THE PHOENIX LANDER'S RELATIVE HUMIDITY SENSOR RECALIBRATION: NEW RESULTS AND ANALYSIS. E. Fischer[1], G. M. Martínez[1], and N. O. Rennó[1], [1]University of Michigan, Ann Arbor, Michigan, USA.

Introduction: The Thermal and Electrical Conductivity Probe (TECP) is a payload on the Phoenix Lander aimed at measuring the exchange of heat and water in the Martian polar terrain. One of its instruments is a capacitive relative humidity (RH) sensor, the first of its kind on the Martian surface [1].

Until recently only the raw, unprocessed output of the TECP RH sensor was available in NASA's Planetary Data System (PDS), due to uncertainties in its pre-flight calibration, which partially overlapped the environmental conditions found at the Phoenix landing site [2]. The sensor's calibration was revised in 2016 to correct for inaccuracies at the lowest temperatures by using three additional calibration points obtained from in-flight data [3], and the new processed RH values were recently posted in the PDS.

Here, we show the results of a novel technique to further recalibrate Phoenix's RH sensor in the entire temperature, pressure and humidity range observed on Mars with an improved coverage using a spare engineering unit of the TECP in our environmental chamber.

Previous Calibrations: The original calibration of the TECP RH sensor covered a range of frost points from 194 to 263 K, and a range of temperatures from 208 to 303 K (with corresponding RH values in the range of ~0% to ~55%) (Fig. 1, red points). A calibration function of the form $RH = f(DNRH, T_b)$ was produced [1], where T_b is the temperature of the TECP board where the RH sensor is mounted, *DNRH* is the raw output of the TECP RH sensor, and *RH* is the processed relative humidity derived from the frost point temperature (T_f) and the board temperature.

Values of *DNRH* and T_b covered in the original calibration only partially overlap the environmental conditions found at the Phoenix landing site, as shown in Fig. 1 (gray points). Therefore, high-level RH values processed using the calibration function presented uncertainties at midday (when T_b is high and *DNRH* is low), and at dawn (when T_b is the lowest) because the calibration data set is sparse at these conditions. An updated calibration function added three additional data points at very low temperatures (<200 K) while assuming a saturated atmosphere, resulting in new high-level RH values presented in [3]. Nonetheless, large parts of the observed in-situ conditions remain sparsely covered by the calibration.

A Novel Recalibration of the RH Sensor Flight Unit using a Spare TECP Engineering Unit: We are producing high-level RH data by significantly augmenting the existing calibration data set. We are simulating the entire range of low-level RH data shown in Fig. 1, including the environmental conditions not covered during preflight tests, in our Michigan Mars Environmental Chamber (MMEC) using a reference hygrometer [4] and the spare TECP engineering unit.

First, we obtain a "translation function" $DNRH_{eu} = g(DNRH_{fu}, T_b)$, relating the engineering unit *DNRH* output (Fig. 1 blue) to that of the flight unit (red) at the same environmental conditions by covering the preflight flight unit calibration with the engineering unit. Using this function we transform the insitu measurements (gray) into the dynamic range of the engineering unit (black). Second, we cover the entire range of transformed environmental conditions (black) in sufficiently small steps in T_b and *RH*, to find a new calibration function for the engineering unit $T_f = f(DNRH_{eu}, T_b)$, which is then used to calculate high-level RH data for the flight unit.

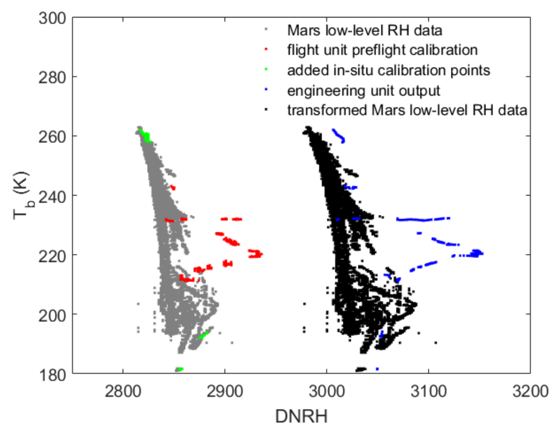

Figure 1. The TECP preflight calibration (red) only partially overlaps the recorded RH measurements at the Phoenix landing site (gray). We use the output of a TECP engineering unit (blue) at the same environmental conditions as the preflight calibration (red) and at additional known landing site conditions (green) to transform the insitu measurements (gray) into the dynamic range of the engineering unit (black). We then cover this entire range of T and RH conditions (black) to calibrate the engineering unit and find a recalibration for the flight unit.

Results of our Recalibration: Results of our recalibration are shown in Fig. 2. The recalibrated data shows saturated conditions at nighttime after about sol 90 (top), consistent with independent observations of near-surface fog [5]. Moreover, inferred values of the maximum diurnal water vapor pressure (bottom) increase during roughly the first half of the mission, reaching the maximum around sol 80 and then decrease during the second half. This trend is consistent with independent water vapor pressure estimations from satellite (Fig. 3). Furthermore, the range of values obtained in our recalibration is of the same order of magnitude as that from satellite estimations (Fig. 3).

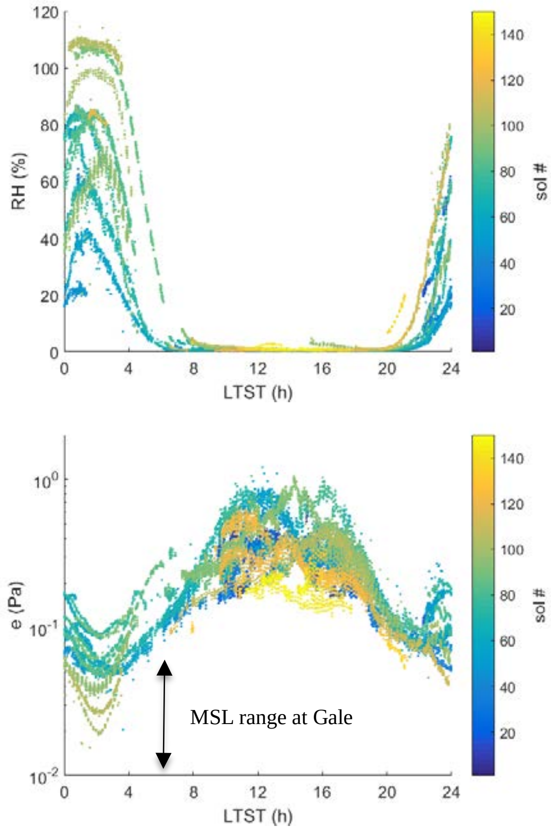

Figure 2. The recalibrated TECP RH sensor measurements at the Phoenix landing site color-coded by sol number as local relative humidity at the sensor location (top) and the resulting water vapor pressure (bottom) over local time. The range of water vapor pressure at the MSL landing site is shown for comparison at 6 am [6].

Comparison with Past Calibrations: Fig. 4 shows a comparison of the data obtained by our recalibration compared to previous calibrations [1,3]. Even though our recalibration shows nighttime values similar to those currently available in the PDS (based on [3]), daytime values differ by nearly an order of magnitude (compare yellow and orange points). Our daytime values are consistent with those of the first calibration (compare yellow and blue points), as well as with orbital estimations (Fig. 3).

We plan to shed light on this discrepancy and make our recalibrated humidity values available in the NASA PDS.

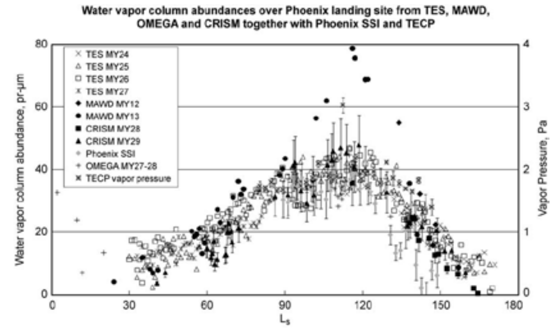

Figure 3. Orbital and in-situ estimates of water vapor pressure at the Phoenix landing site based on other instruments for comparison. The TECP data shown here are based on the 2009 calibration. The water vapor pressure values obtained from our recalibration are in the range of the values shown here. Figure adapted from [2].

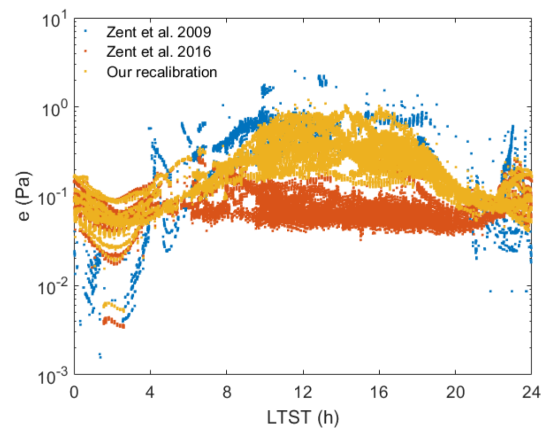

Figure 4. Comparison of our recalibrated TECP data with past calibrations [1,3] showing the diurnal cycle of the water vapor pressure. Our results show near-noon water vapor pressure values similar to the original 2009 calibration (as inferred from orbital measurements in Fig. 3), and nighttime water vapor pressure values similar to the 2016 calibration.

References: [1] Zent A. P. et al. (2009) *J. Geophys. Res.*, *114*, E00A27. [2] Tamppari L. K. at al. (2010) *J. Geophys. Res.*, *114*, E00E17. [3] Zent A. P. et al. (2016) *J. Geophys. Res. Planets, 121*, 626-651. [4] Fischer E. et al. (2016) *Astrobiology*, *16 (12)* 937-948. [5] Whiteway J. A. (2009) *Science*, *325*, 68-70. [6] Martínez, G. M. et al. (2017) *Space Sci. Rev.*, 1-44.