Essential Background Information For Meteorologists About Climate Science

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My goal...all this (and more) in 40 minutes
Frequently Asked Questions

• “How do we know that greenhouse gas emissions can cause climate change?”
• “Was Hurricane Sandy a result of global warming?”
• “How can we project what the earth’s temperature will be in 50 years if we don’t always get tomorrow’s weather forecast right?”
• “I’ve heard that global warming stopped in 1998. Is that true?”
• “If global warming is occurring, why did we have such a cold spring?”
• “Why don’t all scientists agree about global warming?”
• “How can I talk about climate change without getting those angry phone calls and e-mails?”
“How do we know that greenhouse gas emissions can cause climate change?”
Three lines of evidence link CO$_2$ and climate:

• Basic physics
• Observations
• Modeling
Climate change: How did we learn about it?

Based on laboratory measurements, stated in an 1895 paper that carbon dioxide in the atmosphere could affect surface temperature of the earth.

In 1938, compiled early estimates of carbon dioxide and temperature and found that both were rising.

Performed the first climate model simulations of global warming due to increased atmospheric carbon dioxide.
Basic physics of CO$_2$ and climate

- If an object receives energy in the form of visible light, as the earth does from the sun, it warms up.

- The warmer an object is, the more energy it emits in the form of infrared radiation. This is the earth’s cooling mechanism that balances the heating from the sun’s visible light.

- CO$_2$ and water vapor are “greenhouse gases” that absorb infrared radiation, making it more difficult for energy to escape into space.

- Without greenhouse gases the earth would be much colder (i.e., its average temperature would be well below freezing).
“Was Hurricane Sandy a result of global warming?”
“But I think part of learning from this is the recognition that climate change is a reality, extreme weather is a reality, it is a reality that we are vulnerable. Climate change is a controversial subject, right? People will debate whether there is climate change … that’s a whole political debate that I don’t want to get into. I want to talk about the frequency of extreme weather situations, which is not political … There’s only so long you can say, ‘This is once in a lifetime and it’s not going to happen again.’ ”  -- Gov. Andrew Cuomo

“Well, first of all, I don’t agree with the premise of your question because I don’t think there’s been any proof thus far that Sandy was caused by climate change.”  
-- Gov. Chris Christie
A baseball analogy

• Justin Singleman is a five-year veteran with career averages of .303 BA, 4 HR, 57 RBI.
• He undertakes an off-season weight-training program.
• In his first at-bat of the new season, he hits a towering, 470-foot home run.
• Was this monstrous blast a result of his off-season weight training?
Possible answers

- “Of course not. One home run doesn’t prove anything. The pitcher may have thrown a batting practice fastball that anybody could crush.”

- “I knew all his off-season work would pay off. He’s always been able to get his bat on the ball, he just needed some more strength. I bet he wins the home run title.”

- He’s been visiting that clinic in Miami.
Getting back to Sandy...two (hypothetical) perspectives

- “Everything came together perfectly for Sandy to be a destructive storm. There just happened to be a hurricane moving northeastward off the Atlantic coast as a blocking pattern developed. Sandy could have happened 60 years ago if the pattern had been the same.”

- “Climate change has warmed the offshore waters, providing more energy for Sandy. There is also more moisture in the atmosphere and the reduction in Arctic sea ice has changed the upper-air circulation.”
A better perspective...

- Current model results indicate that climate change will produce little change or a small decrease in the number of tropical cyclones in the Atlantic, but with an increase in the frequency of the strongest storms.

- Sea level rise will exacerbate the effects on coastal flooding from tropical cyclones (extratropical cyclones too), so future storms that are less intense than Sandy will likely cause comparable flooding.
“How can we project what the earth’s temperature will be in 50 years if we don’t always get tomorrow’s weather forecast right?”
Weather forecasting: Initial conditions are crucial

Edward Lorenz
Sensitivity to initial conditions

Results from three different simulations, each starting from different initial conditions. Changes in atmospheric composition are identical.
Future long-term climate trends: Changes in Earth’s energy balance are crucial

• Just as the seasonal change in the energy balance of Northern Hemisphere makes July warmer than January, long-term changes in Earth’s energy balance can induce trends in temperature and other climatic variables.

• If the changes in Earth’s energy balance are large enough, they can produce trends in the climate that are large enough that they exceed the variations due to differences in initial conditions.
Global warming occurs in all simulations

The global warming signal eventually emerges in all three simulations, despite the pronounced internal variability that is evident.
“I’ve heard that global warming stopped in 1998. Is that true?”
Decades without warming are not unexpected


Figure 2. One realization of the globally averaged surface air temperature from the ECHAM5 coupled climate model forced with the SRES A2 greenhouse gas increase scenario for the 21st century.
Changes in energy balance

• A measure of the change in earth’s energy balance that results from a process is the radiative forcing.

• For the change in CO$_2$ during the last decade, the radiative forcing is $+0.29$ W/m$^2$.

• There have been other potential sources of radiative forcing that could offset some of the CO$_2$ forcing
  – Particles from “small” volcanic eruptions: $-0.1$ W/m$^2$
  – Decrease in stratospheric water vapor: $-0.1$ W/m$^2$
  – Variations in solar output due to sunspot cycle: $\pm 0.1$ W/m$^2$

• There is also evidence for a redistribution of heat within the ocean (i.e., heat going into deeper layers)
“If global warming is occurring, why did we have such a cold spring?”
NCAR-CCSM3.0 Ensemble July U.S. Average Temperature Anomaly Box Plot
“Why don’t all scientists agree about global warming?”
The story of Alfred Wegener and continental drift

"Utter, damned rot!" said the president of the prestigious American Philosophical Society.

"If we are to believe [this] hypothesis, we must forget everything we have learned in the last 70 years and start all over again," said another American scientist.

Anyone who "valued his reputation for scientific sanity" would never dare support such a theory, said a British geologist.

(Patrick Hughes, “The Meteorologist Who Started A Revolution”)
Plate tectonics and continental drift

Age of rocks that make up the floor of the Atlantic Ocean
(oldest in blue; youngest in red)

(Source: University of California Museum of Paleontology)
Science can be messy!

- Science does not typically follow a straight line. Often it takes some time to gather and analyze evidence.

- Not every piece of evidence points in the same direction. Scientific understanding becomes established based on the totality of evidence, not because a new paper is written. Even breakthrough papers are often recognized as such only well after they have been published.

- Consensus does not mean unanimous agreement. Consensus emerges gradually as scientific evidence for a hypothesis increases. Scientists do not have identical thresholds for accepting the evidence in favor of a hypothesis.
Climate science has policy implications

• Scientific issues with public policy implications can trigger controversies that often continue beyond the point at which most scientists would consider the issue to be settled.

• There are many examples of such controversies (especially involving human health):
  – Tobacco smoking and health hazards (1960s and 1970s)
  – Health effects of high-voltage transmission lines (1990s)
  – Cell phones and brain tumors
  – Vaccination and autism
“How can I talk about climate change without getting those angry phone calls and e-mails?”
Science and policy

• Climate change often enters public discourse as a combination of science and policy.

• The blurring of the boundary between science and policy often leads the general public to conclude that the science of climate is highly controversial. It may also make some broadcasters reluctant to discuss climate change for fear of alienating many of their viewers or listeners.

• Survey research has found that opinions about climate change depend somewhat on political philosophy.
Yale Survey on “Six Americas”

Figure 1: Proportion of the U.S. Adult Population in the Six Americas, March 2012

- Alarmed: 13%
- Concerned: 26%
- Cautious: 29%
- Disengaged: 6%
- Doubtful: 15%
- Dismissive: 10%

March 2012, n=992

Proportion represented by area
Source: Yale / George Mason University

Source: Leiserowitz et al., (2012)
Jerry Mahlman (1940-2012)

- Former director of NOAA/GFDL in Princeton
- As a federal employee, Jerry respected the line between science and policy
- He viewed his role as that of a trusted source of information—a “neutral broker”
- Yet he never failed to convey the importance and the urgency of addressing climate change

(Source: Ricky Rood)
How do I respond to the question “What should we do about global warming?”

- It’s not just a scientific question.
- Policymakers must balance a variety of considerations.
- Because this is a policy question, your opinion counts just as much as mine.
- There are no easy solutions.
- New sources of energy will ultimately be required.
- The consequences of today’s actions will be felt decades to centuries in the future.
The Global Warming Dilemma (Mahlman, 2002)

• “There are no quick policy fixes, nationally or globally. If we don't begin to chip away at the problem soon, it is very likely that serious consequences will be wired in for the world of our great-grandchildren and for their great-grandchildren....

• The long time scales and robustness of the problem almost guarantees that our descendants in the 22nd century will, with historical perspective, see that we were actually confronted with a major planet-scale stewardship/management problem.

• They will most assuredly note how we responded, or how we did not respond, to the problem.”