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P. M. van Riel. The influence of sea disturbance on surface temperature.

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THE INFLUENCE OF SEA DISTURBANCE ON SURFACE TEMPERATURE.

Owing to the poor conduction of heat in water and the fact, that heat rays penetrate into a small depth only, the difference in undisturbed *fresh water* between the surface temperature and that of the lower layers may be considerable in consequence of the sun's radiation. However the cooling effect of evaporation plays also an important part here. Hence the maximum temperature is displaced from the surface to a deeper layer [1]).

In *seawater* — under the same conditions — the exchange of heat between the upper layer and the lower ones will be greater, salinity increasing as a consequence of evaporation by day. The surface water becomes heavier and will cause vertical convection to take place.

If the sea surface is disturbed by waves, currents or the ship's motion a lower surface temperature may be expected the deeper the mixing takes place, *if the temperature decreases with increasing depth.*

Though sea disturbance forms the most important element, even when the sea is perfectly calm a mixing is already effected on taking observations of surface temperature, as a consequence of the way in which the water is hauled up. On ships, regularly observing for the Dutch Meteorological Office, this is done by keeping a thermometer for a few minutes in seawater, that has been drawn up in a canvas bucket from over the ship's side.

In order to investigate the question how far this method furnishes too low readings, it is desirable to study in this connection the part played by sea disturbance.

The last problem deserves also attention now that people plead in favour of registering as a surface observation the temperature of the inflow condensor water. Moreover the differences found as a consequence of sea disturbance may give us an idea about the importance to be attached to a certain deviation from the normal surface temperature.

The available material has been used at the same time for studying the influence of sea disturbance *on the daily range* of surface temperature, which involved also consideration of the influence of cloudiness.

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[1]) W. SCHMIDT. Der Massenaustausch in freier Luft und verwandte Erscheinungen. Probleme der Kosmischen Physik 7, 1925, p. 39.

W. SCHMIDT. Uber Boden- und Wassertemperaturen. Meteorologisches Zeitschrift 1927, p. 406.

TABLE 1.

Sea disturbance and surface temperature.
(d in hundredths of °C.)

Sea disturbance.	$\frac{45°-50° \text{ N.}}{10°-20° \text{ W.}}$ (A).			$\frac{45°-50° \text{ N.}}{20°-30° \text{ W.}}$ (B).			A + B.	
	t_1	Number of obs.	d_1	t_2	Number of obs.	d_2	$\frac{1}{2}(t_1 + t_2)$	$\frac{1}{2}(d_1 + d_2)$
0	16.02	519	—	16.25	539	—	16.14	—
1	16.07	715	+ 5	16.37	666	+ 12	16.22	+ 8
2	15.96	1582	— 6	16.31	1400	+ 6	16.14	0
3	15.72	1877	— 30	16.15	1662	— 10	15.94	— 20
4	15.45	1296	— 57	15.94	1193	— 31	15.70	— 44
5	15.41	762	— 61	15.84	792	— 41	15.63	— 51
6	15.45	259	— 57	15.42	300	— 83	15.44	— 70
0—2	16.02	0.49	—	16.31	0.53	—	16.17	0.51
3—6	15.51			15.84			15.68	
0—6	15.73			16.04			15.89	

TABLE 2.

$\frac{0°-10° \text{ S.}}{30°-40° \text{ W.}}$ (C).

Sea disturbance and surface temperature.
(d in hundredths of °C.)

Sea disturbance.	t	Number of obs.	d
0	25.88	39	—
1	25.89	211	+ 1
2	25.77	787	— 11
3	25.75	1739	— 13
4	25.63	1509	— 25
5	25.54	754	— 34
6	25.49	194	— 39
0—2	25.85	0.25	
3—6	25.60		
0—6	25.71		

TABLE 3.

$\frac{5°-15° \text{ N.}}{60°-70° \text{ E.}}$ (D.)

Sea disturbance and surface temperature.
(d in hundredths of °C.)

Sea disturbance.	t	Number of obs.	d
0	26.99	338	—
1	26.82	1256	— 17
2	26.56	3151	— 43
3	26.42	2980	— 57
4	26.23	902	— 76
5	26.21	201	— 78
0—2	26.79	0.50	
3—5	26.29		
0—5	26.54		

1. *Influence on the mean temperature.*

The material for this investigation has been derived from the observations in meteorological logs from Dutch ships in the squares $\frac{45-50 \text{ N.}}{10-20 \text{ W.}}$ (A), $\frac{45-50 \text{ N.}}{20-30 \text{ W.}}$ (B), $\frac{0-10 \text{ S.}}{30-40 \text{ W.}}$ (C), $\frac{5-15 \text{ N.}}{60-70 \text{ E.}}$ (D) and from an area extending over some 100 nautical miles east of the South-American coast between 25°—30° and 30°—35° Lat. S. (E and F.) The observations, punched on Power- or Hollerithcards, in order to ensure quick mechanical work [1]), are from the Atlantic Ocean for the months June, July and August and from the Indian Ocean for December, January and February. It was thought desirable for time-saving purposes to limit the inquiry to the observations available on cards. Consequently observations, made during high sea conditions, were too scanty for trustworthy results in case of sea disturbance higher than 6.

The scale numbers have the following meaning: 0 = calm, 1 = very smooth, 2 = smooth, 3 = slight, 4 = moderate, 5 = rather rough, 6 = rough, 7 = high, 8 = very high, 9 = phenomenal.

For each of the scale numbers a mean temperature has been calculated. Table 1 gives the results for the squares A and B separately and those for the whole area; the tables 2 and 3 regard squares C and D and table 5 the squares E and F.

In the tables mean temperature is indicated by t and expressed in °C; d means the difference from the temperature for sea disturbance 0 multiplied by 100. The number of observations has been given as well in order to indicate the value of the results. Here the fact must be taken into account that the temperatures in the areas A + B, E and F diverge more than those in the two squares C and D.

According to tables 1, 2 and 3 the temperature appears to *decrease* from scale number 2 upwards. With the exception of square D the mean temperatures for sea disturbance 0 to 2 are nearly identical.

In the diagrams 1, 2 and 3 the differences with regard to the temperature for sea disturbance 0 have been plotted for various scale numbers. The points, obtained in this way, allowed to draw a curve, representing the relation between sea disturbance and surface temperature in the areas A + B, C and D.

If the dotted curve is understood to represent the real course, the flattening of the full curve must be caused by the way the watersample

[1]) This method is used by the Marine Division of the Dutch Meteorological Office since 1923.

has been obtained on board. This would mean sensibly too low readings for scale number 0 and 1 only, a condition which does not occur too often. For this reason the influence on the accuracy of the mean temperature may be regarded as of small account. Let us suppose that, according to diagram 3, the readings for scale number 0, 1 and 2 have been respectively $0^{\circ}.6$, $0^{\circ}.3$ and $0^{\circ}.05$ too low. In this case the real mean temperature derived from *all* observations (8828, see table 3) would have been only $0^{\circ}.09$ higher than that obtained by means of the bucket-method. Anyhow by following this method we may come nearer to the mean surface condition than by measuring the temperature at an always changing rather considerable depth (inflow condensor.)

The drawing of the curve in diagram 3 with a maximum between scale numbers 0 and 1 is somewhat hypothetical; as a matter of fact the results of table 3 show everywhere a fall of the mean temperature with increasing sea disturbance. Now the results in this tropical square (Indian Ocean) are the most trustworthy in consequence of the considerable number of observations and their small divergency. On the contrary the results for sea disturbance 0 in the Atlantic equatorial area (39 observations only) are less reliable.

Probably a maximum for disturbance 1 would have been observed in the Indian Ocean too (Table 3, diagram 3), if the cooling of the surface was due to increasing sea disturbance only. Other influences are however also at work, f. i. heat exchange between air and water and evaporation.

In order to judge of the influence of the atmosphere, the differences were calculated between the mean air temperature and that of the sea surface, for the three areas A + B, C and D. (A—S, table 4.)

TABLE 4.

Difference between air and surface temperature (A—S).

Area.	June.	July.	August.	Mean.
A + B.	+ 0.53	+ 0.46	+ 0.31	+ 0.43
C.	+ 0.03	+ 0.00	+ 0.16	+ 0.06
	December.	January.	February.	
D.	— 0.15	— 0.06	— 0.02	— 0.08

The air temperature appears to be higher in the Atlantic Ocean, considerably so in the area A + B. In the Indian Ocean however the reverse is observed. Direct heating or cooling of the sea-surface by air will be generally slight; greater however, where a constant N.E. monsoon wind is in continual touch with a surface current moving in the same direction, as is the case in square D. Here it is possible that the first breeze causes enough cooling to mask the effect of mixing of the water-layers.

More importance is however attached to evaporation. If the temperature of the air is lower than that of the sea, the air-layers near the surface are heated and an unstable condition is the result. As a consequence more vapour is being removed from the air-layers near the surface, followed by more evaporation and more cooling. In the Indian Ocean therefore the transport of vapour to higher layers, accompanied by cooling of the surface water as a result of strong evaporation, will be important even in calm weather. This proces will be increased, when after a period of calm, the dry N.E. monsoon comes through and might outweigh the influence of mixing of water-layers.

If we average the mean temperatures for sea disturbance 0, 1 and 2 and compare the results with the averages of the remaining scale numbers (Tables 1, 2 and 3), it appears that for the area A + B as well as for D increased sea disturbance is accompanied by *a fall of half a degree*. Table 2 shows a somewhat smaller difference.

Finally we will examine, whether in conditions, different from those treated above — i. e. summer months and tropical regions — a fall of surface temperature always ensues in consequence of increased sea disturbance. For this reason an area has been chosen ± 100 nautical miles east of the South-American coast between 25° and 35° S., and this area was investigated for a winterperiod.

An outstanding feature of this region is that, on approaching the coast, the surface temperature rapidly falls in consequence of a cold northward bound current near the coast. This current reaches in June and July a latitude of about 27° S. and does not extend beyond 30° S. in August [1]). Probably the surface temperature in this area is influenced by cold la Plata-water, whereas — especially in June and south of 30° — this water is mixed with cold bottom-water.

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[1]) See Publication 110 of the Royal Dutch Meteor. Inst.

For these reasons the parts of this region, north and south of the parallel of 30°, have been investigated separately as areas E and F. For calculating the mean temperature the observations for sea disturbance 0—2 and 3—6 were combined. (Table 5.)

TABLE 5.

Sea disturbance and surface temperature.
(d in hundredths of °C.)

Sea disturbance.	25°—30° S. (E).			30°—35° S. (F).		
	t_1	Number of obs.	d_1	t_2	Number of obs.	d_2
0—2	18.86	1414		13.08	1011	
3—6	19.19	2284	+33	13.71	1342	+63
0—6	19.06	3698		13.44	2353	

It appears from this table that the mean surface temperature *rises* (with increasing sea disturbance), resp. 0°.33 and 0°.63 C. for the areas E and F. This points to a relatively thin colder surface layer, the temperature of which differs considerably from that of the lower layers, especially south of 30°. This would be in accordance with the supposition of a supply of water from the mouth of the la Plata, as has been mentioned above.

In order to decide whether this increase of temperature might be caused by heat-exchange between the atmosfere and the surface water, the mean difference has been calculated between air and surface temperature in both the areas E and F for the period June, July and August. These differences are — 0.°43 and — 0.°45 C. respectively, which means that the sea surface is warmer than the air. The supposition of a heating of the surface by the atmosphere may therefore be dismissed. For June the differences A minus S in the northern and southern squares are — 0°.53 and — 1°.10 C.

2. *Influence on the daily range.*

In order to examine the influence of the sea disturbance on the daily range of the surface temperature, the 4-hourly observations in the above mentioned areas were used again. All series of observations for sea disturbance 0, 1, etc. (6 and 7 were combined) have been arranged according to the hours of observation: midnight, 4 a.m., 8 a.m., noon, 4 p. m. and 8 p. m. Then the mean temperatures for each scale number and for these six moments with their general mean value have been calculated. The observations for sea disturbance 0 and 6 in the area of the S. E. trade of the Atlantic Ocean and those for scale number 6 in the Indian Ocean were too scanty to allow a division into 6 groups.

Tables 6, 7 and 8 contain the 4-hourly deviations from the mean value, combined for the lower, the higher and all scale numbers in order to diminish the influence of accidental variations and inaccuracies in the observations. The formulae in table 9 are based on these results.

TABLES 6, 7 AND 8.

Sea disturbance and daily range of surface temperature.
(In hundredths of °C.)

Sea disturbance.	m.	4 a	8 a	Noon.	4 p	8 p	Number of obs.
Table 6, $\frac{45^\circ\text{—}50^\circ \text{ N.}}{10^\circ\text{—}30^\circ \text{ W.}}$ (A + B).							
0—2	— 22	— 30*	— 10	+ 27	+ 33	+ 2	5 421
3—6	— 20	— 22*	— 4	+ 21	+ 19	+ 4	8 193
0—6	— 20	— 25*	— 7	+ 24	+ 25	+ 3	13 614
Table 7, $\frac{0^\circ\text{—}10^\circ \text{ S.}}{30^\circ\text{—}40^\circ \text{ W.}}$ (C).							
1—2	— 16	— 19*	+ 2	+ 21	+ 20	— 7	998
3—5	— 16	— 20*	— 2	+ 21	+ 21	— 4	4 002
1—5	— 16	— 19*	0	+ 21	+ 20	— 6	5 000
Table 8, $\frac{5^\circ\text{—}15^\circ \text{ N.}}{60^\circ\text{—}70^\circ \text{ E.}}$ (D).							
0—2	— 22	— 35*	— 1	+ 25	+ 34	— 2	4 745
3—5	— 21	— 22*	+ 1	+ 27	+ 22	— 9	4 083
0—5	— 21	— 28*	0	+ 26	+ 28	— 5	8 828

TABLE 9.

Daily range of surface temperature.

Area.		Surface condition mean smooth.
$\frac{45^\circ-50^\circ \text{ N.}}{10^\circ-30^\circ \text{ W.}}$	(A + B)	$t = 16.17 + 0.33 \cos (nt - 221^\circ) + 0.04 \cos (2nt - 52^\circ)$
$\frac{5^\circ-15^\circ \text{ N.}}{60^\circ-70^\circ \text{ E.}}$	(D)	$t = 26.79 + 0.34 \cos (nt - 206^\circ) + 0.02 \cos (2nt - 19^\circ)$
$\frac{0^\circ-10^\circ \text{ S.}}{30^\circ-40^\circ \text{ W.}}$	(C)	$t = 25.85 + 0.22 \cos (nt - 203^\circ) + 0.03 \cos (2nt - 37^\circ)$
		Surface condition mean moderate.
$\frac{45^\circ-50^\circ \text{ N.}}{10^\circ-30^\circ \text{ W.}}$	(A + B)	$t = 15.68 + 0.24 \cos (nt - 216^\circ) + 0.01 \cos (2nt - 314^\circ)$
$\frac{5^\circ-15^\circ \text{ N.}}{60^\circ-70^\circ \text{ E.}}$	(D)	$t = 26.29 + 0.27 \cos (nt - 201^\circ) + 0.04 \cos (2nt - 36^\circ)$
$\frac{0^\circ-10^\circ \text{ S.}}{30^\circ-40^\circ \text{ W.}}$	(C)	$t = 25.60 + 0.23 \cos (nt - 210^\circ) + 0.04 \cos (2nt - 39^\circ)$
		All observations.
$\frac{45^\circ-50^\circ \text{ N.}}{10^\circ-30^\circ \text{ W.}}$	(A + B)	$t = 15.89 + 0.27 \cos (nt - 219^\circ) + 0.02 \cos (2nt - 30^\circ)$
$\frac{5^\circ-15^\circ \text{ N.}}{60^\circ-70^\circ \text{ E.}}$	(D)	$t = 26.54 + 0.30 \cos (nt - 210^\circ) + 0.03 \cos (2nt - 30^\circ)$
$\frac{0^\circ-10^\circ \text{ S.}}{30^\circ-40^\circ \text{ W.}}$	(C)	$t = 25.71 + 0.22 \cos (nt - 206^\circ) + 0.04 \cos (2nt - 39^\circ)$

It appears from this table, that under various conditions the diurnal variations are the more important, the semi-diurnal influence being of no account. The mean amplitude (maximum — minimum) amounts to $0^\circ.57$ for A + B and D and $0^\circ.45$ for area C. The amplitudes grow smaller with increasing disturbance as far as concerns A + B and D. This cannot be said for area C; this again will be probably due to the lack of observations in this square for sea disturbance 0 and 1. For mean moderate disturbance, a condition which often occurs, the amplitudes agree for all areas.

4-hourly deviations and formulae were likewise deduced from the observations in the areas E and F in the South-Atlantic Ocean. (Tables 10 and 11). The semi-diurnal variations are more important here, probably owing to the considerably divergent temperature in this region, especially in the southern part. The mean diurnal amplitude for E and F is $0^\circ.53$. The coefficient of the diurnal term decreases with increasing sea disturbance in E; for area F it remains unchanged.

As an average for the two squares the diurnal amplitude decreases by 0°.16 C. for mean smooth to mean moderate sea disturbance. That exactly the same mean decrease has been found here as for the areas A + B and D is only accidental.

TABLE 10.

Sea disturbance and daily range of surface temperature.
(In hundredths of °C.)

Sea disturbance.	m.	4 a	8 a	noon.	4 p	8 p	number of obs.
			25°—30° S. (E).				
0—2	—24	—30*	0	+24	+36	—7	1414
3—6	—15*	—7	—1	+24	+8	—11	2284
0—6	—19*	—18	0	+24	+22	—9	3698
			30°—35° S. (F).				
0—2	—16	—24*	—17	+20	+34	+2	1011
3—6	—29*	—20	—7	+25	+25	+6	1342
0—6	—22*	—22*	—12	+23	+29	+4	2353

TABLE 11.

Daily range of surface temperature.

Area.	Surface condition mean smooth.
25°—30° S. (E)	$18.86 + 0.33 \cos (nt - 211°) + 0{,}04 \cos (2\,nt - 87°)$
30 —35 S. (F)	$13.08 + 0.29 \cos (nt - 230°) + 0.08 \cos (2\,nt - 73°)$
	Surface condition mean moderate.
25°—30° S. (E)	$19.19 + 0.17 \cos (nt - 185°) + 0.04 \cos (2\,nt - 38°)$
30 —35 S. (F)	$13.71 + 0.29 \cos (nt - 216°) + 0.03 \cos (2\,nt - 139°)$
	All observations.
25°—30° S. (E)	$19.06 + 0.25 \cos (nt - 203°) + 0.05 \cos (2\,nt - 56°)$
30 —35 S. (F)	$13.44 + 0.28 \cos (nt - 223°) + 0.07 \cos (2\,nt - 41°)$

O. KRÜMMEL [1]) mentions the following amplitudes based on observations made by G. SCHOTT in tropical regions:

	Mean	Max.	Min.
1. Moderate to fresh wind:			
a. Overcast	$0^{\circ}.39$	$0^{\circ}.6$	$0^{\circ}.0$
b. Nearly or wholly cloudless . .	$0^{\circ}.71$	$1^{\circ}.1$	$0^{\circ}.3$
2. Calm or light air:			
a. Overcast	$0^{\circ}.93$	$1^{\circ}.4$	$0^{\circ}.6$
b. Nearly or wholly cloudless . .	$1^{\circ}.59$	$1^{\circ}.9$	$1^{\circ}.2$

This means a mean value for moderate to fresh winds of $0^{\circ}.55$ and for calm and light air $1^{\circ}.26$, i. e. an increase of $0^{\circ}.71$. These results point to much larger differences than those found by us for sea disturbance mean smooth and mean moderate, conditions, which may be regarded to correspond nearly with the above mentioned wind conditions.

KRÜMMEL supposes however that the number of observations, on which SCHOTT bases his results, may not have been sufficient.

From a table published by P. H. GALLÉ [2]) we calculate the following amplitudes for light-vessel „Haaks" (Southern North sea) and a period of 10 years.

Windforce 0—3 (Beaufort scale) $= 0^{\circ}.36$.
,, 4—6 $= 0^{\circ}.21$.

These results show that an increase of windforce from mean light to mean fresh is followed by a decrease of the amplitude of the surface temperature of $0^{\circ}.15$, a value which agrees better with what we found for area A + B in the Atlantic Ocean (Table 9).

Although in most areas increasing sea disturbance coincides with an earlier maximum and minimum (Tables 9 and 11), nothing can be stated with certainty, because very slight inaccuracies may be the cause of considerable changes in phase.

For the average conditions of the sea surface the maximum temperature in the tropics is being observed at 13.7 h. (C) and 14.0 h. (D);

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[1]) KRÜMMEL. Handbuch der Ozeanographie I, p. 385.
[2]) Kon. Nederlandsch Meteor. Instituut N°. 102. Mededeelingen en verhandelingen N°. 18. P. H. GALLÉ. Luft- und Wassertemperatur im Indischen Ozean, p. 14.

in higher latitudes at 14.2 h. (E + F) and 14.6 h. (A + B); i. e. on an average 0.5 h. later.

3. *The influence of clouds.*

Usually increasing cloudiness may be expected with increasing sea disturbance. The question arises whether the fall of temperature with increasing sea disturbance is not partly due to the difference in cloudiness.

In order to find out whether an influence exists, the mean amount of clouds for mean smooth and mean moderate disturbance has been calculated. The results of this investigation, to be found in table 12, point to small differences only. [1]

TABLE 12.

Sea disturbance and cloud amount.

Area.	Sea disturbance.	Cloud amount.
$\frac{45^\circ-50^\circ \text{ N.}}{10^\circ-30^\circ \text{ W.}}$ (A + B)	0—2	7.0
	3—6	7.6
$\frac{5^\circ-15^\circ \text{ N.}}{60^\circ-70^\circ \text{ E.}}$ (D)	0—2	3.7
	3—5	5.1
$\frac{0^\circ-10^\circ \text{ S.}}{30^\circ-40^\circ \text{ W.}}$ (C)	0—2	4.6
	3—6	5.0
25°—35° S. (E + F)	0—2	5.0
	3—6	5.8

The greatest difference in cloudiness being found in the Indian Ocean (D), the mean temperatures have been calculated for the scale numbers 3, 4 and 5 of cloud amount for this area. In order to show that these mean temperatures of the surface were not influenced by sea disturbance, the mean surface conditions have been calculated too.

[1]) The mean amount of cloud has been calculated for the square $\frac{45-50 \text{ N.}}{20-30 \text{ W.}}$; the difference of 0.6 may be considered valid for the whole area.

Table 13 contains the results together with the number of observations from which they have been derived.

TABLE 13.

$\frac{5^\circ\text{—}15^\circ \text{ N.}}{60^\circ\text{—}70^\circ \text{ E.}}$ (D).

Cloud amount and surface temperature.

Cloud amount.	t	Sea disturbance.	Number of obs.
3	26.53	2.3	1639
4	26.53	2.4	1433
5	26.53	2.5	1065

It appears from this table, that the differences in cloudiness, given in table 12 for mean smooth and mean moderate sea disturbance, has not influenced *the mean temperature of the surface itself*.

A second question is: Are not the differences in mean cloudiness (Table 12) responsible for the differences in the *daily variations* of the surface temperature for mean smooth and mean moderate sea disturbance? If this should be the case, the influence might be expected in the first place in the Indian Ocean, where the difference in cloudiness (Table 12, D) is not negligeable and the influence of the suns radiation is greatest.

Consequently the variations of the daily range have been calculated from observations in area D of this Ocean for cloud amount 3, 4 and 5. The results in hundredths of degrees C, together with the number of observations are to be found in table 14.

TABLE 14.

$\frac{5^\circ\text{—}15^\circ \text{ N.}}{60^\circ\text{—}70^\circ \text{ E.}}$ (D).

Cloud amount and daily range of surface temperature.
(In hundredths of °C.)

Cloud amount.	m.	4 a	8 a	Noon.	4 p	8 p	Number of obs.
3	—22	—28*	+6	+17	+33	—7	1637
4	—19	—25*	0	+19	+28	—3	1411
5	—20	—25*	+6	+18	+27	—8	1064

With increasing cloudiness from 3 to 5 the amplitude decreases by $0^{\circ}.09$. This would mean a difference in amplitude of $0^{\circ}.06$ for 1.4 difference in cloud amount, supposing that the influence of the latter changes linearly from scale number 3 to 5. In any case part of the decrease in the daily amplitude with increasing sea disturbance may be ascribed to the accompanying increase of cloud amount.

Instead of calculating the difference in daily range of surface temperature for various cloud numbers and nearly the same sea-disturbance, as has been done here, GALLÉ [1]) compares in square $\frac{2^{\circ}-6^{\circ}\text{ N.}}{86^{\circ}-90^{\circ}\text{ E.}}$ the deviation of mean monthly cloudiness at 6 a. m. and 2 p. m. from the yearly mean with the deviation of the mean monthly amplitude from the yearly mean.

Supposing a fixed difference in cloudiness has the same influence on the maximum in the afternoon as on the morning-minimum, G. gives also the sum of these cloud deviations in the following table.

Month.	Deviation.			
	Cloud Amount.			Amplitude.
	2 p. m.	6 a. m.	2 + 6	
January	— 0.02	— 0.07	— 0.09	— $0^{\circ}.017$
February . . .	— 0.33	— 0.26	— 0.59	+ 0.011
March	— 0.64	— 0.85	— 1.49	+ 0.103
April	— 0.21	— 0.25	— 0.46	+ 0.117
May	+ 0.22	+ 0.41	+ 0.63	+ 0.009
June	+ 0.21	+ 0.23	+ 0.44	— 0.011
July	+ 0.15	— 0.11	+ 0.04	— 0.019
August	+ 0.09	+ 0.15	+ 0.24	— 0.029
September . .	+ 0.17	+ 0.27	+ 0.44	— 0.097
October . . .	+ 0.57	+ 0.56	+ 1.13	— 0.151
November . . .	— 0.08	— 0.08	— 0.16	+ 0.043
December . . .	— 0.10	— 0.02	— 0.12	+ 0.047

Columns 4 and 5 show that on the whole a decrease (increase) of cloud amount corresponds with an increase (decrease) of amplitude.

[1]) l. c. p. 12.

Putting together the results for November—April and May—October it appears that a mean decrease (increase) of cloud amount of 0.5 is followed by an increase (decrease) of $0^{\circ}.05$ in amplitude. This result points to a larger influence of clouds than we found ($0^{\circ}.09$ for 2 scale numbers) but this is not surprising because in GALLÉ'S table the influence of sea disturbance plays a part also.

In columns 2 and 3 nearly all figures have the same sign. This points to the fact, that it is allowable to use mean cloud amount as has been done in table 14; although the moment at which the maxima and minima of clouds occur, and not the mean value, has the greatest influence on the daily range.

Summarising the above, we find:

A. The consequences of increasing sea disturbance from mean smooth to mean moderate, both in the temperate zone in summer and in the equatorial zone in the Indian Ocean are:

1. *A fall of surface temperature* of about $0^{\circ}.50$ C. (Tables 1 and 3).
2. *A decrease of the amplitude* of the daily range of about $0^{\circ}.16$ C. (table 9).

B. In the equatorial area of the Atlantic Ocean this *fall of temperature is only* $0^{\circ}.25$ *C.*, whereas the *amplitude remains practically the same* when the sea disturbance increases [1]. (Tables 2 and 9).

C. In the coastal area of the South-Atlantic Ocean the increase of sea disturbance *in winter* is accompanied by *a mean rise of the surface temperature* of about $0^{\circ}.50$ C., whereas *the daily amplitude decreases* by about $0^{\circ}.16$ C. (Tables 5 and 11.)

D. Although the results for the diurnal variations mainly point to an *earlier* moment of the *maximum and minimum* temperature with *increasing sea disturbance*, this result is not considered as final.

E. The increase of cloud amount, which may be expected when sea disturbance changes from mean smooth to mean moderate (Table 12), has *no influence on the mean temperature itself.* (Table 13.)

F. Only in the N. E. monsoon region of the Indian Ocean this influence *on the daily range* is such that at least *part* of the decrease in daily amplitude with increasing sea disturbance may be *due to cloud influence*. (Tables 12 and 14.)

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[1]) Observations in this area for the condition „mean smooth" are rather scarce.

G. According to the diagrams 1, 2 and 3 *the unaccuracy*, caused by the method, by which the surface water sample has been obtained, *may be of importance* for disturbance 1 and 0. For higher scale numbers the differences in temperature in the *upper* layers will be so small, that the reading obtained may be regarded as surface temperature.

The normal values, derived from *all* observations obtained by the bucket method may be regarded as *differing very little from real surface conditions*.

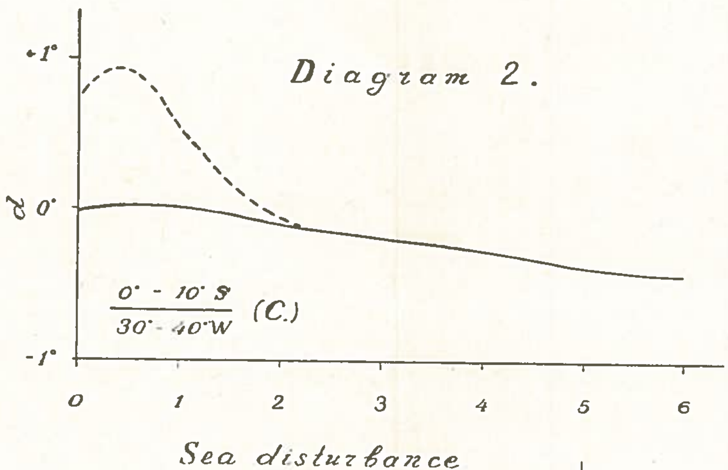

Diagram 2.
+1°
α 0°
-1°
0° - 10° S
30° - 40° W
(C.)
0
1
2
3
4
5
6
Sea disturbance

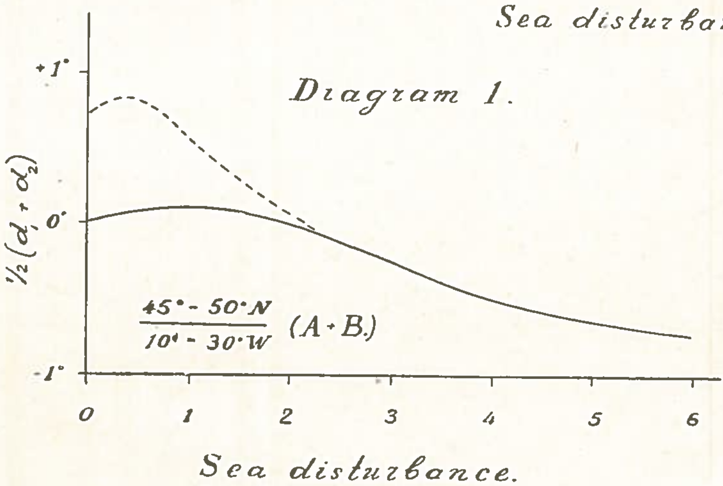

Diagram 1.
+1°
½(α1 + α2) 0°
-1°
45° - 50° N
10° - 30° W
(A + B.)
0
1
2
3
4
5
6
Sea disturbance.

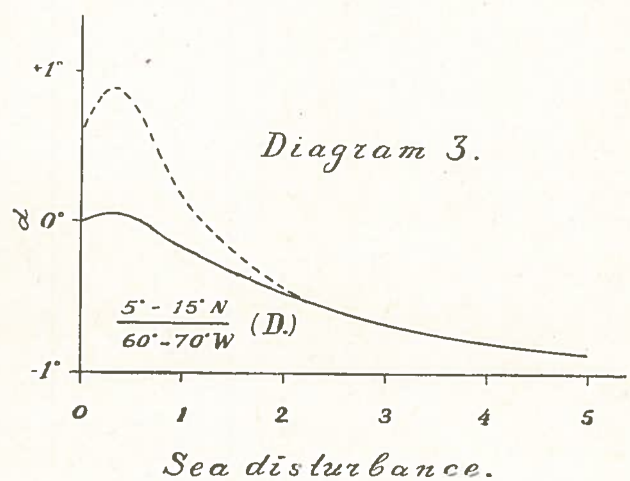

Diagram 3.
+1°
α 0°
-1°
5° - 15° N
60° - 70° W
(D.)
0
1
2
3
4
5
Sea disturbance.