Lowering the temperature on a hot topic: A climate change primer
20 April 2022, by John Spizzirri

Supercell storm outside of Harrisburg, Nebraska, that produced severe storms and multiple tornadoes. Climate change is expected to increase the frequency and severity of weather-related events, from wildfires to hurricanes. Credit: Shutterstock/Cammie Czuchnicki.

Climate changes. It has done so, often dramatically, over the course of Earth’s geologic timescales, measured in hundreds of thousands and millions of years. Some of these changes might have caused a phenomenon called snowball Earth, a period in which the entire planet froze over. Other changes have taken the planet in the opposite direction.

As science gets better at measuring and deciphering evidence from those atmospheres of the past, researchers are discovering that large climatic episodes are linked to mass extinction events, when much of life on Earth died off.

So, if the climate does change and has tended toward the drastic in the past, why the kerfuffle when we talk about climate change, today?

One of the main points of contention among remaining skeptics, and the point most climate scientists agree on—as well as scientists from many other fields—is whether human activities are the main drivers of rapid climate change.

What once took those long geologic periods to melt glaciers or transform lush tropical forest to dry savannah is now happening on the scale of a human lifetime, or even faster.

We call this anthropogenic, or human-driven, change.

Researchers at the U.S. Department of Energy's (DOE) Argonne National Laboratory are working to sort out the details and provide a clearer understanding of climate change.

They are involved, for example, in profiling day-to-day changes in wind, temperature and humidity to assist in accurate weather forecasts. They have developed groundbreaking models that predict future hazardous conditions, like wildfires, drought and tropical storms. And they use those models to help communities make better decisions on how to locate or support critical infrastructure needed to deliver electricity, gas and communications.

One such researcher is Scott Collis, an atmospheric scientist specializing in thunderstorms. A public voice on the issue of climate change, Collis has tried to make scientific information accessible to audiences on broadcasts ranging from PBS to Fox.

Outlining the broader picture of climate change is easy, suggests Collis, it's in the finer points—the interactions of ocean currents, heat and clouds, for example—where things start to get complicated. But that doesn't mean that the main ideas are hard to understand.

So, let's break it down.

Weather or not
A good place to start is to define the difference
between weather and climate, a common sticking point for many people.

You may hear someone say that it's colder than it should be at a certain time of year, or we're getting more snow in places that typically aren't known for snow.

For some, this is evidence that climate change doesn't exist or that it defeats the idea of global warming. But it's not that simple.

In a nod to a former Argonne mentor, Collis said climate is what you expect, weather is what you get.

While weather changes all the time, over the long term there are consistent patterns. If you live in or around Chicago, for example, you've likely experienced several seasons in one day (thus the maxim, "if you don't like the weather in Chicago, wait 15 minutes").

Yet, Midwesterners expect that the summer will be warmest in August, and January will most always bring cold temps, angry winds and slick roads.

This repeated and consistent cycle of weather over a given region and an expanse of time is called climate.

The National Oceanic and Atmospheric Administration (NOAA) keeps track of both weather and climate. Every 10 years, it releases climate normals, or averaged weather observations collected from weather stations across a region, a continent or the globe.

Each 10-year report is based on 30 years' worth of weather observations and helps scientists predict what temperatures and other conditions might look like over the next 10 years. The most recent climate normal report includes the two hottest decades on record, globally, from 2000 to 2019.

"The latest climate normal showed not only a massive increase in temperatures, but interesting changes in precipitation as well," said Collis.

These changes in precipitation are driving larger, more severe storms—yes, even snow—and piquing the interest of scientists like Collis.

So that's weather and climate. Now, here's why scientists call current events anthropogenic climate change.

**Understanding the cause**

Just as climate is an accumulation of weather, climate change is caused by the over-accumulation of certain gases in the atmosphere.

Some of these gases, like carbon dioxide (CO₂), are important for capturing the sun's infrared radiation, which can harm us—sunburns and skin cancer—and keeping our planet from getting too cold. But too much can cause a greenhouse effect that traps heat in the atmosphere and really starts to warm things up.

"Carbon dioxide gets really excited when it gets hit by infrared radiation," explained Collis. "It absorbs that energy and reemits it. But instead of sending it back out to space, it sends some back to Earth."

Collis likened this to the inside of a car on a hot day. The windows of a car act just like CO₂, letting in visible radiation, but blocking the heat trying to escape; we feel it immediately when we get into a car that's had its windows rolled up on a hot day.

Our planet is becoming that vehicle, and the gases we put into the atmosphere are the culprits.

**How do we know this?**

There is a direct correlation between the increased levels of CO₂ in the atmosphere and current temperature increases. Scientists date this connection to the beginning of the Industrial Revolution in Europe and the United States in the 1800s, when societies witnessed the large-scale conversion to coal—a large contributor of CO₂—to advance manufacturing.

Scientists make this relationship using historical weather records and CO₂ measurements taken from ice core and ocean sediment samples, tree rings and coral reefs, all of which capture such data.
going back 150 years, in some cases, millennia.

From such evidence, we know that temperatures have increased as greenhouse gases did. And as humans began to record changes in their environment, whether through scientific instruments or photographs and videos, we began to witness the effects as they occurred.

Coal remained the prominent source of energy production until the arrival of cleaner nuclear energy in the late 1950s, and the slow but increased use of renewables since the 1970s. But the United States, and nations around the world, continue to release huge amounts of CO$_2$ and other potent greenhouse gases, like methane, from many other sources that drive life as we know it.

Transportation, for example, accounts for over one-quarter of CO$_2$ emissions released in the United States, while power generation—coal, oil and gas—is responsible for just slightly less. Industry accounts for about 20% and agriculture adds 10%.

But agricultural practices, farming cattle in particular, release more methane than any other form of industry. And while CO$_2$ is more abundant, methane is a more potent greenhouse gas. In fact, as long-frozen land, or permafrost regions, near the Arctic Circle begin to thaw, scientists are worried about the release of large amounts of stored methane that could further exacerbate the problem.

To better understand the relationship between humans, the release of greenhouse gases and climate change, scientists use the latest, greatest tools available to them. For example, Collis points to NASA's Orbiting Carbon Observatory 2, a satellite which tracks the release of CO$_2$ across the globe, whether from natural or human sources.

Research facilities around the world also use simulations, or models, to confirm ideas about past climate and CO$_2$ levels, and predict future scenarios.

"At Argonne, we run simulations about temperature and weather and we get one value, one that might reflect the pre-industrial era," described Collis. "Then we add more CO$_2$, the amount we're producing, and get another value. And then we do things like put in huge amounts of CO$_2$ to see what happens. And, yeah, science tells us it's us."

According to NASA's climate Web page, the amount of CO$_2$ in today's atmosphere, measured in parts per million (ppm), has nearly doubled since 1850—considered pre-industrial—to about 415 ppm. "This is more than what had happened naturally over a 20,000-year period (from the Last Glacial Maximum to 1850, when the level raised from 185 ppm to 280 ppm)," the site notes.

You can find more numbers about this relationship between greenhouse gases and rising temperatures from any number of research facilities, but the most compelling argument for human-driven climate change is observation.

Record-breaking heat, increased frequency and severity of storms, melting glaciers and rising sea levels are hard to ignore.

Harder still are the droughts and wildfires that plague not only the western United States, but regions as far away as Siberia, leaving millions of acres of land barren.

Some still might argue that this is just the natural course of things, but research suggests otherwise. An article in the science journal *Nature* reported that the record-breaking heat in the United States and Canada was 150 times more likely to occur because of climate change than pure chance, and would begin to happen more frequently as temperatures rise.

**Hard to ignore negative feedback**

As temperatures increase and become consistent over time, the Earth begins to develop something called a feedback loop in many different ecological systems.

For example, the reason scientists care about losing snowpack and ice cover in regions like the Antarctic and Greenland is that the white of the ice reflects heat back toward the sky, while the dark waters surrounding them absorb it.
So, heat melts the ice and snow, leaving less of it to reflect heat back. This opens larger areas of the surrounding ocean to absorb more heat, further melting the ice caps and keeping heat trapped on the planet.

In addition to rising temps from this process, the other concern is rising sea levels. Ice doesn't just disappear; it adds to the volumes of oceans and changes tides, displacing people along already precarious shorelines, from New Orleans to Bangladesh.

Another, perhaps more immediately noticeable, effect of the feedback loop is the occurrence of more severe storms.

"The greenhouse gas that might surprise some people is water vapor," exclaimed Collis. "It also presents some very interesting feedback issues. To simplify a complicated physics equation that we use, the warmer the air, the more water vapor there is in the atmosphere. This leads to greater rainfall and larger storms and hurricanes."

As evidence for this phenomenon, recall 2021's massive floods in parts of Europe and China, many of which occurred in areas not known for receiving heavy rains.

"We get these severe sorts of feedback cycles because things aren't happening on geologic timescales. They're happening many orders of magnitude faster," said Collis. "Instead of having adaptation, we get migration. Places that were once farmable no longer are, sea level changes are pushing people out, species are searching for cooler latitudes. Things are happening much too quickly for species, humans and plants to adapt."

Despite these forebodings, all is not grim, just as Scrooge acknowledges during the last of his ghostly visitations in "A Christmas Carol": "But if the courses be departed from, the ends will change." In our story, the future will be decided by those of us who make environmentally conscious choices in our daily lives; by governments and industries that strive to reduce greenhouse gas emissions; and by research institutions, like Argonne, that are at the forefront of innovations for a cleaner planet.