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GREENLAND SEA CURRENTS

Knut Aagaard

Washington University

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TECHNICAL REPORT

Principal Investigator: Knut Aagaard
(206) 543-7978

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Department of the Navy
800 North Quincy Street
Arlington, Virginia 22217

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Technical Report Summary

Introduction

The Greenland Sea holds a position of unique importance and interest among all the Arctic seas. There are two essentially different reasons for this.

One, the northern portion constitutes the major connection of the Arctic Basin with the rest of the world ocean, both in terms of depth and cross-sectional area, and in terms of the actual flow of water (cf. Coachman and Aagaard, in press). No satisfactory heat and mass budgets for the Arctic can be constructed without a considerable improvement in our knowledge of the heat and mass transports through the Greenland Sea. There is evidence that the present budgets may have underestimated the actual transports through the Greenland-Spitsbergen passage by one-half order of magnitude, and that the internal transports in the Greenland Sea have been underestimated by a full order (Aagaard and Coachman, 1968a). It is certainly clear that the dominant barotropicity of the area makes it impossible to substitute dynamic calculations based on temperature and salinity measurements for direct current observations (Aagaard and Coachman 1968b).

Two, the Greenland Sea (and the Norwegian and Iceland seas, together with which it forms an intricately combined system) is a large, deep, partially ice-covered sea: it is one of the northern hemisphere's primary heat exchangers (cf., e.g., Fletcher, 1965), and as such of vital importance in the total global energy budget; it routinely permits navigation farther north than anywhere else in the world: it exhibits a circulation of the same order of magnitude as the Gulf Stream system. In all these ways, it is an area of great importance and interest in its own right.

The Present Problem

The single most important line of investigation to further our environmental understanding of the area must be direct current measurements. It seems clear that the logical first area of concentration should be the Greenland-Spitsbergen passage, through which the exchange with the Arctic Ocean occurs. Eventually the current measurements must extend throughout the year, for our flow observations in the East Greenland Current (Aagaard, 1968), our wind stress calculations (Aagaard, 1970), and analytical work on the thermohaline circulation (Carmack and Aagaard, in press), all imply substantial seasonal differences in the circulation. However, the practical obstacles are formidable, for during winter (1) the area is largely ice-covered; (2) there is total darkness for about four months: (3) bad weather and severe icing conditions are common. Furthermore, logistics and navigation are always problematic in this part of the world.

Methods

In view of the above it was decided to deploy moored current meters, anchored for one year beneath the reach of the drifting ice. The successful deployment and retrieval of such instruments would not only avoid the problems of winter field operations, but would also represent a quantum jump advance both scientifically and technologically. That is, it would provide the urgently needed oceanographic data, and it would also be the first successful year-long current meter deployment anywhere in the world.

A total of six current meters were moored in the Greenland-Spitsbergen passage in September 1971. They were designed to be recovered by acoustic activation of the explosive release mechanism which frees the mooring from its anchor. The subsurface float then rises to the surface, and the equipment is taken aboard the recovery vessel. The details of the instruments and methods were described in the Technical Report of 30 December 1971.

For the recovery of the moorings, five weeks time during August-September 1972 was obtained aboard the largest and newest of the Icelandic research vessels, the 165-foot *Bjarni Saemundsson*. She is equipped with a large array of sonar, thus maximizing the opportunity for locating and recovering the moorings. To fully utilize the opportunity afforded by the availability of the *Bjarni Saemundsson*, we undertook an additional program of hydrographic measurements and direct current measurements using drogues equipped with active radar transponders and satellite navigation aboard ship. The details of this technique have been described in the Technical Report of 1 June 1972. An important feature of such measurements is that by the simultaneous deployment of drogues at different depths, the vertical shear can be measured directly for comparison with the calculated geostrophic shear.

A chronological exposition of the cruise is provided in Appendix A; and the locations of recovered current meters, hydrographic and XBT stations, and current measurements using drogues are shown in Fig. 1. The highlight of the cruise was the recovery of two moorings with four current meters. Some details of the current measurements are provided in Table 1.

Technical Results

The recovery of moored instruments after a one-year deployment is unique in oceanographic experience, and it represents an important technical advance in that it demonstrates the practicality of such measurements. The latter is essential to substantial further progress in Arctic oceanography. It is noteworthy that although the third mooring was not recovered, it was still in position. The mooring design itself can therefore be considered extremely sound, and the effects of failure of a release can, in the future, be negated by using two releases per mooring.

The quality of the current data is excellent, and the sensors proved to be very stable. One current meter at each mooring (total of two meters) operated the entire time, one for approximately five months, and one for two-and-one-half months. Preliminary analysis indicates characteristic current speeds in the middle of the Greenland-Spitsbergen passage of about

20 cm sec^{-1} at 120 m (occasionally in excess of 60 cm sec^{-1}) and rather variable in direction, but with a net northerly component. At 1360 m, the current is about one-half as fast and somewhat less variable in direction. In the West Spitsbergen Current, the speeds at 150 m are typically 30 cm sec^{-1} (occasionally 90 cm sec^{-1}) and the direction predominantly northerly. At 500 m, the current is about two-thirds as fast and persistently northerly. The current records exhibit important tidal components, of order 5 cm sec^{-1}, which is comparable to the annual mean current speed.

The drogue current measurements point to a rather sluggish summer circulation and very weak mean vertical shear.

Department of Defense Implications

When analyzed, the large body of data from these two years will provide a substantial increase in our environmental understanding of the strategically and tactically important Greenland Sea. Such understanding would seem particularly essential to problems of submarine operations.

There is, in addition, a host of Department of Defense sponsored research in the Arctic with climatological aspects. An improved knowledge of the heat and mass exchange through the Greenland-Spitsbergen passage bears directly on these aspects.

Finally, I believe that an important addition has been made to the fund of Arctic buoy technology and operational experience.

Implications for Further Research

I look forward to a productive analysis pointing toward new and improved experiments.

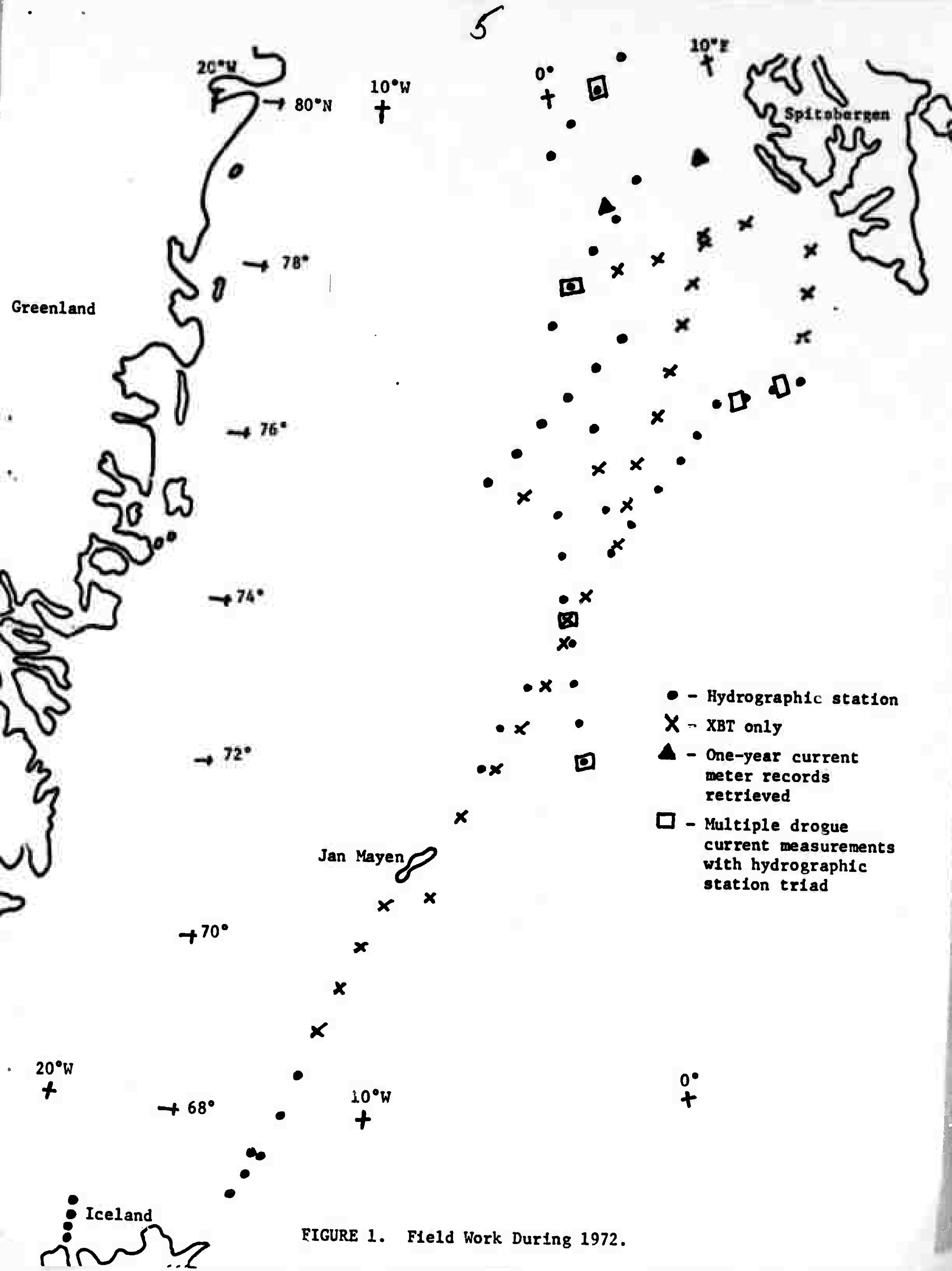

FIGURE 1. Field Work During 1972.

Table 1

Current Measurements

Type	Approx. Location	Nominal Depth of Measurement	Start of Measurements	Duration
moored meter	78° 35'N, 2° 20'E	116 m	8 September 1971	142 days 19 hrs
moored meter	78° 35'N, 2° 20'E	1360 m	8 September 1971	337 days 11 hrs
moored meter	78° 55'N, 8° 4'E	148 m	10 September 1971	335 days 2 hrs
moored meter	78° 55'N, 8° 4'E	494 m	10 September 1971	74 days 19 hrs
drogue	80°N, 3°E	100 m	12 August 1972	35 hrs
drogue	80°N, 3°E	1000 m	12 August 1972	35 hrs
drogue	77° 50'N, 0°E	80 m	15 August 1972	48 hrs
drogue	77° 50'N, 0°E	200 m	15 August 1972	48 hrs
drogue	77° 50'N, 0°E	1000 m	15 August 1972	48 hrs
drogue	76°N, 7°E	100 m	21 August 1972	50 hrs
drogue	76°N, 7°E	1000 m	21 August 1972	50 hrs
drogue	76°N, 9°E	100 m	21 August 1972	22 hrs
drogue	76°N, 9°E	1000 m	21 August 1972	22 hrs
drogue	72°N, 2°W	100 m	28 August 1972	25 hrs
drogue	72°N, 2°W	1000 m	28 August 1972	25 hrs
drogue	73° 50'N, 2°W	75 m	29 August 1972	32 hrs
drogue	73° 50'N, 2°W	1000 m	29 August 1972	32 hrs

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Appendix A

A Chronological Exposition of the Cruise

Our scientific party of four departed Seattle on 25 July 1972. All staging and equipment installation, including a satellite navigator, was completed prior to our departure from Reykjavik, Iceland on 1 August aboard the Icelandic research vessel, *Bjarni Saemundsson*. The ship was manned by six Icelandic scientific personnel and fourteen crew. We made a number of oceanographic stations en route to 78° 37'N, 8° 14' E, the site of our first current meter mooring from last year. Shortly after noon on 7 August we made sonar contact with the mooring, located in 1000 m depth, on the Spitsbergen continental slope. The acoustic release failed to function, and we then spent over three days trawling and dragging for it. We had contact at one point, but failed to bring it up. The retreival attempts were abandoned at 1600 GMT on 10 August. The same afternoon, we arrived at the site of the second mooring, 78° 55' N, 8° 14' E, also located in 1000 m depth. The acoustic release responded on the second interrogation and was fired at 1945 GMT, the buoys surfacing a few hundred meters astern. The entire mooring was aboard within an hour, with its two current meters intact. We then proceeded to the final mooring site at 78° 35' N, 2° 20' E, in 2500 m depth. The release responded to the fifth interrogation and was fired at 0545 GMT on 11 August, the buoys surfacing about one mile to the north, where they were retrieved after a short search. Both current meters were again intact. These are the first successful moorings to have been underneath the ice, and they are also the first to have been recovered after a year's duration.

The ship then proceeded to 80° 20' N, 5° E, to begin a comprehensive series of oceanographic stations and current measurements extending south nearly to Jan Mayen. A total of thirteen series of such current measurements were made, extending to 1000 m depth and of typical duration 36 hours. The measurements utilized current followers, radar transponders, and satellite navigation, and were successfully conducted in sea states to Beaufort force 8. The measurements were done simultaneously at differing depths, thus directly determining the mean vertical shear.

The ship returned to Reykjavik the evening of 3 September after an extremely successful cruise of 4637 nautical miles. A total of 66 hydrographic stations and 30 expendable bathythermograph stations were made.