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THE CLEAREST EVIDENCE YET THAT
Earth is warming and that CO2 emissions are largely responsible was presented by researchers in February at the annual meeting of the American Association for the Advancement of Science (AAAS), in Washington, D.C.
The researchers also presented evidence that increasing concentrations of atmospheric CO2 may be causing some biosystems, such as coral reefs, to approach the threshold for damage. If global temperatures rise more than 1.5 °C over todays level, the world's tropical coral reefs may be irreversibly destroyed, they said.

Beginning in the 1960s, the average temperatures of surface waters in all of the world's major oceans began to rise, said T'uII P Barnett, research marine physicist at Scripps Institution of Oceanography. 'The results of computer models simulating the rise in ocean temperatures from increasing levels of atmospheric CO2 are nearly identical to temperature measurements taken since 1960 at various oceanic depths, he said.

"This is perhaps the most compelling evidence yet that global warming is happening right now and it shows that we can successfully simulate its past and likely future evolution," Barnett explained. For the Pacific, Atlantic, and Indian Oceans, graphs representing computer generated temperatures are almost identical to the plots of actual temperatures, he observed. "The models have captured the observed warming with stunning realism."
The warming experienced across the globe will have practical effects on water supplies, Barnett said. During the summer, 300 million people in China depend, in whole or in part, on meltwater from glaciers for drinking and irrigation. By 2050, two-thirds of these glaciers will have disappeared, he noted.

"There is ample evidence that the planetary water cycle is already altered as a result of global warming," said Ruth Curry, research specialist in physical oceanography at Woods Hole Oceanographic Institution. In the past four decades, oceanic surface water at low latitudes has become markedly more saline, while the high-latitude

surface ocean has become much fresher, she said.

One reason for the freshening is the melting of Arctic sea ice, Curry explained. (Sea ice is always less saline than ocean water because of a distillation effect during sea ice formation.) Another reason is the melting of the Greenland Ice Sheet. Greenland used to be in mass balance-new snowfall balanced summer meltwater from the ice sheet each year. "But now Greenland is melting faster and faster," she said. A third reason is that there is more rainfall in northern latitudes, resulting in a larger annual discharge from Eurasian rivers into the Arctic Ocean and from there into the North Atlantic. "Too much freshwater added to key locations in the North Atlantic-the areas where surface water falls to great depths-would disrupt ocean circulation and its transport of heat," she said.

The circulation in the NorthAtlantic has switched off in the past, "but we don' t know if it will switch off in the future," Curr explained. If salinity and thus density of the North Atlantic keep declining, however, "the conveyor belt will stop," she warned. In the North Atlantic, the conveyor draws warm tropical waters northward, moderating winter temperatures in Northern Europe.

The Arctic Ocean is undergoing dramatic changes because of global warming, said Sharon L. Smith, a professor of marine biology and fisheries at the University of Miami. From 1979 to 2003, the extent of summer sea ice in the Arctic declined 20%. In 1997, an unpredicted and unprecedented change in the ecosystem of the Bering Sea led to the deaths of hundreds of thousands of short-tailed shearwaters, probably from starvation. A surface layer of calcifying single-celled plants prevented the seabirds from seeing their krill prey

At the same time, populations of walrus, seals, and polar bears are declining because they depend on sea ice for foraging, birthing, and resting, Smith said. If current CO2 emissions trends continue, the Arctic is likely to be ice-free in summer sometime in this century

RICHARD A. FEELY, supervisory oceanographer at the National

Oceanic & Atmospheric Administration' s Pacific Marin Environmental Laboratory, said that rising CO2 concentrations in the atmosphere have led to greater CO2 uptake by the oceans. This process of acidification from carbonic acid has already changed the saturation state of the ocean surface water-the first 100 meters-with respect to calcium carbonate, he said. Eventually, if the CO2 concentration in the atmosphere reaches 700 ppm-which is likely during this century-the carbonate ion concentration would drop 48%, and eventually the coral reefs' ability to produce CaCO3 structures that make up the reef systems would cease. The carbonate ion concentration of the surface ocean has already been reduced 16%.

"Terapods-free-swimming marine mollusks-are currently reacting to the changed conditions by dissolving their shells," Feely said. "What we do know for sure is the calcification rate will be reduced by 15 to 45% as a result of acidification," he said. These changes will have profound impacts on the health of coral reefs. By 2060, if present trends continue, "tropical corals will all be in a marginal state," he said. "There is no evidence that corals will be able to adapt to these changed conditions."

"Economic models of climate change typically assume that changes occur gradually and reversibly," said Klaus Keller, assistant professor of geosciences at Pennsylvania State University. "Some environmental effects, however, show threshold responses. For a long time, very little happens, and then suddenly a large change occurs." Three of these are widespread coral bleaching, collapse of the West Antarctic Ice Sheet, and collapse of oceanic circulation systems, he said.

A global temperature increase of just 1.5 °C over today' s averag level could cause widespread and irreversible coral bleaching, Keller warned. This temperature increase is expected before 2100 unless strong near-term action is taken to reduce CO2 emissions, he added. ' The West Antarctic Ice Sheet may di integrate in response to greenhouse gas emissions, according to Keller This would lead to a global sea level rise of around 6 meters, which would inundate half of Florida and many of the world' major cities. It could also disrupt global oceanic circulation

patterns, he observed.

ANOTHER WAY to look at it is that a rapid rise of atmospheric CO2 to 500 to 700 ppm might cause the North Atlantic meridional overturning circulation-the ocean conveyor belt-to collapse, Keller explained. This would mean that warm tropical waters would no longer warm Northern Europe. One trigger for the collapse could be the melting or partial melting of the Greenland Ice Sheet.
It may not be feasible to limit the global temperature increase to 1.5 °C, Keller warned. "But if you want to limit the temperature increase to 2.5 °C, you have to decarbonize the economy during this century" he said. In other words, society must start deriving energy from sources other than fossil fuel or find some way to sequester the CO2 from fossil fuel.

Keller pointed out that "these predictions of threshold responses are deeply uncertain because of uncertainties in the structural models and in observational constraints." Resolving the uncertainties could have considerable economic benefits, he said.

All of the scientists who spoke during this AAAS session agreed that, despite uncertainties about when climate thresholds will be reached, near term action should be taken to reduce emissions. If society waits for the research that will nail down the thresholds with greater clarity, it may well be too late to avoid exceeding them, they said. "If we don' t reduce CO2 emissions now then futur generations may bear the cost," Keller said.