

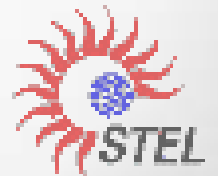
Automatic identification of Pc5 waves using RBSP mode data from Hokkaido radar

RBSPモードを用いた北海道 - 陸別HFレーダーのPc5波動自動検出



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¹名大STE研



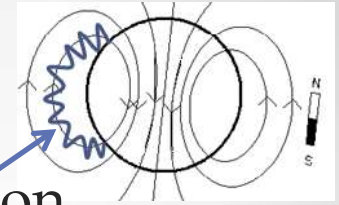
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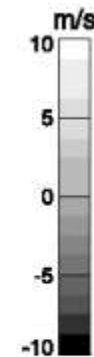
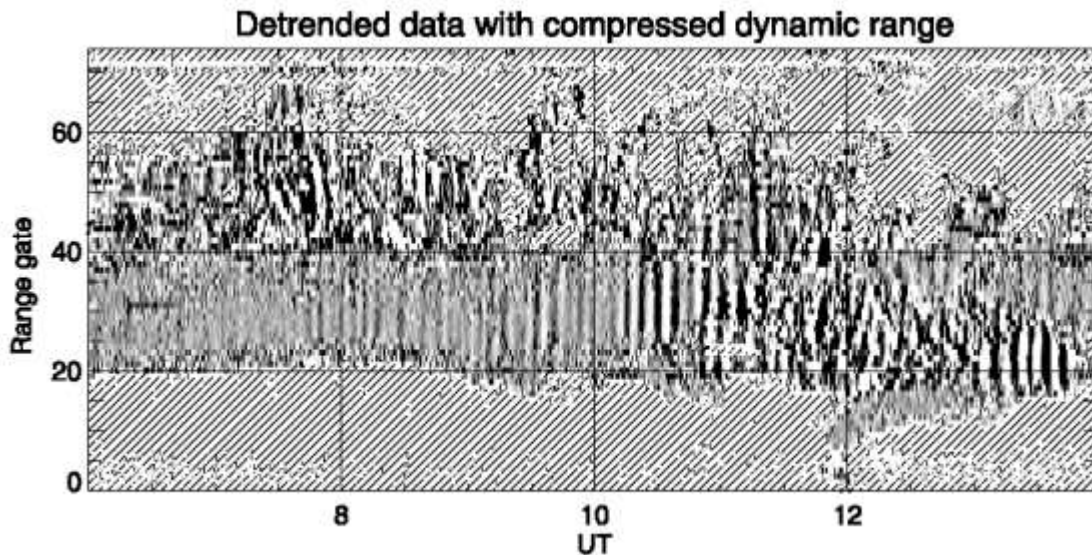
What is ULF waves?

Magnetic pulsations that are Ultra Low Frequency (ULF) waves have been observed by many methods such as ground-based magnetometer, HF radar and satellite in the magnetosphere.

In this study, we focus on Pc5 range ULF waves in mid latitudes.



pulsation



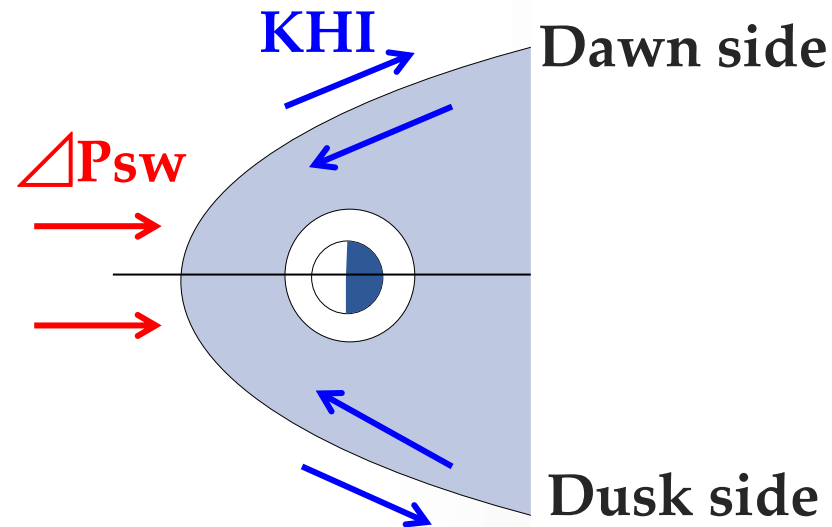
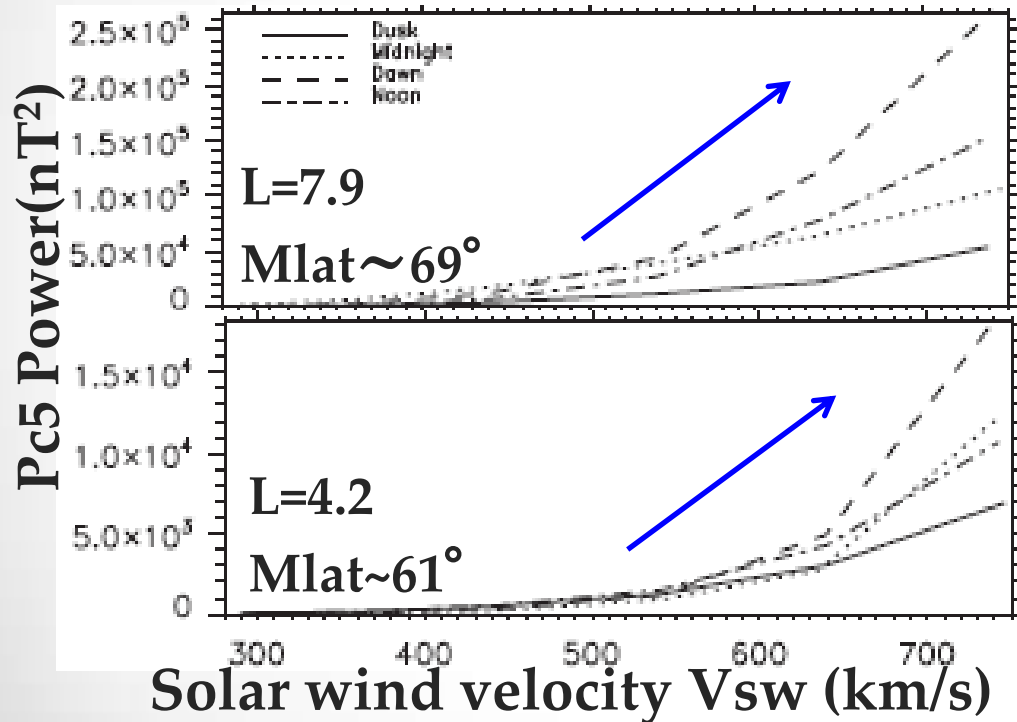
pattern	Notation	Period (sec)
Continuous	Pc1	0.2 ~ 5
	Pc2	5 ~ 10
	Pc3	10 ~ 45
	Pc4	45 ~ 150
	Pc5	150 ~ 600
Irregular	Pi1	1 ~ 40
	Pi2	40 ~ 150

The Pc5 waves have been observed by SuperDARN Tiger radar [Ponomarenko et al., GRL, 2003]

The classification of ULF waves [Jacobs et al., JGR, 1964] The ULF waves are classified based on the pattern and the frequency.

The source of Pc5 waves

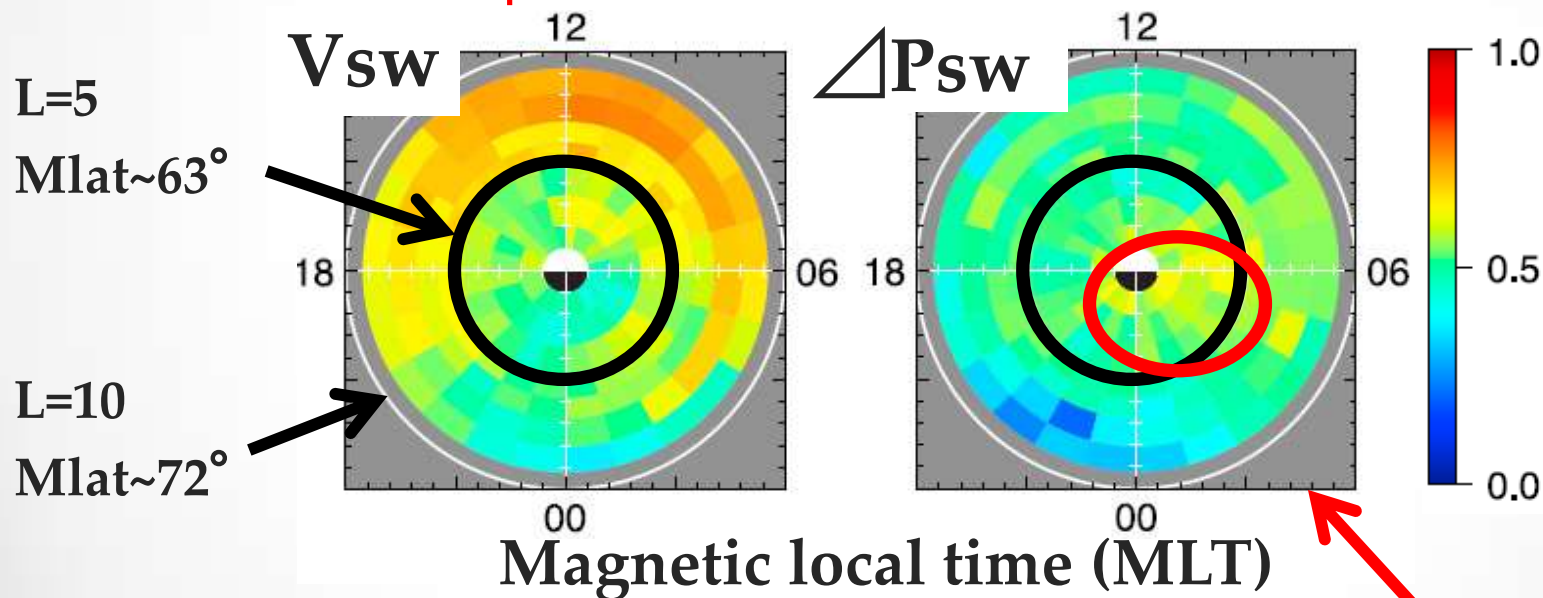
- Solar wind dynamic pressure variation (ΔP_{sw})
 - The dominant frequency **depends on ΔP_{sw}**
- KHI due to flow shear in the magnetopause
 - The dominant frequency **depends on V_{sw} (solar wind velocity)**



The statistical analysis by the CANOPUS/CARISMA magnetometer array during 20 years [Pahud et al., 2009]. **It shows positive correlation between V_{sw} and Pc5 power ($L=4\sim 8$).**

The spatial distribution of Pc5 waves

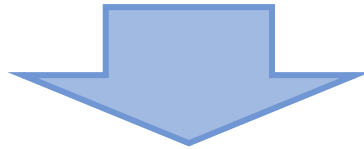
- Many previous studies have suggested importance of KHI. However, a recent statistical study by Takahashi et al. [2012] indicated **importance of ΔP_{sw} for the low-latitude Pc5.**
- Most of previous statistical studies based only on magnetic field observations. **It will be useful to investigate characteristics of electric field component of the Pc5 waves.**



The statistical analysis by the ground-based magnetometer ($L=1.3\sim 8.7$) [Takahashi et al., JGR, 2012] It shows the linear correlation coefficient between Pc5 waves' power on north-south component and solar wind parameters.

The motivation

- What is the driver of Pc5 waves in mid latitudes?
 - What is their dependence on the solar wind parameters?
- What is the propagation path of mid-latitude Pc5 waves?



- We plan to study **the dependence of Pc5 waves (150~600 sec) on the solar wind parameters in the mid latitudes statistically** based on the Hokkaido HF radar observations.
- We try to develop an automated identification method of Pc5 from the HF radar data.

Previous automatic identification method

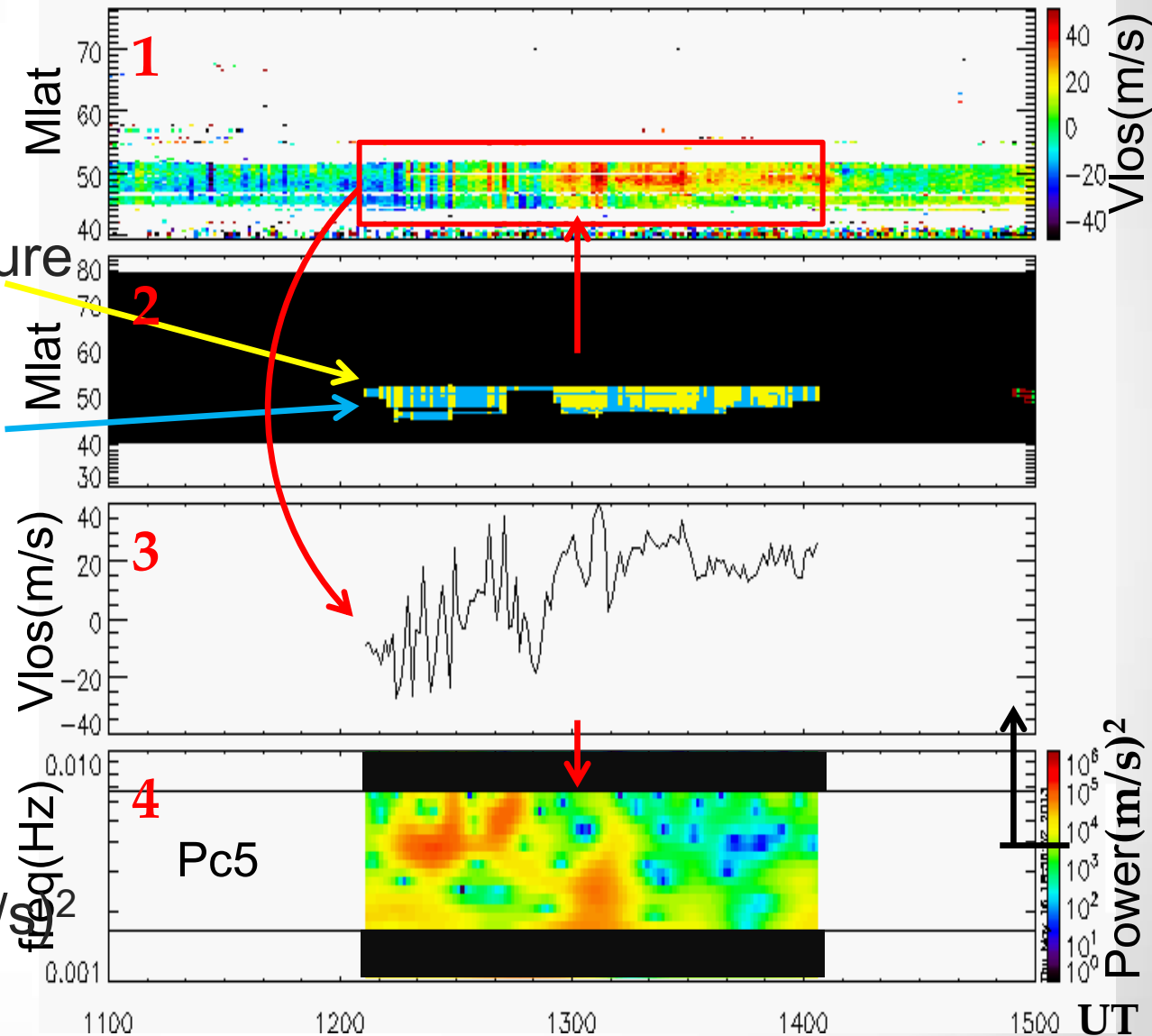
1. Remove noise
($|V_{sw}| > 200\text{m/s}$)

2. Identify stripe structure

Interpolate along time
($< 10\text{ min}$)

3. Create time series
data from the median
($> 20\text{ min}$)

4. Wavelet transfer
Max Power $> 5000(\text{m/s})^2$



(Then confirm by the inspection.)

(Mar. 2 2011) 9

Identification method

We use the Doppler velocity data by the Pc5 waves' identification method. The Pc5 waves' identification method has five steps. These steps are the followings.

1. Remove noise ($|V_{los}| > 200$ m/s)
2. Interpolate (Linear)
3. Frequency analysis (Wavelet)
4. Calculate the ratio between the following power
 1. the maximum power
 2. the power at nearly the power-weighted average frequency
5. Identify the event from the candidates
 1. The power ratio over the threshold (0.5)
 2. The time span over the threshold (300 sec)
 3. The range width over the threshold (3 range gates)

We show the detail and the example for the steps by the next slide, and we use the Hokkaido HF data during RBSP mode from 2013 Jan 18 1200 to 1800UT.

Noise removal and Interpolation

The Doppler velocity data before and after step 1 and 2. The upper panel shows the original data. The lower panel displays the processing data.

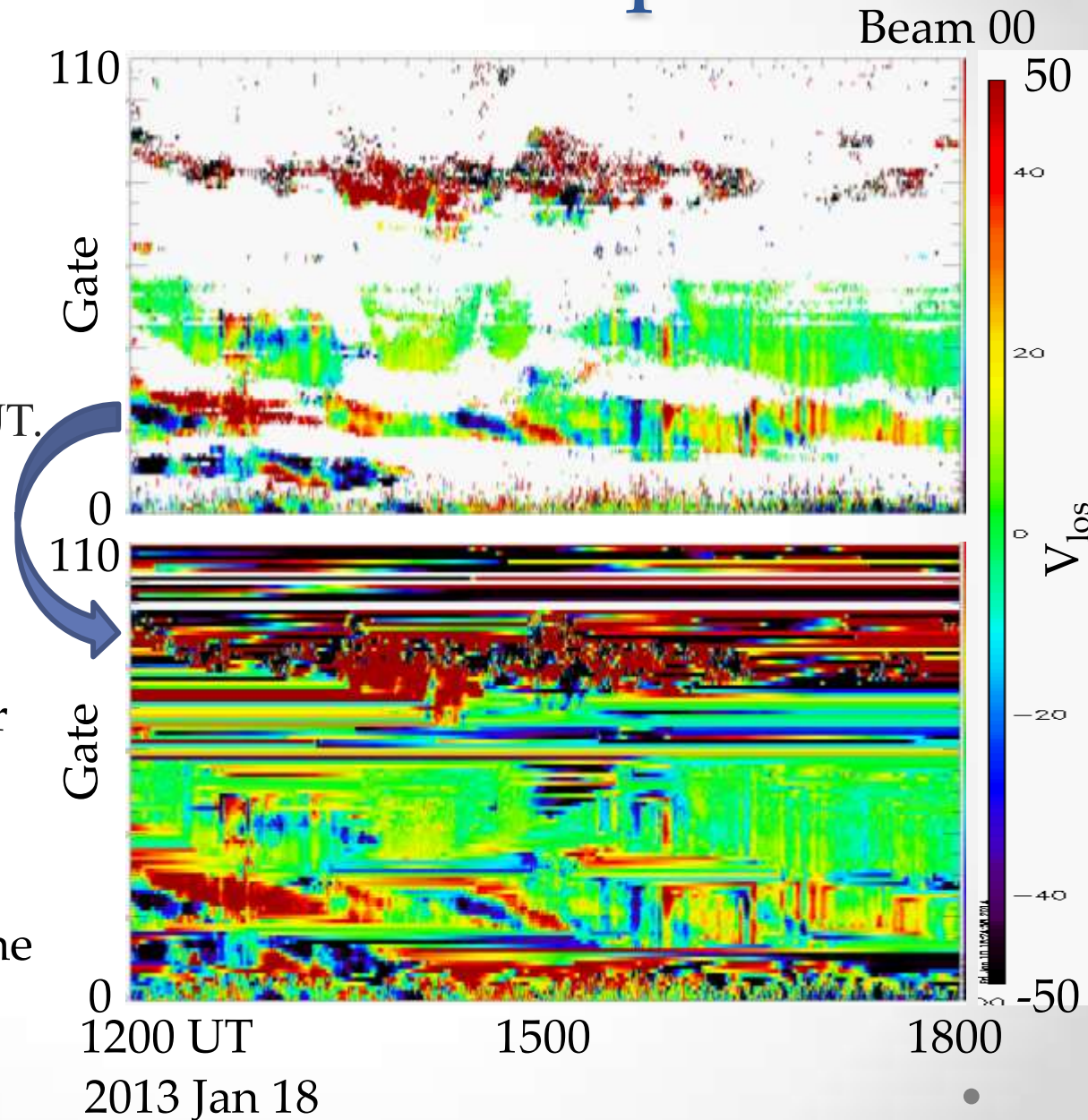
We can see the Pc5 events around 1230, 1600 and 1700UT.

Step 1

We Remove the data over 200 m/s as noise.

Step 2

We linearly-interpolate the data after noise removal.

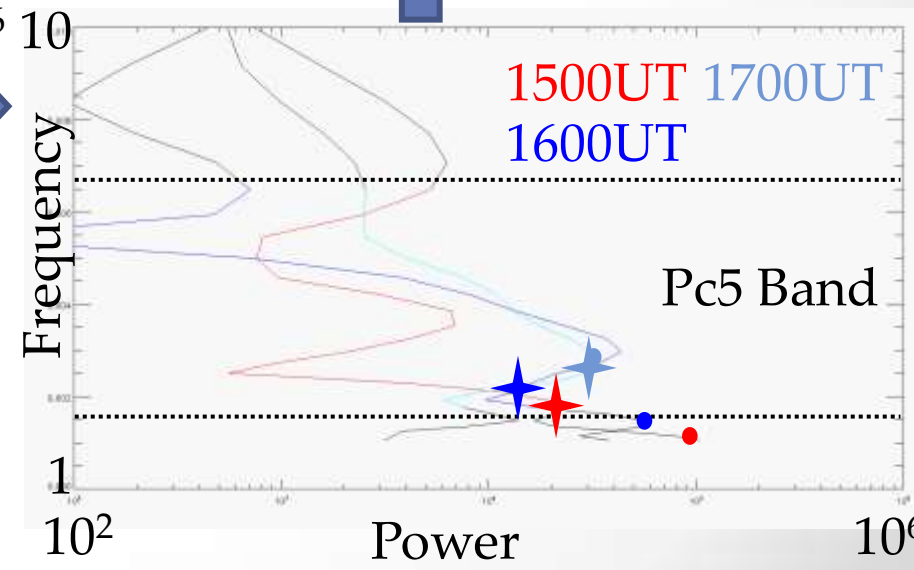
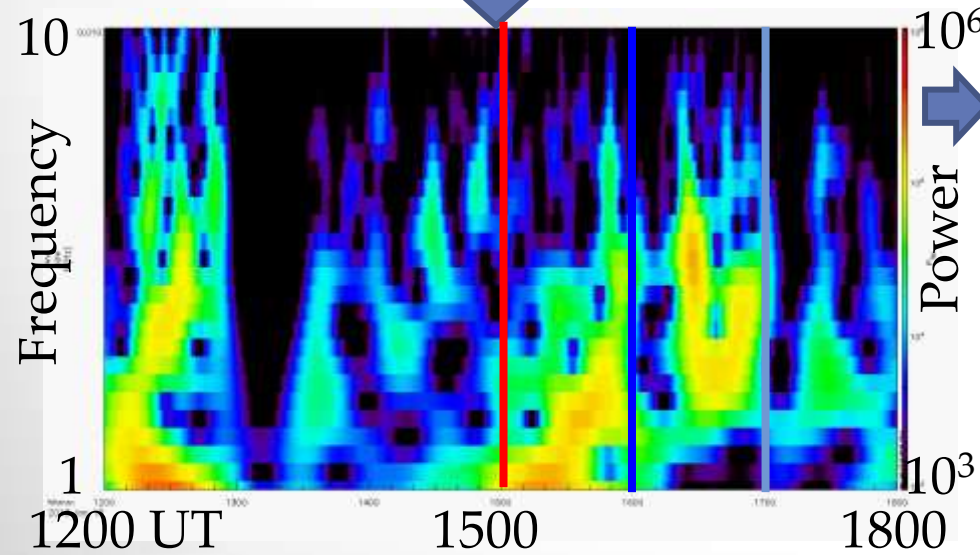
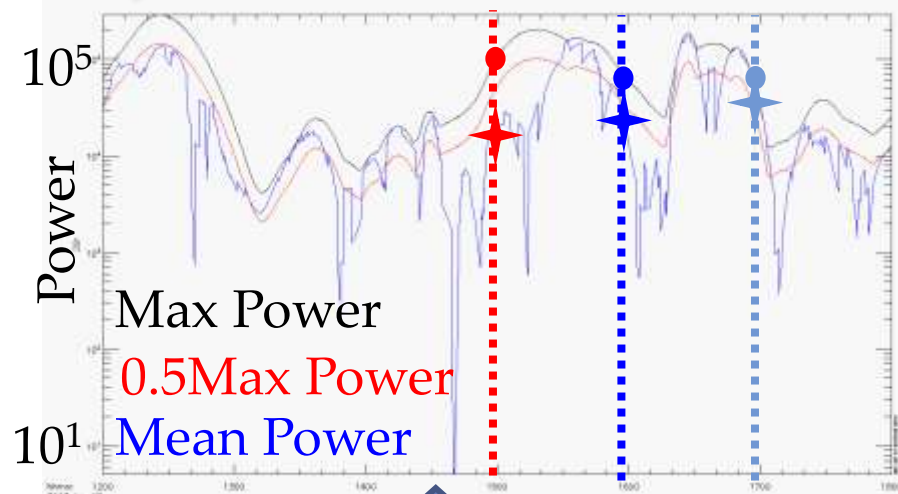
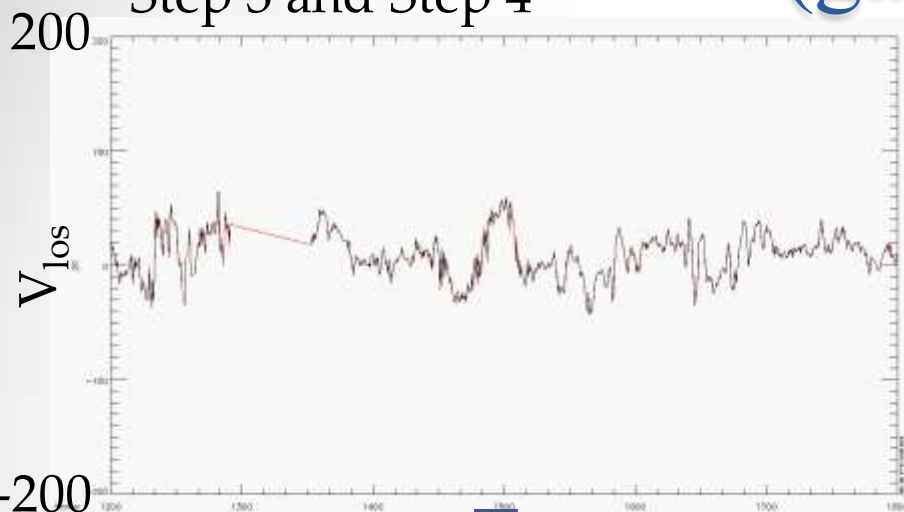


Wavelet analysis and power ratio calculation

(gate 20)

Beam 00

Step 3 and Step 4



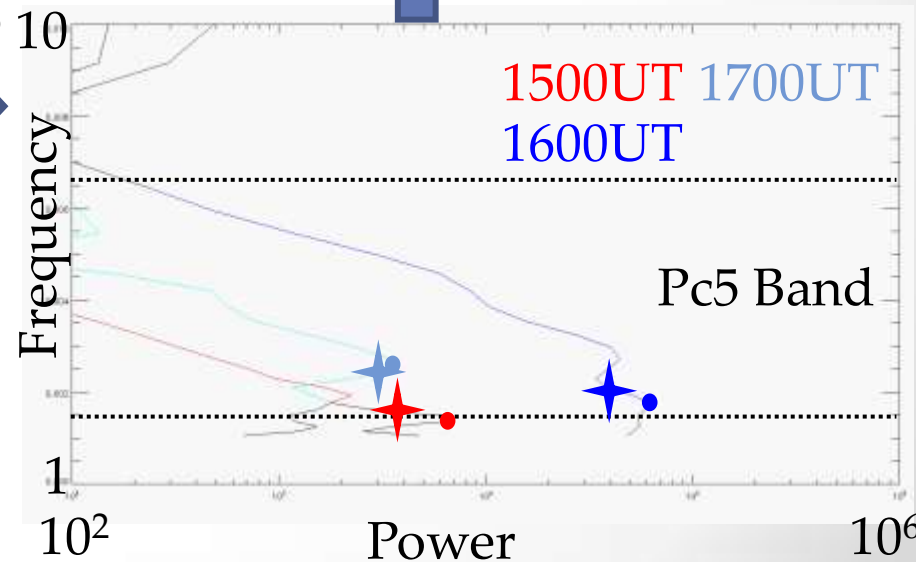
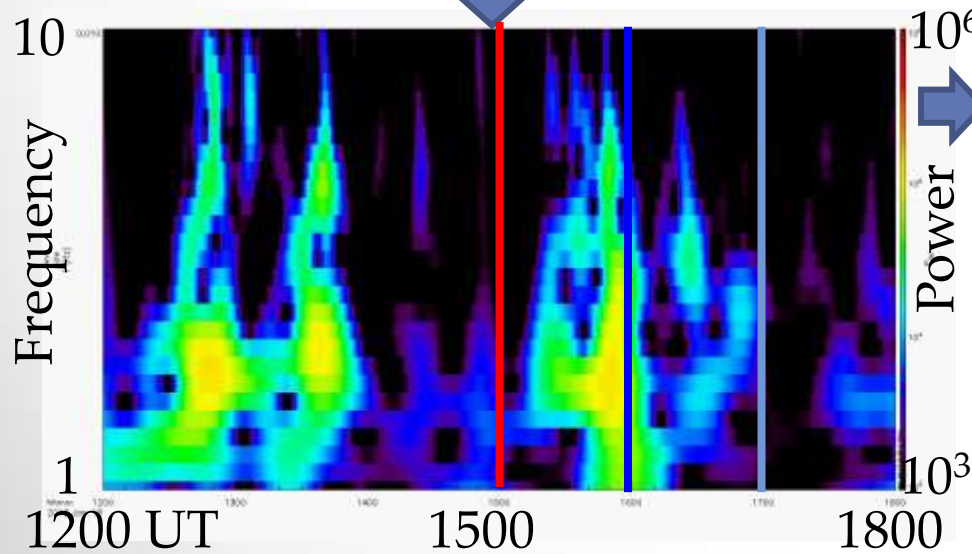
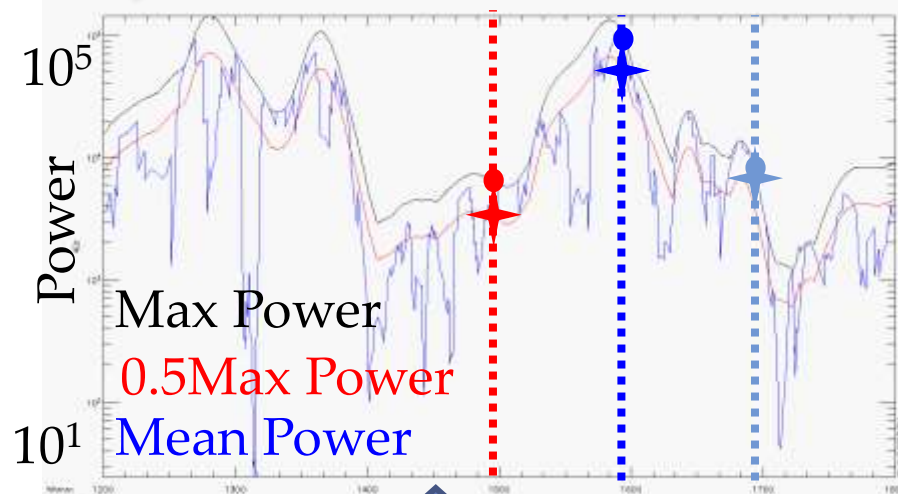
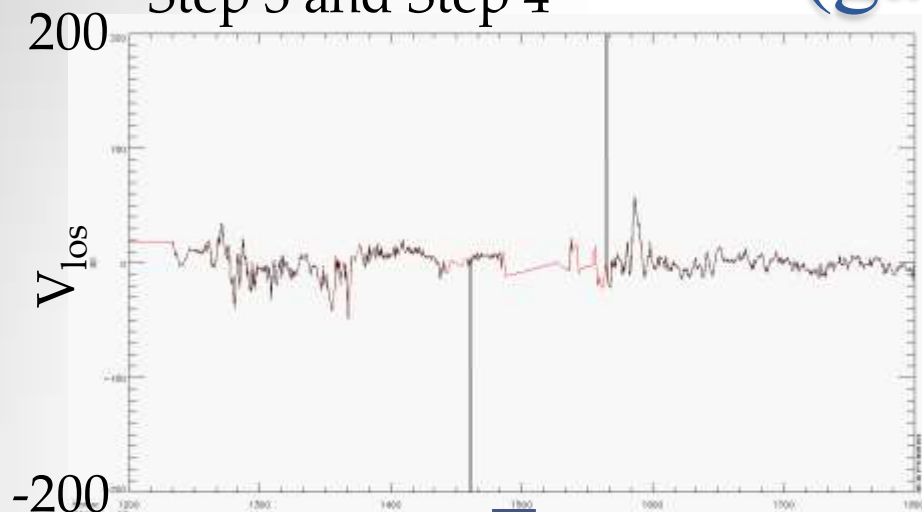
2013 Jan 18

Wavelet analysis and power ratio calculation

(gate 40)

Beam 00

Step 3 and Step 4

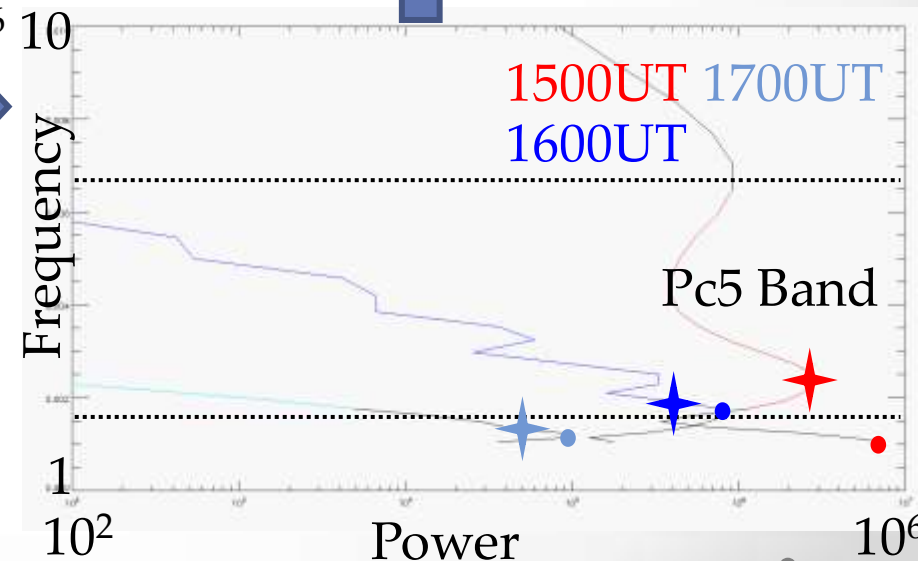
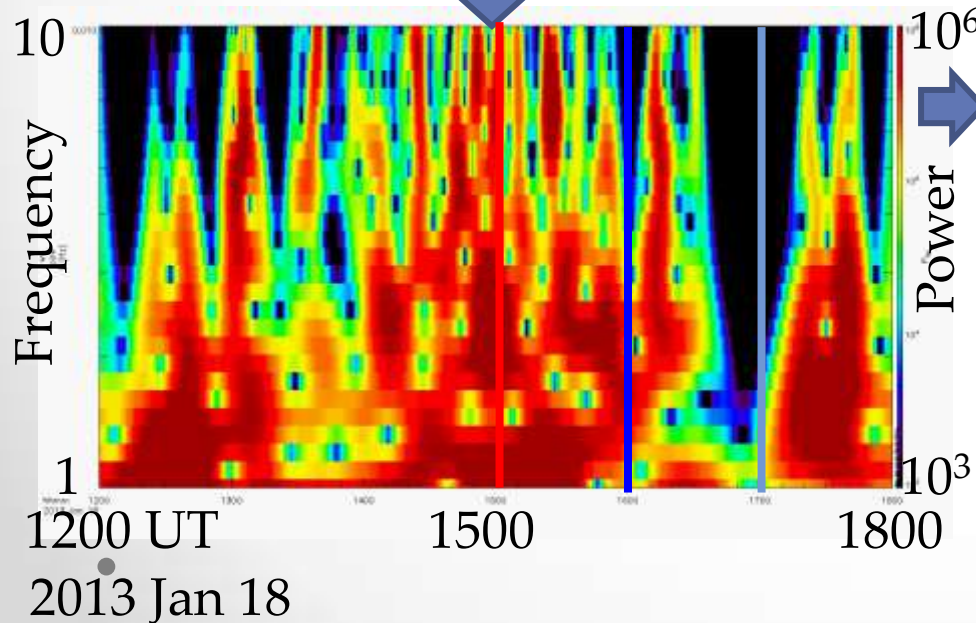
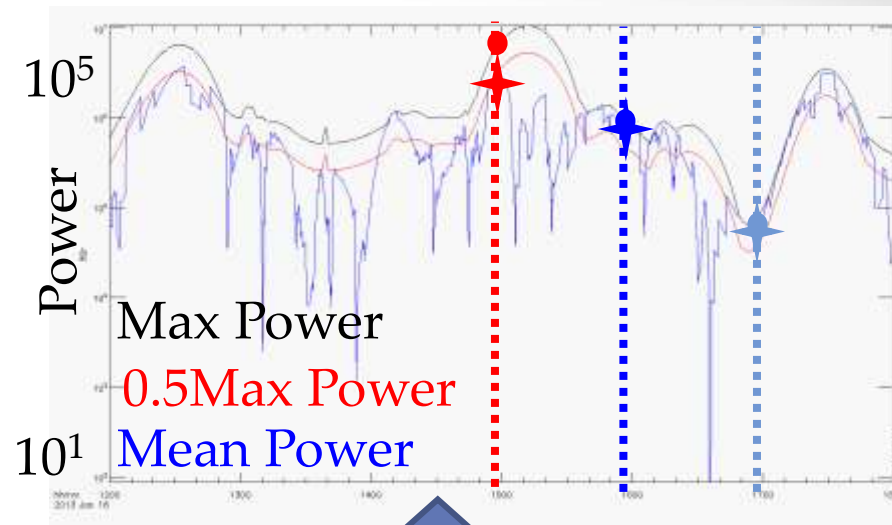
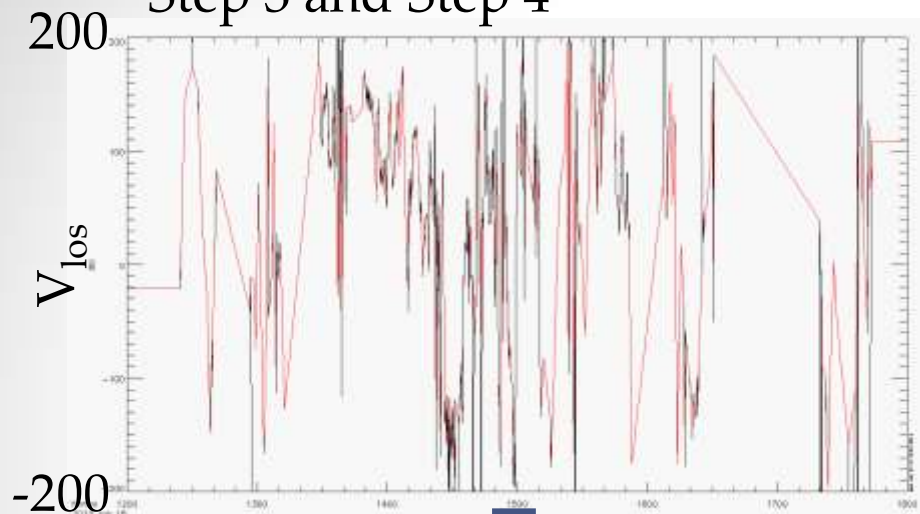


2013 Jan 18

Wavelet analysis and power ratio calculation (gate 80)

Beam 00

Step 3 and Step 4



Wavelet analysis and power ratio calculation (all gates)

Step 3 and Step 4

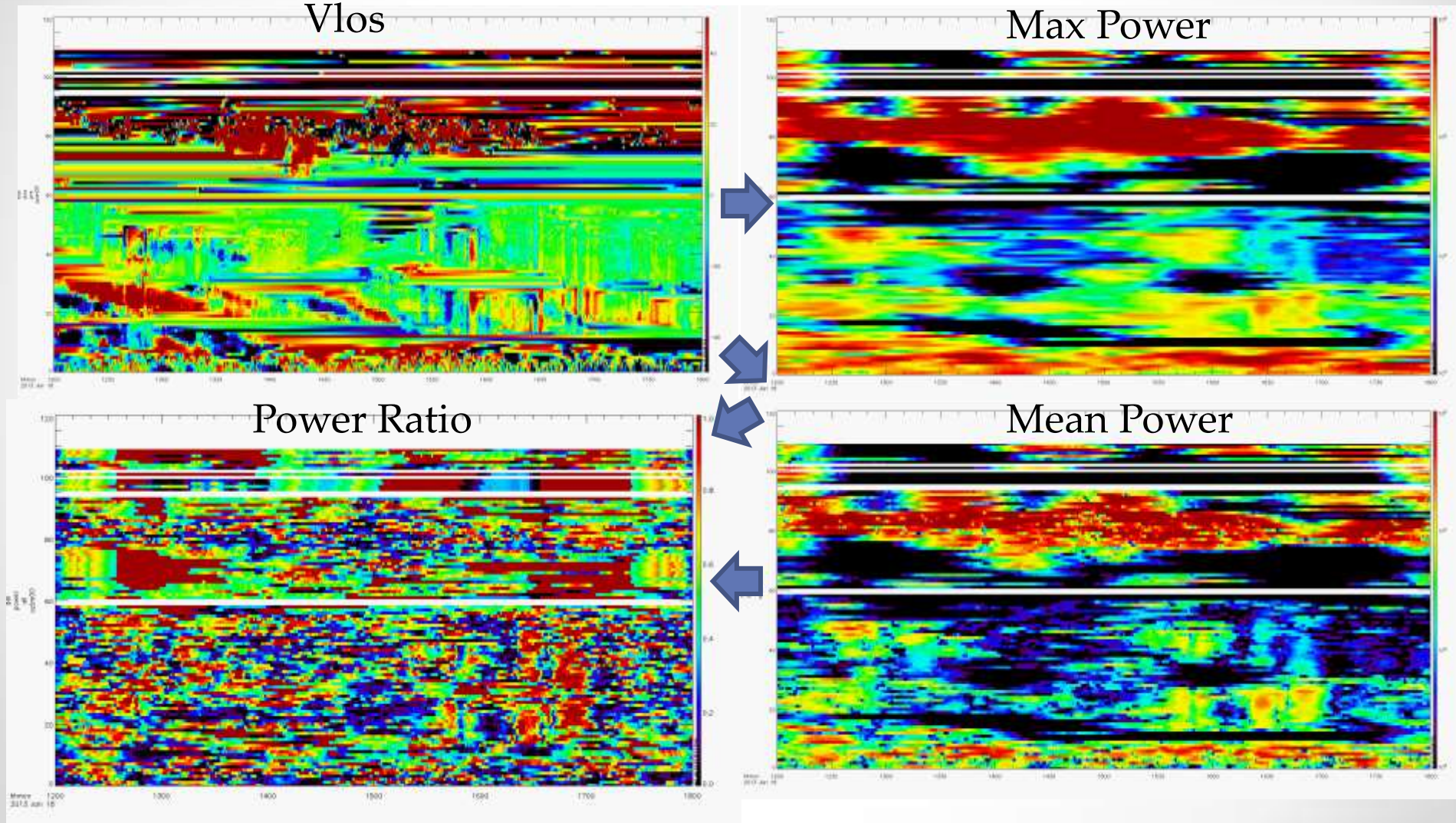
Beam 00

Vlos

Max Power

Power Ratio

Mean Power

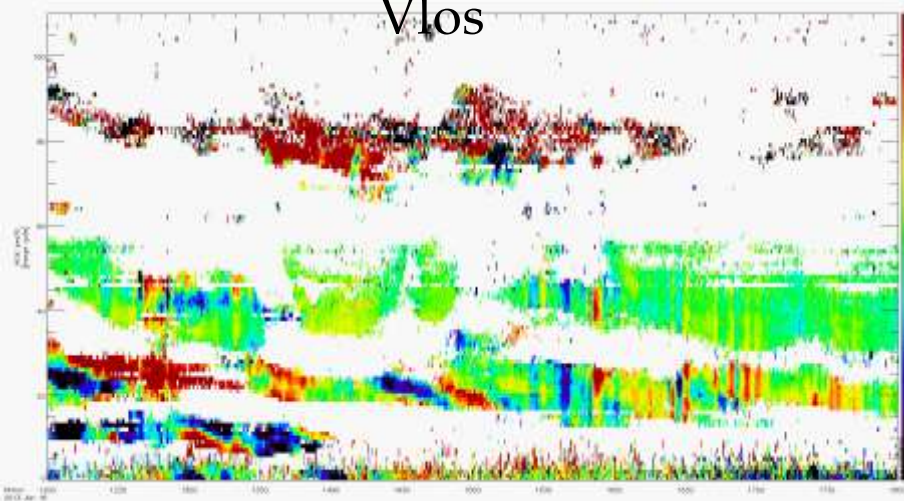


Wavelet analysis and power ratio calculation (all gates)

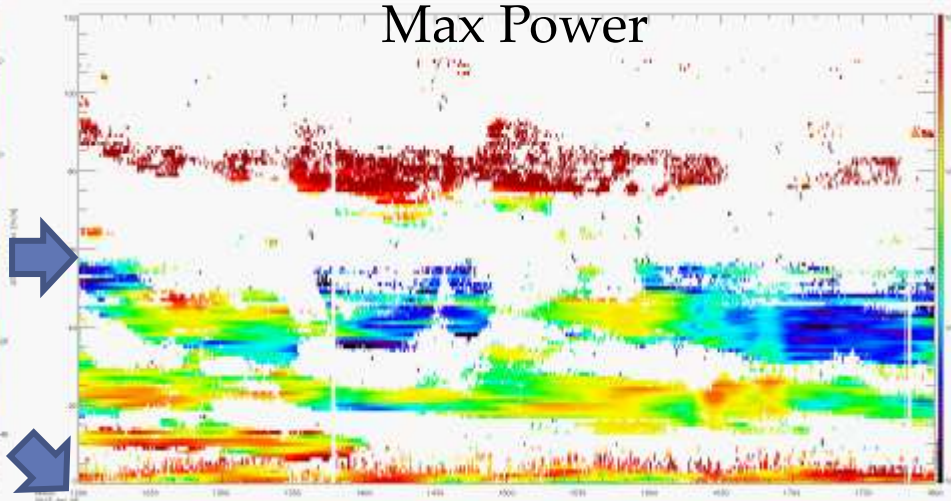
Step 3 and Step 4

Beam 00

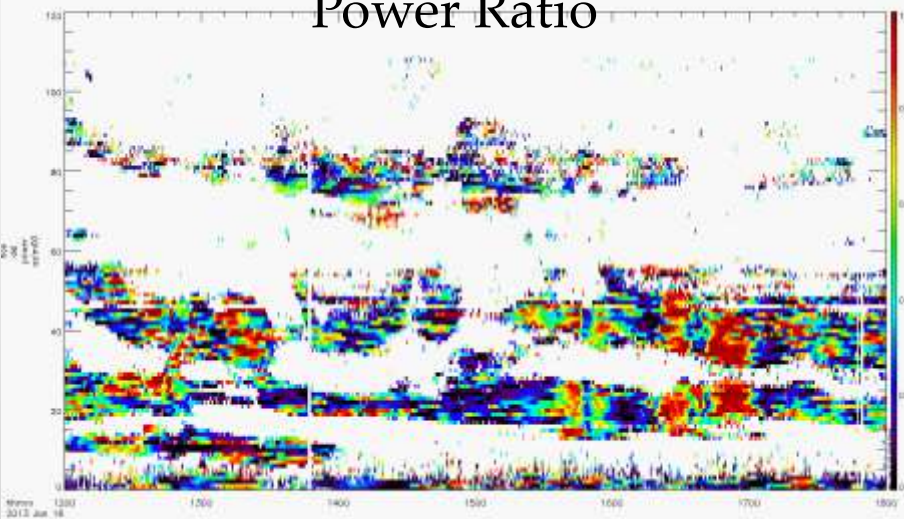
Vlos



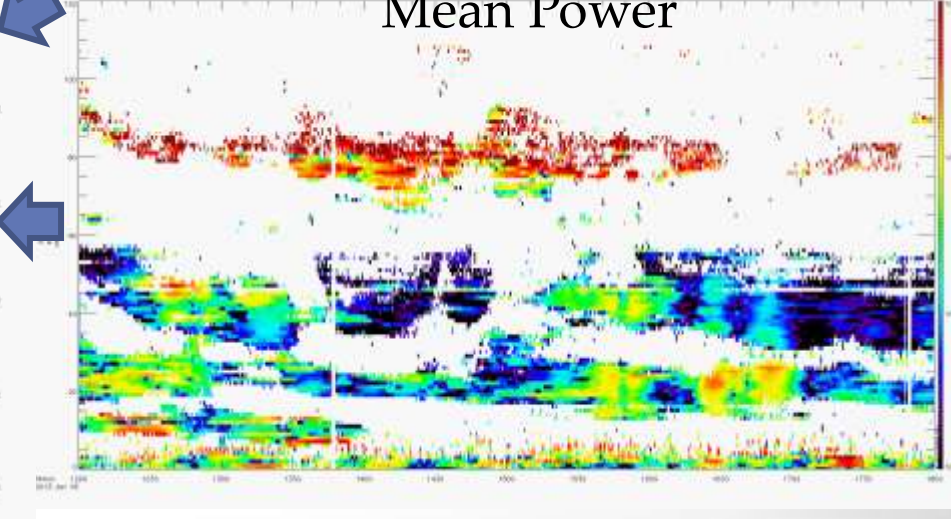
Max Power



Power Ratio



Mean Power

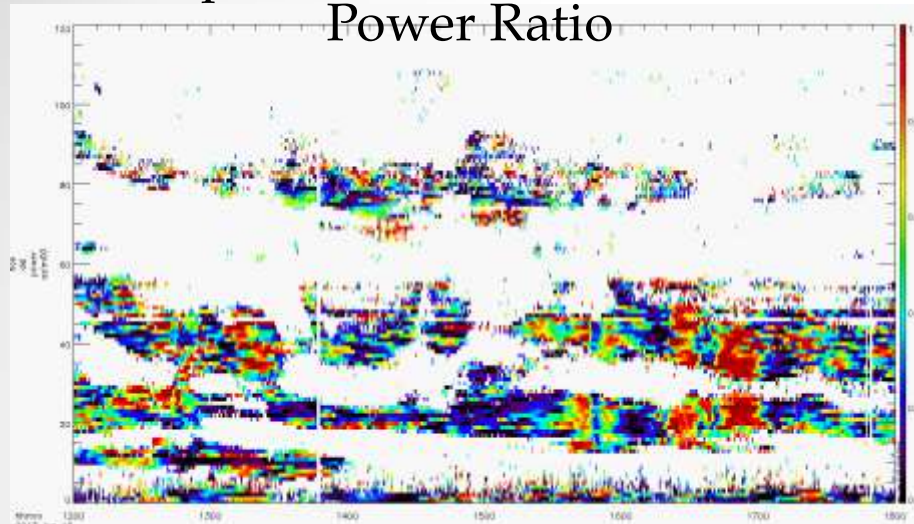


Event Identification

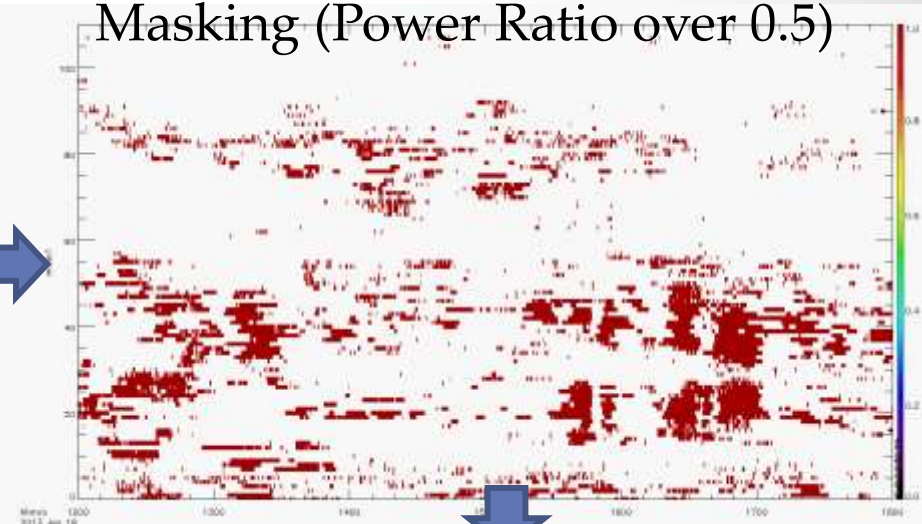
Beam 00

Step 5

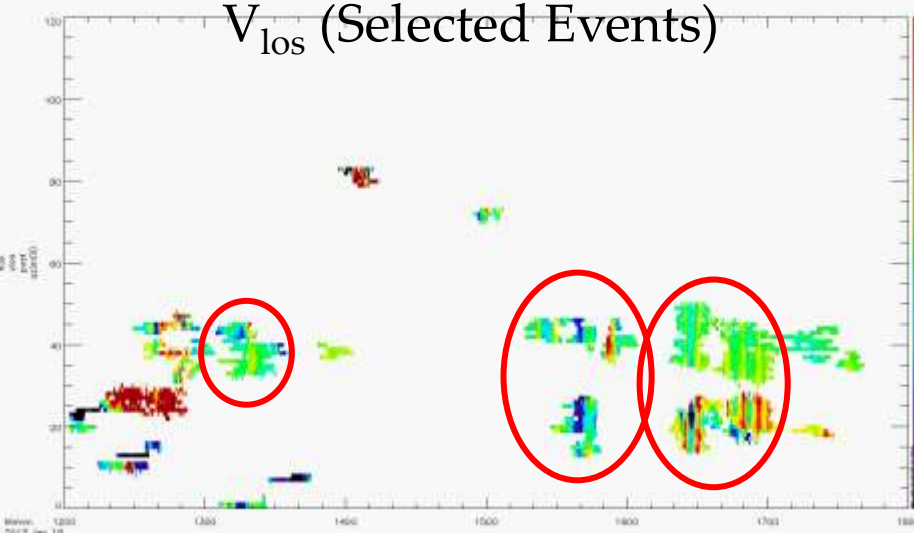
Power Ratio



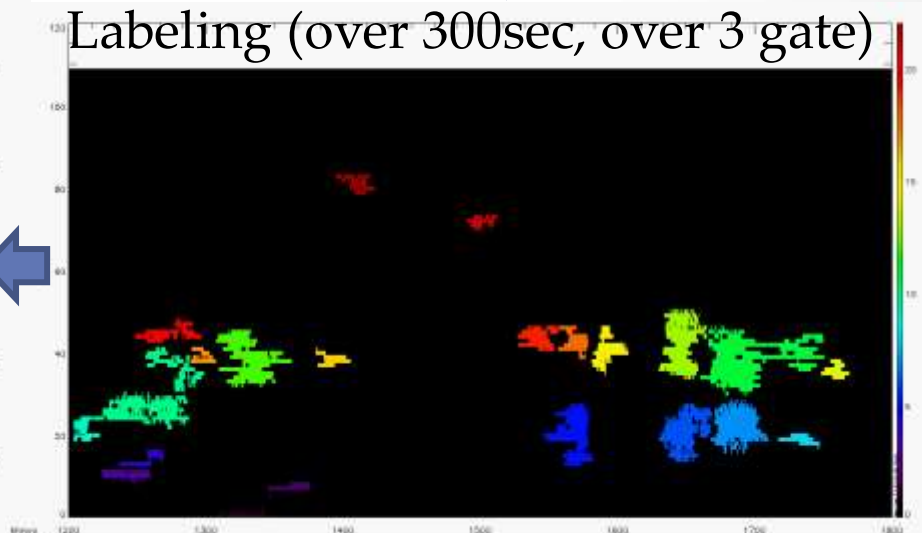
Masking (Power Ratio over 0.5)



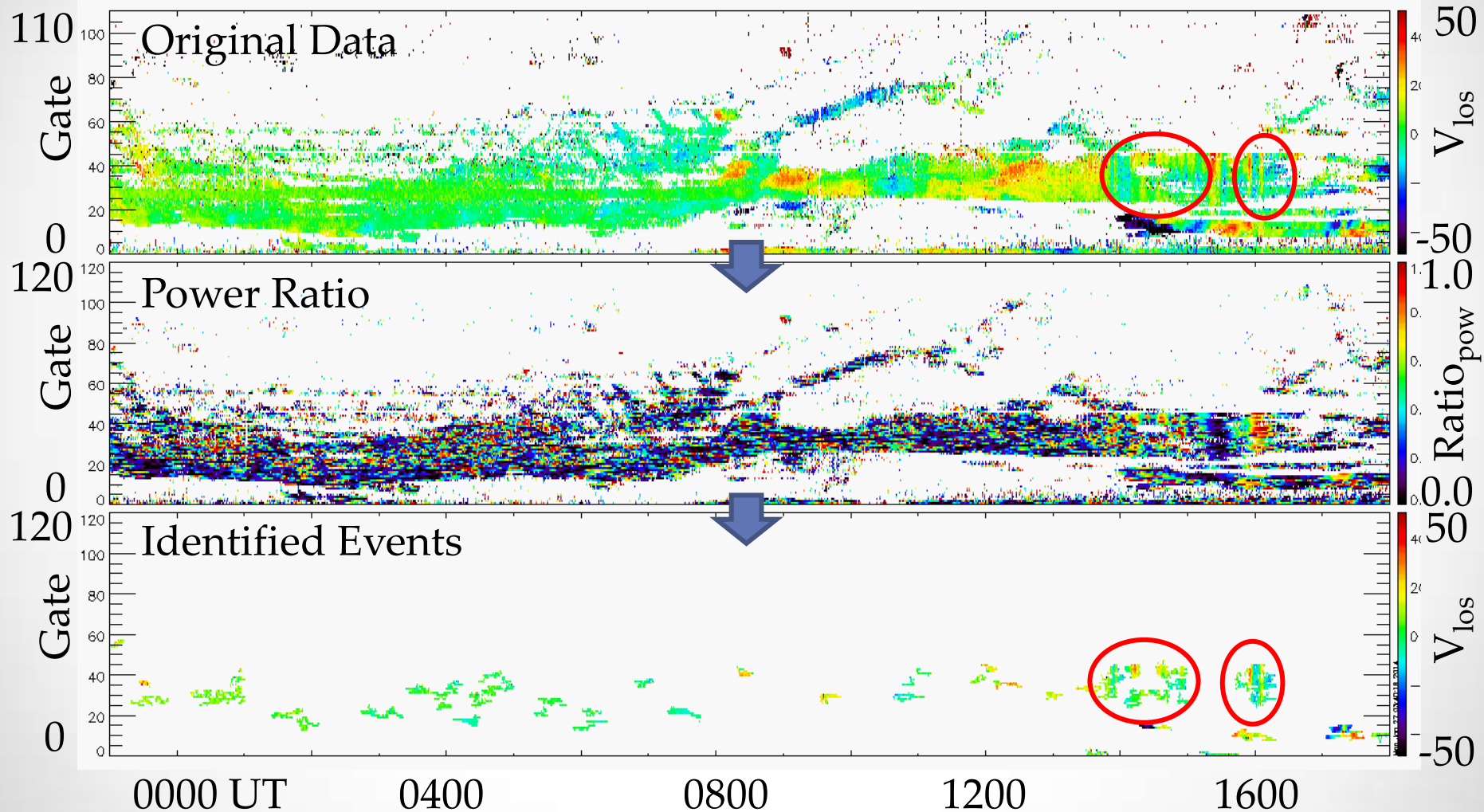
V_{los} (Selected Events)



Labeling (over 300sec, over 3 gate)



Another example (2013 Jan. 27th)



2013 Jan 27

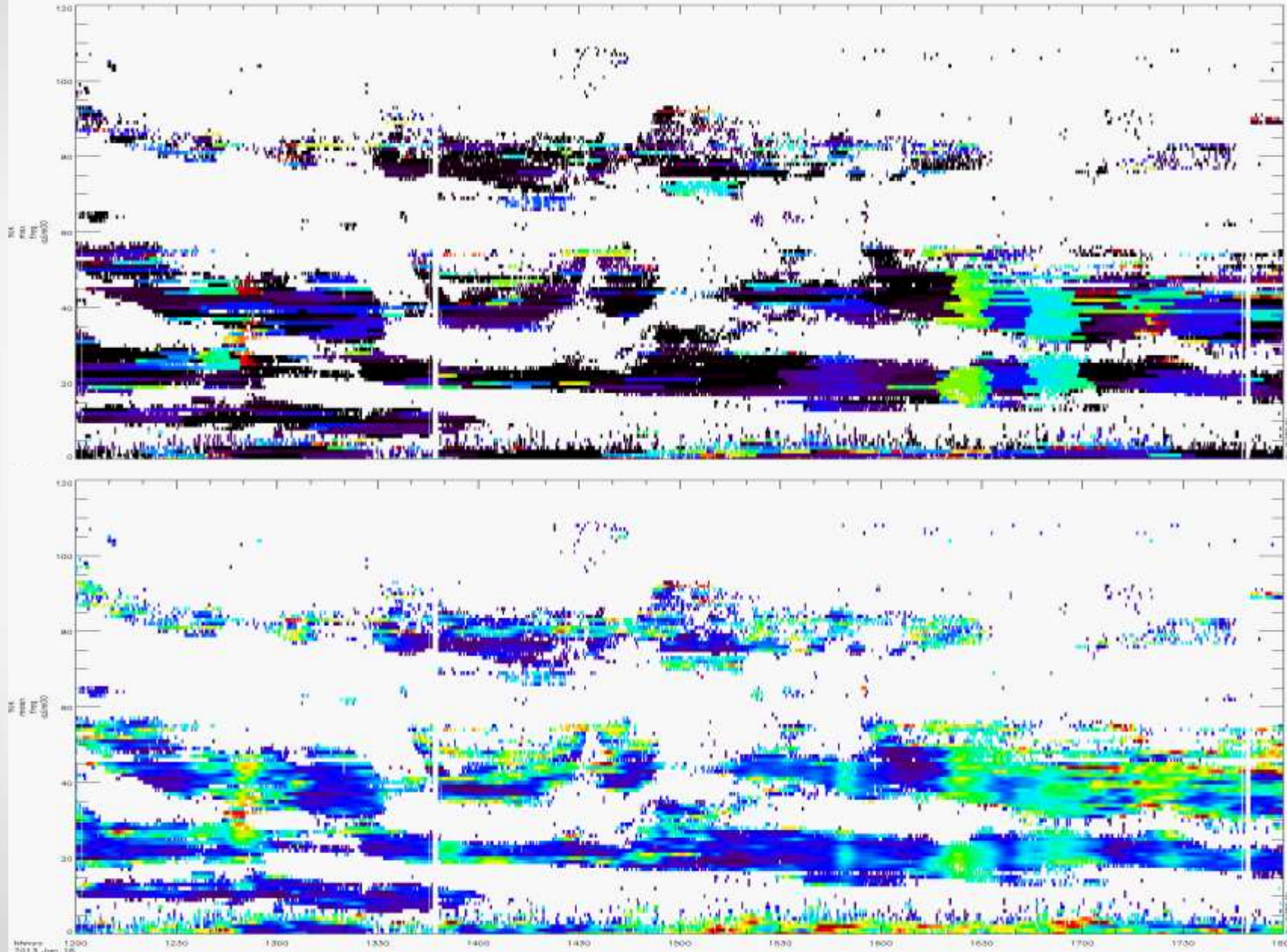
Summary

- We tried to develop automatic identification method of Pc5 waves using RBSP mode data from the Hokkaido radar.
- This identification method has 5 steps: 1. noise removal, 2. linear interpolation, 3. wavelet analysis, 4. power ratio calculation, and 5. event identification.
- By this method, we identified the following events.
 - The Pc5 event on 2013 Jan. 18th is identified clearly.
 - The Pc5 event on 2013 Jan. 27th is identified partially.
 - However, the method cannot completely exclude the time intervals with no Pc5 events.

Future works

- Improvement of the identification method
 - Parameter survey.
(Adjustments of the noise level, the frequency band, the threshold for the power ratio, time threshold, and gate number threshold are to be conducted)
- The statistical analysis of the Pc5 waves using RBSP mode data
 - MLT dependence
 - Magnetic latitude dependence
 - Frequency dependence
- Conjunction studies with the Van Allen probes data
- Application of the improved identification method to other SuperDARN HF radars data.





5

Frequency (mHz)

1