STRATIFICATION OF HDO DURING CLOUD FORMATION ON MARS. John E. Moores[1], Gordon Osinski[1], James A. Whiteway[2], and Frank Daerden[3]. [1]Centre for Planetary Science and Exploration, University of Western Ontario (Department of Physics and Astronomy 1151 Richmond Street, London, ON, N6A 5B7 Canada john.e.moores@gmail.com), [2]Centre for Research in Earth and Space Science, York University. [3]Belgian Institute for Space Aeronomy, Division of Planetary Aeronomy.

Introduction: The elevated D/H ratio of the Martian atmosphere, close to 5.5 [1,2] times the value of Vienna Standard Mean Ocean Water (VSMOW) is often cited as evidence for significant water loss from Mars over the course of geologic history [3]. However, this neglects two factors. First, the low mass of water in the atmosphere allows the reservoir to rapidly attain a high-deuterium state [4] and significant fractionation during cycling at low temperatures during the current era affects the surface reservoirs of water-ice in contact with the atmosphere [5]. Regolith/dust-gas interactions have already been investigated in the context of Mars [5], and there is an equilibrium fractionation between solid and gas [6].

Recently, clouds have been observed within the Planetary Boundary Layer (PBL) at high northern latitudes [7] and a latitudinal trend in the atmospheric inventory of HDO (the main deuterium-bearing species) has been observed [4, 8]. As PBL clouds are produced overnight at low temperatures in regions of the atmosphere where the water mixing ratio is high, the cloud particles should be significantly enriched in HDO compared to the remaining water vapour. As many of these particles sediment to lower levels, this provides a mechanism to separate and redistribute HDO and H2O on a diurnal basis.

Theory and Modelling: Simulations of the martian atmosphere will be presented which examine the diurnal variation in the D/H ratio of atmospheric water vapour as the result of cloud condensation and eddy diffusion throughout the PBL. By combining a dynamic PBL model [9] with a microphysical model [10] similar to the model discussed in [11] it is possible to simulate clouds and precipitation, the relative proportions of H2O and HDO in each phase and, therefore, the vertical stratification of the D/H Ratio. As boundary conditions, the surface temperature is known from MET observations [9] and the total humidity at the surface has been measured over the diurnal cycle by the TECP [12].

Since there was sufficient regolith at the Phoenix landing site to prevent exchange with the subsurface ice on the timescale of hours [5], the low-temperature fractionation from [5] of 1.97 will be used.

Finally, the question of how stratification of HDO is expected to affect transport of HDO and thus any geographic variation in the D/H ratio is addressed by considering the prevailing winds observed by the wind telltale near the surface [13] and by the Surface Stereo Imager aloft [14]. The velocity and direction from these sources can be used to calculate the direction of travel of each isotopic species over the day at different levels throughout the PBL.

Preliminary Results: The overnight period of sol 113 is given as an example due to the availability of joint SSI-LIDAR data which can be used to constrain the cloud thickness close to the surface [11]. The near-surface environment is of particular interest as fogs composed of water-ice can sediment out entirely, leading to significant isotopic stratification.

The model was initialized at 19:00 hrs by supplying water with a D/H ratio of 5.5 x VSMOW at all levels equivalent to the surface vapour density observed by the TECP [12]. Dynamical modelling described in [9] suggests this is appropriate as the PBL should be well mixed up to 4 km at this hour. Next the model was permitted to run forwards in time for 9 hrs, terminating close to 04:00.

By first running without any condensation, it is possible to observe the stratification of isotopes as the result of eddy diffusion alone. Figure 1 shows this stratification in the water vapour in the upper left panel with the surface fractionation set by [5]. Very low values for the D/H ratio near 2 x VSMOW are obtainable close to the surface with values below 3.5 x VSMOW up to 40 m above the surface and depletions of greater than 10% observed below 200 m of altitude.

Next, condensation was turned on, as shown in the lower left panel of figure 1. This condensation causes an ice-water fog to form, beginning close to 21:30. As the PBL cools overnight this ice-water fog climbs in altitude. This results in additional depletion aloft compared to the case without condensation with D/H values of less than 3.5 x VSMOW obtainable up to almost 80 m of altitude.

To better understand the significance of this stratification for transport, rose diagrams show the amount of depletion (5.5 x VSMOW – D/H) multiplied by the wind speed. These are plotted against the wind direction at the time of the measurement for two separate altitudes, 0-50 m and 200-250 m (see Fig. 1). For simplicity, no stratification is assumed outside of the period described by this example (1900-0400). These rose diagrams imply that air transported from northeast to southwest is depleted in HDO compared to air flowing in other directions. This suggests that the stratification of HDO overnight by diffusion and condensation provides a mechanism for geographically separating HDO in the Martian atmosphere. This may explain, in part, the variations in D/H observed over the surface in the IR [4, 8].

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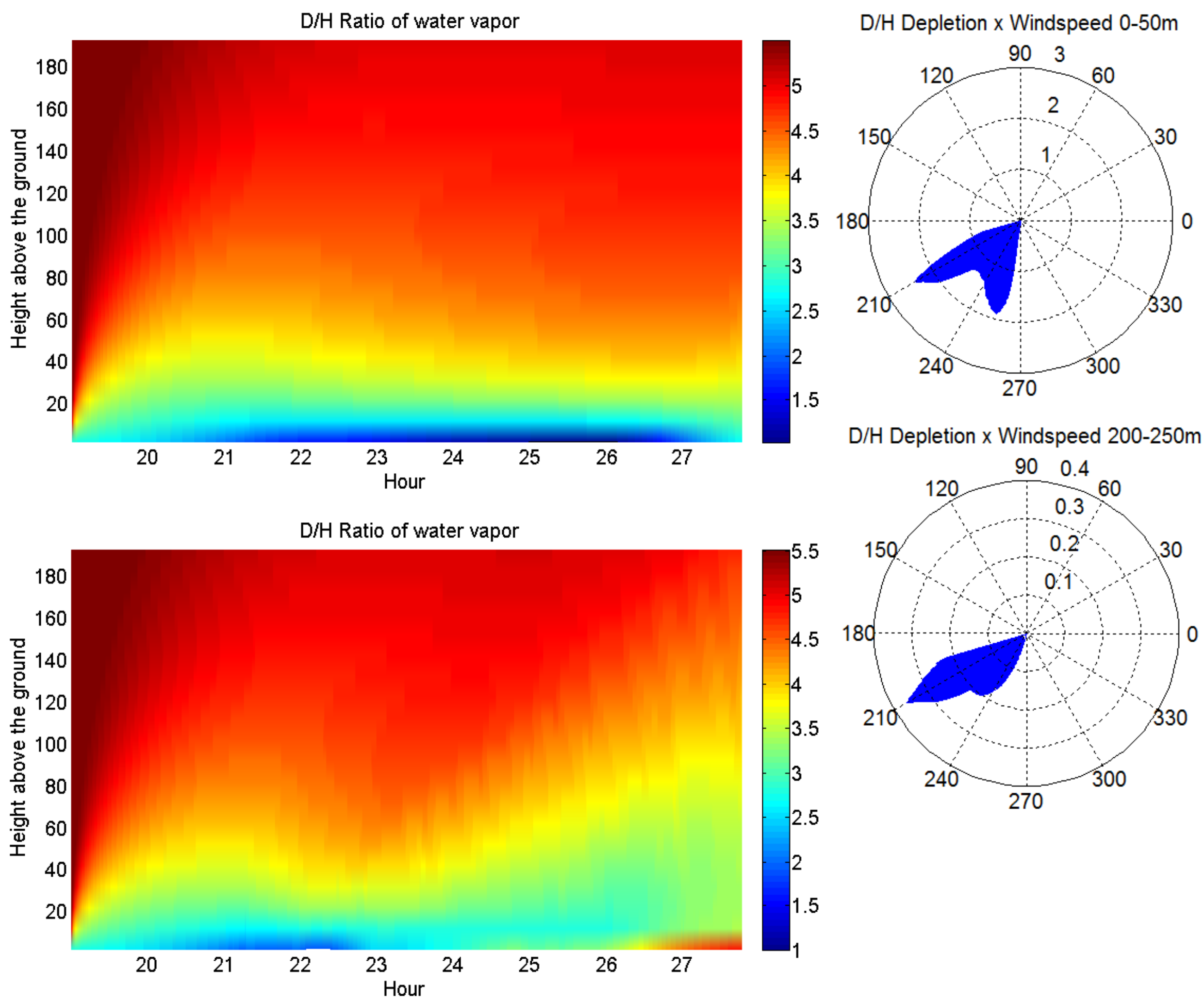

Figure 1: Stratification of HDO in the lower 200m of the Martian Atmosphere at the Phoenix Landing Site on sol 113 from 1900 LTST through 0400. (Top Left) Without Condensation (Bottom Right) With Condensation included. Rose diagrams show the depletion depth (from 5.5 x VSMOW) multiplied by the windspeed for two heights: 0-50m above the surface (top right) and 200-250m above the surface (bottom right)