LEO GPS measurements to study the topside ionospheric irregularities

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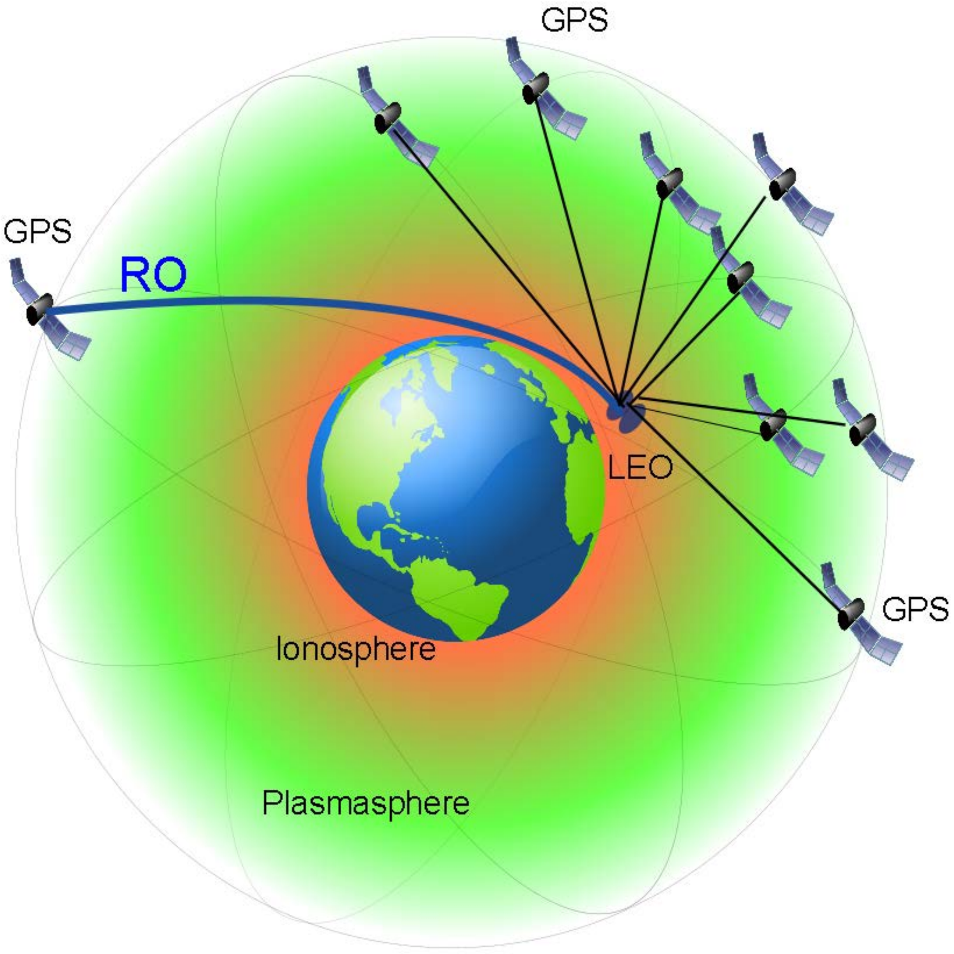
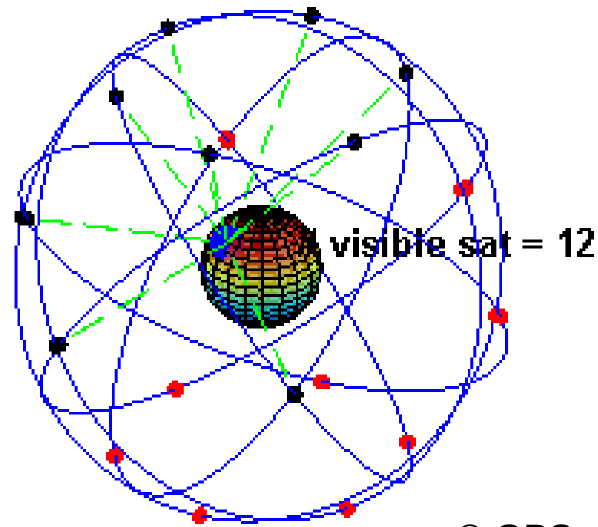


GPS (GNSS) Measurements

Global Navigation Satellite Systems (GNSS):

GPS, GLONASS, Galileo etc

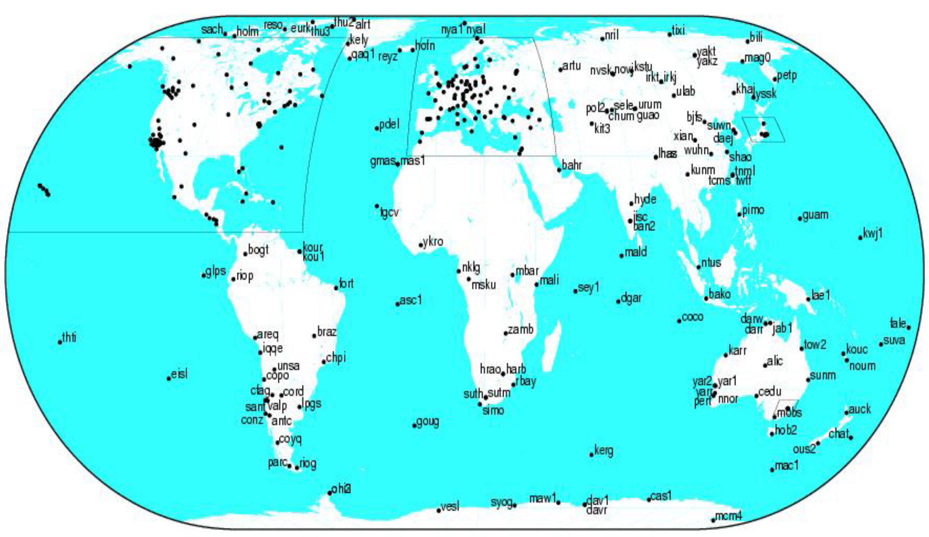
- Orbit altitude ~ 20000 km
- Satellite number – at least 24 for full constellation



GNSS ground-based network

- several thousands GPS receivers worldwide
- ionosphere monitoring on a global scale
- continuous 24 h measurements
- high temporal resolution (at least 30 sec)

International GNSS Service (IGS) network



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GPS TEC (total electron content):
represents the total number of electrons along line-of-sight GPS satellite - GPS receiver, this value can be considered as the combined contribution of the ionosphere, IEC, and overlying plasmasphere, PEC.

Ionospheric irregularities on the base of GPS measurements

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

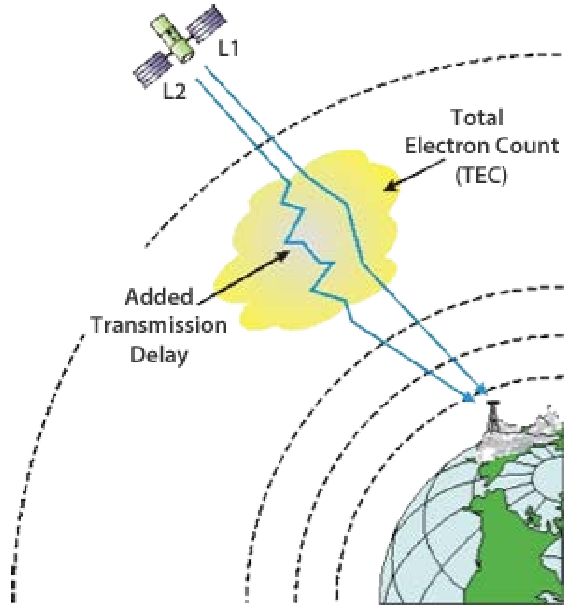
Pi et al. [1997] proposed to use:

• **ROT** (rate of TEC change) as a measure of phase fluctuation activity

• Rate of TEC Index (**ROTI**) as a GPS-based index that characterizes the severity of the GPS phase fluctuations and detects the presence of ionospheric irregularities

$$ROT = \frac{TEC_k^i - TEC_{k-1}^i}{(t_k - t_{k-1})}$$

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



Ionospheric refraction

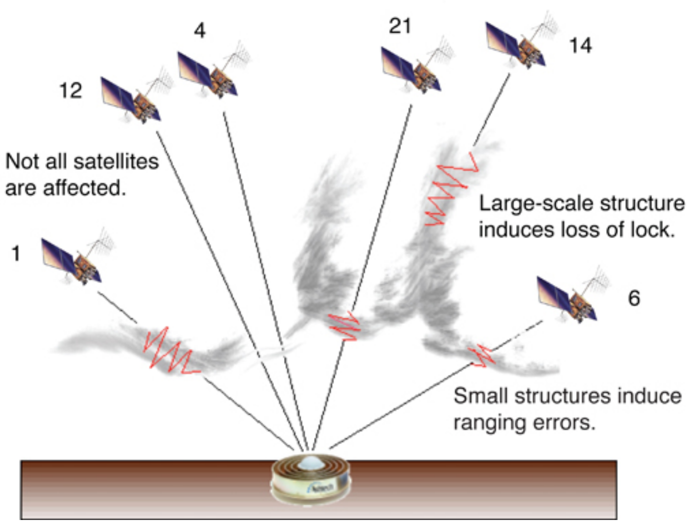
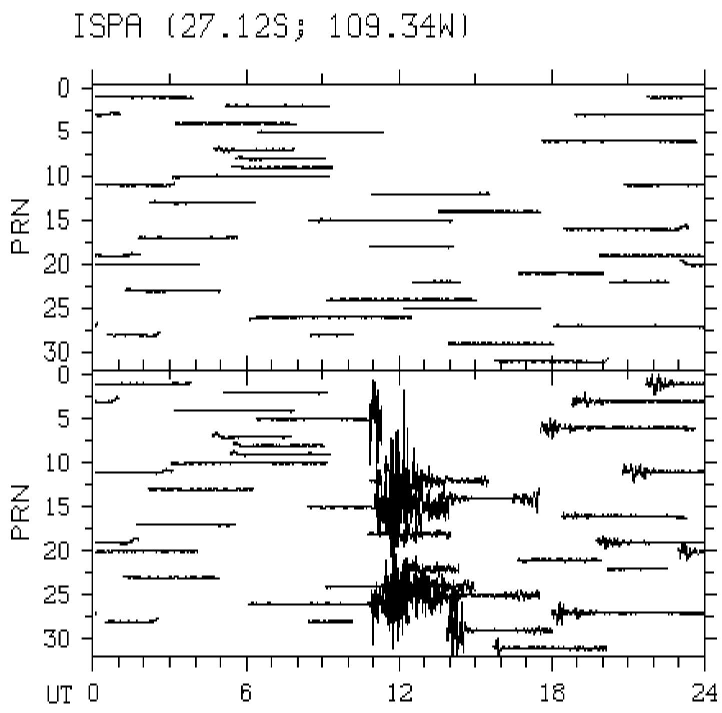


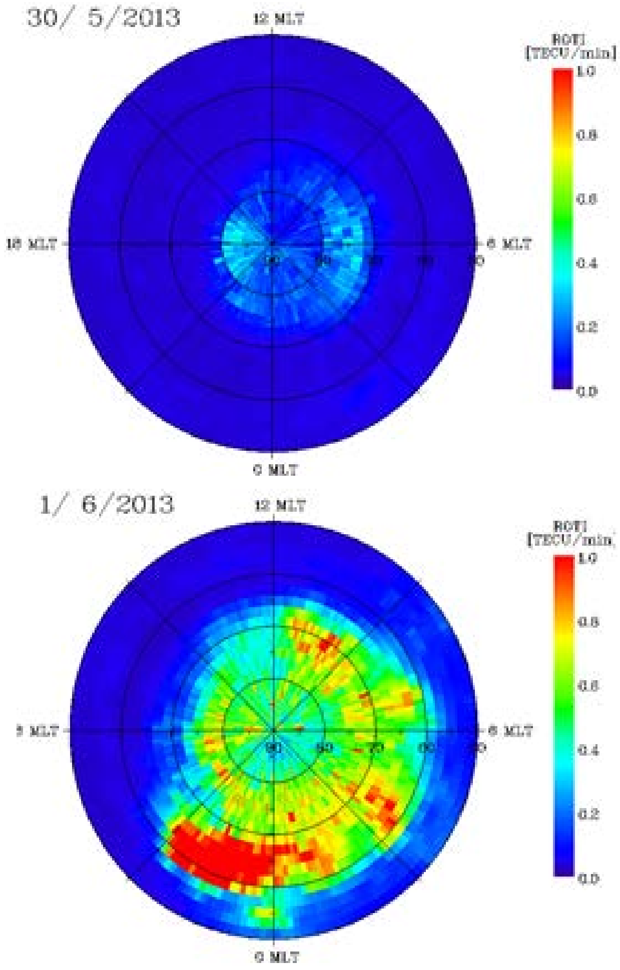
Image credit: GPS World

Ionospheric irregularities observed using ground-based GPS network

GPS ROT



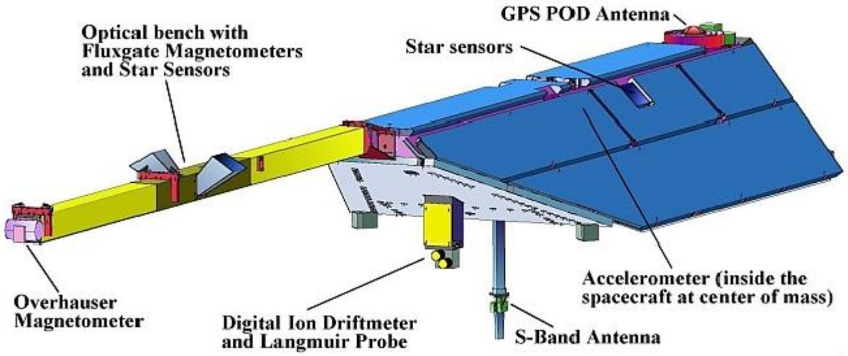
GPS ROTI



Cherniak et al., 2014

LEO GPS technique: CHAMP POD measurements

CHAMP (CHAllenging Mini-satellite Payload) is a German LEO mission with various scientific objectives.

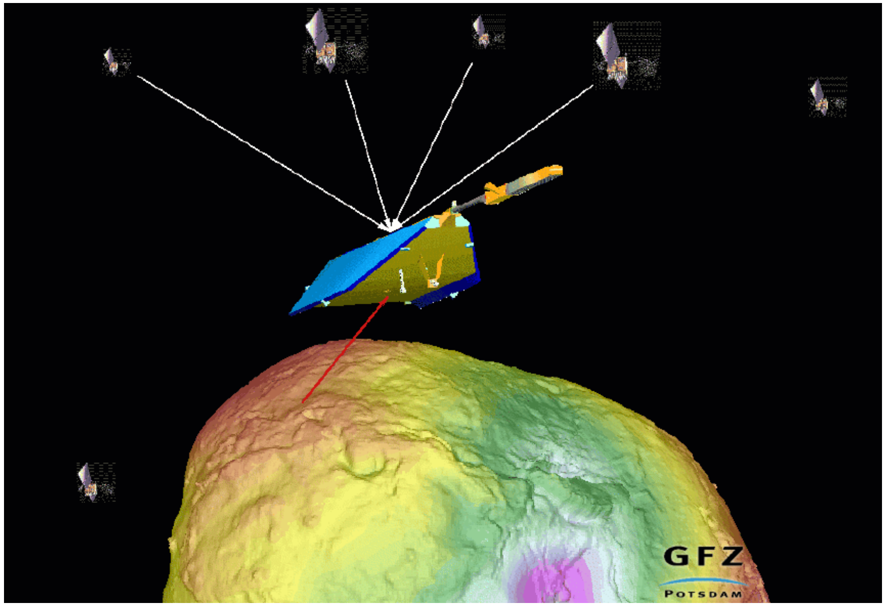


Launch – 15 July 2000

Orbit – circular, near polar, inclination 87.3°

Period ~90 min

Altitude ~390 km (as of August 2004)



POD – precise orbit determination

GPS receiver - a dual frequency TRSR-2 (TurboRogue Space Receiver 2)

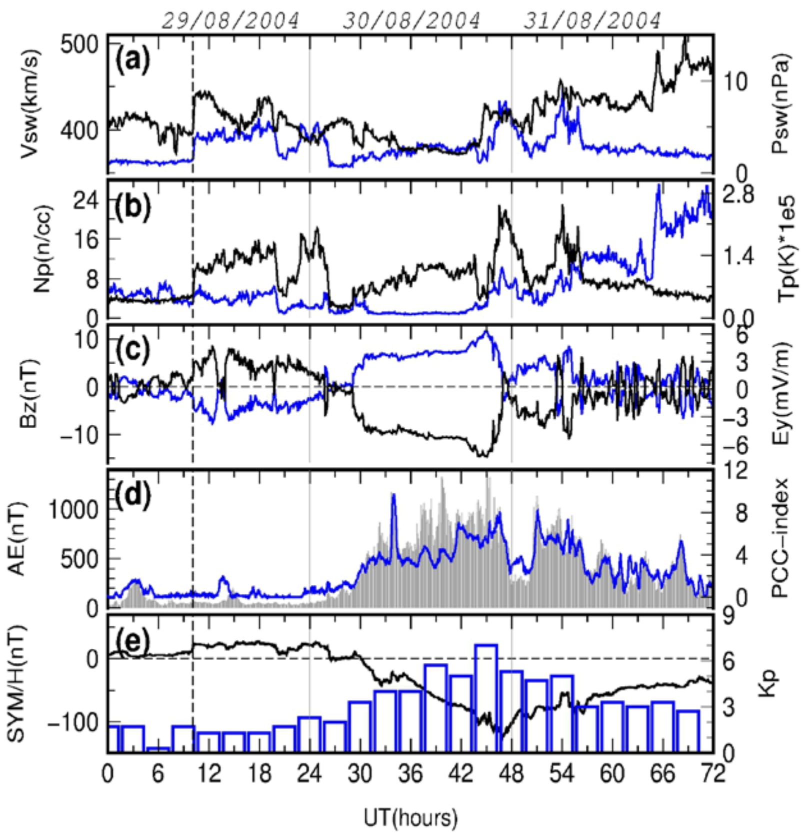
Output:

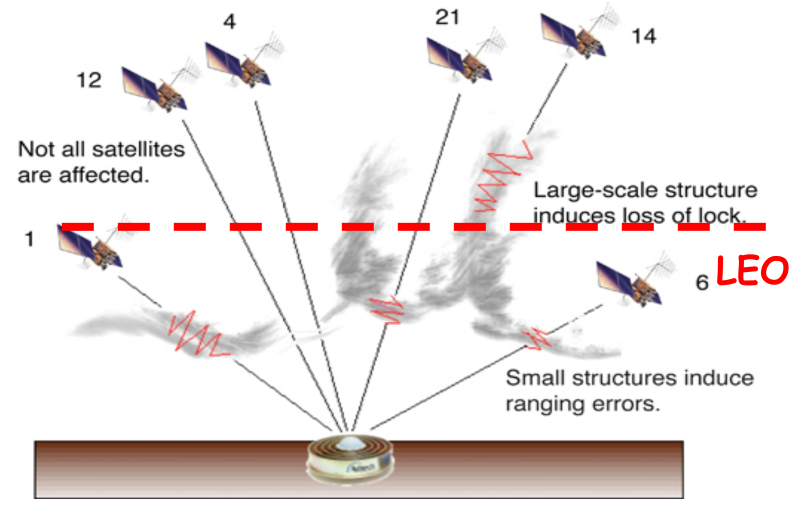
RINEX 2.20

Time sampling – 10 s

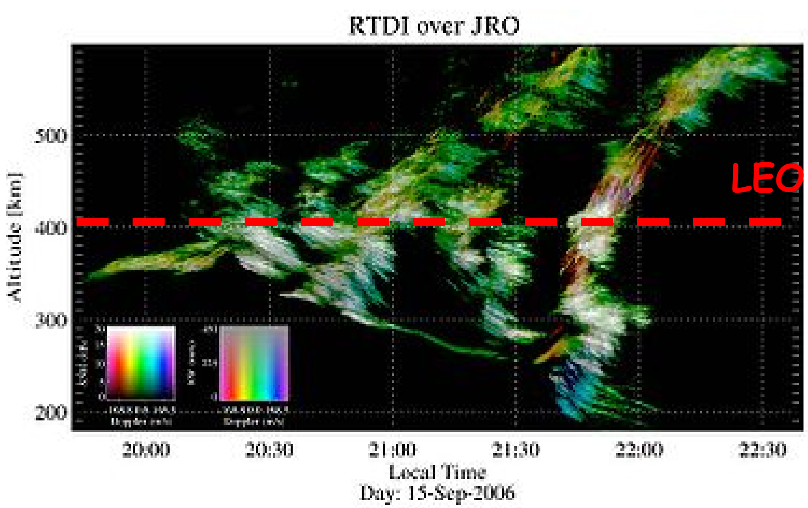
Images credit: GFZ, Potsdam

Case Study: Geomagnetic storm of 30-31 August 2004





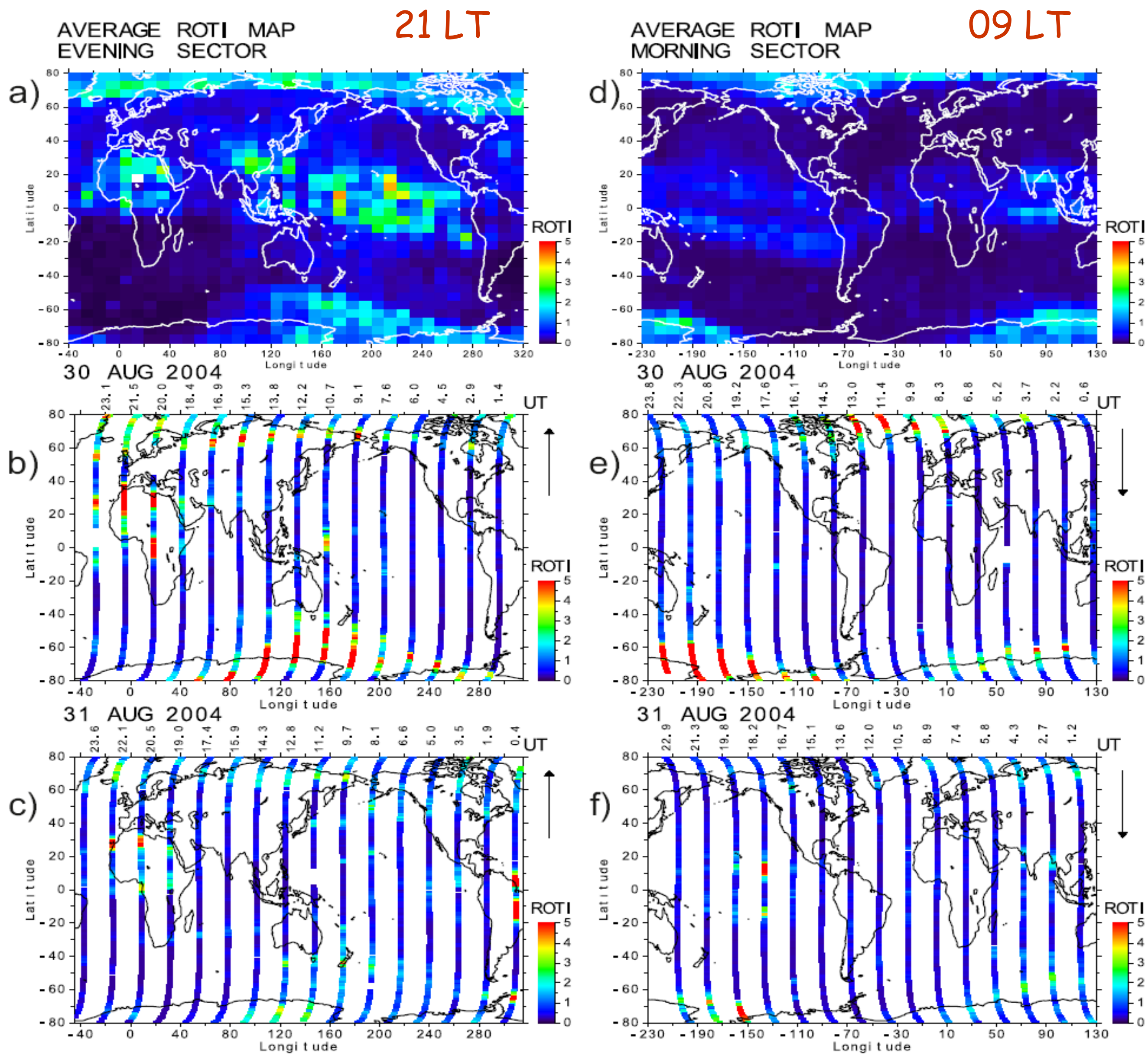
Courtesy of GPS World



Courtesy of JRO

LEO ROTI technique: overall view on the topside ionosphere irregularities

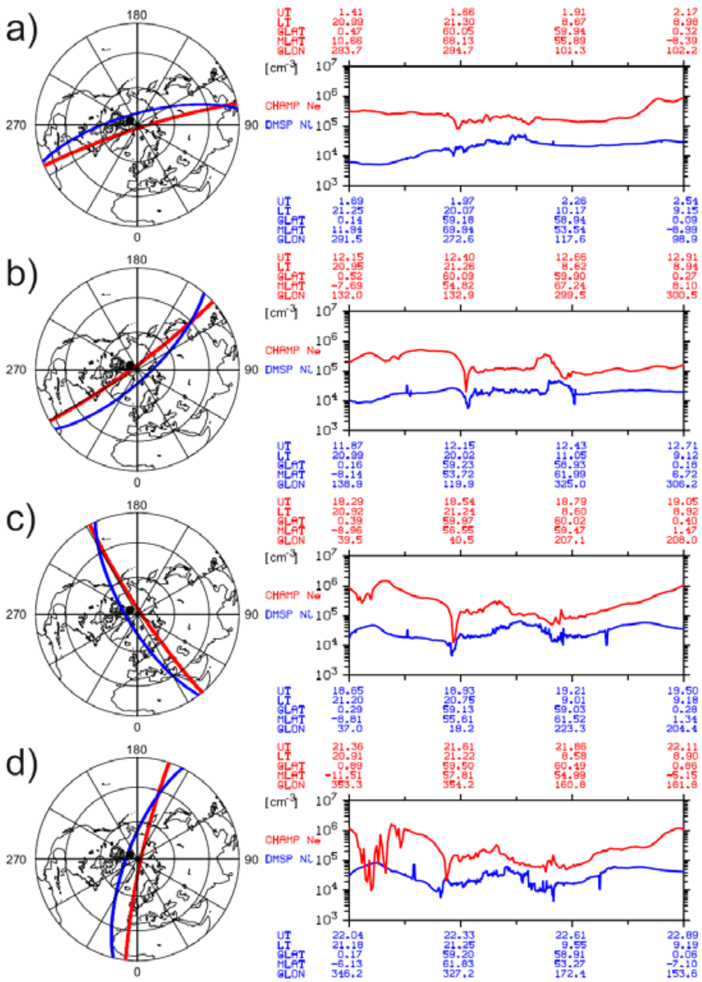
CHAMP GPS data



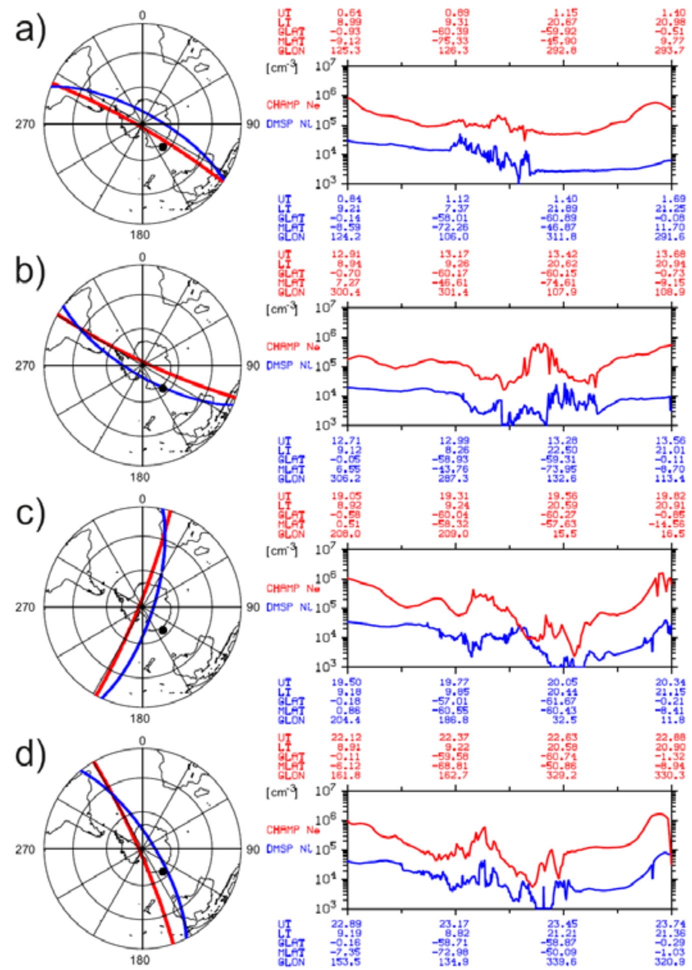
Zakharenkova and Astafyeva, JGR, 2015

High latitude ionospheric irregularities

Northern Hemisphere



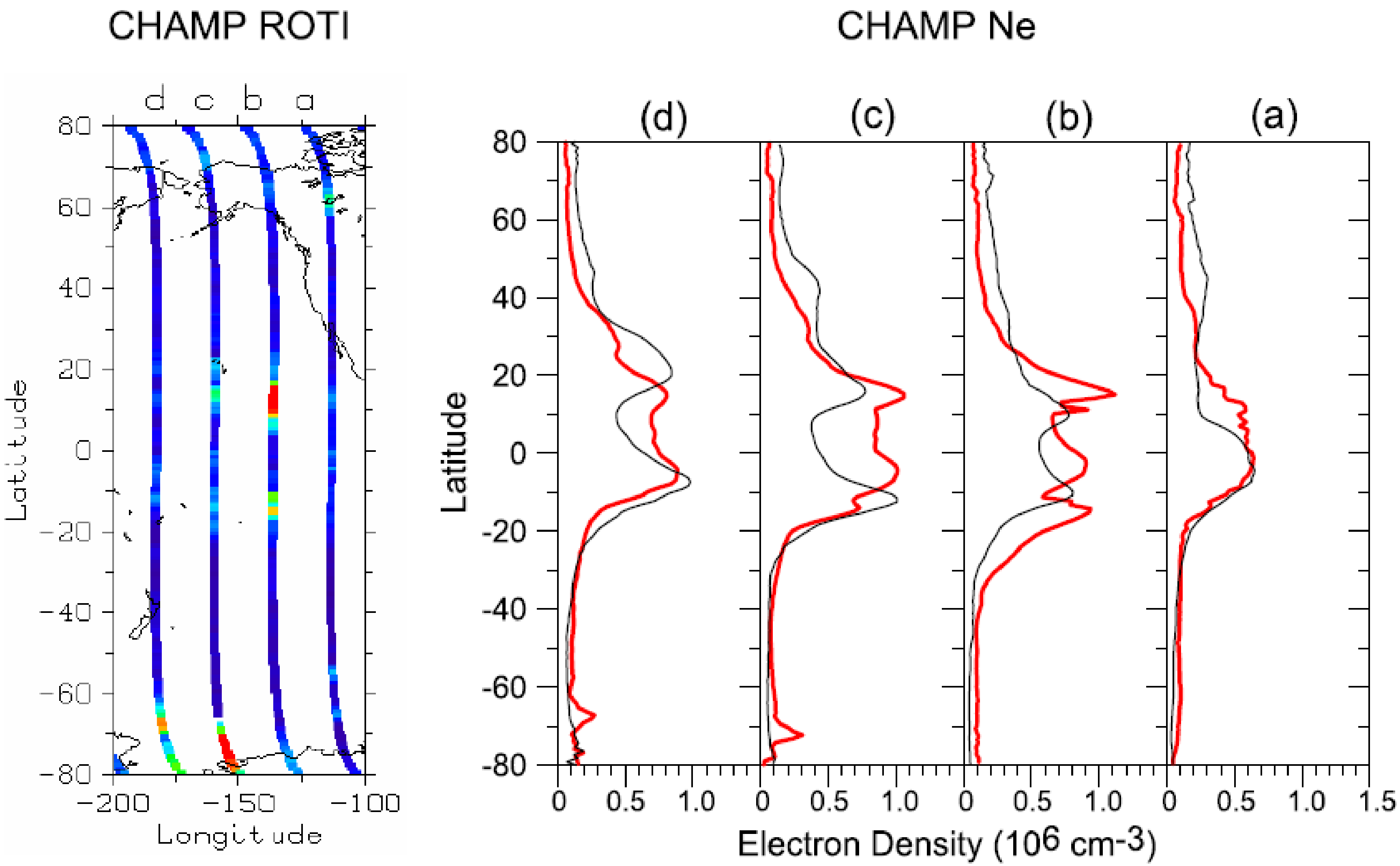
Southern Hemisphere



CHAMP Ne at 390 km

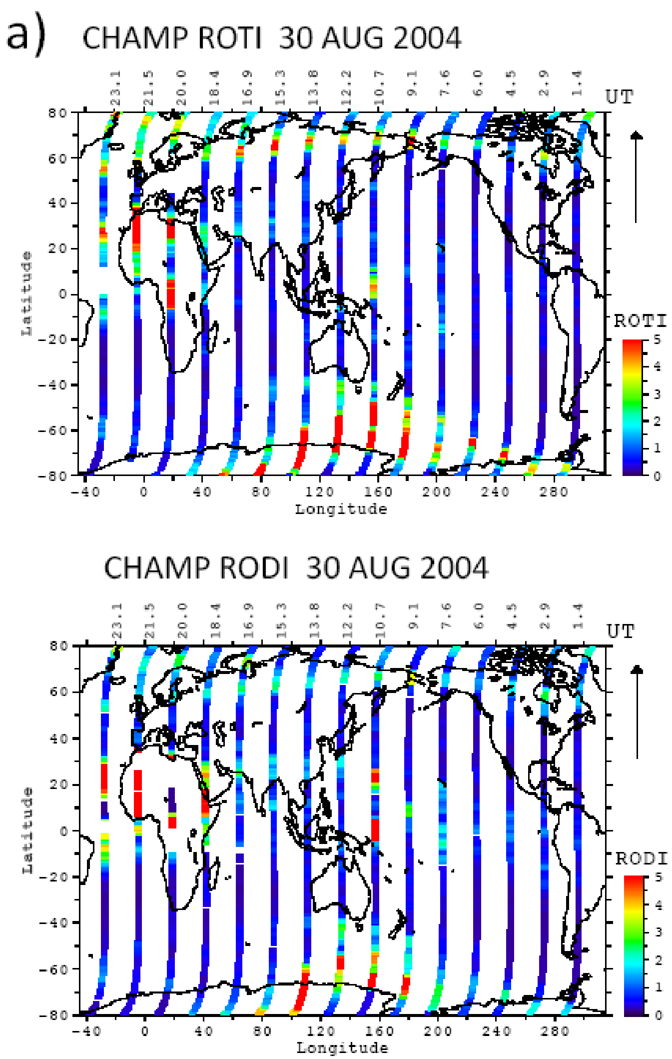
DMSP Ni at 840 km

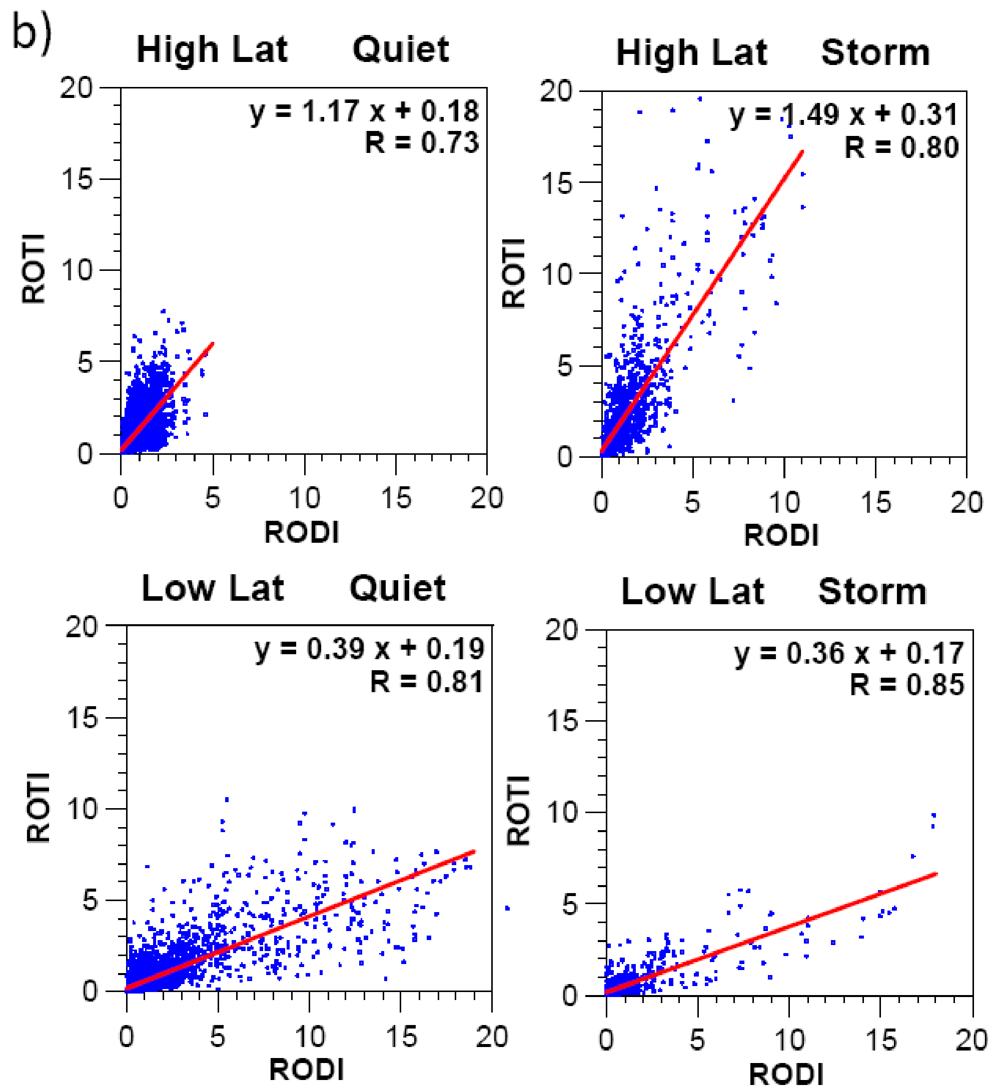
Equatorial irregularities



Zakharenkova and Astafyeva, JGR, 2015

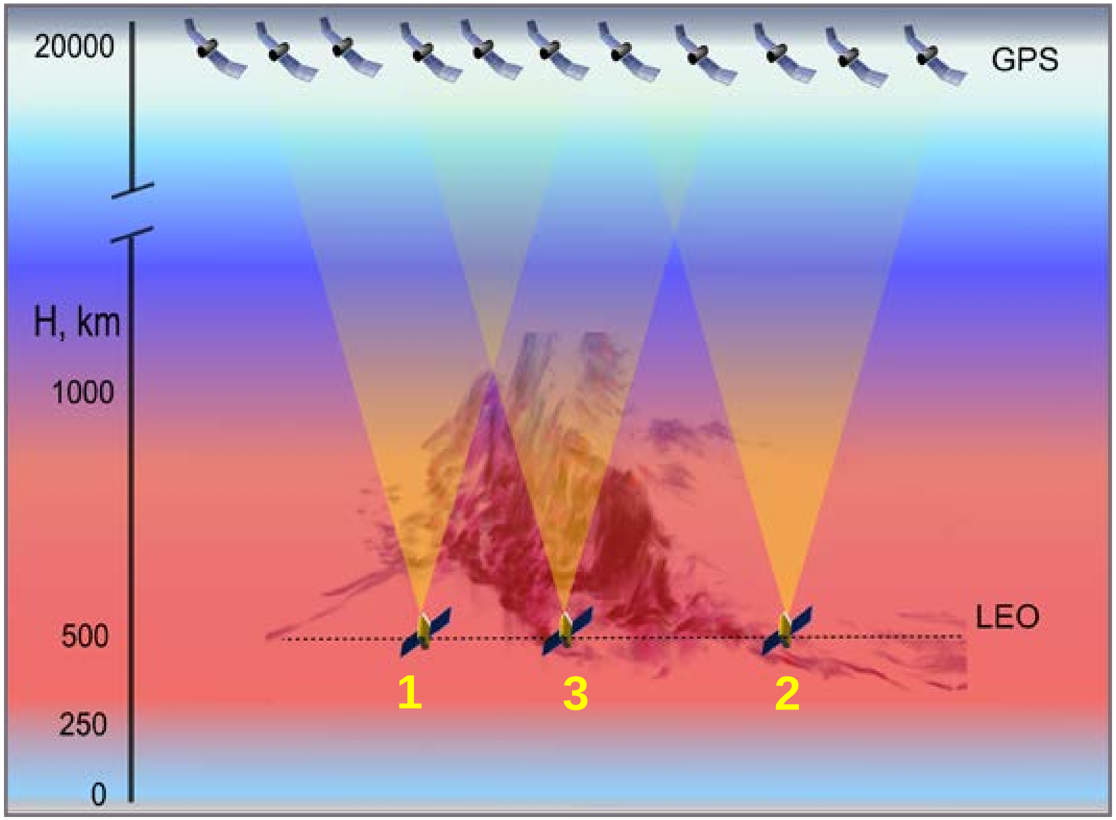
Ionospheric irregularities: LEO ROTI vs LEO RODI





Ionospheric irregularities: LEO ROTI vs LEO RODI

The principal difference between techniques: in situ data is a kind of 1 D punctual measurements whereas GPS relates to the kind of 2D measurements.



(1) Topside irregularities cannot be detected by the in situ measurements while they are clearly visible in the POD TEC.

(2) Bottomside irregularities are observed by the in situ measurements but cannot be de detected by the upward looking GPS antenna.

(3) Largely extended irregularities can be detected by both techniques, but the intensity may differ with the altitudinal distribution of irregularities as compared to the orbital height of the satellite.

So, in general, the interchangeability of these techniques cannot be extended to all cases

Thank you for your attention!