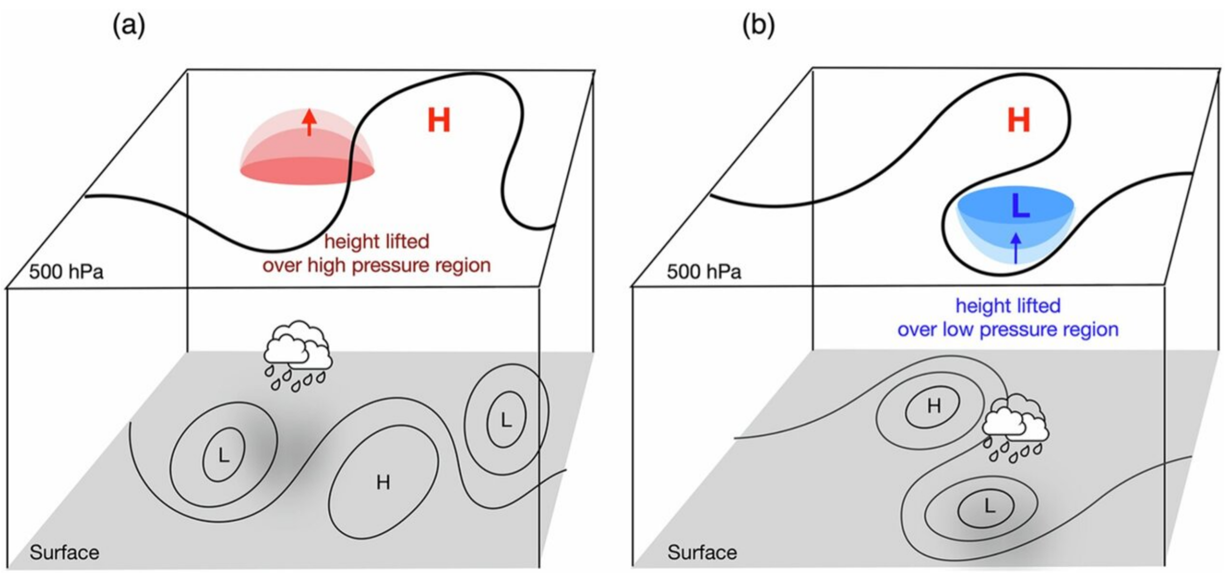
How moisture changes the rules of atmospheric blocking

August 21 2025, by David Siple



In the ridge block (a), the dark red dome represents the original high system without the modification by moisture, while the light red dome represents the lifted high system due to moisture. Similarly, in the dipole block (b), the light blue dome indicates the original low system while the dark blue dome indicates the lifted and thus dampened low system due to moisture. Clouds represent the location of moisture-induced diabatic heating in two types of blocks. Credit: provided by Lei Wang

New research from Purdue University reveals how moisture influences atmospheric blocking, a phenomenon that often drives heat waves, droughts, cold outbreaks and floods, helping solve a mystery in climate science and improving future extreme weather predictions.

The study, titled "Blocking Diversity Causes Distinct Roles of Diabatic Heating in the Northern Hemisphere," is published in *Nature Communications*.

Zhaoyu Liu, a Ph.D. student in the Department of Earth, Atmospheric, and Planetary Sciences, and Lei Wang, an assistant professor in EAPS, were both involved in this publication. Liu served as the study's first author and performed the analysis, while Wang was the corresponding author and conceived the original idea for the research.

Atmospheric blocking occurs when stagnant air patterns disrupt normal weather flow, often causing prolonged extreme weather. Wang and Liu's research challenges decades-old theories that assumed a dry atmosphere.

"Since the beginning of modern meteorology (around the 1940s), most classical theories for atmospheric blocking were developed based on the assumption that we are living in a completely dry world," Wang said. "Obviously, that assumption was helpful for simplifying the processes to its essence, but a completely dry assumption is not the case in the real atmosphere."

Atmospheric blocking comes in two main forms: ridge blocks, which create large, high-pressure "bubbles" that push the jet stream north and often lead to heat waves, and dipole blocks, which pair high and low pressure side by side, trapping contrasting weather patterns in place. Diabatic heating refers to the warming or cooling of air due to the exchange of heat with its environment.

Their study introduces a new mechanism showing that moisture-induced diabatic heating strengthens ridge blocks but weakens dipole blocks. "We find that, while moisture-induced diabatic heating is conducive to the persistence of ridge blocks, it exerts a surprising damping effect that significantly weakens the amplitude of dipole blocks," Wang explained.

This finding resolves a long-standing mystery about why some climate models predict fewer blocking events in a warming climate. To explain the new results on the dampening effect of dipole blocks, they offered a physical interpretation using the geopotential height tendency equation, a foundational concept of earth science/atmospheric science.

Wang compares atmospheric blocking to a traffic jam on a highway. "Without considering moisture, yes, blocks can happen," Wang said. "However, the role of moisture is just like the road condition at the time of the traffic jam. Sometimes, if the blocks are of different shapes (such as trough or dipole), they may exert an influence to reduce the strength of the blocks." He compared this to drivers following traffic flow intentionally to ease a jam, rather than worsening it with erratic braking.

This discovery could enhance subseasonal to seasonal forecasts for extreme weather events, which are notoriously difficult to predict. "Blocking events usually lead to extreme weather events, such as heat waves or cold spells or droughts," Wang said. "Recognizing and unraveling these distinct roles of diabatic heating for different types of blocks will help us to better predict the evolution of blocking events."

Wang's group studies large-scale atmospheric dynamics on Earth and other planets, focusing on blocking and extreme weather. Subseasonal to seasonal variability creates a forecast gap for these events, which are hard to predict. The goal is to improve understanding and forecasting of these challenging extremes.

The research, conducted entirely at Purdue, relied on high-performance computing resources at the Rosen Center for Advanced Computing for data storage, analysis and numerical simulations. Wang is also associated with Purdue's Institute for a Sustainable Future and served as a faculty co-leader for the weather and climate research community.

More information: Zhaoyu Liu et al, Blocking diversity causes distinct roles of diabatic heating in the Northern Hemisphere, *Nature Communications* (2025). DOI: 10.1038/s41467-025-60811-4

Provided by Purdue University