# Extreme weather from the stratosphere

January 11 2021, by Peter Rüegg

The stratosphere is the second layer of the Earth's atmosphere. It lies above the troposphere and forms part of the homosphere. Credit: NASA

ETH climate researcher Daniela Domeisen has documented how the stratosphere influences extreme weather events. What surprised her was the sheer range of potential impacts. She explains what this means for climate research and long-term weather forecasts.

## ETH News: In your new study, you've collated many examples of extreme weather events that are linked to

## what happens in the stratosphere. But we've always been told that such extreme events are due to global warming. Is that no longer the case?

Daniela Domeisen: No, that's still true. Scientists have known for a long time that the stratosphere—the atmospheric layer between 15 and 50 kilometers above the Earth's surface—also influences surface weather. But very few people have explored how the stratosphere can also cause and influence extreme events. That's what we show in our study.

## What are some examples of extreme events linked to the stratosphere?

Extreme cold snaps in the northern hemisphere are the most thoroughly investigated among the discussed weather extremes. These can occur when the polar vortex in the stratosphere suddenly heats up and collapses—as is happening right now. Another example is the series of severe storms that hit England in February 2020, leading to heavy flooding. It was remarkable that the storms all followed the same path. This had a direct connection to what was happening in the stratosphere at the time: Back in February, the polar vortex was unusually strong, which allowed it to stabilize the path of the storms. Typically, storms frequently change paths, but in this case, they kept following the same path. We also found evidence that the stratosphere plays a role in other extremes, for example the extreme forest fires in Australia and mini-hurricanes in the Arctic Ocean.

## Did the sheer number of such extreme events surprise you?

Yes. This is what the study brings to light. In the course of our research, we kept finding further indications for links between these erratic weather conditions and the stratosphere.

## Why is it almost always areas of the northern hemisphere that are affected? Are such events simply less common in the southern hemisphere?

That's a case of publication bias: there are far more studies of extreme events in the northern than in the southern hemisphere. The forest fires in Australia are a prime example of a southern hemisphere event. The polar vortex over the southern hemisphere collapsed much earlier than usual, which encouraged the ferocious fires. Then there's the fact that more people live in the northern than in the southern hemisphere because the latter has fewer land masses. Currently, we know very little about the extent to which the stratosphere influences the weather in e.g. South America or southern Africa.

## How is the stratosphere linked to the troposphere, where our weather occurs?

The main signals sent from the troposphere up to the stratosphere come in the form of large-scale atmospheric waves caused by mountains and by differences in temperature between the land and the ocean. Up in the stratosphere, these waves disrupt the winds and can be strong enough to destroy the polar vortex at a height of around 30 km with typical wind speeds of over 200 km/h. What is less clear is how signals return from the stratosphere to the Earth's surface. After a disruption of the polar vortex we often observe that the temperature in the lower stratosphere increases by several degrees Celsius at a height of 10–15 km. This in turn affects our weather, but we haven't yet got to the bottom of how such an event can determine e.g. a storm's path over England.

## Do you know how the stratosphere will develop in future?

No, we don't. Today's climate models project entirely divergent tendencies, ranging from a trend towards a warmer or a cooler stratosphere. But we can estimate that the stratosphere is responsible for around 10 percent of our winter weather. The stratosphere may actually mask climate change in the northern hemisphere in that, without the stratosphere's influence, global warming would perhaps be even more pronounced.

## What are your research goals?

One of our goals is to improve long-term weather forecasts that cover several weeks to months. Due to its influence on our weather, the stratosphere is a source of predictability for such forecasts. Although an event in the stratosphere doesn't allow us to predict the weather for a specific day several weeks ahead, it does let us estimate the likelihood of events such as cold snaps and heat waves. If, say, the winds in the stratosphere pick up, it's then more likely that northern Europe will see more storms in the weeks that follow. But at the moment, the polar vortex is particularly weak.

## So it will be a while before this kind of data is fed into the long-term forecasts offered by weather apps?

Weather models already simulate the stratosphere, just not well enough. This is one of the reasons why we continue to have unreliable long-range forecasts. We have much more experience in making standard, short-term forecasts that cover several days because we have spent decades verifying and improving them. We currently know far less about making forecasts for longer timescales, which involves understanding interactions on a global scale and not just how what happens over the North Atlantic can impact the weather that we expect. Our research is about understanding these global interactions so we can then use what we learn to improve weather and climate models.

## What's the next step towards using stratosphere events to improve weather forecasts?

First, we must improve our understanding of the link between the stratosphere and our weather. We know that when something happens in the stratosphere, we often see an effect at the Earth's surface. But one-third of cases leave no trace—and we don't yet know why. In such cases, it's a question of whether it was the stratospheric event or the link to the surface that was too weak. It is also possible that the weather at the Earth's surface was too chaotic, leaving it with no opportunity to react to the stratospheric event. Then there is the question of how long the lower stratosphere maintains the signal. I think of the lower stratosphere as a signaling layer: If the weather receives the signal, its influence can last for a relatively long time—several weeks, for instance.

## What new projects do you have lined up?

I want to more closely investigate the regions where long-term forecasts are challenging to make. These include e.g. Europe and parts of South America. What's more, since certain regions in Africa, Asia and South America are underrepresented in the research done to date, we know very little about them. We've launched projects in Brazil and South Africa to help correct this deficit. We want to find out if we can map processes that the models do not yet contain or that we could better integrate into the models by way of numerical methods or machine learning combined with a better understanding of the processes themselves. We also want to find further extreme events for which we can generate long-term predictability. When it comes to heat waves and cold snaps, we already know a lot about how these relate to the weather and how they affect people. But there are also indications of how the stratosphere and further processes influence other extreme events, such as effects on air quality or instances of heavy rain, which have a profound impact on people's lives.

**More information:** Daniela I. V. Domeisen et al. Stratospheric drivers of extreme events at the Earth's surface, *Communications Earth & Environment* (2020). DOI: 10.1038/s43247-020-00060-z

Provided by ETH Zurich