FIG WORKING WEEK 2019

22–26 April, Hanoi, Vietnam

"Geospatial Information for a Smarter Life and Environmental Resilience"

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Comparison of the Effect of High-Latitude and Equatorial Ionospheric Scintillation on GPS Signals During the Maximum of Solar Cycle 24

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Brief : What is Ionospheric Scintillation

Random amplitude and phase fluctuations observed in radio signals propagating through electron density irregularities in the ionospheric plasma and most commonly occurs in equatorial, auroral, and polar regions

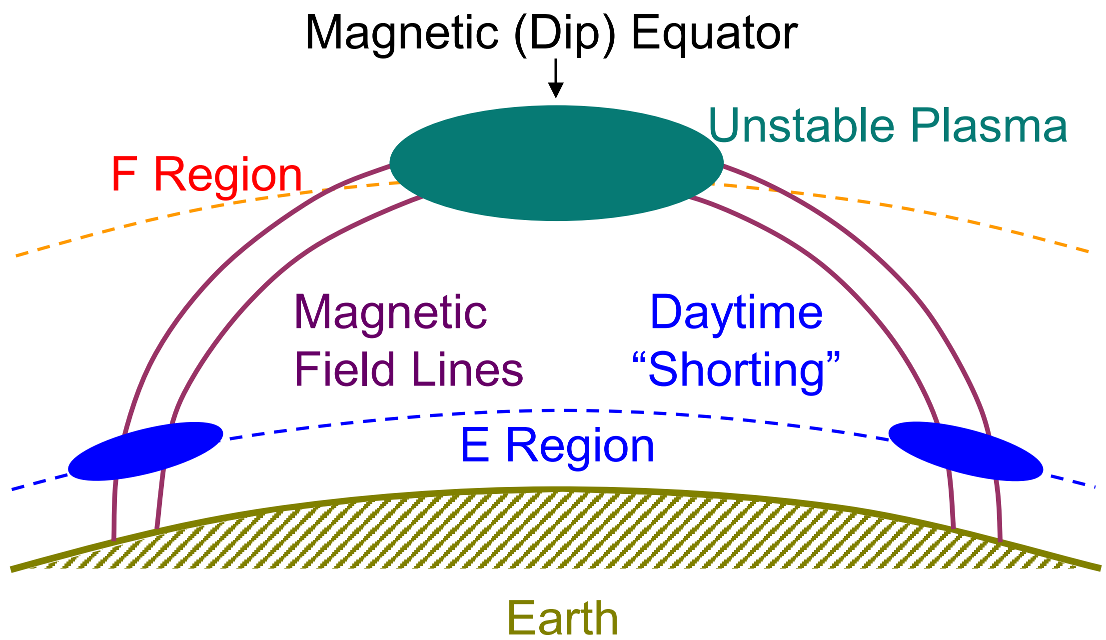
- Radio scintillation is the term used to represent the random fluctuations in signal phase and amplitude that develop when the radio waves propagate through ionospheric electron density irregularities

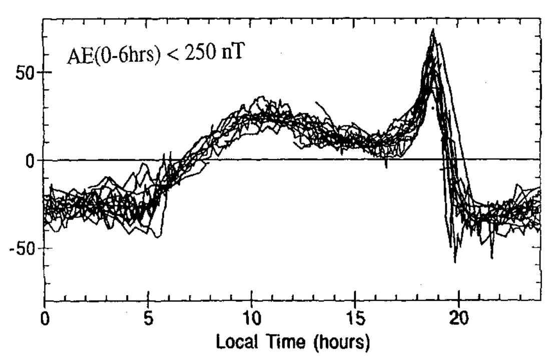
- Irregularly structured ionospheric regions can cause diffraction and scattering of trans-ionospheric radio signals. When received at an antenna, these signals present random temporal fluctuations in both amplitude and phase. This is known as ionospheric scintillation.

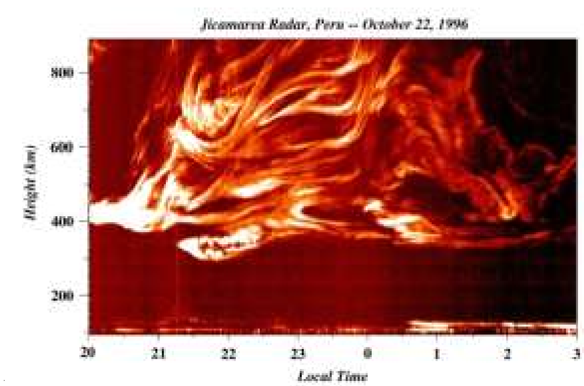
- Severe scintillation of the GPS satellite signals can result in loss of satellite tracking, which degrades GPS positioning accuracy. Even when satellite tracking is maintained, scintillation can cause errors decoding the GPS data messages, cycle slips, and ranging errors.

Equatorial Plasma Bubbles

- **Plasma moves easily along field lines**
- **Upward plasma drift supports plasma against gravity ⇒ unstable configuration**
- **E-region "shuts out" electrodynamic instability during day**
- **At night, E-region conductivity too small to shut-out E field**
- **Instability in plasma grows to form equatorial plasma bubbles (EPBs), which contain irregularities seen by radars (right image) & which disrupt communications**
- **Irregularities mainly present during quiet times**







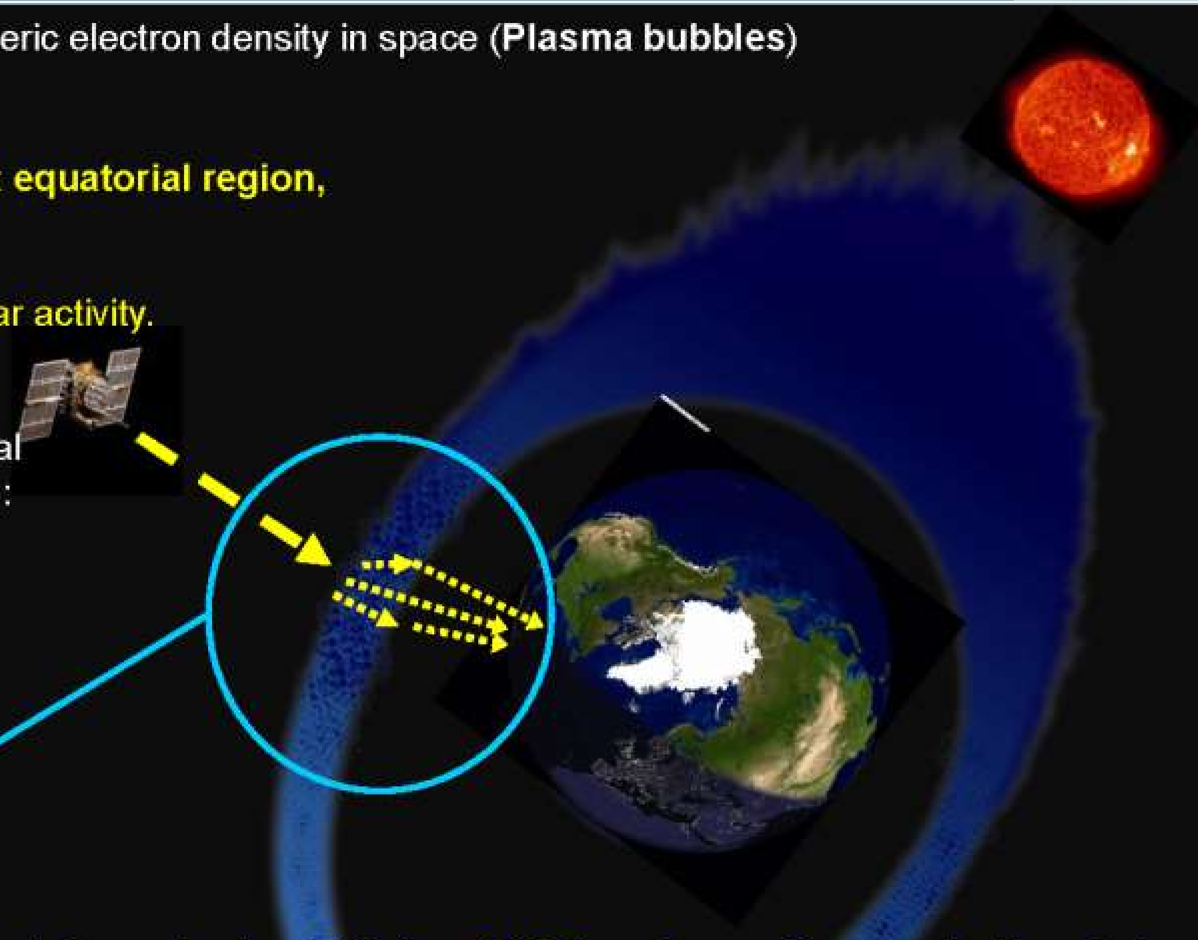
GNSS Signal Scintillation in Equatorial Region

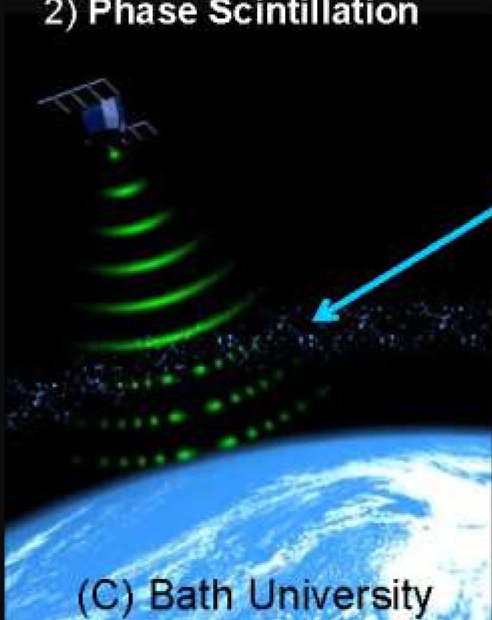
Small-scale irregularities of ionospheric electron density in space (**Plasma bubbles**) causes GNSS signal scintillation.

Plasma bubbles is more common at **equatorial region,**
Mostly evening after sunset,
Seasonal variation,
Bubbles increase during severe solar activity.

By the plasma bubbles, GNSS signal diffracted and refracted this leads to:

1) **Amplitude Scintillation**
2) **Phase Scintillation**





Due to ionospheric scintillation, GNSS receiver performance is degraded:

- Signal power loss (likely Loss-of-Lock)
- Affects signal tracking
- Increase measurement noise

NOAA Space Weather Workshop, 4 May 2017, Broomfield Colorado

The most affected sites by Scintillation (2014-2016)

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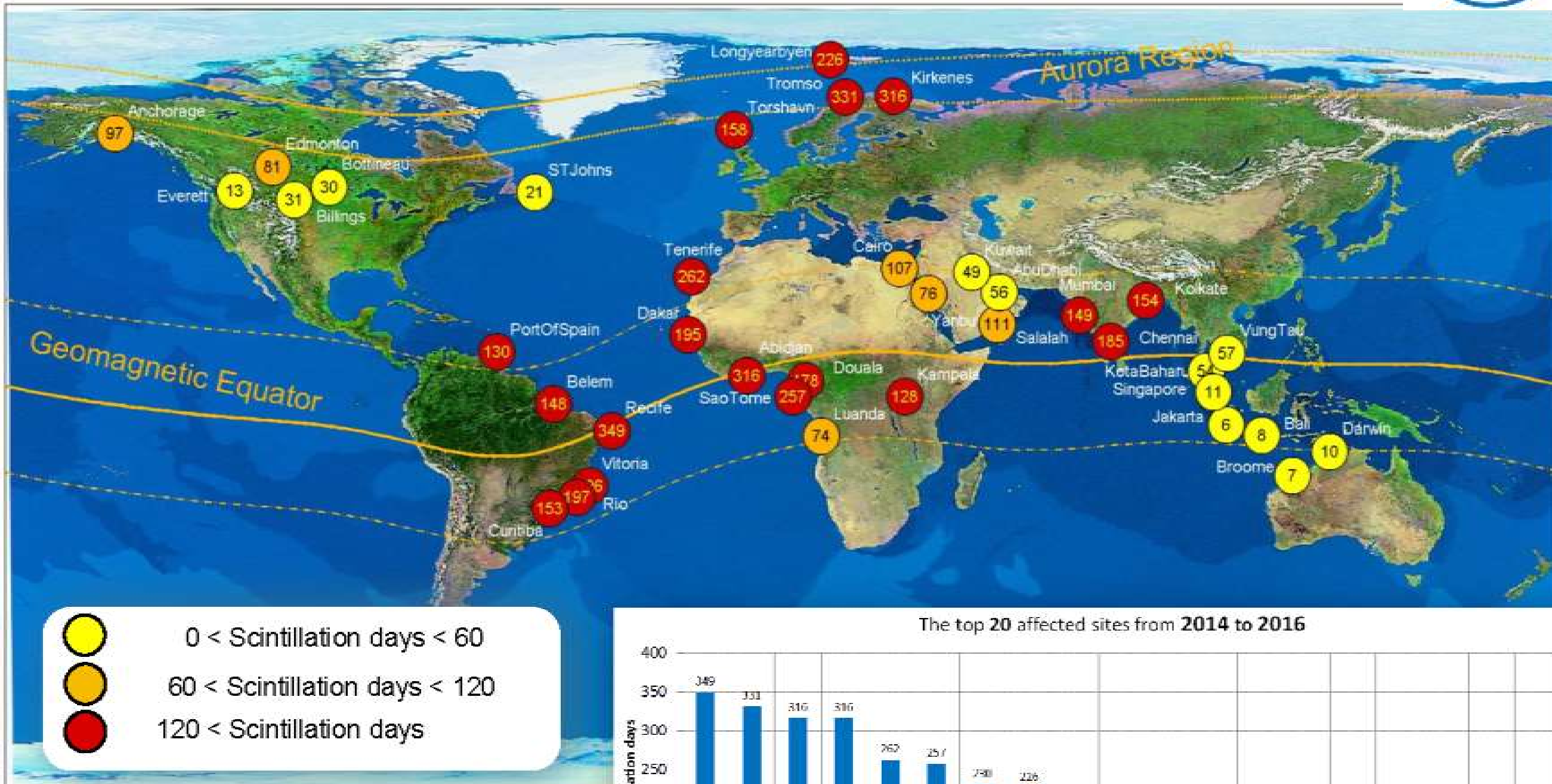
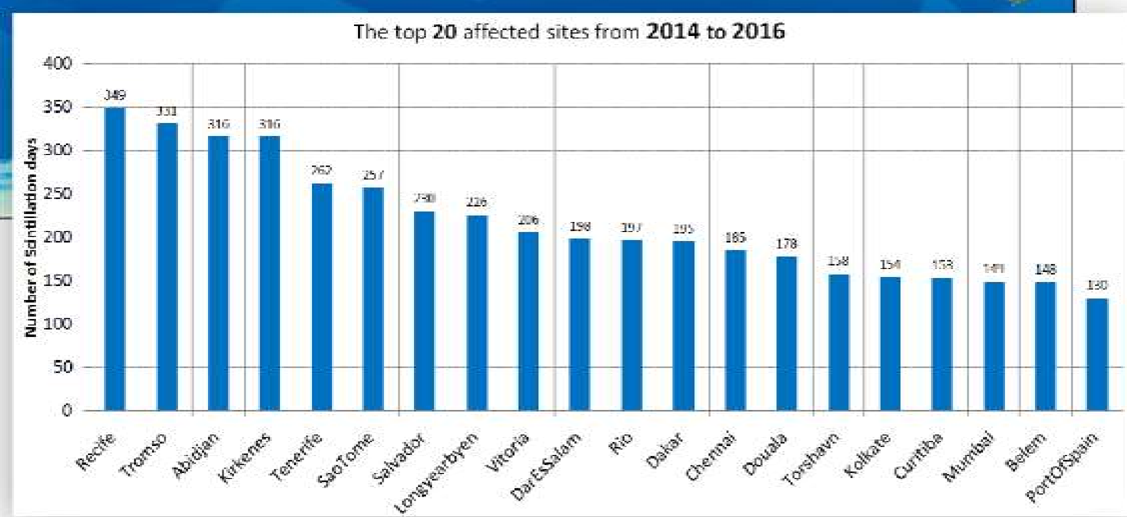
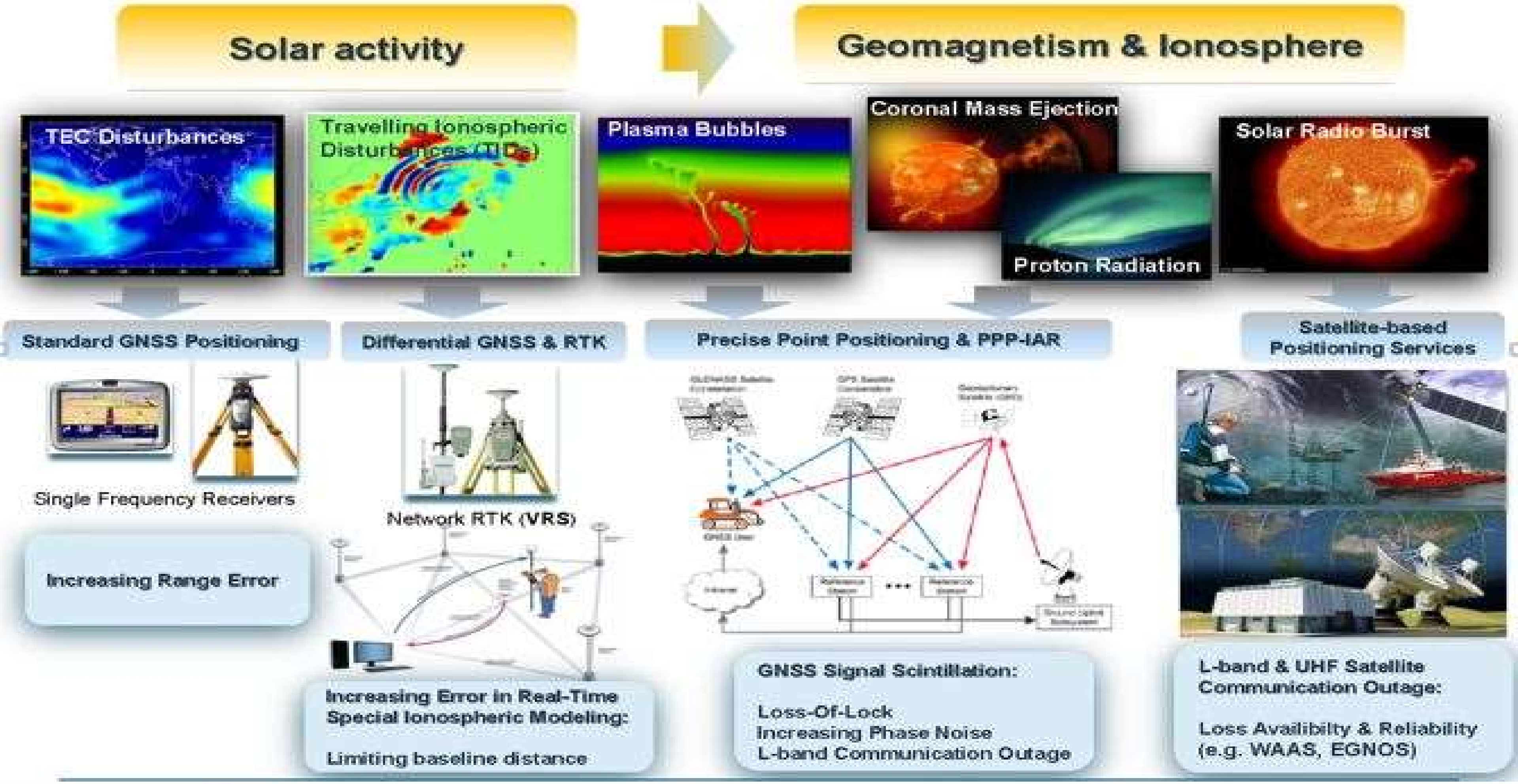


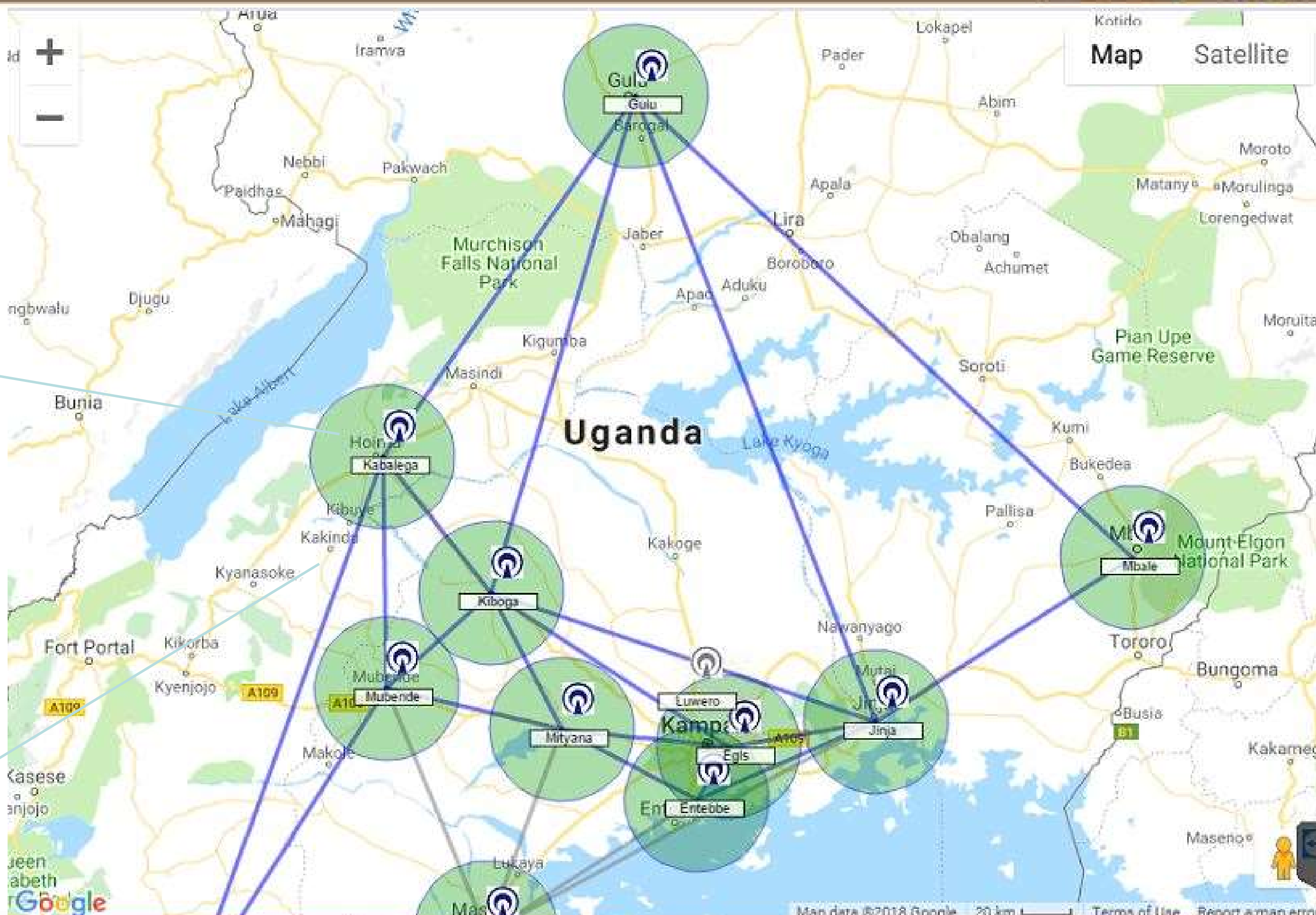


The most affected sites are in:

Brazil
West Africa
Scandinavia


Solar activity
Geomagnetism & Ionosphere
TEC Disturbances
Travelling Ionospheric Disturbances (TIDs)
Plasma Bubbles
Coronal Mass Ejection
Proton Radiation
Solar Radio Burst
Standard GNSS Positioning
Differential GNSS & RTK
Precise Point Positioning & PPP-IAR
Satellite-based Positioning Services
Single Frequency Receivers
Network RTK (VRS)
Increasing Range Error
Increasing Error in Real-Time Special Ionospheric Modeling:
Limiting baseline distance
GNSS Signal Scintillation:
Loss-Of-Lock
Increasing Phase Noise
L-band Communication Outage
L-band & UHF Satellite Communication Outage:
Loss Availibilty & Reliability
(e.g. WAAS, EGNOS)

Areas of Research:
Hoima
Masaka
Kampla



Registered drop in received satellites during "storms" that are often in the areas close to the rift valley

Challenges:

- Amplitude scintillation, or short-term fading, can be so severe that signal levels drop below a GPS receiver's lock threshold, requiring the receiver to attempt reacquisition of the satellite signal.

- Phase scintillation, characterized by rapid carrier-phase changes, can produce cycle slips in static observations.

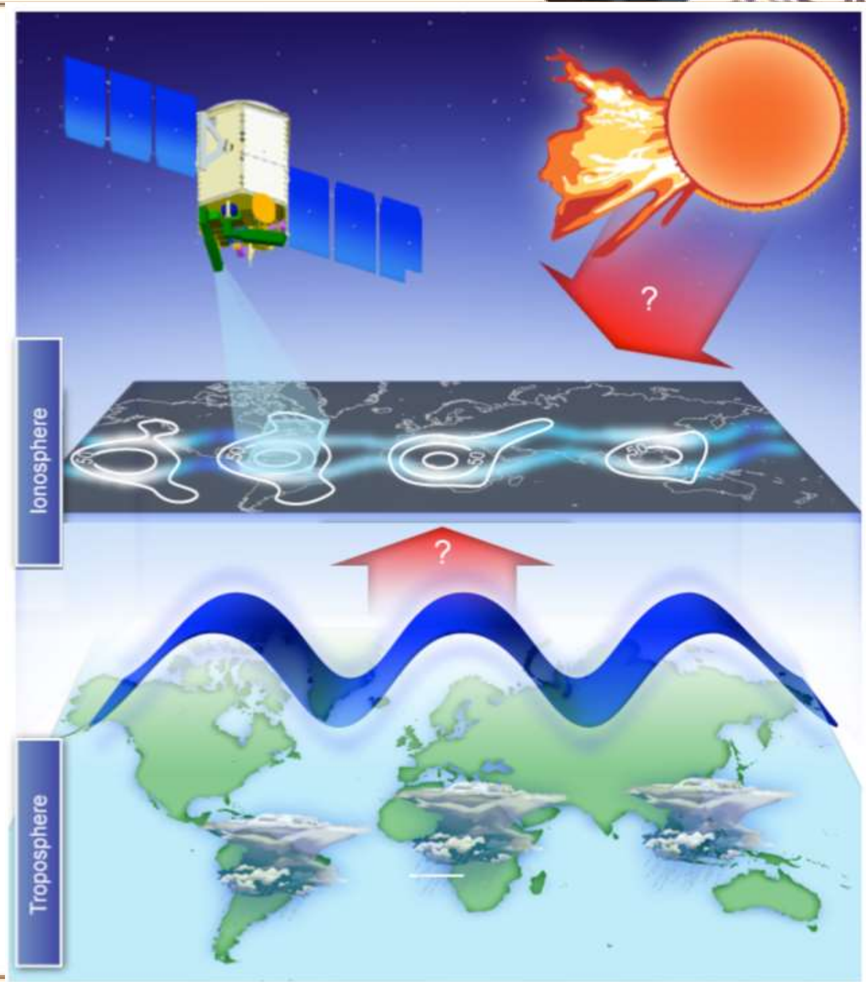
- It can degrade the quantity and quality of the user measurements as well as the quantity and quality of measurement at the reference station;

- Sometimes "**IS**" challenges a receiver's ability to hold lock on a signal or cause complete loss of use of signals for extended periods.

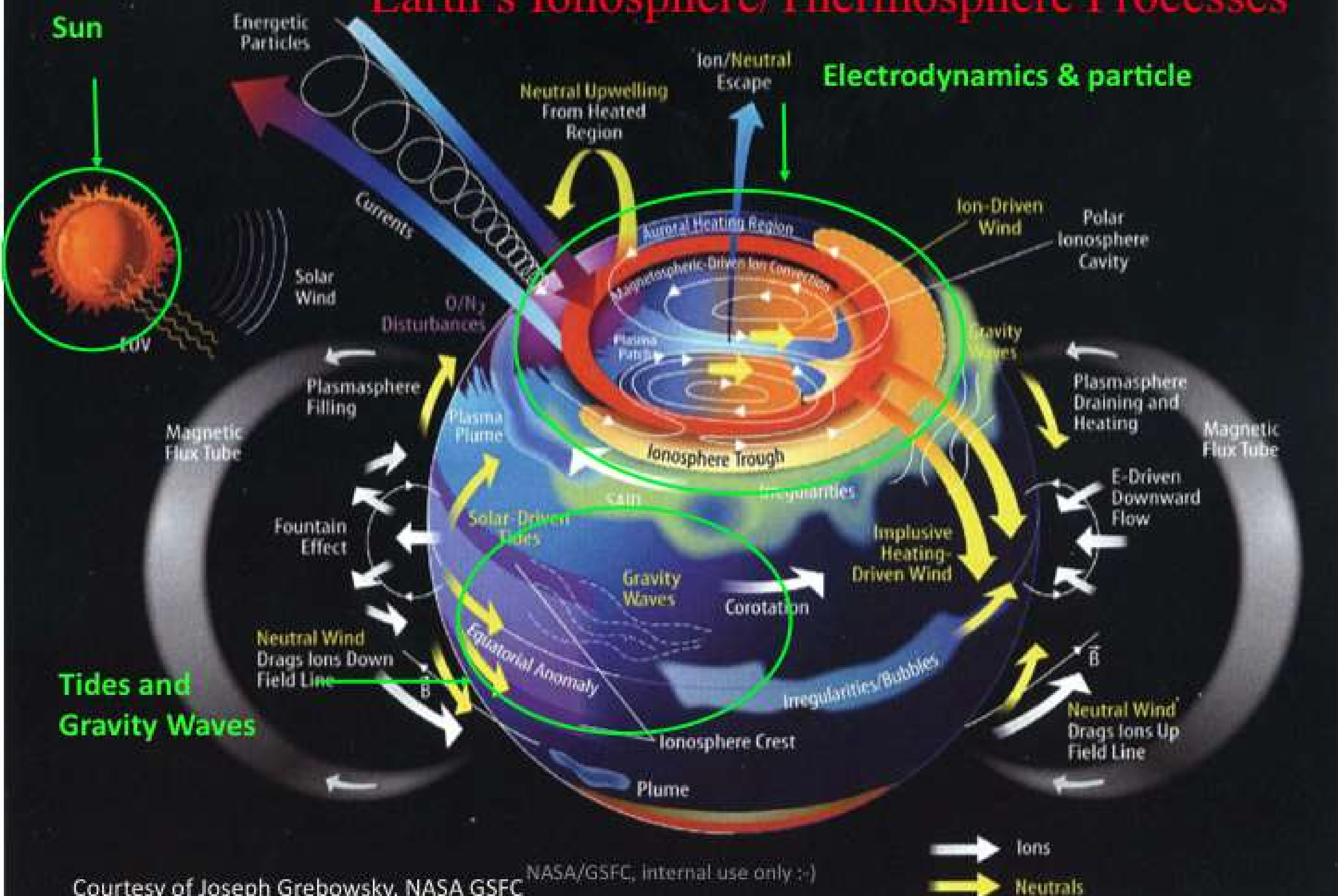
The ionosphere is the densest plasma between the Earth and Sun, and is traditionally believed to be mainly influenced by forcing from above (solar radiation, solar wind/magnetosphere)

Recent scientific results show that the ionosphere is strongly influenced by forces acting from below.

Research remains to be done:
How competing influences from above and below shape our space environment.



Earth's Ionosphere/Thermosphere Processes



Courtesy of Joseph Grebowsky, NASA GSFC

Mitigations:

- Incorporation of many satellites during observations(Use a complete GNSS Constellation) will improve the performance under scintillation conditions.
- Reduce on the re-acquisition time for a GNSS receiver. For deep fades that last less than a few tenths of a second, signals should be reintroduced back into the position solution within a few seconds or less.

Way forward

- In Uganda and central Africa, there is need to establish forecasting tools which will allow issuing warnings ahead of time, when a certain region will be affected by scintillations exceeding a certain threshold. This will allow to plan for "ionospheric outages" in a similar way as weather forecast is currently used for suspension of operation of airports when thunderstorms are approaching.

EagleCORS Uganda is looking for partners to develop such early warning systems along side the CORS network already established in Uganda.

Thank you for listening

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