DYNAMIC AND ISOTOPIC EVOLUTION OF MARS ICE RESERVOIRS. E. Vos[1], O. Aharonson[1,2], N. Schorghofer[2], [1]Department of Earth and Planetary Sciences, Weizmann Institute of Science, Rehovot, Israel 76100; Planetary Science Institute, Tucson, AZ 85719, USA (Eran.Vos@weizmann.ac.il)

Introduction: The Layered Polar Deposits on Mars are widely believed to harbor a record of past climatic oscillations driven by orbital elements variations [1, 2]. However, establishing a mechanistic link between climate variations and the observed stratigraphy has proven elusive. The isotopic ratios in terrestrial ice cores preserve a record of past temperature [3]. Here we provide a model that attempts such a link by accounting for the three primary reservoirs seen today: the North Polar Layered Deposits (NPLD), mid-latitude subsurface deposits (SSD), and near-equatorial glacial deposits (GD). Tracking the fluxes exchanged among these reservoirs enables quantitative estimates of their development, as well as reveals the dynamics of the isotopic record predicted to exist in the stratigraphy.

Previous attempts to calculate the D/H variations of the polar cap assumed an atmospheric reservoir and tracked its isotopic evolution [4]. This is appropriate if the atmospheric mixing time is comparable to the characteristic exchange times in the model. However, because the amount of water exchanged between the reservoirs on kyr timescales is several orders of magnitude greater than the atmospheric water content, the atmosphere is effectively only a conduit through which the reservoirs exchange. Thus, the atmospheric reservoir is negligible for the timescale under consideration. For the long-term (Gyr) evolution atmospheric loss must be considered, as must be atmospheric dynamics for understanding seasonal dynamics [4-6].

In this reservoir model fractionation relative to an initial value occurs due to temperature differences between accumulating reservoirs [7]. This initial value is arbitrary in our model, and we define it as Standard Mean Mars Water (SMMW).

NPLD: Although both poles are capped by ice deposits, here we focus on the NPLD as the larger reservoir, composed of exchangeable water ice and a few % dust. Dust and dust-rich lag layers in the NPLD act to protect the ice from sublimation, both as diffusion barriers and thermal insulators [8, 9].

SSD: Ice is found under a protective regolith layer by the Phoenix Lander and in fresh craters exposing the subsurface [10, 11]. Subsurface ice is stable in mid to high latitudes where a dry layer protects the ice from the diurnal and seasonal temperature variations [11, 12].

GD: Geologic evidence points to a significant near-equatorial reservoir of water in form of remnants glacier deposits concentrated on mountain flanks. Geologic mapping suggests the area of this deposits are at least 7.1×10^5 km^2 [12-15] but the volume and exchange rates of this reservoir are only poorly constrained. Therefore, in this model, we assume an initial volume for this reservoir that provides a reasonable thickness for the present-day NPLD.

Model: We construct a model which tracks the transfer of H_2O and HDO among the relevant reservoirs, and calculates the resulting abundances. The polar flux is taken from previous GCM-based models [9], with a modification in the ablation rate that accounts for the dependence of the loss rate on the thickness of the growing lag [8]. Layer formation in the cap is tracked, as is the D/H ratio of each layer. Ice loss or gain is assumed to occur at the top-most layer. Kinetic fractionation is assumed at deposition, while ablation is complete and non-fractionating.

Atmospheric humidity is prescribed here by simulations of the global circulation as function of obliquity [16]. The SSD latitudinal margin is calculated from a thermal model [17], by equating the mean saturation water vapor density in the subsurface with the mean atmospheric vapor density. For simplicity, we assume the ice table thickness is constant. The SSD is stratified horizontally, and the D/H ratio in latitude bands is tracked, with analogous assumptions to the cap.

Lastly, the equatorial glacier flux is obtained from mass conservation. The HDO deposition flux of the other reservoirs is apportioned according their relative fluxes and temperature-dependent kinetic fractionation factor [7]. At least two simultaneous sinks are required to cause D/H fractionation among ice reservoirs.

Results: Our model predicts D/H variations in the polar cap which may be measurable by future missions. The variations exhibit several notable features.

The polar layered record is not a simple function of obliquity; instead, the D/H ratio reflects out-of-phase changes in reservoir fluxes, modified by a non-linear and discontinuous transfer function due to deposition and ablation rates variations.

Temperature differences between reservoirs control the NPLD D/H ratio, and its range. Although the polar cap is colder than lower latitude reservoirs, the D/H ratio of a polar ice layer can be lower than SMMW. This occurs when the ice is sourced from SSD condensed at an epoch of cap growth, hence the SSD was depleted in

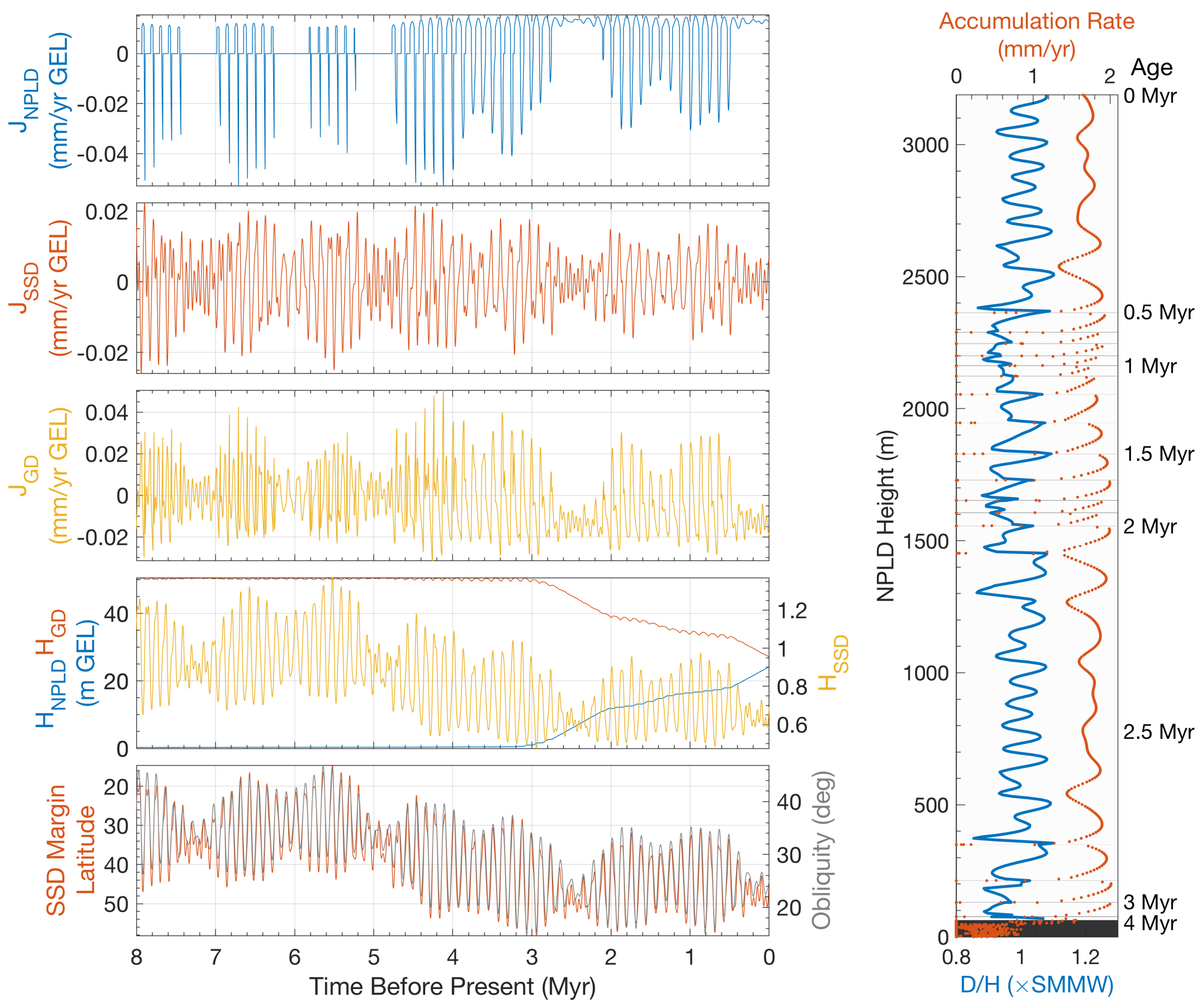

Figure 1: Left panels show the time evolution of various quantities tracked by the model with initial dust fraction of 1% and SSD thickness of 3 m. Right panel shows the layers of the cap as function of height, with their D/H ratio and accumulation rate.

the heavy isotope due to competition from the cap. During times when the SSD grows, any polar ice that is deposited is always enriched in the heavy isotope. The amplitude of the predicted D/H variation is on the order of 10%, comparable to the variation within terrestrial ice cores.

The cap basal layer thickness depends only on the dust fraction on ice, not on diffusion parameters. The ice cap size, as well as the thicknesses of dust lag layers, are a function of both the ice dust fraction and diffusion parameters. As can be seen in Figure 1, reasonable choice of parameters results in a cap height similar to present-day.

The latitude of the SSD is controlled almost entirely by obliquity. But periods of relatively constant obliquity are of particular importance because it is during those times that the cap grows significantly (without intermittent ablation period; at 2.7 - 2.15 Myr ago and 0.4 Myr ago - today). During these times perihelion precession cycles with period of ~50 kyr are evident in the SSD fluctuations, and hence in the D/H variations of the growing cap. Note, the accumulation rate variations are not coherent with the D/H signal, so they may provide a separate record (for example in brightness variations). We thus expect a climate signal to be present in the cap, although the obliquity is constant. Sampling the top 100 m is expected to reveal more than one climate cycle in isotopic composition, driven by the precession oscillation.

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