Detection of Solar Flares from the Analysis of Signal-To-Noise Ratio Records from the Ebro Observatory

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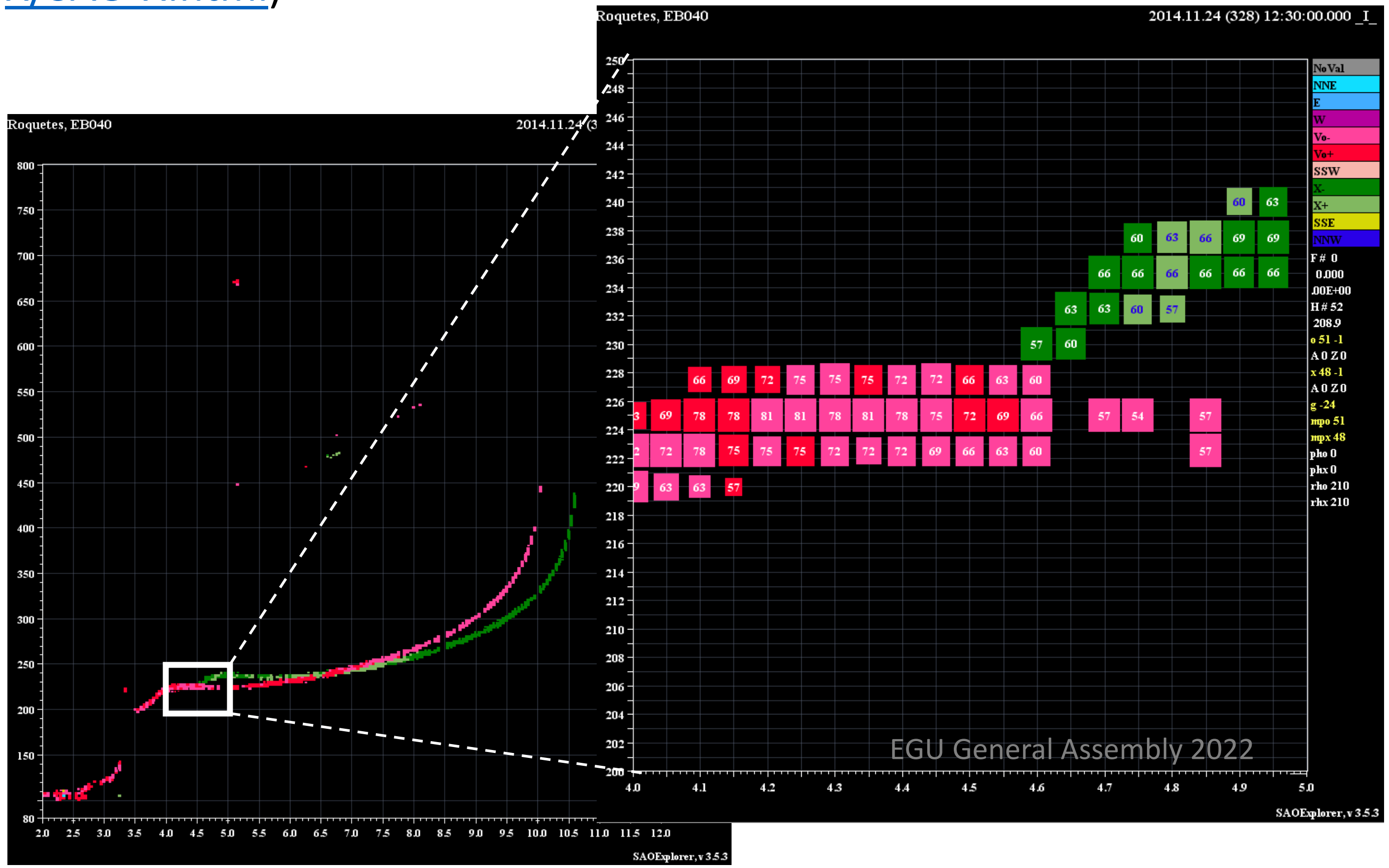
Data

-Data from the ionograms at Ebro Observatory station (40.82N, 0.50E) (EB040). Ground-based Digisonde-Portable-Sounder-4D (DPS4D) routinely performs vertical at different time samplings, usually at 5 or 15 min

-Data available at the GIRO portal (https://giro.uml.edu/)

-Software tool Data Visualization/Editing Tool known as SAO Explorer (SAO-X). (https://ulcar.uml.edu/SAO-X/SAO-X.html)



-SAO-X allows to extract the DPS4D amplitudes for each reflected radio signal and the most probable amplitude (MPA)

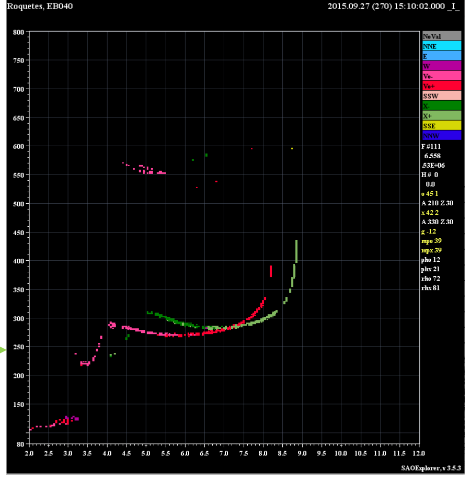
-The MPA is the amplitude threshold below the noise level.

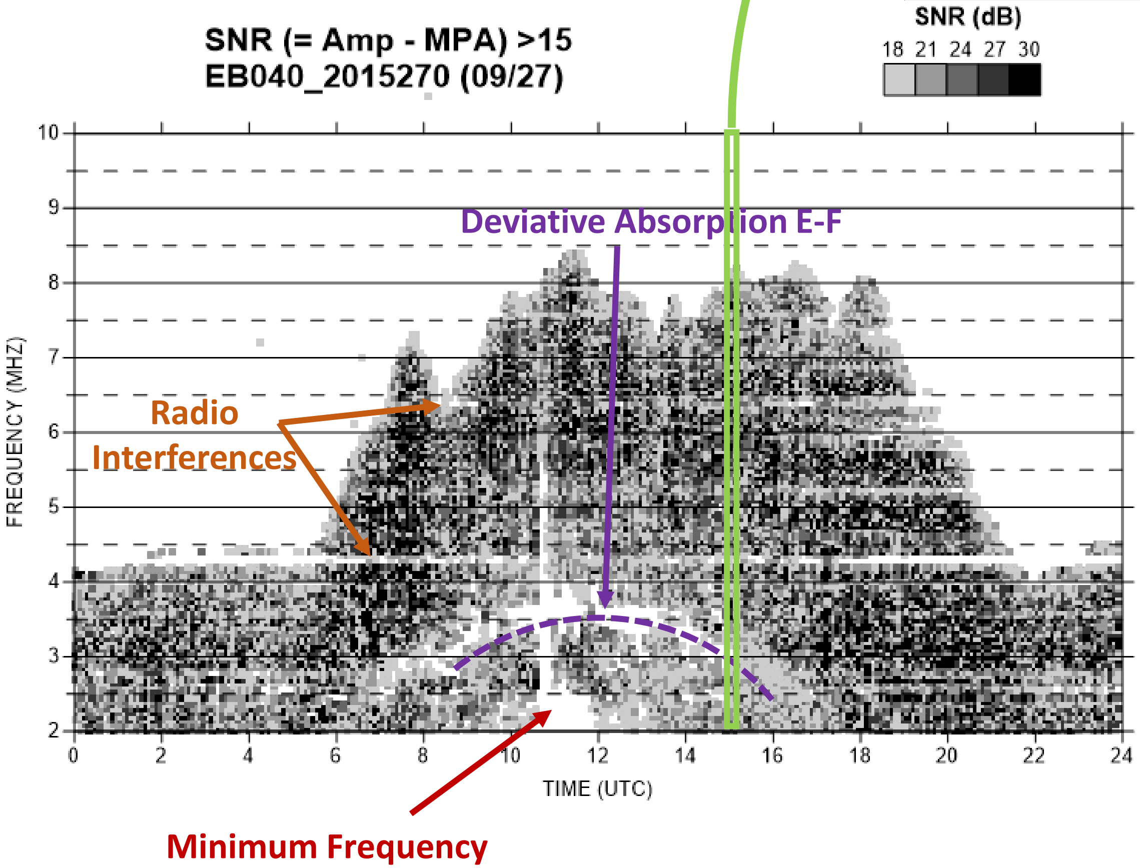
-For a given frequency of sounding, signal-to-noise ratio

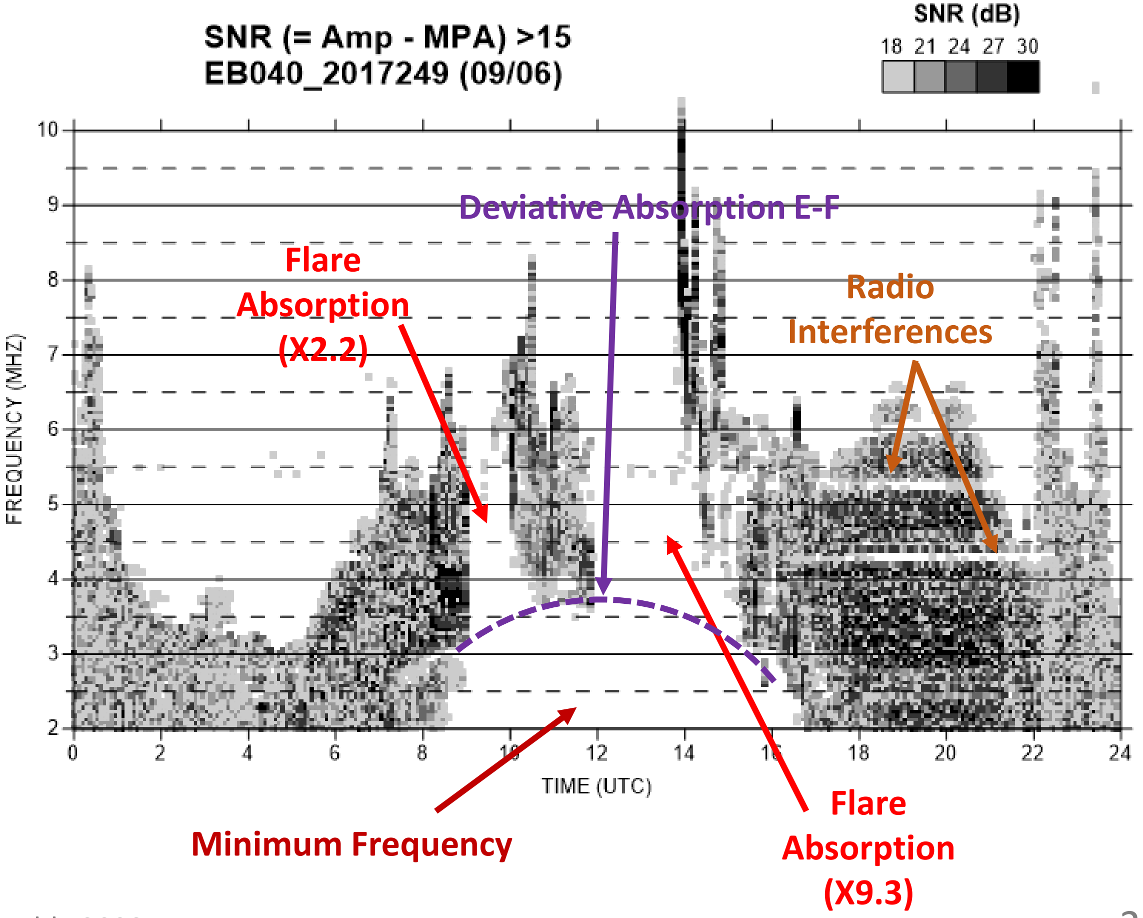
SNR = Amp-MPA

Short user manual to manage these data in supplementary material on *de Paula et al., 2022*
doi.org/10.3390/rs14081898

Signal-to-Noise Ratio (SNR)





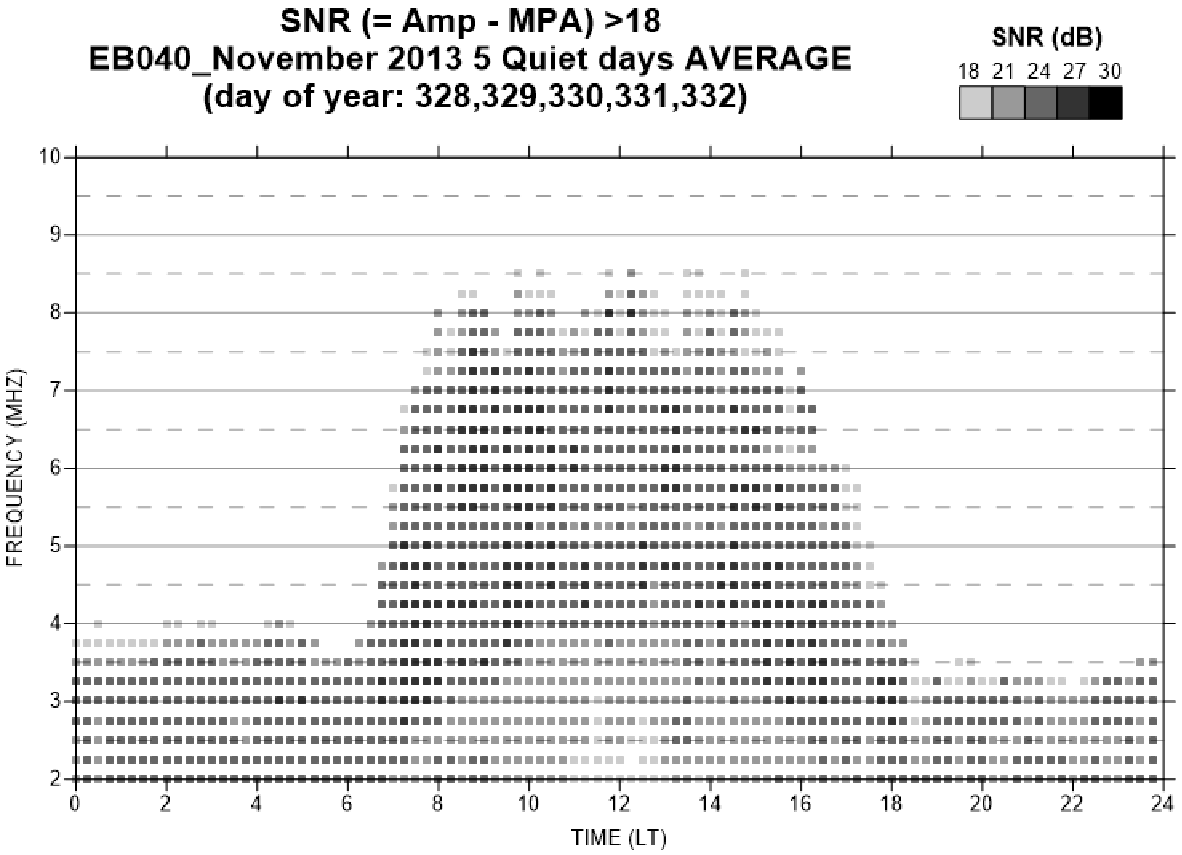


Detection methodology

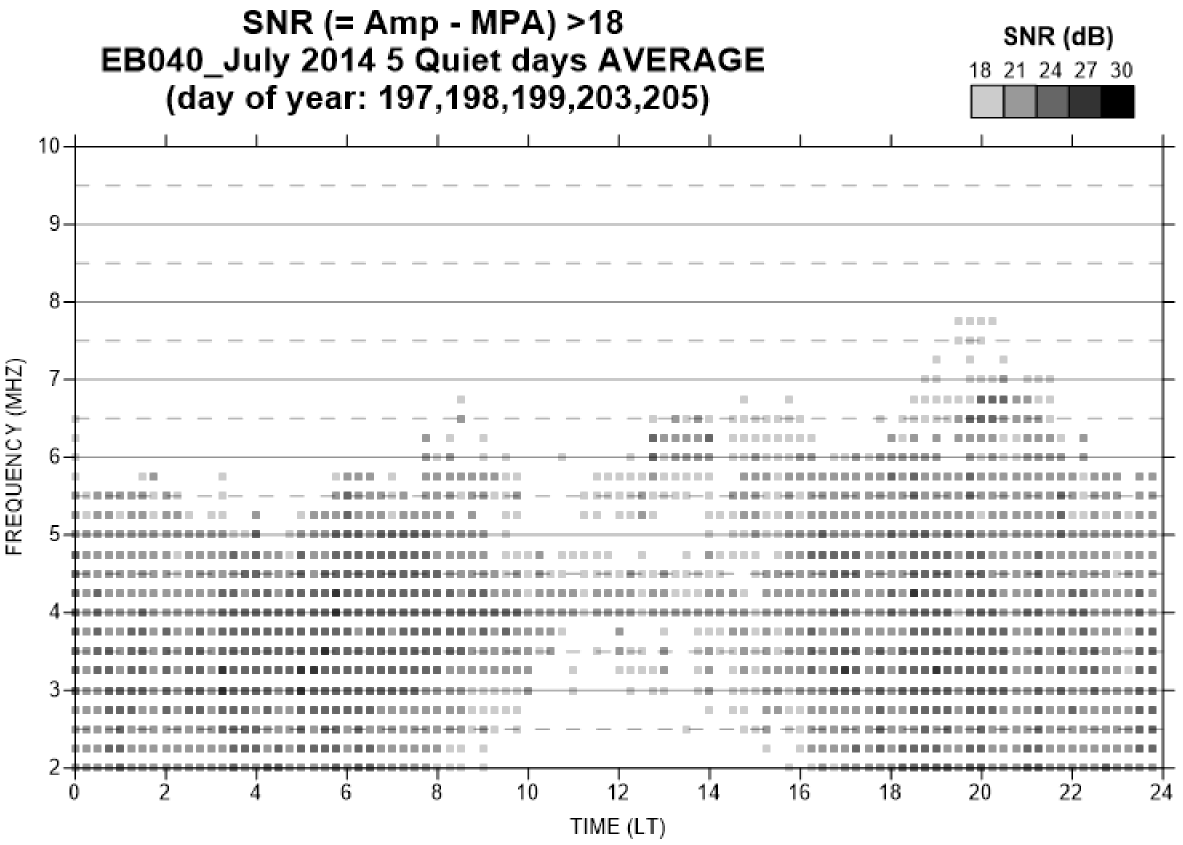
❖ Determination of the quiet monthly pattern.

Quiet monthly pattern:

Winter



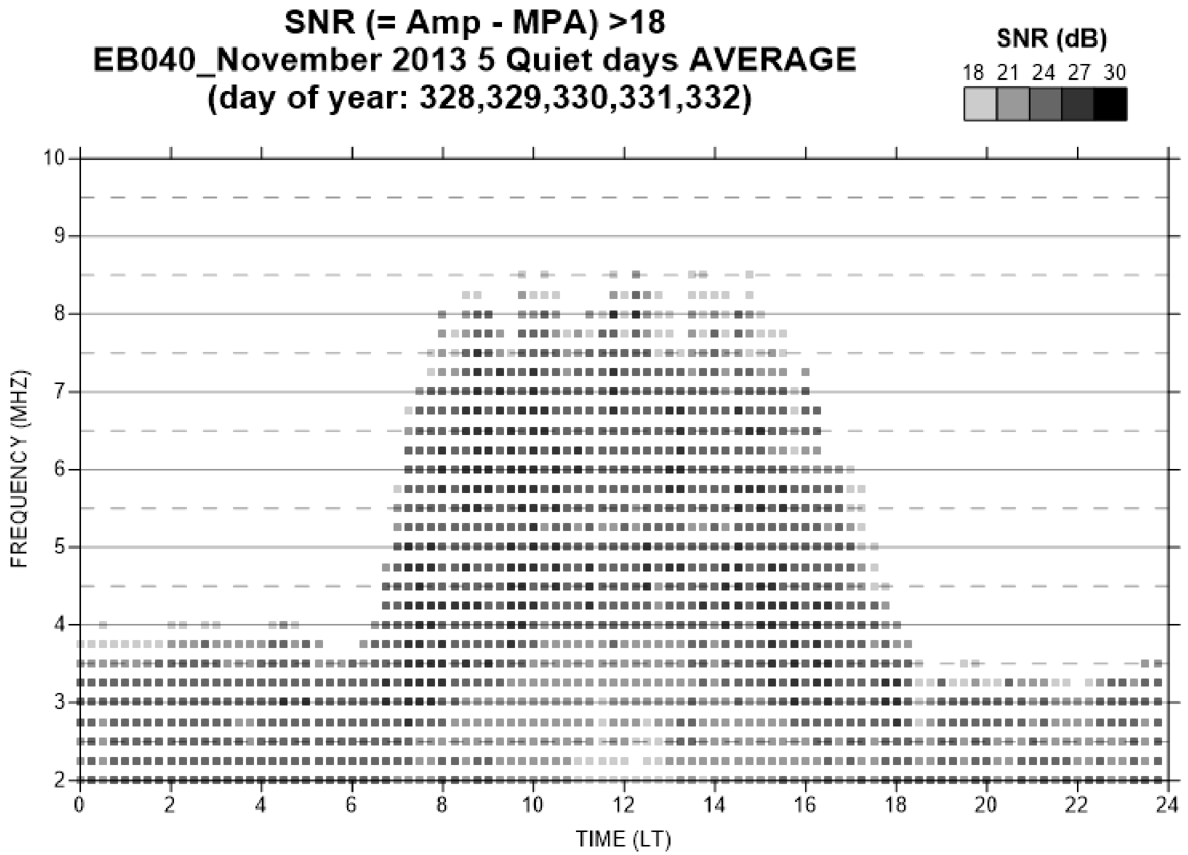
Summer



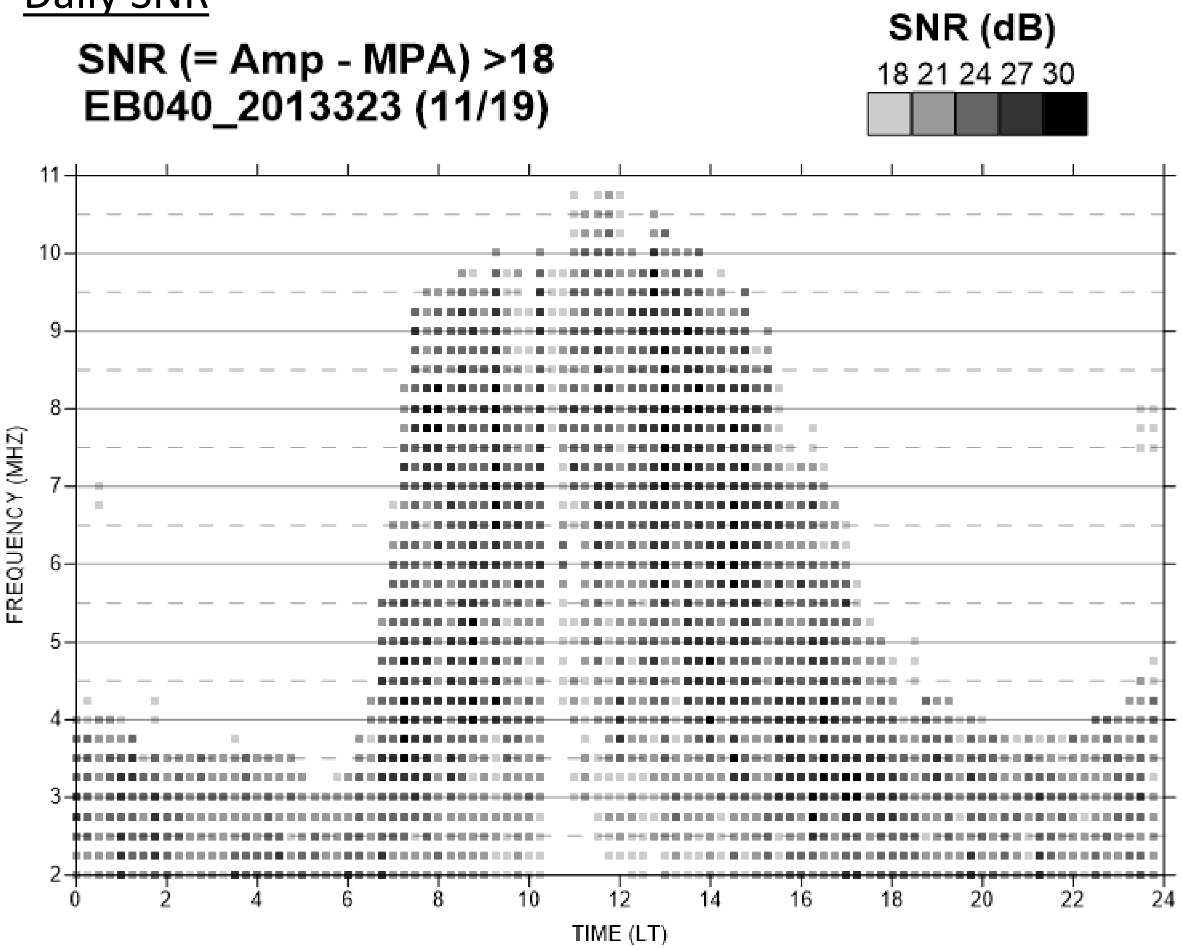
Detection methodology

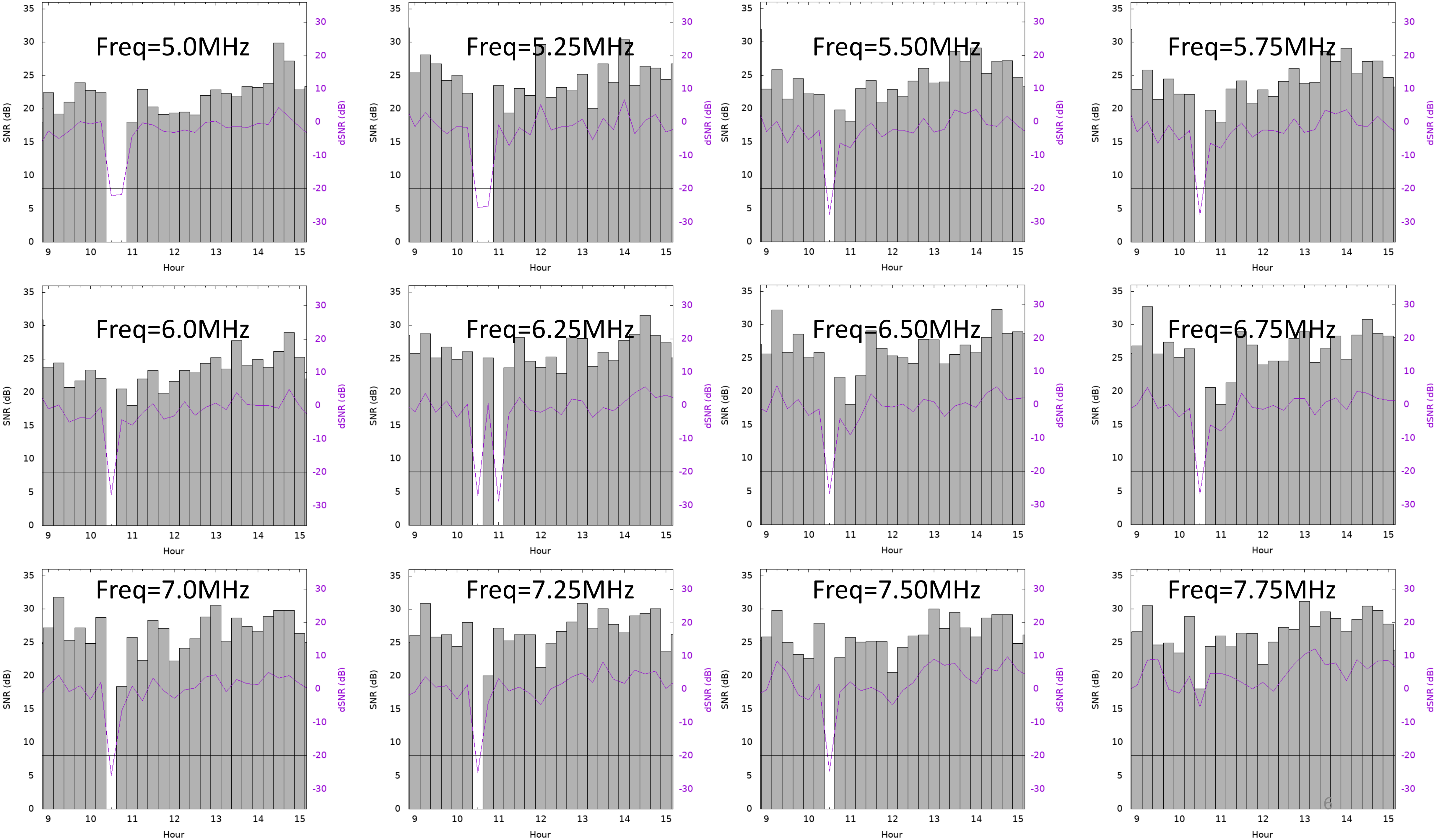
❖ Comparison between the daily SNR with the quiet monthly pattern.

Quiet monthly pattern



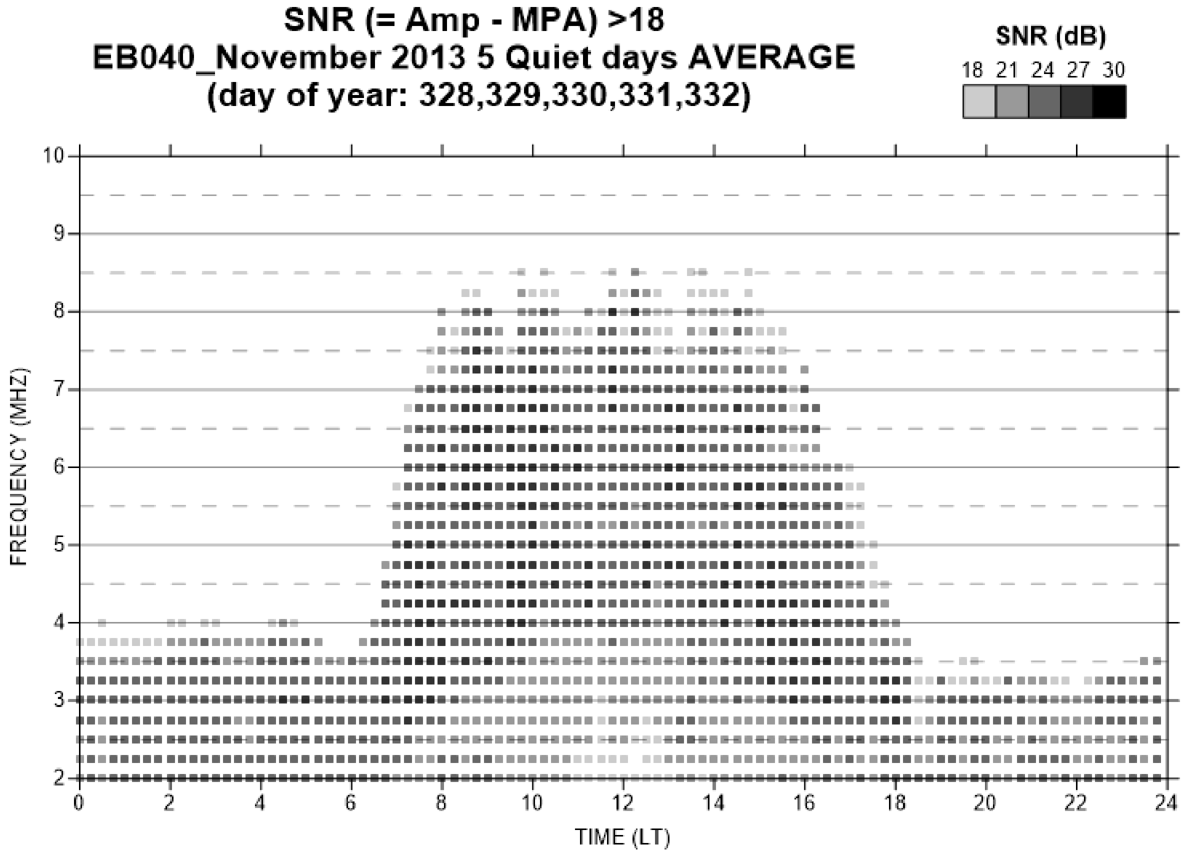
Daily SNR

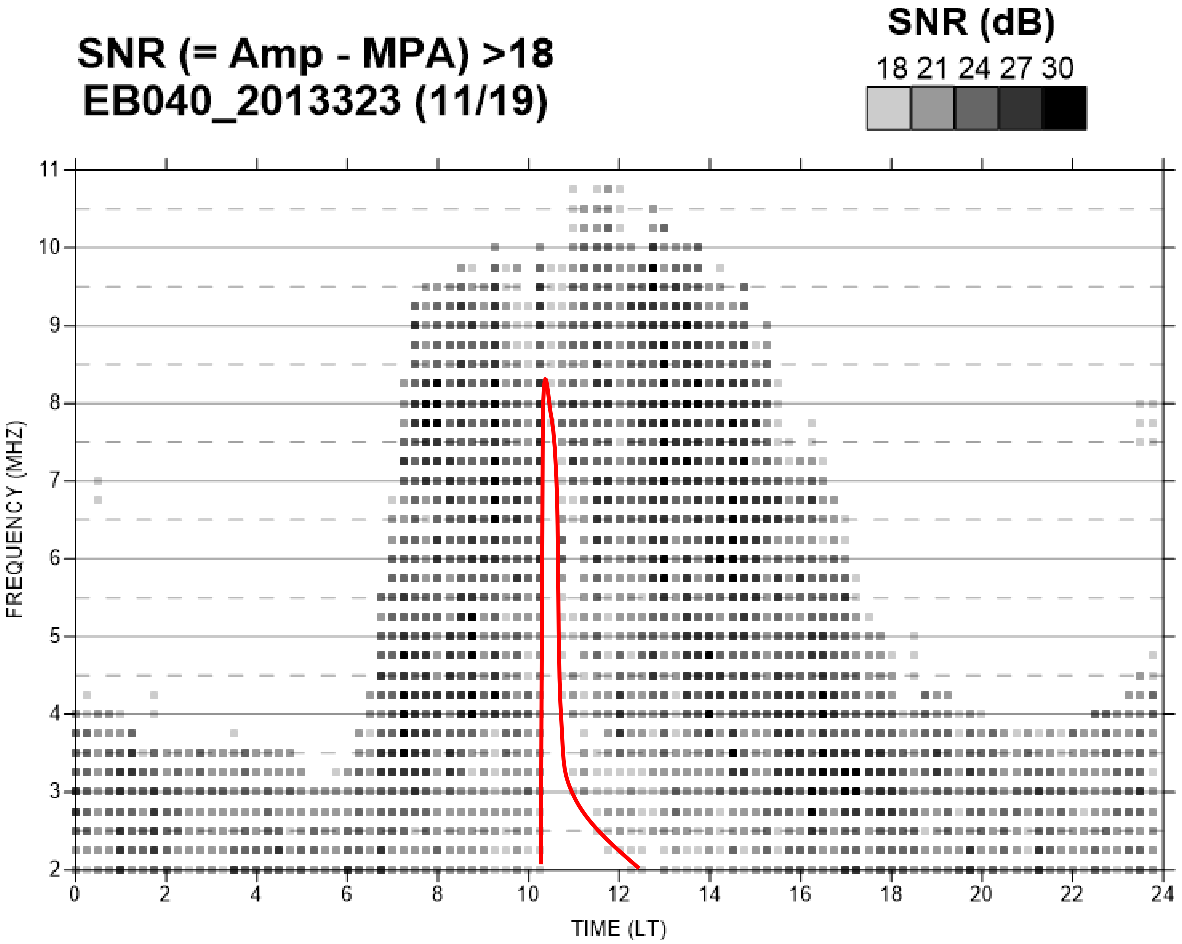



Freq=5.0MHz
Freq=5.25MHz
Freq=5.50MHz
Freq=5.75MHz
Freq=6.0MHz
Freq=6.25MHz
Freq=6.50MHz
Freq=6.75MHz
Freq=7.0MHz
Freq=7.25MHz
Freq=7.50MHz
Freq=7.75MHz
SNR (dB)
dSNR (dB)
Hour

Detection methodology

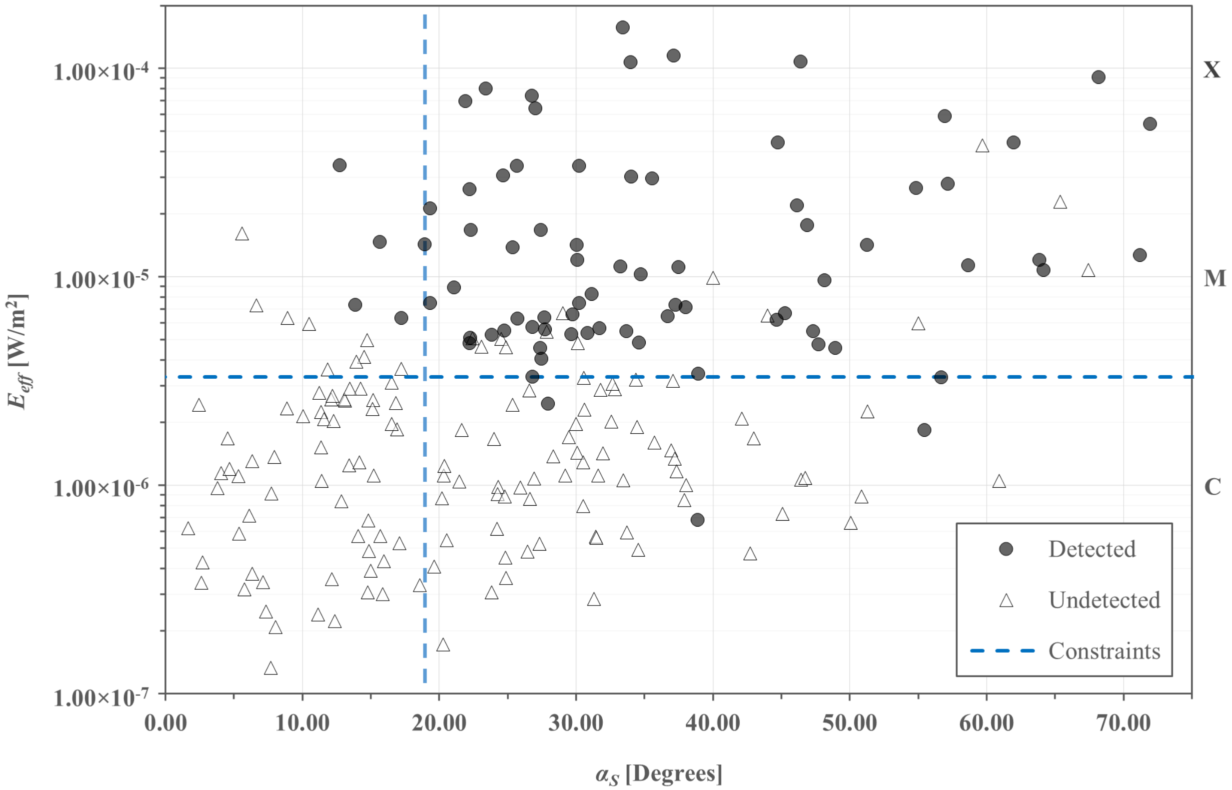
- ❖ Comparison between the daily SNR with the quiet monthly pattern.
- ❖ If the difference is below -20dB in 4 consecutive frequencies ⟶ event detection!!





Results

After running the detection method for the period 2013-2014 only a 36% of events are detected. Comprehensive analysis indicated which parameters have an influence on the detection of the absorption effects on the local ionosphere by our method.



- Relationship between Solar Altitude Angle (α_S) and Geoeffective Hard X-ray Incidence (E_{eff})

$$E_{eff} = F \cdot sin\alpha_S$$

$$sin\alpha_S = sin\delta \cdot sin\phi + cos\delta \cdot cos\phi \cdot cos(h)$$

$$\delta = 23.45 \cdot sin\left[2\pi\left(\frac{284+n}{365}\right)\right]$$

δ Sun's declination, ϕ local latitude, h hour angle and n day of the year

Constraints:

$$\boldsymbol{\alpha_S \geq 18.94°}$$

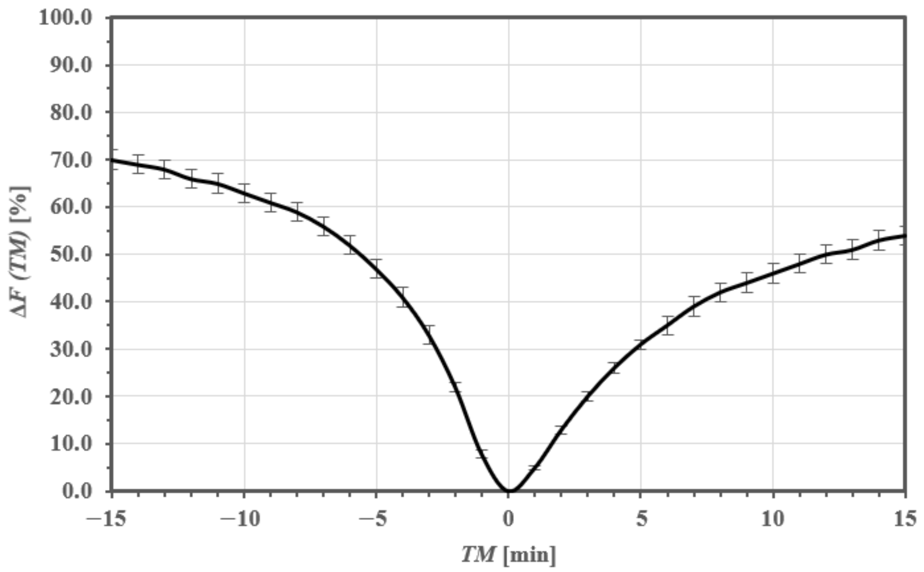
$$\boldsymbol{E_{eff} \geq 3.30 \times 10^{-6}\ W/m^2}$$

Results

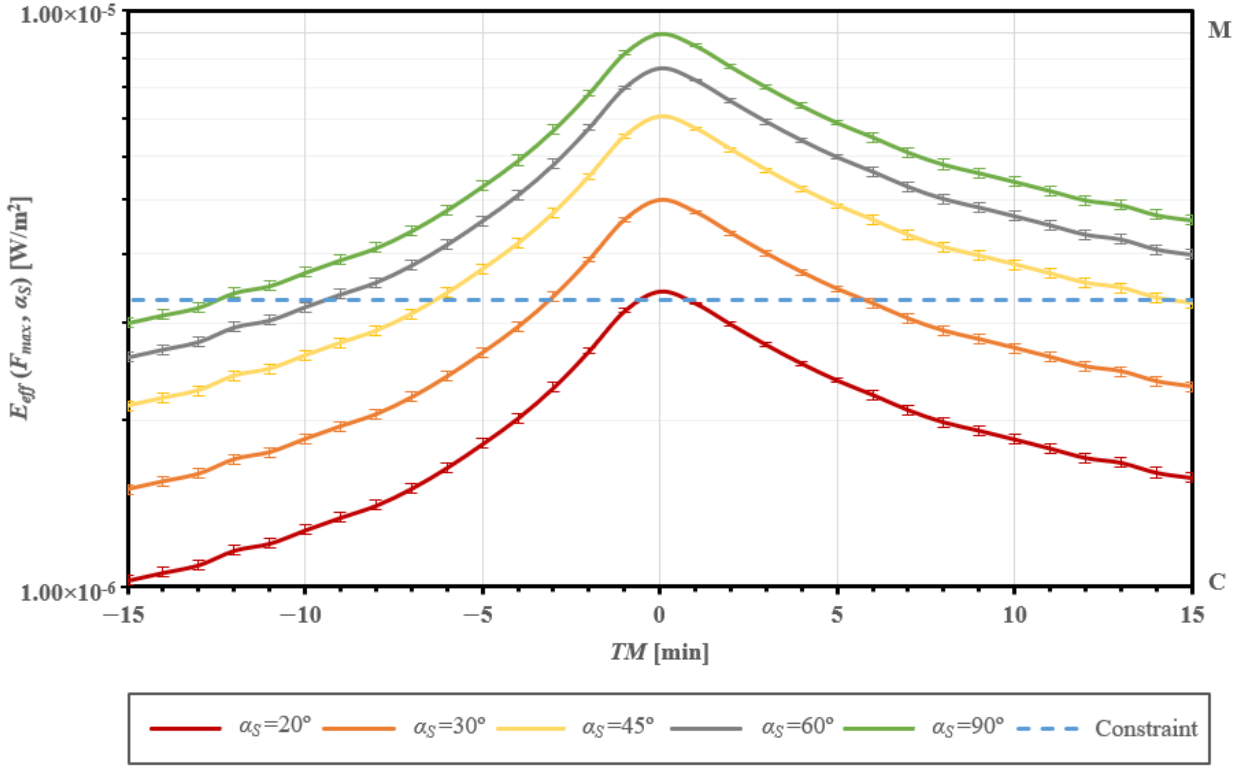
- Asynchronous measurement: Temporal Mismatch (TM)

$$E_{eff_{TW}}(F_{max}, \Delta F, \alpha_S) = \left[F_{max} - \left(F_{max} \cdot \frac{\Delta F}{100}\right)\right] \cdot sin\alpha_S$$

$$\Delta F(TM) \leq 100\left(1 - \frac{E_{eff_{min}}}{F_{max} \cdot sin\alpha_S}\right)$$



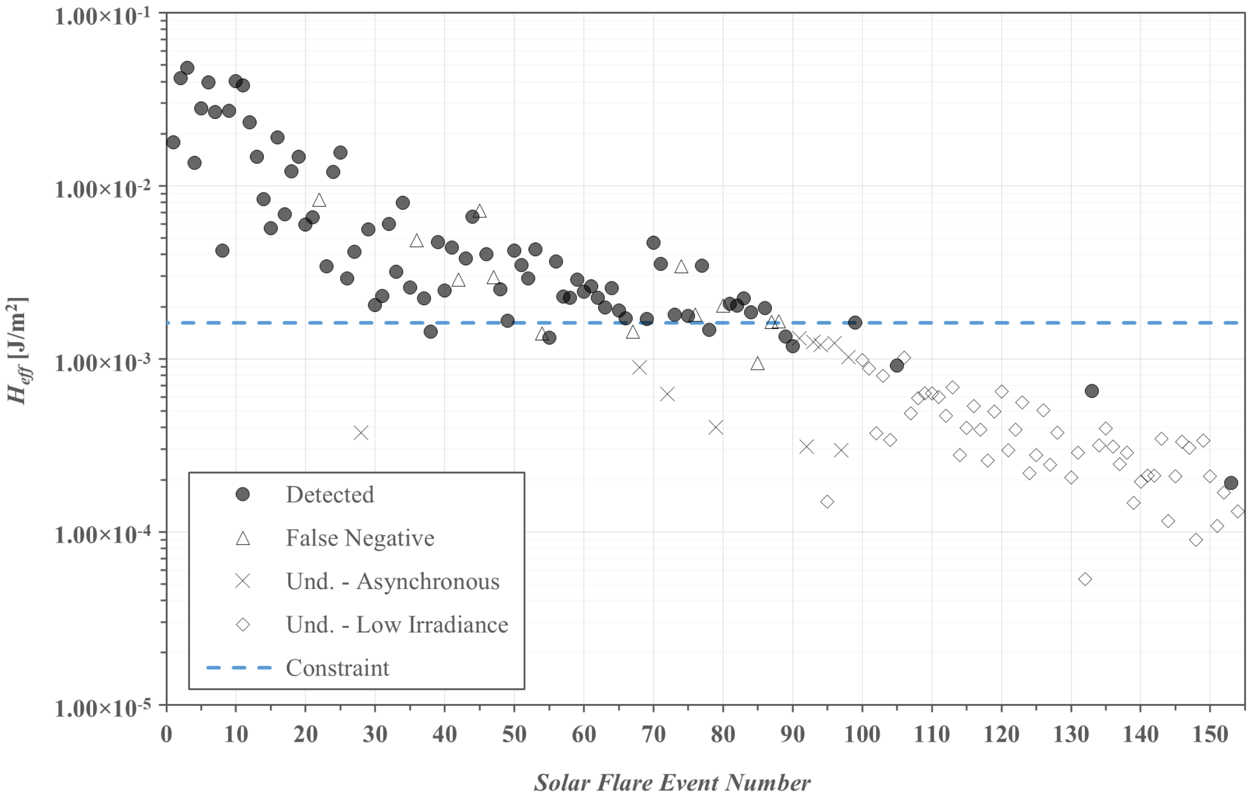
Trend of the hard X-ray flux reduction from the peak vs. TM.



Variation of the geoeffective hard X-ray irradiance vs. TM for a **M1.0** class solar flare.

Results

➢ Geoeffective Hard X-ray Radiant Exposure



The total amount of energy that the local ionosphere is receiving from a solar flare from the previous 5 min interval to the time to the measurement: the geoeffective hard X-ray radiant exposure,

$$H_{eff} = 60 \cdot \sum_{t=-5}^{0} E_{eff_t}$$

Constraint:

$$\boldsymbol{H_{eff} \geq 1.61 \times 10^{-3}\ J/m^2}$$

Detection Rate Summary

Solar flare detection rate of the Ebro ionospheric station (EB040) **considering those events that accomplish all constraints** ($\alpha_S \geq 18.94°$; $E_{eff} \geq 3.30 \times 10^{-6}\ W/m^2$; $H_{eff} \geq 1.61 \times 10^{-3}\ J/m^2$).

X-Class	M-Class	C-Class	All Classes
100.0% (14/14)	82.6% (57/69)	46.2% (6/13)	80.2% (77/96)
Cause undetected events: ▪ Asynchronous Meas.: 0 events ▪ False Negative: 0 events	*Cause undetected events:* ▪ Asynchronous Meas.: 4 events ▪ False Negative: 8 events	*Cause undetected events:* ▪ Asynchronous Meas.: 7 events ▪ False Negative: 0 events	*Cause undetected events:* ▪ Asynchronous Meas.: 11 events ▪ False Negative: 8 events

References:

de Paula, V.; Segarra, A.; Altadill, D.; Curto, J.J.; Blanch, E. Detection of Solar Flares from the Analysis of Signal-to-Noise Ratio Recorded by Digisonde at Mid-Latitudes. Remote Sens. **2022**, 14, 1898. https://doi.org/10.3390/rs14081898

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THANK YOU FOR YOUR ATTENTION

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MIRA
detection, Monitoring and modelling of Ionospheric irRegulArities
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