Snow Movement — Drift Control for Surface (At-Grade) Camps

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ABSTRACT. Snow movement in polar areas creates problems for surface (at-grade) camps, particularly in areas of net annual snow accumulation. Snowdrift studies, which were made over a 4-year period around a single unprotected building and around a cluster of buildings in an area of net annual snow accumulation on the Ross Ice Shelf near McMurdo Station, Antarctica, showed that at-grade camps will eventually become covered with drifting snow. Drift control measures, however, can be used to increase the usefulness and life of such camps. The measures developed cover proper building orientation and camp layout with respect to the major storm winds. In addition, mobile foundations may be used for buildings to facilitate camp moves when snowdrift becomes excessive.

RÉSUMÉ. *Mouvement de la neige et maîtrise des amoncellements dans les campements de surface*. Dans les régions polaires, le mouvement de la neige pose des problèmes aux campements de surface, surtout dans les zones d'accumulation nivale annuelle nette. Pendant quatre ans, on a mené des études sur les amoncellements de neige autour d'un bâtiment isolé et non protégé et autour d'un groupe de bâtiments, dans une zone d'accumulation nivale annuelle nette, sur la barrière de Ross, près de la base de McMurdo en Antarctique: ces études ont démontré que les campements de surface sont éventuellement recouverts par la neige amoncelée. Cependant, on peut faire appel à certaines techniques de maîtrise des amoncellements et prolonger ainsi l'utilité et la vie de ces campements. Parmi les mesures mises au point, mentionnons l'orientation correcte des bâtiments et un tracé du campement en rapport avec les principaux vents de tempête. De plus, on peut munir les bâtiments de fondations mobiles, ce qui facilite les déménagements lorsque l'accumulation de neige devient excessive.

РЕЗЮМЕ. *Защита от снежных заносов полярных лагерей, установленных на поверхности грунта*. Движение снега в полярных районах создает проблемы для лагерей, установленных на поверхности грунта, в частности в районах активного накопления снега. Исследования снежных заносов, проведенные в течение четырех лет вокруг единичного незащищенного здания, а также вокруг группы зданий, в районе активного накопления снега на шельфовом леднике Росса около станции Мэк Мурдо в Антарктике показали, что такие лагеря в конечном счете заносятся снегом. Однако, возможно применение мероприятий по защите от снежных заносов, как например, правильная ориентация зданий и схема расположения лагерей относительно наиболее сильных штормовых ветров. В случае необходимости возможно также применение передвижных оснований зданий для переноса лагерей на другую площадку.

INTRODUCTION

Drifting snow is a particularly critical problem in those polar areas where there is no depletion of the annual supply of snow. The snow accumulates both uniformly and in drifts around any obstruction. In the past, the snow has been allowed to bury surface (at-grade) camps, but this presents problems of hampered

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access, added weight on the structures, and reduced ventilation. In addition, some specialized buildings must be kept free of snow. In order to study the problem of minimizing drift in at-grade camps, measurements were made around an unprotected building and on clusters of buildings on the Ross Ice Shelf at the U.S. Naval Civil Engineering Laboratory (NCEL) camp from 1962 to 1967, and at the Williams Field camp from 1965 to 1967 (Stehle and Sherwood 1965, Stehle 1966, Stehle 1968). The results of this study show that although at-grade camps eventually become covered with snow, their usefulness and life can be increased by exercising certain drift control measures.

LOCATION

During these studies, the NCEL antarctic camp was located at the western extremity of the Ross Ice Shelf (Fig. 1), about 3 miles south of McMurdo Station and Scott Base, which are situated on Ross Island. Williams Field lay to the east and McMurdo Sound to the west of the NCEL camp.

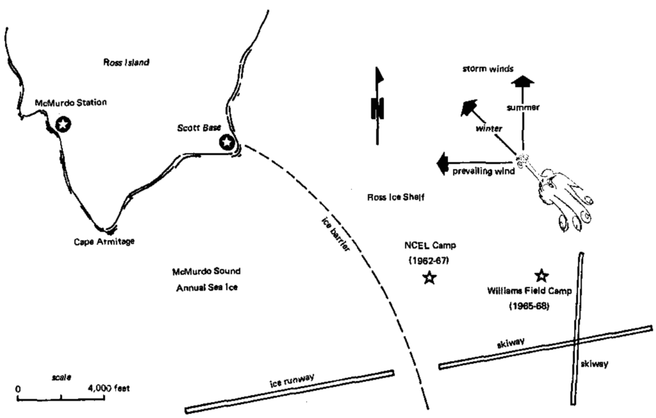

FIG. 1. Map of McMurdo area.

The climate of the McMurdo Sound region is characterized by low temperatures, frequent high winds, and drifting snow. At the NCEL and Williams Field camps, the prevailing winds are from the east, the major summer storm winds are from the south, and major winter storm winds are from the southeast. Over a period of 9 years, the average wind speed was 15 m.p.h., and the high daily average wind was 30 m.p.h. The average annual snow accumulation was 0.9 foot per year during this period of observation.

Protected Cluster of Buildings

During the austral summer of 1962-63, the major portion of the NCEL camp was constructed on a levelled, compacted, at-grade snow site on the Ross Ice Shelf (Fig. 1). By January the camp consisted of a 16- by 32-foot Jamesway hut parallel with a 16- by 60-foot Jamesway and two 8- by 20-foot wanigans. All rectangular buildings were oriented north-south, with the long axis parallel with the storm wind (Fig. 2). Each Jamesway, in addition to the endwall entrances, had a sidewall entrance.

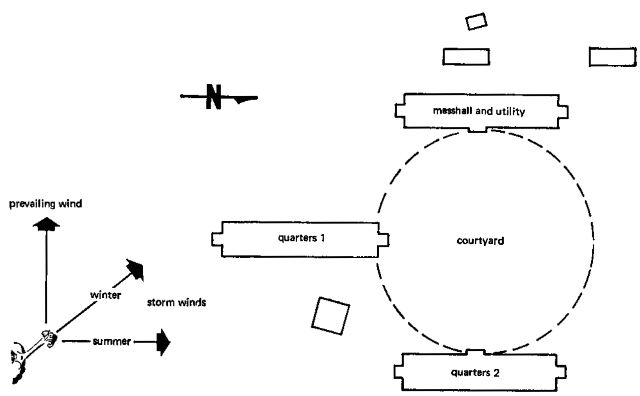

FIG. 2. General NCEL camp layout as of November 1963.

A 5½-foot-high, U-shaped snow wall, which was constructed upwind, reduced drift accumulation in the camp the first summer. In February 1963, this wall was extended and widened to 12 feet on the sides for storage of equipment. In addition, two triangular-shaped, 5½-foot-high secondary snow walls were built 100 and 200 feet upwind of this main wall; the outer one extended 200 feet either side of centre, and the inner one about 100 feet either side. The grouping of the buildings behind the snow wall was designed to observe drift in a protected cluster of buildings.

Early in November 1963, the snow around the Jamesways was cleared out, and the camp was modified to consist of two 16- by 64-foot Jamesways, one 16- by 56-foot Jamesway, and two 8- by 20-foot wanigans. Because of the complete inundation of the camp after 4 years, it was moved to a new location in December 1966, thus terminating observations on this at-grade cluster of buildings.

Unprotected Cluster of Buildings

The Williams Field camp, which was erected in its present location (Fig. 1) in September 1965, consists of three rows of Jamesways, with 8 to 10 Jamesways in each row (Fig. 3). All buildings are oriented with their long axes perpendicular to the major storm winds. In late February 1966, all the buildings in the Williams Field camp were 1 to 2 feet above the surrounding surface due to ablation of the surrounding snow.

Single Unprotected Building

In late January 1963, a 28- by 56-foot T5M shop building was erected on an at-grade compacted-snow mat; the long axis was oriented north-south, parallel with the southerly storm winds. This building was situated on the snow surface 0.4 mile northeast of the NCEL camp in order to observe drift around a single, large unprotected building. Observations on this single, at-grade building were terminated in January 1967, when the T5M was dismantled and moved to a new location.

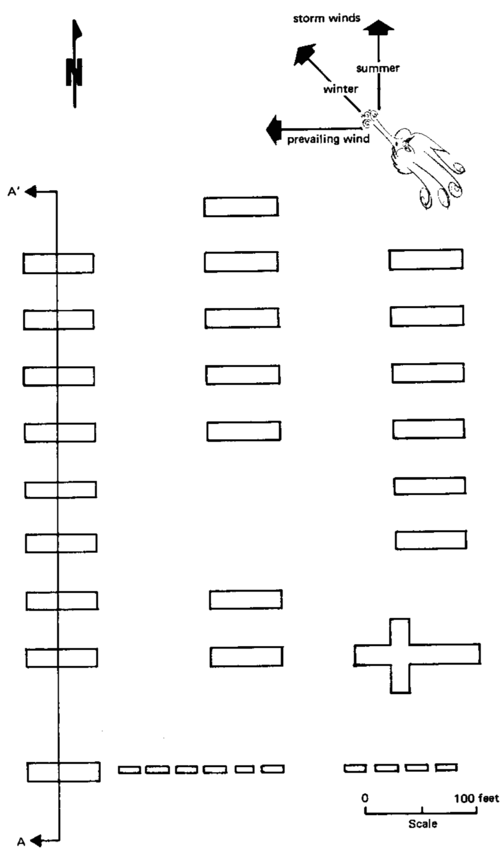

FIG. 3. Plan view of Williams Field camp as of October 1965. Cross section A-A' shown in Fig. 4.

COMPARISON OF RATES

The total depth of drift around each of the building arrangements maintained approximately the same relationship to the total depth of natural accumulation throughout the test period. Table 1 shows that the estimated average drift in the unprotected cluster of buildings and around the single building was about 3 times the total depth of natural accumulation for each year, whereas the protected cluster started with about twice the depth of drift during the first year and increased to about 2½ times by the fourth year.

TABLE 1. Drift Accumulation Around Three Building Arrangements Compared to the Natural Accumulation.

Year	Average depth of natural Accumulation (ft)	*Protected Cluster* Average Drift (ft)	*Protected Cluster* Increase Over Natural (times)	*Single Building* Average Drift (ft)	*Single Building* Increase Over Natural (times)	*Unprotected Cluster* Average Drift (ft)	*Unprotected Cluster* Increase Over Natural (times)
1	1	2.2	2.2	3	3	3	3
2	2	4.6	2.3	5.5	2.7	6	3
3	3	7.2	2.4	8.1	2.7	—	—
4	4	10.0	2.5	14.0	3.5	—	—

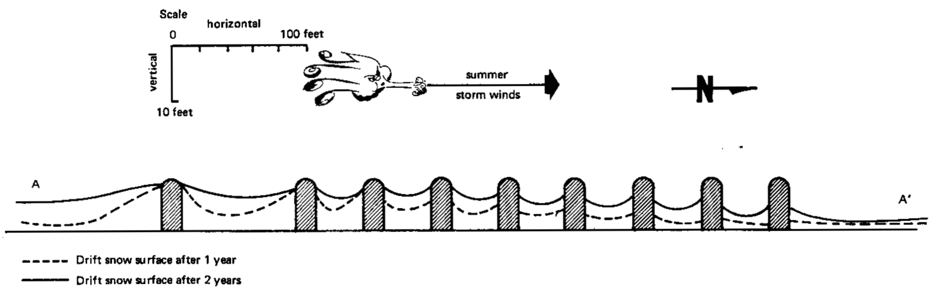

FIG. 4. Generalized cross section of Williams Field showing drift accumulation after 1 and 2 years of accumulation. See Fig. 3 for location of cross section.

In comparing the amount of drift at the end of the first year of exposure, the three different building arrangements show distinct differences in drift accumulation (Table 1). The snow berms upwind of the NCEL camp protected the camp buildings so that they accumulated only about 2 feet of drift as opposed to the unprotected buildings of Williams Field which averaged about 3 feet of drift (Fig. 4). In addition, the upwind buildings at Williams Field were almost completely inundated with snow. About 3 feet of drift also accumulated around the unprotected T5M shop building. These snow walls provided protection only during the first year; improper orientation of snow fences may be detrimental or of no use.

After only 2 years of accumulation, however, 4,500 cubic yards of snow had to be moved to provide access to the NCEL camp buildings. Drift snow continued to accumulate in this cleared area so that an additional 1,500 cubic yards had to be removed after every storm. Clearing was again required at the end of the third year (October 1965). At that time, however, a smaller, relatively deep depression was cleared and only 3,000 cubic yards were removed. Because of the greater depth of the cleared area, two-thirds of the depression was filled with snow after each storm, compared with one-third the previous year; this required the removal of 2,000 cubic yards after every storm.

After 4 years of exposure the NCEL camp and the T5M were completely covered with snow, although only about 4 feet of snow had accumulated on the surrounding natural surface. From Table 1 it is apparent that the drift accumulation around the T5M during the fourth year was nearly as great as that of the first 2 years combined, but the rate of accumulation during that time around the initially protected cluster of buildings was quite uniform. Even though the T5M shop building was 4 feet higher than the buildings in the NCEL camp, it was nearly covered with snow in the same 4-year period.

In the McMurdo area, where the average annual snow accumulation is about 1 foot per year, single buildings and camps become completely inundated with snow within 4 years. Precise information on drift accumulation around buildings versus annual accumulation is available only for the McMurdo area. However, general observations indicate that other coastal and some inland locations in Antarctica with greater annual snow accumulation, such as Little America Station, become covered within 2 years.

As pointed out by Moser (1954) and later confirmed by Roots and Swithinbank (1955) and Reese (1955), drift around buildings can be minimized by avoiding the coalescence of drift; this can be accomplished by placing the buildings in a line perpendicular to the storm wind because major drifts form down-wind. Buildings oriented with their long axis perpendicular to the wind form a short drift the length of the building on the leeward side; those oriented with the long axis parallel to the storm wind form a long, narrow shallower drift on the leeward side. Consequently, drift in the NCEL camp could have been lessened if the 3 Jamesways (Fig. 2) had been placed in a line perpendicular to the storm wind rather than with the central one offset upwind. This offset building caused the drift which normally accumulates downwind to form between the other two buildings. The smaller buildings should also have been set to the side rather than upwind to prevent drift caused by them from accumulating around other buildings. Orientation and placement of buildings are generally more reliable means of minimizing drift accumulation than is the use of snow fencing.

Drift accumulation in the Williams Field camp also was accentuated by arrangement of buildings (Fig. 3). Nearly complete burial of the windward buildings occurred because they were placed with the long axis perpendicular to the storm winds. Distance between buildings was such that the short, deep leeward drifts from the upwind building coalesced with drift on the windward side of the downwind building (Fig. 4).

Drift accumulation was greater in the Williams Field camp during this first year than in the NCEL camp because Williams Field was completely unprotected, the buildings were downwind of others, and each building was oriented so the long axis was perpendicular to the storm winds. As the windward buildings at Williams Field are buried and present a smooth surface, the buildings downwind will become drifted in further.

The amount of drift accumulation could have been decreased considerably at Williams Field by rotating the camp layout 90 degrees (Fig. 5). With such a layout, the 3 long rows of buildings would be perpendicular to the storm winds,

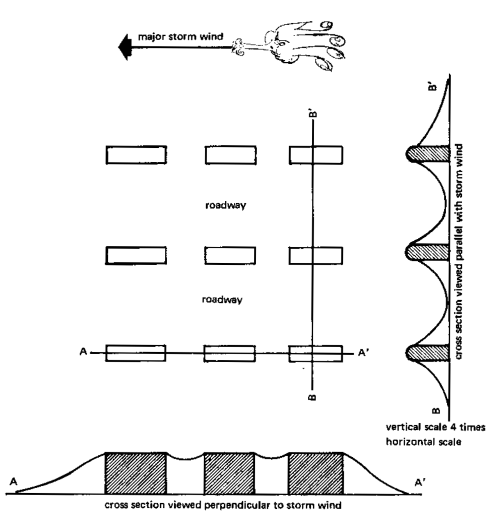

FIG. 5. Illustrative layout of multi-building camp and expected drift pattern.

with the long axis of each building parallel with the storm wind. In addition, the ends of the buildings in each row should be placed close together as in a train, and the camp roadways should parallel the long axis of the buildings. To provide access with such a plan, all buildings would need sidewall entries, since the ends would be drifted in.

RELATED RESEARCH

Scale model tests by Sherwood (1967a) in the NCEL wind duct have shown that the rate of drift accumulation around the types of at-grade polar buildings at present in use can be reduced by orienting them 45 degrees to the storm wind. These tests have also shown that buildings elevated on solid platforms 2 to 4 feet above the surrounding surface have much less drift than when directly on the surface.

Field studies of drift around elevated roads and storage areas (Stehle and Sherwood 1965, Moser 1964) have shown that drift on the road is minimal until the surface of the surrounding area becomes level with the elevated area. The length of time it is drift-free depends on the initial elevation, side slopes and the rate of annual snow accumulation.

To elevate a camp of three Jamesways and associated buildings similar to the NCEL camp would require a 300- by 100-foot area about 4 feet high, or 4,500 cubic yards of snow. This is a reasonable amount of snow to move considering that 4,500 cubic yards had to be moved to clear the courtyard of the NCEL camp after 2 years of exposure, particularly since elevating would increase the life of the camp by at least 1 year. To elevate a camp the size of Williams Field camp, however, would require an area 500 by 620 feet, 4 feet high; this amounts to 45,000 cubic yards of snow, or 10 times the amount for the NCEL camp. Not only would this take longer, but snow would have to be transported farther. Consequently, size would definitely limit the feasibility of elevating surface camps.

Ordinarily, when a Jamesway building is relocated, it must be completely disassembled, regardless of the distance to be moved. When the labour involved in this is compared with the labour to keep a camp accessible, there is little justification for moving the camp any sooner than is necessary. To provide a rapid means for relocating completely assembled Jamesway buildings in the same general area, NCEL developed a mobile foundation (Sherwood 1967b) for Jamesways up to 64 feet long. Relocation of a Jamesway erected on such a mobile foundation can be made at any time with minimum manpower, loss of occupancy, and building damage. Foundations of this type could also be used with other polar buildings.

DRIFT CONTROL MEASURES

Regardless of the size (number of buildings) of a camp located in an area of drifting snow, the following measures should be used to minimize drift and to make relocation as easy as possible:

1) Orient the buildings 45 degrees to the summer storm wind with the long axis parallel to the winter storm wind where these directions are 45 degrees apart,

as in the McMurdo area. Elsewhere, approach this arrangement as closely as possible.

2) Place the buildings in a line perpendicular to the winter storm wind sufficiently far apart to avoid coalescence of drift, generally 25 times the height. If more than one line of buildings is necessary, place the rows of buildings in a train arrangement with the row parallel to the winter storm wind.

3) Treat equipment and material as a separate line of buildings, placed far enough apart to prevent coalescence of drift.

4) Where practicable, erect the buildings on mobile foundations so that they can be easily moved when drift becomes a problem.

5) Because buildings are obstacles to the wind, each will accumulate drift snow and some clearing will be necessary. Consequently, arrange the buildings so that there is sufficient room to permit easy clearing; at least 60 feet is needed by either a size 4 or size 8 snow tractor.

From these limited field data it was determined that small camps should be elevated on snow platforms when 5,000 cubic yards or less of snow are required to build the platform. In addition to the above drift control measures, the following measures should also be observed when setting up an elevated camp:

1) The platform should be constructed about 4 feet above the surrounding snow surface for a 2-year life in an area with an annual accumulation of snow of 1 foot or less; where accumulation is greater, the elevation will have to be greater or the life expectancy will be less.

2) Drift accumulation will increase downwind of an elevated camp; therefore, other buildings or supplies should not be located within 10 to 30 times the height of the obstruction downwind of an elevated area; the length of a drift is at least 10 times the height of the obstruction.

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