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The Early Climate History of Mars: "Warm and Wet" or "Cold and Icy"?

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The Amazonian climate (last ∼66% of history) was much like today, a cold and dry climate regime, characterized by the latitudinal migration of surface ice in response to variations in spin-axis/orbital parameters. But what characterized the Noachian climate (first ∼20% of history)? Some data support a “warm and wet” early Mars, but this evidence has been challenged. New models of early Mars climate (Forget, Wordsworth et al.) find that for atmospheric pressures greater than a few hundred millibars, surface temperatures vary with altitude due to atmosphere-surface thermal coupling: an adiabatic cooling effect (ACE) results in deposition of snow and ice at high altitudes, in contrast to Amazonian conditions. Without other warming mechanisms, no combination of parameters lead to mean annual surface temperatures (MAT) consistent with widespread liquid water anywhere on the planet. The ACE causes southern highland region temperatures to fall significantly below the global average leading to a “Noachian Icy Highlands” scenario: Water is transported to the highlands from low-lying regions due to the ACE and snows out to form an extended H_2O ice cap at the southern pole, and altitude-dependent snow and ice deposits down to lower southern latitudes. Could the predictions of this “Noachian Icy Highlands” model be consistent with the many lines of evidence traditionally cited for a “warm, wet” early Mars? Perturbing this predominant Noachian environment with punctuated impacts and volcanism/greenhouse gases would lead to raising of global surface temperatures toward the melting point of water, with the following consequences: 1) ice above the surface ice stability line undergoes rapid altitude/latitude dependent warming during each Mars summer; 2) meltwater runoff from the continuous ice sheet drains and flows downslope to the edge of the ice sheet, where meltwater channels encounter cratered terrain, forming closed-basin and open-basin lakes; 3) seasonal top-down heating and melting of the top tens of meters of continuous ice produce a volume of water well in excess of the total volume interpreted to have occupied open-basin/closed basin lakes; 4) this meltwater initially erodes into the dry regolith down to the top of the ice table, producing a perched aquifer and more efficient erosion than infiltration alone; 5) at the end of the annual melting period, temperatures return to below 0°C, meltwater freezes and sublimes, returning to high altitudes as snowfall to replenish the snow and ice deposit; 6) this Noachian icy highlands, ACE-dominated water cycle persists until MAT drops to <0°C. The icy Noachian highlands/punctuated volcanism scenario appears to be able to account for the: 1) source and volume of water required for valley networks; 2) presence of closed/open-basin lakes; 4) evidence for recurring phases of activity over millions of years; 5) small amounts of net erosion; 6) relatively poor stream integration and lower order; 7) presence of a surface hydrological cycle that can replenish the source area and cause recurring activity with a small total budget of water; and 8) presence of melting and runoff in a Late Noachian climate compatible with other constraints (e.g., faint young Sun, low atmospheric pressure).