action, and they tell themselves, "I'm going to get out there and say whatever it takes." Some of these guys may well be acting on their true view of environmental protection. If you see what I'm saying.

Q: Yes, but the [Rep.] Claudine Schneider [R-R.I.] bill is very explicit in specifically calling for the U.S. to cut off all loans to the Third World nations which would invest money in building up industry there. She claims that this must be stopped because it would aggravate the greenhouse effect. She also proposes that hydroelectric plants not be built because that destroys the land and rain forests. Instead, she proposes that the Third World use wood as an energy source and raise sugar cane to make ethanol to replace gasoline. From the work I have done this is a major reason why the rain forests have been destroyed.

Wood: Yes, I don't know the particulars, although I have a copy of the bill. But I think your point is well taken. The complexities are very great. Even if the nations of the world decided that climate change is a top priority issue, what you decide to do about these things is not straightforward, because this is such a complex area.

Q: Several of the scientists that I have interviewed state that not only has the Earth not warmed, but there is a lot of evidence that the Earth is actually cooling. Is it possible that we are entering a new glaciation?

Wood: The evidence that is clear is that in geologic terms, we would be expecting to see close to the end of this interglacial period. There is a great deal of evidence that the interglacial periods are normally around 10-12,000 years long. It's hard to estimate exactly, but there's been roughly 11,000 years since the last glacial period. This is based on evidence from ice cores, from sediments in interglacial lakes, and so forth. It would make geological sense normally to expect an ending of the present interglacial period soon, but can you say whether that's happening right now, or in 100 or 500 years, or maybe even 1,000? It could be today, but then again it could be a few hundred years down the line.

In terms of the current indicators, I've tried to look at most of them, and I will say this—that supposedly we had in the last decade, the warmest decade on record according to Jim Hansen and others. There's been, at least as far as I can find, no indication that there's been a reduction in snow cover, or in alpine glaciers, or in the ice sheets during that period of time. Now I don't know that they have increased either. But, I guess what I'm saying is, it is hard for me to find the evidence that there is a global glaciation. But on the other hand, the indicators that one would have expected to be detected from the kind of warming that we have had, or allegedly had, haven't been turning up either.

One thing you have to keep in mind here is that this warming that we've been having has been observed at the lower latitudes and not at the higher. That could be a way to possibly explain why there hasn't been a radical change in snow cover, because if, in fact, the warming is not at high latitudes, then you wouldn't expect to see a change. But, if *that* is true, that is not consistent with the usual scenario, where you have amplified warming in the high latitudes. So, I guess what we're saying here is that the evidence at the moment is not really supportive of the original greenhouse warming theory.

Interview: Kevin Trenberth

'Warming trend has been exaggerated'

Dr. Trenberth is from the National Center for Atmospheric Research (NCAR) at Boulder, Colorado.

Q: I've been talking to a number of people on their criticisms of the greenouse effect.

Trenberth: You probably already found out that there are some people who are emotional at both extremes. I would be somewhere in the middle. I'm certainly familiar with the data. The people who have often been the stronger advocates, have tended to ignore inconvenient facts that perhaps don't show things quite as strongly as they might like at this time.

I think there's no question that the greenhouse effect is a real thing. I think it's very clear that the climate in the future is going to be different from what it has been in the past. Where the main scientific debate is occurring, I think are the questions—how quickly is it going to be different, how will it be different, and how much will that difference be?

One of the main things used as a basis for making statements about this, is climate models of various kinds. Some people have tended to believe the results of climate models, much more than I think is warranted, and have tended to make statements that I think cannot really be justified, because if you look at two different climate models, they give you two different results.

There is quite a lot of uncertainty as to exactly what climate change will occur in an individual location. For example, there is a fairly nice graph figure that has been put together by Jones and Wigley which shows trends in temperatures, over the Northern Hemisphere, over the last 40 years. What it shows, is regions where the temperature has increased, and regions where it has decreased. And in fact, over the last 40 years, that's a particular period where there hasn't been very much net change. Because any time you

look at a trend, it's fairly sensitive to when you start and when you finish that trend.

And the thing that's revealing about that, is the variability from place to place. And I think that's one thing which is not fully appreciated—is that although people speak of global warming, it's not going to be warming everywhere. There will be places that get colder, and there will be places that get warmer, and on balance, maybe it'll be a little warmer; but exactly what happens in any given location, is much more uncertain than I think has been generally appreciated.

Q: On Hansen's models, specifically, I have a couple of questions. How reliable is his data base?

Trenberth: He got his data base from NCAR, which is the institution I'm with, here. He did very little quality control on the data, so that there are some bad data in his record, which has influenced his conclusions a little bit. But aside from that, I think that he has somewhat misrepresented the temperature curves which he has produced. People talk about global temperature trends, what has happened globally. Well, it turns out, of course—this will probably make sense to you, but it hasn't been properly appreciated—that there are many places where there aren't observations—in particular, over a lot of the oceans, and especially over the Southern Hemisphere oceans, I estimate that about 45% of the Southern Hemisphere oceans really can't establish reliable trends. This is especially south of Australia, New Zealand, all the way down to Antarctica—all of the southern oceans, there are just no observations down there, and no one is down there making observations to make reliable trends. Over Antarctica, we only have data since the International Geophysical Year, which is 1957-58. So you can establish trends over Antarctica after that period, but prior to that, you really can't do it. So, there is a big chunk of the globe that is not very well represented, in the so-called global trends.

So these global trends really are, in some ways, approximations of what has happened. That's the nature of one of the problems. But the second problem is, what happens when you have these results: How representative are they of true climate change? And the main issue that arises there, is the issue of how much is due to things like carbon dioxide, which affects global climate, versus how much is due to the so-called urban heat-island effect.

This is the effect of taking a thermometer and making measurements in a specific place, but then you build a city around the place where you're making measurements! Or, if your thermometer is out at an airport, you go from an age of propeller-driven aircraft, to a great big jetport, with a tremendous amount of traffic and a lot of concrete and so on; and you're building that around the place where you're making your measurements! And there have been some good estimates of that for the U.S. now, and it shows, for Hansen's curve for the U.S., that quite a large fraction—in fact, the dominant fraction of his temperature increases—appear to be due to urbanization effects, rather than due to what you might call greenhouse effects. But that can be quantified.

That's a pervasive problem in making measurements throughout the globe. Another place where it can be documented, to a limited extent, is in Australia. I think the urbanization effect is perhaps not so much related to population, as it is to, say, the amount of roads, or the amount of concrete in the area. And there are no good numbers on that; but a lot of the development that has occurred in, like, African countries—a lot of that has occurred in the last 40 years or so, since the war.

I suspect that a lot of the urbanization effect is being seen in those records. But I don't know that there are good numbers, to say how much of that is urbanization, and how much is a real carbon dioxide effect. So it's a little bit up in the air, from my standpoint. There, there has been apparently some warming—I think some of the warming is real—but it's been exaggerated, again, by urbanization effects. And I think that's in not only Hansen's, but also Jones and Wigley's records of temperatures.

So that's the comment that I would make on the temperature records. I think there is something in there, but the biggest problem is, that most of the warming appears to have occurred around the 1920s. There appears to have been sort of a jump in temperature, according to the climate record, from 1880 to 1910 or thereabouts. And during the 1920s, there was a jump. However, as I mentioned before, since 1946—the past 40 years, in fact, even since the 1930s and up to the present time—there hasn't been very much of a warming trend. In fact, it was colder in the 1960s. So there is a sort of up and downward trend, if you like.

Q: Could the trend in the 1980s—which Hansen claims is the hottest period in the last 100 years—be the result of the fact that thousands of meteorological stations were closed down in the U.S.?

Trenberth: There is a complicating factor here. One of the things that has happened is that weather observations, which used to be done in the U.S., for example, by the National Weather Service, have tended to be turned over to commercial enterprises, which do not have the same quality standards. There is a standard procedure for making measurements. They are supposed to be taken over a grassy patch of a certain reasonable size—at least a few square yards in area—and they are supposed to be taken four feet off the ground.

You need what is called a ventilated screen. The thermometer is supposed to be sheltered from the sun; otherwise you would be just measuring the temperature of the glass in the thermometer, rather than measuring the temperature of the air. So it's supposed to be sheltered; but it's also supposed to be ventilated, with a reasonable flow-through of air, so it's not measuring only the little piece of air that's right in that spot. It's supposed to be representative of an area around

that space.

That's supposed to be standard. But what has happened, especially in cities these days, is that radio stations, for example, have thermometers in all kinds of strange places, like the top of a roof or somewhere. And these non-standard kinds of exposures may be included in data readings. That's one factor. The other factor is that a lot of places have started to automate the recording of temperatures. So that instead of doing it with a thermometer—and the tradition, the most accurate, is mercury in a bulb, a glass-bulb thermometer—what is being used more, are thermisters, and these are electronic devices. That's fine to a certain extent, but the problem is that the calibration on these can drift with time. So here too, quality control becomes important. You have to go back and check on a regular basis; probably a couple of times a year, at least—to check that the electronic recording device is measuring the correct value.

Q: How much scientific truth do you think there is behind what's being published in the media today?

Trenberth: My evaluation of that, is to say that there has indeed been some warming, but it's been quite small, and to date, my assessment is that it is not outside the realm of what you would say is natural variation. The temperatures that we've had—it's even hard to get a good handle on exactly what's happened in the last couple of years; because some of the data are still not in.

Q: What other aspects of the greenhouse effect do you think are important?

Trenberth: The oceans are enormous; they have a tremendous heat capacity, it gets distributed throughout the depth of the oceans. It only takes one meter or so of the ocean—I don't remember precisely but it's a very small amount—and you've got the same heat capacity as the entire atmosphere! That is to say, that if you took a 1°C increase in temperature of the atmosphere, and put it into the ocean, it would only warm up the top meter or so of the ocean. And the ocean is deeper than 4,000 meters in some places.

Q: What would you suggest should be done about the greenhouse effect, in the short and the long term?

Trenberth: Well, one of the things that has been discussed, is to try to draw a parallel between carbon dioxide and other greenhouse gas increases, and the problem of the ozone hole. Now, on the ozone hole, what they did was to have a so-called Montreal Protocol, where there was an international agreement to decrease the amount of chlorofluorocarbons in the atmosphere, because of the threat to the ozone layer. Now, reducing CFCs is one of the things that will also help the greenhouse problem. That is one thing that could be strengthened even more, is to get rid of those CFCs; that would be one thing.

But one of the things that has been bandied around, is: Should there be a similar kind of thing for carbon dioxide. And my assessment of that is that it's unlikely to occur? And one of the reasons for that is because you're talking about a climate change. With the ozone hole, I think there was much more convincing evidence that the effects were bad for everybody. In the case of climate change, it's not clearly going to be bad for everybody. In fact, when you talk about climate change, you should be aware that in some places, the climate is likely to improve in some respects, and in other places it will get worse. In fact, there are almost inevitably going to be winners and losers. And one of the possibilities, for instance, is that the American farmer might be a loser, relative to a Canadian farmer. So why, then, should the Canadians want to agree to limit the carbon dioxide, if they think they might benefit?

Over-warmed data?

The blackout by major U.S. media of the prevalent view of the greenhouse effect in the scientific community, was finally broken by an article by Patrick Michaels published in the *Washington Post*'s Sunday Outlook of Jan. 8. Michaels wrote, "Attempting to squash one side of a scientific story is a treacherous business that can have only a negative outcome."

The alleged warming of the Earth may just be the result of faulty data, according to Michaels: "Twentieth-century U.S. temperature data, which formed a part of NASA's [Hansen's] congressional testimony last year, hide a drastic warm-measurement bias. NOAA scientist Tom Karl, who arguably knows more about regional climate variation than anyone in the world, has calculated that NASA's record over the U.S. has warmed up nearly a degree during this century mainly because cities tend to grow up around their weather stations, not because of the greenhouse effect. . . . Karl's finding surprised none of us who daily toil with the data. But it should be a major shock to those who are using those figures for policy purposes. Is it irresponsible to point this out in public?. . .

"Surprisingly, the Antarctic ozone depletion was three times less severe this past winter than it was in 1987. No proponents of the anthropo-generated ozone depletion model and none of the computer simulations expected such a big change. The total concentration may indeed have been in the 'natural' range that should occur there most every year."