How the "greenhouse effect" impacts weather

Most of us rarely think about the atmosphere. Even though we may be mindful of our surrounding environments, like when we admire a beautiful tree, we entirely ignore that we are looking through the atmosphere, as it is, of course, entirely invisible. Although we can feel it, as when we delight in a soft breeze, we rarely think about the fact that what we are really feeling is the atmosphere.

Nonetheless, the atmosphere is profoundly important for all life on earth. Without it, earth would be a dead planet - in, as we shall see, more ways than one.

To understand the impact that CO2 and other greenhouse gasses (like methane) have on our global climate, we need to consider how the earth's atmosphere reacts to solar radiation.
Even though our atmosphere is incredibly thin (a single layer of lacquer on a basketball would be proportionately thicker), it nonetheless keeps our planet from getting too hot - and, somewhat paradoxically, from being too cold.

Without our atmosphere, during the day (when the sun is shining on our part of the earth) it would quickly get hotter than any temperature ever recorded on earth - up to 260° Fahrenheit. Alternately, at night (when the earth rotates so that we are moved away from the sun and hence into darkness), it would quickly become far colder than any temperature ever recorded on earth - as low as 280° Fahrenheit.

How do we know this? These temperature extremes are exactly what happens on the moon, which has no atmosphere.

Consequently, even if we didn't need the atmosphere to supply us with air to breath (for example, if we were wearing spacesuits), the earth would still be uninhabitable because there would be no atmosphere to trap just the right amount of heat (solar radiation) to make our days neither too hot nor too cold.

The simplest way to imagine the atmosphere in this regard is to think of it like a blanket over the planet. As with a blanket on your bed, the goal is to get one that is just right, so that you will neither be too hot nor too cold. What you are looking for is a blanket that Goldilocks would love: one that is just right.

Incidentally, some scientist argue that the blanket analogy is better than imagining a greenhouse (see Bending the Curve, chapter 1). Hence, if they had their way, we would not be talking about the "greenhouse effect," but rather the "blanket effect."

Although the analogy of a blanket is useful, it nonetheless quickly breaks down. For example, our atmosphere not only keeps heat in like a blanket, it also reflects some (about 29%) of solar radiation back into space. Blankets do not usually both keep heat in and keep it out at the same time. Nonetheless, this is an especially important service that the atmosphere performs, as some of the radiation reflected back is deadly to life on earth.

Thus, the atmosphere makes life possible in three major ways: 1) we need it to breath, 2) it keeps the earth's surface temperature just right for life, and 3) it shields life on earth from particular forms of solar radiation that are deadly.

Consequently, maybe we should all think about the atmosphere a little more than we do! (Incidentally, practitioners of meditation do just that, as the primary focus is on the life-giving atmosphere, the breath, from when it enters the body to it leaves.)

So what is the role of these so-called greenhouse gases in the atmosphere?

99.9% of the earth's atmosphere is composed of nitrogen (78%), oxygen (21%), and argon (just under 1%). As these molecules don't have an electric charge, they do not trap incoming solar radiation. If the earth's atmosphere did not have trace amounts of other gases, such as CO2 and methane, it wouldn't be able to hold the sun's heat in like a blanket. Hence we call these trace gases "greenhouse gases," as they are responsible for the greenhouse (or blanket) effect on earth.

Specifically, once solar radiation strikes the earth (or oceans or ice), it bounces back toward space. This especially happens with light-colored surfaces, like sheets of ice near the poles, which work sort of like mirrors. (This is also why wearing white or light-colored clothing in the summer is far cooler than wearing black.)

As 99.9% of the gases in the atmosphere (nitrogen, oxygen, and argon) would let this energy go right back into space, the earth would quickly heat up so that the oceans would begin to boil during the day. Alternately at night, it would get so cold that even CO2 would turn to (dry) ice.

However, when this outgoing solar radiation hits a molecule of a greenhouse gas, which are electrically charged and vibrating, its trip back into space is blocked, as it bounces off these molecules. Even though these greenhouse gas molecules only exist in trace amounts in the atmosphere, there are enough of them so that the outgoing solar radiation then begins to bounce around between these molecules instead of going directly out to space.

Hence, thanks to greenhouse gases, our atmosphere is warmed by this solar warmth bouncing back and forth between these molecules. However, because there are not too many of these greenhouse gas molecules in the atmosphere, they do not trap in so much heat that they make the planet uninhabitable for human beings and other life. (This is, incidentally, what happens on the planet Venus, where there are so many greenhouse gases that the average temperature is between 800 and 900°F.)

Most of these greenhouse gases are, in one way or another, naturally occurring on earth. For example, the gas that traps more heat than any other is water vapor, such as in the form of clouds. Next in line is CO2, which also has natural sources, such as deeps ocean vents (usually caused by volcanic activity) and when plant and animal material decays, which, incidentally, also releases methane. Other greenhouse gases like ozone and nitrous oxide can also naturally occur.

These naturally occurring greenhouse gases are a good thing; without them, the earth would, like the moon, wildly swing from being either too cold or too hot to support life.

However, these gases need to be in a delicate balance in the atmosphere.

If, for example, there were not a sufficient number of these greenhouse gas molecules floating around, the atmosphere would not be able to retain enough incoming solar radiation to make the earth habitable. Alternately, as with Venus, if there are too many of these gases, then the earth would heat up so much that it would be largely uninhabitable for most life that now lives on it.

One could imagine a lab experiment in which we played with the percentages of these greenhouse gases. As we added more, the temperature would go up and down when we subtracted some.

Unfortunately, this is not a hypothetical experiment, but rather one that human beings have been inadvertently conducting on earth for the past few hundred years - especially the last 60 or 85 years, during which our species has been releasing vast amounts of greenhouse gases into the atmosphere, principally CO2 and methane.

While it may seem surprising that human beings were able to emit a sufficient number of greenhouse gases to make changes to the global climate, recall that 99.9% of the atmosphere is not composed of these gases. Hence, adding just a few parts per million of CO2 can make a difference. Adding a hundred parts per million, which we did in the past 60 years, has made a profound difference to our climate.

Not surprisingly, all these greenhouse gases are heating up the planet. We call this global warming.

Incidentally, even though the sun is heating our planet via the greenhouse effect, this solar energy is nonetheless essential to our future as we leave fossil fuels behind. Solar energy is, either directly or indirectly, the source of four out of the five principal forms of renewable energy: solar, wind, hydroelectric, biomass.

Photovoltaic solar cells transform solar energy into electricity. They do so directly, as these extraordinary solid-state devices convert photons hitting their surface into electrons (electricity). Solar energy can also be used to heat water into steam in order to turn generators that produce electricity, or heated to lower temperatures to provide domestic hot water. Solar energy can also directly heat properly designed buildings.

The sun’s energy also indirectly causes wind by way of differences in the atmospheric (i.e barometric) pressure. In other words, because the sun does not uniformly heat the earth (owing largely to cloud cover and the way that different landscapes absorb heat), air moves from source to sink: from hotter, high pressure areas to cooler, low-pressure ones.

We call this atmospheric movement “wind.” Wind turbines use the moving air to turn generators that produce electricity.

When the sun's heat hits the earth or oceans, it can can release water into the atmosphere through evaporation. Similarly, during the process of photosynthesis, plants add water to the air through transpiration. When this water returns to the surface as rain and is not directly absorbed by the earth, the runoff forms streams and rivers, which can be used to turn generators that produce electricity (usually after the water is dammed in order to make sure that it is constantly available).

While there are other form of renewable energy, like geothermal, which use the earth's heat, and tidal, which uses the moon's pull on the earth (specifically our oceans) to produce electricity or heat, the lion's share of renewable energy in our future will, either directly or indirectly, come from solar energy.

In any event, CO2, methane, and other gases are called "greenhouse gases" because they all contribute to the greenhouse effect. As we have seen, greenhouse gases (GHGs) are not in themselves bad. Without them, earth would be too cold to be habitable. However, because we have been pumping greenhouse gases into the atmosphere over the past 400 years (especially the past 60 years), our planet is quickly warming.

We initially referred to the impact that increased levels of greenhouse gases have on the planet as the "greenhouse effect." This name was supplanted by "global warming," as it underscored the fact that the greenhouse effect was heating up our planet.

However, when we realized that an increase in atmospheric gases like CO2 and methane is changing our global climate in a range of ways, such as with more severe weather events (like hurricanes and monsoons), more severe droughts, changes in regional weather patterns, etc. (which we will be taking up in detail in the next segment), we began referring to all this and global warming as "climate change."

More than just a name change, this marked a significant change in conceptualizing the problem. When we thought in terms of global warming, we often just imagined a single cause and effect: melting polar ice would result in global sea level rise. Consequently, while this alarmed (or at least should have alarmed) people who lived near oceans, for many inland people, this did not seem like a cause for much concern.

Moreover, as all this ice was taking quite a while to melt, it meant that the oceans were only slowly rising. Between 1900 and 1990, they were only rising at a rate of 1.2 to 1.7mm, which is a little as 1/20th of an inch, per year. Even though this rate increased to 3.4mm (about 1/12th of an inch) per year by 2016, it still seemed slow.

However, sea level rise, when coupled with low atmospheric pressure and very powerful winds can drive ocean water inland (which is what happens during a hurricane or typhoon). This "storm surge" can be extraordinary. When it happens during high tide, this "tidal surge," can be almost incomprehensible.

At one point during Superstorm Sandy, tidal surge was 19 feet. During Hurricane Katrina, tidal surge was over 34 feet. Imagine a wall of water taller than a three-story building coming from the ocean and moving down your street. Not surprisingly, whole houses and their occupants have been swept away during such tidal surges.

People used to ask me, pretty regularly, “when is global warming or climate change is going to begin?” This is a misguided question. It has already begun. Since 1880, average global temperatures have risen around 2 degrees Fahrenheit.

Indeed, it has not only already begun, it is already at crisis level. Hence, we have recently given it yet another name, not “climate change,” but “the climate crisis.”

In order to underscore that the problem is at crisis level, the climate activist Greta Thunberg expressed the severity of the immediacy and problem in just five words: “Our house is on fire.” Imagine someone running through your house screaming “Our house is on fire, our house is on fire!” You would no doubt immediately become alarmed and do something - which is exactly what Thunberg wants you to feel and do about the climate crisis.

In order to understand the immediacy of our climate problem, we need to consider how it is impacting more than just sea level rise through weather events like tidal surges. These are the subject of the next segment.