Low latitude ionospheric scintillation and zonal plasma irregularity drifts climatology around the equatorial anomaly crest over Kenya and its contribution to errors in GPS.

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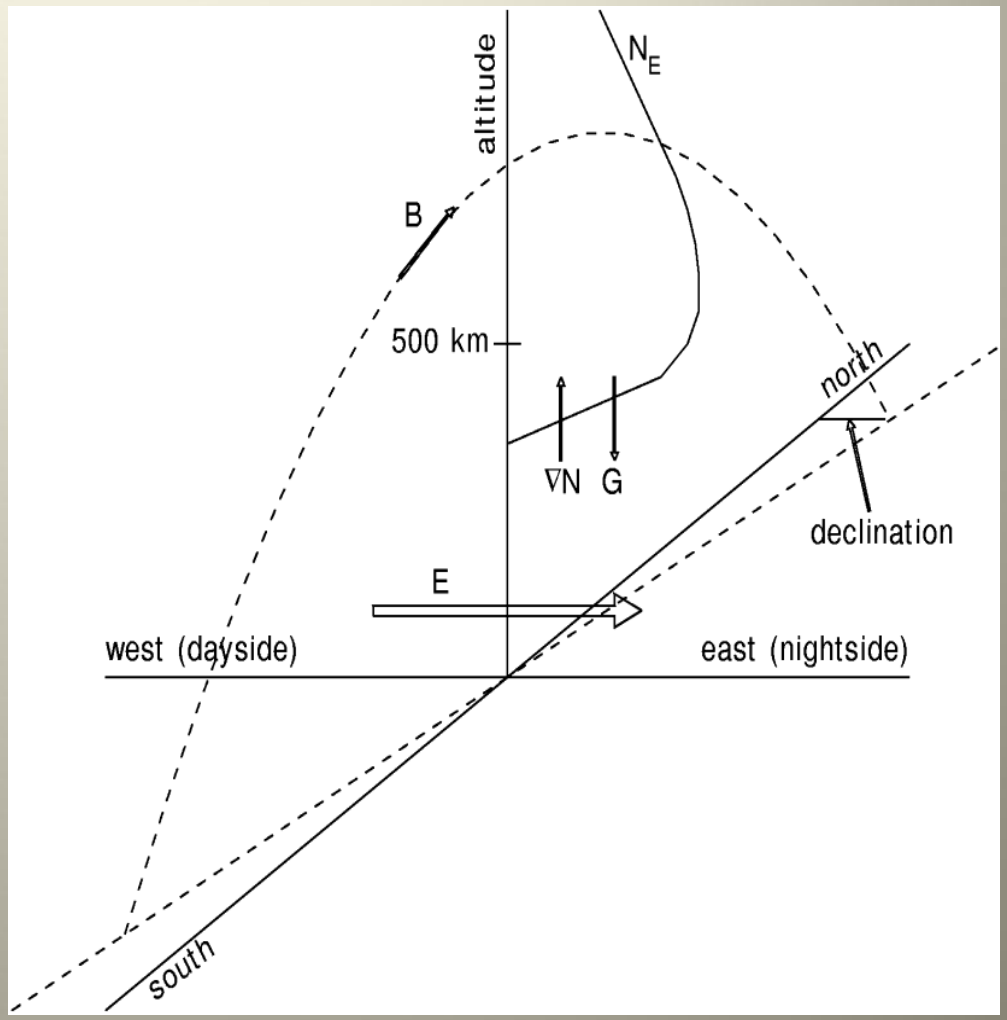
Outline

- ✓ Low latitude scintillation Phenomena
- ✓Measurement techniques
- ✓ Climatology-Temporal and Spatial trends in Scintillation
- ✓Post-midnight scintillation observations at VHF and L-band
- ✓Effects of scintillation on precise positioning applications
- ✓Summary

Ionospheric dynamics at the local sunset hours: plasma formation

•Towards dusk the enhanced zonal E is established to keep divergence J = 0 from a sharp east-west (day-night) conductivity (density) gradient: Zonal E leads to prereversal enhancement in the eastward electric field.

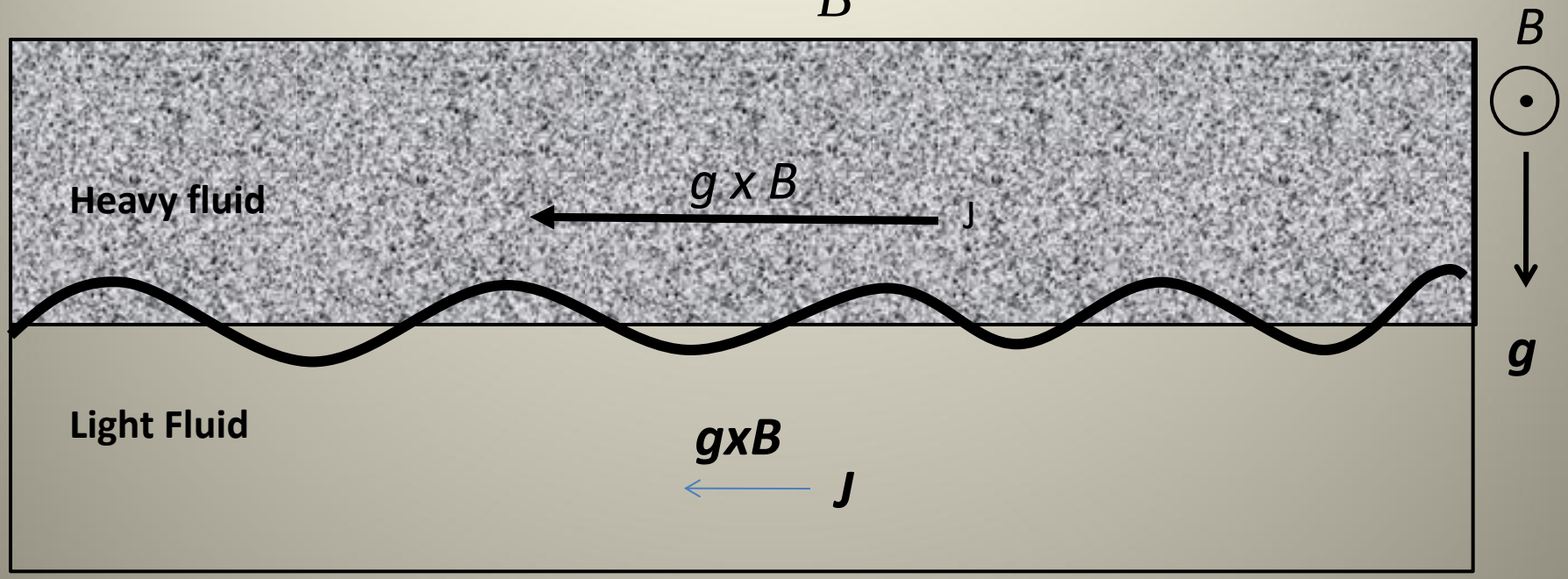
•The F- layer thus rises as the ionosphere co-rotates into darkness. The lower part rapidly decays and a steep vertical density gradient develops leading to a classical Rayleigh-Taylor (R-T) instability.



Schunk and Nagy, 2009, Figure 11.29

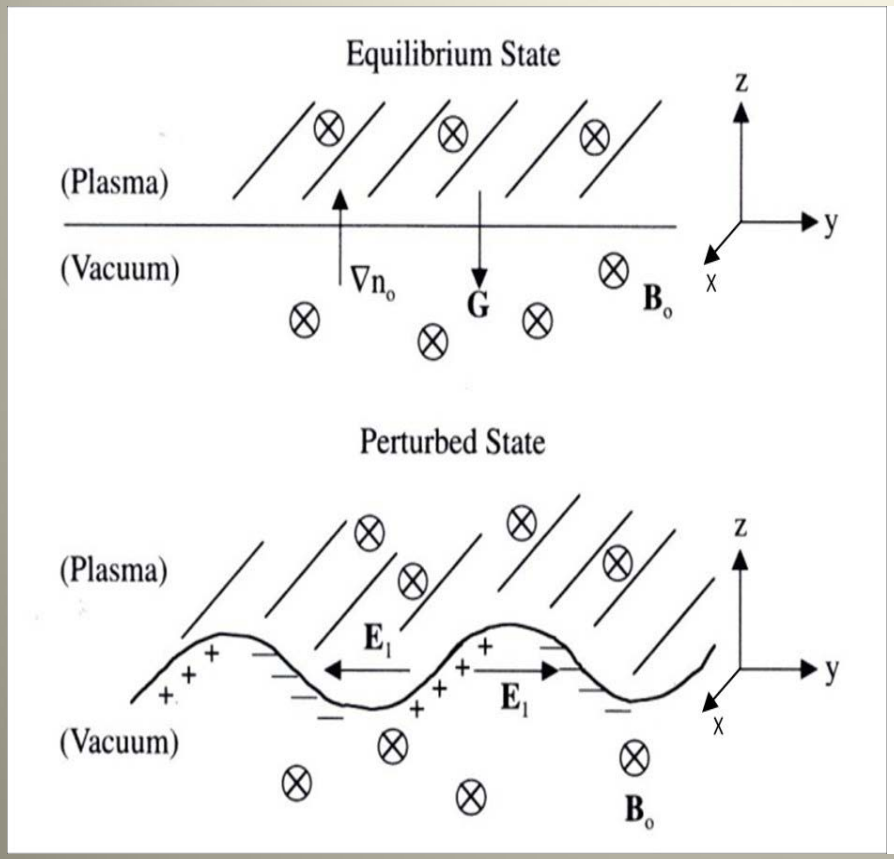
The earth's magnetic field supports the ionospheric plasma against gravity; a current flows along the bottom of the ionosphere which is perpendicular to both *g* and *B*.

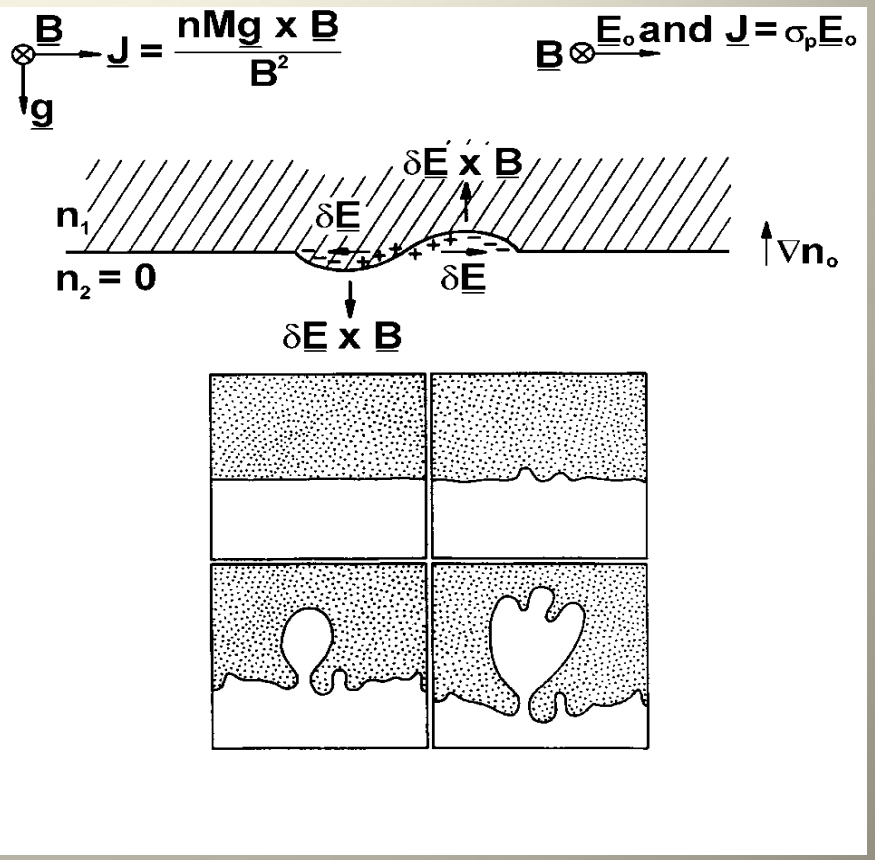
$$J = ne(V_i)_\perp = nM_i \vec{g} \times \frac{\vec{B}}{B^2}$$



If the bottom of the ionosphere is vertically perturbed, the perturbation tends to block the current flow and a charge builds up on either side. The resulting electric fields combined with the background *B* tends to drive the plasma further upward where it initially went up and downward where it initially went down

Linear Theory of Rayleigh-Taylor instability [Schunk and Nagy, 2009, Figure 11.30





Bottom side unstable to perturbation (density gradient against gravity).

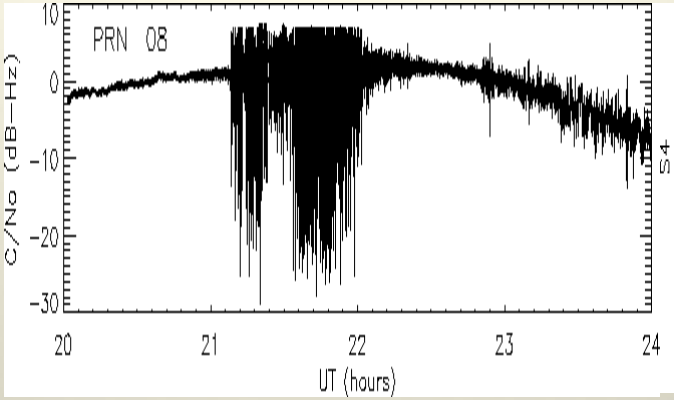
An exponential growth of instability

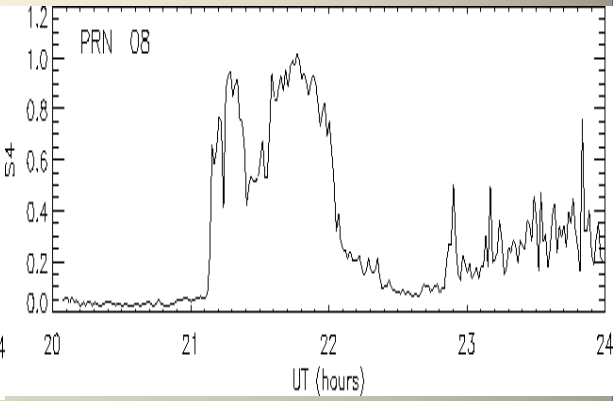
$$A = A_0 e^{\gamma t} \qquad \gamma \approx \frac{\sum_F}{\sum_F + \sum_E}\left[\frac{\boldsymbol{E}\times\boldsymbol{B}}{B^2} + U_n + \frac{g}{\nu^{eff}}\right]\frac{1}{N}\frac{\partial N}{\partial h}$$

Measurement Techniques

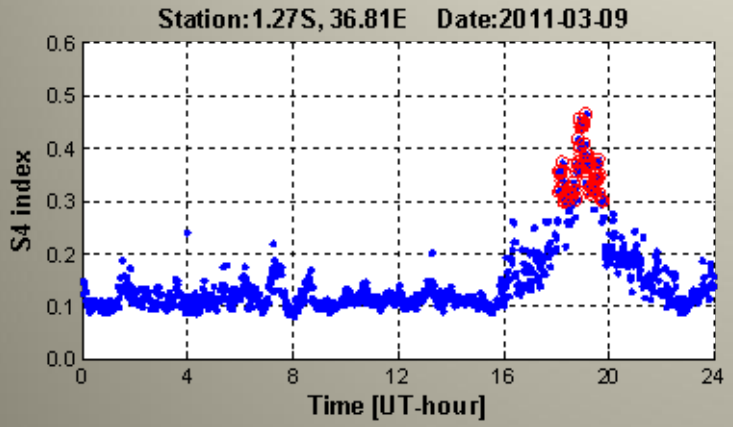
$$S_4 = \sqrt{\frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2}}$$

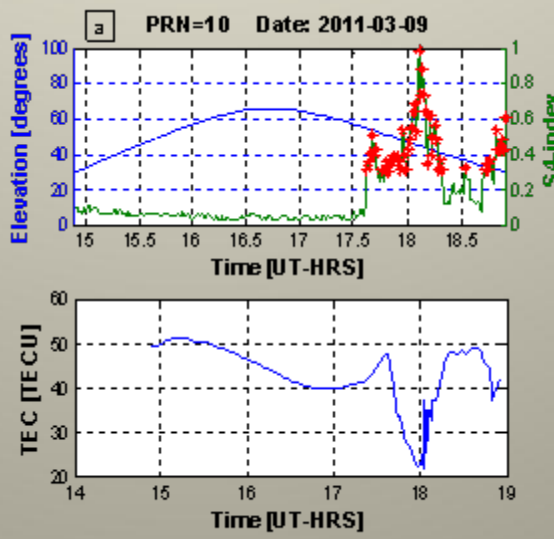
SCINDA MANUAL
(Carrano, 2007) p 14

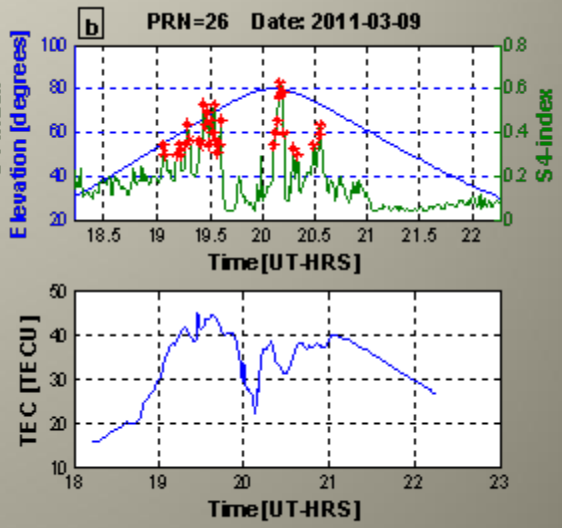




Diurnal Variations of S4 and what it means



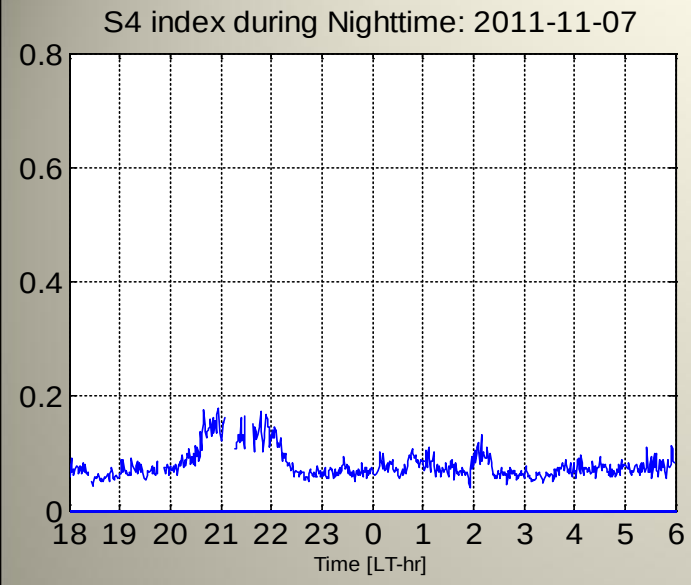


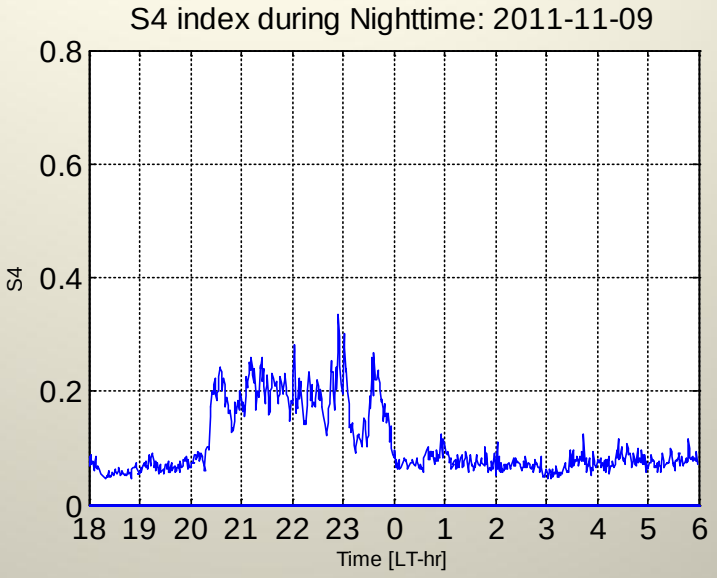


Depletion in TEC are signatures of plasma density irregularities in the ionosphere- Plasma Pubbles

Olwendo et al. 51(2013), 1715-1726, ASR

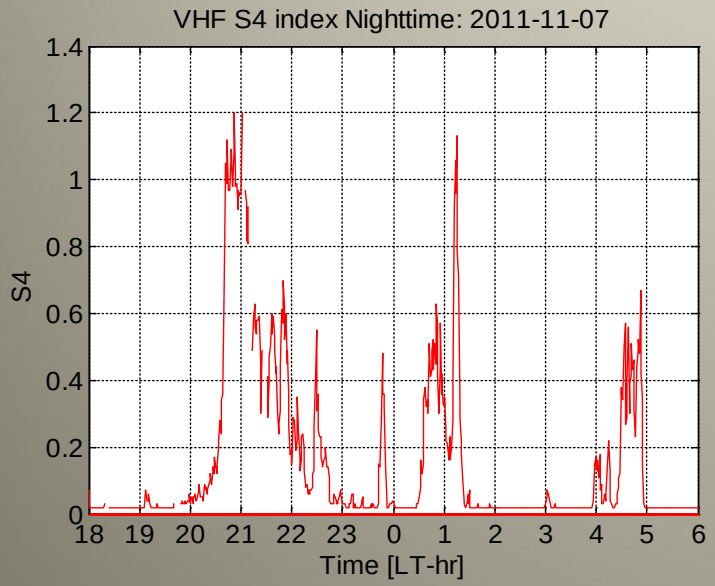
L-band scintillation and VHF scintillation observations

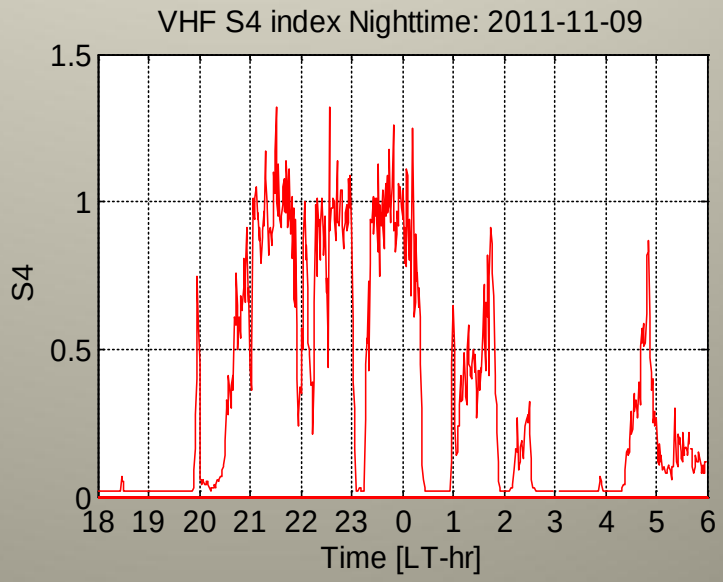




Amplitude scintillation are caused by Irregularities with size of the order of 1st FZ

$$d_F = \sqrt{\lambda\left(z - L/2\right)}$$



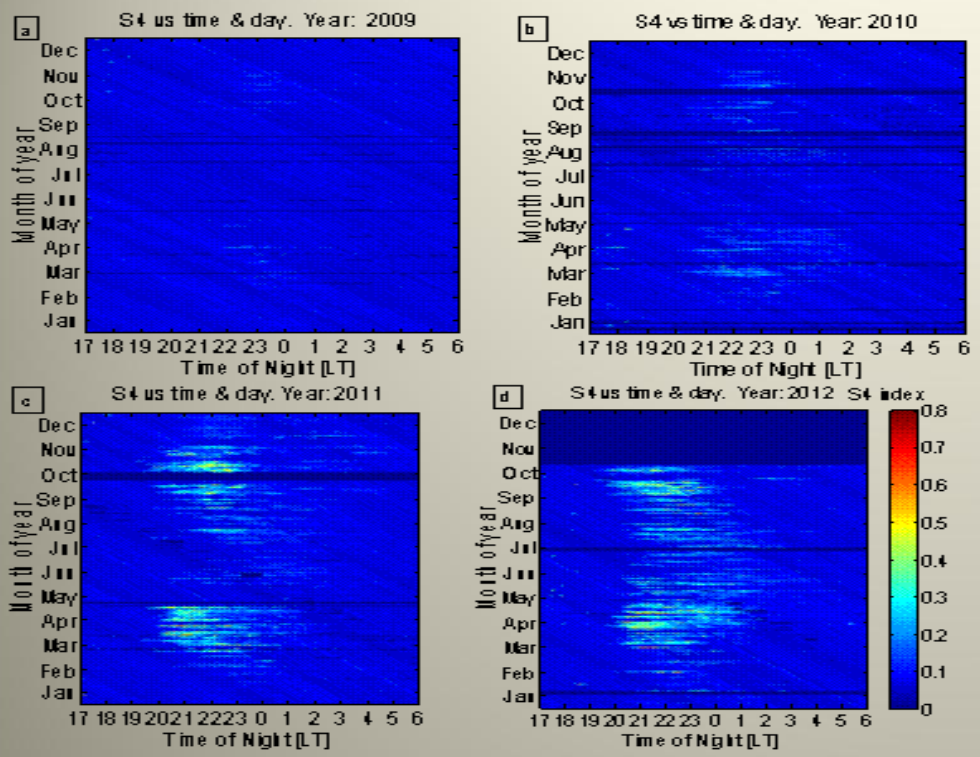


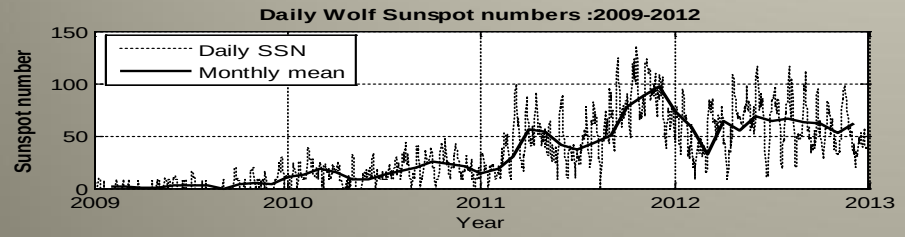
Thin layer

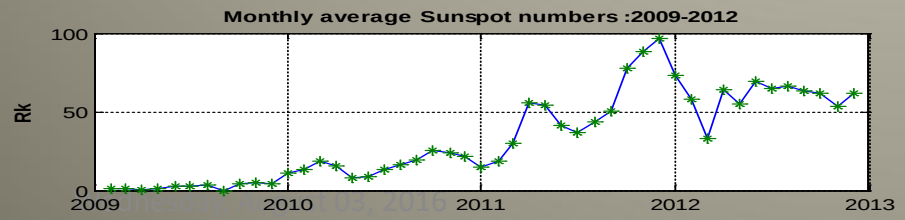
$$d_F = \sqrt{L\lambda}$$

Climatology: Diurnal and Seasonal Variation of S4 index

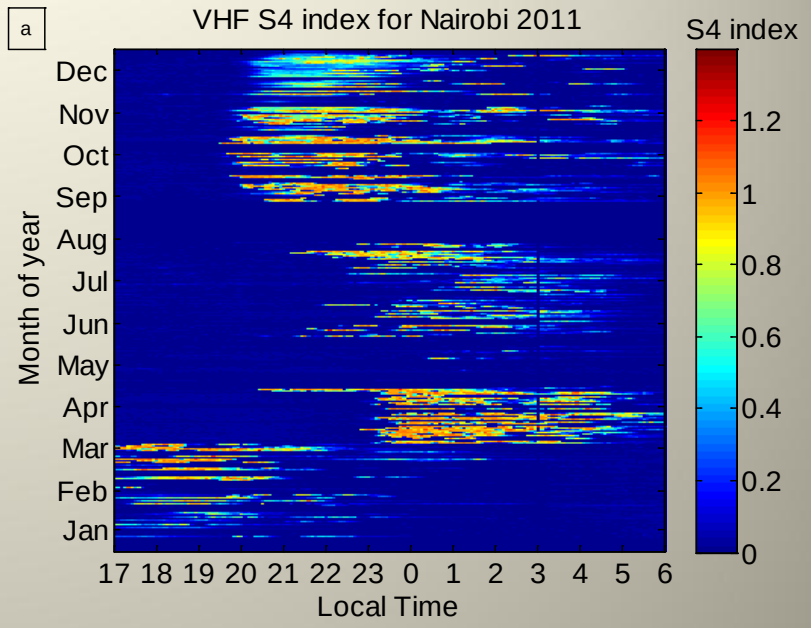
L-band Scintillation







VHF Scintillation

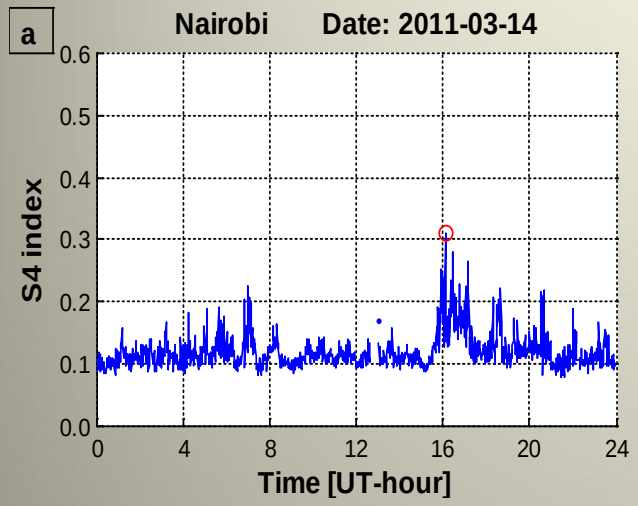


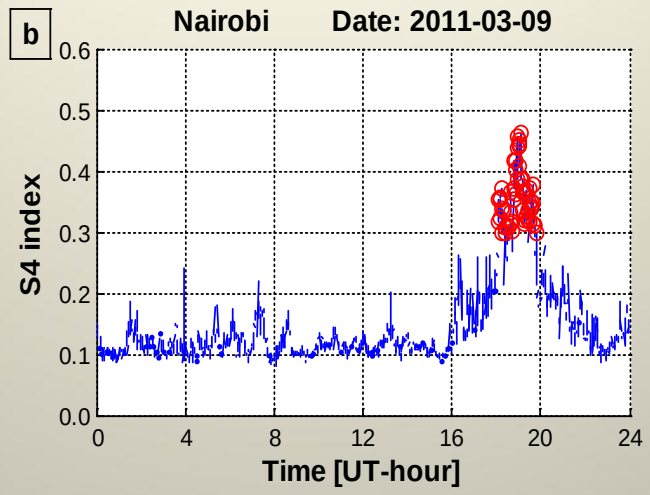
Occur all year round and persist till morning hours

Olwendo et al. 51(2013), 1715-1726, ASR

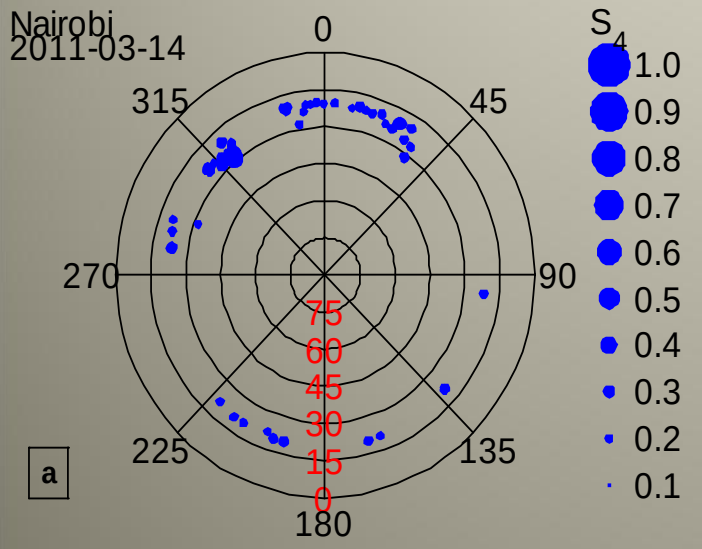
Olwendo et al., 138-139(2016), 9-22, JASTP

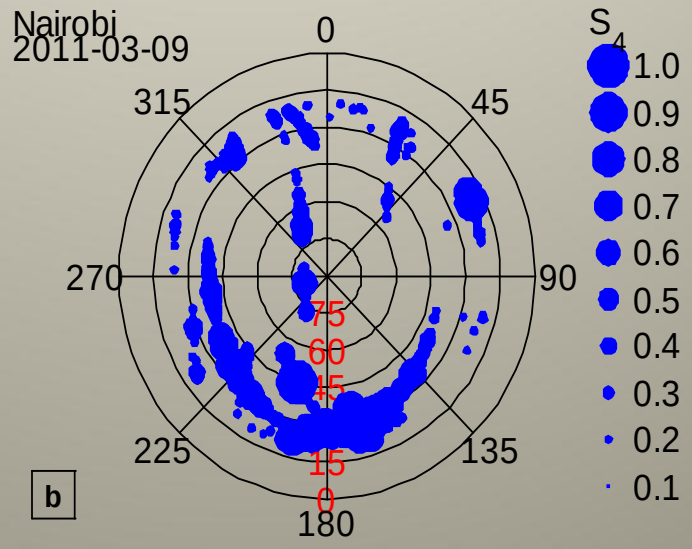
Climatology on directional Analysis : Spatial Distribution of irregularities





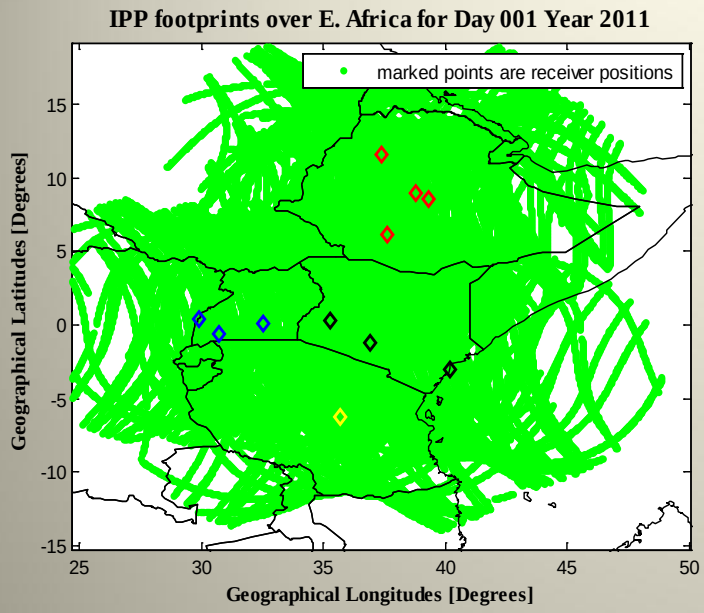
Temporal variation of S4 is already well known to some level





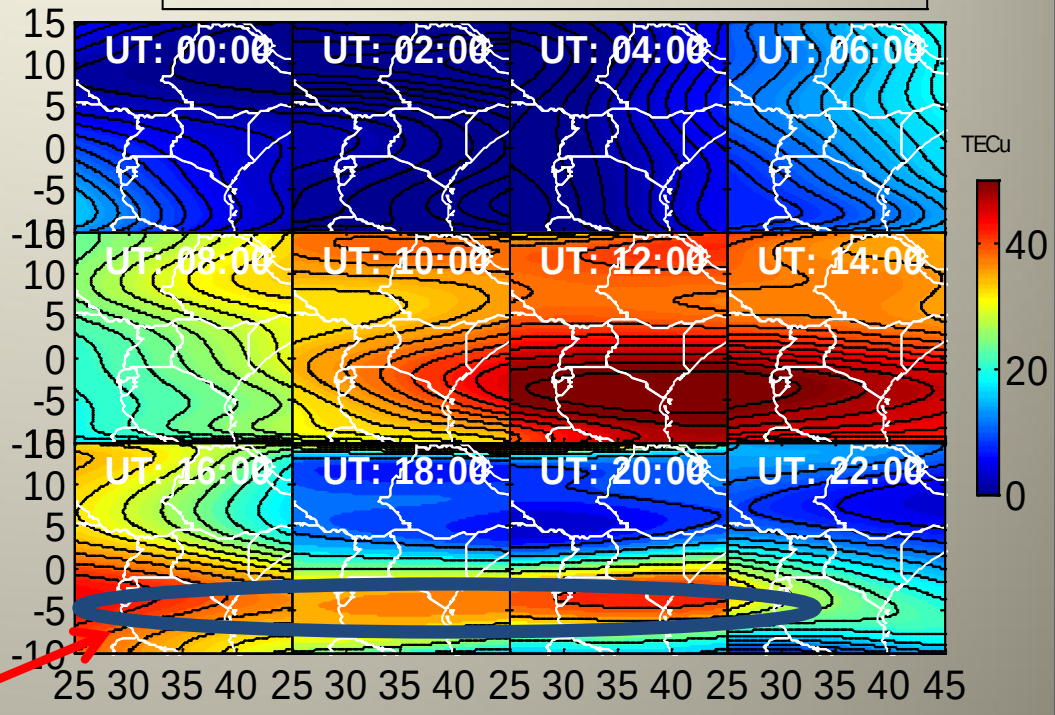
Spatial distribution of irregularities causing scintillation

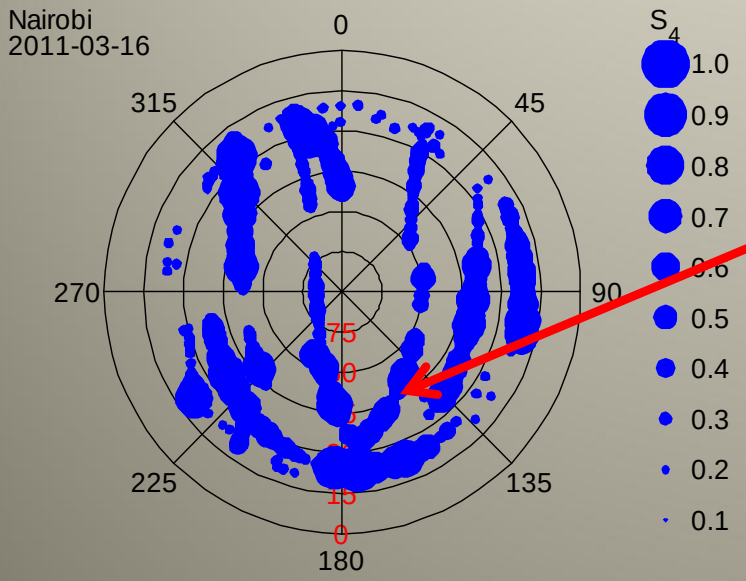
Spatial distribution of irregularities and the ionization anomaly crests



$$TEC(\lambda,\phi)=\sum_{n=0}^{N}\sum_{m=0}^{a}\overline{P_{nm}}\left[\cos(\phi)\right]\left\{a_{nm}\sin(m\lambda)+b_{nm}\cos(m\lambda)\right\}$$

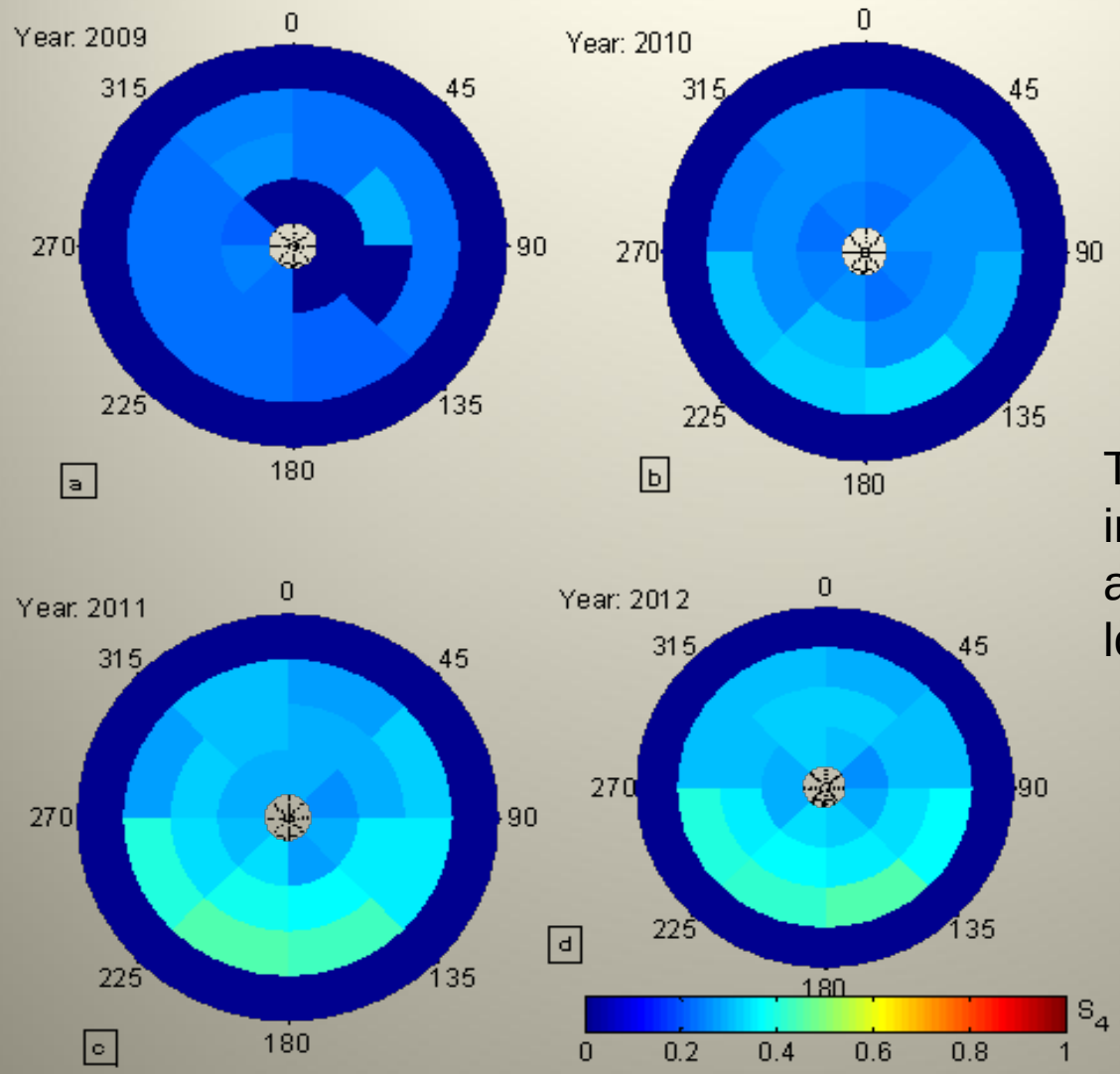
TEC Image over the East African Sector. Date: 2011-03-16





Ionospheric irregularities are within the region with high background electron density –Equatorial Ionization Anomaly

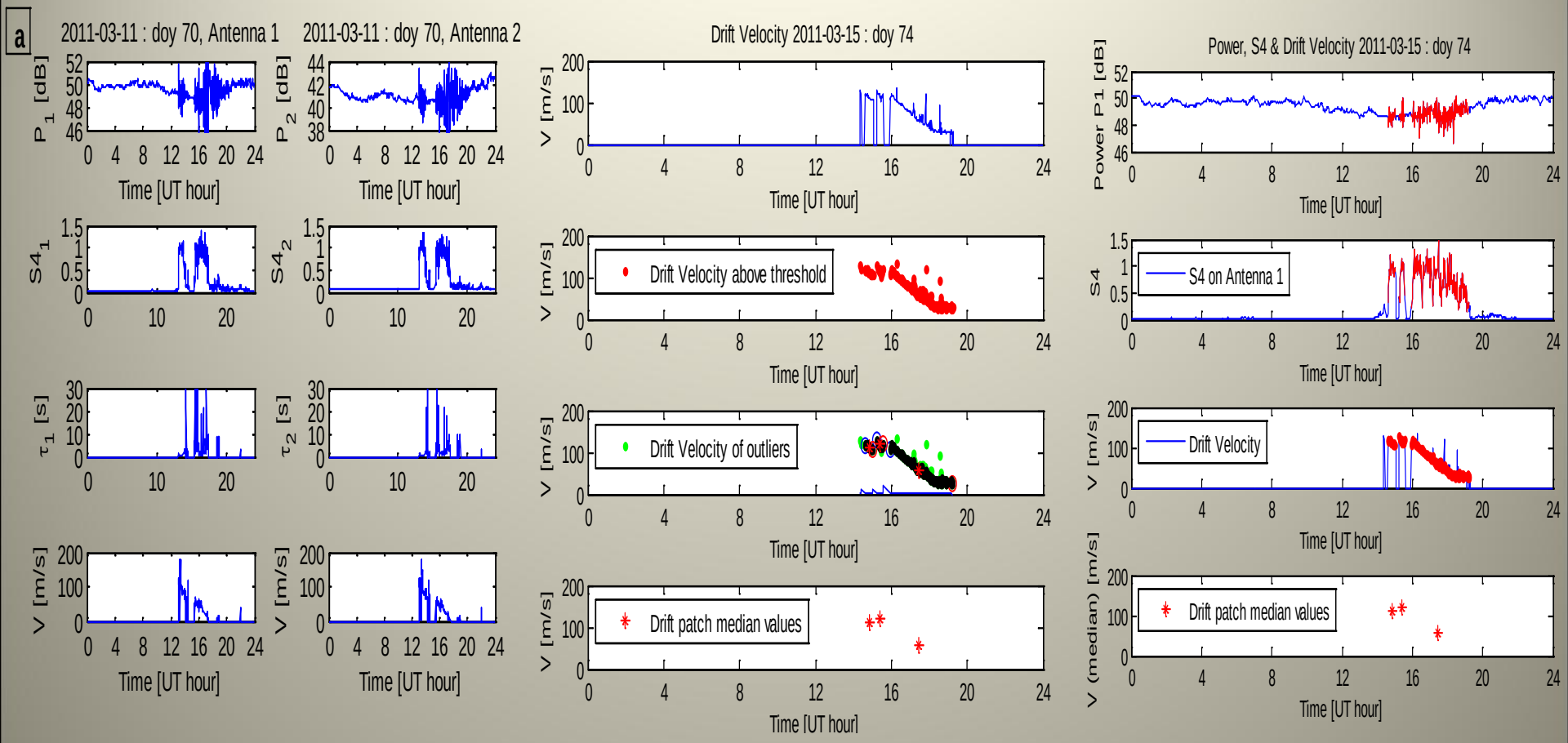
Spatial distribution of irregularities: A climatology



The S4 values are stronger in Southern parts of the sky as viewed from the Receiver location in Nairobi (Kenya)

Olwendo et al., 138-139 (2016), 9-22, JASTP

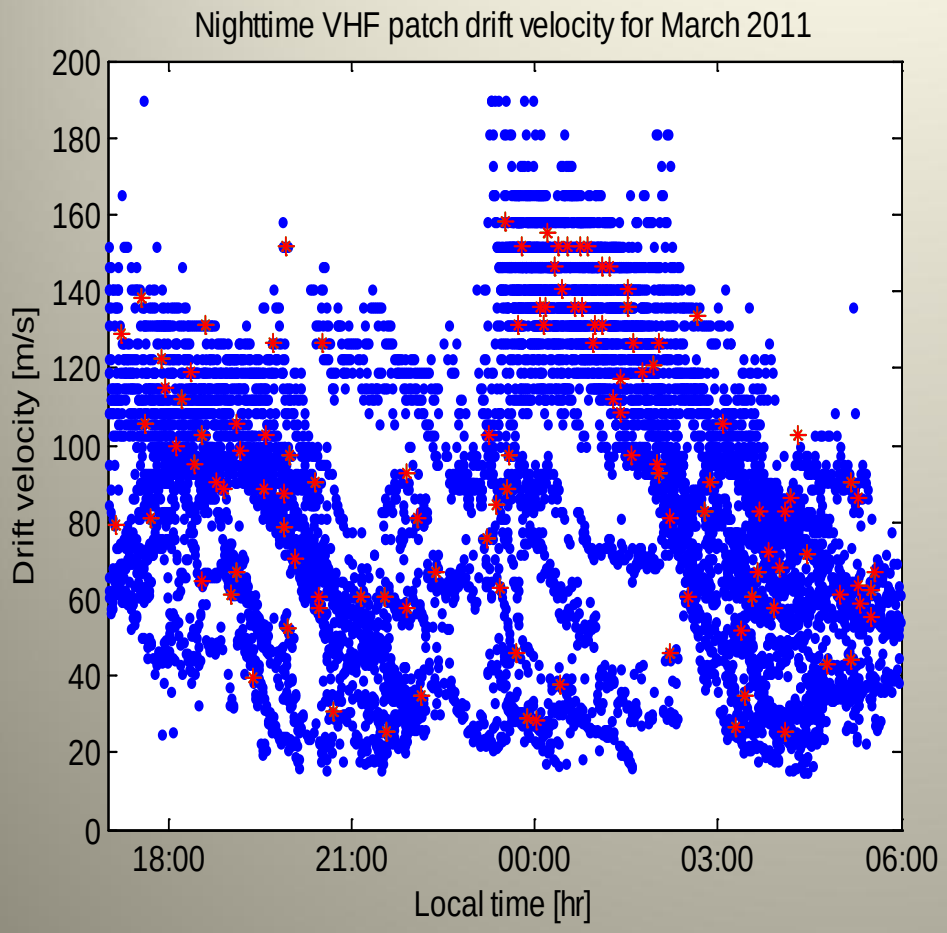
Seasonal variations in zonal plasma drifts

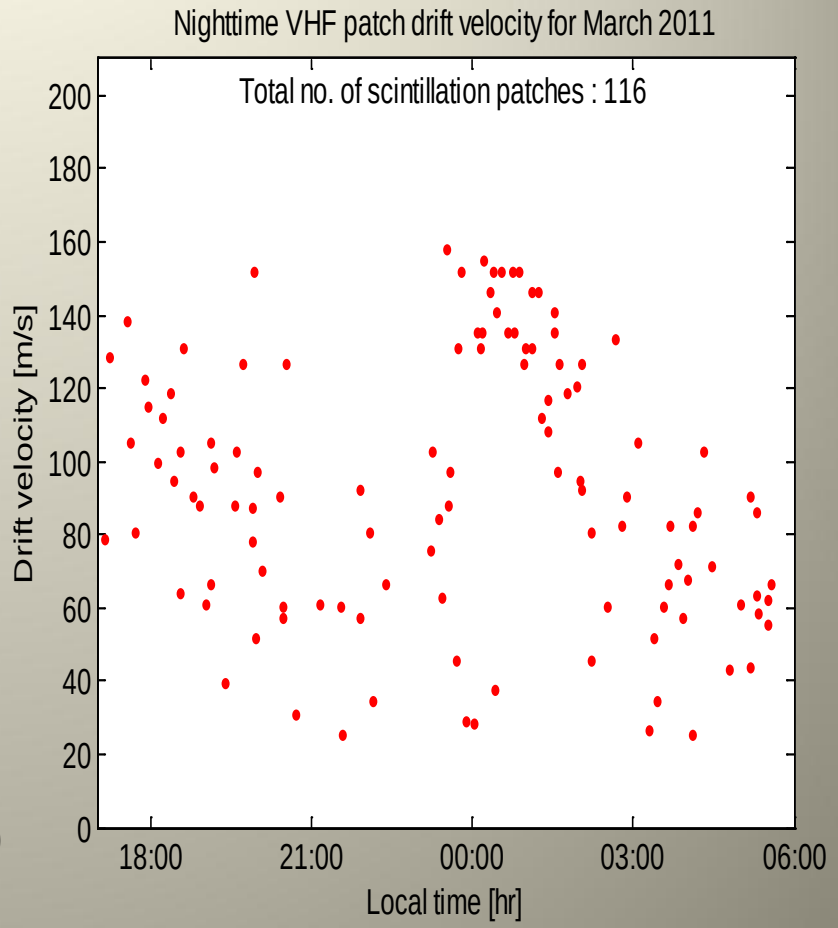


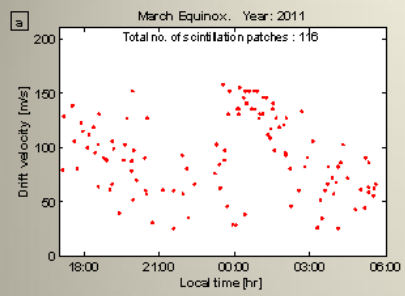
Raw measurements

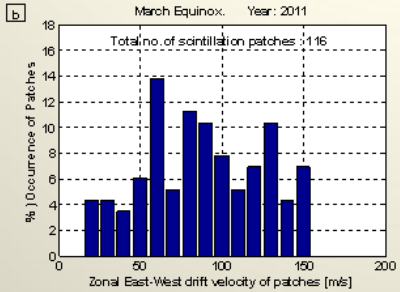
Automation plasma drift patches detection

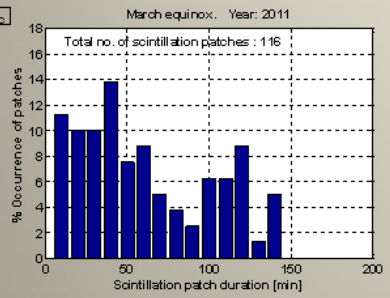
Isolating the drift patches from VHF raw data

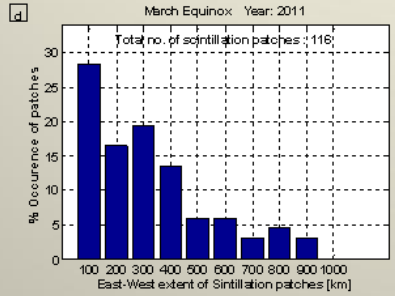


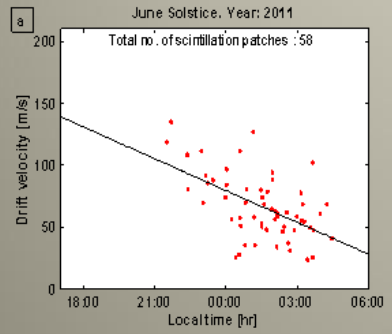


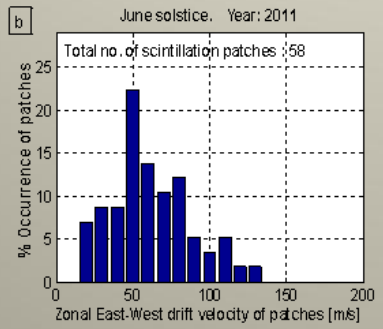

a
March Equinox. Year: 2011
Total no. of scintillation patches : 116
Drift velocity [m/s]
Local time [hr]


b
March Equinox. Year: 2011
Total no. of scintillation patches : 116
% Occurrence of Patches
Zonal East-West drift velocity of patches [m/s]


c
March equinox. Year: 2011
Total no. of scintillation patches : 116
% Occurrence of patches
Scintillation patch duration [min]


d
March Equinox Year: 2011
Total no. of scintillation patches : 116
% Occurrence of patches
East-West extent of Sintillation patches [km]


a
June Solstice. Year: 2011
Total no. of scintillation patches : 58
Drift velocity [m/s]
Local time [hr]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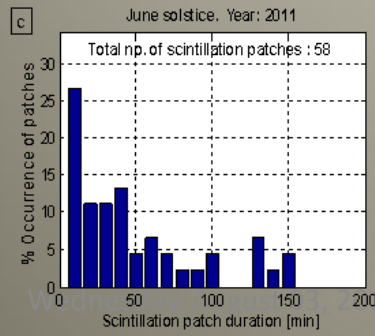
Zonal East-West drift velocity of patches [m/s]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June solstice. Year: 2011
Total no. of scintillation patches : 58
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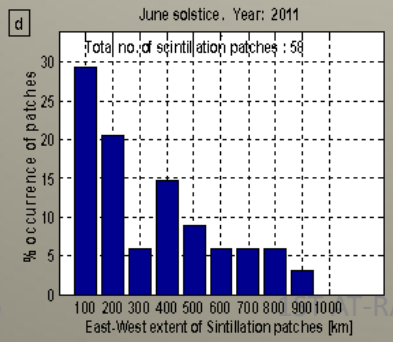
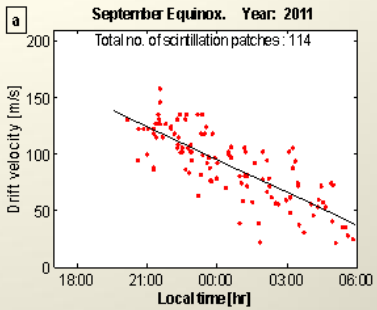
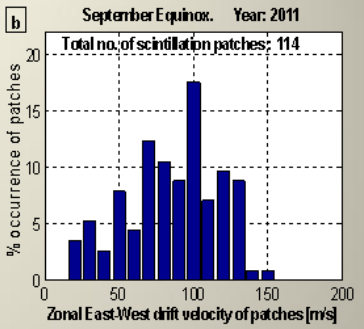
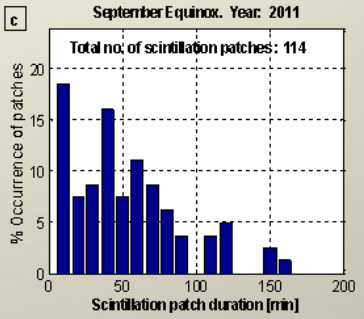
Scintillation patch duration [min]


d
June solstice. Year: 2011
Total no. of scintillation patches : 58
% occurrence of patches
East-West extent of Sintillation patches [km]


a
September Equinox. Year: 2011
Total no. of scintillation patches : 114
Drift velocity [m/s]
Local time [hr]


b
September Equinox. Year: 2011
Total no. of scintillation patches : 114
% occurrence of patches
Zonal East-West drift velocity of patches [m/s]


c
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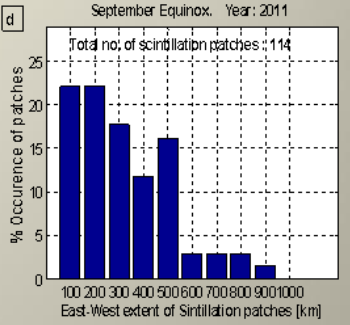
Total no. of scintillation patches : 114
% Occurrence of patches
Scintillation patch duration [min]


d
September Equinox. Year: 2011
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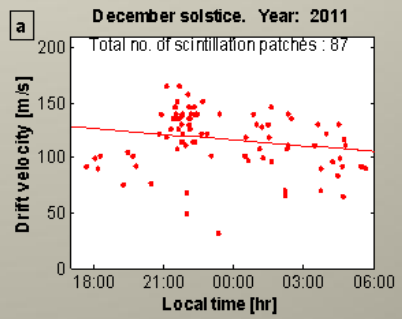
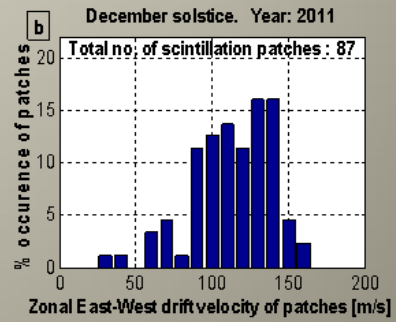
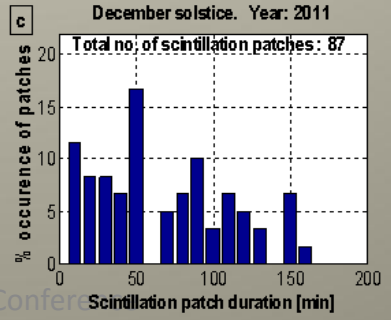
East-West extent of Sintillation patches [km]


a
December solstice. Year: 2011
Total no. of scintillation patches : 87
Drift velocity [m/s]
Local time [hr]


b
December solstice. Year: 2011
Total no. of scintillation patches : 87
% occurence of patches
Zonal East-West drift velocity of patches [m/s]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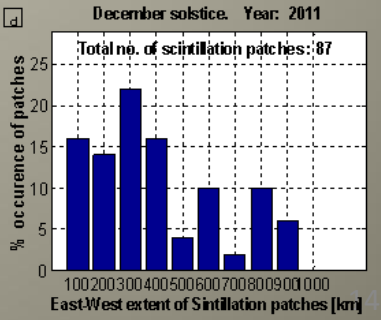
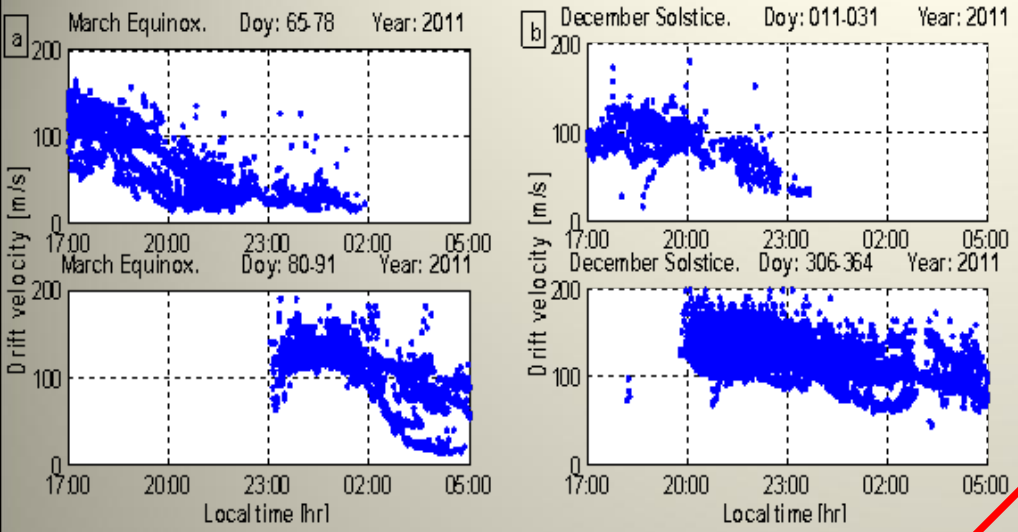
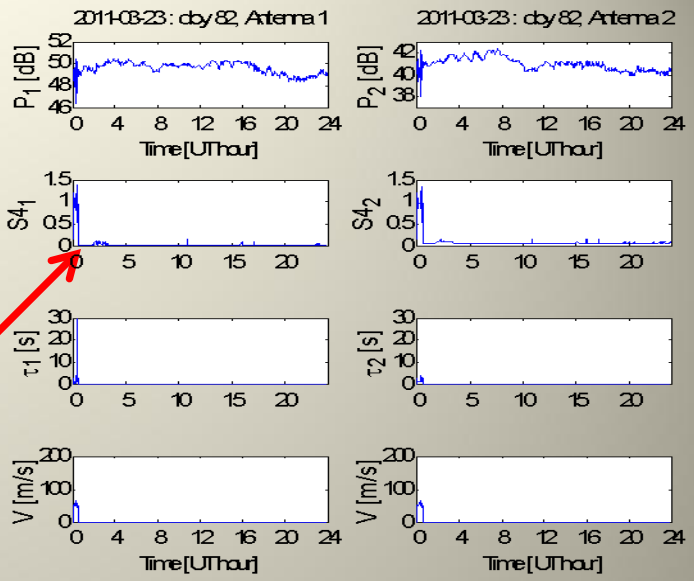
December solstice. Year: 2011
Total no. of scintillation patches : 87
% occurence of patches
Scintillation patch duration [min]

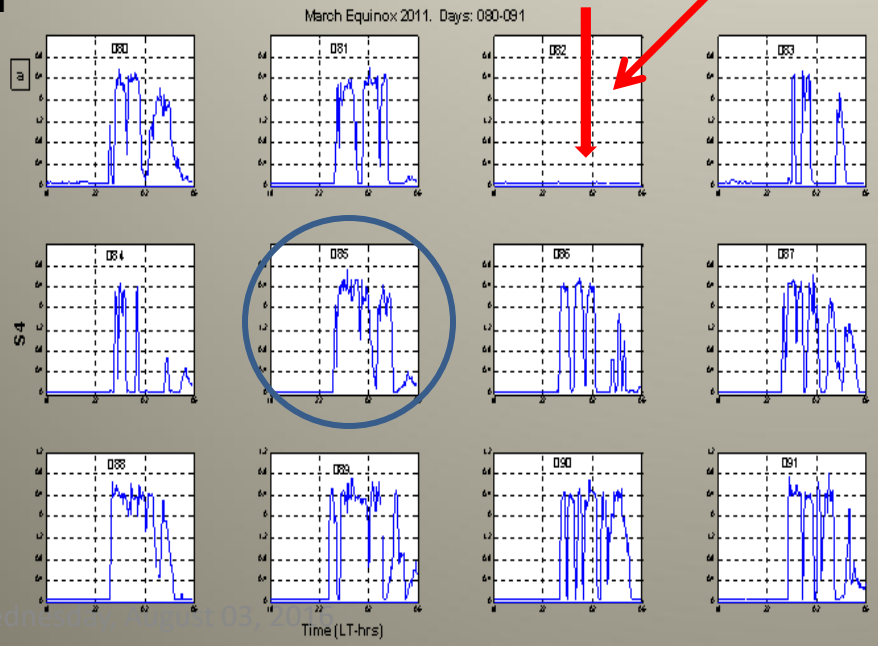

d
December solstice. Year: 2011
Total no. of scintillation patches : 87
% occurence of patches
East-West extent of Sintillation patches [km]

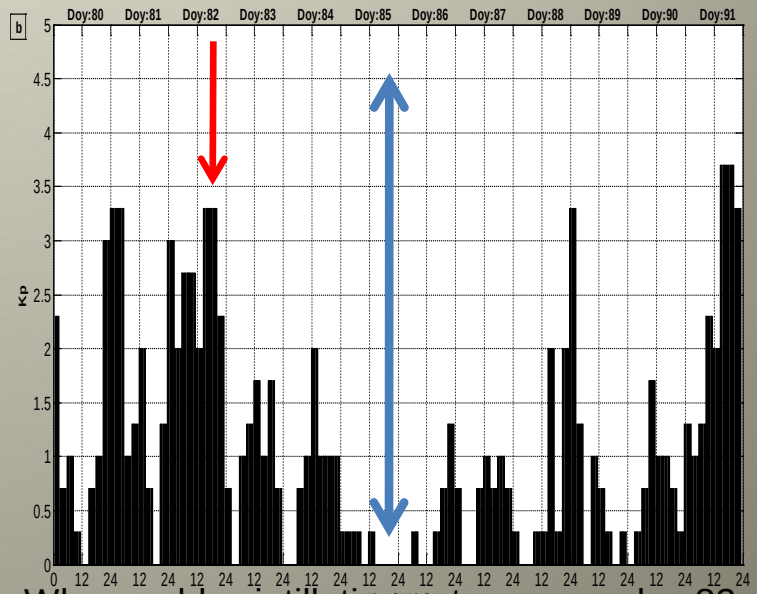
March equinox and December solstice: Post-midnight scintillation occurrence





Olwendo et al., 138-139(2016), 9-22, JASTP

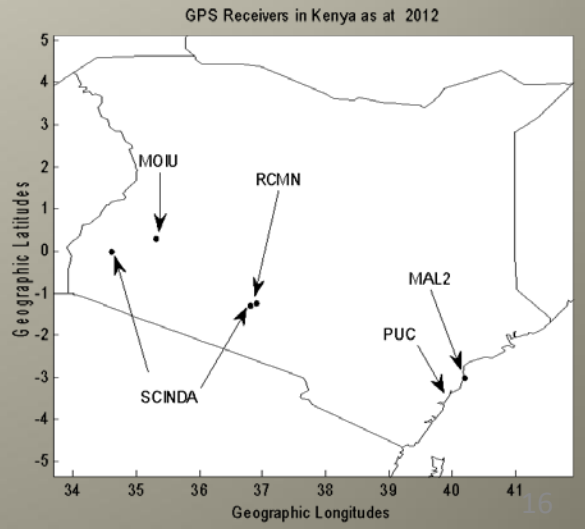




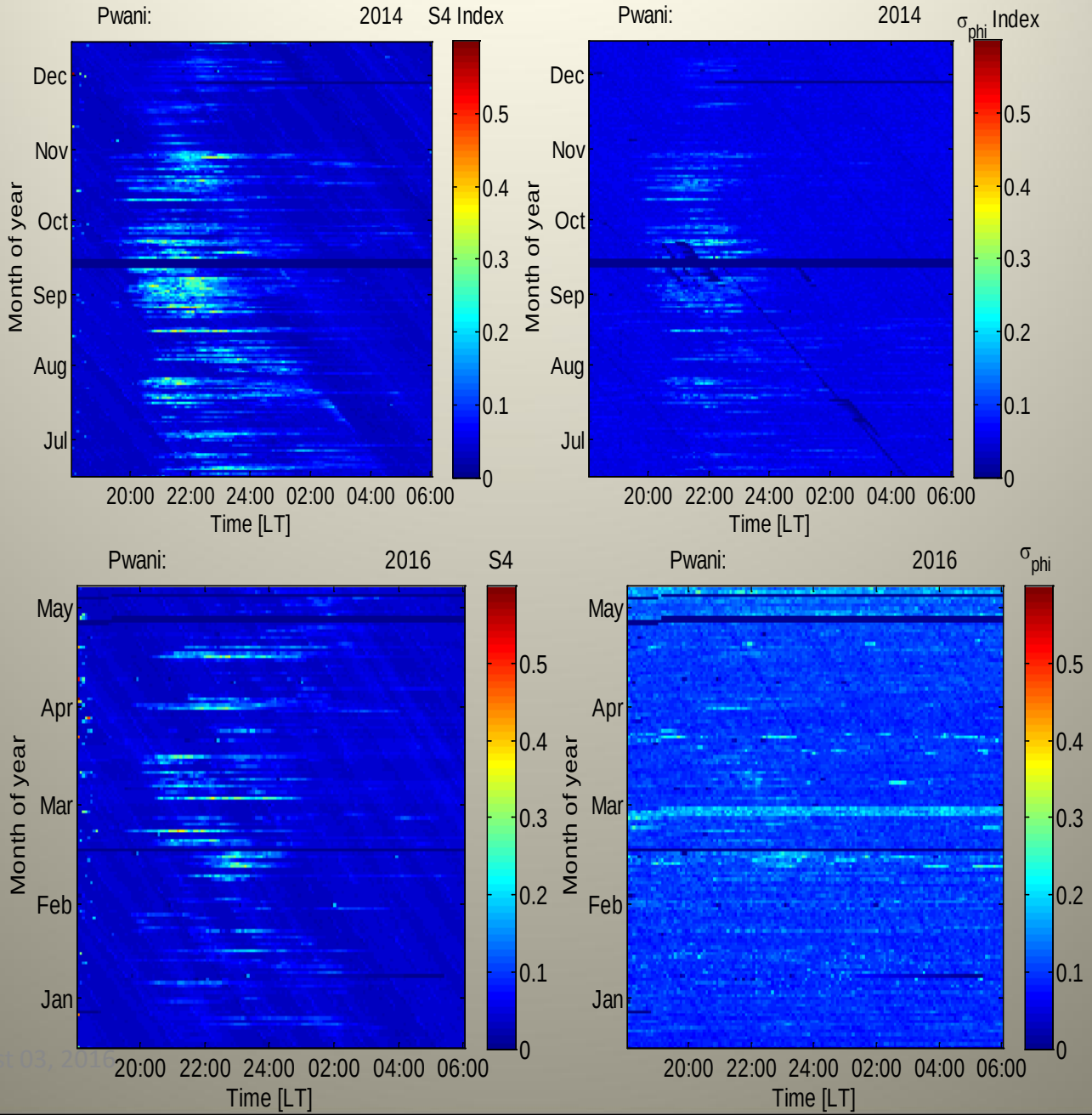
Why would scintillation not occur on day 82 when Kp>3 and again why would it occur on day 85 when Kp is nearly ~0

Latest Observations from a New Receiver: Developed by CRIRP

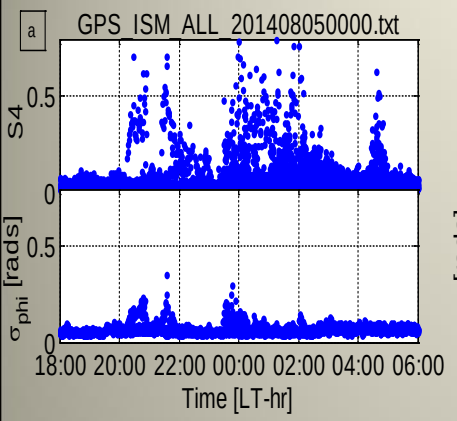
New receiver located in Pwani University marked as PUC on the map of Kenya

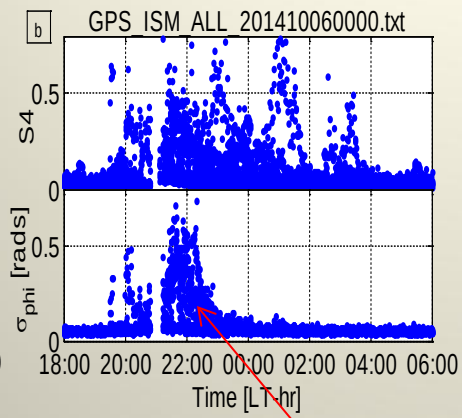


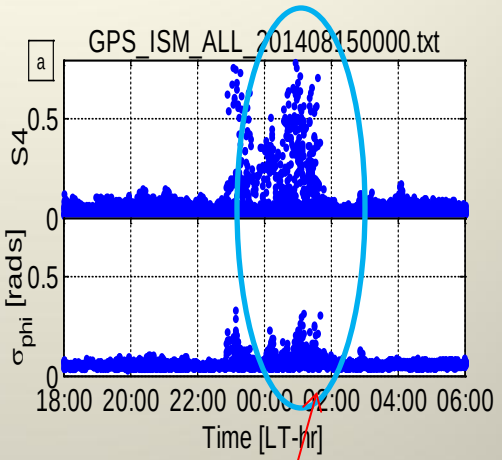
What are our latest observations from the new receiver:

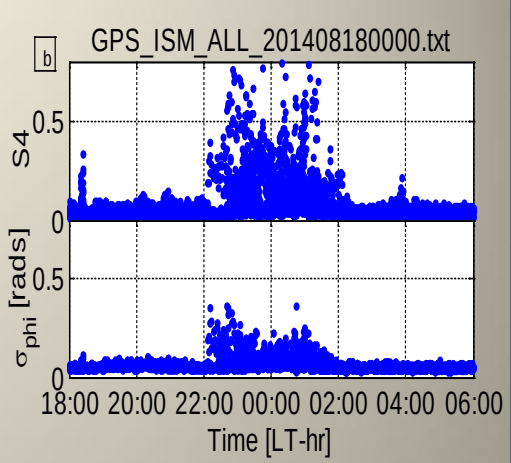


Post-midnight at L-band frequency: New observations



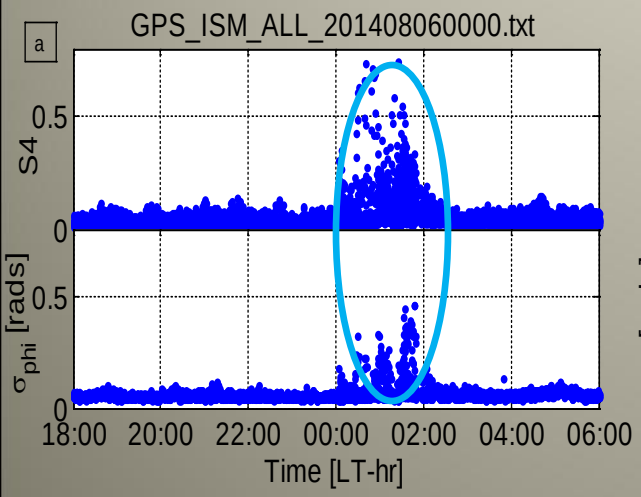


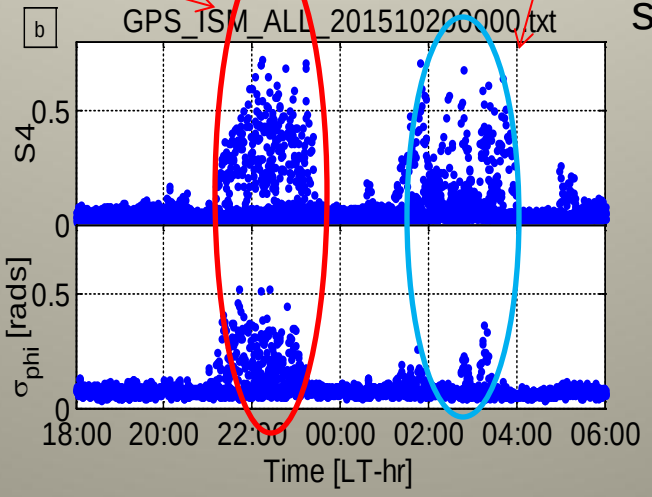


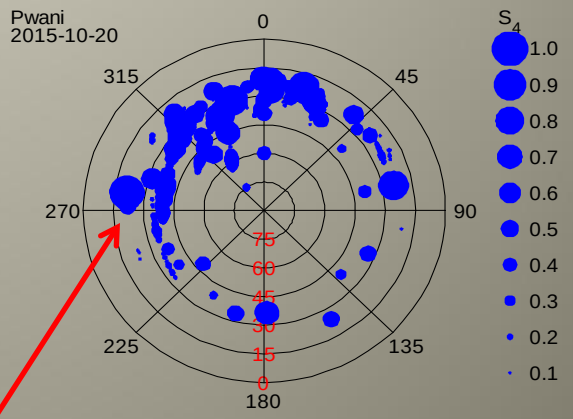


Amplitude and phase scintillation occurring concurrently

Amplitude scintillation Observations without phase scintillation. WHY?

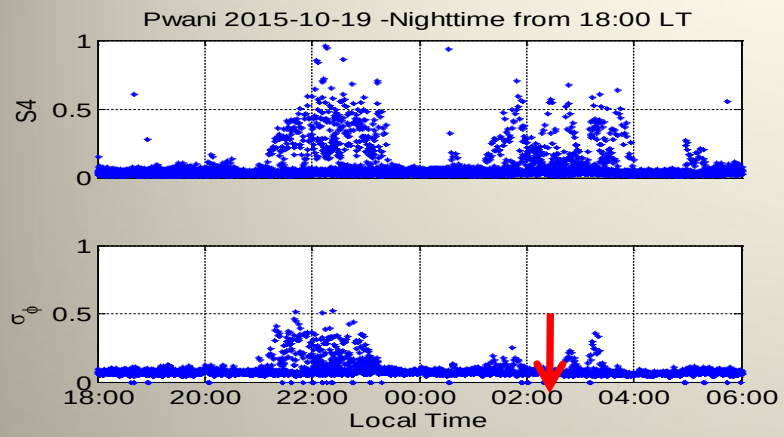


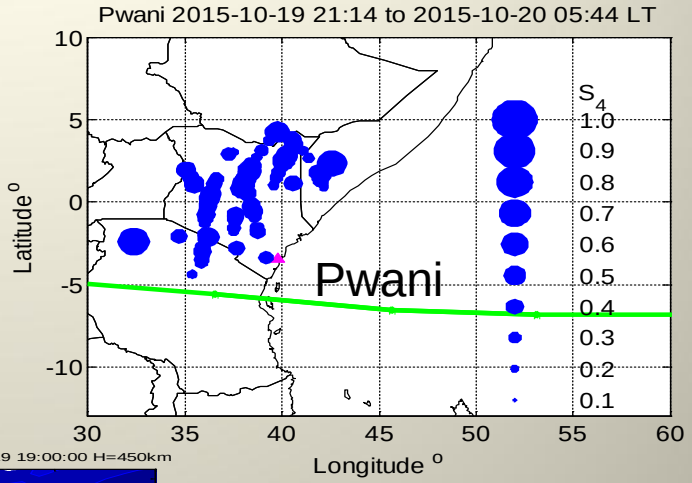


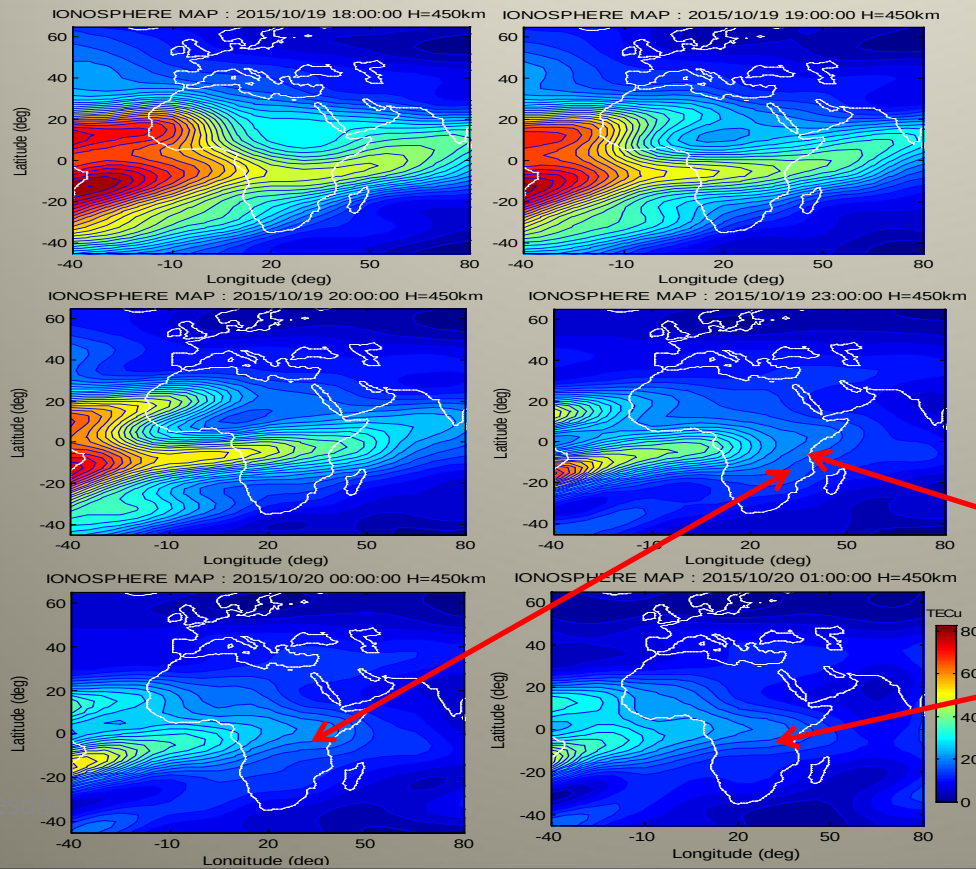


Scintillation Events mainly to the Northern part from receiver location

What about the post-midnight background electron density during scintillation?



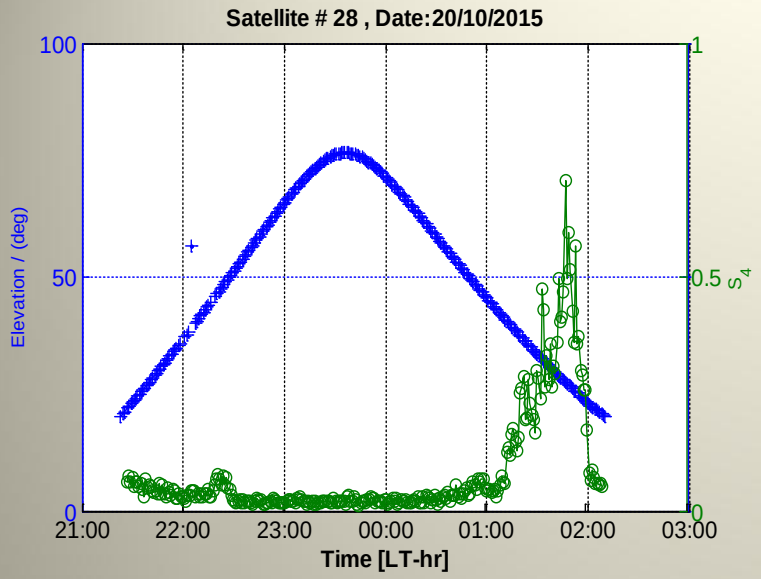


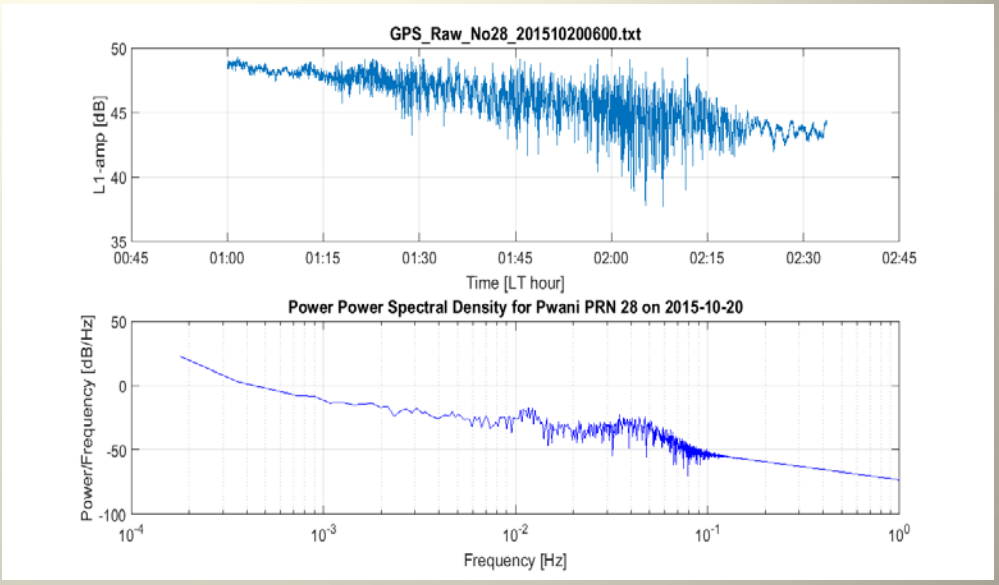


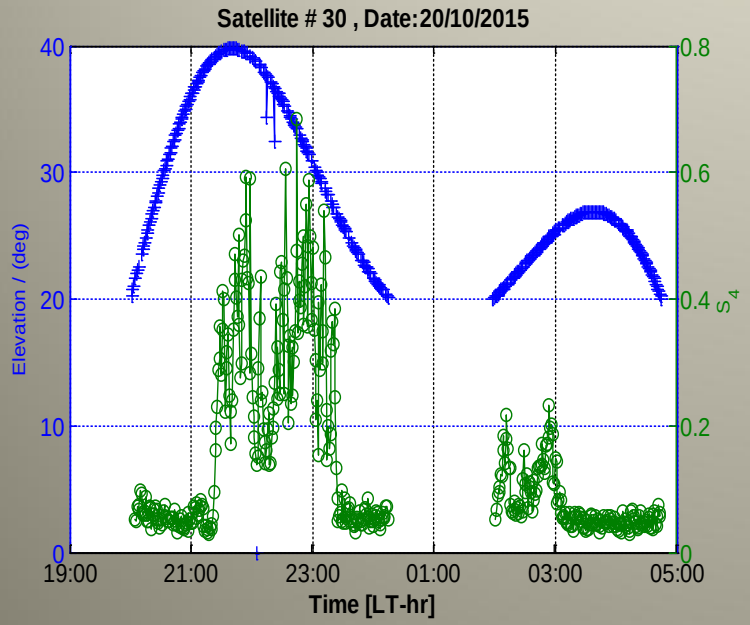
Background electron density generated from GIM data

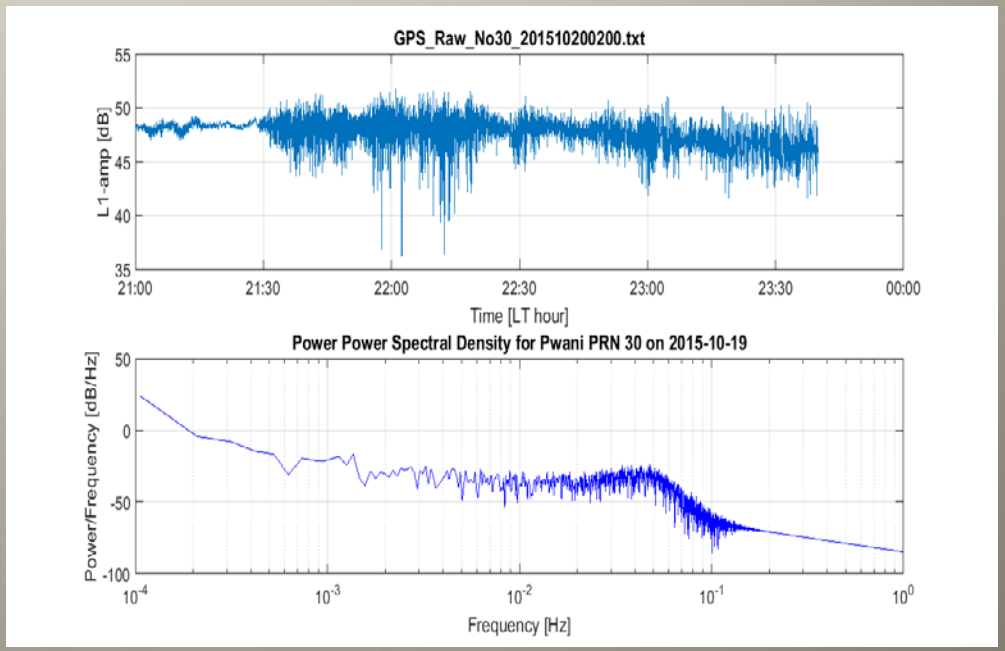
Could lack of Background Electron density Suppress phase Scintillation at 02:00 LT (23:00UT) till 04:00 LT (01:00UT)?

Power spectral density for post-midnight and pre-midnight scintillation events



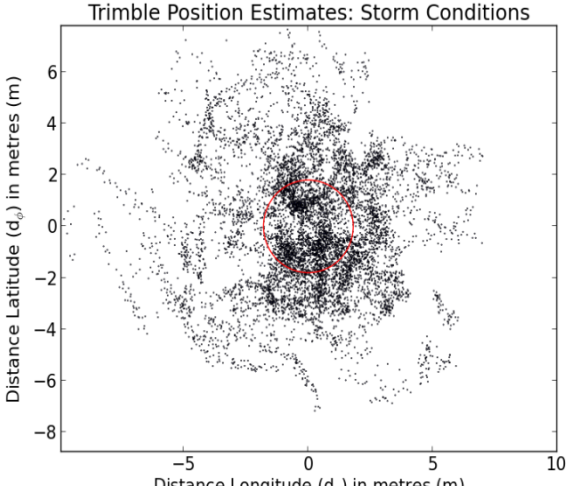


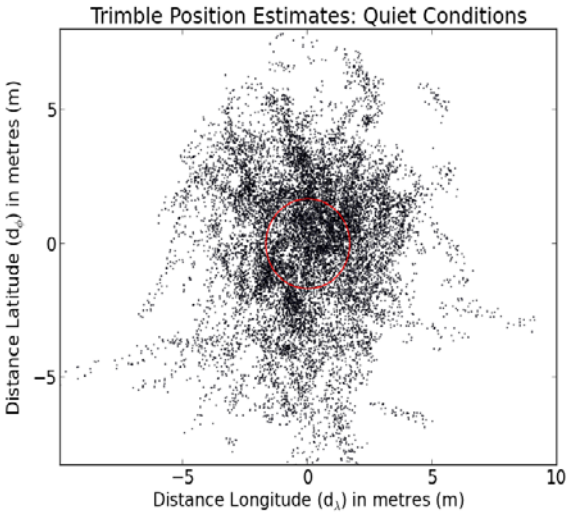




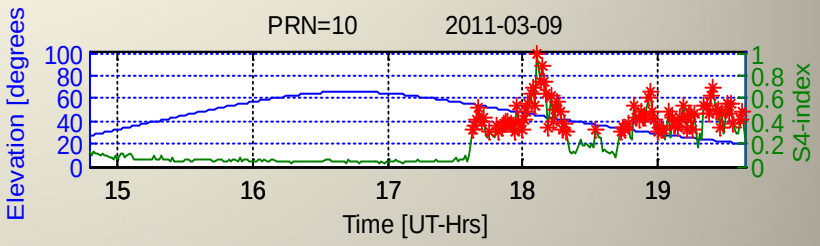
Errors in Precise Positioning due to ionospheric scintillation

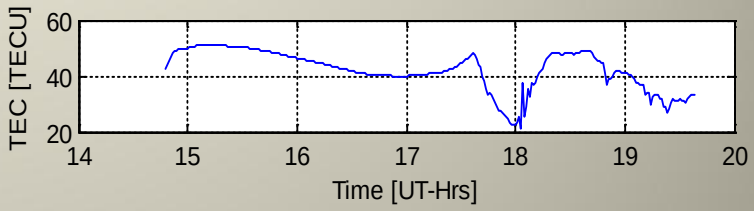
Single Frequency receiver

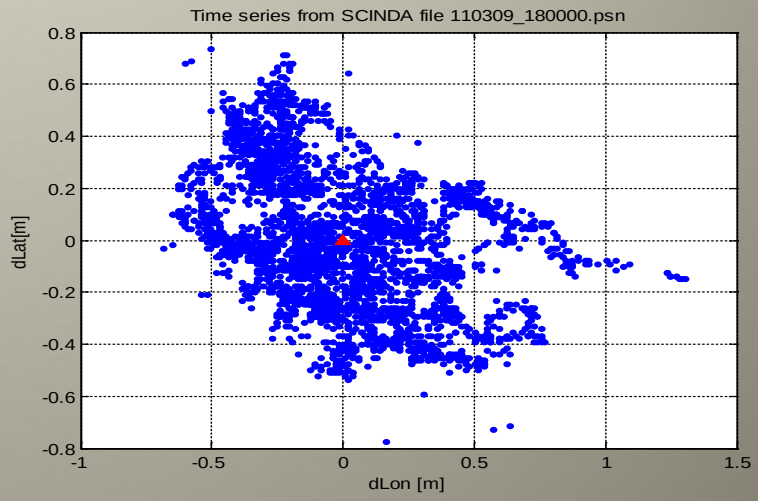




Positioning errors in Dual Frequency reference receiver







Summary

- Equatorial scintillation follows a regular diurnal and seasonal behaviors driven by the formation of ionospheric plasma depletions few hours after local post-sunset hrs.

- The spatial locations of ionospheric irregularities (plasma depletions) that cause scintillation are mainly with the proximity to the edges of the Equatorial Ionization Anomaly crest over the Kenyan region.

- The spatial distribution of scintillation events is important since it gives information on the exact locations in the sky where scintillation is intense and can thus form a basis for fore casting and now casting of scintillation occurrence.

- The occurrence of post-midnight scintillation without pre-midnight events particularly during extremely magnetically quiet times reveals a possibility of ionospheric drivers from the lower atmosphere (troposhere).

- The ionosphere-troposphere coupling thus needs further investigation with right data.

- The significance of phase scintillation in regard to mitigation of scintillation on GNSS signals should be considered.

THE END

THANKS FOR LISTENING

ANY QUESTIONS?