Statistics of High Latitude Sporadic E Layer Occurrence derived using Incoherent Scatter Radar Observations

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Abstract

Sporadic-E (Es) layers are characterized as thin layers (1-5 km) of enhanced electron density that occur between 90-120 km in altitude. Sporadic E at mid- and low-latitudes has a reasonably well established climatology, while at high latitudes there have been fewer investigations that have characterized the climatology of sporadic E occurrence using altitude resolved measurements. Incoherent scatter radar provides direct altitude resolved measurements of the E-region ionosphere with relatively high altitude resolution. Since 2008, the Poker Flat Incoherent Scatter Radar (PFISR) has been operating in nearly continuous operations through a low duty cycle mode, thus enabling observations of sporadic E. The distinction between Es and auroral precipitation is detectable and is generally associated with the differences in structure height with Es being on average smaller in altitudinal range and shorter time duration. The purpose of this investigation is to present observations of sporadic E derived from this nearly continuous database of alternating code and Barker code PFISR data spanning the years from 2007-2021. We visually identified the sporadic E layers and have found approximately 300 events. We present statistical results of the occurrence, duration, and characteristics of high latitude sporadic E derived from these events. The preponderance of events manifested within 95 to 120 km, typically lasted 1 to 3 hours, and mostly occurred during May through September with observance peaking in July. In addition, the trends indicated a potential disconnect between sporadic-E events and auroral activity, which was previously considered the primary driving force behind high latitude sporadic-E events. The climatology of high latitude sporadic E is an important contribution that must be considered in future high latitude models of the ionosphere.

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Introduction

Sporadic-E (Es) layers are characterized as thin layers (1-5 km) of enhanced electron density that occur between 90-120 km in altitude. Sporadic-E at mid- and low-latitudes have a reasonably well established climatology, while at high latitudes there have been fewer investigations that have characterized the climatology of sporadic-E occurrence using altitude resolved measurements. Incoherent scatter radar provides direct altitude resolved measurements of the E-region ionosphere with relatively high altitude resolution. Since 2008, the Poker Flat Incoherent Scatter Radar (PFISR) has been operating in nearly continuous operations through a low duty cycle mode, thus enabling observations of sporadic-E. The distinction between Es and auroral precipitation is detectable and is generally associated with the differences in structure height with Es being on average smaller in altitudinal range and shorter time duration. The purpose of this investigation is to present observations of sporadic-E derived from this nearly continuous database of alternating code and Barker code PFISR data spanning the years from 2007-2020.

Methods

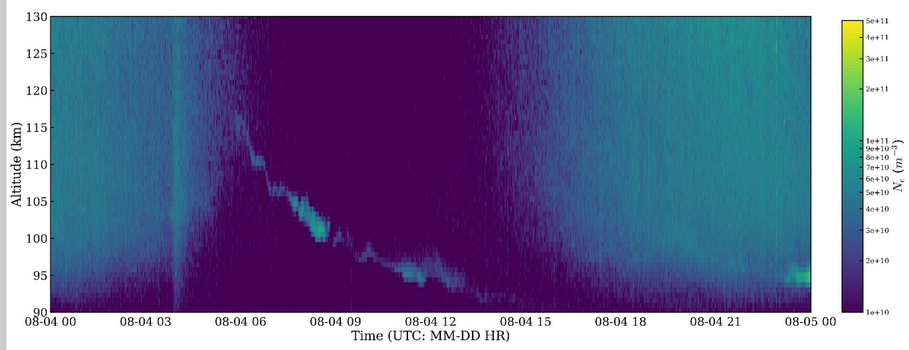

Figure 1. Plot of the distribution of electron density from 90 km to 130 km over the course of 8/4/2011. An identified sporadic-E is seen in between the diurnal cycle caused high density edges. The code plotted is Barker code.

The purpose of this investigation was to present observations of sporadic-E derived from the nearly continuous database of alternating code PFISR data, along with higher resolution barker coded data, spanning the years from 2007-2020. Utilizing these datasets, daily electron density plots were developed with Python; an example plot is shown to the left. The identification process consisted of analyzing plots in search of standout/lasting density enhancements which were verified by three researchers. In total 235 events were identified. Events from each researchers database underwent a thorough auditing process before a master database was made containing the date, start time, end time, lower altitude, upper altitude, and experiment of origin for each event.

Results

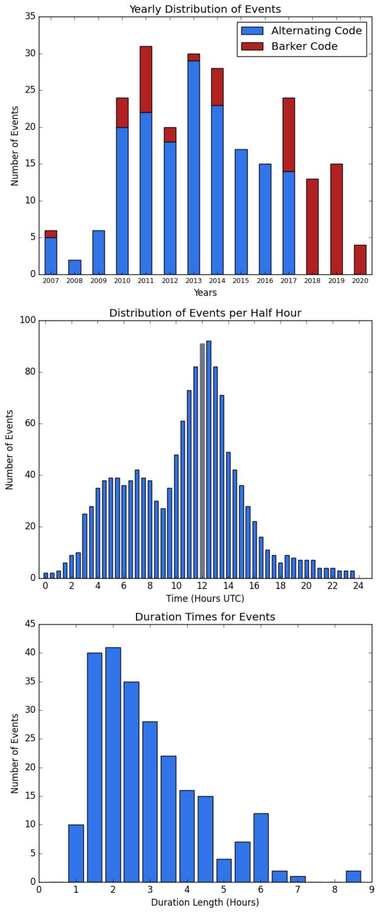

Figure 2. Depicted is the number of observed events between 2007 and 2020. The peak of events took place between 2010 to 2014, although the amount of data present for analysis varied among the years (data from the Poker Flat Incoherent Scatter Radar in Poker Flats, Alaska). The distinction is also made between the data collection codes.

Figure 3. Plot of daily occurrence rates per half hour given in UTC. The nightly trend of occurrences is evident although a slight bias may be present due to seasonal variations. These values peak around 12 UTC (3:00 local time, marked in gray) with a smaller peak around 6 UTC (data from the Poker Flat Incoherent Scatter Radar in Poker Flats, Alaska).

Figure 4. Depicted is the number of observed events binned based on their duration every half hour. The most common duration is 1.5 to 2.5 hours while longer lasting events became increasingly less prevalent; two outliers existed lasting 8.5 hours (these events took place on 8/4-5/2011).

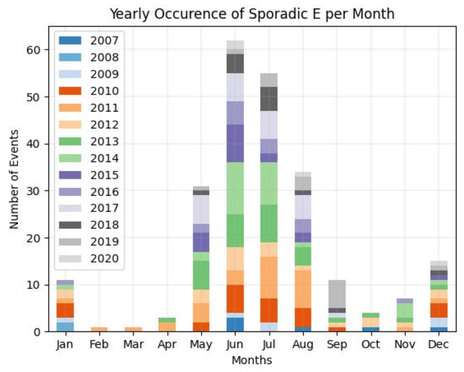

Figure 5. Shown is the number of observed events separated by months for the corresponding years. The summer months highlighted the peak in number of events over the time frame considered. In addition, during the winter months of December and January another minor peak was observed (data from the Poker Flat Incoherent Scatter Radar in Poker Flats, Alaska).

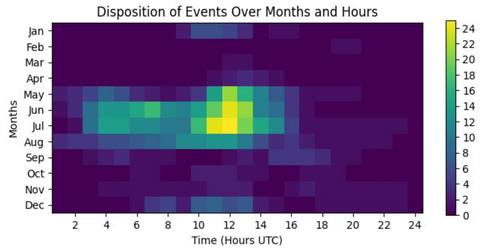

Figure 6. Plotted is the number of events over both time and months. A majority of events were seen surrounding magnetic midnight during the summer months. Additionally, a smaller highlight is seen surrounding magnetic midnight in the winter months. Events were also observed more during the early night versus early morning hours (data from the Poker Flat Incoherent Scatter Radar in Poker Flats, Alaska).

Discussion and Conclusion

Ultimately, occurrence rates and observations were found to be in agreement with mid- and low-latitude studies. The preponderance of events lasted 1.5 to 2.5 hours and were found clustering around magnetic midnight. In addition, trends were found in the time of year and time of day of events. An overall peak of observations was present during the summer months; a local increase was seen during the winter months relative to the fall and spring months which were mostly quiet. While most of the events were discovered in alternating code data, the rate of discovery with barker coded data was overall higher.

Some limitations of the data include:

- The diurnal cycle decreases visibility in the morning and evening hours; this effect is exacerbated during high latitude summer months with considerably shorter nights, however these months are when events are most observed.
- In general, barker coded data, which has a higher spatial resolution, is more sparsely available than alternating coded data.
- The data resulted from the collection only at PFISR in Poker Flats, Alaska with strict limitations on datasets used.

Finally, the climatology of high latitude sporadic-E is an important contribution that must be considered in future high latitude models of the ionosphere. We wish to expand this study to derive volumetric information regarding sporadic-E layers and verify the generators of their formation in the high latitude region.

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