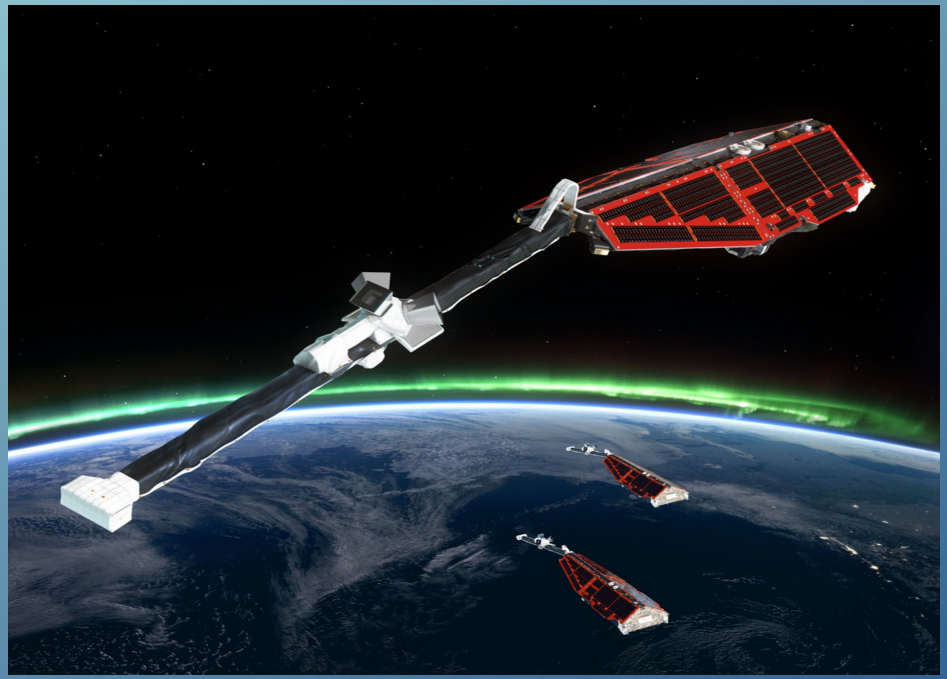
The *Swarm* constellation mission: upper atmosphere parameters and high precision magnetic field

Claudia Stolle[1,2]

& Swarm Science Team

[1]GFZ Potsdam [2]University of Potsdam

Swarm constellation mission



Mission and Constellation

- Earth Explorer Mission of the European Space Agency (ESA)
- Launched 22 November 2013
- Operation 5+ years

Satellite A + C:

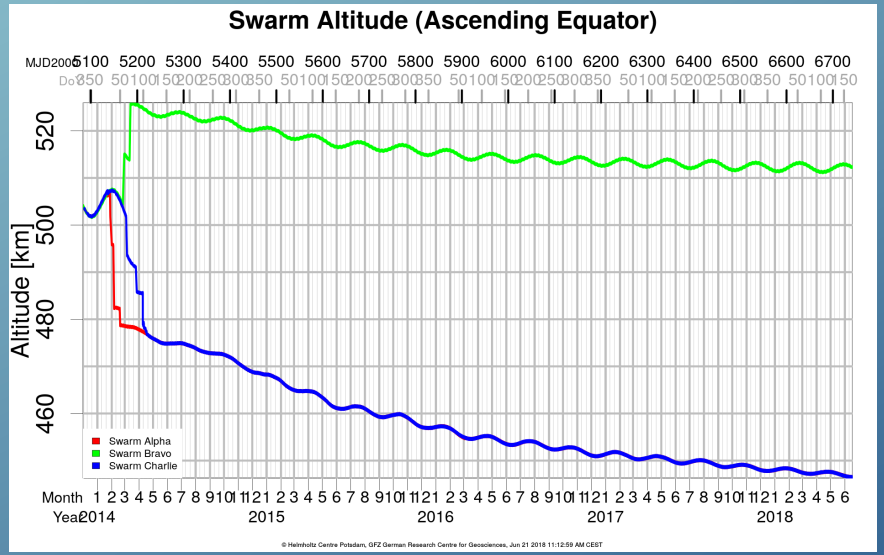
- Altitude 448km
- Side-by-side flying (Δlon: 1.4°, ΔLT: 6 min, 160km distance (at equator))
- Longitudinal difference Δt=7-13s, Δlat: 56-104km

Satellite B:

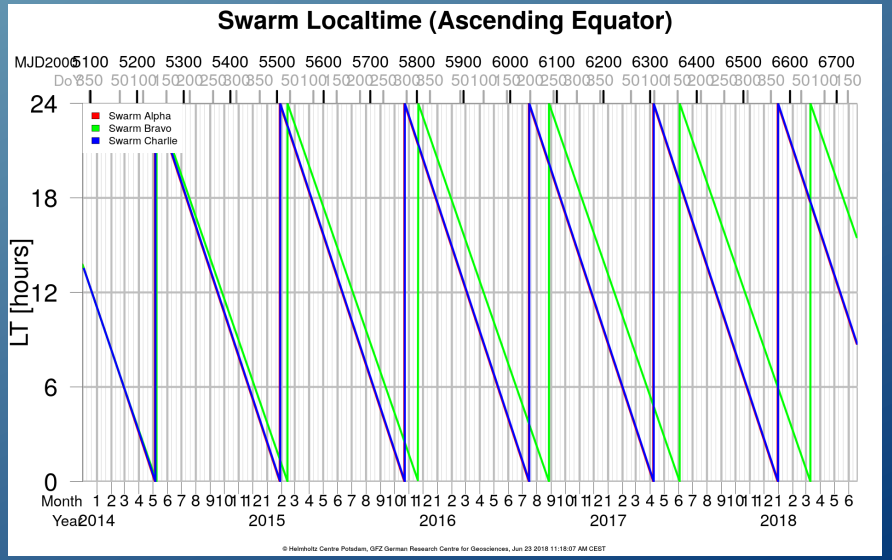
- Altitude 512km

Swarm constellation mission

Orbit altitude



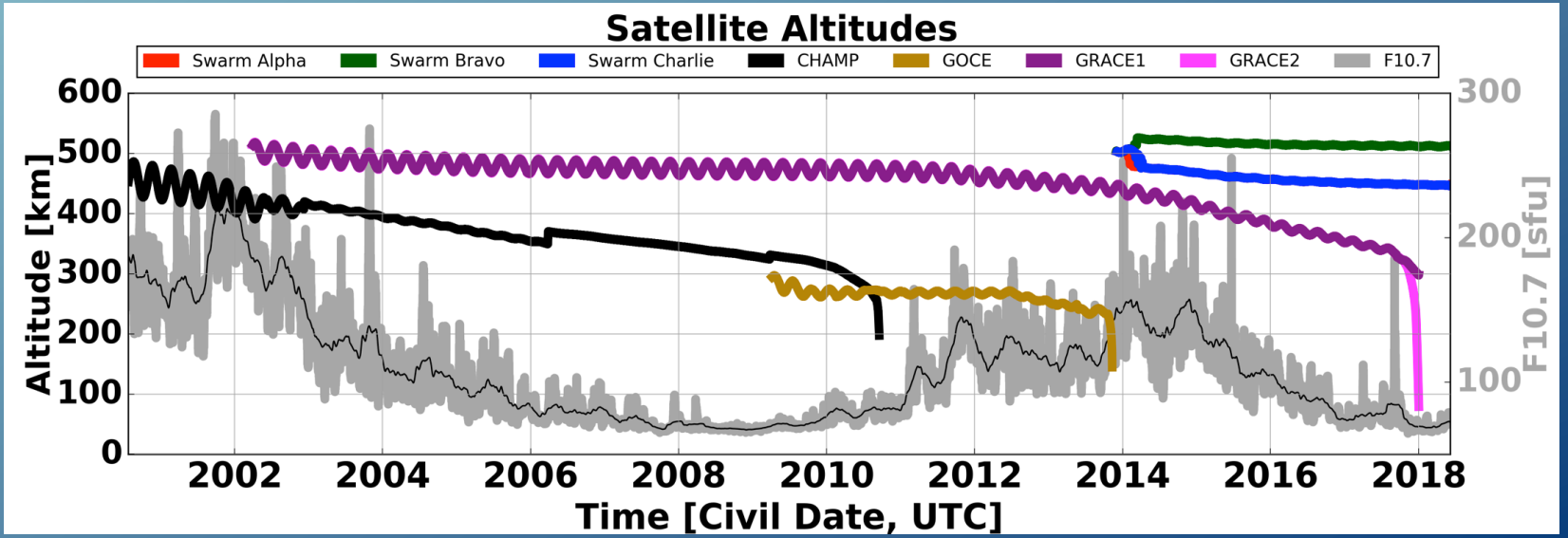
Local time



> movie

Long-term observations from polar orbiting LEO satellites

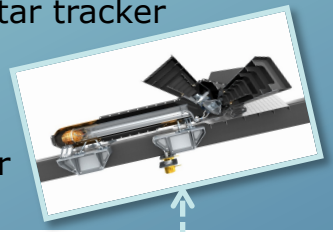
- Coverage: Global, local time fix or slowly processing, 250-550 km altitude
- Multiple event studies
- Regular and periodic processes, climatology



Swarm payload

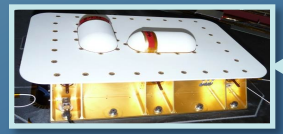
Flight direction

Star tracker

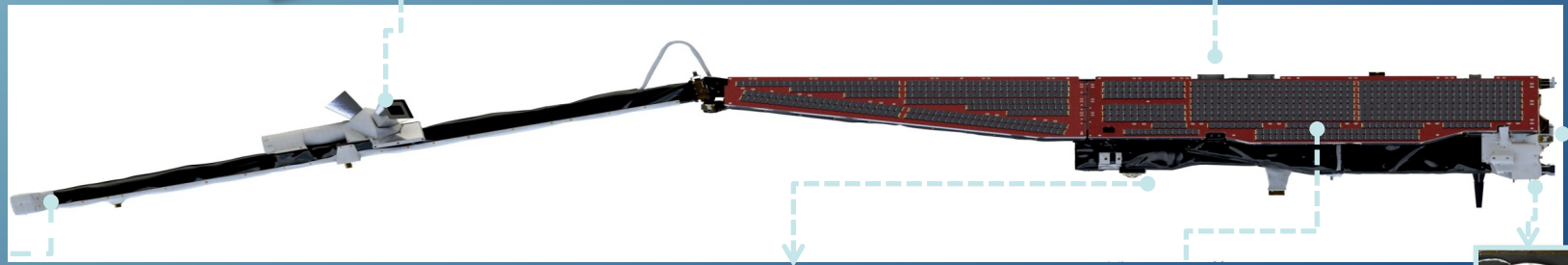


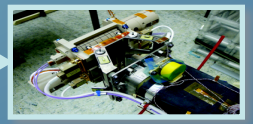
GPS receiver

3D-ion imager



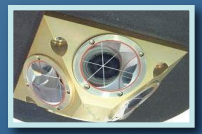
Vector magnetometer



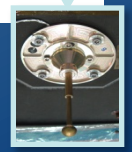


Absolute scalar magnetometer

Laser reflector

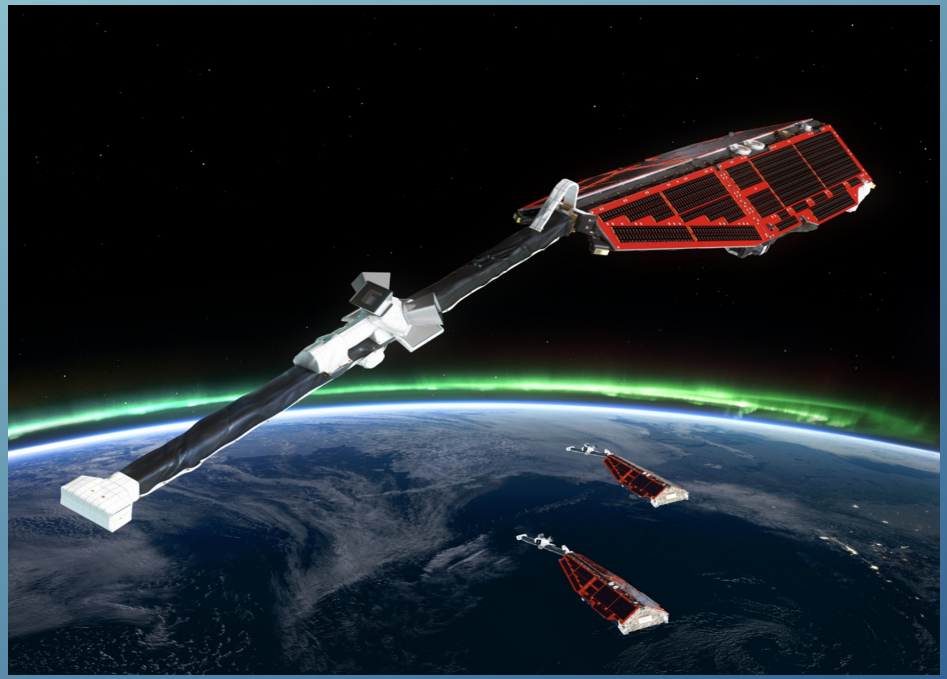


Accelerometer



Langmuir probe

Swarm data products



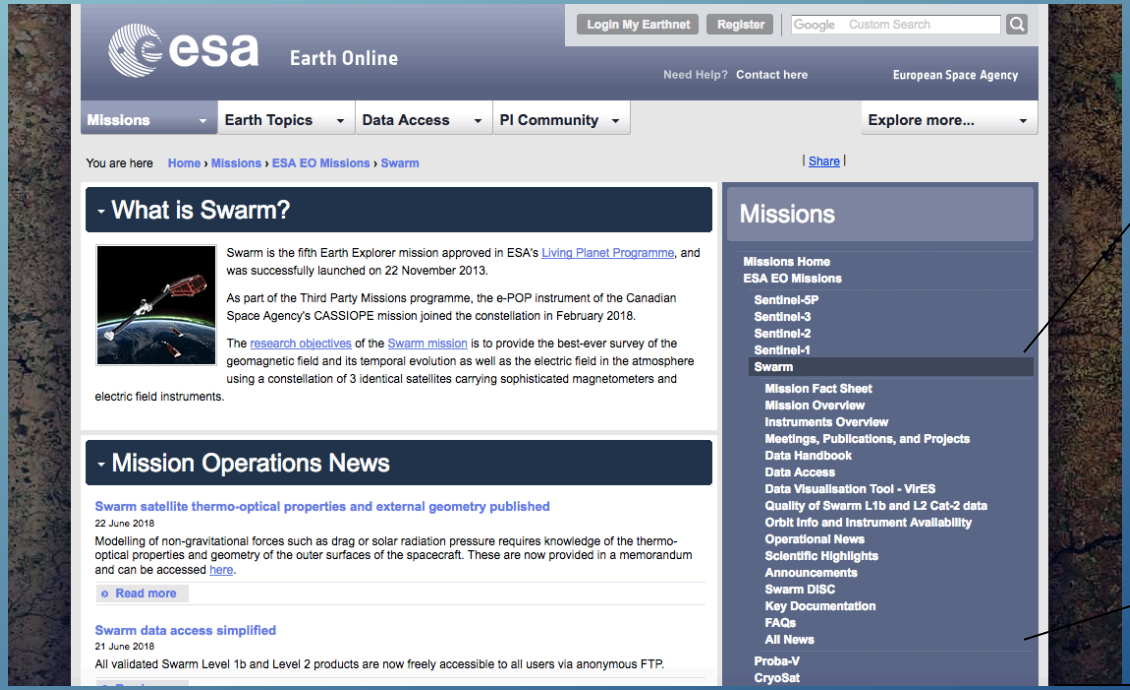
Calibrated time series; derived products

- High-precision magnetic field (1Hz, 50Hz)
- Attitude, Orbit, GPS RINEX (1Hz)
- Electron and ion density and temperature, ion drift velocity, electric field (2Hz)

- Radial and field-aligned currents (1Hz)
- Equatorial "bubble" index (plasma irregularities, 1 Hz)
- Dayside equatorial eastward electric field, EEJ (orbit)
- Total Electron Content (1Hz)
- Thermospheric density
- Main magnetic field models

Swarm information and data

earth.esa.int/swarm swarm_feedback@esa.int twitter.com/esa_swarm



Swarm

- Mission Fact Sheet
- Mission Overview
- Instruments Overview
- Meetings, Publications, and Projects
- Data Handbook
- Data Access
- Data Visualisation Tool - VirES
- Quality of Swarm L1b and L2 Cat-2 data
- Orbit Info and Instrument Availability
- Operational News
- Scientific Highlights
- Announcements
- Swarm DISC
- Key Documentation
- FAQs
- All News

@esa_swarm

Swarm radial and field-aligned currents (FAC)

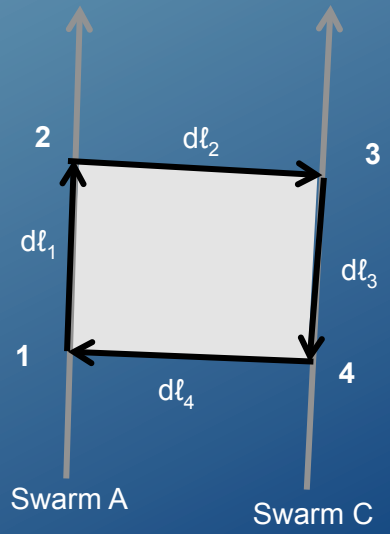
- Derived from magnetic field time series
- **Radial currents** from Ampère's law $j = \frac{1}{\mu_0 A} \oint \vec{B} \cdot d\vec{\ell}$ in its discrete form

Option 1: Single-satellite approach (*Swarm* A, B, C, 1Hz)

- Variations of Δ***B*** in east-west direction neglected

Option 2: Dual-satellite approach (*Swarm* A, C, 1Hz – 20s filt)

- Variations of Δ***B*** from discrete square ➔



FAC are obtained

from projection of radial currents on the field direction

$j_{FAC} = -\frac{j_{IRC}}{\sin I} \left[\frac{\mu A}{m^2}\right]$, where I is magnetic field inclination

https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/activities/conferences/swarm-ionospheric-currents

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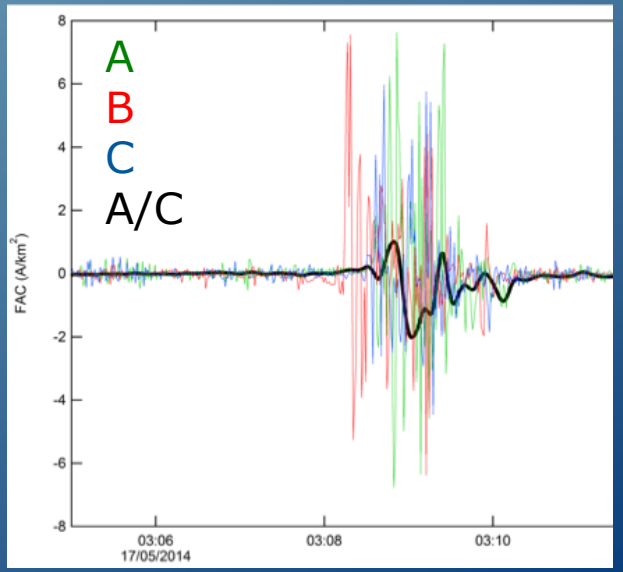

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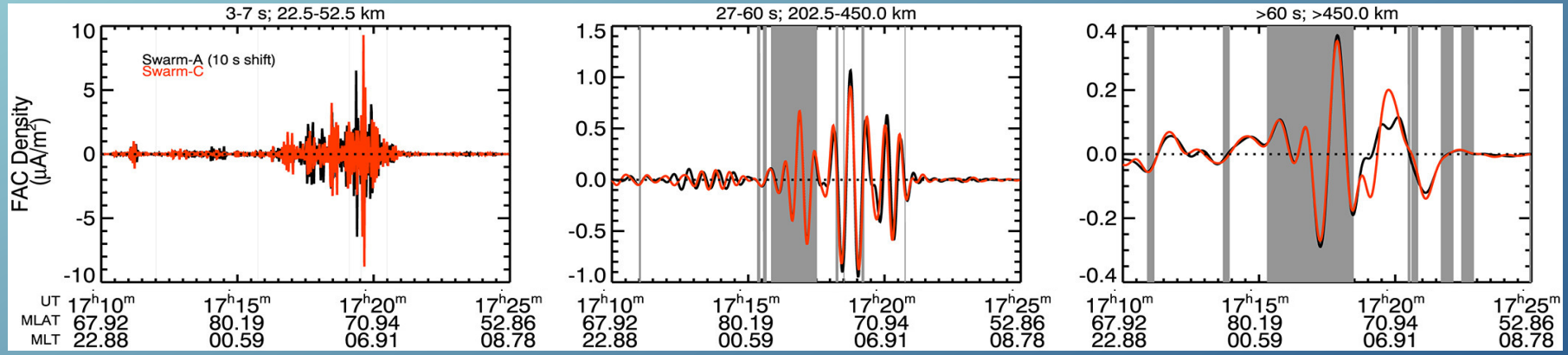
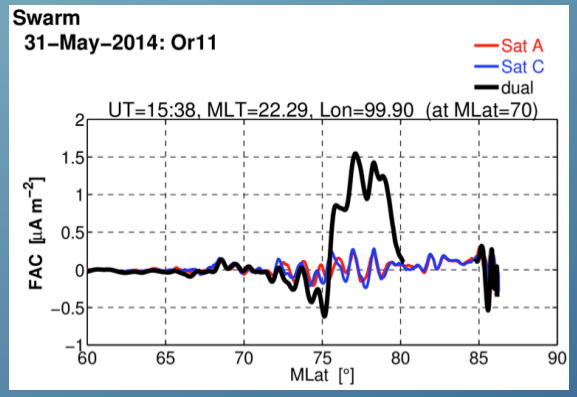
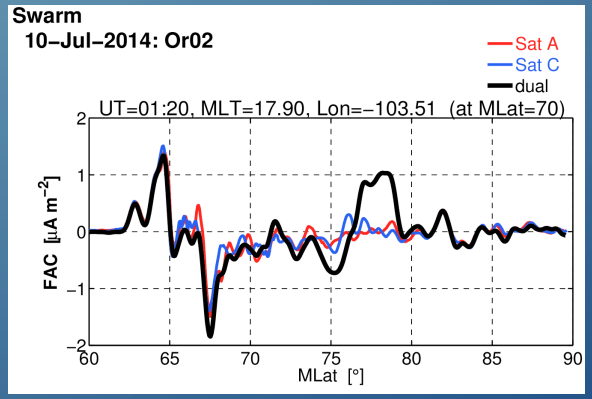
Swarm field-aligned currents (FAC)

Forsyth et al., JGR, 2017







- Dayside FACs poleward of auroral oval
- Preference for northward IMF
- IMF By dependency

Lühr et al., *AnGeo*, 2016

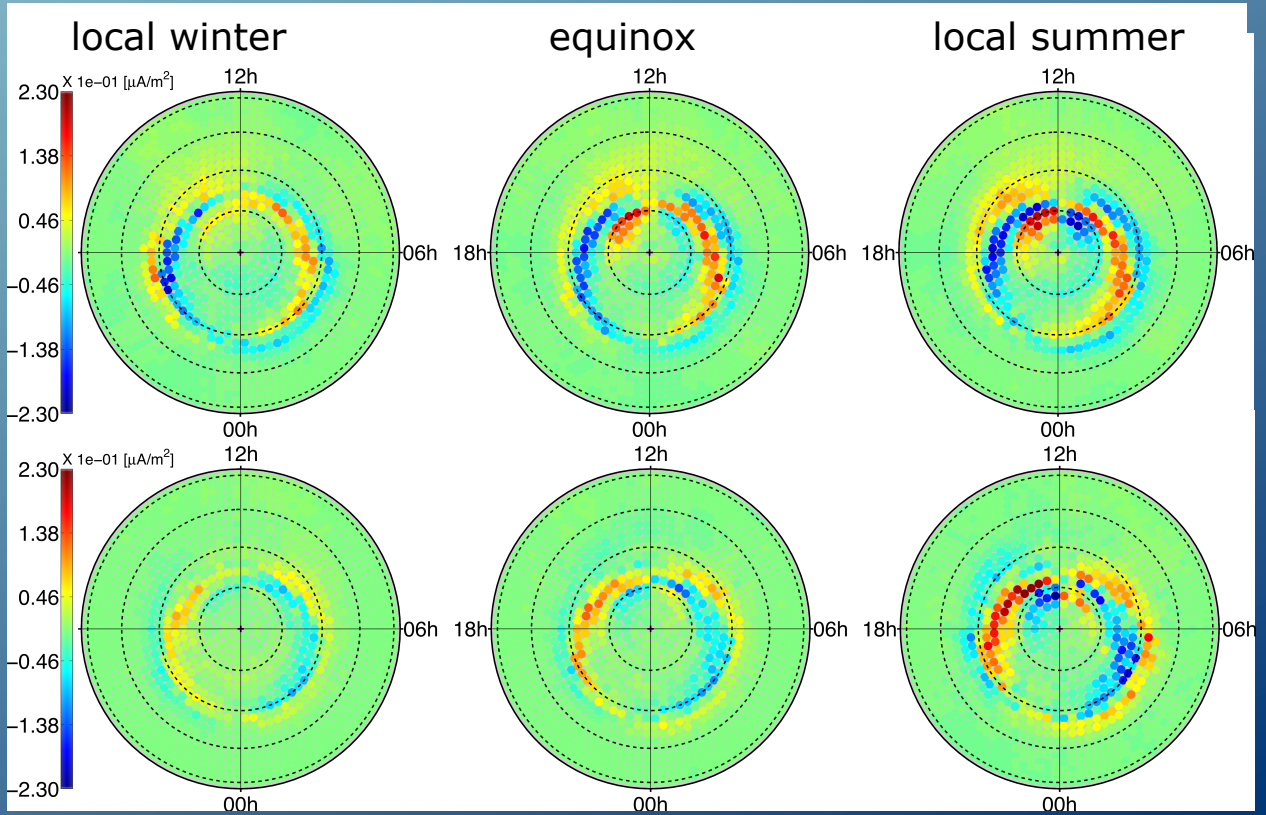
Swarm field-aligned currents (FAC)

Northern hemisphere
Ap < 8nT

Southern hemisphere
Ap < 8nT

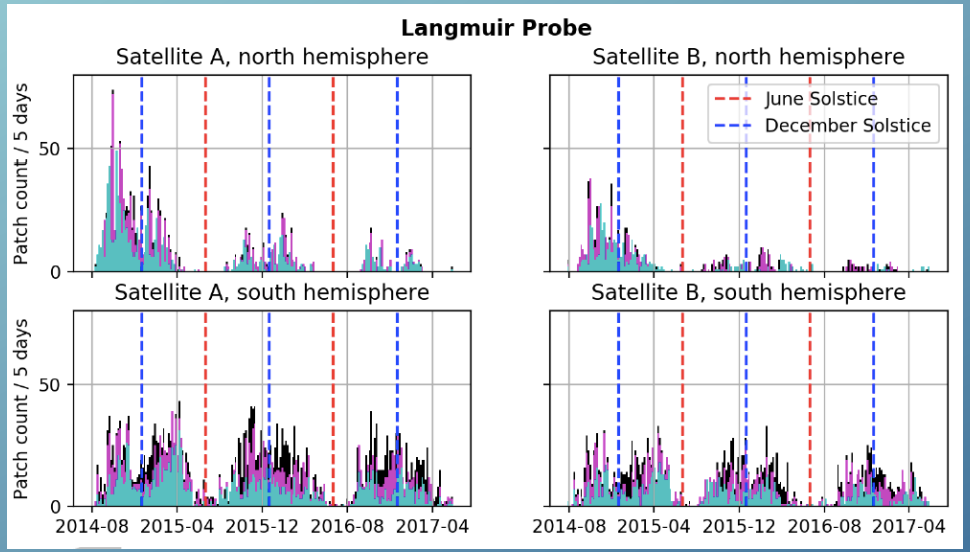
FAC and horizontal current model:
Laundal et al., *JGR*, 2018
https://klaundal.w.uib.no/

FAC scale analyses:
McGranaghan et al., *JGR*, 2018



Polar patch climatology

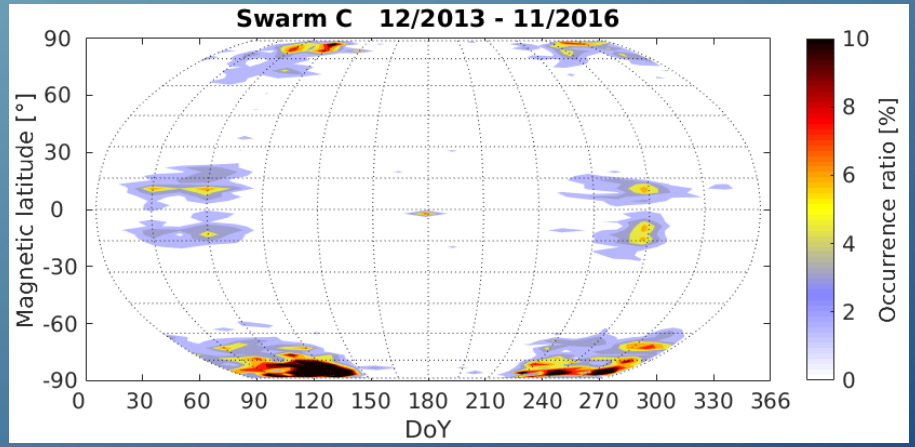
Number of identified patches in Ne



Chartier et al., *JGR*, 2018

- *Swarm* Ne + TEC polar patches (2014-2017)
- Absolute threshold + solar cycle adaptations
- Maxima at Dec. solstice/Equinox

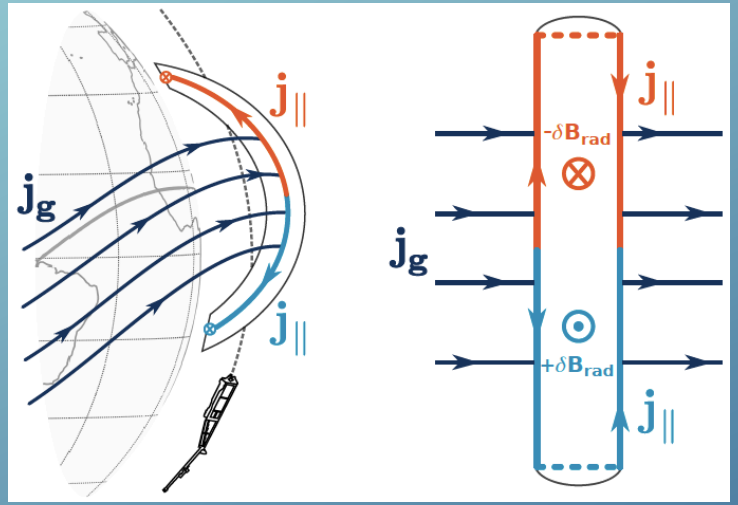
Occurrence of GPS signal losses

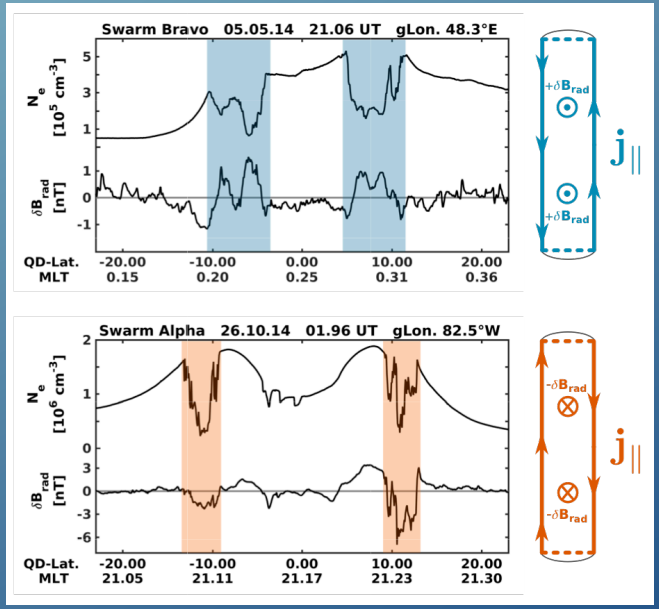


Xiong et al., *Space Weather*, 2016; *AnGeo*, 2018

- All GPS signal losses coincide with strong ΔNe
- lat/lon/DoY distribution as ionospheric events
- **Low lats: postsunset depletions**

Postsunset equatorial F-region depletions



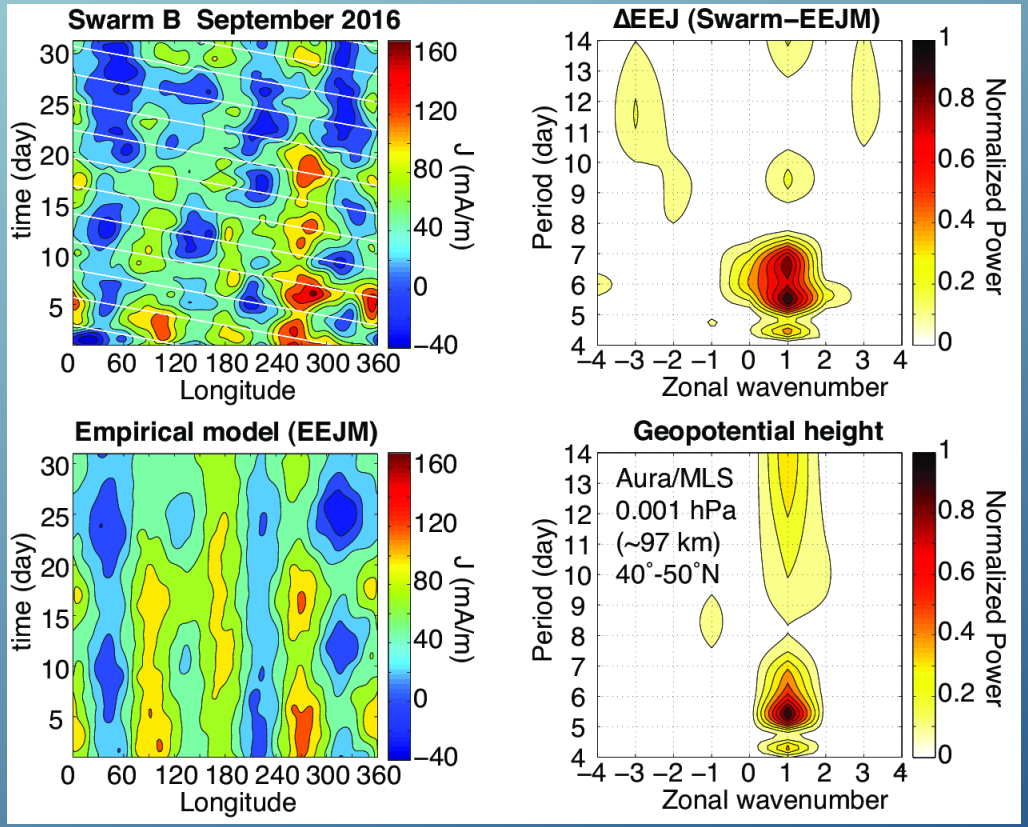


- FACs + Poynting flux are mainly interhemispheric
- Distinct lon/ seasonal distribution
- Suggestion for hemispherically anti-symmetric conductivity

Gravity driven currents diverge poleward, e.g.,
Aveiro et al., *GRL*, 2011
Yokoyama and Stolle, *Space Sci. Rev.*, 2017

Rodriguez-Zuluaga et al., *Geophys. Res. Lett.*, 2017
Rodriguez-Zuluaga and Stolle, *Sci.Rep.*, under review, 2018

Quasi 6-day wave in EEJ (Swarm: 11:30LT – 09:00LT)



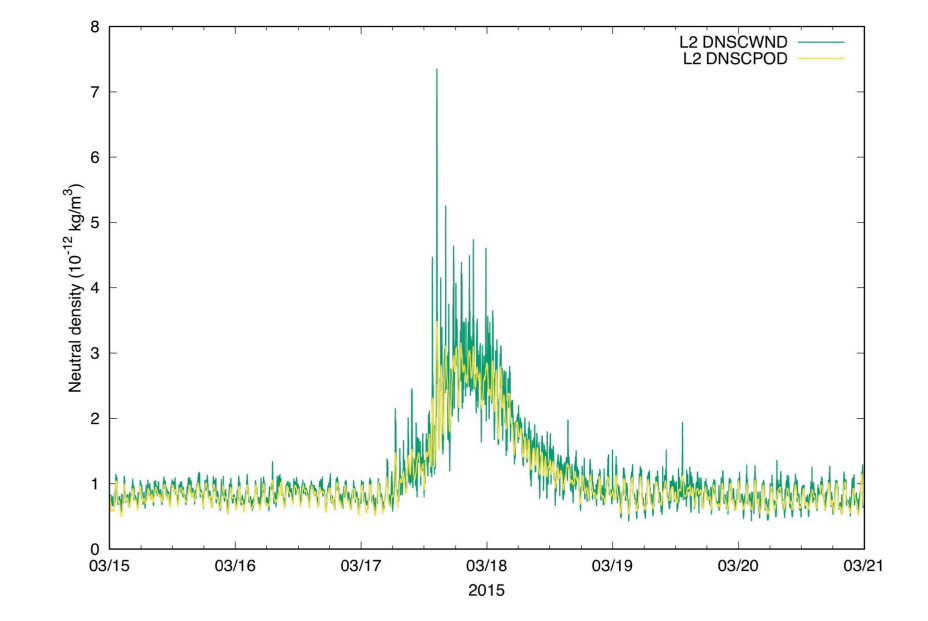
- Quasi 6-day wave is an important part of day-to-day variability of the EEJ
- 5 events detected so far in CHAMP and Swarm
- Global observation reveals longitudinal differences
- Dependence on LT, solar flux, magnitude of forcing to be investigated

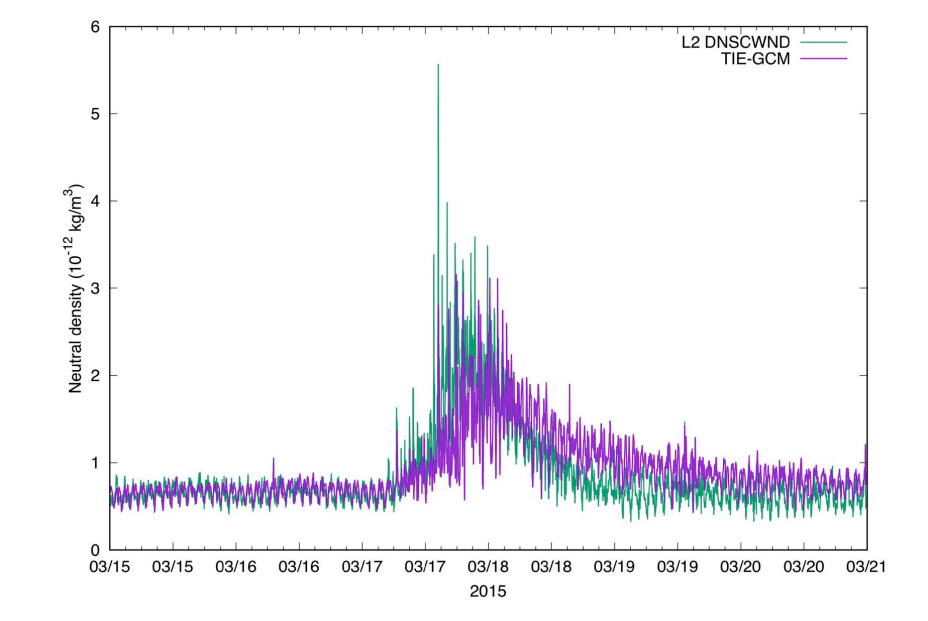
Yamazaki et al., *JGR*, 2018

Swarm thermospheric density

- Derived from GPS for all three satellite (DNSxPOD)
- Combined GPS/ACC for satellite C (DNSxWND)
- Large scale variations well monitored!

Courtesy E. Doornbos and G. Lu





Conclusion: *Swarm* is a successful **multi-parameter constellation** mission to investigate **Earth and its space environment** also in combination with other data and models; now and in future