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Corresponding in order of magnitude with my figures.

There seems to exist no relation with the density of the solid. But it seems that substances with many atoms in the molecule have a larger radius.

Although the results found may still need correction from the fact, that the boundary of the waterlayer and the vapour is not so sharply defined as has been supposed, and because the compressibility of liquid water has been neglected, the results seem interesting enough to call attention to them. Perhaps then some one more competent on this subject, will deduce a less approximate theory. This theory will also have to answer the question, what is the relation between the maximum and the minimum in TROUTON's curves with the maximum and the minimum in the isotherm of VAN DER WAALS, and if the supposition is right, that it is possible to calculate the maximum and the minimum of the equation of state from the minimum and maximum in TROUTON's curves.

The importance of these investigations for the problem of swelling (imbibition) will be treated later.

**Meteorology.** — *"The Correlation between Atmospheric Pressure and Rainfall in the East-Indian Archipelago in connection with the 3,5 yearly barometric period".* By Dr. C. BRAAK. (Communicated by Dr. VAN DER STOK).

(Communicated in the meeting of June 29, 1912).

The regularity of the East-Indian climate renders it eminently fit for clearly revealing weather variations of longer period. There the interest in the weather of next day is quite subordinate to the question whether the coming season will bring much or little rain and since predictions for the immediate future are not wanted, full attention can be paid to those for a more distant future. And this the more so as the circumstances there promise a much better chance of success for a prognosis of the seasons than elsewhere.

That the variations from one year to another are very considerable and an investigation of their character and origin is important, may, perhaps superfluously, be proved by the following summary: (p. 455)

One naturally looks for a relation between the oscillations in the rainfall and the barometric changes of long period.

These variations of the atmospheric pressure are of the same character over an area extending from British India over the Indian

TOTAL RAINFALL IN M.M. IN THE MONTHS JULY, AUGUST, AND SEPTEMBER

| | Wet East monsoons | | | | Dry East monsoons | | |
|---|---|---|---|---|---|---|---|
| | Batavia | Ternate | Koepang | | Batavia | Ternate | Koepang |
| 1880 | 363 | 599 | 0 | 1881 | 121 | 268 | 0 |
| 82 | 144 | 485 | 36 | 83 | 30 | 254 | 0 |
| 89 | 148 | 475 | 4 | 85 | 22 | 61 | 0 |
| 90 | 290 | 452 | 18 | 88 | 34 | 42 | 1 |
| 92 | 248 | 353 | 1 | 91 | 102 | 321 | 0 |
| 95 | 262 | 470 | 44 | 96 | 51 | 393 | 0 |
| 98 | 162 | 402 | 10 | 1902 | 16 | 38 | 0 |
| 1900 | 146 | 370 | 82 | 05 | 119 | 261 | 22 |
| 04 | 340 | 145 | 16 | 11 | 155 | 133 | 0 |
| 06 | 364 | 434 | 3 | | | | |
| 09 | 215 | 697 | 37 | | | | |
| 10 | 258 | 305 | 5 | | | | |
| Average | 245 | 432 | 21 | | 72 | 197 | 3 |

Archipelago as far as Australia. They are regular and can with great approximation be represented by a series of waves with periods of 3 to 5 years; the other periods are quite subordinate. As a typical example we mention the amospheric pressure at Port-Darwin where not only the amplitude is maximal, but also the variations are characterised by an extraordinary regularity [1]). For this reason in what follows the rainfall in various parts of the Archipelago has been referred to the indications of the barometer at this station.

The stations whose observations are regularly published by the Batavia Observatory under the title "Rainfall observations in the Dutch East Indies" were arranged in groups, containing places of approximately similar situation. These contain from 1 to 5 stations and are:

1 North Sumatra, 2 North East Sumatra, 3 East Middle Sumatra, 4 Padang Highlands, 5 West Middle Sumatra, 6 South East Sumatra, 7 South West Sumatra, 8 West Borneo, 9 South Borneo, 10 North coast of West Java, 11 the Preanger district, 12 North coast of

[1]) Cf. Meteorologische Zeitschrift, Heft 1, 1912, p. 1.

Middle Java, 13 Madioen, Kediri, Blitar and Malang, 14 North coast
of East Java, 15 the Lesser Sunda Islands and Timor, 16 West
coast of South West Celebes, 17 East coast of South West Celebes,
18 South coast of North Celebes, 19 North coast of North Celebes,
20 Amahai, Banda, Ambon and Saparoea, 21 Wahai and Kajeli,
22 Ternate.

For our analysis the period 1883—1908 was chosen.

For each group the deviations of the monthly means were calcu-
lated from the monthly means of all the years of observation,
including 1908. Since probably the oscillations in the rainfall have
a retardation of about two months with respect to those of the atmos-
pheric pressure [1]), the barometric deviation for January, February
etc. was always compared with the rainfall for March, April etc.
Being only a small fraction of the total period, this shifting is indeed
of secondary importance, but still it has the advantage of eliminating
the pressure variations of short duration, which as a rule last a
month or less and probably are not without any influence on the
formation of rain.

In order to express mathematically the relation between rainfall
and atmospheric pressure, the correlation factors between them were
calculated for each group and for the twelve months. Denoting by
$x_1 \, x_2 \, x_3 \ldots x_n$ the deviations of the separate monthly averages from
the general monthly mean for the rainfall and by $y_1 \, y_2 \, y_3 \ldots y_n$ for
the atmospheric pressure, the correlation factors are represented by [2]):

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \times \Sigma y^2}}.$$

The values of $r$ have been collected in the following table.

From these data the following conclusions may be drawn:

*An influence of the mountain ranges on the correlation cannot be
proved with certainty.* For the Preanger district behaves in the same
way as the coast stations of Java and the stations of group 13,
lying between high volcanoes. Also the West and East coast of
South-West Celebes (except in January, February, March, and
May), the South and North coast of North Celebes (except in
April) and the stations to the North (group 21) and to the South
(group 20) of the mountains of Ceram and Buru (except in February
and April) behave generally in a similar way; besides, during

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[1]) Cf. Natuurk. Tijdsch. voor Nederl. Indië, Vol. LXX, p. 110.

[2]) Cf. R. H. Hooker: An elementary explanation of correlation ..., Quarterly
Journal Royal Met. Soc. Vol. 34, p. 277, 1908 and the extract by Felix M. Exner
in Meteorol. Zeitschr. June 1910, p. 263.

# CORRELATION FACTORS

Atmosph. pressure at Port-Darwin — Rainfall in the Archipelago.

| Group | Jan. | Febr. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.04 | —0.10 | —0.11 | —0.00 | 0.07 | 0.14 | 0.22 | —0.18 | —0.09 | 0.16 | 0.10 | 0.07 |
| 2 | .06 | — .32 | — .35 | — .21 | .05 | .17 | — .28 | .09 | .33 | — .09 | — .10 | — .07 |
| 3 | — .02 | — .07 | — .50 | .45 | .23 | — .32 | — .45 | — .12 | — .06 | .13 | .46 | .19 |
| 4 | .44 | .42 | — .15 | .23 | .09 | .17 | .06 | — .26 | .09 | .12 | .19 | .03 |
| 5 | .19 | .29 | — .10 | .12 | .38 | .02 | — .05 | — .10 | — .23 | — .14 | — .05 | .01 |
| 6 | .22 | .01 | — .30 | .19 | .05 | — .12 | — .12 | — .29 | — .23 | — .52 | — .61 | — .17 |
| 7 | — .15 | .49 | .03 | — .04 | .28 | .19 | — .32 | — .43 | — .31 | — .53 | — .25 | — .14 |
| 8 | .41 | .25 | — .06 | .40 | .19 | .23 | .02 | — .29 | — .30 | .04 | .00 | .34 |
| 9 | .16 | .16 | — .07 | .46 | — .03 | — .03 | — .29 | — .27 | — .33 | — .25 | — .25 | — .05 |
| 10 | .16 | .01 | .13 | .40 | .15 | — .16 | .00 | — .20 | — .28 | — .45 | — .06 | .05 |
| 11 | .34 | .36 | .05 | .22 | .07 | — .19 | — .03 | — .19 | — .25 | — .44 | — .38 | — .03 |
| 12 | — .08 | — .05 | .24 | .00 | — .32 | — .16 | .02 | — .15 | — .23 | — .60 | — .32 | — .32 |
| 13 | .37 | .21 | .31 | .39 | .01 | — .06 | .01 | — .15 | — .45 | — .57 | — .64 | .38 |
| 14 | .38 | .12 | .27 | .11 | — .35 | — .30 | .10 | .09 | — .20 | — .41 | — .69 | — .12 |
| 15 | — .04 | — .11 | .15 | — .20 | — .40 | — .06 | .12 | .22 | — .38 | — .18 | — .59 | — .05 |
| 16 | — .22 | — .30 | — .29 | .22 | .02 | — .05 | — .14 | — .24 | — .25 | — .39 | — .54 | — .25 |
| 17 | .35 | .20 | .42 | .38 | — .22 | — .14 | — .22 | — .34 | — .37 | — .46 | — .41 | - .10 |
| 18 | — .18 | — .40 | — .19 | .30 | .18 | — .22 | — .12 | — .37 | — .43 | — .35 | — .40 | .30 |
| 19 | — .46 | — .22 | — .37 | - .04 | .49 | - .31 | — .25 | — .40 | — .55 | — .35 | — .37 | .18 |
| 20 | .11 | — .12 | .32 | — .33 | — .50 | — .38 | — .33 | — .54 | — .36 | — .18 | — .37 | — .35 |
| 21 | .09 | .48 | .47 | .42 | — .36 | — .27 | — ..30 | — .37 | — .28 | — .23 | — .55 | — .24 |
| 22 | — .35 | — .37 | — .40 | — .28 | — .00 | — .38 | — .33 | — .39 | — .37 | — .37 | — .53 | — .26 |

the bracketed exceptional months the minus sign prevails on the South coast of South West Celebes and the plus sign on the East coast, while the stations of group 21, similarly situated with respect to the monsoons as the West coast, have the plus sign and those of group 20, situated like those on the East coast, the minus sign, which is exactly contrary to what one would expect if the mountains determined the sign.

On the other hand we clearly perceive a *variation of the correlation with the geographical longitude and latitude and with the season*. Leaving aside for the present the western part of the archipelago north of the equator, we find in the remaining part in the East monsoon with a few unimportant exceptions negative correlation, increasing in amount from West to East. In the West monsoon the negative sign still prevails in the East, in the West however the positive sign appears almost without exception, so that there a surplus of rain falls during the barometric maximum.

The explanation suggests itself that this change of sign of the correlation depends on the wind, which has also opposite directions in both monsoons. Now the relation between the barometric changes and the force of the monsoons is such that during the maximum of atmospheric pressure (caused by the relatively large amplitude of the barometric oscillation over Australia) the wind is reinforced during the East monsoon and weakened during the West monsoon, while at the minimum the opposite occurs [1]). From this we conclude that *strengthening of the monsoon, either East or West, impedes the formation of rain*. This phenomenon must be partly ascribed to the development of fewer local showers when a stronger wind prevails, partly, especially in the East monsoon, but perhaps also in the West, to the circumstance that the air, when it moves in a quicker current, remains a shorter time above the sea.

The stronger negative correlation in the East would indicate that here, besides the influence mentioned above, still another factor makes itself felt, as well in the West as in the East monsoon. Very likely we have here a more direct influence of the neighbouring active centre in North Australia, *causing drought during the maximum by falling air-currents, rain during the minimum by rising currents*.

Though the variation of the correlation finds in this way a natural explanation for the greater part of the Archipelago, the matter is less simple for the remaining North-western part. There, as in Java, the correlation is, generally speaking, opposite for both monsoons, but it is negative when Java has a positive correlation and vice versa.

It is possible that the Barisan range, which in the northern part of Sumatra lies straight across the path of the monsoon, makes its influence felt. Also another explanation can however be given.

While during the maximum the influence of Australia increases the pressure difference in other places, it is quite possible that here

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[1]) Cf. Natuurk. Tijdschrift voor Ned. Indië, Vol. LXX, p. 105.

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the opposite occurs. The difference namely of the barometric devia-
tions at Batavia and Singapore changes in an irregular manner and
points to a transitional region between these two places, whereas the
difference between the deviations at Port-Blair (Andaman Islands),
and those observed at Singapore, runs parallel with the barometric
deviations at Port-Darwin, although with a small correlation ($r=0,15$).

While the atmospheric pressure goes through its 3 to 5-yearly
cycle, during the maximum in the South, Middle and East air-
currents from the South would be superposed on the general flow
of the monsoon and in the North-East, although to a smaller extent,
from the North and currents from opposite directions during the
minimum. Between the two currents a rising or falling movement
should appear. The predominant positive correlation during the whole
year in the Padang Highlands and in group 8 (Pontianak and Sing-
kawang), which are approximately situated on the border line, might
be a consequence of this vertical movement of the air. The corre-
lation factors in the North-western exceptional region are small
however, so that not much importance must be attached to these
speculations.

Nor can we expect much for this region in the way of predictions,
at any rate on the lines here developed. *Matters are quite different
for the remaining part of the Archipelago, where the correlation under-
goes regular changes and reaches fairly considerable values.*

The great question thus remains how we can obtain sufficient cer-
tainty about coming changes in the atmospheric pressure. Very likely
we shall have to pay less attention than was done until now to the
sun and the changes occurring there, but we shall have to look
especially for a terrestrial cause and shall have to study the coope-
ration of metereological phenomena over the whole world.

*For the temperature changes, observed in British India, the Archi-
pelago and Australia find a natural explanation from the fluctua-
tions in the general circulation of the atmosphere, accompanying the
barometric changes, while it is difficult to bring them into relation
with changes in the solar radiation,* which surely would reveal
themselves in a direct manner in temperature changes.

These temperature changes are of a twofold nature:

1.  In this tropical region, where long-period changes in the
atmospheric pressure are brought about not dynamically, but enti-
rely thermally, these must be accompanied by simultaneous tem-
perature changes of opposite sign in the air-column above the
spot of observation. In agreement with this we find e.g. from a
comparison of the changes in atmospheric pressure at the mountain

station Kodaikanal (height 2340 m.) in the South of British India with those at the base-station Peryakalam (290 m.) that the average temperature of the intermediate layer undergoes oscillations of about 0,7° C., opposite to the simultaneous barometric changes at the base-station. The correlation factor between the two is $r = 0,75$. The station Kadaikanal evidently still lies in the stratum in which these temperature changes occur, for the temperature there changes in the same way as in the layer underneath. The correlation factor between the two temperature changes is $r = 0,69$.

With an amplitude of the atmospheric oscillation of 0,6 mm. at sea-level and of the temperature oscillation of 0,7° C., the air-stratum in which both changes would be in harmony would lie at about 1000 m. above the mountain station. The temperature changes are in this case restricted to the *condensation level.*

The results of ELIOT's investigations [1]) would show that this is a general phenomenon. From a comparison of the barometric changes at the mountain stations in British India with those of the stations in the plains, he deduced that during the barometric maxima at sea-level, an abnormally large quantity of air is found below the level of the mountain stations and an abnormally small quantity during the minima. The temperature changes that determine the barometric pressure here occur in the lower 2000 tot 3000 metres in the region where the heat of condensation plays an important part.

2. In the very lowest strata of the atmosphere the oscillation of the temperature is of a different nature. Over the whole of the area here considered the temperature of the stations in the plains follows namely very regularly the identical barometric change with a lag of about six months [2]). This oscillation of the temperature must have had a disturbing action on the observed barometric oscillation, since the phase differs by about a year (i.e. more than $^1/_4$ period) from the value required for the formation of the barometric oscillation (see 1). Still no disturbance is observed and the curves representing the barometric oscillation and these temperature changes generally show great similarity. This must probably be ascribed to the small thickness of this layer, which consequently has to be considered as a thin transition layer resting on the surface of the earth.

The temperature oscillations mentioned sub 1 and 2 are in complete agreement with the following scheme of changes :

If we suppose the general circulation of the air to be subjected to fluctuations in such a way that it is increased by the barometric

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[1]) Indian Metereological Memoirs VI, p. 102.
[2]) Cf. Metereol. Zeitschrift loc. cit.

minimum in India and Australia and weakened by the maximum, as must undoubtedly be the case, the successive stages may be imagined as follows. During the barometric minimum an increased mixing takes place with the cool air from higher latitude together with an increased supply of cold water. By these causes after the barometric minimum a temperature minimum is developed in the lower strata of the atmosphere. In the upper strata, however, by the greater heat of condensation, resulting from the increased ascending motion of the air, a temperature maximum will develop simultaneously with the barometric minimum and this maximum will in its turn determine and strengthen the barometric minimum. This latter process will continue until the progressive sinking of the temperature of the water and the air below, cause the condensation to diminish and the atmospheric pressure to rise by a smaller supply of water-vapour and greater density of the air and in this way the following phase is prepared.

The energy required for keeping up this process is partly supplied by the increased heat of condensation during the barometric minimum and may for another part be derived from the interaction with the active centres of higher latitude where the deviations, once started, reinforce themselves, contrary to the tropical system of circulation where they are self-regulating [1]).

*Weltevreden*, May 10, 1912.

**Geology.** — *"On Orbitoids of Sumba"*. By Dr. L. RUTTEN. (Communicated by Prof. A. WICHMANN).

(Communicated of the meeting of September 28, 1912).

From Professor WICHMANN I received a short time ago a small collection of specimens of rocks and fossils belonging to a collection gathered by Mr. H. WITKAMP, geologist of the Bataafsche Petroleum-Maatschappy in the southern part of the Island of Sumba.

I beg to communicate here some particulars about the Orbitoids found in this collection. In 5 of the samples sent to me I discovered Orbitoids i.e. in 4 numbers (81, 114, 166 and 167) the subgenus Orthophragmina, and in 1 number (105) the subgenus Lepidocyclina.

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[1]) Cf. Metereol. Zeitschr. loc. cit.