Climate & Climate Change
Ray W. Arritt, Ph.D., Iowa State University
Presented August 2012, at the annual conference of the Climate & Corn-based Cropping Systems Coordinated Agricultural Project, in Wooster, Ohio.

… just a few minutes this morning about climate and climate change, which is sort of the large-scale backdrop to what we're doing here today. And being a professor and looking forward to the professor that's going to be starting in just a couple of weeks, I'm going to start out with a quiz. Okay?

Okay, so what's this all about? We've got the atmosphere here, we've got the earth. All the energy ultimately comes from the sun. so the sun comes in, some of the sunlight gets reflected off, about half of it gets absorbed at the earth's surface, some of it gets returned to the atmosphere in various ways. But the bottom line is – the atmosphere has a temperature. And because it has a temperature, it radiates. What makes it radiate is not the nitrogen and oxygen but a few specific gases called greenhouse gases. So we've got this orange arrow that's coming down, the ones that are circled in blue there, and it's the amount of these greenhouse gases that controls the radiation for a given temperature.

So if we add more of these greenhouse gases, we increase this downward radiation coming down to the surface – very simple, very straightforward. Got this stuff that radiates, put more of it in there, get more radiation downward.

So how long have we known about all this stuff? Quite a long time. The greenhouse effect was first described by Joseph Fourier in 1824. If you're familiar with Fourier's series in math, it's the same Fourier. The specific gases that cause almost all the greenhouse effect were identified in the mid-19th century, 1859, by John Tyndall. The three biggies were methane, water vapor and carbon dioxide – he found those. Later some other people found other things like nitrous oxide, which is of specific concern to us here because agriculture is a big source of that.

And the first prediction of global warming from doubled atmospheric carbon dioxide was made by a Swedish chemist and Nobel Prize winner by the name of Svante Arrhenius in 1896. And he came up with an answer that is not too much higher than our best estimates now. He got about 5.4 degrees; we think it's something on the order of 3 to 3½. He was a little high but not really out of the ballpark. So this is old science, very robust. Okay, the basics of it are very robust; we've known it for a long time.

So what are the greenhouse gases that I talked about? Well, there's a bunch of them. Water vapor causes about two thirds or so of the greenhouse effect, depending upon how you count. These things are all ranges instead of specific numbers because there's overlap between the radiation bands and so forth. So there's the ones that Arrhenius came up with, water vapor, carbon dioxide and methane. O-zone, 5 percentage or so. Nitrous oxide is small but growing fairly rapidly; okay, it has a long atmospheric lifetime, and molecule for molecule it's very effective.

So if water vapor causes two thirds of the greenhouse effect, why do we, you know, care about other things? The reason is, it turns out that water vapor falls out of the atmosphere fairly quickly. It has an average residence time of only nine days compared to nine days up to hundreds or even thousands of years for some of the other greenhouse gases. So water vapor reacts to the other greenhouse gases.

Carbon dioxide goes up a bit, methane goes up a bit, makes it warmer, then more water vapor evaporates; it amplifies that greenhouse effect. So water vapor is a feedback process. It feeds back on the way up, feeds back on the way down with cooling.

So that's the basics. That's the science, the physics of… transfer greenhouse gases and so forth – you've gotten in, what, eight minutes now, something like that? Okay.

So carbon dioxide, what's been happening, we know from ice cores taken in Antarctica that atmospheric carbon dioxide now is considerably higher than it's been anytime in the past at least 800,000 years. So you see the dot there for 2012, and it's rising. There's a lower emissions scenario and a higher emissions scenario for what it's supposed to be at the end of this century. For the past 20 years we have had been riding at or slightly above the higher emissions scenario. So the higher one is probably the more realistic.

If we look at the carbon dioxide increase during the industrial era, we start from about 1770, 1780 with the invention of the steam engine, use of coke for steel making or iron producing and so forth. And you see that's right about the time the carbon dioxide starts to increase. So we've gone from roughly 280 parts to million to I think 393 as of this month. The first half of that increase took about 200 years from roughly 1780 or so up to 1979. Second half of that increase took 33 years, so it's increasing at an increasing rate. Most of the carbon dioxide that has accumulated in the atmosphere since the Industrial Revolution has come in the past 33 years.

So then we take that knowledge, we look at this in terms of the global mean surface temperature. We see that we had a little bit of warming in the early part of the 20^{th} century, stabilized a little bit, and then right about 1970 or so, the temperature started rising pretty rapidly.

What does this graph tell us about global warming due to increased carbon dioxide? It tells us nothing, okay. The temperature curve itself doesn't really tell us anything. Yes, it's consistent with what we would expect, but we need to do very careful studies in terms of attribution, energy balances and so forth, in order to be able to sort out the real causality, the real physics of the problem.

And when we do that, we start with the fact that most of the carbon dioxide has come since the mid-1970s, and if we look at various terms in the radiation balance, we see that up until, say, 1950 or so, the variations were mostly natural causes. There was a period where there was some greenhouse warming where the carbon dioxide was starting to accumulate, but it was partly covered up by other pollution, dust and things, that make reflections. And then the rapid rise since the mid-1970s or so has been mostly human caused.

What are the effects of this? Well, first of all, it's called "global warming," is the name that most people give to it. And we see things like the northward creeping of plant hardiness zones. Plant hardiness zones are going northward at something like one half to a full zone every 30 years. So we see what happened from 1990 to 2006, you can pick out your state and see how it has changed. And then we have on the right what is projected to happen according to those two emission scenarios that I showed you earlier.

You also hear a term, “climate change.” Climate change is really the more complete term for what’s going on here, because when you warm up the system, all sorts of other things happen. You throw clothes in the dryer, you know that if you put it on heat, it’s going to dry faster than if you put it on air dry. So if we heat up the atmosphere, we evaporate more moisture, it’s going to change the water budgets and so forth.

And what climate really is is transferring energy around. If we didn’t transfer that energy around, in the winter in the Corn Belt we would have such a radiation, such an energy deficit, that our average temperature – not our record low or even our average low – but our average temperature would be about minus 40 to minus 50 degrees Fahrenheit. So climate, those energy transfers, is what keeps us from freezing to death in the winter, practically. And then as the climate warms, those transports will change, and it’s going to change everything else that has to do with the transport of energy and water vapor.

Like this – those of us in Iowa, can you remember when hundred-year floods came less frequently than every five or ten years? Okay, we have this flood in 1993, the year I moved to Ames. I was really starting to wonder at one point. We had another big flood in 2010; we’ve had a couple in between there, okay. One of the most robust signals to come out of climate change is the one you see on the lower right here, which is an increase in the amounts of very heavy precipitation. Events over four inches per day, events over three inches, five inches per day have gone way, way up, giving us things like you see on the left there.

So what do you take away from all this? First of all, this is not a new thing. Projections of global warming are based on long-established physics, going back to the early to mid-19th century. The temperature trends themselves are not really evidence of global warming due to increased greenhouse gases. You’ve got to do studies having to do with energy transfers and so forth. But the signal that we’re seeing is what we would expect.

And then as the climate warms, because we’re affecting transports of energy, all parts of the climate system will change, like the floods I showed you. There will be changes to winds, ocean currents, snowpack, snow cover for those of you who grow winter wheat, those sorts of things, frequency of droughts and floods. It’s not just temperatures, not just global warming but climate change – change to all parts of the system.

There’s my checkered flag. Thank you.

Transcribed by WORDS Unlimited
Des Moines, Iowa