Polarforschung 59 (1/2): 9—16, 1989

Measuring Blowing Snow with a Photo-Electric Particle Counter at Pole Station, Antarctica

By Gerd Wendler*

Summary: A photo-electric snow particle counter was built by G. Mimken, following the basic design by SCHMIDT (1977). This instrument was tested at South Pole station, and later on, measurements in Eastern Antarctica were carried out. It was found that the number of particles as well as the mean size of the particles increased with increasing wind speed; in other words, strong winds pick up not only more particles, but also larger ones. Compared to traditional snow traps, this instrument has a high time resolution, and does not disturb the wind field. Calculation of the total flux of snow agreed with those carried out by previous investigators in Antarctica who used conventional snow traps. The instrument performed well under extremely low temperature conditions.

Zusammenfassung: Ein photoelektrischer Schneeteilchenzähler nach SCHMIDT (1977) wurde von G. Mimken gebaut. Das Gerät wurde an der Südpol-Station getestet und später in der Antarktis eingesetzt. Es zeigte sich, daß die Partikelzahl ebenso wie die mittlere Partikelgröße mit der Windgeschwindigkeit zunimmt, d. h. Starkwind nimmt nicht nur mehr, sondern auch größere Partikel auf. Im Vergleich mit traditionellen Schneefallen ermöglicht dieses Instrument eine bessere zeitliche Auflösung und stört nicht das Windfeld. Die Abschätzung des gesamten Schneeflusses stimmt mit den Werten aus Schneefallen früherer Messungen überein. Das Gerät bewährte sich auch unter extrem niedrigen Temperaturen.

INTRODUCTION

When the surface is snow covered and the winds are strong, snow particles are suspended in the air. If this transport takes place close to the surface, one speaks of drifting snow. When the wind speed increases, so does the thickness of the air layer with suspended snow particles, and one speaks of blowing snow. Blowing snow by itself modifies the boundary layer. KÖNIG (1985) observed changes in the roughness parameter and KODAMA et al. (1985) discussed the effect of the blowing snow on the wind speed. In Antarctica, these phenomena are common occurrences which have been studied for a long time (MELLOR & RADOK 1960, BUDD 1966, BUDD et al. 1966, RADOK 1970, KOBAYASHI 1978). Mechanical snow traps were used for these measurements. Such devices are put outside for a specific time interval, during which they collect blowing snow. They are then brought inside, the snow is melted, and the amount is determined. Thereafter, they can be deployed outside again. The combination of strong winds and cold temperatures makes a very difficult environment to work in, which also affects the quality of such measurements. MAWSON (1917) described the blizzard conditions in Antarctica eloquently.

When SCHMIDT (1977) designed a remote sensing blowing snow device following work by LANDON-SMITH & WOODBERRY (1963), we became very interested, as we were to carry out, together with the French, a major boundary layer experiment in Adelie Land, Eastern Antarctica (WENDLER & POGGI 1981, POGGI et al. 1982). The snow particle sensing devices work photo-electrically and can detect individual snow particles by their shadows on photo-sensitive semiconductors. Not only the number of particles, but also information on size and speed can be obtained. Mimken and Hill, of Fairbanks, Alaska, built two instruments for us (see Figure 1), following the basic design of SCHMIDT (1977). Some improvement was possible, as electronics had improved over time. SCHMIDT (1984) made his measurements in the Rocky Mountains, where the temperature is relatively mild. In contrast to this, the temperature in Antarctica can be very cold, and hence we wanted to test the instrument under these more severe conditions. We chose South Pole station for this, as it is substantially colder than McMurdo. The personnel of GMCC of the Environmental Research Laboratory were kind enough to take care of our instruments.

Recently, TÜG (1988) built and tested an instrument for the measurement of blowing snow, which physical principle depends on the pulse counting technique. It offers an alternative to the Schmidt type snow gauge. In this gauge the principle is the momentum transfer of individual snow particles to a sensitive surface, and it is also capable of making continuous measurements over long time periods.

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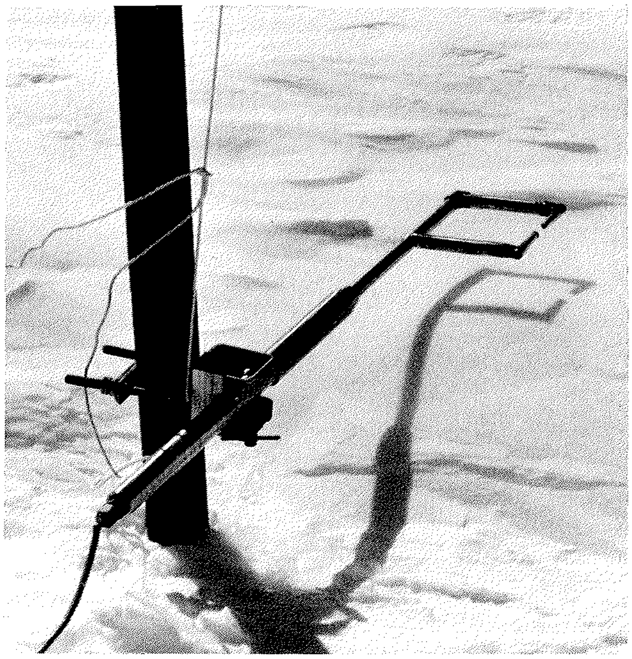


Fig. 1a: Photo of snow particle counter and its schematic function.

Abb. 1a: Schneeteilchenzähler im Feldeinsatz und seine schematische Funktionsweise.

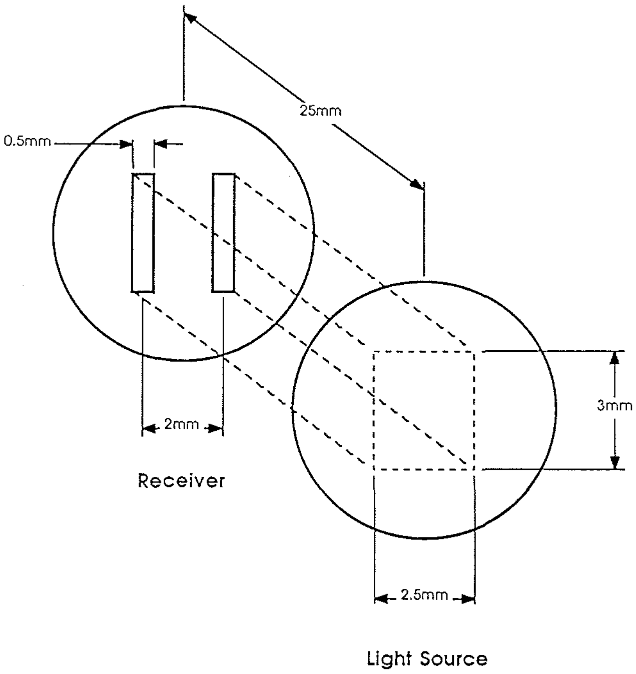
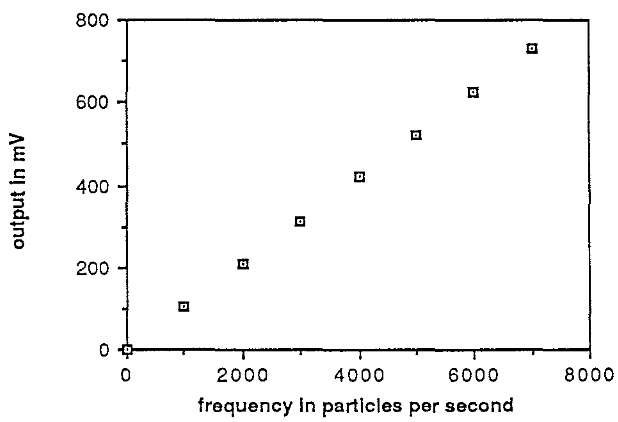


Fig. 1b: Schematic diagram of snow particle counter.

Abb. 1b: Schematischer Aufbau des Schneepartikel-Zählers.

THE SNOW PARTICLE COUNTER

Figure 1b shows a schematic diagram of the snow particle counter. The receiver and the light source are 25 mm apart. The two slits in the receiver are 3 mm long, 2 mm apart, and 0,5 mm wide. As the instrument is small, it does not — in contrast to mechanical snow collecting devices — cause an obstruction to the wind. Hence, its efficiency is close to unity; whereas the efficiency of mechanical devices can vary widely, and be quite low (KOBAYASHI 1978). The collection efficiency is essential to know for the flux calculations; difficult and time consuming measurements in a wind tunnel are often necessary to establish is for mechanical devices. The instruments were calibrated for frequency and size of particles. Linear relationships between the number of particles and output voltage, and size and output voltage, were found (Fig. 2). The frequency calibration was done by the use of a signal generator, while following a suggestion of SCHMIDT (1977), the size calibration was carried out with a rotating wire. In both cases, the calibration curve goes approximately through (0,0). The size calibration of SCHMIDT's original design (1977) did not, and it is believed that this is a definite improvement over his instrument. His original instrument gave 0 mV output for a size of about 80 microns, which is on the lower end of the size distribution we found in Antarctica. If the flux is considered, accuracy in the size of the snow particles becomes very important, as the cube of the size is used in the flux calculations; an error of 10% in the size determination represents an error of about 30% in the flux.



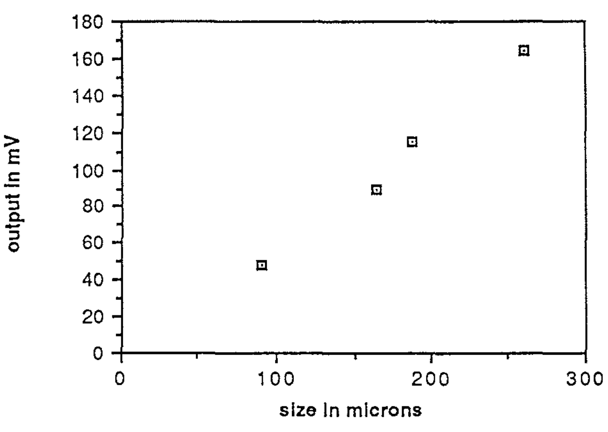


Fig. 2: Calibration curves for frequency and size of snow particles.

Abb. 2: Kalibrierungskurven für Teilchengröße und Häufigkeit von Schneepartikeln.

In addition to the calibrations carried out in the laboratory, we wanted to check our snow particle counter in the field. Therefore, a mechanical snow trap was built. It has a round opening with a diameter of 16 mm. In the first 80 mm, the wind was decelerated 3 to 4 times, then in the vertical direction by another factor of about 2. The snow fell into an inner box, which was surrounded by an outer box. The boxes were buried in the snow so that the disturbances in the wind field were minimal. A schematic diagram of the mechanical snow trap is given in Figure 3. Both instruments were exposed at a height of 38 cm above the snow surface. The intercomparison was carried out for one hour, with a mean wind speed at the four meter level of 17.1 m s^{-1}. Moderate to strong blowing snow was observed during the period. Snow weighing 78.8 g was found in the box, which results in a flux of 30.8 g cm^{-2} h^{-1} or 85.5 g m^{-2} s^{-1}. Our photo-electric device gave the mean diameter of the particles as 185 µm, and a mean frequency of 1480 particles per second. On this occasion the diameter of the snow crystals was unusually large, which might be due to some snow fall. On the average, the sizes were smaller. More typical values are given by WENDLER (1988, see Fig. 2b) who found for the height of 10 cm values between 94—130 µm depending on the wind speed. These latter values are in general agreement with the literature (e. g. SCHMIDT 1984, ISHIMOTO & TAKEUCHI 1984). For the above intercomparison, we made our calculations for shorter time periods, so that a higher accuracy should be obtained. As the flux is proportional to the third power of the diameter, mean values normally underestimate the total flux. The photo-electric device gave a flux of 35.6 g cm^{-2} h^{-1} or 98.9 g m^{-2} s^{-1}. Assuming there to be no error in the photo-electric device, these values would give a collection efficiency of 86% for the mechanical device. However, this should not be taken as a calibration, but rather as an intercomparison, as we had no opportunity to calibrate the collection efficiency of the mechanical device in a wind tunnel with blowing snow.

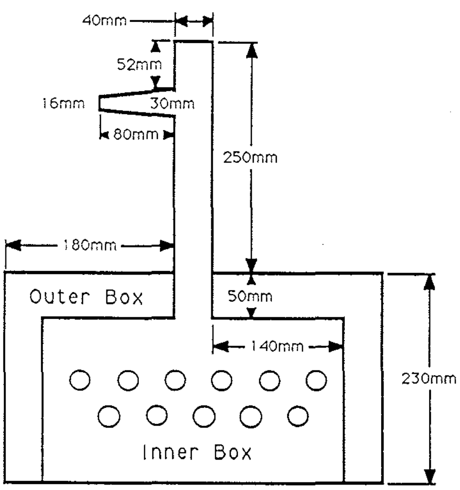


Fig. 3: Schematic diagram of conventional snow trap used in an intercomparison.

Abb. 3: Schema einer konventionellen Schneefalle.

This is not the first comparison with the Schmidt-type snow particle counter. ISHIMOTO & TAKEUCHI (1984) compared an instrument supplied by Schmidt to traditional snow traps. Their measurements were made on Hokkaido, Japan and they found agreement within 10%.

MEASUREMENTS

In 1982, one instrument was brought to South Pole station, where it was installed at one meter above the snow surface for testing purposes. It was installed in such a manner that the sensor was perpendicular to north-northeast, the most frequent wind direction.

In Figure 4, temperature and wind speed are presented. It can be seen that the temperatures drop down to —80 °C, hence it is a very good place for cold weather testing. However, the wind speeds are fairly low. Wind speeds of 10 m s^{-1}, normally considered the starting wind speed for blowing snow, are seldom observed. As wind speed

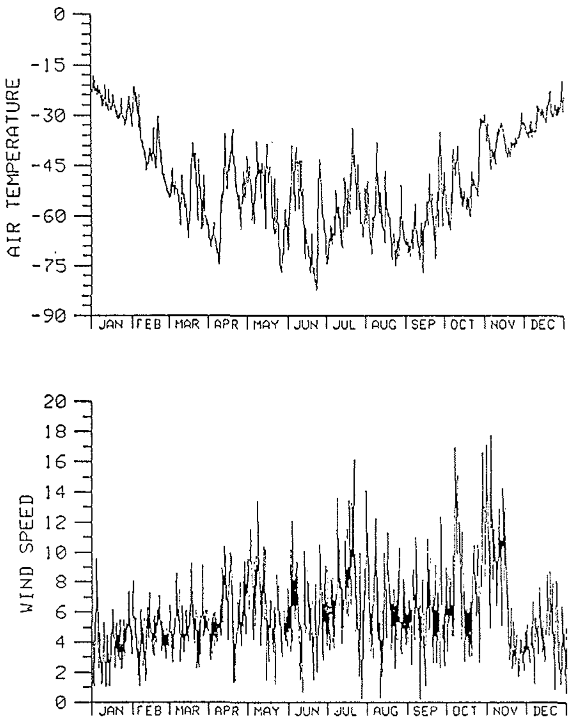


Fig. 4: Wind speed and temperature at South Pole Station in 1982.

Abb. 4: Windgeschwindigkeit und Temperatur an der Station Südpol im Jahre 1982.

was only available at hourly intervals, only the long lasting events are of interest. At a later event, good results between the drift intensity and wind speed were obtained for observational periods as short as four seconds. Indeed, these relationships were better than for ten minute events. Only episodes in which the wind direction was within 30° of the most frequent wind direction were studied, further reducing the number of observable events. A total of ten episodes was found. In Figure 5, the relationship between the number of particles and wind speed is presented. In general, it can be seen that the logarithm of the flux increases with the wind speed. In Figure 6, all data points in 1982 are presented. Lots of scatter is evident, indicating that the amount of blowing snow is not only a function of wind speed, but also of the availability of snow crystals and hardness of the snow surface, a fact already pointed out by MAWSON (1917). The resolution for size distribution was insufficient. However, for a later event, a relationship between size and wind speed could be established (WENDLER 1988, Fig. 2b). Also, at these later events, which took place under similar conditions in Antarctica, the density flux with height was studied. Assuming these relationships from this later study with the same instrument, the total flux can be calculated for each of the ten cases. This step is not without ambiguity, as one of the unknown reviewers pointed out correctly. Size does not vary only with height and wind speed, but also variation occurs from event to event. Further, there is a fair amount of scatter for each event. However, taking the uniformity of the surfaces and the total absence of any obstructions for both places into account, such an assumption might not be too unreasonable. Now by integrating with height the total flux can be expressed in grams per second and per meter perpendicular to the wind direction. The results are shown in Figure 7. Further, the results compiled by KOBAYASHI (1978) but obtained with traditional snow traps are given in the same figure. In general, a good agreement can be observed.

CONCLUSION

A photo-electric snow particle counter was built and tested in the harsh climate of Antarctica. It was found that reasonable data could be obtained with this device. Compared to traditional snow traps, it displays a much higher time resolution and does not disturb the wind field. Further, the time spent outdoors under these difficult and somewhat dangerous conditions is substantially reduced.

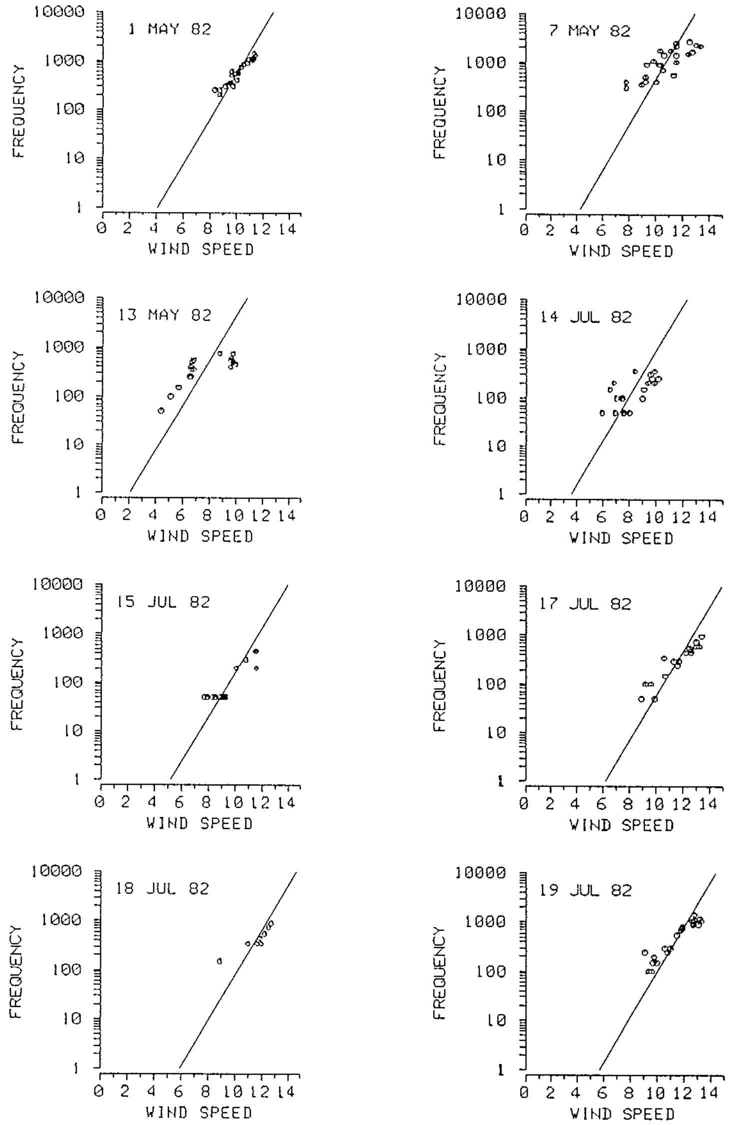


Fig. 5: Frequency (particles cm^{-2}s^{-1}) against wind speed (m s^{-1}) for eight separate events in 1982, South Pole.

Abb. 5: Schneeteilchen-Häufigkeit (Partikel cm^{-2}s^{-1}) in Abhängigkeit von der Windgeschwindigkeit (m s^{-1}) während verschiedener Ereignisse im Bereich der Station Südpol.

ACKNOWLEDGEMENT

Dr. R. A. Schmidt supplied the design criteria for the snow particle counter, and Mimken and Hill built the instrument. The personnel of GMCC of South Pole station, Robert Williscroft and Mark VandeRiet, serviced the blowing snow devices. Dr. Gary Herbert, also from GMCC, supplied the meteorological data from South Pole station on magnetic tape. Drs. F. Eaton and Y. Kodama installed the instrument and Y. Kodama helped me to retrieve it. F. Brill carried out the data analyses, computer programming, and drafting. NSF Grant DPP-8714828 supported this project financially. To all of them, my sincere thanks.

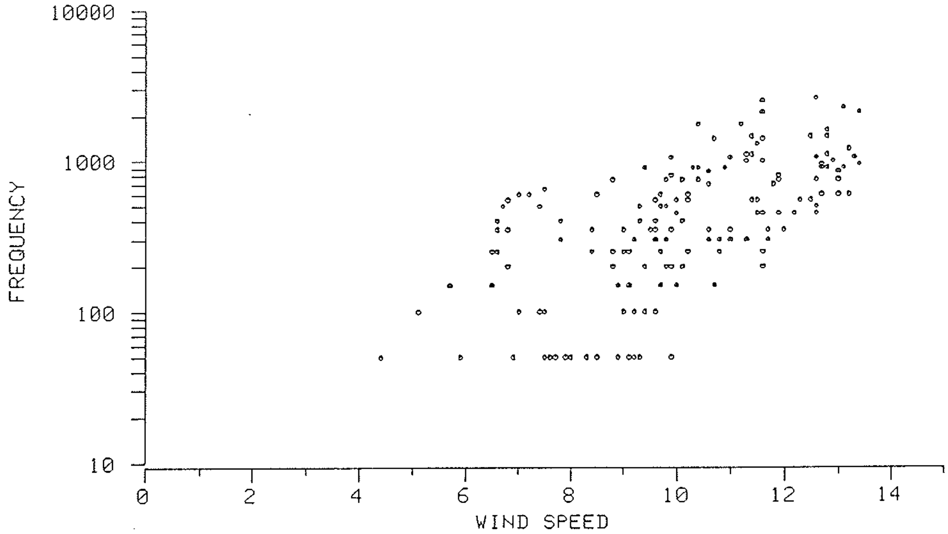


Fig. 6: Frequency (particles cm^{-2} s^{-1}) against wind speed (m s^{-1}), all events of 1982, South Pole station.

Abb. 6: Schneeteilchen-Häufigkeit (Partikel cm^{-2} s^{-1}) in Abhängigkeit von der Windgeschwindigkeit während aller Ereignisse, 1982, Südpol-Station.

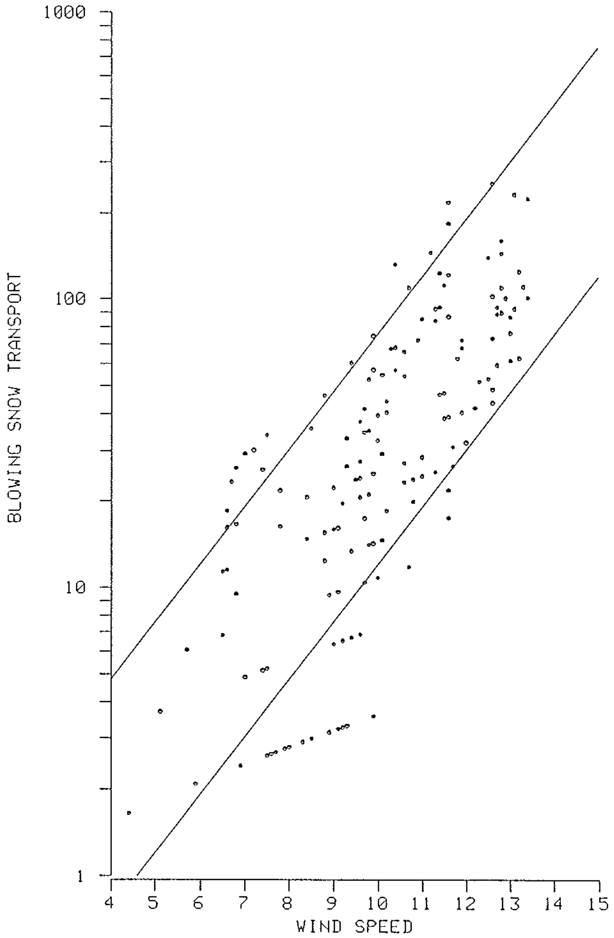


Fig. 7: Total flux of drifting snow (g m^{-1} s^{-1}) against wind speed (m s^{-1}) as observed in 1982, South Pole station. The two lines represent values from traditional snow traps as summarized by KOBAYASHI (1978).

Abb. 7: Gesamtfluß von Driftschnee (g m^{-1} s^{-1}) in Abhängigkeit von der Windgeschwindigkeit (m s^{-1}) nach Messungen an der Station Südpol, 1982. Die zwei Geraden markieren den Bereich traditioneller Schneefallen nach KOBAYASHI (1978).

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