

**THE FIRST TREE ON MARS.** R. Olszewski<sup>1</sup>, P. Pałka<sup>1</sup>, A. Wendland<sup>1</sup>, A.F.C. Bridger<sup>2</sup>, M.A. Kahre<sup>3</sup>, Ch. Körner<sup>4</sup>, C.P. McKay<sup>3</sup>, <sup>1</sup>Warsaw University of Technology, robert.olszewski@pw.edu.pl, <sup>2</sup>San Jose State University, <sup>3</sup>NASA Ames Research Center, <sup>4</sup>University of Basel

**Summary:** Using a high resolution surface energy balance model for Mars, we have computed the amount of greenhouse warming required to warm Mars enough that trees can grow. We find that for a 10 kPa CO<sub>2</sub> atmosphere (a pressure level known to support plant growth), temperatures suitable for trees to grow occur when the added, artificial, greenhouse thermal infrared gray opacity is ~0.27 optical depths. Surprisingly, the conditions that allow plant growth do not occur first in the tropics ( $\pm 25^\circ$ ) but in the Hellas Basin region.

**Introduction:** We have developed a surface energy balance model for Mars based on representing the surface of Mars with a Goldberg polyhedral of 4002 cells (Fig. 1). The energy balance equation is applied to each cell. In addition to the radiation terms, the surface energy balance includes the diffusive exchange of heat between cells, CO<sub>2</sub> condensation and evaporation, heat exchange with the subsurface, and the transport of heat by the atmospheric circulation.

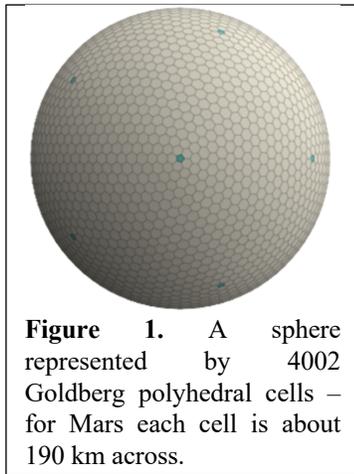
We calibrate the model parameters by comparing to the Viking landers temperature and pressure datasets, and by comparison to Mars GCMs. The model has high spatial resolution but is still computationally efficient, and can be used to simulate a variety of processes on Mars, both at present and in past/future epochs. Here, we use the baseline model to investigate the greenhouse effect caused by an increase in CO<sub>2</sub> plus artificial greenhouse warming.

The atmospheric conditions existing on Mars today make the existence of life impossible. The requirements for plant growth on Mars have been considered in the context of terraforming [1] and for low-pressure greenhouses [2]. The total pressure must be above ~10 kPa and while a high percentage of CO<sub>2</sub> is acceptable [2], O<sub>2</sub> is needed for respiration at a level of ~ 0.1 kPa [1]. Water must be available, and the temperatures must be in the range required for growth. Here we focus on temperature as this is the fundamental environmental variable that changes during terraforming and it controls the CO<sub>2</sub> cycle and the formation of liquid water. O<sub>2</sub> levels in a thick warmer atmosphere remain an important separate concern. Focusing on the temperature, it must be several tens of

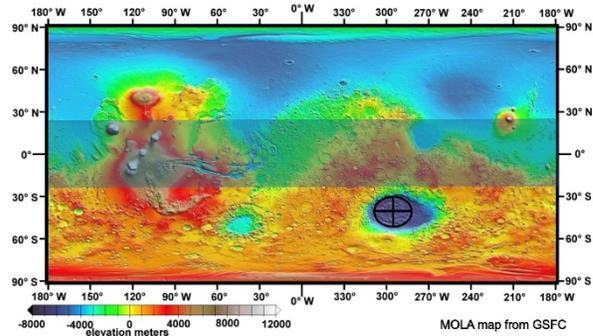
degrees higher, while the diurnal fluctuations should be much lower. For the growth of trees, the growing season must last at least 110 sols (Martian days) during which the minimum temperature  $> -6^\circ\text{C}$ , average temperature  $> 6^\circ\text{C}$ , and maximum temperature  $< 40^\circ\text{C}$  [3-5].

**Results:** We present results for an assumed CO<sub>2</sub> surface pressure of 10 kPa, which is known to support plant growth [2]. We find that temperatures suitable for trees to grow occur when the added, artificial, greenhouse thermal infrared gray opacity is ~0.27 optical depths. Surprisingly, the conditions that allow plant growth do not occur first within the tropics ( $\pm 25^\circ$ ) but in the Hellas Basin region (Fig. 2). A further increase in the greenhouse effect expands the area suitable for plant growth in the southern hemisphere.

**Discussion:** On Earth the highest elevation treelines are primarily found in the tropics – but modulated by the location of the thermal equator [6]. Thus, it may be expected that equatorial regions of Mars would be the location of the first tree. However, due to Mars' relatively large orbital eccentricity (0.1) the southern hemisphere, which has summer near perihelion, has relatively warm summers. In addition, the orbital period of Mars is 1.9 Earth years. Thus, the long warm southern summer provides the first growing season suitable for trees. Specifically, we find that the low elevation of the Hellas Basin allows the creation of the first conditions favorable to tree growth.



**Figure 1.** A sphere represented by 4002 Goldberg polyhedral cells – for Mars each cell is about 190 km across.



**Figure 2.** MOLA map of Mars with the tropics ( $\pm 25^\circ$ ) shaded. With sufficient greenhouse warming, the first tree on Mars grows outside the tropics in Hellas Basin.

**References:** [1] McKay Ch. P., Toon O.B. and Kasting J.F. (1991) *Nature*, 352. [2] Richards, J.T., et al., 2006. *Astrobiology*, 6(6), pp.851-866. [3] Körner, Ch. 2012 *Alpine Treelines*, Springer, p. 229. [4] Körner, Ch. and Paulsen, J. 2004 *Journal of Biogeography* 31, 713–732. [5] Hoch, G. and Körner, Ch. 2009 *Journal of Ecology*, 97, 57–66. [6] McKay, C.P. and Cintron, M.N. 2024 *Bull. Am. Met. Soc.*, 105(6), E1015-E1021.

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