GLOBAL CLIMATE MODEL PREDICTIONS FOR A TRANSIENT CHANGE FROM A LONG-LIVED "COLD AND ICY" CLIMATE TO A SHORT-LIVED "WARM AND WET" CLIMATE IN THE LATE NOACHIAN-EARLY HESPERIAN

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NASA

Abstract 2086

Previous work has shown that widespread snowmelt and runoff might have been the dominant mechanism of fluvial erosion on early Mars [1].
Is the distribution of valley networks and lakes more consistent with snowmelt in a long-lived "warm and wet" climate or a long-lived "cold and icy" climate with one or more periods of punctuated heating?

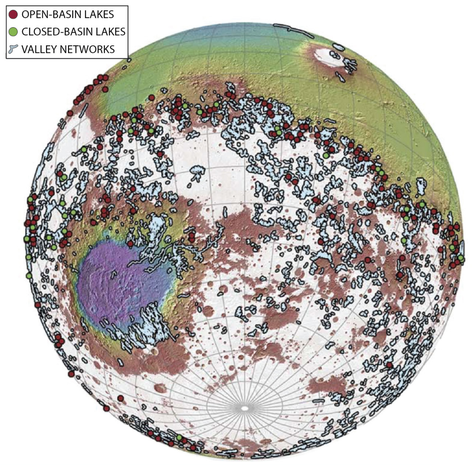


Figure 1 (right). Map showing spatial correlation between valley networks and lakes and the predicted Noachian ice distribution in a "cold and icy" climate. Figure from [2].

Results

We describe our results through figures prduced with GCM data that mimic those illustrated in the methods section (figure 2 and 3, below) and determine the percentage of valley networks and lakes that are located in areas of predicted meltwater (summarized in table 1, below).

Distribution of predicted snowmelt in a long-lived "warm and wet" climate:

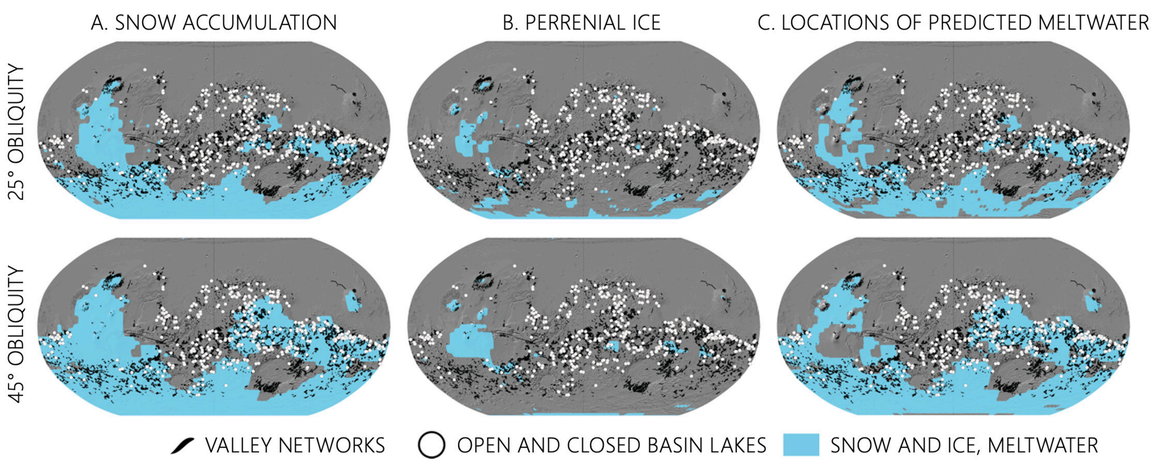


Figure 2. Model results for "warm and wet" climate. Shaded in blue: areas where (A) snow accumulates at some point in the year, (B) snow/ice present year-round, (c) melting and runoff is predicted.

Distribution of predicted snowmelt in a long-lived "cold and icy" climate with one or more periods of punctuated heating:

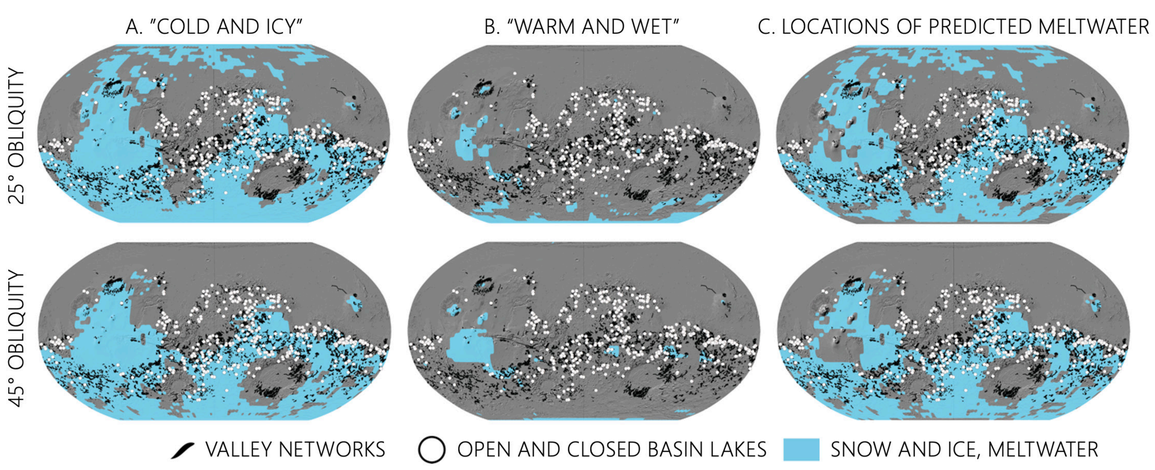


Figure 3. Model results for "cold and icy" climate. Shaded in blue: areas where (A) snow/ice present year-round in "cold and icy", (B) snow/ice present year-round in "warm and wet", (c) melting and runoff is predicted.

Table 1. Assessment of percentage of valley networks and lakes that are located in areas of model-predicted rainfall or snow/ice melting for all GCM simulations and climate scenarios considered. The highest percentage of valley networks and lakes are located in areas of predicted fluvial activity for the scenario of a long-lived "cold and icy" climate with punctuated heating (shaded blue).

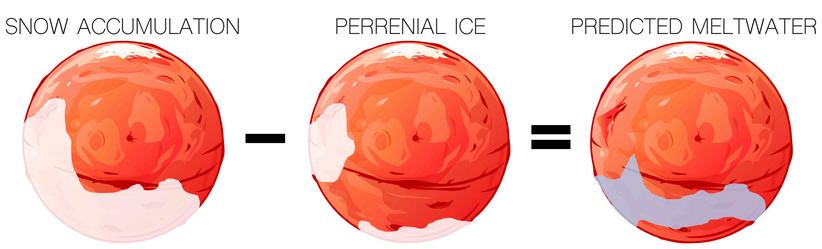
	Long-lived "warm and wet" climate				Long-lived "cold and icy" climate with punctuated heating	
	RAINFALL		SNOWMELT		SNOWMELT	
Obliquity	25°	45°	25°	45°	25°	45°
Percent VNs	<1%	<1%	27%	58%	57%	72%
Percent lakes	<1%	<1%	14%	46%	39%	61%

Methods

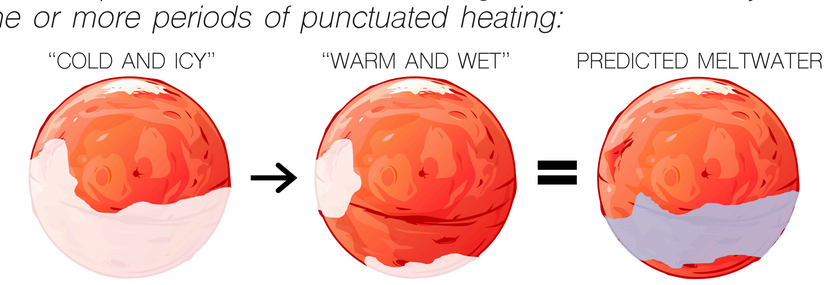
We implement the LMD GCM for early Mars and produce simulations with Noachian spin-axis/orbital and atmospheric pressure conditions:
- 1 bar CO_2 atmopshere [e.g. 3]
- 24 m global equivalent layer (GEL) surface/near-surface water [4]
- 25° and 45° obliquity [5]
- circular orbit, chosen to limit suite of simulations

These two simulations produce "cold and icy" conditions [6,7]. Because we are also interested in "warm and wet" conditions, we run an additional two simulations with gray gas to mimic greenhouse warming. The amount of gray gas is chosen to produce global mean annual temperature (MAT) ~275 K [e.g. 8].

Distribution of predicted snowmelt in a long-lived "warm and wet" climate:



Distribution of predicted snowmelt in a long-lived "cold and icy" climate with one or more periods of punctuated heating:



We then compare the distributions of predicted meltwater with the distributions of valley networks [9] and lakes [10,11] to determine which climate scenario is more consistent with observed fluvial and lacustrine features.

Conclusions

We have utilized GCM simulations and analyzed the model-predicted distributions for fluvial activity, including rainfall and snow/ice melting, for the scenarios of:
(1) a long-lived "warm and wet" climate
(2) a long-lived "cold and icy" climate with punctuated heating

Our results show that:
(1) Rainfall is negligible in both climate scenarios.
(2) Melting of snow/ice in a "warm and wet" climate would not occur in all regions where valley networks and lakes are abundant.
(3) On average, ~20-30% more of the valley networks and lakes are in areas of predicted fluvial activity in a long-lived "cold and icy" climate with punctuated heating than in a long-lived "warm and wet" climate.

These results are consistent with the hypothesis that (1) the long-lived climate was "cold and icy" with little-to-no fluvial activity and (2) punctuated heating could have led to short-lived "warm and wet" conditions near the Noachian-Hesperian boundary, characterized by abundant snow/ice melting, runoff, and fluvial activity.

References. [1] Palumbo and Head (2018), GRL. [2] Head and Marchant (2014), Antarctic Science [3] Jakosky et al. (2017), Science. [4] Carr and Head (2015), GRL. [5] Laskar et al. (2004), Icarus. [6] Forget et al. (2013), Icarus. [7] Wordsworth et al. (2013), Icarus. [8] Ramirez and Craddock (2018), Nature Geoscience Perspective. [9] Hynek et al. (2010), JGR: Planets. [10] Fassett and Head (2008), Icarus. [11] Goudge et al. (2015), Icarus.

Acknowledgements. This work was supported by NASA Headquarters under NESSF to AMP; Grant 90NSSC170487.