A Study Of Micro-physical Characteristics and Seedability Of Cold Stratiform Clouds In North China

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Introduction

Precipitation of stratiform clouds were detected with the particle measurement technology (DMT) in Shanxi test area on 11-12 March 2009. The aircraft made vertical and synthetic detecting flying purposefully. the micro-probe data obtained in the cloud processing, analysis, and to find the cloud cooled water content in the cloud distribution, while Gu zhen-chao three-layered model of stratiform cloud to analyze the cloud structure, precipitation formation and precipitation of stratiform cloud microphysical characteristics, in order to better understand the structure of precipitation and cloud formation mechanism of natural rainfall, provide a theoretical basis for artificial rainfall operations.

1 Weather Background

On 11-12 March 2009, there was a large range of stable stratiform precipitation process in North China. Rainband was basically northeast - southwest direction, the move are basically the same as the upper trough.

2 Flight probe program design

This probe uses Y-12 aircraft, using airborne cloud particle probes from the United States DMT (Droplet measurement technologies) company introduced, CAPS (Cloud Aerosol and Precipitation Spectrometer), CCN (Cloud Condensation Nuclei Counter) and other probes. March 11, 2009 08 pm, rain clouds began to go over the western, to understand the cloud microphysical structure of different levels, access to specific stratiform precipitate formation in North China, the new understanding of potential and mechanisms analysis of artificial rainfall, we conducted a series of vertically stratified cloud detection. 600 meter spacing between layers, starting from the cloud base, spiral, each level flight for 5 minutes, after the genting , the interval is still 600 meters , vertical layered down until the security level. This method can give particle spectrum flight phase state, with Vertical distribution with height of moisture and other continuous, through the analysis of the vertical distribution of particle spectra, can deduce the main physical processes of precipitation formation.

From the ground to upper air, the atmosphere is stable, the air humidity, Zero level is at 850 hPa (1500 m) near. It is a cold cloud precipitation process.

3 Cloud microstructure characteristic and seedable analysis of artificial rainfall

According to Gu zhen-chao three-layered model of stratiform cloud l, there are three layers in maturity stages of stratiform cloud, where the first layer is ice layer, the second layer is super-cooled water layer, the third layer is warm layers. The aircraft detected in the mid to late in the process of precipitation, there is only the second and third tiers, with the second layer (mixing layer) thickness of 3-4 km, a temperature range of 0 - 17.7 °C, the third layer ( warm layer) thickness of about 0.6 km, the main objective of the program to detect is the mixed layer.

3.1 Cooled water content characteristics of the cloud

According to the CDP probe data, time series in the probe, the average cooled water content in the cloud is 0.012g/m³.we calculate the change of cooled water content with height from 0 °C .In order to facilitate comparative analysis, calculate the cloud super-cooled water content with the height of each one hundred meters intervals by height from 0 °C . calculated by the cloud of super-cooled water content from 0 °C height distribution shown in Figure 1.

As can be seen from Figure 1, vertical distribution of the cloud cooled water content from 0 °C height: in height 100 m from 0 °C , the super-cooled water is low. With the height of from
0 °C to increase, the super-cooled water content increase, in the probe process, the super-cooled water content maximum come out in height of the 400m from 0 °C, at its maximum value, respectively 0.416g/m³; later with a height of from 0 °C to increase, the super-cooled water content decreases rapidly, at 600m height from 0 °C, come up to the minimum, until Genting, the super-cooled water content maintain low levels. This generation and distribution structure is related to the weather of Shanxi Province.

Then, according to the statistics history of exploration data, in Shanxi Province in the precipitation of stratiform clouds, above 300 ~ 500 m layer from 0 °C the cloud updraft at the maximum speed, entrusted with most of the droplets, so in this height range of super-cooled water content produced a large value area.

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3.2 The vertical distribution of cloud micro-physical

By the height of the cloud particle concentration distribution can be seen, changes in cloud droplet concentration with height turn multimodal distribution, and undulating, LWC and N has a good positive correlation, correlation coefficient is 0.84. 0 °C layer near the cloud droplets, cloud particles spectrum, ice particle spectrum, scale precipitation changes in particle concentrations are large, messy image layers indicating that there are rapid change of particles state in the zero phase. After maintaining Low in 1650 a high degree of increases and then rapidly decreased near to zero, then increases with height, cloud droplet concentration of 1800m near the maximum 452 / cm³, LWC also increase up to the maximum. In the height (altitude 1500-2000m) rich super-cooled water near, the average diameter of cloud droplet concentrations are positively correlated with, but above 2000 meters the concentration decreases rapidly as the cloud droplets, cloud droplets of average diameter turn a clear jump in, negative correlation.

Particle concentration, mean diameter CIP, PIP probed, distribution with height tell us. the height (altitude 1500-2000m) rich super-cooled water near, a little change in particle concentration, more consistent, and CIP, PIP probe showed the average diameter ,the particle concentration turn more obvious anti-correlation, large cloud droplet diameter corresponding to small cloud droplets concentration, the average particle concentration CIP probed is 10-2 / cm³ magnitude, average particle concentration PIP measured is 10-3 / cm³ magnitude, in the cloud ,especially in the cold (0 °C layer above) layer, particles concentration CDP probed is about four orders of magnitude what CIP probed, indicating The number of particles less than 25µm in diameter are more.

In the height (altitude 1500-2000m) rich super-cooled water near, the average particle diameter has a little change, the average diameter of three probe are 8.01µm, 385.18µm and 165.28µm. Description Cloud particles in cold clouds, the average diameter is less. It can be seen from Figure 2, in the supercooled water-rich zone, in the down process to detect particles, the diameter increases, we can see where Raindrops hitting and growth, cloud droplets condensating and growth.

![Fig. 1 Vertical distribution between the content cold water in cloud with height from 0 °C during detecting on 11 March 2009](image)

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![Fig. 2 Two-dimensional particle image](image)

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Hobbs has been suggested that when using FSSP-100 probe observed, cloud total concentration of particles larger than 2µm over 107/m³ or 10/cm³ time, as the cloud water area. You
According to this criterion, it seems that when the cloud droplets concentration exceeds 10/cm³, the clouds have been super-cooled water rich in supercooled water, with great potential for artificial rainfall.

3.3 Cloud particle characteristics change over time

In order to understand the different detection time, the cloud microphysical structure, precipitation distribution characteristics, the precipitation formation mechanism, the seedability of artificial precipitation, the detection of line added to the radar echoes, Figure 3 shows the detection process the CDP to detect the particles concentration in the cloud N1, L water content, CIP probe to detect the number of large particles of the cloud concentration N2, T for the detection of temperature, we refer to the configuration of the four physical conditions, such as the detection time is divided into shown the different sections, average of the various sections of the cloud are shown in Table 1, the following the seedability artificial rainfall analysis is made separately for each segment.

<table>
<thead>
<tr>
<th>Tab1. Cloud micro-physical values sampled with DMT probe and seedability</th>
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<tbody>
<tr>
<td>Section No</td>
</tr>
<tr>
<td>N₁/cm³</td>
</tr>
<tr>
<td>L/(g/m³)</td>
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<tr>
<td>N₂/cm³</td>
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<tr>
<td>T (°C)</td>
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It can be seen from Figure 3, the cloud droplet concentration N within a maximum of 432 / cm³, the minimum is only 0.11 / cm³, a difference of four orders of magnitude. C₁ segment is the aircraft down, Slightly larger changes in the micro-physical value, LWC maximum 0.42g/m², the smallest almost 0g/m², C₁ section of cloud droplet number concentration, liquid water content and number concentration of ice crystals appear peak, in this layer the growth of precipitation particles is active. In C₂ segment aircraft continued to decline, reducing micro-physical changes, C₃ segment 20:08:34, aircraft reach the level of 0 and flight. Radar echo from the RHI (figure omitted) shows a clear zero-layer melting layer bright band, near the melting layer bright band echo intensity has increased, caused by the snow, ice melt and precipitation particle collision in the clouds and reflected there is a clear ice-water conversion layer in the stratiform precipitation. C₄ segment near the zero level detection, changes in micro-physical value is still large.

Fig. 3 Variations of the Cloud micro-physical values with time sampled with CDP probe

Reference to the configuration of the four physical conditions, given the various layers of the probe particle spectrum as shown. Figure 4 shows the distribution of the cloud particle spectrum, super-cooled water rich in the over 2000m, 1800m, 1500m cloud droplet particles spectrum turn bimodal distribution, and the spectral width is significantly greater than the super-cooled water has a low level of 1700 m height, 0 layer 1500 m peak diameter is 29µm, 1700 m peak diameter is 24µm, we can see the main the LWC come from the large-scale cloud droplet. Figure 4 shows the four types showed a high degree of cloud droplet spectrum bimodal distribution, which is related to the large particle fall in high levels, cloud particle concentration value in the period are higher than LWC lower time. Shows that in the LWC less time there are snow crystal polymer, more ice, a small amount of smaller scale supercooled cloud droplets, and higher LWC time can be significantly found the dominated presence of supercooled cloud droplets.
indicating ice crystal particles produced ion in the cloud consume the supercooled cloud droplets, making the supercooled water content decreased, Cloud droplets concentration of each range reduce and the particle spectrum wider, the particle number concentration of scale precipitation increase and spectrum broader.

Fig. 4 The particless spectrum distribution
You lai-guang (1994) have discussed the cloud particle phase state, to distinguish the problem that when the ice crystals and cloud droplets are present, the particle spectrum is discontinuous and come out a second peak, which suggested the approach that with the cloud particle scale spectrum distribution to determine the cloud particles phase-state. Figure 4 shows the particle spectra of this detection, we can see, the section which the particle spectrum to detect a second peak, the N$_1$ on this section is not more than 30/cm$^3$, but often to a very substantial water content, but the emergence of second peak in the particle spectrum marks the ice particles on the corresponding section of may exist, which gives the water content is actually false, the artificial rainfall, there is no meaning, conversely, the sections where the N$_1$ is below 30/cm$^3$, the particle spectral shapes are like this, it can be considered only when N$_1$ is no less than 30/cm$^3$, the corresponding area will be seedable.

4 Conclusion and discussion

Based on integrated analysis of the cloud data obtained by digital radar, the particle measuring system (DMT) the main cloud physical parameters used to identify cloud seedability are proposed. Calculated cloud water content from 0 to over layer height (1500m) in the vertical distribution: the cloud water content had a maximum in height above 0, followed until the cloud, the cloud had to maintain low water content. Only when the relevant cloud particle concentration obtained by CDP probe of DMT is larger than 30/cm$^3$, has the cloud area certain seedability. Furthermore, when the particle concentration obtained by CIP probe of DMT is less than 10/cm$^3$, the cloud is highly seedable and otherwise it is not seedable.

In cloud, droplet concentration with height is multi-peak distribution, and the undulating, LWC and N has a good positive correlation, correlation coefficient is 0.84. 0 layer near the cloud droplets, cloud particle spectrum, ice particle spectra, particle-scale precipitation changes are large, rich in supercooled water near the height (altitude 1500-2000m), the average diameter of cloud droplet concentrations were positively correlated with, but above 2000 meters the concentration decreases rapidly as the cloud droplets, the average diameter of cloud droplets there is a clear jump, and the concentration is negative correlation.

Key word: Micro-physical Characteristics; Seedability; Cold Stratiform Clouds

References: