# MARS: COLD AND WET

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**Introduction:** "Early Mars: warm and wet, or cold and dry?" This is one of the major uncertainties in martian science. Geomorphologies derived from liquid water flowing and ponding on the surface of the planet cover most of the martian landscape [1], and the evidences of water related mineralogies on the surface of Mars are widespread and abundant [2], implying that early Mars was wet. But several lines of evidence suggest that Mars has also been permanently cold [3], with mean global temperatures well below the freezing point of pure water. The role of solutes as a way to depress the melting point of water in a frozen martian environment provides a plausible solution to the early Mars climate paradox.

**Model assumptions:** The freezing point depression of aqueous solutions is a function of chemical composition and pressure. On Mars, large evaporitic deposits of sulfates [4] and chlorides [5], as well as hydrated and anhydrous salts and phyllosilicates [2], have been detected in numerous locations. Orbiter and lander data also show that the composition of water-related minerals on the martian surface must have derived from complex multicomponent solutions. Therefore, geochemical models of early Mars aqueous solutions point to salty rather than dilute fluids. Also, certain degree of climate warming was necessary in order to achieve surface temperatures that allow surface solutions to flow, otherwise global mean temperatures would have always been below 200 K, similar to those today. We assume a $CO_2$ atmosphere with an average pressure on the surface of 2 bar. This $pCO_2$ atmospheric levels result in surface temperatures near 245 K [6], which is enough warming to enable the flow of the solutions modelled here.

**Results:** Equilibrium models were developed inducing lineal processes of evaporation and freezing of the liquid solutions. At subzero temperatures, evaporation and freezing are very efficient at increasing the ionic activity and depressing the freezing point of the solution. Our results on the evolution of residual liquid water and the phase transitions as a function of temperature are presented in Fig. 1. Liquid water remains stable at temperatures below 273 K. For example, at temperatures of 263, 250, 245, 230 and 223K, up to 78%, 22%, 14%, 7.5% and 6% of the original water reservoir remains in the liquid state, respectively. A direct comparison can be done with what is expected to occur in terrestrial sea water, where at 263 and 223 K, 20% and 0.31% of the original water would remain unfrozen [7]. As a result of liquid water loss through freezing and evaporation, a sequence of phase transitions dependent on the saturation equilibrium of the different components in the solution is observed. It's worth noting the opposite behavior of the different evaporitic phases (mainly gypsum vs jarosite) and the influence of these behaviors in the modification of the available liquid water mass.

**Conclusions:** At temperatures between 273 and 250 K, less than half of the initial liquid water reservoir of Mars would have been lost through evaporation or by entrapment in the crystal structure of the precipitated hydrated salts, further supporting the idea that the majority of the water on the surface of the planet was forming super-cooled water solutions shaping valleys and seas, with large masses of ice covering parts of them. In conclusion, the early martian environment was indeed wet, albeit also permanently cold, resulting in a really alien, martian Mars.

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**Figure 1:** Residual water mass, ice formation and change in ion concentrations as a function of temperature in a hypothetical Martian solution after Opportunity lander data, in a model of evaporation and freezing, followed by continuing freezing down to 215 K. Element mass fraction in Meridiani Planum are shown in % [8].

| Al | Ca | Cl | Cr | Fe | K | Mg | Mn | Na | P | S | Si | Ti |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.69 | 4.53 | 0.47 | 0.3 | 13.8 | 0.34 | 4.18 | 0.27 | 1.58 | 0.32 | 2.1 | 20.2 | 0.68 |