Equatorial vertical plasma drift, the EEJ, the EIA, and spread-F

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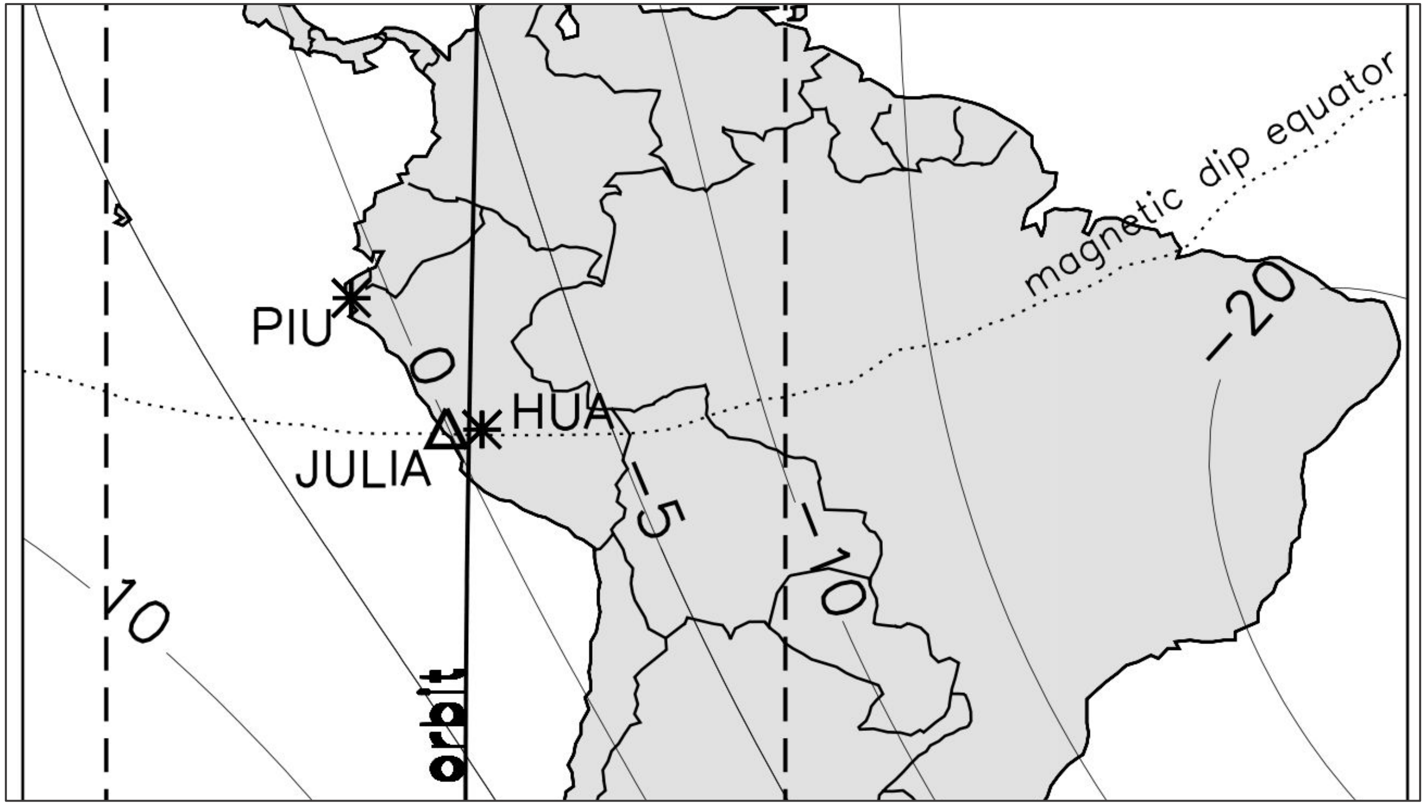


esa

SWARM DISC

swarm

DFG Deutsche Forschungsgemeinschaft
German Research Foundation

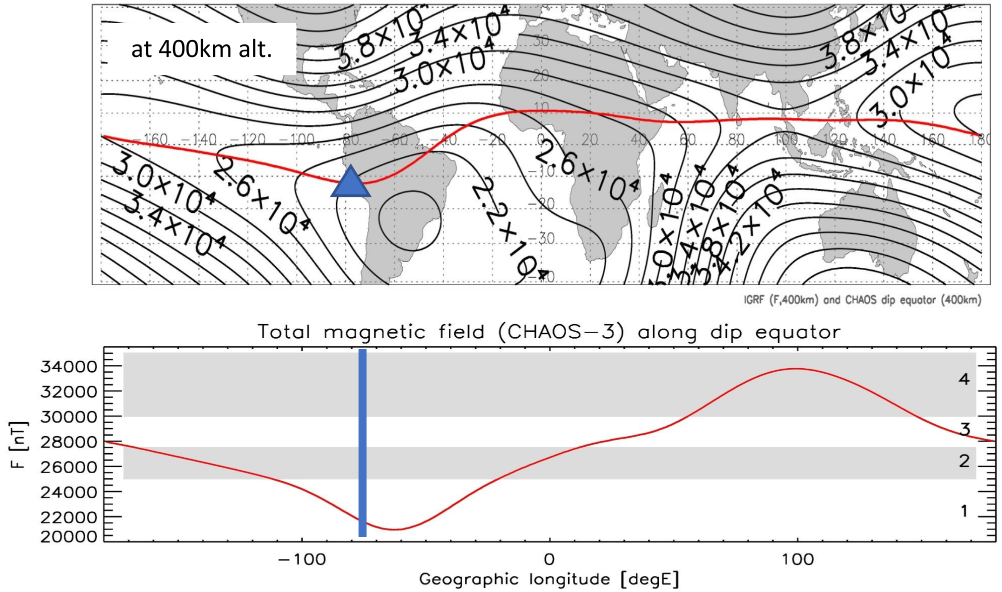
LEIBNIZ INSTITUTE OF ATMOSPHERIC PHYSICS IAP

JRO 60 25 July 2022

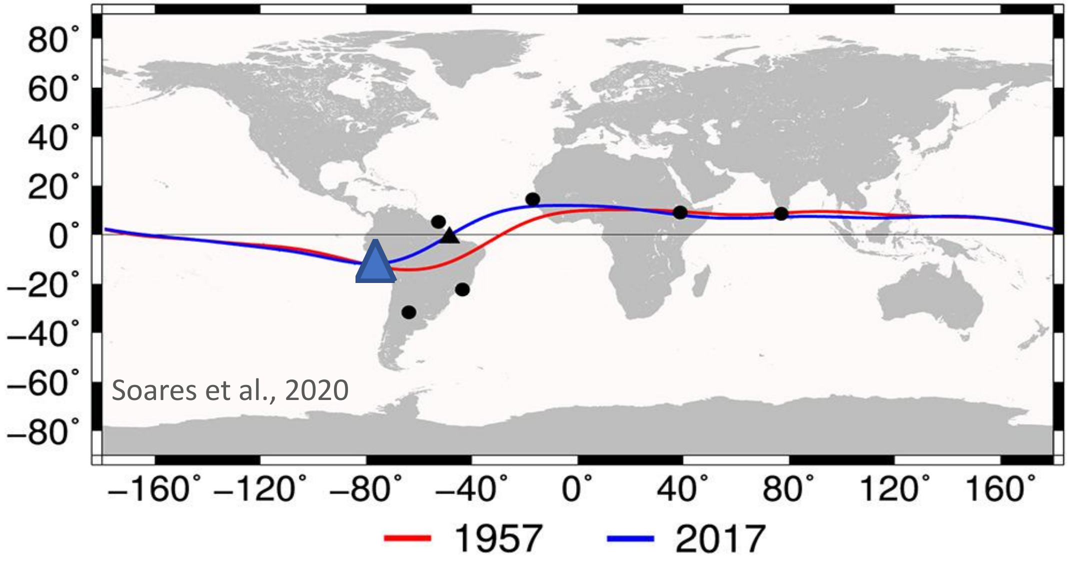
Leibniz Association

JRO location

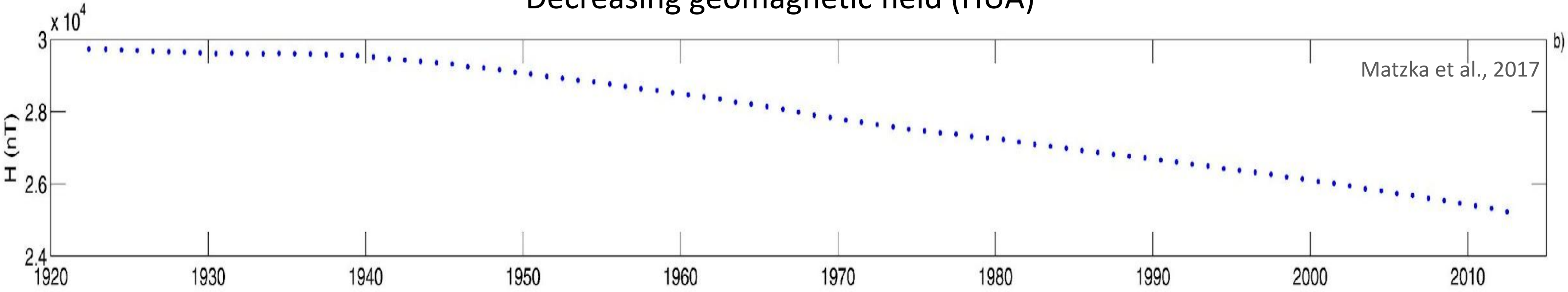
Lowest geomagnetic field



Southernmost location at the dip equator

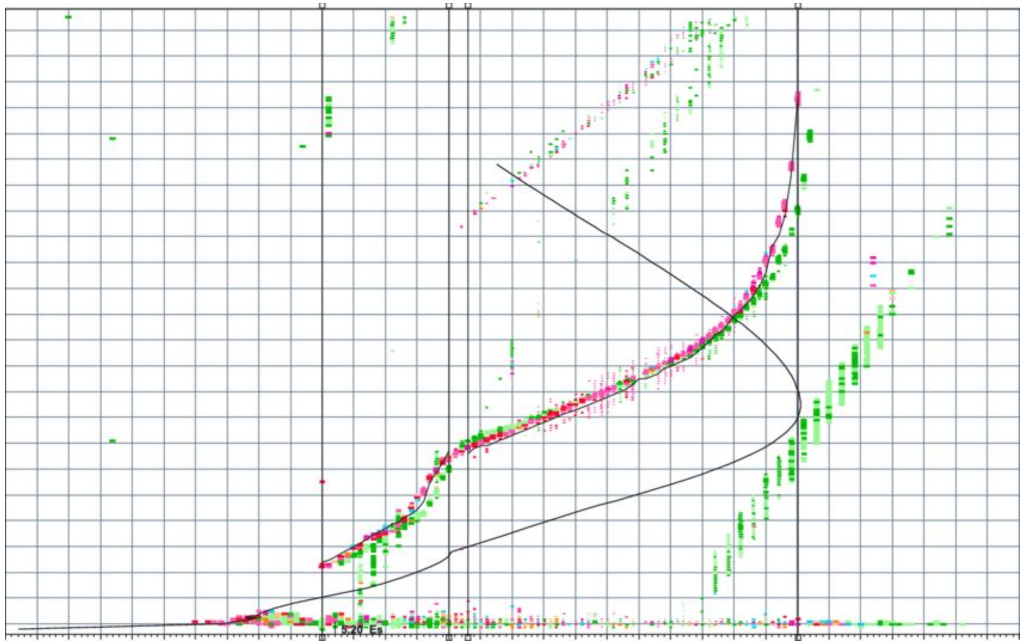


Decreasing geomagnetic field (HUA)



JRO multiple instrumentation

incoherent and coherent radar facilities

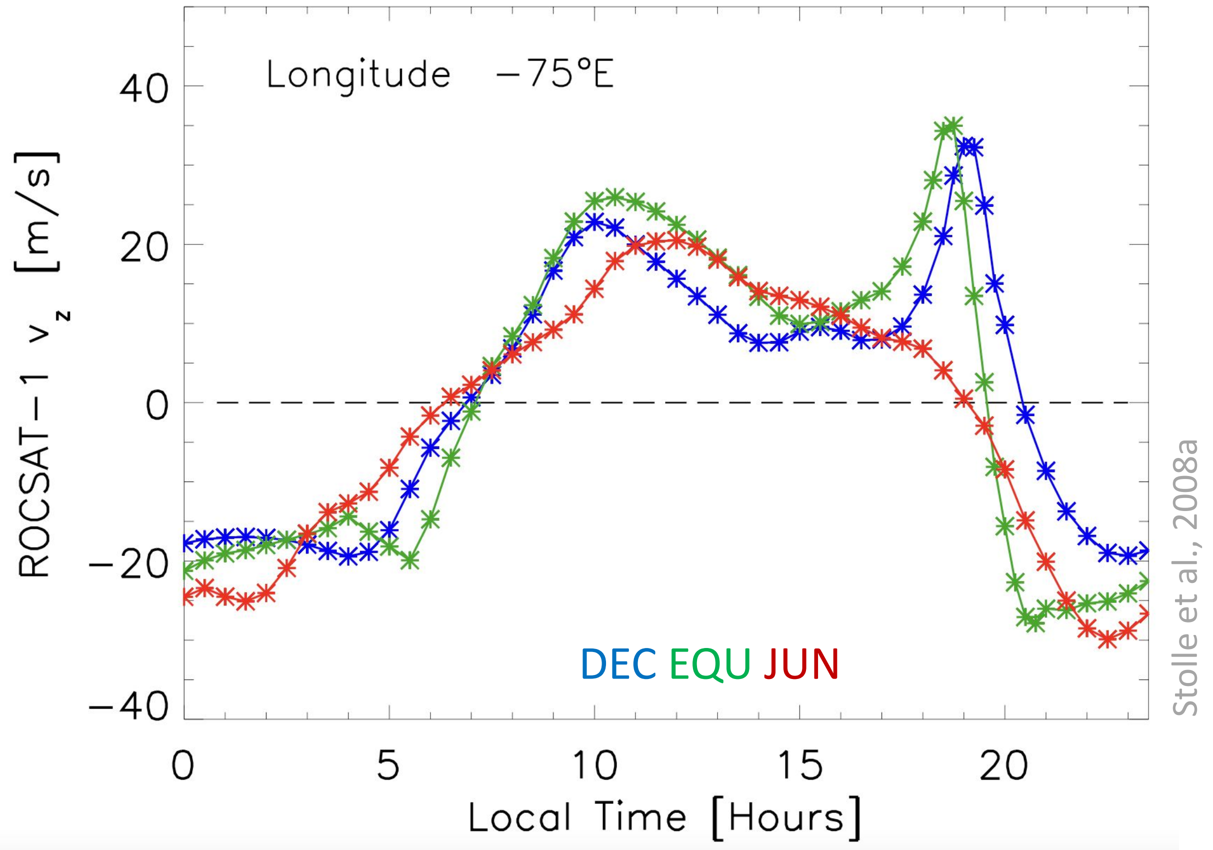


ionosonde

… magnetometer, GPS receiver, scintillation receivers, cameras, FPI, …

Vertical plasma drift

Vertical plasma drift at the magnetic equator
- related to horizontal electric field
- perpendicular to the magnetic field (I = 0°)

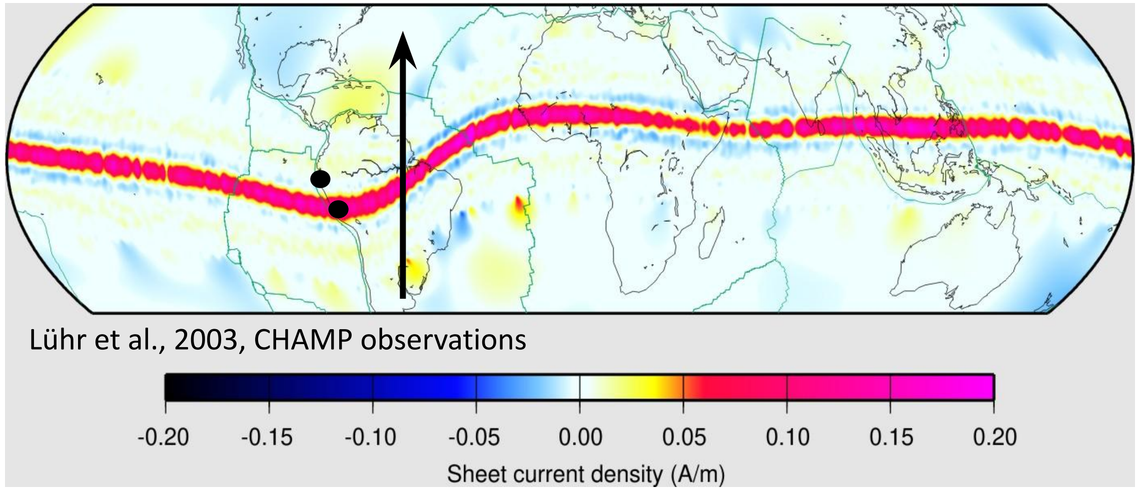


→ highly correlated with the daytime equatorial

→ drives the equatorial ionisation anomaly

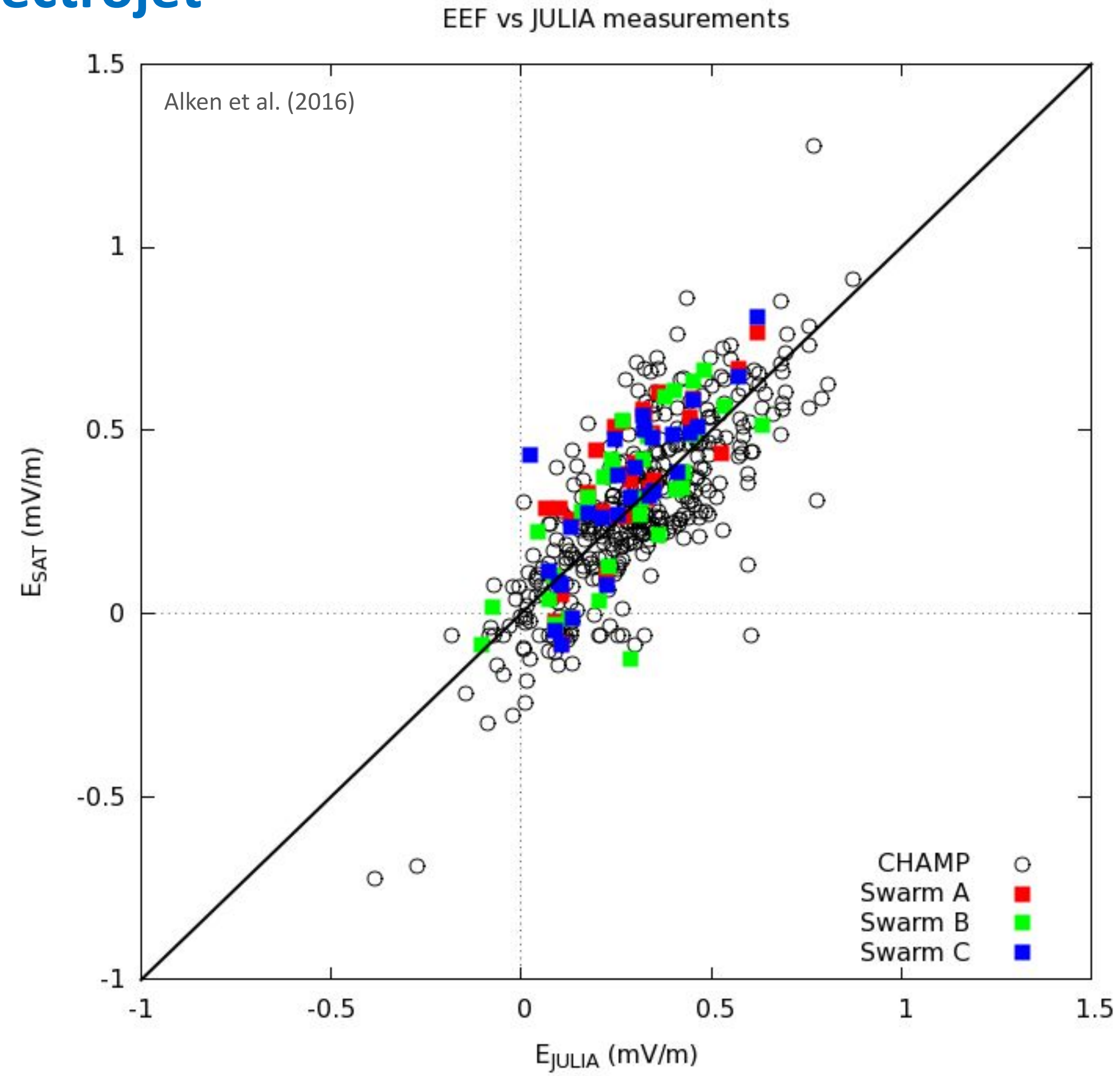
→ main driver of equatorial post-sunset plasma irregularities

Equatorial Electrojet



Ionospheric Ohm's Law $\mathbf{J} = \sigma \mathbf{E} + \sigma \mathbf{U} \times \mathbf{B}$

- $\mathbf{J}$: *current density*
- σ : *ionospheric conductivity*
- $\mathbf{E}$: *electric field*
- $\mathbf{U}$: *neutral wind velocity*
- $\mathbf{B}$: *magnetic field*



Equatorial Ionization Anomaly

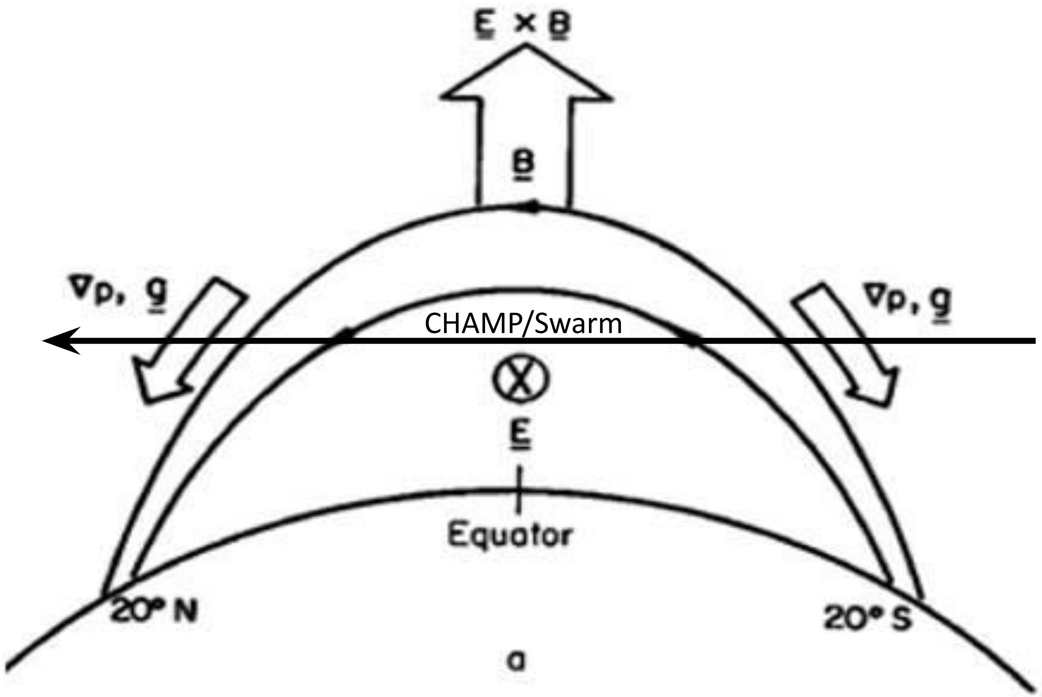
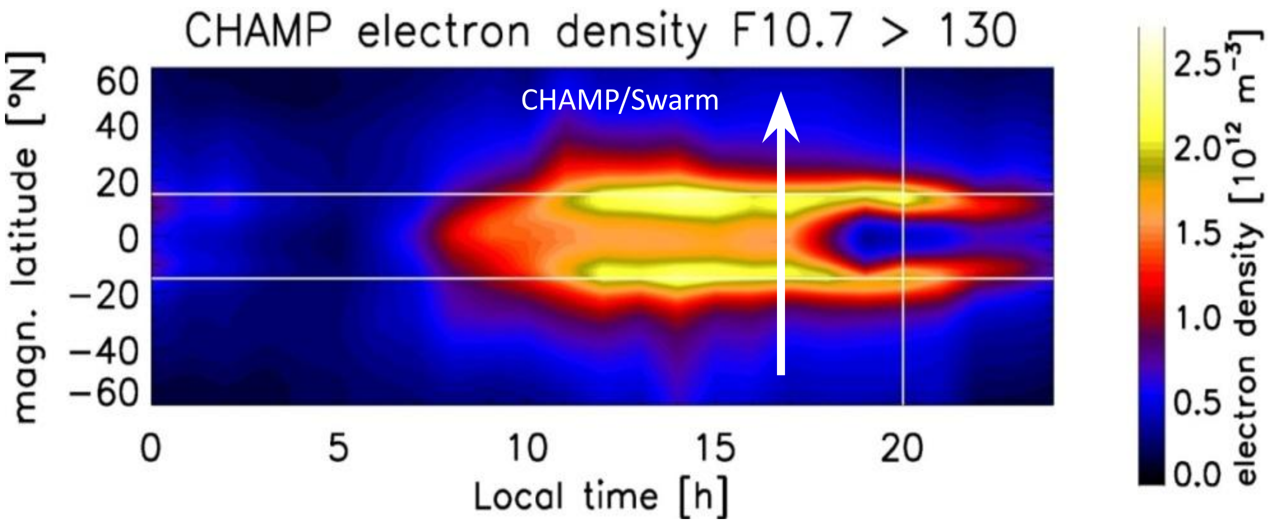
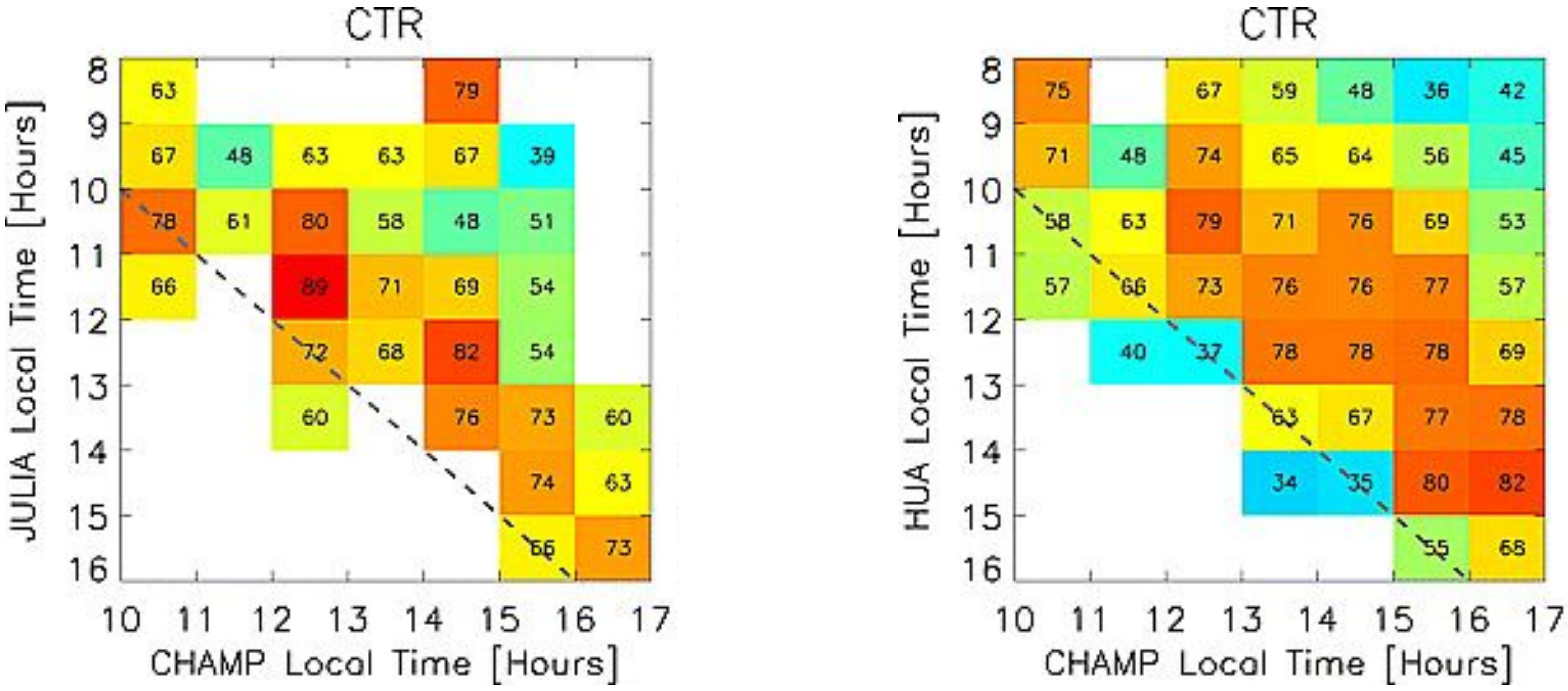


Figure 3 – Appleton Anomaly scheme.



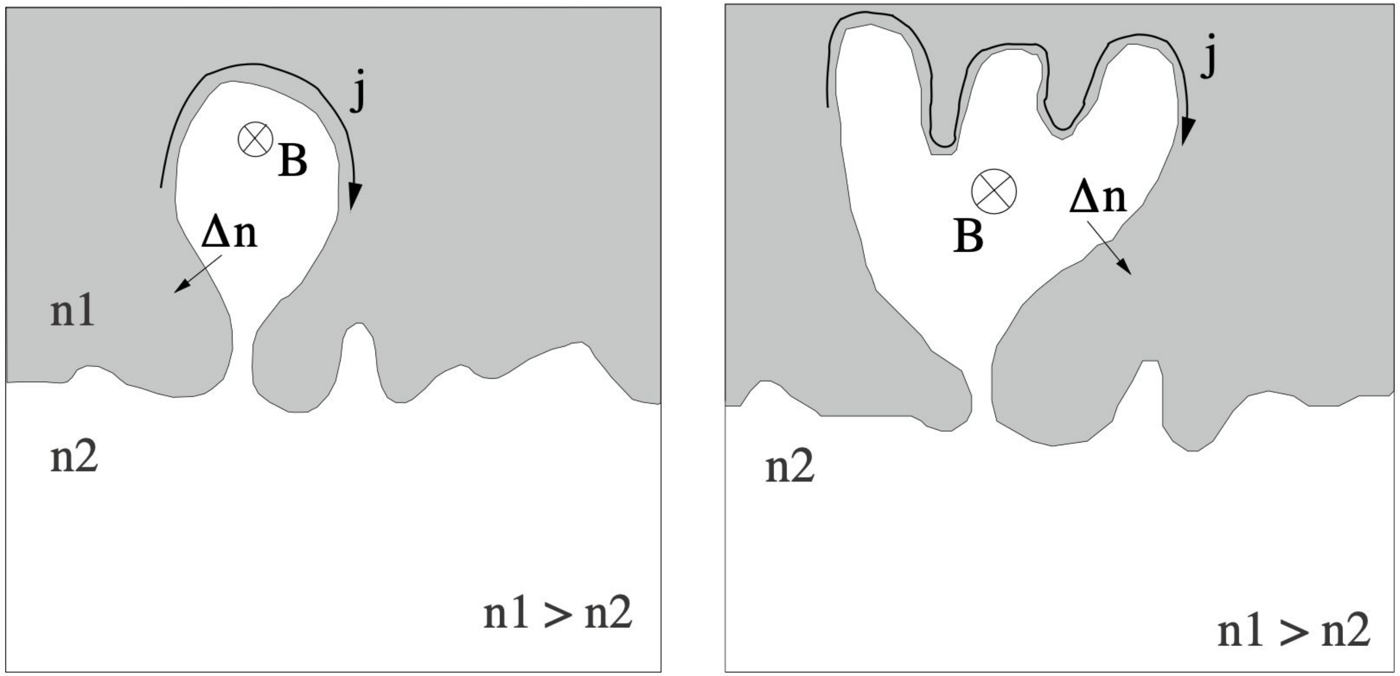
Equatorial Ionization Anomaly



Stolle et al., 2008a

- lower correlation between EIA and E-field than between EIA and EEJ
- Delay of EIA by about 3 hours to EEJ

Equatorial plasma plumes

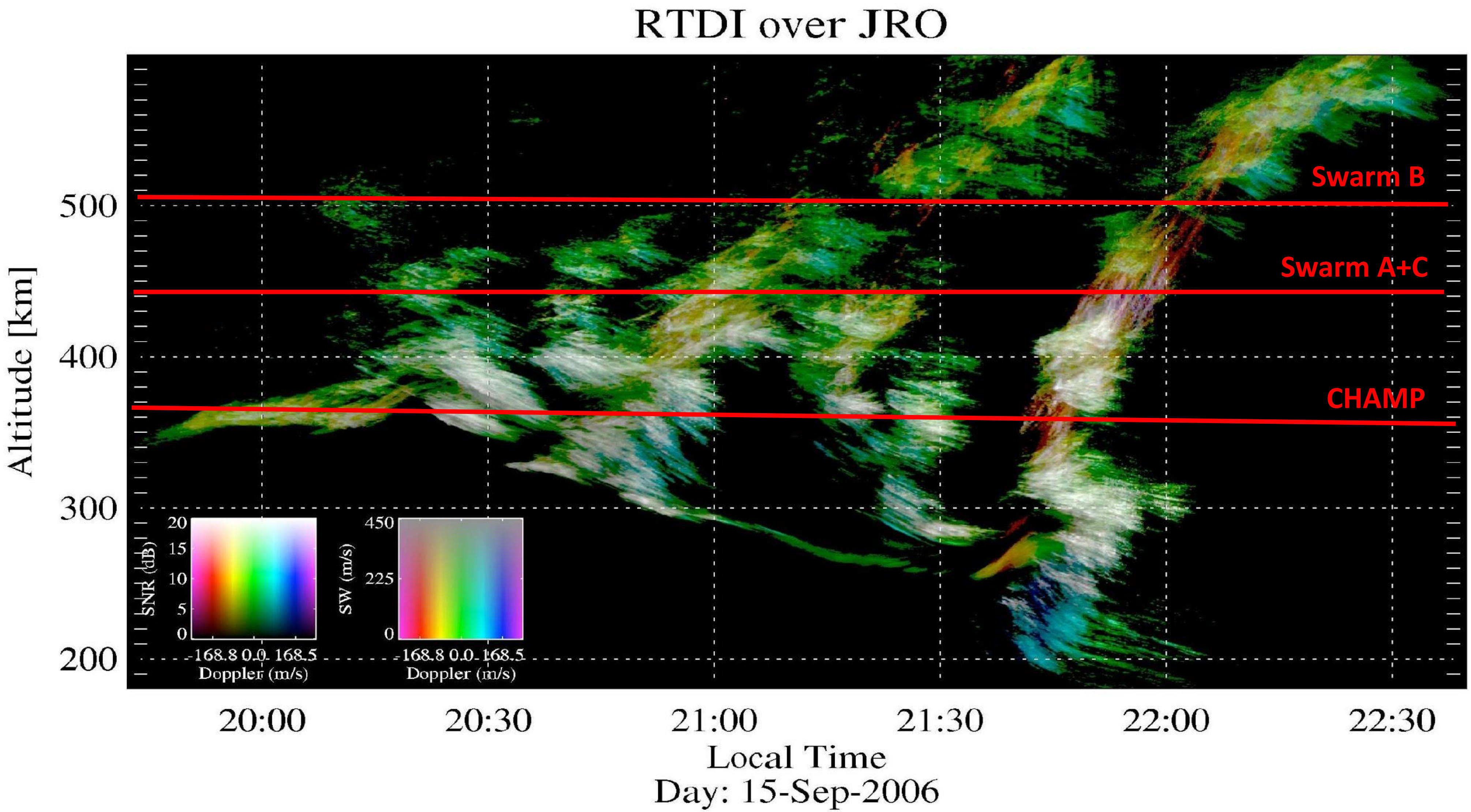


Generalized RTI – growth rate:

$$\gamma \approx \frac{\Sigma_P^F}{\Sigma_P^F + \Sigma_P^E}\left[\boldsymbol{v}_z - \frac{\boldsymbol{g}}{\nu_{in}}\right] \cdot \frac{\nabla n}{n_0}$$

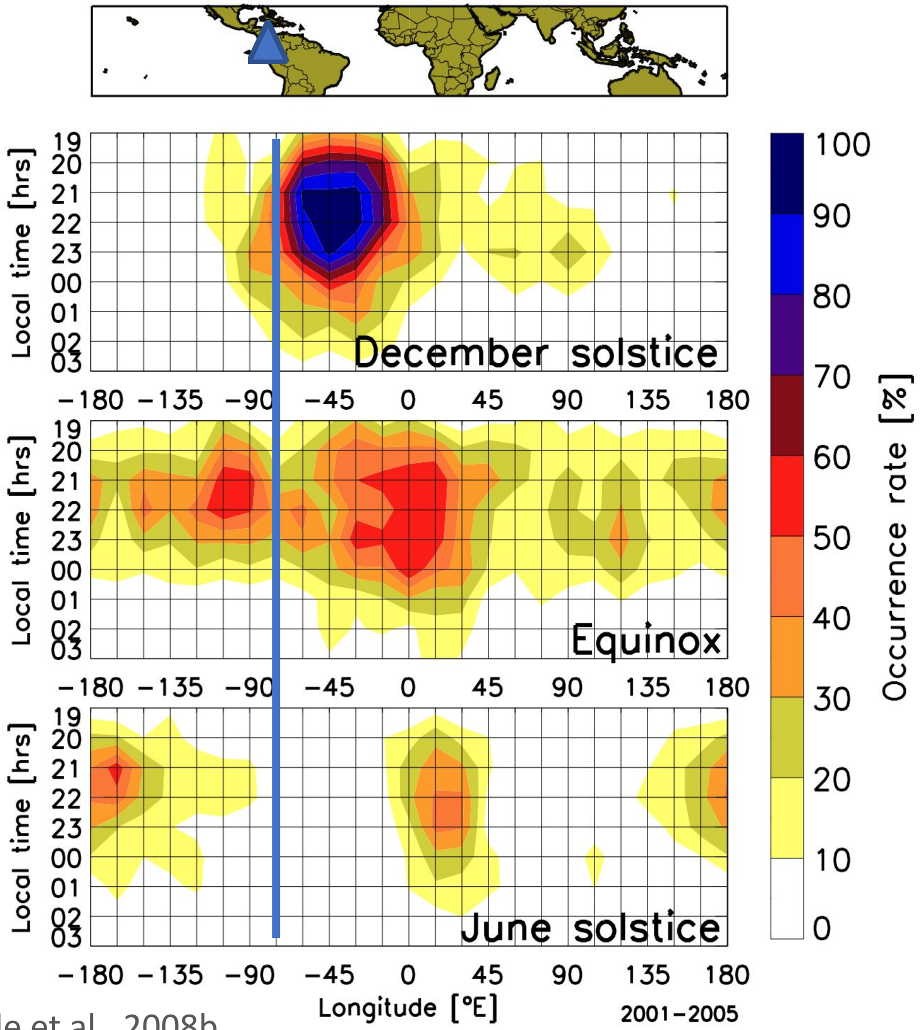
Ossakow, 1981

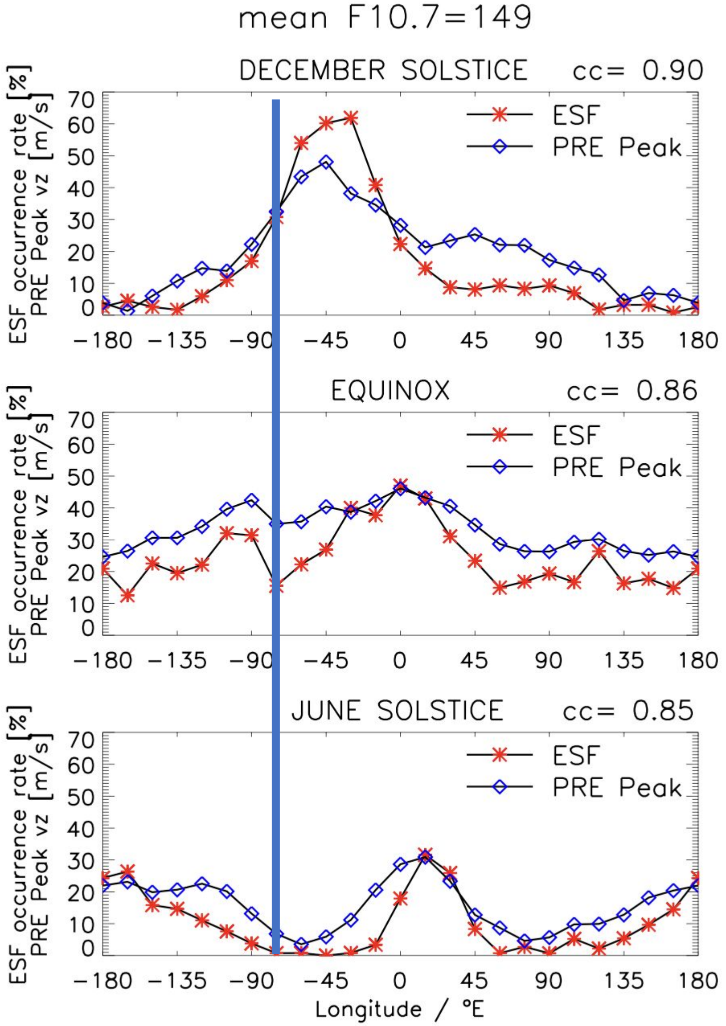
Equatorial plasma plumes



Equatorial plasma plumes

CHAMP + ROCSAT

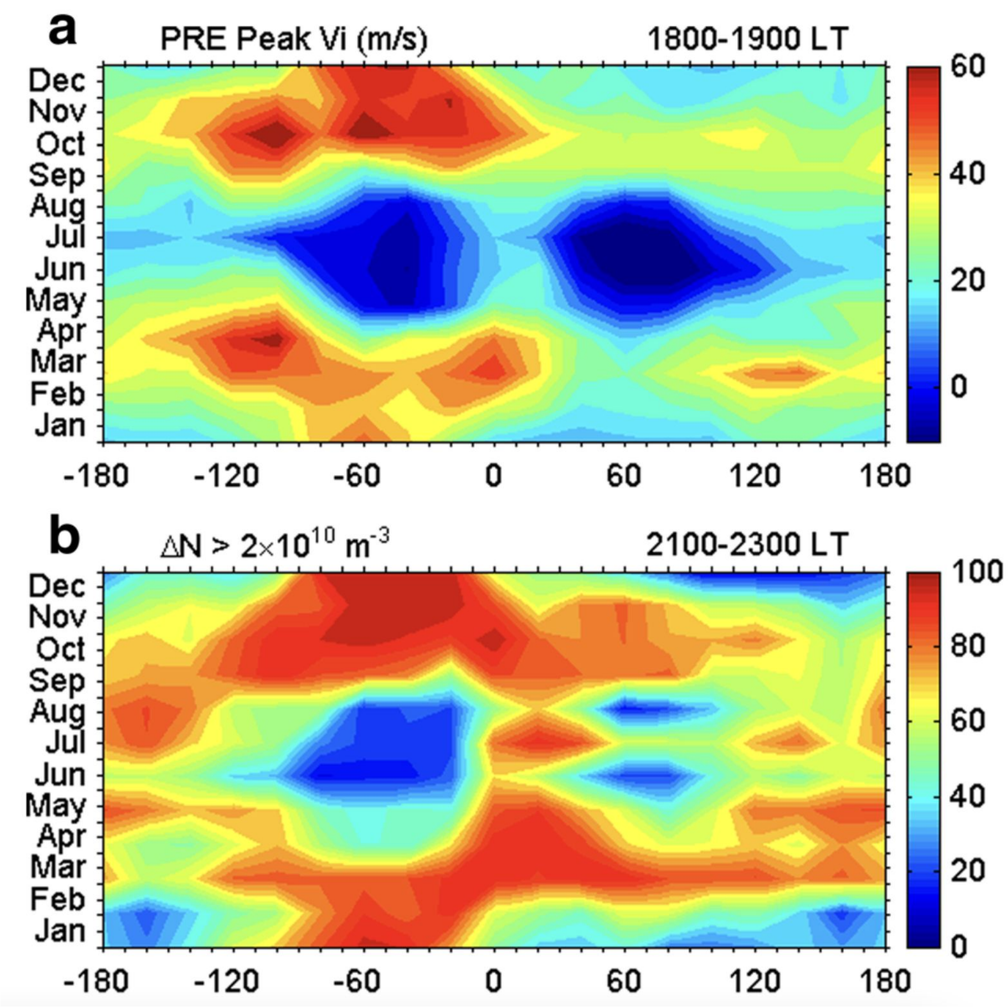




Stolle et al., 2008b

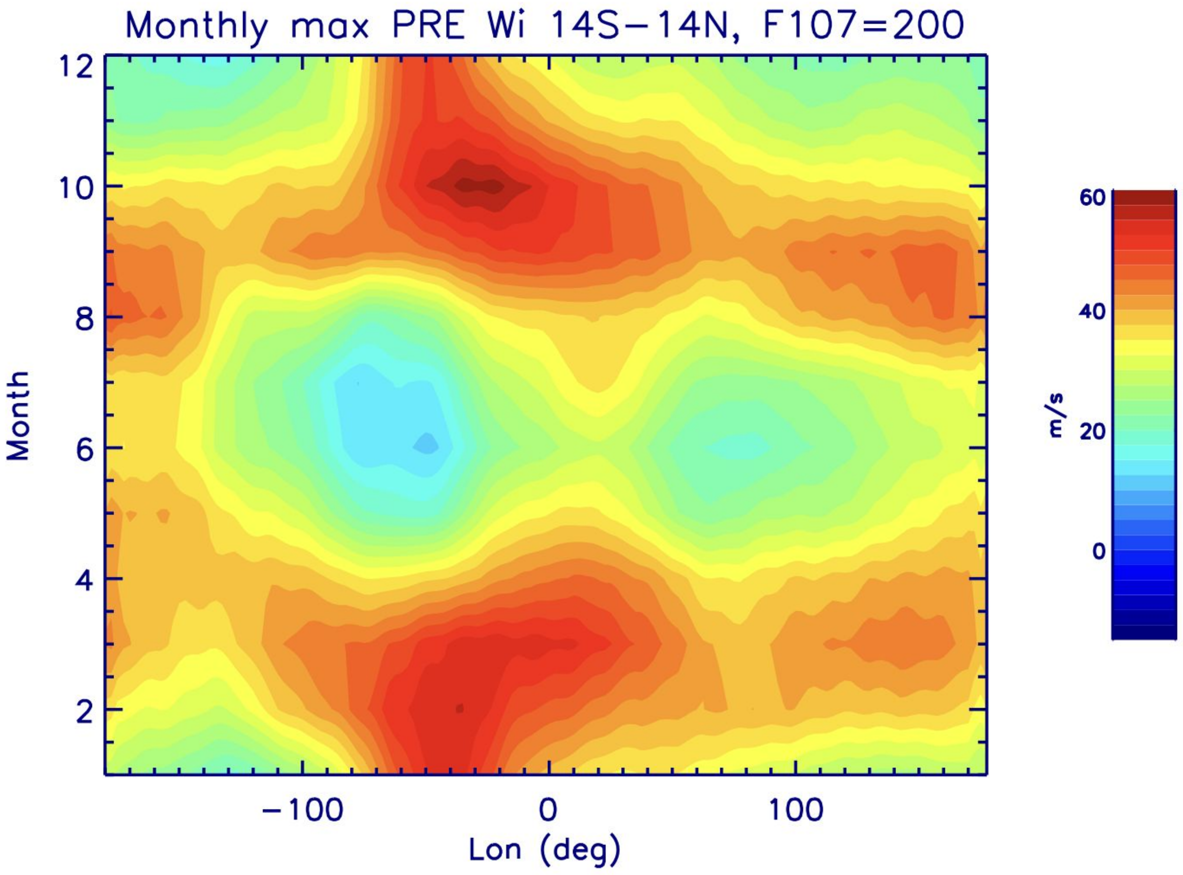
Equatorial plasma plumes

CNOF/S



Huang et al., 2014

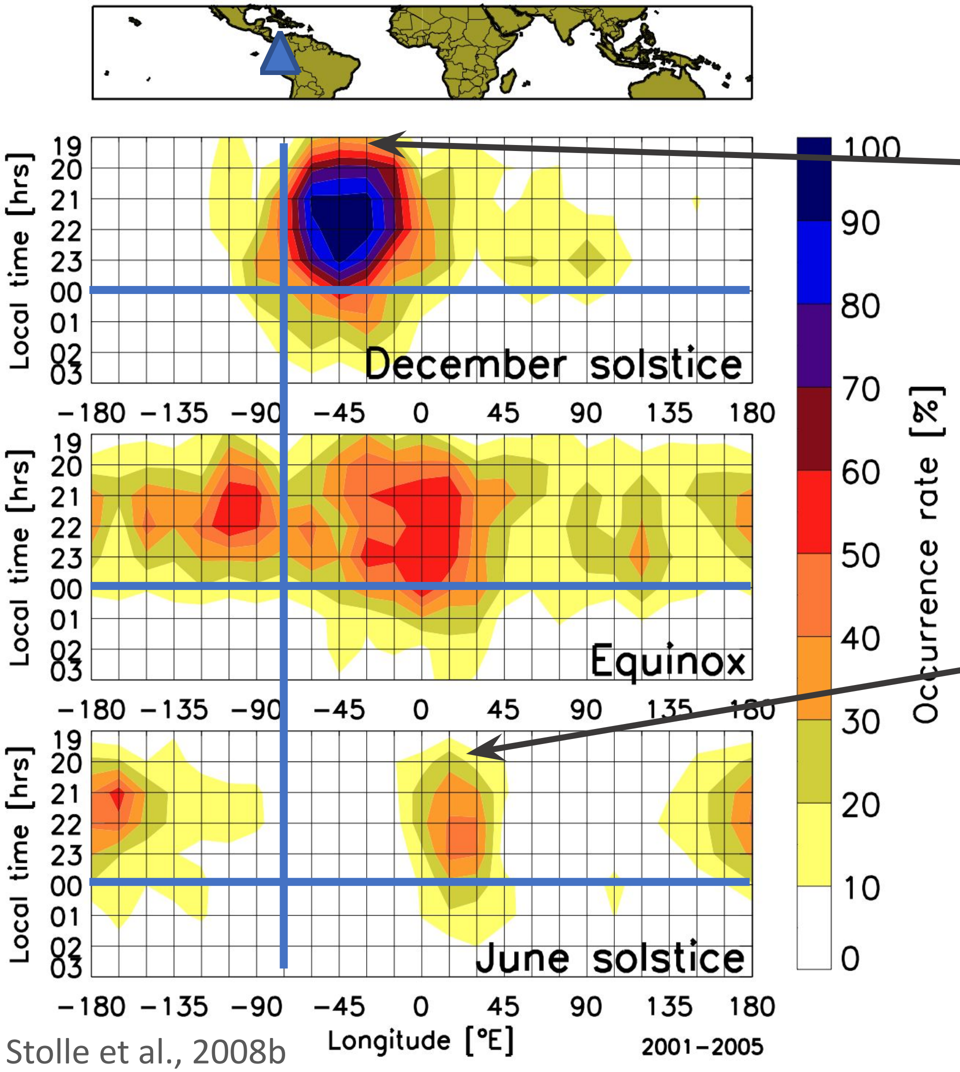
WACCM-X



Liu, H.-L. et al., 2018

Equatorial plasma plumes

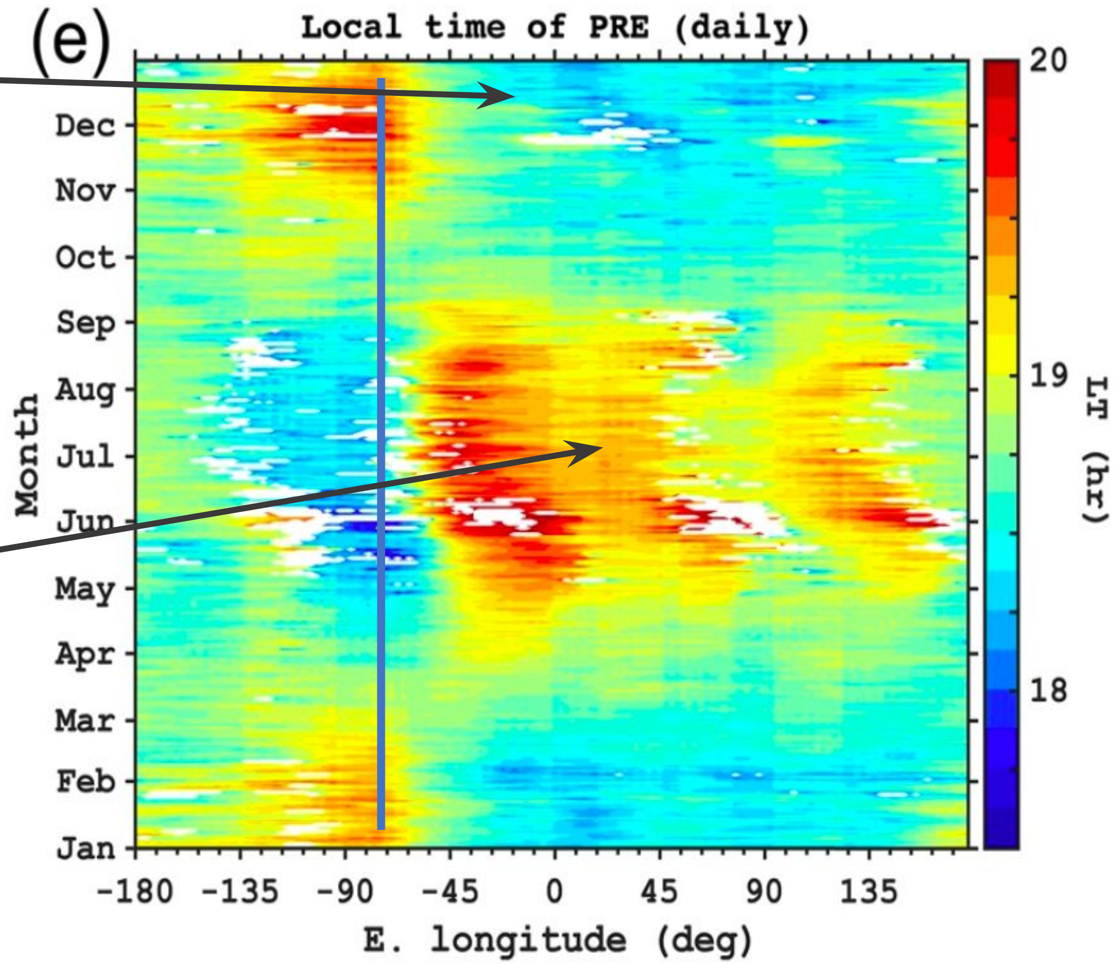
CHAMP



Stolle et al., 2008b

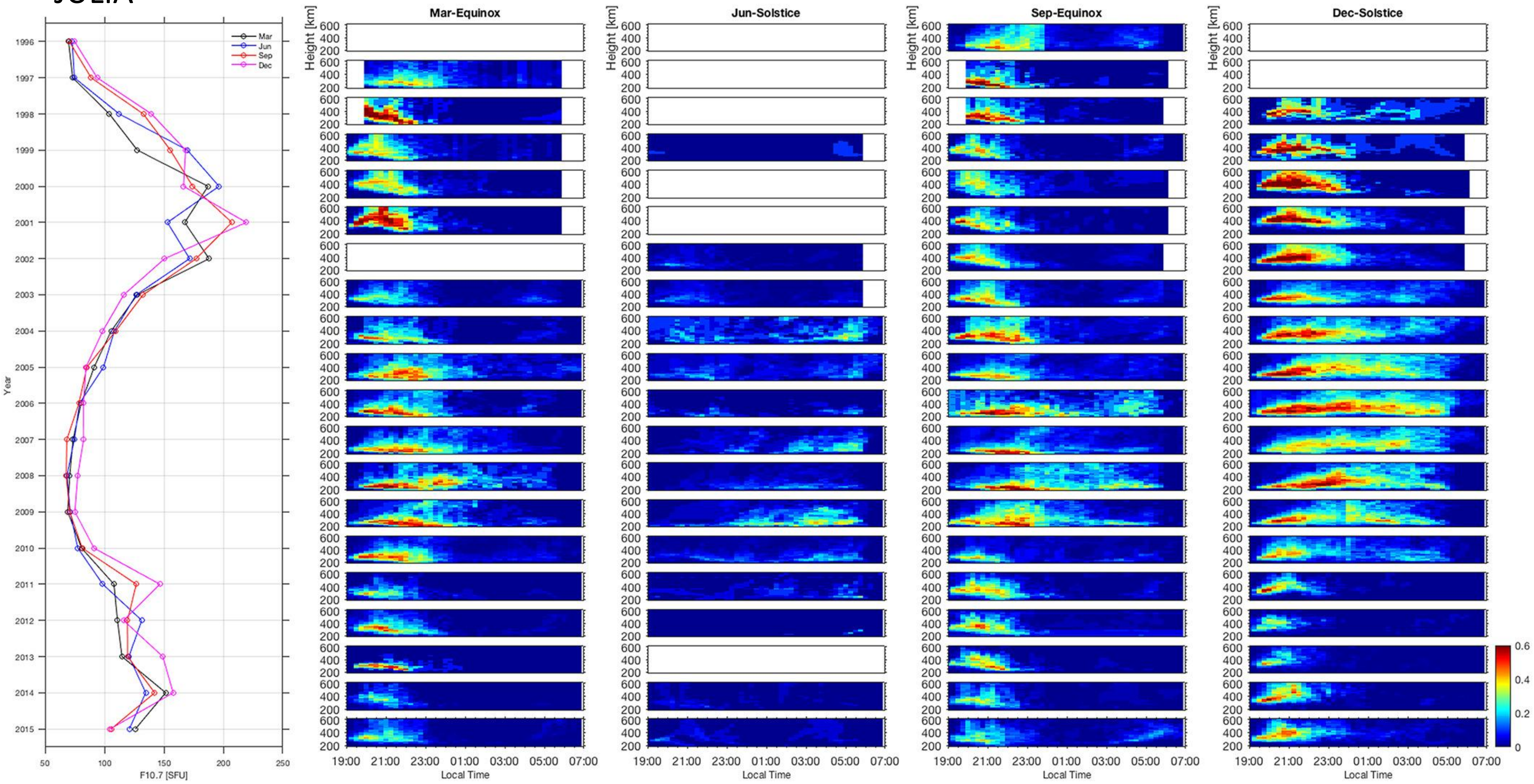
TIE-GCM

Yamazaki and Dieval, 2021



Equatorial plasma plumes

JULIA



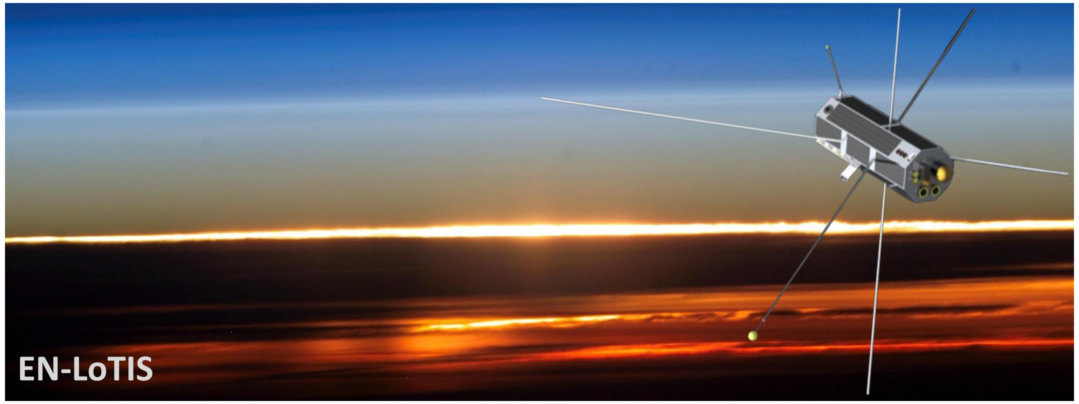
Zhan et al., 2018

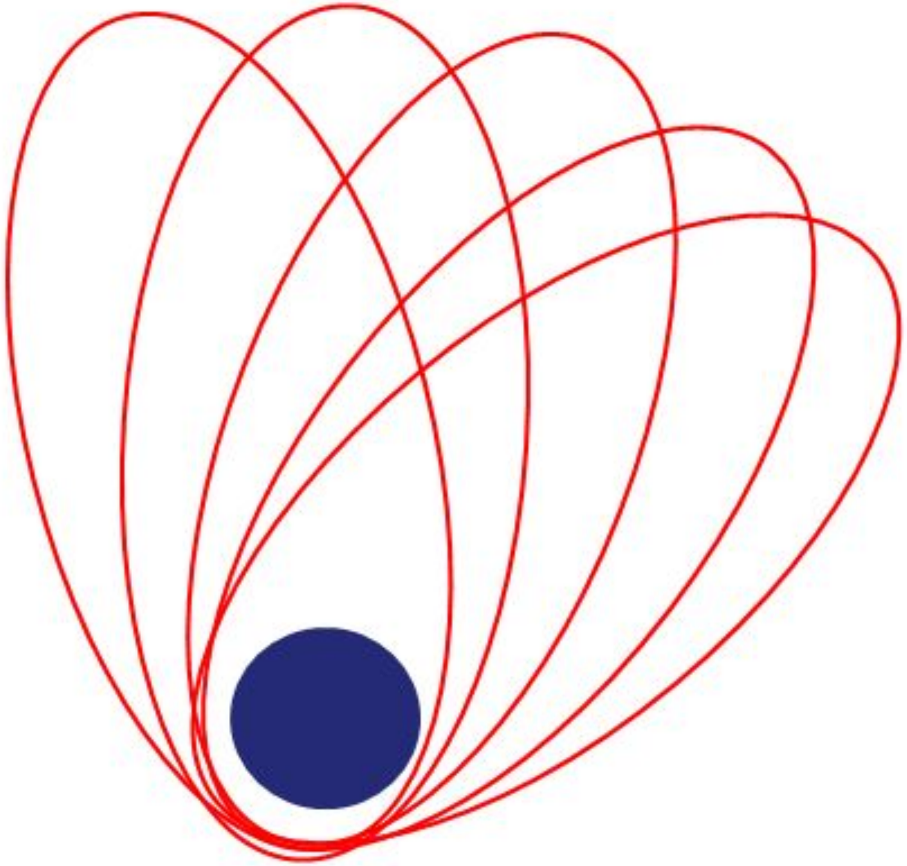
In situ observations of the Lower Thermosphere

EN-LoTIS-WG (Since 2022)

ESA/NASA Lower Thermosphere Ionosphere Science Working Group

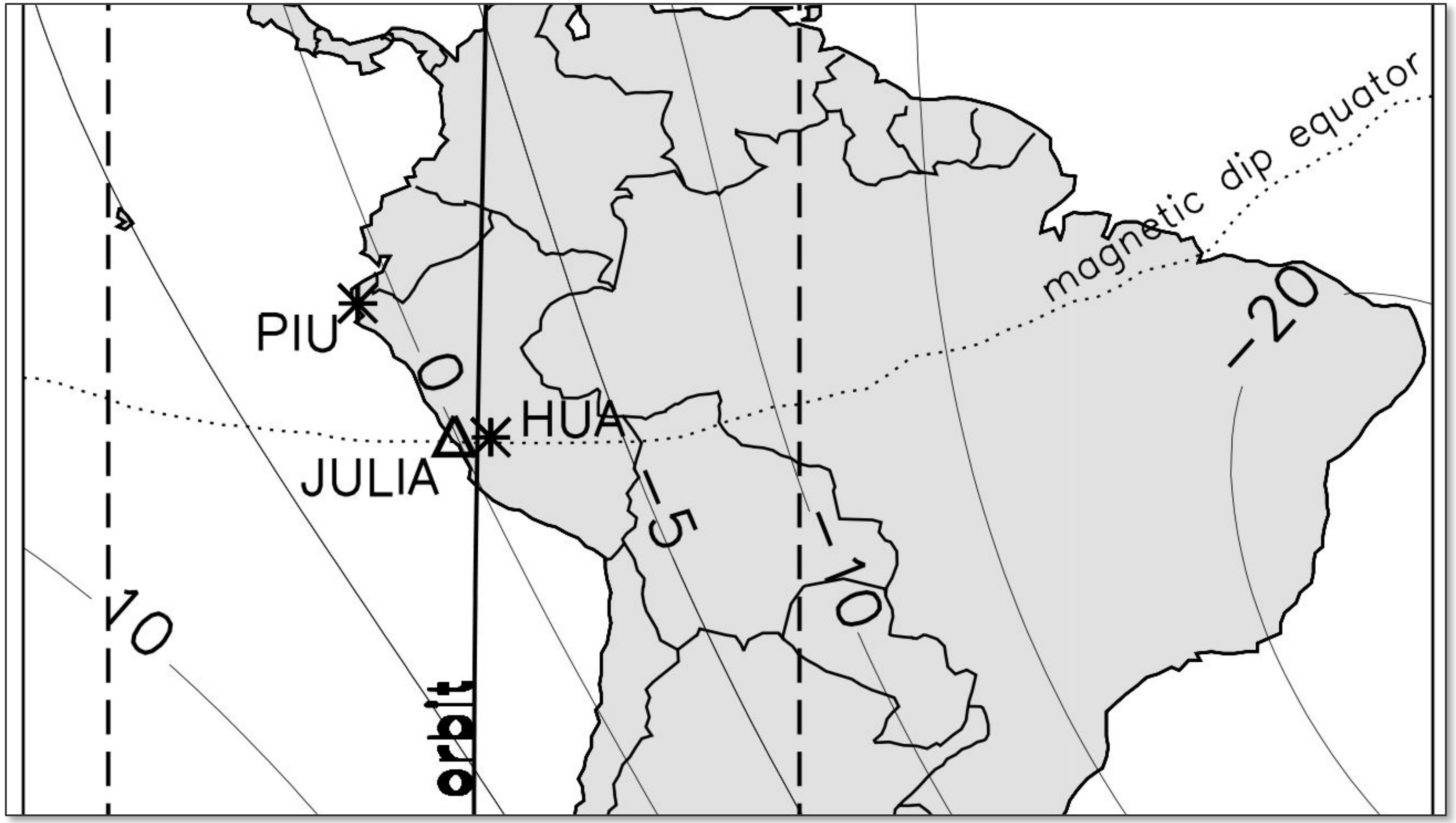
- Explore cooperation on future lower thermosphere-ionosphere satellite mission reference concepts, **targeting very low orbiting in situ sampling** between **150 – 200 km**





Top-located Jicamarca observatory indispensable for

- Multiparameter analysis of equatorial aeronomy
- Day-to-day variations vs. climatological observations
- Fully exploiting global/satellite observations

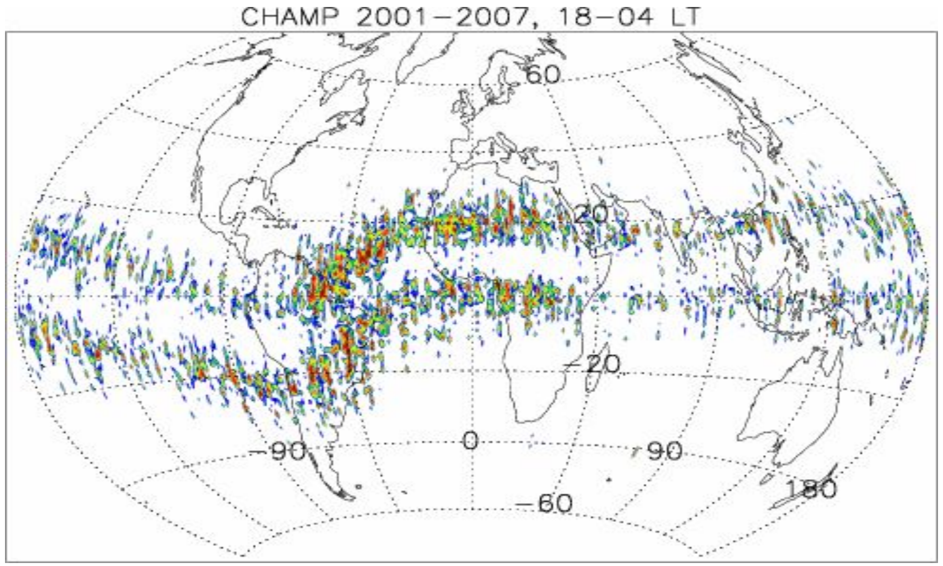


Empirical model of equatorial plasma plumes

CHAMP:

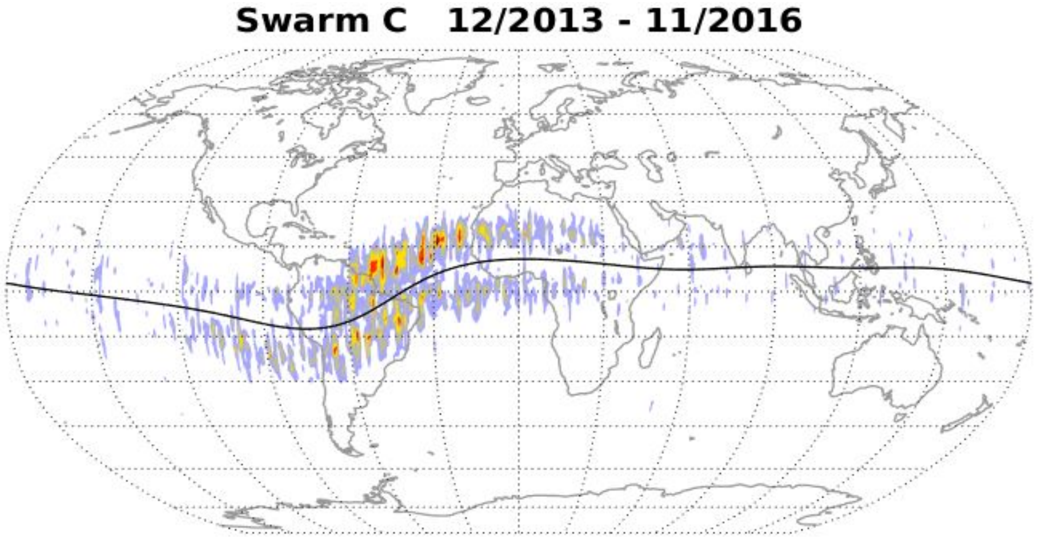
Years: 2000-2010
Altitude: 300-480km
Detection threshold: 0.25nT

Declining solar cycle 23 (F10.7>80sfu)



Swarm:

Years: 2013-2022 - Swarm A,B,C
Altitude: 450-520km
Detection threshold: 0.15nT
cc with e-density: >0.7
Declining solar cycle 24 (F10.7>80sfu)



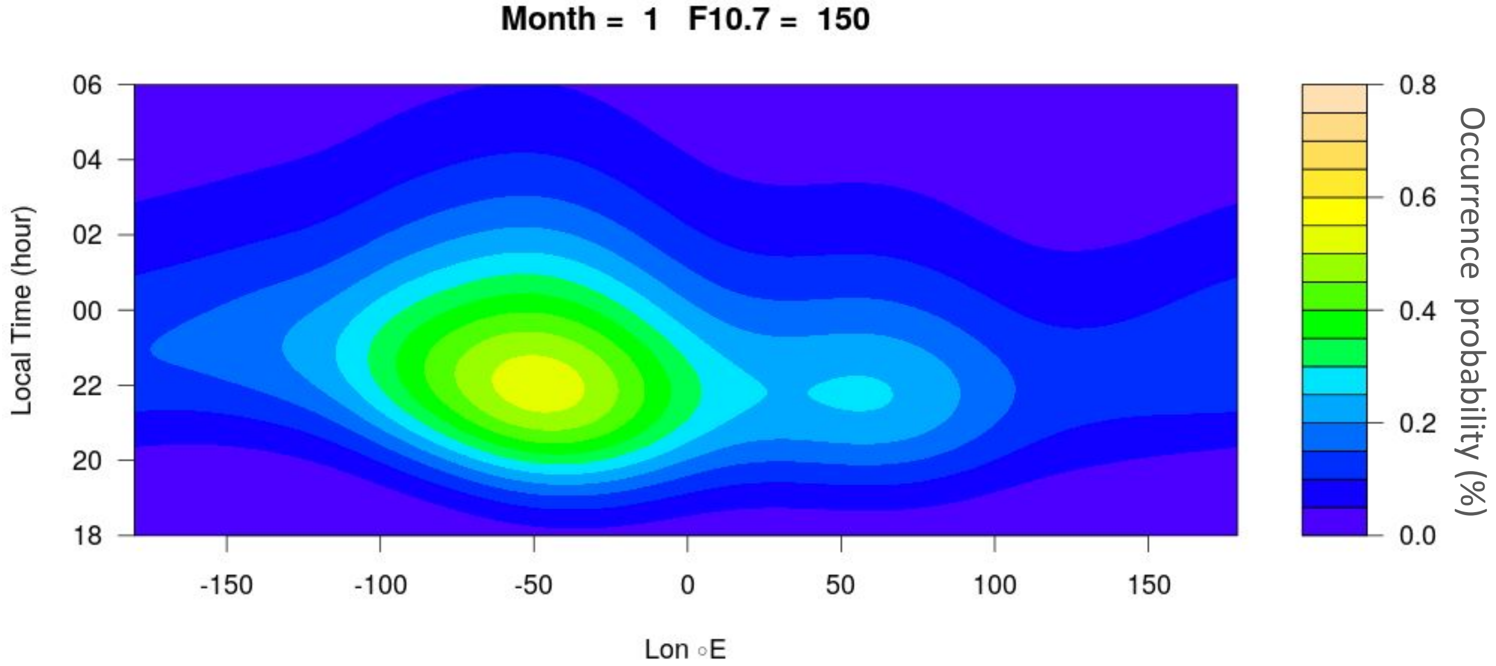
Empirical model of equatorial plasma plumes

Input:

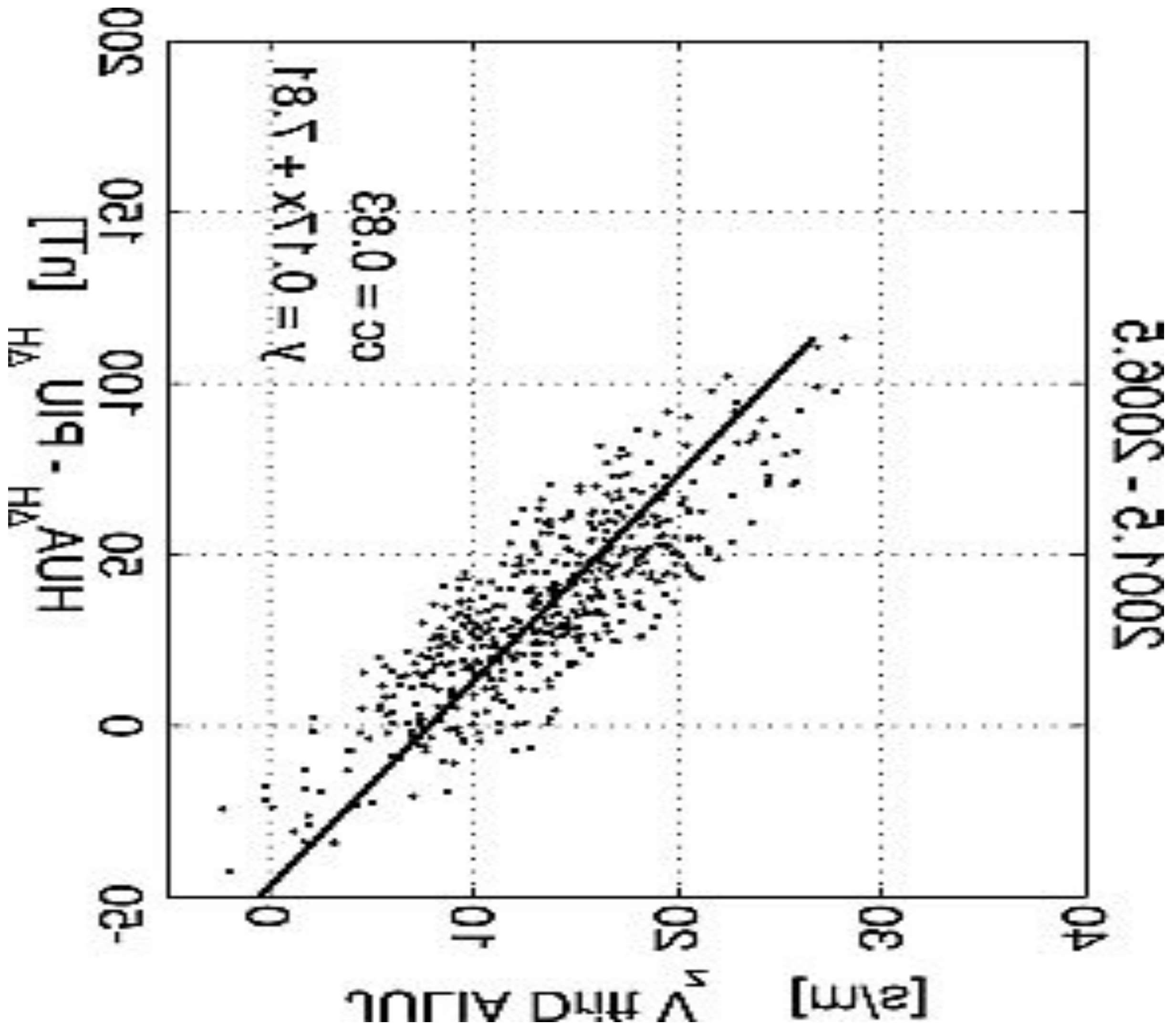
− local time
− longitude
− month
− solar flux

Output:

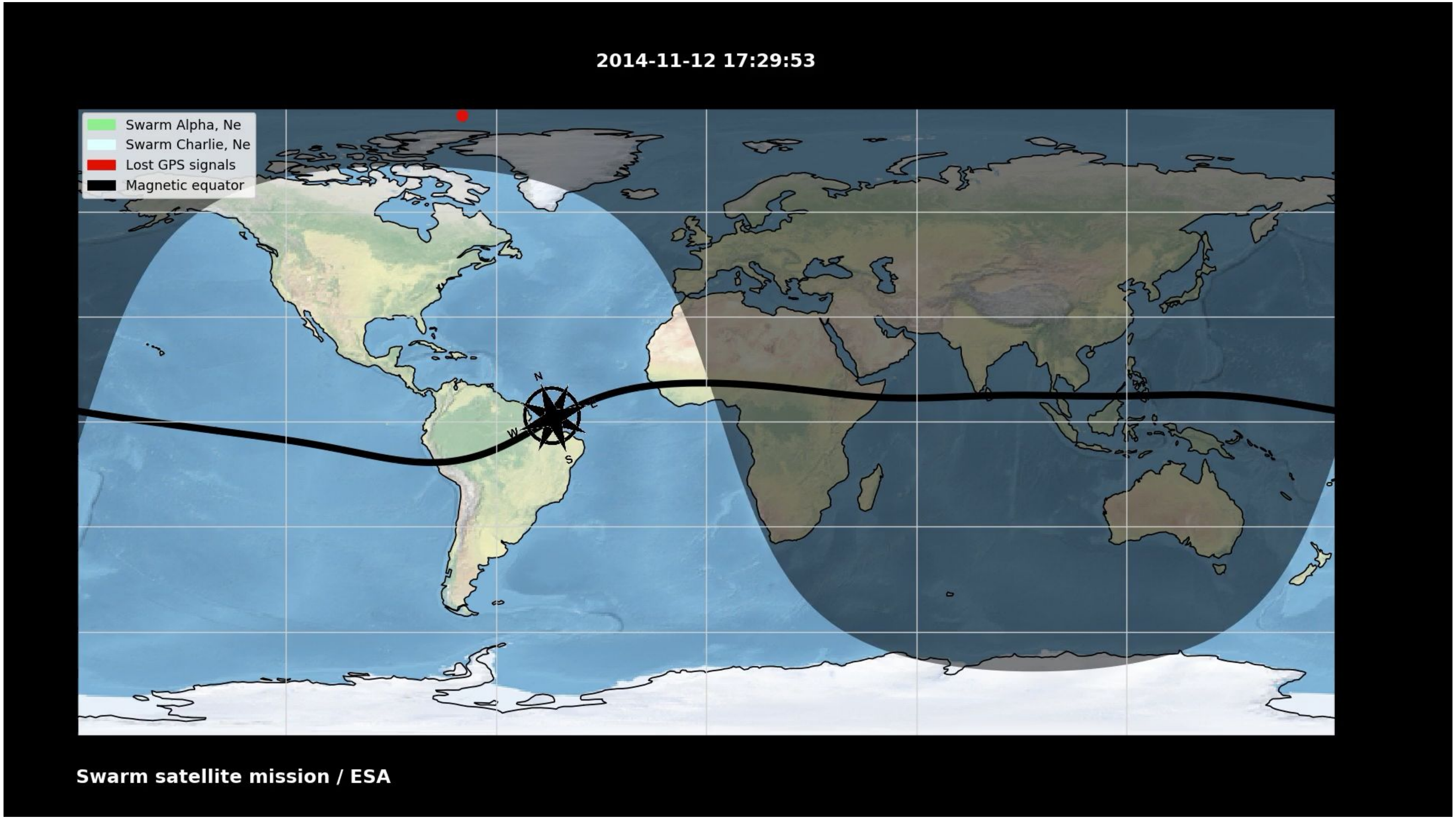
− Occurrence probability



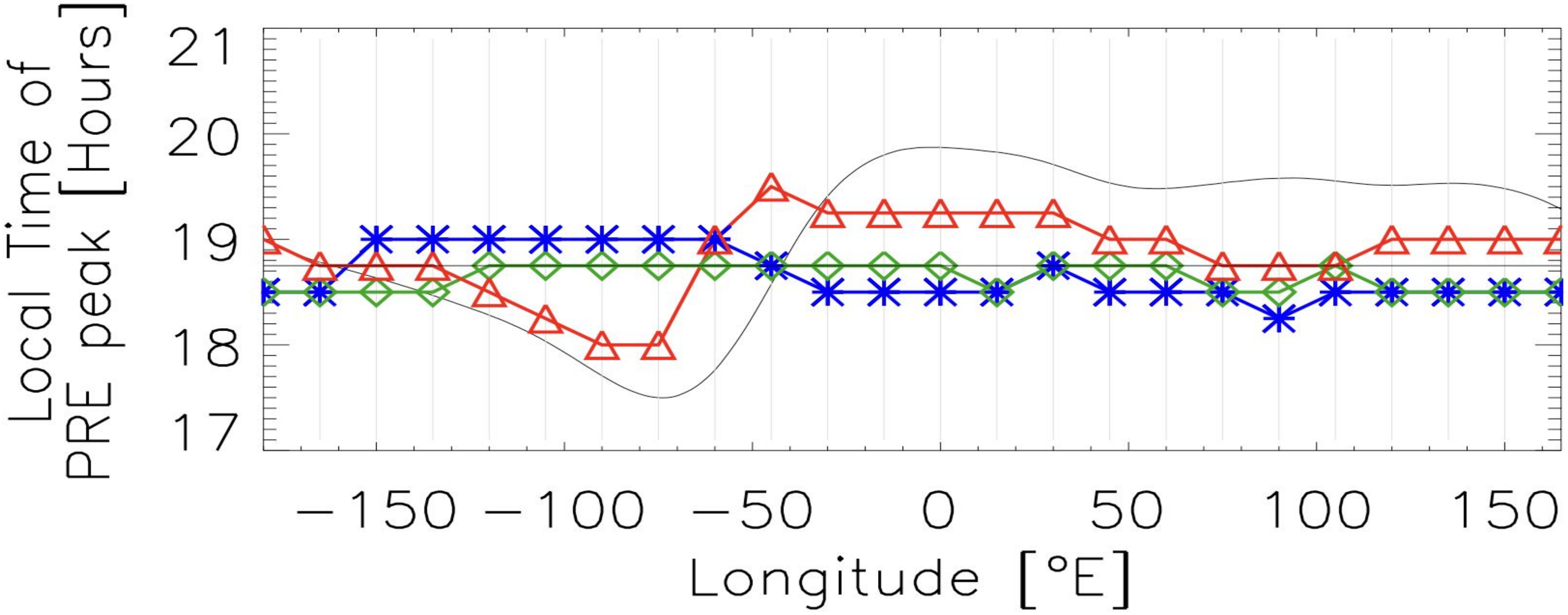
- empirical model on occurrence probability of equatorial plasma depletions between 350-520km altitude, for 200> F10.7> 80
- forward modelling code (FORTRAN, Python) will be available within Swarm ESA-DISC



HUA_VHF - Piura_VHF [nT]
y = 0.17x + 18.7
cc = 0.83
2001.5 - 2009.5
JULIA Drift V_z [m/s]



2014-11-12 17:29:53
Swarm Alpha, Ne
Swarm Charlie, Ne
Lost GPS signals
Magnetic equator
N
W
S
Swarm satellite mission / ESA



Local Time of
PRE peak [Hours]
21
20
19
18
17
−150
−100
−50
0
50
100
150
Longitude [°E]