In contrast to Earth, Mars's middle atmosphere appears driven by gravity waves

March 6 2025

The thermal impact of dust storms on Mars is significant, and is thought to play a similar role to that of water vapor in Earth's atmosphere. Credit: NASA CC0

A new study by researchers including those at the University of Tokyo revealed that atmospheric gravity waves play a crucial role in driving latitudinal air currents on Mars, particularly at high altitudes.

The work has been published in the *Journal of Geophysical Research Planets*.

The findings, based on long-term atmospheric data, offer a fresh perspective on the behaviors of Mars' middle atmosphere, highlighting fundamental differences from Earth's. The study applied methods developed to explore Earth's atmosphere to quantitatively estimate the influence of gravity waves on Mars' planetary circulation.

Despite it being a very cold planet, Mars is quite a hot topic these days. With human visitation seemingly on the horizon, it will pay to know more about the conditions there so all involved can plan and prepare accordingly. Something that has become possible to explore in detail in recent years is a range of Martian atmospheric phenomena.

"On Earth, large-scale atmospheric waves caused by the planet's rotation, known as Rossby waves, are the primary influence on the way air circulates in the stratosphere, or the lower part of the middle atmosphere. But our study shows that on Mars, gravity waves (GWs) have a dominant effect at the mid and high latitudes of the middle atmosphere," said Professor Kaoru Sato from the Department of Earth and Planetary Science.

"Rossby waves are large-scale atmospheric waves, or resolved waves, whereas GWs are unresolved waves, meaning they are too fine to be directly measured or modeled and must be estimated by more indirect means."

Not to be confused with gravitational waves from massive stellar bodies, GWs are an atmospheric phenomenon when a packet of air rises and falls due to variations in buoyancy. That oscillating motion is what gives rise to GWs.

Due to the small-scale nature of them and the limitations of observational data, researchers have previously found it challenging to quantify their significance in the Martian atmosphere. So Sato and her team turned to the Ensemble Mars Atmosphere Reanalysis System (EMARS) dataset, produced by a range of space-based observations over many years, to analyze seasonal variations up there.

"We found something interesting, that GWs facilitate the rapid vertical transfer of angular momentum, significantly influencing the meridional, or north-south, in the middle atmosphere circulations on Mars," said graduate student Anzu Asumi.

"It's interesting because it more closely resembles the behavior seen in Earth's mesosphere rather than in our stratosphere. This suggests existing Martian atmospheric circulation models may need to be refined to better incorporate these wave effects, potentially improving future climate and weather simulations."

The research also underscores the importance of planetary comparisons in atmospheric science. Mars' similarity to Earth in terms of rotational speed and axial tilt makes it an ideal test case for studying planetary weather systems.

At the same time, its distinct characteristics, such as a thin carbon dioxide-rich atmosphere and pronounced seasonal variations, offer insights into alien atmospheres. By analyzing these differences, researchers can improve their understanding of fundamental atmospheric dynamics, which may ultimately contribute to better climate models for Earth too.

"Looking ahead, we plan to investigate the impact of Martian dust storms on atmospheric circulation. So far, our analysis has focused on years without major dust storms," said Sato.

"However, these storms dramatically alter atmospheric conditions, and we suspect they may intensify the role of GWs in circulation. Our research lays the groundwork for forecasting Martian weather, which will be essential for ensuring the success of future Mars missions."

Future studies will examine how these storms lead to significant shifts in global atmospheric patterns. With these advancements, the prospect of accurately predicting atmospheric conditions on Mars moves one step closer to reality.

More information: Climatology of the Residual Mean Circulation of the Martian Atmosphere and Contributions of Resolved and Unresolved Waves Based on a Reanalysis Dataset, *Journal of Geophysical Research Planets* (2025). DOI: 10.1029/2023JE008137

Provided by University of Tokyo

Citation: In contrast to Earth, Mars's middle atmosphere appears driven by gravity waves (2025, March 6) retrieved 8 March 2025 from https://phys.org/news/2025-03-contrast-earth-mars-middle-atmosphere.html