Water transport driven by the barometric pumping on Mars

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Introduction:

Mars experiences diurnal pressure changes with variations of tens of pascals due to atmospheric thermal tides [1]. It also has seasonal pressure cycles, where the atmosphere expands and compresses by 20–30% as CO_2 sublimates and condensates [2]. These drastic pressure cycles are one of the unique characteristics of the Martian atmosphere, and they could drive the transport of tracers between the subsurface and the atmosphere.

The barometric pumping is a gaseous advective transport mechanism driven by barometric pressure changes [3]. When the air pressure rises, it pushes air into the ground; when the pressure drops, it pulls air back out of the ground. Etiope & Oehler (2019) first suggested that this could be an effective way to transport gases, such as methane and water vapor, in the ground [4]. Since then, this phenomenon has been discussed in the context of the main driver of the methane supply from the deeper ground [5–9]. However, the effect of the barometric pumping on the water vapor transport in the shallow subsurface is not well-explored. The water transport induced by the barometric pumping could influence the ice table depth at middle latitudes and potentially affect the exchange of water between the subsurface and the atmosphere at lower latitudes with intense thermal tides. This study investigates the effect of the water transport driven by the barometric pumping itself, and the combined effect with the water diffusion, adsorption, and condensation.

Methods:

We compute the 1-D vertical advective transport of water vapor in the subsurface. The water flux is determined by Darcy's law, which is applicable to low velocity flow, which is generally the case in porous media flow [10]. The water transport equation is given by

$$\frac{\partial \rho q}{\partial t} + \frac{\partial}{\partial z}(\rho q u) = 0, \qquad u = -\frac{k}{\varphi \mu}\frac{\partial P}{\partial z},$$

where t is time, z is the vertical coordinate, ρ is the air density, q is the water vapor mass mixing ratio, u is the pore velocity, k is permeability, φ is porosity, μ is the viscosity of water vapor, and P is pressure. The pressure gradient in the equation is derived by combining the continuity equation, the ideal gas law, and Darcy's law. The surface pressure, as well as surface and ground temperatures required for modeling water advective transport, are provided by the DRAMATIC MGCM [11,12]. The water advective transport is coupled with the water adsorption model [13] to examine the combined effect of the water advective transport, adsorption, and condensation.

Results and Implications:

Our preliminary results, considering only the water advective transport in the subsurface, show that the water flux at the surface ranges -2×10^{-14} to 2.6×10^{-14} kg m^{-2} s^{-1} with the permeability of 10^{-12} m^2. The water flux reaches the maximum amplitude in southern summer, induced by the intense pressure cycle in that season. The water flux driven by the barometric pumping is smaller than the water diffusion flux determined by Fick's law [14–16], but the water advective transport may play a more significant role in deeper layers, such as several meters below the surface, than water diffusion.

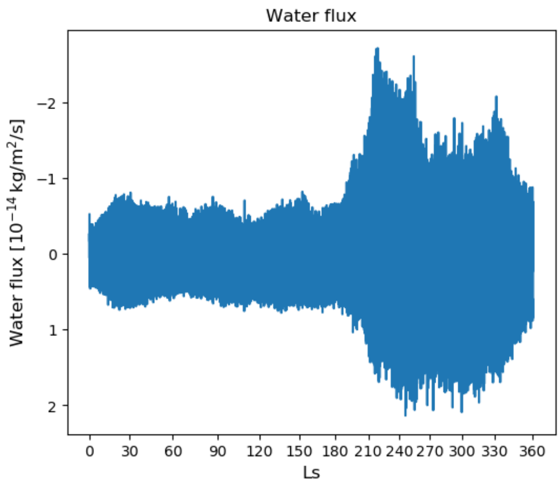

Figure 1. Time series of the advective transport flux at the surface at 0°E and 60°N. The subsurface is initialized with the water vapor amount of 10^{-9} kg m^{-3}.

Considering the combined effect of the water advective transport, adsorption, and condensation, previously unidentified mechanisms of the vertical water transport in the Martian subsurface could be revealed.

References

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