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Observations of Ionospheric irregularities in the low and mid latitude regions across the Africa-Europe sector during 2014, at the peak of solar cycle 24

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Abstract

Contrary to the low latitude ionosphere, the mid latitude region is generally considered to lack the necessary processes required to generate the irregularities that causes scintillation and thus commonly regarded as a less scintillation active region. However, recently, the dynamics of the mid latitude ionosphere have been deeply studied to observe and model the development of plasma instabilities.
The ionospheric disturbances associated with mid-latitudes ionospheric irregularities are mainly the mid-latitude ExB instability which can be excited when there is significantly strong eastward electric field.
And the classical medium scale traveling ionospheric disturbances have all been related to the spread F phenomenon that indicates ionospheric irregularities.

In this work, using the IGS network of GNSS receivers spread across the low latitude and mid-latitude regions over the African and Europe sectors we present the trends in ionospheric irregularity activity levels based on Rate of TEC Index (ROTI) fluctuations. The trends are statistically represented based on counts of nighttime ROTI values above a threshold of 0.4 TECU/min. we further investigate on the possible mechanism responsible for mid latitude ionospheric irregularities shown in this study. Our results highlights on the need to further study the mechanisms responsible for ionospheric irregularity formations at mid-latitude and how these irregularities cause scintillation observations.

1 Introduction

While low-latitude regions of Africa are known to have regular occurrence of ionospheric scintillation, the mid latitude region is generally considered to lack the necessary processes required to generate the irregularities that causes scintillation. The mid-latitudes are thus commonly regarded as low activity regions particularly regarding ionospheric scintillation. However, in 2014, during the peak of solar cycle 24, there were periods of significant irregularities in the mid-latitude ionosphere over Africa, which prompted a several studies of the dynamics of the mid latitude ionosphere to observe and model the development of plasma instabilities. The ionospheric disturbances associated with mid-latitudes ionospheric irregularities are mainly the mid-latitude ExB instability which can be excited when there is a strong eastward electric field. Another mechanism which causes mid-latitude scintillation is medium scale traveling ionospheric disturbances, which have been related to the spread F phenomenon that indicates ionospheric irregularities.

2 Data & methods

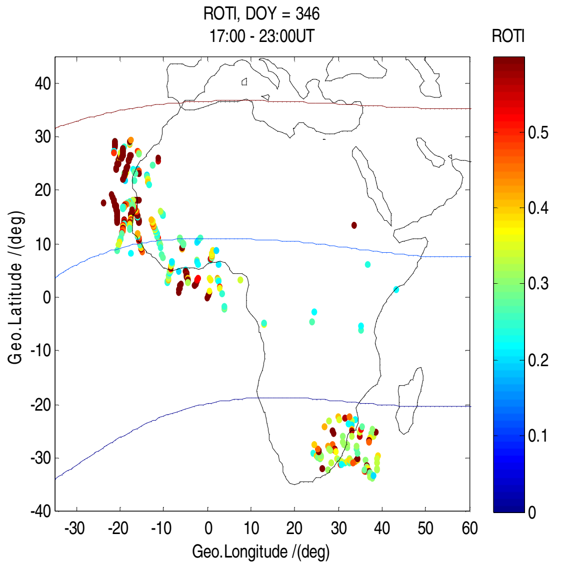
In this work, using data from the IGS network of GNSS receivers spread across the low –and mid-latitude regions of the African and Europe sectors, we present the trends in ionospheric irregularity activity levels based on Rate of TEC Index (ROTI) fluctuations. The trends are statistically represented in terms of counts of nighttime ROTI values above a threshold of 0.4 TECU/min.

For the low-latitude region of Africa, we demonstrate the longitudinal variation of irregularities which may give rise to ionospheric scintillation. There are times when the irregularities are limited to Western Africa, with no activity in East Africa on the same day, and other times when there are significant irregularities' in the East Africa region, with little or no activity in the West Africa Region.

3 Results

Figure 1 shows some typical results obtained on 12 December 2014, at the peak of solar cycle 24. It demonstrates the occurrences of Southern mid-latitude irregularities. Figure 2 gives some statistical results for the month of December 2014. Figure 3 shows an ionogram recorded at 18:45 UT on 12 December 2014, which shows clear evidence of spread-F occurrence.

We investigate the possible mechanisms responsible for mid-latitude ionospheric irregularities demonstrated in this study. Our results highlight the need for further studies of the mechanisms responsible for creating ionospheric irregularities at mid latitudes and how these irregularities cause ionospheric scintillation. The role of poleward travelling ionospheric disturbances (TIDs) in the generation of mid latitude irregularities will be investigated.



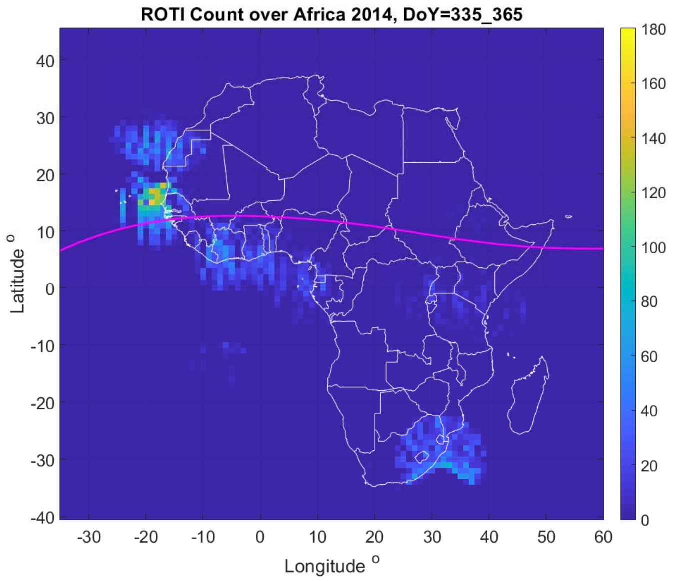


Figure 1. Spatial distribution of ionospheric irregularities based on monthly ROTI counts binned over 1x1 degree pixels for December 2014. Note the occurence of ROTI over Southern Africa, a mid-latitude region during the peak of the solar cycle.

Figure 2. Spatial distribution of ionospheric irregularities based on monthly ROTI counts binned over 1x1 degree pixels for December 2014. Note the occurence of ROTI over Southern Africa, a mid-latitude region during the peak of the solar cycle.

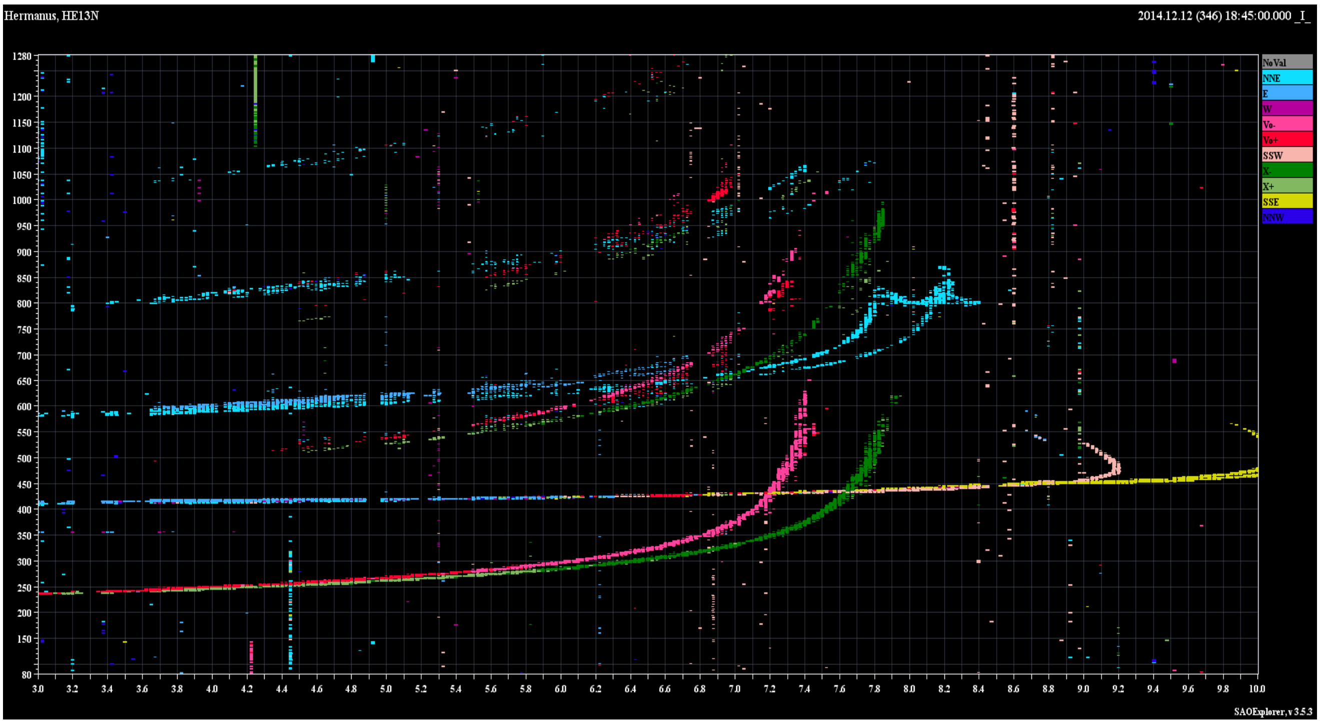


Figure 3: Ionogram recorded on 12 December 2014 in Hermanus at 18:45 UT. Note the occurence of spread-F which coincides with the ROTI observations over the South African region.

4 Conclusions

In this work we have investigated spatial distribution of ionospheric irregularities across the African sector using ground based GNSS receivers in the IGS network. The overall distribution of ionospheric irregularity structures across Africa region remains a complex process. The assymmetry of irregularity structures on West and East regions of the African sector have previously been mentioned in the works by Puznikhov et al., (2012). The occurrence of irregularitiy structures on the West side of the region without occurrence on the East side of the region on the same night remains unexplained. The West side of Africa appears to have stronger irregularity occurrence than the East side of Africa. The observations have also revealed that in the West side of Africa, the irregularities may extend to North latitudes of between 20 and 30 degrees, which is not matched by a similar extent on the East.

A clear seasonal trend has also emerged on the occurrence of irregularities across Africa sector. Irregularities are dominant on the West side of Africa during the first four months of the year and the last four months of the year. The East side of Africa seems to have stronger irregularity in May, June and July. Of greater interest in the observations across the African region is the occurrence of strong ROTI in the mid-latitude, region mainly in the South African sector, during December 2014. Our study covered three years of the descending phase of solar cycle 24, namely 2014, 2016 and 2018. Only in December 2014 did we observe strong occurrence of irregularities at the midlatitude region. We ascribe the high occurence to high solar activity since 2014 was a high solar activity phase of solar cycle 24. A further investigation has shown that these irregularities were mainly occuring in the F-region as was evident from Ionosonde measurements (See Figure 3). In conclusion we have observed new features about the low latitude irregularities that should inform further research. The occurrence of irregularities on the same day on only one side of the continent needs further investigations to understand what the drivers for such assymmetric irregularity events are. The observation that irregularity structures on the West side of Africa externded to the far Northern latitudes while the same has not occured on the East side on the same day, has likewise not been clearly explained. The presence of strong ROTI over the mid-latitude has also shown that the mid-latitude ionosphere may be more active than previously thought. Further studies on the mid-latitude to high latitude coupling may be necessary to advance the understanding of mid-latitude irregularity structures during geomagnetically quiet times.

5 Acknowledgements

UNAVCO is acknowledged for the provision of GNSS data used in this paper.

6 References

1. Akala, A. O et al., “Climatology of GPS amplitude scintillations over equatorial Africa during the minimum and ascending phases of solar cycle 24,” *Astrophys Space Sci.* 357:17, 2015, doi:10.1007/s10509-015-2292-9.

2. Olwendo J., P. J. Cilliers and O. Ming, “Comparison of ground based ionopheric scintillation observations with in situ electron density variation as measured by the Swarm satellites,” *Radio Sci.* **54**, 2019, doi:10.1029/2018RS006734.