A 'Round-Robin' inter-comparison of spectral emissivity measurements made in different international laboratories

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1 Introduction

Background

- Emissivity (the ratio of thermal radiation emitted by a body to that from a perfect blackbody) is essential for remote sensing of land surface temperature (LST) among other applications
- It is wavelength-dependent and commonly measured in laboratories with Fourier Transform InfraRed (FTIR) spectrometers, with some results available in online spectral libraries e.g. the ECOSTRESS (formerly ASTER) spectral library (Baldridge et al., 2009)
- Despite wide use of these spectral libraries, there has been relatively little work comparing the results from different laboratories

Objectives

1. To investigate the **consistency of measurements** made in different international laboratories
2. To assess the **impact of any differences** from these types of measurements on LST evaluation

2 Method

Participants from **8 international laboratories** in Europe, US and Australia

2 artificial samples (aluminium + gold sheets laminated in polyethylene) were measured, with specular and Lambertian characteristics respectively

13 different instruments and setups were used in their standard setups, all measuring directional hemispherical reflectance (ρ) over 2.5 – 14 μm at 4 cm^{-1} and 8 cm^{-1}.

Emissivity (ε) spectra were calculated from each reflectance spectra using **Kirchhoff's Law** ($\varepsilon = 1 - \rho$). Spectra were then convolved to ASTER bands 10 – 14 (centered at 8.3 μm, 8.7 μm, 9.1 μm, 10.6 μm and 11.3 μm respectively) to get **band-specific emissivities** for each participant measurement. **Corresponding LSTs were calculated** as in Guillevic et al. (2018), assuming a surface brightness temperature (BT) of 300K, sky temperature of 260K and near-surface observation (with negligible atmospheric transmissivity or path radiance effects).

WANT MORE INFO?

Further information on participant setups and measurement techniques is available at https://tinyurl.com/y3tabkhn and through the QR code.

3 Results

Consistency of measurements

- For both samples, there are **absolute emissivity differences** evident in the measured spectra across the full wavelength range (Fig. 1) with mean emissivity differences for Samples 1a and 2a over 2.5 – 14 μm of 0.44 and 0.77 respectively. Each measurement technique in this plot is described in the online methods.

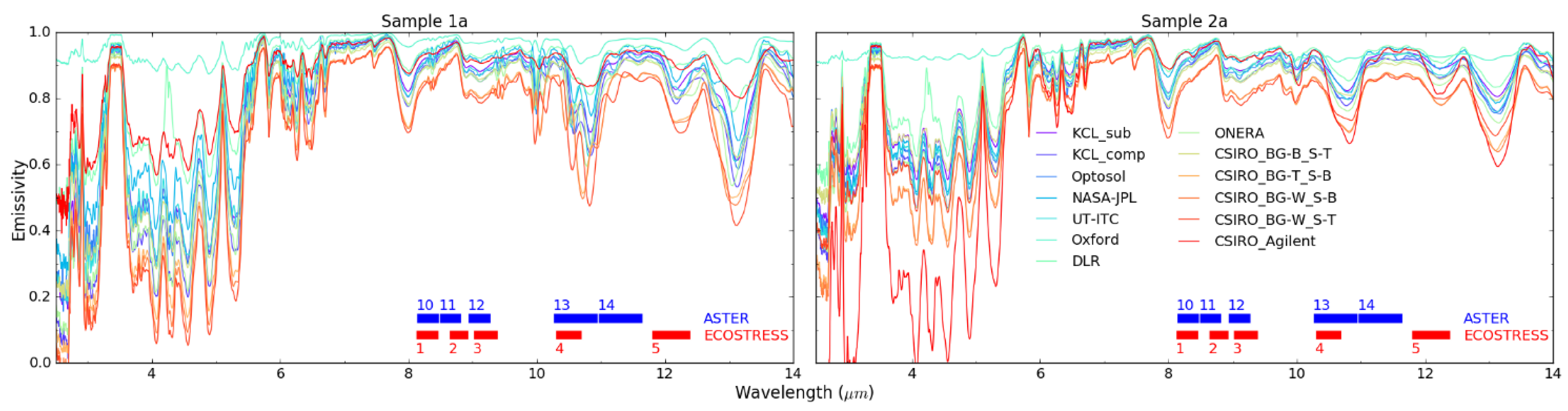

Fig 1: All participants' emissivity measurements for both samples over 2.5 – 14 μm with ECOSTESS and ASTER thermal band locations shown.

- **Spectral shape is generally consistent** between participant measurements for the Lambertian sample **(Sample 2a)**, with the exception of those made at Oxford and CSIRO using the handheld Agilent FTIR (Fig. 1)
- **Wavelength shifts** of up 0.08 μm to are evident in the specular sample spectra **(Sample 1a),** particularly in the 10 – 11 μm spectral region (Fig 2). These shifts are not observed with the sample with Lambertian properties (Sample 2a).

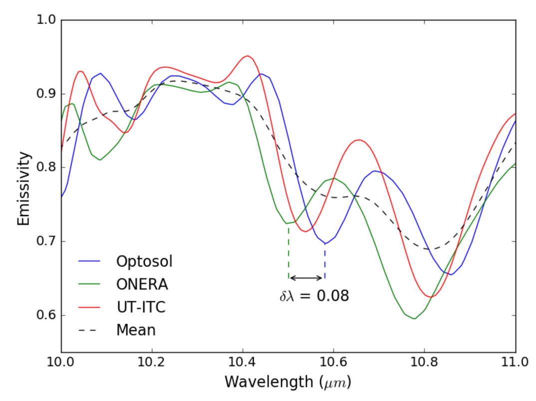

Fig. 2: A subset of the participants' measurements of the specular sample showing the wavelength shifts over 10 – 11 μm

Impact of differences

- Emissivities convolved to ASTER bands for both samples differed by over 0.10 for most bands, with greater range for the specular sample (Sample 1a). Calculated LSTs (Fig. 3) using these emissivities ranged by over 3.5 K in each band, with a **maximum difference of 21.3 K** (Sample 1a, Band 13). This corresponds with the area of wavelength shifts and increased atmospheric effects.

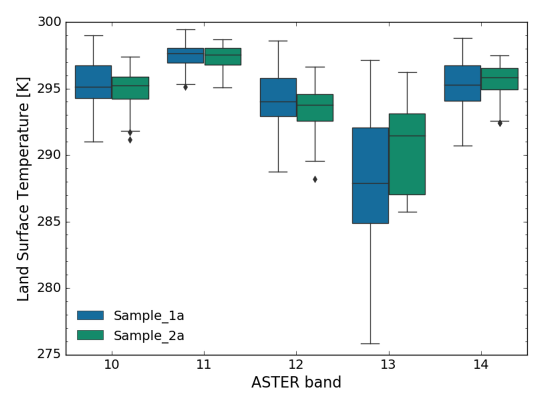

Fig. 3: Predicted LSTs (K) calculated assuming surface BTs of 300K and sky temperature of 260K and the measured emissivities for both samples convolved to ASTER TIR bands 10 – 14. See Fig. 1 for ASTER waveband locations.

4 Conclusions

- A **round-robin investigation into laboratory-based spectral emissivity measurements** was conducted. Eight international laboratories compared measurements of two specially prepared test samples with specular and Lambertian properties respectively
- **Spectral emissivity differences were observed** over the 2.5 – 14 μm range for both samples between the participant measurements
- **Wavelength shifts (~0.08 μm) were also observed** in the specular sample measurements
- The impact of these differences were assessed by calculating the equivalent LST of a near-surface observation with surface BT of 300K, sky temperature of 260K and emissivity equal to the measured emissivities convolved to ASTER bands 10 - 14
- **Calculated LSTs ranged by at least 3.5K**, with the variability wavelength dependent and with greater variability observed for the specular sample

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References

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