Characterization of the ionosphere in the Seychelles

Brian D. Curtis[1,2], Clayton Coker[2] and Kenneth F. Dymond[2]

[1]National Research Council
2101 Constitution Avenue, NW
Washington, D.C. 20375

[2]Naval Research Laboratory
Space Science Division
4555 Overlook Ave, SW
Washington, D.C. 20375

ABSTRACT

An all-sky imager and GPS receiver are located at a geographic latitude and longitude of 4.67°S and 55.51°E respectively, on the Mahe island of the Seychelles in the Indian Ocean. At a magnetic latitude of -16.75 this low latitude site provides a view of the southern crest of equatorial ionization anomaly (EIA). In this paper we describe the Ionospheric features visible from the Seychelles region for the years of 2015 to present. A common event in the Seychelles nighttime ionosphere is the presence of equatorial plasma depletions. A daily occurrence rate of depletions, the number of depletions observed each night, and their latitudinal extent are calculated. Depletions are typically observed in the filters of 557.7, 630.0 and 777.4 nm with an exception where the ionosphere may not be strong enough to see the depletions in the 777.4-nm filter. An analysis of the southern EIA crest characteristics will be discussed as well as a summary on significant events like the geomagnetic storm effects on the Seychelles ionosphere from March 17th, 2015. The data from the all-sky imager during that event shows the depletion movement stop and reverse in direction.

1. INTRODUCTION

The Seychelles are an island chain in the western Indian Ocean, east of Somalia and northeast of Madagascar. An all-sky imager is located on the island of Mahe which is at a geographic latitude and longitude of -4.67 and 55.51 respectively and a magnetic latitude and longitude from the Apex model of -16.75 and 128.21 respectively. The Seychelles location is interesting due to its proximity to the southern crest of the eastern African sector of the Equatorial Ionization Anomaly (EIA).

2. EQUIPMENT

The all-sky imager is a Keo scientific PIXIS 1024 CCD with a 50mm lens. The attached filter wheel can hold up to 5 3-inch optical filters. The filters in this imager are 557.7nm, 630.0nm, with a background 620.0nm and a 777.4nm with a background 765.0nm. The camera is automatically controlled by a small computer using Ubuntu Linux OS.

3. ANALYSIS

We use the images to characterize the Ionosphere in the vicinity of Seychelles. At sunset local time in the equatorial regions there is typically a peak in the vertical plasma drift that causes a lift of the Ionosphere. The plasma diffuses down the magnetic field lines to higher latitudes (Walker 1981.) An imager positioned at the EIA may see a brightening around that time frame due to this. The brightness of the Ionosphere should decrease through the night until sunrise due to Ionospheric decay. Any depletions seen will typically drift eastward as well as decay along with the Ionosphere (Kil et al., 2009.)

The Ionosphere also has seasonal, which affect its visibility as well as the depletion frequency and depletion extent (Fuller-Rowell et al., 1996.) We verify the Ionosphere in Seychelles follows these expected trends and lastly we look into rare events seen in the Seychelles. We identify a few atypical events, as well as how these events are correlated with geomagnetic activity.

3.1 TYPICAL NIGHT

The all-sky imager starts shortly after sunset. A typical night as seen by the imagers in the Seychelles is impacted by stars, clouds, moon, rain, and planes. The clouds are more prevalent in the Seychelles due to a meteorological region known as the Inter-tropical Convergence Zone (ITCZ) in which cloud formation is higher. There is no location in the Seychelles that is above the cloud deck. The nightly decay of the Ionosphere is seen until the imager stops prior to sunrise.

3.2 DATA COLLECTION

The images were inspected visually to determine conditions affecting image quality and Ionospheric characteristics such as the presence of an anomaly crest and plasma depletions. The visibility of the moon in Pre-Midnight (PMN) and After Midnight (AMN) is recorded as a 1 for yes and 0 for no. The percentage of view obstruction is recorded in PMN and AMN with the following integers: 0 = 0%-25%, 1 = 25%-50%, 2 = 50%-75%, and 3=75%-100%. A 1 for yes and 0 for no is recorded if the gradient in the Ionosphere is visible in either 557.7nm, 630.0nm and 777.4nm. A 1 for yes and 0 for no was recorded if there were depletions visible, along with a 1 for yes and 0 for no for each 557.7, 630.0 and 777.4nm image for both PMN and AMN. Last, the depletion extent and number of channels as well as the EIA starting and ending location being either N,S,E,W,NE,SE,SW,NE was recorded.

4. DATA

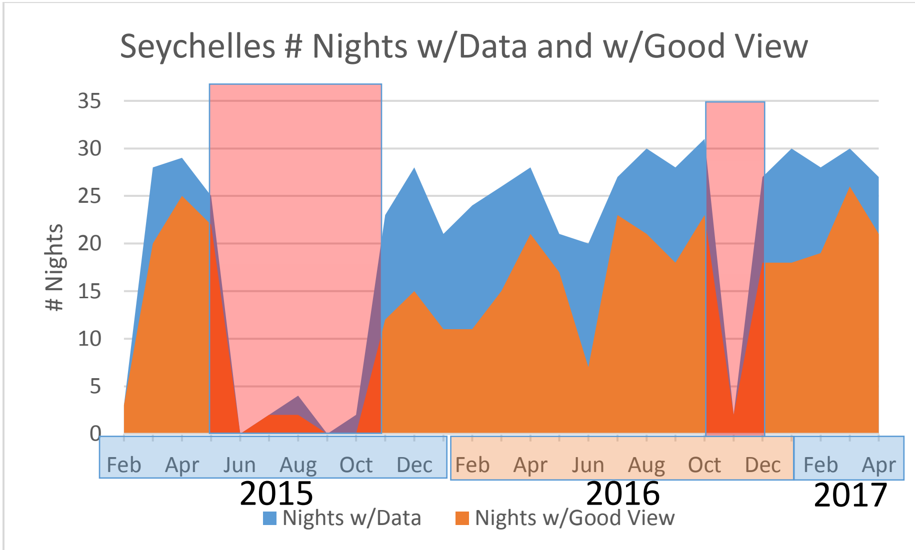


Figure 1

Figure 1 shows the number of nights per month where the imager collected data in blue and the number of nights with good viewing conditions in orange. The determination of whether or not a night had a good view, for the orange data set, was if both AMN and PMN for a night was 3, then the night was considered not to have a good view. The red sections in the plot show the months where there were issues with the software or hardware and did not have a sufficient amount of data to use. There is full year worth of data without any software or hardware issues that can be used to study the seasonal variation of the Ionosphere in the Seychelles.

4.1 MONTHLY

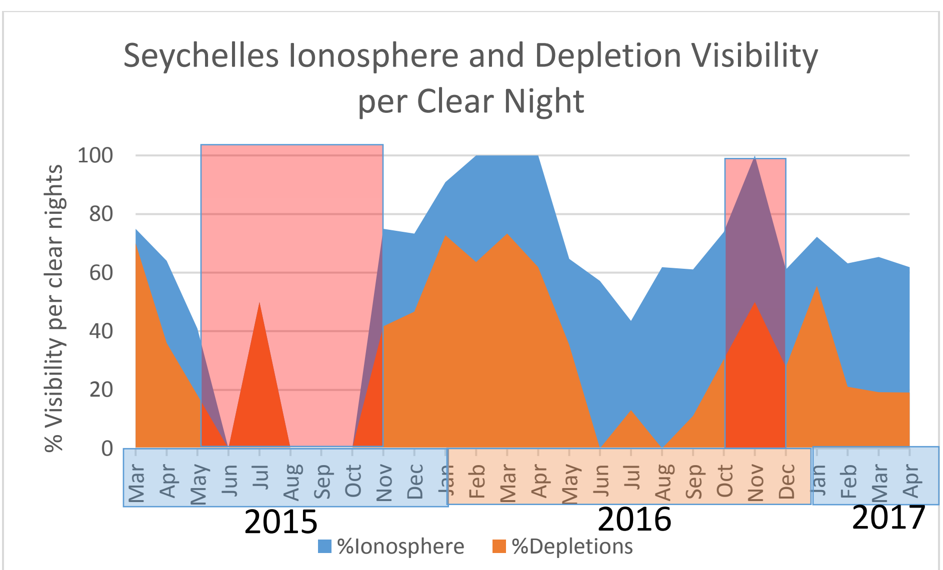


Figure 2

Figure 2 shows the percent visibility of the Ionosphere per clear night in blue and the percent visibility of depletions per clear night in orange. The denominator that was used to get a percentage is from the number of nights with a good view and shown on Figure 1. From December 2015 to March 2016, there is an increase in the percent visibility of the ionosphere and percent visibility of depletions. From March 2016 to June 2016 there is a decrease in both parameters.

4.2 SEASONAL

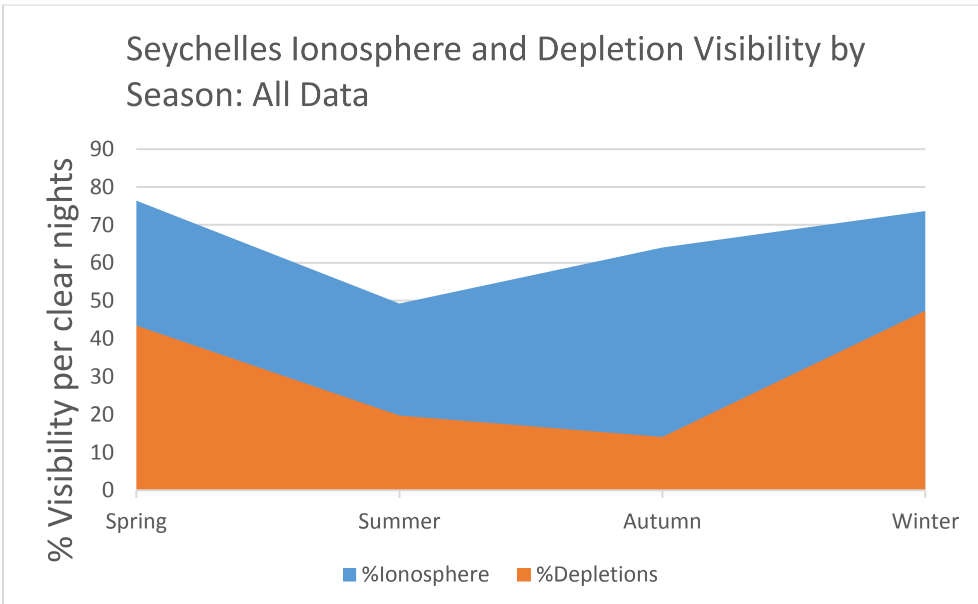


Figure 3

Figure 3 shows the seasonal information for the percent visibility of the Ionosphere and the percent visibility of depletions using all of the data for the Seychelles. The spring to summer changes show a decrease in the parameters. The summer to autumn trend shows an increase in percent visibility of the Ionosphere and a decrease in the percent visibility of depletions. Both parameters show in increase from autumn to winter.

4.3 DEPLETIONS

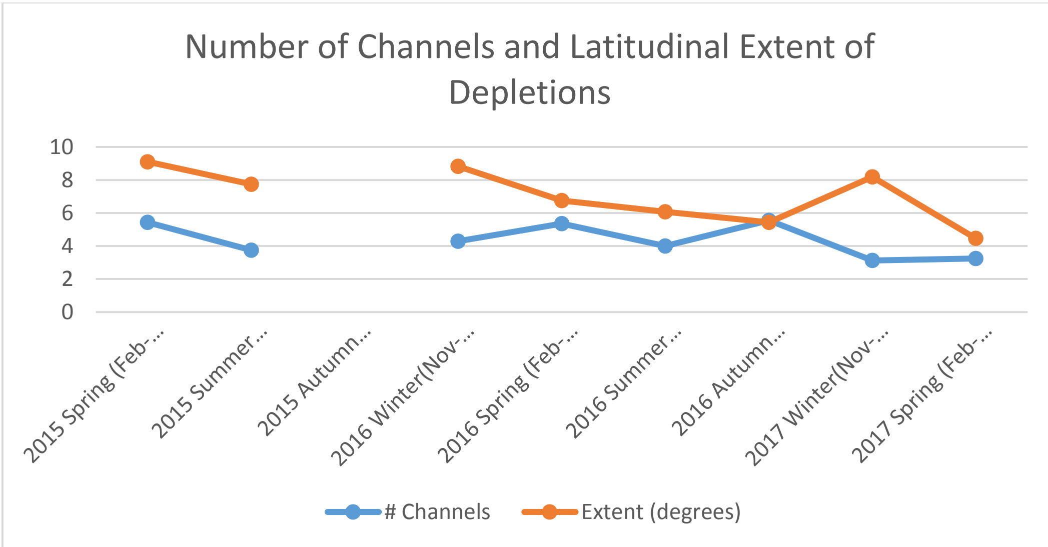


Figure 4

Figure 4 shows seasonal trends for the number of depletion channels and the absolute value of the latitudinal extent of all depletions from the spring of 2015 to the spring of 2017. The extent is the southernmost point of a depletion that was visible in the images. Any depletion that extended beyond the bottom of the image was capped at a maximum extent of -12 degrees while being recorded in this data set. The trend of the number of channels and the absolute value of their their extent over the entire data set is decreasing. The downward trend in data correlates with the downward trend seen in the current solar cycle.

5. STORM EVENTS

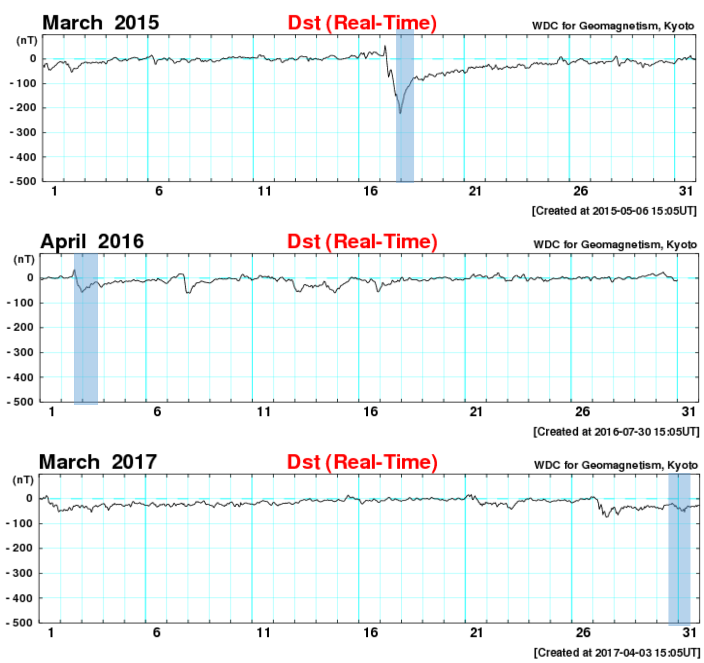
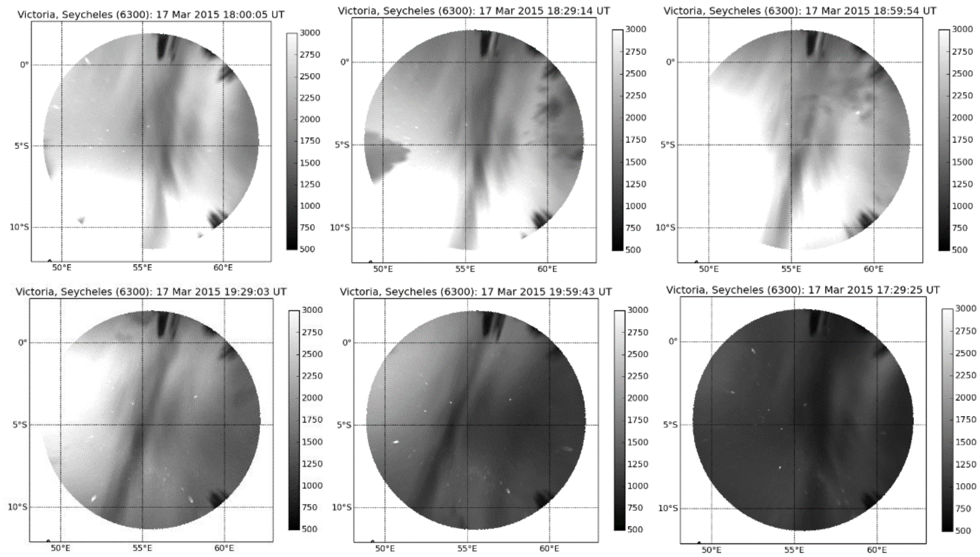


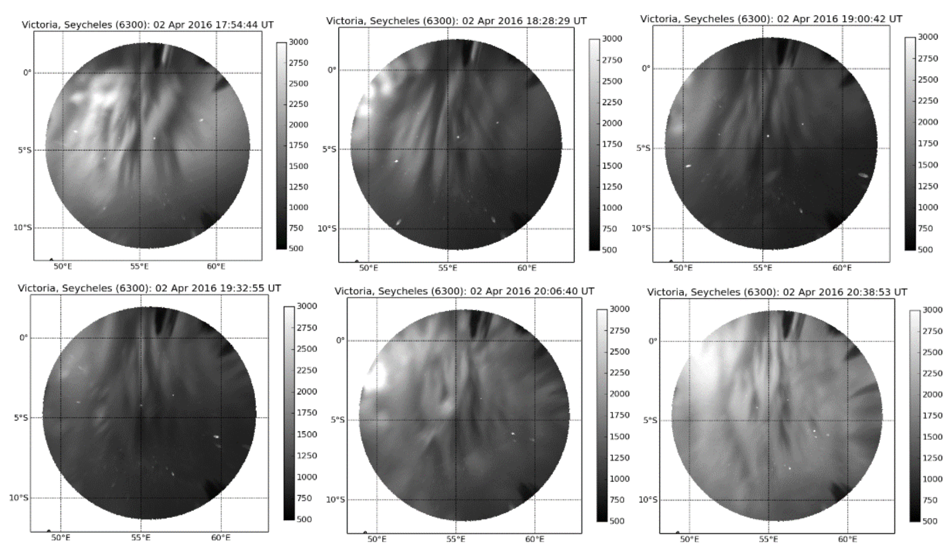
Figure 5

Three events were chosen in the timeframe of the Seychelles data set. Each event explains what was seen in the images from the all-sky imager. Seen in Figure 5, first a recent intense storm from March 17th, 2015, second a smaller storm from April 2nd, 2016 and third on March 30th, 2017 at the end of a long time period of negative D_{st} . D_{st} is a measurement of the effects from the ring current during storm time on ground based magnetometers.



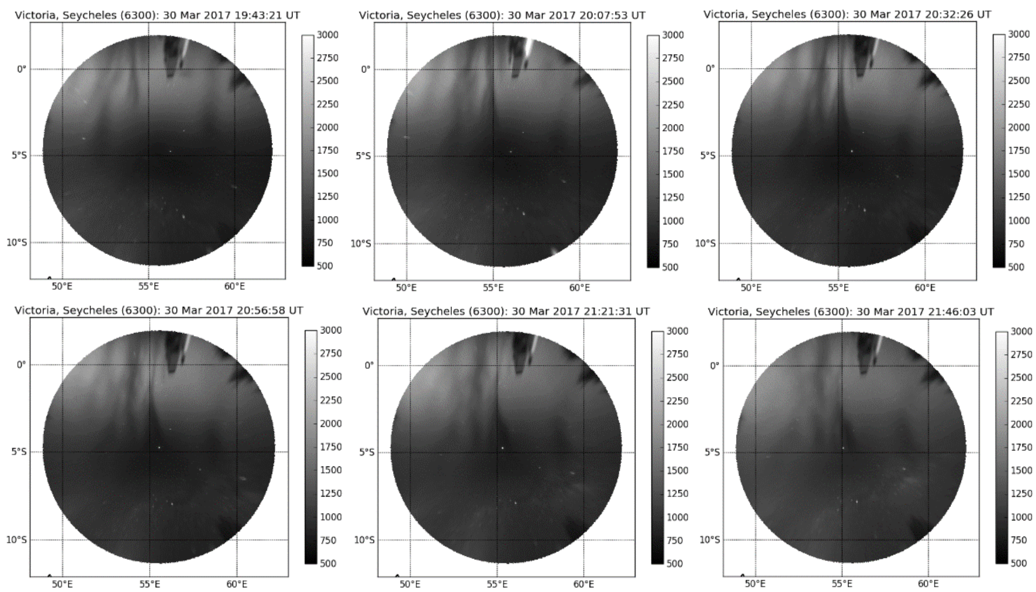
March 17th, 2015

The March 17th, 2015 event had a strong drop in D_{st}. The initial Ionospheric crest is at approximately 22:00LT, 4 hours after sunset, with LT meaning local time. There were two large depletion channels reaching from the top of the image to the bottom. The depletions traveled westward with a tilt on the southern end. There was one time period where the ionosphere brightened on the northern end of the image.



April 2nd, 2016

The April, 2nd, 2016 event had a much weaker drop in D_{st}. The initial Ionospheric crest is at approximately 20:15LT, 2 hours after sunset. A second Ionospheric crest happened at 00:40LT. The depletions drifted eastward, stopped, and then drifted westward. They also showed a slight tilt, but not nearly as defined as seen in the March, 17th, 2015 event. This event had two separate brightness peaks.



March 30th, 2017

The March 30th, 2017 event had no major drop in D_{st} but showed both eastward and westward movement with a slight tilt as it moved westward. This event also had two separate brightness peaks as in the April 2nd, 2016 event, but not as strong. The first peak happening at approximately 21:15LT, and the second peak happening at approximately 23:45LT.

6 SUMMARY

We were able to verify that the Ionosphere showed a brightening between 2-4 hours after sunset. On some occasions, based on the geomagnetic conditions for the night, there was a second brightening. The Ionosphere also decayed post sunset. The movement of depletions is largely eastward with the special cases being those caused by strong geomagnetic activity causing a reversal and westward movement. The Ionosphere and depletions appeared to degrade together. We were also able to verify seasonal similarities where the Ionosphere visibility was higher in equinox months, and the number of nights with depletions were higher in equinox months. The downward trend of the depletion statistics is similar to the downward trend in solar cycle activity. For the three selected events, we shows the Seychelles Ionospheres reaction to a sharp and mild D_{st} drop as well as after a prolonged negative D_{st}, which is what appears to cause much of the differences seen. The time of the D_{st} drop seemed to play a role in what part of the Ionospheres response we were able to see.

ACKNOWLEDGEMENTS

This work is supported by Midway Research Center and Windie Borodin (8140) of the Naval Center for Space Technology, Naval Research Laboratory, and the U.S. Air Force.

The All-Sky Camera was provided by the Naval Research Laboratory Capital Procurement Program.

REFERENCES

T.J. Fuller-Rowell & M.V. Codrescu. (1996). On the seasonal response of the thermosphere and ionosphere to geomagnetic storms. Journal of Geophysical Research, 101(A2), 2343-2353

Hyosub Kil, Heelis, R. A., Paxton, L. J. & Oh, S.J. (2009). Formation of a plasma depletion shell in the equatorial ionosphere. Journal of Geophysical Research, 114.

G.O. Walker. (1981). Longitudinal structure of the F-region equatorial anomaly—a review. Journal of Atmospheric and Terrestrial Physics, 43(8), 763-774.