Atmospheric electricity at base „Koning Boudewijn" 1964/66

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Abstracts: The results of two years on atmospheric electricity measurements are presented in short. The mean electric field strength near the surface was 139 V/m, the mean positive and negative conductivity were 1.75×10^{-14} ohm $^{-1}$ .m^{-1} and 0.95×10^{-14} ohm $^{-1}$ m $^{-1}$ respectivelly. Some special topics such as the influence of aurorae, the electrode effect and the electric field as function of height are briefly discussed.

Zusammenfassung: Die Ergebnisse von zweijährigen atmosphärischen Elektrizitäts-Messungen werden dargelegt. Der Mittelwert der elektrischen Feldstärke nahe der Oberfläche war 139 V/m. Über einige spezielle Themen wie das Polarlicht, der Elektrodeneffekt und das elektrische Feld als Funktion der Höhe wird berichtet.

1. Introduction

During the first and the third Belgian-Netherlands Antarctic Expedition, as organized by the Belgian-Netherlands Antarctic Committee, atmospheric electricity observations were performed at base "Roi Baudouin". The base was constructed by the 1958 Expédition Antarctique Belge (leader G. de Gerlache). The base (70 ° S, 24 ° E, height 40 m), was situated on a flat ice shelf, 300 metres thick. The region is appropriate for atmospheric electricity observations, because, in the first place, the antarctic air is almost without disturbing nuclei. Secondly, southeasternly winds are prevailing, so that, in general, the atmospheric electric observatory, situated south of the base, was not disturbed by human activity. Thirdly, the ionization of the air is completely due to cosmic radiation and therefore practically constant. The ionization due to radioactivity can be neglected because of thick ice layers covering the rocks. This simplifies the interpretation of the observations. There is only one severe problem: about 70 % of the time the observations are disturbed by electrically charged drifting snow due to local catabatic winds and blizzards. When no drifting snow occurs the conditions are excellent.

In 1964 the "fair weather" electric field near the surface and in the upper air was observed. During this year the position of the base turned out to be very suitable to study special effects. Therefore, in 1966 the programm was extended with conductivity measurements and the observation of electrode-effect and auroral influences. The results are presented here in short, the unabridged observations are given in the reports of the expedition (Buis 1969, Kraan 1969).

2. The electric field near the surface

During 1964 and 1966 the observations of the electric field were performed by measuring the potential difference of the air at various heights and at the earth's surface. For this purpose horizontal antennae, ten metres long, were stretched between two poles. Each antenna, carrying two radioactive sheets (RaD, 10 μC), was attached to the poles by perspex insulators. The potential difference between the antennae and the surface was measured by various electrometres with an input impedance of 2×10^{12} ohm or more. During 1964 the electric field was observed at a mean height of 0.75 m, during 1966 the electric field was measured at 0.5, 1.0, 3.0 and 5.0 metres. Observations at these different heights served to study the electrode effect. (part 6). Moreover, the influence of aurora upon the electric field was studied by measuring the electric

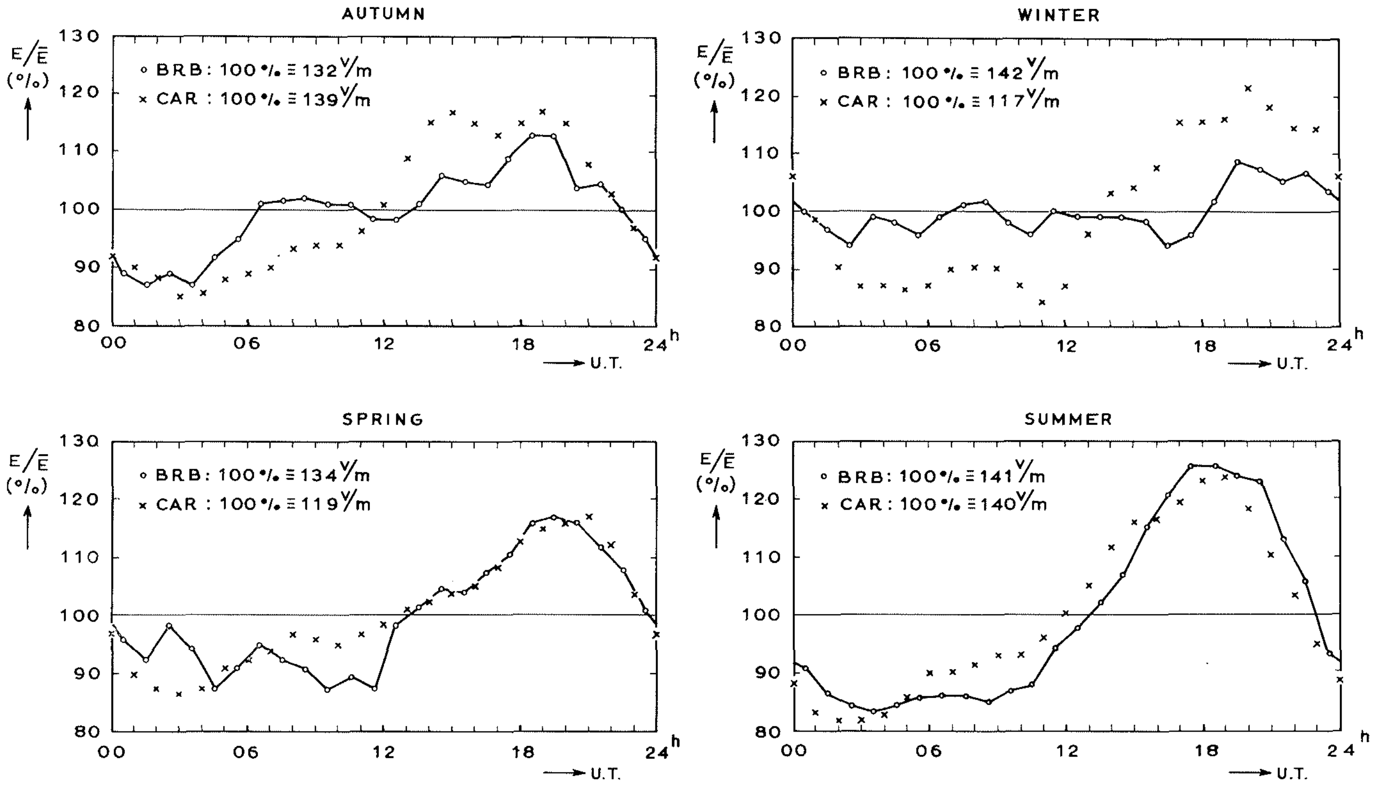


FIGURE : 1 DIURNAL VARIATIONS OF THE ELECTRIC FIELD NEAR THE SURFACE; FOR THREE MONTH'S PERIODS. (THE VALUES ARE PLOTTED IN PERCENTS OF THE MEAN VALUE). BRB : BASE "ROI BAUDOUIN" '64 - '66 ; CAR : CARNEGIE CRUISES '28 -'29 field five metres above the earth's surface. The observations were performed simultaneously at two places, 0.2 and 4.0 km south of the base. All registrating instruments were situated at the base.

Only "fair weather" electricity was studied and therefore only those observations were taken into account which satisfied the following conditions:

— Windspeed v: $0.5\ \mathrm{m.\,s.}^{-1} < v < 7.5\ \mathrm{m.s}^{-1}$. At low winds, $v < 0.5\ \mathrm{m.s}^{-1}$, space charge, produced by the radioactive sheets, disturbed the observations. Windspeeds more than $7.5\ \mathrm{m.s}^{-1}$ generally generated drifting snow.

— Observations during northern winds were disregarded in order to avoid perturbation of the measurements by dust or smoke of the base.

— Only hours without hydrometeors were used.

— Bandwidth: the registration points show a certain spread around a mean value, caused by the short time fluctuations of the electric field. The bandwidth is the width of the band around the mean value that includes 95 % of the registration points. The bandwidth is expressed in percents of the mean value. Only periods with registrations with bandwidth less than 20 % were taken into account.

Because of this selection only 30 % of the observations are useful as fair weather results.

Daily variation

During 1964 and 1966 the annual mean value of the electric field strength at 0.75 and 0.50 metres was —141 (± 7) $\mathrm{V.m}^{-1}$ and —136 (± 14) $\mathrm{V.m}^{-1}$, respectively.

In figure 1 the mean diurnal variation is compared with the observations during the Carnegie Cruise 1928/29. (Torreson 1946).

This figure shows that daily variation of the fair weather electric field are observed during spring, summer and autumn. That his daily variation is not due to selection of the observations, is shown by the fact that every single, complete day of fair weather a clear daily variation was observed. During the winter no such variation was distinguishable, which is in deviation from the results of the Carnegie Cruises. This deviation was observed in 1964 and in 1966, both in the mean results and in the results of single days.

Annual variation

The annual variation during 1964 and 1966 is compared with the Carnegie observations in tabel 1. In general the results agree except for Juli 1966. The explanation is unknown.

Table 1

Annual variation of the electric field in %

	Jan.	Febr.	Mar.	April	Mai	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average			
E (1964)	106	108	—	—	—	96	89	88	94	104	104	108	100 %	=	141	V/m
E (1966)	88	102	103	90	107	97	117	86	95	103	99	100	100 %	=	136	V/m
E (Carn)	114	113	105	99	90	86	87	89	92	97	103	112	100 %	=	116	V/m

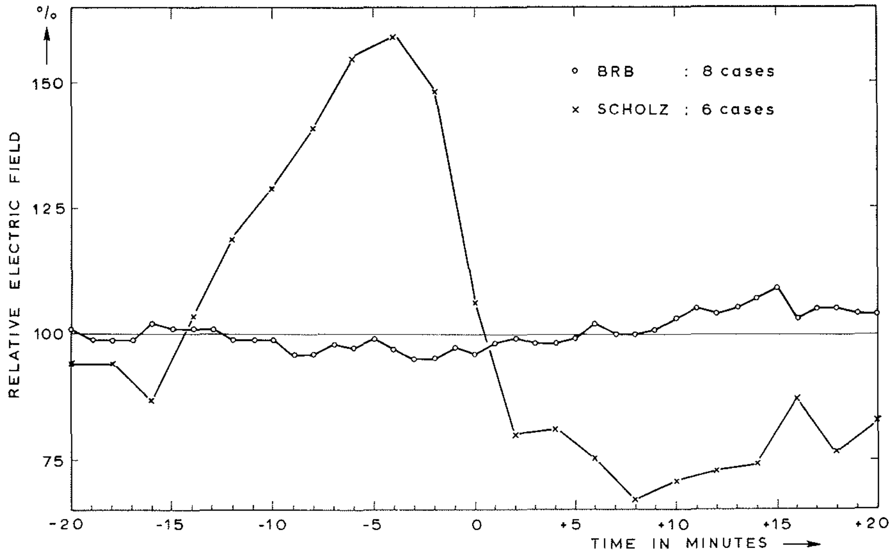


FIGURE: 2 MEAN VARIATION OF THE ELECTRIC FIELD NEAR THE SURFACE DURING AURORAE (in percents)

3. *The influence of auroral activity*

In 1966 the influence of auroral activity upon the electric field near the surface was studied. Such an influence was reported by several authors (Scholz 1935, Freier 1961). The results of Scholz are plotted in *figure* 2. However, other observations have been reported, which did not show any influence of auroral activity (Israël 1961). For theoretical reasons such influences are possible. During auroral activity electric fields of 60 mV.m^{-1} occur in the ionosphere (Böstrom 1966), which might lead to a potential difference of 100 kV across the auroral zone. Normally, the potential difference between the ionosphere and the earth's is about 270 kV and, as the electric field near the surface is virtually proportional to the ionosphere-earth potential difference, a change of 100 kV would readily be detected in surface observations. An investigation of such an effect is interesting as little is known about the actual potential difference which occurs during auroral activity in the ionosphere.

However, the observations of the electric field during aurorae encounters three practical problems. In the first place, changes of the ionosphere potential cannot be observed near the surface, if they last less than one minute. Namely, the electric field near the surface follows only slowly sudden changes of the ionosphere potential and an equilibrium value after such sudden changes will be reached only after ten minutes (Israël, 1961). Secondly, meteorological and auroral influences upon the electric field near the surface can be mixed up. In order to avoid misinterpretation two identical stations were used at a distance of 0.2 and 4.0 km south of the base. In contrast with meteorological influences, auroral effects will appear simultaneously at both stations, so that both effects can be separated. Thirdly, many different auroral forms can be distinguished. A complete investigation of the influence of all forms upon the electric field will take several years at least.

South of the base, a quiet arc, brightness 1—2, elevation 10 ° — 15 °, was often visible. Any influence of this kind of aurora upon the electric field was not observed. Other auroral forms only occurred during auroral substorms. Because of drifting snow only eight substorms occurred during fair weather. Generally these substorms developed as follows. During the first minutes of the substorm the present quiet arc changed into draperies, brightness 2—4, which passed right over the base. After ten minutes or more the draperies were replaced by patches and other diffuse structures. No changes of the electric field were observed that could have been caused by any of the auroral forms. During the auroral substorm the bandwidth sometimes increased 30 %, althought the mean value remained normal. Such increase of the bandwidth may be an indication that the auroral effects are of very short duration.

To compare the observations with the results of Scholz, the mean variation of the electric field was computed for the eight cases observed. The result is given in figure 2. The time $t = 0$ refers to the moment that the aurora passes right over the base. This moment can be evaluated with an accuracy of one minute. The figure shows that no auroral effect was observed.

The conclusion of these observations is that long-lasting changes of 20 % or more in the potential of the ionosphere did not occur during the observed quiet auroral forms and auroral substorms.

4. *Electric field measurements in the upper air*

The electric field in the upper air was observed by means of an American meteorological radiosonde (AN/AMT-4B), which had been altered in order to measure the electric field, the temperature and the pressure during the flight. The electric field measurements were performed by an "inverted-triode" electrometer (Koenigsfeld, 1963), measuring the potential difference between two radioactive collectors (Ra-D, radiation, 10 μCi). The collectors were attached to two antennae with a vertical distance of 1.5 metre in 1964 (1.0 metre in 1966). The radiosonde box, carrying the electrometer and the two antennae, was suspended about 50 metres under a balloon which was combined with a parachute. A high insulation between balloon and radiosonde box was maintained.

The possible error, caused by inaccurate calibration and reading of the registrations, is less than 5 % or 0.5 Volt/metre. The influence of the balloon and the cable upon the measurements is uncertain. Abnormal fluctuations were registrated during the ascent, probably as a result of an influence of the balloon. However, during the descent the registrations were stable and regular; therefore only the data of the descents are used.

Results:
On cloudless days the electric field as a fuction of altitude can be described by an exponential function. For altitudes between 100 metres and 10 kilometres this function was:

— in 1964: $E(h) = -85 \exp\left\{ - 0{,}29_5{}^3 h \right\}$
— in 1966: $E(h) = -80 \exp\left\{ - 0{,}31\ h \right\}$, h in km

The number of successful balloon flights was eleven and seventeen during 1964 and during 1966 respectively.

The potential difference between earth and ionosphere is computed in two steps:

1. The potential difference between the earth and a level of 10 kilometres (the mean top-altitude of the balloon flights) was calculated by graphical integration of the observed electric field as a function of altitude.

2. The potential difference between 10 kilometres altitude and the ionosphere can be estimated from the results of some balloon flights, which reached altitudes up to 20 kilometres.

In order to determine the mean value of the potential difference between earth and ionosphere a correction has to be applied for the diurnal variation. For this correction the results of the Carnegie Cruises of 1928 and 1929 were used.

With this correction, the normalized potential difference between earth and ionosphere was found to be:

— in 1964: $V = 270 \pm 40$ kV
— in 1966: $V = 258 \pm 20$ kV

These results are in good agreement with the measurements of other observations:

Kraakevik	(1957)	: $V = 278$ kV
Ungethüm	(1967)	: $V = 254$ kV
Fischer	(1962)	: $V = 282$ kV

5. *Measurements of the conductivity of the air*

In 1966 the positive and negative conductivity of the air were continuously observed by means of two "Gerdiensche" capacitors (7.1 pF each). The voltage between the electrodes of the capacities was 100 volts. The current to the inner electrode was measured by an electrometer, input impedance 10^{11} ohm. During 1966 the average height of observation was about one metre above snow level.

Results:

The annual averages of the diurnal variation of both polarities are given in table 2. The daily variation of the conductivity is mainly due to changes of the atmospheric Turbulence in the course of the day (chapter 6).

The annual averages were found to be:

$\lambda_+ = 1.8 \times 10^{-14}$ ohm^{-1}. m^{-1}
$\lambda_- = 1.0 \times 10^{-14}$ ohm^{-1}. m^{-1}

This result is in agreement with other observations in Arctic regions. For instance: Ruhnke (Ruhnke 1962) found on Greenland, at altitude of 790 mbar:

$\lambda_+ = 3.3 \times 10^{-14}$ and $\lambda_- = 1.7 \times 10^{-14}$ ohm $^{-1}$. m^{-1}.

Correction to sea level yields:

$\lambda_+ = 1.9 \times 10^{-14}$ and $\lambda_- = 0.98 \times 10^{-14}$ ohm^{-1}.m^{-1}.

Table 2

Daily variation of the conductivity in % of the annutl averages

hour:	0—1	—2	—3	—4	—5	—6	—7	—8	—9	—10	—11	—12	—13	—14	—15	—16	—17	—18	—19	—20	—21	—22	—23	—24
λ_+:	94	97	103	97	103	108	114	108	108	100	100	97	97	97	97	100	100	103	103	100	100	100	97	94
λ_-:	95	110	110	105	105	105	110	105	110	116	116	116	100	100	95	95	95	95	95	89	89	95	95	95

6. *The electrode effect:*

In this section some representative observations of the electrode effect are presented. For theory, the reader is referred to litterature (Swann 1913, Hoppel 1967, Buis 1969). As an example the observations obtained during December 1966 are suitable. The weather during most of this month was fine and showed a clear daily course: in the morning the atmospheric mixing was strong because of strong winds and heating of the surface by the sun, which reaches its top at 10.30 U.T. After 12.00 U.T. the atmospheric mixing decreased and reached a minimum during the evening. After midnight the mixing quickly increased again. The electrode effect depends on atmospheric mixing and so daily variation of the atmospheric mixing is easily recognized in atmospheric electricity observations.

In the first place, this daily variation is visible in *figure 3,* showing observations of the positive and negative conductivity. The positive conductivity is higher and more constant than the negative conductivity, which shows a daily variation according to the changes of the atmospheric mixing. This behaviour agrees with theory. The theoretical minimum is not reached in these monthly mean values, but is observed during single evenings without wind when the negative conductiviy becomes 0.2 x 10^{-14} ohm^{-1} m^{-1} and less. The positive conductivity is only slightly affected by the daily variation of atmospheric mixing, which agrees with theory.

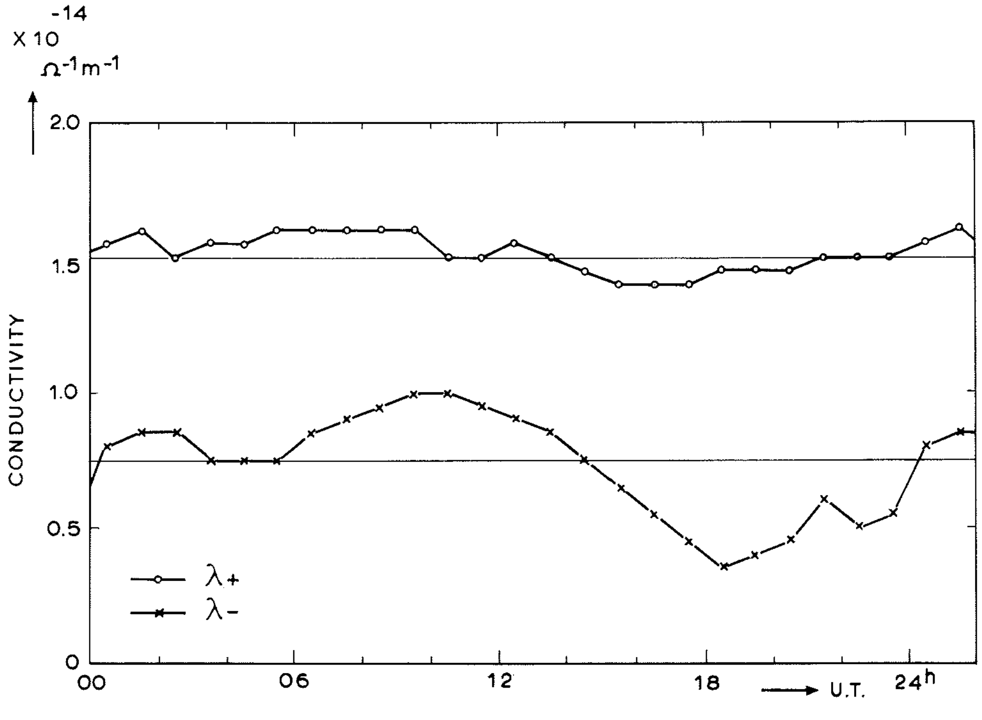
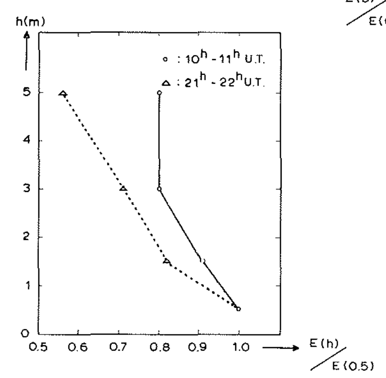


FIGURE: 3. DIURNAL VARIATION OF THE CONDUCTIVITY OF THE AIR DURING DECEMBER 1966 AT AN AVERAGE HEIGHT OF 1m.



FIGUUR : 4 RELATIVE ELECTRIC FIELD AS FUNCTION OF HEIGHT AT: 10^h–11^h AND 21^h–22^h DECEMBER 1966

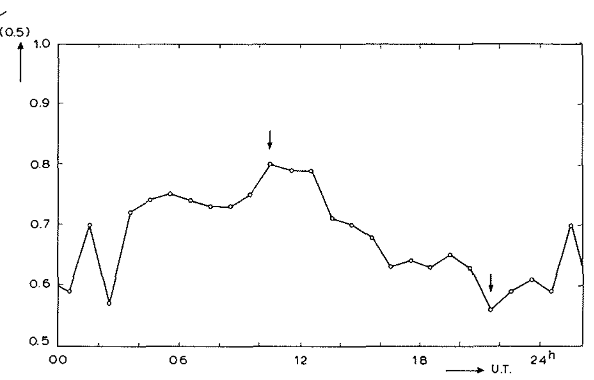


FIGURE : 5 DIURNAL VARIATION OF THE RELATIVE ELECTRIC FIELD AT 5 m. ABOVE THE SURFACE DURING DECEMBER 1966.

Secondly, the theory of the electrode effect predicts that the electric field doubles near the surface. Observations during weak atmospheric mixing clearly shows this effect (figure 4, 21.30 U. T.): the electric field at 0,5 m is almost twice the electric field at 5 m. When the atmospheric mixing is strong, the electrode effect stretches out to a level of twenty metres and higher. In such a case, the electric field changes more gradually *(fig. 4,* 10.30 U. T.). This is also apparent from *figure 5:* the quotient E(5)/E(0.5) reaches maximum and minimum in the morning and evening respectively.

The figure is irregular at 02.00 U. T., because during this hour some drifting snow often occurred, which spoiled observations completely. Another way to show that the electric field doubles near the surface is a comparison of the soundings and the mean surface observations. When the electric field-height function, obtained during 1966 (section 4), is extrapolated the mean electric field strenght at the surface is -80 V.m $^{-1}$.

From the surface observations follows that the mean electric field strength at the surface is about -146 V.m $^{-1}$, because the field strength at the surface is about -10 V.m $^{-1}$ more than at 0,5 m (Buis 1968). So within the measuring occuracy the electric field is doubled near the surface.

Thirdly, another consequence of the electrode effect is the invalidity of the ohmic law for evaluating the current density from ionosphere to earth, I. This current density can be estimated from $I = E(0).\ \lambda_+\ (0)\ E(0).\ \lambda_+(1)$, from which the mean current density at base "Roi Baudoin" can be estimated: $I = 2.6 \times 10^{-12}$ A.m $^{-2}$.

This agrees reasonably with the results obtained by other observators using different methods, which confirms the presence of the electrode effect.

Conclusion: the electrode effect is readily recognized by its effect on the electric field, the conductivity and the computed current density.

7. *Conclusion.*

Polar regions are suitable both for research into the global electric circuit and detailed topics. This is demonstrated by the fact that in contrast to the other continents, the daily variation of the electric field and the electrode effect can be observed every day of fair weather. As many basic questions in tmospheric electricity are still unanswered, observations in polar regions are preferable to observations on the other continents.

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Untersuchungen an Strukturböden in Ostspitzbergen, ihre Bedeutung für die Erforschung rezenter und fossiler Frostmusterformen in den Alpen bzw. im Alpenvorland.

Von Gerhard Furrer, Zürich *)

Strukturböden sind Formen, die unter subnivalen Klimabedingungen entstehen. Sie treten daher nicht nur in der Frostschuttzone hoher Breiten, sondern auch in der Frostschuttstufe der Hochgebirge auf. Allerdings finden sie in Ostspitzbergen — teilweise aus Reliefgründen — eine erheblich weitere Verbreitung als in den Alpen, bieten sich doch der Strukturbodenbildung im Hochgebirge keine derart weiten horizontalen oder nur schwach geneigten Flächen an, wie dies in arktischen Breiten der Fall ist. Dieser Umstand ist wohl mitverantwortlich, daß die arktischen Vertreter dieses Formenschatzes weit besser bekannt sind als die alpinen.

Während in der Regel die Strukturböden hoher Breiten über Dauerfrostboden zu beobachten sind, liegen in den Alpen nur einzelne, allerdings prachtvoll ausgebildete Strukturbodenfelder auf Permafrost: In unserem Hochgebirge läßt sich bei einzelnen Vorkommen während des ganzen Sommers unter gemusterten Flächen in $^{1}/_{2}$ bis 1 m Tiefe gefrorener Boden nachweisen — dessen Oberfläche im Herbst ansteigt —, so daß die Strukturböden im Winter mit ihrer Unterlage fest zusammengefroren sind (Furrer 1955 und 1966, Elsasser 1968). Solche Frostböden betrachten wir als lokale Dauerfrostbodenvorkommen [1]).

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