Radio-quiet ionosonde observations for HF absorption monitoring

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Solar-Terrestrial Centre of Excellence

Overview

HF-absorption monitoring with ionosondes

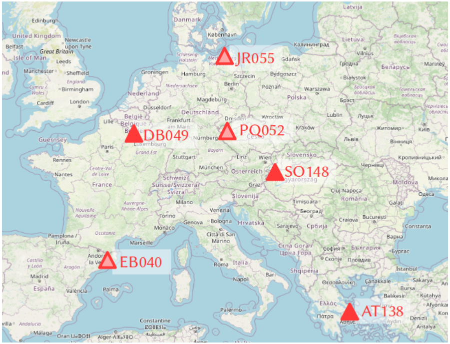
Various techniques are being investigated to monitor HF-absorption with ionosondes:

1. Monitor f_{min} parameter, the lowest frequency echo in the ionogram: easy to get, but limited information.
2. Echo amplitude monitoring: signal strength of reflection from E/F layer compared, as function of frequency; higher frequencies monitored using OI traces, but still limited to MUF.
3. X- *vs.* O-polarised amplitudes: more complicated data processing, but detailed D-layer observations (up to foF_2).
4. Passive listening (using signals of opportunity): should be able to monitor higher frequencies (up to the limit of the instrument).

Our experiment

This was a proof of concept experiment, started in March 2024.

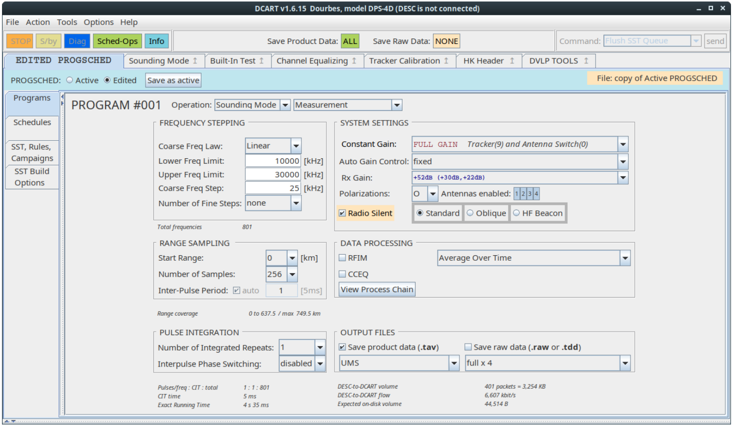
- We use European ionosondes at mid-latitudes.
- Passive listening to frequencies from 10 to 30 MHz, swept in small steps.
- 5 minute cadence of sweeps.
- Ionosonde schedule time is scarce, so very short samples at each frequency.



Initially, we wanted to listen to extraterrestrial noise, but better signals from terrestrial broadcasting bands.

Programming passive sweep

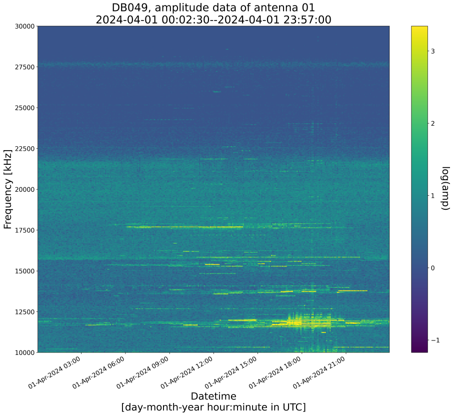
Original program requested for IM-1 lunar mission.

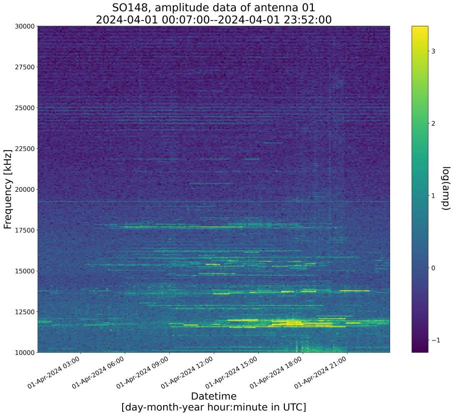


These data were not originally recorded for our absorption measurements; instrument configuration can be optimised.

Spectrograms

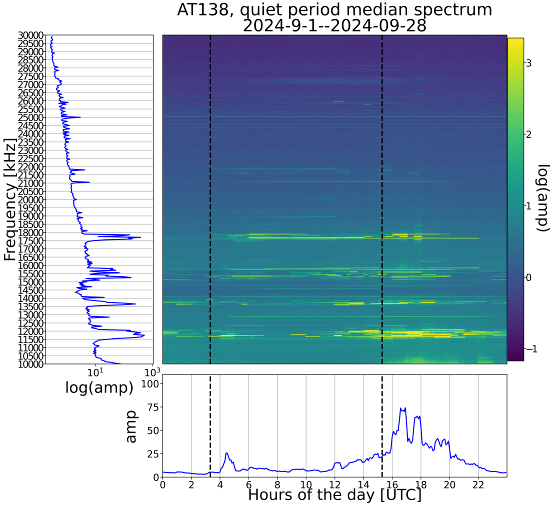
24 hour spectrogram between 10 and 30 MHz on a quiet day (2024-04-01) at DB049 and SO138.





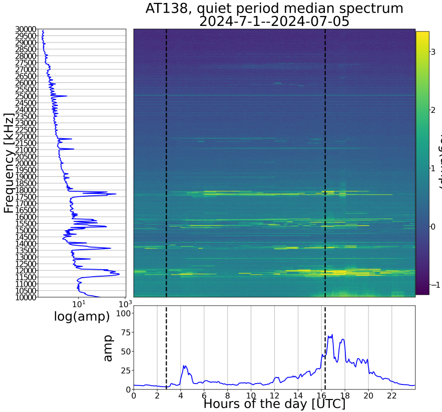
Spectrograms are very similar at different observatories.

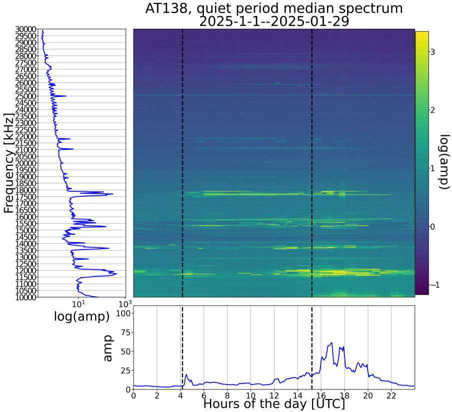
Quiet time median behaviour



- Spectrum comprises power-law noise (line-of-sight & instrument) + HF broadcast bands (sky-wave propagation).
- Clear diurnal variation in sky-wave propagation, especially after sunset.

Seasonal variations

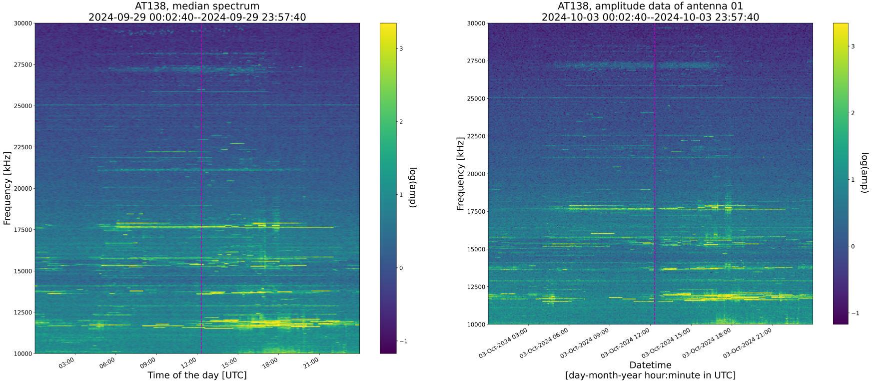




Obviously some differences between seasons, but main patterns (especially greyline enhancements) are remarkably consistent.

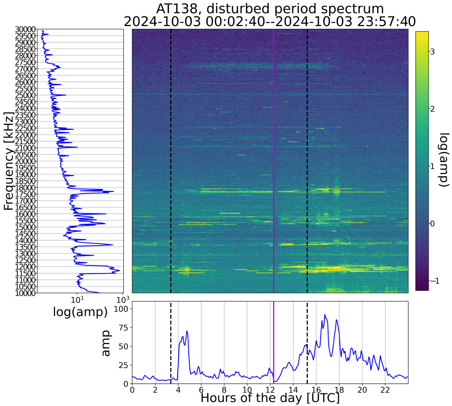
Spectrograms during a major flare

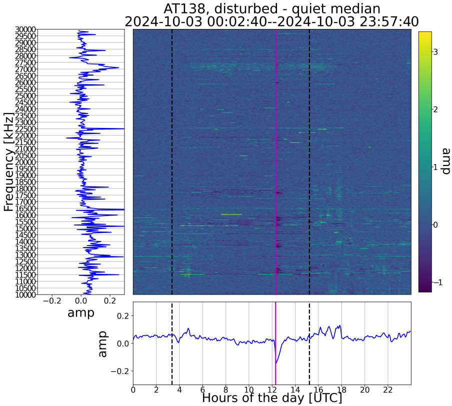
An X9.0 flare occurred on 3 October 2024, peaking at 12:18 UTC.



Left: trailing median spectrogram; right: spectrogram on day of flare.

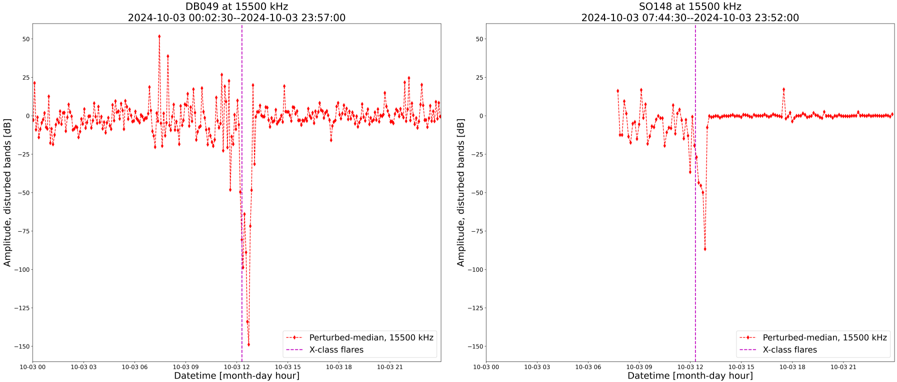
The solar flare effect becomes more obvious when subtracting the median.





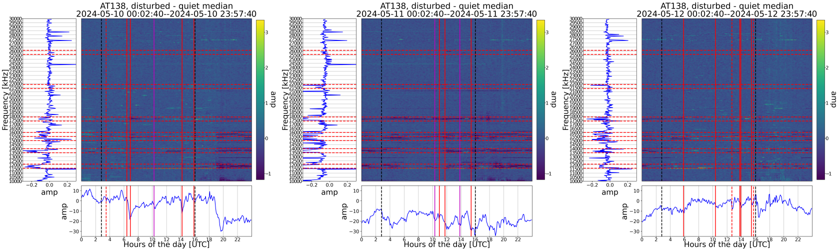
Solar flare effect on terrestrial HF noise

Zooming in on one frequency (15.5 MHz) with significant sky-wave noise.



Deviation from median at DB049 (left) and SO148 (right).

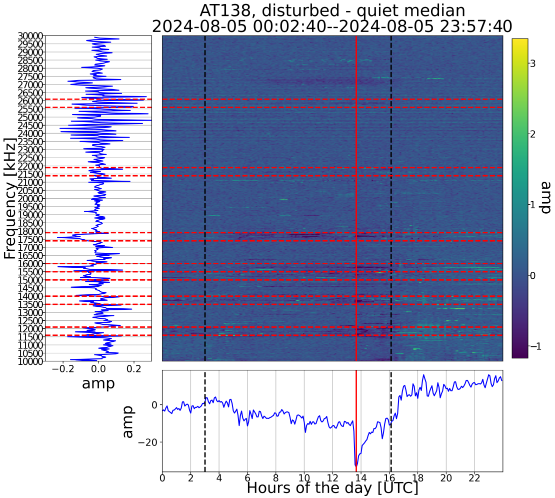
Data from the 2024 Mothers Day storm show various absorption sources.



1. Some X- and M-class flares.
2. Auroral precipitation starting May 10 around 19 UTC.
3. Enhanced background X-rays on May 11.

Analysis still in progress...

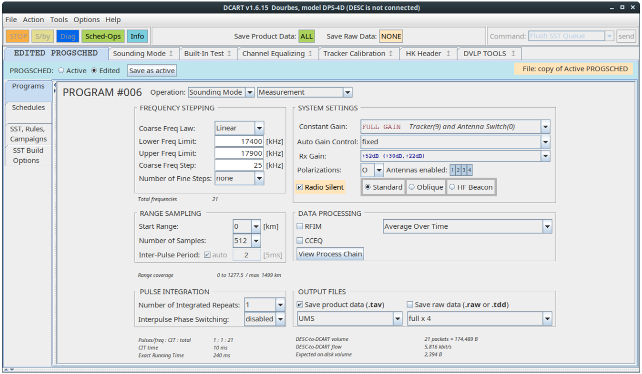
Next steps in data analyses



- Many frequencies don't have sky-wave signals, and can be removed.
- We identified 7 bands (0.5 MHz bandwidth) reserved for radio broadcasting systems.
- Flare (X1.73) effect becomes more obvious.

Future measurements

We are interested in monitoring small broadcasting bands, most of the spectrogram is not useful. Thus: replace full sweep with small bands.



Advantage: monitor 7 bands in less than 1 sec., Disadvantage: complicates data processing.

Also: we will look at frequencies below 10 MHz.

Summary

The main conclusions:

1. Existing HF broadcast signals can be used as beacons of opportunity to assess D-layer absorption.
2. Possibility for studies of quiet ionosphere as well as solar flare effects.

Future work:

1. Establish detailed quiet-time diurnal variations in function of seasons/frequency; investigate quiet time patterns.
2. Analyse data from more observatories.
3. Extend the measurements to frequencies below 10 MHz.
4. Improve data processing method, remove power law noise background.
5. Set up measurements in bands of interest, to monitor solar flare effects as a function of frequency.

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The end!

Questions, comments, suggestions?