In science of climate change, still much to be learned

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The science of climate change has advanced significantly in the years since the release of the last Intergovernmental Panel on Climate Change (IPCC) physical science report in early 2007.

Yet despite key advances in areas like sea-level rise and humans' role in a changing climate, a nagging question remains. The question, often referred to as climate sensitivity, is simple: Given a particular level of increase in greenhouse gases -- a doubling of CO2, say -- how much will the Earth warm?

It may sound like a simple query, but scientists have struggled to pin down the answer. A large part of this uncertainty has to do with difficulties in modeling the role of clouds in a warming world, say researchers.

These continuing struggles, as well as key progress in climate science, are outlined in the 14-chapter, 2,200-page draft physical science fifth assessment report released on the IPCC website yesterday.

"One of the things that is extraordinary, [compared to] the fourth assessment report, is how many things we can actually attribute to human influence," said Nathan Bindoff, a professor of physical oceanography at the University of Tasmania who led the report chapter on the detection and attribution of climate change.

Such events directly linked with high likelihood to human output of greenhouse gases include half the warming on land since 1951, sea-level rise and upper ocean warming since the 1970s, ocean acidification, loss of Arctic sea ice and Greenland glacier melt, and extreme temperatures.

More confidence about ice melt and sea-level rise

The document paints a sobering picture of ice melt, noting that since the last IPCC report was released, there has been a continued net loss of ice from the cryosphere, a broad term encompassing all parts of the Earth where a "substantial" fraction of water is in the frozen state.

The IPCC also notes that the rate of ice loss from the Greenland ice sheet has accelerated since 1992, and snow cover extent has decreased in the Northern Hemisphere, especially in spring.

"Since the [last report], many new observations indicate that changes in ice sheets can happen more rapidly than was previously recognized," the assessment states.

Since 2007, "substantial progress" with satellite data collection has allowed for better estimates of ice mass and volume. A global glacier inventory now includes all glaciers, compared to roughly 42 percent in 2007.

However, the new report still does not resolve one of the biggest uncertainties with ice loss -- the likely time frame for when the Arctic will experience an ice-free summer. The range of uncertainty is about the same as it was six years ago, said Julienne Stroeve, a scientist at the National Snow & Ice Data Center.

Although there have been improvements, computers still are not modeling clouds and aerosols well, despite their key role in ice melt, she said. Arctic ice loss is happening at a faster rate than computer models predict, she added.

Similarly, models have predicted that Antarctic sea ice cover would decrease, when it actually increased, noted Stroeve. That discrepancy could be partially explained by natural climate variability, she said.

The ongoing melt of the world's glaciers is playing a key role in observed sea-level rise, according to the report. Glacier melting, along with thermal expansion of oceans, accounts for 75 percent of the global mean sea-level rise in the 20th century, the IPCC said.

"There has been a lot of progress in modeling the ice sheets, but there's still a lot more to be done there in understanding how quickly they respond to warming, and that feeds in, of course, with what the timing of sea-level rise will be," said Steven Nerem, a professor at the University of Colorado, Boulder's Colorado Center for Astrodynamics Research, who was a lead author on the sea-level change chapter of the report.

Since the last report, scientists have increased their level of confidence about recent trends with sea-level rise. "It is virtually certain that the rate of global mean sea level rise has accelerated during the last two centuries," the report states.

The confidence comes from now-documented consistency between satellite observations and tide gauge measurements, said Virginia Burkett, a scientist at the U.S. Geological Survey.

The confidence among scientists should help coastal officials trying to incorporate numbers into land use plans and building codes, she said.

"If you are building a hospital or power plant, you might want to look at the high end" of the estimates, she said.

The IPCC analysis concludes that the global mean sea-level rise during the 21st century will reach 0.26 to 0.97 meter (0.85 to 3.18 feet), depending on greenhouse gas emissions. Burkett said the numbers come down on the "conservative end," in her personal view. The National Climate Assessment released earlier this year projected a higher range for the United States -- 1 to 4 feet.

Cloud questions remain

Clouds and aerosols remain another key area of uncertainty, said the report authors.

This was highlighted in the last assessment, and it remains an area with considerable unknowns, said Graham Feingold, a physicist at the National Oceanic and Atmospheric Administration's Earth System Research Laboratory and a lead author of the clouds and aerosols chapter of the report.

"Six years later, we are still facing this situation, with this huge uncertainty associated with these [aerosol] particles and their interaction with clouds," Feingold said.

A big challenge, said Feingold, is that climate models work at large scales, with grids of 100 by 100 kilometers. Clouds are much smaller, and the processes that go on inside clouds take place at a minuscule scale compared to that of the climate models.

Scientists know that the way shallow clouds are treated in a climate model can greatly affect climate sensitivity, the measure of how much the Earth warms in response to a certain increase in carbon dioxide.

"Just understanding how shallow clouds work is probably our key challenge," said Feingold. "If we could narrow some of these climate sensitivity parameters, then we would be going a long way."

A chapter for policymakers

An entirely new chapter exploring near-term climate change was included in the latest report at the request of

the IPCC's member governments, said report author Gerald Meehl of the National Center for Atmospheric Research in Boulder, Colo., during a teleconference Friday.

"That's the time frame that's relevant to a lot of the decisions we have to make for infrastructure planning, water resource management and all kinds of other things," Meehl said.

According to this chapter, there is very little that policymakers can do to alter how the climate will act between now and 2035. It says projections of what could happen until that point show only "modest sensitivity" to a range of different emissions scenarios.

This is due to what is called committed warming, explained Gabriel Vecchi, one of the report's lead authors and a researcher at NOAA's Geophysical Fluid Dynamics Laboratory.

Committed warming means greenhouse gas concentrations already in the atmosphere are high enough to have irreversible impacts.

"CO2 is special," Vecchi said. "Once you get it in the atmosphere, it takes a long time to get out."

The report predicts that it is more than 66 percent certain that the mean global temperature increase will be between 0.3 and 0.7 degree Celsius over the next two decades, relative to temperatures over the last two decades.

Also over this time, the chapter authors project that ocean temperatures are likely to increase, Arctic sea ice cover is likely to thin and average precipitation will very likely increase in the Earth's higher latitudes, in line with the full report's more robust predictions for the end of the century.

Near-term certainties hard to find

The authors steer clear of making any near-future forecasts that are "virtually certain" or "extremely likely." Predicting what might happen over the next 20 years turns out to be more difficult than predicting what might happen in a century.

This is because year to year and even decade to decade, carbon dioxide concentrations in the atmosphere are not the single most powerful factor in determining global weather patterns, the authors explained.

Scientists now have a fairly advanced understanding of how high levels of greenhouse gases affect the climate over the long term. "The greenhouse gas changes will be the dominant factor in controlling climate a hundred years from now, relative to the present climate," said Vecchi.

The science of predicting how natural fluctuations of the Earth's climate, like El Niño and the Pacific Decadal Oscillation, will interact with greenhouse gas forcing is still relatively new.

While models can't yet predict how a warming world will affect El Niño, they're getting closer, said Isaac Held, a researcher at the Geophysical Fluid Dynamics Laboratory who helped review the report's chapter on models.

"I think we're reaching a stage where we can predict how El Niño will change in the future," said Held.

Climate scientists are also studying the Atlantic Meridional Overturning Circulation, a major current in the Atlantic Ocean that carries heat from low to high latitudes, as a possible predictor of near-term climatic variability in the northern latitudes, said Tom Delworth, also of NOAA's Geophysical Fluid Dynamics Laboratory.

Yet this research, while promising, has not yet come to any conclusive results.

However, Vecchi stressed that any uncertainty about the near future is not meant to overshadow the fact that human-caused emissions are definitely having an impact on the climate -- the new report is more certain than ever on this point.