Investigating The Effects of Detector-Averaged SRFs

NOAA Satellite Science Week , Kansas City, MO, May 2012

Mat Gunshor, Szuchia Moeller -- CIMSS/SSEC UW-Madison ~ Tim Schmit -- STAR/NESDIS NOAA*

*matg@ssec.wisc.edu

STAR Center for Satellite Applications and Research
formerly ORA — Office of Research and Applications

Introduction and Background

- The spectral response of an instrument varies from detector to detector
- For current GOES individual detector SRFs are averaged for product generation and conversion to brightness temperature
  - This works if detectors are very similar such that their differences are smaller than the measurement noise.
  - Using detector-averaged SRFs in forward model calculations has been standard practice for the current GOES series.
  - McIDAS-X uses individual detector SRFs for brightness temperature calculations for the current Imager when detector information is available; individual detector level brightness temperatures are then used in the display of imagery. Averaged SRFs are used for the Sounder.
- For ABI it is expected that an averaged SRF will be used for radiance to brightness temperature conversions;
  - This could affect imagery, products, and forward model calculations.
  - Due to remapping to the Fixed Grid Format (FGF), the use of averaged SRFs may be unavoidable (going from detectors to pixels).
  - Current GOES Sounder has 4 detectors per band and Imager generally has 2 (except when there was just 1).
  - ABI will have 100s of detectors per band.
- As technology has evolved, instruments have become less noisy
  - Detector-Averaged vs Individual Detector SRFs more critical.

Question: How large do detector to detector differences have to be before they matter?

ABI Spectral Characteristics

Future GOES imager (ABI) band	Wavelength range (µm)	Central wavelength (µm)	Nominal subsatellite IGFOV (km)	Sample use
1	0.45–0.49	0.47	1	Daytime aerosol over land, coastal water mapping
2	0.59–0.69	0.64	0.5	Daytime clouds fog, insolation, winds
3	0.846–0.885	0.865	1	Daytime vegetation/burn scar and aerosol over water, winds
4	1.371–1.386	1.378	2	Daytime cirrus cloud
5	1.58–1.64	1.61	1	Daytime cloud-top phase and particle size, snow
6	2.225–2.275	2.25	2	Daytime land/cloud properties, particle size, vegetation, snow
7	3.80–4.00	3.90	2	Surface and cloud, fog at night, fire, winds
8	5.77–6.6	6.19	2	High-level atmospheric water vapor, winds, rainfall
9	6.75–7.15	6.95	2	Midlevel atmospheric water vapor, winds, rainfall
10	7.24–7.44	7.34	2	Lower-level water vapor, winds, and SO_2
11	8.3–8.7	8.5	2	Total water for stability, cloud phase, dust, SO_2, rainfall
12	9.42–9.8	9.61	2	Total ozone, turbulence, and winds
13	10.1–10.6	10.35	2	Surface and cloud
14	10.8–11.6	11.2	2	Imagery, SST, clouds, rainfall
15	11.8–12.8	12.3	2	Total water, ash, and SST
16	13.0–13.6	13.3	2	Air temperature, cloud heights and amounts

Current GOES (I-M) Sounder NEdN

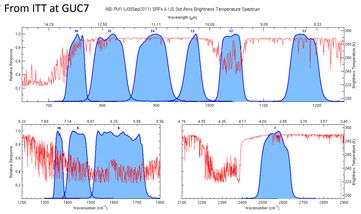
Channel	Wavelength (um)	Spec NEdN (mW/m²/ster/cm⁻¹)
18	3.70	0.004
17	3.98	0.008
16	4.13	0.008
15	4.45	0.013
14	4.52	0.013
13	4.57	0.013
12	6.50	0.15
11	7.00	0.12
10	7.40	0.16
9	9.7	0.33
8	11.00	0.16
7	12.00	0.16
6	12.70	0.25
5	13.40	0.44
4	13.90	0.45
3	14.10	0.54
2	14.40	0.58
1	14.70	0.66

ABI vs Current Imager NEdT

ABI #	ABI Freq. (um)	ABI Spec*	ABI Worst Case Estimate**	GOES #	GOES Freq (um)	GOES Spec	GOES Measured (GOES-12 PLT)	GOES Measured (GOES-15 PLT)
7	3.9	0.1	0.10	2	3.9	1.4	0.130	0.063
8	6.185	0.1	0.06					
9	6.95	0.1	0.09	3	6.x	1.0	0.15	0.17
10	7.34	0.1	0.11					
11	8.5	0.1	0.04					
12	9.61	0.1	0.04					
13	10.35	0.1	0.05					
14	11.2	0.1	0.04	4	10.7	0.35	0.11	0.06
15	12.3	0.1	0.05	5	12.0	0.35	-	-
16	13.3	0.3	0.14	6	13.3	0.32	0.19	0.13

* NEdT (K) is @300K for all bands except Water Vapor where it is @240K for ABI, 230K for GOES

** From ITT at GUC7

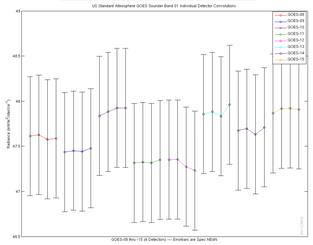


ABI FM1 SRFs plotted with the US Standard Atmosphere spectrum

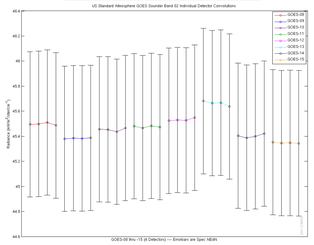
Current GOES Sounder Detectors vs NEdN

- Each detector (4 per band, per satellite) convolved with US Standard Atmosphere Spectra.
- Convolved radiances displayed with spec noise (+/-NEdN) as an error bar.
- Most detector sets for each band are "in family" (detector to detector differences less than NEdN), but several are not.

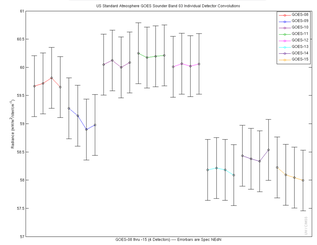
GOES Sounder Band 01



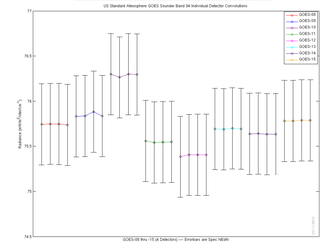
GOES Sounder Band 02



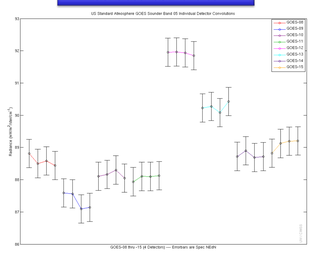
GOES Sounder Band 03



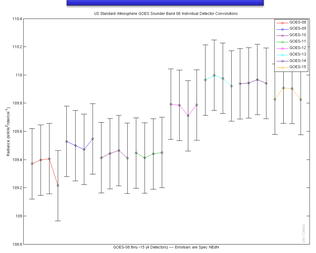
GOES Sounder Band 04



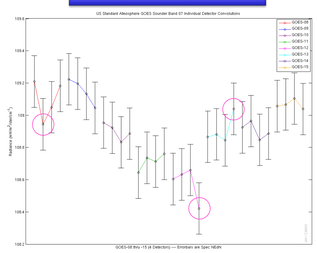
GOES Sounder Band 05



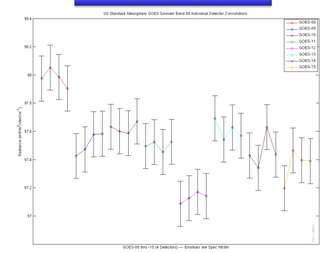
GOES Sounder Band 06



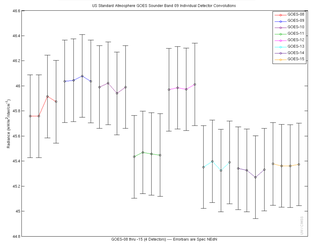
GOES Sounder Band 07



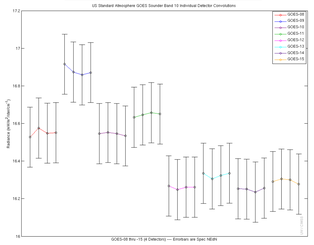
GOES Sounder Band 08



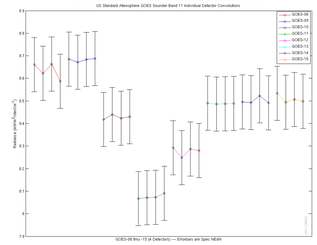
GOES Sounder Band 09



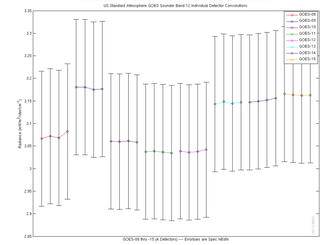
GOES Sounder Band 10



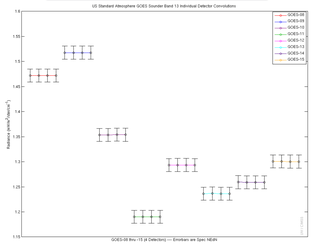
GOES Sounder Band 11



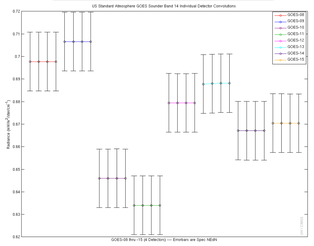
GOES Sounder Band 12



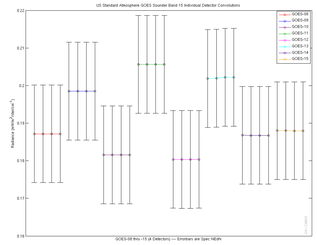
GOES Sounder Band 13



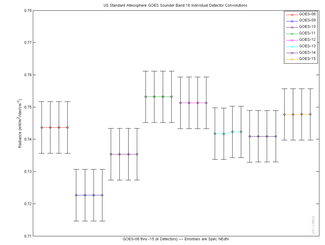
GOES Sounder Band 14



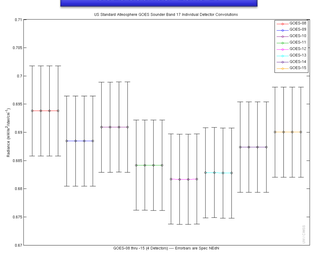
GOES Sounder Band 15



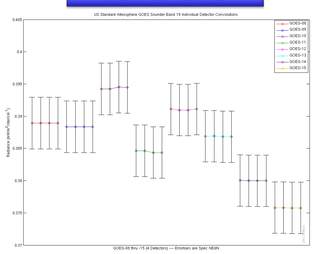
GOES Sounder Band 16

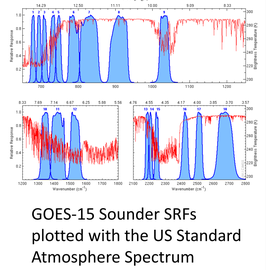


GOES Sounder Band 17

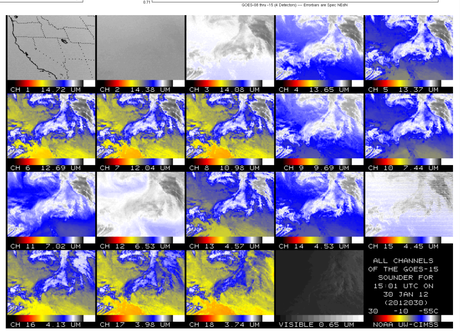


GOES Sounder Band 18



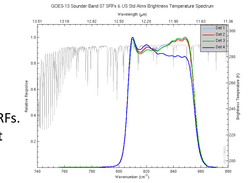


GOES-15 Sounder SRFs plotted with the US Standard Atmosphere Spectrum

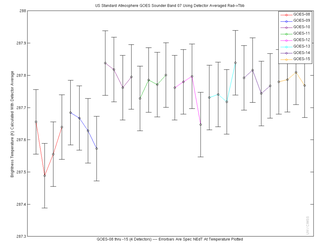


Converting to Brightness Temperature

GOES Sounder Band 7



GOES-13 Band 07 Individual Detector SRFs. Note how different Detector 4 is.

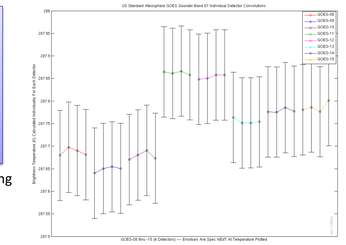


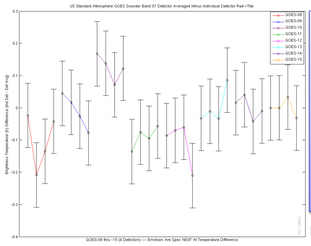
GOES Sounder Band 7 has several satellites with detector to detector differences exceeding the noise.

Converting Rad to Temp using Detector Averaged SRFs (with +/-NEdT)

Detector to detector differences are all within spec NEdT when using detector-specific conversion from radiance to brightness temperature!

Converting Rad to Temp using Individual Detector SRFs (with +/-NEdT)





Detector to detector differences are not the only issue. Using a detector-averaged SRF to convert radiance to brightness temp. can introduce biases significant compared to the NEdT!

Difference between Temps calculated with detector averaged SRFs and individual detector SRFs (with +/-NEdT)

Summary

- On GOES-R ABI: If differences between individual detectors of the same band exceed the noise, radiometric accuracy may suffer because we will not be able to use individual detector SRFs.
  - The effects may be partially mitigated, or masked by the spatial averaging.
- Current Sounder imagery exhibits "striping" but it is not always in bands with a detector-to-detector difference in the SRFs
- There is significant amount of instrument to instrument variability on bands considered to be identical.

Not shown:

- There are 32 sample atmospheres (including the one shown).
- These calculations were generated for the GOES-08 thru -15 Imagers.

Still to do:

- Determine how results vary for atmosphere type.
- Repeat with high spectral resolution polar orbiting data to get atmospheres containing cloud and other factors.