MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

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Telephone: 617-715-5533

To: EDGES group

From: Alan E.E. Rogers
Subject: Further study of the RFI in data from Devon Island in 2022

The data from Devon Island which is severely effected by RFI of uncertain origin as discussed in memo 419.

Extensive tests were made at the site for locally generated RFI but none was found. Further study has now been made of the possibility that it is thermal noise from the high temperature electrons in the plasma of the aurora.

Schunk et al. report that the electron temperature could be as high as 10,000 K and the electron densities as high as 1.5e6 per cm^{-3} in the polar cap and auroral oval. If this is the dominant medium the dominant medium between the antenna and the sky EDGES would observe

$$Ta = Tsky\ exp(-tau) + Telectron\big(1 - exp(-tau)\big)$$

where

Tant is the observed antenna temperature
Tsky is the sky noise temperature
Telectron is the electron temperature
tau is the opacity of the medium

If the sky noise temperature is much higher than the electron temperature and the opacity is small we would see the sky with its spectral index of about 2.5. If the opacity is small but the electron temperature is much higher than the sky noise spectrum we should see the observed spectral index moving from 2.5 towards 2.0 because the opacity of an electron plasma increases with frequency to the power of minus 2. This is seen in some of the data plotted in figure 4 of memo 419. A waterfall plot of the data from day 229 from 6 to 7 hours UT is shown in Figure 1. The residuals with 2 physical terms removed of each 6 minutes are shown in Figure 2. Data from day 232 was found to have times with very large dips at 65 MHz like those shown in Figure 7 of memo 419 but these large dips are thought to be the result of the moisture that was present that day which also effected the antenna S11 as discussed in memo 397.

If the “RFI” is from plasma patches like those seen by the SuperDarn radar which change on a time scale of seconds the changes seen by EDGES could be from multiple patches. In this case the frequency structure seen by EDGES which changes on the scale of 5 MHz but is otherwise quite smooth could be due to the beam chromaticity difference for patches at different azimuth and elevation in the beam. Figure 3 is a simulation of a “bright spot” with constant spectrum in the aurora at a fixed elevation of 30 degrees for different azimuths which shows how the spectrum changes with azimuth. The azimuth changes for 00 and 12 hours UT on day 2022_225 produce slightly different effects owing to the influence of the change in the sky noise angular distribution relative to the antenna beam with the rotation of the earth.

Table 1 lists the Tsky temperature at 75 MHz obtained from the data residuals shown in Figure 2. The change in calibrated antenna temperature changes by about 10 K from one measurement to the next measurement 36 seconds later. There is a marginal indication that there is an increase in temperature with increase in rms which would be expected for an electron temperature higher than the sky noise temperature.

Tsky K at 75 MHz	rms K	UTC hour	Tsky – average K
2578	9.13	6.00	-16
2599	11.74	6.01	+5
2598	8.69	6.02	+4
2574	6.69	6.03	-20
2604	14.87	6.04	+10
2558	6.76	6.05	-36
2585	5.35	6.06	-9
2598	6.23	6.07	+4
2595	5.36	6.08	+1
2617	15.6	6.09	+23
2628	11.9	6.10	+34
2594	9.31	Average 6.0 to 6.1	

Table 1. Sky temperature values of data on day 229 with residuals shown in Figure 2

In summary while the auroral plasma might be the source of the "RFI" in the EDGES-3 data from Devon Island I have not been able to confirm the role "plasma patches" as the source the noise rather than power line noise via sporadic E as power line noise would also add to the average observed sky temperature. Also if a reduction in the average sky noise is the usual case it would also be the case for the data from riometers and the changes seen by EDGES are probably too small to be evident in the data from riometers.

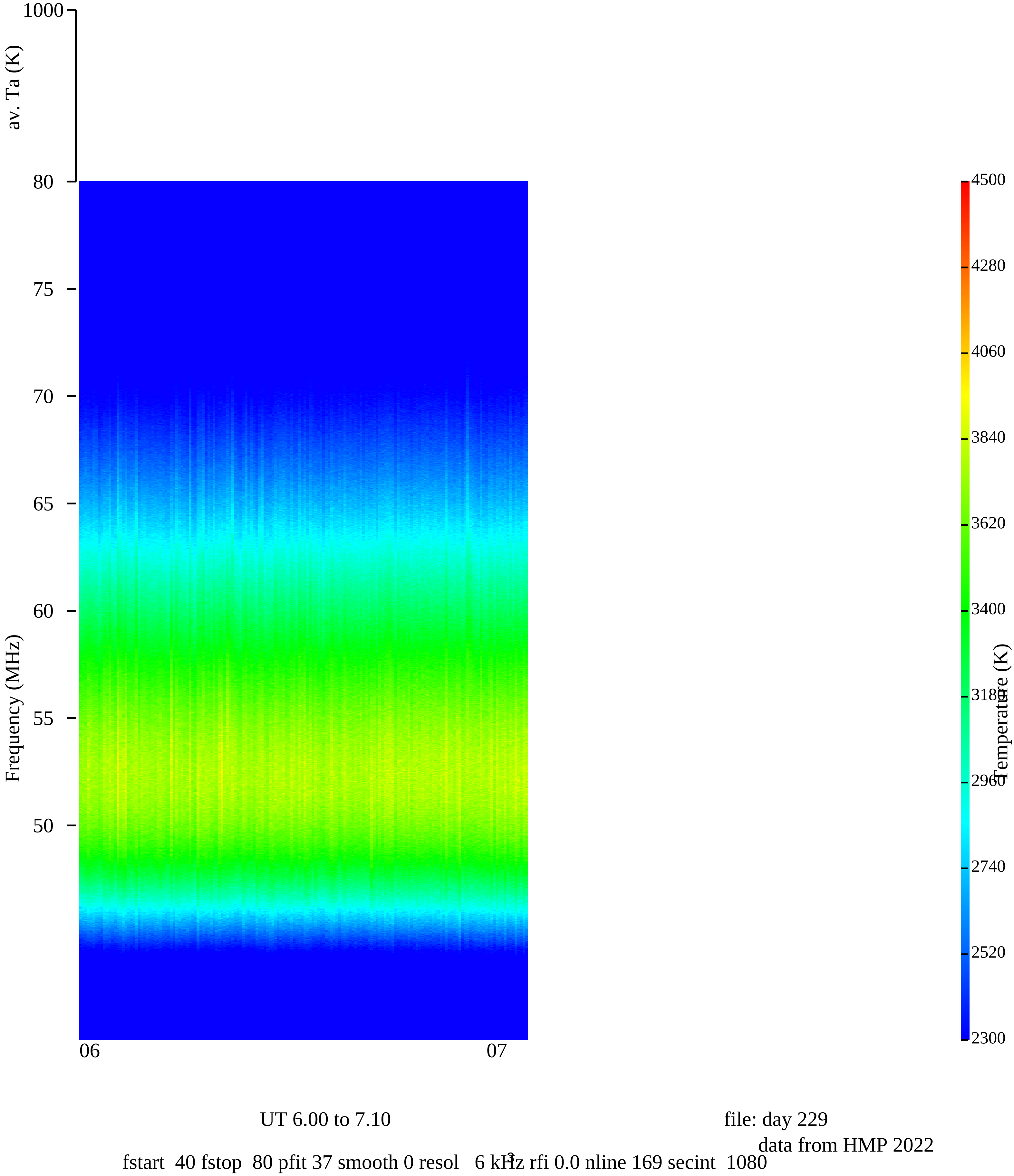
References:

Schunk, R.W., Sojka, J.J. and Bowline, M.D., 1987. Theoretical study of the effect of ionospheric return currents on the electron temperature. Journal of Geophysical Research: Space Physics, 92(A6), pp.6013-6022.

Xiong, C., Yin, F., Luo, X., Jin, Y. and Wan, X., 2019. Plasma patches inside the polar cap and auroral oval: the impact on the spaceborne GPS receiver. Journal of Space Weather and Space Climate, 9, p.A25.

Rogers, A.E., Bowman, J.D., Vierinen, J., Monsalve, R. and Mozdzen, T., 2015. Radiometric measurements of electron temperature and opacity of ionospheric perturbations. Radio Science, 50(2), pp.130-137.

Figure 1. Waterfall plot of the spectra from Devon Island 6 to 7 hours UT on day 229 of 2022.



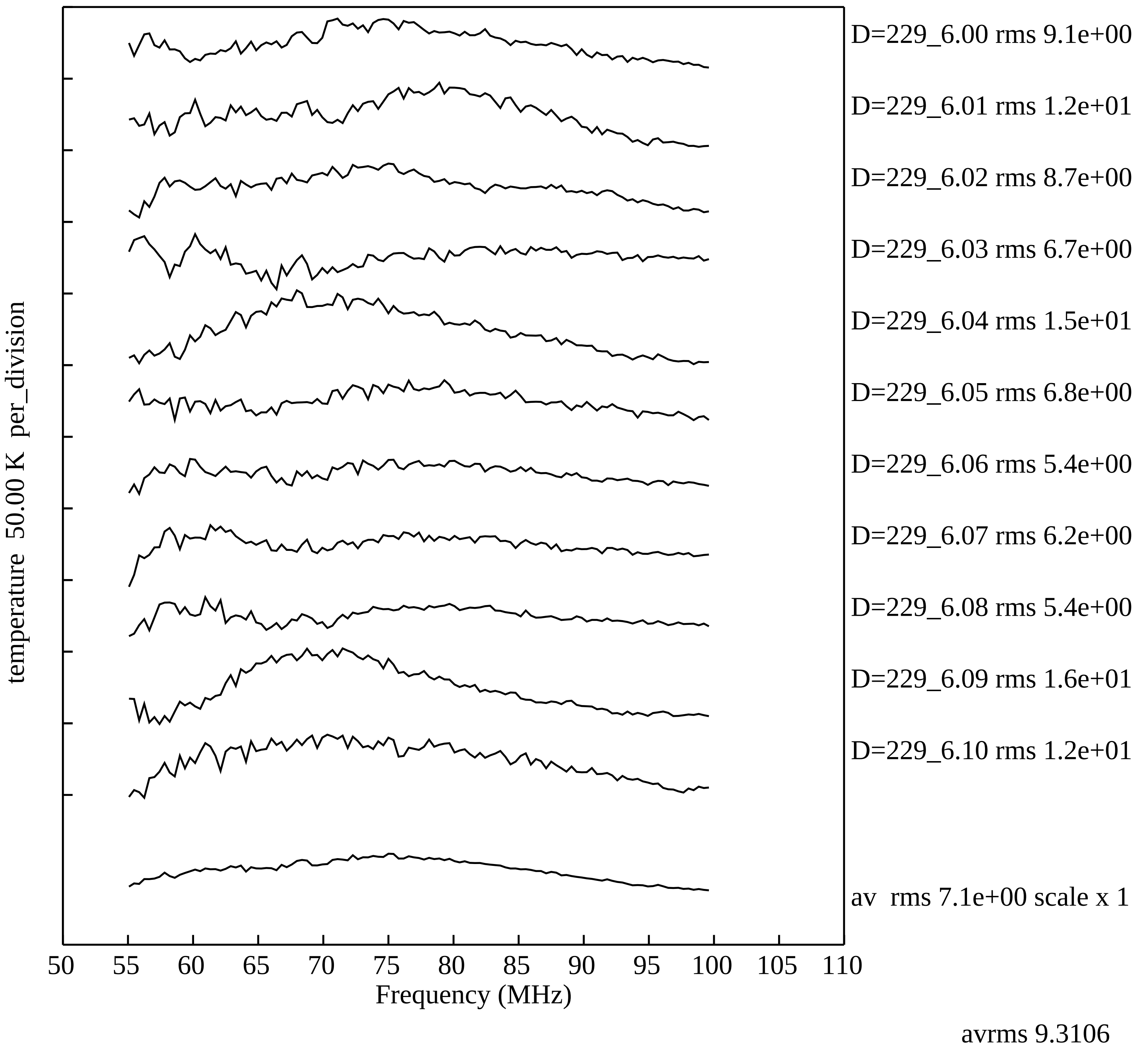


Figure 2. Spectral residuals from day 229 6.0 to 6.1 UT with 2 physical terms removed.

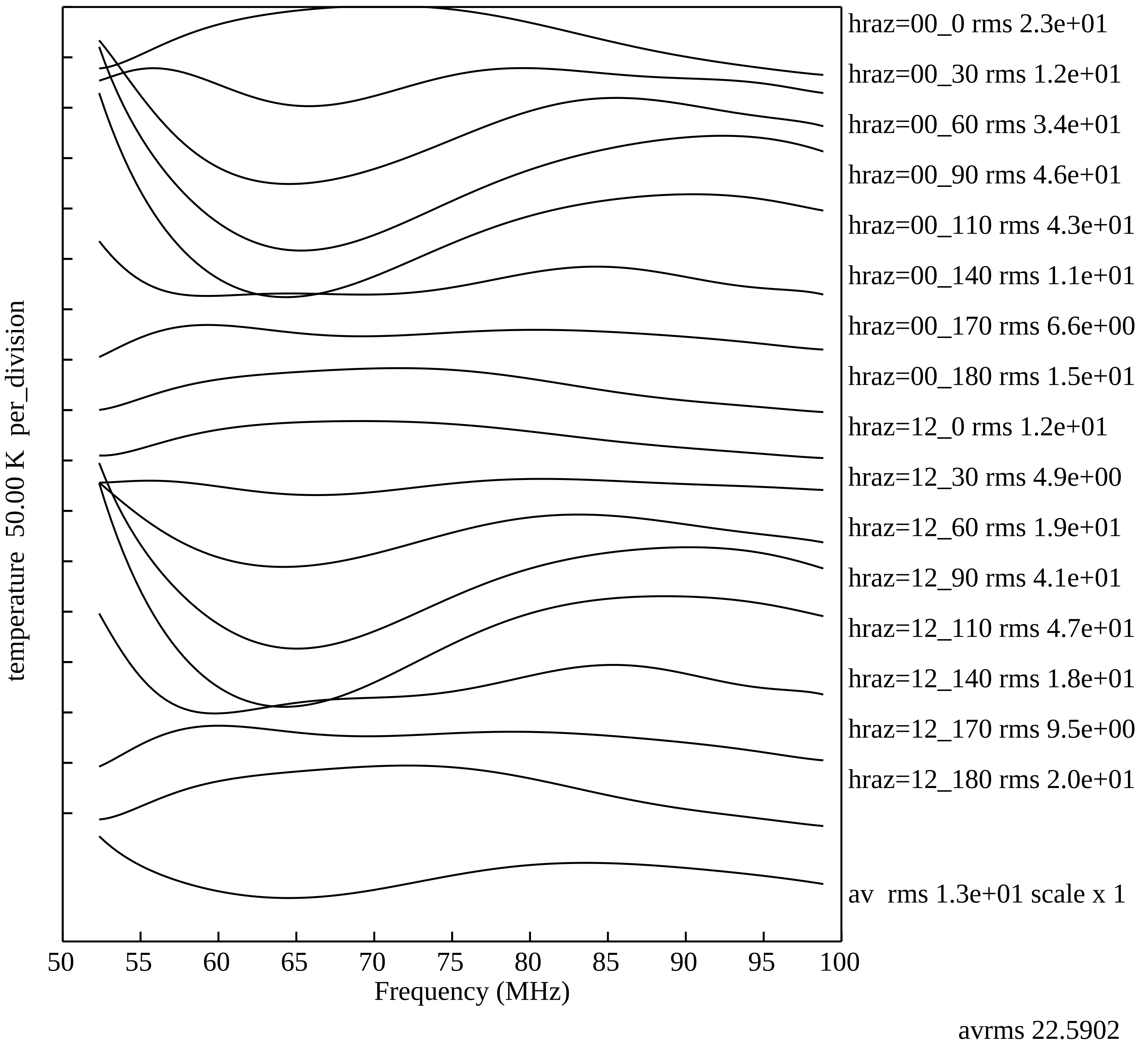


Figure 3. Simulation of a "bright spot" in the aurora at a fixed elevation of 30 degrees as function of time for different azimuths. Plots are the residuals with 3 terms removed.