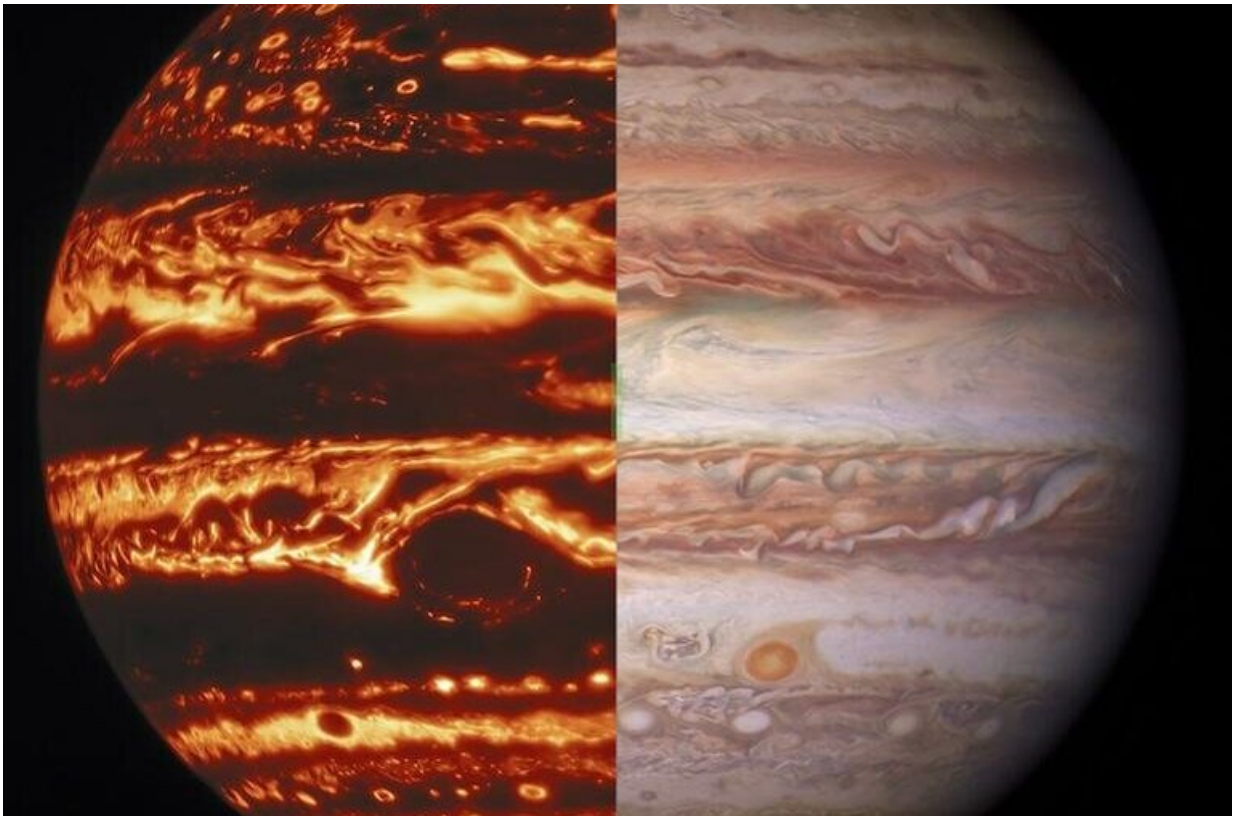


NASA's Juno: Science results offer first 3D view of Jupiter atmosphere

October 28 2021



Jupiter's banded appearance is created by the cloud-forming weather layer. This composite image shows views of Jupiter in infrared and visible light taken by the Gemini North telescope and NASA's Hubble Space Telescope. Credit: International Gemini Observatory/NOIRLab/NSF/AURA/NASA/ESA, M.H. Wong and I. de Pater (UC Berkeley) et al.

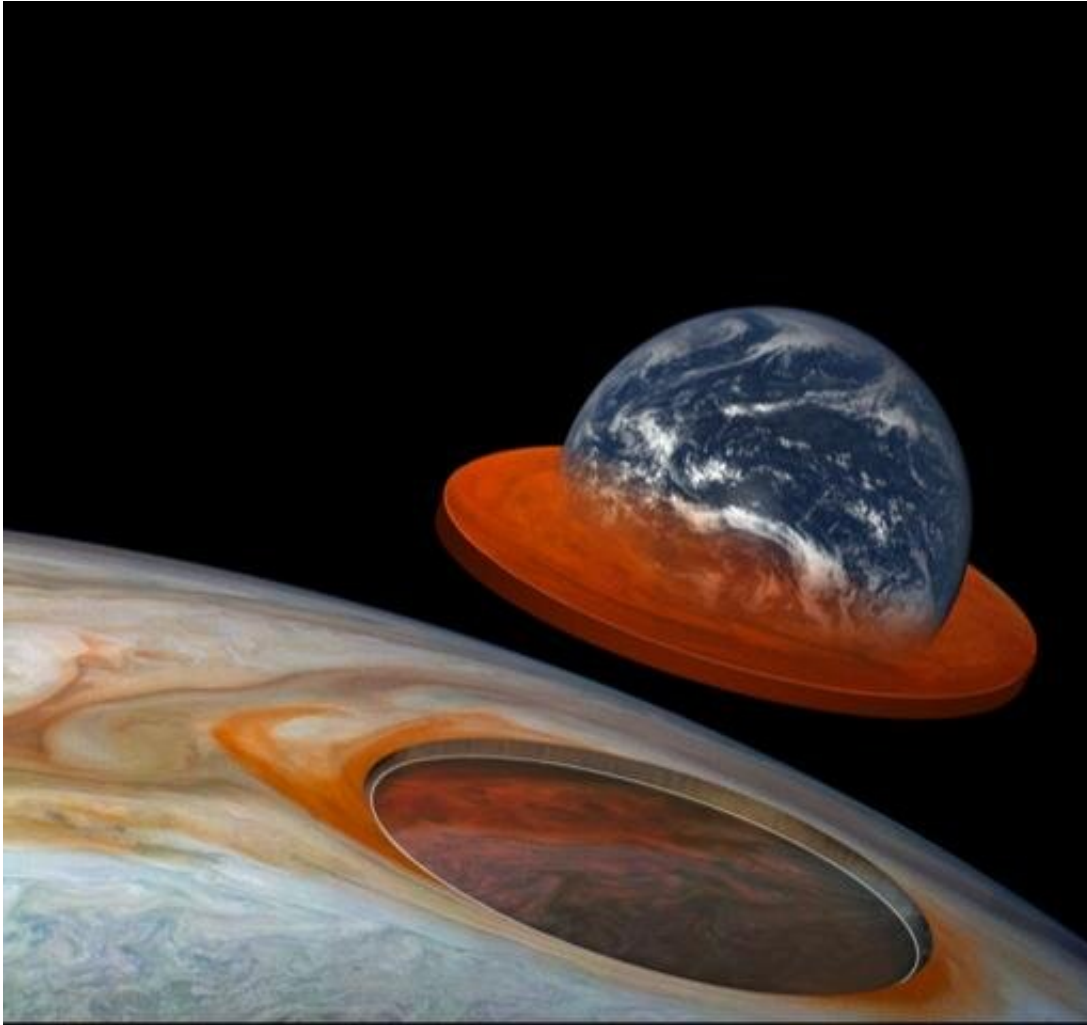
New findings from NASA's Juno probe orbiting Jupiter provide a fuller picture of how the planet's distinctive and colorful atmospheric features offer clues about the unseen processes below its clouds. The results highlight the inner workings of the belts and zones of clouds encircling Jupiter, as well as its polar cyclones and even the Great Red Spot.

Researchers published several papers on Juno's atmospheric discoveries today in the journal *Science* and the *Journal of Geophysical Research: Planets*. Additional papers appeared in two recent issues of *Geophysical Research Letters*.

"These new observations from Juno open up a treasure chest of new information about Jupiter's enigmatic observable features," said Lori Glaze, director of NASA's planetary science division at the agency's headquarters in Washington. "Each paper sheds light on different aspects of the planet's atmospheric processes—a wonderful example of how our internationally-diverse science teams strengthen understanding of our solar system."

Juno entered Jupiter's orbit in 2016. During each of the spacecraft's 37 passes of the planet to date, a specialized suite of instruments has peered below its turbulent cloud deck.

"Previously, Juno surprised us with hints that phenomena in Jupiter's atmosphere went deeper than expected," said Scott Bolton, principal investigator of Juno from the Southwest Research Institute in San Antonio and lead author of the *Science* journal paper on the depth of Jupiter's vortices. "Now, we're starting to put all these individual pieces together and getting our first real understanding of how Jupiter's beautiful and violent atmosphere works—in 3D."



This illustration combines an image of Jupiter from the JunoCam instrument aboard NASA's Juno spacecraft with a composite image of Earth to depict the size and depth of Jupiter's Great Red Spot. Credit: JunoCam Image data: NASA/JPL-Caltech/SwRI/MSSS JunoCam Image processing by Kevin M. Gill (CC BY) Earth Image: NASA

Juno's [microwave radiometer](#) (MWR) allows mission scientists to peer beneath Jupiter's cloud tops and probe the structure of its numerous vortex storms. The most famous of these storms is the iconic anticyclone known as the Great Red Spot. Wider than Earth, this crimson vortex has intrigued scientists since its discovery almost two centuries ago.

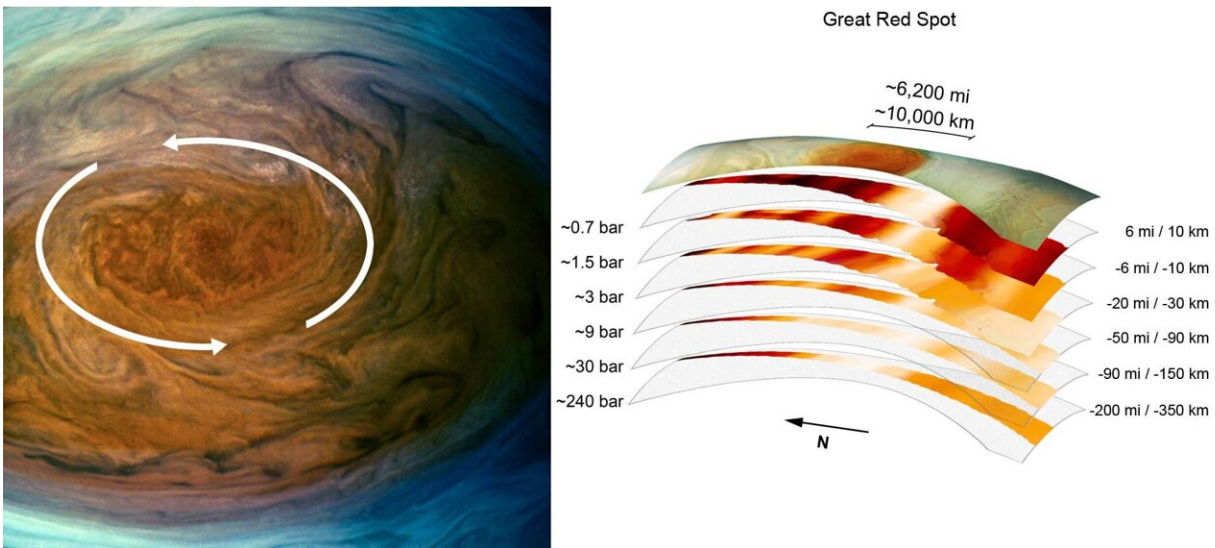
The new results show that the cyclones are warmer on top, with lower atmospheric densities, while they are colder at the bottom, with higher densities. Anticyclones, which rotate in the opposite direction, are colder at the top but warmer at the bottom.

The findings also indicate these storms are far taller than expected, with some extending 60 miles (100 kilometers) below the cloud tops and others, including the Great Red Spot, extending over 200 miles (350 kilometers). This surprise discovery demonstrates that the vortices cover regions beyond those where water condenses and clouds form, below the depth where sunlight warms the atmosphere.

The height and size of the Great Red Spot means the concentration of atmospheric mass within the storm potentially could be detectable by instruments studying Jupiter's [gravity field](#). Two close Juno flybys over Jupiter's most famous spot provided the opportunity to search for the storm's gravity signature and complement the MWR results on its depth.

With Juno traveling low over Jupiter's cloud deck at about 130,000 mph (209,000 kph) Juno scientists were able to measure velocity changes as small 0.01 millimeter per second using a NASA Deep Space Network tracking antenna, from a distance of more than 400 million miles (650 million kilometers). This enabled the team to constrain the depth of the Great Red Spot to about 300 miles (500 kilometers) below the cloud tops.

"The precision required to get the Great Red Spot's gravity during the July 2019 flyby is staggering," said Marzia Parisi, a Juno scientist from NASA's Jet Propulsion Laboratory in Southern California and lead author of a paper in the journal *Science* on gravity overflights of the Great Red Spot. "Being able to complement MWR's finding on the depth gives us great confidence that future gravity experiments at Jupiter will yield equally intriguing results."



Data collected by the JunoCam imager and microwave radiometer from a flyover of the Great Red Spot on July 11, 2017 provides a glimpse of the inner-workings of Jupiter's most iconic anticyclone. Credit: NASA/JPL-Caltech/SwRI/MSSSI image processing: Kevin Gill CC BY

Belts and Zones

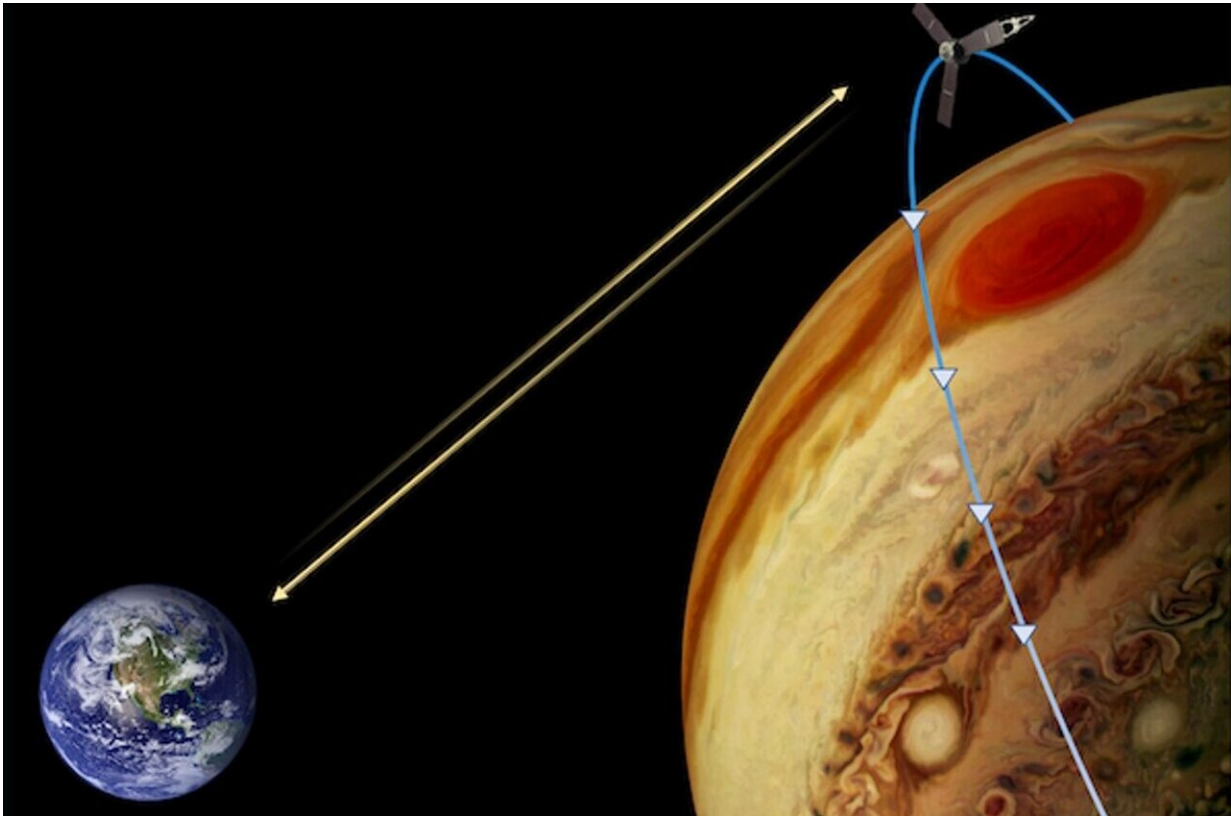
In addition to cyclones and anticyclones, Jupiter is known for its distinctive belts and zones—white and reddish bands of clouds that wrap around the planet. Strong east-west winds moving in opposite directions separate the bands. Juno previously discovered that these winds, or jet streams, reach depths of about 2,000 miles (roughly 3,200 kilometers). Researchers are still trying to solve the mystery of how the jet streams form. Data collected by Juno's MWR during multiple passes reveal one possible clue: that the atmosphere's ammonia gas travels up and down in

remarkable alignment with the observed jet streams.

"By following the ammonia, we found circulation cells in both the north and south hemispheres that are similar in nature to 'Ferrel cells,' which control much of our climate here on Earth," said Keren Duer, a graduate student from the Weizmann Institute of Science in Israel and lead author of the *Science* journal paper on Ferrel-like cells on Jupiter. "While Earth has one Ferrel cell per hemisphere, Jupiter has eight—each at least 30 times larger."

Juno's MWR data also shows that the belts and zones undergo a transition around 40 miles (65 kilometers) beneath Jupiter's water clouds. At shallow depths, Jupiter's belts are brighter in microwave light than the neighboring zones. But at deeper levels, below the water clouds, the opposite is true—which reveals a similarity to our oceans.

"We are calling this level the 'Jovicline' in analogy to a transitional layer seen in Earth's oceans, known as the thermocline—where seawater transitions sharply from being relative warm to relative cold," said Leigh Fletcher, a Juno participating scientist from the University of Leicester in the United Kingdom and lead author of the paper in the *Journal of Geophysical Research: Planets* highlighting Juno's microwave observations of Jupiter's temperate belts and zones.



During a flyby of Jupiter in July 2019, mission scientists conducted an experiment measuring minute velocity changes in the Juno spacecraft as a result in the gravity field near the Great Red Spot. Credit: NASA/JPL-Caltech/SwRI

Polar Cyclones

Juno previously discovered polygonal arrangements of giant cyclonic storms at both of Jupiter's poles—eight arranged in an octagonal pattern in the north and five arranged in a pentagonal pattern in the south. Now, five years later, mission scientists using observations by the spacecraft's Jovian Infrared Auroral Mapper (JIRAM) have determined these atmospheric phenomena are extremely resilient, remaining in the same location.

"Jupiter's cyclones affect each other's motion, causing them to oscillate about an equilibrium position," said Alessandro Mura, a Juno co-investigator at the National Institute for Astrophysics in Rome and lead author of a recent paper in *Geophysical Research Letters* on oscillations and stability in Jupiter's polar cyclones. "The behavior of these slow oscillations suggests that they have deep roots."

JIRAM data also indicates that, like hurricanes on Earth, these cyclones want to move poleward, but cyclones located at the center of each pole push them back. This balance explains where the cyclones reside and the different numbers at each pole.

More information: S. J. Bolton et al, Microwave observations reveal the deep extent and structure of Jupiter's atmospheric vortices, *Science* (2021). [DOI: 10.1126/science.abf1015](https://doi.org/10.1126/science.abf1015)

Marzia Parisi et al, The depth of Jupiter's Great Red Spot constrained by Juno gravity overflights, *Science* (2021). [DOI: 10.1126/science.abf1396](https://doi.org/10.1126/science.abf1396)

Provided by Jet Propulsion Laboratory

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