Consistent calibration and data quality control of ground-based microwave radiometers for a network use

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JOYCE - CF

ACTRIS

DFG Deutsche Forschungsgemeinschaft

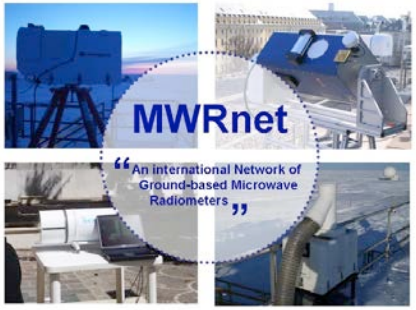
Introduction

- Networks of ground-based remote sensing observations can be very valiable for model evaluation and assimilation

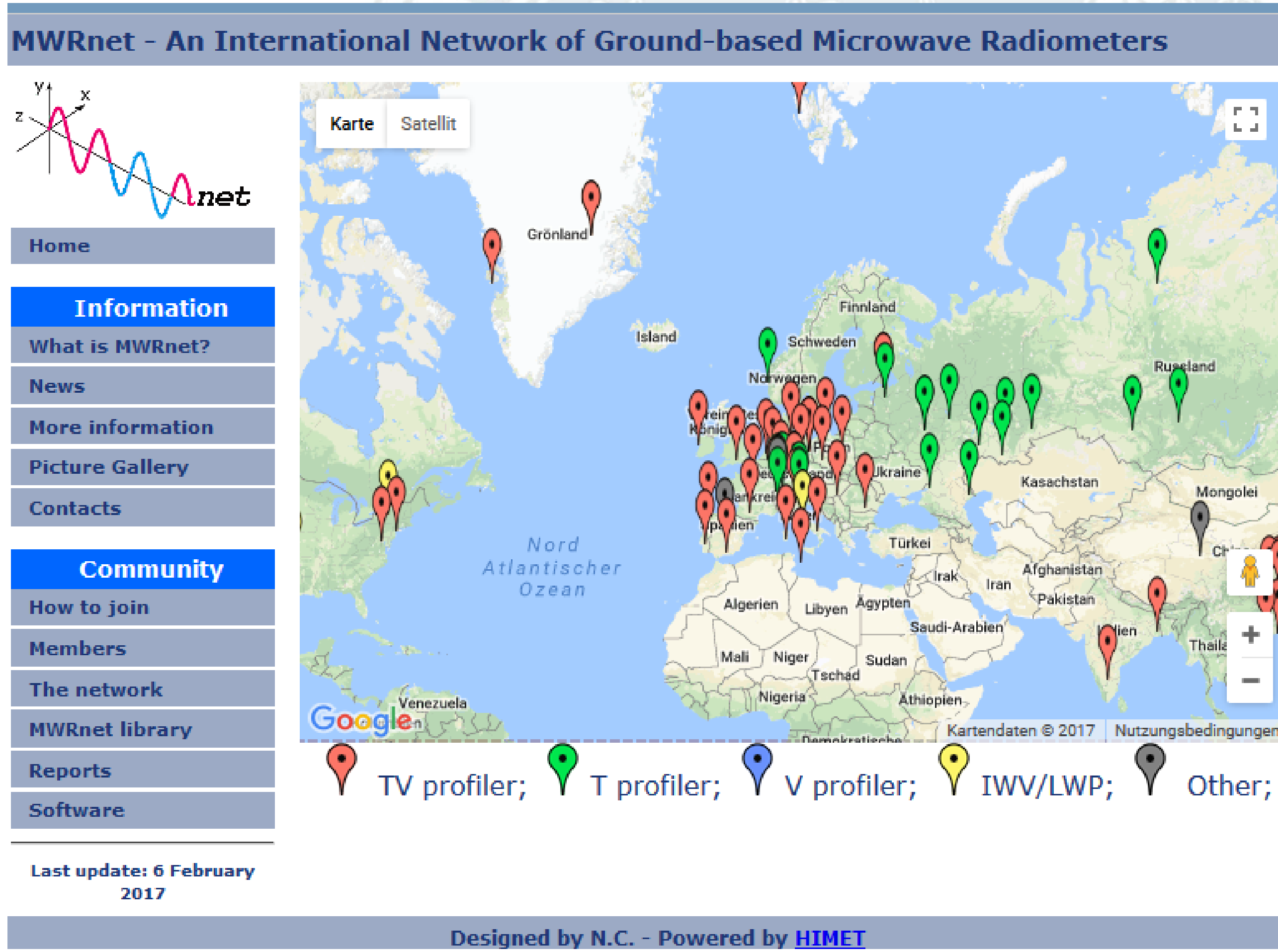
- Variety of operators and instrument types make coordinated measurements challenging

- Calibration and standardization necessary for comparison and common retrieved products

Microwave radiometers around the World



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



http://cetemps.aquila.infn.it/mwrnet/

Networks (Cloudnet/ACTRIS)

> 15 Cloud remote sensing stations (cloud radar, ceilometer, Doppler lidar, MWR)

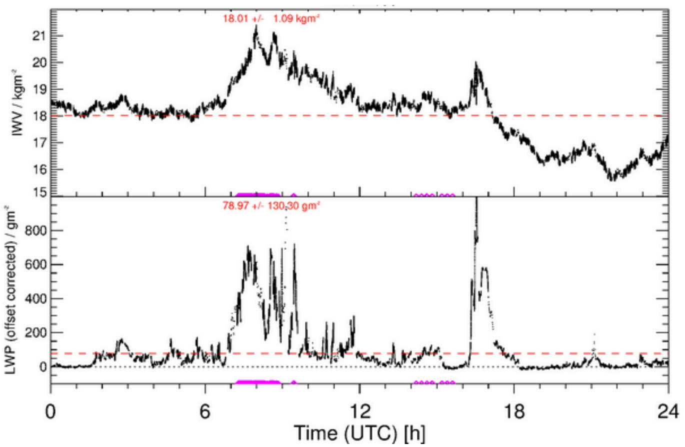
- Setup of ACTRIS (Aerosol, Cloud and Trace gas Research Infrastructure
- Network of operational MWR in Europe getting denser > combination with other instruments!
- Within ACTRIS, every Cloudnet station needs to have a MWR
- Data quality control is becoming more and more important

Network potential: what can we expect from ground-based MWR?

path-integrated **cloud liquid water (LWP)** (**essential for Cloudnet**)

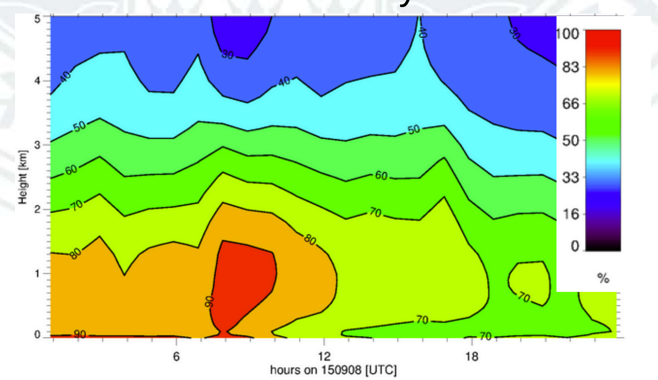
continuous data: resolution of seconds to minutes

temperature profile of the PBL, low resolution profile above



low resolution **water vapor profile**, but excellent path-integrated values

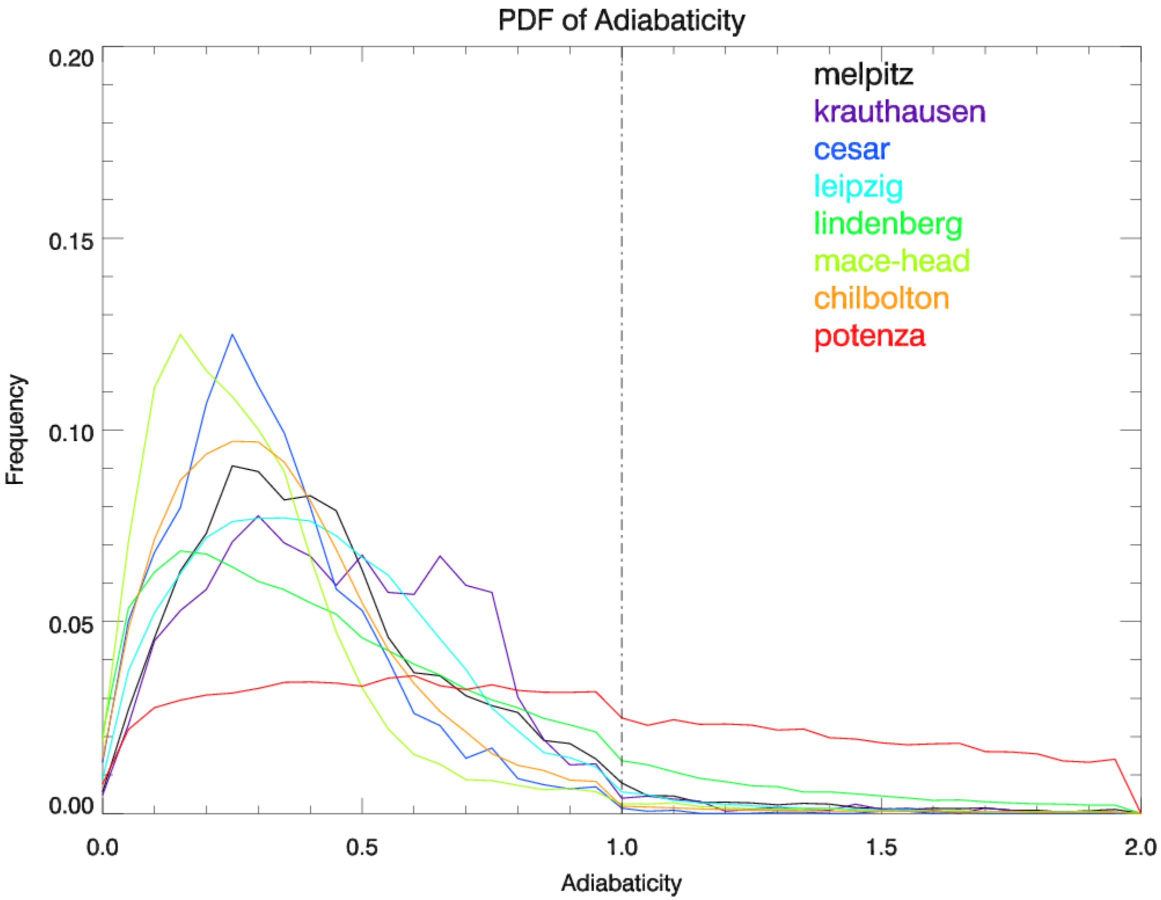
rel. humidity



level1: brightness temperatures (TB) → calibration dependent

level2: atmospheric products → forward model and retrieval dependent

Example: Cloudnet liquid water statistics



Statistics over many 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

Different statistics due to local climate or data quality issues?

Common calibration and retrieval development needed!

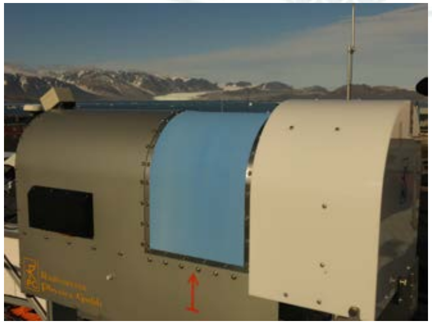
Ground-based microwave radiometers

Products & Benefits

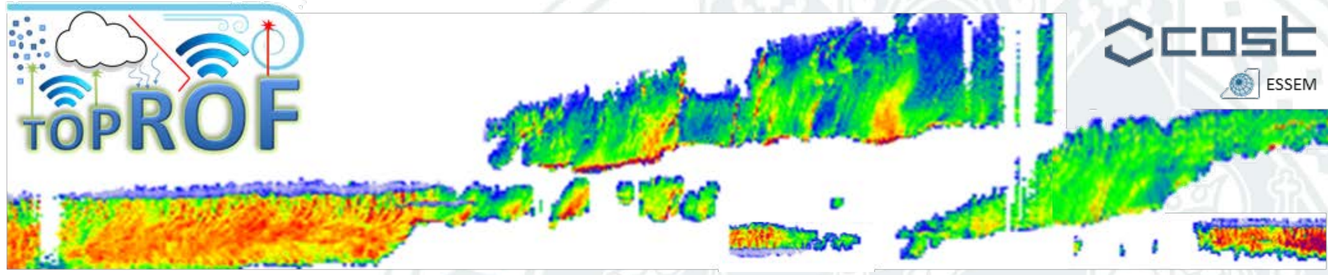
- Integrated properties (Liquid water path LWP / Integrated Water Vapor IWV)
- Temperature (T) & humidity profiles (WV)
- Continuous long-term, unmanned observations on temporal scales down to seconds → fill gaps between radiosondes
- Measurements during both cloudy and clear air
- Price, commercial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



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

Central calibration facility for MWR within ACTRIS (jointly with manufacturers)

Setting standards for existing network

- On-site training for calibration & operation
- Dissemination of calibration and operation procedures
  - Real-time calibration quality control
  - When is a calibration necessary?
  - Traceability: what calibrations to use, system parameters to store?
- Harmonized system uncertainty characterization
- Data processing chain (from brightness temperatures > automatic data quality control > retrieved produces

Evaluation of improved calibration approaches

- Experiments, comparative campaigns
- Long-term monitoring

Jülich ObservatorY for Cloud Evolution

Observation platform jointly operated by

- University of Cologne / Research Centre Jülich
- continuous monitoring of **winds, temperature, water vapor, clouds,** and **precipitation** over many years

http://joyce.cloud

Sources for MWR product errors and uncertainties

- Random errors **0.1-0.2 K TB**
  - Instrument noise
- Systematic errors **0.1-0.5 K TB**
  - Calibration offsets
- Retrieval uncertainties
  - Non-representative data for retrieval training
  - Measurement process not modelled correctly (noise levels, etc.)
  - Forward model uncertainties

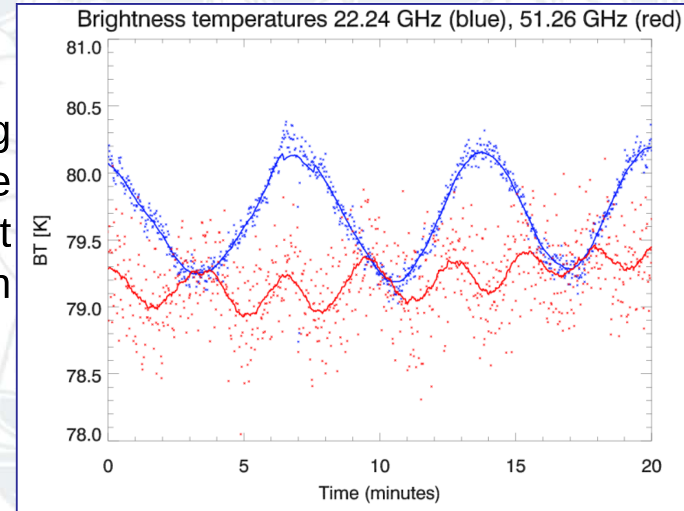
20 g/m² LWP, <0.5 kg/m² IWV, Tprof 0.3-1.5 K

- Automatic data quality control > filter low quality data
  - Spectral consistency check (detect single channel problems)
  - Thresholds for retrieved products

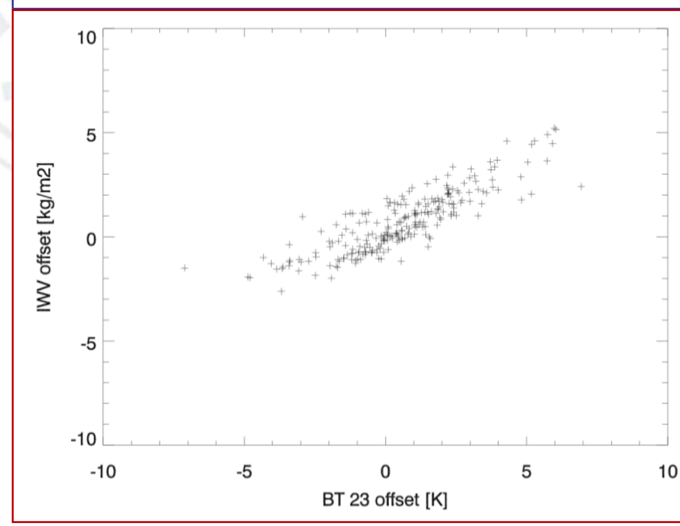
Quality monitoring of MWR

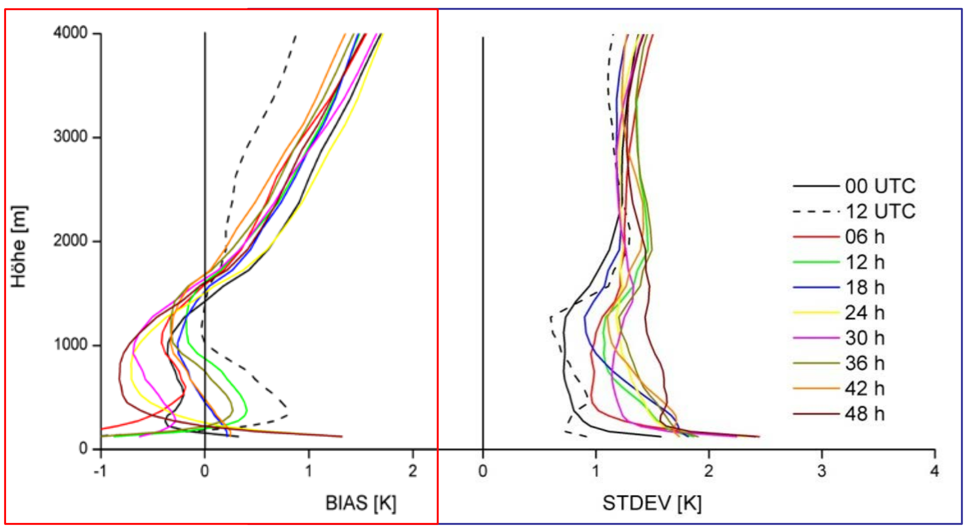
- Different ways to detect spurious data
- Goal: Common analysis of data quality, by comparing to models, reference data (radiosonde, etc.)

standing wave pattern at calibration



IWV offset as a function of BT offset (Polarstern data



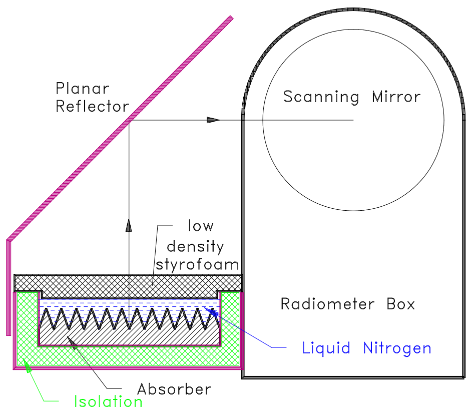


comparison of HATPRO T-profiles vs. WRF forecasts (different lead times)

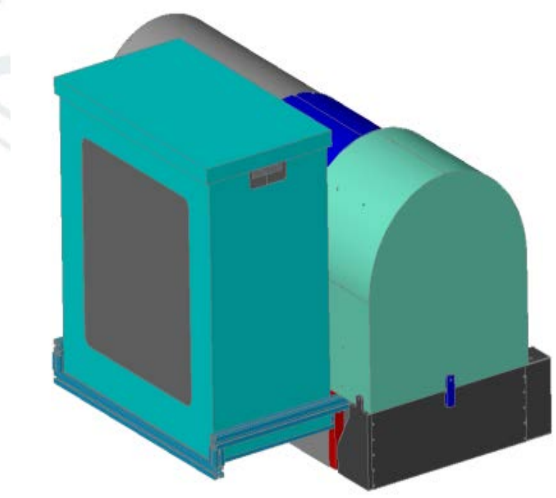
New development in calibration load design for RPG-HATPRO instr.

- Uncertainties of liquid nitrogen (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.

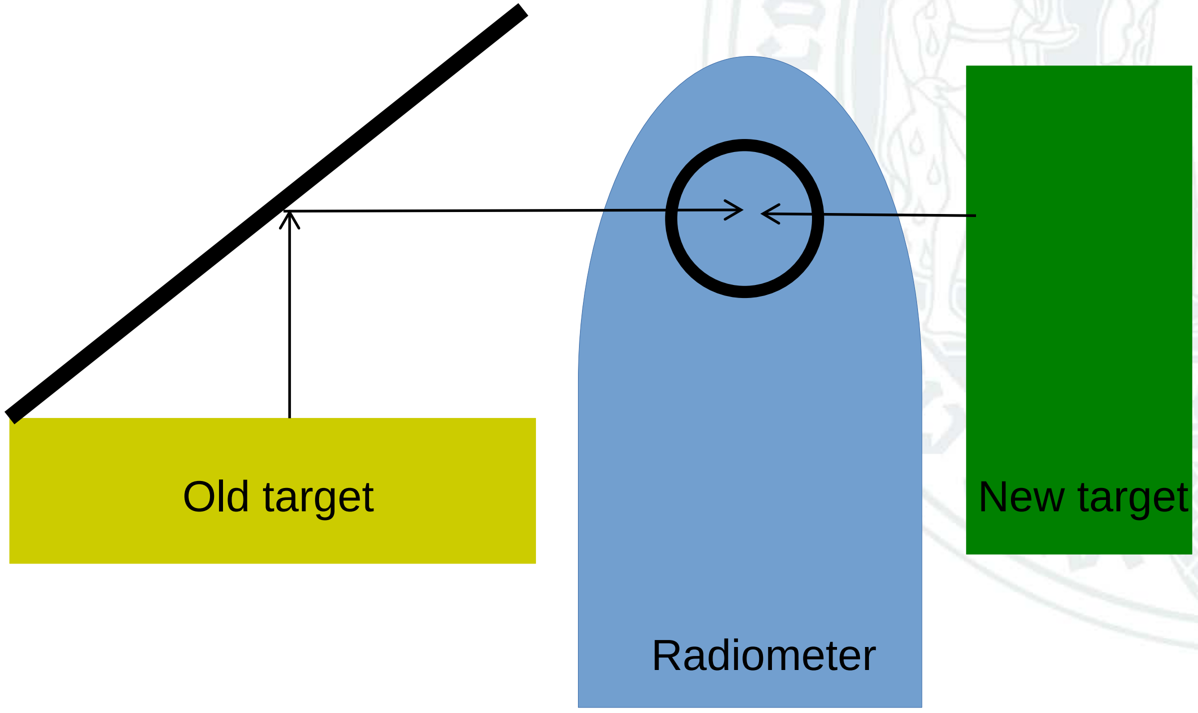
old design



new design



Comparison old/new load
Experimental Setup



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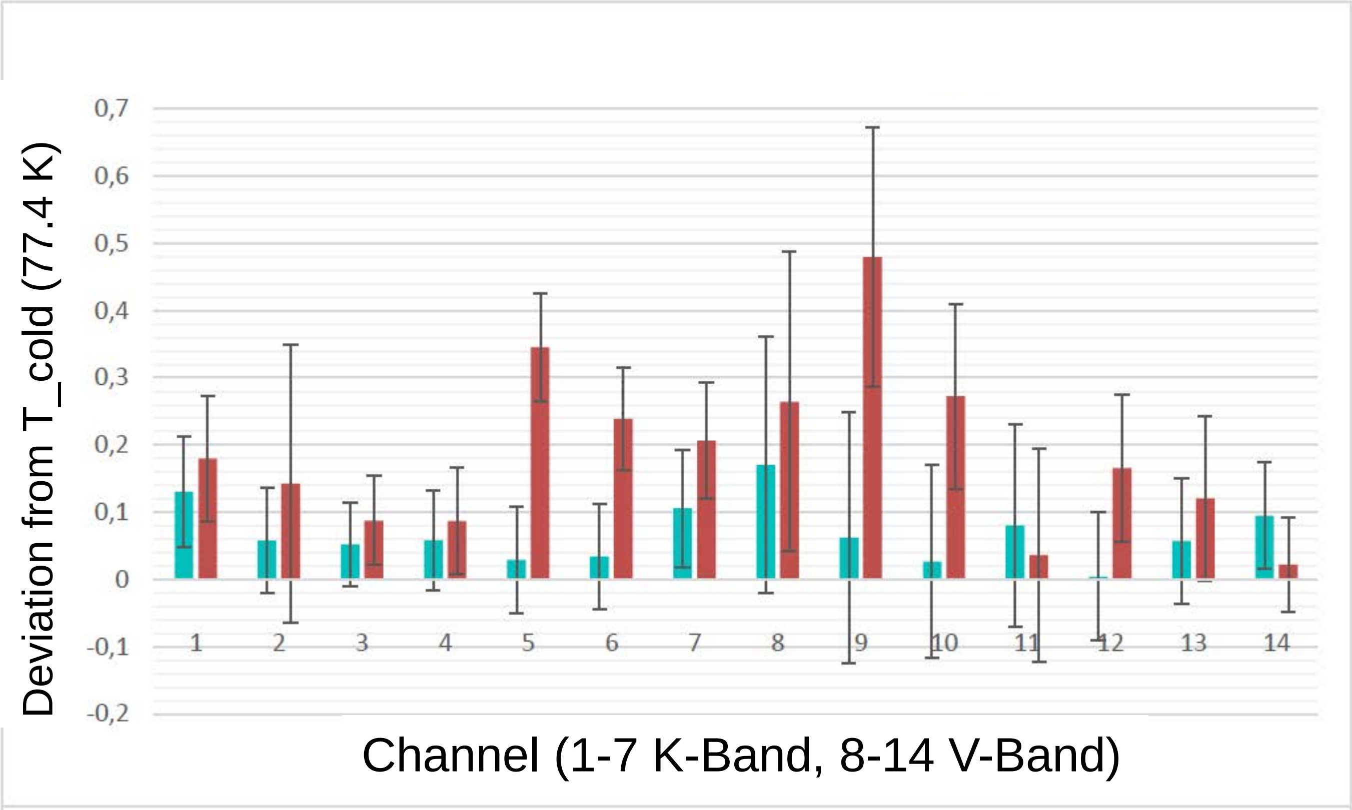

BSc thesis Tobias Böck (2018)

View on cold loads directly after LN2 calibration

blue: new target
red: old target

Mean (bias) and noise (standard deviation) for a 2 minute period (1 second integration time)

new target mostly < 0.1K bias/RMS

Discussion of results

Liquid nitrogen calibration					
ν [GHz]	n_{LN_2}	res	hot	α	total
22.24	±0.7	±0.4	±0.1	±0.04	±1.2
23.04	±0.7	±0.8	±0.1	±0.04	±1.6
23.84	±0.7	±0.2	±0.1	±0.03	±1.0
25.44	±0.7	±0.1	±0.1	±0.03	±0.9
26.24	±0.7	±0.3	±0.1	±0.03	±1.1
27.84	±0.7	±0.2	±0.1	±0.03	±1.0
31.40	±0.7	±0.2	±0.1	±0.02	±1.0
51.26	±0.6	±0.3	±0.1	±0.03	±1.0
52.28	±0.6	±0.1	±0.0	±0.00	±0.7
53.86	±0.4	±0.1	±0.0	±0.00	±0.5
54.94	±0.1	±0.0	±0.1	±0.00	±0.2
56.66	±0.1	±0.0	±0.2	±0.00	±0.3
57.30	±0.1	±0.0	±0.2	±0.01	±0.3
58.00	±0.1	±0.0	±0.1	±0.01	±0.2

uncertainties of 0.9-1.5 K (K-Band) 0.1-0.9 K (V-Band) eliminated

remaining uncertainties of 0.1-0.2 K (all channels)

Main uncertainties for observed brightness temperatures that were discussed by Maschwitz et al. (2013) are eliminated by new target

- **n_{LN2}** (uncertainties in LN2 refractive index) **> OK now!**
- **res** (uncertainties due to resonance effects, standing waves) **> OK now!**
- **hot** (hotload temperature uncertainties)
- **α** (uncertainties in receiver non-linearity)

Summary

- Ground-based microwave radiometers become more and more widespread over the world, running 24/7
- For data assimilation and/or model evaluation, detailed error knowledge is vital
- We provide recommendations for MWR operation, calibration, retrieval development, 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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