**USING ATMOSPHERIC MODELING TO PINPOINT RIPPLE MIGRATION TIMING IN MERIDIANI PLANUM DURING THE LAST 400 KY.** H. Carson[1], L. K. Fenton[2] and T. I. Michaels[2], [1]Bellevue College, 3000 Landerholm Cir SE, Bellevue, WA 98007, [2]SETI Institute, 189 Bernardo Ave., Suite 100, Mountain View, CA, 94043 (lfenton@seti.org).

**Introduction:** The climatic system of Mars is primarily driven by the absorption of shortwave solar radiation (insolation), modulated by the emission of longwave radiation to space. The chief parameters which control the insolation over seasonal and longer intervals are the axial obliquity, the orbital eccentricity, and the season ($L_s$) of perihelion. Small variations in Mars' orbital configuration translate into potentially large changes in atmospheric density and wind stress.

Over the course of Mars' history, the wind has played a major role in both sculpting the landscape and recording the planet's climate variations. The only well-constrained ancient period of bedform migration has been that of coarse-grained "plains ripples" in Meridiani Planum, which are inactive today and last experienced significant migration ~50-200 ka [1]. It was proposed [1] that known variability in Mars' orbit was responsible for influencing wind patterns that mobilized the ripples. Since then, the discovery of a large but geologically young $CO_2$-ice reservoir in the south polar layered deposits was announced, with the ramification that Mars' atmospheric pressure may have been double its current value in the recent past [2,3].

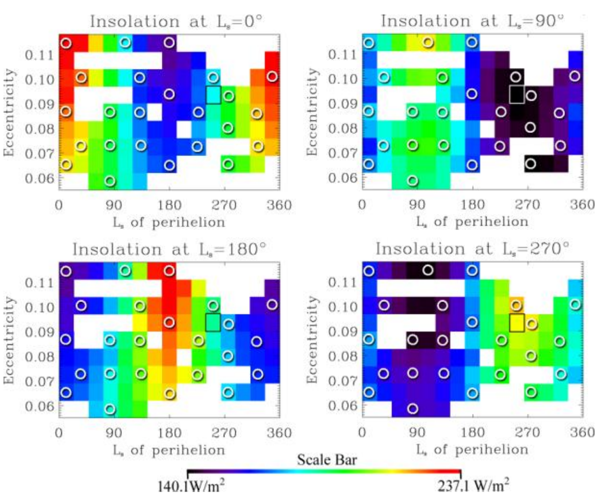


**Figure 1. Daily mean insolation in Meridiani Planum at eccentricity and $L_s$ of perihelion states that have occurred in the past 400 ky. Circles correspond with Cases #1-24; the present-day is outlined in a rectangle.**

**GCM simulations:** The NASA Ames Research Center Mars global climate model (MGCM) [4-6] was run with a 5°x6° horizontal grid with 24 vertical levels (more numerous within the boundary layer than aloft). This model explicitly predicts the $CO_2$ and $H_2O$ cycles (including water-ice cloud microphysics), with atmospheric dust loading prescribed as a function of season and location based on TES dust opacity data from Mars Year 26. Potential sand transport (PST) from each 1.5 Mars-hour output snapshot was calculated using [7].

**Table 1. GCM simulations run in this study**

| Case # | $p_{surf}$ | $e^a$ | Obl$^b$ | $L_p^c$ |
|---|---|---|---|---|
| **0** | 7 mbar | 0.093379 | 25.2193 | 250.925° |
| **25** | 14 mbar | 0.093379 | 25.2193 | 250.925° |
| **1** | 7 mbar | 0.0585 | 25.19° | 84° |
| **2** | 7 mbar | 0.0725 | 23.04° | 84° |
| **3** | 7 mbar | 0.0865 | 29.49° | 84° |
| **4** | 7 mbar | 0.1110 | 25.19° | 108° |
| **5** | 7 mbar | 0.0725 | 23.04° | 132° |
| **6** | 7 mbar | 0.0865 | 23.04° | 132° |
| **7** | 7 mbar | 0.1005 | 27.34° | 132° |
| **8** | 7 mbar | 0.1005 | 23.04° | 252° |
| **9** | 7 mbar | 0.0655 | 29.49° | 276° |
| **10** | 7 mbar | 0.0795 | 25.19° | 276° |
| **11** | 7 mbar | 0.0935 | 23.04° | 276° |
| **12** | 7 mbar | 0.1005 | 27.34° | 348° |
| **13** | 7 mbar | 0.0655 | 23.04° | 12° |
| **14** | 7 mbar | 0.0865 | 20.89° | 12° |
| **15** | 7 mbar | 0.1110 | 23.04° | 12° |
| **16** | 7 mbar | 0.0725 | 23.04° | 36° |
| **17** | 7 mbar | 0.1005 | 27.34° | 36° |
| **18** | 7 mbar | 0.0655 | 25.19° | 180° |
| **19** | 7 mbar | 0.0935 | 27.34° | 180° |
| **20** | 7 mbar | 0.1110 | 23.04° | 180° |
| **21** | 7 mbar | 0.0725 | 25.19° | 228° |
| **22** | 7 mbar | 0.0865 | 25.19° | 228° |
| **23** | 7 mbar | 0.0725 | 29.49° | 324° |
| **24** | 7 mbar | 0.0865 | 23.04° | 324° |

[a]eccentricity, [b]obliquity, [c]$L_s$ of perihelion

We have simulated annual wind patterns in 25 orbital configurations (see Table 1), which were selected to represent the range that has occurred over the past 400 ky, and also that of the present day (Case #0). Cases #1 through #24 were selected to span the distributions of eccentricity and $L_s$ of perihelion, which (using [8]) produce a wide range of seasonally-varying insolation magnitudes in Meridiani Planum (see Fig. 1). The original hypothesis driving this work was that changes in the seasonal pattern of insolation in Meridiani Planum (mainly due to varying eccentricity and $L_s$ of perihelion) would be the primary driver affecting wind patterns (and thus bedform activity), and that these changes would impact winds more than variations in obliquity (which varies from only 20-26º in the past ~350 ky, in contrast to the 15-35º variations over the past 3 Ma [8]). Finally, Case #25 represents the present-day orbital configuration, but with a thicker atmosphere that could affect net transport, as well as wind patterns.

**Results:** The present-day case reflects a relatively high PST, the 4th highest of the 25 7-mbar GCM cases. However, the high pressure case (Case #25) had the highest net potential sand transport, at nearly twice that modeled for the present-day.

In all simulations, peak winds occurred during northern summer and winter. The peak northern summer winds blew in the morning (0800-0900h) from the SE to SW, reflecting both Hadley return flow and the diurnal thermal tide (both of which pull wind northward). The peak northern winter winds blew in the morning (~1000h) from the east, being driven by both planetary rotation and flow up the Isidis/Syrtis Major slope (enhanced by the diurnal thermal tide).

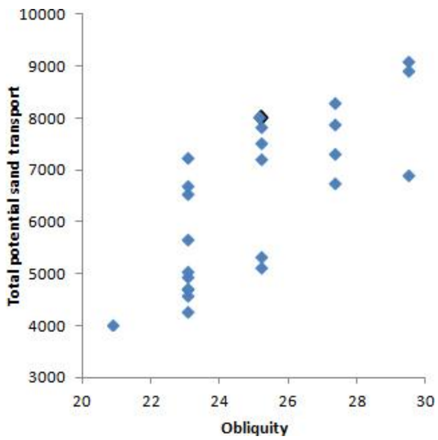


**Figure 2. Total annual potential sand transport correlates with obliquity (black outline = present day).**

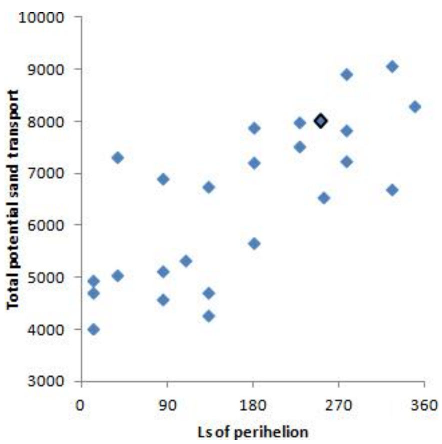


**Figure 3. Total annual potential sand transport correlates with $L_s$ of perihelion (black outline = present day)**

Because higher obliquity strengthens both the Hadley circulation and the thermal tide, higher PST correlates positively with obliquity (see Fig. 2). Eccentricity does not have a simple relation to annual PST (not shown), but $L_s$ of perihelion does (see Fig. 3). In particular, an $L_s$ of perihelion near northern winter solstice (similar to today) enhances both the Hadley return flow and diurnal tide, strengthening the winds. Cases #9 and #23, which had a high obliquity and $L_s$ of perihelion near northern winter solstice, produced the highest PST (with the exception of the high-pressure Case #25).

Figure 4 shows daily mean insolation in Meridiani Planum at four different seasons, and the corresponding mean PST at that season for each GCM simulation. Northern winter and summer both correlate strongly with local insolation (with correlation coefficients of 0.882 and 0.748, respectively), reflecting the strong impact of insolation on global winds.

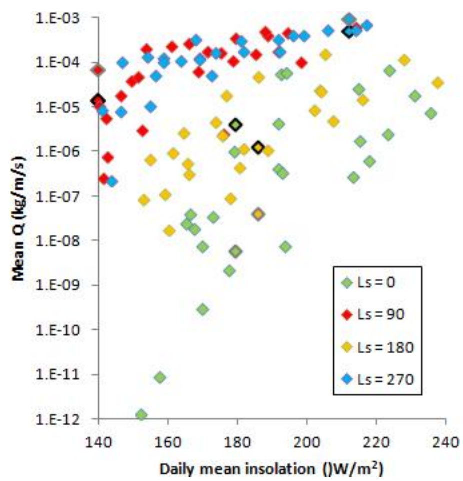


**Figure 4. Seasonal insolation patterns in Meridiani Planum correlate with seasonal mean potential sand transport (black outline = present day, gray outline = high pressure case).**

**Further work:** Continued work will focus on changes in wind direction with both orbital configuration and higher air pressure, and their collective impact on bedform alignment in Meridiani Planum. We will also investigate smaller-scale flows using a mesoscale atmospheric model.

**References:** [1] Golombek et al. (2010) *JGR 115*, E00F08, doi:10.1029/2010JE003628. [2] Phillips et al. (2011) *Science, 332*, doi: 10.1126/science.1203091. [3] Bierson et al. (2006) *GRL, 43*, doi:10.1002/2016GL068457.[4] Haberle et al. (1993) *JGR, 98*, doi:10.1029/92JE02946. [5] Haberle et al. (2011) *4th Int'l. Wkshp. Mars Atm.*, p. 223-226. [6] Hollingsworth et al. (2011) *4th Int'l. Wkshp. Mars Atm.*, p 70-73. [7] Kok (2010) *GRL, 37*, doi:10.1029/2010GL043646. [8] Laskar et al. (2004) *Icarus, 170*, doi:10.1016/j.icarus.2004.04.005.