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Plasma turbulence, intermittency and wave-coupling in the polar cap based on the ICI-2 sounding rocket experiment

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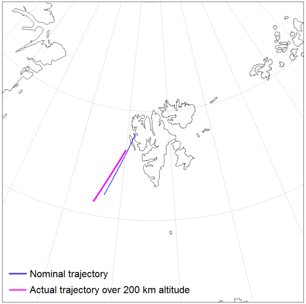
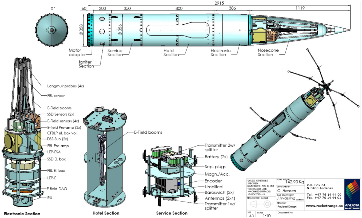
The ICI-2 sounding rocket

The Investigation of Cusp Irregularities 2 (ICI-2) sounding rocket

- Launched from Ny-Ålesund, Svalbard, Norway (78.9° N, 11.9° E) at 1035 UT on the 5th of December 2008.
- **Objectives**: Resolve irregularity structures at meter-scales and quantify the gradient drift instability process.
- **Instruments**: m-NLP, AC/DC Electric field experiment, low-energy electron spectrometer (LEP), solid-state spectrometer...

Lorentzen et al., JGR, [2010], *Oksavik et al., JGR,* [2012],





Space conditions

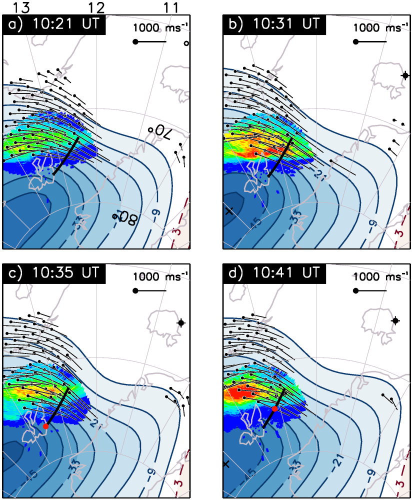


Figure: SuperDARN velocity maps over Svalbard superimposed on 6300 Å all-sky Imager (ASI) data from Longyearbyen. The two top panels and the two bottom panels show the plasma velocities before and during the ICI-2 launch, respectively. The flow close to Svalbard was mostly directed north-west, in the range $\mathbf{v} \in [750, 1250]\,\mathrm{m/s}$.

The ICI-2 Flight

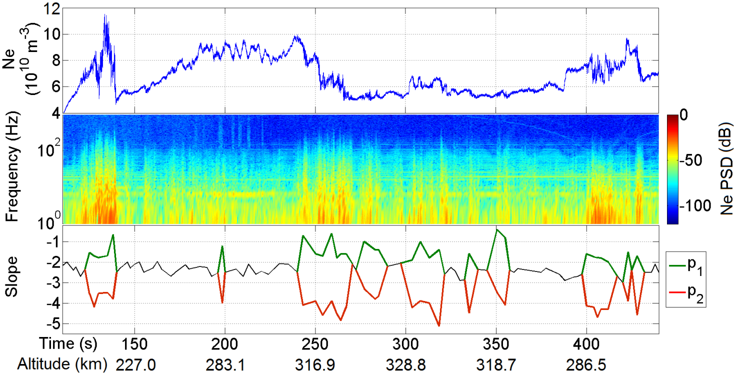


Figure: Top) Electron density. Middle) Spectrogram of $\Delta Ne/Ne$. Bottom) Slopes of the power spectra.

Examples of power spectra

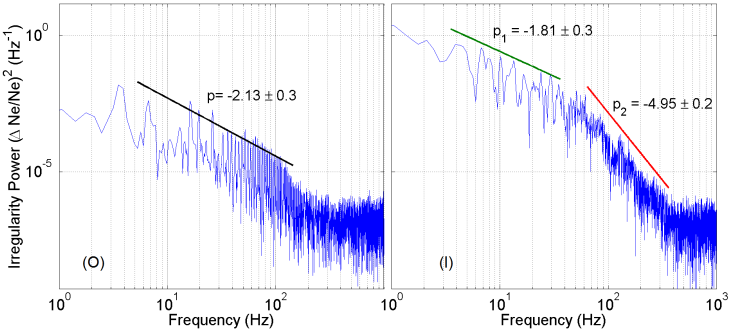
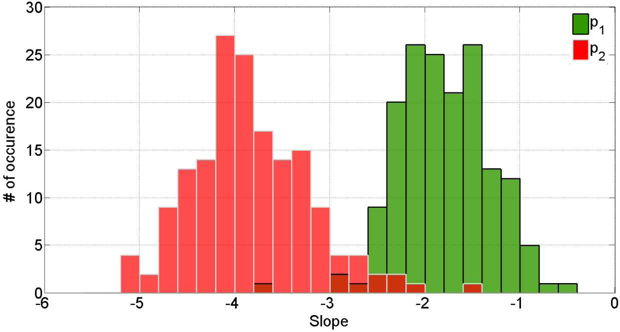


Figure: left) PSD between 271.5 s and 273.5 s. right) PSD between 265 s and 267 s. *Spicher et al., GRL,* [2014]

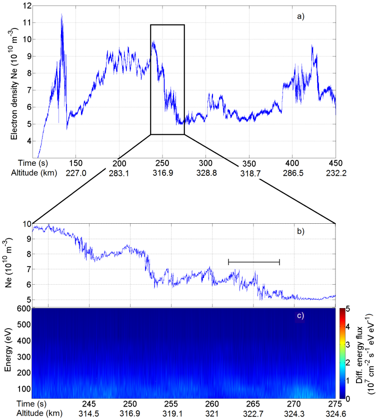
Spectral indices



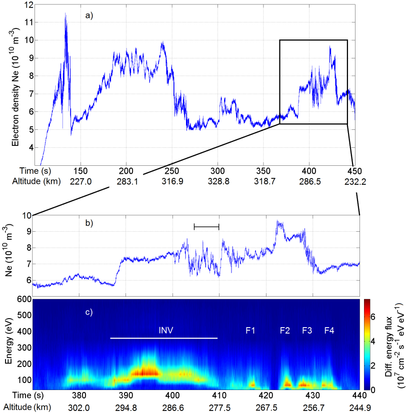
Spicher et al., GRL, [2014]

Random vs Coherent structures

Case A

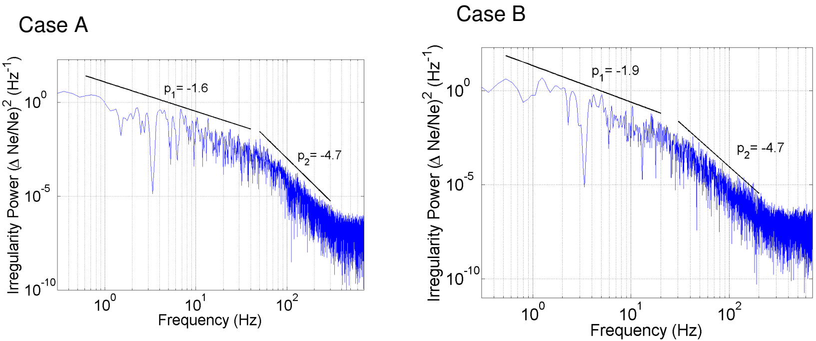


Case B



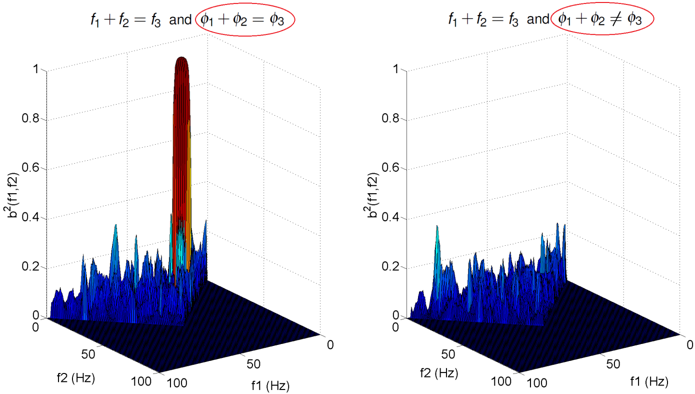
Moen et al., GRL, [2012]

Random vs Coherent structures: Spectra

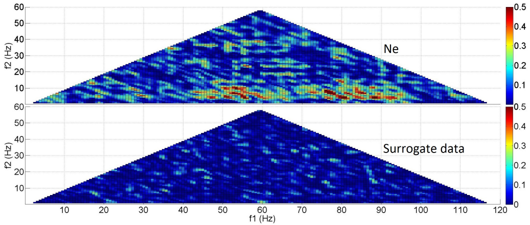


Bispectral Analysis: Example

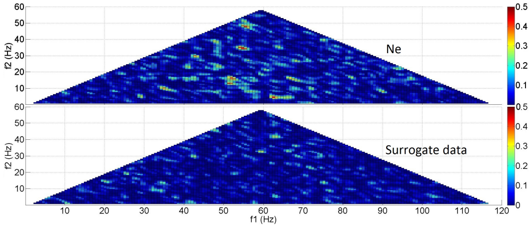
$$f(t) = cos(f_1 t + \phi_1) + cos(f_2 t + \phi_2) + cos(f_3 t + \phi_3) + rand \quad (1)$$



Bicoherence Case A



Bicoherence Case B



Higher Order Statistics

The Structure function

The *m*-th rder *structure functions* is defined as

$$S(m,\tau) = < |y(t+\tau) - y(t)|^m >, \quad (2)$$

Intermittency

For a *scale invariant* system, the structure function obeys a universal scaling law

$$S(m,\tau) \propto \tau^{g(m)}, \quad (3)$$

where $g(m)$ is the scaling exponent. In the case of the K41 turbulence theory, the velocity fluctuations and their *m*-th moments would follow a power law with exponent $g(m) = m/3$. Deviations from a linear dependence of $g(m)$ are attributed to spatial inhomogeneous redistribution of the energy: **Intermittency**

Structure Function

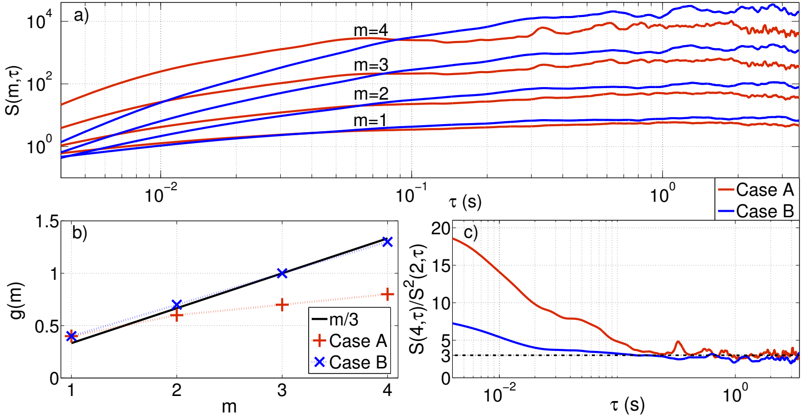
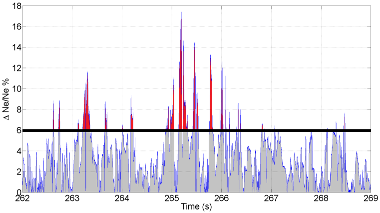
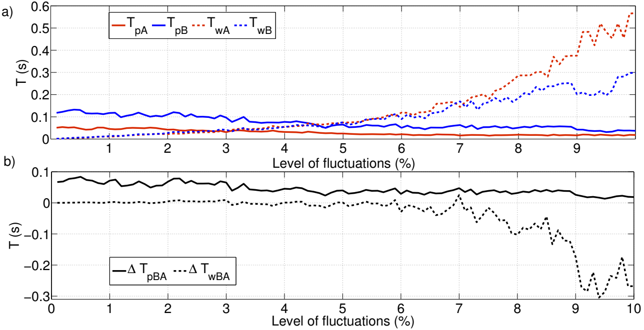


Figure: a) Structure functions of order $m = 1, 2, 3, 4$ for Case A (red) and Case B (blue). b) Slopes $g(m)$ of the structure functions in the inertial ranges. c) Empirical Flatness.

Waiting-Time





Summary

Spectral Analysis

- The power spectra of the strong electron density fluctuations exhibit a dual-slope characteristic, with $p_1 \approx -1.8$ below $f \approx 40\,\mathrm{Hz}$ and $p_2 \approx -4$ above $f \approx 40\,\mathrm{Hz}$.
- **Bispectrum** and **Intermittency**: possibly two different mechanisms but similar power spectra. Difference due to direct particle precipitation?

Outlook

- ICI-3, ICI-4, MICA ...
- Simulations
- Multi-instruments

Thank you for your attention!