Contribution of DORIS System to Global Ionospheric Scintillation Mapping

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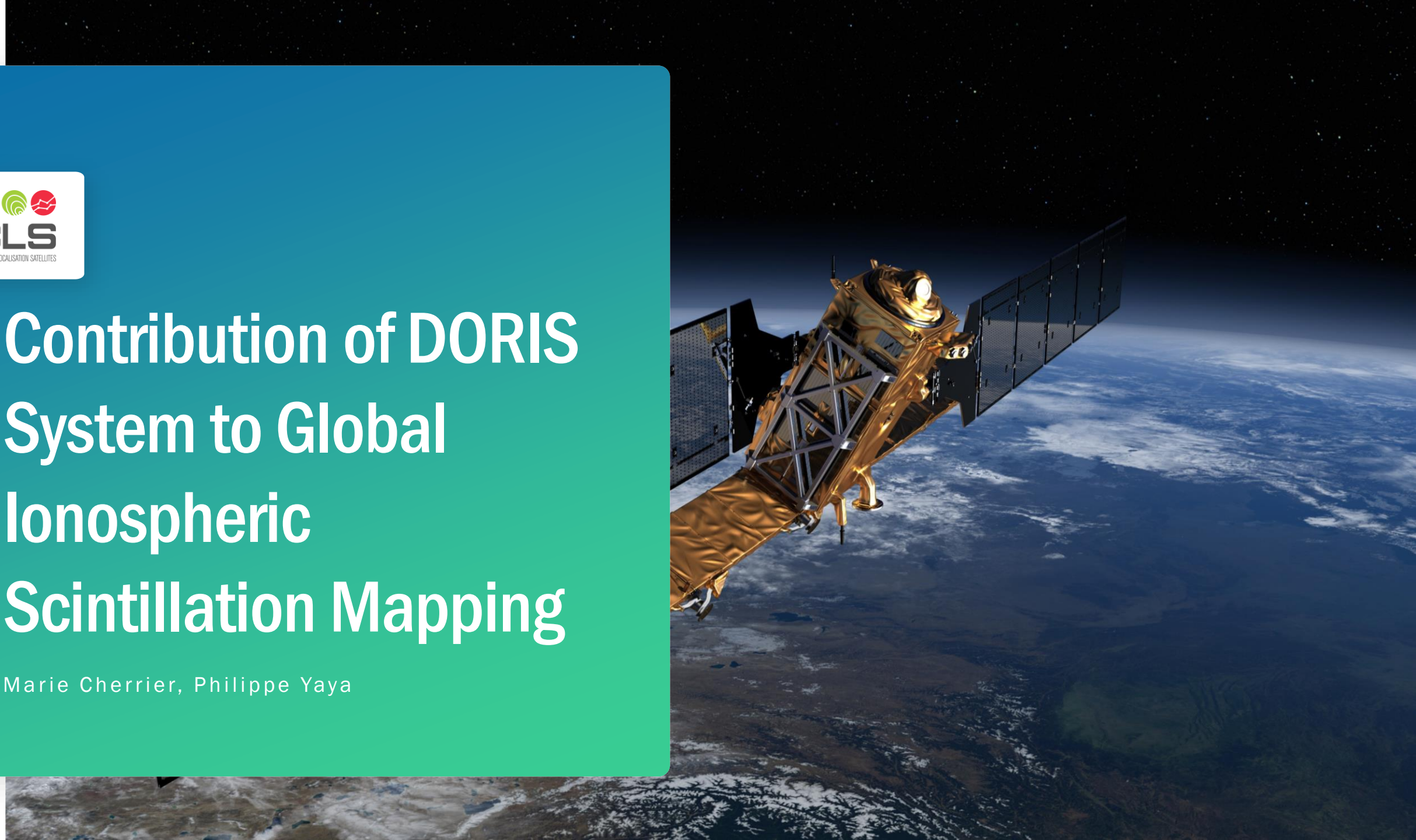


Table of contents

1. Introduction

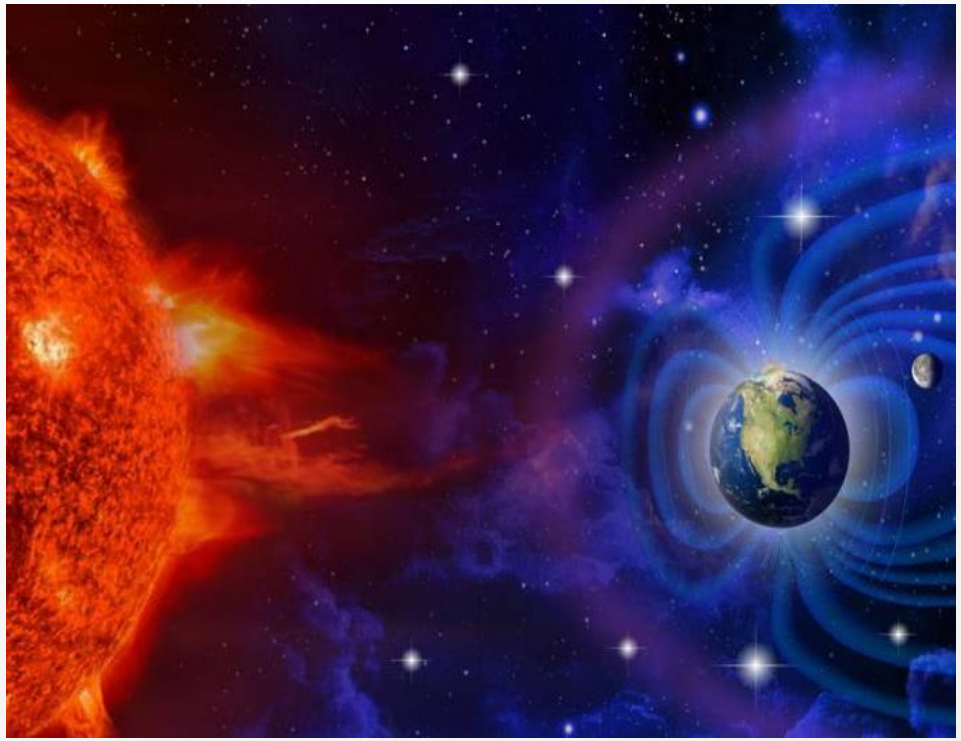
2. Long-term statistics

3. Short-term impact

- DORIS data losses
- Phase signal degradation
- Power signal attenuation

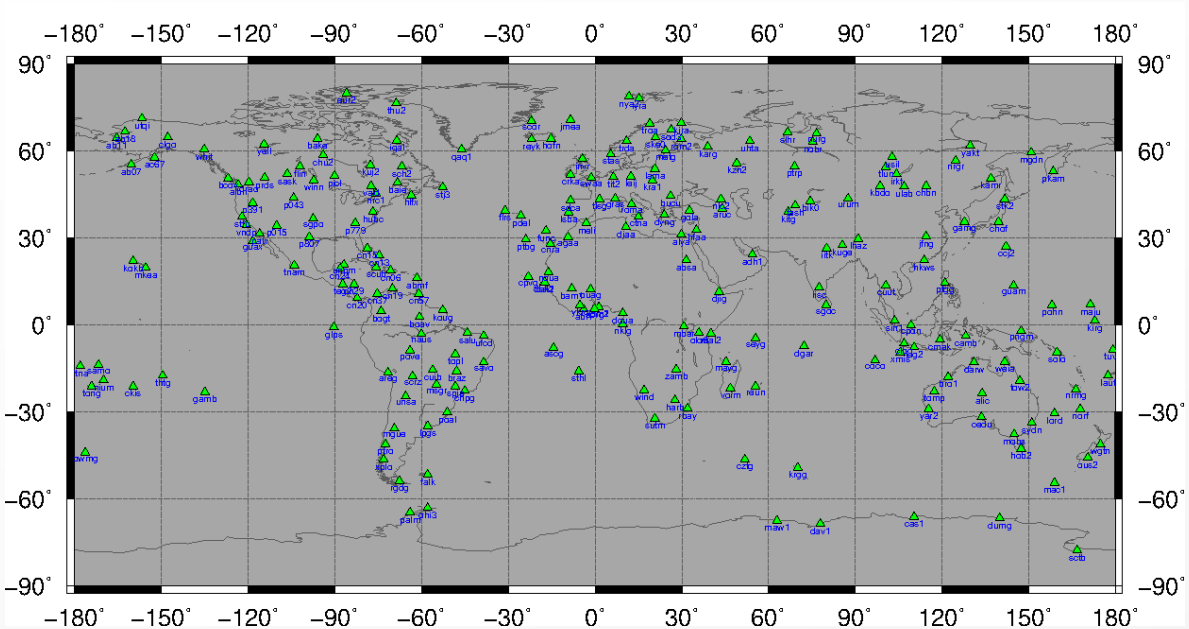
1. Introduction

- Problematic : ionospheric scintillations due to ionosphere irregularities may severely degrade GNSS data in equatorial and high latitudes regions. Networks of ground based GNSS receivers are used to derive maps of scintillation intensity, but it inevitably leads to sparse coverage.
- Purpose of the study : add original data points based on the DORIS system (DORIS 2GHz is near the L1 GNSS frequency at ~1.5 GHz) to improve the scintillation coverage.
- What will be done : explore if it is possible to define scintillation proxies based on DORIS data losses, phase signal degradation, or power signal attenuation, by a comparison to a scintillation data base from GNSS measurements.

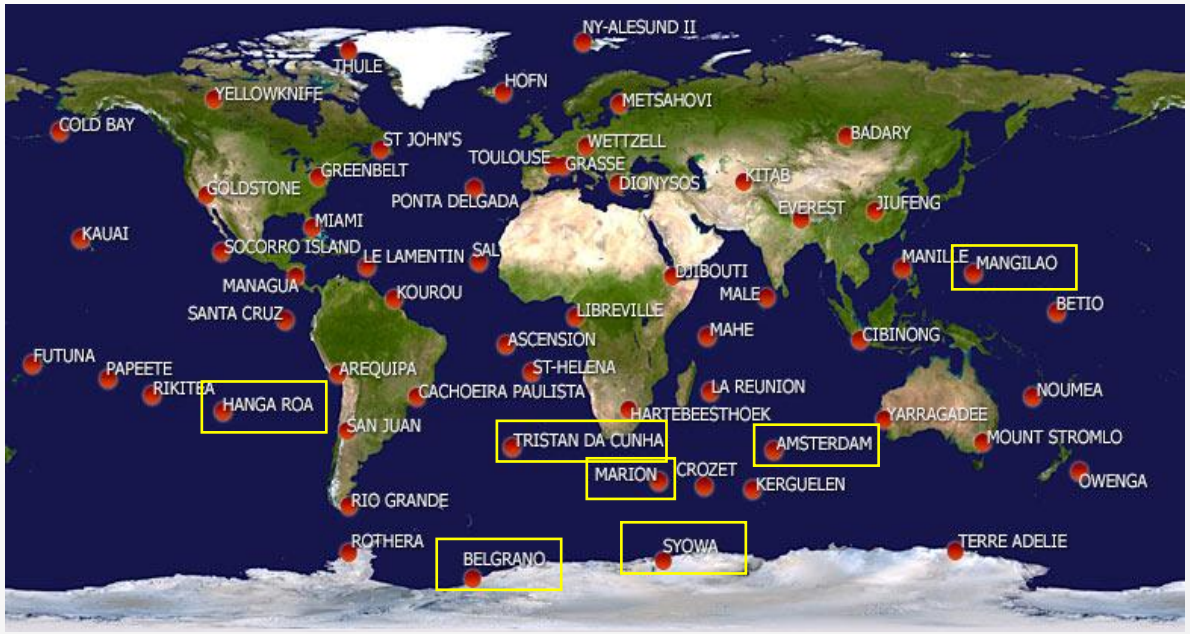


1. Introduction

→ Despite a lower data rate (0,1 Hz instead of 1 Hz for the GNSS) and a lower number of satellites, DORIS can add valuable information where there is no GNSS receivers



Selection of real-time or near-real-time (15') GNSS stations

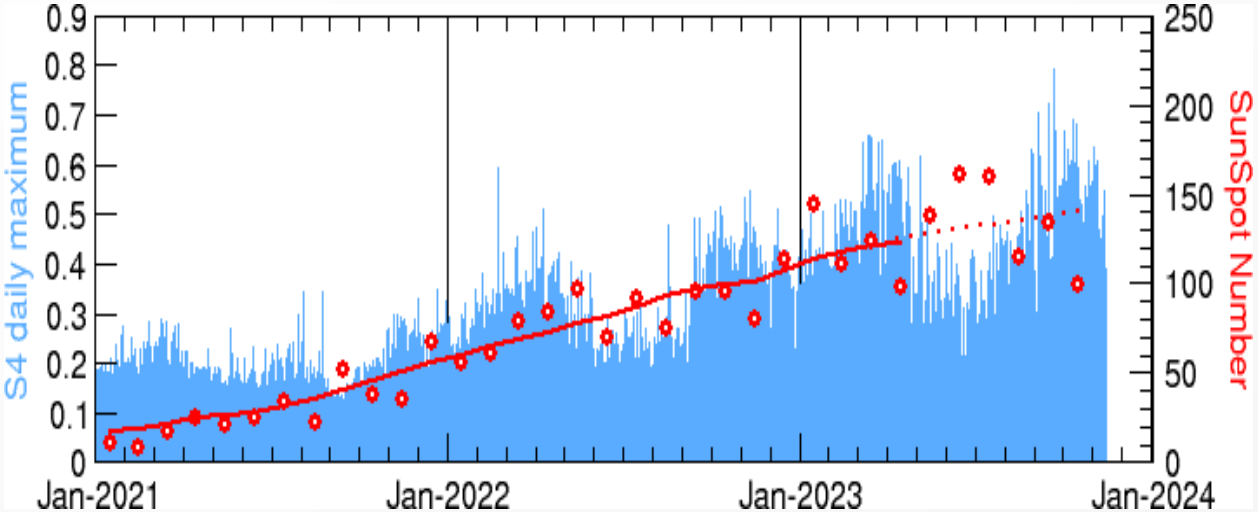


DORIS network (in November 2023) – Yellow rectangles show where DORIS could add valuable information

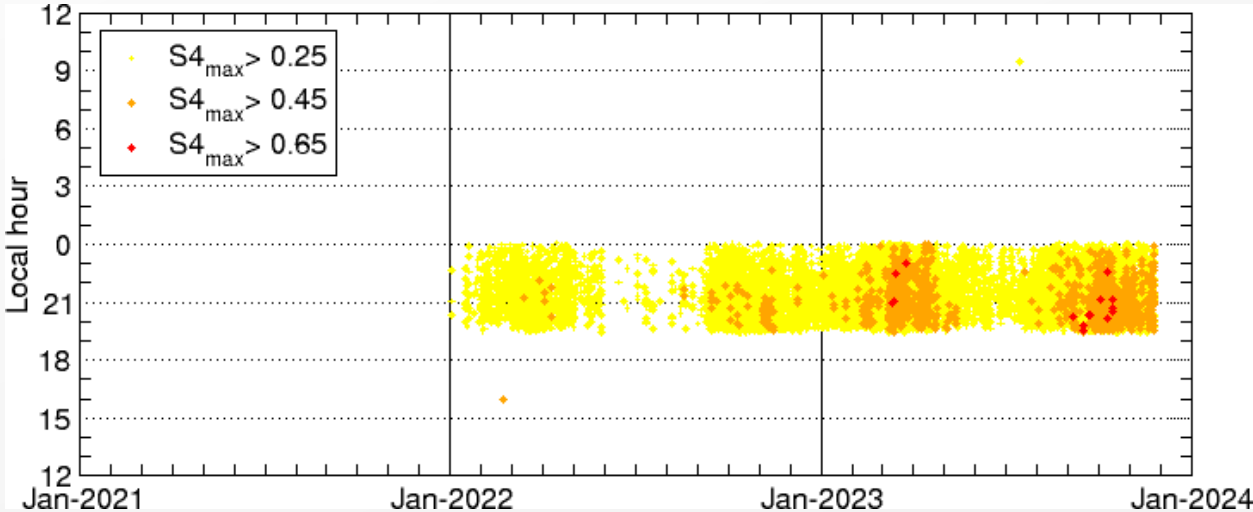
2. Long-term statistics

→ As the current solar cycle continues to progress, the level of amplitude scintillation observed worldwide by GNSS receivers also increases. It peaks during the equinoxes and occurs during the night, starting at the sunset.

→ One of DORIS frequency channel is not so far from the GNSS L1 frequency, therefore DORIS signal may also be affected by scintillations.



Sunspot number & Amplitude scintillation maximum over a 3-year period

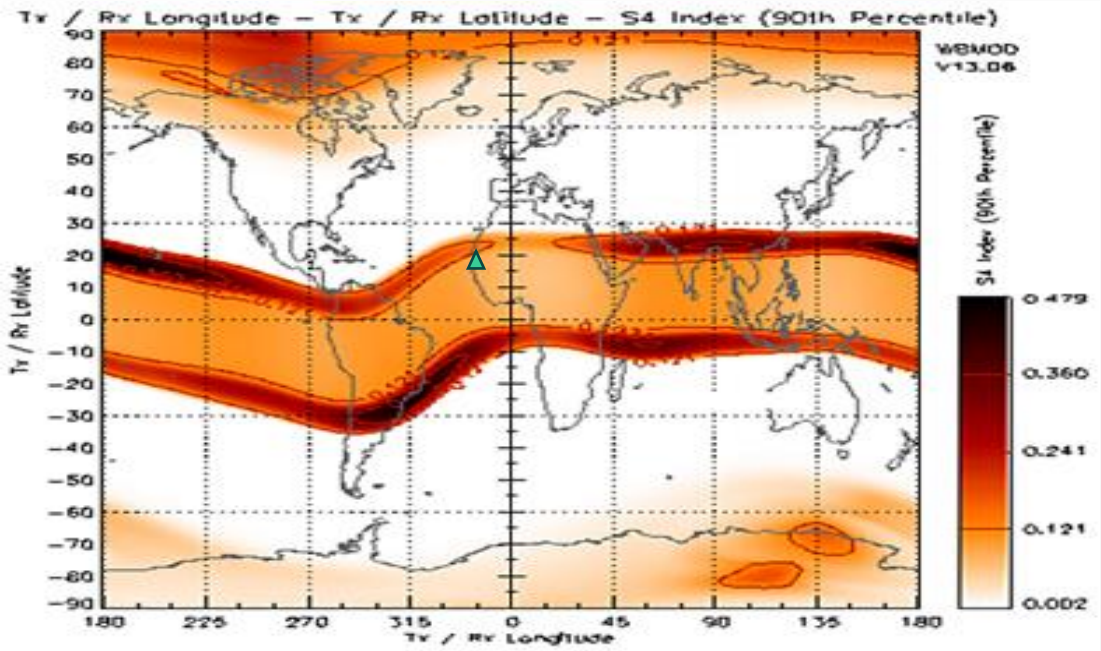


Local hour of the S4 daily maximum (worldwide)

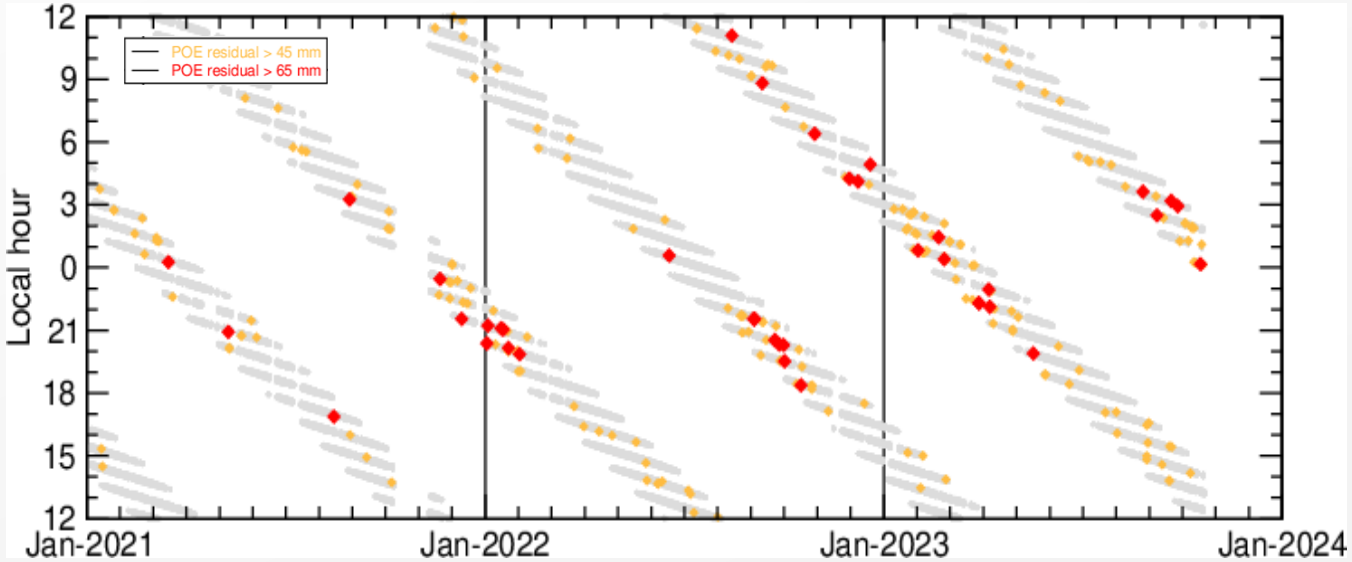
2. Long-term statistics

→ Statistics from Precise Orbit Determination (POD) of Cryosat2 DORIS satellite with the Sal beacon data

→ Measurements show that there are higher POE residuals (> 45 mm and > 65 mm) during the night, between 21h and 3h at local hour. Furthermore, there number of red and orange dots increases as the solar cycle progresses.



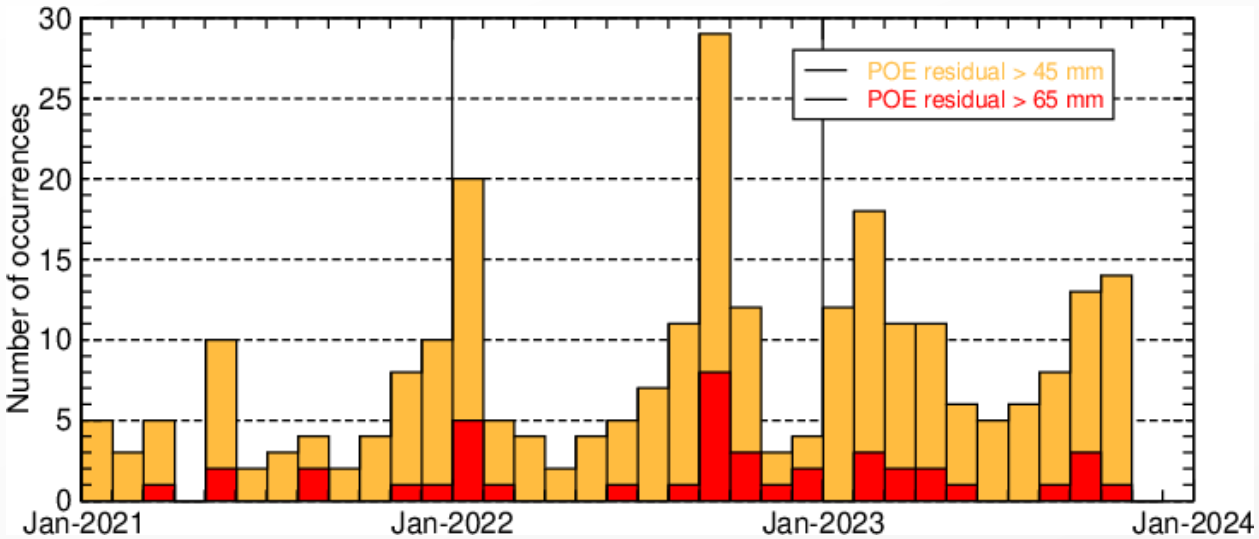
WBMOD Scintillation climatological model (NorthWest Research Associates, Inc).



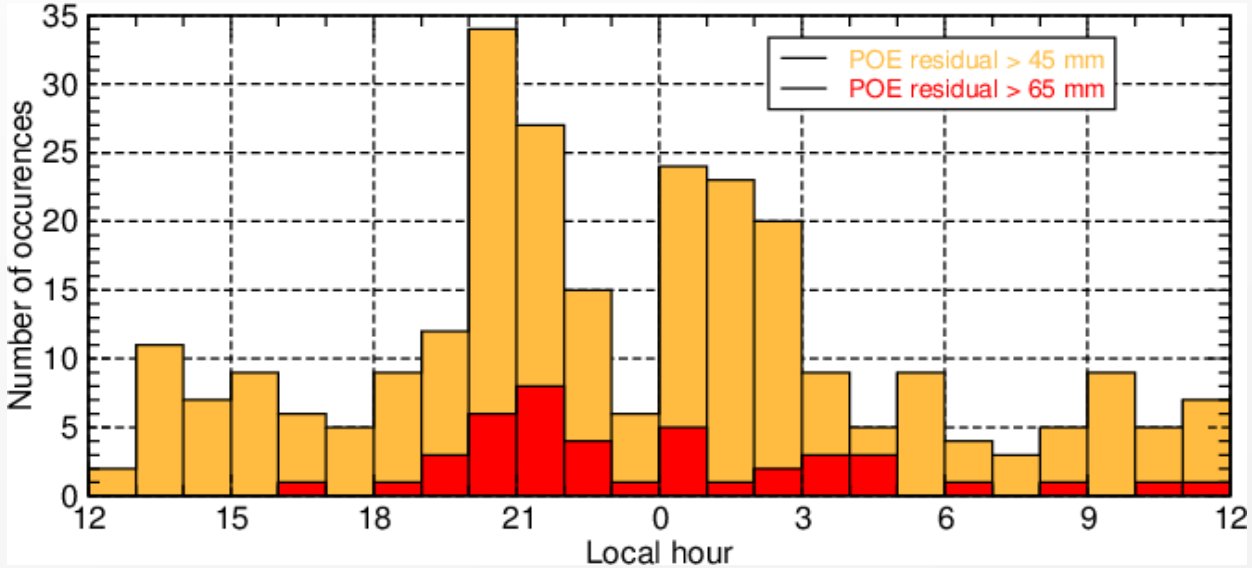
Plot of the measurements on a time vs local hour

2. Long-term statistics

→ Both derived statistics figures clearly show a correlation with scintillation level : high residuals are becoming higher with the solar cycle, during equinoxes and after sunset.



Derived statistics of the occurrence of high values VS time

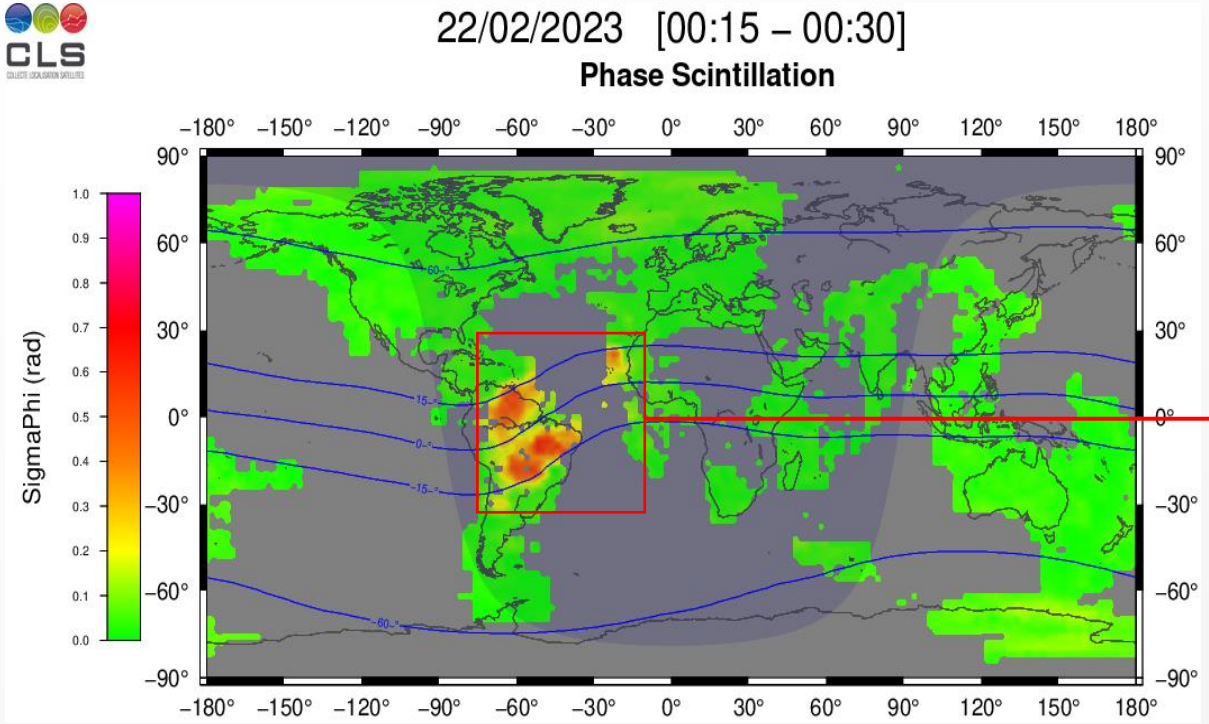


Derived statistics of the occurrence of high values VS local hour

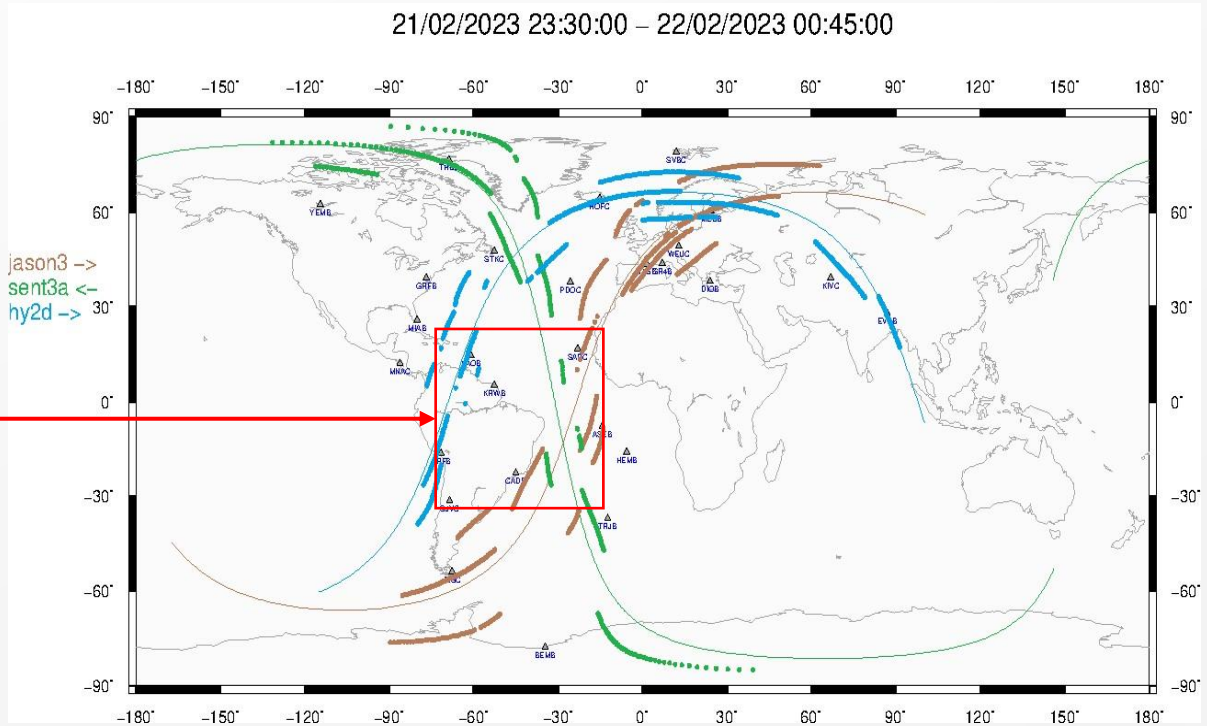
3. Short-term impact : DORIS data losses

→ Studied scintillation event : February 22^{sd}, 2023 – S_Φ = 0,73 rad

→ During the phase scintillation event at the equator, beacons located in the zone of maximum scintillation show data losses. The same behavior has been observed for beacons located at higher latitudes.



Phase scintillation map based on a GNSS network



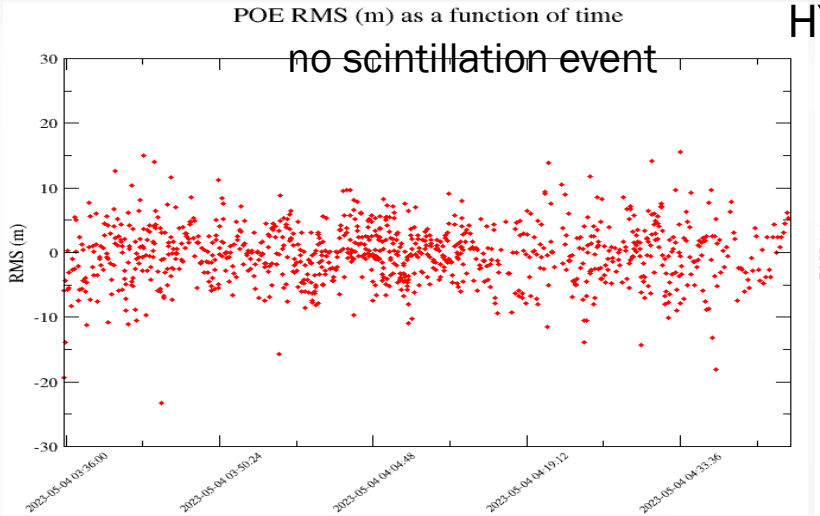
Ground track of DORIS satellites

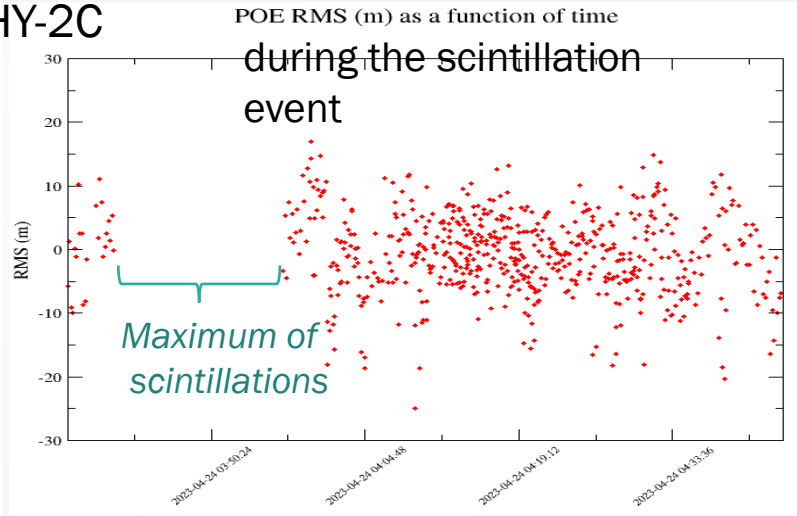
3. Short-term impact : phase signal degradation

→ Studied event : April 24th, 2023 – S_Φ = 0,79 rad

→ Analysis of least-square residuals of the orbit fitting on DORIS data is also a good way of monitoring scintillation events. On the POE residual plots, one can see that when the scintillation peak is reached, a complete data loss is observed during a few minutes. Over the scintillation period, the residuals have a wider distribution.

HY-2C





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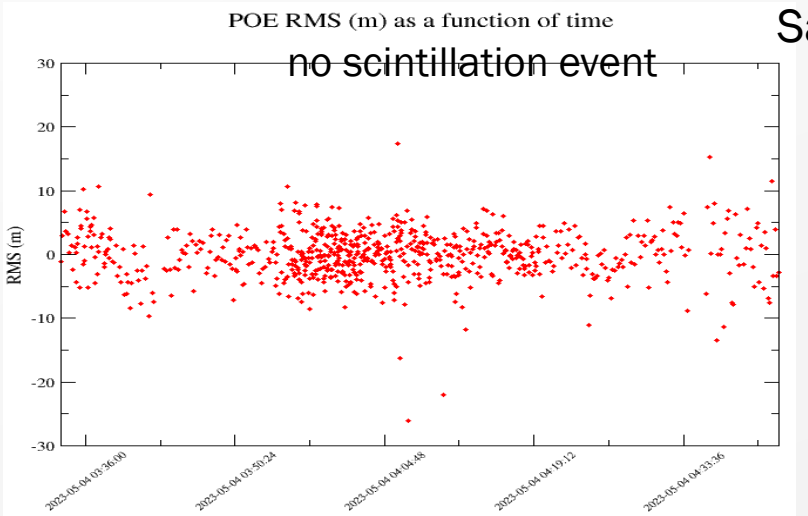
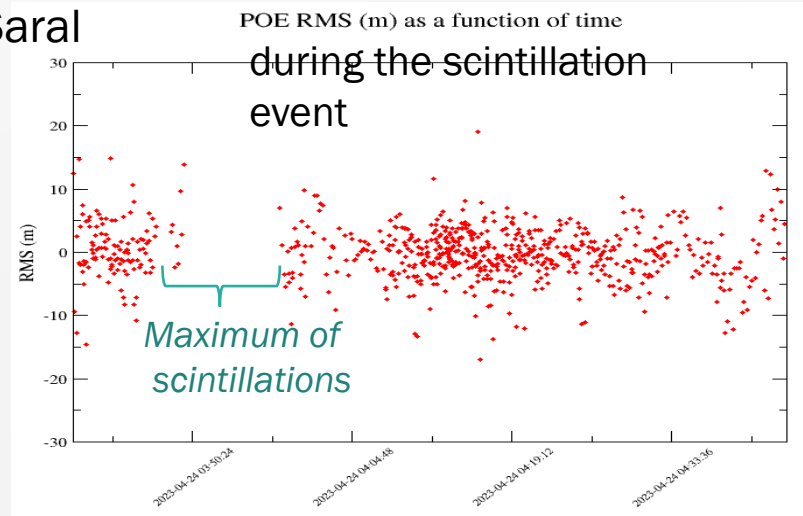
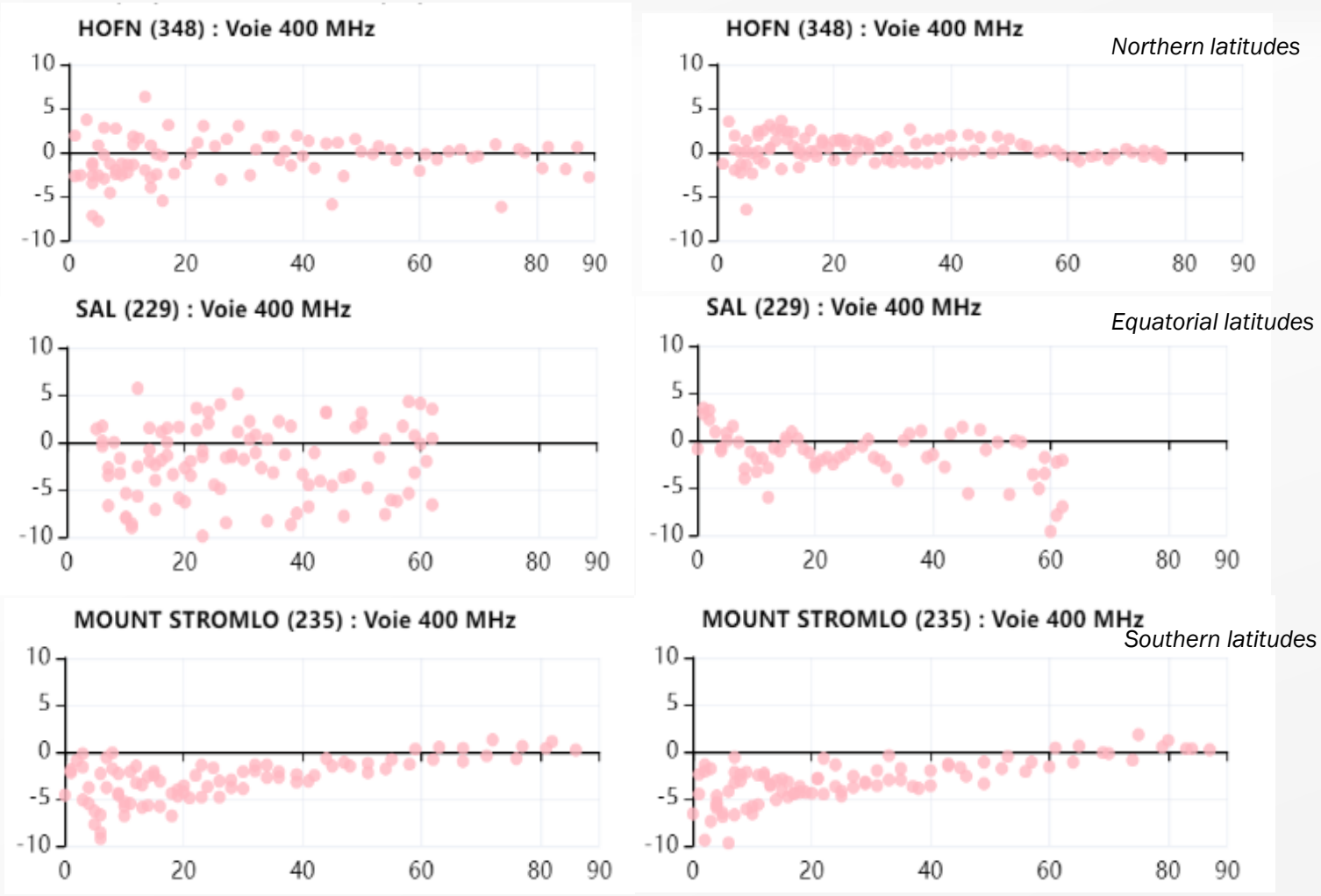




3. Short-term impact : power signal attenuation

Scintillation event

No scintillation event



Power attenuation of 3 DORIS beacons during a scintillation event or not

→ Studied scintillation events : the two previous event + March 23rd, 2023 - SΦ = 0,79 rad

→ We are looking for potential power loss or greater fluctuation during strong scintillation events.

→ For equatorial scintillation events, we can see a slightly greater dispersion and a slightly lower event average. These observations are less visible on high-latitude events.

Conclusions

- Results regarding DORIS data losses and the phase signal degradation suggest that adding original data points based on the DORIS system would be a good way of completing the global scintillation maps and thus obtaining better coverage of the event.
- Regarding the analysis of the power signal attenuation, results are more mitigated.
- This study still needs further investigations to:
  - confirm the correlation between DORIS degradation and ionospheric scintillation
  - and to establish a near real time mapping of a DORIS-derived scintillation proxy.

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