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session AS1.26

Combining dual—frequency radar and microwave radiometer for water vapor profiling in the cloudy trade-wind environment

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Motivation:

- boundary-layer water vapor structure: key variable
- quantification requires high-resolution+continuous observations

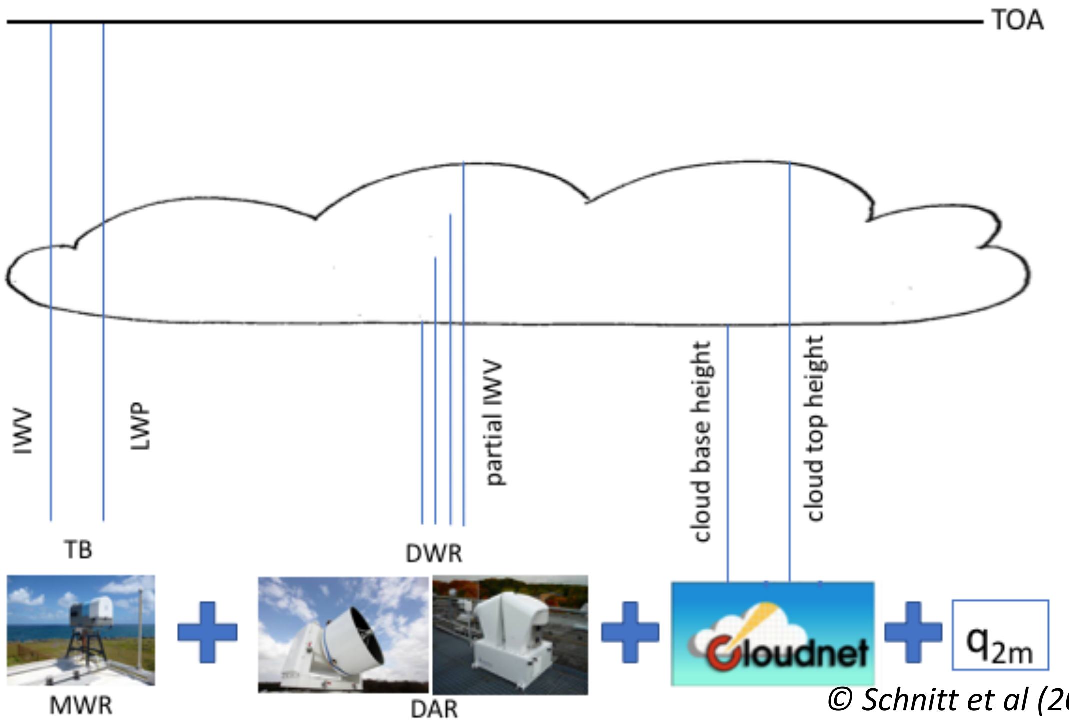
Central question: synergistic benefits of instrument combination for water vapor profiling retrieval

Methods and Tools:

- optimal estimation retrieval: absolute humidity and LWP
- synthetic observations: MWR TBs and KaW/G-band radar DWRs
- single-layer+double-layer cloud cases at Barbados Cloud Observatory
- compare performance of MWR+KaW vs MWR+G2 vs MWR-only

Main Results:

- MWR+G-band combination shows highest synergistic benefit
- information partitioning:
  - MWR: above cloud, LWP
  - radar: below and in cloud
- MWR+G2 compared to MWR-only:
  - gain of 1 Degree of Freedom
  - decrease of retrieval error by 0.5 gm^{-3} (on average at 1km)
  - gain of information content above cloud layer
- real application restricted by current G-band technology sensitivities



Future Work:

- expand variety of analysed cloud scenes
- simultaneous temperature retrieval
- humidity content of boundary-layer vs free troposphere: partial IWV quantification

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Microwave Radiometer (MWR):

- TB in 14 channels (**7 K-band**, 7 V-band)
- profile retrieval:
  - 1 – 2 Degrees of Freedom
  - vert. resolution: 100-1000m

Dual-Frequency Radar:

- Dual Wavelength Ratio (DWR):

  DWR = Ze (f_1) – Ze (f_2) $\propto$ differential 2-way attenuation
- **G2**: ground-based prototype (*Roy et al (2020)*):
  - (**167, 174.8**) GHz (differential absorption radar)
- **KaW:** radars available at Barbados Cloud Observatory (*Stevens et al (2016)*):
  - (**35.5, 94**) GHz (difference in continuum absorption)

Observation Characteristics:

	MWR HATPRO	dual-frequency radar Ka	W	G2	2m humidity
Channels [GHz]	22.24, 23.44 23.84, 25.44 26.24, 27.84 31.4	35.5	94.0	167.0 174.8	
Measurement	Brightness Temperature **TB**	Equivalent Reflectivity Factor (Z_e [dBz]); **DWR** [dB]			$\mathbf{q}_{2m}$
Uncertainty	0.4 K	$\Delta Z_e = 0.4$ dBz ΔDWR $= 0.56$ dB			10 %
Sensitivity @1km		−55 dBz	−51 dBz	−40 dBz	

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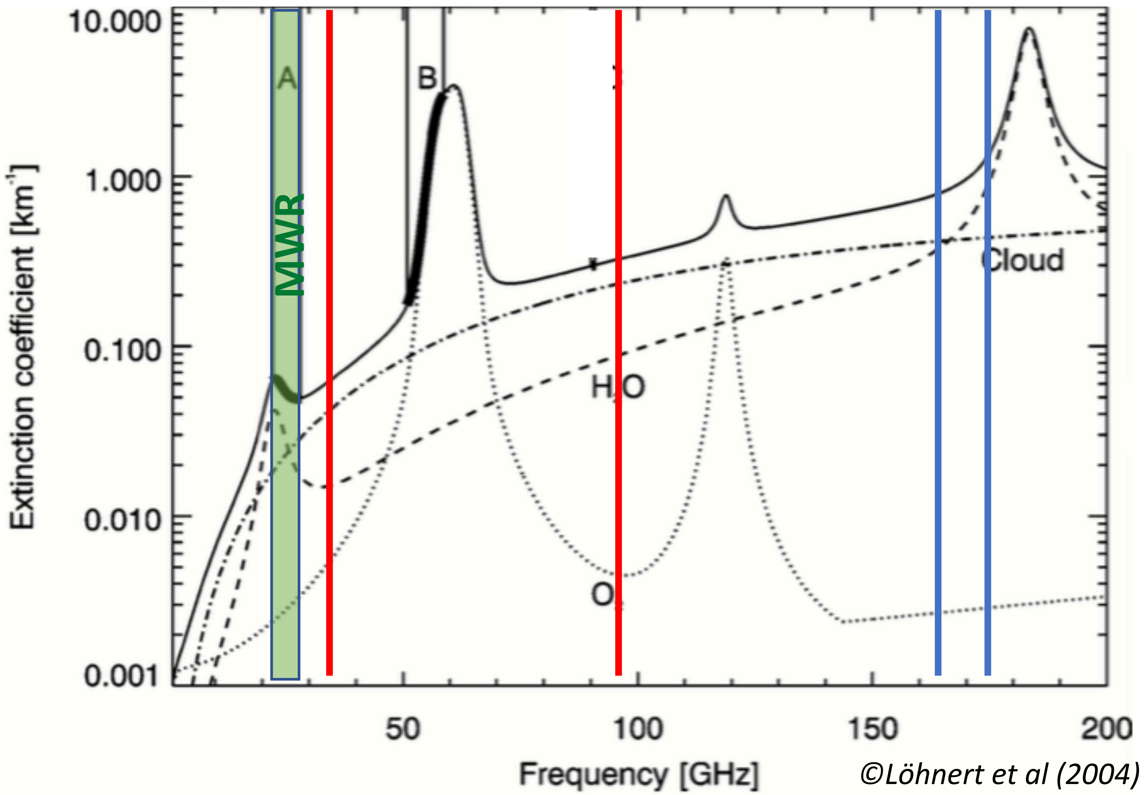

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Optimal Estimation Framework:

- state: absolute humidity profile, LWP
- observations: TB, DWR, q_{2m}
- prior sounding climatology

Synthetic Observations:

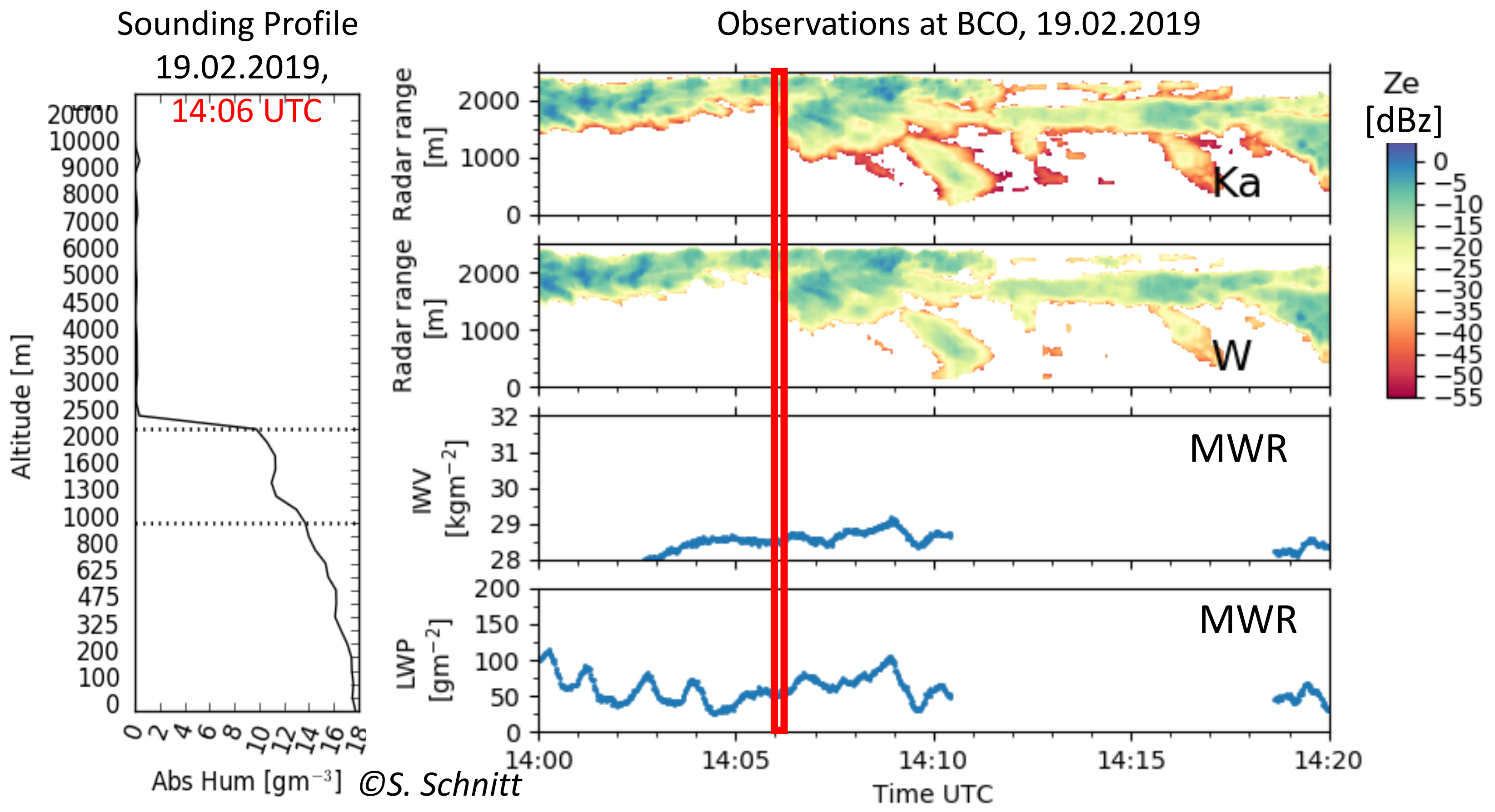
- forward model: PAMTRA (*Mech et al 2020*)
- liquid cloud layer:
    - 1000-2300m
    - LWP = $50gm^{-2}$
    - r_{eff} = 10µm
- synthetic noise added
- no sensitivity thresholds applied

Evaluation of setups by comparing:

- retrieved vs original sounding profile
- information content
- aposteriori retrieval error

Analysed Scenes:

- case studies:
    - single-layer case 19.02.19
    - double-layer liquid cloud
- statistics using available soundings 2018



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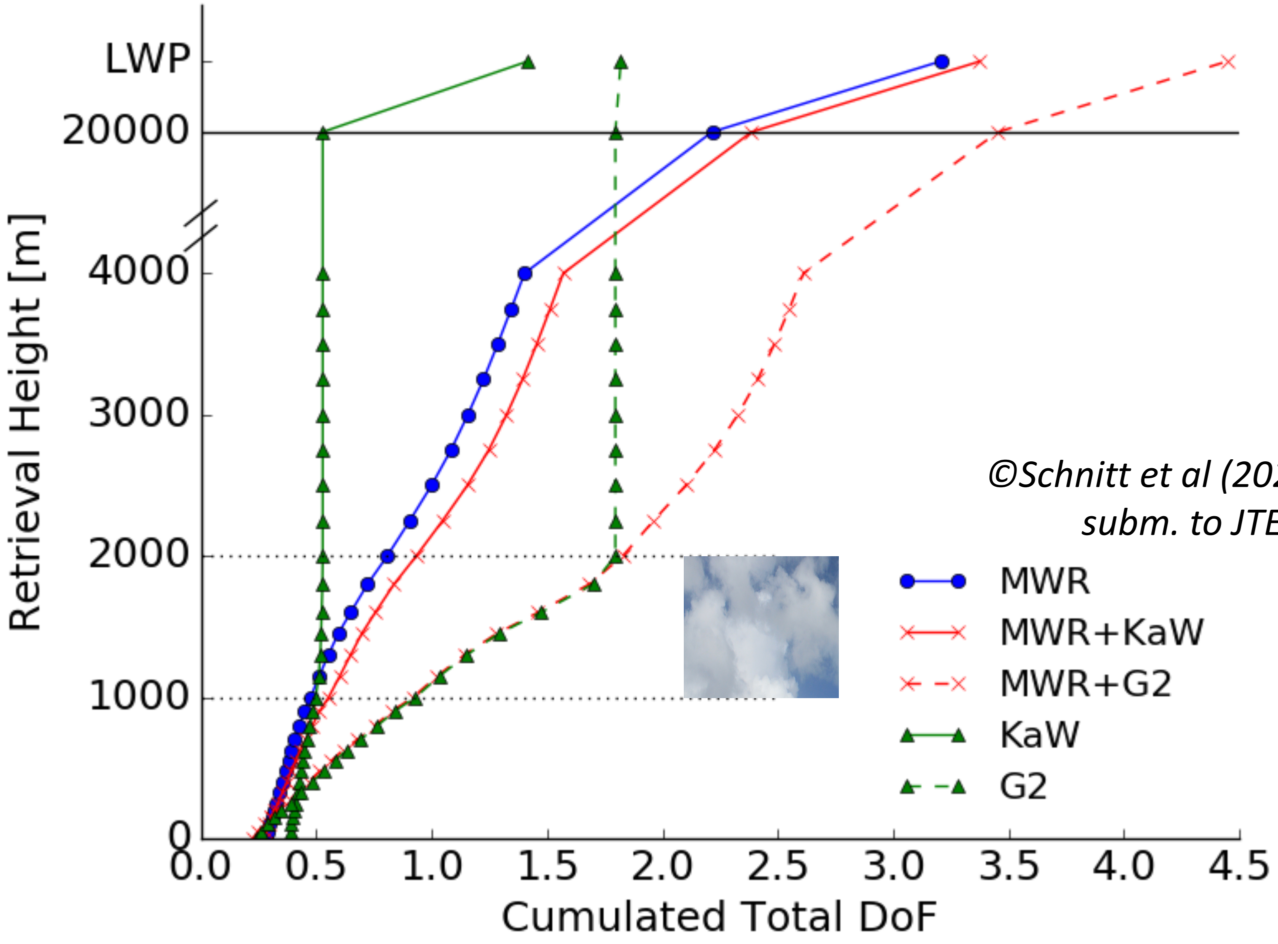
Statistical Analysis:

Setup:

- 212 quality controlled sounding profiles
- assume liquid cloud layer:
  1000-2000m, LWP = 50gm^{-2}
- generate synthetic observations

Results:

- information partitionning:
  - radar: below and in cloud layer
  - MWR: above cloud
  - MWR and KaW: LWP information
- gain of total Degrees of Freedom (DoF):
  - MWR+KaW: 5% (3.4 vs 3.2 MWR-only)
  - MWR+G2: 39% (4.4 vs 3.2 MWR-only)
- decreasing retrieval error particularly below and in cloud:
  - MWR: $\Delta q = 1.4$ gm^{-3}
  - MWR + KaW: $\Delta q = 1.3$ gm^{-3}
  - MWR + G2: $\Delta q = 1.0$ gm^{-3}



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