Changes of NmF2 and hmF2 over Biak (1°S, 136°E) during total solar eclipse on March 9, 2016

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Abstract. Ionospheric responses to solar eclipse is interesting to learn. In this paper, we presented ionspheric F2 responses to total solar eclipse on March 9, 2016 over Indonesia from Biak station (-1°; 136.0°) which is within the obscuration 86.55%. The total solar eclipse over Biak occurred at 00:58 UT (09:58 local time) in F2 layer height of ionosphere (h ≈ 300 km). Observation of the ionospheric F2 over Biak during the total solar eclipse investigated using ionosonde with 15 minutes resolution. Ionization and recombination processes that occur in the ionosphere proceed by solar radiation. At the time of the ionosphere receives solar radiation, ionization process dominated in the F2 layer. Diurnal ionosphere parameters changed following the solar radiation. During the solar eclipse, the process of ionization in the F2 layer disturbed. Total solar eclipse on March 9, 2016 affected almost simultaneous decrease in maximum electron density (NmF2) ~52% and increase hmF2 ~24% at the elapsed time of totality observed from Biak Station.

1. Introduction
Total solar eclipse on March 9, 2016 that occurred over Indonesia crosses over the archipelago with its path of totality passing over 12 provinces and partial solar eclipse with obscuration more than 60% to the rest. The eclipse occurred during declining phase of solar activity cycle-24 (http://www.swpc.noaa.gov/). This event provides unique and rare opportunities to study the ionosphere effects associated with an accurately estimated variation of solar radiation. During this event, the amount of solar radiation that reaching earth is decrease which result in reduction of plasma. It is the opportunity to do ionospheric study especially on electron density of F2 layer (NmF2) and the height of F2 layer.

Study on ionospheric response to solar eclipse have been conducted since the 1940s [1]. One of the results of the study was an ultraviolet effecting the ionoszation in F2 region of ionosphere. The next study by [2], has shown that the F2 layer has unequally behavior, with the result that was not surprising that a difference of phenomena occur during eclipses. There are some things that control the upper ionosphere, which are transport processes, photoionization and loss rate. [2, 3, 4]. The F2 region have different behavior, during eclipse events. So the objective of this study is to obtain information on ionospheric electron density of foF2 (NmF2) and the height of F2 (hmF2) during total solar eclipse.

2. Data and method
The data used in this study are maximum electron density of F2 layer (NmF2) derived from critical frequency of F2 layer (foF2) and maximum height of F2 layer (hmF2) observed by ionosonde from Biak Station. The value of NmF2 and hmF2 compared with normal day (moving average 5 quiet days data
based on quiet geomagnetic storm). The data also calculated to the relative value using a modified form analysis of Adekoya [5] (equation (1) and (2)). At Biak station, on Earth’s surface (h ≈ 0 km), eclipse started at 08:46 LT (UT+9) and ended at 11:40 LT. Assuming that Sun’s altitude was ~ 60° at maximum eclipse, we can approximate the time of eclipse at F2 layer (h ≈ 300 km). At this height, eclipse occurred ~5 minutes earlier. It is explained from the study before that there is a shifted zone of Eclipse based on geometry of Earth [6]. The shifted zone of Eclipse is showed in figure 1. On F2 ionospheric height at Biak Station, eclipse started at 09:58 LT and ended at 10:14 LT. The maximum obscuration 86% occurred at 10:09 LT.

![Figure 1. Path of total solar eclipse on March 9, 2016. Black diamond mark observation on surface. Red diamond mark observation on ionosphere (h ≈ 300 km).](image)

3. Result and discussion

3.1. Decrement of maximum ionospheric density (NmF2)

Figure 2 shows the value of maximum electron density on F2 layer compared by normal day. The blue shade marks the time of eclipse. The maximum electron density started to decrease and drop almost simultaneously with the first contact and gradually increase at the end of eclipse. The relative value of NmF2 over Biak is shown on figure 3. The NmF2 relative plot shows negative value in most time of eclipse. The negative value during eclipse almost equal to negative relative value at night and morning. At night until just before sunrise, the electron density of the ionosphere is at the minimum value. If the 5 days average data is considered as the normal condition, then the density decreased maximum ~52% during eclipse.

The decrement of NmF2 during eclipse can be caused by reduction in the ionosphere ionization due to the reduction in the intensity of the sun because of the closure of the moon’s shadow. The decrement in solar radiation causes change in the photochemical of the atmosphere with night time chemistry dominating [7]. However, the F-2 behavior may be quite different as it is governed by photochemical processes as well as by electro dynamical and neutral forcing. When the F-2 layer is normal in state of quasi-equilibrium, the obscured changes in electron density during eclipse are almost entire due to loss by recombination and production by photo-ionization [8]. Noteworthy that the ionospheric behavior is
governed by photochemical processes, so the decrease in solar radiation during solar eclipse leads to the
decrease in electron production [9].

![Figure 2](image1.png)

**Figure 2.** Maximum electron density at F2 layer (NmF2) over Biak Station (red) superimposed with moving average 20 days NmF2 (blue) with 30% deviation. Grey shade mark the time of total solar eclipse.

**Figure 3.** Relative Maximum electron density at F2 layer (NmF2) over Biak Station (blue) Grey shade mark the time of total solar eclipse.

3.2. Increment of F2 region height (hmF2)

Figure 4 shows the height of F2 layer ionosphere (hmF2) compared with normal day. The gray shade marks the time of eclipse. During eclipse, the value of hmF2 tend to increase. The relative hmF2 showed on figure 5. The relative hmF2 plot shows the vary value. Positive value occurred at beginning of eclipse and negative value occurred at end of eclipse. During the solar eclipse, maximum height of ionosphere (hmF2) increase ~24% from the normal condition.

The increment of hmF2 is most likely due to the influence of gravity in the event of a solar eclipse is greater than the force of gravity. The increment can also caused by electro dynamic processes. The vertically upward E×B drift pushes the plasma upward in altitude. In the meantime, the electrons tend to diffuse along the magnetic field lines to higher latitudes creating the fountain effect [10]. Biak station that located at ~10° affected by that effect. Le et al also showed that total solar eclipse on March 9, 2016 that peaked at 10:20 LT is more unaffected by morning [11].

Generation of Gravity waves due to the transit of locally cooled region of the atmosphere moving at supersonic speed and a reduction in the plasma density as the source of ionization is switched. The Earth’s atmosphere may produce wave motions due to localized time dependent heating or cooling action. A solar eclipse, by interfering with the heat balance in the shadowed portion of the atmosphere, is expected to generate atmospheric gravity waves (AGW) [5].
4. Conclusion
Total solar eclipse on March 9, 2016 that passes through some areas in Indonesia led to a state of the ionosphere was different from the conditions on a normal day. The change was shown from observations of values NmF2 and hmF2 over Biak. The eclipse affected almost simultaneous decrease in maximum electron density (NmF2) ~52% and increase hmF2 ~24% at the elapsed time of totality observed from Biak Station. The decrement of maximum electron density comparable with the part of the result by Nayak et al. [10]. Ionospheric parameters change was not too large because of the solar eclipse occurred in the morning.

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