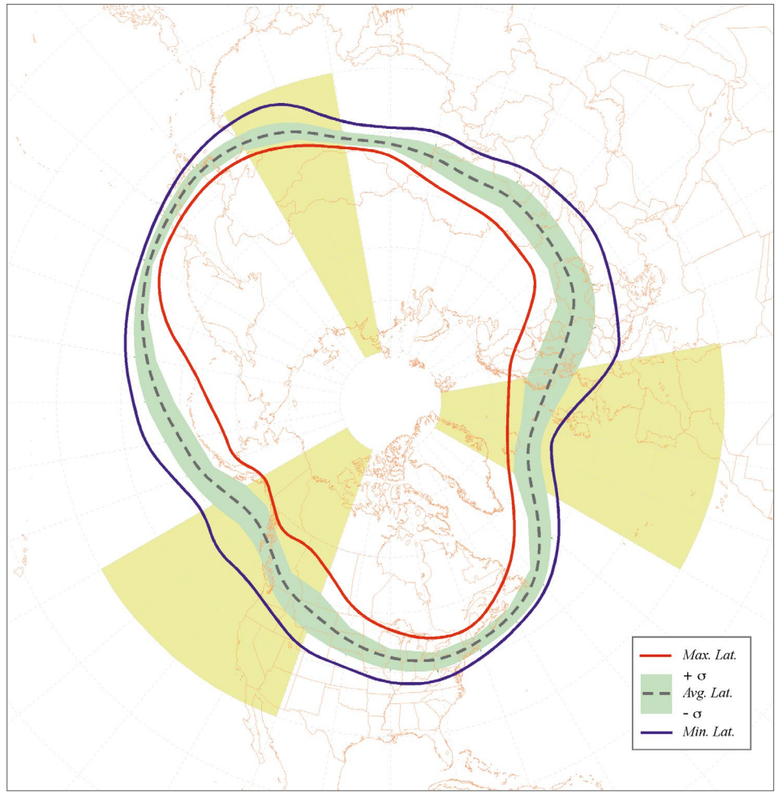
Our warming winters – canary in the climate coal mine?

Professor Jonathan Martin has found irrefutable evidence for warming in the Northern Hemisphere

The warming of our planet is a very real issue, yet there are still many out there who are unwilling to accept the harsh reality of climate change. **Professor Jonathan Martin** from the University of Wisconsin-Madison provides yet another undeniable example of climatic shift, this time drawing upon the behaviour of cold air in the Northern Hemisphere from 69 years of data.

Deducing and understanding general climatic trends in the Earth's atmosphere is extremely difficult. Our planet's natural climate is governed by a multitude of factors all of which vary over time and space, often occurring in cycles. Adding in human interference from an ever-expanding population producing vast quantities of pollution only further complicates these natural processes. Finding a way to measure (and accurately diagnose) climate change is an essential challenge facing climatologists worldwide today.

Careful monitoring of specific observed quantities has long been a primary means of assessing subtle changes in the climate system. Often, such scrutiny also leads to increased understanding of how (and why) the climate is changing. After analysing 69 winters' worth of meteorological data, Professor Jonathan Martin has found irrefutable evidence for warming in the Northern Hemisphere, and suggested it is linked to both increased greenhouse gas concentrations and changes in the wintertime storm tracks.



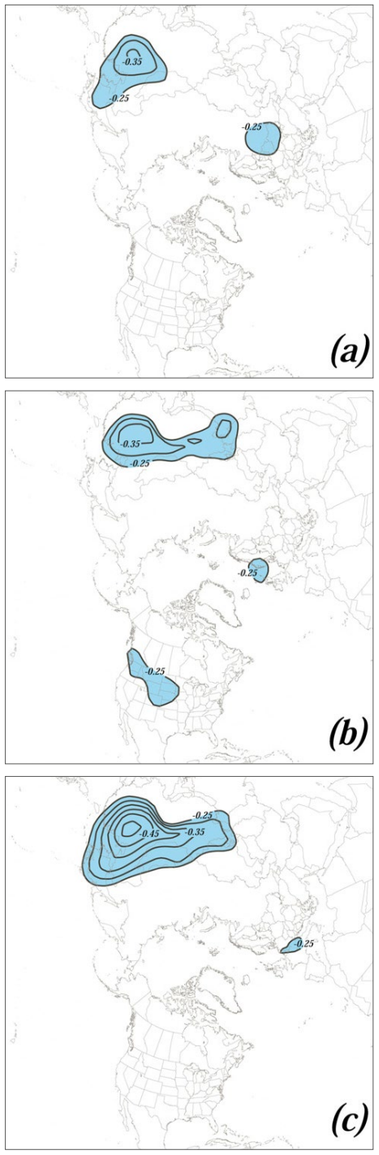
66-year average DJF latitude (dashed line) of the -5°C isotherm at 850 hPa from the NCEP Reanalysis data. Green shading indicates +/- 1° from that average while the solid blue (red) line represents the minimum (maximum) latitude of the -5°C isotherm at each longitude over the time series. Yellow shading indicates regions in which the northward trend in latitude over the 66-year time series is significant above the 95%.

THE 'LOWER TROPOSPHERIC COLD POOL'

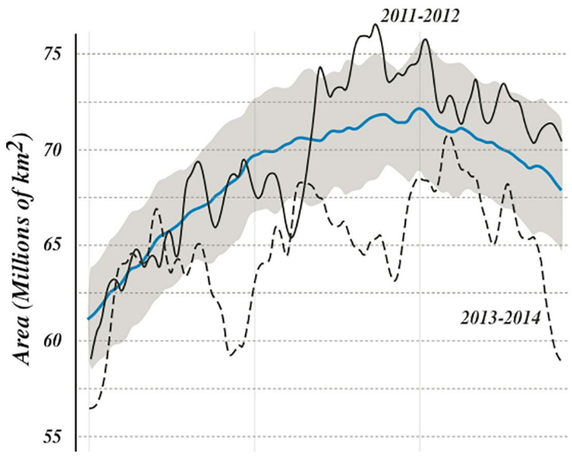
Though we all know that air gets colder as we move away from the equator, air temperature is also influenced by specific geographical area as well as elevation. Meteorologists use balloon-borne radiosondes (instruments carried by a balloon or other means to various levels of the atmosphere to transmit weather data by radio) to routinely take measurements further above the ground in the troposphere (0-10km), using standard air pressure levels rather than altitudes. To minimise the effects of surface level microclimates in his analysis, Prof Martin considered air temperatures at the 850 hPa (hectopascal) level – normally around 1.5 km above sea-level – for every day in the winter season, defined as from 1st December – 28th February each year. He simply calculated the area covered by air colder than a series of threshold temperatures (-5°, -10°, -15°, -20°, and -25°C), focusing most intensely on the outer boundary of -5°C air. He referred to the areal extent of the -5°C air as the "lower tropospheric cold pool".

In context, the cold pool can be imagined as a 'cap' of air that sits above the Arctic (and Antarctic) region of the globe – a little like the icing on a Christmas pudding! Three different reanalysis datasets were used to measure the daily and seasonal extent of this cold pool: The National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalysis, ERA-40, and the NCEP Climate Forecast System Reanalysis (CFSR). Atmospheric reanalyses are outputs from sets of models which consistently process huge amounts of raw climate data (both direct observations and remotely sensed measurements from satellites) to produce the best possible overall estimate. Though each of these data sets covered different periods of time, when the data overlapped the results were remarkably similar. By examining the available data back to the winter of 1948/49, Prof Martin came to a robust and reliable conclusion. As we might expect, his results are not great news.

The area of the 'cold pool' has significantly decreased over the last 69 years, by 4.74% to be precise. This seemingly small number is a huge area in reality (more than 3.3 million square kilometres, or 1.24 million square miles). To put these numbers in a clearer perspective, the cold pool is steadily shrinking by an area slightly larger than England every three years! Furthermore, the rate of decrease of the seasonal cold pool extent mirrors the rate of decrease of late



(a) Map of correlation between the daily average December 850 hPa temperature at each grid point (from 1948-2013) in the NCEP Reanalysis data to the daily time series of normalised Northern Hemisphere cold pool area for each December day in that interval. Magnitude of correlations significant at the 95% level are contoured and shaded every 0.05 beginning at -0.25. (b) For January days from 1949-2014. (c) For February days from 1949-2014.



Daily average area for DJF (1st December-28th February) in 2011-2012 (solid black line) and 2013-2014 (dashed black line). Thick blue line represents the 66-year daily average over DJF from the NCEP Reanalysis data. Grey shading indicates the +/-1 standard deviation of the daily average area.

The observed systematic shrinking of the lower tropospheric cold pool offers complimentary evidence that our planet is very much getting warmer and that there has not been a "global warming hiatus

winter Arctic sea ice, a well-regarded signal of global warming.

STORMS ON THE HORIZON

When examining the shape of the cold pool in more detail, Prof Martin found that there were large bulges of cold air over land masses. The cold pool shape changed the most over northwest Europe and western North America, suggesting that these regions experience the most variable winters.

He also discovered that there were only three areas in the Northern Hemisphere where the -5˚C boundary had systematically migrated closer to the North Pole over the 69 winters. Two of these warming 'hotspots' are localised around the ends of the two major winter storm tracks (narrow corridors where storms travel) in the Atlantic and Pacific oceans. In fact, the contraction of the cold pool at these two locations accounts for around 50% of its total size decrease. A substantial body of research has concluded that these storm tracks are moving poleward due to global warming, and Prof Martin believes that this tendency has resulted in greater volumes of warm air being sent to high latitude during winter – contributing to the shrinkage of the cold pool.

HELPFUL ANOMALIES

Another way that Prof Martin shed a light on the changing size of the 850 hPa cold pool, was by analysing its most extreme behaviours. He compared the number of days it had been unusually large (at least two standard deviations greater in extent than the calendar day average), or unusually small (at least two standard deviations smaller than average). He found that across 69 years of data, 79.7% of all unusually small days occurred since 1990, and over 55.6% since 2000. In fact, the last time the Northern Hemisphere winter had an extreme cold day was 13th February 1994. Since then, the tally of extreme warm to extreme cold days has been a remarkable 191-0! This is strong evidence of a persistent global warming.

Prof Martin also observed how and where the -5˚C boundary shifted during these extreme events. The main finding was that during unusually cold winter days, cold air was always present across central and southern China. This hinted at a relationship between extreme Northern Hemisphere cold events and the intermittent cold surges of the East Asian Winter Monsoon (EAWM) which is currently being investigated. No such characteristic connection appears to be associated with extreme warm days.

So, what does Prof Martin's research tell us? First and foremost, the observed systematic shrinking of the lower tropospheric cold pool offers complimentary evidence that our planet is very much getting warmer and that there has not been a "global warming hiatus" as has been suggested by skeptics. Secondly, the primary warming areas in the Northern Hemisphere appear to be intimately linked to the northward migration of the storm tracks, which is, itself, attributed to global warming. The feedback between the hemispheric warming and broad circulation changes arising from increased greenhouse gas concentrations is complex and sometimes counterintuitive. This only highlights the need for more research like that of Prof Martin to provide answers and solutions to this pressing global challenge.

Q&A

Why is 850 hPa a preferential air pressure to take data from?

850 hPa is only 1.5 km above sea-level and so it is truly located in the lower troposphere. Other standard levels such as 700, 500, and 300 hPa would be interesting to consider but would not testify to conditions in the "lower troposphere" and, since we have a very good record of surface temperatures, it seemed best to try to construct trends at a near surface level for direct comparison.

Why might there be warmer air at the end of storm tracks?

The "storms" in the Northern Hemisphere have a characteristic counter clockwise circulation around them. Therefore, the air on the eastern (western) side of the storm is moving northward (southward). The ends of the storm tracks are locations in which the warm air that has been dragged northward on the eastern side of the developing storms in the track, is finally "dumped" so they do tend to be places where warmer air might be deposited.

How did you define an unusually small, or unusually large cold pool winter day?

Since I can measure the daily extent of the cold air at 850 hPa, I can develop statistics about each calendar day in the winter season. By taking the areal extent on a given day, subtracting the average for that day, and then dividing the difference by the standard deviation for that same calendar day, I can get a normalised anomaly for every day in the record. I arbitrarily termed days with a standardised anomaly of +2 (-2) as extreme warm (cold) days.

How might you use the reanalysis datasets to look at the cold pool in three dimensions? What could this tell us?

Looking at the areal extent of certain threshold temperatures at different levels would be of interest. The lower stratosphere, for instance, (pressures of ~100 hPa) are supposed to be cooling during global warming and this should be reflected in an increase in the areal extent of cold air at 100 hPa. Another 3D trick one can play involves calculating the volume of air that has a potential temperature at or below a certain threshold. I have done this calculation but still need to think some about what it means.

This is a huge global problem. How can the everyday person make a difference to these vast climatological changes?

I think the key is to not be overwhelmed by the enormity of the problem while simultaneously focusing on one's personal smallness. I am a big believer in the power of incrementalism – small changes to habits that one incorporates into daily life are substantial actions that can mitigate this problem. Simple ones mostly involve energy conservation issues and there are numerous opportunities for everyone to make some contribution. Turning off lights in your home or workplace that are not being used, turning off your computer, television, and radio when not in use. Taking the bus to work if possible or riding a bike on a nice day. The integral of these small decisions over the course of a 25-year work career can be substantial.

Detail

RESEARCH OBJECTIVES

Dr Jonathan Martin is combining new and old data with an aim to understand the complex relationship between meteorological processes and climate change, and further demonstrate the irrefutable state of warming our planet is experiencing.

FUNDING

National Science Foundation (NSF)

BIO

Professor Jonathan Martin joined the faculty at UW-Madison in 1994 after completing his PhD in atmospheric sciences at the University of Washington. His research expertise is in mid-latitude weather systems and he has authored over 60 scientific papers, as well as a leading textbook on mid-latitude atmospheric dynamics.

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