GOES: Current (10/12/11/N/O/P) to Future (GOES-R+)

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Madison, WI

and many others

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Many others to be acknowledged…

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Topics

GOES-12/11/10
GOES-N
GOES-O/P
GOES-R+
  ABI
  HES
  Data Compression
  GUC-IV
  etc.
GIFTS

More information
Current GOES
A GOES (Geostationary Operational Environmental Satellite) Incident Report (GIR) was submitted.

GOES-12 Imager 4 um band just before eclipse

Imager Cloud-top pressure product affected…

Due to the 4um data being affected…

These space looks showed large standard deviations.

During several space looks…

From D. Han
GOES-11

- The current plan is for GOES-11 to come out of storage in mid-June of 2006 and replace GOES-10 approximately on the 20th of July, 2006.

- Plan to transmit GVAR during the move to 135 West
Sample from GOES-11 view from 105 West
GOES-11 During PLT in 2000
GOES-10 at 60 West

Imager – 15 minute scans? Sounder – hourly scans?

Late 2006 or early 2007
GOES-10 at 60W

• Need to deal with a Large inclination
  – via on-ground remapping
  – Will be GVAR changes (to be announced)
On March 10, 2006 (DOY 69), SOCC Engineers changed the GOES-10 Sounder patch temperature from its MID setpoint (100.1 K) to its MID setpoint (92.5 K) at about 8:22 z (3:22 ET). The change was done during keep out zone time and prior to eclipse to minimize the impact on users. The temperature transition will take approximately 4 hours. The users may see slight data degradation (venetian blinding) in the first few frame after the eclipse (11:01:50 CONUS) until the patch temperature stabilizes at its new setpoint. The signal to noise ratio will improve as a result of operation at a lower patch (detector) temperature. The patch will be controlled at this temperature (92.5 K) until October 2006 when it will be switched back to MID setting during the autumn eclipse/KOZ season.
Patch Temperature 100K
Patch Temperature  92K
Near-term GOES
GOES-N Spacecraft

Star Trackers
GOES Schedules

• GOES-N is slated to be launched no earlier than **early May 2006** and operational in mid-2008. GOES-N will be called GOES-13 when it reaches geostationary orbit.

• GOES-O is slated to be launched in 2007 and operational in late 2009.
GOES-8/12

GOES-N/O/P will have similar instruments to GOES-8-12, but will be on a different spacecraft bus. The new bus will allow improvements both to the navigation and registration, as well as the radiometrics.

GOES-N/P
Position of the boom allows for colder detectors and hence less instrument noise.
Limitations of Current GOES Imagers

- Regional/Hemispheric scan conflicts
- Low spatial resolution
- Missing spectral bands
- Eclipse and related outages

GOES-R (2012+) addresses the first 3 limitations, but GOES-N addresses the data outage issues!
The Onset Of Hurricane Ivan: 16 September 2004

Outage during landfall

GOES-10 & -12 Sounder Cloud Top Pressure Coverage
Note: GOES-10 was taking images during this time.

GOES satellite loop: http://www.ssec.wisc.edu/~rickk/eclipseivan.html
Note: GOES-10 was taking images during this time.

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Note satellite outage during landfall

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GOES satellite loop: http://www.ssec.wisc.edu/~rickk/eclipseivan.html
Reduced KOZ

The values have not yet been defined for GOES-N operations
Improved radiometrics on GOES-N+

The GOES-N+ instruments will be less noisy.

Lower (colder) patch (detector) temperature is the main driver.

Other modifications have been made to improve the noise performance on both instruments.
Improved GOES-N (Sounder) noise compared to GOES-12

GOES-N Sounder Prelaunch Noise

- GOES-12 NEdT (space)
- GOES-N NEdT (lab)

Noise (K)

Sounder Band

longwave

shortwave
Improved **calibration** on GOES-N+

Reduction in striping to be achieved through increasing the Imager's scan-mirror's dwell time on the blackbody from 0.2 sec to 2 sec.

The more accurate blackbody characterization improves the calibration of the infrared detectors.
Example infrared image with striping:
Improved **navigation** on GOES-N+
- The GOES-N navigation will be improved
  - New spacecraft bus
  - Use of star trackers
- GOES-N performance will be verified on-orbit

### GOES-I/M Performance & GOES-N Expected Performance

<table>
<thead>
<tr>
<th>Navigation at Nadir</th>
<th>GOES-I/M</th>
<th>GOES-N+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daytime (Visible)</td>
<td>112 urad</td>
<td>53 urad</td>
</tr>
<tr>
<td></td>
<td>= 4 km</td>
<td>(&lt;2 km)</td>
</tr>
<tr>
<td>Nighttime (IR)</td>
<td>168 urad</td>
<td>85 urad</td>
</tr>
<tr>
<td></td>
<td>= 6 km</td>
<td>(~3 km)</td>
</tr>
</tbody>
</table>
GOES-N  Imager and Sounder spectral response functions.

Note the imager band selection is similar to GOES-12.
GOES-12 Imager and Sounder spectral response functions.

Note the imager band selection is similar to GOES-12.
GOES-N **Imager** Weighting Functions

Pressure

GOES-N Imager
Satellite Zenith Angle = 0.00

US Std Atmosphere
GOES-12 Imager Weighting Functions

Pressure vs. Pressure (hPa)

GOES-12 Imager
Satellite Zenith Angle = 0.00
US Std Atmosphere
GOES-N Sounder Weighting Functions

Pressure vs. Pressure (hPa)

GOES-N Sounder
Satellite Zenith Angle = 0.00

US Std Atmosphere
GOES-12 Sounder Weighting Functions

GOES-12 Sounder
Satellite Zenith Angle = 0.00

US Std Atmosphere
GOES-O – improved spatial resolution of the 13.3 um band.
Future GOES
GOES R Baseline Instruments

- Advanced Baseline Imager (ABI)
- Hyperspectral Environmental Suite (HES)
  - Disk Sounding
  - Severe Weather Mesoscale
  - Coastal Waters
- Geostationary Lightning Mapper (GLM)
- Solar Instrument Suite (SIS)
- Space Environment In Situ Suite (SEISS)
- Auxiliary Services
Advanced Baseline Imager (ABI)

- ITT Industries has been selected to build the ABIs
- Completed a successful System Preliminary Design Review (December 2005)
<table>
<thead>
<tr>
<th></th>
<th>ABI</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spectral Coverage</strong></td>
<td>16 bands</td>
<td>5 bands</td>
</tr>
<tr>
<td><strong>Spatial resolution</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.64 μm Visible</td>
<td>0.5 km</td>
<td>Approx. 1 km</td>
</tr>
<tr>
<td>Other Visible/near-IR Bands</td>
<td>1.0 km</td>
<td>n/a</td>
</tr>
<tr>
<td>Bands (&gt;2 μm)</td>
<td>2 km</td>
<td>Approx. 4 km</td>
</tr>
<tr>
<td><strong>Spatial coverage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full disk</td>
<td>4 per hour</td>
<td>Every 3 hours</td>
</tr>
<tr>
<td>CONUS</td>
<td>12 per hour</td>
<td>~4 per hour</td>
</tr>
<tr>
<td>Mesoscale</td>
<td>Every 30 sec</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Visible (reflective bands)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-orbit calibration</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
### ABI Visible/Near-IR Bands

<table>
<thead>
<tr>
<th>Future GOES imager (ABI) band</th>
<th>Wavelength range (μm)</th>
<th>Central wavelength (μm)</th>
<th>Nominal subsatellite IGFOV (km)</th>
<th>Sample use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.45–0.49</td>
<td>0.47</td>
<td>1</td>
<td>Daytime aerosol over land, coastal water mapping</td>
</tr>
<tr>
<td>2</td>
<td>0.59–0.69</td>
<td>0.64</td>
<td>0.5</td>
<td>Daytime clouds fog, insolation, winds</td>
</tr>
<tr>
<td>3</td>
<td>0.846–0.885</td>
<td>0.865</td>
<td>1</td>
<td>Daytime vegetation/burn scar and aerosol over water, winds</td>
</tr>
<tr>
<td>4</td>
<td>1.371–1.386</td>
<td>1.378</td>
<td>2</td>
<td>Daytime cirrus cloud</td>
</tr>
<tr>
<td>5</td>
<td>1.58–1.64</td>
<td>1.61</td>
<td>1</td>
<td>Daytime cloud-top phase and particle size, snow</td>
</tr>
<tr>
<td>6</td>
<td>2.225–2.275</td>
<td>2.25</td>
<td>2</td>
<td>Daytime land/cloud properties, particle size, vegetation, snow</td>
</tr>
<tr>
<td>Band</td>
<td>Waveband (μm)</td>
<td>Central Waveband (μm)</td>
<td>Resolution (km)</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>---------------</td>
<td>-----------------------</td>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>7</td>
<td>3.80–4.00</td>
<td>3.90</td>
<td>2</td>
<td>Surface and cloud, fog at night, fire, winds</td>
</tr>
<tr>
<td>8</td>
<td>5.77–6.6</td>
<td>6.19</td>
<td>2</td>
<td>High-level atmospheric water vapor, winds, rainfall</td>
</tr>
<tr>
<td>9</td>
<td>6.75–7.15</td>
<td>6.95</td>
<td>2</td>
<td>Midlevel atmospheric water vapor, winds, rainfall</td>
</tr>
<tr>
<td>10</td>
<td>7.24–7.44</td>
<td>7.34</td>
<td>2</td>
<td>Lower-level water vapor, winds, and SO$_2$</td>
</tr>
<tr>
<td>11</td>
<td>8.3–8.7</td>
<td>8.5</td>
<td>2</td>
<td>Total water for stability, cloud phase, dust, SO$_2$ rainfall</td>
</tr>
<tr>
<td>12</td>
<td>9.42–9.8</td>
<td>9.61</td>
<td>2</td>
<td>Total ozone, turbulence, and winds</td>
</tr>
<tr>
<td>13</td>
<td>10.1–10.6</td>
<td>10.35</td>
<td>2</td>
<td>Surface and cloud</td>
</tr>
<tr>
<td>14</td>
<td>10.8–11.6</td>
<td>11.2</td>
<td>2</td>
<td>Imagery, SST, clouds, rainfall</td>
</tr>
<tr>
<td>15</td>
<td>11.8–12.8</td>
<td>12.3</td>
<td>2</td>
<td>Total water, ash, and SST</td>
</tr>
<tr>
<td>16</td>
<td>13.0–13.6</td>
<td>13.3</td>
<td>2</td>
<td>Air temperature, cloud heights and amounts</td>
</tr>
</tbody>
</table>
The ABI visible and near-IR bands have many uses.
While there are differences, there are also many similarities for the spectral bands on MET-8 and the Advanced Baseline Imager (ABI). Both the MET-8 and ABI have many more bands than the current operational imagers.
Simulating 5-minute full-disk IR imagery
Three-color composite (0.64, 1.6 and 11 µm) shows the low cloud over the snow and the water versus ice clouds.
Volcanic Ash Plume: 11-12 and 8.5-11 µm images

One day after the Mt. Cleveland eruption
20 February 2001, 8:45 UTC

Simulated ABI (11-12 µm)

Simulated ABI (8.5-11 µm)
GOES-R ABI will detect SO2 plumes
Water Vapor Band Difference convolved from AIRS data sees SO₂ plume from Montserrat Island, West Indies

Current GOES Imager
No skill in monitoring

Current GOES Imager can not detect SO₂

ABI 7.34 µm – 13.3 µm
GOES-R and GOES-I/M Simulations of Southern California Fires

GOES-12 Simulated 3.9 micron Data
Padua/Grand Prix Fires
Date: 27-Oct-03    Time:  09:50 UTC

GOES-R Simulated 3.9 micron Data
Padua/Grand Prix Fires
Date: 27-Oct-03    Time:  09:50 UTC

Brightness Temperature (K)

260-280  280-300  300-320  320-340  340-360  360-380  380-400
Mountain waves over Colorado and New Mexico were induced by strong northwesterly flow associated with a pair of upper-tropospheric jet streaks moving across the elevated terrain of the southern and central Rocky Mountains. The mountain waves appear more well-defined over Colorado; in fact, several aircraft reported moderate to severe turbulence over that region.

Both images are shown in GOES projection.
Using MODIS, MET-8 and AIRS to simulate the spectral bands on the Advanced Baseline Imager (ABI)
Similar bands on the GOES-12 Imager

- 0.64 µm
- 0.86 µm
- 1.38 µm
- 1.61 µm
- 2.26 µm
- 3.9 µm
- 6.19 µm
- 6.95 µm
- 7.34 µm
- 8.5 µm
- 9.61 µm
- 10.35 µm
- 11.2 µm
- 12.3 µm
- 13.3 µm
Using MODIS, MET-8 and AIRS to simulate the spectral bands on the Advanced Baseline Imager (ABI)
“ABI” data for Data Compression

- Sample MODIS/ABI datasets have been developed by CIMSS for a range of phenomena.
- Some of the processing steps include:
  - Case selection
  - De-striping
  - Averaging to ABI spatial resolution
  - Stretch over expected bit depth range
  - Output as scaled radiances
There are two anticipated scan modes for the ABI:
- Full disk images every 15 minutes + CONUS images every 5 minutes + mesoscale,
or - Full disk every 5 minutes.

Current GOES scans 5 times slower than the ABI.
ABI can offer Continental US images every 5 minutes for routine monitoring of a wide range of events (storms, dust, volcanoes, fires, hurricanes, etc). This is only every 15 or 30 minutes with the current GOES the routine mode.
Mesoscale images every 30 seconds for rapidly changing phenomena (thunderstorms, hurricanes, fires, etc). Current GOES can not offer these rapid scans while still scanning other important regions.
GOES-West view from 135
GOES-West view from 138
Fixed Grid Format

• The distributed, calibrated and navigationally corrected image data will be rectified [re-grid] to a fixed grid. The grid is defined relative to an ideal geostationary satellite viewpoint centered and fixed above the equator. The image pixels will have an angular separation in both the East/West and North/South directions of:
  – 14 microradians (0.5 km) in the 0.64 micron channel,
  – 28 microradians (1 km) in the 0.47, 0.86 and 1.61 um channel,
  – 56 microradians (2 km) in all other channels.
HES

• The Hyperspectral Environmental Suite (HES) will be located on a geostationary platform.
  – Late 2012
  – NOAA operational
  – Currently in formulation phase

• Two modes
  – Full Disk (10km)
  – Severe Weather/Mesoscale (4km)

• HES is an outgrowth of earlier ABS efforts
  – HES includes the functionality of the old Advanced Baseline Sounder (ABS)
Spectral coverage details are not yet fully defined.
Hourly HES Scan Scenario -- Targeted Observations

Local Zenith Angle ~ 62 Degrees

Targeted observations -- look where we need the information
Sample GOES-R 3-hour schedule for the ABI and (1 telescope design) HES

<table>
<thead>
<tr>
<th>Time (UTC)</th>
<th>ABI</th>
<th>HES-Sounder</th>
<th>HES-CW</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:45</td>
<td>FD</td>
<td></td>
<td>10km-CONUS</td>
</tr>
<tr>
<td>12:50</td>
<td>FD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:55</td>
<td>FD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:00</td>
<td>CONUS+MSS</td>
<td>4km-MS</td>
<td>CW area</td>
</tr>
<tr>
<td>13:05</td>
<td>CONUS+MSS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:10</td>
<td>CONUS+MSS</td>
<td>4km-MS</td>
<td>CW area</td>
</tr>
<tr>
<td>13:15</td>
<td>FD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:20</td>
<td>CONUS+MSS</td>
<td>4km-MS</td>
<td>CW area</td>
</tr>
<tr>
<td>13:25</td>
<td>CONUS+MSS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:30</td>
<td>FD</td>
<td></td>
<td>4km-MS</td>
</tr>
<tr>
<td>13:35</td>
<td>CONUS+MSS</td>
<td></td>
<td>CW area</td>
</tr>
<tr>
<td>13:40</td>
<td>CONUS+MSS</td>
<td>4km-MS</td>
<td></td>
</tr>
<tr>
<td>13:45</td>
<td>FD</td>
<td></td>
<td>10km-CONUS</td>
</tr>
<tr>
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<td>FD</td>
<td></td>
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<td>13:55</td>
<td>FD</td>
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<td></td>
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<td>14:25</td>
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<td>4km-MS</td>
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<td>10km-CONUS</td>
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<td></td>
<td>CW area</td>
</tr>
<tr>
<td>15:55</td>
<td>FD</td>
<td></td>
<td>4km-MS</td>
</tr>
<tr>
<td>16:00</td>
<td>CONUS+MSS</td>
<td></td>
<td>Land mode (1200kmx1200km)</td>
</tr>
</tbody>
</table>
Visible image example

- Visible image to show the cloud cover (GOES-East Example).
- What follows is a HES example coverage loop.
HES-Sounding simulation at 10 km

20:45 UTC
HES-Coastal Waters

20:55 UTC
HES-Coastal Waters
HES-Sounding 10 km

21:45 UTC
HES-Coastal Waters

22:15 UTC
What follows represents today’s coverage:
- no IR hyperspectral data;
- no coastal waters task;
- no higher spatial resolution mesoscale task.
Low spectral resolution – Current GOES Sounder  10 km

20:45 UTC
Low spectral resolution – Current GOES Sounder 10 km
Low spectral resolution – Current GOES Sounder  10 km
Real-time, autonomous test on February 5th

From Dan Mandl, NASA
Hyperspectral Data Compression

Co-lead (with Roger Heymann of OSD) a data compression project. Project was begun in January of 2002. Built two data compression teams (CIMSS and CREST) and others. First focused on high spectral resolution data. Beginning ABI data compression.

GOES R series large data volumes at 80-200Mbps exceed ability for low cost distribution. Data compression can reduce data volume and hence allow all or nearly all information to be distributed at low cost.

Research (with AIRS data) has developed new mathematical approaches that far exceed lossless compression ratios from current standards.
Fourth GOES-R Users’ Conference:

- May 1-3, 2006:
  - Location: Broomfield CO
  - Will focus on User Readiness

For more info:
- [http://www.osd.noaa.gov/announcement/index.htm](http://www.osd.noaa.gov/announcement/index.htm)
- **There will be a poster session, abstracts due March 31st.**
• GIFTS longwave signal to noise and focal plane detector operability performance summary from December 2005 thermal vacuum tests performed at Space Dynamics Laboratory in Logan, Utah. In both performance areas GIFTS is exceeding specification.
Summary:

GOES-N/O/P instrument changes
- GOES-N post-launch check-out is upcoming
- better calibration (longer BlackBody looks)
- better resolution of the 13.3 um on GOES-O/P

GOES-N/O/P bus change
- no spring and fall eclipse outages
- reduced Keep-Out-Zone outages
- better calibration (colder detectors)
- better navigation (earth sensor -> star tracker)
<table>
<thead>
<tr>
<th>Band Center (μm)</th>
<th>GOES-6/7</th>
<th>GOES-8/11</th>
<th>GOES-12N</th>
<th>GOES-OP</th>
<th>GOES-R+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible</td>
<td>13.3</td>
<td>12.3</td>
<td>11.2</td>
<td>10.35</td>
<td>9.7</td>
</tr>
<tr>
<td>Near-IR</td>
<td>8.5</td>
<td>7.3</td>
<td>6.2</td>
<td>1.6</td>
<td>2.2</td>
</tr>
<tr>
<td>Infrared</td>
<td>7.3/6.7/7</td>
<td>0.86</td>
<td>1.38</td>
<td>3.9</td>
<td>6.2</td>
</tr>
<tr>
<td>Box size</td>
<td>14 km</td>
<td>8</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Approximate spectral and spatial resolutions of US GOES Imagers.
Summary

The great amount of information from the GOES-R will offer a continuation of current products and services.

These products, based on validated requirements, will cover a wide range of phenomena. This includes applications relating to: weather, ocean, land, climate, and hazards.

The ABI improves over the current GOES Imager the spectral, temporal, spatial and radiometric performance.

The Advanced Baseline Imager (ABI), along with the Hyperspectral Environmental Suite (HES), and the Geostationary Lightning Mapper (GLM) on GOES-R will enable much improved monitoring compared to current capabilities.
More information

• GOES-11 PLT NOAA Tech Memo
• GOES-I/M Databook
• http://www.osd.noaa.gov/GOES/GOES_NQ Booklet.pdf
• GOES-N Databook
AMS ABI BAMS article by Schmit et al. from August 2005

ABI Research Home page:
  • http://cimss.ssec.wisc.edu/goes/abi/

NOAA GOES-R page:
  • https://osd.goes.noaa.gov/

GOES and MODIS Galleries:
  • http://cimss.ssec.wisc.edu/goes/misc/interesting_images.html
  • http://www.ssec.wisc.edu/~gumley/modis_gallery/

ABI Documentation from NASA:
  • http://goespoes.gsfc.nasa.gov/abihome.htm

ABI Simulated Spectral Response functions:
  • ftp://ftp.ssec.wisc.edu/ABI/SRF
Disclaimer

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