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IS CO_2 CAPABLE OF KEEPING EARLY MARS WARM?

J. F. Kasting*
Department of Geosciences, The Pennsylvania State University

One of the goals of NASA's Exobiology Research Program is to determine whether life exists today on Mars (unlikely) or whether it might have existed there at some time in the past (more likely). Speculation about extinct life is driven by the observation of channels on the Martian surface, thought to indicate the past presence of liquid water and, hence, the existence of a warmer climate. Current thinking suggests that such a climate could have been maintained if early Mars had a dense CO_2 atmosphere with a surface pressure of 1 to 5 bars.

One of the phenomena that Martian climate modelers (including myself) have not looked at very carefully is the process of CO_2 condensation. Reexamination of some of my own calculations indicates that condensation should occur at high altitudes in some high-CO_2, Martian atmospheres, particularly those in which the solar constant is set to its initial main sequence value, about 70% of present. CO_2 condensation should affect the surface temperature in at least two ways: 1) If it occurs in the convective lower atmosphere, condensation will reduce the magnitude of the greenhouse effect by decreasing the lapse rate. 2) Condensation at any altitude will produce clouds, which can either warm or cool the climate depending on their altitude and optical depth. (The dominant effect, however, is likely to be cooling.) Preliminary calculations with a one-dimensional, radiative-convective climate model indicate that the lapse rate change is substantial for low solar luminosity models. Indeed, the calculations imply that no amount of CO_2 is capable of raising the mean surface temperature of early Mars above the freezing point of water, because the increase in planetary albedo due to Rayleigh scattering outstrips the greenhouse effect at high CO_2 partial pressures! These calculations are preliminary and do not take into account changes in cloudiness (which may worsen matters) or the nonideal behavior of CO_2 along its saturation vapor pressure curve (effect not yet determined). More detailed calculations are presently being performed. If this climate problem persists, then the question of what kept early Mars warm may need to be reexamined.