The E_s occurrence rate during the simultaneous observation period of Na layer over Qingdao (36°N, 120°E), China

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Abstract

Sporadic E (E_s) layers have been detected by an ionosonde during 2008 to 2011 at Qingdao (36°N, 120°E), China. At the same time, we have observed nocturnal Na layers by a lidar with a horizontal distance of only ~30 m away from the ionosonde. In order to study the correlation between the occurrences of E_s and sporadic Na (Na_s) layers, we can compare the E_s occurrence rate during the period of Na_s layers with that during the entire observation period of Na layer. It should be noted that the E_s occurrence rate during the observation period of Na layer could be different with the nighttime mean E_s occurrence rate. Based on the four years simultaneous and closely colocated observations at Qingdao, it is found that the temporal coverage of Na data possessed remarkably seasonal and nocturnal distribution asymmetry. Consequently the E_s occurrence probability during Na data period (11%) was different with the nighttime mean E_s occurrence probability (20%).

1. Introduction

Sporadic E (E_s) layers are thin layers of metallic ions, typically only 1-3 km wide, that occur between 90 and 140 km [1]. They can significantly impact radio communications. Sporadic Na (Na_s) layers are enhanced Na atoms layers just within a narrow height region (typically ~2 km full width at half maximum) and between about 90 and 120 km majorly [2-4].

The formation mechanisms of both sporadic E and Na layers are not very clear. A high correlation between the occurrences of E_s and Na_s layers leads to suggesting the neutralization of Na ion reservoir in the E_s layers is a source of the enhanced neutral Na atoms in Na_s layers [5, 6]. Nevertheless, there were also observation results that didn't show high correlation between E_s and Na_s layers [2]. Based on the ionosonde and lidar observations, the correlation between E_s and Na_s layers are usually judged by the temporal difference of their occurrences. For example, an E_s layer and a sporadic Fe (Fe_s) layer that appeared within two hours were considered a pair of correlated ones [7].

From another point of view, the E_s occurrence rate around the appearing period of Na_s layer may be different with the average E_s occurrence rate during the entire observation period of Na layer. Obviously, their difference extent can reflect the correlativity between E_s and Na_s layers. However, note that the E_s occurrence rate should possess evident seasonal and nocturnal variations. Consequently, the fact that the temporal coverage distribution of Qingdao Na data was not seasonal and nocturnal uniform will cause the E_s occurrence rate during Na layer observation period to be different with the nighttime mean E_s occurrence rate. In this study, we will survey the E_s occurrence rate during the simultaneous observation period of Na layer through 2008 to 2011 at Qingdao (36°N, 120°E), China.

2. Instruments

The TYC-1 ionosonde of China Research Institute of Radiowave Propagation (CRIRP) locates at Qingdao, China. Its frequency scans from 1 to 32 MHz, and the altitude uncertainty for sporadic E layer is 5 km. Some main parameters of this ionosonde are listed in table 1. This ionosonde operates every hour on the hour. Consequently, the period of E_s layer data covers all Na data. The ionograms are scaled according to the Manual of Ionogram Scaling by Wakai et al. [8].

Table 1. Some main parameters of CRIRP TYC-1 ionosonde.

Frequency range	1-32 MHz
Frequency stability	better than 5×10^{-7}/d
Frequency precision	better than 5×10^{-7}
Frequency-hopping mode	linearity/logarithm
Signal shape	pulse/code

Detection period	1-60 min
Altitude range	80-720 km
Altitude resolution	$\leq$5 km
Altitude error	$\leq$5 km
Sensitivity	~100 dBm
Intermediate frequency rejection	$\geq$70 dB
Dynamic range	$\geq$70 dB
Pulse power	5000 W±1 dB
Harmonic suppression	$\geq$50 dBc
Spur suppression	$\geq$60 dBc
Output impedance	50 Ω
Output data	h'-f curve data

The multifunctional Aerosol-Temperature-Sodium (ATS) lidar of CRIRP locates with a horizontal distance of only ~30 m away from the ionosonde. Observations are performed routinely at night and one of operational modes (Mie and Raman for aerosol, Rayleigh for temperature and density, and resonance fluorescence for Na atom) is adopted roughly alternately for each night. The time bin length is 1 μm corresponding to the range bin length of 150 m. The time resolution of obtained Na profiles is normally 250 seconds (5000 laser shots), and was momently adjusted to 300 seconds (6000 laser shots) through 20 February to 15 October 2009.

3. Observations

Our observation of Na atom layer by lidar was first carried out in December 2007. And the observation is still performed until now. In order to ensure the integrality, the data used in this study are through 2008 to 2011. Through a statistical work, there were totally 83 nights and 378 hours of Na data during these 4 years. With respect to the ionosonde, it totally operated 403 times during the observation period (378 hours) of Na layer. As seen in table 2, here we define these 403 ionosonde data as sample 1. Then the ionosonde data during the entire night through 2008 to 2011 are defined as sample 2. The sample 2 roughly includes 16000 data totally.

Table 2. Two samples of ionosonde data.

Sample	Period	Number of data
1	during the observation period of Na layer through 2008 to 2011	403
2	during the entire nighttime (20 to 06 LT) through 2008 to 2011	~16000

The strength of a sporadic E layer detected by ionosonde is normally recorded by the plasma frequency, foEs (MHz), which is related to the electron concentration (N_e=1.24×10^4foEs^2 cm^{-3}). Here we set the threshold foEs of the E_s layer to 4.0 MHz [9]. Obviously, the E_s occurrence rate during the observation period of Na layer can be obtained from sample 1. And the nighttime (20 to 06 LT) mean E_s occurrence rate can be obtained from sample 2.

We have surveyed the seasonal and nocturnal variations of E_s occurrence rate, as well as the seasonal and nocturnal distributions of sample 1 and 2. As seen in figure 1, the nighttime mean E_s occurrence rate (solid line) possessed remarkably seasonal variation. E_s occurrence rates were very low (no more than 0.1) through September to April. Whereas E_s occurrence rates were more than 0.3 around summer (through May to August). With respect to the ionosonde data of sample 1, they were considerably scarce around summer (less than 15 through June to September). Hence the sample 1 majorly sampled the ionosonde data with low E_s occurrence rate in sample 2. The E_s occurrence rate of sample 1 was close to that of sample 2 (dashed line).

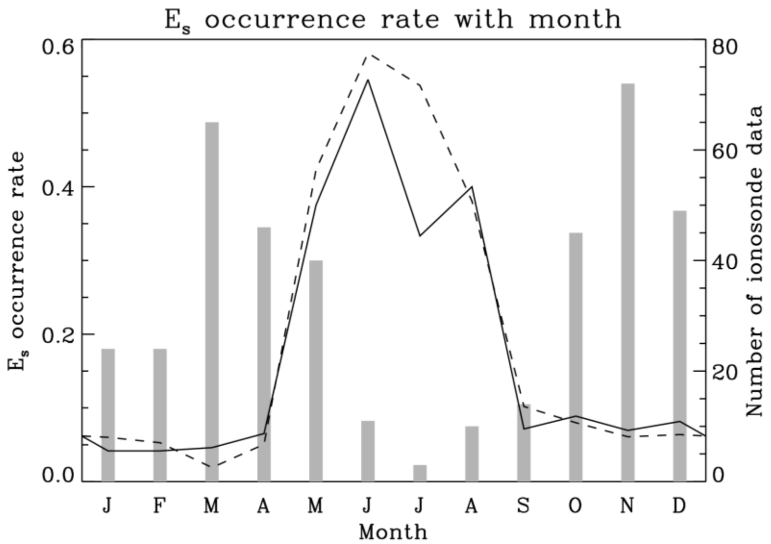

Figure 1. E_s occurrence rates and number of ionosonde data with month. The solid line is E_s occurrence rate of ionosonde data during observation period of Na layer and the dashed line is the mean E_s occurrence rate. The gray bars are numbers of ionosonde data during observation period of Na layer.

Figure 2 shows the E_s occurrence rate variations and temporal distribution of sample 1 with local time. It is found that the nighttime mean E_s occurrence rate was considerably higher before midnight than that after midnight. With respect to the ionosonde data of sample 1, they were majorly distributed through 20 to 00 LT. Hence the sample 1 majorly sampled the ionosonde data with high E_s occurrence rate in sample 2. In addition, the E_s occurrence rate of sample 1 was considerably lower than that of sample 2. This result should be caused by the uneven seasonal distribution of sample 1.

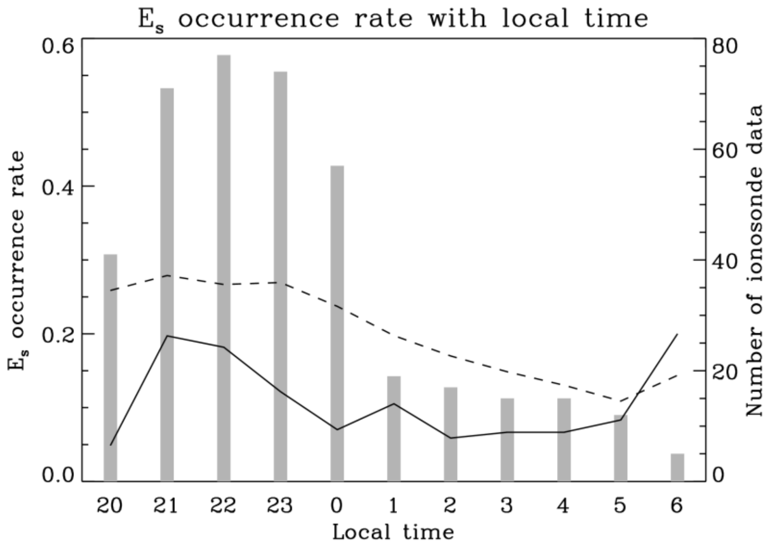

Figure 2. E_s occurrence rates and number of ionosonde data with local time. The solid line is E_s occurrence rate of ionosonde data during observation period of Na layer and the dashed line is the mean E_s occurrence rate. The gray bars are numbers of ionosonde data during observation period of Na layer.

Taking one with another, ionosonde data of sample 1 tended to sample ionosonde data in month with low E_s occurrence rate but in local time with high E_s occurrence rate. Through an overall calculation, the mean E_s occurrence rate of sample 2 was 20% (3289 E_s layer events among 16060 ionosonde data). Whereas the mean E_s occurrence rate of sample 1 was only 11% (46 E_s layer events among 403 ionosonde data).

4. Conclusion

Based on the simultaneous and closely colocated observations by ionosonde and lidar through 2008 and 2011 at Qingdao, China, we have surveyed the E_s occurrence rate variations with month and local time, as well as the temporal distributions of ionosonde data sample during observation period of Na layer. It is found that the nighttime mean E_s occurrence rate was high around summer. And the nighttime E_s occurrence rate was high before midnight. However, ionosonde data during the observation period of Na layer tended to sample ionosonde data in month with low E_s occurrence rate but in local time with high E_s occurrence rate. The study shows that the uneven temporal distribution of ionosonde data during the observation period of Na layer did affect the mean E_s occurrence rate. Consequently, the mean E_s occurrence rate of sample 1 (11%) was considerably lower than that of sample 2 (20%).

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