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In Situ Cloud Measurements at AMF3 Field Campaign Report

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Acronyms and Abbreviations

AGL	above ground level
AMF3	third ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
ASR	Atmospheric System Research
BCP	backscatter cloud probe
CDMS	cloud droplet measurement system
CDP	cloud droplet probe
DOE	U.S. Department of Energy
GMT	Greenwich Mean Time
LRRS	Long-Range Radar Site
PI	principal investigator
RX/TX	receive/transmit
SGP	Southern Great Plains
SNL	Sandia National Laboratories
TBS	tethered balloon system

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1.0 Summary

This campaign is a follow-up project to the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) user facility field campaign entitled Cloud Droplet Measurement System for TBS that was focused on integration of the Mesa Photonics' cloud droplet measurement system (CDMS) into the DOE ARM tethered balloon system (TBS) and its initial field testing at ARM's Southern Great Plains (SGP) atmospheric observatory in February−March 2020. The CDMS performs in situ measurement of droplet size distribution function and droplet number density in clouds. These characteristics are important cloud microphysical properties that are critical input parameters for atmospheric models and are also useful for proper calibration and validation of performance of other atmospheric measurement instrumentation. The overall goals of this campaign were to deploy the CDMS on the DOE ARM TBS, test its compatibility with the TBS under relevant conditions, and perform a series of in-cloud measurements at the third ARM Mobile Facility (AMF3) at Oliktok Point, Alaska. The TBS flights were conducted on November 12−19, 2020.

The specific technical objectives included the following: (1) Integration of the CDMS into the ARM TBS, (2) testing of the wireless telecommunication system of the CDMS under relevant conditions, and (3) performing in-cloud measurements using the CDMS. All objectives have been successfully met. The instrument was shipped to Alaska, and all testing was performed by the TBS operational crew led by D. Dexheimer using the instrument reference manual and instructions provided by the principal investigator (PI), who did not personally participate in the field campaign. The field testing demonstrated good compatibility of the CDMS with the TBS. The mounting hardware (designed earlier at Sandia National Laboratories [SNL]) allowed reliable mounting of the CDMS on the TBS, which included the possibility of co-locating of the CDMS with other instruments. During the TBS flights, the crew did not experience any operational issues with the CDMS. The instrument demonstrated reliable operational characteristics, including sufficient battery life, good thermal management, and efficiency of the optical window heating system. The ruggedness of the instrument's optical alignment was evaluated by performing calibration of the CDMS (using Mesa Photonics' fixed-size monodisperse droplet generator) before and after the campaign. The calibration was stable within the instrument's measurement precision. During all flights, the raw data were stored locally on a memory card and post-processed later.

The CDMS wireless telecommunication system was tested separately by flying the CDMS transceiver on the TBS and measuring two-way data transmission rate between the transceiver and the ground station using software developed at Mesa Photonics. Under all flight conditions, the measured data rate was sufficient to support the expected data rate required to transmit the CDMS raw data.

Several in-cloud TBS flights carrying the CDMS provided an opportunity to perform in situ measurements of the cloud droplet size distributions. Processing of the raw data has confirmed the basic performance characteristics of the instrument, e.g., the smallest detectable droplet size and the capability of measuring the droplet size distribution functions. A few data processing issues have been identified, which are currently being fixed. Intercomparison of the in situ cloud data obtained using the CDMS and other co-located cloud probes is planned.

In summary, the field campaign provided valuable information on the performance and operation of the CDMS under relevant conditions and also revealed data processing issues. This information is extremely helpful and will result in refining the technical specifications of the instrument and improved data processing algorithms and software.

2.0 Results

This campaign is a follow-up project to the Cloud Droplet Measurement System for TBS campaign that focused on integration of the Mesa Photonics' CDMS into the ARM TBS and its initial testing at SGP in February−March 2020. The CDMS performs in situ measurement of droplet size distribution function and droplet number density in clouds. These characteristics are important cloud microphysical properties that are critical input parameters for atmospheric models and are also useful for proper calibration and validation of performance of other atmospheric measurement instrumentation. The overall goals of this campaign were to deploy the CDMS on the DOE ARM TBS, test its compatibility with the TBS under relevant conditions, and perform a series of in-cloud measurements at AMF3 (Oliktok Point, Alaska). The TBS flights were conducted November 12−19, 2020.

The specific technical objectives included: (1) integration of the CDMS into the ARM TBS, (2) testing the wireless telecommunication system of the CDMS under relevant conditions, and (3) performing in-cloud measurements using the CDMS. All objectives have been successfully met.

2.1 Integration of the CDMS into the ARM TBS

Most of the work on TBS integration was completed during the preceding project, which included designing and building a CDMS mounting plate, wireless transceiver mount, and battery compartment at SNL. In this project, a new battery compartment capable of holding a larger battery was constructed. It was decided that, for flight tests at AMF3, it is less risky to operate the CDMS in the local data storage mode (which involves storing the raw data on a local memory card followed by post-processing) and perform testing of the wireless data communication system separately. The instrument was shipped to Alaska, and all field testing was performed by the SNL TBS operational crew led by D. Dexheimer using the instrument reference manual and instructions provided by the PI (who did not personally participate in the field campaign). The field testing demonstrated good compatibility of the CDMS with the TBS. The mounting hardware allowed reliable mounting of the CDMS on the TBS, which included the possibility of co-locating of the CDMS with other instruments. During the TBS flights, the crew did not experience any operational issues with the CDMS. The instrument demonstrated reliable operational characteristics, including sufficient battery life, good thermal management, and efficiency of the optical window heating system. The ruggedness of the instrument's optical alignment was evaluated by performing calibration of the CDMS (using Mesa Photonics' fixed-size monodisperse droplet generator) before and after the campaign. The calibration was stable within the instrument's measurement precision.

2.2 Testing the CDMS Wireless Telecommunication System

The CDMS wireless telecommunication system was tested separately by flying the CDMS transceiver on the TBS and measuring two-way data transmission characteristics between the transceiver and the ground station using software developed at Mesa Photonics. In the previous campaign, the telecommunication system was successfully tested at SGP at TBS flight altitudes of up to 1000 m AGL, at daytime, under clear-sky conditions. The plan for this campaign included testing the telecommunication system at the maximum possible altitudes (ideally, up to 1.5 km at AMF3), including flights in clouds. One test flight was conducted:

11/18/2020, Flight 2, 4:50-5:13 GMT, -11.9 °C, winds S at 3-4 m/s, 0 °C at 300 m, clear

The maximum flight altitude was 350 m (weather limited). During the flight, the measured data receive/transmit (RX/TX) throughput, RX/TX signal strength, and the noise and interference were recorded at 10 s intervals. During the whole flight, the measured maximum data rate (throughput) was 180-400 Mb/s, which is sufficient to support the expected data rate (about 78 Mb/s) required to transmit the CDMS raw data.

2.3 Performing In-Cloud Measurements Using the CDMS

Before this field campaign, we have had very limited experience of performing measurements in real clouds. During this campaign, several in-cloud TBS flights carrying the CDMS have been performed:

11/13/2020, Flight 2, 08:45-11:00 GMT, Surface temperature -18.5 °C, winds NE at 4-5 m/s, speed decreased during second profile, then increased during Flight 2. Intermittent cloud layer with base between 150 and 250m and top ~400m. Occasional decrease in visibility to the north and east.
11/15/2020, Flight 1, 19:25-19:47 GMT, Surface temperature -11.5 C, winds SW at 5-7 m/s, CB 740 m, CT 900 m, light snow
11/15/2020, Flight 2, 23:55-00:31+ GMT, Surface temperature -9.6 C, winds SW at 2-4 m/s, CB 11300 m, CT 900 m
11/17/2020, Flight 1, 17:45-18:51 GMT, -3.9 °C, winds E at 3-4 m/s, CB 780 m, Drizzle
11/17/2020, Flight 2, 18:57-20:04 GMT, -6.0 C, winds E at 2-4 m/s, CB 60 m
11/18/2020, Flight 1, 1:15-4:13 GMT, -11.9 °C, winds S at 3-4 m/s, 0 °C at 300 m, clear
11/19/2020, Flight 1, 23:58-00:51+ GMT, CB1 60 m, CB2 90 m, Fog – Long-Range Radar Site (LRRS) radar dome barely visible from runway; SLWC E does not depress after 100 m, appear to be out of top of fog

These experiments provided an opportunity to perform in situ measurements of the cloud droplet size distributions. Processing of the raw data has confirmed the basic performance characteristics of the instrument, e.g., the smallest detectable droplet size and the capability of measuring the droplet size distribution functions in real clouds. Most flights were performed during nighttime, which resulted in somewhat better performance characteristics because of elimination of the background light illumination issue. For example, it appears that the smallest reliably detectable scattering signal corresponds to equivalent droplet diameter of about 6-7 μm (instead of the nominal 10 μm), which is a significant performance gain. This may justify further effort towards minimizing the background illumination signal. A few data processing issues have been identified, which are currently being fixed. We are still processing the data. Intercomparison of the in situ cloud data obtained using the CDMS and other co-located cloud probes is planned. In particular, we are planning to compare the CDMS data with the data obtained using a cloud droplet probe (CDP) and backscatter cloud probe (BCP; "Gondola") co-located on the same TBS mounting platform (I. Gultepe, Environment and Climate Change of Canada, Toronto, Canada). Other collaborations are also possible. For example, interest has been expressed in testing the Mesa Photonics generator of monodispersed water droplets as a potential tool for calibration of in situ aerosol and cloud probes.

In summary, the field campaign provided valuable information on the performance and operation of the CDMS under relevant conditions and also revealed data processing issues. This information is extremely helpful and will result in refining the technical specifications of the instrument and improved data processing algorithms and software.

The results will be presented at the 2021 ARM/ASR PI Meeting (June 21−24, 2021).

3.0 Publications and References

Vakhtin, A, L Krasnoperov, and D Dexheimer. Field Testing of Cloud Droplet Measurement System (CDMS) deployed on Tethered Balloon System (TBS). 2021 ARM/ASR PI Meeting, June 21−24,2021 (accepted).

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