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Qualitative analysis of ionospheric disorders in Solok earthquake (March 6, 2007) viewed from anomalous critical frequency of layer F (f0F2) and genesis spread F

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Abstract. A qualitative analysis has been conducted by comparing the critical frequency anomalies of layer F (f0F2) and Spread F events to see the correlation with seismic activity before the Solok earthquake (March 6, 2007) in West Sumatra. The ionospherics data used was taken using the FMCW ionosonde at LAPAN SPD Kototabang, Palupuah, West Sumatra. The process of ionogramme scaling is done first to get the daily value of f0F2. The value of f0F2 is then compared with its monthly median to see the daily variations that appear. Anomalies of f0F2 and Spread F events were observed from February 20, 2007 to March 6, 2007. The presence of f0F2 anomalies was the negative deviation and the presence of Spread F before earthquake events were recommended as Solok earthquake precursors as they occurred when geomagneticsics and solar activities were normal.

1. Introduction

Along with the development of seismology, theories for earthquake prediction are increasingly emerging. Some methods used to predict earthquakes are seismogeologic, statistic analysis of seismicity, correlation analysis and precursor methods. Such theories are generally obtained by conducting case studies of major earthquakes that have occurred. One study of earthquake prediction ever done is to observe the earth's atmosphere.

Ionosphere is a region of Earth's upper atmosphere, from about 50 km to 1,000 km altitude from the earth's surface, and contains charged particles [1]. The morphology of the ionosphere layer is divided into layers D, E, E-Sporadic (Es), F_1 and F_2 [2]. Layer D has the properties to absorb high-frequency HF (High Frequency) radio and VHF (Very High Frequency) waves, while others reflect radio wave energy, thus the readable layers of the ionosonde are layers E, Es, F_1 and F_2, while layer D not [3].

Deformation in the earthquake preparation zone will cause radon deposited in the rock to break out into the air and decay. The radon decay energy ionizes atoms in the atmosphere and causes changes in ionic composition of ions [4-6]. Earthquake prediction can be done on all four layers because there are electromagnetic waves as the effect of plate interaction in the ionosphere layer

More research is done on the ionosphere F layer because this layer appears during the day and night. Based on a case study conducted by T. Xu [7], a decrease in the critical frequency (foF_2) in the ionosphere F layer from its monthly median 3 days before the Wenchuan earthquake, China on May 12, 2008. At the time of disturbance occurs geomagneticsic activity was normal. So also with solar activity. Therefore, the disturbance of the F layer is likely to be caused by an earthquake that will occur. In addition to the critical frequency change of foF_2 (up or down of the monthly median) of the ionosphere F layer, there is also a disturbance of Spread F. Spread F is the distribution of the radio wave traces reflected by ionosphere layer F. This trace spread occurs due to instability that occurs below the layer height F ionosphere [8]. According to Muslim [9], Spread F disruption rate is proportional to disturbance by solar activity. In the event of Spread F the ionosphere the critical frequency of layer F can not be observed anymore. Spread F observation can be done without long time, because it can be observed directly on an ionogramme of ionosonde recording without having to separate ionogramme parameters.

In this research will be seen the influence of the Solok earthquake (March 6, 2007) against the ionosphere F layer condition. Specific observations were made by comparing the critical frequency anomaly characteristics of layer F (foF_2) and the occurrence of Spread F prior to the earthquake that was detached from the effects of magnetics storm and solar storm.

2. Research Methods

The data used is the critical frequency data of layer F (foF_2) recorded on FMCW (Frequency Modular Continous Wave) ionosonde located in LAPAN Kototabang, Agam Regency, West Sumatera at Koto Tabang from February 20, 2007 to March 6, 2007. As data comparators were used magnetic storm data and solar activity data. The data of Dst Index is the number of units of magnetic activity every hour in 24 hours for 30 or 31 days according to the number of dates of the month. The solar activity data is the X-Ray Solar Flare data downloaded from the Space Weather Prediction Center (SWPC). The X-Ray Solar Flare data form is a graph that states the solar activity for each class for 3 days.

Scaling of the ionogramme to obtain the critical frequency value of layer F (foF_2) is carried out according to the method suggested by Jiyo [10]. In the ionogramme, foF_2 is the rightmost peak and is the highest peak in the ionogramme curve. To change the pixel value to frequency, the formula used is $f = 2 + (P_x - 80) \times 2/30$, with P_x being the pixel value on the x-axis.

After obtaining the value foF2 for 29 days every 15 minutes, then carried out statistical operations to get the median foF_2. Median used as a benchmark in viewing foF_2 variations that occur in every time. The foF_2 deviation (δfoF_2) is obtained from the median difference with the observed foF_2, and any deviations exceeding the standard deviation value ($\pm \sigma$) are marked as an anomaly.

To get the result of Spread F is done by observing all ionogramme data from February 20, 2007 until March 6, 2007 and record the time of Spread F. The results of this study separated spread F data from ionogramme data that is not disturbed. Furthermore, the anomalous results (foF_2) and Spread F obtained are compared with Geomagneticsic activity data and solar storm activity over that time span.

3. Results and Discussion

Observation of ionospheric data recorded by FMCW ionosonde, observation of geomagneticsic activity and observation of solar activity (sunspot number parameter) done before Solok earthquake starting from February 20, 2007 until March 6, 2007

3.1. Radius zone Preparation of the earthquake Solok March 6, 2007

Radius of the Solok earthquake preparation zone calculated by the Dobrovolsky equation [5] is 564.94 km. The earthquake preparation zone radius includes also Kototabang area where ionosonde equipment is located. Thus, it is certain that the ionosphere in the Kototabang region is interfering with seismic activity in the earthquake preparation zones.

3.2. Dst Index around the time of the Solok 2007 earthquake

The plot of the Dst index around the time of the Solok 2007 earthquake is shown in Figure 1. Although it looks fluctuating, the drop in the Dst index around the maximum Solok earthquake is only about 50 nT. The existence of disturbance in geomagneticsic activity can be known by the existence of fluctuation of the amplitude of geomagneticsic activity which decreased drastically enough to reach hundreds of nT [11]. So it can be said during 14 days before and after the Solok earthquake 2007 did not happened magnetic storm.

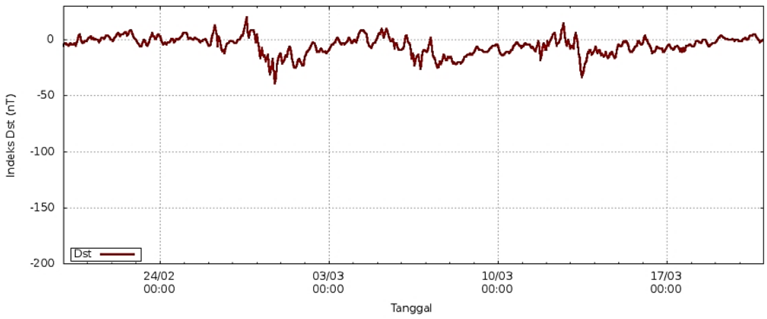
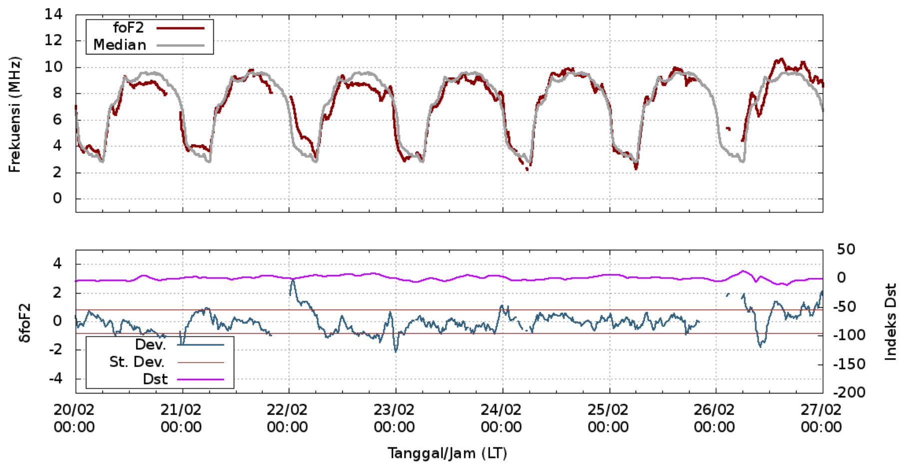


Figure 1. Dst index plot for February 20 - March 20, 2007, where there is no earth geomagneticsics field disturbance.

3.3 Critical Frequency (foF_2) before the 2007 Solok earthquake

Figure 2a shows plot foF_2, median, and plot deviation (δfoF_2) for the March 6th Solok earthquake, each for 7-14 days before the earthquake (Figure 2a) and 0 - 7 days before the earthquake (Figure 2b). Standard deviation used σ = 0; 84 MHz. Based on these limits, we select a significant decrease (exceeding the normal limits) during the day, ie on 20, 22, 26, 27 February, 05 and 06 March 2011.



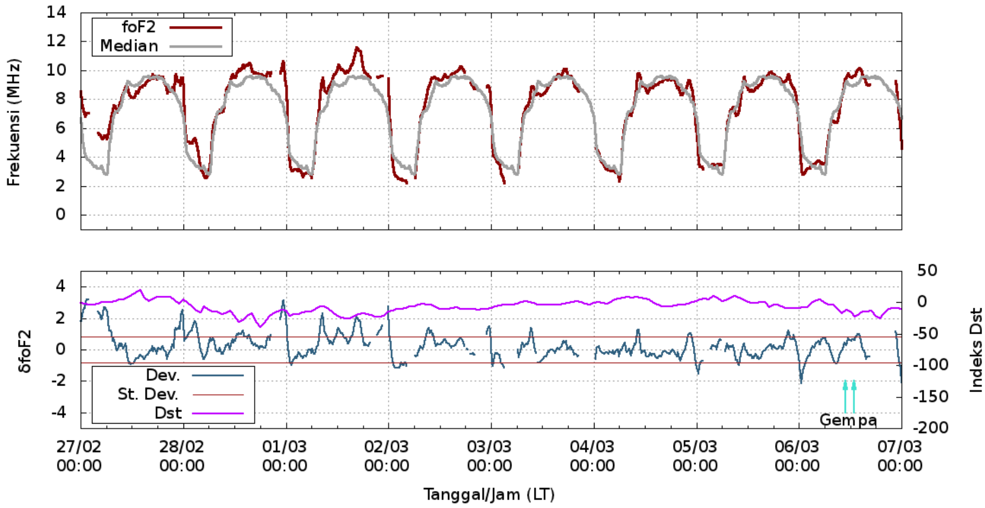


Figure 2. Plot foF_2 and its deviation for a) 14 - 7 days before the Solok earthquake and b) 7 - 0 days before the Solok earthquake.

The daily variation for February 20 is shown in Figure 3. In the early hours of February 20 foF_2 is quite stable with values that are not much different from the monthly median. Then, starting at 08.00 am foF_2 down and for the next 3 hours the value of foF_2 is below the median.

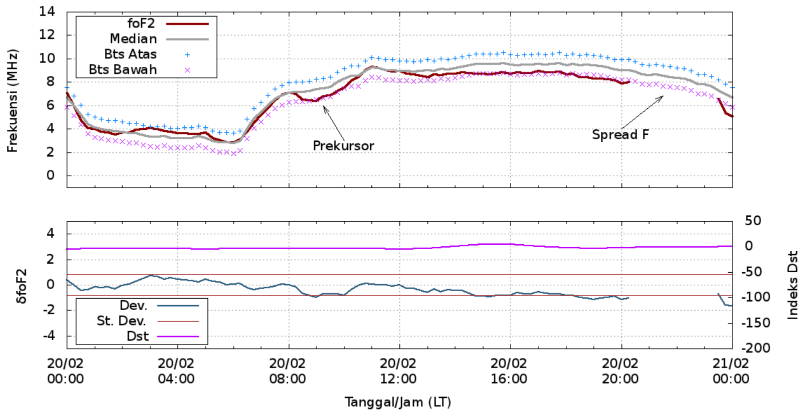


Figure 3. Plot foF_2 and deviation for February 20, 2007.

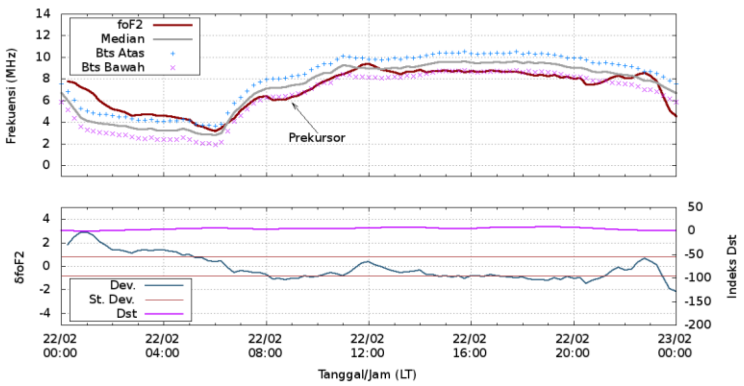


Figure 4. Plot foF_2 and deviation for February 22, 2007.

Next, the daily variations for February 22 are shown in Figure 4. Since the early days the foF_2 values look high. The critical frequency foF_2 has returned to its normal limit at 5:00 am, but continues to fall until it reaches a negative deviation. For February 26, 2007 or 8 days before the earthquake (Figure 5), foF_2 decrease occurs after the previous foF_2 exceeds the upper limit. Visible foF_2 has negative deviation starting at 09.00 WIB.

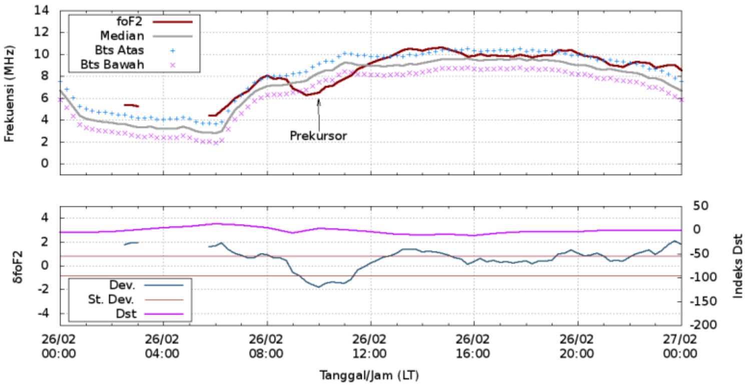


Figure 5. Plot foF_2 and deviation for February 26, 2007.

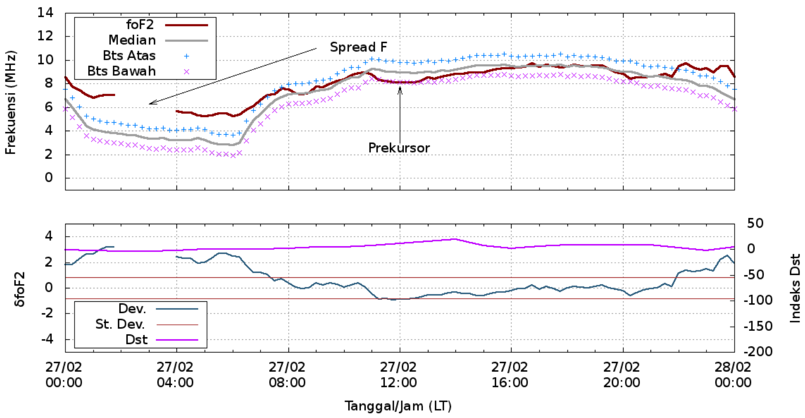


Figure 6. Plot foF_2 and deviation for February 27, 2007.

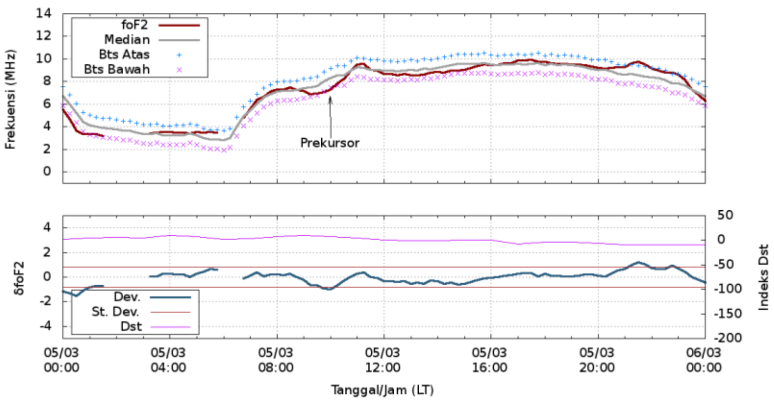


Figure 7. Plot foF_2 and deviation for March 5, 2007.

For February 27 (7 days before the earthquake), plot foF_2 and its deviation are shown in Figure 6. It appears that foF_2 is also high since the night, allegedly because there is Spread F. Around 11.00 WIB decreases, and at 16.00 WIB foF_2 is back in parallel with median. For one day before the earthquake, March 5, 2007, plots foF_2 and foF_2 are shown in Figure 7. The deviation pattern for March 5 looks the same as on 20 February.

Last for the 6th of March, 2007 which is the day of the earthquake, the plot is shown with Figure 8. The first earthquake occurred at 1049 WIB, while foF_2 began to look down at 06.00 WIB, 5 hours before the earthquake.

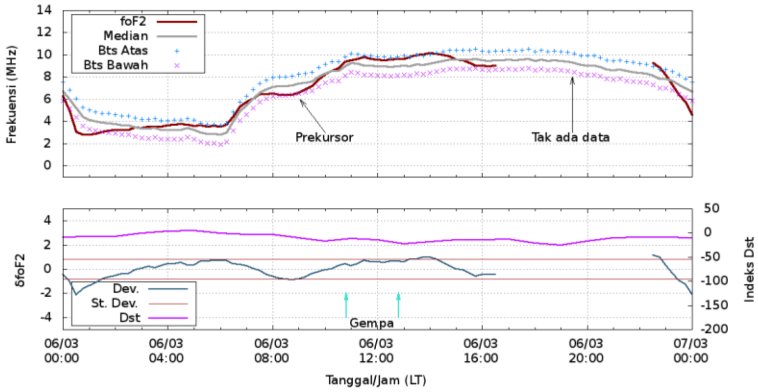


Figure 8. Plot foF_2 and deviation for March 6, 2007.

3.4 Spread F before the Solok 2007 earthquake

Spread F observations were performed starting from February 20, 2007. Figure 9 shows the critical frequency fluctuations of the uninterrupted layer of the ionosphere F (foF_2) and the critical frequency of the maximum ionosphere F (foF_2) layer occurring during the day, and decreasing in the early morning. This shows the activity of the ionosphere F coating under normal conditions. This ionospherics activity cycle will recur each day.

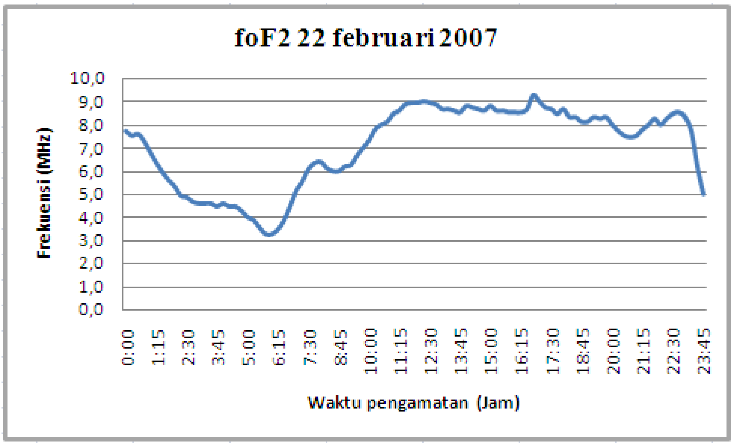


Figure 9. Critical Frequency of Ionosphere February 22, 2007.

On February 23, 2007, the ionosphere condition showed a low frequency at 00:00 to 06:15, which is small from 4 MHz and increased to 10 MHz during the day. This condition is still normal because the critical frequency pattern can be observed at any time as in Figure 10.

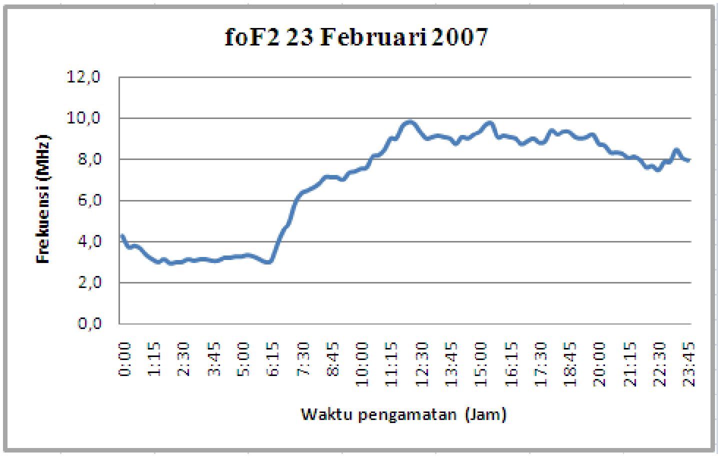


Figure 10. Ionosphere Critical Frequency February 23, 2007.

On February 24, 2007, the condition of the ionosphere F layer which did not undergo the ionosphere F layer trace spread (Spread F) but there was an E layer (E-Sporadic) disturbance at 5:00 am and the critical frequency of the ionosphere F layer (foF_2) was at outside the observed frequency limit so that it can not be observed on the ionogramme. At 07:00, the critical frequency of the ionosphere F layer begins to increase with increasing heat emitted by the sun, as shown in Figure 11.

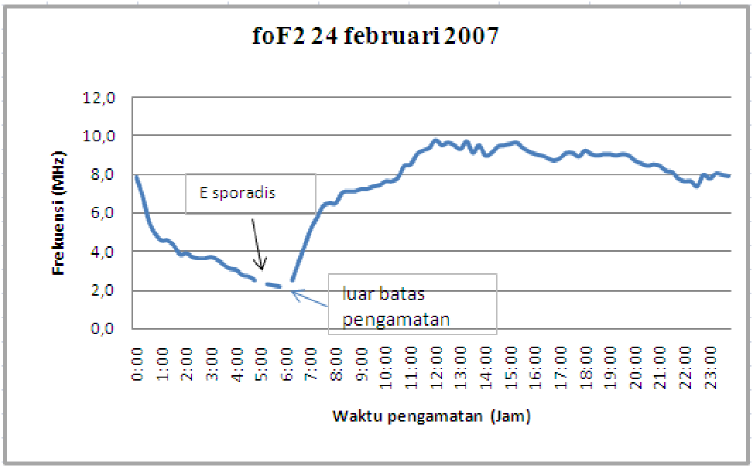


Figure 11. Critical Frequency of the ionosphere February 24, 2007.

Observations for the first period of ionospheric data from February 20, 2007 to February 26, 2007 showed that the ionosphere F layer is normal. As of 22, 23, February 24, 2007 there was no interruption. The observation of ionospherics data for this second period was conducted from February 27, 2007 to March 6, 2007. On March 2, 2007 the critical frequency of the ionosphere F layer was interrupted on04:30 until 05:30 because the critical frequency of the ionosphere F layer is beyond the observed frequency limit . This shows that the critical frequency of low ionosphere F coating is small from 2MHz. At 05:45 to 06:00 am accompanied by E-Sporadic (E_S) occurrence on layer E causes the reflected wave of ionosonde can not reach layer F. Then at 17: 45-19: 00 appears E-Sporadic again and continues with the incident Spread F at 19: 15-20: 00. After 45 minutes, Spread F occurs again from 20: 45-22: 45 as shown in Figure 12.

The ionosphere conditions on March 3, 2007 showed a decrease in frequency from 00:00 to 02:30 due to decreased solar intensity. From 03:00 to 06:15 and at 20:00, there is a disturbance in the E layer that is E-Sporadic. At 20:45 until 23:45, there is the appearance of Spread F as shown in Figure 13.

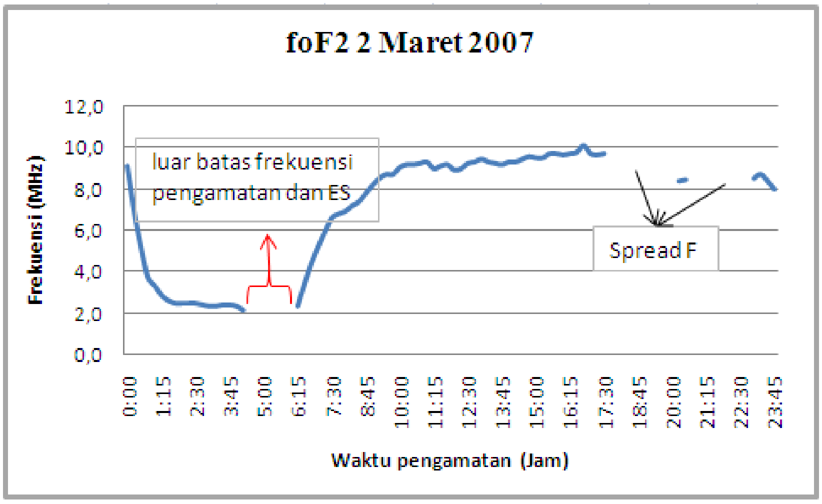


Figure 12. Critical Frequency of the ionosphere March 2, 2007.

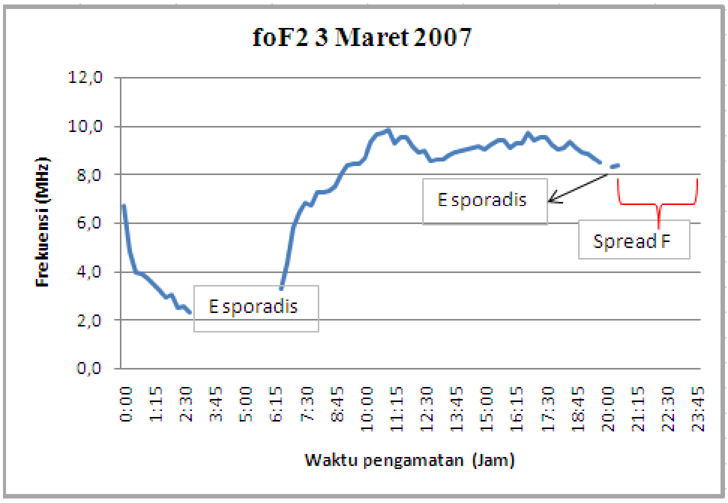


Figure 13. The Critical Frequency of the ionosphere March 3, 2007.

On March 5, 2007 Spread F took place at the end of the night at 02:00 to 03:00 as shown in Figure 14. Observations for the second period were from February 27, 2007 to March 6, 2007, ie, a week before the earthquake showed an emergence Spread F at ionosphere F layer. The appearance of Spread F is not influenced by geomagnetics activity, because from observation of geomagnetics data there is no interference at the geomagnetics so it does not affect layers of ionosphere F.

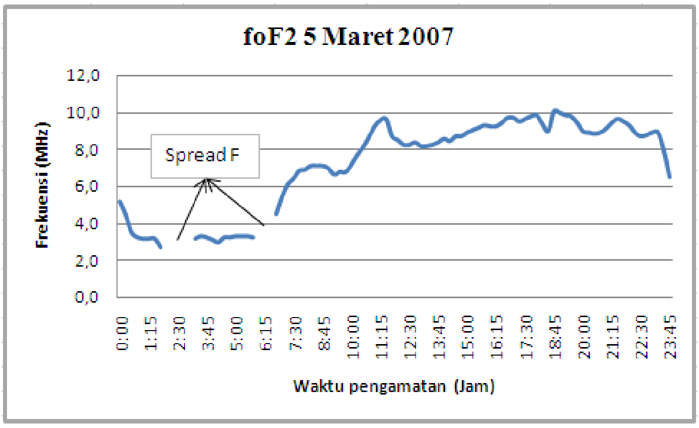


Figure 14. The Critical Frequency of the ionosphere March 5, 2007.

3.5 Sunspot Activity Chart based on Sunspot Numbers Around Time of Solok Earthquake

Figure 15 shows the solar activity based on the sunspot number. Sun activity decreased from February 19, 2007 to February 21, 2007 from sunspot number 20 to 10 and increased again on February 22, 2007, this condition repeated until February 27, 2007. On March 1, 2007 to March 3, 2007, the number the sunspot was 7, then increased on March 5, 2007 with the number of sunspot 17 and decreased until the sunspot became zero on March 7, 2007 until March 20, 2007. This number of sunspots is the number of black spots on the sun that can cause an explosion at the surface of the sun. The sunspot number has a positive correlation with Spread F. In the long run from 1992 to 1995 the annual solar activity has a strong enough relationship to Equatorial Spread F or ESF [9]. If the number of sunspots large then the frequency of Spread F will be large as well.

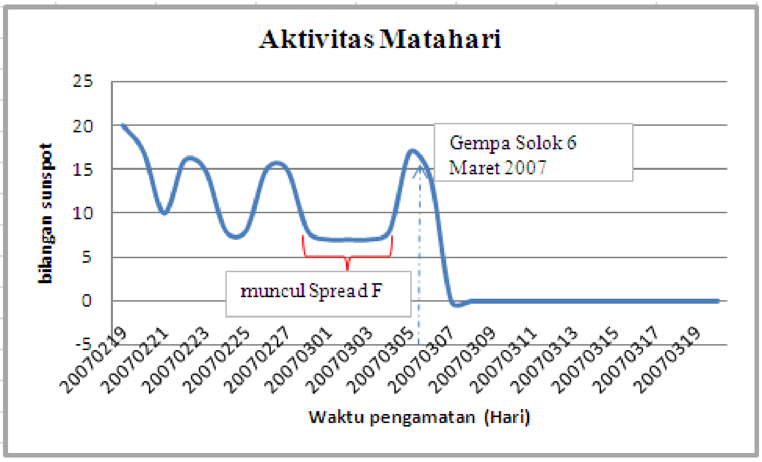


Figure 15. Sun activity with sunspot number parameter.

3.6 Comparison of critical Frequency (foF$_2$) and Spread F before The Solok earthquake 2007 as precursor of The Solok Earthquake

In this research, there is a disturbance of critical frequency in the F (foF$_2$) layer and Spread F before the earthquake of the Solok March 6, 2007. For Solok earthquake (2007), precursors appeared on 20, 22, 26, 27 Februari, 5 and 6 March 2007. The emergence the foF$_2$ anomaly identified as the precursor in the earthquake Solok dominant occurs during the day when there is a negative deviation of the foF$_2$ value whereas Spread F is the spread of radio waves in the F-region due to ionospherics irregularity in the area appear at night and in the Solok earthquake predominant about 5 days before the earthquake. On observation foF$_2$ indicated the possibility of Spread F on February 20 and 27 due to foF$_2$

fluctuation. This result is different from the result obtained on direct observation of fluctuation of layers F frequency.

From the above results, we can see that there is a time difference between precursors between precursor analysis with critical frequency foF_2 and Spread F. The time of the emergence of faster precursors in critical frequency analysis occurs because the observations are performed more thoroughly by using statistical analysis to find the anomaly of foF_2 deviation and separation parameter parameter of ionosphere layer F_2. Meanwhile, for Spread F analysis done by direct analysis of the critical frequency fluctuation of the ionosphere F layer where at the time of the occurrence of Spread F, the critical frequency of layer F can not be observed anymore. Spread F observation can be done without long time, because it can be observed directly on the ionogramme of ionosonde recording without having to separate ionogramme parameters.

From the comparison of two ways above analysis shows that the analysis of critical frequency fluctuations with the separation of layer F parameters ie on layer F_2 and the application of statistical methods resulted in the detection of the possibility of precursor earthquake earlier than observation of direct layer F-fluctuation fluctuations.

4. Conclusion

From the research that has been done this, some conclusions that can be taken that is: (1) Observation of ionospheric anomalies using critical frequency foF_2 appeared on 20, 22, 26, 27 February, 5 and 6 March 2007, (2) The occurrence of Spread F with observations of F layer frequency fluctuations is directly seen on 2, 3, and 5 March 2007, (3) The timing of faster precursors in critical frequency analysis occurs because the observations are performed more thoroughly by using statistical analysis to find the anomaly of the deviation value foF_2 and the parameter parameter of ionosphere, F_2 layer, is performed. While for analysis of Spread F is done by direct analysis of the critical frequency fluctuations of the ionosphere F layer without separating the layer F parameters where at the time of the occurrence of the critical frequency Spread F layer can not be observed again, (4) The existence of the foF_2 critical anomaly and the occurrence of Spread F are predicted as earthquake precursors because they occur when geomagneticsic and sun activities are normal.

Acknowledgment
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