Dusting the Climate for Fingerprints

Has greenhouse warming arrived? Will we ever know?

By RICHARD MONASTERSY

After lurking in the back pages amid the ads for the past few years, the topic of global warming has once again clambered onto the front pages of newspapers around the world.

In recent months, an iceberg nearly as large as Rhode Island broke off an Antarctic ice shelf, apparently because of rising temperatures there. A statistician declared that the seasons have slipped out of sync with the calendar, perhaps because of greenhouse gas pollution. And just in time for a climate summit in Berlin 2 months ago, a German research team reported finding an abnormal pattern of change in climate records that does not correspond to any known natural causes.

Although the annual average global temperature has risen by about 0.5°C since the late 19th century, investigators have had difficulty determining whether natural forces or human actions deserve the blame. But in late February, Klaus Hasselmann, director of the prestigious Max-Planck Institute for Meteorology in Hamburg, Germany, stepped forward to point a finger.

The Max-Planck researchers find it highly improbable—only 1 chance in 20—that natural forces caused the temperature rise during the last century.

Environmental groups attending the Berlin climate summit rallied around the recent findings. Proof of greenhouse warming has arrived, many trumpeted.

Not quite, say Hasselmann and other researchers intimately involved in the hunt for human influences on climate. Recent developments do indeed bolster the theory that greenhouse gases have reset Earth's climate dial. But scientists acknowledge that uncertainties continue to plague studies aimed at detecting the human fingerprint in climate change—a distinctive change attributable only to human activities. Proof remains elusive.

What's more, researchers warn that the public should not hold its breath waiting for the unambiguous detection of human-caused greenhouse warming. Studies aimed at such a detection, while illuminating, will never give a definitive answer. "From the scientific point of view, I think it's just a sport, frankly. I really think it's wrong to pin all one's hopes on this proof," says Hasselmann.

Sport or not, the search for a greenhouse fingerprint has become the rage among climate scientists. As the name suggests, such efforts resemble the methods employed by police trying to crack a crime—especially the new technique of DNA fingerprinting, which has figured prominently in the current trial of O.J. Simpson.

In the forensic process of DNA fingerprinting, investigators compare a suspect's complex DNA pattern with samples found at the crime scene. In the case of global warming, the purported crime scene is the environment, and greenhouse gases are the prime suspects. Clues such as out-of-sync seasons (SN: 4/8/95, p.214) or giant icebergs (SN: 4/29/95, p. 271) do not, by themselves, implicate any one culprit. Researchers must sift through climate records for specific patterns that could only arise from the effects of greenhouse pollution.

What does the fingerprint of greenhouse warming look like? Hasselmann's group and others use computer climate models to calculate the kind of abnormal signal that human tinkering with the climate might create. The German team generated an anthropogenic, or human-caused, climate change by slowly boosting the amount of greenhouse gases in the model's atmosphere, starting from 1935 values. As the simulation progressed through the decades, a greenhouse fingerprint emerged: a specific pattern of global changes with temperatures increasing most dramatically in the interior of continents.

The team then compared this pattern with available temperature records for the period 1854 through 1993. Using statistical analyses, they tested how closely their computer-generated fingerprint matched the observations.

To solidify their case, Hasselmann's team had to address the same concerns that confront experts who use DNA fingerprinting in a criminal trial. Just as prosecutors must convince juries that the forensic technique will not implicate the wrong person, climate researchers must argue that their fingerprinting methods do not yield false matches.

Because natural factors can alter climate, Hasselmann and his colleagues needed to estimate the extent to which conditions can vary on their own. Ideally, this information would come out of the available climate data. But useful regional records of surface temperatures reach back only 140 years, not nearly long enough to give a full picture of the kind of changes that nature alone can produce. Moreover, the records are probably compromised because they contain changes wrought by greenhouse gases and other pollutants.

So the researchers again turned to computer climate models. To estimate Earth's own variability, they let the climate model run for 1,000 years, with greenhouse gas concentrations locked in at modern values. They also removed the estimated contribution of greenhouse gases from the climate observations to obtain another gauge of natural variability.

Pulling the entire case together, Hasselmann and his coworkers estimate a 95 percent chance that the observed climate changes exceed the range of natural variability. In a paper to appear in the JOURNAL OF CLIMATE, they declare the recent warming abnormal. But they do not take the next step, which would be to attribute the warming to greenhouse gases.

"We simply think the probability is very high that we can see a human impact. But we're not saying that we have detected it. That's a too deterministic statement," Hasselmann says.

Several hurdles stand in the way of making clear-cut declarations about climate change. Hasselmann notes that the fingerprinting study relies on estimates of natural variability taken from a computer model. If these calculations are incorrect, then the German group may have underestimated the chance that Earth itself caused the observed pattern. Moreover, the model estimates of natural variability don't include volcanic eruptions and solar fluctuations, two features that can alter climate and skew the detection tests.

The study currently in press also suffers because it left out the influence of sulfur pollution, which exerts a cooling effect on industrial regions. The German researchers have included this factor in more recent computer runs. That addition tempers the simulated warming over the United States and other regions, bringing the model fingerprint more in line with actual observations and increasing the statistical significance of the detection work, Hasselmann says.

As the techniques used in these detection efforts improve, researchers have edged closer toward identifying a signal of human-induced warming in the climate record. Aside from the German study, teams at the Lawrence Livermore (Calif.) National Laboratory and at the Hadley Center for Climate Prediction and Research in Bracknell, England, are also searching for a human signal.

"It would be premature to claim unambiguous detection and attribution of some human influence on climate. But preliminary evidence suggests that if you believe the model signal and the model noise, something unusual is going on," says Benjamin D. Santer of Lawrence Livermore, who participated in the German study. Santer also served as lead author for a chapter on detection that will appear in an upcoming report of the Intergovernmental Panel on Climate Change (IPCC).

Thomas R. Karl of the National Climatic Data Center in Asheville, N.C., also sees current experiments pointing toward successful detection.

"The bottom line on a number of these studies is that if one considers both the greenhouse [factor] and the sulfur aerosol [factor], then one comes much closer to seeing an anthropogenic effect in the climate record," he says. "And a number of these studies are very close to the 95 percent significance level. But if you really wanted to be unequivocal, you'd probably like to see that there is less than 1 chance in 100 that you could be misled."

That level of certainty—99 percent statistically significant—might take a while, however. In an article published in the Jan. 21, 1994 SCIENCE, Stephen H. Schneider of Stanford University wrote: "For the detection of anthropogenic climate signals, we must recognize that a goal of 99 percent statistically significant signal detection over the next decade or two is unrealistic."

For scientists, the recognition of greenhouse warming will never come from a specific detection study or any single observation. Rather, it grows from a steady accumulation of evidence. "Detection and attribution will be an evolutionary, not a revolutionary process," says Livermore's Santer.

What's more, some scientists now voice the conclusion that they misled the public by giving false hope for unequivocal detection of changes caused by greenhouse gases. Researchers always strive for more certainty by ruling out alternative explanations. But they can never reach the 100 percent level, even in establishing a link between smoking and cancer.

"I am beating very hard on the community to drop forever from our vocabulary that pernicious term 'unambiguous detection,' " Schneider told SCIENCE NEWS.

In the case of greenhouse warming, scientists warn that built-in delays in the climate system compound the potential dangers of waiting for certainty. Greenhouse gas pollution emitted into the atmosphere this year will take decades to warm the atmosphere and oceans. So society has already committed to a certain amount of warming.

If government leaders want to head off the potential for greater changes, they will have to act before ever seeing the major effects of greenhouse gas pollution. At the climate summit in April, 115 countries agreed to negotiate a treaty on emissions reductions by 1997, but they did not specify the extent of such cuts (SN: 4/29/95, p. 271).

Santer, Schneider, and others draw a distinction between the needs of scientists and policy makers when it comes to seeking answers. "We're talking about being very certain about things when we talk about 99 percent or 95 percent certainty," says Santer.

But politicians often take actions in the face of uncertainty, balancing risks on one side versus risks on another. "A politician usually takes a decision at a far lower level of confidence about things," Santer says. "They don't wait until they are 99 percent confident. Decisions are made against a background of substantially greater risk." □

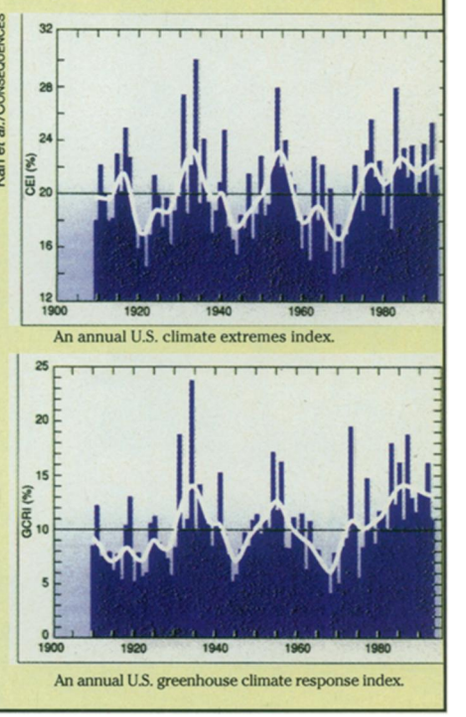
A greenhouse fingerprint in the United States?

U.S. meteorological records contain hints of a climate knocked askew by greenhouse gases, a new study concludes. But scientists say they cannot rule out the possibility that the changes represent natural variations.

In the spring issue of the journal CONSEQUENCES, Thomas R. Karl and his colleagues at the National Climatic Data Center report that precipitation and temperature in the United States have been reaching high and low extremes more often in recent years. An index of such extremes of weather (top graph) has averaged 1.5 percent higher since 1976 than during the previous 65 years.

The scientists also detected a 2.8 percent increase since 1976 in an index designed to track the changes expected from greenhouse warming (bottom graph). Those changes include above normal minimum temperatures, above normal winter precipitation, extreme summer drought, and extreme 1-day precipitation events.

"We see changes in the climate record that are at least heading in the same direction that one would anticipate from a greenhouse world," Karl says. Because the changes remain subtle thus far, scientists cannot firmly link them to rising concentrations of greenhouse gases. "But the odds are that they probably are related," Karl says. "If you do a statistical test, you would say that that is most likely to be the case." —*R. Monastersky*



An annual U.S. climate extremes index.

An annual U.S. greenhouse climate response index.