



GLOBAL WARMING

Projections of Climate Change Go From Bad to Worse, Scientists Report

COPENHAGEN—Meeting 2 years after the most recent report of the authoritative Intergovernmental Panel on Climate Change (IPCC), some 2000 scientists delivered a consistent if not unequivocal message here last week on the state of Earth's warming climate. "The worst-case IPCC projections, or even worse, are being realized," said the event's co-chair, University of Copenhagen biological oceanographer Katherine Richardson. Emissions are soaring, projections of sea level rise are higher than expected, and climate impacts around the world are appearing with increasing frequency, she told delegates in the opening session of the 3-day meeting.

The 11 universities that convened the Copenhagen Climate Congress hoped to provide a comprehensive picture of the status of world climate science before another set of delegates meets here in December to hammer out a follow-up to the 1997 Kyoto Accords, which expire in 2012. "This is our opportunity to get science back on the agenda," said climate modeler Vicky Pope of the U.K. Met Office. British Member of Parliament Colin Challen, who attended several sessions, said the update was crucial as nations are making plans "on data that's out of date."

Outside the conference center, a 75-m wind turbine reminded delegates of the promise, yet unfulfilled, of sustainable

energy. And inside, the organizers definitely felt the wind at their backs. Unlike IPCC, which is affiliated with the United Nations and its member governments, last week's congress answered to no political bosses and, therefore, participants were free to make prescriptive statements at its conclusion. "Inaction is inexcusable" and "weaker [emissions] targets for 2020 increase the risk of crossing tipping points" were two of the six "messages" that organizers disseminated in a press release. Some scientists, however, felt that those messages suggested a false consensus among participants.

The meeting's 58 sessions were grouped into three general themes: physical climate science, prospects for mitigation, and impacts and adaptation. On the prognosis for the climate system, Richardson warned that there's "no good news." Some scientists criticized how the 2007 IPCC report addressed the loss of the world's ice sheets, because it explicitly omitted calculations of the movement of glaciers, which at the time was poorly understood (*Science*, 9 February 2007, p. 754). Two years later, the picture is clearer. Konrad Steffen of the Cooperative Institute for Research in Environmental Sciences in Boulder, Colorado, said that the loss of Greenland ice was accelerating, with the speedup of the glaciers contributing up to two-thirds of the loss.



◀ **Friendly climate.** Danish Prime Minister Anders Rasmussen (*far right*) quizzed four climate scientists at the Copenhagen meeting.

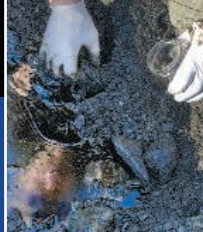
Another question left unanswered by the last IPCC report was whether the Antarctic ice sheets were losing mass. University of California (UC), Irvine, glaciologist Eric Rignot said that more recent data from satellites and field studies "very clearly" show that the ice sheets are shrinking. Rignot said the accelerating movement of glaciers in Greenland and Antarctica would, on the current trajectory, lead to sea level rise of 1 m or more by 2100—flooding coastal residents around the world.

New modeling work presented by Jonathan Bamber of the University of Bristol, U.K., showed that a complete disintegration of the Greenland sheet would require a 6°C rise in global temperatures, double the conventional wisdom. But before the audience could digest what sounded like a rare piece of good news, Bamber added that a 15% loss to the sheet would translate into a 1-m rise in sea level. "[That] is a horrendous prospect whichever way you cut it," Bamber told *Science*.

Elsewhere, the science was just as gloomy. Ecologist Chris Field of the Carnegie Institution for Science, who is overseeing the next IPCC report's section on impacts, gave an update on his analysis of the behavior of carbon stocks in the soil, permafrost, and plants. It's a problem IPCC "underemphasized" 2 years ago, he said. The latest estimate of the amount of carbon in permafrost is 1.7 trillion tons, more than twice the 2007 estimate.

Scientists know that warming temperatures could unlock this carbon, making the yearly effort to cut the atmospheric concentration of carbon dioxide "that much tougher" in the coming decades, Field says. Modeling of carbon frozen in soils remains primitive, he said. But new findings from field studies suggest that a type of soil known as Yedoma sediments could be especially problematic because it decomposes easily and 30% of its emissions are methane, a potent greenhouse gas. Plus, he said, scientists have been unable to find evidence for the hypothesis that some natural carbon sinks like forests may be increasing their ability to take in CO₂ as the planet warms.

A number of sessions examined the frightening possibility that warming temperatures could trigger catastrophic tipping points,



such as the loss of the Amazon rainforest through drought, which would create a vicious feedback. For example, modelers from the U.K.'s Met Office presented new data showing that even a global cessation of greenhouse gas emissions by 2050 could lead to a loss of up to 40% of the Amazon rainforest. "We thought we didn't need to worry till we got to 3°C of warming," says Pope (see graphic). Tim Lenton, an Earth systems scientist from the University of East Anglia, U.K., describes the change in looking at deforestation as going from "high-impact, low-probability events [to] high-impact, larger probability events." Atmospheric scientist Allan Gadian of the University of Leeds, U.K., says that the model "lacks credibility" because it fails to reproduce the current climate. But Chris Jones of the Met Office says the model closely replicates 20th century Amazon rain patterns.

The challenge of change

Although transforming the world energy economy poses what Ian Chubb, vice-chancellor of Australian National University in Canberra, calls "a diabolical policy problem," sessions on mitigating carbon emissions offered a mixed bag. UC Berkeley energy scientist Daniel Kammen explained how a Berkeley city employee had come up with a novel financing technique to fund residential energy-efficiency upgrades and solar panels. It's too early to assess the success of the 6-month-old program, which offers homeowners loans through a city bond. But a handful of U.S. cities have adopted it, he says, and officials in Lisbon and New York City are monitoring it. "Green growth is the answer to our climate problems and our economic problems," Danish Prime Minister Anders Fogh Rasmussen told the delegates during an appearance in which he quizzed a panel of scientists on what emissions cuts are required.

Nations like Denmark have shown the reliability of wind power. But one challenge has been getting businesses to work together. Danish engineering professor Erik Petersen of Risoe National Laboratory for Sustainable

Energy in Denmark said that "surprisingly" turbulent wind conditions at sea have made the turbines less efficient but that scientists are having trouble studying the problem because the companies are concerned about giving their competitors an advantage by disclosing their data.

Scientists also examined how carbon-friendly mitigation techniques might cause other problems. Dozens of companies are developing new strains of algae to make biodiesel fuel, said Anthony Marchese of Colorado State University in Fort Collins, but his studies show that the resulting fuel can emit

plies. A better alternative would be to plant mixtures of species, he says, but that requirement is not included in the system.

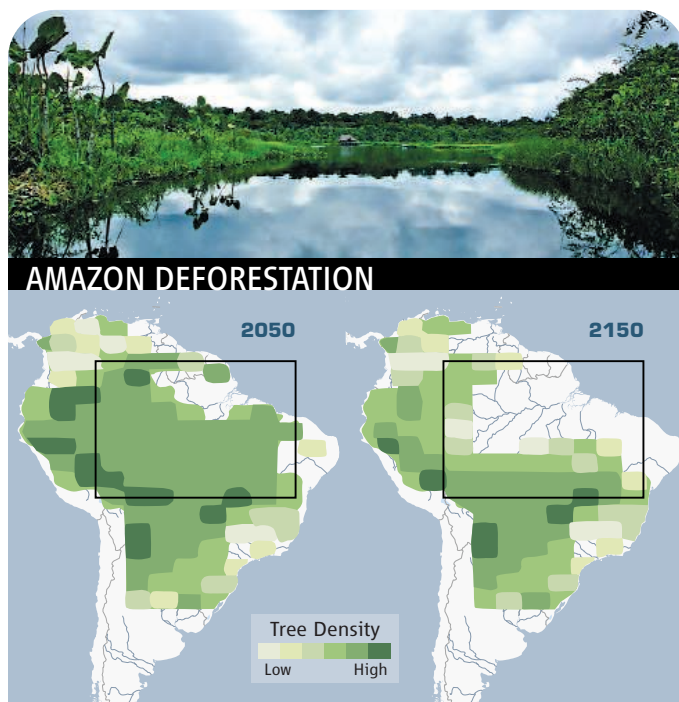
The conference included dozens of sessions on how scientists are helping countries begin to adapt to climate impacts. "Adaptation is rapidly evolving as a new area of science," said Roger Street of the University of Oxford in the U.K. and an expert on impacts and adaptation. There's a lot to learn, however. Oxford plant ecologist Pam Berry showed how adaptation can hinder efforts to mitigate emissions and protect biodiversity. "We need triple wins," she said. A project to reroute streams to reduce the

risk of flooding, for example, offered relatively cheap flood protection and increased aquatic biodiversity, she said. But the new ecosystem might feature additional sources of methane. Beach-restoration efforts to battle rising tides often involve the addition of sands, which have a chemical composition that can harm local species. Scientists are learning that climate change creates challenges more complicated than the "single stressor, single species" models that were used in the past, she said.

Attendees said that they appreciated the breadth of climate-related research presented at the meeting, which was much more political than the average scientific conference but far more scientific than a gathering of diplomats. Still, Field echoed the comments of several researchers in worrying about the stated message of the effort. Field said the scientists on stage in the final plenary session were overstating the level of support among climate scientists for the scientific validity of the 2°C target. Also troubling, he said, was that the organizers of the congress "were very unclear on the difference between [the messages] at the end of the meeting and the incredibly thorough, careful IPCC review and evaluation process."

Conference organizers plan to release a 30-page, peer-reviewed summary report of the conference findings in June. They hope the document will serve as a guide for this fall's negotiators of the evolving science.

—ELI KINTISCH



Emptying out. New models forecast that Amazonian forests could be decimated by 2150 even if greenhouse gas emissions fall to zero by 2050.

higher organic carbon or NO_x pollution levels than fossil fuels do when burned. "We have to consider issues like the emissions and health effects, not just how much oil bio algae fuel provides," he said.

Along similar lines, Australian geographer and ecologist Neville Crossman of the Australian Commonwealth Scientific and Industrial Research Organisation said that a carbon-trading system in Australia provided farmers with an incentive to plant certain native eucalyptus trees in dry areas. But the trees increase the demand on scarce water sup-