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Investigating the variation of the ionospheric absorption during large solar flares based on modern Digisonde data

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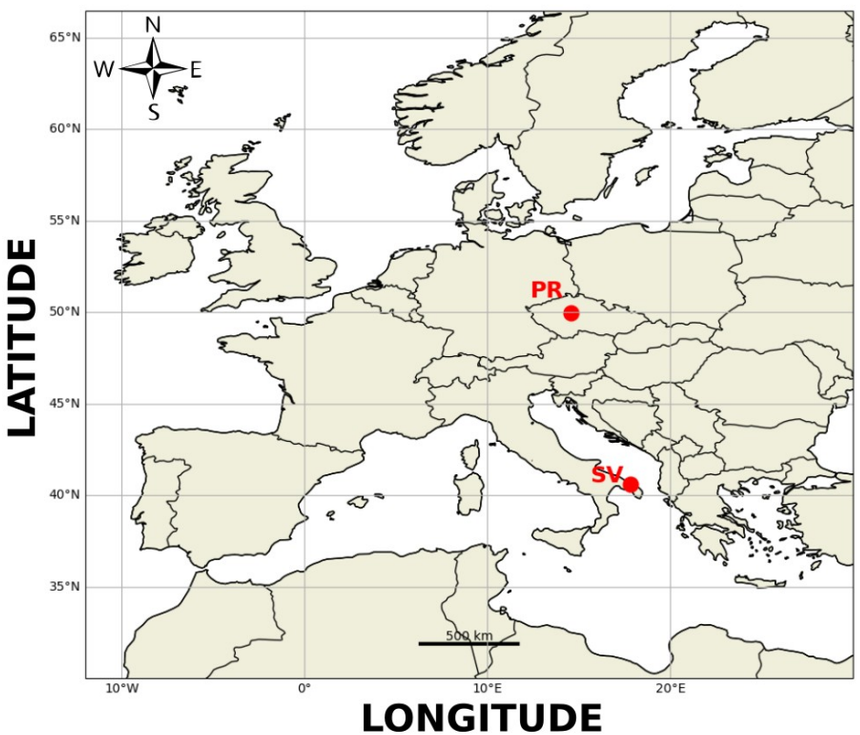
IAP

Introduction and Data

The **main objectives** of this study are:

- To use **Digisonde data** to calculate **ionospheric absorption**,
- To study the **effects of solar flares** on the ionosphere,
- And to compare the results of the absorption analysis with the corresponding $\mathbf{f_{min}}$ and **SNR** (Signal-to-Noise Ratio) data.



Data:

- **Digisonde data** (i.e., amplitudes at given frequencies) from **Průhonice** (**PR**, 49.98° N, 14.55° E, Czech Republic) and **San Vito** (**SV**, 40.6° N, 17.8° E, Italy) stations.
- Data from **quiet** (173 days from 2017 and 2018) **and disturbed** (06-10. September 2017) **periods**.

Data and Methodology

Investigated flares:

Flares	Datetime (UT) (dd.mm.yyyy)	06.09.2017 09:10	06.09.2017 12:02	07.09.2017 10:15	07.09.2017 14:36	08.09.2017 07:49	09.09.2017 11:04	10.09.2017 16:06
	Class	X2.2	X9.3	M7.3	X1.3	M8.1	M3.7	X8.2

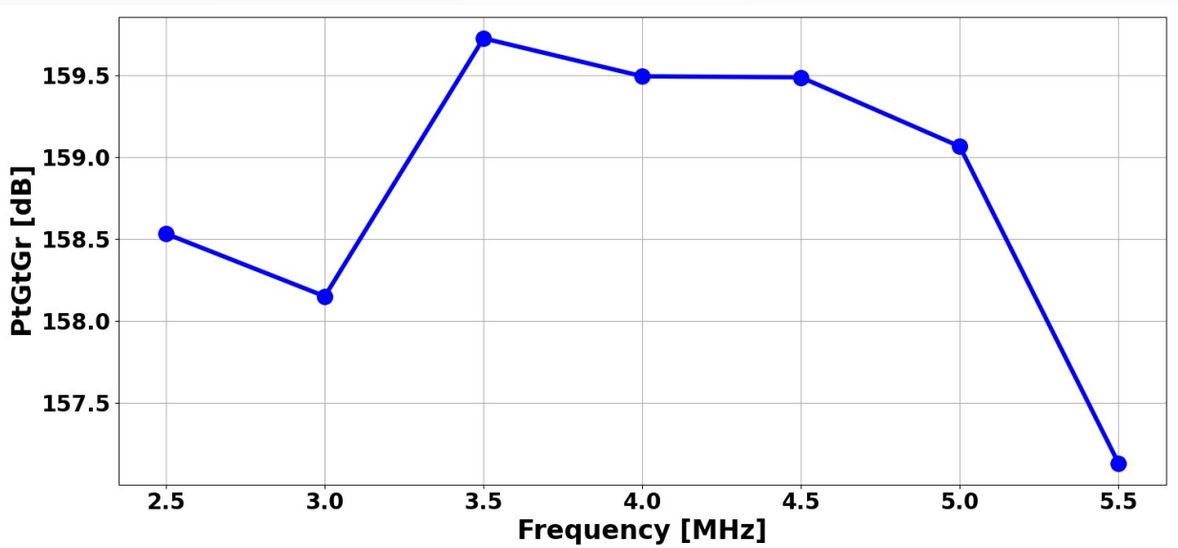
- Calculating the **loss term from Digisonde data** according to the method presented by Sales (2009, [1]).
- This method involves the **calibration of the used Digisonde system** at certain frequencies (i.e., at 2.5, 3, 3.5, 4, 4.5, 5, and 5.5 MHz, +/-200 kHz) by using nighttime (i.e., 20-05 LT) data from quiet days.
- Afterwards, the losses at the chosen frequencies can be determined, however this approach is only eligible to **detect relative changes in the absorption**.
- The calibration was carried out based on the **Friis transmission equation**:

$$10\lg(L) = 10\lg(P_t G_t G_R) + 20\lg\left(\frac{\lambda}{4\pi 2h}\right) - 10\lg(P_R)$$

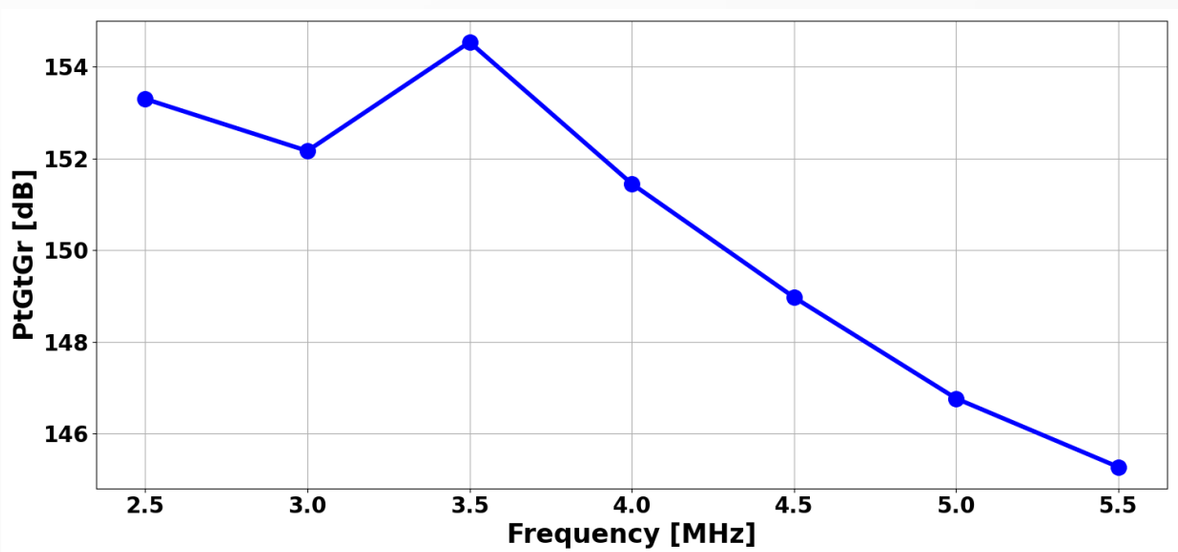
Methodology and Results

$$10\lg(L) = 10\lg(P_t G_t G_R) + 20\lg\left(\frac{\lambda}{4\pi 2h}\right) - 10\lg(P_R)$$

- The **unknown terms** are: P_t , G_t , G_R , and L(f), the power of the transmitted signal, the gain of the transmitter, the gain of the receiver, and the loss, respectively. λ is the wavelength and h is the (approximate) height of the reflection.
- Firstly, **we determined the $P_tG_tG_R$ product at the given frequencies (calibration)** for nighttime data from a quiet period (**173 days from 2017 and 2018**) for both stations (PR and SV).



PR

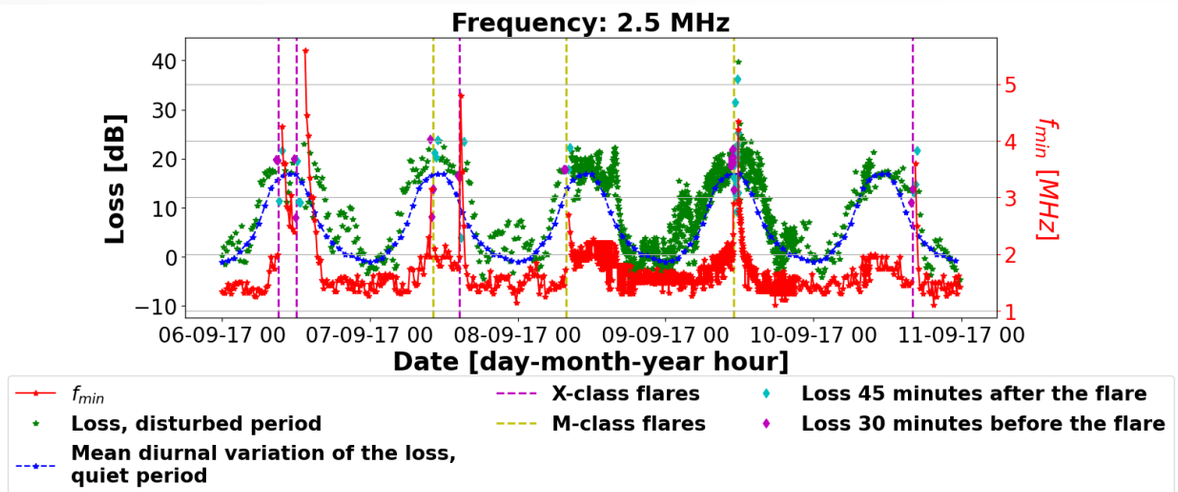


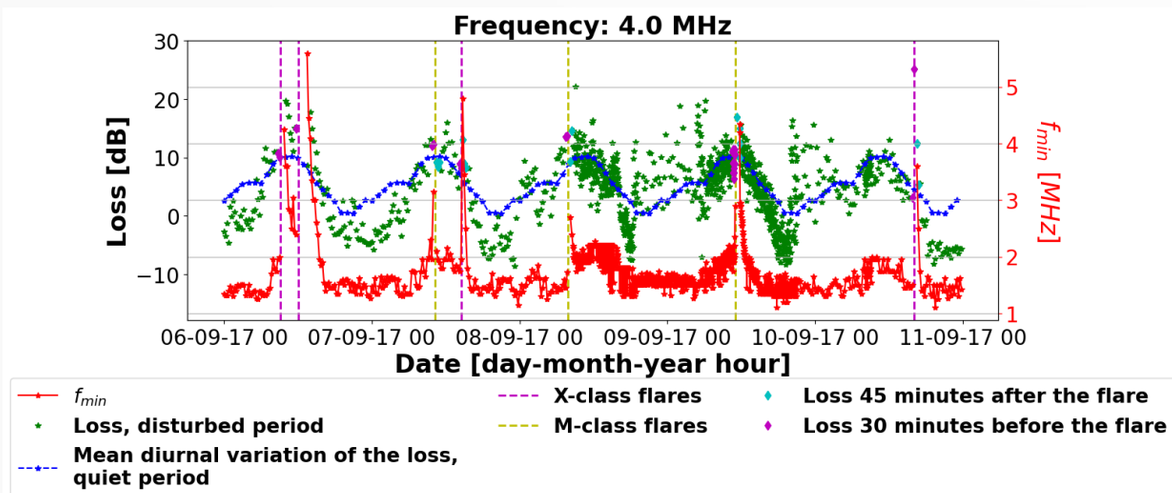
SV

Results

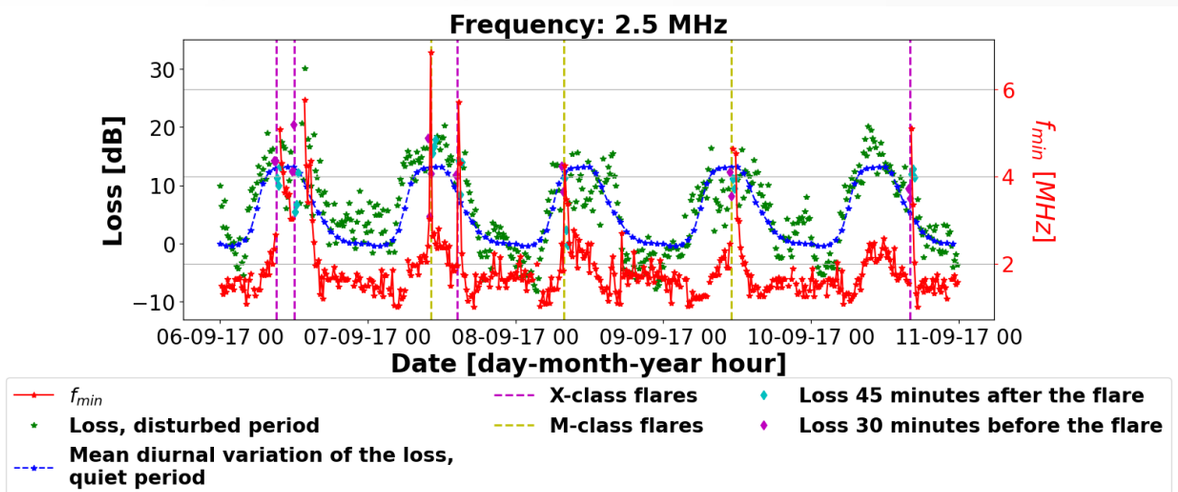
- After calculating the $P_tG_tG_R$ product **we determined the loss term and compared it to the f_{min} parameter.**

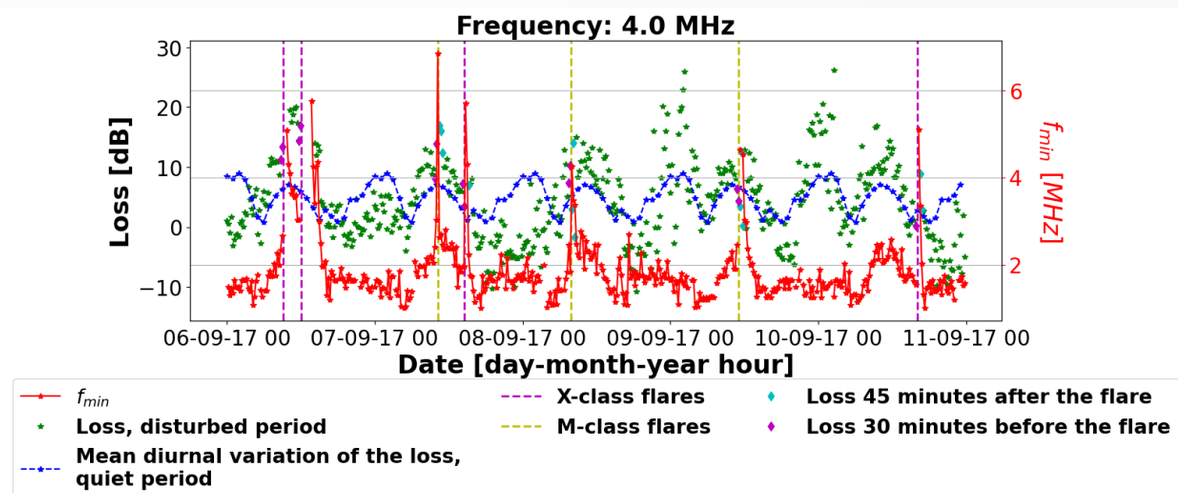
PR





SV

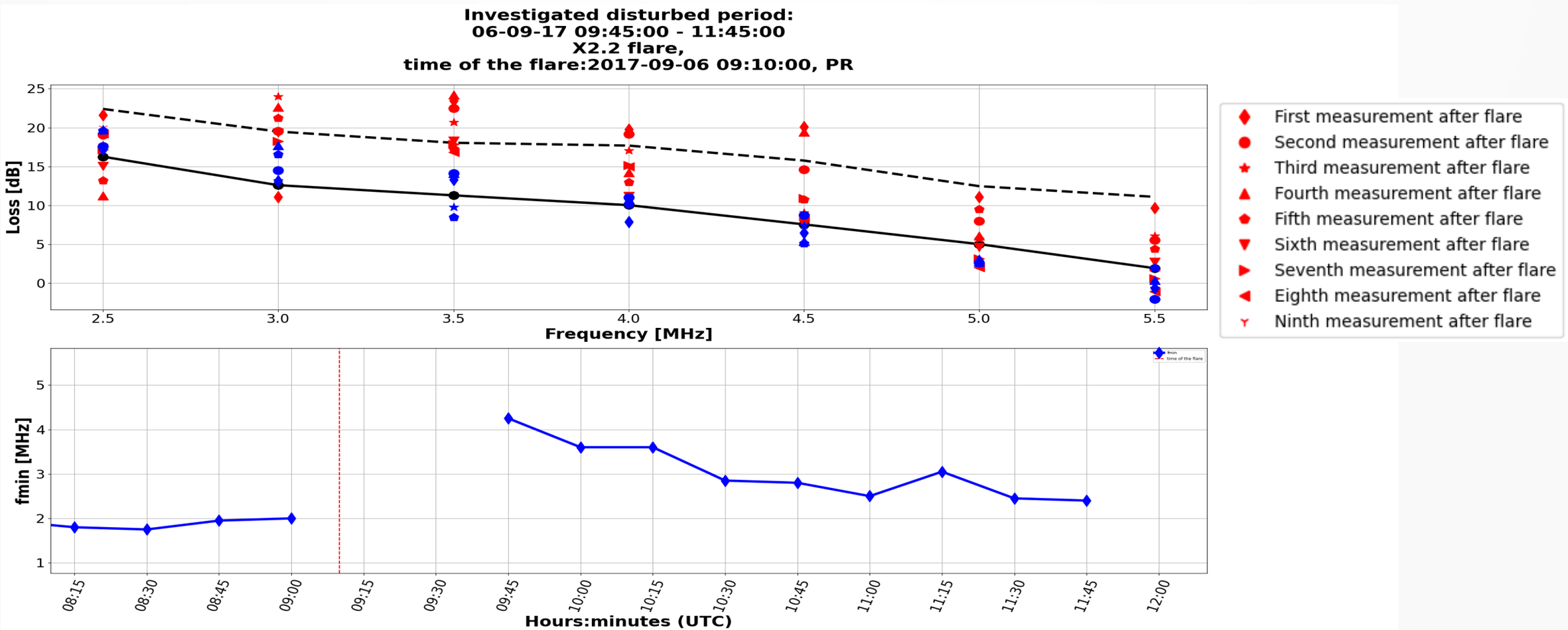




Results

- Subsequently, **we analyzed the impact of the selected solar flare events** based on the determined loss.

PR



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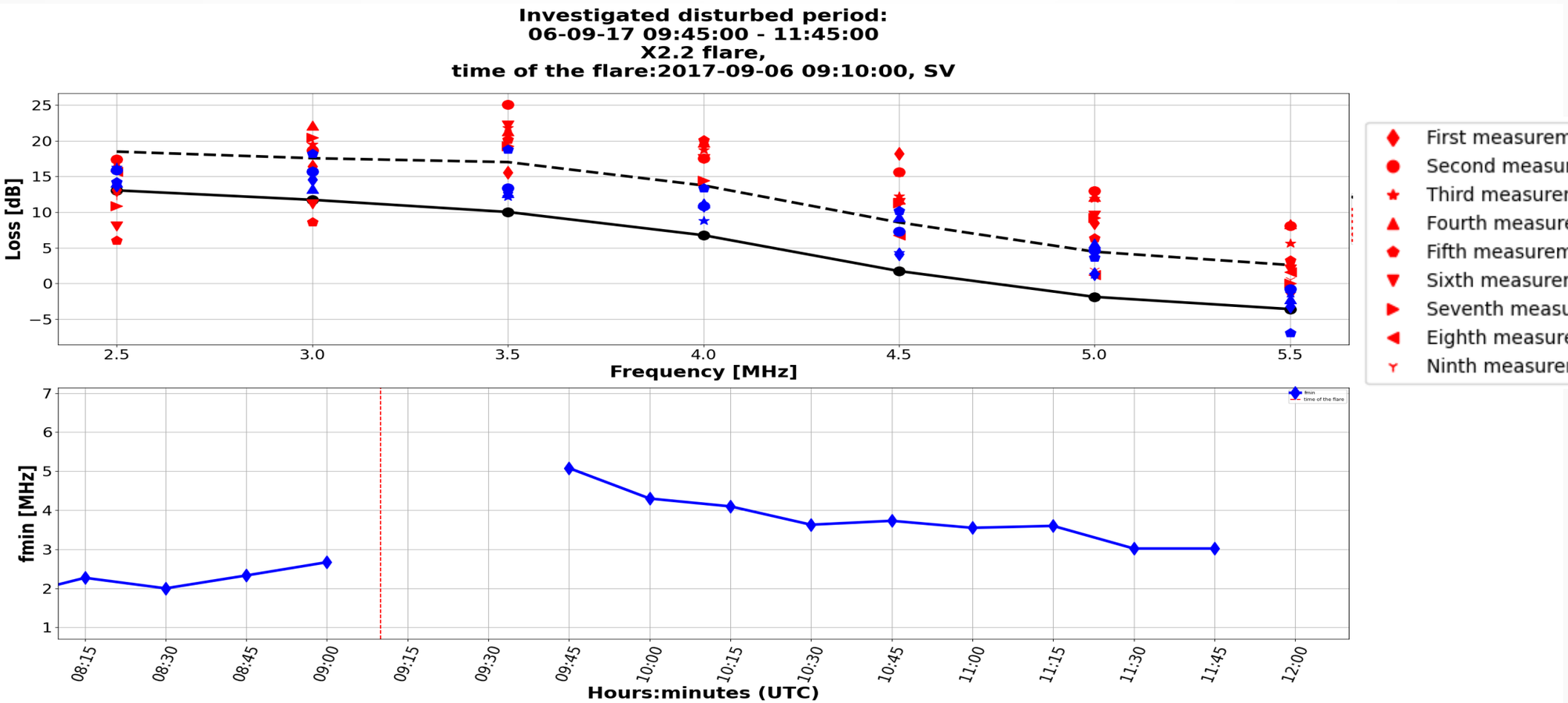
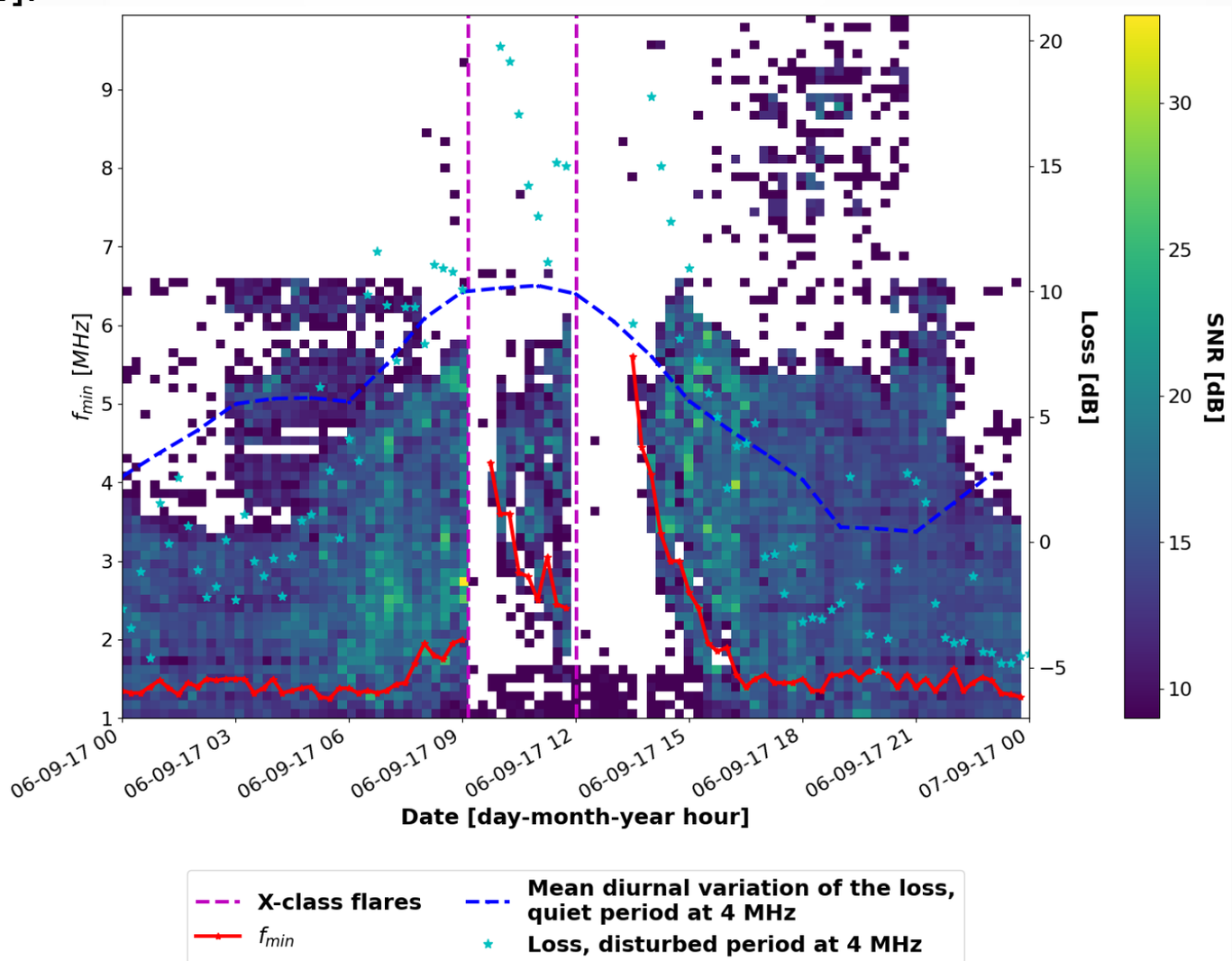
SV



Results

- Additionally, **the analysis of the SNR table** can further help us to study the effect of solar flares on the ionosphere [2].

PR



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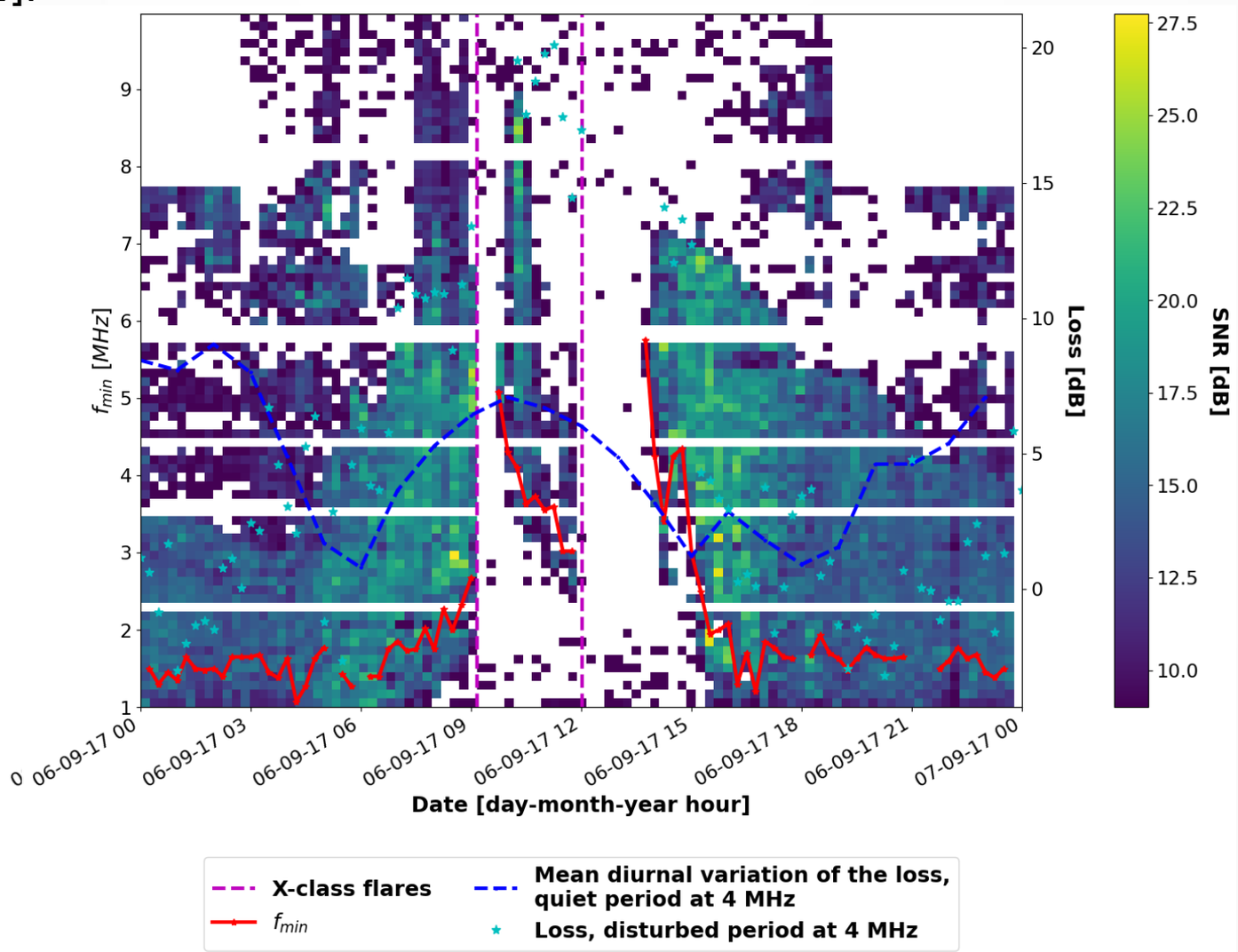
SV



Conclusions

- With the **method proposed by Sales** [1] we were able to **determine the relative ionospheric loss** of HF radio waves based on **Digisonde data**.
- In some cases, the **ionospheric loss increased significantly during larger (M- and X-class) solar flares**. However, based on the data and methods used in the present study, **this behavior is not unambiguous**.
- The calculated **ionospheric loss and the f_{min} parameter shows similar behavior**, with increased values during daytime than nighttime and an enhancement during the flare events.
- Together **with the analysis of the SNR table [2] and the f_{min} method** we can get a more detailed view about the ionospheric response to solar flares
- Ultimately, **this method could be a useful addition to studying the ionospheric response during solar flares** but other corrections and selection criteria should be introduced in future research.

Thank you very much for your attention!

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References

[1] Gary Sales: D-region absorption normal and solar flare using the digisonde; oral presentation at the XIII. International GIRO Forum, Lowell MA USA, 10-13 May 2011.

[2] 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