The convergence field in northern Taiwan under stable environment

穩定大氣下北台灣的輻合場

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ABSTRACT

During the winter time air pollution could become serious in the Taipei area when atmospheric is stable. A three-dimensional numerical model was used to investigate the horizontal convergence pattern in the Taipei area due to the interaction of north-east wind and mountain. Stations which observed high concentrations of TSP were located inside this area. If the terrain could be changed then the convergence area would change.

Key words : Air pollution, stable environment, convergence

摘　　要

冬天在台北地區，當大氣不穩定時空氣污染就會變得嚴重，1988及1989年的資料顯示出這種情形。利用三維數值來研究在穩定大氣下，在東北風吹襲下之台北地區水平輻合的情形。發現測站觀測到高的TSP是位在此輻合區，如果地形改變，輻合區便改變。

關鍵詞：空氣污染，穩定大氣，輻合

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INTRODUCTION

In northern Taiwan air pollution has become recently the subject of increasing public concern , especcially during winter time when the atmosphere becomes very stable. Many examples have shown that serious air pollution occurred when an inversion took place in the low level in northern Taiwan. Liu and Lee (1989) and Kuo et al. (1991) demonstrate this situation.

Table 1. Date of high TSP (Tiny Suspend Particle).

1988.02.04
1988.02.05
1988.02.06
1988.12.19
1988.12.20
1988.12.21
1989.01.07
1989.01.08
1989.01.09
1989.01.10
1989.02.16
1989.02.17
1989.12.04
1989.12.05
1989.12.06
1989.12.07

During the winter time of 1988 and 1989, we found several days (table 1) where the TSP (Tiny Suspend Particle) count was higher than 350 μ g/m^3 in northern Taiwan. A TSP greater than 350 μ g/m^3 corresponds to a PSI (Pollution Stardard Index) higher than 200 which is very bad for pollution. For example, Fig.1 a and b show that several stations observed heavy TSP in northern Taiwan on Feb. 5, 1988 and December 20, 1988. The locations of these stations are shown in Fig.2. On these two particular days wind was either weak or calm in northern Taiwan (Fig.3). A strong low level inversion also existed between 800 to 850 hPa (Fig.4). The Froude number U/NH were between 0.1 to 0.2, where U is the wind speed, N the Brunt-vasaila frequency and H the height of mountain

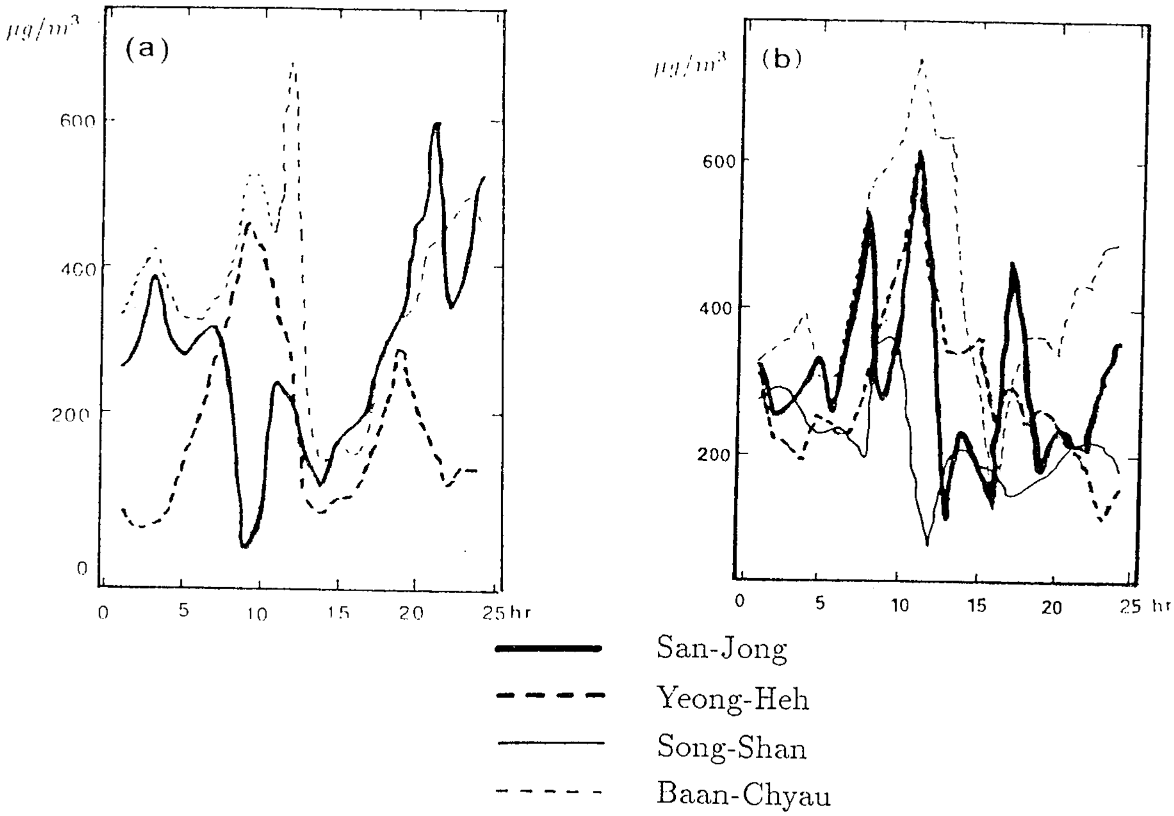


Fig.1 The concentraction of Tiny suspend particles on (a) Feb. 5, 1988 and (b) Dec. 20, 1988.

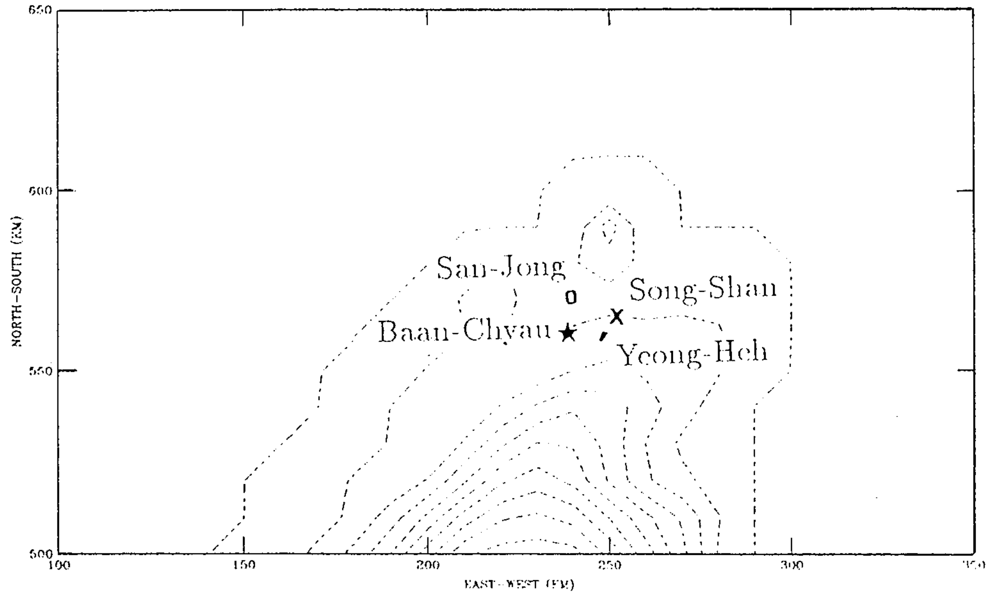


Fig.2 The location of air pollution stations in the Taipei area. The contour interval for the topography is 200 m.

If the Froude number is low, the airflow does not easily climb over the mountain but will divert arond the terrain. Thus the convergence and divergence pattern can happen near topography. The smooth topography in northern Taiwan is shown in Fig.2. In the Taipei area high mountains (Central Mountain Range) are located to the south, the Lin-Ku plateau to the west and Yangmingshan to the north. Hence the convergence pattern due to the interaction between the ambient wind and the mountains under a stable environment may affect the distribution of pollution.

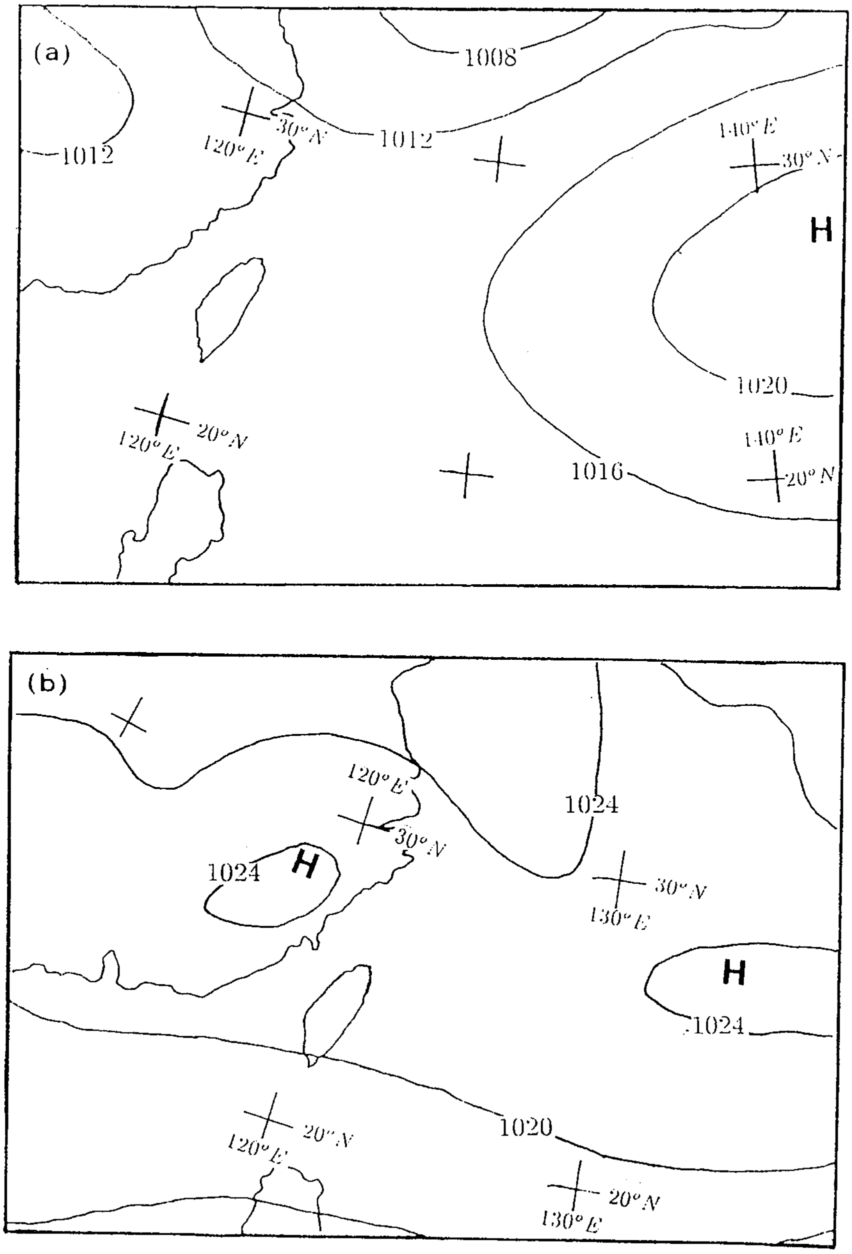
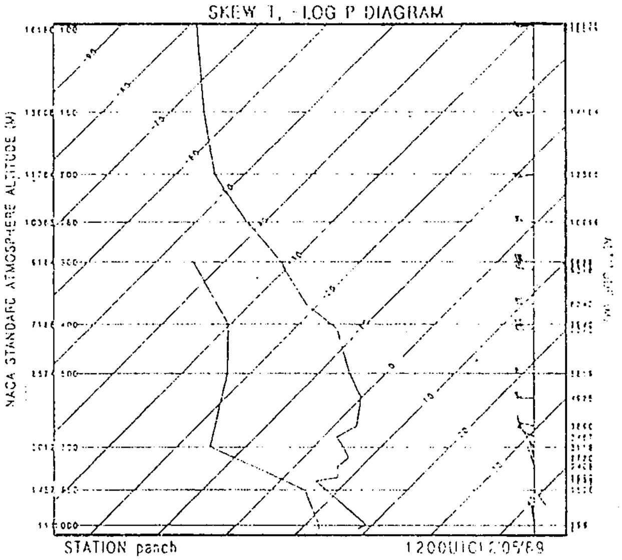


Fig.3 Synoptic scale surface map on (a) Feb. 5, 1988 and (b) Dec. 20, 1988.

Since it is not easy to obtain an analytical solution of wind patterns around the complex terrain, we need a numerical model to obtain flow patterns and to find the convergence near the mountain area. It is our purpose to present the convergence pattern for the northern Taiwan area under stable conditions from a dynamical model through numerical solution.

(a)



(b)

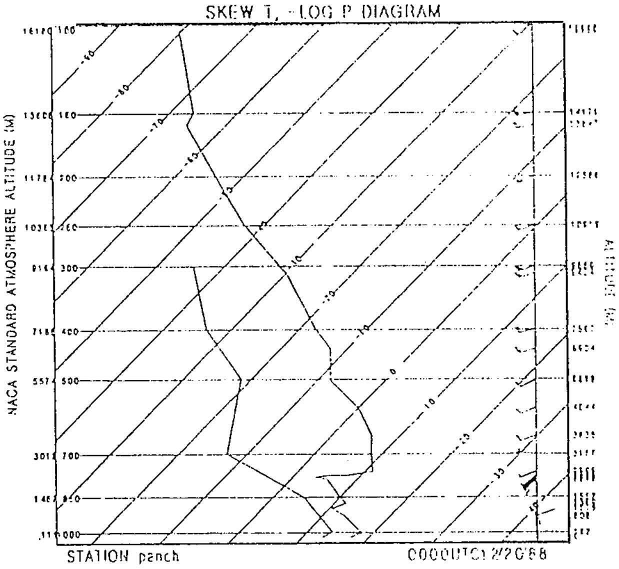


Fig.4 Pan-Chiao sounding on (a) 0800 LST (local standard time), Feb. 5,1988 and (b) 0800 LST, Dec. 20, 1988.

SIMULATION RESULT

a. A brief description of the numerical model

A three-dimentioinal terrain-following coordinate model was used to investigate the convergence pattern due to the interaction between the terrain and the ambient wind. The base of the domain (Z=0) and the pressure were assumed to be 0 m and 1000 hPa, respectively. The grid size in the X - and Y - direction was 10 km for case A and B except for one case (case C) where the grid size was 7.5 km. In the vertical it is stretched along the vertical to allow for finer resolutioin in the lower atmosphere. There are 41, 81, and 20 grid points in the X, Y, and vertical directions, respectively. Thus the model domain was 400 × 800 × 10 km^3. A sponge layer 5 km thick was assumed at the top of the model. The locations of the horizontal velocity, vertical velocity, nondimentional pressure perturbation, potential temperature, and subgrid-scale mixing coeifficient in the vertical direction Z were all shown in Table 2. Their locations in the vertical direction (zeta) for the terrain-following coordinate system is calculated by

(zeta) = Zt(Z-Zs) / (Zt-Zs)

Table 2. The location of variables in the Z direction. Vertical velocity is located at the ZRW position and all other variables are located at the ZRT position.

Level	ZRT (m)	ZRW (m)
		10000
20	9673	9350
19	9031	8716
18	8405	8097
17	7794	7495
16	7199	6908
15	6620	6337
14	6057	5782
13	5510	5242
12	4978	4718
11	4463	4211
10	3963	3718
9	3478	3242
8	3010	2782
7	2557	2337
6	2120	1908
5	1699	1495
4	1294	1097
3	905	716
2	531	350
1	173	0

where Zt is the top of the domain (10 km). The terrain features (Zs) used in the model are shown in Fig.2. The Brunt-vasaila frequency is assumed to be 0.01 s^{-1} and the wind is assumed to be from the north-west. The wind speed is 2 ms^{-1}. The environmental wind is added slowly from 0 to 2 ms^{-1} during the initial 3 hours of model time in the simulation. Simulation results are presented at 10 hours of model time. After this time the convergence pattern in northern Taiwan remained almost the same.

b. Dicussion of the simulation result

The surface streamline at 36,000 s of model time due to a north-east wind of case A was presented in Fig. 5. Most of the air is diverted around the Central Mountain Range and flows toward the south-west. The horizontal convergence pattern in northern Taiwan is shown in Fig.6a. One horizontal convergence area was bounded by the Central Mountain Range, the Lin-Ku plateau and Yangmingshan. Station San-Jong, Baan-Chyau, Song-Shan, and Yeong-Heh were located inside this area. The concentrations of TSP at those stations were higher (Fig.1). Other factors such as emmission sources may influence the concentration of TSP. If there was no Yangmingshan (case B) the convergence area was reduced (Fig.7a), but station Baan-Chyau and Yeong-Heh were located near higher convergence area. If there were no Yangmingshan and Lin-ku plateau (case C) the convergence area decreased further (Fig. 8a). From these three experiments the interaction between terrain and ambient wind plays an important role for creating a horizontal convergence pattern.

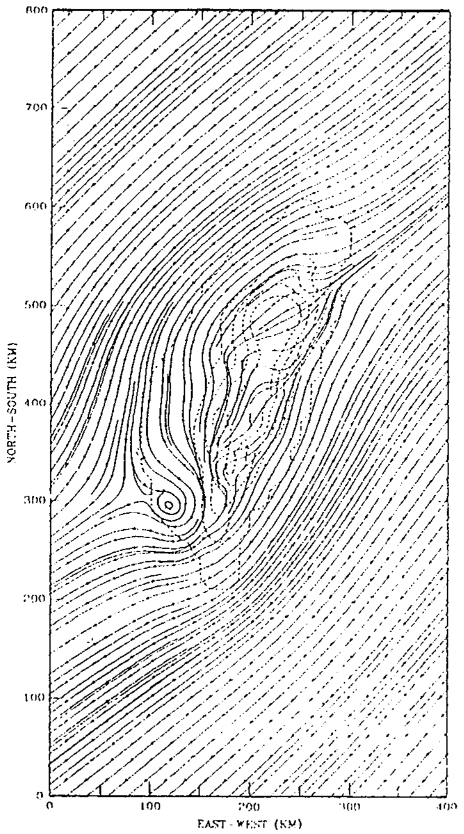
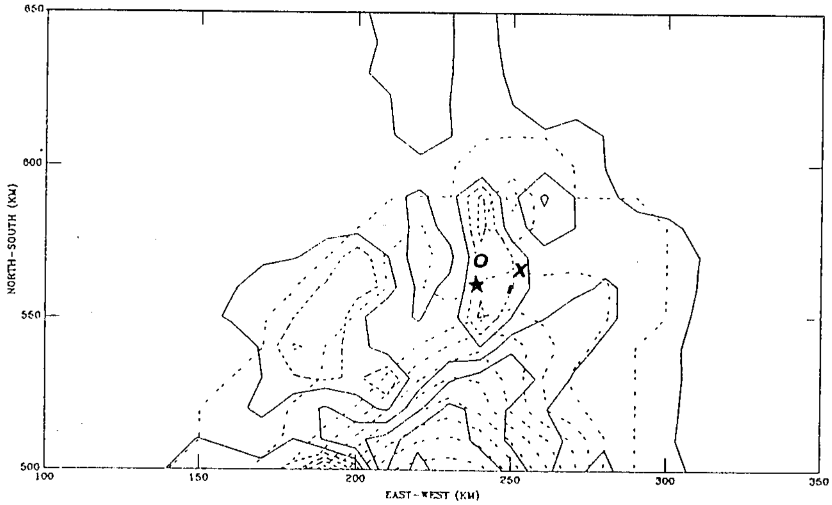


Fig.5. The surface streamlines derived from model results at 36000 s of model time for case A. The contour interval is 400m.

When the horizontal resolution is reduced from 10 km to 7.5 km as in case D, the convergence pattern is shown in Fig. 9a. This pattern was similar to that of case A (Fig. 6a) except the magnitude of the convergence was larger. San-Jong, Baan-Chyau, Song-Shan, and Yeong-Heh were located inside the convergence area. If the ambient wind was from southwest, the convergence pattern is shown in Fig. 10a. The four stations, San-Jong, Baan-Chyau, Song-Shan and Yeong-Heh were not located in the convergence.



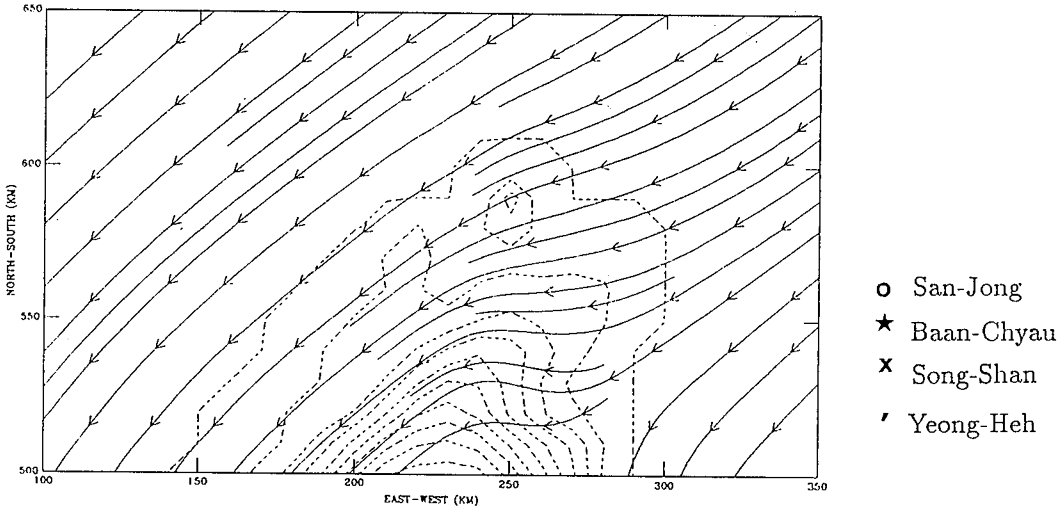
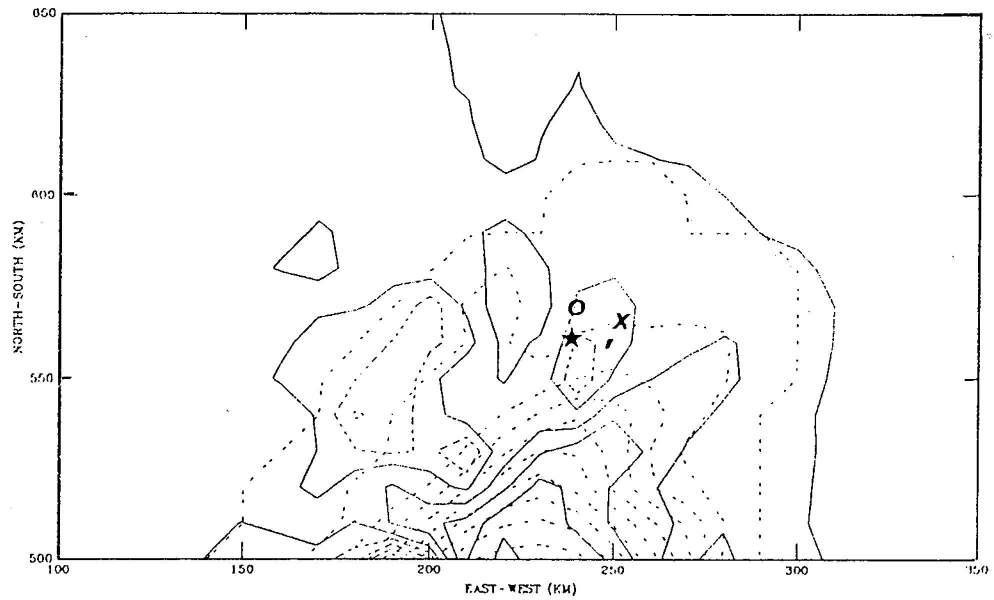
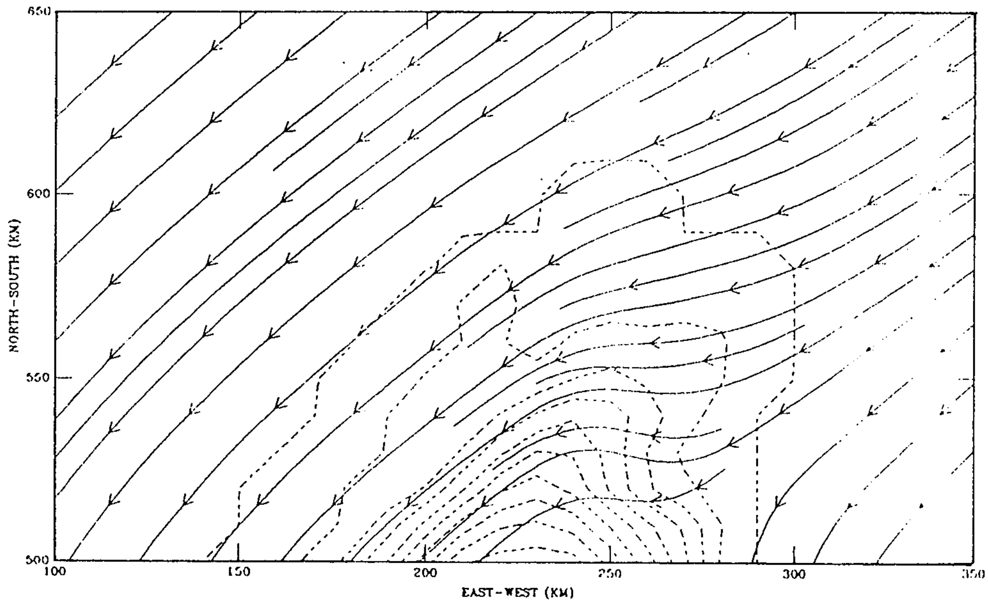


Fig.6 (a) The surface horizontal convergence pattern in northern Taiwan at 36000 s of model time for case A. Dashed lines denote negative areas. The contour interval is 0.5×10^{-5} s^{-1}. The contour interval for the topography is 200 m.

(b) The surface stream line in northern Taiwan.





o San-Jong

★ Baan-Chyau

x Song-Shan

, Yeong-Heh

Fig.7 (a) same as in Fig.6(a) but for case (B).
(b) same as in Fig.6(b) but for case (B).

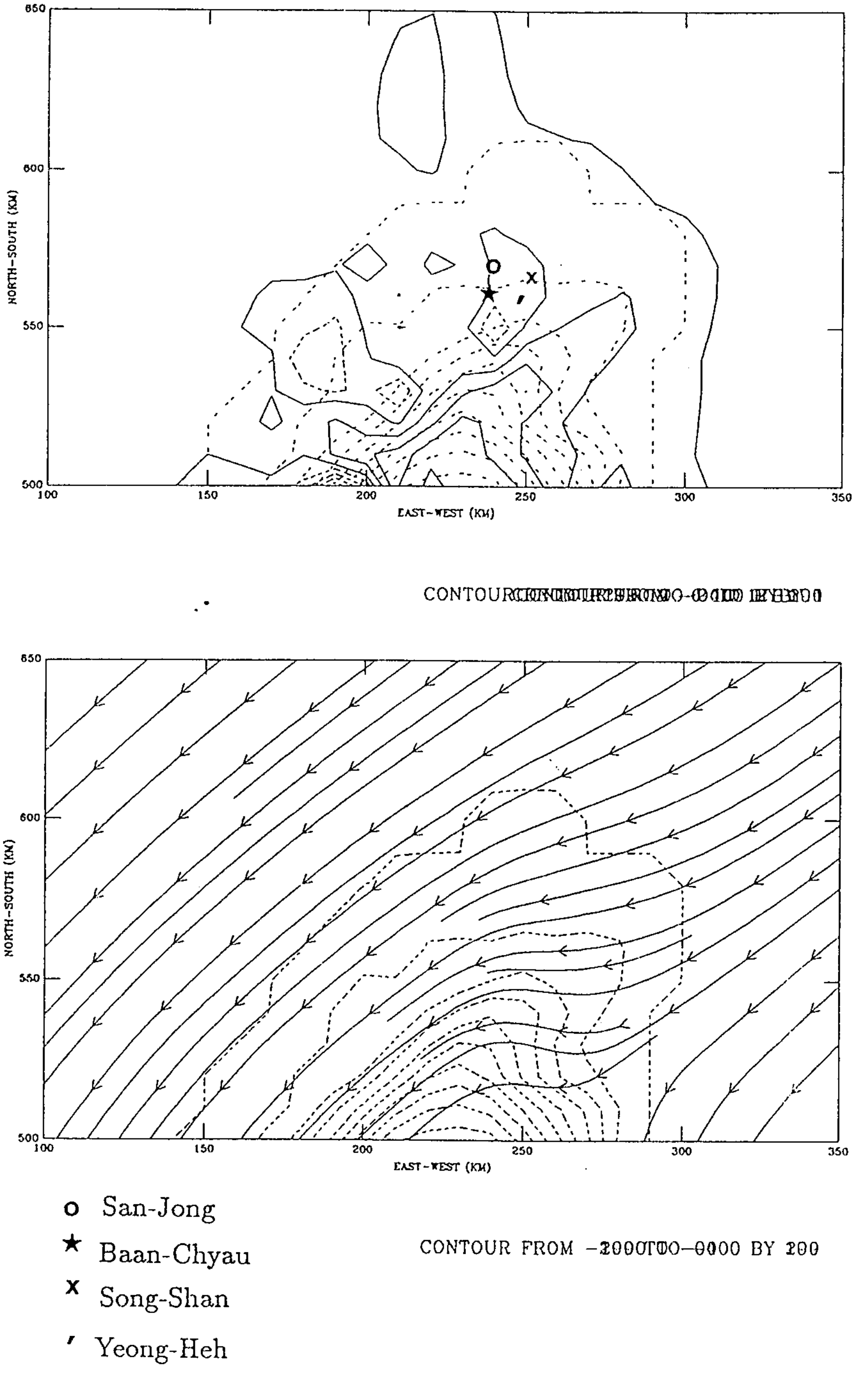
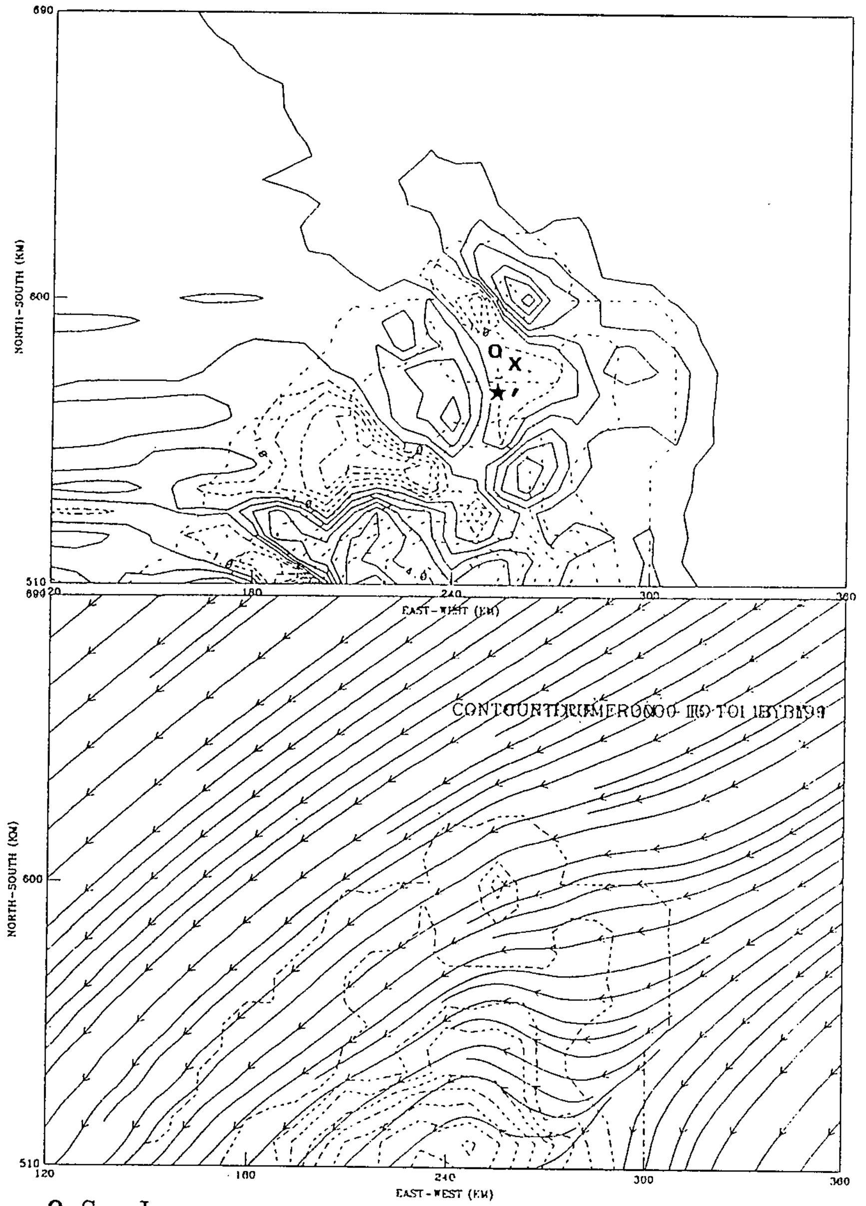


Fig. 8 (a) same as in Fig.6(a) but for case (C). (b) same as in Fig.6(b) but for case (C).



o San-Jong

★ Baan-Chyau

x Song-Shan

, Yeong-Heh

Fig. 9 (a) same as in Fig.6(a) but for case (D). The contour interval was 1×10^{-5} s^{-1}.

(b) same as in Fig.6(b) but for case (D).

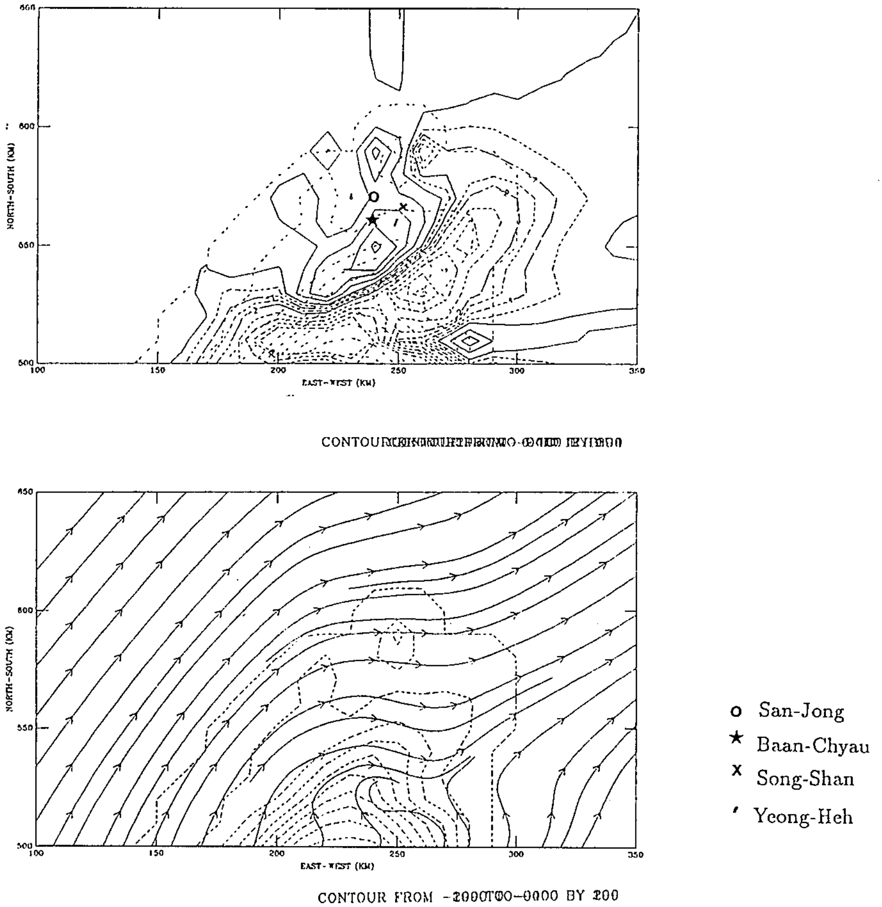


Fig. 10 (a) same as in Fig.6(a) but for case (E). The contour interval is 0.5×10^{-5} s^{-1}.
(b) same as in Fig.6(b) but for case (E).

CONCLUSIONS

Many factors can influence the concentration of TSP in the Taipei area. However, the horizontal convergence area due to the interaction between the ambient wind and terrain under stable conditions is one of these factors. We have employed a three-dimensional numerical model to demonstrate this phenomenon. The study of the convergence area in northern Taiwan under other environmental conditions is being pursued now.

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