Simultaneous measurement of land surface temperature and emissivity using ground multiband radiometers

C. Coll, R. Niclòs, J. Puchades, V. García-Santos, J. M. Galve, L. Pérez-Planells, E. Valor
Thermal Remote Sensing Group, Department of Earth Physics and Thermodynamics, Faculty of Physics, University of Valencia, Spain

Abstract
The Thermal Remote Sensing Group of the University of Valencia (TRSG-UV) participated in the FRAMS57 field radiometer comparison at NPL in 2016, including the laboratory radiometer and black body comparison, the water surface temperature and the land surface temperature (LST) measurements. The aim of this paper is to show the methodology followed by the TRSG-UV team for field measurements of LST and emissivity. As opposed to water, land surface emissivity is not usually known for many ground covers, so an emissivity value has to be either assumed, or assigned from spectral emissivity libraries or measured for each land cover in order to retrieve emissivity from thermal infrared radiometric measurements. We used multiband CE-312 radiometers (five narrow bands in 8-13 μm) to simultaneously retrieve LST and band emissivities by means of the temperature-emissivity separation (TES) method for the different ground covers considered in the experiment (soil, sand, gravel, cover and tarmac). The TES method requires near-simultaneous measurements of ground-leaving radiances and sky-downwelling radiances; the latter measured using a gold reflectance panel. For each surface cover, TES provided the band emissivities in the five CE-312 bands and the LST in continuous radiances measurements performed over time. As a result of the experiment, we present the LST series and band emissivity values for the ground covers considered, together with a detailed LST uncertainty analysis including the uncertainties associated to the calibration of ground radiometers, the emissivity estimation by means of the TES method, and the sky radiance measurements, among others. According to these results, the total LST uncertainty was estimated at 0.4 – 0.5 K for the ground covers measured during the comparison.

Multiband radiometer CE-312-2. Calibration

A gold-coated mirror enables comparison between the target radiance and the radiation from the detector cavity. The temperature of the detector is measured with a calibrated PT1, thus allowing compensation for the cavity radiation.

Laboratory calibration (Valencia, May 2016).

Blackbody source Landal Radiometer, Temperature range: 0 – 50 °C
Linear calibration equations

1. Linearly calibrated (blackbody) temperature
2. Radiometric temperature with standard calibration
3. Calibration coefficients (linear regression)

Temperature-emissivity separation (TES)

Radiance at surface level:

1. Land Surface Temperature (LST)
2. Surface emissivity. Not usually known for land surfaces and needs to be measured for each land cover
3. Sky downwelling radiance. Measured in the field (gold plate) simultaneously to the target radiance

The TES method (Gillespie et al., 1998) simultaneous retrieval of T and of and from multiband measurements

Lab calibration

FRAMS57 laboratory comparison (NPL, June 2016).

Comparison of blackbody Radiometer with AMBR Radiometer (D购 – 50 °C)

1. Normalized emissivity method (NEM): Assume an emissivity value $e_{bb}=0.98$ for all bands and calculate $T_{bb}$ for each band
2. Select the maximum value of $T_{bb}$ and calculate $T_{em}$ for each band
3. Use $T_{em}$ to obtain a rough estimate of the N EMISSIVITIES
4. Calculate the minimum-maximum difference (MMD) between the emissivities. The minimum band emissivity ($e_{min}$) is obtained using an empirical relationship with the MMD
5. The N emissivities obtained are scaled with $e_{min}$ and used to calculate the target LST for each band. The LST is taken as the maximum band temperature

The TES method was applied to the measurements of the 5 narrow bands of the CE-312-2 radiometers (CE1 for $e_1$, CE2 for $e_2$).

Results

FRAMS57 LST comparison (NPL, June 2016). LST was obtained at the band with maximum emissivity, i. e. B2 (10.9-11.7 μm)

Conclusions

- CE-312-2 radiometers showed good accuracy and precision in the FRAMS57 laboratory comparison, with total uncertainty of 0.15 K (CE1) and 0.12 K (CE2) for the temperature range relevant for LST.
- The TES method can be applied to multiband ground radiometers to simultaneously retrieve LST and band emissivities.
- The uncertainty in the retrieved LSTs ranges between 0.4 K (clover) and 0.6 K (soil), the largest source of error being the land target emissivity.

References

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