Special Issue: Climate Change

November 30, 2012
By Nicholas St. Fleur and Sarah Cohen

http://cornellsun.com/section/science/content/2012/11/30/special-issue-climate-change

This week in Science we take a closer look at what climate change it is and its possible effects toward extreme weather and species extinction, as well as how Cornell scientists are monitoring it to help create future mitigation plans. Winter 2011-2012 in Ithaca has been notably snowless despite December's rapid approach. The past decade has brought an increase in global temperatures, a decrease in arctic ice and an increase in destructive hurricanes – with Hurricane Sandy battering the Northeast this past month in an unprecedented series of weather events. What appears to be a drastic change in regional weather patterns, many scientists attribute to global climate change. The temperature changes occurring on the Earth are expected to have a cascading effect that may change the lives of many of the planet's flora and fauna. This week in Science we take a closer look at what climate change it is and its possible effects toward extreme weather and species extinction, as well as how Cornell scientists are monitoring it to help create future mitigation plans.

The Mechanisms of Climate Change

"Climate change refers to a long term change in the properties of the climate system," said Prof. Charles Greene, earth and atmospheric sciences. Recently, climate change has been used to refer to man-made changes that cause global warming. Although many factors combine to produce climate change and global warming, greenhouse gases such as carbon dioxide, methane, chlorofluorocarbons and nitrous oxide are some of the more well-known factors. While the most concentrated greenhouse gas is water vapor, according to Greene, carbon dioxide is the most concerning greenhouse gas, because humans are changing how much of it is airborne most rapidly.

Although the climate is always changing, recent changes may exceed what some scientists can explain through natural variations in climate change. According to Prof. Arthur DeGaetano, earth and atmospheric sciences, the scientific evidence points towards human created increases of greenhouse gases as the primary cause for these changes. He said in an email "as the concentration of these "greenhouse gases" increases in the atmosphere, the Earth loses less and less to space. This in turn warms the atmosphere and oceans."

DeGaetano referred to these processes as feedbacks. The feedbacks, he said in his email, often exaggerate the changes that increased greenhouse gases produce. "For instance, as temperatures warm, the area of the Earth covered by ice will shrink. Ice reflects large quantities of the sun's energy to space. With less ice, more of the sun's energy is absorbed by Earth, further warming the climate," he said.

According to DeGaetano, the warming may also lead to changes in precipitation that may cause normally dry areas to get drier while wet areas get wetter. Scientists are currently using climate models to predict future temperature changes cause by climate change over the next hundred years, and plan to use that data to create possible ways of mitigating its effects.

A Link to Hurricane Sandy?

Earth's climate system is complex, so climate change affects almost all weather patterns in some way. But are these changes to blame for current extreme weather events such as Hurricane Sandy? Scientists have said that no one weather event could be linked to the effects of climate change.

“The question of whether climate change affected hurricane Sandy does not have a simple answer. I would say yes and no,” said DeGatano. “Climate change did not cause hurricane Sandy, it may have helped to increase the storm's strength.”

Scientists have compared the effects of climate change on hurricanes like Sandy to that of steroid use in major league baseball players. Although a player may increase the amount of homeruns he hits in a season while on steroids, it would not be possible to determine which specific homerun was the result of the steroid use. Only the increasing trend can be measured. This related to climate change and super storms because scientists cannot attribute an individual hurricane, whether it is Sandy or Katrina, to climate change. But they can attribute the increasing trend of strong storms to climate change in general.

“Scientists are expecting more extreme weather conditions like higher frequencies of heat waves and droughts in some regions, floods, harsh winter cold and snow storms in other regions,” said Greene.

According to DeGaetano the take home lesson from Hurricane Sandy is that it shows the impacts of climate change. One of the impacts, he said, would be rising sea levels, which may reach more than two-feet in some locations.

“Most of Sandy's impacts were caused by very high storm surges. Her winds and motion caused sea-levels to rise by over 12 feet in some locations,” he said. Increased sea levels may strengthen typical storms, like the ones generally seen every 5 to 10 years, to be levels similar to that of Sandy, said DeGaetano.

Extinction and Climate Change

In addition to impacting weather trends and sea levels, climate change has an effect on the lives of species on earth as well. Slight changes in temperature can make a once habitable location less than suitable for certain species to live in. As a result, many organisms that are sensitive to slight changes in temperature are faced with two options: relocate or perish.

“Species start trying to adapt to climate change, and if they can, then fine, they move somewhere else,” said Prof. Warren Allmon, earth and atmospheric sciences, and an author of the book *Climate Change- Past Present and Future: a Very Short Guide*. “But if they can’t move somewhere else, what do they do? And that’s when they start disappearing.”

He said that climate change is a current threat for the extinction of many species living today. Increased temperatures have already caused certain species of insects, birds and marine species to change their geographic ranges. According to Allmon as little as two-degree increases in temperature could kill off coral reefs and push maple sugars outside of New York.

Allmon uses exhibits at the Museum of Earth, where he is director of the Paleontological Research Institution, to help explain the link between climate change and extinction. Many museum visitors ask him, if life goes on after certain species go extinct, why is extinction a problem? The problem, he said, deals with the quality of life on earth after certain extinction events.

“The short answer is, you wouldn’t have wanted to live on the Earth the day after the dinosaurs disappeared, and you wouldn’t want to live on the earth if global temperatures go up 5 degrees. And you don’t want your grandchildren or your great grandchildren to live on that earth, either.”

According to Allmon, the rates of climate change that are occurring now may not be unprecedented in the history of the Earth, but they are most likely unprecedented in the 10,000 year history of our species. “The message from the geological record is not that this has never happened before, the message is that when climate change of this magnitude happens, large and unpredictable things can occur.”

A striking example of an extinction event happening now that is related to climate change is coral reefs. Currently coral reefs are suffering under multiple problems such as having pollutants dumped on them from people, silt dumped on them from erosion and warming ocean waters that are becoming more acidified. Although corals could probably survive one of these insults, they may not thrive in the face of all of them, according to Allmon.

"It's like with people," he said. "Your roommate has one bad habit you can tolerate it, but if your roommate has ten bad habits you can't."

Coral Reefs and a Warming Ocean

Coral reefs are the most biodiverse ecosystem in the ocean, providing shelter for 25-50 percent of the world's marine life. In addition to providing fish with a place to call home, coral reefs also help create nutrients for other marine wildlife. The corals are like cathedrals of calcium carbonate that are covered with algae. The algae form a symbiotic, or a mutually beneficial, relationship with the coral. They act as the coral's solar powered energy source using photosynthesis to fix carbon dioxide into organic compounds.

But coral reefs are currently threatened by warming ocean waters because slight increases in water temperature can make them more susceptible to certain diseases. Using a remote satellite study scientists have found that regions where the most warming has occurred also have the highest probabilities of coral disease outbreak. The worst damage from coral disease occurred in the Caribbean in 2005 and 2010, which were two of the warmest years on record besides this year.

"It's kind of ironic," said Prof. Drew Harvell, ecology and evolutionary biology. "Here you have these creatures that only live in the tropics, and yet a two-degree temperature increase totally blows their symbiosis. And it's partly because the algal symbiosis are so temperature sensitive."

Harvell studies coral microbial interactions, or how corals interact with a fungus or a protozoan, or bacteria. The central focus of her lab group is the immune system of the corals and how corals are susceptible to climate change. She said that the warmer ocean temperatures caused by climate change can create massive coral bleaching, which is when the normally brown, green, purple or orange coral turns white. Coral bleaching occurs because the algae attached to the coral break down as a result of the increased temperature. This causes the coral to turn white because they are no longer connect with the algae in their tissues which give them their color. Devoid of its endosymbionts for a long time can cause the coral to die, which would cause adverse effects on the marine life that depend on it.

"The effect of the bleaching is as if all of the trees outside had their leaves turn white" said Harvell. "You'd be pretty shocked if you went outside and all the trees were white, that's what it looks like on the reef."

According to Harvell, one of the reasons she has spent so much effort studying the corals is because she thinks that they are sentinels for impacts that are affecting sustainability marine resources. The coral acts like the ocean's canary in the coalmine, providing an easy to see warning of the impacts of climate warming and disease.

Related to the coral reef are sea fans, another organism that Harvell studies which are similarly affected by climate change. The sea fans are susceptible to a fungus-caused disease called aspergillosis. To fight the disease, the sea fan creates zones of anti-fungal proteins, which are identifiable by their bright purple colors, protect it from aspergillosis' advances. The zones of immunity act as the front lines in the sea fan's efforts to prevent the fungus from spreading. As scientists like Harvell have studied, the lesions have been growing faster and bigger the in the past 15 years due to the warmer temperatures. Their research shows that the increase in ocean warming caused by climate change, does not bode well for the sea fan's defenses.

Climate Models: Predicting the Change

To identify the regions that are most susceptible to climate change, scientists have tools like climate models which help them identify changes in the atmosphere and predict future effects of climate change. Prof. Peter Hess, biological engineering, and Prof. Natalie Mahowald, earth and atmospheric sciences, have used a type of modeling system known as the Climate Earth System Model (CESM) to simulate past, present and future climate states. The CESM is a climate model supported by the National Science Foundation and the Department of Energy.

The CESM provides a computer simulation of different climate states by splitting up the Earth into millions of 3-dimensional boxes that can partition off certain areas of the atmosphere, land or oceans or a combination of the three. These 3-D boxes are only about a few kilometers in height, but typically stretch a few hundred kilometers wide in latitude and longitude. The boxes stack in columns that hold anywhere between 30 to 40 vertical layers.

According to Hess, the models look at how heat moves within a box and transfers between boxes. The typical box in the computer simulation has incoming heat radiating from the sun. It also has outgoing heat, which can be lost transferred through wind and water processes like condensation and evaporation. The models can provide average temperature in a box over the course of years.

When predicting the climate under different scenarios, the scientists input different codes into the computer simulation. The CESM consists of millions of lines of code. Some of these codes are variables within the system that can be altered, such as CO2 emissions. The system will show what temperature changes occur when the variables for CO2 emissions are changed within the model formulation.

"If I add so much CO2 emissions for the next hundred years, [the model] will tell what the temperature will be over the US or over Europe," said Hess.

There are many different types of scenarios that scientists use when predicting climate change. Two of the most reference scenarios are the "climate commitment" scenarios and the "business as usual" scenario. According to Mahowald, the "climate commitment" scenario portrays the climate in the future as it would be if CO2 levels stayed constant at the current level of about 390 parts per million. The "business as usual" scenario predicts what future climates would be if carbon dioxide emissions continued to increase at the same rate as they are now — about 1-2% per year. Mahowald said that this scenario would increase CO2 levels by 3 or 4 parts per million per year into the atmosphere, bringing the total amount to around 700 to 800 ppm by 2100.

The "business as usual" scenarios is not synonymous with a worst-case climate change scenario, rather it's the result of aggressive mitigation in future carbon emissions. The "carbon commitment" scenarios would occur if only a miniscule amount of carbon emission was produced in the future and alternative sources of energy came more prominently into play worldwide.

Mahowald uses climate models as one of her primary resources for providing as a scientific view on the current condition of climate change as well as its potential environmental and socio-economic consequences as a lead author for the Intergovernmental Panel on Climate Change Assessment report. The report, which is one of the key documents in the scientific and policy debates on climate change, is due to come out sometime between 2013 and 2014.

Both and Hess and Mahowald pointed out that though the models provide useful estimates, scientists still need to treat the predictions with caution. Still, models like the CESM are the best methods for predicting future climate change effects according to Hess. He said that the model provides a way to interpret different chemical measurements in the atmosphere as well as shows how the different processes and observations are linked together.

“It lets you experiment with the system because the Earth isn’t something you could put in a laboratory, so one of the easiest ways to experiment with it is with one of these models.”

Mahowald agrees. “They’re one of many tools that help us assess how much CO2 we can emit safely as well as identify regions of vulnerability” Mahowald said. She also said that by identifying vulnerable areas, scientists could help make efforts towards creating resiliency in those regions for the future.