

Detection, implications, and possible mitigation of RFI affecting ground-based microwave radiometers

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- Introduction
 - Why gb MWR
 - Retrievals and applications
- RFI affecting gb MWR
 - Postcards from the world
 - Affected retrievals
- Mitigation solutions
 - Hardware
 - Software
 - Scanning strategy

- Part of this work is done within the EU PROBE cooperation action

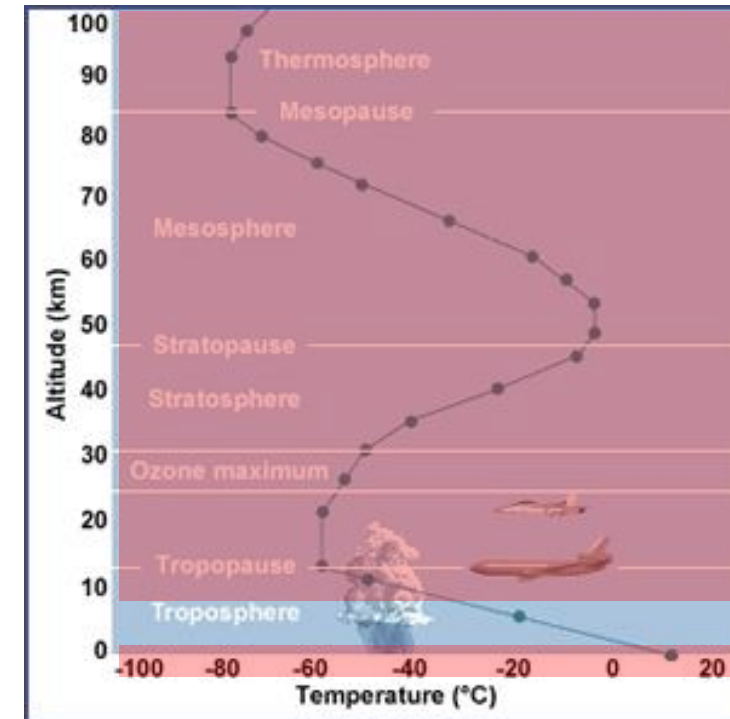


PROfiling the atmospheric
Boundary layer at
European scale



19/10/2019 – 18/10/2023

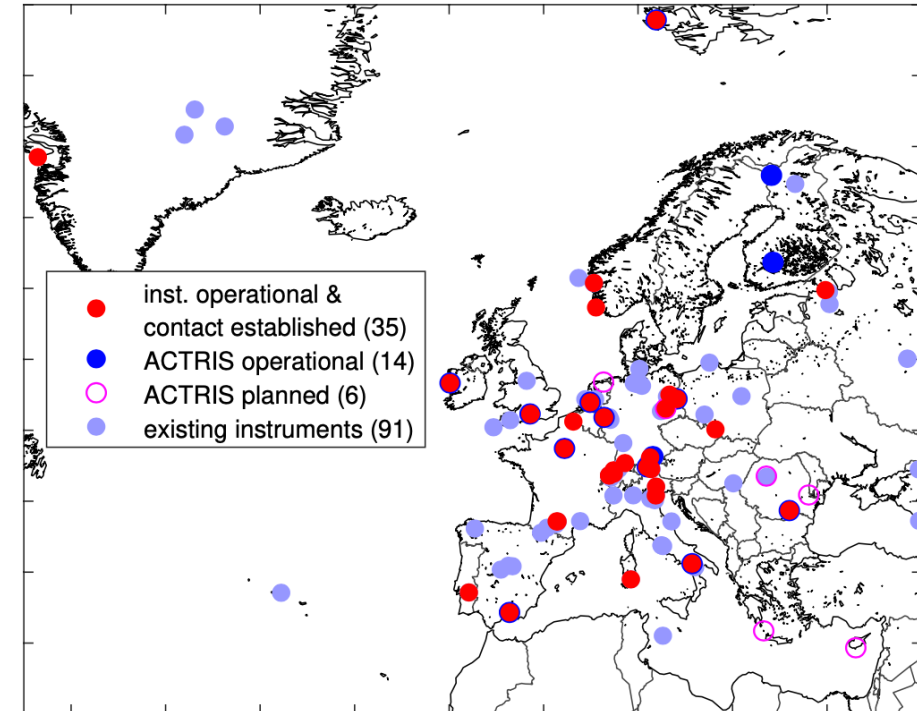
- Observational gap in the ABL
 - The atmospheric boundary layer (ABL) is the single most important **under-sampled** part of the atmosphere¹
 - Particularly important for meteorology, air quality, renewable energy, and NWP²



¹US National Research Council Reports

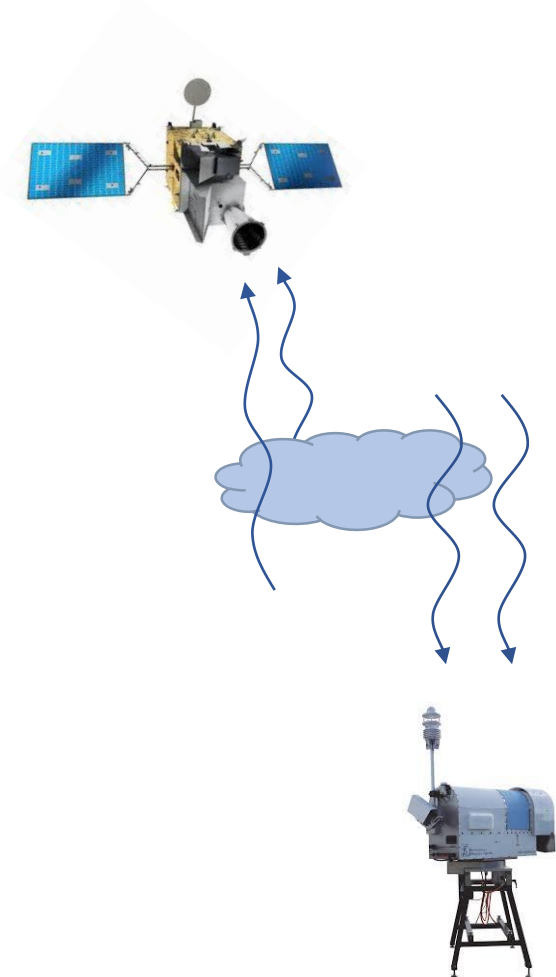
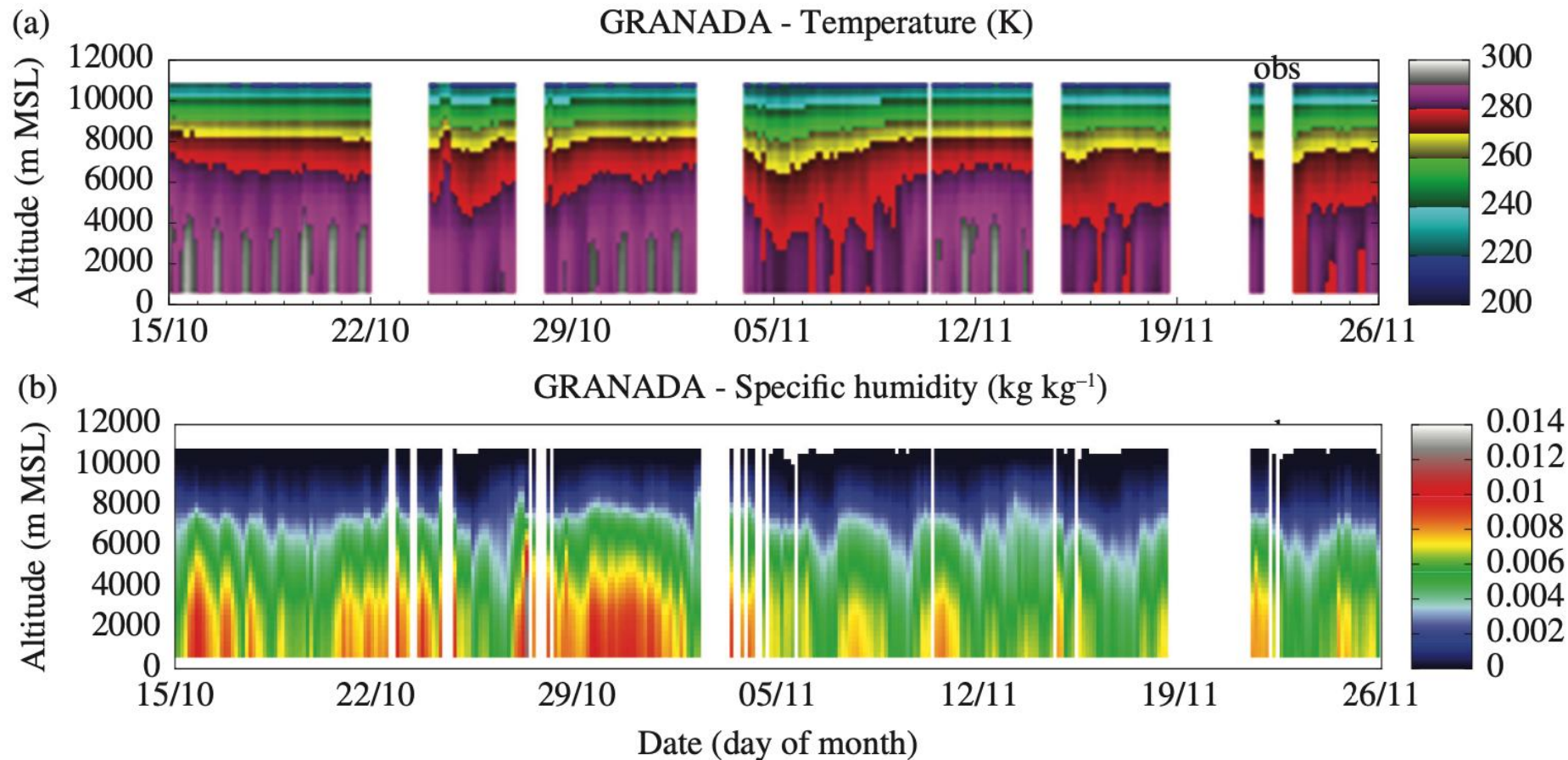
²WMO guidance on NWP obs.

- One of PROBE's contribution is towards the establishment of gb MWR networks in Europe, in cooperation with:
 - EUMETNET E-PROFILE (NWP oriented)
 - ACTRIS (long-term commitment)
- Other established/ing gb MWR networks:
 - US DoE ARM Program
 - NYS Mesonet
 - Tokyo Metropolitan Area
 - Seoul Metropolitan Area
 - ...



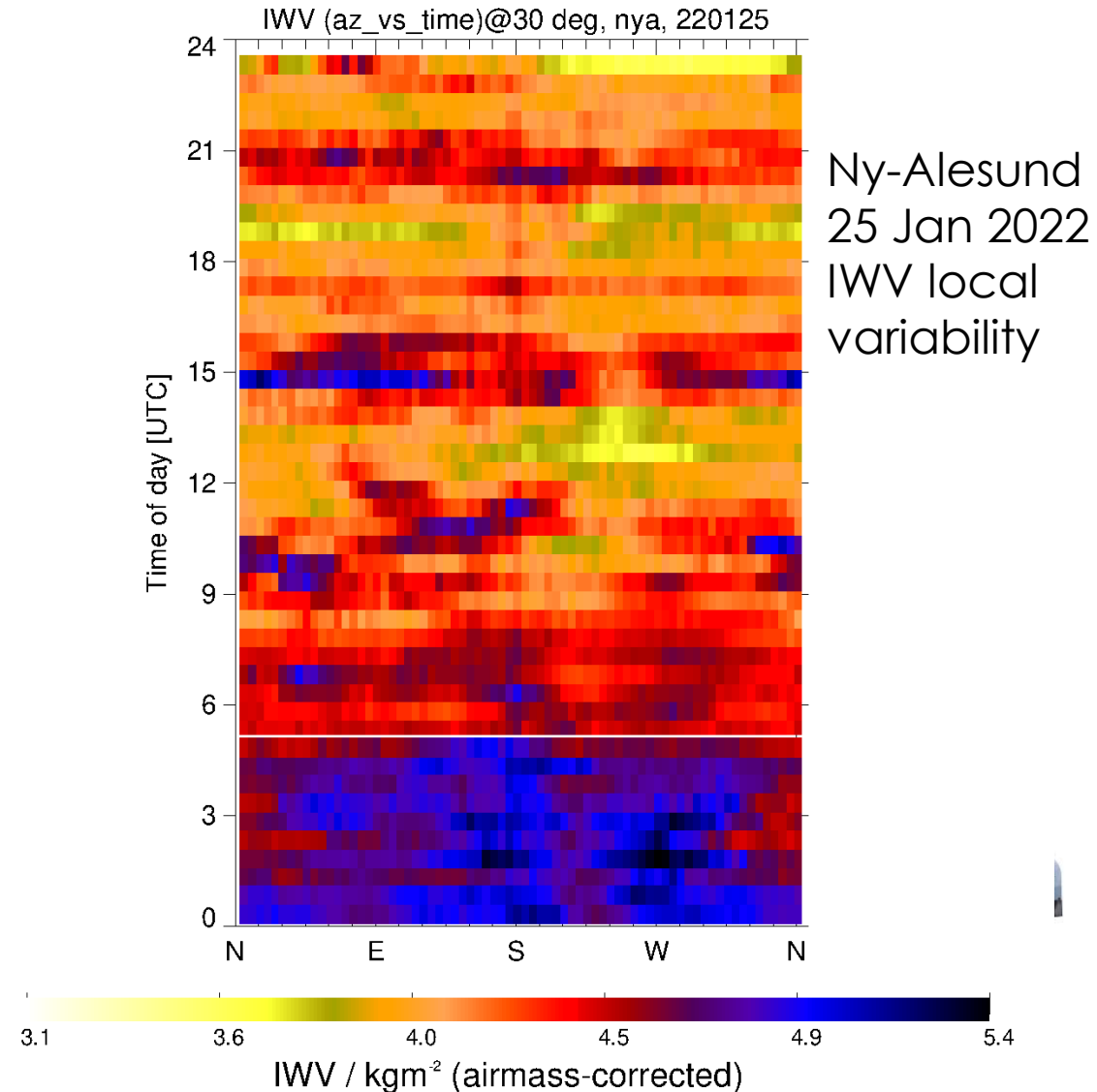
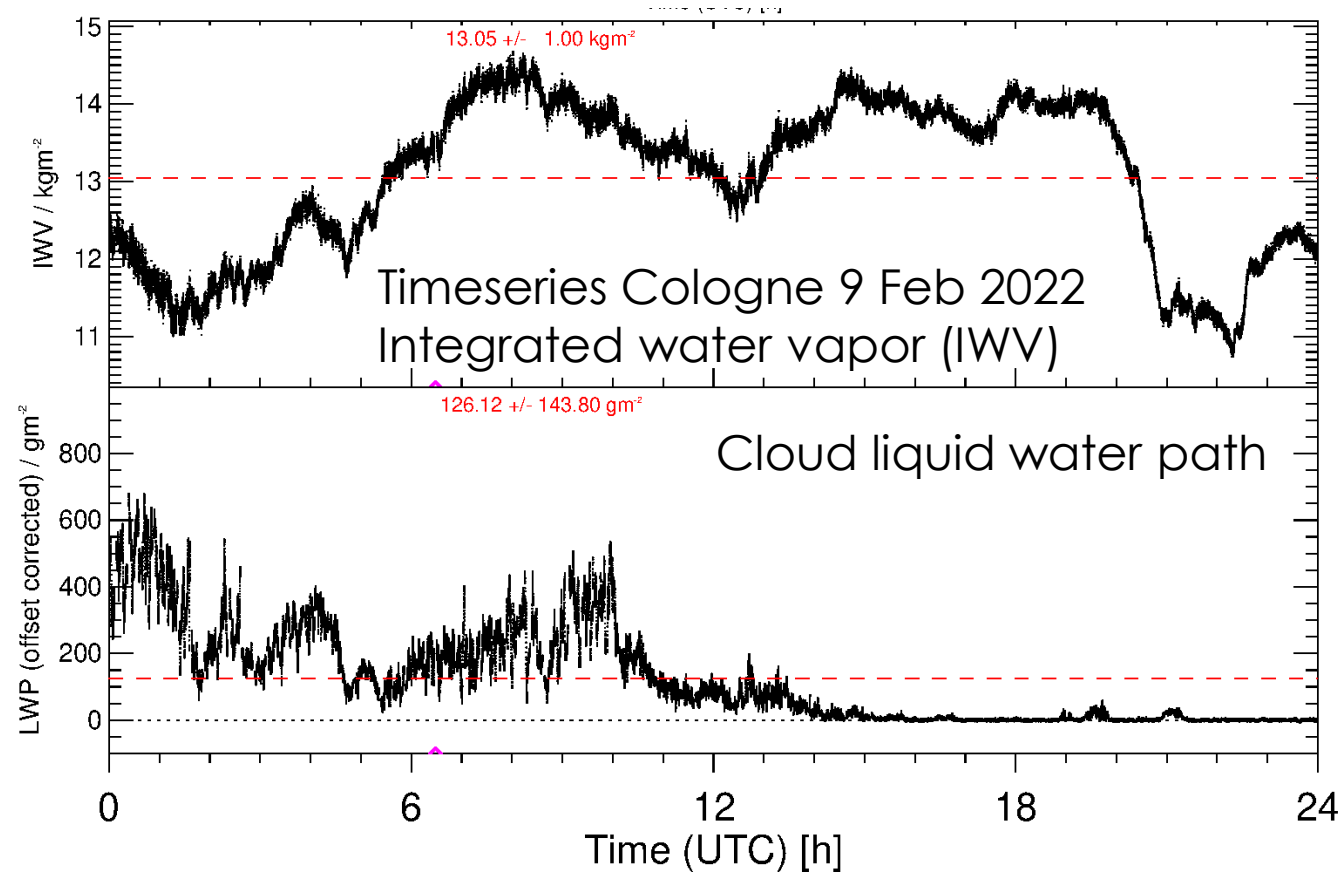
Retrievals and applications

- What a gb MWR can provide?
 - temperature and humidity profiles



Retrievals and applications

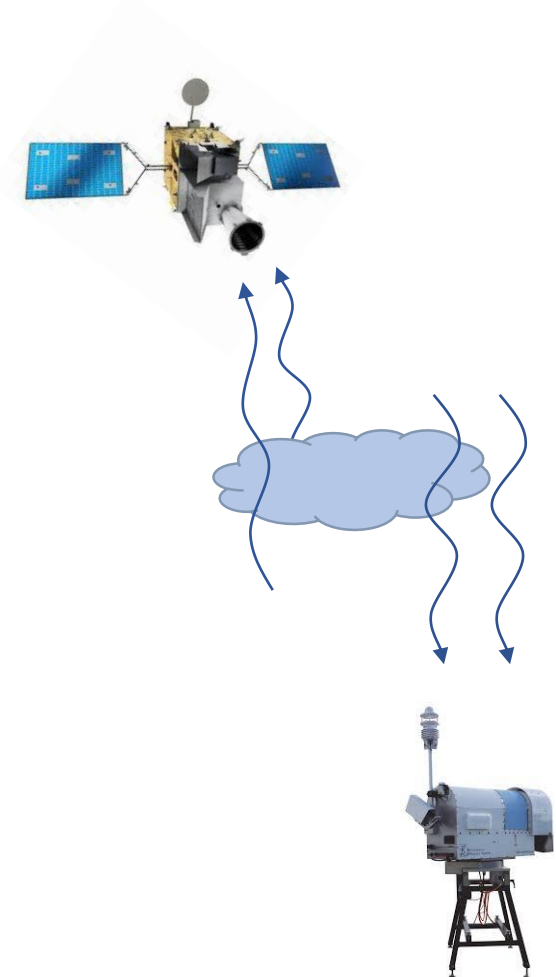
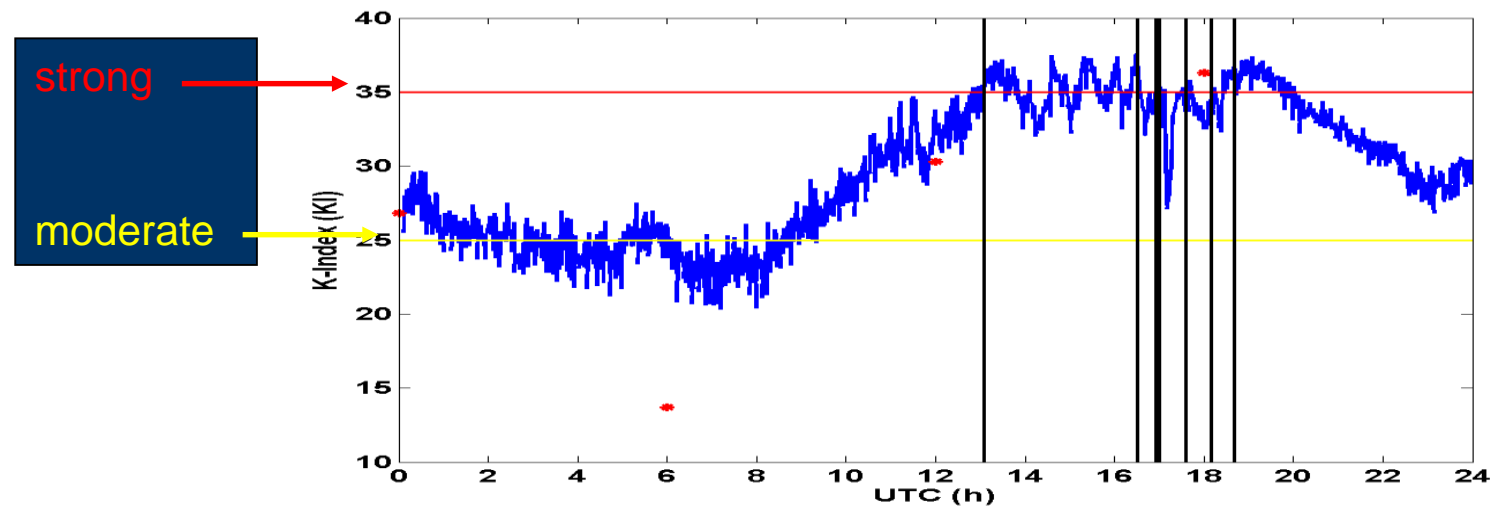
- What a gb MWR can provide?
 - Integrated contents of vapor and liquid water



Retrievals and applications

- What a gb MWR can provide?
 - Forecast indices

e.g., K Index $K = (T_{850} - T_{500}) + T_{d850} - (T_{700} - T_{d700})$
related to atmosphere stability (the higher, the more probable are thunderstorms)



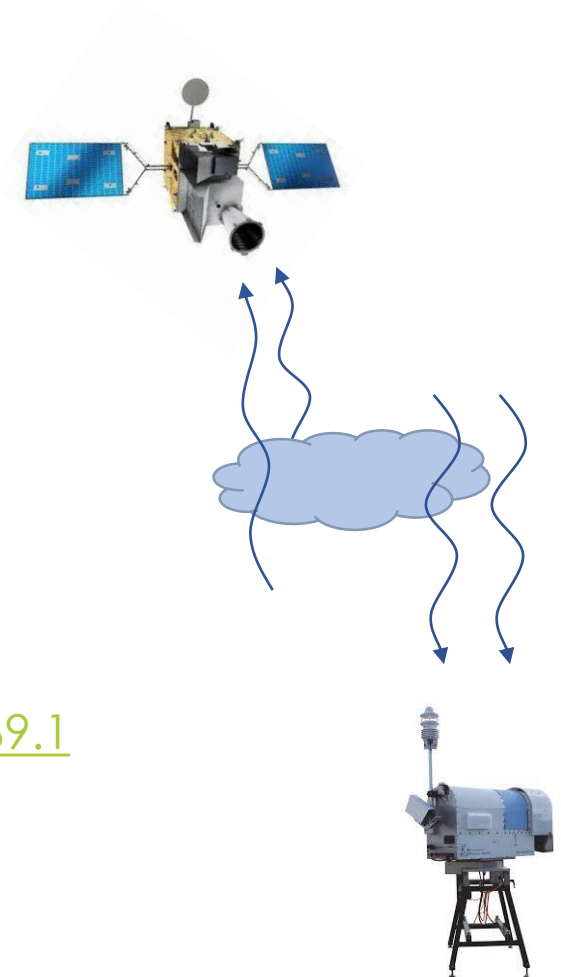
- What a gb MWR can provide?

- Data assimilation

- Caumont et al., QJRMS 2016, <https://doi.org/10.1002/qj.2860>
- Current work at:
 - DWD (Vural et al.)
 - MeteoSwiss (Merker et al.)
 - MeteoFrance (Martinet et al.)

- SAT-GB Synergy

- Toporov & Löhnert, JAMC 2020, <https://doi.org/10.1175/JAMC-D-19-0169.1>

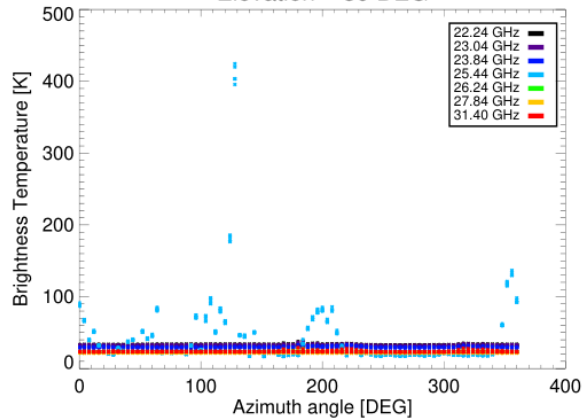


RFI affecting gb MWR

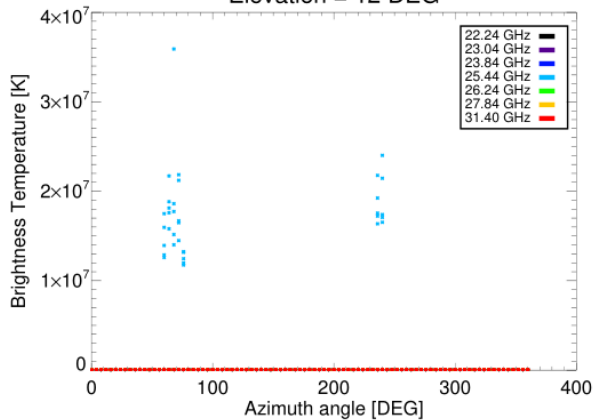
- Postcards from the world

Wroclaw University, PL

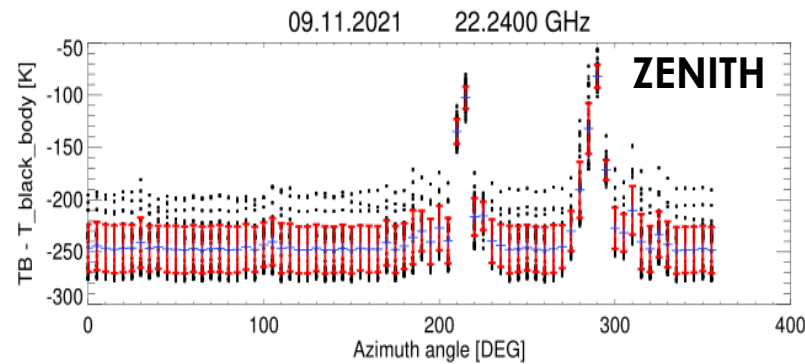
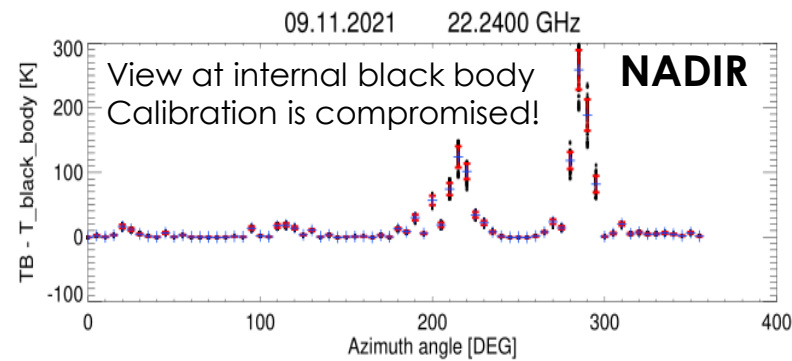
Elevation = 30 DEG



Elevation = 12 DEG

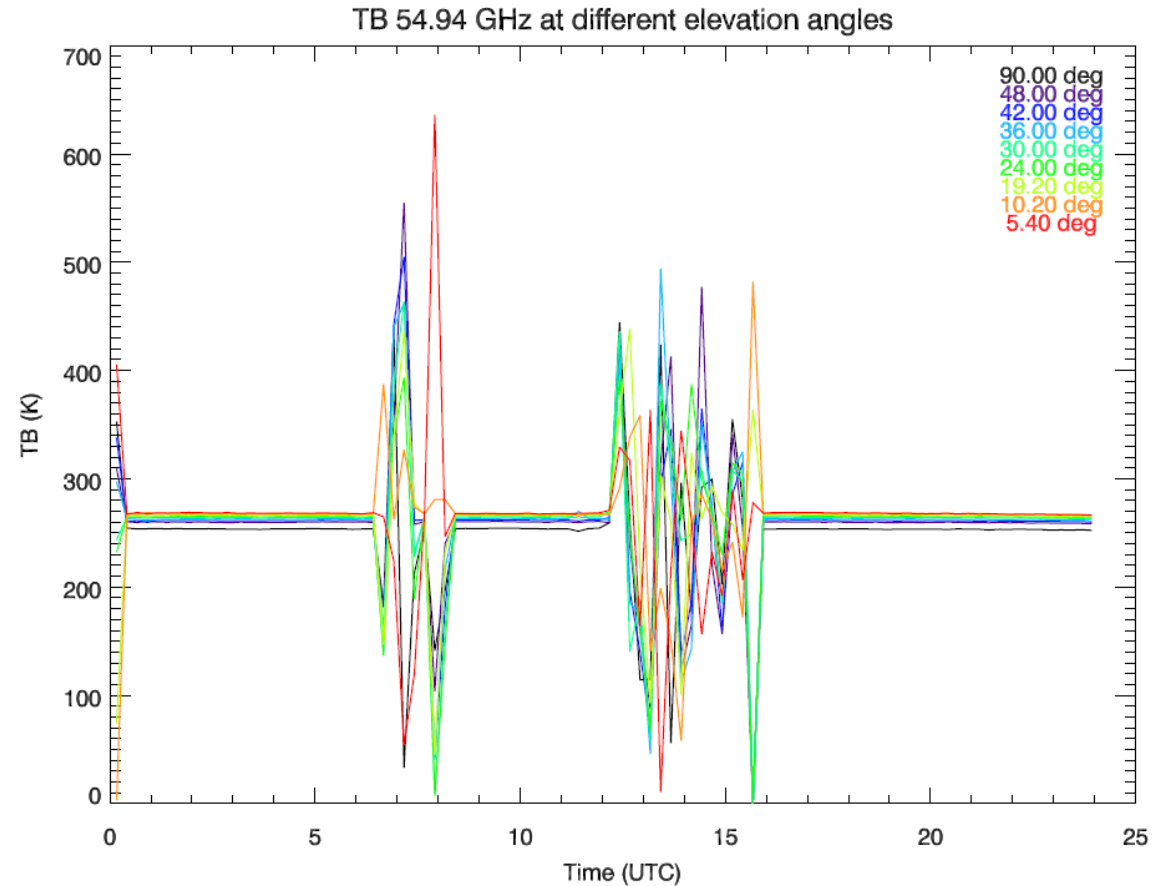
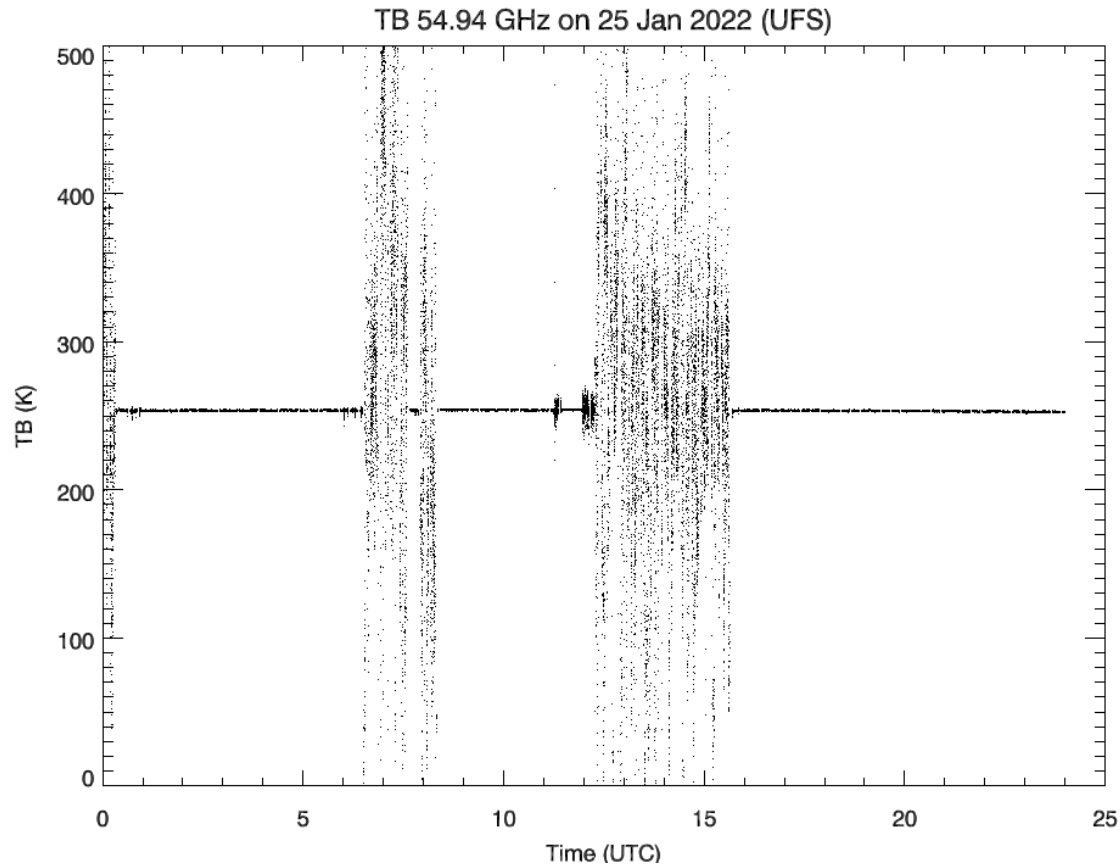


Galati University, RO



RFI affecting gb MWR

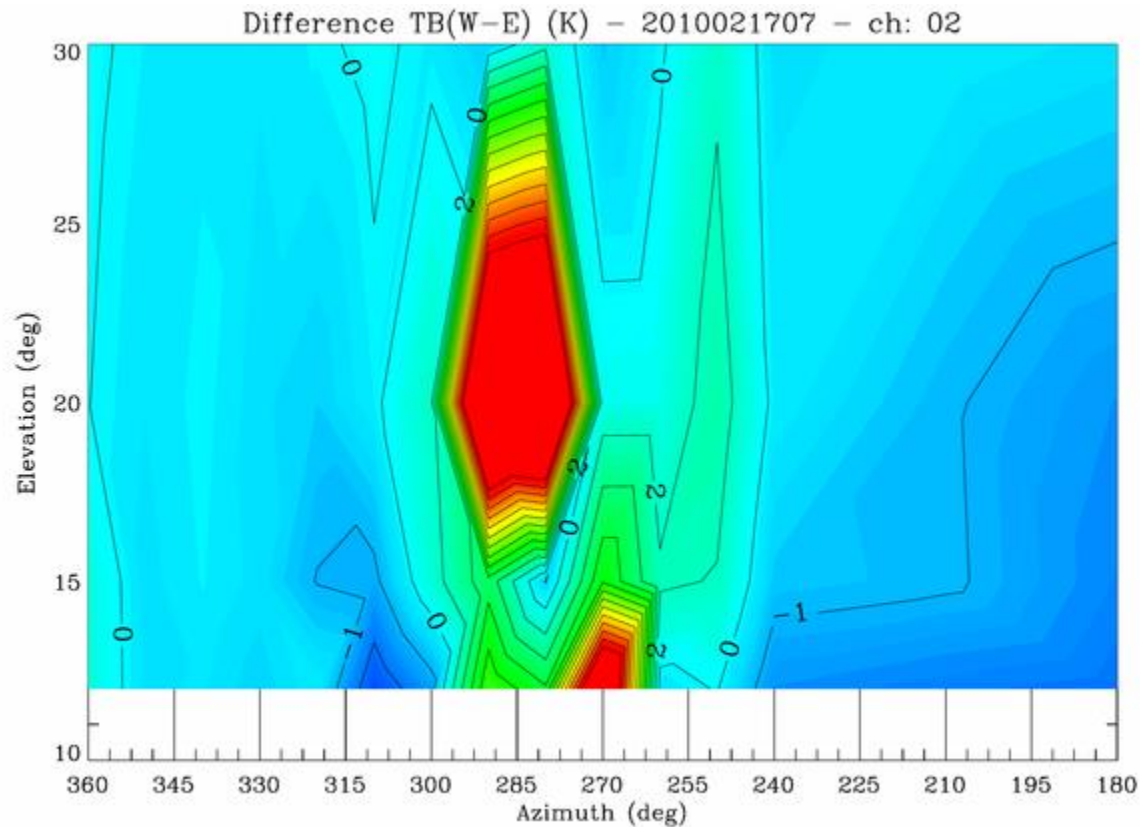
- Research station Schneefernerhaus (German alps)



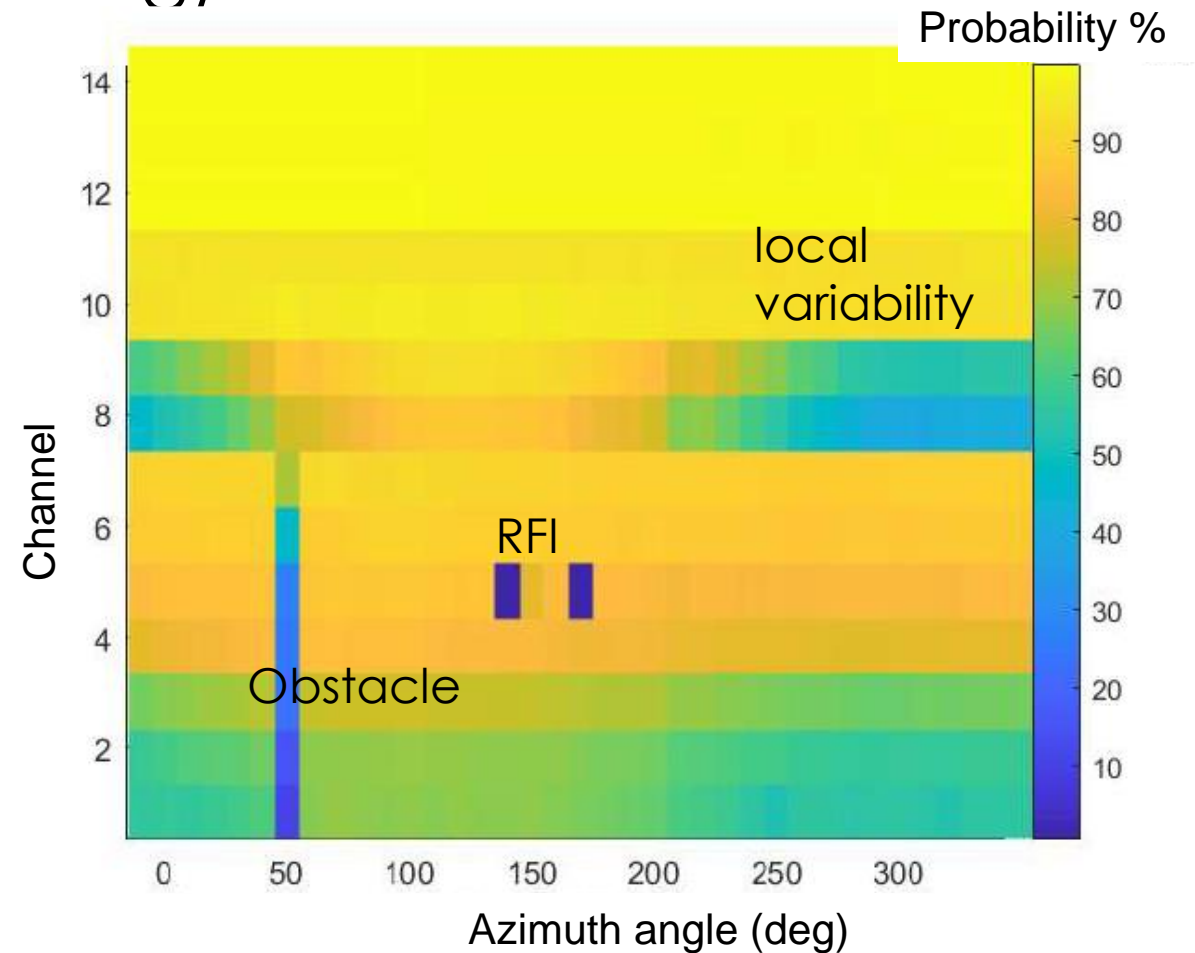
Timeseries of zenith brightness temperatures at 54.94 GHz (left) and elevation scan (right) on 25 Jan 2022

RFI affecting gb MWR

- Observed examples (Azimut scanning)



Lindenberg (Azimuth scans with RFI), left
Jülich (right): Observations at 30 deg elevation



• In/out protected bands

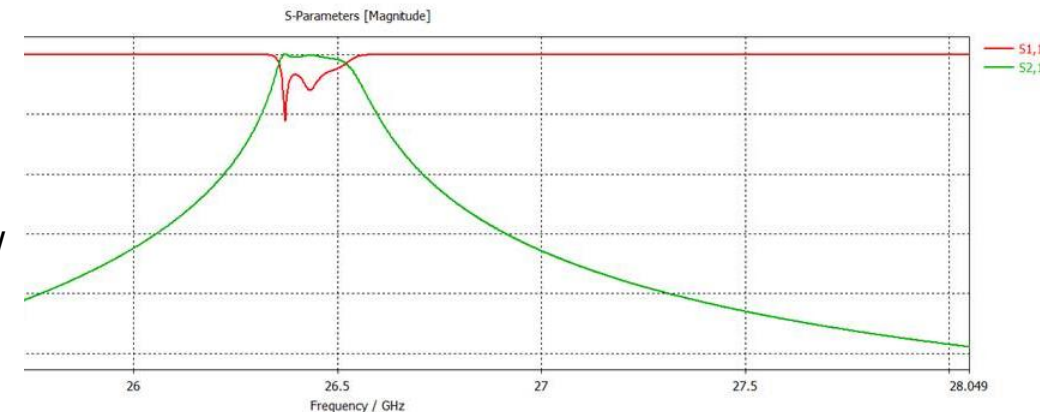
1. Loosing all the non-protected channel in K-band would make humidity profile retrieval impossible
2. Even channels in protected bands can be contaminated: a) Filter shape, b) Saturation

a. Filter Shape:

- Filter is not rectangle, but has a slope into rejected band
- at one (two, three) bandwidth above / below the filter, filter receives still -40 dB to -80 dB)
- with enough RFI Power, intrusion visible
(thermal radiation is the range or -130 dBm, equals $10^{**}(-13)$ mW)

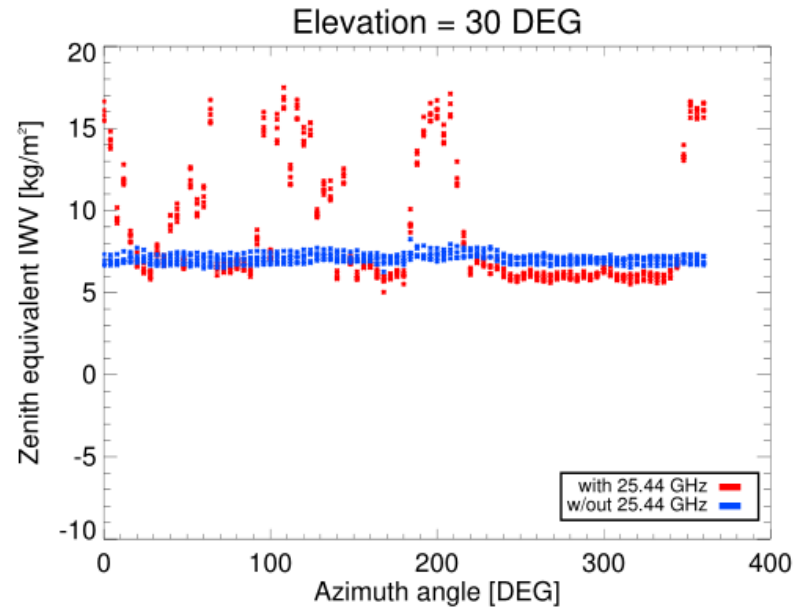
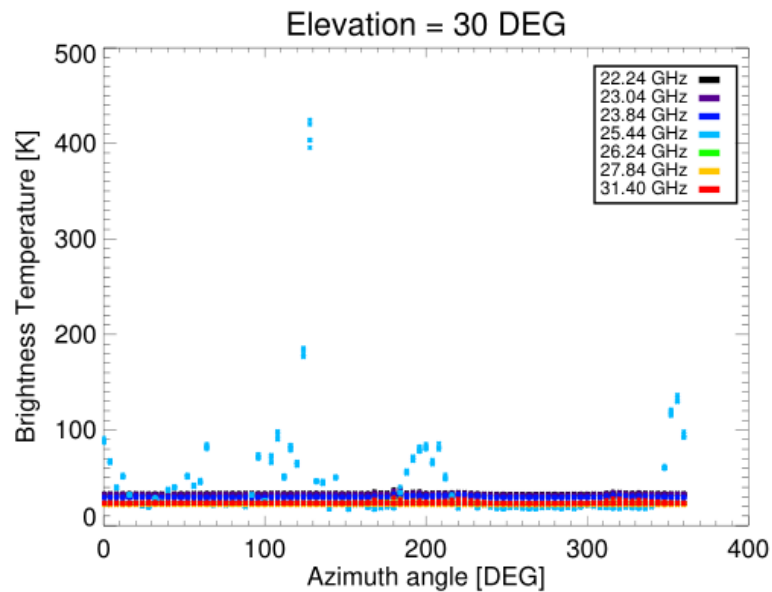
b. Saturation of the broad-band low noise amplifier (LNA):

- The LNA is common to all the K-band channels
- LNA behavior becomes non-linear if loaded with too high power and can offset all the channel of the K-band receiver
- If the whole band is lost, no software mitigation strategy can be applied



- Affected retrievals

Wroclaw University



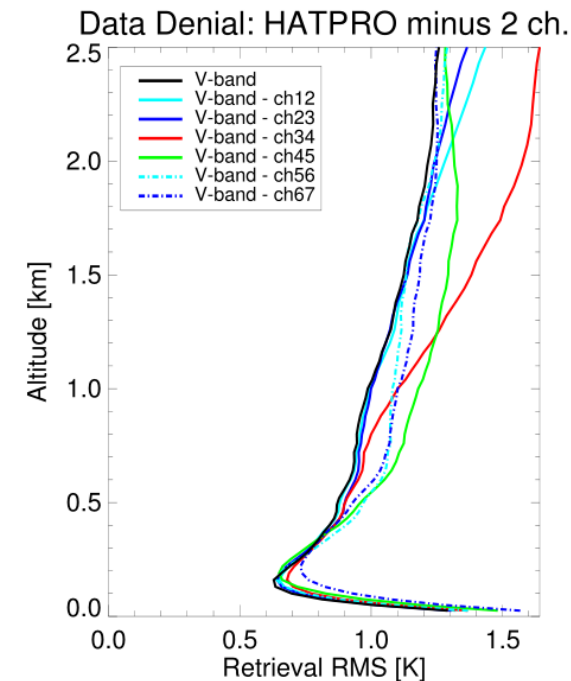
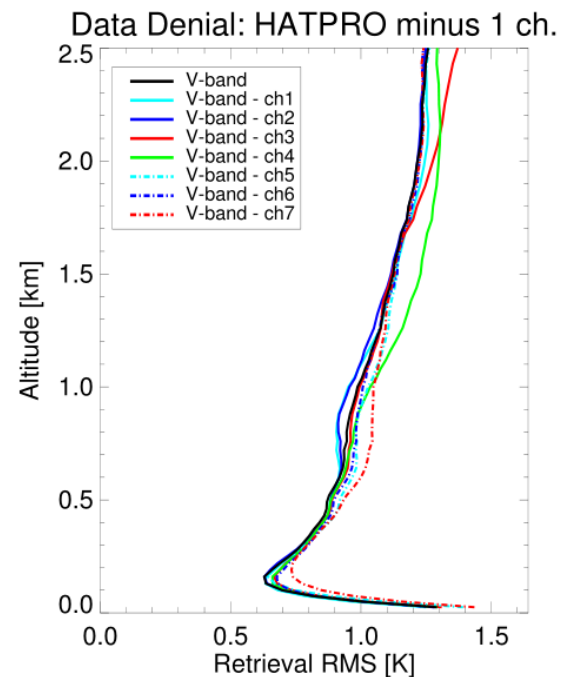
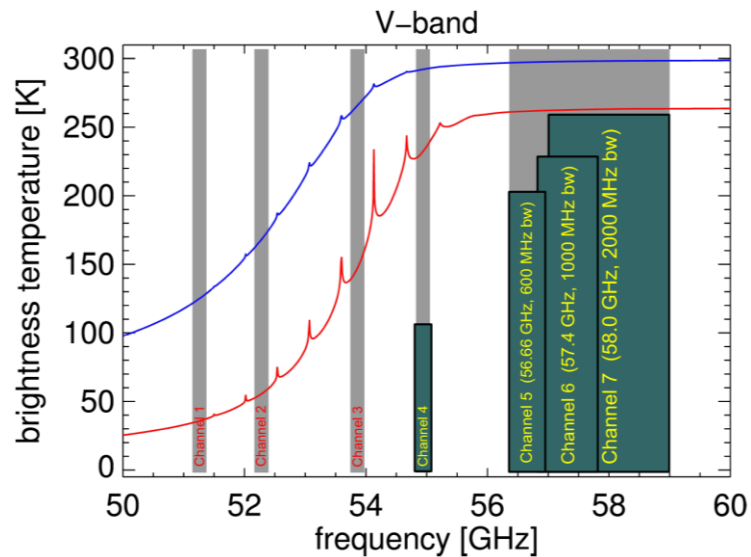
Courtesy of **Witold Rohm**, Wroclaw University

Retrievals of atmospheric parameters can be greatly affected by RFI (depending on amount of contaminated channels)

- **Hardware**
- Ramp up **number of channels** (more filters, or spectrometers)
 - Positive: More ways to identify RFI, recover by using the rest of spectrum
 - Negative:
- „Overkill“: block or **blank the spectral range** which may be 5G-affected, ramp up channel number in other parts of spectrum
 - Positive: Avoids saturation
 - Negative: always loses that region, and excessive hardware cost!
- Not fully developed: **digital IF** (I/Q, identify higher moments)
 - Hope for ways to identify and remove in-band RFI
 - By discrimination of natural thermal radiation from artificial carriers

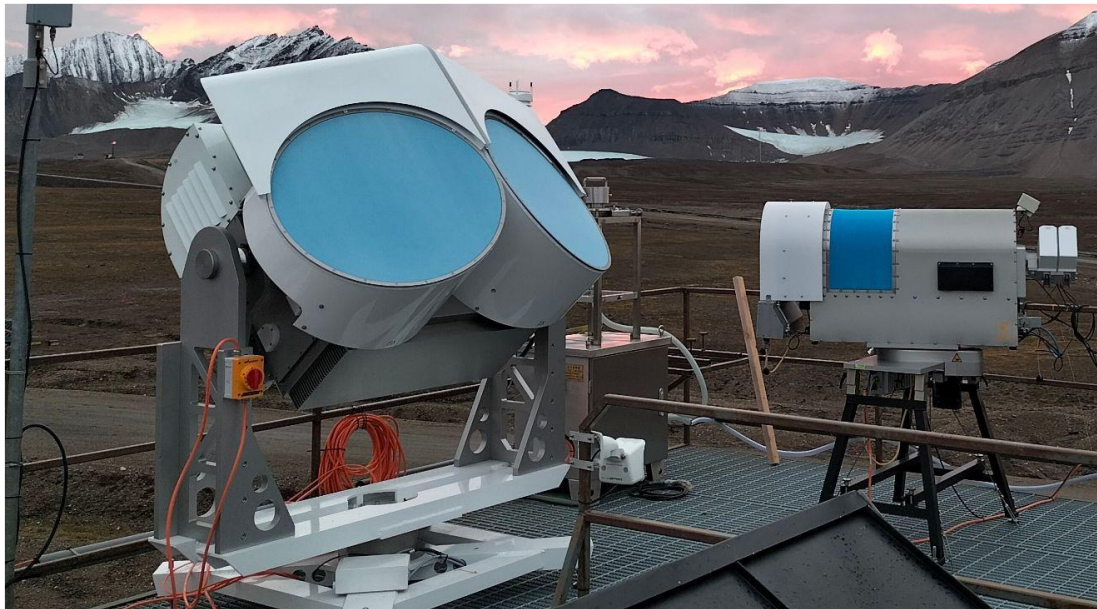
• Software

- Exclude RFI affected channels from retrievals
- K-band: use only the protected channels at 23.84 and 31.4 GHz → NO profiling capability left. Only water vapor and liquid water column.
- V-band: exclude one or 2 channels degrade the Temperature profiling accuracy

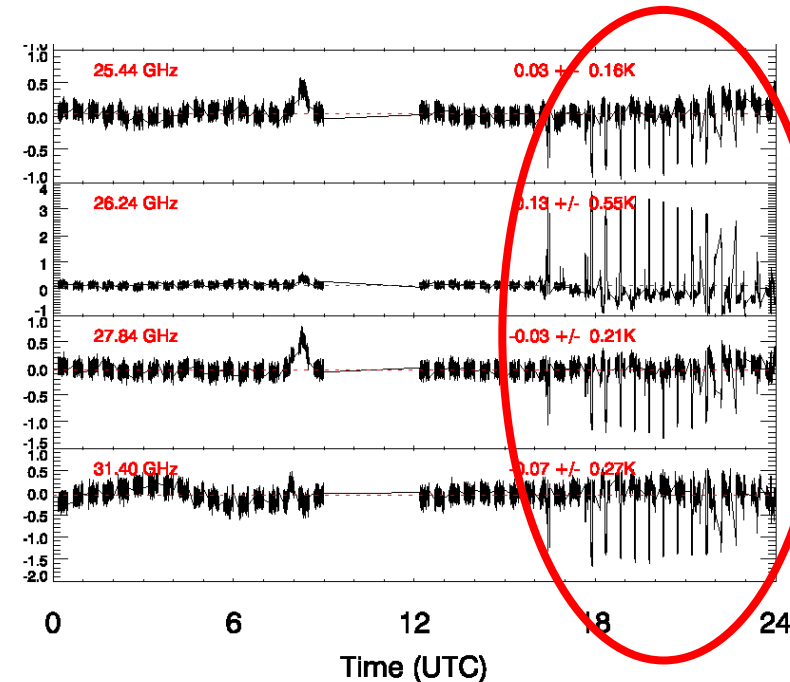


Mitigation solutions

- **Scanning strategy**
- With a co-located scanning cloud radar (35 GHz) at Ny-Alesund, at some specific radar scan angles, RFI could be detected in MWR observations
- Mitigation was possible by turning MWR looking into other azimuth direction



Courtesy of Giovanni Chellini, Univ. Cologne



Plot: Deviation from expected brightness temperature values (difference obs-retrieval) Ny-Alesund 1 Oct 2021

- Ground-based microwave radiometry has a high potential for boundary layer profiling
 - Main products: Temperature profiles, water vapor, cloud liquid water, stability indices
- Observations often in unprotected bands (several channels in K- and V-Band)
- Also in protected bands, strong signals can affect the observations
- Mitigation partly possible
 - by sampling more/other channels (Hardware change)
 - by excluding some channels in retrievals (only up to a certain extent)



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