1. MIraCalE

The Microwave Radiometer Calibration Experiment (MIraCalE) took place in fall 2014. Ten “Liquid Nitrogen Calibrations” and 2841 “Tipping Curve Calibrations” were performed with a state-of-the-art microwave radiometer to assess calibration uncertainties and instrument drifts.

2. Calibration Techniques

Liquid Nitrogen Calibration (LN2cal)

- LN2-cooled blackbody at $\approx 77$ K as „cold“ load
- Ambient temperature blackbody at $\approx 300$ K as „hot“ load
- Internal noise source added to „cold“ and „hot“ signals

Tipping Curve Calibration (TCC)

- Zenith radiances ($B_{\text{zen}}$) as „cold“ load:
  1) Opacity-airmass pairs at several elevation angles
  2) Linear regression of pairs provides zenith opacity $B_{\text{zen}}$ from radiative transfer equation without scattering

The relation between the detected voltage $U_{\text{dv}}$ and the scene radiance $B_{\text{sc}}$ is determined by the instrument’s gain $g$, the receiver’s equivalent noise radiation $B_{\text{r}}$, and the instrument’s non-linearity $\alpha$:

$$ U_{\text{dv}} = g(B_{\text{sc}} + B_{\text{r}})^\alpha $$

(1)

The three unknowns ($\alpha$, $g$, $B_{\text{r}}$) are determined by observing two calibration references both with and without an additional, constant noise signal $B_{\text{r}}$ leading to four unknowns and four calibration points.

3. Drifts

Frequent calibrations of the parameters in eq. (1) are necessary to ensure measurement accuracy:

Figure 4 shows how drifts of the calibration parameter $B_{\text{r}}$ influence the retrieval of cryogenic load radiances by solving eq. (1) for $B_{\text{r}}$ (shown in the temperature regime as $T_{\text{r}}$) using a reference voltage signal and TCCs that were performed at different times.

4. Accuracy of the Cryogenic Load

Uncertainty sources:
- Resonant effects [Pospichal et al. 2012]
- Entrainment of oxygen [Paine et al. 2014]
- Uncertainty of the refractive index of LN2 [Maschwitz et al. 2013].

We found a total uncertainty of 0.5 K for the LN2 cooled blackbody by using TCCs to retrieve the cold load’s temperature (Fig. 5). Drifts of $B_{\text{r}}$ were taken into account.

5. Spectral Consistency

- Calibration biases can differ between radiometer channels (Fig. 6), which influence multi-frequency retrievals: Integrated water vapor (IWV) retrieval $\rightarrow$ 1 K offset between two channels $\rightarrow$ Error of 0.73 mm (corresponds to 70 % of the diurnal cycle of IWV; Fig. 7).
- Control measurements (Fig. 6) can identify biased calibrations by testing for “spectral consistency”.

6. Summary

- Frequently updating calibration parameters ensures stable long-term measurements.
- The spectral consistency of control measurements is useful to estimate calibration accuracy.
- The brightness temperature of the LN2-cooled load is accurate within 0.5 K.

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