Accuracy of the relative humidity sensor MEDA HS onboard Perseverance rover

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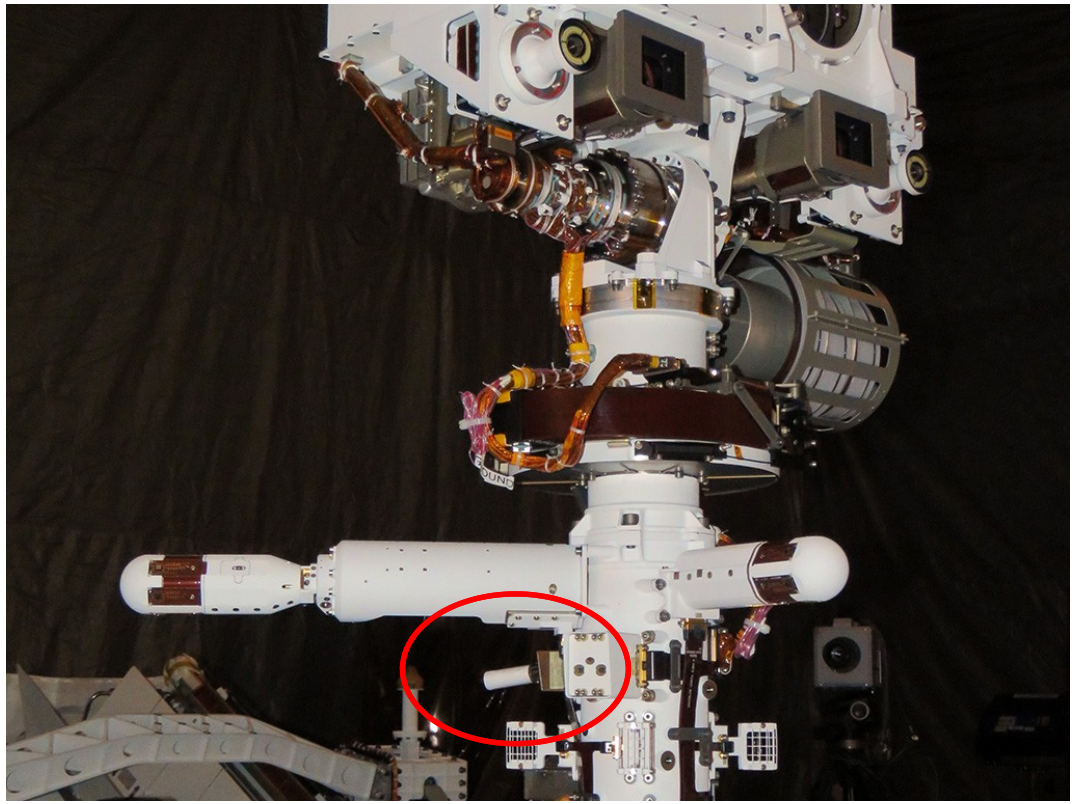
MEDA HS – Relative humidity sensor

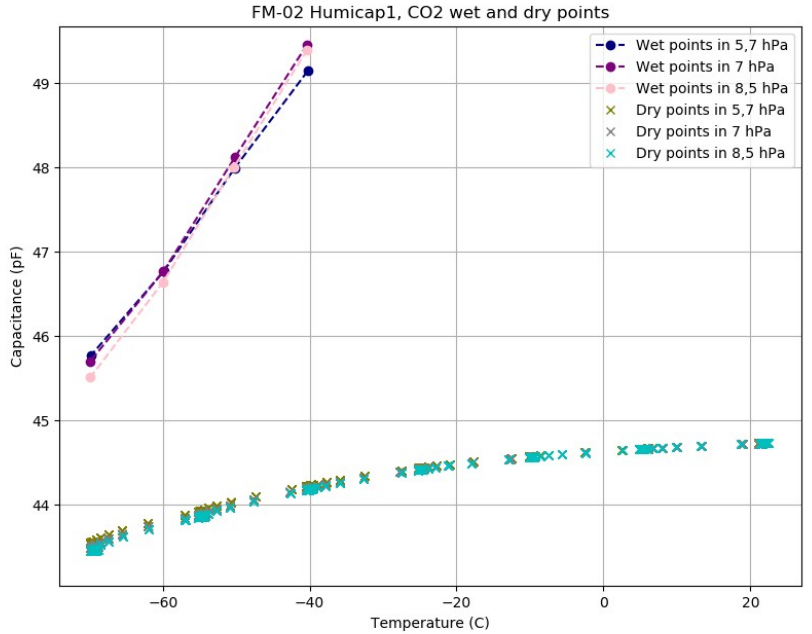
- Provided for M2020[1] by the Finnish Meteorological Institute (FMI)
- Part of the Mars Environmental Dynamic Analyzer (MEDA)[2] provided by by Centro de Astrobiología in Madrid, Spain
- MEDA HS is a successor of REMS-H on board Curiosity with some improvements:
  - New generation HUMICAP® sensor heads providing larger dynamic capacitance range and faster response
  - Temperature measurement from PRT integrated in the HUMICAP chip
- The relative humidity of the HS is referenced to the sensor's own temperature sensor. It might differ from the actual gas temperature in the environment.
- Water vapor volume mixing ratio (VMR) derived from the relative humidity, sensor temperature and local pressure is also provided. From the VMR it is possible to derive relative humidity in the ambient air using for example ATS data.
- MEDA HS RH and sensor temperature is available in PDS currently up to sol 299.[3]

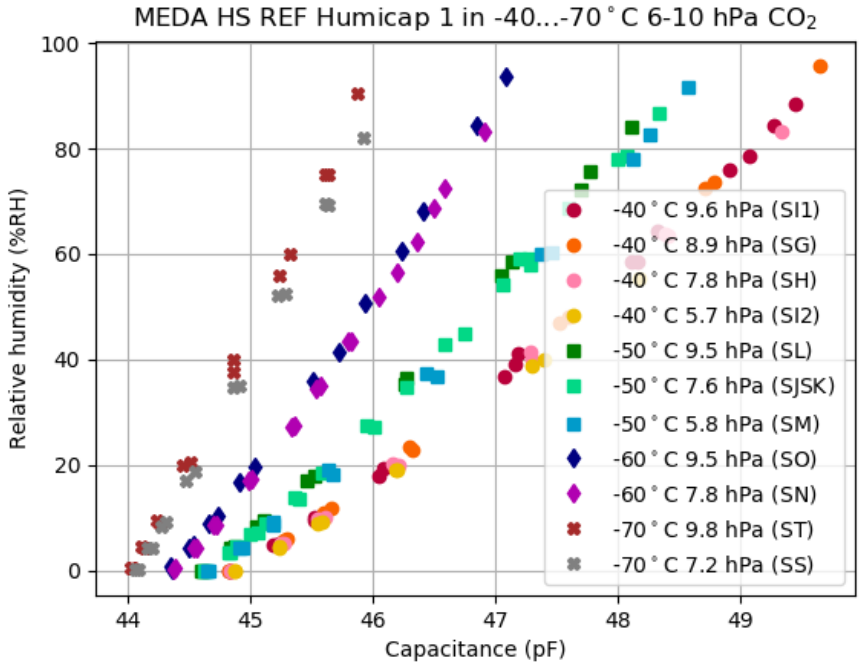


Credit: NASA/JPL-Caltech

Calibration

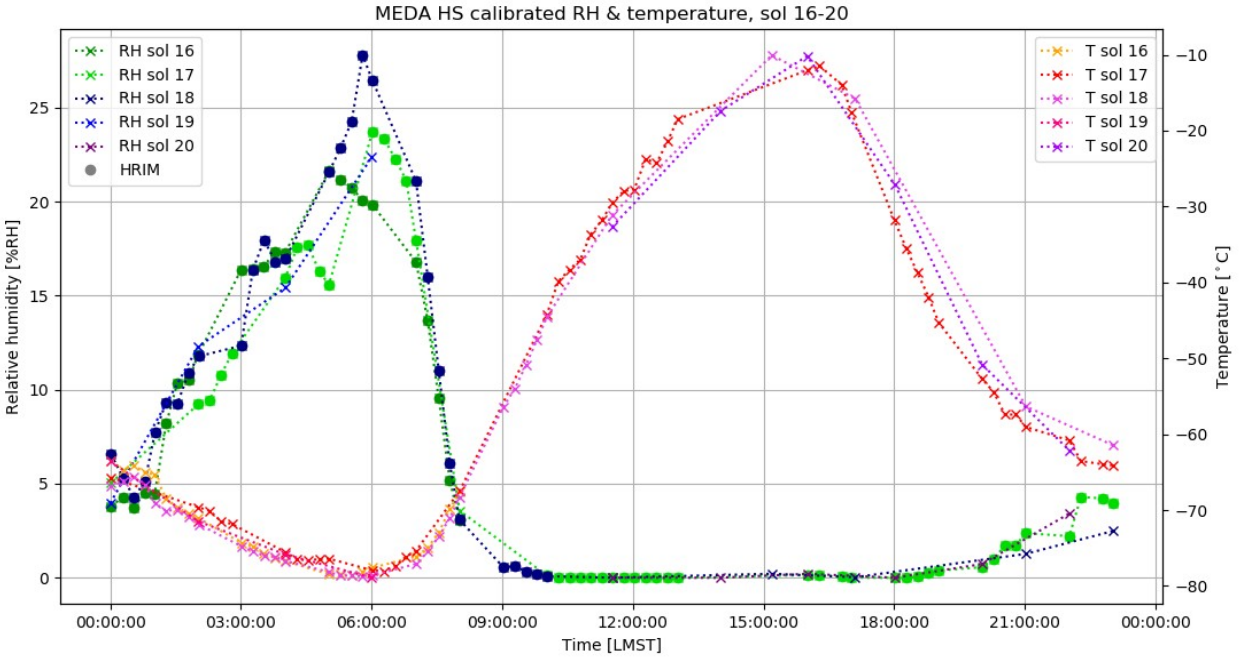
- HS flight model was tested at FMI together with flight spare and ground reference models in low pressure CO_2
  - Dry gas from +22ºC to -70ºC
  - Saturation conditions from -40ºC down to -70ºC
- Final calibration is complemented by calibration data transferred from the identical ground reference model
- Complementary measurements have been performed in Michigan Mars Environmental Chamber (MMEC)[5] and DLR PASLAB (Planetary Analog Simulation Laboratory)[6,7]
- Mars-like composition tested at DLR (3,7% air (ca. 2,96% N_2 and 0,74% O_2), 1,6% Ar and 94,7%CO_2), no difference to 100% CO_2
- Time constant is longer in colder temperatures and time response testing is challenging. According to tests performed in e.g. MMEC the time constant (63,2%) is ~2-3 minutes at -50°C and less than 30 min. at -70°C.

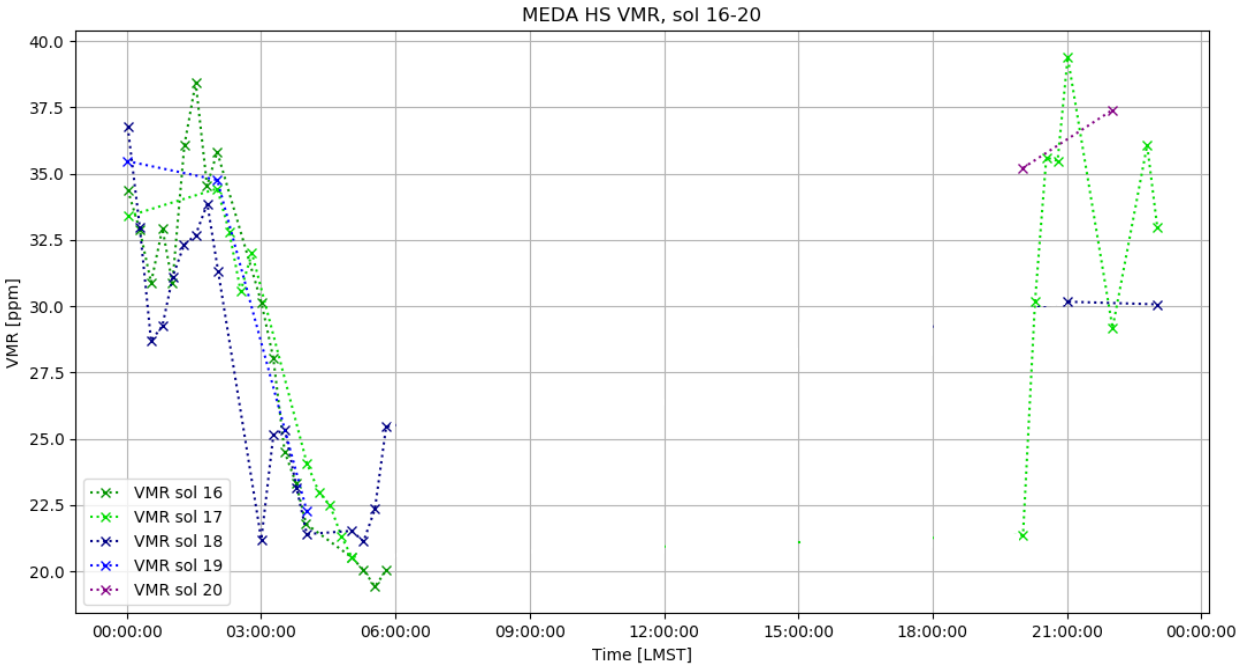




First results

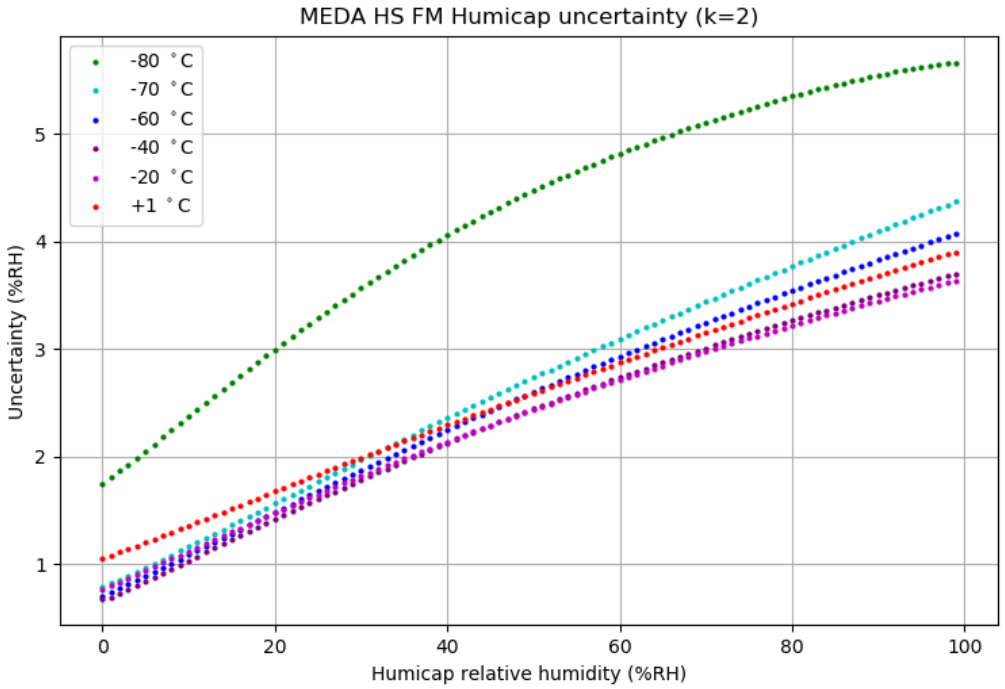
- All channels work without issues. Results are as expected compared to Jezero predictions[4].
- Data products: Relative humidity, sensor local temperature, and water vapour volume mixing ratio (VMR)
- Two HUMICAP® relative humidity sensor heads included. Calibrated values are very close to each other, their average used as the final local relative humidity.
- Temperature sensor integrated in the HUMICAP chip is used for calculation of the local relative humidity
- Nominal measurement mode: high-resolution interval mode (HRIM) which means switching the sensor on and off during MEDA measurement block to minimize sensor heating
- Derived VMR cannot be provided in daytime warm temperatures because of the very large uncertainty. Just 0.5%RH difference at -0°C results in thousands ppm difference in VMR





Uncertainty analysis

- The overall calibration uncertainty of MEDA HS has contributions from several physical terms:
  - uncertainty of the temperature sensors,
  - the reference pressure measurements,
  - the atmospheric reference pressure measurements,
  - the dew/frost point reference temperature measurements,
  - uncertainty contributed by fitting residuals,
  - uncertainty contributed by empirical thermodynamic equations and
  - the calibration information transfer from REF to FM.
- The main uncertainty contribution is the non-linearity represented by the residual of the **calibration curve fitting.** → A compensation model was developed during the uncertainty analysis to minimize the fitting residuals
- Finally the uncertainty is a function of temperature and relative humidity



Relative humidity uncertainty in some temperatures. Uncertainty below -70°C is larger because the lack of calibration data.

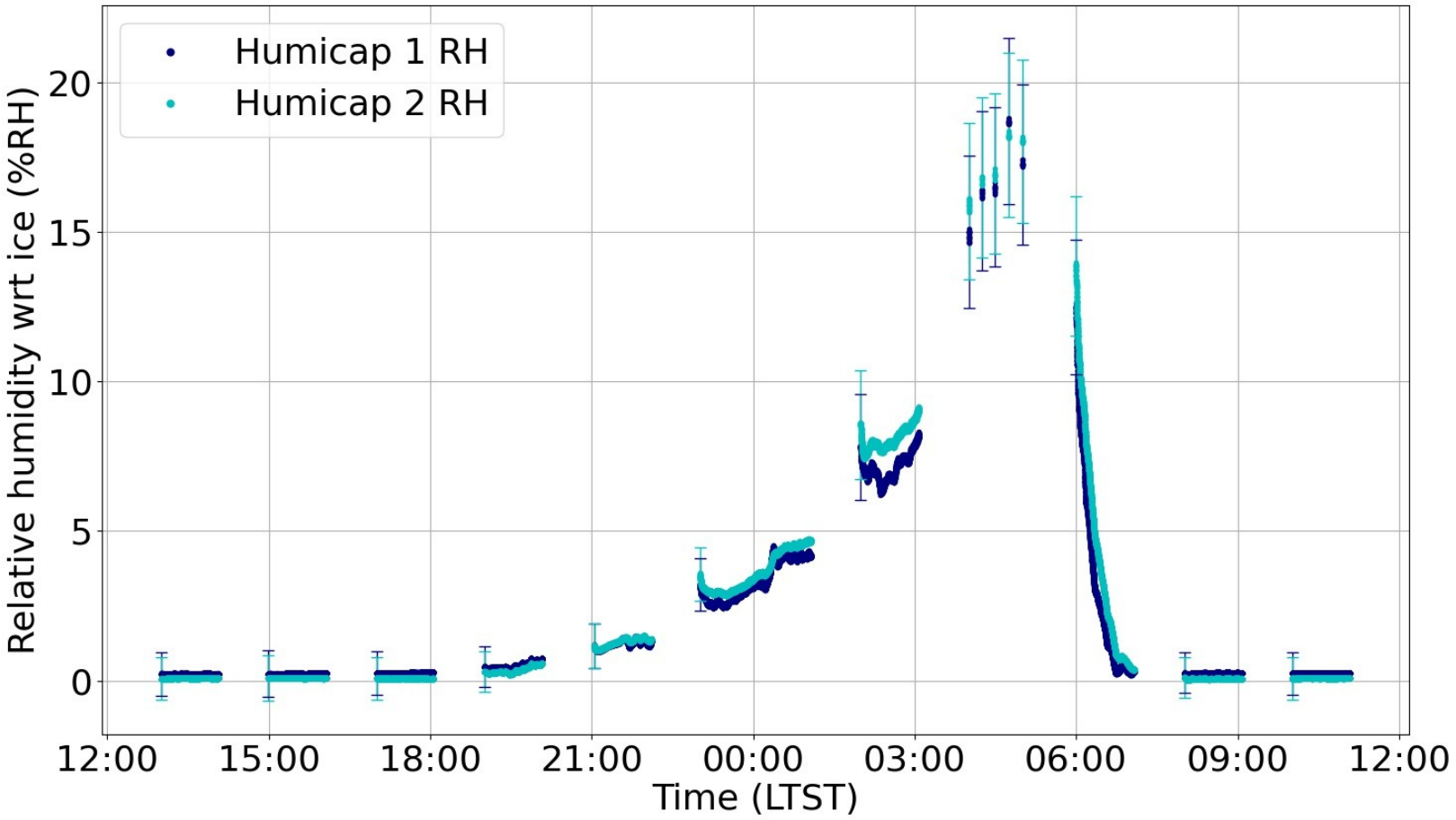
NOTE: A calibration uncertainty budget differs from a measurement uncertainty. The analysis was performed by using calibration data from laboratory measurements and the changing environment on Mars can affect the measurement uncertainty.

MEDA HS accuracy

The uncertainty applied to MEDA HS relative humidity data in practice. HRIM measurements give the best accuracy and the uncertainty is shown here as error bars. During the highest RH during one sol the temperature is also lowest resulting in larger error bars. During the day the relative uncertainty is large compared to RH readings and therefore daytime RH is not scientifically very meaningful.

The performance of the two HUMICAP sensor heads is very similar in terms of accuracy, but they have some difference in dynamic behavior. Currently the derived RH is the average of both sensor heads.

During continuous mode the HS experiences self heating and the current uncertainty can be applied to first seconds of the data. The continuous mode measurements can be used to investigate the short term dynamic phenomena but with larger error margin.



References & more information

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