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THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

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Climate Change is Already Here

...and it won't spare North Carolina.

by Mark Derewicz

In February of 2010 huge winter storms blasted the northeastern United States, where major news organizations and political leaders are headquartered. On FOX News Channel, Sean Hannity said, "The storm seems to contradict Al Gore's theory of global warming." Senator Jim DeMint tweeted, "It's going to keep snowing until Al Gore cries uncle." Senator James Inhofe's grandsons built an igloo on Capitol Hill, topping it with a sign that read, "Al Gore's new home."

Three mentions of Al Gore, but nothing about the unusually balmy weather in Alaska, throughout the Arctic Circle, or at the Winter Olympics in Whistler, British Columbia. No mention of the fact that January 2010 was the world's fourth warmest January on record or that only 5 percent of Earth's surface experienced cooler-than-usual temperatures in January. The year 2009 was the second-warmest ever (tied with 1998). The past decade was the warmest since humans started keeping reliable records in the mid-nineteenth century.

The truth is that a rare high-pressure system sat atop the Arctic for much of the winter, causing the jet stream to weaken and cold air to pour southward.

"We're performing an incredible experiment, the likes of which has never been performed before. We're loading

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the atmosphere with CO_2, and we're not sure what's going to happen."

—Chip Konrad, Department of Geography

Scientists, even those few dubious of man-made climate change, say it's ludicrous to think that individual weather events can debunk climate science. But many Americans still see the snow and doubt global warming. Other people point to a few hot summer days as *proof* of global warming. Both thoughts are misguided.

"There's a huge gap between what the vast majority of climatologists understand about climate change and what the average person thinks," says climatologist James Hansen, who came to UNC in 2010 as a visiting professor. "Part of the reason for that gap," he says, "is that scientists are not very good communicators." (See "Blame the messenger.")

Every scientist I spoke to for this story — fifteen at UNC plus Hansen — said that the evidence in support of human-induced climate change is overwhelming and that too many people are missing the main point about climate change. Earth does have and will always have natural climate patterns, says UNC climatologist Chip Konrad. But greenhouse gases that come from burning fossil fuels have loaded the dice and are causing variations within that natural cycle.

"We're performing an incredible experiment, the likes of which has never been performed before," Konrad says. "We're loading the atmosphere with CO_2, and we're not sure what's going to happen."

Some climate models predict frightening changes: massive sea level rise, category 5 hurricanes, decade-long droughts, mass extinctions. Those models are, to say the least, imperfect. Scientists readily admit this. But they don't need perfect models to understand how the climate works. If we perturb the natural climate cycle by, say, trapping heat in the atmosphere and oceans, then the resulting environmental changes will likely include longer droughts, considerable sea level rise, and more intense storms.

Baby fat: Not so cute?
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IN PRINT:

Some people point out that the scientific community is uncertain about the consequences of greenhouse gas emissions. But we are already seeing changes in the climate, UNC scientists say, especially in the oceans and at the poles. These changes aren't the stuff of science fiction movies. They are real and touching people's lives right now.

It's not a stretch, scientists say, to think that if we continue to burn fossil fuels at the present rate, things will get worse. We just don't know exactly how much worse. One thing, though, is clear: the case for human-induced climate change is a matter of physics, chemistry, and the biology of the environment — not seasonal and local weather phenomena or Al Gore's activism. And if we want to know what's going on, we can listen to the scientists.

Mountains of data

Hansen, a physicist who directs NASA's Goddard Institute for Space Studies, created a climate model in 1981 that predicted an unusually warm decade ahead, and an even warmer one after that. Another of his models calculated that 1990 would be the warmest year on record. In 1991 it predicted that the eruption of Mt. Pinatubo in the Philippines would cause global temperatures to drop, but that in a few years they'd start climbing again. Each time the models were right. Today Hansen warns that we've experienced only about half of the warming that we will eventually see from greenhouse gases *already* in the atmosphere. That's because of Earth's massive oceans, which warm slowly in response to added heat from greenhouse gases.

Think of CO_2 as water in a pan on the stove. Applying heat to the pan doesn't make the water hot immediately. And CO_2 that's released into the air doesn't immediately increase atmospheric temperatures.

Hansen came to UNC in early 2010 as a Frey Foundation Distinguished Visiting Professor. When we met, I asked him what the most convincing evidence is for man-made climate change. He answered: "The proof that the planet is out of energy balance: human-made greenhouse gases trap the earth's heat radiation, which causes the planet to emit less energy into space than it did before the gases were added."

One for the books.
(filed in: *language & lit.*)

The politics that polarize voters.
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The world is fat.
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ENDVIEW:

The ice at the bottom of the world.

Much of that energy goes into the ocean. “And we can measure it by measuring how the internal ocean temperature is changing. It turns out that the planet is gaining heat at the rate we had calculated: three-fourths of a watt per square meter.”

Before the Industrial Revolution, the CO_2 in the atmosphere was measured at 280 parts per million. Today CO_2 is at 387 parts per million and is rising at a rate of 2 parts per million annually. Over the same span, average global temperatures have fluctuated from year to year because of natural climate variations such as El Niño and La Niña. Over the long haul, though, temperatures have increased consistently. And fourteen of the warmest years on record have occurred in the last twenty years. But things could have been worse had the sun cooperated.

When climatologists began studying global warming, they first suspected that the sun was the main culprit. At a solar maximum, hundreds of sunspots and solar flares heave massive amounts of energy toward Earth. But from 2008 to 2009 the sun was in a deep solar minimum, the deepest since 1913. Very few sunspots were detected. In the next five years, as the sun approaches its maximum phase again, any solar impact on our climate will be in synergy with the warming trend already in place.

Scientists know this because they can measure the eleven-year solar cycle precisely. On a graph, the amount of energy released by the sun looks like a wavy line, with the maximum phase at the top of the wave and the minimum at the bottom. But global temperatures don’t match that cycle: they’ve been increasing for more than a century.

Hansen says that many things alter the balance between incoming energy from the sun and outgoing energy that seeps through the atmosphere and into space. The things that disturb this balance the most are what concern climatologists the most.

The vast majority of climate science experts — including the United Nations Intergovernmental Panel on Climate Change (IPCC), the U.S. National Academy of Sciences, the American Meteorological Society, the American Geophysical Union, and the American Association for the Advancement of Science —

agree that greenhouse gases, more than anything else, are affecting Earth's energy balance. These gases, including carbon dioxide, methane, and water vapor, are now driving climate change.

What this means for the global climate and North Carolina in particular is not easy to forecast. But scientists at UNC are already seeing some of the results.

A warmer world

Tamlin Pavelsky, a UNC geologist who studies how water moves in the Arctic, tells me that the climate at higher latitudes is changing faster than in most places. The classic case is the Arctic sea ice, which has been receding during the summer for years. In the winter the ice continues to extend great distances from the poles. "But it's getting much thinner," Pavelsky says. And that changes atmospheric temperatures.

"For years, the Arctic sea ice has been receding during the summer. In the winter the ice continues to extend great distances from the poles, "but it's getting much thinner."

— Tamlin Pavelsky, Geological Sciences

Typically air is warmer near Earth's surface; the farther up a mountain you go, the cooler the air gets. But Pavelsky's research shows that in the Arctic winter, the ice is so frigid that the coldest air is near the surface. The thicker the ice, the colder the temperatures. "But if the ice is thin, you get more cracks and you get more ocean water circulating through the brine channels," he says. This allows more heat to transfer from the relatively warm seawater to the atmosphere. And the warmer the Arctic gets, the more likely that the ice will be thinner, adding more heat from the ocean to the atmosphere.

In Alaska, Pavelsky's home state, temperatures have risen about 1.9 degrees Celsius — 3.5 degrees in the winters — since the 1950s. Sea ice has retreated more than 14 percent since 1978. Spring and summer are longer. Melting permafrost has caused erosion and landslides. And millions of acres of spruce trees on the Kenai Peninsula have died since 1992 from beetle infestations brought on, scientists think, by warmer temperatures.

In the lower forty-eight states, changes have been far less drastic, and future changes are less certain. The prevailing theory is that dry areas of the country will get drier and wet areas will get wetter.

According to Larry Band, director of UNC's Institute for the Environment, there's nothing that suggests North Carolina rainfall averages will change substantially in a warmer world. But he tells me that the state will likely see more intense droughts and storms that will cause severe flooding and landslides. In the mountains, Band points out, we used to build roads and villages in valleys, mostly to be closer to farm fields. Now we're building homes and winding roads on ridges, resulting in more landslides and erosion. More intense storms will only exacerbate the problem.

If there are droughts, Band says, we'll face greater water supply issues and pollution problems, especially increased surface-level ozone that contributes to respiratory illnesses. Methane, the main component of natural gas, plays a major role in the creation of ozone. In fact, methane is much more efficient than CO_2 at trapping heat, says UNC environmental engineer Jason West.

"That's why methane was controlled under the Kyoto Protocol," West tells me. "But it's not much talked about from an air quality perspective."

"There's a lot of ozone pollution forming over cities such as Los Angeles, Houston, and Atlanta. But if you go to the remote South Pacific, the amount of ozone is also increasing. It's increasing everywhere, not just over cities."

— Jason West, Environmental Sciences

West conducted a study showing that reducing man-made methane emissions by 20 percent would prevent an estimated 370,000 deaths worldwide between 2010 and 2030. Using computer models, he calculated that each metric ton of methane eliminated would produce $240 in public health benefits. And it would cost less than $100 per metric ton to reduce methane emissions by 20 percent.

Right now the United States is one of the few nations where methane emissions are declining, though West says that more can be done. North Carolina, for instance, could capture all methane released from landfills and water-treatment plants.

Band made sure to address droughts, floods, and health issues in UNC's 2007 Climate Change Report, a 180-page document that forty Carolina faculty put together for the North Carolina General Assembly. Band, who spearheaded the report, says that two major issues for North Carolina will be intense storms and sea level rise, both of which could alter the coastline in significant ways.

Rumblings

Rising sea level is often tied to dire predictions about the collapse of the Greenland ice sheet, though sea levels have been rising for decades without such a catastrophe occurring.

"We know how nature has affected climate because we have records from ice cores that date back millions of years. In the past fifty million years, the rate of CO_2 increase in the atmosphere has never been as high and rapid as it is now."

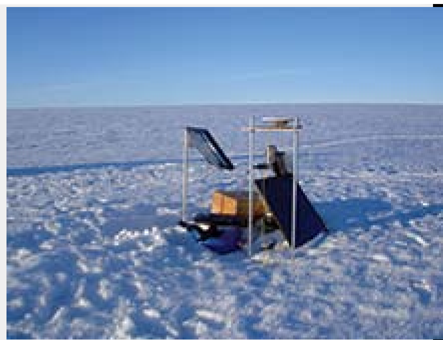
—Jose Rial, Geological Sciences

Jose Rial, a geophysicist at UNC who conducts research in Greenland, tells me that all of Greenland's major outlet glaciers, where the ice sheet sends water to the ocean, are seismically active. Don't think of tectonic earthquakes. "They don't last a few seconds or minutes," he says. "They last forty-five minutes to an hour. They happen when ice slides over ice. Basically, these rumblings are the ice sheet cracking."

Jose Rial sets up sensors to monitor ice quakes near Greenland's moulins — gaps in the ice that send meltwater to the ice sheet's base and then to the ocean. Rial is trying to measure how moulins affect Greenland's peripheral ice. Photos by Jose Rial.

The global network of seismographs records some of the rumblings, but data are spotty, Rial says. Last year in Greenland he placed sensors next to moulins, large shafts where water from seasonal snow and ice flows through cracks toward the bottom of the permanent ice shelf. Moulins are ground zero for Greenland's rumblings.

When combined with past research, Rial's data show that summertime moulin rumblings are



intensifying. This is a big deal, he says, because moulins occur along Greenland's periphery, and that peripheral ice acts as a buttress holding up the entire ice sheet. Moulins, with their melting water and cracking ice, undermine the integrity of the buttress. As the peripheral ice goes, so goes the Greenland ice sheet. At least that's the theory.

A collapse of less than half of Greenland's ice sheet would cause sea levels along the eastern U.S. seaboard to rise two meters, enough to inundate coastal cities.

This year Rial will put sensors around moulins to measure how deep the water goes. "We use all the noise that water and cracking produce to detect that," he says. "And we're going to find out exactly how moulins work and at what time of year they form. We don't know if a collapse will happen, but things are changing there much faster than we'd like them to."

Rial is hesitant to say that the cracking and melting are definitely tied to temperature increases and global climate change, though temperatures there have risen steadily for decades. And as for the connection between moulins and total collapse of the ice sheet, Rial tells me, "There are no models for this. The physics is not well understood."

That's why the IPCC doesn't include Greenland in sea level models. James Hansen, though, published research in 2007 showing that polar ice will not melt gradually. According to the geological record, ice sheets can suddenly destabilize when a certain temperature threshold is reached. What that threshold is, no one knows. But warming the Arctic won't help, and may cause Greenland to reach a tipping point, Hansen says.

Yet IPCC scientists and others point out that Greenland's ice sheet doesn't have to collapse for sea levels to rise. Nearly every glacier in the world is melting faster than scientists a decade ago predicted. Also, when water warms it expands, making sea levels rise. And the oceans have been warming.

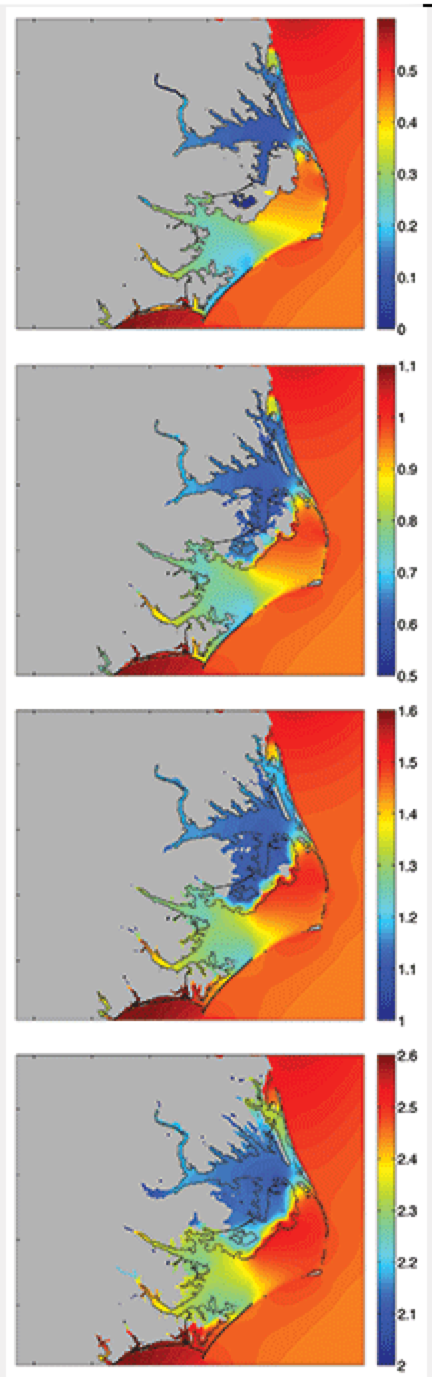
The rising tides

Oceans absorb 80 percent of the heat added to our environment from greenhouse gas emissions. This absorption is part of the climate system's inertia, Hansen tells me. "The ocean is essentially a four-kilometer-deep heat sink." Ocean temperatures near the surface have definitely risen over the past forty years, though the ocean depths are harder to gauge.

"Because of the Outer Banks, there's not much of a tide in the Pamlico Sound. But as sea level rises and those barrier islands degrade, the whole nature of the sound — ecosystems, habitats — would change because of a strong tide."

—Rick Luettich, Institute of Marine Sciences

This warming, along with melting mountain glaciers, is expected to cause sea levels to rise 18 to 59 centimeters by the end of the twenty-first century, according to the 2007 IPCC report. But many scientists, including Hansen, think the IPCC's estimates are low. The IPCC does not conduct research; it gathers more than 2,000 scientists from 154 countries to review peer-reviewed scientific papers and come to a consensus. Then the scientists draft carefully worded reports. Each country's representative has a say, which makes the final documents conservative. For instance, the 2007 IPCC report does not include current melting rates of glaciers in Antarctica and Greenland because such rates are difficult to quantify with the physics equations that climate modelers use. Yet scientists agree that those glaciers are melting and contributing to sea level rise.



This model shows what will happen to the North Carolina coast as sea levels rise. The top image shows a normal sea level. In the second image, sea levels have risen by half a meter: at this level, half of Dare County is under water. In the third image, sea levels have risen by one meter. The fourth image shows a sea level increase of two meters. Images by Rick Luettich and Tom Shay. ©2010 Endeavors magazine.

Still, the waters off North Carolina's coast have been rising for decades. Rick Luettich, director of UNC's Institute of Marine Sciences (IMS), has created high-resolution models to show what further sea level rise will look like.

After Hurricane Isabel hit North Carolina 2003, Luettich's team collected all the data available — tides, winds, topography, flooding — and plugged it into his models, which have been time-tested and honed to near perfection. Now Luettich can tinker with these models — adding higher sea levels, for instance — and see what would happen at the coast. If ocean waters were to rise half a meter, according the model half of Dare County would be under water — at least during high tide. In fact, the county would become an island. At two meters, hundreds more acres would be permanently flooded and nearly every bit of the Outer Banks would be gone.

Luettich and marine sciences colleague Tom Shay have also modeled hurricane storm surge with and without sea level rise. And this year, Luettich and Shay are constructing models to show how storms of varying intensity would affect the coast, assuming higher sea levels. That kind of model might be more valuable, because storm surge happens over the course of hours. Long-term sea level rise would take decades, which means that we'd have time to respond. And so would the marine habitats we rely on for food.

IMS researcher Mike Piehler studies how sea level rise would affect marshes, sea grasses, and oyster reefs. Piehler says that these habitats could adjust to rising sea levels; they'd move inland along with the water. But in parts of North Carolina, marshes and other habitats would bump into wooden walls or move into people's back yards. If a rising sea level wouldn't wipe out those habitats, Piehler says, it would definitely change them. He wanted to find out what the economic value of those habitats was.

"Marshes, sea grasses, and oyster reefs are all capable of keeping up with sea level rise, but at some point they will reach a backstop. And that's us — humans are the backstop."

— Mike Piehler, Institute of Marine Sciences

Piehler collects organic matter samples from an oyster reef near Beaufort, North Carolina. Reefs and other habitats perform processes, such as removing nitrogen from estuaries, that humans would have to do should rising sea level force marine habitats to the brink. Photo courtesy of Mike Piehler. ©2010 Endeavors magazine.

Marine habitats are involved in several valuable processes that no one had put a dollar amount on. One process is denitrification. Sea grasses, marshes, and oyster reefs remove nitrogen from ocean water and sea-floor sediments. (Too much nitrogen is bad for water quality.)

Piehler calculated the value of the process by multiplying the mass of nitrogen that these habitats remove each year by the cost per mass for things we'd have to buy to remove the nitrogen, such as storm-water treatment ponds. In his calculations Piehler also used the North Carolina trading credit number for nitrogen — essentially the amount of money people get paid for doing things that keep nutrients such as nitrogen out of water. He says it would cost eight thousand dollars per habitat acre per year to perform the same denitrification that marshes, sea grasses, and oyster reefs do automatically. There are hundreds of acres of such habitats at the coast.

If nutrients such as nitrogen are allowed to accumulate in water, then blue-green algae and other undesirable inhabitants will have a field day. Some blue-green algae are toxic, and once they start to dominate they can change an entire habitat for the worse.

Hans Paerl, also at IMS, has seen that happen in China, where he conducts research on Lake Taihu. (See Endeavors, Fall 2008, "Slime and the City.") Paerl tells me that blue-green algae blooms — also known as cyanobacteria — are now appearing in northern Europe and boreal regions of Canada, largely because of warming. Longer warm seasons mean that the blooms have more time to take over an area. And once they take hold, they trap heat, which produces positive feedback — the water keeps getting warmer. Because they often form surface scum, blooms block sunlight that bottom-dwelling plants need for photosynthesis. This leads to oxygen-deprived bottom waters that can harm plants, fish, and other organisms.

"Temperatures of Lake Taihu in China have increased two to three degrees Celsius since World War II. The water's not warming for any reason other than the climate is changing."

— Hans Paerl, Institute of Marine Sciences

Lake Taihu in Southeastern China has full blooms of cyanobacteria throughout most of the year because of pollution from industry and too much nitrogen and phosphorus from agricultural runoff.

Paerl has seen cyanobacteria in

North Carolina lakes, rivers, and estuaries. So far only a few dominant species have shown up during hot droughts. But if waters continue to warm or accumulate nutrients from storm runoff, then cyanobacteria could have their way here, too.

The Neuse River turned green with cyanobacteria after a particularly dry spring and hot summer in 1985. Cyanobacteria are gaining footholds around the world — even as far north as the Baltic Sea — partly because of warming waters. They can be toxic to humans and can decimate marine habitats. Photos by Hans Paerl. ©2010 Endeavors magazine.

On the other hand, right now some fish and other creatures aren't minding the warmer waters.

Something fishy

Joel Fodrie, an IMS biological oceanographer, was studying fish habitats in the northern Gulf of Mexico when he started reeling in a lot of snapper and grouper, which usually prefer warm tropical waters. He decided to conduct research on fish populations and compare his findings to research from the 1970s.

"Parrotfish, grouper, and snapper are just way more abundant now," Fodrie tells me. Lane snappers are the fifth or sixth most abundant fish species in northern Gulf sea-grass meadows. They were completely absent in the 1970s. "Gray snappers are now one hundred times more abundant," he says. "Gag grouper, two hundredfold. Parrotfish, we caught twenty to thirty times more." All those fish prefer warm water and will die if winter waters get too cold. But winter waters are no longer getting too cold, he says.

Fodrie found that water temperatures have increased about 2.8 degrees Celsius since the 1970s. He says there's a correlation between ocean warming and changes in fisheries. "But we know there could be other things going on," he says. Some people say that red snapper fisheries in the Gulf are depleted. If so, it's possible that other snapper are filling the void. Competition between adult fish may have opened a niche for other snapper and grouper. Sea-grass habitats may have changed, possibly because of warmer temperatures. Or water quality might have changed.

"It's a complex system," Fodrie tells me. "We can't say absolutely that the changes are due to climate change. It's likely, though, that climate change is interacting with all these other things, because we're not talking about just one kind of fish. It's all these different species."

A strong snapper fishery in the middle of the Gulf of Mexico is probably not a bad thing, Fodrie says. But now he's studying how these new species interact with endemic species.

In North Carolina, fishers and divers have spotted lionfish, which thrive in warm waters. Lionfish are native to the Indo-Pacific Ocean; they were introduced into the Caribbean and have worked their way north. Now they survive off the North Carolina coast. "They are a voracious predator," Fodrie says. "They eat smaller fish of many other species, including grouper."

Fodrie says that wherever researchers look they see changes in fish populations. Natural fisheries are slowly shifting toward the poles. Spawning and feeding times are changing. And Fodrie says it's tough to know whether the things fish eat will be available when the fish need them.

Another concern, Fodrie says, is carbon dioxide, which makes the oceans more acidic. It's unclear how fish will respond to ocean acidification, but marine geochemist Justin Ries has done lab experiments to show what happens to some crustaceans and shellfish. He grew eighteen species of economically and ecologically important marine animals that make their shells out of calcium carbonate. Ries added CO_2 to their tanks. CO_2 mixed with water makes carbonic acid and raises the amount of carbon in the water while reducing the carbonate ion that organisms need for calcification. Scientists have suspected that acidification would negatively affect all calcifying creatures.

But Ries found that seven animals, including crabs, lobsters, and shrimp, got bigger when the water was more acidic. Ten organisms, including oysters and scallops, got smaller. And some — clams and conchs — dissolved altogether. Mussels showed no response. "The organisms that responded positively are apparently more adept at converting inorganic carbon in the seawater back into a form they can use for calcification," Ries says. "Others appear to be less adept at manipulating carbon." His work shows that there's no magic formula to predict how different species will respond. For one, his team kept the creatures well-fed. But with ocean acidification, no one knows what the nutrients in seawater will be like.

"One thing you can be sure of," Ries says, "is that ecosystems as a whole will change because of these varied individual responses." Simply put, increased CO_2 will disrupt the food chain.

Better tests and models

In the last five years, toxic bacteria called *Vibrio vulnificus* have become more prevalent off the coast of North Carolina and elsewhere. This species is native to estuaries, and it proliferates as water warms. It infects oysters and has now been found as far north as Long Island Sound and Narragansett Bay in Rhode Island. In significant numbers *Vibrio vulnificus* can be lethal to humans.

"In the eastern part of the state, the water table is only sixteen to eighteen inches below the surface in some places." Heavy rains can cause the water table and septic systems to mix. "This is happening now."

— Rachel Noble, Institute of Marine Sciences

Rachel Noble, an IMS microbiologist, has created a quick method to test water for microbial contaminants, including *Vibrio* species. The test takes between one and two hours to get results and can be done on-site. Other methods take at least eighteen hours and are typically done in a lab. Noble has also created rapid methods to test for *E. coli* and *Enterococcus* from fecal matter that can enter coastal waters during extreme weather events such as hurricanes or torrential downpours. Down east there are huge lagoons full of hog waste that hurricanes have already disrupted. There are also a lot of septic systems.

"Some people don't realize that in the eastern part of the state, the water table is only sixteen to eighteen inches below the surface in some places," Noble tells me. When there's a lot of rain — not necessarily from a hurricane — the ground can get so saturated that the water table and septic systems mix. "This is happening now," Noble says.

Bacteria also pose a more global threat. They release CO_2 into the atmosphere like humans do. With warmer oceans, there will likely be more viruses and bacteria. Such organisms account for more biomass than any other species living in the ocean. “The problem right now,” Noble says, “is that scientists are using models that don’t accurately show the roles of bacteria and viruses in current global CO_2 models of the ocean.”

Noble is now working with researchers from Italy, the Netherlands, Canada, and California to understand those roles. They are creating a single data set from all the disparate studies on ocean viruses and bacteria, and they hand over their findings to climate modelers.

UNC marine ecologist John Bruno has a similar goal. He’s been in Australia working with other scientists and economists to put together data for the next IPCC report about the economic implications of losing coral reefs. In the past decade, Bruno has seen warmer ocean water imperil coral around the world. Along with former UNC grad student Elizabeth Selig, he found that more than fifteen hundred square kilometers of coral reefs around the world have disappeared every year since the mid-1980s. They are now dying at a rate of 1 to 2 percent a year. (See Endeavors, Winter 2008, “In Hot Water.”)

Researchers had placed some of the blame on seaweed, which thrives so much in warm water that it chokes baby coral. But in a separate study with Australian collaborators, Bruno found that seaweeds are not dominating coral nearly as much as other scientists had suspected. His team analyzed scientific reports on eighteen hundred reefs and found no general trend of seaweed dominance over coral since 1995.

Because coral death is a global phenomenon, Bruno places most of the blame on diseases that like warm water. Disease spreads easily among coral. Reefs die and can no longer provide buffers from storms. And those storms, thanks to warmer water *and* air, will likely be much more intense in the future.

But will there be more of these storms, as some scientists have speculated? Not necessarily, Chip Konrad says.

Storms of our grandchildren

Konrad, a synoptic climatologist, looks at long-term climate records, particularly extreme weather events and atmospheric patterns of the past. When he studies those patterns, he sees way too many variables to predict accurately what the details of our future hurricane seasons will look like.

“There’s no telling where the Bermuda High will be when a hurricane comes,” Konrad tells me. No one can predict the positioning of fronts and other weather features that could keep future hurricanes from pounding North Carolina. Konrad also says that it’s difficult to pin down how future hurricanes will form.

When Atlantic hurricanes form off the coast of West Africa, they start as large thunderstorms and then organize into hurricanes over the ocean with the help of warm air, warm water, and little wind shear. “Our hurricane season starts June 1 because the ocean is definitely warm enough to support a hurricane,” he says. “But we don’t see many until August because the mid and upper-level winds blow too strongly until then. Stronger winds aloft tend to mix things up so storms have a hard time organizing.”

He tells me that the upper-level winds will probably blow a bit stronger in a warmer world, making it more difficult for storms to organize into hurricanes.

“Still, there will be periods when upper-level winds relax,” Konrad says. “And with a warmer ocean you could breed some exceptionally strong systems.”

There has never been a category 5 hurricane documented in North Carolina history. But in a warmer world the chances would increase, according to Konrad. “A category 5 storm would be just unbelievable,” he says. “Billions of dollars of damage and lots of lives lost.”

How likely is it? No one knows.

That’s the thing about climate change. We don’t know exactly what the changes will be or how fast they’ll manifest. We don’t know whether the Southeast will be drier or wetter, or how future floods and droughts will compare to historical trends. We don’t know whether the Greenland ice sheet will collapse or how crucial snow pack will respond to increased temperatures. We don’t know exactly how fisheries, marshes, coral, and oysters will respond.

But what we do know is that events have been unfolding faster than scientists predicted not that long ago. We know that temperatures have been increasing steadily since 1880, the earliest date scientists say they can trust the instrumental record. And thanks to ice core samples, we know that the amount of CO_2 in the atmosphere has never been so high, or its rate of increase so rapid, in the past fifty million years. Rial says that scientists have looked back at the geological record to see how fast nature has responded to natural climate changes. Never before have such changes occurred as fast as they are today, he says.

The 2007 IPCC report states that there’s a 90 percent probability that greenhouse gases are now the biggest cause of climate change. Some powerful people clamor about the remaining 10 percent.

“But I don’t know any major scientific issue for which there’s no dissent,” Band tells me. There’s still debate about man-made climate change; every scientist I spoke to readily admits this. But this debate is not among climate scientists. Nor does any reputable organization dispute the physics of how greenhouse gases work.

Moreover, Band says, our society has never operated on the premise of 100 percent certainty. “We’ll wager billions of dollars on highly uncertain speculation,” he says, pointing to the housing market, oil, and interest rates. “But we’re unwilling to even take small steps toward mitigating climate change? We don’t make decisions in life based on knowing things for sure. If we did that, then we’d never do anything.”

Band, Hansen, and everyone else I spoke to agree that it will be too late to address climate change if we wait until we’re 100 percent certain that greenhouse gases have caused wild environmental changes.

At the very least, scientists tell me, we should think of taking action now as a kind of insurance. The government forces homeowners to buy insurance even though it’s unlikely our houses will burn down. Regarding climate change in North Carolina, this “buying insurance” could mean several things, including improving energy efficiency and changing development patterns, especially at the coast and in the mountains.

Every scientist I spoke to also agreed that, on the national and global scale, we must drastically reduce our dependence on fossil fuels. And according to Hansen, holding the CO_2 level steady at 387 parts per million won't be good enough; we need to reduce that to 350 parts to avoid drastic climate change. He says we ought to cut out coal entirely from the energy picture within the next decade. That's unlikely to happen, given the current political climate and the weight of the coal industry. Hansen knows this. But he also knows the science.

When he was in Chapel Hill in February 2010, he gave a talk at Memorial Hall and lectured in campus classrooms. But he also attended a protest at UNC's coal-power plant, the leading emitter of CO_2 in Orange County. In 2009 Hansen was arrested for trespassing during a protest at a coal-power plant in West Virginia. It's this sort of activism that has made him a target. He's supposed to be a scientist, his critics say, not an activist.

But Hansen, often dubbed the father of global warming, is also a grandfather, a fact he points to when discussing his activism.

"I can't desert my grandkids," he tells me. "Climate change is an enormous intergenerational injustice. The present generation should know that there will be consequences for continuing to burn fossil fuels, consequences that will be borne by our children and grandchildren."

From the College of Arts and Sciences: Larry Band is the Voit Gilmore Distinguished Professor of Geography and director of the Institute for the Environment. Chip Konrad is an associate professor of geography and director of the Southeastern Regional Climate Center. Tamlin Pavelsky is an assistant professor and Jose Rial is a professor in the Department of Geological Sciences. John Bruno is an associate professor and Justin Ries an assistant professor in the Department of Marine Sciences. James Hansen is the director of NASA's Goddard Institute for Space Studies. He came to Carolina in February 2010 as the Frey Distinguished Visiting Professor in the College of Arts and Sciences. *From the Institute of Marine Sciences:* Rick Luettich is a professor of marine sciences and director of the institute; Mike Piehler is an assistant professor, Rachel

Noble is an associate professor, and Joel Fodrie is a research assistant professor. Hans Paerl is the Kenan Professor of Marine and Environmental Sciences. *From the Gillings School of Global Public Health:* Jason West is an assistant professor of environmental science and engineering.

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