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An Overview of the GOES-13 Science Test

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1. INTRODUCTION*

The latest Geostationary Operational Environmental Satellite (GOES), GOES-N, was launched on 24 May 2006, and reached geostationary orbit on 4 June 2006 to become GOES-13. GOES-13 has instruments similar to the instruments on GOES-8/12, but is on a different spacecraft bus (Figure 1). The new bus allows improvements both to navigation and registration, as well as the radiometrics. Current plans call for GOES-13 not to become operational until it would replace either GOES-12 or GOES-11, whichever fails or runs out of fuel first. GOES-12 is currently in the GOES-east position, and GOES-11 is in the GOES-west position.

By supplying data through the eclipse, the GOES-N/O/P system addresses one of the major current Imager limitations which are eclipse and related outages. This is possible due to larger spacecraft batteries. Outages due to Keep Out Zones (KOZ) will be minimized.

There will be radiometric improvements, since the GOES-13 instruments (Imager and Sounder) are less noisy. A colder patch temperature is the main reason. In addition, there is a potential reduction in detector-to-detector striping to be achieved through increasing the Imager scan-mirror dwell time on the blackbody from 0.2 sec to 2 sec.

There will be improvements in both the navigation and registration on GOES-N+. The navigation will be improved due to the new spacecraft bus and the use of star trackers (as opposed to the current method of edge-of-earth sensors). In general, the navigation (at nadir) will go from between 4-6 km with today's Imager to less than 2 km with those on the GOES-N/O/P satellites. Both within-frame and frame-to-frame registration will also be improved.

All these enhancements will be monitored during the NOAA post-launch Science Test. As with previous GOES check-outs, there are several goals for the GOES-13 Science Test. First, the quality of the GOES-13 data will be investigated. This will be accomplished by comparison to data from other satellites or by calculating the signal-to-noise ratio. The second goal will be to generate products from the GOES-13 data stream and compare to those produced from other satellites. These products may include several Imager and Sounder products: visible and shortwave albedo, land skin temperatures, temperature/moisture

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retrievals, total precipitable water, lifted index, cloud-top pressure, atmospheric motion vectors, and sea surface temperatures. The third goal is to investigate the impact of the recent instrument changes. For example, the better navigation, improved calibration and the operation through eclipse periods will be investigated. In addition, rapid-scan imagery of severe weather cases will hopefully be investigated as part of GOES-R Risk Reduction activities.

2. POST LAUNCH TESTING

Similar to previous GOES checkouts following launch, there will be a pre-operational period, during which the instruments are run in various routine schedules to provide radiance measurements to be validated, as well as to generate products from the radiances. These post-launch check-out periods are essential to the subsequent operational use of the satellite assets. A number of groups within NOAA NESDIS and its Cooperative Institutes take part in the Post-Launch Tests (PLT).

The possible Science Tests and schedule are not entirely firmed up at this time, nor may be until the GOES-13 Science Tests begin. This paper outlines the proposed Science Tests that will be accomplished. The Science Tests follow the engineering tests that must take place first. This means that the Science Tests do not occur until several months after launch of GOES-13. Since the engineering tests are well underway, the Science Tests will occur in December 2006. as in Figure 2. That means that no results from the December tests are available at this writing, but some preliminary analysis of GOES-13 imagery and data have already taken place and are presented below.

The first Science Test results will be available in poster form at the Satellite Conference. The results will also be presented in a *NOAA NESDIS Technical Report*, very similar to the reports produced for GOES-11 (Daniels et al. 2001) and GOES-12 (Hillger et al. 2003, and Figure 3).

2.1 Proposed Tests

The satellite operations for the Science Tests will include choices of image sectors and the timing of those sectors. Choices will range from operational-type schedules to super-rapid-interval (rapid-scan) imagery that might otherwise not be available during normal operations of the satellite.

Table 1 is the latest version of the proposed Science Tests. To limit the possible choices that may occur, the Imager and Sounder tests are linked. There are eight (8) different proposed Science Tests at this time, with other tests likely. The last column of the table gives the main purpose for each of the proposed tests.

The proposed tests will be invoked on a daily basis, depending on the occurrence of various weather events. The default schedule is the emulation of current GOES operations, either GOES-east or GOES-west, with some time for each. Those emulations allow products generated from GOES-13 to be compared to products from current GOES.

The schedules for more rapid collection of data are for severe weather and other special purposes, such as comparison of imagery to data from lightning detection networks.

3. PREPARATIONS

In preparation for GOES-N, the detector-averaged spectral coverage of the four GOES-N Imager infrared bands and the eighteen GOES-N Sounder bands have been plotted in Figure 4 along with the earth-emitted spectra calculated from the U.S. Standard Atmosphere. These are very similar to the GOES-12 spectral bands, where the Imager has a 13.3 μm band. The GOES-N Imager and Sounder IR-band weighting functions are plotted in Figure 5 top and bottom, respectively.

4. PRELIMINARY RESULTS

Because GOES-13 data have been sent to ground stations in GVAR (GOES Variable) format through most of the engineering tests, some preliminary analysis of that data have already taken place.

On 22 June 2006 the first GOES-13 full-disk visible (0.7 µm) images were captured at 1730 UTC. Figure 6 shows the 1801 UTC visible image captured at CIRA's satellite ground station. The first Sounder visible images were also captured on that date as well, but were not calibrated and appeared quite dark on first viewing.

On 12 July 2006 the first preliminary, un-calibrated GOES-13 full-disk infrared images were captured at 1820 UTC. Some issues were noted with those images, which were later corrected. Then, on 20 July the first GOES-13 calibrated full-disk infrared images were captured at 1800 UTC. The band-4 (10.7 µm) longwave window band image is shown in Figure 7.

Figure 8 shows a composite of the GOES-13 Sounder images for all 19 bands for a sector over the western U.S. The images in all bands compared well, in a qualitative sense, with those from the GOES-11 Sounder (not shown). The GOES-13 radiance images are also visually less noisy than either GOES-11 or GOES-10 Sounder data. For example, note the clean band-15 panel. These data were captured at the SSEC Data Center.

With GOES-13 data continuing to arrive, it was possible to do a preliminary analysis of the noise level of the data. Both GOES-13 and current operational GOES data were analyzed for the same dates and time. The results are shown in Figure 9, which is a comparison of GOES-13 noise to current GOES. The improvements are given as noise level ratios, with the results ranging from an almost even comparison for band-3 (6.5 µm), to an improvement by a factor of 2 for band-4 (10.7 µm), by a factor of 2.5 for band-2 (3.9 µm), and by a factor of 3 for band-6 (13.3 µm).

Preliminary estimates of detector-to-detector striping in the GOES-13 infrared images were also made. Results of the striping analysis for GOES-13 were comparable to those from GOES-12 (not shown).

In September, GOES-13 went into eclipse operations, when the satellite passed into the shadow of the earth. Previous GOES were not able to collect imagery in these circumstances. However GOES-13 has larger batteries that allow it to collect imagery through eclipse conditions.

Figure 10 contains sequences of images from GOES-13 and from GOES-12, showing the gaps that exist in the images from each satellite. Whereas there is one large gap, of about 3 hours, in the current GOES imagery, as shown by the GOES-12 example on top, there are two shorter gaps in the GOES-13 imagery as shown in the bottom part of the figure. Those two gaps are caused by keep out zones (KOZ), when there is potential for contamination of the images from the sun being viewed on either side of the earth.

An example of solar contamination in a GOES-13 image collected in an otherwise KOZ is shown in Figure 11. To avoid this possibility, a smaller/reduced KOZ is suggested, since the radiation affects some areas/bands only. It's possible that imagery can be collected from portions of the earth that are away from the side of the earth where the sun may be found.

Finally, Figure 12 shows a preliminary GOES-13 and GOES-12 Sounder cloud-top pressure comparison from 6 October 2006.

5. SUMMARY

The GOES-13 NOAA Science Tests will take place starting 4 December 2006, and last for 3 weeks. Some of the results of those tests, as well as the preliminary analyses that are shown here, will be available in poster form at this conference. The test results, which are the combined efforts of number of groups within NOAA NESDIS and its Cooperative Institutes, will also be distributed as a new *NOAA NESDIS Technical Report* that should become available about 6 months after the conclusion of the Science Tests.

The NOAA Science Post Launch Test (PLT) web site (http://rammb.cira.colostate.edu/projects/goes_n/) continues to be updated as new Science Test results are obtained.

ACKNOWLEDGEMENTS

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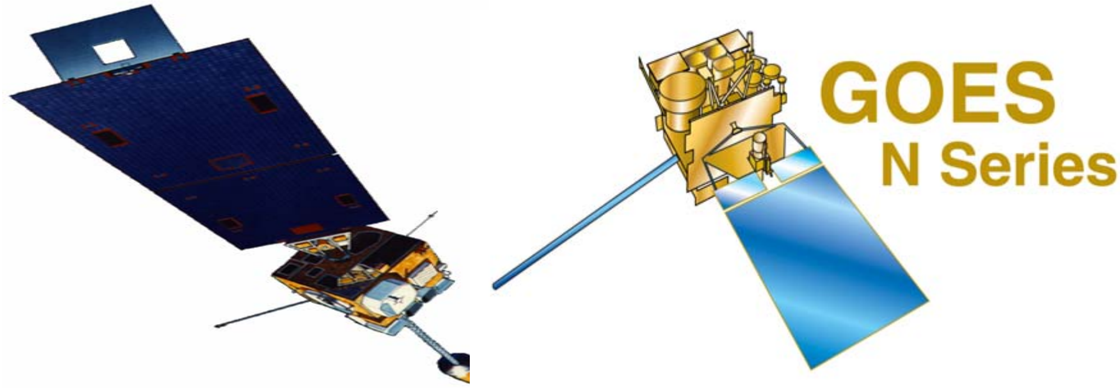
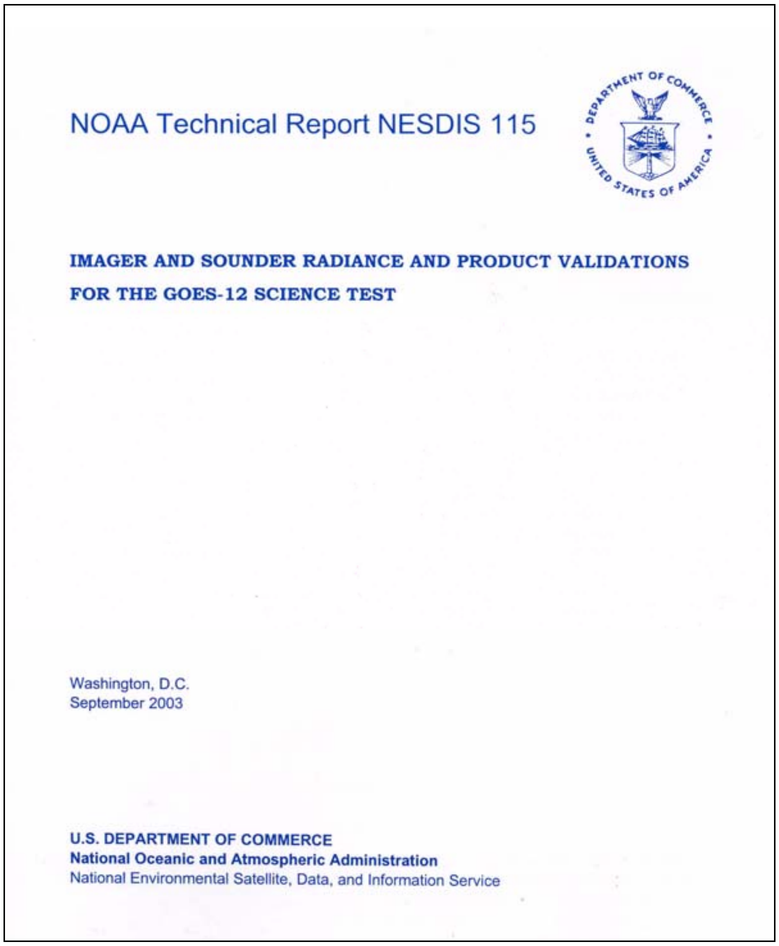


Figure 1: GOES-8/12 (left) and GOES-N (right) spacecraft. (Images courtesy of NASA.)

December

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1/335 Steady-state Normal Mode ops & INR recovery	2/336 Steady-state Normal Mode ops & INR recovery
3/337 Steady-state Normal Mode ops & INR recovery	4/338 NOAA Science Testing	5/339 NOAA Science Testing	6/340 NOAA Science Testing	7/341 NOAA Science Testing	8/342 NOAA Science Testing **GOES-13 (OAR) Operational Acceptance Review** Operations handover to NOAA	9/343 NOAA Science Testing
10/344 NOAA Science Testing	11/345 NOAA Science Testing	12/346 NOAA Science Testing	13/347 NOAA Science Testing	14/348 NOAA Science Testing	15/349 NOAA Science Testing	16/350 NOAA Science Testing
17/351 NOAA Science Testing	18/352 NOAA Science Testing	19/353 NOAA Science Testing	20/354 NOAA Science Testing	21/355 NOAA Science Testing	22/356 NOAA Science Testing	23/357 NOAA Science Testing
24/358 NOAA Science Testing	25/359 Long-term storage mode entry (start long term storage mode trending & characterization)	26/360	27/361	28/362	29/363	30/364
31/365						

Figure 2: Current GOES-13 NOAA Science Test Schedule, starting 4 December 2006 and occupying three weeks.



NOAA Technical Report NESDIS 115

IMAGER AND SOUNDER RADIANCE AND PRODUCT VALIDATIONS FOR THE GOES-12 SCIENCE TEST

Washington, D.C.
September 2003

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Figure 3: Cover of *NOAA Technical Report NESDIS 115*: Imager and Sounder Radiance and Product Validations for the GOES-12 Science Test

Table 1: Suggested NOAA Science Tests for the GOES-13 Imager and Sounder

Schedules will change daily at ~1800 UTC (unless under special circumstances) and will run for 24 hours, except on weekends when the same schedule will be run all weekend (2 days, from Friday afternoon thru Monday morning).

Test Schedule	Imager	Sounder	Purpose
1	Emulation of GOES-east operations	Emulation of GOES-east operations	Radiance and product comparisons
2	Emulation of GOES-west operations	Emulation of GOES-west operations	Radiance and product comparisons
3	Continuous 5 minute (conus sector)	26-minute sector every 30 minutes (conus sector)	Test navigation, ABI-like (temporal) CONUS scans
4	Continuous 1 minute (with center point specified for storm analysis)[1]	26-minute sector every 30 minutes (with center point same as Imager)	Test navigation, ABI-like (temporal) mesoscale scans
5	Continuous 30 second (with center point over either Huntsville or DC area)[2]	26-minute sector every 30 minutes (with center same as Imager)	To coordinate with lightning detection arrays in Huntsville and DC areas
6	Continuous 30-min Full Disk (including off-earth measurements)	Sectors on both east and west limbs every hour (including off-earth measurements.)[3]	Imagery, noise, fires, etc.
7	Capture moon off edge of earth (when possible) for calibration purposes	Emulation of GOES-east operations	Test ABI lunar calibration concepts
8	Emulation of 2 km ABI thru spatial over-sampling (Continuous 19 minute for same sector per specific line-shifted scan strategy)	Emulation of GOES-east operations	ABI higher-resolution product development

[1] The 30 and 60 second scans may need a center point update later in the day.

[2] Including the Hazardous Weather Testbed in North Alabama (centered at Huntsville)

[3] Similar to previous GOES Sounder scans during the check-outs: http://cimss.ssec.wisc.edu/goes/g11_report/GOES11_SNDR_NOISE.GIF

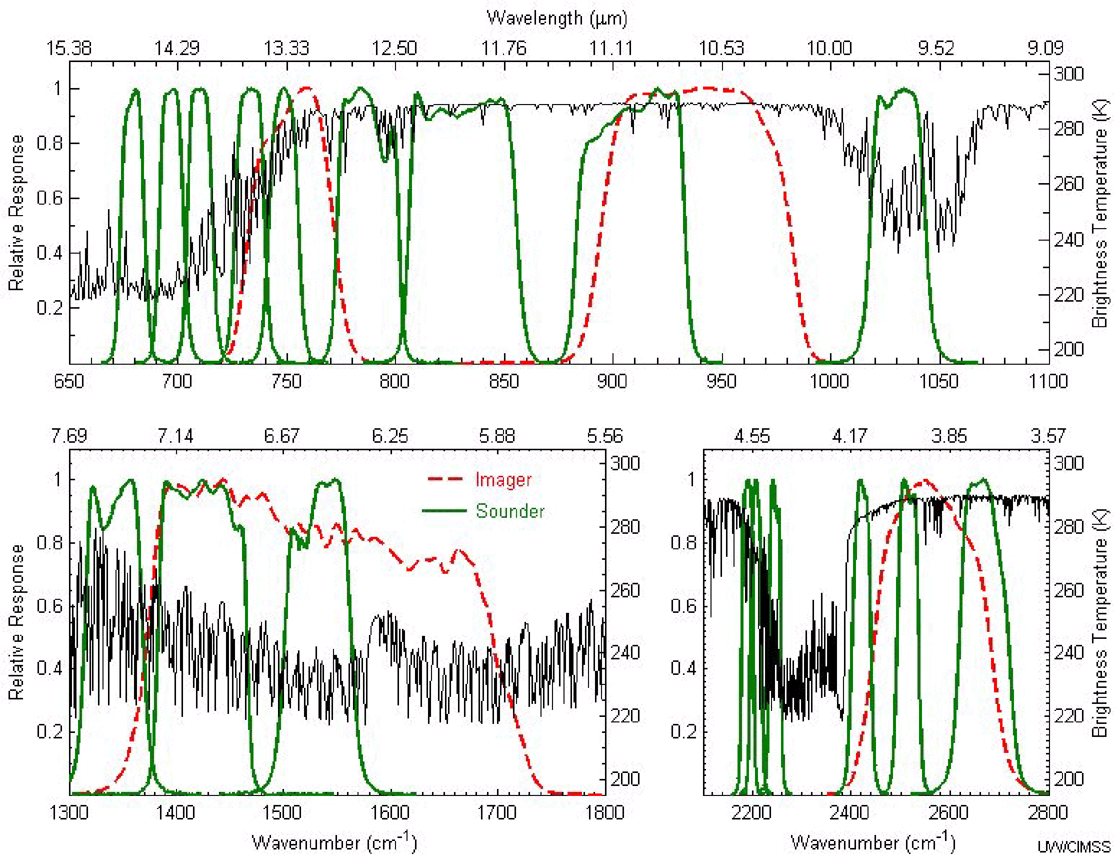
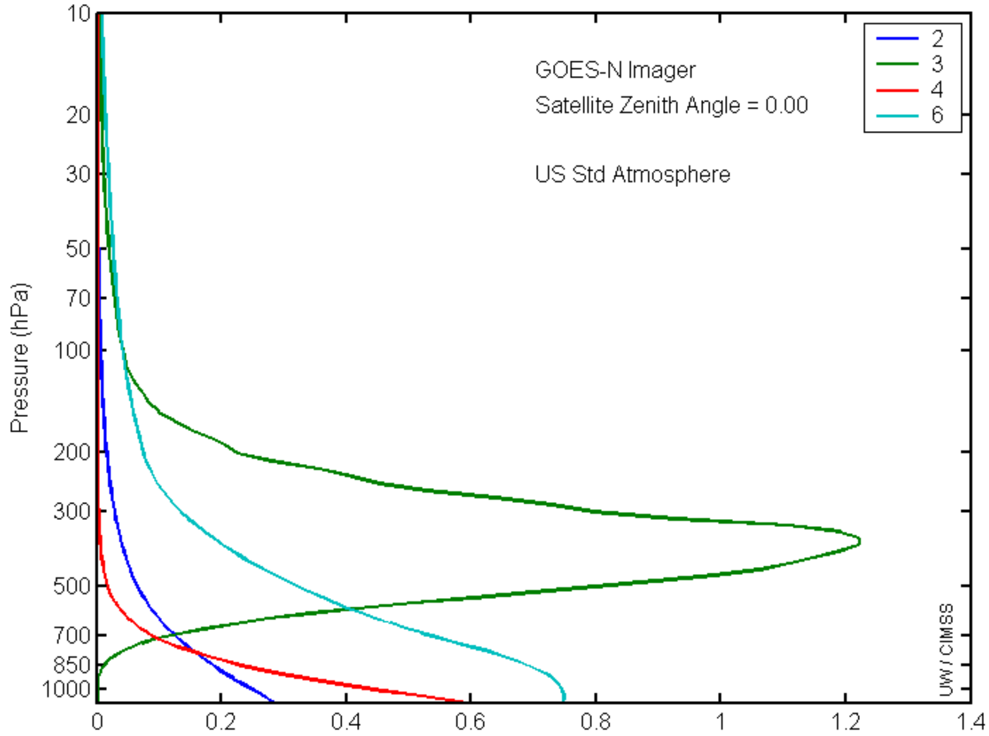


Figure 4: The spectral coverage of the four GOES-N Imager infrared bands (dashed-red) and the eighteen GOES-N Sounder bands (solid-green) plotted with the earth-emitted spectra calculated from the U.S. Standard Atmosphere. (Figure courtesy of Mat Gunshor/CIMSS.)



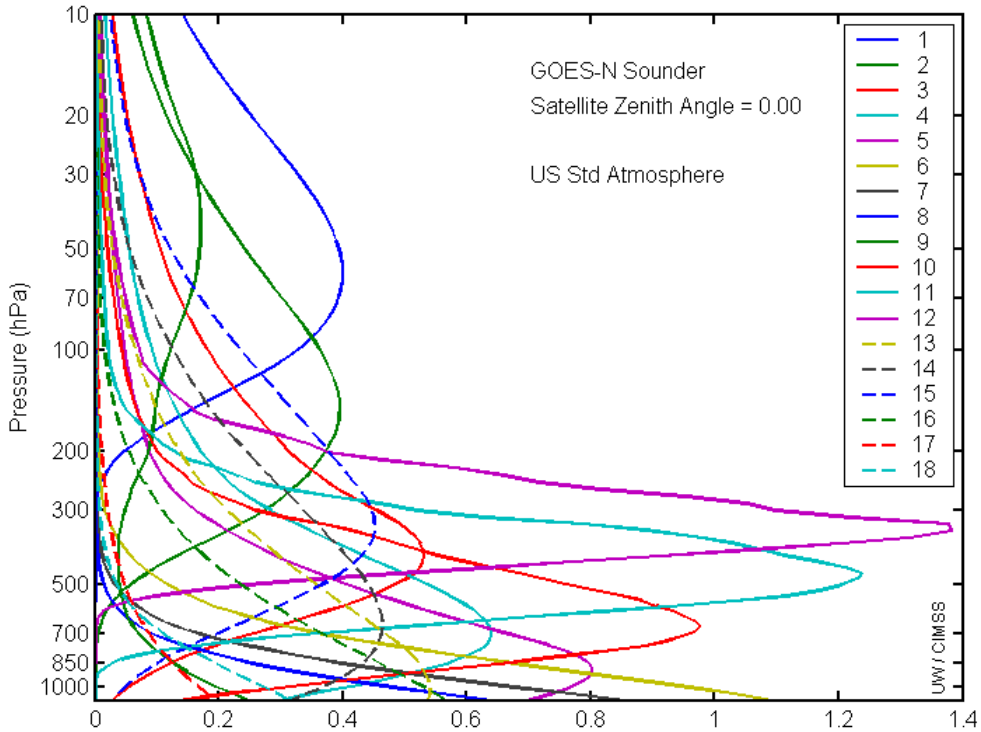


Figure 5: GOES-N Imager (top) and Sounder (bottom) IR-band weighting functions. (Figures courtesy of Mat Gunshor/CIMSS.)

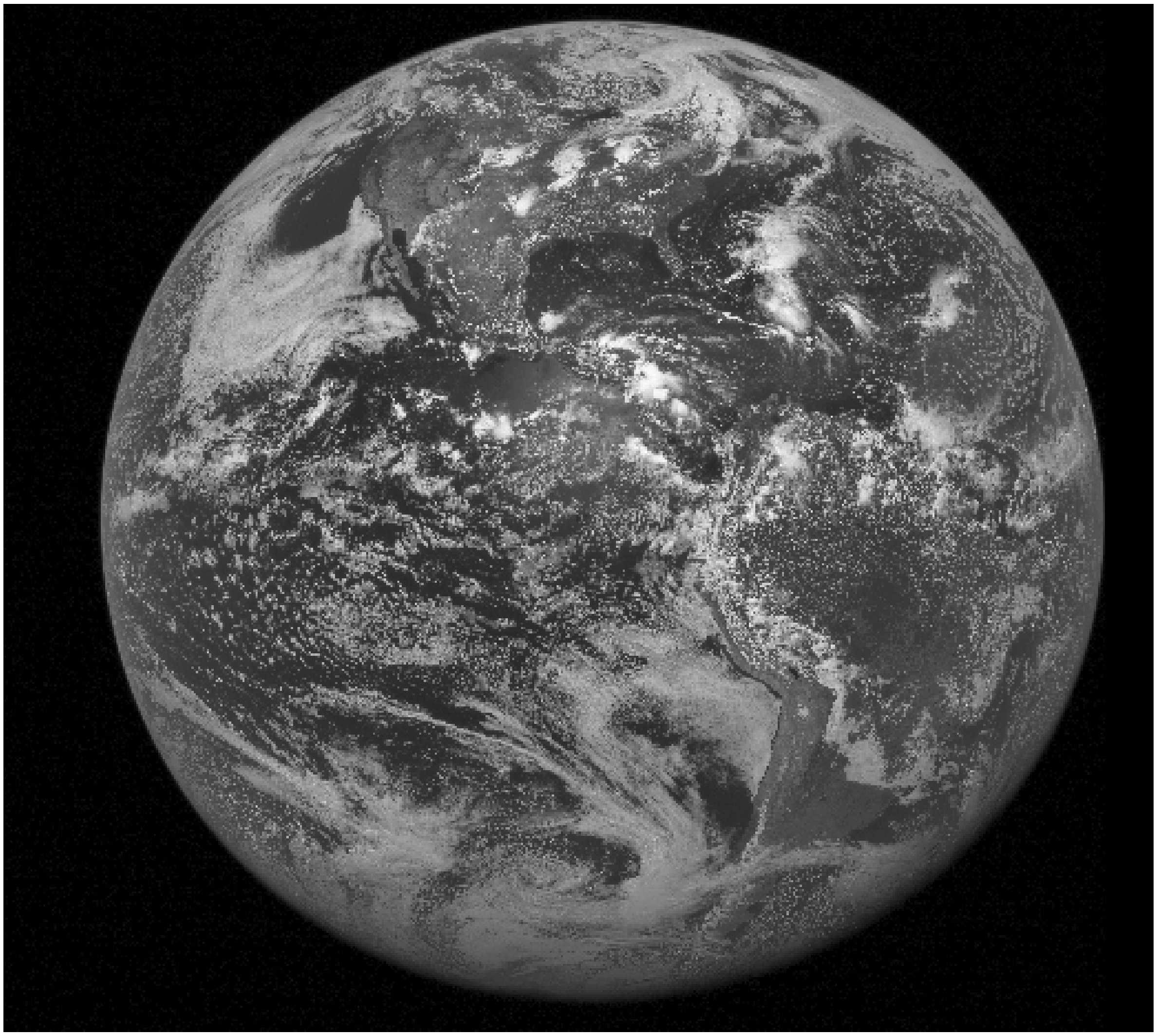


Figure 6: GOES-13 visible (0.7 µm) image at 1801 UTC on 22 June 2006, the first image captured at CIRA's satellite ground station.

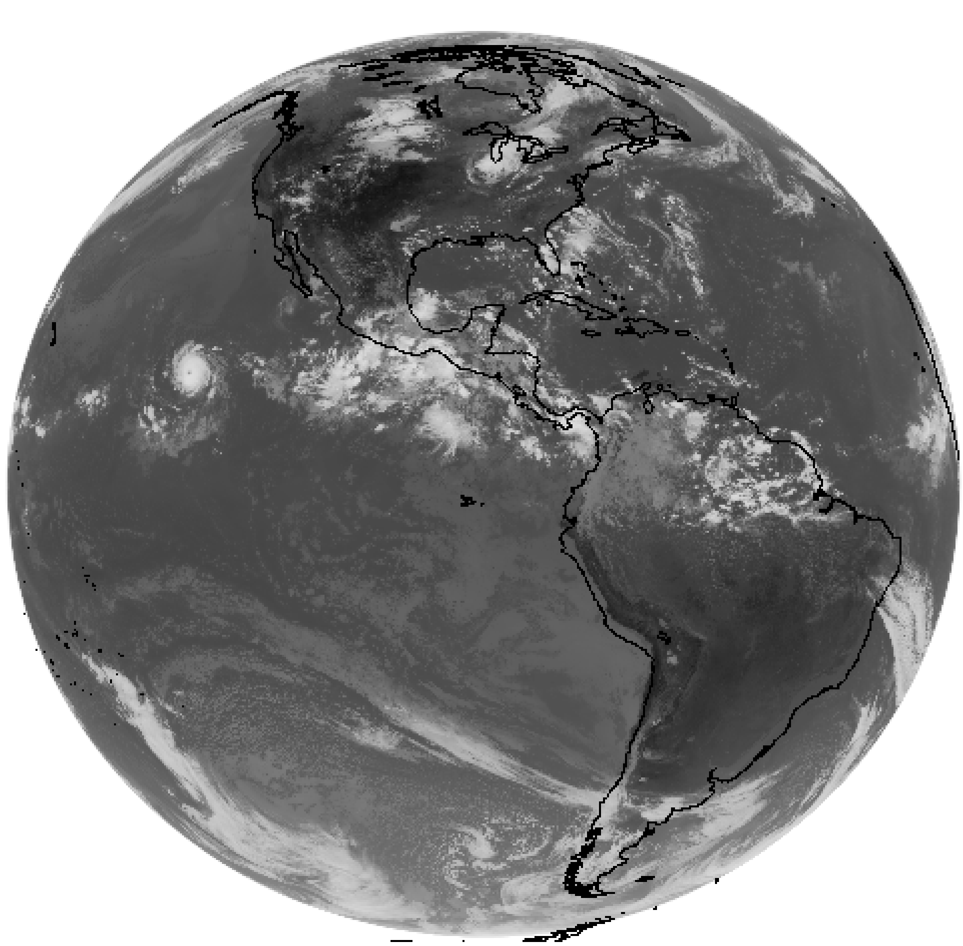


Figure 7: GOES-13 band-4 (10.7 µm) longwave window image at 1800 UTC on 20 July 2006.

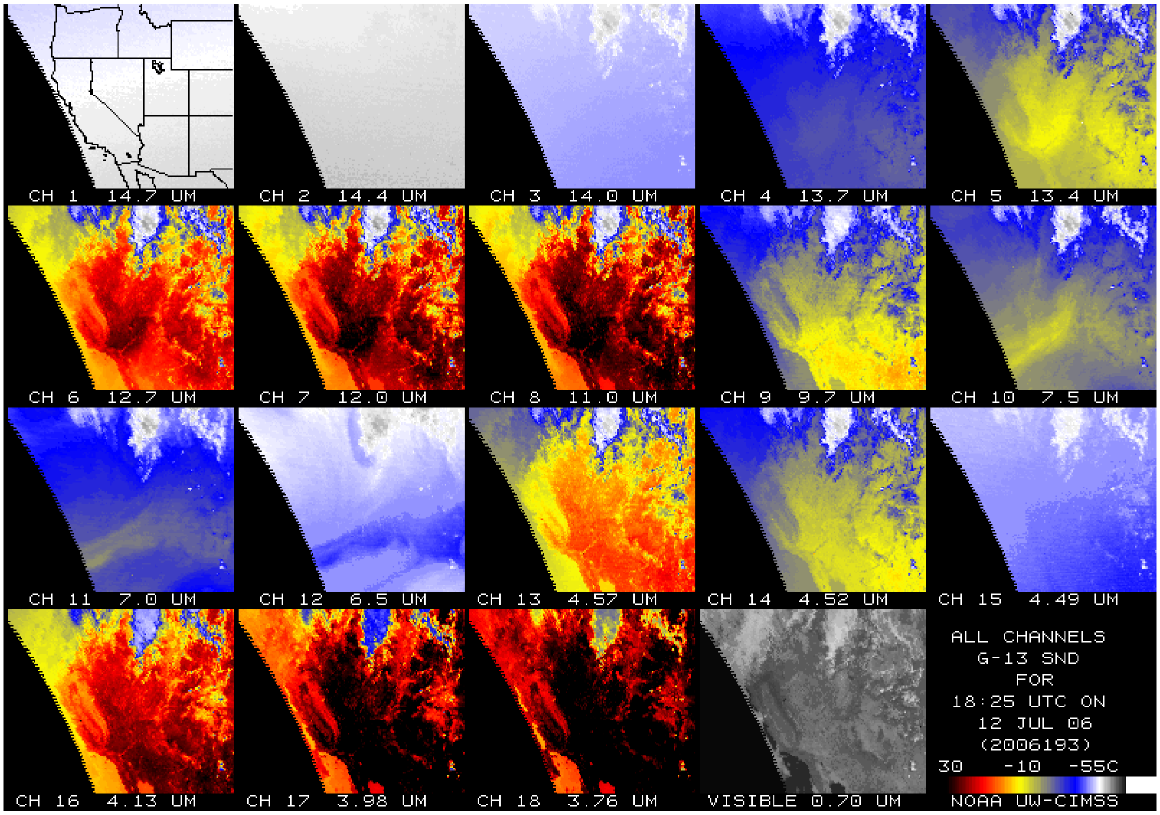


Figure 8: Composite of the GOES-13 Sounder images for all 19 bands for a sector over the western U.S. These data were ingested by the SSEC Data Center.

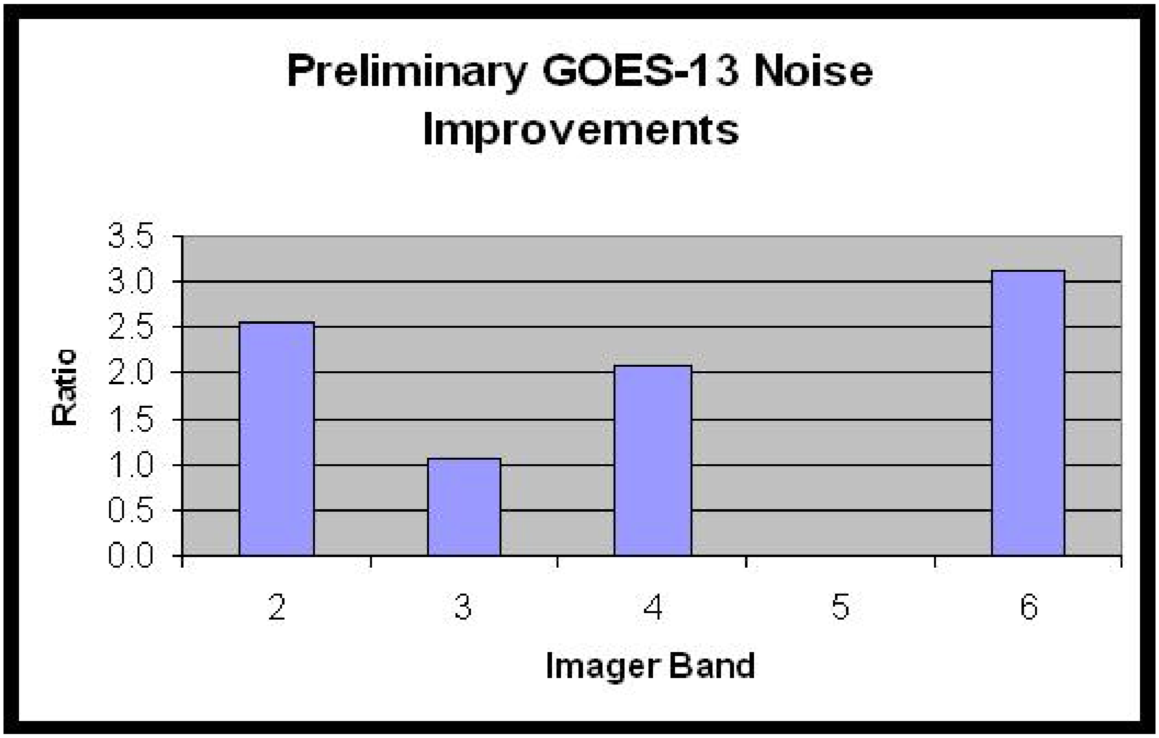


Figure 9: First estimates of noise for the GOES-13 Imager, as compared to the operational GOES-12 Imager.

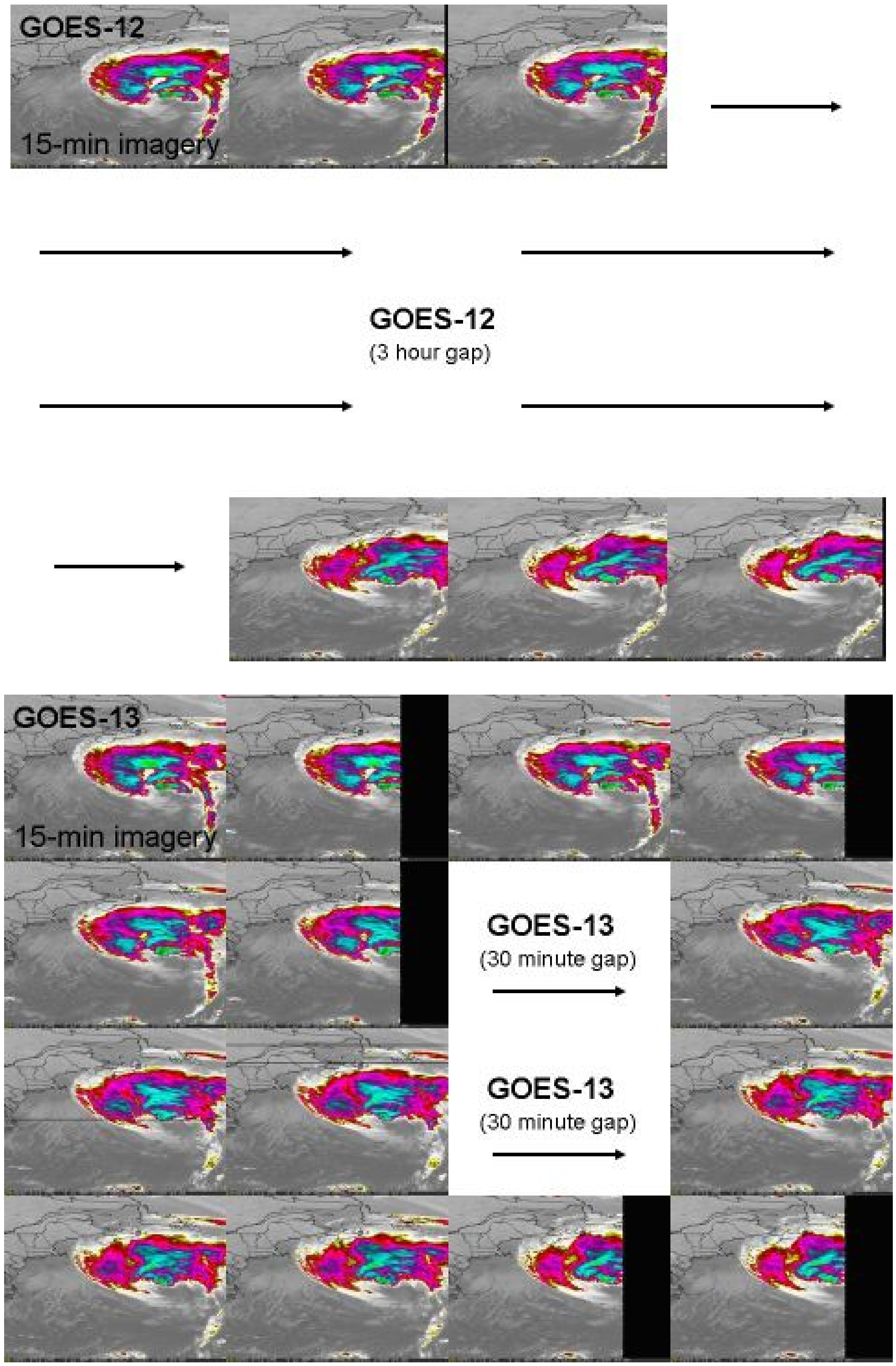


Figure 10: Sequences of images comparing GOES-13 to GOES-12 through eclipse. Rather than one long gap while the sun is behind the earth, there are two gaps when the sun is within view on each side of the earth.

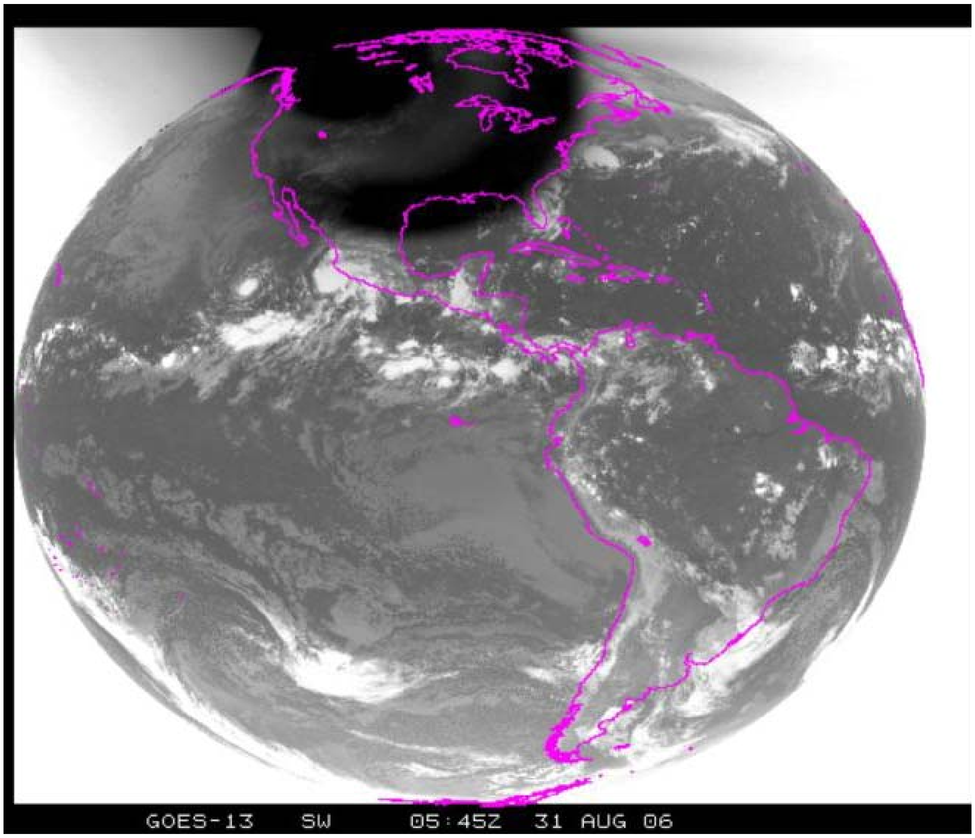


Figure 11: An example of stray solar radiation from the sun next to the earth just before the "eclipse" of GOES-13.

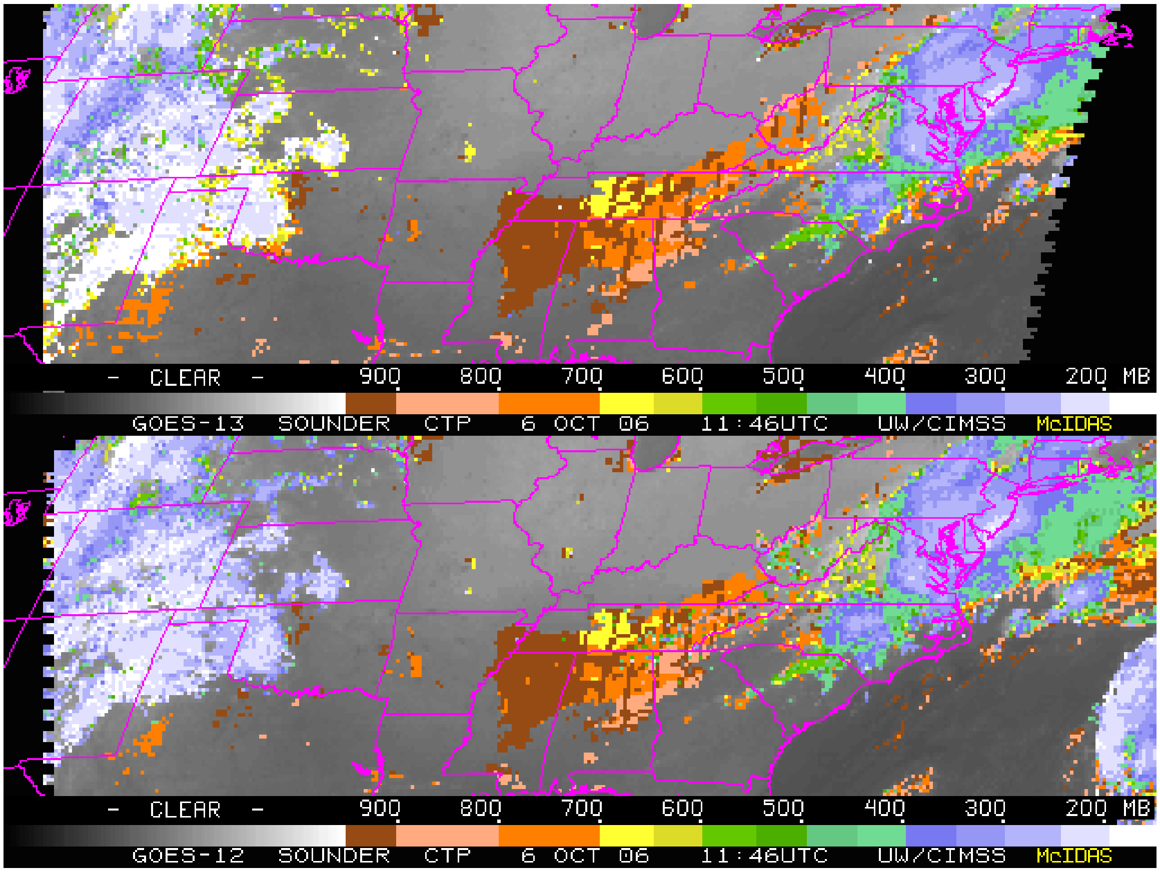


Figure 12: Preliminary comparison of GOES-13 (top) and GOES-12 (bottom) Sounder cloud-top pressure images. The images have been remapped into a common GOES-12 projection. (Figure courtesy of Tony Schreiner/CIMSS)