The Global Environmental Monitoring System (GEMS) Constellation of Passive Microwave Satellites

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Observation System Impact on Forecast Error

← Percentage contribution of various observation types to the total forecast error reduction:

- Microwave sounders provide the largest forecast error (FE) reductions relative to all other systems.

- Key fundamental reasons include their relative insensitivity (WRT IR) to clouds in sensing meso-γ scale T,Q thermodynamic variables.

- Primary challenges to deployment include spatial resolution, calibration, and scale-up costs for high temporal resolution sampling.

GEMS MiniRad-01 Radiometer:

- First commercial passive microwave mission
- Cross-track scanned, 410 km release orbit
- 8 channels at 118.7503 GHz O₂ resonance
- 16 km 3dB nadir spatial resolution
- Nyquist sampling across and along track
- 3U CubeSat, 1.5U payload, 4W, 14kB/s
- ~15% achieved average duty cycle
- Total mission cost <$2M

Launch April 2019 on ISS resupply mission, commissioning complete 10/2019, ~7 months of successful acquisition to date. L1c pre-launch (day 1) calibration algorithm used in initial data release.
GEMS-01 Ch 8 (±3.7-6.3 GHz) overlays on FY3C MWHS-2 Ch 9 (±4-6 GHz) with ~15-min overpass coincidence

- MiniRad-01 spatial resolution and $\Delta T_{rms}$ prelaunch goals (as engineered) achieved to within ~1.2x
- GEMS-01 bus-limited georegistration goal of ~2 beam widths maximum error
- MiniRad-01 radiometer exhibited zero faults or sporadic samples during 8+ months on-orbit
GEMS-01 IOD Weighting Functions & Convolutional Bandwidths:

Designed, measured (by IF sweep), and idealized boxcar weighting function closely match.

Negligible passband variation with temperature observed during testing.

CRTM effective-passband coefficient generation and on-orbit $\Delta T_{rms}$ estimation in progress.

<table>
<thead>
<tr>
<th>Ch #</th>
<th>$B_C$ (MHz)</th>
<th>$\Delta T_{rms}$ (K) (theoretical)</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>265.72</td>
<td>2.22</td>
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<tr>
<td>2</td>
<td>204.22</td>
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<td>0.74</td>
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<tr>
<td>8</td>
<td>2708.7</td>
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</table>

$B_C = \left( \frac{\int_{0}^{+\infty} T_{SYS}(f)G_{SYS}(f)|H_{BPF}(f)|^2 df}{\int_{0}^{+\infty} T_{SYS}^2(f)G_{SYS}^2(f)|H_{BPF}(f)|^4 df} \right)^2$

Integration time = 4.096 ms

L. Periasamy, Ph.D. Thesis, University of Colorado at Boulder, 2019
GEMS-01 IOD / FY3C Nadir Radiance Validation

Δ$T_b$

mean:
7.5 +/- 7.02 K

mean:
-2.52 +/- 4.46 K

mean:
-4.9 K +/- 10.1 K

mean:
-5.7 +/- 10.5 K

- GEMS-01 L1c pre-launch (day 1, v1.0) calibration algorithm
- Matchup latitude range <55°
- Nadir 15km / 5 min matchups
- No passband response corrections
  - High stability over 3 months
  - Channel response corrections underway
  - Post-launch recalibration underway (v1.1)
18 total soundings from NOAA Integrated Global Radiosonde Archive (IGRA) Version 2, Zhengzhou sonde CHM00057083 @ (34.7167,113.6500)

Clear-air, 15 minute/0.5° coincidence

MRT (Liebe MPM87) forward RT model calculations, land background with 5% reflectivity, multiple view angles 29-48°

<Δ> ~ 8 to -2 K, roughly consistent with FY3C comparisons

Biases being considered along with FY3C matchups for post-launch v1.1 recalibration
OMS GEMS Constellation: 48x Revisit Times

Minimum 2 year average on-orbit lifetime (6U)

Assumed 2-year lifetime at 450-500 km altitude is conservative.

~10-25 minute average revisit time achievable using a large “random orbit” 48-satellite GEMS constellation array.
Summary

• The GEMS-01 IOD mission is achieving its planned engineering and observational goals

  ➢ Nyquist sampling – highest resolution microwave temperature sounder to date!
  ➢ Highly stable radiometric performance, validation with pre-launch L1c calibration algorithm validation, post-launch re-calibration underway
  ➢ Georegistration and spatial resolution within engineered design specifications
  ➢ Compelling cost model feeding into future GEMS instrument designs and risk reduction
  ➢ Improvements include additional bands and channels, improved calibration accuracy, spatial resolution, and bus navigation and communications capabilities.