Liquid Groundwater on Mars Across Time & Implications for Subsurface Habitability

*Vlada Stamenkovic[1], Ana-Catalina Plesa[2], Doris Breuer[2], Jack Mustard[3], Jesse Tarnas[3]

1. Jet Propulsion Laboratory, 2. DLR Berlin, 3. Brown University

There is little debate as to whether liquid water has been shaping the Martian surface in early time and that groundwater was a major source of that water [e.g., Fassett and Head, 2011; Edwards and Ehlmann, 2015; Salese et al., 2019]. The modern Martian subsurface has had and still has the potential to enable environments with stable liquid groundwater. The possibility of such modern-day liquid underground waters has gained more interest since the claim of a potential subsurface lake beneath the South Polar Layered Deposits on Mars with MARSIS [Orosei et al., Science 2018]. However, due to attenuation, orbiting radar such as MARSIS have difficulties to detect groundwater beneath a depth of a few hundred meters away from the poles. As estimates of the average groundwater table are generally far beyond a depth of 1 km [Clifford et al., JGR, 2010], it is possible that Martian groundwater might be much more widespread but has so far remained undetected. Thus, a new opportunity to study the hydrology and habitability of the deep Martian subsurface across time awaits.

We show results of 4D (*three dimensions in space and across time*) interior models of Mars that self-consistently compute the subsurface thermal profile, groundwater stability depth, porosity, and permeability as a function of location and planet age across the last 4.5 billion years. The two models used are (**A**) a 3D spherical full mantle convection [Plesa et al., JGR, 2016] and (**B**) a preliminary parameterized thermal evolution model both coupled to a 3D crustal model that is compatible with today’s gravity and topography data. The spherical full mantle convection model explicitly considers both lateral variations of the crustal and mantle heat flow contributions, which can lead to regional perturbations that can shift the groundwater table closer to the surface. The advantage of the parameterized model on the other hand is the inclusion of various uncertainties in initial conditions, rheology, subsurface rock composition, thermal properties of crust and mantle, radiogenic heart source distribution, and groundwater chemistry (variable amounts of Ca- and Mg-perchlorates and chlorides as well as sulfates).

We show how groundwater levels vary as a function of location on Mars today and across time, and discuss implications for the deep subsurface habitability of Mars across time, from the Noachian to modern day.

Acknowledgments: This work was performed in part at the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA.

Keywords: Mars, Hydrology, Evolution, Habitability

