Analysis of nonstationarity in LIGO S5 data using the NoiseFloorMon output

A proposal for a seismic Data Quality flag.

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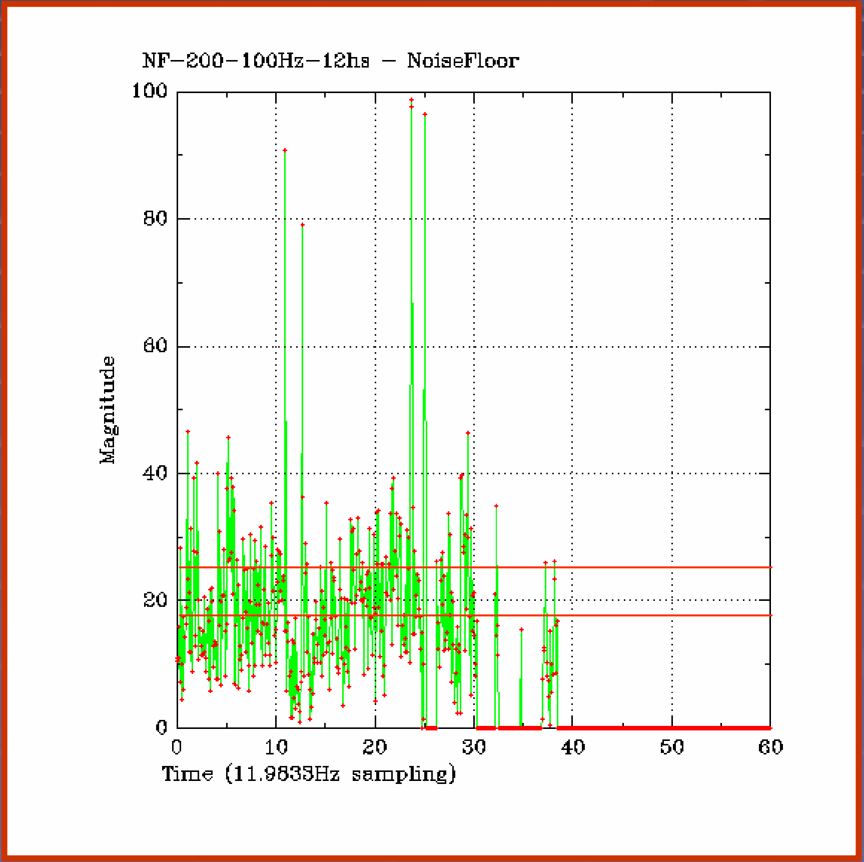
Overview

NoiseFloorMon is a DMT monitor that analyzes LIGO data for slow nonstationarity. This poster presents a subset of results from the S5 run. The study focuses on coupling between the gravitational wave (gw) channels and the seismic channels in different frequency bands that is manifested as nonstationarity in the gw channel. Development of a seismic data quality flag based on these studies is also presented.

NoiseFloorMon DMT

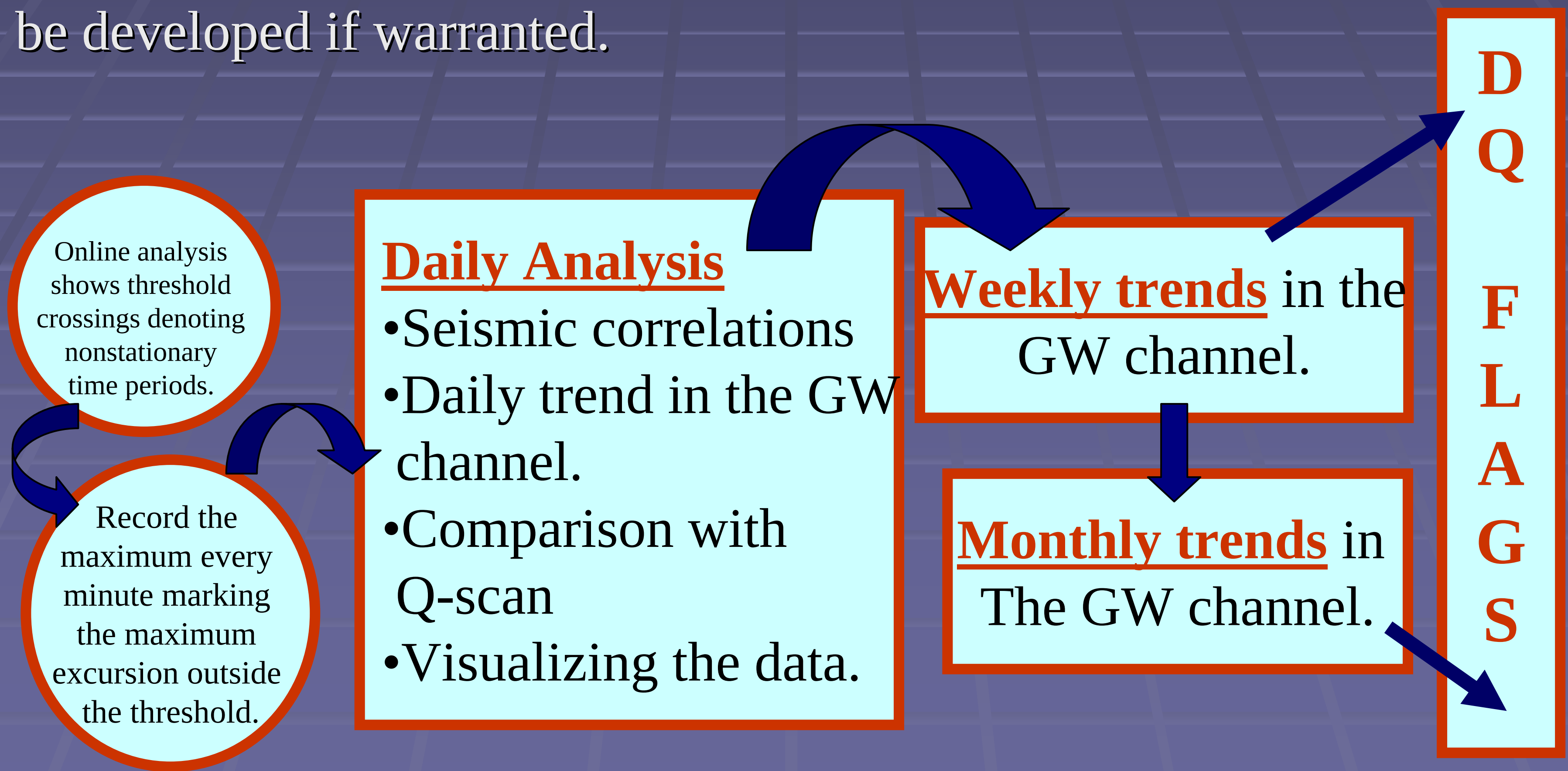
- NoiseFloorMon is a data monitoring tool that tracks the gw and seismic channels
- The cross-correlation between the gw and seismic channels is monitored in 0-16 Hz, 16-32 Hz, 32-64 Hz, and 64-128 Hz bands
- A threshold to indicate nonstationarity is set. The largest threshold crossings are stored each minute.



Online output of the NoiseFloorMon DMT

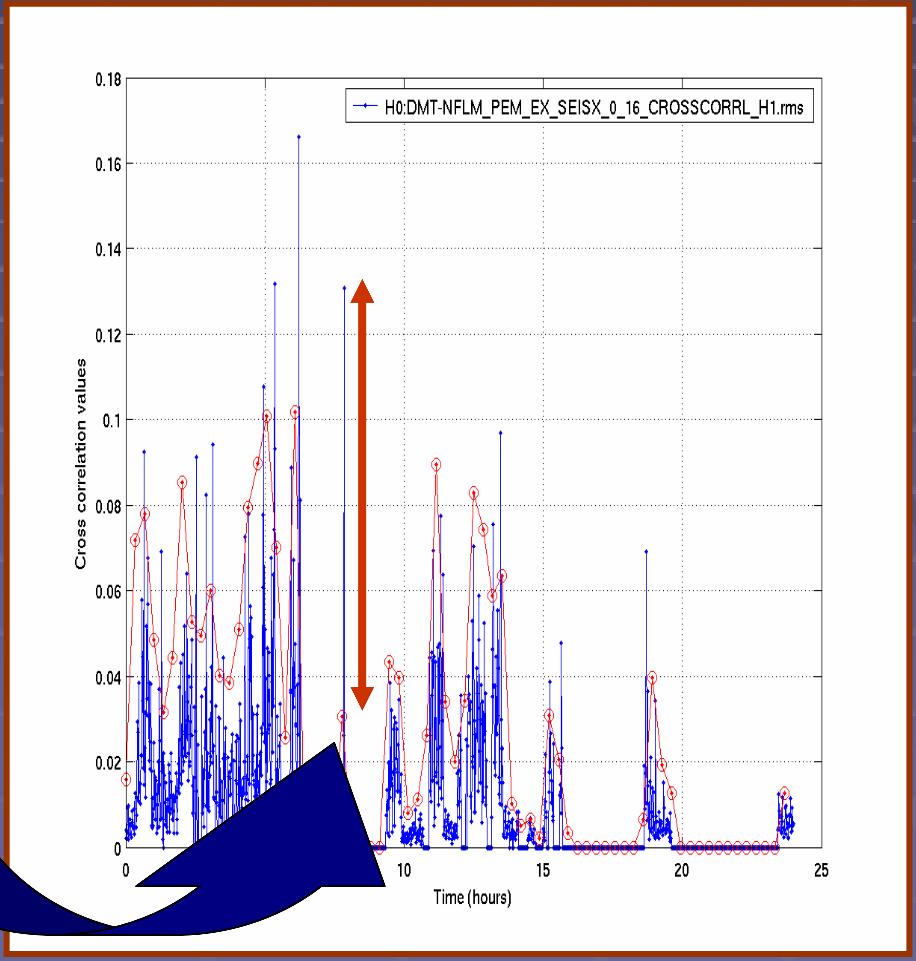
Developing a Seismic Data Quality Flag

- Analysis of entire S5 data for H1, H2 and L1 is ongoing.
- Offline analysis: The top 10 threshold crossings are analyzed daily.
- The analyses will be inserted in the DQ database with relevant frequency and channel information.   A seismic data quality flag can be developed if warranted.



Offline Analysis

- A median-based algorithm is used to set the threshold for offline analysis.[1, 2]
- The top 10 threshold crossings across all seismic channels are identified daily. The criterion used is the distance from the threshold.



Typical output of NoiseFloorMon offline analysis, January 2007.

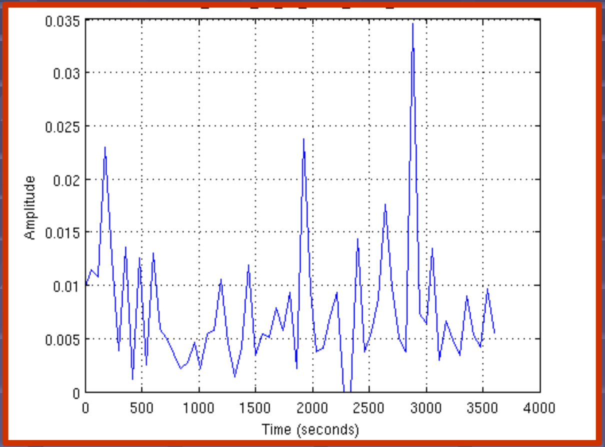
Offline Analysis

- The top threshold crossings are organized daily. The analysis includes a search for the causes of nonstationarity.

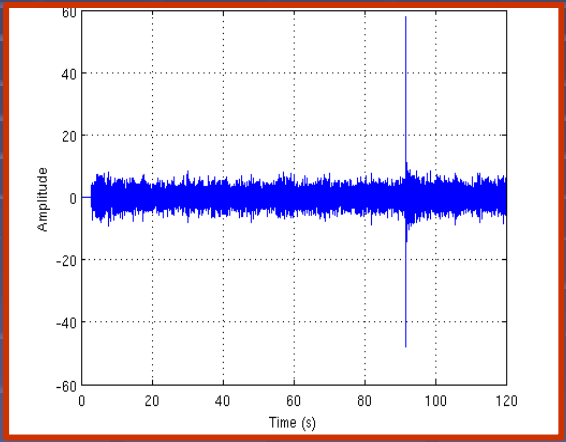
Largest Threshold Crossings

#	Site	GPS time	Channels	Frequency Bands(Hz)	Q-Scans	Comments
1	H0		PEM:EX_SEISX PEM:EX_SEISZ	64-128	Qscan	Loudest glitch in H2:ASC channels, but H2 not in science mode.
2	H0		PEM:MX_SEISZ PEM:EX_SEISZ	64-128	Qscan	Possibly due to earthquake in the Philippines.
			LSC:AS_Q			

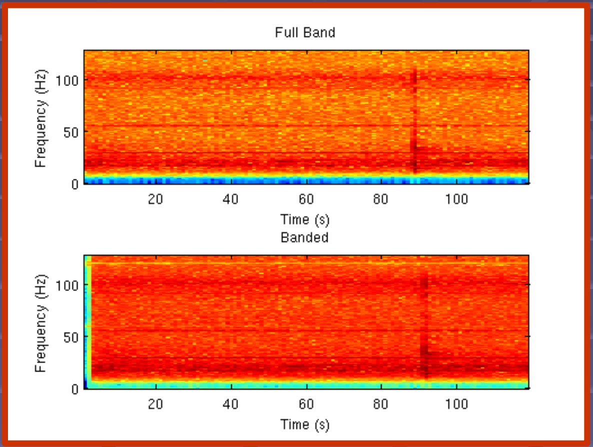
Offline Analysis



NoiseFloorMon output



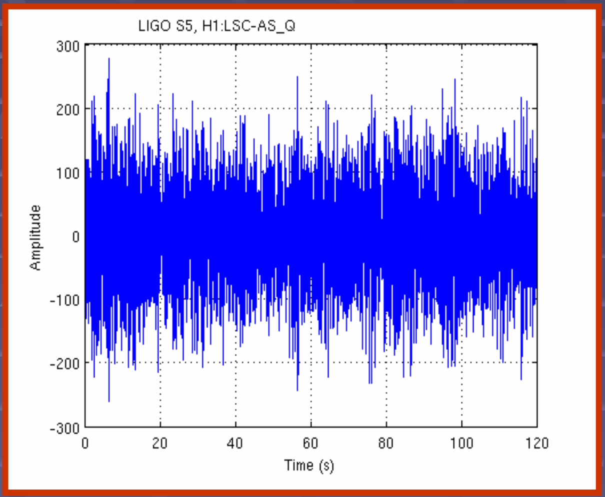
whitened time series



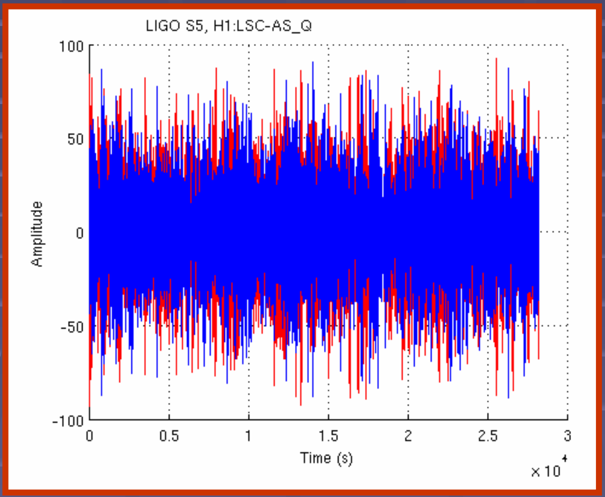
time-frequency

- A more thorough analysis of threshold crossings has been initiated in order to determine the coupling between seismic background and nonstationarity in the gw channel.
- The analysis includes visual examinations of data around the threshold crossing, including the NoiseFloorMon output, the seismic channel time series, and the full-band and banded time-frequency plots.

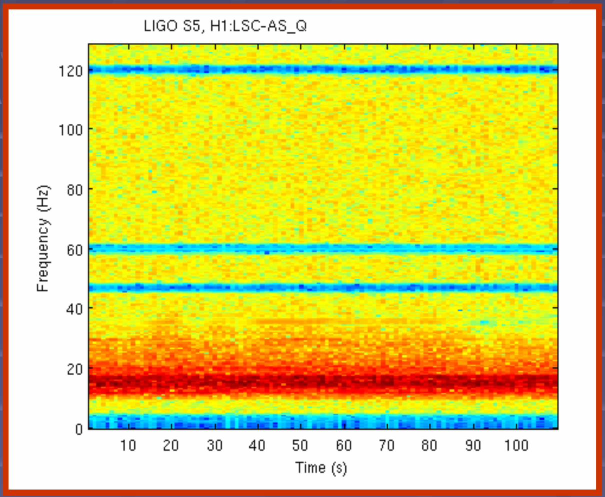
Offline Analysis



raw gw time series



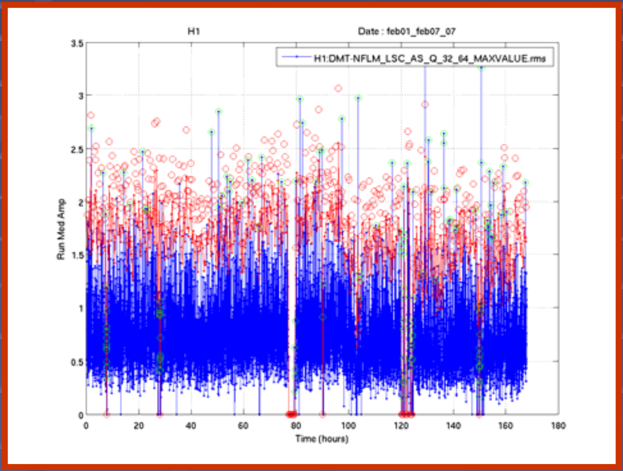
whitened gw time series

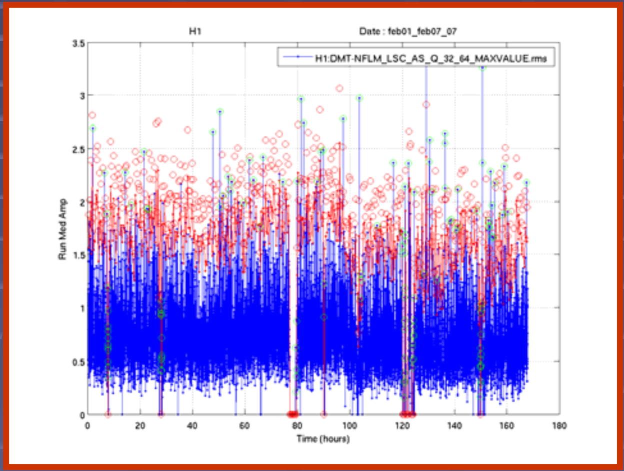


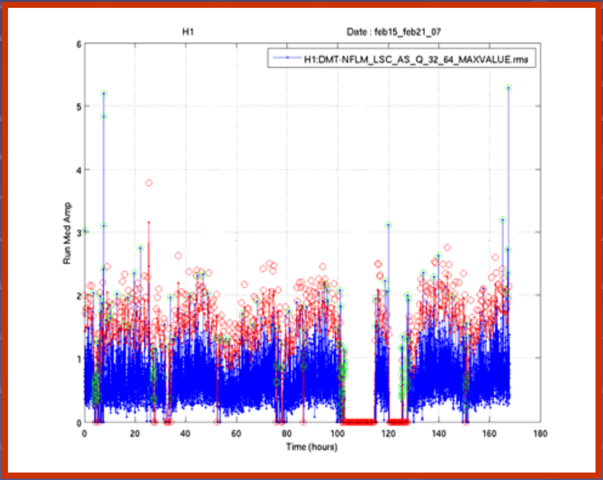
whitened time-frequency

- The gw channel signal is visually inspected around the time of the threshold crossing in order to determine obvious correlations, and to monitor the performance of NoiseFloorMon.
- The time-frequency plot is shown with known environmentally-induced frequency lines removed.

Monitoring Weekly Trends



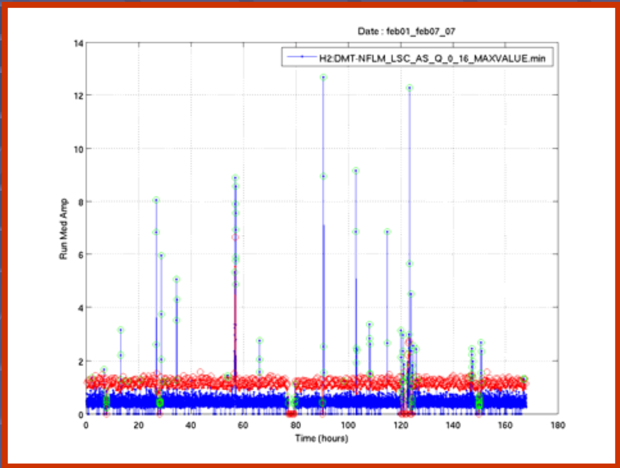


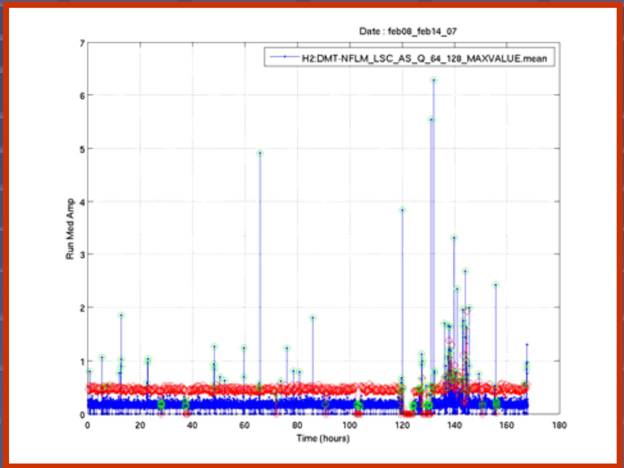


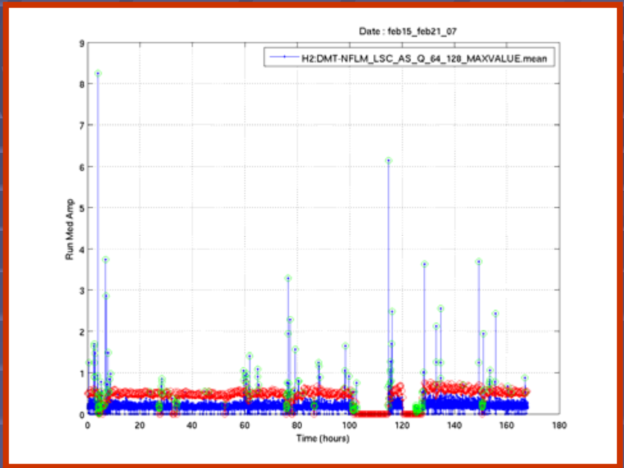
Weekly trends for H1

- In addition to monitoring daily nonstationarity in the gw channel, the analysis is expanding to weekly and monthly trends in order to gauge long-range interactions between the seismic and gw channels.
- Blue data points are the monitor output, solid red connected circles are 2.5 times above the median-based threshold, and clear red circles are 3 times the median-based threshold. The green circles are the crossings above the solid circles.

Monitoring Weekly Trends







Weekly trends for H2

- Compared to H1, the threshold crossings from H2 are significantly higher than the baseline noisefloor for the same time periods.

Analysis of Weekly Trends

93.3295673	0.03003598	H0:DMT-NFLM_PEM_LVEA_SEISX_32_64_CROSSCORRL_H1.mean
89.8406059	0.074084236	H0:DMT-NFLM_PEM_LVEA_SEISX_32_64_CROSSCORRL_H2.rms
67.5640206	0.047234325	H0:DMT-NFLM_PEM_LVEA_SEISX_32_64_CROSSCORRL_H2.rms
59.1067029	0.016026439	H0:DMT-NFLM_PEM_LVEA_SEISY_32_64_CROSSCORRL_H2.mean
52.7898967	0.049625855	H0:DMT-NFLM_PEM_EY_SEISX_0_16_CROSSCORRL_H2.max
51.6505452	0.019820598	H0:DMT-NFLM_PEM_EX_SEISY_32_64_CROSSCORRL_H1.mean
49.3873668	0.035984073	H0:DMT-NFLM_PEM_LVEA_SEISY_32_64_CROSSCORRL_H2.mean
48.7687204	0.010536067	H0:DMT-NFLM_PEM_EY_SEISZ_32_64_CROSSCORRL_H2.mean
44.4839012	0.06100485	H0:DMT-NFLM_PEM_LVEA_SEISY_0_16_CROSSCORRL_H2.mean
44.1324675	0.019813388	H0:DMT-NFLM_PEM_EY_SEISY_32_64_CROSSCORRL_H1.mean
43.9296794	0.049602888	H0:DMT-NFLM_PEM_EY_SEISY_32_64_CROSSCORRL_H1.mean
43.8131352	0.023455464	H0:DMT-NFLM_PEM_EX_SEISX_0_16_CROSSCORRL_H2.mean
43.5920156	0.008480184	H0:DMT-NFLM_PEM_MY_SEISX_32_64_CROSSCORRL_H1.mean
43.3049053	0.004073788	H0:DMT-NFLM_PEM_LVEA_SEISY_64_128_CROSSCORRL_H2.mean
40.1811661	0.028511347	H0:DMT-NFLM_PEM_LVEA_SEISY_16_32_CROSSCORRL_H1.max
39.0752772	0.009744926	H0:DMT-NFLM_PEM_EX_SEISZ_32_64_CROSSCORRL_H2.mean
37.4932132	0.03441869	H0:DMT-NFLM_PEM_EY_SEISZ_32_64_CROSSCORRL_H1.rms
37.3841942	0.00983748	H0:DMT-NFLM_PEM_MY_SEISX_32_64_CROSSCORRL_H2.mean
36.6532329	0.014901032	H0:DMT-NFLM_PEM_EX_SEISX_32_64_CROSSCORRL_H2.max
35.6694719	0.043388133	H0:DMT-NFLM_PEM_LVEA_SEISY_0_16_CROSSCORRL_H2.mean
34.629342	0.067750703	H0:DMT-NFLM_PEM_MY_SEISX_0_16_CROSSCORRL_H1.rms
33.7798654	0.042464027	H0:DMT-NFLM_PEM_EX_SEISX_0_16_CROSSCORRL_H2.mean
33.7621239	0.008522559	H0:DMT-NFLM_PEM_LVEA_SEISX_32_64_CROSSCORRL_H2.rms
33.5855059	0.007438474	H0:DMT-NFLM_PEM_MX_SEISX_32_64_CROSSCORRL_H1.mean
33.1659758	0.042178537	H0:DMT-NFLM_PEM_MY_SEISX_0_16_CROSSCORRL_H1.rms
32.7344129	0.025770824	H0:DMT-NFLM_PEM_EX_SEISX_32_64_CROSSCORRL_H2.max
32.3483445	1.08365023	H2:DMT-NFLM_LSC_AS_Q_0_16_MAXVALUE.min
31.5083573	0.003309672	H0:DMT-NFLM_PEM_EX_SEISX_64_128_CROSSCORRL_H2.mean
30.6469108	0.003082496	H0:DMT-NFLM_PEM_EX_SEISZ_64_128_CROSSCORRL_H2.mean
30.5086964	0.055200399	H0:DMT-NFLM_PEM_EY_SEISY_32_64_CROSSCORRL_H1.mean
29.9777821	0.012474043	H0:DMT-NFLM_PEM_MY_SEISZ_16_32_CROSSCORRL_H1.rms
29.541666	0.03368857	H0:DMT-NFLM_PEM_EX_SEISX_0_16_CROSSCORRL_H2.mean
29.4194716	0.027862951	H0:DMT-NFLM_PEM_EY_SEISZ_32_64_CROSSCORRL_H2.mean
28.1154166	0.010262137	H0:DMT-NFLM_PEM_EY_SEISZ_32_64_CROSSCORRL_H1.rms

- On a weekly basis the top threshold crossings are analyzed to determine the seismic channels with the greatest number of crossings, as well as the corresponding frequency bands.
- The columns in the table correspond to the magnitude of the threshold crossings, the cross-correlation parameter, and the channel name.

Conclusions and Future Directions

Future goals include:

- Continue analyzing S5 and future data.
- Looking for correlation with other monitor results *(See The LSC Glitch Hunters: Monitoring Noise Transients in S5)*.
- Extending the study to micro-seismic band.
- Charting monthly trends, possibly leading to a seismic data quality flag
- Developing a new monitor to measure microseism correlations/upconversions with the gw channel

References:

1. Development of a DMT monitor for tracking slow non-stationarities present in LIGO science data. Soma Mukherjee for LIGO Science Collaboration, Journal of Physics conference series, 32, 44-51, 2006.
2. Median based noise floor tracker : robust estimation of noise floor drifts in interferometric data. Soma Mukherjee, Classical and Quantum Gravity, 20, S925-S936,2003.

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