



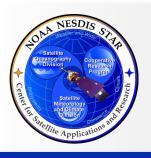
GOES Coherent Noise Analysis and Online Monitoring

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Abstract



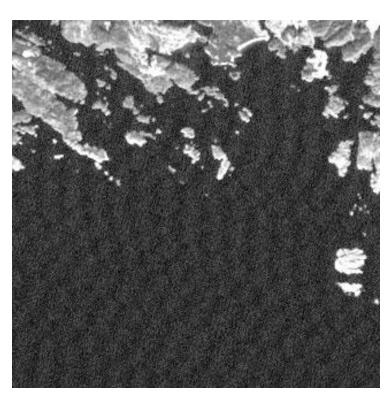
On September 23rd, 2012, the Geostationary Operational Environmental Satellite (GOES)-13 Imager and Sounder were placed in standby in response to a scan motor overload in each instrument. Several days prior to this event, GOES-13 Imager Channel 3 imagery exhibited oscillatory noise. In response, a Fourier coherent noise analysis tool with the ability to measure small signals was created and applied to GOES-13 Imager space data. The analysis confirmed a noise frequency calculation by the National Oceanic and Atmospheric Administration (NOAA) Office of Satellite and Product Operations (OSPO) and showed that the GOES-13 Imager Channel 1 was also exhibiting oscillatory noise. After the instruments' return to service, the coherent noise persisted but with a significantly reduced amplitude. Using historical data, the Fourier analysis tool also showed that the GOES-13 Imager coherent noise originated on July 13th, 2012. To provide potential warnings of future anomalies, daily GOES-EAST and GOES-WEST Imager coherent noise measurements are provided on the GOES Imager Data Quality Monitoring website.



Background: Coherent Noise



Coherent Noise: Noise with a consistent pattern



Coherent noise
Landsat 7 Enhanced Thematic Mapper
Plus Band 3 image (courtesy USGS)



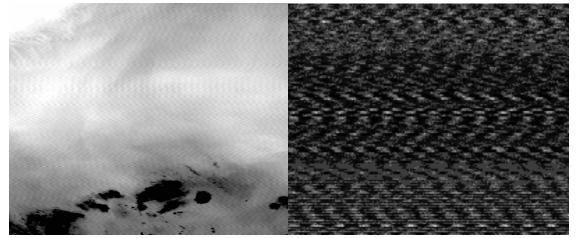
Incoherent noise



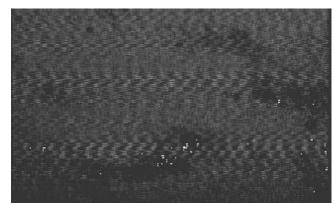
GOES-13 Coherent Noise ERT



Starting around July 24, 2012, the GOES-13 Sounder Ch. 13-16 were exhibiting visually apparent coherent noise, as was the Imager Ch. 3 beginning around Sept. 21, 2012.



GOES-13 Imager Channel 3 Earth image (left) and Channel 3 space data image (right) from Sept. 21st, 2012, 8:15 UTC.



GOES-13 Sounder Channel 15 Earth image from July 24th, 2012, 9:46 UTC.

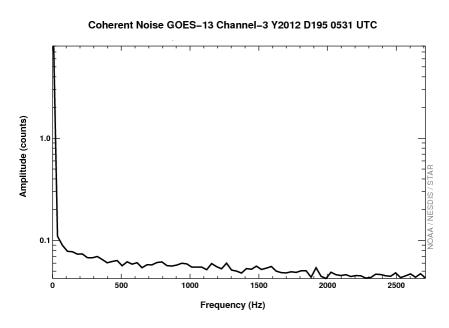
Sept. 23, 2012: Both instruments were shut down.



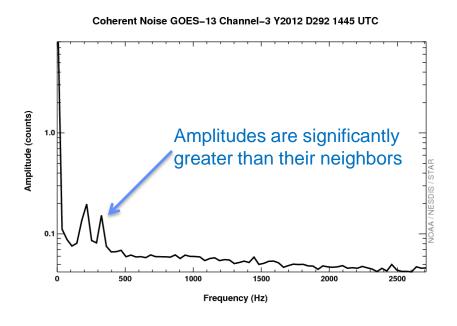
Detecting Coherent Noise



Coherent noise can be measured using the amplitude¹ spectrum of the Fourier Transform of the imager data:



Amplitude spectrum for incoherent noise



Amplitude spectrum for **coherent** noise

^{1:} In this presentation, amplitude and magnitude are used interchangeably.



STAR Quantification of Coherent Noise



Coherent Noise Measurement method:

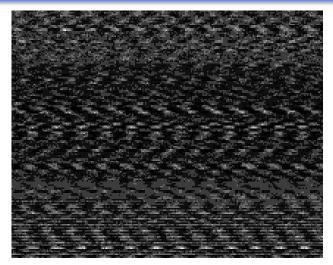
1) Perform Discrete Fourier Transform of one line of space data in the East-West direction

$$\mathcal{F}_{n} = \frac{1}{N} \sum_{k=0}^{N-1} f_{k} e^{-2\pi nk/N}$$

2) Obtain the Fourier amplitudes for the line (eliminates phase information)

$$A_n = |\mathcal{F}_n| = \sqrt{\mathcal{F}_n \mathcal{F}_n^*}$$

- 3) Repeat 1&2 for several lines and find the average amplitudes
- 4) Change frequencies from spatial (#oscillations/pixel) to temporal (#oscillations/sec) using Imager scan rate



GOES-13 Imager Channel 3 space data image from Sept. 21st, 2012, showed earlier.

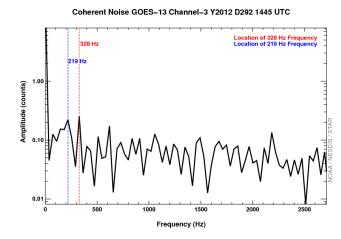
Each scan has a similar noise frequency but different phase (peak-to-peak offset between scans).

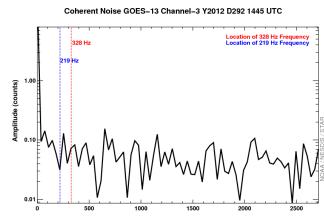


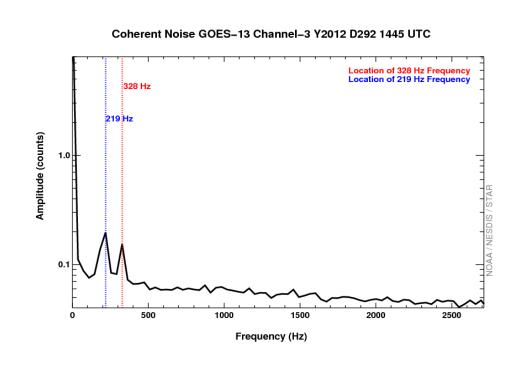
Use of Multiple Image Lines



The Fourier amplitudes from several lines are averaged together to "smooth out" random noise and detect smaller coherent noise signals.







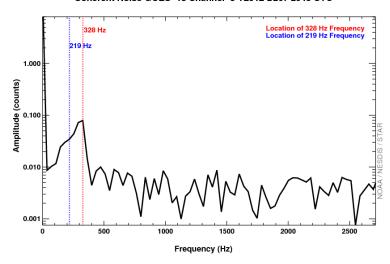
Spectral amplitude for one line (left) and averaged for multiple lines (right) of data



Averaging Fourier Amplitudes



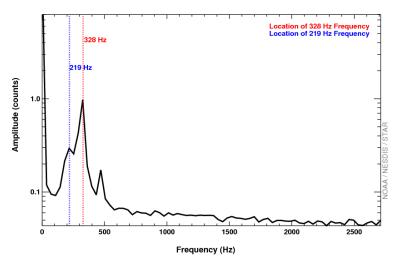




Result after averaging the entire Fourier Transform of each line



Coherent Noise GOES-13 Channel-3 Y2012 D267 2045 UTC

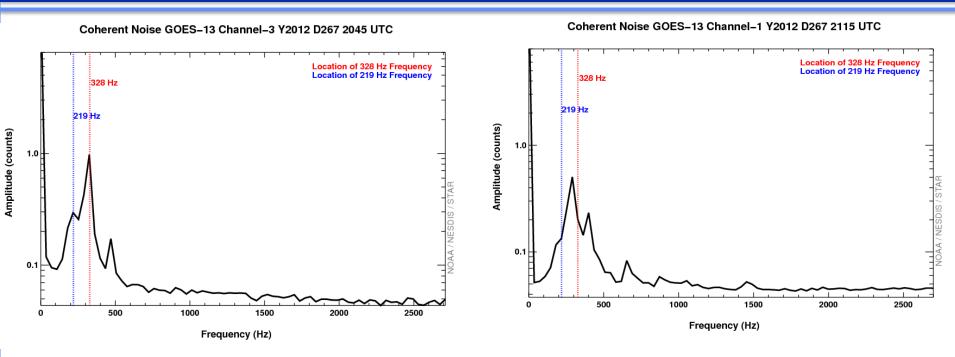


Result after averaging only the Fourier magnitudes of each line

The peak-to-peak positions change lineby-line (different phase), so only the Fourier magnitudes are averaged.



GOES-13 Imager Coherent ERT Noise before shutdown



Channel 3 (left) and Channel 1 (right) coherent noise measurements on Sept. 21, 2012.

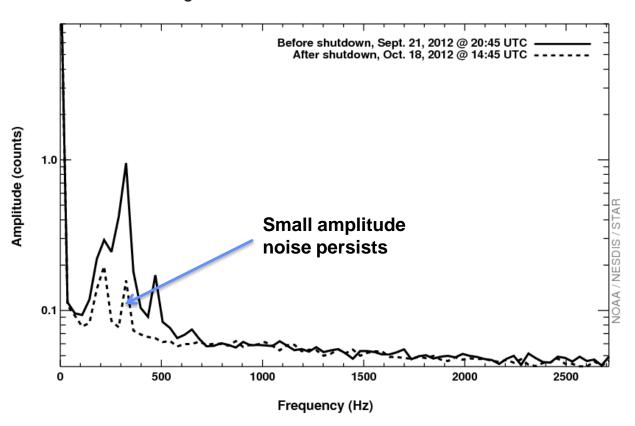
The peak frequency of ~326 Hz is similar to the ~308 Hz reported by GOES Operations using a different method.



GOES-13Return to Service



GOES-13 Imager Channel 3 Coherent Noise Before/After Shutdown



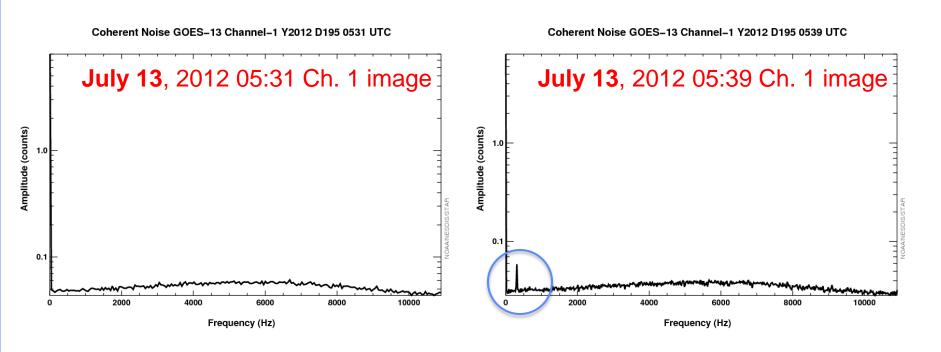
Channel 3 coherent noise measurement on Sept. 21, 2012, before the shutdown, and Oct. 18, 2012, after the shutdown. The coherent noise after the shutdown is not visibly apparent.



Initial Noise Signature



Since the Fourier-based coherent noise tool can detect noise that is not visibly apparent, we can find the time at which the noise first appeared:



The noise appeared in Ch. 3 a couple weeks later.



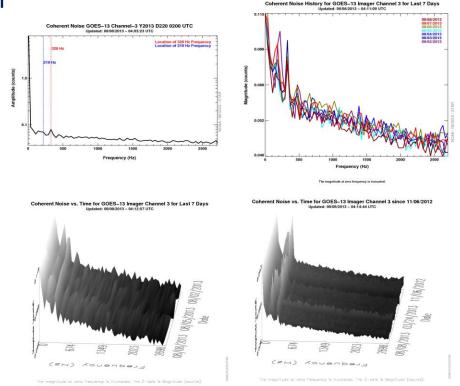
Coherent Noise on GOES Imager Data Quality Monitoring website



Coherent noise is being monitored daily for GOES-EAST/WEST as a potential warning system:

Coherent Noise History for GOES-13 Imager Channel 3 for Last 7 Days

Coherent Noise History for GOES-13 Imager Channel 3 for Last 7 Days



http://www.star.nesdis.noaa.gov/smcd/spb/fwu/homepage/GOES_Imager_Data QualityMonitoring.php

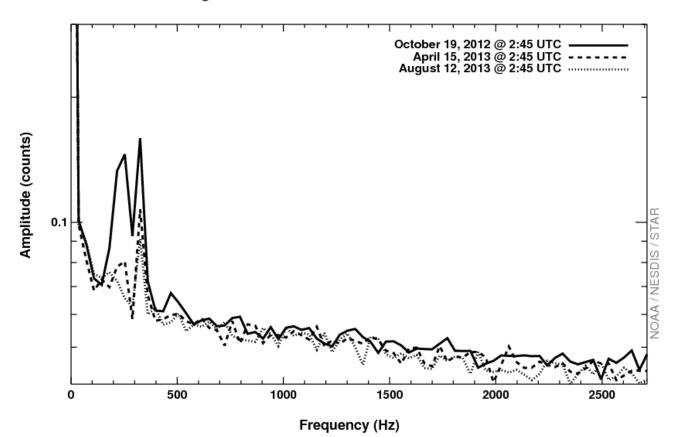


GOES-13 Decreasing Coherent Noise



Since the GOES-13 return to service in October 2012, the coherent noise has been generally decreasing in amplitude:

GOES-13 Imager Channel 3 Coherent Noise Before/After Shutdown





Summary



- Prior to the GOES-13 Imager and Sounder shutdown in Sept. 2012, noises at certain frequencies increased in some channels for both instruments (coherent noise).
- In response, NOAA/NESDIS/STAR developed a Fourier-based coherent noise measurement tool.
- After the return to service, the coherent noise persisted with smaller amplitudes. It
 has been generally decreasing in amplitude since.
- Historical data shows that the coherent noise could be detected as early as July 13th, 2012.
- Coherent noise is being monitored for GOES-EAST/WEST at http://www.star.nesdis.noaa.gov/smcd/spb/fwu/homepage/GOES_Imager_DataQualit yMonitoring.php