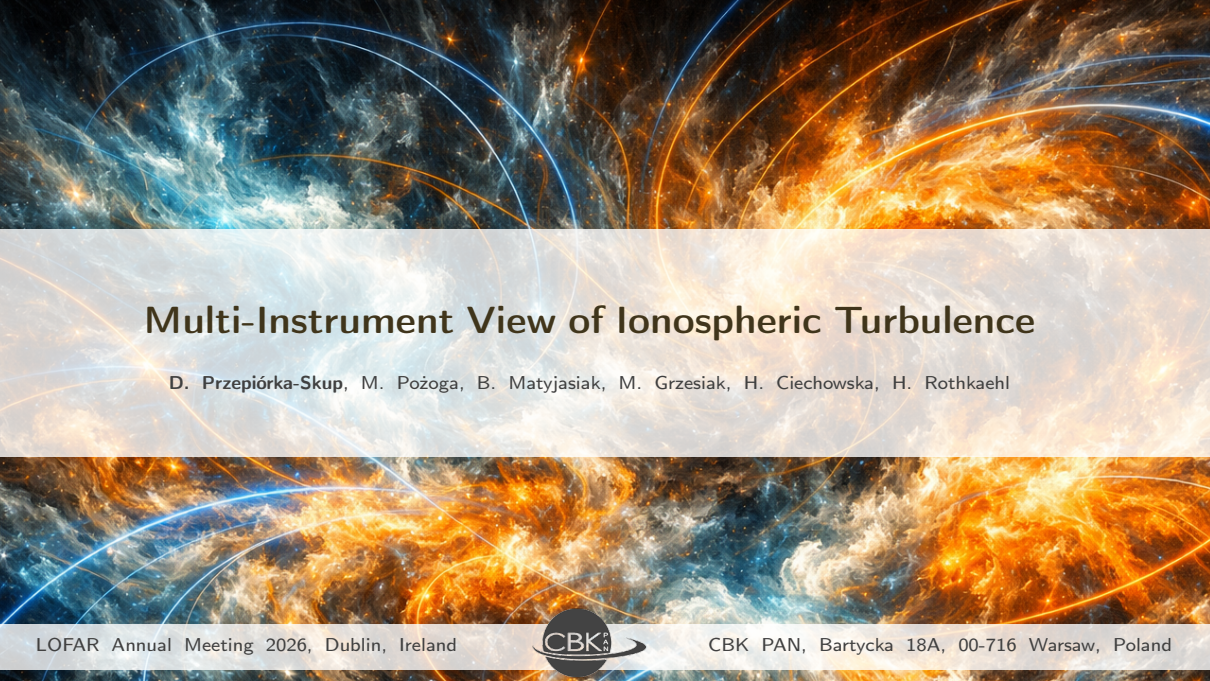
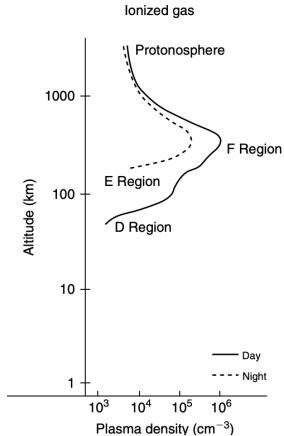


The background of the slide is a composite image of cosmic phenomena. It features vibrant nebulae in shades of blue, orange, and white, with glowing stars scattered throughout. Overlaid on these are several thin, curved lines in blue and orange, resembling orbital paths or magnetic field lines. A semi-transparent white horizontal band runs across the middle of the image, serving as a backdrop for the title and author information.

Multi-Instrument View of Ionospheric Turbulence

D. Przepiórka-Skup, M. Pożoga, B. Matyjasiak, M. Grzesiak, H. Ciechowska, H. Rothkaehl

The ionosphere: general picture

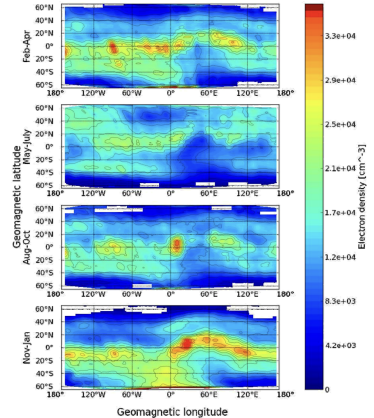


Kelley, 1989

Depends on:

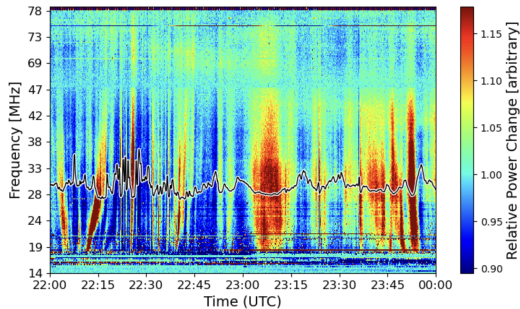
- LT/MLT
- seasons
- solar activity
- geomagnetic activity
- location
- ...

Electron density maps from DEMETER data
Kp index = 0-2, year 2007



Matyjasiak+, 2016

Irregularities of various scales



Požoga+,2025

- TIDs
- Fresnel-scale irregularities
- small-scale irregularities preceded by large gradients (Fallows+,2020)
- structuring of large gradients, i.e. main trough (Liu+,2021)

Why do we care?



science

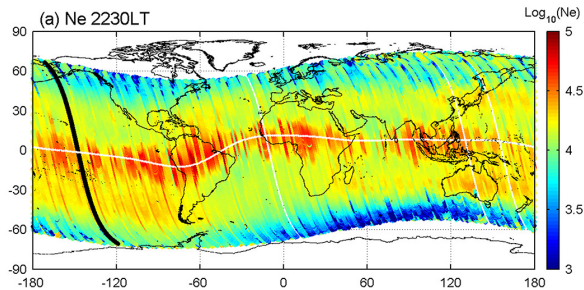


technology

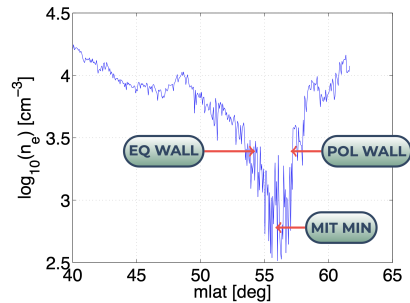


services

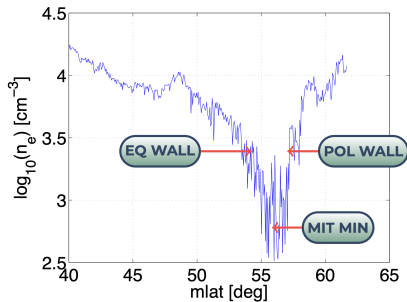
Fine structure of large gradients



Chen+, 2018



Fine structure of large gradients



Depends on:

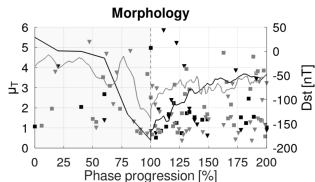
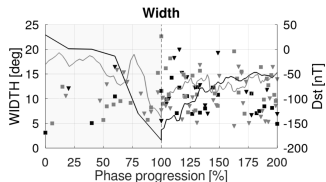
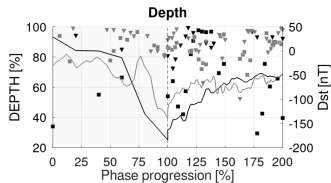
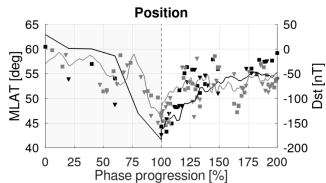
- LT/MLT
- seasons
- solar activity
- geomagnetic activity
- location
- ...

Case study

Storm Date	Onset & Time (UT)	Date	Onset value [nT]	Dst	End Date & Time (UT)	End value [nT]	Dst	Minimum Dst [nT]
Aug 24, 2005	Aug 24, 2005, 06:00		-26		Aug 26, 2005, 09:00	-47		-184
Sep 11, 2005	Sep 10, 2005, 00:00		-31		Sep 14, 2005, 17:00	-49		-139

Mission: DEMETER
Altitude: 660-700 km (~ **fixed**)
Time: LT 1030 / 2230 (**fixed**)

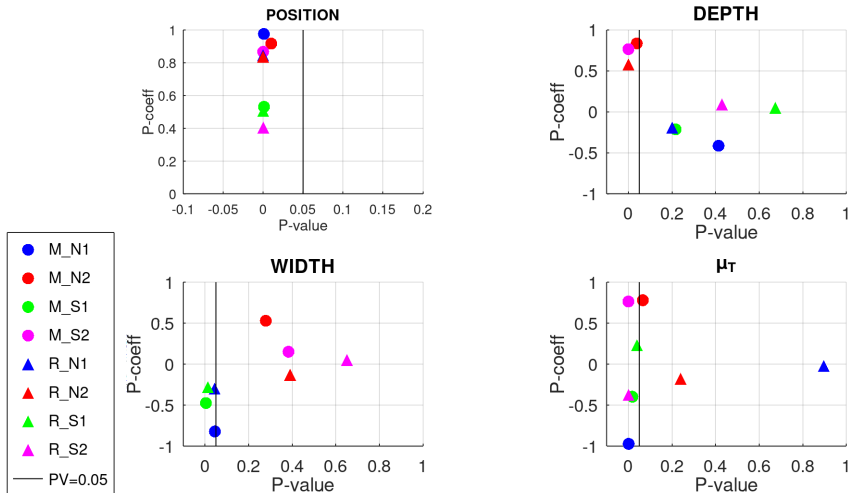
Density analysis: instrument 1 - ISL



$$\mu_T = \frac{\text{polar_wall_gradient}}{\text{equatorial_wall_gradient}}$$

usually: $\mu_T > 1$

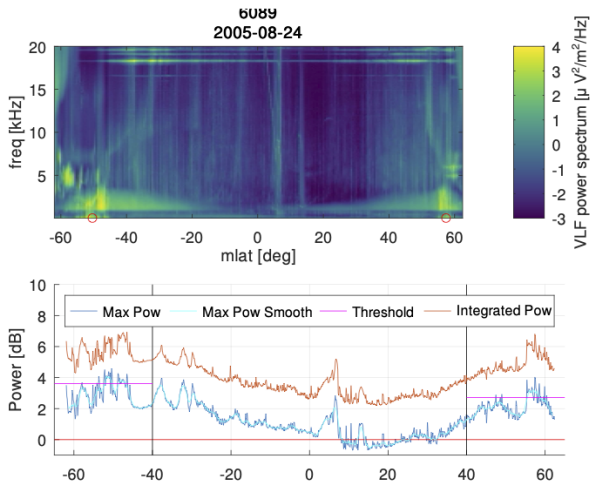
Correlations with Dst



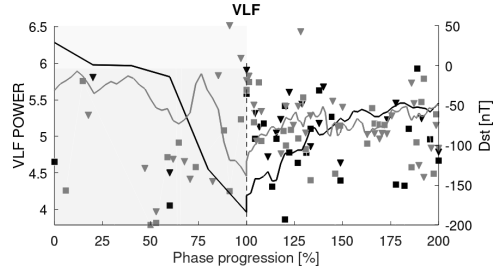
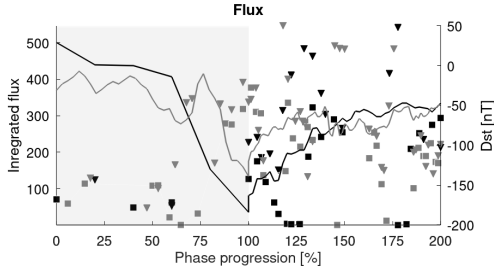
Why only position follows the Dst trend?

- Large-scale MIT dynamics: well described by MHD models
- Smaller-scale features (width, depth, morphology): driven by turbulent processes & ion-scale energy cascades, including TGDI on both walls
- TGDI may be a possible mechanism responsible for the cascading on MIT walls (Nishimura+,2021; Liu+,2021)

Particle precipitation and VLF emissions: instruments 2, 3 - ICE, IDP



Particle precipitation and VLF emissions

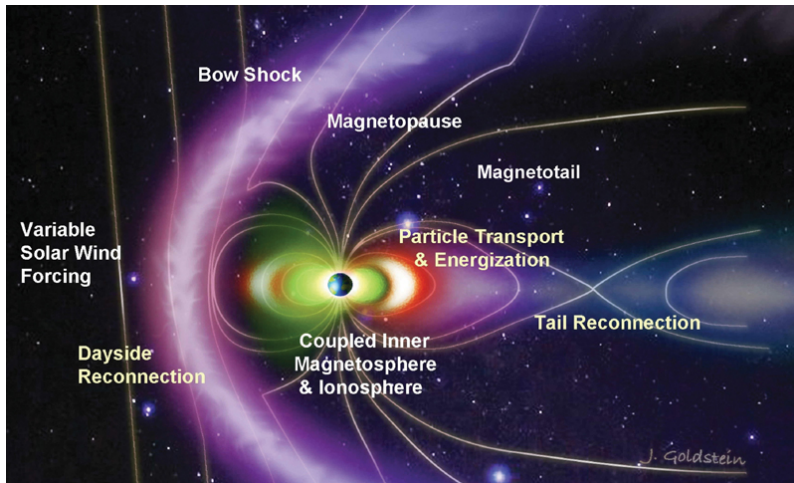


Intensification of fluxes and VLF emissions occurs at the end of the main phase and beginning of the recovery phase.

Future work

- Calculating intermittency metrics on each wall
- Identification of specific emission
- Linking to specific instability mechanisms
- Get FAC estimates
- Extend the sample

Think wide



Summary

- Turbulence is a common/fundamental process in space plasmas
- The resulting small-scales irregularities impacts GNSS, telecommunication, radio-astronomical observations
- Ionosphere interacts multidirectional - and depends on many factor - hard to decouple or find a single source of instability
- To resolve (for some extent) turbulence in ionosphere and understand its role in the energy exchange in the system multi-instrument is a must

Thank you!!