Journal of Glaciology, Vol. 11, No. 61, 1972

SNOW ACCUMULATION AT "BYRD" STATION, ANTARCTICA

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Abstract. The rate of snow accumulation at "Byrd" station, Antarctica, was measured by various methods. Surface measurements yield a mean accumulation of 117 kg m^{-2} $year^{-1}$ for the time interval 1962–70, within a 10 m radius of the station. The distribution of fission products with depth indicates a rate of 67 ± 4 kg m^{-2} $year^{-1}$ for the period 1955–68 and of 100 ± 10 kg m^{-2} $year^{-1}$ for the period 1965–68. The ^{210}Pb method yields a 60 year average of 110 ± 10 kg m^{-2} $year^{-1}$.

Résumé. *L'accumulation de la neige à "Byrd" station, Antarctique.* Le taux d'accumulation de la neige à "Byrd" station, Antarctique, a été mesuré par diverses méthodes. Les mesures de surface fournissent une accumulation moyenne de 117 kg m^{-2} a^{-1} pour la période 1962–70, dans un rayon de 10 km autour de la station. La distribution des produits de fission en fonction de la profondeur indique des valeurs de 67 ± 4 kg m^{-2} a^{-1} pour la période 1955–68 et 100 ± 10 kg m^{-2} a^{-1} pour la période 1965–68. La méthode du ^{210}Pb donne une accumulation moyenne, sur les 60 dernières années, de 110 ± 10 kg m^{-2} a^{-1}.

Zusammenfassung. *Die Schneeakkumulation an der "Byrd"-Station, Antarktika.* Die Schneeakkumulation an der "Byrd"-Station, Antarktika, wurde nach verschiedenen Methoden gemessen. Messungen an der Oberfläche ergeben eine mittlere Akkumulation von 117 kg m^{-2} a^{-1} für die Zeitspanne 1962–70 innerhalb eines Kreises von 10 km Radius um die Station. Die Verteilung von Spaltprodukten in Abhängigkeit von der Tiefe führt zu einem Betrag von 67 ± 4 kg m^{-2} a^{-1} für die Zeit 1955–68 und von 100 ± 10 kg m^{-2} a^{-1} für die Zeit 1965–68. Die ^{210}Pb-Methode ergibt über 60 Jahre ein Mittel von 110 ± 10 kg m^{-2} a^{-1}.

Introduction

The purpose of this study is to estimate the snow accumulation rate at "Byrd" station, at the location of the first core hole to bedrock in Antarctica (Gow and others, 1968).

This knowledge, together with that of dynamic factors, is essential to the establishment of a time scale most useful for the interpretation of the data obtained by other investigators.

We report here the results obtained by surface measurements and by two radiometric methods based respectively on the distribution of the fission products and of ^{210}Pb with depth in the firn.

Surface measurements

Two 10 km long accumulation stake lines were established in February 1962 and have been monitored each year since. One line was oriented in an east–west direction, the other in a north–south direction (Fig. 1); measurements at these stakes have provided the most reliable record of accumulation variations within a 10 km radius of "Byrd" station.

Results of the first 3 years' observations (Gow and Rowland, 1965) indicated a strong topographic control on accumulation rates which all subsequent measurements continue to reflect, namely, that surface depressions accumulate appreciably more snow than the exposed ridges or crests. These relationships are clearly demonstrated in Figure 2, depicting measurements from the east–west line.

Snow stakes were originally emplaced on 16 February 1962, the distance between stakes being set at 0.5 km. A total of 43 stakes was planted but records are incomplete at two

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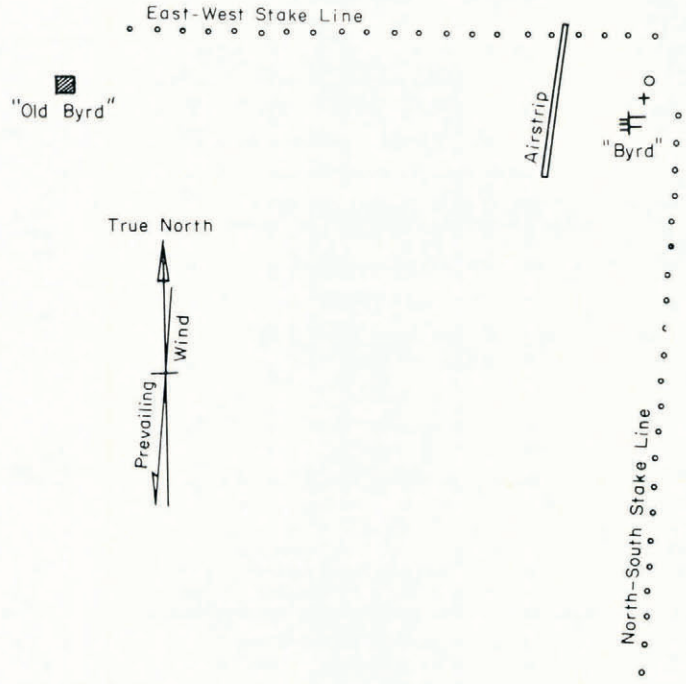

Fig. 1. Sketch map of "Byrd" station and environs showing locations of accumulation stake lines and radiometric sampling sites. Spacing between accumulation stakes is approximately 0.5 km. Location of samples used in this study is shown by a cross. Windom's (1969) sampling site is indicated by a circle.

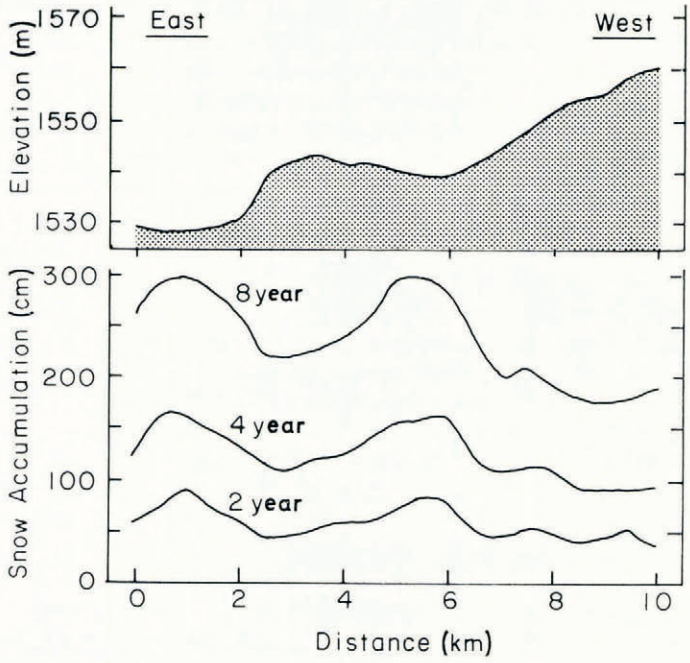

Fig. 2. Relationship of snow accumulation to undulating surface topography along the east–west stake line at "Byrd" station Antarctica. Surface depressions are accumulating 30–50% more snow than the exposed crests.

https://doi.org/10.3189/S0022143000022498 Published online by Cambridge University Press

stakes. Snow accumulation at 41 stakes for the past 8 years has averaged 117 kg m^{-2} $year^{-1}$. The stake showing the greatest accumulation in 8 years averaged 157 kg m^{-2} $year^{-1}$; that with the least accumulation averaged 86 kg m^{-2} $year^{-1}$. The largest accumulation recorded at any one stake in a given accumulation year (February to February) was 195 kg m^{-2} $year^{-1}$.

Measurements made by R. L. Cameron (personal communication) at 100 snow stakes, laid out in a 1 km grid near the eastern corner of the east–west line, have yielded an average accumulation of 103 kg m^{-2} $year^{-1}$ based on 2 years' measurements.

Fission products distribution in the firn

The observation, by Picciotto and Wilgain (1963) and Vickers (1963), that a well-defined reference level in the upper layers of the Antarctic ice sheet has been formed by the stratospheric fall-out of radioactive debris released from the first large thermonuclear bomb test has provided a criterion for measuring the average accumulation rate since 1955. This 1955 horizon (Wilgain and others, 1965), easily identified by a sudden and large increase in ^{90}Sr or in gross β activity, has been used systematically to estimate snow accumulation rates at 75 stations on the east Antarctic plateau (Picciotto and others, in press).

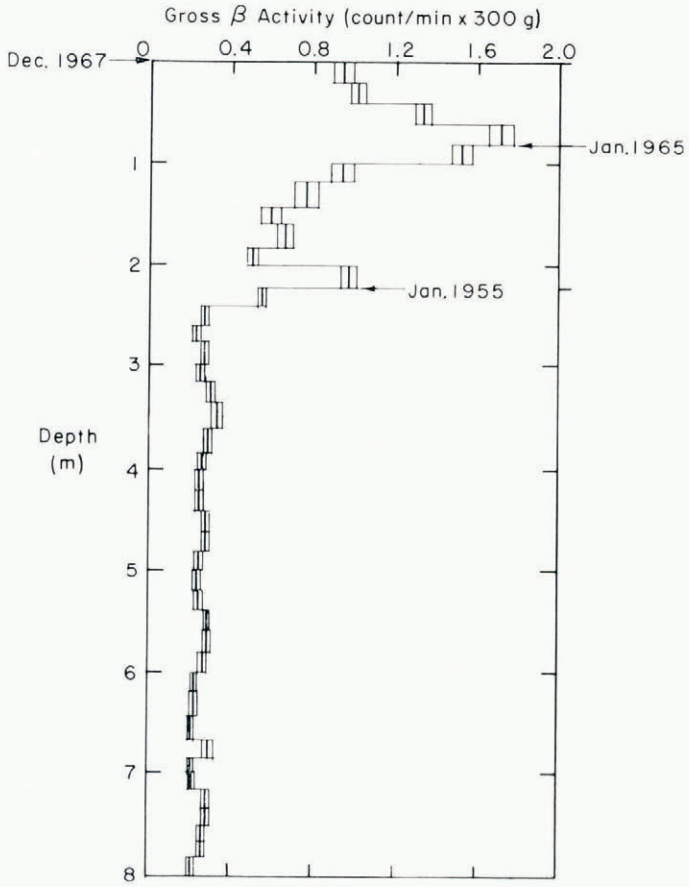

Fig. 3. Gross β activity in the firn at "Byrd" station. The β activity is expressed in counts per minute and per 300 g sample, without background correction. The error interval represents the standard deviation on the number of counts. The arrows show the positions of the β-activity maxima attributed respectively to January 1955 and January 1965.

An additional reference level, in January 1965, corresponding to the fall-out of the atmospheric thermonuclear bombs detonated in 1962 has been recognized by Crozaz (1969).

The firn analysed here was collected in December 1967 near the northern corner of the north–south line. Five bulk samples were used for the depth interval from 0 to 1 m, and seven 1 m cores (7.6 cm diameter hand-augered cores) from 1 m down to 8 m. Each core was cut in five pieces and 300 g samples were treated. The samples were kept frozen until analysed. The gross β activity was measured after coprecipitation of the fission products with suitable carriers (see Picciotto and others, in press).

The distribution of the gross β activity with depth is shown in Figure 3. The interpretation of these data is straightforward; the low, almost constant, activity below 240 cm is essentially due to the detector background and partially to the natural activity of ^{210}Pb. The jump at 220 ± 10 cm is attributed to the January 1955 (±1 month) precipitations; above this level the usual decrease in activity is followed by a second important increase which culminates in January 1965, at 80 ± 10 cm.

The resulting mean accumulation rates are 67 ± 4 kg m^{-2} year^{-1} for the time period 1955–68 and 100 ± 10 kg m^{-2} year^{-1} for 1965–68. The errors on the accumulation rates include the uncertainties on the β surges, due to the finite thickness of the samples and the uncertainty on the time of occurrence of the respective horizons (±1 month).

Table I. "Byrd" station—^{218}Pb in firn samples

Depth interval m	$\frac{^{210}Po}{^{208}Po}$	$\frac{^{210}Po}{^{208}Po}$ *corrected*	*Middle of depth interval* m (in water equivalent)
0–2	1.04 ± 0.04	0.93 ± 0.04	0.38
2–4	0.87 ± 0.03	0.76 ± 0.03	1.25
4–6	0.82 ± 0.03	0.71 ± 0.03	2.16
7–9	0.48 ± 0.02	0.37 ± 0.02	3.69
9–10	0.49 ± 0.02	0.38 ± 0.02	4.49
9.68–10.64	0.40 ± 0.01	0.29 ± 0.01	4.76
43.36–44.01	0.11 ± 0.01	—	—

The ^{210}Pb relative activities are expressed in ^{210}Po/^{208}Po activity ratios. From a rough evaluation of the counting efficiency, a ^{210}Po/^{208}Po ratio of one corresponds to an absolute ^{210}Pb activity of about 0.8 destint. min^{-1} kg^{-1}.

^{210}Pb

The ^{210}Pb method (Goldberg, 1963; Crozaz and others, 1964) is based on the radioactive decay of the ^{210}Pb occurring naturally in the atmosphere as a decay product of ^{222}Ra. Its 22 year half life allows dating of firn samples up to 100 years old. This method has previously been applied at "Byrd" station by Windom (1969), who derived a mean accumulation rate of 98 kg m^{-2} year^{-1}.

The ^{210}Pb activity as a function of depth was measured on hand-drilled cores from the same location, from the surface down to 10 m. Two additional 16 cm diameter cores (covering the depth intervals 9.68–10.64 m and 43.36–44.01 m) were obtained from the deep drill hole at "Byrd" station.

The radiochemical procedure has been described in Crozaz and Fabri (1966) and Picciotto and others (in press). It is based on the α counting of ^{210}Po in equilibrium with ^{210}Pb. The chemical recovery yield is controlled by the use of a ^{208}Po tracer.

The concentrations of ^{210}Po as a function of the depth in water equivalent are shown in Table I. The results are expressed in ^{210}Po/^{208}Po activity ratios; the activities measured are taken to represent the activity at the middle of the depth interval covered by each sample.

A blank correction was applied by subtracting the activity found in the deepest sample, from 43.36 to 44.01 m (which is more than 200 years old).

From the slope of the best straight-line fit through the corrected values (Fig. 4) an accumulation rate of 120 ± 10 kg m^{-2} year^{-1}, averaged over the last 50 years, is deduced.

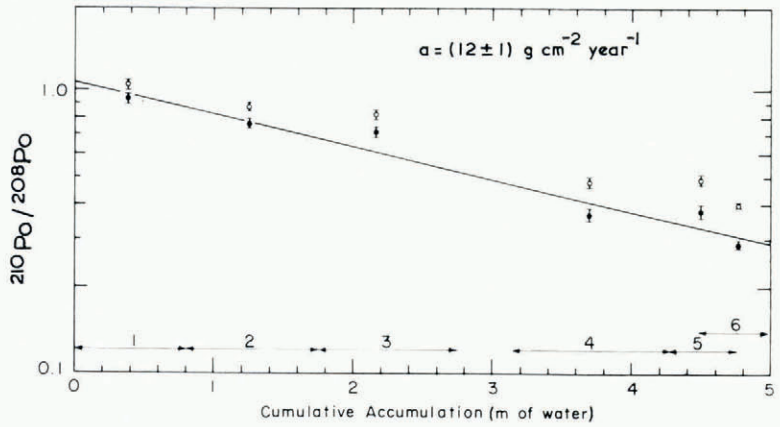

Fig. 4. Variation of the ^{210}Pb activity in the firn as a function of depth in water equivalent. ^{210}Pb activities are expressed relatively to the activity of the ^{208}Po tracer. Open circles represent uncorrected activity ratios. Dots represent activity ratios corrected for background. Error bars indicate the uncertainty due to counting statistics.

Conclusion

The results are summarized in Table II.

Consideration of surface stake measurements indicates that the average snow accumulation for the time interval 1962–70, within a 10 km radius of "Byrd" station, varies from 86 to 157 kg m^{-2} year^{-1} with a mean value of 117 kg m^{-2} year^{-1}.

Table II. Estimates of the annual accumulation at "Byrd" station

Annual interval (estimated)	*Method of measurement*	*Accumulation* kg m^{-2} year^{-1}	*Reference*
1890–1965	^{210}Pb	97	Windom (1969)
1964–65	Stakes	103	R. L. Cameron (personal communication)
1962–70	Stakes	117	Present work
1955–68	Fission products	67 ± 4	Present work
1965–68	Fission products	100 ± 10	Present work
1910–68	^{210}Pb	120 ± 10	Present work

The value for the time interval 1955–68, inferred from the fission products, is rather low but still compatible with the stake measurements since the cores used were from the same general area as the stakes with the lowest accumulation.

The accumulation derived from the ^{210}Pb is in reasonable agreement with the one found by Windom at the same location. Combining both results, we conclude that the average accumulation at "Byrd" station for the time interval 1910–68 is 110 ± 10 kg m^{-2} year^{-1}.

Acknowledgements

The support of the Office of Antarctic Programs, National Science Foundation and of Task Force 43, U.S. Navy is gratefully acknowledged.

MS. received 23 August 1971

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