Polarforschung 56 (1/2): 99—107, 1986

Mitteilungen

Life Span of Arctic Data Buoys

By Esther A. Muñoz*

Summary: Since 1979 the Arctic Buoy Program has maintained an array of automatic data buoys providing surface atmospheric pressure and temperature and information on ice motion in the Arctic Ocean. Of the more than 132 buoys deployed, 104 were air dropped, often in the dark or during cloudy weather when it was impossible to select the kind of ice on which they landed. The remainder were installed by hand directly on the ice. The buoys have operated an average of 10 months with a range of 2 to 26 months. In addition to battery depletion, buoy lifetime is affected by environmental factors such as ice melting, which allows the buoy to sink, and extremely low temperatures which sometimes cause the power supplies to fail. Also affecting buoy life span, though difficult to see in the data, are polar bear attacks and destruction by the ice.

Zusammenfassung: Seit dem Jahr 1979 wird im Polarmeer ein Netz von automatischen Datenbojen in Betrieb gehalten, die Luftdruck- und Lufttemperaturwerte im Meeresniveau sowie die jeweiligen geographischen Koordinaten (Eisdrift) übermitteln. Von den insgesamt 132 ausgesetzten Bojen wurden 104 mit Fallschirm abgeworfen, oft in Dunkelheit oder durch eine Wolkendecke, so daß es unmöglich war, ein geeignetes Stück der Eisoberfläche auszuwählen; die restlichen Bojen wurden von Hand installiert. Die Lebensdauer der Bojen betrug zwischen 2 und 26 Monaten, im Mittel 10 Monate. Die Bojen versagten meist durch Erschöpfung der Batterien, aber auch durch Einsinken in schmelzendes Eis oder auf Grund extrem tiefer Temperaturen, welche die Lebensdauer der Batterien einschränkten. Auch Beschädigungen durch Eisbären kamen zweifellos vor, ebenso Zerstörung durch Eis, doch läßt sich die Häufigkeit solcher Ereignisse aus den Daten nicht ermitteln.

1. INTRODUCTION

Automatic data buoys, designed to provide fundamental information from a relatively inaccessible region, were made possible by technological advances achieved during the 1970s. Satellite navigation and data transmission, stable pressure sensors, better power supplies, and lower power requirements by sensors and transmitters, helped in the development of a low cost data buoy that could be parachute dropped from aircraft (UNTERSTEINER & THORNDIKE, 1982).

The Arctic Buoy Program was established in 1979 and has since maintained a network of up to 20 buoys in the Arctic Basin (THORNDIKE et al., 1980—1983, 1985). Beginning as a polar component of the Global Weather Experiment, the program was funded by the National Science Foundation (NSF) and the Office of Naval Research (ONR) to monitor ice motion along with atmospheric pressure and temperature.

The buoys transmit the data to a satellite; position is computed from the Doppler shift of the buoy transmission. The real-time data are routed to the Global Telecommunications System (GTS) and used internationally for weather forecasting. The success of the program, and an endorsement from the National Academy of Sciences, induced the National Oceanic and Atmospheric Administration (NOAA), NSF, and ONR to continue funding for an additional 5 years. Recognizing their increasing reliance on data from this network for various operational and research activities, other agencies began to contribute to the program: the Norwegian Polar Institute, the U. S. Coast Guard, the Atmospheric Environment Service in Canada, and the Minerals Management Service of the Department of the Interior. The program continues in 1986 as the Coordinated Arctic Buoy Program and the Operational Arctic Buoy Program. The number of buoys in the network will be increased to 30.

Buoy technology has continued to advance during the past 6 years. The 1986 "smart" buoy with its onboard microprocessor, wide range of sensor configurations, and expected 3-year lifetime is different from the 1979 buoy with its hardwired electronics. The variations between the buoys make it necessary to

* Esther A. Muñoz, Polar Science Center, Applied Physics Laboratory, University of Washington, Seattle WA 98195 (USA).

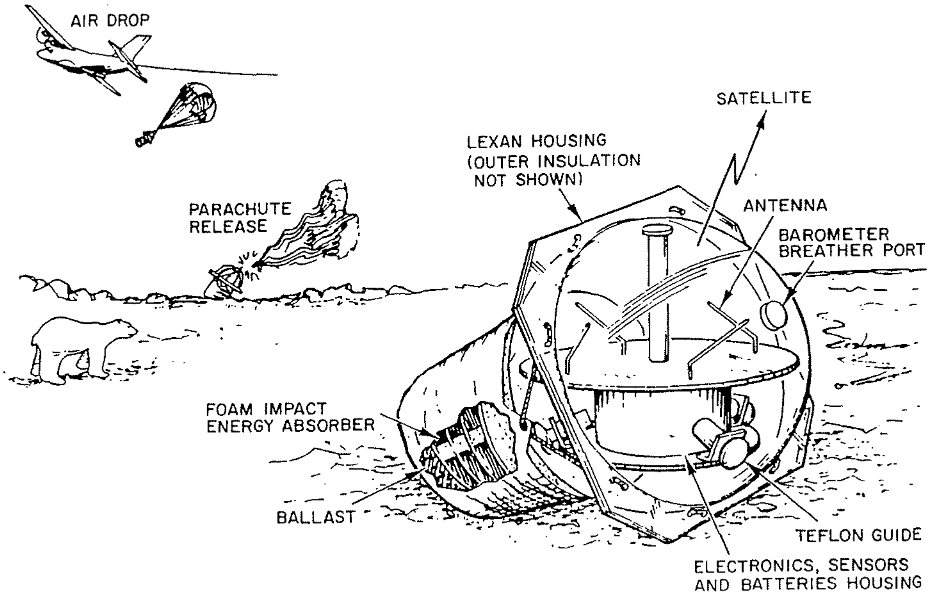

Fig. 1: Air-deployable automatic data buoy for use in the Arctic (from BROWN & KERUT, 1978).

Abb. 1: Mit Fallschirm abwerfbare automatische Datenboje für den Einsatz in der Arktis (aus BROWN & KERUT 1978).

Fig. 2: Specially designed to be deployed on the ice, this buoy has been installed in a 1 m deep hole.

Abb. 2: Speziell für die Anwendung auf dem Eis konstruiert, wird diese Boje in einem 1 m tiefen Bohrloch installiert.

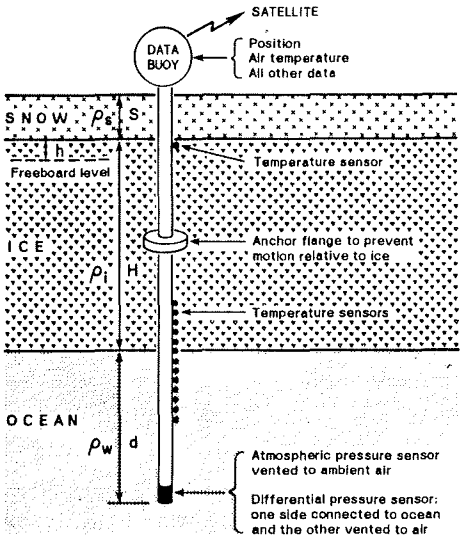

Fig. 3: The Meteorological Buoy MET (provided courtesy of Coastal Climate Co., Ltd.).

Abb. 3: Die meteorologische Boje „MET" (zur Verfügung gestellt von Coastal Climate Co., Ltd.).

look at buoy performance in terms of the percentage of the expected lifetime that was actually realized. After 6 years of the program, the performance of the buoys was evaluated to look at causes of buoy failure, whether instrumental or environmental, and to identify regions or seasons of greater risk for buoy failure.

2. BUOY DESIGNS

The buoy used in the first 2 years of the program was the Air-Droppable Random Access Measuring System (ADRAMS), originally built by Polar Research Laboratory Inc. of Santa Barbara, California. A fiberglass sphere equipped with parachute and crash pad that disengaged upon contact with the ground, it contained temperature and pressure sensors, electronic equipment including a transmitter and antenna, and batteries designed to last 1 year. The buoy's internal package rotated freely and righted its antenna for optimum satellite reception regardless of the attitude of the hull (Fig. 1). The quartz oscillator pressure sensor had a range of 950 to 1050 mb, a 0.1 mb resolution with short-term error of less than 0.2 mb, and an observed drift rate of less than 0.1 mb per year. The thermistor, with a range of +30° to —50° C and better than 0.1° C resolution, was primarily used to monitor the temperature to make necessary corrections to pressure readings. Inorganic lithium cell batteries provided very high energy on a weight and volume basis and operated reliably well below —50° C (BROWN & KERUT, 1978). The buoy, weighing 38 kg and measuring 62 cm in diameter, was compact and light enought to be deployed by any aircraft with an opening of 65 x 100 cm. The ARGOS system computed buoy position with an error of 500 m from the Doppler shift of the buoy transmissions to satellite.

In 1982, the expected lifetime of the battery was extended to 18 months by adopting a 2 hour on/2 hour off duty cycle. Three-year batteries were introduced in 1983.

In 1984, buoys began to be deployed by "ships of opportunity" such as the Coast Guard icebreaker *Polar Sea*. Scientific expeditions desiring to mark their ice camps with ARGOS-tracked transmitters also deployed buoys, so that only 3 of the 14 buoys deployed in 1985 were dropped from aircraft. The buoy especially designed for ground deployment is a metal cylinder, 120 cm long by 20 cm in diameter, that contains the same meteorological sensors, electronic equipment, and batteries as the air deployable buoy.

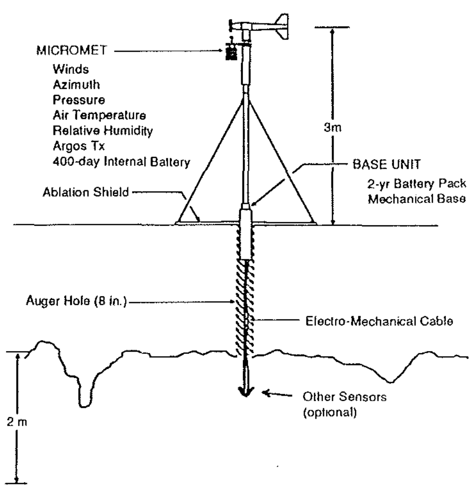

Fig. 4: The Mass Balance Buoy ALPHA (from UNTERSTEINER & THORNDIKE, 1984).

Abb. 4: Die Massenbilanz-Boje „ALPHA" (aus UNTERSTEINER & THORNDIKE 1984).

It is installed upright in a 1 m deep hole drilled in the ice (Fig. 2).

Ground installment also made possible the use of more complex automatic data buoys: the Meteorological Buoy (MET) and the Mass Balance Buoy (ALPHA). The MET buoy contains an internal micro processor that collects, processes, and formats data from an anemometer, compass, barometer, and humidity and air temperature sensors (Fig. 3). The ALPHA buoy is designed to measure changes in ice floe mass due to temperature changes on the surface, snow accumulation, and bottom melting by oceanic heat flux. Its pressure sensor is in contact with the ocean on one side and the atmosphere, though a vent, on the other side. A string of thermistors resolves the temperature profile of the water and ice (Fig. 4).

3. BUOY PRODUCTS

Data from the buoys are made available in real time for use in weather forecasting in two ways. They are broadcast directly from the satellite, so that local stations in the far north see the satellite at the same time it sees the buoys and receive the data with no time lag. Stations in Edmonton, Canada, and Tromsö, Norway, receive the buoy data, process the meteorological information, compute buoy positions, and route the data onto GTS. Service ARGOS processes the data and routes them to GTS with a total lag of 3 hours after they are relayed from satellite to a mid-latitude receiving station and on to the ARGOS data processing center in Toulouse, France.

Data for each month are also sent on magnetic tape to interested users the following month. These data are processed at the Polar Science Center and archived at the World Data Center A-Glaciology in Boulder, Colorado. Daily, monthly, annual, and multi-year mean pressure fields are constructed (Figs. 5—8). From the buoy positions, ice motion is calculated and the mean ice motion of the Arctic Basin has been resolved (Figs. 9 and 10).

4. BUOY PERFORMANCE

Since the beginning of the program, 132 buoys have been deployed, of which 23 are operating at this time (January 1986); 11 failed on deployment, and 90 collected useful data for a period and then failed.

The 11 buoys that failed during deployment, all air-dropped, were closely scrutinized because such fail-

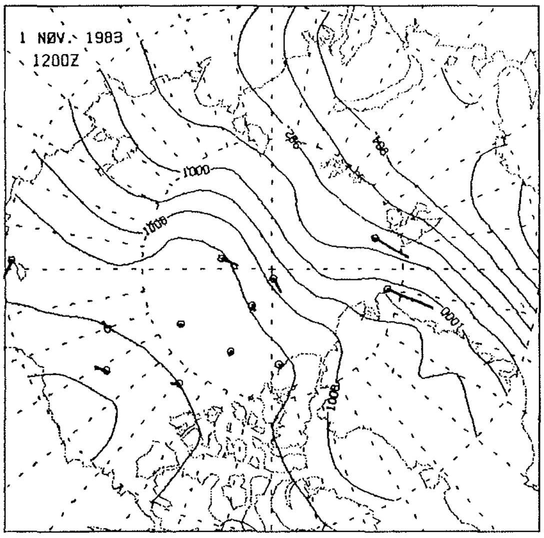

Fig. 5: Daily pressure field constructed from atmospheric pressure data reported by the buoys.

Abb. 5: Nach den Luftdruckdaten der Bojen erstelltes tägliches Druckfeld.

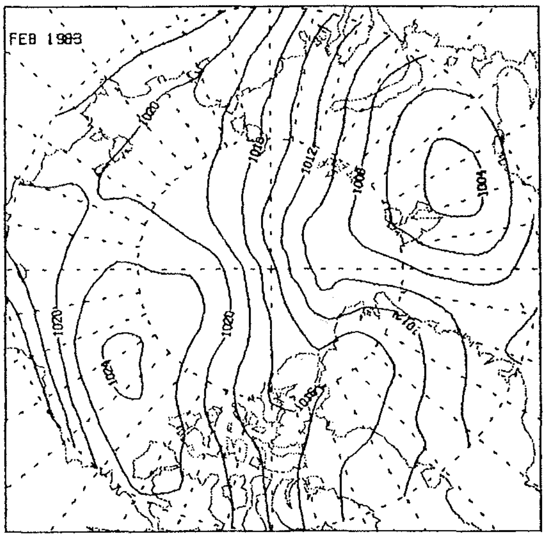

Fig. 6: Monthly mean pressure field for February 1983.

Abb. 6: Monatsmittel des Luftdrucks für Februar 1983.

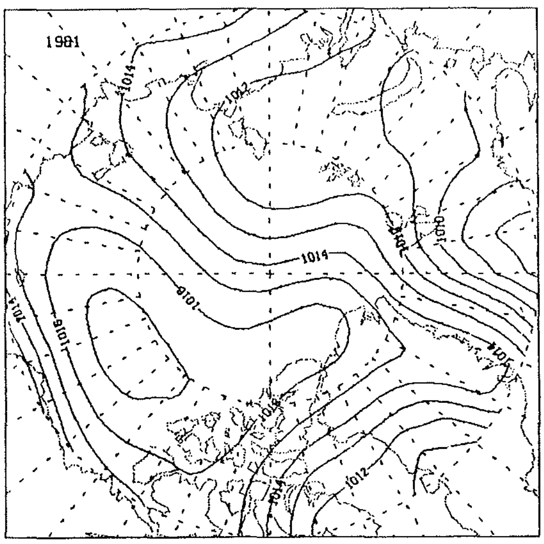

Fig. 7: Annual mean pressure field for 1981.

Abb. 7: Jahresmittel des Luftdrucks für 1981.

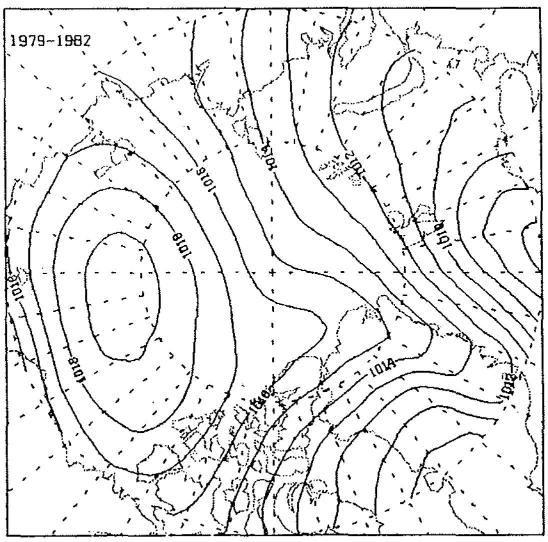

Fig. 8: Five year mean pressure field (1979—1983).

Abb. 8: Fünfjähriges Mittel des Luftdrucks (1979—1983).

ures threatened the viability of the program. In the five cases for which the cause of failure is known, the buoy package broke loose from the parachute immediately after it opened. After the manufacturer redesigned the harness that connects the parachute to the buoy, there were no further failures during deployment of air-dropped buoys.

Because of the diverse expected lifetimes of the buoys, performance was characterized in terms of the per-

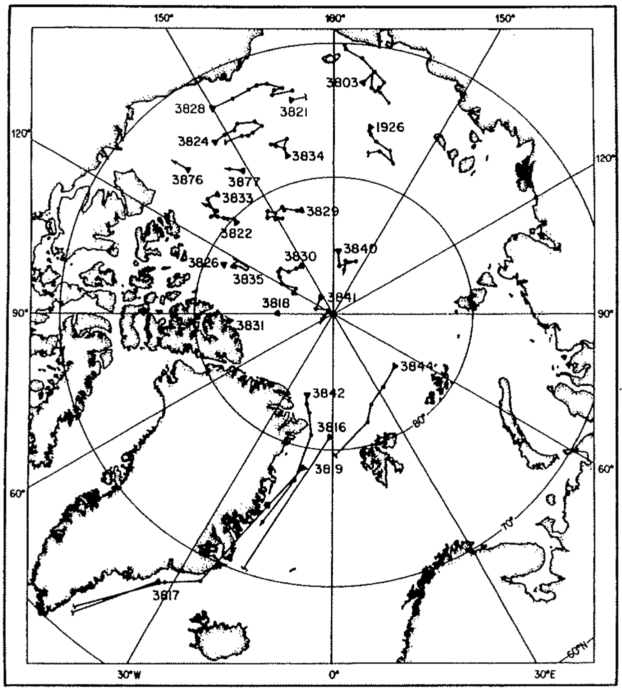

Fig. 9: Buoy displacements in 1983 (1 January—31 December).

Abb. 9: Drift der Bojen 1983.

centage of the expected lifetime that was actually realized. Ninety of the buoys that were successfully deployed completed their life cycles. (Because of unusual circumstances, some buoy failures could not be evaluated.) These 90 buoys account for 898 buoy-months of data with an average of 72% of their expected lifetimes actually realized (Figs. 11 — 12). Of these, 17 buoys failed in spring, 26 in summer, 24 in autumn, and 23 in winter.

The data from these 90 buoys were examined for evidence of cause of failure. A weakening of the transmission with gradually fewer reports culminating in final failure is interpreted as evidence of battery exhaustion. Extremely low temperatures coupled with a low battery can cause cessation of transmission.

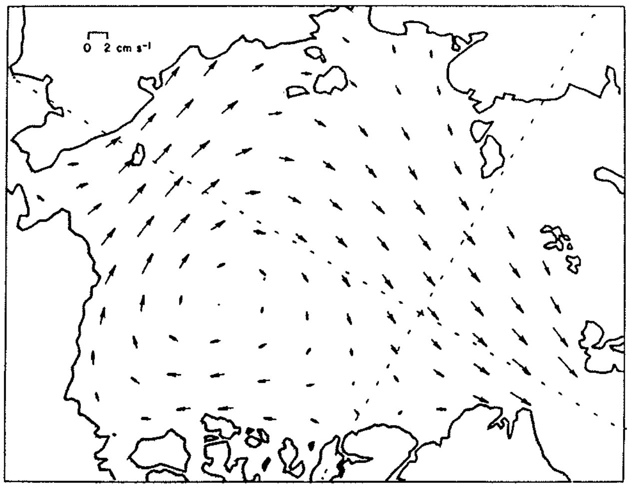

Fig. 10: Mean ice motion (from COLONY & THORNDIKE, 1984).

Abb. 10: Durchschnittliche Eisbewegung (aus COLONY & THORNDIKE 1984).

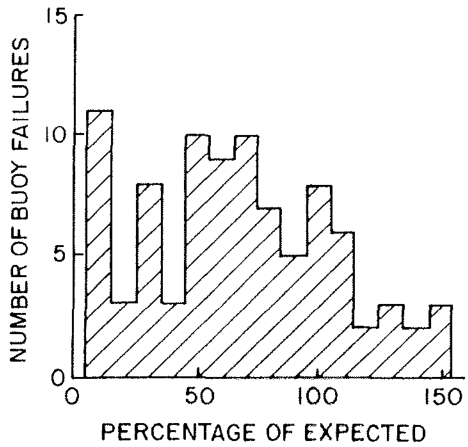

Fig. 11: The distribution of buoy life spans.

Abb. 11: Die Verteilung der Bojen-Lebensdauer.

Forty-five of the buoys showed evidence of failure due to low batteries. The average percentage of expected life realized from these buoys was 95%.

A closer look at the performance of these buoys revealed the startling information that the buoys designed to last 12 months were actually realizing a *longer* average life than those designed for 18 months:

	Expected Life	
	12 months	18 months
Percent of Expected Life Realized	107%	65%
Average Life (months)	12.8	11.8

The buoy manufacturer had become aware of a similar problem in another buoy model, a problem that involved passivation due to low average power drain from the lithium batteries and corrected it early in 1985. Although previously unaware of this problem in the 18-month buoys, the manufacturer thought that the smaller power demands from a greater pool of lithium batteries during the off period would intensify the passivation and lead to high battery impedance and, finally, lack of power production.

A temperature change in the direction of water temperature (0° C) and abrupt cessation of transmission after no signs of battery depletion are interpreted as evidence that a buoy fell into the water and sank or was crushed (Fig. 13). Data from 30 of the buoys showed failure due to falling into the water.

Ice deformation resulting in a buoy being crushed, polar bear attacks, and other causes of catastrophic failure could be expected to be seen in the data only as a strong buoy transmission (strong battery) followed by an abrupt cessation of transmission. Buoy 3839 is an example of one such failure, with a strong signal and then abrupt silence after only 3 months of life. After recovery of the buoy by the *Polar Sea,* it was apparent that the buoy had been attacked by a polar bear. Of the eight buoys that were revisited during the Arctic Ice Dynamics Joint Experiment (AIDJEX), all showed signs of having been tampered with by polar bears or arctic foxes (Patrick Martin, pers. communication). The ice probably accounts for more failures than the fauna. Only two buoys (both were still transmitting) were recovered from the northern coast of Iceland. Fifteen of the ninety buoys lack evidence of other causes of failure and are assumed to have failed because they were damaged by arctic animals, or crushed by ice.

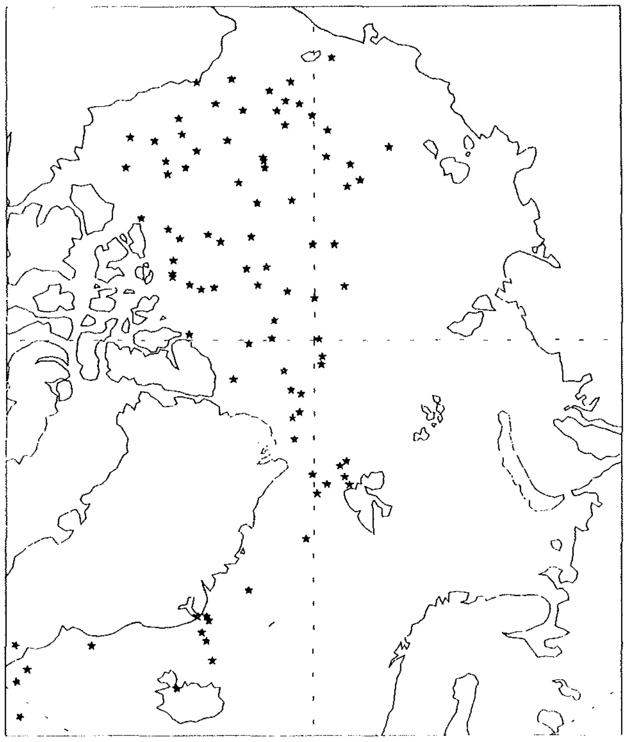

Fig. 12: Positions of the buoys when they last reported.

Abb. 12: Standorte der Bojen während der letzten Datenübermittlung.

5. CONCLUSIONS AND REMARKS

The positions of the buoys at the time of their final transmissions make it apparent that the Denmark Strait and the region north of Svalbard are areas in which buoys are more at risk. There does not appear

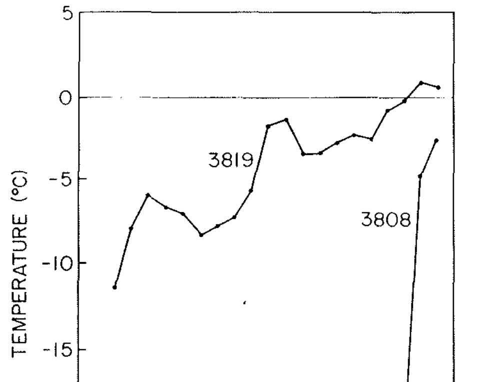

Fig. 13: Temperature curves of two buoys that are believed to have fallen into the water. Buoy 3819 shows a gradually rising temperature (ice is melting) and the last transmission reports a temperature close to that of water. Buoy 3808 reports very low temperatures, then in 48 hours, goes from -21 ° C to water temperature. Neither buoy showed signs of low battery levels. Buoy 3819 failed in the Denmark Strait in late spring and buoy 3808 failed in mid winter in the central Arctic Basin.

Abb. 13: Die Temperaturkurven von zwei Bojen, die vermutlich ins Wasser gefallen sind. Boje 3819 zeigt eine allmählich steigende Temperatur (Eisschmelze), die letztlich fast die Temperatur des Wassers erreichte. Boje 3808 zeigt sehr niedrige Temperaturen, dann während 48 Stunden einen Anstieg von -21 ° C bis zur Wassertemperatur. Keine der beiden Bojen wies irgendwelche Anzeichen von reduzierter Batteriekapazität auf. Boje 3819 übermittelte die letzten Daten im Frühjahr aus der Dänemark-Straße, Boje 3808 im Winter aus dem zentralen Polarmeer.

to be a season during which buoys are more likely to fail. Nor does there appear to be an interaction between season and area for more buoy failures. The field of mean ice motion can be used to decide where to position buoys.

Identifying the causes of buoy failure and evaluating their performance can be based on patterns of data transmission and temperature. Such an evaluation, for example, revealed a problem with the electronics in the 18-month buoy and highlighted the need for continuous performance evaluations. An examination of differential perfomance due to buoy type should be made when a large enough number of the new buoys complete their cycles.

Given that approximately 50% of the buoys can be expected to realize their designed lifetimes, buoys have proved to be a reliable, low-cost method of monitoring parameters from a remote region. The other 50% that fail from environmental causes may provide other information, i. e., ice edge location or frequency of opening of leads.

6. ACKNOWLEDGEMENTS

The Arctic Buoy Program is funded by NOAA Grant NA85-AA-D-CA060. I wish to thank Alan Thorndike for discussions, and Peggy Dent and Karen Schiffer for their patience and word processing.

References

Brown, W. P. & E. G. Kerut (1978): Air-droppable RAMS (ADRAMS) buoys. — AIDJEX Bull. 40: 21—28.

Colony, R. & A. S. Thorndike (1984): An estimate of the mean field of Arctic sea ice motion. — J. Geophys. Res. 89: 10623—10629.

Thorndike, A. S., Colony, R. & E. A. Muñoz (1980—1985): Arctic Ocean Buoy Program data report. — Polar Science Center, Univ. of Washington, Seattle, WA (Yearly data reports).

Untersteiner, N. & A. S. Thorndike (1982): Arctic Data Buoy Program. — Polar Record 21 (131): 127—135.

Untersteiner, N. & A. S. Thorndike (1984): Automatic measurements of vertical ocean heat flux and ice mass balance. — APL-UW-2-84, Seattle, WA.

Berichtigung / Erratum

Miotke, F.-D. (1985): Die Dünen im Victoria Valley, Victoria-Land, Antarktis: Ein Beitrag zur äolischen Formung im extrem kalten Klima. — Polarforschung 55 (2): 79—125.

Abb. 21 (S. 105) erhielt irrtümlicherweise eine falsche Unterschrift; die richtige lautet:

Abb. 21: Das von der NASA-Viking-1-Sonde übermittelte Bild einer Sand- und Schuttwüste auf dem Mars zeigt überraschend große Ähnlichkeit mit den Oberflächenformen im Victoria Valley. Schuttbildung durch extreme Temperaturgegensätze bei sehr hoher Trockenheit und hohe Windgeschwindigkeiten sind in beiden Gebieten dominante Faktoren der Reliefformung. Da die Marsatmosphäre nur ein Hundertstel der Dichte der Erdatmosphäre aufweist, müssen die Windgeschwindigkeiten dort sehr hoch sein, um den Sand zu verlagern.

Fig. 21: The Martian regolith desert as shown in the photograph which was transmitted by the NASA Viking-1 probe shows a surprising similarity to surface features of Victoria Valley. Debris produced by extreme temperature changes within a dry environment and very high wind velocities are the dominant relief-forming factors in both areas. Since the density of the Martian atmosphere is only one hundredth that of the Earth, wind velocities must be very high on Mars in order to dislocate sand grains.