

The Ancient Martian Climate System

Robert M. Haberle

Today Mars is a cold, dry, desert planet. The atmosphere is thin and liquid water is not stable. But there is evidence that very early in its history it was warmer and wetter. Since Mariner 9 first detected fluvial features on its ancient terrains researchers have been trying to understand what climatic conditions could have permitted liquid water to flow on the surface. Though the evidence is compelling, the problem is not yet solved.

The main issue is coping with the faint young sun. During the period when warmer conditions prevailed 3.5-3.8 Gy the sun's luminosity was ~25% less than it is today. How can we explain the presence of liquid water on the surface of Mars under such conditions? A similar problem exists for Earth, which would have frozen over under a faint sun even though the evidence suggests otherwise.

Attempts to solve the "Faint Young Sun Paradox" rely on greenhouse warming from an atmosphere with a different mass and composition than we see today. This is true for both Mars and Earth. However, it is not a straightforward solution. Any greenhouse theory must (a) produce the warming and rainfall needed, (b) have a plausible source for the gases required, (c) be sustainable, and (d) explain how the atmosphere evolved to its present state. These are challenging requirements and judging from the literature they have yet to be met.

In this talk I will review the large and growing body of work on the early Mars climate system. I will take a holistic approach that involves many disciplines since our goal is to present an integrated view that touches on each of the requirements listed in the preceding paragraph. I will begin with the observational evidence, which comes from the geology, mineralogy, and isotopic data. Each of the data sets presents a consistent picture of a warmer and wetter past with a thicker atmosphere. How much warmer and wetter and how much thicker is a matter of debate, but conditions then were certainly different than what they are today.

I will then discuss the origin and evolution of the early atmosphere from accretion and core formation to the end of the late heavy bombardment, including estimates of the volatile inventory, outgassing history, and potential escape mechanisms. This sets the stage for a comprehensive look at the climate system of early Mars and the attempts to solve the faint young sun problem. I will review the basic physics involved and then step through the different ideas highlighting their strengths and weaknesses. I will then conclude with a summary and a discussion of potentially promising avenues of future research.