A SUSTAINED GREENHOUSE CLIMATE AND EROSION PERIOD ON MARS FOLLOWING AN IMPACT EVENT. T.L. Segura[1], O.B. Toon[2], A. Colaprete[3], and K. Zahnle[3], [1]Northrop Grumman Space Technology 1 Space Park Dr. E1/4037 Redondo Beach, CA 90278 teresa.segura@ngc.com, [2]University of Colorado Boulder Campus Box 392 Boulder, CO 80303, [3]NASA Ames Research Center MS 245-3 Moffett Field, CA 94035.

Introduction: The existence of craters of size 200 km and greater proves that large (30-250 km diameter) impacts were abundant in the early history of Mars. Injected water from three sources (the impactor, water innate to the crater, and from melting of the polar caps) provide periods of rain following such impacts. Very hot, global debris blankets are another consequence of these large impacts, and these layers create a thermal pulse that propagates into the subsurface, melting additional water. The melted and precipitated water and debris blanket combine to produce a temporarily altered climate [1].

Modeling Effects of Impacts in 1-D: We have modeled the effects of large (30 - 100 km diameter) impacts on Mars using a 1-dimensional radiative-convective model. This paper is an extension of the work done by *Segura et al*. [2002]. In that study, the latent heat effects of the cloud formation and modeling of the full hydrological cycle were not included, but it was determined that one 250 km diameter impactor would provide enough melting and rainfall to produce the 50 m global water layer suggested [2] to be necessary to form all known networks. However, these impacts correspond to the earliest history of the planet (> 4.2 billion years ago), and hence would have been responsible for formation of the oldest networks on the planet. Since there is evidence of later valley network formation (3.3-3.8 billion years ago) modeling of smaller objects, corresponding to impacts later in geologic time, must be completed. In this study, we focus on the effects of impacts 30, 50, and 100 km in diameter. We used a new model that includes a full hydrological cycle (triggered by the melting, evaporation, and precipitation of water at the surface), the latent heat release/absorption during the condensation/evaporation of clouds, and the radiative effects of the water clouds once they have formed. Our model is a 1-D radiative-convective model coupled to a 1-D model of the regolith to compute the evolution of the atmospheric temperature following impact. It includes a subsurface model to compute the evolution of the ground temperature, a hydrological cycle to follow the evaporation, condensation and precipitation of injected and surface evaporated water, a radiative transfer code to compute greenhouse warming by CO2, water vapor, and the radiative effects of water clouds, and an atmospheric module to compute the latent heating due to cloud formation/dissipation. We have found that the Martian surface may be kept above freezing for from 95 days to several decades by the modeled events, although by including the radiative effects of clouds a new sustained greenhouse climate is observed for objects 50 km in size, which could be centuries-long. The length of time the planet is above 273 K is determined by the assumed CO2 surface pressure, whether the radiative effects of clouds are considered, and of course, by the size of the event itself. The amount of water precipitated out of the atmosphere from vaporization of impactor, target, and polar caps, and melted below ground for different diameter asteroid impactors yields global water totals ranging from 40 cm to 5 m for modeled examples.

Computing the Subsequent Erosion Volume: Denudation rates for Mars in the Noachian have been estimated in the past based on crater degradation. Rates of 0.1-5 microns/year would be consistent with the erosion that seems to have occurred on early Mars [3]. It has been estimated [4] that these high (by Martian standards) erosion rates existed for about a half billion years during the Noachian. If so, then they correspond to 50-2500 meters of total erosion during this period. We now attempt to make rough estimates of the amount of erosion provided by precipitation following these events and compare this number to the 50-2500 meters introduced above.

Erosion due to surface runoff on the Earth can be either measured outright or calculated using the Universal Soil Loss Equation (USLE) or some variant of it. Here we estimate the erosion due to precipitation following impacts and compare this with the predicted erosion on Mars during the Noachian. Using a version of the USLE modified for Mars we estimate the erosion rates due to precipitation following each single event and compute a total erosion for the planet that is of the same order of magnitude as that computed by Golombek and Bridges [2000].

Conclusions: After consideration of these results, a picture emerges in which the Martian valley networks were formed not during a long, sustained, warm, and wet past Martian climate, but instead during brief periods of intense erosion following impacts.

The erosion due to precipitation computed here is the same order of magnitude as the assumed lower limit of erosion during the Noachian but it is possible that these 1-D results represent minima to precipitation and surface water totals. The effects of impacts has been studied in three dimensions using the General Circulation Model (GCM) at NASA-Ames Research Center [5]. The GCM includes many more processes than are included in this simple 1-D model such as cloud microphysics, atmospheric dynamics, and polar cap sublimation/deposition. Initial results from the GCM suggest that the global average rainfall totals might be a factor of three or more larger than the values reported here, with some individual areas possibly receiving a hundred meters or so of direct rainfall. The same sustained greenhouse climate is seen in both the 1-D and the 3-D models when the radiative effects of water clouds are included. When the effects of clouds are considered, it has been found that perhaps 10-20 seasons of warmth are possible following impact with only a 10 km diameter object [5], which may be long enough to form some observed fluvial features [6]. Additional runs should be attempted where the radiative effects of clouds and an ambient CO_2 atmosphere greater than 150 mbar are included. There is obviously much more we can do building off the research in this paper.

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