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in der Helmholtz-Gemeinschaft
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Synergetic use of polarimetric doppler radars at C- and Ka-band for retrieval of hydrometeor type and quantity

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Motivation

The verification of radar retrieval results like hydrometeor type, quantity, and dynamics of clouds is an essential requirement for assimilating observation data into Numerical Weather Prediction (NWP) models. Field campaigns were executed to enrich the observational data base. One of the aims of Convection and Orographically Induced Precipitation Study (COPS) in 2007 – took place in south-west Germany and eastern France - was to improve the Quantitative Precipitation Forecast (QPF) in mountainous areas. For this purpose, a huge amount of different observation instruments were concentrated in the region around Black Forest, Vogues and Rhine valley, especially at so-called supersites. The current study focus on comparison between polarimetric C-band and vertically pointed Ka-band radar, to retrieve profiles of hydrometeor content and quantity.

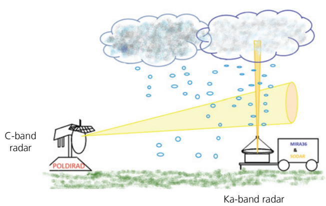

Fig 1: Schematic view of principle of measurement: vertically pointed Ka-band and range height indicator (RHI) scans of C-band radar were synchronized to observe a common volume. The synergetic use help to improve the retrieval of hydrometeor content and quantity.

Data

Ka-band radar: MIRA-36

- Vertically pointed at supersite Achern (provided by MPI Hamburg)
- Time resolution: 10 sec
- Used parameters: reflectivity, Doppler velocity, depolarization ratio (LDR)

C-band radar: POLDIRAD

- Located at Waltenheim sur Zorn (36 km from Ka-band radar at Achern)
- RHI-scans in direction of Achern were taken every 10 min
- Used parameters: reflectivity, Doppler velocity, depolarization ratio (LDR)

Additional data sources:

- **Sounding** at Achern (for 8 July 2007 at 7, 11, 14, 15, 16, 20, 23 UTC for estimating temperature profile
- **SODAR wind data** for comparing vertical wind at low level

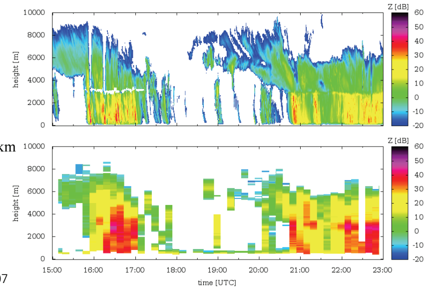

Fig 2: Time evolution of radar reflectivity at 8 July 2007 from 15 to 23 UTC for vertical column above Achern supersite measured by Ka-band (top) with 10 sec and C-band (bottom) with 10 min time resolution.

Statistics of measured reflectivity

After temporal and spatial synchronization, all measured reflectivity tuples (Ka and C band) from 1st July to 31st July 2007 were evaluated. After Rayleigh theory all reflectivity values should be identical. Differences were expected mainly due to stronger attenuation at Ka-band and Mie-scattering for particles larger than 2 mm.

For low reflectivity (<-10 dBZ) the Rayleigh assumption is warranted in a statistical manner. For higher reflectivity, the attenuation due to the water column had to take into account for the Ka-band radar. For very high reflectivity values (35-40 dBZ) an aligning trend is observed due to Mie scattering regime at Ka-band for larger particles.

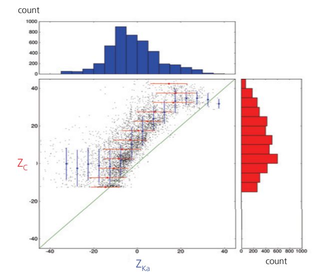

Fig 3: Statistics on synchronized data points of measured reflectivity from Ka-band (x-axis) and C-band (y-axis) for 8th July 2007. Without attenuation effects, a straight line will be expected (green line). Blue (red) bars show mean value and standard deviation of C (Ka)-band reflectivity by given Ka (C)-band reflectivity interval. Frequency distribution of Ka-band reflectivity in blue, C-band in red.

Case Studies (8th July 2007)

16:58 UTC — **Strong attenuation** at 2 km altitude probably due to **high LWC**

18:58 UTC — Abruptly changing of mean drop fall velocity at 1 km probably due to **cloud border**

20:48 UTC — **Different** fall velocity **regimes** below 3 km probably due to different drop size distributions

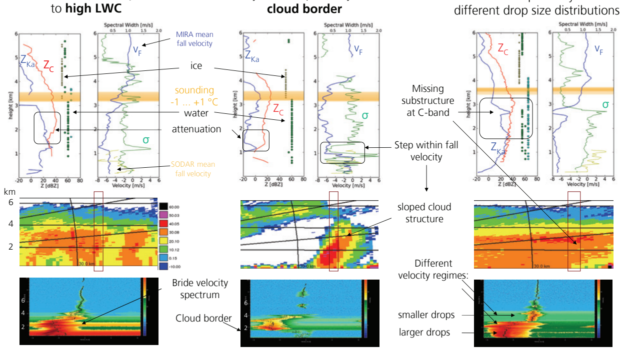

Fig 4: Profiles of reflectivity (top, left), mean fall velocity and spectral width (top, right), vertical cross section of POLDIRAD with marked position of MIRA-36 (middle) and fall spectrum analysis (bottom) for three selected cases.

Simulation

To evaluate the effect of attenuation within the column above the Ka-band radar, radar simulation software **quick-beam** (Haynes, 2007) was used under the condition of **Mie-scattering**. For that purpose, samples of different rain rate profiles were tested and rain drop size distributions after **Marschall and Palmer** were estimated.

$$N(D)\,[m^{-3}mm^{-1}] = 8000 \cdot e^{-\Lambda\, D[mm]} \quad ,with \;\; \Lambda = 4.1(RR[mm/h])^{-0.21}$$

For the assumed profiles, the liquid water content (LWC), radar beam attenuation at Ka-band, radar reflectivity at Ka- and C-band were simulated (Figure 5). Further, to retrieve the measured velocity spectra of Ka-band radar, for each drop size interval the fall velocity were estimated by assuming formula after Atlas (1973).

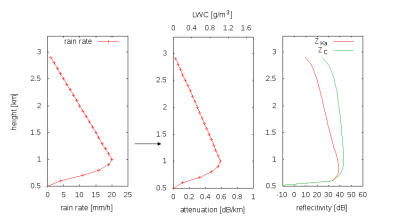

Fig 5: Simulation of attenuation effects by using Marschall-Palmer distribution with given profile of rain rate (a). From that, LWC and attenuation at Ka-band (b) as well as resulting reflectivity at Ka and C-band were estimated.

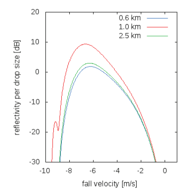

Fig 6: Simulation of drop fall velocity spectra as measured by Ka-band radar (MIRA-36)

Summary and Outlook

Radar data from vertical pointed Ka-band and synchronized range height indicator scans (RHI) from polarimetric C-band were compared during the COPS- field campaign. Statistics of reflectivity show equivalent values for low reflectivity, due to smaller ice particles (mostly snow) or light rain. For larger particles and higher liquid water content, the attenuation at Ka-band increases. From reflectivity differences between C- and Ka- band radar the amount of water and ice could be determined roughly after Matrosov (2009).

For the current study, the type of hydrometeor were estimated by using polarimetric radar information after Höller et al. (1994) and additional the freezing level by using soundings. By analyzing reflectivity and fall Doppler spectrum for some case studies, the amount of hydrometeor could be roughly estimated (large/small particles, low/high number concentration). By examining simulations using Marschall-Palmer distribution, the effect of attenuation could be quantified with rain rate as the only parameter.

For further studies, more realistic drop size distributions have to retrieve by using measured velocity spectra from vertically pointed Ka-band radar. Together with measured Ka-band and C-band reflectivity, a new method for retrieving amount of hydrometeors should be develop.

References

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