SEASONAL RELEASE OF WATER VAPOR BY GROUND ICE ON MARS: IMPLICATIONS FOR SURFACE FROSTS AND ATMOSPHERIC WATER ABUNDANCE

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Summary

Seasonal cycles of water ice on Mars are important to general climate. We investigate the behavior of water ice and vapor that diffuses into and out of the regolith through seasonal transitions. We also allow surface water frost to form. Such seasonal surface water frost has been observed at the Viking Lander 2 site (Figure 4,5).

Our results are summarized below:

- **The quantity of seasonal ground ice forming on Mars is poorly constrained and difficult to simulate with our current model due to time step requirements.**
  - **Possible role in annual water cycle (Figure 3)**
- **Seasonal surface water frost can exist in a relatively thin latitudinal band outside seasonal carbon dioxide cap**
  - **Requires some recharge mechanism (e.g. atmospheric or regolith) to match observed thicknesses**

Methods

We estimate the vapor flux between the subsurface, surface and atmosphere (including a surface water frost scheme) using a 1-D finite difference numerical model featuring coupled heat and vapor diffusion.

Surface Water Vapor Budget

Subsurface:

Vapor flux (J) is calculated based on the diffusivity of the regolith (D_o) and the vapor density gradient ($\frac{\partial \rho_v}{\partial z}$) via Fick's Law:

$$J = D_o \left(\frac{\Phi}{\tau}\right)\left(\frac{\partial \rho_v}{\partial z}\right)$$

Φ and τ are the porosity and tortuosity of the regolith, respectively. We calculate our gradient using the surface vapor density and the vapor density just below the surface (i.e. 2nd grid point; this should capture transport between the surface and subsurface).

$$\frac{\partial \rho_v}{\partial z} = \frac{\rho_{v,2} - \rho_{v,surface}}{z_2 - z_{surface}} = \frac{\rho_{v,2} - \rho_{v,surface}}{z_2}$$

We assume $D_o = 4 \times 10^{-4}\ \mathrm{m}^2/\mathrm{s}$ after [5], $\Phi_{dry} = 0.40$ and $\tau = 3$.

Atmosphere:

Atmospheric vapor density ($\rho_{v,atm}$) changes when the surface temperature-equivalent saturation vapor density ($\rho_{v,sat}(T)$) is below the prescribed $\rho_{v,atm}$.

The resulting $\Delta\rho_{v,atm}$ is converted to pr-μm (of frost added or removed) after Schorghofer & Aharonson, 2005. This approach assumes the entire atmospheric column exchanges with the surface thus is an overestimate (with respect to frost deposition/removal) but is useful for a first attempt at treating surface water frost.

Seasonal Ground Ice

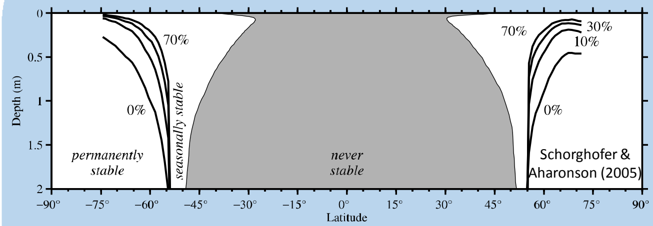

Figure 1. Latitudinal dependence of permanently stable (perennial) and seasonal ground ice.

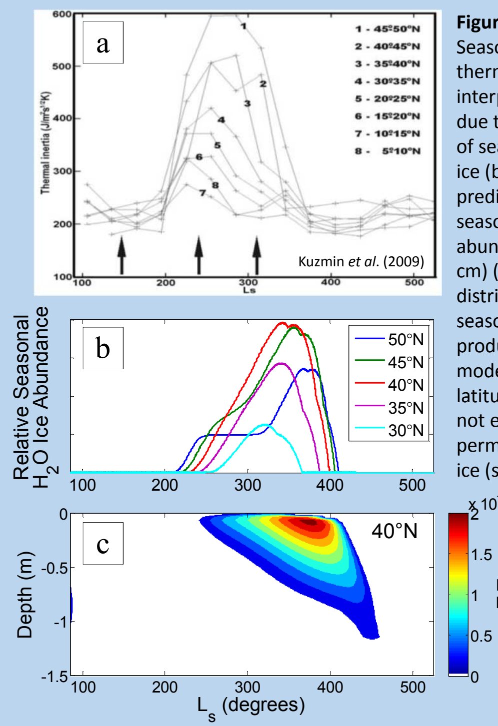

Figure 2. (a) Seasonal variation in thermal inertia interpreted to be due to the presence of seasonal ground ice (b) Our model's prediction for seasonal ground ice abundance (upper 5 cm) (c) Vertical distribution of seasonal ground ice produced by our model at one latitude which does not exhibit permanently stable ice (see Figure 1).

How Much Ground Ice Forms Every Year?

- Kuzmin *et al.* (2009) suggest at least 3% ice fractions >40°N (Figure 2a)
- Our model does not produce consistent results for different time steps (see Figure 3)

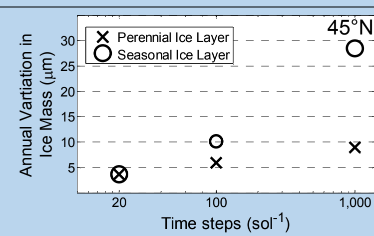

Figure 3. Variation in model results.

Surface Water Frost

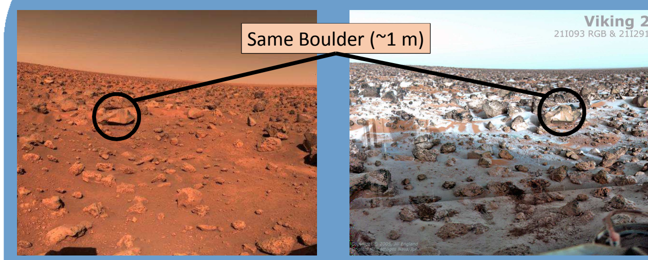

Figure 4. Images from Viking Lander 2 showing unfrosted (left) and frosted (right) surfaces in Utopia Planitia (48°N).

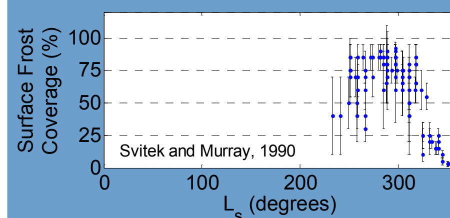

Figure 5. Observations at VL2 site of surface water frost coverage during winter.

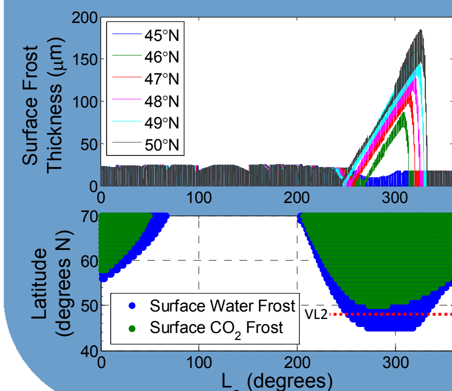

Figure 6. Model results for surface water frost including interaction with the atmosphere and subsurface. An additional 1 μm of surface frost was added each sol, year round. Without a recharge mechanism surface frost never lasts >1 sol. The bottom figure portrays seasonal behavior with CO_2 surface frost.

References & Acknowledgments

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