EDGES MEMO #397

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To: EDGES Group

From: Alan E.E. Rogers

Subject: Preliminary analysis of EDGES-3 data taken on Devon Island

The EDGES-3 setup near the HMP base camp is described by John Barrett, Rigel Cappallo and Jason Soohoo in memo 396. EDGES data was taken from 2022 day 220 to 235 summarized in Table 1

Date	data used	Calibration files	Antenna S11	comments
2022-220			s11ant220.csv	
2022-221	Y			Temp control set to 20C
2022-222		specal222.txt	s11ant222.csv	rain 18 to 22 UT
2022-223	Y			
2022-224		specal224.txt	s11ant224.csv	Temp control set to 10C
2022-225	Y			
2022-226	Y			
2022-227		specal227.txt	s11ant227.csv	Temp control set to 10C
2022-228				
2022-229	Y			Solar burst M2.05 ~14 UT
2022-230	Y			
2022-231	Y			
2022-232	Y		s11ant232.csv	bad s11 probably due to moisture
2022-233	Y			Internal battery test
2022-234				Cover resonance missing gasket
2022-235			s11ant235.csv	or intermittent bad connection

Table 1 List of days and data.

The data is affected by solar bursts. Figure 1 shows the solar event at about 14 UT on 17 August 2022 from the Sun which is labeled as a M2.05 event on the GOES web site. This is an example of just one of several strong events of thousands of degree Kelvin which are filtered out in the subsequent analysis:

Analysis of 1 hour data blocks

Reasonably low residuals of under 300 mK with 5 terms removed are obtained using the standard filter parameters of

-rfi 2.5 -tcal 1000 -pfit 37 -fstart 40 -fstop 120 -smooth 8 -pkpwrm 40 -peakpwr 10 -minpwr 0.7 -nrfi 4 -dloadmax 1000 -adcov 0.4 -maxrmsf 100 -maxfm 200

for acqplot7amoon and filter threshold in first stage of longav

-lim 0.3 -nfit 5 -dmax 1 -fstart 65 -fstop 110 -schk 0 -tchk 200 -rfi 0 -sig 0 for each 1 hour block of each day and

-lim 0.3 -nfit 5 -dmax 0.5 -fstart 69 -fstop 110 -seor -1 -tau 7 -sig 30 -md 1 -fsmin 70 -fsmax 85 -rfi 2

in the second stage of longav.
These filtered results are shown for each set of up to 24 1-hour blocks averaged over each day in Figure 2 along with a VERY tentative verification that the Nature feature is present in the data in Figure 3. The problem is that the residuals rise sharply below 69 MHz. To help understand the effects of what might be a combination of solar emission, ionospheric absorption and other phenomena like "Sporadic E" I have plotted the 1 hour blocks with 1 term of spectral index -2.5 removed in Figure 4 along with some comments in Table 2 below:

Table 2 is a partial list of events seen in the 1 hour blocks

Date	UT times CDT = UT - 5	comments
225	11	Spectral event at strongest at low end
226	12	Spectrum rising at 51 MHz and not smooth
227	05 11 to 18	05 rising at 51 MHz 11 to 18 falling at 51 MHz
228	15,16,17	Large deviations in spectra with rms values
229	10 to 15	Falling at 51 MHz
230	22,23	Large dips
231	20	Deviations in spectrum at 100 MHz
232	03 to 18	Large smooth dip at 65 MHz due to moisture?
233	03 09 - 12	Rising power at 51 MHz
233	18 to 20	leakage from missing gasket or bad input connection

Table 2 list of changes in spectrum with 1 term removed from 51 to 110 MHz

The plots for each spectrum are on a scale of 100K per division which is necessary as the effects of the Sun and what might be Sporadic E are large and if not extremely smooth will make it difficult to extract the 21-cm signal. Note that most of the variation is at the low frequency end below 70 MHz with the exception of the noise introduced by what was initially thought to be the result of a break in the cover gasket at one screw location but was more likely an intermittently bad connection to the antenna pipes which started on day 233 at 20 UT. This problem not only resulted in large changes of the spectrum also resulted in very large changes in the antenna s11. A check of resistance made on September 24 when EDGES-3 returned to Haystack found that it probably resulted from an intermittently bad connection between the pipe with fiber and DC power cable and the box with the electronics. The connection probably became loose following the removal of the batteries used for the internal battery test (see memo 396) and the return to the connection to the external batteries for the remainder of the EDGES-3 observations. S11 data from 235_08 was bad and last S11 taken at 235_14 just before disassembly of the antenna for return to Haystack was consistent with the S11 measurements prior to the start of the problem on day 233.

Figure 5 shows the residuals with 5 logpoly terms removed 60 to 100 MHz prior to excluding the 1 hour blocks with rms greater than 300 mK used in the final stage of filtering. The plots in Figure 4 are similar to those of the Sun in MRO EDGES-1 data shown in Figure 1 of memo 159 but the data from the arctic is clearly much more complex.

The plots in Figure 5 are compared with plots of the EDGES-2 lowband data from 2016 days 344 to 355 shown in Figure 6 which have been processed in the same way as the EDGES-3 data. The comparison clearly shows that there are much larger residuals and larger changes in the data from Devon Island from day to day at the same time than in the data from the MRO especially below 69 MHz. It should be noted that the random noise in the MRO data is large at the transit of the Galactic center which is at about 3 UT for this data. This is expected as the Galactic sky noise is about a factor of 3 larger at the MRO with the Galaxy "UP" than it is at Devon Island.

Table 3 shows that the effects of using different calibrations and different antenna S11 measurements on the rms residuals listed in rms1 before including a grid search for an absorption with fixed value of tau = 7 are relatively small. The residuals listed in rms2, which are the residuals with the best fit feature parameters are large due to remaining systematics and the noise due to the limited set of only 9 days data. The significance of the results might be improved with more restrictive filtering the data to allow data below 69 MHz to be included.

Table 3

calibration	fcen MHz	snr	amp K	width MHz	rms1 mK	rms2 mK	Ant S11 day used
224	80.5	23.4	0.70	22.3	77.5	39.6	235
227	80.5	23.4	0.70	22.3	77.5	39.6	235
tst	80.5	23.4	0.70	22.3	77.8	39.9	235
tst	80.5	21.4	0.56	22.9	80.9	34.5	220
tst	80.1	20.7	0.66	22.0	58.6	43.5	222
tst	80.5	18.7	0.59	22.5	80.5	41.8	224
tst	81.7	20.1	0.61	18.8	64.9	46.2	227
tst	80.5	26.0	0.72	22.9	87.9	35.1	235 wbeam
tst	81.7	23.7	0.67	19.3	82.4	42.3	235 0.35

Table 3. Results of absorption feature solutions using 5 logpoly foreground terms from 69 to 110 MHz.

The tst calibration is the day 227 calibration with a small adjustment in the VNA path to the LNA. Beam correction was only used for the second from the last entry in the table. The last entry is obtained when the the rms limit on each 1 hour block is raised from 0.3 to 0.35 K which then included data from days 227 and 228.

The Devon Island data is severely limited by solar emission and what is most likely to be sporadic E reflections from the ionosphere which drive up the residuals very sharply below 69 MHz. In order to help understand the very complex environment I have plotted the residuals vs UT hour for the same first stage analysis used in figures 2 and 3 but without the 0.3 K rms threshold one hour block filter in Figure 7. This shows lower residuals around noon at the site.

Figures 8 shows that there are large variations on the residuals on the scale of minutes on day 225 especially below 69 MHz but note that there are also short periods of a relatively flat spectrum with lower rms. Figure 9 shows similar large variations on day 227 around local midnight when the sun is on the horizon. I have checked other days and times the time scale and magnitude of the changes are similar with less variation at local noon. This opens the possibility that applying a rms threshold filtering on a time scale shorter than 1 hour used might enable extending the frequency range below 69 MHz for a 21-cm absorption search. Figures 10 and 11 show the spectra with 5-terms removed from 65 to 110 MHz for 30 minute blocks with and without rms filter. Figure 11 can be compared with times of solar activity. The large deviations in the residuals above 69 MHz are definitely from the solar activity as the times of the activity agree with the solar activity data obtained by Rigel Cappallo from solar radio observatories shown in Figure 12.

Understanding the spectral variations below 69 MHz

Figures 8 and 9 show these “come and go” on a time scale of minutes and further tests the time scale is about a minute. The phenomenon is consistent with Sporadic E observed by the LWA reported by Obenberger, K. S., J. Dowell, C. T. Fallen, J. M. Holmes, G. B. Taylor, and S. S. Varghese. "Using broadband radio noise from power-lines to map and track dense Es structures." *Radio Science* 56, no. 2 (2021): 1-17. In the case of Devon Island it is also possible that some of the broadband “noise” could also include echoes the MAARSY 53.5 MHz radar.

More details of the resistivity tests made on the return of the antenna to Haystack

Using a standard ohmmeter in the normal 2-terminal mode with standard probes all metal to metal contacts were under 0.2 ohms with 2 exceptions one screw 0.5 ohms and ¾” chase nipple conduit (part 7513K18) tapped into threaded hole of bottom cover of electronics box 8 ohms. While the Hammond 1590G contact does not normally rely on the chase nipple it would rely on it if the 7513K242 lock nut is not tight enough to get good metal to metal contact between the bottom of the electronics box and the Hammond box attached to the pipe. Using the ohmmeter to probe the metal to the exposed edges of the gasket between the metal plates show a resistance under 2 ohms. FEKO simulations show S11 effects for covers in contact without screws has a large effect but with a slot at only one screw the effects are very small – also see EMI Rule-of-Thumb for Calculating Aperture Size Technical Notes. I have not been able to accurately reproduce pipe contact problem with FEKO simulations so I cannot be absolutely sure that an intermittent pipe connection was the problem that started on day 323.

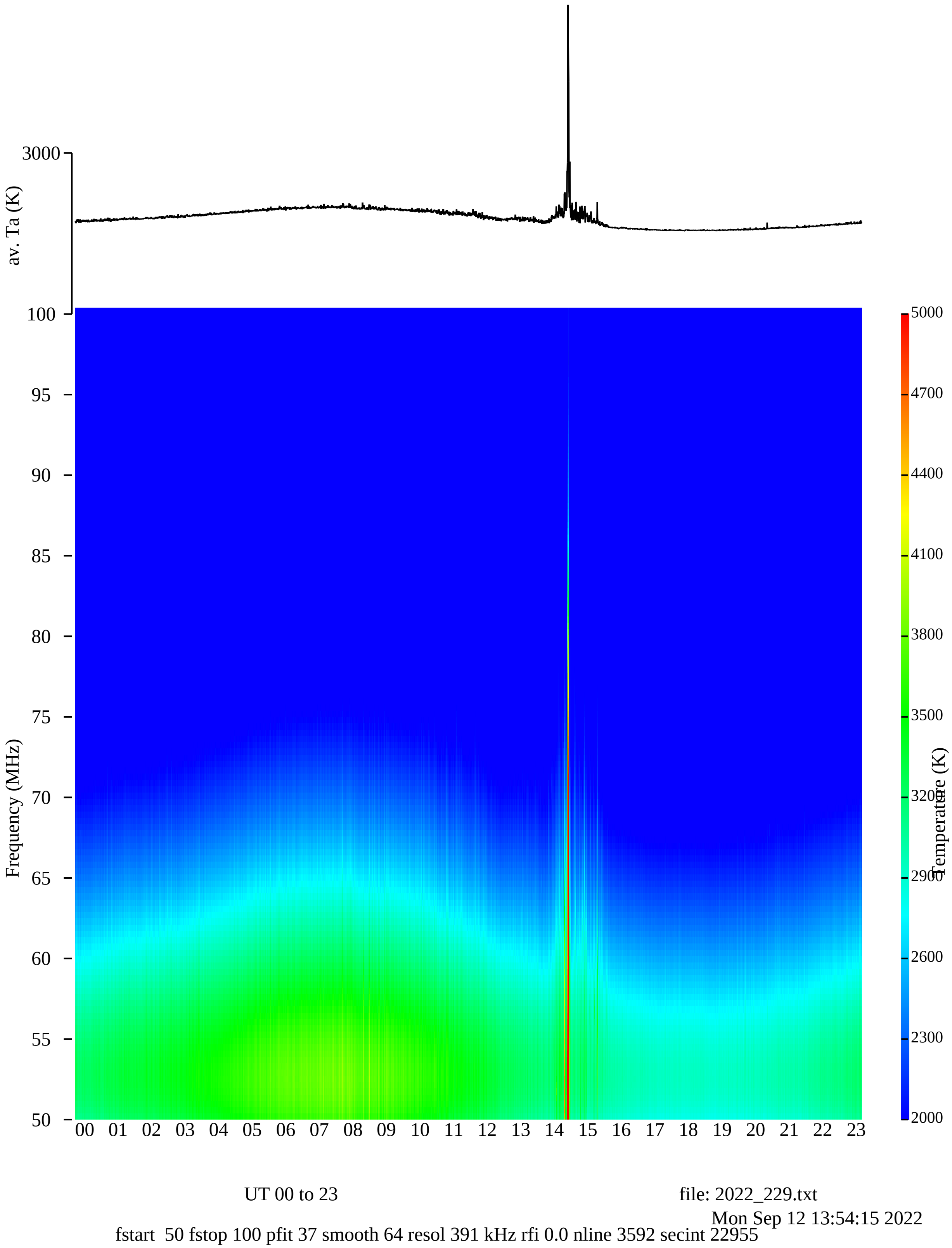

Figure 1 Waterfall plot of the data from day 229 17 August 2022 showing solar burst M2.05

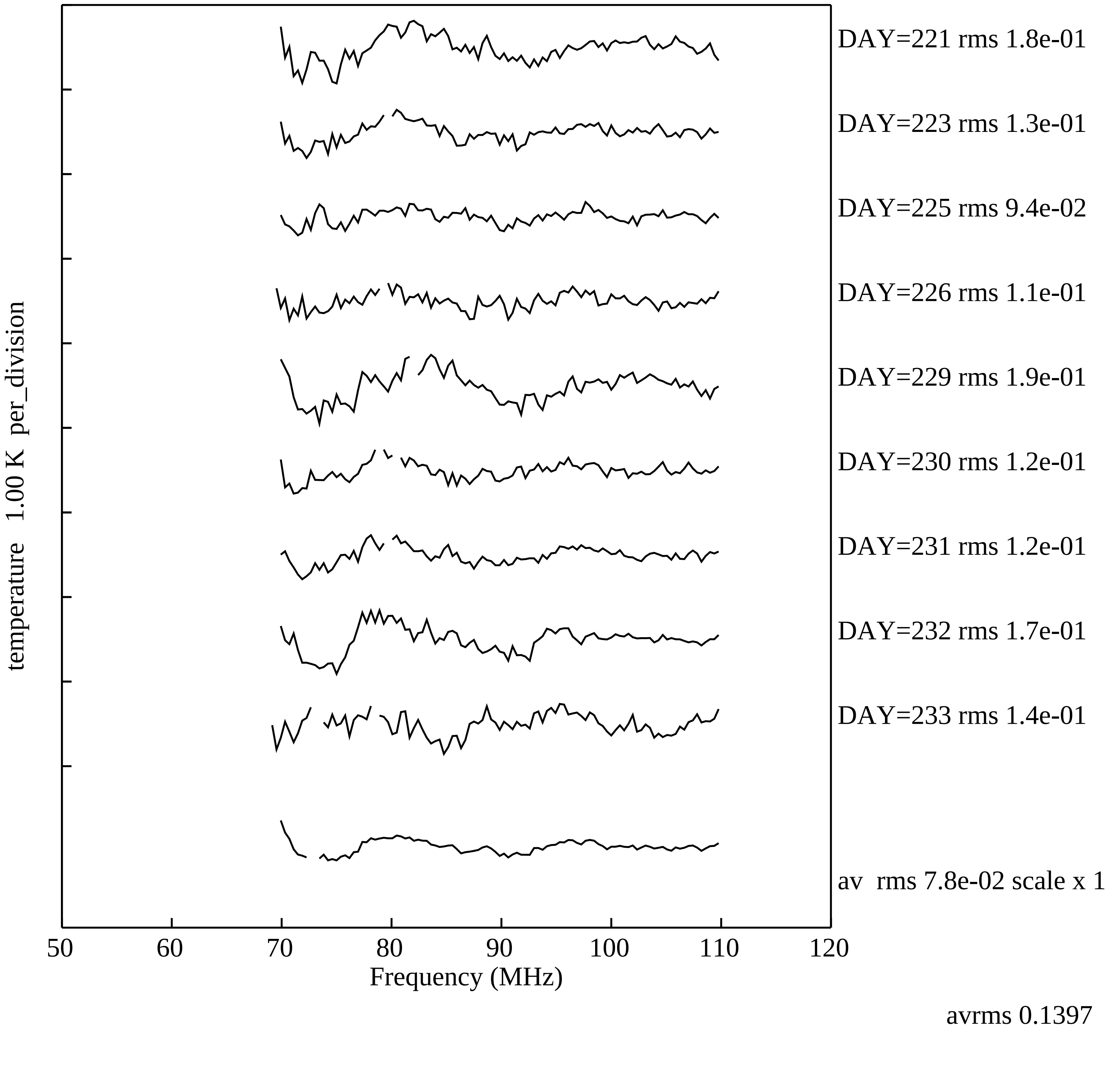

Figure 2. Filtered rms residuals using 5 logpoly terms prior to fitting absorption feature

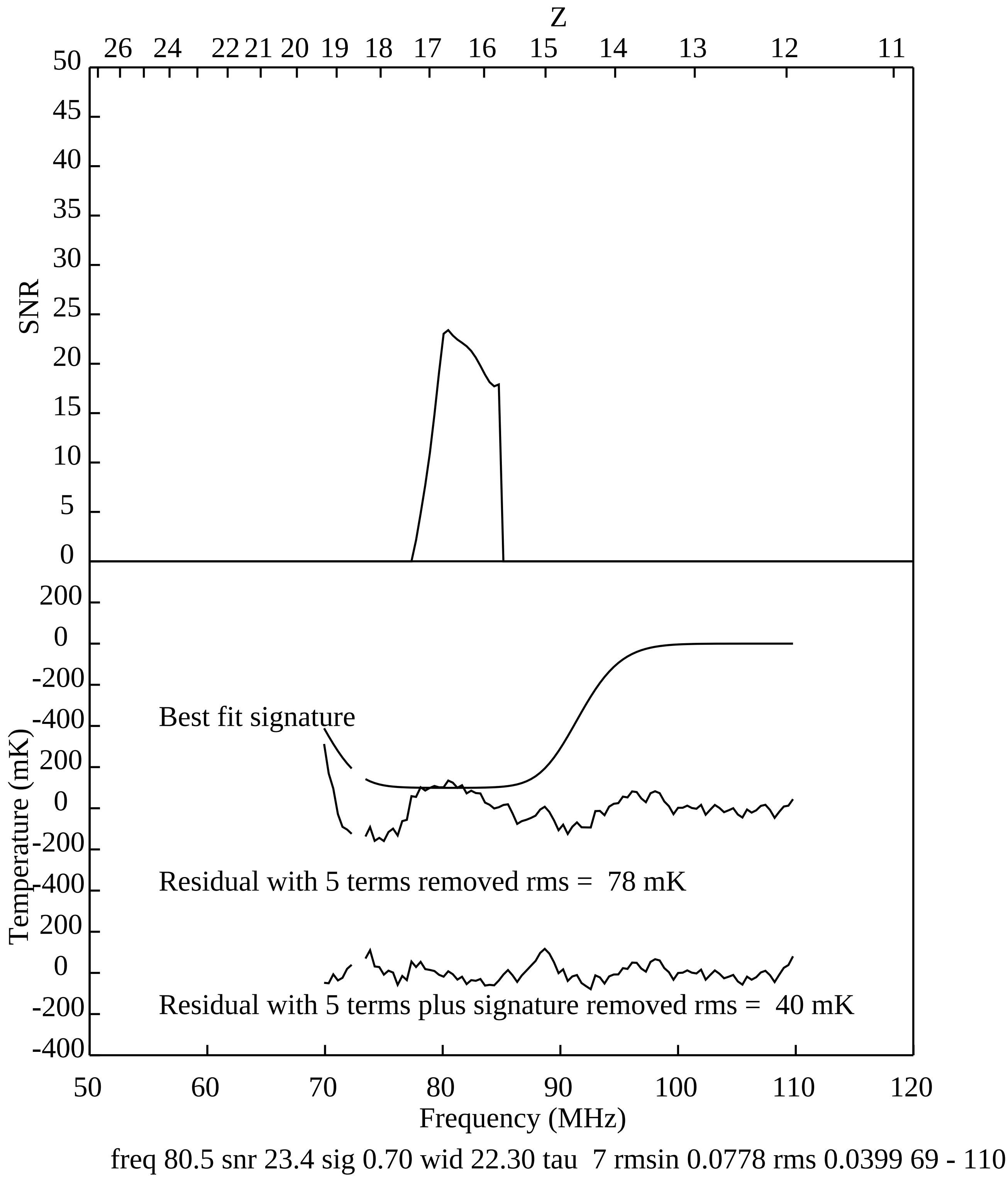

Figure 3. Best fit signature for fixed tau=7 using data shown in figure 2

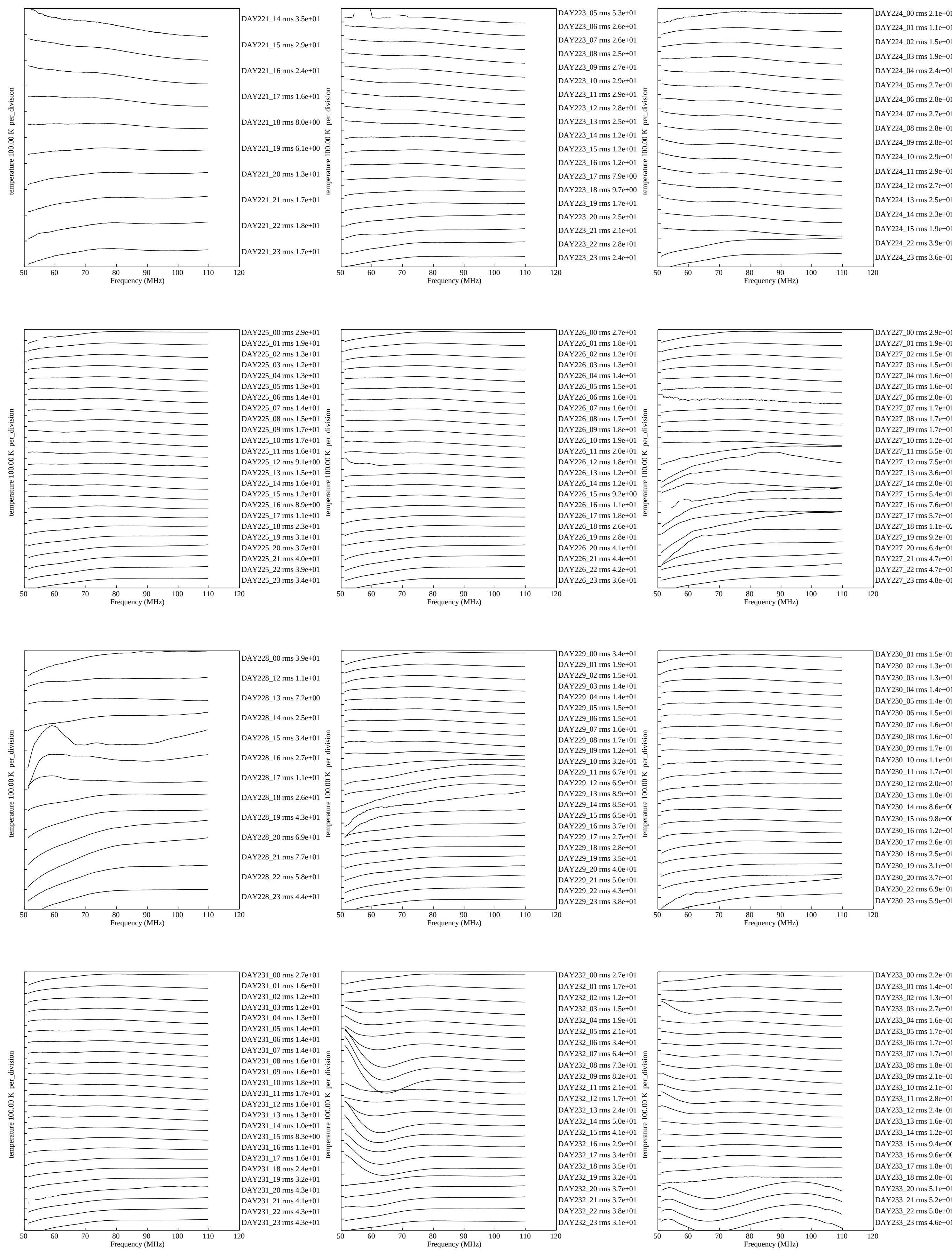

Figure 4. Residuals for using 1-term with spectral index -2.5 for all 1 hour blocks using only first stage filtering

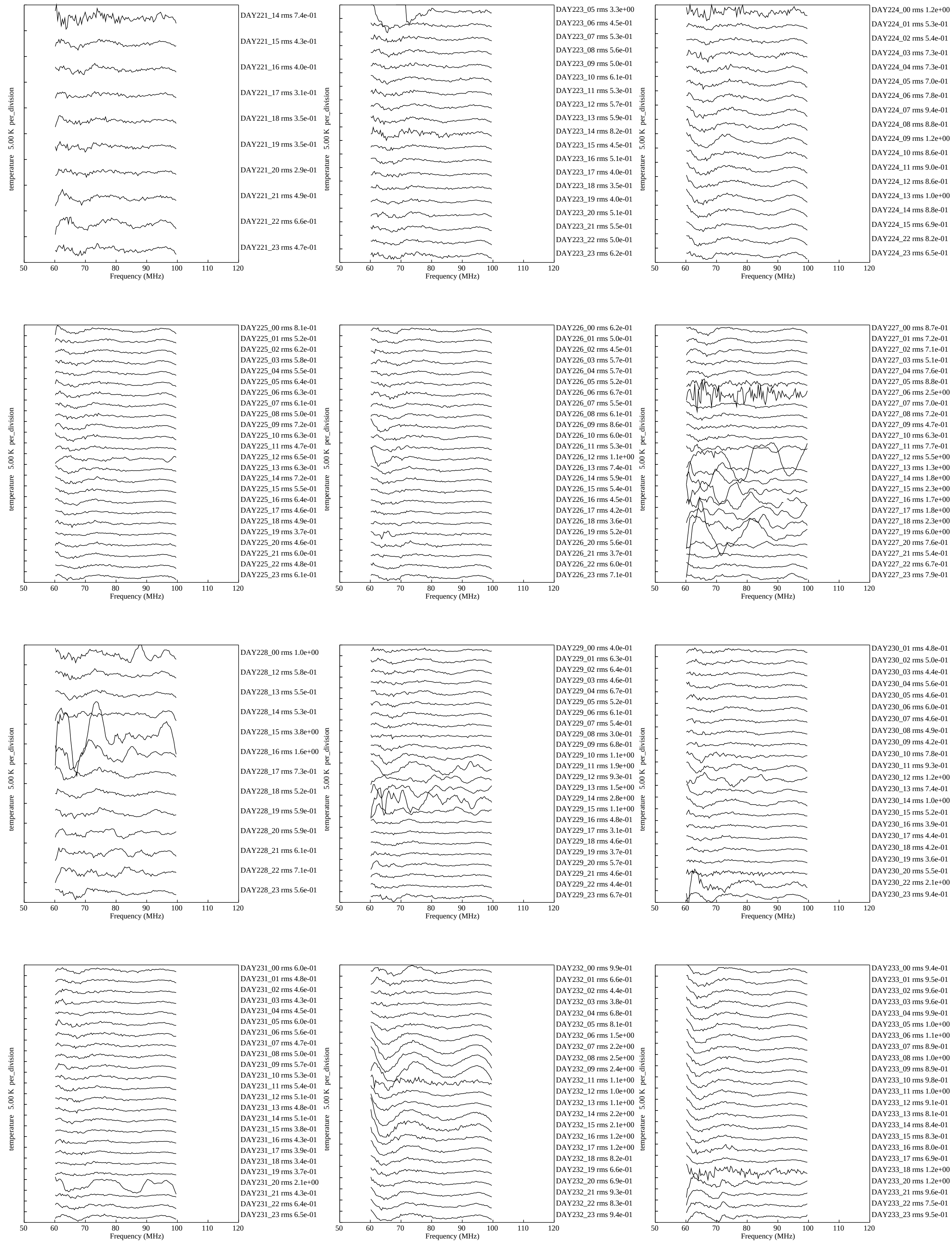

Figure 5. Residuals for all 1 hour blocks with 5 logpoly terms 60 to 100 MHz

Figure 6. Data from the MRO 2016 day 344 to 355 for comparison

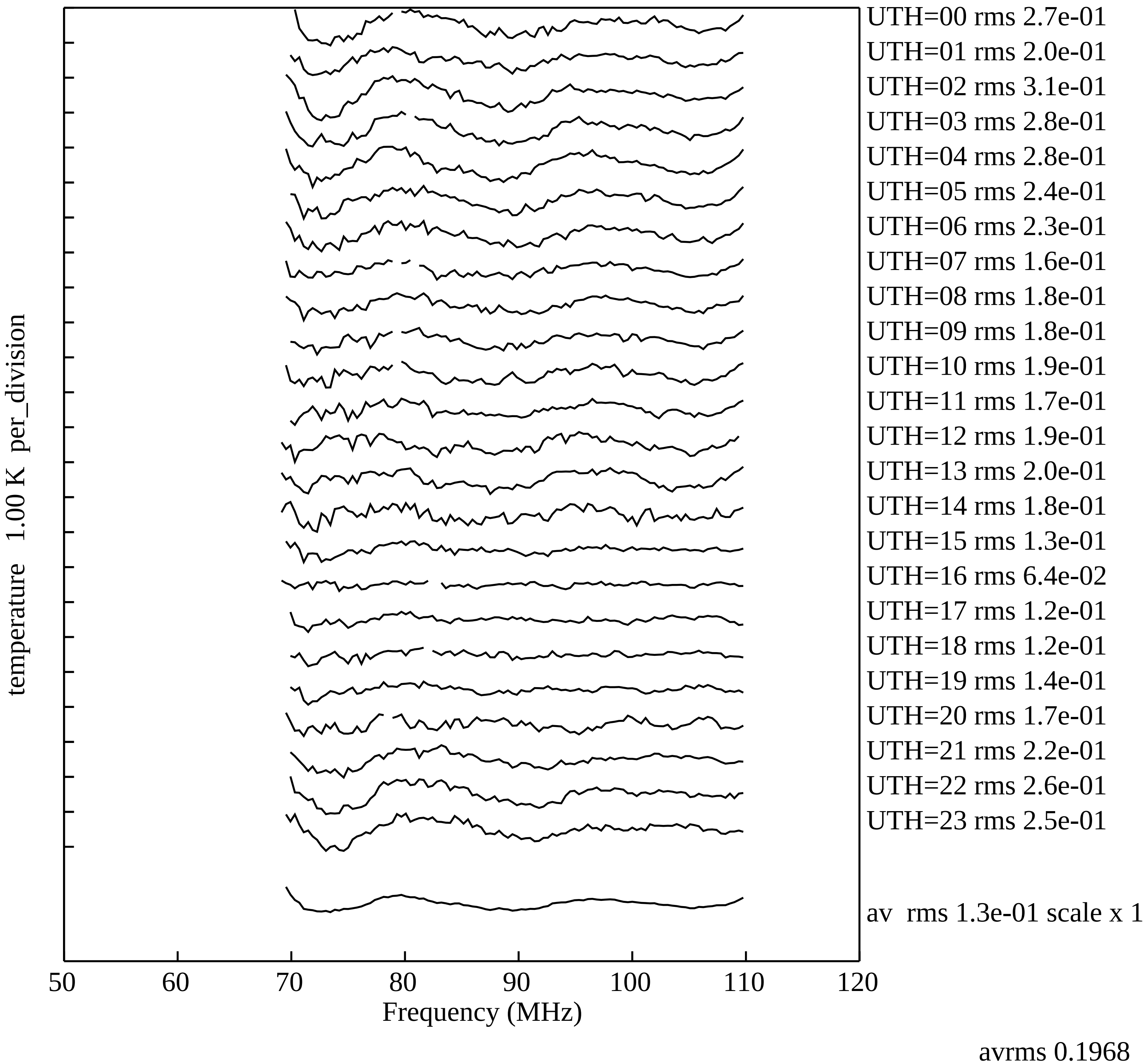

Figure 7. First stage filtered rms residuals vs UT hour with 5 logpoly terms removed averaged over days 221 to 231

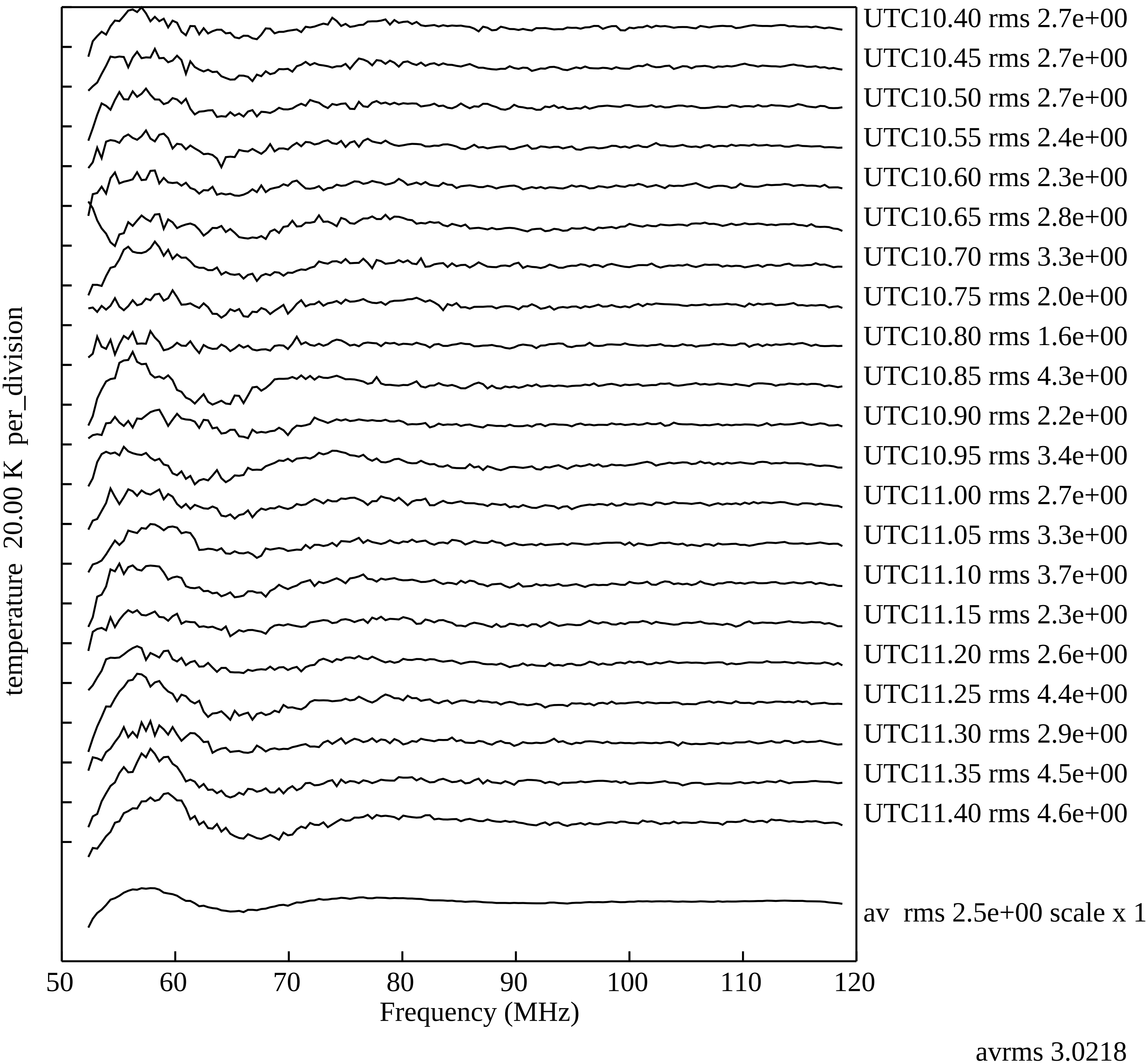

Figure 8. Spectra with 5 logpoly terms removed for twenty 3 minutes blocks from 10:16 to 11:17 UT on day 225

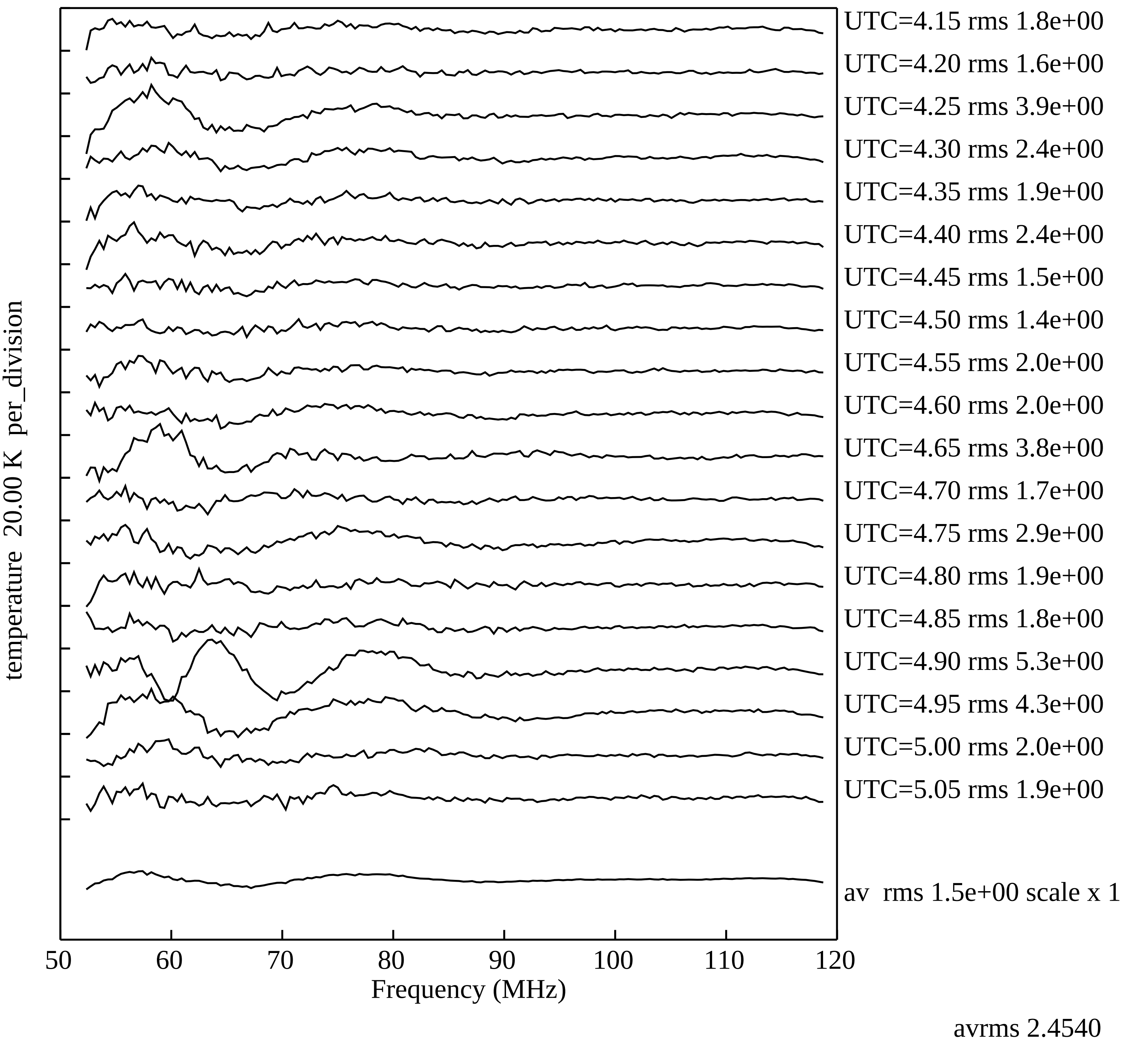

Figure 9. Spectra with 5 logpoly terms removed shows similar event which peaks at 04:54 UT on day 227

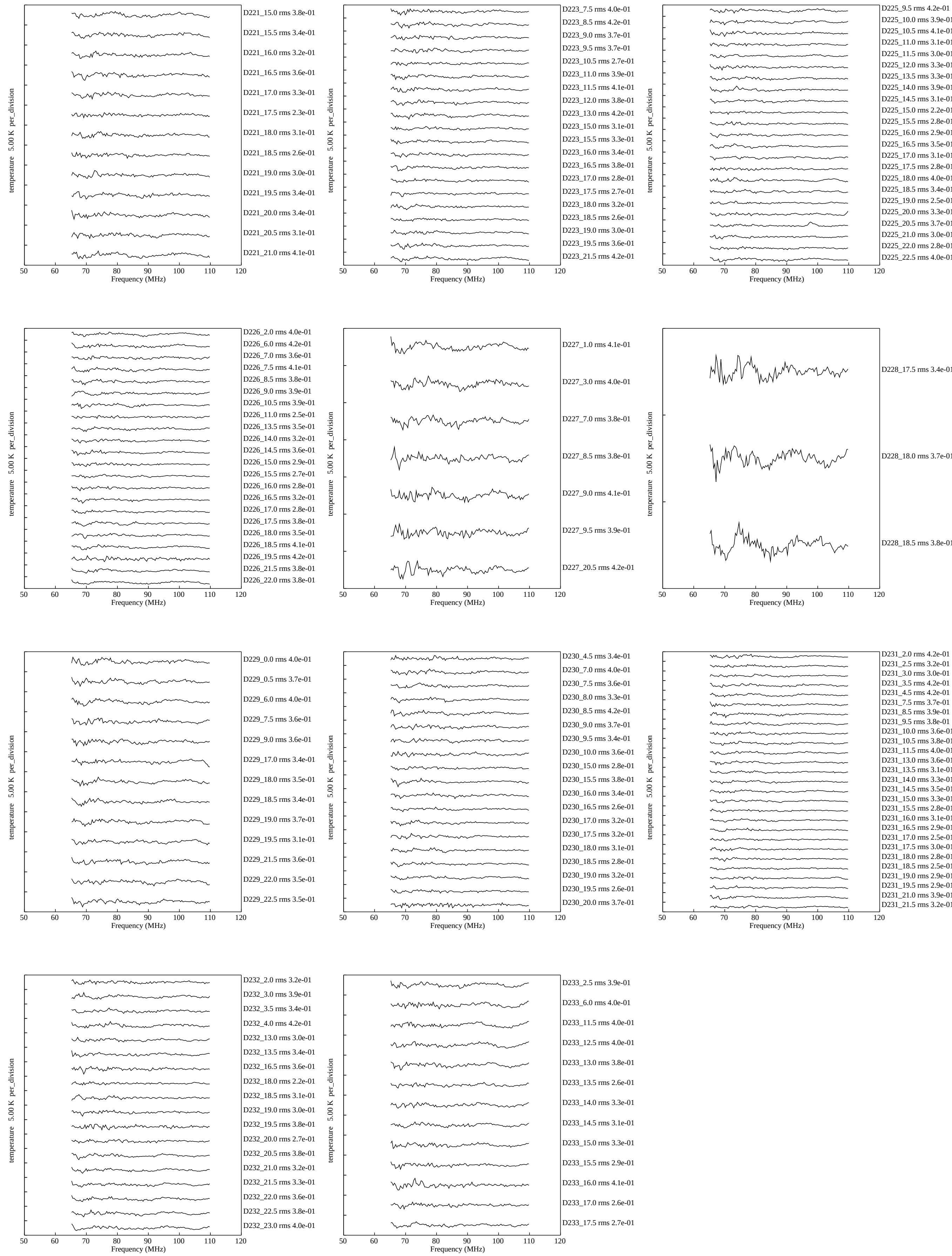

Figure 10. Spectra with 5 EDGES terms removed for 30 minute blocks for each day and filtered with a 0.424 K rms threshold

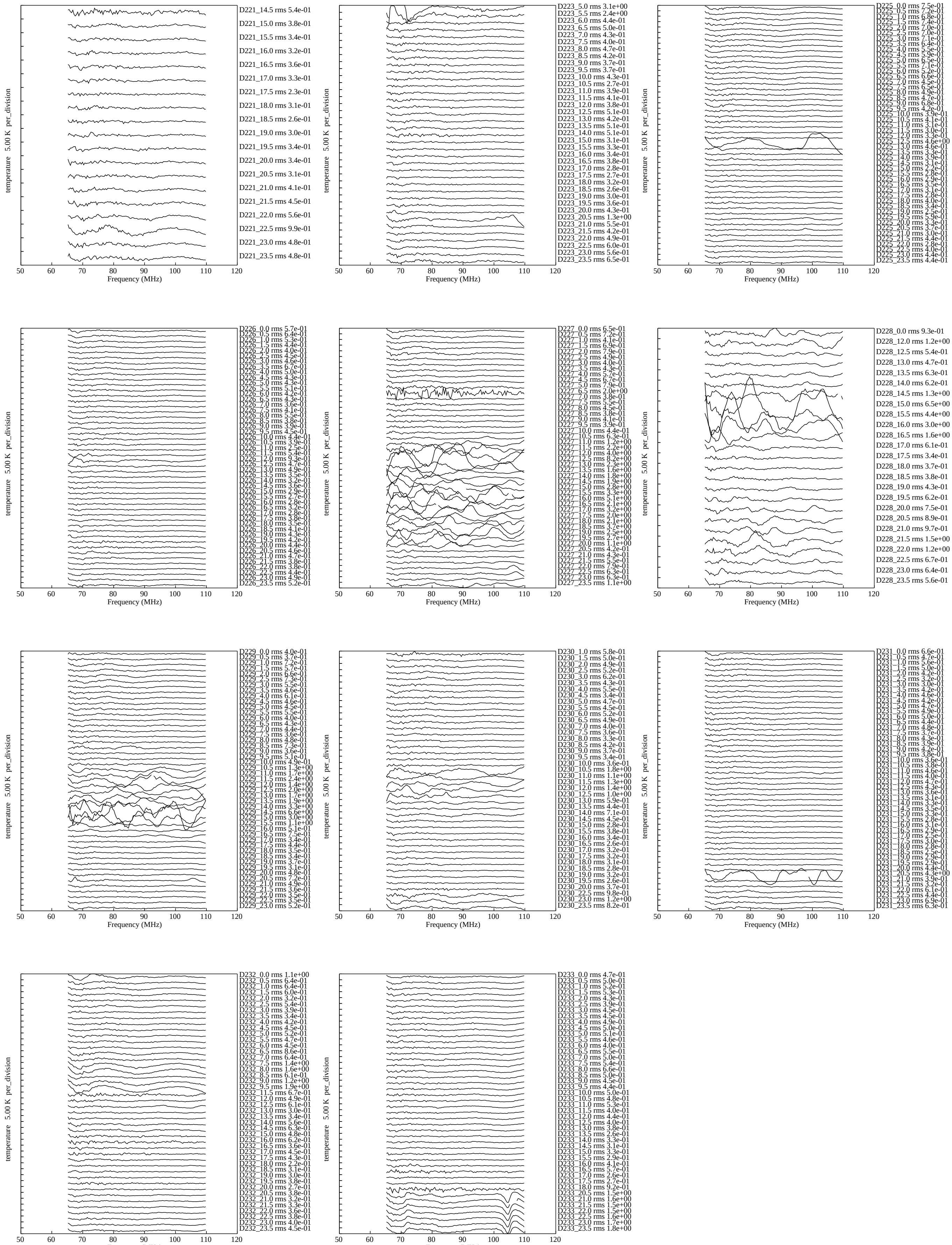

Figure 11. Spectra with 5 terms removed for 30 minute blocks without filtering for comparison with solar activity chart

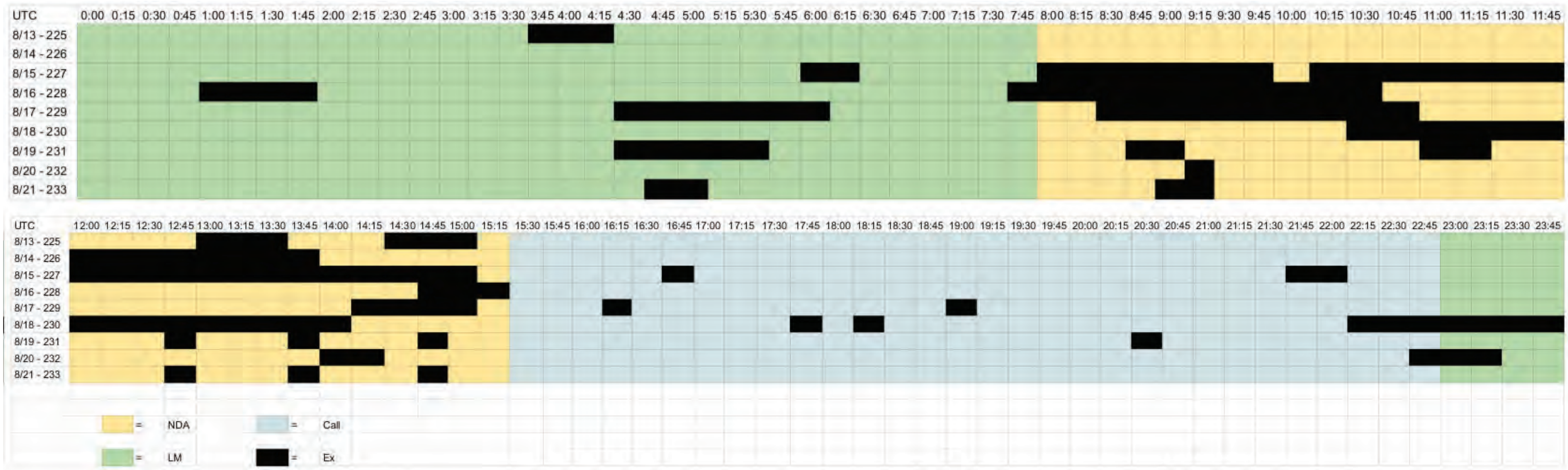

Figure 12. Chart of times when the Sun was particularly active in the 50 to 80 MHz band during the nine-day block of Devon data