HISTORY AND PROGRESS OF GCM SIMULATIONS ON RECENT MARS CLIMATE CHANGE. R. M. Haberle, NASA/Ames Research Center, Moffett Field, CA 94035 (Robert.M.Haberle@nasa.gov)

The Mars Global Surveyor and Odyssey spacecraft reveal evidence that Mars may have experienced significant climate change in the recent past (10^5-10^6 Myr ago). Examples include gullies [1], cold-based tropical glaciers [2], paleolakes [3], and youthful near-surface ice [4]. Except for the gullies, the evidence for recent climate change requires ice and/or liquid water at low latitudes. An obvious question, therefore, is how is it possible for ice and/or liquid water to exist at low latitudes which is not possible in the present climate system?

There are several mechanisms to consider. An episode of intense volcanic activity could alter the mean composition of the atmosphere and, therefore, the climate system. Impacts, depending on the size, composition, and velocity of the impactor are another way to dramatically alter the climate system. Polar wander and solar variability are also possibilities. However, the most promising way to change the climate is through changes in orbital properties. Mars, because of its proximity to Jupiter and lack of a large stabilizing moon, experiences much greater changes in its orbit properties than the Earth.

The key orbit properties are the obliquity, eccentricity, and longitude of perihelion. Recent calculations by Laskar et al. [5] have shown that the obliquity and eccentricity vary on time scales of 10^5-10^6 years. During the past 10 Myr the obliquity has exceeded 45° and the eccentricity has been as high as 0.14. Beyond that orbit variations are chaotic, but the obliquity may have exceeded 60°. The fastest orbital variation is the precession cycle, which varies on a 50,000 year time scale. Of these three orbit parameters, the obliquity is the most important for controlling the latitudinal distribution of solar insolation. As the obliquity increases, the poles warm with respect to lower latitudes. For obliquities exceeding 54°, the poles actually receive more insolation at the top of the atmosphere on an annual basis.

Jakosky and Carr [6] recognized the importance of obliquity on the stability of surface ice deposits. They used simple scaling arguments to suggest that at high obliquity water evaporating from the north polar cap would be transported southward by the general circulation and precipitate out at low latitudes forming tropical ice deposits. Fifteen years later, general circulation models finally developed the capability to begin addressing this question. Haberle et al. [7] used a coarse resolution model with a very simple cloud scheme to show that ice did indeed accumulate at low latitudes, but that the distribution was not uniform in longitude. Since then, Forget [8], Richardson and Wilson [9], Mischna et al. [10], and Levrard et al. [11] have obtained similar results but with different distributions.

The reason ice stabilizes at low latitudes at high obliquity has not yet been completely explained. It is not as simple as ice going to the coldest place on the planet since in some of the simulations the tropics remain the warmest places. And it is not as simple as the scaling arguments of Jakosky and Carr since some of the simulations with flat topography show no ice accumulating in the tropics. These results suggest that it is the topographically-modulated general circulation that plays the dominant role in determining where ice is stable at the surface. However, more research is needed to confirm this.

A major concern is the role of clouds. Understandably, most of these early simulations utilized very simple cloud schemes. However, clouds can have a major impact on the ultimate distribution of water [11,12]. These studies clearly indicate that more sophisticated schemes are needed. Clouds will also impact the radiation budget since they are in considerable abundance at high obliquity. Thus far, none of the models treat the radiative effects of the clouds very well.

While much progress has been made in modeling past climates, the field is still very much in its infancy. The major thrust of future work will be improving the model's physical parameterizations, understanding why water goes where it does, and comparing model results with surface geology. The convergence of the geological and atmospheric science communities on this topic is very exciting and holds great promise for solving questions regarding past climate change on Mars.

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