Calibration and standardization efforts for a network operation of ground-based microwave radiometers

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Introduction

- Networks of ground-based remote sensing observations can be very valiable for model evaluation and assimilation
- Variety of operators and instrument types make coordinated measurements challenging
- Calibration and standardization necessary for comparison

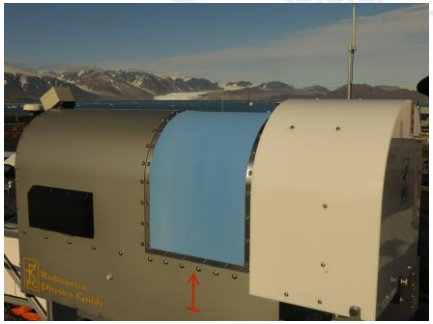
Ground-based microwave radiometers (MWR)

Benefits

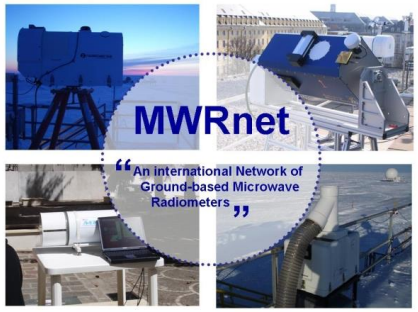
- Integrated properties (Liquid water path LWP / Integrated Water Vapor IWV)
- Temperature (T) & humidity profiles (WV)
- Continuous long-term, unmanned observations on temporal scales down to seconds → fill gaps between radiosondes
- Measurements during both cloudy and clear air
- Price, commercial availability

Limitations & challenges

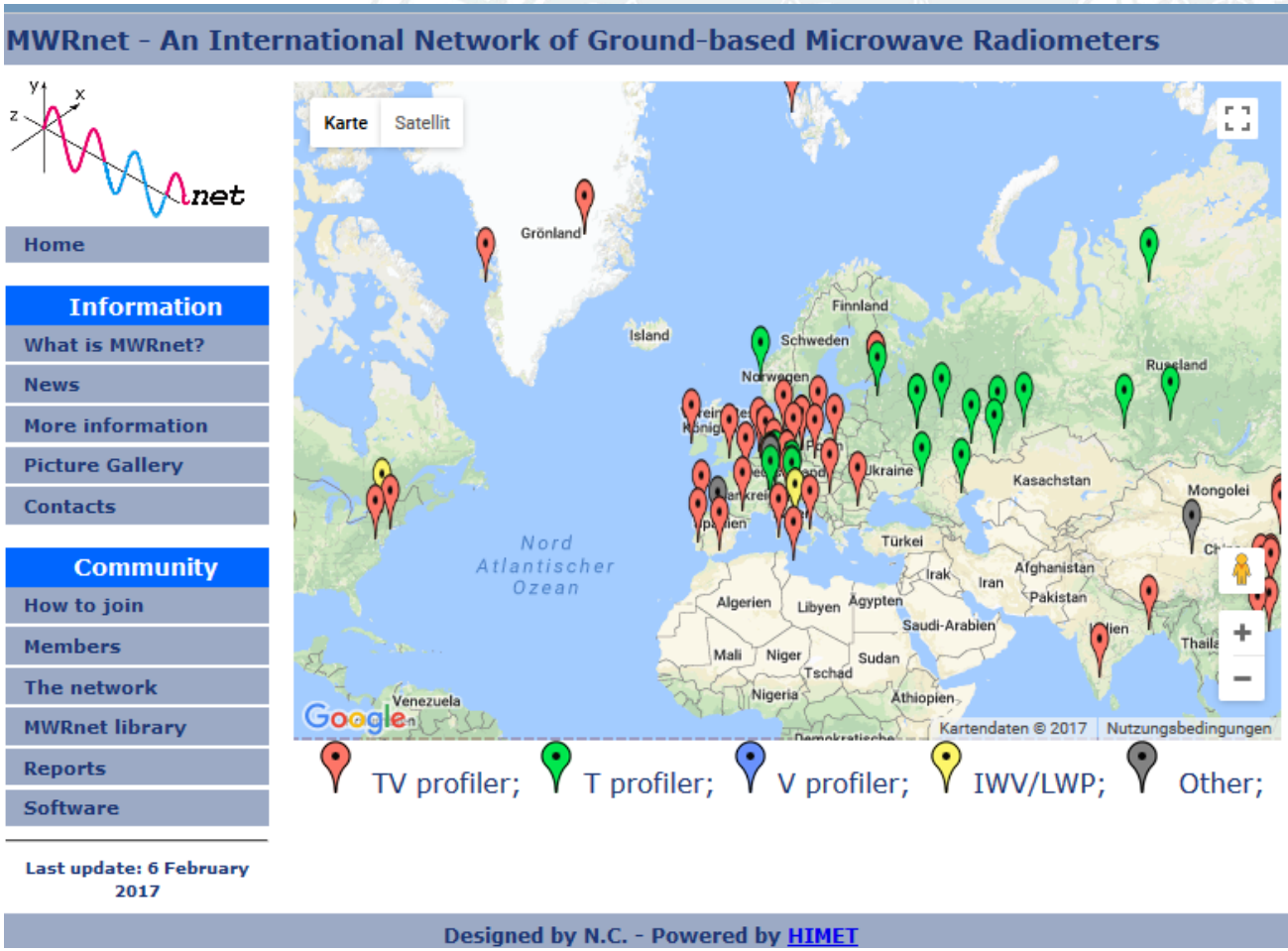
- Limited vertical resolution (2-4 deg. of freedom), declines with height
- Coordinated networks
- Calibration
- Absorption modeling
- Automatic data quality control (QC) systems



Microwave radiometers around the World



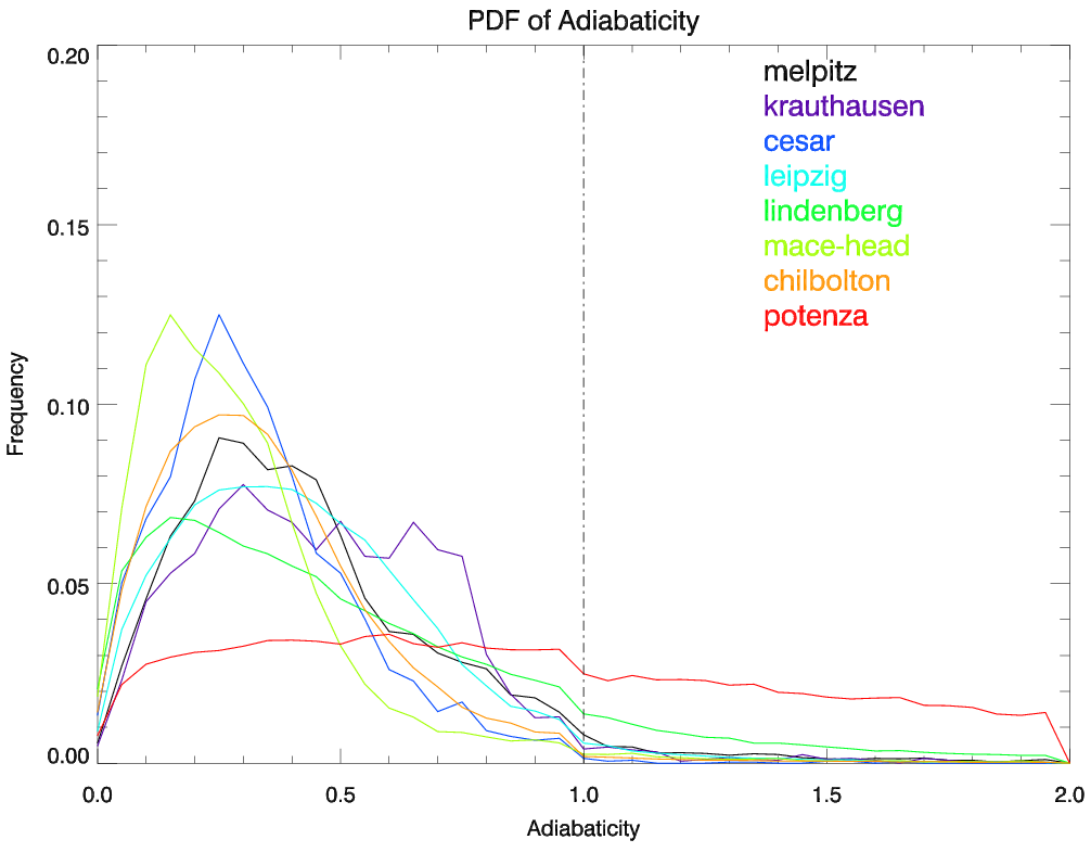
- MWRnet is a network of ground-based MWR
- Set up of a network sharing knowledge, software, procedures, formats, calibration, quality control, etc.



Networks (Cloudnet, ACTRIS)

- Network of operational MWR in Europe getting denser
- Within ACTRIS, every Cloudnet station needs to have a MWR
- For network activities, common calibration procedures and data quality important
- Calibration was not considered being the crucial issue until now

Cloudnet liquid water statistics



Statistics over years of Cloudnet obs., only single-layer non-drizzling and purely liquid clouds chosen!

PDFs of cloud adiabaticity depend highly on accurate LWP from microwave radiometer

Potenza? Lindenberg?

Common calibration and retrieval development needed!

J-CAL TOPROF

2 Calibration experiments **J-CAL** in 2014 (Lindenberg) and 2015 (Meckenheim) in the frame of COST-TOPROF

>> Intercomparison of different MWR calibrations

>> Recommendations for operation and calibration of MWR

Recommendations for MWR in networks

- **Operation**
  - regular maintenance
  - automated data quality control
- **Data handling**
  - common data processing, retrieval development
- **Calibration**
  - Frequency of automatic calibrations
  - Perfomance of LN2 calibrations
- **Error characterisation**
  - random errors

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

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
    chi^2=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

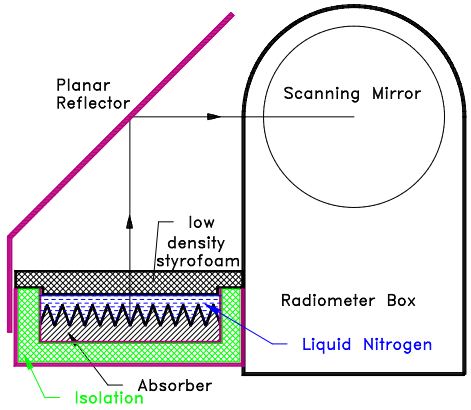
Detecting systematic/calibration errors

- 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.

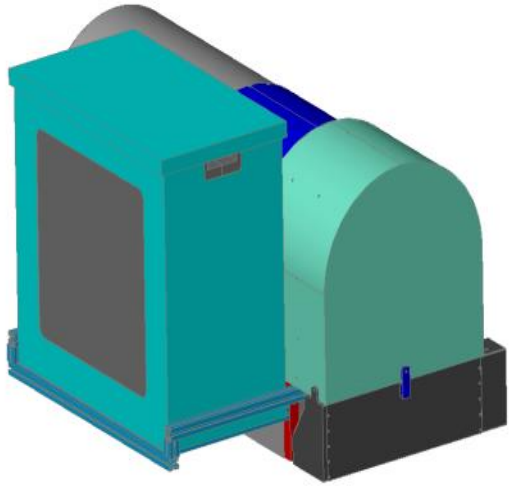
New development in calibration load design for RPG-HATPRO instr.

- Uncertainties of LN_2 calibrations due to:
  standing wave effects, reflections, O_2 entrainment, condensation of water on cold surfaces,
- RPG has developed a non-reflecting LN_2 target which eliminates most of these effects > significant improvement in absolute accuracy (~0.1 K).
- TOPROF WG3 recommends updating the calibration equipment as soon as possible.

old design



new design



Jülich ObservatorY for Cloud Evolution

http://joyce.cloud

Observation platform jointly operated by

- University of Cologne / Research Centre Jülich
- SFB/TR 32 „Patterns in Soil-Vegetation-Atmosphere-Systems Monitoring, Modelling and Data Assimilation“
- → continuously monitor **winds, temperature, water vapor, clouds,** and **precipitation** over many years

JOYCE-CF Scientific goals

Goals

- to disentangle water vapor variations due to advection and to local surface influence (validate coupled models)
- to better understand the development of boundary layer clouds including cloud radiation interaction
- to observe precipitation formation and improve parametrization schemes
- **to serve as international centre of expertise for microwave radiometers**

http://joyce.cloud

Jülich Observatory for Cloud Evolution – Core Facility (JOYCE – CF)

Kick-Off Symposium
12-13 October 2017 in Jülich

Summary

- Ground-based microwave radiometers become more and more widespread over the world, running 24/7
- For data assimilation, model evaluation, detailed error knowledge is vital
- We provide recommendations for MWR operation, calibration and automated data quality control
- Progress in reducing absolute calibration uncertainties
- JOYCE-CF in Jülich will serve as reference center for MWR operation and provide standards

Thank you for your attention!

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