FIRST RESULTS OF THE RELATIVE HUMIDITY SENSOR ON BOARD M2020 PERSEVERANCE ROVER

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Introduction:
MEDA HS is a relative humidity sensor for Mars 2020 Perseverance rover [1] provided by the Finnish Meteorological Institute (FMI). MEDA HS is a part of Mars Environmental Dynamic Analyzer (MEDA), a set of environmental sensors provided to NASA by the Centro de Astrobiología (CAB) at the Instituto Nacional de Técnica Aeroespacial in Madrid, Spain [2].

MEDA's principal goals are to provide continuous measurements that characterize the diurnal to seasonal cycles of near-surface environment and local environmental dust properties. The main scientific goal of the humidity sensor is to measure relative humidity of the Martian atmosphere near the surface and to complement the previous Mars mission atmospheric measurements for better understanding of the Martian atmospheric conditions and the hydrological cycle. Relative humidity has been measured from the surface of Mars previously only by Phoenix and Curiosity so MEDA HS will provide valuable data from the near surface environment [3,4,5].

Accuracy of the sensor calibration has been analysed in detail and assessment of sensor performance after landing on Mars confirms that the calibration has been successful and sensor performance is as expected. MEDA HS has been operating on Martian surface for over 400 sols without issues and is providing high quality data for the science community. This presentation describes the MEDA HS sensor and the first results from M2020 mission.

MEDA humidity sensor description:
The MEDA HS is a humidity instrument which measures relative humidity. MEDA HS is built around the capacitive HUMICAP® sensor technology by Vaisala and the reading electronics are based on an oscillator transducer that converts the capacitance of the sensors into frequency.

Each HUMICAP sensor head has its own temperature sensor: on-chip platinum Pt1000 platinum resistance thermometer (PRT). Pt1000 sensors are read by the MEDA Instrument Control Unit (ICU) and they are used for two purposes. $Pt1000_1$ with 2-wire measurement is used for monitoring regeneration temperature, and $Pt1000_2$ with 4-wire measurement is used for for scientific temperature measurement during nominal operation. Having the reference temperature measurement in the actual HUMICAP sensor chip is a major improvement compared to the previous generation sensors.

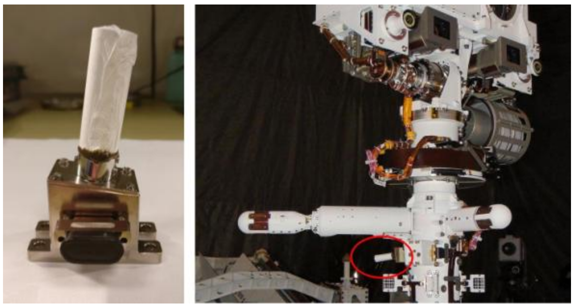

Figure 1: Left: MEDA humidity sensor assembly. The PCB and sensor heads are located inside the cylindrical part covered with white PTFE filter to protect from dust. Right: MEDA HS location in the remote sensing mast. Credit: NASA/JPL-Caltech

MEDA HS operational modes:
Humidity sensor operations are controlled by ICU's flight software. In the beginning of the mission MEDA nominal operational cadence was to measure autonomously around the clock, 1 hour on and 1 hour off alternating between even and odd hours. The nominal acquisition of HS is to get readings from all transducer channels with 1 Hz interval. The HUMICAP sensor heads react to the surrounding relative humidity even when the sensor is off so after powering on the relative humidity can be read almost instantly. After 1 s the readings are considered reliable and during HS calibration seconds 2-5 are averaged to get the most accurate reading of the sensor. Self heating will start to affect the readings after few seconds.

The HS has two operational modes: *high-resolution interval mode (HRIM)* and *continuous mode*. In HRIM the HS is powered on only for 10 seconds and then powered off to avoid self-heating. HRIM can be used with different intervals and 15 minute and 5 minute intervals are configured in MEDA. In continuous mode the sensor stays powered on for long periods. Both HRIM and continuous mode can be used in HS operations considering the advantages and limitations of each mode. HRIM is best for measurements requiring the best accuracy but temporal coverage is better in continuous mode.

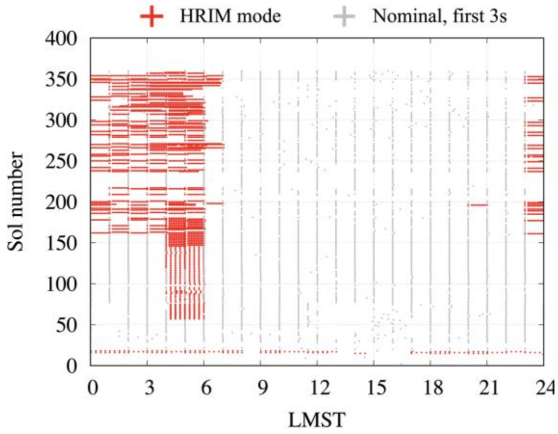

Figure 2: Measuring cadence of different measurement modes of the MEDA HS. High accuracy HRIM measurements have been used during the peak RH hours of the sol.

MEDA HS maintenance regeneration:

Regeneration heating can be performed periodically to remove any possible contaminants from the sensor head. The HUMICAP sensor heads are heated to 160°C - 170°C which also removes the CO_2 absorbed in the sensor polymer. This operation causes a temporary recovery effect in the RH readings for few sols when the daytime RH rises and nighttime RH drops. We recommend not using 2 sols right after each regeneration at all, sols 3-10 can be used with increased uncertainty. After 10 sols the readings can be used normally. Very first regeneration of the HS was in sol 63 and we don't recommend using HS data before that. Following regenerations have been performed on sol 74 and 180 so the data between the sols 63-80 and 180-190 are compromised.

MEDA HS data products:

The main data products of the MEDA HS are the local relative humidity, local sensor temperature and water vapour volume mixing ratio (VMR). The derived relative humidity is the average of both sensor heads. Local temperature is sensor temperature and measured from $Pt1000_2$ sensor integrated in HUMICAP sensor head. Relative humidity is given relative to ice. The sensor temperature is not the same as local atmospheric temperature so it needs to be taken into account when using the relative humidity data. The HS data is archived and published in the Planetary Data System (PDS) for further use of the scientific community.

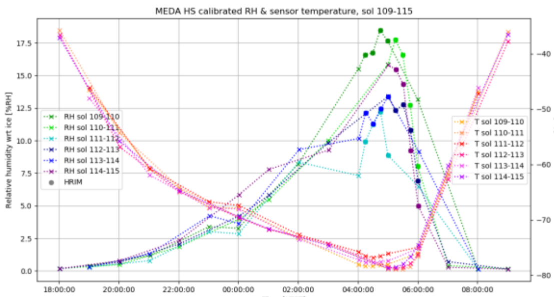

Figure 3: Example of daily relative humidity and sensor temperature from sols 109-115. Only high accuracy measurements are included.

Daily relative humidity cycle and nighttime VMR:

MEDA has been measuring the environmental parameters around the sol day and night. An example of daily relative humidity and sensor temperature can be seen in Figure 3. Relative humidity reaches its maximum value in dawn before sunrise when the temperature is lowest. After sunrise the RH drops close to zero. While HS does show these low daytime values, the humidity is below the accuracy of the sensor and the readings are not scientifically useful.

VMR is derived from RH readings only when the relative humidity is high enough (for example >2% RH is a good limit) to give meaningful readings. Figure 4 shows an example of nighttime VMR measurements and Figure 5 shows maximum RH up to sol 299.

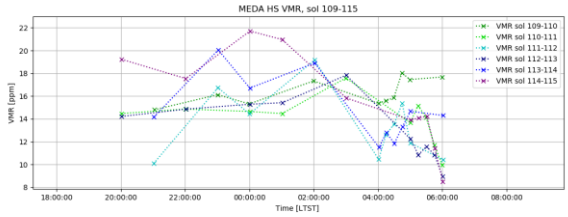

Figure 4: Example of nighttime VMR values derived from RH. During day the relative humidity is close to zero and the relative uncertainty is large and would lead to very large uncertainties in daytime VMR values.

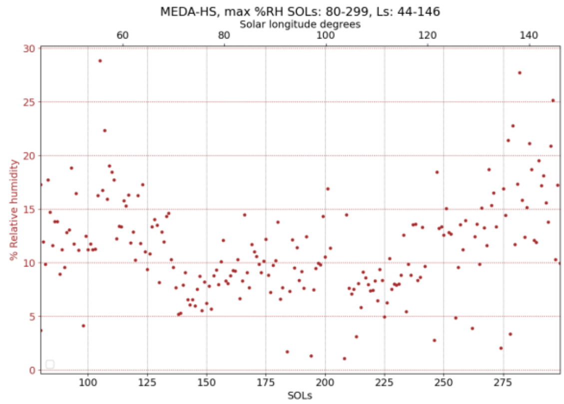

Figure 5: Maximum relative humidity values measured by MEDA HS up to sol 299. RH is referenced to sensor internal temperature.

Seasonal changes:

Perseverance rover has been on the surface of Mars for over 400 sols and seasonal changes begin to show in the MEDA HS data. Figure 6 shows the changing daily cycle of relative humidity and Figure 7 the evolution of nighttime VMRs. The landing was during the spring season and VMR started to rise towards the summer. Gaps in the data are due to operational limitations like the solar conjuction. For meteorological predictions for Jezero crater see for example Pla-García (2020) [6].

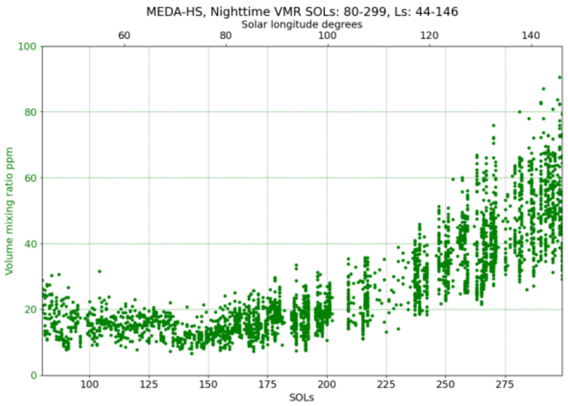

Figure 6: First 299 sols of nighttime VMR values provided by MEDA HS

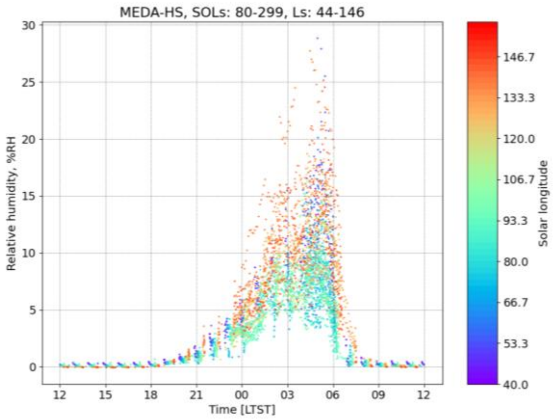

Figure 7: First 299 sols of daily relative humidity profiles provided by MEDA HS.

Conclusions:

MEDA HS on board the M2020 rover provides relative humidity readings of the near surface atmosphere. MEDA HS has operated flawlessly after integration to Perseverance rover, during cruise and finally after landing. The first measurements from the surface of Mars were as expected and the first regeneration cycles of the sensor heads has been performed successfully. A comprehensive measurement uncertainty analysis has been performed for the sensor and the results show that HS is providing high quality data from the Martian surface to provide important meteorological observations and to support MEDA and other M2020 investigations.

References:

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