EDGES MEMO #441

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To: EDGES group

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Subject: Tests of systematics in EDGES-3 data

The data from EDGES-3 taken from 2023 day 54 to 2024 day 40 was analyzed in memo 440. In this memo I analyze the data in 20 day bins to check for evidence of changes in calibration and antenna S11 since the failure of the Fieldfox VNA on day 335 2023. In addition, more tests of the effects of different FEKO beam models and the sensitivity to RFI filtering are examined and compared with simulations and with the data.

Figure 1a shows the residuals to a 3-term EDGES physical polynomial using data from day 300 2023 in 20 day bins of data blocks of data for each day from GHA 6 to 18 hours for which the sun is more than 2 degrees below the horizon. Apart from limiting the data to the range GHA and the elevation of the sun the only other filtering is that applied to each single 3-position switch cycle which are a FM limit of 2000 and rms limit of 200 and the frequency channel selection based on a 2.1 sigma SNR limit that is made at the end of the data block. The only reason for the 20 day bins is to make the residual curves and rms for each day easy to see. With the limit of the sun elevation of only -2 degrees the effects of the scintillations discussed in memo 438 are visible when compared with Figure 1b for which the sun elevation limit has been set to 20 degrees. The effects of the scintillations have a significant effect with the sun less than 20 degrees below the horizon. This is especially apparent starting at day 350 in figure 1a compared with figure 1b. Figure 1c shows the results of a grid search for the 21cm absorption using 5 physical terms for each 20 day bin using a rms limit of 250 mK for each day on data with the sun more than 20 degrees below the horizon. Figure 1d shows the results of a test using data with the sun more than 2 degrees below the horizon and despite using the same rms threshold limit of 250 mK for each day the effects of not excluding the scintillations which in the days in bins which start with day 320 and 340 are very apparent and lead to a failure to obtain a reasonable absorption result from the day 340 – 359 bin.

Figure 1e shows the result of using the same processing as Figure 1c with the removal of an absorption with center frequency 78 MHz, width 19 MHz, depth 0.5 K and tau = 4 from the sky noise before the polynomial fitting results in a reduction in the rms before the fit for the absorption parameters. The test adds to the confidence that the absorption feature is present in the sky and is not just a product of the instrumental and processing effects.

Figure 2 compares the results of a grid search using data from day 363 2023 to day 45 2024 covering a GHA range of 6 to 18 hours with a sun limit of -20 degrees in two different ways. The plot on the left is the result of the first stage processing each 1 hour block of GHA separately for each day and the plot on the right which is for the first stage processing of a single 12 hour block centered at GHA = 12 for each day. This comparison shows that a result with slight lower final residual of 22 mK is obtained for the case of processing separate 1 hour blocks and setting a threshold rms on each 1 hour block is better than setting a single threshold on the 12 hour blocks. However, bare in mind, that in general the 12 hour blocks with have less than 12 hours of data owing to the sun elevation limit.

The next test is to check the effects of different choices in the parameters used in the absorption grid search used to generate the results shown in the plot on the left side of figure 2. Table 1 lists the "reference case" results followed by changes that can be made on the final processing step (EDGES longav.c code) up to the case of no beam correction which requires a more complete reprocessing. The changes, which are made one at a time, are listed in the first column. The "reference" processing used a beam from FEKO using soil conductivity of 2e-2 S/m.

case	center Freq MHz	SNR	sig K	width MHz	rmsin mK	rms mK
loglog ref, fig2 left	79.7	40	0.64	20.1	121	22
physical	79.7	39	0.62	20.2	63	21
tau 7	80.1	30	0.46	19.2	121	28
tau 0	82.4	27	0.88	20.9	121	32
6-terms	79.3	17	0.49	20.9	28	19
4-terms	87.1	21	0.81	19.6	211	76
no rms limit on block	79.3	28	0.64	19.9	125	32
60-100	79.7	28	0.58	19.9	75	22
54-104	80.1	32	0.52	20.9	199	32
No beam corr.	79.7	34	0.56	20.3	135	22
Soil 2e-3 S/m	80.9	37	0.47	18.5	110	22
Soil 1e-2 S/m	80.9	36	0.48	18.3	116	24

Table 1. The effect of the changes of a single processing parameter

The results in table show that for the frequency coverage of 58 and 102 MHz 5 terms are needed to model the observed foreground. The small changes in residual before fitting for a feature (rmsin) with after fitting for the feature (rms) with no beam correction show that the beam chromaticity is probably not the major source of systematics. The major source of systematics are relatively smooth changes in sky noise, ionospheric absorption and emission, calibration errors which require 5-terms to model as the search using only 4-terms has large residuals and is clearly biased by systematics.

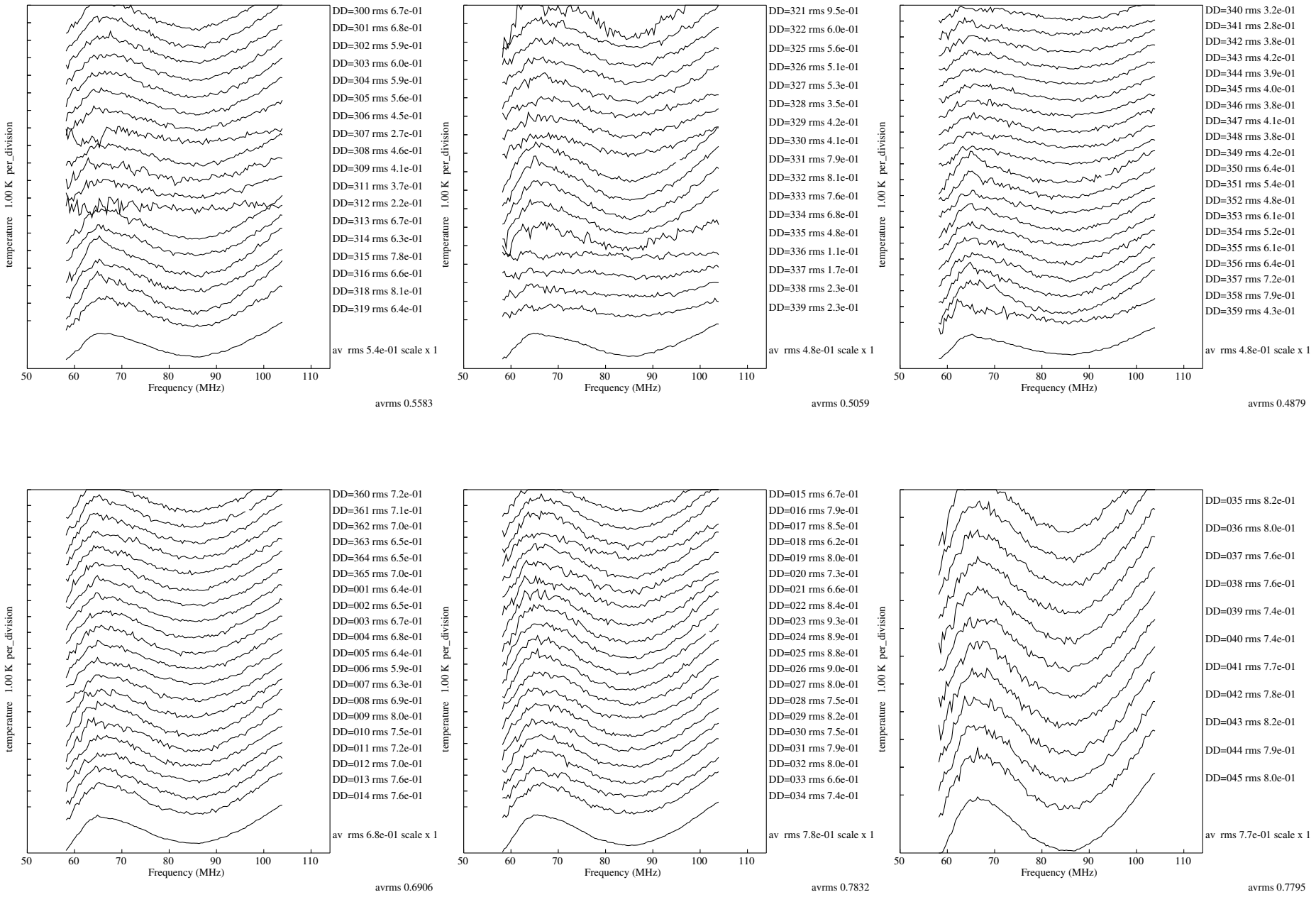


Figure 1a. 20 day bins of data blocks of data for each day from GHA 6 to 18 hours with sun limit of -2 degrees.

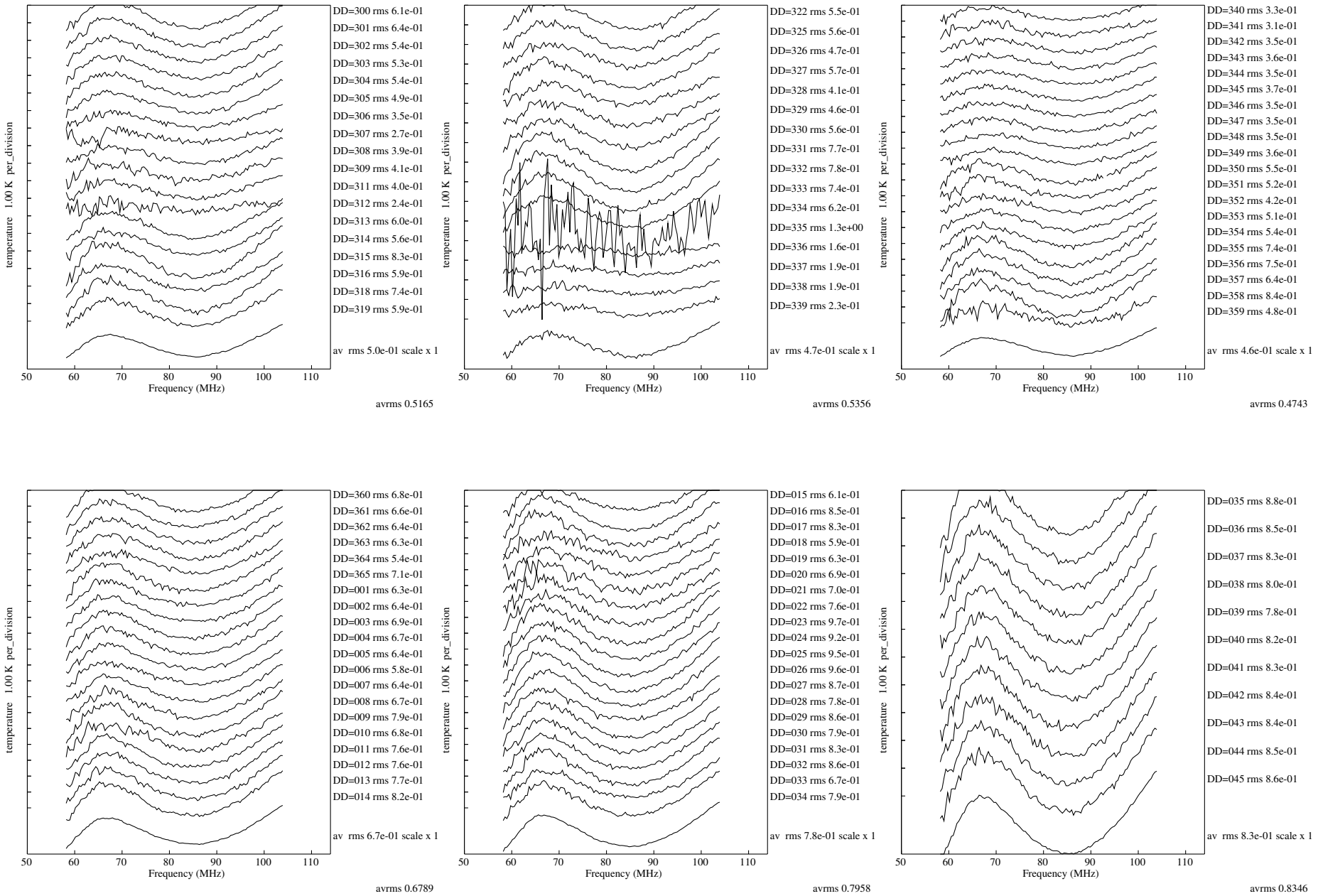


Figure 1b. Same as figure 1a with sun limit of -20 degrees.

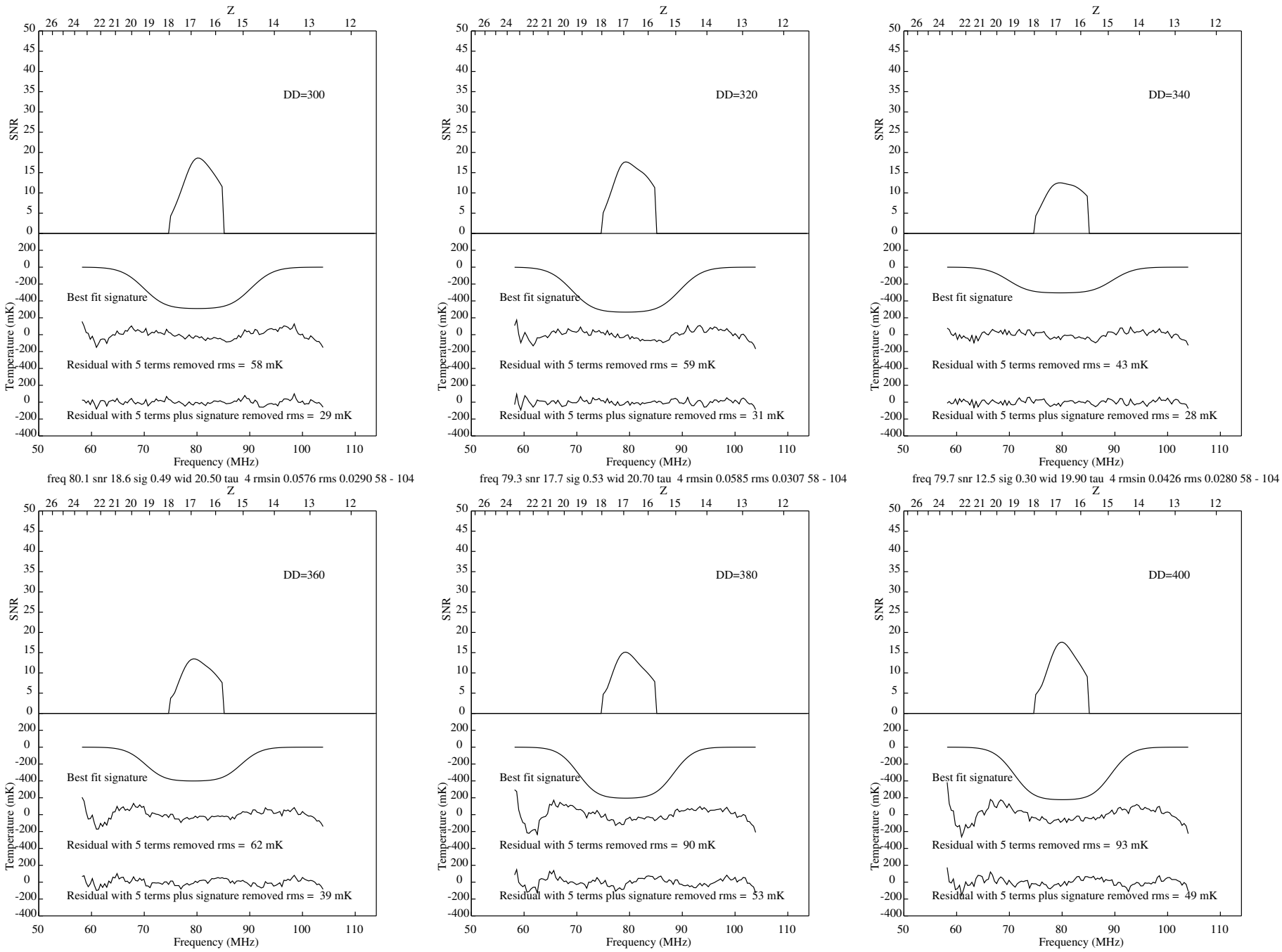
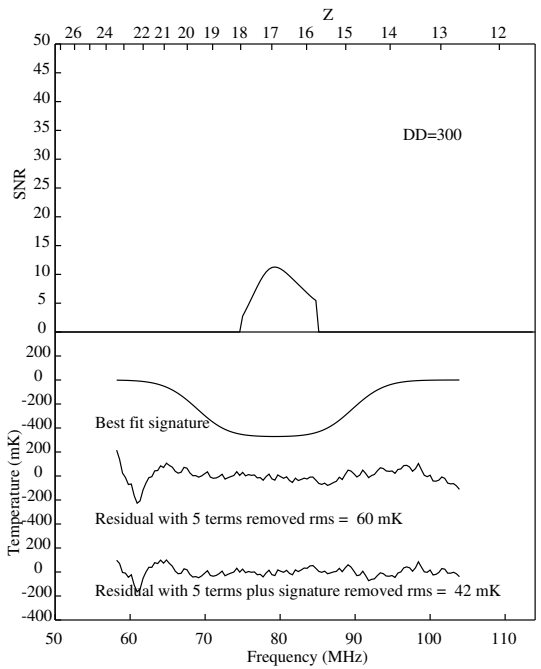
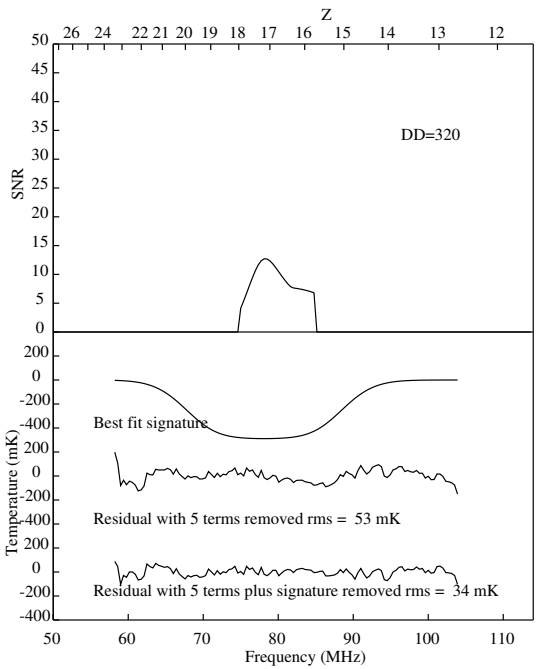


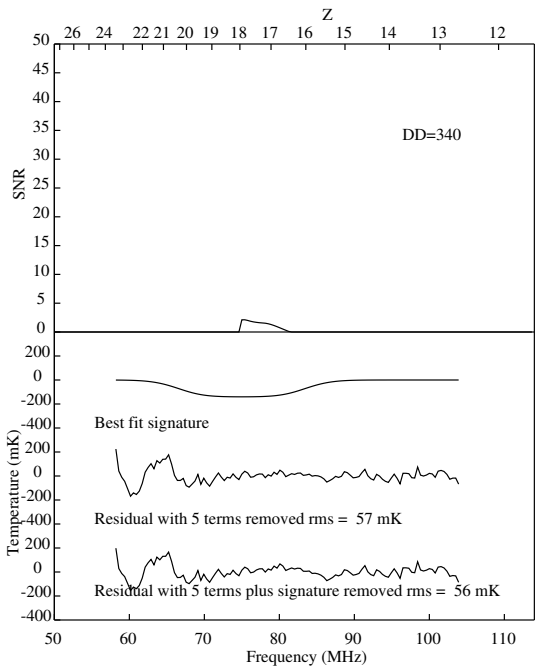
Figure 1c. Absorption grid search for each 20 day bin in figure 1b using 5 physical terms and tau = 4.



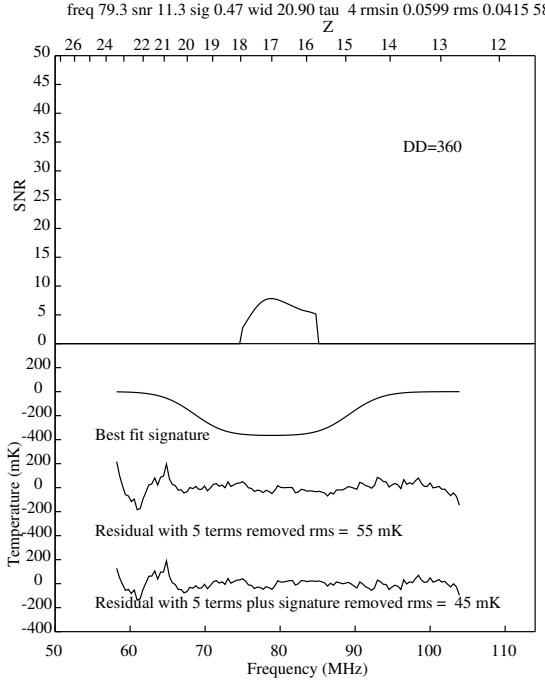
freq 79.3 snr 11.3 sig 0.47 wid 20.90 tau 4 rmsin 0.0599 rms 0.0415 58 - 104



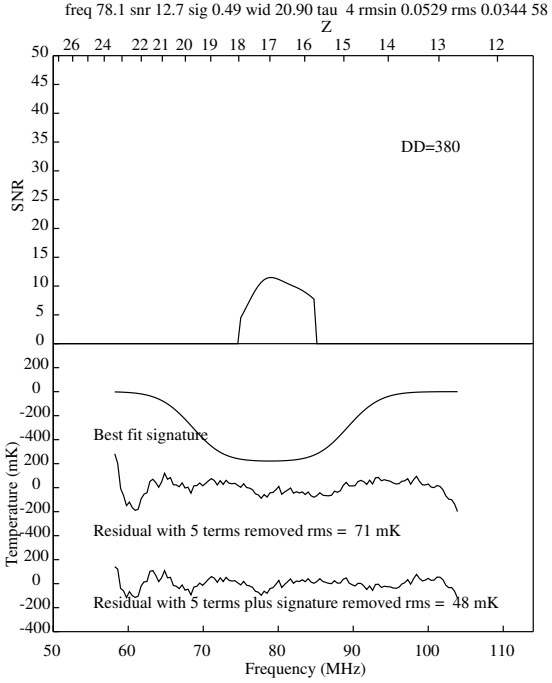
freq 78.1 snr 12.7 sig 0.49 wid 20.90 tau 4 rmsin 0.0529 rms 0.0344 58 - 104



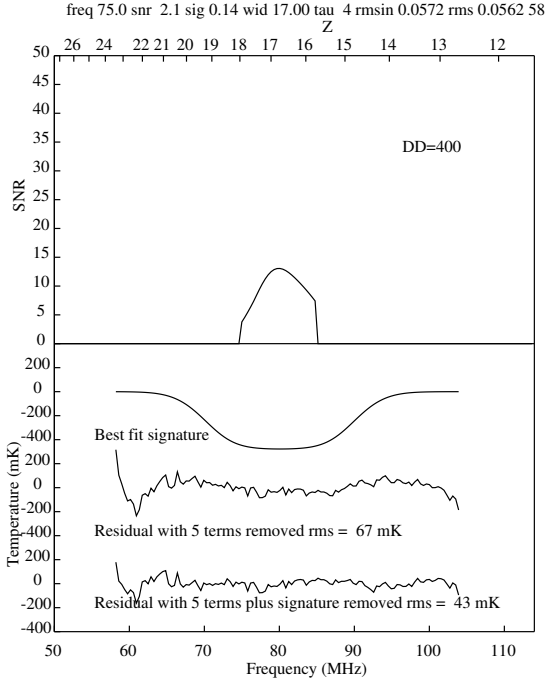
freq 75.0 snr 2.1 sig 0.14 wid 17.00 tau 4 rmsin 0.0572 rms 0.0562 58 - 104



freq 78.9 snr 7.8 sig 0.36 wid 20.90 tau 4 rmsin 0.0553 rms 0.0449 58 - 104



freq 78.9 snr 11.5 sig 0.58 wid 20.90 tau 4 rmsin 0.0705 rms 0.0485 58 - 104



freq 80.1 snr 13.1 sig 0.48 wid 20.00 tau 4 rmsin 0.0670 rms 0.0428 58 - 104

Figure 1d. Same as figure 1c for each 20 day bin in figure 1a.

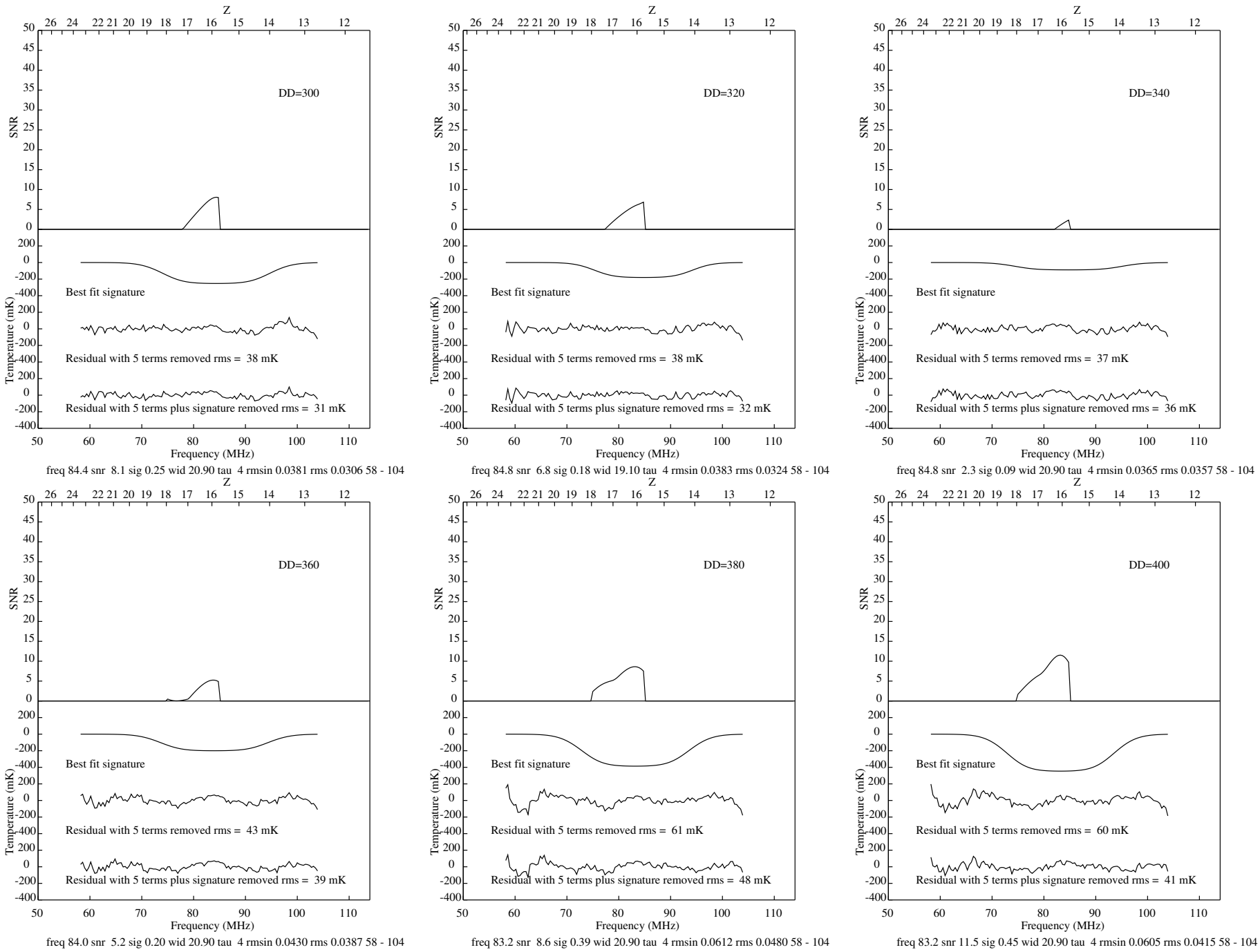
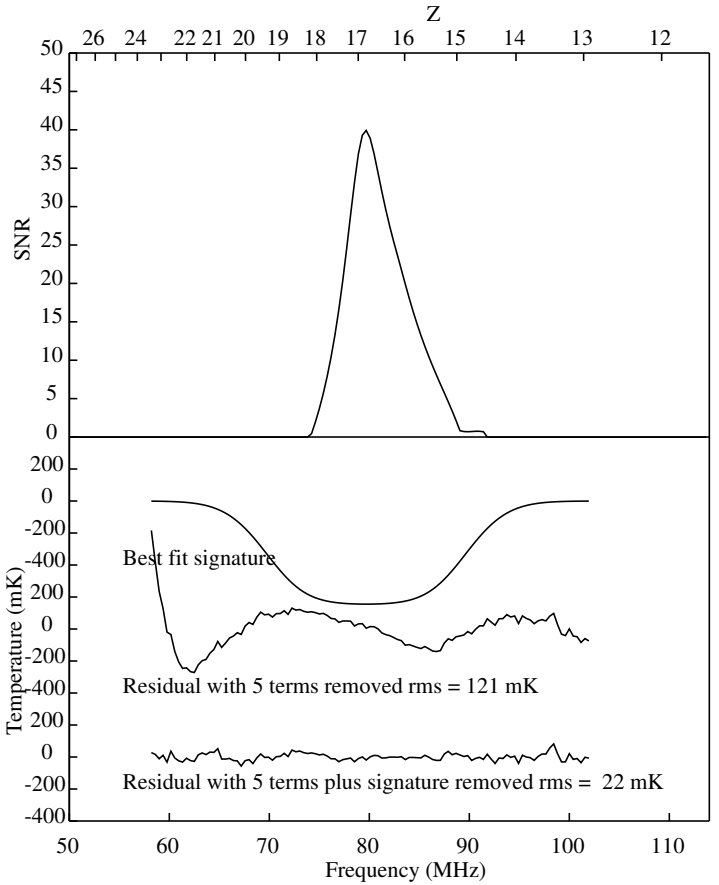
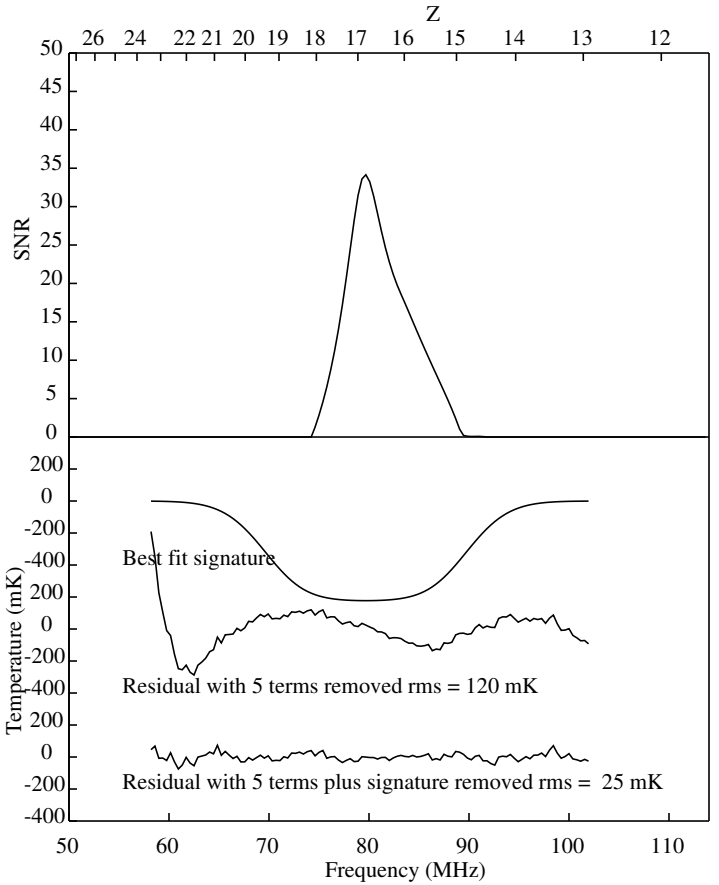


Figure 1e Same as processing used for figure 1c but with the subtraction of an absorption feature from the sky - see text for details.



freq 79.7 snr 39.9 sig 0.64 wid 20.10 tau 4 rmsin 0.1210 rms 0.0221 58 - 102



freq 79.7 snr 34.1 sig 0.62 wid 20.30 tau 4 rmsin 0.1195 rms 0.0246 58 - 102

Figure 2. Absorption grid search for day 363 2023 to day 45 2023. The result on the left is for 1 hour blocks of GHA and the result of the right is for 12 hour blocks of GHA – see text for more details.