Is the jet stream changing?

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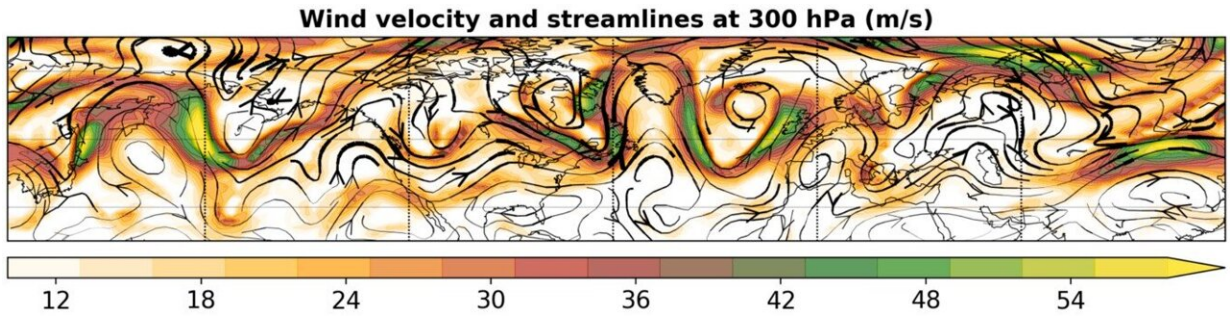

Wind velocity and streamlines at an altitude of about 10 kilometers above the Earth's surface on the onset of a Western Europe heat wave (23 August 2016). Credit: Georgios Fragkoulidis

Heavy precipitation, wind storms, heat waves—when severe weather events such as these occur they are frequently attributed to a wavy jet stream. The jet stream is a powerful air current in the upper troposphere that balances the pressure gradient and Coriolis forces. It is still not known whether the jet stream is really undergoing changes at decadal timescales and, if so, to what extent.

"There are various theories as to what we can expect from the jet stream in future. However, these are all based on highly idealized assumptions," said Dr. Georgios Fragkoulidis of the Institute of Atmospheric Physics at Johannes Gutenberg University Mainz (JGU). "Although it is quite clear that carbon dioxide emissions make a direct contribution to the global mean temperature, changes in the atmospheric circulation are

highly uncertain due to the chaotic processes that govern its evolution."

The pattern of changes over the last 40 years

In order to find out what is actually happening to the jet stream, Fragkoulidis analyzed upper-tropospheric wind data of the last 40 years. His objective was to determine how this air current at 10 kilometers above the Earth's surface in the 1980s differs from that of today and so to assess trends it may undergo over Germany or other locations.

"When the jet stream is particularly wavy, cold air from the north or hot air from the south can reach the atmosphere above Germany, making it more likely for cold spells or heat waves to occur," he pointed out. As a member of Professor Volkmar Wirth's Dynamic Meteorology group at the JGU Institute of Atmospheric Physics, Fragkoulidis has conducted research into this particular topic over a number of years. In general, his results indicate that two important aspects characterize the jet stream changes.

"In winter, many regions in the Northern Hemisphere experience positive trends, while these become negative trends in summer. In other words, the jet stream becomes wavier in winter but less so in summer," Fragkoulidis concluded. As of yet, there is no explanation for this phenomenon that partly contradicts the typical hypothesis, which asserts that the jet stream gets wavier in all seasons.

The other aspect that the Mainz-based researcher identified was that changes to the jet stream are not the same everywhere, but differ from region to region. What happens over North America is not necessarily the same as what happens over China or Europe. "We can't assess trends on the basis of simple mottos such as 'The jet stream is becoming wavier' or 'The jet stream is becoming less wavy.' It is far more complicated than that," he summed up.

Dr. Georgios Fragkoulidis did not only look at the waviness of the jet stream but also at the phase speed of the waves to establish how rapidly the waves moved from west to east. When they propagate slowly, this can result in stationary weather systems associated with heavy rainfall or prolonged periods of high temperatures and even drought.

"Although we may have the impression that it should be otherwise, there has been no significant change to the phase speed of waves in the Northern Hemisphere, particularly over Europe, in the last 40 years," stated Fragkoulidis. This conclusion also contradicts some conjectures that wave movements are slowing down.

However, the results of his research show that the situation is different in the Southern Hemisphere, where more substantial changes in phase speed are observed. Again, they vary with the season and the region. His findings have been published in *Weather and Climate Dynamics*.

Forecasts for the end of the century

Fragkoulidis is currently examining hypotheses on how the jet stream may change in future, specifically in the end of the 21st century. For this purpose, he uses forecasts based on climate models generated by the National Center for Atmospheric Research (NCAR) in the U.S. They are based on the assumption that carbon dioxide emissions will continue to rise and remain high and that the Earth's climate will have warmed by about 4°C by 2100.

The question is how this scenario could influence the jet stream. In theory, there is no easy answer to this because the warming effect will not be identical across all of the globe. In fact, the oceans will heat up more slowly than the land masses and different heights in the troposphere will heat up at different rates. All these aspects will consequently have an impact on atmospheric circulation.

Despite all the existing uncertainties, the climate model provides some evidence that future summer trends will be similar to those of the past and that the jet stream in the Northern Hemisphere will probably be less wavy towards the end of the century. Besides, it is much more uncertain what the future winter jet stream will look like.

More information: Georgios Fragkoulidis, Decadal variability and trends in extratropical Rossby wave packet amplitude, phase, and phase speed, *Weather and Climate Dynamics* (2022). DOI: 10.5194/wcd-3-1381-2022

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