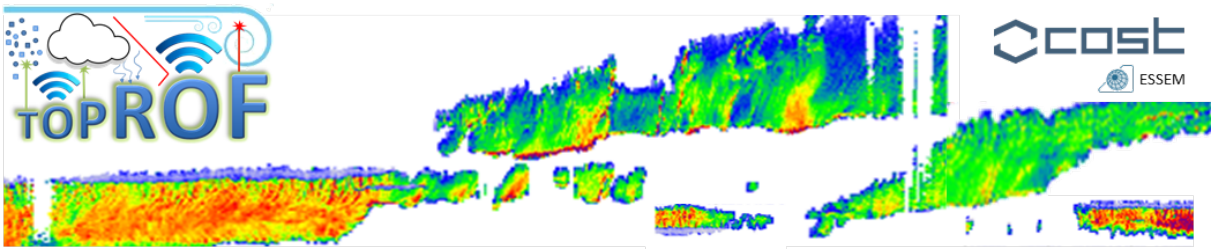

J-CAL (Joint microwave calibration)

Recommendations for operation and calibration of Microwave Radiometers (MWR) within a network

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Introduction

Ground-based passive microwave radiometers (MWR) are becoming widely used in atmospheric remote sensing and are routinely operated by national weather services and other scientific institutions. However, common standards for calibration of these radiometers and a detailed knowledge about the error characteristics is needed, in order to assimilate the data into models.

Intercomparison experiments with calibrations by different MWRs have rarely been done. Therefore, two calibration campaigns were performed in order to assess uncertainties and differences between various instruments. After the first field campaign at Lindenberg in 2014, it was found that additional effort needed to be done, therefore a second campaign was held at Meckenheim in 2015.

In the frame of TOPROF (COST action ES1303), the joint calibration experiment (J-CAL) made an effort towards establishing protocols for providing quality controlled (QC) MWR data and their uncertainties. To this end, standardized calibration procedures for MWR were developed, by jointly performing calibration experiments and establishing standards for error characterization.

The focus of the two J-CAL experiments lay on the performance of the two main instrument types which are currently used operationally. These are the MP-Profiler series by Radiometrics Corporation as well as the HATPRO series by Radiometer Physics GmbH (RPG) Both instruments are operating in two frequency bands, one along the 22 GHz water vapour line, the other one at the lower wing of the 60 GHz oxygen absorption complex.

Further information on MWR is provided in the final report of the EG_CLIMET COST action (http://cfa.aquila.infn.it/wiki.eg-climet.org/index.php5/Microwave_radiometer).

This report provides guidelines for operators of ground-based microwave radiometers within networks. The recommendations we give are the best of our knowledge, but we recognize that there might be improvements in the future. We will update these recommendations as soon as new scientific or technological methods that show better performance are developed.

Recommendations

Operation of MWR (HATPRO, Radiometrics)
• If possible, install instrument with unobstructed view towards north (for elevation scan)
• Keep instrument always on power. This ensures permanent temperature stabilization.
• Check housekeeping data regularly. Take warning messages seriously.
• Use blower heating with a threshold of 60% relative humidity

Data types
• Store data with highest possible temporal resolution (1 s for HATPRO)
• Perform at least one elevation (boundary layer) scan every 30 minutes (HATPRO: > 100 seconds integration time)

• Store all raw data (voltages, brightness temperatures, calibration data). Atmospheric data can be always reproduced
  ○ **HATPRO:** BRT, BLB, HKD, IRT, MET, LV0, (SPC), LOG-files
  ○ **Radiometrics:** LV0, LV1

• Data to be stored in NetCDF format following CF-1.6. conventions.
  ○ Current recommend data structure based upon HD(CP)^2 data standard (https://icdc.zmaw.de/index.php?id=821)
  ○ For access to example MWR data & data reprocessing software (mwr_pro) see ftp://gop.meteo.uni-koeln.de/pub/loehnert/mwr_data_flow/
  ○ Future operational data flow structure in development

Calibrations HATPRO a. Automatic calibrations
• Hot load (gain) calibrations every 5 minutes with 10 seconds integration time
• Automatic noise switching in V-Band should be turned off
• Noise diode calibrations every 60 minutes with 30 seconds integration time (both humidity and temperature channels)

• Enable sky tipping every 60 minutes
  ○ Recommended for all HATPROs as an absolute calibration standard in K-Band
  ○ Strict quality criteria:
  no daytime calibrations
  zenith temperature threshold @22.24 GHz=80 K
  chi²=0.1
  linear correlation coefficient=0.9999

b. Liquid nitrogen (LN2) calibration
• Should be performed at least every 6 months and/or after instrument relocation or shutdown
• Good weather conditions (low wind speed, rel. humidity < 70%, no precipitation)

mandatory! If possible, bring your instrument to a shelter and perform calibration there.
• Compare brightness temperatures before and after calibration
• Due to evaporation of LN2 and oxygen mixing into LN2, keep times as short as possible!
• If repeating a calibration, do not refill the load when it is not completely empty in order to minimize O2/LN2 mixing!

Calibrations Radiometrics profiler **a. Automatic calibrations**
• Users are well advised to follow the recommendations described in the Operator's manual
b. Liquid nitrogen (LN2) calibration
• Should be performed at least every 6 months and/or after instrument relocation or shutdown
• Good weather conditions (low wind speed, rel. humidity < 70%, no precipitation) mandatory! If possible, bring your instrument to a shelter and perform calibration there.
• Stable operation temperature is needed and therefore in Lindenberg indoor calibrations are preferred. After moving from outdoor to indoor and before the calibration begins the radiometer needs time for adaption
• The bottom of the target must be clean and dry
• User should observe the displayed ND values to ensure that they remain stable during the calibration period of about 1 h.

Random error characterization
• HATPRO: Covariance calculation relative to running mean of HL-temperature. 1 hour HL-view with gain calibration every 5 minutes > difference to running mean of HL-temp (20 seconds). variable 14x14x2 (correlation/covariance matrix) > should be performed after every LN2 calibration
• Radiometrics: Calculation of 12x12(TP/WVP 3000)/22x22 (MP-3000 A) correlation and covariance matrix of the difference between calculated and measured HL-temperature

Detecting systematic/calibration errors
• HATPRO: Always compare BTs with spectrum retrieval (SPC files). During clear sky conditions, any spurious channel can be easily distinguished if the deviation to the retrieved spectrum is larger than a threshold value of 2 K. $. If permanent offsets/outliers larger than this threshold appear in single channels, the instrument has to be recalibrated.