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On the Feasibility to Combine Observations from Multi-wavelength Radar and the Multi-frequency Radiometer ADMIRARI to Retrieve Precipitating Cloud Parameters

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Abstract. During the last two NASA GPM Ground Validation field campaigns i.e. MC3E and GCPEx in USA and Canada correspondingly, the microwave radiometer ADMIRARI has been operating nearby two dual-frequency radars: the Ka/W band SACR from DOE ARM and the NASA's Ku/Ka band D3R. In addition, observations have currently been performed at the CSU CHILL National Radar Facility with the D3R Ku/Ka band radar synchronized with ADMIRARI for dedicated precipitation events. The present work put into consideration the first results from the aforementioned field campaigns with as a first attempt to combine these multi-sensor, multi-frequency, dual-polarized measurements in a common retrieval approach; limitations and pitfalls will be critically discussed as well.

Keywords: Microwave Passive/Active remote sensing, NASA GPM/GV, Cloud/Rain water content, ADMIRARI, D3R.
PACS: 92.60.N-; 92.60.Jq; 07.57.Kp; 42.68.Mj

INTRODUCTION

Theoretical studies have highlighted the possibility to estimate the cloud liquid water content from dual-wavelength radar observations. The advantage of that kind of techniques is that they don not require assumptions about the nature of the size distribution but simple that observations fall into the Rayleigh regime for both frequencies. Other authors have made first attempts for the application of multi-wavelength techniques to stratiform rain conditions by exploiting radar differential attenuation of droplets and rain drops and differential backscattering of raindrops; however large uncertainties are typically introduced in the cloud product depending on the rain rate.

Saavedra et al. [1] and Battaglia et al. [2] have presented the University of Bonn's passive radiometer ADMIRARI and shown successful utilization of polarization information produced by non-spherical raindrops to partition rain and cloud from the total liquid water content. A Bayesian retrieval approach has a good performance in cases with large cloud and rain water content, while it is prone to large uncertainties in the cloud component when low liquid water contents are observed. In such cases, Saavedra et al. [1] have shown that the introduction of a radar reflectivity profile along the radiometer's observation path can improve the performance of the retrievals by adding information to the passive instrument. In order to properly combine the passive (radiometer) and active (radar) in an unified retrieval approach, the mismatch between the sampled volumes must be solved. The developing of innovative scanning dual-wavelength radars as part of the DOE ARM and NASA GPM Ground Validation programs provides a unique opportunity to overcome this drawback.

MICROWAVE PASSIVE AND ACTIVE INSTRUMENTATION

Microwave Passive Radiometer ADMIRARI

The University of Bonn's **AD**vanced **MI**crowave **RA**diometer for **R**ain **I**dentification **ADMIRARI** is a triple-frequency (10.7, 21.0 and 36.5 GHz) dual-polarized (H & V) microwave passive radiometer with scanning capabilities. Its main characteristics are: 6° beam-width, 0.5 K RMS @ 1 second integration time, direct detection auto-calibration receivers with Noise injection and Dicke switching and an absolute system stability 1.0 K.

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Beside the passive radiometer, ADMIRARI measures along two ancillary co-located active instruments: a micro rain radar 24.1 GHz and a 902nm cloud lidar (Figure 1(a)). They are mounted to the pedestal and have equally scanning capabilities alike the radiometer [1], http://www2.meteo.uni-bonn.de/admirari.

Ka/W Band Scanning Radar SACR

The USA Department of Energy **S**canning **A**RM **C**loud **R**adar **SACR** is installed in every one ARM site around the world. This work refers only the one at the South Great Plains ARM central facility in Oklahoma (Figure 1 (b)). The ARM scanning cloud radar is fully coherent dual-frequency, dual-polarized Doppler radars mounted on a common scanning pedestal, includes a Ka-band radar (35 GHz, 2 kW peak power) and the second radar is a W-band (95 GHz and 1.7 kW peak power). The beam-width for Ka-band paired with W-band are roughly matched at 0.3 degrees. The Ka/W SACR utilizes scanning strategies that are unlike typical weather radars e.g. RHI, scans at numerous azimuths; http://www.arm.gov/instruments/kasacr.

Ku/Ka NADA D3R

The NASA's **D**ual-frequency **D**ual-polarized **D**oppler **R**adar **D3R** has been developed as a fully polarimetric scanning weather radar system operating at nominal frequencies of 13.9 GHz (Ku) and 35.5 GHz (Ka) covering a maximum range of 30 km with minimum operational range of 450 m and nominal range resolution of 150 m [3, 4]. The D3R (Figure 1 (c)) has a solid state transmitter with peaks power of 160 W for Ku and *pro-tempore* 1 W for Ka. The standard products for Ku and Ka are equivalent reflectivity factor Zh, Doppler velocity, differential reflectivities Zdr, differential propagation phase, co-polar correlation coefficient and linear depolarization ratio LDR; http://pmm.nasa.gov/science/ground-validation/D3R.

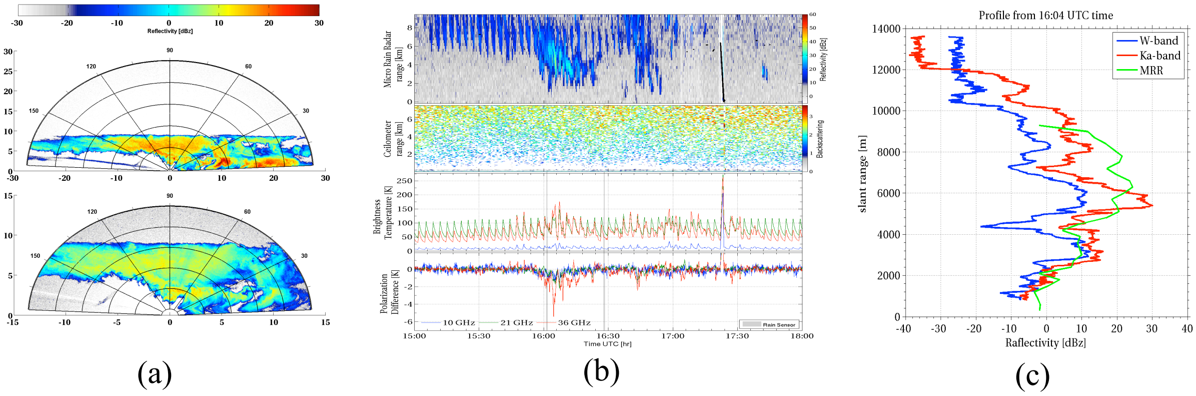
FIGURE 1. (a) Radiometer ADMIRARI, with auxiliary instruments attached to the pedestal: cloud lidar (left) and micro rain radar (right). (b) DOE ARM Ka/W SACR radar (c) NASA's Ku/Ka D3R.

DUAL-WAVELENGTH RADAR OBSERVATIONS WITH ADMIRARI

MC3E, South Great Plains, Oklahoma-USA 2011: During the MC3E GPM/GV field experiment in Oklahoma, the first attempt to make synergistic observations with the radiometer ADMIRARI and a dual-wavelength radar has been pursued. In that occasion the Ka/W SACR radar was performing horizon to horizon scans every 30° azimuth while ADMIRARI's azimuth was fixed to 300°. Figure 2 (a) shows an example of SACR reflectivity. Unfortunately the scans were not frequent enough to achieve the proper temporal resolution to cover ADMIRARI's data. Figure 2 (c) is an example of reflectivity slant profile at the same ADMIRARI's FOV.

CHILL Radar Facility, Colorado USA 2012: During the last GPM/GV field experiment in Canada (GCPEx campaign) the NASA's D3R radar was installed nearby ADMIRARI and performing observations of snowfall. After GCPEx, ADMIRARI and D3R were transported to Colorado State University's CHILL National Radar Facility (http://www.chill.colostate.edu) where both instruments have been set up to perform synchronized observations. Here the most significant event is presented motivated due to the fact that in this event the pure radiometric retrieval is not able to invert the measured Brightness temperatures to the atmospheric variables i.e. Integrated Water Vapor and Cloud/Rain Liquid Water Path, which are the state-of-the-art ADMIRARI products [1].

A case study comprised of a storm from June 8th 2012, when the rain shaft has been approaching from Northwest to the CHILL site. The Figure 3 shows a sequence of the D3R Ku RHI at 3:17, 3:45, 4:10 and 4:27 UTC where the evolution of the storm is clearly depicted. Note that during this event, ADMIRARI was measuring at a fixed 30° elevation angle, thus the radar variables need to be extracted and reconstructed at slant 30° elevation according to ADMIRARI's real field of view i.e. 6°.



(a) (b) (c)

FIGURE 2. (a) Ka/W SACR radar horizon to horizon RHI from June 9th 2011. (b) ADMIRARI data set for the same event, SACR RHI are available only at 15:05, 15:40, 16:05,16:55, 17:30 and 17:55 UTC mirroring the SACR's poor temporal resolution, (c) example slant reflectivity profile for SACR (bue and red) and the ADMIRARI's co-located MRR (green).

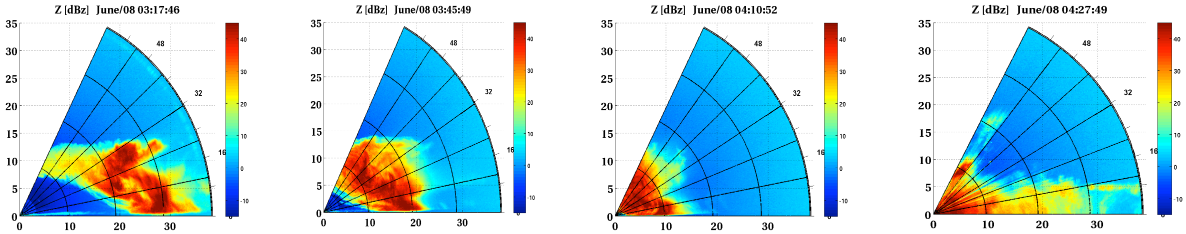


FIGURE 3. Sequence of RHI reflectivity factor by the Ku D3R radar, from left to right 03:17, 03:45, 04:10 and 04:27 UTC. Note that ADMIRARI was measuring at fixed 30° elevation angle.

The radiometer ADMIRARI was collecting data continuously during this event (Figure 4 (a)), while D3R only collected from 3:17 to 4:27 UTC. Figure 4 (b) shows the extracted D3R Ku and Ka reflectivity for ADMIRARI's FOV. Note that due to the low Ka transmitter power, its sensitivity is not the optimal and the signal is quickly attenuated. Figure 4 (c) is the same but for the differential reflectivity Zdr. Simulations have been done for the case when the storm reaches the instruments site, mimicking the radiometer's geometry (Figure 3 04:27 UTC) when the instruments sense the lower part of the rain shaft i.e mostly liquid drops instead as hail. These simulations highlight the usability of the dual-wavelength-ratio (**DWR=Zh**[Ku]-**Zh**[Ka]) which gives a hint on the rain drop size distribution (DSD) observed, in this case four DSDs: Thunderstorm (TS), Heavy-rain (HR), Marshall-Palmer (MP) and Light-rain (LR) in Figure 4 (d). On the other hand, the Path Integrated Attenuation (PIA) has been estimated from ADMIRARI's brightness temperatures at its three frequencies (Figure 4 (e)) which gives a clue in term of expected attenuation (below 15 dB) before and after 4:27 UTC when hail and heavy-rain (up to 45dB) is sensed respectively. Finally Figure 4(f) depicts the ADMIRARI's retrievals highlighting the fact that during the observation of the upper part of the storm (hail) none retrievals cannot be obtained due to the lack of *a-priori* information, in that case hydrometeor profiles may be obtained from radar to enrich the radiometer's inversion technique.

CONCLUSIONS

From these experiences we have learned that in order to attempt combined radiometer and radar studies, radar RHI scans are necessary to reconstruct the radiometers observations FOV and high synchronization is mandatory to have a good temporal coverage of the precipitating events. In case of the Ka/W SACR at ARM the resolution is 20 minutes which is not optimal for further studies. On the contrary, the D3R have performed RHI's every 1 minute, which gives a good time synchronization with the radiometer's sampling. Next step is to utilize radar data to build up hydrometeor profiles as representative information for the radiometer's *a-priori* database and incorporate them to the radiometer Bayesian retrieval. Therefore mimicking the foreseen GPM core satellite combined radar/radiometer algorithm, since the D3R and ADMIRARI posses the same frequencies as the GPM DPR and part of TMI respectively.

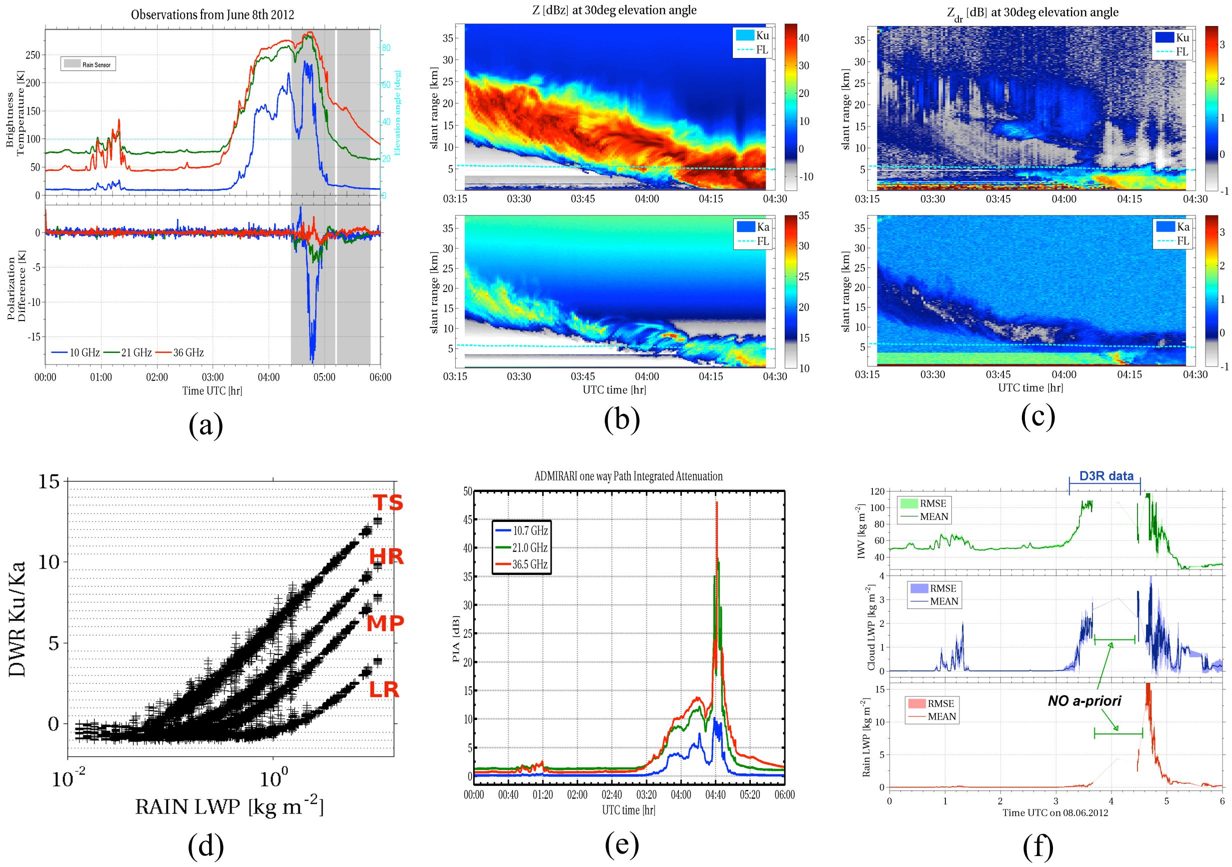


FIGURE 4. (a) ADMIRARI data for June 8th 2012, (b) D3R Zh extracted for 30° elevation and 6° FOV, (c) same for differential reflectivity Zdr, (d) DWR simulations (see text), (e) PIA estimated from ADMIRARI, (f) retrieval for IWV, cloud and rain LWP.

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REFERENCES

1. P. Saavedra, A. Battaglia and C. Simmer, *J. Geo. Research* **117**, D05203, doi:10.1029/2011JD016382, (2011).
2. A. Battaglia, P. Saavedra, T. Rose and C. Simmer, *J. Appl. Met. Clim.* **49**(3), 394-414 (2011).
3. V. Chandrasekar, M. Schwaller, M. Vega, J. Carswell, K.V. Mishra, A. Steinberg, C. Nguyen, M. Le, F. Junyent and J. George, *Dual-frequency dual-polarized doppler radar (D3R) system for GPM ground validation: Update and recent field observations* Ext. Abst., IGARSS 2012, Munich-Germany.
4. M. Vega, V. Chandrasekar, C. Nguyen, K. V. Mishra and J. Carswell, *Calibration of the NASA dual-frequency, dual-polarized, Doppler radar*, Ext. Abst., IGARSS 2012, Munich-Germany.