Detection and Analysis of “Noisy” LIGO Auxiliary Channels in O3

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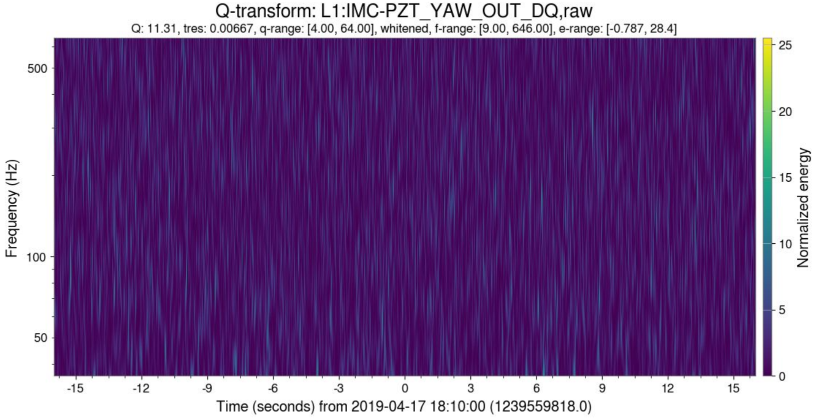
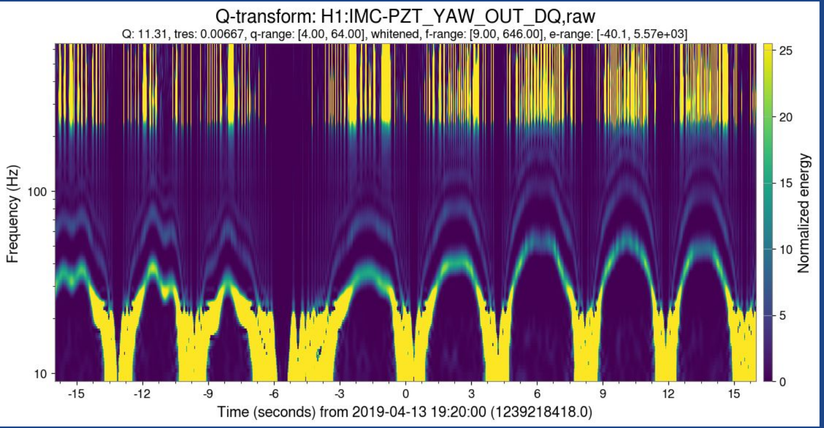
Acknowledgements:
Dr. Beverly Berger, Stanford LIGO Group, UBC Detchar Group

Quiet Channel



Noisy Channel



Goal

Create a streamlined process that isolates noisy auxiliary channels with signals occurring at time of glitch in h(t)-calibrated channel, however are different from the original h(t)-signal.

Finding auxiliary channels that are independently noisy with respect to the h(t)-calibrated channel.

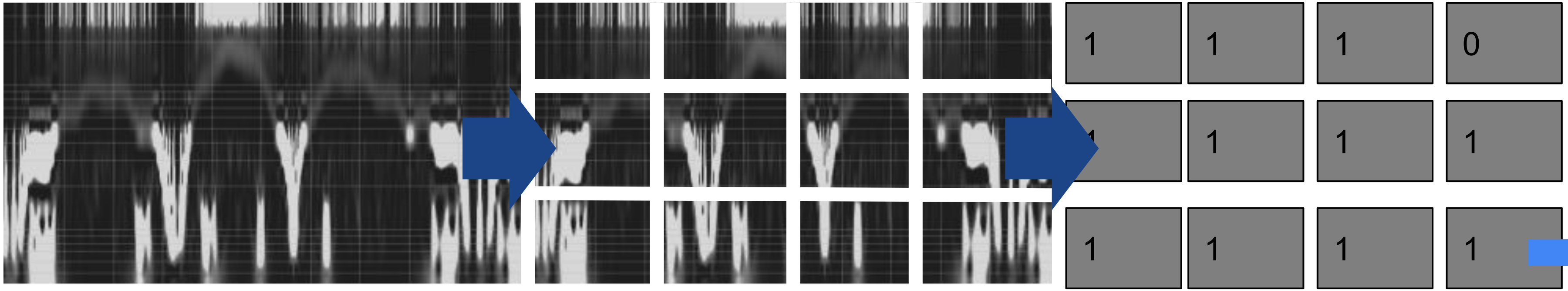
Motivations

1) Event Validation
2) Instrument Fixes

1. Data Collection Methods

Scoring Spectrograms

H1-IMC_PZT_PIT_OUT_DQ, on 4/1/2019



1. Apply BW Filter to Q-scan.

2. Partition into grids.

3. Store 1 or 0, depending on activity in specific frequency-time tile.

Final Score = Sum(Array)/(No. Cells) * 100 = 0.94

Average, 10x10 Grid

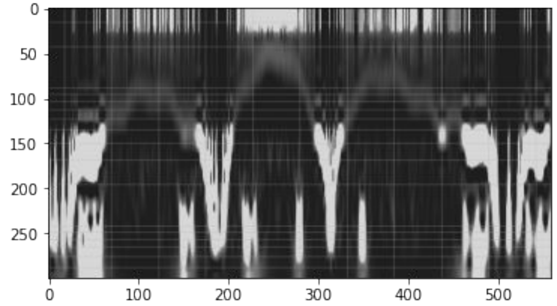
Test Steps (2) -> (3) on whether:

- We utilized an average or maximum of the tile's pixel values when analyzing whether it passed our threshold test.
- Lower thresholds pick up "smaller" noisy signals (see bottom).
- Tile Size - smaller tile size, more accurate, but slower to compute.

Final Parameters: Averaged pixel values over a 10x10 pixel grid, with a threshold of 150.

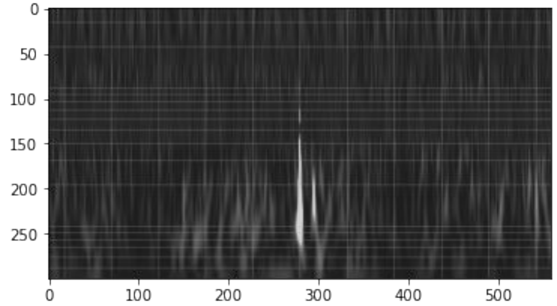
Maintained accurate representation of spectrograms, and minimized computing time.

H1-IMC_PZT_PIT_OUT_DQ, on 4/1/2019



Score = 0.94

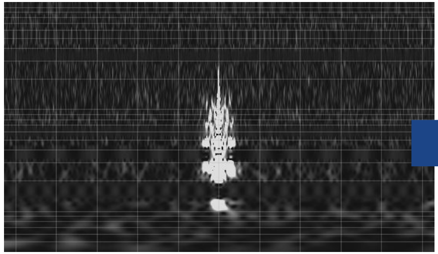
H1-LSC_REFL_A_LF_OUT_DQ, on 4/1/2019



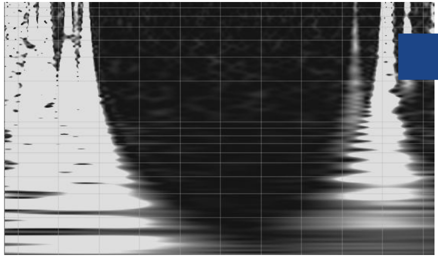
Score = 0.125

Comparison with Gravitational-Wave Channel

H1-GDS_CALIB_STRAIN



H1-SUS_ITMX_L3_OPLEV_SUM_OUT_DQ



1.Apply B+W Filter.

0	0	0	0
0	1	1	0
0	0	0	0

1	0	0	1
1	0	0	1
1	1	1	1

2. Partition into grids.
Store 1 or 0 in grid, depending on activity in specific frequency-time tile.

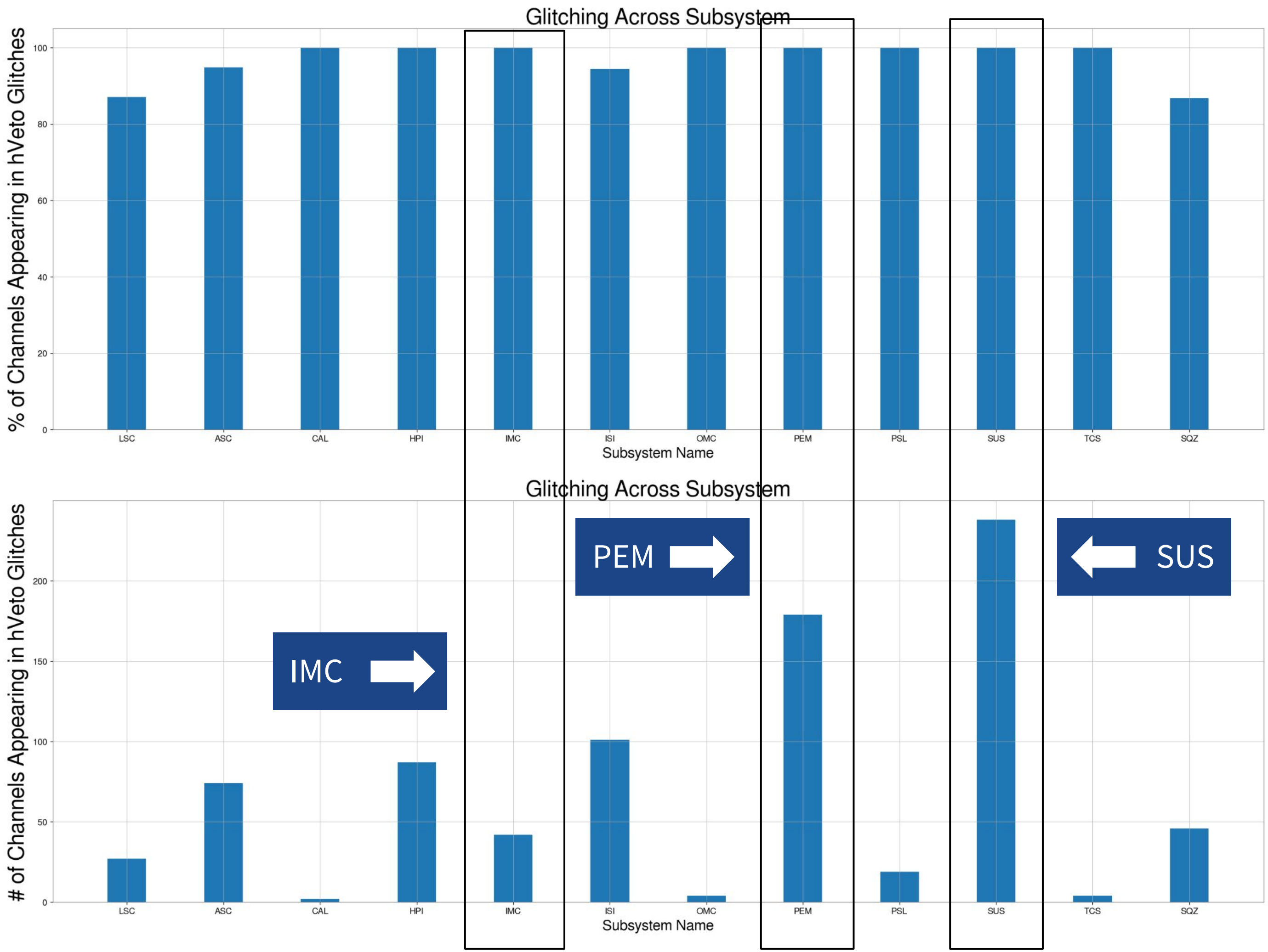
0	0	0	0
0	0	0	0
0	0	0	0

3. 1 if corresponding grid values are equal, 0 if not.

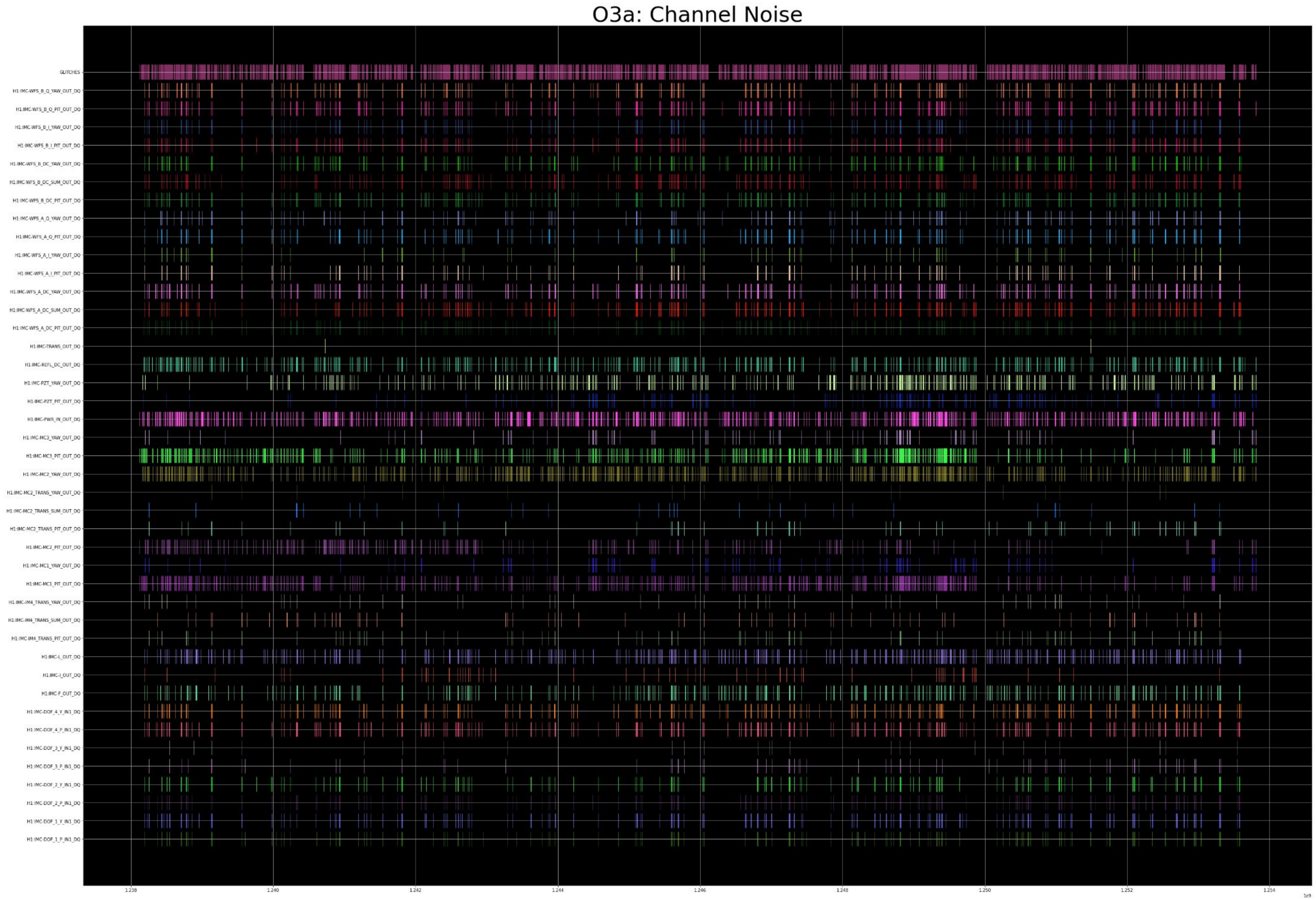
Score = 0

4. Score = Sum(Array)/Num(Tiles)

2. Results

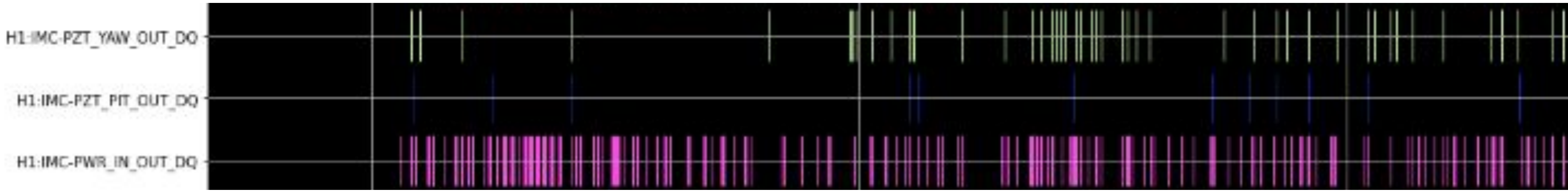


- Graphs depicting results of glitching over each subsystem.
- PEM and SUS subsystems had most auxiliary channels, along with # of glitching auxiliary channels.



Visualization of presence of auxiliary channels in hVeto Glitches.

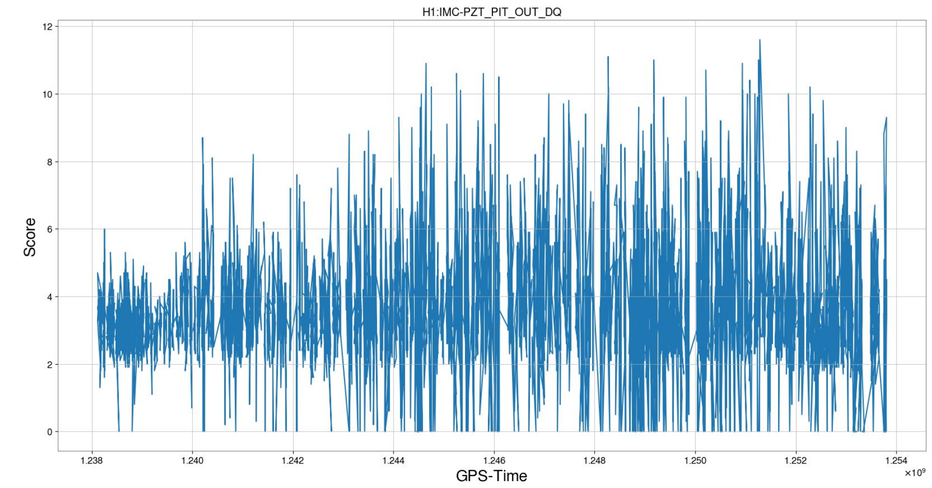
Rows correspond to channels, each tick mark corresponds to the time at which the hVeto glitch corresponded to activity in channel.



Here is an example of a channel that has significant noise appearing more frequently correlated to hVeto glitches. (H1:IMC-PWR_IN_OUT_DQ).

Overall , these plots helped us visualize which channels where noisy at times when there was a signal/glitch in the GW channel.

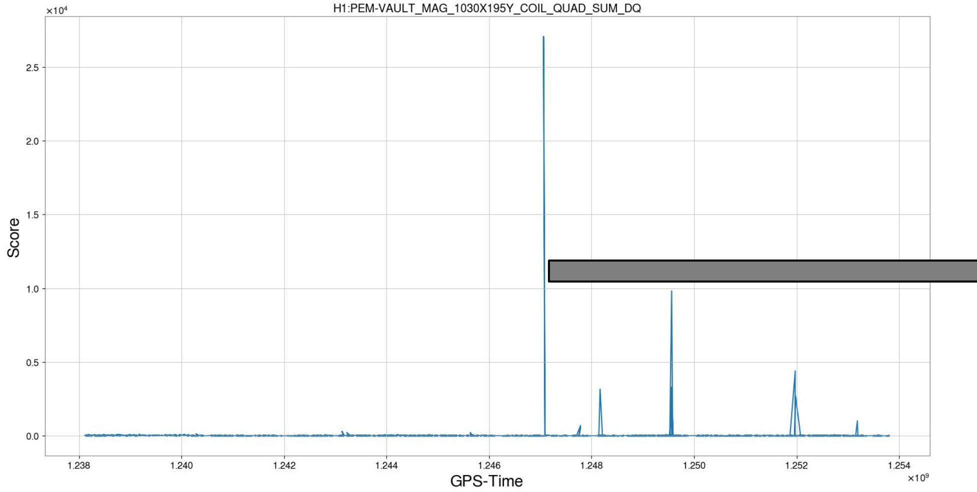
Changes in Noisy Channels Over Time

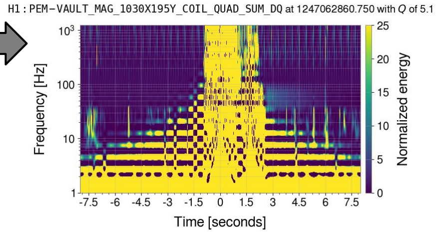


Further analyzed patterns of auxiliary channels over time. Consistently noisy channels like that of the IMC subsystem.

Most noisy channels were more consistent in noise (see above).

A *few* of the noisy channels that were picked up (by ranking with their average noise score over time), would only be extremely noisy for short periods of time (see the bottom graph).





O3a
H1:SUS-ITMX_L3_OPLEV_SUM_OUT_DQ
H1:SUS-PR3_M3_OPLEV_SUM_OUT_DQ
H1:SUS-SR3_M3_OPLEV_SUM_OUT_DQ
H1:PSL-FSS_FAST_MON_OUT_DQ
H1:PEM-VAULT_SEIS_1030X195Y_STS2_X_DQ
H1:LSC-Y_ARM_OUT_DQ
H1:PEM-VAULT_SEIS_1030X195Y_STS2_QUAD_SUM_DQ
H1:LSC-X_ARM_OUT_DQ
H1:PEM-VAULT_SEIS_1030X195Y_STS2_Y_DQ
H1:PEM-EY_SEIS_VEA_FLOOR_QUAD_SUM_DQ
O3b
H1:SUS-ITMX_L3_OPLEV_SUM_OUT_DQ
H1:PEM-EX_ADC_0_17_OUT_DQ
H1:PEM-EY_SEIS_VEA_FLOOR_QUAD_SUM_DQ
H1:PEM-VAULT_SEIS_1030X195Y_STS2_Z_DQ
H1:PEM-EX_SEIS_VEA_FLOOR_QUAD_SUM_DQ
H1:SUS-PR3_M3_OPLEV_SUM_OUT_DQ
H1:PEM-MX_SEIS_VEA_FLOOR_QUAD_SUM_DQ
H1:PEM-CS_ADC_4_30_16K_OUT_DQ
H1:ISI-GND_STS_ETMY_Z_DQ
H1:PEM-EY_SEIS_VEA_FLOOR_Z_DQ

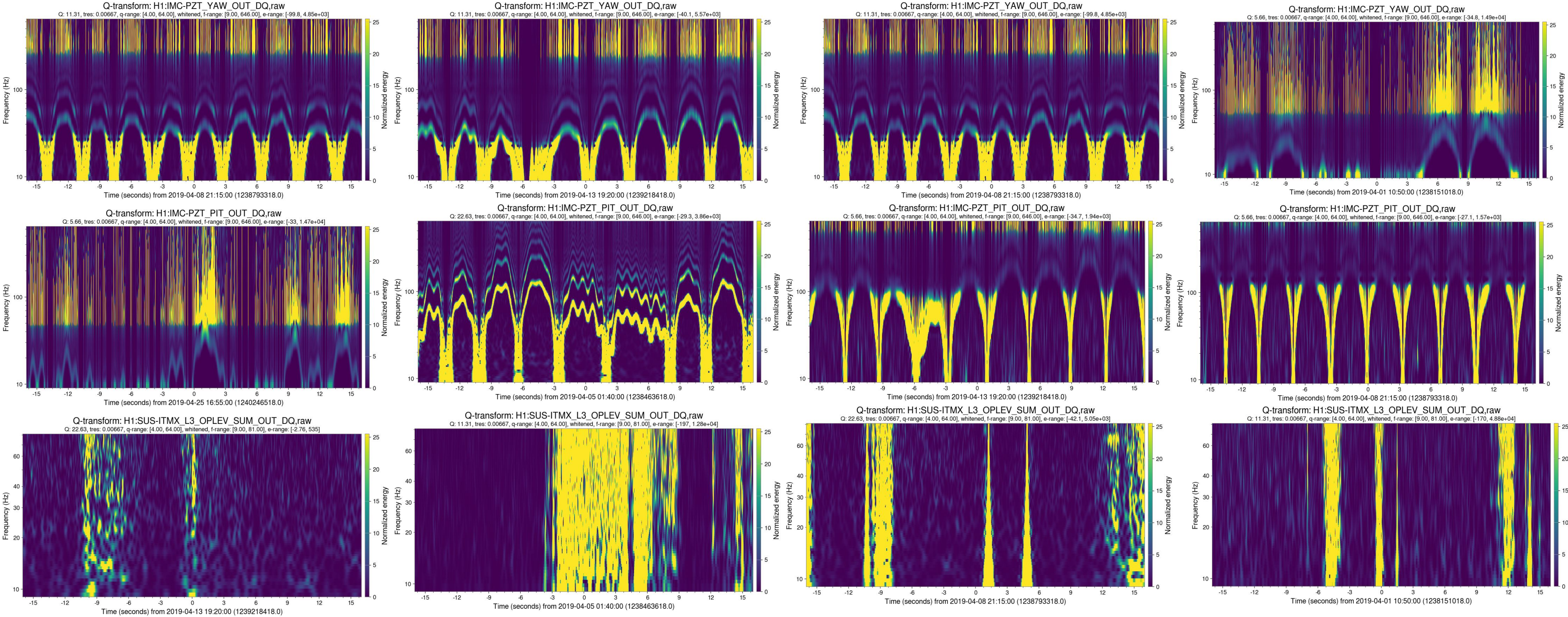
Notable Noisy Channels:

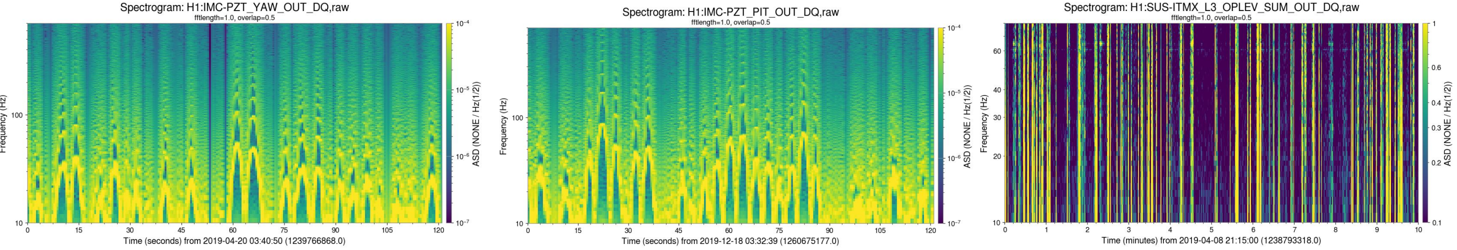
IMC Actuators*:
H1:IMC-PZT_YAW_OUT_DQ +
H1:IMC-PZT_PIT_OUT_DQ:

IMC Mirrors*:
H1:IMC-MC1_YAW_OUT_DQ
H1:IMC-MC3_YAW_OUT_DQ
H1:IMC-MC2_PIT_OUT_DQ

Test Mass Suspensions:
H1:SUS-ITMX_L3_OPLEV_SUM_OUT_DQ

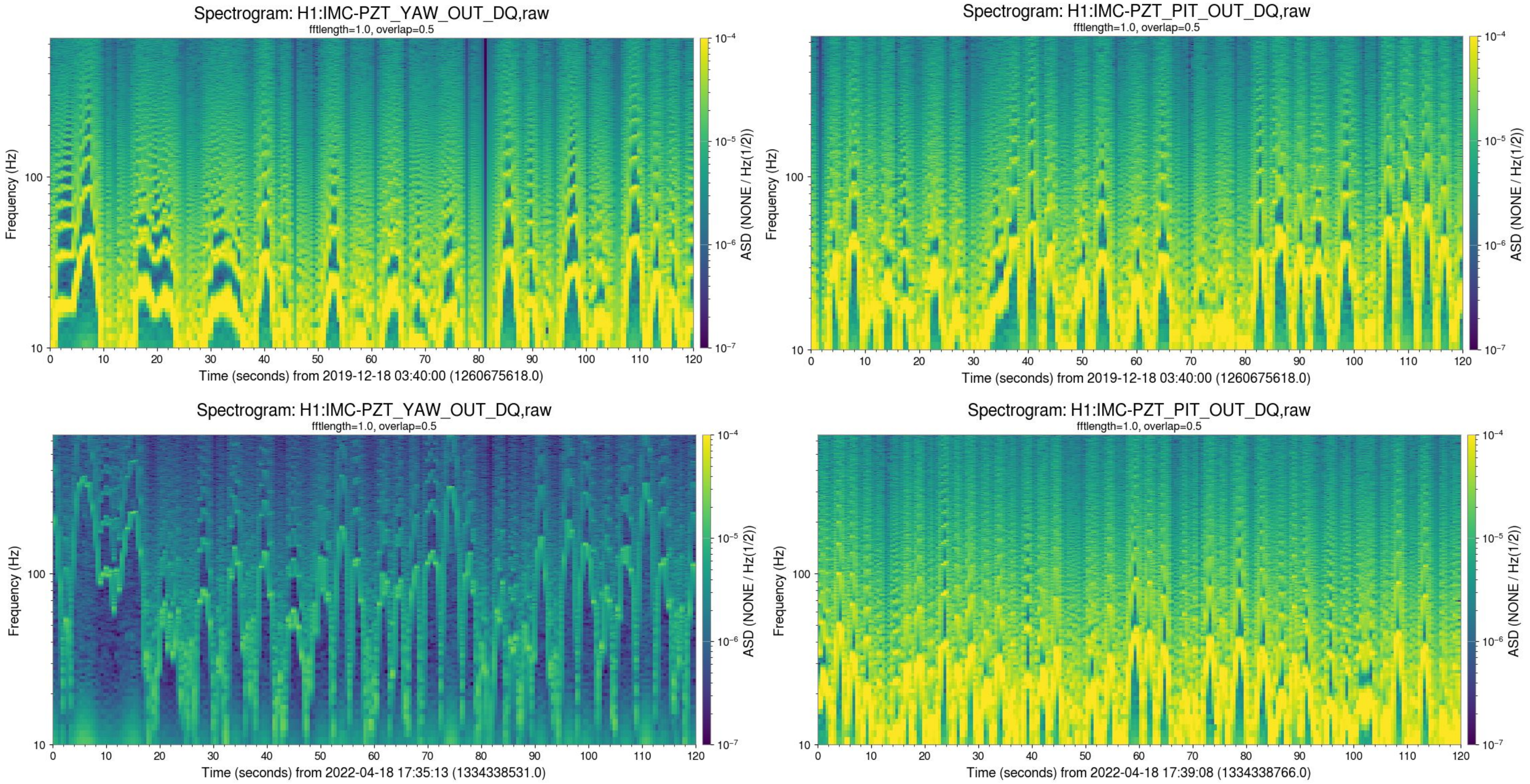
*Noise associated with limited “streaming” quality of data.





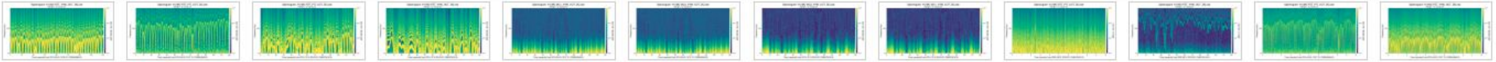
Noisy Channel Examples

3. Example Detected Noisy Channels



Noise in Both PIT, YAW, orientations of piezoelectric actuator sensor.

Images attached to this report



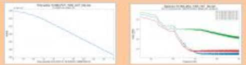
Comments related to this report

andrew.lundgren@LIGO.ORG - 01:52, Thursday 08 September 2022 (64900)DetChar Link

This is usually a symptom of quantization, or badly-tuned whitening. In the time domain (plot 1) there's a very big DC offset and a lot of stair-stepping. There are no features visible in the spectrum (plot 2) above a few Hz for the MCs, and 1 Hz for the PZT. I think the way to fix this is to change the analog whitening so the high frequencies are boosted more going into the ADC. It may not be worth changing though, since these are likely just slow alignment channels and any motion above a Hz doesn't couple into anything else.

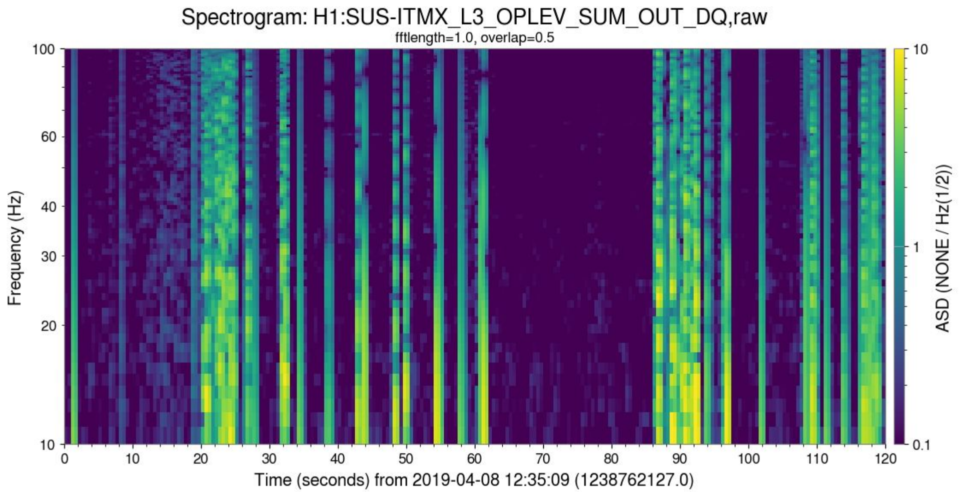
Edit: On thinking about it a bit more, this is actually more a problem on the digital side. A single-precision float can't represent both the large DC value and the small changes in the channel. A PDF of a notebook is attached showing with more details, including a simple diagnostic test if anyone needs to automate checks for this problem.

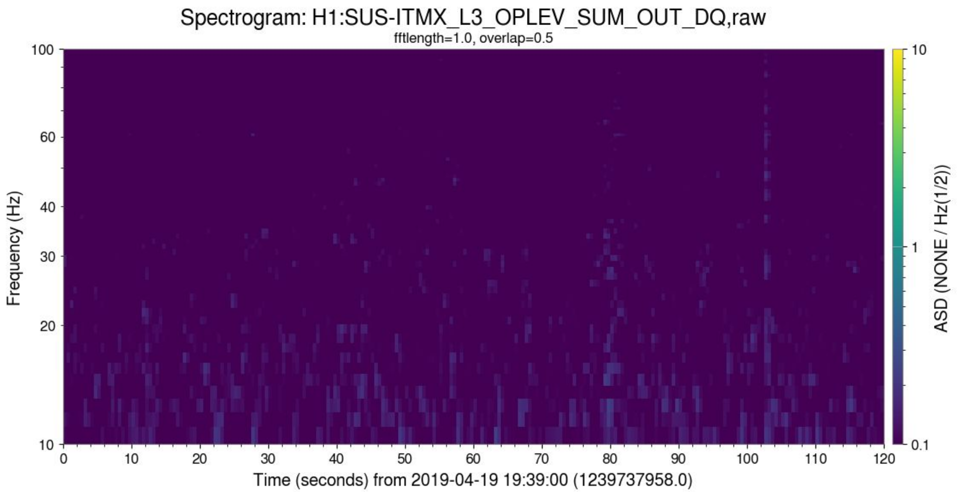
Images attached to this comment

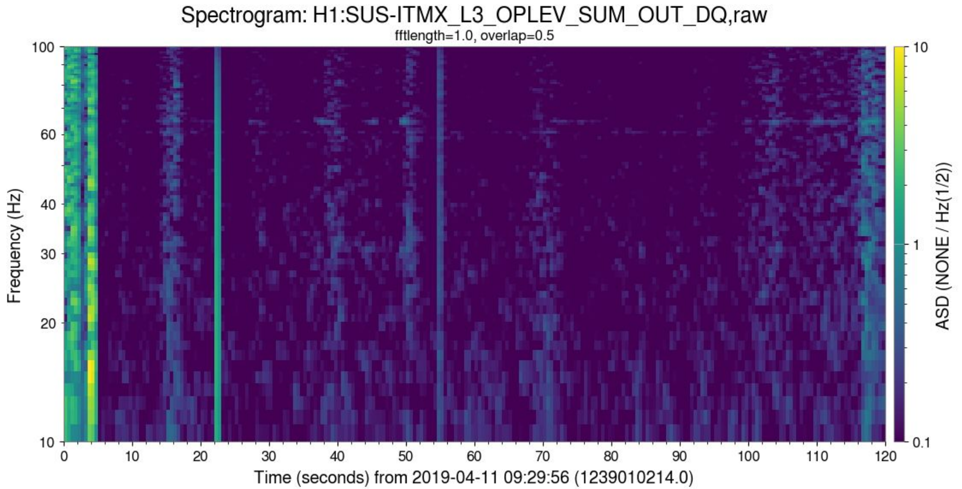


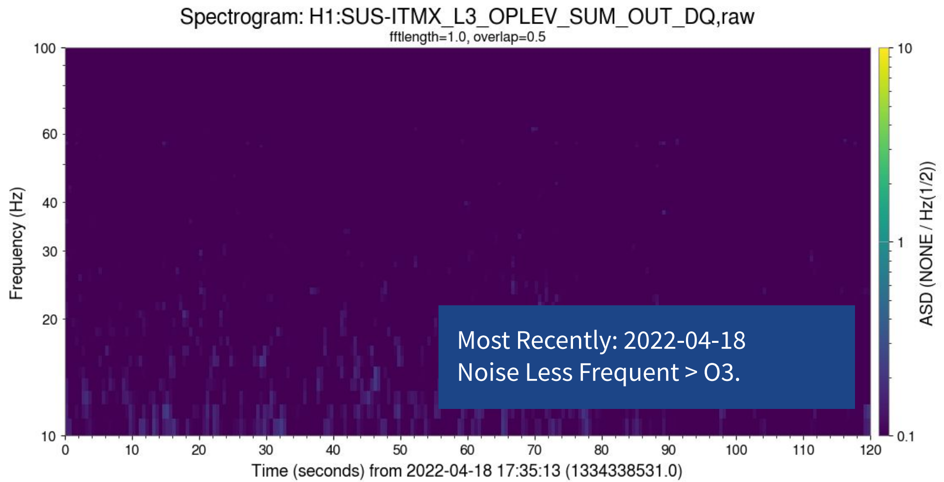
Artifacts of limited data quality when whitening:

Large DC values measured in IMC channels are not fully represented precisely by one float value along with small steps between these large DC values - hence the large sweeps.









Most Recently: 2022-04-18
Noise Less Frequent > O3.

H1:SUS-ITMX-L3_OPLEV_SUM_OUT_DQ

Next Steps

1. Currently compiling documentation on all detected “noisy” channels in Hanford over the course of O3.
2. Hope to test scripts on engineering data, and compare them to O3 trends before the next observing run.