

INFLUENCE OF DUST ADSORPTION EFFECTS ON THE MARTIAN WATER CYCLE. Madison A. Stratton¹ and Bruce M. Jakosky¹, ¹Laboratory for Atmospheric and Space Physics, University of Colorado Boulder

Introduction: Montmorillonite is a known component of the Martian regolith in certain regions of the planet. This dust has shown the capacity to adsorb significant amounts of water to its surface given appropriate temperature and water vapor pressure conditions, which are found at the surface, indicating that it can be treated as a significant source of water. If that dust were to then be raised into the atmosphere as the source of a dust storm the temperature and H₂O pressures will change which can cause the dust to either adsorb or desorb water. This could mean that dust storms may have an impact on the water cycle as either a possible sink or source.

Our main goal is to calculate changes in adsorption amounts given different temperature and H₂O pressure conditions and then apply these changes to a distributed dust column to estimate the impact on the overall water content. The changes of temperature and pressure will be considered diurnally as well as at the beginning and mid-dust storm so that the full processes may be considered.

Methods: An equation for the partial pressure, N , at a given altitude can be given as Eq(1) where Z is the altitude, H is the step size of the atmosphere, and N_0 is the partial pressure at ground-level.

$$N = N_0 e^{Z/H} \quad (1)$$

N_0 must be derived using the total water column of the atmosphere which equates to 10 precipitable micrometers. The equation can then be integrated, using 200km as the ultimate height of the atmosphere, to calculate N_0 which comes out to be approximately $9.26 \cdot 10^9 \frac{g}{cm^3}$. Applying this equation over the Murphy and Koop [1] equation for water saturation pressure over ice, (Eq.2) a model can be created for the relative humidity of H₂O at any given altitude and temperature.

$$\log(P_i) = 9.550 - \frac{5723}{T} + 3.531 * \log(T) - 0.0073 * T \quad (2)$$

Data points containing the temperature profiles of a nominal day and night as well as a dust storm day and night can then be taken from the temperature versus altitude profile found in Jakosky [3] to calculate the relative humidity, RH, profile of Mars. Following this, data points are pulled from Fig 1, then the previously calculated RH numbers are then each compared to the closest RH number obtained from the graph to calculate the adsorbed amount of water in mg per g of clay of montmorillonite. From the relative humidity, we use the adsorption isotherm of montmorillonite from Mooney et al. [2] to determine the amount of water adsorbed. Before apply-

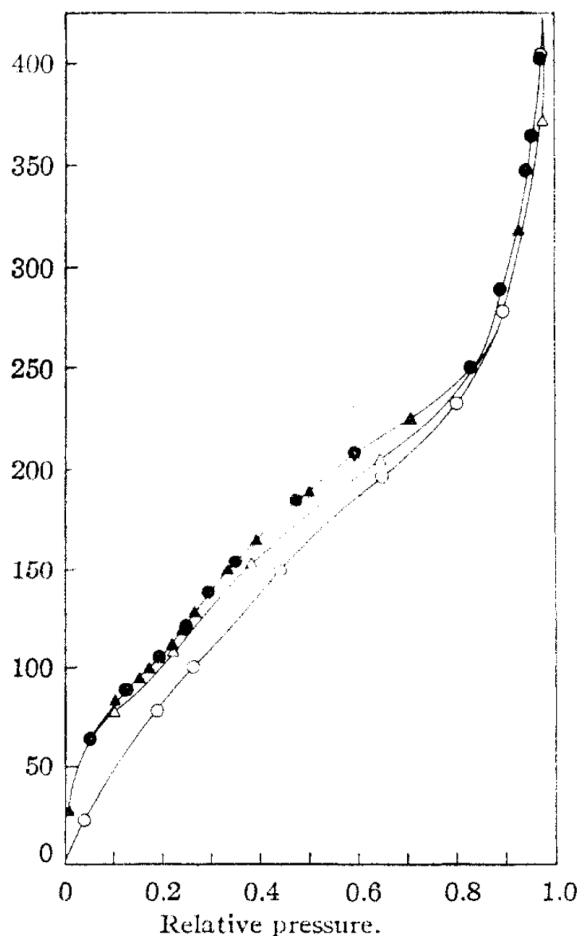


Figure 1: This is Figure 1 from Mooney et al. [2]. It shows the adsorption amounts in mg of H₂O/ g of clay over relative humidity.

ing these numbers, the adsorption amount at 0km of altitude must be used as a starting number to compare the total change in adsorption over altitude, since on a nominal day the existing conditions at the very top of the surface will not change and thus can be used as a base preexisting amount of water adsorbed on any given grain. These numbers can then be used alongside a dust column calculated from Eq. 1, where the total dust column is assumed to have an opacity of 10 rendering a complete column of $10^{-3} g$ per cm^2 , to find the total amount of H₂O adsorbed and or desorbed during given pressure and temperature conditions at a specific altitude. Those numbers can then be added to the previous total water column to find a percent change in order to conclude the overall impact on the water column.

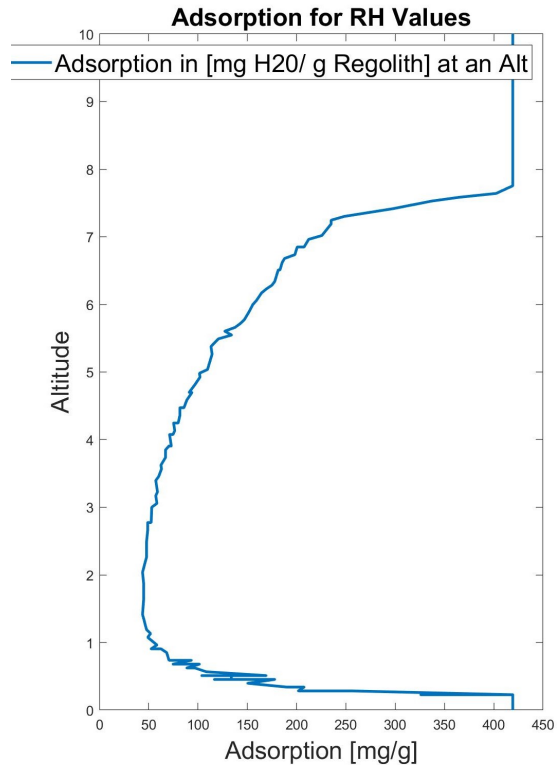


Figure 2: Adsorption Values versus altitude [km] given a nominal night.

Results: Using the calculated RH values and subsequent adsorption amounts it can be determined that at night the RH values at the surface reach saturation levels for H₂O. If montmorillonite is present in these conditions it will adsorb around 400 mg of H₂O/g dust as shown in Fig.2. This changes during the day where warmer temperatures will cause the RH to drop and thus the dust will expel water as the adsorption levels drop to about 20 mg/g. If then dust were raised into the atmosphere it would at each given altitude release enough water to disperse about 2.65×10^{-4} g H₂O/cm². This change would increase the water column by about 27% as shown in Fig 3. Following that as the dust storm begins the atmospheric pressure and temperature will change as will the adsorption amounts to match this change. Over time this shift will then cause a majority of H₂O in the atmosphere to be present in vapor form as the ratio of adsorbed water to vapor water decreases causing the water levels to swell from about 0.12% to about 7.0%.

Conclusions:

- Dust raised into the atmosphere during a global dust storm will find itself in different water vapor pressure and temperature conditions than when it

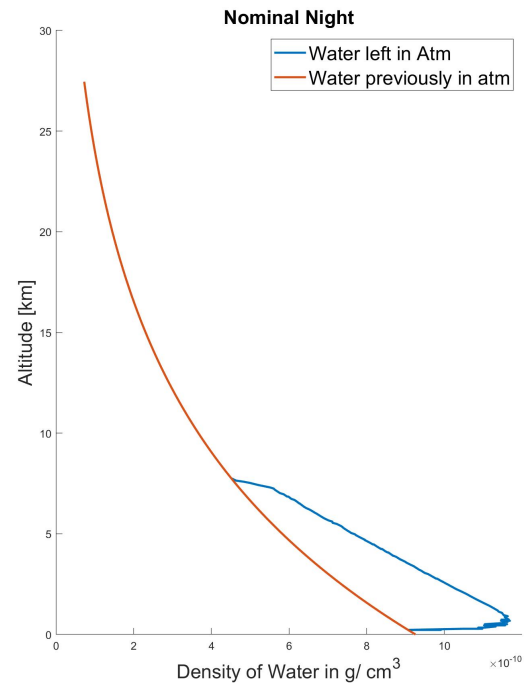


Figure 3: This shows the typical water content on a nominal day versus the water content if a dust column were introduced in similar conditions.

resided on the surface.

- There will be a resulting change in the equilibrium between the amounts of water in the vapor state and adsorbed onto the dust grain.
- Water will tend to be released into the atmosphere, increasing the water content of the atmosphere.
- The largest effects will occur for dust composed of clays, such as montmorillonite, due to their high adsorptive capacity.
- With clay minerals comprising 3% of the exposed material on the surface [4], the importance of this source of water will depend on where the dust in the dust storm originates.

References: [1] D. M. Murphy and T. Koop. “Review of the vapour pressures of ice and supercooled water for atmospheric applications”. In: *QJRMS* 131.608 (Apr. 2005), pp. 1539–1565. [2] Mooney et al. “Adsorption of water vapor by montmorillonite. I. Heat of desorption and application of BET theory”. In: *JACS* 74 (Jan. 1952), pp. 1367–1374. [3] B.M. Jakosky. “The seasonal cycle of water on Mars”. In: *SSR* 41.1 (June 1985), pp. 131–200. [4] B.M Jakosky L.J. Wernike. In: *Submitted to JGR* (Dec. 2019).