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Data and Machine Learning Challenges via an analysis of GNSS Network Position Errors during the March 2015 St. Patrick Storm

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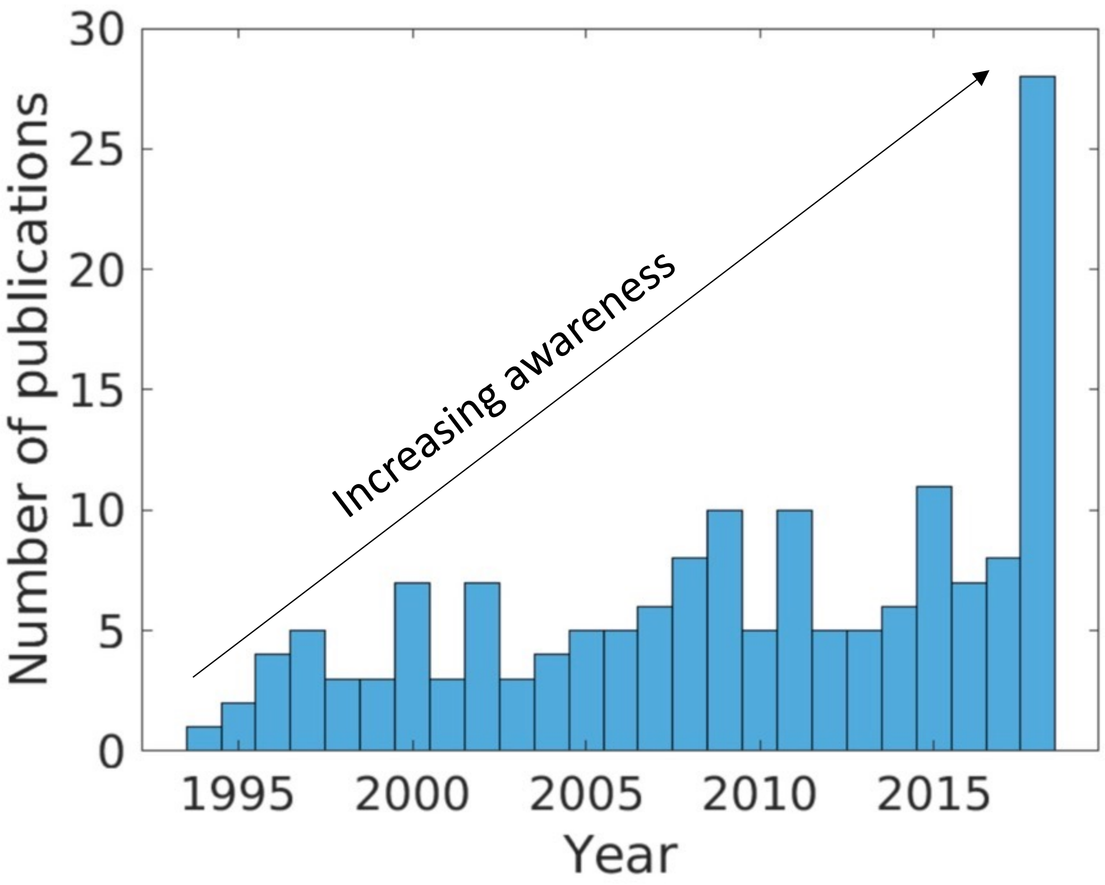
ILLUSTRATION BY NASA

❑ Machine Learning in Space Weather

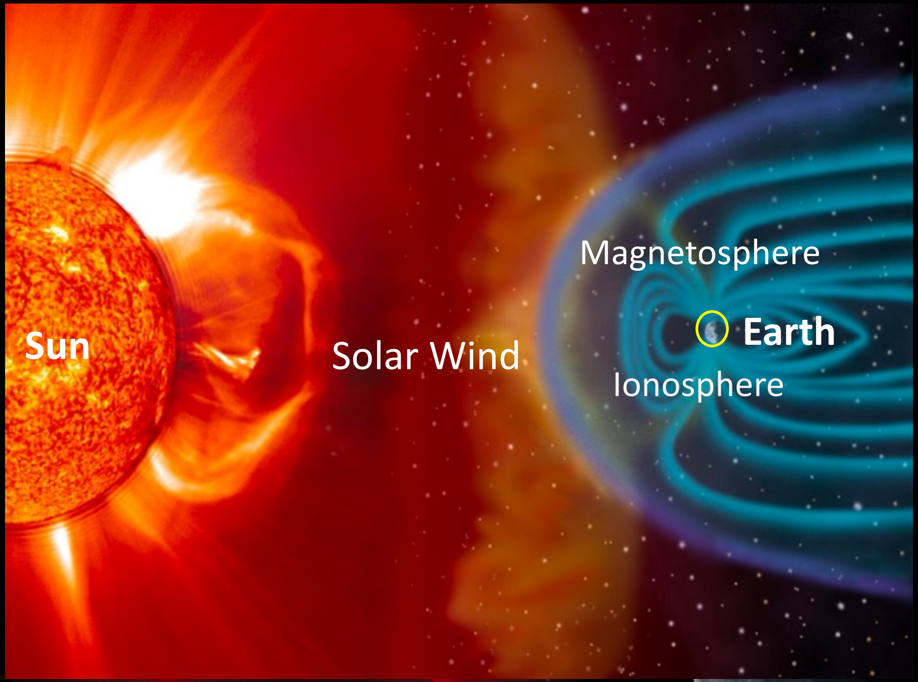
Review paper:

E. Camporeale, **The Challenge of Machine Learning in Space Weather Nowcasting and Forecasting**, *Space Weather* (under review). Available on arXiv:1903.05192

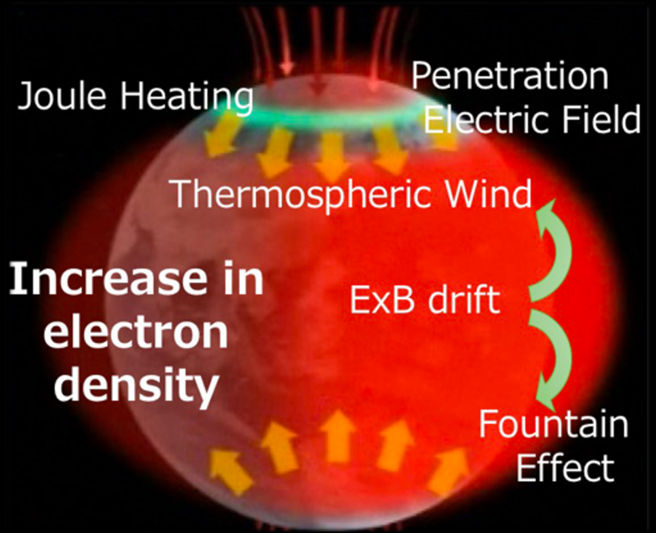


- Geomagnetic indices, Dst and Kp
- Relativistic electrons at geosynchronous orbit
- Solar Energetic Particles (SEP)
- F10.7 index and Sunspot number
- Solar wind speed
- CME arrival time
- Solar flares
- Ionospheric TEC and scintillation, etc.
- ……

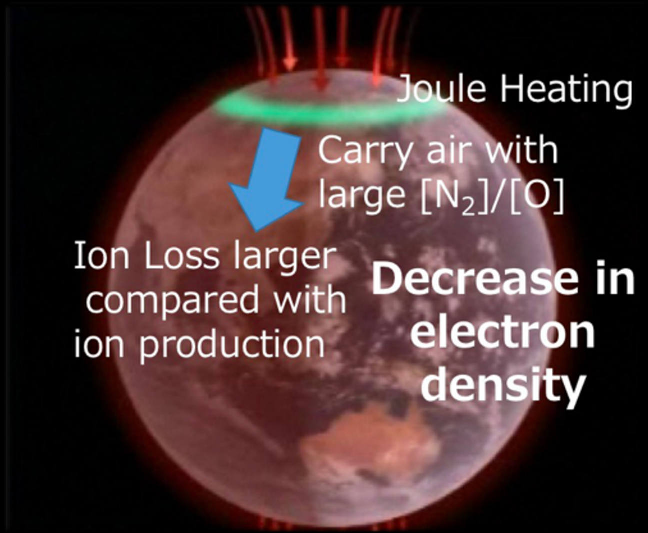
Space Weather Phenomenon: Geomagnetic Storm



Response



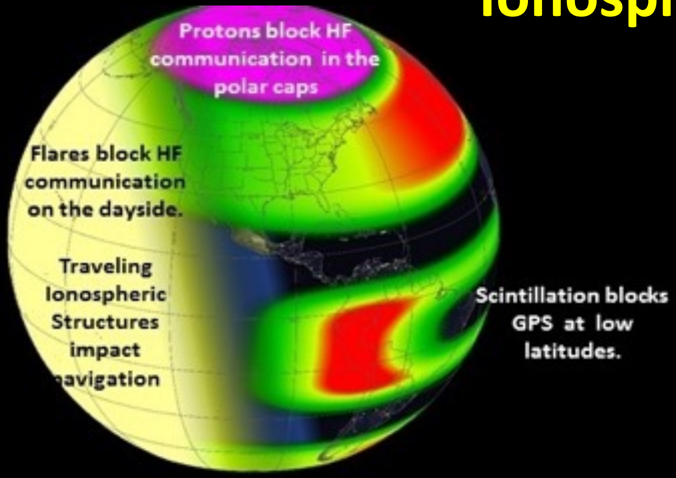
Positive storm

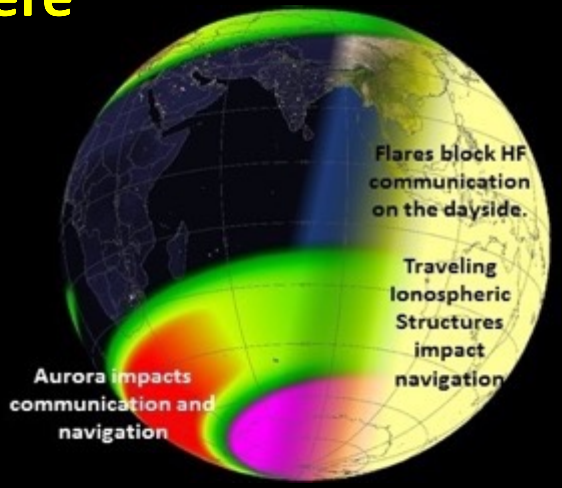


Negative storm

Ionosphere

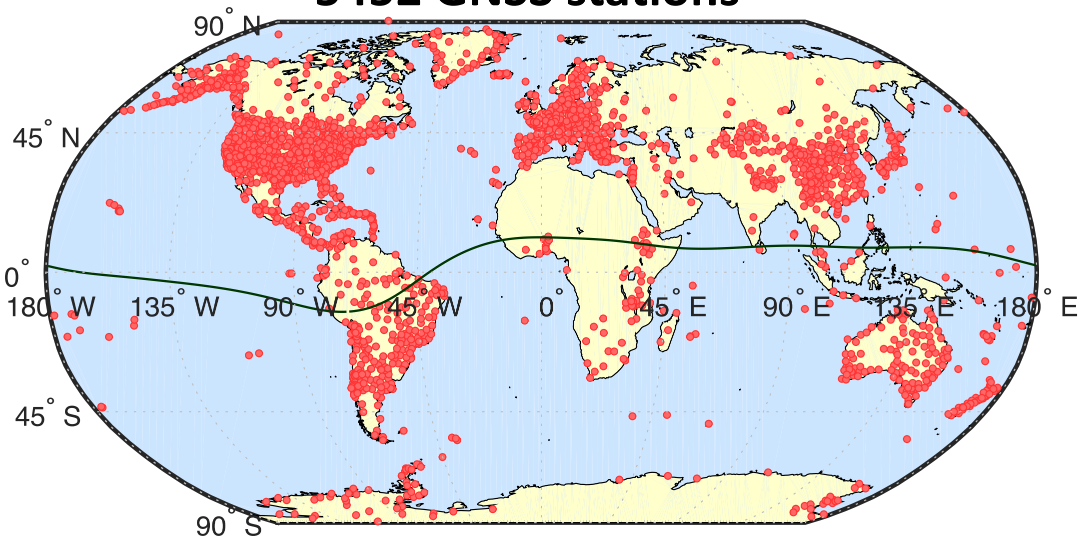
Impacts



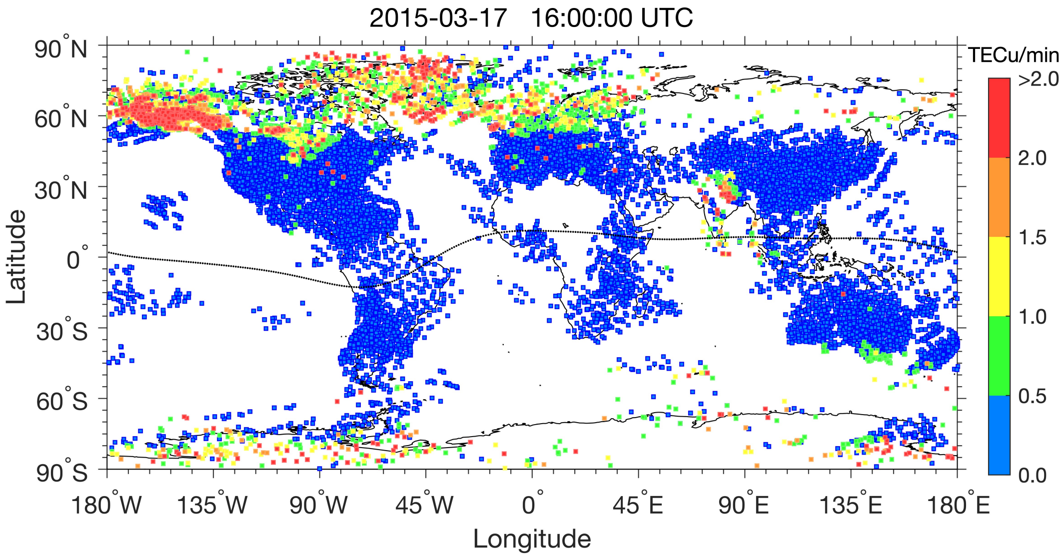


Global GNSS Networks

5452 GNSS stations

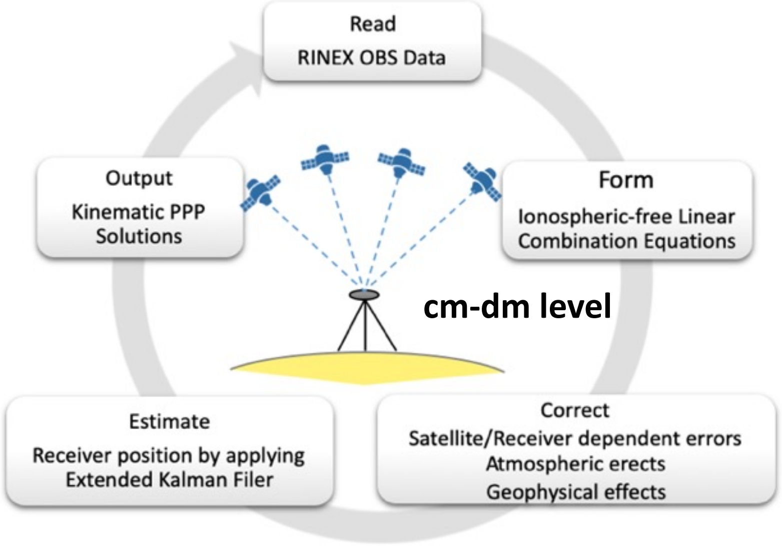


Ionospheric Disturbances



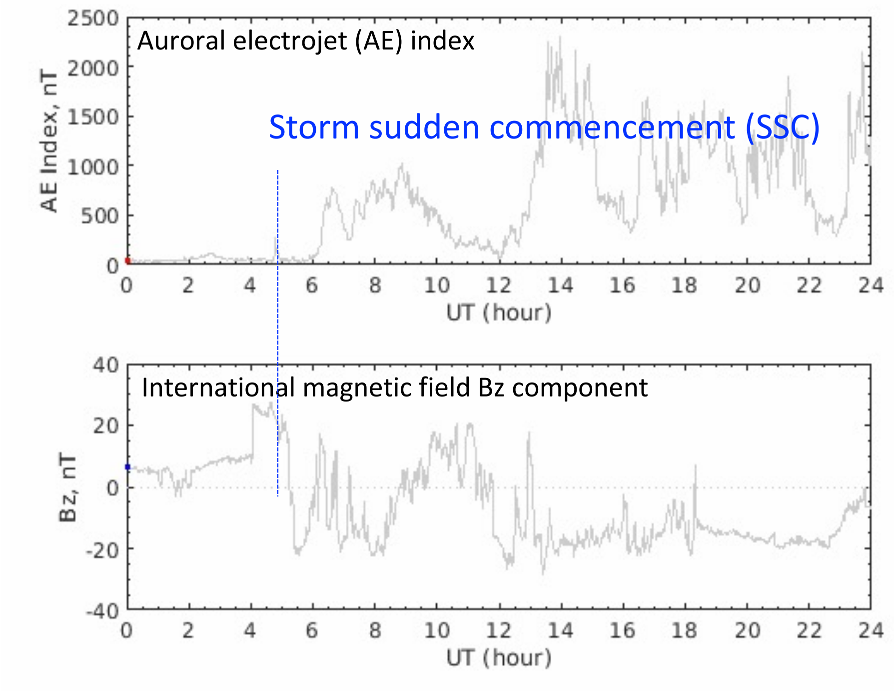
impacts

Kinematic Precise Point Positioning (PPP)

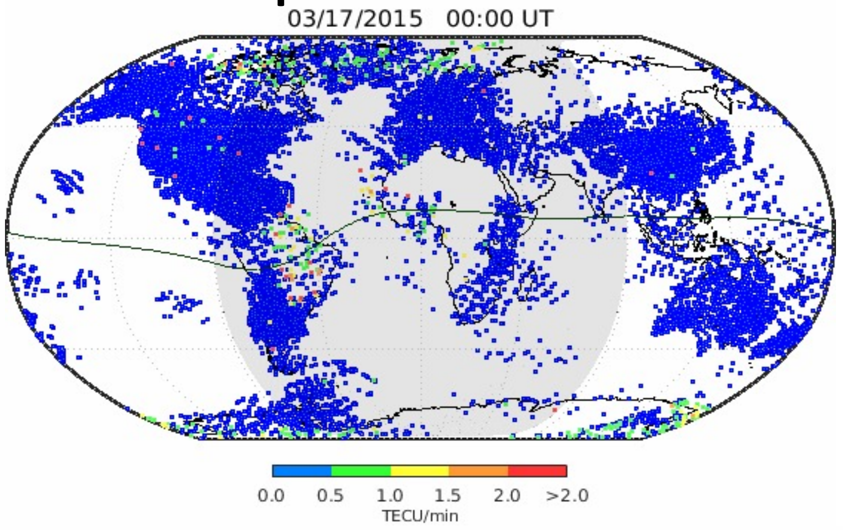


❑ Overview of storm-induced ionospheric disturbances and PPP errors

March 2015 St. Patrick's Day Storm



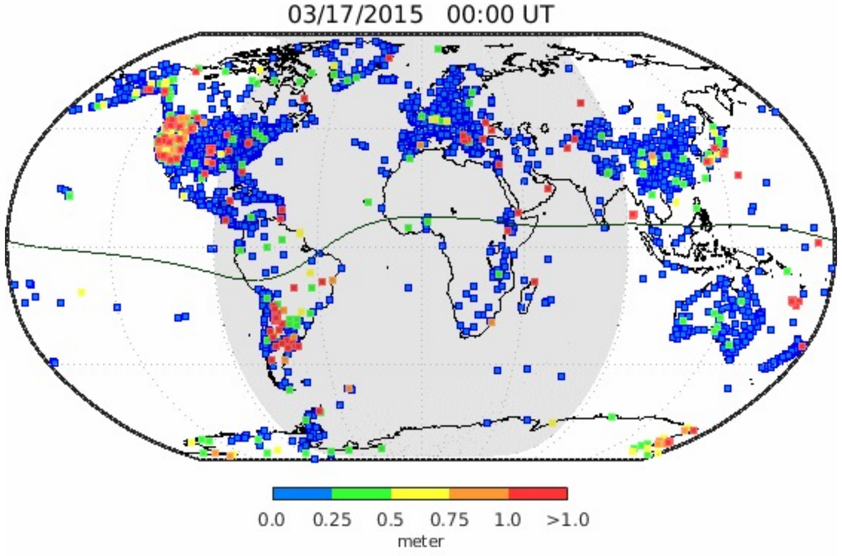
Ionospheric disturbances



Rate of TEC (ROT) Index

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

Kinematic GPS PPP errors



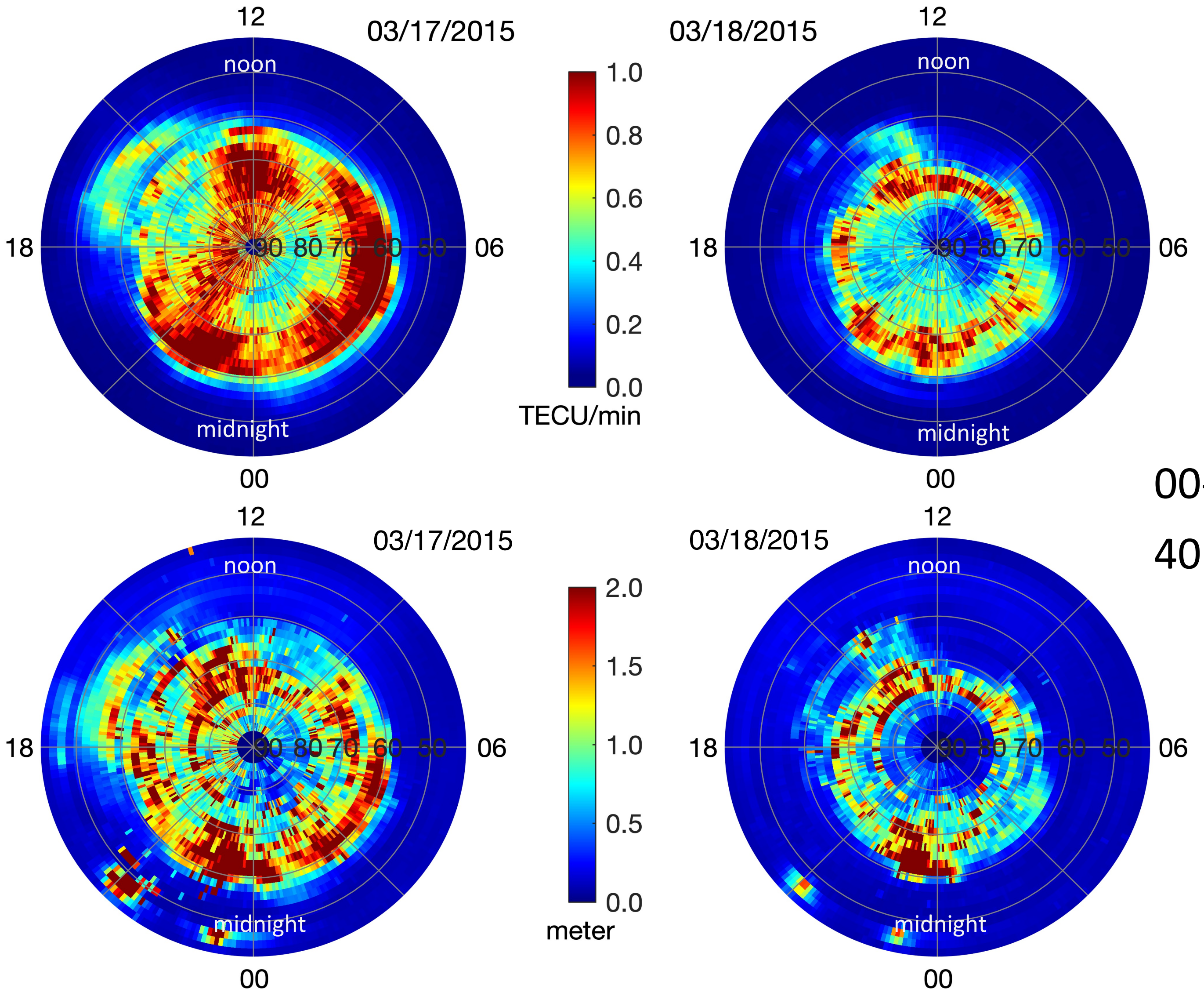
PPP 3-Dimensional errors:

3-D = $\sqrt{Horizontal^2 + Vertical^2}$

❑ High latitude-Northern Hemisphere (polar view)

ROTI

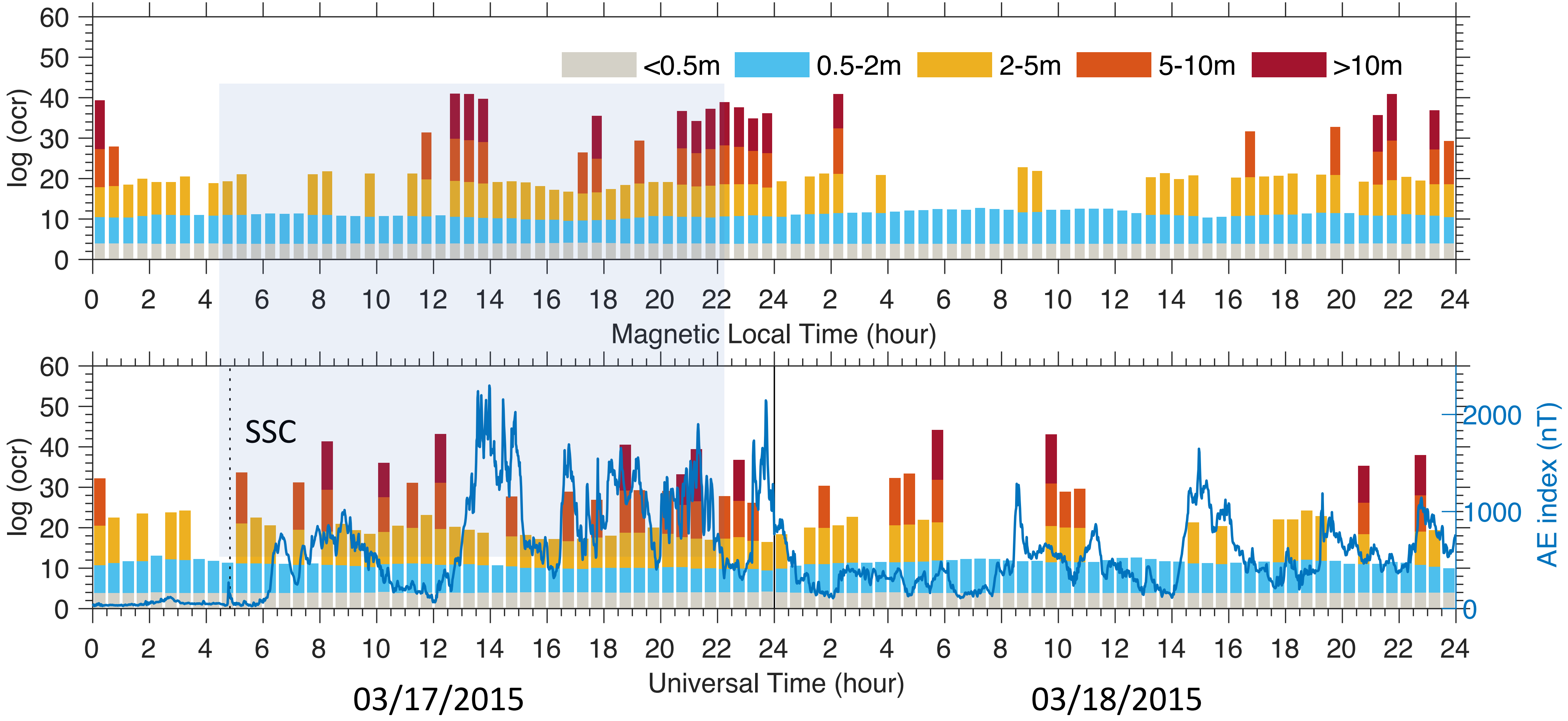
GPS PPP errors



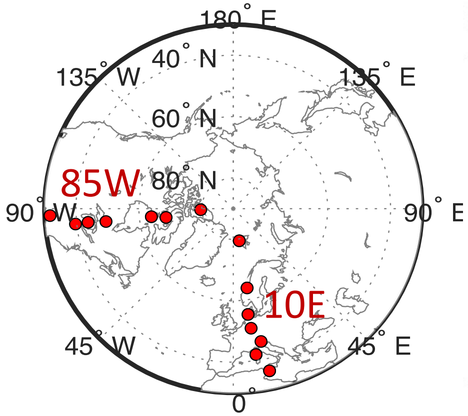
00-24 magnetic local time

40°-90°N magnetic latitude

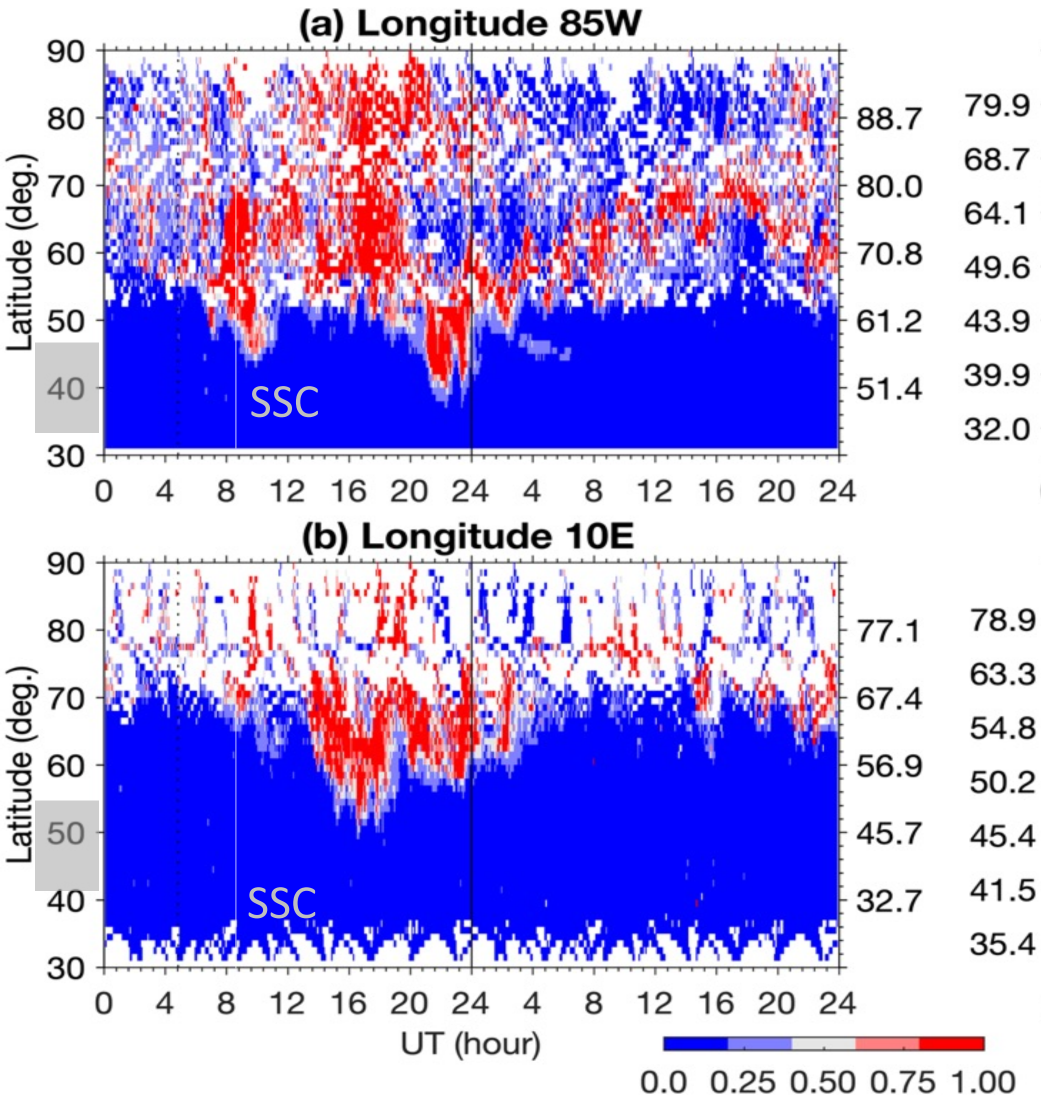
❑ High latitude-Northern Hemisphere (error distribution)



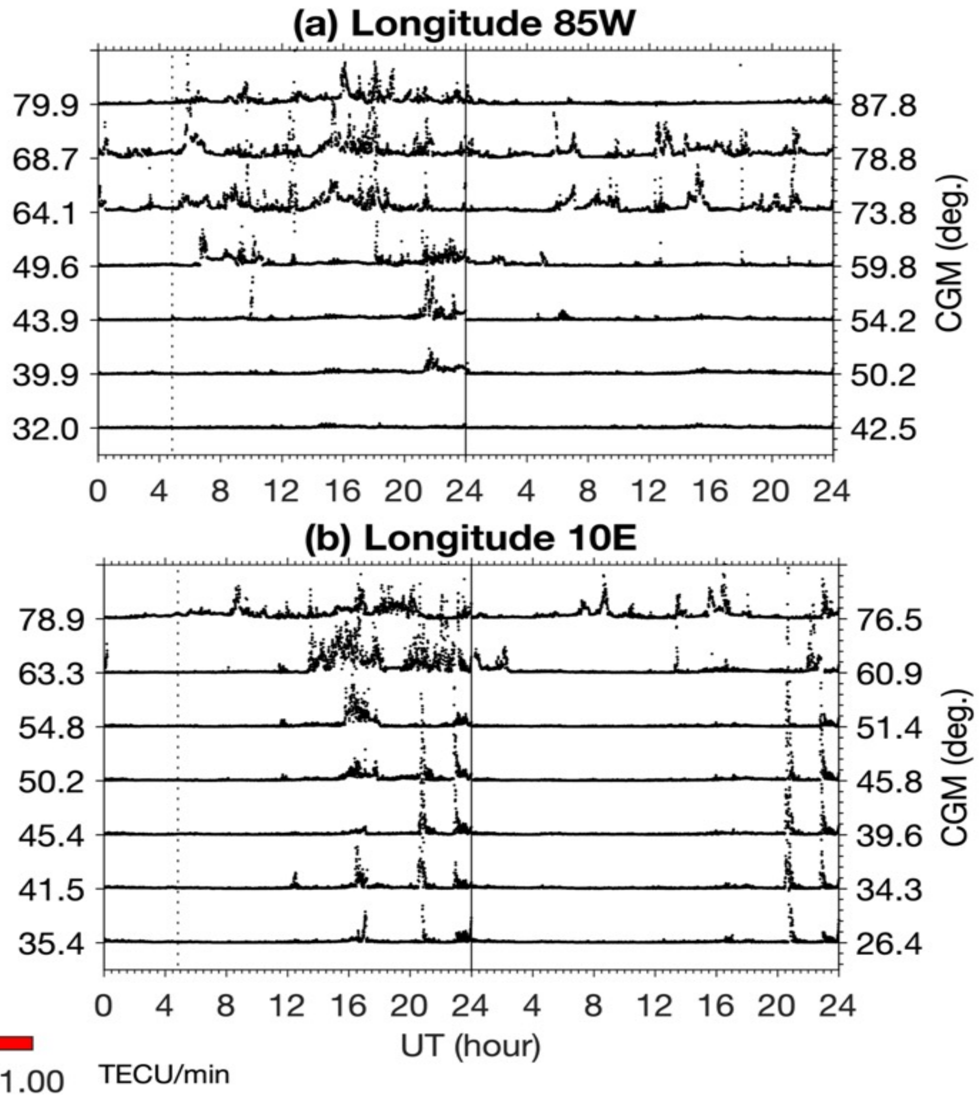
❑ High latitude-Northern Hemisphere (selected longitudes)



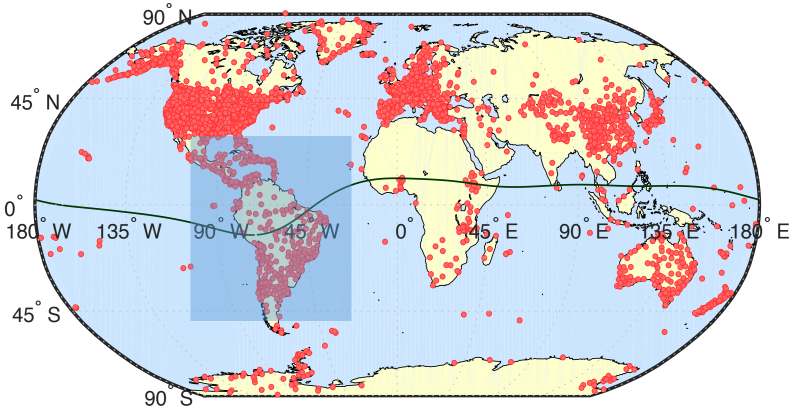
ROTI



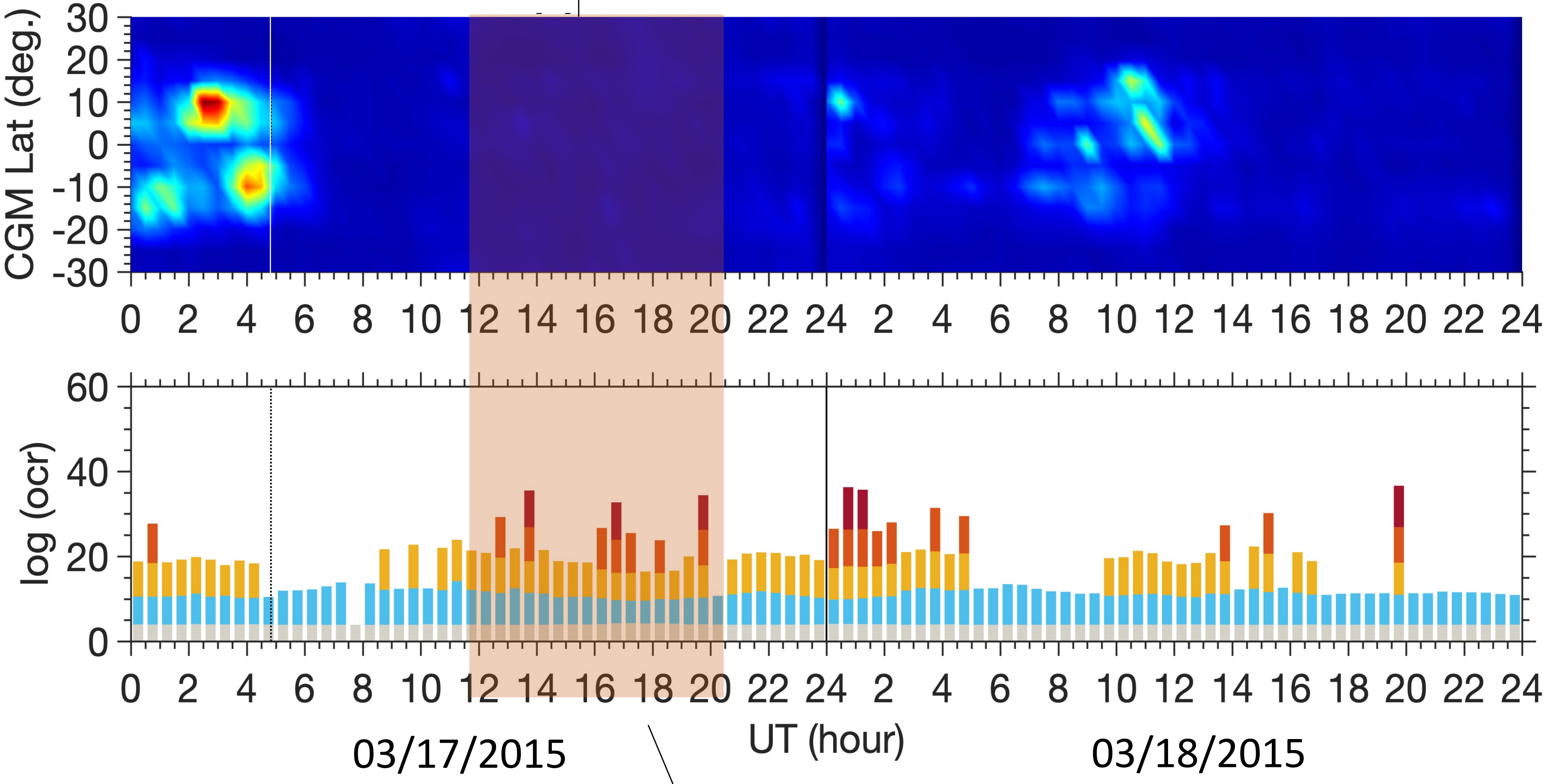
GPS kinematic PPP error



❑ Low latitude-Central and South America



Insignificant ROTI



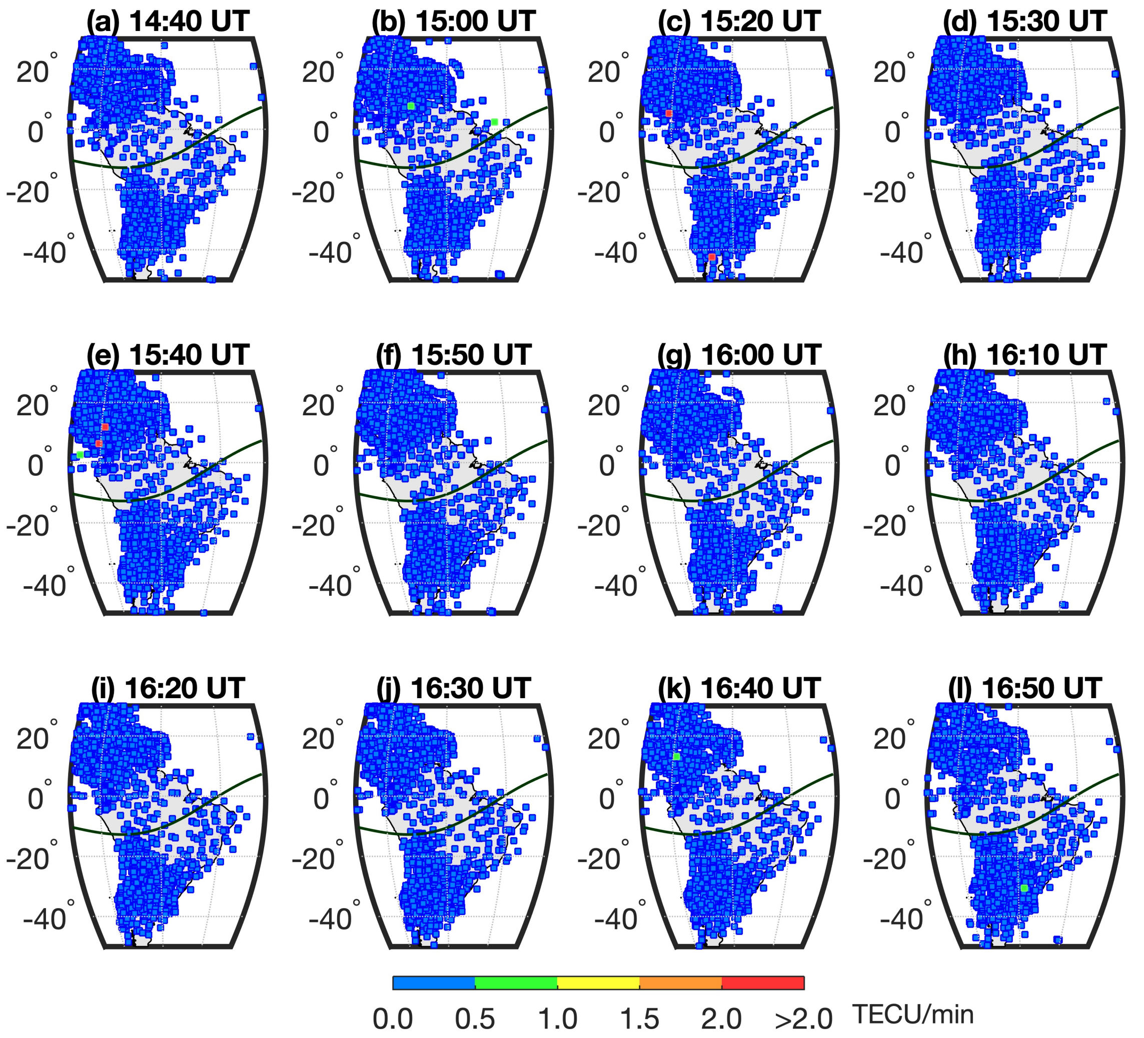
Large position error

❑ Low latitude-Central and South America

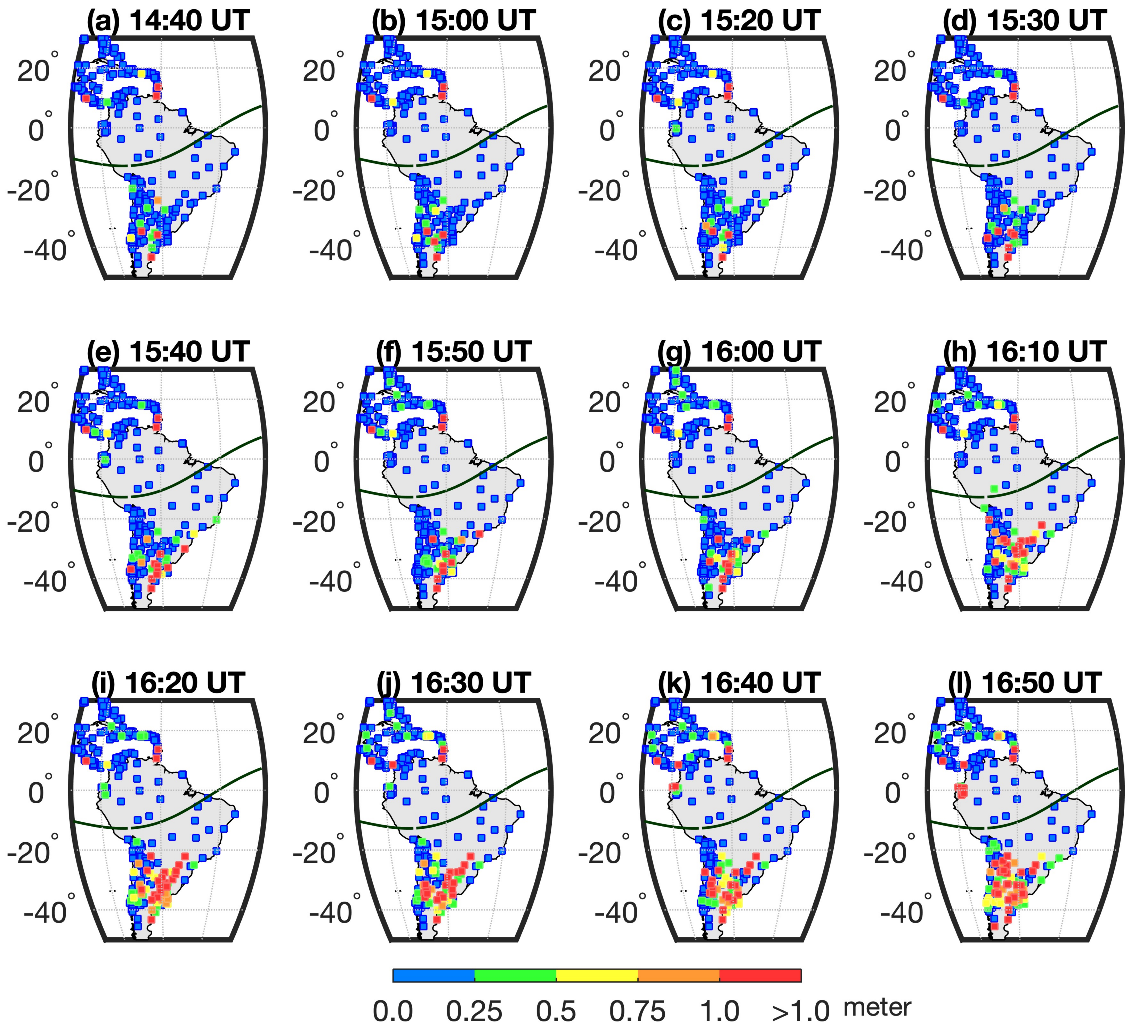
Daytime: 14:40-16:50 UT

03/17/2015

ROTI



Kinematic GPS PPP error

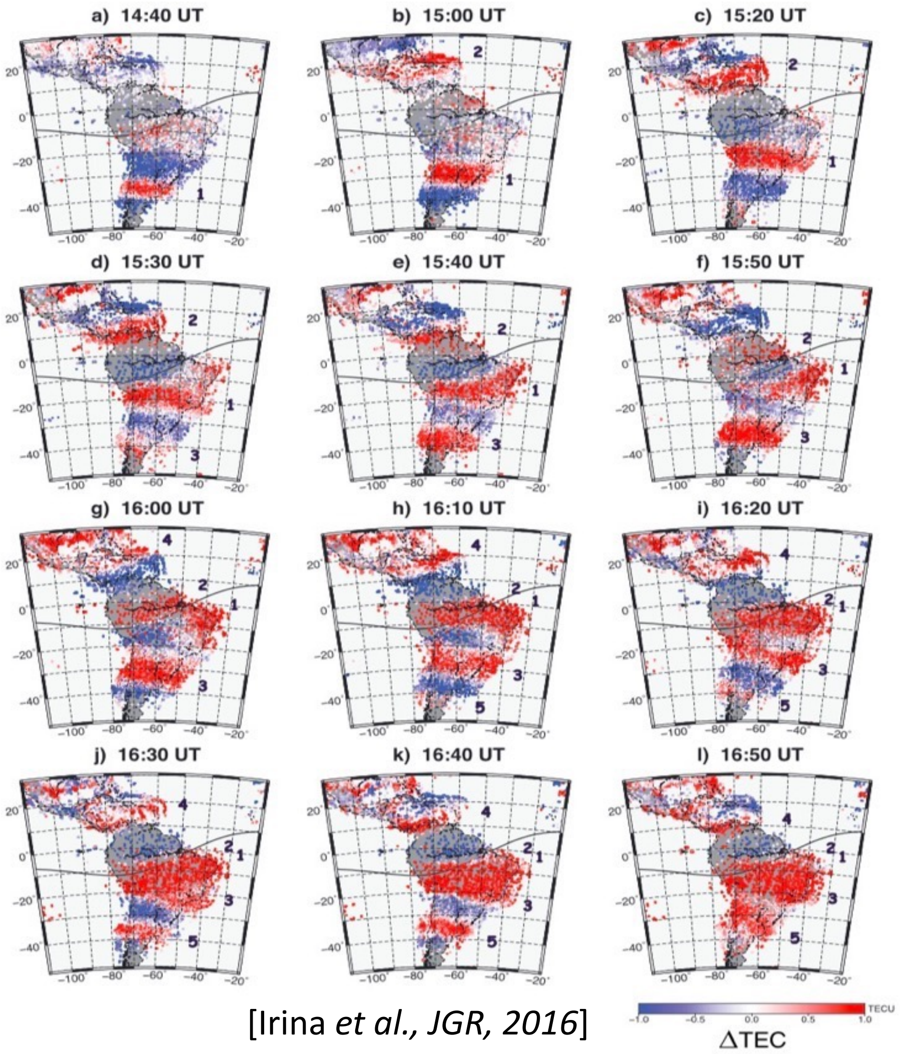


❑ Low latitude-Central and South America

Daytime: 14:40-16:50 UT

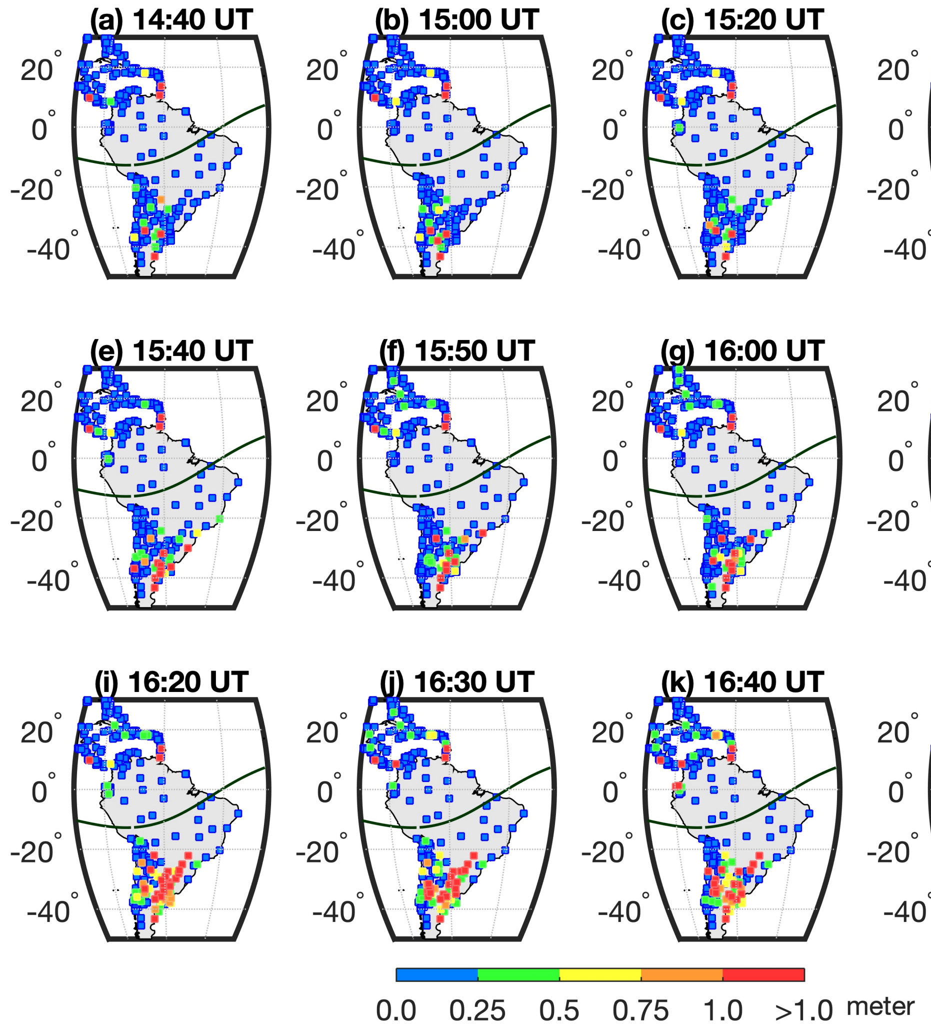
03/17/2015

Convergence of LSTIDs



[Irina *et al., JGR, 2016*]

Kinematic GPS PPP error



Summary

❑ Ionospheric storm and associated PPP errors

- **At high latitude**
  - -PPP error, >10 m, or even loss of lock
  - -Ionospheric plasma irregularities (ROTI)
- **At low latitude**
  - -PPP error, > 10 m, not as significant as at high latitude
  - -EIA enhancements, Convergence of LSTIDs

❑ ML challenges in ionospheric space weather

- Storm-induced ionospheric response is complex;
- Define meaningful indicators for ionospheric disturbances;
- Establish benchmarks for ionospheric disturbances;

❑ Global GNSS networks (~5500 stations)

- large and freely available dataset for ML in ionospheric space weather.

Thank you!