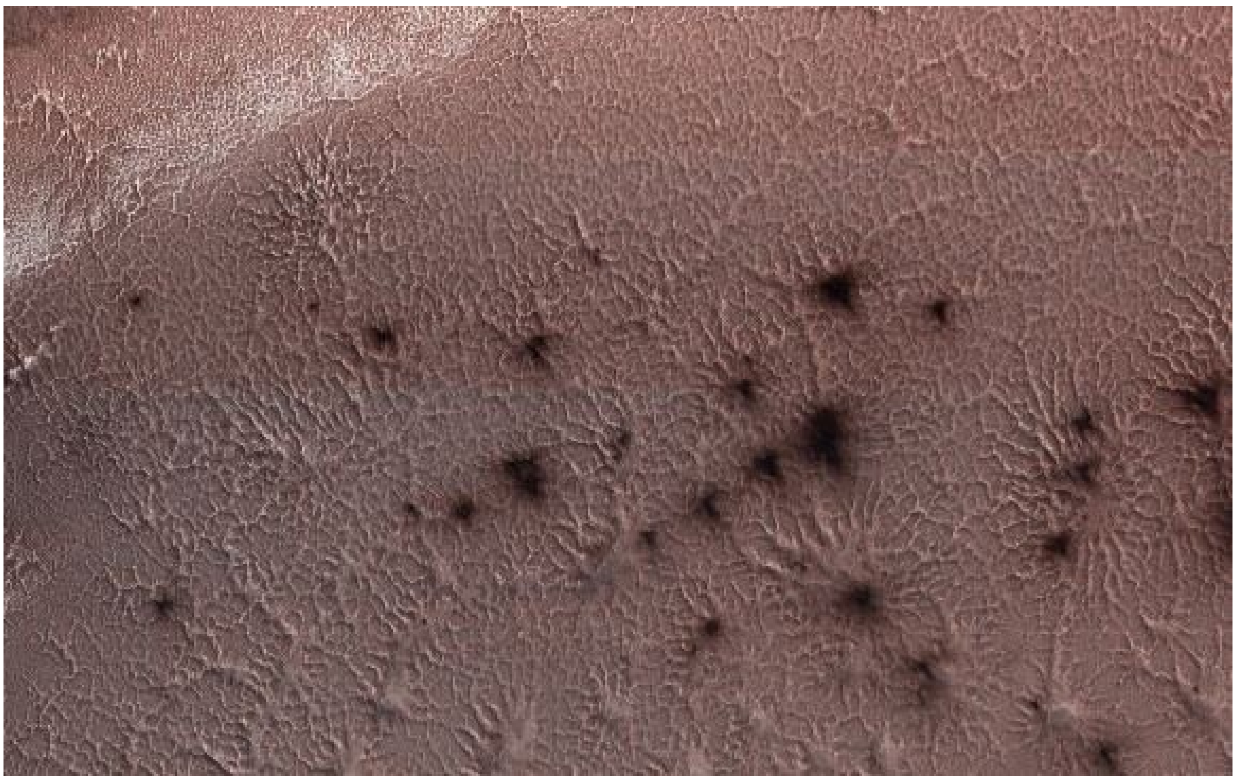
How much carbon dioxide snow falls every winter on Mars?

September 29 2021, by Matt Williams



This image from the Mars Reconnaissance Orbiter (MRO) shows the "spiders" emerging from the carbon dioxide ice cap at the South Pole of Mars. Credit: NASA/JPL-Caltech

Like Earth, Mars experiences climatic variations during the course of a year because of the tilted nature of its orbit (aka. seasonal change).

Similarly, these variations in temperature result in interaction between the atmosphere and the polar ice caps. On Earth, seasonal variations in temperature and precipitation cause the polar ice cap in one hemisphere to grow while the ice cap in the other hemisphere shrinks.

On Mars, however, things work a little differently. In addition to snow raining down on the polar ice caps during winter, the Martian polar ice caps also receive a great deal of frozen carbon dioxide ("dry ice") in addition to snow. Recently, an international team of scientists used data from NASA's Mars Global Surveyor (MGS) mission to measure how the planet's polar ice caps grow and recede. Their results could provide new insights into how the Martian climate varies due to seasonal change.

The study that describes their findings was led by Haifeng Xiao, a research assistant with the Institute of Geodesy and Geoinformation Science at the Berlin Technical University. He was joined by researchers from Stanford University, the Université Paris-Saclay, the Institut Universitaire de France, and the German Aerospace Center's (DLR) Institute of Planetary Research and Institute of Atmospheric Physics.

What we know about the Martian polar ice caps indicates that they are composed of three parts. First, there is the Residual (or Permanent) Ice Cap, which consists of sheets of water ice several meters thick at the North Pole, and an 8-meter (~10 feet) thick sheet of frozen carbon dioxide at the South Pole. Beneath that are the Polar Layered Deposits (PLDs), which are 2 to 3 km (mi) thick and composed of water ice and dust.

Last is the Seasonal Ice Cap, a layer of frozen CO_2 deposited on top of the permanent ice caps every winter. For the sake of their study, Haifeng and his colleagues focused on the Seasonal Ice Caps to reveal how they are affected by variations in seasonal temperatures and solar radiation—and how this is associated with annual variations in Mars' climate. As Haifeng told Universe Today via email:

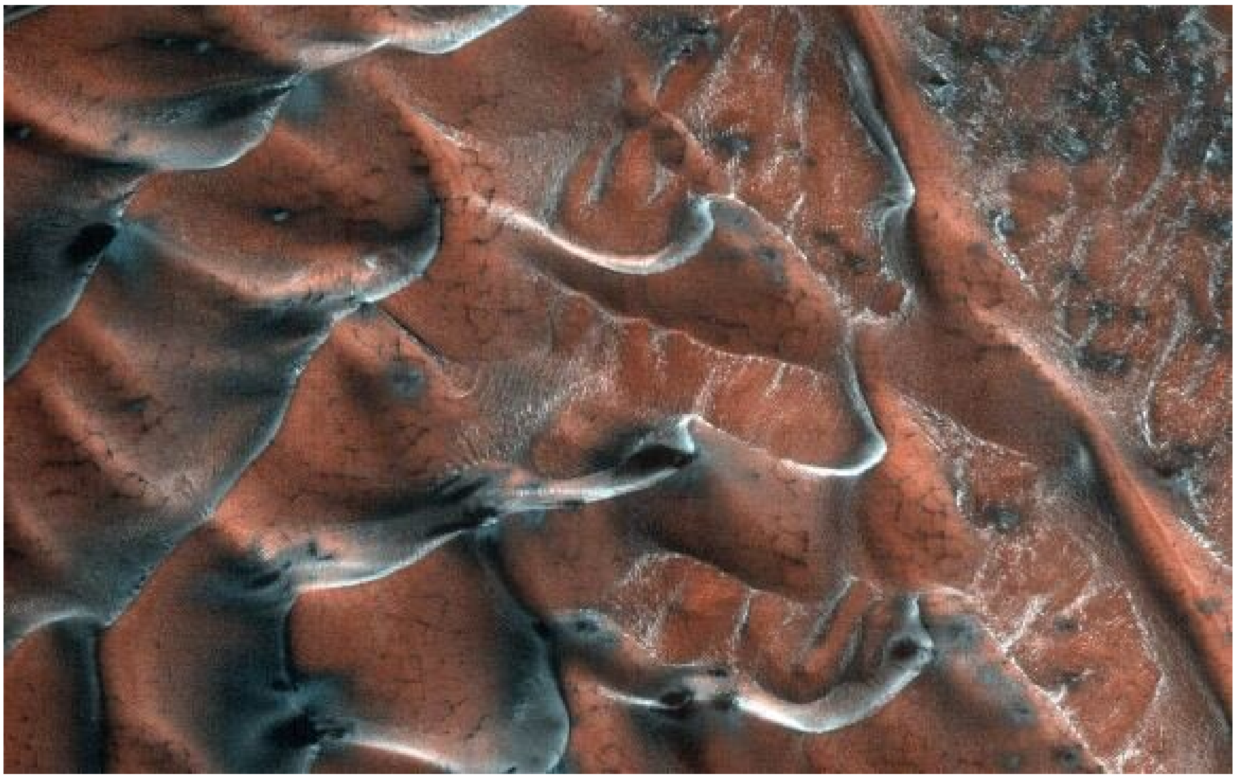
"Each Martian year, approximately 30% of the atmosphere's CO_2 mass is in vivid exchange with the polar surfaces through the seasonal deposition/sublimation. Temporal variations of levels and volumes of snow/ice associated with this process can put crucial constraints on the Mars climate system and volatile circulation models.

"In addition, the seasonal accumulation of the CO_2 ice to form these seasonal polar caps can be affected by dust storms, cold spots, katabatic and orographic winds, and local shadowing. Thus, short and long-term variabilities of the seasonal polar caps could also indicate the variabilities of the Mars climate."

During a Martian year, which lasts over 687 Earth days (or 668.5 Sols), seasonal changes lead to atmospheric carbon dioxide migrating from the North Pole to the South Pole (and vise versa). These seasonal actions are responsible for transporting large amounts of dust and water vapor, which leads to frosts and the formation of large cirrus clouds visible from space.

This process of sublimation and exchange between the poles is also responsible for notable geological features on Mars, such as the araneiform terrain (aka. "spiders") near the South Pole and the way the dune fields in the northern planes become furrowed with the arrival of seasonals. As Haifeng explained, understanding the relationship between the seasonal polar caps and the formation of geological features on Mars could lead to a better understanding of the Martian environment.

Over the past two decades, measurements of the polar ice caps have been conducted using various methods—gravity variation, neutron, and gamma-ray flux—and modeled based on General Circulation and Energy Balance models. For their study, Haifeng and his colleagues relied on data obtained by the Mars Orbiter Laser Altimeter (MOLA) instrument aboard the MGS to obtain accurate measurements of the height and volume of Mars's polar ice caps over time.



“Furrowed” dunes in the cratered region near the Martian North Pole. Credit: NASA/JPL-Caltech/University of Arizona

This consisted of reprocessing the MOLA Precision Experiment Data Records (PEDR) – or MOLA's individual altimetry readings—using the latest available MGS orbit data and Mars rotational model. They then self-registered these profiles into a self-consistent Digital Terrain Model (DTM), which served as a static mean surface measurement for Mars. As Haifeng explained:

"We have proposed and validated the co-registration of local dynamic Mars Orbiter Laser Altimeter (MOLA) profile segments to static Digital Terrain Models (DTMs) as an approach for obtaining seasonal CO_2 ice cover depth variations on Mars. In addition, we have also proposed a post-correction procedure based on the pseudo cross-overs of MOLA profiles to further improve the precision of the depth variation time series."

The result of this was a series of height-change measurements with a precision of ~4.9 cm (1.93 inches) and peak-to-peak height variations of ~2.2 m (7.2 ft). The team also extended these results to the entire South Pole, which they hope to cover in greater detail in another soon-to-be-published study. Haifeng and his colleagues also plan to compare their results with radar altimetry data obtained by the SHAllow RADar sounder (SHARAD) aboard NASA's Mars Reconnaissance Orbiter's (MRO).

"As the next step, We will try the SHARAD radar altimetry to cross-validate the MOLA measurements and to derive the long-term seasonal depth evolution of the seasonal polar caps of Mars, which will also be important for assessing the long-term stability of the underlying Martian Residual Polar Caps, especial the Residual South Polar Cap that is considered to be in a quasi-stable state," said Haifeng.

These measurements will allow planetary scientists to learn a great deal more about the Martian climate and the annual changes it goes through. They will also help prepare future robotic and human exploration missions to the Red Planet, which are still anticipated for some time in the next decade.

More information: Haifeng Xiao et al, Prospects for Mapping Temporal Height Variations of the Seasonal CO2 Snow/Ice Caps at the Martian Poles by Co-registration of MOLA Profiles.

arXiv:2109.04899v1 [astro-ph.EP], arxiv.org/abs/2109.04899

Source Universe Today