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# VARIABILITY IN THE OCCURRENCE OF SPORADIC E IN THE GEMINID METEOR SHOWER USING IONOSONDE BPAA AGAM DATA

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**ABSTRACT**

*Variability in the appearance of sporadic E in the Geminid Meteor Shower. The appearance of sporadic E does not always exist and suddenly appears, so sporadic E appears as a result of the Geminid Meteor Shower. Therefore, this research aimed to determine the variability in the appearance of sporadic E during the Geminid Meteor Shower. This type of research was descriptive analysis research. This research includes data collection, data processing, and data analysis on sporadic E layers. The data was linked to the Geminid Meteor Shower events on December 12, 13, and 14 in 2014, 2019, and 2020. The results of this research show that there were significant differences in the appearance of the Sporadic E layer at the peak of the Geminid Meteor shower. Where it had increased foEs and h'Es as Sporadic E layer parameters. foEs and h'Es before the peak of the Geminid Meteor Shower were known to be normal with foEs values between 2-4.2 MHz and h'Es at an altitude of 102-147 km. When the Geminid Meteor Shower peaked, foEs increased to 11.67 MHz and h'Es at an altitude of 147 km. After the peak of the Geminid Meteor Shower, there was a decline until it returned to normal with foEs ranging between 2-4.4 MHz and h'Es at an altitude of 99-147 km. An increase in foEs and h'Es was associated with the Geminid Meteor Shower phenomenon, so the Geminid Meteor Shower was variability in the appearance of Sporadic E during the Geminid meteor shower.*

**Keywords:**Geminid Meteor Rain; Sporadic E Layer; Ionosonde



## I. INTRODUCTION

The solar system consists of celestial objects that move according to their respective orbits, which were controlled by the Sun's gravity. One of the celestial objects was a meteoroid. Meteoroids were solid objects ranged in size from 10 $\mu m$ to 1 $m$ that move in interplanetary space [1]. When a meteoroid enters the Earth,s atmosphere, it rubs against the layers, became hot and blazed and taked on the appearance of a shot star or meteor. A meteor was a high-velocity meteoroid that burns and glows as it enters the Earth's atmosphere [2]. Meanwhile, a meteor was a phenomenon of the path of falled celestial objects entered the Earth's atmosphere [3]. Meteoroids entered the Earth's atmosphere in large numbers, so the event was called a meteor shower or meteor shower.

Based on observations and theoretical models of meteor showers, the Geminids were showed to be the densest Geminid stream, with the nucleus of comet 3200 Phaethon traversed Earth's orbit since the began of the 19th century and continued for another 100 years [4]. The Geminid meteor shower was one of the annual meteor showers with the highest peak activity on December 13$^{th}$ [5]. Therefore, these research data were aligned with the peak of the Geminid meteor shower. The data dates in this studied were three days, namely, before the peak on December 12$^{th}$, at the peak on December 13$^{th}$, and after the peak of the Geminid meteor shower on December 14$^{th}$. The Geminid meteor shower was a meteor that came from the emanation of the constellation Gemini. Geminid meteor shower activity was become one of the most intense annual meteor showers in recent years, with peaks of 120 to 140 meteors [6]. Based on the spectroscopic analysis of the Geminid meteor, the *Mg/Fe*

ratio was found to be 1.5 to 3 times greater than the chondrite value [5]. The abundance of metals from the Geminid meteor spectrum in 2004 shows that the Geminid meteor shower was different from other meteors.

The thermosphere was the name of the layer of Earth,s atmosphere through which meteor showers pass. There was a layer with significant ionized power in the thermosphere at an altitude of 100 and 175 kilometers. This layer, known as the ionospheric layer, serves as a field of reflection for radio waves that the Earth can emit and receive [7]. The ionospheric layer can enrich metal ions in the Earth's atmospheric layer at an altitude of about 100 km. An increase in metal ions in the Earth's atmospheric layers, particularly in the E layer, can trigger the formation of the sporadic E layer. Sporadic E shift, i.e. H a layer occurred at any time, the existence of which was unusual, and which appears suddenly at an altitude of about 90 km to 120 km above the Earth's surface. Several meteor showers has been researched in the past. There were 45 meteor showers among them, all of varying intensity [8]. 70 of the 95 meteor showers that the International Astronomical Union estimated to have occurred between October 21$^{th}$, 2010, and March 31$^{th}$, 2013, were caused by orbital elements [9]. One of the meteor showers that appears to have had an impact on the development of the intermittent E layer over Sumedang in 2014–2015 was the Geminid meteor shower. As a result, there were variations in the parameters' standard data values for the ionospheric layer.

Differences in standard parameter values can be detected using the *Frequency Modulation Continuous Wave (FMCW*) ionosonde at the Agam Center for Space and Atmospheric Observations (BPAA). This tool was located at BPAA Agam, Kototabang. Ionosonde FMCW was the result of a collaboration between LAPAN and the National Institute of Information and Communication Technology (NICT) Japan, starting with observations in 2004. The results of Ionosonde's data were ionograms that describe the state of the ionosphere [10]. An ionogram was a record of the state of the ionospheric layer, presented in the form of a curve of the relationship between frequency and apparent height. The frequency of the sporadic E-layer (*foEs)* was the highest frequency that lies between its peak frequency and the ceiling frequency (lowest frequency). The apparent height of the sporadic E-layer (*h'Es)* was the highest height reflected from the Ionosonde.

Based on the above background explanation, the author was interested in conducting this research titled "Variability In The Occurrence Of Sporadic E In The Geminid Meteor Shower Using Ionosonde BPAA Agam Data". The appearance of sporadic E does not always occur and occurs suddenly. Its occurrence can be caused by various factors. One factor in the formation of Sporadic E was the occurrence of meteor showers. The Geminid meteor shower was one of many that has seen an increase in activity in recent years. Therefore, it was thought that the Geminid meteor shower was to blame for the appearance of E Sporadic. Was the sporadic E's frequency variable during the Geminid meteor shower? This study tries to quantify the variability of the occasional E layer's appearance during the Geminid meteor shower. The Geminid meteor shower occurred in the BPAA Agam region on December 12, 13, and 14 in 2014, 2019, and 2020, respectively. It was believed that this study's findings will contribute to forecasted ionospheric layer conditions, enabled smooth HF radio communication in Indonesia during natural events.

## II. METHOD

This research used qualitative research as its methodology. Descriptive analysis research was employed in this study. Now, research observation was the research methodology adopted. In this work, the sporadic E parameters used to calculate the variability of sporadic E occurrence were the foEs and h'Es. Ionographic FMCW recordings at BPAA Agam were used to generate the ionogram data. The Geminid meteor shower in December was linked to the ionogram data used in this investigation.

The Geminid meteor shower was a peak event, so three days of data were collected for this study. The three data days were December 12$^{th}$ before the peak of the Geminid meteor shower, December 13$^{th}$ when the Geminid meteor shower peaks, and December 14$^{th}$ after the peak of the Geminid meteor shower in 2014, 2019 and 2020. The research was conducted through the data collection process at BPAA Agam was also a research area. BPAA Agam was located in the West Sumatra region. This area was located at an altitude of 865 meters above sea level with the coordinates of 100.32°E longitude and 0.23°S latitude in Kototabang, Kec. Palupuh, Kab. Agam, West Sumatera [11]. Kototabang was a vegetation area (30 km) consisting mostly of tropical forests, located in the equatorial region and far from urban areas [12]. Therefore, the urban light pollution was very far from the observation site, so it was very suitable for observing the sky at night.

The celestial observation used in this research was the FMCW Ionosonde. Ionosonde FMCW was a frequency recorder for the ionospheric layer. Radar capable of transmitting and receiving frequencies in the HF band (2-30 *MHz*) in a direction perpendicular to the ionosphere. Ionograms were observation data from the

FMCW Ionosonde in PNG file format. It was then processed by scaling using various software programs such as Matlab. Matlab was an abbreviation for *MATrix LABoratory*, a computer software that uses vectors and matrices as the main data elements. This computer-aided calculation method was called a calculation method. The advantage of using computers was that very precise/accurate calculations can be made [13]. The computer software used in this research was *Matlab R2016b*. The results of the ionograms data were recorded in *Excel* and extracted into graphical form using Matlab. Ionogram data was in the form of a digital image. Frequency values were read based on the *pixel* position of the desired point converted into frequency.

*Scaling* involves extracting frequency and height values for the ionospheric layer from the ionogram. The BPAA Agam ionogram was an image file in PNG format that displays a graph of frequency (*x-axis*) versus height (*y-axis).* The respective values of the foEs and h'Es were grouped in a table with columns with date (per day) and rows with time (per 15 minutes). Then the time was determined by the median, so that the median was obtained for 00.00, 00.15, 00.30, etc. This type of research was descriptive analysis research using primary data such as ionogram data recorded on the FMCW Ionosonde device at BPAA Agam.

## III. RESULTS AND DISCUSSION

Ionogram data were obtained from FMCW Ionosonde. Therefore, the data obtained was in the form of foEs and h'Es data based on frequency and altitude. foEs before occurrence, during occurrence, and after the peak of the Geminid meteor shower. The data in the image was frequency data in *MHz* units, which goes beyond the normal limits of foEs and time unit data (hours). foEs that exceed normal limits were visible in the bar chart in Figure 1. Figure 1 shows FoEs data to determine the existence of value differences (variability) at specific times.

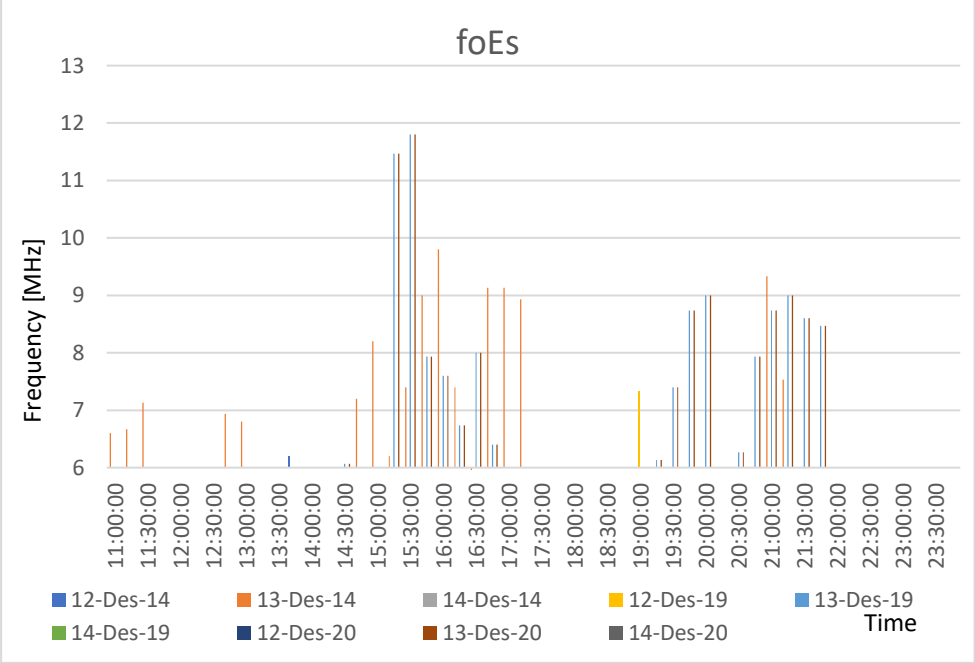


**Fig 1** . Sporadic critical E frequency (foEs)

The peak of the Geminid meteor shower had the highest frequency value, which was FoEs. Prior to the height of the Geminid meteor shower, the frequency had a usual frequency value of 2–6 MHz. The number of foEs decreased when the Geminid meteor shower peaked. This indicates a decline in the quantity of foEs followed the peak of the Geminid meteor shower. The quantity of foEs following the peak and during the peak of the Geminid meteor shower in 2014, thus, varied noticeably. The peak of the Geminid meteor shower occurred on December 13$^{th}$ [5]. Therefore, the data in this study were collected for three days, namely, December 12$^{th}$ before the peak of the Geminid meteor shower, December 13$^{th}$ when the Geminid meteor shower peaked, and December 14$^{th}$ after the peak of the Geminid meteor shower.

Data for 2019, the highest value of FoEs reached a frequency of 7.33 *MHz* on December 12$^{th}$, 2019. Before the peak of the Geminid meteor shower, there was a frequency increase that exceeded the normal frequency. This increase was also greater than the data from December 12$^{th}$, 2014, where the frequency was known to be 6.2 *MHz*. There was also data from the peak of the Geminid meteor shower on December 13$^{th}$, 2019. It can be seen

that there was an increase in FoEs, which reached a frequency of 10.4 *MHz*. This increase was greater than the previous day and also compared to the frequency on December 13th, 2014, which was known to have reached 9.8 *MHz*. Ionogram data from December 14th, 2019, was the period after the Geminid meteor shower. This data cannot be read by the Ionosonde *SK Manager device*. If Ionosonde was not read, it was because Ionosonde was not working or there was an error. Therefore, ionogram data for December 14th, 2019 was missing.

Furthermore, the data for 2020 FoEs showed the highest frequency of 4.40 *MHz* on December 12th, 2020. This highest frequency was normal in the sporadic E layer. However, there were several increases in foEs on December 13th, 2020, with the highest frequency reaching 11.80 *MHz*. This frequency represents a significant increase compared to the previous day. The increase in foEs during the peak of the Geminid meteor shower was higher than before the peak of the Geminid meteor shower. Compared to the year of the peak of the Geminid meteor shower, the foEs in 2020 were higher than the FoEs in 2014 and 2019. After the peak of the Geminid meteor shower, the highest frequency reached 4.53 *MHz*. This frequency was lower than the frequency on December 13th, 2020. Therefore, there was a decrease in FoEs after the peak of the Geminid meteor shower. The frequency on December 14th, 2020, was included in the Normal category in the Sporadic E layer.

The sharp increase in foEs on December 13th was consistent with research by Reddy, KC, Kumar, DVP and Yellaiah, G. The Geminid meteor shower was one of the annual meteor showers with the highest flow and peaks on December 13th [14]. The latest research by Murtazov, AK also states that the peak activity of the Geminid meteor shower always occurs on December 13th to 15th [13]. The activity of the Geminid meteor shower increases every year. The frequency of data in 2020 was higher than in 2014 and 2019. Previous research by Ryabova, G. and Rendtel, J. also found that the activity of the Geminid meteor shower will slowly increase. The rise was caused by *Phaethon's* flow, as the core of the Geminid flow gradually approaches Earth's orbit [15]. Therefore, the occurrence of sporadic E during the Geminid meteor shower was variable.

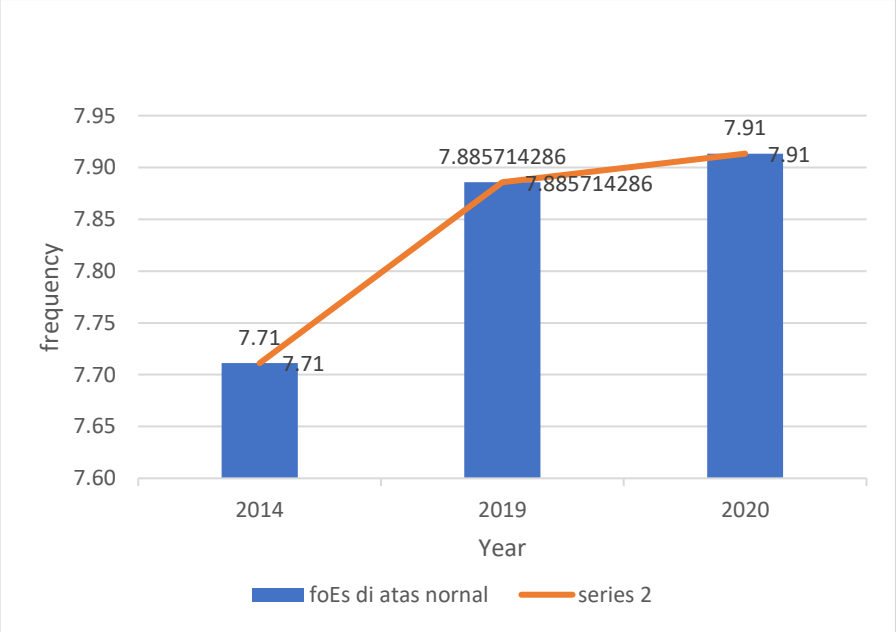


**Fig 2**. Average foEs

The increase in foEs increases gradually every year. This can be seen in Figure 2, which shows the average FoEs plot above normal. This increase occurs every year. This increase occurs when the Geminid meteor shower occurs in December. However, there was no primary data on the Geminid meteor shower. It was known that the timing of the Geminid meteor shower was determined from data published by the National Aeronautics Institute (LAPAN) in a news article by CNN Indonesia. The article stated that LAPAN explained the Geminid meteor shower phenomenon with the Geminid meteor shower peaking on December 13th, 2020. Not only in 2020, there will be LAPAN observation reports in several online articles every year. The increase in FoEs during the day was due to the accumulated ionization effects of the mesosphere and lower thermosphere dynamics in the Earth's ionospheric layer [8]. During the peak of the Geminid meteor shower, there was an increase in foEs at night. As Ristanti [9] noted, the cause of the formation of sporadic E was very strong meteor showers, which increased the number of electrons in the E layer. Therefore, the sporadic E layer may be influenced by the Geminid meteor shower. Increasing the high frequencies in layer E can have both positive and negative effects [4]. The negative

effects on the formation of the E layer can hinder the propagation or reflection of radio waves in the ionospheric layer. The wave propagation blocked by the sporadic E layer suddenly appears as an instantaneous change in the height of the radio wave reflecting layer.

Next were the apparent elevation data for the sporadic E layer (h'Es) in Figure 3. These data show data before the occurrence, during the occurrence, and after the peak of the Geminid meteor shower. The data in the image was apparent elevation data in km units, which was above the normal h'Es limit, and data in time units (hours).

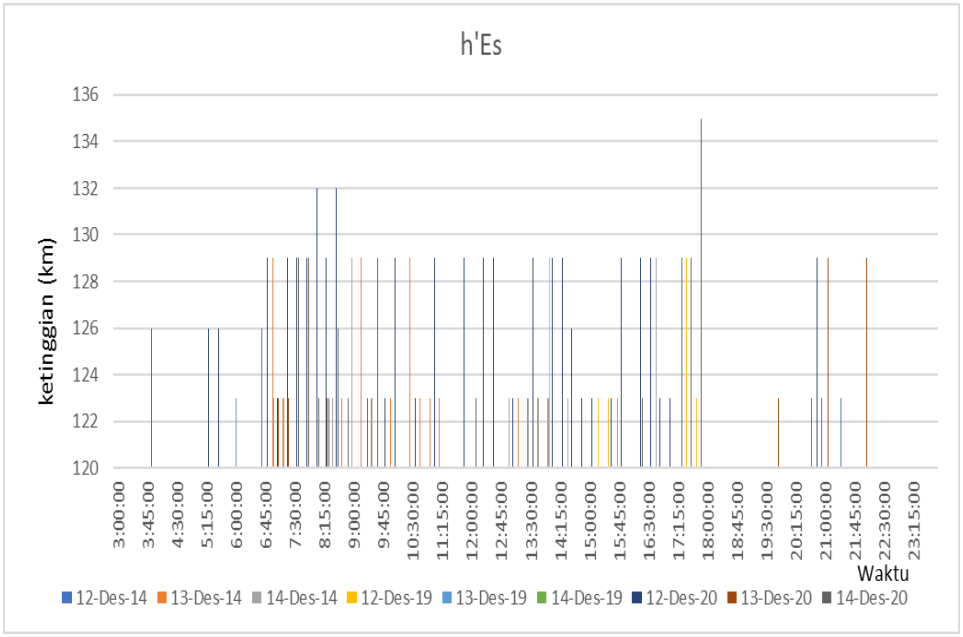


**Fig 3** . Sporadic E height (*h'Es)*

Before the peak of the Geminid meteor shower in 2014, the h'Es data only increased once, which was not very significant. Other than that, the height prior to the top was typical. The range of normal h'Es values was 90 to 120 kilometers. At the peak of the Geminid meteor shower, H'Es was located 129 kilometers above Earth. This value did not increase significantly compared to the previous day, in fact, the h'Es value normalized at night when the Geminid meteor shower reached its peak. According to the data from December 14$^{th}$, 2014, there were no appreciable differences from the data from the day before. After the height of the Geminid meteor shower, h'Es began to decline.

The apparent height of E Sporadic in 2019 shows that h'Es was the highest with an altitude of 129 km. The h'Es value normalizes at an altitude of 99 km at night. h'Es data as of December 13$^{th}$, 2019, the height of h'Es was about 100 km to 123 km. The h'Es value normalizes at an altitude of 99 km at night. The increase in h'Es during the peak of the Geminid meteor shower in 2019 did not increase significantly compared to 2014. The Ionosonde was destroyed after the meteor shower's peak on December 14, 2019, so no data could be read.

The h'Es data before the peak of the Geminid meteor shower was normal, with an altitude of 99 km. The highest h'Es value was 132 km. The increase in h'Es before the peak of the Geminid meteor shower in 2020 was higher than in 2014 and 2019. The h'Es data for December 13$^{th}$, 2020, was normal with an h'Es value of 99 km. The highest h'Es value with an h'Es value of 129 km. At night, when the Geminid meteor shower reached its peak, there was an increase in h'Es. h'Es data for December 14$^{th}$, 2020, were dates after the peak of the Geminid meteor shower. There was an increase with an h'Es value of 126 km at 03:45:00 WIB and an h'Es value of 129 km at 07:30:00 WIB to 07:45:00 WIB. The highest h'ES value with an h'ES value of 135 km occurred at 17:45:00 WIB. Apart from this time, the altitude was normal.

The occurrence of h'Es during the day, expressed by Varuliantor that the occurrence of the height of the E layer usually occurs during the day, but sometimes also at night [4]. The rise during the peak of the Geminid meteor shower occurs for longer than before the peak of the Geminid meteor shower. Meanwhile, after the peak of the Geminid meteor shower, there was a decrease in h'Es values compared to during and before the Geminid meteor shower.

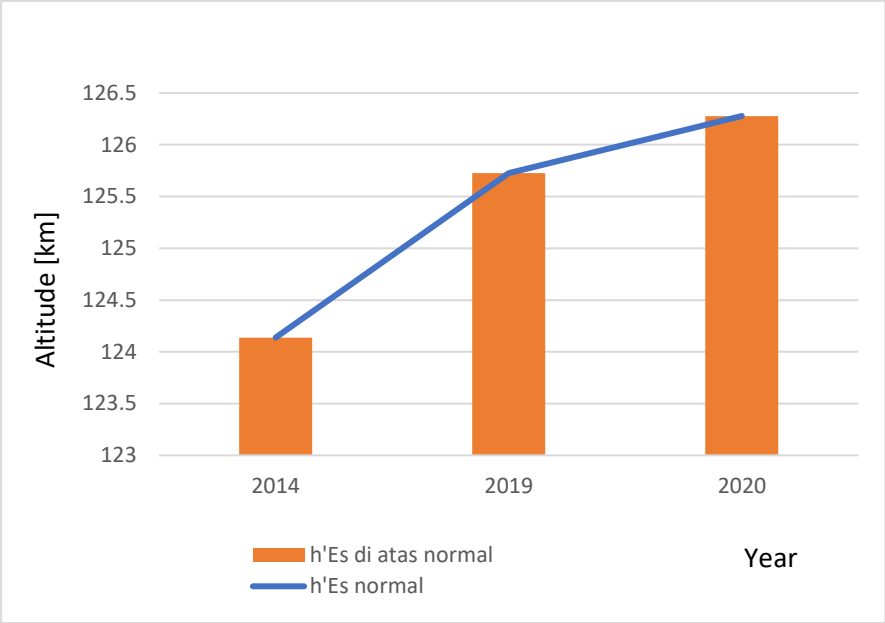


**Fig 4**. Average h'Es

The increase in foEs and h'Es during the day was due to the accumulated ionization effects of the mesosphere and lower thermosphere dynamics in the Earth's ionospheric layer [8]. During the peak of the Geminid meteor shower, there was an increase in foEs at night. Strong meteor showers boosted the amount of electrons in the E layer, which led to occasional E. As a result, the Geminid meteor shower might have an impact on the occasional E layer. The consequences of raising the high frequencies in layer E can be both beneficial and detrimental. The propagation or reflection of radio waves in layer E may be hampered by the presence of favorable or unfavorable effects on the layer's creation. An immediate shift in the height of the radio wave-reflecting layer signals the wave propagation obstructed by the sporadic E layer.

## IV. CONCLUSION

This study came to the conclusion that Sporadic E's appearance had a variable value during the Geminid meteor shower. A difference in value (variability) between the two variables can be seen in the occurrence of a very high sporadic E occurrence linked to the Geminid Meteor shower. The annual average h'Es exceeded the typical frequencies of 7.71 MHz, 7.88 MHz, and 7.91 MHz in 2014, 2019, and 2020, respectively. H'Es exceeded the average height by 124.2 km, 125.8 km, and 126.3 km each year in 2014, 2019, and 2020, respectively. Every year when the Geminid Meteor shower occurs, the annual average of foEs and h'Es shows an increase in foEs and h'Es.

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