Relative humidity and vapor amount at Jezero Crater

L. K. Tamppari, *Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA, USA (leslie.tamppari@jpl.nasa.gov)*, **G. Martínez**, *Lunar and Planetary Institute, Houston, TX, USA,* **J. A. Rodríguez-Manfredi,** *Centro de Astrobiologia (INTA-CSIC), Madrid, Spain,* **M. de la Torre-Juárez,** *Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA, USA,* **M. Hieta, J. Polkko, I. Jaakonaho, M. Genzer, A.-M. Harri**, *Finnish Meteorological Institute, Helsinki, Finland*, **T. McConnochie**, *Space Science Institute, Boulder, CO, USA,* **F. Montmessin**, LATMOS, Guyancourt, France, **M. Smith**, *NASA Goddard Space Flight Center, Greenbelt, MD, USA,* **M. Wolff**, *Space Science Institute, Boulder, CO, USA*, **E. Fischer**, *University of Michigan, Ann Arbor, MI, USA*, **P. Conrad**, Carnegie Institution of Science, Washington, D.C., USA, **F. Gómez**, **M.-P. Zorzano,** and **D. Viudez-Moreiras,** *Centro de Astrobiologia (INTA-CSIC), Madrid, Spain*, **P. Patel,** *Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA, USA*, **M. Lemmon**, *Space Science Institute, Boulder, CO, USA*, and the **MEDA Team**.

Introduction:

Near-surface water content and relative humidity are important for understanding the overall column distribution of water, the exchange with the surface and near-subsurface, the potential for brine or frost formation, and general modern habitability potential of the local environment (see e.g., [1-3]). Humidity sensors have been used on Phoenix, MSL, and now Perseverance to gain this understanding.

The Perseverance MEDA relative humidity measurements at Jezero crater add additional time coverage and an additional location to help discern the regional similarities and differences across Mars. In combination with independent measurements by the Perseverance SuperCam or TIRS instruments, measurements of relative humidity can be used to detect frost formation [4], to check whether the environmental conditions at the surface and in the near surface are compatible with the formation of liquid brines [5-6], and to assess diurnal changes in the near-surface water content, possibly due to subsurface exchange (e.g., [7-8, 3]) or consistent with surface frost [4].

The relative humidity sensor supports the science and human exploration goals of the rover, the sample collection via documenting the atmospheric field context in which the sample was acquired, and the Ingenuity helicopter flights.

Methods:

The Mars Environmental Dynamics Analyzer (MEDA; [1]) aboard the Mars Perseverance Rover is a suite of environmental sensors to measure relative humidity (HS), wind (WS), atmospheric temperature (ATS), atmospheric pressure (PS), brightness temperature of the surface and lower atmosphere (TIRS), atmospheric optical depth and particle properties (RDS). Here we focus on the relative humidity sensor (HS), which is on the rover mast at about 1.6m above the surface **(**Fig. 1, 2**)**. The HS contains two Humicap® by Vaisala, Inc. which have an active polymer that changes the sensor head capacitance as a function of atmospheric relative humidity and temperature, measuring 0 to 100% RH. The humicaps have PT1000 platinum resistance temperature sensors to provide accurate temperature of the sensor chip. These two measurements, along with the PS, can then be used to derive the volume mixing ratio (VMR) of water vapor in the atmosphere.

Improvements in the HS from the Curiosity rover version have been made to enable a more rapid response to the environment and to have a wider dynamic range, allowing for better resolution in the measurements.

The MEDA RH sensor is healthy and operating nominally. Data are acquired along with other MEDA sensors in ~1 hour Observation Table (OT) blocks that are scheduled every other hour throughout the diurnal sol and alternate every sol to cover even hours and then odd hours. There are two RH instrument modes that are used regularly: Continuous (CM) and High-Resolution Interval (HRIM). CM will measure continuously throughout the hour block and gives more insight into short-timescale variability, but is less accurate after the first few seconds. HRIM takes a few s of data every 5 min throughout the hour block. The first few s are most accurate owing to self-heating over time. This mode is used in 24-06h period.

For more information on the MEDA humidity sensor, see **Hieta *et al.***, this conference.

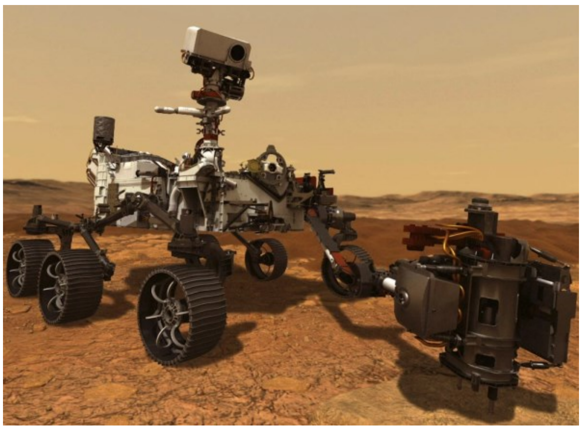

Figure 1. Artist's concept of the Perseverance Rover on the surface of Mars. MEDA has sensors on the mast and on the rover itself (see also Fig. 2). The Humidity Sensor (HS) is near the one of the Wind Sensor (WS) booms on the mast and also near some of the Atmospheric Temperature Sensors (ATS). Image credit: NASA

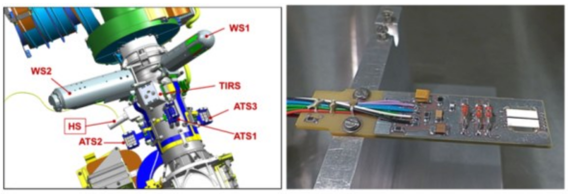

Figure 2. (Left) HS, WS, and ATS locations on the Remote Sensing Mast. (Right) HS without the cover; Humicaps®, which measure the relative humidity, are on right (white rectangles), Thermocap sensor heads next to them [1].

Results:

Comparison of seasonal RH/VMR to column abundances in Jezero. Fig. 2 shows the seasonal behavior of nighttime (21-06h) relative humidity and the derived volume mixing ratio (VMR). The variability of the nighttime relative humidity has decreased as the season progressed. Fig. 3 shows the VMR, which has a seasonal peak near sol 300-320 (Ls=146.3-156.8). There is a clear VMR trend of decreasing vapor amount as spring progressed, followed by an increase later in the summer, as is seasonally expected (Fig. 4, 5).

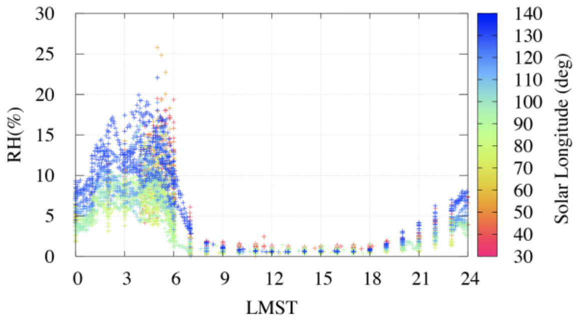

Fig. 2. Diurnal atmospheric relative humidity (%) for sols 65-275 (Ls ~ 36-134).

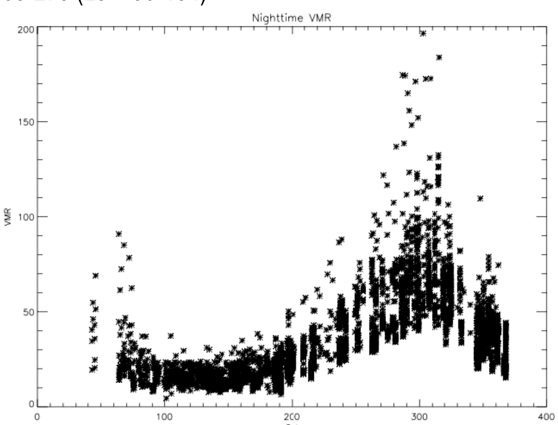

Fig. 3. MEDA nighttime "best" VMR through sol 368.

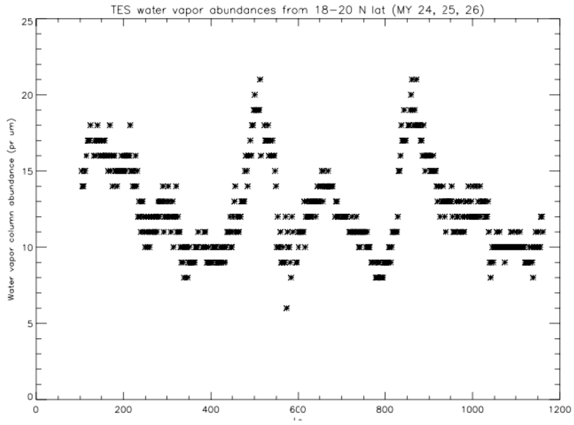

Fig.4. TES zonally averaged (18-20N) column water vapor abundances over 3 MY. (Note that Ls (x-axis) continually increments, so MY25 is 360-720, for example.)

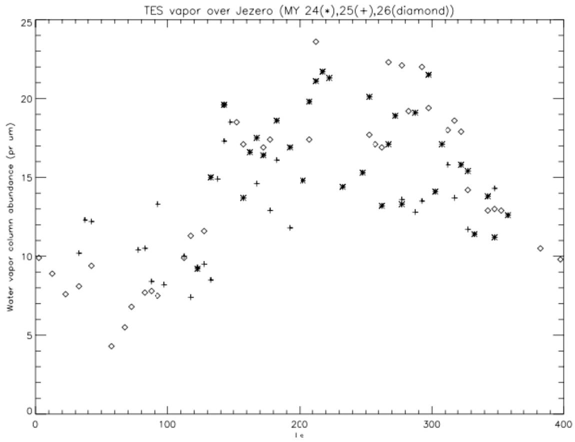

Fig. 5. TES water vapor abundances over 3 MY located over Jezero (5° lat, 7.5 deg lon, 5 deg Ls averaging).

Diurnal measurements. The diurnal behavior of relative humidity is also shown in Fig. 2. As expected, the highest relative humidity values are in the midnight-pre-dawn timeframe. Because there is so little water on Mars, the daytime relative humidity values approach zero and are smaller than the uncertainty for most of the ~07-18h period.

Comparing the measurements to models can both help interpret the measurements and validate or improve the models. In Fig. 6, we show output from a single column model (SCM) which takes into account sub-surface exchange and which is driven by precipitable water content as taken from either the Laboratoire de Meteorologie Dynamique (LMD) Mars Climate Database (MCD) in Jezero crater or from the Thermal Emission Spectrometer (TES) zonal mean measurements [9].

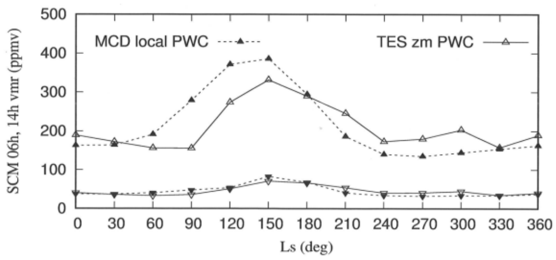

Fig. 6. The daily maximum (14h) and minimum (06h) VMR at 1.6 m for Jezero as predicted from a single-column model (SCM; [1]). The SCM is initialized with the MCD local precipitable water content (PWC) and also by TES MY26 zonal mean PWC near 18°N. The nighttime VMRs predicted are higher than observed by MEDA RH (Fig. 5, 6), but the seasonal trend appears to be similar.

Comparing the minimum values (06h) to the nighttime values in Fig. 2, 3, it appears that the model is over-predicting by about a factor of 2 the amount of vapor compared to what is measured. A direct comparison of the HS measured vs. SCM modeling minimum VMR values is shown in Fig. 7. The model does show a seasonal trend with increasing minimum vapor, peaking near Ls=150 (~Sol 3000; Fig. 6).

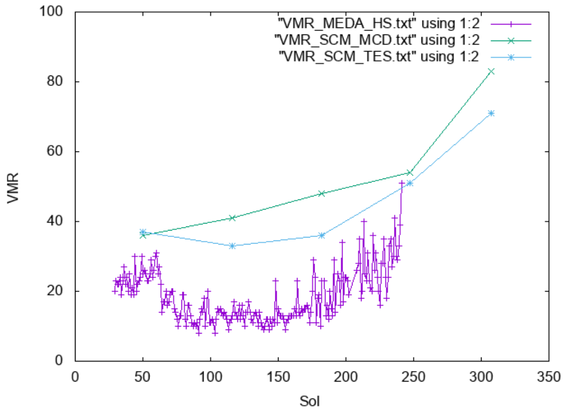

Figure 7. Comparison of the minimum diurnal VMR (05-07h) determined from the MEDA HS data to the VMR at 06h produced using the single-column model (SCM; Pla-García et al., 2020). The SCM output is initialized by the MCD local PWC (green) or via the TES MY26 zonal mean PWC for the Jezero latitude of 18°N (blue).

The differences between the modeled near-surface VMR and the measurements could be the result of a number of factors. The LMD-MCD does not include sub-surface exchange and is based on monthly quantities. The SCM does not include horizontal advection, so it is possible that drier air flows into Jezero crater every night that wouldn't be reflected in the model. It could also be that the near-surface atmosphere is losing more water to the subsurface at night than predicted.

In order to obtain a better understanding of these differences model improvements could be made, such as investigating the surface porosity and/or efficiency of surface-atmosphere exchange, combining these HS data with Supercam column water values to better understand the vertical distribution of water, and initializing the models' column water amounts for just the rover location and season (e.g., non-zonal mean TES data). All of these are the subject of future work.

Comparison of Jezero to Gale and Phoenix landing site. Previous spacecraft that flew relative humidity sensors were the Phoenix lander [10-13] and the Mars Science Laboratory/Curiosity rover [14-15, 7].

The MEDA HS nighttime VMR values more closely match those measured at Curiosity by the REMS relative humidity sensor (Fig. 8) that what would be expected from TES column abundances, but the MEDA HS values are even drier than REMS early in the season. This is surprising since the column abundances during this season are higher for the Jezero location than for the Gale location. Later in the season, the two are more alike.

The MEDA HS measures somewhat lower nighttime VMR values during a similar seasonal period compared to Phoenix (Fig. 9), which is not surprising given that Phoenix was close to the northern polar cap during northern summer when sublimation of water ice is expected.

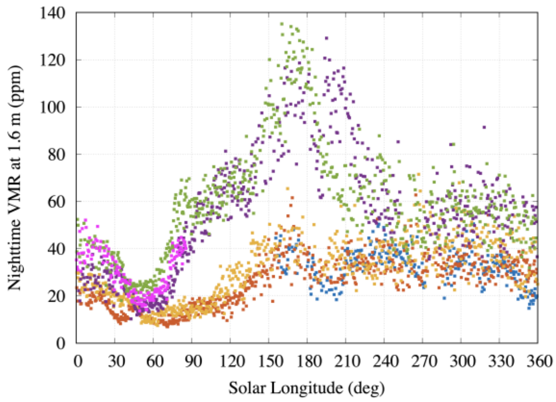

Figure 8. Curiosity REMS nighttime VMR values by season. Magenta values are for MY36 through Ls=90, concurrent with the MEDA HS measurements.

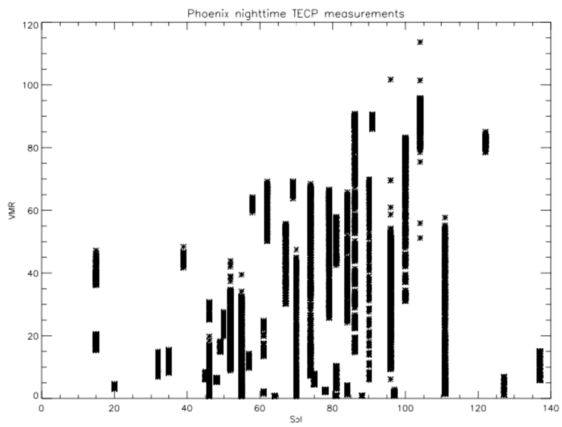

Figure 9. Phoenix nighttime TECP VMR values. Phoenix operated for 142 sols between Ls=76-150.

Summary:
The Perseverance MEDA RH sensor is working well and producing a rich dataset that is sure to expand our knowledge of water on Mars. The presentation will provide an overview of the dataset in more depth.

Bibliography: [1] Rodríguez-Manfredi *et al.,* 2014, [2] Savijärvi *et al.,* 2019a, [3] Tamppari and Lemmon, 2020, [4] Martínez et al., 2016, [5] Martín-Torres *et al.,* 2015, [6] Rivera Valentín *et al.* 2018, [7] Martínez *et al.*, 2017; [8] Savijärvi et al., 2019b; Pla-García *et al.*, 2021, [10-12] Zent *et al.*, 2009; 2010; 2016, [13] Fischer *et al.*, 2019, [14] Gómez-Elvira *et al.*, 2014; [15] Harri *et al.*, 2014.