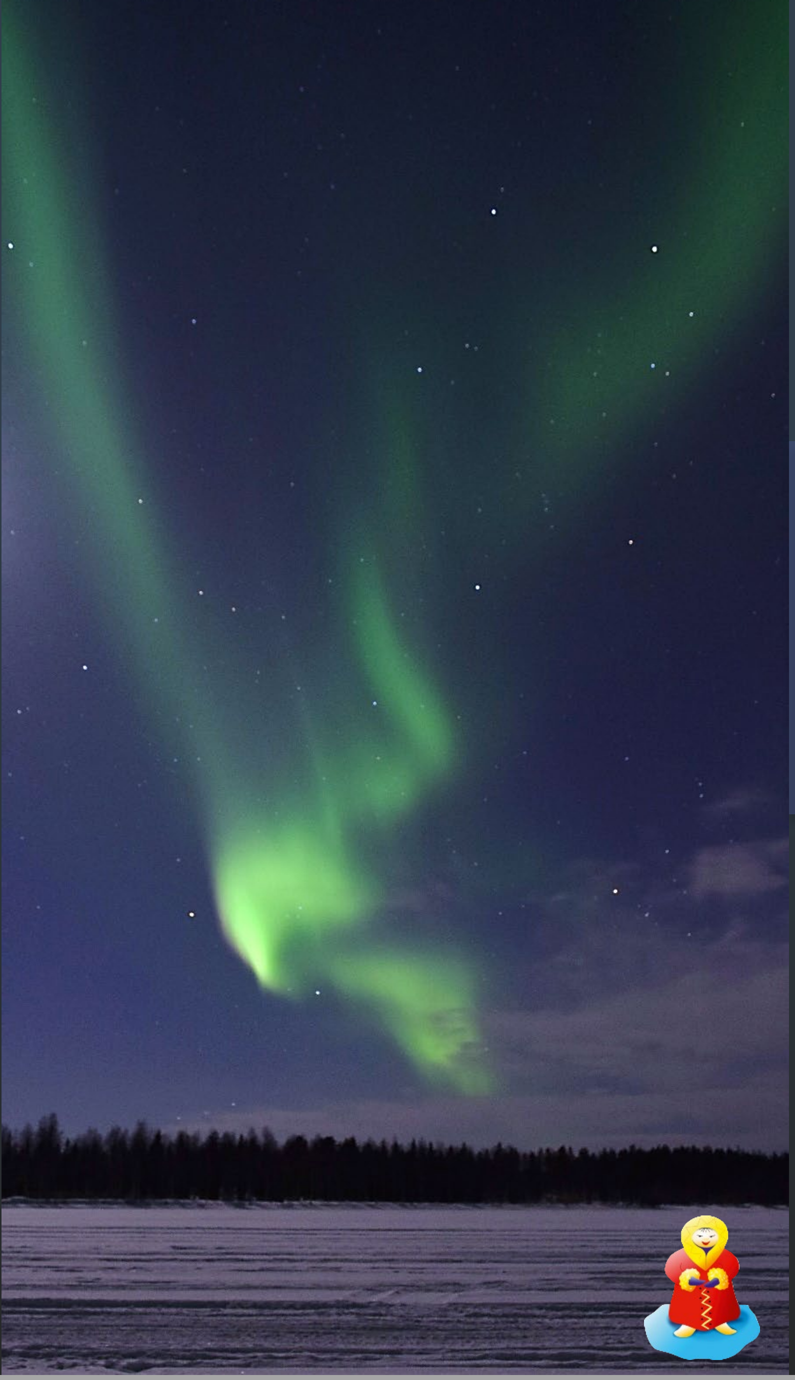


aurora @ finland – nov. 2018

Institute for Space-Earth Environmental Research

名古屋大学 NAGOYA UNIVERSITY

claudia@isee.nagoya-u.ac.jp

Statistical properties and propagation characteristics of unusual high-frequency VLF emissions observed at Kannuslehto, Finland

Claudia MARTINEZ-CALDERON[1], J. K. Manninen[2], J. T. Manninen[2], and T. Turunen[2]

[1]ISEE, Nagoya University; [2]SGO, University of Oulu

March 17, 2021

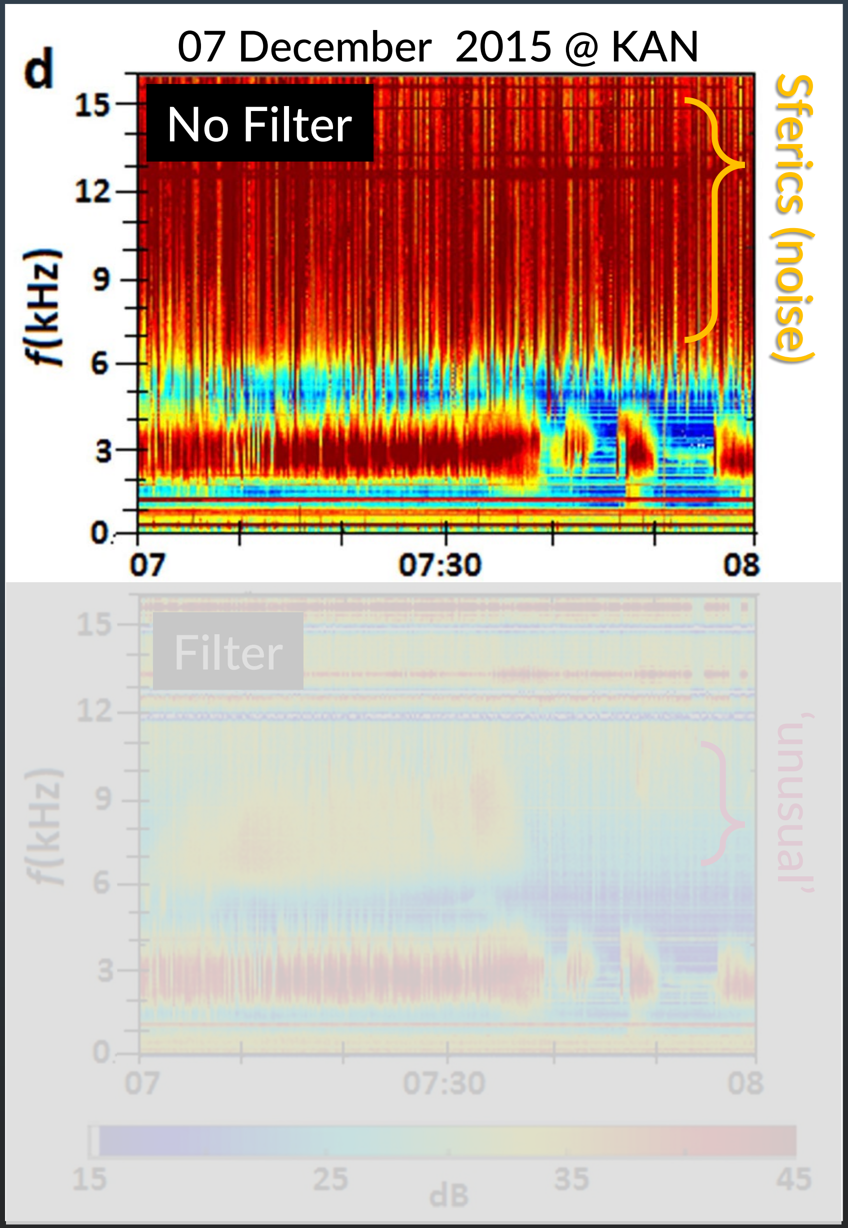
44th Physics of Auroral Phenomena Seminar

What are these 'unusually' high frequency emissions?

Sferics filtering

Problem: On the ground sferics are too strong, covering large frequency ranges, for our study they are 'noise'.

How to remove this noise? Creating a sferics filter!



[Manninen+2016, ERL]

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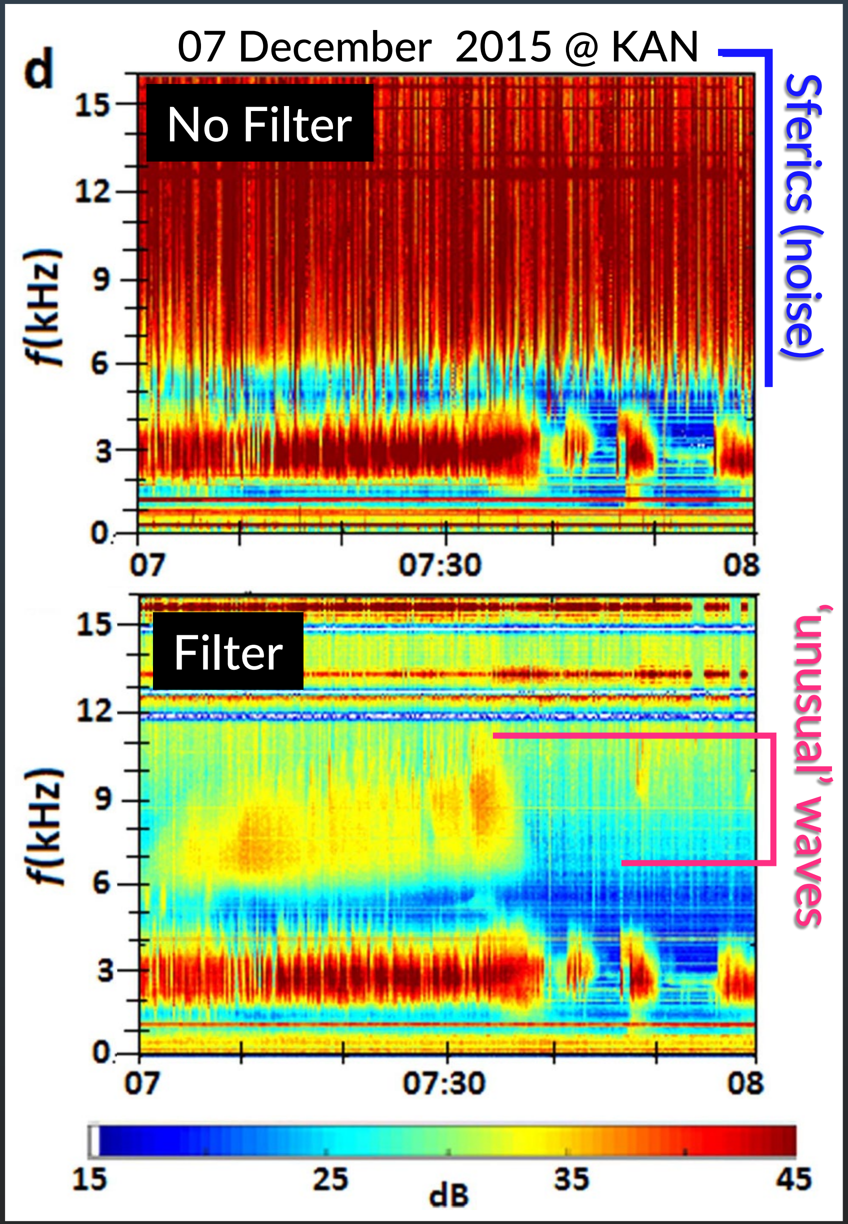
! Unexpected result !

There are waves at higher frequencies behind the sferics
→ Are these usual VLF waves or a different phenomena?
Usually waves travel along field lines and propagate below local gyrofrequency at KAN ~ 5-6 kHz.

More questions…

- Are 'unusual' waves coming from different lower source region?
- Are they linked to the waves observed below?
- If not, how are they propagating?
- What parameters are affecting their propagation to the ground?



[Manninen+2016, ERL]

Ground-based Measurements: Kannuslehto, Finland

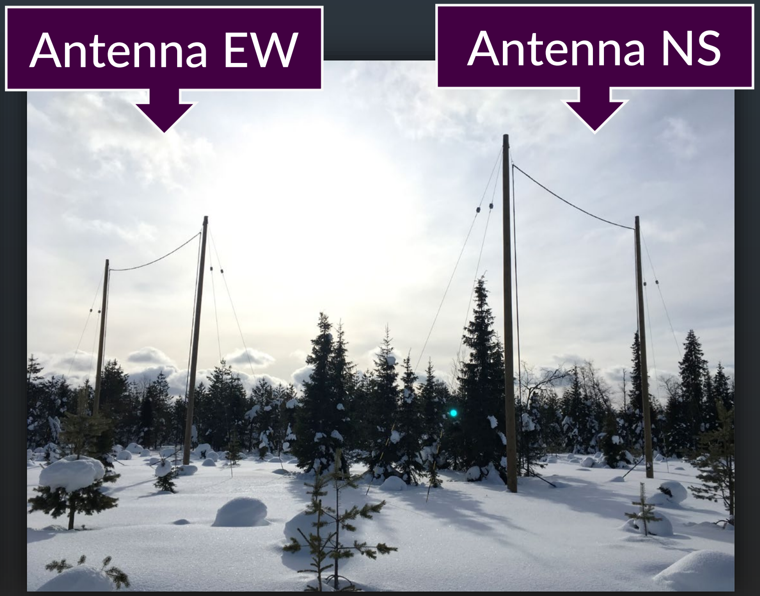
Kannuslehto (KAN)

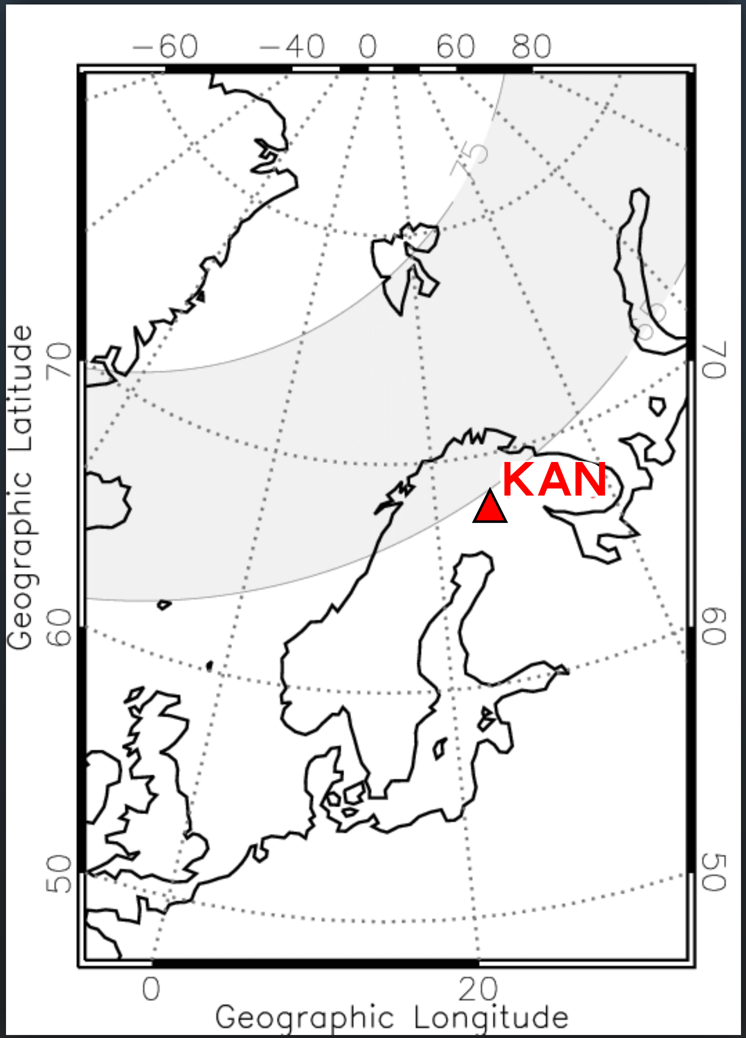
- ✓ Campaign-based VLF measurements since 2006
- ✓ Recently more or less continuous for 8-9 months/year
- ✓ Sampling frequency : 78.125 kHz

Location: Auroral latitudes

GLAT: 67.74° N GLON: 26.27° E L-shell: 5.5

MLAT: 64.4° N





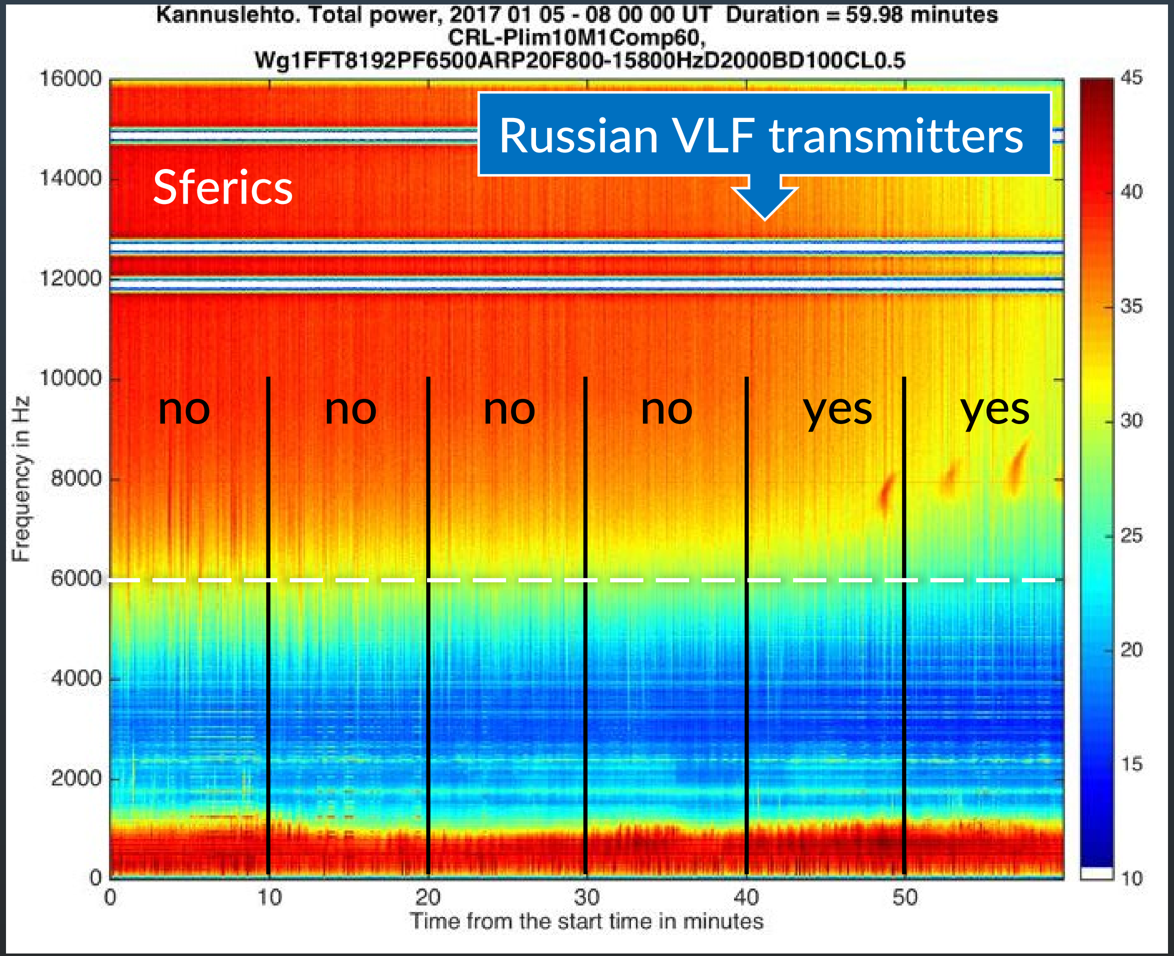
Data Selection

Total: ~8 months x 4 years (2017 – 2020)
January – March + September – December
→ Receiver is not operational in the summer months!

Processed now: 24 months ⇋ 2017 - 2019

Available observation hours: 16 072 in 3 years
(coverage ~ 92% of all possible hours)

'Unusual' wave hours: 377 in 3 years
→ 2.4% global occurrence rate



1 hour time frame divided into 10 min bins

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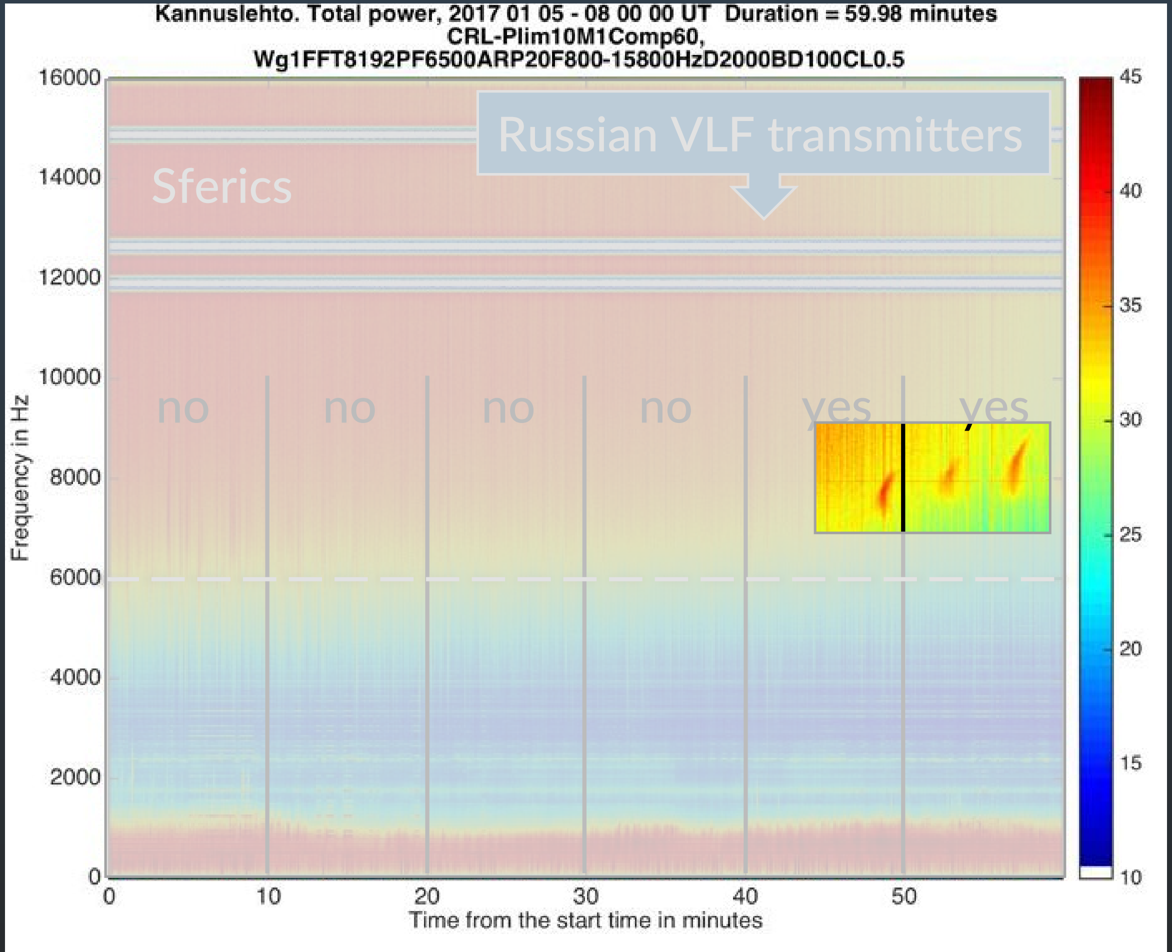
➞ Any clear emission above 6 kHz
(1-hr figures but counting by 10-min bins)



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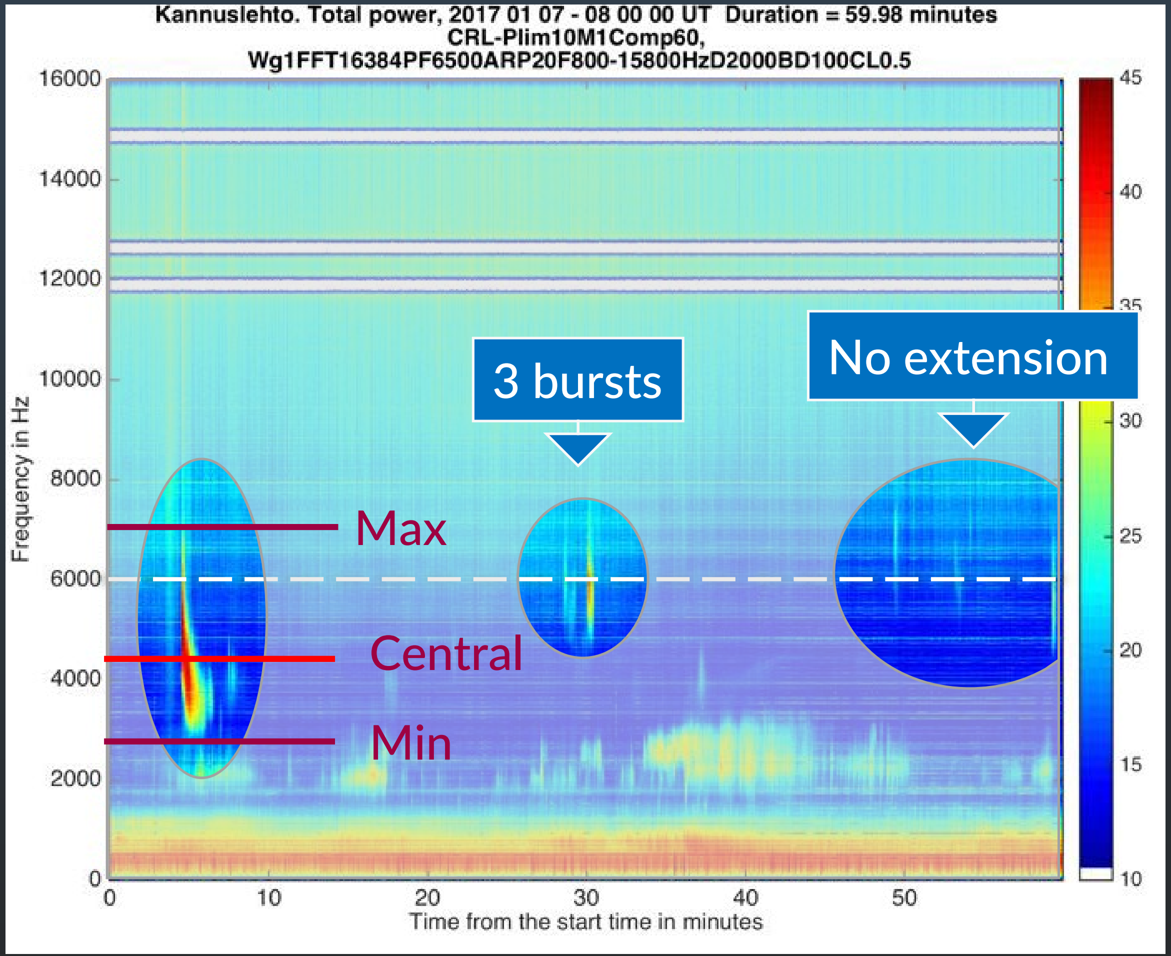

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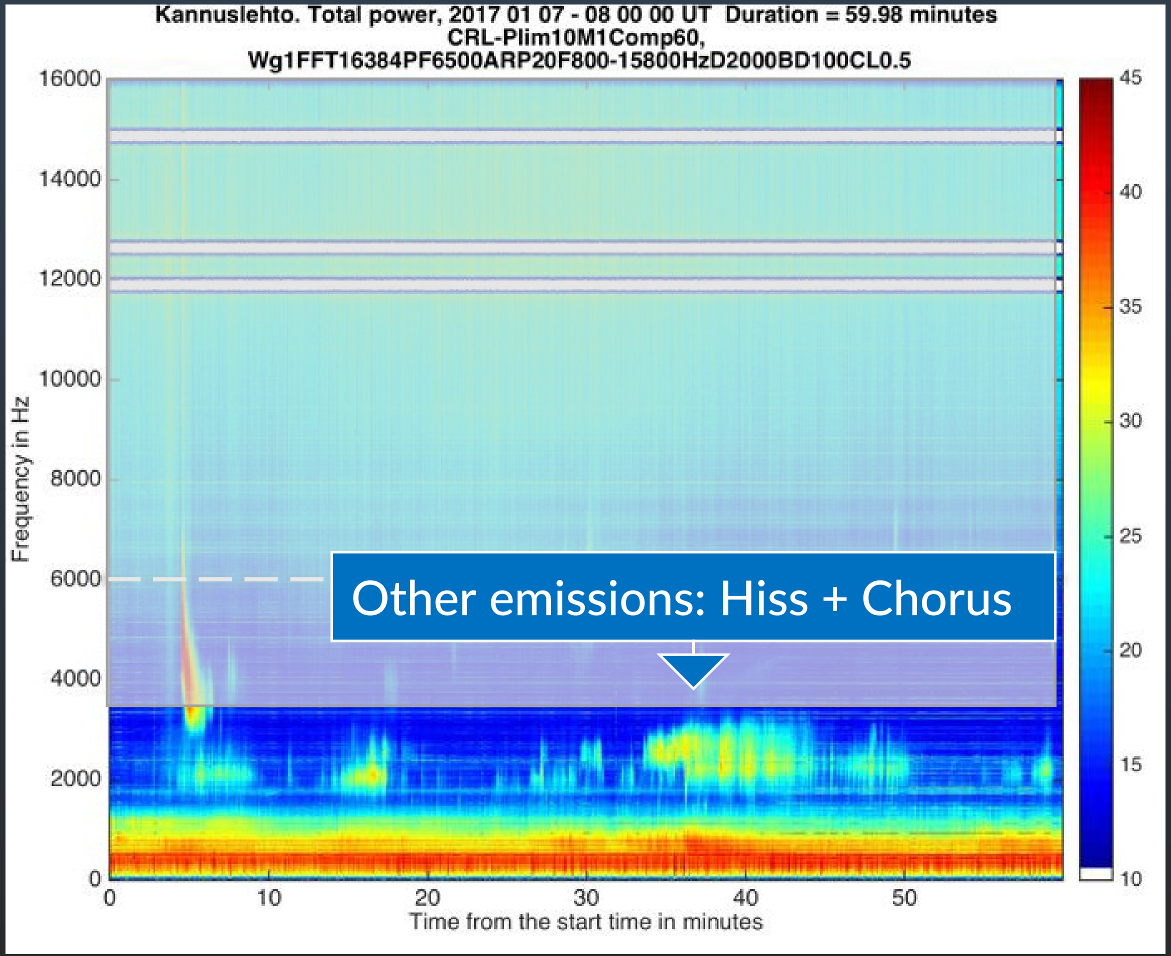


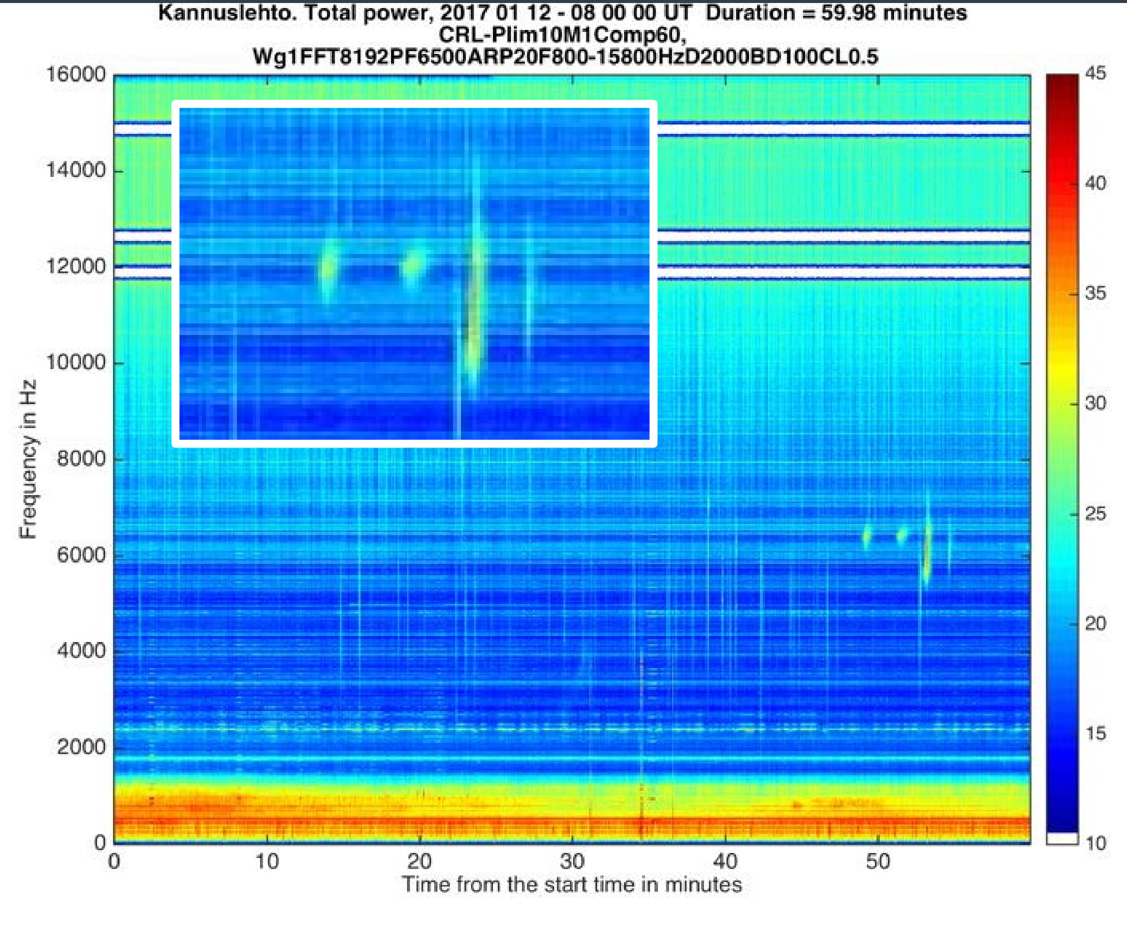
1 hour time frame divided into 10 min bins

Type of 'unusual' high frequency emissions

Separate the type by observing differences in spectral features in the 1-hour plots

Examples:

- Bursts: anything discrete, lasting a few minutes and not extending df ~ 1 kHz



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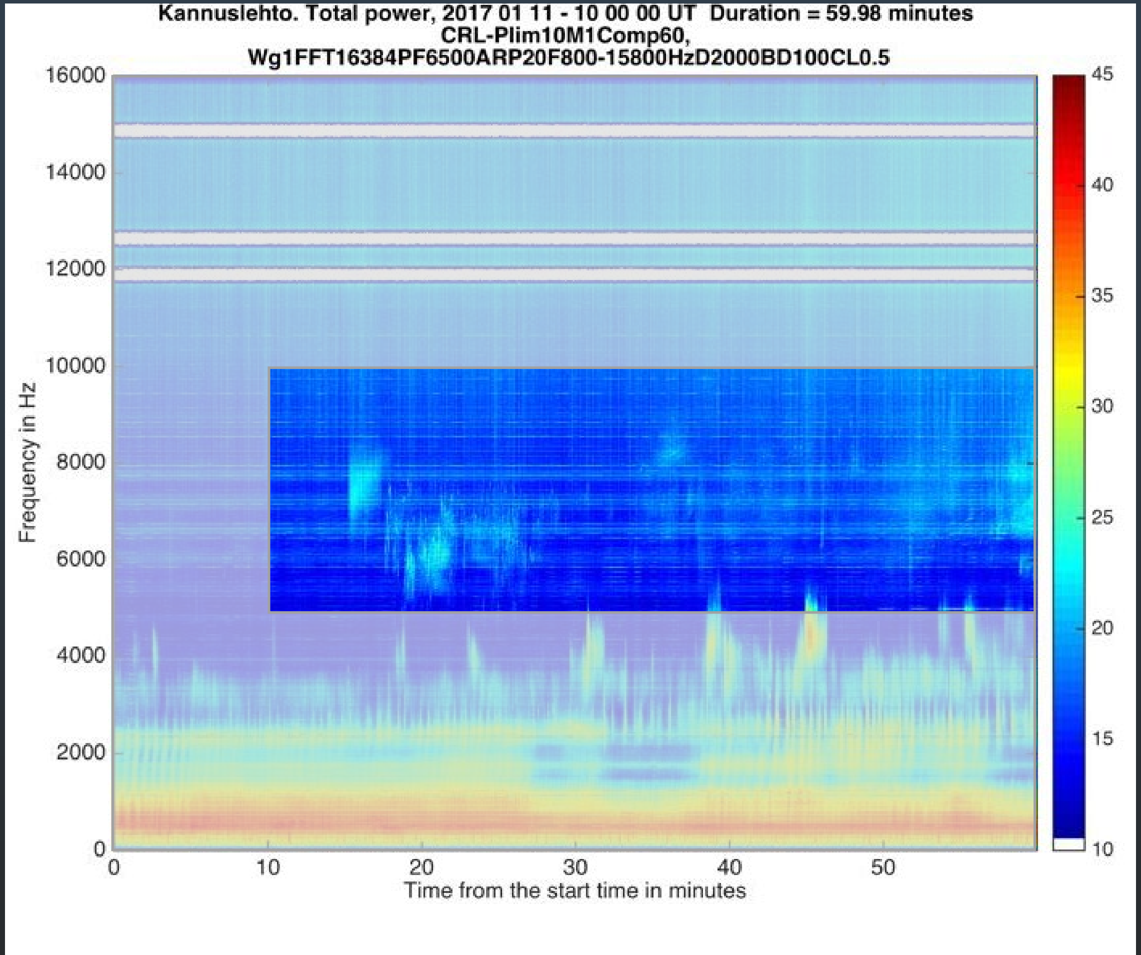

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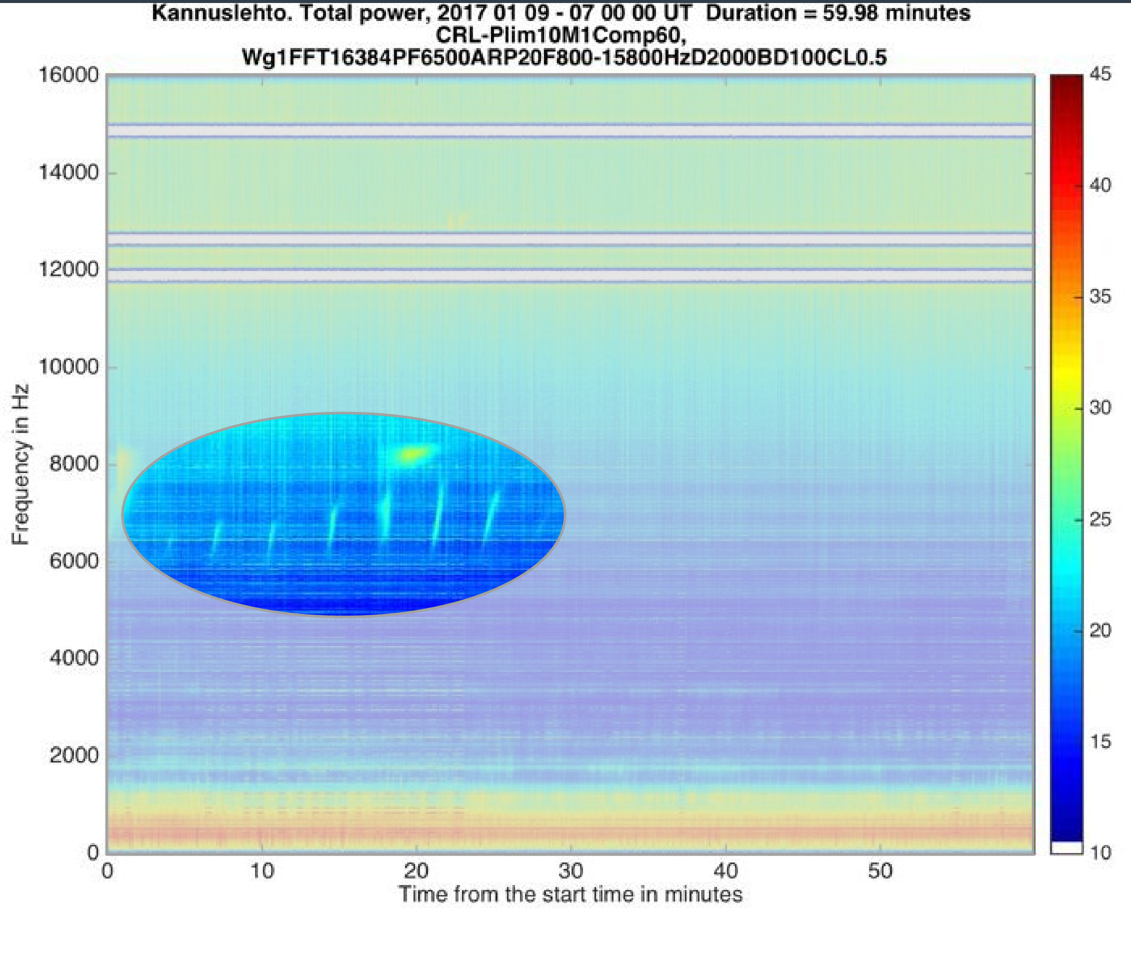

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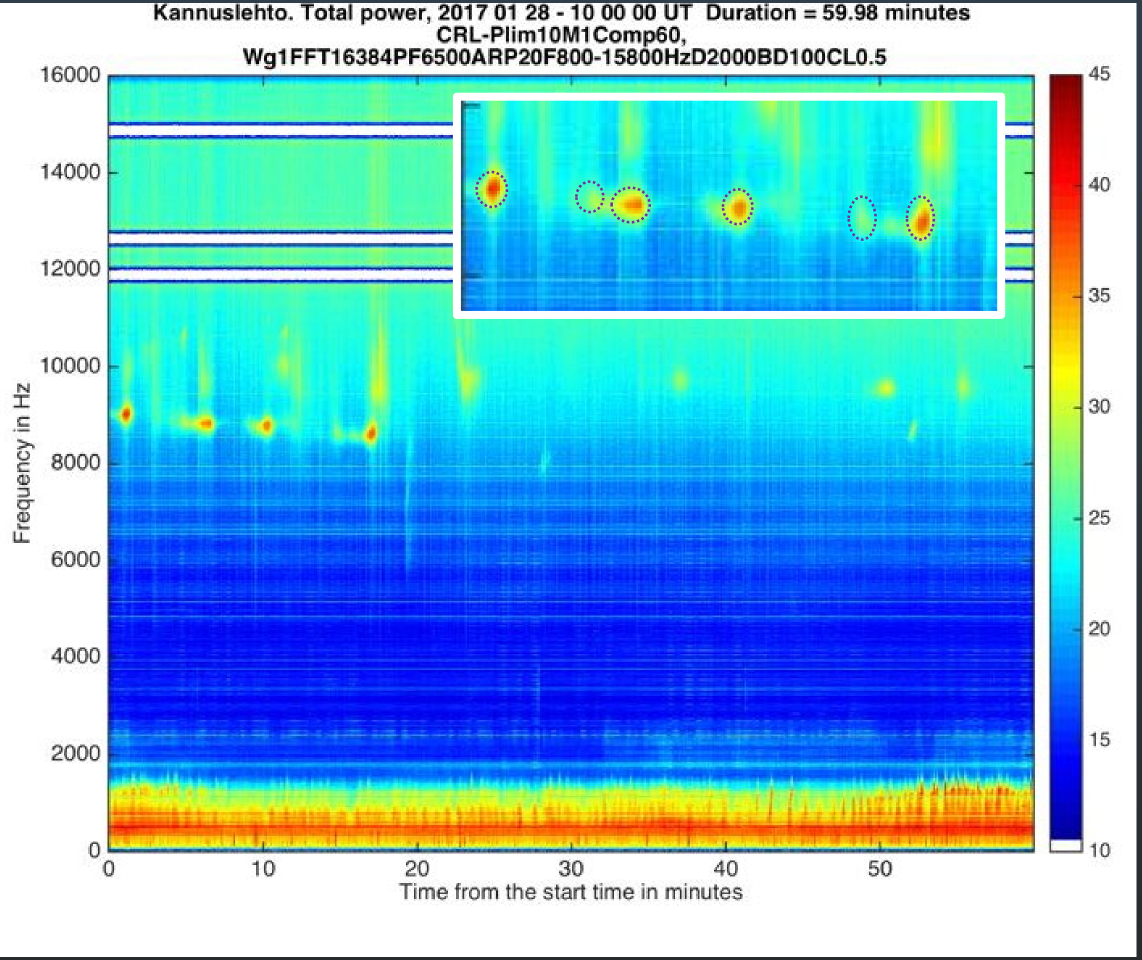

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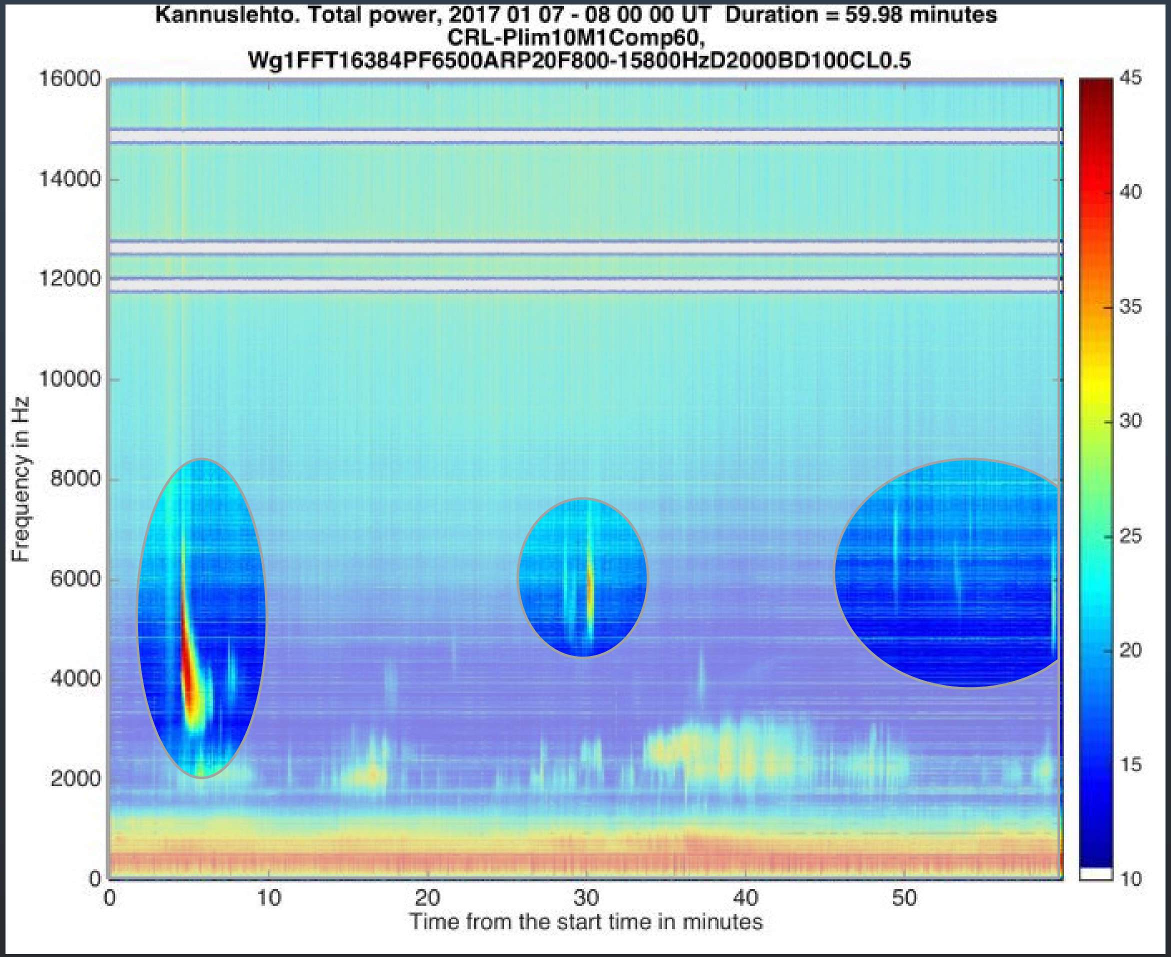
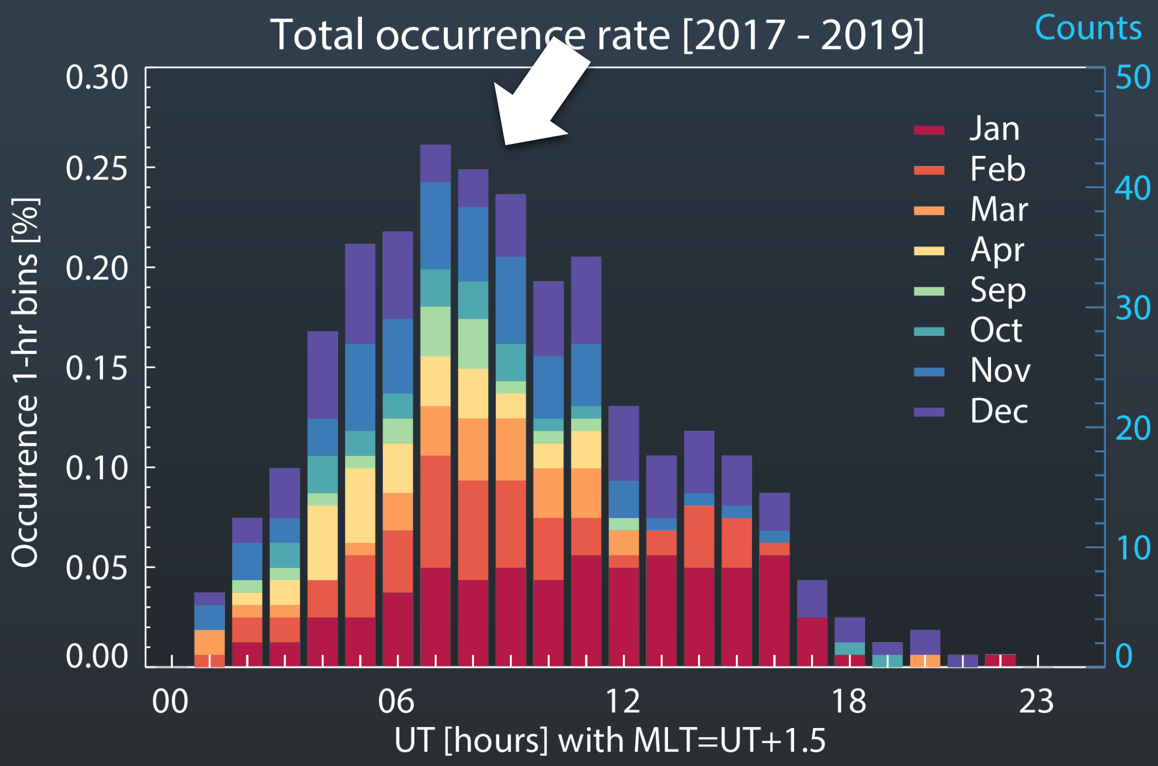


For short, these 'unusual' high frequency emissions will be shortened as KHF in the following presentation.

Statistical Results / Discussion

Overall occurrence

- High occurrence between 05 – 11 UT corresponding to the morning sector (06.5 – 12.5 MLT)



Rate = occurrence * 100 / total available hours

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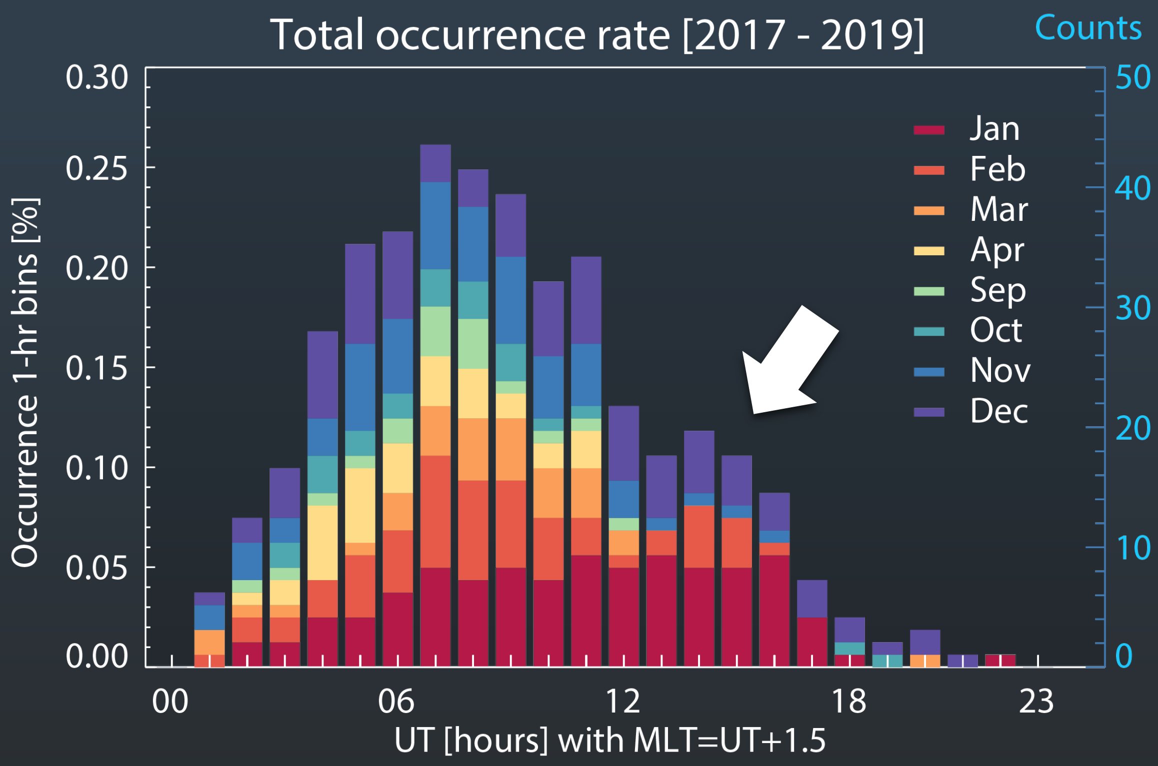

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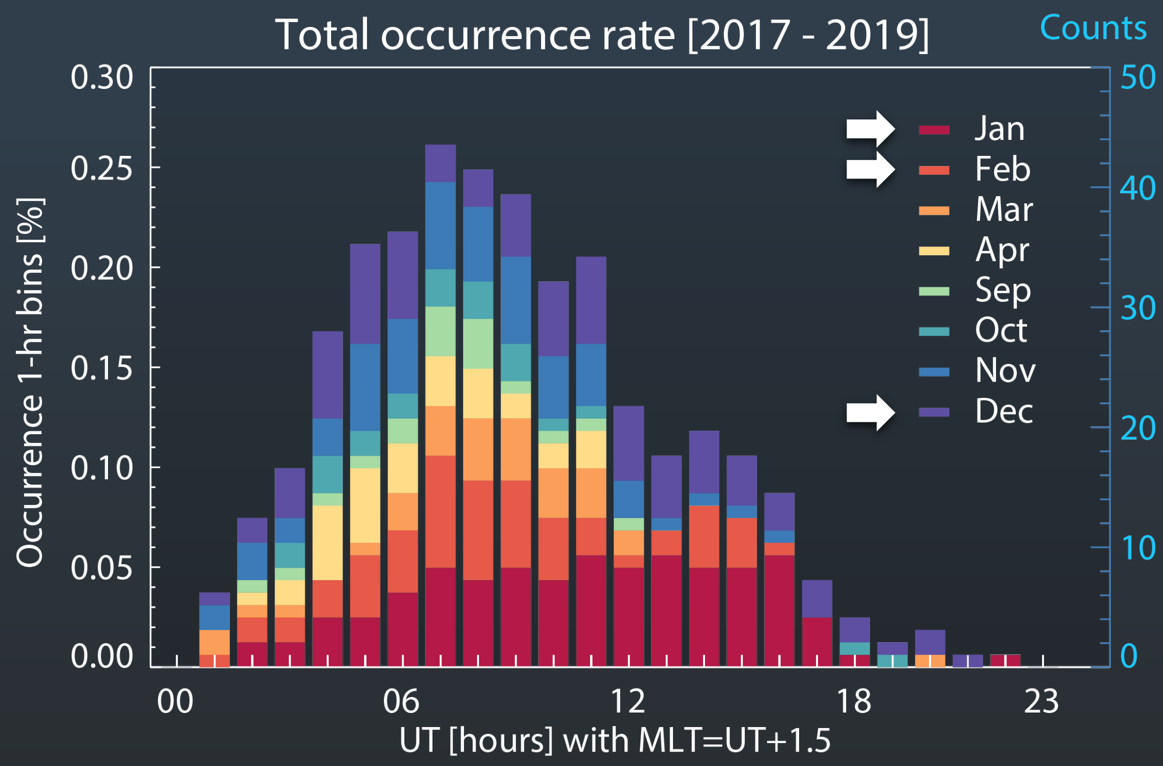

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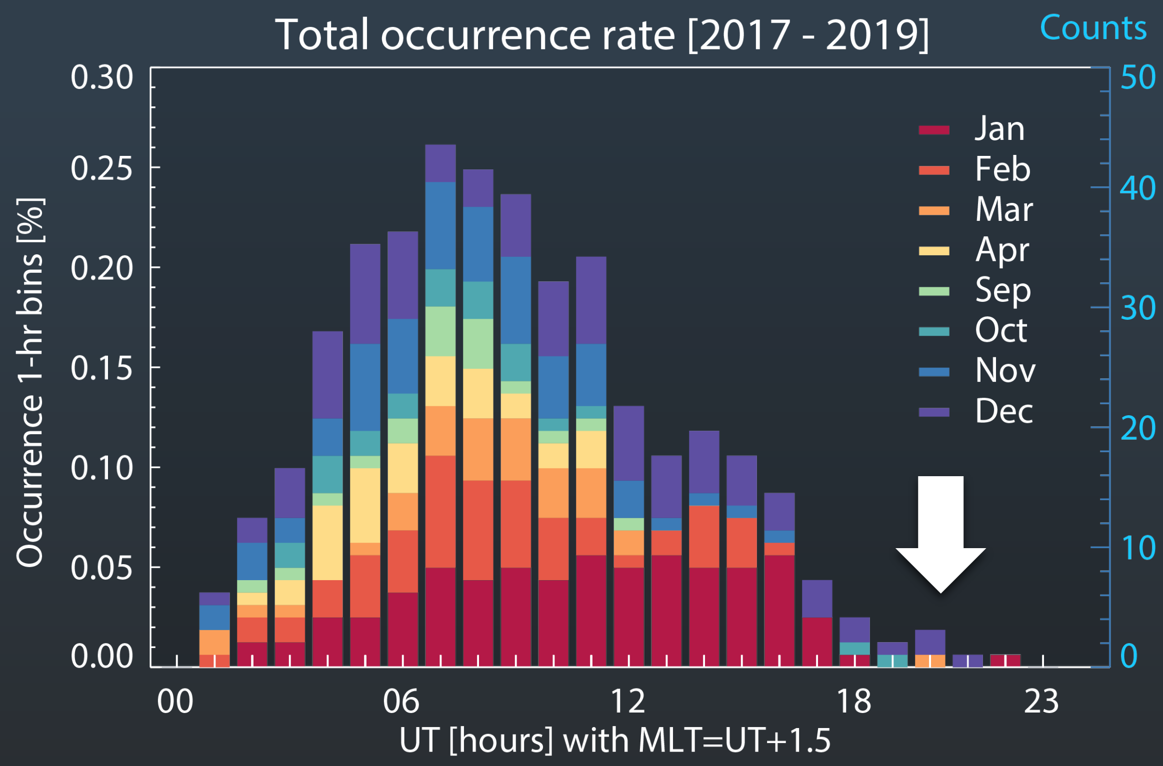
- Highest occurrence during winter months (December to February)
- Almost no cases after 19 UT (20.5 MLT)

→ Are KHF not being generated or not propagating in the night time?



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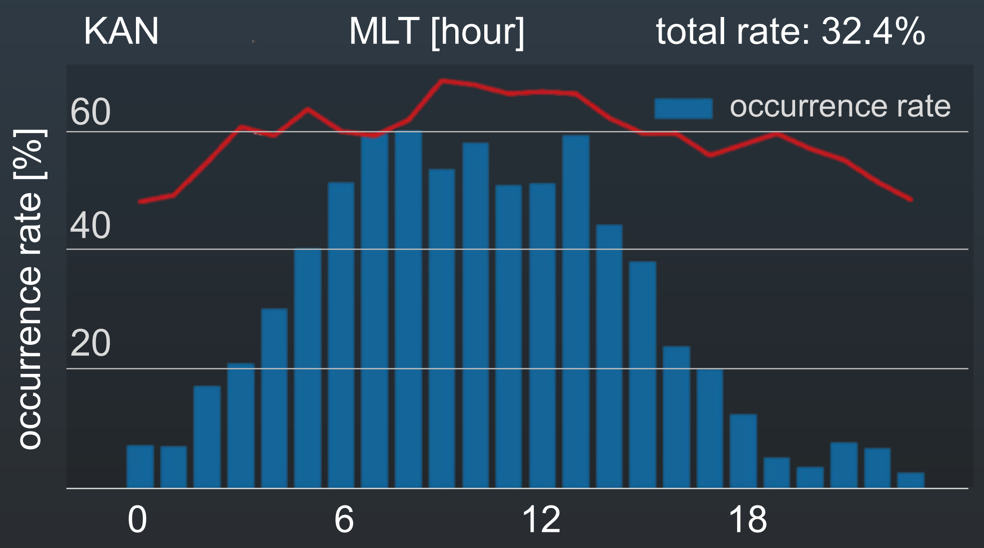
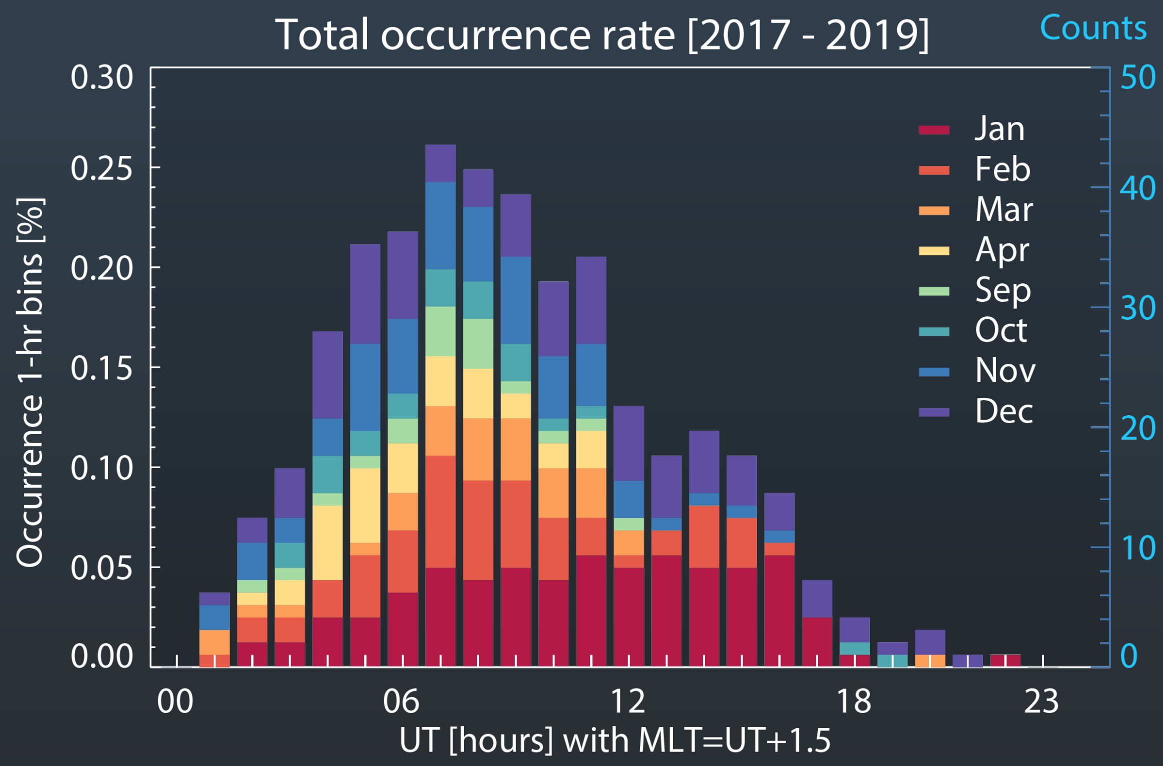


Modified from [Takeshita+2019]



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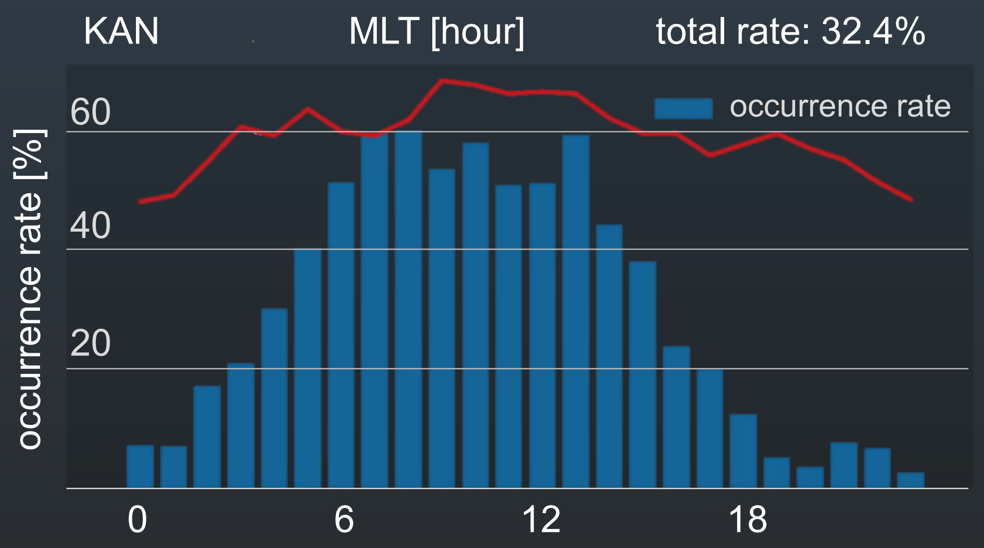

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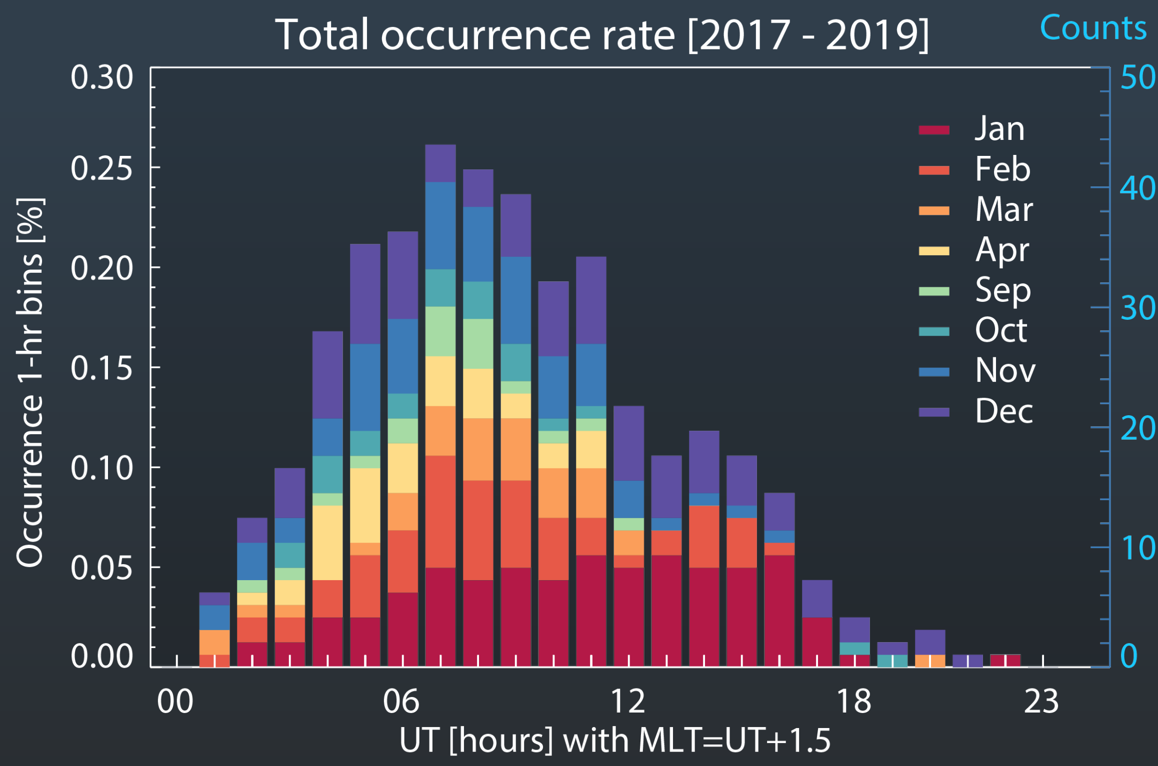


Rate = occurrence * 100 / total available hours

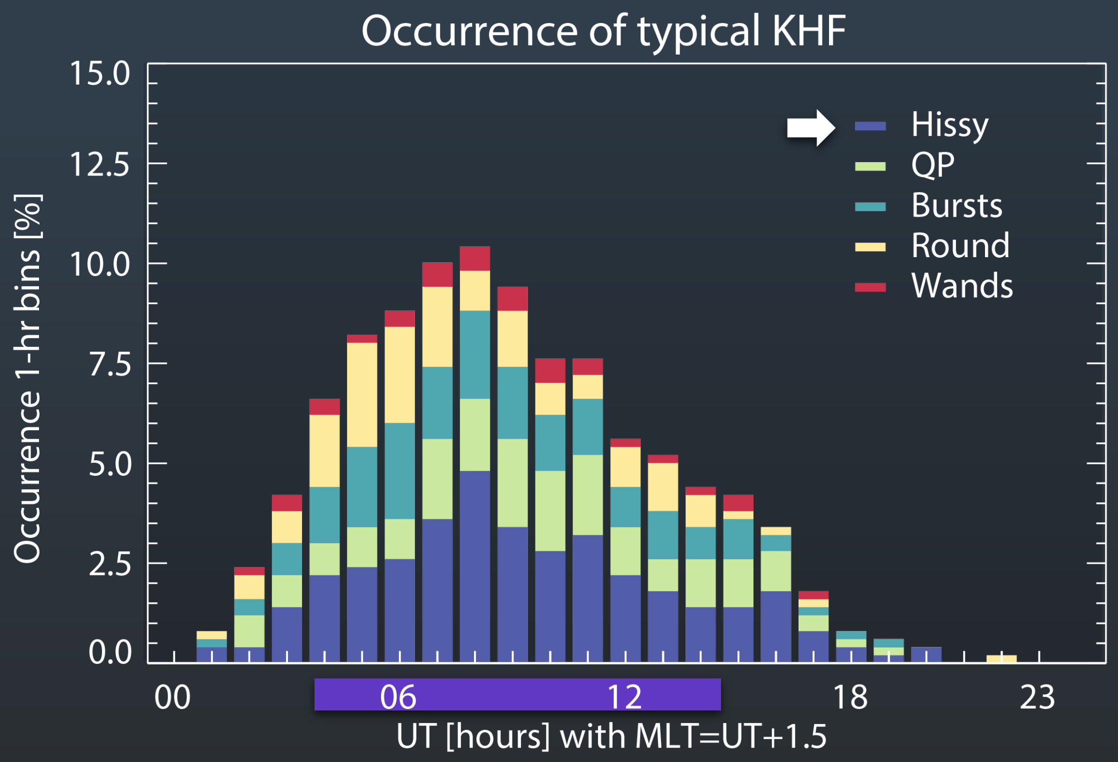
→ similar generation mechanism as more usual lower frequency VLF emissions ?

→ In general, is it easier for VLF waves to reach the ground at this time?

Statistical Results / Emission Type

Occurrence by type

- Most common type globally is hiss-like KHF or ‘Hissy’
  → largest occurrence 05.5 – 14.5 MLT



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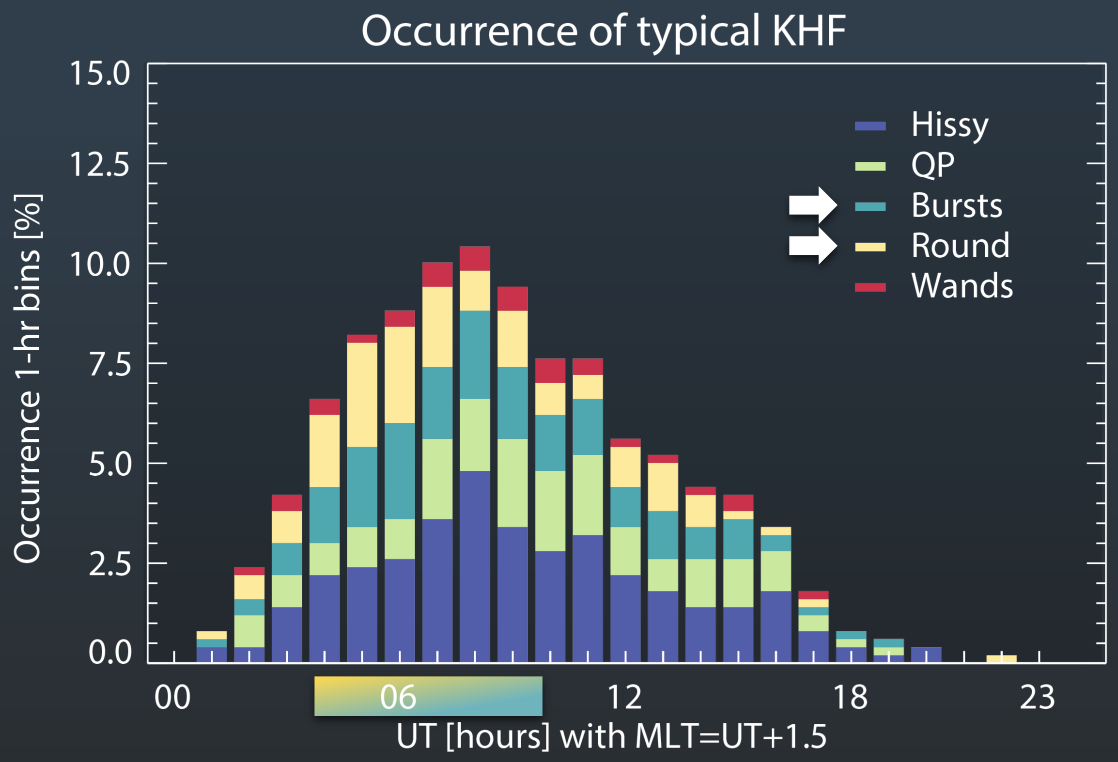

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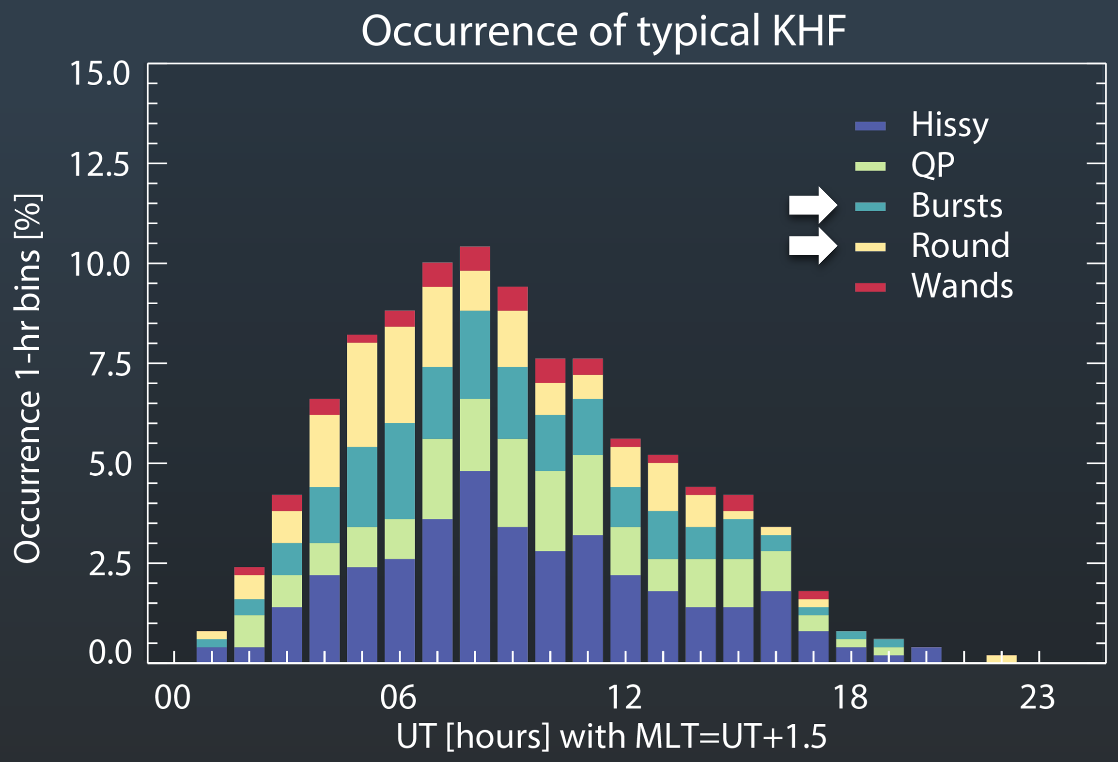
- Most cases show no changes in frequency tones, followed by rising tones and small percentage of falling tones (not shown here)



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Statistical Results / Emission Type

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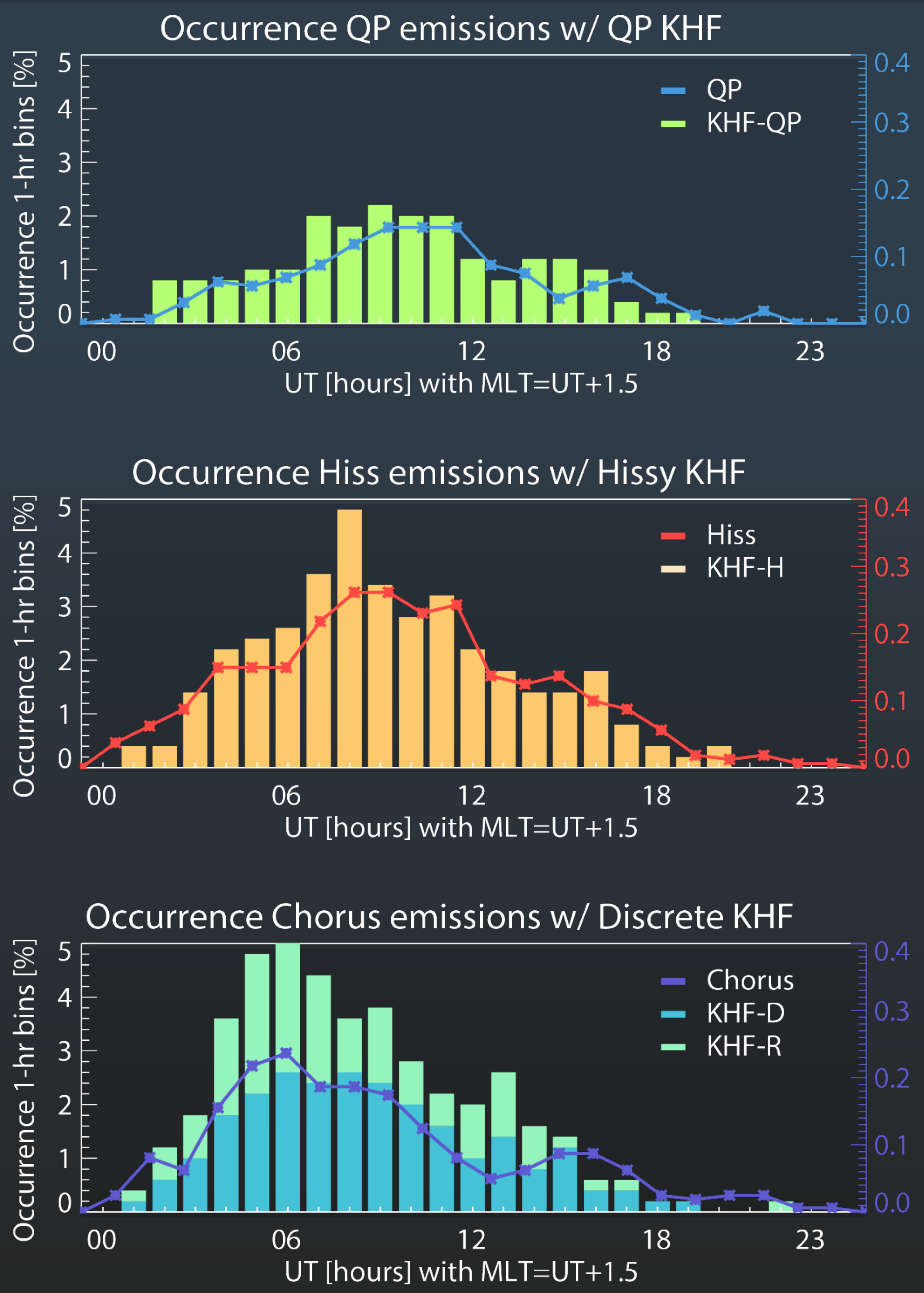

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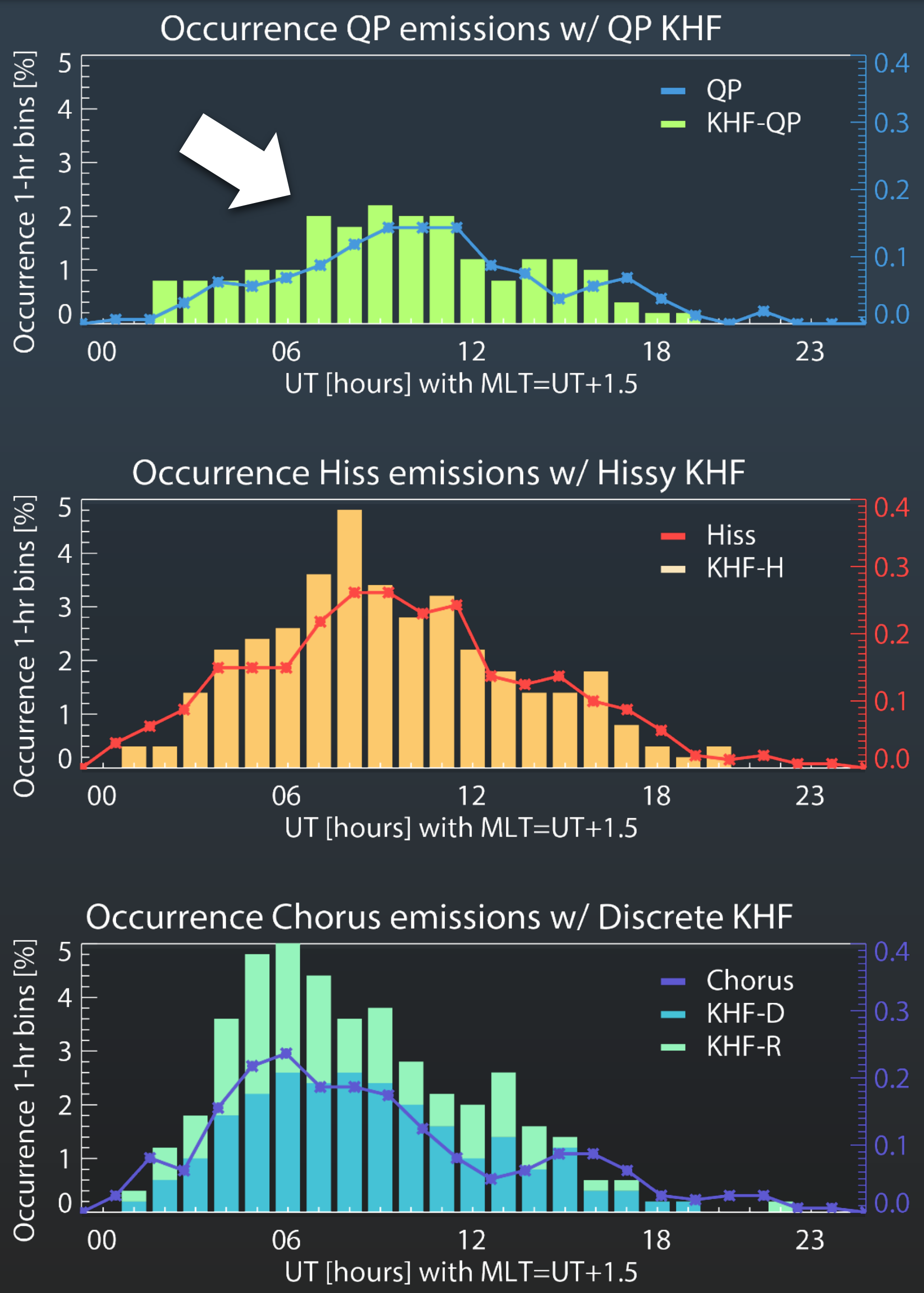

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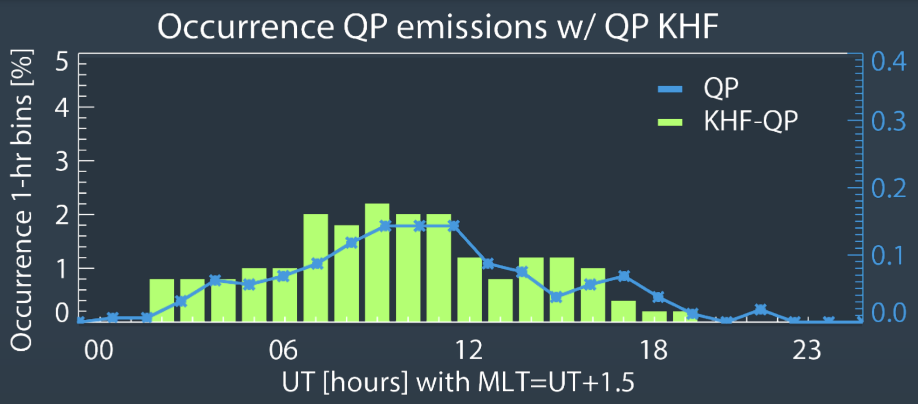

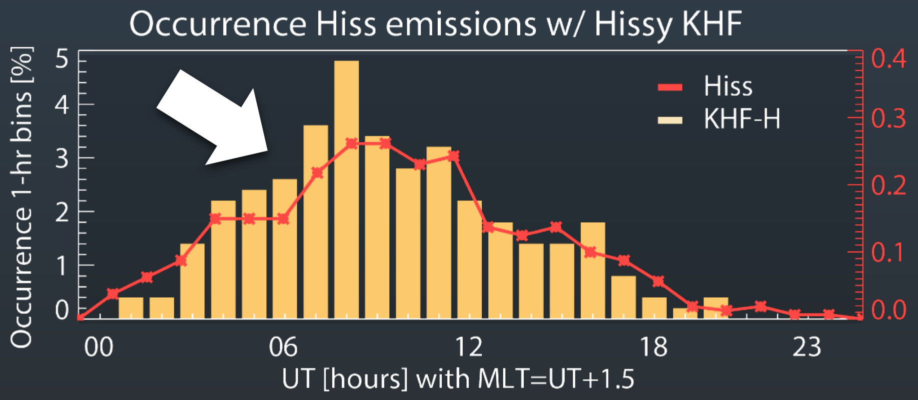

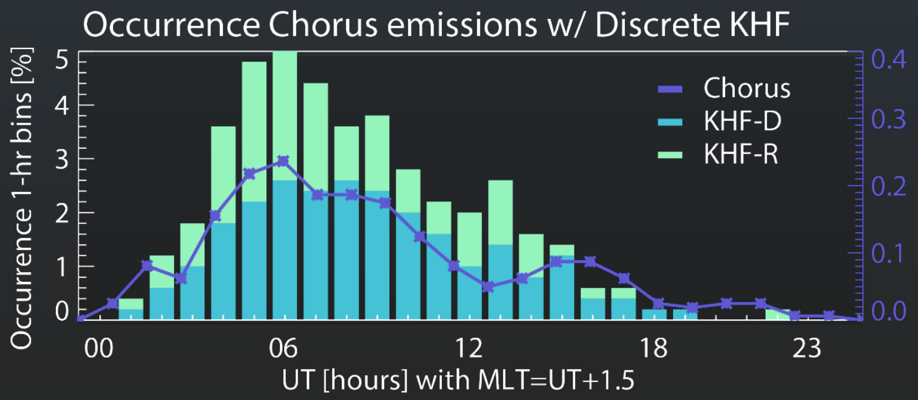

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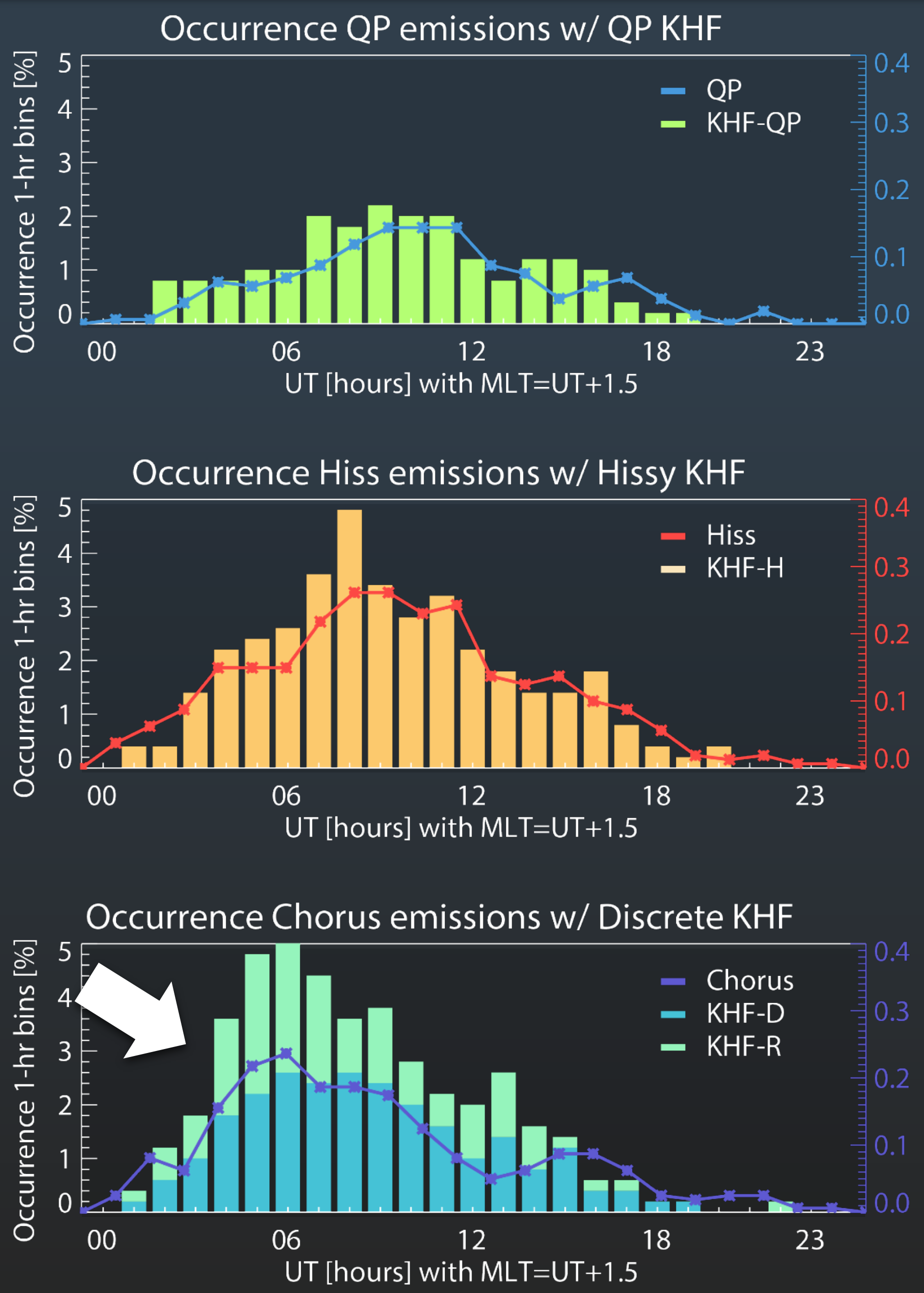

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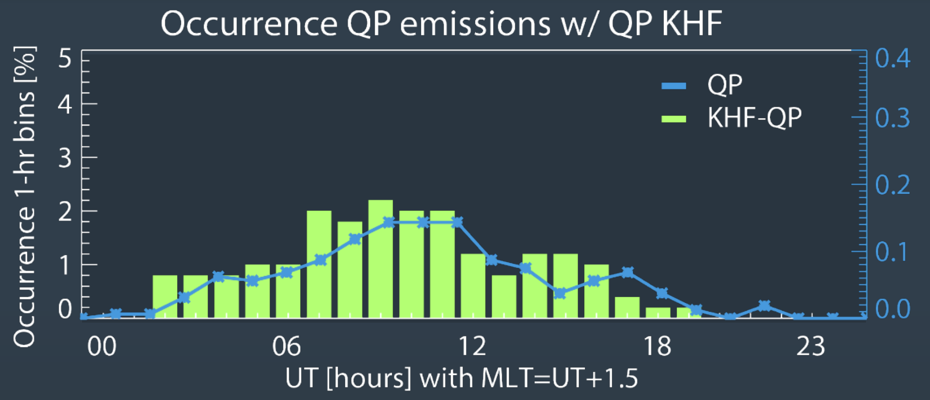
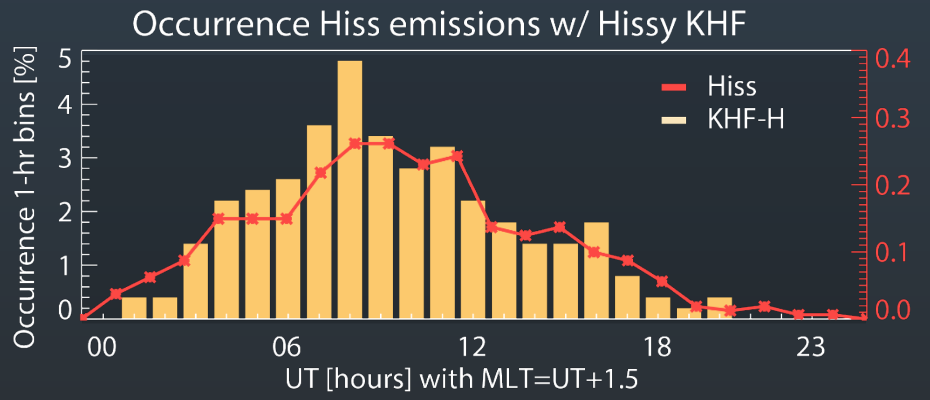
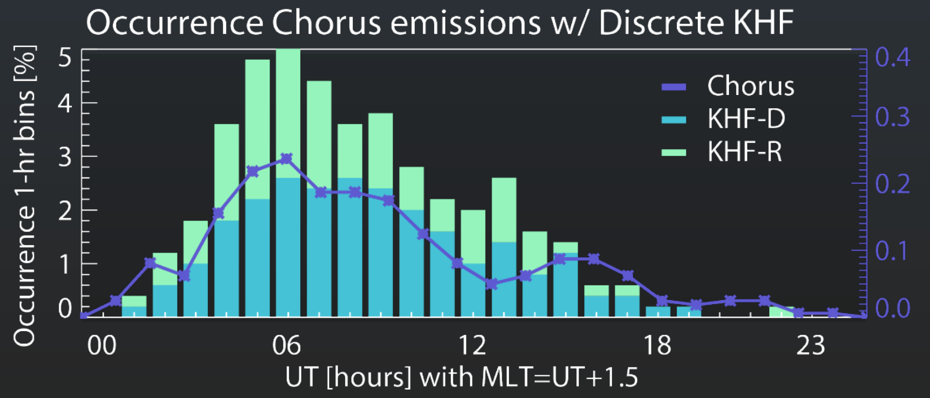
- When separated by similar type of emission, the occurrence rate for KHF and accompanying VLF waves follow very similar trends







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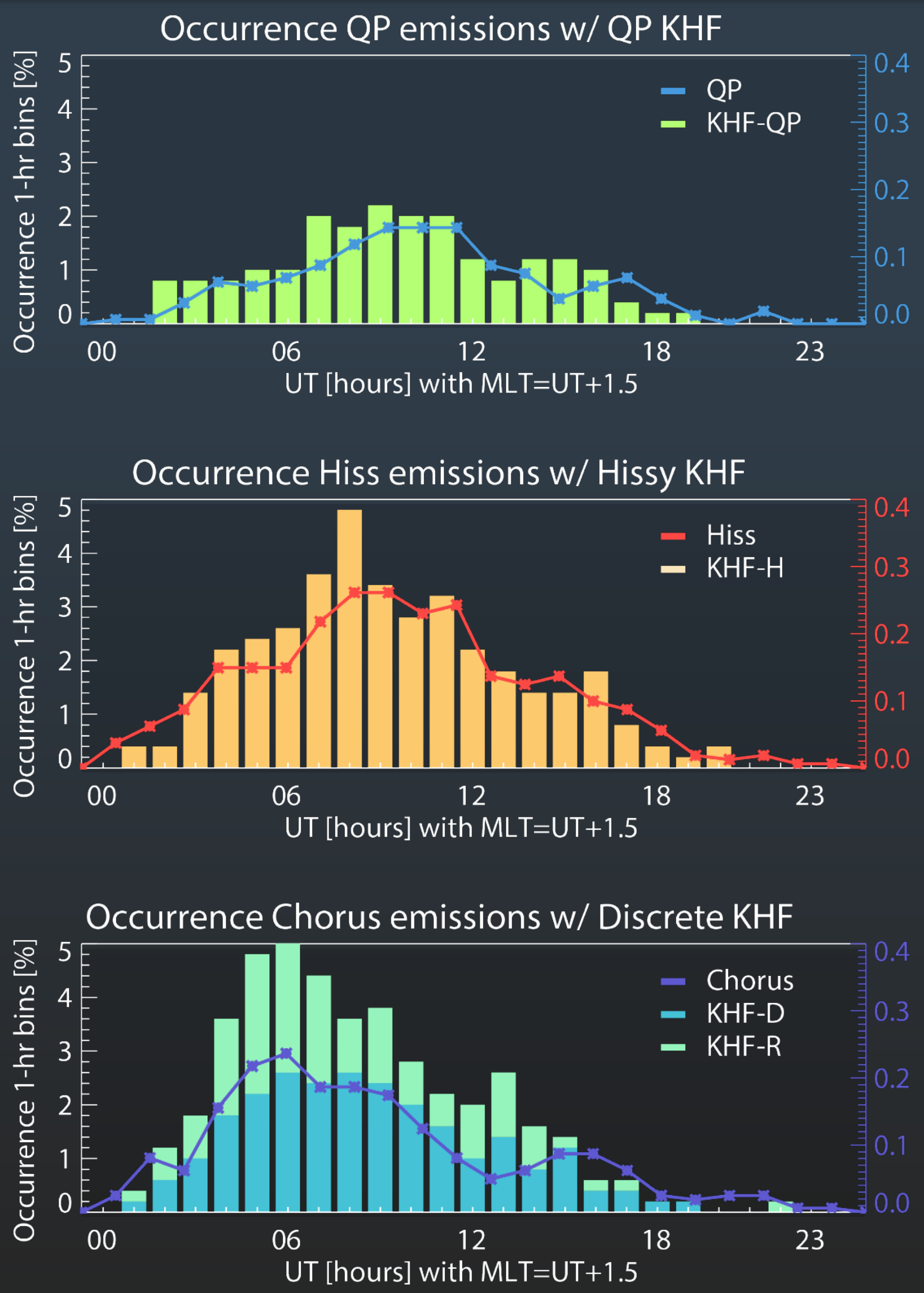
→ Both KHF and usual VLF emissions with similar characteristics are being generated at the same time in the magnetosphere.

KHF are <u>not</u> ionospheric in nature but generated by temperature anisotropy like usual VLF emissions.



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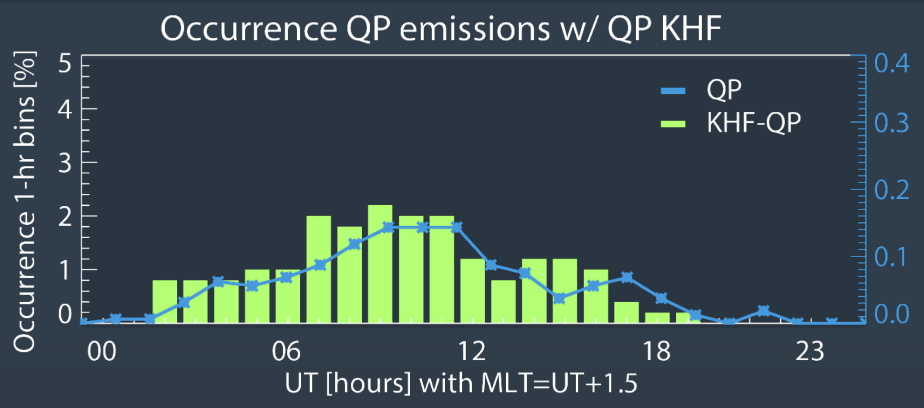
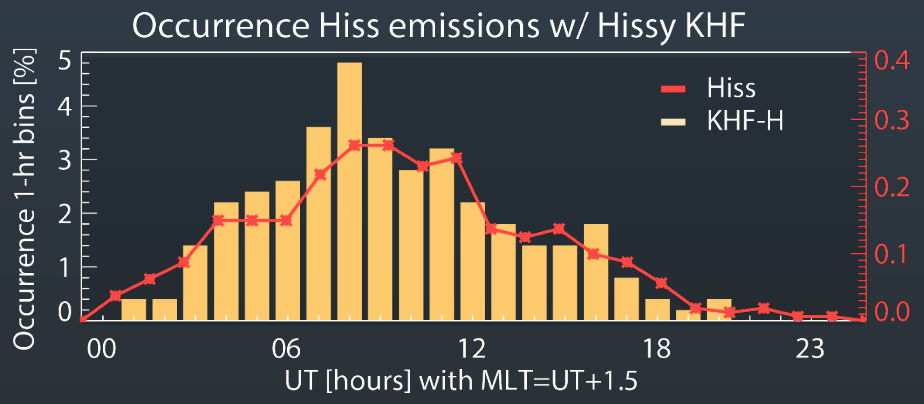
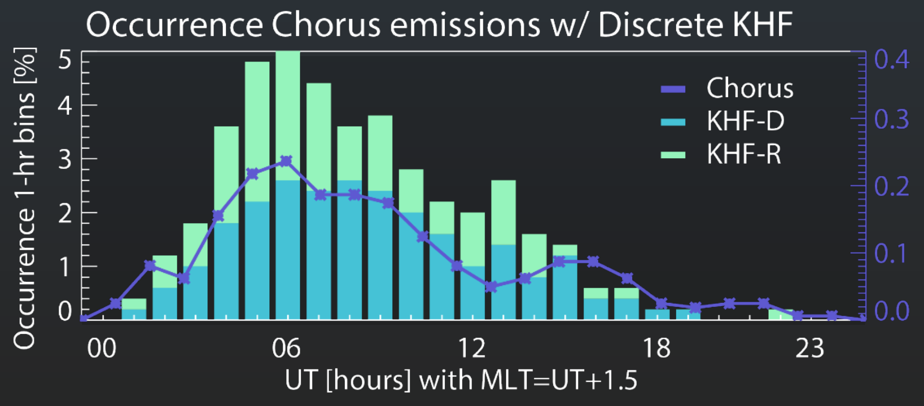
→ are these waves coming from the same source ?
→ how are they propagating to KAN?



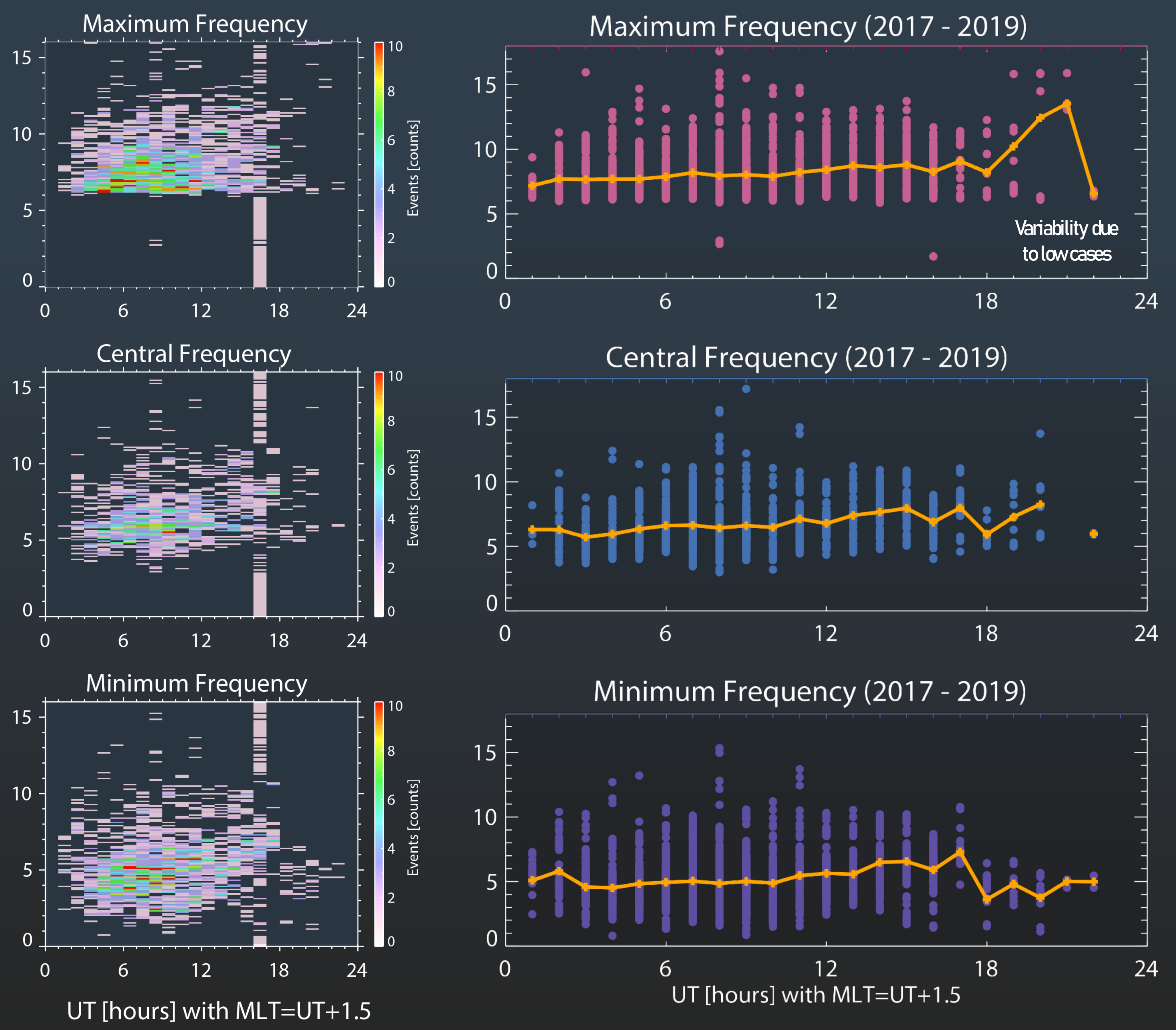




Statistical Results / Frequencies

Frequency distribution

Maximum frequency is less variable while central and minimum frequency shows more variability.



Statistical Results / Frequencies

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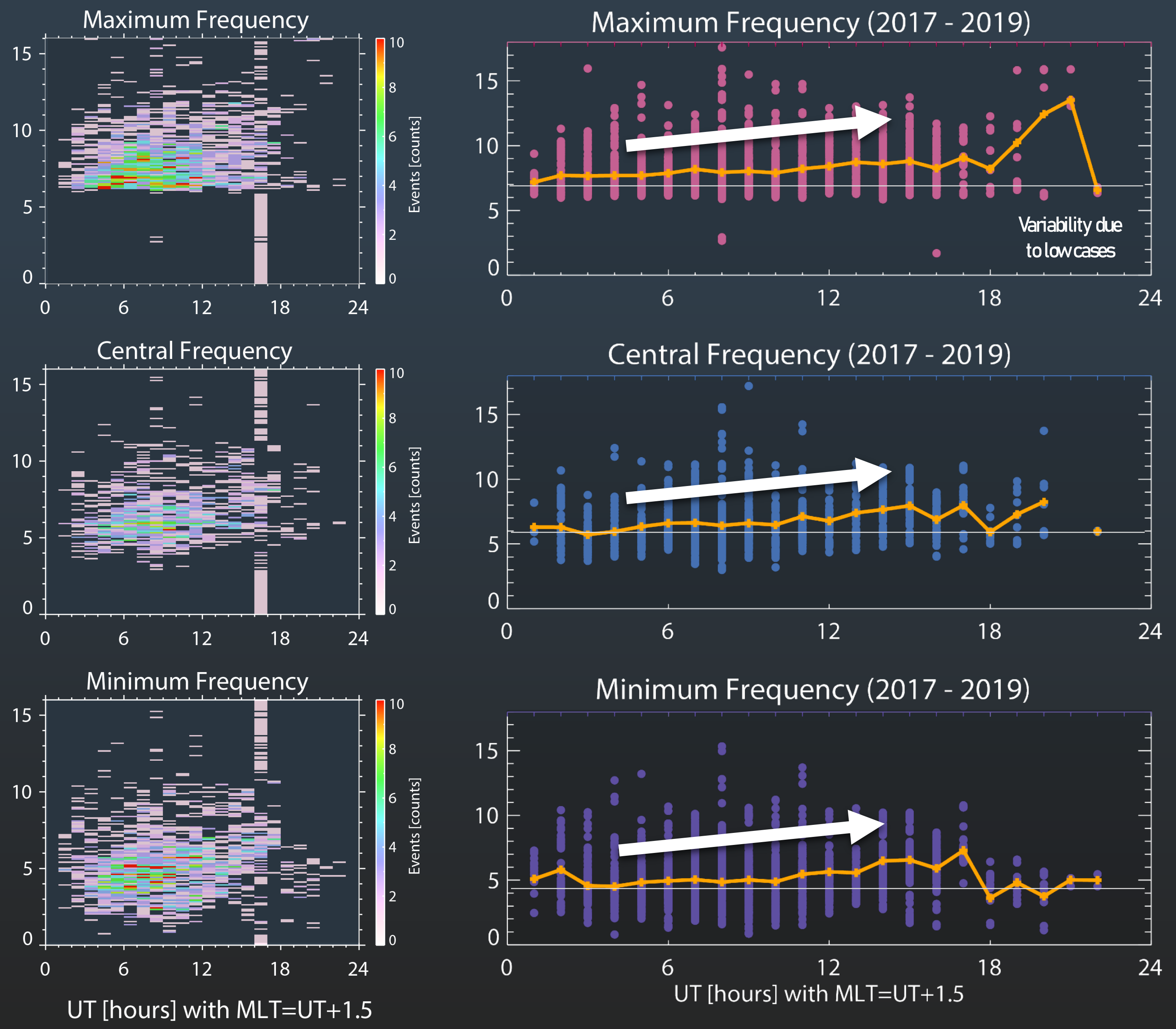
Slight upwards trend for all frequencies
→ global mean increases with MLT

Is it possible that the source region gets closer to the Earth in afternoon MLT?



Statistical Results / Propagation

Relationship with AE index ?

Some correlation between KHF occurrence and substorm activity however, not systematic.

→ likely KHF are generated by standard anisotropy but can only reach the ground under some conditions

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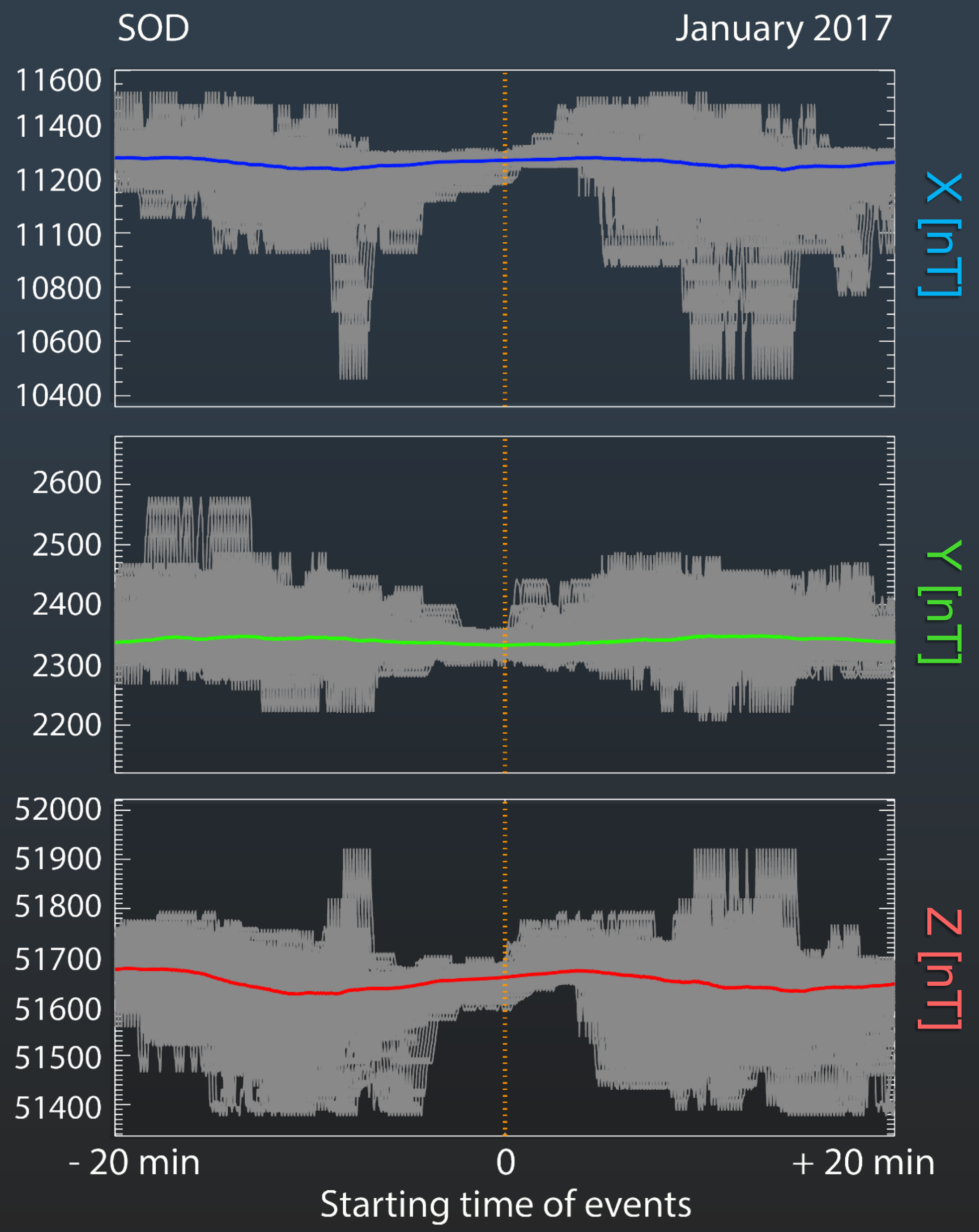
Relationship with magnetic field?

Superposed epoch analysis of X, Y, Z component from magnetometer at Sodankyla (~ 40 km from KAN).

→ KHF are detected when the magnetic field has a local minimum, suggesting propagation of KHF to the ground might be only when magnetic activity is low.

Valid for magnetic field variations in 2017, however I still need to check for 2018-2020 data!

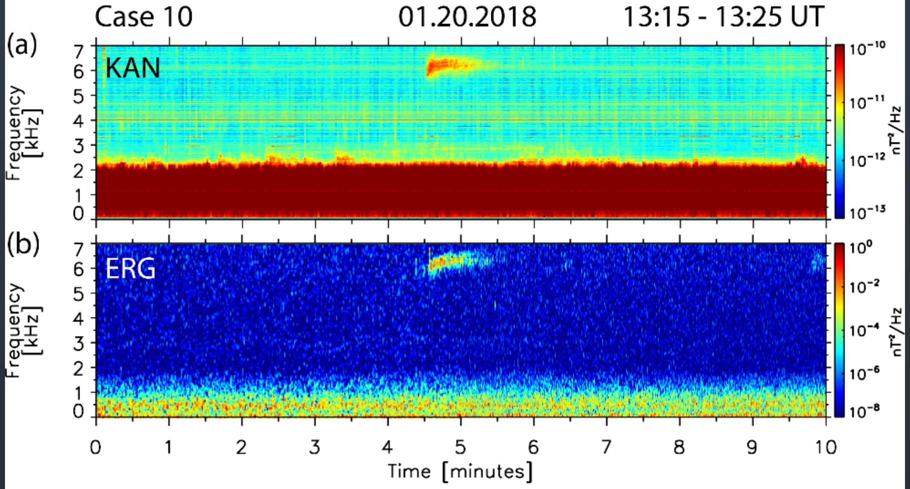


Ray Tracing / Propagation

KAN-ERG conjugated event

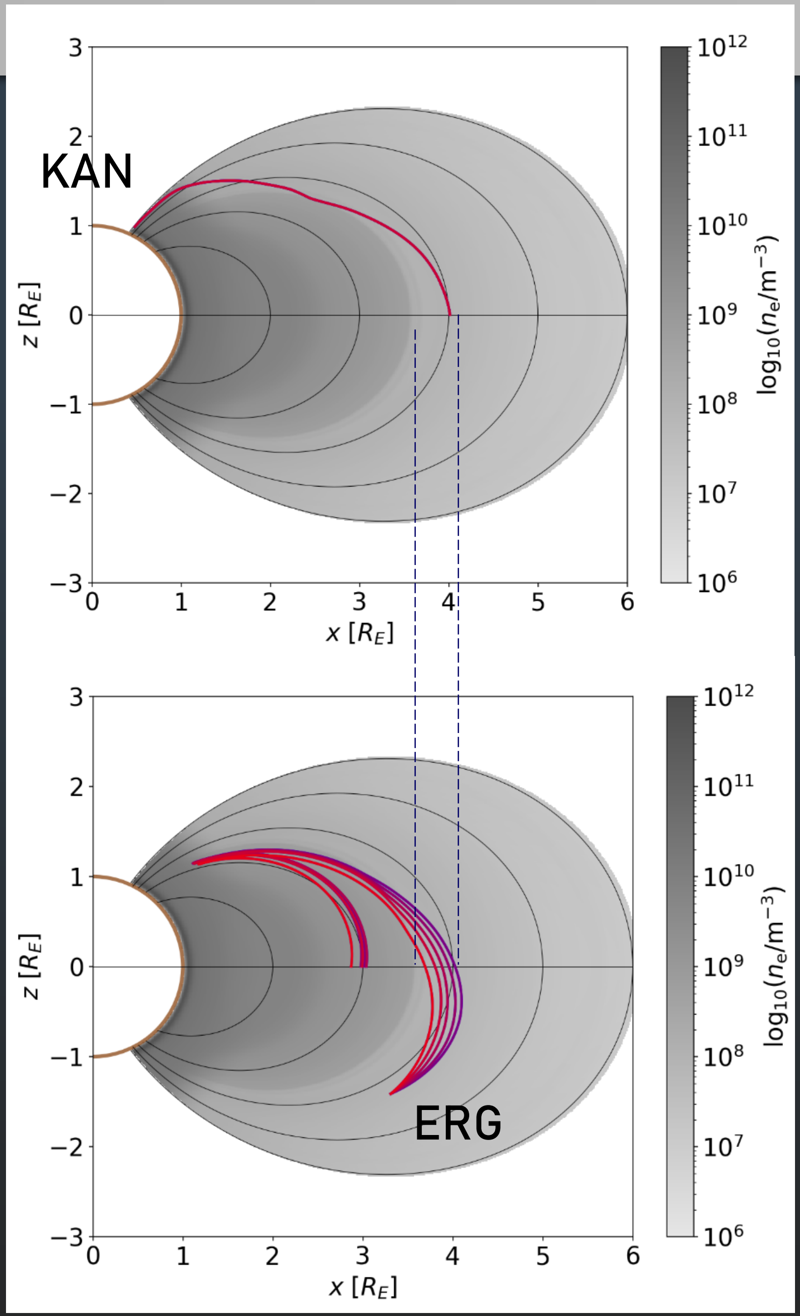
We have one case of a 2-min burst showing 1-to-1 correspondence between ERG and KAN.

Also observed by LOZ (400 km E of KAN)!



💣 I cannot stress enough how very preliminary these ray tracing results are!

[Thanks to M. Hanzelka (IAP) for the ray tracing program]




In a nutshell:
KHF are generated like usual VLF waves but propagate during quiet times and local minimum magnetic field... but how?
?
Thank you!
Questions? Comments?

Extra / AE index

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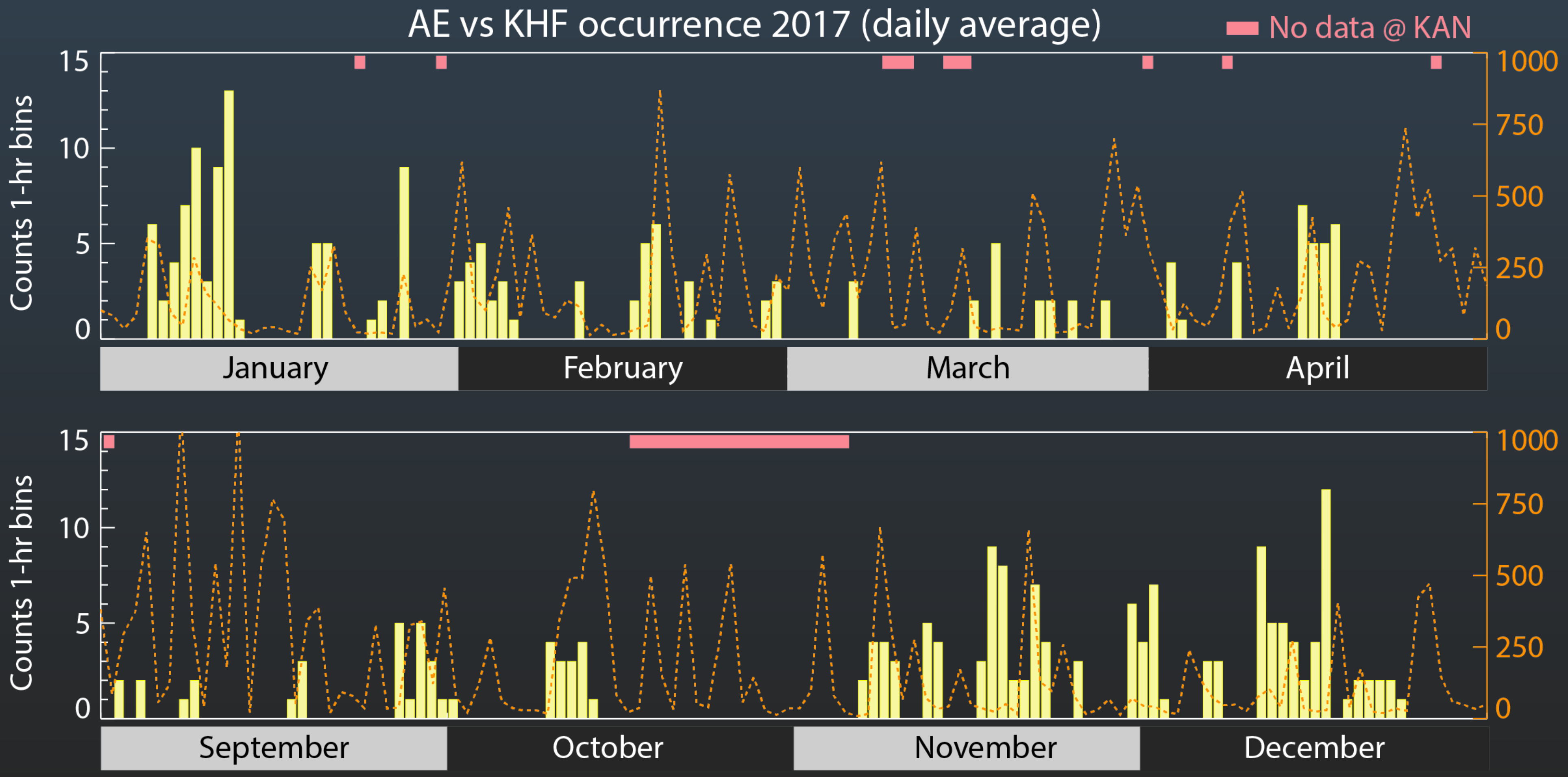
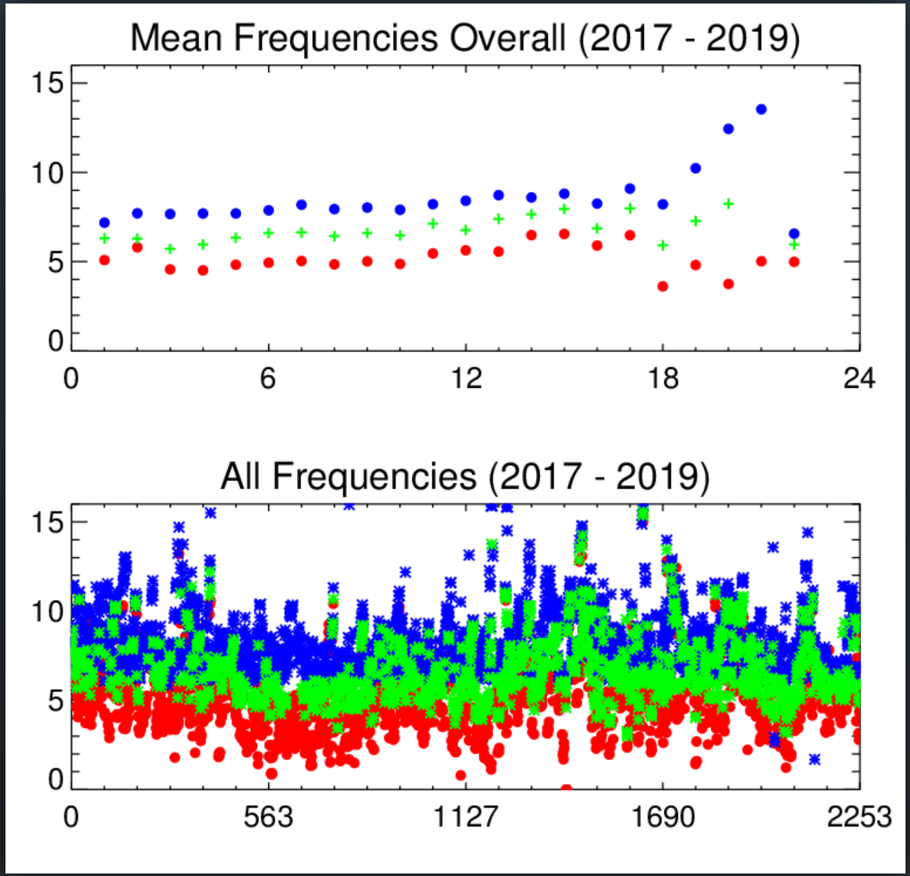
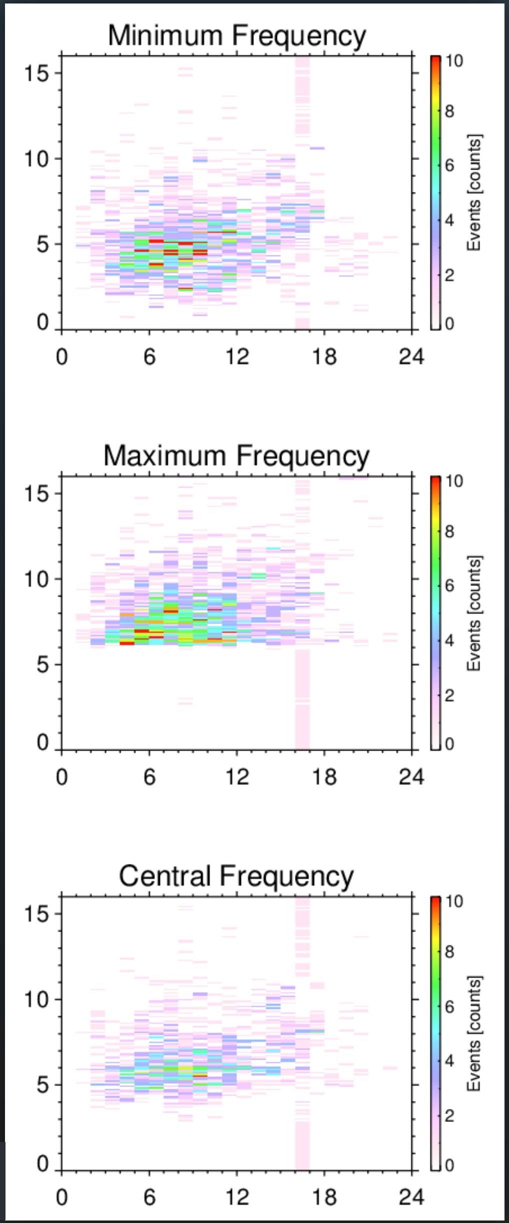
Some correlation between KHF occurrence and substorm activity however, not systematic.

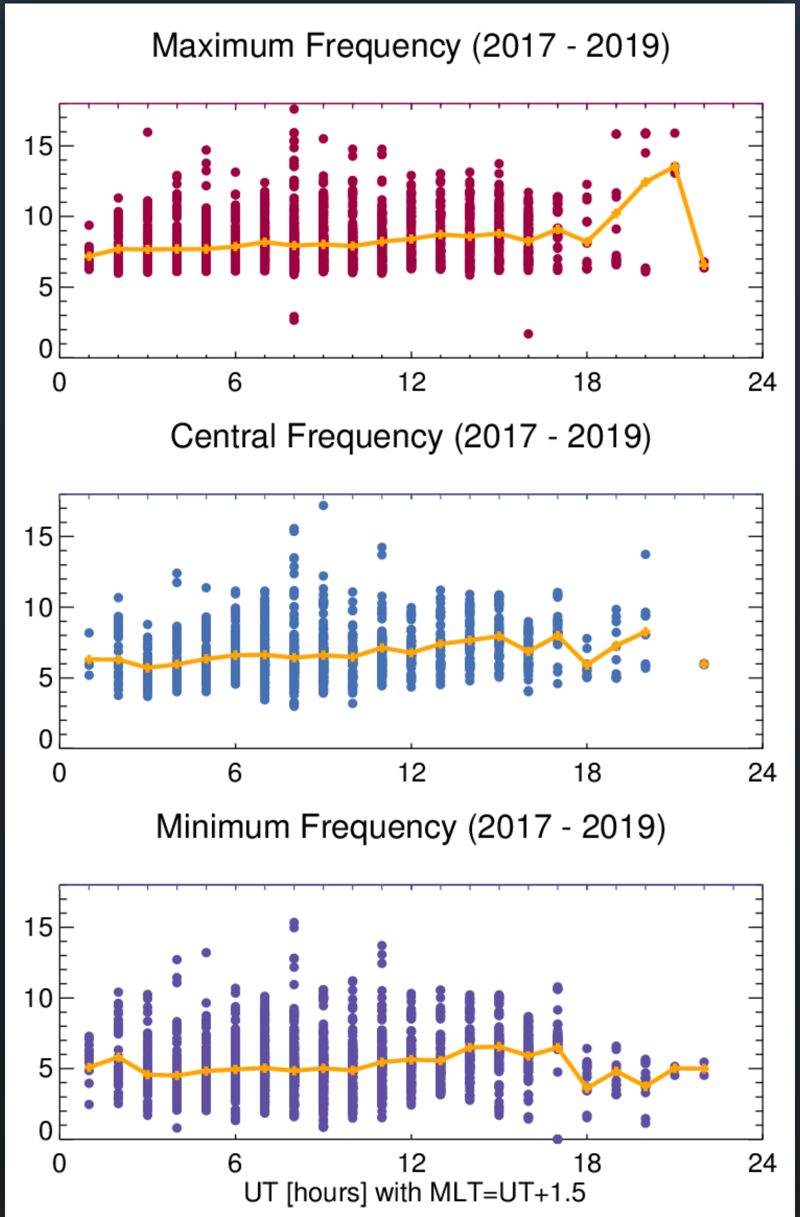
→ likely KHF are generated by standard anisotropy but can only reach the ground under some conditions



Extra / Frequency







Frequency vs MLT