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Analysis of Recalibrated Phoenix Relative Humidity Sensor Data

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1. Introduction

The Phoenix Lander mission carried the Thermal and Electrical Conductivity Probe (TECP) to investigate heat and water exchange between the surface and the atmosphere close to the Martian North Pole. One of its sensors is a capacitive relative humidity (RH) sensor, the first to measure humidity at the Martian surface [4]. Due to preflight calibration uncertainties, only unprocessed sensor output data was available in NASA's Planetary Data System (PDS) until recent efforts in improving the calibration, which corrected for low temperature inaccuracies by using three new calibration points obtained from in-flight data [5]. We have further improved the RH sensor's calibration in the entire range of temperature and RH observed on Mars, with focus on the warmest and driest conditions achieved during daytime, using a novel technique that involves testing a spare engineering unit of the TECP at Martian conditions in our environmental chamber. Here we give an overview of our methodology and results and discuss recent improvements of the recalibration and sensitivity studies.

2. Preflight Calibration

Values of TECP board temperature (T_b), frost point temperature (T_f) and resulting raw output of the RH sensor (*DNRH*) that were covered in the pre-flight calibration only partially overlap the environmental conditions at the Phoenix landing site (Fig. 1, red and gray points). This resulted in large uncertainties in the calibration of the RH values, especially around noon (when T_b is high), and dawn (when T_b is low). 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 [5]. Nonetheless, large parts of the observed in-situ conditions, particularly the warmest and driest conditions achieved during daytime, remained sparsely covered by the calibration.

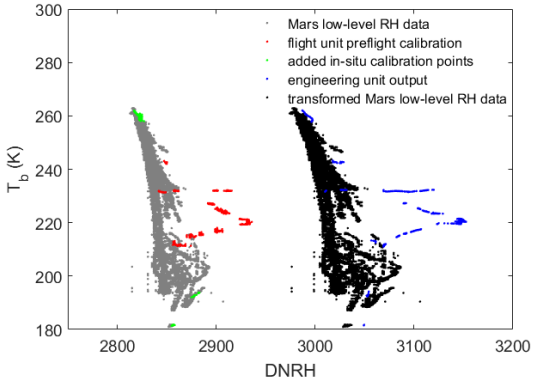

Figure 1: The TECP preflight calibration (red) only partially overlaps the recorded RH measurements at the Phoenix landing site (gray). We use the output of a TECP engineering unit (blue) at the same environmental conditions as the preflight calibration (red) and at additional known landing site conditions (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.

3. A Novel Recalibration Method

We use a spare engineering unit of the TECP in combination with a reference hygrometer in our environmental chamber to significantly augment the calibration data set and to improve the calibration function. Being able to accurately simulate the entire range of polar Martian environmental conditions allows us to produce high level RH data from the existing raw output of the TECP flight unit [1]. First, to ensure comparability of the TECP engineering unit output (Fig. 1, blue) with that of the flight unit (Fig. 1, red), we obtain a "translation function" $DNRH_{eu} = g(DNRH_{fu}, T_b)$ by covering the preflight flight unit calibration with the engineering unit. To improve the accuracy of this function we use additional in-situ measurements at the lowest and highest end of the T_b range (Fig. 1, green). At the lower end we can safely

assume saturated RH conditions based on independent and contemporaneous data sets [3], whereas at the higher end we assume maximum water vapor pressure (e) values between 1 and 10 Pa based on satellite retrievals of atmospheric water content and numerical modeling [2]. Second, we cover the entire range of transformed environmental conditions (black) 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.

4. Recalibration Results and Comparison with Previous Data

Our recalibration function yields the most accurate results when a maximum water vapor pressure (e) of 2 Pa is assumed. Results of our recalibration are shown in Fig. 2. Sensitivity studies of this assumption between 1 and 10 Pa show resulting maximum errors of 30%. Values of e increase during roughly the first half of the mission, until around sol 80 and then decrease. This trend and the range of values obtained are consistent with independent estimations of e from satellite [2]. The recalibrated relative humidity at 2 m above the surface based on Phoenix MET data shows saturated conditions at nighttime after sol ~80 (Fig. 2, middle), consistent with independent observations of near-surface fog [3]. Fig. 2 (bottom) shows a comparison of the data obtained by our recalibration compared to previous calibrations [4,5]. Even though our recalibration shows nighttime values similar to those currently available in the PDS [5], daytime values differ by an order of magnitude (regardless the e assumption at the warmest conditions). Our daytime values resemble those of the first calibration.

Acknowledgements

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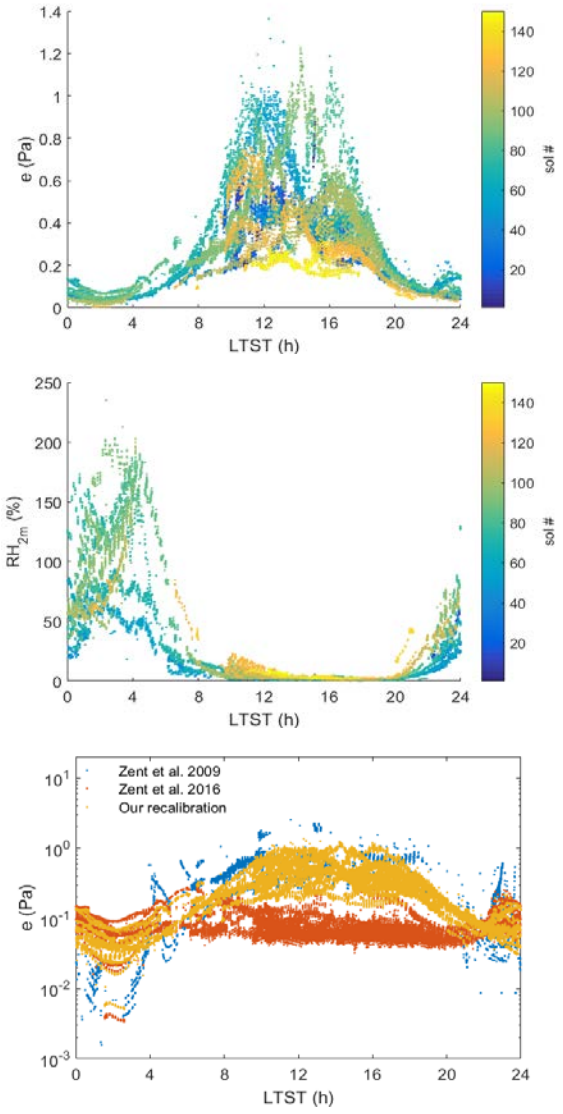

Figure 2: The recalibrated TECP RH sensor measurements color-coded by sol number in terms of water vapor pressure (top) and relative humidity at 2 m height (middle) over local time and comparison with past calibrations (bottom).