How fast can water ice grains grow on the summertime Martian north pole?

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Introduction

During the spring and summer seasons, the CO_2 ice disappears at the northern polar region, but the H_2O ice remains. During this period, there is significant metamorphism of ice and snow grains within the snowpack, which is caused by temperature changes and water vapor fluxes [1]. The greatest change occurs during the Ls 80-90 at the northern-most region of Mars, and Ls 45-65 at latitude of around 75º [2]. We are interested in determining the size of snow grains after the seasonal shift of a Martian year. It has been suggested that rapid grain growth cannot be accomplished by temperature gradients alone [3]. Utilizing GCM (General Circulation Modeling) data to show the meteorological changes in time intervals throughout the year and adjusting the initial snowpack profile accordingly will yield better outcomes. It is important to understand how accurately this model will perform with the adjusted data set, as the results are compared to the existing CRISM data.

Methods

In order to study and research the metamorphism process, data was extrapolated from the Mars-GCM to be used as input parameters. The data we are interested in are incident solar radiation, reflected solar radiation, incident longwave radiation, air temperature, all at a time frame incremented each hour and a half. We have controlled the model by fixing precipitation levels to zero, relative humidity levels to 1%, and wind speeds within 0-5 m/sec values. These constraints will help us understand the computer model's (SNTHERM) behavior with the most basic of settings. SNTHERM is a physically driven one dimensional mass and energy balance model for computing temperatures within a snowpack [4] and has shown accurate temperatures, energy fluxes, and melts timing [5]. Due to radiative fluxes, the temperature gradients on the upper layers are greater compared to the lowest layers of the snowpack. Adjustments were made to the mean-annual temperature profile [1] by having the top layer temperature correlate with that of the air during the presence of CO_2 ice (150K), and dropping the temperature of each node by the difference between the top node's initial value and 150K we adjusted it to, as shown in Figure 1.

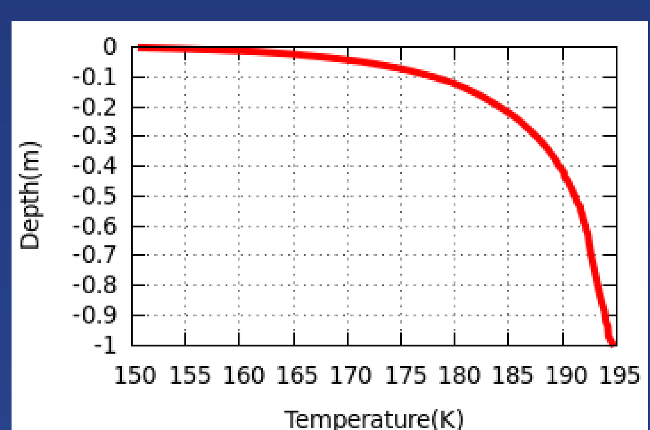

Figure 1. Adjusted initial temperature profile, displaying the higher temperature gradients around the surface nodes.

Methods (Continued)

Since the incident and reflected radiation values were inputted into the meteorological data, albedo changes did not affect our model. This was tested using the same input files for two very different albedo values (0.78 and 0.10) and the outcome was indifferent. We can see how the grain growth is actually calculated from the equation:

$$\frac{\partial d}{\partial t} = \frac{(g1|U_v|)}{d} = \frac{g1}{d} D_{eos} \left(\frac{1000}{P_a}\right)\left(\frac{T}{273.15}\right)^6 C_{kT} \left|\frac{\partial T}{\partial z}\right|$$

where U_v = mass vapor flux (kg/m^2.s)
g1 = grain growth parameter (m^4/kg)
d = diameter of snow grains (m)
D_{eos} = diffusion coefficient (m^2/s)
P_a = atmospheric pressure (mb)
T = Temperature (K)
C_{kT} = Variation of saturation vapor pressure with temperature relative to phase (N/m^{2}K)

	Ls	CRISM	SNTHERM
Caps	46	50 microns	132 microns
	89	90 micron	1.09 mm
	93	100 micron	1.31 mm
	127	1.2mm / 0.7-1.0mm	2.59 mm
Outlier	46	80 micron	162 micron
	65	200 micron	620 micron
	89	400 micron	1.38 mm
	127	≈ 1.2mm	2.52 mm

Table 1. Compares the CRISM grain size results[6] to those from the SNTHERM simulation at the poles and 75º latitude. The complete data plot is shown in figure2.

Some of the parameters that influence grain growth rate are U_v, which provides the necessary vapor source for growth, temperature gradient between two different nodes which proportionally affects grain growth, and lower Martian atmospheric pressure which will give us a larger ($1000/P_a$) ratio, all changing the grain size.

Results

After running the simulation for both the most northern part and the latitudinal area of 75º, within the period of Ls 38 to Ls 170, significant grain growth was found around the time where the CO_2 ice gets fully evaporated. This is an expected result as the air temperature values are drastically increased from 150K to around 200K. The diurnal cycle also creates temperature variations in the air, directly influencing the surface temperature of the snowpack. The GCM data also shows increased radiation levels during the summer season, melting the snow and creating higher water vapor fluxes within the pack. This combined with the temperature gradients throughout the different nodes, drives the rapid metamorphism. As seen in Figure 2, the grain size is consistently growing, very slowly during the CO_2 ice phase, quickly after it melts, and slowing down as the grain size increases, which is an expected growth pattern [4]. Figure 2 shows a discontinuous graph for growth, as the grain size jumps from higher to lower size at certain time steps.

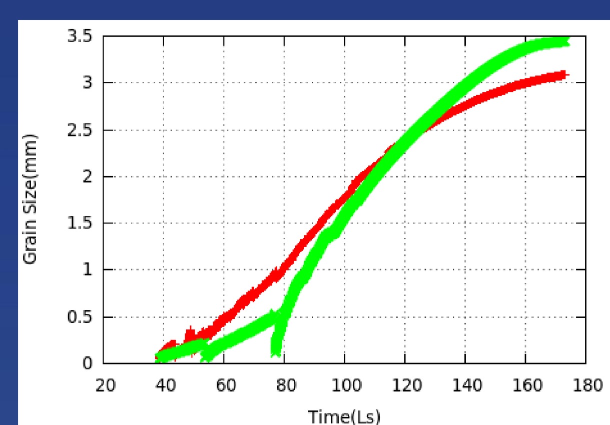

Figure 2. Grain growth at the northern most region shown in green, and the 75º latitudinal region shown in red.

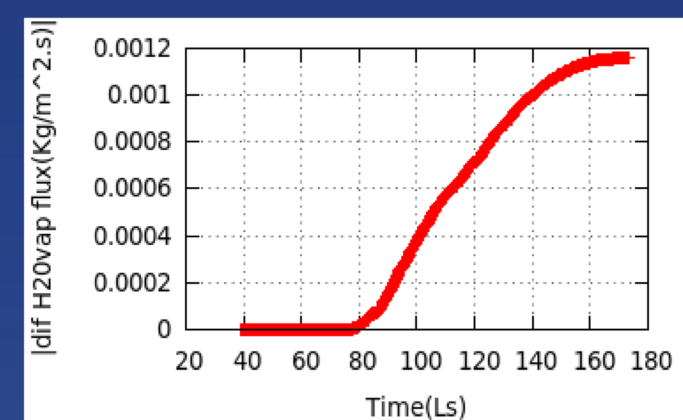

Figure 3. Absolute value of the diffusive water vapor flux within the top two nodes added for all time steps from Ls 38 to Ls 170 at the 75º latitude region.

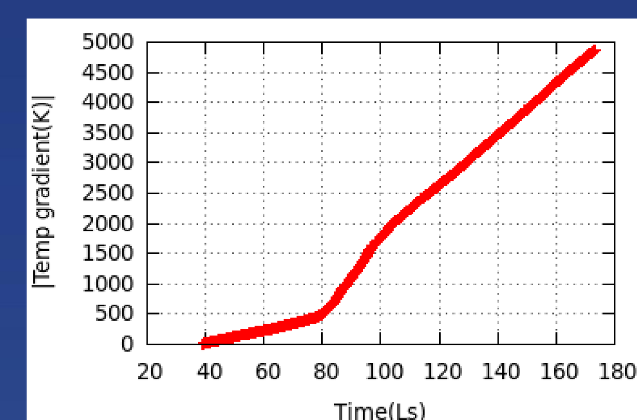

Figure 4. Absolute value of the temperature gradient within the top two nodes added for all time steps from Ls 38 to Ls 170 at the 75º latitude region.

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Results (Continued)

We analyzed liquid water content in the pack as it can affect grain growth, and concluded that it is zero and does not change during the entire process, meaning it has no effect on grain size. Thus these graph jumps are caused by the disappearance of the top node, where the grain size is measured by this model. To make sure this is an acceptable pattern, we checked the two parameters that drive the grain size growth, the water vapor flux and temperature gradients between the nodes. Figure 3 and Figure 4 show a familiar curve. These results support our initial grain growth pattern, and justify the sudden jumps from Figure 2, as the top nodes are evaporating faster than the grain size can grow the nodal dimension.

Conclusions

We were able to produce a computer model that approximates the grain size at the surface of the northern Polar Region of Mars. The results are close to the CRISM data which shows a grain size of 3mm during this cycle [2]. The model resulted in a grain size slightly larger than expected, but this gives us enough room to accommodate future factors that may decrease the grain growth rate, such as inhomogeneities. Figure 5 on the other hand displays a pattern similar to the terrestrial average temperature profile [7]. Further research is necessary to improve the accuracy of the computer model.

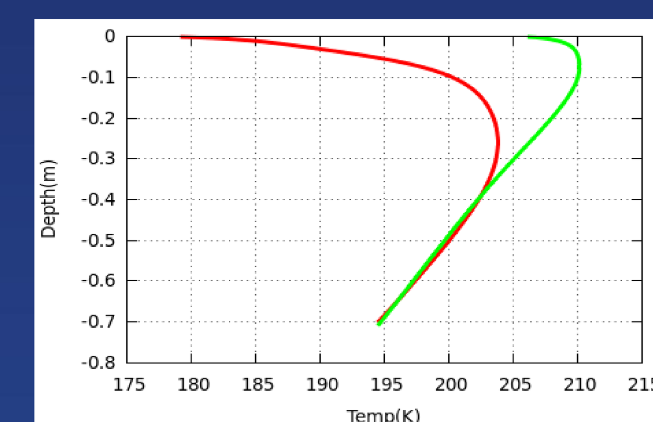

Figure 5. Snowpack temperature profiles at the end of the simulation (Ls 170) at the northern-most region in green and the 75º latitude region in red.

References

[1] Clow, G.D. (1987), *Icarus, 72,* doi: 10.1016/0019-1035(87) 90123-0 [2] Brown A.J. et al. (2012) *Journal of geophysical research, Vol. 117,* E00J29, doi: 10.1029/2012JE004113, 2012. [3] Langevin, Y., *et al.* (2008), *paper presented at Mars Atmosphere: Modeling and Observations, Lunar and Planet. Inst., Jamestown, Va.* [4] Jordan R. (1991) *U.S. Army Cold Reg. Res. And Eng. Lab., Special report 91-16.* [5] A. R. Dove et al. (2009), *40th Lunar and Planetary Science Conference (2009),* #1730. [6] Brown and Calvin (2012), *LPSC abstract #1742.* [7] Brandt R.E. et al (1992), *Journal of Glaciology, Vol. 39, No. 131, 1993.*