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Improved in-situ methods for determining land surface emissivity

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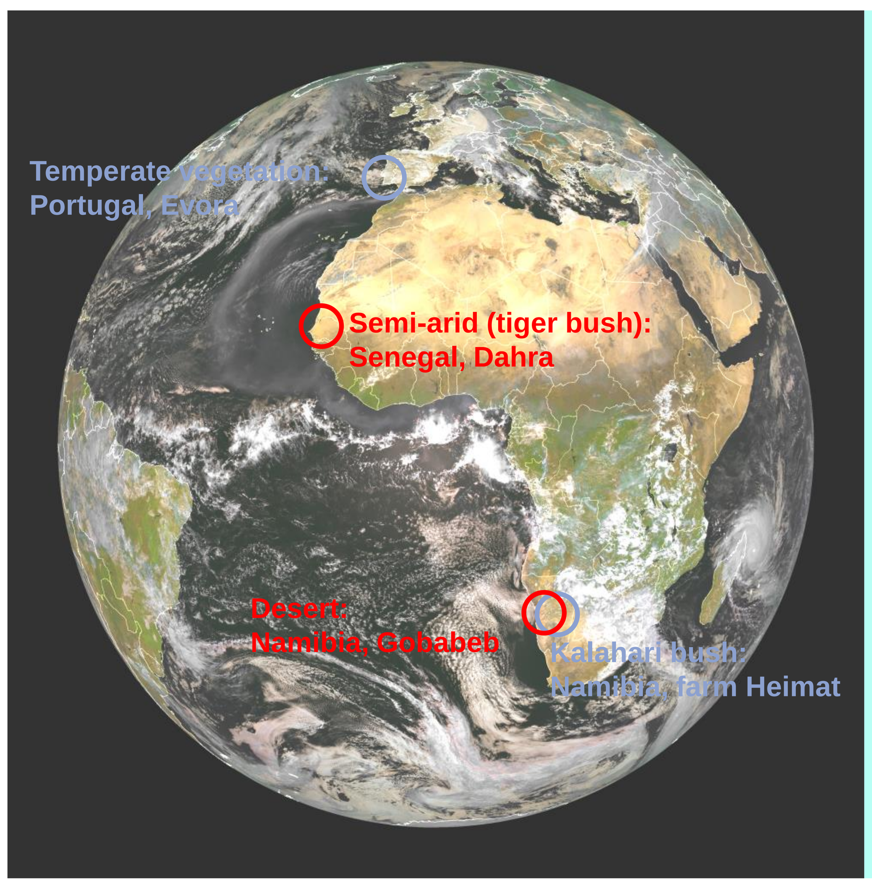
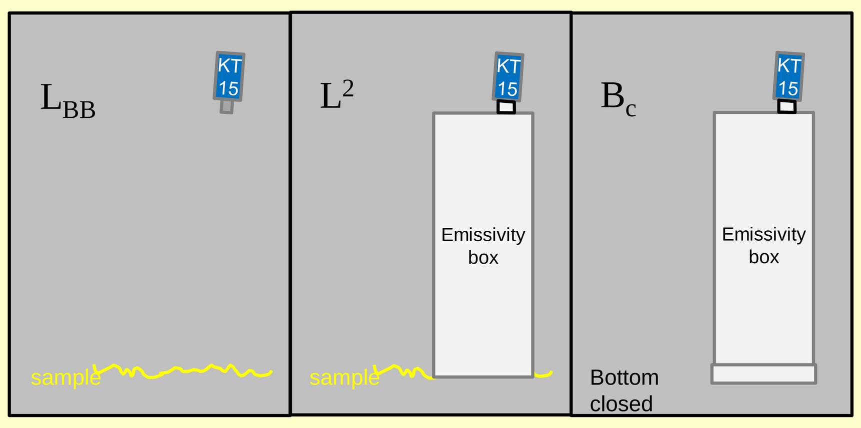


Accurate validation of land surface temperature (LST) products requires accurate knowledge of emissivity for the areas observed by the ground radiometers and the satellite sensor. Especially over arid regions the relatively high uncertainty in land surface emissivity (LSE) limits the accuracy of LST retrieved from thermal infrared radiance measurements. Furthermore, direct comparisons between satellite sensors and ground based sensors are complicated by spatial scale mismatch: ground radiometers usually observe some 10 m², whereas satellite sensors typically observe between 1 km² and 100 km². Therefore, validation sites have to be carefully selected and characterized on the scale of the ground radiometer as well as on the scale of the satellite pixel. Near **Gobabeb** (Namibia; hyper-arid desert climate) and **Dahra** (Senegal; hot-arid steppe-prairie climate) are two of KIT's four dedicated, permanent LST validation stations. In-situ emissivities of dominant surface cover types were determined with the so-called 'box method' and from spectra obtained for soil samples with a Nicolet 520 FTIR spectrometer. The box method was improved by recording radiance measurements at a sampling rate of 1 Hz: this allows the identification of erroneous measurements, the picking of the first undisturbed temperature after each change in box configuration, and to reduce the number of measurements.

Single-lid emissivity box method

Inside of box



Improvements of measuring technique:

- **5° view angle w.r.t. nadir, slightly off-center**: avoids so-called 'narcissus effect', i.e. radiometer self-observation in reflection
- **1Hz sampling rate**: temperature dynamics, off-line evaluation
- Emissivity obtained when box is put on sample **and** removed

First described by Combs et al. (1965): inner walls made of highly polished aluminum. KIT's box has the same dimensions as the box of Rubio et al. (1997).

Uncorrected emissivity ε_0 is determined from a sequence of three measurements:

$$\varepsilon_0 = \frac{L_{BB} - L_a^{\downarrow}}{L^2 - L_a^{\downarrow}}$$

L_{BB} Radiance measured over 'pure' sample (without the box)

L^2 Sample radiance measured through **bottomless** box

$$L_a^{\downarrow} = 1.3 \times B[T(0°)]$$

Downwelling sky radiance obtained from brightness temperature T measured at zenith & Planck's law.

Correction for box:

$$\varepsilon = \varepsilon_0 + \delta\varepsilon \quad \text{with} \quad \delta\varepsilon = (1-\varepsilon_0)\left\{1 - \frac{L^2 - L_a^{\downarrow}}{L^2 - L_a^{\downarrow} - R(L^2 - B_c)}\right\}$$

Box-specific R = **0.265**, see Rubio et al. (1997)
B_c: radiance measured for **closed box**

Land Surface Emissivity (LSE) at Gobabeb, Namibia

Surface type	ε_0 ± stderr	ε ± stderr	N
Gravel	0.919 ±0.008	**0.916 ±0.007**	10
Gravel (disturbed)	0.932 ±0.003	**0.931 ±0.003**	2
Grass (dry)	0.964 ±0.012	**0.962 ±0.013**	6
Sand (dunes)	0.930 ±0.004	**0.928 ±0.004**	16
Granite (inselberg)	0.914 ±0.010	**0.909 ±0.011**	5

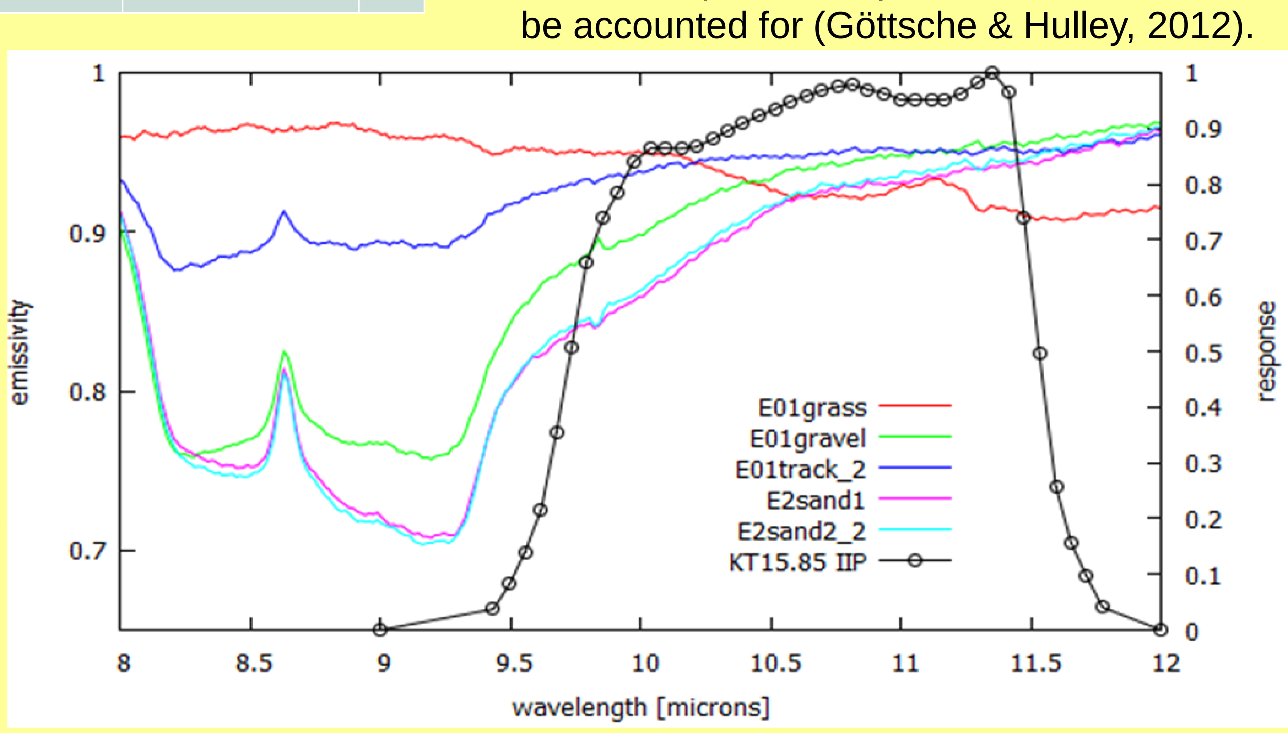
Emissivities obtained with the modified box method for the KT15-85 IIP radiometer (9.6-11.5µm)

For meaningful comparisons between emissivities from different sensors (e.g. in-situ vs satellite) their response functions have to be accounted for (Göttsche & Hulley, 2012).

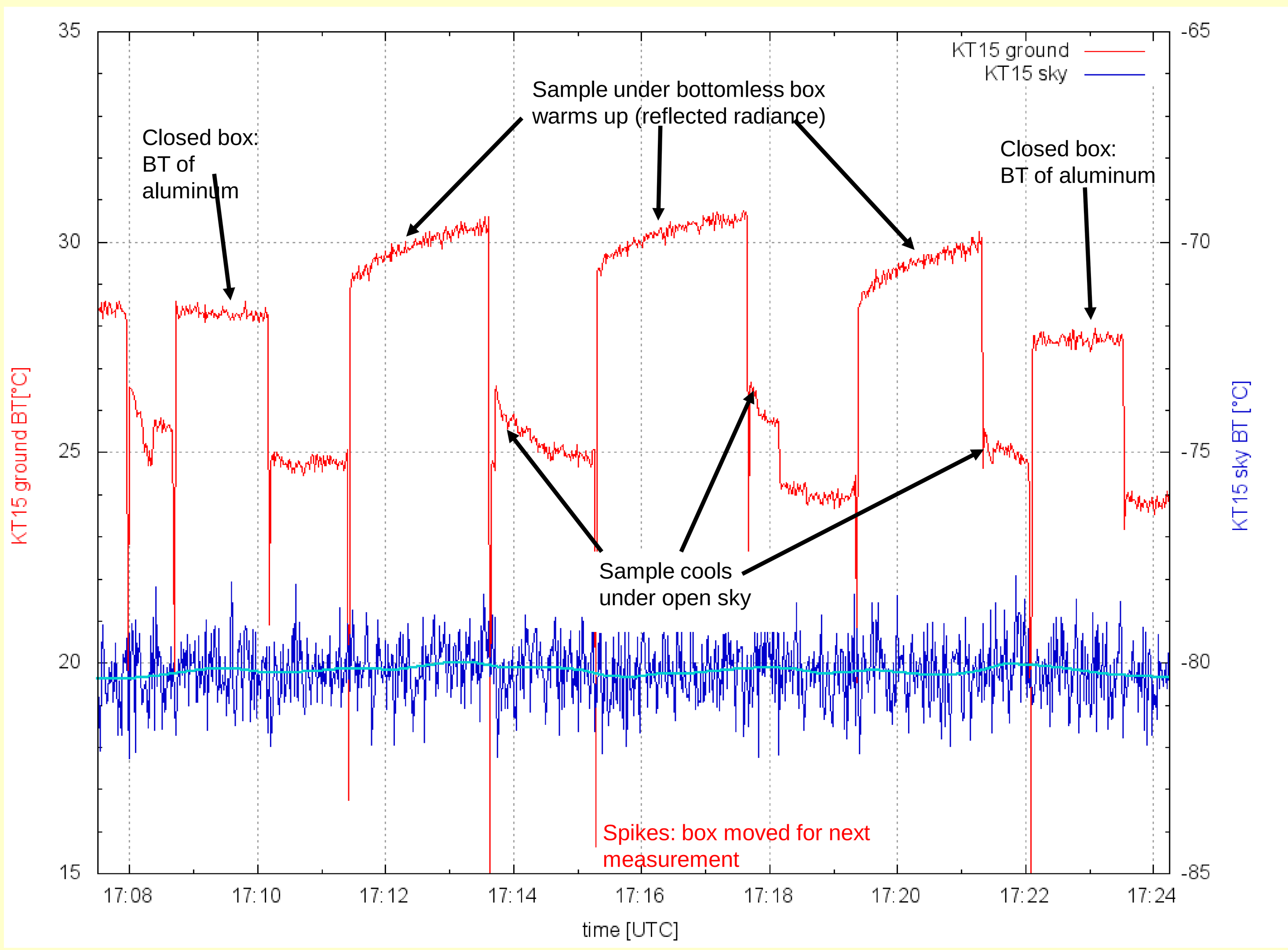
Emissivity spectra of some samples and the KT15 response function.

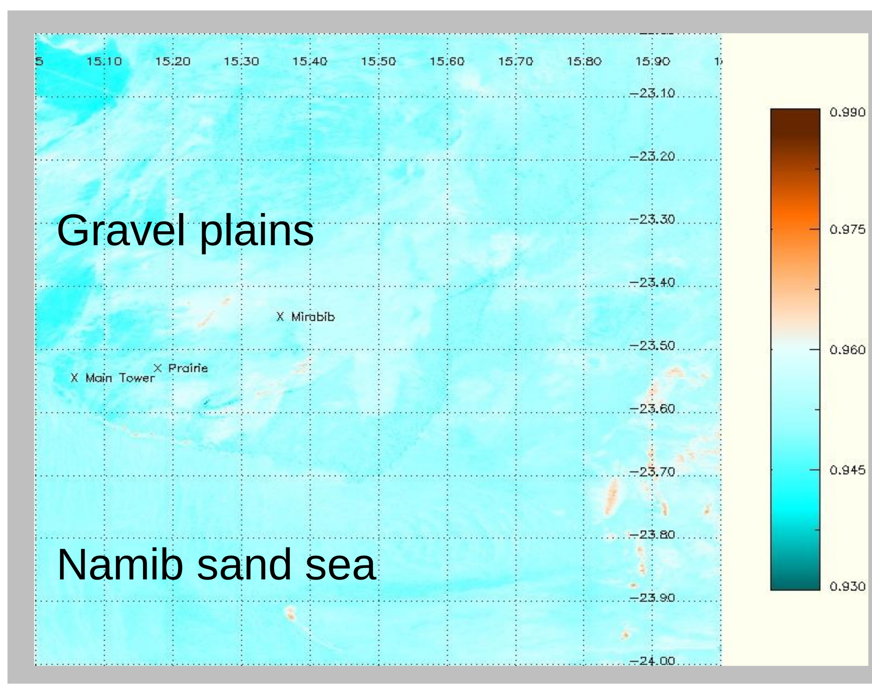
Dry 'E01grass' sample: emissivity decreases with wavelength

Pronounced reststrahlen bands (SiO2-stretching at 8-9.5 µm) for sand and gravel are indicative of a high quartz content.



Brightness temp. (BT) measured with the box method





ASTER-TES at 120m resolution, transformed to SEVIRI ch10.8

In-situ LSE for SEVIRI ch10.8 near 'Prairie':
0.944 ±0.015
(Göttsche & Hulley, 2012)

Summary of results for Gobabeb and Senegal

- Favourable conditions for the 'single lid emissivity box method': frequently clear-sky with **surface BT - sky BT > 80K**, giving high SNR
- New field technique gives stable results with fewer measurements
- Gobabeb: several current LSE satellite products had errors of 3% or more
- Dahra: the strong seasonal cycle (monsoon; from bare soil to full vegetation cover) caused errors of up to 7% in some LSE products

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Göttsche, F.-M., and Hulley, G. C. (2012). Validation of six satellite-retrieved land surface emissivity products over two land cover types in a hyper-arid region. Remote Sensing of Environment, 124, pp. 149-158.
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