Temporal Variations in Nighttime Scintillation Near MUF Communication Link at the Equatorial Region

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Abstract

Scintillation of long distance HF communications signals near the MUF band is influenced by the equatorial ionospheric dynamics and electrodynamics, particularly from post-sunset to midnight.

Study Location

Station Name	Station ID	Geog. Lat (°N)	Geog. Long. (°E)	Geomag Lat.(°N)	Geomag Long.(°E)
Ascension Is	AS004	-7.95	345.6	-2.56	57.12

Data Acquisition

- The amplitude scintillation data was obtained from the GNSS scintillation receiver at Ascension Island (-7.95°S, 345.6°), a low-latitude station located in the South Atlantic western longitude sector. The GNSS scintillation receiver is managed by Boston College and provides continuous ionospheric scintillation measurements.
- While the MUF data at 3000 km was extracted from Global Ionospheric Radio Observatory (GIRO) website (https://giro.uml.edu/didbase/scaled.php).

Data and Selection Criteria

- To ensure robust statistical analysis and minimize non-ionospheric influences, three data cut-off criteria were applied for the amplitude scintillation based on Akala *et al.,* 2011:
  1. Equatorial Scintillation Hours: Only data recorded during equatorial scintillation-prone hours (18:00 LT – 06:00 LT) were considered.
  2. Satellite Elevation Angle Filter: Data from satellites with elevation angles ≥ 30° were included to eliminate signal fluctuations caused by multipath effects and other non-ionospheric disturbances.
  3. Highest S4 Selection: Each one-minute scintillation event was characterized using the satellite that recorded the highest scintillation index (S4), defined as the standard deviation of the factor $I/<I>$, where I is the intensity of the received signal and $<I>$ is its average value.
- Secondly, the corresponding hourly values of MUF were used in this research.

Methodology

- We performed correlation coefficient analysis to assess the relationships between:

1. MUF and Solar Flux and
2. S4 Scintillation and Solar Flux.

Correlation coefficient is given in equation 1 as:

$$r = \frac{\sum(x_i-\bar{x})\,(y_i-\bar{y})}{\sqrt{\sum(x_i-\bar{x})^2\,\sum(y_i-\bar{y})^2}} \qquad (1)$$

where r is correlation coefficient, while x and y are independent variables.

- Also, Linear regression was employed to quantify the expected changes in MUF and S4 per unit increase in solar flux, providing insight into the ionospheric response to solar activity.

Generally, due to the dearth of MUF and corresponding S4 data at the chosen location, only the days that present minimum of three consecutive data availability for both parameters was selected for the present study.

Hence, three days in the month of July, 2011 representing June solstice and three days in the month of September, 2011 representing September equinox were selected.

Introduction

- The ionosphere is a prerequisite for high frequency (HF) sky-wave signal propagation (Rush, 1986). Unfortunately, the ionosphere is unstable in time and space, making it difficult to determine the role of solar ionization on the propagation of HF radio wave signals.
- Scintillation is one of the ionospheric phenomena that disrupts HF communication near the MUF band, by causing fading, twinkling, etc., of HF radio waves returned from the ionospheric F region at oblique incidence (Booker et al., 1987).
- The climatology of scintillation of GNSS signals at the equatorial region is reasonably understood. Whereas, the climatology of scintillation of MUF signals from ionosonde/digisonde is poorly understood.

Variations in MUF and S4

Fig. 1 and 2 show the hourly and daily variations in MUF and S4 for July 4 – 6, 2011 and September 25 – 27, respectively at Ascension Island in the Southern Atlantic Western longitude sector.

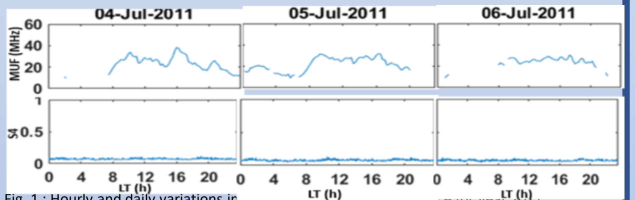


Fig. 1 : Hourly and daily variations in MUF and S4 during June solstice for year 2011.

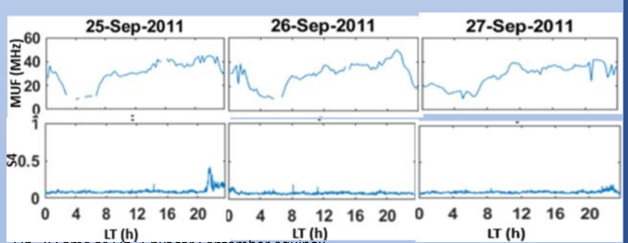
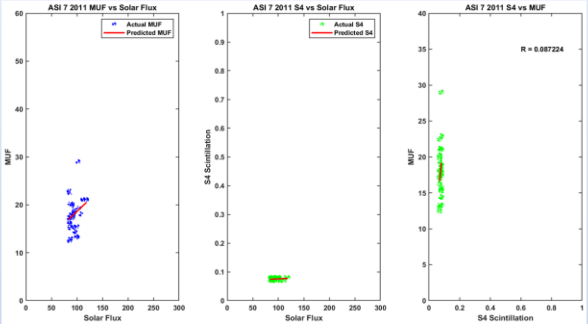


Fig. 2: Same as Fig. 1 but for September equinox.

Discussion

- MUF and S4 show higher magnitude during September equinox than June solstice.
- Statistical analysis reveals weak and inconsistent correlations, with alternating negative and positive values showing monthly and seasonal variations.
- Despite the presence of some seasonal or temporal trends, the low R-squared and correlation values suggest that other factors significantly influence the variations in MUF and S4.
- In relation to solar flux, there was an increasing trend between MUF and Solar flux, while S4 does not show strong correlation with solar flux at nighttime.

Correlation and Regression Analysis



(Middle) and regression between MUF and S4 (right) during June solstice for year 2011.

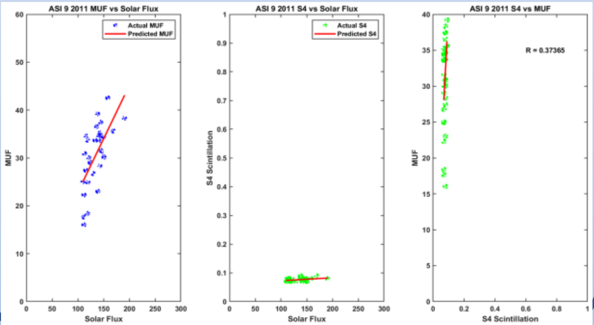


Fig. 4: Same as Fig. 3 but for September equinox.

Conclusion

- Preliminary findings suggest that MUF depends significantly on solar flux, whereas scintillation (S4) does not depend on solar flux. However, S4 is not strongly linked to MUF.
- These findings highlight the complexity of ionospheric dynamics and underscore the need for further research incorporating additional data and parameters to better understand the interplay between MUF and scintillation.

References

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