HYDROGRAPHIC OBSERVATIONS.

Morphology of the Java Sea and the S. China Sea, and of the Strait of Malacca. Limits, extents and contents.

The entire bottom of the Java Sea, the S. China Sea and the Strait of Malacca is part of the East Asiatic shelf which, as far as the Neth. East Indies are concerned, stretches as far as the 100 fathom line of the Strait of Malacca, the West coast of Sumatra and the South coast of Java. To the East this shelf is bounded by the same depth line in the Strait of Macassar and in the Bali Sea.

The accompanying deep sea charts on which the isobathic lines for 10, 20, 30, 40 M. etc. have been traced, were composed after the soundings occurring on the sea charts issued by the N.E.I. Admiralty, complemented with soundings taken on board the exploration craft "Brak" itself. The courses followed being mostly at right angles to the depth lines, and the stations on each of the cruises being different, these depth lines could be traced with a fair degree of accuracy, thanks to the numerous soundings. The 20 M. line in the Java Sea E. of Sumatra and that for 50 M. and upwards in the easternmost part of that sea are less accurate owing to the inequality of the sea-bottom there. The sea-charts of the area situated between 6° Lat. S. and the Kangean islands have not yet appeared; these waters indeed we had to avoid as the navigation was too perilous for us to explore them.

For purposes of geological investigation a sample of the bottom was taken at all the stations; Dr. Mohr of Buitenzorg has kindly undertaken the investigation of the mineralogy and the slime proportion; the data acquired have not, however, been completely elaborated as yet.

As appears from the depth lines the bottom of the Java Sea is a level basin faintly sloping towards the East, and somewhat resembling a plateau. The gradient of the axis of this basin, from the East-coast of Sumatra down to the Strait of Macassar, amounts to barely $\frac{1}{2}$ minute. In the Strait of Madura the isobaths are beautifully parallel: the depths increase rapidly and regularly towards the Bali Sea.

The maximum depths in the Eastern part exceed 80 M. slightly and over a small area only (*). The 100 M. isobath in the Strait of Macassar runs close

(*) On the Chart of the Eastern part of the Java Sea there occurs N. of Madura a sounding of $\frac{\bullet}{50}$ fathoms. Though on each cruise we shaped our course for this point and a few soundings were taken there, this depth was never met with again.

alongside and parallel to the 100 fathom line; in the Bali Sea these lines keep further apart; the 100 M. line just enters the Java Sea by twisting between the islands of Sapudi and Raäs.

In the West, in the Sunda Strait there is a threshold forming the connection between Java and Sumatra with a minimum depth of 26 fathoms (47 M); this threshold is narrow, hardly a nautical mile broad. Towards the Indian Ocean the downward gradient is very steep; towards the side of the Java Sea we find on both sides of the island of Dwars-in-den-Weg ("Right-in-the-Way") a channel with depths down to 128 M., which continues in a N.E. direction into the Java Sea. It soon swerves to the Easterly and S. Easterly direction, after which it proceeds in the directions East and E.N.E. to beyond the Bight of Batavia. In this channel we find the maximum depth of the Java Sea, viz. 94 M.

The origin and formation of this channel still remains an open question. The straight course of the channel in the Strait of Sunda itself in the first place suggests erosion by the strong current which moves principally towards the S.W. The continuation of the deep channel on the S.W. side of the island Dwars-in-den-Weg (situated in the middle of the narrowest part of the strait), producing two separate channels with a less deep part in between, points that way. But it is difficult to imagine that the erosive action of the current could be very great before the threshold at such a great depth, the less so since in analogy with the rocky coast of Java and Sumatra firm rock is to be assumed there.

The deep channel might also be explained by a tectonic chasm between the two great Sunda islands, as is done by various geologists (vide VAN ES, Jaarboek voor het Mijnwezen, 1916, p. 137). The difficulty, however, is in the curve which the channel describes round the Thousand Isles, and this cannot be accounted for by the simple flowing away of the water of the Java Sea to the Indian Ocean, nor by the formation of a chasm. A chasm would here have too complicated a form, such as has not yet been observed anywhere, according to information from experts in these geological matters.

The most plausible explanation is contained in MOLENGRAAFF's hypothesis (11). He supposes that in the older pleistocene period there was a continent where the Java Sea, the Strait of Malacca and the South China Sea are now. It is assumed that this land was not submerged until the period of the melting away of the diluvial ice caps, since this phenomenon is calculated to have raised the surface of the Oceans by about 80 M. in consequence of the huge masses of water disengaged.

The sinuous channel may then naturally be explained on this hypothesis as the lower course of a big river which should have drained this immense Sunda land in a S. W.-ly direction.

Examining the isobathic chart of the South China Sea we see that the isobathic lines are far less regular than in the Java Sea. Like the great vein of a leaf there runs somewhere about the middle a channel whose depth ever increases towards the north, and which twists itself between Gr. Natuna and the South Natuna islands; just as is the case in the Eastern part of the Java Sea and in the Strait of Malacca, at a depth of some 90 M. it begins to lose its shape. The regularly recurring bending of nearly every depth line towards the mouths of the great rivers of Sumatra and Borneo suggest the lateral veins of the leaf. Here also a big main river may be conjectured, which should have had the great rivers of South Sumatra and W. Borneo as its affluents, and whose mouth would have been East of Great Natuna.

VAN ES (12) assumes that in the newer Pleiocene, Malacca, Borneo, Sumatra and Java were connected; that in diluvial times a lowering of the sea bottom took place and that the curves of the isobaths are drowned river beds. They are distinctly traceable on the charts from the mouths of the Mussi-, Djambi-, Indragiri-, and Kampar-rivers on Sumatra, and from the mouths of the river Kapuas on Borneo.

In the Gaspar and Karimata straits which form the connection between the S. China Sea and the Java Sea, there are deep current gullies.

The Strait of Malacca is divided into two parts bij a threshold near One-fathom Bank. In the Southern part the current has ground out deep channels; in the Northern funnel-shaped mouth there again commences at this bank another channel increasing in depth towards the Indian Ocean and showing bends of the isobathic lines towards the mouth of the Rokan river. The 110 fathom line runs from Diamond-point in a N. N. E.direction towards the Malacca Shore.

Boundaries, Extent and Content of the Java Sea [1]).

The Java Sea is bounded on the West by Sumatra, on the North by the islands of Banka, Billiton and Pulu Laut with the straits between them; the Southern boundary is formed by the Sunda Strait, the N. coast of Java and the 100 fathom line to the South of the islands of the Sapudi and Kangean Archipelago. From a morphological point of view it is desirable to accept as East boundary the Eastern limit of the Continental shelf. The parallel of 4° Lat. S. then forms the Northern boundary, from Pulu Laut onwards.

For the purpose of determining the superficial area the limits of the straits contiguous to the Java Sea were fixed as follows:

Sunda Strait: a line from St. Nicholas-point to the little island of Logak, therefore across the direction of the strait.

Banka Strait: a line from Lucipara to Tandjong Nangka.

Gaspar Straits: the line from Tandjong Baginda, viâ the South-corner of Seliu, to Tandjong Genting.

[1]) For the purpose of determining the Content and the Average Depth, the method of the 1 degree fields was adopted (13, Vol. 1, p. 140). The large number of soundings occurring on sea charts and their regular distribution guarantee a fair amount of accuracy. The farthest S. E. part of the Java Sea, as has been mentioned before, forms an exception.

Karimata Strait: the line from Tandjong Kalumpang to Tandjong Sambar.

Laut Strait: the line from Tandjong Petang to Tandjong Kiwi.

Measured planimetrically the surface area of the Java Sea, deducting that of the larger islands (Thousand isl., Pulu Pandjang, Babi, Hoorn, Schaarvogel islands, Karimon Djawa isl,, Bawean, Arends isl., Greater and Lesser Solombo, the Polo isl., the Sapudi-isl., Kangean isl., Madura, Gili Jang, Puteran, Gili Genteng and Gili Rajah, the Moresses and Laurot isl., Karamputan, Bira Birahan and the Lima islands), amounts to 466.300 K.M².

The cubic contents of the Java Sea amount to 18.800 K.M³; the average depth is 40.3 M.

Boundaries and extent of the S. China Sea.

The S. China Sea corresponds through the Banka, Gaspar and Karimata Straits with the Java Sea; to the West it is bounded by Sumatra, the Strait of Malacca and the Malay Peninsula; to the East by Borneo. For the purpose of determining its superficial area the boundaries adopted were as follows: as the Southern boundary was adopted the Northern limit fixed for the Java Sea, between Sumatra and Borneo; the parallel in Lat N. 2°. constituted the Northern boundary, whilst in the Strait of Malacca the boundary was considered to run along the line passing from Tandjong Bulus (S. W.-point of Malacca, near Singapore) viâ the N. point of Great- and Little Karimon right across the Strait to the island Rangsang.

The surface of this part of the S. China Sea, exclusive of the numerous larger and smaller islands, is 294.200 K.M².

As to the Strait of Malacca, taking as the Southern boundary the line heretofore referred to from Tandjong Bulus straight across the Strait, and as the Northern boundary the line stretching from the N. point of Pulu Beras via the N. W. point of Pulu Weh to the N. corner of the island Lantar near the Malacca shore in the direction N. 65° E., we find for the superficial area 185.800 K.M².

The Surface-temperatures in the Java Sea, the S. China Sea and in the Strait of Malacca.

The temperature of these inland seas depends, besides on the well-known factors that influence the surface temperature (the intensity of the sun's radiation, the position of the sun, the winds and the accompanying wave movement mixing the water from the deeper layers with the surface water and causing a greater total reflection of the suns rays, the evaporation by which heat is bound and convection currents are produced, the radiation, and the rainfall) also in part on the temperature of the surrounding sea areas.

Therefore and at the same time to explain further the salinity and density, we will here begin by treating briefly the movement of the water in the seas investigated.

The sea currents in the Western part of the Archipelago are almost absolutely dominated by the monsoons: they are mainly drift-currents; aspiration and stowing however, thoug to a smaller extent, may in certain definite cases also play a part in determining the movements of the water.

During the northern winter (the N. W. monsoon for the Neth. E. Indies there runs from the Yellow Sea along the coast of China and Cochin-China in a Southerly and South-Westerly direction a cold stream, which continues as far as in the S. China Sea. In the pocket formed bij Sumtra Borneo, Malacca and the islands Banka and Billiton, when the N. E. and N. winds prevail with force for any length of time, there arises a stowing of the water-masses through which in that season the surface of the water rises on an average by about a foot; this stowing strengthens the drift current and leads to the influence of the cooler water becoming sometrift noticeable far into the Java Sea.

In the Java Sea are found drifts (S. E. — E.) whic prvail with more or less force, dependent on the strength and regularity of the wind. Strong Westerly winds from the Indian Ocean squeezing trough the funnel of the Sunda Strait, sometimes push the light surface water that makes its way along the E.-coast of Sumatra southward to the Sunda Strait, far into the Java Sea.

The data concerning the monsoon current in the Strait of Malacca are scarce, the Sailors' Guide for the E. Ind. Archip. Part II, 4th Ed. states that between Diamond Point and Tamiang Hook there is more current perceptible along the coast round the N. W. tha round the S. E., but that in the offing the current follows the direction o the wind, which is now N. W.-ly. and at other times S. E.-ly. The Supplementary page 1^{A} to that volume, describing the West-coast of Malacca between Penang and Singapore (taken from the „China Pilot", Vol I. 1916) states for the velocity at One-Fathom-Bank of the floodtide, at springtide, 1.5 — 17. mar. mile, that for the ebb-tide is given as 2.5 — 3. m. miles (the direction of the rising-tide is S. E., of the ebbing-tide N. W.) For the seaport of Malacca, however, the velocity of the flood-tide is given as 2.5 miles, the ebbinf-tide as 1.5 miles. The Meteorological Institute of de Bildt (14) registers for this season a N. W.-current, similarly V.D. STOK (3). This direction of the current becomos explicable when one considers the movement of the water in the Indian Ocean : in the Bay of Bengal, in consequence of the N. E. monsoon there, there are created S. W.-fy to W. S. W.-ly drift-currents, which south of Ceylon bend round to the West. The water driven westward is compensated from the Andaman marginal sea and the Malacca Strait. The stream induced hereby towards the N. W., is reinforced in that strait by the stowing-up of the water in the S. China Sea to which reference has been made before.

In the S. E. monsoon the drift of the waters is the other way about: the general direction of the drift-current in the Java Sea is from W. to N. W. This causes a stowing-up in the Western part, which is however slight, not more than 1 d.M. The flowing off takes palce partly through the Sunda and Banka Straits, though by far the greater volume of the water finds its way through the Gaspar and Karimata Straits, partly because the drift-stream is directed that way and partly also because through these straits must be effected the replenishing of the water driven onward by the S. W. monsoon from the Southern part of the S. China Sea.

The Eastern part of the Java Sea experiences the influence of the permanent Southerly stream from the Strait of Macassar. In the W. monsoon this assumes a S. S. E. direction, in consequence of the N. W.-ly winds in that Strait; in the S. E. monsoon it turns to the West, South of the island of Pulu Laut already.

The main direction of the water displacement in the S. China Sea is from N. W. — N. N. E., chiefly depending upon the latitude; the currents, however, are very subject to local circumstances and consequently variable.

The Strait of Malacca is under the influence of the condition of currents in the Indian Ocean, there is in that part of the Ocean an Easterly stream to the South of Ceylon, which bifurcates near the North-point of Sumatra into a Southern branch along the W.-coast of Sumatra, and a Northern one which flows into the Andaman marginal sea. To the west of the Malay peninsula this bends to the South, subsequently adopting a Westerly direction in Lat. N. 6°, towards the Northpoint of Sumatra (Vide the „Weltkarte der Meeresströmungen", Deutsche Seewarte 1913, by G. SCHOTT.). As a consequence of this it would seem that in the Strait of Malacca the effects of aspiration set in again, since throughout the S. E. monsoon the main direction of the stream there is N. W.-ly.

During the transition months the movement of the water masses in the whole of the western area is from the nature of the case very weak and irregular.

As far as we know the tidal streams are of little importance on the high seas; in the Strait of Malacca, in the straits between the islands East of Sumatra, in the Sunda Strait and along the coasts of the large islands they may, however, attain a great velocity.

If now we consider the temperatures found for the Java Sea, as exhibited in the charts, we see that in February 1917 the Western part was considerably lower in temperature than the Eastern part, in consequence of the greater amount of rainfall there and of the onflow of the cooler Pacific water; the isotherms for 26.5° and 27.0° C. were nicely parallel, both mutually and with the isohalines. There was however no regularity perceptible in the increase towards the East: the thermometer readings fluctuate irregularly between 27.5° and 29.5° C.

February 1918 was a month of heavy rainfall over the entire Java Sea, which kept the surface temperature low everywhere (below 27°), with the exception of a broad belt of coast water south of Borneo; the isotherm of 27° C. there was practically identical with the isohaline of 31.5 ‰ (the isohalines for 31.5 ‰. of 1917 and 1918 practically coincide). The water driven bij the tidal stream from the Indian Ocean into the Java Sea had a temperature of 27.0 — 27.1° C.

For the purpose of studying the combined influence of the greater rainfall and of the onflow of the colder Pacific water in the Western part, the average surface temperature was calculated of that part of the Java Sea which is situated East of the meridian of 109° 30' Long. E, and of the part to the West of that meridian. The observations of 1914 and 1916 were likewise adduced for the same purpose.

		Western Part.	Eastern Part.	Difference.
February	1914.	28° C.	28.3° C.	0.3° C.
id.	1916.	27.4° C.	27.8° „	0.4° „
id.	1917.	27.0° „	28.2° „	1.2° „
id.	1918.	26.4° „	26.6° „	0.2° „

During the transition months the surface temperature is highest in consequence of the frequent calms and the generally slight wind force. The isohalines show that in the month of May there stil occurs a displacement of water from the Northern straits southwards, but the water brought down has a very high temperature, just as the water of the Java Sea. In the Eastern part the movement of the water is very weak — in 1917 it was not possible to observe a lowering of the temperature there. This was, however, the case in 1918 as a result of the somewhat stronger prevalence of the S. E. monsoon; the lowest temperatures, however, still fluctuated about 28° C.

During the months when the S. E. monsoon prevails in full force and regularity the water in the Java Sea has a considerably lower temperature than in the transition months. The main causes of this must be considered to be: 1° the onflow of water from higher latitudes, 2° the increased evaporation and radiation especially in the more Easterly seas ,3° the greater windforce, and 4° the position of the sun.

Studying the course of the isotherms of August 1917 we perceive a gradual increase in temperature from East to West. The isotherm for 27.5° C. extends beyond the meridian of 112° Lat. E. — that for 28° C. reaches the East side of the island of Billiton. The year after that the monsoon blew with greater strength and persistence, which caused the isotherm for 27.5° C. to approach within a short distance of the East-side of Billiton (108° 30' Lat. E.) — that for 28° C. running on to South of the S. E. corner of Banka.

November, owing to the small windforce and the insignificant water movement during the two years of observation, yielded high surface temperatures over the whole of the Java Sea (see the averages to be given further below.).

In February 1920 we undertook the investigation of the S. China Sea, and the surface temperatures appeared to be considerably higher than those in the corresponding month of the years 1917 and 1918. Though in those years the isotherm of 26.5° C. extended into the Java Sea, such a low temperature is now vainly looked for up to Lat. N. 2° ; the climatic conditions were very favourable to a higher temperature : a light Northerly breeze, hardly any rain, together with a weak Southerly water-drift, which points to a faint blowing of the N. E. monsoon at the more Northerly latitudes. The 27° C. isotherm pushes Southward as a tongue along the Malacca shore down to Lat. South 1°, that for 27.5° C. runs parallel to the Borneo coast.

In the Strait of Malacca where one is practically outside the influence of the water-movement from the China Sea, and in the straits between the islands along the East coast of Sumatra the temperature was considerably higher ; from the Strait of Singapore it increased towards the North, in the Strait of Malacca ; to the North of One Fathom Bank it rose even above 29° C.

In the month of August the temperatures in the S. China Sea fitted very well with those of the Java Sea in 1917 and 1918 ; the water of low temperature driven on through Strait Karimata from the Java Sea by the S. E. monsoon (below 28° C.) may be readily followed to a part north of the parallel of Lat. North 2°, in a N. W.-ly direction.

In the straits and between the islands along Sumatra the temperature increases towards the N. (diminishing influence of the monsoon) : nearly the whole of the Banka-Strait still has a surface temperature below 28.5° C. — but more northerly as far as Strait Durian (just South of Singapore) it rises to 29°, whilst the Malacca Strait, lying entirely outside the influence of the monsoon and having a weak, atmospheric movement, shows temperatures of from 29° to over 30° C.

More than in the Java Sea, May is the typical transition month in the sea-area situated more towards the north. Hence also the very high temperatures found over the entire area investigated there (min. 29.3° C., max. 32.6° C., av. 30.2° C.).

In November on the other hand the approach of the West-monsoon is already heralded by a faint waterdrift setting towards the South, together with increased rainfall ; the wind being variable. Nevertheless the surface temperature in the open sea still reached an average as high as 28.9° C. The temperatures were very unevenly distributed, rendering the drawing of isotherms impossible. Along the coasts of Borneo and Sumatra and in the Strait of Malacca the temperature was between 29° C. and 29,5° C. ; it was only near the mouth of the Deli-river that the saltwater brought up proved to be a little lower in temperature (28.8°).

The average temperatures.

From the periodical cruises made before 1917 for the purpose of investigating the Java Sea fairly satisfactory series of observations are still available; they are, however, not so complete as those for the years 1917 and 1918. The annual average of the surface temperature in the Java Sea, calculated from the months of February, May, August and November, amounts to approximately 28.2° C. — as against an average temperature in the Indian Ocean of 27.4° C., between 0° and Lat. S. 10° (see KRÜMMEL I, p. 401). In table 4 have been collected the averages, together with the absolute maxima and minima of the temperatures, relative to the different periods of observation; each series refers to a complete period of 24 hours.

Seeing that we do not possess an average based on many years' observation of the surface temperatures in the various months of observation, the deviations from the normal cannot be determined.

The daily amplitude.

The irregularity of the temperatures caused by the movement of the ship as she advances, the rainfall and the changing cloudiness, sometimes obscure the daily course of the surface temperature; perfectly regular series are scarce. In the course of 5 observation years it was, for instance, not even approximately possible to determine an average amplitude for the month of February.

In May the av. ampl. out of 38 practicable series was 0.9° max. 1.7° C.
,, Aug. ,, ,, ,, 27 ,, ,, ,, 0.6° ,, 1.6° ,,
,, Nov. ,, ,, ,, 21 ,, ,, ,, 1.2° ,, 2.1° ,,

The surface temperature is most stable in the month of August.

Maximum and Minimum Temperatures.

The highest surface temperature observed in the Java Sea was 32.1° C. (May 1914), in the S. China Sea 32.0° C. (May 1919), in the straits between the islands 32.6° C. (Strait of Banka, May 1919).

The lowest temperature in the Java Sea fell in the month of February '18 and was 25.8° C.; in the S. China Sea 26.4° C. (February 1920), and in the straits 27.3° C. (Febr. 1919).

The hours on which the maxima and the minima fall in the month of February cannot be stated owing to lack of regularity.

In May the maxima mainly fall between 2-4 p.m.; the minima scattered.
,, Aug. ,, ,, ,, ,, ,, 12-4p.m.; ,, ,, chiefly 4 a.m.
,, Nov. ,, ,, almost exclusively ,, 2-4 p.m.; ,, ,, ,, 4 a.m,

It seems a strange phenomenon to find several minimum temperatures falling before or at midnight. Besides from local influences this phenomenon may be naturally accounted for from the high temperatures of the previous day, owing to which the morning temperatures are relatively high (see tables). Now if in the course of the day there is only a slight rise, and then between 8 p.m. and 12 p.m. a strong radiation, which takes place frequently, for instance in the E. monsoon, in consequence of the cloudiness being then least of any part of the 24 hours, then about 12 p.m. the temperature must be the lowest in those 24 hours.

The differences in temperature between the surface water and the air.

With but very few exceptions the temperature of the surface water, throughout the year and at all hours of the day, is higher than that of the atmosphere. As is apparent from the table the differences in the Java Sea and in the S. China Sea, vary rather considerably according to the seasons: against a monthly average of half a degree in August, and of 0.5 — 1.0° C. in February, there exists an average difference of 1.0° — 1.5° C. in the transition months of May and November.

It results from the observations in the Java Sea during 1917 and 1918 that the annual differences may also be important; the averages for May differ by 0.4° C., as a consequence of a greater amount of rainfall and more gusty weather in 1918; February '17 and '18 yield a difference of 0.5° C. as regards the averages.

In the South China Sea the differences are slight in February and March, owing to the cooler water that has flowed in; they are greatest in May and November, the influence of the greater rainfall in November, causing a great cooling of the air, is clearly perceptible in the average.

In the straits between the islands the surface temperature is higher than in the open sea, by which the margins between the temperatures of the surface water and of the atmosphere are increased. This is especially the case in the Strait of Malacca in the month of August, and this may account for the great differences observed by CARL H. SEEMANN at Singare in this month, being 1.4° C. and more (15, p. 57).

The fluctuations of the daily-averages of the margins, around the monthly-averages were usually not in excess of 0.5°. The maxima of these amounted to:

in February	'17	+ 1.0°	and	— 0.5° C.
,, May	'17	+ 0.5°	,,	— 0.6° ,,
,, August	'17	+ 0.6°	,,	— 0.4° ,,
,, November	'17	+ 0.7°	,,	— 0.4° ,,
,, February	'18	+ 0.9°	,,	— 0.7° ,,
,, May	'18	+ 0.8°	,,	— 0.8° ,,
,, August	'18	+ 0.5°	,,	— 0.2° ,,
,, November	'18	+ 0.7°	,,	— 0.9° ,,

in March	'19	+ 0.6°	and	— 0.3° C.
„ May	'19	+ 0.2°	„	— 0.3° „
„ August	'19	+ 0.1°	„	— 0.2° „
„ November	'19	+ 0.5°	„	— 0.2° „
„ February	'20	+ 0.5°	„	— 0.3° „

Salinity and density at the surface.

Similarly to what is the case with temperatures in the Java- and S. China Seas, the salinity at the surface in the months of February and August is chiefly conditioned by the water movement from the surrounding seas, which becomes immediately apparent when looking at the salinity charts. Though our observations in the S. China Sea only extended as far as L. N. 2°, the isohalines obtained in Febr. 1920 tallied well with those occurring in the isohaline chart of the East Asiatic waters by SCHOTT (1). There was likewise a correspondence between the isohalines in this month of 1920 with those in the Java Sea of 1917 and 1918.

We observe the water of 33.5 ‰, sal. pushed forward by the S. W.-ly stream in the S. China Sea, thrust itself tongue-shaped between the Anambas islands and the Malacca shore as far down as the Equator; by mixture with the river water of Borneo and Sumatra the salinity regularly decreases towards the South, down to 32 ‰ sal. To the S. E. of Singapore the isohaline of 33 ‰ describes a deep curve towards the East; this should be ascribed to the hard N.W.- to W.-ly winds (strength 5 — 6) which blew during the crossing from Borneo to Sumatra.

Sumatra and Borneo, owing to the large quantities of water discharged by their rivers, are surrounded by broad belts of water of low salinity. Along the N. coast of Java the salinity is higher, since there are here no rivers of great importance emptying into the sea.

Nearly the entire surface of the Java Sea would furthermore have been of a salinity of 31.5 — 32 ‰, if the Sunda Strait had not exercised a disturbing influence on this. In this strait the greatest velocity of the N. E. tidal stream in February is from 2 to 2.5 miles an hour. Now, if hard Westerly winds prevail, the fresh water from Sumatra streaming South, is driven by these winds and by the tidal stream referred to, sometimes as far as the South coast of Borneo. This, according to our observations, was the case in 1914, 1916 and 1917; in 1918 the influence of the Sunda Strait was noticeable only as far as a little East of the Thousand Islands. The salinity chart for February 1917 shows the tongue of water of less than 30 ‰, stretching to a point South of the middle of Strait Karimata, and then proceeding as a broad band of water with a salinity of 31 — 31.5 ‰, until it merges in the coast water of Borneo. Between 113° and 115° Lat. E. the water from the deeper layers and having a salinity of 32 ‰, rose to the surface over a great area. In consequence of the pressure against the shore the same thing took place at the stations 80, 81 and 74.

Proceeding from the Strait of Singapore through the Strait of Malacca to the N. W. we found the salinities constantly decreasing. There is therefore a N. W.-ly current in that strait. The lowest salinities North of One-Fathom-Bank were found along the Malacca shore; off the mouth of the Deli-river the salinity increased again in the W. half of that strait (Station 35, 31.98 ‰; St. 36, 31.64 ‰ sal.); this increase in salinity being more marked at greater depths (see the sections).

In August, during the S. E. monsoon, water of 34 — 34.5 ‰ sal. penetrates into the Java Sea. About the origin of this water we however know very little; the only data rest upon the often quoted salinity chart of SCHOTT and upon our knowledge of the interrelations of the streams in the Eastern Seas of the Indian Archipelago. Prof. SCHOTT compiled the few salinity observations taken there into one chart; it is however very probable that in the two monsoons great differences are brought about in the course of the isohalines.

Through the Torresstrait great volumes of water are pressed during the S. E. monsoon; this water is of a high salinity (35 — 35.5 ‰) and comes from the S. Equatorial Stream, which is conducted partly round the N. W. into the Banda Sea, partly, we may assume, shifted towards the West through the Flores Sea. A flowing away then takes place round the S. W. through the Arafura Sea, the Savu Sea and the Straits between the Lesser Sunda islands. In the Celebes Sea salinities upwards of 34 ‰ do indeed occur, but with regard to the question as to whether this high salinity of the surface water continues throughout the Strait of Macassar, we are still in the dark. It is probably so in the East monsoon, Borneo alone being bordered with a belt of less salt water; not Celebes because there are no large rivers that empty from this island into the Strait of Macassar. It would be a very desirable thing if during the N. W. and S. E. monsoon in the Eastern part of the Archipelago detailed observations relative to salinity and density, likewise temperature, should be taken, in order that we may possess definite knowledge of that area of the sea also in these respects.

In 1917 in the Java Sea water was found possessing a salinity of 34 — 34.5 ‰ as far as Long. E. 113.5°; further Westward the salinity decreased to 32 ‰ at Long. E. 107°; the draining to the Straits of Sunda, Banka, Gaspar and Karimata is clearly apparent from the isohalines, which correspond well with those of the S. China Sea, 1919; the salt line for 32.5 ‰ runs to N. of the island of Billiton.

The year 1918 yielded a corresponding picture of isohalines; the S. E. monsoon prevailing however with more constant force, the 34 ‰ isohaline reached to Long. E. 113.5°; that for 32.5 ‰ stretched from the S. E. corner of Banka in a S.S.E. direction. In the furthest western part of the Java Sea no salinities below 32.5 $^0/_{00}$ were observed ; the highest salinity in the Easternmost part amounted to 34.5 — 34.6 $^0/_{00}$.

The discharge of water from the South coast of Borneo is considerably less than in the rainy West-monsoon, which is clearly expressed in the chart of surface isohalines ; on the Westcoast, however, owing to the N. W.-ly stream, the water is caused to move further West; at the equator the 32 $^0/_{00}$ isohaline reaches beyond Long. East 108°, and subsequently bends Eastward under the influence of the Southerly and South-Westerly winds and the Northerly and North-Easterly current produced thereby. The isohalines for lower salinities run parallel with those for 32 $^0/_{00}$. The onflow of water from the Java Sea was perceptible as far as North of the Equator : at stations 41 and 42 already water of 33.2 — 33.4 $^0/_{00}$ occurred at the surface.

The salinities in the Strait of Malacca slowly increased from South to North, a consequence of the unimportant discharge of water from rivers into that strait ; of the weak N. W.-ly monsoon stream and of the strong tidal streams, which latter push the masses of water about. The quantity of water from the Indian Ocean penetrating into the S. China Sea, if any, must certainly be small.

Also in the month of May a good correspondence was obtained between the isohalines of the S. China Sea and the Java Sea. From the higher salinity indices at the surface of the S. China Sea in comparison with those for August (over the entire central portion more than 32.5 $^0/_{00}$, as against 32 — 32.5 $^0/_{00}$ in August with the S. E. monsoon prevailing) it is apparent that in that part there is still a Southward water-drift (in spite of the irregularity of the currents that were met with), which Southward drift is still perceptible in the Java Sea down to 5° 30' Lat. S. (vide the isohaline for 32.5 $^0/_{00}$). In the Eastern part the influence of the approching S. E. monsoon already begins to demonstrate itself ; the boundary line of the fresh Borneo water, which had shifted far towards the South during the time when the water movement in the Java Sea was about nil, is already shoved a considerable way round the W. and N. W. In 1918, owing to the stronger monsoon, a tongue of salt water was already beginning to form (sal. 33 $^0/_{00}$) whilst the isohaline for 31.5 $^0/_{00}$ already had a regular course in the direction of the coast of Borneo, keeping however more than 60 miles away from it.

In and South of the Strait of Karimata it was evident that the drift also contained a powerful Southerly component.

In the Strait of Malacca the monsoon current appeared to be very weak in the Northern part, judging from the salinity figures ; during the periodical cruise water of less than 31 $^0/_{00}$ was observed between Stat. 25 and 31, probably originating from the rivers Perak and Bernam on Malacca and then moved towards the South-East by the flood-current.

Also in November the progress of the autumnal transition in the S. China Sea and in the Java Sea exerts a strong influence on the course of the isohalines. In the Eastern part, as a rule, the S. E. monsoon, though weakened, still prevails; in the S. China Sea, however, the approach of the N. W. monsoon begins to make itself felt by variable winds, by greater rainfall and by stowing-up of waters. In 1919 the transition of the season was in full swing there: very gusty weather was met with, the most prevalent winds being Westerly. During the crossing over a Southerly stream had already set in in the W. part. The isohalines do not coincide with those of the year 1917; from the passage, however, which was made that year North along Billiton, from the isotherm for 28.5° C. at 20 M. depth for the Java Sea, and from the saline indexes of the stations 24, 25 and 26 (+ 32 ‰), it is sufficiently clear that there then took place a weak though not constant water-drift from the North. The direction of the isohalines in the Eastern part of the Java Sea further shows, that the bending of the stream from the Strait of Macassar towards the West, has already diminished a good deal.

The Western part of the Java Sea experienced the influence of the increasing N. E-ly component of the tidal stream from the Sunda Strait; water of a salinity of more than 33 ‰ is carried into the Java Sea; this was not, however, perceptible beyond Lat. East 107°.

In 1919, in spite of the turning of the weather taking place much later than in 1917, there was a stowing up of water towards the South as far as nearly 6° Lat. S. (coast water from Borneo).

In de Eastern part of the Java Sea the salinity still amounted to 34 — 34.5 ‰; there was even a tongue of water of more than 34.5 ‰ stretching in a W. S. W.-ly direction along the South-corner of Pulu Laut; here were found the highest salinities that have thus far been met with in the Java Sea, viz. 34.68 and 34.73.

As to the density (σ) of the surface water we may be brief: for generally speaking there is a conformity between the courses of the isopycnic lines and those of the isohalines and the isotherms, as in the main water movement an increase of salinity is accompanied by a lowering of the temperature and vice versa.

From the surface map we see that in February the greater part of the surface of the S. China Sea has a density of 21.0 — 21.5; in the middle it is slightly more (21.5 — 21.7); the isopycnic line for 21.5 runs parallel to the isohaline for 33.5 ‰. The differences in surface temperature for different years are great, as appears from the observations made in 1917 and 1920, so that these data may not be taken as the standard measure.

In the Java Sea the density in the Eastern part was from 20.0 — 20.5; along the coasts and in the Western part it decreases in consequence of the arrival of fresh water.

The Strait of Malacca has very light water owing to the rivers that discharge into it, and to the N. W.-ly set of the current (less than 19.0, diminishing towards the N. W., with a density exceeding 19.5 under the Sumatra shore off the Deli river.).

In August we see the density decrease in the Java Sea, in the direction from East to West, from very near 22.0 to 20.5 South of the island of Billiton, and 19.75 near the Sumatra coast; in the S. China Sea over the greater part of the surface, up to Lat. N. 2°, we find a density equal to 20.5 — 21. In the Strait of Malacca it increases from the Singapore Strait to the Deli river (18.0 — 19.75).

In the months of May and November the differences from one year to another in both areas of the sea are too great for us to give density figures. Thus, for instance, in May '17 the surface temperatures North of Billiton amounted to 28.5° C., and in the corresponding month of '19 they were 30.0° C. For our observations of densities the reader is referred to the surface maps.

We have but very few sources at our disposal for comparison with the salinities found by us. Mr. VAN WIJNGAARDEN (16), on a voyage from Padang to America viâ Japan, between February and July 1917 determined the surface salinities by titration for chlorine at 99 stations; out of this number 7 fell within the limits of our area of investigation (Strait of Malacca 4, Roads of Singapore 1, S. China Sea 2). These records coincide fairly well with the figures found by ourselves.

The salinities published by Prof. DAHL (2) obtained by hydrometrical weighing, are too high for the Java Sea (exceptions are the Stations in Lat. S. 5° 30' and Long. E. 106° 48', and in Lat. S. 6° 7' and Long. E. 116° 47'). These weighings took place in the month of April; salinities exceeding 33 ‰ were not even observed in May [1]).

Close correspondence was obtained with the determinations of BOUQUET DE LA GRYE (17) as regards the Western part of the Java Sea; as to the Eastern part his salinities in the month of August are probably too high at the Stations Lat. S. 6° 42' and Long. E. 110° 32' (Sal. 34.11 ‰) and at Lat. S. 7° 46' and Long. E. 113° 16' (Sal. 34. 85 ‰).

---

[1]) In order to ascertain whether the KNUDSEN tables for the determination of ϱ 17.5 of the Java Sea water from the salinities produced important deviations from the results obtained by pycnometric weighing, two series of weighings were effected. In forming a judgment on this it should be remembered that the writer of this paper had not had much experience of making this kind of determinations. They yielded the following results:

S = 32.14 ϱ 17.5 from weighing = 24.51; ϱ 17.5 according to tables = 24.55
S = 34.45 „ „ „ = 26.34; „ „ „ „ = 26.31.

Dr. WUNDERLICH, Director of the Commercial Laboratory of Buitenzorg most kindly weighed 3 samples of water for me, in 1917. The result follows here:

S = 22.39	ϱ 17.5 acc. to tables = 1.01712;	by weighing = 1.0171(7)
S = 30.77	„ „ „ „ = 1.02350;	„ „ = 1.0235(5)
S = 34.99 (water from the Indian Ocean)	„ „ „ „ = 1.02673;	„ „ = 1.0267(8)

General Survey of the Temperature, Salinity and Density in the deeper layers.

February. In discussing the surface temperature and the salinity in the Java Sea we saw that the direct influence of the cooler, salter and consequently heavier water from the S. China Sea, could only be ascertained over a small area; and further that East of the 110 th Meridian the temperature fluctuated considerably.

When we study the horizontal sections at 20, 40 and 60 M. and the vertical one made along the Stations 1 — 8, 69 — 32, 122 — 132 and 113 — 106, it wil then be clear that from the depth of 20 — 30 M. downwards the water from the S. China Sea penetrates unhampered into the Java Sea; at greater depths it penetrates forwards towards the East in the shape of a wedge. This causes the entire South part of the Java Sea up to a part near the E. corner of Madura to be filled, from a level of about 25 M. downward, with water possessing a salinity of 32.5 — 33 ‰. In the fourth cross-section we observe that between the stations 113 and 111 this is only the case beneath a level of 40 M.

The isotherms for 27° and 27.5° C. likewise shift towards the East at greater depths; at 20 M. this latter was still vaguely traceable; at 30 M. this level has everywhere a lower temperature. The isotherm of 27° at a depth of 20 M. runs in the direction from N. to S. from the Karimata Strait down to the vicinity of the Java shore; at 40 and 60 M. it extends as far as Long. E. 112°. In the N. E.-ly part the influence of the water from the Strait of Macassar is observable down to the bottom, expressing itself in higher temperatures (see the horizontal sections); along the Borneo coast the 27.5° isothermal line keeps approximately parallel with the coast line and with the isohalines.

The influence of the N. E. tidal stream and the wind blowing from the Sunda strait has quite disappeared already at 20 M. as to what refers to the salinity (In the Sunda Strait salinities of 31 — 31.5 ‰ were found East of the line "Dwars in den Weg" to "Prinsen-island", down to the depth of the threshold to the South of the former island, which points to the circumstance that at this season the main stream from the Java Sea runs along the Java shore). In the deep channel that runs South of the Thousand Islands the temperature was higher than that of the surrounding area of the sea (+ 27.°5) and that as far as Long. E. 107°, which points to an incoming current.

In the central part of the Java Sea the isohalines of 33 ‰ occurring on the horizontal sections at 40 M. and 60 M., between the meridians of 110° and 112° Long E. and further at the Stations 28 and 29, attract special notice, because such a high salinity was not met with anywhere else, except at station 113 near the East-point of Madura. From the fact that the stations 28 and 29 are situated in the channel connecting the S. China Sea with the Java Sea, and from the course of the isohaline for 33 ‰ in the S. China Sea, which in 1920 reached to a part near the N. coast of Billiton, we must conclude that we have to do here with masses of water which have been driven through the Strait of Karimata owing to pressure in consequence of the powerful and constant Northerly winds.

Generally speaking the isotherms and isopycnal lines run parallel to the isohalines at more considerable depths.

Section 4 shows us that at the stations 113 and 110 compensatory movements take place along the slopes of the deep channel situated between Lat. S. 6° and 7°, a phenomenon likewise observed in 1918, but then along the Southern slope only. This compensatory stream was ascertained in February 1914 as far as Lat. S. 6° 29' and Long. E. 113° 18' (therefore considerably further Westward) ; in Lat. South 6° 31' and Long. E. 113° 44' the following current measurements were made :

5 M.	N. 81° E.	71 c.M. p. second.		
15 ,,	,, 79° ,,	57.1 ,, ,,		
25 ,,	,, 82° ,,	51.2 ,, ,,		
35 ,,	,, 86° ,,	49.2 ,, ,,		
45 ,,	,, 92° ,,	41.9 ,, ,,	S. 32.5 ‰	by hydrometer
55 ,,	,, 273° ,,	27.4 ,, ,,	S. 34.0 ‰	

Among the observations by VAN KOESVELD in 1916 the undercurrent was still met with at 55 M. depth, and at about the same Lat. and with Long. E. 113° 49' as the Westernmost point ; more Eastward it was observed on both sides of the channel.

At station 113 the min. temp. is 24.96° C. ; the max. sal. 33.96 ‰ ; on the opposite side of the channel the min. temp. is 25.22° C., the max. sal. 32.43 ‰. The difference in salinities is to be probably accounted for by the immediate vicinity of the deep Raas Strait, from which station 113 receives water (see the depth chart).

The equilines at station 110 are steep ; this phenomenon may be explained in part by a Westerly current prevailing there, as appears from the low temperatures (see for a similar case 27, p. 298) ; the action was, however, strengthened by a heavy shower accompanied by wind from the N. E. which during the observation blew steadily with a force of 6 — 7 ; the hydrostatic equilibrium must have been severely disturbed there owing to the relief of pressure, leading to the formation of wave-apices in the equilines [1]). The stratification of the water in the S. China Sea is comparatively simple, as may be gathered from the profiles : the equilines are straight lines. From stations 38 — 46 the entire body of water below 20 M. has a uniform salinity of 33.5 — 33.7 ‰. The layer above this is mixed with Borneo water (—33 ‰). The temperatures decline rapidly ; at 20 M. already thermometer readings as low as

[1]) See on this subject a.o. SANDSTRÖM, J. W., Annale der Hydr. 1908; and WEDDERBURN in Proceedings. R. Soc. Edinburgh 1907.

26° C. and less are met with at stations 38 — 44. More towards the West the influence of the shore is noticeable and the water gets warmer (27.0° C. at Strait Singapore).

The density is considerable in the middle portion (22.00 — 22.20); the isopycnal line for 22.00 is accurately parallel with the isotherm for 26° C. More towards the South the salinity and density decrease regularly by the admixture of coastal water, and the temperature increases.

The investigation of the Strait of Malacca had for its object to find out whether perhaps in the deeper layers there was a compensatory current by which water from the Indian Ocean could flow into the S. China Sea. As a matter of fact MAKAROFF found at different stations in the Strait of Malacca at a depth of 75 M. salinities of 34 — 34.2 $^0/_{00}$; seeing that his work "Le Vitiaz etc." is not at our disposal, we do not know the situation of those stations, neither do we know when the observations were taken.

Our observations have made it clear that in the shallow part between One-Fathom-Bank and the Strait of Singapore such a compensatory current does not exist in any of the months over which our investigation extends, so that in view of the predominantly N. W.-ly direction of the current in this part of the Strait throughout the year, no Indian Ocean water in any important proportion enters the S. China Sea.

Our cross-profiles at Lat. N. 4° give high salinities in February for the deeper layers (33.6 — 33.8 $^0/_{00}$); from this and from the stretching of the equilines beneath 30 M. in the months of May, August and November we may conclude that in the Northern part there exists a faint compensatory current.

August. The water movement in the Java Sea in this month is not complex; this sea lying practically open to the S. E. monsoon, masses of water virtually unmixed penetrate here across the Borneo bank and from the Bali Sea. The water discharged from Borneo is of no great quantity; in section 3 we see that only along the Borneo coast a narrow belt of mixed water is found, which however has still a salinity of more than 33 $^0/_{00}$ (St. 89). Section 2 situated more to the Westward shows a markedly lighter layer, resting with a sharply cut plane on the heavier and less mixed seawater.

The variations of S, t and σ_t between the surface and the bottom for each separate station are slight, sometimes nihil, so that there is homogeneous water. See e.g. the stations 49, 50, 51 and 52 in Section 1 below 20 M.; the stations 106 and 107 in Section 2, below 40 M., and in Section 3 the stations 92, 93 and 94 from 20 M. downwards. The cause of this homogenity is in the convection currents already referred to in dealing with the surface.

The mutual differences between the stations as to S., t and σ_t are slight; this made possible e.g. the steep apex of the isotherm for 27.5° C. (St. 95): we are dealing here with temperatures fluctuating closely around 27.5° C.; the column of water of station 95 has a temperature 0.1° lower than those of the stations 96 and 94. The surface column of water from 0-10 M. has risen in temperature above 27.5° owing to the irradiation of the sun. We should have obtained an exactly similar curve at station 93 if the observation there had also taken place in the daytime instead of at night.

In the S. China Sea we gather from the course of the equilines in the transverse profile at Lat. N. 2° that a double circulation takes place in the Northerm portion; in the Western and Eastern part a N. W.-ly current, in the central portion a compensatory stream round the S. E. In the lowest strata this latter carries on water of low temperature (min. 22.38° C.) and of high salinity (34.2 ‰).

May. In the Java Sea we can tell by the isotherms and the isohalines of the horizontal profiles of 20, 40 and 60 M. that a strongly marked displacement of water towards the W. S. W. and W. sets in along the slope of the Borneo shore. The cooler and salter layers already reach as far as the 111 th meridian; at greater depths (50 and 60 M.) the temperature has fallen to 24° C., the salinity and the density have increased to 33.7 ‰ and 22.50 respectively (stations 88 and 89 on the Borneo bank). In 1917 an influx from round the North still took place in the Western part, as is apparent from the salinity-lines. It clearly manifests itself further in the vertical profile No. 2 for this month, and in the salinity indices at stations 12 — 21, which are situated on a crossing from Banka to Borneo along the North of Billiton (more than 33 ‰, see the tables).

The higher salinities near the narrowest part of the Sunda Strait show that there has been an influx from the Indian Ocean.

Our sections of the Java Sea in 1918 display a fairly corresponding image; here likewise we come across the lowest temperatures and the highest salinities on the acclivity of the Borneo shore.

In the S. China Sea in 1919 the displacement of the water was very variable; e.g. on the crossing from Singapore to Borneo, between stations 37 and 41 a Northerly current was met with running 14 nautical miles in 11 hours — between St. 41 and 49 the ship shifted 14 n. miles in 11 hrs. towards the East. On the more Southerly crossings between Borneo and Sumatra little drift was experienced. In the deepest part an under-current, especially in the Eastern portion, carries on water of a minimum temperature of 22.03° C. (St. 47); the maximum salinity was met with in the deepest part of the channel, viz. 34 ‰ at a density of 23.13.

November. The water movement in the Java Sea in 1917 showed analogous features for both the deeper and the superficial strata. The tongue of sal. 33.5 ‰ which stretches along the N. coast of Madura and Java already reached as far as Long. E. 111° at a depth of 20 M.; the maximum salinity in the bottom strata there amounts to 34 — 34.1 ‰. The temperatures do not sink below 28° C.; stations 97 and 98 at 70 M. depth constitute exceptions, 27.01° and 27.51° C. being found there. As at both stations S. is likewise higher than at the other stations near by, it is surmised that Strait Raäs again plays a part here.

The Sunda Strait carries on water from the Indian Ocean; this is very clearly marked by the isohaline for 33 ‰ and the isopycnal of 21.—; the effect of the inflow is perceptible at 20 and 40 M. to a part beyond 107° Long E.

The Southward water displacement from the Northern straits was weak and only to be perceived by the lower temperature of the inflowing water (difference ± 0.5° C.). According to the isotherm of 28.5° C. this influx would reach, at the depth of 20 M., as far as Lat. S. 5°; the greatest onflow taking place through the Gaspar Straits, i.e. from the Western part of the S. China Sea. This concurs with the observations made there in 1919. The salinities and densities decreased from Strait Karimata in the Northerly direction (see the isopycnal of 20.75 at 20 M. depth). The tongue of S. 33 ‰ which goes from the N. W. corner of Borneo round to the S. W. conveys an impression of a drift in that direction; yet this is not so: between 30 and 50 M. the whole of the S. China Sea is filled with Java Sea water of more than S. 33 ‰ which comes up to the surface in this tongue. This becomes clearly apparent on constructing the more southern cross profiles; the horizontal sections at 10, 20, 30 M. etc. show that we are in the presence of a N. E.-ly displacement of water. At the 30 M. section e. g. the 32.20 ‰ isohaline goes from the Karimata Strait tongue-shaped towards the N. E. to a point North of stations 13 and 14; West of station 14 we may assume a faint Southward current. In the deepest part there is found to exist a Southerly bottom current with a max. Sal. of 33.78 ‰, a max. σ_t of 22.— and a min. temp. of 26.45° C.

The line of demarcation between Pacific and Indian Ocean water.

In conclusion we should like to discuss this boundary line. In the Ergänzungsheft No. 109 of Petermann's Mitteilungen, SCHOTT assumes that this meeting line would be along the 3 rd parallel N. between Malacca and Borneo; further right across the narrowest part of the Strait of Macassar at Lat. N. 1° and in a straight line to N. Australia. In Peterm. Mitt. 1902, p. 223 the same author reverts to the subject: it is now assumed that the water from the Torres Strait probably reaches as far as the Strait of Macassar, and the limit is supposed to be a line connecting S. Celebes with Flores and then proceeding Eastward.

Now on considering this problem in connection with the data produced by our inquiry, specialised for the N. W. and S. E. monsoons, the following points are noticed:

In the N. W. monsoon it has become apparent that in the S. China Sea the isohaline of 33.5 ‰, which SCHOTT according to his data adopts as the border-line there, reaches to the equator when the monsoon prevails only weakly. The Strait of Malacca carries no water from the Indian Ocean into the S. China Sea, so that the Southern portion of this latter sea consists entirely of Pacific water mixed with river water from Borneo and Sumatra.

expected, because in both monsoons the water flowing away from the Java Sea through the Sunda Strait (Febr. sal. $\pm$ 30‰, Aug. sal. $\pm$ 31.5‰) is carried Eastward and South-Eastward along Java and partly determines the salinity there (*); when we come outside the influence of the main current from the Sunda Strait the salinities also vary rather importantly in the various seasons. In the mouth of the Sunda Strait between Prinsen island and Vlakke Hoek (the S. E. corner of Sumatra) we observed the following salinities:

February	'17	33.30‰.	
id.	'18	33.68 ,,	
May	'17	33.20 ,,	
id.	'18	33.27 ,,	
August	'17	32.38 ,,	coincides with observ. Planet.
id.	'18	.....	
Nov.	'17	33.14 ,,	
id.	'18	33.92 ,,	

On the strength of the above we would like to have the Southern demarcation line shifted further South during the N. W. monsoon, in the N. W. part; and that at least as far as where the Straits of Banka, Gaspar and Karimata open into the Java Sea, during the S. E. monsoon there is no objection to SCHOTT's boundary line at 3° Lat. N., considering that the S. E. wind carries water round to the N. W. and the West, which water has been slightly mixed with water from the Indian Ocean in the south of the Bali and Flores seas by the tidal streams between the islands. Provisionally, until further detail observations have been made in the more Eastward seas, the line running from Tandjong Selatau (S. E. corner of Borneo, 115° Long. E.) to the West point of Flores, has a fair chance of being correct, both in the N. W. and in the S. E. monsoon.

Literature at our disposal and consulted.

1. SCHOTT, G. Wissenschaftliche Ergebnisse einer Forschungsreise zur See. Petermann's Mitt. Ergänzungsheft 109, 1893.
2. KRÜMMEL, O. Prof. Dr. Fr. DAHL's Areometer Beobachtungen auf der Fahrt von Neapel nach Matupi. Ann. Hydr. 1896.
3. V. D. STOK, P. J. Wind and Weather, Tides and Tidal Streams in the Indian Archipelago.
4. SMITS, P. J. De Regenwaarschijnlijkheid in de zeeën van den Ned. Ind. Archipel. Natuurkundig Tijdschr. voor Ned. Indië, deel 67.
5. BRAAK, C. De Regenverdeeling in den O. I. Archipel. Nat. Tijdschr. v. Ned. Ind Deel 74, p. 57.

(*) This has already been pointed out by Dr. BRENNECKE (Planet 3, p. 126).

Only in the Westernmost part of the Java Sea there is an inflow of Indian Ocean water through the Sunda Straits by the N. E.-ly tidal stream and meteorological conditions. This water, however, is still strongly mixed with that which flows off from the Java Sea during the prevalence of the S. Westerly current. We may therefore consider the inflow of water from the Indian Ocean as not important.

During the S. E. monsoon the isohaline of 34 $^0/_{00}$ runs to North of the island of Madura; there are no indications showing that the salinity is lower in the Southern part of the Strait of Macassar, where throughout the year there is a permanent current to the South; if so this lower salinity would immediately betray itself in the isohalines of the Java Sea (the current referred to bends round to the West immediately south of Pulu Laut). The contrary is true; outside the Borneo Bank at the Easternmost observation station of the Java Sea (5° 50' Lat. S. and 116° 50' Long. E.)the following salinities were found at the surface:

February	'17	30.95 $^0/_{00}$.			
id.	'18	31.94 $^0/_{00}$.			
May	'17	32.00 $^0/_{00}$.			
id.	'18	33.93 $^0/_{00}$.	(a more regular prevalence of the S.E. monsoon; Southerly current.)		
Aug.	'17	*34.14* $^0/_{00}$.	id.	id.	S. E. current.
id.	'18	*34.51* $^0/_{00}$.			id. id.
Nov.	'17	*34.18* $^0/_{00}$.			id. id.
id.	'18	*34.18* $^0/_{00}$.			id. id.

The salinity figures of the "Planet" (21, 3 p. 118) do not yet sufficiently account for the situation in the seas East of Java: for in August salinities fluctuating about 34.50 $^0/_{00}$ were found at the surface, south of the Bali Strait, in the Lombok Strait and on the crossing from Lombok to Macassar; this tallies with our observations in the Java Sea. Further East on the route Celebes-Timor - Ambon these figures declined considerably, which is difficult to account for in connection with the surface currents prevailing there and the high salinity of the S. Equatorial Stream. In Nov. '18 it appeared from a series of surface samples — kindly collected for me by the commander of the Governm. steamer *Canopus*, during the crossing from the E. corner of Flores to Ambon and back, — that the salinities were then considerably higher (34.7 — 34.8 $^0/_{00}$). Also in this domain an adequate explanation can only be obtained by detailed enquiries on several crossings South and East of Celebes.

We do not know how far the influence of the Northerly tidal streams through the straits between the Lesser Sunda islands is noticeable in the Bali and Flores seas; it is possible that, besides salinity determinations, this might be illustrated and reflected by the different concentration of the (neg.) hydroxyl-ions of the Pacific water and of the Indian Ocean water. During the N.W. and the S. E. monsoon appreciable differences in salinity are to be expected, because in both monsoons the water flowing away from the Java Sea through the Sunda Strait (Febr. sal. $\pm 30^0/_{00}$, Aug. sal. $\pm 31.5^0/_{00}$) is carried Eastward and South-Eastward along Java and partly determines the salinity there (*); when we come outside the influence of the main current from the Sunda Strait the salinities also vary rather importantly in the various seasons. In the mouth of the Sunda Strait between Prinsen island and Vlakke Hoek (the S. E. corner of Sumatra) we observed the following salinities :

February	'17	$33.30^0/_{00}$.	
id.	'18	33.68 ,,	
May	'17	33.20 ,,	
id.	'18	33.27 ,,	
August	'17	32.38 ,,	coincides with observ. Planet.
id.	'18	.....	
Nov.	'17	33.14 ,,	
id.	'18	33.92 ,,	

On the strength of the above we would like to have the Southern demarcation line shifted further South during the N. W. monsoon, in the N. W. part; and that at least as far as where the Straits of Banka, Gaspar and Karimata open into the Java Sea, during the S. E. monsoon there is no objection to SCHOTT's boundary line at 3° Lat. N., considering that the S. E. wind carries water round to the N. W. and the West, which water has been slightly mixed with water from the Indian Ocean in the south of the Bali and Flores seas by the tidal streams between the islands. Provisionally, until further detail observations have been made in the more Eastward seas, the line running from Tandjong Selatau (S. E. corner of Borneo, 115° Long. E.) to the West point of Flores, has a fair chance of being correct, both in the N. W. and in the S. E. monsoon.

Literature at our disposal and consulted.

1. SCHOTT, G. Wissenschaftliche Ergebnisse einer Forschungsreise zur See. Petermann's Mitt. Ergänzungsheft 109, 1893.
2. KRÜMMEL, O. Prof. Dr. Fr. DAHL's Areometer Beobachtungen auf der Fahrt von Neapel nach Matupi. Ann. Hydr. 1896.
3. V. D. STOK, P. J. Wind and Weather, Tides and Tidal Streams in the Indian Archipelago.
4. SMITS, P. J. De Regenwaarschijnlijkheid in de zeeën van den Ned. Ind. Archipel. Natuurkundig Tijdschr. voor Ned. Indië, deel 67.
5. BRAAK, C. De Regenverdeeling in den O. I. Archipel. Nat. Tijdschr. v. Ned. Ind Deel 74, p. 57.

(*) This has already been pointed out by Dr. BRENNECKE (Planet 3, p. 126).

6. Aus dem Reisebericht des Herrn Dr. PLEHN, über eine Reise im tropischen Theil des Indischen Ozeans. Ann. Hydr. 1892.
7. HANN, J. Lehrbuch der Meteorologie.
8. Zeemansgidsen van den O. I. Archipel, uitgegeven door het Departement van Marine.
9. Encyclopaedie van Ned. Indië, 1ste druk. Art. „Zee", deel 4, p. 739.
10. BRAAK, C. Een moessonvoorspelling voor den Indischen Archipel. Nat. Tijdschr. voor N. I. Deel 73.
11. MOLENGRAAFF G. A. F. en MAX WEBER. Het verband tusschen den plistoceenen ijstijd en het ontstaan der Soenda Zee, enz. enz. Verslag gewone vergadering der Wis- en Nat. Afd. der Kon. Akad. van Wetenschappen te Amsterdam, 1919. Deel 28.
12. VAN ES, L. J. C. De Voorhistorische Verhoudingen van Land en Zee in den O. I. Archipel. Jaarboek van het Mijnwezen in Ned. O. Indië. 1916.
13. KRÜMMEL, O. Handbuch der Ozeanographie.
14. Ocean. en Meteor. Waarnemingen i/d. Indischen Oceaan. Verhandelingen v/h. Kon. Ned. Meteor. Inst. te de Bildt.
15. SEEMAN, C. H. Unterschiede zwischen Luft- und Wassertemperatur in der China See und den angrenzenden Gewässern. Ann. Hydr. 1892.
16. V. WIJNGAARDEN. Zoutgehalte bepalingen enz. Tijdschrift „de Zee", May 1918.
17. BOUQUET DE LA GRYE. Recherches sur la chloruration de l'eau de mer. Annales de Chimie et de Pharmacie. 5ième Série p. 433.
18. SCHOTT, G. Die Meeresströmungen und Temperaturverhältnisse in den O.-Asiatischen Gewässern. Peterm. Mitt. 1891.
19. SCHOTT, G. Die Strömungen zwischen Singapore und Taku. Ann. Hydr. 1900, p. 428.
20. KOPPEN. Ueber das Verhältnis der Temperatur des Wassers und der Luft an der Oberfläche des Ozeans. Ann. Hydr. 1890, p. 445.
21. SCHOTT, G. Die Verteilung des Salzgehalts im Oberflächenwasser der Ozeane. Peterm. Mitt. p. 217.
22. BRENNECKE, W. Forschungsreise S. M. S. „Planet", 1906/07, Band III.
23. POLACK. Ueber Strömungen in den Chinesischen Gewässern. Ann. Hydr. 1890. p. 33.
24. PLEHN. Eine Reise auf dem Dampfer „Priok" nach O. Asien. Ann. Hydr. 1893, p. 149.
25. BRAAK, C. Der Temperaturgang bei Tage über dem Meere. Verhandelingen No. 3. Kon. Magn. en Meteor. Obs. Batavia 1915, p. 49.
26. HELLAND HANSEN, B. The Norwegian Sea. Report on Norwegian Fishery and Marine Investigations. Vol. 1909. No. 2.
27. SCHOTT, G. Wissenschaftliche Ergebnisse der Deutschen Tiefsee-Expedition auf dem Dampfer „Valdivia", 1898 — 1899.
28. MURRAY, J. and HJORT, J. The Depth of the Ocean. Physical part by B. HELLAND HANSEN.