Identification of ULF waves in SuperDARN data

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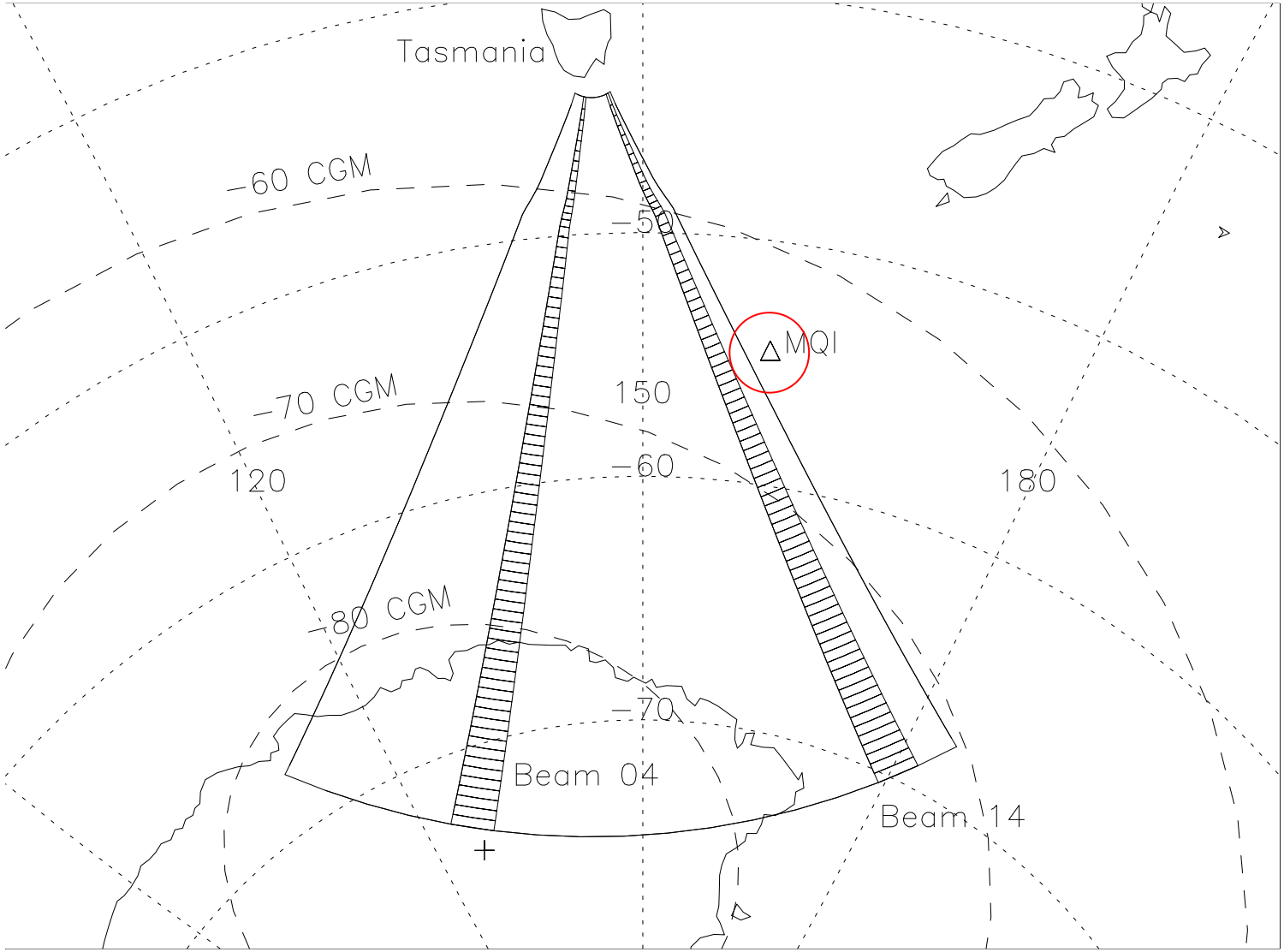
HF Radars vs Ground Magnetometers

- *In-situ* measurements
- Higher spatial resolution (15 km vs ~200 km)
- Larger field of view (over-the-horizon)
- Measurements over hardly accessible areas
- Comparable sampling rate ~1-10 s

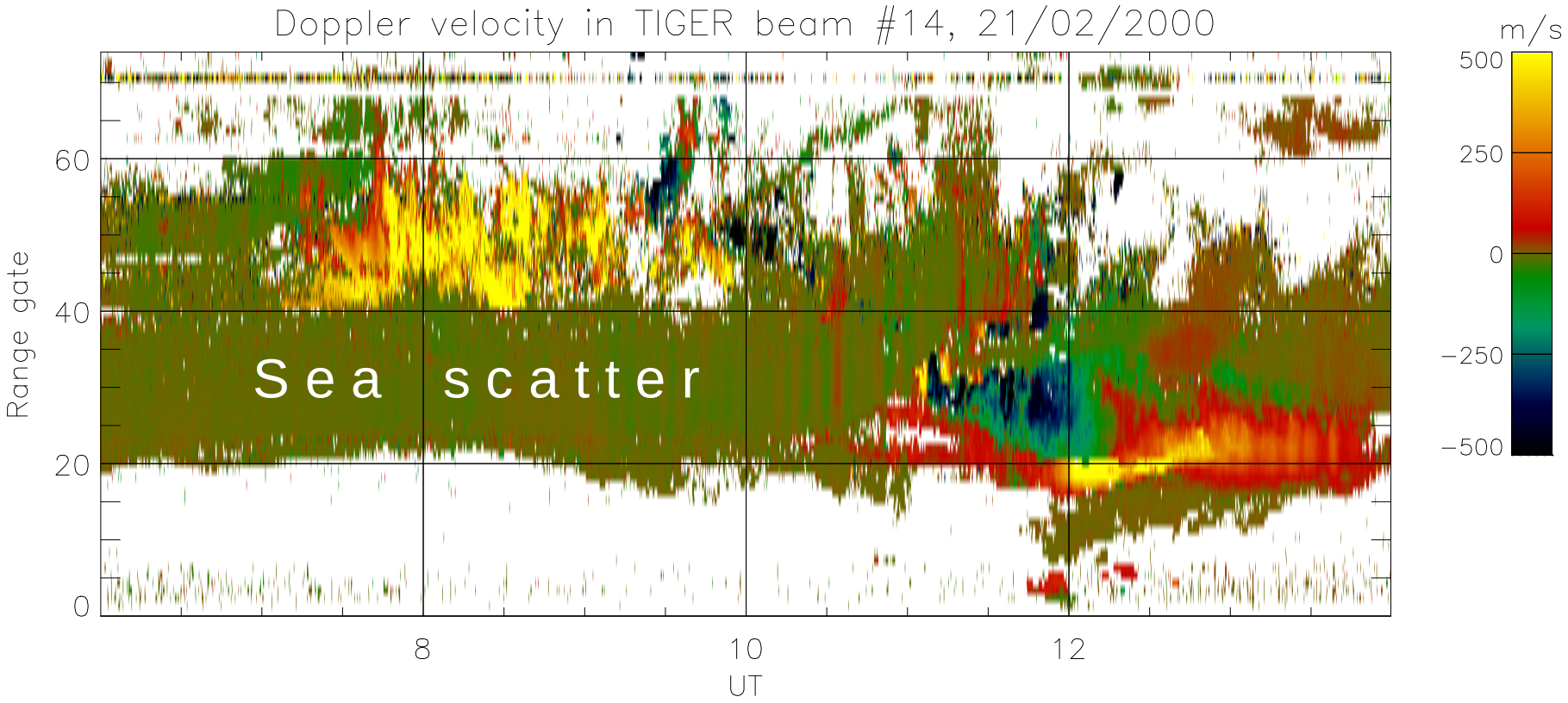
Experimental setup



Limiting factors

- Ionospheric HF propagation
- Fast background drifts $V_{drift} >> V_{ULF}$
- Mutlidimensional data (radar/time/range/beam)

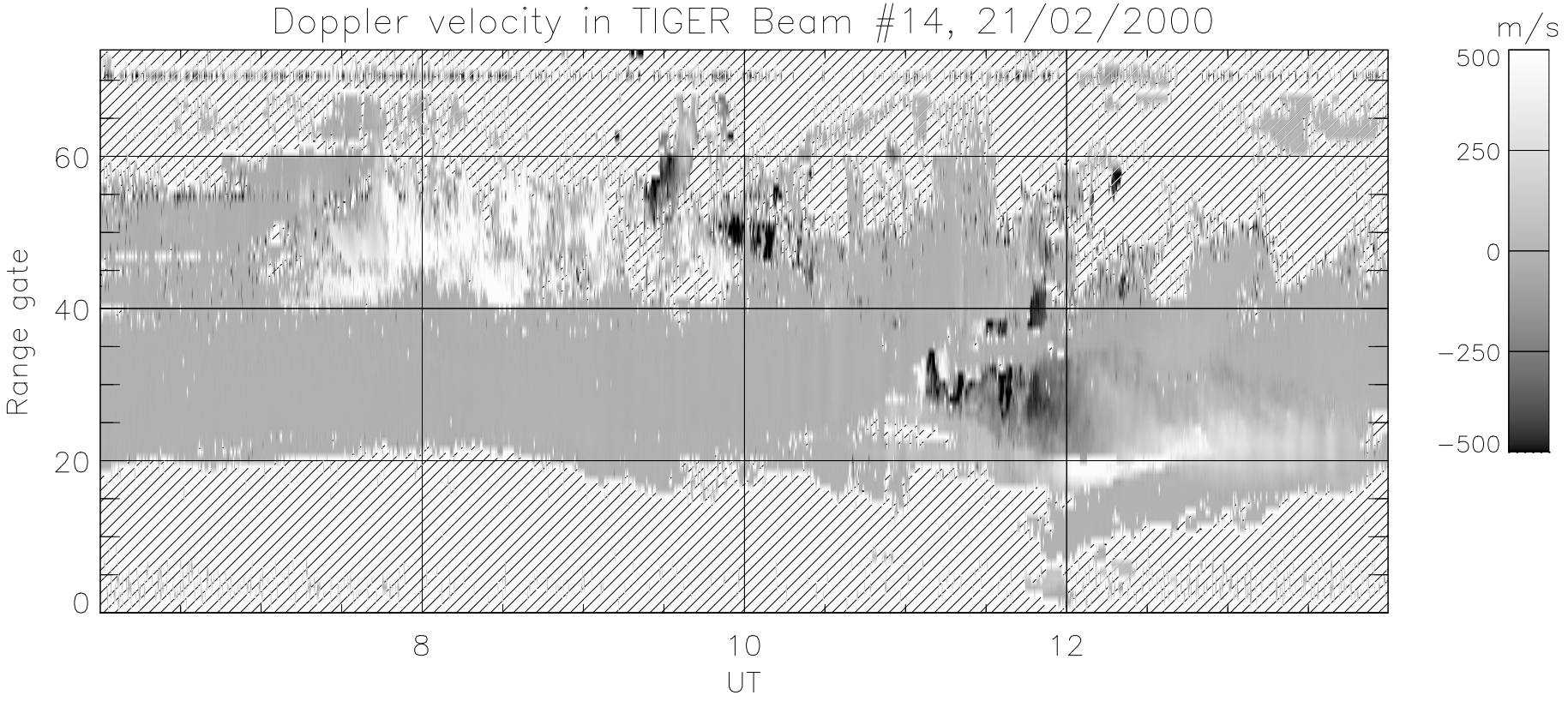
Sample Doppler data (colour)



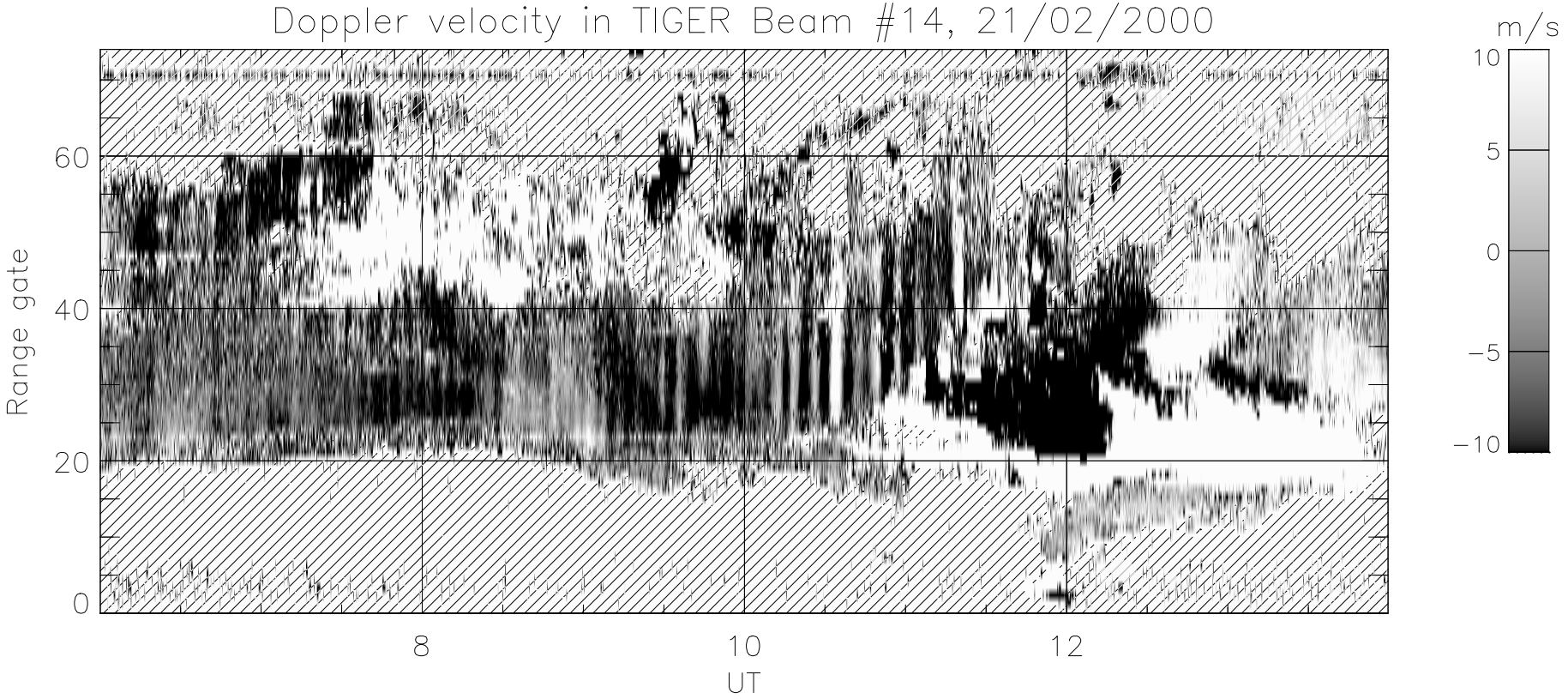
What to do?

- Utilizing ground/sea scatter
- Removing background
- Optimizing colour map

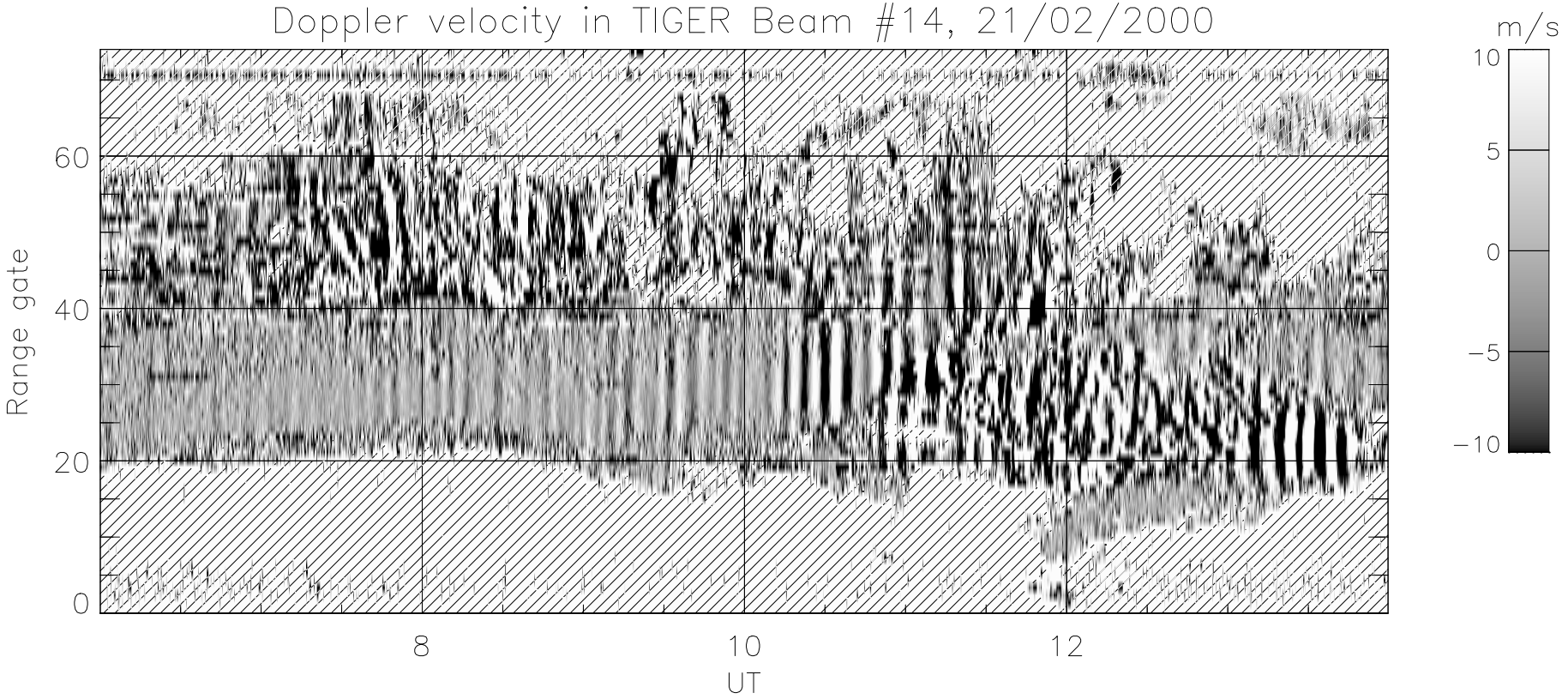
Sample Doppler data (B&W)



Compressed dynamic range



De-trended and compressed



How we do it

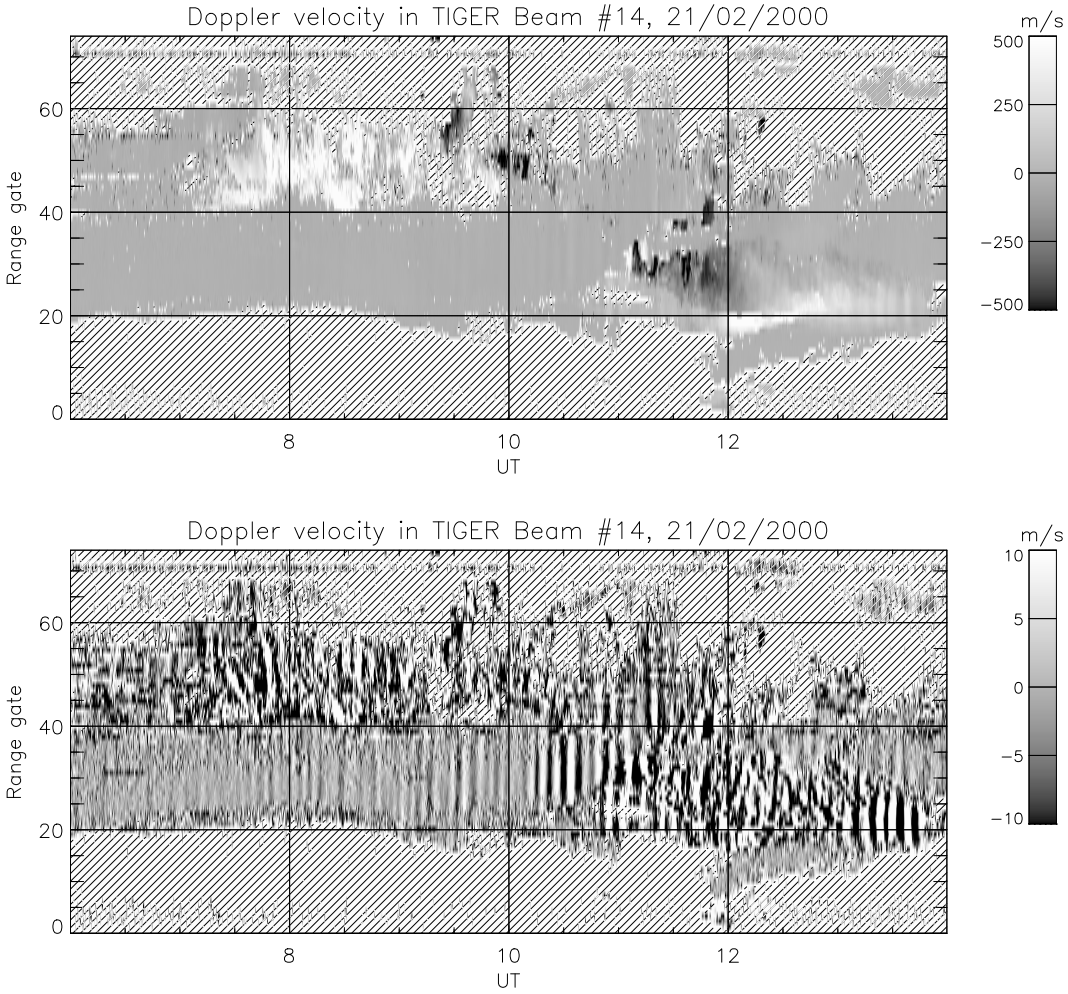
- De-spiking

  (3pt median filter in time domain)
- De-trending

  (sliding window ~ 600-800 s)
- Saturated velocity scale

  (±10 m/s)
- Grayscale colour map

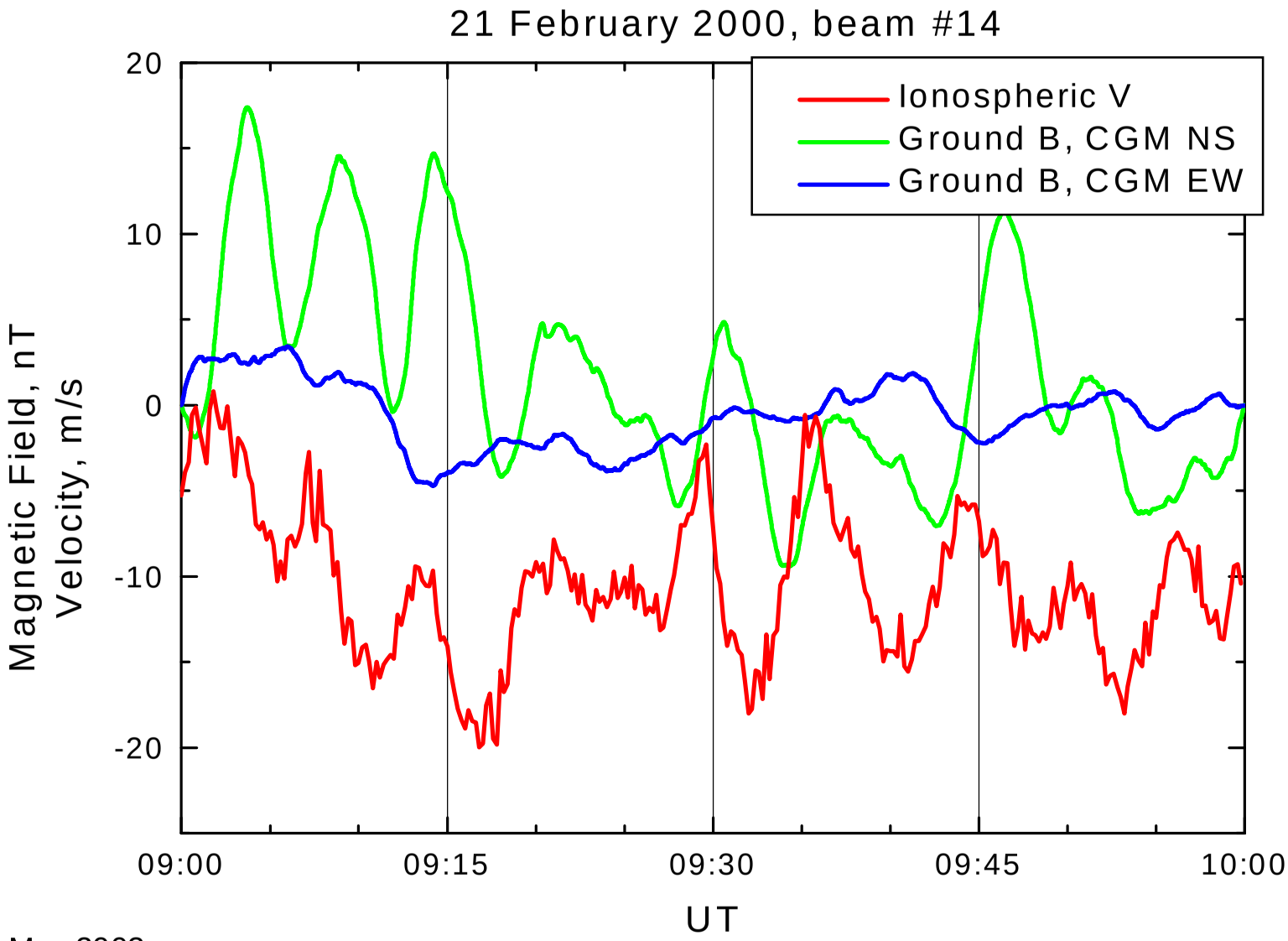
Now it looks better!



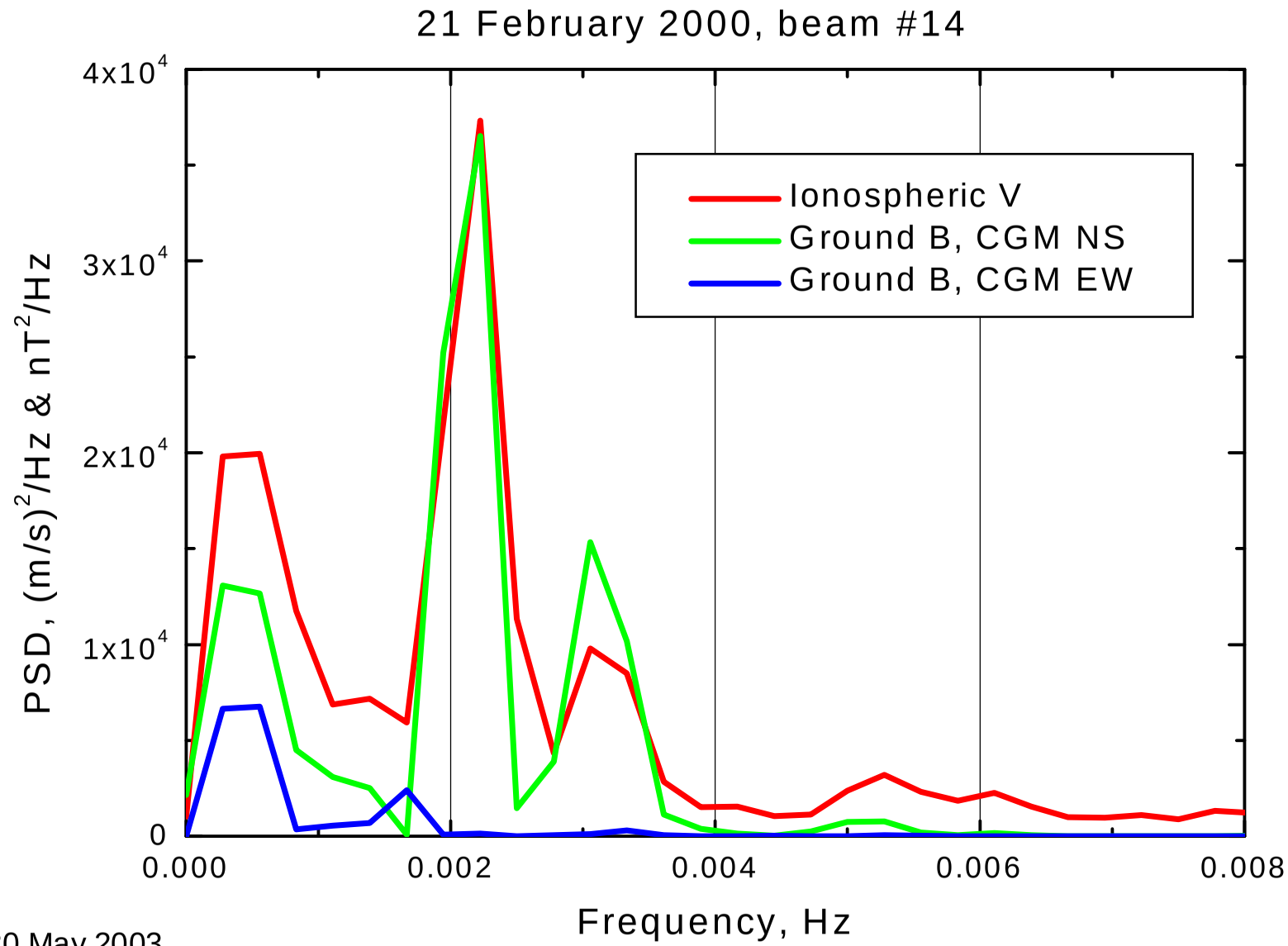
De-trending

Saturated BW scale

Are they ULF waves?

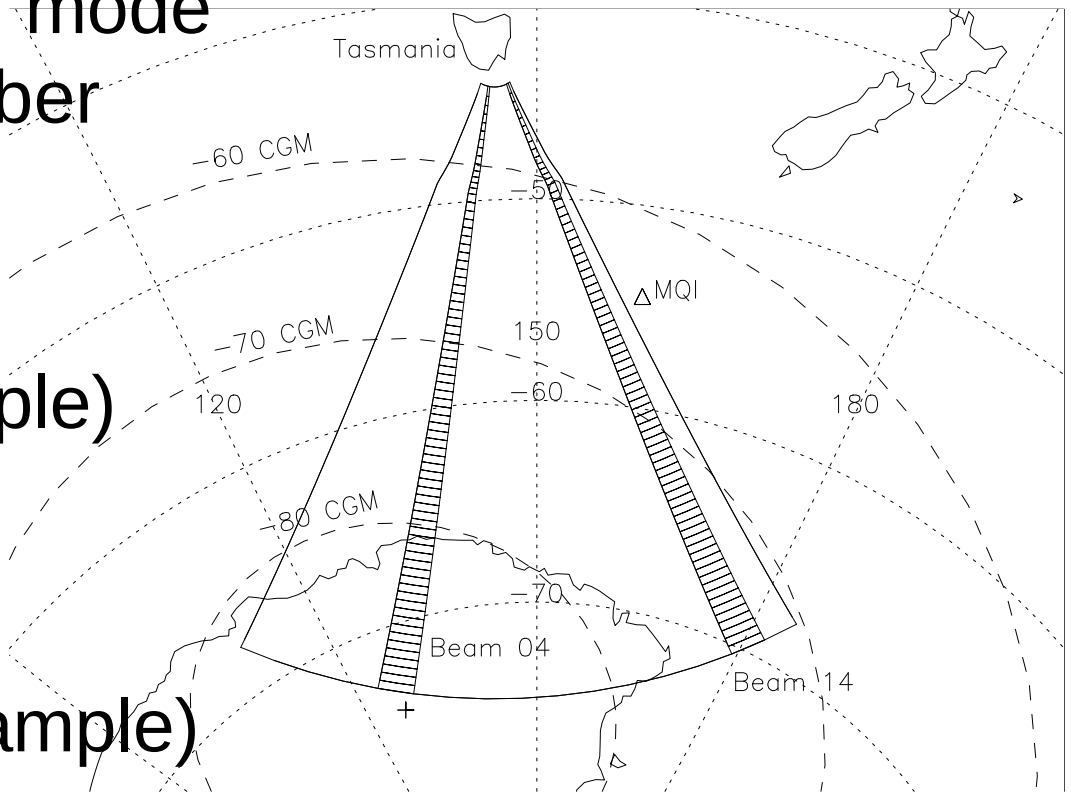


Power spectra



Database for statistical studies

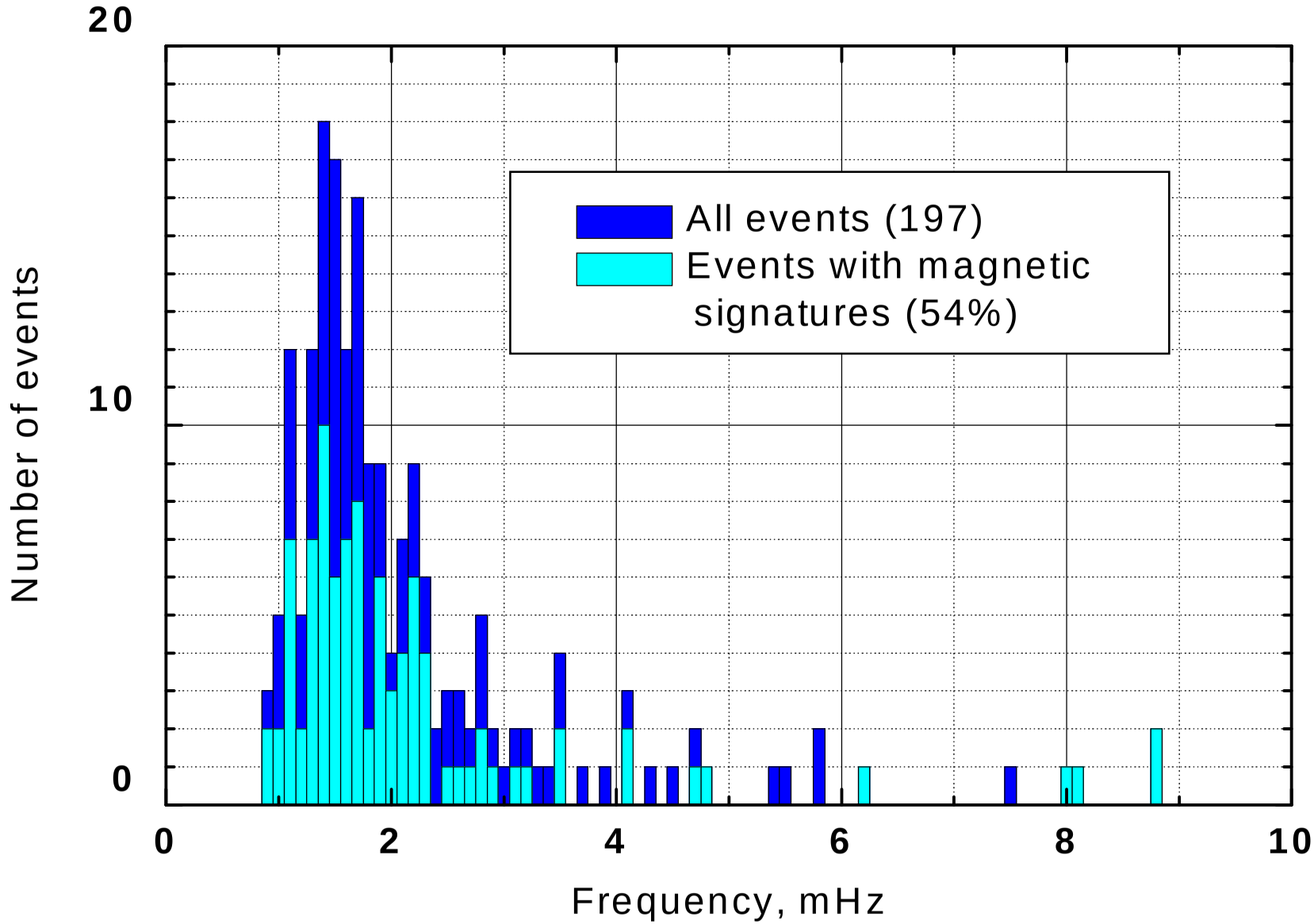
- 43 days of special mode in January-November 2000
- Beam #4 (6 s/sample) 28 days
- Beam #14 (12 s/sample) 15 days



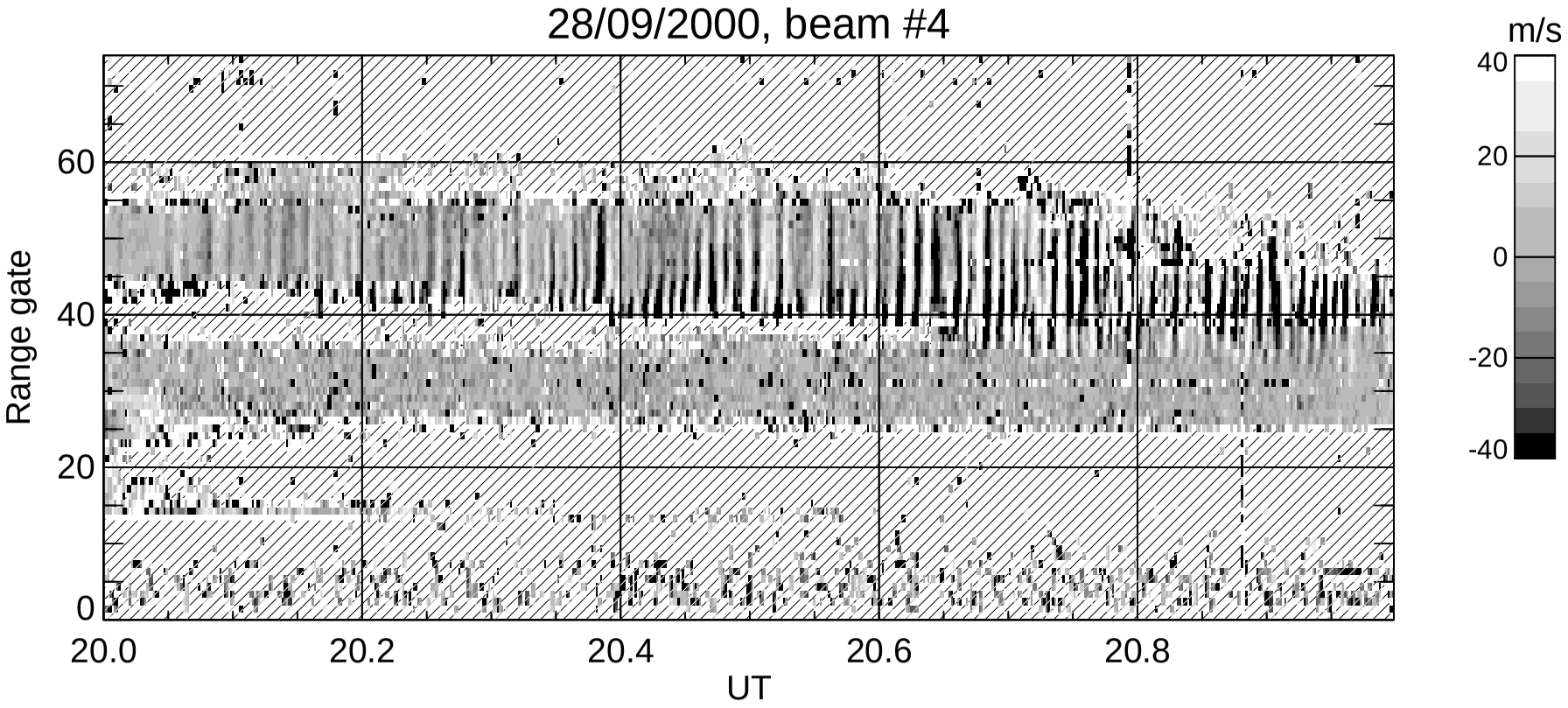
Statistical study of Pc4-5 waves

- Number of identified 1-hour events:
  - Total: 197 (4.6 hr/day)
    - Sea scatter: 60%
    - Ionospheric scatter: 40%
  - Beam # 4: 113 (4.0 hr/day)
  - Beam #14: 85 (5.7 hr/day)
- Those with magnetic signatures at MQI
  - Beam # 4: 48%
  - Beam #14: 61%
  - Total: 54%

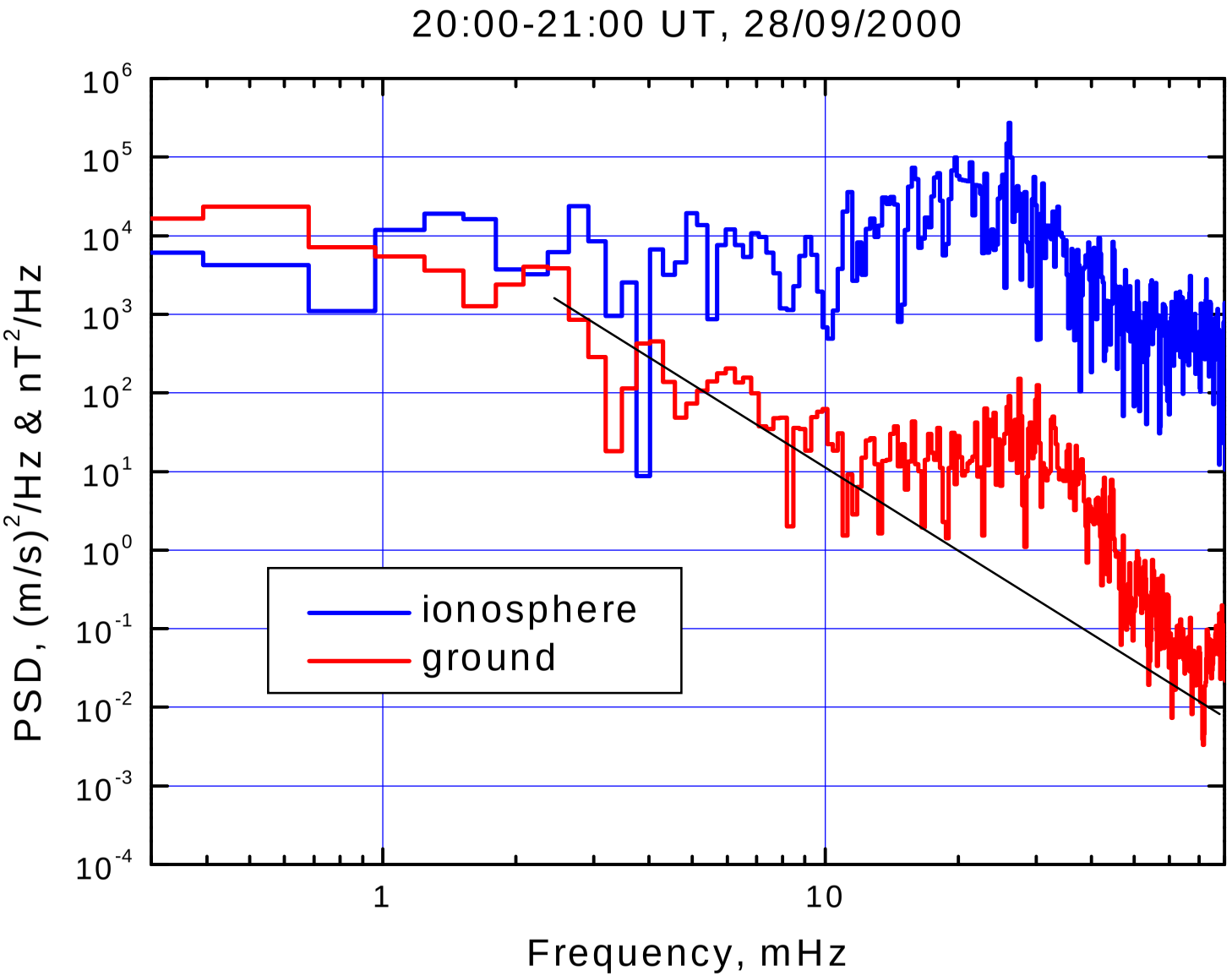
Frequency histogram for Jan-Nov 2000



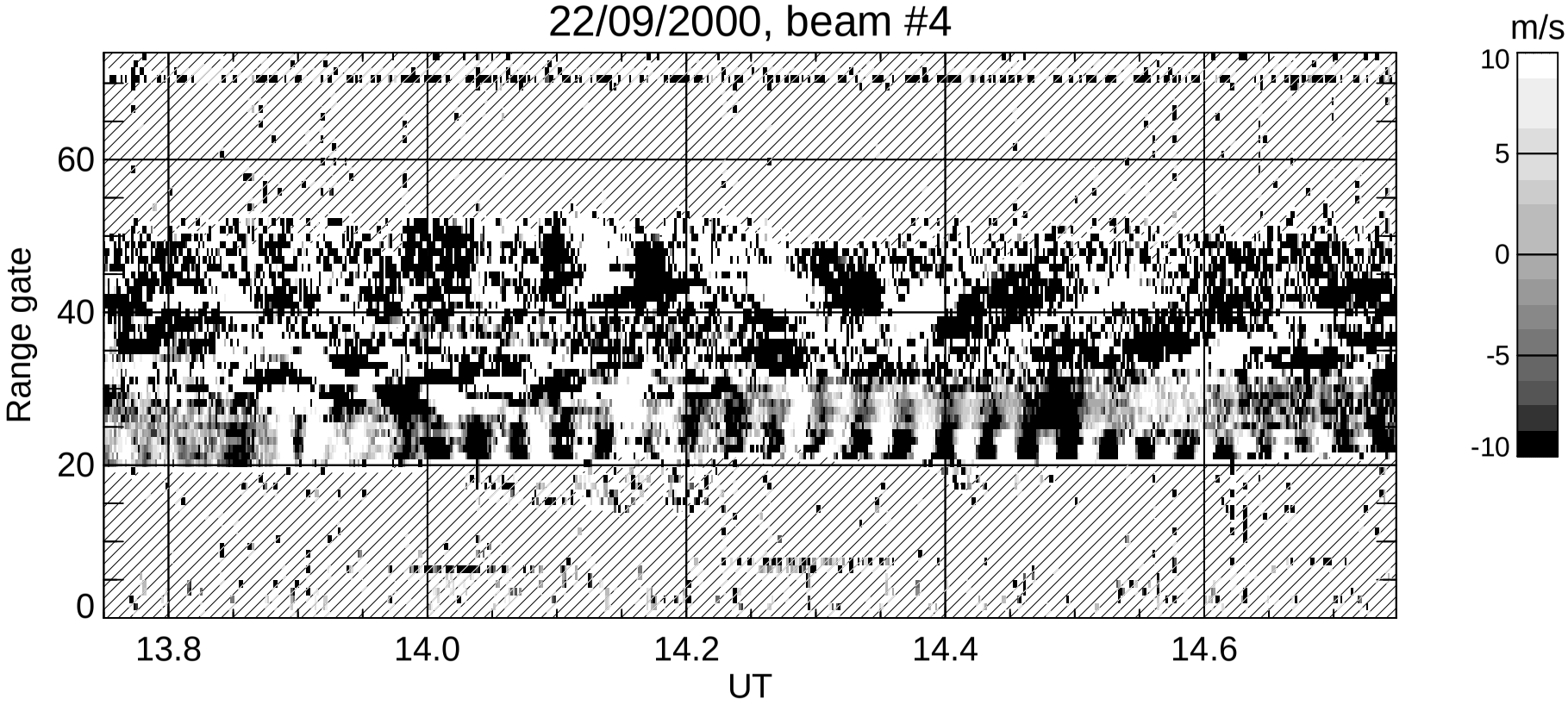
Band-limited Pc3-4



Pc3-4 frequency spectra

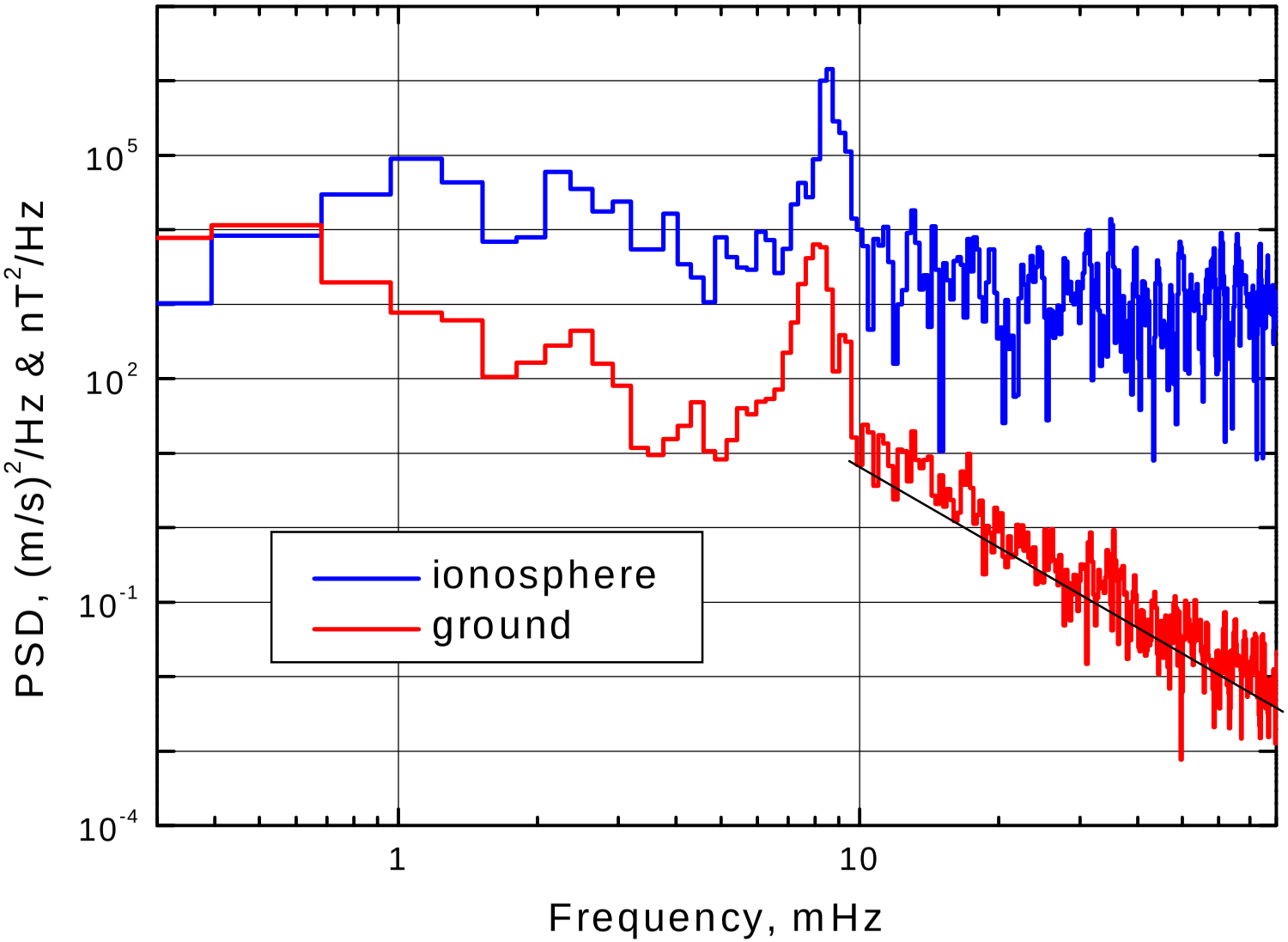


Narrowband night-time Pc4



Pc4 power spectra (beam #4)

13:45-14:45 22/09/2000



Summary

- Removal of the low-frequency trend in combination with compressed dynamic range considerably improved efficiency of visual detection of ULF waves in the SuperDARN data.
- Analysis of 43 days of special mode data revealed abundance of ULF waves observed for ~4-5 hrs/day. More than a half of them were also observed by the ground magnetometers.
- Sea/ground-scatter component, which has been overlooked in most of previous studies, is very useful in monitoring wavelike processes in the ionosphere providing ~60% of the observed events.
- Four distinct classes of waves were observed:
  - Low-*m* Pc5 (global mode?..)
  - High-*m* Pc5 (drift or drift-bouncing)
  - Narrowband nighttime Pc4 (?..)
  - Band-limited daytime Pc3-4 (upstream)

Future directions

- Nature of low-*m* Pc5 waves
- Origin of narrowband nighttime Pc4 waves
- Propagation characteristics of Pc3-4 waves
- Automatic identification procedure

…Primary tool for ULF wave studies in the ionosphere?..