NASA/Kathryn Hansen

Bouncing towards an **ice-free** summer

One warm year and we're told an Arctic without sea ice is just around the corner; the next cold one and it's claimed the ice is recovering. Ed Hawkins explains why Arctic melting will continue to be erratic for the foreseeable future – but says the overall trend is only heading one way.

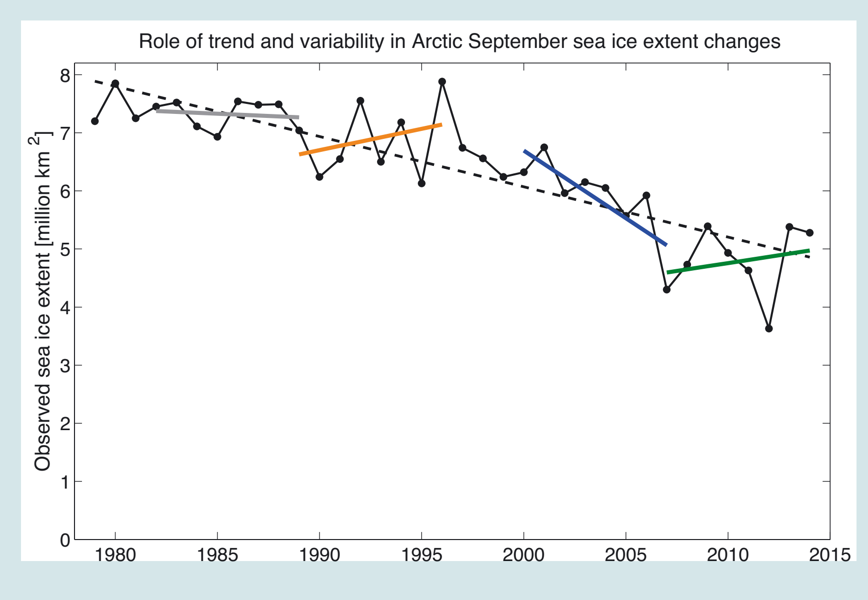
Arctic sea ice melts each summer, reaching its minimum extent sometime in September, before refreezing through the winter. Over the past 35 years, the area of sea covered by ice in September, known as sea-ice extent, has fallen by about 35 per cent overall, and this decline is projected to continue as global temperatures increase.

As a result, commercial Arctic shipping has increased, taking advantage of shorter journey times from Europe to Asia, while possibilities for oil, gas and mineral extraction are being explored and Arctic tourism is growing. Decisions about such activities need to assess both risks and opportunities. To do this, we have to consider both the overall long-term decline in sea ice and, importantly, the natural fluctuations that cause the sea ice to vary from year to year.

In 2007 and 2012 the summer ice extent was dramatically lower than in previous years, causing some prominent forecasts and media speculation that we would soon see Arctic summers which were 'ice-free' (meaning there would be less than a million square kilometres of sea ice).

Most climate scientists were more cautious. The weather in 2007 and 2012 had been warmer than usual and the weather was particularly favourable for melting sea ice. Although we have detected a human influence on Arctic sea ice, there was no evidence that

Satellite observations of September Arctic sea ice extent.



these particular weather patterns would happen every year.

In contrast, 2013 and 2014 had more sea ice than 2012, leading to contrasting speculation that a recovery was under way. But is this true?

The graph shows that Arctic sea ice extent – the black line – has fallen over the long term, with the dashed line representing the linear trend. But there have also been shorter periods of rapid melt, no change, and apparent increases in extent during this decline – represented by coloured trend lines for some deliberately-chosen eight-year periods.

analogy for the changing Arctic sea ice.

The hill represents the long-term downward trend in Arctic sea ice due to increasing global temperatures, and the bumps introduce deviations from this smooth trajectory. These erratic bounces could be in either direction, causing the melt rate to accelerate or temporarily slow down. If you only watch the ball for a short time, you might conclude it was moving against gravity. A longer-term view would show this was just a bounce.

There is no reason to think that sea ice, or any other aspect of the climate, will change smoothly over time. The climate system simply does not work that way.

> *Erratic changes are what we expect to see. Short periods are not a guide to long-term trends.*

The most recent eight-year period, starting from the extreme low of 2007, shows an upward trend. This does not mean Arctic sea ice is recovering. As with global temperature, these erratic changes are what we expect to see. Short periods should not be used as a guide to long-term trends.

How long before the ice is gone?

Imagine a ball bouncing down a bumpy hill. Gravity will ensure that the ball will move downwards. But if the ball hits a bump at a certain angle it might move horizontally or even upwards for a time, before resuming its inevitable downward trajectory. This bouncing ball is an

Previous studies have suggested that natural climate variations (or 'bounces') play a key role in how sea ice evolves, and suggested that some of the rapid melt in the early 2000s was a temporary acceleration.

New research by a team of Canadian and American scientists and me, published in *Nature Climate Change*, suggests that the recent apparent pause in melt rate is a temporary 'bounce' in the opposite direction, and that this is exactly what you might expect.

We analysed the state-of-the-art climate models that are used to make projections of future climate. These simulations show a long-term decline of sea ice, but also exhibit shorter periods of both little change and faster change in Arctic sea ice, just like those seen in the satellite observations. What we have seen recently in the Arctic is well within the range of these simulated expectations. We also found that a decade or more with little apparent change in sea ice would not be a surprise – this often happens in the climate simulations, even in a warmer future.

The causes of these fluctuations in melt rate are still being explored. One suggestion is that slow variations in Atlantic Ocean temperatures are involved. More observations of the Arctic Ocean, atmosphere and sea ice would help answer this question. Satellite measurements of ice thickness, such as from CryoSat, are also transforming our understanding of how sea ice varies from year to year.

We expect the long-term decline in Arctic sea ice to continue as global temperatures rise. There will also be further bounces, both up and down. An often-asked question is 'when will the Arctic be ice-free?' – or equivalently, when will the ball reach the bottom of the hill? The Intergovernmental Panel on Climate Change (IPCC) concluded it was likely that the Arctic would be reliably ice-free in September before 2050, assuming high future greenhouse-gas emissions (where 'reliably ice-free' means five consecutive years with less than a million square kilometres of sea ice). Individual years will be ice-free sometime earlier – in the 2020s, 2030s or 2040s – depending on both future greenhouse-gas emissions and the natural erratic fluctuations.

Even when it reaches the bottom of the hill the ball will continue to bounce. Similarly, not every future year will be ice-free in summer. But if global temperatures continue to increase, the bounces will get smaller and the ice-free periods will get longer and spread from early autumn into summer and later autumn.

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