Is there ice on Mars?

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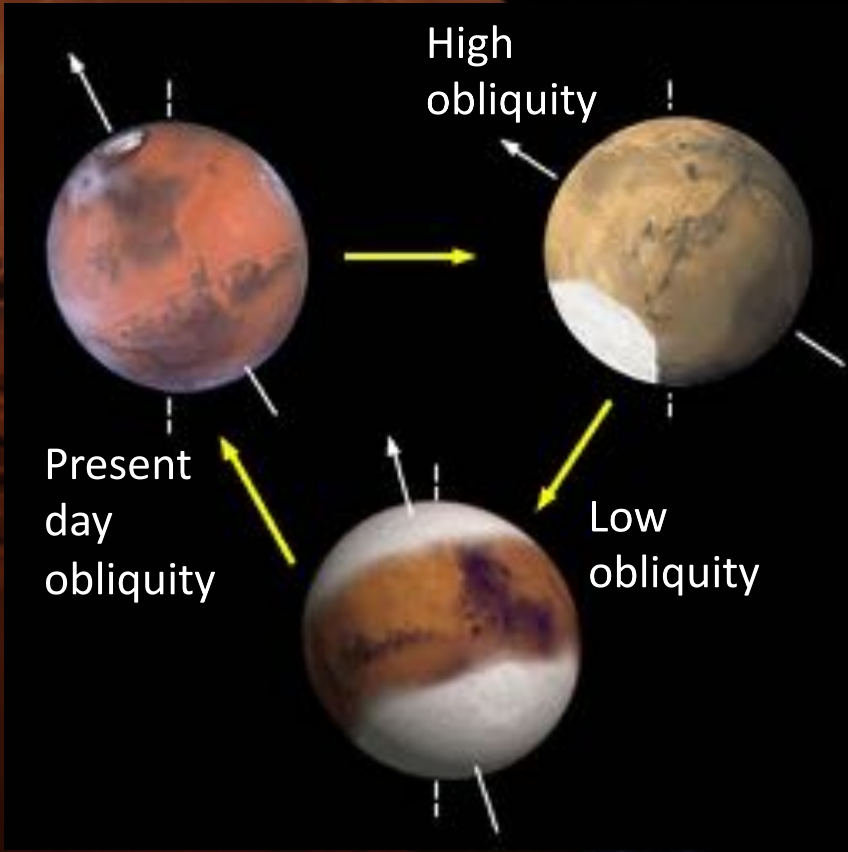
Background

- The water cycle is a key element of the Martian climate and has significant effects on the planet's geology. [1, 2, 3, 4]
- It is affected by changes in the climate and the climate is affected by changes in orbital parameters: [3, 5]
  - obliquity – the angle between the rotational and orbital axes,
  - eccentricity – how much the orbit deviates from a circle, and
  - perihelion – the time of year when the planet is closest to the sun.

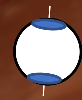
My research

- Obliquity-driven climate change has a big influence on the distribution of solar heating across the planet's surface. [3, 7]
- Climate models using a range of obliquity values can provide insight into the processes which control the behaviour of the water cycle and surface ice. [6, 7]
- Simulations with obliquities ranging from 5° to 55° were run using the LMD-UK Mars Global Climate Model [8], with ice sources placed at one pole, both poles or in the tropics.
- Output focused on the movement of water vapour and surface ice around the planet during the year.

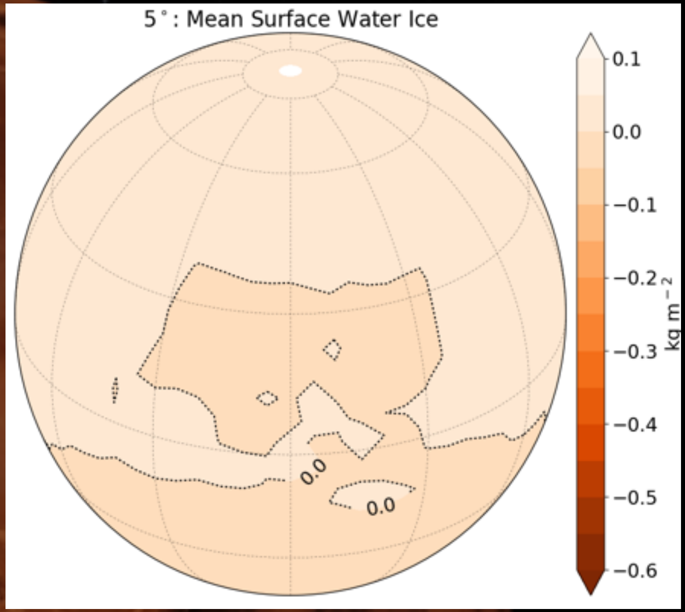


Mars's obliquity, or the tilt of the planet's axis, has changed over the millennia from very high to very low values, which affects where on the planet's surface ice can form. The dotted line represents the upright position; the arrow shows the tilt of the planet's axis. Adapted from an image by NASA.

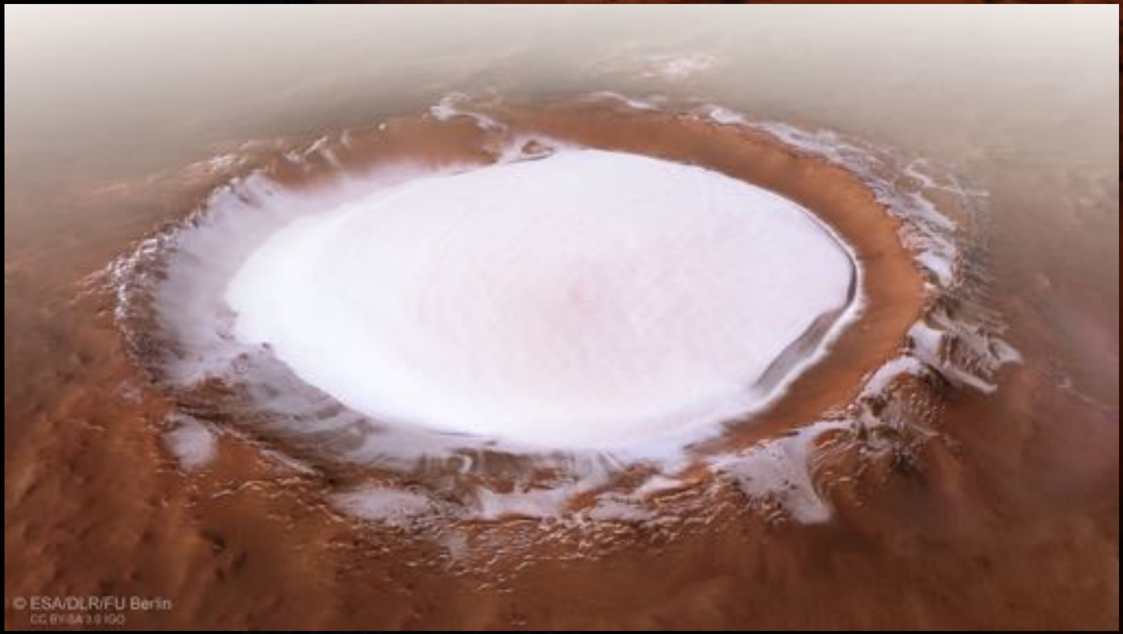
Results and discussion

5° obliquity; ice source at both poles: 

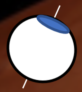
- When the planet is nearly upright, the poles receive very little solar heating and so only small amounts of water vapour sublimate (evaporate) from the ice at both poles.
- There is little water vapour in the atmosphere to be transported around the planet, so there is little change in the distribution of surface ice.
- During these periods, the ice caps grow larger over time.



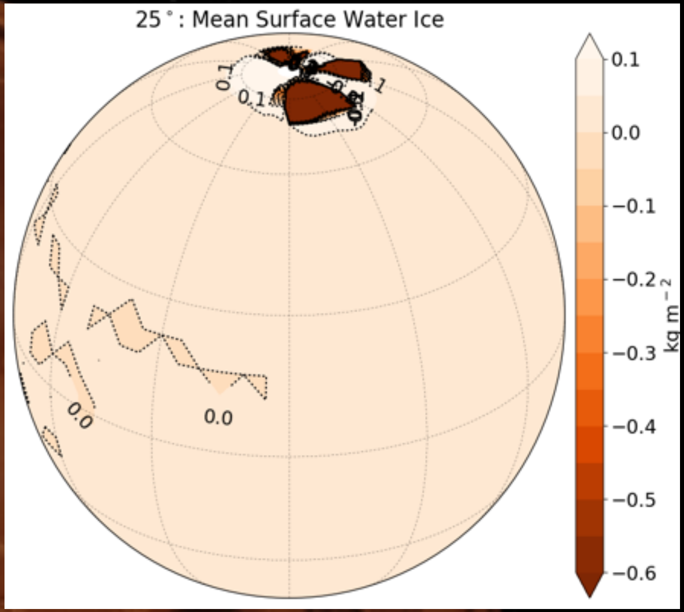
The graphic shows output from the climate model with small amounts of sublimation (dark) and some deposition (light) of surface ice around the planet, averaged over the year.



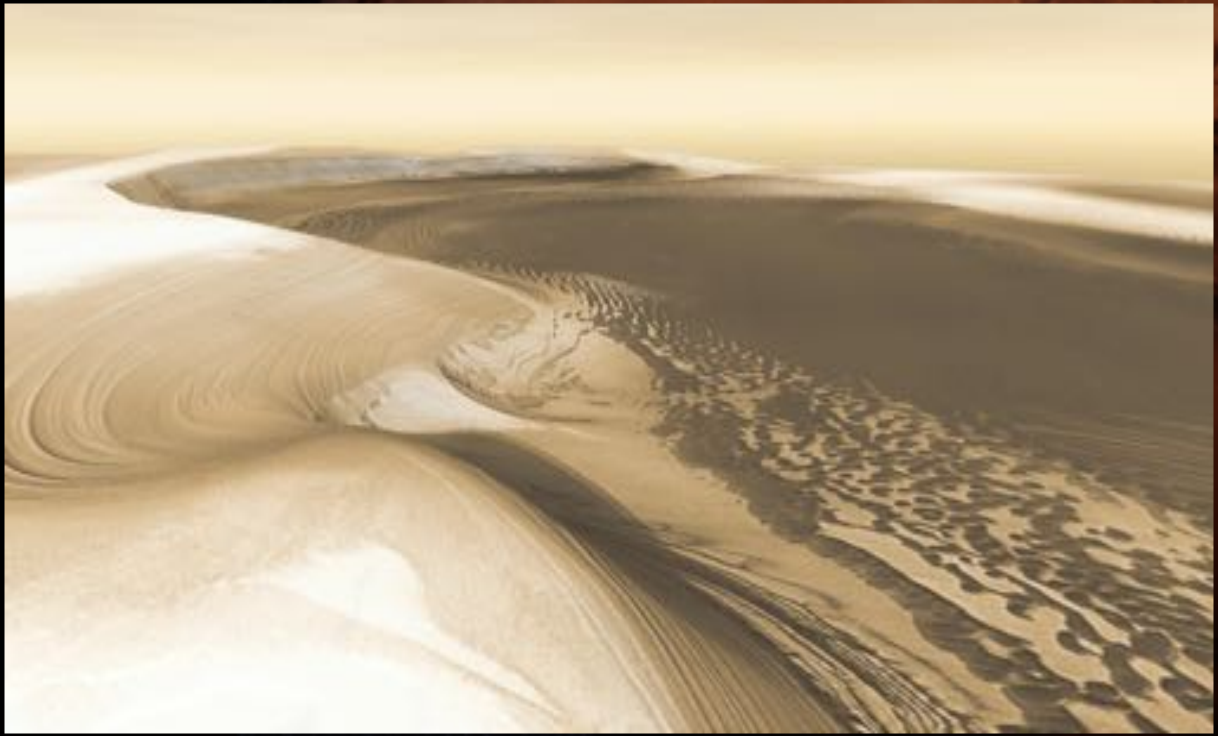
The 80 km-wide Korolev crater is filled with 2,200 cubic kilometres of water ice. At 73° N, it would be within the icy reach of the planet's polar ice cap during periods of low obliquity.
Taken by ESA's Mars Express Orbiter.

25° obliquity; ice source at north pole: 

- With the planet more tilted, the north pole receives more solar heating during the northern summer and more water vapour sublimates into the atmosphere.
- It is transported to the equator and southern hemisphere.
- Some condenses at the south pole; the rest returns to condense on the north polar ice cap during the northern winter.



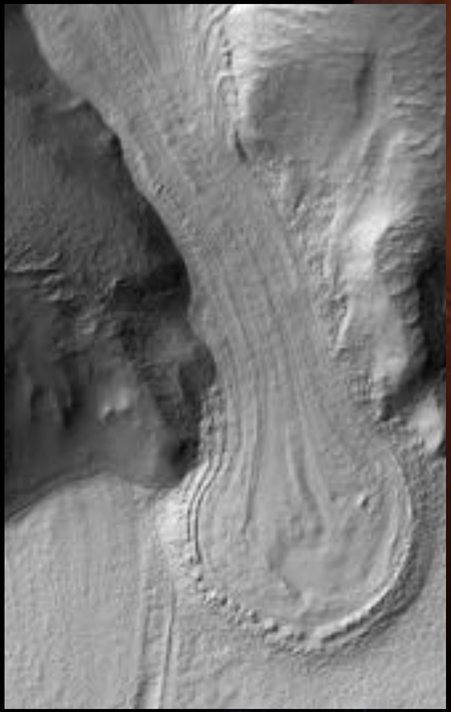
The graphic shows output from the climate model with areas of both high sublimation (dark) and high deposition (light) of surface ice at the north pole, averaged over the year.



The north polar ice cap is a source of water vapour in the summer and a sink for surface ice deposited in the winter during times of medium obliquity, leading to layers of material.
Taken by the THEMIS camera on NASA's Mars Odyssey Orbiter.

45° obliquity; ice source in tropics:

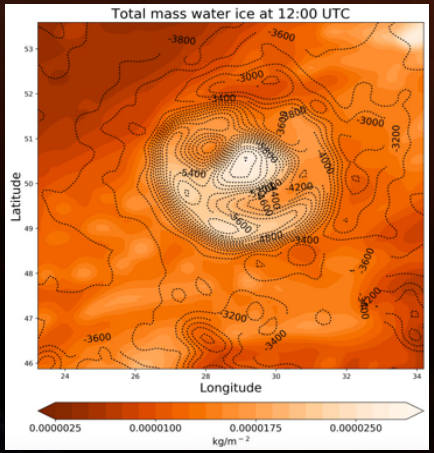
- With the planet at an even greater tilt, the poles receive more solar heating and most of their ice caps sublimate.
- The water vapour condenses in the now much cooler tropics, where equatorial ice caps form on the higher ground.[9, 10]



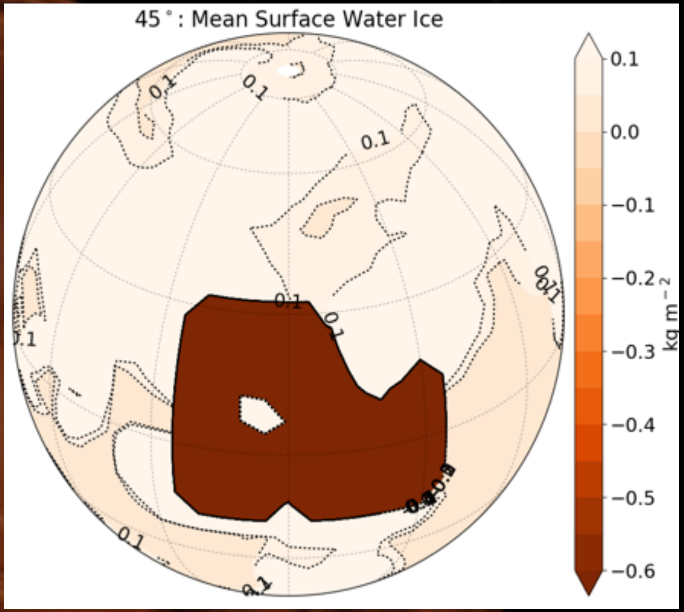
The Protonilus Mensae glacier is one of many found in the tropics, formed at times of high obliquity and now covered with dust. Taken by the HiRISE camera on NASA's Mars Reconnaissance Orbiter.

Future work

- Simulations on the LMD Mars Mesoscale Model, using the data above, will provide information on the relationship between the local mesoscale water cycle and the ice-rich deposits found in and around Lyot Crater, and how they have changed over time.



The graphic shows output from the mesoscale model, centred on Lyot crater, with the water ice present at noon local time under current climatic conditions.



The graphic shows output from the climate model with large amounts of sublimation (dark) of surface ice from the high ground in the tropics, where new ice caps have formed, and small amounts of deposition (light) around the rest of the planet, averaged over the year.

References: 1. Read & Lewis, *The Martian Climate Revisited* , **2004**. 2. Montmessin et al, in *Atmos. Clim. Mars*, **2017**. 3. Laskar et al, *Icarus* 170(343), **2004**. 4. Dickson et al, *Geophys. Res. Lett*. 36(2), **2009**. 5. Nerozzi & Holt, *Geophys. Res. Lett*., GL082114, **2019**. 6. Jakosky et al, *Icarus* 102(286), **1993**. 7. Jakosky et al, *J. Geophys. Res.*, 100(1579), **1995**. 8. Forget et al, *J. Geophys. Res. Planets*, 104 (24155), **1999**. 9. Jakosky & Carr, *Nature*, 315(559), **1985**. 10. Forget et al, *Science*, 311(368), **2006**.