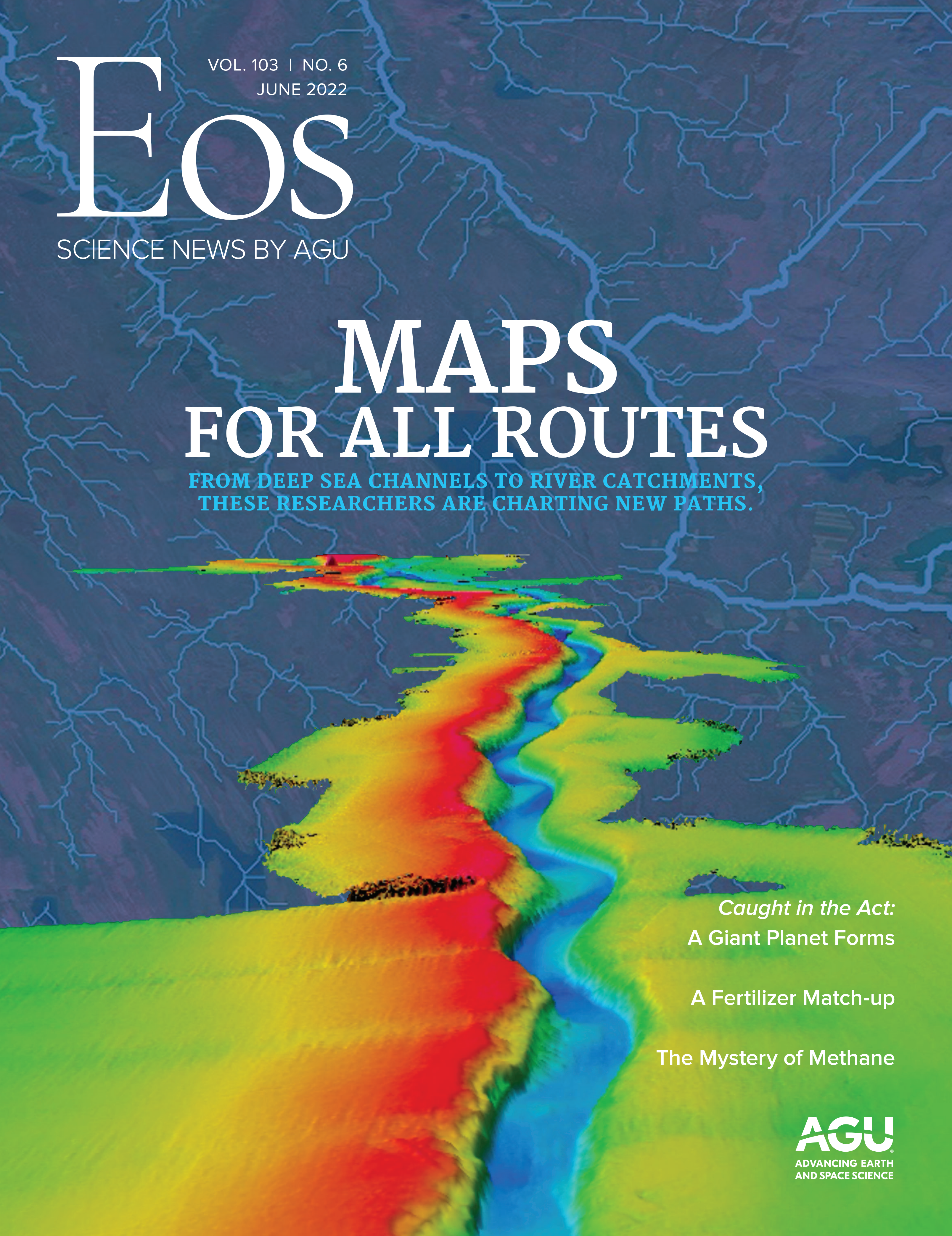

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For Citlali Rosas, archaeologist in chief of the Department of Legal and Technical Protection of the Archaeological Zone of Teotihuacan administered by Mexico's National Institute of Anthropology and History (INAH), such construction around Teotihuacan is "worrying." An airport at that distance, she said, will encourage construction of restaurants, hotels, and other businesses catering to tourists that may put delicate artifacts at risk.

A 1988 presidential decree cracked down on illegal extractive activities in the area, but more could be done, said Rosas. On average, the Department of Legal and Technical Protection suspends around 100 construction projects being carried out without INAH's permission every year.

"It's chaotic [on the periphery of the monument area]; there are constructions everywhere. It's sad."

"It's chaotic [on the periphery of the monument area]; there are constructions everywhere. It's sad," said Veronica Ortega, an archaeologist with Mexico City's National School of Anthropology and History who has spent the past 20 years studying ancient structures around the zone. Ortega was not involved in the new study.

Ortega explained that 60% of the territory of the Valley of Teotihuacan has archaeological remains underneath, but much of the area remains unmapped. Lidar efforts like Sugiyama's would help archaeologists generate a new protection polygon for sediments, artifacts, and remains that lie beyond the archaeological zone.

However, having scientific evidence is not enough, Ortega warned. Stopping the "destruction of one of the most important cultural heritages on the planet" will need broad participation and articulation from Mexico's federal government, municipal authorities, and local communities, she said.

By **Humberto Basilio** (@HumbertoBasilio), Science Writer

Mars's Dust Cycle Controls Its Polar Vortex and Snowfall

Stronger southern dust cycles on Mars stifle its northern polar vortex and increase its snowfall rate, up to a point at least. These results, which are based on an analysis of observations taken over 10 Earth years (5 Mars years), shed light on the global connection between Mars's dominant dust cycle and its global climate.

Mars's atmosphere is less complex than Earth's, explained Noora Alsaeed, and has circulation patterns that directly connect the equatorial regions with the poles. Alsaeed is a doctoral candidate in atmospheric and planetary science at the University of Colorado Boulder. "What this means is that any process that occurs elsewhere on the planet is going to have a more direct impact on the polar region than it would on Earth."

If Mars's polar vortex worked like Earth's, Alsaeed said, it would grow larger, colder, and more stable in winter. "My work is showing that that doesn't happen on Mars, and the reason it doesn't happen is that the dust cycle inhibits the growth and messes with the stability of the northern polar vortex."

Shrinking in the Face of Dust

On lush Earth, the water cycle has significant influence over nearly every atmospheric and surface process. On desiccated Mars, however, it's the dust cycle that dominates, creating beautiful features on the surface and, at times, completely enveloping the entire planet. The dusty season in the southern hemisphere coincides with northern winter, and even a dust season of average strength has been observed to coincide with changes in Mars's weather and climate, including its polar vortices and how much carbon dioxide (CO_2) snow falls in winter. However, not much is known about how or why changes in dust conditions lead to changes in polar vortex strength and size or changes in CO_2 snow emplacement.

Carbon dioxide snow and ice linger on dunes during Mars's northern spring, as seen by the High Resolution Imaging Experiment (HiRISE) camera on the Mars Reconnaissance Orbiter (MRO). Credit: NASA/JPL/University of Arizona, Public Domain

Alsaeed and her team sought to quantify how dust, the polar vortex, and snowfall are connected to better understand the mechanisms that drive it. They gathered infrared radiometry data on Mars's southern hemisphere dust seasons, northern polar vortex, and northern atmospheric CO_2 density for 2008–2018 from the Mars Climate Sounder on NASA's Mars Reconnaissance Orbiter (MRO). MRO has been studying Mars from orbit since 2006. Using these data, the team examined how yearly changes in Mars's southern dust season correlated with the size and intensity of the northern polar vortex and how much snow fell that year.

The researchers found that when dust activity increased in the south, the northern polar vortex shrank in size and grew colder regardless of whether it was winter or summer in the north. And although CO_2 snow fell all throughout northern winter, the combination of colder polar temperatures and the increased availability of dust as condensation nuclei enhanced snowfall when dust activity rose. They also saw that snow didn't fall evenly at all longitudes around the planet; one hemisphere saw significantly more snow than the other each year, a lopsidedness that the researchers attributed to topography altering the shape of the vortex. Alsaeed presented these results at the 53rd Lunar and Planetary Science Conference (bit.ly/Mars-polar-vortex).

"The results broadly agree with previous modeling work in the sense that they see a drop in vortex area with increased dust loading," commented Emily Ball, a doctoral student in geographical sciences at the University of Bristol in the United Kingdom who was not involved with this research. Ball's past research has modeled the connection between heat, snow, and the polar vortex on Mars. The longitudinally uneven snowfall also matched the past modeling efforts of Ball

Images from the MRO showcase the variety of snowy landscapes that grace Mars's surface. Clockwise from top left: frost in late fall, summer ice at the south pole, crescent dunes at the north pole, frost in the dunes of Aonia Terra in the southern hemisphere, and cracked ice over dunes in springtime. Credit: MRO/NASA, Public Domain

and her colleagues, she said, "although I'm not sure if [that] pattern has been seen in CO_2 cloud density before, so that's cool."

There's Such a Thing as Too Much Dust

Alsaeed and her team speculated that as dust is carried from south to north, it brings with it enough heat to press against the boundaries of the polar vortex and restrict its growth; thus, more dust leads to a smaller vortex. That theory is supported not just by average dust cycles but also by the global dust storm that encircled Mars in 2018. The team's MRO data from that year showed that the northern polar vortex never grew during winter.

"The dust event starts off much earlier that year," Alsaeed said. "[Dust] doesn't even give a chance for the polar vortex to begin growing. It's immediately shut down." Moreover, despite the all-encompassing dust, snowfall was enhanced only along the lower-latitude boundaries of the vortex rather than throughout.

William Seviour, an atmosphere dynamics researcher at the University of Exeter in the United Kingdom and one of Ball's research supervisors, agreed that Alsaeed's observations agree with past modeling results and said that he hopes that future work "will focus on better understanding transport and mixing across the polar vortices, and any potential connections this may have to understanding the formation of Mars's polar layered deposits, [the] stratified layers of ice and dust at the poles."

Alsaeed said that she and the team plan to explore in more detail the year-to-year variations in the strength and shape of the polar vortex due to dust storms. They also plan to expand their data set to include what happened after 2018's global dust storm to see whether it matches what happened after the previous planetwide storm. That might give them more insight into the mechanics of dust and heat transport and how Mars's climate reacts during extreme events.

"The Mars dust cycle is very important, and the poles are very important in terms of regulating heat and atmospheric circulation," Alsaeed emphasized. "The fact that they're so tightly coupled makes sense in a way, but it's really important to understand just how that coupling works. This work highlights just how tightly coupled they are, and I hope that more work in the future looks at what the direct line of influence is."

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer