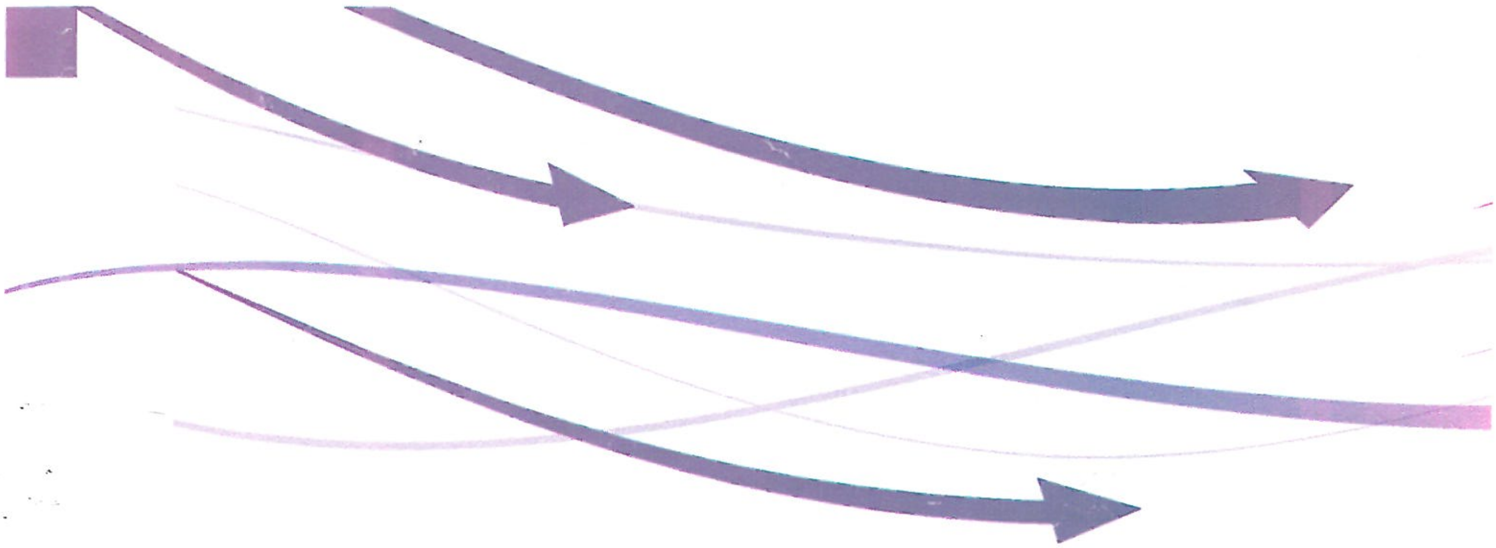

Winds of change?

Severe weather has been big news in recent years. The cold European winter of 2009-10 was followed by a deadly heatwave in Russia and devastating floods in Pakistan. Unsurprisingly, people want to know why these events happen and whether they are caused by climate change. Tim Woollings responds.

The key feature that links many severe weather events is their persistence. Individual storms can be very damaging of course, but when storm after storm hits the same region the effects are much worse. Similarly, a period of settled weather is warmly received, but as weeks without rainfall mount up, it begins to outstay its welcome. These are examples of long-lived weather regimes and, outside the tropics, these regimes are usually linked in some way to a movement of the jet streams.

The jet streams are literally jets of fast-moving air that are strongest about 10km up in the atmosphere – around the level where airliners fly. They are still felt at the surface, however, and in Europe our prevailing westerly winds are part of the west-to-east flow of air across the Atlantic, called the North Atlantic jet stream. Jet streams steer storm systems, so changes in the jet stream determine which regions are battered by storms and which are starved of rainfall.

Jet streams vary in strength from week to week. One of the most common variations in the North Atlantic jet stream is for the whole jet to shift to the north or the south. These shifts are referred to as the North Atlantic Oscillation (NAO) and they have a particularly strong impact on the weather in Europe. The prevailing westerly winds have a moderating, 'maritime' influence on Europe, keeping us warm in winter (when the Atlantic Ocean is warmer than the land) and cool in summer (when the land is warmer). The bitterly cold winter of 2009-10 was a classic example of a negative NAO event, when the jet stream shifted to the south and Europe lost its maritime influence. It's the persistence of these shifts that has such strong effects: in this case the jet stream stayed south for much of the winter, and Europe remained gripped by cold.

While the North Atlantic jet stream generally points roughly due east, straight across the Atlantic, it often meanders north and south. These meanders are the signature of so-called Rossby waves, which are similar to the familiar waves on the surface of water. However, instead of water moving up and down, Rossby waves consist of large air masses, often thousands of kilometres across, moving north and south. When an air mass moves north it starts to spin clockwise (when viewed from above), forming what's called an anticyclonic weather system – a high-pressure system associated with settled weather. When air moves south it spins anti-clockwise and becomes cyclonic – a low-pressure system which is prone to wet weather. A Rossby wave can therefore lead to a string of alternating high- and low-pressure systems, with the jet stream snaking around them from west to east.

Like water waves, Rossby waves generally move relative to an observer on the ground, and this movement leads to changes in the weather from week to week. In fact, the Rossby waves themselves always move towards the west, which means they are always swimming 'upstream' against the eastward-flowing jet. If conditions are right and the wave speed matches that of the jet, the wave will remain stationary. Then the high- and low-pressure systems are no longer moving relative to the ground, and a persistent weather regime is born. Summer 2007 was a good example of this: a low-pressure system remained stationary over the UK and led to widespread flooding, while just downstream a high-pressure system brought heatwaves and drought to the Mediterranean and Eastern Europe. The UK had the trough of the wave and Eastern Europe had the peak – see the top right image.

When waves on the ocean surface become too large they overturn and break, resulting in very turbulent motion. When Rossby waves break, the resulting weather situation is known as blocking. In this case the turbulent flow often becomes dominated by an anticyclonic air mass cut off from its origin in the subtropics. This high-pressure system blocks the normal passage of the jet stream, and a regime of dry, settled weather sets in.

When this happens in winter, blocking leads to a bitterly cold spell, as the mild westerly winds are replaced by winds bringing cold continental air from the east. When it happens in summer the result is drought and heatwaves, and blocking contributed to the events seen this summer in Russia. At the same time, downstream of Russia, a Rossby wave trough remained and interacted with the monsoon system to bring flooding to Pakistan.

So, is climate change to blame? The short answer is no, but the longer answer is more complicated. There is a well-known analogy between weather regimes and rolling a dice. Imagine you have a loaded dice that comes up with a six more often than it should, then imagine you roll the dice and it comes up six. Now ask yourself, did you get that six because the dice is loaded or would it have come up anyway? By loading the dice you have changed the statistics of how it behaves over many rolls – if you roll it 1000 times and get a six on 500 of those rolls, you know that's because the dice is loaded but you can't attribute any individual six to that fact.

That's the equivalent of the question about climate change – by adding greenhouse gases to the atmosphere we are effectively loading the dice, so that the statistics of climate are changed. But it does not make sense to ask if any given weather regime occurred because of climate change. Persistent weather regimes such as the examples above are, thankfully, fairly rare, but they are not unprecedented and they might well have happened anyway.

To begin to answer the climate change question properly, we have to look at the numbers of these events over several decades. Of course, we'd rather not wait for several decades to see if the occurrence of certain weather regimes is changing, so we look at hundreds of years of simulated weather data from climate models. Here, however, there is still much uncertainty.

Climate models are starting to show some agreement that the jet streams will shift slightly closer to the poles in response to increases in greenhouse gases, but there is still considerable disagreement between different models. This discrepancy will only be reduced through steady improvement in our understanding and modelling of climate. The future is particularly uncertain for regions like Europe, whose climate is so strongly influenced by the jet stream – because Europe lies at the boundary between maritime and continental climate zones it is particularly sensitive to changes in the winds.

So can we really say nothing about whether events like these will become more common? One thing we can say is that even if the statistics of weather regimes do not change, we may feel the impact of some of them more strongly. In particular, if the background temperature is a few degrees higher than it is now, settled weather regimes in the summer will lead to more intense heatwaves and droughts than they do now.

To stretch the dice analogy a bit further, this is like having a larger bet on the outcome of our throw, so we're hit harder when the dice don't go our way.

MORE INFORMATION

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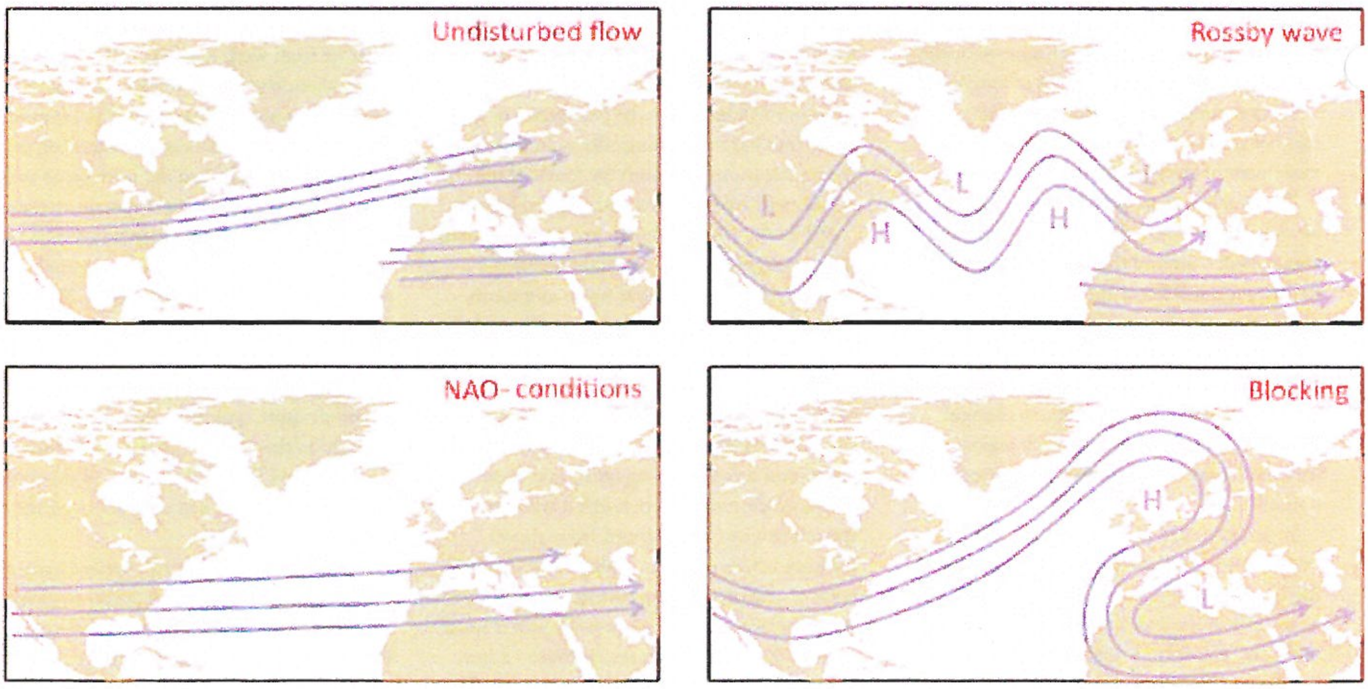
Woollings, T (2010) Dynamical influences on European climate: an uncertain future. *Phil Trans R Soc A*, 368:3733-56 (doi:10.1098/rsta.2010.0040).



Some examples of jet stream winds during weather regimes, with high and low pressure systems marked.