PREDICTING CLIMATE CHANGE

Vital Details of Global Warming Are Eluding Forecasters

Decision-makers need to know how to prepare for inevitable climate change, but climate researchers are still struggling to sharpen their fuzzy picture of what the future holds

Seattle Public Utilities officials had a question for meteorologist Clifford Mass. They were planning to install a quarter-billion dollars' worth of storm-drain pipes that would serve the city for up to 75 years. "Their question was, what diameter should the pipe be? How will the intensity of extreme precipitation change?" Mass says. If global warming means that the past century's rain records are no guide to how heavy future rains will be, he was asked, what could climate modeling say about adapting to future climate change? "I told them I couldn't give them an answer," says the University of Washington (UW), Seattle, researcher.

Climate researchers are quite comfortable with their projections for the world under a strengthening greenhouse, at least on the broadest scales. Relying heavily on climate modeling, they find that on average the globe will continue warming, more at high northern latitudes than elsewhere. Precipitation will tend to increase at high latitudes and decrease at low latitudes.

But ask researchers what's in store for the Seattle area, the Pacific Northwest, or even the western half of the United States, and they'll often demur. As Mass notes, "there's tremendous uncertainty here," and he's not just talking about the Pacific Northwest. Switching from global models to models focusing on a single region creates a more detailed forecast, but it also "piles uncertainty on top of uncertainty," says meteorologist David Battisti of UW Seattle.

First of all, there are the uncertainties inherent in the regional model itself. Then there are the global model's uncertainties at the regional scale, which it feeds into the regional model. As the saying goes, if the global model gives you garbage, regional modeling will only give you more detailed garbage. And still more uncertainties are created as data are transferred from the global to the regional model.

Although uncertainties abound, "uncertainty tends to be downplayed in a lot of [regional] modeling for adaptation," says global modeler Christopher Bretherton of UW Seattle. But help is on the way. Regional modelers are well into their first extensive comparison of global-regional model combinations to sort out the uncertainties, although that won't help Seattle's storm-drain builders.

Most humble origins

Policymakers have long asked for regional forecasts to help them adapt to climate change, some of which is now unavoidable. Even immediate, rather drastic action to curb emissions of greenhouse gases would not likely limit warming globally to 2°C, generally considered the threshold above which "dangerous" effects set in. And nothing at all can be done to reduce the global warming effects expected in the next several decades. They are already locked into climate change.

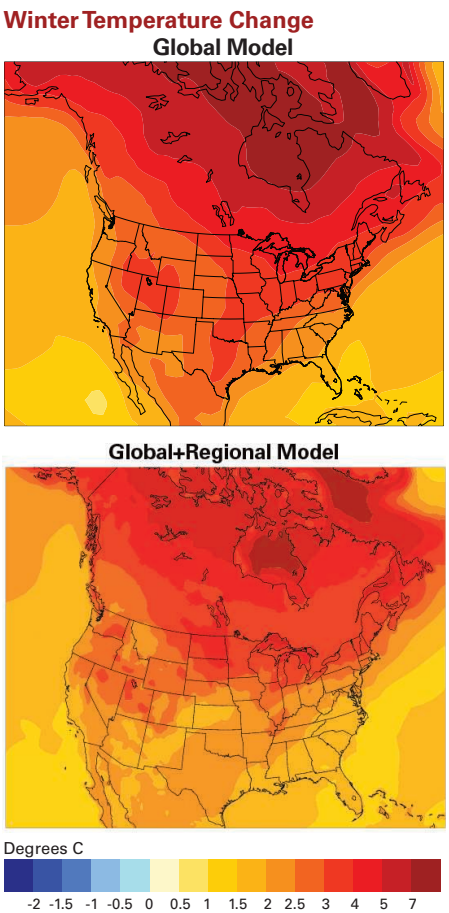
So scientists have been doing what they can for decision-makers. Early on, it wasn't much. A U.S. government assessment released in 2000, *Climate Change Impacts on the United States*, relied on the most rudimentary regional forecasting technique (*Science*, 23 June 2000, p. 2113). Expert committee members divided the country into eight regions and then considered what two of their best global climate models had to say about each region over the next century. The two models were somewhat consistent in the far southwest, where the report's authors found it was likely that warmer and drier conditions would eliminate alpine ecosystems and shorten the ski season.

But elsewhere, there was far less consistency. Over the eastern two-thirds of the contiguous 48 states, for example, the two models couldn't agree on how much moisture soils would hold in the summer. Kansas corn would either suffer severe droughts more frequently, as one model had it, or enjoy even more moisture than it currently does, as the other indicated. But at least the uncertainties were plain for all to see.

The uncertainties of regional projections nearly faded from view in the next U.S. effort, *Global Climate Change Impacts in the United States*. The 2009 study drew on not two but 15 global models melded into single projections. In a technique called statistical downscaling, its authors assumed that local changes would be proportional to changes on the larger scales. And they adjusted regional projections of future climate according to how well model simulations of past climate matched actual climate.

Statistical downscaling yielded a broad warming across the lower 48 states with less warming across the southeast and up the West Coast. Precipitation was mostly down, especially in the southwest. But discussion of uncertainties in the modeling fell largely to a footnote (number 110), in which the authors cite a half-dozen papers to support their assertion that statistical downscaling techniques are "well-documented" and thoroughly corroborated.

The other sort of downscaling, known as dynamical downscaling or regional modeling, has yet to be fully incorporated into a U.S. national assessment. But an example of state-of-the-art regional modeling appeared 30 June in *Environmental Research Letters*. To investigate what will happen in the U.S. wine industry, regional modeler Noah Diffenbaugh of Purdue University in West Lafayette, Indiana, and his colleagues embedded a detailed model that spanned



Sharp but true? Feeding a global climate model's prediction for midcentury (*top*) into a regional model gives more details (*bottom*), but modelers aren't sure how accurate the details are.

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the lower 48 states in a climate model that spanned the globe. The global model's relatively fuzzy simulation of evolving climate from 1950 to 2039—calculated at points about 150 kilometers apart—then fed into the embedded regional model, which calculated a sharper picture of climate change at points only 25 kilometers apart.

Closely analyzing the regional model's temperature projections on the West Coast, the group found that the projected warming would decrease the area suitable for production of premium wine grapes by 30% to 50% in parts of central and northern California. The loss in Washington state's Columbia Valley would be more than 30%. But adaptation to the warming, such as the introduction of heat-tolerant varieties of grapes, could sharply reduce the losses in California and turn the Washington loss into a 150% gain.

Not so fast

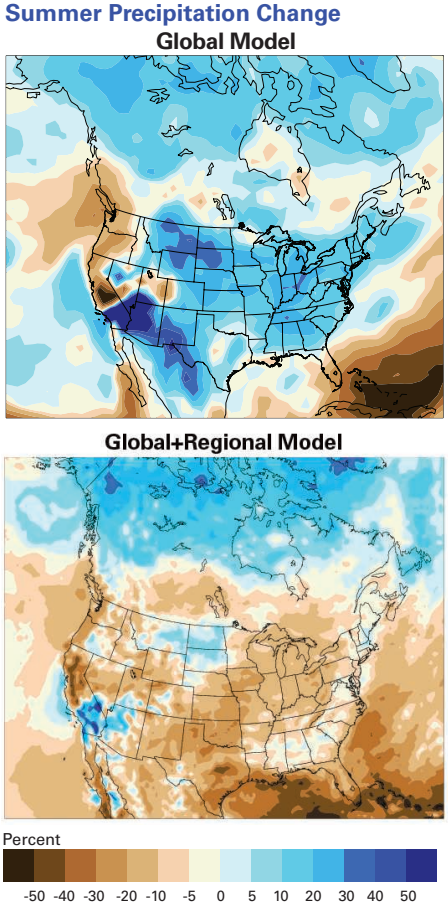
A rapidly growing community of regional modelers is turning out increasingly detailed projections of future climate, but many researchers, mostly outside the downscaling community, have serious reservations. "Many regional modelers don't do an adequate job of quantifying issues of uncertainty," says Bretherton, who is chairing a National Academy of Sciences study committee on a national strategy for advancing climate modeling. "We're not confident predicting the very things people are most interested in being predicted," such as changes in precipitation.

Regional models produce strikingly detailed maps of changed climate, but they might be far off base. "The problem is that precision is often mistaken for accuracy," Bretherton says. Battisti just doesn't see the point of downscaling. "I would never use one of these products," he says.

The problems start with the global models, as critics see it. Regional models must fill in the detail in the fuzzy picture of climate provided by global models, notes atmospheric scientist Edward Sarachik, professor emeritus at UW Seattle. But if the fuzzy picture of the region is wrong, the details will be wrong as well. And global models aren't very good at painting regional pictures, he says. A glaring example, according to Sarachik, is the way global models place the cooler waters of the tropical Pacific farther west than they are in reality. Such ocean temperature differences drive weather and climate shifts in specific regions halfway around the world, but with the cold water in the wrong place, the global models drive climate change in the wrong regions.

Gregory Tripoli's complaint about the global models is that they can't create the medium-size weather systems that they should be sending into any embedded regional model. Tripoli, a meteorologist and modeler at the University of Wisconsin, Madison, cites the case of summertime weather disturbances that churn down off the Rocky Mountains and account for 80% of the Midwest's summer rainfall. If a regional model forecasting for Wisconsin doesn't extend to the Rockies, Wisconsin won't get the major weather events that add up to be climate. And some atmospheric disturbances travel from as far away as Thailand to wreak havoc in the Midwest, he says, so they could never be included in the regional model.

Even the things the global models get right have a hard time getting into regional models, critics say. "There are a lot of problems matching regional and global models," Tripoli says. In one problem area, global and regional models usually have different ways of accounting for atmospheric processes such as individual cloud development that neither model can simulate directly, creating further clashes. Even the different philosophies involved in building global models and regional models can lead to mismatches that create phantom atmospheric circulations, Tripoli says. "It's not straightforward you're going to get anything realistic," he says.



A tougher nut. Predicting the details of precipitation using a regional model (*bottom*) fed by a global model (*top*) is even more uncertain than projecting regional temperature change.

Redeeming regional modeling

"You could say all the global and regional models are wrong; some people do say that," notes regional modeler Filippo Giorgi of the Abdus Salam International Centre for Theoretical Physics in Trieste, Italy. "My personal opinion is we do know something now. A few reports ago, it was really very, very difficult to say anything about regional climate change."

But Giorgi says that in recent years he has been seeing increasingly consistent regional projections coming from combinations of many different models and from successive generations of models. "This means the projections are more and more reliable," he says. "I would be confident saying the Mediterranean area will see a general decrease in precipitation in the next decades. I've seen this in several generations of models, and we understand the processes underlying this phenomenon. This is fairly reliable information, qualitatively. Saying whether the decrease will be 10% or 50% is a different issue."

The skill of regional climate forecasting also varies from region to region and with what is being forecast. "Temperature is much, much easier" than precipitation, Giorgi notes. Precipitation depends on processes like atmospheric convection that operate on scales too small for any model to render in detail. Trouble simulating convection also means that higher-latitude climate is easier to project than that of the tropics, where convection dominates.

Regional modeling does have a clear advantage in areas with complex terrain such as mountainous regions, notes UW's Mass, who does regional forecasting of both weather and climate. In the Pacific Northwest, the mountains running parallel to the coast direct onshore winds upward, predictably wringing rain and snow from the air without much difficult-to-simulate convection.

The downscaling of climate projections should be getting a boost as the Coordinated Regional Climate Downscaling Experiment (CORDEX) gets up to speed. Begun in 2009, CORDEX "is really the first time we'll get a handle on all these uncertainties," Giorgi says. Various groups will take on each of the world's continent-size regions. Multiple global models will be matched with multiple regional models and run multiple times to tease out the uncertainties in each. "It's a landmark for the regional climate modeling community," Giorgi says. **–RICHARD A. KERR**

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