IMPACTS

Heated debate on cold weather

Arctic warming has reduced cold-season temperature variability in the northern mid- to high-latitudes. Thus, the coldest autumn and winter days have warmed more than the warmest days, contrary to recent speculations.

Erich M. Fischer and Reto Knutti

Pictures of partly frozen Niagara Falls and ice-covered orange trees in Florida dominated the news for weeks last winter. The jet stream — a ribbon of strong winds at high altitude — followed an unusual route and brought bitterly cold weather to the eastern US and unusually warm temperatures to Alaska. Likewise, Eurasia experienced some very cold winters in recent years. A number of studies proposed that strong Arctic warming and declining sea ice extent caused the jet stream to meander more[1], thereby making temperatures more volatile and causing more intense cold spells in mid-latitudes of the northern hemisphere[2,3]. As he reports in *Nature Climate Change*, James Screen[4] challenges this hypothesis and provides observational evidence for the opposite effect. Again, anomalous Arctic warming is put forward as the primary driver, but for making northern hemispheric autumn and winter temperatures less, rather than more, variable.

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Screen observed a decline in daily temperature variance during the cold season at northern mid- to high-latitudes. The coldest autumn and winter days have warmed more than the warmest days. This behaviour is explained with a remarkably simple mechanism[4] — cold days predominantly occur when winds are blowing from the north and warm days occur when they are blowing from the south. Arctic amplification, meaning that warming is greater in the Arctic than at low latitudes, causes northerly winds to warm to a greater degree than southerly winds. Consequently, the coldest days warm more rapidly than the warmest days at the latitudes between. A comparable mechanism has been used to explain the simulated variance reduction in central European winters[5], where the east–west land–sea warming contrast — that is, the land warms more than the surrounding ocean — is considered instead of the north–south contrast.

Consistent with the observed changes, global climate models project a continuing trend of less variable land temperatures in the region 50–80 °N in autumn, winter and spring. Screen demonstrates that models projecting a stronger Arctic amplification show a stronger variability reduction, which supports the proposed mechanism. Reduced variance of daily and interannual winter temperatures[5–6], and thereby amplified warming of cold extremes[7,8], in a warmer climate was originally proposed two decades ago[9] based on climate model simulations. This view is now complemented by observational evidence and improved physical understanding.

Changes in variance strongly affect climate extremes and may require different adaptation than changes in mean climate. Consequently, assessing such variance changes is vital but challenging, as model biases and uncertainties are large. What is robust, however, is that the popular picture of a general 'global weirding' — of all kinds of weather becoming more extreme and volatile across the globe — is simplistic and misleading. Enhanced day-to-day and year-to-year variations have been observed[10] and projected in European summer climate[8], whereas in other regions temperatures are expected to become less variable[11]. Processes controlling variability are distinctly different for daily, interannual or multi-decadal timescales. Thus, variability increases, decreases or remains unchanged, depending on timescale, region and season. Confidence in variability changes is highest when observations and models are consistent, and where plausible mechanisms have been proposed, such as for the reduced daily temperature variance during the cold season[4].

After the recent cold spells, some people were quick to use pictures of frozen lakes and waterfalls to claim that anthropogenic warming was a hoax, or that its influence was overestimated. Others, in defence, were searching for explanations to reconcile the occurrence of cold spells with an overall warming trend. They argued that the cold spells were part of internal climate variability and a temporary excursion from the long-term trend towards warmer winters, or that Arctic sea ice decline — and therefore potentially human influence — was playing a decisive role in this counterintuitive trend.

The debate about the recent cold spells followed the familiar pattern that characterises public reaction to surprising events such as disasters, aircraft accidents or crimes. A causal explanation is immediately called for, and experts are tempted (or forced) to speculate, even though little is known. The media happily runs the resulting stories, hypotheses further develop in the blogosphere and sometimes become accepted as facts despite a lack of evidence. It is natural to ask for explanations quickly after events happen. It is also valuable to publish hypotheses and propose causal mechanisms based on simple correlation and regression analyses. Thereafter, however, these hypotheses need to be scrutinized with observational evidence, confronted with the existing body of literature and rigorously quantified to test whether they play a dominant role in determining cold spells. Such a scientific debate can be stimulating and fruitful[12], but it takes time.

The proposed link between sea ice decline and enhanced meandering of the jet stream has been found to be sensitive to the analysis method used[13,14]. However, some of the proposed mechanisms linking Arctic amplification, declining sea ice or Pacific warm anomalies[15] to mid-latitudinal weather are indeed plausible. Nevertheless, it first needs to be demonstrated that their signature is strong enough to emerge from the noise of the ordinarily highly variable winter weather[16]. In the end, the most powerful argument is the observational evidence and our quantitative physical understanding. Screen demonstrates that despite recent cold winters, cold days have become less, rather than more, extreme.

This debate should remind both the public and the scientific community that drawing conclusions too quickly may not help, just as it does not help to prejudge suspects after a crime. It should be possible for scientists to say 'we do not know yet' — in fact, such a statement should increase, not decrease, their credibility. Sometimes explanations are not straightforward. It takes time to assemble the required data, study mechanisms, run model experiments and challenge each other on various hypotheses[12]. The final verdict on the linkage between Arctic amplification and mid-latitudinal winter weather is still out, but the explanation for the recent cold spells may indeed be quite straightforward, as Screen argues. Internal variability of cold weather is very high, and recent cold spells may just be a few excursions from a long-term trend to warmer winters. ❐

Erich M. Fischer and Reto Knutti are at the Institute for Atmospheric and Climate Science, ETH Zürich, Universitätstrasse 16, 8092 Zürich, Switzerland.
e-mail: erich.fischer@env.ethz.ch; reto.knutti@env.ethz.ch

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CLIMATE AND LAND USE

Forgive us our carbon debts

Sugar cane ethanol replaces fossil fuels, but changes in soil carbon could offset some of the benefit. Now, a study shows minor loss of soil carbon when pastures and croplands are converted to cane, but larger losses when converting native savannahs.

Marcia N. Macedo and Eric A. Davidson

As if growing enough food without clearing native forests and savannahs were not hard enough, an increasingly large land area is now being used to grow biofuel crops[1]. Brazil alone grew 98,000 km^2 of sugar cane in 2012, harvesting 721 million tonnes of cane, about half of which was destined for producing ethanol[2]. Burning biofuels in lieu of fossil fuels may increase energy security and mitigate climate change, but fully accounting for net greenhouse gas (GHG) savings has proved challenging. Among other things, limited data exist on potential soil carbon losses or gains when sugar cane replaces other land uses. As they report in *Nature Climate Change*, Mello and colleagues[3] use field measurements of soil carbon in Brazil to estimate the carbon debt and payback time associated with sugar cane expansion over a range of land covers.

Accounting for the GHG savings associated with sugar cane ethanol production requires reliable estimates of: (1) fossil fuels used during sugar cane production, transport and ethanol processing; (2) carbon and other GHG emissions when native forests or savannahs are cut down for cane production; (3) changes in soil carbon stocks during land conversion and crop production. These emissions add up to a 'carbon debt' that must be 'paid back' before a biofuel crop can be considered a net benefit for climate change mitigation. The paybacks include the sequestering of carbon in soils as biofuel crops grow and the fossil fuel emissions avoided through ethanol use.

Mello *et al.*[3] report field measurements of changes in soil carbon when cattle pastures, croplands or native savannahs were converted to sugar cane. Earlier studies[4,5] were based on broad-brush assumptions about how much soil carbon would be lost with tillage. The current study supports those conclusions, but provides greater confidence based on soil data from 75 pairwise comparisons of land conversion