CHARACTERISTICS OF LOW LEVEL TEMPERATURE INVERSION IN TAIWAN

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ABSTRACT:

The observation data from MTP-5HE of EPA are used to study the temperature inversion phenomenon in the lower boundary layer in Taipei, Taichung and Kaohsiung of Taiwan. Characteristics of temperature inversion at three cities are extracted using different classification methods. The characteristics of temperature inversion in Taichung and Kaohsiung show a similar trend but are different from that in Taipei. The numbers of the occurrence of temperature inversion in Taichung and Kaohsiung were much larger than that in Taipei. The main types of temperature inversion in Taiwan are radiation inversion and frontal inversion. Compared to frontal inversion, radiation inversion on average occurs at a lower altitude, lasts a longer period, has a deeper thickness, and reaches a higher temperature difference of inversion. Frontal inversion plays a significant role for the inversion event lasting over 12 hours.

KEY WORDS: temperature inversion, radiation inversion, frontal inversion, radiometer

1. INTRODUCTION

Temperature inversion which the atmospheric temperature decreases with increasing the height tends to inhibit the vertical motion of the atmosphere. Under this condition, air pollutants can't be dissipated through the vertical motion of the atmosphere and are accumulated near the surface. When a temperature inversion lasts for a long time, human health is significantly affected due to the deterioration of air quality and secondary pollutants which are formed through atmospheric photochemistry and more toxic than primary ones. It is vital to investigate the dynamics of temperature inversion.

Remote sensing of atmospheric temperature profiles with sufficient temporal and vertical resolutions can provide enough information to study temperature inversion phenomena. A viable newly-developed technique is to deploy a angular-scanning single-channel microwave radiometer with a operating frequency around 60 GHz which is in a oxygen absorption band (Troitsky et al., 1993; Kadygrov and Pick, 1998;Westwater et al.,1999). This instrument such as MTP-5HE of Kipp & Zonen can continuously provide low-altitude atmospheric temperature profiles with high vertical resolution. In this paper, the observation data from MTP-5HE of environmental protection agency (EPA) of Taiwan are used to study characteristics of low-level temperature inversion phenomena in Taipei (northern Taiwan), Taichung (middle Taiwan) and Kaohsiung (southern Taiwan).

2. DESCRIPTION OF RADIOMETER

MTP-5HE of Kipp & Zonen is a angular-scanning single-channel microwave radiometer similar to those used by (Kadygrov and Pick, 1998) and (Westwater et al.,1999). The operating frequency based on the manufacture's specification is 56.7 GHz, although the exact operating frequency is slightly higher through a theoretical analysis and the result is confirmed by Kipp & Zonen. The sensitivity of MTP-5HE is 0.08K for an integration time 1 second. MTP-5HE can measure the brightness temperatures at 31 different zenith angles ranging from 0° to 90° with an increment of 3°, and a complete scanning takes 600 seconds. The temperature profiles up to 1000 m are retrieved with a vertical resolution of 50 m. The accuracy of the temperature profile for the adiabatic condition is 0.3K below 500m and 0.4K from 500m to 1000m, while for the inversion condition the accuracy is 0.8K below 500m and 1.2K from 500m to 1000m.

3. RESULTS

Table 1 MTP-5HE observation data

	Taipei	Taichung	Kaohsiung
Total observation number	90575	93394	89653
Number of the inversion condition	6194	28253	28379
Probability of the inversion condition	6.8%	30.2%	31.7%

The observation data from December of 2002 to December of 2004 are used to study the temperature inversion phenomenon in the low level boundary layer in Taipei, Taichung and Kaohsiung. Table 1 tabulates total observation numbers and numbers and probabilities of occurrence of the temperature inversion condition at three sites. The inversion condition whose starting height exceeds 800 m excludes due to possible retrieval errors. The probabilities of the inversion condition in Taichung and Kaohsiung just exceed 0.3 and the probability in Taipei shows the lowest value, 0.068, among three sites. The numbers of the occurrence of temperature inversion in Taichung and Kaohsiung are much larger than that in Taipei. The main cause for this low value is heat island effect in Taipei basin which reduces the radiation cooling effect and decreases the intensity of a inversion event.

Figure 1 shows the probabilities of the inversion condition in different months for three sities. For Taichung and Kaohsiung, the probabilities exceed 0.5 in later winter and early spring. The probability reach a minimum of 0.1 in summer for Kaohsiung, while the probability decreases to a minimum of 0.01 in September for Taichung. The probability for Taipei varies little as compared to the other sites. The maximum value is 0.13 in April and the minimum value is 0.035 in September.

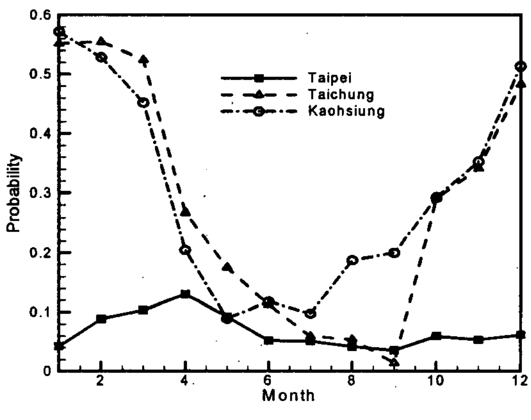

Figure 1 the probabilities of the inversion condition in different months for three sites.

Figures 2-4 show average hourly probabilities of the inversion condition of different seasons in three sites, and a similar pattern emerges. After sunset, because radiation cooling effect dissipates the low level atmospheric energy, the probability of the inversion condition increases as time advances and reaches a maximum at dawn. The main type of temperature inversion is radiation inversion. After sunrise, the solar energy replenishes the low level atmospheric energy, so the probability of the inversion condition decreases abruptly to a minimum and maintains this trend until nightfall. The main type of temperature inversion is frontal inversion.

Figure 2 shows spring gets the highest probability of the inversion condition among seasons for Taipei, and its probability reaches a maximum of 0.24 at 6:30 am. Winter is the secondary with the maximum probability of 0.16 at 6:30 am, and the probabilities of the inversion condition are the lowest in summer and autumn.

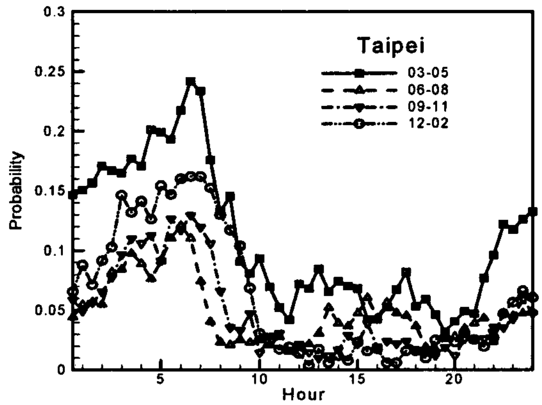

Figure 2 average hourly probabilities of the inversion condition of different seasons in Taipei.

Figure 3 shows winter has the highest probability of the inversion condition among seasons for Taichung, and its probability reaches a maximum of 0.79 at 8 am. The probability in spring is slightly larger than that in autumn, and their main difference lay between 9 am to 6 pm in which frontal inversion is the dominant type of temperature inversion. In Taichung, frontal inversion almost occurs in winter and spring.

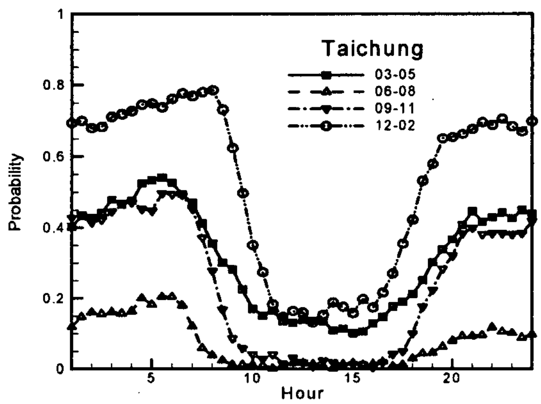

Figure 3 average hourly probabilities of the inversion condition of different seasons in Taichung.

Figure 4 shows winter has the highest probability of the inversion condition among seasons for Kaohsiung, and its probability reaches a maximum of 0.955 at 7:30

am. The value is the highest among three sites and indicates that radiation inversion occurs almost every day in winter. The probability in autumn is slightly larger than that in spring except from 9 am to 12 am, and this trend is different to the other sites. The probability reaches a maximum of 0.6 at 8 am in autumn, while the value is 0.5 at 7 am in spring. Frontal inversion occurs evenly in all seasons in Kaohsiung.

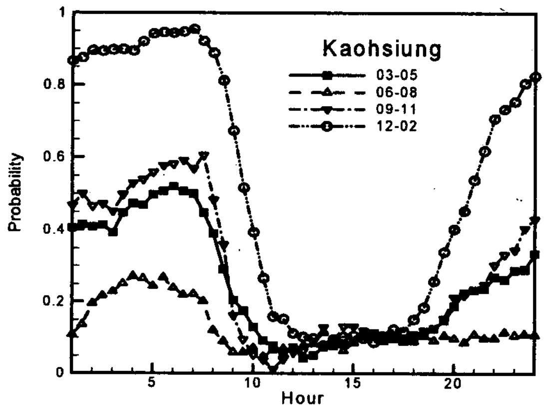

Figure 4 average hourly probabilities of the inversion condition of different seasons in Kaohsiung.

Figure 5 shows the probabilities as a function of the temperature difference (the inversion intensity) and indicates the probability increases as the temperature difference decreases for three sites. The probabilities in Taichung and Kaohsiung show a similar trend, and the decline rate of the probability in Taipei is larger than those in the other sites. The percentages of the temperature difference smaller than 2 degree are 96%, 86%, and 84% for Taipei, Taichung, and Kaohsiung, respectively.

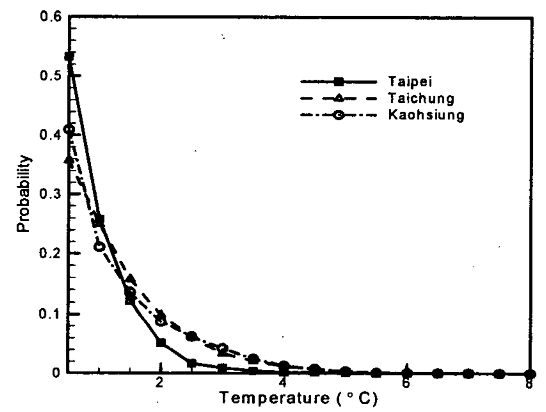

Figure 5 probabilities as a function of the temperature difference (the inversion intensity).

Figure 6 shows the probabilities as a function of the starting height of the inversion condition for three sites. The main types of temperature inversion in the low level atmosphere are radiation inversion and frontal inversion. Contrasted to frontal inversion, radiation inversion tends to occur at a lower altitude. The percentages of the starting height lower than 300 m are 61%, 80%, and 91% for Taipei, Taichung, and Kaohsiung, respectively. This shows that the dominate type of temperature inversion in Taichung and Kaohsiung is radiation inversion. The percentages of the ground inversion are 12.2%, 24.8%, and 21.4% for Taipei, Taichung, and Kaohsiung, respectively. A local maximum occurs between 100m and 200m for all three sites. While the starting height exceeds 500 m, the probabilities in Taipei and Taichung increases as the starting height increases and the probability in Kaohsiung maintains about 1%. This indicates frontal inversion in Kaohsiung occurs much less frequently than those in Taiwan and Taichung.

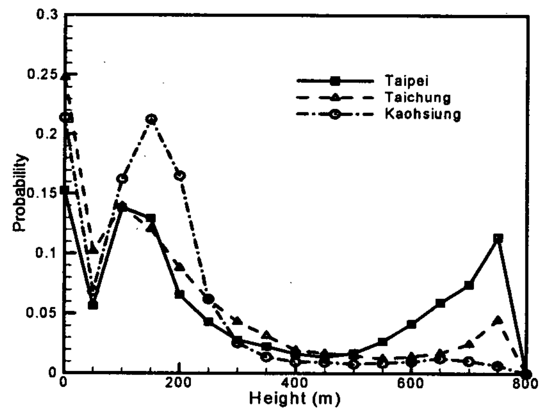

Figure 6 the probabilities as a function of the starting height of the inversion condition for three sites

Figure 7 shows the probabilities as a function of the thickness of the inversion layer for three sites. The maximum probability occurs between 250 m and 300 m for all three sites. The percentages of the thickness lower than 300 m are 72%, 56%, and 72% for Taipei, Taichung, and Kaohsiung, respectively.

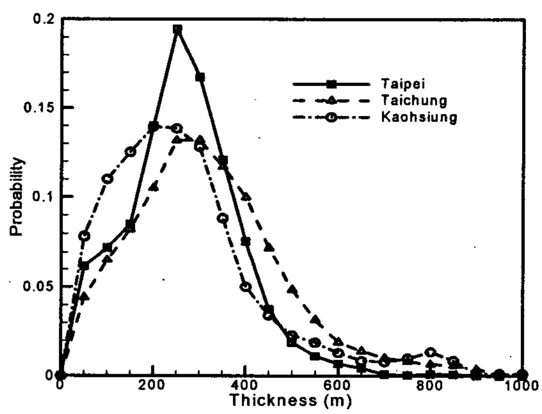

Figure 7 the probabilities as a function of the thickness of the inversion layer for three sites.

Figure 8 shows average hourly T_{av}-T_i for three sites where Ti is the ground temperature while a inversion condition occurs, and T_{av} is the average ground temperature at the same time over previous 7 days. The value becomes larger while the inversion condition stems from the transient weather condition such as the passage of a cold front. T_{av}-T_i shows abrupt increase and decrease at dawn and nightfall, respectively, for three sites. The dominant type of temperature inversion switches rapidly from radiation inversion to frontal inversion after dawn, and radiation inversion dominates gradually again after nightfall.

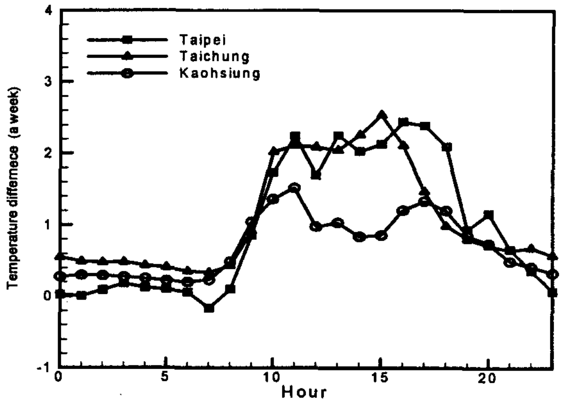

Figure 8 average hourly T_{av}-T_i for three sites where Ti is the ground temperature while a inversion condition occurs, and T_{av} is the average ground temperature at the same time over previous 7 days..

4. CONCLUSIONS

The characteristics of temperature inversion in Taichung and Kaohsiung show a similar trend but are different from that in Taipei. The numbers of the occurrence of temperature inversion in Taichung and Kaohsiung were much larger than that in Taipei. The main types of temperature inversion in Taiwan are radiation inversion and frontal inversion. Compared to frontal inversion, radiation inversion on average occurs at a lower altitude, lasts a longer period, has a deeper thickness, and reaches a higher temperature difference of inversion. Frontal inversion plays a significant role for the inversion event lasting over 12 hours.

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