Analysis of data recorded in the frame of the ESA Monitor project

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Contents

- Occurrence of scintillation at high and low latitudes
- Case study : magnetic storm
- High latitude scintillation characteristics
- Modelling aspects

Monitor Project

Funded by: ESA's European GNSS Evolutions Prog. (EGEP)

Team: 8 subcontractors + 2 consultants

Interagency agreements: 2 (CNES & ASECNA) – MoUs

New monitoring stations: 6 (+ 5 from CNES SAGAIE)

New products types received routinely: 6

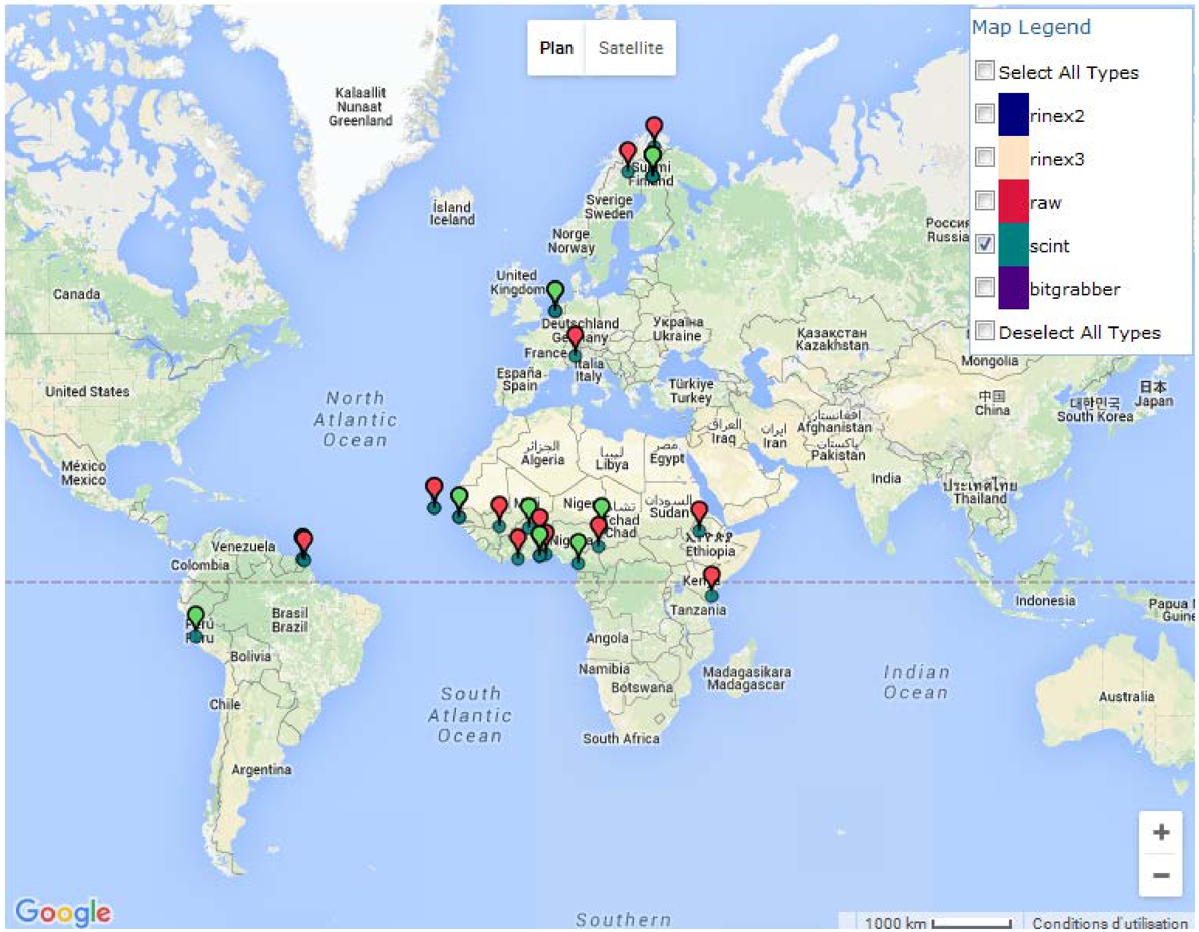
Near Real Time Data & Products

MONITOR Scintillations Receivers Network

MONITOR Content

- Introduction
- Project partners
- Documentation
- Stations map - data
- Stations map - products
- Search input data
- Search products
- Data policy
- Contact

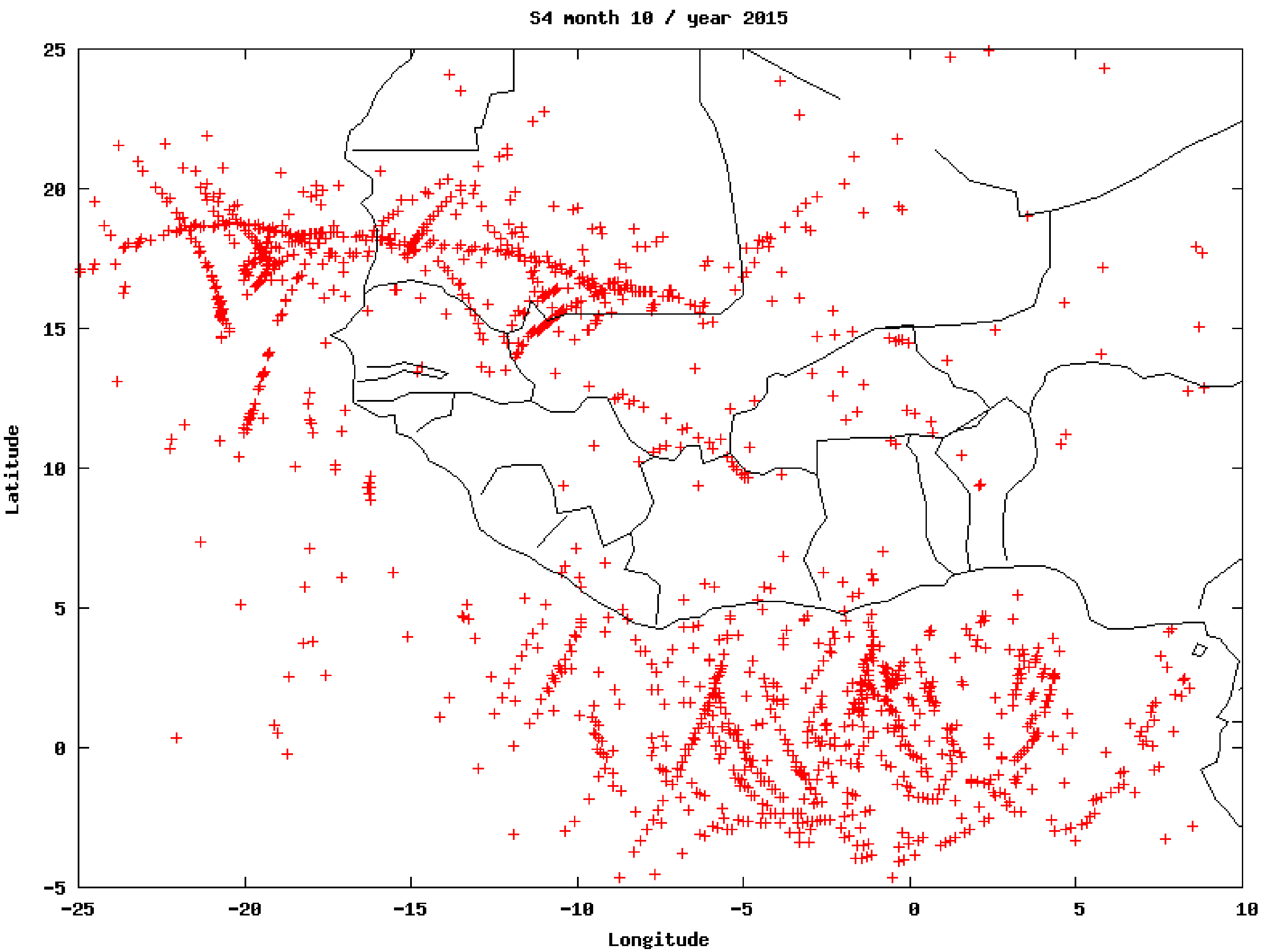
STATIONS MAP - DATA TYPES



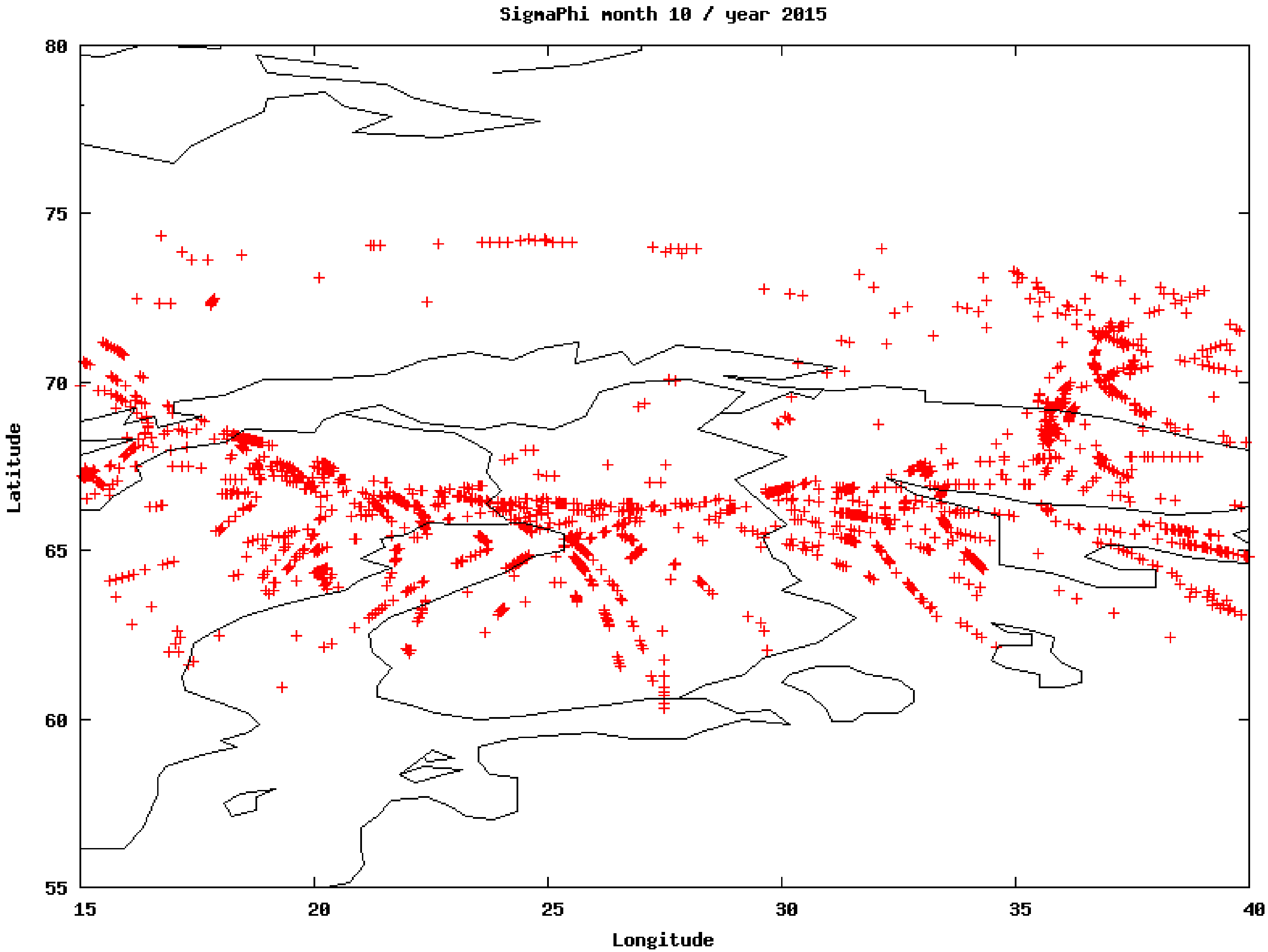
Y. Béniguel, M. Hernandez-Pajares, A. Garcia-Rigo, R. Orus-Perez, R. Prieto-Cerdeira, S. Schlueter, H.Secretan, M. Monnerat, D. Serant "MONITOR Ionospheric Monitoring System: GNSS Performance Estimation", European Navigation Conference, Bordeaux, April 2015

IEEA

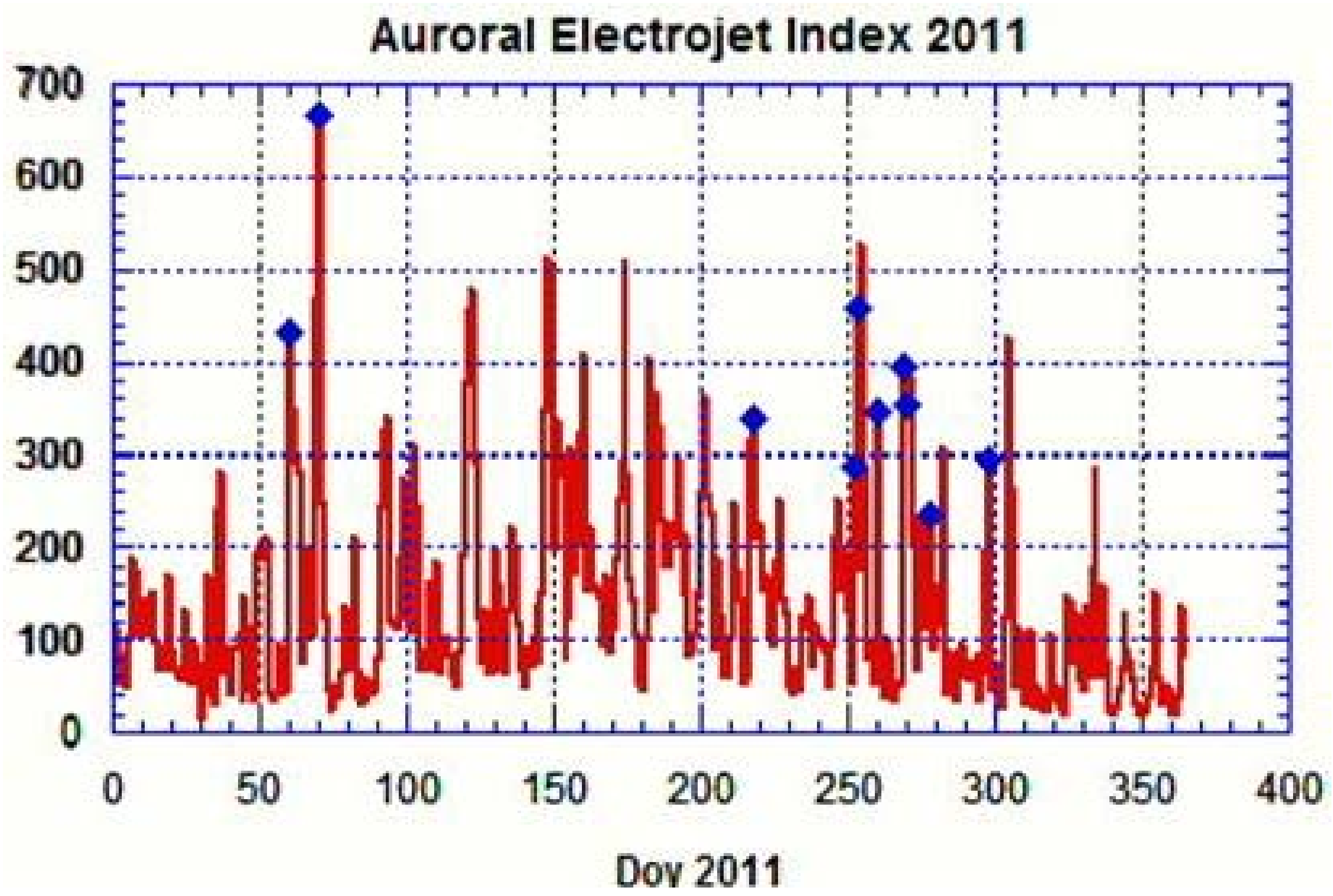
Scintillation Map / Low Latitudes



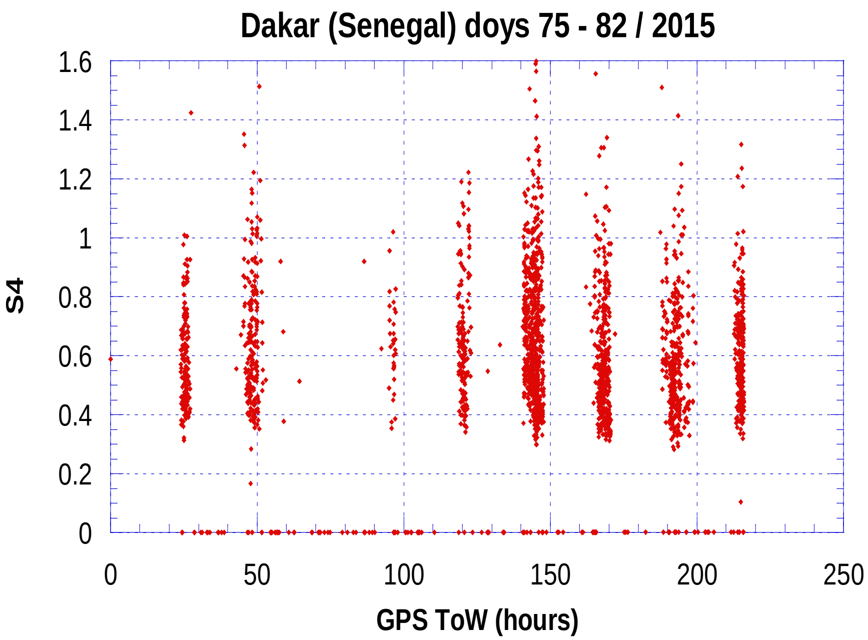
Scintillation Map / High Latitudes

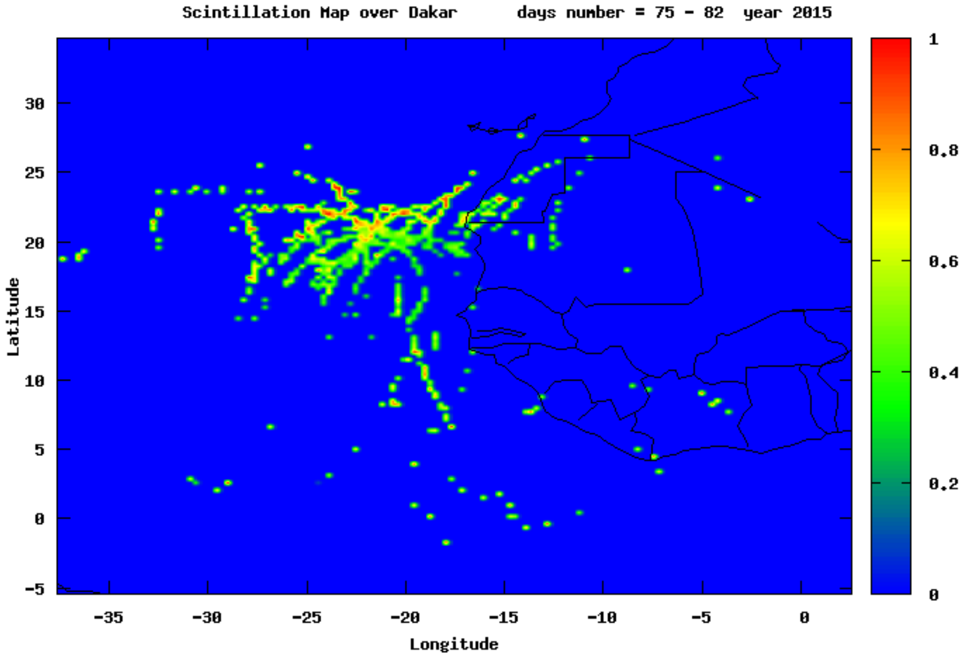


EGNOS Days of Decrease Performance

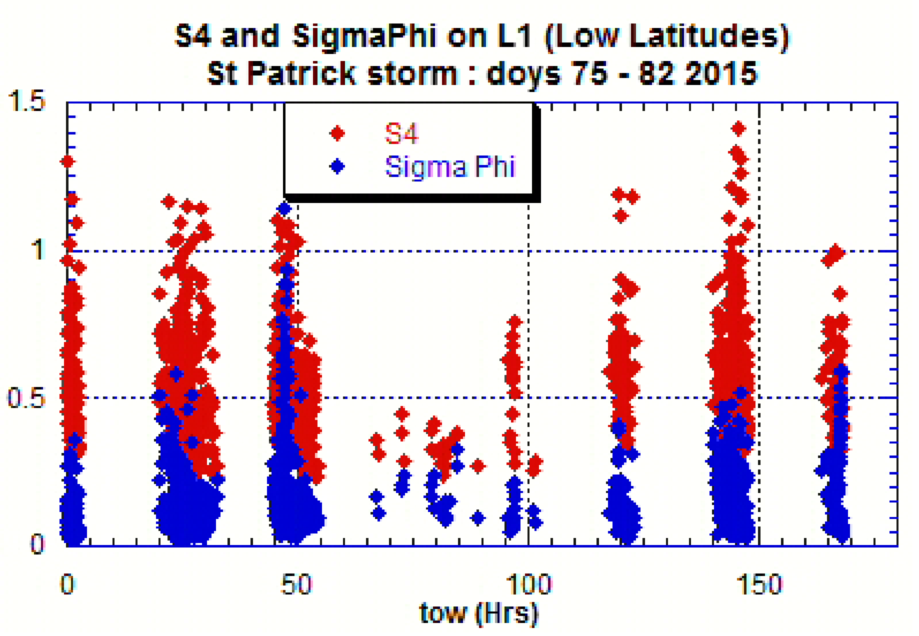


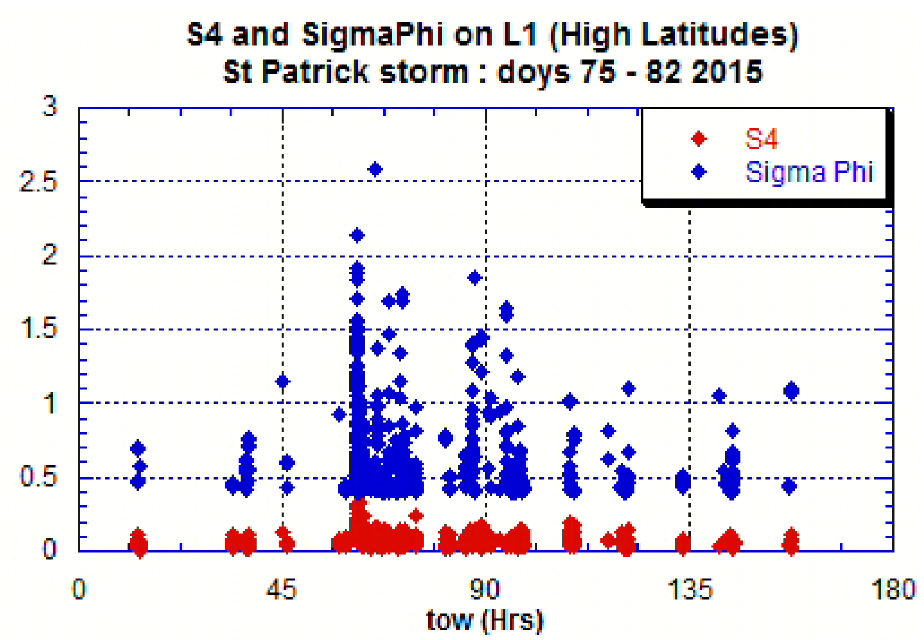
Case Study : St Patrick Storm doys 75-82 2015





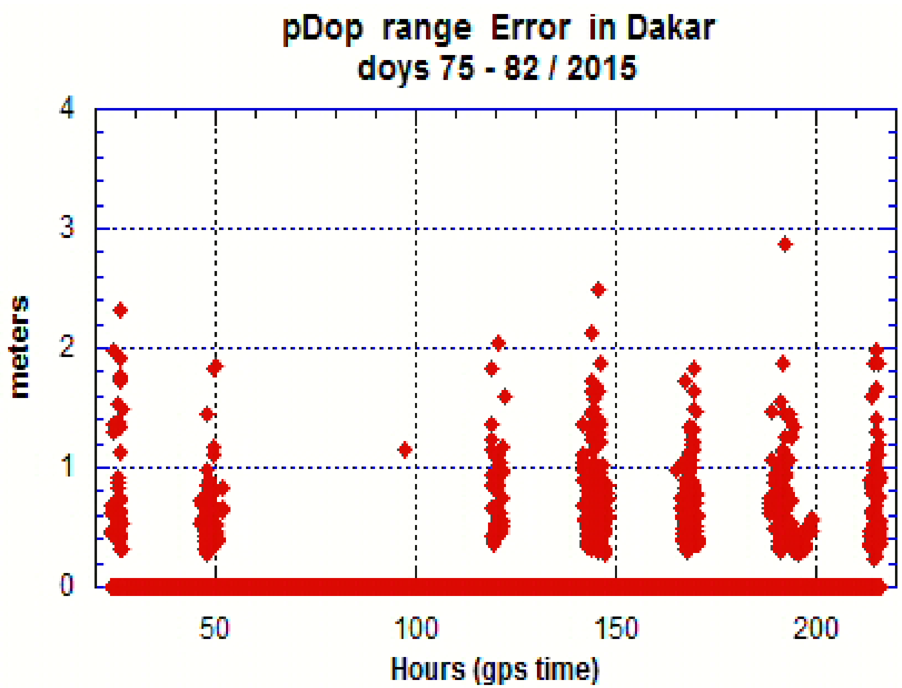
Scintillation Indices
75 – 82 / 2015



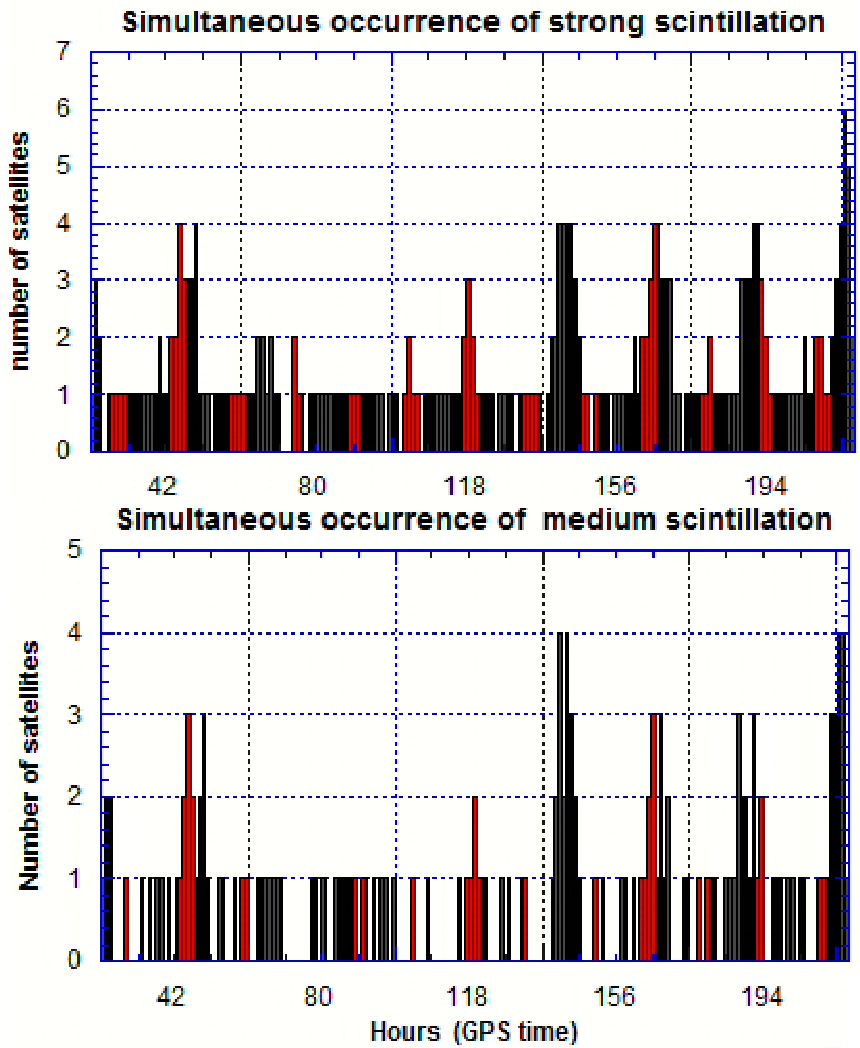


Low Latitudes

PDop Range Error

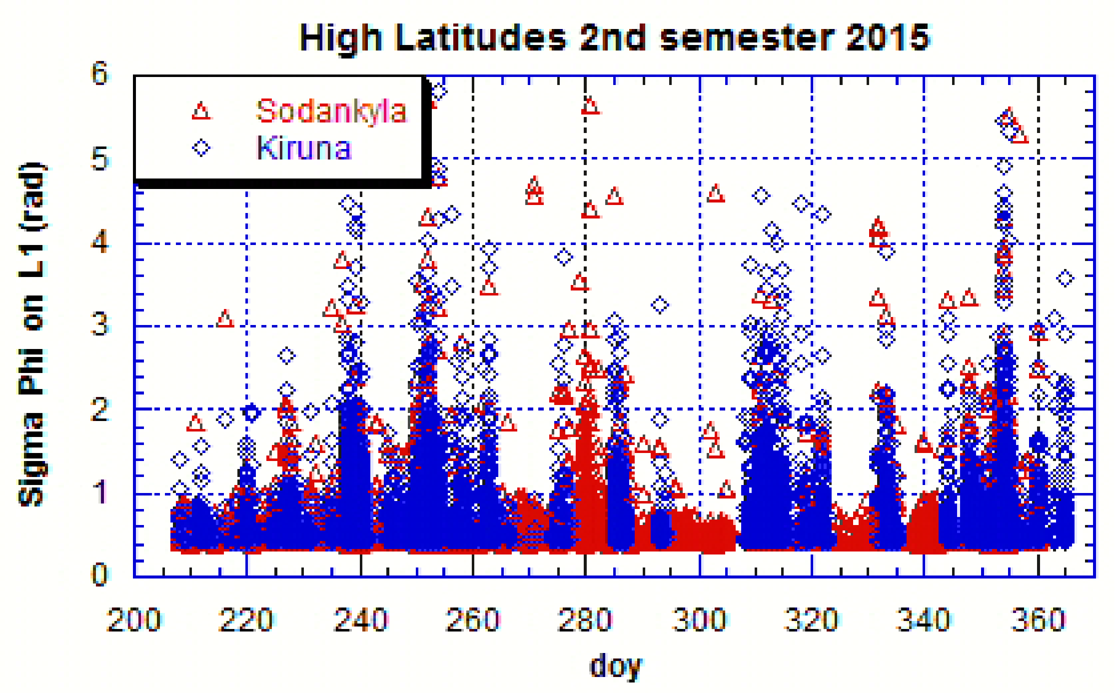


Related probability : 0.85



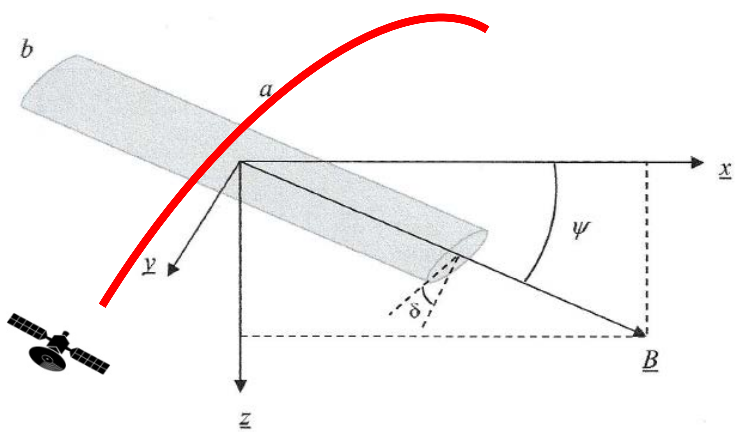
High Latitudes

High Latitudes Scintillation



Sodankyla : Novatel
Kiruna : Septentrio

Temporal Autocorrelation Function



$$B_\Phi \left(V_{eff}\, \delta t\right)$$

V_{eff}

- Source velocity
- Medium drift velocity

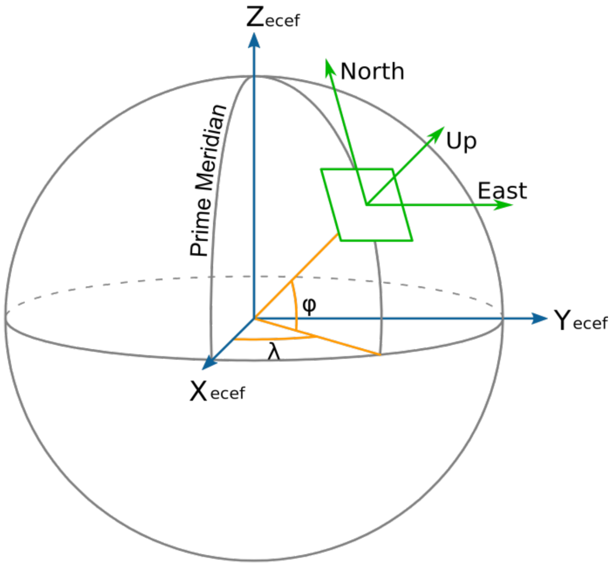
$$\gamma(f) = \int_{-\infty}^{\infty} B_\Phi\left(V_{eff}\,\delta t\right) \exp\left(-j\omega\delta t\right) d\left(\delta t\right) = A\, C_P \left(V_{eff}\right)^{p-2} \frac{1}{\left(f^2 + f_0^2\right)^{(p-1)/2}}$$

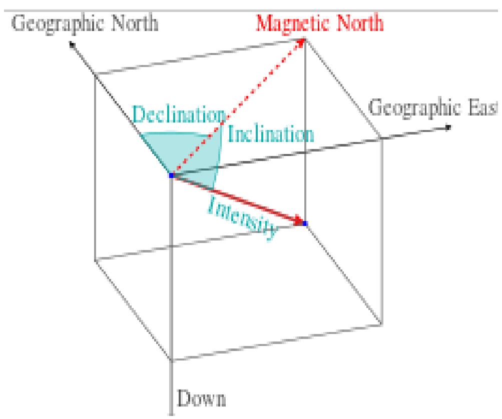
$$f_0 = q_0 V_{eff} / (2\pi)$$

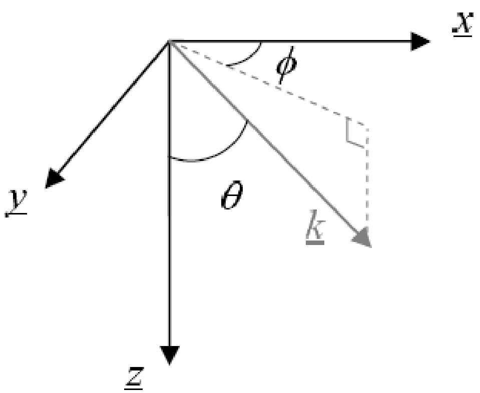
Vdrift / Veff Relationship

$$v_{\mathrm{eff}} = \left[\frac{C\, v_{\mathrm{sx}}^2 - B\, v_{\mathrm{sx}}\, v_{\mathrm{sy}} + A\, v_{\mathrm{sy}}^2}{A\,C - B^2/4} \right]^{1/2}$$

$$\begin{cases} v_{sx} = v_{\mathrm{IPP,x}} - \tan\vartheta\, \cos\varphi\, v_{\mathrm{IPP,z}} \\ v_{sy} = v_{\mathrm{IPP,y}} - V_{\mathrm{D}} - \tan\vartheta\, \sin\varphi\, v_{\mathrm{IPP,z}} \end{cases}$$

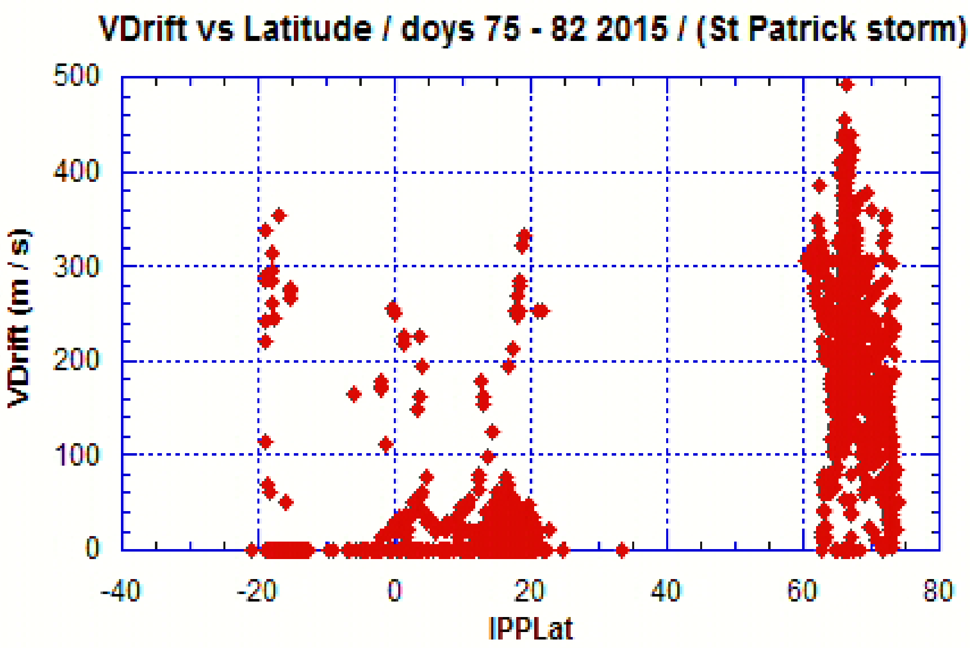


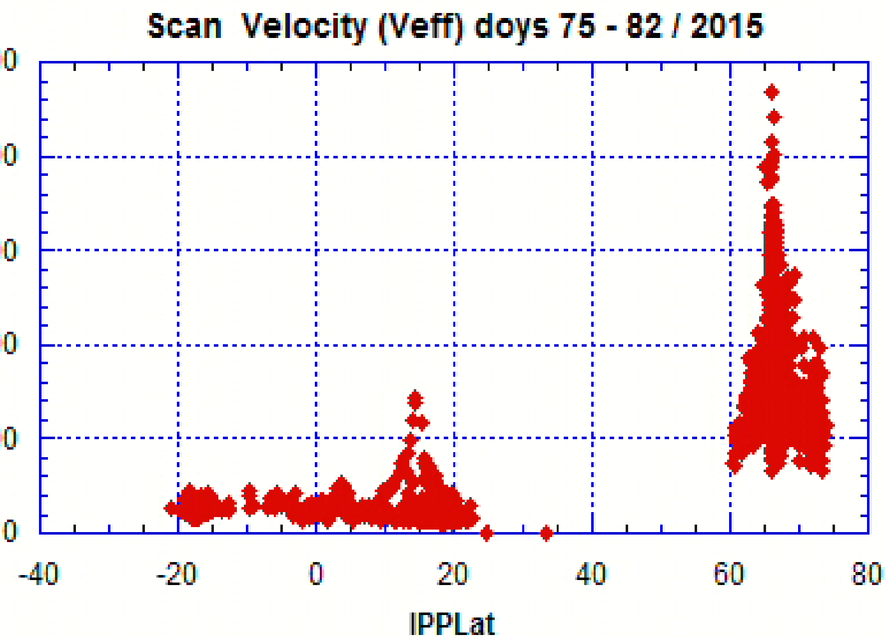




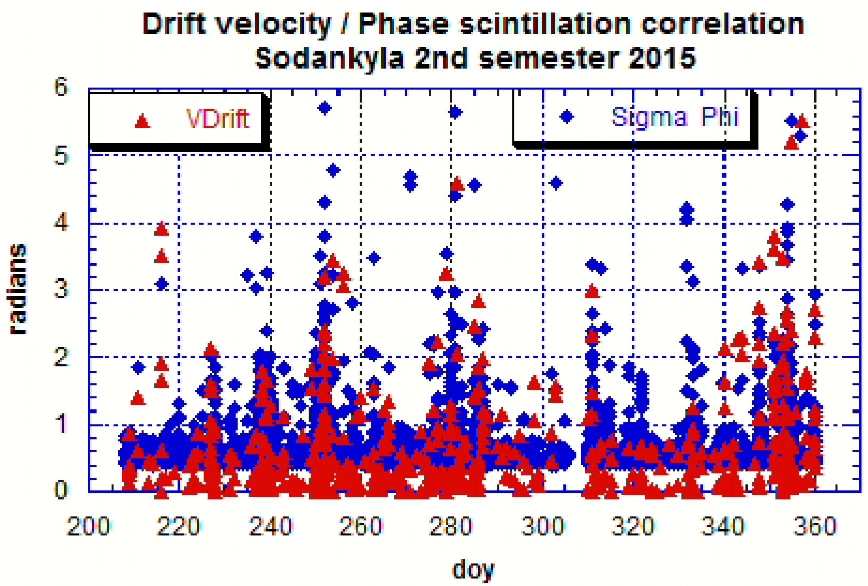
C. Rino, The Theory of Scintillation with Applications in Remote Sensing, Wiley, 2011

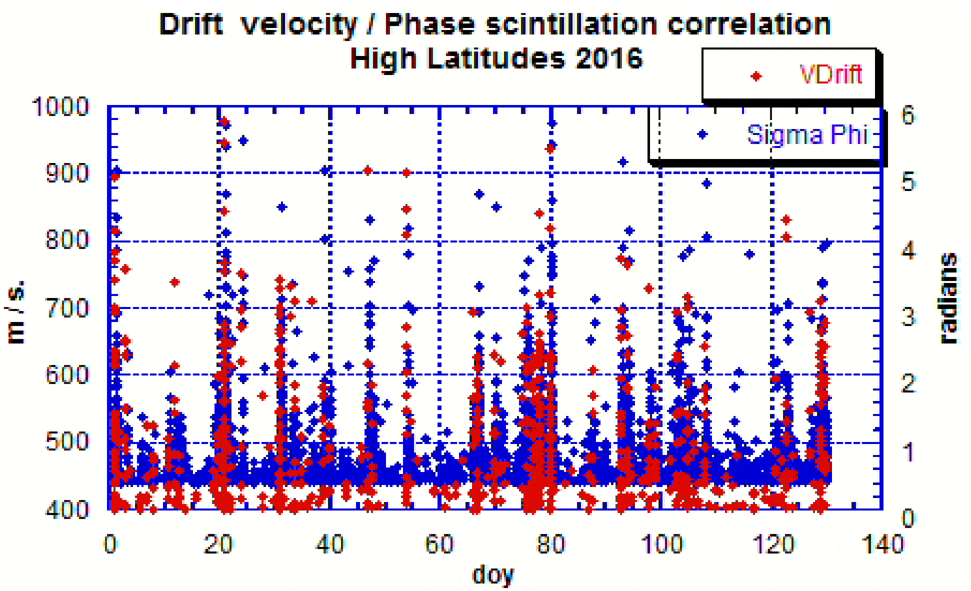
Medium Drift Velocity / Scan velocity



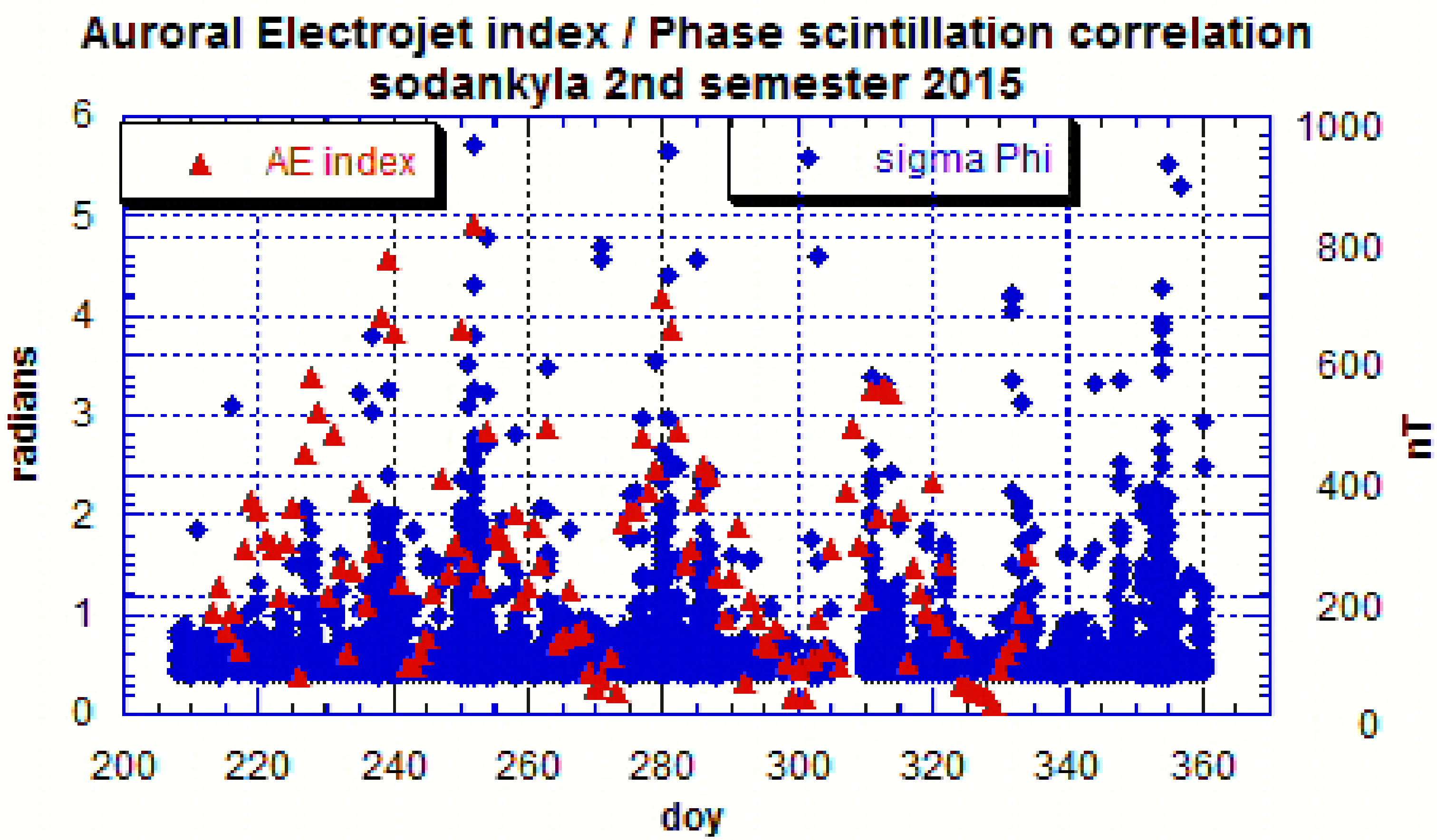


Relationship Phase Scintillation / Drift Velocity High Latitudes





Relationship Phase Scintillation / AE Index High Latitudes



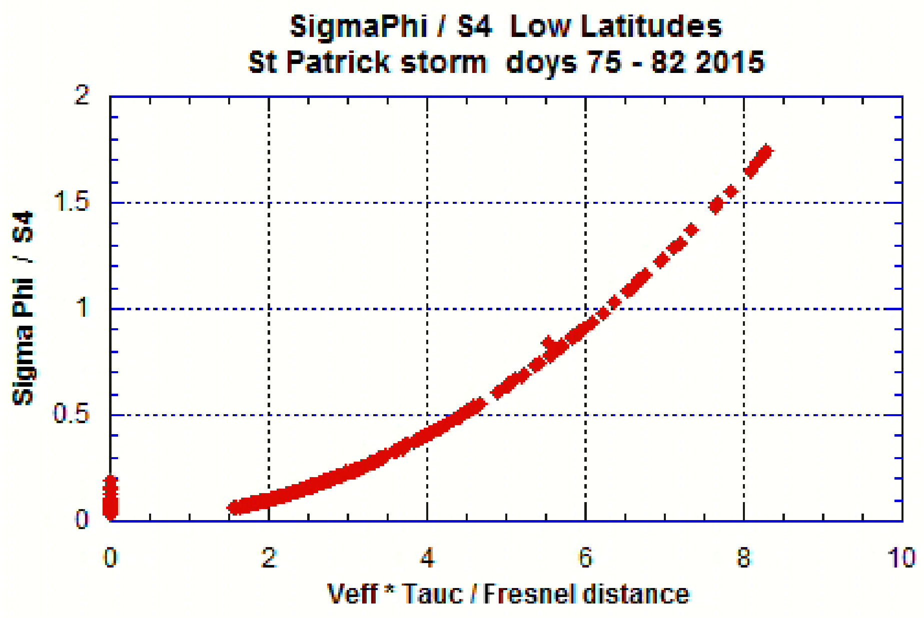
Scintillation Indices Relationship

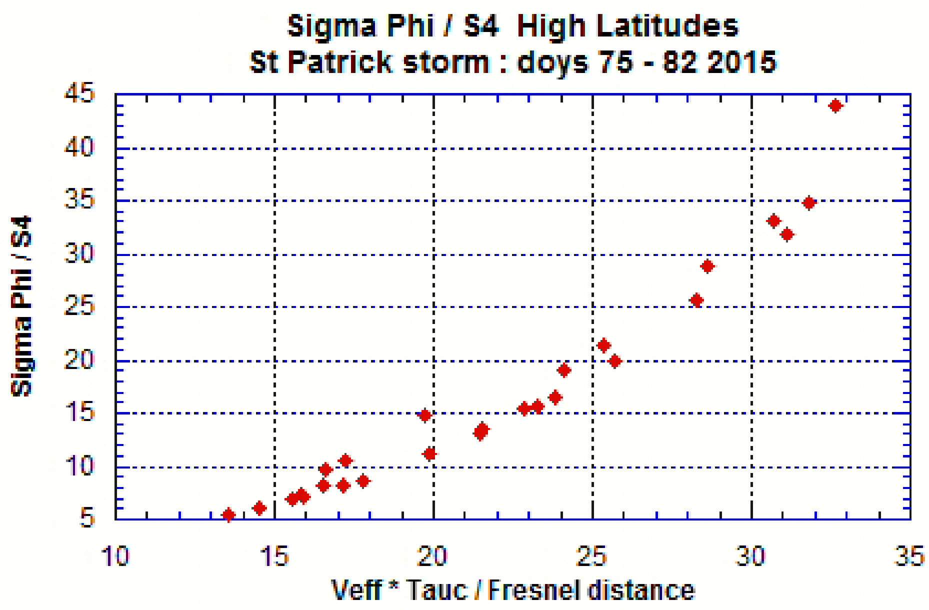
$$\frac{\sigma_\Phi^2}{S_4^2} = \frac{F_{Phi}(p)}{F_I(p)} \left(\frac{\tau_c V_{eff}}{\rho_F} \right)^{(p-2)}$$

τ_c Inverse of the receiver cutoff frequency

ρ_F Fresnel distance

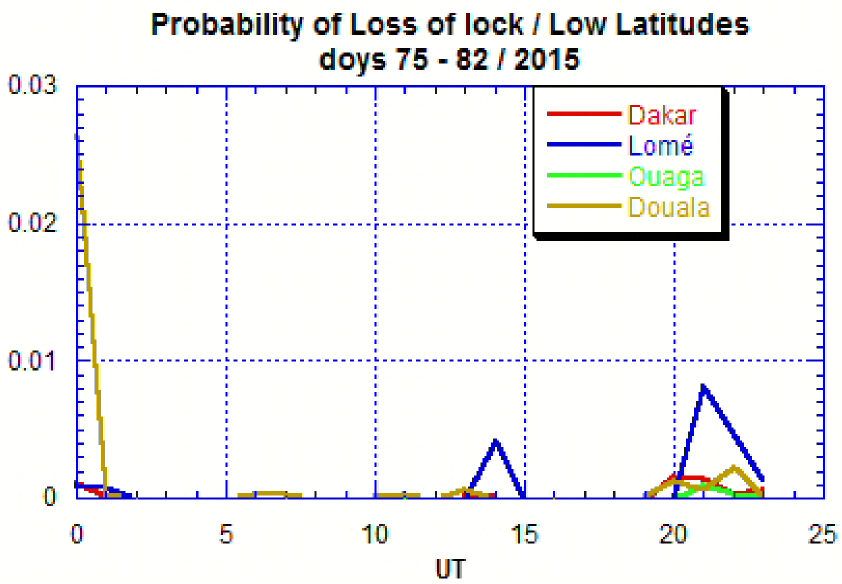
V_{eff} Scan velocity

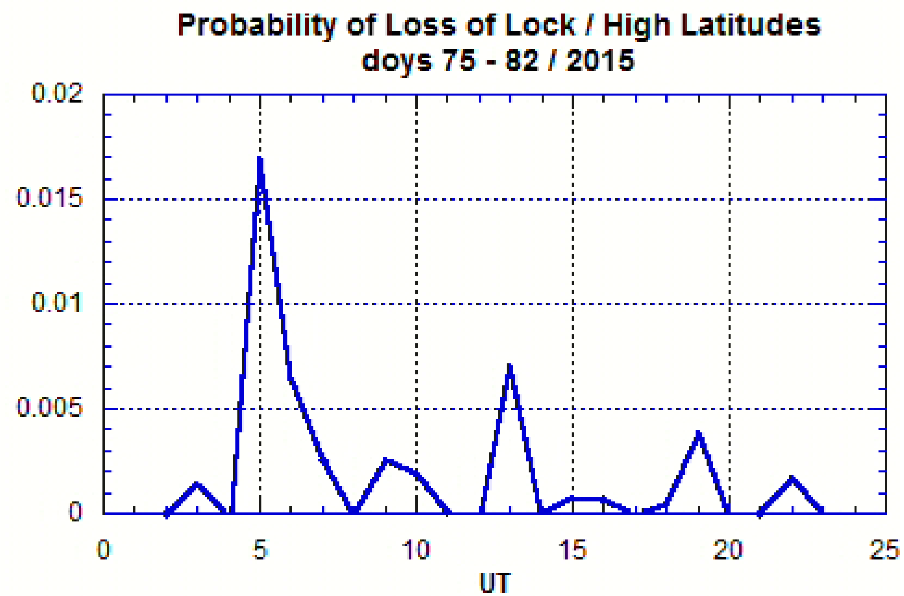


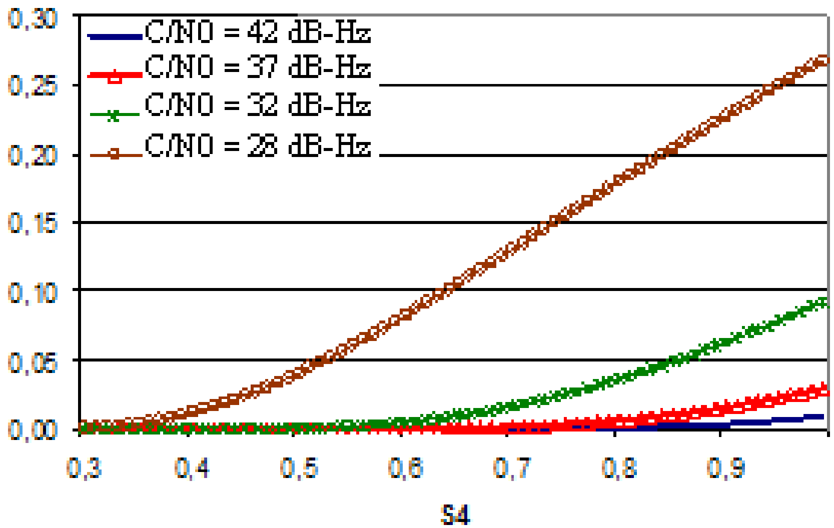


"Inferring Zonal Irregularity Drift from Single- Station Measurements of Amplitude (S4) and Phase (Sigma-phi) Scintillations", C. Carrano, IES, Alexandria, Va 2015

Probability of Loss of Lock







Modelling (GISM) vs Measurements

http://www.ieea.fr/en/softwares/references/gism-ionospheric-model.html

- 2D phase screen model

  + geometrical factor to take the misalignment into account

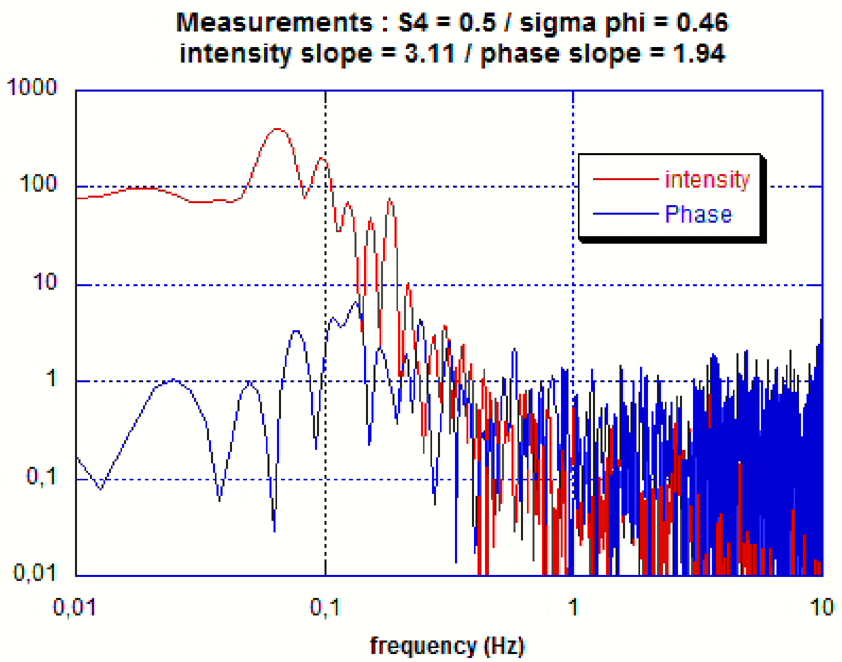
- Seasonal, diurnal & Latitudinal dependency laws included based on the results of the measurement campaigns (PRIS, Monitor)

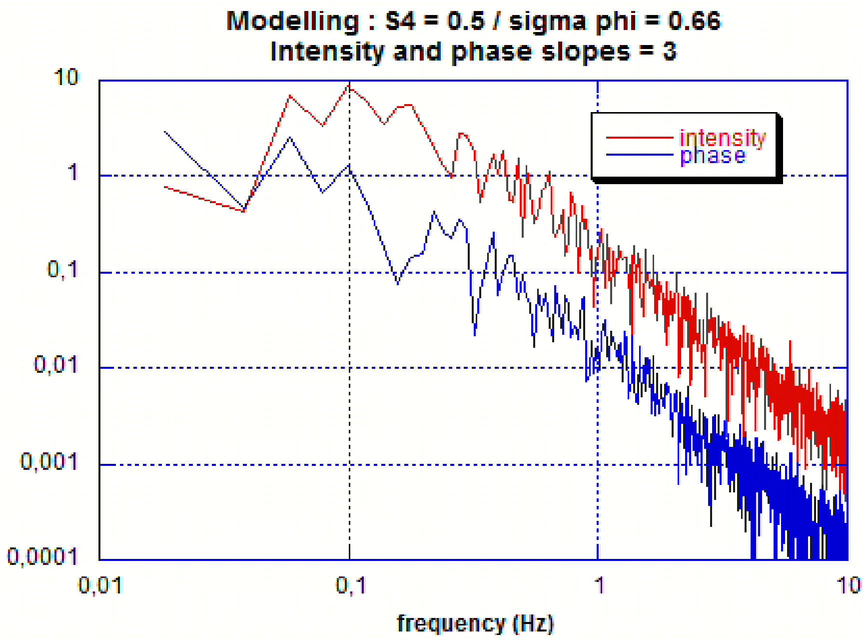
- Related to the solar activity : low latitudes

- Related to the magnetic activity : high latitudes (under implementation)

Béniguel Y., P. Hamel, "A Global Ionosphere Scintillation Propagation Model for Equatorial Regions", Journal of Space Weather Space Climate, 1, (2011), doi: 10.1051 / swsc / 2011004

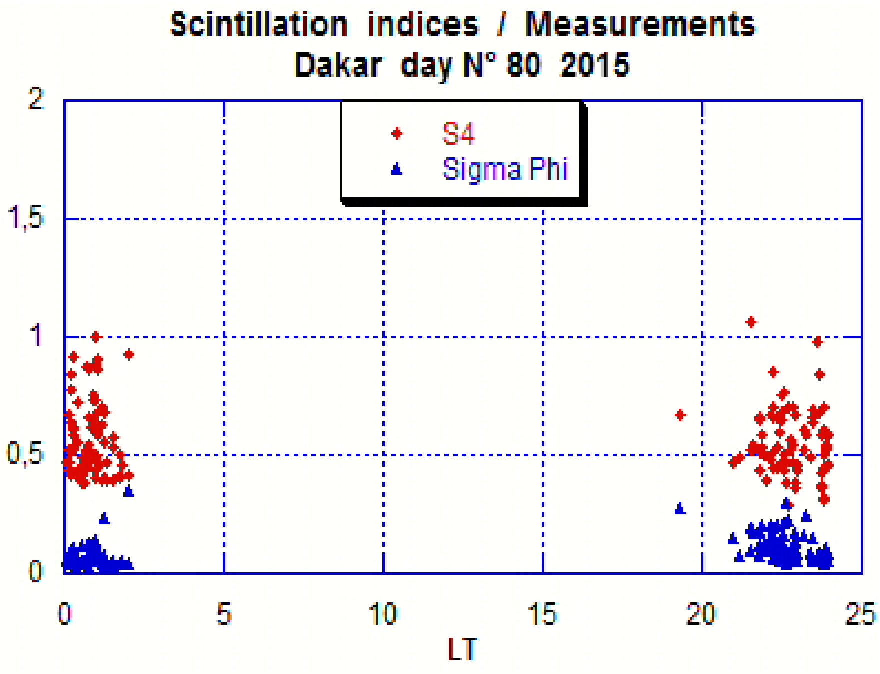
Spectrum of Received Signal
Low Latitudes

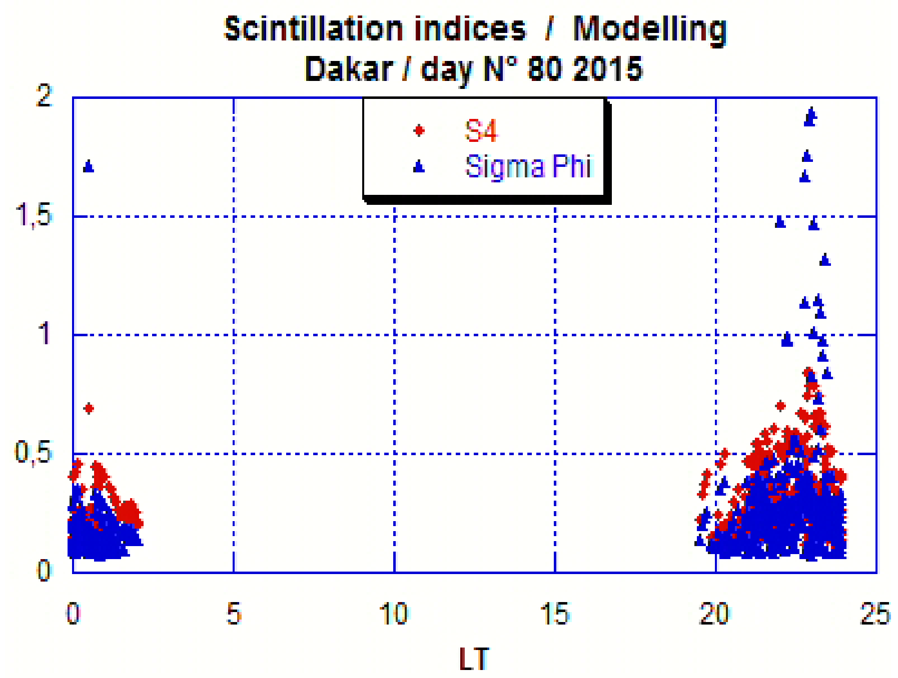




Cut off frequency : $V_{eff} \ / \ L_0 \ \# \ 0.1\,\mathrm{Hz}$

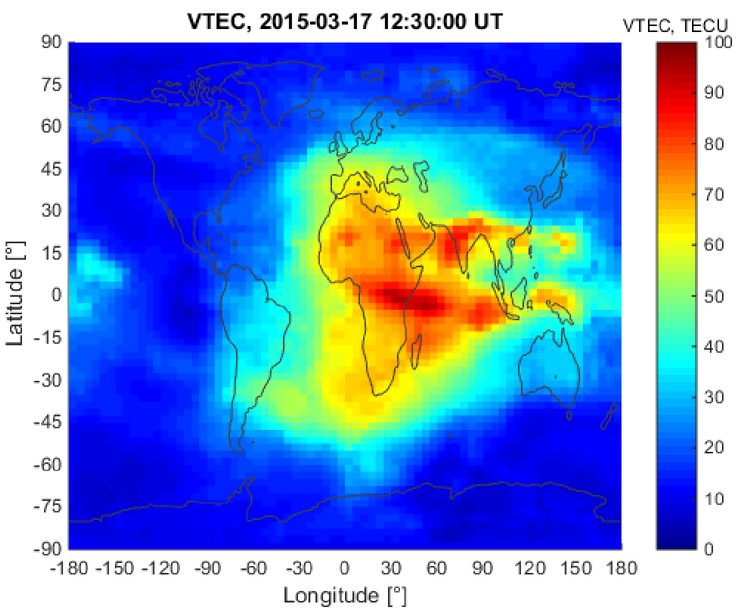
Modelling vs Measurements

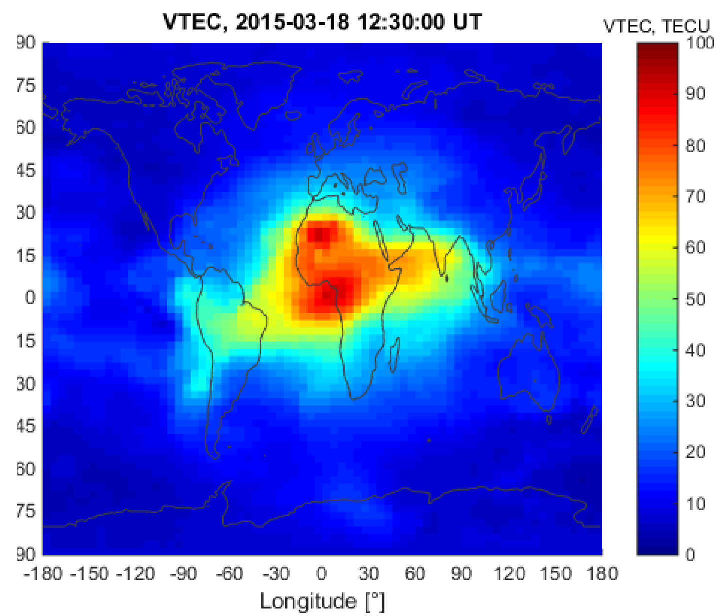




ICTP contribution to MONITOR Project

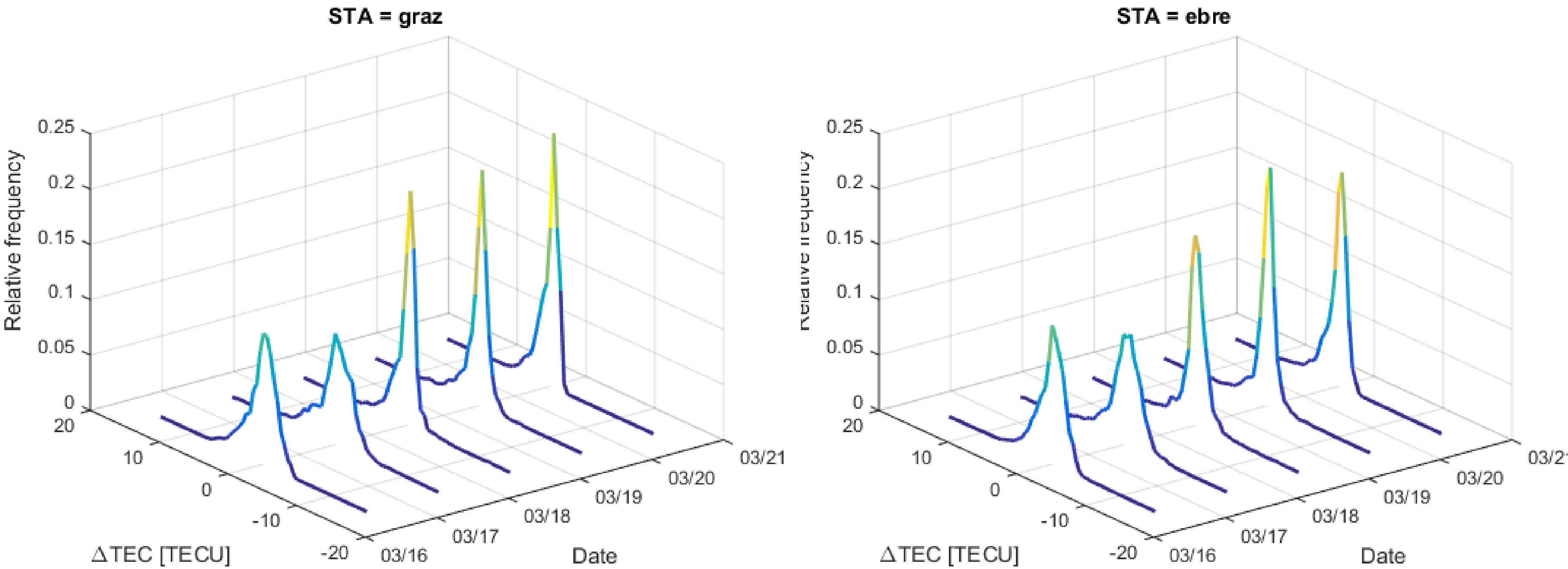
- Software package for Ionospheric Scenario Generation
  - The methodology is based on the NeQuick 2 (Nava et al., 2008) model. It includes a procedure to ingest vertical TEC maps to improve the "weather like" description of the ionosphere electron density.
  - The software package allows the user to compute slant TEC values for any ground-to-satellite link for the geographic region of interest.





ICTP contribution to MONITOR Project

- Validation tests have been performed for a scenario representing the ionosphere during the St. Patrick's day storm of 2015



STEC error statistics for graz and ebre receivers

Conclusion

- ➢ The Occurrence of ionosphere scintillation and its relationship to the geophysical parameters has been inferred. Laws have been derived for Low and high latitudes

- ➢ At high latitudes the medium drift velocity (related to the magnetic activity) was shown to be the main driver for phase scintillation

- ➢ The pdop range error & Probability of Loss of lock have been calculated

- ➢ The Modelling aspects have been discussed with comparison with measurements results