Climate Science II

The Complex Stuff

Just because it's complex, doesn't mean we can't make good predictions!

Hundreds of millions of years ago, tiny creatures and swampy plants breathed in vast quantities of carbon dioxide, storing it in their bodies. They stored enough carbon to perform a sort of global air-conditioning service for us, turning the Earth's inhospitable atmosphere into one in which mammals like us could thrive. Over millions of years, the remains of these organisms became the coal and oil that now power our cars, iPods and air conditioners.

As power plants burn this fuel and release all that stored-up carbon, it sets off a complicated chain of events. The Earth's climate may be one of the most complex systems ever studied, but the endgame is simple: Releasing that carbon into the atmosphere will eventually undo what that ancient life did. That story begins in "Climate Science III—The Bad Stuff."

Complex as it is, the role of carbon dioxide in our evolving climate is well understood. The question is not whether we understand the mechanisms—we do—but how accurately we can predict the future. The climate system is "chaotic," meaning there are ways it is stable, but also ways it can change rapidly into something quite different.

Predicting chaotic systems is like predicting hurricanes. You know one is coming—and soon—but you can't say exactly when. Not being able to give a precise day and time doesn't mean you don't understand hurricanes, and it doesn't mean you can't give meaningful predictions. No one in Florida doubts the prediction that more hurricanes are coming or the advice that they should fortify their homes, even though no one can say exactly when it will happen. The same goes for predictions about climate change.

People sometimes think that since we can't predict the weather two weeks from now, we can't predict the climate 20 years down the road. But that assumes that weather and climate are the same thing. For example, we have no idea what the weather will be like on December 10, 2030, in New York City. But we do know that the average temperature in December of that year will be lower than the average temperature in June. Climate predictions are not about particular events; they're about trends and probabilities. We're pretty good at those predictions.

The ice at the poles reflects sunlight and heat back into space. As the ice disappears, the dark water that replaces it will absorb heat.

What makes climate so complicated? Everything is interlinked: Carbon affects temperature, temperature affects carbon, and temperature affects temperature. This is called "feedback." Positive feedback means a change causes more of the same—things speed up. Negative feedback means a change causes less of the same—a braking system. Positive feedback is a pencil balanced on the tip—any tipping causes more tipping, because it's unstable. Negative feedback is a marble in a bowl—any rolling causes it to roll back, because it's stable. Our climate is a mix of positive and negative feedbacks.

What worries scientists are positive feedbacks, which accelerate climate change. We can't predict exactly *when* positive feedbacks will occur, but we can predict that they *will* occur, and we know what will happen when they do. Two basic positive feedbacks look like this:

Higher carbon levels increase temperature, which increases carbon levels (which increases temperature…).

Right now, the oceans absorb between one-third and half of the carbon we emit. Water and plankton act as a carbon *sink*. When temperatures rise, they'll flip into being carbon *sources*. Climate change will cause itself to speed up. Why? Warm air causes warmer oceans, and just like a can of pop fizzing in the sun, they'll release stored carbon.

Same goes for our great rainforests. The Amazon is a giant carbon storehouse. But rising temperatures cause desertification, and eventually the Amazon will stop absorbing carbon and release it all in one great gasp. Even our soil will flip from a sink to a source. Warmer soil means microbes get more active, releasing stored carbon. That's already happening.[1] It is predicted that by 2040,[2] living systems will begin to release more carbon than they absorb.

There's an elephant in the room—a bigger, badder feedback than either of these. The Arctic permafrost holds huge amounts of methane, a potent greenhouse gas. Were it to be released, it would effectively[3] *triple* the amount of carbon in the atmosphere. It's already happening—lakes in Russia are bubbling with the stuff.

Oceans and rainforests act as a carbon *sink*. When temperatures rise, they'll flip into being carbon *sources*.

Higher temperatures cause higher temperatures (which cause higher temperatures…).

The ice at the poles reflects sunlight and heat back into space, acting as a giant mirror. As the ice disappears, the dark water that replaces it will absorb heat. As temperatures increase enough to melt the ice, it will cause temperatures to increase. Again, this is already happening.

There are all sorts of other feedback effects, but you get the idea. Climate science tries to predict which of these changes will occur at what temperatures and what levels of carbon. It is entirely up to us when (and if) we reach those levels.

The bottom line? It's thought that the really bad stuff—all those positive feedback mechanisms—start to kick in around 450 parts per million, and 500 parts per million is a "no-go zone," where all bets are off and the system might be yanked out of our control. We're at 380 now.

Endnotes

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[1] Bellamy, Pat H., et al, "Carbon Losses from All Soils Across England and Wales 1978-2003," in *Nature*, Vol. 437, Sept 8, 2005

[2] Jones, Chris D., et al, "Strong Carbon Cycle Feedbacks in a Climate Model with Interactive CO2 and Sulphate Aerosols," in *Geophysical Research Letters*, Vol. 30, May 2003

[3] Methane is about 20 times as effective as carbon dioxide at trapping the sun's heat. When I say it will effectively triple the amount of carbon, I mean that the amount of methane released will have the same heating effect itself as twice the current levels of carbon dioxide.