Evaporation/Sublimation & Heat Transfer Model for a Paleolake at Columbus Crater, Terra Sirenum, Mars

V. O. Akunyili[1], E. G. Rivera-Valentin[2], V. F. Chevrier[2], and R. Ulrich[3]

[1]Dept. of Physics, Drury University (vakunyili@drury.edu), [2]Arkansas Center for Space and Planetary Sciences, [3]Dept. of Chemical Engineering, University of Arkansas Fayetteville

Introduction

- Paleolakes have been identified on Mars.
- Columbus Crater shows signatures of hydrated minerals [1].
- HiRISE images have been used to identify sharp paleoshorelines [2].
- Stability of the lakes identified are unknown.
- We try to determine how long water in any phase was there.
- To help understand this, we create a theoretical model.

Fig. 1: Columbus crater showing light-toned hydrated mineral deposits on the top portion of the crater rim [1]. *Photo Credit: Mars Express (HRSC).*

Methods

- Heat Transfer through lake modeled using conduction.

$$Q_{atm} = I_{sun}(1-A)\varepsilon f_{atm}\cos(\delta-\varphi) \quad (1)$$

$$Q_{DB} = I_{sun}(1-A)\cos(z)T(z,\tau) \quad (2)$$

$$Q_{scat} = \left(I_{sun}\left(1-e^{-\frac{\tau}{\cos(z)}}\right) - I_{ab}\right)(1-A) f_{scat} \quad (3)$$

$$Q_{atm\_night} = I_{sun} f_{atm}(1-A)\varepsilon\cos(z)\big|_t \quad (4)$$

$$E = 0.17 D_{H_2O/CO_2} a_{H_2O}\frac{\rho_{sat}}{\rho_{sol}}\left[\frac{g\left(\Delta\rho/\rho\right)}{\nu^2}\right]^{\frac{1}{3}} \quad (5)$$

Eqs. 1-4: Equations describing the incident heat flux [3-6].

Eq.5: One direction vertical transport equation proposed by Chevrier et al., which is modified from the semi-empirical Ingersoll equation [7,8].

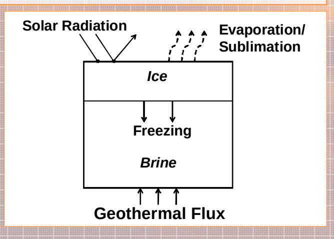

Fig. 3: Schematic showing lake geometry with boundary conditions.

Results

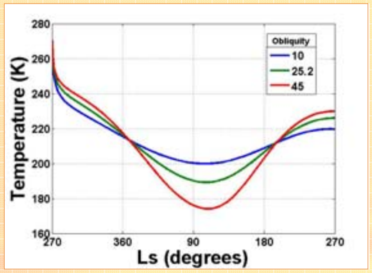

Fig. 4: Mean surface temperature for each Ls for the first year with an initial temperature of 280 K

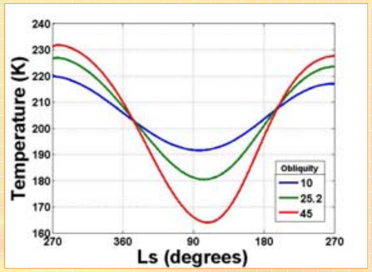

Fig. 5: Mean surface temperature of the lake for the second year.

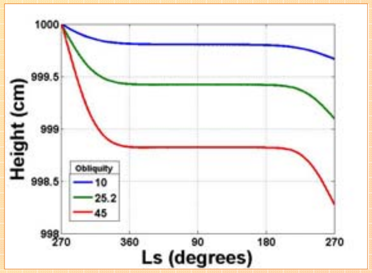

Fig. 6: Calculated change in height using the temperatures in Fig. 5.

Obliquity (deg.)	Change in Ht. (cm/yr)	Lifespan (yrs)
10	0.33	455,000
25.2	0.90	167,000
45	1.7	88,000

Table 1: Total change in height and extrapolated lifespan of the lake due to continuous sublimation. Initial height of lake is 1.5 km.

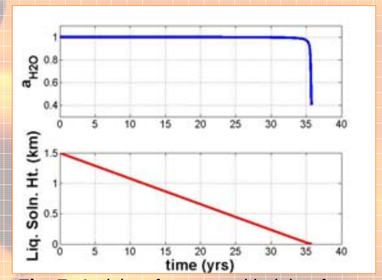

Fig. 7: Activity of water and height of liquid solution.

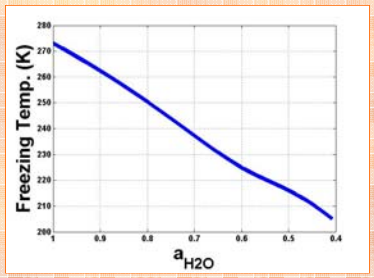

Fig. 8: Freezing point depression due to drop in activity of water.

Analysis

- 1st year: Temperature drops to a mean of 270 K for the first Ls (Fig. 4).
- 2nd year: Lake surface temps. stabilize (Fig. 5).
- For our current obliquity of 25.2°:
  - o Surface temp. range is 180 K – 227 K (Fig. 5).
  - o Lifespan of the lake assuming instantaneous phase change is 167,000 yrs (Table 1).
  - o Preliminary results on freezing rate indicate that an ice cap will form in the first 36 yrs sealing a liquid solution of 1.95 m (Fig. 7).
  - o Activity is reduced to 0.4, depressing its freezing point below the temp. at skin depth (205 K) (Fig. 8)
  - o Due to negligible leftover liquid solution the ice cap will take ~167,000 yrs to sublimate as well.
  - o Key factor is how long the liquid solution will remain after the ice cap melts.

Conclusions

- Rapid temperature drop indicates that the lake will start freezing within the first Ls (Fig. 4).
- Estimated upper bound lifespan at current obliquity is 167,000 yrs.
- Lower bound lifespan of liquid solution (a_{H2O} 0.4, temp. 205 K) is 167,000 yrs.
- Calculations indicate that freezing occurs much faster than sublimation/evaporation.
- *Future work:* To refine the freezing rate parameters and calculate how long the solution below the ice cap remains once the ice cap is fully sublimated.

References

[1] Altheide, T. S. et al. (2009) *Workshop on Modeling Martian Hydrous Environments*, Abstract #4030. [2] Di Achille, G. et al. (2009) *GRL, 36*, L14201. [3] Rivera-Valentin, E. G. et al. (2009) *Workshop on Modeling Martian Hydrous Environments*, Abstract #4020. [4] Schmidt, F. et al. (2009) *Icarus*, doi:10.1016. [5] Applebaum, J. et al. (1993) NASA Technical Memorandum 106321. [6] Ulrich, R. et al. (submitted) *Astrobiology*. [7] Altheide, T. S. et al. (2009) *EPSL, 282*, 69-78. [8] Ingersoll, A. P. (1970) *Science, 168*, 972-973.