Novel Validation of the Tomorrow.io Pathfinder Radars over the Contiguous U.S.

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Smallsats are supporting earth observations from space though their performance is generally unknown, especially with respect to classical spaceborne missions. The Tomorrow.io Pathfinder radars (R1 & R2) are the first commercial smallsat Ka-band radars to observe precipitation, though their performance in retrieving surface precipitation rates is yet to be quantified by the scientific community. To address this gap, we conduct the first validation of the Tomorrow.io Pathfinder radars relative to the Ground Validation Multi-Radar Multi-Sensor (GV-MRMS) product, a trusted ground reference for precipitation over the Contiguous U.S. (CONUS) which is used to support spaceborne retrieval validation and development. Specifically, GV-MRMS ingests the MRMS surface precipitation estimates (0.01°, 2-minute resolution), produced from NEXRAD ground-based radars, rain gauges and models, and subjects them to a range of quantity and quality control procedures to tailor the product toward validation of spaceborne precipitation products. Furthermore, we quantify the performance of Tomorrow-R1 & -R2 relative to the Global Precipitation Measurement (GPM) mission's Ka-band Precipitation Radar (KaPR) by setting the GPM KaPR ground validation metrics relative to GV-MRMS as a benchmark for the Tomorrow.io sensors. The Tomorrow-R1 & -R2 level-2 surface precipitation footprint retrievals are validated against GV-MRMS over CONUS during October-November 2023, the subset period acquired from NASA's Commercial Satellite Data Acquisition division, whilst the GPM KaPR is validated both in this period and over a larger timeframe. Initial results highlight that the Tomorrow.io radars are skillful in distinguishing between rain and no rain events, including detecting approximately 82% of rain events over CONUS. Furthermore, Tomorrow-R1 & -R2 tend to overestimate light precipitation rates and underestimate heavier precipitation rates (>1-2 mm h^{-1}) over CONUS, as similarly found for the GPM KaPR. Tomorrow-R2 outperforms Tomorrow-R1 in quantifying CONUS rain rates as demonstrated by a smaller underestimating mean relative bias (R1: -6%; R2: -22%) and superior correlation coefficient (R1: 0.73; R2: 0.93). The innovation of this research is to provide a benchmark for smallsat performance that can support the scientific community and federal agencies as we navigate the future of satellite precipitation observations.