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DOE/SC-ARM-16-042

Observations and Modeling of the Green Ocean Amazon 2014/15: Parsivel2 Field Campaign Report

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July 2016

ARM CLIMATE RESEARCH FACILITY

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Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acknowledgements

We acknowledge the support from the Central Office of the Large Scale Biosphere Atmosphere Experiment in Amazonia (LBA), the Instituto Nacional de Pesquisas da Amazonia (INPA), and the Universidade do Estado do Amazonia (UEA). The work was conducted under 001030.2012-4 of the Brazilian National Council for Scientific and Technological Development (CNPq).

Acronyms and Abbreviations

AGU	American Geophysical Union
AMF	ARM Mobile Facility
AMS	American Meteorological Society
ARM	Atmospheric Radiation Measurement Climate Research Facility
ASR	Atmospheric System Research
CNPq	Brazilian National Council for Scientific and Technological Development
DOE	U.S. Department of Energy
DSD	drop size distribution
GoAmazon	Green Ocean Amazon 2014/15
hr	hour
INPA	Instituto Nacional de Pesquisas da Amazonia
IOP	Intensive Operational Period
km	kilometer
LBA	Large Scale Biosphere Atmosphere Experiment in Amazonia
min	minute
mm	millimeter
RWP	radar wind profiler
SIPAM	Sistema de Protecao da Amazonia
UEA	Universidade do Estado do Amazonia
UHF	ultra-high-frequency
WACR	W Band ARM Cloud Radar
Z-R	reflectivity-rain rate

Contents

Figures

1.0 Summary

One of the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility's Parsivel2 disdrometers was deployed at the first ARM Mobile Facility (AMF1) T3 site in Manacapuru, Brazil at the beginning of the second Green Ocean Amazon (GoAmazon)2014/15 intensive operational period (IOP2) in September 2014 through the end of the field campaign in December 2015. The Parsivel2 provided one-minute drop-size distribution (DSD) observations that have already been used for a number of applications related to GoAmazon2014/15 science objectives. The first use was the creation of a reflectivity-rain rate (Z-R) relation enabling the calculation of rain rates from the Brazilian Sistema de Protecao da Amazonia (SIPAM) S-band operational radar in Manaus. The radar-derived rainfall is an important constraint for the variational analysis of a large-scale forcing data set, which was recently released for the two IOPs that took place in the 2014 wet and transition seasons, respectively. The SIPAM radar rainfall is also being used to validate a number of cloud-resolving model simulations being run for the campaign. A second use of the Parsivel2 DSDs has been to provide a necessary reference point to calibrate the vertical velocity retrievals from the AMF1 W Band ARM Cloud Radar (WACR) cloud-profiling and ultra-high-frequency (UHF) wind-profiling instruments. Accurate retrievals of in-cloud vertical velocities are important to understand the microphysical and kinematic properties of Amazonian convective clouds and their interaction with the land surface and atmospheric aerosols. Further use of the Parsivel2 DSD observations can be made to better understand precipitation characteristics and their variability during GoAmazon2014/15.

2.0 Results

The Parsivel2 observations were first quality controlled to ensure high DSD accuracy. The counts are for 1-min samples. The DSD data was quality controlled as follows:

1. Removal of drops +- 50% of Beard terminal velocity
2. Removal of drops <= 0.2 mm in diameter

Figure 1 shows that these quality control measures removed a third of the 1-min samples, thereby providing a cleaner relationship between observed drop diameter and theoretical terminal velocity expectations.

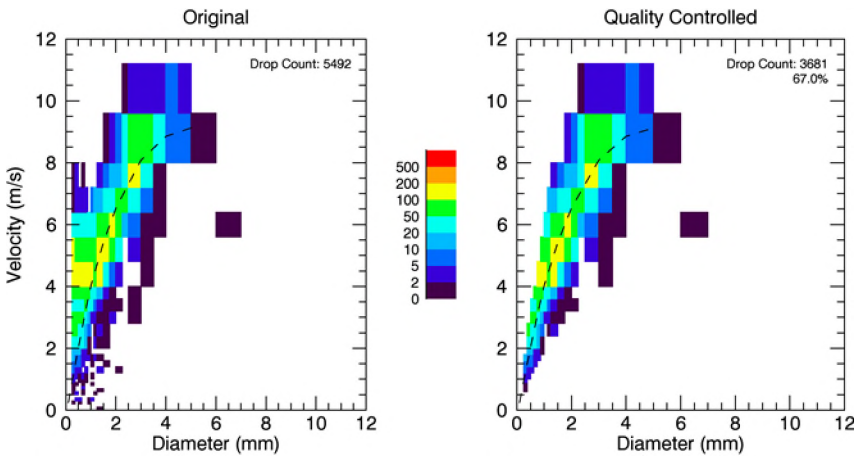

Figure 1. Parsivel2 drop diameters versus terminal velocity before and after quality control.

Further, the Parsivel2 Z-R fits were generated using additional quality control:

1. Removal of drops > 4.75 mm in diameter (per Mary Jane Bartholomew's results)
2. 1-min samples with counts >= 100
3. 1-min samples with rain rate >= 0.1 mm/hr

Z-R curve fitting was accomplished using DSD-based reflectivity values and principle component analysis (Figure 2). The resulting Z-R relation from the first six months of the Parsivel2 deployment was applied to the SIPAM S-band radar data to calculate area-wide rain rates. Future work will further refine these Z-R relations using the full Parsivel2 data set.

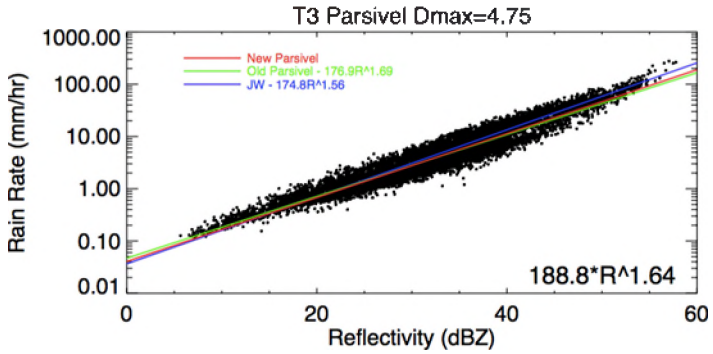

Figure 2. Parsivel2 Z-R fits at T3 before (green line) and after (red line) excluding drops > 4.75 mm in diameter. The JW relation (blue line) is from the Brazilian Joss-Waldvogel disdrometer located about 8 km away.

Figure 3 shows DSD-based reflectivity Z versus reflectivity-weighted mean Doppler velocity estimates during GoAmazon2014/15 with color-coding representing collocated radar wind profiler (RWP) echo classifications. The dashed line plots an 'a'-coefficient = 2.65 ms^{-1} that is better matched to the convective rain DSDs found during GoAmazon2014/15 compared to the Oklahoma fit represented by the solid line.

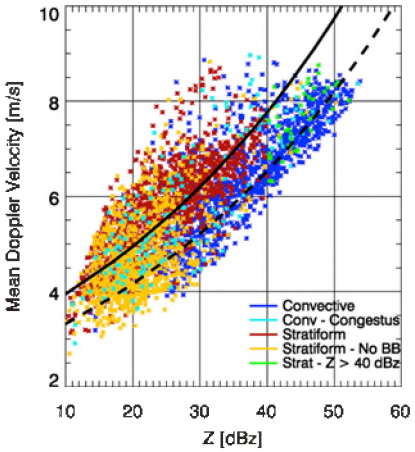

Figure 3. Parsivel2 DSD-based estimates for Z versus mean Doppler velocity (September 2014 to December 2015). Each point represents a 5-minute DSD aggregation, color-coded to highlight stratiform (2233 total, yellow and red) and convective (1216 total, blue) DSDs as based on RWP echo classifications. The solid line represents the Giangrande et al. (2013) relationship for 'rain'. The dashed line represents the convective rain relationship for GoAmazon 2014/15. From Giangrande et al. (2016).

Ongoing work is expanding upon the Parsivel2 DSD observations to further understand the microphysical and dynamical properties of convection over the Amazon during the GoAmazon2014/15 campaign. For example, Figure 4 shows how DSD-derived quantities vary based on cloud type with distinct variations between convective and stratiform rain properties.

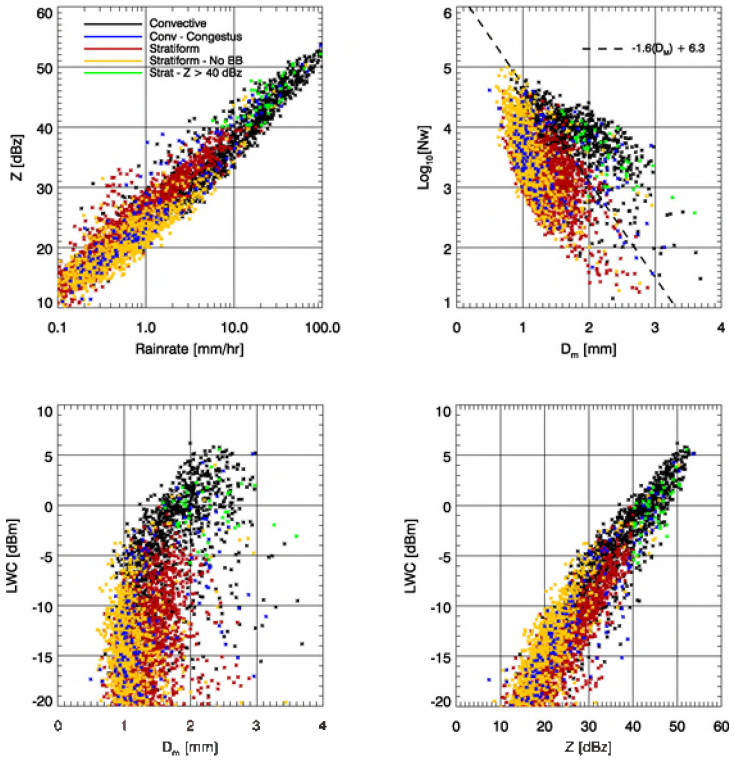

Figure 4. Parsivel2 DSD-based relationships between Z, rain rate, drop diameter (D_m), the normalized intercept or concentration parameter (Nw), and liquid water content (LWC). Courtesy of Scott Giangrande.

Figure 5 shows that the DSD spread is minimal throughout the day during weak, less organized rain situations (left panel), but broadens considerably throughout the day during heavy, more organized rain situations (right panel). This initial analysis was done with only a small subset of the Parsivel2 data set so future diurnal analysis will include the full GoAmazon2014/15 period. Additional compositing will be done by polluted and non-polluted days based on the Manaus plume location.

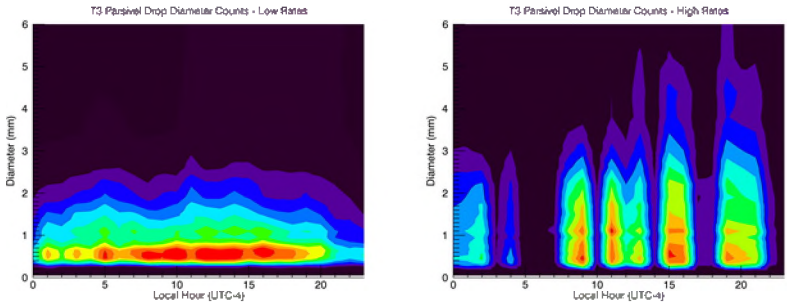

Figure 5. Diurnal variation in Parsivel2 DSD counts during low (left) and high (right) rain rates.

3.0 Publications and References

The following are publications to date that have used the SIPAM radar rain rates or ARM vertical velocity retrievals, which depended on the Parsivel2 DSD observations. Many more studies are underway.

The Parsivel2 DSD observations and related retrievals have also been used in studies presented at American Geophysical Union (AGU) and American Meteorological Society (AMS) special sessions, as well as DOE Atmospheric System Research (ASR) science team and working group meetings and the GoAmazon2014/15 Harvard University meeting.

Martin, ST, P Artaxo, LAT Machado, AO Manzi, RAF Souza, C Schumacher, J Wang, M.O Andreae, HMJ Barbosa, J Fan, G Fisch, AH Goldstein, A Guenther, JL Jimenez, U Poschl, MA Silva Dias, JN Smith, and M Wendisch. 2016. "Introduction: Observations and modeling of the Green Ocean Amazon (GoAmazon2014/5)." *Atmospheric Chemistry and Physics* 16: 4785-4797, doi:10.519/acp-16-4785-2016.

Giangrande, SE, T Toto, MP Jensen, MJ Bartholomew, Z Feng, A Protat, CR Williams, C Schumacher, and L Machado. 2016. "Convective cloud vertical velocity and mass-flux characteristics from radar wind profiler observations during GoAmazon2014/5." *Journal of Geophysical Research*, conditionally accepted.

Tang, S, S Xie, Y Zhang, M Zhang, C Schumacher, H Upton, M Jensen, K Johnson, M Wang, M Ahlgrimm, Z Feng, P Minnis, and M Thieman. 2016. "Large-scale vertical velocity, diabatic heating and drying profiles associated with seasonal and diurnal variations of convective systems observed in the GoAmazon2014/5 experiment." *Atmospheric Chemistry and Physics*, submitted.

4.0 Lessons Learned

While ARM responded rapidly to my request to deploy a Parsivel2 after the field campaign had already started (I made the request in March 2014 during the first IOP and it was deployed by the second IOP in September 2014), I would highly recommend that a Parsivel2 or other disdrometer be deployed with every AMF campaign because of the importance of DSD observations to precipitation and vertical velocity retrievals.


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