Transport of ice nuclei over the north pacific ocean

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(Manuscript received June 11, 1970; revised version August 20, 1970)

ABSTRACT

Simultaneous measurements have been made over extended periods of time of the relative concentrations of ice nuclei in the air at stations in Alaska, Hawaii and Washington State. On occasions large increases in ice nucleus counts lasting for a week or more ("ice nucleus storms") were observed. The ice nucleus storms sometimes occurred in close proximity in time at different stations and it is shown that in some cases this can be explained by the advection of particles in the lower troposphere between stations. On other occasions the ice nucleus storms appeared to be of local origin.

Introduction

Although the first measurements of the concentrations of ice nuclei in the atmosphere were made over 20 years age, there have been comparatively few organized simultaneous measurements of ice nuclei at widely separated locations over the earth's surface for extended periods of time. Bigg & Miles (1964) made such measurements in Eastern Australia and they concluded that the distribution of ice nuclei at the surface of the earth was more related to upper air circulations than to the synoptic conditions at the surface. They hypothesized that the downward transport of air containing ice nuclei from the stratosphere occurred in the vicinity of jet streams. This idea received support, in a few situations at least, by the work of Droessler (1964) and Rosinski (1967).

In this paper we describe the results of simultaneous measurements of the concentrations of ice nuclei in the air at three widely separated locations, namely, Hawaii, Alaska and Washington State. The main purpose of the project was to investigate the relationship between large increases in ice nucleus counts lasting for a week or more (so-called "ice nucleus storms") at these three locations. In particular, advection in the troposphere and the jet stream are considered in seeking an explanation for the migration of ice nucleus storms.

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Locations and times of measurements

The locations of the sites at which the measurements were taken are shown in Fig. 1. The station in Alaska was Ester Dome Observatory (720 m MSL) which is situated six miles WNW of Fairbanks. The observations in Hawaii were made at the Mauna Loa Observatory (3 500 m MSL). During the first period of observations, which extended from 23 January to 1 April, 1968, the measurements in Washington State were made at the Blue Glacier Observatory (2 070 m MSL) which is situated on

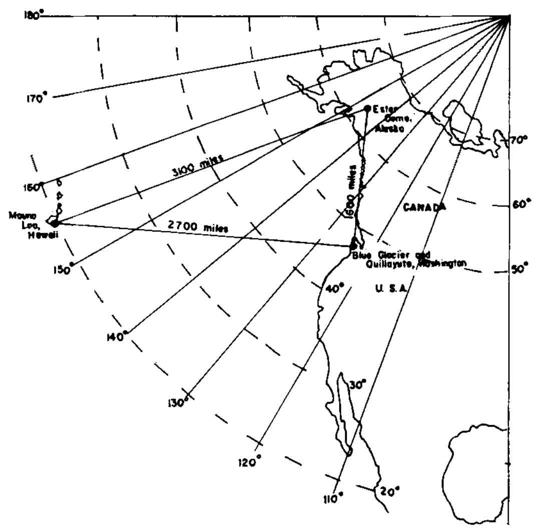

Fig. 1. Locations of the measuring sites.

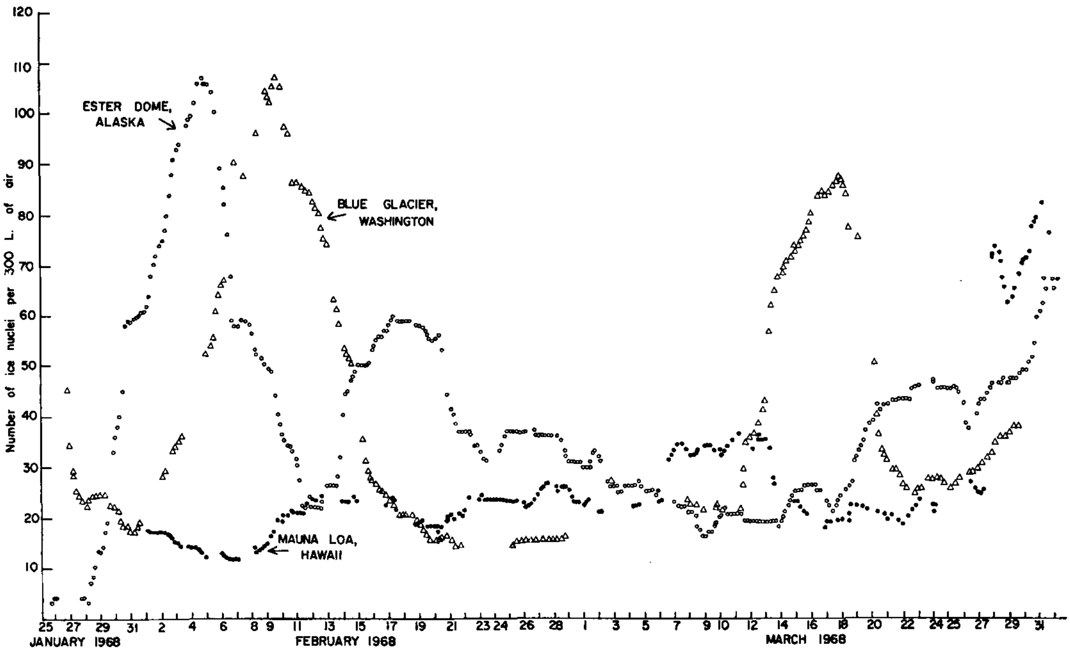

Fig. 2. Ice nucleus counts at −21°C at Ester Dome (Alaska), Mauna Loa (Hawaii) and Blue Glacier (Washington), during the period 25 January to 24 March, 1968. The counts have been smoothed by taking 1 week running means.

the Olympic Peninsula about 20 miles east of the Pacific Coast. During the second period of observations, which was from 4 June to 11 July, 1969, the measurements in Washington State were taken at Quillayute (54 m MSL) which is also on the Olympic Peninsula but about 10 miles east of the Pacific Coast.

Instrumentation

At the present time the best that can be aspired to in trying to measure the concentrations of ice nuclei in the air is to obtain reliable *relative* measurements, so that the spatial and temporal variations in the numbers of ice nuclei in the air can be recorded and studied. Consequently, when the expression "concentration of ice nuclei" (or "ice nucleus count") is used in this paper it is to be understood that this is short for "relative concentration of ice nuclei (or "relative ice nucleus count").

The concentrations of ice nuclei in the air were measured at each of the three sites with a NCAR acoustical ice nucleus counter (Langer et al., 1967). This counter operates automatically and the number of ice nuclei detected in a given volume of air is printed out periodically on a strip chart. The microphones and printers used with each counter were calibrated before and after each of the two periods of measurements to ensure that they had the same sensitivity to similar signals from the acoustical sensor. When operated side by side the calibrated counters recorded essentially the same ice nucleus count.

Outside air was drawn into the cold chamber of each ice nucleus counter at a rate of 10 liter min^{-1}, and the number of ice nuclei per 300 liters of air active at a given temperature was printed out together with the time and date. During the first period of measurements one counter was operated at each of the three stations and all measurements were taken at a chamber temperature of −21°C. During the second period of measurements two ice nucleus counters were operated side by side at each station. The chamber temperature of one counter was −15°C and that of the other was −21°C. In all cases the water in the humidifier was held

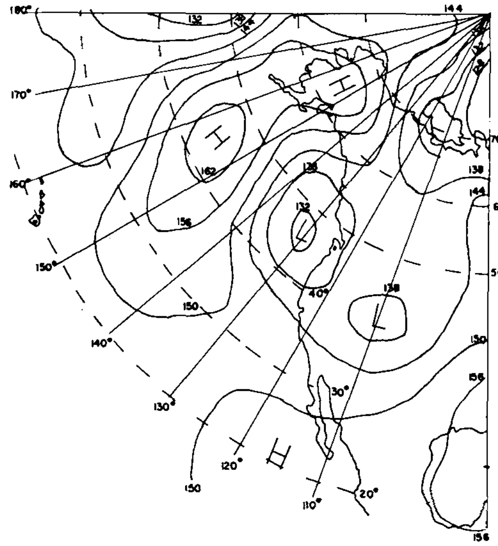

Fig. 3. Height (in 10's of meters) of the 850 mb pressure surface at 1200 hours GMT on 28 January, 1968.

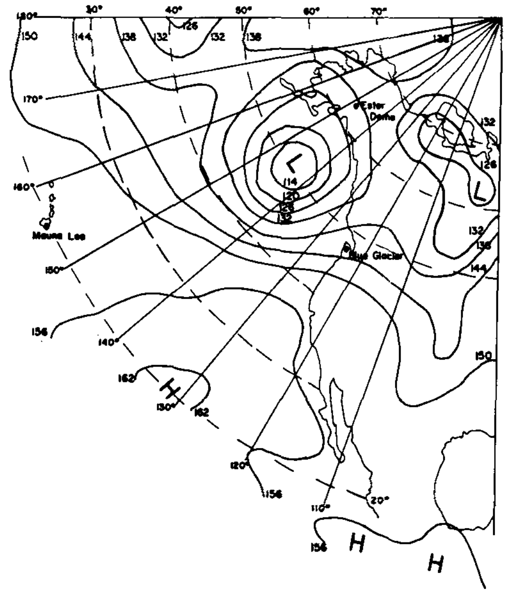

Fig. 4. Height (in 10's of meters) of the 850 mb pressure surface at 1200 hours GMT on 3 February, 1968.

at a temperature of 40°C and the aerosol salt generator was operated continuously in order to ensure a uniform and dense cloud of water droplets in the cold chamber.

Method of analysis

Since we were interested in ice nucleus storms lasting for fairly long periods of time, short term fluctuations in the ice nucleus counts were filtered out by taking 1 week running means. (The factors which gave rise to short term fluctuations in ice nucleus counts at one of the stations—Quillayute—have been described by Hobbs & Locatelli, 1970.) The simultaneous data from the three stations were then displayed on a diagram to see if there were any obvious relationships between ice nucleus storms at the different stations.

The advection of air between stations was investigated by graphical trajectory analysis. Danielsen (1961) has pointed out that trajectory analysis on an isobaric surface may have little relation to true air parcel trajectory especially in cases of thermal advection on a pressure surface. It was felt therefore that numerous isobaric trajectories at short-time intervals at several different pressure levels would probably mask rather than reveal the time trajectories of the air parcels. Unfortunately, due to the scarcity of data points over the Pacific Ocean, the isentropic trajectory methods suggested by Danielsen were not feasible. As a compromise it was decided to construct trajectories and keep track of the verticle motion of the air by using the 6 hour vertical velocity prognosis from the American National Weather Center in which the changes in vertical velocities are given directly in micromillibars per second. The vertical velocities are averaged in the horizontal over areas of 250 000 square miles and they are averaged vertically over a column of air about 10 000 feet in height. If the vertical motions indicated that the air parcel was within 40 mb of a standard pressure surface the trajectory for that 12-hour period was computed from the height field on that pressure surface. However, if the air parcel was not within 40 mb of a standard pressure surface a vector average of the wind computed at the standard levels above and below the height of the air parcel was used to compute the trajectory for that 12-hour period.

In carrying out the trajectory analysis the geostrophic approximation was used, that is, only the Coriolis and the pressure terms were considered in the horizontal equation of motion on a constant pressure surface. Even at the

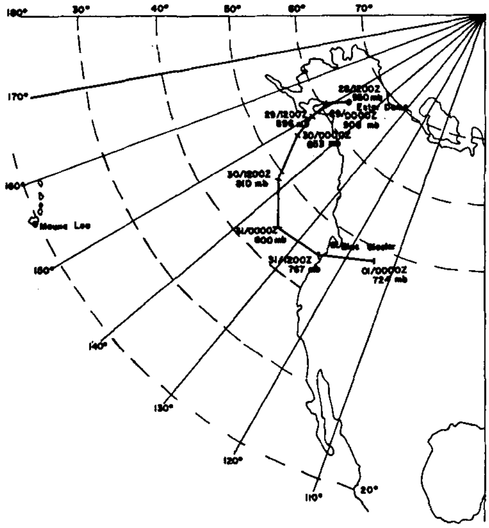

Fig. 5. Trajectory analysis started at Ester Dome, Alaska at 1200 hours GMT on 28 January, 1968, and worked forward in time (N.B. 28/1200Z indicates the horizontal position of the air parcel on 28 January, 1968, at 1200 hours GMT. The pressure levels at which the air parcel is located at each point is also noted on the diagram.)

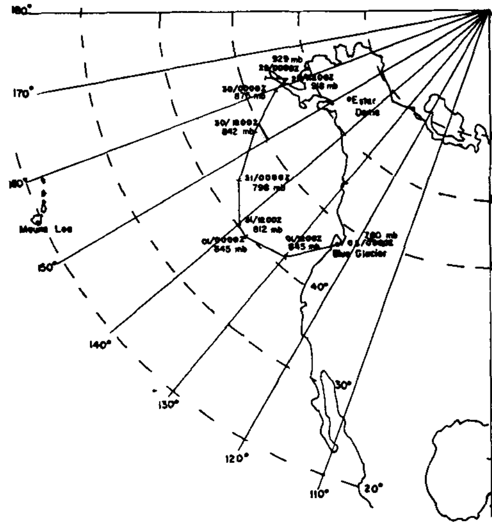

Fig. 6. Trajectory analysis started at the Blue Glacier, Washington, at 0000 hours GMT on 2 February and worked backwards in time (N.B. 02/0000Z indicates the horizontal position of the air parcel on 2 February, 1968, at 0000 hours GMT. The pressure level at which the air parcel is located at each point is also noted on the diagram.)

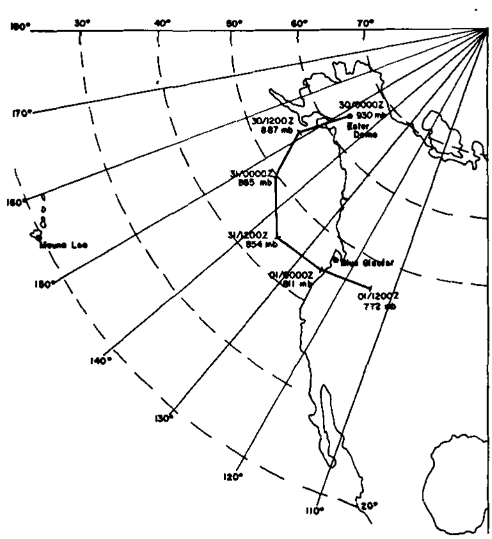

Fig. 7. Trajectory analysis started at Ester Dome, Alaska at 0000 hours GMT on 30 January, 1968, and worked forward in time (N.B. 30/0000Z indicates the horizontal position of the air parcel on 30 January 1968, at 0000 hours GMT. The pressure level at which the air parcel is located at each point is also noted on the diagram.)

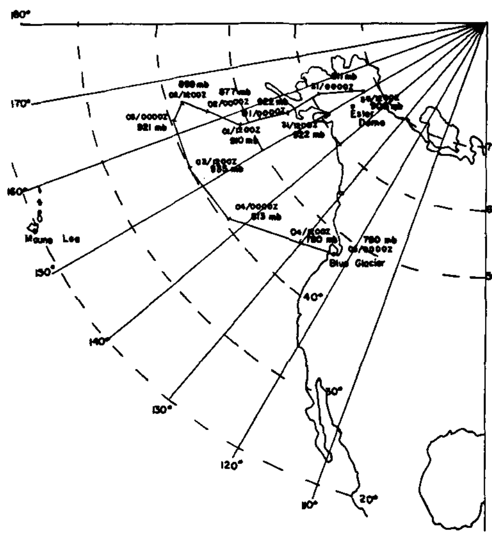

Fig. 8. Trajectory analysis started at the Blue Glacier, Washington, at 0000 hours GMT on 5 February, 1968, and worked backwards in time. (N.B. 05/0000Z indicates the horizontal position of the air parcel on 5 February, 1968, at 0000 hours GMT. The pressure level at which the air parcel is located at each point is also noted on the diagram.)

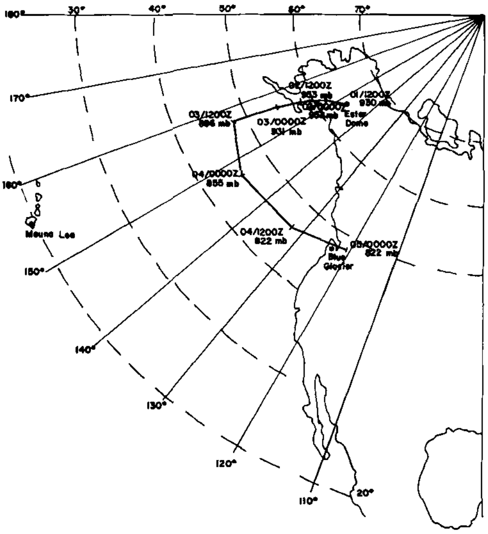

Fig. 9. Trajectory analysis started at Ester Dome, Alaska at 1200 hours GMT on 1 February, 1968, and worked forwards in time (N.B. 01/1200Z indicates the horizontal position of the air parcel on 1 February 1968, at 1200 hours GMT. The pressure level at which the air parcel is located at each point is also noted on the diagram.)

latitude of Hawaii (20° N) the geostrophic approximation is reasonably good and it is even better for Washington and Alaska. It was assumed also that the direction of air motion is parallel to the height contours on a constant pressure surface. A wind scale was computed based on the equation

$$V = \frac{g}{f}\frac{\Delta z}{\Delta n}$$

where, V is the horizontal wind on a constant pressure surface, g the acceleration due to gravity, f the Coriolis parameter, and $\Delta z/\Delta n$ the gradient of the height of the pressure surface in a direction perpendicular and to the left of a parcel of air when viewed in the direction of its motion. This equation was used to convert the heights of the pressure fields to a wind field. The trajectory analysis was then carried out following the methods suggested by Petterson (1940). In all cases the trajectories were started both from the upstream station and worked forward in time and from the downstream station and worked backward in time.

Result of analysis

We consider first the results of the first period of measurements. The ice nucleus counts at the three stations, smoothed by taking 1 week running means, are shown in Fig. 2. It can be seen that during the period of the measurements several ice nucleus storms occurred at the three stations. The relationships between these storms are discussed below.

The ice nucleus storm which occurred at Ester Dome, Alaska, from about 27 January to 10 February, 1968, was followed about 4 days later by an ice nucleus storm at the Blue Glacier, Washington. The synoptic features which were typical of the period 27 January to 10 February, when the ice nucleus count at Ester Dome was increasing rapidly, are shown in Fig. 3. There was a northsouth oriented high extending from Central Alaska to a latitude of about 25° N and a low situated about 300 miles off the Washington coast. From 1 to 4 February the ice nucleus count at Ester Dome, Alaska, continued to rise and during this period the low deepened and moved northwest (Fig. 4). The situation was then favorable for air to be advected from Ester Dome to the Blue Glacier, and it was during this period that ice nucleus storm started at the Blue Glacier.

Trajectory analyses which are typical of the period 1 to 6 February are shown in Figs. 5 through 9. In Figs. 5, 7 and 9 the trajectories start at Ester Dome, Alaska, and are computed forward in time. Whereas, in Figs. 6 and 8 the trajectories which start at the Blue Glacier, Washington, are traced backwards in time. In Fig. 5 the starting time at Ester Dome was 1200 hours GMT on the 28 January and the arrival time near the Blue Glacier was about 1500 hours GMT on the 31 January, which is close to the time at which the ice nucleus storm started at the Blue Glacier (Fig. 2). In Fig. 9 the starting time at Ester Dome was 1200 hours GMT on 1 February and the arrival time at Blue Glacier was about 0000 hours GMT on 5 February, which was just before the ice nucleus count reached a maximum in Washington State. Figs. 6, 7 and 8 show the trajectory between Ester Dome and the Blue Glacier at various times. Throughout the period 28 January to 6 February the air parcels moved to higher elevations as they were transported under cyclonic flow from Ester Dome, Alaska, to the Blue

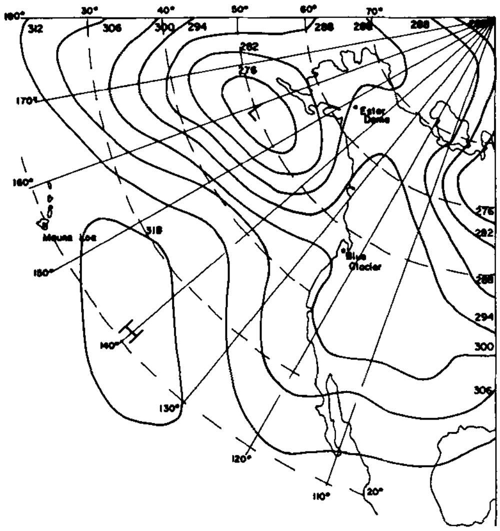

Fig. 10. A typical 700 mb analysis for the period 7 to 11 March during which time the ice nucleus count at Mauna Loa remained constant. Map shows the heights (in 10's of meters) of the 700 mb pressure surface at 1200 hours GMT on 9 March, 1968.

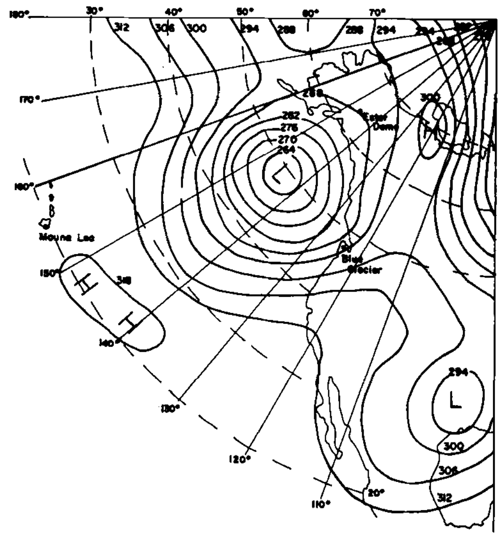

Fig. 11. Heights (in 10's of meters) of the 700 mb pressure surface at 0000 hours GMT on 12 March, 1968.

Glacier, Washington. It should be noted that the Blue Glacier is about 4 500 feet higher than Ester Dome.

It can be seen from Figs. 5 to 9 that the time taken for air to be transported between Ester Dome and the Blue Glacier during the period 28 January to 6 February was from 3 to 5 days (the average for all the trajectories computed for this period was 3.7 days). This is in excellent agreement with the observed time lag of about 4 days between the build-up of the ice nucleus storm at Blue Glacier between 31 January and 3 February, 1968, and that which occurred at Ester Dome from 27 January to 3 February, 1968.

We conclude from this analysis that the initiation of the ice nucleus storm at the Blue Glacier between 31 January and the 6 February, 1968, was due to the particles which were responsible for the ice nucleus storm at Ester Dome being advected through the troposphere to the Blue Glacier, Washington.

For the remainder of the period of the ice nucleus storm at the Blue Glacier (6–14 February) the high ice nucleus count cannot be explained by advection from Ester Dome, Alaska. However, as the low continued to recede a high pressure center built up over Western Canada and this produced an easterly flow over Western Washington. Since the Puget Sound basin is known to be a local source of ice nuclei (Hobbs & Locatelli, 1970) easterly winds would have transported these particles to the Blue Glacier and thereby have maintained the high count. Starting at 1200 hours on the 11 February the winds shifted to the north and the ice nuclei count at the Blue Glacier decreased sharply.

We consider next the behaviour of the jet stream during the period 27 January to 14 February, 1968. From 27 to 31 January, when the ice nucleus count at Ester Dome was increasing, the jet stream was almost directly over this station. Subsequently, the jet stream moved northwest and was over 600 miles from Ester Dome during the period 1 to 5 February but the ice nucleus count at Ester Dome continued to rise (Fig. 2). During the same period, when the ice nucleus count at the Blue Glacier was rising, the jet stream was, on average, about 250 miles north of the Blue Glacier. From 6 to 9 February the jet stream moved further north over Northern Canada and passed directly over Ester Dome, however, the ice nucleus count at this station was then falling rapidly. The ice nucleus count at the Blue Glacier continued to rise from 6 to 9 February even though the jet stream was more

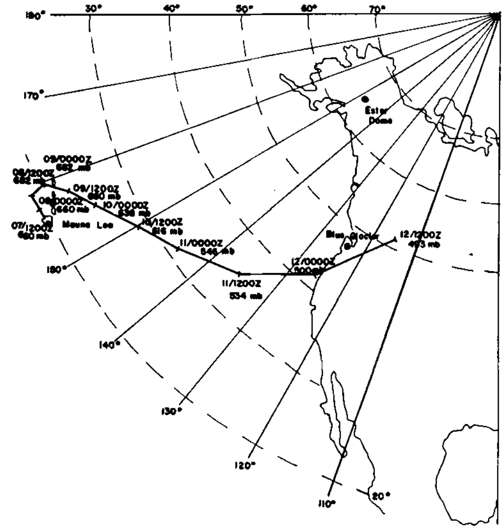

Fig. 12. Trajectory analysis starting at Mauna Loa at 1200 hours GMT on 7 March, 1968, and worked forward in time (N.B. 07/1200Z indicates the horizontal position of the air parcel on 7 March, 1968, at 1200 GMT. The pressure level at which the air is located at each point is also noted on the diagram.)

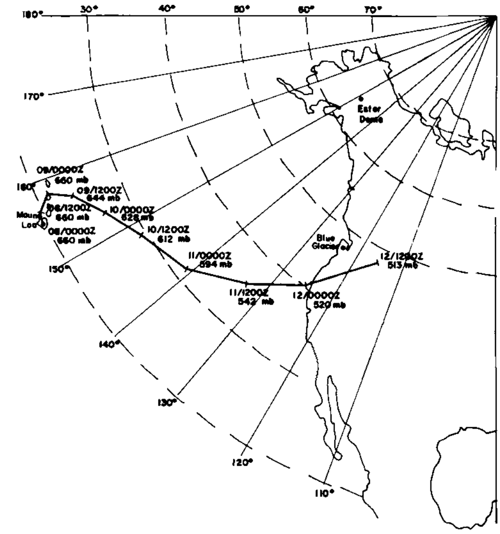

Fig. 13. Trajectory analysis started at Mauna Loa, Hawaii at 0000 hours GMT 8 March, 1968, and worked forward in time (N.B. 08/0000Z indicates the horizontal position of the air parcel on 8 March, 1968, at 0000 GMT. The pressure level at which the air parcel is located at each point is also noted on the diagram.)

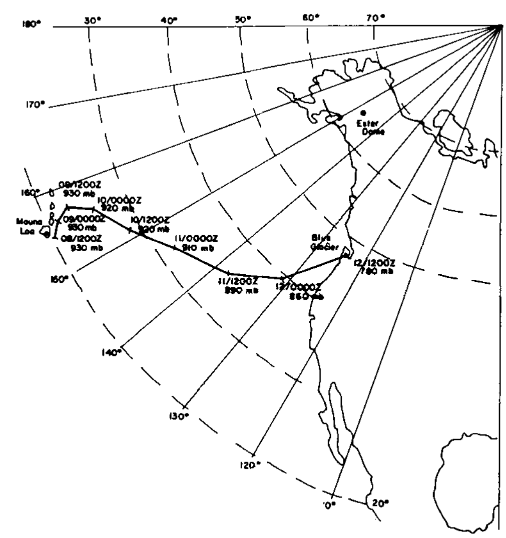

Fig. 14. Trajectory analysis started at Blue Glacier at 1200 hours GMT on 12 March, 1968, and worked backwards in time (N.B. 12/1200Z indicates the horizontal position of the air parcel on 12 March, 1968, at 1200 GMT. The pressure level at which the air parcel is located at each point is also noted on the diagram.)

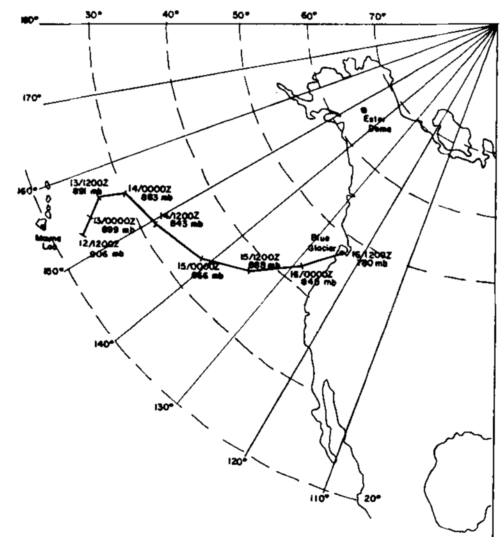

Fig. 15. Trajectory analysis starting at Blue Glacier, Washington at 1200 hours GMT on 16 March, 1968, and worked backwards in time (N.B. 16/1200Z indicates the horizontal position of the air parcel on 16 March, 1968, at 1200 GMT. The pressure level at which the air parcel is located at each point is also noted on the diagram.)

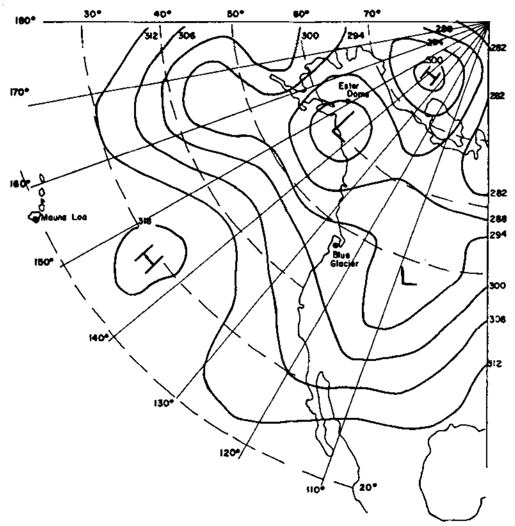

Fig. 16. A typical height pattern of the 700 mb surface during the period 18 to 21 March, 1968. Heights (in 10's of meters) of the 700 mb surface at 0000 hours GMT on 18 March, 1968.

than 1 000 miles away. From 10 to 15 February the jet stream moved about 400 miles north of Ester Dome; the ice nucleus count at the Blue Glacier was falling and that at Ester Dome initially decreased by then increased again. It appears, therefore, that during the period 27 January to 14 February, 1968, the ice nucleus counts at Ester Dome and the Blue Glacier were not related in any systematic fashion to the position of the jet stream.

The increase in the ice nucleus count which occurred at Mauna Loa, Hawaii, from 4 to 15 March, 1968, and the ice nucleus storm at Blue Glacier, Washington, from 11 to 21 March appear to be related (Fig. 2). To check whether advection in the troposphere might explain the time difference between these two events several trajectory analyses were carried out.

During the period 3 to 7 March, when the ice nucleus count was increasing at Mauna Loa, a stationary high pressure area dominated the flow south of 25° N latitude from 130° to 180° W longitude and this produced very light surface winds. From 7 to 11 March the ice nucleus count at Mauna Loa remained approximately constant. It was during this period that an upper level trough moved eastward from 180° W to produce a 700 mb trough west of Mauna Loa; this forced the high pressure area over Hawaii to move to the northeast. A typical 700 mb map for the period 7 to 11 March 1968, is shown in Fig. 10. The resulting pattern provided a small pressure gradient to move air away from Mauna Loa toward the northeast. During this time (7 to 11 March) air arriving at the Blue Glacier came from a mid-latitude source over the Pacific Ocean.

From 11 to 16 March the low pressure center in the Gulf of Alaska continued to move eastward and an air flow was established which advected air parcels, which had already moved northeast from Hawaii, toward the Pacific northwest. A 700 mb analysis, typical of the synoptic features during this period is shown in Fig. 11. Air trajectories, shown in Figs. 12 and 13, were started at Mauna Loa at 1200 hours GMT on 7 March and at 0000 hours GMT on 8 March and were traced forward in time. Both of these analyses place air parcels leaving Hawaii over the Western United States 4 1/2 days later. Further trajectories started at the Blue Glacier at 1200 hours GMT on 12 March and at 1200 hours GMT on 16 March were traced backwards in time to the Mauna Loa area 4 days earlier (Figs. 14 and 15). In all cases during this period the trajectory analyses show air parcels moving to higher elevations as they were transported from Hawaii to the Western United States. It can be seen from these results that air reaching the Blue Glacier, Washington, from 11 to 18 March should have passed over Hawaii about 4 to 5 days earlier. In this case, therefore, it appears likely that particles which produced the increase in the ice nucleus count at Mauna Loa from 4 to 15 March were advected to the Pacific Coast of Washington State to produce the ice nucleus storm observed at the Blue Glacier from 11 to 18 March, 1968.

During the period 18 to 21 March the upper level trough moved further eastward with its associated low at the 700 mb level into north-central United States. Fig. 16 also shows a much weakened low in the Alaskan Gulf with another trough moving eastward toward Hawaii and a ridge extending northward east of Hawaii. This caused northwest flow over the Olympic Mountains, and during this period the ice nucleus count at the Blue Glacier fell.

When the ice nucleus count at Mauna Loa was increasing from 4 to 7 March, the jet stream was over 1200 miles north of Hawaii. From 11 to 14 March the jet stream moved south to

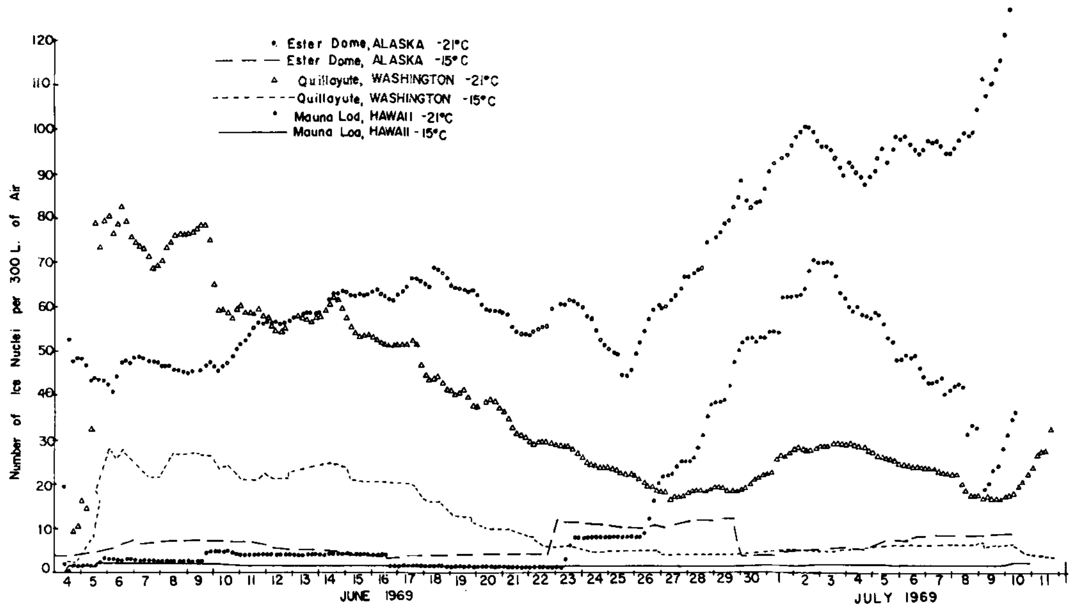

Fig. 17. Ice nucleus counts at −21 and −15°C at Ester Dome (Alaska), Mauna Loa (Hawaii), and Quillayute (Washington) during the period May 24 to July 11, 1969. The counts have been smoothed by taking 1 week running means.

within 420 miles of Hawaii but the ice nucleus count at Mauna Loa decreased during this period (Fig. 2). The jet stream moved to within 180 miles of Hawaii from 15 to 18 March but the ice nucleus count remained low at Mauna Loa. During this same period of time there was no jet stream near Washington but the ice nucleus count was rising. From 19 to 21 March the jet stream passed almost over the Blue Glacier, Washington, but the ice nucleus count at this station was decreasing. Again, therefore, there appeared to be little correlation between the ice nucleus count at a station and the location of the jet stream.

The ice nucleus storm which occurred at Ester Dome, Alaska, from 13 to 21 February, 1968, did not have a counterpart at either of the other two stations (Fig. 2). Tropospheric trajectory analyses to and from Ester Dome showed that air could not have been advected between the three stations during this period.

We turn now to the results obtained during the second period of measurements (June 4 to 11 July, 1969). The ice nucleus counts at −21°C and −15°C at the three stations are shown in Fig. 17, however, it should be noted that the counts at −15°C were generally too low to be recorded reliably by the acoustical counter.

The main features of the measurements shown in Fig. 17 are the ice nucleus storms observed

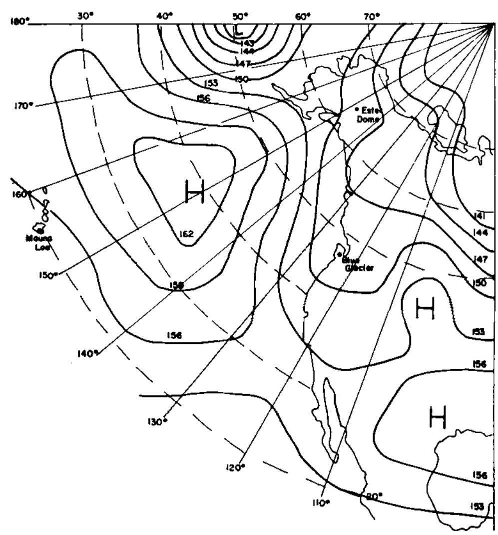

Fig. 18. A typical 850 mb analysis for the period 27 June to 6 July, 1969 showing a pattern which would cause northwest flow from Ester Dome, Alaska, to Quillayute, Washington. (Analysis for1200Z, 2 July 1969.)

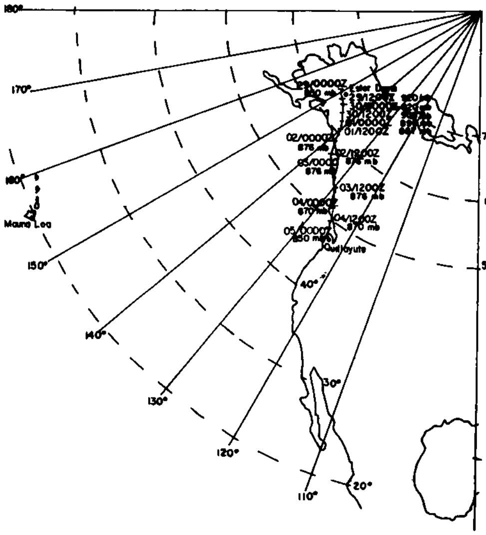

Fig. 19. Trajectories analysis on the 850 mb pressure surface starting at Quillayute, Washington, at 0000 hours GMT on 5 July, 1969, and working backwards in time (N.B. 05/0000Z indicates the position of the air parcel on 5 July, 1969 at 0000 hours GMT. The pressure level at which the air parcel is located at each point is also noted on the diagram.)

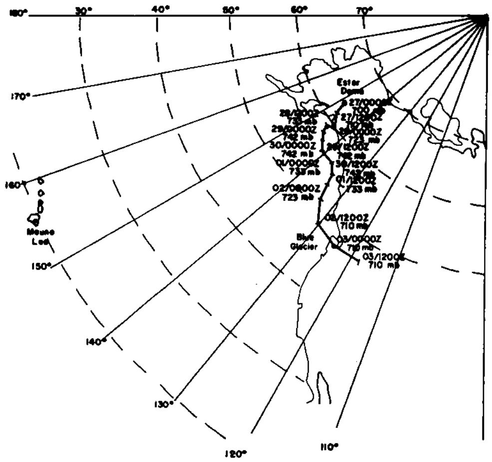

Fig. 20. Trajectory analysis started at Ester Dome, Alaska, at 0000 hours GMT on 27 June, 1969, and traced forward in time (N.B. 27/0000Z indicates the horizontal position of the air parcel on 27 June, 1969, at 0000 GMT. The pressure level at which the air parcel is located at each point is also noted on the diagram.)

at −21°C at Ester Dome and Mauna Loa and the increase in count at Quillayute at −21°C during the latter part of June and early July, 1969. The synoptic situation during this period was quite stationary. A high pressure center was located 900 miles north and 500 miles east of Hawaii, and there was a well-developed stationary low pressure center at 52° N 180° W. Another low pressure center was situated over northeastern Canada (Fig. 18). These synoptic features set up a weak pressure gradient to cause a gentle northwest flow of air from Ester Dome, Alaska, to Quillayute, Washington. There was very little verticle motion associated with this flow. Trajectories started from Quillayute, Washington, at 0000 hours GMT on 5 July, 1969, were traced backwards in time and thost started from Ester Dome, Alaska, at 0000 hours GMT on 27 June, 1969, were traced forward in time (Figs. 19 and 20). These analyses show that air was transported from Ester Dome to the Blue Glacier in a period of about 6 days. The trajectories also show that air parcels starting out from the elevation of Ester Dome would have moved to a lower elevation as they were transported south, but would have subsequently moved up to about the same elevation as Quillayute as they approached Washington State.

We see from this analysis that the transport of air in the troposphere could explain the close proximity in time of the ice nucleus storm observed at Ester Dome, Alaska, and the increase in the ice nucleus count at Quillayute, Washington, during this period. However, trajectory analysis showed that during the same period there was no possibility of air being advected between Hawaii and the other two stations. It appears, therefore, that the occurrence of the ice nucleus storm at Mauna Loa within a few days of the ice nucleus storm which occurred at Ester Dome was coincidental. The jet stream remained fairly constant in its position during the period of the three ice nucleus storms and remote from all three stations, being about 1 600 miles from Hawaii, 700 miles from Ester Dome and 500 miles from Quillayute.

Finally, some general comments may be made about the variations in the ice nucleus counts at −21°C at Quillayute and Mauna Loa during the second period of measurements. During the first 10 days of June, 1969, the airflow in Washington was from the east which allowed air from the city of Seattle to be transported to Quillayute, Washington. Since

Hobbs & Locatelli (1970) have shown that Seattle is a prolific source of ice nuclei, this may well account for the high ice nucleus count at Quillayute during the early part of June. During the remainder of the month the airflow at Quillayute became increasingly westerly and the ice nucleus count showed a general decline (Fig. 17).

From 4 to 23 June, 1969, the ice nucleus counts at −21°C at Mauna Loa, Hawaii, were too low to be recorded reliably by the acoustical counter. During this period the synoptic situation at Hawaii was dominated by a stable high and subsiding air and there was no precipitation reported. The ice nucleus storm which started at Mauna Loa on about 26 July occurred under more unstable and convective conditions. It is also interesting note that the volcano Kilauea was in eruption from midnight on the 26 June to midday on the 27 June and that the lava flowed into the ocean. The ice nucleus storm at Mauna Loa which started on 26 June might well have been due to this eruption (see Hobbs et al., 1971).

Summary and conclusions

During the first period of the simultaneous ice nucleus measurements at Ester Dome (Alaska), Mauna Loa (Hawaii) and the Blue Glacier (Washington) ice nucleus storms occurred within about 4 days of one another during late January and early February, 1968, at Ester Dome and the Blue Glacier. Trajectory analysis showed that during this period air was being transported from Ester Dome to the Blue Glacier in a time of about 4 to 5 days. An increase in ice nucleus count at Mauna Loa from 4 to 15 March, 1968, and an ice nucleus storm at the Blue Glacier from 11 to 21 March, 1968, also occurred under synoptic conditions which allowed for the advection of particles from Mauna Loa to the Blue Glacier in a matter of days. The only other ice nucleus storm which occurred during the first period was at Ester Dome from 13 to 21 February, 1968, and this did not have a counterpart at either of the other two stations. During this period the synoptic situation was such that particles could not have been advected in the troposphere between the three stations.

During the second period of measurements ice nucleus storms (at −21°C) were observed at Ester Dome, Alaska, and Mauna Loa, Hawaii, and there was an increase in ice nucleus count at Quillayute, Washington, during late June and early July, 1969. During this period air was being advected in the troposphere from Central Alaska to Western Washington and this could well explain the close proximity in time of the ice nucleus storm at Ester Dome, Alaska, and the increase in count at Quillayute, Washington. However, during the same period, it was not possible for air to have been transported between Hawaii and the other two stations. In this case, therefore, the ice nucleus storm observed at Mauna Loa was probably unrelated to the increases in ice nucleus counts observed at the other two stations and it was probably due to local sources of ice nuclei.

Consideration of the position of the jet stream with respect to the occurrence of the ice nucleus storms observed in the present measurements has failed to reveal any systematic relationship between these two phenomena.

We conclude from this study that ice nuclei can be advected by tropospheric winds over distances of thousands of miles. Consequently, an ice nucleus storm which originates locally may, under suitable conditions, be transported over large distances to produce ice nucleus storms at various locations around the world. In this connection we note than Isono, Komabayasi & Ono (1969) observed ice nucleus storms in Tokyo at the time of arrival of loess particles which originated from large dust storms in Northern China and Mongolia. More recently, Prospero & Carlson (1970) have found that particles originating from dust storms in Africa may be transported by the North Atlantic trade winds to the eastern coast of the United States.

Acknowledgements

Thanks are due to Dr E. J. Workman and Dr C. M. Fullerton for arranging for the measurements to be made at Mauna Loa. The help of Mr J. D. Locatelli in obtaining the measurements in Washington and in reducing some of the data, and Mr T. Henmi in assisting with the measurements in Alaska is also acknowledged.

This work was supported by the National

Science Foundation under the United States –Japan Cooperative Science Program (NSF Grants GF-285 and GF-326) and by the Atmospheric Sciences Section of NSF (Grant GA-17381). It is Contribution No. 224 from the Department of Atmospheric Sciences, University of Washington.

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ПЕРЕНОС ЛЕДЯНЫХ ЗАРОДЫШЕЙ НАД СЕВЕРНОЙ ЧАСТЬЮ ТИХОГО ОКЕАНА

В течение длительных промежутков времени на станциях в Аляске, Гавайях и штате Вашингтон в воздухе производились одновременные измерения относительной концентрации ледяных зародышей. В ряде случаев наблюдались большие увеличения числа зародышей, продолжавшиеся неделю или дольше («штормы ледяных зародышей»). Иногда эти штормы ледяных зародышей на разных станциях происходили вскоре друг за другом, что, как показано, в некоторых случаях может быть объяснено адвекцией частиц в нижней тропосфере между станциями. В других случаях представляется, что эти штормы были локального происхождения.