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AMF3 CloudSat Overpasses Field Campaign Report

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ARM CLIMATE RESEARCH FACILITY

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Acronyms and Abbreviations

AGL	above ground level
AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
CPR	cloud-profiling radar
DOE	U.S. Department of Energy
ESRL	Earth System Research Laboratory
GHz	gigahertz
IOP	intensive operational period
km	kilometer
min	minute
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
SACR	Scanning ARM Cloud Radar
UC	University of Colorado
UTC	Coordinated Universal Time

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1.0 Summary

Synergy between ground-based and satellite radar observations of clouds and precipitation is important for refining the algorithms to retrieve hydrometeor microphysical parameters, improvements in the retrieval accuracy, and better understanding the advantages and limitations of different retrieval approaches. The new dual-frequency (Ka- and W-band, 35 GHz and 94 GHz) fully polarimetric scanning U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Research Facility cloud radars (SACRs-2) are advanced sensors aimed to significantly enhance remote sensing capabilities (Kollias et al. 2016). One of these radars was deployed as part of the third ARM Mobile Facility (AMF3) at Oliktok Point, Alaska (70.495o N, 149.886oW). The National Aeronautics and Space Administration (NASA) CloudSat satellite, which is part of the polar-orbiting A-train satellite constellation, passes over the vicinity of the AMF3 location (typically within 0-7 km depending on a particular overpass) on a descending orbit every 16 days at approximately 13:21 UTC. The nadir pointing W-band CloudSat cloud profiling radar (CPR) provides vertical profiles of reflectivity that are then used for retrievals of hydrometeor parameters (Tanelli et al. 2008).

The main objective of the AMF3 CloudSat overpasses intensive operating period (IOP) campaign, which occurred between March 1, 2017 and May 30, 2017, was to collect approximately collocated in space and time radar data from the SACR-2 and the CloudSat CPR measurements for subsequent joint analysis of radar variables and microphysical retrievals of cloud and precipitation parameters. Providing the reference for the SACR-2 absolute calibration from the well-calibrated CloudSat CPR was another objective of this IOP. The IOP objectives were achieved by conducting seven special SACR-2 scans during the 10.5-min period centered at the exact time of the CloudSat overpass over the AMF3 (~1321 UTC) on six dates of the CloudSat overpasses during the three-month period allocated to this IOP. These six days were March 5 and 21, April 6 and 22, and May 8 and 24.

The special scanning sequence for the AMF3 SACR-2 was designed for this IOP. This scanning sequence was commenced at 1315 UTC on the overpass days and consisted of seven hemispheric RHI (HSRHI) scans. The first three scans were conducted in the azimuthal direction of 26.30, which provided measurements in the vertical plane parallel to the plane of the CloudSat overpass. The next two HSRHIs were conducted in the azimuth direction of 116.30 to provide measurements for reconstructing vertical profiles of SACR-2 data, which were approximately collocated with the CPR measurement profiles and were closest to the AMF3. The last two HSRHIs were conducted again in the azimuthal direction of 26.30 to provide information on time evolution of the hydrometeor scene during the comparison period. Except for the azimuthal directions, the scan parameters of these special HSRHI scans were standard ones employed for the AMF3 SACR-2 baseline scanning.

The notable CloudSat overpass events during the official IOP campaign were 21 March, 2017 and 24 May, 2017. On these dates both the AMF3 SACR-2 and the CloudSat CPR collected good cloud and precipitation data for the future joint analysis. The SACR-2 collected cloud data also on 8 May, 2017. However, the cloud top echoes on 8 May, 2017 were observed at about 0.6 km above the ground level (AGL). CloudSat CPR measurements at such low altitudes were contaminated by the ground clutter, which limits meaningful interpretation of satellite radar data.

2.0 Results

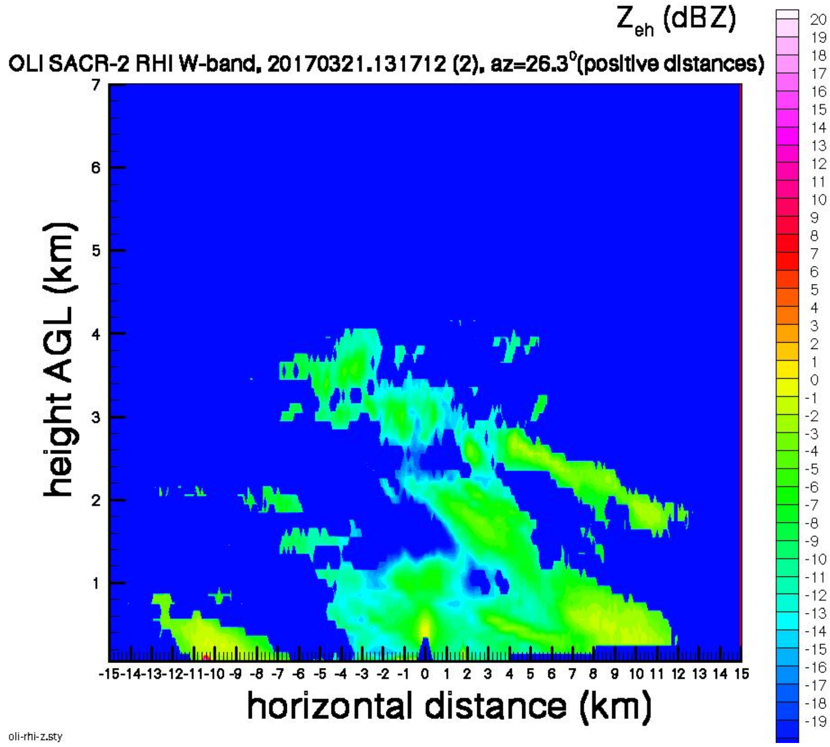
A brief description of the CloudSat overpass events that occurred during the IOP campaign is given below. The dates when clouds/precipitation were sampled by both the SACR and CloudSat IOP during the satellite overpass event are shown in red.

1. March 5, 2017: No SACR-2 measurements were performed. The SACR-2 was not operational due to inclement weather conditions at the AMF3.
2. March 21, 2017: The SACR-2 performed the special scanning sequence designed for this IOP. A lightly precipitating ice cloud was observed in a lowest 1-km-thick level. Some thinner ice clouds were observed at altitudes between 1 and 4 km AGL
3. April 6, 2017: No SACR-2 measurements were performed. The SACR-2 was not operational due to inclement weather conditions at the AMF3. No usable hydrometeor echo was detected by the CPR during the overpass.
4. April 22, 2017: No SACR-2 CloudSat overpass special scan sequence was performed. There were no usable hydrometeor echoes detected by the CPR during the overpass.
5. May 8, 2017: The SACR-2 performed the special scanning sequence designed for this IOP. SACR-2 cloud echo tops were observed at altitudes of about 0.6 km. The CloudSat CPR signals from these shallow clouds were masked by the ground clutter.
6. May 24, 2017: The SACR-2 performed the special scanning sequence designed for this IOP. A lightly precipitating ice cloud with echo tops of around 2.5 km was observed by both the SACR-2 and CPR.

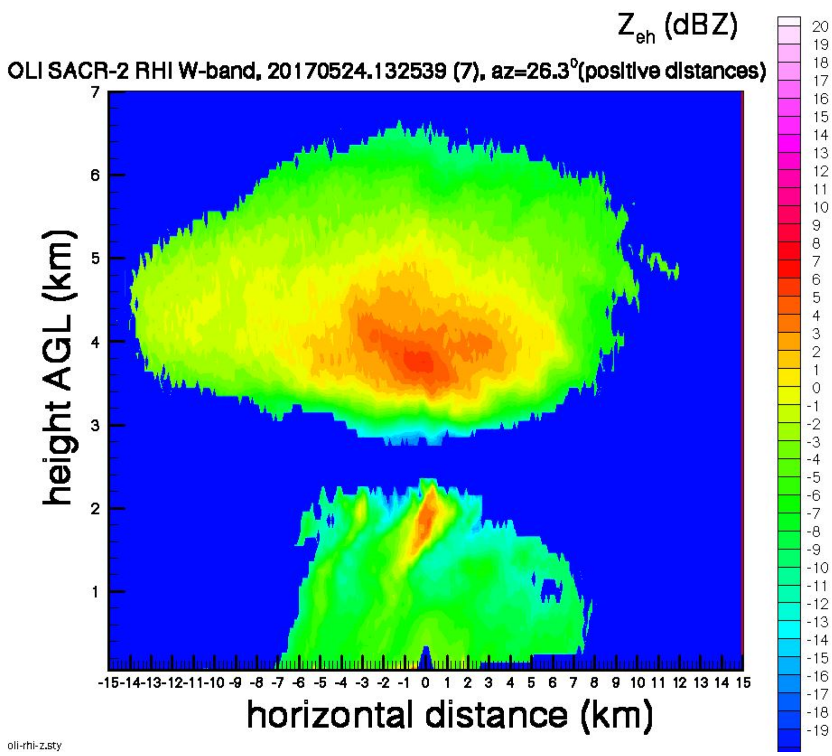
After the official end of the IOP, the CloudSat overpass scanning procedure for the SACR-2 was automated in an attempt to collect some more coincident satellite and ground-based radar measurements before the AMF3 SACR operations were discontinued in late-September 2017. However, the collection of the coincident radar ground-based and satellite radar measurements during this additional time period failed for most June-September overpasses because of a gap in CloudSat CPR measurements due to the reaction wheel problem or the SACR-2 hardware/software problems. The list of the post-IOP overpasses is given below.

June 9, 2017: The CloudSat CPR was not operational.
June 25, 2017: The CloudSat CPR was not operational.
July 11, 2017: The CloudSat CPR was not operational.
July 27, 2017: The CloudSat CPR was not operational.
August 12, 2017: No CloudSat IOP SACR-2 scans (a mid-altitude cloud over the AMF3).
August 28, 2017: SACR CloudSat overpass scans, CPR operational (a high ice cloud over the AMF3).
September 13, 2017: The SACR was not operational.

Examples of SACR RHI reflectivity measurements in the vertical plane of the CloudSat overpass for the three dates when CloudSat CPR measurements were available and hydrometeors were present above the CPR ground clutter are shown in the figure below.



Z_eh (dBZ)
OLI SACR-2 RHI W-band, 20170321.131712 (2), az=26.3°(positive distances)
height AGL (km)
horizontal distance (km)
oli-rhi-z.sty



Z_eh (dBZ)
OLI SACR-2 RHI W-band, 20170524.132539 (7), az=26.3°(positive distances)
height AGL (km)
horizontal distance (km)
oli-rhi-z.sty

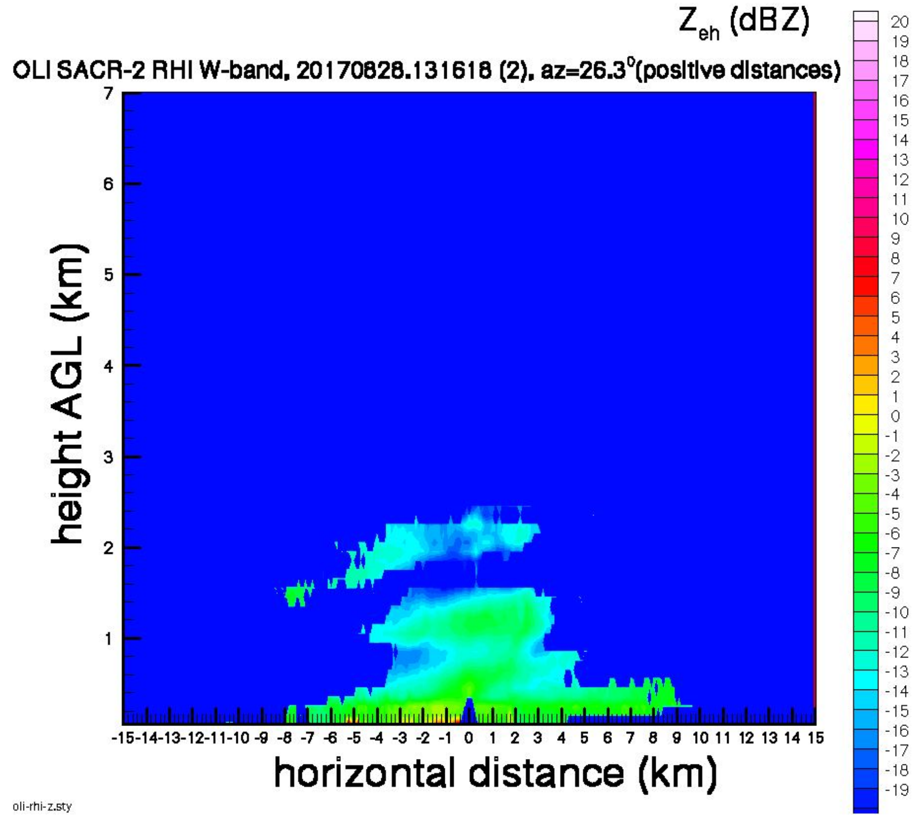


Figure 1. A hemispheric RHIs of SACR W-band reflectivity measurements in the plane of CloudSat overpass on 21 March, 2017 (upper frame), 24 May, 2017 (middle frame) and 28 August, 2017 (lower frame).

Further research will be focused on the analysis of synergetic ground-based and satellite data from overpasses 2 and 6. The data collected during this campaign will be used to refine absolute calibration of the AMF3 SACR-2 data. The microphysical retrievals from ground-based and satellite measurements will be intercompared for closely collocated profiles of radar measurements. It will help to better understand the uncertainties of both types of retrievals and clarify approaches for the synergetic use of radar data from different platforms. The collocated data set will allow for an independent evaluation of the extent of the SACR-2 spatial coverage under different cloud conditions.

The special scanning data from the SACR-2 Ka- and W-band channels were processed and the data in the netcdf format were uploaded to the ARM Data Archive. For the overpass days mentioned above and the time interval 1315 UTC-1326 UTC, they can be found as SACR-2 HSRHI files.

3.0 Publications and References

Kollias, P, EE Clothiaux, TP Ackerman, BA Albrecht, KB Widener, KP Moran, EP Luke, KL Johnson, N Bharadwaj, J. B. Mead, MA Miller, J Verlinde, RT Marchand, and GG Mace. 2016. "Development and Applications of ARM Millimeter-Wavelength Cloud Radars." *Meteorological Monographs* 57: 17.1-17.19, doi:10.1175/AMSMONOGRAPHS-D-15-0037.1.

Tanelli, S, SL Durden, E Im, KS Pak, DG Reinke, P Partain, JM Heynes, and RT Marchand. 2008. "CloudSat's cloud profiling radar after two years in orbit: Performance, calibration, and processing." IEEE *Transactions on Geoscience and Remote Sensing* 46(11): 3560-3573, doi:10.1109/TGRS.2008.2002030.

4.0 Lessons Learned

When planning the operations we realized that we would not likely be able to get collocated satellite and ground-based radar measurement data sets during all six overpasses occurring during the three-month period allocated for this IOP. We knew that possible intervening factors that could limit the collocation data set include potential technical problems with the SACR-2 and/or CPR, the inclement weather conditions at Oliktok Point preventing radar operations, and the lack of clouds and/or precipitation over the AMF3 during satellite overpasses. All these factors played a role during the IOP. As a result, only two overpasses were successful in terms of collecting the ground-based and spaceborne collocated radar measurements. Automated CloudSat overpass SACR scans after the official three-month IOP period provided one more combined data set. That was less than we hoped for, though a useful data set was still obtained. The lesson here is that expectations of getting combined data sets from very different platforms probably should not be very high when so many independent interfering factors are involved.

Another important lesson learned from this IOP is that the special scanning procedures for the ARM radars can be developed and automated for use in collecting data that are synchronous with satellite measurements. This experience can be used for future attempts in combining measurements from different platforms.

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