Initial Radiance Validation of On-orbit MicroMAS-2A Data

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***Abstract*—Constellations of nanosatellites allow increased observations, improved revisit time, and expanded spatial coverage. Miniaturized microwave radiometers are particularly well-suited to nanosatellite constellations given the relatively wide receive beamwidth and high impact of their contribution to weather forecasting [1]. The Micro-sized Microwave Atmospheric Satellite (MicroMAS)-2A is a 3U CubeSat that launched on January 11, 2018, and provided the first CubeSat microwave atmospheric sounder data from orbit. MicroMAS-2A has a 1U 10-channel passive microwave radiometer with channels near 90, 118, 183, and 206 GHz for moisture and temperature profiling and precipitation imaging [2]. MicroMAS-2A is a pathfinder for the future mission Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS), which is projected to launch in 2020. In this work, we provide an initial radiance validation assessment of MicroMAS-2A data.**

I. INTRODUCTION

In order to effectively use nanosatellites such as MicroMAS-2A and TROPICS as a weather monitoring platform, we must show that they can provide well-calibrated data that can be incorporated into Numerical Weather Prediction (NWP) models. In this work, we determine radiometric accuracy of the MicroMAS-2A payload by using the Joint Center for Satellite Data Assimilation (JCSDA)-developed Community Radiative Transfer Model (CRTM). We use inputs from radiosondes and the ERA5 Numerical Weather Prediction (NWP) reanalysis dataset in CRTM in order to develop simulated brightness temperatures that we compare to actual brightness temperatures in order to determine bias. Results will be compared to the Advanced Technology Microwave Sounder (ATMS) and FengYun (FY)-3 biases that are calculated using the same process over a similar geographic region and time, and this comparison will provide us an initial assessment of the bias of the MicroMAS-2A microwave radiometer.

II. APPROACH

We determine radiometric accuracy using the fast radiative transfer model CRTM, which uses lookup tables and parameterizations in order to ingest large amounts of satellite data. CRTM uses atmospheric profiles, surface properties, and satellite characteristics as inputs into its radiative transfer model and outputs parameters such as radiance and brightness temperature, as shown in Fig. 1.

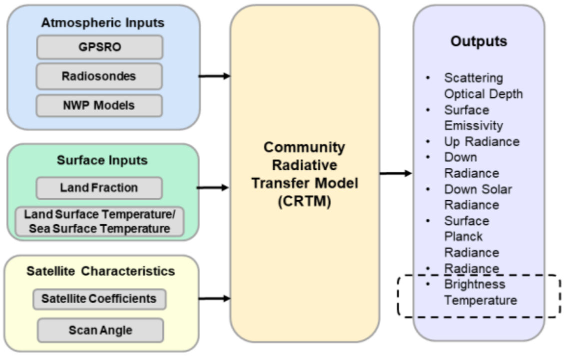

Fig. 1. CRTM is a fast radiative transfer model that calculates brightness temperature based on atmospheric profiles, surface properties, and satellite characteristics.

We have written scripts that ingest atmospheric profiles from sources such as GPS Radio Occultation (GPSRO), radiosondes, and Numerical Weather Prediction (NWP) models. The profiles are then filtered to meet time and distance criteria of one hour and 55 deg FOV, as well as additional criteria of occurring over water and clear sky conditions between 60°S and 60°N latitudes. The process has been validated using ATMS data from Jan 1-7 2018, and we have shown that the results compare favorably to literature [3].

III. RESULTS

We next use the CRTM approach to analyze MicroMAS-2A on-orbit data. Fig. 2 shows initial MicroMAS-2A data compared to ATMS data that has been geolocated over an ice sheet in Alaska; the measurements take place seven hours apart.

This comparison qualitatively shows that the MicroMAS-2A sensor is performing as expected; however, because the comparison is seven hours apart, we must also complete a quantitative analysis and use a radiative transfer model such as CRTM to determine sensor bias.

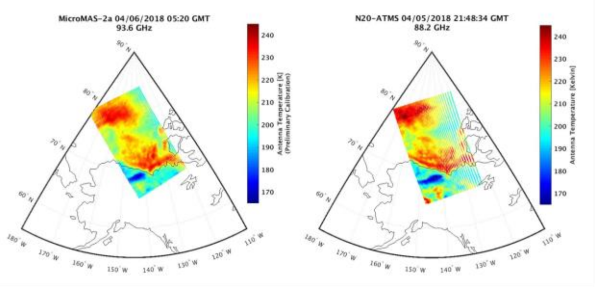

Fig. 2. Comparison of MicroMAS-2A data to ATMS data taken seven hours apart over an ice sheet in Alaska [3]. (*M. DiLiberto*)

We initially analyze the first two segments of MicroMAS-2A data. Both segments of data are located over Alaska. Although no GPSRO profiles are available that meet the time and distance filters for CRTM, a nearby radiosonde station and the ERA5 reanalysis dataset can be used to provide radiance validation.

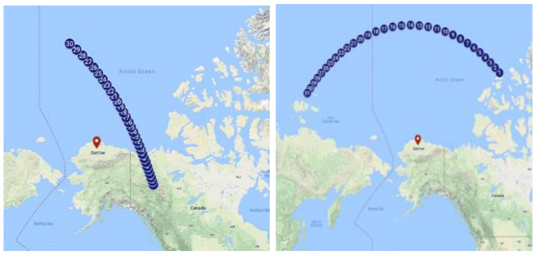

Fig. 3. MicroMAS-2A data segment 1 (left) and data segment 2 (right). Although no GPSRO profiles meet the time and distance filter, the Barrow radiosonde station and ERA5 are available for comparison [3].

It should be noted that the two segments of MicroMAS-2A data are located in a polar region which is outside of the 60°S-60°N filter. The variable surface emissivity of ice causes greater biases between CRTM and actual satellite data, so in order to determine the quality of the MicroMAS-2A data we also analyze the biases of ATMS at a similar geographic location and time.

We use the ERA5 reanalysis dataset as inputs to CRTM and analyze the first segment of MicroMAS-2A data. We then choose ATMS data from Suomi-NPP that overflew a similar region as MicroMAS-2A segment 1 within 8 hours, and choose data points that meet the filter conditions over water and clear sky. We then compare the differences between measured brightness temperature between the MicroMAS-2A and ATMS and the ERA5 CRTM simulated brightness temperatures for similar frequency channels. We use double differencing [4] to compare the results, which are shown in Table 1. The double difference was less than 2.0 K for MicroMAS-2A Ch 1/ATMS Ch 16, which have a 5 GHz difference in frequencies. The double differences for the channels with the same frequencies (MicroMAS-2A Ch 7/ATMS Ch22 and MicroMAS-2A Ch 9/ATMS Ch18) were less than 0.2 K.

We follow a similar analysis using the Barrow radiosonde as input into CRTM. The analysis is completed using the same MicroMAS-2A and ATMS data points as the ERA5 analysis. The double difference is found to be less than 2.0 K for each of the channels compared.

TABLE I. DOUBLE DIFFERENCE COMPARISON BETWEEN MICROMAS-2A AND ATMS FOR DATA SEGMENT 1.

Channel	**Frequency (GHz)**	**Double Difference: ERA5 (K)**	**Double Difference: Radiosonde (K)**
MicroMAS-2A Ch. 1/ ATMS Ch. 16	93.596 88.2	-1.91	-1.90
MicroMAS-2A Ch. 7/ ATMS Ch. 22	183.31 +/-1 183.31 +/- 1	0.15	0.97
MicroMAS-2A Ch. 9/ ATMS Ch. 18	183.31 +/-7 183.31 +/-7	-0.14	1.02

IV. CONCLUSION

We have developed a radiance validation process using CRTM and have validated it using ATMS data. A double difference technique for similar channels was used to compare MicroMAS-2A measurements with ATMS measurements over a similar geographic area and time using ERA5 and radiosonde inputs in CRTM, with a result of less than 2.0 K. Future work will refine MicroMAS-2A calibration and complete a similar comparison between the MicroMAS-2A channels that have a similar frequency to FY-3C (Channels 2-6). We will also continue analyzing additional MicroMAS-2A segments.

ACKNOWLEDGEMENT

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