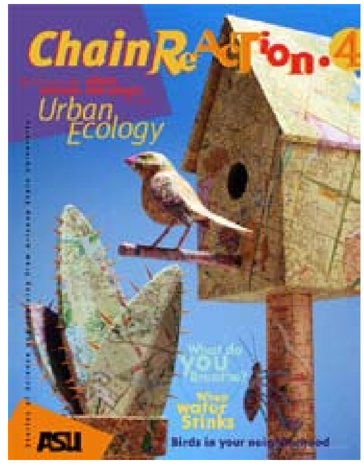
ARIZONA STATE UNIVERSITY



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CO_2 Questions

Carbon Dioxide is the second most common greenhouse gas. Water vapor is first. Greenhouse gases act like a blanket around the Earth. They trap in the sun's heat. Without greenhouse gases, we could not survive. Earth would be way too cold. We don't have to worry about that, however. CO_2 levels in the atmosphere are rising. So is the average global temperature. If CO_2 continues to increase, what will it mean for Earth's climate?

BY DIANE BOUDREAU

YOU CAN'T SEE IT. YOU CAN'T SMELL IT. YOU CAN'T TASTE OR FEEL IT. It enters your body with every breath and you don't even know it. Carbon dioxide (CO_2) has no direct effect on people. Most of us hardly think about it at all. But climate scientists think about it a lot, because it does affect our planet, and it's on the rise.

Scientists aren't exactly sure how this rise will change the planet, but most researchers believe it will be bad. They predict the Earth's temperature will go up, and rising sea levels will flood whole islands and coastal cities. Entire forests, like the Amazon, could be destroyed. A few scientists, however, claim that global warming will actually slow the rise in sea levels. They say that high levels of CO_2 will help plants and trees.

These theories are very different, but they do have something in common. Both theories are based on computer models.

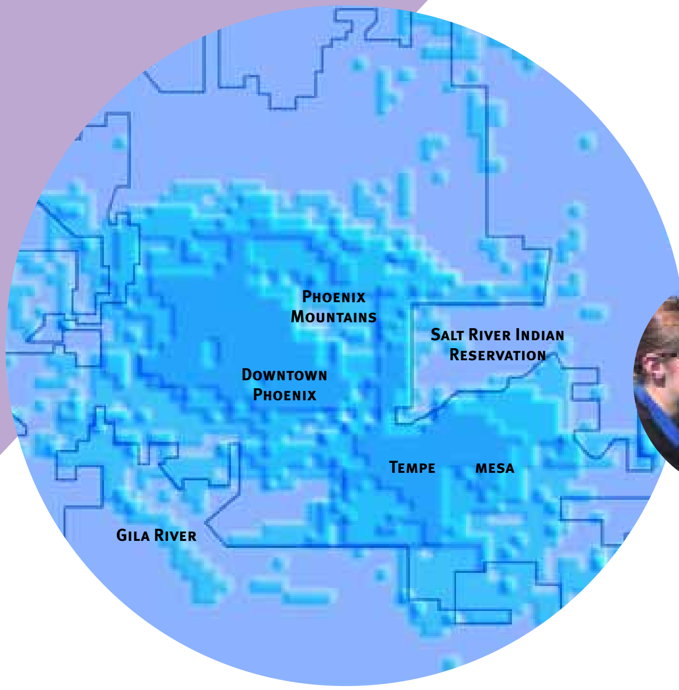
"Most future climate predictions are based on mathematical models," explains Craig Idso, a climatologist at Arizona State University. "You can't just double the CO_2 concentration and see what happens in the real world. We don't have the technology to do that."

Computer models are not perfect. But they have been the only way to study the effects of CO_2 in the atmosphere. Until now.

In 1998, Idso discovered that Phoenix lies under a carbon dioxide "dome." The city has CO_2 levels up to 50 percent higher than the global average. Those high levels are what scientists expect to see around the world in about 50 years. Because Phoenix is ahead of the game, scientists can use the city as a natural "laboratory" to study the effects of these changes.

"People are running around saying we'll double carbon dioxide sometime in the next century," says ASU climatologist Robert Balling. "We are saying that we've already come close to doing it in Phoenix. You don't have to wait around." This type of CO_2 dome hasn't been seen in any other city, says Balling. Very few cities have even measured CO_2 levels. Those that have show only small increases of CO_2 over urban areas.

Where does all that carbon dioxide come from?



ASU scientist Craig Idso and other students attached tubes to their cars to pipe air inside to a CO_2 sampling instrument. The map of the Phoenix area shows CO_2 concentrations measured by researchers. Blue-colored areas indicate how much CO_2 was found in air at ground level. Darker blue areas show the highest concentrations.

"It looks like everything comes together in Phoenix to produce this carbon dioxide dome," says Balling. For one thing, the desert does not have many trees or other plants. Trees and green plants normally absorb lots and lots of CO_2. Also, people in Phoenix drive a lot. Cars, trucks, and buses spew tons of CO_2 from their tailpipes as they go. Finally, Phoenix has very little wind compared to other cities. As a result, he CO_2 in Phoenix doesn't get blown away.

Balling leads a group of scientists who study the relationship between CO_2, humans, and the environment. The team has found that CO_2 levels change throughout the day, week, and year. For instance, CO_2 levels before dawn are higher than they are in the middle of the afternoon.

ASU ecologist Jeff Klopatek suggests reasons for this difference. "CO_2 is heavy. At night, it tends to settle in," he says. "During the day we think the CO_2 may just be rising with the warmer air. It could also be a function of vegetation. In most natural ecosystems the CO_2's going to be a lot lower during the day because the plants are taking in the gas for photosynthesis."

The team also found that CO_2 levels are higher on weekdays than on weekends, and higher in mid-winter than in the summer.

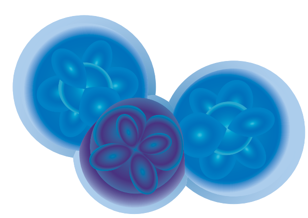
Vegetation is one of the trickiest pieces of the CO_2 puzzle. Plant life affects the CO_2 dome but is affected by it as well. At night, plants give off CO_2. But during the day, plants take in CO_2 to use for photosynthesis. Photosynthesis is the process plants use to turn sunlight into food. ›››

There are many sources of CO_2.
Cars, power plants, and anything else that burns fossil fuels will produce CO_2. Cement production also releases the gas. Rotting materials produce CO_2, so landfills may be a big contributor. And plant life gives off CO_2 at night.

Even people are a source, because we all exhale CO_2. "You're producing carbon dioxide right now, never forget it," says ASU scientist Robert Balling. "We have plans sometime in the next year to go out in Sun Devil Stadium. We want to measure the carbon dioxide dome around that stadium when 70,000 great Sun Devil fans are out there screaming and yelling. We think that the level probably goes way up."

ASU students, led by researcher Craig Idso, have measured CO_2 over time and space. They drove all over the Phoenix metropolitan area taking air samples and measuring their CO_2 content. They also set up several permanent sampling sites.

So far, the results all support Idso's earlier findings of a huge CO_2 dome over Phoenix. They also found that CO_2 levels in the heart of Phoenix are higher than those on the outskirts of the city.



EACH CARBON DIOXIDE MOLECULE IS MADE OF ONE PART CARBON (C) AND TWO PARTS OXYGEN (O_2)

John C. Phillips photos

ASU plant biologist Tad Day studies the relationship between plants and the CO_2 dome. He is looking at CO_2 levels over four types of land: turf (grass) outside the CO_2 dome, turf inside the dome, desert remnant outside the dome, and desert remnant inside the dome. There is a wider daily range of CO_2 levels over turf than over desert areas. Over turf, nightly spikes are higher than over desert. Daily lows are lower over turf. "This makes sense because turf vegetation draws in much more CO_2 per ground surface area [during the day]," says Day.

Thought questions:

Why might global warming cause sea levels to rise?

Why are CO_2 levels higher in winter than summer?

Why are CO_2 levels lower on weekends than weekdays?

Human activities are at the heart of Phoenix's CO_2 dome. It's easy to see that CO_2 levels spike over areas where the most people live. The researchers want to know which human activities produce the most CO_2.

Tim Hogan is the director of ASU's Center for Business Research. He provides information on human-made sources of CO_2. Hogan and his co-workers locate major CO_2 sources in Phoenix. They find out just how much electricity the power plants are producing, or how many miles people are driving, to learn how much CO_2 is being produced. He also looks at how these numbers vary over time. As the Phoenix area grows, so will the carbon dioxide dome. Hogan works to predict how the CO_2 dome will change, and how it will affect the area.

Collecting data is the first step. That takes lots of time. The work to understand it all starts once the data is collected. The researchers have to put it all together and try to figure out what it means.

Patricia Gober and Elizabeth Wentz are geographers. They collect data on traffic patterns, population, land use, and employment. They use numbers from Hogan's office, along with other local and national sources. They also gather the CO_2 data from the other researchers. Then they plug all the information into Geographic Information Systems software and use the computer to look for patterns among the jumble of numbers.

For example, they can make a map showing where the highest CO_2 levels occur in the Phoenix area. They can overlay that map onto a map of traffic patterns to see if there is more CO_2 over high-traffic areas such as freeways. Their findings will help researchers answer some of the important questions about carbon dioxide.

"There are all these linkages," says Balling. "We're working together as a grand team. The goal is to better understand the carbon dioxide all around us."

Jeff Klopatek digs deeper into the vegetation issue. He studies underground and soil contribution to the CO_2 dome. "In most ecosystems, about 80 to 90 percent of the CO_2 in the system is being emitted from the soil," he says.

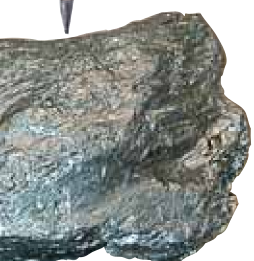
Soil CO_2 comes from root and fungal activity. It also comes from rotting organic matter. Klopatek is comparing these below-ground sources of CO_2 across Phoenix, especially in landfills. "We expect that they're significant sources," he says. "When the organic matter buried in landfills starts to decompose, it also starts to release carbon dioxide."

COAL Coal is formed mainly from the carbon in ancient plant material

Where Does All the Carbon Go?

Carbon is an element with many forms. Those different forms flow between the biosphere, the atmosphere, and the oceans. This global flow is called the carbon cycle. Scientists study how carbon is exchanged between these elements. They also look at where carbon is stored for long periods of time. Because the amounts of carbon involved are so huge, scientists use the term *gigaton* as a unit of measure. One gigaton is equal to 1 billion tons of carbon!

The largest stores of carbon lie underground. The carbon is part of fossil fuels like oil and coal, and in sedimentary rock deposits. Other huge amounts are found at the bottom of the oceans. About 44,000 gigatons of carbon is trapped in these stores. When humans burn fossil fuels and clear land they release huge amounts of carbon into the atmosphere. These activities release about 6 gigatons of carbon each year.



The atmosphere holds about 750 gigatons of carbon in the form of carbon dioxide. Scientists say that the amount of CO_2 in the atmosphere is on the rise. Current levels are 25 percent higher than they were before the Industrial Revolution began in the late 1700s.

GRAPHITE The "lead" in pencils is really a form of carbon called graphite.

Many sea creatures–some of microscopic size–build shells of carbon minerals.

Plants absorb carbon dioxide from the atmosphere during photosynthesis. That is the process plants use to turn sunlight into food. Plants also release CO_2 back into the air through respiration.

About 800 gigatons of carbon is dissolved in the surface layers of the world's oceans. Marine plants use that dissolved CO_2. Plants and animals also store carbon in their bodies. About half the weight of a mature tree is carbon. Scientists believe that 550 gigatons of carbon exists in living plant and animal matter. Another 1,300 gigatons of carbon is trapped in dead leaves, twigs, branches, other ground litter, and soils.

These numbers are estimates, of course. Scientists only have a general understanding of the carbon cycle. They have not totally accounted for the rates of change between the atmosphere, land, and ocean. Scientists still can't account for about 20 percent of the CO_2 released each year. That is between 1 and 2 gigatons. Not a small amount! Scientists are still working to discover where this disappearing carbon goes.

Diane Boudreau

Chalk–just like the kind teachers use on blackboards–is formed from the shells of ancient sea creatures. **CHALK**

SEAWATER

Plants decay into soil and release carbon into the atmosphere.