphere.

In our laboratory, we develop instruments to detect and quantify reactive trace gases in the atmosphere. These measurements can help us identify and quantify pollutants, and determine their origins, how long they will persist, and how they react in the atmosphere.

To collect data, our instruments are installed on research aircraft that can fly throughout much of the atmosphere. Over the past several years, we have participated in four large-scale missions ranging from the tropical rain forests of Colombia to the North Pole, involving multiple aircraft and more than 100 scientists. Our 2004 mission focused on determining how long pollution generated along the eastern seaboard of the United States persisted in the atmosphere. We found that it can remain in the atmosphere long enough to be carried by the wind to European countries, where it can affect their air quality. Two years later, while studying pollution along the U.S. west coast, we found that pollution from Asia can be transported to the western U.S. and affect our air quality. Air quality issues are no longer viewed as local or even regional problems, but as global problems that require global cooperation to solve.

As we compare data collected on these missions to what models have predicted, we can also test our understanding of atmospheric chemistry processes and discover new ones. What we find will help us more accurately predict outcomes in various scenarios for Earth's future. As we reduce

the uncertainties and unknowns in the models, we'll generate more accurate predictions. And as in the case of CFCs, what we find may lead to change that will benefit us all.

John Crounse completed his undergraduate studies at Andrews University in Michigan and is now finishing his Ph.D. in atmospheric chemistry at the California Institute of Technology. When not collecting data, he enjoys spending time with his wife and preparing for a new addition to their family.

GLACIER DYNAMICS

Why are the world's large glaciers moving more ice, more quickly?

by Leigh Stearns, Ph.D.

I grew up in Manhattan, where ice and snow are predominantly viewed as a total inconvenience. But my opinions on the matter changed dramatically while at Carleton College in Minnesota, where I got hooked on geology and, more specifically, on climate change and ice sheet dynamics. I went on to study glacier dynamics for both my master's degree and my Ph.D.

My research focuses on the interaction between ice sheets, climate, and sea level. In particular, I use a combination of fieldwork, satellite remote sensing, and numerical modeling to study the behavior of glaciers draining the Greenland and Antarctic ice sheets.

Glaciers are among the best indicators of sustained changes in climate, such as atmospheric warming or an increase or decrease in snowfall. In many low-latitude glaciers, such as Africa's Kilimanjaro and the Peruvian Andes, and in alpine glaciers such as those in Alaska and the Himalayas, changes in glacier length and thickness lag behind climate changes by only a few years. Until recently, most glaciologists thought large glaciers and ice sheets respond much more slowly, on the scale of about 1,000 years, to variations in climate. But recent, rapid changes in all glaciers, from the small mountain glaciers to the outlet glaciers in Greenland and Antarctica, have challenged this thinking.

My first trip to Greenland was in 2005, after several particularly warm summers in the Arctic. Three of the largest glaciers in Greenland had recently undergone large changes in their dynamics. They were all flowing faster (by 100 to 300 percent), thinning (by about 100 meters in a few years), and retreating (each by about 5 kilometers). All these changes lead to more ice moving from the ice sheets into the oceans. We calculated that approximately 30 percent of the rise in sea level from 2001 to 2006 resulted from the speed-up of just a few large glaciers in Greenland.

After measuring the changes in glacier dynamics, the next obvious step was to determine what was triggering the changes. The fact that several glaciers over a wide geographical area were simultaneously undergoing large-scale changes pointed to a common mechanism. The only change common to all regions was climate warming. But what we don't know is how a warming climate influenced these glaciers that, according to convention, are supposed to respond slowly to climate changes. Are warmer air temperatures causing increased surface melt, which eventually moves to the base of the glacier and lubricates it? Or is the ocean warming and causing increased melt at the front of the glaciers? Answering these questions is important when trying to predict how glaciers and ice sheets will behave in the future.

We are now collecting measurements, both in the fjords where the glaciers terminate and on the glacier surfaces, to better understand what these glaciers are sensitive to. We install GPS devices on the glacier surface and measure how the flow speed changes after a range of different perturbations, such as an iceberg breaking off the front, the range of tidal motion, warm air temperatures, or sea ice changes. Understanding these small-scale dynamics will help us understand how the glaciers may behave when the climate warms even more. Our results will be incorporated into large-scale ice sheet-climate models to better predict sea level rise. i

Leigh Stearns is a new assistant professor in the geology department at the University of Kansas. When she's not on the ice, she enjoys running, skiing, biking, chocolate, and spending time with her dog, Hudson.