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2 Degrees of Separation

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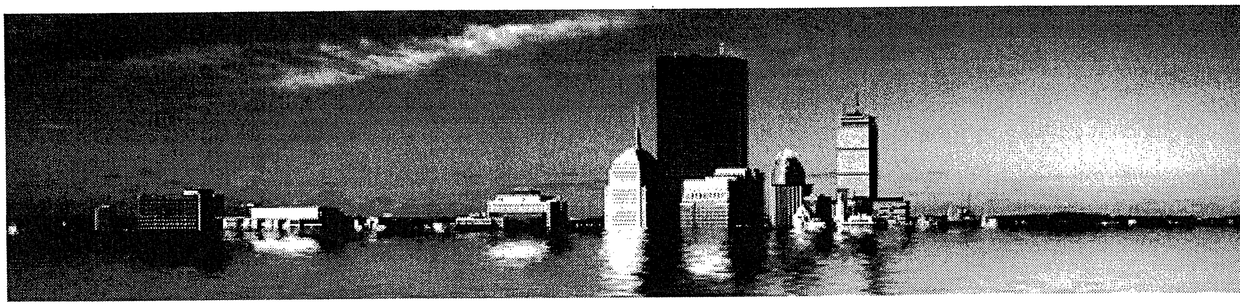
Climatologists fear global temperatures may be reaching a dangerous tipping point. Can humanity handle the heat?

by Gregory Mone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Outside Boston's Faneuil Hall, where American revolutionaries first began clamoring for independence in the 1770s, the water is nowhere in sight. Tourists click photos, office workers hurry across the cobblestone paths, and everyone is perfectly dry. As I look around, I try to imagine a different Boston—a Boston of the future, a city that has to fear the ocean.

This is not an easy scene to conjure. The edge of Boston Harbor is several blocks to the east, on the far side of a small green park on a low hill, held back by a seawall of kelp-covered concrete. When I look over the edge at low tide, the water is a good 15 feet below the bulwark. Even at extreme highs, it never reaches the top. Yet the sea level here is slowly but steadily rising. If the trend continues as predicted, ocean waters could climb several feet in the next hundred years. It would then take only one big storm surge to breach the seawall, just as hurricane Katrina sent floodwaters racing past New Orleans's levees. Faneuil Hall would be inundated by six feet of water, and Boston would temporarily turn into a series of small island neighborhoods.

Extreme flood risk is just one of many dramatic changes that will come with a warmer planet. The average summer temperature in Boston stands to increase by as much as 14 degrees Fahrenheit by 2100, bringing with it a sharp rise in the number of deadly hot spells. In the 1970s this city experienced only one 100-degree day per year. By the 2070s, forecasts call for at least 24 such hellish days annually.

I'm interested in Boston because my family lives here, but many cities across the United States and around the globe would suffer far worse in a warmer world. The extremely flat coastline of Florida is particularly vulnerable to rising sea levels and violent storms; 8 percent of the state, including much of the Everglades aquifer, lies less than five feet above sea level. Warmer, wetter weather there is already fueling an increase in mosquito-borne tropical diseases such as dengue fever. The outlook is even bleaker in Southeast Asia, where overpopulation, poverty, and hot temperatures stand to exacerbate the impacts of climate change.

At this point you may be thinking, "Yes, we've heard all this before." Such doomsday warnings seem almost cliché today because of the rush of books, movies, TV specials, and articles illustrating the most dire climate-change forecasts. For a while, many scientists doubted that such worst-case scenarios would come to pass, because they assumed governments would act to reduce emissions of carbon dioxide and other gases widely believed to be causing global warming. The 2007 International Panel on Climate Change (IPCC), the most authoritative source of climate science, spelled out the likely consequences of inaction, including extreme heat and precipitation, droughts, and rising seas. Some amount of continued warming is inevitable. But with an international ceiling on greenhouse gases, scientists argued, we could limit the rise to no more than two degrees Celsius (about 3.5 degrees Fahrenheit). Even at that level we would face challenges. A two-degree spike could create freshwater shortages, dry out arable regions, and increase the severity of extreme cyclones, but the challenges would largely be manageable (see The Planet Fixers).

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Four years after the IPCC report, there is no international agreement, however. The drive to curb carbon emissions has waned further in the wake of financial meltdowns, global instability, and slumping public confidence in the science of climate change. All the while, the mercury keeps rising. Last year tied 2005 for the hottest year since 1880, when record-keeping began, marking the 34th straight year with global temperatures above the 20th-century average. Climate researchers now find themselves staring down an unsettling reality: In this century, average global temperature may increase more than two degrees C—possibly quite a bit more. Limiting climate change to two degrees is now "a very, very difficult target to achieve," says Mark New, a climatologist at the Tyndall Centre for Climate Change Research at the University of Oxford.

For reasons researchers are still trying to sort out, four degrees appears to be a tipping point beyond which the human risks increase dramatically. Added sea-level rise, shifts in precipitation, and jumps in local temperatures could lead to vast water and food shortages. Nearly 200 million people could be displaced, and many of our standard methods of adaptation to weather extremes—developing new crops, bolstering freshwater supplies in advance of heat waves, responding to disasters after the fact—could have little effect. "In moving from two to four degrees you really do see, in all our best estimates, a major increase in the level of action required," says climate-adaptation expert Mark Stafford Smith, science director for Australia's national science agency. "Suddenly, dramatic adaptation is going to be needed."

The concept of rapid, full-scale mobilization against global warming is a hard sell; dramatic actions are normally driven by immediate threats, not distant, uncertain trends. To most climate scientists, though, the changes are real and upsetting, even if they are years or decades away.

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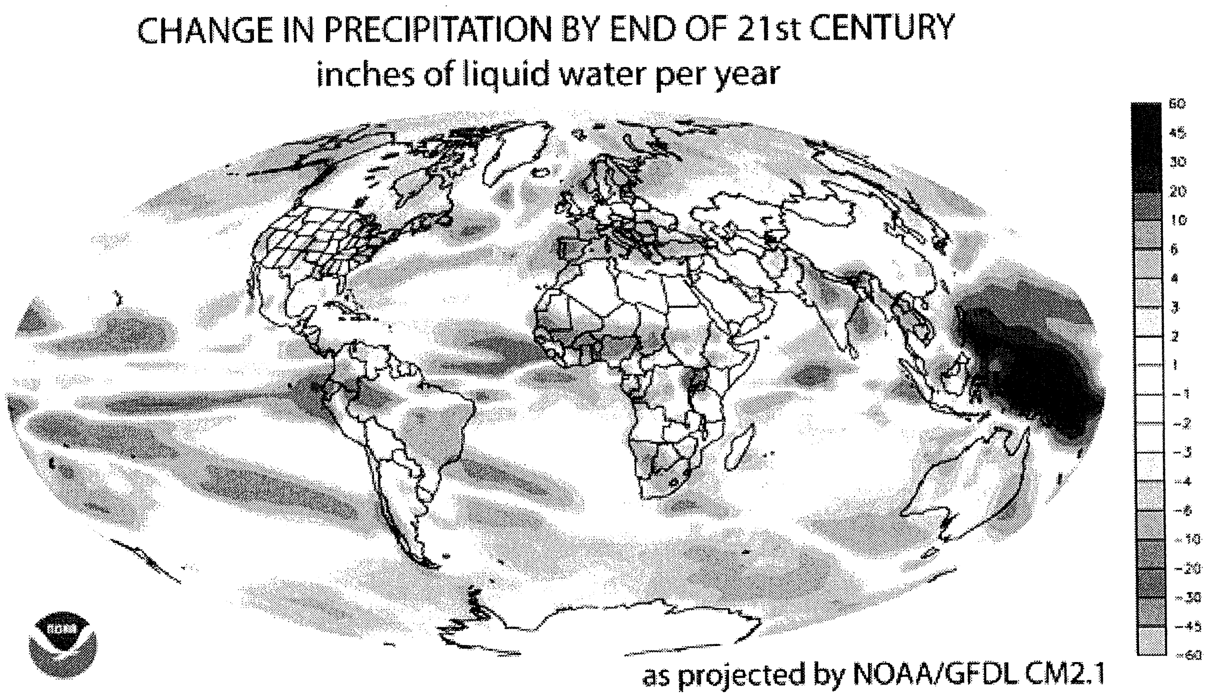

NOAA

As I lean over the edge of Boston's seawall, I try to think through the chain of events that could lift the waters up and send them rushing through the hilly park behind me and back toward Faneuil Hall. Carbon emissions will trap more solar heat, which will increase atmospheric temperatures. This will warm the oceans, causing the water to expand and sea levels to rise.

Actually the process is more complicated than that. Countless additional forces—melting ice sheets, shifts in precipitation, changes in atmospheric and oceanic circulation, to name a few—will influence the process as well. Some regions will feel the impact more than others.

The reality is that there is no simple chain: The future of climate is too complex and too full of uncertainties for one person to fathom. That is why we give computers the job.

The big picture of a future earth altered by climate change comes primarily from intricate simulations called global climate models. These models divide the globe into a grid whose lines intersect every 62 to 124 miles. There are more than 10,000 of these intersections, or grid points, and more than 20 layers of the grid extending up into the atmosphere and down beneath the surface of the oceans. At each grid point, computers churn through equations to determine the winds, temperature, moisture, currents, or other variables at a given moment. Then they run these equations forward in time, solving them at each grid point every 20 or 30 minutes. This way, they can see how the values change over months, years, even centuries.

On a basic level, global climate models are similar to today's weather forecasting tools, explains Jerry Meehl, a senior scientist at the National Center for Atmospheric Research in Boulder, Colorado, and a leading climate modeler. The difference is that in weather forecasting, meteorologists try to predict conditions, such as major storms, at specific places and times. They attempt to figure out where the storms are going to be from day to day and if they're going to intensify or fade. Climate modelers, in contrast, do not attempt to predict weather or track individual storms years into the future. Instead they predict, on average, whether there might be 10 storms per winter in the future, or a certain number of additional hot days in the summer. "It's more of a statistical interpretation of weather," Meehl says.

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Climate forecasting brings many more variables into play than weather prediction does. Global climate models need to account for what Meehl calls "slowly varying systems"—how warmer air gradually heats the ocean, for example, and what effect this warming ocean then has on the air. They have to factor in phenomena like ice melt and its influence on sea level; they also need to consider how the darker land surfaces exposed by melting ice and snow will absorb more of the sun's energy, potentially exacerbating warming in the affected area. The models must track how carbon dioxide and other greenhouse gases cycle through the whole system—how the gases interact with plant life, oceans, the atmosphere—and how this influences overall global temperatures.

Our knowledge of the physical processes that feed the models is continually growing, which only adds to the complexity. Meehl points to clouds. In the future, if our planet has fewer of them, more sunlight will penetrate through to the earth's surface, which could potentially enhance warming. The warming, in turn, could further reduce cloud cover, possibly producing a feedback loop. But if climate change ended up generating more clouds, then these clouds would reflect sunlight, which would most likely have a cooling effect. The world would still warm on average, Meehl says, but the effect would be ameliorated.

Until recently, climate forecasters have not been able to say with confidence which pattern will hold because clouds have been too difficult to model. Scientists know what clouds look like from the ground and from above, Meehl notes, but they have not had a detailed picture of their three-dimensional structure. For researchers like Meehl, who are essentially trying to create a planet in a box, this is a significant gap. "You can't represent something accurately in a model if you don't understand it in the real world," he says. But the situation is improving. NASA's Aqua satellite is currently measuring cloud formations using laser range finders. Armed with those data, Meehl and other modelers will be able to build more realistic pictures of clouds into their simulations, formulating much more confident projections about how clouds will influence future climate.

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Clouds are just one example. Any new scientific knowledge about the global environment, whether the biochemistry of how plants suck up CO_2 and release moisture or the optical properties of sulfate aerosols, is eventually transformed into equations and woven into the computer simulations. "We're putting more and more elements of the physical system into equations in the model," Meehl says, "and it hopefully all interacts and produces something that looks like the world we're living in."

There are more than a dozen widely used global climate models today, and despite the fact that they are constantly being upgraded, they have already proved successful in predicting seasonal rainfall averages and tracking temperature changes. With temperature, the scientists test their models by replaying history. They can wind the clock back to 1850, plug in the known climate variables at the start, then roll the models forward in time and see whether their forecasts match the historical records. So far, they do. Says Meehl, "It's kind of a sanity check."

A major drawback of computer models is that they offer broad, often frightening results without any explanation. Imagine a doctor walking into an exam room, telling you that something terrible will probably happen to your brain in 20 years, then offering nothing but vague shrugs when pressed on the precise what and when, or even whether it might be preventable. All the computers can do is give us a starting point. Then it is up to scientists to work out the specifics (as best they can) of how particular areas will be affected. "We know that these large global mean changes are going to be associated with local and regional changes that are going to cause real problems in some areas," says Andy Challinor, an expert on climate and agriculture at the University of Leeds in England. "The problem lies in working out those details."

When scientists try to understand the local impacts of rising global temperatures, for example, they find immense variation. In a world that's four degrees warmer, many agricultural regions could dry out, become too hot, or both. Overall the planet stands to lose approximately 15 percent of today's farmland. At the same time, other regions that are too cold today could become arable. One study puts the increase at 20 percent, creating a net increase in productive land. If agricultural production were to shift to currently colder climates, we would still have enough food in the United States; it would just be coming from new locations.

But for sub-Saharan Africa, the changes would be far more calamitous. Most of the people there lack access to a secure, inexpensive global food system. They rely heavily on what is grown and raised locally, so they are far more sensitive to local changes in climate. And farming is a huge part of the economy: 60 percent of the workforce is in agriculture. In a recent paper exploring the consequences of a four-degree world, Challinor and his colleagues, including lead author Philip Thornton of the International Livestock Research Institute in Nairobi, Kenya, found that a four-degree rise in temperatures would decrease the length of the growing season by more than 20 percent. Yields of many key crops in the region, including maize, beans, and a kind of grass used for feeding cattle, would drop significantly in an altered climate, the scientists determined.

At the same time, the population of sub-Saharan Africa is expected to double by 2050, surpassing 1.7 billion people. Growing population and declining food production could have a cascade effect: Food shortages lead to hunger, hunger leads to conflict, conflict leads to mass migration and political instability. (It is worth noting that the current unrest in the Middle East coincides with sharply escalating food prices.) To avoid stumbling into this nightmarish future, Thornton and his coauthors say the region will need extensive investment in agricultural productivity, improved data collection to track the weather, organized testing of how crops and livestock will fare in a hotter, drier climate, and a program to educate local farmers. No farmer, they note, will grow a crop he doesn't know.

> "One model tells you it's potentially catastrophic, and others tell you it isn't. You have two physically plausible scenarios. How do you use that in policymaking?"

South America should fare better in terms of agriculture, but it faces its own major loss: the Amazon rain forest. Rising ocean surface temperatures in the tropical North Atlantic, combined with warmer ocean surface temperatures in the tropical east Pacific, will affect atmospheric circulation and pressure patterns, reports climate scientist Richard Betts of the Met Office Hadley Centre in England. According to his climate model, precipitation in the region will shift and possibly decline over the Amazon. This is a proven phenomenon: Atlantic Ocean surface temperature is already being used to predict seasonal rainfall in South America.

In the future, Betts says, a consistent decline in annual rainfall could trigger a feedback loop. The rain forest, which covers 2.3 million square miles, needs a certain amount of precipitation to support itself, and if rainfall drops below that level, the forest could start to shrink. Normally trees extract huge amounts of water from the soil and return it to the atmosphere through their leaves. As the forest shrinks, there would be fewer trees to do that. "You get less evaporation, less moisture in the atmosphere, and less rainfall again. The process can feed on itself," Betts says. "The future of the forest could be threatened."

The caveat is that other climate models yield different results. Betts traces some of the discrepancy to a disagreement about future ocean temperatures in the tropical North Atlantic. (Scientists have not yet been able to determine why the models disagree.) "One model tells you it's potentially catastrophic, and others tell you it isn't," he says. "You have two physically plausible scenarios. How do you use that in policymaking?"

A four-degree-warmer world will therefore demand a range of responses, from immediate and bold to slow and cautious. Australia, for example, faces both near-term and long-term drought risks due to climate change. In the west, water shortages are a reality now, so the country is considering the construction of three massive desalination plants, at a cost of more than a billion dollars each, to create freshwater. Some experts question the wisdom of planning facilities in parts of Australia that might dry up decades from now, and instead advocate water-conservation efforts. Such adaptation could give the region more time to examine its options and make informed decisions. "We've got a lot to do, but we don't have to do it all at once," Smith says.

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That mix of immediate and measured responses is also taking hold here in Boston. Facing the likelihood of more heat waves and heavier rainfall, officials are trying to plan for a future that could strain the city's infrastructure. A few years ago they announced a climate action campaign that includes a goal of reducing emissions 80 percent by 2050. (That is the target the climate scientists wanted the whole world to aim for following the 2007 IPCC report.) There is also a mandate in place to increase the city's tree canopy cover by 20 percent, which would improve air quality and provide more shady refuges on intensely hot days.

Boston still has time to prepare for the threat of rising ocean levels. At the moment, its seawalls are high enough to hold back a major storm. The prudent next step, says Ellen Douglas, a hydrologist at the University of Massachusetts, is creating more precise flood maps of the downtown area. That will help identify the city's vulnerable spots and enable planners to make informed decisions.

And Boston is not the only metropolis bracing for climate change. Virtually every major American city has vowed to reduce emissions and energy consumption. New York City is on track to plant a million trees by 2020. It is also investigating ways to update the building code to protect against more extreme weather events, and to build effective storm-surge barriers. Chicago has some 400 green roofs—covering about 7 million square feet—installed or under construction to absorb rainwater and improve air quality. In Miami, where the city's climate action plan (pdf) calls for a 25 percent reduction in greenhouse gas emissions by 2020, researchers claim that projects to mitigate rising sea levels could also fuel economic growth.

Worldwide, the trend is much the same: Even as nations fail to reach a consensus on carbon-emissions standards, many local communities and municipalities are taking precautions on their own. Helpful as such steps may be, though, they will not be enough to steer us away from a four-degree future unless they are part of a comprehensive, global response. I plan to keep living in Boston for a while and hope my kids will choose to live here as well, so I'm particularly encouraged that my city is doing something about climate change. All the same, it is easy to see why global leaders keep stalling or ignoring the problem. Any detailed, careful reading of the climate models includes a great deal of uncertainty. The uncertainty is maddening, and it gives policymakers a way out of making tough decisions. Uncertainty is not the whole problem, however. If NASA held a press conference tomorrow announcing that a large asteroid is headed our way and that there is a 50 percent chance it will hit the planet in 2080, potentially killing millions of people, surely we would act. We would develop plans to knock the asteroid off track and come up with strategies for evacuating people from its expected impact zone if the deflection plans were to fail.

A large asteroid is a contained, well-defined threat. It is an enemy you can point at. Even an ambiguous threat like a major flu pandemic offers a concrete problem with a concrete solution. Climate change, on the other hand, is a complicated, diffuse, slow-moving set of forces. And yet it is happening. Temperatures are going up. The seas are rising. We might not know its exact size or trajectory, but that asteroid is going to strike, and it is time we got serious about dealing with it.