THE STUDY OF MACRO-MICROPHYSICAL CHARACTERISTICS

P2.14 ON *STRATIFORM CLOUDS OVER NORTH CHINA*

Duan Ying*, Wu Zhihui and Shi Lixin
Weather Modification Office of Hebei Province, Shijiazhuang, 050021, China

1. Introduction

Hebei Province lies in the north of China, with continental monsoon climate; the average annual precipitation is 541mm. It is one of the least water resources areas in China; the average water resources amount only accounts for 1/10 of the national average amount and 1/40 of the world average amount. In order to solve the problem of water shortage, aircraft rain enhancement operation and cloud physics research have been conducted for 21 years since 1990. The aircraft is An-26 (made in pre-Soviet) with airborne PMS (PMS Inc., USA),Weather radar, satellite, ground-based microwave radiometer, lighting detection and positioning system (LDPS) and cloud simulation models are used unremitting in the field operation and research. After from 2004 another an equipped aircraft was using with airborne PMS (DMT Inc., USA).

Some researches had been completed by different researcher for this area more than twenty years in past. For instance, Duan ying, Qian chunsheng and Wu zhihui (1994); Duan ying and You laiguang (1994); Duan Ying, Wu Zhihu and Shi Lixin (1998); Duan et.al (2000, 2007).

The purpose of this paper is introducing the main research results of Hebei Province in China since 1990.

2. Concept model and macro characteristics on stratiform clouds

2.1 Concept model

According to the study results of precipitation weather system of stratiform clouds, stratiform cloud system is the main object in aircraft cloud seeding in north China.

* *Corresponding author address* :Duan ying, Weather Modification Office of Hebei Province, Shijiazhuang,China ;e-mail: hbwmo@heinfo.net

There are 4 kinds of weather systems suitable for aircraft rain enhancement operation in this area of China: Westerly Trough, Southwest Vortex, Cold Front and Returning Flow weather system. For instance, based on radar, satellite, 3-hour rainfall intensive, radiosoudage and aircraft observations, fig.1 shows the cross section of cloud structure concept model during a Returning Flow weather system on 24 May 1991. In front of the system, the temperature is -5℃ at 4000m: the supercooled liquid water content (SLWC) is 0.16g m^{-3}; the ice crystal concentration is 30-50 L^{-1}. It shows the lack of natural seeding mechanism (ice crystal process) in cloud, the weather system is suitable for cloud seeding.

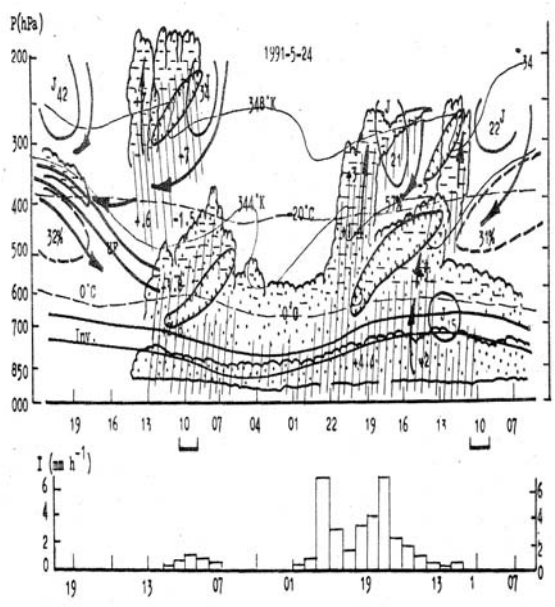

Fig.1 The concept model of returning flow weather system is suitable cloud seeding. Underside short beeline above figure is seeded period of time by aircraft. Underside figure is rainfall change with every hour .

2.2 Macro Characteristics

According to 62 flights observations, 28 flights are 3000~4000m in cloud depth, 22 flights are more than 4000m. 9 flights are 0~-4℃ in cloud top temperature, 26 flights are -4℃~-10℃ in cloud top temperature, 24 flights are -10℃~-20℃in cloud top temperature, 2 flights are below -20℃. When average surface rain rate is less than 1mm, the corresponding average cloud depth is 3300m; when surface rain rate is 1~2.5mm, the the average cloud depth is 4510m; When surface rain rate is more than 2.5mm, the average cloud depth is 5050m. Compared with average surface rain rate, most of the cloud top temperatures are -4--20℃ when rain occurs. When cloud top temperature is more than -10℃, the precipitation with average rain rate more than 1mm occurs. Accumulated frequencies distribution of cloud base height and cloud depth are shown in fig.2, fig.3 and table 1.

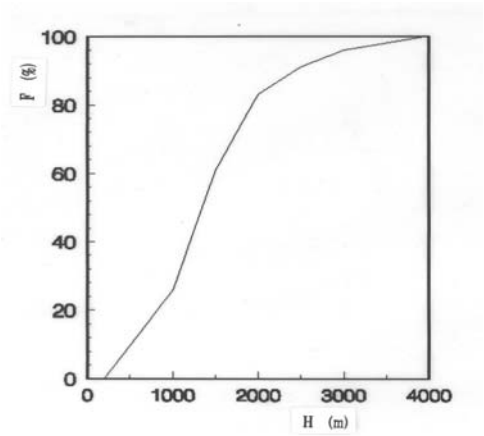

fig.2 Accumulated frequencies distribution of cloud base height

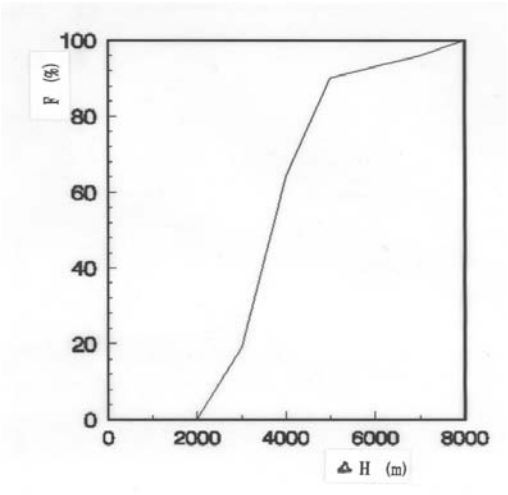

Fig.3 Accumulated frequencies distribution of cloud depth

Table.1Macro Characteristics of Stratiform clouds

Cloud Form	Percent (%)	Average Cloud Base Height (m)	Average cloud Depth (m)	Average rain Rate (m)
As-Sc	58	1270	3800	0.86
As-Ns	31	950	4400	1.53
Asop	6	3060	2510	0.30
Scop	5	1830	2360	0.59

3. The microphysical characteristics of stratiform clouds

3.1 Cloud liquid water content (LWC) in clouds

Observed by PMS FSSP probe, the average LWC is very small in middle level of stratiform clouds over Hebei Province, it is only 0.04 g/m^3, the max LWC is 0.45g/ m^3. Further analysis shows that more than 67% flights observed the supercooled water region with LWC more then 0.1g/m^3. In seeding level, the LWC is inhomogeneous. Above analyzed results as underside fig.4 and fig.5.

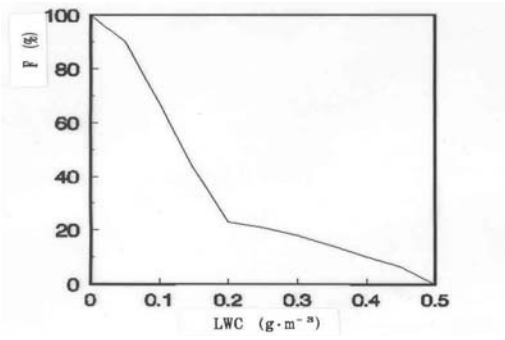

fig.4 Accumulated frequencies distribution of max LWC

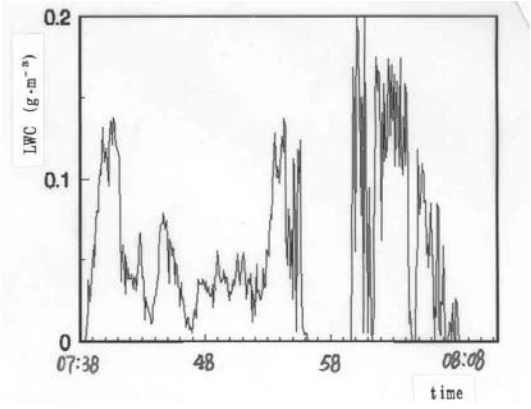

Fig.5 horizontal distribution of LWC in stratiform clouds

3.2 Ice crystal concentration

Observed by PMS 2D-C probe, the average ice crystal concentration is 15.6 L^{-1} in stratiform clouds over Hebei Province. It has the similar result with Jilin Provinces (14.6L^{-1}). The ice crystal concentration varies greatly with weather system, cloud top temperature and upper seeding cloud band etc. According to the statistics in flight, 88% of flights observed that the average ice crystal concentration was less than 30 L^{-1}; according to the statistics in total samples, 49% of flights observed that the average ice crystal concentration was less than 10 L^{-1} and 84% of flights observed that the averaged ice crystal concentration was less than 30 L^{-1}. The results show in fig.6a.

3.3 Cloud droplet concentration and size

The average cloud droplet concentration is 62 cm^{-3} in 4000-6500m MSL. It is 200 cm^{-3} in lower level. 93% of cloud droplet diameters are 4-12μm, and the average is 9μm. The droplet spectrum is narrow; it shows that the cloud droplets have the continental characteristics in Hebei Province of north China. The results show in fig.6b.

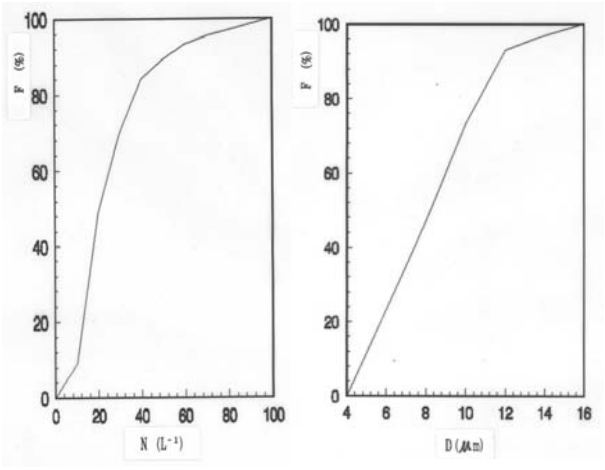

Fig.6 (a) Accumulated frequencies distribution of ice crystal concentration (left); (b) Accumulated frequencies distribution of droplet diameter (right)

4. The microphysical characteristics of stratiform clouds in different region of north China

According to previously many observed and analyzed results by Duan ying and Wu zhihui et.al, the precipitating stratiform clouds is the main object in aircraft cloud seeding. The microphysical characteristics of precipitating stratiform clouds between Hebei Province area and other areas in north China is shown in table 2. It shows in table 2, LWC value is 0.01~0.45gm^{-3} by PMS probed over Hebei province area. It is equivalent with other province area of north China, for example, Jilin, Xinjiang, Inner Mongolia, Shaanxi, Ningxia, Shandong etc.

Table 2 The Microphysical characteristics of precipitating stratiform clouds between Hebei Province area and other areas in north of China

Area	LWC（g m^{-3}）	Ice crystal concentration(L^{-1})
Hebei	0.01～0.45（PMS）	15.6（PMS）
Jinlin	0.04～0.25	14.6
Xinjiang	0.01～0.25 0.04～0.30（PMS）	39.2 10～70（PMS）
Inner Mongolia	0.01～0.25	46.5
Shaanxi	0.19～0.25	0.01
Ningxia	0.05～0.11	26.5
Shangdong	0.01～0.36（PMS）	13.9（PMS）
Henan	0.01～0.25（PMS）	14.2（PMS）

Acknowledgements

This study was jointly supported by the social commonweal research Project (GYHY(QX)2007-6-36) and the national science and technology pillar Project (2006BAC12B00-01-01-02) of the Ministry of Science and Technology of China.

References

Duan ying, Qian chunsheng and Wu zhihui, 1994: An observation and analysis on Southwest Vortex cloud series for artificial precipitation. The physics on the precipitating stratiform cloud system with artificial rain enhancement technique. Chinese Meteorological Press, Beijing. p69-82.

Duan ying and You laiguang, 1994:The Clouds

and precipitation physics with artificial rain enhancement technique. Chinese Meteorological Press (in Chinese).

Duan Ying, Wu Zhihu and Shi Lixin', 1998: The Study of Operational Technique on Aircraft Rain Enhancement. Chinese Journal of Eco- Agriculture.Vol.6, p80-83.

Duan et.al, 2000: The Observation and Analysis of Precipitating Stratiform Cloud Structure over Northern China Area. 13th International Conference on Clouds and Precipitation , Proceedings, p367-370. Reno, Nevada, America.

Duan et.al, 2007: The Study of Macro-microphysical Characteristics of Seeding Clouds for Aircraft Rain Enhancement over North China. 9th WMO Conference on Weather Modification, Antalya, Turkey