The table shows that during the greater part of the first cruise the scattering was principally due to the state of the sea. The disturbance of the needle increases strongly with the sea waves on account of the ship's rolling. The second part of the table demonstrates the improved balancing, the variations have been reduced to the half value; nevertheless there remains an influence of the waves with moderate sea.

The suspending is good only after March 12, 1930. The influence of the waves has disappeared, the scattering is greatest now when the sea is calmest. And here we meet with the true effect of a steep temperature gradient on calm days, recorded because of the turbulent disturbance caused by the steaming ship.

The influence of the sea is also evident in the daily variation of the maximal scattering. We found the following results.

TABLE 5. Daily Variation of „Scattering" and State of the Sea.

| | 0 h | 2 h | 4 h | 6 h | 8 h | 10 h | 12 h | 14 h | 16 h | 18 h | 20 h | 22 h |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| State of the sea 0. All observations. | | | | | | | | | | | | |
| | 1.2° | 1.8° | 1.4° | 1.4° | 1.0° | 1.8° | 3.0° | 2.9° | 5.1° | 2.2° | 2.4° | 1.5° |
| number | 4 | 9 | 5 | 7 | 5 | 9 | 6 | 7 | 7 | 5 | 5 | 4 |
| State of the sea 1. March 12—Nov. 5, 1930. | | | | | | | | | | | | |
| | 0.7 | 0.8 | 0.5 | 0.7 | 0.9 | 0.8 | 1.6 | 1.6 | 1.7 | 1.0 | 1.1 | 0.6 |
| number | 38 | 26 | 32 | 30 | 44 | 35 | 38 | 44 | 38 | 37 | 42 | 36 |
| State of the sea 2. March 12—Nov. 5, 1930. | | | | | | | | | | | | |
| | 0.7 | 0.5 | 0.8 | 0.4 | 0.2 | 0.5 | 1.0 | 1.1 | 1.4 | 1.4 | 1.5 | 1.7 |
| number | 15 | 16 | 12 | 12 | 8 | 18 | 20 | 17 | 15 | 16 | 13 | 14 |
| State of the sea 3 and 4. March 12—Nov. 5, 1930. | | | | | | | | | | | | |
| | 0.4 | 1.0 | 0.5 | 0.6 | 0.5 | 0.8 | 0.6 | 0.3 | 1.1 | 0.9 | 0.7 | 0.6 |
| number | 9 | 10 | 10 | 9 | 11 | 9 | 10 | 9 | 10 | 8 | 9 | 9 |

Though the number of observations is rather small, an extensive range is obvious with calm sea. This range is reduced to the half value already with very smooth sea, and though present, it is scarcely perceptible with sea 2 or higher. Even such smooth seas as prevail in the Indies are sufficient to spoil the regular decrease of the temperature in the upper layers.

We find a small secondary maximum in the later night hours, which may be due to a reversal of the temperature effect, the sea water now being cooled at the surface. Though the descent of the cold surface water gives a natural mixing, temperature differences still will occur, causing again an increase of the short variations.

### 3. *Comparison with the bucket observations*

The cooling of the sea water in the canvas bucket, before the thermometer was read, was found by Hamaker to be 0.1° per minute.

TABLE 6. Cooling of the Seawater in the Canvas Bucket.

| Date 1930 | Time h m | Temp. after 1—6 min 20° +... | | | | | | Cooling | | | | Air temp. | Rel. hum. | Apparent wind Beaufort | Def. of Sat. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 m | 2 m | 3 m | 4 m | 5 m | 6 m | 1–3 m | 2–4 m | 3–5 m | 4–6 m | | | | |
| 12.4 | 16 | — | 8.5 | 8.3 | 8.22 | 8.12 | — | — | 0.28 | 0.18 | — | 28.4° | 65% | 4 | 10.2 g |
| 14.4 | 14 15 | 8.58 | 8.48 | 8.32 | 8.22 | 8.10 | — | 0.26 | 0.26 | 0.22 | — | 28.3 | 60 | 3 | 11.6 |
| 30.4 | 14 20 | 9.55 | 9.50 | 9.45 | 9.40 | 9.38 | 9.33 | 0.10 | 0.10 | 0.07 | 0.07 | 28.2 | 80 | faint | 5.7 |
| 22.6 | 10 00 | — | 8.70 | 8.59 | 8.49 | — | — | — | 0.21 | — | — | 25.5 | 87 | 2 | 3.2 |
| | 14 00 | — | 9.73 | 9.68 | 9.62 | — | — | — | 0.11 | — | — | 27.0 | 80 | 1 | 5.4 |
| | 18 00 | 9.08 | 8.98 | 8.89 | — | — | — | 0.19 | — | — | — | 28.0 | 75 | 2—3 | 7.1 |
| 23.6 | 14 00 | 8.25 | 8.20 | 8.11 | 8.07 | — | — | 0.14 | 0.13 | — | — | 25.0 | 88 | 3 | 2.9 |

The cooling seems to depend principally upon the wind. We find for its cooling effect from the second to the fourth minute,

TABLE 7. Wind Effect of Cooling.

| Wind | 4 | 3 | 2—3 | 2 | 1 | faint |
|---|---|---|---|---|---|---|
| Cooling | 0.28° | 0.26° | (0.19°) | 0.21° | 0.11° | 0.10° |
| | | 0.13 | | | | |

The low second value at wind force 3 is apparently due to the then low temperature and high humidity (deficit of saturation resp. 11.6 and 2.9).

The temperature decrease because of the wind is 0.14° per minute at wind force 4; 0.05° at wind force 1. We must point here to a direct influence of the wind on the thermometer bulb, when being read in the air in stead of in the water!

Besides the wind other meteorological factors influence the cooling of the bucket water. The principal cause must be the temperature difference *d* between the sea water and the air, the sea water as a rule being warmer than the air (in the mean 0.8°). The cooling will be intensified by the wind and the evaporation. Hence the difference Δ found between the recorded temperature and that of the water in the bucket, is not merely a constant one but depends upon the meteorological factors mentioned. It is possible to unravel these features. The observations after March 12, 1930, reveal the following behaviour of the difference Δ dependent on *d*.

TABLE 8. Temperature Effect of Cooling.

| Difference *d* | —1.0° - —0.2° | —0.1° - +0.1° | +0.1° - +0.3° | +0.4° - +0.6° | +0.7° - +0.9° | +1.0° - +1.2° | +1.3° - +1.5° | +1.6° - +2.0° | +2.1° - +2.5° |
|---|---|---|---|---|---|---|---|---|---|
| mean *d* | —0.40° | +0.04° | +0.21° | +0.48° | +0.78° | +1.08° | +1.37° | +1.74° | +2.30° |
| mean Δ | 0.24 | 0.23 | 0.25 | 0.27 | 0.23 | 0.33 | 0.38 | 0.41 | 0.36 |
| number | 33 | 67 | 107 | 107 | 83 | 62 | 30 | 39 | 16 |

The evaporation depends upon the temperature and the relative humidity and their combined effect is determined by the deficit of saturation. We deduced the following relations between the temperature difference Δ and wind and deficit of saturation.

TABLE 9. Deficit of Saturation Effect of Cooling in Connection with Wind Effect.

| Apparent wind | | Δ | n | Average deficit of sat. | Deficit of saturation | | | |
|---|---|---|---|---|---|---|---|---|
| m/s | Mean | | | | 4—5 | 5—6 | 6—7 | >7 |
| | | | | | Δ | Δ | Δ | Δ |
| 0.0—1.0 | 0.66 | 0.12° | 17 | 6.29 | | | | |
| 1.1—2.0 | 1.81 | 0.14 | 27 | 5.97 | 0.29° | 0.21° | 0.21° | 0.19° |
| 2.1—3.0 | 2.74 | 0.24 | 41 | 5.68 | | | | |
| 5.1—6.0 | 5.75 | 0.25 | 71 | 5.73 | 0.30 | 0.19 | 0.18 | 0.44 |
| 8.1—9.0 | 8.44 | 0.28 | 27 | 4.94 | | | | |
| 9.1—10.0 | 9.78 | 0.33 | 16 | 5.56 | 0.29 | 0.34 | — | 0.50 |
| 10.1—12.0 | 10.97 | 0.36 | 19 | 6.21 | | | | |

The influence of the wind is evident: Δ increases to its threefold value, when the wind increases from 0.7 to 11 m/s.

With regard to the deficit of saturation, we find the influence of the wind to be negligible, when the deficit is small, 4—5 mm, but strong with a large deficit (> 7). With faint winds (0—3 m/s) the influence of the deficit is small, but with strong winds (8—12 m/s) we state a strong influence of the deficit upon Δ. The irregularities of the table may be ascribed to the rather small number of observations, being only 218 in total.

It is clear that bucket temperatures represent by no means the true surface temperatures. Whereas the general average value of all 1045 measurements of Δ is 0.35°, tallying exactly with Hamaker's result, in 32.4% of all cases Δ was between 0.30 and 0.40, in 54.8% between 0.20 and 0.50. We must be aware that systematic errors of 0.2° C. occur in about 50% of all the observations; they are due to meteorological factors, of which the wind is the most important.

We should therefore advise to avoid carefully wind influences on the canvas bucket.

The meteorological influences cause a daily variation in the temperature differences Δ.

TABLE 10. Daily Variation of the Difference: Recorded Temp — Bucket Water Temp.

| | 0 h | 2 h | 4 h | 6 h | 8 h | 10 h | 12 h | 14 h | 16 h | 18 h | 20 h | 22 h |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| First cruise | 0.35 | 0.28 | 0.31 | 0.12 | 0.02 | 0.09 | 0.28 | 0.18 | 0.04 | 0.09 | 0.20 | 0.37 |
| Second cruise | 0.49 | 0.47 | 0.47 | 0.38 | 0.23 | 0.11 | 0.19 | 0.18 | 0.23 | 0.35 | 0.37 | 0.36 |
| Third cruise | 0.29 | 0.21 | 0.38 | 0.35 | 0.05 | 0.14 | 0.12 | 0.08 | 0.12 | 0.28 | 0.38 | 0.33 |

We find a well-marked maximum during the night, a minimum during day time with a secondary maximum about noon.

Here too uncertainties of the temperature of 0.2° C are evident.

## e. MEAN MONTHLY VALUES

Though we have detected some features of the bucket temperatures, it is impossible to apply corrections to all individual readings. We may reduce them to the thermograph readings by adding a constant correction of 0.35° to the mean monthly values of Table 12 (Met Obs. bibl. 11, p. 12) and then we must be aware that we do not obtain real surface temperatures, but temperatures at the depth of the water inlet of the thermograph at about 1.2 m below the surface.

The monthly mean values obtained are as follows.

TABLE 11. Monthly Mean Values of Sea Water Temperature.

| | | | | | |
|---|---|---|---|---|---|
| I 1929 Aug. | 28.3° | II 1930 Feb. | 28.5° | III Aug. | 26.8° |
| Sep. | 28.4 | March | 29.0 | Sep. | 26.7 |
| Oct. | 28.0 | Apr. | 28.7 | Oct. | 27.9 |
| Nov. | 28.5 | May | 28.9 | Nov. | 28.5 |
| Dec. | 29.0 | June | 29.0 | | |
| | | July | 27.7 | | |

The second decimal has been omitted having by no means real value. The general average is 28.3° C, being 1.2° warmer than the air.

The influence of the rain has wholly disappeared at the depth of the electric resistance. The temperature appears to be constant during the whole period from 6 hours before till 6 hours after the rain for the same rain showers made use of in Vol. III (bibl. 11, p. 13, Table 14), varying only irregularly between 28.3° and 28.5°.

## f. DIURNAL VARIATION

Because of the inadequate suspension of the galvanometer during the beginning of the expedition we fear that the values of the daily variation stated at this period, are untrustworthy. Therefore we have only deduced the diurnal range after March 12, 1930. The following values have been found.

TABLE 12. Daily Variation of Seawater Temperature; 20° + ...

| | 0 h | 2 h | 4 h | 6 h | 8 h | 10 h | 12 h | 14 h | 16 h | 18 h | 20 h | 22 h | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| > 100 km from coast | 8.56 | 8.46 | 8.39 | 8.38 | 8.31 | 8.35 | 8.50 | 8.78 | 8.86 | 8.75 | 8.70 | 8.68 | 8.56 |
| < 100 km from coast | 8.21 | 8.10 | 8.11 | 8.10 | 8.12 | 8.10 | 8.24 | 8.34 | 8.37 | 8.25 | 8.14 | 8.19 | 8.20 |

| | | |
|---|---|---|
| > 100 km | $t = 28.56° + 0.24 \sin(x + 178.9) + 0.06 \sin(2x + 350.6)$ | 277 observ. |
| < 100 km | $t = 28.20 + 0.10 \sin(x + 206.7) + 0.06 \sin(2x + 16.5)$ | 737 observ. |

The bucket observations yielded the following harmonic equations (bibl. 11, p. 15).

> 100 km $t = 27.96° + 0.18 \sin(x + 223.9) + 0.03 \sin(2x + 332.5)$

< 100 km $t = 28.01° + 0.33 \sin(x + 226.0) + 0.10 \sin(2x + 49.5)$

The differences are due partly to the correction of 0.3° not being applied to the bucket temperatures, partly to the much more extensive bucket observations.

We state a well defined retardation of the diurnal period in the thermograph records: whereas the maximum occurred at 15 h for the surface observations, it is for the thermograph at 16.2 h within the 100-km limit, and even at 18 h beyond. This retardation is also due to the fact that the thermograph recorded the temperature at about 1.2 m below the surface.

The records on roadsteads or in harbours do not furnish trustworthy results. The circumstances were too heterogeneous in the different places and the stay in each harbour was too short. Moreover when the ship lay stopped, the sticking of the needle was considerable.

We make an exception for Amboina. The ship stayed here April 19—22 and October 13—20, 1930, and by happy accident the sticking was pretty rare: 9 hours only had to be scratched.

The temperature in the bay of Amboina shows a remarkable dependency on the tides.

The bay of Amboina is long and narrow and consists of two parts, the outer and the inner bay, the town of Amboina being situated between.

The tide, April 19—22, was principally diurnal with a steep fall from 17 to 1 h. There was only a small indication of the semidiurnal wave. The range decreased in the course of these days, being 168 cm on the 18th, 144 cm on the 19th, 121 cm on the 20th, 102 cm on the 21st and 55 on the 22nd.

Temperature records are available from April 19, 9 h, till April 22, 6 h. They are characterized by the common daily maximum at about 14 h, but moreover a strong increase is present every night at about 22 h, about four hours after high tide.

We may represent the features of tide and temperature by their average values during the three-days' stay at Amboina (fig. 4) and then we understand that the high night temperatures of the sea water are due to warm water from the inner bay pouring out during falling tide.

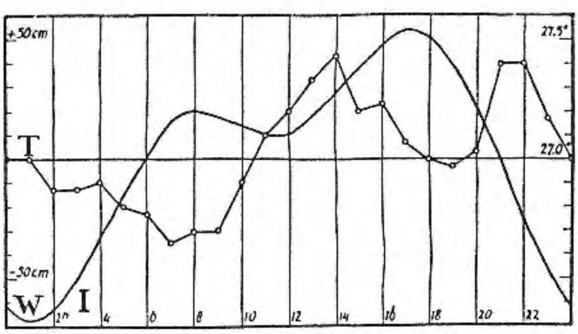


Fig. 4. Seawater temperatures and tides at Ambon, April 19—22, 1930.

During the second stay at Amboina, Oct. 13—20, the tide was at first evidently diurnal with a strong fall from 4 till 11 h (Oct. 13 173 cm; Oct. 14 183 cm; Oct. 15 156 cm; Oct. 16 131 cm; Oct 17 114 cm). The semidiurnal wave increases at the same time and after Oct. 17 the tide has become semidiurnal.