Predicting Space Weather:
Impact On Fugro Offshore Precise Positioning Services

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Overview

Introduction to Fugro

- Infrastructure
- Services

Effects of Space Weather on GNSS Precise Applications

- Ionospheric Disturbances
- L-band Communication Outages
- Solar Storm on17th March 2015

Ionospheric Scintillations

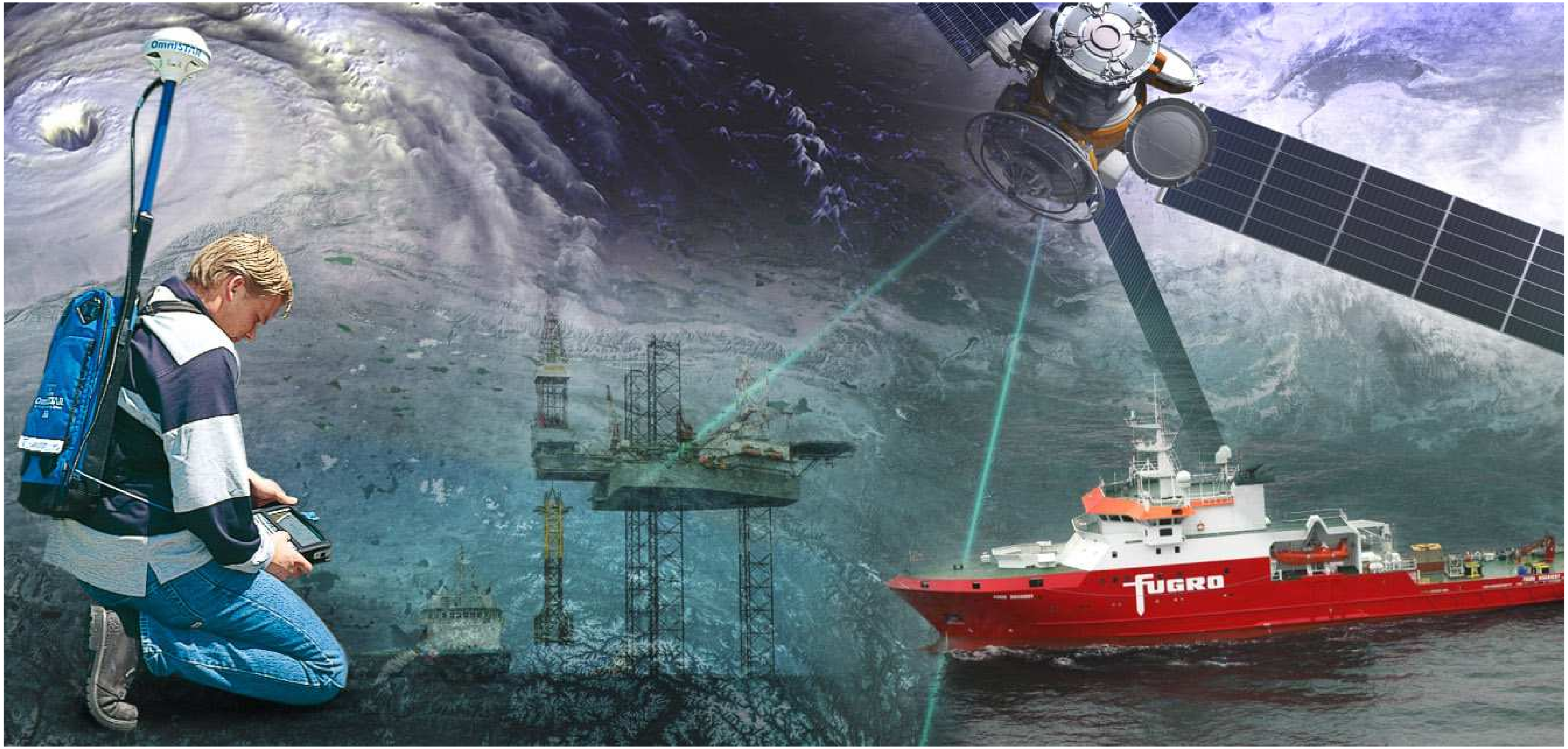
- Occurrence
- Fugro Scintillation Prediction Service
- Regional/World map of Scintillations

Summary

Fugro Mission

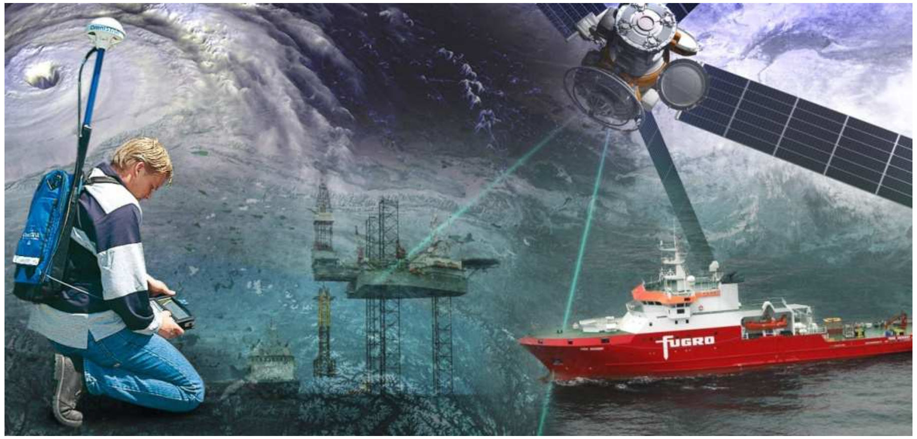
Our mission is to be the **world's leading service provider** in the collection and interpretation of data relating to the Earth's surface and sub-surface, and in the support of infrastructure developments on land, at the coast and on the seabed.

Survey Services



Fugro provides the energy sector, commercial and engineering industries, governments and other agencies with **offshore survey** and **geospatial services** tailored to the specific needs of each client.

Services



Survey

Geotechnical

Subsea

Seabed geosolutions

Client Sectors

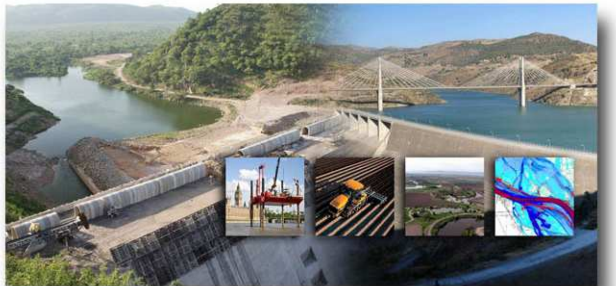
Oil and gas

Mining

Building and infrastructure

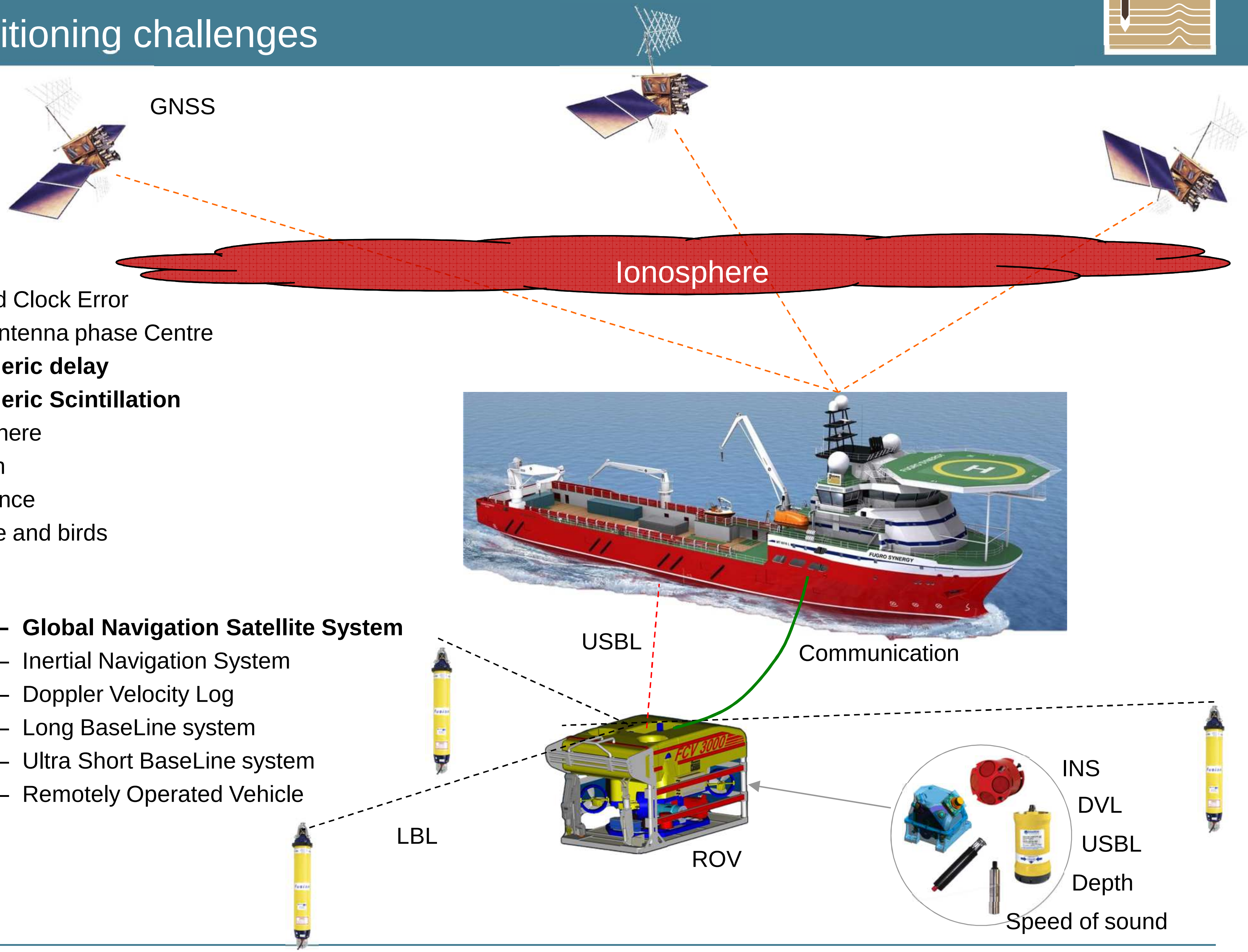
Sustainable energy

Public sector



Other sectors

Positioning challenges

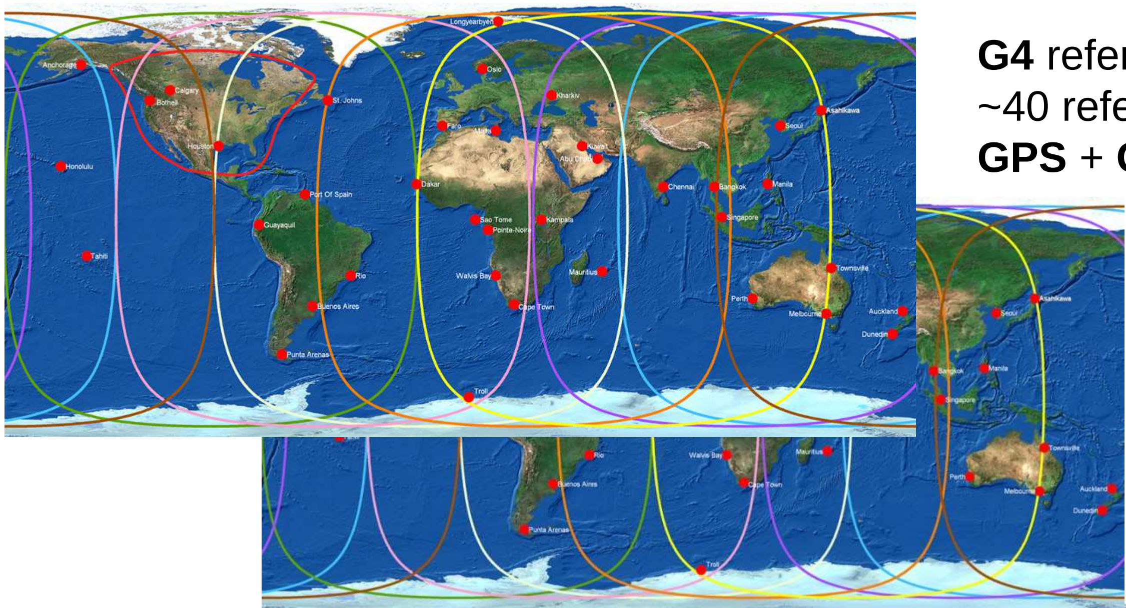


Orbit and Clock Error
GNSS Antenna phase Centre
Ionospheric delay
Ionospheric Scintillation
Troposphere
Multipath
Interference
Blockage and birds

GNSS – Global Navigation Satellite System
INS – Inertial Navigation System
DVL – Doppler Velocity Log
LBL – Long BaseLine system
USBL – Ultra Short BaseLine system
ROV – Remotely Operated Vehicle

GNSS Infrastructure

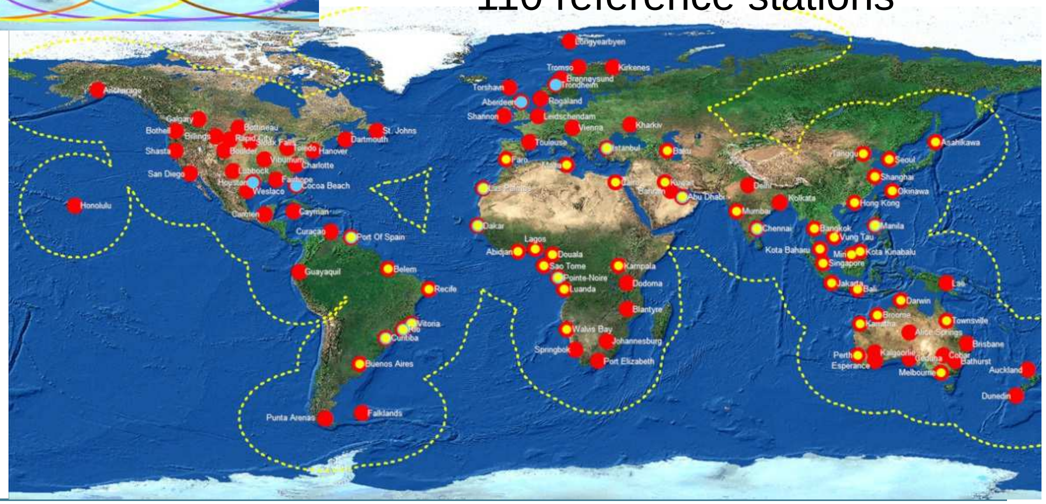
More than **150** Reference Stations in Multiple Network Configurations
Using **8** Geostationary Satellite Channels



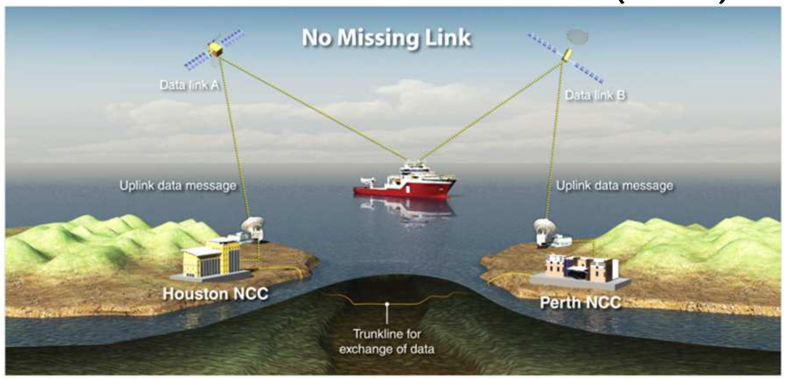
G4 reference network
~40 reference station
GPS + **GLONASS** + **BeiDou** + **Galileo**

XP independent
orbit and clock network
~60 reference stations GPS

L1 and **HP** reference network
~110 reference stations



Two Network Control Center (NCC)



Fugro GNSS Positioning Services

Service	Since	Accuracy	Method	System	Frequency	Technique
VBS	1996	Meter	Reference Stations	GPS/ Glonass	Single	Differential
HP	2000	Sub Decimeter	Reference Stations	GPS	Dual	Differential
G2	2009	Decimeter	Orbit1 Clock1	GPS GLONASS	Dual	PPP
XP2	2014	Decimeter	Orbit2 Clock2		Dual	PPP
G4	2015	Decimeter	Orbit2 Clock2	GPS GLONASS BeiDou Galileo	Dual	PPP
G2+	2015	**Centimeter**	Orbit2 & Clock2 & UPDs	GPS GLONASS	Dual	PPP-RTK

Effects of Space Weather on GNSS Positioning:

Range Error

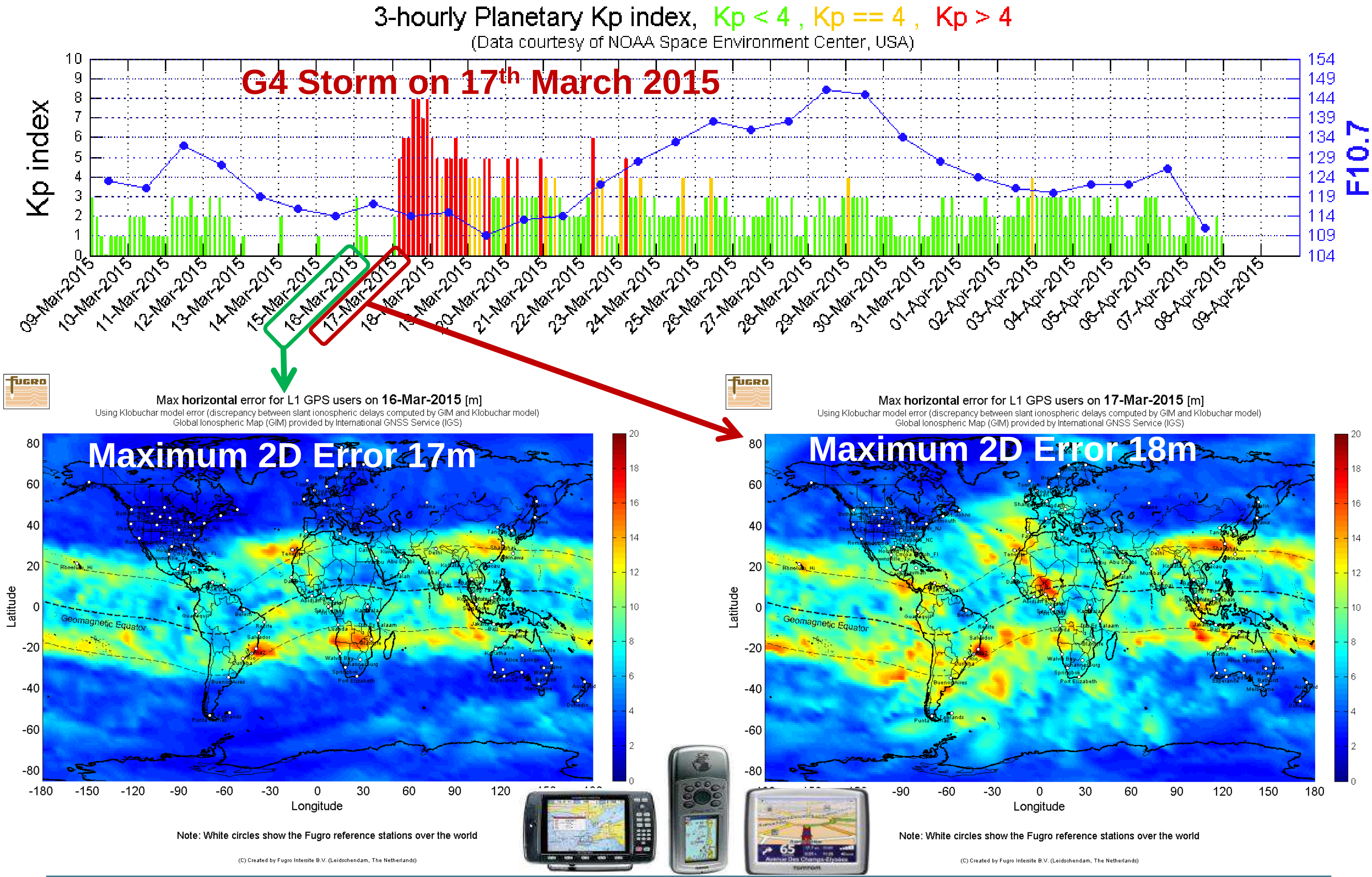
TEC Disturbances & Gradient

Phase Scintillations (Increase Phase Noise)

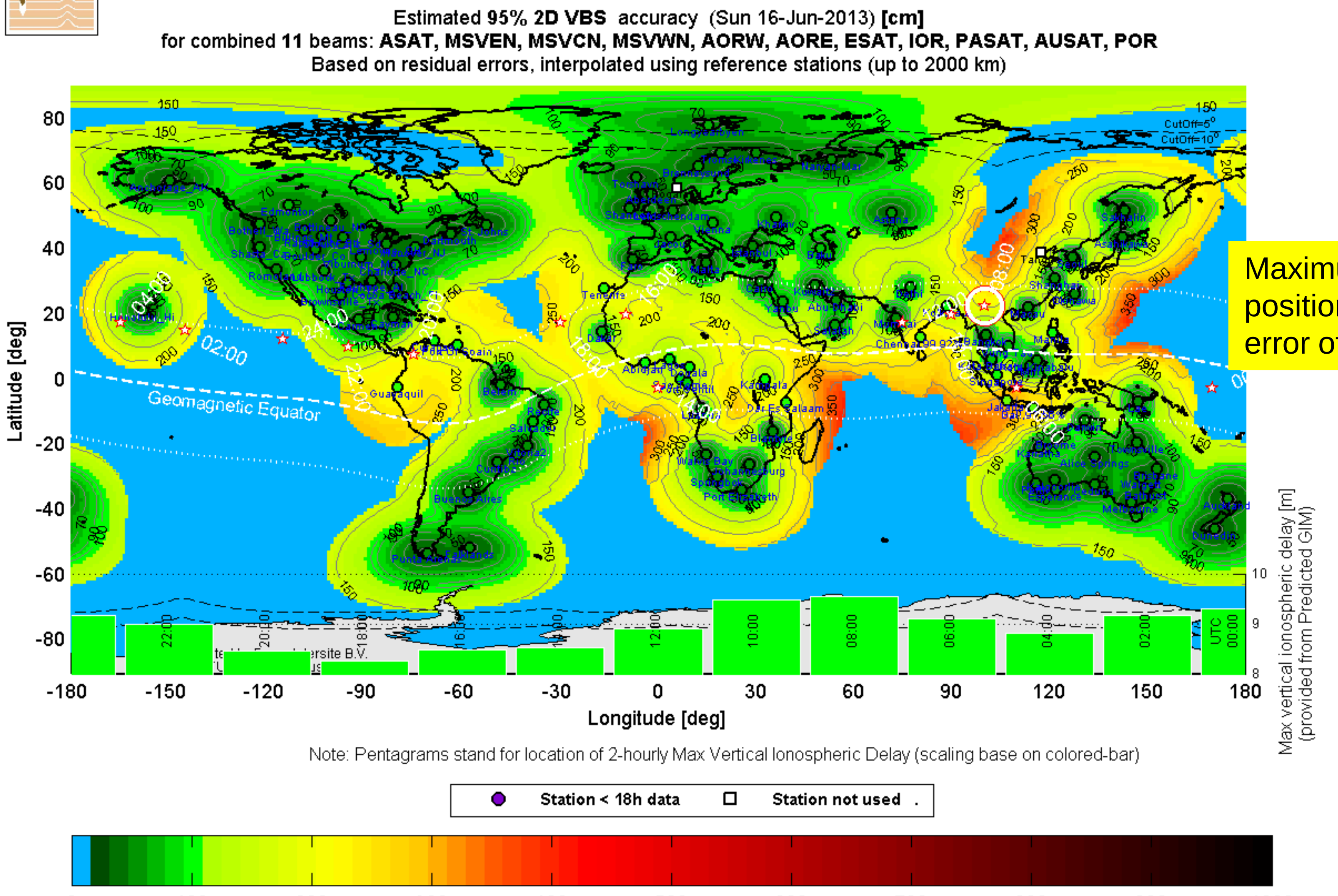
Amplitude Scintillations (Loss Of Lock)

Loss of Communication to Geostationary Satellites

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



Typical Quality of Fugro L1 VBS Service

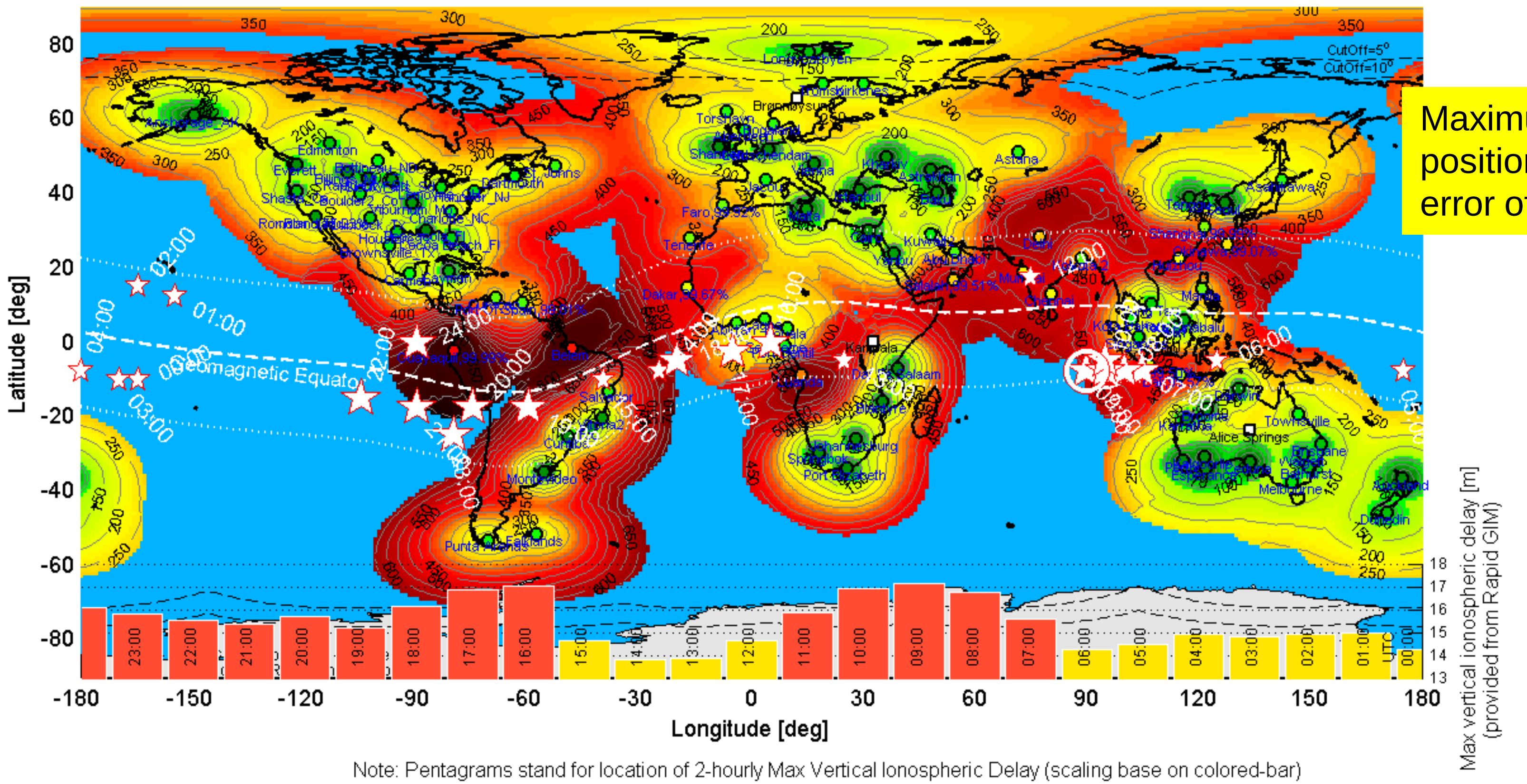


Maximum 2D positioning error of 1m

☆ – Location of maximum vertical delay at two hour intervals for one day

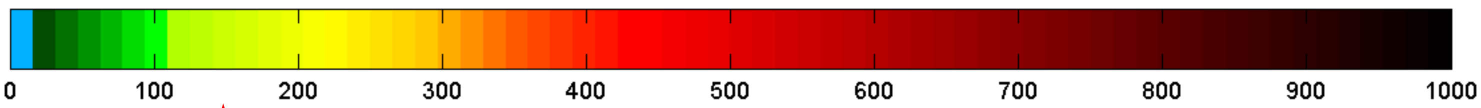
Distance degradation from reference sites

Maximum 2D positioning error of **10m**



Note: Pentagrams stand for location of 2-hourly Max Vertical Ionospheric Delay (scaling base on colored-bar)

● Station < 18h data □ Station not used .



☆ – Location of maximum vertical delay at two hour intervals for one day

SCINTILLATIONS EFFECT ON GNSS

Ionospheric Scintillation

Ionosphere Plasma Bubbles

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

Occur in the **equatorial** and **high-latitudes** regions
Mostly evening after sunset
Seasonal variation
Bubbles increasing during strong solar activity

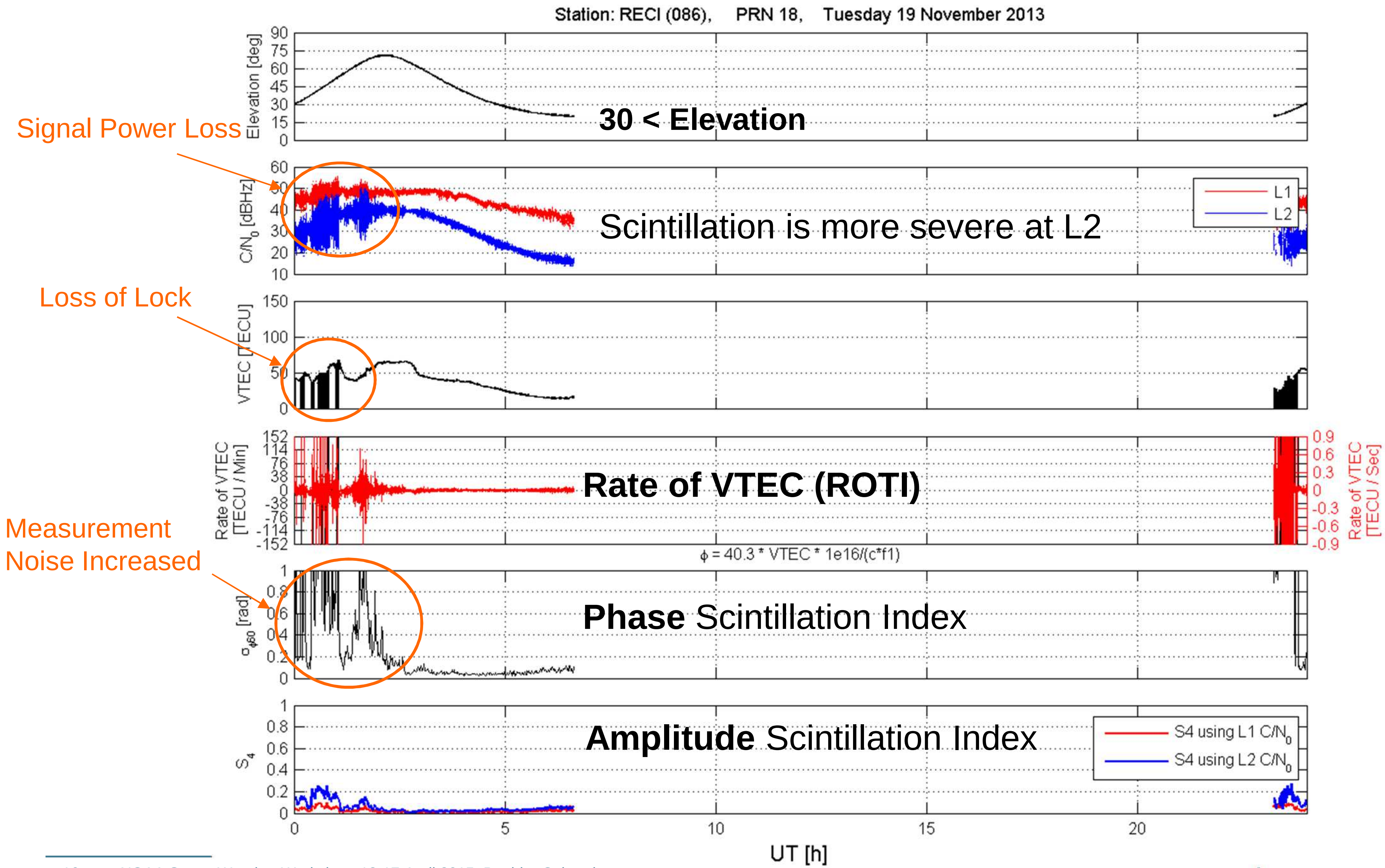
Plasma bubbles diffract and refract GNSS signals and lead to:

Amplitude Scintillation (rapid fluctuations in the signal intensity fading amplitude)
Phase Scintillation (phase jittering)

Scintillation is important because GNSS receiver performance is degraded:

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

Scintillations Effect on GNSS Signal

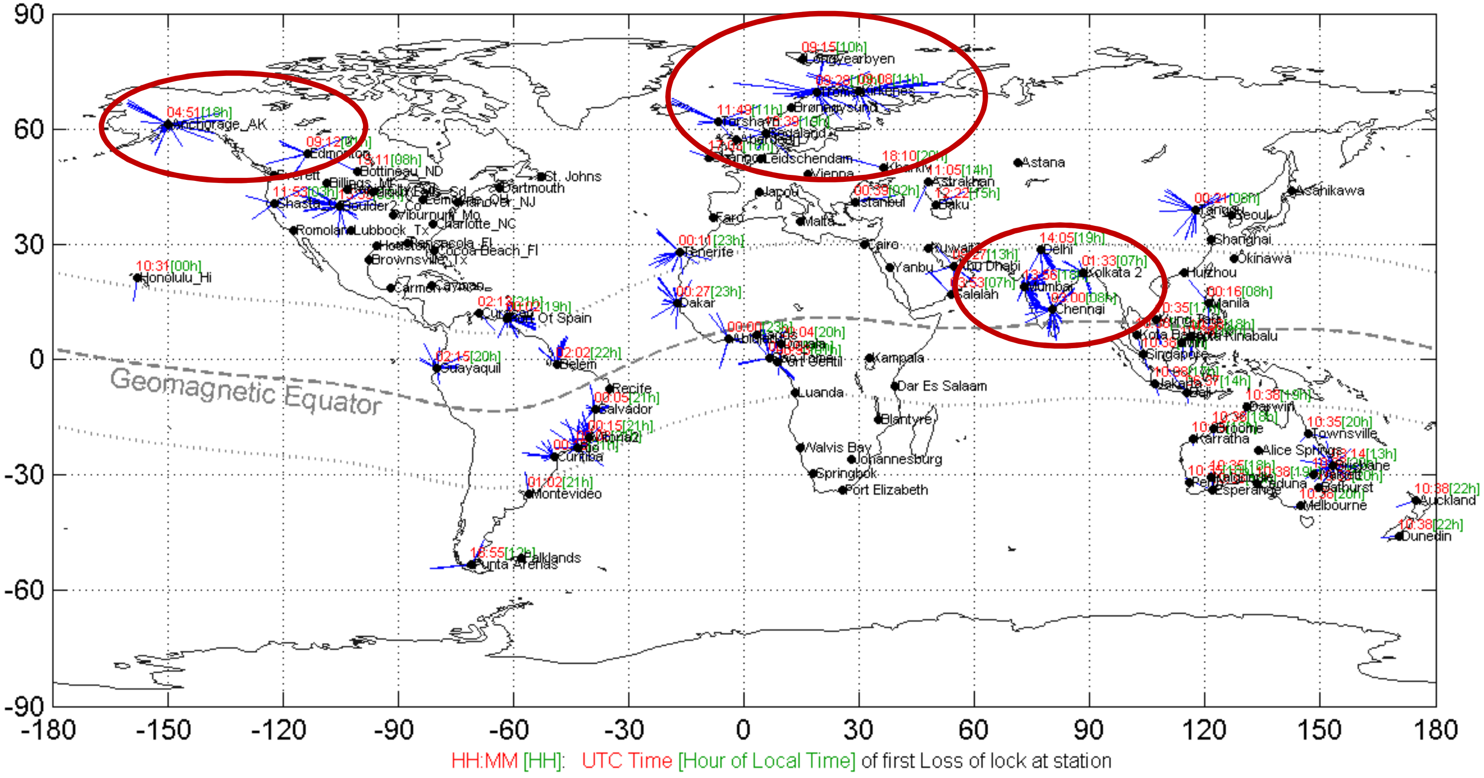


Loss of Lock Indicator graph (**Amplitude Scintillation**)

17th March 2015

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

Ionospheric Pierce Points for all satellites at the ionospheric height of 350 km (Mask=20°)

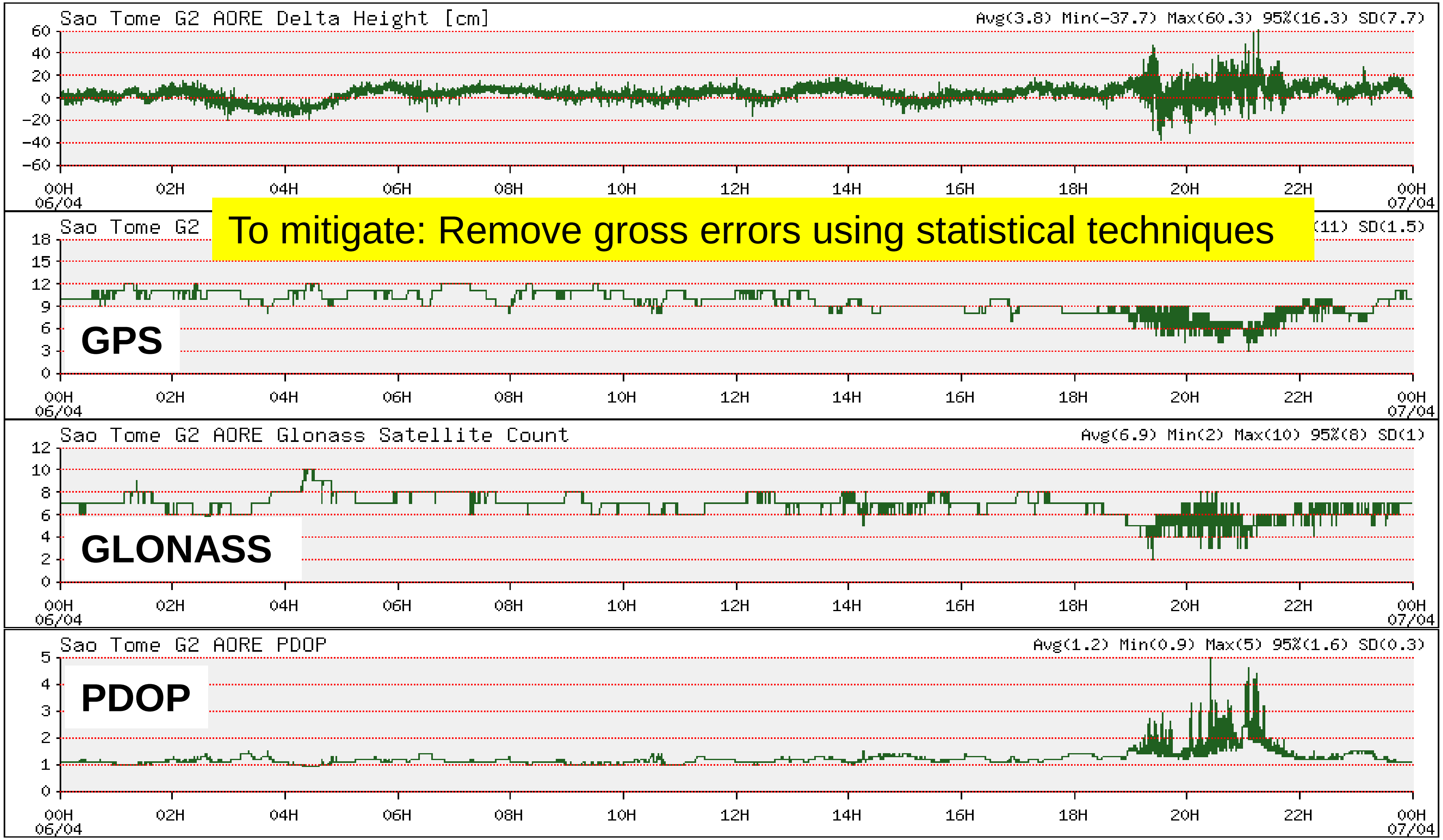


High Latitudes: Heavy Charged Particle Radiation due to **CME** on 17th March
Resulting Loss-Of-Lock

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

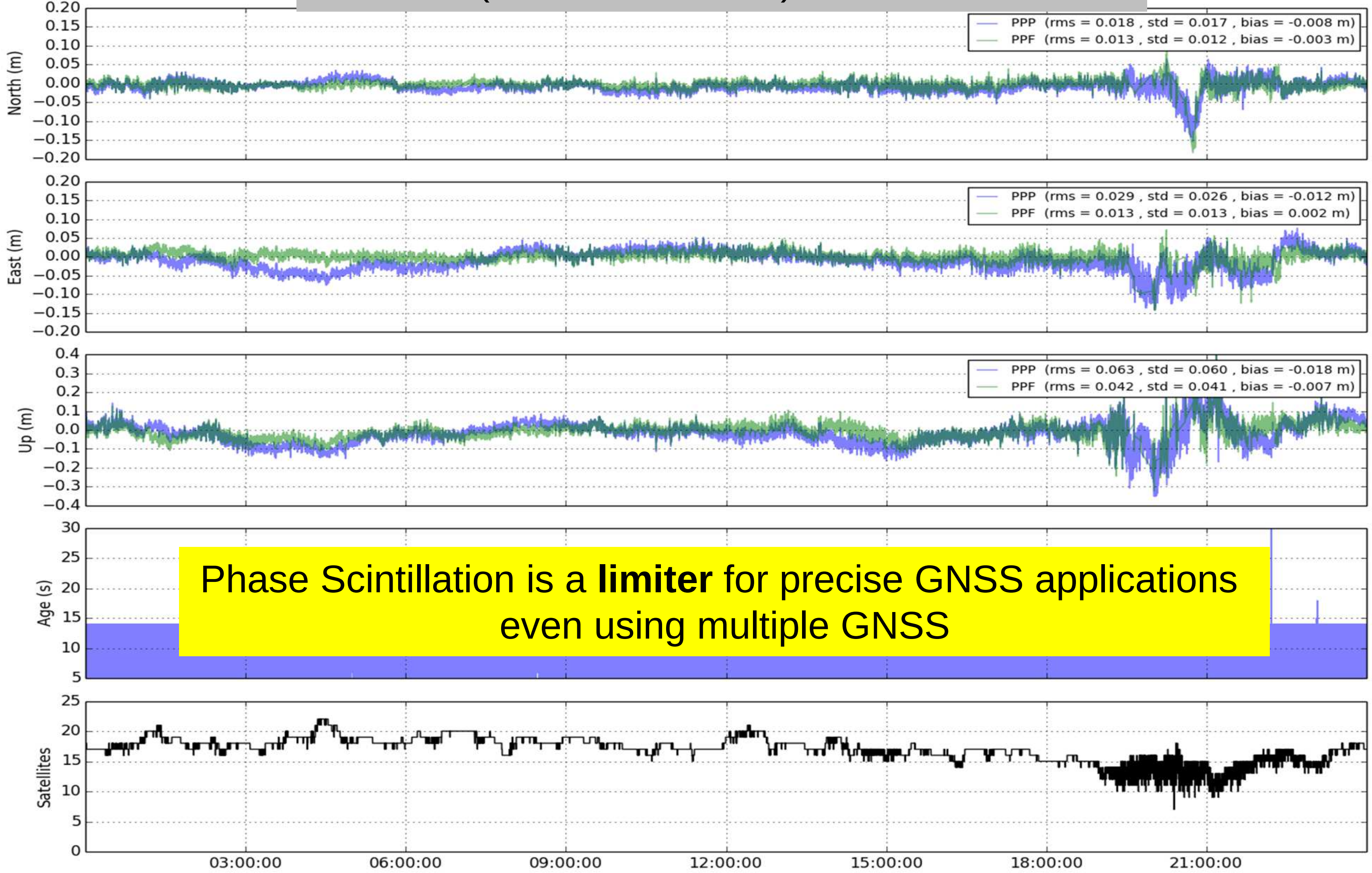
West Africa, Sao Tome (6th April 2015)

G2 Height Error (GPS+GLONASS)



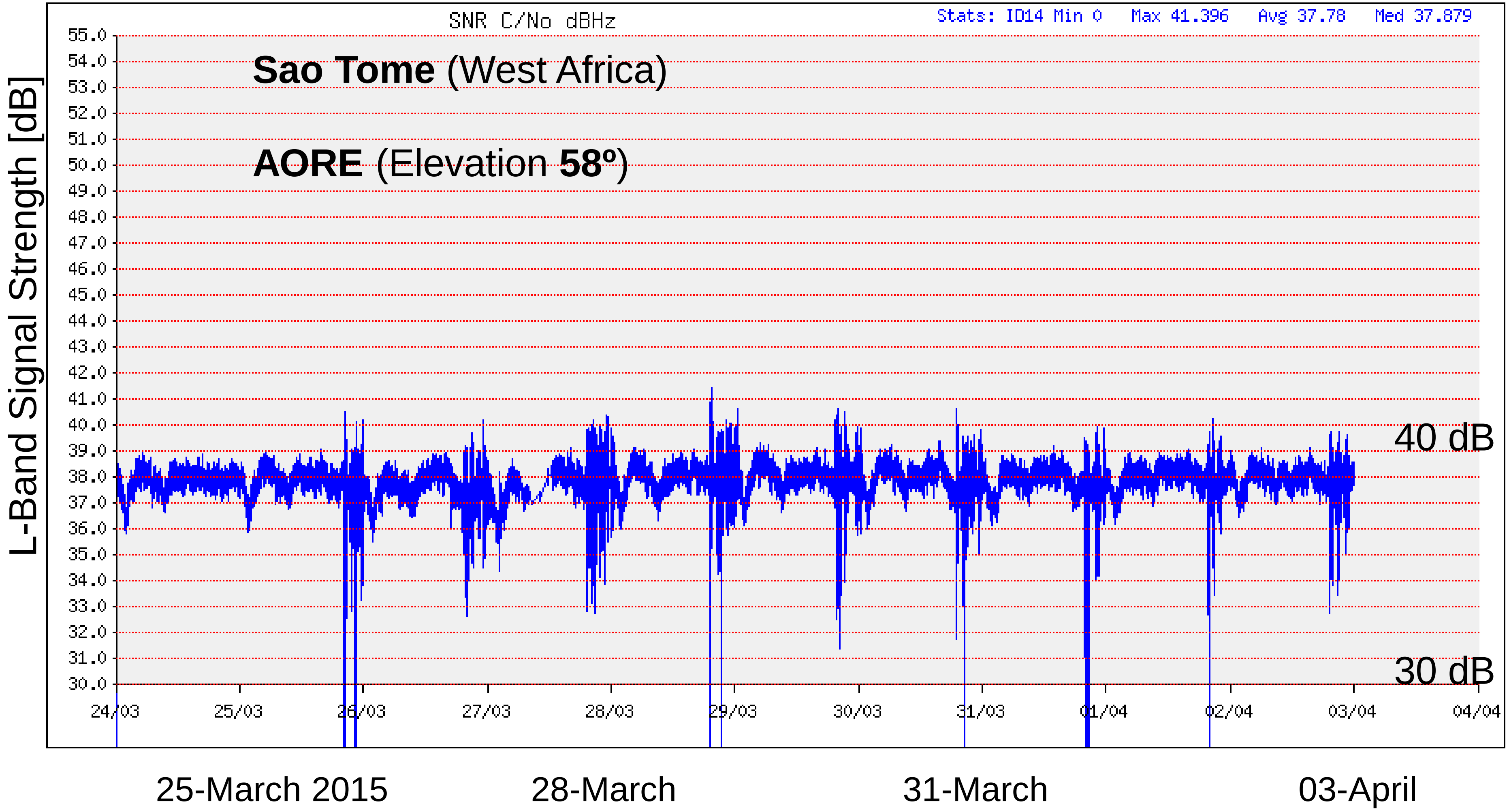
Scintillation Impact on Precise GNSS Positioning (**G2+**)

PPPRTK (GPS+GLONASS) and Standard PPP



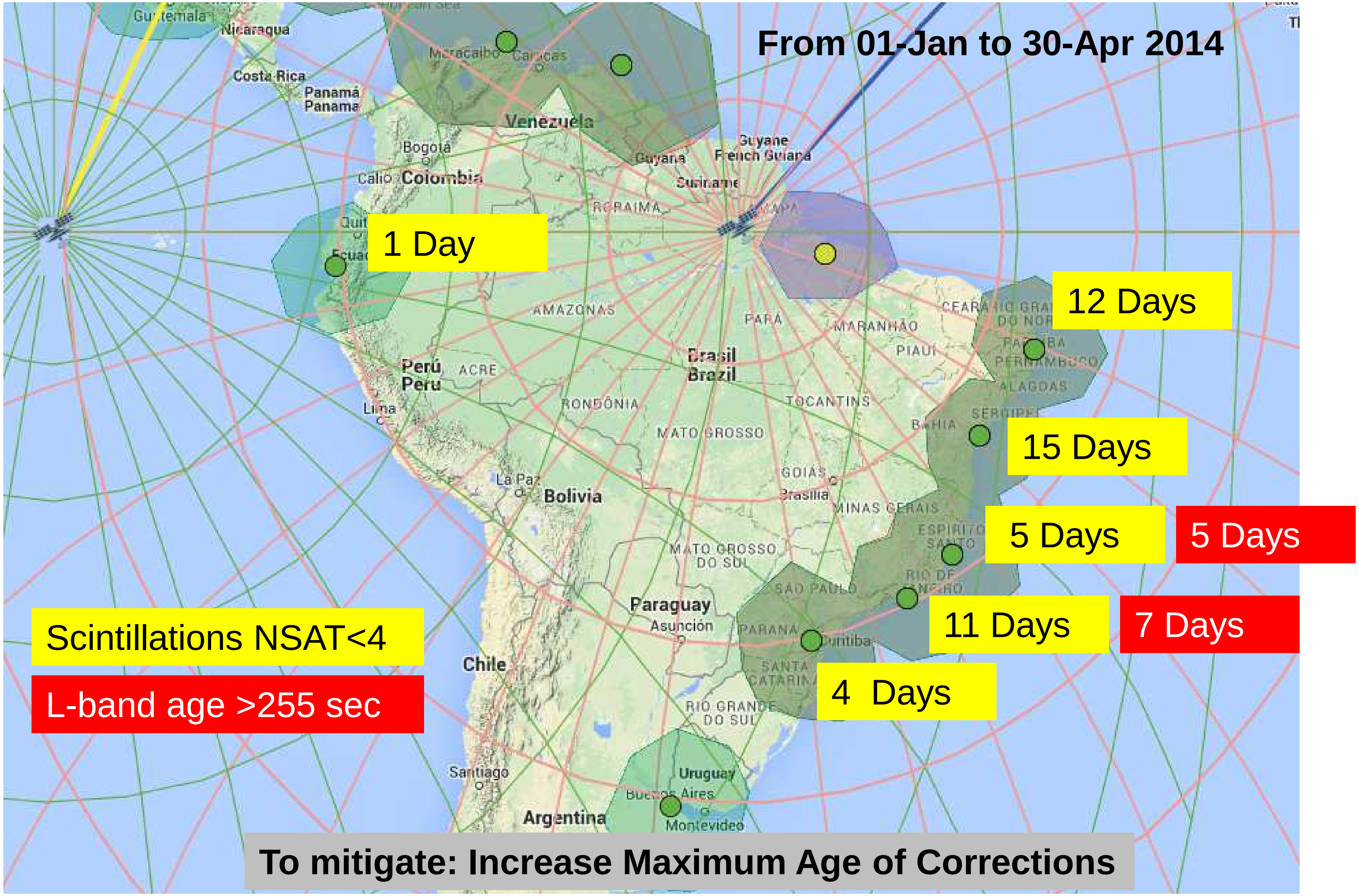
Phase Scintillation is a **limiter** for precise GNSS applications even using multiple GNSS

Scintillation Impact on **L-band Communications**



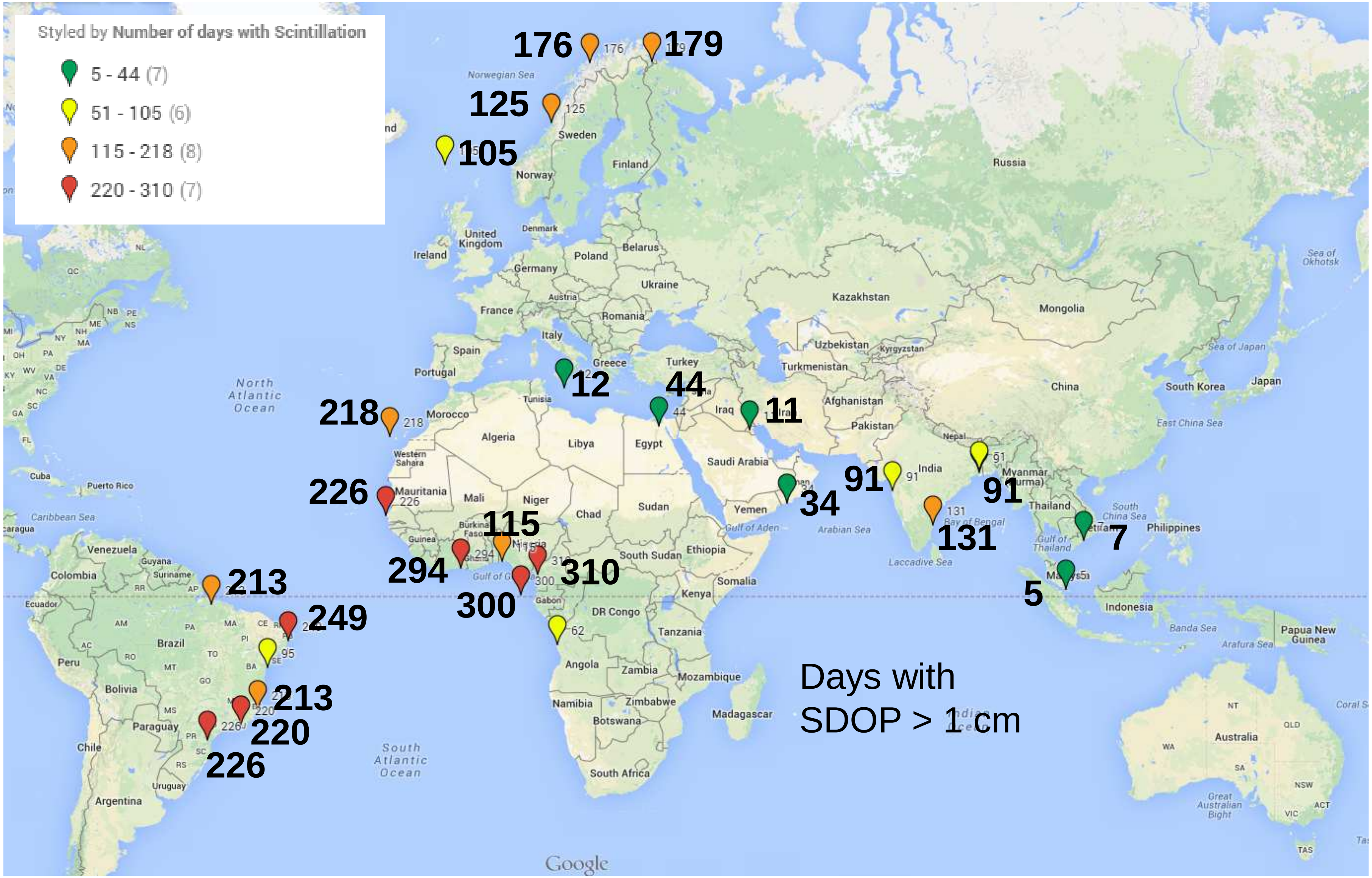
Typical L-band correction outages are short <150 seconds and do not have an effect on position

Scintillations Effect on G2 Positioning (**Reset**)

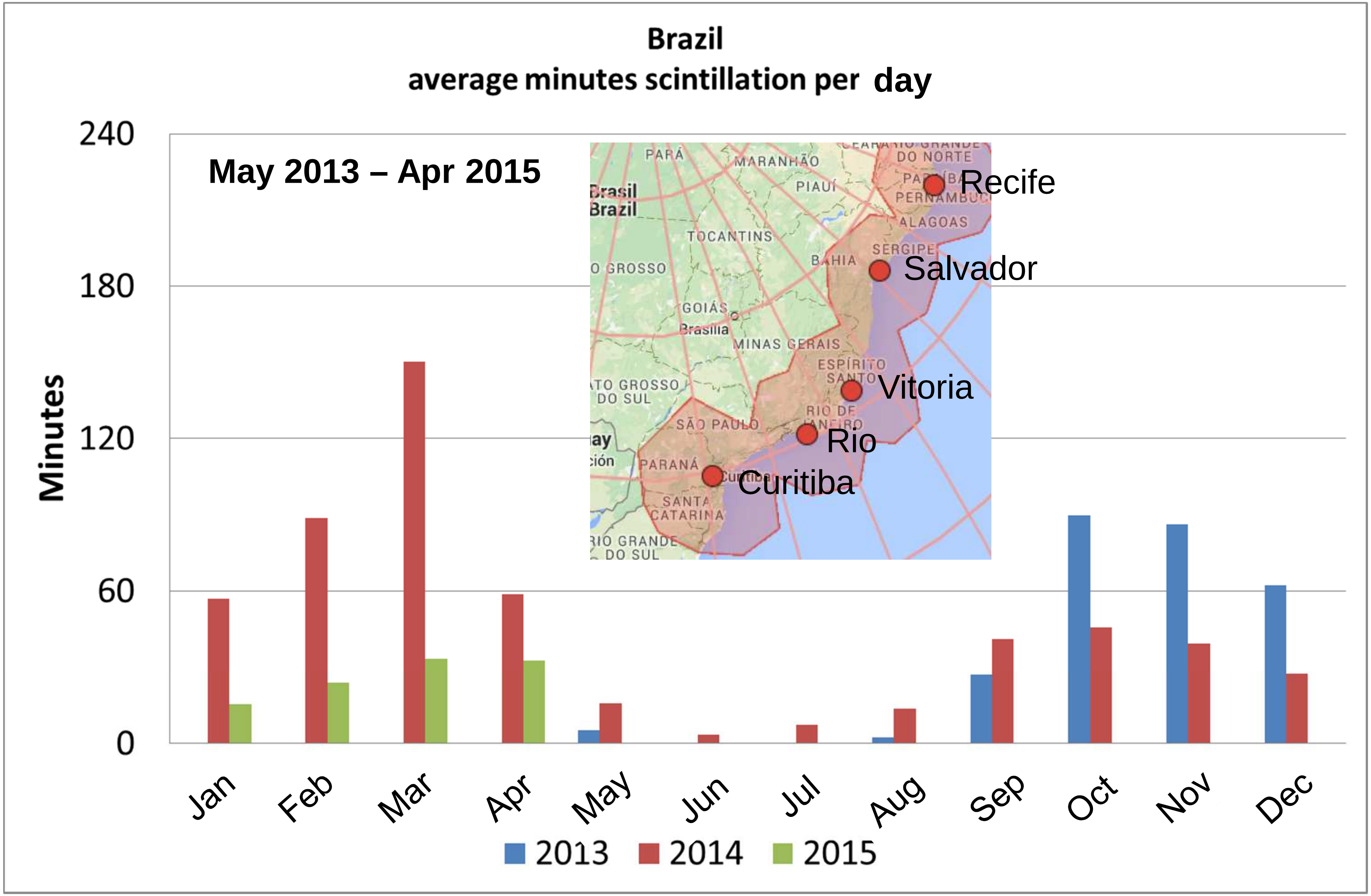


SCINTILLATIONS OCCURRENCES

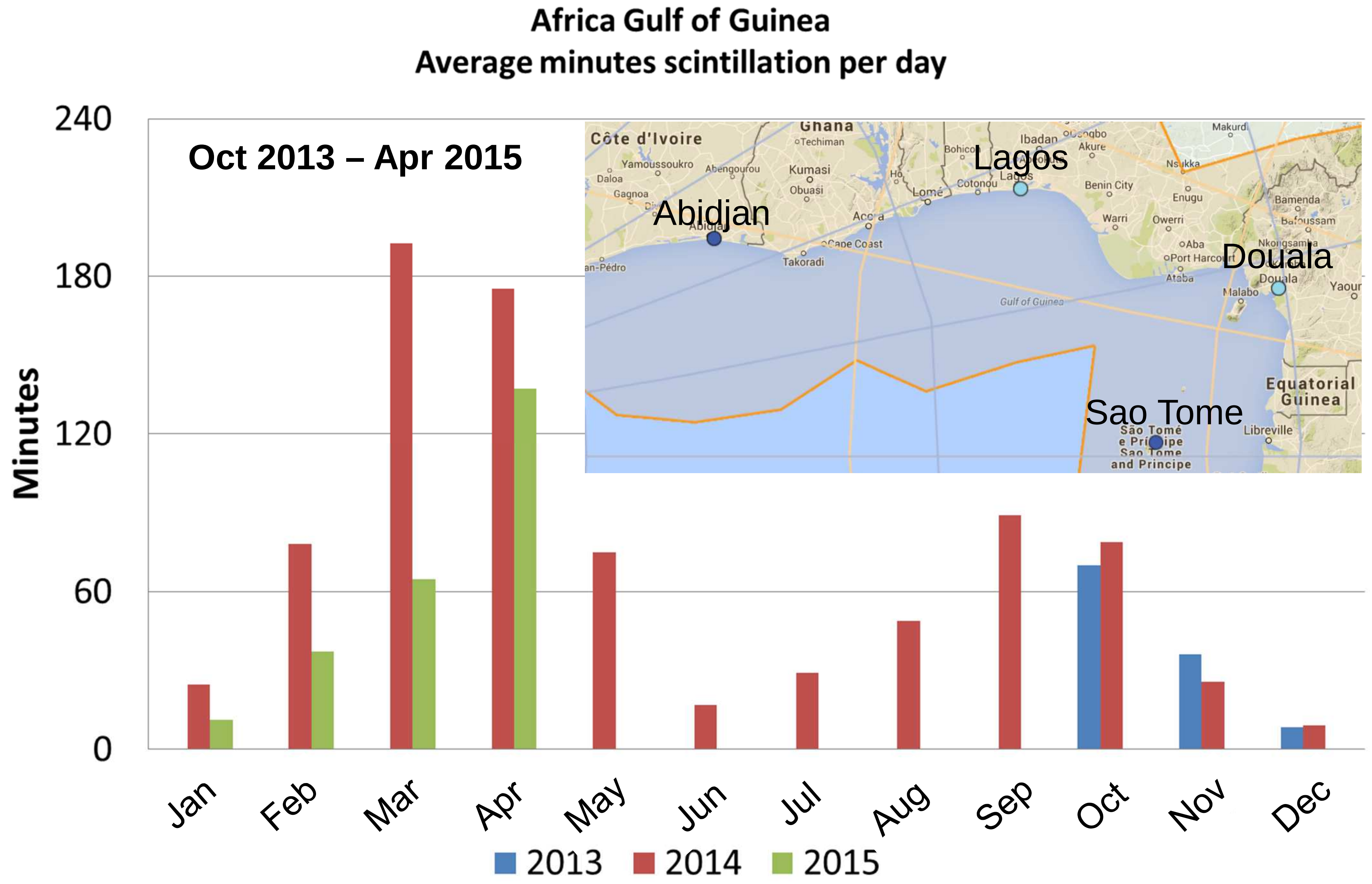
Occurrence of Scintillations (Sep 2013 – Oct 2014)



Seasonal Variation of Scintillations



Seasonal Variation of Scintillations (West Africa)



SCINTILLATIONS PREDICTION

Objectives

- ❑ **Near real time scintillation prediction**
  - **in Time and Space for the next 24 hours**

- ❑ **Provide specific scintillation index (Scintillation DOP)**
  - **for the location of a GNSS user**
  - **for Marine GNSS applications**

Any GNSS user being able to answer the following questions:

What is the scintillation status in my working area?

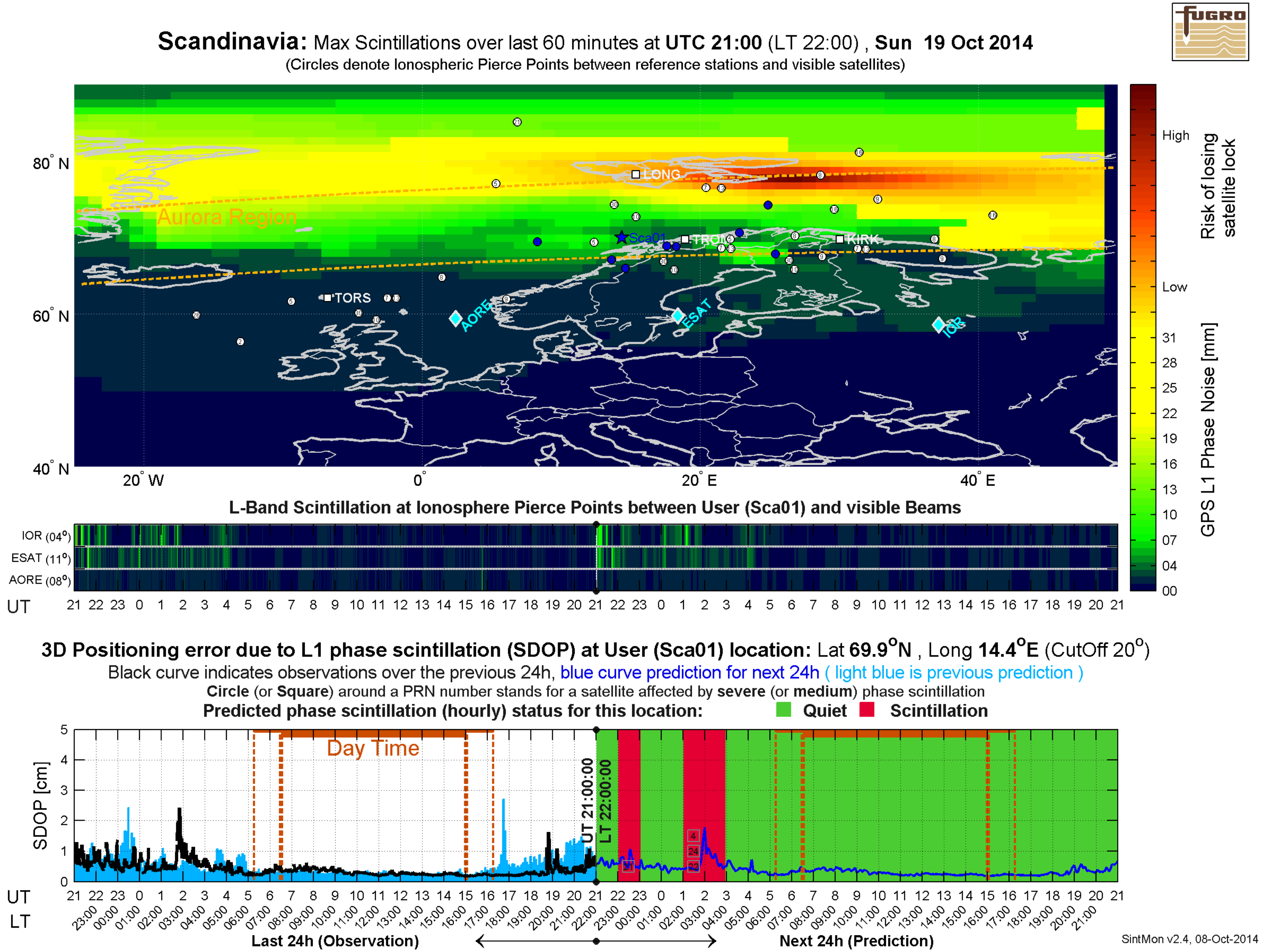
When will scintillation begin and end for me?

Which visible GNSS satellites are likely to be affected by scintillation?

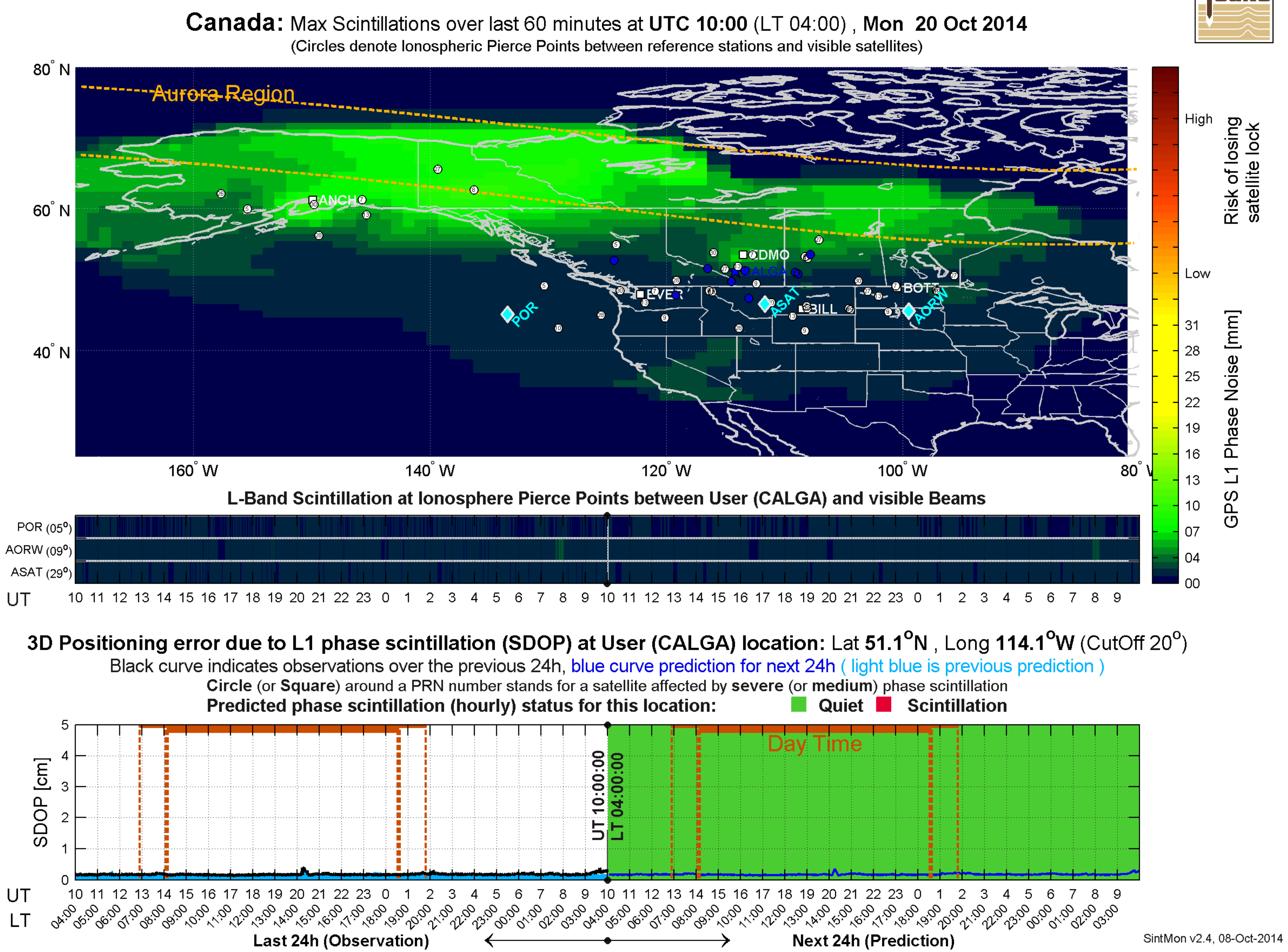
Am I likely to lose lock on any GNSS satellites? If so, which ones and when?

Is there any chance that I may lose communication with L-Band satellites?

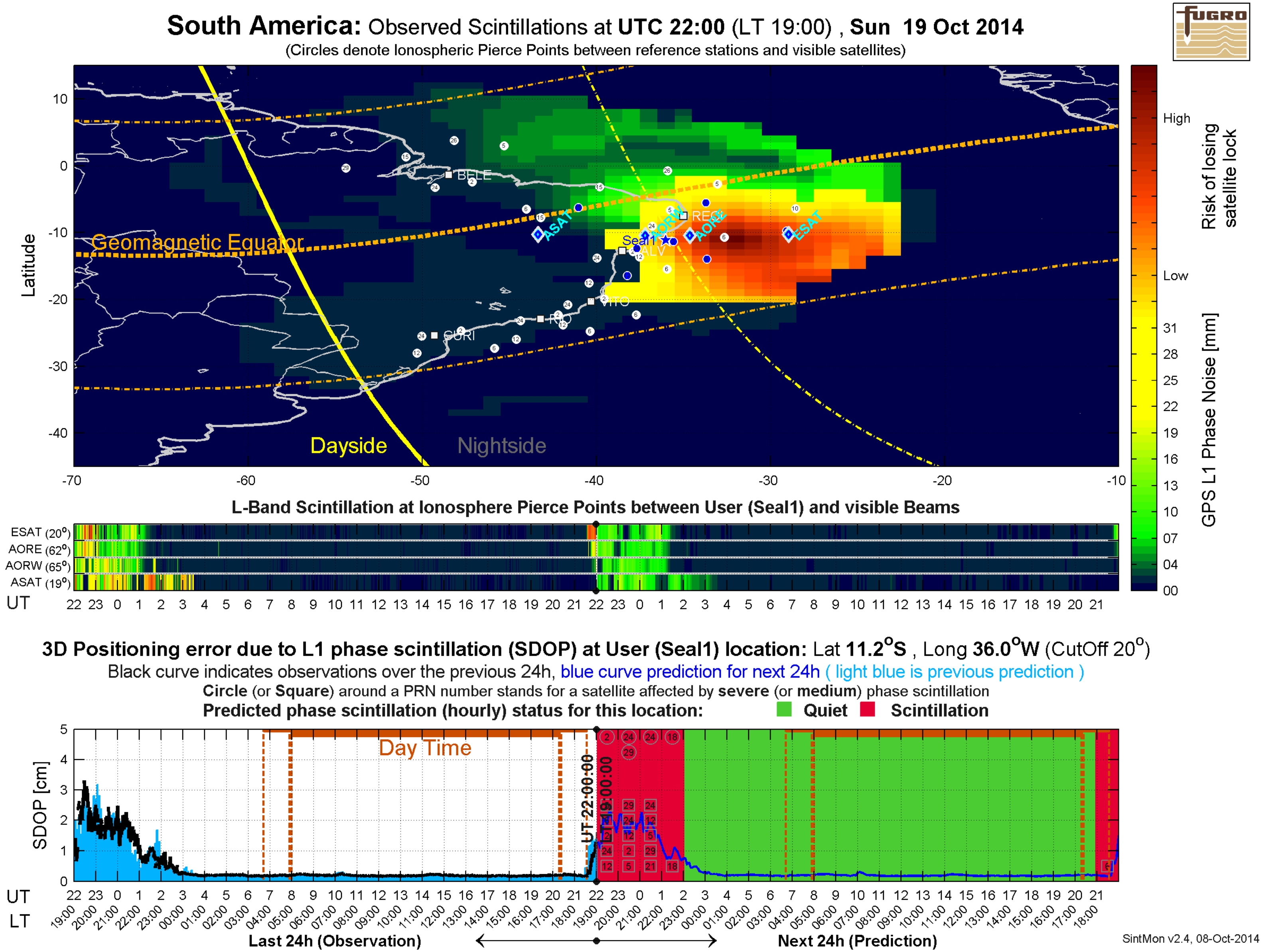
Regional Scintillation Prediction, **Scandinavia**



Regional Scintillation Prediction, **Alaska**

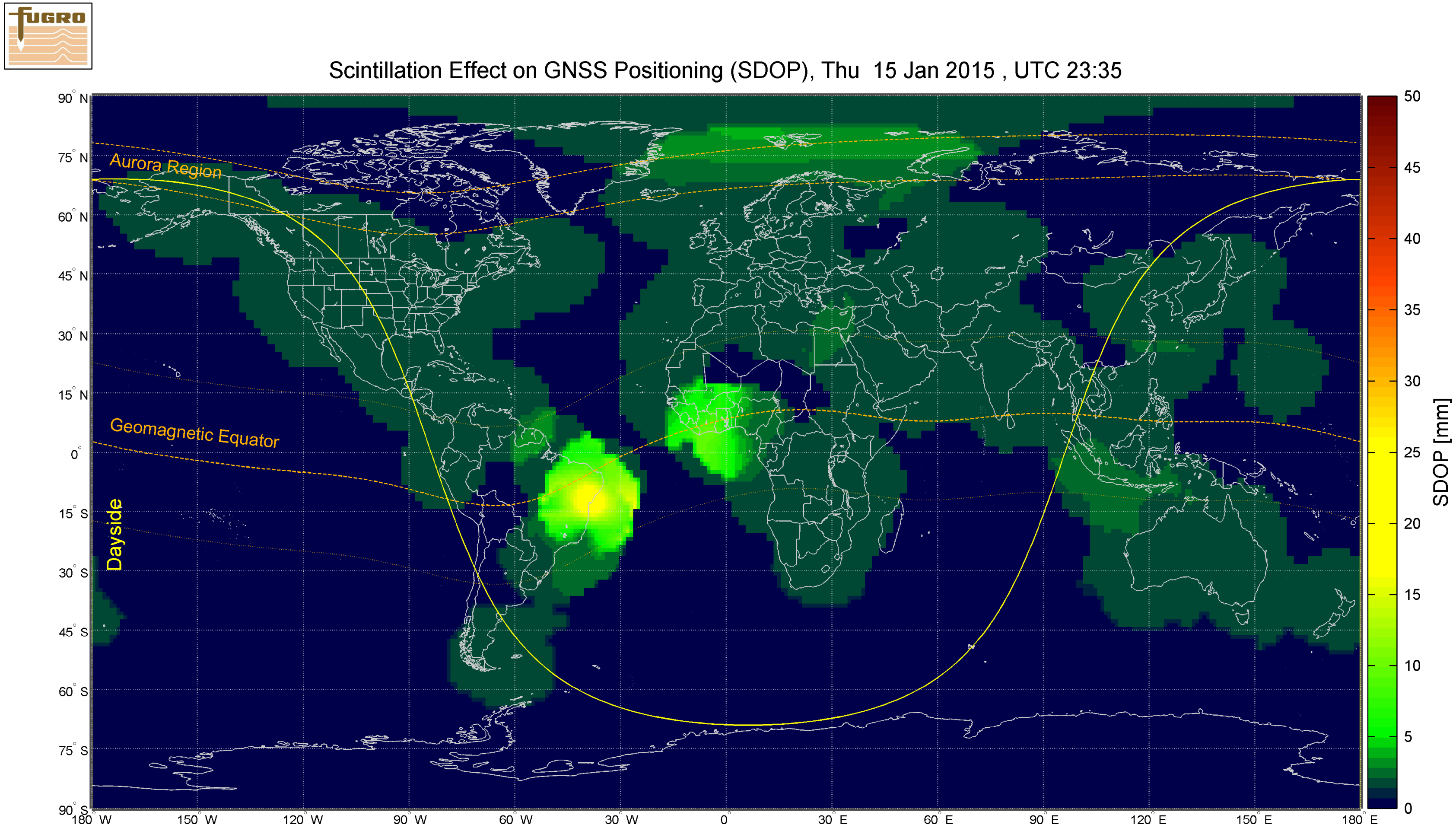


Regional Scintillation Prediction, **Brazil**



WORLD MAP OF SDOP

World Map of SDOP (Initial Results)



Quality of the Fugro Scintillations Prediction

From Oct-2013 to Oct-2014

Evaluating scintillation prediction in Brazil

		Predicted		Comment
Measured	Scintillation	Quiet	Severe	
	Quiet	85%	2%	13% No prediction
	Severe	25%	68%	7% No prediction

Evaluating scintillation prediction in West Africa

		Predicted		Comment
Measured	Scintillation	Quiet	Severe	
	Quiet	92%	6%	2% No prediction
	Severe	23%	72%	5% No prediction

Scintillations Warning Message to GNSS users

Hourly scintillation forecast for next 24 hours

Date	UTC	Scintillation	Service Affected	NSAT	PRNs with risk of losing lock
14-Nov-2014	21:00-22:00	Strong	None	02	G05,G24
14-Nov-2014	22:00-23:00	Strong	HP, XP	06	G05,G12,G21,G24,G25,G29
14-Nov-2014	23:00-00:00	Severe	HP, XP2, G2	08	G05,G12,G15,G18,G21,G25,G29,G31
15-Nov-2014	00:00-01:00	Strong	HP, XP	06	G15,G18,G21,G22,G25,G29
15-Nov-2014	01:00-02:00	Strong	HP, XP	05	G15,G16,G18,G22,G29
15-Nov-2014	03:00-04:00	Strong	None	02	G16,G32

Quality of Prediction over last **~33** days (**364h**) with **657h** Quiet and **129h** Severe scintillation:

- In case of **Quiet 235** hours, prediction was: **88.1% Quiet** and 11.1% Severe Scintillation
- In case of **Severe 129** hours, prediction was: **72.9% Severe** and 27.1% Quiet Scintillation

Summary

L1 GPS VBS around equator can have large errors day time during solar maximum
L1/L2 HP GPS only do not have enough satellites
Loose of Satellites due to Scintillation is the most severe cause
Phase scintillation is a limiter for G2+
Loss of L-band corrections is less frequent.
Scintillation has seasonal patterns

Improvements made for Number of Satellites

Adding of Glonass, Beidou and Galileo (G4) reduces the problem

For L-band reception

1) Use dual satellite demodulators
2) Increase maximum age

Prediction

1) Prediction of Scintillations near equator for 24 hours is ~70% accurate
2) Using SDOP for GNSS is highly valuable
3) Warning email is appreciated by customers

Thanks for your attention

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