The Unique Radiometric Calibration Trending Behavior of the GOES Imagers and Sounders

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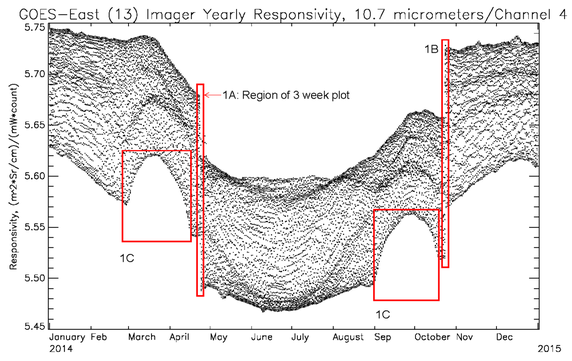
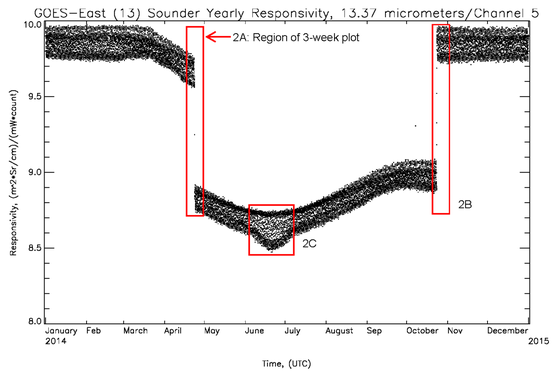
Introduction

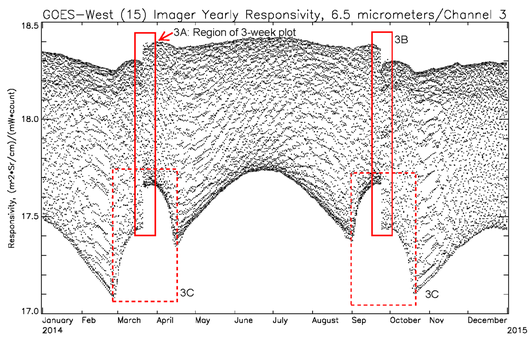
The subtitle for this poster could be *"what you see is NOT what you get."* That is, the variable radiometric environment of the on-orbit GOES Imager and Sounder instruments that is displayed in the trend plots below is NOT what users find in the radiometrically stable infrared (IR) radiances (and brightness temperatures) that are contained in the delivered GOES L1b products. And this transition, from unstable to stable, is due to the application of the very responsivity coefficients that are displayed in this poster (via the process called calibration). Specifically, this poster seeks: (1) to provide users with a feel for the (variable) trending behavior of the GOES Imager and Sounder radiometric responsivities over yearly and shorter time scales; (2) to provide explanations for the origin of the variability in the displayed responsivities; and (3) to categorize the various causes of the responsivity variability as either intrinsic instrument behavior or due to commanded instrument operations which seek to maximize overall radiometric performance of the GOES instruments throughout the year.

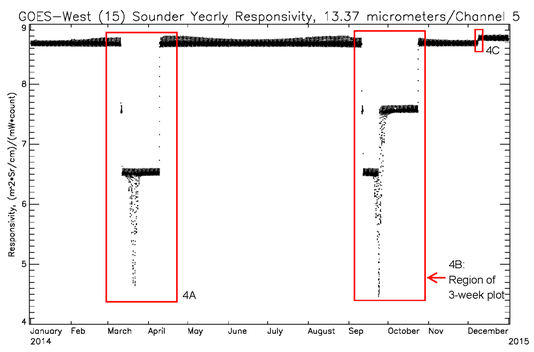
The Yearly Responsivity Plots

Directly below, in the left-hand column of this poster, are displayed four yearly trend plots for the radiometric responsivities for one of the IR Channels/detectors from each of the GOES-13 (EAST) and GOES-15 (WEST) Imagers and Sounders. These trend plots are meant to provide feel for the instrumental responsivity variability encountered on annual and seasonal timescales. Interesting features are annotated on the plots for explanation over in the right-hand column. Indicated also in each of these yearly plots is the smaller time window that is displayed in the middle-column plot, where more detail in the responsivity trending is revealed over shorter-timescales.







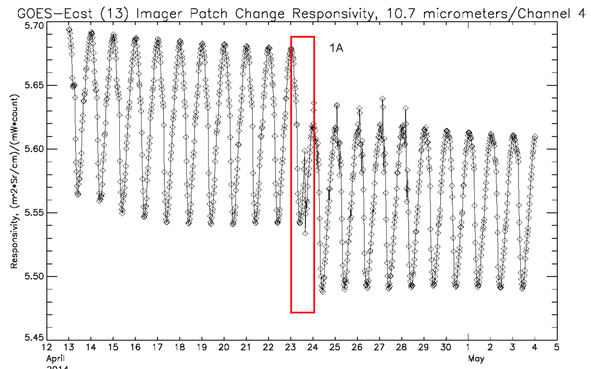


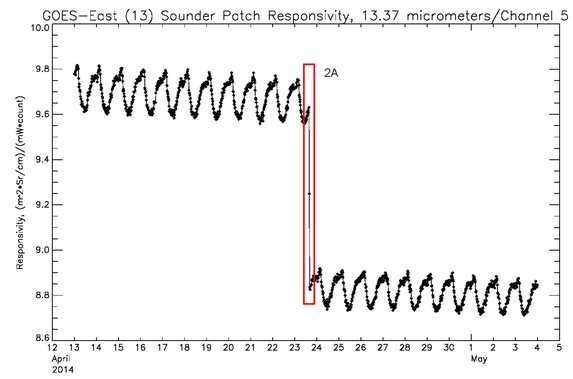
The Radiometric Responsivities

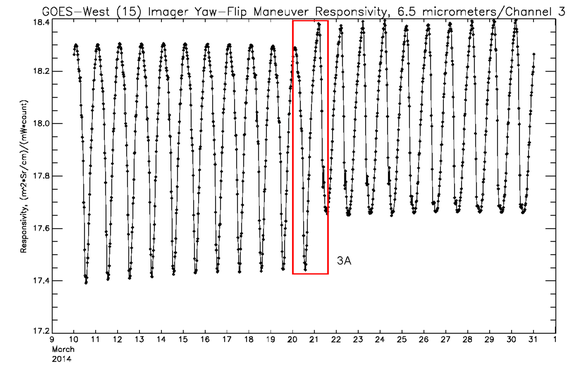
The radiometric response of every IR Channel/detector for each Imager (total of 8 detectors in 4 IR Channels) and Sounder (total of 72 detectors in 18 IR Channels) instrument is measured 2 to 3 times every hour by observing an on-board blackbody (BB) target whose temperature is monitored. Thus at each BB observation the raw instrument output while observing the BB can be compared to the known radiance of the BB, and that ratio [(raw instrument output)/ (BB radiance)] leads to a measurement of the instrumental **responsivity**. These responsivity measurements are calculated and stored as coefficients by the L1b calibration algorithm in the ground processing system; and these responsivity coefficients, along with special calibration measurements of zero-radiance space (not shown in this poster), are used to radiometrically calibrate the Earth frame observations. The responsivity coefficients for all GOES Imagers and Sounders are archived for the full-mission as a record of responsivity stability and instrument performance. It is these responsivity coefficients that are plotted in the figures in this poster.

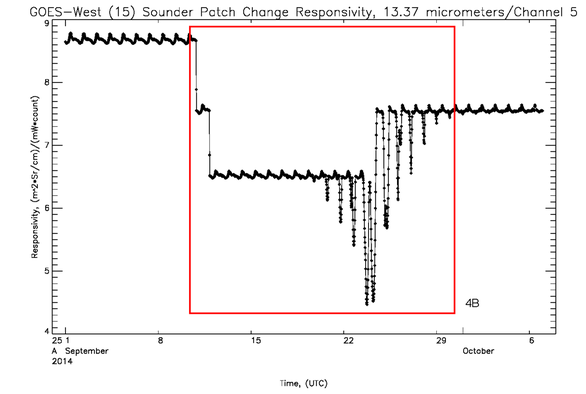
The 3-week Responsivity Plots

Directly below, in the middle column of this poster, are displayed four shorter time windows (~3-weeks) of responsivity trends for each instrument, each window selected to cover an "interesting" feature in the responsivity trend as seen in the corresponding yearly trend plot in the left-hand column as noted. These plots allow more detail to be seen in the responsivity variations, covering from hourly to weekly timescales. Again, interesting features are annotated for explanation in the right-hand column.









Instrument Responsivity Variability

The causes for each instrument's responsivity variations fall into two major categories:
Intrinsic instrument behavior in response to the conditions encountered on-orbit, such as:

- variable instrument-component and electronics temperatures over naturally occurring daily, seasonal, yearly cycles, which are primarily driven by the instrument's and spacecraft's exposure to solar heating
- non-optimally performing instrument or spacecraft components

Commanded instrument operations which purposefully change the instrument's controlled environment in order to maximize its overall radiometric performance, such as:

- seasonal changes to the detectors' thermostatically controlled temperatures
- spacecraft yaw-flips
- changes to instrument-characterization parameters stored in the ground processing calibration database.

Explanations

Examples of the above drivers of responsivity variations can be seen in the responsivity trend plots displayed in the left-hand and center columns. Directly below, in the right-hand column of this poster, explanations are provided for the various variability trends seen in the responsivity plots for each GOES Imager and Sounder. Each of the features specifically annotated on the yearly and 3-week trend plots are explained, as are some of the more general aspects of the trend plots.

GOES-EAST Imager, IR Channel 4

Diurnal Trends – On the 3-week plots, note the periodic, diurnal variations of the responsivities. This is ***intrinsic*** on-orbit behavior for *all* of the GOES Imagers and Sounders. This diurnal behavior is perceived on the yearly plots as the band of data undergoing seasonally varying minima and maxima.
The few-percent diurnal responsivity variations are mainly caused by diurnal changes to the solar heating of: (1) the instrument components; and (2) the electronics …. both of which lead to a diurnal change in the efficiency of converting input photons to output signal for the detectors.

1A and 1B – The sudden change of responsivity level in mid-April and mid-October is caused by a ***commanded*** change to the thermostatically controlled temperature of the detectors.
(See further explanation associated with "2A and 2B" for the GOES-East Sounder.)

1C – The seasonal variations in the diurnal responsivity minima centered on the equinoxes are part of the Imager's ***intrinsic***, on-orbit response to a decrease in solar heating.
Near the equinoxes the sun spends some time during the day behind the Earth as seen from the instrument. The resulting cooler instrument-component temperatures lead to increased detector responsivities, especially at the time of its diurnal responsivity minimum.

GOES-EAST Sounder, IR Channel 5

Diurnal Trends – On the 3-week plots, note the periodic, diurnal variations of the responsivities, which is ***intrinsic*** instrument behavior on-orbit.
(See further explanation under "Diurnal Trend" for the GOES-East Imager.)

2A and 2B – The sudden change of detector responsivity levels in mid-April and mid-October for the GOES-East Sounder (and Imager) are caused by ***commanded*** changes to the controlled temperature of the detectors.
Since the responsivity of the IR detectors is *very* sensitive to their temperature, the detector temperatures are thermostatically controlled at a constant level. In the summer months, the control-temperature is commanded to a higher, constant level to ensure its stability in the face of increased solar heating of the instrument; the higher detector temperature causes a decrease in responsivity.

2C – The depression in the diurnal responsivity minima centered on the summer solstice, and lasting about 3 weeks, is **intrinsic** instrument behavior, in response to a slight loss of control of the detector temperatures.
Despite the summer change to a higher controlled detector temperature, at summer solstice when the solar heating effects are at their annual maximum, the GOES-East Sounder cannot cool itself enough to avoid the detector temperatures from rising slightly for part of the day and causing a decrease in the diurnal minimum of responsivity.

GOES-WEST Imager, IR Channel 3

Diurnal Trends – On the 3-week plots, note the periodic, diurnal variations of the responsivities, which is ***intrinsic*** instrument behavior on-orbit.
(See further explanation under "Diurnal Trend" for the GOES-East Imager.)

3A and 3B – The sudden change of responsivity levels near the equinoxes are caused by ***commanded*** yaw-flips (instrument orientation flips north-south) to the GOES-West spacecraft.
The spacecraft yaw flips are necessitated by a problem with the GOES-West Sounder (see the explanation associated with "4A and 4B" for the GOES-West Sounder). Although the Imager itself has no special problem, each spacecraft yaw flip suddenly changes the altitude and azimuthal orientation of the sun with respect to the Imager's instrument components, and so it likewise suddenly changes the amount of solar heating of the instrument. This sudden shift in the solar heating trend for the instrument is what causes the jump in responsivity level for the GOES-West Imager detectors.

3C – The seasonal variations in the diurnal responsivity minima centered on the equinoxes are part of the Imager's ***intrinsic***, on-orbit response to a decrease in solar heating.
(See further explanation associated with "1C" for the GOES-East Imager.)

GOES-WEST Sounder, IR Channel 5

Diurnal Trends – On the 3-week plots, note the periodic, diurnal variations of the responsivities, which is ***intrinsic*** instrument behavior on-orbit.
(See further explanation under "Diurnal Trend" for the GOES-East Imager.)

4A and 4B – The multiple changes of detector responsivity levels near the equinoxes are due to ***commanded*** changes to the controlled detector temperatures, which are implemented in response to an ***intrinsic*** problem with the GOES-West Sounder.
The GOES-West Sounder undergoes extreme solar heating due to a malfunctioning, loose insulation blanket near its cooler assembly. Although the spacecraft performs yaw flips to avoid the worst of these heating effects, the controlled detector temperatures must also be raised near each equinox to further minimize the effects of unstable detector temperatures/responsivities. However, even with these preventative measures in place, the detector temperatures cannot be controlled at all times of the day, with the result that the detector responsivities 'spike' to lower values during parts of the day, but only for the ~10 days surrounding each equinox.

4C -- The December jump in responsivity is due to the introduction into the ground calibration processing of an improved scan-mirror emissivity model for the GOES-West Sounder. Thus, this apparent change in detector responsivity is really due a ***commanded*** change in the instrument characterization.

2015 NOAA Satellite Conference Greenbelt, Maryland