Measuring Solar Flux Density with EDGES-3

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Background and Data

Despite extensive research on the Sun, our quantitative understanding of low-frequency radio emissions leading up to a solar maximum remains limited. This limitation arises because the solar spectrum decreases steeply, while the galactic background grows increasingly brighter with low frequencies, making precise measurements challenging. EDGES, however, is capable of these measurements as it is the most precise instrument in the 60-120 MHz band.

EDGES-3: Located at Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory in Western Australia, EDGES-3 is a single horizontally polarized broadband dipole antenna that measures an all-sky spectrum between 50 and 200 MHz. With the electronics within the antenna box, EDGES-3 eliminates the need for pre- and post-observation calibrations.

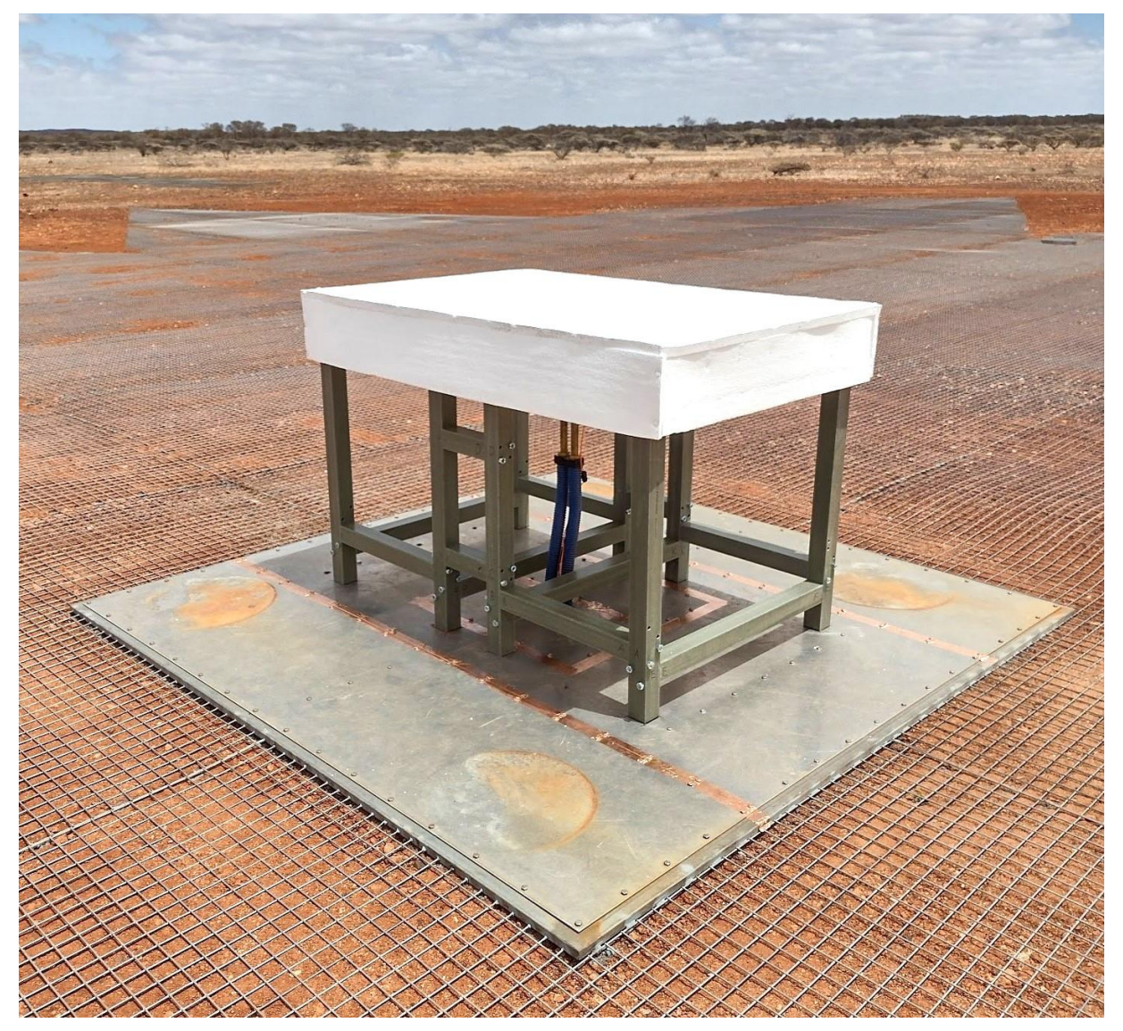


Figure 1: EDGES-3 instrument

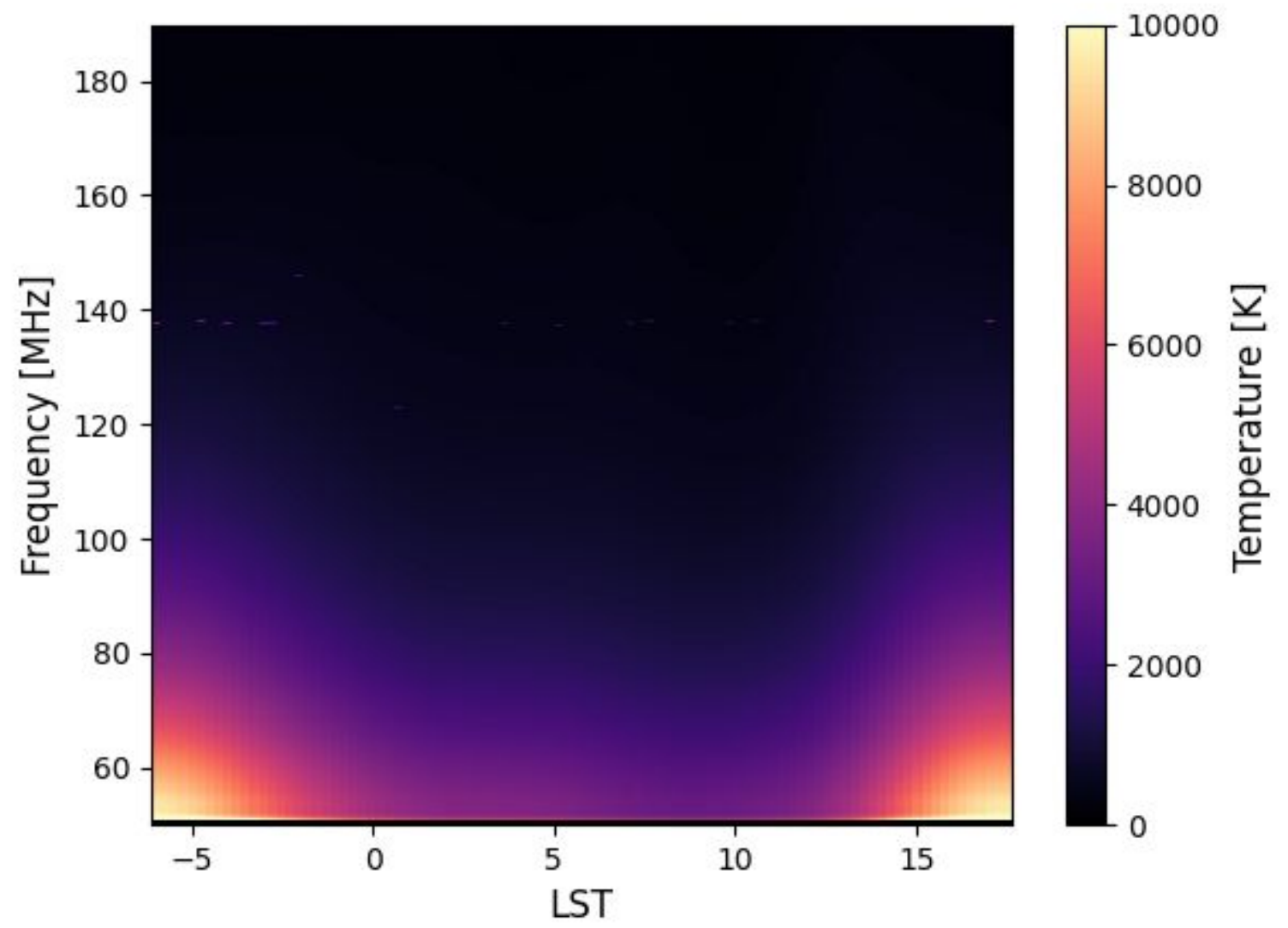


Figure 2: Representative waterfall plot from edges-analysis pipeline

Edges-analysis: Our study utilizes EDGES-3 data taken between March 2023 and July 2024 in the frequency band of 60-120 MHz. We calibrate the data using the newly developed edges-analysis Python package and apply a filter for radio frequency interference (Murray). The data for each day is in 15 minute local sidereal time (LST) bins and 0.39 MHz frequency bins.

Ionospheric correction: We use the dionpy Python package to model and correct for ionospheric attenuation (Bidula, 2022). This package models the ionosphere refraction and attenuation based on the International Reference Ionosphere (IRI) model. We only use values extending to 30 degrees below the zenith.

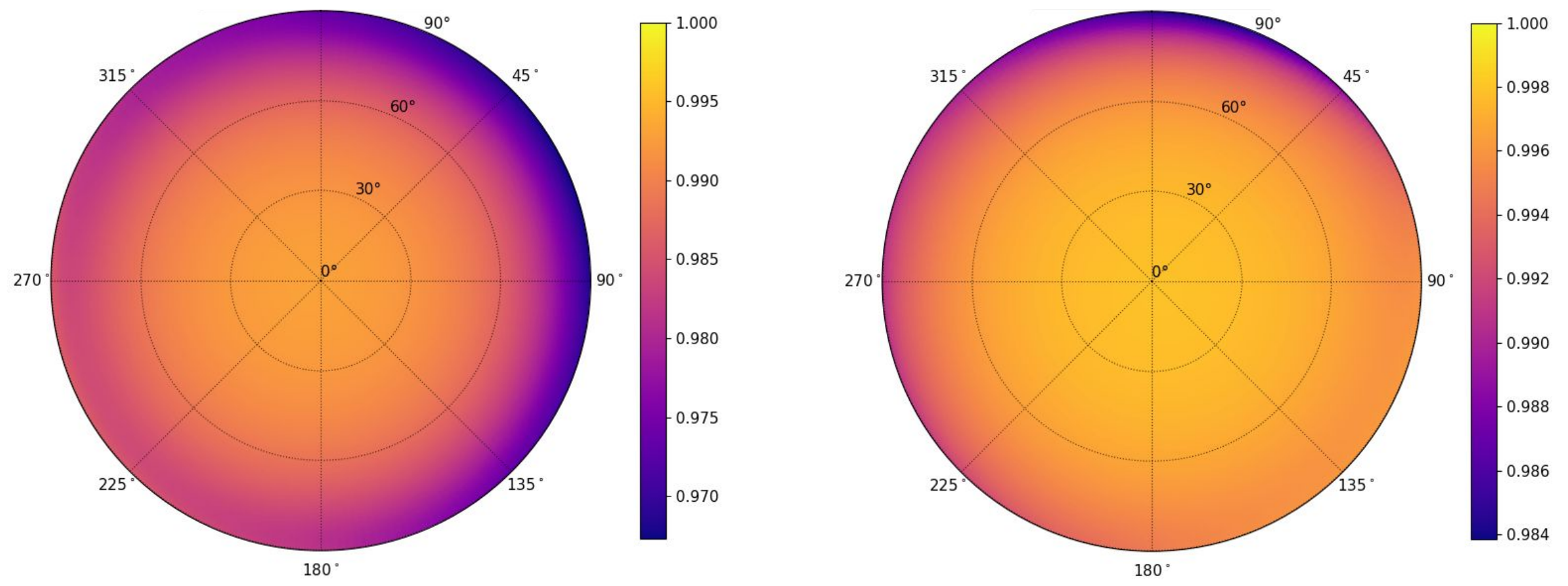


Figure 3: Ionospheric attenuation modelled by dionpy while the sun is above (left) and below (right) the horizon.

Results

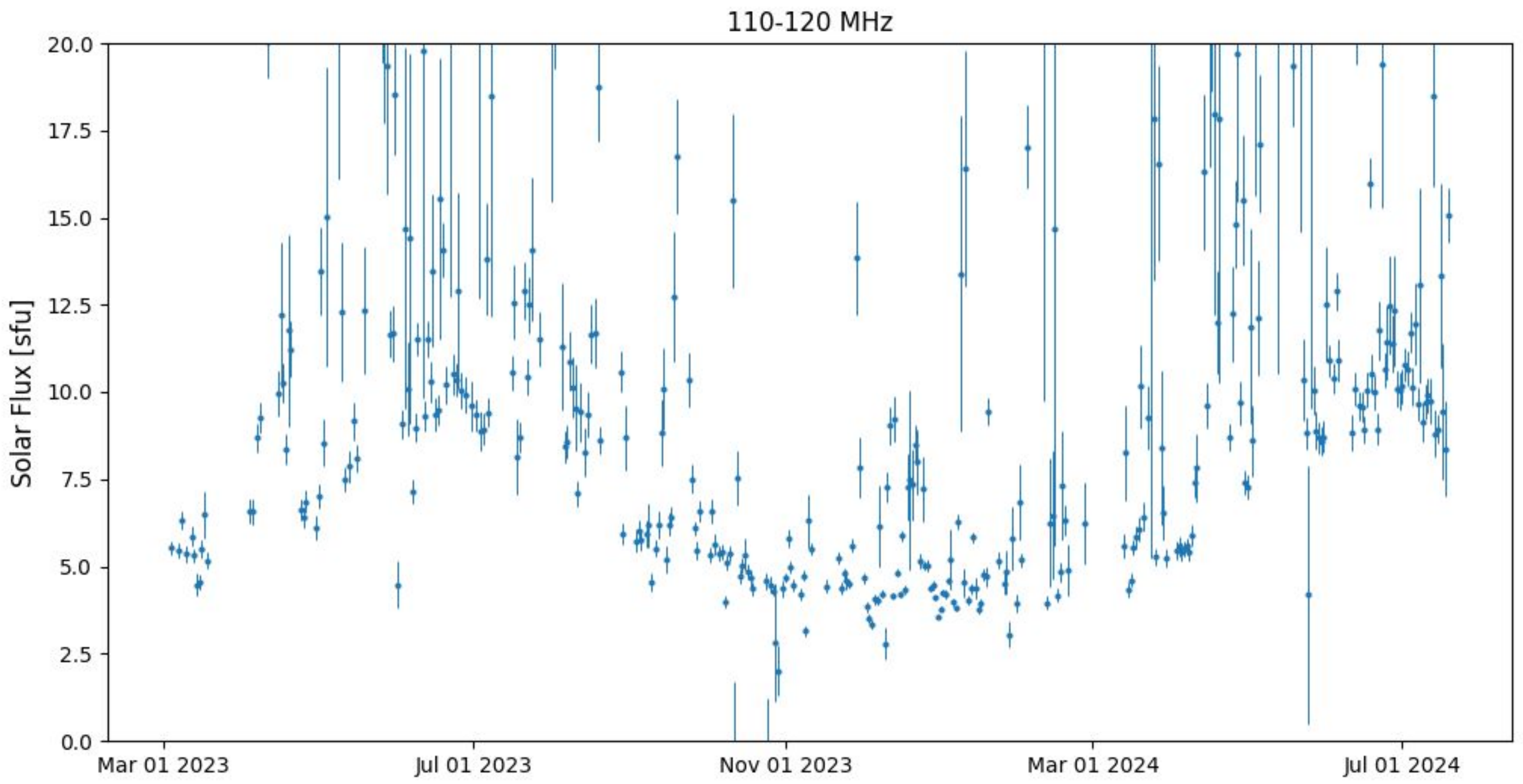
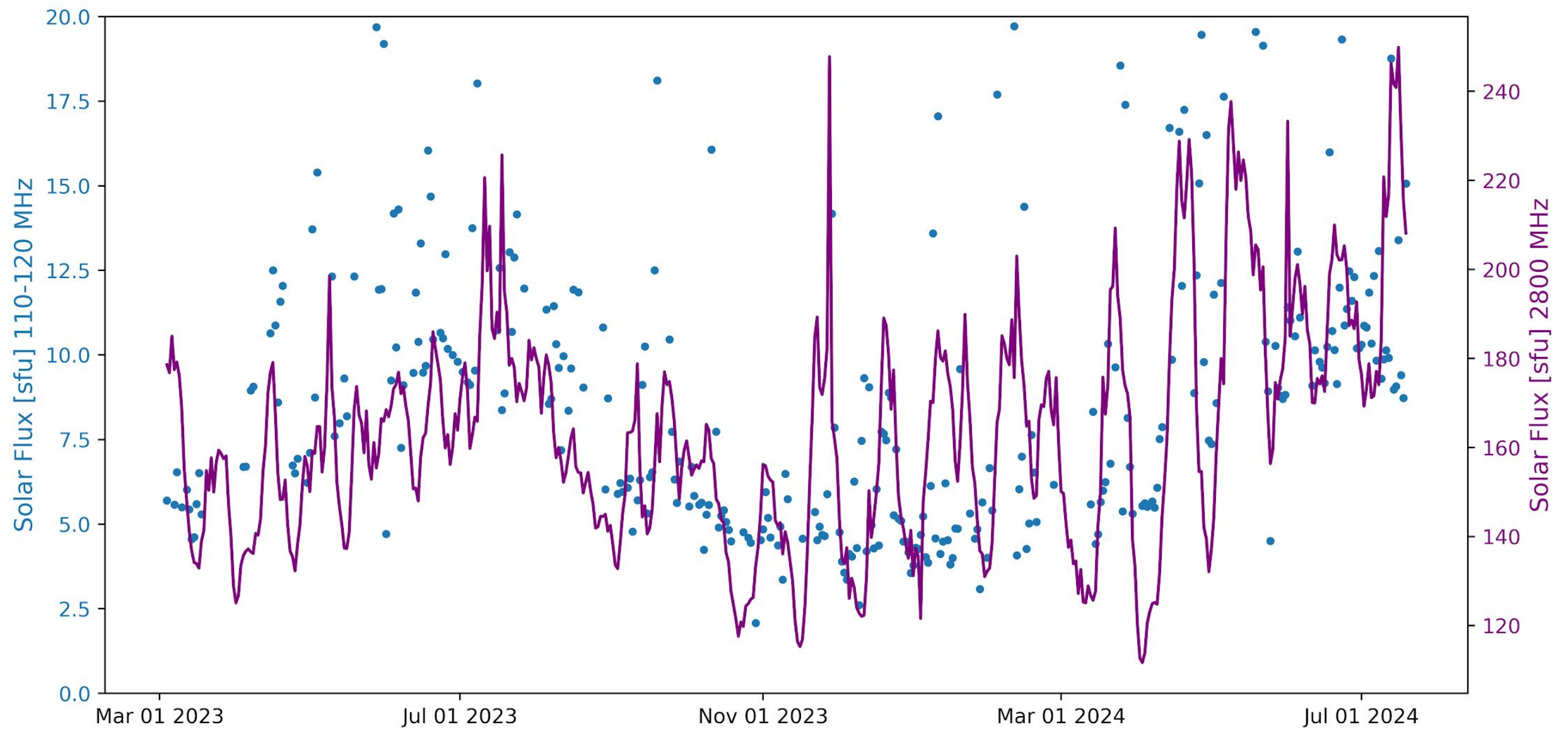
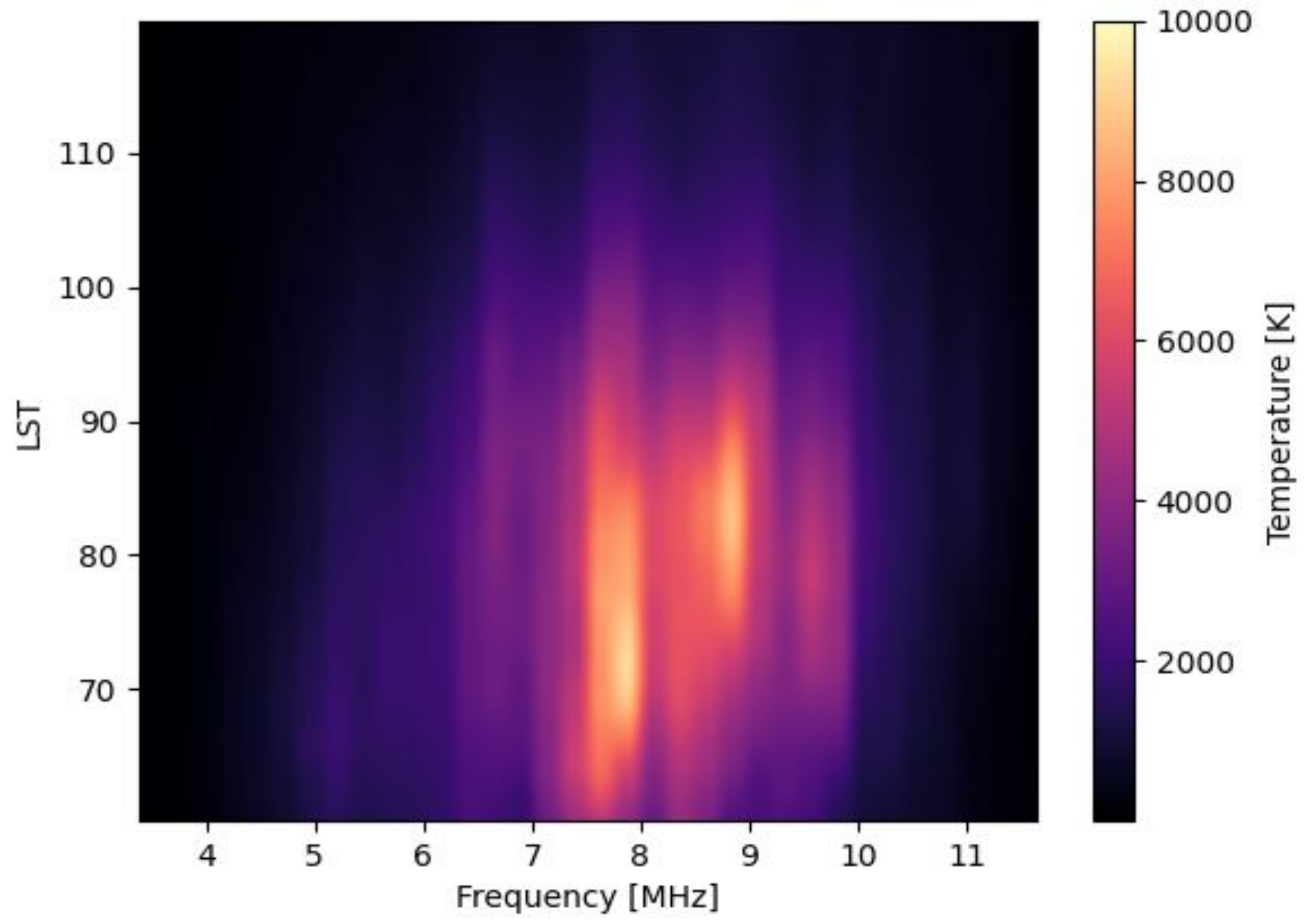


Figure 5: Absolute solar flux measured by EDGES-3 from March 2023 to July 2024. The error bars represent the standard error of the distribution of values for a given day.

Figure 5 shows the representative daily average of solar flux [sfu] over the span of 16 months in the 110-120 MHz band. Additional plots for lower frequencies reveal a consistent pattern, with solar flux values increasing with frequency, The data exhibits a distinct annual variation, characterized by an increase from March to July of 2023, a decrease until December of 2023 and a subsequent increase as we approach a solar maximum. The data is also consistent with trends seen by other instruments at higher frequencies (Figure 6).

Figure 6: Absolute solar flux measured by EDGES-3 and adjusted solar flux at 2800 MHz (Papitashvil &, King, 2024). Our solar flux measurements follows similar trends seen at shorter wavelengths.





When averaging solar flux density over time, the presence of large solar flares results in substantial fluctuations, increasing the uncertainty and leading to large error bars in our data.

Figure 7: Typical waterfall plot of a solar flare

Methods

Subtraction: We select two days, 182.5 solar days (183 LST days) apart and determine the time at which the Sun rises and sets in one observation. That observation will include both the foreground and the Sun, while the other will contain only the foreground. By subtracting the observation without the Sun from the observation with the sun, we obtain a temperature due to solar radiation.

Gain pattern: To obtain absolute solar flux measurements throughout the day, we convolve the solar radiation with the beam's gain pattern.

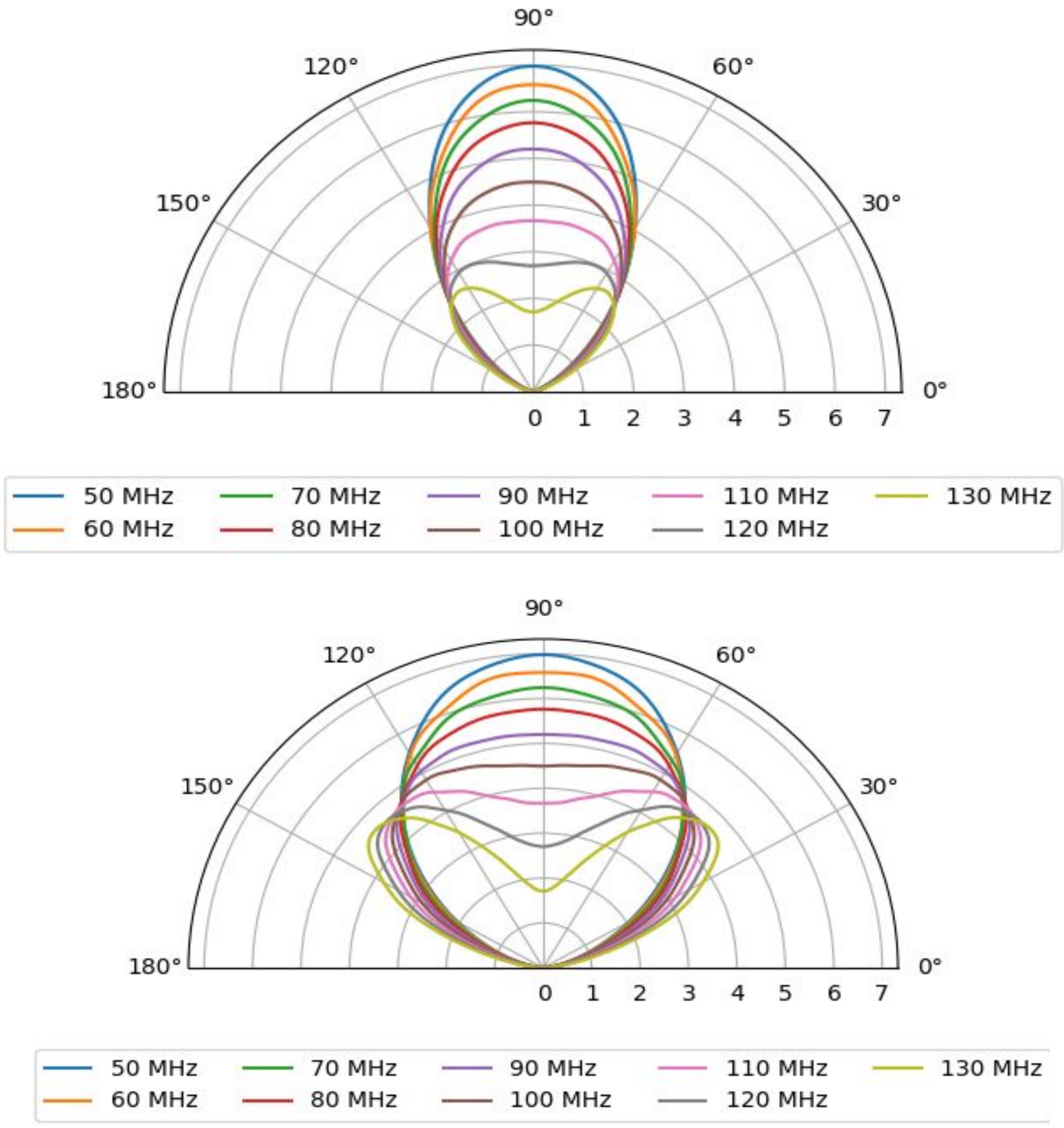


Figure 4: EDGES-3 beam pattern (linear scale). Top: north/south, Bottom: east/west

Daily Averages: To reduce the effects of antenna gain, the analyzed data was confined to times when the Sun was within thirty degrees of local noon.

References

Bidula, V, 2022, MIST Memo 69 Ionosphere simulation with dionpy
Murray, Steven, Edges Collaboration, https://github.com/edges-collab
Papitashvili, Natalia E. and King, Joseph H., 2024, "OMNI Daily Data Solar Index F10.7", NASA Space Physics Data Facility, https://doi.org/10.48322/5fmx-hv56, Accessed on August 6, 2024
Rogers, A. E. E. 2019, Haystack EDGES Memo Series, 300, doi: 1721.1/154692

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