Equatorial Scintillation Impact On GNSS Precise Positioning Services

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Overview

Introduction to Fugro

GNSS Infrastructure
Positioning Services

Space Weather Impact on GNSS Positioning

Ionospheric Disturbances
Ionospheric Plasma Bubbles

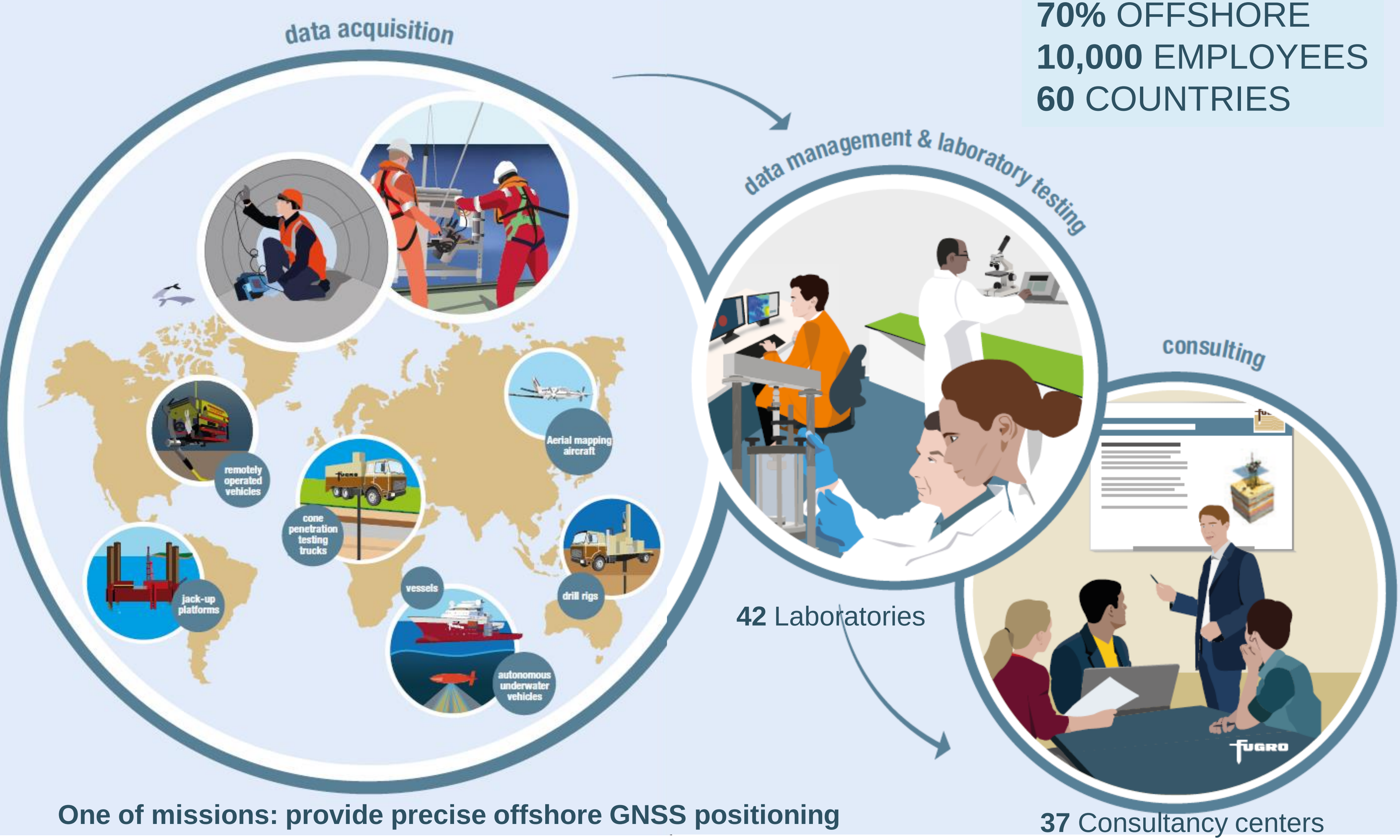
Ionospheric Scintillation

Occurrence in Equatorial Region
Fugro Scintillation Prediction Service

Summary

Fugro

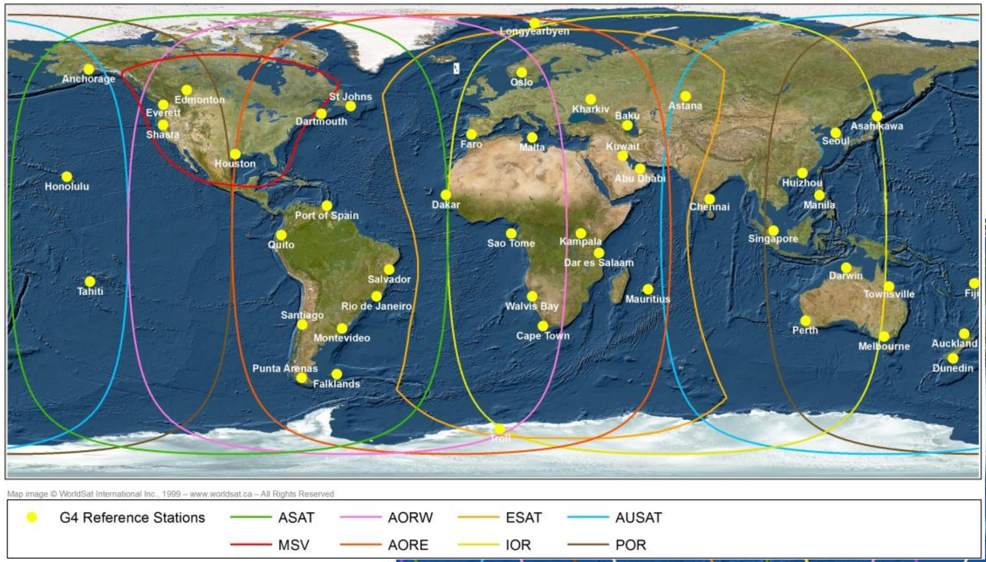
70% OFFSHORE
10,000 EMPLOYEES
60 COUNTRIES



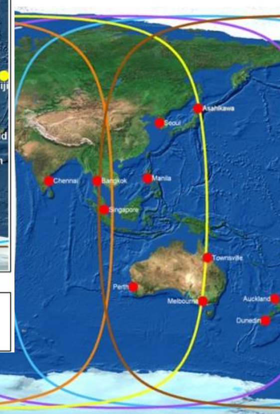
One of missions: provide precise offshore GNSS positioning

GNSS Infrastructure

More than **150** Reference Stations in Multiple Network Configurations
Using **8** Geostationary Satellite Channels

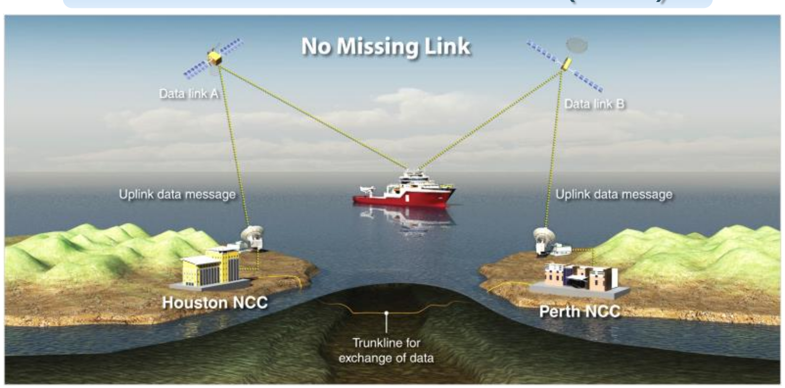


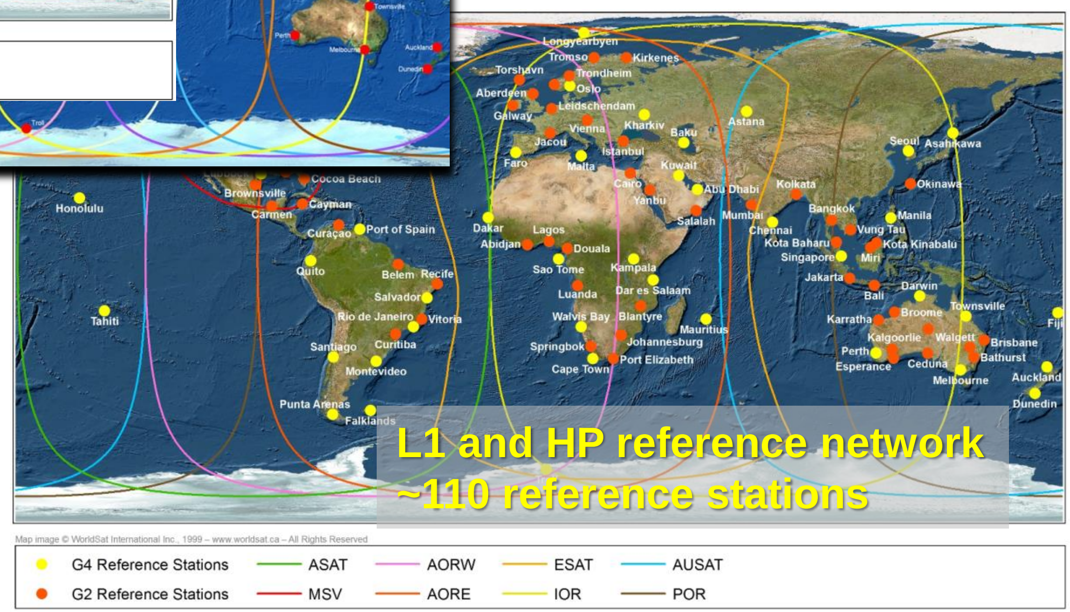
G4 reference network
~40 reference station
GPS + **GLONASS** + **BeiDou** + **Galileo**



XP independent
orbit and clock network
~60 reference stations GPS

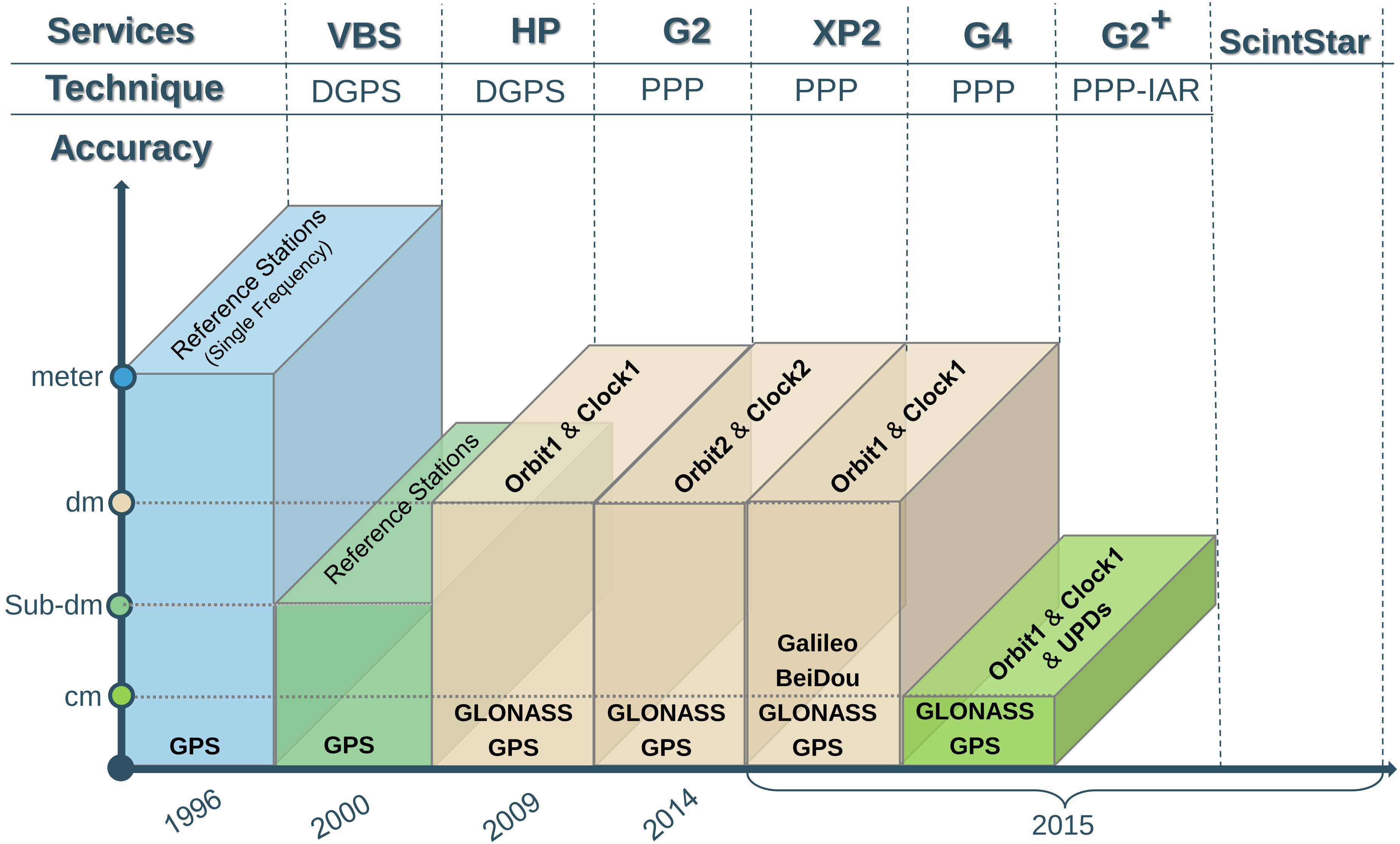
Two Network Control Center (NCC)





L1 and HP reference network
~110 reference stations

Fugro GNSS Positioning Services



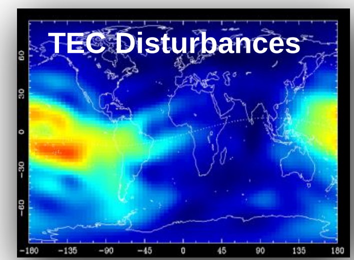
ScintStar provides scintillation prediction service specific for a GNSS user location

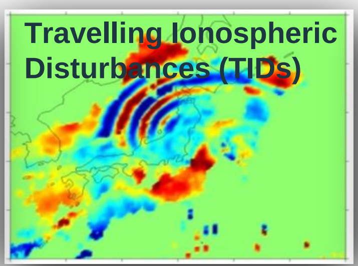
SPACE WEATHER IMPACT ON GNSS

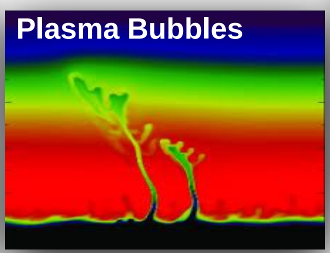
Space Weather Impact on GNSS

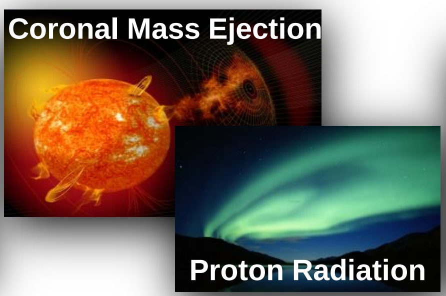
Solar activity

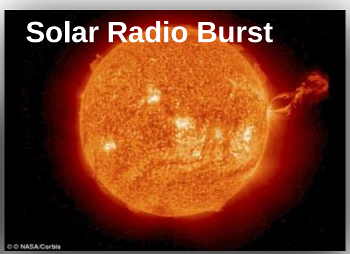
Geomagnetism & Ionosphere











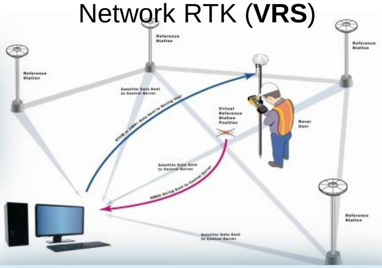
Standard GNSS Positioning

Single Frequency Receivers

Increasing Range Error

Differential GNSS & RTK

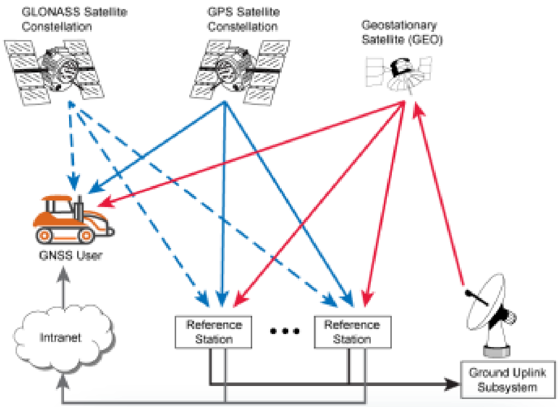
Network RTK (**VRS**)



Increasing Error in Real-Time Special Ionospheric Modeling:

Limiting baseline distance

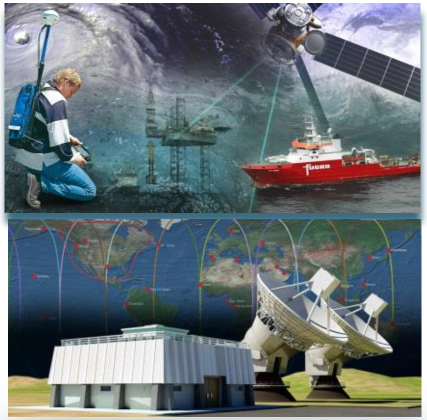
Precise Point Positioning & PPP-IAR



GNSS Signal Scintillation:

Loss-Of-Lock
Increasing Phase Noise
L-band Communication Outage

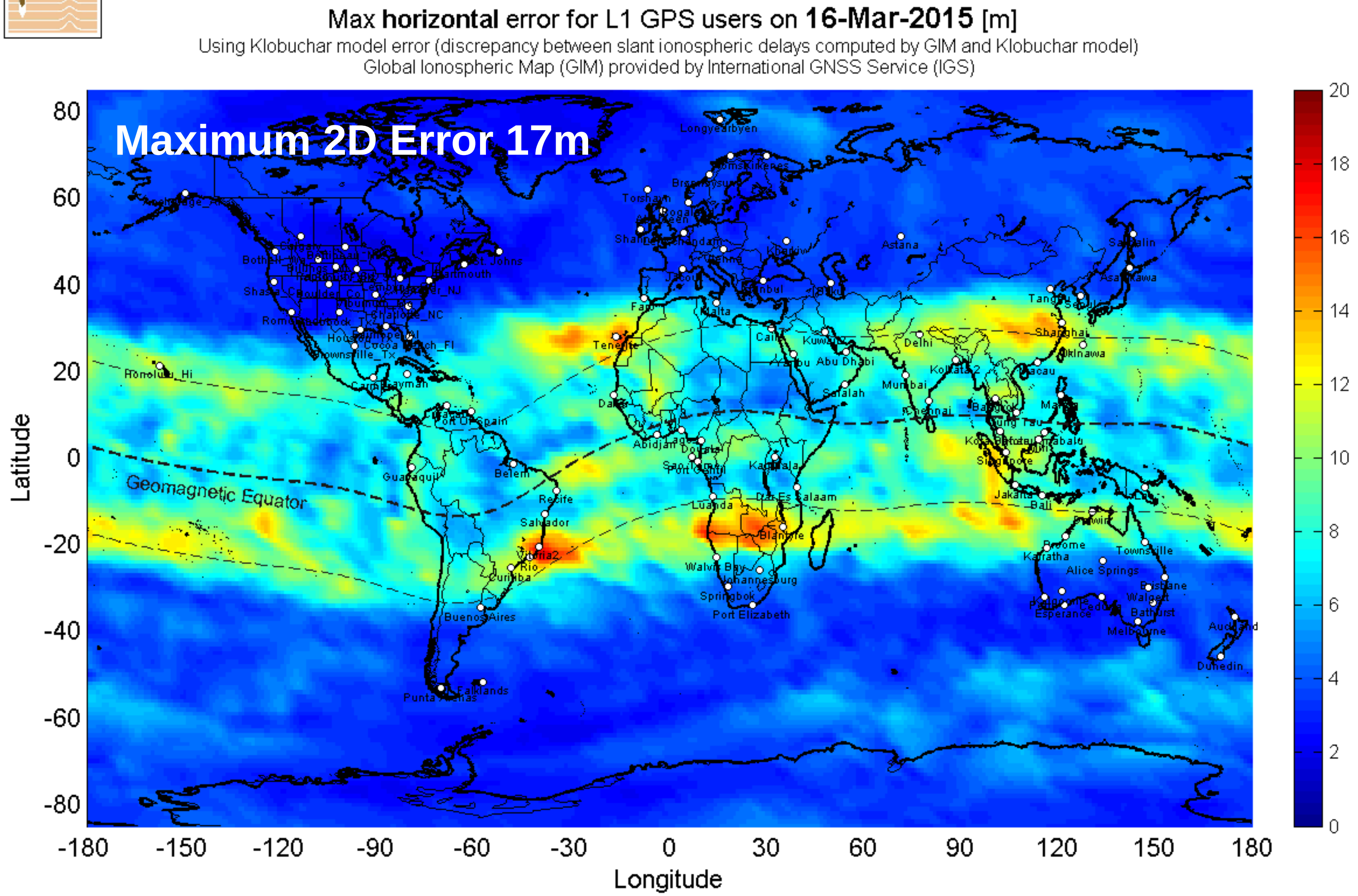
Satellite-based Positioning Services



L-band & UHF Satellite Communication Outage:

Loss Availibilty & Reliability (e.g. WAAS, EGNOS)

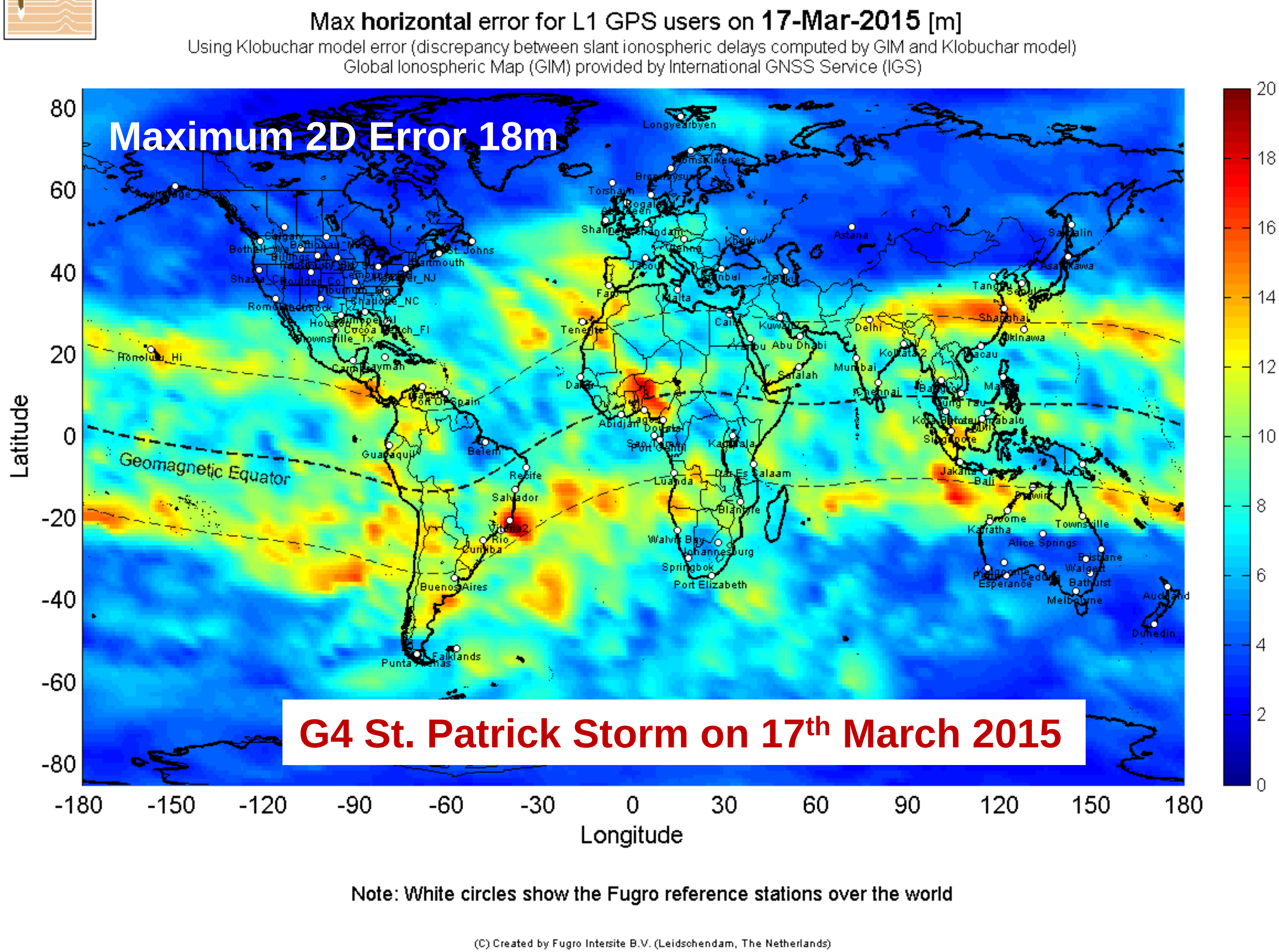
Space Weather Impact on GNSS Positioning (**Range Error**)



Note: White circles show the Fugro reference stations over the world

(C) Created by Fugro Intersite B.V. (Leidschendam, The Netherlands)

TEC Disturbances (**Range Error**)

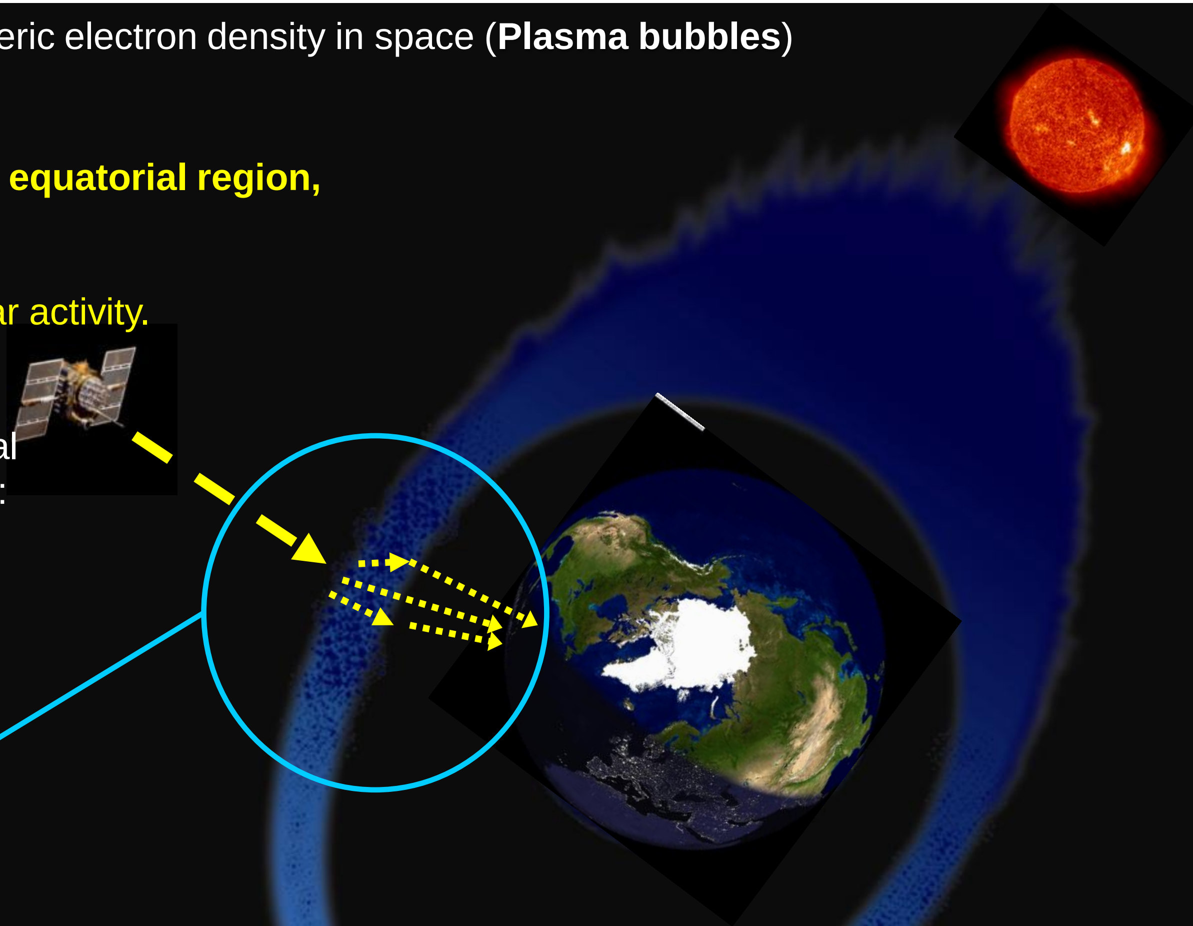


EQUATORIAL SCINTILLATION

GNSS Signal Scintillation in Equatorial Region

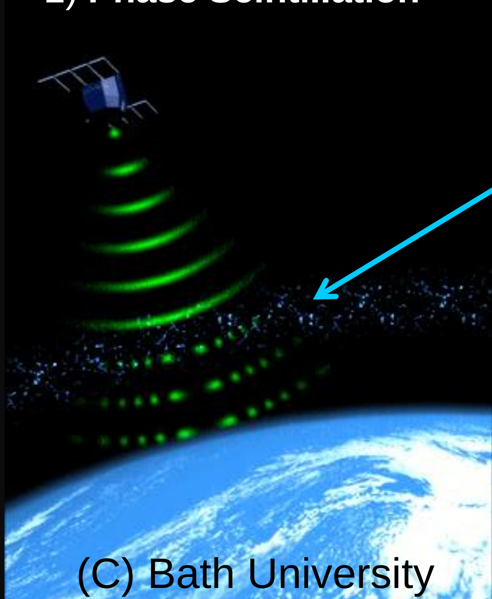
Small-scale irregularities of ionospheric electron density in space (**Plasma bubbles**) causes GNSS signal scintillation.

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:

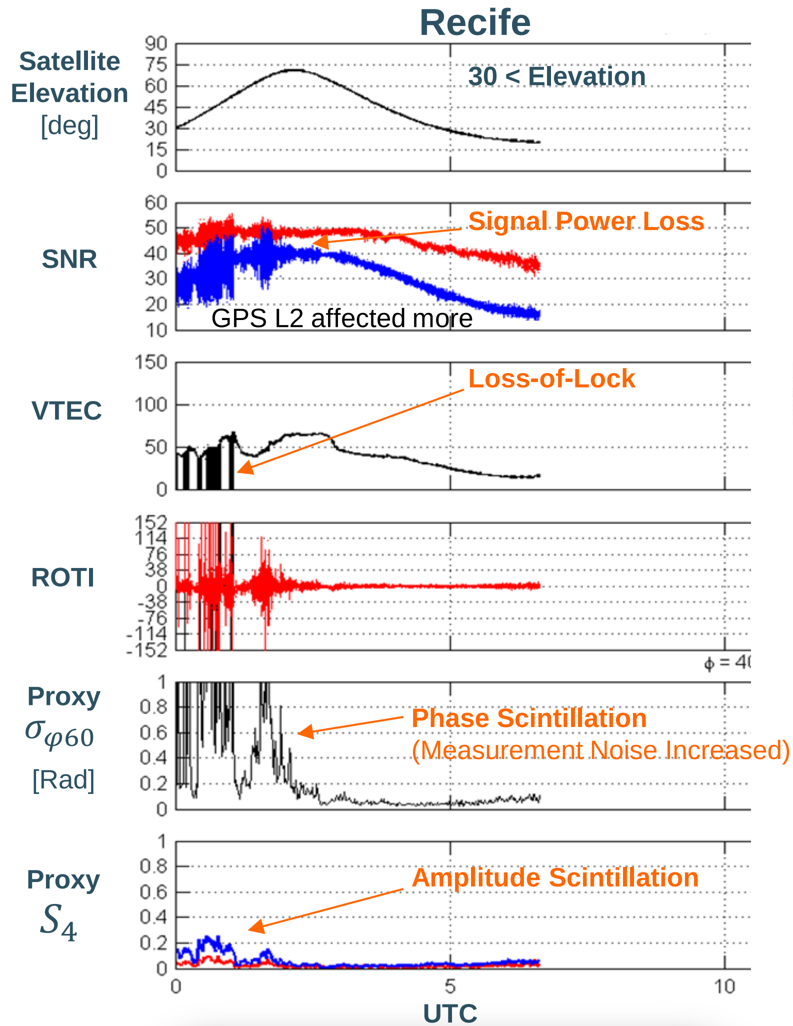
1) **Amplitude Scintillation**
2) **Phase Scintillation**

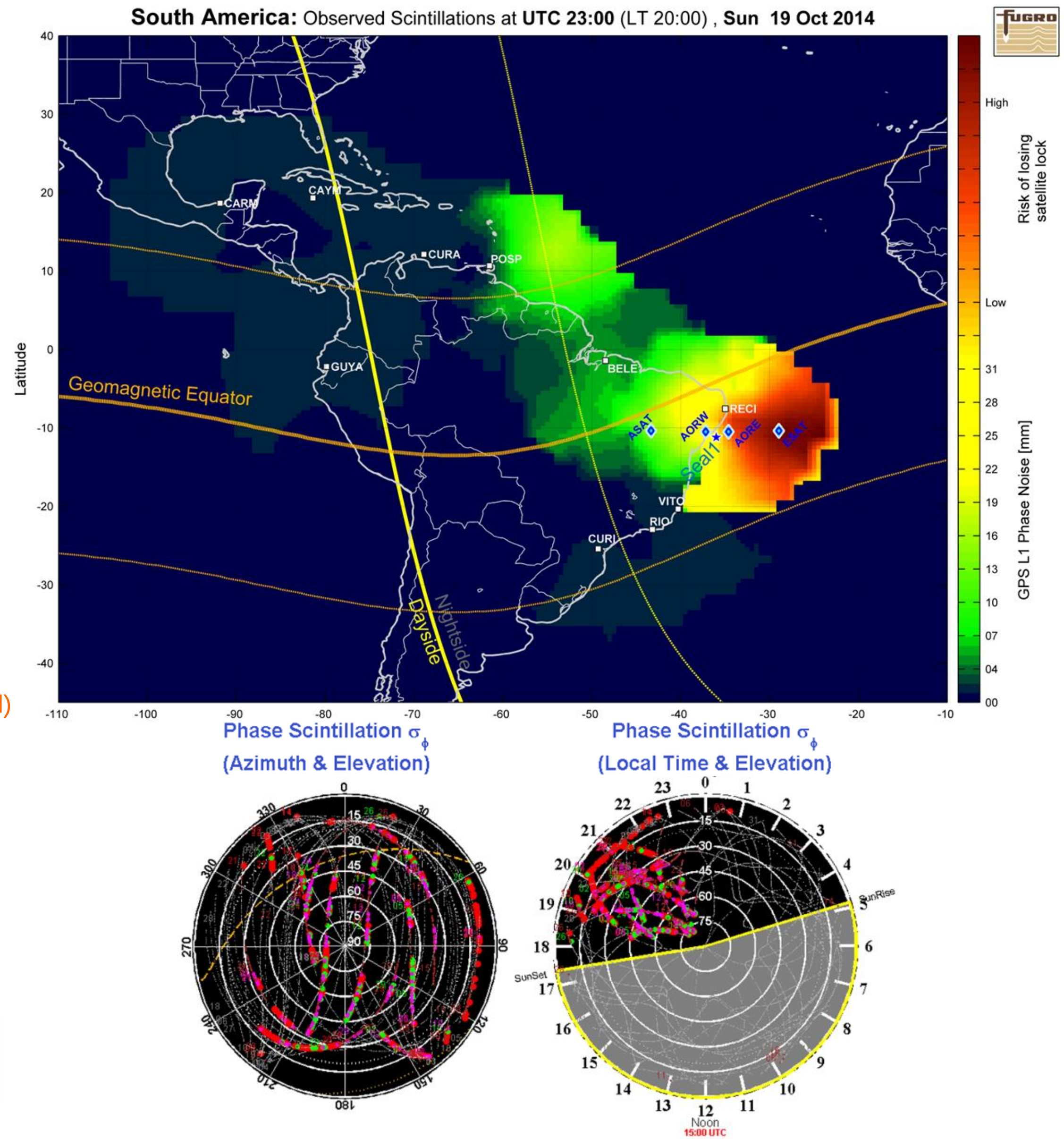


Due to ionospheric scintillation, GNSS receiver performance is degraded:

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

Typical GNSS Signal Scintillation

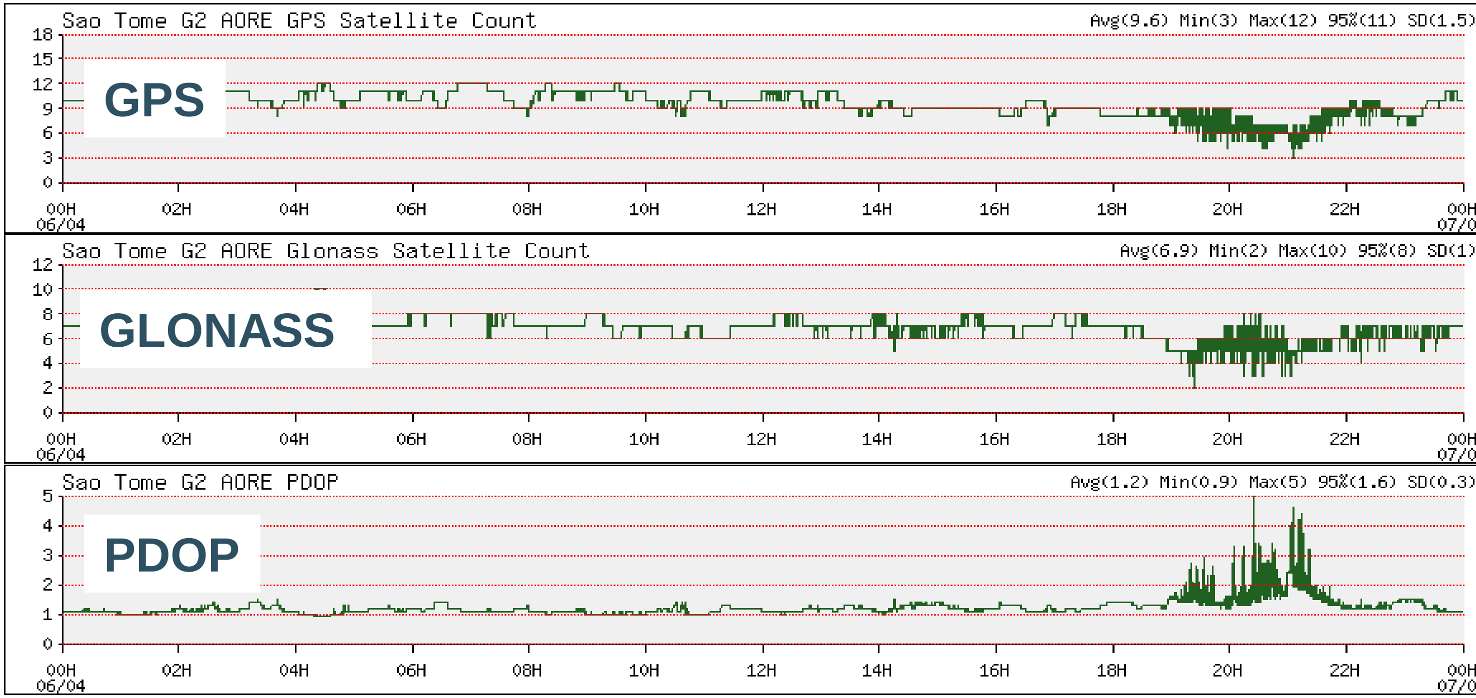




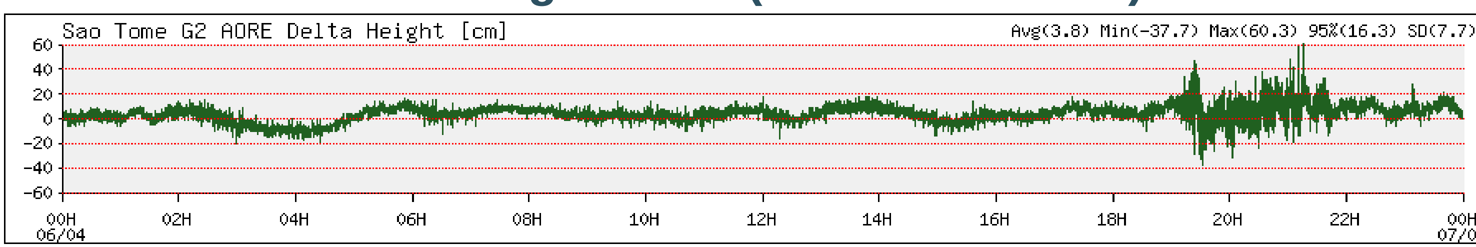
Measurement noise increases
Signal power loss (Loss-of-Lock)

Amplitude Scintillation Impact

West Africa, Sao Tome (6th April 2015)



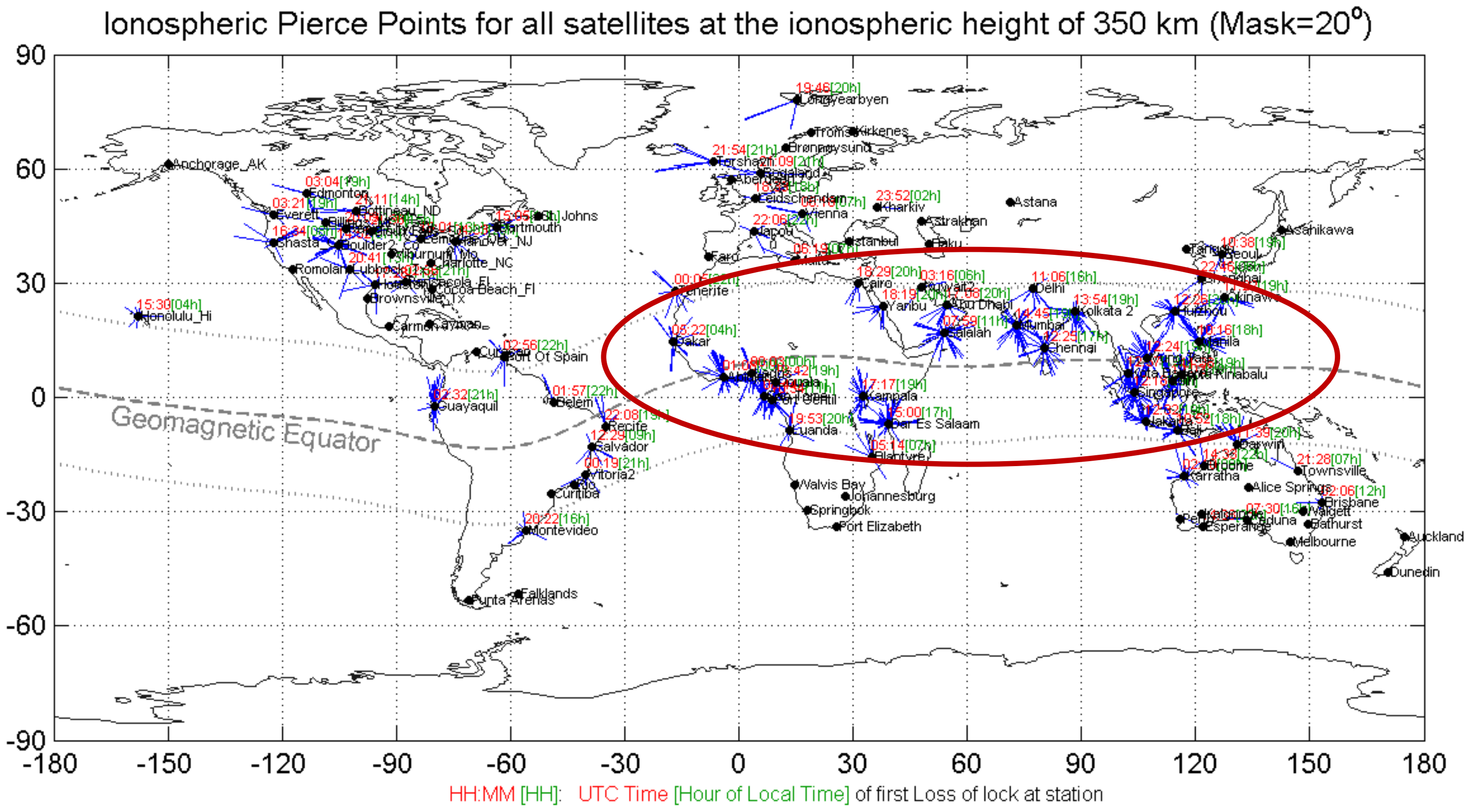
G2 Height Error (GPS+GLONASS)



Loose of satellites due to amplitude scintillation is the **most severe cause**

Loss of Lock Indicator graph (Amplitude Scintillation)

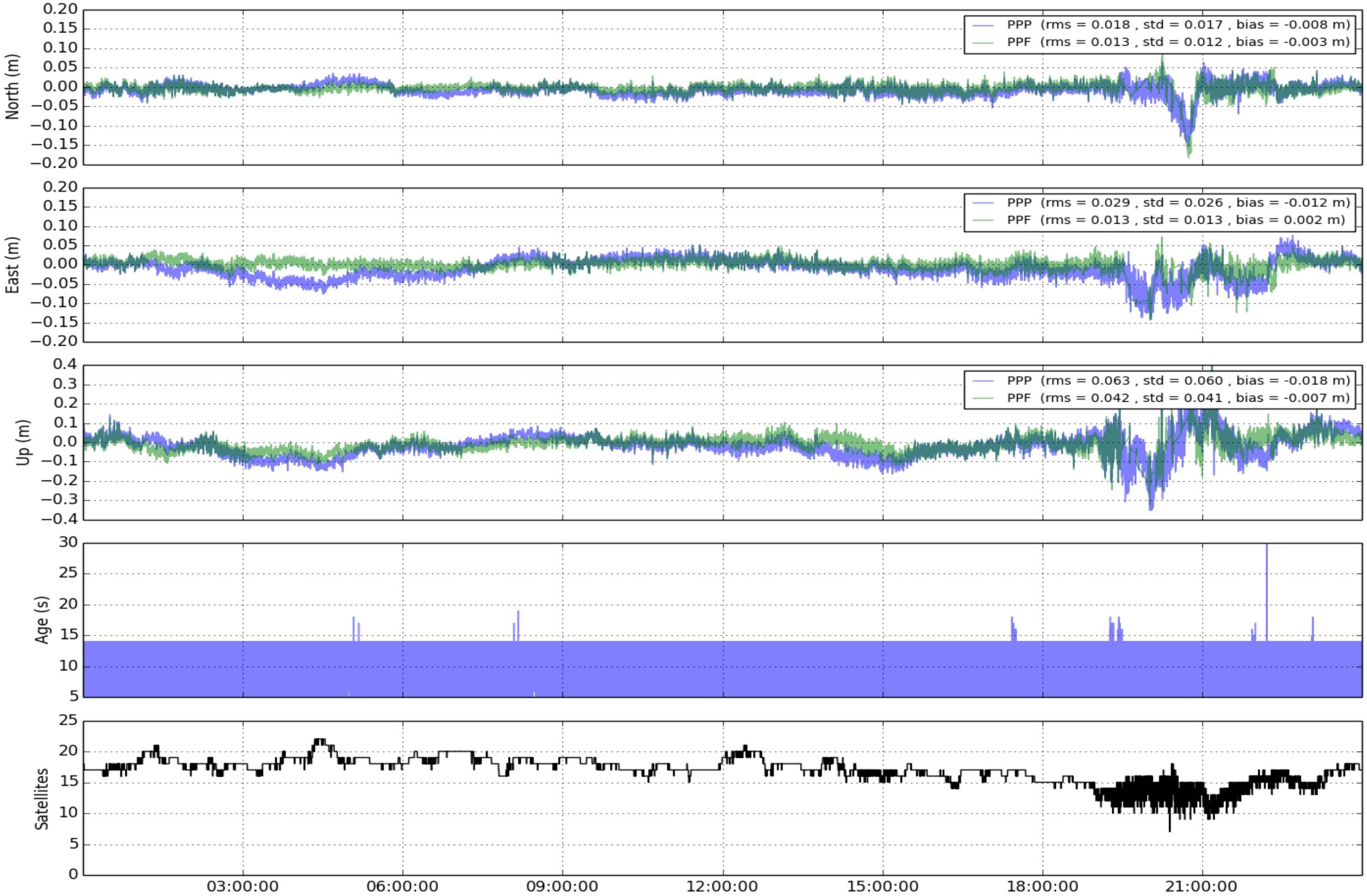
Tue 07 Apr 2015: L1/L2 Loss of Lock in Fugro GPS Network over 24 Hours
Area: World



To mitigate: Use Multiple GNSS

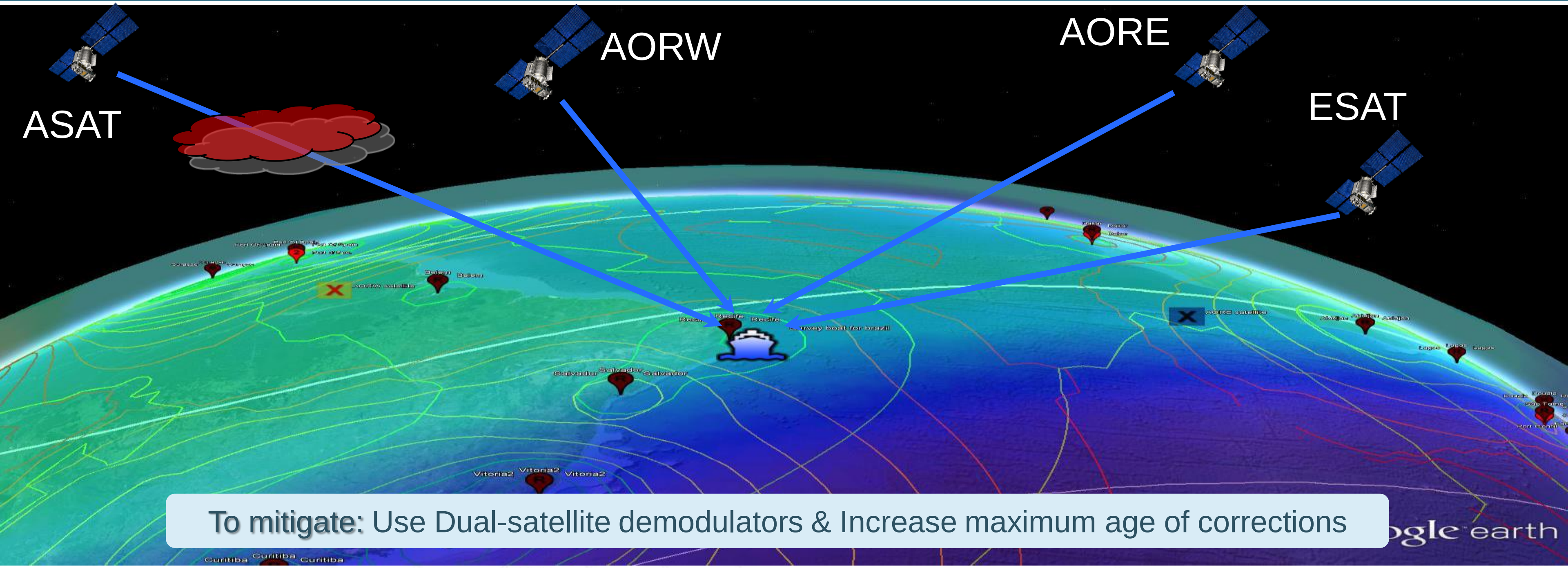
Scintillation Impact on Precise GNSS Positioning (**G2+**)

G2+ using GPS+GLONASS

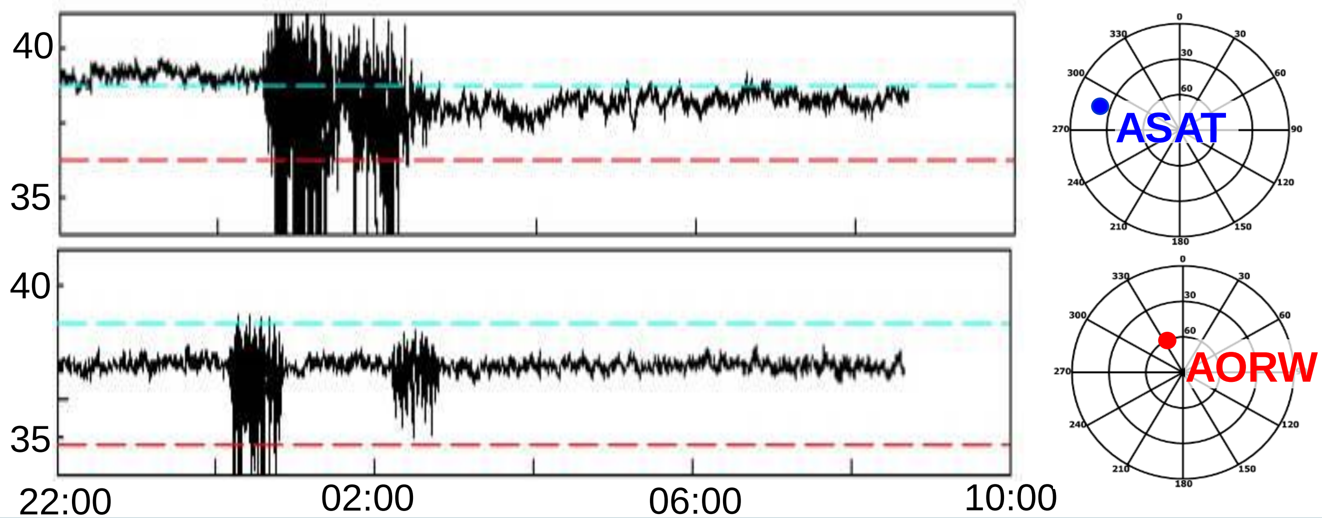


Phase Scintillations could be a **limiter** for precise GNSS applications even using multiple GNSS

L-Band Scintillation & Communication Outage

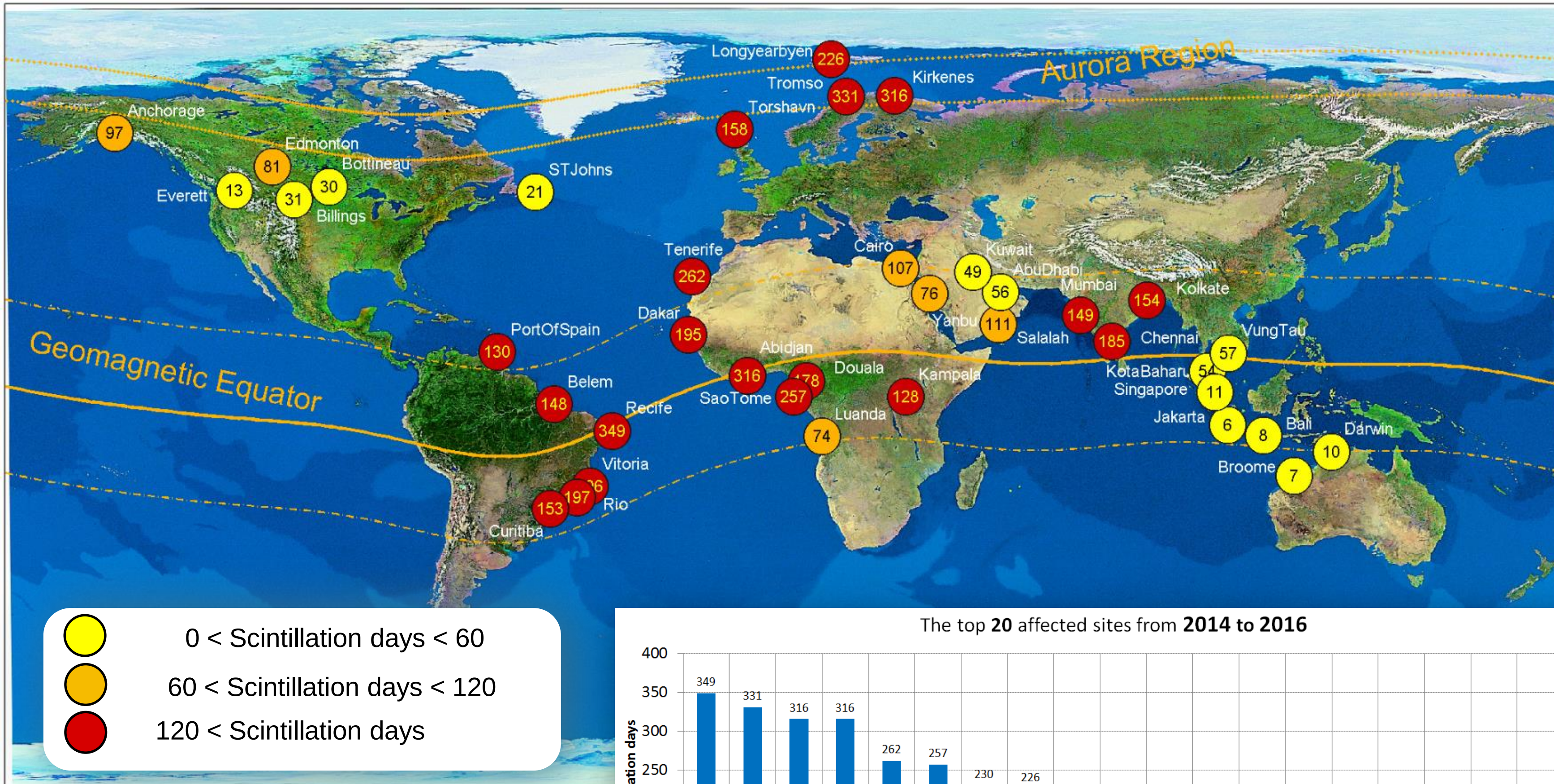


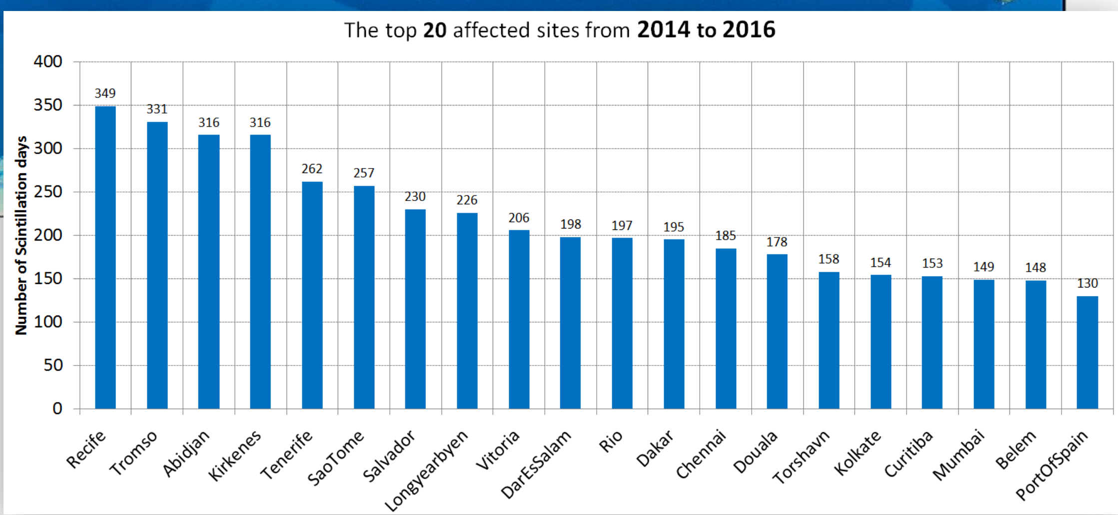
To mitigate: Use Dual-satellite demodulators & Increase maximum age of corrections



SCINTILLATION OCCURRENCE

The most affected sites by Scintillation (2014-2016)

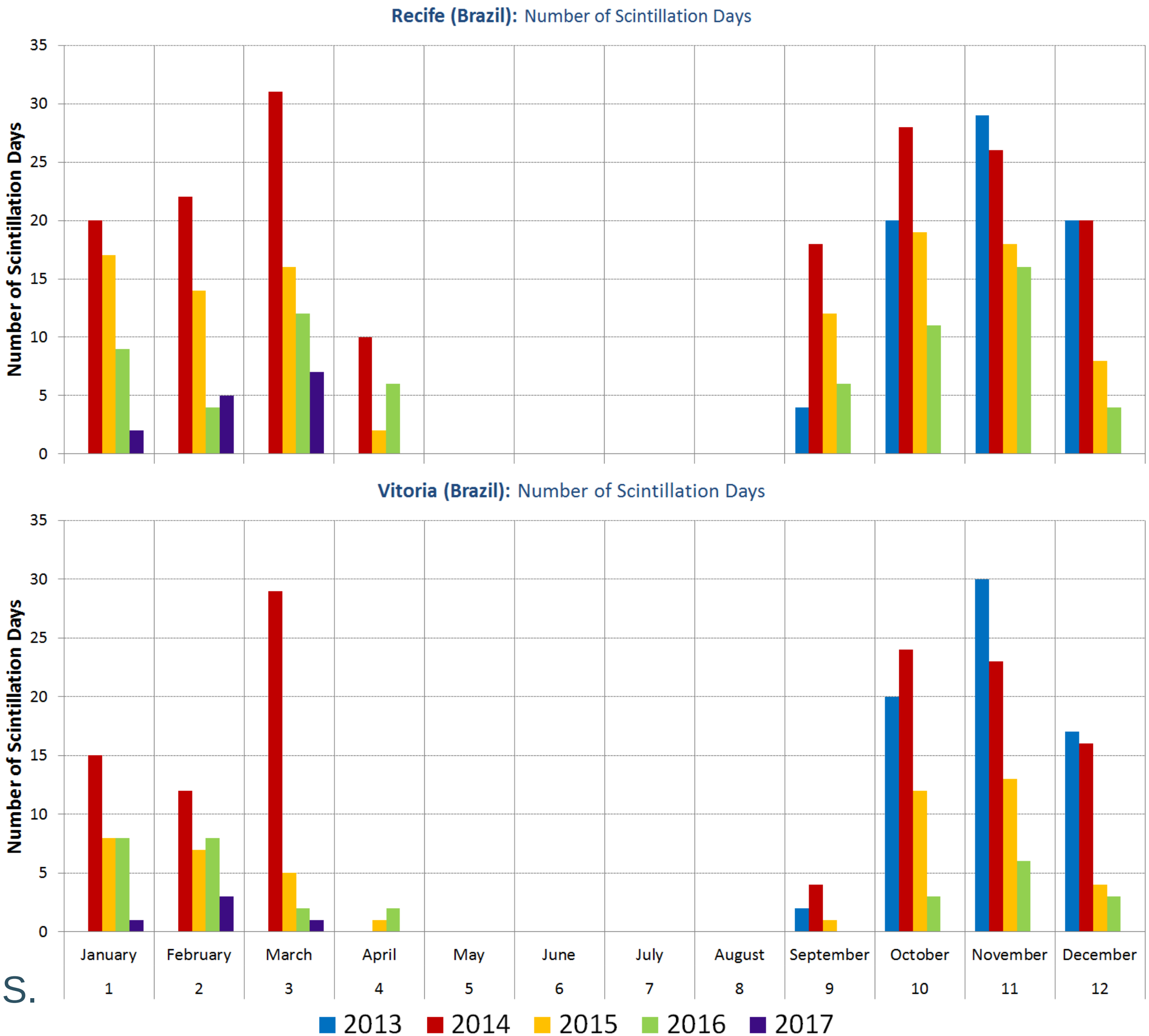




The most affected sites are in:

Brazil
West Africa
Scandinavia

Seasonal Variation of Scintillations in **Brazilian Sector**

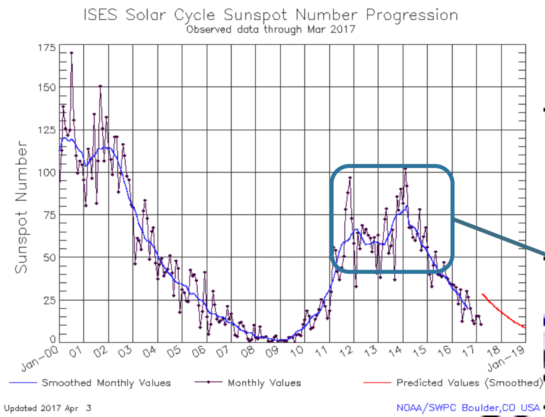


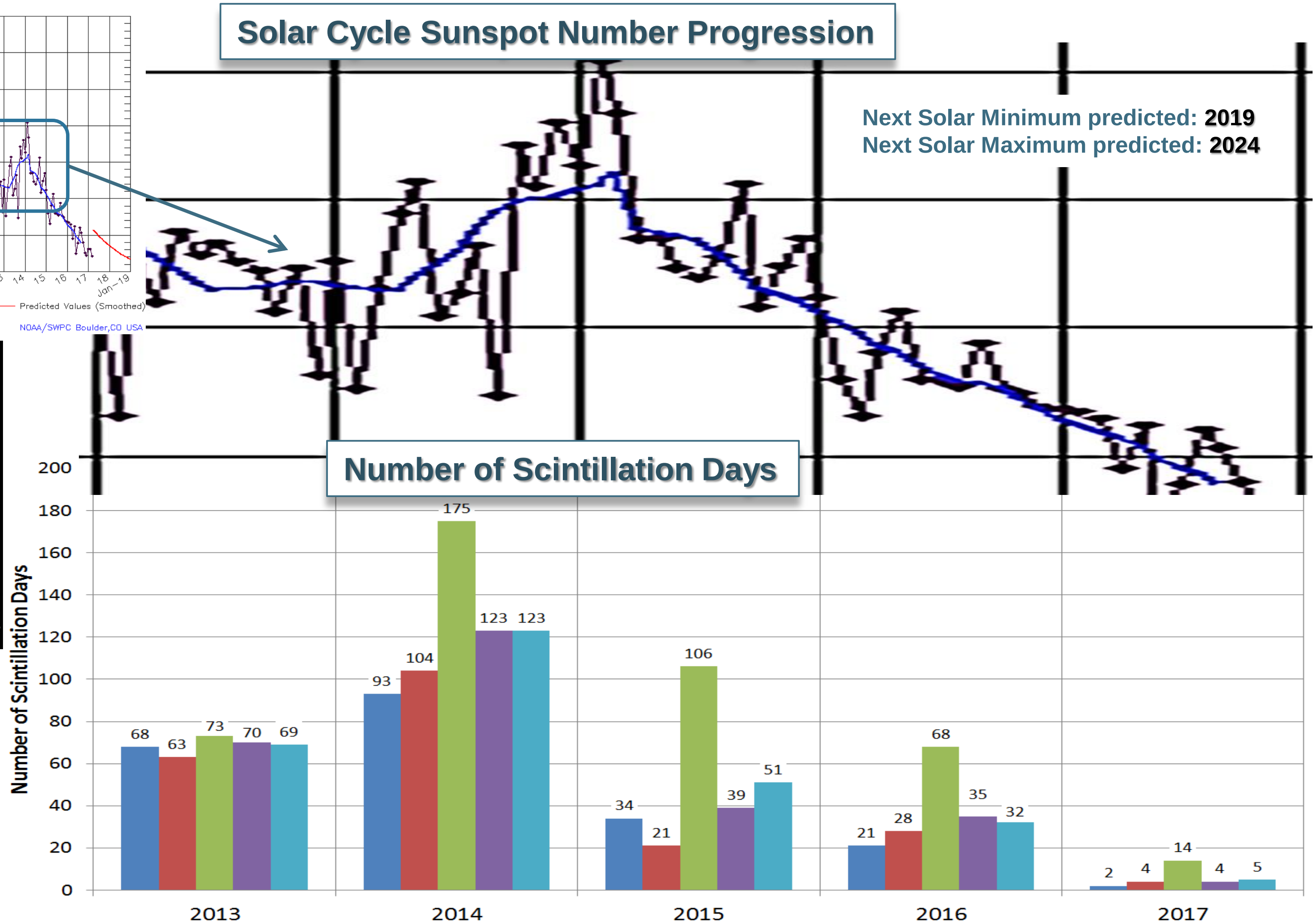
In **summer**, scintillation is **calm** and **no impact** on GNSS.

Seasonal Variation of Scintillations in **West Africa**

In **summer**, scintillation is **calm** and **less impact** on GNSS.

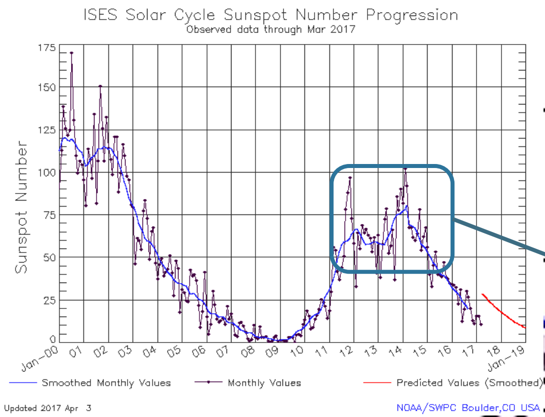
Occurrence of Scintillations in **Brazilian Sector** (2013–2017)

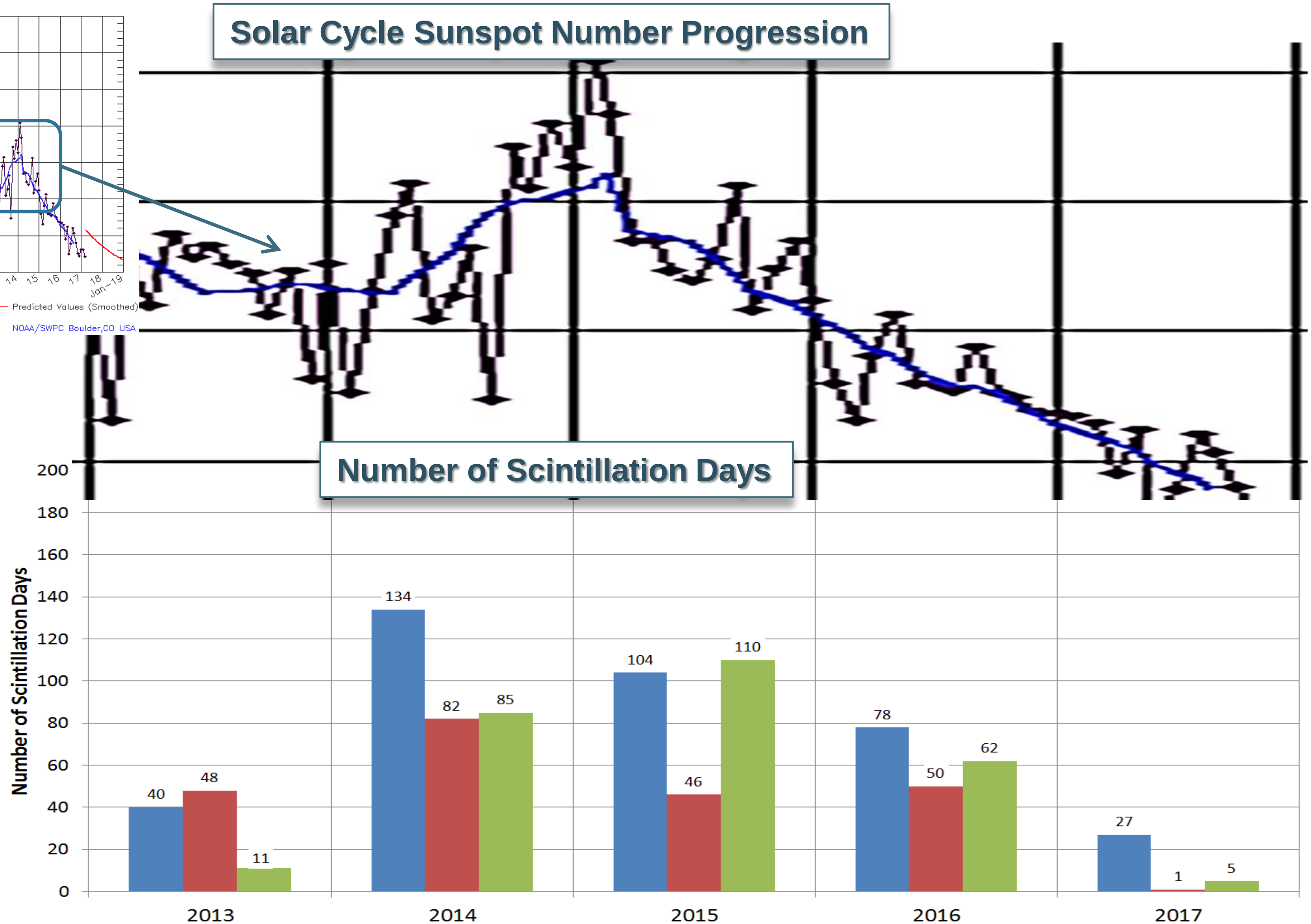




Significant reduction of scintillation toward solar minimum

Occurrence of Scintillations in **West Africa** (2013–2017)



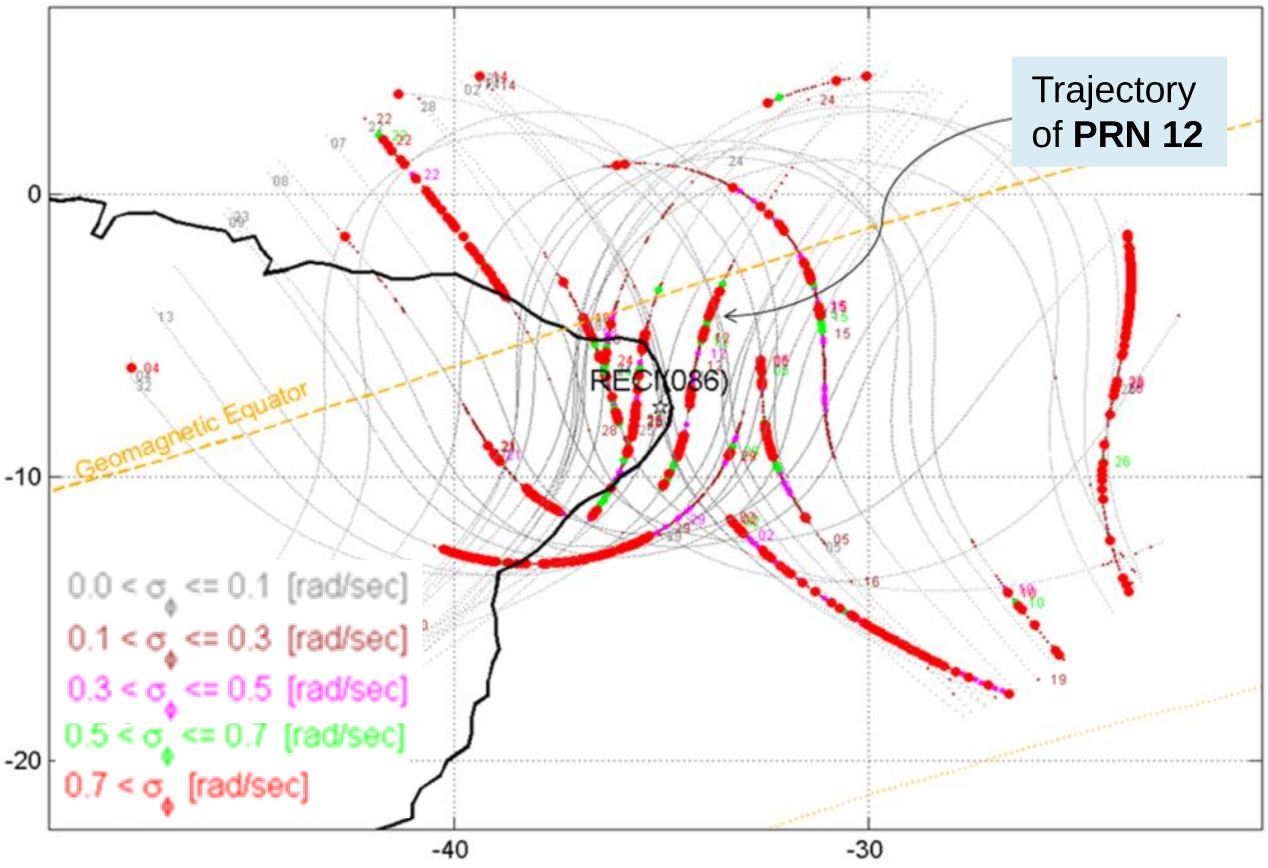


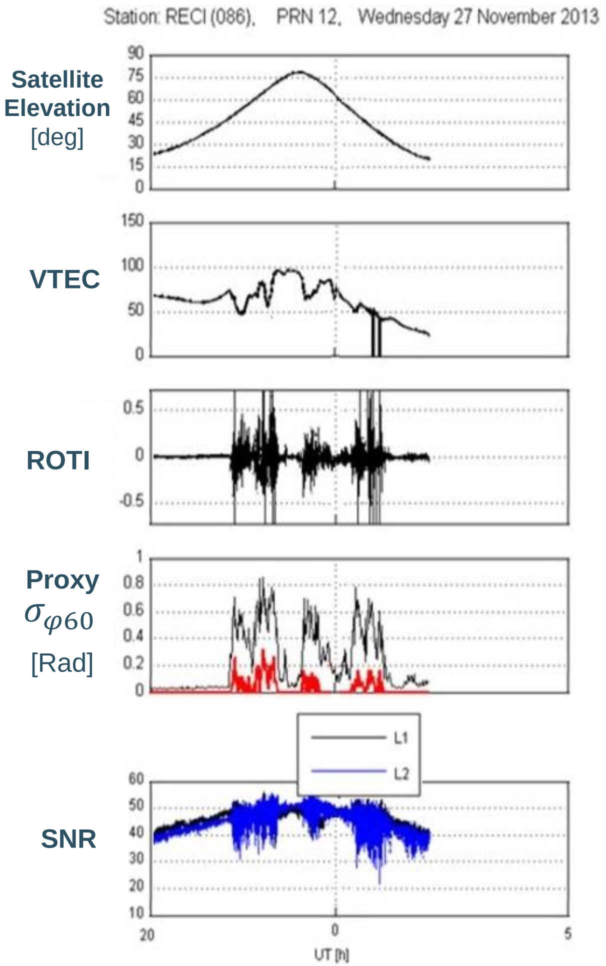
- Abidjan
- Douala
- SaoTome

Significant reduction of scintillation toward solar minimum

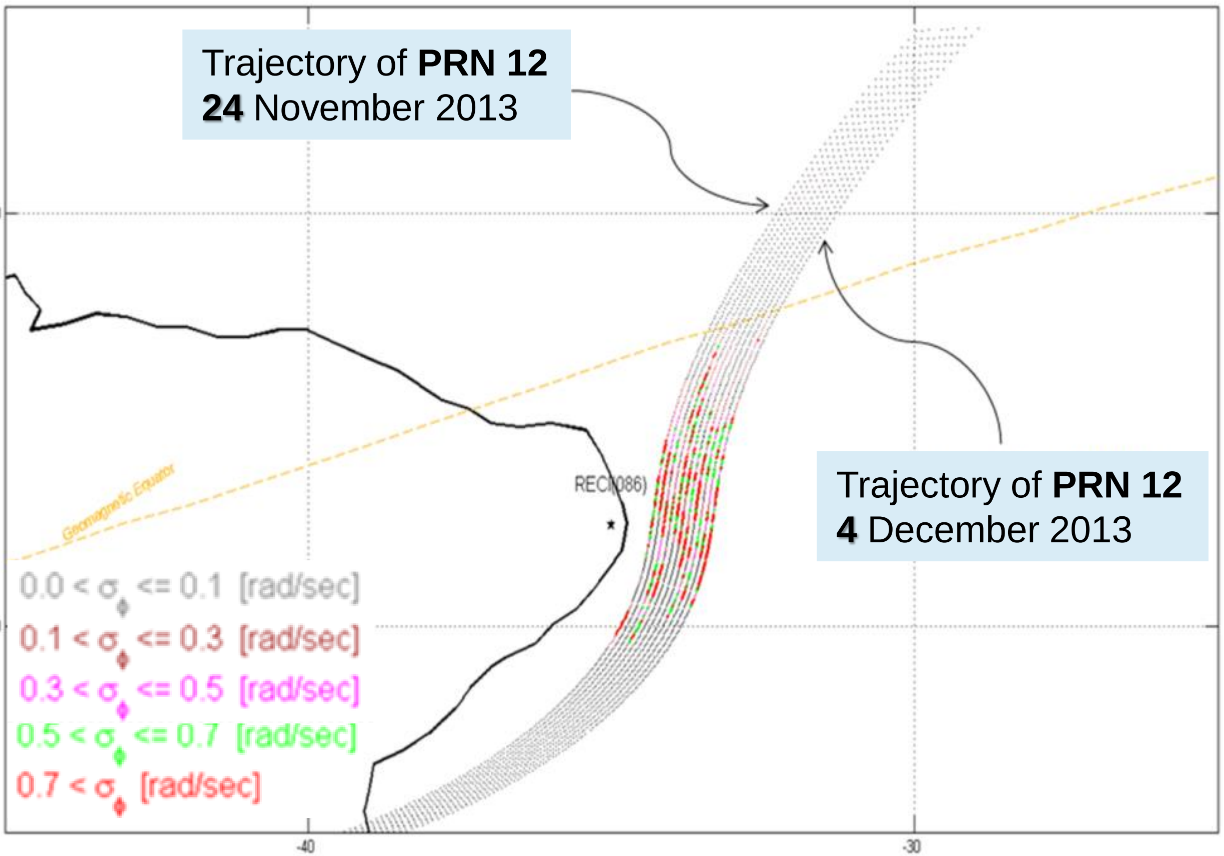
SCINTILLATIONS PREDICTION

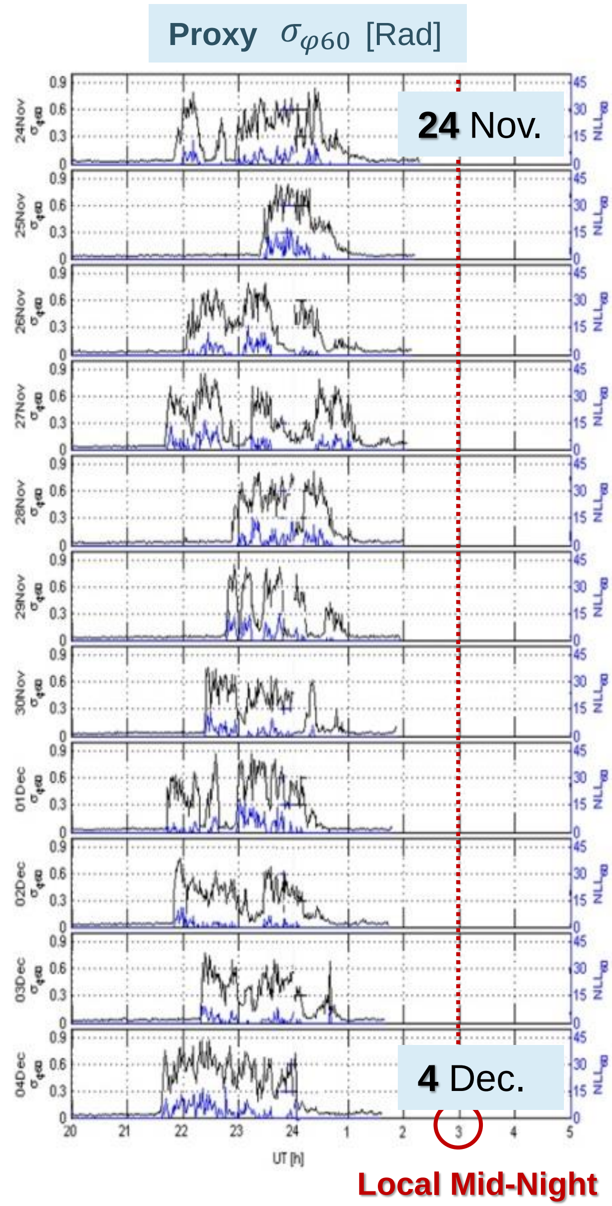
Predictability of Equatorial Scintillation



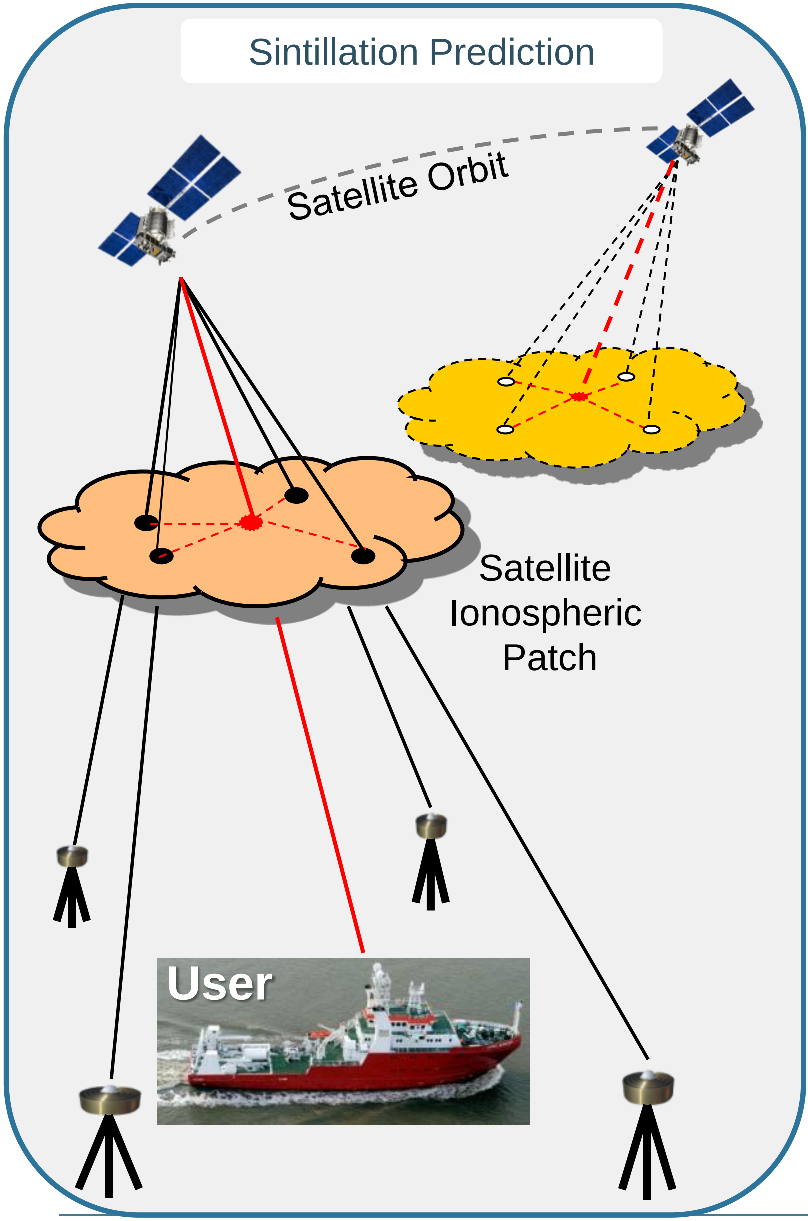


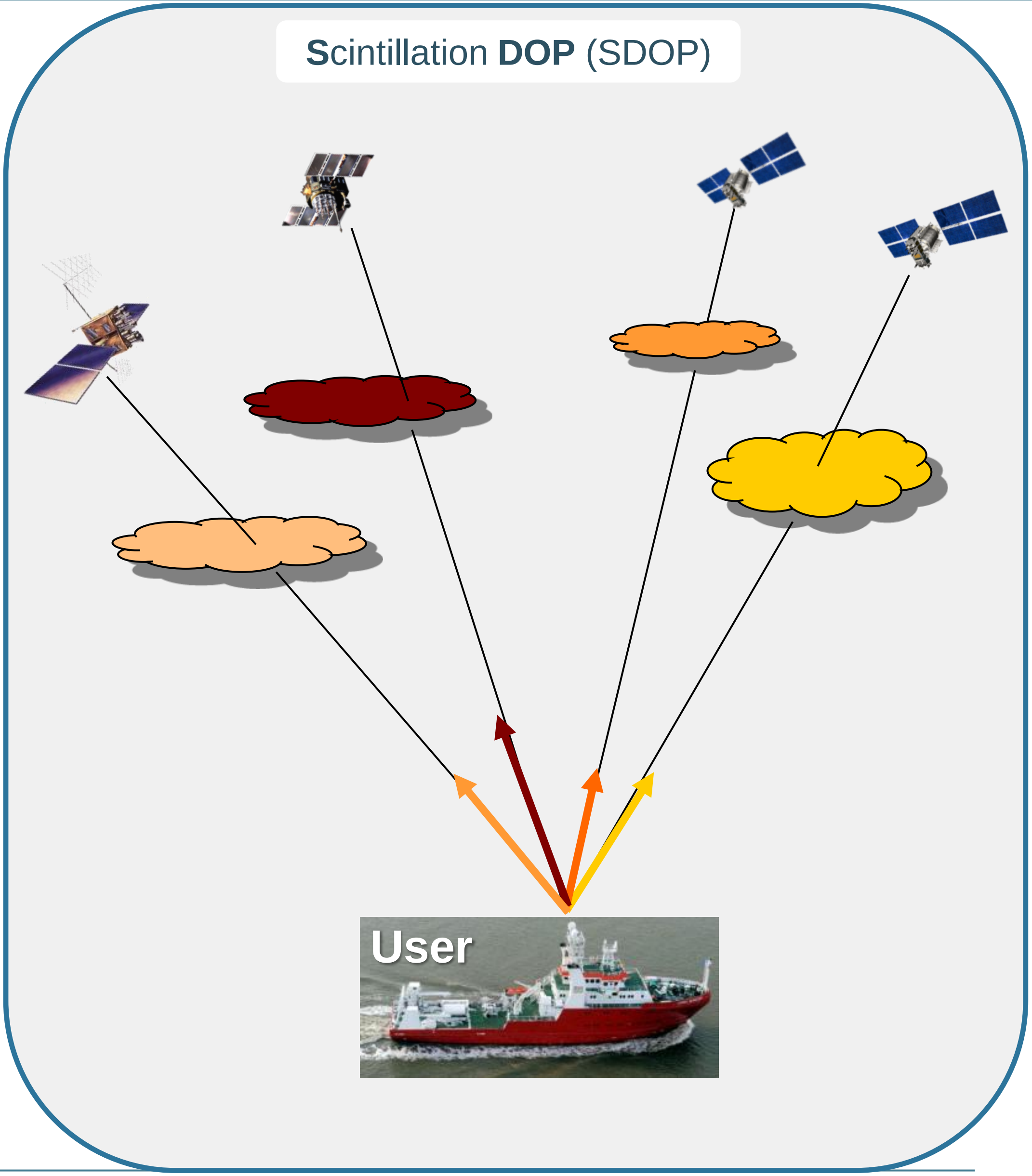
Predictability of Equatorial Scintillation



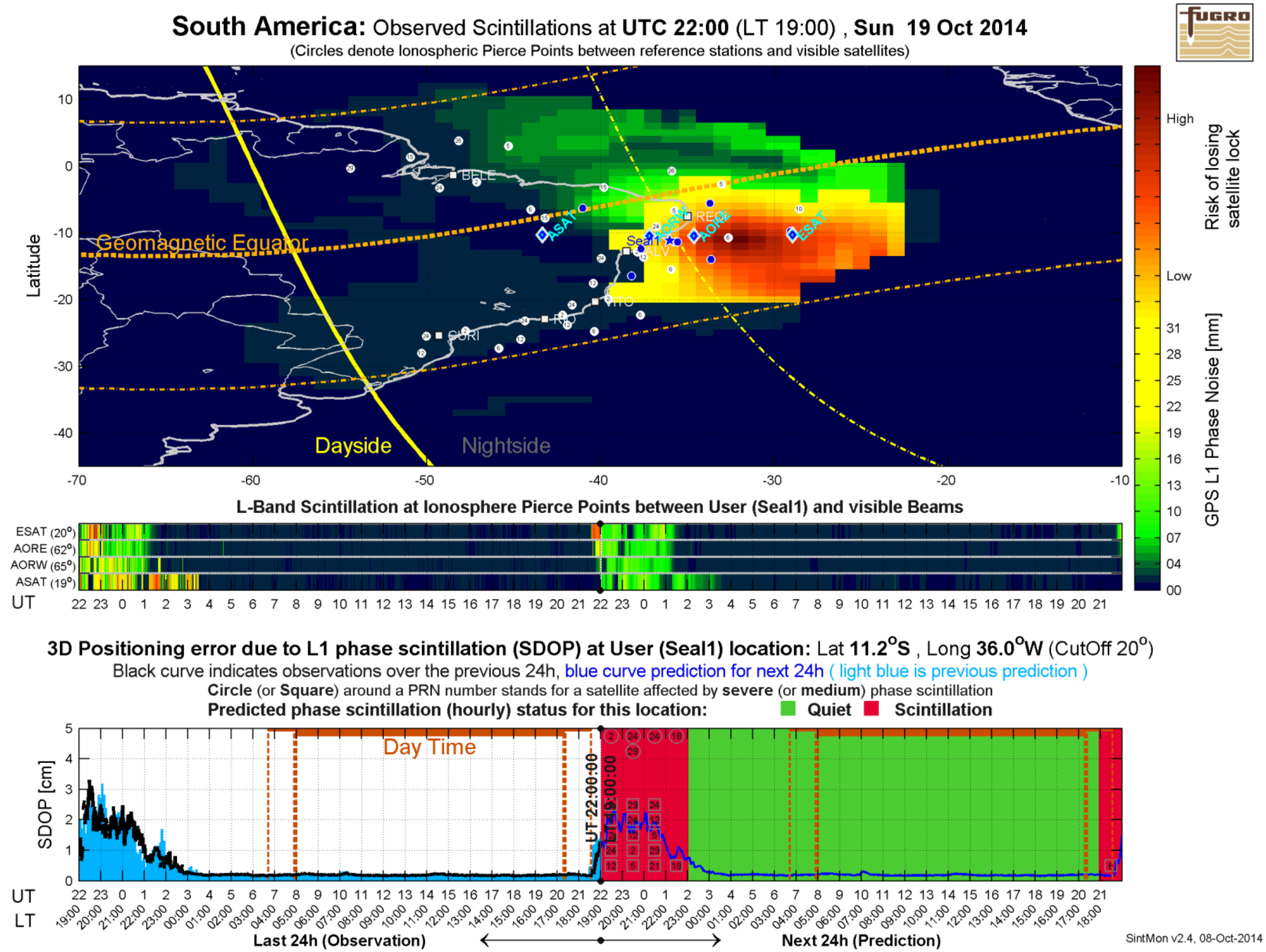


Fugro Proposed Scintillation Index for GNSS Users

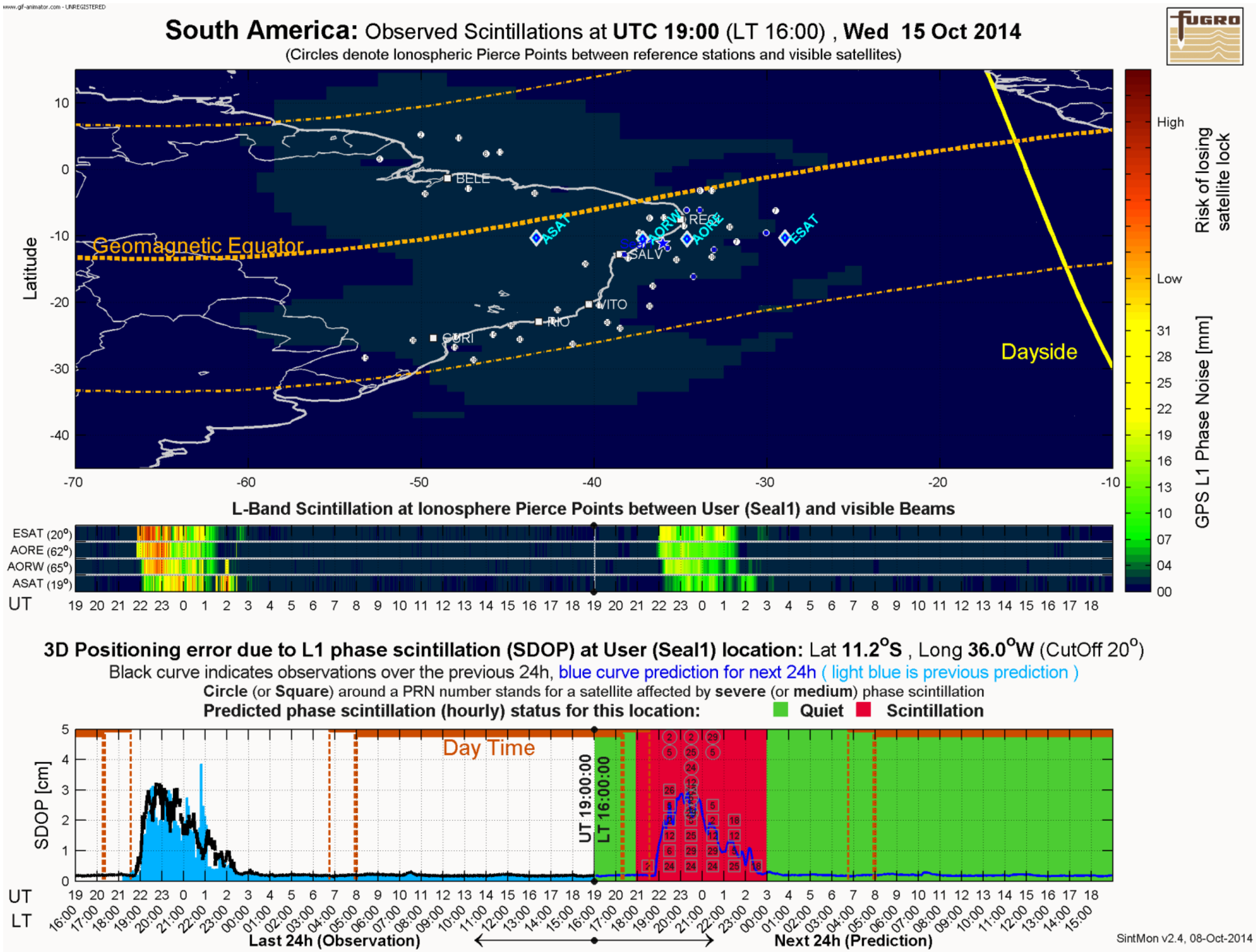




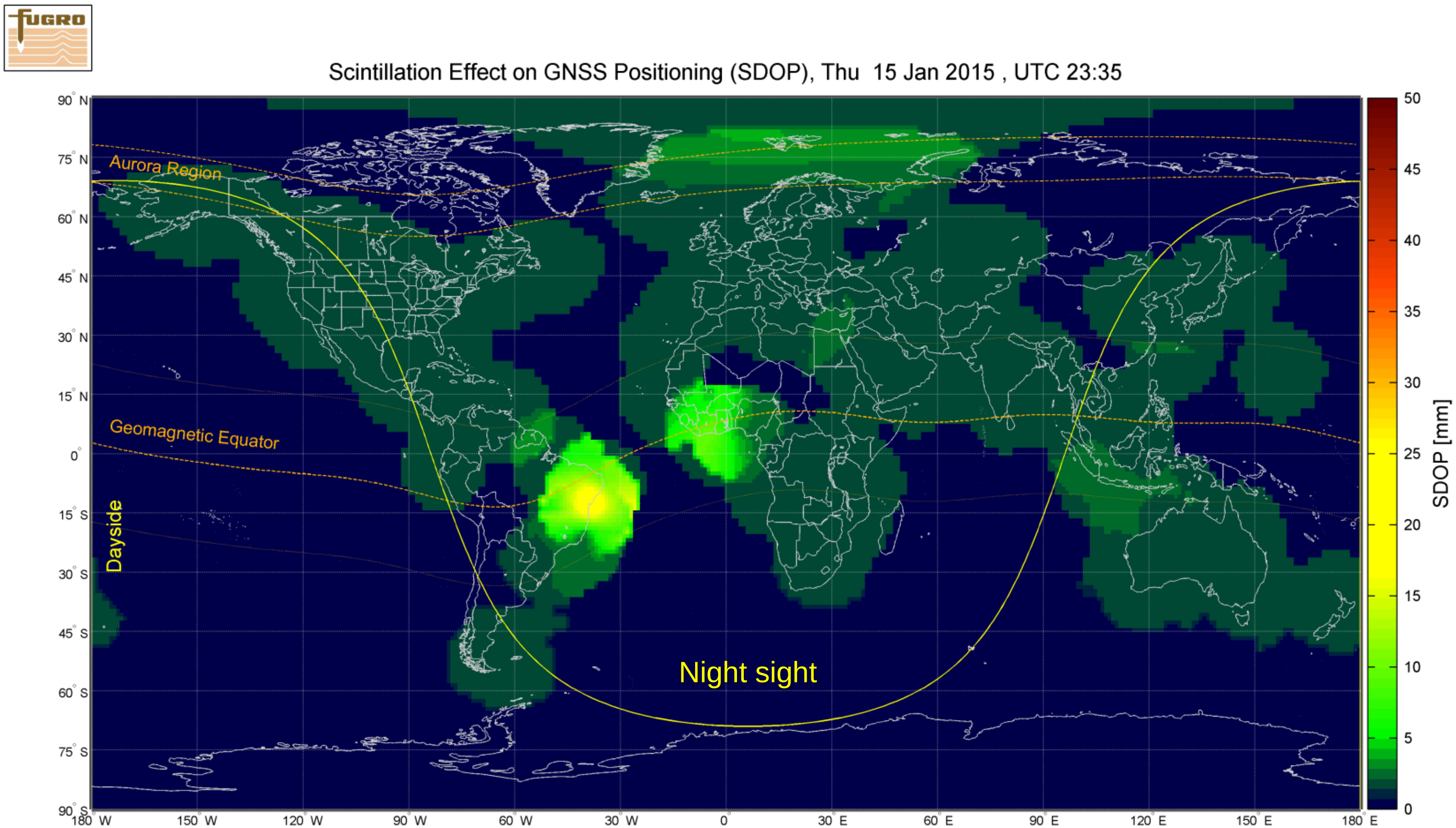
Regional Scintillation Prediction, **Brazil**



Regional Scintillation Prediction, **Brazil (Animated)**



World Map of SDOP



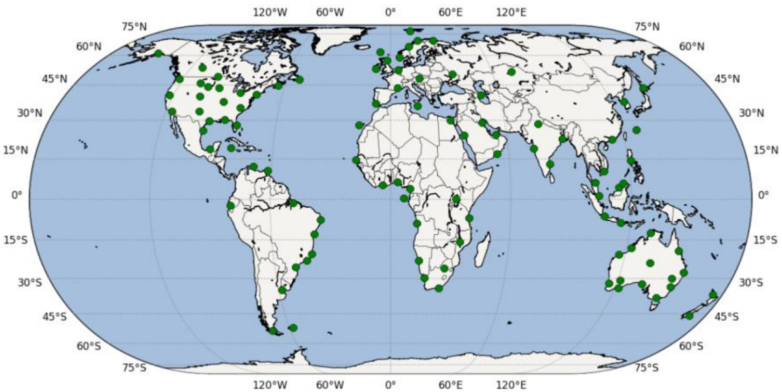
In the equatorial region, **accuracy** of predicted **severe scintillation** is ~**70%**

Fugro Scintillation Service (**ScintStar**)

Objective: **Near real-time** scintillation prediction (in time & space) for **24 ahead** specific for a GNSS **user location**.

The service provides the following information:

- Scintillation status in the user working area,
- Start and end times of scintillation,
- GNSS satellites affected by scintillation,
- Risk of L-band communication outage.



GNSS Data of Reference Network

Scintillation Prediction Server

Daily Warning Message

On-Event Warning Message

Near Real-Time Alerts

GNSS Users

Emailing

Summary

GNSS data from a network of geodetic receivers are sufficient for detecting and monitoring ionospheric scintillations.

Equatorial Scintillations:

- Occurrence of scintillation significantly reduced towards **solar minimum**.
- **Brazilian Sector** and **west Africa** are the most affected regions.
- In **Brazilian Sector** and **West Africa** from **May** to **August**, scintillation is **calm** and no impact on GNSS.
- **GPS only DGPS** and **PPP** services may suffer from not having enough satellites due to **amplitude Scintillation.**
- **Phase scintillation** can be a **limiter** for GNSS precise services (e.g. **G2+**).

Fugro Scintillation Prediction Service:

- Product works for Fugro Offshore customers.
- Prediction of scintillations around equator (for 24h ahead) is ~**70**% accurate.
- Using **SDOP** for GNSS is highly valuable.
- New markets are Satellite Communication users (e.g. Iridium, Globalstar, Satcom).

Thanks for your attention

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Geodesist

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