P3.51

Validation of GOES-11 Data

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1. Introduction

After successful launch of the 11'th Geostationary Operational Environmental Satellite (GOES-11, Menzel and Purdom, 1994) and the engineering check-out period, the National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) conducted a GOES-11 Science Test from June 30 to August 13, 2000. At the Cooperative Institute for Meteorological Satellite Studies (CIMSS) and Advanced Satellite Products Team (ASPT), there were two goals for the GOES-11 science test. One was to investigate the quality of the GOES-11 data, the results of which are summarized in this poster. The other was to generate GOES-11 products (temperature and moisture profiles, total precipitable water, lifted index, cloud-top pressure, satellite-derived winds, sea surface temperature, and biomass burning) and compare these products to those from other satellites. These results, as well as more details of the first goal, are reported by Daniels and Schmit (2001).

2. Instrument Noise

2.1. Sounder

Special GOES-11 Sounder scans of space allowed the determination of noise values by calculating the scatter of radiance when looking at uniform space. Results for all 18 infrared bands of GOES-11 Sounder, taken at 23:46 UTC of July 8, 2000, is presented in Fig. 1. The noise values are generally within specification and lower than those from GOES-8. These noise values have also been monitored for a 24-hour period (between July 7-8, 2000) to confirm that the noise has little diurnal change.

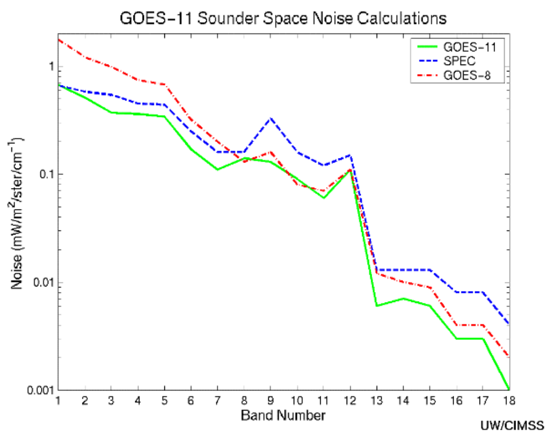

Figure. 1: The noise values of 18 infrared bands of GOES-11 Sounder.

2.2. Imager

Imager noise has been determined in the same way and reported in Table 1. These noise values were once monitored every 15 minutes for a period of 3 hours and were found to vary less than 0.01 to 0.02K. Additionally, they were found to be well within specification and comparable to previous GOES (personal communication, Donald W. Hillger).

Table 1: The noise values of the infrared channels of GOES-11 Imager in terms of brightness temperatures (K). The counterpart values from previous GOES and the specified NEdT values (SPEC) are also listed. The reference temperature is 230K for Band 3 and 300K for other bands.

Band	SPEC	G11	G10	G09	G08
2 (3.9µm)	1.40	0.13	0.17	0.08	0.16
3 (6.7µm)	1.00	0.21	0.09	0.15	0.27
4 (11µm)	0.35	0.07	0.20	0.07	0.12
5 (12µm)	0.35	0.18	0.24	0.14	0.20

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3. Imager-to-Imager Comparison

Imager-related comparisons are primarily based on GOES-11 Imager data collected every half hour between 20N-40N, from 00 UTC July 21 to 19 UTC July 24, 2000. The latitude range was chosen to cover both land and sea. To minimize the difference due to view angle, the longitude was limited to 88W-92W and 118W-122W. Corresponding GOES-11 Sounder and GOES-8/10 Imager data were also collected. Weinreb et al. 1997 discusses the calibration methods.

3.1. Visible

Due to the lack of a visible on-board calibration source, visible channels are not absolutely calibrated after launch, hence measurements in these channels are expected to be different. Figure 2 suggests that the sensitivity of GOES-8 (10) visible channel is about 60% (83%) of that of GOES-11.

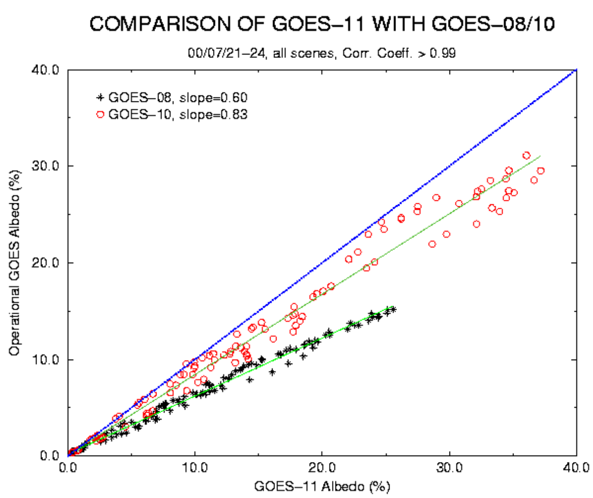

Figure 2: Scatter plot of GOES-8 (*) and GOES-10 (°) albedo as a function of GOES-11 albedo. Albedo is the arithmetic mean of individual pixel albedo within the area of comparison. A diagonal line is shown for reference. The lines of least-squares regression are also shown, whose slopes indicate the sensitivity of the operational GOES relative to GOES-11.

Fig. 2 offers an opportunity to assess the degradation rate of the visible channels of GOES-8/10. In April 1998, a similar comparison revealed that the sensitivity of GOES-8 was about 70% of that of GOES-10 (GOES-K Report). In July 2000, the sensitivity of GOES-8 was about 0.60/0.83=72% of that of GOES-10. This indicates that, in the past two years, the rate of degradation for the two operational satellites have been similar (GOES-10 slightly faster). However, had the degradation rate been constant for each satellite since their launch times, the degradation rate for GOES-8 would be larger:

G08 (6.3 yrs in space): 6.3x=(1-60%) => x=6.3%/yr
G10 (3.3 yrs in space): 3.3x=(1-83%) => x=5.2%/yr

Typically, though, the sensitivity of visible channels experiences a rapid drop shortly after launch, followed by relatively constant degradation. Also note that GOES-10 was in a stowed position for more than a year in space, during which time there probably was little degradation. Taking these into consideration, the rate of degradation can be estimated as following:

G08 (6.3 years in service): x + 6.3y = (1-60%)
G10 (2.1 years in service): x + 2.1y = (1-83%)

which leads to a one-time post-launch drop of x=5.5% and annual degradation of y=5.5%/yr. According to these results, GOES-10 in the past 2.3 years should have lost 5.5+2.1*5.5=17% of its sensitivity (two months in stowed position), whereas GOES-8 should have lost only 2.3*5.5=12.7% of its sensitivity during the same period. This agrees with early observation that GOES-10 has been degrading faster than GOES-8 since April 1998. Also, the sensitivity of GOES-8 in July 2000 would be 70%*(1-12.7%)=61%, close to the 60% obtained by direct comparison.

Knapp and Vonder Haar (2000, referred to as KH hereafter) recently found a 7.6% one-time post-launch drop followed by a 5.6% annual degradation for the visible band of GOES-8 Imager. These results are in reasonable agreement with other studies including ours. Such agreement is remarkable for several reasons. First, their approach of using a radiative transfer model is theoretical in nature, whereas our approach is largely empirical. The consistency of the results from these two very different approaches lends credit to both.

Second, KH restricted their study to the dark ocean scene at local noon. Other studies, for example Greenwald et al (1997), focused on highly reflecting surfaces such as clouds. In our case, scenes for a wide range of illuminations and albedo were examined. Despite of these differences in target selection, the results are similar. In particular, Fig. 2 shows that a linear least-squares regression is a good fit for comparisons of dark and bright scenes. These reconfirm a conclusion by KH that the degradation is relatively uniform throughout the dynamic range of instrument response.

Finally, KH were focused on GOES-8 only, whereas we studied the degradation of both GOES-8/10. Our approach has implicitly assumed that: (1) the sensitivity of the visible channel of GOES-8/10/11 Imagers are the same when first operated on orbit; and (2) the degradation pattern are the same for both GOES-8/10, i.e., a post-launch drop and annual degradation at the same rate. The agreement between the two studies suggests that these assumptions may be valid.

3.2. Infrared

The differences in brightness temperature between GOES-11 and GOES-8/10 for the Imager infrared bands are summarized in Table 2. The infrared bands are expected to be well calibrated without systematic bias among the Imagers, although an absolute calibration difference of 1K is allowed. Table 2 shows that the brightness temperature measured by GOES-11 is about 1K cooler (0.8K warmer) than that by GOES-8/10 for the 3.9 µm (6.7 µm) band. These differences are larger and more persistent than expected. For the split-window bands (11 and 12 µm), the differences are smaller and more variable.

Table 2: Mean difference (K) between GOES-11 Imager and GOES-8/10 Imagers and GOES-11 Sounder for the IR bands.

Band	G11-G08	G11-G10	Img-Snd
2 (3.9µm)	-0.98	-1.43	-1.67
3 (6.7µm)	+0.80	+0.75	+1.33
4 (11µm)	+0.75	+0.45	+0.71
5 (12µm)	-0.01	-0.70	-0.44

In addition to the mean difference, the standard deviations of the differences were analyzed but no significant patterns emerged. The area has also been divided into land and ocean, again the differences are similar to those of the whole. To examine whether the overall difference is caused by a few isolated events, the time series of the differences is studied, which concluded that the differences are fairly steady throughout the 5-day period. The differences do exhibit some diurnal variations, though, which are believed to be caused by a combination of differential heating and viewing geometry of the target and GOES-11 calibration. Finally, to investigate whether the differences are caused by a poor calibration at certain temperatures, for example the very cold/hot scenes, histograms of the differences are examined, which showed that the differences are persistent throughout the range of temperature.

4. Sounder-to-Sounder Comparison

4.1. Visible

On Friday 30 June (14:42 UTC), GOES-11 Sounder normalization software was installed by SOCC, leading to less striping in the Sounder visible imagery (Fig. 3).

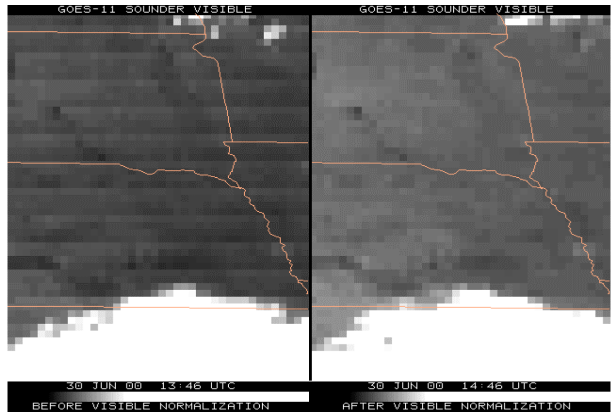

Figure 3: Before (left) and after (right) the application of GOES-11 Sounder visible normalization.

4.2. Infrared

Fig. 4 shows the Sounder brightness temperature differences for all 18 infrared bands between GOES-11 and GOES-8/10 during a nighttime period. Only measurements of similar view angles were compared. The GOES-11 Sounder brightness temperatures are in better agreement with those from GOES-10 than from GOES-8. The operational spectral response functions for both GOES-8 and GOES-10 Sounders were used. The largest differences are for Sounder bands on the edges of absorption features (e.g. 3, 13 and 15).

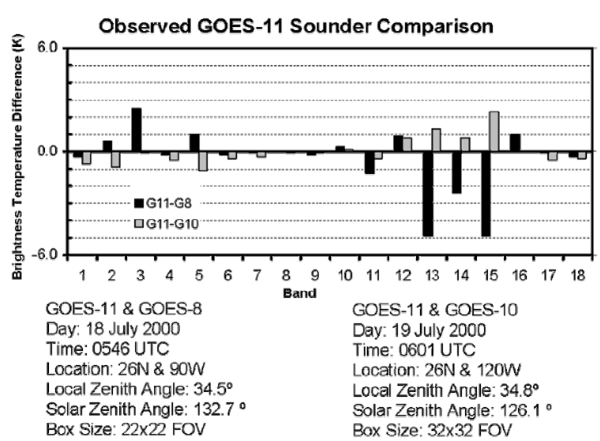

Figure 4: Sounder brightness Temperature differences between GOES-11 and GOES-8/10.

5. Imager-to-Sounder Comparison

Fig. 5 is a comparison of GOES-11 Imager with Sounder. The Imager Band 1 is compared with Sounder band 19; Imager band 4 is compared with Sounder band 8; and Imager band 5 is compared with Sounder band 7. Since there is no Sounder band corresponding closely to the other two Imager bands, Imager band 2 is compared with the mean of Sounder bands 17 and 18 and Imager band 3 is compared with the mean of Sounder bands 11 and 12.

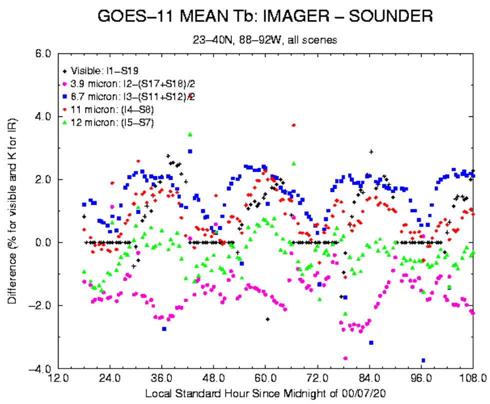

Figure 5: Differences of GOES-11 Imager and Sounder brightness temperatures plotted as a function of time.

The mean differences of Imager-Sounder during this 4-day period have been reported earlier in Table 2. The overall differences for the first three bands could be due to spectral response differences, and the differences for the last two bands are reasonably small. It is interesting, however, that the Imager-Sounder differences are quite similar to the Imager-Imager differences, which could result from a less well calibrated GOES-11 Imager compared with a well-calibrated GOES-11 Sounder and GOES-08/10 Imagers. Fig. 5 also depicts a rather obvious diurnal variation of the differences, particularly for the 6.7 and 11 μm bands. The minima occurred close to the satellite midnight, which is one hour later than the local midnight. This is more likely caused by calibration uncertainties.

6. Summary

The NOAA Science checkout phase of the GOES post-launch testing offers an opportunity to compare various satellite radiances and products. GOES-11 imager and sounder data were taken during the six-week NOAA science test, when the satellite was stationed at 105W. The imager-to-imager radiance comparisons show fair agreement, although the GOES-11 imager shows the greatest differences. The visible sensors of GOES-8/10 were shown to degrade 5.5% shortly after launch, followed by a steady annual rate of degradation of 5.5%. These results are in close agreement with previous studies. Overall, the sounder data from GOES-11 are slightly better than those from GOES-8. The GOES-11 data exhibited less noise and less striping.

7. References

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