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COMPREHENSIVE ANALYSIS OF THE MACRO- AND MICRO-PHYSICAL CHARACTERISTICS OF DENSE FOG IN THE AREA SOUTH OF THE NANLING MOUNTAINS

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Abstract: Using the composite field observational data collected in the area south of the Nanling Mts. and numerical modeling, the seasonal features of dense fog and visibility, fog drop spectrum and physical concept of fog forming have been analyzed. The occurring frequency of low visibility(≤200 m) is very high with a mean of 24.7%, a maximum of 41.8% from the end of autumn to winter and next spring. The fog processes that occur in the area south of the Nanling Mts. in spring and winter result from the interactions of complicated micro-physical processes, the local terrain, water vapor transportation and the influencing weather system. The fog processes are arisen from advection or windward slope, which is much different from the radiation fog. Cooling condensation due to the air lifted by the local mountain plays an important role in fog formation. Windward slope of the mountain is favorable to the fog formation. Dense fog can occur at lower altitudes in the windward slope of mountain, resulting in the lower visibility. The fog is mainly of small-drop spectrum with smaller number-density than that of urban fog, and its drop spectrum has descending trend in the section of smaller diameter. The inverse relationship between fog water content and visibility is the best among several relationships of micro-variables. In addition to micro-physical processes of fog body itself, the motion of irregular climbing and crossing over hillside while the fog body is being transported by the wind are also important reasons for the fluctuation of micro-physical parameters such as fog water content.

Key words: dense fog; visibility; weather system; fog drop spectrum; fog water content

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1 INTRODUCTION

As a weather phenomenon that brings about disasters, fog has been receiving more and more attention[1, 2]. Since 1958, fog has been studied in China in terms of its physics. Efforts were on the observational study on the micro-structure of fog prior to the 1970s while great progress has been made in observational experiments in recent years. On large scale, the latter has been carried out [3 - 13]. In recent years, the effect of fog and haze on high ways, airports and aviation traffic has been studied intensively.

Part of a national expressway from Beijing to Zhuhai passes northern Guangdong province where it climbs over the main section of a mountain range in varying altitudes above sea level. In winter and spring, fog appears frequently over the road in altitude from 200 m to 800 m and then back to 200 m, most heavily within the highest 15 km of altitude of the expressway, posing great threats on traffic safety. Characteristics, on both micro and macro scales, were studied in 1999 with the first-hand data measured from field observations.

2 BRIEF ACCOUNT OF THE DATA

Two large-scale field observations were carried

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out from Dec. 1998 to Jan. 1999 and from Feb. to Mar. 2001 in the section of the expressway of interest. The primary site of observation was at 815 m and the sounding site 435 m above sea level. Items like dual-parameter low-level sounding, tethered sounding, spectrum of aerosols, chemical compositions of fog / rain water, spectrum of fog droplets and liquid water content (LWC), visibility based on instrument and the bare eye were measured as well as conventional elements of wind, temperature, pressure and humidity. Additionally, a continuous observation was made from Nov. 1998 to Apr. 2001 in which visual measurements of visibility were obtained for a period of 2 and 1/2 years.

3 SEASONAL DISTRIBUTION OF POOR VISIBILITY IN THE MOUNTAINOUS REGION OF NANLING MTS.

Generally, the threats to road safety are the maximum when visibility reduces to less than 200 m. Heavy fogs in which visibility $\leqslant$ 200 m appeared are labeled poor processes of visibility. Tab.1 and Fig.1 give the relevant statistics. It is shown that poor visibility appears in all months, with high frequency (of 24.7% in average) in late autumn, winter and spring. The maximum monthly frequency is 41.8% (Feb. 2002). The average frequency is 3.0% for summer and early autumn. Poor visibility appears the most in Feb., followed by Jan., Nov., Dec., Oct., Mar. and Apr. It is then concluded that destructive heavy fog usually happens in winter and spring over the mountainous region of Nan Ling Mts.

Tab.1 Annual distribution frequency of hourly visibility in the mountainous region of Nan Ling Mts.(Unit of visibility L: m)

month	$L\leqslant 50$	$50<L\leqslant 100$	$100<L\leqslant 200$	$200<L\leqslant 500$	$500<L\leqslant 1\,000$	$L>1\,000$
Jan.	6.3	16.4	7.6	15.7	4.8	49.3
Feb.	6.2	14.6	9.8	12.7	5.5	51.3
Mar.	4.2	9.0	8.0	17.1	6.5	55.3
Apr.	4.2	8.3	5.6	12.0	7.4	62.4
May	0.4	1.3	0.9	1.6	2.4	93.3
Jun.	0.3	0.7	0.7	1.0	0.8	96.5
Jul.	0.4	0.0	0.0	0.3	0.0	99.3
Aug.	0.7	0.5	0.7	0.7	0.3	97.2
Sept.	3.2	3.2	1.7	2.8	1.0	88.2
Oct.	6.6	10.8	5.0	12.2	6.3	59.1
Nov.	4.7	14.9	8.7	11.0	5.0	55.7
Dec.	5.3	12.0	5.3	6.9	3.4	67.1
May – Sept.	1.0	1.2	0.8	1.3	0.9	94.9
remainder	5.3	12.3	7.1	12.5	5.6	57.2

4 SPECTRUM OF FOG DROPLETS, LWC AND VISIBILITY OF HEAVY FOG IN NANLING MTS.

From the observational comparison between five processes of heavy fog obtained from the two field observations and those made elsewhere in China, it is known that fog droplets with diameter $\leqslant$ 25 μm take up the majority of all the processes (more than 89% of the number density total). The difference of number density varies much from fog to fog, with the largest being four folds or above. The fog processes with large number density are usually with small mean diameter of droplets. The mean number density is about 138 per cm^3 for the heavy fog in Nan Ling Mts. and about 9.5 μm in mean diameter. LWC does not vary much of the five fog processes and no significant difference is found between LWC determined with spectrum of fog droplets and the one observed, which is usually smaller.

For analyses of other aspects, refer to the Chinese edition of the journal.

5 SUMMARY AND CONCLUSIONS

The analysis above reveals the following characteristics of the fog taking place in the section of the Beijing – Zhuhai expressway through the Nan Ling Mts.

(1) During late autumn, winter and spring, the frequency is very high for poor visibility to appear in the mountainous region of Nan Ling Mts., with heavy fog with visibility $\leqslant$ 200 m appearing at a rate of 24.7% and poor visibility appearing as frequently as 41.8%. In the order of severity, the months with poor visibility are Feb., Jan., Nov., Dec., Oct., Mar. and Apr.

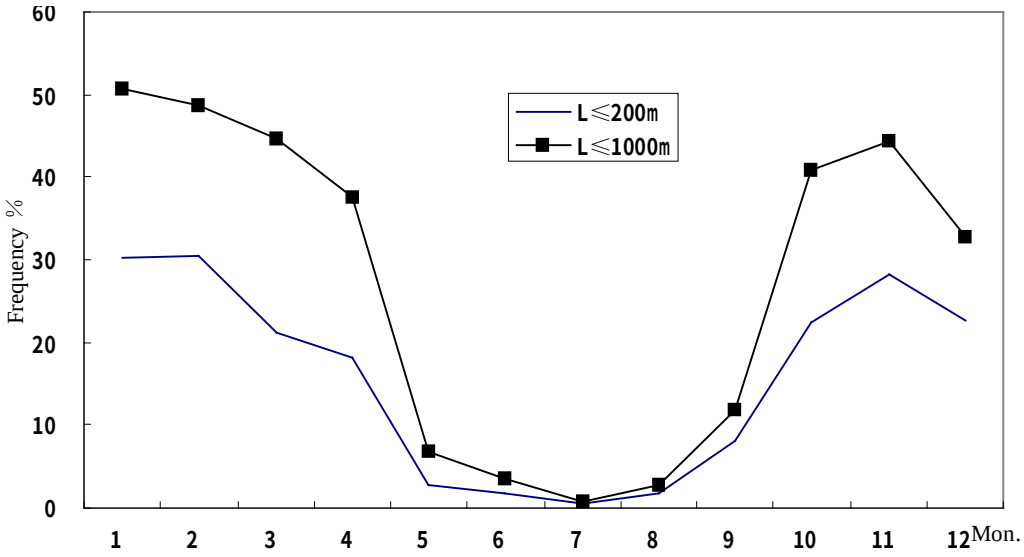

Fig.1 Distribution of annual frequency of hourly visibility in the mountainous area of Nan Ling Mts.

(2) Fogs appearing in the mountainous region of Nan Ling Mts. during winter and spring are the results of complicated interactions between atmospheric physics and local terrain. Advection dynamically driven by weather systems and condensation due to cooling by lifting effect over local mountains are playing important roles in the formation of fogs. Windward slopes are a favorable condition. Fogs during this time of the year in this area are mainly of weather systems, from which low-level saturated air expands towards the surface to form fog at the bottom of clouds. They are actually low-lying clouds. A preliminary conceptual picture can be outlined of the formation of mountainous heavy fog in Nan Ling Mts: Under the effect of weather systems, dominant airflow changes into fog due to the lifting effect of mountain slopes and the fog interacts with the cloud system of the weather system to form heavy fog weather typical of the local area.

(3) The fog appearing during the winter and spring seasons in Nan Ling Mts. is of the types of advection and hill-climbing, which are much different from the radiation fog. For the latter, visibility shows distinct diurnal characteristics: Fog begins to appear at midnight and dissipates in the morning or midday. For the fog related with weather systems, however, fog does not show any significant diurnal variation during the life cycle and maintains for a period consistent with the weather system.

(4) Spectrum of fine droplets is dominant in the fog of Nan Ling Mts. with smaller number density than in cities. The spectral pattern shows a basic tendency of falling in the section of fine particles. Among a number of micro variables, the anti-correlation between LWC and visibility is the best at –0.762. The fluctuation of characteristic quantities of micro-structure of LWC are associated with irregular climbing of air up and over mountains, which results in inhomogeneous structure and fluctuating fog body, as well as the micro-physics of the fog itself.

Deep understanding of the heavy fog weather taking place in winter and spring in the Nan Ling Mts. area has been achieved through the analysis of the two comprehensive field observations. The unique geophysical environment, high terrain and complicated local land forms make it one of the important climatic divides in China. Lying across the northern Guangdong province that borders with Hunan province, the Nan Ling Mts. is evidently blocking the movement of weather systems, especially during winter and spring when they (such as frontal surfaces) are more frequent and tend to shift back and forth and stagnate over the mountain range, resulting in complicated cloud systems due to the convergence of cold and warm air flows. At the same time, places with high altitudes above sea level, such as peaks, are usually covered with low-lying clouds that become heavy fog locally. The weather process can last for several days, accompanied with phenomena of alternately appearing clouds, rains and fogs, glaze, rime and drizzle and possibly with the icing of roads and antenna. The influence on local traffic, people and ecosystem is made worse by fog water and rainwater, which have high acidity. The analysis and research based on the two filed observations are mainly for clouds and fogs under the condition of weather systems while work remains insufficient on radiation fog with the effect of local terrain in Nan Ling Mts.

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