THE IMPACT OF VERY LARGE METEORITIC IMPACTS ON EARLY MARS MODELED WITH A HIERARCHY OF NUMERICAL CLIMATE MODELS

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Introduction: The origin of the formation of the Martian valley networks is now a half-century mystery. It has been proposed that very large meteoritic impacts could have triggered a long-term climate change conducive to the formation of these valley networks [1,2,3].

Method: We use a hierarchy of numerical climate models (the 3-D LMD Generic Global Climate Model [4,5], the 1-D LMD Generic radiative-convective model [6,7]) to test that hypothesis and more generally explore the environmental effect of very large meteoritic impacts ($D_{impactor}$ > 100 km) on the atmosphere, surface and interior of early Mars.

Results: Using a combination of 1-D and 3-D climate simulations, we show that the environmental effect of the largest impact events recorded on Mars are characterized by:

(i) a short impact-induced warm period. The surface and atmosphere of Mars cool down below 0°C in ~10^1 Martian years only, for our very large reference[1] impact event (Fig.1A). 1D radiative-convective simulations show that this result is robust for a wide range of parameters (in particular, for a wide range of initial CO_2 atmospheric pressure). We find that the impact-induced stable runaway greenhouse state predicted by [3] is physically inconsistent. Although we confirm the result of [2] and [8] that water ice clouds could in theory significantly extend the duration of the post-impact warm period (and even for cloud coverage significantly lower than predicted in [9]), we find that the range of cloud microphysical properties for which this scenario works is very narrow, in agreement with [9].

1 Reference simulation: A very large impactor hitting the surface of Mars, initially assumed to be endowed with a 1 bar pure CO_2 atmosphere. The impactor is assumed to be large enough to trigger the vaporization of ∼ 2 bar (i.e. 54 m GEL) of water into the atmosphere. The atmosphere, surface, and subsurface are assumed to be suddenly and uniformly heated up to 500K.

(ii) a low amount of precipitation, because there is almost no surface re-evaporation of precipitation (Fig.1D). The amount of precipitation can be reasonably well approximated by the initial post-impact atmospheric reservoir of water vapour (coming from the impactor, the impacted terrain and from the sublimation of permanent ice reservoirs heated by the hot ejecta layer);

(iii) deluge-style precipitation. About 2.6 m Global Equivalent Layer of surface precipitation per Earth year for our reference simulation, quantitatively in agreement with previous 1-D cloud free climate calculations of [1], and also in agreement with the ICASE (Impact Cratering Atmospheric/Surface Effects) model of [10];

(iv) precipitation patterns that are uncorrelated with the observed regions of valley networks formation (Fig. 2).

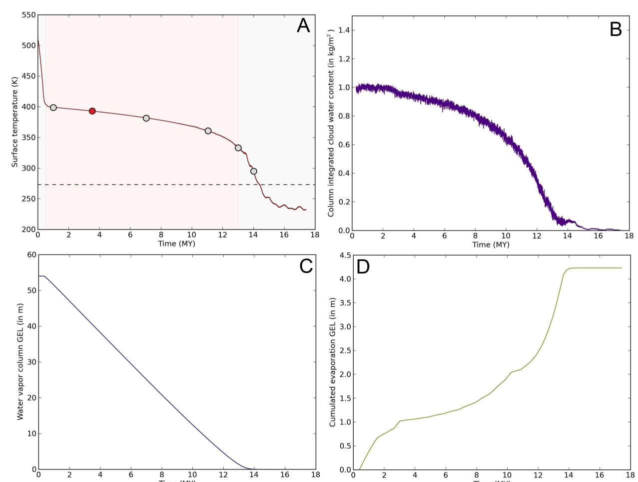

Figure 1: Globally averaged temporal evolution of the (A) surface temperature (in K), (B) column integrated cloud water content (in kg/m²) , (C) integrated column of water vapour (in m GEL), and (D) cumulated surface evaporation of water (in m GEL). MY is for Martian Years.

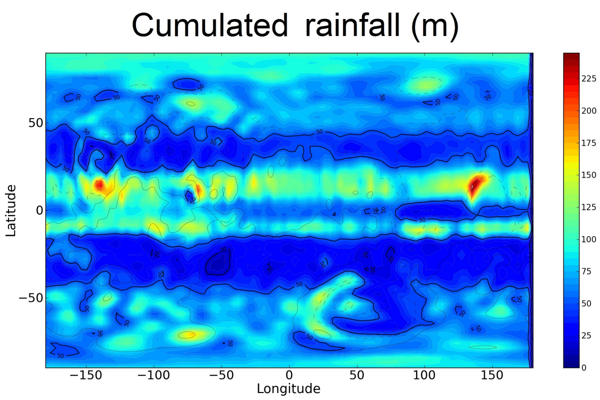

Figure 2: *Cumulated rainfall map (in m) 15 martian years after the meteoritic reference impact event. We used here the topography of [11], i.e. a pre-True Polar Wander (Tharsis-induced) topography.*

Conclusion: Altogether, these arguments indicate that the largest impact events recorded on Mars are unlikely to be the direct cause of formation of the Noachian valley networks.

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