The detection of spectral signatures with IRS/SuperCam, Perseverance rover: instrument performance.

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Introduction: The Perseverance rover (Mars 2020 mission, NASA) landed in Jerezo, the host crater of a paleolake, on February 18th 2021. Its main objective is the search for evidence of past habitability and the presence of potential biosignatures [1]. Amongst its science payload, the SuperCam instrument (LANL, JPL, and a consortium of French and Spanish laboratories) plays a central role in the geochemistry investigation by providing rapid, synergistic, fine-scale mineralogy, chemistry, and color imaging [2, 3]. In particular, it carries the first near-infrared spectrometer, IRS, to be operated on the Martian surface. IRS is a miniaturized point spectrometer (~1.15 mrad field of view) located in the SuperCam's mast unit. Its spectral range (1.3 – 2.6 µm range) covers major silicate and hydrated mineral absorption features. It extends the 0.4 – 0.85 µm range of other SuperCam spectrometers to the near IR. IRS is an AOTF (Acousto-Optic Tunable Filter) based spectrometer, meaning that the light filtering is performed by a crystal excited by an acoustic wave, itself generated from a radiofrequency (RF) signal [4].

Instrument calibration: The AOTF technology allows unprecedented compactness and robustness, with excellent performance (SNR, spectra resolution, sensitivity). However, this type of monochromator is sensitive to internal thermal effects. These effects have been calibrated during the dedicated ground calibration [5]. This calibration shall be extended with new inputs from use of the instrument in real conditions, about sensitivity (I/F) to the instrument temperature. A dedicated flight calibration is currently

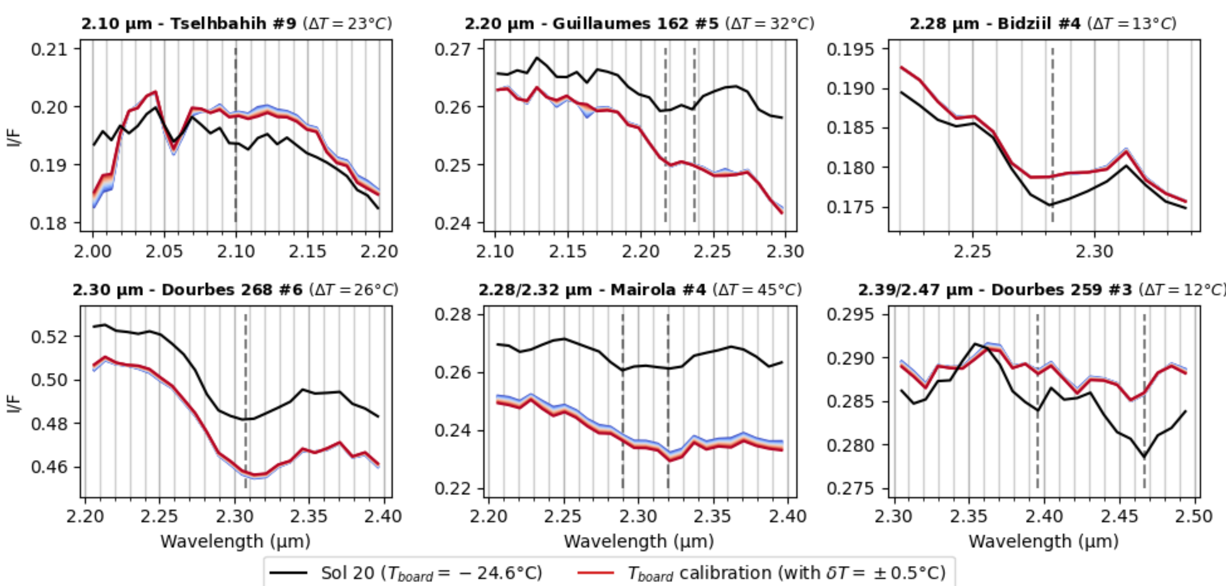

Figure 1: Sensitivity of various spectral signatures in the 2.0 – 2.5 µm range, the most sensitive to thermal effects, illustrated on the most representative observations. In each panel, the black line is the current flight calibration based on Sol 20 White SCCT observation, the color lines are the IR board temperature (T_{board}) calibration and the color gradient indicates its sensitivity at ± 0.5°C, corresponding to the T_{board} measurement precision. Dashed vertical lines highlight the detected absorption features. The temperature shift in parenthesis is the T_{board} difference between Sol 20 and the observation.

in progress to characterize these effects and provide unbiased reflectance spectra.

The actual state of the calibration, released in the NASA's Planetary Data System (Nov. 2021), relies on the observation of the IR White SuperCam Calibration Target (SCCT) [6] as a reflectance reference, and various algorithms to remove anomalous spectral points, atmospheric spectral signatures and increase the global signal to noise ratio (SNR). Finally, data are converted into reflectance using a local illumination model. The thermal behavior of IRS is still under study to derive a correction vector to the instrument transfer function (ITF) beyond what was done on the ground, and mostly above 2.0 µm. The main thermal effect is the sensitivity of the RF power generator to the temperature of its electronic board (called T_{board}). The data acquired so far allow to estimate potential biases and the detection limits of diagnostic spectral features, induced by this thermal effect (Fig. 1). The thermal calibration is thus derived from the interpolation of every IR White SCCT measurements over their value of T_{board} (Fig. 2).

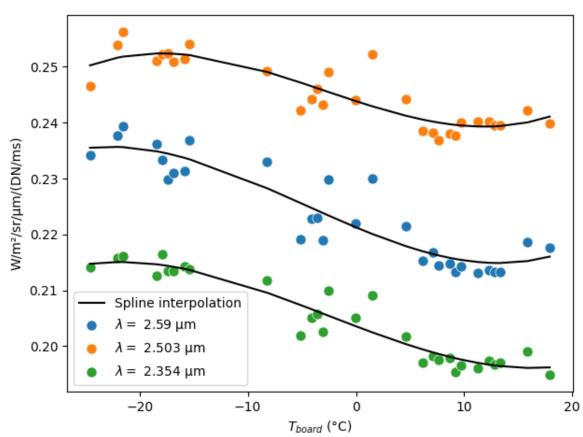

Figure 2: variation of the instrument response (ITF) with T_{board} for three sensitive wavelengths and their spline interpolation

Updated sensitivity from flight calibration: After about 300 Sols of exploration of the two geologic units Cf-fr and Seitah (up to Dec. 2021), many spectral features have been identified in the near-IR range and attributed to various primary and altered minerals, and salts [7]. The detection of these features is sensitive to the instrument calibration through several effects, illustrated in Fig. 1, mainly in the 2.0 – 2.6 µm range. The first effect of the thermal calibration is the absolute reflectance shift, which is stronger for important temperature differences between the reference (Sol 20) and the actual measurements. More locally, the 2.28 and 2.30 µm spectral signatures are often shifted by ~ 10 nm and some other signatures are less deep or even disappear. The calibration's intrinsic sensitivity to T_{board} is also assessed within the precision of the IR board thermal probe (± 0.5°C). It corresponds to an additional error on the evaluation of the absolute level of the reflectance and is very faint (< 1 %) and stronger for high T_{board}. The 2.5 – 2.6 µm range is particularly affected by temperature shifts due to a strong sensitivity of the instrument response.

Discussion: The effects of the IR board dependence with temperature are still under investigation. Lab measurements on IRS flight spare are ongoing to better constrain the behavior of the ITF than using only White SCCT observations – which are sensitive to photometric effects, aging – and then calibrate flight data. Notwithstanding the difference between Sol 20 and T_{board}-dependent calibrations, and photometric effects, the IRS' thermal behavior and SNR allow high confidence into the absolute reflectance, with a precision of a few percent (compliant with the required absolute precision of 20 %).

References: [1] Farley et al. (2020) Space Sci. Rev. 216.8, [2] Wiens et al. (2020), Space Sci. Rev. 217.1, [3] Maurice et al. (2021) Space Sci. Rev. 217.3, [4] Fouchet et al. (2022) Icarus 373, [5] Royer et al. (2020), RScI, [6] Manrique et al. (2020), Space Sci. Rev., [7] Mandon et al (2022), this conf.