Geostationary Passive Microwave Observation System Simulation Experiments for Hydrometric Tracking

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GeoMicrowave System Concepts

GeoSTAR

Image courtesy: BATC

GOMAS

Solar Wing

Space Calibration Tube

S-band Antenna for TT&C

3-meter antenna

NADIR Europe

S-band Antenna for TT&C

Star Sensors

S-band antenna for LRIT

GEM

Nodding / Morphing Subreflector

2-m Reflector 3”-Thick Composite

Space Calibration

Receiver Package

50-430 GHz Feeds

Elevation Motor & Compensator

Azimuth Motor & Compensator

Thin Struts

Backup Structure

GeoSTARS

Bizzarri et al., 2002

GeoMicrowave System Concepts

Image courtesy: BATC
GeoSTAR Concept
2-D Geostationary Sounder/Imager

Y-Array of ~300-600 receiver elements and tens of thousands of one-bit correlators in each of three bands: 50-56, 89, and 183 GHz

GeoSTAR spatial response pattern for 298 elements with 2.8 km spacing
- ~50 km spatial resolution
- Full disk image every one hour
- No moving parts
- ~2.5 m maximum baseline
- NASA/JPL concept
GeoMicrowave Pathway Study

• **Goal:** Provide an independent NOAA-led assessment of GEM and GeoSTAR systems based on NOAA operational forecasting requirements

• **Basis:** OSSEs using optimal precipitation and sounding retrieval and radiance assimilation techniques

• **Strategy:** Leads necessarily to concept of hydrometric tracking (“precipitation locking”) introduced by Gasiewski at ITSC 13 in St. Adele, Quebec, Canada.
Geo-Microwave Spectral Selection

5 principle bands being considered:

- (A) Summer Low Latitude
- (B) Annual Midlatitude
- (C) Winter High Latitude
- (D) Annual Midlatitude (Dry) with Ozone
- (E) Annual Midlatitude: Nitrogen Only
- (F) Annual Midlatitude: Oxygen Only
GeoMicrowave Pathway Study Issues

GEM/GOMAS

• Impact of reduced penetrability of 340/380 and 424 GHz channels on temperature and moisture soundings and precipitation retrievals
• Momentum transfer to the host platform, and how much can be compensated by the GEM/GOMAS drive mechanism
• Resolution improvement obtainable by beam deconvolution using GEM/GOMAS
• Reliability of GEM/GOMAS reciprocating scanning mechanism and comparison of risk with that of previous mechanically-scanned spaceborne sensors
• Impact of regional (vs full disk) imaging/sounding capability at best temporal resolution

GeoSTAR

• Required number of receiver elements, bands, channels, cost, and associated power requirements for NOAA applications
• Impact of limited channel bandwidth, observation time, and photon capture area on the accuracy of soundings and precipitation retrievals
• Impact of lower main beam efficiency of a synthetic versus filled aperture system on spatial resolution and sounding capability
• Oversampling and beam deconvolution capability, actual resolution using optimal apodizing function
• Impact of aliased off-disk sources (e.g., sun and moon) on temperature and humidity soundings
• Impact of correlator or receiver dropouts on sounding and imaging capabilities
• Impact of calibration errors for the single central (calibrated) element on soundings across the entire disk
• Use of LEO measurements from, e.g., ATMS or CMIS to cross-calibrate GeoSTAR
• Information lost by not using GEM/GOMAS channels at frequencies above 183 GHz
NWP Hurricane Example

- Hurricane Bonnie, August 26, 1998, 0000-2430 UTC
- 24-Hr simulation, 6-km innermost nested grid, 15-minute archived frames
- MM5/MRT Reisner 5-phase simulations, statistically validated*
- DOTLRTv1.0b Fast DO Radiative Jacobian with 60 vertical levels**


**GOCTAS/GEM Sensitivity & Scan Modes**
- 2m Diameter Aperture -

### Assumptions:
- Midlatitude (30°-60° annual averaged atmosphere)
- Spatial sampling at native Nyquist sampled resolution for each specific band.
  * Further reductions in \( \Delta T_{\text{RMS}} \) achievable by further downsampling and/or time averaging.

### CONUS Imaging Time
- **Regional** (1000 x 1000 km²) : ~15 minutes
- **CONUS** imaging time (3000 x 5000 km²) : ~80 minutes

<table>
<thead>
<tr>
<th>Band (GHz)</th>
<th>3-dB IFOV (km, SSP)</th>
<th>Deconvolved Resolution (km, SSP)</th>
<th>( \Delta T_{\text{RMS}} ) (K)</th>
<th>( \Delta T_{\text{RMS}} ) Required (K,SNR=100)</th>
<th>Probing Height (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-56</td>
<td>138.6</td>
<td>~104</td>
<td>0.04-0.07</td>
<td>0.1-0.6</td>
<td>Surf</td>
</tr>
<tr>
<td>118.705</td>
<td>60.2</td>
<td>~45</td>
<td>0.03-0.6</td>
<td>0.1-0.6</td>
<td>Surf</td>
</tr>
<tr>
<td>183.310</td>
<td>41.9</td>
<td>~31</td>
<td>0.04-0.15</td>
<td>0.3-0.6</td>
<td>Surf</td>
</tr>
<tr>
<td>380.153</td>
<td>20.5</td>
<td>~16</td>
<td>0.2-2.1 *</td>
<td>0.3-0.5</td>
<td>~2.5</td>
</tr>
<tr>
<td>424.763</td>
<td>16.4</td>
<td>~12</td>
<td>0.5-5.3 *</td>
<td>0.4-0.6</td>
<td>~4</td>
</tr>
</tbody>
</table>

Downlink rate ~40 kb/sec at ~31 msec effective sample period
Hurricane Warm Core Observations
- Transparent 424 and 118 GHz Channels -
AMSU-B Moisture/Precipitation Imagery
AMSU-A Upper Atmosphere Temperature Imagery
NWP Hydrometric Tracking (Precipitation “Locking”)

NWP Precipitation “Locking”

- To realize “locking” of an NWP model onto precipitation, observations are needed at time and space scales of order ~5-15 km and ~15 minutes.

- Locking is analogous to phase-locked loop in electrical engineering wherein linear phase differencing is achieved only when oscillator and signal remain within same phase cycle.

- Similarly, linear NWP model updates can be achieved provided that the cloud and precipitation state does not decorrelate between satellite observations.
MM5 24-Hr Simulation of GEM Imagery
Hurricane Bonnie    August 26, 1998    424±4 GHz

15 min time steps

MM5/DO Hurricane Bonnie 424.763±4GHz
26 August 1998 00:15 UTC

Vertical X-section $\frac{\partial T_B}{\partial \kappa_S}$ at 33° N
min = -2.10, max = 0.00

Vertical X-section $\frac{\partial T_B}{\partial \kappa_A}$ at 33° N
min = -2.53, max = 17.60

Vertical X-section $\frac{\partial T_B}{\partial T}$ at 33° N
min = 0.09, max = 0.62
MM5 24-Hr Simulation of GEM Imagery
Hurricane Bonnie    August 26, 1998    424±4 GHz

3 hour time steps

MM5/DO Hurricane Bonnie 424.763±4GHz
26 August 1998 00:15 UTC

Vertical X-section $\Delta T_B / \Delta \kappa_S$ at 33° N
min = -21.20, max = 0.00

Vertical X-section $\Delta T_B / \Delta \kappa_A$ at 33° N
min = -2.53, max = 17.66

Vertical X-section $\Delta T_B / \Delta T$ at 33° N
min = 0.09, max = 0.62

ITSC-15    October 4-10, 2006    Maratea, Italy
Summary

- Detailed GEM/GOMAS and GeoSTAR simulations are underway within the NOAA GeoMicrowave Pathway study, now ongoing at the CU Center for Environmental Technology (CET).

- Simulations to date suggest dynamic information not present or utilized in retrievals may be valuable for nowcasting and forecasting using NWP models.

- We suggest that GEM or GeoSTAR 15-minute data will be key to facilitating hydrometric tracking.

- Ongoing OSSE tasks include:
  - GeoSTAR full disk background field generation
  - GeoSTAR simulation (as per GEM simulations)
  - Error covariance update module
  - Hydrometric tracking demonstration
International TOVS Study Conference, 15\textsuperscript{th}, ITSC-15, Maratea, Italy, 4-10 October 2006
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,