NOTES

Vertical Profiles of Condensation Nuclei

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ABSTRACT

Condensation nuclei measurements using a low supersaturation (~10%) thermal gradient diffusion cloud chamber (TGDCC) and a high supersaturation (~200%) expansion type instrument were compared on a series of three balloon flights over Laramie, Wyoming. In general the two instruments produced similar vertical profiles but some discrepancies remain unexplained. Agreement between the two would indicate that the low supersaturations used in the TGDCC were still large enough to cause the instrument to count essentially all of the particles present. The TGDCC condensation nuclei (CN) counter was flown at several sites in both the Northern and Southern Hemispheres. The results indicate the existance of a relative maximum in the CN mixing ratio associated with the upper equatorial troposphere and what appears to be a worldwide constant mixing ratio of CN above 20–25 km.

1. Introduction

In an earlier paper Rosen and Hofmann (1977) presented the results of a number of condensation nuclei (CN) soundings made over Laramie, using an experimental thermal gradient diffusion cloud chamber (TGDCC) operated at about 10% supersaturation. This note describes further developments in the evaluation of the TGDCC CN counter and presents the vertical profiles as measured with the instrument at several locations in both the Northern and Southern Hemispheres.

2. Progress in CN counter development and evaluation

In the early evaluation of the TGDCC, no conclusive evidence could be established that at above 20 km the supersaturation (~10%) was high enough to produce growth on all the particles, and hence, it was not known whether all of the CN present were being counted (Rosen and Hofmann, 1977). To further investigate this aspect of the counter, simultaneous comparison soundings were made with an expansion type CN counter developed by one of the authors (Kaselau, 1974), that was operated at a much higher supersaturation (~200%) than the TGDCC. It should be mentioned that the working fluid in the expansion type CN counter was water, while in the other counter it was glycol. Three soundings were made with both instruments on the same balloon. The results of the average of all three soundings are shown in Fig. 1. Most of the data has been smoothed by taking a 7-point running average.

There is a good relative agreement between the two instruments at altitudes below 15 km. The small discrepancy in the absolute values may be attributed to the diversity of the two counters and the general problem of obtaining accurate absolute values. The precise reason for the discrepancy is not known at this time but a factor of 2 disagreement is of relatively minor significance for most considerations. Above 15 km, there is lack of agreement in the discrete data points, but a general agreement in the average absolute values within about a factor of 2 is apparent. Statistical fluctuations in the expansion chamber data account for a large part of the lack of agreement in the fine detail. Each point in an individual profile is derived from the number of particles counted after an expansion, and since this number is small (frequently zero) at high altitude, large excursions in the apparent vertical profile would be expected. The statistical counting error of the TGDCC, on the other hand, is 4% or less.

In the earlier efforts to use the TGDCC at high altitude, it was found that the instrument ceased to function altogether above about 25 km for reasons

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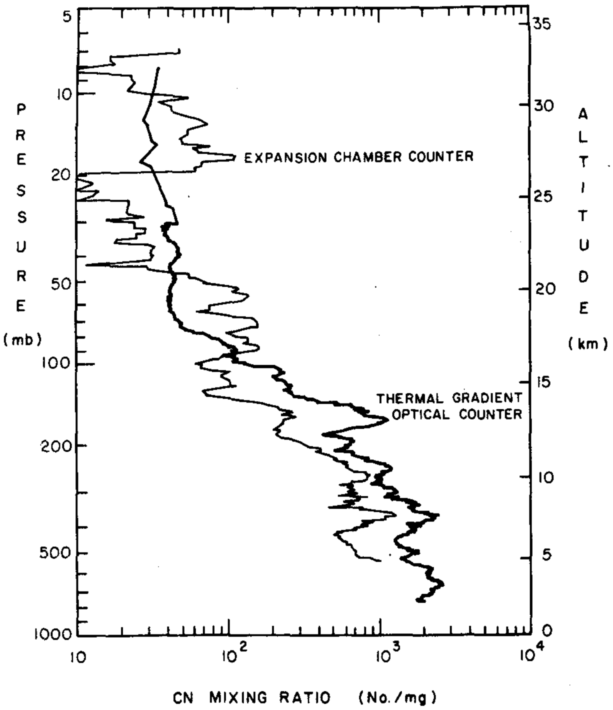

FIG. 1. A comparison of the average of three profiles as simultaneously measured by two different types of CN counters. The flights were made on 18, 22 and 25 September 1976 over Laramie, Wyoming.

not fully understood but which were undoubtedly related to the particles growing too big causing sedimentation losses to become large. It was later discovered that by gradually decreasing the supersaturation at altitudes above 25 km to a theoretical value of less than 1%, the instrument continued to function to balloon ceiling. The TGDCC data shown in Fig. 1 above 23 km were obtained on one of the three comparison flights with a reduced supersaturation, and it is only these data in the figure that have not been smoothed. These results have led us to the tentative conclusion that the relatively low supersaturations employed in the TGDCC are still high enough to allow the instrument to count a large fraction if not all of the CN present, to an altitude of about 30 km.

TABLE 1. Summary of condensation nuclei soundings

Location	Number of soundings	Date of soundings	Tropopause height above sea level (km)
South Pole (90°S)	1	1/19/77	10.5
McMurdo, Antarctica (72°S)	1	1/19/76	8.3
Mildura, Australia (34°S)	1	2/ 3/77	15.0
Quixeramobim, Brazil (5°S)	1	3/ 9/78	17.0
Panama (9°N)	3	4/ 1/76	16.0
		3/27/77	17.9
		3/31/77	16.8
Fairbanks, Alaska (65°N)	2	5/14/76	8.0
		5/16/76	9.3
Laramie, Wyoming (41°N)	17	12/19/73–9/13/77	9–15

3. CN profiles at other latitudes

In addition to the measurements made in Laramie, a number of soundings have been made at other locations. Table 1 contains a summary of this activity. Before a meaningful examination of the latitudinal variations can be made, typical profiles at each site must be identified by comparing the results of several soundings. From the information contained in the table, it is clear that a very limited number of soundings at the field sites have been made, and hence, there may be some question as to whether the profiles presented here are representative. However, in view of the fact that there seems to be a good deal of consistency in the present data and that additional soundings at each site may not be forthcoming, we feel that it is justifiable at this time to present and discuss the results so far obtained.

Evidence that the present set of profiles is at least somewhat typical can be found in Figs. 2–5. Fig. 2 shows a comparison of three soundings made over Panama, and within a certain range of variation they all appear quite similar. A comparison of two soundings made over Fairbanks, Alaska, is shown in Fig. 3, and except for the layer at 10 km (to be discussed later) they are also quite similar. Even soundings made in the Arctic (Fairbanks) and Antarctic (McMurdo), as compared in Fig. 4, show a great deal of similarity. However, the two Antarctic sound-

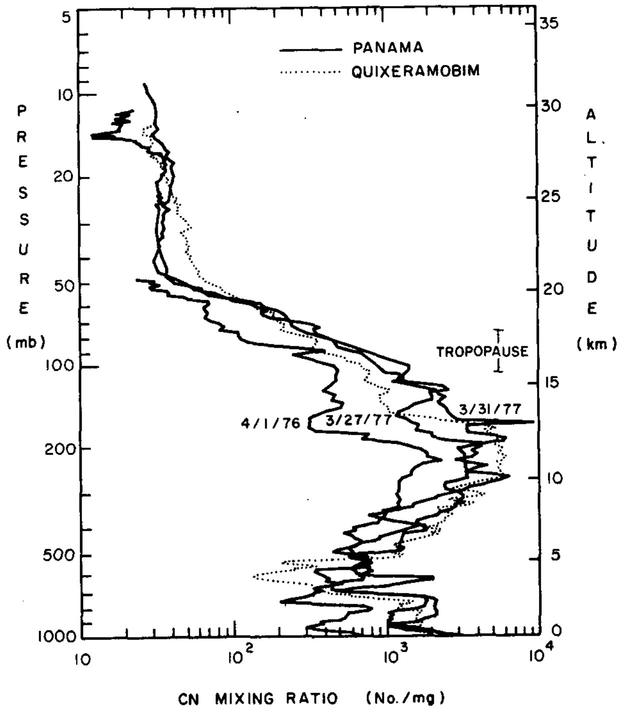

FIG. 2. A comparison of three soundings made over Panama (on given dates) and one sounding made over Quixeramobim, Brazil, on 9 March 1978.

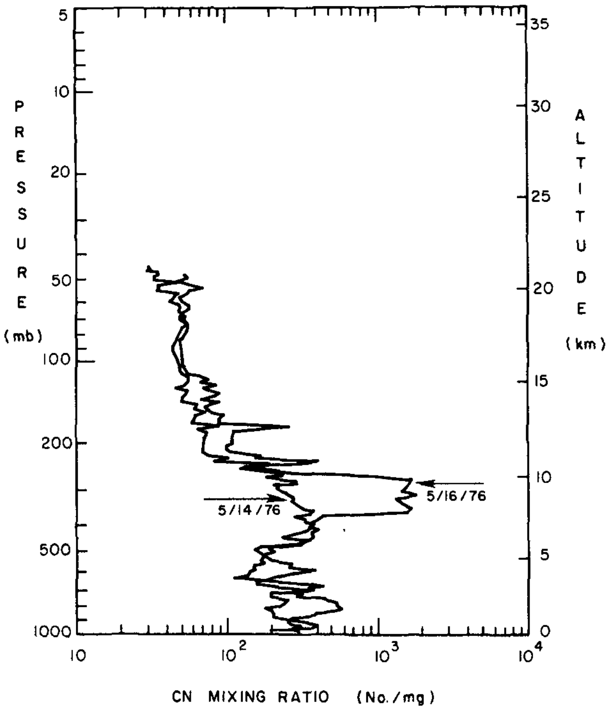

FIG. 3. A comparison of two soundings made over Fairbanks, Alaska, on the given dates. The tropopause heights are marked by arrows.

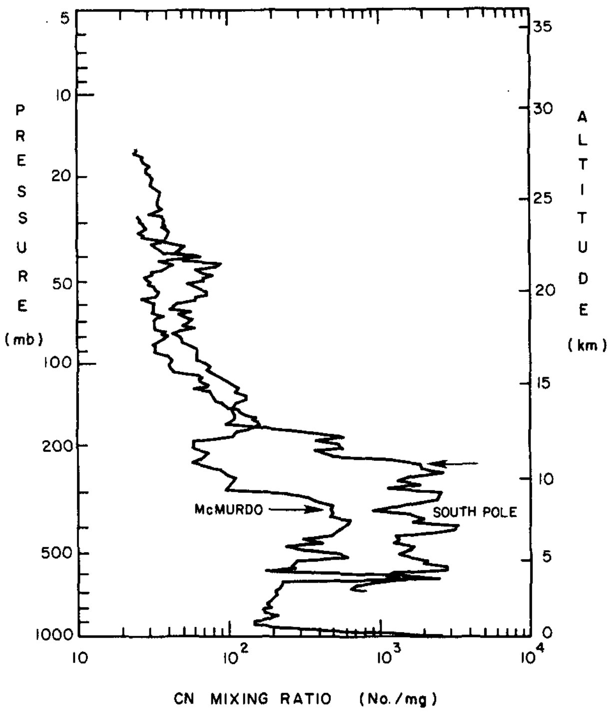

FIG. 5. A comparison of the McMurdo, Antarctica, and the South Pole soundings. The arrows mark the tropopause heights.

ings illustrated in Fig. 5 show a large difference in mixing ratio in the troposphere. At the present time (for reasons discussed later), we believe that the high values of mixing ratio observed in the South Pole profile in Fig. 5 are atypical and probably related to advection of midlatitude air with its associated higher CN content. The 10 km layer in one of the Fairbanks

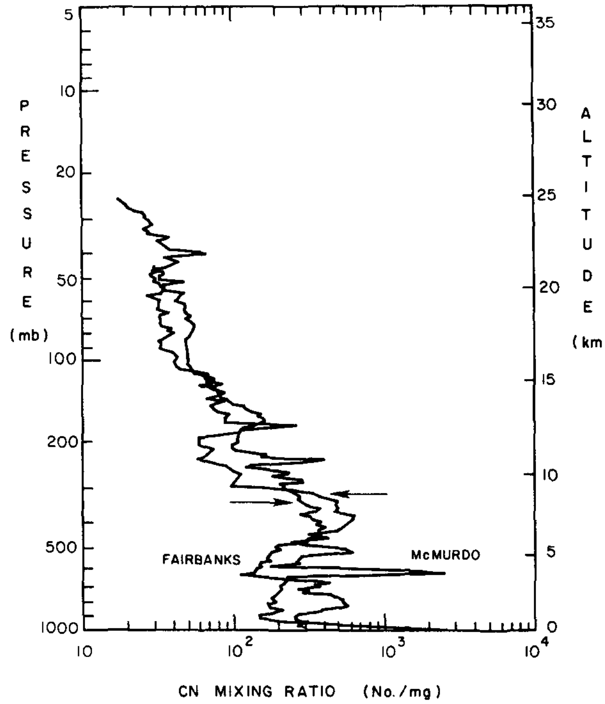

FIG. 4. A comparison of a sounding made over Fairbanks, Alaska (14 May 1976), and one made over McMurdo, Antarctica (19 January 1976). The tropopause heights are marked by arrows.

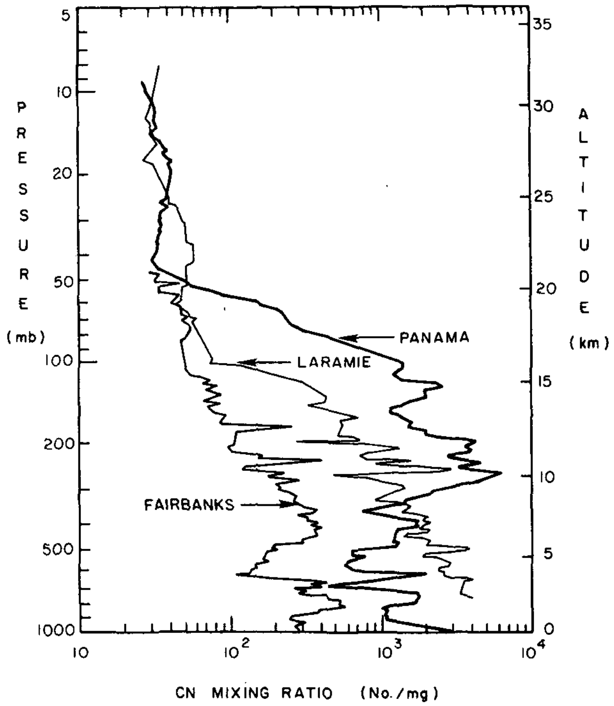

FIG. 6. A comparison of what is believed to be typical soundings from three different latitudes. The Laramie sounding was made on 25 September 1976.

soundings (Fig. 3) and the 4 km layer in the McMurdo sounding (Fig. 5) could lend themselves to this same interpretation.

Although it is not strictly possible to determine whether or not the single soundings made over Mildura, Australia (not shown), and Quixeramobim, Brazil (see Fig. 2), are typical, they do appear quite similar to the equatorial soundings made over Panama.

4. Discussion

The relatively high CN mixing ratios in the troposphere are indicative of a tropospheric source. A decrease in CN concentration is generally observed near the local tropopause and frequently it is rather dramatic. The equatorial and midlatitude troposphere apparently exhibit a CN mixing ratio about an order of magnitude larger than polar regions.

In tropospheric regions where the polar and lower latitude air masses mix, large fluctuations may be expected: polar air would be characterized by a low CN mixing ratio, while air masses from midlatitudes would display a relatively high mixing ratio. As previously mentioned, the high-latitude CN soundings so far obtained do, in fact, suggest the presence of two distinct air masses, each characterized by their CN mixing ratio. For instance, the layer at 10 km in Fig. 3 is characterized by a CN mixing ratio typical of midlatitude air, which has led us to tentatively identify it with a lower latitude origin. Other researchers have also seen these same types of fluctuations in the polar CN concentration (Hogan, 1975; Flyger *et al.*, 1973). Thus, CN may prove to be a valuable tracer of tropospheric air masses in polar regions.

The large difference in the characteristic CN mixing ratio between the stratosphere and troposphere suggests that here too CN may prove to be a useful tracer. A tropospheric air mass transported into the stratosphere would exhibit a much larger CN mixing ratio than the surrounding air, and hence, it could easily be identified until extensive mixing destroyed its original character.

Fig. 6 is a composite of soundings made at three different latitudes. The variation of the profiles with latitude, as apparently governed by the tropopause height, can easily be recognized. It is also clear from this figure that above 20 km, all profiles display approximately the same constant mixing ratio. If the mixing ratio remains constant to higher altitudes, as the data suggest, then an extraterrestrial or very high altitude source for the stratospheric CN would be probable. However, some researchers (Junge *et al.*, 1961) have considered a tropospheric source for CN and successfully described the lower stratospheric profile by applying coagulation-diffusion processes. In the high-altitude limit of this argument, the CN mixing ratio should decrease, because sedimentation becomes large enough to prevent the particles from being well mixed. Thus, extending the measurements to higher altitudes will help to determine the source of stratospheric CN. Studies of the chemical composition and size may also be of considerable help, but they are much more difficult to carry out for the very small particles under consideration here.

5. Conclusion

Even though the TGDCC CN counter is still in the development stage, we believe it shows enough promise, in terms of producing consistent and interpretable profiles, to warrant its further use and development. In addition, the present measurements suggest that CN may be a useful atmospheric tracer.

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