

**The Occurrence and Variability of Ice Forming Nuclei During
the Hail Season in Northeastern Colorado as Measured
at 11,300 ft. M.S.L. at an Upwind Mountain Station**

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Presented at the International Congress on the Physics of Clouds (Hailstorms)
at Verona 9-13 August 1960

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SOMMARIO

A Climax nel Colorado (11.360 piedi s.l.d.m.) sono state osservate in modo continuo le concentrazioni dei nuclei di ghiaccio per mezzo di un contatore a camera fredda (dall'autunno del 1954) e con un contatore a tipo espansione (dall'autunno del 1959). Viene presentato un sommario delle concentrazioni dei nuclei di ghiaccio osservati con il contatore a camera fredda nella zona Nord-orientale del Colorado per il periodo 1955-1959, considerando sia i giorni con la grandine che quelli senza.

Nel periodo in cui vennero effettuate le osservazioni insieme, è stato fatto un confronto tra la concentrazione dei nuclei osservati con il contatore ad espansione e con quello a camera fredda.

SUMMARY

Ice nuclei concentrations have been observed continuously at 11,300 ft m.s.l. at Climax, Colorado, since the fall of 1954 with a cold chamber counter and with an expansion-type counter since the fall of 1959. A summary of concentrations of ice nuclei observed with the cold chamber counter is presented for days with and without hail in northeastern Colorado for the 1955-1959 hail seasons.

Comparisons have been made between the nuclei concentration observed with the expansion-type counter and the cold chamber counter for periods of concurrent observations.

1. Introduction

The western Great Plains immediately east of the Rocky Mountains experience frequent and severe hailstorms. On a typical hail day warm moist air moves westward against the mountains at elevations up to 8,000-12,000 feet above m.s.l. Wind flow at higher levels usually is from the west. Individual cells become extremely intense

as thunderstorms develop and move eastward into increasing low-level moisture supply.

Measurements of ice nuclei have been made since the fall of 1954 at Climax, Colorado, a mountain station in the Rockies southwest of the area that suffers the most severe hail damage. These observations provide a representative sampling of the ice nuclei for the upper air mass into which the intense convective storms build. The observations in most cases are not necessarily representative of the lower-level warm and moist air masses which are the primary source of cloud moisture.

Fig. 1 shows the area of northeastern Colorado for which extensive hail information has been and is being collected. Most of the area is at an elevation of 4,000 to 5,000 ft m.s.l. The location of the ice nuclei observing site at Climax, Colorado, at 11,300 ft m.s.l. elevation, is also shown.

2. Observation Program

Ice nuclei observations have been made continuously since the fall of 1954 by personnel of the High Altitude Observatory of the University of Colorado at Climax, Colorado. The work was spon-

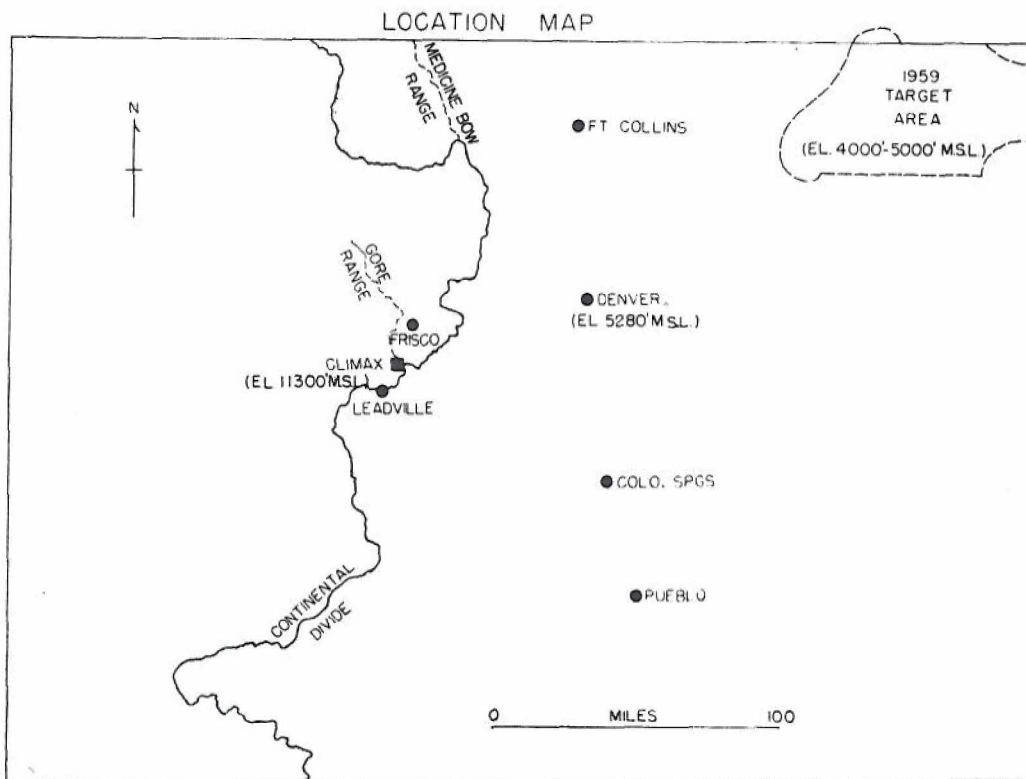


Figure 1

sored by the American Institute of Aerological Research from 1954 through the summer of 1959, and on a cooperative basis by the High Altitude Observatory and Colorado State University since the fall of 1959.

Observations were made at -20°C in a cold chamber into which samples of outside air were drawn. Comparative observations with various type ice nuclei counters, including the type used at Climax (the WRDC Box), were made during the Pasadena cooperative program of ice nuclei measuring techniques in 1957 (1).

The U. S. Weather Bureau placed an expansion-type ice nuclei counter at Climax in the fall of 1959 and direct comparison of the two counters has been possible. Daily observations with the expansion chamber have been made at -20°C , corresponding to the fixed observation temperature of the cold chamber. The mean concentration of ice nuclei for 219 observations with the expansion chamber from 1 January 1960 through 18 May 1960, was $1.46 \times 10^3/\text{m}^3$. The mean concentration for the corresponding cold chamber observations was $1.07 \times 10^3/\text{m}^3$.

The observations given for the expansion chamber are the mean of a series of readings taken during a 30-60 minute period and those for the cold chamber are the average of the cold chamber observations taken during the corresponding time interval. There were large variations in individual readings between the two units. The comparative observations for the first observation of each day during March 1960 are shown in Fig. 2. The rank correlation coefficient

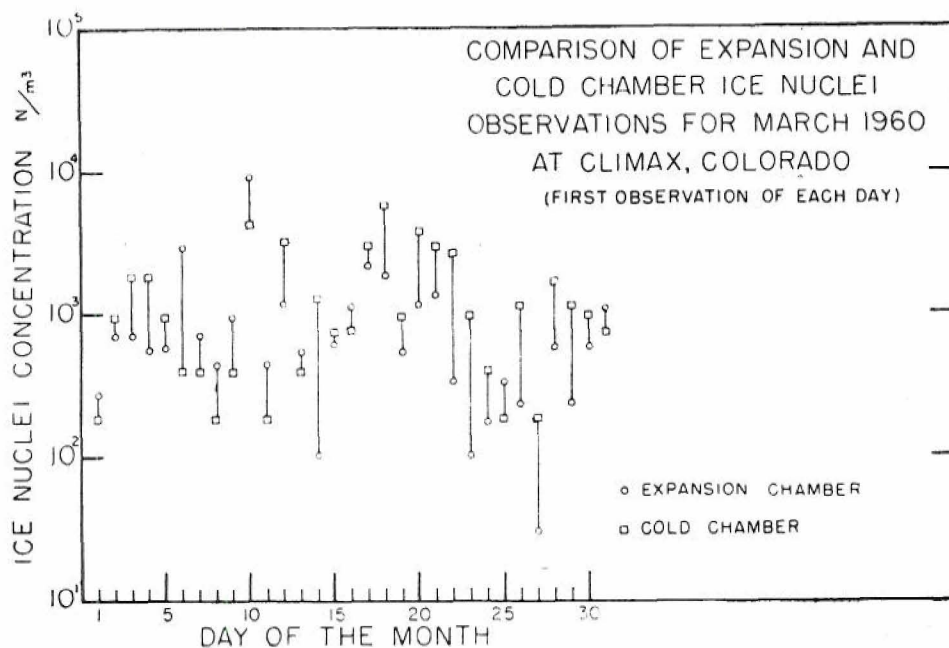


Figure 2

between 1 January and 18 May is .34. This is statistically highly significant for 219 observations.

3. Summer Observations of Ice Nuclei at Climax, Colorado

There were 55 days from 1955-1959 during the summer months (May through August) when hail damage occurred to sugar beets of the Great Western Sugar Company in northeastern Colorado ⁽¹⁾. There were undoubtedly other hail days in the area, since sugar beets cover only a relatively small portion of the area and are confined to the irrigated sections. Observations of ice nuclei were taken at Climax before noon on 32 of these 55 days. The air from which these samples were taken could generally be expected to have been over eastern Colorado during the afternoon when most hail storms occurred although it would not necessarily be in the immediate vicinity of actual hailstorms. On 13 of the 55 days when hail damaged sugar beets in northeastern Colorado the airflow during the day was from the southwest directly toward northeastern Colorado. Ice nuclei observations were made on 6 of these days before noon and could be expected to have sampled the portion of the air mass which was over the study area in the vicinity of the hailstorms during the afternoon.

Table I summarizes the summer hail season observations of ice nuclei made at -20°C at Climax, Colorado.

TABLE 1
Ice nuclei concentrations (at -20°C) at Climax, Colorado on "hail" and "no hail" days for Northeastern Colorado.

	All "hail days" 1955-59	"Haildays" with southwest winds 1955-59	"No hail" days 1956-59	"No hail" days 1955-59
Number of days with nuclei ob- servations	32	6	95	129
Mean	$1.76 \times 10^3/\text{m}^3$	$.91 \times 10^3/\text{m}^3$	$.92 \times 10^3/\text{m}^3$	$2.95 \times 10^3/\text{m}^3$
Median	$.55 \times 10^3/\text{m}^3$	$1.10 \times 10^3/\text{m}^3$		
Maximum	$11.5 \times 10^3/\text{m}^3$	$1.64 \times 10^3/\text{m}^3$		
Minimum	$.18 \times 10^3/\text{m}^3$	$.18 \times 10^3/\text{m}^3$		

(1) Data were obtained from the Sterling, Fort Morgan, and Ovid Factory Districts.

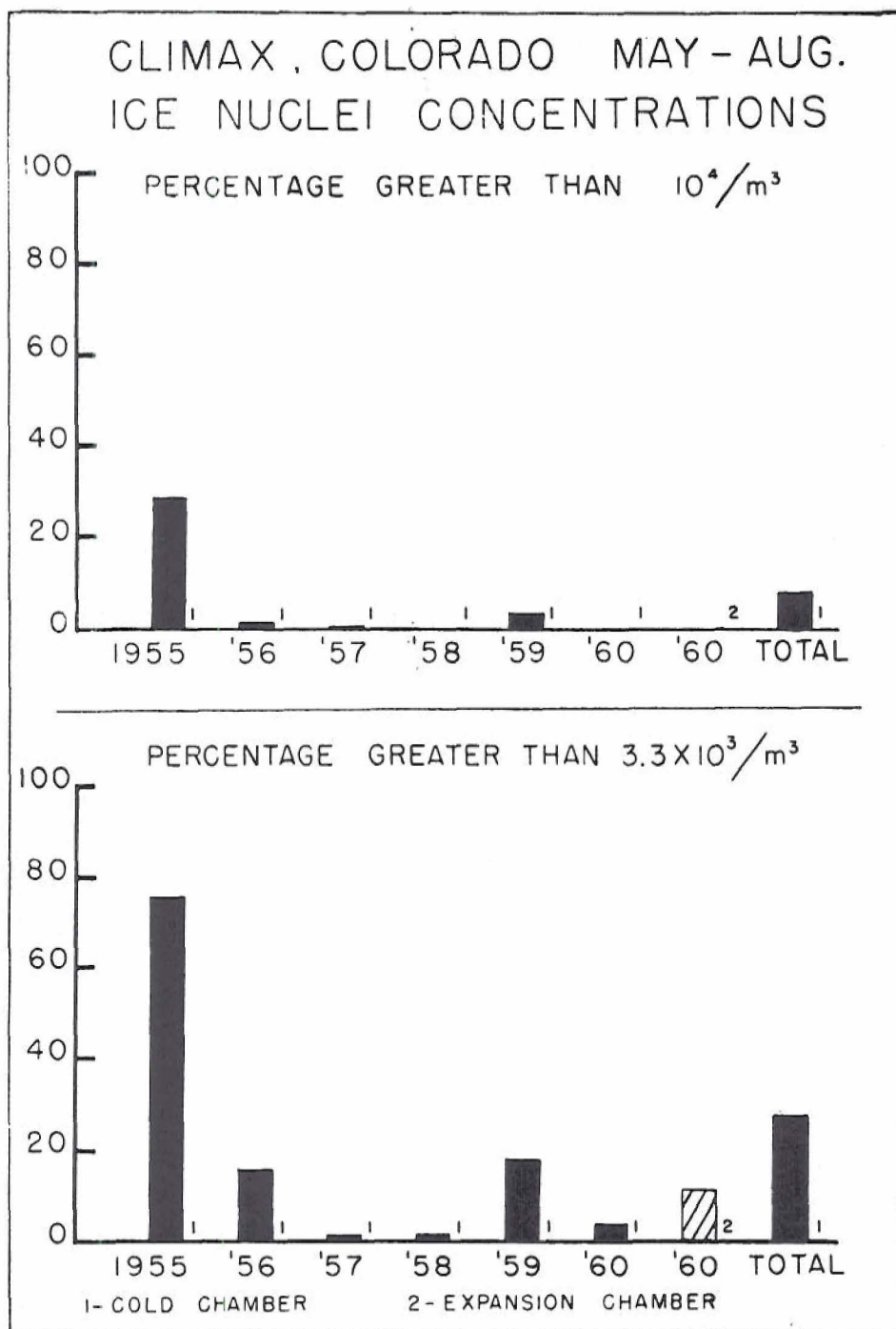


Figure 3

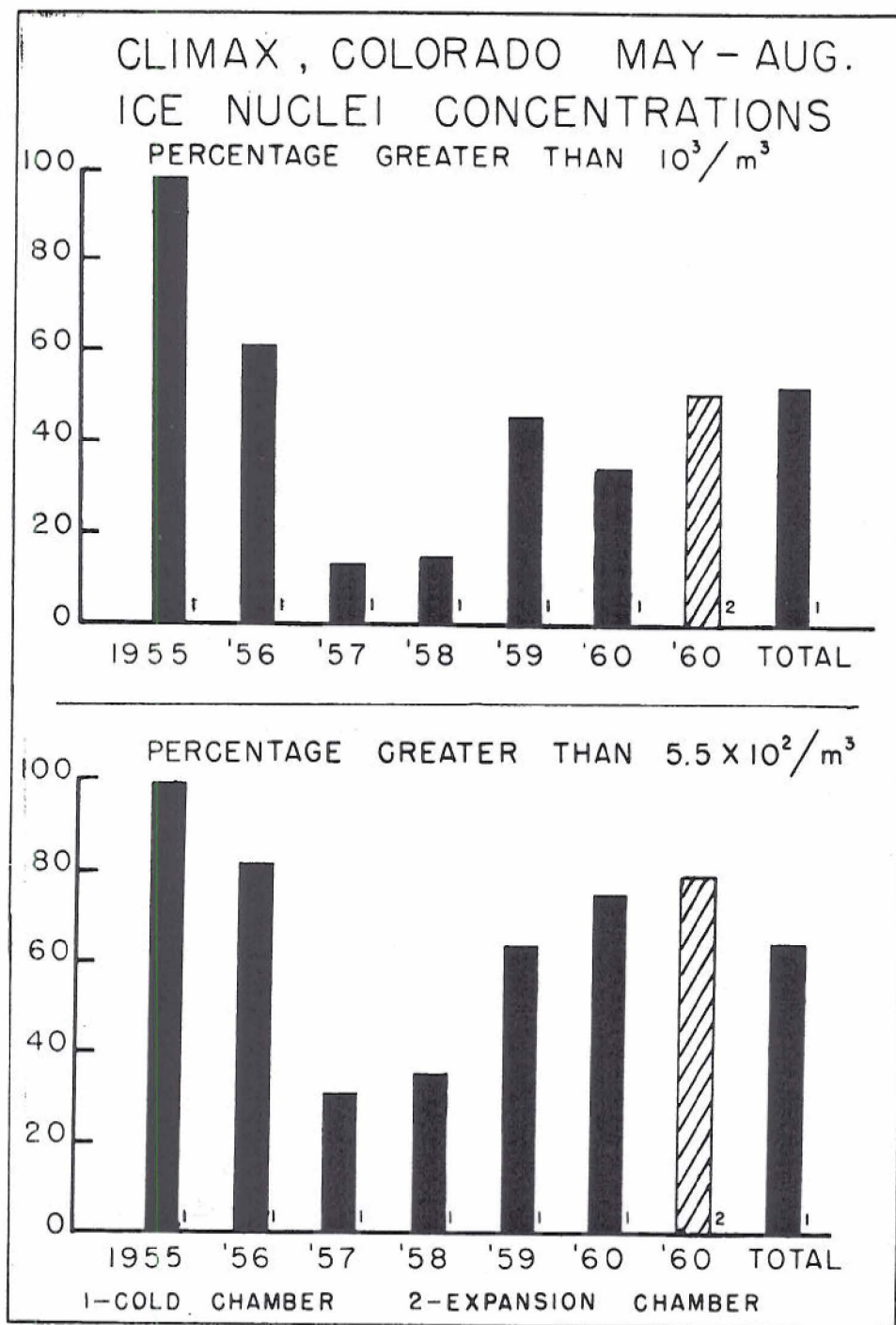


Figure 4

The mean concentration of ice nuclei for all days, 1955-1959, when hail *was not* reported was $2.95 \times 10^3/\text{m}^3$. This includes 35 days for 1955, however, when cloud seeding in the vicinity of Climax, Colorado, might have affected the observations. The mean concentration of ice nuclei for the "no hail" days for the years 1956-1959 was $.92 \times 10^3/\text{m}^3$.

The frequency of occurrence of various observed concentrations of ice nuclei for all summer observations both on "hail" and "no hail" days, and for all times of day, is shown in figures 3 and 4 ⁽¹⁾. These figures show that ice nuclei concentrations greater than $1 \times 10^4/\text{m}^3$, and excepting 1955, concentrations greater than $3.3 \times 10^3/\text{m}^3$ have been infrequent.

4. Summary

Ice nuclei concentrations have been observed continuously at 11,300 ft m.s.l. at Climax, Colorado, since the fall of 1954 with a cold chamber counter and with an expansion-type counter since the fall of 1959. A comparison of the two counters shows the same order of magnitude for the concentrations observed at -20°C during the period of simultaneous readings although important variations in individual observations occur.

The mean concentrations of ice nuclei observed are the order of 1 to $2 \times 10^3/\text{m}^3$ both on days when hail occurred and on days when hail did not occur. For the five-year period during the hail season summer months 9 per cent of all observations were $\geq 1 \times 10^4/\text{m}^3$, 28 per cent $\geq 3.33 \times 10^3/\text{m}^3$, 55 per cent $\geq 1 \times 10^3/\text{m}^3$ and 69 per cent $\geq .55 \times 10^3/\text{m}^3$.

REFERENCES

- 1 Meteorology Research, Inc., 1957 - Report on the Pasadena Cooperative Program of ice nuclei measuring techniques, Report to advisory committee on weather control.

(1) Figures 3 and 4 are based on measured concentrations of ice nuclei for May-August for 1955-59, but only for 1 April-18 May for 1960.