VERTICAL DISTRIBUTIONS OF IN AND CCN IN EASTERN MONTANA

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INTRODUCTION

Field investigations associated with the High Plains Experiment (HIPLEX) were initiated at the Northern High Plains site in Miles City, Montana, during 1975. As part of the program, a ground-based facility for measurement of background concentrations of ice nuclei (IN) and cloud condensation nuclei (CCN) was established at the Miles City airport. This was operated from mid-July to mid-September. No cloud seeding was conducted near the Miles City area during the summer, and the data collected are believed to be representative of natural near-surface background conditions. It was realized, however, that near-surface measurements of IN and CCN might not adequately represent concentrations available at levels of cloud formation. Summer cumulus cloud bases in the area average approximately 3,000 m (M.S.L.), while the surface elevation is 800 m. A series of aircraft sampling flights was initiated in an attempt to ascertain the adequacy of ground sampling for prediction of cloud base conditions.

BACKGROUND

Networks for routine surface measurement of background IN and CCN concentrations have been established and operated in various locations (for example, Allee, 1974; Hobbs and Locatelli, 1970; Bigg and Miles, 1964; Radke and Hobbs, 1969; Twomey and Davidson, 1975). In addition, a number of authors have reported findings obtained during aerial survey flights (for example, Squires and Twomey, 1966; Twomey and Wojciechowski, 1969; Flyger et al., 1973; Hoppel et al., 1973; and Bigg, 1967). Little information appears to be available in the literature, however, to relate ground and airborne measurements. Bigg (1967) made a series of upper level flights in Australia which showed that ground level measurements of IN generally were in good agreement with high level samples (11.3 km) but not with intermediate levels (3 to 4 km).

EQUIPMENT AND PROCEDURES

Aircraft sampling flights were made on 10 occasions during late August and early September. Each flight was made during the mid-afternoon period of maximum surface heating. A local aircraft

(Cessna 182) and pilot were used for the sampling flights. Modifications to the aircraft to adapt it to the sampling missions were minimal, consisting only of installation of a rotary inverter to provide a 115-V a-c power source and connection of an air sample line to the aircraft ventilator system. The ventilator filter near the wing root was removed.

Ground measurements were conducted in a small laboratory facility at the Miles City airport. An elevated air sampling system was constructed in an attempt to minimize contamination from ground level sources. This consisted of a 16-m tower which supported a 9-cm-diameter sampling line constructed of plastic piping. The air sampling line was run through the laboratory and a large squirrel cage fan downstream of the instrumentation was used to continuously draw sample air through the pipeline. Delay time in the sampling line was considerably less than a minute.

Cloud condensation nuclei (CCN) were measured using an Allee-type thermal diffusion chamber (described in Allee, 1971). The unit uses a camera to record droplet concentrations in the chamber. Supersaturations are controlled by raising the temperature of the top of the chamber relative to that of the bottom. A thermometer and thermocouple arrangement allows both the base and top temperatures to be recorded. Wetted surfaces on the chamber top and bottom provide the moisture source. The chamber surfaces were wetted prior to each use. Air samples were drawn into the chamber after predetermined base-to-top temperature differences had been established so that samples were analyzed at a supersaturation as close as practical to 1 percent. The chamber was completely flushed with air between samples. Care was taken to insure that the temperature of the incoming sample air was always greater than the chamber base temperature. A heated section of copper tubing was used for this purpose when outside air temperatures were low.

CCN concentrations were obtained by projecting the photographic record of each sample on a screen and counting droplets within a precisely defined area of the picture. That portion of the picture represented a known volume within the central portion of the chamber. This volume was determined from a series of calibration photographs. The number of droplets counted was converted to a concentration per cm^3.

Ice nuclei concentrations were measured using a membrane filter sampling system. Samples were obtained by drawing a known volume of air (104 ℓ) through 0.45 μ Millipore field monitor filters (Millipore Catalog No. MHWP037AD). Exposed membranes were sealed in their original plastic holders and sent to Dr. G. Langer at NCAR for processing. The samples were developed at -16° C using an improved version of the condensation technique described in Langer and Rodgers (1975). Development takes place at a supersaturation of approximately 3 percent.

Just prior to each sampling mission, a CCN count (1 percent supersaturation) and a membrane filter sample were taken in the laboratory using the equipment described above. The instruments were then transferred to the aircraft (installation time was approximately 5 minutes) and the flight started immediately. Each sampling flight was intended to collect data at elevations of 1160, 1520, 2290, 3050, and 3660 m. The aircraft was flown at each selected elevation for a sufficient time period (approximately 12 minutes) to obtain one membrane and about three CCN samples. It was somewhat difficult to operate the CCN counter in the typical afternoon thermal turbulence and three or more samples were taken to obtain at least one within the range 0.8 to 1.2 percent supersaturation. The sample closest to 1.0 percent supersaturation was used in Figure 1. Immediately after completion of a flight, ground samples again were obtained in the laboratory.

RESULTS

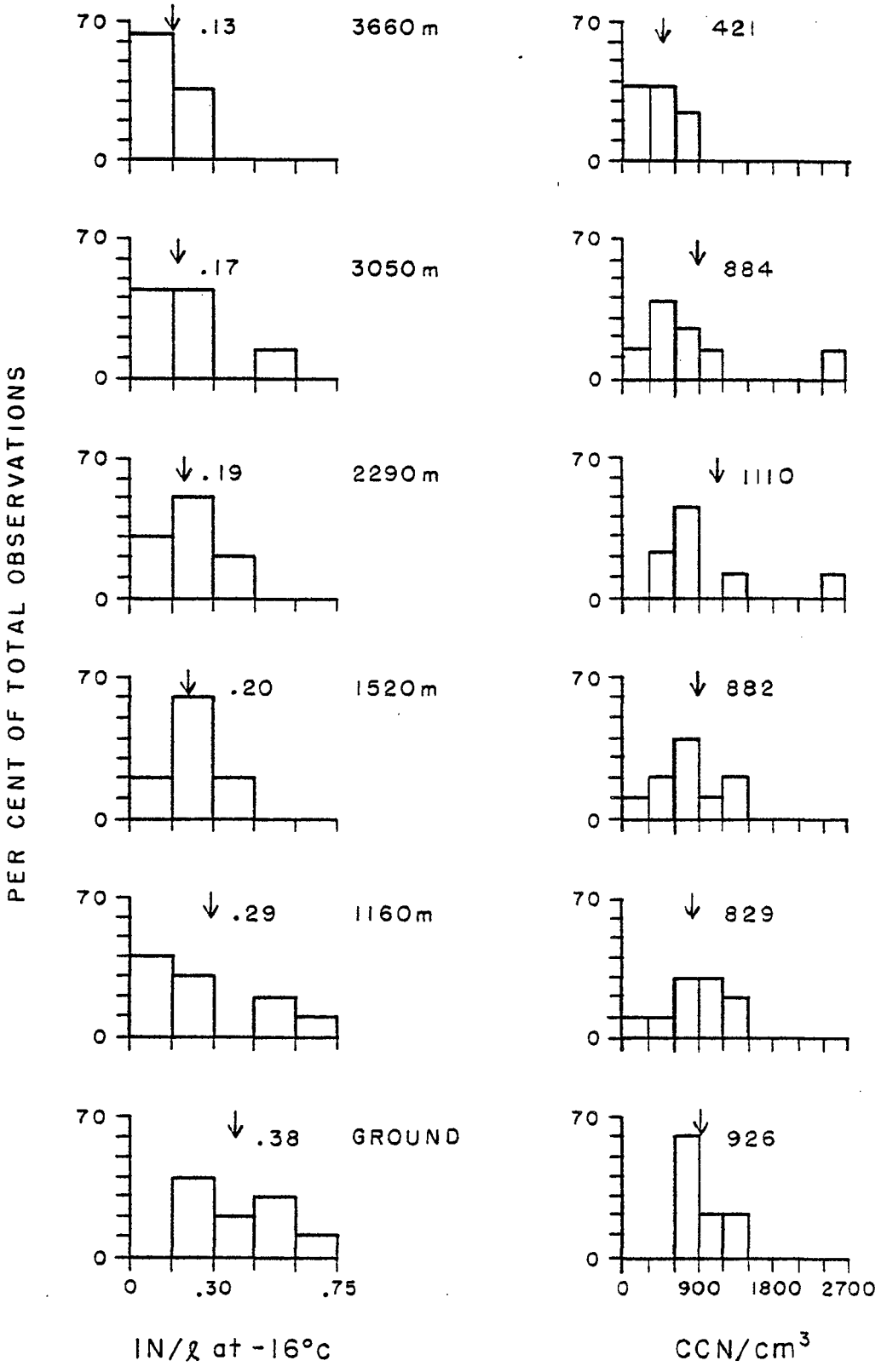
All data collected during the sampling flights are summarized in Figure 1. The percent of the total observations falling within various IN and CCN ranges and the mean value of all observations are shown for each sampling level.

The figure shows that IN concentrations tend to decrease with height above ground. Mean concentrations at typical cloud base elevations are a factor of two to three lower than near-surface samples. This suggests some local IN production, e.g., by wind action over the surface. Also, it appears that the mixing processes are not uniformly distributing particulates from the surface to cloud base elevations, possibly because the larger IN settle back to the surface relatively soon after becoming airborne. Nevertheless, the results also indicate that the surface IN data collected during the summer afternoons provide a reasonable estimate of concentrations available in the region of cloud formation. IN concentrations at typical cloud base altitudes averaged 0.2 nuclei per liter, effective at -16^{o} C.

FIGURE 1

FREQUENCY DISTRIBUTIONS OF IN. AND CCN AT INDICATED ELEVATIONS

ARROWS INDICATE MEAN VALUES



Mean CCN concentrations were quite similar from near the surface to about 3,000 m and thereafter appeared to decrease by about a factor of 2 at the 3,660 m level. The top of the visible haze layer was observed to be between 3,000 and 3,660 on several of the sampling flights, and fair weather cumulus were based between these levels on about half the flights (the other half had clear skies or high cirrus only). Thus, the top of the mixing layer was generally at or slightly above 3,000 m, and CCN concentrations were fairly uniform throughout the mixing layer. Therefore, near ground level measurements of CCN were representative of conditions at cloud base where average CCN concentrations were approximately 900 per cm^3.

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