New findings using VLF data from SAVNET and Kannuslehto radio receivers

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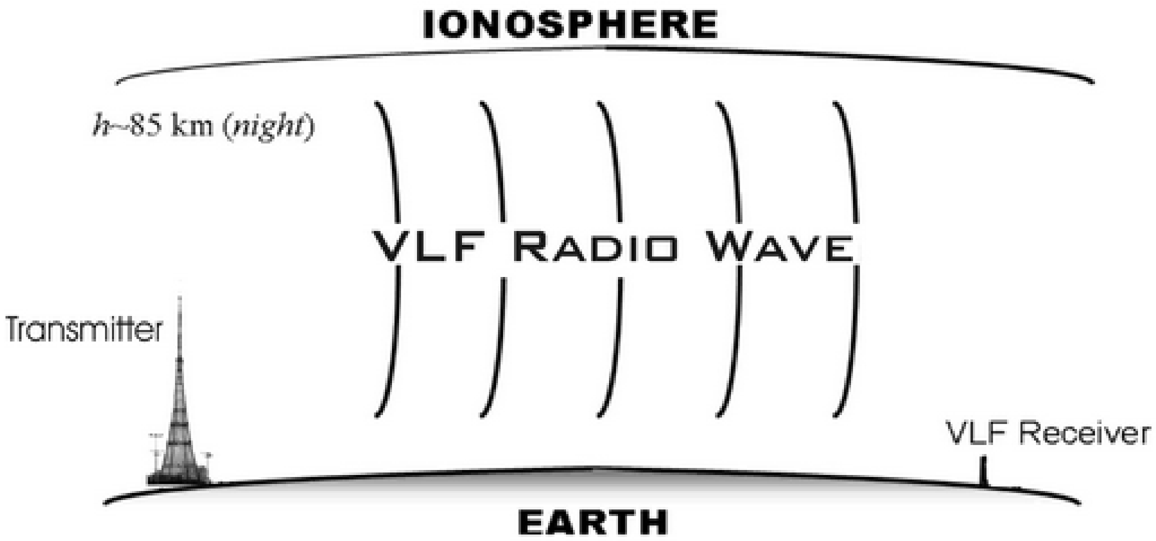
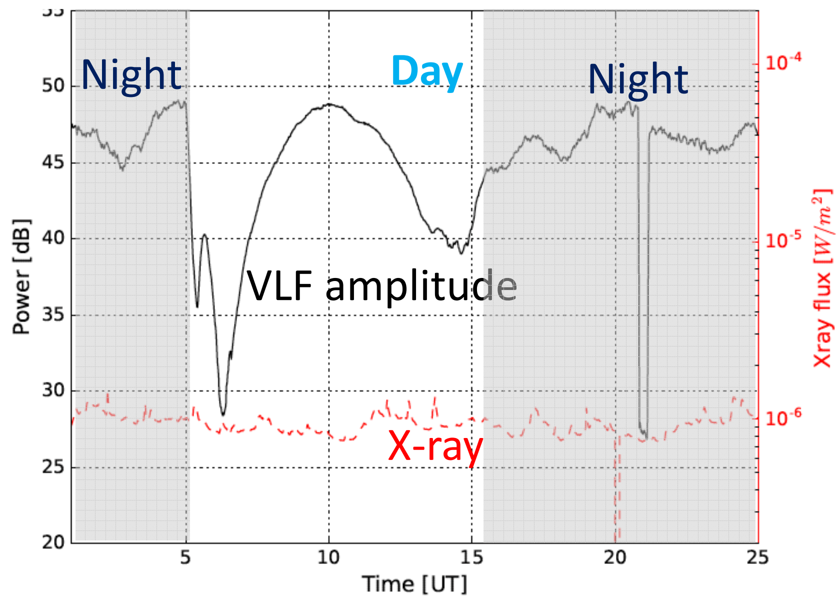
UN/US Workshop on ISWI 2017

INTRODUCTION

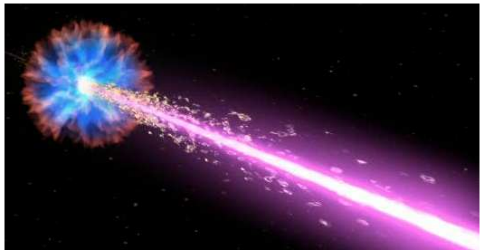
Introduction



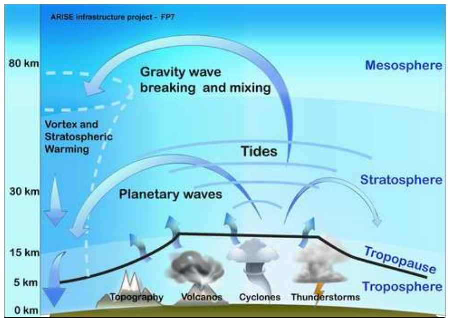
VLF waves propagate efficiently over long distances inside a natural waveguide known as the Earth-ionosphere waveguide



Lower ionospheric disturbances



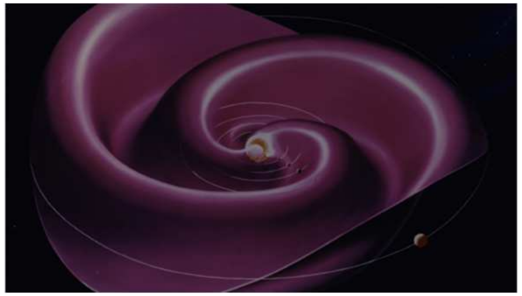
Gamma ray bursts

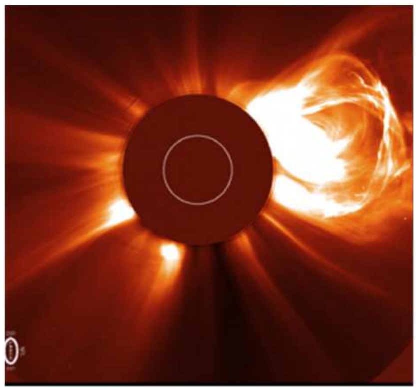


Atmospheric waves

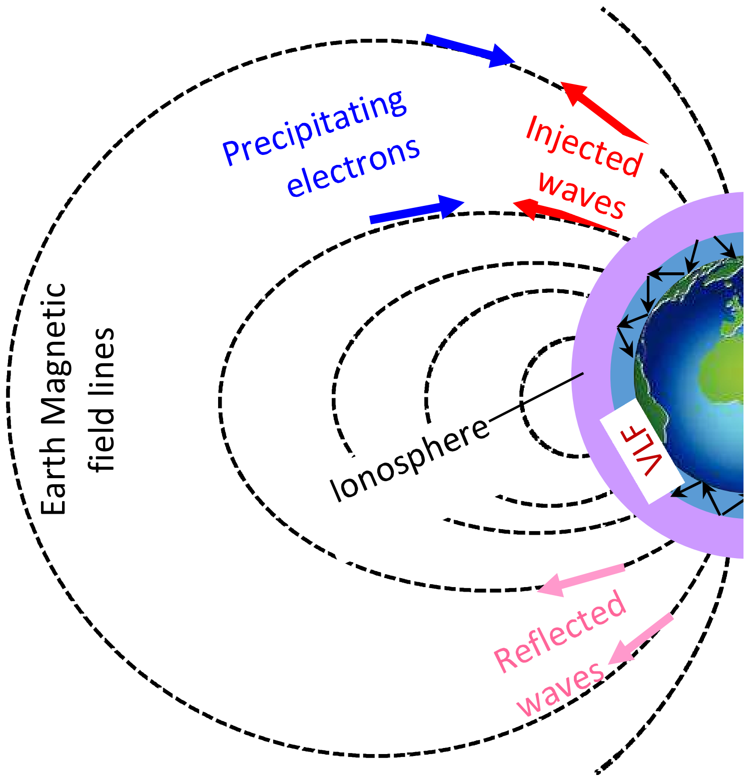
Introduction

Solar wind



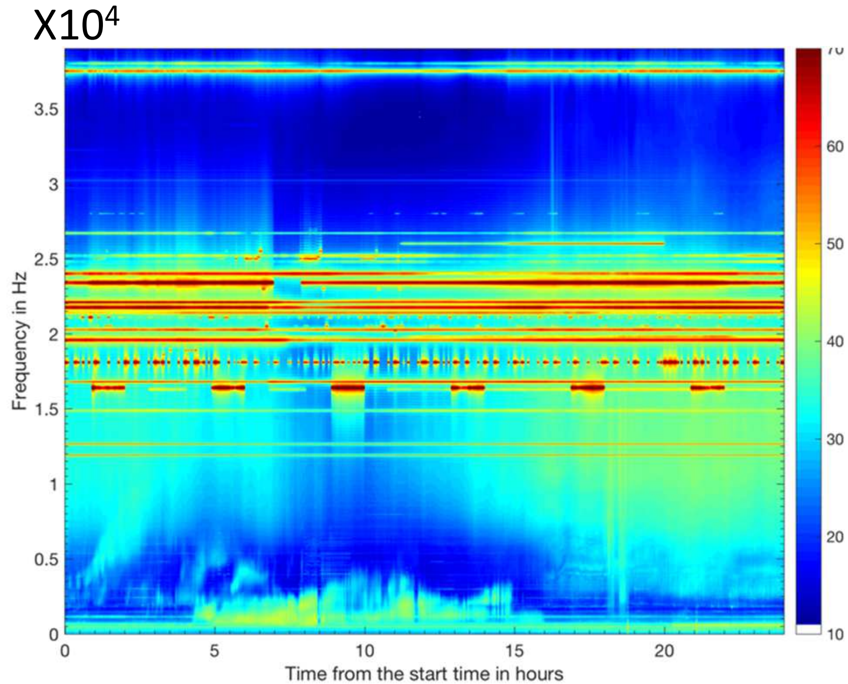


CME



Magnetospheric plasma

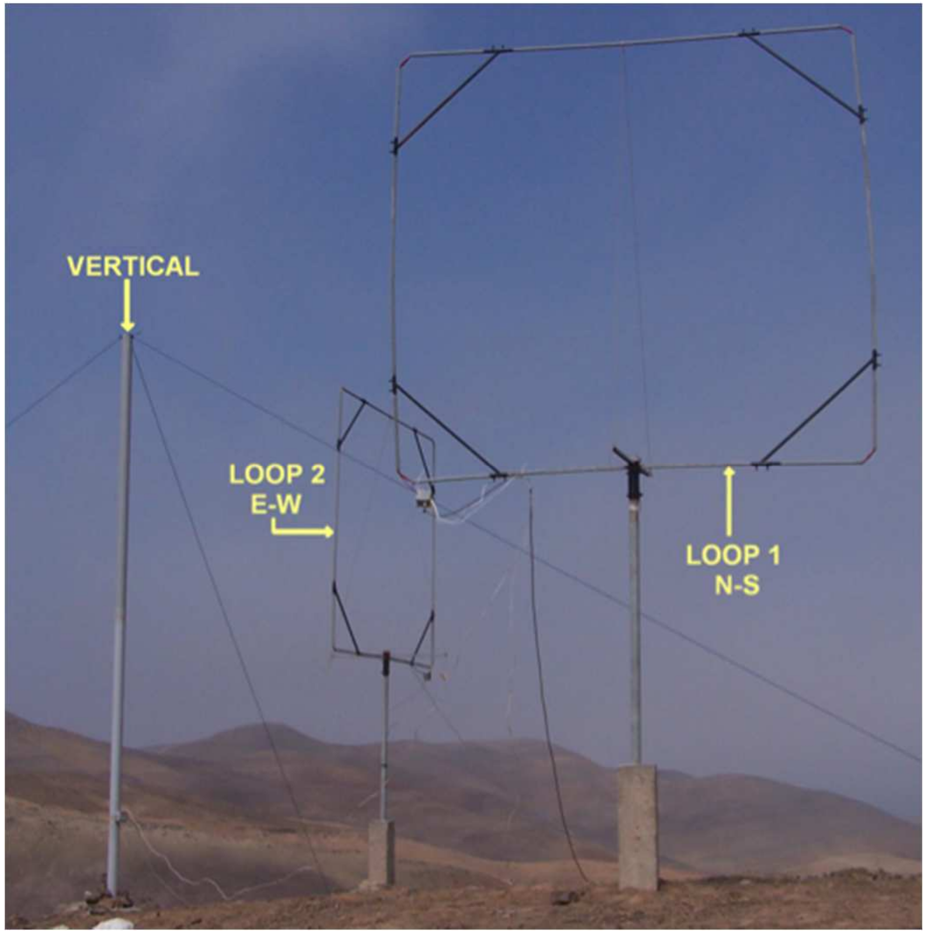
24H VLF measurements 20131208



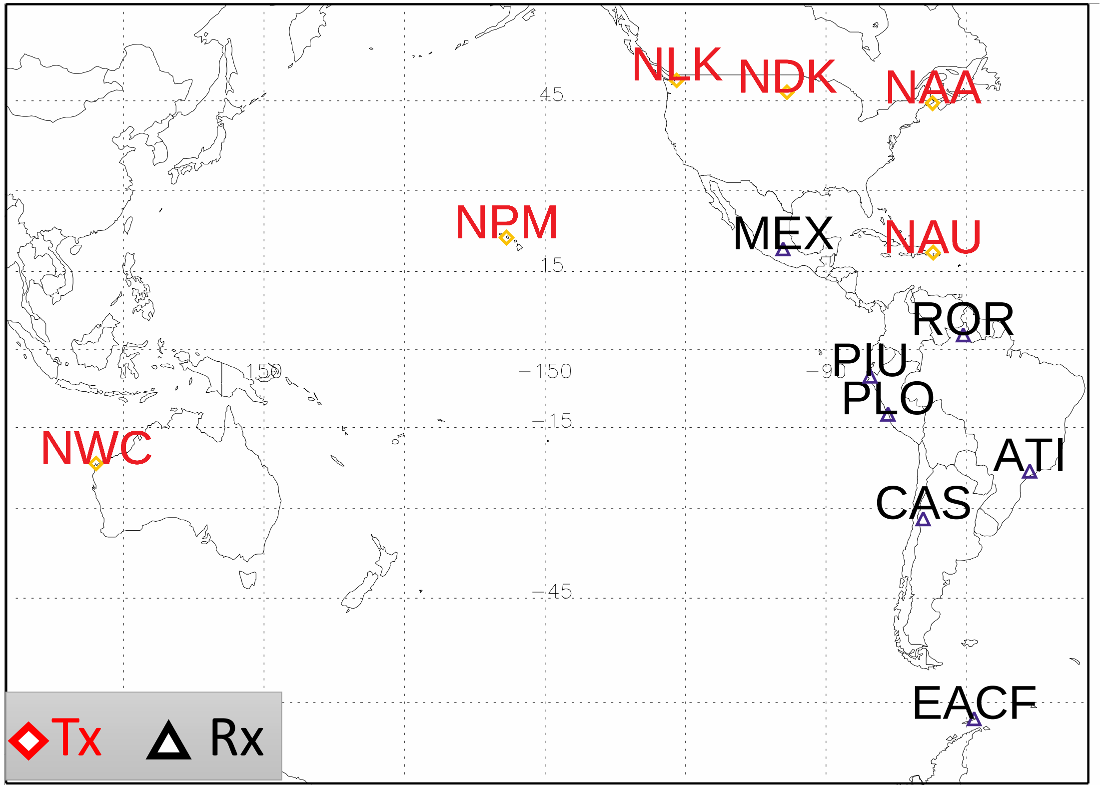
The magnetosphere is monitored using natural VLF emissions

INSTRUMENTATION AND DATA

Instrumentation and Data: SAVNET



Two square loop antennas of 3m by side and one vertical antenna



Narrowband recorded systems

First light: **2006**

Record **up to 6** transmitter signals with 0.1 time resolution

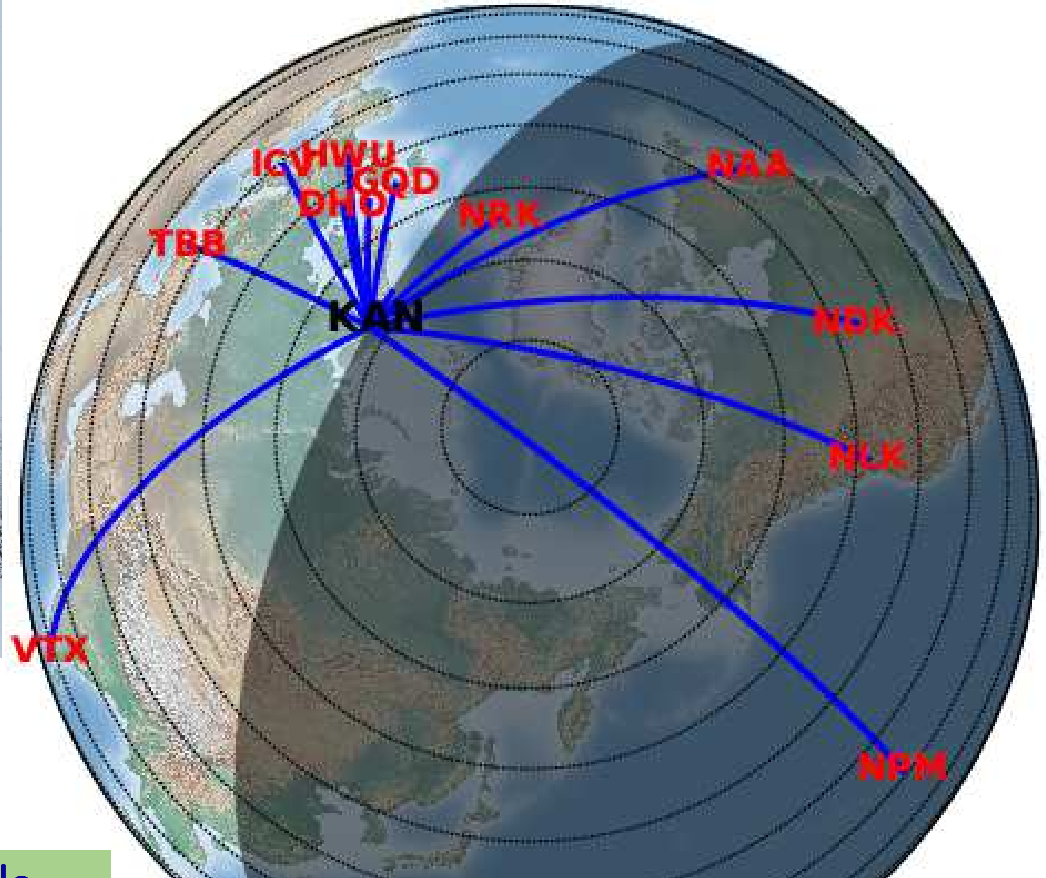
Instrumentation and Data: KANNUSLEHTO

Two square loop antennas of 10m by side

Wideband recorded systems

First light: **2006**

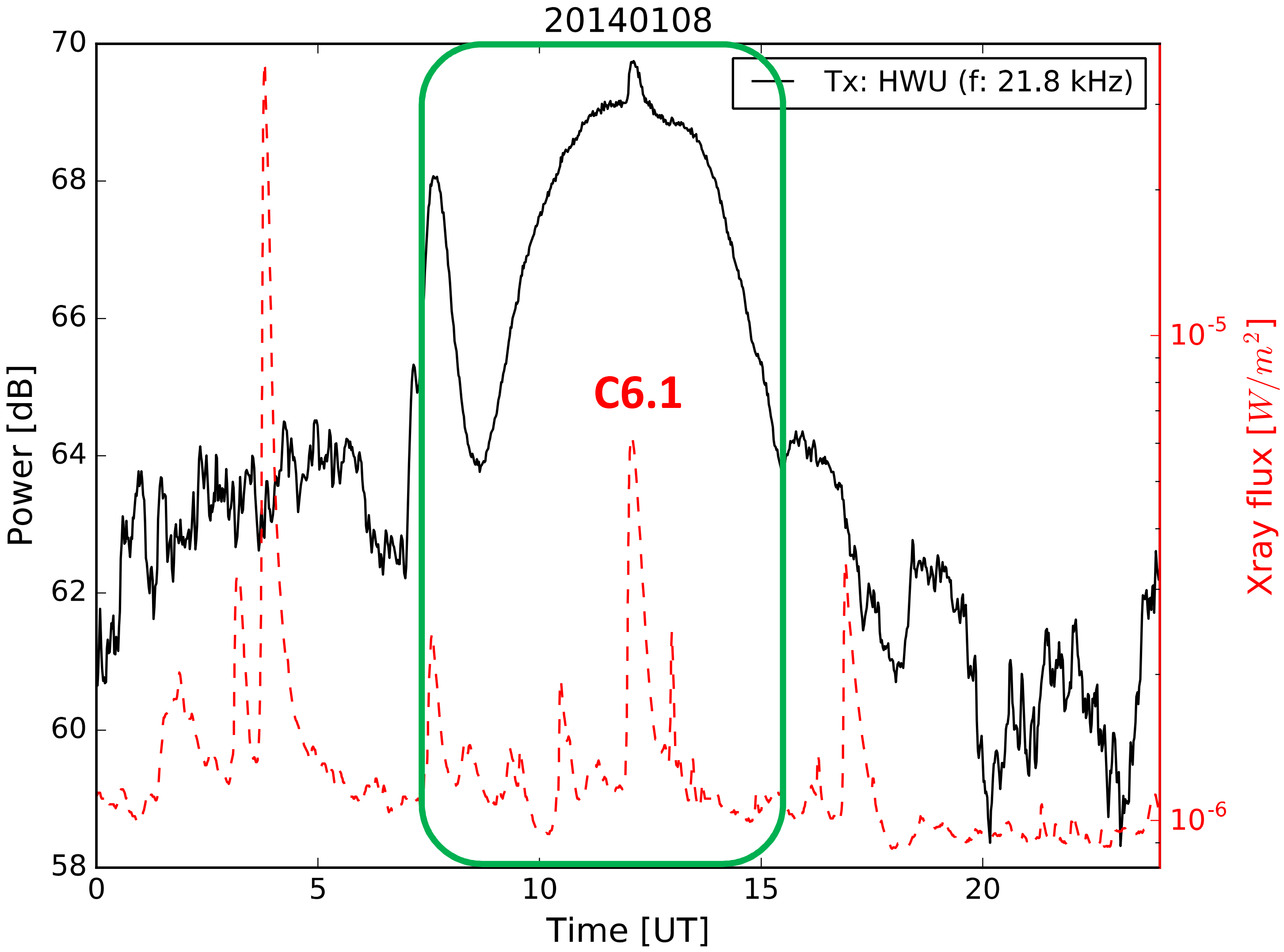
Record **all** transmitting signals between 0.2 and 39 kHz



Propagation paths of transmitter signals

DAYTIME
LOWER IONOSPHERE SENSITIVITY

Methodology



Data selection:

Period of analysis: **Dec-Jan**

Dec 2011- Jan 2016
KAN

Dec 2007- Jan 2016
SAVNET

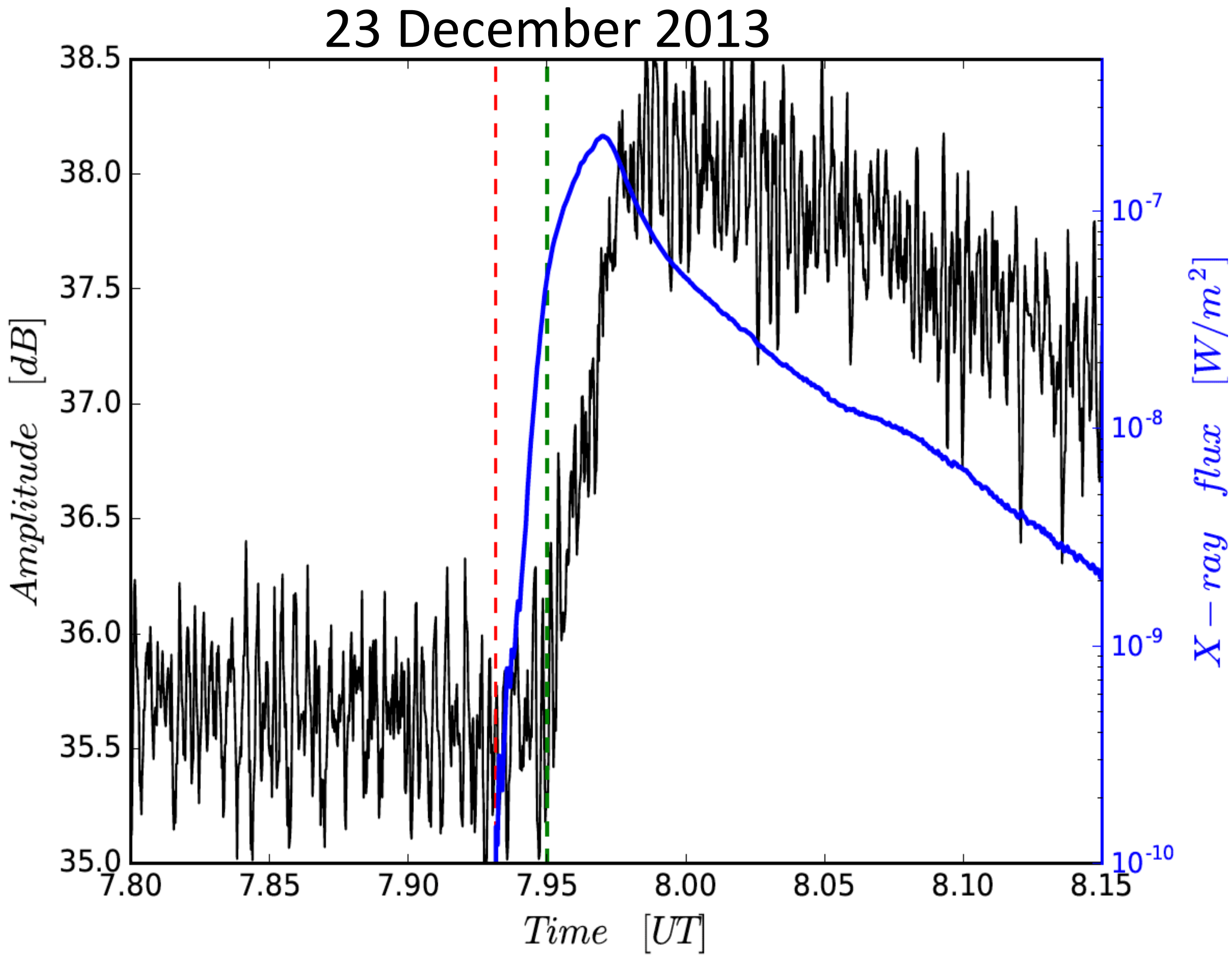
Type of flares: **Simple**

Geomagnetic conditions: **quiet**

AP < 20 AE < 400

KP < 4 Dst > -30

Methodology



computation of minimum fluence (F_{Xmin})

$$F_{Xmin} = \int_{t_{XF}}^{t_{VLF}} f(t)dt$$

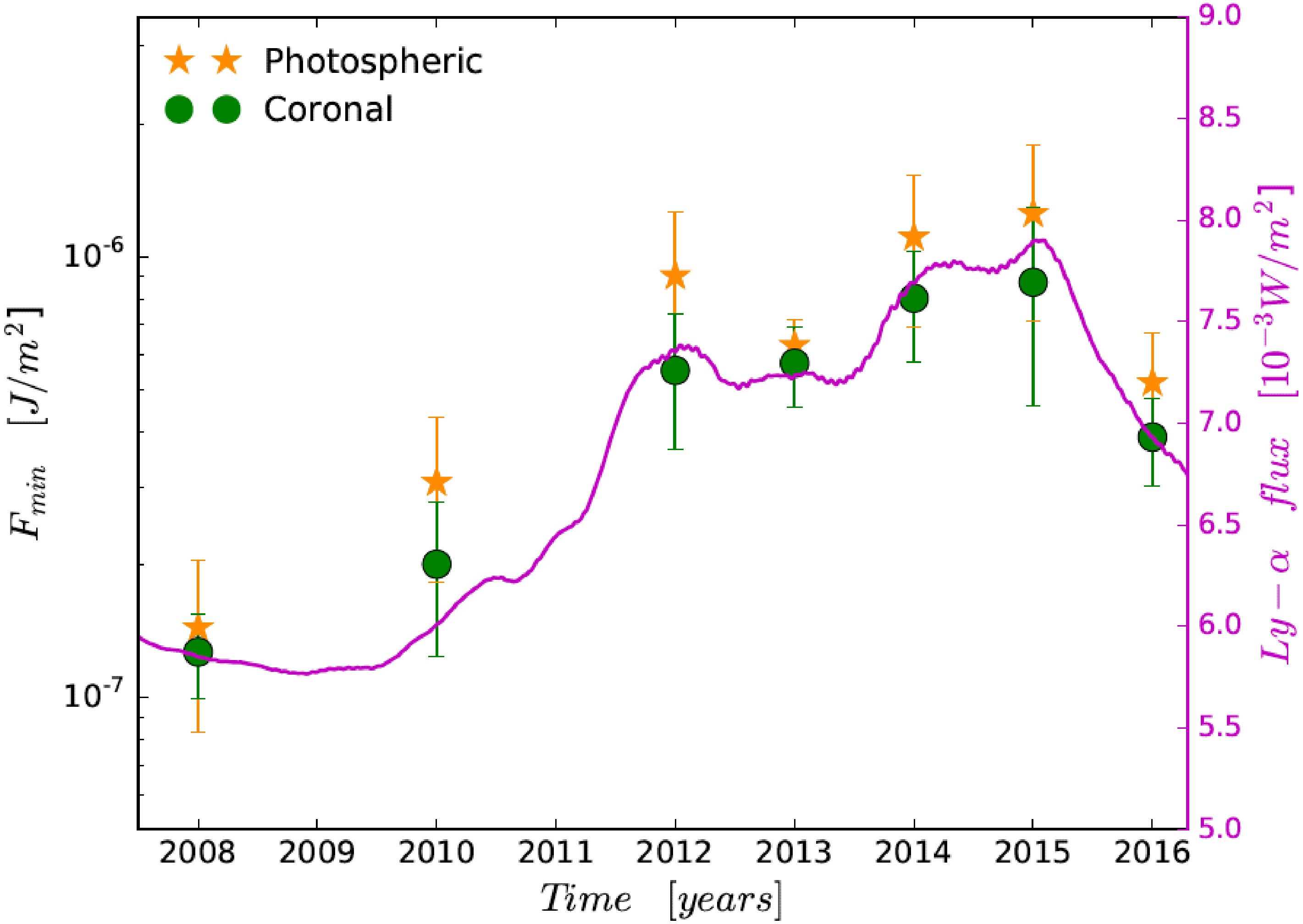
X-ray flux with wavelength less than 0.2 nm

amplitude of the VLF signal transmitted by TBB and recorded at KAN

onset time of the flare

start of the VLF amplitude deviation.

Results: Ionospheric sensitivity



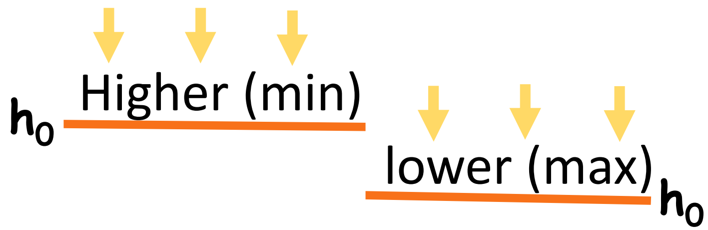
Solar cycle dependence

average of the F_{min} computed for each model of abundance.

F_{min} depends on the solar cycle activity.

Reference height variation

The height of the lower ionosphere:

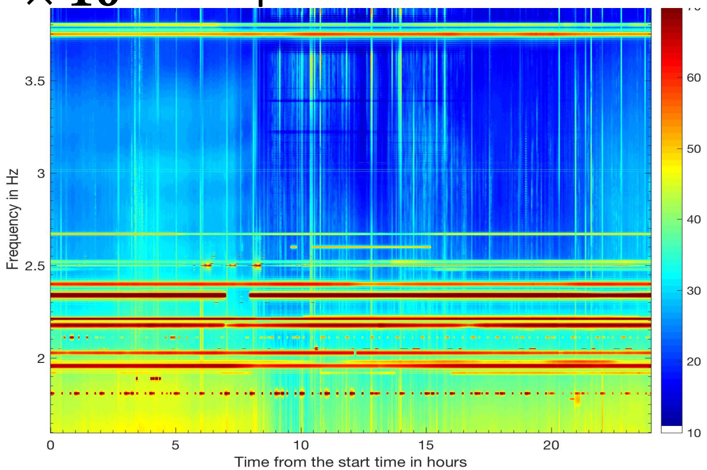


NATURAL EMISSIONS OBSERVED IN THE FREQUENCY BAND 25-37 KHZ

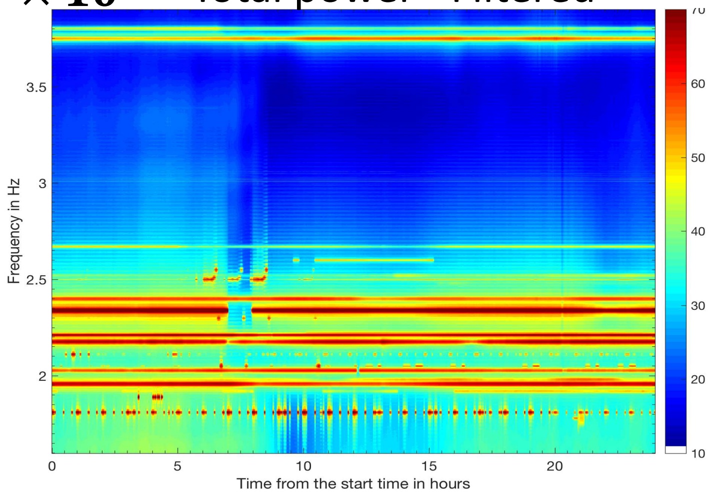
Methodology

2014-01-11

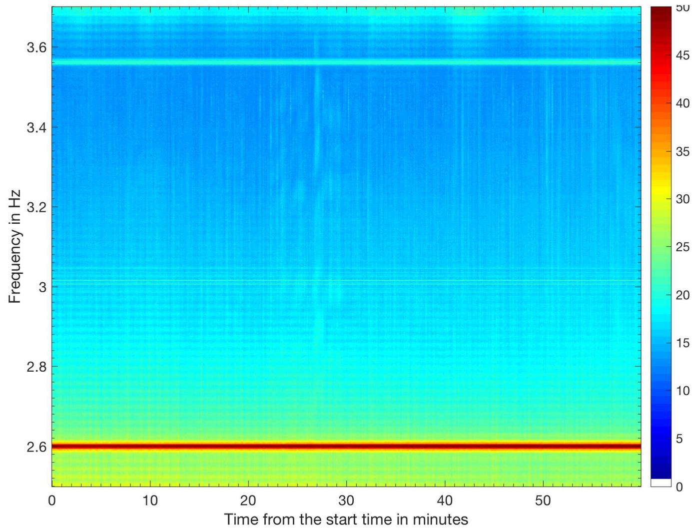
$\times 10^4$ Total power – non-filtered



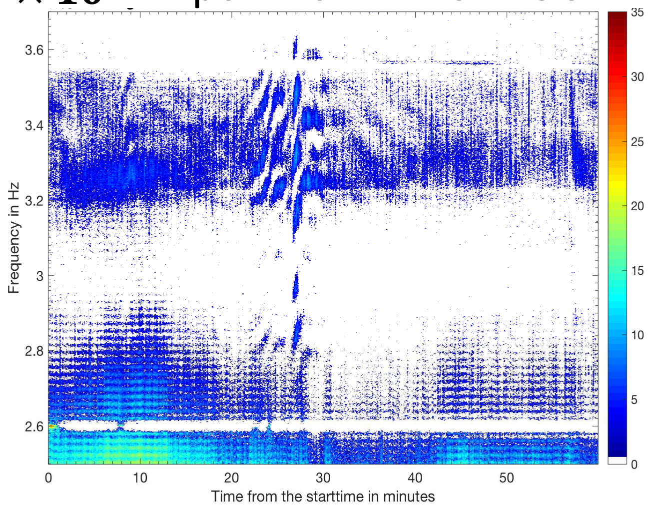
$\times 10^4$ Total power - Filtered



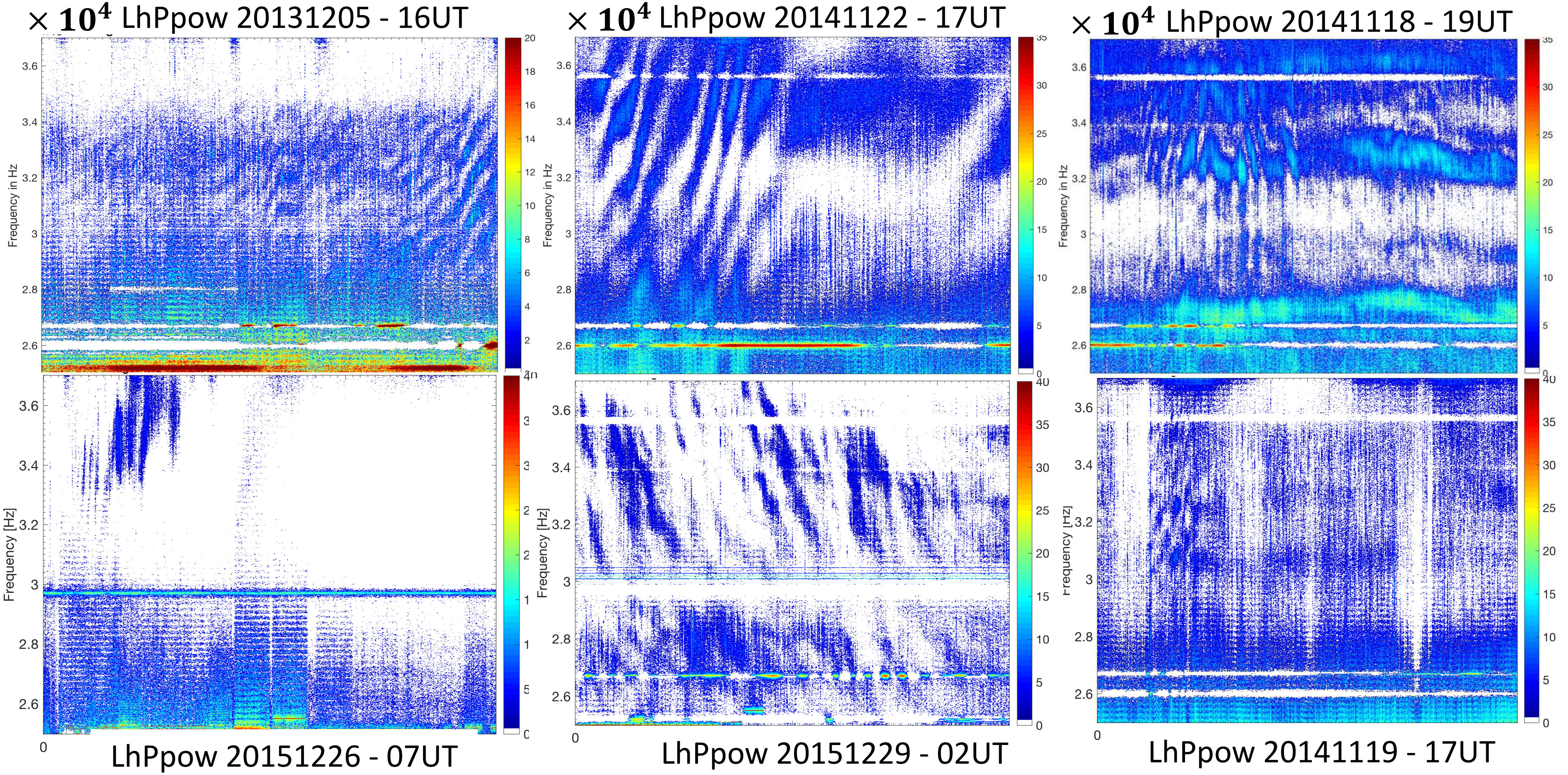
$\times 10^4$ TOTpow_20141129 - 19



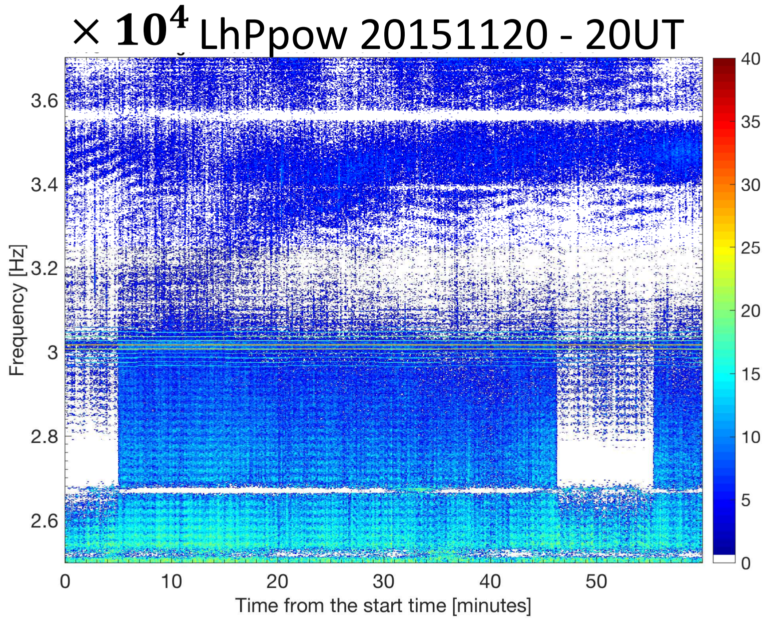
$\times 10^4$LhPpow 20141129 - 19UT

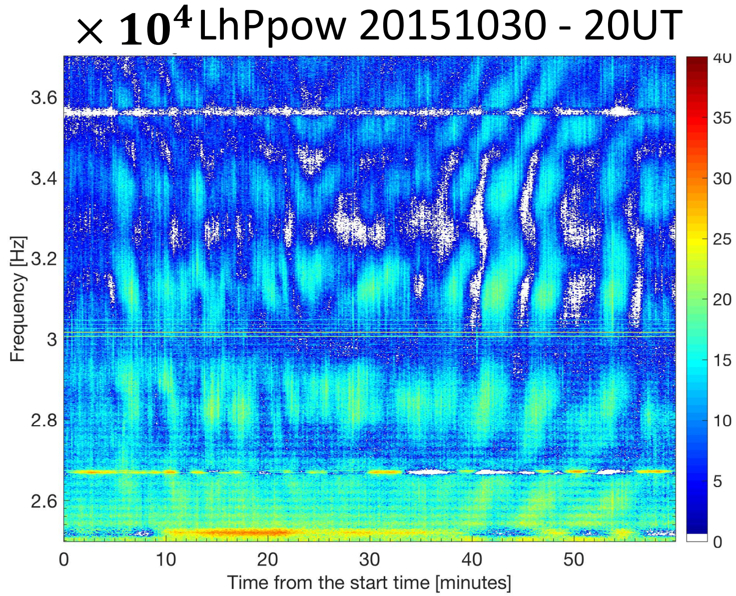


Types



× 10^4 LhPpow 20131205 - 16UT
× 10^4 LhPpow 20141122 - 17UT
× 10^4 LhPpow 20141118 - 19UT
Frequency in Hz
Frequency [Hz]
LhPpow 20151226 - 07UT
LhPpow 20151229 - 02UT
LhPpow 20141119 - 17UT





	2013		2014		2015	
Occurrence	16-7 UT	13 (40) 3	16-7 UT	26 (58) 4	16-4 UT	19 (91) 3
Polarization	13 LHP	3 RHP	25 LHP	13 RHP	19 LHP	4 RHP
Total power [dB]	12-20	16-18	14-25	14-25	14-26	17-26
Duration [min]	10-150	10-100	10-130	10-130	10-250	30-210
Angle of arrival [?]	140-170	150-160	140-180	120-180	120-180	150-160

CONCLUSIONS

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- We found that the variation of the ionospheric sensitivity is anti-correlated to the solar activity cycle.
- Our result is important for identification of the minimum fluence that a given external source of ionization must overcome in order to cause a measurable disturbance in the daytime lower ionosphere.
- We have identified 9 types of natural emissions observed between 25-37 kHz.
- Some of the events are also observed at frequencies between 1-10 kHz.
- Next task: possible sources of natural emissions observed between 25-37 kHz will be identified.

Thank you very much for your attention