

METEOROLOGICAL OBSERVATIONS.

Marine Meteorological Observations.

The mechanism of the monsoons and its influence on the wind system and the rainfall in the Indian Archipelago may be assumed as sufficiently well-known. Anyone interested is referred to the brief but excellent article by Dr. C. BRAAK on "Climate" in the Encyclopaedia of the Neth. Indies, 2nd. Ed., and to the article "The distribution of rainfall in the E. I. Archipelago", by the same author in Part LXXIV of the *Natuurkundig Tijdschrift voor Ned. Indie*.

During the cruises it was endeavoured to obtain more data concerning those meteorological factors which bear directly on the hydrographic conditions of the area investigated, viz. the cloudiness, the force of the wind, the temperature of the air and the relative humidity.

In the months of February and August the force and regularity with which the N.W. and the S.E. monsoons respectively prevail, are of preponderant importance; in the months of May and November these meteorological factors are largely dominated by the degree of progress made by the changing of the monsoons. It will not be amiss to set down a concise survey of the weather conditions, derived from the "Weatherreports of the R. Magn. and Meteorol. Observatory of Batavia", and from observations of my own for the years under consideration.

1917. JAVA SEA.

February. — In the W. part of the Java Sea the monsoon prevails moderately. Intensity of the wind force 3 — 4. A great deal of rain S. of Banka and Billiton. Weak monsoon in the E. part of the Java Sea, with fairly much rain.

May. — The change from the W. monsoon to the E. monsoon is already past. Light E-winds over the whole sea area. Little rain.

August. — The E. monsoon blowing irregularly, on the whole weak. Sporadic showers.

November. — The transition from the E. to the W. monsoon is already complete. Mainly light Westerly winds. At the end of the month frequent showers marking the setting in of the wet season.

1918. **JAVA SEA.**

February. — The N.W. monsoon prevailing with great force and constancy. Heavy rainfall over the entire Java Sea. Very showery weather with a few fine days in between.

May. — The S.E. monsoon already prevails perceptibly. Intensity of wind force 1—4. Gusty weather, little rain.

August. — S.E. monsoon fully prevailing. Very dry.

November. — The S.E. monsoon continues to hold, though faintly, in the E. part. Dry weather. In the W. the turn of the season sets in towards the latter part of the month.

1919. **S. CHINA SEA.**

March. — Northerly winds largely predominant; the wind not veering round to the S. till the last week. Little rain.

May. — During the first 10 days of the month the wind was Northerly, though light, subsequently S; consequently turn of the season in full swing. Fairly much rain.

August. — During the early half of the month the S.E. monsoon continued to prevail with force, but in the latter half it slackened in the Northern part. The direction of the wind then was S.E. to S.W., in accordance with the latitude; force 1—4.

November. — Very variable winds in the early half of the month (S. — N.W.); gusty weather with plenty of rain. In the latter part of the month the direction of the wind was S.W. — N.W.

1920. **S. CHINA SEA.**

February. — Exceptionally fine weather found throughout the entire S. China Sea. Sky overcast. Very little rain. Light Northerly breezes.

1919. **STRAIT OF MALACCA.**

February. — Northerly to Westerly winds. Little rain.

May. — Variable winds.

August. — idem.

November. — The turn of the season starts in the first half of the month, afterwards W. winds. Gusty weather.

Temperature of the air. The reader is invited to consult the tables on p. 40 a. f.

The lack of regularity in the daily movement of the temperature is at once apparent; no doubt various deviations must be attributed to radiating influences emitted by the vessel, but by far the majority were produced by disturbing influences in the atmosphere itself, i. e. the rainfall, the changes in the clouding and in the strength of the wind. Especially the rainfall is a troublesome factor: a heavy shower may cause the temperature to drop several degrees and its influence may continue to make itself felt as long as 8 — 12 hours after (see temperature tables 5 May 1918 and 16 November 1919). It should furthermore not be forgotten that the ship moves along, so that the observer continually gets to places where the forementioned disturbing influences still make their after-effects noticeable. However, judging from the hour-averages, I think I have to some extent attained the main object in view, viz. to obtain a fairly correct average of the atmospheric temperature of the entire area investigated, during the period of observation.

The average daily temperature for the different months of observation was in the Java Sea:

in February	1917.....	26.6°C.
id.	1918.....	26.0°, ,
May	1917.....	27.9°, ,
id.	1918.....	27.6°, ,
August	1917.....	27.3°, ,
id.	1918.....	27.0°, ,
November	1917.....	27.9°, ,
id.	1918.....	28.2°, ,

In the S. China Sea:

(in the open sea, not in the straits)

in February	1920.....	26.7°C.
March	1919.....	28.4°, ,
May	1919.....	28.9°, ,
August	1919.....	27.4°, ,
November	1919.....	27.4°, ,

The number of observation days is not sufficient for establishing the average temperatures in the Strait of Malacca and between the islands East of Sumatra; moreover the disturbing influences owing to the proximity of the shore are too great. Special mention should be made of the high atmospheric temperatures in August in the Strait of Malacca.

The differences between the separate day-averages and the average for the whole of the period of observation, proved to be greatest in the Java Sea in the months of January and February; in the S. China Sea in the month of November.

They varied:

in the Java Sea, during	Febr.	'17	between	-1.4°	and	+1.0°	C.
	id.	'18	„	-1.4°	„	+1.1°	„
	May	'17	„	-0.8°	„	+0.5°	„
	id.	'18	„	-0.9°	„	+0.6°	„
	Aug.	'17	„	-0.5°	„	+0.6°	„
	id.	'18	„	-0.3°	„	+0.4°	„
	Nov.	'17	„	-0.9°	„	+0.4°	„
	id.	'18	„	-1.0°	„	+0.7°	„
in the S. China Sea, during	March	'19	„	-0.4°	„	+0.3°	C.
	May	'19	„	-0.5°	„	+0.5°	„
	Aug.	'19	„	-0.6°	„	+0.3°	„
	Nov.	'19	„	-0.7°	„	+0.6°	„
	Febr.	'20	„	-0.4°	„	+0.2°	„

Deviations from the annual average. These can hardly be expressed in figures as we unfortunately do not possess averages based upon many years of observations of the atmospheric temperatures in the monsoon months and the transition months. The „Oceanographic and Hydrographic Observations in the Indian Ocean” published by the R. Meteorological Institute of de Bildt give monthly statements of average temperatures for one-degree areas of the seas investigated, but for many of those areas the number of observations is as yet too small to derive an average from.

Seasonal differences. The greater heat in the transition months of May and November is clearly marked in the average temperatures. The difference between the average atmospheric temperatures in the months of August and February, the typical months of the E. and W. monsoons, was for the Java Sea in 1917, 0.7° C., in 1918 1.0° C. The greatest difference between the monthly averages was found in the Java Sea in 1918 (Febr. and Nov.), amounting to 2.2° C.

The intensity of the monsoons in the years '17 and '18 is also indicated by the monthly averages; for generally speaking the temperature of the air will be lower as the monsoon prevails with more strength and regularity, among other causes through the greater supply of air from higher latitudes. In the W. monsoon this is accompanied by increased rainfall. Thus in February '18 we find the atmospheric temperature lower than in the corresponding month of '17, owing to the greater intensity of the wind-force and the accompanying increased rainfall; the same is the case in August '18 in consequence of the more regular prevalence of the East monsoon.

Likewise, in both years the temperatures of the air follow the progress of the transition in the months of May and November: in May '18 the E-winds prevailing more forcibly than in '17, we had consequently lower temperatures;

in Nov. '17 the temperature was lower than in Nov. '18, because in the former year the turn of the season was already complete in that month, whereas in 1918 it was just taking place in that month.

Maximum and minimum temperature. The maxima of the temperatures fall very irregularly in the month of February, owing to the great amount of rainfall and the lack of regularity of the cloudiness — in the other months of observation these maxima occurred preponderantly after 12 o'clock noon; out of 72 fairly practicable series the maxima fall at noon in 19% of the cases; in 71% after 12 o'clock noon, especially between 2 and 4 p.m.; and in 10% of these cases before noon. The lowest temperatures fall with such irregularity that no figures can be given for them.

The following table shows the maxima and minima observed:

			max. t.	min. t.
Java Sea,	February	'17	28.7° C.	23.3° C.
id.	id.	'18	28.1° "	23.5° "
id.	May	'17	29.8° "	25.1° "
id.	May	'18	29.2° "	24.9° "
id.	August	'17	28.7° "	25.2° "
id.	id.	'18	28.2° "	26.1° "
id.	November	'17	29.3° "	25.2° "
id.	id.	'18	29.4° "	26.1° "
S. China Sea.	March	'19	29.5° "	27.2° "
id.	May	'19	30.4° "	27.3° "
id.	August	'19	28.3° "	26.3° "
id.	November	'19	30.8° "	24.0° "
id.	February	'20	27.6° "	24.8° "
Straits.	February	'19	28.9° "	25.2° "
	May	'19	30.4° "	27.3° "
	August	'19 (Strait of Malacca.)	29.7° "	27.1° "
	November	'19	29.6° "	24.4° "

Daily amplitude. For the determination of the amplitude only very few series were suitable. As far as can be ascertained the amplitude amounted to:

in	February	'17	?	Java Sea.
	id.	'18	?	id.
	May	'17	1.2°	id.
	id.	'18	1.1°	id.
	August	'17	0.9°	id.
	id.	'18	0.9°	id.
	November	'17	1.2°	id.
	id.	'18	1.0°	id.

March	'19	0.9°	S. China Sea.
May	'19	?	"
August	'19	0.9°	"
November	'19	?	"
February	'20	?	"

In the transition months of May and November the amplitudes are somewhat greater than in the month of August, in consequence of the greater nightly radiation in the latter month and the greater wind-force. From one season to another, however, the differences are so slight, that for the entire yearly average we may approximately assume an amplitude of 1.0° C.

Influence of wind and cloudiness on the temperature of the air. It is very difficult to trace the influence of somewhat longer duration owing to the very frequent disturbances. The influence of the wind is clearly marked only in the month of August 1919: we see, in a dry period and at a constant cloudiness, that the temperature rises considerably as the force of the wind decreases, the figures being 26.8° C at a velocity of 5, 27.4° at velocity 4, and 27.6° at vel. 3. Attention is further drawn to the high temperatures in this same month in the Strait of Malacca (29.0° C 20 — 22 Aug.), where very light winds prevailed (vel. 1 — 2), as against an average temp. of 27.4° in the S. China Sea and 27.8° in the straits between the islands E. of Sumatra, where the S.E. monsoon prevailed with some degree of force (velocity 3 — 5).

Relative humidity. The reader is invited to consult the tables at the end of this article, on p. 64.

In the following table (p. 12) are marked, for the different observation months, the averages and the minima of the relative humidity, the average monthtemperature and windforce, besides the hours when, in the course of the day, the relative humidity is greatest and least, as calculated from the hourly observations.

In the Java Sea the relative humidity decreases from February to November; the rainfall, which is great during the first two months of the year, lessens during the transition months and dwindles as soon as the E-monsoon begins to prevail. This blows from May to November and brings relatively dry air, partly because the wind comes from the neighbourhood of Australia, partly because the movement of the air takes place from the higher to a lower latitude. Moreover, there is produced in this season also a downward movement of air which makes the air drier.

Another factor influencing the relative humidity of the air in the Java Sea is the high temperature and the dryness of the wind which blows in Central and East Java through the valleys between the volcanos (the continuation of the S.E. wind from the Indian Ocean), after having lost more or less of its moisture on the southern slope of the Southern mountains of Java. An instance of this influence is afforded by Aug. 16 th. '17. The ship was then

Observation month.	× 24 hrs.	Average relative humidity in %.	Absolute minimum of rel. hum.	Av. temp.	Average wind force.	Hour of maximal rel. hum.	Hour of minimal rel. hum.
JAVA SEA							
Febr. '17	11	81	70 (18 Feb. 4 p.m.)	26.6° C	2	irregular	irregular
id. '18	17	86	73 (25 Jan. 10 p.m.)	26.—	4	"	"
May. '17	10	82	72 (5 May 1 p.m.)	27.9	2	3-6 a.m.	12-1 p.m.
id. '18	14	84	72 { (7 May 6 p.m.) (15 May 12 noon)	27.6	3	4-6 " "	4-8 p.m.
Aug. '17	15	80	69 (16 Aug. 12-2 p.m.)	27.3	3-4	12-1 " "	1-4 p.m.
id. '18	10	83	73 (19 Aug. 12 noon)	27.—	4	12 m-night	12 noon
Nov. '17	14	78	66 (11 Nov. 4 p.m.)	27.9	2	2-5 a.m.	3-4 p.m.
id. '18	12	81	74 { (13 Nov. 4 p.m.) (30 Nov. 8 p.m.)	28.1	2	6 "	4-6 p.m.
S. CHINA SEA							
March '19	6	82	76 (16 Mar. 10 p.m.)	28.4	2-3	irreg.	irregular
May '19	6	81	72 (22 May. 2 p.m.)	28.9	2	"	"
Aug. '19	5	86	82 { (15 Aug. 6 p.m.) (17 Aug. 4 p.m.)	27.4	4	"	"
Nov. '19	6	84	73 (30 Oct. 6 p.m.)	27.4	3	6 a.m.	"
Febr. '20	5	84	72 (9 Febr. 6 p.m.)	26.7	3	4-6 a.m.	"

from 6 a.m. to 5 p.m. within 30 miles of the Java shore off Japara and Rembang ($\pm 111^{\circ}$ Long. E.). From 12 noon till 4 p.m. the relative humidity was from 69 to 73 %.

In perfect accordance with the observations of SCHOTT (I, p. 112) we see in the S. China Sea the relative humidity decrease from February till May. Contrary to expectation August in this part of the sea showed a very high relative humidity (86 %), unlike the Strait of Malacca (79 %) and the sounds between the islands along the E.-coast of Sumatra (83 %). Influences from the land being out of the question with the S. and S.E. winds, and the rainfall being nihil, the present writer is unable to satisfactorily account for this.

In November owing to the gradual prevalence of the W-monsoon the average relative humidity was 84 %, therefore as much as in February 1920.

The rainfall during the months of observation. As far as I am aware no quantitative data have as yet been published covering a long period of observations of the rainfall at sea in the Indian Archipelago. There is but one official rain-station which is absolutely free from land influences and from which observations covering any length of time are known, viz. on the coast-light Discovery-Eastbank, situated in Strait Karimata at 75 miles from Borneo and 60 miles from Billiton. The average annual rainfall on that sandbank is considerably less than at the nearest rain-stations in Billiton (Dendang) and in Borneo (Sukamara and Ketapang).

Discovery E-bank	12 y. of observation;	av. ann. rainfall	1498 m.M.
Sukamara	8 id	id	; id. id. 2963 id.
Ketapang	12 id.	id.	; id. id. 3348 id.

We are not so uninformed as to the number of rainy days. VAN DER STOK already, in the work previously referred to (3), indicates the probability of rainfall for certain zones. There afterwards appeared an article by Mr. SMITS in the *Natuurkundig Tijdschrift voor Nederlandsch-Indië* (4, p. 89), in which the data concerning the number of wet days and the probability of rainfall for each month separately in different zones have been worked out. The data have been obtained from the Dutch men-of-war and from a few Government of India steamers, and they extended over the period from 1887 — 1902.

On comparing the number of rainy days in each month and of each zone with those of the official rain-gauges at places on the coast near those zones, SMITS arrived at the conclusion that the probability of rainfall for any given area of the sea is on an average equal to that for the adjacent stretch of coast. He also assumed it to be fairly certain that the intensity of rainfall at sea is just as great as ashore. The rain-figures of Discovery East-bank, however, do not point that way, and the experience of the present writer is that, though the intensity of rain-showers in the proximity of the shore may perhaps be no less than ashore, it is considerably less in the open sea.

Month	Distribution of the number of showers over the 24 hrs.				Number of days of observation	Number of rain days.	Rainprobability according to SMITS.	REMARKS.
	a.m.	a.m.	p.m.	p.m.				
	12-6	6-12	12-6	6-2				
JAVA SEA.								
Febr. '17	2	19	10	5	11	8 (73%)	50% *	* For the Java Sea the figures taken were the averages between those for the W. and the E. part, which, except with regard to Nov. (W. part 46 ⁰ / ₁₀ , E. part 26 ⁰ / ₁₀), differ by only a few per centum. The N. W. part of the Java Sea was eliminated; the rainfall was greater there, but we only navigated there for half a day in each month.
May '17	2	4	0	1	10	4 (40%)	30%	
August. '17	0	4	2	0	15	4 (27%)	11%	
Nov. '17	8	3	7	5	14	9 (64%)	?	
Febr. '18	18	16	15	12	18	12 (67%)	50%	
May '18	3	8	2	3	14	5 (36%)	30%	
Aug. '18	0	0	0	0	10	0 —	11%	
Nov. '18	2	2	1	1	12	5 (42%)	?	
S. CHINA SEA.								
March. '19	1	2	0	1	6	3	—	
May '19	1	2	2	0	6	4	—	
August. '19	0	0	0	0	5	0	—	
Nov. '19	3	3	2	0	6	5	—	
February '20	1	0	1	0	5	2	—	

In the above table the probability figures of Mr. SMITS are given side by side with the number of days when rain actually fell during our period of observation; to these was added the distribution of the rainfall over the period of 24 hours. From this it appears that in 1917 the months of May and November were normal, February and August being too wet. May and November 1918 were likewise normal, February too rainy and August too dry.

Clouds. The averages relating to cloudiness for the different seasons did not vary much, excepting the months of February 1918 and November 1919, as appears from the following:

Months		Average Cloudiness
	<i>Java Sea.</i>	
February	'17	6
id.	'18	7
May	'17	4
id.	'18	6
August	'17	5
id.	'18	4
November	'17	6
id.	'18	5
	<i>S. China Sea.</i>	
February	'20	5
March	'19	5
May	'19	5
August	'19	5
November	'19	8

The wind. The monsoons never prevail with perfect regularity; the W-monsoon is characterized by periods of great gustiness, with frequent showers continuing sometimes for days together, which may be followed by several fine days. The E. monsoon is more constant, but almost every year it shows periods when the constancy and the windforce present marked differences. During the transition seasons the windforce is very slight. For the constancy and the windforce in the area investigated VAN DER STOK (¹) states the averages given in the table of page 15.

The intensity of the wind-force was :

a. in the Java Sea.

February	'17,	all the observation-days, less than 4.
id.	'18,	2 days, below 4; 15 days, 4 or more.
May	'17,	all the days, less than 4.
id.	'18,	9 days, less than 4; 4 days, 4 or more.

August	'17,	9 days, less than 4; 6 days, 4 or more.
id.	'18,	2 days, less than 4; 11 days, 4 or more.
November	'17,	all the days less than 4;
id.	'18,	all the days less than 4.

b. in the South China Sea.

February	'20,	all the days less than 4.
March	'19,	all the days less than 4.
August	'19,	2 days, less than 4; 3 days, 4 or more.
November	'19,	5 days, less than 4; 1 day, 4 or more.

Area of the Sea	Month of greatest constancy, and direction of the wind.	Month when the greatest wind-force is found, and average windforce.	REMARKS.
S. China-Sea (N. of Equator)	{ January N. 78% Sept. S.S.W. 68%	{ February 2.3 July—Sept. 1.7	The scale of the wind-force is <i>not</i> BEAUFORT's. v. D. STOK's terms of division are: 0. — calm. 1. light air and light breeze. 2. gentle breeze. 3. moderate and fresh breeze. Force 3 therefore corresponds with 4-5 of BEAUFORT's scale.
id. (S. of Eq.)	{ Jan.—Febr. N. 85% Aug. S.S.E. 71%	{ January 2.6 Aug.—Sept. 1.7	
Caspar and Karimata straits.	{ January N.W. 78% August. S.E. 75%	{ December 1.7 August. 1.8	
Western part of Java Sea	{ Jan. W.S.W. 79% June E.S.E. 71%	{ January 1.8 June—Sept. 1.7	
Central part of id.	{ Febr. W.N.W. 75% July-Aug. E.S.E. 74%	{ February 1.9 May—Aug. 1.7	
Eastern part of id.	{ Febr. W.N.W. 70% July-Aug. S.E. 77%	{ Augustus 1.7 February 1.9	
Strait of Malacca (S. part) (Singapore-Deli River)	{ Dec. N.N.W. 47% June S.E. 39%	{ ? June 1 1.5	
Strait of Malacca (middle) Deli-river-Diamond point.)	—	—	
Str. of Malacca (N. part)	{ Jan. E.S.E. 50% August. S. 26%	—	