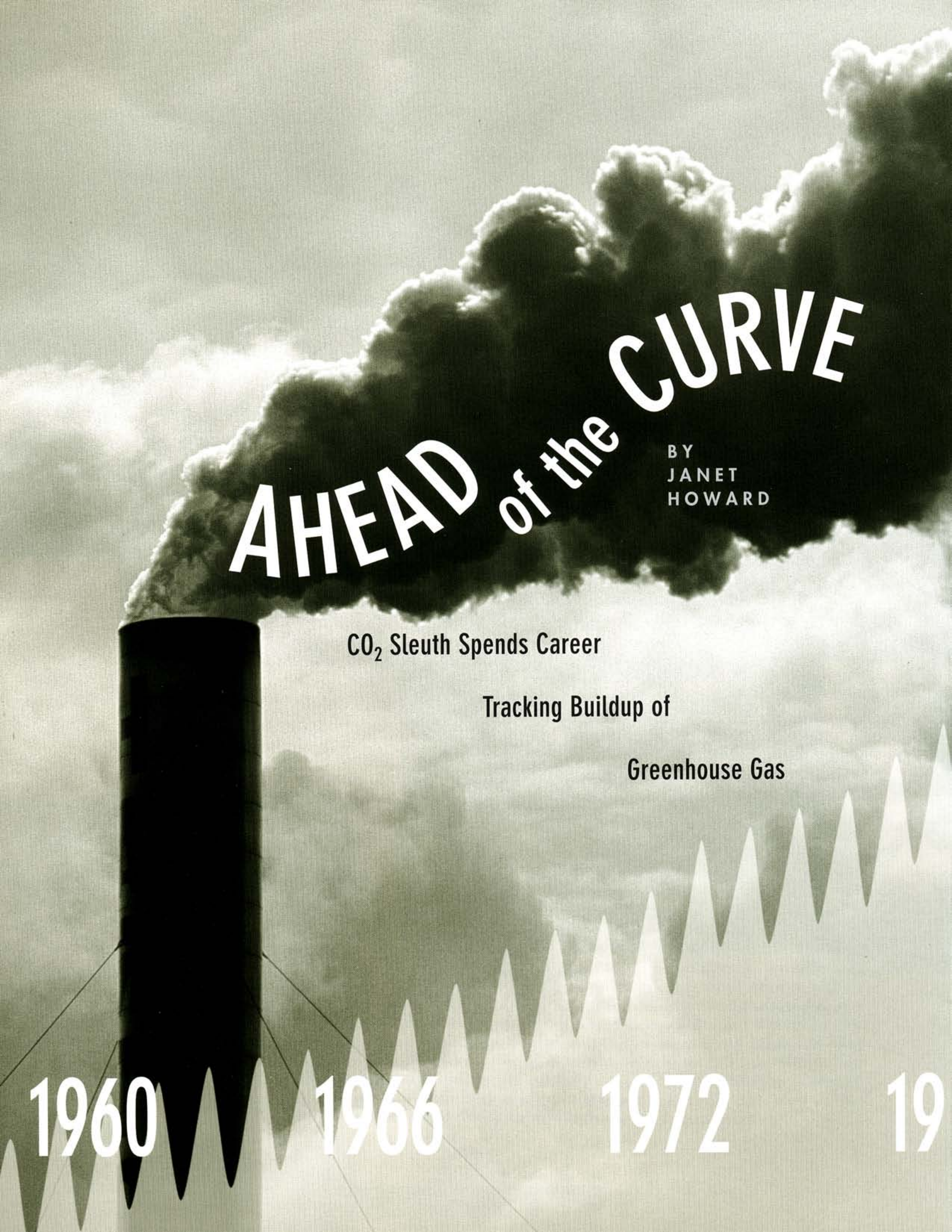
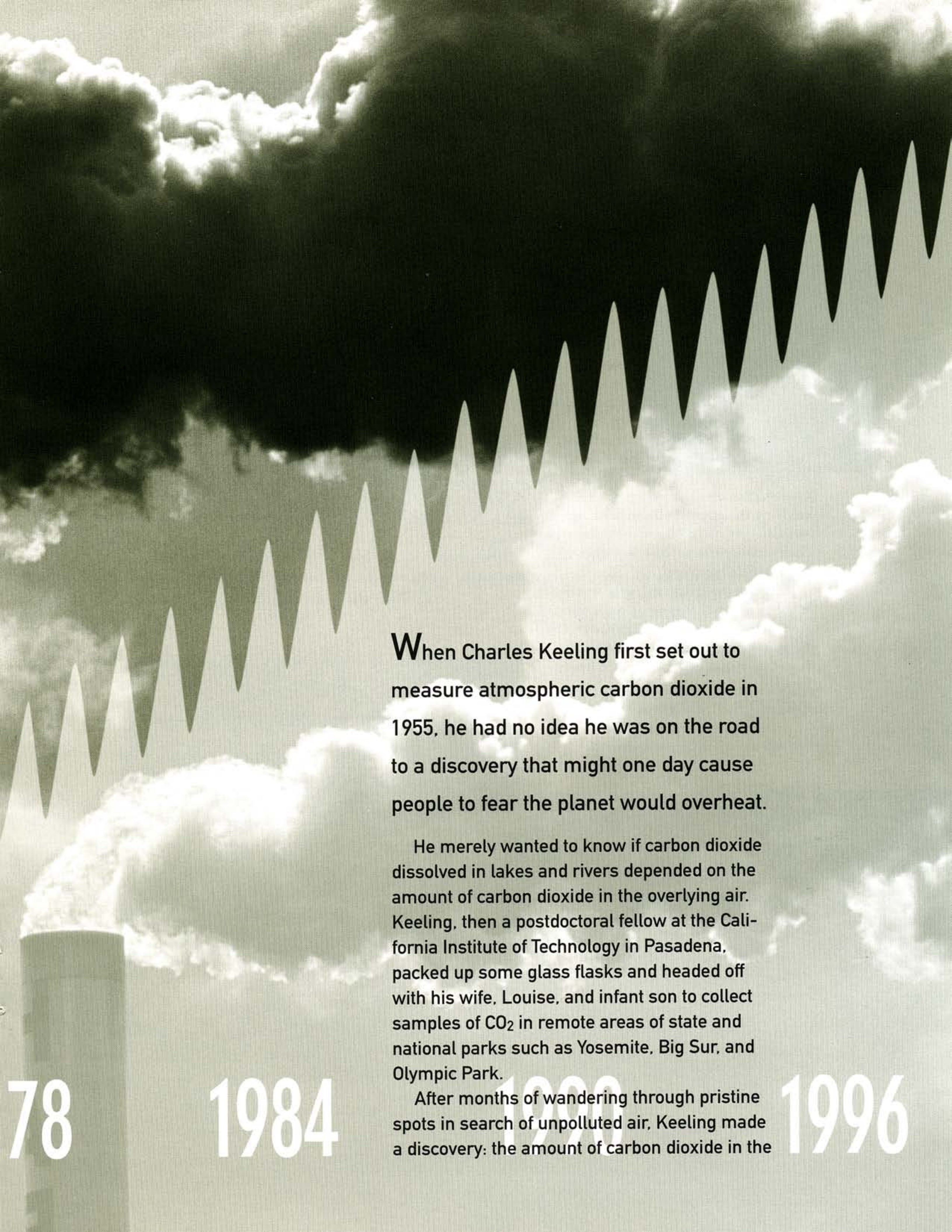
AHEAD of the CURVE

BY JANET HOWARD

CO_2 Sleuth Spends Career Tracking Buildup of Greenhouse Gas





When Charles Keeling first set out to measure atmospheric carbon dioxide in 1955, he had no idea he was on the road to a discovery that might one day cause people to fear the planet would overheat.

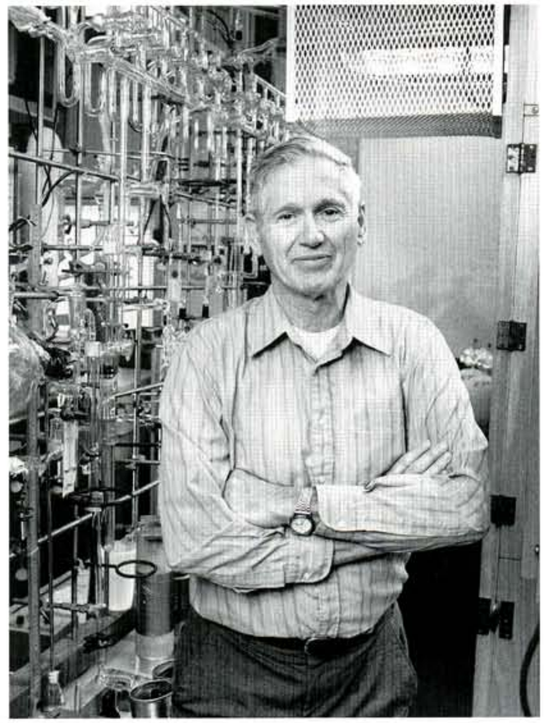
He merely wanted to know if carbon dioxide dissolved in lakes and rivers depended on the amount of carbon dioxide in the overlying air. Keeling, then a postdoctoral fellow at the California Institute of Technology in Pasadena, packed up some glass flasks and headed off with his wife, Louise, and infant son to collect samples of CO_2 in remote areas of state and national parks such as Yosemite, Big Sur, and Olympic Park.

After months of wandering through pristine spots in search of unpolluted air, Keeling made a discovery: the amount of carbon dioxide in the air on any given sunny afternoon appeared to be the same everywhere he sampled—about 315 ppm. That went against the scientific thinking of the time, which held that CO_2 levels generally varied from place to place.

On a hunch, Keeling headed for the Inyo Mountains, located across the Owens Valley from Mt. Whitney in California, in search of even more pristine air.

"I was driven up the 12,000 foot mountain in a military vehicle called a weasel that could go over snowfields," Keeling said. "There was this huge Quonset hut up there and they were studying the effects of altitude on animals, so they had a bunch of chickens and dogs running around. But they didn't mind having me there."

Because the mountain range was buffeted by winds that blew up to 60 miles an hour, Keeling was confident any CO_2 measurements would be free of local influences, including the effects of heavy vegetation, and thus be representative of much of the air in the global atmosphere.



Charles Keeling in his lab at Scripps

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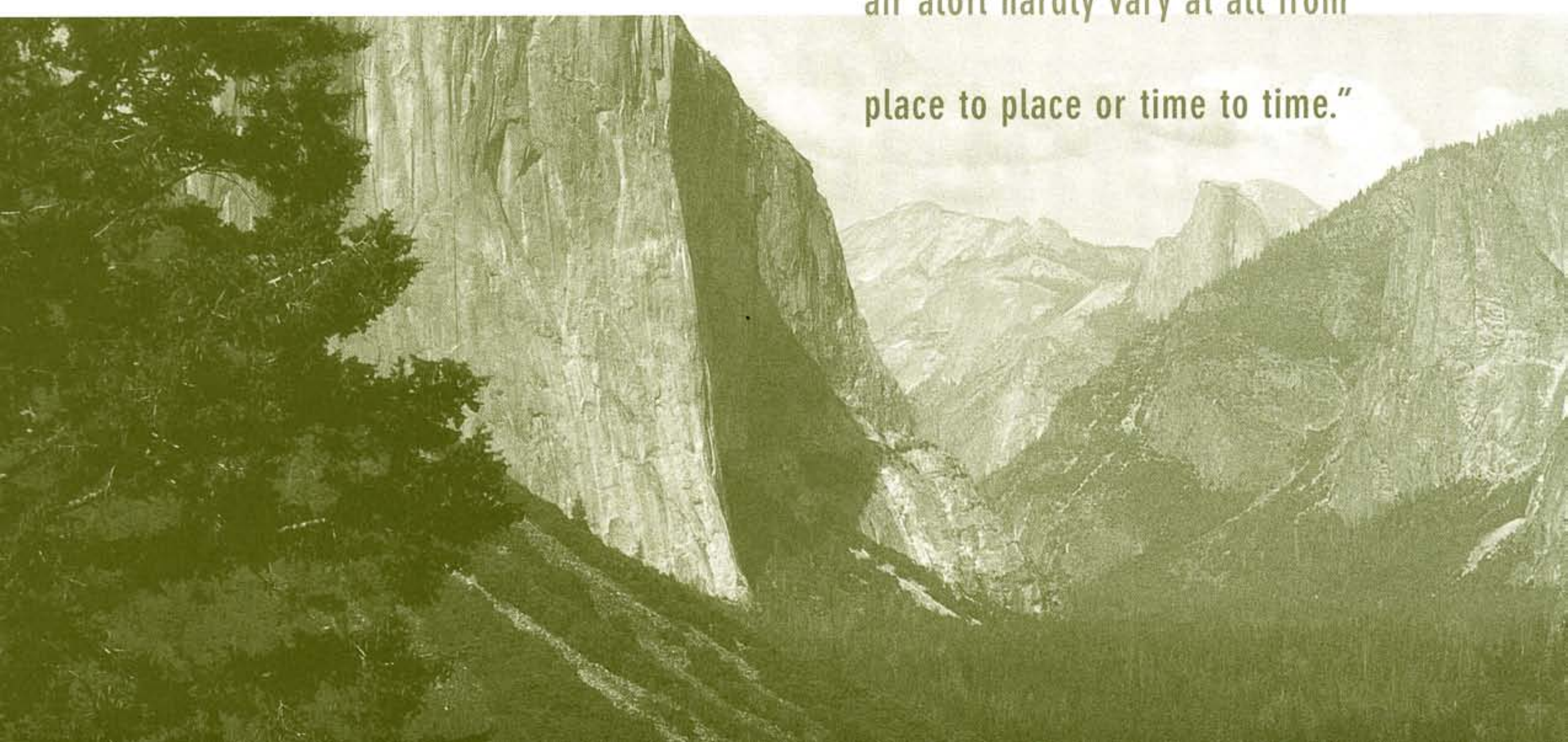


Sure enough, his CO_2 measurements registered at 315 ppm.

"I decided I was onto something—that CO_2 away from human activities and growing plants was probably about the same all the time, contrary to what was written in the scientific literature," Keeling said.

The reason Keeling obtained the same results in forested areas like Yosemite on sunny afternoons was because the air was thoroughly mixed and, thus, similar to that found in the Inyo Mountains.

"It was only by studying air in forests that I happened to stumble onto the fact that CO_2 levels in the air aloft hardly vary at all from place to place or time to time," Keeling said. "That's what brought me into the field of carbon dioxide research."

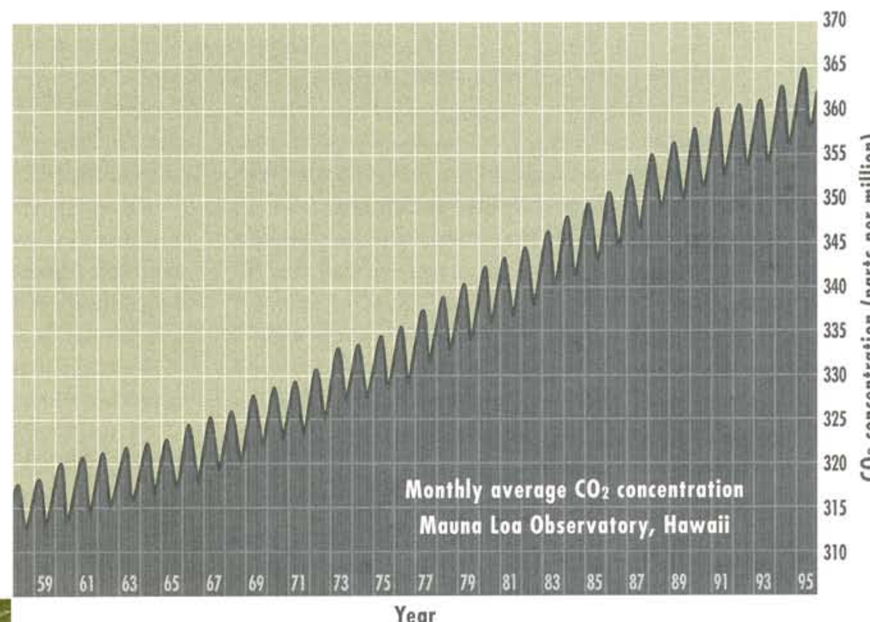
Luckily for Keeling, 1957 was to be the International Geophysical Year and he heard that Roger Revelle, then director of Scripps Institution of Oceanography, was interested in taking global measurements of carbon dioxide.

"Roger Revelle was well acquainted with the prospect of global warming," Keeling said. "He wanted to know if CO_2 was rising because of the burning of coal, petroleum, and natural gas."

Revelle was concerned that a build-up of carbon dioxide in the atmosphere could act like a blanket and trap heat near Earth, a phenomenon known as the greenhouse effect.

In addition to meeting with Revelle, Keeling also was invited to travel to Washington to discuss his work with Harry Wexler, director of the U.S. Weather Bureau's Office of Meteorological Research. Wexler was interested in taking CO_2 measurements at a new high-altitude observatory recently established on a Hawaiian volcano, Mauna Loa.

"He was willing to put up some money for it out of his funds for the International Geophysical Year," Keeling said. "He even invited me to come and work in Washington. But, meanwhile, Roger Revelle had invited me to come to Scripps. So that was an easy choice of which place to go," he said with a chuckle. "I came to Scripps."



The Keeling curve: Keeling first measured CO_2 levels of 315 ppm at the Mauna Loa Observatory in Hawaii in 1958. That number has now jumped to about 360 ppm—a 14 percent increase in less than four decades.

Within months, however, Keeling and Revelle were to butt heads over which method was best for studying whether carbon dioxide levels were in fact rising.

"Roger was of the mind that it wouldn't be possible to make measurements over a short time period and be able to tell whether it was increasing," Keeling said. He thought the best plan was to go to a lot of places and make measurements during the International Geophysical Year and then wait 20 years and come back and do the whole thing over again and see whether the CO_2 had meanwhile gone up."

Because Keeling had already discovered that the amount of CO_2 in the atmosphere appeared to be the same globally, he was convinced that he could determine whether CO_2 levels were rising by taking very precise measurements in only a few locations.

"Roger was a very strong-willed person," Keeling said, his blue eyes alight with amusement. "He wouldn't sign my travel orders to go out and set up my instruments at the Mauna Loa Observatory because he wanted me to do it his way first."

Keeling acquiesced to Revelle's request but also arranged to begin taking samples at Mauna Loa.

"I stuck to my guns and stayed with the idea that we ought to take detailed measurements over time," he said. "The remarkable thing was that by the second year of taking readings at Mauna Loa, we could already see the rise in CO_2."

Dave Moss, of the Scripps Geosciences Research Division, installs air intake lines on the 126-foot tower at Mauna Loa Observatory. The lines are installed at the top of the tower to prevent effluents from observatory operations, emissions from vehicles traveling in and out of the observatory, and outgassing from volcanic vents from contaminating samples.

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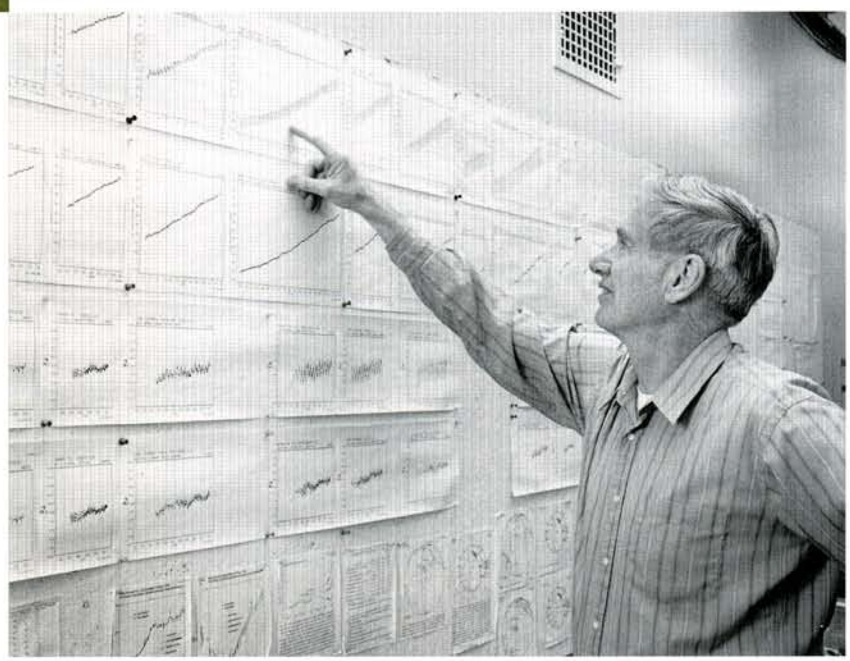

Keeling points out the steady rise in carbon dioxide recorded in charts outside his office.

The year was 1958. Keeling, now a full professor at Scripps, was to spend the next 38 years faithfully repeating the same measurements using a very precise gas analysis system he had developed for the International Geophysical Year.

A visitor to Keeling's lab on the third floor of Ritter Hall cannot help but notice numerous boxes of glass flasks filled with carbon dioxide samples stacked in the hallway outside his office. The return addresses read—Christmas Island; Barrow, Alaska; South Pole, and other exotic places.

But it is the graphs posted on a bulletin board outside of Keeling's office that make people stop and consider the import of what the 68-year-old scientist has learned about the planet's atmosphere.

Information shown on the charts for Mauna Loa, Hawaii, now known as the Keeling curve, demonstrates an ever-rising, yearly increase in the level of carbon dioxide in the atmosphere. The 315-ppm readings Keeling took in 1958 are far below the current measurements of almost 360 ppm—a 14 percent increase in less than four decades.

A quiet-spoken man, Keeling has pretty much stayed out of the political fray surrounding the controversial issue of global warming, happy to concentrate strictly on his science. But he now believes the signs of greenhouse warming are becoming too strong to ignore.

"I've been fairly guarded in making a personal decision about the reality of global warming," Keeling said, leaning back in an old wooden chair in his book-lined office. "Recently, the manifestations have been more and more consistent, so that I now believe there is certainly a better than 50-50 chance that global warming is already here."

Keeling has taken particular note of the extreme swings in weather that have been observed throughout the world over the last few years. Like some other scientists, he is concerned that the

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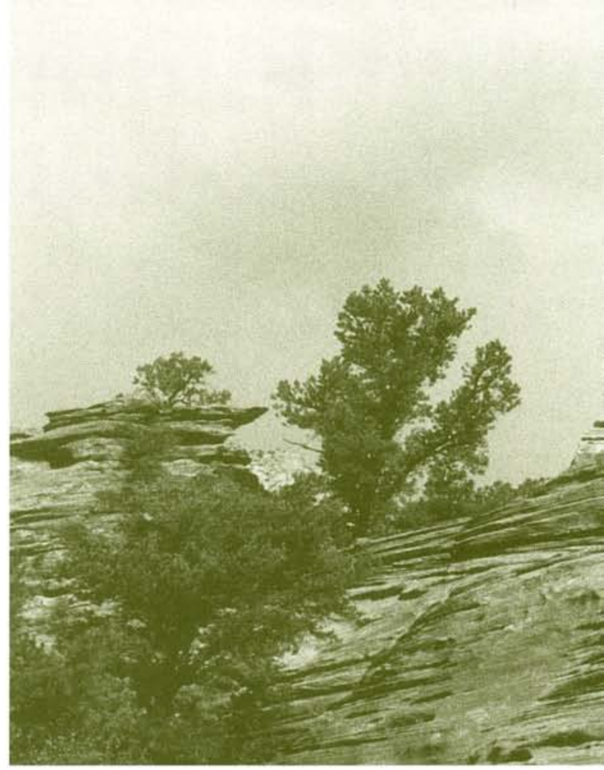
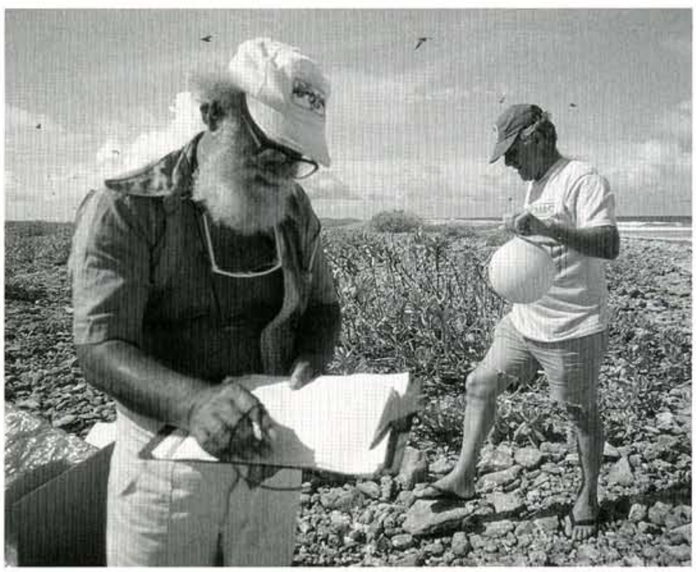




Phil Wilder, a local resident observer, (left) and Dave Moss collect air samples for Keeling on Christmas Island, a remote Pacific island located about 1300 miles south of Hawaii.

recent rash of floods, hurricanes, and snowstorms may be partly a result of global warming.

How can rising temperatures cause more snowstorms? As Keeling explains it, adding heat to the global climate system causes more moist air to evaporate over the warmer oceans. Because the greenhouse "heat engine" also creates more circulation in the atmosphere, this warm, moist air is now more likely to clash with cold air coming down from the north, resulting in unusually severe storms.

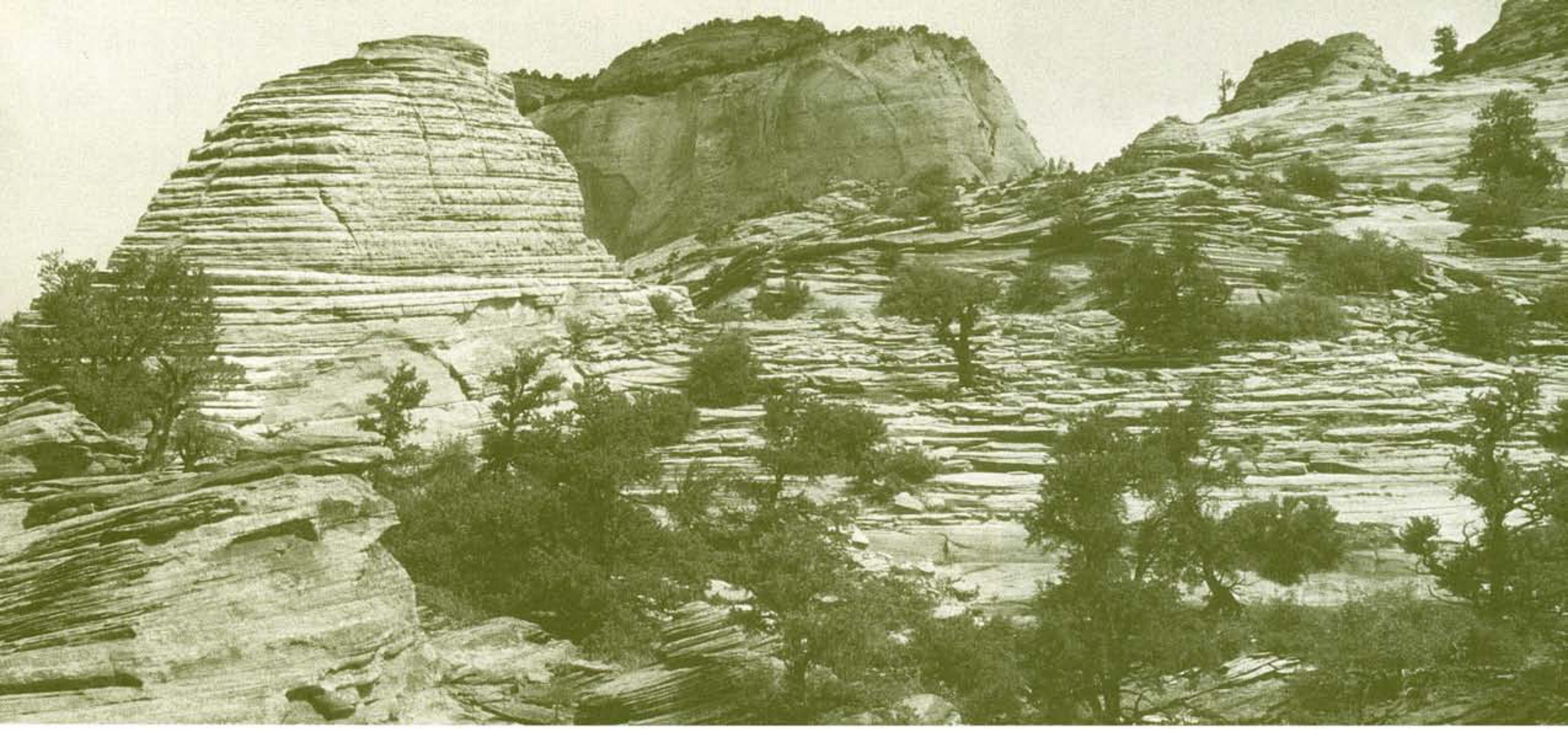
Keeling also believes other changes are taking place in the CO_2 cycle beyond its steady upward rise.

Recent work by Keeling and Scripps researcher Tim Whorf indicates that the seasonal cycles of carbon dioxide also are changing. As Keeling learned during his first few years of measuring CO_2 on Mauna Loa, the level of carbon dioxide in the atmosphere follows a predictable pattern. In the spring and summer, when plants and trees in the Northern Hemisphere are in full foliage and are taking up large amounts of carbon dioxide by photosynthesis, the amount of CO_2 in the atmosphere drops. Then in fall and winter, when the leaves fall to the ground and begin to decay, most of this CO_2 is returned to the atmosphere.

Keeling noticed, however, that beginning in 1975, a subtle shift began to occur so that the change in CO_2 levels in the atmosphere between summer and winter started becoming greater.

"If you look at the Mauna Loa record, it seesaws up and down every year," Keeling said. "If you look at it closely, you can see that the seesaws have become bigger over time."

Curiously, the trend stopped for a while in the mid-80s. About two years ago, Keeling and Whorf noticed that the changes in amplitude between summer and winter were again rapidly escalating. After analyzing carbon dioxide measurements taken in Alaska and at Mauna Loa over the previous 30 years, Keeling and Whorf found that the



difference in CO_2 levels between winter and summer cycles has now increased by 20 to 30 percent.

"I suspect that means the greening of plants has increased by 20 to 30 percent over 30 years," Keeling said. "I think the likely reason for it is the growing season of plants in the Northern Hemisphere has increased, particularly in the far north. That would be because it is getting warmer, especially in late winter and spring."

Keeling points to such discoveries whenever someone asks if he has ever become bored with studying carbon dioxide.

"Here I am approaching my 41st year of measuring CO_2 if you count my time at the California Institute of Technology, and yet we are only now discovering this seasonal effect because we needed these long time records before we could see the trend," Keeling said. "So why shouldn't I be interested? It is more interesting than ever."

Keeling is the first to admit, however, that scientists are far from gaining a complete understanding of carbon dioxide or an ability to predict what effect its rise may have on the planet in years to come.

"I have a suspicion that temperatures are going to rise again in the next five or ten years and that we'll see more records broken," he said. "But watch out, because any time you make a prediction like that without really knowing the system, you can get very surprised. In fact, most of my career I've been surprised by what we've measured. It's never stopped being interesting because it keeps doing something we didn't expect."

Dave Moss follows a special procedure while collecting air samples. Holding his breath and walking into the wind, Moss opens the stopcock of a 5-liter glass collection flask. He also must ensure that the sample is not contaminated by local influences, such as vegetation or human activities. In this case, birds must be shooed away from the site.