TIME-DEPENDENT CALCULATIONS OF AN IMPACT-TRIGGERED RUNAWAY GREENHOUSE ATMOSPHERE ON MARS. T. L. Segura1, O. B. Toon[1], A. Colaprete[2] [1]Laboratory for Atmospheric and Space Physics, University of Colorado (Mailing Address for first author: NASA-Ames Research Center MS 245-3 Moffett Field, CA 94035 segurat@colorado.edu), [2]NASA-Ames Research Center.

Introduction: Large asteroid and comet impacts result in the production of thick (> tens of meters) global debris layers of 1500+ K and the release (through precipitation of impact-injected steam and melting ground ice) of large amounts (> tens of meters global equivalent thickness) of water on the surface of Mars [1]. Modeling shows [1] that the surface of Mars is still above the freezing point of water after the rainout of the impact-injected steam and melting of subsurface ice. The energy remaining in the hot debris layer will allow evaporation of this water back into the atmosphere where it may rain out at a later time. Given a sufficiently rapid supply of this water to the atmosphere it will initiate a temporary "runaway" greenhouse state.

Impact Energy Discussion: The kinetic energies involved in these large impacts are huge. Between 6 x 10^{25} and 9 x 10^{26} J are delivered to the planet for asteroids of sizes 100 - 250 km, traveling at 9 km/s. The ejecta generated from the impact are distributed globally both ballistically and via the thermally expanding vapor cloud to produce global rock debris layers of 2.2 - 34 m thick [1]. The energy in the hot debris layer is from 2.5 - 3% of the total kinetic energy from the impact event, and the hot rock debris volume is from 4.2 - 7.8% of the crater volume and about 60% of the impactor volume (Fig. 1, [2]). Thus the energy in the rock layer is not a significant part of the total energy of the impact event itself, nor is the mass a significant portion of the mass lofted from the crater. If we imagine that all of the kinetic energy of the impactor is available to contribute to a runaway greenhouse state, we find that the planet may be in such a state for hundreds of years (Fig. 2).

Current Study: The research presented here focuses on how much warming can result from an impact-triggered runaway state, and how long such a state will last. We speculate on how this mechanism might have formed the valley networks on Mars.

Model desctiption. The model used is a 1-D radiative-convective model coupled to a 1-D model of the regolith to calculate the evolution of the surface and subsurface temperatures. In the atmosphere, condensation of the injected water occurs when the relative humidity exceeds 100%. As the cloud moves downward through the atmosphere, rainout of the injected water occurs when the bottom layer has finally saturated. If the surface of the planet is warmer and moister than the atmosphere, this water is allowed to re-evaporate into the atmosphere, removing energy from the surface (rock layer), and adding water to the bottom atmospheric layer. We assume that this water is instantaneosly redistributed throughout the atmosphere chaning the water mixing ratios such that they are constant in height (but not in time). We have a background CO_2 amount equivalent to a surface pressure of 150 mb such that when all of the water has precipitated out, and the surface is no longer warm enough to promote re-evaporation, the final surface pressure is 150 mb, all CO_2.

Discussion. These calculations differ from those done by Segura et al. in [1]. By adding the effect of latent heating in the atmosphere, the period of time the planet is above 273 K has increased almost 500% to several centuries for the largest (~ 250 km) objects. We believe the brief warming periods and large amounts of global water released from large impacts are definite keys to the study of formation of the Valley Networks on Mars. This idea is further supported by the work of Gregoire-Mazzocco et al. [3] who find from statistical analyses of the valley networks that they are immature and probably formed by catastrophic flows over short periods of time.

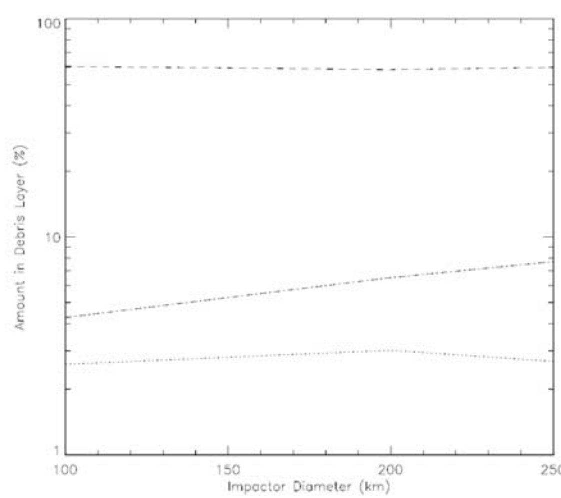

Figure 1. Fraction of total kinetic energy from the impact event that goes into the debris layer (dotted curve), fraction of the total lofted crater mass made up by the debris layer (dash-dot curve), and fraction of the impactor volume made up by the debris layer (dashed curve) as functions of impactor diameter.

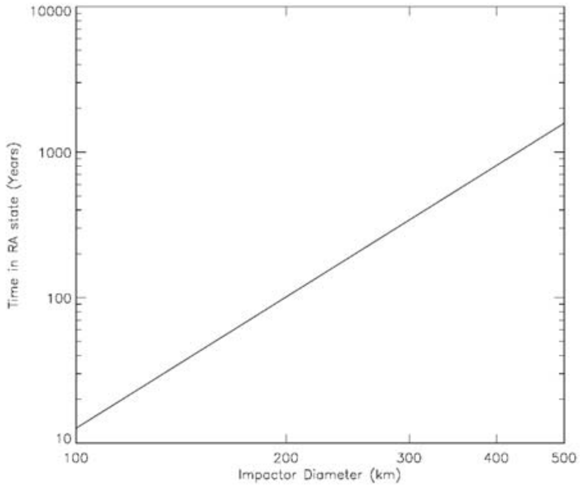

Figure 2. Time we expect Mars to be in a "runaway" state as a function of impactor diameter. This curve assumes that all available energy in the rock layer goes to promoting runaway.

References: [1] Segura T. L. et al. (2002) *Science, 298,* 1977-1980. [2] Melosh H.G. (1989) I*mpact Cratering A Geologic Process*, Oxford University Press, New York, NY. [3] Gregoire-Mazzocco H. et al. (2003) EGS-AGU-EUG, Abstract #EAE03-A-05401.