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

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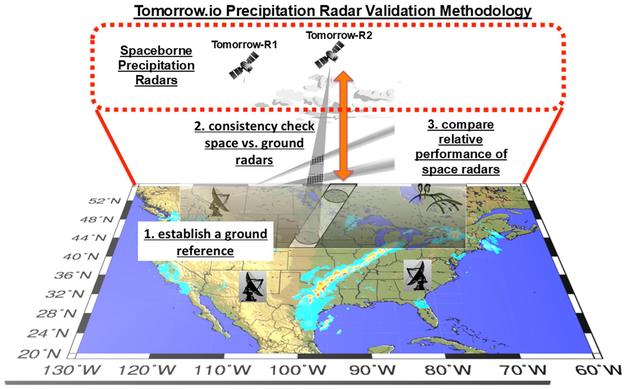
1) Background

- **Goal: To quantify the performance of the commerical Tomorrow.io Pathfinder radars (R1 & R2) in retrieving surface precipitation rates over the Contiguous U.S. (CONUS).**
- **Novelty:** Tomorrow.io launched the first two commercial satellites with precipitation radars in April and June 2023, respectively, and their precipitation retrieval accuracy is undetermined.
- **Complementarity**: The Tomorrow.io radars can complement the NASA-JAXA Global Precipitation Measurement (GPM) mission in advancing our understanding of storms.
- **Innovation**: To provide a benchmark for smallsat performance that the scientific community and federal agencies can utilize for the future of satellite precipitation observations.

2) Validation Framework



Analysis Period:

- Tomorrow-R1: Oct 1 – Nov 30, 2023
- Tomorrow-R2: Oct 10 – 30, 2023

GV-MRMS: Ground Validation Multi-Radar/Multi-Sensor

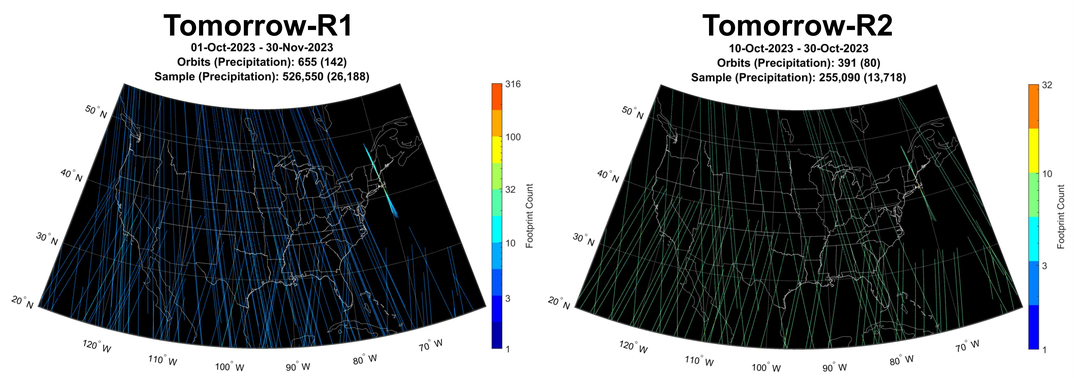
Tomorrow.io Pathfinder Radars

- Frequency: Ka-Band (35.5-36 GHz)
- Horizontal Resolution: 5 km
- Vertical Resolution: 0.25 km
- Altitude: 550 km
- Orbit: Sun-Synchronous
- Time of Overpass:
  - R1: 08:00 ascend
  - R2: 12:00 descend

Ground Reference: GV-MRMS

- Domain: 20-55°N, 130-60°W
- Horizontal Resolution: 0.01°
- Temporal Resolution: 2-minute
- Data Sources:
  - ~180 polarimetric radars (2-min.)
  - ~9000 gauges (hourly)
  - RAP model 3D analyses (hourly)

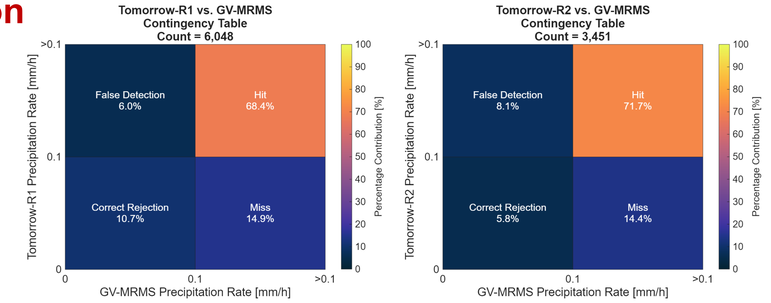
3) Tomorrow.io Radar Sampling of CONUS



- R1 has over double the sampling of R2 in the data periods made available to NASA.
- Higher sample concentration is found over the ground calibration site in Massachusetts.

4) Precipitation Detection Evaluation

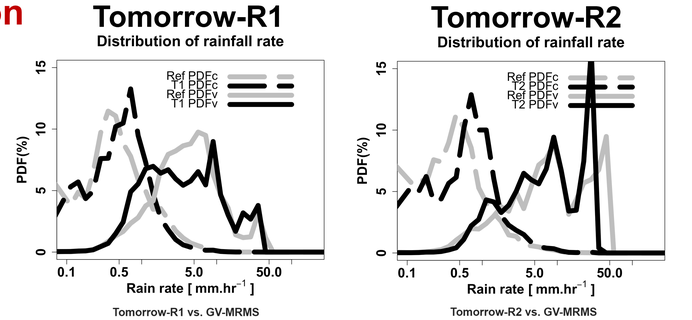
- The Tomorrow.io radars exhibit skill in detecting precipitation – the probability of detection is 82% and 83% for R1 and R2, respectively.
- Tomorrow-R1 slightly outperforms Tomorrow-R2 with an enhanced ability to detect instances of no rain, and a superior Heidke Skill Score (i.e., ability to delineate precipitation and no precipitation relative to random chance) – R1 = 0.38; R2 = 0.21.



5) Precipitation Quantification Evaluation

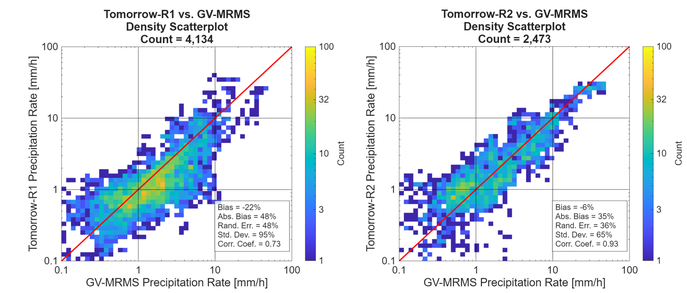
Precipitation Distribution by Occurrence (c) & Volume (v)

- Tomorrow-R2 better captures the distribution of light-intermediate rainfall volume, whilst Tomorrow-R1 better represents the distribution of heavy rainfall volume.
- Both Tomorrow.io radars estimate peak occurrence at higher rainfall rates than the GV-MRMS reference.

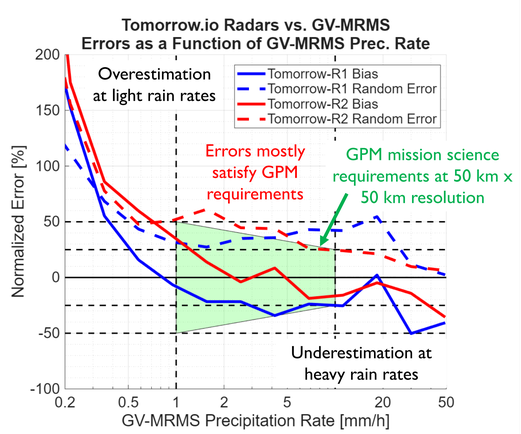


Precipitation Rate

- The Tomorrow.io R1 and R2 radars tend to underestimate precipitation by -22% and -6%, respectively.
- Tomorrow-R2 outperforms R1 in every validation metric, with a particularly strong correlation to GV-MRMS (R1 = 0.73; R2 = 0.93).
- Downselecting R1 to the same 21-day period as R2 does not significantly impact the results.



6) GPM Science Requirements



7) Conclusions

- The Tomorrow.io Pathfinder radars show skill in detecting and quantifying precipitation over CONUS relative to GV-MRMS, and mostly satisfy the GPM mission science requirements at a much finer spatial scale than required.
- Future work – Evaluate the GPM Ka-band radar over CONUS to provide a benchmark for Tomorrow.io radar performance.
- A manuscript on this work is in preparation.
- NASA Report: S. Ringerud, D. Watters, P. Kirstetter, M. Grecu, J. Nickeson, and F. Policelli (2026). NASA Commercial Satellite Data Acquisition Program: Tomorrow.io Radar Quality Assessment Report. ⟶

Acknowledgments This work contributed to the NASA Commercial Satellite Data Acquisition Program's quality assessment of the Tomorrow.io Pathfinder radars.

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