Scientists map Mars' global wind patterns for the first time

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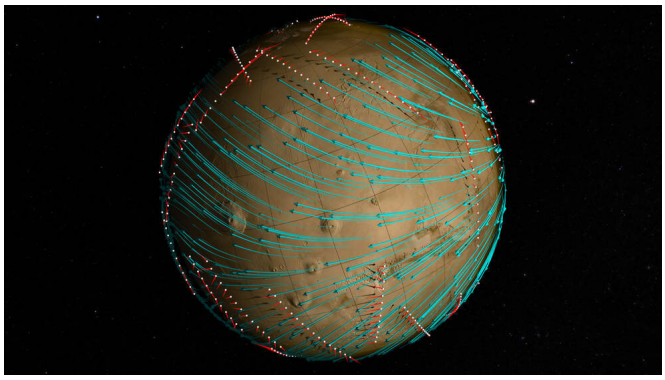

Computer-generated visualization of the orbital paths (white dots) taken by the MAVEN spacecraft as it mapped winds (blue lines) in the Martian upper atmosphere. Red lines coming from the white dots represent local wind speed and direction, measured by MAVEN's Neutral Gas and Ion Mass Spectrometer instrument. Credit: NASA Goddard/MAVEN/SVS/Greg Shirah

Today, a paper published in *Science* documents for the first time the global wind circulation patterns in the upper atmosphere of a planet, 120 to 300 kilometers above the surface. The findings are based on local observations, rather than indirect measurements, unlike many prior measurements taken on Earth's upper atmosphere. But it didn't happen on Earth: it happened on Mars. On top of that, all the data came from an instrument and a spacecraft that weren't originally designed to collect wind measurements.

In 2016, Mehdi Benna and his colleagues proposed to the Mars Atmosphere and Volatile EvolutioN (MAVEN) project team that they remotely reprogram the MAVEN spacecraft and its Natural Gas and Ion Mass Spectrometer (NGIMS) instrument to do a unique experiment. They wanted to see if parts of the instrument that were normally stationary could "swing back and forth like a windshield wiper fast enough," to enable the tool to gather a new kind of data.

Initially, the MAVEN project team was reluctant to implement the modifications Benna and his colleagues requested. After all, MAVEN and NGIMS had been orbiting Mars since 2013, and they were working quite well collecting information about the composition of the Mars atmosphere. Why put all that at risk? Benna and his colleagues argued that this project would collect new kinds of data that could shape our understanding of the upper atmosphere on Mars, inform similar studies on Earth, and help us better understand planetary climate.

Benna, a planetary scientist operating out of the NASA Goddard Space Flight Center with the UMBC Center for Space Sciences Technology (CSST), came up with the windshield-wiper idea while brainstorming how to create an instrument that could collect information about global circulation patterns in Earth's upper atmosphere. It occurred to him that, together, MAVEN and NGIMS could do the same thing on Mars—and they were already in space.

With some persistence and a lot of preliminary analyses, Benna and his colleagues convinced the MAVEN mission leadership to give their idea a try, after Lockheed Martin, the spacecraft manufacturer, determined the modifications might be possible without damaging the satellite. "It's a clever reengineering in flight of how to operate the spacecraft and the instrument," Benna says. "And by doing both—the spacecraft doing something it was not designed to and the instrument doing something it was not designed to do—we made the wind measurements possible."

Ripple effect

The new paper was completed in collaboration with Yuni Lee, also of UMBC's CSST, and colleagues

from the University of Michigan, George Mason University, and NASA. It is based on data collected two days per month for two years from 2016 to 2018. Some results were expected, and others were big surprises. "The refreshing thing is that the patterns that we observed in the upper atmosphere match globally what one would predict from models," says Benna. "The physics works."

Overall, the average circulation patterns from season to season were very stable on Mars. This is like saying that on the East Coast of the United States, throughout the year, weather systems generally flow from the West to the East in a predictable way.

One surprise came when the team analyzed the shorter-term variability of winds in the upper atmosphere, which was greater than anticipated. "On Mars, the average circulation is steady, but if you take a snapshot at any given time, the winds are highly variable," Benna says. More work is needed to determine why these contrasting patterns exist.

A second surprise was that the wind hundreds of kilometers above the planet's surface still contained information about landforms below, like mountains, canyons, and basins. As the air mass flows over those features, "it creates waves—ripple effects—that flow up to the upper atmosphere" and can be detected by MAVEN and NGIMS, Benna explains. "On Earth, we see the same kind of waves, but not at such high altitudes. That was the big surprise, that these can go up to 280 kilometers high."

Benna and colleagues have two hypotheses for why the waves, called "orthographic waves," last so long unchanged. For one, the atmosphere on Mars is much thinner than it is on Earth, so the waves can travel farther unimpeded, like ripples traveling farther in water than in molasses. Also, the average difference between geographic peaks and valleys is much greater on Mars than it is on Earth. It's not uncommon for mountains to be 20 kilometers tall on Mars, whereas Mt. Everest is not quite nine kilometers tall, and most terrestrial mountains are much shorter.

"The topography of Mars is driving this in a more pronounced way than it is on Earth," Benna says.

Forging ahead

Continuing to analyze the data from this study may help scientists figure out whether the same basic processes are in action on Earth's upper atmosphere. Ironically, "We had to go take these measurements on Mars to eventually understand the same phenomenon on Earth," Benna says. "Ultimately the results will help us understand the climate of Mars. What is its state and how is it evolving?"

But the team isn't satisfied with the current data set. "We want to keep measuring. We have two years of data, but we're not stopping there," Benna says. Even with the data set they already have, "We have many years of modeling and analysis ahead of us." It's a trove of information that can be examined in ways not yet imagined, to learn even more about how planets work.

More information: M. Benna el al., "Global circulation of Mars' upper atmosphere," *Science* (2019). science.sciencemag.org/cgi/doi … 1126/science.aax1553

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