

A. Defant. "Die Gezeiten und inneren Gezeitenwellen des Atlantischen Ozeans." Wiss. Ergebnisse der Deutschen Atlantischen Expedition 1925—1927. Bd. VII, Teil I. Berlin und Leipzig, 1932.

During the expedition the "Meteor" anchored at 9 stations in the open sea in depths between 2100 and 4600 metres. The periods of anchorage ranged from 27 up to 64 hours. They were used chiefly for measurement of currents — with the log and with current-meters of various construction — and for investigation, by means of repeated hydrographic series of temperatures and salinities etc., of the internal movements of the water-layers, which have for the last 20 years attracted increasing attention. Results of these investigations, which were in their kind unequalled, form the chief subject of the important volume under review. It opens with a discussion, from a general point of view, of the motions of an anchored ship and their influence on the measurements of current. On one point the writer does not share the views here presented, viz. in considering the initial effect of a motion which is just beginning; the matter does not, however, seem on any essential point to influence the final results of the work.

From experience at the earlier stations the scheme of observations was gradually made more comprehensive at the later stations. The latter are for this and other reasons particularly instructive. The reader will appreciate the author's arrangement in analysing them first, before examining the observations taken at the earlier stations.

One of the chief purposes of the current-measurements seems to have been the direct investigation of the general circulation of the waters of the Atlantic. The present volume does not contain conclusions touching that problem, and only the average velocities and directions of the current at the various depths of observation are stated. The important problem of the connection between wind and current is occasionally touched upon, e.g., in the case of anchor station 241, but with no considerable positive result. The problem is certainly a complicated and difficult one. In the case of the above-mentioned station, for instance, the winds varied considerably during the three days that the anchorage lasted, and since on the latitude of that station half a pendulum day is no less than $7\frac{1}{2}$ days, a close relationship between the currents and the *simultaneous* wind could not be expected to exist.

The expedition had the good fortune to observe on one of its equatorial anchor stations (No. 254) a large, single, internal wave, which in the course of some 8 hours passed the station, and the striking phenomenon is made the subject of a most interesting analysis. Strange to say, the wave manifested itself in vertical displacements of the water-layers only. No noticeable alterations of the currents were observed while the wave was passing, although at 50 metres (where measurements were repeatedly carried out) it ought to have caused rather considerable currents — up to at least 20 cm. per second according to the present writer's calculation.

The greater part of the volume is devoted to a comprehensive study of the periodic movements of the water. It is worth noticing that, in addition to other measurements, the observation every 10 minutes of the ship's head at anchor proved to be very useful. It should be mentioned that at most anchor stations there was found a top layer of nearly homogeneous water, 20 to 120 m. thick and separated from the Deep Water by a transition layer with very rapid vertical variations of temperature and density and (in most cases) of salinity.

As far as the short-period internal movements are considered, particular

interest is attached to the last anchor station 288, where observations were carried out for nearly 40 hours according to a comprehensive scheme. The present writer has on a previous occasion thrown doubt upon the reality of certain short-period waves which, according to a preliminary report, were found at this station. The complete analysis now published gives increased credibility to these waves, additional evidence being obtained from the observations of the ship's head, which allowed the construction of periodograms. The author discerns three periods of about 1.9, 2.9 and 5.5 hours, of which the latter manifests itself quite clearly in the currents and reappears in the hourly observations of temperature and salinity in various standard levels. The difference of phase between current and vertical displacement of the water-layers indicates *progressive* waves proceeding in this case in a northerly direction. The author is certainly right when he considers these short-period waves as an incidental phenomenon that may be absent on another occasion at the same station or may reappear with quite different periods and amplitudes and direction of propagation. Similar waves are observed once or twice at other anchor stations.

At most stations the results of the measurements did not suggest periods other than 12 and 24 hours. Since the series of observations were not long enough for an empirical distinction between solar and lunar periods, *lunar* diurnal and semidiurnal periods were anticipated except for the variation of temperature and salinity of the *surface water*, in which case the period of 24 solar hours was assumed.

The determinations of the daily variation of temperature deserve great attention. They are more reliable than earlier determinations and give lower values than these. The range of variation was found to be about 0.4° at equatorial stations and gradually decreased towards the poles, the value 0.16° being observed at the latitude of 21° . At some stations, where the depth of the homogeneous top-layer exceeded 50 metres, the daily variation of temperature could be determined in this latter level as well, and the range of variation was found to be something like 0.05° . For three of these stations the investigation further led to calculation of the eddy-conductivity ("Austausch") with results lying between 117 and 410. (A still greater value might have been given alternatively.) A comprehensive study of the variations of temperature of the surface water and of the air confirmed Hann's statement, that both media are heated and cooled independently, but parallel with one another, by radiation.

The investigation of tidal motions — horizontal currents as well as vertical displacements of the water-layers — is extremely interesting, since it is the first time that measurements of tidal currents have been carried out at stations distributed over a large area of the deep open ocean. The reviewer is inclined on some points to regard the author's confidence in his analysis as optimistic, but this remark has reference to details only and not to the general results. Semidiurnal internal waves, which have previously been found by Danish investigators in the Faeroe-Shetland Channel, were found, and comprehensively studied, at almost all the "Meteor"'s anchor stations, and their reality cannot be doubted, even if the semidiurnal period may occasionally, as, e.g., at stat. 176, seem somewhat arbitrary. To judge from the phase difference between the currents and the vertical displacements they seem as a rule to be progressive waves. Diurnal internal waves have also been analysed. The author furthermore develops theoretically an interesting type of internal wave under the influence of the earth's rotation. The question how such tidal internal waves could be excited — or maintained against friction — by tide-generating forces seems, however, to be still as

mysterious as ever. The only possibly acceptable explanation that I am aware of — Z e i l o n's "secondary boundary waves" — seems rather unlikely, and it would certainly be no easy task to put it to test by means of the observations here referred to.

The reader is puzzled by other seeming or real periodicities of unknown origin. The variations of the number of plankton organisms in the water in standard depths are interpreted as having a semidiurnal periodicity and depending on the periodic vertical displacements of the water-layers. To one of the series examined, which refers to the plankton content of *surface* water, this explanation cannot, of course, be applicable; and even in the cases of the other series the reviewer does not find the empirical evidence of a semidiurnal periodicity very strong.

The observations on tidal currents command the greatest respect, and the theory of the Atlantic tides has now, thanks to the "Meteor" Expedition, a much more solid foundation than before. Various conclusions from the theory are confirmed. Thus the direction of the semidiurnal as well as of the diurnal current as a rule turned *cum sole*, and also the ratios between the axes of the elliptical orbits are found to be in a satisfactory agreement with theory. The maximum velocity of the semidiurnal component of the current generally lay between 5 and 10 cm. per sec. but exceptionally ran up to nearly 20 cm. per sec. Approximate isochrones for the semidiurnal tides are — for the first time — drawn within the whole region between 30° S. and 30° N. The geographical distribution of phase and amplitude confirms — or at any rate is in good agreement with — D e f a n t's views on the Atlantic tides as produced by the superposition of progressive waves, coming from the south, and standing waves. It has even been possible to a certain extent to draw up his theory numerically. Since a detailed account of the matter would extend this review beyond reasonable limits, the reader must, however, be referred to the original work.

In spite of the important results already arrived at, and in spite of the often surprisingly good agreement between observation and theory, the difficult problems of tides and internal waves could not, of course, be expected to be definitively settled. There are still serious questions which must be answered; and for that purpose it will again be necessary to fall back upon D e f a n t's work, in which the reader will find an ample fund of suggestive observations.

V. W. Ekman.

George F. McEwen. "Results of evaporation studies conducted at the Scripps Institution of Oceanography and the California Institute of Technology." Bull. Scripps Inst. of Oceanog., La Jolla. Tech. Series, Vol. 2, No. 11, pp. 401—415. Berkeley, California, 1930.

Der Aufsatz gibt eine knappe Übersicht über sehr umfangreiche theoretische und praktische Studien zum Problem der Verdunstung, die auf M c E w e n's Anregung von verschiedenen Mitarbeitern, N. W. Cummings, I. S. Bowen, B. Richardson und C. Montgomery durchgeführt worden sind. —

Die statistischen Vorstudien von C u m m i n g s an umfangreichem älteren Beobachtungsmaterial liessen eine klare Abhängigkeit der Verdunstungshöhe von der Lufttemperatur, dem Wind und insbesondere der Luftfeuchtigkeit nicht erkennen — angesichts der Methode der meisten früheren Untersuchungen ein bemerkenswertes Ergebnis. Daraufhin auf thermodynamischer und molekulartheoretischer Grundlage vorgehend, formulierte C u m m i n g s zu-