EVIDENCE OF ADDITIONAL LAYER FORMATION IN THE LOW LATITUDE IONOSPHERE

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ABSTRACT

Ionogram recorded from four ionosonde stations are employed to study the occurrence of an additional layer at F-region altitudes during 1-15 March 1998. It was found that the appearance of the additional layer at the local noontime hours is a typical phenomenon at Parepare (4°S geographic, 14.8°S geomagnetic). The additional layer was not clearly observed at Cebu (0.4°S geomagnetic) and Manila (3.7°N geomagnetic), and was not observed at Chung-Li (14.2°N geomagnetic). Furthermore, the additional layer was not seen from any of the station on 11 March 1998, a magnetically disturbed day. These results indicate that the fountain effect plays an important role in the formation of the additional layer. However, they also suggest the dynamics of the layer formation are in some way influenced by the location of the station relative to the geographic equator.

ABSTRAK

Ionogram yang diperoleh dari empat stasiun ionosonda digunakan untuk mempelajari proses pembentukan lapisan tambahan di daerah F dalam kurun waktu 1-15 Maret 1998. Telah ditemukan kemunculan lapisan tambahan pada tengah hari waktu lokal sebagai fenomena yang terjadi di Parepare (4°LS geografis, 14.8°LS geomagnet). Lapisan tambahan tidak teramati dengan jelas di Cebu (0.4°LS geomagnet) dan Manila (3.7°LU geomagnet), dan di Chung-Li (14.2°LU geomagnet) sama sekali tidak teramati. Pada tanggal 11 Maret 1998, saat terjadinya gangguan geomagnet, lapisan tambahan juga tidak teramati di empat stasiun ionosonda tersebut. Hal ini menunjukkan bahwa efek *fountain* sangat berpengaruh pada proses pembentukan lapisan tambahan. Selain itu, dinamika dari proses pembentukan lapisan tambahan juga dipengaruhi oleh lokasi stasiun relatif terhadap ekuator geografis.

Key words: *ionosphere, ionogram, F-region, F3-layer, low latitude*

1 INTRODUCTION

It is well known that the altitude profile of electron density in the ionosphere contains horizontally stratified features that have been labeled as the D, E, Fl and F2 layers. Researchers have also reported the existence of additional layers in the F-region. Balan et. al. (1997) indicated the additional layer (F3 layer) forming during the morning-noon period within ± 10° of the magnetic equator and at heights near and above the normal F2 peak. They

explained that the upward ExB drift raised the ionization peak and plasma converged in the top side ionosphere, with the cumulative process forming the F3 layer. Balan et al. (2000) proposed that although the additional layer occurs most frequently in local summer, there are consecutive and individual magnetically quiet and disturbed days when the layer does not occur. In this paper, measurements from four ionosondes which is located between the equatorial and anomaly regions obtained during 1-15 March 1998 are used to study the appearance of the additional layer as a function of geomagnetic and geographic latitudes under various geomagnetic conditions.

2 OBSERVATIONS

In order to investigate the occurrence of an additional layer at F-region altitudes we used the ionogram recorded from four ionospheric observing stations distributed at low magnetic latitudes near the 192°E magnetic meridian. Table 2-1 shows the locations of the four ionosonde stations in geographic and geomagnetic coordinates. Note that the locations of Parepare and Cebu are close to the geographic and geomagnetic equators, respectively. Manila is at a very low magnetic latitude while Chung-Li is within the equatorial anomaly region. During that period, the 10 March magnetic storm significantly disturbed the low-latitude ionosphere on 11 March 1998. The four ionosonde were concurrently operated during 9-15 March 1998.

Figure 2-1 illustrates the Dst index during 9-15 March 1998. It shows that the magnetic field was significantly depressed on 11 March. Figure 2-2 shows typical ionograms recorded at the four ionosonde stations.

Table 2-1: THE LOCATIONS OF THE FOUR IONOSONDE STATIONS

STATION	GEOGRAPHIC		GEOMAGNETIC		DIP LAT. (°N)
	Lat. (°N)	Long. (°E)	Lat. (°N)	Long. (°E)	
Chung-Li	25.0	121.2	14.2	191.3	19.2
Manila	14.5	120.5	3.7	191.1	7.6
Cebu	10.2	123.9	-0.4	194.5	2.6
Parepare	-4.0	119.6	-14.8	190.8	-13.9

The vertical and horizontal axes represent the virtual height (km) and the plasma frequency (MHz), respectively. Note that except for Cebu, a logarithm scale is used on the horizontal axes. The observations display that the additional layer appeared in the morning (0805-0910 LT) at Manila, and during the noontime hours (1140-1410 LT) at Parepare, while the F2 layer drifting upward. This dynamic feature is similar to that of the F3 layer (additional layer) formation presented in previous papers (Balan et al., 1997; 1998; and 2000). We found that the additional layer at Parepare occurred persistenly, while another type of the additional layer at Manila and Cebu appeared intermittently. Furthermore, no additional layer was observed at Chung-Li during that period. On the other hand, Figure 3.2 shows that when the Dst index became significantly depressed on 11 March, no additional layer was observed at the four ionosonde stations.

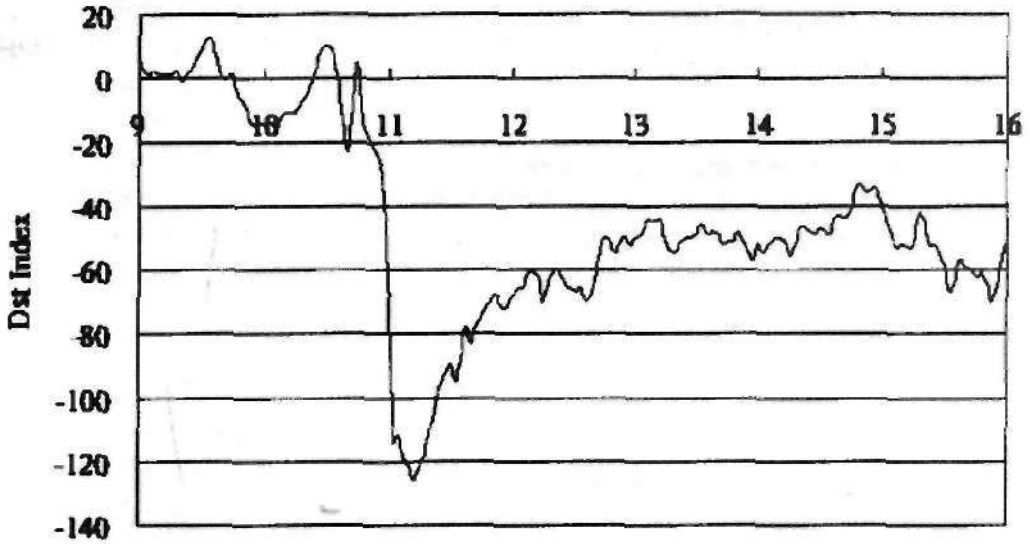

Figure 2-1: Variation of the geomagnetic index Dst during 9-15 March 1998

3 DISCUSSION AND SUMMARY

Evidence for an additional layer, the F3 layer, in the equatorial ionosphere has been report by scientists (Balan et al. 1997; 1998; and 2000). They showed that the F3 layer mainly was a short trace and extended within a small frequency range, about 0.5 - 1.5 MHz attached to the end of the main F2 layer and the minimum virtual height of F_3 layer, h' F3, is higher than h' F2 by about of 100 - 200 km. It can be seen that the frequency gap, about 5 MHz, as well as the virtual height difference, about 5-100 km, between the additional and existing F2 layers observed at Parepare are much greater and less than those of the previous, respectively. Although, the frequency gaps and virtual height differences are very different, we notice that at Parepare, a new additional layer develops when the F_2 layer drifts upward, which agrees with the formation of the F3 layer observed previously (Balan et al. 1997; 1998; and 2000). Meanwhile, at Manila, the frequency cf the new (additional) layer is only slighter greater than the foFi, which is difficult to treat it as a new fo F2. It seem that this additional layer could be identified as an F1.5 layer. However, we notice that the nomenclature of F1.5 has been widely used by many scientists (see papers listed in Sterling and Hanson, 1970; and Liu et al., 2000) to specifically name the additional layer appeared during the solar eclipses. Due to no solar eclipse occurred, the nomenclature of F1.5 might not be suitable for the additional layer appearing at Manila. Nevertheless, we report that the additional layers are observed at Cebu, Manila, and Parepare during the period of 9-15 March 1998.

The Kp index represents planetary magnetic activity on a global scale, while the Dst index records the equatorial ring current variations (Mayaud, 1980). We accept the Dst index to be more suitable for studying ionospheric dynamics near the magnetic equator. Therefore in this paper we use the Dst index to study the appearance of additional layers. Liu etal. (1999) examined the

effects of magnetic storms on ionospheric total electron content (TEC) in the equatorial anomaly region. They showed that due to the ionospheric disturbance dynamo (for detail see, Blanc and Richmond, 1980), which produces low-latitude electric fields opposing their normal quiet-day values, the equatorial anomaly crest in TEC diminishes or disappears during magnetically disturbed days. Balan et al. (1997 and 1998) proposed that the equatorial upward ExB is important to the formation of additional layers. During the 11 March 1998 magnetic disturbance, due to the inverted Sq electric fields at low latitudes, the upward ExB drift near the equator was significantly decreased. This may have caused the absence of the additional layer at all of the ionosonde stations.

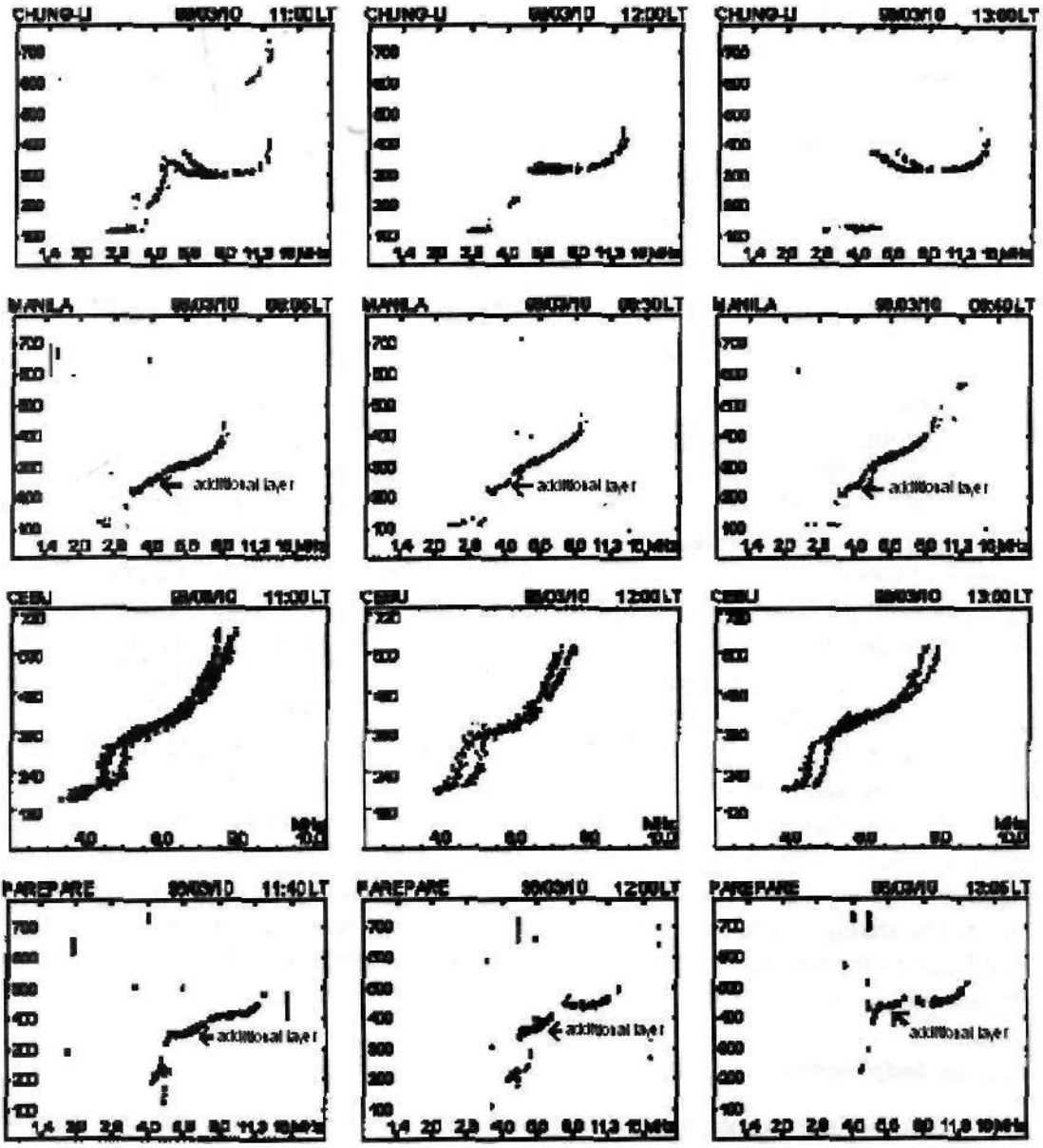

Figure 3-1: Selected ionograms recorded at Chung-Li, Manila, Cebu, and Parepare on 10 March 1998.

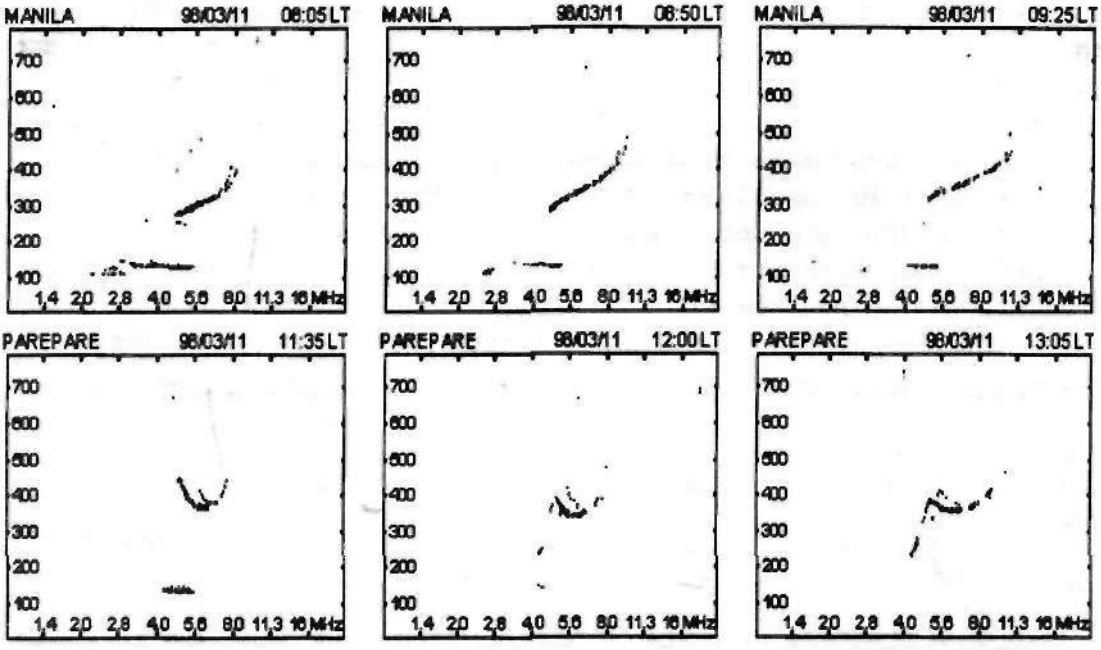

Figure 3-2: Selected ionograms recorded at Manila and Parepare on 11 March 1998

Balan et al. (1997) indicated that the daytime plasma fountain and its effects in the regions outside the fountain lead to the formation of the additional layer within ± 10° of the magnetic equator. Results of this paper show that although Manila (3.7°N geomagnetic) and Cebu (0.4°S geomagnetic) lie within the ± 10° magnetic zone, the additional layer was observed intermittently at the two stations. On the other hand, Parepare (14.8°S geomagnetic, 4°S geographic) is outside of the ± 10° magnetic zone but close to the geographic equator. Yet the additional layer occurred persistently above Parepare during the period of 9-15 March 1998. Note that our results are different to those found by Balan et al. (1997). Since the direction of ExB is almost vertical at the magnetic equator, the ExB upward drift is the most efficient there. However, due to seasonal variability in the thermospheric tides and ionospheric conductivity which is driven by changes in the solar zenith angle, the intensity of the electric field at the geographic equator is greater than at the magnetic equator during equinox. Even though the direction of ExB upward drift at the geographic equator is not vertical, due to the enhanced electric field, the upward component of ExB drift will still be stronger. The persistence of the additional layers at Parepare suggests that in addition to the fountain effect, proximity to the geographic equator should be taken into account when modeling the occurrence of the additional layer.

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REFERENCES

Balan, N., G. J. Bailey, M. A. Abdu, K. I. Oyama, P. G. Richards, J. MacDougall, and I. S. Batista, 1997. Equatorial plasma fountain and its effects over three locations: Evidence for an additional layer, the Fa layer, *J. Geophys. Res.,* 102, 2,047-2,056.

Balan, N., I. S. Batista, M. A. Abdu, J. MacDougall, and G. J. Bailey, 1998. Physical Mechanism and statistics of occurrence of an additional layer in the equatorial ionosphere, *J. Geophys. Res.,* 103, 29,169-29,181.

Balan, N., I. S. Batista, M. A. Abdu, G. J. Bailey, S. Watanabe, J. MacDougall, and J. H. A. Sobral, 2000. Variability of additional layer in the equatorial ionosphere over Fortaleza, *J. Geophys. Res.,* 105, 10,603-10,613.

Blanc, M. and A. D. Richmond, 1980. The ionospheric disturbance dynamo, *J. Geophys. Res.,* 85, 1,669-1,686.

Sterling, D. L., and W. B. Hanson, 1970. Calculations for an equatorial F2-region solar eclipse. *Radio Set, 5,* 1,029-1,039.

Liu, J. Y., H. F. Tsai, C- C. Wu, C. L. Tseng, L.- C. Tsai, W. H. Tsai, K. Liou, and J. K. Chao, 1999. The effect of geomagnetic storm on ionospheric total electron content at the equatorial anomaly, *Adv. Space Res.,* 24, 1,491-1,494.

Liu, Li-Bo, Wei-Xing Wan, Jian-Nan Tu and Zong-Ti Bao, 2000. Modeling of the ionospheric response to the solar eclipse of 24 October 1995, *TAO,* 11, 543-554.

Mayaud, P. N., 1980. Derivation, Meaning, and Use of Geomagnetic indices, Geophys. Monograph 22, American Geophys. Union, Washington, D. C.