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MARSTEM FIELD TEST IN MARS ANALOG ENVIRONMENT

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***Abstract*— The Temperature sensor of the DREAMS (Dust characterization, Risk assessment and Environment Analyzer on the Martian Surface) package, MarsTEM, on board the Exomars2016 Entry and Descent Module (EDM) was tested in the Moroccan desert during summer 2014. The sensor collected data for almost 3 days during which it measured stability of the atmospheric surface layer and experienced both rainy days and nights and weak desert dust storms. The present paper highlights the meteorology of the desert night behavior showing strong correlation between the measured atmospheric principal parameters and the near and far topography.**

Keywords*— *MarsTEM; Mars; Exomars; temperature; atmospheric stability

I. INTRODUCTION

The Phoenix Mars mission of 2008 showed that the measurement of the temperature of the Surface Planetary Layer can help the analysis of the meteorology of the atmosphere of Mars. Large adiabatic heat fluxes in the air (see Phoenix data [1]) are caused by the near-surface atmosphere changes due to the surface temperature variations [2]. This is characterized by turbulent fluctuations in the daytime near-surface temperatures and a strong surface inversion each night [3, 4] and more stable conditions during night.

In the framework of the Monin-Obukhov similarity theory, using temperature and wind data the heat fluxes and the temperature spectra have been calculated both for terrestrial semi-arid or desert sites [5] and for Mars [1]. Turbulence and non-stationarity of the atmospheric surface layer has been investigated and thermal stratification and surface roughness has been retrieved from temperature and hot wire sensors [6].

In particular the influence of low relief under conditions of strong stability have been analysed in desert regions of Australia: sudden temperature variations can be due to flow over minor topographic variations [7].

These interesting results strongly pushed DREAMS-Exomars2016 team [8] for testing the sensor performance in a Mars analog site. The Moroccan desert, near the selected site in Merzouga, is characterised by a very flat base rock surrounded by sand dunes and small reliefs. This paper presents preliminary analysis on the temperature data collected during the second night of operations, 11 July 2014.

II. METEOROLOGICAL FRAMEWORK

A. Site description

The test site was located in the east part of Morocco, near the city of Merzouga, in a an open flat area, precisely at 31°11'35.31"N 4° 6'35.40"W (Figure 1) at an altitude of 700 m. Small sand dunes are present on the west at 250 m distance; on the east, at 7.6 km, there are higher dunes. The Atlas mountains (with elevation around 1400m) are at 110km on the north and the Sahara desert is at 33 km on the east and on the north-east (with a mean altitude of 700 m).

B. Instrumentation

The MarsTEM sensor is a platinum resistance thermometer, the sensing element is a 99.99% platinum, 0.0508 mm diameter, 700 mm long wire in order to have a low response time on Mars (around 10-15s) on the surface. The expected performance of MarsTEM at Mars' surface is accuracy of 0.1 K and resolution of 0.04 K.

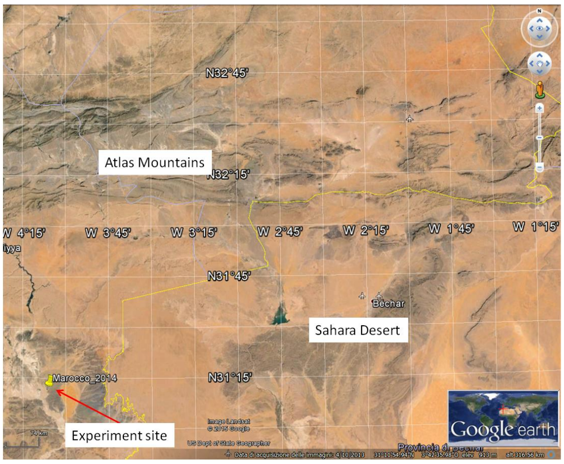

Figure 1. Experiment site located in Morocco.

Figure 2. MarsTEM temperature subsystem. On the far left the MISSUS temperature sensor without the shield; on the right side the MarsTEM sensor protected the aluminum shield. On top, fixed to the shield, the PT100 B sensor and in the shadow of the shield the PT100 A, directly exposed to air.

Other 3 sensors composed the MarsTEM subsystem: MISSUS temperature sensor, similar to MarsTEM but with a slightly different supporting structure, and without the solar radiation shield; and two PT100 sensors located un top and below the MarsTEM shield (Figure 2).

In the present paper data from MarsTEM without shield (i.e. MISSUS) will be discussed. Other sensor used for the test site are a 1) Humidity and Temperature Probe HMP155 Vaisala positioned at 2.5 m; 2) LI-COR LI-200 Pyranometer located at 4.5m height; 3) BAROCAP Barometer PTB110 Vaisala 2.0m height; 4) 3x Gill WindSonic Anemometer at 0.5, 1.4 and 4m heights; 5) 2x Cambpell Scientific model 10x thermometer at 2.5 and 4.5m heights. All the data were collected throughout a Campbell Scientific CR1000 DataLogger (see Figure 3).

III. METEOROLOGICAL MEASUREMENTS

Measurements were conducted for 3 days during the 2014 Moroccan summer, between 10th and 13th of July. During the measurements weather was variable, clouds formation were present during both daytime and nighttime and wind was changing both in velocity and direction. Some rainy events occurred lasting not more than half an hour each and several weak dust storms were detected by the instruments. Data were sampled at a 1Hz frequency.

A. Temperature data

In this paper, preliminary analysis of the data collected during the second night of test are presented and discussed.

The temperature data show a very particular structure and several events have been identified. A first drop of 2 seconds occurred around 21:30 with a very constant and stable temperature lasting for at least 15 minutes (event 1 in Figure 4); six minutes later a pair of relevant decreases in temperature on two of the three sensors (2 in Figure 4) and finally a wavy temperature event (3 in Figure 4) of the duration of almost 2 hours. All the events are different and possible explanation are presented.

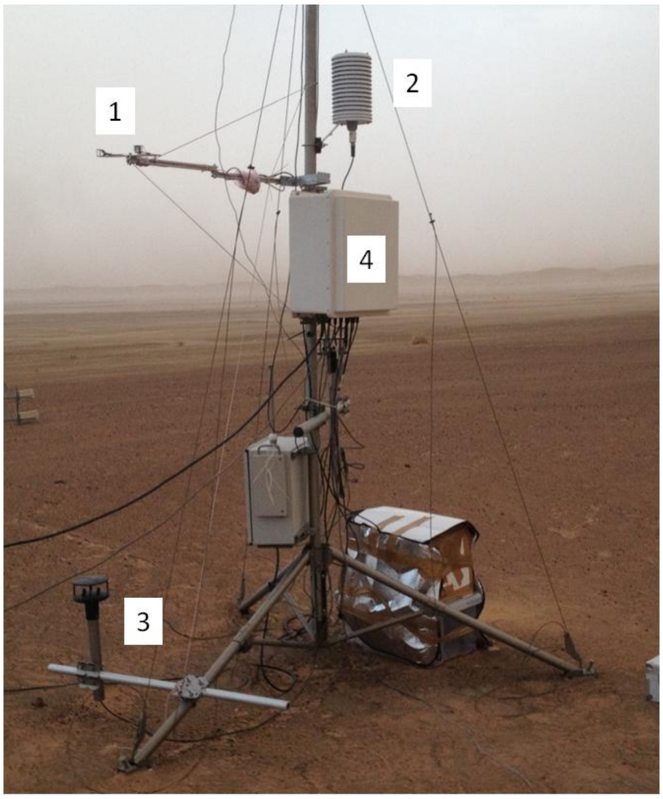

Figure 3. Sensors tower. 1) MarsTEM h. 2.17m; 2) temperature sensor h. 2.5m; 3) wind sensor h. 0.5m; 4) datalogger and pressure sensor.

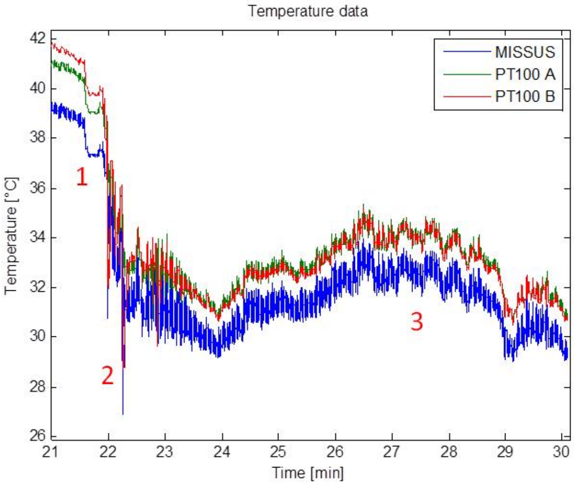

Figure 4. Nocturnal temperature data. The numbers indicate the analysed events (see text for explanation).

B. Wind and other significant data

Similar trends have been registered by all the other sensors (see Figure **5**). In particular, wind velocity and direction have a identical tendency of the temperature data and can be easily correlated to those measurements.

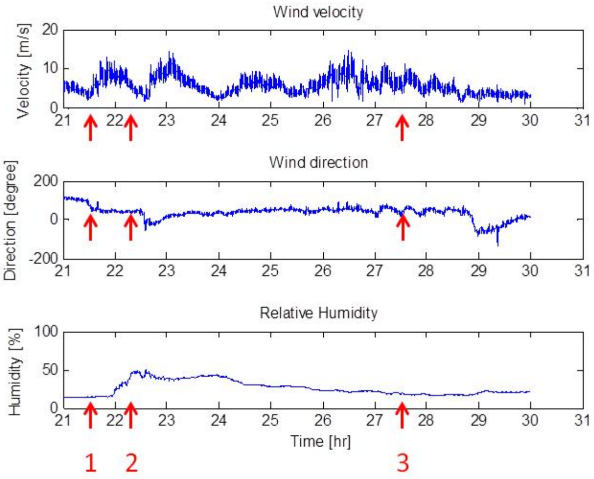

Figure 5. Wind velocity (top), wind direction (middle) and relative humidity (bottom) data sets for the nocturnal window events

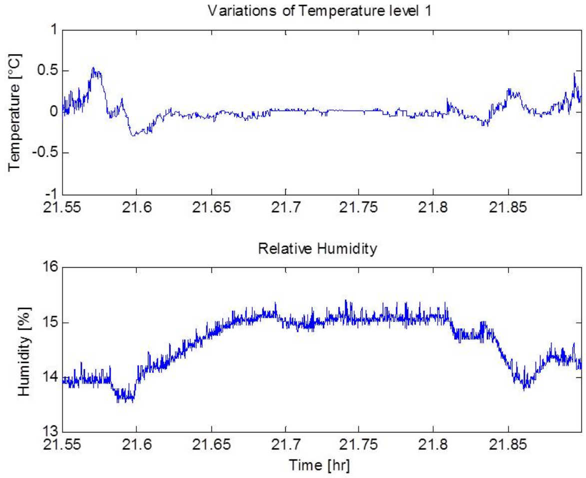

Figure 6. Top, fluctuation of temperature during event 1; bottom, increase in relative humidity.

On the other hand, relative humidity is increasing from 15% up to 50% in 50 minutes from 21:30 and then starts to decrease to previous levels.

C. Observations

1) Event between 21:36 and 21:48

The first event is characterised by a stable temperature: fluctuations T' is the remaining component after having removed from the original data T a running mean $\langle T \rangle_t$ of period t (in the present case t = 300s) :

$$T' = T - \langle T \rangle_t$$

As it is possible to see in Figure **6** the temperature fluctuations decrease very rapidly from $T' = \pm 0.4$°C down to $T' = \pm 0.07$°C, in less than 3 seconds. This means that the temperature of the inflowing air is really stable, while wind velocity is not constant and the direction is constantly changing. All the event is lasting 12 minutes. Air is flowing 50 degrees from north (in a clockwise direction) at the beginning

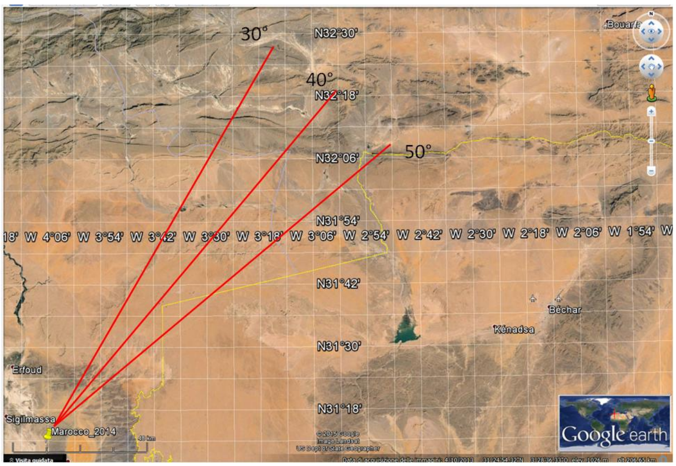

Figure 7. Site location with direction from North.

of the event reaching 40 degrees at the end of the event. The region from which the air is coming is changing and in fact it can be observed that at 50 degrees the air is coming from the edge of the Sahara desert, while the air coming from 40 degrees north is coming from the Atlas Mountains (see). This fact is confirmed by the increase, even if small, of the relative humidity of the air coming down from the mountains.

The temperature fluctuations T' are proportional to the change of enthalpy H' and inversely to the c_p, the heat capacity at constant pressure ($c_p \approx 1.0$ (kJ/kg°C) for dry air; $c_p > 1.8$ (kJ/kg°C) for humid air):

$$T' \propto \frac{1}{c_p} Q'$$

The humid air coming down from the Atlas mountains has a higher heat capacity c_p and this causes the temperature fluctuations to be lower respect to dry air, giving the flow a higher thermal stability.

2) Event between 21:54 and 22:18

Few minutes after the first event the temperature trace becomes more complex and variable; very rapid changes in temperature measurements were observed by the MISSUS sensor and the PT100 sensor located on top of the MarsTEM shield. The other two sensors, PT100A and MarsTEM, did not measure any sensible variation in temperature: the event is not related to a change in flow because this would have affect all the four sensors, and more precisely is relevant to changes coming from the above.

The first of the two drops (drop A in Figure 8) in temperature - of about 6°C - was measured by the PT100B and after 30 seconds a similar decrease was registered by MISSUS sensor; the second drop (drop B in Figure 8 - of about 7°C), on the other side, was measured first by MISSUS and 42 seconds later by PT100B (see Figure 8); similar values of temperature decrease were measured by Anderson [9] in a sea experiment. Only a 180 degree rotation of flow could explain this drop if caused by change in flow characteristics directly. But the direction and the velocity (here not shown) of the flow are

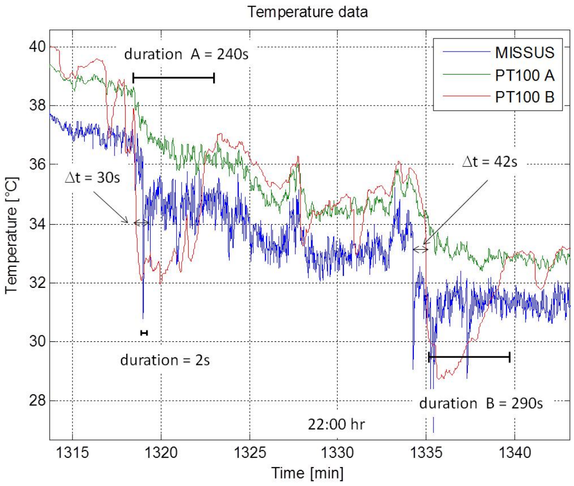

Figure 8. Temperature measurements during event number 2.

pretty constant. What is continuously changing is the humidity that is still increasing, passing from 15% to 45%.

The increase in humidity is an evidence of water increase in air: rain. In fact, around 21:15 some raindrops fell at the site and lightning was registered around 22:30, as tested by the local personnel present in loco. Measurements of solar radiation (here not presented) over the entire daytime showed the continuous presence of clouds; it can be easily supposed that also during the night many clouds were passing above the site location.

The high difference in drop temperature duration between the two sensors (MISSUS and PT100B) can be explained considering that a raindrop hitting the top of the shield remains there until evaporation, while the very small exposed area of the MISSUS sensor does not allow a raindrop to remain there causing it to hit the sensing element and then continue its fall to the ground.

Dimension of the droplet can be inferred by the duration of the evaporation phase (240s for drop A and 290s for drop B) assuming that all the change in temperature of the top of the shield is used to evaporate the drop. Using the Mass evaporation rate formula presented by Kinzer in [10] we can find that the diameters of the droplet are around 0.2cm.

IV. CONCLUSIONS

Analysis of MarsTEM-DREAMS payload temperature data collected during 3 days of field test in the Moroccan desert during summer 2014 was performed. In particular, the second night of measurement was investigated and several events were emphasized. Evidence of a strong correlation of temperature, wind – velocity and direction, humidity and topography was found. The air temperature shows, as expected, that air flowing from the Atlas mountains, 110 km away, is more humid and fresh than the air coming from the much nearer Sahara desert (border at 30-50 km on the east); this implies that the flatness of the land between the site and the mountains does not influence the flow.

During both day and nighttime several rainy windows were present; sudden change in the measured temperature was correlated to cold raindrops hitting the sensors. Different temperature profiles were registered due to the fact that on one sensor the raindrop remains until complete evaporation.

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