PRELIMINARY REPORT ON LONG-PERIOD VARIATIONS IN THE TRANSPORT OF THE GULF STREAM SYSTEM

by

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In 1937 the Woods Hole Oceanographic Institution and the Bermuda Biological Station for Research agreed to co-operate on a five-year program of observations. This was designed to throw light on the general problem of long-period fluctuations in the transport of the Gulf Stream, and their possible significance for fisheries research and for meteorology. The investigation originated at the suggestion of the Bermuda Oceanographic Committee of the Royal Society of London, which also arranged for a generous grant of money to enable the Bermuda laboratory to undertake part of the field work.

Although the primary objective has been a study of long-period trends in the strength of the Gulf Stream and only two and a half years have elapsed since the work at sea began, nevertheless it now seems desirable to set forth some of the preliminary results and to discuss further the underlying assumptions. It is hoped that in this way we can gain the benefits of criticism and thus be more wisely guided during the remainder of the five years for which field work is now planned.

SUMMARY AND CONCLUSIONS

(1) On fifteen occasions since June 1937 a line of stations, extending across the Gulf Stream off Montauk Point, has been occupied by the *Atlantis*. These temperature and salinity observations form part of a co-operative investigation of long-period variations in the transport of the current and were undertaken at the suggestion of the Bermuda Oceanographic Committee of the Royal Society of London.

(2) If the fluctuations in transport of the Gulf Stream are to be computed from subsurface temperature and salinity observations by use of the circulation theorem, only complete sections of closely-spaced stations can be expected to yield comparable results. It is unlikely that any considerable simplification of such observations can be developed to produce reliable values.

(3) For the period June 1937 to January 1940 the available subsurface observations indicate that the transport of the Gulf Stream has varied between a maximum of about 93 and a minimum of about 76 million cubic metres per second, assuming the 2000 decibar level as motionless. The sections analyzed dynamically indicate that the current is relatively strong during the early summer, falls off rapidly in strength to a minimum in October or November and then increases rapidly until January or later. A secondary minimum is called for in April or May, but it is not clear from the available transport determinations whether or not the more prolonged winter maximum usually surpasses the summer maximum in strength.

(4) These results have been compared with tide-gauge records from Miami, Florida and Charleston, South Carolina. On the assumption that the sea-level difference across the current varies with the transport of the Florida Current, the monthly sea-level values at these two stations not only corroborate the seasonal cycle indicated by the dynamic analysis but also show that in 13 out of 15 cases these results are comparatively accurate.

(5) If the mean yearly sea-level values along the southeastern American coast reflect fluctuations from year to year in the strength of the Florida Current and hence of the Gulf Stream, the years since 1934 have been on the whole characterized by weak currents, while during the previous 10 years, notably in 1926 and 1931, they were relatively strong. This

evidence also suggests that during the past 17 years the long-period fluctuations in transport have not quite equalled the seasonal cycle in magnitude.

(6) A study of the thermograph records collected by steamers running regularly between Boston and Bermuda during the years 1930-1938 gives support to the results derived from the available tide-gauge records and from the dynamic analysis. The method used rests on the assumption that during periods when the Gulf Stream is weak, warm water will from time to time be carried north of its usual limit and vice versa.

(7) A tentative explanation of the agreement between these three methods, and of the rôle of the Gulf Stream in the circulation of the North Atlantic is presented. This explanation depends primarily on the assumption that the major, permanent, warm currents of the North Atlantic are comparable to a huge eddy, from which various shallower offshoots, such as the Norwegian Atlantic Current, are derived. The Gulf Stream System forms the western and northern quadrants of the circuit, while the Canaries Current and the Northern Equatorial Current constitute the eastern and southern. Because of the seasonal variation in the strength of the anticyclonic wind system over this area and its annual north-south migration, the main circular currents will vary in transport. In winter, when the torque of the winds increases, the Gulf Stream system can be expected to strengthen. But in summer, when the winds move northward, a larger percentage of the Northern Equatorial Current is able to supply the Gulf Stream without passing through the Caribbean and the Straits of Florida. Thus the friction centred in the south-west is lessened and the Gulf Stream increases in volume, although the summer winds are comparatively weak. This seems to explain the double annual rhythm called for by the tide-gauge record and by the computed transport values.

(8) Variations in transport having a period of more than one year probably depend both on the long-period fluctuations in the strength of the general atmospheric circulation of the northern hemisphere and on the effectiveness of the northeast trade winds. Since the strength of the Gulf Stream System is the integrated result of all winds over the North Atlantic, it is supposed that mean sea level values along the southeastern coast of the United States, which reflect changes in the transport of the current, can be considered an index of the general atmospheric circulation.

(9) On the assumption that the clockwise current system of the North Atlantic surrounds a large core of relatively motionless water, the Sargasso Sea, gradual variations in the transport of the huge eddy can be expected under the circulation theorem to change its diameter and to cause fluctuations in the discharge of the warm surface water towards northeastern Europe. Increasing currents should cause the eddy to contract and should lessen or even interrupt the flow of surface water towards the northeast. On the other hand, a long period of weakening currents should greatly increase the area of the northeastern North Atlantic covered by a relatively warm and saline surface layer. In this way quite small variations in the transport of the Gulf Stream may influence surface conditions at a considerable distance.

(10) While a prolonged decrease in the strength of the winds of the northern hemisphere by altering the climate can be expected eventually to lower sea surface temperatures in high latitudes, the first effect may be just the opposite, because of the necessity of decreasing the amount of warm water in the Sargasso Sea area. The converse, namely the temporary lowering of surface temperatures beyond the limits of the main eddy with a gradual strengthening of the wind system, is not so clearly indicated because the currents are free to make dynamic adjustment by contracting in diameter.

(11) There appears to be little possibility of securing adequate oceanographic surveys in the near future to test the validity of the assumption that the Gulf Stream System forms part of a relatively simple eddy. However, some preliminary correlation studies have indicated that it may be possible to link the Gulf Stream fluctuations with temperature changes in northern seas in such a way as to support the essential correctness of the much simplified circulation pattern assumed in this analysis.

(12) Perhaps one of the most significant results of this investigation is that the seasonal fluctuations in the transport of the Gulf Stream turn out to be greater than the year to year changes have been during the past 17 years. This means that in order to learn about the effects of long-period variations in the volume of this current, it is only necessary to study the changes in current pattern and subsurface structure which occur each year in the North Atlantic. Man has often speculated concerning the meteorological and biological consequences of long-period changes in the strength of the Gulf Stream. Subsequent to 1922 the prolonged displacements of warm surface waters produced by such variations probably did not exceed those which might be observed in the course of any single year.

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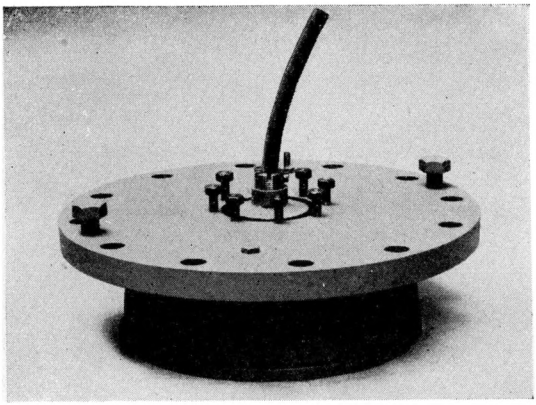

Fig. 1
S. 24 Projector.

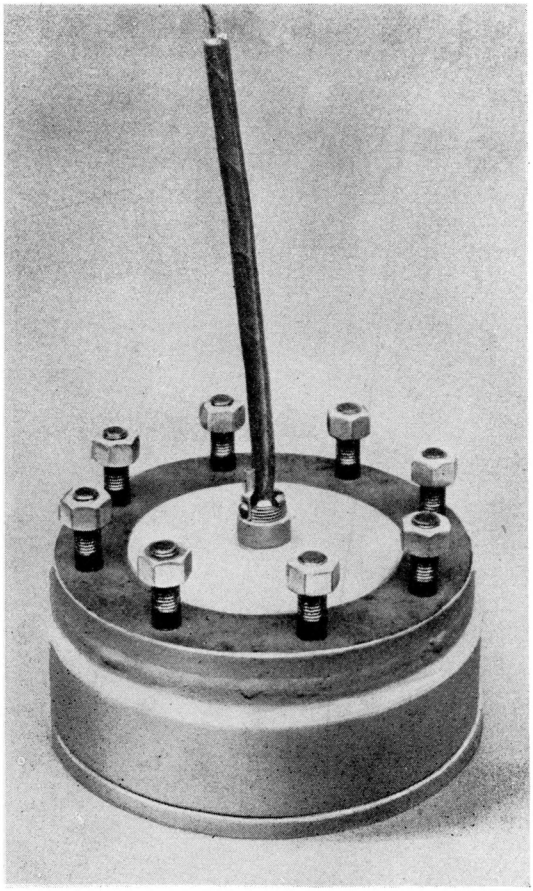

Fig. 2
S. 30 Projector.