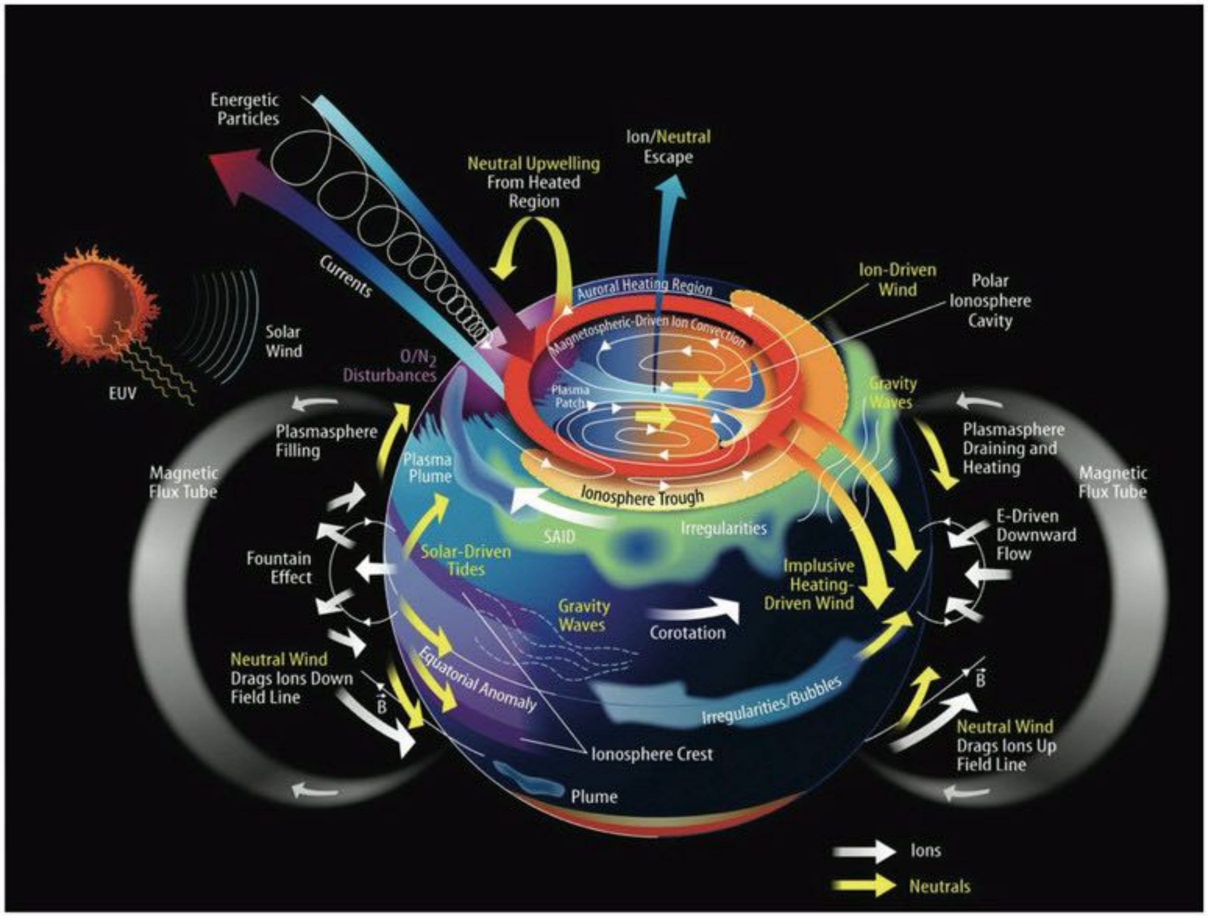
UiO : Faculty of Mathematics and Natural Sciences
University of Oslo

Characterizing ionospheric plasma irregularities with in-situ measurements over the African sector

Wojciech Miloch
with
4DSpace & IPIR teams

Space weather – a global view.



- Interaction between the Sun and the Earth (not only magnetically) drives a multitude of physical phenomena

- Some of these phenomena affect technological systems, like global navigation satellite systems or power grids

Image credit: NASA / J. Grobowsky

Plasma irregularities and ionospheric scintillations

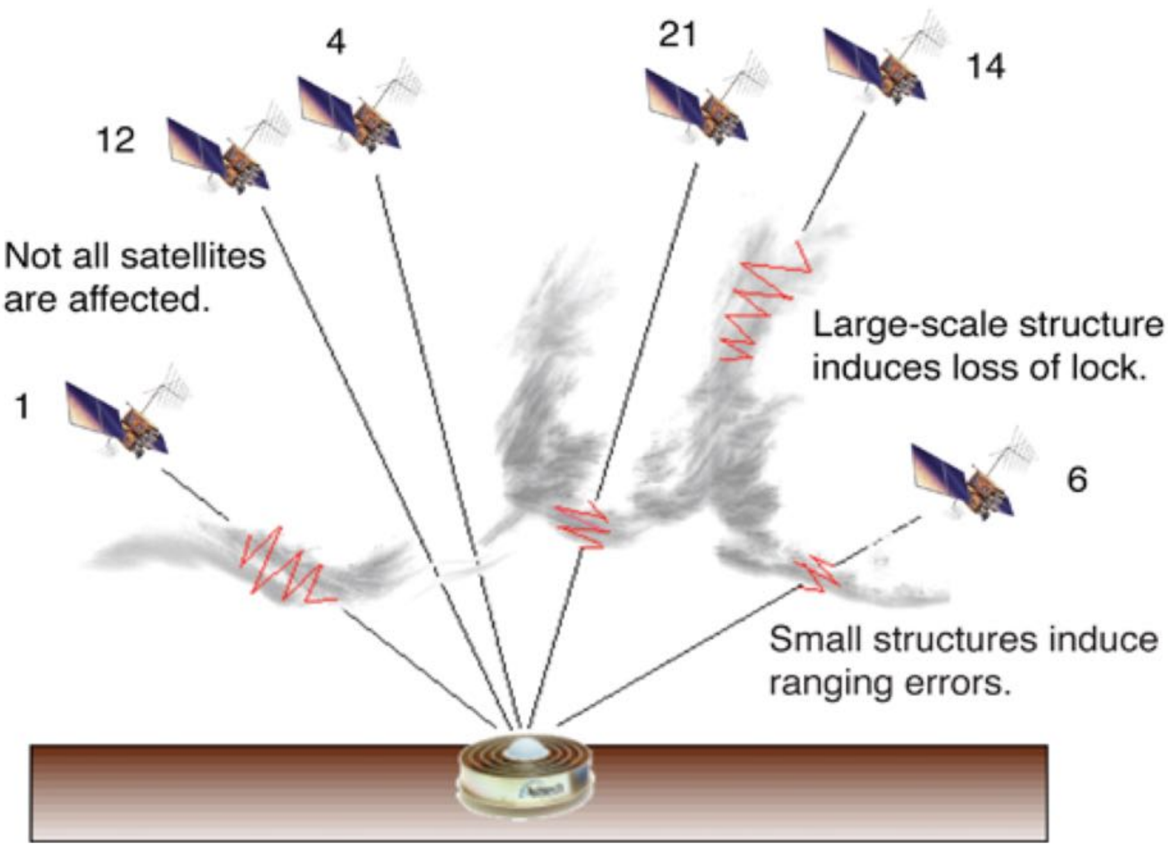


Image after: Ahmed, W. A. et al. Proc. SPIE 10425, 104250A, 2017

$$\widetilde{\sigma_\phi} = \sqrt{<\phi^2> - <\phi>^2},$$

$$S_4^2 = \frac{(<I^2> - <I>^2}{<I>^2}$$

Phase and amplitude scintillation indices.

Swarm - orbit determination at high latitudes

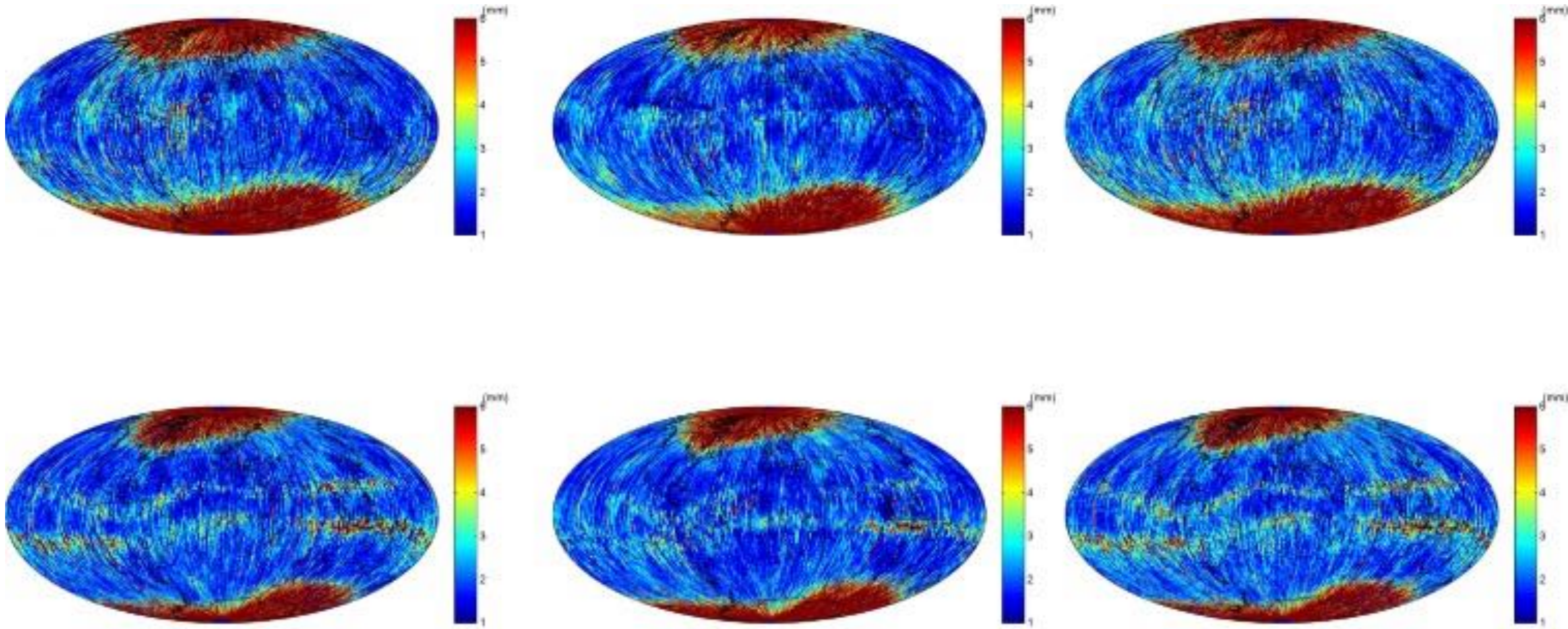
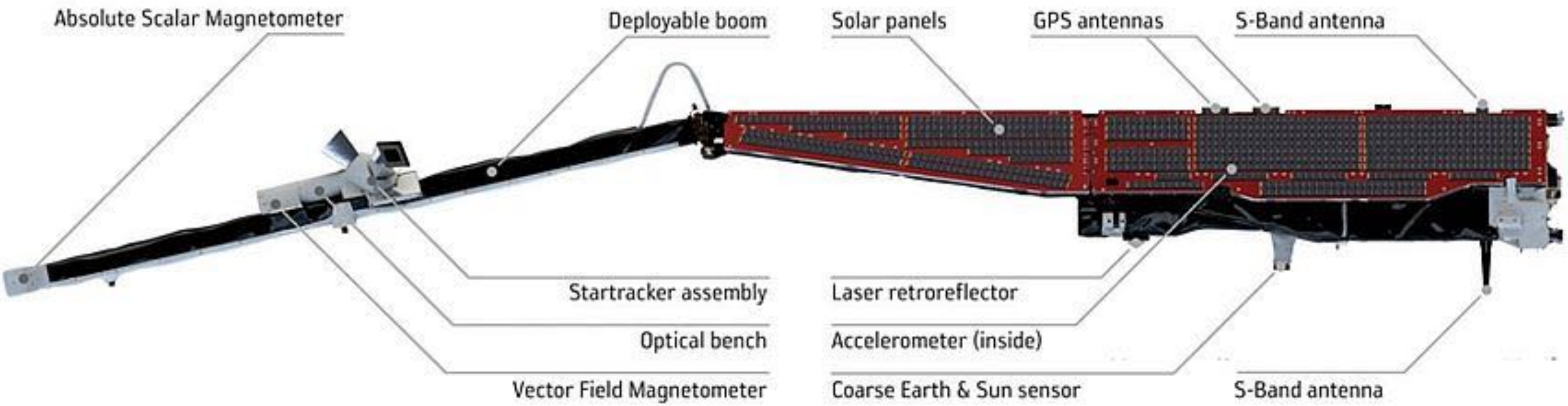


Figure 3.5: Global distribution of the bin-wise RMS error of the residuals from kinematic orbit determination of Swarm-A (left column), Swarm-B (middle column), Swarm-C (right column) for ascending (top row) and descending (bottom row) arcs in the period of days 320–365 of the year 2014 (*Jäggi et al.*, 2016).

Swarm



All the three Swarm satellite are equipped with a set of six instruments:

Absolute Scalar Magnetometer (ASM)
Vector Field Magnetometer (VFM)
Star Tracker (STR)
Electric Field Instrument (EFI)
GPS Receiver (GPSR)
Accelerometer (ACC)

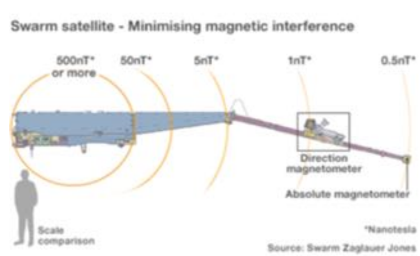
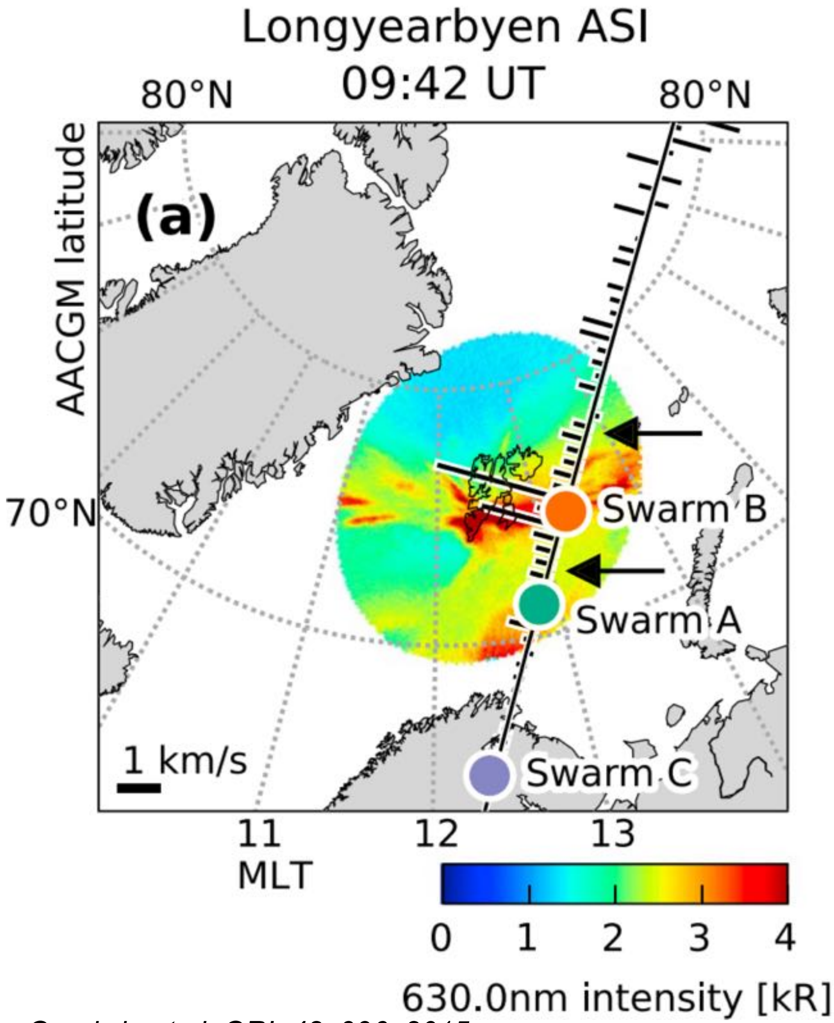
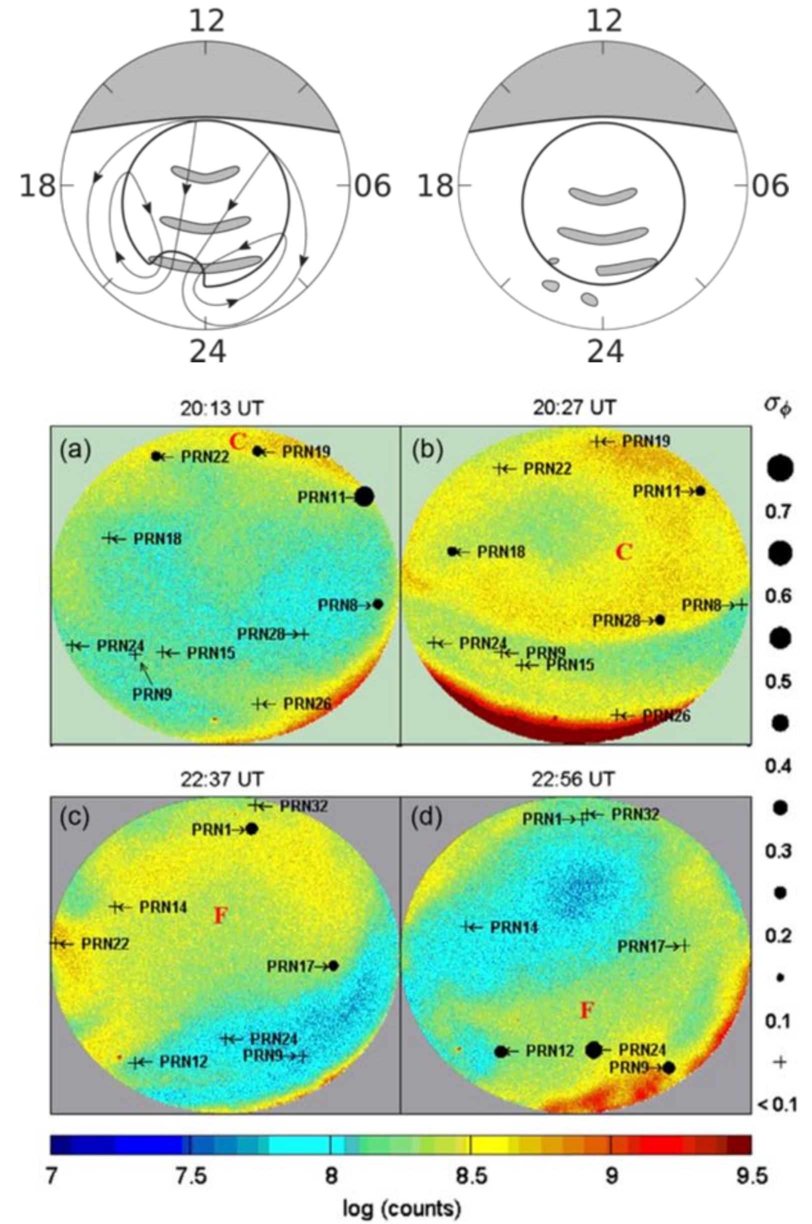


Image credits: ESA

Swarm can detect polar cap patches

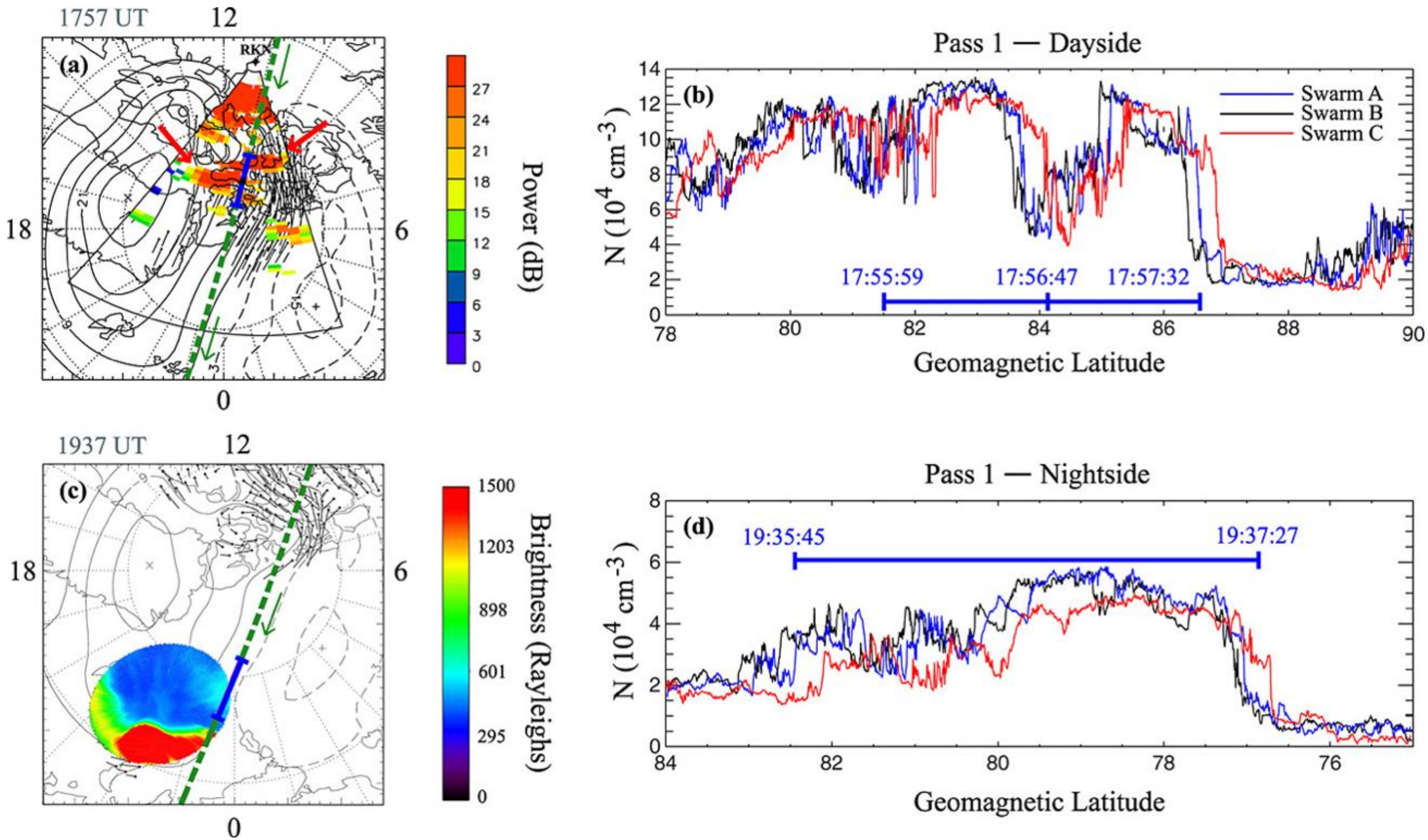


Goodwin et al. GRL 42, 996, 2015



Jin et al, JSWSC 4, A23, 2014

Polar cap patches observed with Swarm



Spicher et al. GRL 42, 201, 2014

Equatorial Bubbles – Swarm IBI

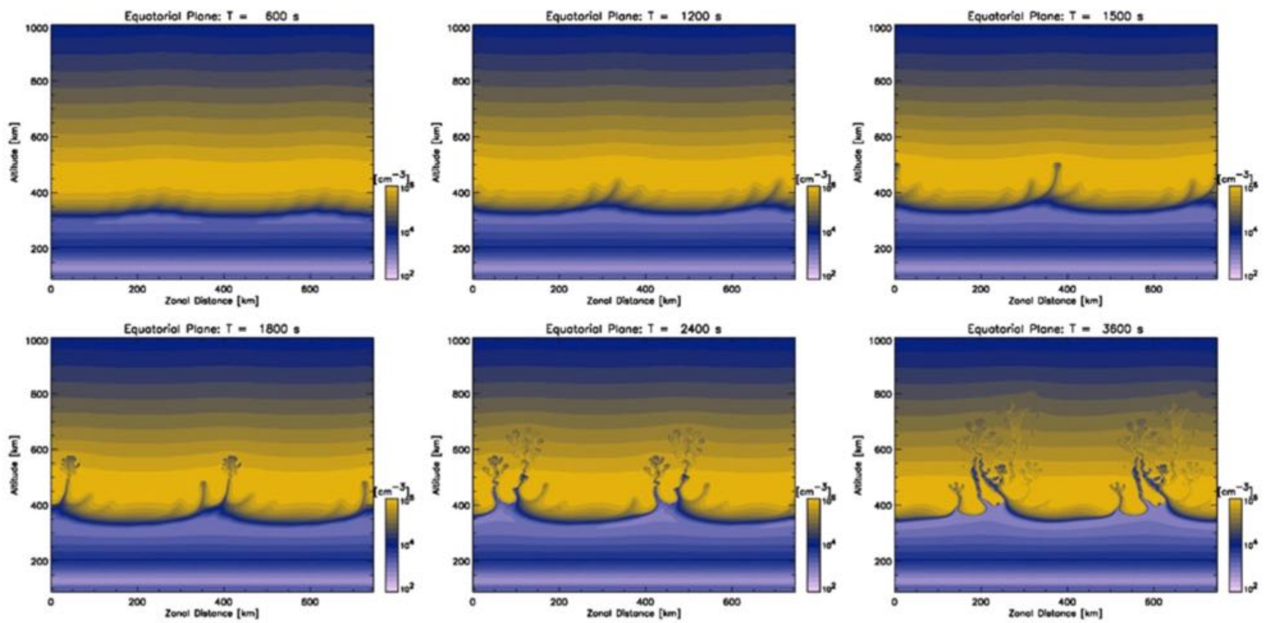
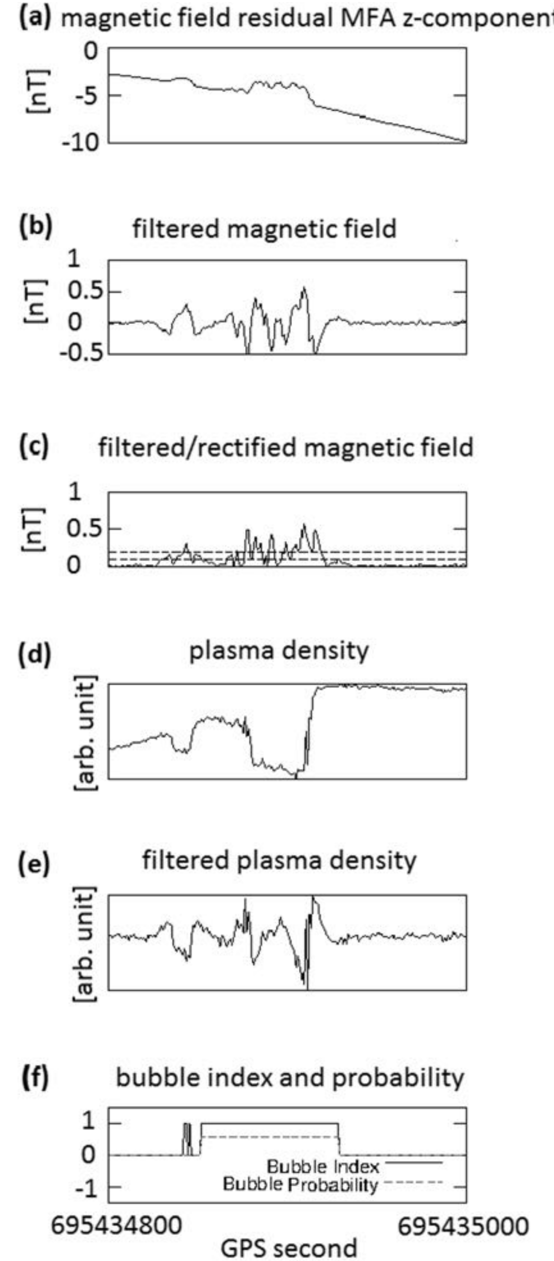


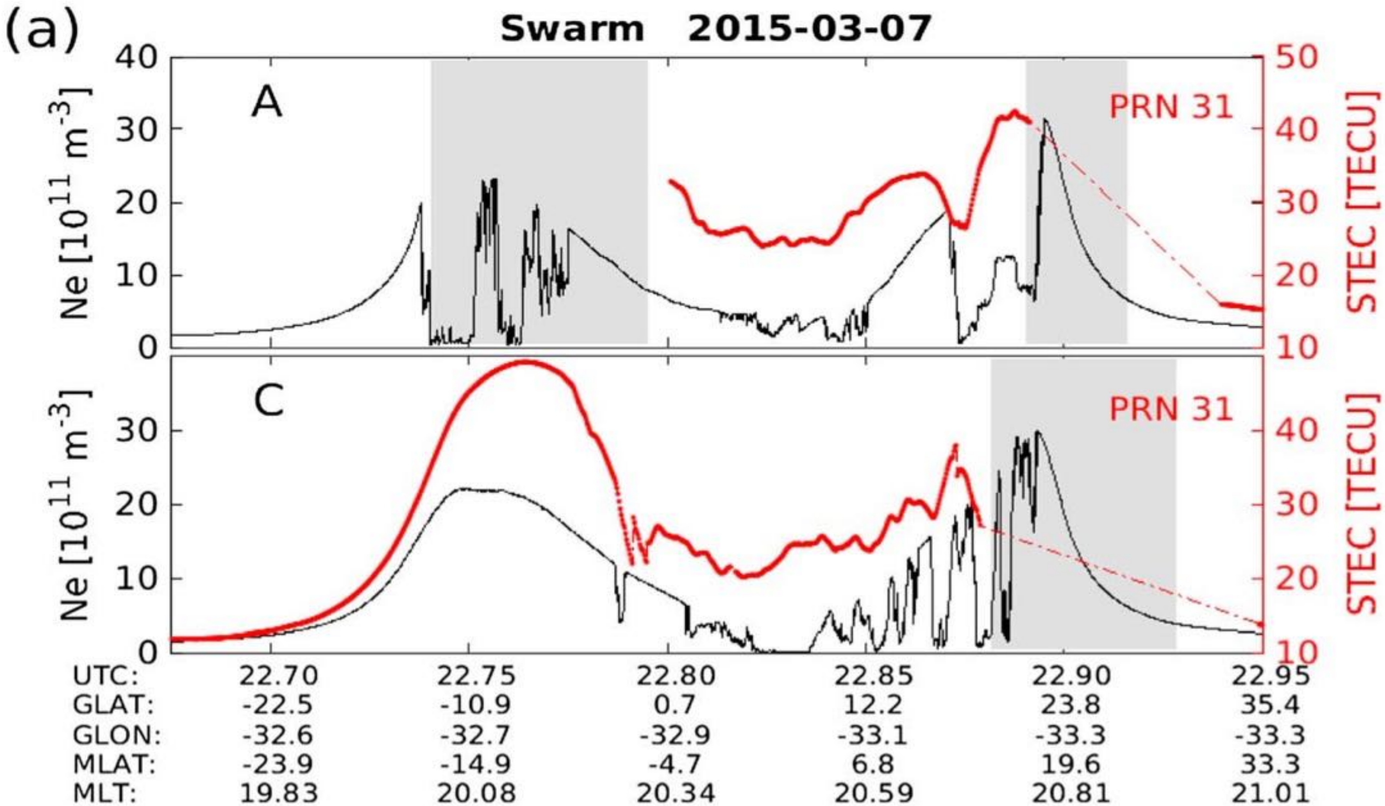
Fig. 8 East–west asymmetry of EPBs simulated using the HIRB model. Reproduced from Yokoyama et al. (2015)

Yokohama, Prog. Earth Plant. Sci. 4, 37, 2017



Park et al. EPS, 65, 1333, 2013

Density vs. TEC



An example of relation between the plasma density variations and the slant-TEC (STEC) data for Swarm A and Swarm C. It is evident that in case of strong density gradients and irregularities in density, the GPS signal is lost (gray – shaded areas), while otherwise the STEC data variations follow the plasma density (Figure 6(a) from Xiong et al. *Space Weather* 14, 563, 2016).

Density

- Rate of change of Density (ROD),
- Rate of change of Density Index in 10 seconds (RODI10s),
- Rate of change of Density Index in 20 seconds (RODI20s),
- filtered *Ne* fluctuations in 10 seconds (Delta_Ne10s),
- filtered *Ne* fluctuations in 20 seconds (Delta_Ne20s),
- filtered *Ne* fluctuations in 40 seconds (Delta_Ne40s),
- *Ne* gradient in 100 km scale (Grad_Ne@100km),
- *Ne* gradient in 50 km scale (Grad_Ne@50km),
- *Ne* gradient in 20 km scale (Grad_Ne@20km),
- *Ne* gradient near the edge of a polar cap patch (Grad_Ne@PCP_edge).

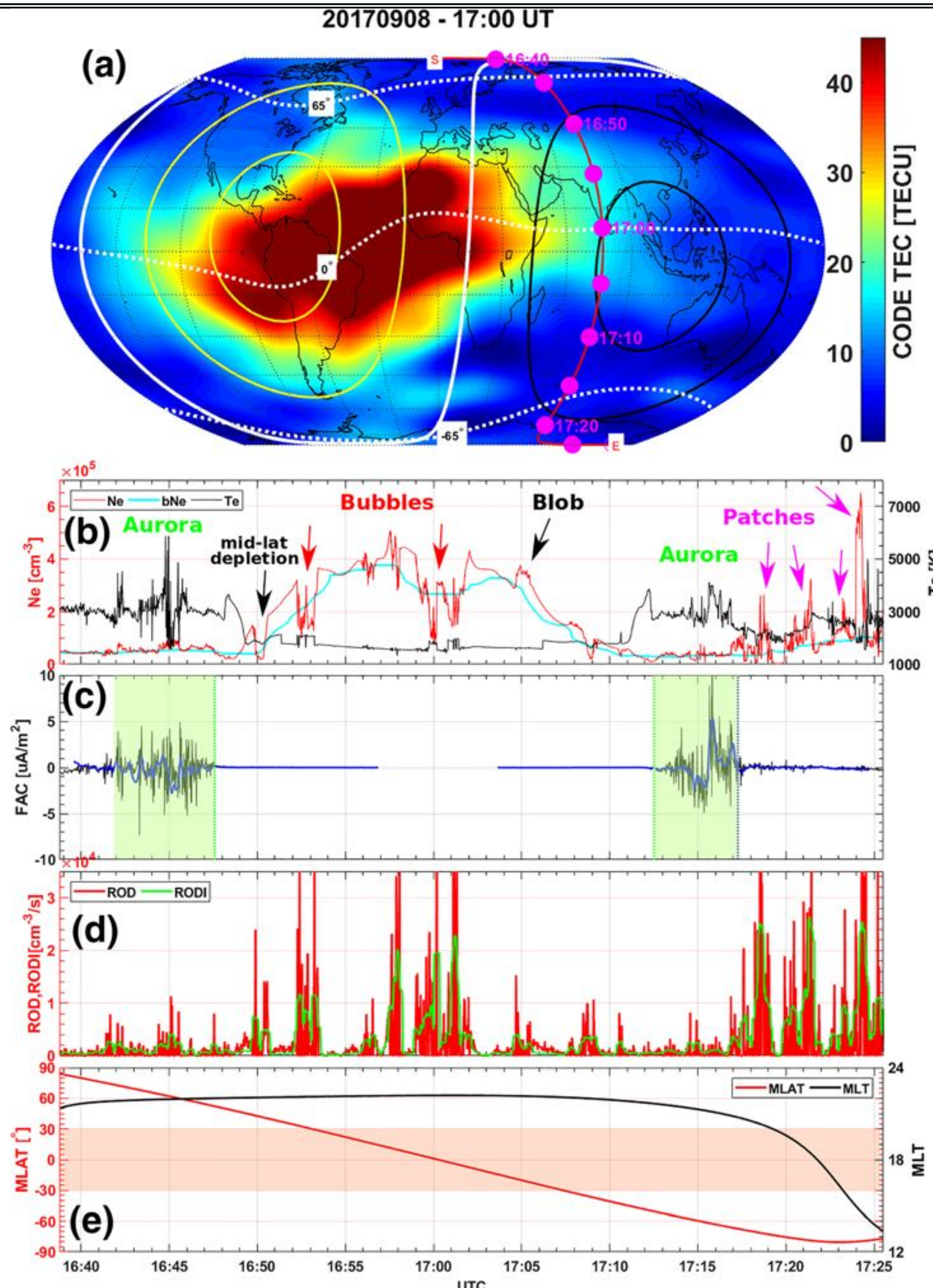
TEC

- Rate of change of TEC (*ROT*),
- Rate of change of TEC index (*ROTI*).

IPIR – ca. 30 entries

IPIR index

++ IBI, PCP, foreground, background densities, etc.



Observations by Swarm A during one pass from the north toward and over the South Pole.

(a) The ground-based global ionosphere map from CODE. Magnetic equator and ±65° MLAT are displayed as white dotted lines. Black and yellow solid lines correspond to the solar zenith angles, and the white line presents the solar terminator. The orbit of Swarm A is shown as a magenta line with timestamps annotated.

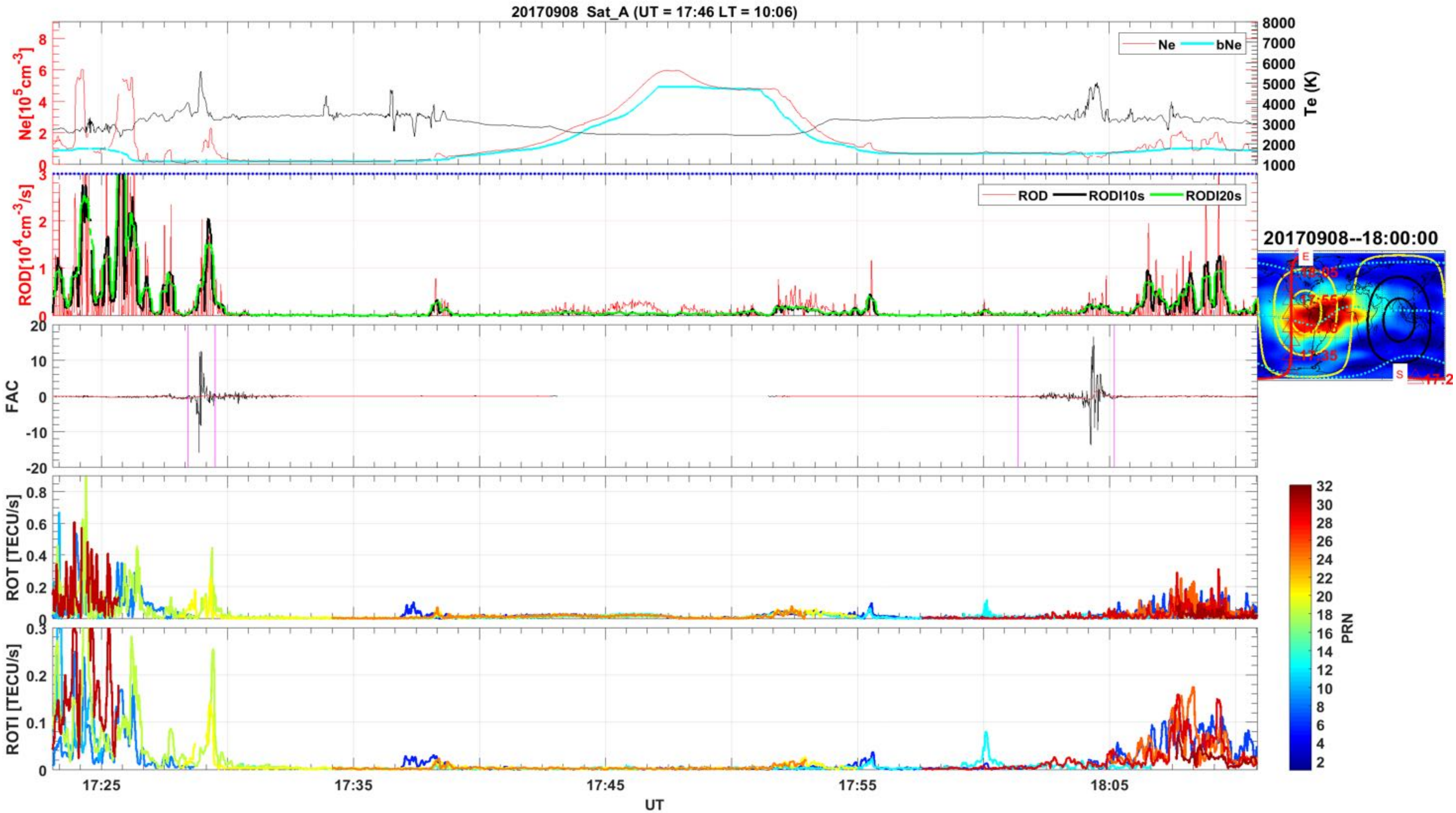
(b) The electron density (unfiltered, red), background electron density (*bNe*, cyan), and electron temperature (*Te*, black).

(c) The field-aligned current (FAC) from the single spacecraft (black) and dual spacecraft (Swarm A and C, blue). The auroral region derived from the FAC dataset is shaded in green.

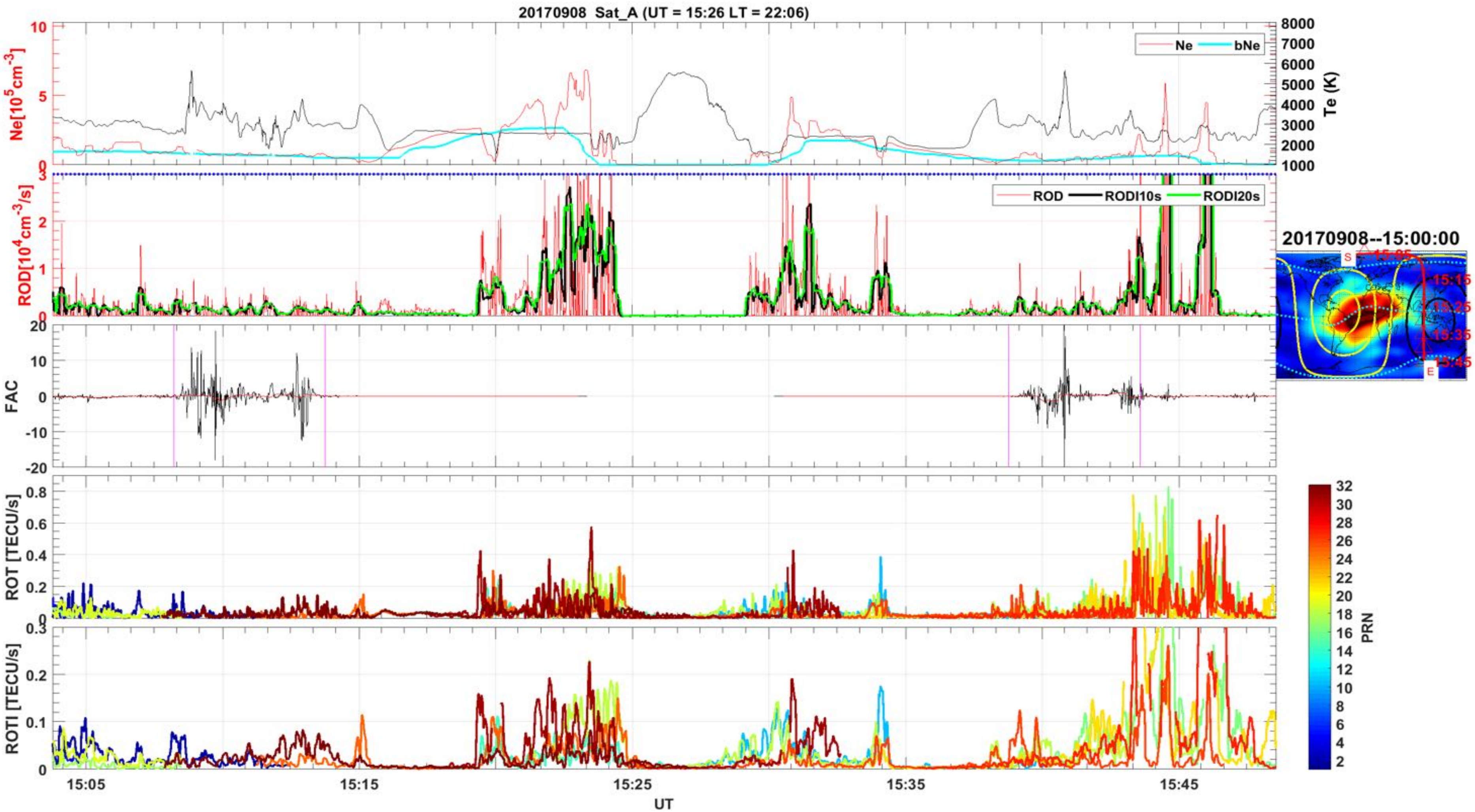
(d) The derived irregularity parameter ROD in absolute values (red) and RODI (green).

(e) The MLAT and MLT of the Swarm satellite.

Jin et al. JGR 124, e2020JA028103, 2020

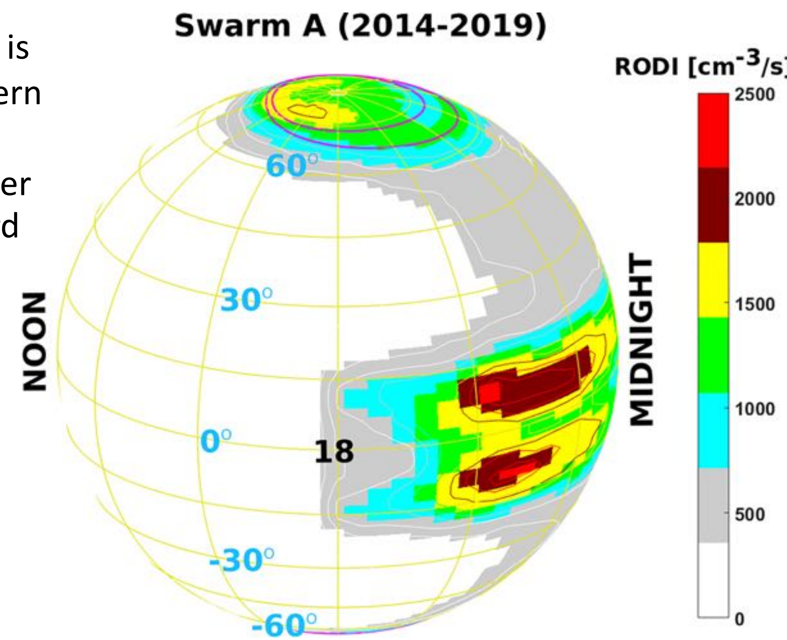


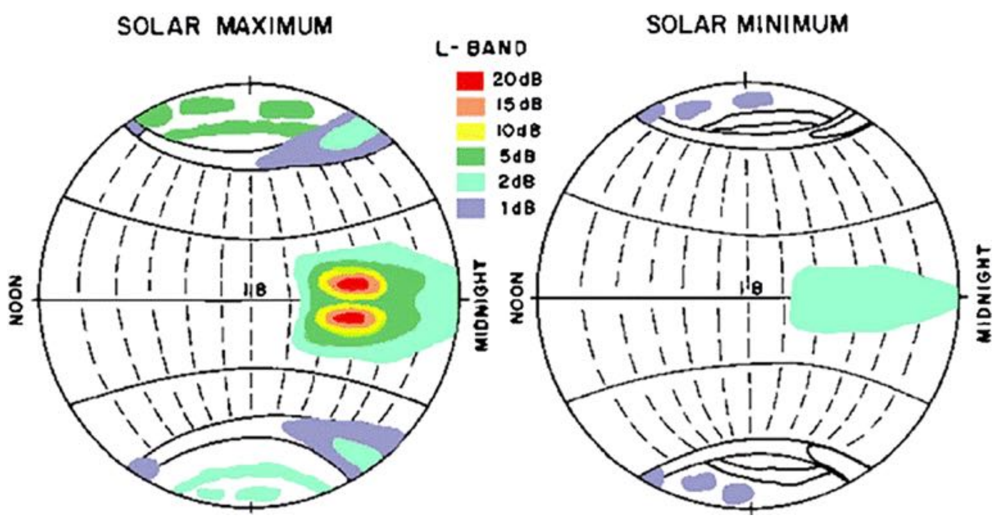
An example of the parameters during one full orbit from the South to the North. The equatorial ionosphere show smooth variation in the early morning (10 LT), while the ionosphere at high latitudes shows irregularities.



An example of the parameters during one full orbit from the North to the South. The equatorial ionosphere is characterized by plasma bubble (density depletion region) during premidnight morning (22 LT). The high-latitude ionosphere is characterized by polar cap patches and auroral blobs.

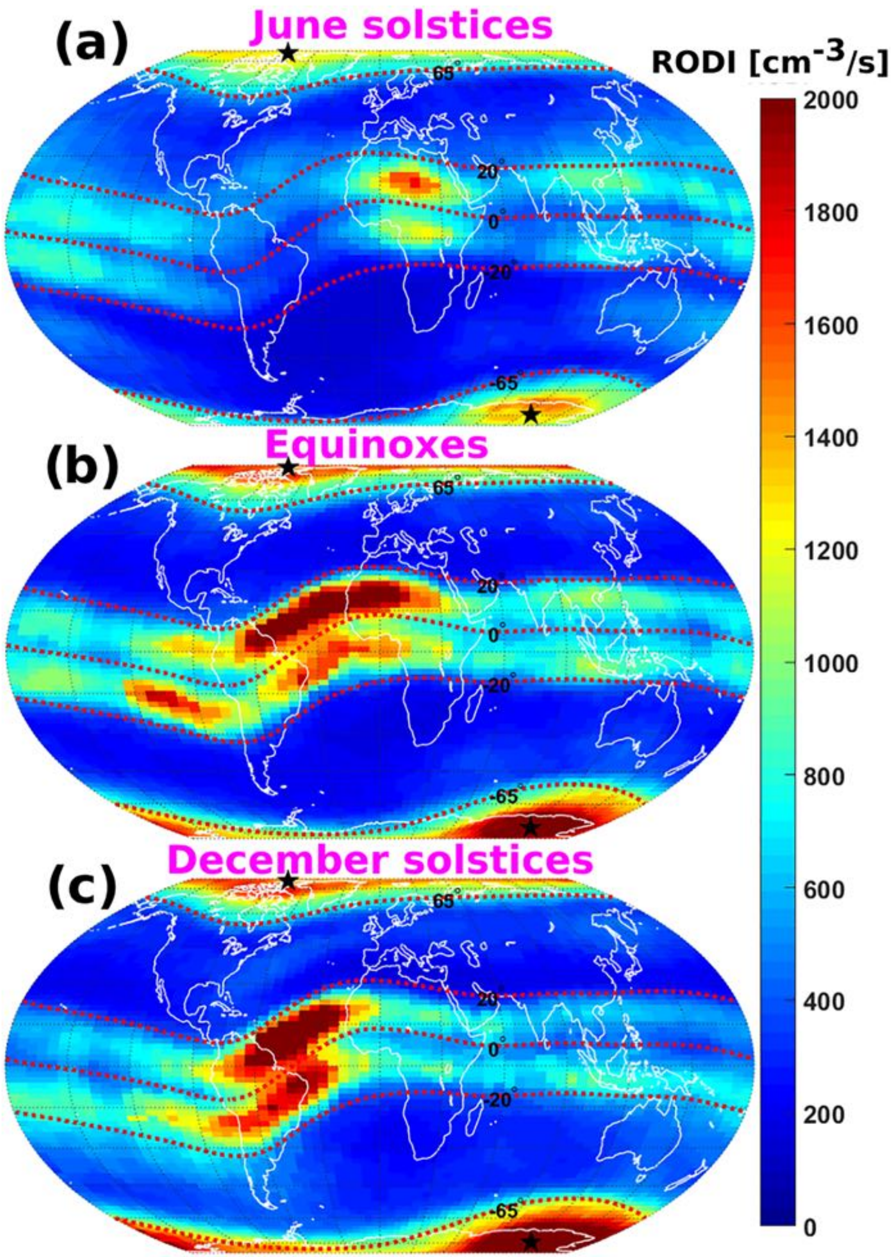
Global distribution of RODI in MLAT/MLT coordinates. The Sun is to the left (12 MLT), and the globe is shifted toward the northern hemisphere to show the northern polar area. A movie can be found in the supporting information that presents RODI at other latitudes and local times. The magenta curves are the poleward and equatorward boundaries of the auroral oval from the Feldstein model (*Q* = 3).





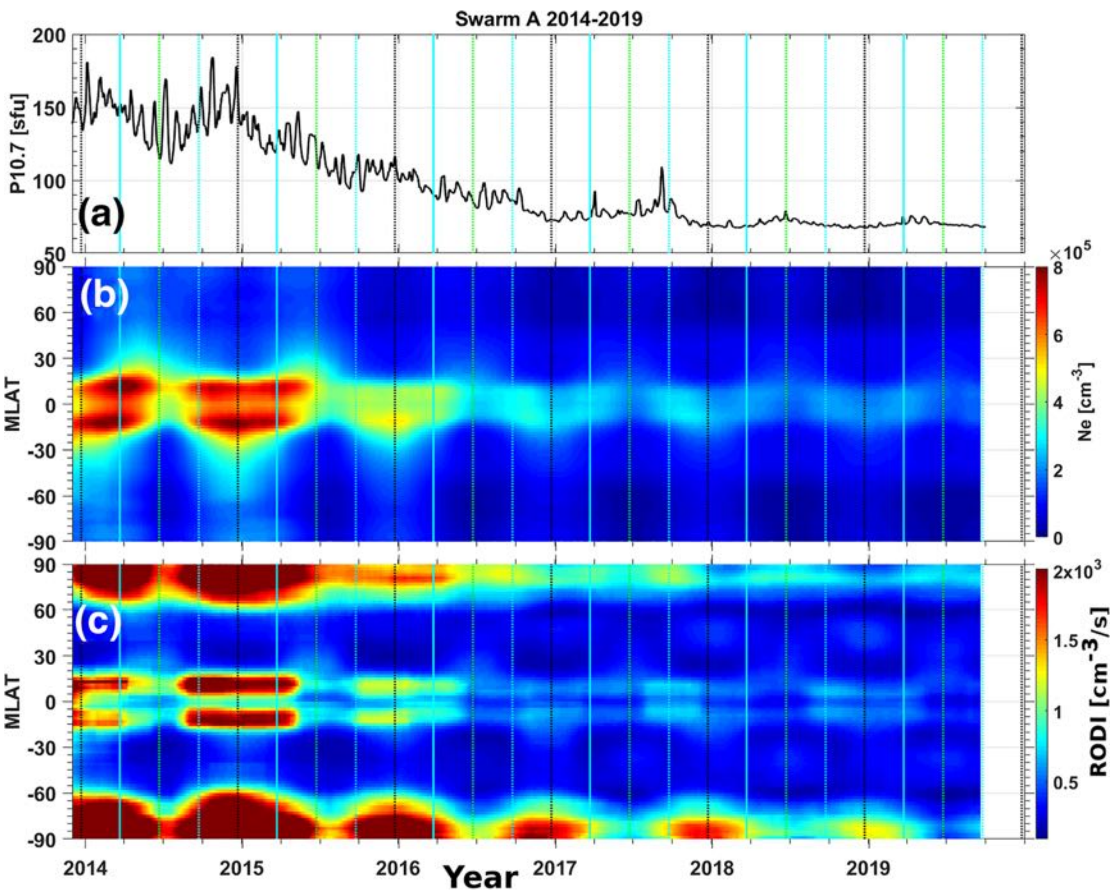
The global characteristics of ionospheric scintillations during the solar maximum and solar minimum in terms of the power fade as summarized by Basu, Mackenzie, and Basu (1988).

Jin et al. JGR 124, e2020JA028103, 2020

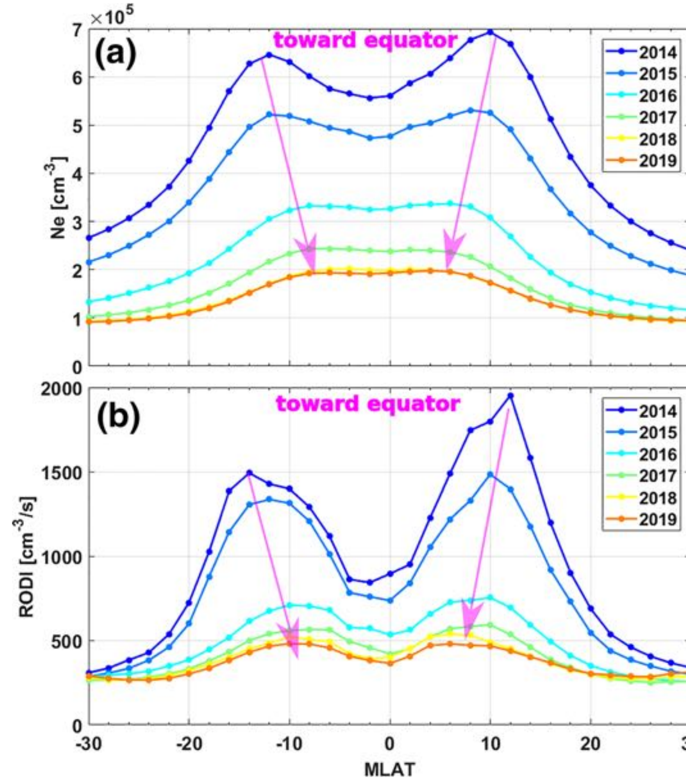


The global distribution of RODI for three different seasons in geographic coordinates. The magnetic latitudes of 0°, ±20°, and ±65° are plotted as magenta dotted lines. The geomagnetic poles in the northern and southern hemispheres are presented as black stars. Seasonal and longitudinal variations are observed at low latitudes.

Jin et al. JGR 124, e2020JA028103, 2020

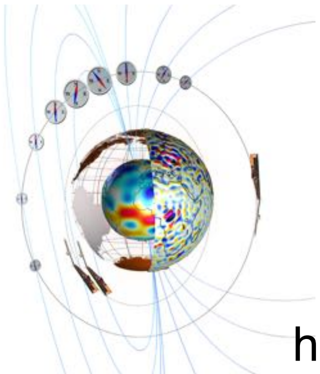


(a) The P10.7 index that is running averaged in 31 days. The long-term variations electron density (b) and RODI (c) as a function of day (November 2013 to September 2019) and MLAT. The vertical lines mark the equinoxes and solstices. The solar flux index P10.7 is given in the solar flux units (sfu), where 1 sfu = 10^{-22} W m^{-2} Hz^{-1}.



The distribution of electron density (a) and RODI (b) as a function of MLAT for different years.

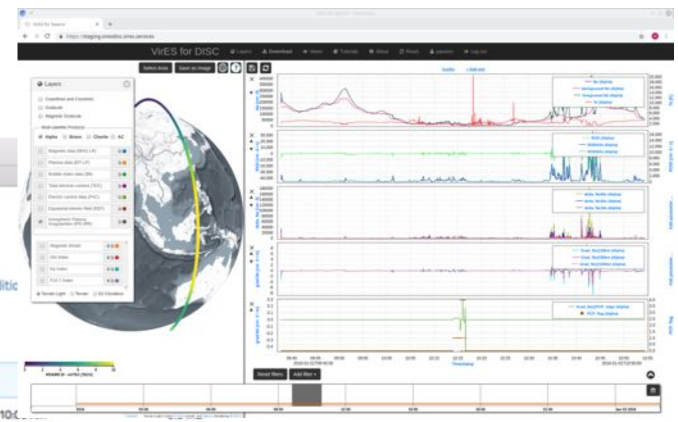
Jin et al. JGR 124, e2020JA028103, 2020

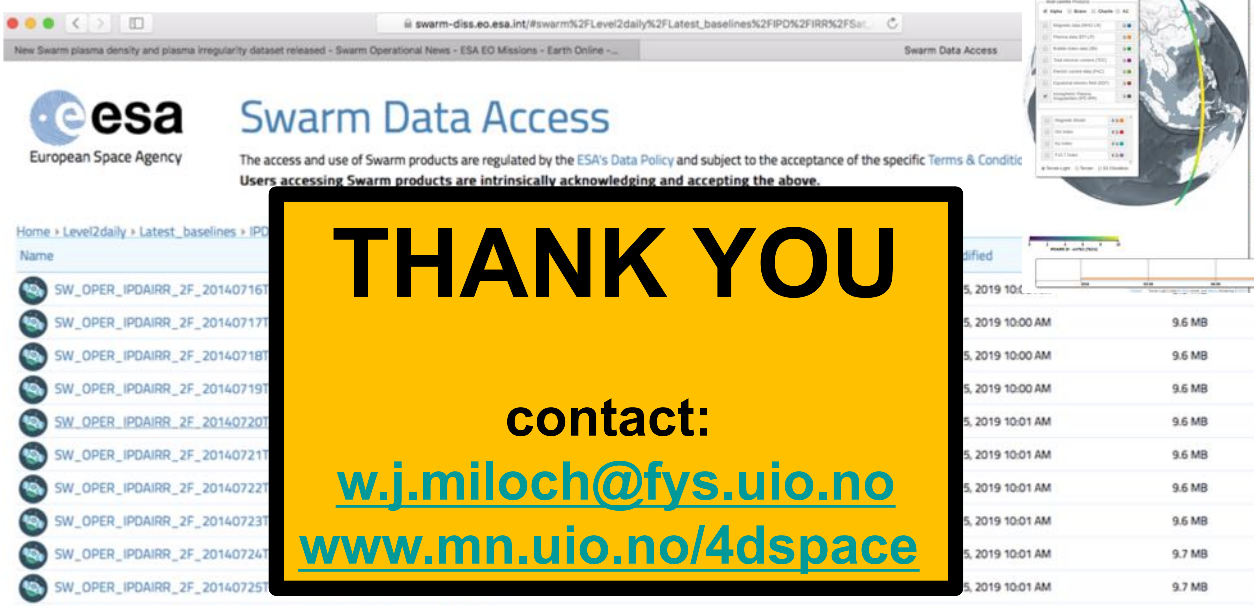


IPIR: Ionospheric Plasma IRregularities characterised by the Swarm satellites

https://swarm-diss.eo.esa.int/Level2daily/Latest_baselines/IPD/IRR/

VirES for Swarm ->





THANK YOU

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