MEASUREMENT OF CLOUD CONDENSATION NUCLEI OVER NORTH CHINA

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1. INTRODUCTION

Cloud condensation nuclei (CCN) have close relation with cloud. With the increasing of global climate studies, the interest of cloud physics has shifted emphasis away from precipitation toward radiative properties (Hudson, 1993). CCN are the aerosol particles that can form cloud droplets. There is indirect effect arises from the possible influence of anthropogenic CCN. The first is Twomey effect that the increase in cloud droplets number concentration could increase the multiple scattering within clouds thereby increasing cloud-top albedo (Twomey et al., 1984; Platnick et al., 1994). The second is Albrecht effect that the increase in cloud droplet concentration may also inhibit precipitation development, enhancing cloud lifetime and resulting in an increase in planetary shortwave albedo (Albrecht, 1989) and possibly also in the atmospheric absorption of longwave radiation by the resultant increased atmospheric loading of liquid water and water vapour (Schwartz, 1996).

Observations of CCN in North China were made by Lixin and Ying (2007). The paper is to present the measurement of CCN and preliminary analysis of the relation of CCN and cloud droplet over North China.

2. INSTRUMENTATION

A Piper Cheyenne ⅢA twin turbo-prop aircraft was used for the observations. The cloud droplet was measured by a PMI (Particle Metrics Inc, USA) Forward Scattering Spectrum Probe FSSP-100ER. CCN were measured by a DMT (Droplet Measurement Technologies, USA) continuous flow streamwise thermal gradient CCN counter (Roberts et al., 2005). It has a cylindrical continuous flow thermal gradient diffusion chamber employing a novel technique by establishing a constant streamwise temperature gradient so that the difference in water vapor and thermal diffusivity yielding a quasi-uniform centerline supersaturation (S). An optical particle counter at the outlet of the chamber counts droplets with diameters larger than 0.75 μm. Those particles larger than 0.75 μm are considered activated CCN and comprise the CCN concentration. The temperature gradient and the flow though the column control the S and may be modified to retrieve CCN spectra. The instrument can operate between S = 0.1% and S = 2% at sampling rate of 1 Hz. CCN spectra can be derived by different supersaturation cycling measurements.

3. CASE ANALYSIS

The flight was performed on 21 May 2007. The non-precipitating stratiform cloud was observed with cloud top temperature more than 0°C. Cloud droplets were measured in traverse within 150m of cloud base. Sub-cloud CCN concentration was obtained at 0.1%, 0.2%, 0.3% and 0.5% saturation cycling measurements.

Fig.1 shows the flight track during cloud traverse and sub-cloud observation. The measurements of CCN and cloud droplet are given in Table 1. N_{CCN} is the averaged concentration, and N_{cd} is the averaged concentration of cloud droplet. It can be seen that the relation between N_{cd} and N_{CCN} is close at S=0.1%.

CCN spectrum can be fitted by the expression $N = CS^k$ (Twomey, 1959), where

N is the number of CCN activated at supersaturation S, C is the number activated at S=1%, and k is a constant.

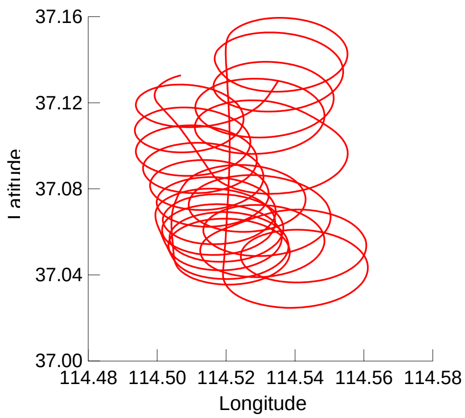

Fig.1 Flight track on 21 May, 2007

Fig.2 shows the sub-cloud CCN spectrum fitted by Twomey expression. The high values of C and k represent the polluted continental type of cloud.

Table 1 Sub-cloud CCN and cloud measurements

N_{CCN} (cm^{-3})				N_{cd} (cm^{-3})	N_{cd}/N_{ccn}
S=0.1%	S=0.2%	S=0.3%	S=0.5%	102	S=0.1%
207.89	1120.22	1962.91	2354.53		0.49

Twomey (1959) also derived a simple analytical approximation to obtain cloud droplet concentration from updraft velocity and a two-parameter fit to the CCN spectrum,

$$N_{cd} = C^{2/(k+2)} \left[\frac{0.069w^{3/2}}{kB(k/2,3/2)}\right]^{k/(k+2)}$$

where w is updraft velocity, B is the beta function, C and k are the fitted parameters from CCN spectrum.

Because there is no way to derive the updraft velocity (w) during the observation, the different w is assumed for calculating the N_{cd} by Twomey equation.

Table 2 Calculated N_{cd} at different w

W(cm s^{-1})	10	35	50
Predicted N_{cd} (cm^{-3})	213	483	609

Table 2 shows the predicted N_{cd} from Twomey equation at w=10, 35 and 50 cm s^{-1}. If Twomey equation could properly describe the relation between cloud droplet and updraft velocity, the lower velocity is suitable

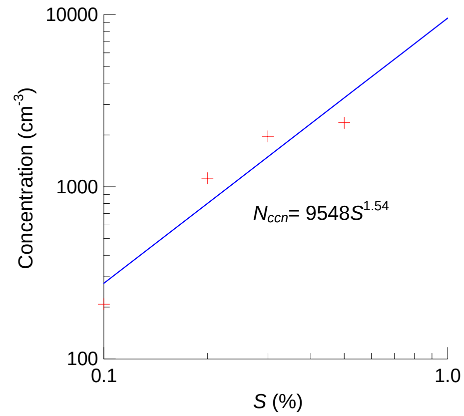

Fig.2 CCN spectrum below cloud base

for the stratiform cloud in the case.

4. DICUSSION

Twomey and Warner (1967) compared the cloud droplet concentrations with that computed from below cloud CCN spectrum with an updraft of 3 m s^{-1} in cumulus clouds. They found the high degree of agreement. Chuang et al. (2000) compared CCN data (S=0.1%) obtained during ACE-2 with cloud droplet data acquired by FSSP-100 in summer marine stratocumulus clouds. They found N_{cd} was closely related with sub-cloud CCN as N_{cd}~0.71N_{CCN} (R=0.9) or N_{cd}~$N_{CCN}^{0.31}$ (R=0.88). There is a relation of N_{cd}~0.49 N_{CCN} here, but it was derived only from one flight measurement, more observations need to be made.

REFERENCES

Albrecht B. A., Aerosols, cloud microphysics, and fractional cloudiness. Science, 245, 1227-1230, 1989

Chuang P. Y., D. R. Collins, H. Pawlowska, J. R. Snider,H. H. Josson, J. L. Brenguier, R. C. Flagan and J. H. Seinfeld, CCN measurements during ACE-2 and their relationship to cloud microphysical properties. Tellus, 52B, 843-867, 2000

Hudson J. G., Cloud condensation nuclei. J. Appl. Meteor., 32, 596-607, 1993

Lixin S. and Ying D., Observations of cloud condensation nuclei in North China. Acta Meteor Sinica, 65(4), 644-652, 2007. (in Chinese)

Platnick S. E. and S. Twomey, Determining the susceptibility of cloud albedo to changes in droplet concentration with the advanced very high resolution radiometer. J. Appl. Meteor., 33, 334-347, 1994

Roberts G. C. and A. Nenes, A continuous-flow streamwise thermal-gradient CCN chamber for atmospheric measurements. Aeros. Sci. Tech., 39, 206-221, 2005

Schwartz, S. E., Cloud droplet nucleation and its connection to aerosol properties, In Nucleation and Atmospheric Aerosols 1996. Edited by M. Kulmala et al., Oxford, Elsevier Science Ltd, 770-779, 1996

Twomey, S., The supersaturation in natural clouds and the variation of cloud droplet concentration. Geofis. Pura Appl., 43, 243-249, 1959

Twomey, S. and J. Warner, Comparison of measurements of cloud droplets and cloud nuclei. J. Atmos. Sci. 24, 702-703, 1967

Twomey S., M. Piepgrass, and T. L. Wolfe, An assessment of the impact of pollution on global cloud albedo. Tellus, 36B, 356-366, 1984

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