EXISTENCE OF MARTIAN SPECIAL REGIONS BASED ON THE STABILITY AND DISTRIBUTION OF LIQUID BRINES. V. F. Chevrier[1], E.G. Rivera-Valentín[2], A. Soto[3], T. Altheide[4], R. Melchiorri[5]. [1]Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR, 72701; [2]USRA/Lunar and Planetary Institue, Houston, TX; [3]Southwest Research Institute, Boulder, CO; [4]Eastern Kentucky University, Richmond, KY; [5]SOFIA, NASA Washington; vchevrie@uark.edu.

Introduction: The habitability of the surface of Mars depends on multiple factors, including, but not limited to, temperature, relative humidity, UV, and nutrients [1]. Of these parameters, temperature and relative humidity control the presence of liquid water, which is of primary astrobiological importance and has driven the exploration of Mars for the past two decades. Pure water is generally unstable on the surface of Mars, being subjected to freezing, evaporation and boiling (Fig. 1), but these processes are highly variable depending on the location and intrinsic properties of the liquid [2]. Indeed, the presence of abundant hydrated salts on the surface of Mars suggests the possible presence of brines [3,4], which present the advantage of stabilizing liquid water at lower temperatures [2,5]. Here we present new results on the stability and formation of various types of brines on the surface of Mars, focusing on the processes that affect them: freezing, evaporation, boiling and deliquescence. This study will help refine the regions of astrobiological interest or potential contamination risk, e.g., the "special regions" [1].

Methods: The stability maps presented in this study were determined by overlapping the evaporation rates, calculated using our previously well-developed model of water diffusion modified by the buoyancy of H_2O in heavier CO_2 [2]. This model is also adapted for highly concentrated solutions relevant to Mars, using the Pitzer model [2,5]. Moreover, the behavior of brines as a function of water activity allows comparing various salts on the same basis.

In addition, these maps are overlaid with the limits for boiling, e.g., where the saturation pressure of water overcomes the atmospheric pressure. We also include freezing, which can be permanent or occasional. Maps are presented on the surface using maximum temperatures (Fig. 1) or in the subsurface using average temperatures (Fig. 2), and so are relevant to several times the annual thermal skin depth.

Finally we also determined the potential for deliquescence of salts on Mars based on water activity as well [6]. We determined the number of hours per year at which temperature and relative humidity were above the deliquescence relative humidity (DRH) and the eutectic temperature simultaneously. We used the Mars Weather Research and Forecasting (MarsWRF) general circulation model [7] to simulate the availability of water at the surface on an hourly basis throughout a Martian year.

Results and discussion:

Brines stability. The first result is that pure water is never stable on the surface of Mars (Fig. 1). Not only does it undergo fast evaporation rates, but it also boils most of the time. Northern regions are permanently frozen, confirming previous observations by Phoenix. An interesting region, though, is around 30˚ North, where there is the possibility of liquid water occasionally boiling. This would be a potential region where mass movement events could be triggered by liquid due to the "relatively higher" stability of water.

Salts with lower water activity show a similar pattern except that their frozen region is much more reduced to higher latitudes. For the lowest eutectics, liquid can always be stable in high latitudes. Boiling will still occur at low latitudes.

These salty brines can nevertheless be stable in the subsurface because of their much lower eutectics (Fig. 2). This allows them to remain permanently liquid in the low latitudes, but only for the lowest eutectics ($CaCl_2$, $Ca(ClO_4)_2$, $Mg(ClO_4)_2$, $Fe_2(SO_4)_3$). This happens because in the subsurface, temperature variations are dampened until several times the annual thermal skin depth when the subsurface temperature approaches the average annual surface temperature. This is a tradeoff with the surface, brines are permanently stable at lower temperature but only for the lowest water activity values.

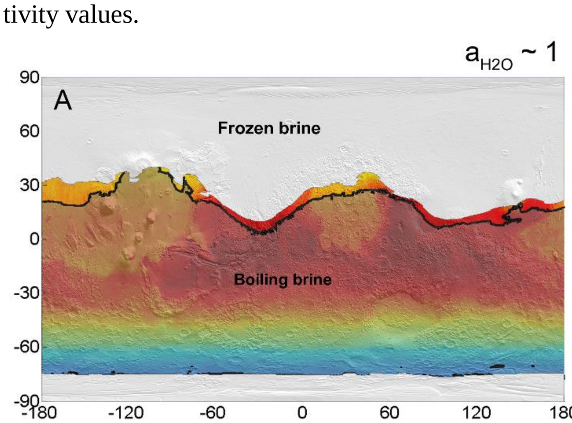

Figure 1: Stability map for pure water or poorly soluble salts (e.g., gypsum) on the surface. Liquids are mostly permanently frozen (grey zone) or boiling (shadow area southern of the thick black line).

Deliquescence of salts. Because of the anticorrelation between temperature and relative humidity (observed by Phoenix and MSL, e.g., [8-10]), it is very difficult to find conditions when both are above the DRH. Only the salts with very low eutectics ($CaCl_2$, and Mg, Ca-perchlorates, Fig. 3) can deliquesce on the surface. Deliquescence only occurs for a maximum of ~1500 hours per year, less than 10%, and mostly in the northern regions (Fig. 4). $CaCl_2$ barely deliquesces, but very low eutectics like $Mg/Ca(ClO_4)_2$ can deliquesce over larger portions of the planet, down to mid-latitudes in the northern regions. Therefore, deliquescence could be a possible process for liquid formation, but only for salts with extremely low eutectics and for very limited timescales.

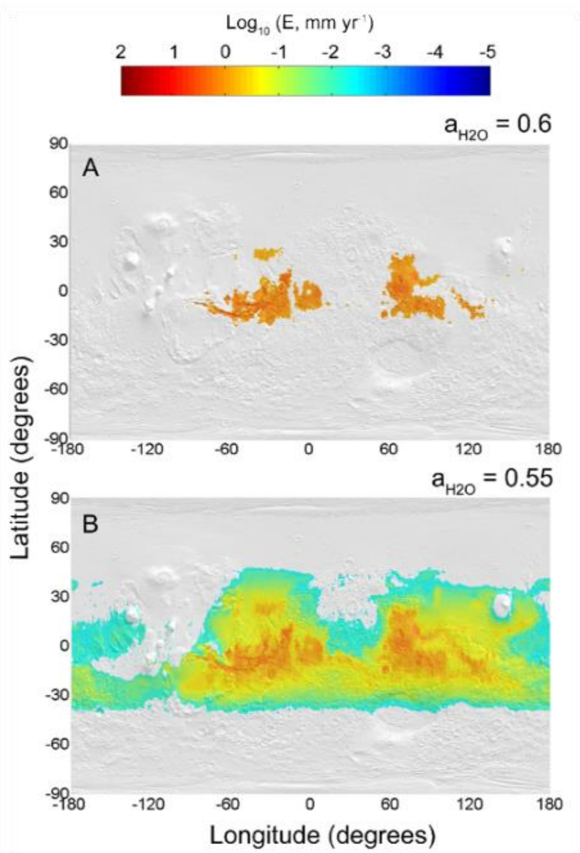

Figure 2: Map of the evaporation rate of salts of varying water activity (in Log scale) projected on a shaded MOLA topographic map. The grey zones correspond to permanently frozen regions (any salt with aH2O > 0.6 is permanently frozen). The colored regions indicate evaporation rates, which are lower than on the surface due to diffusion through the regolith.

It is interesting to note that the northern mid-latitude zone (~30 to 45˚) is a "limit" for almost all the processes. For example, south of this latitude, liquids are permanently stable in the subsurface, but evaporate too quickly at the surface (or boil away). However, north of this latitude zone, permanent freezing occurs for low eutectic salts in the subsurface and high eutectics at the surface, but deliquescence becomes possible. Therefore, northern mid-latitudes are probably the most interesting in terms of seasonal and cyclic processes.

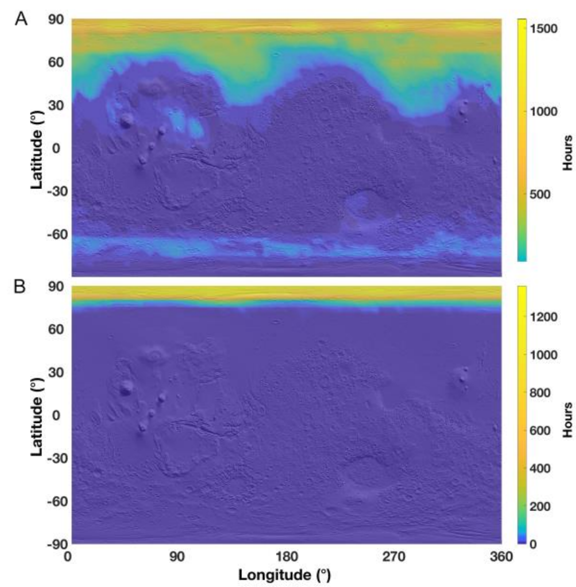

Figure 3: Map of deliquescence, determined as when the temperature is above the eutectic and relative humidity above the deliquescence relative humidity (DRH) at this tmperature, for Ca-perchlorate (A) and $CaCl_2$ (B). Note that salts with a higher eutectic will not deliquesce on Mars.

Conclusions: Brines with the lowest eutectic temperatures, such as perchlorates [5], are stable on the surface and at relatively high latitude, where they can form by melting or deliquescence [11,12]. Liquid stability is constrained by permanent freezing at very high latitudes and by fast evaporation and boiling at low latitudes, unless the liquid is in the shallow subsurface. Our results demonstrate that special regions of astrobiological interest [1] are probably very restricted on the surface of Mars and potential contamination by terrestrial organisms should be limited.

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