

Movie Warming

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Today's Science On File, June 2004

Global warming is at the movies, and it's a disaster!

This summer sees the release of director Roland Emmerich's latest total-destruction epic, entitled *The Day After Tomorrow*. In the new film, New York and Los Angeles (along with the rest of the Northern Hemisphere) are annihilated by the extremely rapid onset of a new ice age, all thanks to global warming. This is not the first time the German director has wreaked havoc on the big screen. In his 1996 film *Independence Day*, Emmerich portrayed the obliteration of New York, Los Angeles and other major Earthling cities at the hands (tentacles?) of alien invaders flying gigantic space-saucers. Emmerich's 1998 remake of the classic monster film *Godzilla* confined most of the wreckage to Manhattan (New York is a perennial disaster movie target). The culprit in that film was a gargantuan nuclear-powered lizard.

The crises portrayed in *Independence Day* and *Godzilla* were clearly far-fetched. Global warming, in contrast, is a legitimate concern, and scientists are currently investigating what it could do to our planet. In fact, many experts agree that global warming could disrupt the circulation of ocean currents and throw off weather patterns—just as the film suggests. However, while the basic premise of *The Day After Tomorrow* is scientifically valid, the movie itself is, for the most part, just as absurd as the disaster flicks that preceded it.

"A Critical Desalinization Point"?

In *The Day After Tomorrow*, hero paleoclimatologist Jack Hall of the National Oceanic and Atmospheric Administration (played by Randy Quaid) tells an unconcerned world that global warming is melting polar glaciers into the oceans. This freshwater torrent will shut down oceanic currents, he warns, leading to catastrophic climate change in the near future. (Paleoclimatology is a real scientific discipline that studies the history of Earth's climate by using evidence from geology and paleontology; the National Oceanic and Atmospheric Administration [NOAA] is a real government agency, formed in 1970 as a division of the U.S. Department of Commerce.) Hall's ominous predictions are glibly dismissed as "sensationalist" by the U.S. vice president (Ken Welsh), who claims that the economy is more "fragile" than the environment. It doesn't take a disaster movie scientist to foresee the outcome: later in the film, Hall informs the vice president that "we've hit a critical desalinization point," and cataclysm ensues.

It is true that much of western Europe and the northeastern United States are kept relatively balmy by the Gulf Stream, an oceanic current that begins in the Gulf of Mexico, runs up the East Coast of the U.S., and finally flows across the Atlantic Ocean to Great Britain and Scandinavia. Without the additional atmospheric heat provided by the warm surface waters of the Gulf Stream current, temperatures in these high latitude

regions would be colder by between 2.8 and 5.6 degrees Celsius (5 and 10 degrees Fahrenheit).

The Gulf Stream is a part of the North Atlantic Ocean Current, itself part of a global system of winding ocean currents involved in "thermohaline circulation," also known as "meridional overturning circulation." (The word "thermohaline" comes from Greek *therm-* "heat" + *hal-* "salt"; it refers to an interaction between salinity, or saltiness, and temperature. "Meridional" circulation moves along North-South longitude lines, or meridians.) Like aquatic conveyor belts, these massive underwater currents deliver warm tropical water to the north, and recycle cold arctic water back to equatorial seas. Thermohaline circulation works because both cold and salinity increase the density of water. Thus, warmer water on the surface of the current cools and sinks after releasing its heat into the European atmosphere. This sinking, frigid water joins a deep current that moves south, pushing warm water back up north to continue the cycle.

How could North Atlantic thermohaline circulation be slowed, or even shut down, by torrents of freshwater? Global warming is causing mountain ice caps, polar glaciers, and arctic sea-ice to melt, releasing freshwater into the northern oceans. Furthermore, in a letter published in the April 16, 2004 issue of *Science*, geologist Wallace S. Broecker of Columbia University's Lamont-Doherty Earth Observatory wrote that "computer simulations do suggest that a greenhouse-induced warming would increase the delivery of precipitation and river runoff to the North Atlantic." Freshwater dilutes the concentration of salt in seawater, making it less dense. Therefore, if too much freshwater were added to the North Atlantic Ocean, the arctic water at the northern end of the current would sink less quickly. This would slow the pumping of warm water from the southern tropics. It is also possible that if enough freshwater were added, northern seawater could lose the density required for it to sink deeply. As Broecker observes in his letter, this might shut off the North Atlantic Ocean Current completely: "Given a large enough warming, this excess fresh water could cause the conveyor to sag and, in the extreme, shut down."

There is some evidence that a freshwater infusion to the North Atlantic is currently underway. Worldwide sea levels have risen by almost 20 centimeters (7.8 inches) in the last 13 years. And in the April 25, 2002 issue of *Nature*, Bob Dickson of the Centre for Environment, Fisheries, and Aquaculture Science in the U.K. and his colleagues reported "a widespread, sustained, rapid and surprisingly uniform freshening of the deep and abyssal North Atlantic...over the past four decades." The scientists do not know whether the freshening they observed is directly attributable to global warming, and whether it indicates the early stages of a change in North Atlantic thermohaline circulation.

More recently, scientists discovered that the rotation of a "gyre" (a circular current) in the northwestern Atlantic has slowed significantly during the last decade. This gyre, located in the Labrador Sea south of Greenland, is part of the North Atlantic Ocean Current and interacts with thermohaline circulation. The scientists, oceanographers Sirpa Häkkinen of the NASA Goddard Space Flight Center and Peter B. Rhines of the University of Washington in Seattle, published their findings in the April 16, 2004 issue of *Science*.

They used satellite measurements to detect a slowing of about 20% of the gyre's flow since 1992. It is not known whether this slowdown is due to normal fluctuations in the current, or whether it is caused by global warming side effects such as a decrease in ocean salinity. But in their report, Häkkinen and Rhines caution that "because Labrador Sea processes are intimately linked to the meridional overturning circulation, involving both intermediate-depth and deep waters, these observations of rapid climatic changes over one decade may merit some concern for the future state of the [meridional overturning circulation]" in the North Atlantic.

Timing Is Everything

Before fleeing for the Mexican border or donning arctic survival gear like the characters in *The Day After Tomorrow*, remember: it's only a movie! As director Roland Emmerlich said to *National Geographic*, "In a movie everything is more extreme."

The basic premise of the film—that a global-warming-induced freshwater deluge could disrupt thermohaline circulation in the North Atlantic with serious consequences for the climate of Europe and the U.S.—is a real possibility, and scientific evidence for such a future scenario is accumulating. Global warming, of course, is an undisputed scientific fact—the average surface temperature of Earth has risen by a record 0.6 degrees Celsius (1 degree Fahrenheit) in the last 100 years. Most scientists believe that global warming is caused by human activity. Current atmospheric levels of carbon dioxide (CO₂)—a greenhouse gas released by burning fossil fuels like oil and coal—stand at about 370 parts per million by volume—a 420,000-year record high. (Parts per million by volume [ppmv] is a measurement often used for trace gases in the atmosphere. In this context, parts per million by volume is the ratio of atmospheric CO₂ volume to total atmospheric volume.)

But the rest of *The Day After Tomorrow* is straightforward, if spectacular, science fiction. For one thing, shutting down the North Atlantic Ocean Current simply could not bring on an apocalyptic new global ice age like the one so vividly portrayed in the movie. Glacier and sea ice formation, a prerequisite for global ice ages, cannot take place when Earth's average temperature is rising. If thermohaline circulation in the North Atlantic were shut down, there would be significant cooling only in western Europe and parts of the northeastern U. S. But the consequences of such cooling would certainly be unpleasant. From about 1650 to 1850, a "Little Ice Age" afflicted the region, resulting in harsh, long winters and other severe weather related conditions such as sea storms and glacier enlargement. The Little Ice Age caused serious agricultural, economic, and health problems, especially in Europe: famines, malnutrition, and diseases killed millions of people during this period.

Timing is perhaps the most fictionalized aspect of *The Day After Tomorrow*. It should be obvious that no Earthly storm, however monstrous, could cause air temperature to drop at a rate of 10 degrees Fahrenheit per second, flash-freezing human beings into ice sculptures where they stand (but sparing our heroes, who are able to outrun cold air). It is equally true that a shutdown of thermohaline circulation in the North Atlantic cannot

happen the day after tomorrow, or next month, or even next year. "The Earth's climate is never going to flip in a matter of days the way it does in the movie," Janet Sawin of Washington D.C.'s Worldwatch Institution told *National Geographic*.

Nor is the climate likely to “flip” in a single decade. This is the worst-case scenario presented in a recently declassified report prepared by consultants at the Pentagon. The Pentagon report predicts that famines, refugee crises, nuclear proliferation and resource wars will erupt after a new ice age, caused by global warming, begins as soon as 10 or 15 years from now. In his letter to *Science*, Broecker argues that such “exaggerated scenarios serve only to intensify the existing polarization over global warming.” He writes that “there is no reason to believe that [a shutdown] could occur in a mere decade...the time required for this to happen is more likely a century, not a decade.”

The real problem, as Sawin points out, is that “climate change is already happening now, not the day after tomorrow.” The effects of global warming are local—recent examples include increasingly strong storms in the South Pacific, flooding in Bangladesh, and severe summer heat in Europe (which killed an estimated 35,000 people in August 2003). “What is needed,” Broecker writes at the conclusion of his letter, “is not more words”—or, presumably, more science fiction disaster movies—“but rather a means to shut down CO₂ emissions to the atmosphere. Although we are powerless to accomplish this by 2015, we certainly have the wherewithal to do it by 2075.”

Further Reading:

“Decline of Subpolar North Atlantic Circulation During the 1990s.” Sirpa Häkkinen and Peter B. Rhines. *Science*, April 23, 2004, page 555.

“Global Warming and the Next Ice Age.” Andrew J. Weaver and Claude Hillaire-Marcel. *Science*, April 16, 2004, page 400.

“Climate Change Science: Adapt, Mitigate, or Ignore?” David A. King. *Science*, January 9, 2004, page 176.

“Abrupt Climate Change.” R. B. Alley, et al. *Science*, March 28, 2003, page 2005.

“Rapid Freshening of the Deep North Atlantic Ocean Over the Past Four Decades.” Bob Dickson, et al. *Nature*, April 25, 2002, page 832.

Internet Resources:

“Abrupt Climate Change Paleo Perspective.” (<http://www.ncdc.noaa.gov/paleo/abrupt/>) From the Paleoclimatology Branch of the National Climatic Data Center at the National Oceanic and Atmospheric Administration (NOAA), a website with information about climate change events in the history of Earth.

“Environment Report—Climate Change.”

(<http://www.newscientist.com/hottopics/climate/>) Latest science news and information about climate change, from *New Scientist*.

“Global Warming”

(www.ucsusa.org/global_environment/global_warming/index.cfm) Union of Concerned Scientists’ website on global warming, with FAQs, policy reports, links, and other resources.

“Intuitor Insultingly Stupid Movie Physics” (www.intuitor.com/moviephysics/) A very funny website about physics in the movies, with detailed analyses of gross errors in physics from a number of films. Includes a review of Emmerlich’s *Independence Day*.

“The Little Ice Age in Europe.”

(www2.sunysuffolk.edu/mandias/lia/little_ice_age.html) Detailed information about the Little Ice Age and its effects in Europe.

Keywords for electronic searches:

global warming, greenhouse gas, climate change, abrupt climate change, thermohaline circulation, meridional circulation, Little Ice Age, paleoclimatology, The Day After Tomorrow