3D geolocation of ionospheric plasma irregularities by combination of RO, in situ, and ground-based GNSS measurements

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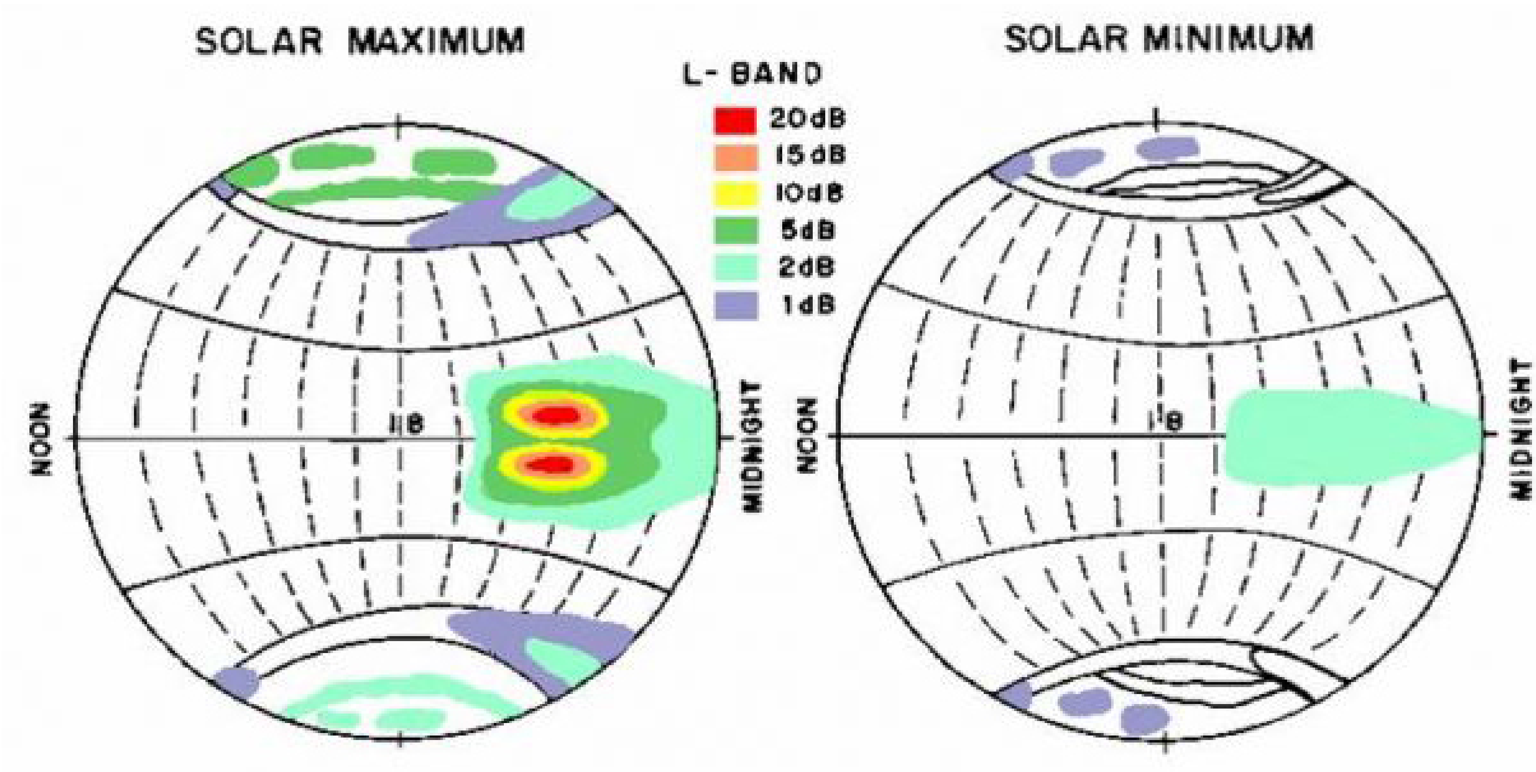
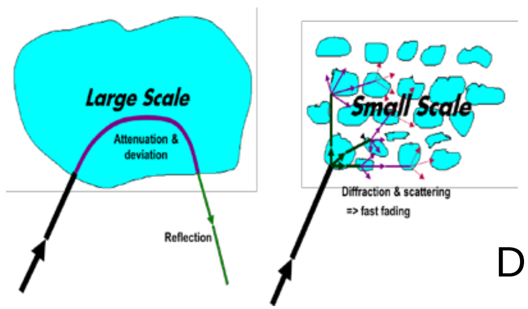
UNIWERSYTET WARMIŃSKO-MAZURSKI W OLSZTYNIE

Ionospheric plasma irregularities. Global distribution

Occurrence of L band scintillation during high and low solar activity

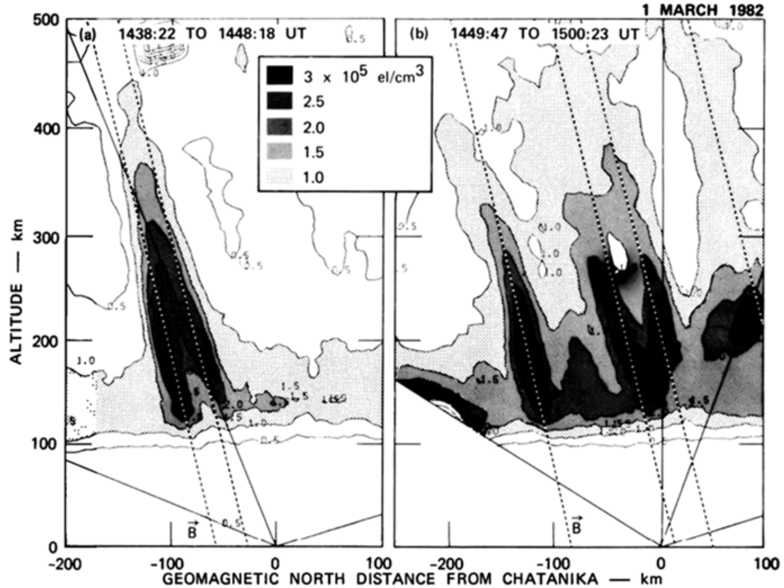


(Basu. et al., J. Atmos. Terr. Phys, 2002)

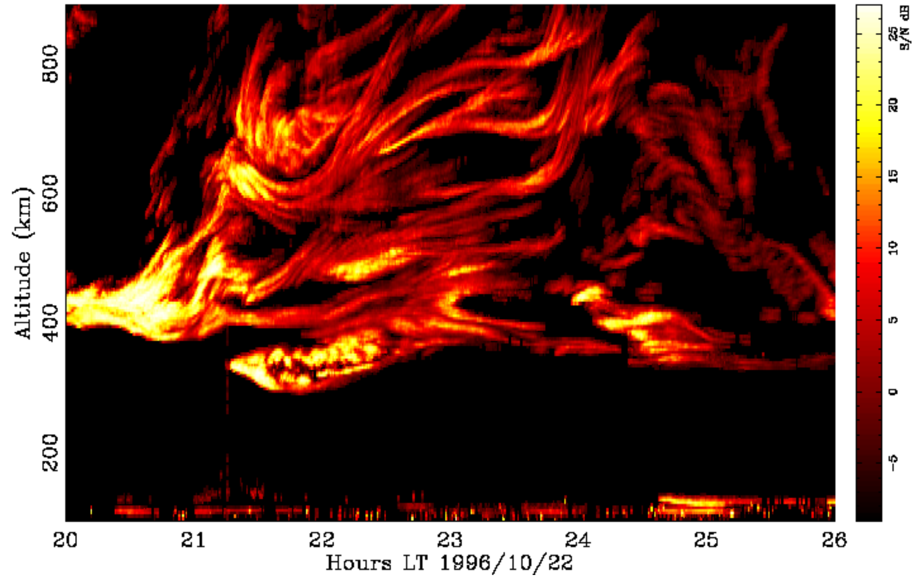


Different physical drivers leading to the structures generation

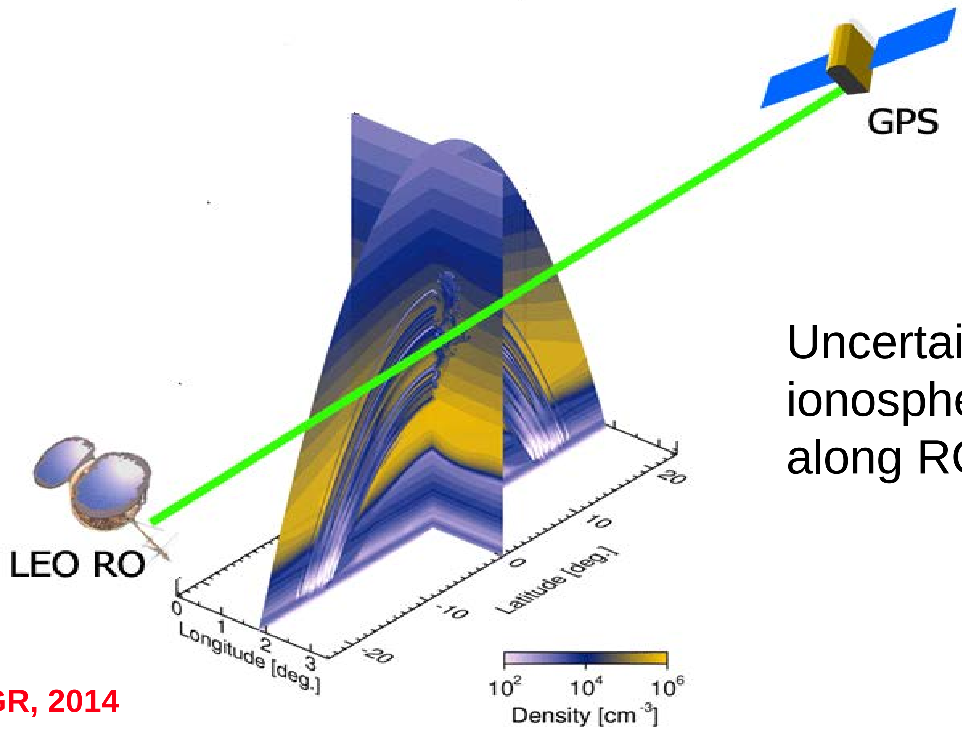
Spartial structure of ionospheric plasma irregularities



High-latitude irregularities over Chatanika incoherent scatter radar



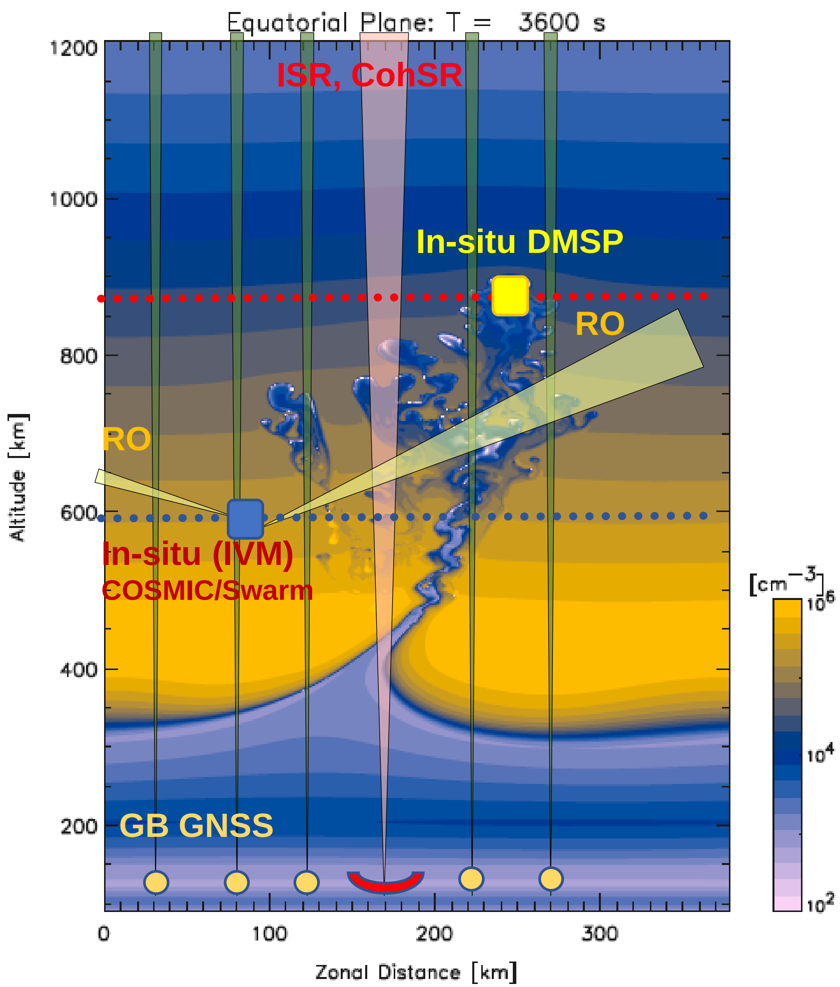
Altitudinal extent of equatorial irregularities observed by Jicamarca radar



Uncertainties to locate ionospheric plasma irregularities along RO line of sight

On base of Yokoyama et al., JGR, 2014

Mutiinstrumental approach to specify 3d structure of ionospheric plasma irregularities



Challenge - source of irregularities / scintillations location and size estimation by single instrument

Using multiply instruments to detect plasma irregularities in 3D

On base of Yokoyama et al., JGR, 2014

Ionospheric irregularities signatures in GNSS measurements

Ionospheric irregularities can be characterized by measuring its impact on amplitude and phase of the received GPS signal.

Pi et al. [GRL, 1997] introduced into the use two GPS-based indices:

• **ROT** (Rate of TEC change, dTEC/dt) as a measure of GPS signal phase fluctuations

$$\mathrm{ROT} = \frac{\mathrm{sTEC}_k^i - \mathrm{sTEC}_{k-1}^i}{t_k - t_{k-1}}$$

• **ROTI** (Rate of TEC Index, standard deviation of ROT) characterizes the severity of the GPS phase fluctuations

$$\mathrm{ROTI} = \sqrt{\langle \mathrm{ROT}^2 \rangle - \langle \mathrm{ROT} \rangle^2}$$

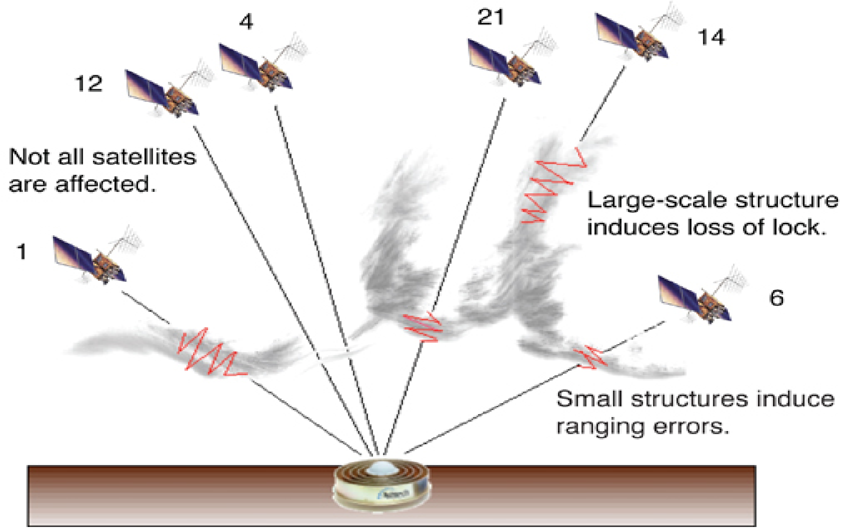
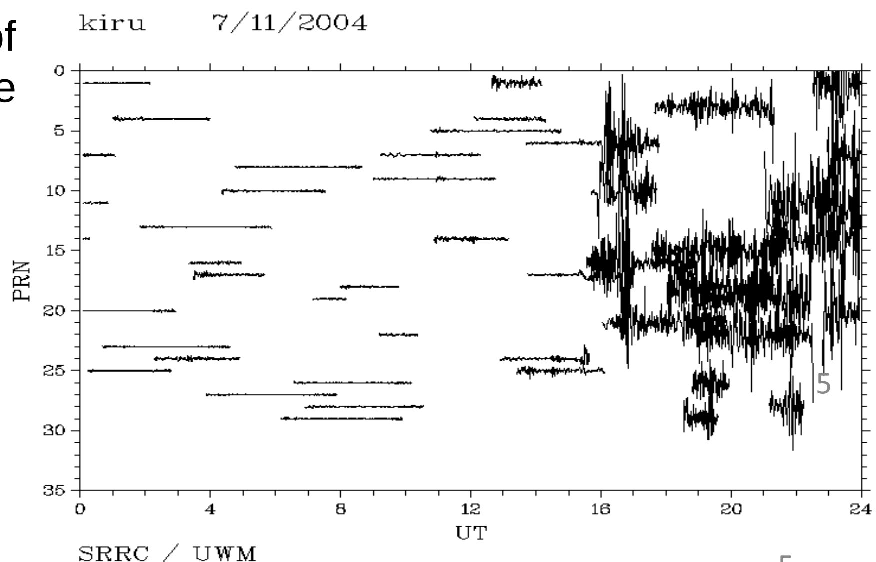
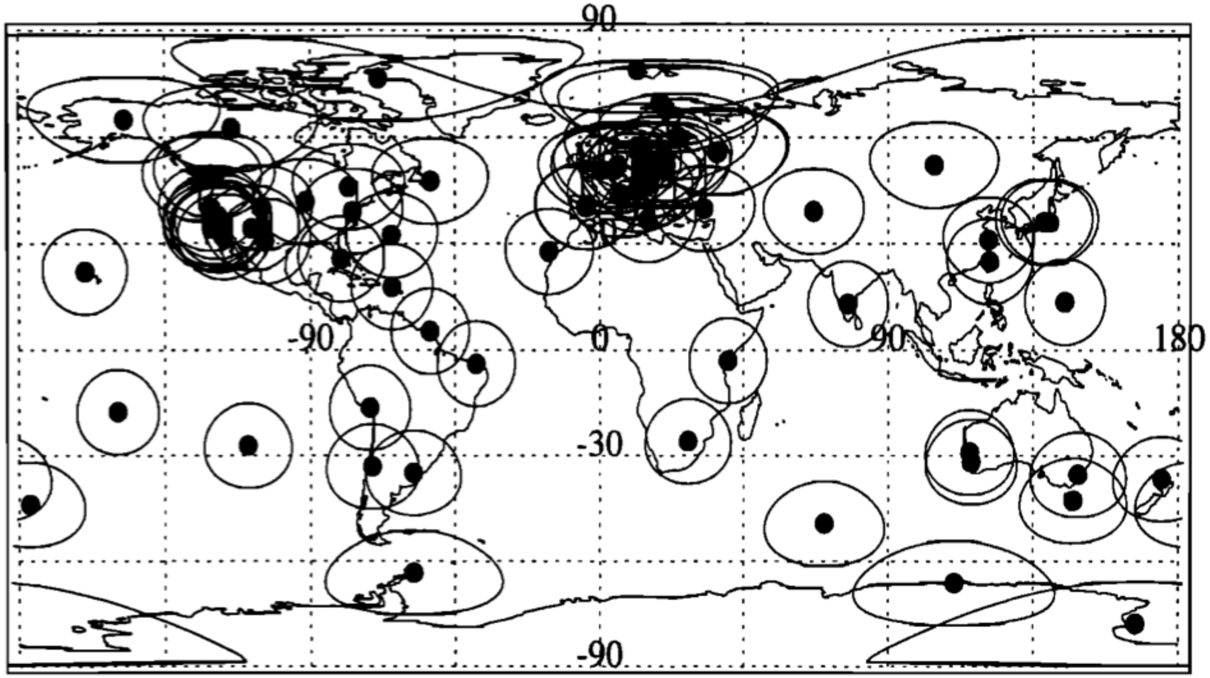


Image credit: GPS World

Example of ROT variations:

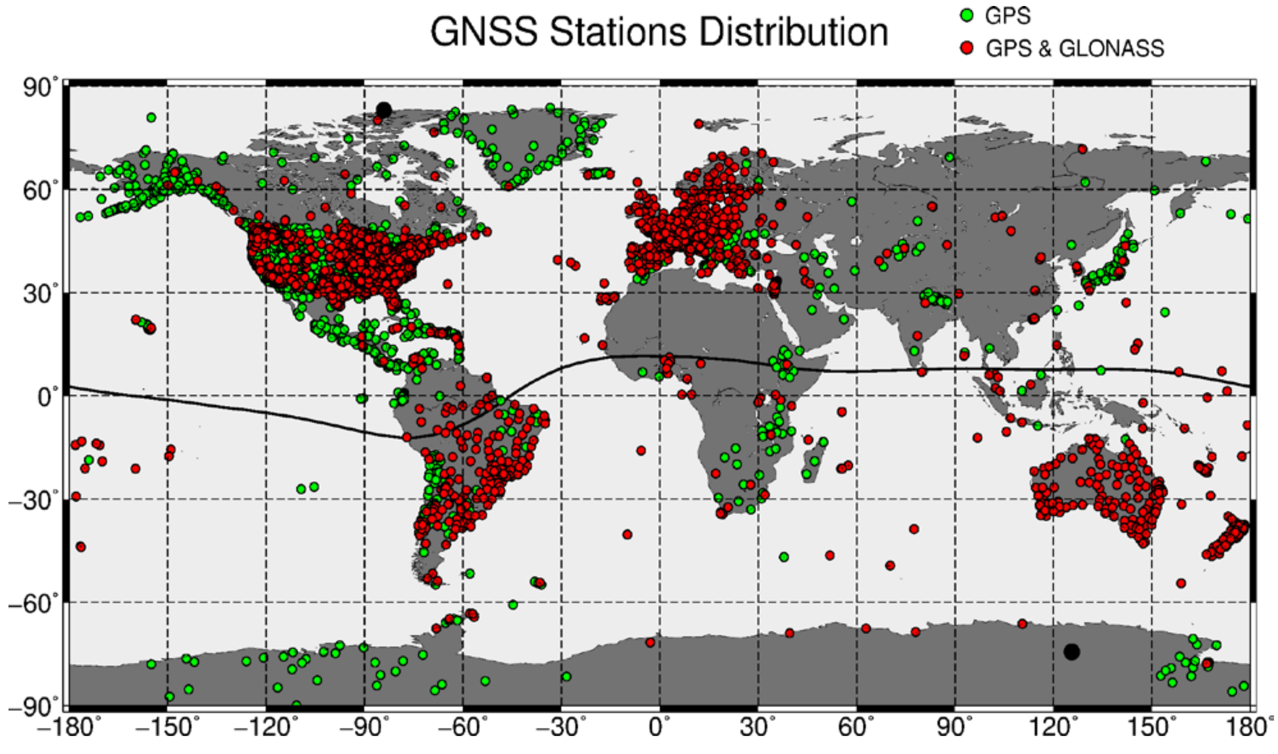


GNSS as global observational network for ionosphere monitoring



Year 1996
More than 100 GPS stations

Courtesy Manucci et al, 1998

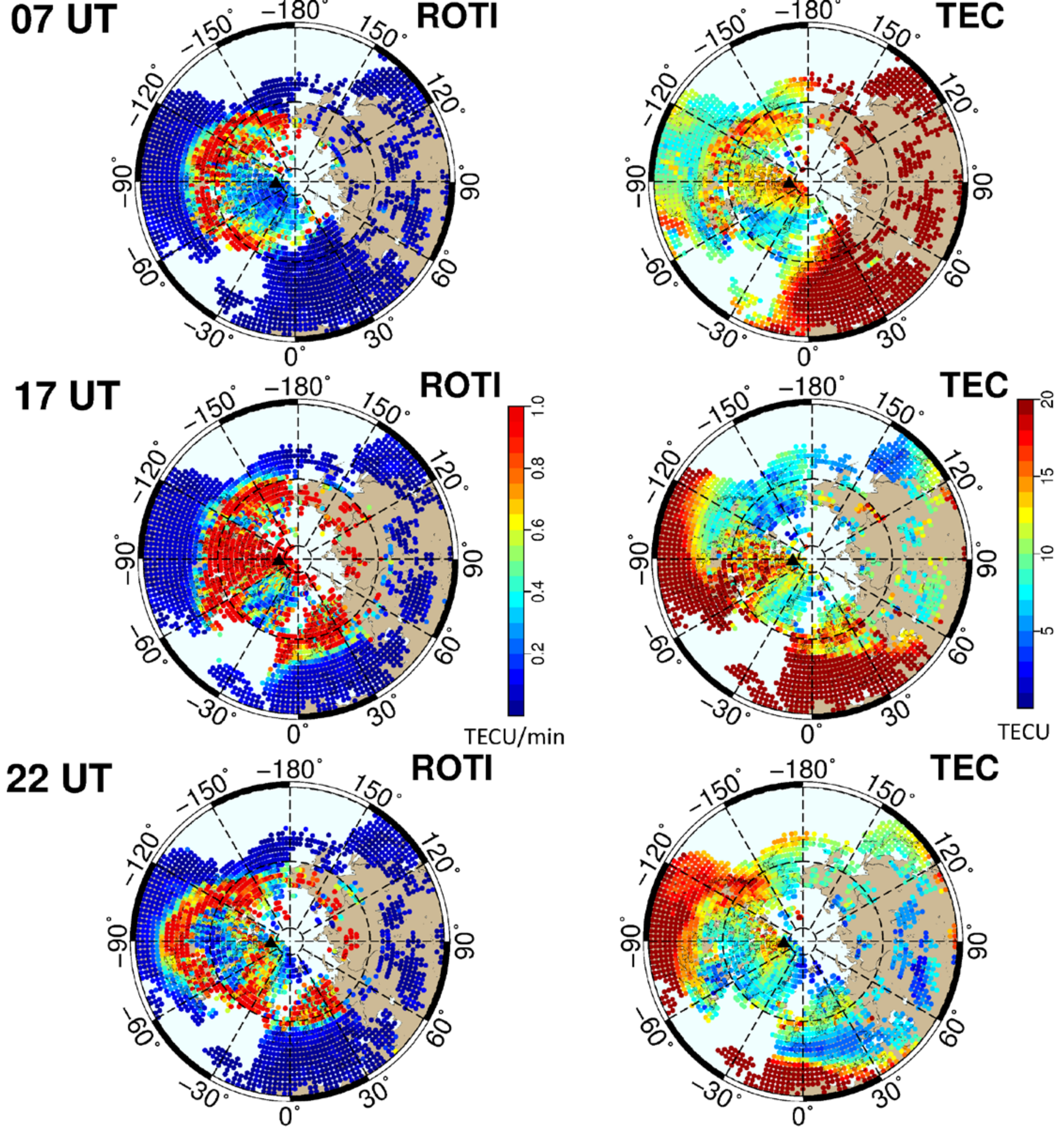


Year 2019
~ 6300 stations
~3500 multi-GNSS stations (GPS + GLONASS)

Ionospheric plasma irregularities location.
SED-TOI structures
ROTI vs TEC maps

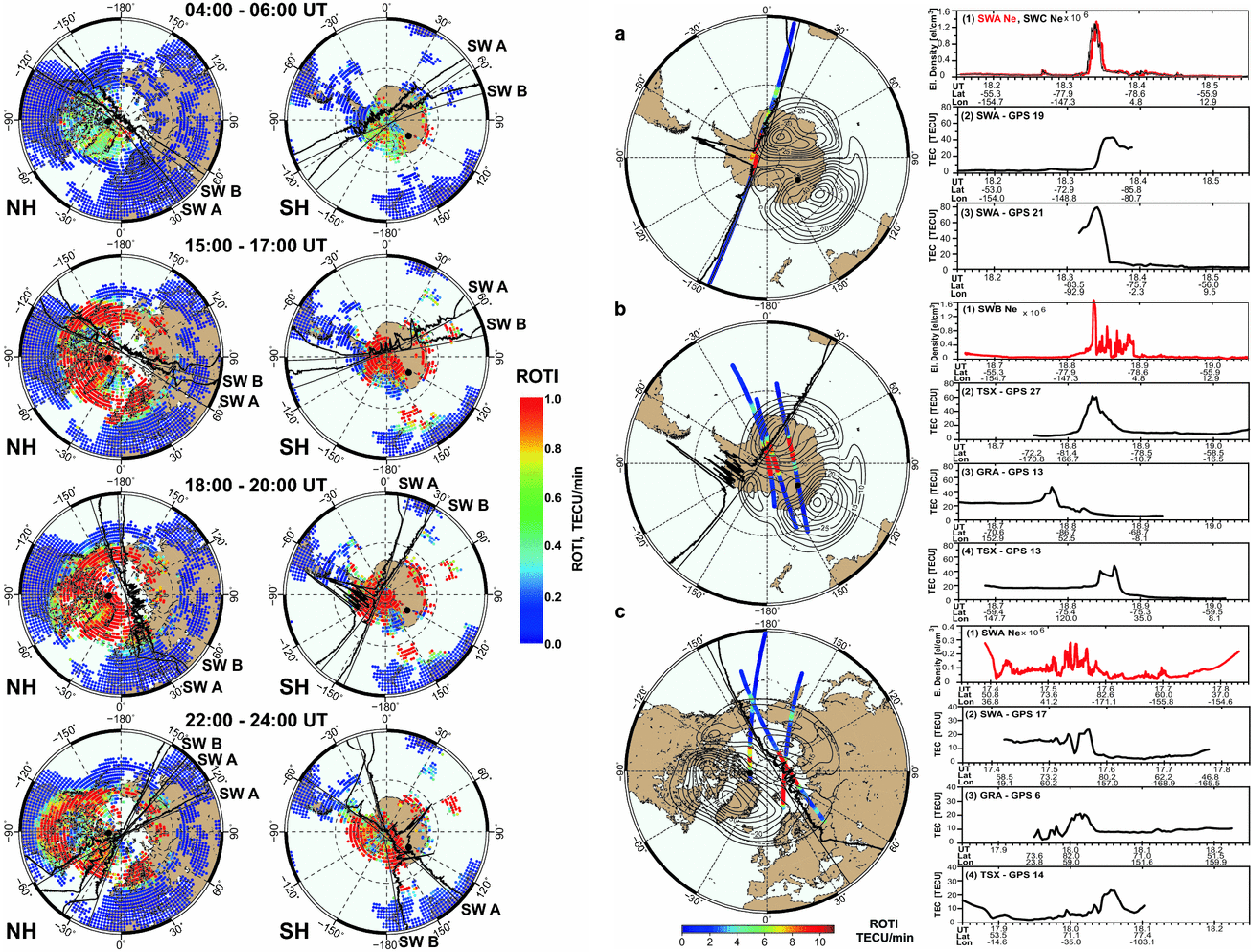
Ground based GNSS observations

2015 St. Patrick's Day storm



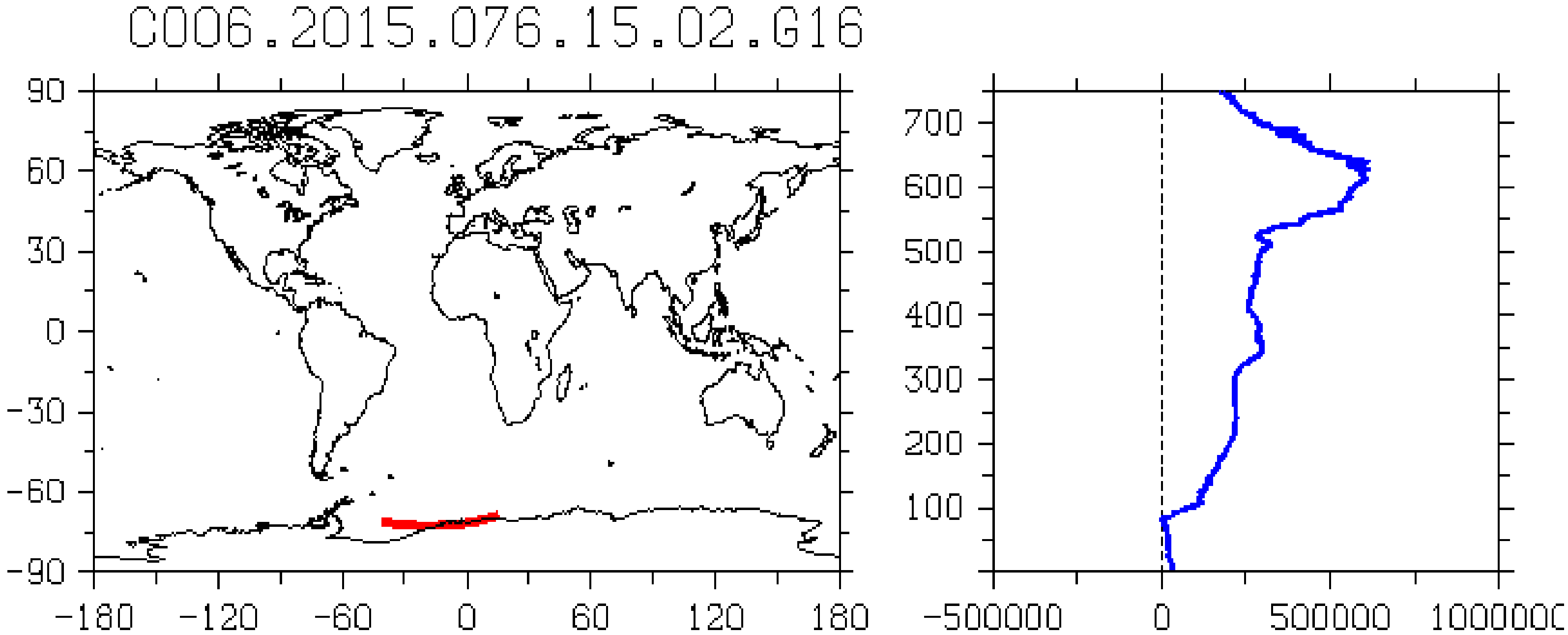
Cherniak et al,
Space Weather, 2015

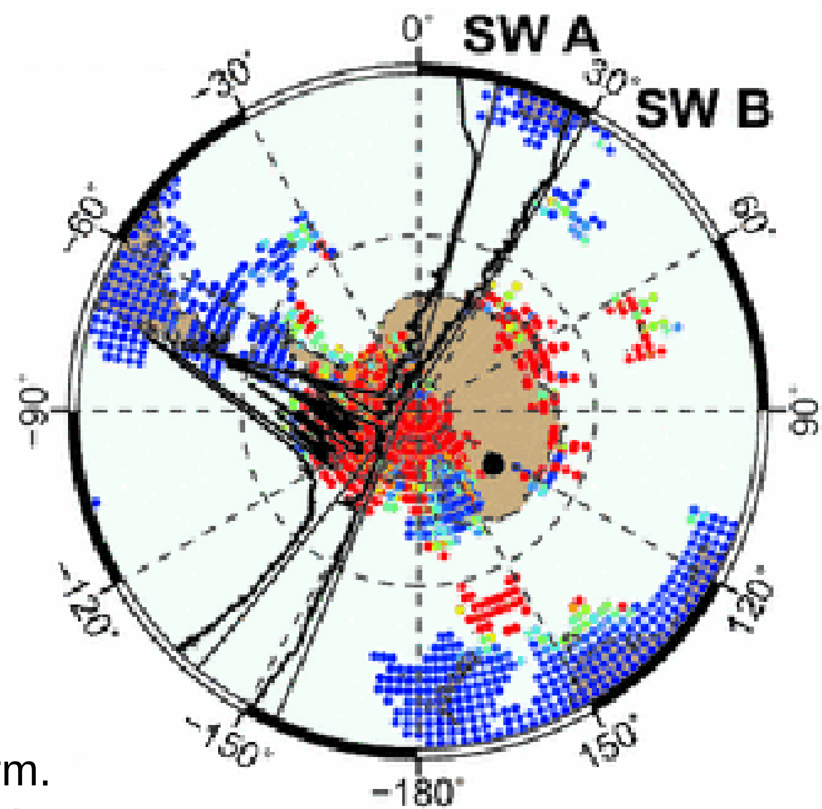
Ionospheric irregularities location. ROTI maps vs LEO GPS and in-situ observations

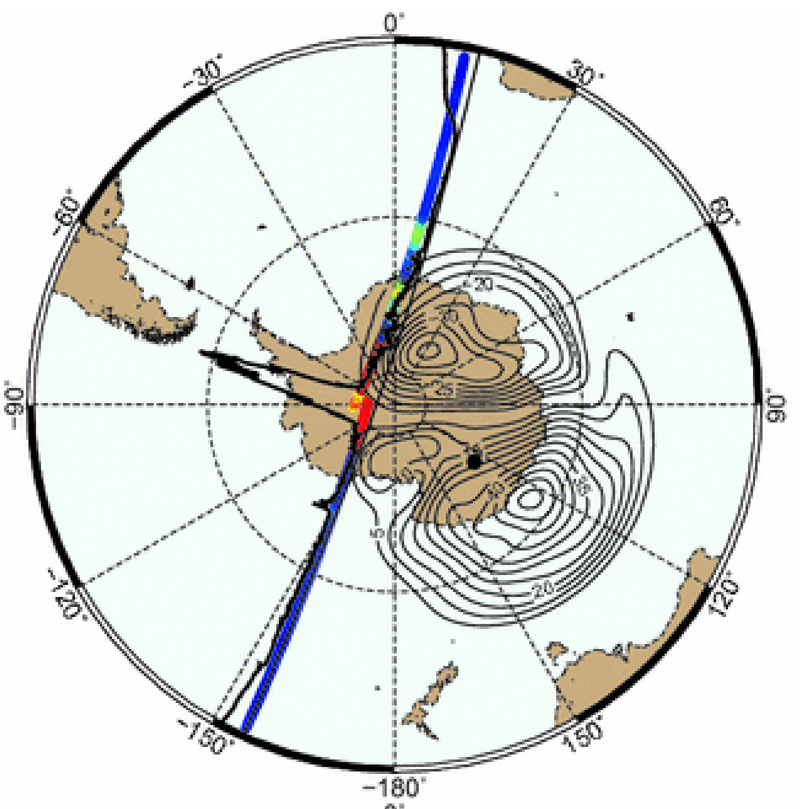


Ionospheric plasma irregularities location. SED/TOI signatures in the COSMIC RO

Superimposing to the TEC/ROTI maps vs LEO GPS and in-situ observations



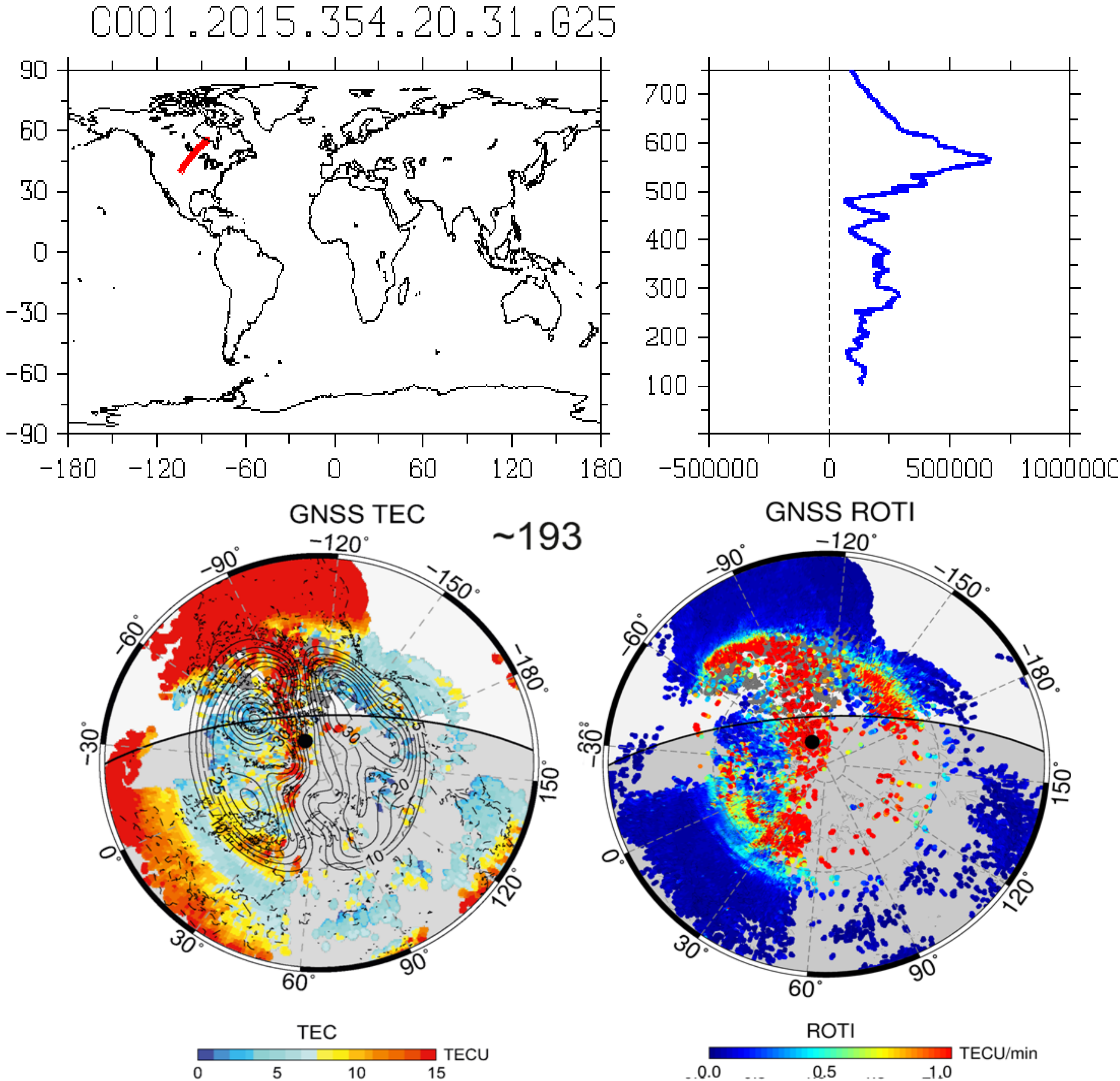




Formation of the SED/TOI topside structures over Southern hemisphere, March, 2015 geomagnetic storm.

Ionospheric plasma irregularities location. SED/TOI signatures in the COSMIC RO

Superimposing to the TEC/ROTI maps vs LEO GPS and in-situ observations

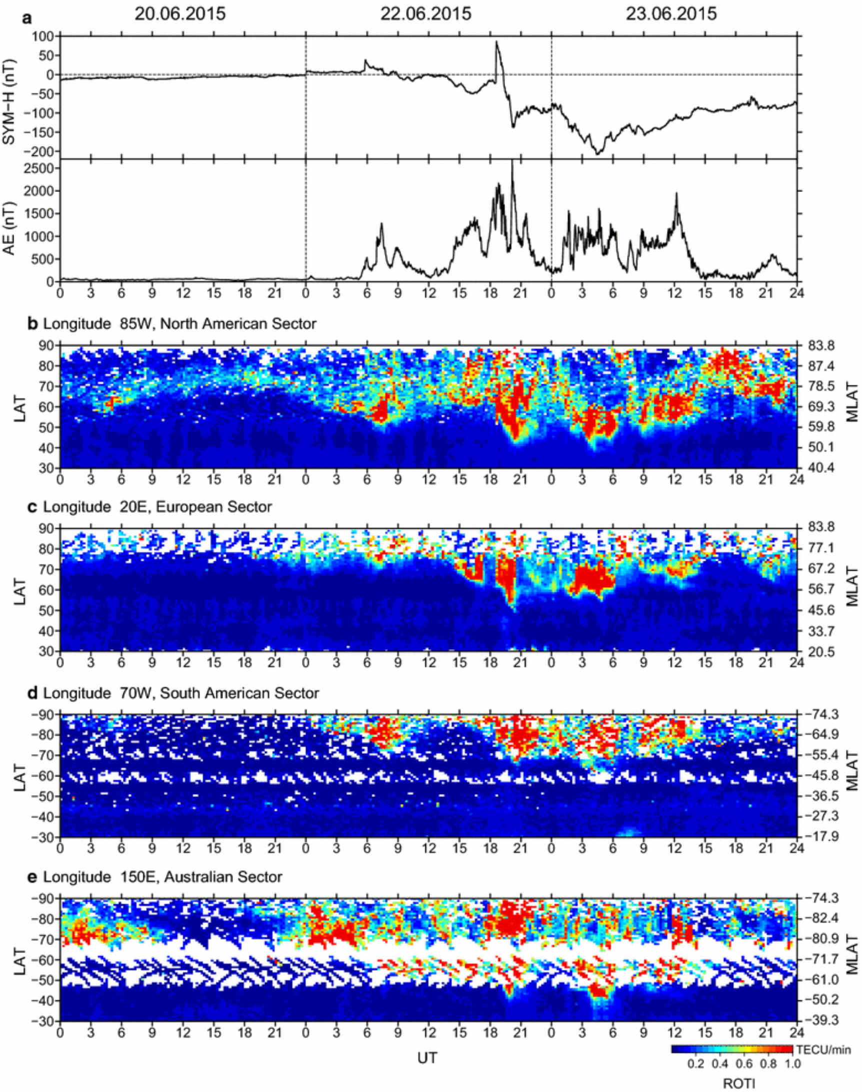


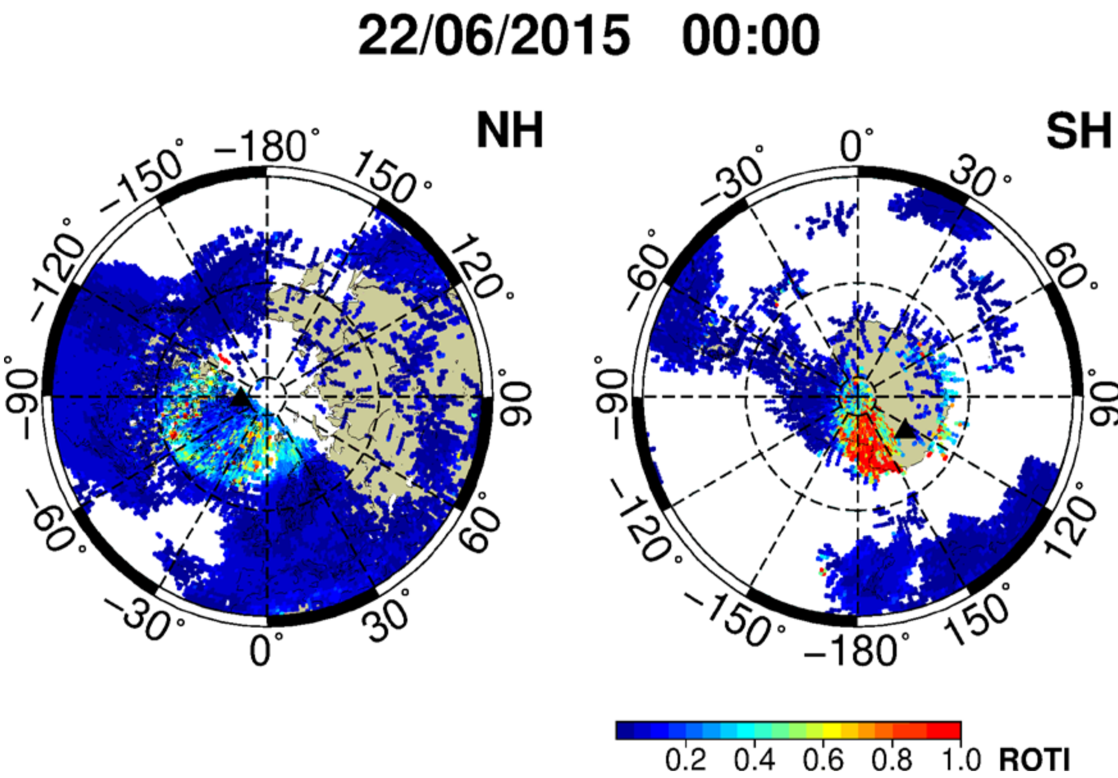
Formation of the SED/TOI topside structures over Northern hemisphere, December, 2015 geomagnetic storm.

Ground-based ROTI.

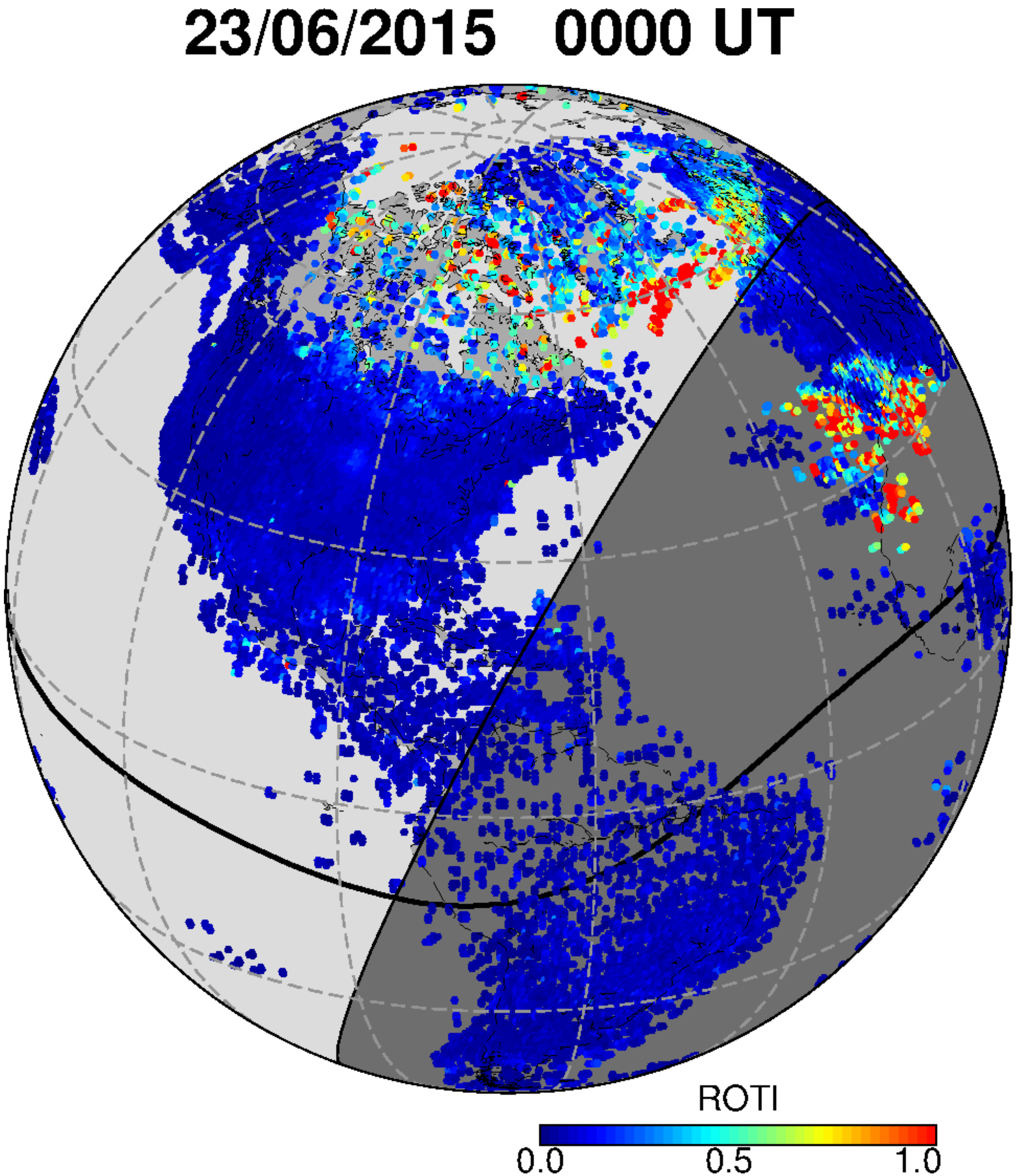
June 2015 geomagnetic storm

High-latitude ionospheric irregularities location vs Space Weather drivers



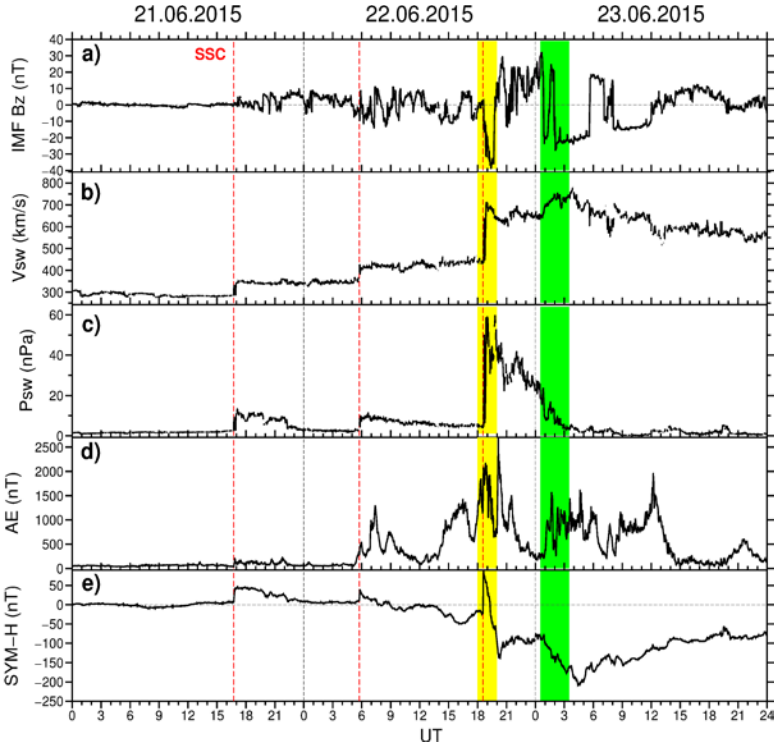


Ground-based ROTI.

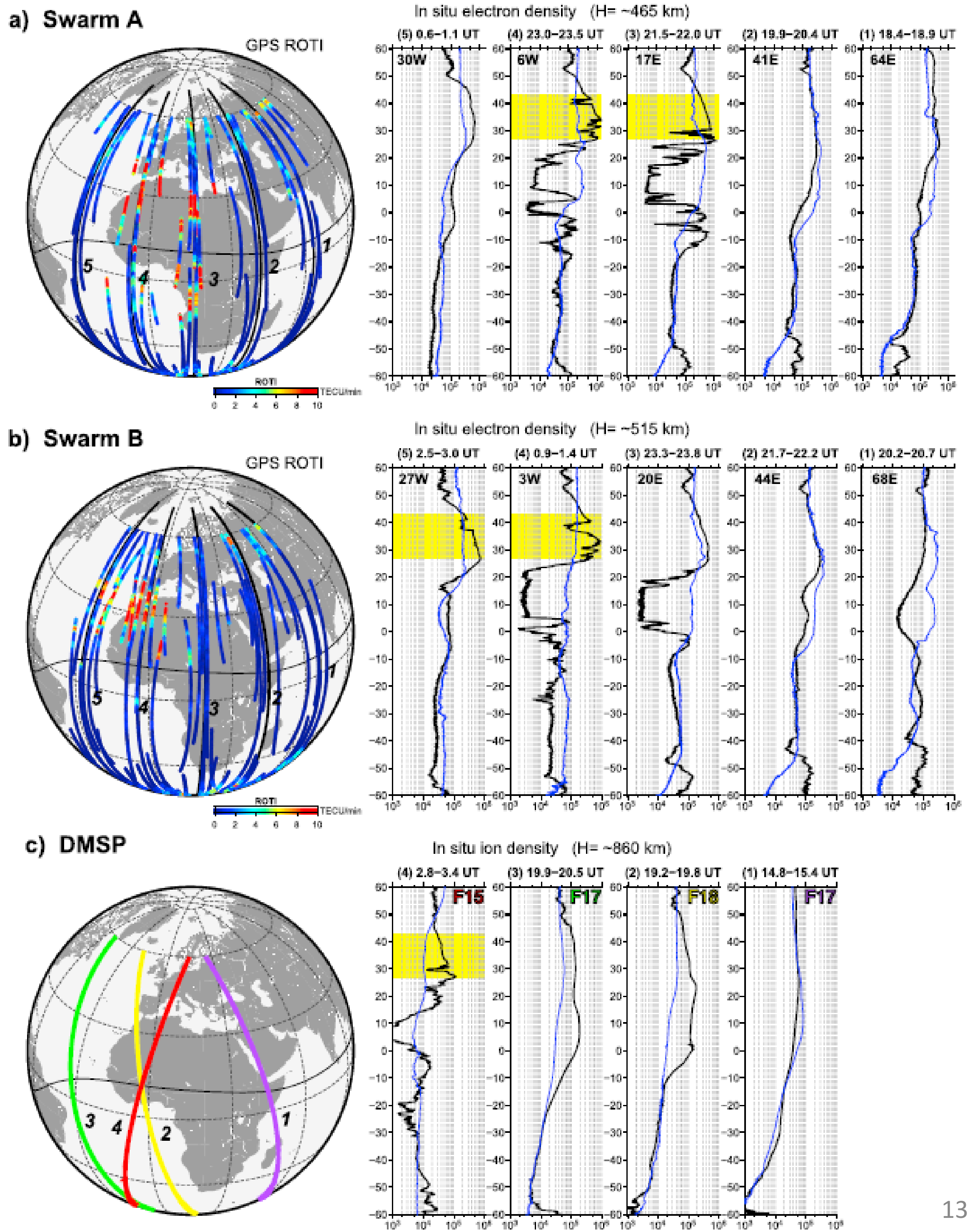


Cherniak et al, JGR, 2019

The June 2015 geomagnetic storm
Plasma bubbles on midlatitudes



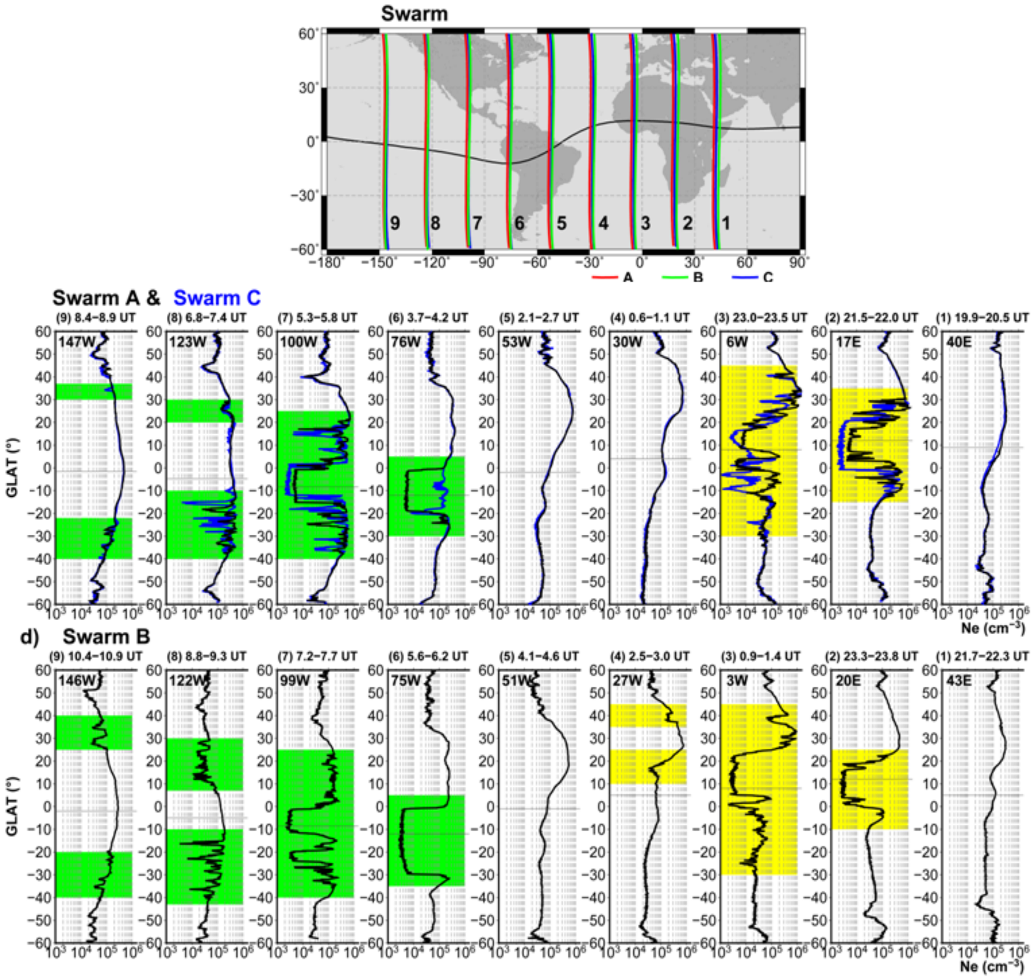
The plasma bubbles in signatures space-borne GPS ROTI and Ne from Swarm satellites passes and DMSP in situ ion density.



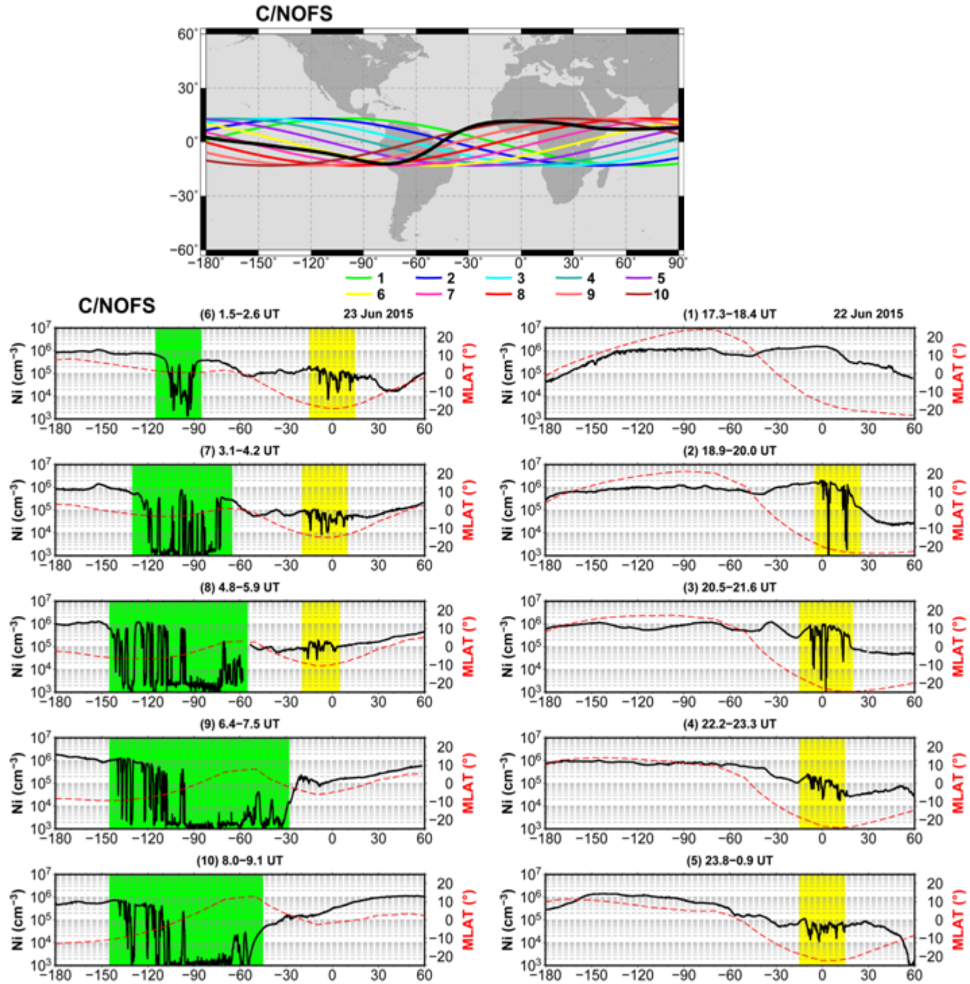
Cherniak&Zakharenkova, GRL, 2016

Swarm and C/NOFS in situ

polar orbits



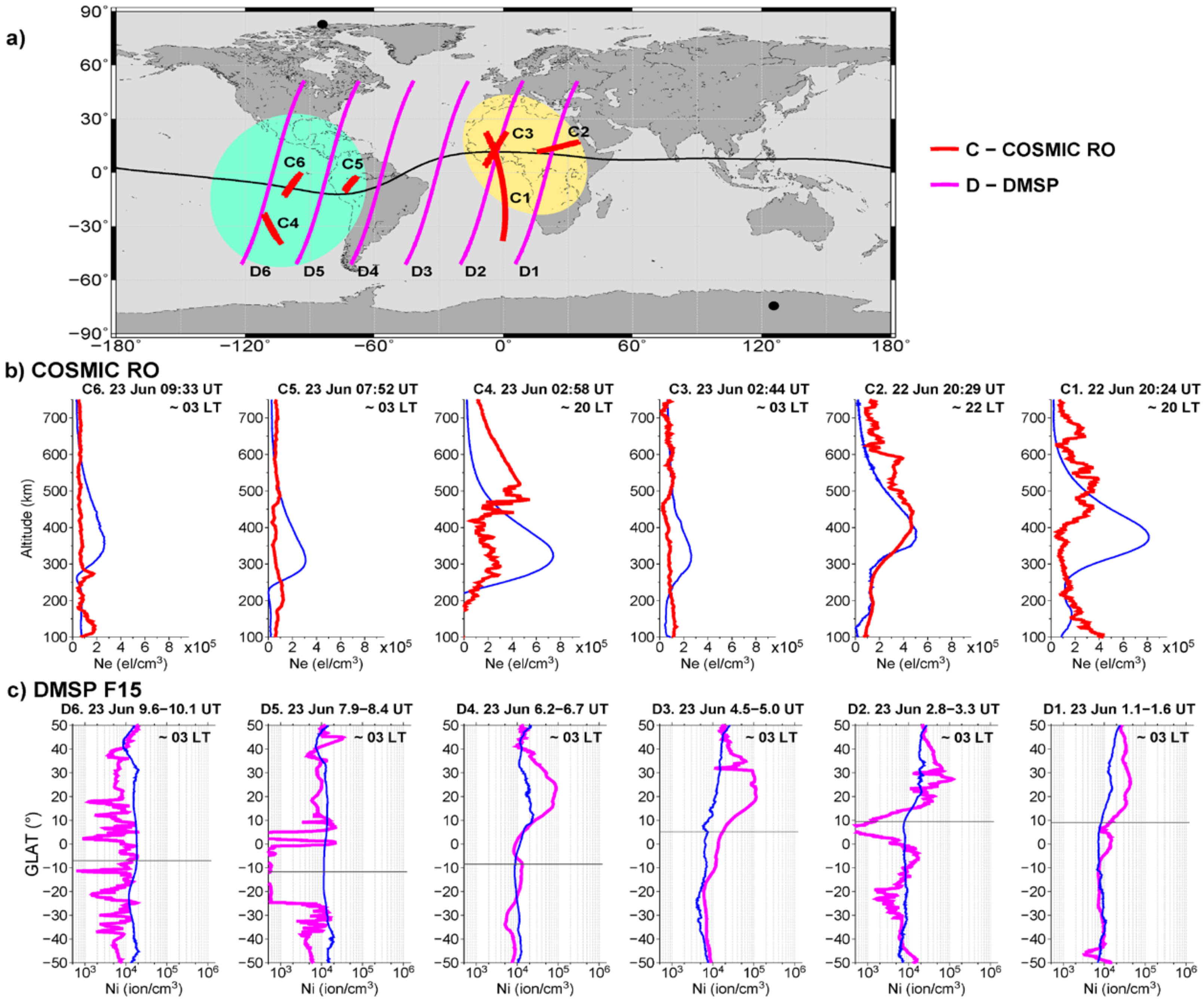
equatorial orbits



The June 2015 geomagnetic storm

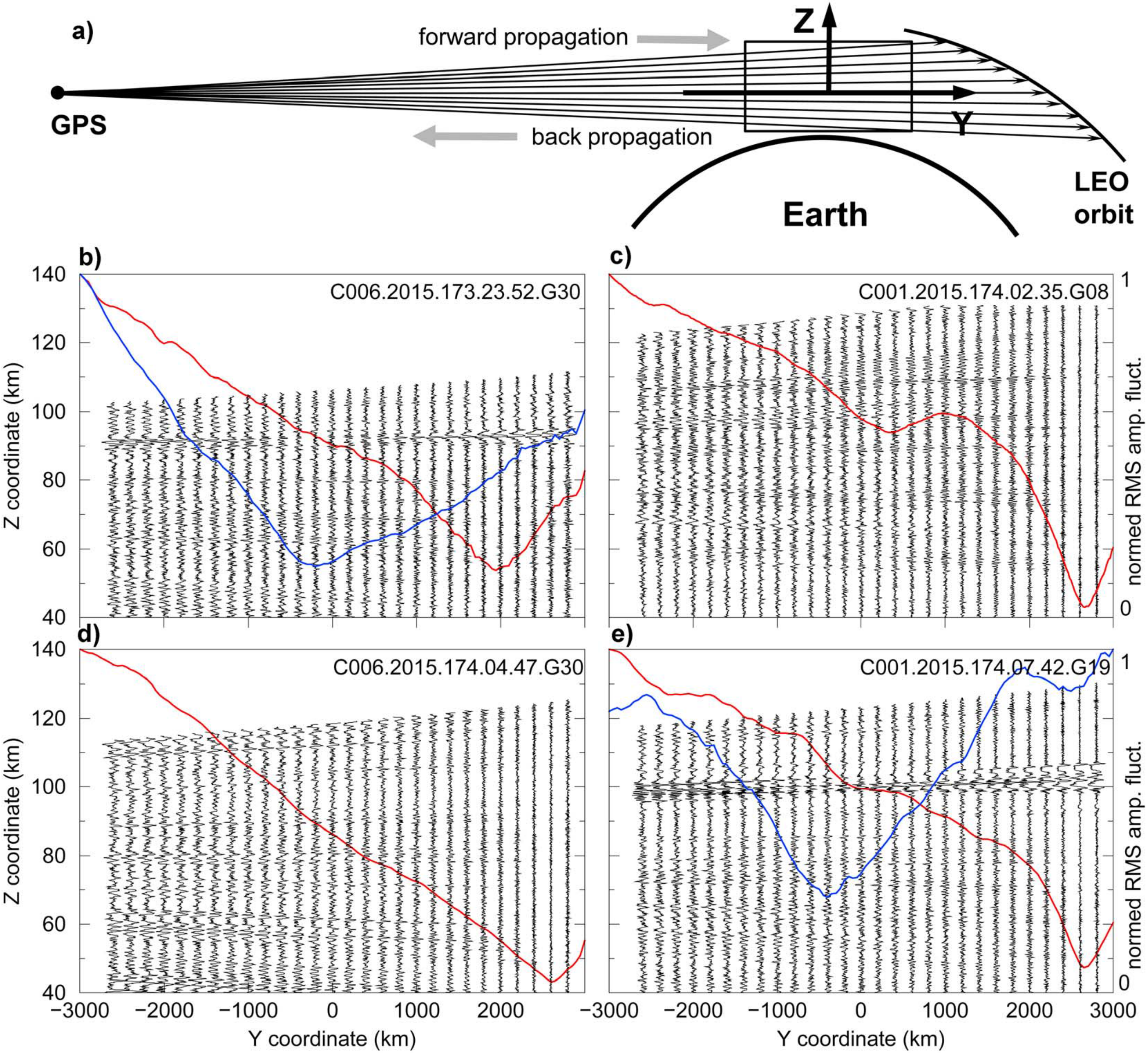
Cherniak et al, JGR, 2019

COSMIC RO vs in situ DMSP

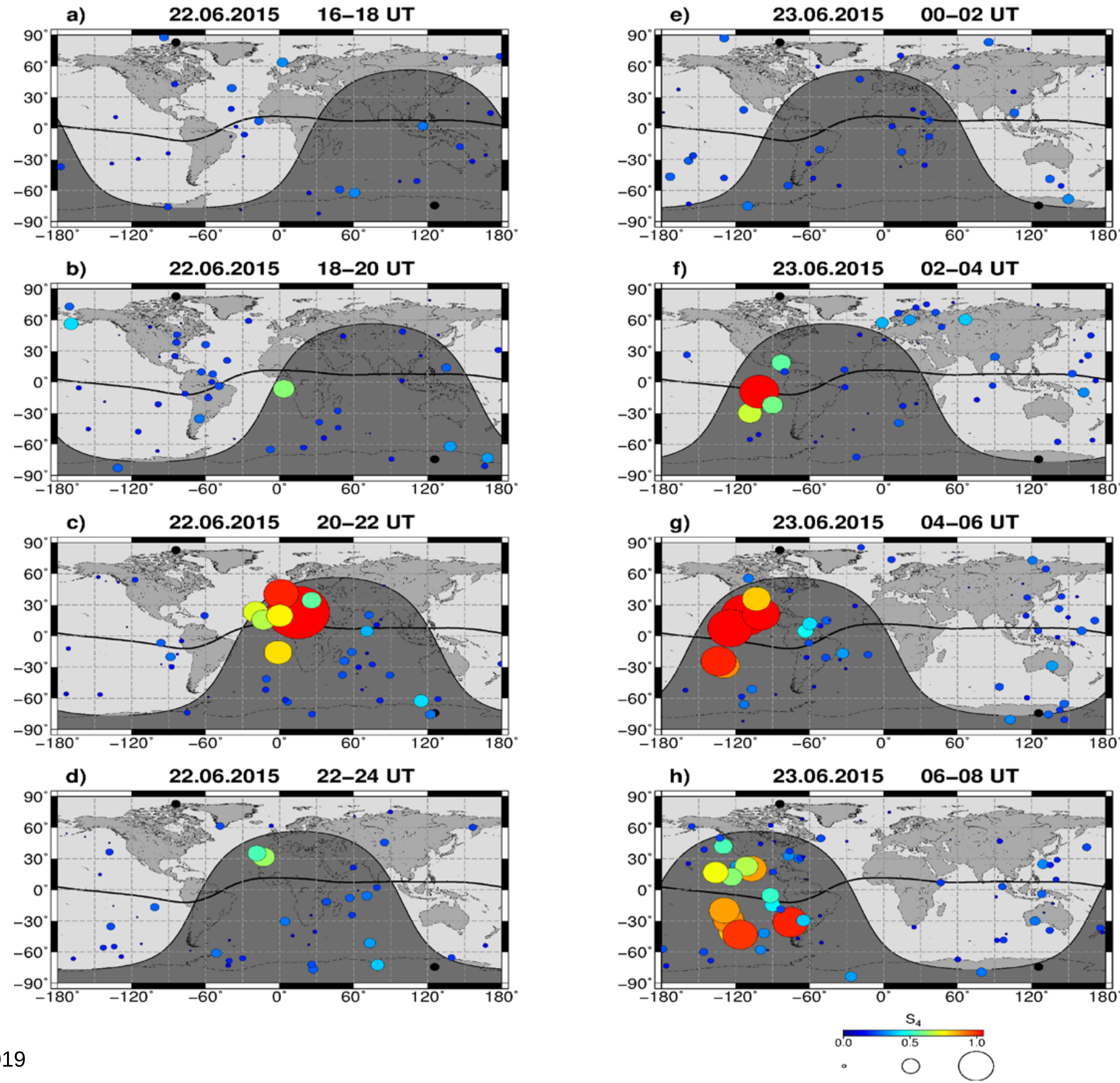


Cherniak et al, JGR, 2019

Ionospheric plasma irregularities location by back propagation approach



COSMIC RO S4



Cherniak et al, JGR, 2019

Ionospheric plasma irregularities location by multi-instrumental observations

Measurements technique	Area of application
GNSS RO	Altitudinal distribution
RO BP	Distance from receiver, altitudinal distribution
GNSS POD	Location above satellite orbit
Ground based GNSS	Geographical location
In situ LP/IVM	Location along satellite orbit

Summary

- Combination of different ground-based and space-borne observations can allow to assess plasma irregularities parameters in geographical and altitudinal domain.

- Independent multi-instrumental measurements provide a consistent global view on the ionospheric density irregularity distribution and dynamics and allow estimating space weather drivers for plasma irregularities generation.

- Results confirm a high potency of the COSMIC-2 mission for ionospheric irregularities monitoring as it’s equipped by both in situ plasma probes and GNSS remote sensing payload, including RO and POD instruments.

Thank you!