Outliers in minute trends for L1:ASQ-LSC-AS_Q and suggested vetoed times

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1 Introduction

I collected the minute trends for all six interferometer channels, and sensitivity and noise indicators in the web page `http://www.phys.lsu.edu/faculty/gonzalez/S2Trends/L1/`. The interferometer channels are L1:LSC-AS_Q ("gravity wave" channel, error signal of the differential arm length loop); L1:LSC-AS_I; L1:LSC-POB_I (error signal of recycling cavity length loop); L1:LSC-POB_Q (error signal of Michelson loop); L1:LSC-REFL_I (error signal of sum of arm lengths loop), and L1:LSC-REFL_I. The information in channel L1:LSC-AS_I is not well understood, except that is known to be very sensitive to alignment fluctuations; it is however used in a servo loop that feeds back to the electronic signal (not to mirror positions). The channel L1:LSC-REFL_Q has in principle only information on residual Michelson length, but again it is not well understood and observed to be sensitive to alignment fluctuations. This channel is not used as an error signal, so the mean value is not close to zero.

The other channels included are L1:LSC-LA_PTRT_NORM, L1:LSC-LA_PTRR_NORM (proportional to arm powers in the X and Y arms, respectively), L1:LSC-LA_SPOB_NORM (proportional to sideband power in the recycling cavity), and L1:LSC-AS_DC (proportional to DC power in the antisymmetric photodiode). The signal of the gravitational wave is in principle proportional to $\sqrt{(PTRT + PTRR) * SPOB}$; the shot noise in the gravitational wave signal is proportional to AS_DC.

Each of these channels (and of all DAQ channels in general) is "minute trended", which means that for every minute, the mean value and the maximum and minimum values during that minute are stored on disk, labeled by the GPS time of the beginning of the trended minute. The analysis presented here is based on the minute trends of these channels, considered only at times when the interferometer was in "science mode", as indicated by the minimum value of L1:IFO-SV_STATE_VECTOR during that minute being 65534. The minute trends were retrieved using DataViewer.

Finally, two other time series were retrieved, produced by SenseMon: L1:LSC-Range_kpc, indicating the range of the interferometer to binary neutron systems with average orientation; and L1:LSC-CalLine_Ampl_ASQcounts, indicating the amplitude of the calibration line at 927.7 Hz. These quantities are calculated once per minute, and saved in frame files that can also be retrieved with DataViewer.

The time series and histograms of the interferometer channels are presented in Figs. 1-5.

2 Outliers in L1:LSC-AS_Q

The histogram of the peak to peak values in L1:LSC-AS_Q minute trends is shown in Fig. 6. The median value is 25 counts; the largest and smallest values are 404 counts and 12 counts, respectively. The histogram shows a double peak structure, and a change in slope for fluctuations larger than about 40 counts. I fitted a straight line to the log-log plot of the histogram between 45 and 70 counts. If we assume the distribution of large values would follow this straight line, then values above 90 are "outliers", as shown in the lower panel of Fig. 6. There are only 24 such points in the minutes trended. It is apparent, however, that there is an excess of minutes with peak-to-peak ASQ values larger than 70 counts. We define as "ASQ outliers" the minutes when the ASQ peak to peak value is larger than 70.

There were 31,558 points (minutes) in the times series trended, or a total of a 526 hours. This does not include some science mode times in S2 for which the trend was unavailable; and in general does not include as much as 59 seconds at the beginning or the end of a science segment, since the trends are produced at 60 second intervals not necessarily coincident with the start or end of science segments. The 89 outliers defined above constitute 0.28 % of the time analyzed.

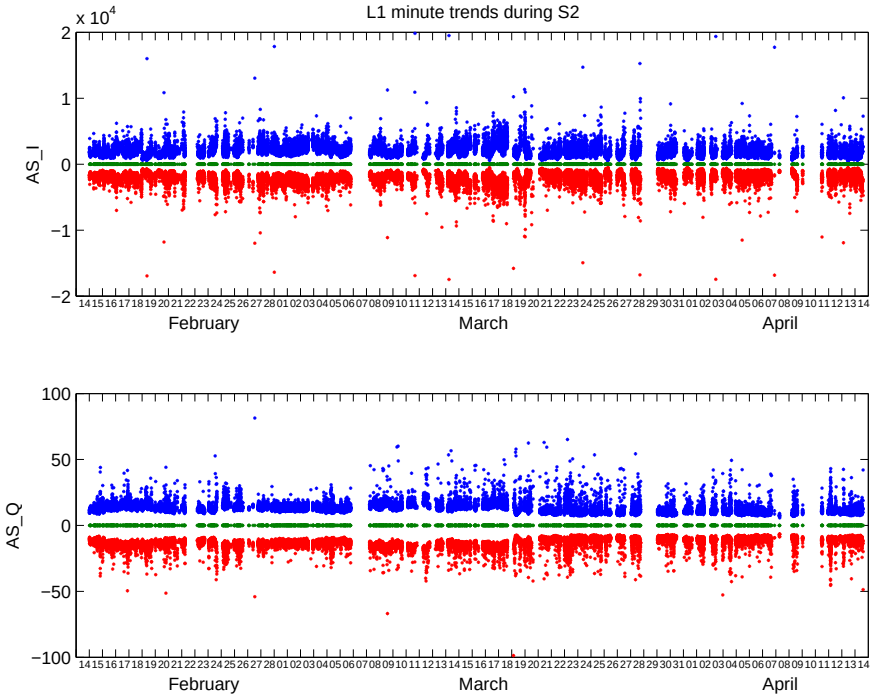

Figure 1: Minute trends of L1:LSC-AS_I and L1:LSC-AS_Q in science segments during S2.

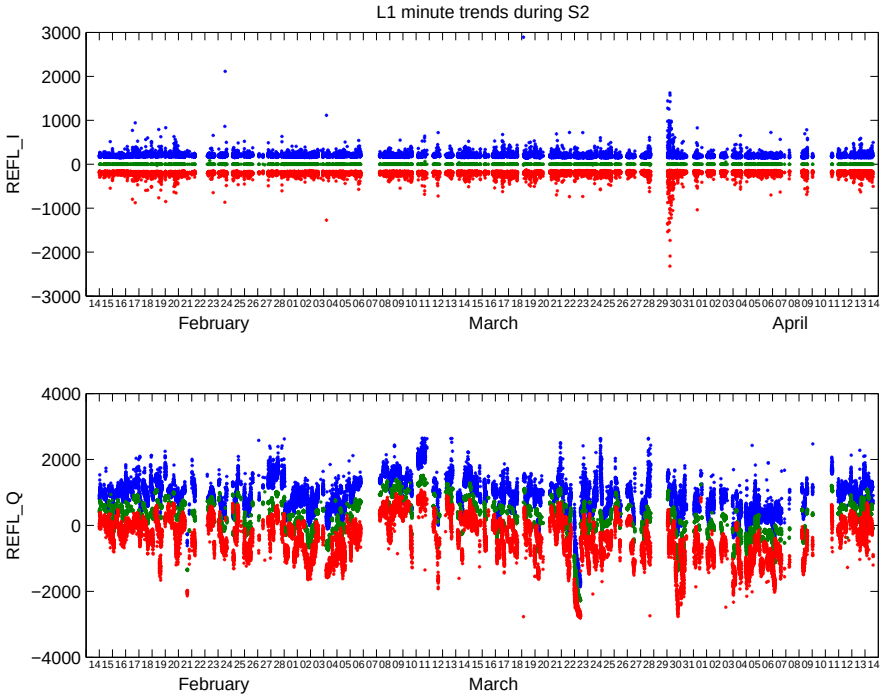

Figure 2: Minute trends of L1:LSC-REFL_I and L1:LSC-REFL_Q in science segments during S2.

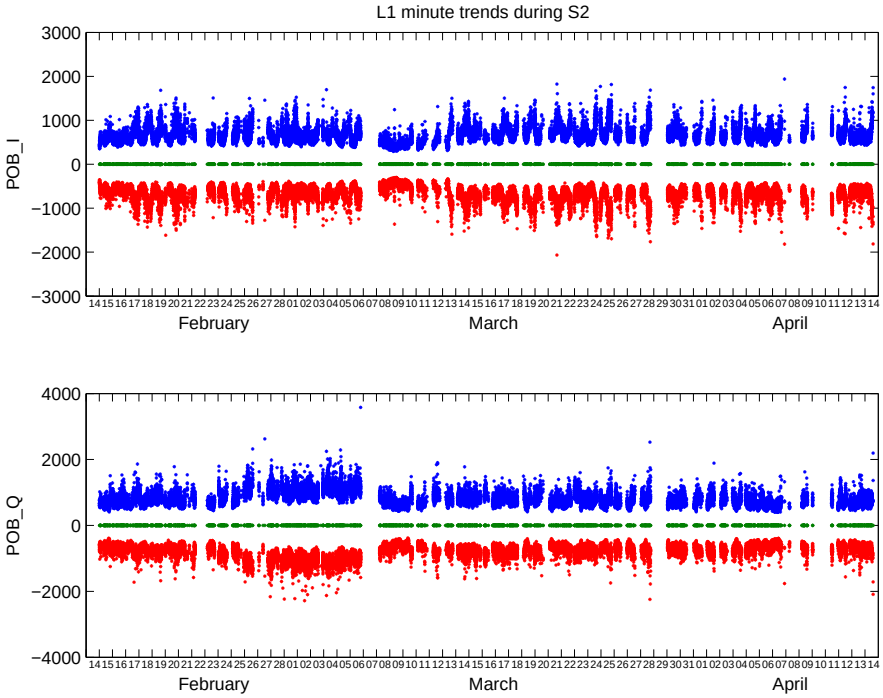

Figure 3: Minute trends of L1:LSC-POB_I and L1:LSC-POB_Q in science segments during S2.

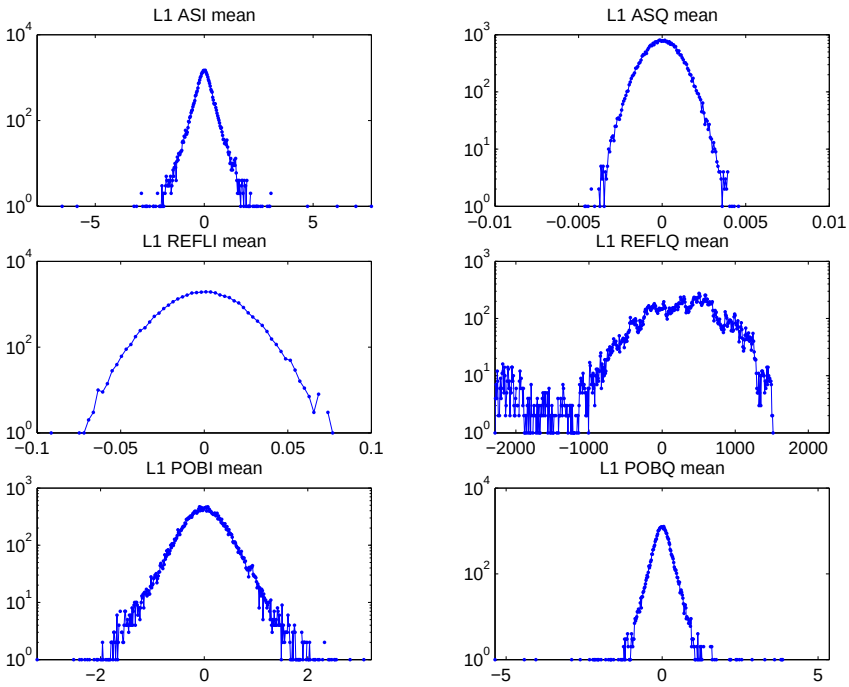

Figure 4: Histogram of mean values of minute trends of L1:LSC-(AS_I, AS_Q, POB_I, POB_Q, REFL_I, REFL_Q) during S2 science segments.

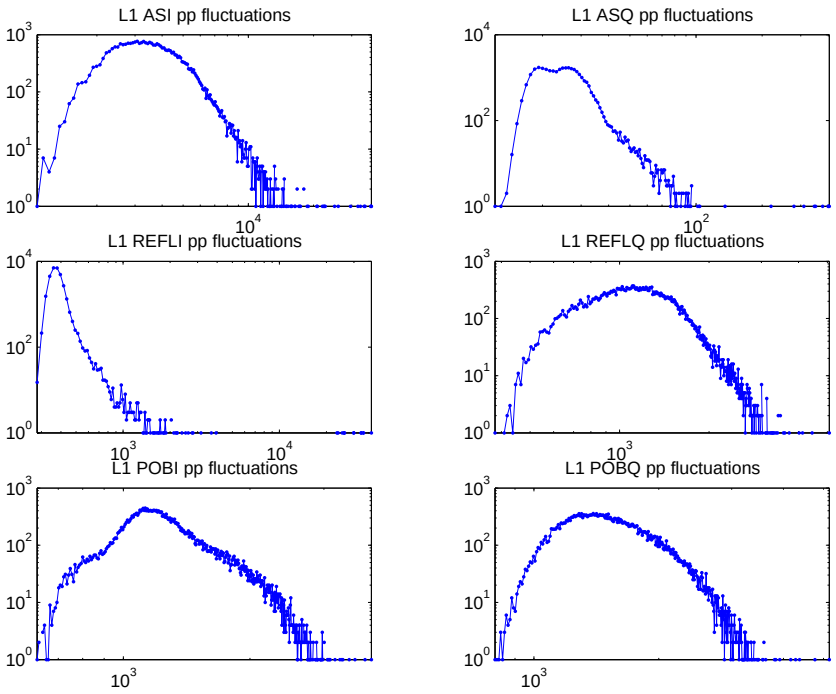

Figure 5: Histogram of peak-to-peak (max-min) values of minute trends of L1:LSC-(AS_I, AS_Q, POB_I, POB_Q, REFL_I, REFL_Q) during S2 science segments.

I have made plots of science segments containing ASQ peak to peak values larger than 140 in `http://www.phys.lsu.edu/fa` ordered by descending magnitude of the outlier. The time of the outlier is indicated in all of the trend of the interferometer channels. From these plots, one can classify the outliers in the following categories:

- Outliers at the end of the segments (last or next to alst minute trended). In these cases, we propose to veto the time between the beginning of hthe minute containing the outlier and the end of the segment.
- Correlated outliers: outliers simultaneous (within the one minute correlation) with glitches in other channels. A "glitch" is loosely defined as a value in the peak-to-peak minute trend which is significantly higher than the few previous and following minutes, and/or significantly higher than the average in that segment. **We propose to veto the minute containing the outlier in the ASQ minute trend, when a glitch is seen in the same minute in at least another interferometer channels, not being ASI**.
- ASQ-only outliers: a large, outlier, peak-peak value in ASQ, not coincident with glitches in the minute trends of any other of the channels investigated. We do not propose any veto associated with these outliers.

3 List of outliers

The tables below has a complete list of the outliers, with the following color code:

- red are outliers at the end of segments. We propose to veto the time between the GPS time of the outlier and the end of the segment.
- black are the outliers that are coincident with glitches in other channels (and their GPS times are the beginning of minutes that we propose to veto).
- green are ASQ outliers which are not found coincident with glitches in other channels; or ASQ outliers found coincident with glitches only in ASI. We do not propose any vetoes associated with the times of these outliers.

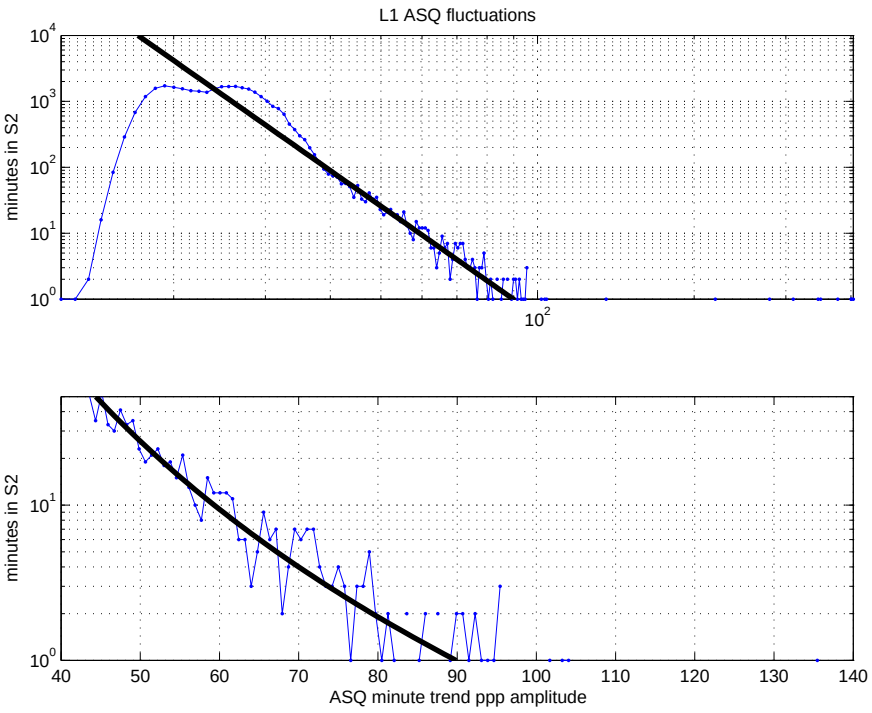

Figure 6: Histogram of peak-to-peak (max-min) values of minute trends of L1:LSC-AS_Q during S2 science segments. A log-log fit with a linear function for the histogram between 60 and 100 counts is also shown.

Outlier#	Science Seg#	GPS time	ASQ pp value	Other glitching channels
1	530	733402620	404.1	
2	483	732905880	400.9	
3	571	733787220	400.0	
4	303	731656320	377.5	
5	67	729680220	350.2	
6	434	732532020	345.8	
7	269	731433840	310.2	
8	149	730513680	279.2	
9	373	732078780	219.8	
10	133	730385460	135.5	Short segment (86sec)
11	421	732431880	104.4	ASI
12	398	732278460	103.4	
13	391	732176520	102.1	
14	399	732296520	95.5	
15	477	732876780	95.4	
16	80	729804240	95.4	ASI, POBI, POBQ REFLI
17	376	732094560	94.7	ASI
18	375	732091740	93.7	
19	249	731315820	92.9	
20	532	733447860	92.1	Next to last
21	544	733504980	92.0	
22	44	729552600	91.3	ASI, POBQ, REFLI
23	606	734367000	90.7	Short segment (472 sec)
24	251	731323920	90.4	
25	445	732608940	90.0	
26	307	731670180	89.8	
27	376	732094920	89.1	ASI, REFLI
28	582	734154180	87.7	ASI
29	303	731653260	87.5	
30	235	731253720	85.9	
31	428	732465360	85.6	Next to last
32	277	731506980	85.1	POBQ; short segment (278 sec)
33	365	732016440	83.6	
34	394	732206760	83.4	
35	582	734153640	82.2	
36	549	733575240	81.3	
37	251	731325000	80.9	POBI, REFLI
38	11	729375120	80.3	
39	215	731141340	79.6	
40	582	734153940	79.5	ASI
41	237	731262780	79.1	ASI
42	103	730125900	79.1	
43	308	731675160	79.1	
44	229	731223900	79.1	
45	10	729373980	78.8	
46	276	731503980	78.2	
47	568	733762020	78.2	
48	230	731228280	77.9	
49	293	731584980	77.7	
50	105	730133400	77.5	ASI, POBQ, REFLI

Outlier#	Science Seg#	GPS time	ASQ pp value	Other glitching channels
51	422	732448740	77.2	
52	596	734290620	76.8	POBI, POBQ, REFLI
53	399	732291720	76.0	ASI, POBQ, REFLI
54	582	734152860	75.8	ASI
55	217	731165580	75.6	
56	543	733498680	75.0	REFLI
57	422	732450600	74.8	
58	366	732022260	74.8	
59	37	729529920	74.7	ASI, REFLI, POBQ
60	263	731411220	74.2	Short segment
61	543	733496700	73.9	
62	450	732632520	73.9	ASI, POBQ
63	283	731510880	73.6	
64	591	734238120	73.4	ASI, POBI, POBQ, REFLI
65	543	733496940	73.2	
66	422	732450480	72.9	ASI
67	335	731883720	72.9	ASI
68	411	732362940	72.4	ASI, POBQ
69	467	732775320	72.3	
70	471	732807120	72.2	
71	286	731519820	72.1	
72	545	733532520	72.0	
73	530	733386360	72.0	ASI
74	486	732910560	71.9	ASI
75	543	733497540	71.9	
76	229	731224560	71.9	
77	544	733504800	71.3	
78	331	731832720	71.2	
79	582	734154840	71.0	
80	383	732123060	70.9	
81	74	729737400	70.8	ASI, POBI, REFLI
82	330	731825760	70.7	
83	315	731742360	70.7	
84	314	731726640	70.3	
85	383	732123000	70.2	Next to last
86	435	732536820	70.2	
87	45	729556260	70.1	
88	104	730127520	70.1	Short segment (146 sec)
89	280	731509140	70.0	Next to last, short segment (160 sec)