ESTIMATION OF THERMAL INERTIA, SENSIBLE HEAT AND LATENT HEAT OVER THREE LANDING SITES ON MARS. Subhadyouti Bose, Vijayan S, Rishitosh K. Sinha, S.V.S. Murty, PLANEX, Physical Research Laboratory, Ahmedabad 380 009, India (bose@prl.res.in).

Introduction: On present day Mars, surface temperature rarely exceeds 300K in the summers, while in winters it ranges around ~200K to ~250K [1]. This presents a very cold and dry picture of Mars, which is also devoid of any form of precipitation. Plenty of evidences, however, exist for a warmer and much wetter Mars in the past [2]. NASA's MSL Curiosity, which landed in Gale Crater in August 2012, provided ample proof of a water-bearing environment within the crater. Phoenix lander, which touched down in the martian arctic region in May, 2008 has observed the present-day martian weather conditions. Phoenix detected surface frost early in the morning, very close to the lander and also subsurface water-ice that was exposed by its robotic arm[3]. Viking Lander 1 (VL1) was the first spacecraft to land on Mars which obtained first in-situ temperature, pressure and wind velocity data.

We aim here to estimate the diurnal boundary layer properties of first order, for top soil moisture at four sites using in-situ temperature, humidity and pressure data measured by Curiosity. We compare the values obtained at Gale Crater, with similar first order calculations at VL1 and Phoenix sites.

Dataset: We used REMS/GTS level 3 data from Curiosity which includes air temperature (T_a), ground Temperature (T_g) pressure (p), and relative humidity (RH) for sols 10, 82, 238 and 436. For the Phoenix site, we used temperature measured at a height of 250mm from the surface (T_{250}) as surface temperature, and another measurement at a height of 1000mm from the surface (T_{1000}) for air temperature, and relative humidity was simulated for 5% and 100% (taken as minimum and maximum values, respectively) [4]. In case of Viking, we used in-situ surface and atmospheric temperatures, surface pressure from the lander and relative humidity measurements were obtained from [5].

Method: We have adopted the method [6] for estimating the sensible heat, which is given as

$$Q_H = k^2 C_p u \rho_a f(R_B)[(T_g - T_a)/\ln^2(z_a/z_o)]$$

where k is the von Karman constant, c_p specific heat of CO_2 at constant pressure, ρ_a is density of air at 1.6m, z_a is 1.6m where the T_a (air temperature) is measured by Curiosity, u is horizontal wind speed which is taken as 10 m/s in this study, $f(R_B)$ is a function of the bulk Richardson number R_B. The latent heat estimation from [6] is given as:

$$Q_E = Lv\beta k^2 C_p u \rho_a f(R_B)[q_s(T=T_g) - T_a/\ln^2(z_a/z_o)]$$

where Lv is the latent heat of sublimation from water vapor, β represents the top soil moisture, q_s the saturation specific humidity at $T=T_g$, q_a is specific humidity at z_a. The values for the constant parameters are obtained from [6]. To obtain β, we used the Bowen's ratio formulation [7] which relates the ratio of sensible heat and latent heat. β is equal to 1, if frost exists on the surface, otherwise it is taken as $\sim 10^{-4}$ [6]. Similar temperature outputs from Phoenix and Viking landers were used for corresponding data analysis.

Discussions: We computed the thermal inertia for Rocknest area in Gale Crater (Curiosity was near Rocknest on sol 82) from THEMIS nighttime IR image using a technique developed by [9] and also from in-situ REMS/GTS derived temperature values. Orbiter-derived thermal inertia values range between 410-450 J $K^{-1}m^{-2}s^{-1/2}$, while in-situ thermal inertia values range from 320 to 350 J $K^{-1}m^{-2}s^{-1/2}$ (Fig.1). The derived thermal inertia suggests that the region consists of finer materials. Moreover, the thermal inertia would affect the surface, which is undergoing periodic heating. The moderate thermal inertia obtained over the Curiosity site suggests that the rate of heat exchange is relatively less as compared to the higher thermal inertia regions.

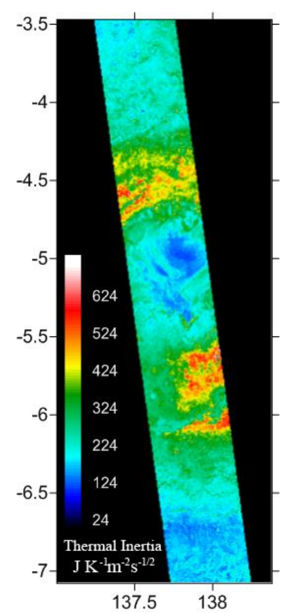

Fig. 1. THEMIS nighttime IR derived thermal inertia map obtained using [8] for the Gale crater region (4.6°S, 137.4° E).

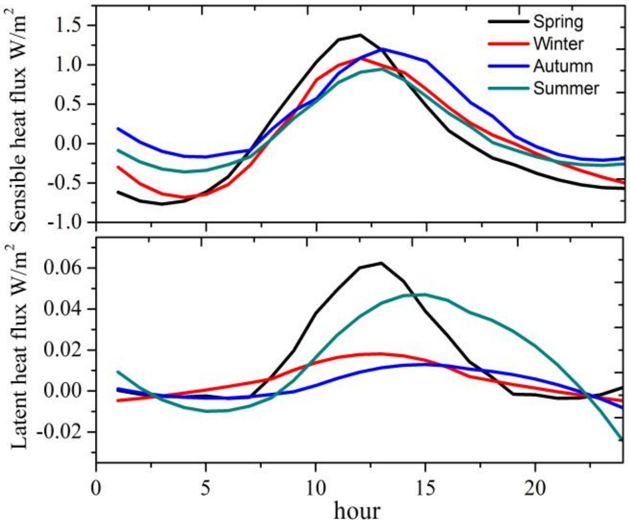

Fig. 2. Sensible and latent heat flux derived for four seasons from the Curiosity REMS. The seasonal effects are reflected in the diurnal curve.

The diurnal variation plots of sensible heat and latent heat for four different seasons are shown in Fig. 2. We obtained first order β values for the studied sols to be in the range of 10^{-2} to 10^{-3}, which is in agreement with the limits proposed by [6]. The seasonal data that we plotted provided several insights on the seasonal influence over the surface.

We have obtained a relatively higher value of β in the spring season as well as in the summer season. We attribute this relatively higher value to the fact that during the months of spring and summer, the daytime as well as nighttime surface temperatures are significantly higher than during other seasons (autumn and winter). Moreover, solar insolation is also higher on Mars at this time. To further support our wetness numbers, we point out to the fact that RSL (Recurring Slope Lineae) [8] appear and fade over the course of spring through autumn at a few places on Mars. Moreover, the linear streaks or, relatively dark markings were observed on steep southern slopes (32° to 48° S) [8]. These features are also known to form only if the surface temperature exceeds 250K. Although RSL have not been observed as far north as Gale crater, we argue that the conditions for the formation are favourable for at least a few hours in the daytime during the late-spring to early-autumn seasons. The atmosphere could also be relatively more humid in summer time at Gale Crater (early in the morning), which we find to be a contributing factor to moisture at that time of day (0300 to 0500 hours LST).

For the Phoenix site, we chose sol 25, due to the detection of water ice just beneath the robotic arm. For this site, we used the relative humidity as 100%, early in the morning and also at late in the night (2200 to 0700 hours LST). RH drops substantially later in the day to almost about 5% by early afternoon, but attains higher values again at around 2200 hrs LST. The first order β was in the order of 10^{-2} in the early morning hours, which suggests that the site could be more moist during that period. Over the Viking landing site, for sol 1, we obtained the same order as that of the Phoenix site. The first order analysis over the three landing sites have thus provided an insight about β, which is well within the limits prescribed [6].

References: [1] Leovy C., (2001), *Nature*, 412, 245-249. [2] Ramirez et al., (2014), *Nature Geoscience, 7*, 59-63. [3] Smith et al., (2009), *Science, 325*, 58-61. [4] Zent et al. (2010) *JGR, 115*. [5] Savijarvi H. (1995) *Icarus, 117*, 120-127. [6] Martinez et al. (2014) *JGR, 90*, 1822-1838. [7] Montieth and Unsworth (2013) *Principles of Environmental Physics: Plants, Animals, and the Atmosphere*. [8] McEwen et al. (2011) *Science, 333*, 740-743. [9] Putzig and Mellon, (2007), *Icarus, 191*, 68-94.