Rapid Arctic Warming and Wacky Weather: Are They Linked?

Arctic amplification describes the tendency for high northern latitudes to be more sensitive to warming or cooling relative to the rest of the northern hemisphere. This heightened response is linked to the presence of snow and sea ice, and the feedback loops they trigger. For example, as sea ice retreats, sunshine that would have been reflected back to space by the bright ice is instead absorbed by the ocean, which then warms the water, and melts even more ice. As the Earth’s temperature has increased since the fossil-fuel revolution following World War II, Arctic temperatures have increased at more than twice the global rate. A dramatic indicator of this warming is the loss of Arctic sea ice in summer months, where area coverage has declined by about 40 percent in just the past three decades (1). In September 2012, the amount of sea ice area hit a new record low after a particularly hot summer, not just breaking but smashing the previous minimum record. The loss of sea ice volume, another metric for evaluating these changes, was even more dramatic; nearly 75% has been lost. This leaves the Arctic ice cover much thinner and more vulnerable to any abnormalities in winds, ocean currents, or injections of warm air from the south. Studies have shown that the main culprit is increased greenhouse gases resulting mostly from burning fossil fuels.

Does it seem as though your weather has become increasingly “static” lately? Day after day of cold, rain, heat, or rainless skies may not be a figment of your imagination. Extremes in weather patterns are clearly on the rise, and there is increasing evidence that rapid Arctic warming – so-called Arctic amplification – may be playing a role.

The extra heat being absorbed by the vast expanses of open water, once covered in ice but now exposed, is substantial. In 2012 alone, the energy was equivalent to what the United States would consume in 25 years. Come fall, most of that heat is released back to the atmosphere; during the past decade this extra heat has resulted in increased near-surface air temperatures of 2 to 4°C over much of the Arctic Ocean (Fig. 1), along with warming that radiates several kilometers up into the atmosphere. All that extra heat cannot help but affect the weather, both locally and on a large scale. But how? The Arctic is generally colder than mid-latitudes, and it is this difference in temperature that propels the west-to-east river of fast-moving air known as the jet stream. This atmospheric feature tends to follow a wavy path as it flows around the northern hemisphere between about 30°N and 60°N, (at an altitude where jets fly, hence the name). As high latitudes warm more than mid-latitudes, however, this north-south temperature difference weakens, which has two impacts on the jet stream.

The first effect is to slow its west-to-east winds, a phenomenon that already appears to be occurring. Upper-level winds around the northern hemisphere have decreased during autumn months (Oct.-Dec.), which is exactly when sea-ice loss exerts its strongest effect on the north-south temperature gradient (Fig. 2). Some regions exhibit even larger drops in...
wind speed, such as over N. America and the N. Atlantic, where winds have slowed by about 14% since 1980 (2). Theory tells us that a decrease in the west-east flow tends to slow the eastward progression of the large north-south waves in the jet stream. Because these waves control the formation and movement of surface weather systems, slower wave progression means that weather conditions will be more persistent. In other words, they will seem more “stuck in place.” This effect appears to be strongest in autumn, because as sea ice reforms in winter, the north-south temperature difference gradually returns to more normal values. As Arctic amplification continues to emerge in the other seasons, however, these same effects on weather patterns are expected to become evident.

The second way that Arctic amplification is expected to influence the jet stream and our weather is by increasing the “waveness” of the jet stream. Because of Arctic amplification, the northern peaks of waves, called ridges, will experience more warming than the southward dips, called troughs. This is expected to cause the ridges to stretch northward (Fig. 3), which will increase the size of the waves. Larger swings in the jet stream allow frigid air from the Arctic to plunge farther south while warm, moist tropical air can penetrate farther northward. This type of wavy pattern has been increasing during fall (Fig. 4) and early summer in the N. Atlantic in particular, which has contributed to the accelerated melting of Greenland’s surface. Meteorologists know that larger jet-stream waves progress eastward more slowly, as will the weather systems associated with them. Consequently this represents another mechanism that will cause weather conditions to linger.

Increased waviness seems to be occurring during summer, as well (2), but in addition to sea ice loss, another culprit appears to be the progressively earlier melt of snow on high latitude

Figure 3:
Schematic of a typical jet stream trajectory (solid line) over North America and the expected elongation of ridge peaks northward (dashed line) in response to Arctic Amplification.
land during spring (Fig. 5). As snow disappears, bare soil is exposed to the strong spring sunshine earlier, which allows it to dry and warm sooner (3, 4). This effect is at least partly responsible for the approximately 2°C of warming over high-latitude land areas since the mid-1980s (5). This heat contributes to Arctic amplification during summer, which is expected once again to stretch ridges northward, increase waviness, and promote sluggish weather.

Many examples of “stuck” weather patterns during the past few years come to mind. Deep troughs in the jet stream hung over the U.S. east coast and Western Europe during the winters of 2009/2010, 2010/2011, and 2012/2013 bringing a seemingly endless string of snow storms and teeth-chattering cold. In the early winter of 2011/2012, in contrast, these same areas were under ridges, which brought unusually warm and snowless conditions, while at the same time a deep trough sat over Alaska, dumping record snows. In contrast, during summer, persistent weather patterns are responsible for droughts and heat. The record heat waves in Europe and Russia have been linked to early snowmelt in Siberia (6). A sluggish high-pressure area caused sweltering conditions in the south-central U.S. during recent summers. When Hurricane Sandy tracked up the eastern seaboard during October 2012, a very wavy trough ridge pattern was in place over N. America and the N. Atlantic. This created the flow that steered the storm on its unprecedented westward path into New Jersey, which resulted in the expansive area of destructive tropical-storm-force winds from Delaware to Nova Scotia and generated the nor’easter that brought record snows to West Virginia. Sandy occurred after a summer of record-shattering Arctic sea-ice loss; whether the two phenomenon are related is not clear at this point (7).

While it’s difficult to say with any certainty that Arctic amplification is the cause of any particular extreme weather event, these are the types of phenomena that are expected to occur more often as the world continues to warm and the Arctic continues to lose its ice. Further research may find ways to predict who will experience which conditions, but in the meantime, it’s increasingly likely that the weather you have today will stick around a while, and that wacky weather will become the new normal.

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### Figure 4:
**Differences between observed and normal snow cover during June in the northern hemisphere from 1967 to 2012.**

Data are from the Rutgers Global Snow Lab, [http://climate.rutgers.edu/snowcover](http://climate.rutgers.edu/snowcover).

### Figure 5:
**Trends in the north-south size of waves in upper-level flow (in degrees of latitude per decade) from 1979 to 2010 versus longitude during autumn (Oct-Dec).** Asterisks show statistical significance at the 90% confidence level. Positive values at nearly all longitudes suggest that the jet stream has become more wavy in recent decades.
Have you tried to explain climate change to a non-scientist?
Please share your approach to making the case that climate change is real and cause of collective action.

I frequently give presentations to groups of local residents -- various clubs, schools, libraries, and other organizations -- who are mostly non-scientists. I usually start by showing a graph of how the Earth's temperature and carbon dioxide concentrations have fluctuated going back 450,000 years. Through almost all of that record, temperature and CO2 fluctuated in lock-step, right up until about 50 years ago, when CO2 began a steep increase while temperature has remained relatively constant. We know that the amount of CO2 in the atmosphere today is higher than it has been in at least 800,000 years, and the last time it was this high, sea levels were tens of feet higher. I explain that we know what caused temperature to vary in the past -- large swings triggered by changes in the Earth's orbit, volcanic eruptions, and variations in the sun's energy output -- and the CO2 amounts followed the initial temperature changes. But now we see a totally different relationship. Through chemical fingerprinting, we know the CO2 increase comes from burning fossil fuels, and we understand well that higher CO2 levels in the atmosphere act like a blanket on the planet to trap heat. It takes a long time for the Earth to adjust to the new CO2 levels, however, because most of that trapped heat goes into the oceans, and it takes a lot of energy to warm water. We see the Earth has started to respond with increasing temperatures, and that is what we call global warming. There are many clear signs of change in the Earth's system that can only be explained by the increase in CO2 from fossil fuel burning: melting Arctic sea ice (75% has been lost in only 30 years), disappearing glaciers world-wide, rising sea levels, and more acidic ocean, to name only a few. Because CO2 lasts a long time in the atmosphere, we know that even if we could stop burning fossil fuels today, the Earth will still undergo a great deal of additional warming. There is no time to lose in taking action to shift away from fossil fuels and slow down the path of warming that we're on.

Tell us how you are reducing your carbon footprint in the battle to reduce greenhouse gases resulting from burning fossil fuels?
I try to reduce my personal carbon footprint in many ways:

- **Our home:**
  - is heated and cooled with a geothermal (heat-pump) system
  - has low-e windows (low emissivity windows are made of glass that has a film coating applied improve thermal efficiency)
  - has efficient insulation
  - our lighting is all with CFL or LED bulbs

- **I have driven a hybrid car since 2005, I consolidate my errands to reduce driving time**

- **I drive my car "gently" – as though a raw egg sat between my foot and the gas or brake pedal.**

- **Our family recycles everything recyclable**

- **I buy locally produced food and items whenever possible**

- **I serve on my town's Energy Management Committee to encourage renewable energy use and energy conservation in our town**

- **I give many presentations to public groups to educate people about the science behind our changing climate and the importance of making choices that reduce fossil fuel use.**

References:


Jennifer Francis, Rutgers University (AISIS Member since 1989) earned a B.S. in Meteorology from San Jose State University in 1988 and a Ph.D. in Atmospheric Sciences from the University of Washington in 1994. As a professor at Rutgers University since 1994, she taught courses in satellite remote sensing and climate change issues, and also co-founded and co-directed the Rutgers Climate and Environmental Change Initiative. Presently she is a Research Professor with the Rutgers Institute of Marine and Coastal Sciences and studies Arctic climate change and Arctic-global climate linkages with ~40 peer-reviewed publications on these topics. During the 13 months from July 2009-July 2010, her family of four spent a year sailing through Central America. She and her husband circumnavigated the world in a sailboat from 1980-1985, including Cape Horn and the Arctic, which is when she first became interested in Arctic weather and climate.