Flash update on:

Progress towards a Microwave Radiometer GRUAN Data Product (MWR GDP)

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ACTRIS: Bernhard Pospichal, Tobias Böck

E-PROFILE: Rolf Rüfenacht

Why a GRUAN MWR product?

Microwave Radiometer (MWR) provides:

- Low-resolution Temperature and Humidity profiles
- Column-integrated water vapor + liquid water (IWV, LWP)
- Continuous measurements at
  - ~1 min temporal resolution
  - ~all weather

With respect to radiosondes:

- Highly redundant (though much lower vertical resolution)
- Independent (e.g. crucial for detecting the RS80 dry bias)
- Complement diurnal cycle
- Provide LWP (no other GRUAN instrument)

What's the status of MWR GDP?

- GRUAN MWR Tech Doc (Programme Guide) exist
  - Reviewed internally, but never published
  - Updates needed once the MWR GDP is more established

- Three EU initiatives are actively cooperating to progress towards MWR networking

  - **ACTRIS**: EU (distributed) research infrastructure – long term

  - **E-PROFILE**: Profiling programme of EUMETNET – NWP oriented

  - **PROBE** Cooperation COST Action

- It seems natural to follow this development for MWR GDP
  - Several EU GRUAN sites are in ACTRIS
  - Keeping in mind GRUAN requirements

- Procedures may be extended to GRUAN sites outside EU (TBC)

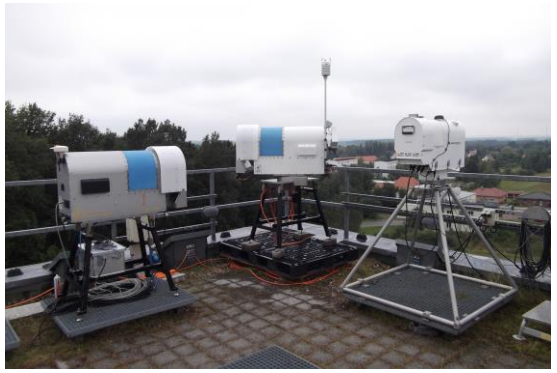
ACTRIS Cloud Remote Sensing

Ref: Bernhard Pospichal, U. Köln

ACTRIS (Aerosol, Cloud and Trace Gases Research Infrastructure)

- Research Infrastructure currently being established
- MWR are essential part of ACTRIS Centre for Cloud Remote Sensing (CCRES)
- Currently ~ 20 MWR are operational at ACTRIS sites
- until 2025 >30 MWR will be installed

Within CCRES, University of Cologne and JOYCE (Jülich Observatory for Cloud Evolution) are hosting the MWR centre of expertise



Updates on MWR activities within ACTRIS

Ref: Bernhard Pospichal, U. Köln

CCRES MWR centre of expertise

- Develop MWR data processing chain (including QC)
- Give recommendations and minimum requirements for MWR operators concerning measurement setup, calibration, maintenance, etc.
- Workshops and hands-on training for MWR operators regarding calibration and data handling
- Ensure homogeneous MWR Level2 data across network
- Near real-time online monitoring of data and data quality
- ACTRIS MWR quality assessment (2021-2023)
    - Calibration uncertainty

Updates on MWR activities within ACTRIS

Ref: Tobias Böck, U. Köln

ACTRIS MWR quality assessment (2021-2023)

- Total maximum uncertainty considering:
  - bias (difference between two collocated calibrated instruments)
  - calibration drifts between calibrations
  - calibration repeatability (differences after consecutive calibrations)

Results available on a PROBE Technical Report

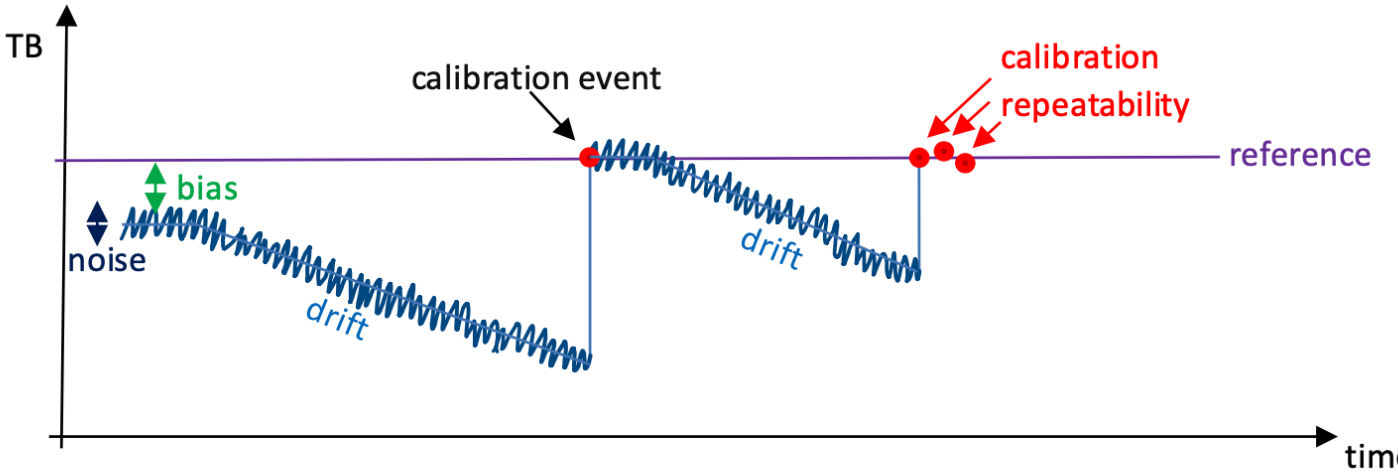


Figure 1: Sketch showing an overview of the HATPRO instrument uncertainties (calibration repeatability, noise, drifts, biases) over time.

Updates on MWR activities within ACTRIS

Ref: Tobias Böck, U. Köln

Calibration drift: Drifts are determined as TB differences at the coldload target before and after a LN2 calibration

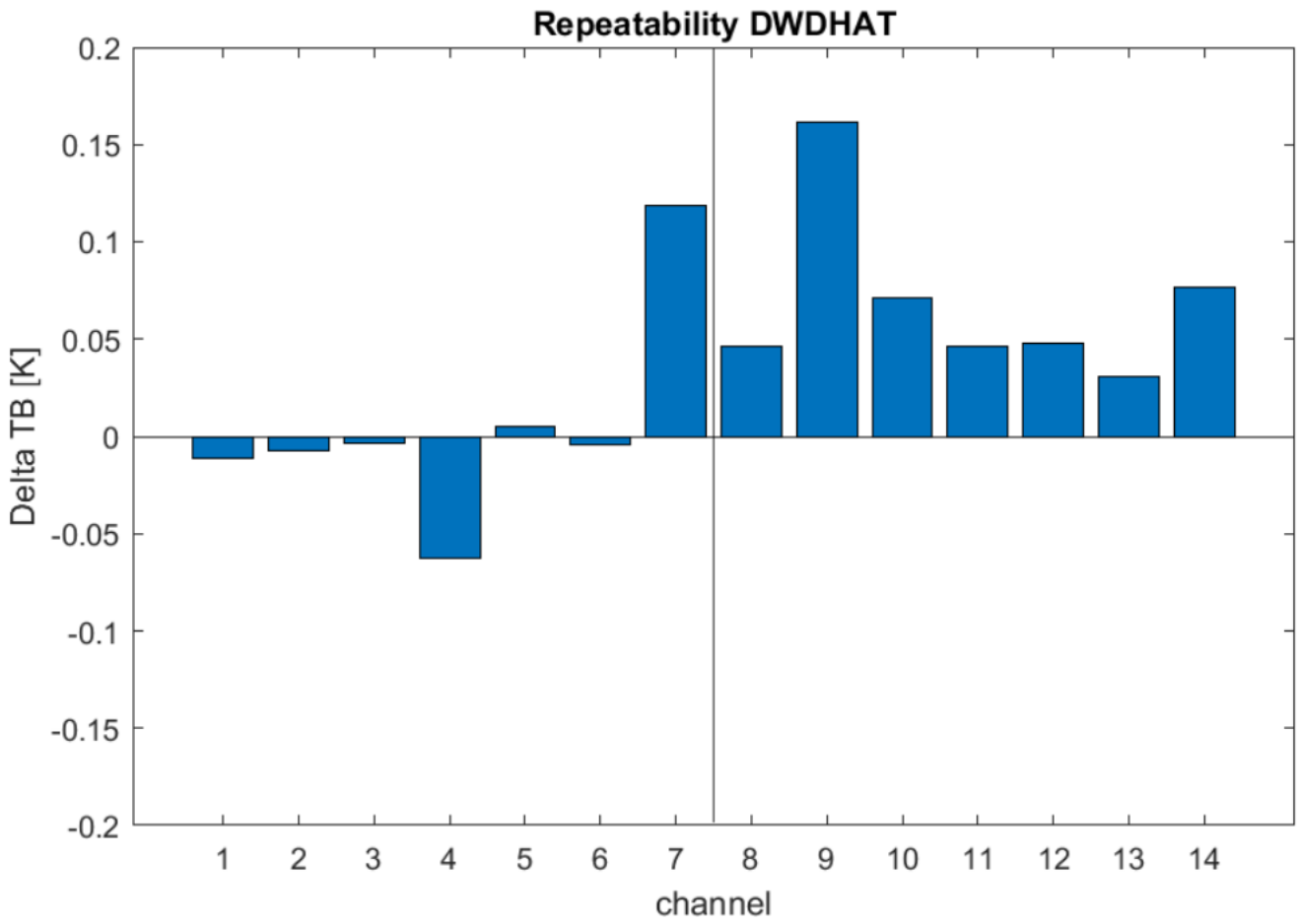
Table 4: Drifts per channel for TOPHAT in Jülich. Crossed out values did not make it into the final assessment due to suspected measurement problems.

DRIFTS PER 6 MONTHS [K]	May2019	Jul2019	Dec2019	Oct2020	Mar2021	Jul2021	abs. mean
Channel 1	−0.04	−0.02	0.22	−0.02	0.14	0.08	0.09
Channel 2	0.06	−0.11	−0.23	0.16	0.41	−0.12	0.18
Channel 3	−0.04	−0.10	−0.07	−0.06	0.39	0.03	0.12
Channel 4	0.002	0.03	−0.27	−0.03	0.36	−0.05	0.12
Channel 5	0.13	−0.78	0.57	−0.01	0.26	−0.10	0.31
~~Channel 6~~	~~0.47~~	~~−1.80~~	~~2.06~~	~~0.26~~	~~0.61~~	~~−1.20~~	~~1.06~~
Channel 7	0.10	−0.06	0.02	−0.03	0.30	~~−0.45~~	0.10
Channel 8	−0.56	−0.85	−0.27	−0.18	0.26	~~−0.70~~	0.42
Channel 9	−0.75	−0.04	−1.23	−0.75	−0.09	~~−2.06~~	0.57
Channel 10	−0.60	0.05	−0.41	−0.41	0.06	~~−1.25~~	0.31
Channel 11	−0.92	−0.33	−0.81	−0.59	−0.01	~~−1.87~~	0.53
Channel 12	−1.21	−1.24	0.65	−0.83	0.02	~~−3.47~~	0.79
Channel 13	−1.11	−1.28	−0.37	−1.09	−0.21	~~−2.56~~	0.81
Channel 14	−0.91	−0.31	−0.45	−0.71	−0.04	~~−2.45~~	0.48

Updates on MWR activities within ACTRIS

Ref: Tobias Böck, U. Köln

Calibration repeatability: determined via changes to zenith reference measurements after two immediate consecutive calibrations



Updates on MWR activities within ACTRIS

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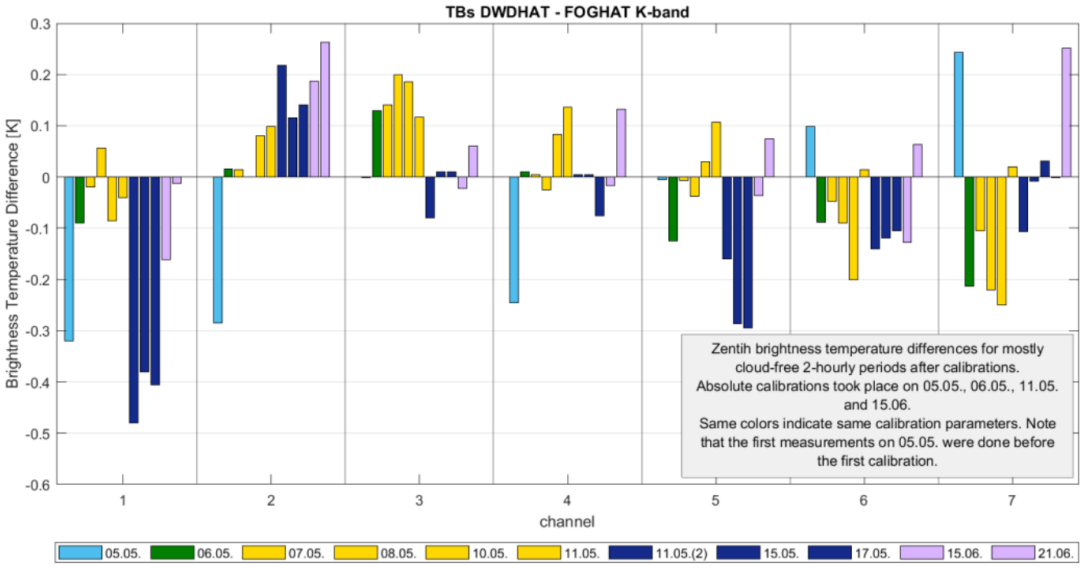
Bias: Systematic differences between two collocated instruments

K-band (22-31 GHz)



V-band (51-58 GHz)

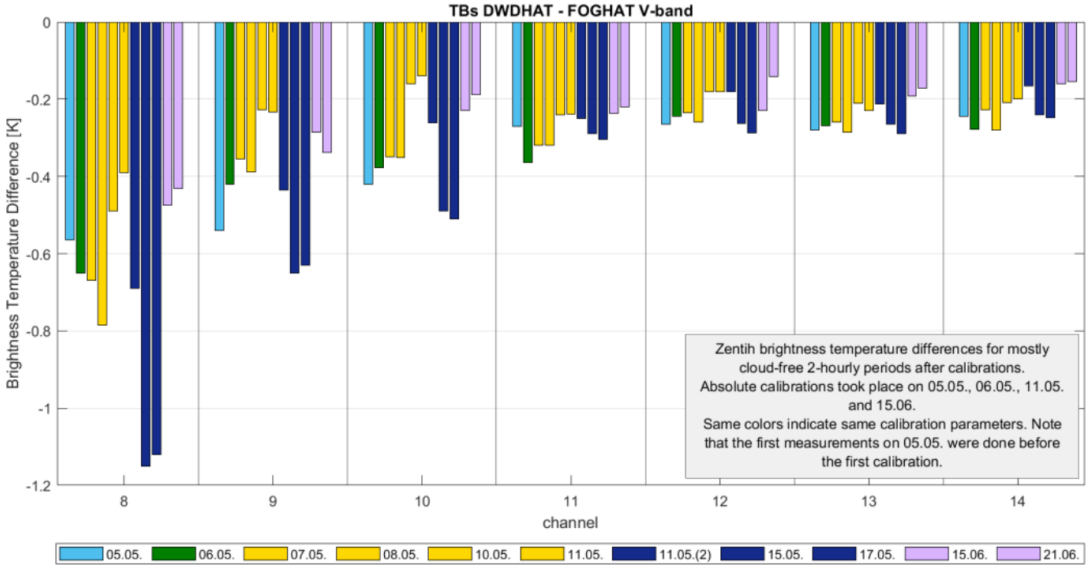


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Table 6: Summary of instrument uncertainties for Gen5 HATPROs. Uncertainties are described as absolute level 1 TBs.

Type of Error	Typical Error Values K-band	Typical Error Values V-band	Determined via	Error influenced by handling?	How to reduce Error?	Should be dermined by the operator
Calibration Repeatability	≤ 0.12 K	≤ 0.16 K	Changes to zenith reference measurements after two immediate consecutive calibrations	yes	Qualtity of calibration	no
Noise Levels (3min coldload – 10 min hotload) (1s)	≤ 0.11 K – 0.19 K	≤ 0.11 K – 0.33 K	Standard deviation (from covariance matrix diagonal)	no	Not possible, instrument specific	yes
Drifts (over 6 months)	usually ≤ 0.3 K (up to 0.78 K)	usually ≤ 0.8 K (up to 1.3 K)	Differences at coldload before and after a calibration	can be	Frequency of calibration	yes
Biases	mostly ≤ 0.3 K (up to 0.48 K)	mostly ≤ 0.5 K (up to 1.15 K)	Zenith measurement differences between two MWRs	yes	Quality of calibration	no

Updates on MWR activities within ACTRIS

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ACTRIS MWR operation training school

- 3-day training workshop held at Jülich for MWR operators in European networks (ACTRIS / PROBE / E-Profile)

Updates on MWR activities within ACTRIS

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ACTRIS MWR data processing

- Lined up a procedure for calibration uncertainty
- Updated QC routines (spectral consistency, etc.)
- Developed processing routine for MWR data (Python)
  - Consistent with E-Profile MWR data format
- Trained few EU MWR operators

- Outlook for 2023:
  - Development of common retrieval framework
  - Implementation of processing routines at ACTRIS data centre for all ACTRIS cloud remote sensing stations

Updates on MWR activities

Chances for non-EU GRUAN MWR programs to join ACTRIS/E-PROFILE

Cannot promise anything yet, but:

- ACTRIS/CCRES **might** be able to accept non-EU GRUAN MWR in their processing (if they run RPG or Radiometrics)
  - Several EU GRUAN stations are already within ACTRIS (all?)

- E-PROFILE first development (pilot network) limited to EU stations.
  - Afterwards, the focus will remain EU, but non-EU stations may be added (as done with wind profilers and some ceilometers)

Towards a GRAUN MWR GDP

Next steps towards a GRUAN MWR GDP:

- 2023/12 - ACTRIS MWR data products for EU sites
  - Cannot say these are "GRUAN" products, but maybe GRAUN can accept them as v0.1
    - Data life cycle is secured

- 2024 – Investigate any gaps wrt GRUAN requirements and consider any evolution
  - Data life cycle needs to be worked out
  - But may be easier starting from ACTRIS data products

- Looks good, but yet to come!

Thanks much for your attention!