ExOb Seminar 22nd Nov. 2022

Institute for Geophysics and Meteorology, University of Cologne

Schedule

- Publication Plans (Tobias Böck)
  - Uncertainty Assessment of HATPRO MWR Measurements and Calibrations
- RFI Update for TOPHAT in Jülich (Johanna Drude)
- Misc.

Uncertainty Assessment of HATPRO MWRs

Motivation

- The atmospheric boundary layer (ABL) is the **most important under-sampled** part of the atmosphere*
- For NWP applications, the top-priority atmospheric variables not currently adequately measured**
  - **temperature (T) and humidity (H) profiles** (specifically in cloudy areas)
- T and H profiles can be obtained by **ground-based microwave radiometer (MWR)** observations
- Yet MWR observations are not assimilated by any operational NWP system

**US National Research Council Reports*

**WMO guidance on observations for NWP: https://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html

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Motivation

- Driven by the **E-PROFILE** program, a business case proposal was recently accepted by **EUMETNET** to continuously provide MWR data to the European meteorological services
- The European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases (**ACTRIS**) and the European COST action **PROBE** (PROfiling the atmospheric Boundary layer at European scale) currently focus on establishing continent-wide quality and observation standards for MWR networks for research as well as for NWP applications
- The German Weather Service (**DWD**) also investigates the potential of HATPRO networks for improving short-term weather forecasts over Germany

→ Uncertainty Assessment of HATPROs needed for DA

Error types

Characterized

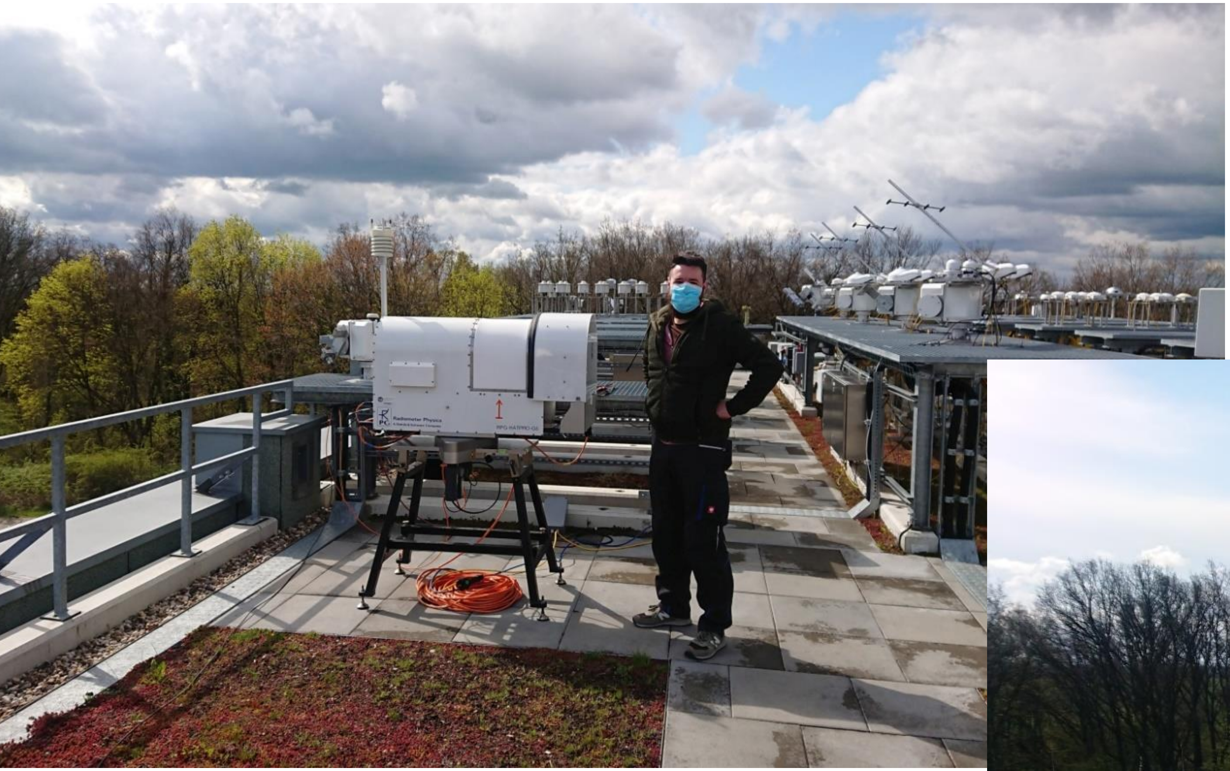
- systematic errors:
  - absolute **calibration errors** (bias)
  - **drifts** (instrument stability, TB leaps between calibrations)
- random errors:
  - **radiometric noise** (e.g. via covariance matrices)
- external errors:
  - **radio frequency interference (RFI)** → Johanna

through coordinated experiments at JOYCE and RAO (FESSTVaL)

Objective:

- **Define & apply procedure for MWR measurement uncertainty characterization (guidance for operators)**
- **Store all error types into lv1 files for each channel after each calibration**

Calibration Campaign during FESSTVaL



Calibration Campaign at RAO in Lindenberg

- **4 HATPROs** (FOGHAT G5, DWDHAT G5, SUNHAT G2, HAMHAT G2)
- Calibration campaign:
  - Calibrate all 3 HATPROs on the roof in a row for **three times** each with the standard procedure
  - **Zenith** measurements in between
  - 4th HATPRO nearby gets calibrated only once and then always measures zenith; is used as a reference later
    - First calibration round: May 5, 2021
    - Second and third calibration round: May 6, 2021

- Comparisons of zenith and blackbody measurements (to find out **biases**, **drifts/leaps**, **noise levels, repeatability**)

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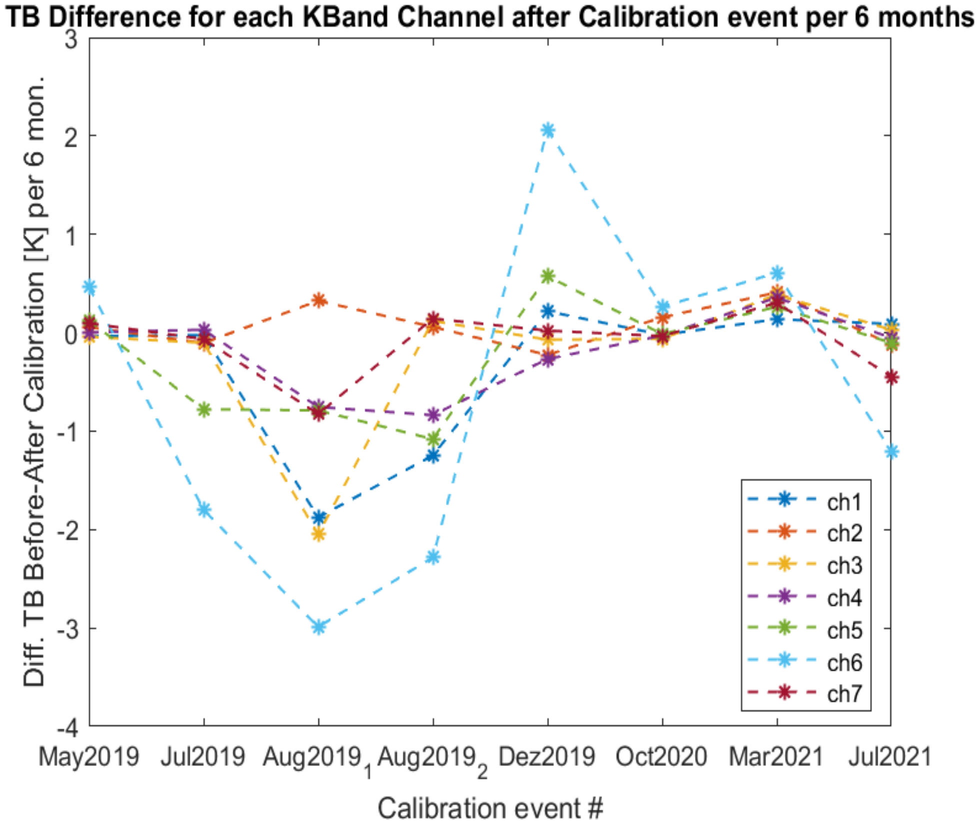
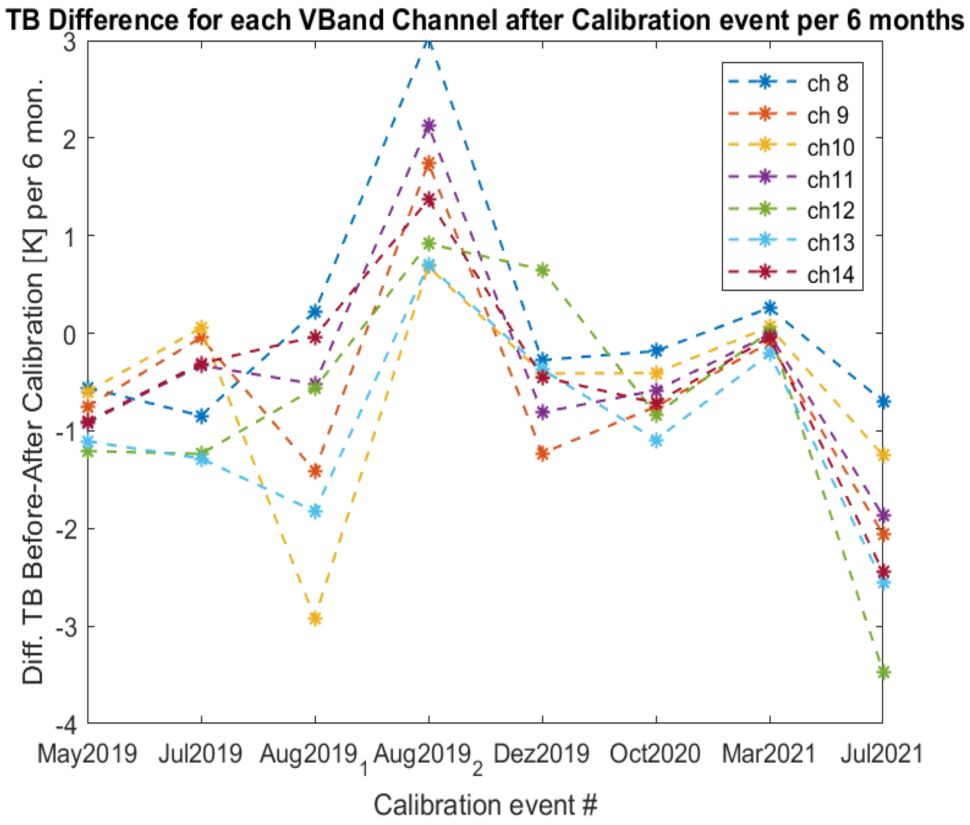
Results Overview

TOPHAT at JOYCE: Drifts per 6 Months





→ Seem unstable and are not linear
→ Cannot be directly influenced by operator
→ Is also influenced by biases (especially when time between calibrations is short)

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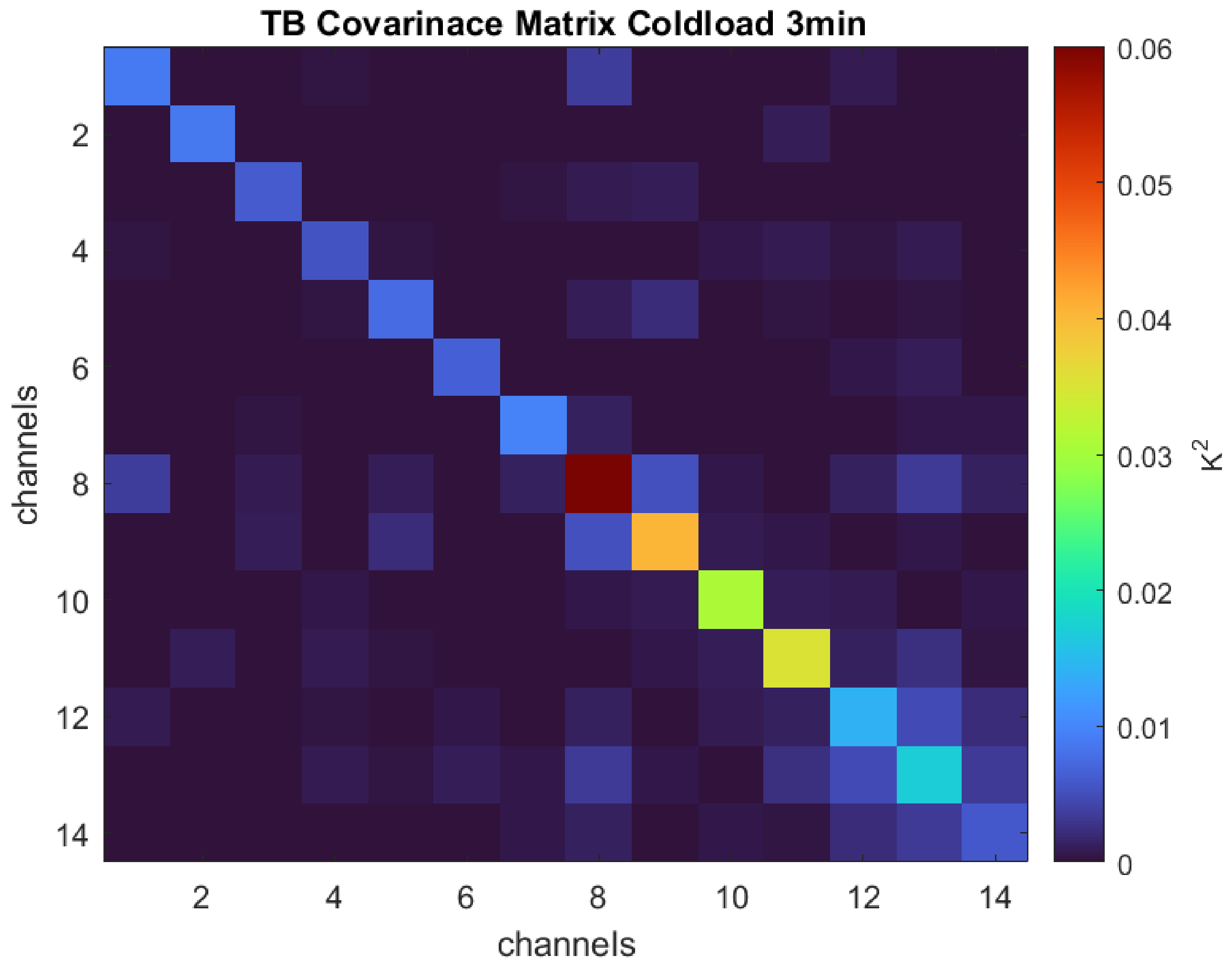
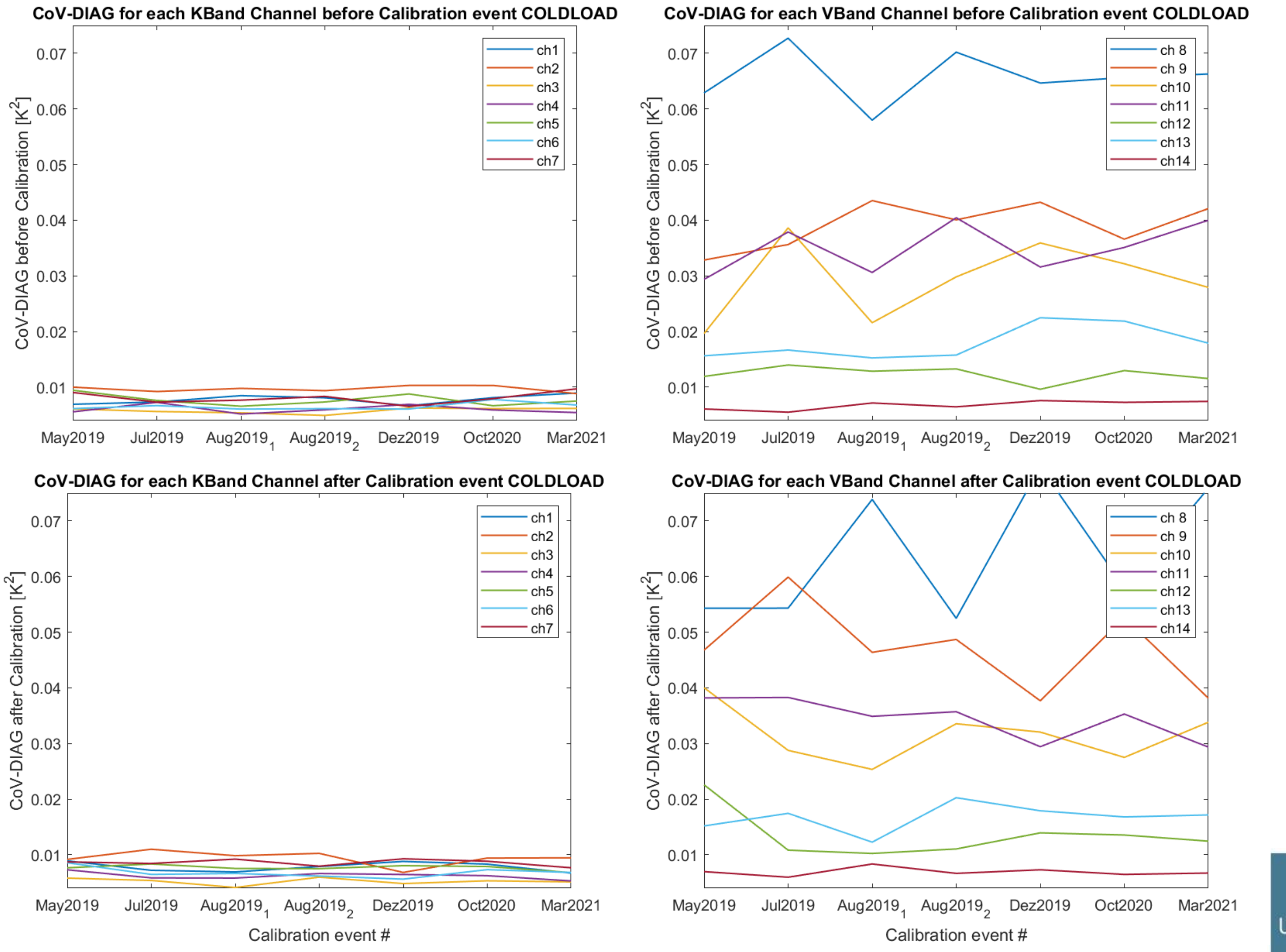
Short Reminder: Covariance Matrix (for Noise Levels)

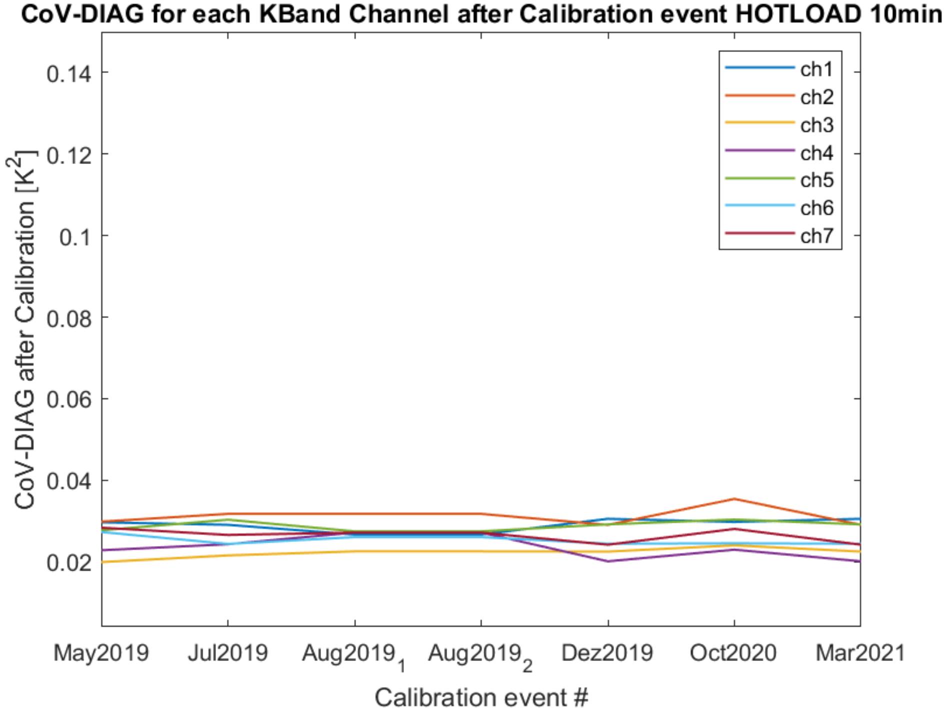
- **Correlated radiometric noise** for all 14 channels (shows dependency of these channels)
- The radiometric noise for a single channel can be determined by calculating the variance when looking on a stable blackbody target
- Highly correlated channels are of no use for retrievals and data assimilations as they don‘t contain additional information

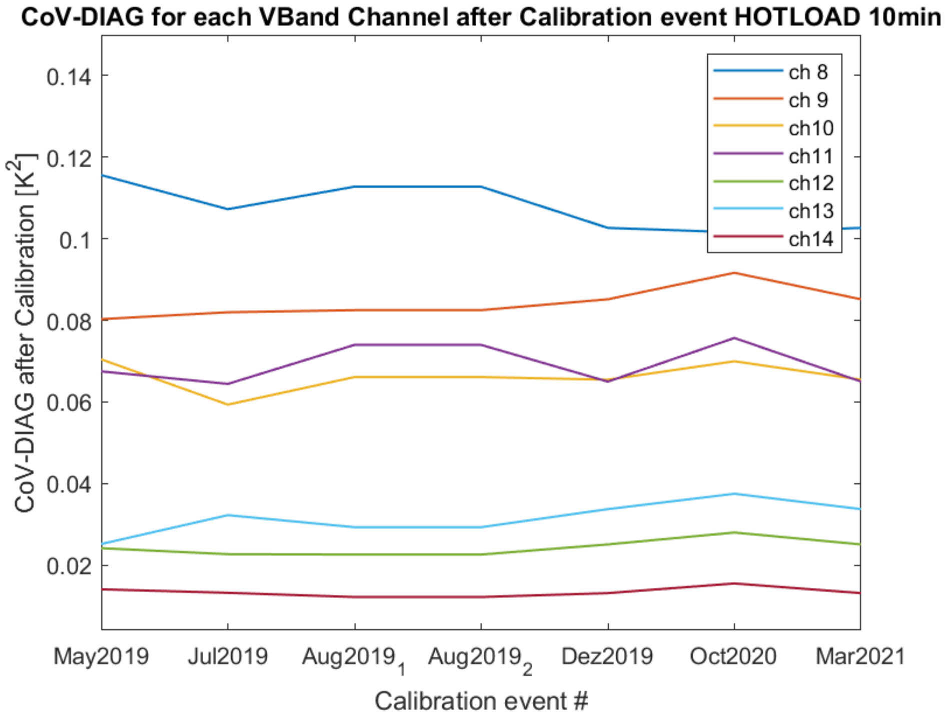


TOPHAT at JOYCE: Covariance Diagonals Coldload



TOPHAT at JOYCE: Covariance Diagonals Hotload



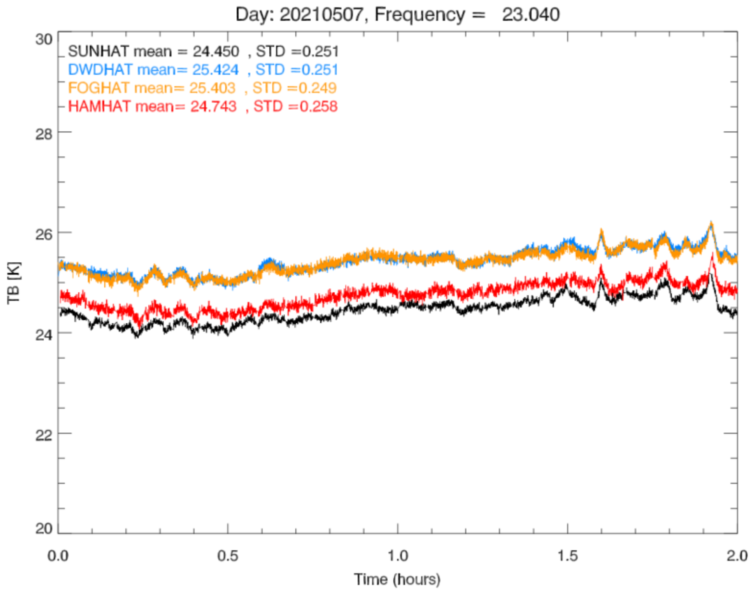


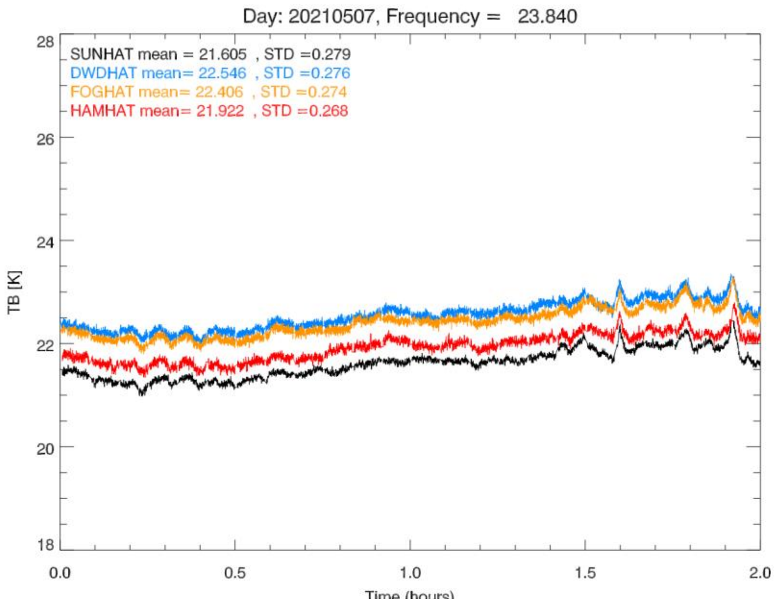
→ Coldload and Hotload Covariances similar for all Gen5 HATPROs, significantly higher values for Gen2

→ Operator independent, instrument specific

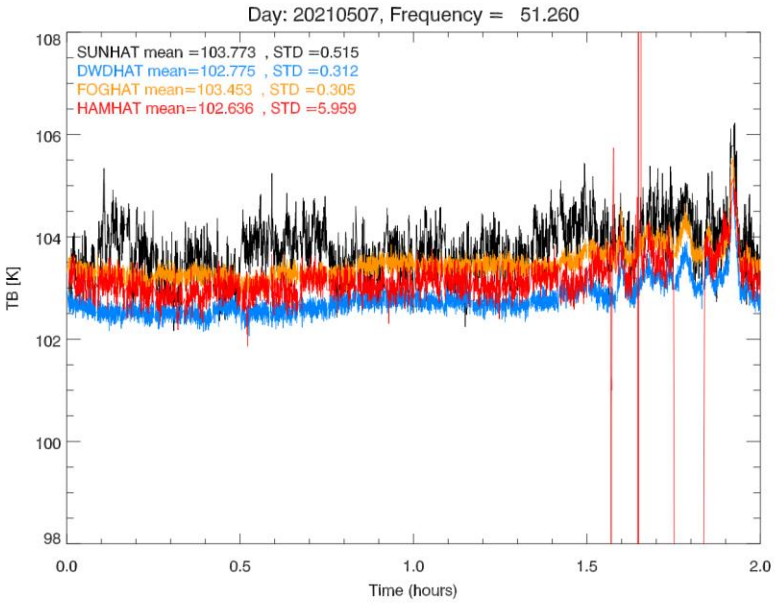
→ Square root of diagonals is the same as standard deviation

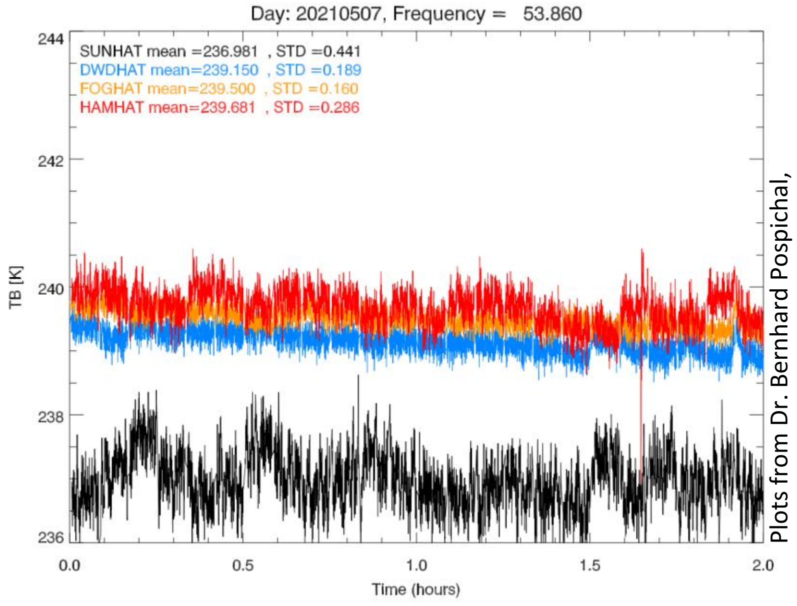
Calibration Campaign First Results: Zenith Comparisons





After calibration campaign
(zenith clear sky)





Plots from Dr. Bernhard Pospichal,
University of Cologne

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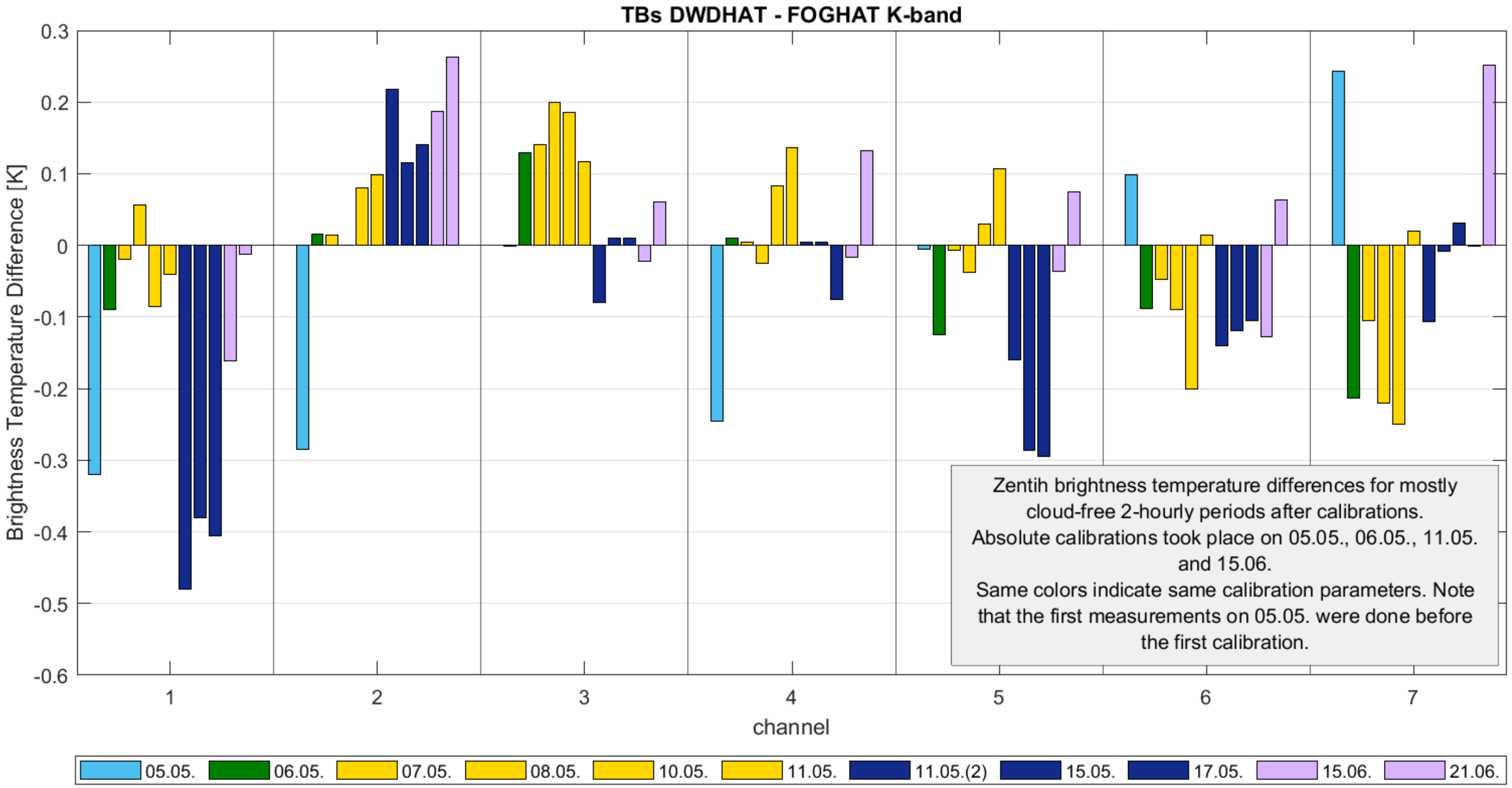
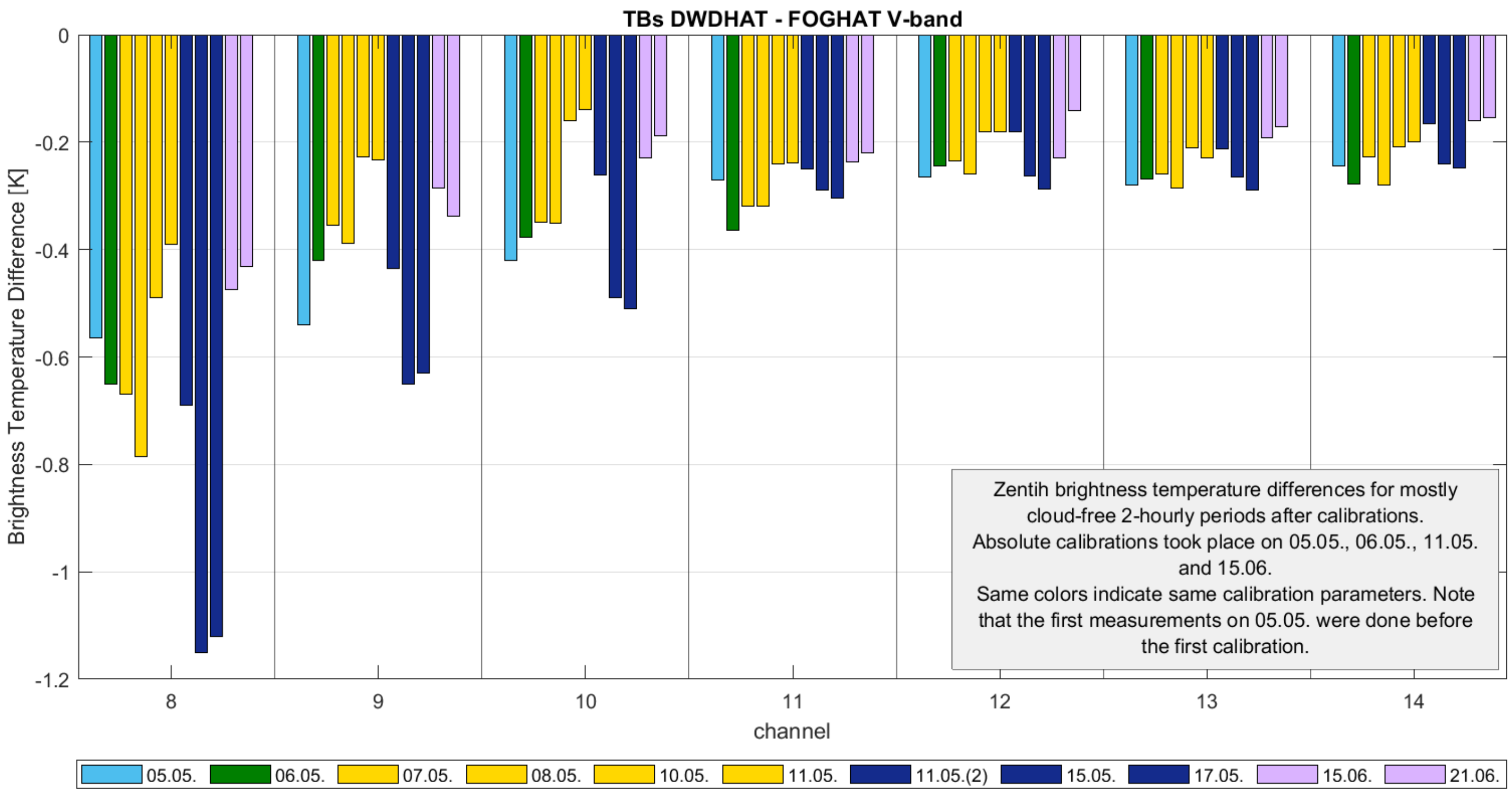
Biases/Offsets via Zenith Comparisons



Biases/Offsets via Zenith Comparisons



→ Biases/Offsets can be reduced by better LN2 calibrations
→ All errors are relative, there is no perfect absolute reference

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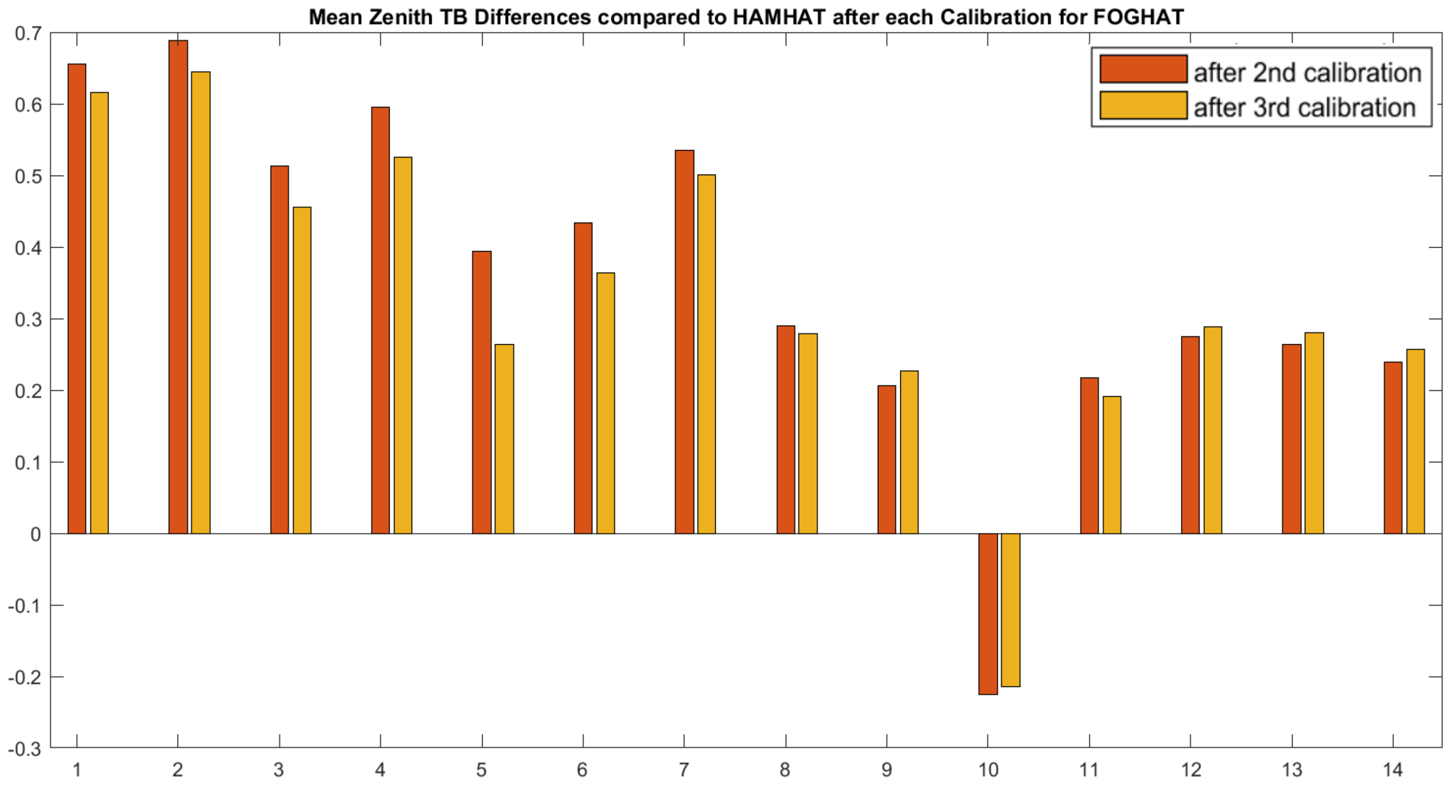
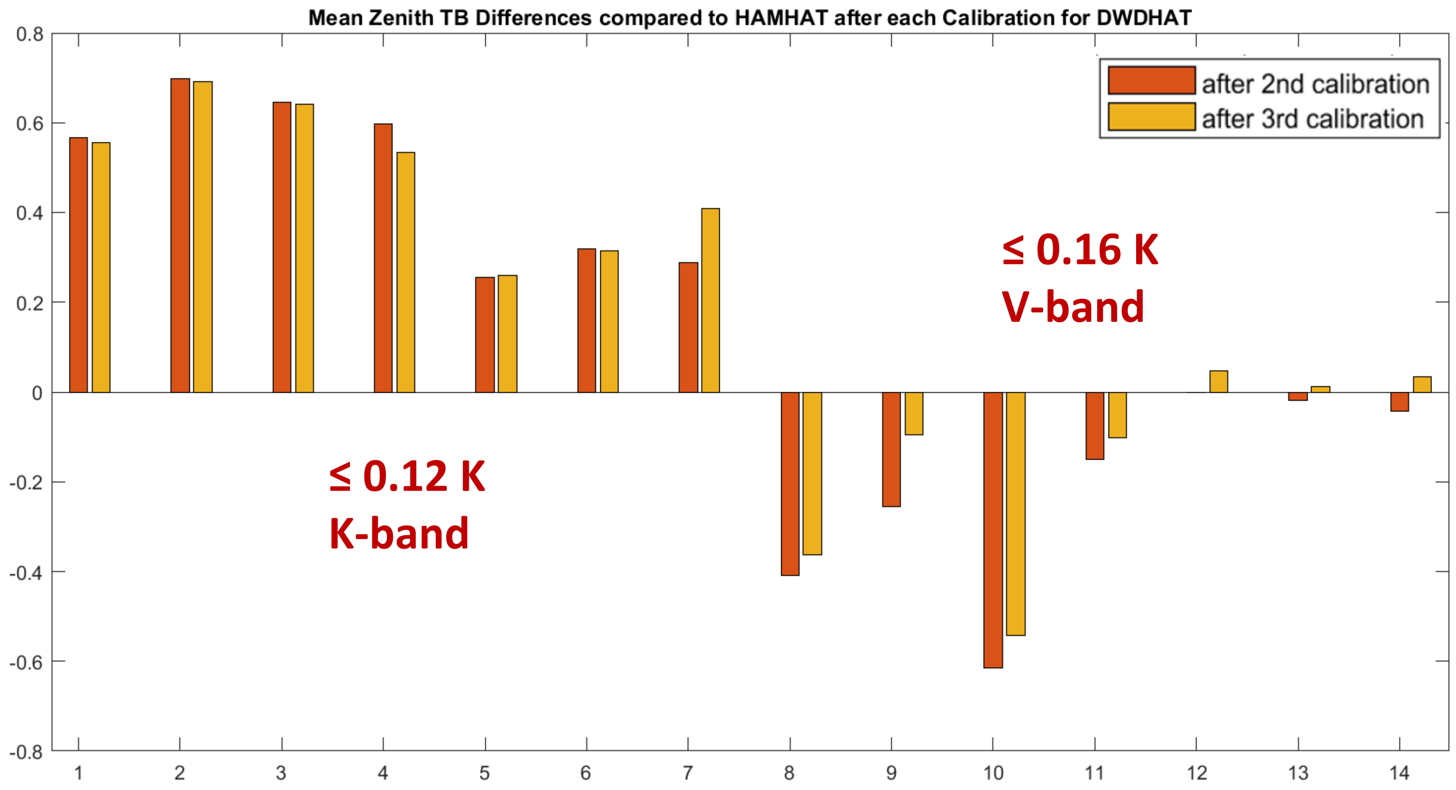
Leaps at Zenith between calibrations FOGHAT (Repeatability)



Leaps at Zenith between calibrations DWDHAT (Repeatability)



- → Should be very similar to the noise level
- → Is influenced by the quality of the calibration
- → Can only be done this way when there are at least two MWRs on the same site simultaneously
- → Meaningful values can only be achieved with the same conditions for each calibration
  (same day, same weather, same target,…)

Summary Uncertainties

Preliminary Results (for Gen5 HATPROs):

Type of Error	Typical Error Values K-band	Typical Error Values V-band	Determined via	Error influenced by handling?	How to reduce Error?
Biases/Offsets	usually ≤ 0.3 K (up to 0.48 K)	usually ≤ 0.5 K (up to 1.15 K)	Zenith measurement differences between two MWRs	yes	Quality of calibration
Drifts (over 6 months)	usually ≤ 0.3 K (up to 0.6 K)	usually ≤ 0.8 K (up to 1.3 K)	Leaps at coldload after calibration	no	Frequency of calibration
Calibration Repeatability	≤ 0.12 K	≤ 0.16 K	Leaps to zenith reference measurements after two immediate consecutive calibrations	yes	Qualtity of calibration
Noise Levels (coldload – hotload) (1s)	≤ 0.11 K – 0.19 K	≤ 0.28 K – 0.42 K	Standard deviation	no	Not possible, instrument specific

→ Errors above 0.5 K may be problematic

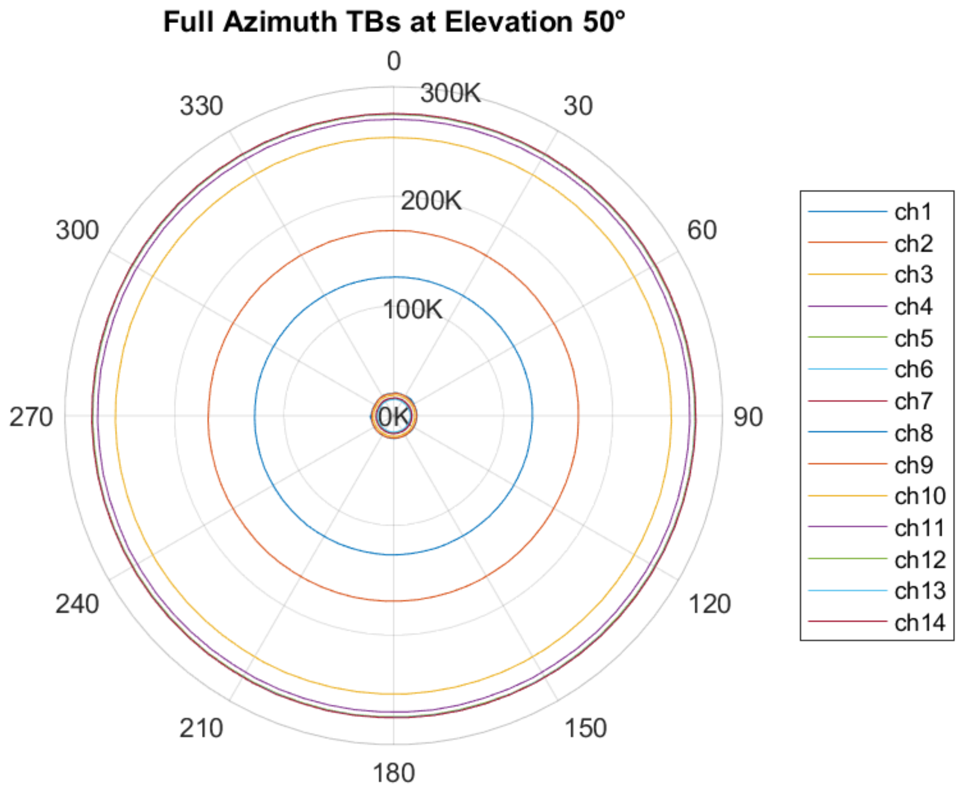
Next Steps

- Detailed guidance for operators on how to operate and calibrate HATPROs and how to avoid mistakes
- Sensitivity experiments with the radiative transfer model
- Compare to literature:
  - Maschwitz et al. (2013): LN2 calibration blackbody uncertainty of ±0.3 to ±1.6 K (old target)
  - Küchler et al. (2016): LN2 calibration blackbody uncertainty of ±0.5 K (newer target, G4 HATPRO)
  - RPG manual for G5: absolute TB uncertainty 0.5 K, noise 0.10 to 0.15 K

Thank you for your attention!

Bonus Slides:
External Errors

FOGHAT at Köln: Azimuth Scans (Obstacles and external Interference)



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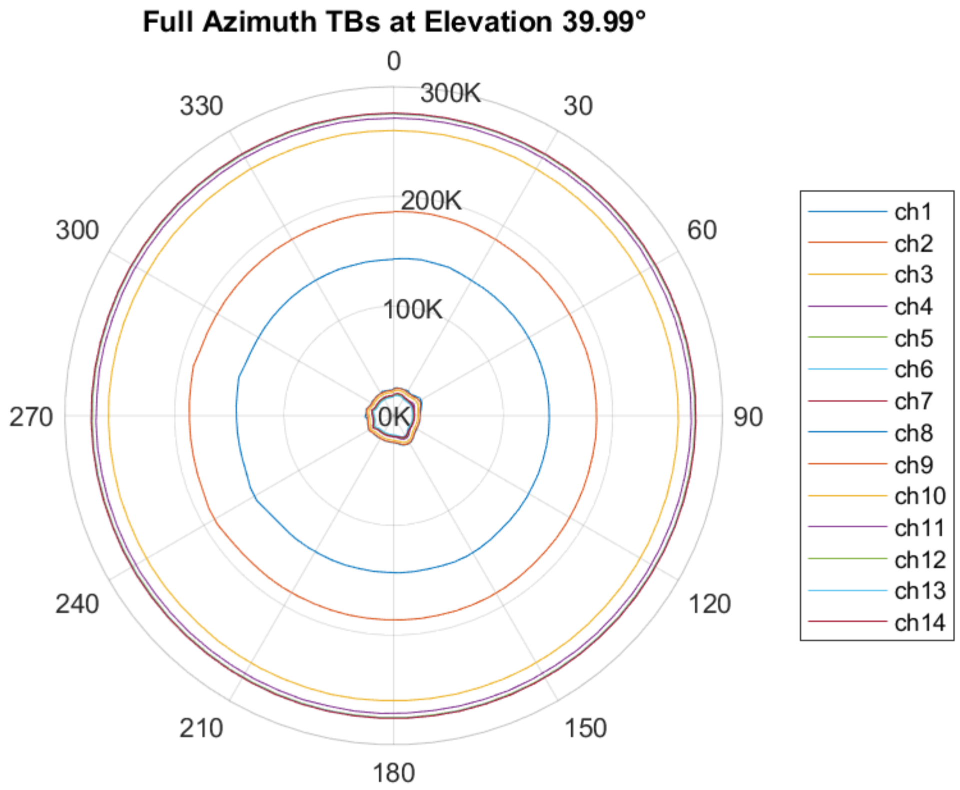

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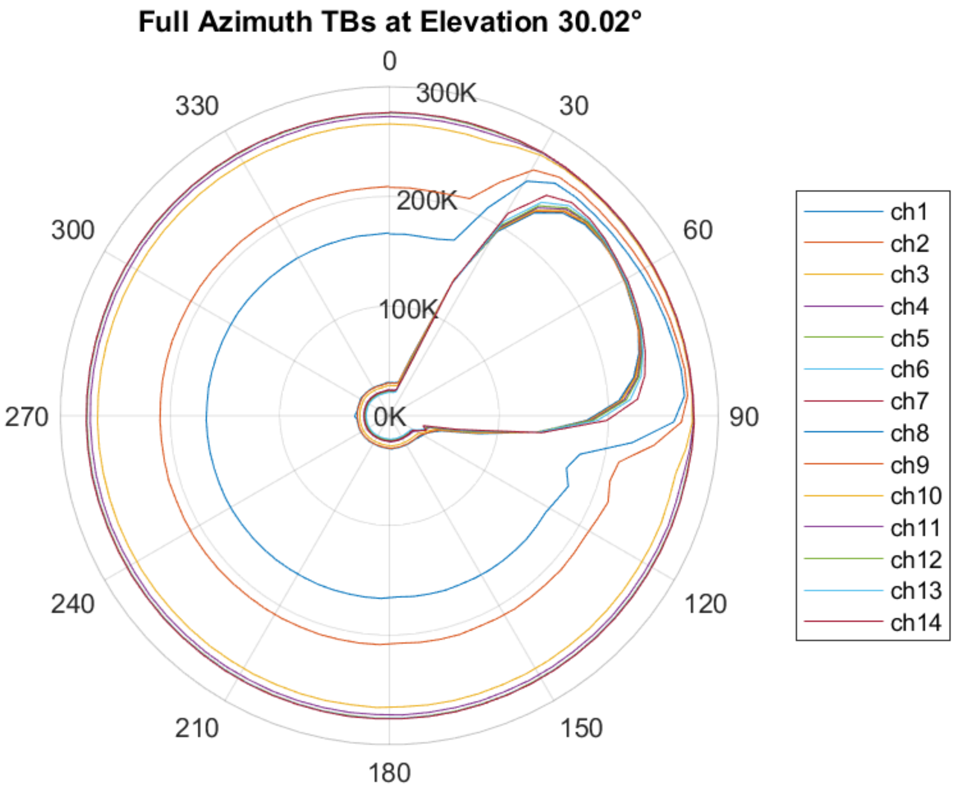

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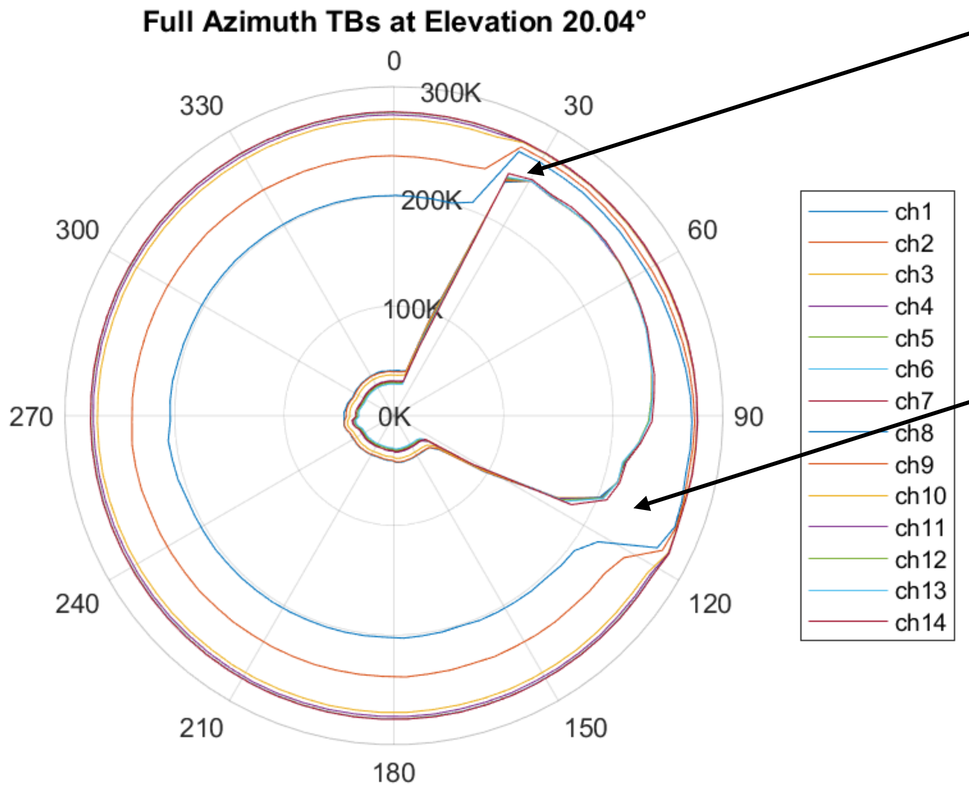

wall from building between NE and SE

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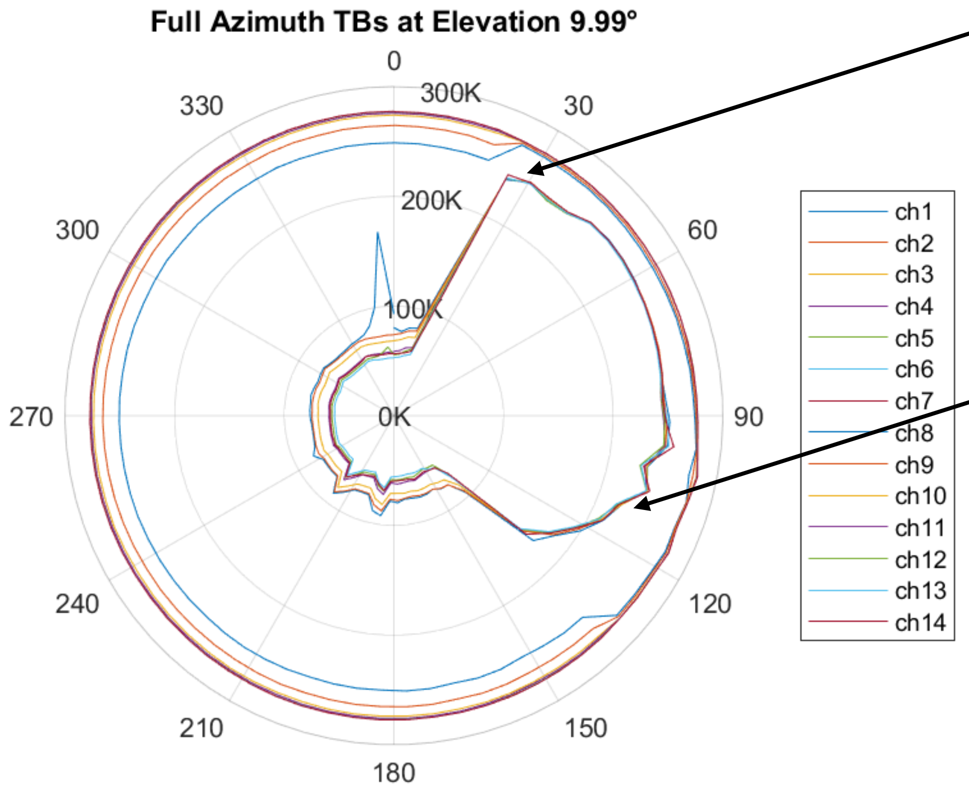

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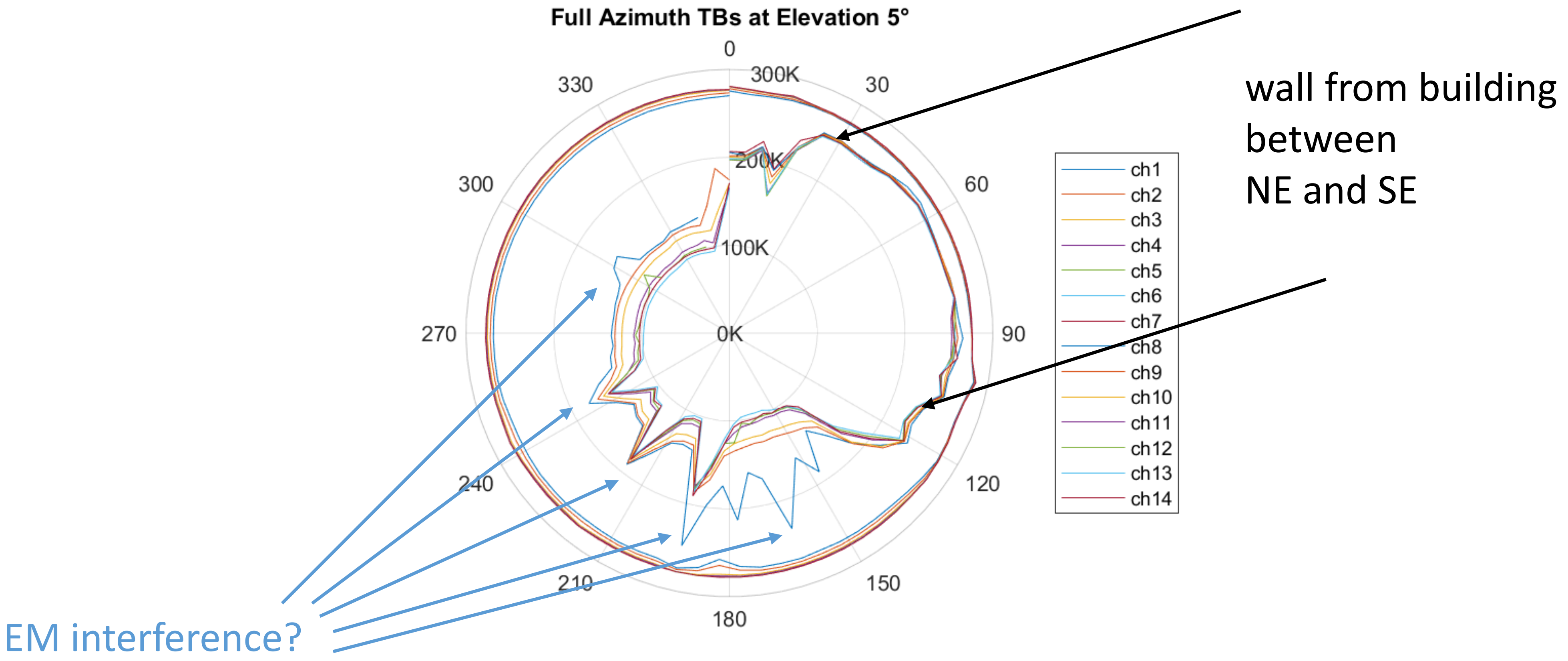

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Other stuff

- More in-depth analysis of all the data from the calibration campaign in order to characterize all instrument errors and uncertainties in detail:
  - Assess differences between different HATPRO generations

    → all uncertainty values **per channel** need to be implemented into level 1 files (necessary for DA)

    values like: **typical biases/offsets**
    typical drifts over a certain time
    typical noise levels (covariance matrix)
    typical calibration repeatability

    (everything above 0.5K may be a problem)

- Determine some kind of **total error**

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TOPHAT at JOYCE: Drifts (via Coldload Leaps)