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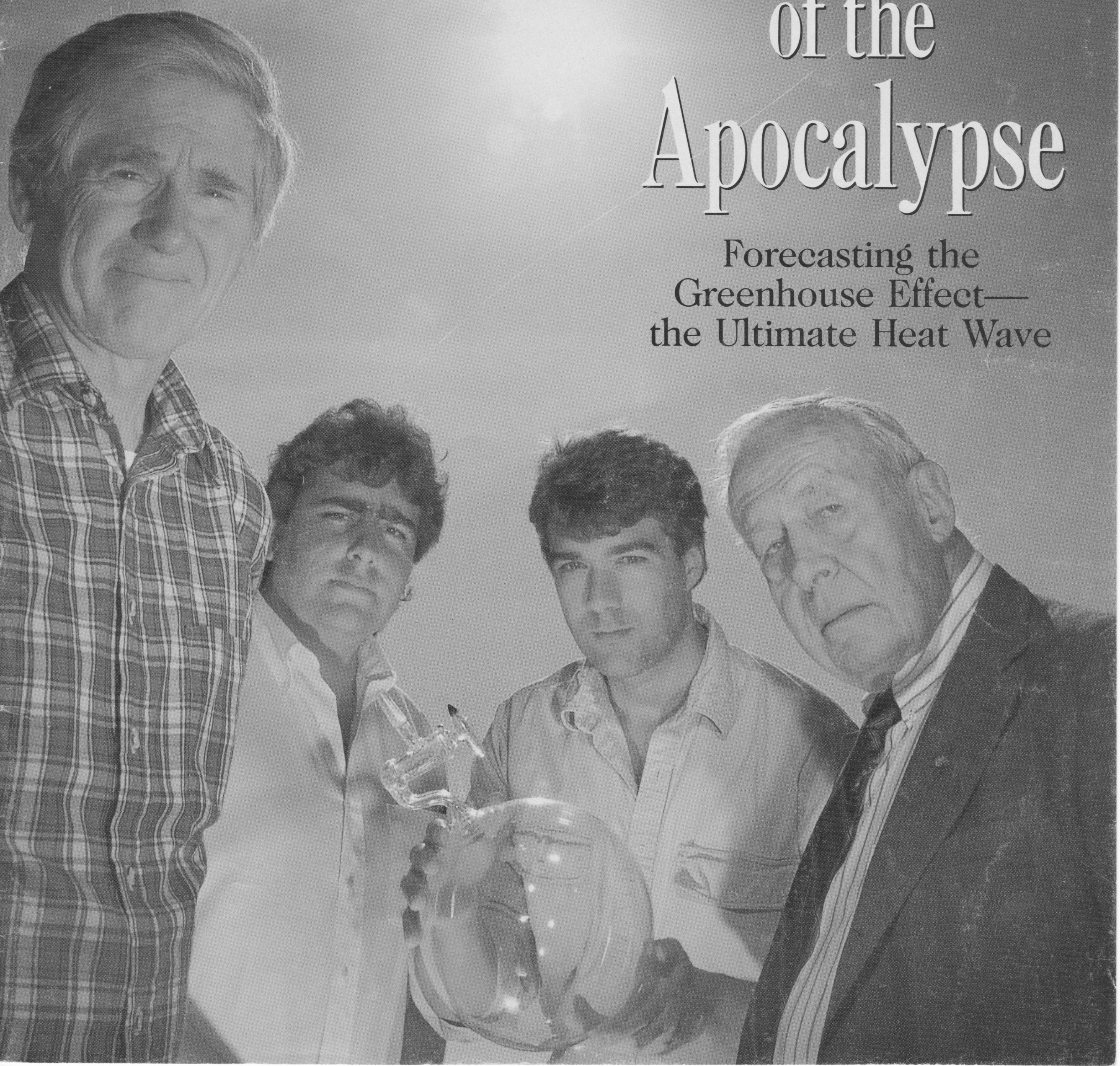
Weathermen of the Apocalypse

Forecasting the Greenhouse Effect—the Ultimate Heat Wave



Five Weathermen of the Apocalypse

The Experts at Scripps Are Trying to Predict What Will Happen When the Ultimate Heat Wave Hits

BY MICHAEL ROGERS

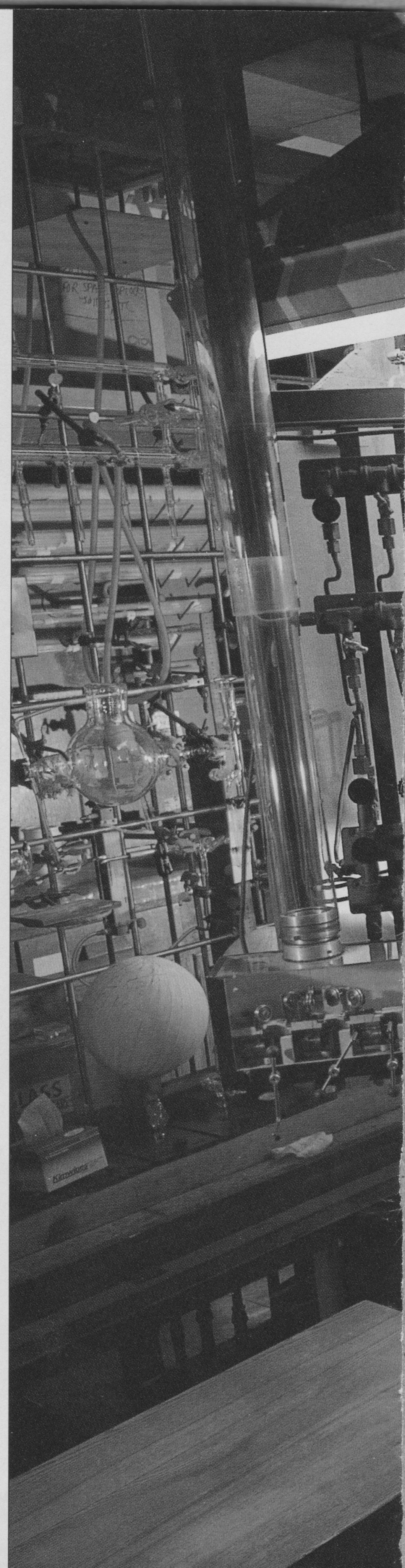
PHOTOGRAPHED BY FREDRICH CANTOR

CONSIDER THE WEATHERMAN: clown prince of the evening news, perpetually ribbed by jovial anchors for once again failing to predict last Saturday's downpour. But there is a new class of weathermen at work today, and their gaze is fixed not on next weekend but next century. Theirs is a one-time, never-to-be-repeated forecast, not quite yet ready for prime time.

So far, it looks like bad news. But how bad? And how certain? Among themselves, the new weathermen are already clearing their throats nervously. Trouble, they agree, almost certainly lies ahead. But one problem remains: What, exactly, do they tell the rest of us?

The villain is the greenhouse effect, a phenomenon now making headlines that in fact has existed for millions of years. And a good thing, too: The greenhouse effect is the planet's mantle of gases, primarily carbon dioxide, that traps the sun's heat, as do greenhouse windows. Without that insulation, our planet would be about 50 degrees cooler, and the Beach Boys would sing about ice hockey.

But we may yet curse the greenhouse effect, for humans are gradually increasing the heat-trapping gases in the atmosphere by burning coal and oil. At the same time, we're destroying the tropical rain forests that in ages past helped remove carbon dioxide from the atmosphere through photosynthesis. By increasing our insulation, we will probably raise temperatures to record highs. The augmented



Roger Revelle, left, was one of the first to theorize that global warming was a threat, in the 1950s; research by Charles Keeling, shown in his Scripps lab, confirmed the theory.

greenhouse effect could unleash floods, droughts, hurricanes, famines, runaway weed growth, mass extinctions of animals and plants and the generalized end of life-as-we-know-it. All this, moreover, could happen within the life span of anyone who can remember "The Brady Bunch."

The disasters haven't started yet. But this exceedingly gradual threat has already changed the lives of many researchers who previously toiled in obscure scientific pastures. This is a story about five of them—two who launched the greenhouse theory decades ago, and three others who are building careers on the concept. All work at Scripps Institution of Oceanography in La Jolla, but their disciplines vary—atmospheric chemist, meteorologist, geophysicist. One manipulates imaginary models within computers, another ships bottles of air halfway around the world. But all of them are also now weathermen of the apocalypse.

RICHARD SOMERVILLE hesitates. As head of Scripps' Climate Research Group, he stands at the forefront of international climatology—weather on the grand scale. A visitor has just asked what seems a simple question: Is greenhouse warming already changing our weather? Somerville is momentarily gazing out the window. Tan and fit in his mid-40s, he has a mildly aristocratic air and a corner office that overlooks an expanse of beach. On this spring morning, the fog has lifted and the Pacific is an ideal shimmering blue, dotted with surfers, a few of them Scripps researchers. This is a campus replete with wet suits, surfboards and offices with towel-bars. But it's no party school: Scripps, officially part of UC San Diego, was instrumental in turning oceanography, once a rich man's hobby, into an accepted science. Scripps was also the birthplace of the greenhouse warming theory.

Today, along with half a dozen other institutions, including MIT and Columbia University, Scripps is on the leading edge of trying to predict just what may lie ahead. "Let me put it this way," Somerville says finally. "There's no disagreement in the scientific community: The greenhouse effect is a problem. We differ on the warming we expect, how quickly it will occur and how it will be distributed over the earth. But there's remarkable unanimity that it's a very, very real problem."

A brief sampler of worst-case scenarios: If global temperatures indeed rise during the next few decades and polar icecaps begin to melt, by 2050 ocean levels could threaten the homes of 40 million coastal residents worldwide. Manhattan might require levees to hold back the tides; Malibu would be a disaster zone. Persistent drought would cripple the corn and wheat belts of the United States. Chicago would overlook acres of mud that had once been Lake Michigan. Northern California would suffer severe spring floods and summer parching. As the Colorado River basin dried, Los Angeles would find its water supply cut by half.

Somerville doesn't like to talk about global disaster. He was trained as a traditional meteorologist, specializing in weather prediction: showers on Thursday, clear for the weekend. "But," he says, "my interest just grew, from tomorrow's weather, to next week's, to the next season's climate, to the decades-long scale of the greenhouse effect."

Now Somerville oversees a research group totaling 25 people, a clutch of costly computers and joint projects that involve laboratories from Los Alamos to Hamburg. The Climate Research Group studies topics ranging from next winter's precipitation to predicting the onset of the Indian monsoon. "Climate," Somerville says, "is the sum total of weather. For me, the dividing line is around a few weeks—that turns out to be the scientific limit on how far one can hope to predict the weather in a specific place."

Increasingly, Scripps researchers gaze into the next century. They are trying to answer two fundamental questions. One is about the greenhouse effect itself: How did carbon dioxide cycle through the oceans, green plants and living organisms during the eons before humans started burning coal and oil? The second, broader question: How will increasing global temperatures affect our climate? This second question requires some notion of how the vast machine of planetary weather works to begin with. Not for the first time, humans are desperately trying to

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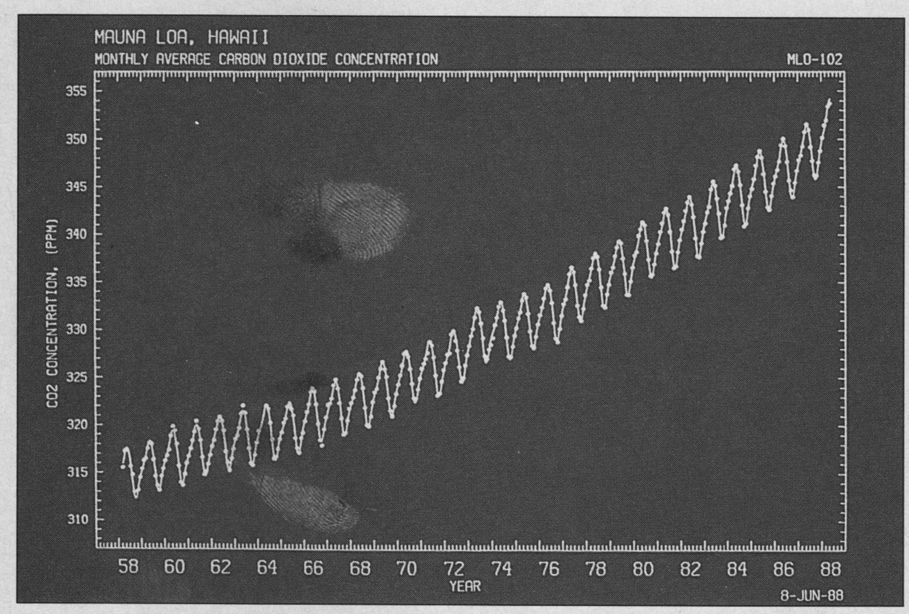
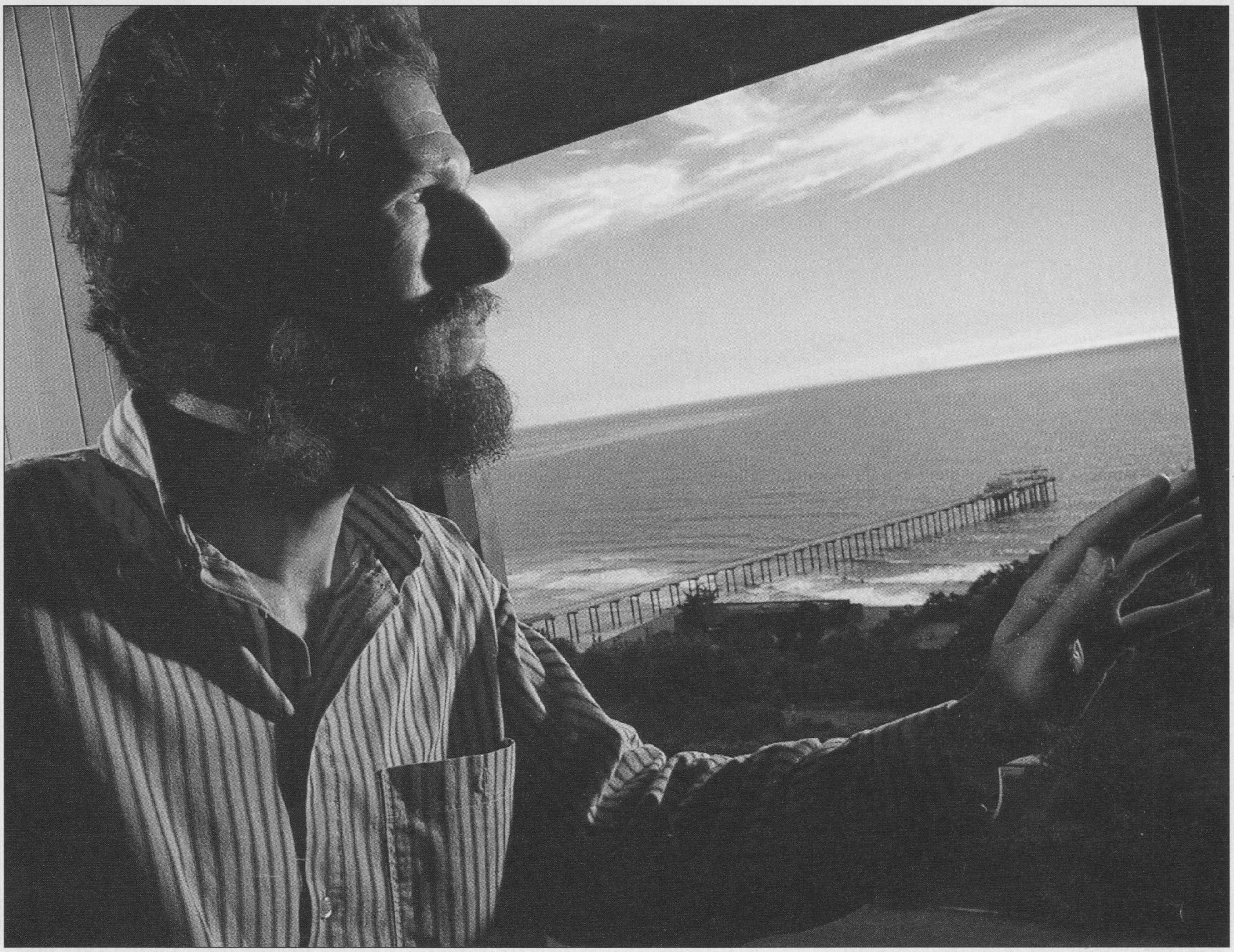


THE KEELING CURVE: The relentless increase of atmospheric CO_2 is demonstrated by measurements made by Keeling at Mauna Loa Observatory. The graph's fluctuations reflect changes in the CO_2 level caused by the natural life cycle of plants.



Richard Somerville, a meteorologist specializing in the study of clouds, oversees the 25-person Climate Research Group at Scripps.

understand natural phenomena even as we are in the midst of altering them.

Today, a single copy of the Journal of Atmospheric Sciences is as thick as a year's worth of issues from 1962, when Somerville started his work. But each year of science seems to produce as many new uncertainties as answers. For example, it's an accepted scientific notion that weather comes from the interaction of the atmosphere and the oceans. But the finer details of how air and sea interact remain mysterious, and that is why researchers such as Somerville pull back from specifics about the greenhouse effect.

"There are lots of feedback loops in the climate," he says, "each like a thermostat in your house. As our climate gets warmer, they'll come on. They may turn on the air conditioner, which is good. But they may turn on the furnace, and warm it up even more. And there are a lot of these thermostats, all connected to a lot of air conditioners and furnaces. And some thermostats even seem to be connected to other thermostats."

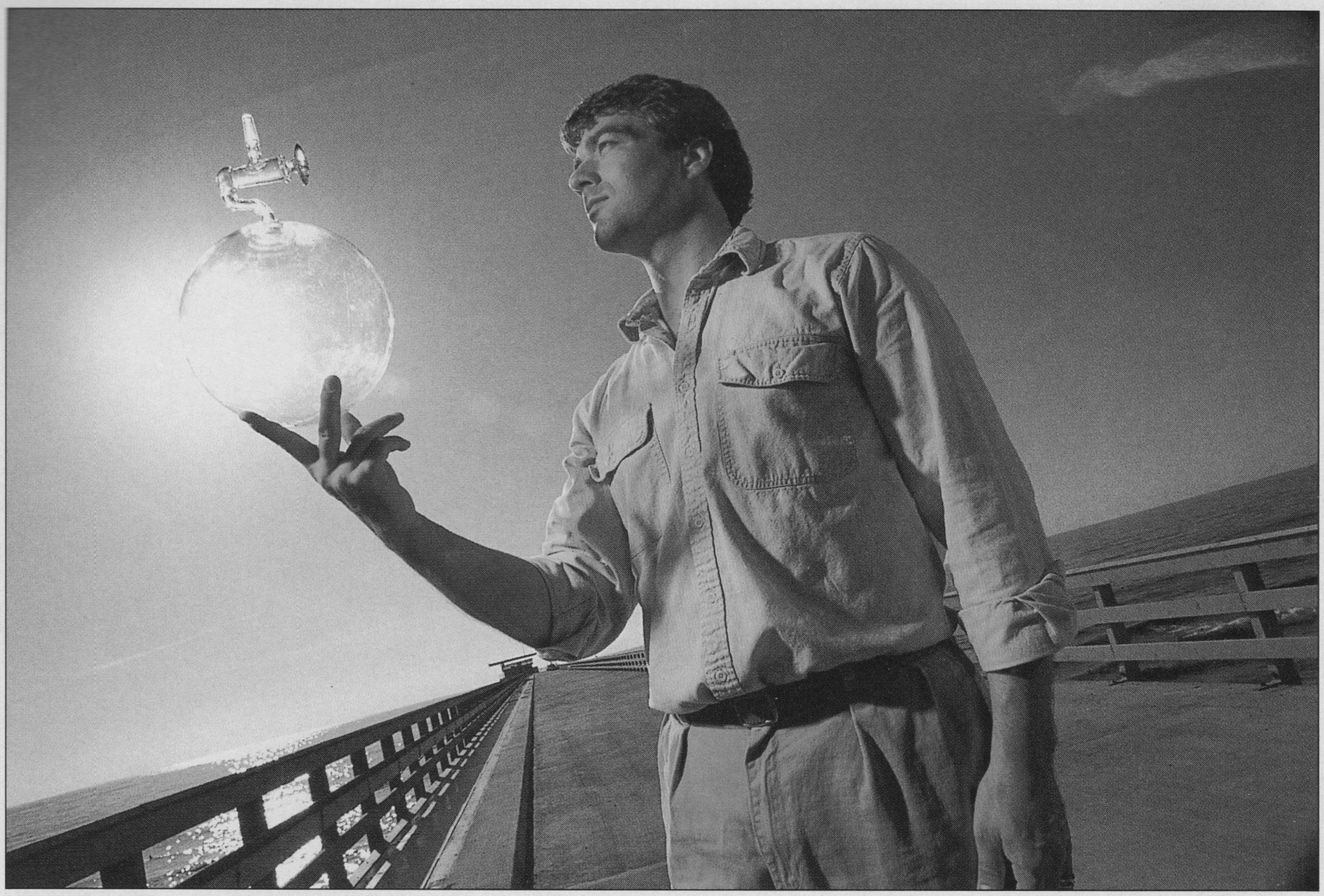
Michael Rogers is a novelist and a senior writer for Newsweek. His most recent novel, "Forbidden Sequence," is about human genetic engineering.

Somerville specializes in one thermostat: clouds. As the climate warms, more moisture will evaporate from the oceans, and the earth will grow more cloudy. But will the clouds reflect solar energy away from the planet and act as an air conditioner? Or will the additional water molecules in the atmosphere trap more infrared radiation—behaving like a furnace? No one knows. "Society rightly wants to know answers about the greenhouse effect," Somerville says, "but sometimes science isn't in the position to provide them. When a congressman asks, 'What will the weather be like in my district in the 21st Century?' we can't yet give an answer to rely on."

When can he expect one? Somerville hesitates. "With new satellite data and faster computers, the uncertainty will decrease. But if we don't understand how the climate works in the first place, the fastest computer in the world will just be solving erroneous equations more quickly."

ROGER REVELLE knows what it is to overturn erroneous equations. Revelle, 80, director emeritus of Scripps and scion of an influential San Diego family, is probably the most formally dressed fellow on campus, clad in gray flannel slacks and a blue blazer. Revelle is also, for practical purposes, the father of the greenhouse warming theory.

Revelle wasn't the first to ponder the topic. Just before the turn of the century, Swedish scientist Svante Arrhenius (whose grandson now teaches at Scripps) theorized that human activities might add to the natural greenhouse effect. But at the time, scientists believed that the oceans could absorb



With a doctorate in oceanography and a degree in law, Justin Lancaster plans to tackle public-policy prescriptions for global recovery.

as much carbon dioxide as our factories and fireplaces could pump out. Microscopic organisms at the sea's surface absorb carbon dioxide as they grow, then die and sink miles to the bottom, where the carbon sits for centuries.

Even so, in the mid-1930s, a mild global warming trend was under way, and an English scientist named G. S. Callendar warned that greenhouse warming might be possible. But then a spell of cold winters ensued, scientists dropped the topic and the world happily went about pumping additional billions of tons of CO_2 into the atmosphere for two more decades.

In 1957, Revelle and Hans Suess, another Scripps researcher, sounded a caution that the ocean wasn't going to bail us out: Only about half of the carbon dioxide gets the deep six. In their paper, they observed dryly that, in putting back into the atmosphere much of the carbon now stored in such fossil fuels as oil and coal, "mankind in spite of itself is conducting a great one-time geophysical experiment." Says Revelle: "It did not occur to me that we'd really have a serious climatic change. I'm not a prophet. I was a scientist and thought we'd learn a lot from it."

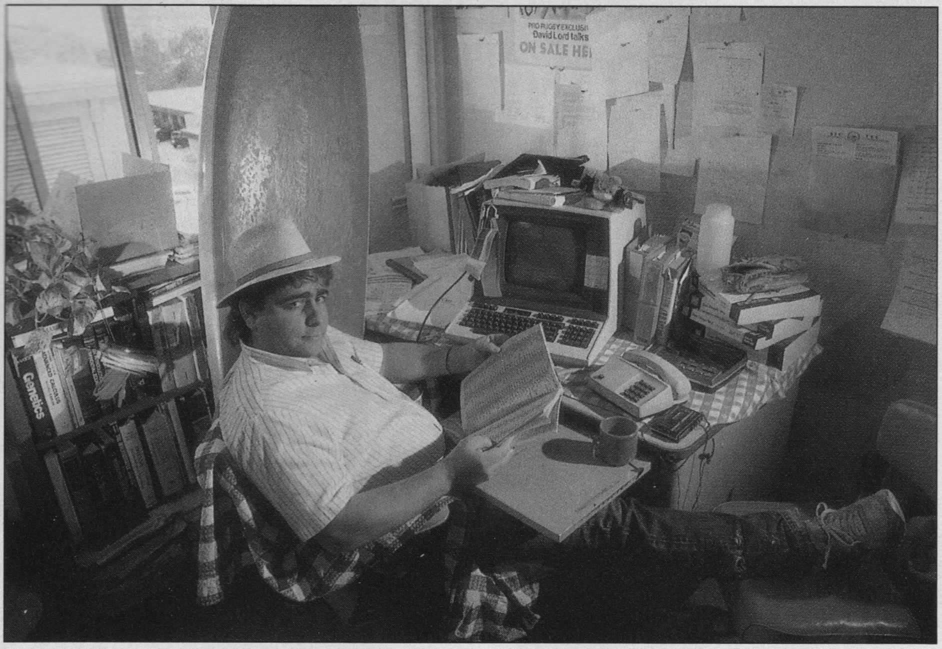
"Dr. Revelle," Time magazine said, "has not reached the stage of warning against this catastrophe, but he and other geophysicists intend to keep watching and recording."

As it turned out, someone was already watching: a young Caltech postdoctoral student named Charles Keeling, who had seized upon the then-thorny problem of measuring the amount of CO_2 in the atmosphere. Thorny because, according to conventional wisdom, CO_2 concentrations varied widely, depending on when and where you took a sample. Keeling, however, was the first to monitor CO_2 levels over a sustained period. In taking measurements from Corona del Mar to the White Mountains near Death Valley, he discovered something surprising: The amount of carbon dioxide in the atmosphere is really quite constant from one place to another.

It was a propitious time for global curiosity. The 1957 International Geophysical Year was under way, an ambitious, well-financed international effort to learn more about the basics of the planet. Revelle, already influential in national science, lobbied hard for the IGY to include CO_2 monitoring and, moreover, helped put the unknown Keeling in charge. Keeling set up monitoring stations atop Mauna Loa in Hawaii and at the South Pole, choosing locations far from any sources of man-made CO_2. He found that even at those remote spots, the CO_2 concentration was very similar to that of California's.

Within three years, Keeling's figures would reveal ominous news: The amount of CO_2 in the atmosphere was rising, precisely as feared. Revelle's 1957 warning proved correct: The oceans absorb only half the CO_2 that human activities churn out. The "Keeling curve," the smoking gun of the greenhouse effect, is now a classic chart in atmospheric chemistry: an undulating but gradually ascending line that begins in 1957 and climbs unabated to this day. The fluctuations reflect the life cycle of plants in the Northern Hemisphere—absorbing carbon dioxide in the spring, releasing it as they decay in the fall. But the relentless ascent is entirely man-made.

The implications are profound. Revelle pulls out a graph that displays



David Erickson captains computers that attempt to simulate the earth's weather system.

Keeling speculates that the world will cool down before it heats up again. But 'by 2040 or so, the greenhouse effect will be upon us again—in spades.'

average global temperatures during the past million years. "The entire temperature range from an ice age to the warmest interglacial period is about four degrees. That's just about the best estimate for the greenhouse-effect increase also." Right now, the earth is in an interglacial period—it's as warm as it ever gets on this planet. When another few degrees are added during the next 50 years, Revelle says softly, "we're moving the climate into uncharted territory."

CHARLES KEELING, a slender, unassuming man of 61, still works in the same small laboratory where, three decades ago, he confirmed the encroaching greenhouse effect. The laboratory looks its age, with racks of handblown glassware and cabinets finished in yellowing oak. Out in the hallway are big wooden shipping crates packed with air samples freighted in from sampling stations around the globe. "Grab samples," they're called, air captured by hand in glass globes slightly smaller than soccer balls, often wrapped in surgical tape. Keeling's assistants carefully siphon each globe's contents through an elaborate tracery of glass, determining—in parts per million—just how much carbon dioxide each sample contains.

"The rate of rise," Keeling says, "has actually accelerated during the past 10 years over what we expected." It may be that increased deforestation of the Amazon is already changing the planet's ability to absorb CO_2. Or else warming in the far north latitudes is melting permafrost, releasing CO_2 into the atmosphere.

The Keeling curve is now accepted by scientists worldwide. Yet the rise in CO_2 hasn't yet translated itself into a similarly ascending chart of temperatures, and that has caused no end of scientific debate. In all probability, the complex interactions of atmosphere and ocean, combined with the centuries-long natural temperature fluctuation, so far have masked the added heating. "Temperature is so variable," Keeling says. "Europe just had a very warm winter, the Pacific Northwest had a cold winter. You can't blame them both on the greenhouse effect, although the Europeans are suspicious."

Last summer's Midwestern drought probably wasn't caused by the greenhouse effect either, any more than was the Dust Bowl of the '30s. In Keeling's view, serious droughts may be more likely these days because of greenhouse warming, but he hesitates to say more. Another Scripps researcher puts it this way: Last year's drought, a century ago, might have ended a few days sooner.

Last June, in the midst of the drought, a NASA researcher named James Hansen made headlines when he told Congress that he was "99%" certain that greenhouse warming had already started. And earlier this month, Hansen told the media that the administration had softened additional testimony he was planning to give on imminent greenhouse dangers.

For researchers such as Keeling, the public interest caused by Hansen's bold statements is encouraging. Early this year, the Bush Administration announced increased funding for greenhouse effect studies. But beneath the temporary boost lies a deeper fear: What happens when it gets cold again?

Hansen's second move into the limelight already showed the administration's reluctance to believe that the worst could happen. And although this decade has seen the six warmest years of the past century, with 1987 and 1988 the hottest of those, Keeling says that in all likelihood, the world's climate will get colder again in the 1990s, perhaps even setting new records for chill winters.

"We'll have to wait about 20 years," he says, "and then we'll break heat records again. The 2010s will be even hotter that the 1980s. There will be another whole set of discussions about the greenhouse effect—and then it might get cold again. But then, the next time around, by 2040 or so, the greenhouse effect will be upon us again—in spades."

DAVID ERICKSON, heavy-set, cheerful, looks like a guy with whom you could have a few beers and shoot some pool. But at the moment, he's communing with a computer terminal,

Continued on Page 46

Weathermen

Continued from Page 16

logged on long-distance to a Cray supercomputer somewhere in the mountains of Colorado.

Erickson, 28, is of the generation of scientists who will make their reputations on the greenhouse effect. Growing up in Rochester, N.Y., he never saw the sea until he was 12; then he became fascinated with the ocean and atmosphere. His degree is in atmospheric chemistry; ironically, now that he's at oceanographers' heaven, he rarely ventures out on research vessels to sample the atmosphere. Instead, he captains supercomputers—the multimillion-dollar machines that are the fastest computers on the planet. "I've never been without a Cray," he says. He now has accounts on six state-of-the-art supercomputers spread across the country. That points up a profound change in the field: When Erickson's boss, Richard Somerville, wrote his thesis 25 years ago, he struggled to find a few hours on a "supercomputer" less powerful than the Apple Macintosh on which he now writes letters.

Erickson's specialty represents the future of weather research: He uses supercomputers to run immense mathematical models that simulate the earth's weather system. A model is an elaborate computer program, often written by several hundred people. The computer code is meant to represent realistically the incredibly complex interaction of winds, clouds, temperature, solar radiation, ocean cooling and the hundreds of other variables that influence weather. The goal: to create an accurate model of current earth climate, then double the CO_2 level, sit back and see what happens to the weather in, say, Wichita.

But that's easier said than done. If the half a dozen giant weather models currently floating around the planet's computer networks have anything in common, it is that they aren't very good at modeling the weather. "Some people in New York do the solar radiation," Erickson says. "Some other group does the clouds, and these people maybe meet each other once a year."

Erickson is one of the few researchers in the country now testing the most recent model from the National Center for Atmospheric Research. He's asking the computer to predict wind speeds in a particular section of the Pacific Ocean, over a "month" that belongs in a Ray Bradbury short story: "perpetual July," a mathematical construct made up of nothing but 1,000 July days. Once the computer has predicted the wind speeds for perpetual July, Erickson will compare the results to Scripps' own records—300,000 observations of real wind speeds during July. "Data from people on boats," he explains. "Captains staring out at sea."

In all likelihood, the model won't match the real numbers, Erickson will write a paper describing the discrepancies, and the modelers will make repairs. Someday Erickson may write his own model. More likely, he will be part of a team that creates a huge model representing both oceans and atmosphere, acting together, just as in life—a model so complex that it will run on half a dozen supercomputers, all at once. Such a model could provide the first real answers about weather half a century hence—but will probably not exist until well into the next decade.

Today, there's a bit of a setback: The

Cray in Colorado has rejected Erickson's code because of some small error in the program. He shrugs with the imperturbability of someone who doesn't mind hacking in FORTRAN and the obscure Cray operating system. "It could just be a period in the wrong place. These models are so massive, you can't really understand everything that's going on."

ALL WEATHERMEN of the apocalypse understand one aspect of their studies: money. Who will fund the long-term research that the greenhouse effect demands? Private industry may grow more interested in the topic. After last summer's drought dropped the Mississippi River 20 feet and halted barge traffic, a major Illinois grain firm invested \$36 million in a railroad that parallels the river—for if there is greenhouse warming, the Mississippi might no longer serve to ship grain to market. In the Northwest, Weyerhaeuser is already planting drought-resistant saplings for harvest in 30 to 60 years. And insurance companies—for whom 40% of casualty and property losses are hurricane-related—have launched programs to determine whether warming might lengthen the hurricane season.

But industry funding usually goes toward specific predictions. For the big picture, researchers must still rely on the federal government. "There are hopeful sounds coming out of Washington," Somerville says, "but we're only beginning to see the glimmering of real dollars."

The 1990 federal budget proposes \$190.5 million for research into the greenhouse effect. Unfortunately, that sum is divided among nine federal agencies. "It's becoming popular to have these enormous global studies programs," says another Scripps researcher. "But sometimes it turns out that the amount of energy that goes into the planning is more than the amount that actually turns into work."

Keeling is even less optimistic. When he set out to measure CO_2 on Mauna Loa in 1957, "it was a time that young scientists could try something out. I suspect very much that I wouldn't have succeeded today, because I had only my own data telling me I was right." Keeling's own funding is now in doubt, since the National Science Foundation isn't enthusiastic about sustaining long-term monitoring programs. "They like new discoveries," Keeling says.

In addition, these days, grant money more often goes for computer simulations than field research. It can cost \$13,000 a day to take a ship out and sample CO_2 in the open ocean; it's far cheaper to let researchers sit at computers. Ironically, Keeling's son, a recent Harvard Ph.D., had to scramble for dollars to conduct a new kind of atmospheric analysis as speculative as his father performed 30 years ago. "Students today," says the elder Keeling, "learn very quickly that a career in this area isn't necessarily going to be a comfortable life style." But for some younger researchers, the motivation is no longer simply scientific curiosity or a stimulating job. "Not to sound corny about it," Somerville says, "but we're starting to see students with deeply held convictions about doing research that leaves the world a better place."

There is, for example, Justin Lancaster, who, in his mid-30s, is athletic, outgoing and looks every bit the ski-racer he was as an undergraduate. A Vermont native, he was practicing environmental law when he realized that there were bigger fish to fry. "I saw my friends pursuing issues that just weren't that important. I wanted to know, 'What's really important?' " In 1980, he rode his bicycle from Vermont to San Diego and presented himself at Scripps. With little background in science, he was told he'd never get in the front door.

"Where's the back door?" he asked.

Within a few months, he was a volunteer in Charles Keeling's laboratory. His first job was to carry the big glass bottles out to the end of the Scripps pier, where he stood into the wind, held his breath to keep from adding his own carbon dioxide to the sample, removed the stopper and let the local air rush in. At the same time, he completed his undergraduate science requirements.

Now Lancaster is within months of earning his doctorate in oceanography. His work uses the newest technology—satellite photographs that give a truly global perspective—to answer a basic question: Just how much carbon dioxide do plants and soils use, and is this affected by changing temperatures and rainfall? Armed with both doctorate and law degree, Lancaster plans to return to public-policy issues. He foresees a day when governments and multinational corporations will need experts versed in science—from acid rain to the greenhouse effect—and who are also willing to write prescriptions for planetary recovery, ranging from local restrictions on automobile fuel economy to international treaties about the use of coal and oil.

The need looms ever larger. In March, NASA released a shocking photograph from last September's Discovery shuttle mission. It showed a dense white smoke cloud, 1 million miles square, covering the Amazon basin—suggesting that the extent of forest burning there has been greatly underestimated. Regardless of what the United States does, in fact, most of the future greenhouse gases will emanate from developing nations, which will inevitably use coal and oil in their attempt to match Western living standards. Indeed, two-thirds of the world's coal remains in China and the Soviet Union—which are almost certain to burn it. Some cynics point out that the Soviet Union is one nation that might gain from a warmer climate.

Lancaster is surprisingly optimistic about a career that deals so directly with doom. He shrugs. "I was just down at Torrey Pines High School for career day. My career was supposed to be saving Mother Earth. And a lot of the students sounded pretty pessimistic. But my response was, sure, you can find plenty to be pessimistic about. Evolution is change, and change is easy to regret. We're losing wilderness. We're losing dirt roads with grass shoulders. We're moving to an engineered surface of the earth. If you can't accept that, then you're stuck in pessimism. But I'm optimistic about technology being able to give us clean air; about governments firming up wilderness protection. I accept change."

At that moment, Lancaster sounds strikingly like Roger Revelle, half a century his senior, architect of the greenhouse warming theory. "Global change isn't something to avoid," Revelle had said earlier that day in his gentle baritone. "It's something to recognize and keep from happening too fast. Human beings can adapt to anything, if we just have enough time. But almost certainly, some of the things we adapt to will shock us."

And Revelle smiled, with the calm that can only come from gazing at the very big picture. ■