[KATHLEEN WENDT:] Extreme climate events are happening all over the world. They are becoming more common and more severe. To help us deal with these challenges, we need to understand the causes.

[CRYSTAL KOLDEN:] In just the last decade, 2010 to 2020, we saw the hottest decade ever.

[RALPH KEELING:] You look at the data, and you can’t deny that humans are having a profound impact on the whole planet.

[WENDT:] It’s only by understanding the science will we find the solutions.

[ASMERET ASEFAW BERHE:] It’s a lot of work, but it also comes with a number of opportunities.

[WENDT:] If the past teaches us anything, it’s that now is a better time than ever to start making major changes.

[KOLDEN:] In 2020, we had the largest number of megafires across the western US that we’ve ever seen. When we have multiyear droughts that then leave behind an enormous amount of dead, downed wood. When an ignition does occur, there’s an enormous amount of fuel. It allows for incredibly explosive growth that spreads the fire quickly across the landscape.

We just didn’t see these megafires 20, 30 years ago. And now we’re seeing them annually.

[WENDT:] The droughts driving these megafires are occurring at a time that the Earth is warming.

[BERHE:] We’ve been monitoring atmospheric temperatures around the world since the 1880s. And the global average temperature has changed by about one degree centigrade since then.

[WENDT:] What is driving this rise? To answer that, we need to understand the factors that control Earth’s temperature.

[BERHE:] There are three factors: the intensity of solar radiation; the composition of the Earth’s atmosphere; and the reflectivity of the ground surface, or albedo. Scientists have continuously been monitoring solar radiation and the surface reflectivity for decades now. And we know that those haven’t changed significantly enough to contribute to warming our planet.

[WENDT:] So that leaves the atmosphere. How does it affect temperature?

[BERHE:] So the sun is the dominant source of energy on Earth. When solar energy comes down to the Earth, some of it is reflected back from reflective surfaces. Some of it is absorbed by the ground surface and is reradiated back to the atmosphere as infrared energy.

Gases such as carbon dioxide, methane, or water vapor that accumulate in the Earth’s atmosphere, they’re absorbing that reradiated heat and are able to trap that heat and cause warming of our planet. And that’s what we call the greenhouse effect.

[WENDT:] Has the atmosphere been changing in a way that could explain the increase in temperatures? To find out, scientists need to measure the greenhouse gases, especially carbon dioxide, which is one of the most abundant in our atmosphere.

[KEELING:] Charles David Keeling pioneered the measurement of carbon dioxide with higher accuracy than had ever been done before. And he was my father. He went by Dave.

[WENDT:] Dave started taking air samples in the mid-1950s with glass flasks.

[KEELING:] This flask…it's been evacuated. So there's no air in it, nothing. So what you do to take an air sample is holding our breath, and then we just turn this stopcock and the air just rushes in.

[hissing sound]

[KEELING:] So this flask will be placed on this rack and then analyzed, and that allows you to very accurately measure how much carbon dioxide is in air.

Among the places he started making measurements was Mauna Loa, which is on the big island of Hawaii. It allows you to sample air that's representative of a large part of the atmosphere.

[WENDT:] Keeling's first monthly reading was 315 parts per million. That means for every million molecules of air, 315 of them were carbon dioxide. From March 1958 to March 1959, daily air measurements were taken.

[KEELING:] So the carbon dioxide went up to a peak. And then came down and then came up again.

[WENDT:] What could cause this pattern to occur?

[KEELING:] In the spring and summer, plants leaf out and they take up CO_2 from the atmosphere, and that produces a drawdown. And then in the fall and the winter, CO_2 is being released back because there's decomposition going on, and that brings CO_2 back up again.

He was seeing the breathing of carbon dioxide in and out of the atmosphere caused by vegetation in the Northern Hemisphere.

[WENDT:] Within the first few years, the same carbon dioxide seasonal cycle appeared, but another pattern began to emerge.

[KEELING:] He could see that the CO_2 overall was rising. Mauna Loa is only one piece of it. There were also measurements being made on ships and airplanes and particularly at the South Pole, all documenting very clearly this rise.

The program my father started, which I continue, involves keeping the measurements going at Mauna Loa. But we also take air samples from around the world, so we get a large-scale view of how CO_2 is varying.

In the late '50s when my father started, the concentrations in the atmosphere were around 315 parts per million. And they're now over 100 parts per million above that. Today we're recording concentrations around 415 parts per million. We are still marching upwards.

[WENDT:] Carbon dioxide levels in the atmosphere are increasing dramatically. But is this a new phenomenon?

And in order to answer that we have to look into the past. So we use ice cores. So when we drill into these Antarctic ice sheets, over a mile deep, these long ice cores allow us a window into the past.

When it snows every year, little packets of air that are in between the individual snowflakes get trapped as bubbles. These snow layers build up on top of each other. The further we drill down, the older the ice. And so far, we've been able to drill down to ice that is 800,000 years old.

Polar ice kind of is like a constellation of bubbles. And trapped inside each of these bubbles is fossil air that's been trapped since that ice formed. And they allow us to study what greenhouse gas concentrations were in the past.

So we place a sample of Antarctic ice in a glass flask. And then we vacuum away all of the modern air. Then we let the Antarctic ice melt, and the tiny bubbles that are trapped inside the ice are released into the vacuum. We can measure what the greenhouse gas concentrations were at the time of this bubble formation.

Going back 800,000 years ago, we see fluctuations in carbon dioxide concentrations over time. From about 180 parts per million up to 300 parts per million. And then we reach a period of the Industrial Revolution. CO_2 concentrations begin to gradually rise. And over the last 30 years, we've seen a skyrocket of CO_2 concentrations, up to the point of 415 parts per million.

Ice cores can also tell scientists about past temperatures. So by analyzing the water molecules in the ice of these ice cores, we can determine what the past temperature of the poles was.

So when we plot the carbon dioxide record and the temperature record, going back 800,000 years, whenever there is a fall or rise in CO_2 concentrations, we see an associated change in temperatures. And this tells us that throughout Earth's history, temperature and CO_2 concentrations are intimately linked.

This rise in carbon dioxide is causing a rise in global average temperatures. And this rate is completely unprecedented. It's something we've never seen over the course of human history.

What is causing it? The carbon atom can help us find out.

Carbon always has six protons. Now, most carbon also has six neutrons in its nucleus, and that gives it a mass of 12. We refer to it as carbon-12. Some carbon, however, has seven neutrons, and so that has a mass of 13, and we call it carbon-13.

The different varieties of carbon in carbon dioxide allow us to determine whether the CO_2 comes from plants, volcanoes, or the oceans.

Plants prefer to take up carbon-12 for photosynthesis. And so what happens is that this plant matter is made up of much, much more carbon-12 than carbon-13. This carbon-12 preference creates a distinctive ratio, which is also in the carbon dioxide released when plants die or are burnt. The carbon dioxide coming from volcanoes and oceans has a different ratio.

Over the past century, the carbon-13 to carbon-12 ratio in the atmosphere has become more and more like the ratio found in plants. But how?

Fossil fuels are made of ancient plants, and so when we dig them up and burn them, we're emitting more and more carbon-12 into the atmosphere. And this is changing the carbon-13 to carbon-12 ratio within the atmosphere. This tells us definitively that the rise in CO_2 concentrations that we're observing today is due to the burning of fossil fuels.

[train whistle]

[WENDT:] The past 250 years of burning fossil fuels has caused global average temperatures to rise by one degree Celsius, which is creating massive disruptions across the planet.

[KOLDEN:] When we trap more heat in our atmosphere, that energy is what actually translates into extreme events. So if we continue to burn fossil fuels, we will see an increase of three to five degrees Celsius over the next century.

Increasing megafires that are incredibly destructive. When you couple sea level rise with events like hurricanes and typhoons, across the globe, you have millions and millions of people, animals, and plants that are likely to be displaced.

[KEELING:] If we don't bend this curve, we're not in a good place. It is something that humans created, this rise, and we're in a position to do something about it.

[WENDT:] To stop carbon dioxide from increasing further, we need to reduce or eliminate the burning of fossil fuels.

[BERHE:] And that has to mean converting our energy sources in all aspects of our lives, in industry and agriculture and transportation, into renewable systems as soon as possible. This transition also brings a number of opportunities for green jobs and green technology.

At the same time, we also have to draw down some of the carbon dioxide that's already in the atmosphere. Another major solution to draw down the carbon dioxide lies right under our foot. And it's soil.

Soil is one of the major reservoirs of carbon in the Earth system. If we can actually transform our agricultural practices to reduce tilling and reduce disruption of the soil, we can offset a third of the current emissions of fossil fuels into the atmosphere with soil carbon sequestration.

We have the solutions for climate change. What we need now is a large number of people to have the will to put those solutions in place and act to address the climate crisis.