Geophysics. — *On a Period of 27 Months in the Rainfall.* By S. W. VISSER. (Communicated by Prof. E. VAN EVERDINGEN).

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A research into the possibility of long range weather forecasting in the Netherlands led to the investigation of a period of 27 months in the weather of different regions. We found clear indications of this period in Eastern America, on Iceland and in Western Europe. It shows close connections with the warm currents of the North Atlantic Ocean.

The data, upon which the following considerations have been based, were taken from "World Weather Records" [1]) and different publications of De Bilt [2]). We have restricted ourselves in this paper to the rainfall. The process applied was as follows. In the first place seasonal totals of rainfall were calculated from the available data, then averages and the deviations therefrom were deduced. These deviations were arranged in nine columns, representing the whole period of 27 months, and the average values representing the character of the oscillation were determined.

The curves obtained are generally very complicated and we have surely not to do with a simple phenomenon. Fig. 1 represents the features of the period for four stations. In Western Europe it is characterized by a well

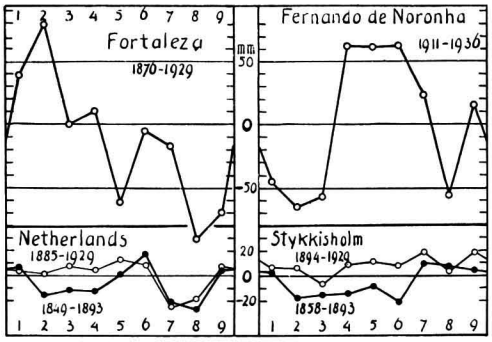

Fig. 1.

developed minimum during the 7th and the 8th season of the period, as is obvious in the curve of the Netherlands. We state very high amplitudes at Fortaleza (Ceara, Brazil) and on Fernando de Noronha. As a rule the

[1]) World Weather Records, Smiths. Misc. Coll. **79**, 1927; **90**, 1934.

[2]) C. BRAAK, The climate of the Netherlands, Precipitation. Meded. en Verh. **34** *a*; C. BRAAK, The climate of the Netherlands West Indies, Meded. en Verh. **36**; Annuaires Inst. royal des P.B.; Maandel. Overzichten der Weersgesteldheid in Nederland; Overzichten Met. Waarn. in Ned. West-Indië.

stability is remarkably good, as appears when comparing the curves for two parts of the interval investigated (Netherlands and Stykkisholm). Even during cycles of nine years duration, containing four periods of 27 months, the stability in the precipitation in the Netherlands is fairly constant (Table 1).

TABLE I. Stability of 27-Month Period in the Rainfall of the Netherlands.

	1	2	3	4	5	6	7	8	9
1849—1857	− 2.2	−18.7	−20.9	−12.9	−22.7	− 2.7	+39.8	−49.3	−26.7
1858—1866	−16.6	−23.9	−17.2	−32.0	−35.6	+ 4.9	−22.6	− 4.4	+ 0.9
1867—1875	+39.2	−32.3	+22.2	−34.4	− 2.2	+30.9	−43.0	−28.3	+23.3
1876—1884	+28.8	+24.1	− 2.5	+16.0	+41.0	+26.0	−15.4	−18.7	+ 2.2
1885—1893	− 3.7	−26.5	− 4.5	+ 0.3	+22.4	+25.8	−64.7	−32.2	+18.5
1894—1902	−24.4	−35.6	+48.9	−18.5	−19.8	+ 1.1	+ 3.8	− 9.7	− 7.6
1903—1911	− 4.5	+37.2	+19.6	+37.7	+ 3.0	−38.7	−47.2	−36.2	+13.0
1912—1920	+36.0	+ 0.0	+15.2	+28.3	+19.9	+37.2	− 2.2	+ 3.4	−28.8
1921—1929	− 9.3	+ 5.4	+ 6.0	−35.3	+ 9.5	− 5.8	−23.2	−16.1	+41.2

The severest exception is that of the cycle 1894—1902. About the end of the century an important change in the weather elements of Europe has been stated [3]) and this fact influences evidently the character of the period.

It seemed worth while to investigate the character of this period on and round about the Northern Atlantic Ocean. Though it is open to question, whether we may apply harmonic analysis, we have done so in order to detect some general features of this period. The calculations have been restricted to the first two terms of the series.

For most of the stations investigated the rainfall between 1876 and 1929, being 54 years or 6 nine-years cycles, has been studied. The successive cycles started, with the winters of 1876 (December 1st, 1875), 1885 etc. (See Table 1). The present period of 27 months started with the autumn of 1936.

We found in the first place that we could subdivide the stations in two groups, 1°, a group with its maximum about the 5th to the 7th month: Fortaleza and Charleston in America and a number of stations in Europe: the Netherlands, Great Britain, Oslo, Breslau and Paris; 2°, a group with its maximum during the 14th month or later, Fernando de Noronha, Barbados, Bermuda, Stykkisholm, Thorshavn (Faroer).

The first group contains continental stations, the other group principally oceanic ones. Therefore we may presume an action at sea differing greatly

[3]) A. SCHMAUSS, Beitr. z. Phys. d. fr. Atm. **14**, 1932.

from that on land. Even at relatively small distances the character differs considerably: Fernando de Noronha and Fortaleza, Aberdeen and Thorshavn, Oslo and Bodö (See Table 4).

The second feature revealed is a retardation combined with a decrease of the amplitude on the Atlantic Ocean in the direction of the Gulfstream, as shown by the following harmonic formulae.

TABLE 2. Harmonic Analysis of 27-Month Period on the Atlantic Ocean.

						Maximum
F. de Noronha	3.8° S 33.5° W	53.9 sin (x + 265.3°) + 40.9 sin (2x + 146.5°)				13.8 month
Barbados	13.1 N 59.6 W	13.2	262.1	8.9	108.0	14.1
Bermuda	32.3 N 64.8 W	24.1	226.1	13.7	120.1	16.8
Ponta Delgada	37.7 N 25.7 W	2.2	209.6	8.5	206.6	18.0
Stykkisholm	65.5 N 22.8 W	8.6	187.2	0.4	204.8	19.7
Thorshavn	62.0 N 6.8 W	9.0	158.1	7.3	68.3	21.9
Bodö	67.3 N 14.4 E	15.1	184.9	11.5	281.2	19.9

N.B. Fernando de Noronha 1911—1936; Barbados 1883—1930; Thorshavn 1873—1925.

The large amplitude on Fernando de Noronha shows that probably here or in the neighbourhood the disturbance takes its origin and the table teaches that the wave needs six or seven months to cross the Ocean; it depends probably on changes in the Gulfstream under the influence of the trade winds or other meteorological factors. This result corresponds with that of GALLÉ [4]), who deduced high correlation coefficients between the trade winds in the summer and the following winter temperatures in Europe.

The rainfall minimum in Western Europe coincides strictly with the arrival of the maximum in the NE Atlantic. Harmonic analysis yields the following results,

TABLE 3. Harmonic Analysis of 27-Month Period in Western Europe.

						Minimum
Greenwich	51.5° N 0.0°	11.8 sin (x + 357.4°) + 10.8 sin (2x + 130.4°)				20.4 month
Netherlands	52 N 5 E	11.2	358.4	12.6	133.8	20.4
Paris	48.8 N 2.5 E	9.1	350.8	8.1	128.3	20.9
Aberdeen	57.2 N 2.1 W	6.6	346.4	12.2	114.0	21.3
Breslau	51.1 N 17.0 E	3.3	354.4	9.4	92.3	20.7

[4]) P. H. GALLÉ, Verslagen K. Ak. v. Wet. Amsterdam, 27 Febr. 1915, 29 Jan. 1916; Proc. Royal Acad. Amsterdam, **17**, 1147 (1915); **18**, 1435 (1916).

The importance of these results for the long range weather forecasting in Western Europe is evident. The superfluous rain in the fifth season on Fernando de Noronha is followed by deficient precipitation in the seventh season in Western Europe. The dryness of the seventh season is best developed at Greenwich. Out of 24 periods, 1876—1929, 19 were here too dry. We have a probability of 80 % when forecasting a too dry seventh season at Greenwich. In the Netherlands 18 seventh seasons during the same time interval were too dry and during the 36 periods, 1849—1929, 26 cases (72 %) gave a deficient precipitation. These figures are foreshadowing a too low rainfall during the coming seventh season: the spring of 1938.

Comparison with the rainfall on Fernando de Noronha is only possible since 1911. The connection between the precipitation for 11 periods, 1911—1936 [5]), during the fifth season on this island and that during the seventh season in the Netherlands is shown in fig. 2. The abscissae procure the deviations of the seasonal averages of Fernando de Noronha, the ordinates those of the Netherlands. The figures refer to the dutch seasons (W winter, L spring, Z summer, H autumn). The contrast is present, but important exceptions exist. Especially we point to the large discrepancies of two seasons, the summer of 1931 and the autumn of 1915.

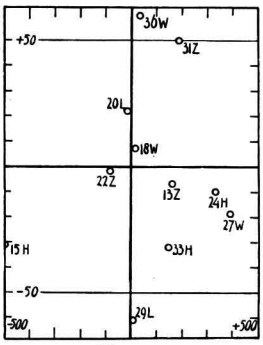

Fig. 2.

We may be sure that the weather in Western Europe does not depend upon the Gulfstream only and other factors doubtless disturb the regular development of the Gulfstream activity.

Moreover the harmonic analysis does not yield trustworthy results, when other actions are present also. So the small irregularities in the months of arrival of the maximum at Thorshavn and Bodö are due to failure of the harmonic analysis. When consulting the original figures we see that the wave arrives at the Faroer at an earlier date, about the 20th month, at Bodö, however, later, about the 21st month (see table 4).

The contrast between the rainfall maximum at sea and the simultaneous minimum on land appears to be a general rule and the figures point clearly to a retardation of the minimum along the eastern coasts of America, everywhere coinciding with the passing of the maximum on the Atlantic. We state exceptions to be present in the NE of North America, at Toronto and Eastport and at Ivigtut on Greenland, evidently being situated outside the area of activity of the Gulfstream.

Table 4 gives the averages of the continental and oceanic stations investigated.

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[5]) Boletim Mensal and Boletim Diario, Dir. Met. Rio de Janeiro.

TABLE 4. 27-Month Period. Average Values for Nine Seasons. Rainfall in mm.

	Oceanic Stations									Max. month
	1	2	3	4	5	6	7	8	9	
F. d. Noronha	−45	−65	−58	**+62**	**+61**	**+62**	+23	−56	+15	14
Barbados	+10	− 2	−30	**+28**	− 2	**+28**	+10	0	−33	14
Bermuda	+15	−33	−41	− 8	**+33**	+ 8	+15	+23	−30	17
P. Delgada	−10	−10	0	+ 4	+ 8	− 1	−10	+10	+ 9	18
Stykkisholm	+ 2	− 3	− 5	− 2	0	− 3	**+ 6**	+ 2	+ 4	20
Thorshavn	+ 4	+11	− 6	−30	− 1	**+20**	**−12**	**+17**	− 5	20
Bodö	−15	− 3	−13	0	−22	+ 4	**+20**	**+26**	+ 3	21
	NE America									
Toronto	**−21**	+19	+ 4	+ 8	−14	+14	− 2	− 7	0	—
Eastport	− 6	+18	−23	+13	− 3	+20	+13	− 5	−18	—
Ivigtut	−20	−32	− 3	+ 9	+27	−16	+12	+33	−11	—

	Continental Stations									Min. month
	1	2	3	4	5	6	7	8	9	
Fortaleza	+39	+79	0	+10	**−60**	− 5	−17	−90	−70	14
Paramaribo	− 3	− 5	− 2	−27	+ 7	**−18**	+21	+19	+ 7	14
Key West	+20	−27	−18	+20	+36	**− 6**	**−10**	− 5	−11	17
Charleston	− 1	+ 5	+13	+37	−13	−17	**−28**	− 7	−22	17
Valentia	+10	+22	− 7	+ 4	− 2	+ 3	**−14**	− 2	−15	19
Greenwich	+ 5	+ 3	+ 3	+11	+11	+ 6	**−24**	−15	− 1	20
Aberdeen	+14	− 5	+ 4	− 2	+11	+11	**−14**	−17	− 2	20
Netherlands	+ 4	+ 1	+ 7	+ 5	+13	+ 8	**−25**	−18	+ 6	20
Paris	− 4	+ 8	+ 6	− 2	+17	+ 7	**−26**	− 5	− 1	20
Oslo	+17	−14	+ 2	− 8	+ 6	+11	+10	**−18**	− 7	22
Breslau	+14	− 3	+ 1	− 8	+16	− 1	− 3	**−14**	− 2	22