CLIMATE CHANGE

Sky-High Findings Drop New Hints of Greenhouse Warming

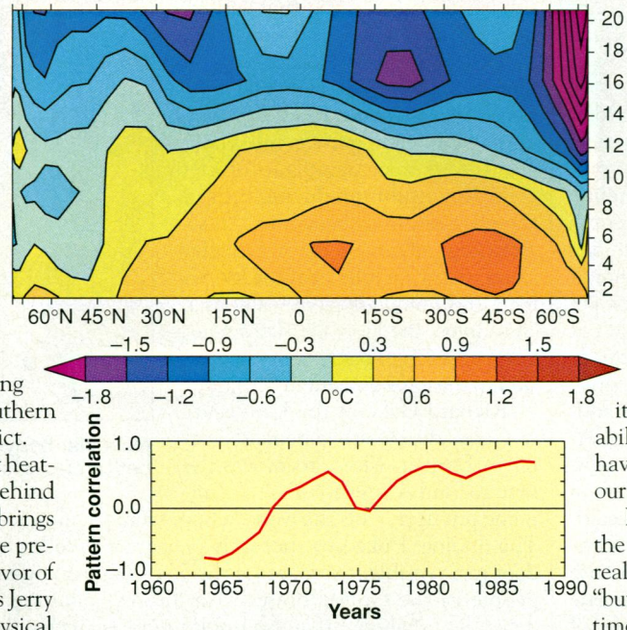
Last December, an international panel of climate scientists released a report saying that despite many lingering uncertainties, the balance of evidence suggests a discernible human influence on global climate. That conclusion was spurred in part by research that had picked out the distinctive signal of greenhouse warming amid the tapestry of surface temperature changes wrought by natural variation and sun-shielding pollutant hazes. The final version of the report from the Intergovernmental Panel on Climate Change (IPCC) has come under fire from industry groups, but its conclusion is now gaining new scientific support—this time from the upper atmosphere.

In this week's issue of *Nature*, Benjamin Santer of Lawrence Livermore National Laboratory and colleagues conclude that the recent pattern of atmospheric temperature change, at altitudes of up to 20 kilometers, is unlikely to reflect only the natural vagaries of climate. As telltale signals, they cite worldwide cooling high in the atmosphere and warming in lower layers, especially in the Southern Hemisphere—just what models predict.

Scientists still can't be certain that heat-trapping gases in the atmosphere are behind the warming, but this latest study brings researchers "much closer to where the preponderance of evidence is clearly in favor of a real change caused by humans," says Jerry D. Mahlman, director of the Geophysical Fluid Dynamics Laboratory in Princeton, New Jersey. "It's a very careful, deliberate piece of work. This is by far the closest [we've gotten] to a smoking gun." The new study doesn't change the tentative, caveat-hedged conclusion of the IPCC, adds Neville Nicholls of the Australian Bureau of Meteorology Research Center in Melbourne—indeed, IPCC scientists were aware of a preliminary version of this result last year. But the new paper makes their conclusion "a little bit more secure," says Nicholls.

Santer, who was lead author of a crucial chapter in the recent report and has come under personal attack for his role (*Science*, 21 June, p. 1734), led the new study but worked closely with a dozen co-authors at six institutions. He says the new work is a logical extension of earlier results on surface climate change (*Science*, 16 June 1995, p. 1567). "If you saw it there you'd expect to see a similar thing" above the surface too, he says. So he and his colleagues posed the same question about the upper atmosphere that had been asked about the surface: How closely does the observed pattern of climate change resemble the pattern predicted by computer greenhouse models?

To find an answer, they used models that included emissions of the greenhouse gas carbon dioxide and pollutant hazes, which should respectively warm and cool the lowermost 10 or 12 kilometers of the atmosphere, called the troposphere. Here the models predicted an uneven warming: Because more pollutant hazes hang over the Northern Hemisphere than the Southern Hemisphere, the warming would be moderated in the north.



SOURCE: SANTER *ET AL.*, *NATURE*

Warming up. Observed temperature changes in the atmosphere between 1963 and 1987 *(top)* correlate increasingly well *(above)* with model predictions of human-induced effects on climate.

Another model predicted the effects of the recent decline in ozone (due to other pollutants) at higher levels, up in the stratosphere. It forecast worldwide stratospheric cooling, as the decline in ozone decreased the absorption of solar ultraviolet radiation; increasing carbon dioxide would add to the cooling because the gas radiates heat. Lower in the atmosphere, that heat warms the globe, but in the upper layers it is radiated into space.

When researchers compared these predictions with temperatures measured by weather balloons from 1963 to 1987, the patterns were similar. Just as predicted, the stratosphere had cooled, and the troposphere had warmed about half a degree more in the south than in the north. And the match improved over time, as all three climate drivers intensified in the real world. "In order to get the best match between the observations and the model predictions," says Santer, "you need to incorporate greenhouse gases."

The Santer study "is probably one of the most convincing pieces of work done to date," says Tim P. Barnett of the Scripps Institution of Oceanography in La Jolla, California. Still, he says, "I'm not 100% convinced" that the greenhouse signal has been detected. "We're getting closer to being able to say so with some confidence, but there's still a number of nagging questions."

One question that the study addressed but could not answer with confidence was the possibility that the match between model and data could be due to a chance climatic fluctuation. There are no long records of atmospheric temperatures, so the team compared observed variations with variations in three different models, each run for hundreds of model years without any external forcing such as greenhouse gases. The resulting "natural" variability was much less than the recent observed variations. Of course, these are models, not the real atmosphere. "The major uncertainty is the credibility of the model estimates of natural variability," concedes Santer, but "they would have to be wrong by a factor of 2 to make our results nonsignificant."

But meteorologist Michael Wallace of the University of Washington fears that's a real possibility. "It's good science," he says, "but I'm a bit skeptical of the idea that every time we see something in the recent record that we haven't seen before, it must be due to greenhouse warming." Wallace's own work has shown that the accentuated wintertime warming seen on the high-latitude continents—a part of the surface greenhouse pattern or "fingerprint"—can also be caused by natural variations in atmospheric circulation. That serves as a warning that other parts of the fingerprint may turn out to be "really ambiguous," he says.

Santer recognizes the concern that natural variability might be masquerading as greenhouse warming but wonders whether the greenhouse itself might be increasing the natural variability. Exploring that idea is part of the work still to be done, he says. Meanwhile, international negotiators will meet later this month in Geneva to discuss placing more stringent limits on greenhouse gas emissions. Santer's latest work—and its caveats—will no doubt be on their minds.

–Richard A. Kerr