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climate research

Why the predictions of global warming are so difficult

Global warming forecasts are still surprisingly inaccurate. Supercomputers and artificial intelligence should help. By Johann Grolle

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It's a simple number, but it will determine the fate of this planet. It's easy to describe, but tricky to calculate. The researchers call them "climate sensitivity".

It indicates how much the average temperature on Earth warms up when the concentration of greenhouse gases in the atmosphere doubles. Back in the 1970s, it was determined using primitive computer models. The researchers came to the conclusion that their value is likely somewhere between 1.5 and 4.5 degrees.

This result has not changed until today, about 40 years later. And that's exactly the problem.

The computational power of computers has risen many millions of dollars, but the prediction of global warming is as imprecise as ever. "It is deeply frustrating," says Bjorn Stevens of the Hamburg Max Planck Institute for Meteorology.

For more than 20 years he has been researching in the field of climate modeling. He has seen how the model earth, on which scientists simulate the climate, has become more and more complicated and realistic. The researchers started ocean currents in the oceans and made forests grow on the continents. Stevens has itself contributed a lot to the progress. And yet he had to admit again and again that his guild, as far as the prediction of climate change is concerned, is stagnant.

It is not easy to convey this failure to the public. Stevens wants to be honest, he does not want to cover up any problems. Nevertheless, he does not want people to think that the latest decades of climate research have been in vain.

"The accuracy of the predictions has not improved, but our confidence in them has grown," he says. The researchers have examined everything that might counteract global warming. "Now we are sure: she is coming."

That's exactly what Stevens says was the message politicians needed to agree on the Paris Climate Agreement. "We have made a decisive contribution," he says.

However, in order to prepare for the future, the models of the climate researchers were not suitable. As a decision-making aid in the construction of dykes and drainage channels they are unsuitable. "Our computers do not even predict with certainty whether the glaciers in the Alps will increase or decrease," explains Stevens.

The difficulties he and his fellow researchers face can be summed up in one word: clouds. The mountains of water vapor slowly moving across the sky are the bane of all climate researchers.

First of all, it is the enormous diversity of its manifestations that makes clouds so unpredictable. Sometimes they form delicate stripes, sometimes they drift in flocks of bulky shapes, or they pile up to kilometer-high weather fronts. Some float high up in the sky as translucent veils, others merge into a dense, low-hanging ceiling. And they also differ in their composition: some consist of tiny water droplets, others contain many small grains of ice.

Each of these types of clouds has a different effect on the climate. And above all: they have a strong effect.

Even laymen know the effect. As soon as a cloud moves in front of the sun, it gets cooler. Conversely, in winter the clouds are often like a cover over the land, keeping the heat on the ground.

Simulating natural processes in the computer is always particularly sensitive when small causes produce great effects. For no other factor in the climatic events, this is as true as for the clouds. All the clouds in the sky taken together, condensed into water, would cover the earth with a film just 0.1 millimeters thick. This tiny amount of water is enough to affect the climate massively.

This is illustrated by another figure: if the proportion of low-hanging clouds on earth also fell by only four percentage points, it would suddenly be two degrees warmer worldwide. The overall temperature effect, which was considered just acceptable in the Paris Agreement, is thus caused by four percent of a 0.1 millimeter thin layer - no wonder that binding predictions are not easy to make.

In addition, the formation of clouds depends heavily on the local conditions. The weather kitchen is determined by vertebrae that measure a few kilometers, often only a few hundred meters or less. But even the most modern climate models, which indeed map the entire planet, are still blind to such small-scale processes.

Scientists' model calculations have become more and more complex over the past 50 years, but the principle has remained the same. Researchers are programming the earth as faithfully as possible into their computers and specifying how much the sun shines in which region of the world. Then they look how the temperature on their model earth adjusts itself.

The large-scale climatic events can represent them quite well in this way. Deep-pressure vortices drag across the North Atlantic in model, as in reality, and India is ravaged by the rainy monsoon all summer.

However, problems are caused by the small-scale details: the air turbulence above the sea surface, for example, or the wake vortices that leave mountains in the passing fronts. Above all, the clouds: The researchers can not evaporate the water in their models, rise and condense, as it does in reality. You have to make do with more or less plausible rules of thumb.

"Parametrization" is the name of the procedure, but the researchers know that, in reality, this is the name of a chronic disease that has affected all of their climate models. Often, they deliver drastically divergent results. Arctic temperatures, for example, are sometimes more than ten degrees apart in the various models. This makes any forecast of ice cover seem like mere coffee grounds reading.

"We need a new strategy," says Stevens. He sees himself as obliged to give better decision support to a society threatened by climate change. "We need new ideas," says Tapio Schneider from Caltech in Pasadena, California.

Schneider researches as a German in America, just as Stevens researches as an American in Germany. Both know each other from study times. Both feel called to crack the puzzle of the clouds. But they disagree which way will lead to the goal. They quarreled about this question.

Together with colleagues from the Jet Propulsion Laboratory and the MIT, Caltech climatologist Schneider has forged a researcher alliance. Their goal: to build the "air conditioning machine". This is what Schneider and his colleagues call their new computer model, which is primarily intended to target the most insidious cloud genre: the stratocumuli.

It is the most common type of cloud on earth. Especially in the subtropics stratokumuli hang in many places in closed ceilings deep over the oceans. For the climate, they are of paramount importance. They are a kind of thermostat of the earth.

Stratocumulus clouds reflect a large part of the incoming sunlight, so they have a strong cooling effect. In the sky over the subtropical oceans, for example, one of the most important parameters of the world temperature is that when new stratocumulus clouds form here, it becomes colder on earth - and warmer when they dissolve.

But just this cloud type is arithmetically very difficult to get a grip on. Because the stratocumulus dynamics is determined by small-scale turbulence. If you want to simulate these faithfully, you need calculation models with a few meters resolution. "That's far beyond the capabilities of today's computers," says Schneider. "If we wait until the necessary computing capacity is available, the climate change we want to predict will have happened long ago."

He hopes to be able to shorten the way with his air conditioning machine. He wants to teach the computer to simulate a few regions of the earth with high resolution, and then to feed these results into large-scale models. The time is ripe, he says. For the first time, the computers are powerful enough to interlock small and large-scale simulations.

Artificial Intelligence (AI) is designed to facilitate this highly complex task. In fact, it might seem that the challenges of climate research are perfect for the application of AI systems. For the meteorologists provide huge data convolutions in which the computers could independently search for patterns. This is precisely the strength of the AI programs, which are also used for facial recognition, for example.

So far, however, the results have been disappointing. Computers have been struggling to recognize patterns learned from today's climate in the future. Also missing are important data, such as the humidity and the currents within the clouds. Schneider, however, believes he knows how to circumvent such problems.

Stevens wishes his friend in Pasadena good luck with his air conditioning machine. "We can use any progress," he says. He does not really believe in a breakthrough. Stevens, too, has long been concerned with the stratocumulus problem and has come to the conclusion that it is currently not cracking with climate models.

The Hamburg Max Planck researcher has therefore turned to another type of cloud, the cumulonimbus. These are mighty thunderclouds, which at times, dark and threatening, rise higher than any mountain range to the edge of the stratosphere.

Although this type of cloud has a comparatively small influence on the average temperature of the earth, Stevens explains. Because they reflect about as much solar radiation into space as they hold on the other hand from the earth radiated heat. But cumulonimbuses are also an important climatic factor. Because these clouds transport energy. If their number or their distribution changes, this can contribute to the displacement of large weather systems or entire climatic zones.

Above all, one feature makes Stevens' powerfully spectacular cumulonimbus clouds interesting: They are dominated by powerful convection currents that swirl generously enough to be predictable for modern supercomputers. The researcher has high hopes for a new generation of climate models that are currently being launched.

While most of its predecessors put a grid with a resolution of about one hundred kilometers over the ground for calculations, these new models have reduced the mesh size to five or even fewer kilometers. To test their reliability, Stevens, together with colleagues in Japan and the US, carried out a first comparison simulation.

It turned out that these models represent the tropical storm systems quite well. It therefore seems that this critical part of the climate change process will be more predictable in the future. However, the simulated period was initially only 40 days. "40 days and 40 nights, for climate researchers has the symbolic value," says the Hamburg researchers - so long drove Noah with the ark through the flood. But, of course, Stevens knows that to portray climate change, he has to run the models for 40 years. Until then it is still a long way.

Global forecasts from Pasadena, regional from Hamburg - it would be nice if everything worked out as the two opponents imagine. For the time being, however, it is only certain that mankind will have to wait for some time for more concrete climate forecasts.

And even if the clouds someday comply with the equations of the researchers, will the world be safe from surprises? Neither researcher can give the all-clear. "We enter uncharted territory," says Schneider. "There are no certainties."

He has just calculated what happens if the stratocumulus clouds over the subtropical oceans should dissolve over a large area. According to his model calculations, this would only happen with a carbon dioxide concentration of 1200 ppm. This value is three times that of today, even in the darkest greenhouse scenarios it is unlikely to be reached.

Nevertheless, Schneider was surprised when he saw the cloud cover over the Pacific and Atlantic evaporate in his model and the world temperature climbed unstoppably - by a full eight degrees. "There seems to be a nonlinearity there that we did not know before," he says. "This shows how poorly the stratocumuli have been understood so far."

Stevens, meanwhile, rather fears that it is the cumulonimbus clouds that could unexpectedly cause discord. Tropical storm systems are notorious for their unpredictability. "The monsoon, for example, could be prone to sudden changes," he says.

It is possible that the calculations of the fine-mesh computer models allowed to predict such climate caprioles early. "But it is also conceivable that there are basically unpredictable climatic phenomena," says Stevens. "Then we can still simulate so exactly and still do not come to any reliable results."

That's the worst of all possibilities. Because then mankind continues to steer into the unknown.