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The effect of Fluctuations of the Gulf Stream on the Distribution of Pressure over the Eastern North Atlantic and Western Europe

By

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THE EFFECT OF FLUCTUATIONS OF THE GULF STREAM ON THE DISTRIBUTION OF PRESSURE OVER THE EASTERN NORTH ATLANTIC AND WESTERN EUROPE

§ 1. INTRODUCTION.

The question, in what way does the Gulf Stream affect the weather of western Europe, is one which has been much debated, but the physical principles involved are complex and the only way in which an answer can be given appears to be by means of a statistical comparison between the fluctuations in the strength of the Gulf Stream and the subsequent weather. The data available as to the volume and temperature of the Gulf Stream are not sufficient for such a comparison to be carried out directly, and we have to go back a step further and consider the variations in the strength of the winds which give rise to the Gulf Stream. These are primarily the north-east and south-east trade winds of the Atlantic Ocean, but the current which originates in the tropical Atlantic has to pass through the Gulf of Mexico and along the eastern coast of the United States to the Newfoundland Banks, whence the greater part of the warm surface water drifts eastwards across the Atlantic under the influence of the prevailing westerly winds. Variations in the conditions in any part of this long course may be expected to influence the distribution of surface temperature in the eastern North Atlantic, and have to be considered as far as possible. Hence the effects of the following variables are discussed :—

1. NE. trade wind.
2. SE. trade wind.
3. Pressure at Havana, Cuba.
4. Pressure difference, Bermuda—Charleston.
5. Pressure difference, Bermuda—Sydney.
6. Pressure difference, Azores—Iceland.
7. Pressure difference, Stornoway—Iceland.

In the first instance the period over which the variations were studied was limited to the years 1891 to 1915 ; it is recognized that this is short, but longer series of observations were not readily available. Other years have in some instances been employed to check the results.

The first point to be investigated is the rate of flow of the various branches of the Atlantic circulation. The following information is taken mainly from a paper by the late Captain Hepworth supplemented from various other sources.*

The NE. and SE. trade winds give rise to currents which gradually turn more and more to the westward and increase in volume as they approach the equator, until they flow side by side as the North Equatorial Current and South Equatorial Current. South of 20° N. the mean surface speed of the North Equatorial Current is 17 nautical miles a day ; the South Equatorial Current is stronger, with a mean speed of 23 miles a day near the equator, varying from 25 in June and July to 18 in October to December. Further south the velocity decreases. The greater part of the North Equatorial Current enters the Caribbean Sea through the passages between the Windward Islands, while the northern edge flows north-westward at the rate of 12 miles a day as the Antilles Current between Cuba and the Bahamas and unites with the main Gulf Stream flowing through the Strait of Florida. The South Equatorial Current divides into two off Cape San Roque on the Brazilian coast, the northern and larger branch passing along the coast of Guiana and uniting with the western branch of the North Equatorial Current. The combined current, with a velocity of 23 miles a day, flows towards the coasts of Honduras and Yucatan, and

* Hepworth, W. Campbell. "The Gulf Stream." London. *Geographical Journal*, 1914. p. 431.
Krummell, O. "Handbuch der Ozeanographie," 2 ed. Stuttgart, 1907, Vol. 2, Chap. 3, pp. 548 ff.
London, Meteorological Office. *Monthly Meteorological Charts of the North Atlantic Ocean*, March, 1921.
"Currents off the Newfoundland Banks, Ice and Fogs." By A. G. W. Howard.

thence mainly through the Yucatan Channel (50 miles a day) into the Gulf of Mexico, where it spreads out and turns eastward, finally passing out between Florida and Cuba with a mean velocity of 72 miles a day. From Florida Strait to Cape Hatteras the mean velocity is 70 miles a day near the centre, and half this amount on the edges ; south of Nova Scotia it is 38 miles a day.

At the south-eastern and southern edge of the Great Bank of Newfoundland the Gulf Stream comes into conflict with the cold southward-flowing Labrador Current ; the latter, aided by the effect of the earth's rotation, deflects it to the eastward, and also greatly retards it and lowers its temperature and salinity. In about 40° N., 40° W. (the "Delta of the Gulf Stream") it divides into several branches of which the southernmost turns east and south-east towards the coasts of south-west Europe and Africa with a velocity of about 10 miles a day Another branch turns towards the east-north-east and crosses the Atlantic with a mean speed of 12 miles a day, finally reaching west and north-west Europe. The approximate time taken by the various parts of the circulation may accordingly be tabulated as follows :

TABLE I.—SPEEDS AND TIMES OF NORTH ATLANTIC CIRCULATION.

CURRENT.	From.	To.	Distance Nautical miles.	Speed miles/ day.	Mean time in days.
North Equatorial	16° N., 25° W.	16° N., 60° W.	1,900	17	112
Antilles	16° N., 60° W.	23° N., 75° W.	850	12	71
South Equatorial	St. Helena.	5° N., 40° W.	2,800	20	140
Guiana Current	5° N., 40° W.	20° N., 80° W.	2,400	35	69
Yucatan to Florida Strait	Round Gulf	of Mexico	(500)	(20)	(25)
Gulf Stream :					
Florida Strait to C. Hatteras ..	23° N., 80° W.	36° N., 75° W.	600	70	9
C. Hatteras to Newfoundland ..	36° N., 75° W.	42° N., 50° W.	1,200	38	32
Newfoundland to Azores	42° N., 50° W.	40° N., 26° W.	1,200	10	120
Newfoundland to North of Scotland	42° N., 50° W.	60° N., 5° W.	1,800	12	150

Speeds and times are of course only the roughest of approximations but they will serve to give an idea of the time required for variations in the currents in one part of the Atlantic Ocean to be propagated along the course of the currents to other parts of the Ocean.

§ 2. CORRELATION BETWEEN THE NE. TRADE AND THE SUBSEQUENT PRESSURE OVER WESTERN EUROPE.

Comparable observations of the velocity of the NE. trade wind were not available over a long period. Hepworth* tabulated the mean velocity for each month of the period 1902 to 1906 inclusive, employing a large number of observations extracted from ships' logs. These data of Hepworth's were compared with the mean pressures in the same month and in the preceding month, at Bermuda, Ponta Delgada, Gibraltar and Sierra Leone, and the following formulæ were adopted as apparently giving the best fit :

Writing : W_1 = Velocity of NE. trade wind in metres per second.
P_1 = pressure in millibars at Ponta Delgada in the same month.
P_2 = pressure in millibars at Gibraltar in the same month.
P_3 = pressure in millibars at Sierra Leone in the same month.
δ = difference from normal.

we have : November to February : $\delta W_1 = 0{\cdot}09\ \delta P_1 - 0{\cdot}09\ \delta P_2 - 0{\cdot}45\ \delta P_3$
March, April, Sept., Oct. : $\delta W_1 = 0{\cdot}07\ \delta P_1 - 0{\cdot}45\ \delta P_3$
May to August : $\delta W_1 = 0{\cdot}055\ \delta P_1 + 0{\cdot}25\ \delta P_2 - 0{\cdot}41\ \delta P_3$

The agreement between Hepworth's means and the velocities given by these

* London, Meteorological Office, M.O. 203. "The Trade Winds of the Atlantic Ocean." By M. W. Campbell Hepworth, 1910.

formulæ is good in winter but less satisfactory in summer. The formulæ may be accepted at their face value, however, as representing the component of the trade wind from north-east, which for the purpose of the investigation is more important than the actual mean velocity. Pressure at Ponta Delgada is much more variable than that at Sierra Leone, and the greater weight given to the observations at the latter station is probably justified. It is important to note that in what follows, wherever the velocity of the NE. trade wind is referred to, it means the velocity calculated by means of this formula, and not actual observations of the speed of the wind. To afford a check, the direct pressure difference, Ponta Delgada minus Sierra Leone, which also should be an approximate measure of the velocity of the NE. trade wind, was also employed, but as will be seen it gave smaller correlation coefficients than the weighted formula.

TABLE II.—MEAN VALUES AND STANDARD DEVIATIONS.

	MEAN VALUES				STANDARD DEVIATIONS			
	Jan.-March	April-June	July-Sept.	Oct.-Dec.	Jan.-March	April-June	July-Sept.	Oct.-Dec.
NE. trade, metres per sec.	5·8	6·0	4·6	4·7	0·47	0·45	0·45	0·49
Pressure-difference in mb., Ponta Delgada-Sierra Leone	10·3	10·5	9·9	8·8	3·91	1·54	1·16	2·73
SE. trade, metres per sec.	7·0	6·5	6·8	8·4	0·54	0·54	0·79	0·66
SE. trade (change from one year to next, m.p.s.*)	0·5	0·4	0·8	0·6	0·70	0·57	0·90	0·81
Mean pressure (M.S.L. 24 hours) at :	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.
Jacobshavn	1008·5	1012·1	1009·2	1005·2	5·00	2·02	2·31	3·71
Stykkisholm	1001·2	1012·2	1009·4	1001·7	6·41	3·17	2·88	3·78
Thorshavn	1003·9	1013·0	1011·0	1004·6	4·09	2·25	1·93	2·52
Ponta Delgada	1020·7	1021·6	1022·2	1019·4	3·91	1·63	1·11	1·87
Valencia	1012·3	1015·5	1016·0	1011·2	5·03	2·51	1·81	3·03
Paris	1017·4	1016·0	1017·5	1016·3	3·70	1·68	1·23	2·71
Berlin (Potsdam)	1015·0	1014·9	1015·2	1015·6	2·97	1·52	1·23	2·49
Bergen	1008·4	1013·2	1011·5	1009·2	4·11	2·46	2·35	3·43
Vardo	1004·8	1012·9	1010·7	1006·5	3·06	2·02	2·08	2·92

*Arithmetical means.

The pressure deviations in the North Atlantic and western Europe were represented by the values for Jacobshavn (West Greenland), Stykkisholm (Iceland), Thorshavn (Faroes), Ponta Delgada (Azores), Valencia, Paris, Berlin, and Bergen and Vardo (Norway). These are termed the "selected stations" for convenient reference. The trade wind velocities and the pressure deviations were first computed for each month, and the monthly means were then combined into quarterly means. The means and standard deviations are shown in Table II.

The pressures at the various stations were then correlated with the trade wind velocities for the same quarter, for the preceding quarter and so on over a period of two years. Thus, for example, the pressures for the quarter January to March at Jacobshavn were correlated with the velocity of the NE. trade wind during January to March of the same year, then successively with October to December, July to September, April to June and January to March of the preceding year, and so on. This method was adopted in preference to the alternative method of taking the velocity of the NE. trade in, say, January to March and correlating with the subsequent pressure distribution in successive quarters because the object of the investigation is to forecast the pressure distribution in any given season, and for this purpose it is convenient to have all the correlations with the pressure in that particular season together. When annual means are formed by combining the correlations for the four seasons it makes no difference which method is adopted.

The various correlation coefficients for the different quarters are shown in Table III†. In addition to the regular series of quarterly coefficients representing

† Throughout the tables, correlation coefficients (except those relating to synchronous data) which have a value of ·20 or above are in heavy type.

intervals of 3, 6, 9 . . . months, pressures were also correlated with the velocities of the NE. trade four months earlier, i.e., pressure January to March with velocity in the preceding September to November, pressure April to June with velocity December to February, and so on. This was because a tendency was suspected for the coefficients to reach a maximum or minimum with an interval of four months.

TABLE III.—CORRELATION OF PRESSURE IN THE NORTH ATLANTIC AND WESTERN EUROPE WITH NE. TRADE.

STATION	LAG IN MONTHS									
	0	3	4	6	9	12	15	18	21	24
Jacobshavn—										
Jan.–Mar. ..	−·03	+·12	+**·23**	+**·34**	+**·37**	−·08	−·13	+·14	+**·30**	−·04
April–June ..	+·40	+**·35**	+**·35**	+**·30**	+**·31**	−·01	−·16	+·14	+·08	+**·36**
July–Sept. ..	+·06	+·09	+·17	−·09	−·05	+·07	+**·29**	−·02	+·14	+**·21**
Oct.–Dec. ..	+·04	+**·28**	+**·43**	+**·37**	+·19	+·14	+**·25**	+**·21**	+·04	−·11
Stykkisholm—										
Jan.–Mar. ..	−·18	+·09	+·16	+**·26**	+**·28**	+·11	·12	+·05	+·10	−·10
April–June ..	−·15	+·13	+**·21**	+**·20**	−·07	−**·23**	·00	+·03	−·13	−·10
July–Sept. ..	−·19	+·11	+·17	+·01	+·07	−·18	−·06	−·15	−·05	−·05
Oct.–Dec. ..	−·15	+·18	+**·22**	·00	+·05	+·01	+·05	−·06	−·18	−**·23**
Thorshavn—										
Jan.–Mar. ..	−·04	+·16	+·10	+·16	+·06	+**·23**	−·12	+·07	+·01	−·03
April–June ..	−·02	−·15	−·13	+·03	+·17	+·14	+·15	+·15	+**·40**	+**·23**
July–Sept. ..	−·51	−·11	−·03	−·05	+·04	−**·26**	−·14	−·04	+·03	−·03
Oct.–Dec. ..	−·20	−·03	−·01	−·01	−·15	−·01	−·04	−**·21**	−**·36**	−**·34**
Ponta Delgada—										
Jan.–Mar. ..	+·51	−·07	−·13	−**·23**	−**·45**	−·11	−·15	−**·51**	−**·51**	−**·20**
April–June ..	+·16	−·06	−·19	−·15	−**·27**	−·11	−·12	−·11	−**·33**	−·05
July–Sept. ..	+·42	+·12	−·02	+·01	−·04	+·15	−·08	+·03	+·02	−·02
Oct.–Dec. ..	+·71	+·09	·05	−·02	−·06	+·13	+·04	−**·24**	−·07	−·11
Valencia—										
Jan.–Mar. ..	+·30	+·04	−·03	+·02	−**·33**	+·10	−·17	−·08	−**·30**	**·24**
April–June ..	+·03	−**·34**	−**·43**	−**·44**	+·07	+**·21**	−·10	−·06	+·13	+**·20**
July–Sept. ..	−·24	+·04	−·02	+**·25**	+·17	−·08	−**·20**	+**·23**	+·02	−·13
Oct.–Dec. ..	−·27	−·04	−·02	+·01	−·11	+·12	+**·20**	−·09	−·02	−·07
Paris—										
Jan.–Mar. ..	+·21	+·02	−·12	−·15	−**·46**	+·03	−·03	−·09	−**·31**	·13
April–June ..	+·02	−**·37**	−**·24**	−**·20**	+·12	+**·25**	·00	−·07	+·10	·14
July–Sept. ..	−·32	−**·30**	−·15	+**·22**	+·06	−·13	−**·26**	+·09	−·08	**·28**
Oct.–Dec. ..	−·23	·00	−·03	+**·21**	+·02	+**·24**	+**·20**	+·04	+·07	−·03
Berlin—										
Jan.–Mar. ..	+·15	+·10	−·05	−·17	−**·38**	+·05	+·03	−·08	−**·23**	·00
April–June ..	+·14	−**·33**	−**·20**	−·18	+**·25**	+**·36**	+·14	−·06	+**·25**	+**·23**
July–Sept. ..	−·34	−**·24**	−·18	+·05	+·04	−·07	−**·24**	+·02	−·13	−**·22**
Oct.–Dec. ..	+·11	+·15	+·10	+**·26**	+**·22**	+**·33**	+·18	−·06	−·07	−·19
Bergen—										
Jan.–Mar. ..	+·07	+**·22**	+·08	+·08	−·09	+**·24**	−·06	·00	−·10	−·03
April–June ..	+·26	−**·27**	+**·24**	−·13	+**·35**	+**·39**	+·16	+·08	+**·51**	**·39**
July–Sept. ..	−·56	−·19	−·15	−·14	−·12	−**·39**	−**·35**	−·01	−·10	**·37**
Oct.–Dec. ..	−·03	+·02	−·01	+·11	+·13	+·18	−**·29**	−**·22**	−**·32**	**·30**
Vardo—										
Jan.–Mar. ..	+·05	+·05	+·04	+**·26**	+**·36**	+·04	+·01	+·02	+·10	·08
April–June ..	+·06	+·04	+·13	+**·30**	+·15	+·04	+·03	+·14	+**·38**	+·11
July–Sept. ..	−24	+·01	+·09	−**·24**	−·15	−**·43**	−**·35**	−·19	**·38**	·13
Oct.–Dec. ..	+·42	+**·22**	+·13	+·01	+·17	+·01	·18	−·18	−**·31**	**·43**

TABLE IV.—CORRELATION OF PRESSURE IN THE NORTH ATLANTIC AND WESTERN EUROPE WITH (A) NE. TRADE AND (B) PONTA DELGADA—SIERRA LEONE PRESSURE DIFFERENCE.

STATION		LAG IN MONTHS									
		0	3	4	6	9	12	15	18	21	24
Jacobshavn ..	(A)	+ ·12	+ **·21**	+ **·30**	+ **·23**	+ **·23**	+ ·03	+ ·06	+ ·12	+ ·14	+ ·11
	(B)	—	+ ·08	+ ·06	− ·07	+ ·01	− ·15	− ·13	—	—	—
Stykkisholm	(A)	− ·17	+ ·13	+ ·19	+ ·12	+ ·08	− ·07	− ·03	− ·04	− ·07	− ·12
	(B)	—	+ ·12	+ ·06	− ·07	− ·09	− ·12	− ·06	—	—	
Thorshavn ..	(A)	− ·19	− ·03	− ·02	+ ·03	+ ·10	+ ·03	− ·04	− ·01	+ ·02	·04
	(B)	—	+ ·13	− ·01	+ ·11	+ ·03	+ ·04	− ·04	—	—	
Ponta Delgada	(A)	+ ·45	+ ·02	− ·10	− ·10	− **·21**	+ ·01	− ·08	− **·21**	− **·22**	·10
	(B)	—	+ ·11	+ ·04	+ ·03	− ·13	+ ·02	− ·03	− ·13	− **·21**	− ·14
Valencia ..	(A)	− ·04	·08	·13	− ·04	− ·05	+ ·09	− ·07	·00	− ·04	− ·06
	(B)	—	·00	·09	− ·02	− **·22**	+ ·10	·19	—	—	—
Paris ..	(A)	− ·08	− ·16	·13	+ ·02	− ·06	+ ·10	− ·02	− ·01	− ·05	− ·07
	(B)	—	·11	− ·11	·00	− **·24**	+ ·19	− ·02	—	—	—
Berlin ..	(A)	+ ·01	− ·08	− ·08	− ·01	+ ·05	+ ·17	+ ·04	− ·04	− ·04	− ·05
	(B)	—	− ·09	·06	·00	− ·15	+ ·12	+ ·11	—	—	—
Bergen ..	(A)	− ·06	·06	+ ·04	− ·02	+ ·07	+ ·11	− ·14	− ·04	·00	− ·08
	(B)		+ ·01	+ ·01	+ ·01	+ ·03	+ ·15	+ ·02	—	—	—
Vardo ..	(A)	+ ·07	+ ·08	+ ·10	+ ·08	+ ·13	− ·09	− ·12	− ·05	− ·05	− ·13
	(B)	—	+ ·02	·00	+ ·13	+ ·18	− ·06	− ·05	—	—	—
Arithmetical Means ..	(A)	·13	·09	·12	·07	·11	·08	·07	·06	·07	·08
	(B)	—	·07	·05	·05	·12	·11	·08	—	—	—

In Table IV the quarterly coefficients between the velocity of the NE. trade and the subsequent pressure have been combined to give the mean value for the year (A). For comparison, under (B) are given the corresponding annual means of the correlation coefficients between the pressure difference Ponta Delgada minus Sierra Leone and the subsequent pressure, but using the period 1894 to 1920 instead of 1891 to 1915. The signs of the corresponding values of (A) and (B) are the same in 41 cases and opposite in only 12, of which 4 occur with a lag of six months. The values of (A) are generally higher than those of (B) with a lag of 3 to 6 months, but slightly lower with a lag of 9 to 15 months. It seems probable that the coefficients on the lines marked (A) best represent the actual trade-wind effects, and that those on the lines marked (B) are partly influenced by the recurrences of pressure at Ponta Delgada itself. In the discussion which follows the former are mainly employed. The values of (A) are shown in Figure 1; the values of (B) in Figure 2.

None of the annual means of the correlation coefficients between the NE. trade wind and the subsequent pressures are large enough in themselves to constitute sufficient proof of a real relationship. Any relationships suspected must therefore be rigorously checked by comparing the results for the different stations, for the four seasons separately, and by comparing them with the relationships which we should expect on physical grounds. The conclusions which may be drawn from Figure 1 are as follows: those based on correlation coefficients of more than ± 0·20 being in heavy type.

Changes following a high velocity of the NE. trade.

After

4 months. High pressure at **Jacobshavn,** Stykkisholm and Vardo; low pressure at Ponta Delgada, Valencia, Paris and Berlin.

9 months. High pressure at **Jacobshavn,** Thorshavn and Vardo; low pressure at **Ponta Delgada.**

12 months. High pressure at Valencia, Paris, Berlin and Bergen; low pressure at Vardo.

Changes following a high velocity of the NE. trade.—continued.

15 months. Low pressure at Bergen and Vardo.

18 and 21 months. High pressure at Jacobshavn ; low pressure at **Ponta Delgada.**

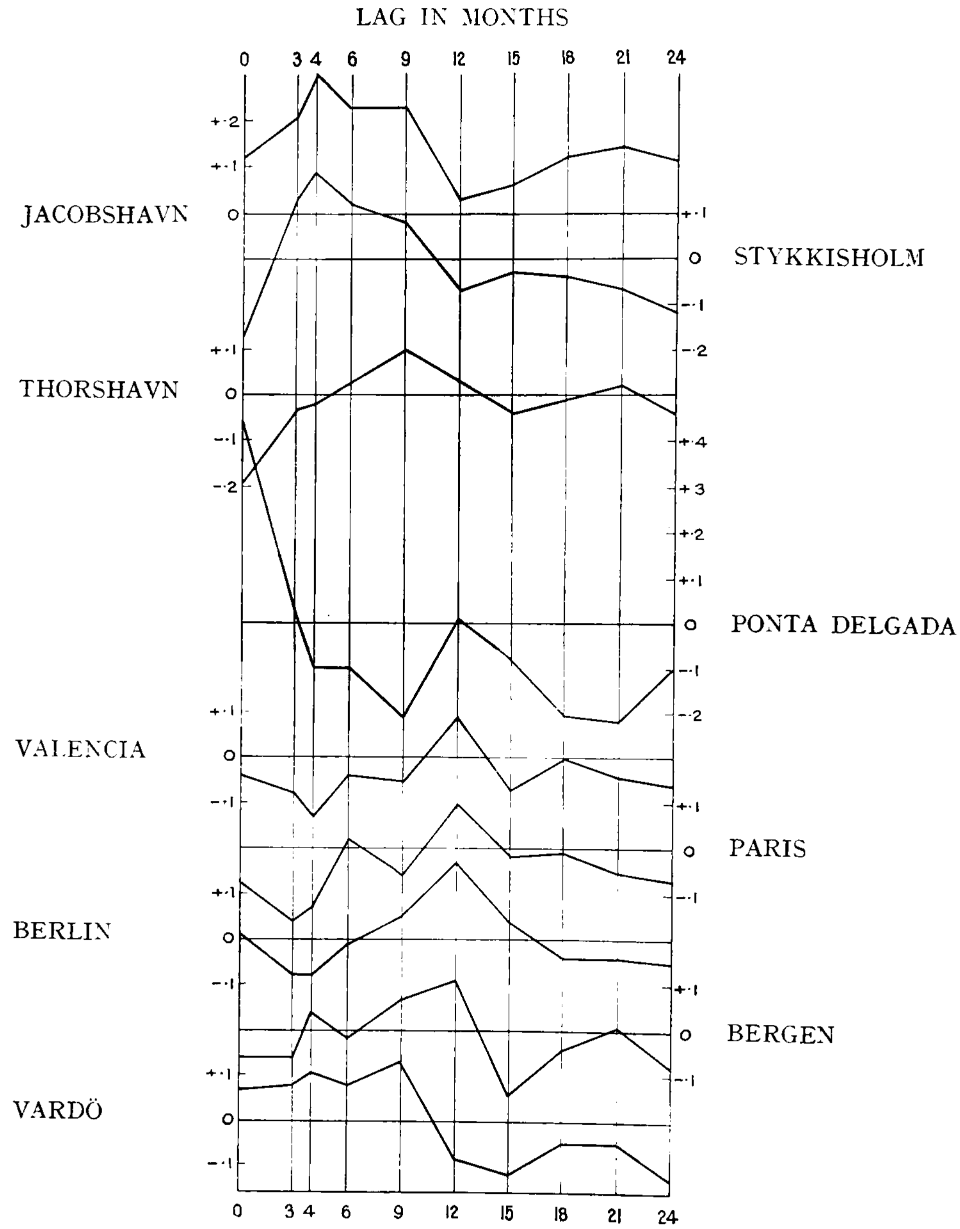

FIG. 1.—CORRELATION BETWEEN NORTH-EAST TRADE AND SUBSEQUENT PRESSURE.

§ 3. CORRELATION BETWEEN THE SE. TRADE AND THE SUBSEQUENT PRESSURE OVER WESTERN EUROPE.

The velocity of the SE. trade wind was represented by the records of the anemometer at St. Helena, in 15° 57′ S., 5° 40′ W. The anemometer, which is at a height of 632 metres above mean sea level, gave its first records in February, 1892 ; since that date there have been a few gaps. the longest extending from January, 1904, to May, 1905. These gaps were filled by means of an empirical interpolation formula which

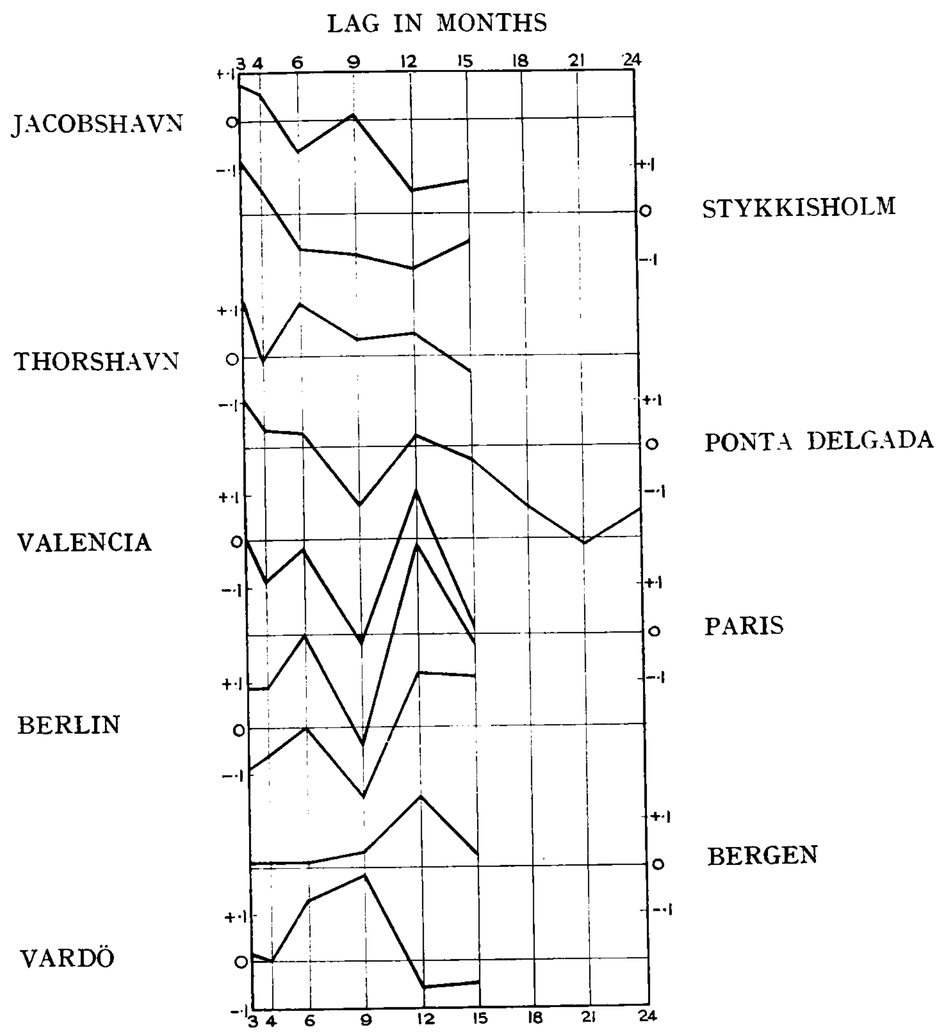

FIG. 2.—CORRELATION BETWEEN PRESSURE GRADIENT PONTA DELGADA—SIERRA LEONE AND SUBSEQUENT PRESSURE.

agreed well with the observations. The mean values and standard deviations of the quarterly means are shown in Table II. These wind velocities were correlated with the pressure at the selected stations in the same and subsequent quarters in the same way as the NE. trade winds, giving the coefficients shown in Table V, the annual means of which are represented in Figure 3.

The wind velocity at St. Helena, after rising to a strongly marked maximum in 1903 has shown a remarkable diminution since that date. The mean velocity for the year 1923 was nearly three metres per second less than that for 1903.* The secular variation of the wind velocity was eliminated by the common artifice of correlating the changes of the variants from one year to the next instead of their actual values. For example, we have the following values of wind velocity at St. Helena in January to March and of pressure at Jacobshavn in April to June :—

Year. (*a*)	Wind Velocity St. Helena. Jan.-Mar. m/s. (*b*)	Pressure Jacobshavn. April-June. mb. (*c*)	Differences one year to next. Wind m/s. (*d*)	Pressure mb. (*e*)
1903	7·8	1013·5		
			—0·2	—1·7
1904	7·6	1011·8		
			—0·8	+1·6
1905	6·8	1013·4		
			+0·1	—1·1
1906	6·9	1012·3		

* The remarkable secular variation of the meteorological elements at St. Helena is discussed in *Geo. Mem.* No. 33.

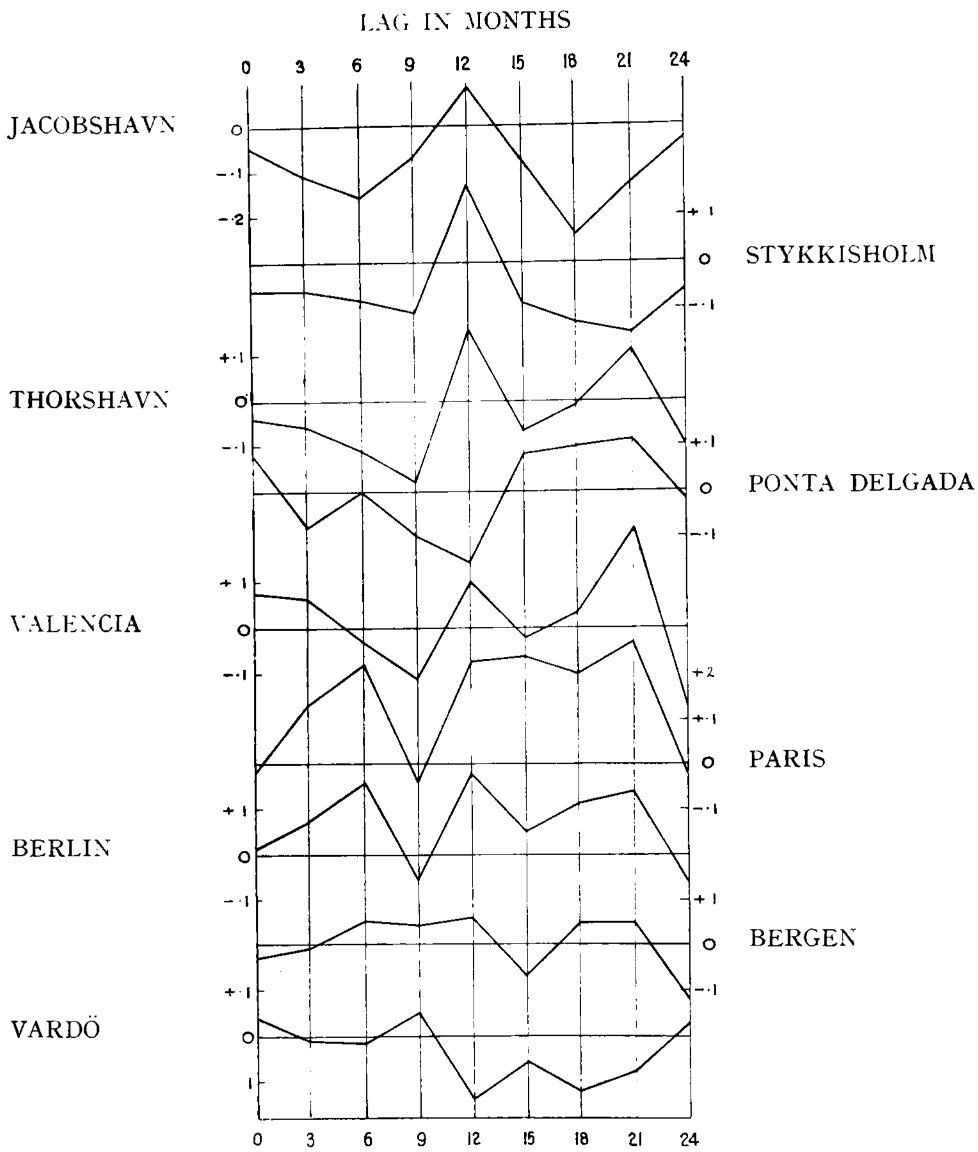

FIG. 3.—CORRELATION BETWEEN SOUTH-EAST TRADE AND SUBSEQUENT PRESSURE.

To eliminate the secular variation, the figures in columns (*d*) and (*e*) are correlated instead of those in columns (*b*) and (*c*). The coefficients obtained in this way are shown in Table VI and the annual means in Figure 4 ; they are generally similar to those in Table V and Figure 3, but the fluctuations are more pronounced. From Table V and Figure 3 we find that the variations of pressure following periods of high velocity of the SE. trade wind are as follows :—

After

3 and 6 months. High pressure at Paris and Berlin ; low pressure at Stykkisholm.

9 months. Low pressure at Stykkisholm, Thorshavn, Valencia, Paris and Berlin.

12 months. High pressure at Jacobshavn, Stykkisholm, Thorshavn, Valencia, **Paris** and Berlin ; low pressure at Ponta Delgada and Vardo.

21 months. High pressure at **Valencia, Paris** and Berlin ; low pressure at Vardo.

TABLE V.—CORRELATION OF PRESSURE IN THE NORTH ATLANTIC AND WESTERN EUROPE WITH SE. TRADE.

STATION	LAG IN MONTHS								
	0	3	6	9	12	15	18	21	24
Jacobshavn—									
January–March ..	−·12	**−·24**	**−·22**	+·13	+·15	+·06	**−·33**	−·09	+·05
April–June	+·12	−·10	−·11	+·04	+·01	−·15	**−·46**	**−·39**	−·04
July–September ..	−·12	**−·34**	**−·23**	**−·38**	**+·22**	**−·22**	**−·25**	+·04	+·09
October–December ..	−·07	**+·25**	−·04	−·08	−·06	−·01	+·08	−·09	**−·21**
Mean	−·05	−·11	−·15	−·07	+·08	−·08	**−·24**	−·13	−·03
Stykkisholm—									
January–March ..	−·08	**−·20**	**−·30**	+·12	**+·26**	**−·23**	**−·23**	**−·25**	−·14
April–June	+·12	·00	+·02	−·03	**+·39**	+·19	−·10	−·09	+·14
July–September ..	−·13	**−·30**	−·02	**−·31**	+·16	**−·24**	**−·26**	**−·21**	−·17
October–December ..	−·14	**+·26**	−·02	**−·24**	−·15	−·09	+·07	−·04	−·06
Mean	−·06	−·06	−·08	−·11	+·17	−·09	−·13	−·15	−·06
Thorshavn—									
January–March ..	+·11	+·05	**−·21**	·00	**+·32**	**−·28**	−·05	−·08	−·14
April–June	−·04	−·16	−·10	−·16	+·16	**+·25**	−·03	+·16	−·11
July–September ..	−·17	−·18	**−·24**	−·12	**+·20**	−·04	−·06	+·11	−·06
October–December ..	−·05	+·03	+·10	**−·43**	−·09	**−·22**	+·11	**+·23**	−·10
Mean	−·04	−·06	−·11	−·18	+·15	−·07	−·01	+·11	−·10
Ponta Delgada—									
January–March ..	+·07	+·05	+·10	−·17	−·17	+·02	−·03	+·15	**+·25**
April–June	−·35	**−·22**	−·02	**−·32**	**−·20**	+·01	**+·22**	+·04	−·20
July–September ..	+·29	**−·25**	−·18	+·10	−·19	+·06	**+·45**	+·19	+·03
October–December ..	+·32	+·11	+·10	+·02	−·02	**+·27**	**−·23**	+·08	−·17
Mean	+·08	−·08	·00	−·09	−·15	+·09	+·10	+·11	−·02
Valencia—									
January–March ..	+·42	+·19	+·08	−·13	+·05	**−·21**	+·12	+·13	+·08
April–June	−·28	**−·20**	**−·27**	**−·51**	−·04	+·10	−·05	+·05	**−·38**
July–September ..	−·07	−·03	+·08	**+·28**	−·01	−·03	+·06	+·05	**−·31**
October–December ..	+·21	**+·30**	−·02	−·06	**+·41**	+·04	−·02	**+·66**	−·09
Mean	+·07	+·06	−·03	−·11	+·10	−·02	+·03	**+·22**	−·17
Paris—									
January–March ..	+·09	**+·35**	+·18	−·07	+·03	+·05	**+·26**	**+·20**	+·10
April–June	−·32	−·17	+·19	**−·32**	+·09	**+·53**	+·03	+·13	**−·26**
July–September ..	−·12	+·19	**+·53**	**+·20**	**+·36**	**+·34**	+·19	**+·26**	+·14
October–December ..	+·26	+·15	+·03	+·03	**+·44**	+·05	**+·36**	**+·50**	−·05
Mean	−·02	+·13	**+·23**	−·04	**+·23**	**+·24**	**+·20**	**+·27**	−·02
Berlin—									
January–March ..	+·24	**+·41**	+·16	−·13	**+·25**	−·02	**+·26**	**+·24**	+·04
April–June	−·39	**−·37**	−·14	**−·40**	−·18	+·17	−·19	·00	**−·39**
July–September ..	−·21	+·13	**+·47**	**+·26**	**+·45**	+·18	+·12	+·15	**+·24**
October–December ..	+·41	+·12	+·14	+·02	**+·24**	−·12	**+·25**	**+·35**	−·13
Mean	+·01	+·07	+·16	−·06	+·18	+·05	+·11	+·14	−·06
Bergen—									
January–March ..	+·20	**+·36**	−·01	−·08	**+·35**	**−·21**	+·14	+·08	−·13
April–June	−·24	**−·37**	−·12	+·14	**−·22**	+·05	−·19	**−·35**	**−·43**
July–September ..	−·28	−·07	+·07	**+·20**	+·04	+·01	+·04	+·19	+·15
October–December ..	+·21	+·05	**+·24**	−·09	+·07	−·12	**+·21**	**+·28**	−·04
Mean	−·03	−·01	+·05	+·04	+·06	−·07	+·05	+·05	−·12
Vardo—									
January–March ..	−·07	−·08	**−·20**	+·06	+·09	+·06	**−·25**	−·11	−·05
April–June	+·38	**+·25**	**+·36**	**+·33**	+·13	−·03	−·05	+·10	+·05
July–September ..	−·21	−·10	**−·21**	+·01	**−·27**	−·10	+·04	−·04	**+·28**
October–December ..	+·06	−·10	−·02	**−·22**	**−·53**	−·19	**−·24**	**−·25**	−·17
Mean	+·04	−·01	−·02	+·05	−·14	−·06	−·12	−·08	+·03

TABLE VI.—CORRELATION OF PRESSURE IN THE NORTH ATLANTIC AND WESTERN EUROPE WITH SE. TRADE, USING DIFFERENCE ONE YEAR TO THE NEXT.

STATION	LAG IN MONTHS							
	3	6	9	12	15	18	21	24
Jacobshavn—								
January–March ..	−·31	−·12	+·11	+**·27**	+**·29**	−·16	+·04	−·10
April–June	−·32	+·02	+·05	−·07	+·12	−**·25**	−·17	+**·23**
July–September ..	−·12	−·09	−**·47**	+·17	−·07	−·08	+**·34**	+·03
October–December ..	+·29	−·02	−·01	+·15	−·05	+·18	+·02	−**·20**
Mean	−·11	−·05	−·08	+·13	+·07	−·08	+·06	−·01
Stykkisholm—								
January–March ..	−·18	−**·40**	+·05	+**·28**	+·09	+·17	+·02	−·18
April–June	−·35	−·18	−**·30**	+**·20**	+·19	·00	−·06	+·13
July–September ..	−·11	−**·31**	−·19	+**·33**	−·03	+·17	−·05	−**·21**
October–December ..	+·38	+·07	−**·30**	−·12	−**·31**	−·09	+**·25**	·00
Mean	−·07	−**·21**	−·19	+·17	−·01	+·06	+·04	−·07
Thorshavn—								
January–March ..	+·09	−**·37**	−·13	+**·21**	−**·23**	+**·21**	+·07	−**·28**
April–June	−·22	−·08	−**·54**	+**·25**	+**·21**	−·05	+·09	−·16
July–September ..	−·18	−·11	+·15	+**·35**	+·06	+·15	−**·26**	−**·21**
October–December ..	+·06	+·12	−**·24**	+·14	−·18	−·09	+**·29**	−**·29**
Mean	−·06	−·11	−·19	+**·24**	−·03	+·05	+·05	−**·23**
Ponta Delgada—								
January–March ..	+·09	+**·38**	−**·33**	−**·38**	−·14	−**·21**	+·09	+**·45**
April–June	−·08	+·10	·00	+·13	+**·39**	+**·20**	+·06	−·11
July–September ..	−·19	−·18	−·02	−**·44**	−·02	+**·31**	+·07	−·06
October–December ..	+·27	−·04	−·12	−**·33**	−·04	−**·50**	−**·33**	−·02
Mean	+·02	+·07	−·12	−**·25**	+·05	−·05	−·03	+·07
Valencia—								
January–March ..	+·20	+·11	−**·47**	−**·28**	−**·33**	−·01	+·11	+·02
April–June	−·03	−·17	−**·64**	+**·22**	+·19	+·13	+**·25**	−**·27**
July–September ..	+·05	+·01	+**·37**	+**·25**	−·11	+·14	−·15	−·18
October–December ..	+·42	−**·20**	−**·46**	+·16	−**·46**	+·17	+**·45**	−·17
Mean	+·16	−·06	−**·30**	+·09	−·18	+·11	+·17	−·15
Paris—								
January–March ..	+·26	+·11	−**·30**	−**·20**	−**·30**	−·02	·00	−·07
April–June	+·03	−·03	−**·57**	+**·33**	+**·42**	+·06	+·18	−**·33**
July–September ..	+·16	+**·29**	+·07	+**·23**	−·10	−·16	+·02	·00
October–December ..	+·32	−**·24**	−**·40**	+**·25**	−**·32**	+**·32**	+**·39**	−**·20**
Mean	+·19	+·03	−**·30**	+·15	−·07	+·05	+·15	−·15
Berlin—								
January–March ..	+·35	+·08	−**·34**	+·03	−**·26**	−·05	+**·21**	−·11
April–June	−·03	+·14	−**·51**	+·18	+**·31**	−·16	+·15	−**·30**
July–September ..	+·07	+**·30**	+·13	+**·32**	−·13	−**·32**	−·16	+·03
October–December ..	+·22	−·18	−**·38**	+·10	−**·29**	+**·29**	+**·36**	−·19
Mean	+·15	+·09	−**·27**	+·16	−·09	−·06	+·14	−·14
Bergen—								
January–March ..	+·30	−·12	−**·34**	+·15	−**·36**	+·16	+**·22**	−**·29**
April–June	−·15	−·13	−**·60**	+·11	+·10	+·05	+·19	−**·25**
July–September ..	−·10	+**·28**	+**·30**	+**·24**	+·09	·00	−·18	+·06
October–December ..	−·15	+·03	−·03	+·03	−·11	+·16	+**·28**	−**·26**
Mean	−·03	+·01	−·17	+·13	−·07	+·09	+·13	−·19
Vardo—								
January–March ..	−·11	−·03	+·11	+·16	+·13	−·08	+·10	+·02
April–June	·00	+**·35**	+**·39**	−·06	−**·21**	−·14	−**·21**	+·03
July–September ..	+·03	+·19	+·14	−·17	+·08	−·01	−**·33**	+**·22**
October–December ..	−·14	+·03	+·07	−**·41**	+**·28**	−**·20**	−·14	−·03
Mean	−·05	+·13	+·18	−·12	+·07	−·11	−·15	+·06

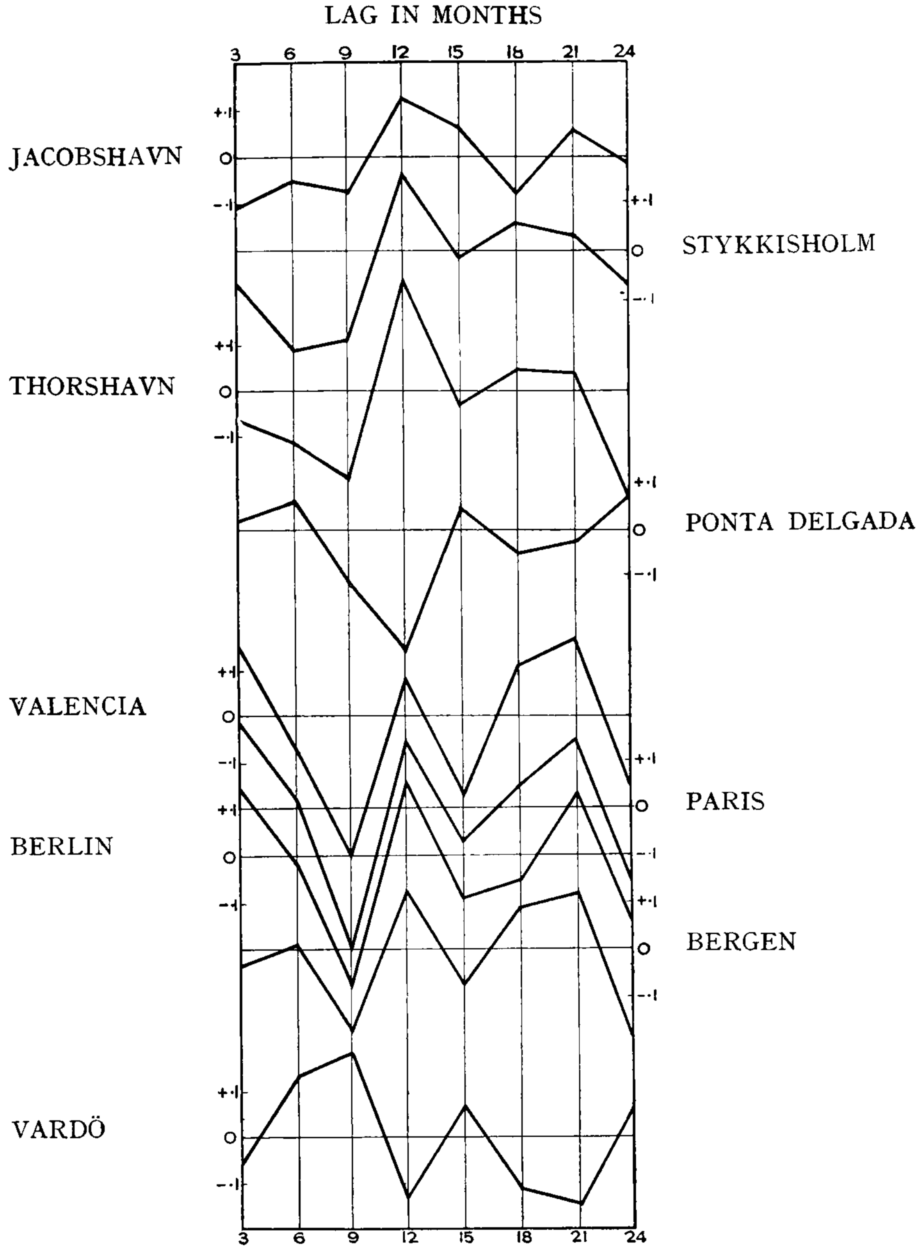

FIG. 4.—CORRELATION BETWEEN SOUTH-EAST TRADE AND SUBSEQUENT PRESSURE; DIFFERENCES ONE YEAR TO THE NEXT.

§ 4. DISCUSSION OF THE CORRELATION COEFFICIENTS BETWEEN TRADE WINDS AND SUBSEQUENT PRESSURE.

From Table I we can calculate the approximate position after any lapse of time of the water set in motion by the trade winds and following the course of the Gulf Stream. The most definite effects of trade winds on subsequent pressure in north-west Europe are seen to occur 4, 9 and 12 months after an abnormal velocity of the NE. trade, as calculated by the formula, and 9, 12 and 21 months after an abnormal velocity of the SE. trade as measured at St. Helena. Taking the NE. trade first, we find that after 4 months the water which it drives is in the neighbourhood of the Antilles, after 9 months in the western Mid-Atlantic and after 12 months in the longitude of the Azores. Since the depressions which influence the pressure over western Europe often originate in the western Atlantic, we can understand the occurrence of an effect on pressure in western Europe 9 or 12 months after the occurrence of an abnormal wind velocity, the effect being propagated along the Gulf Stream, but the effect with a lag of 4 months cannot be accounted for in this way. The latter effect will be discussed later.

The water set in motion by the SE. trade at St. Helena will be found 9 months later off Newfoundland, and 12 months later in Mid-Atlantic. After 21 months it will either be in the Arctic Ocean or will have partially completed a second circuit of the Atlantic, according to which major branch of the Gulf Stream Drift it follows. Here again the effect at 9 and 12 months is intelligible, but not that at 21 months. It should be remarked that the correlation between the NE. and SE. trades is only + ·26.

Captain Hepworth*, in discussing the influence of the Trade winds on the surface temperatures of the North Atlantic, found some evidence that departures from the average strength of either of the trade winds extending over a series of months were reflected in deviations from normal of the average surface temperature of the North Atlantic a year later. For example, if the velocity of the NE. or SE. trade wind were above normal in January to May of one year, the sea temperature would tend to be above normal in January to May of the following year. At times Hepworth recognized a fluctuation in the trade wind velocity lasting for only one month in the variations of sea temperature in the succeeding year.

Hepworth's results were obtained by the comparison of curves; in order to determine the average interval which elapsed between a fluctuation in the NE. or SE. trade wind and the corresponding fluctuation in the Atlantic temperature as nearly as possible, Hepworth's figures of the NE. and SE. trade wind velocities for the years 1902 to 1906 were each combined in sets of three months, and were correlated with his figures of the mean sea surface temperature between Florida and Valencia, 3, 6, 9 . . months afterwards. The results are shown in Table VII.

TABLE VII.—CORRELATION OF NE. AND SE. TRADE WITH SUBSEQUENT SEA SURFACE TEMPERATURE—FLORIDA TO VALENCIA.

	LAG IN MONTHS							
	3	6	9	12	15	18	21	24
NE. trade	+ ·13	+ ·06	− ·02	+ **·24**	− **·35**	− ·10	− **·29**	—
SE. trade	+ ·01	+ ·11	− ·12	+ ·11	+ **·48**	+ **·40**	+ **·47**	− ·03

The figures for these five years show that the maximum positive effect of the NE. trade wind on surface temperatures is experienced after the lapse of 12 months: it is not very definite, and is followed at 15 months by a more pronounced negative effect. The maximum effect of the SE. trade wind is much better shown, and extends from the 15th to the 21st month. This difference in the duration of the warming effect due to the two trade wind systems is probably due to the differences in the configuration of the Atlantic Ocean north and south of the equator. Owing to the great bulge of West Africa, the NE. trade wind blows to a large extent off the coast. Hence a strong NE. trade soon drives into the North Equatorial Current all the available supply of warm surface water; the place of the latter is taken by relatively cold water which is brought to the surface near the coast from the lower layers of the ocean. The SE. trade, on the other hand, blows almost parallel to the coast, and drives before it the warm surface water from a wide area, without bringing up the colder underlying layers from below. This difference in the effects of the two trade wind systems on temperature is closely reflected in their effects on pressure. We may divide the stations considered into two groups, a southern group including

* London, Meteorological Office. *Geophysical Memoirs*, No. 1. "The Effect of the Labrador Current upon the Surface Temperatures of the North Atlantic and of the latter upon the Air Temperature and Pressure over the British Isles." By M. W. Campbell Hepworth, 1912.

Ponta Delgada, Valencia, Paris, Berlin and Bergen, and a northern group including Jacobshavn, Stykkisholm and Vardo. The average coefficients of correlation of trade wind velocities with subsequent pressure are shown by the broken lines in Figure 5, the scale for the northern group being reversed so that negative coefficients appear above the positive. The SE. trade is here represented by the direct correlations of Table V. The correlation coefficients between the trade wind velocities and the sea surface temperature are shown by the continuous lines. The correlation coefficients of the trade winds with pressures at the southern group show good agreement with those of the trade winds with sea temperature, in spite of the difference in the periods utilized ; those with pressure at the northern group (reversed) show a similar but not so close agreement. A tendency also appears for the curves representing the northern group to lag behind those representing the southern group. There is a well-known opposition between pressure in the Azores anticyclone and its north-eastward extension and pressure in the Baffin Bay—Iceland—Norway Coast depression, and this opposition would tend to appear in any correlation coefficients between some third variant and these pressures. Figure 5 shows that powerful trade winds cause high temperature over the North Atlantic after an interval of 12 months for the NE. trade and 15 to 21 months for the SE. trade, and that this high surface temperature in some way brings about a high barometric pressure over the southern part of the region and a low pressure in the northern part, so that a high surface temperature in

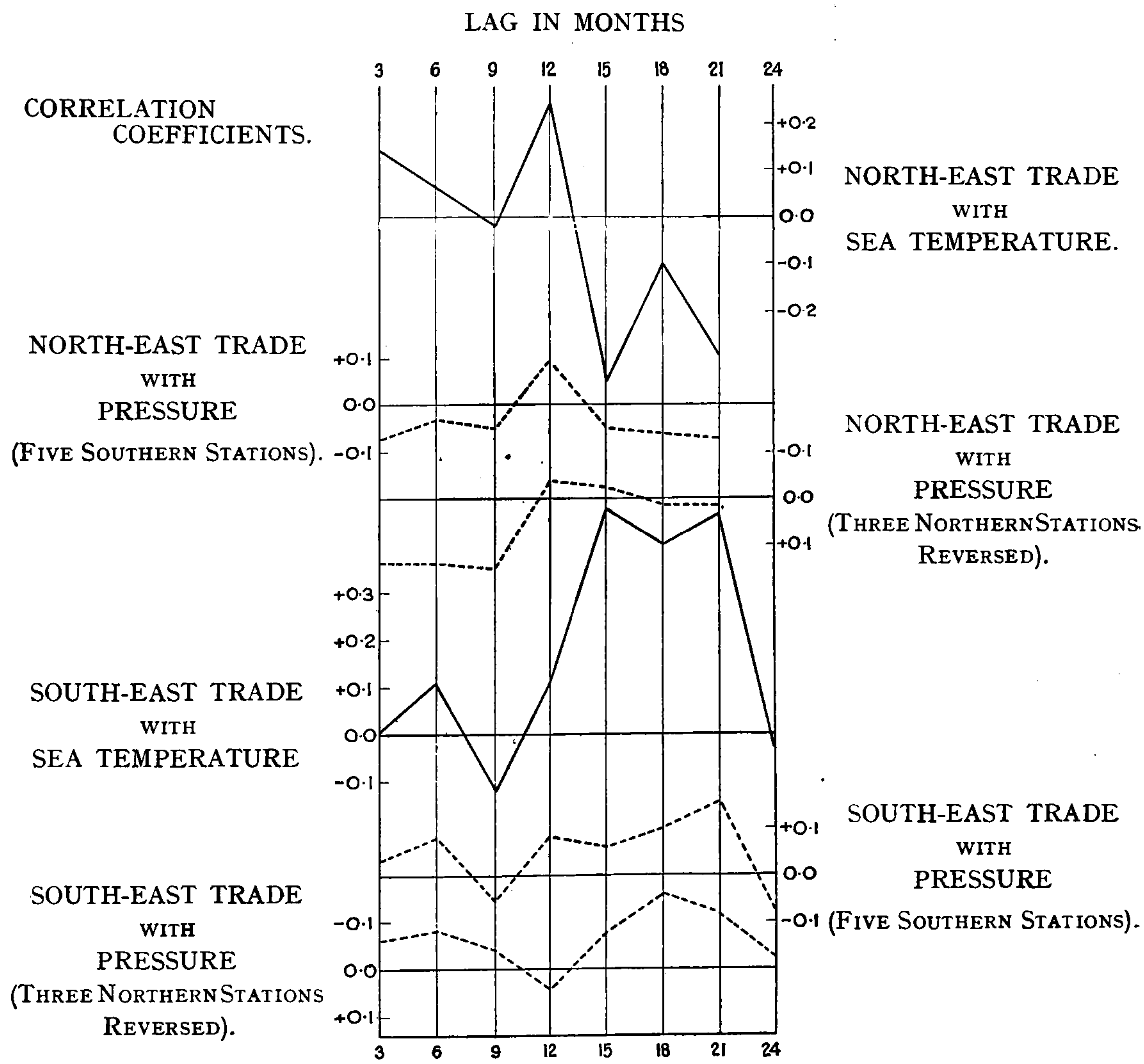

FIG. 5.—COMPARISON OF CORRELATION COEFFICIENTS.
TRADE WIND AND SEA TEMPERATURE AND TRADE WIND AND PRESSURE.

the North Atlantic gives rise to an abnormally steep barometric gradient from south to north.

It will be noticed from Figure 1 that nine months after a strong NE. trade wind the pressure at Ponta Delgada reaches a minimum. At the same time pressures at Thorshavn and Vardo reach a maximum, but the effect is shown only slightly or not at all at the remaining stations. The curves of correlation between trade winds and sea temperatures (Fig. 5) show a slight dip at nine months. Figure 6, which represents the correlation coefficients of the NE. trade with pressure at Ponta Delgada for the four seasons separately, shows that this minimum after nine months occurs in all seasons, but is most marked from January to March. When the warm surface water reaches the eastern part of the North Atlantic after 12 months, it causes high pressure at the southern group of stations. After nine months the warm water may similarly cause high pressure in the western North Atlantic. If so the period nine months after a strong trade wind would have a tendency for north-westerly winds in the middle Atlantic, which would lower the surface temperature and cause the minimum shown in Figure 5.

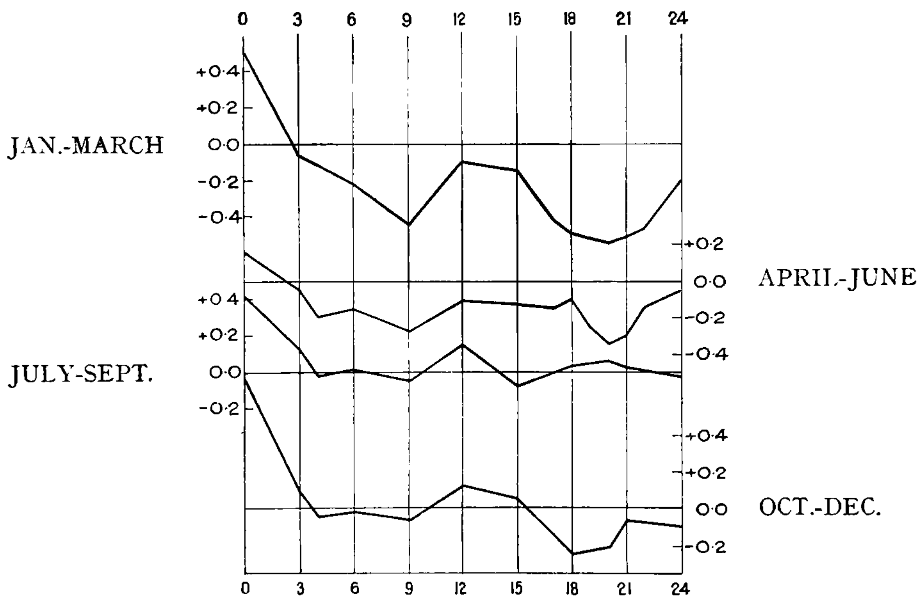

FIG. 6.—CORRELATION BETWEEN NORTH-EAST TRADE AND PRESSURE AT PONTA DELGADA.

§ 5. THE PRESSURE DISTRIBUTION FOUR MONTHS AFTER AN ABNORMAL NE. TRADE WIND.

P. H. Gallé,* in a study of the effect of fluctuations of the NE. trade on the subsequent winter temperature of Western and Central Europe, in which he used the wind observations in the Dutch " Squares " 15°-25° N. 25°-45° W for the years 1899/1900 to 1913/14, found intervals of less than 12 months between an abnormal trade wind velocity and the temperature anomaly which followed it. The winter temperatures were taken as the mean of December to February, and Gallé found that the highest correlation coefficients between trade wind velocity and subsequent winter temperature in Western and Central Europe were given by the trade wind velocities for June to November. For a small region in Germany the coefficients exceeded +·8 ; they exceeded +·7 from Holland to the Black Sea and decreased

* Gallé, P. H. " On the Relation between Fluctuations in the Strength of the Trade Winds of the North Atlantic Ocean in Summer and Departures from the Normal of the Winter Temperature in Europe." *Proc. K. Akad. Wetenschap te Amsterdam*, 18, no. 9.

to zero in the British Isles and central Scandinavia. The highest coefficients between trade wind velocity and winter temperature in Iceland and Greenland were given by the trade wind for May to October, and the coefficients were negative (—·6). The interval between trade wind and temperature anomaly is therefore only 4½ months for Central Europe and 5½ months for Iceland and Greenland. The pressure distribution associated with warm winters shows high pressure in the north (Jacobshavn and Stykkisholm) but low pressure over Europe ; in cold winters this distribution was reversed. From Figure 1 it is seen that four months after a strong NE. trade pressure is high at Jacobshavn and Stykkisholm, low at Ponta Delgada, Valencia, Paris and Berlin. This effect after four months is evidently real, but the interval is too short for it to be brought about by the Gulf Stream. Table I shows that the surface water set in motion by a powerful NE. trade wind would be found four months later near the West Indies and could not possibly affect the temperature of Central Europe directly.

The problem has also been investigated by W Georgii*, who finds a negative correlation between the monsoon rainfall of Northern India, especially in August and September, and the subsequent winter temperature of Central Europe. In this instance also the maximum effect is felt after 4½ months. Heavy Indian rainfall corresponds with a strong SW monsoon and there is a negative correlation (—·42) between the rainfall of the Indian south-west monsoon and the velocity of the NE. trade wind (Gallé's data). Hence, Georgii supposes that a strong SW. monsoon and a weak NE. trade lead to the accumulation of air over eastern Europe and in the Siberian " high," giving cold anticyclonic weather in the following winter. This high pressure over Europe would intensify the normal pressure gradient between Europe and Iceland, increasing the strength of the south-westerly winds and bringing higher temperatures to Iceland.

Georgii's relationship may be set out in another way. A strong NE. trade indicates that a large amount of air is flowing out of the sub-tropical pressure belt. This results in a decrease of pressure in this belt, and for some reason the pressure reaches its minimum 4 or 4½ months later. At the same time, either because of the dynamical opposition between variations of pressure in the sub-tropical high pressure belt and those in the sub-arctic " lows," or for some other reason, pressure rises in the north. If this hypothesis is correct, the NE. trade wind should show a higher correlation with the *change* of pressure in the following four months than with the actual pressure four months later. This was tested by correlating the calculated values of NE. trade velocity with the change of pressure in the following four months at Ponta Delgada and Stykkisholm (Table VIII).

TABLE VIII.—CORRELATION OF NE. TRADE WITH PRESSURE AFTER FOUR MONTHS AND WITH CHANGE OF PRESSURE IN FOUR MONTHS (1891—1915).

TRADE WIND DURING	PONTA DELGADA		STYKKISHOLM	
	Pressure after Four Months	Change of Pressure	Pressure after Four Months	Change of Pressure
	(From Table I)		(From Table I)	
January–March	—·06	—·**52**	+·15	+·**26**
April–June	—·**30**	—·**28**	+·14	+·19
July–September	—·04	—·**32**	+·**34**	+·**36**
October–December	—·13	—·**31**	+·11	+·16
Mean	—·13	—·**36**	+·19	+·**24**

With one slight exception at Ponta Delgada, the change of pressure in four months gives higher correlations with trade wind than does the actual pressure four months after the trade wind. This supports the hypothesis that the pressure anomalies occurring four months after anomalies of the NE. trade are brought about directly by the transference of air which forms the wind and not indirectly through the movement of ocean currents.

* Georgii, W. " Beziehungen zwischen den Monsunregen Nordindiens und der Winterwitterung vou Europa." *Ann. Hydrogr.*, Berlin, 51, 1923, p. 16.

§ 6. The Seasonal Variations of the Coefficients.

We may now pass to a brief discussion of the seasonal variation of the more important effects described above. In doing this we are on less sure ground than in dealing with the annual means owing to the greater possibility of large "chance" coefficients.

Four Months after NE. Trade.—The annual means of the correlation coefficients between the NE. trade and pressure four months later exceed a value of 0·1 at only five stations: Jacobshavn, Stykkisholm, Ponta Delgada, Valencia and Paris. For these stations the coefficients were worked out for overlapping periods of three months: January to March, February to April, March to May, etc. The values are shown in Table IX.

In referring to coefficients for individual quarters it will be convenient to designate any quarter by its middle month, e.g., the quarter January to March will be termed February.

At Jacobshavn and Stykkisholm the coefficients are positive throughout, but are very small in July. At Ponta Delgada the coefficients are mainly negative, but appreciable only from February to May and from September to November, at Valencia only in May and June, and at Paris from April to June. Of the other stations, Berlin also shows appreciable negative coefficients in May and August; Bergen shows a positive coefficient in May, and Vardo shows small positive coefficients throughout. The effect is therefore greatest in spring, but can be traced throughout the year, especially at the northern stations.

Nine Months after NE. Trade.—The coefficients for overlapping quarters for eight stations are shown in Table X.

Table IX.—Correlation between Pressure at certain Stations and NE. Trade Four Months earlier.

	Jan.-Mar.	Feb.-Apr	Mar.-May	Apr-June	May-July	June-Aug.	July-Sept.	Aug.-Oct.	Sept.-Nov.	Oct.-Dec.	Nov.-Jan.	Dec.-Feb.
Jacobshavn ..	+ **·24**	+ ·13	+ **·24**	+ **·31**	+ **·27**	+ ·02	+ **·20**	+ **·33**	+ **·30**	+ **·47**	+ **·44**	+ **·30**
Stykkisholm ..	+ ·14	+ ·11	+ **·27**	+ ·16	+ ·15	+ ·02	+ ·19	+ ·14	+ ·04	+ **·21**	+ **·34**	+ ·09
Ponta Delgada	− ·13	− ·13	− **·32**	− ·16	− ·06	+ ·12	− ·07	− **·30**	− **·22**	− ·17	− ·04	− ·01
Valencia ..	+ ·01	·00	− ·05	− **·44**	− **·30**	+ ·13	− ·07	− ·15	− ·05	− ·01	+ ·12	− ·09
Paris	− ·12	− ·06	− ·19	− **·29**	− **·22**	+ ·15	− ·09	− **·24**	− ·03	·00	·00	− ·10

The positive coefficients at the northern stations are best shown between November and May. Ponta Delgada gives negative coefficients from January to May, but Valencia, Paris and Berlin all show a rapid change from high negative coefficients in February to high positive coefficients in April.

Twelve Months after NE. Trade.—The correlation coefficients between the NE. trade and the pressure 12 months later are largest in the central zone, between latitudes 50° and 65° N., especially at Thorshavn and Bergen. The coefficients for over-lapping quarterly means at six stations are shown in Table XI, which also gives the mean of the six. The annual variation at all stations is roughly similar—positive correlation with pressure in spring and autumn and negative correlation with pressure

TABLE X.—CORRELATION BETWEEN PRESSURE AT CERTAIN STATIONS AND NE. TRADE NINE MONTHS EARLIER.

	Jan.-Mar.	Feb.-Apr.	Mar.-May	Apr.-June	May-July	June-Aug.	July-Sept.	Aug.-Oct.	Sept.-Nov.	Oct.-Dec.	Nov.-Jan.	Dec.-Feb.
Jacobshavn ..	+ **·37**	+ ·14	+ ·12	+ **·26**	+ **·39**	− ·04	− ·06	− ·08	+ ·06	+ ·19	+ ·15	+ ·10
Stykkisholm ..	+ **·30**	− ·01	+ ·03	− ·05	+ ·18	− ·05	+ ·07	− **·26**	− ·05	+ ·05	+ ·10	+ ·07
Thorshavn ..	+ ·04	+ ·01	+ **·33**	+ ·17	− ·03	− ·06	+ ·05	− ·18	+ ·05	+ ·06	+ ·12	+ ·07
Ponta Delgada	− **·47**	− **·34**	− **·26**	− **·27**	− ·02	+ ·18	− ·05	− ·09	+ ·01	− ·10	+ ·08	− **·33**
Valencia ..	− **·26**	− ·09	+ **·39**	+ ·07	− ·08	− ·08	+ ·07	− ·08	+ ·03	− ·11	+ ·16	− ·16
Paris	− **·44**	− ·08	+ **·22**	+ ·16	− ·08	− ·06	+ ·03	+ ·08	+ ·06	+ ·03	+ ·07	− ·09
Berlin	− **·39**	+ ·05	+ **·39**	+ **·22**	− ·11	− ·06	+ ·03	+ ·05	+ **·23**	+ **·22**	+ ·08	+ ·01
Vardo	+ **·36**	+ ·11	− ·02	+ ·15	− ·05	− **·37**	− ·19	− **·25**	+ ·12	+ ·19	+ ·17	+ **·31**

TABLE XI.—CORRELATION BETWEEN PRESSURE AT CERTAIN STATIONS AND NE. TRADE TWELVE MONTHS EARLIER.

	Jan.-Mar.	Feb.-Apr.	Mar.-May	Apr.-June	May-July	June-Aug.	July-Sept.	Aug.-Oct.	Sept.-Nov.	Oct.-Dec.	Nov.-Jan.	Dec.-Feb.
Stykkisholm ..	+ ·11	+ **·28**	+ ·02	− **·21**	− ·16	− ·09	− ·15	·00	+ ·03	+ ·01	+ ·14	+ ·08
Thorshavn ..	+ **·23**	+ **·29**	+ ·08	+ ·14	+ ·08	·00	− **·26**	− ·09	+ ·03	+ ·04	+ ·03	− ·03
Valencia ..	+ ·12	− ·16	− ·04	+ **·24**	+ ·04	− ·12	− ·12	+ ·04	+ **·25**	+ ·19	+ ·08	+ ·07
Paris	+ ·02	− ·19	− ·03	+ **·29**	− ·11	− ·14	− ·11	− ·09	+ **·28**	+ **·30**	+ ·17	+ ·08
Berlin	+ ·04	− ·18	+ ·10	+ **·37**	− ·10	− ·02	− ·09	− **·20**	+ **·22**	+ **·33**	+ **·20**	− ·01
Bergen ..	+ **·23**	+ ·16	+ ·13	+ **·36**	+ ·07	− ·08	− **·40**	− **·30**	·00	+ ·18	+ ·10	− ·07
Mean ..	+ ·13	+ ·03	+ ·04	+ **·20**	− ·03	− ·07	− ·19	− ·11	+ ·13	+ ·17	+ ·12	+ ·02

in summer (Fig. 7). In spring the variation is complicated by the opposition between Stykkisholm and Thorshavn on the one hand, and Valencia, Paris and Berlin on the other hand.

Twenty to Twenty-four Months after NE. Trade.—From Figure 1 we see that from 18 to 21 months after a strong NE. trade pressure is low at Ponta Delgada, and high at Jacobshavn. This effect is not shown on the annual means at any other stations. Figure 6 shows that at Ponta Delgada the appreciable coefficients are limited to the first half of the year, and reach their greatest negative value in the quarter centred on the twentieth month after the trade wind velocity. The over-lapping quarterly coefficients of correlation between pressure at Ponta Delgada and NE. trade 20 months earlier are as follows :—

Jan.-March	Feb.-April	March-May	April-June	May-July	June-Aug.	July-Sept.	Aug.-Oct.	Sept.-Nov.	Oct.-Dec.	Nov.-Jan.	Dec.-Feb.
− **·55**	− **·43**	− **·34**	− **·33**	− ·14	+ ·06	+ ·06	− ·12	− ·07	− **·22**	− **·36**	− **·42**

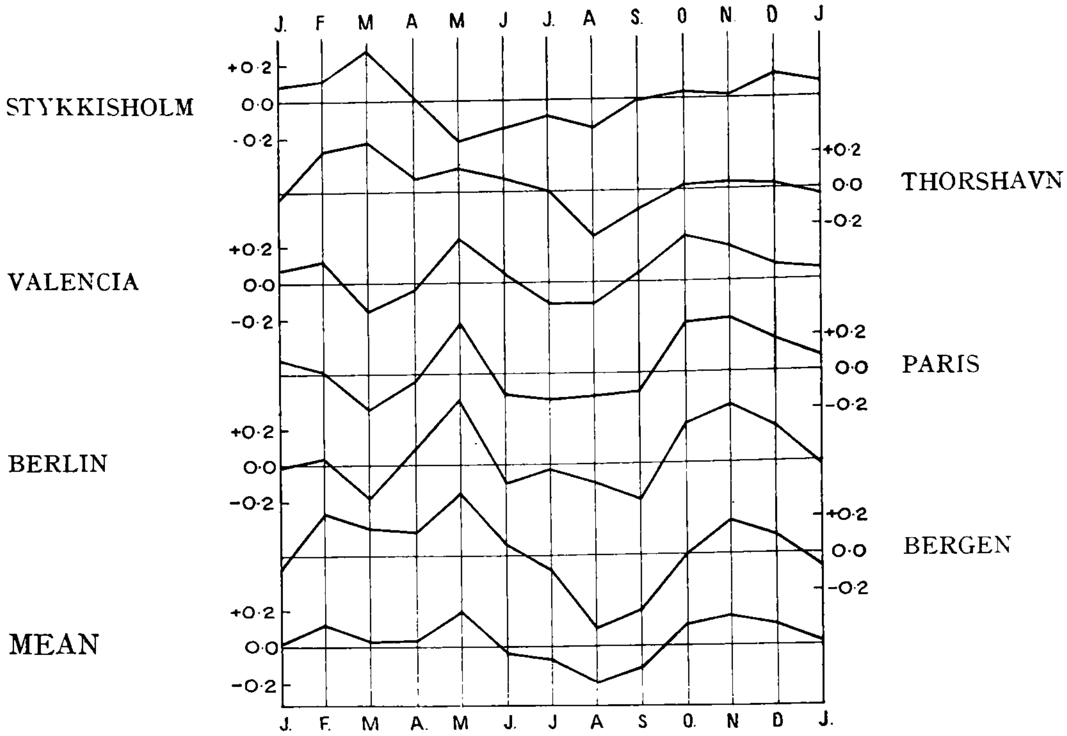

FIG. 7.—CORRELATION COEFFICIENTS BETWEEN NORTH-EAST TRADE AND PRESSURE TWELVE MONTHS LATER.

At Jacobshavn the coefficients are also greatest with pressure in the first half of the year, but the lag is somewhat greater than at Ponta Delgada : pressure, January-March with NE. trade 22 months earlier, +·**37**; pressure March-May with trade 24 months earlier, +·**42**; pressure April-June with trade 24 months earlier, +·**34**; pressure July-September with trade 23 months earlier, +·**31**.

At Valencia, Paris and Berlin there are appreciable negative coefficients between pressure in January to March and trade wind 22 months earlier. At Valencia the coefficients are : November-January —·**24**; December-February —·**38**; January-March —·**44**; February-April +·03. At Paris the coefficient for January to March is —·**36** and at Berlin —·**28**. At all three stations the coefficients for April to June are positive. At Bergen and Vardo the coefficients for January to March are negligible, but the coefficients for April to June reach the high values of +·**51** at Bergen (21 months) and +·**41** at Vardo (22 months) Pressure in October to December gives high negative coefficients with the NE. trade 23 months earlier (Bergen —·**44**, Vardo —·**47**).

Twenty-four months after a strong NE. trade in all seasons except April to June pressure tends to be below normal over the whole of the north-east Atlantic, from Vardo to Ponta Delgada, and over western Europe (Berlin, Paris). In April to June pressure tends to be above normal over the whole area.

Thus the most persistent feature in the seasonal variation of the effect of the NE. trade wind on the subsequent pressure distribution is the way in which one to two years after a high wind velocity high pressure in April to June changes to low pressure in July to September. To show this the correlation coefficients between pressure in the different seasons and the trade wind velocities 12, 15, 18, 21 and 24 months earlier have been averaged for each station, giving the figures shown in Table XII.

The annual range of the correlation coefficients is greatest in Scandinavia, especially at Bergen. A similar annual variation is shown in the average pressure over northern Europe, e.g., at Upsala (near Stockholm), the departures of the seasonal means of pressure from the annual mean are : January to March, +0·2 mb. ; April to June, +1·2 mb. ; July to September, —0·9 mb. ; October to December, —0·3 mb.

TABLE XII.—AVERAGE CORRELATION COEFFICIENTS BETWEEN PRESSURE IN DIFFERENT QUARTERS AND NE. TRADE 12, 15, 18, 21 AND 24 MONTHS EARLIER.

	Jan.-March	April-June	July-Sept	Oct.-Dec
Thorshavn	+·03	+**·21**	−·09	−·19
Valencia	−·14	+·08	−·03	+·03
Paris	−·11	+·08	−·13	+·10
Berlin	−·05	+·18	−·13	+·04
Bergen	+·01	+**·31**	−**·24**	−·19
Vardo	+·02	+·14	−**·30**	−**·22**
Mean of six stations	−·04	+·17	−·18	−·09
Jacobshavn	+·04	+·08	+·14	+·11
Stykkisholm	+·01	−·09	−·10	−·08
Ponta Delgada	−**·30**	−·14	+·02	−·05

This suggests that 12 to 24 months after a strong NE. trade the annual variation of pressure in Scandinavia and neighbouring regions is accentuated, while after a weak NE. trade the annual variation of pressure is weakened.

Twelve Months after SE. Trade.—From Figure 3 it will be seen that the annual means of the coefficients show maxima or minima after 12 months at all stations. The maxima are appreciable only at Paris (+**·23**), Berlin (+·18), and Stykkisholm (+·17); the only minima are at Vardo (—·14) and Ponta Delgada (—·15). Turning now to the seasonal variation it will be seen from Table V that in January to March there is a small negative coefficient at Ponta Delgada (—·17); at Paris, Valencia and Vardo the coefficients are insignificant, and at the remaining stations positive, reaching +**·26** at Stykkisholm, +**·32** at Thorshavn, +**·35** at Bergen, and +**·25** at Berlin. In April to June the distribution is rather irregular, the biggest co-efficient of +**·39** at Stykkisholm being isolated. The same applies to July to September, with isolated coefficients of +**·44** at Berlin, and —**·27** at Vardo. In October to December there is a large isolated coefficient of —**·53** at Vardo and positive coefficients of +**·44** at Paris and +**·24** at Berlin. Thus, in the individual quarters large isolated coefficients predominate; there does not appear to be any systematic annual variation, these large isolated coefficients being probably mainly accidental, and it seems best to consider the annual means as applying to each of the four quarters.

Eighteen to Twenty-one Months after SE. Trade.—Figure 3 shows that the coefficients are negative in the north (Jacobshavn —**·24**, Stykkisholm —·15, Vardo —·12), positive in middle latitudes (Valencia +**·22**, Paris +**·27**, Berlin +·14) and insignificant at Thorshavn, Bergen and Ponta Delgada. The coefficients for the individual seasons given in Table V show, on the whole, a similar distribution. The quarter October to December has some large coefficients (Valencia +**·66**, Paris +**·50**, Berlin +**·35**), which are probably accidental.

The annual variation of the correlation coefficients of pressure with the strength of the SE. trade 12 to 24 months earlier is the reverse of the annual variation of the coefficients of pressure and NE. trade, as will be seen from the following table :—

Correlation between pressure and trade wind 12-24 months earlier.
(Mean of six stations.)

	Jan.-March	April-June	July-Sept.	Oct.-Dec.
SE. trade	+·04	−·03	+·09	+·07
NE. trade	−·04	+·17	−·18	−·09

Since a strong SE. trade leaves the surface waters of the North Atlantic warmer than usual, while a strong NE. trade leaves them colder than usual (see Fig. 5), this opposition is to be expected.

§ 7. The Gulf of Mexico.

The effect of wind velocity along the equatorial current on subsequent pressure in western Europe has not been examined in detail, partly owing to the difficulty of obtaining satisfactory data over a long period, and partly because, even if a close relationship with the subsequent pressure over western Europe could be determined, it would be difficult to obtain the necessary data in time to be of value in forecasting. It may be remarked, however, that in connection with an earlier investigation (unpublished) into the possibility of forecasting the seasonal rainfall of the West Indies, the mean pressure at the point 20° N., 40° W. for the months of April to June, 1900 to 1916, obtained from a publication of the Netherlands Meteorological Institute, was correlated with the average rainfall at three stations in the West Indies during the quarters April to June, May to July, and so on. The results show a maximum correlation of about —·7 between pressure in April to June and the rainfall two to three months later :—

PRESSURE	RAINFALL.				
April-June	April-June	May-July	June-Aug.	July-Sept.	Aug.-Oct.
Correlation coefficient	— ·33	— **·48**	— **·68**	— **·67**	— **·33**

An interesting relationship between the rainfall in Havana, Cuba, and that in the British Isles six to nine months later was brought to light by A. H. Brown.* The correlation coefficients were :—

Rainfall at Havana May to October with rainfall in Southern Ireland in the following January to March, —**·47** ± ·09.

Rainfall at Havana May to October with rainfall in south-west England in the following January to March, —**·54** ± ·08.

The interval of six to nine months is approximately the time taken for the water of the Gulf Stream to travel from Cuba to the Atlantic north of Scotland, but the negative sign of the coefficients is against a relationship which depends directly on the surface temperature. I. R. Tannehill† has shown that at Galveston the July rainfall is greatest when the sea surface temperature is highest, and *a priori* we should expect a similar effect in the British Isles. The effect on the rainfall of the British Isles probably takes place through some modification of the pressure distribution, and the next step therefore was to correlate the rainfall at Havana in May to October with the pressure at various stations in the following January to March. The results were as follows :—

Correlation coefficient, rainfall at Havana and pressure at	Stykkisholm.	Thorshavn.	Bergen.	Valencia.	Paris.	Ponta Delgada.
	— ·04	+ ·16	+ **·37**	+ **·38**	+ **·37**	— ·06

Evidently there is a distinct tendency for heavy rainfall at Havana in May to October to be followed by anticyclonic conditions somewhere in western Europe during the following January to March.

* Brown, A. Hampton. "A Cuban Rain Record and its Application." London, *Q.J.R. Meteor. Soc.*, 40, 1914, p. 295. "The Rainfall of Cuba and England, South-west." *Symons's Meteor. Mag.* London, 50, 1915, p. 14.

† Tannehill, I. R. "Influence of Gulf Water-surface Temperatures on Texas Weather," Washington, D.C. *Monthly Weather Rev.*, 51, 1923, p. 345.

This relationship gives us a useful indication of the probable pressure distribution over western Europe during January to March, but is of no use for the remaining nine months. Since there is probably some relation between the rainfall and pressure at Havana, the latter was correlated with the subsequent pressures at the selected stations in order to determine if there is a connection which could be utilized throughout the year. These coefficients are shown in Table XIII, and the annual means are plotted in Figure 8. The results show that high pressure at Havana in July to September tends to be followed by high pressure in western Europe in January to March of the next year, but that for other seasons of the year the correlation is inappreciable. The coefficients between pressure in western Europe in January to March and pressure at Havana in the preceding July to September are slightly higher than those with preceding rainfall at Havana, and the positive coefficients cover a wider area: Stykkisholm + **·28**, Thorshavn + **·36**, Valencia + **·39**, Bergen + **·39**, Paris + **·26**, Berlin + **·29**. At Ponta Delgada the correlation is negligible when an interval of six months is employed, but there is an appreciable correlation between pressure at Ponta Delgada and pressure at Havana three months before, in all quarters except April to June. This suggests the movement of centres of excess eastward from Havana to the Azores.*

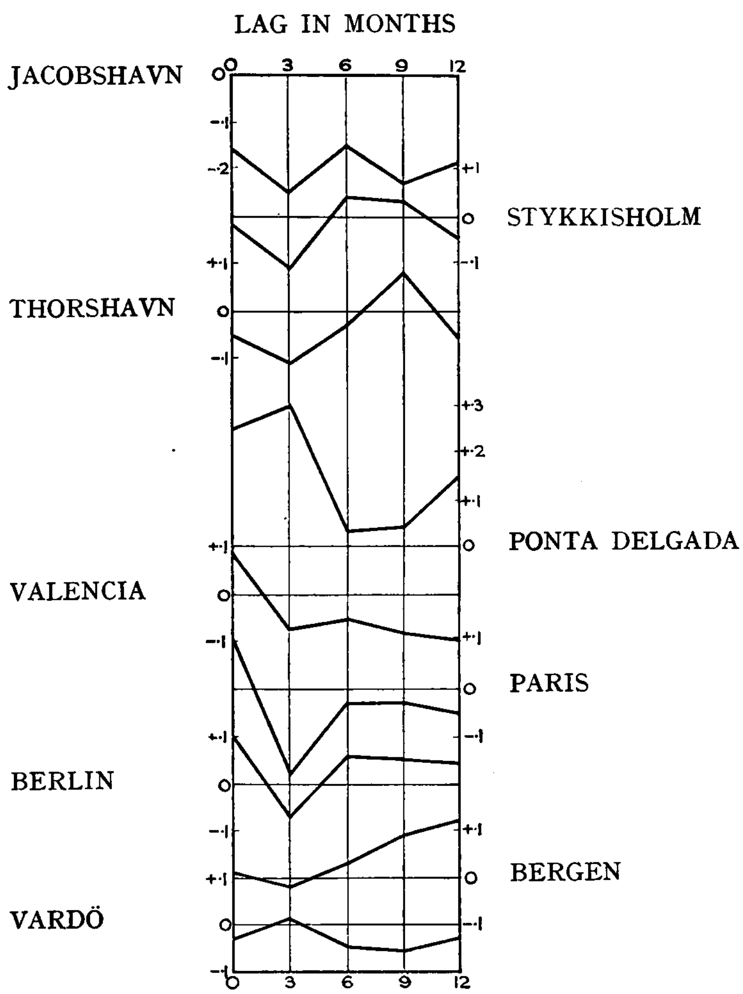

FIG. 8.—CORRELATION COEFFICIENTS BETWEEN HAVANA PRESSURE AND SUBSEQUENT PRESSURE IN WESTERN EUROPE.

* Brooks, C. E. P. "The Variations of Pressure from Month to Month in the Region of the British Isles." London, *Q.J.R. Meteor. Soc.*, 52, 1926, p. 263.

TABLE XIII.—CORRELATION OF PRESSURE IN THE NORTH ATLANTIC AND WESTERN EUROPE WITH PRESSURE AT HAVANA, CUBA, 1891-1915.

LAG IN MONTHS	0	3	6	9	12
Jacobshavn—					
January–March	− ·60	− **·34**	− ·02	− **·42**	− **·23**
April–June	− ·16	+ ·13	− ·11	+ ·04	− **·24**
July–September	+ ·36	− **·51**	− **·31**	− **·66**	+ ·05
October–December	− ·24	− **·29**	− ·18	+ ·13	− **·36**
Mean	− ·16	− **·25**	− ·15	− **·23**	− ·19
Stykkisholm—					
January–March	− ·38	− **·22**	+ **·28**	− ·14	+ ·02
April–June	− ·23	+ **·29**	− ·06	+ ·11	− **·22**
July–September	+ ·51	− **·30**	− ·09	− ·15	+ ·07
October–December	+ ·03	− ·19	+ ·03	+ **·32**	− ·08
Mean	− ·02	− ·11	+ ·04	+ ·03	− ·05
Thorshavn—					
January–March	− ·12	− **·43**	+ **·36**	+ ·01	+ ·11
April–June	− ·28	+ **·28**	− ·04	+ ·08	+ ·02
July–September	+ ·36	− ·09	− ·12	+ ·08	− ·12
October–December	− ·16	− **·21**	− **·31**	+ ·15	− **·25**
Mean	− ·05	− ·11	− ·03	+ ·08	− ·06
Ponta Delgada—					
January–March	+ ·03	+ **·39**	− ·13	+ ·15	+ ·16
April–June	+ ·72	+ ·07	− ·10	− ·03	+ **·32**
July–September	− ·16	+ **·30**	+ ·17	+ **·20**	+ ·14
October–December	+ ·39	+ **·43**	+ ·19	− **·47**	+ ·03
Mean	+ ·25	+ **·30**	+ ·03	+ ·04	+ ·16
Valencia—					
January–March	+ ·33	− **·31**	+ **·39**	− **·31**	+ ·04
April–June	+ ·17	+ **·28**	− ·17	− **·24**	+ **·21**
July–September	+ ·06	− **·25**	− ·17	+ **·23**	− **·25**
October–December	− ·22	− ·01	− **·24**	·00	− **·34**
Mean	+ ·09	− ·07	− ·05	− ·08	− ·09
Paris—					
January–March	+ ·39	− **·54**	+ **·26**	− **·29**	+ ·02
April–June	+ ·10	− ·14	− ·16	− **·21**	+ **·21**
July–September	+ ·24	− ·06	− ·01	+ **·31**	− ·19
October–December	− ·29	+ ·03	− **·20**	+ ·08	− **·23**
Mean	+ ·11	− ·18	− ·03	− ·03	− ·05
Berlin—					
January–March	+ ·36	− **·23**	+ **·29**	·15	− ·01
April–June	+ ·03	− ·14	− ·04	− ·13	+ **·38**
July–September	+ ·34	− ·01	+ ·09	+ **·42**	− ·10
October–December	− ·30	+ ·10	− ·11	+ ·04	− ·11
Mean	+ ·11	− ·07	+ ·06	+ ·05	+ ·04
Bergen—					
January–March	+ ·05	− **·35**	+ **·39**	− ·02	+ ·11
April–June	− ·18	+ **·25**	− ·06	+ ·04	+ **·25**
July–September	+ ·39	+ ·06	+ ·06	+ **·25**	+ ·11
October–December	− ·20	− ·03	− **·26**	+ ·10	+ ·02
Mean	+ ·01	− ·02	+ ·03	+ ·09	+ ·12
Vardo—					
January–March	− ·44	− ·19	+ ·14	+ ·04	− ·10
April–June	− ·30	+ **·39**	− ·06	+ **·23**	− **·49**
July–September	+ ·26	+ ·01	− ·03	− **·54**	+ **·40**
October–December	+ ·34	− ·19	− **·20**	+ ·03	+ ·07
Mean	− ·03	+ ·01	− ·05	− ·06	− ·03

§ 8. The Bermuda-Charleston Pressure Difference.

The next factor along the course of the Gulf Stream which was investigated was the pressure difference between Bermuda and Charleston. Pressures at the selected stations in western Europe and the North Atlantic for each quarter for the period 1891 to 1915 were correlated with the pressure difference Bermuda-Charleston for the same quarter and for the quarters 3, 4, 5, 6, 9, 12, 15, 18, 21 and 24 months previously. The results are shown in Table XV and the annual means of the coefficients are plotted in Figure 9. The mean values and standard deviations of the pressure difference Bermuda-Charleston are shown in Table XIV.

Table XIV.—Bermuda-Charleston Pressure Difference.

	Jan.-March	April-June	July-Sept.	Oct.-Dec.
Mean, mb.	−0·8	+2·0	+1·9	−1·9
Standard deviation, mb. ..	1·45	1·30	1·00	1·21

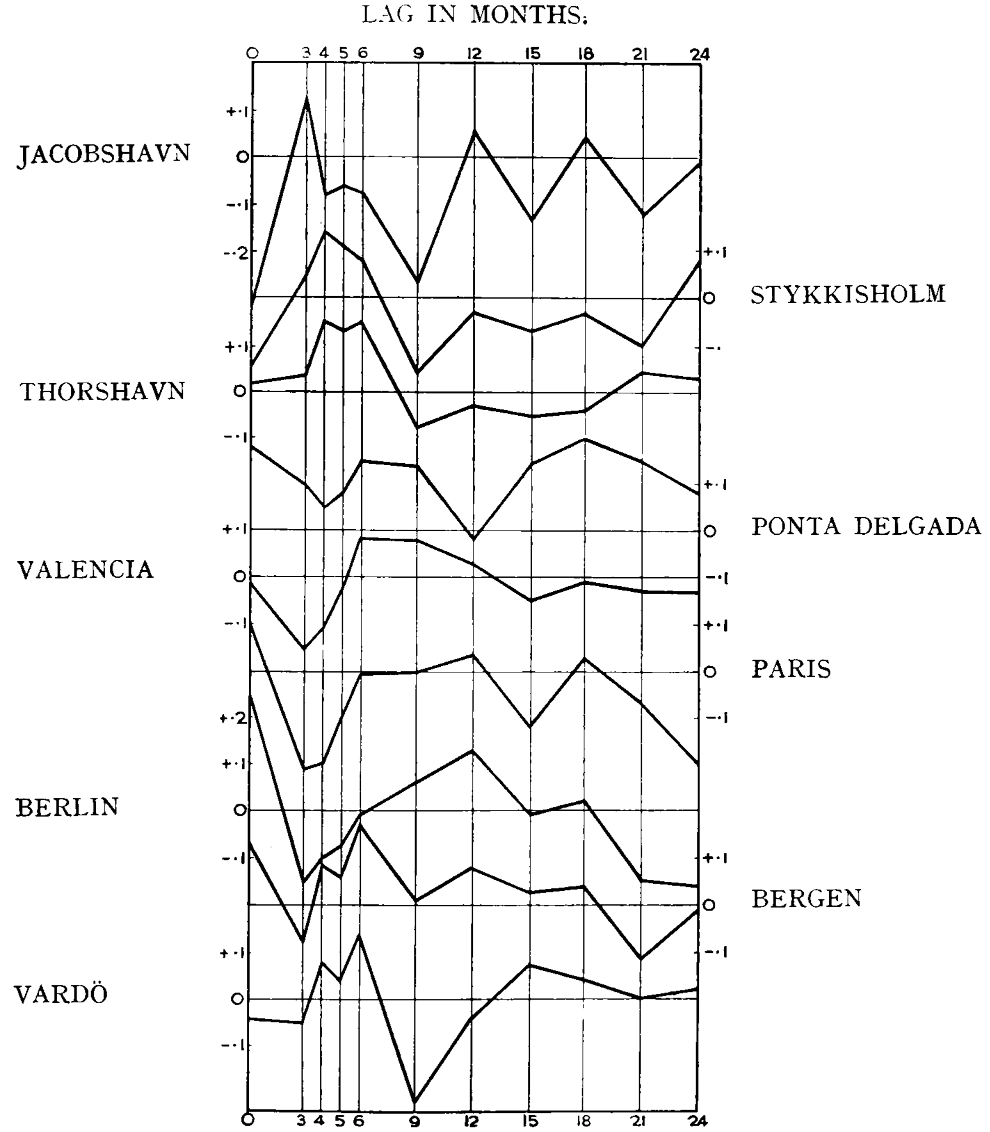

Fig. 9.—Correlation between pressure gradient Bermuda—Charleston and subsequent pressure.

TABLE XV.—CORRELATION OF PRESSURE IN THE NORTH ATLANTIC AND WESTERN EUROPE WITH PRESSURE DIFFERENCE BERMUDA-CHARLESTON.

	LAG IN MONTHS										
	0	3	4	5	6	9	12	15	18	21	24
Jacobshavn—											
January–March ..	−·61	−·11	−·08	−**·20**	−·09	−**·23**	−·15	+**·31**	−·14	−·15	+·12
April–June	−·10	−**·25**	−**·22**	−**·27**	−**·21**	−**·44**	+·01	−**·49**	+·11	−**·20**	−·07
July–September ..	−·02	+·06	−·07	+·11	+·09	−**·27**	+·13	+·01	+·03	+·10	−**·24**
October–December	−·55	−**·20**	+·06	+·11	−·07	−·16	+**·24**	−**·35**	+**·20**	−**·23**	+·14
Mean	−·32	+·13	−·08	−·06	−·07	**·27**	+·06	−·13	+·05	−·12	−·01
Stykkisholm—											
January–March ..	−·38	−·01	+·06	−·04	+·08	−·19	−·03	+·13	−**·25**	−**·20**	+·05
April–June	+·21	+·18	+**·25**	+·07	−·03	+·01	−·03	−**·26**	−·04	·00	−·02
July–September ..	+·14	+·13	+·08	+**·24**	+**·32**	−·01	+·06	+·14	+·01	−·04	+**·26**
October–December	−·54	−·09	+·16	+·15	−·04	−**·45**	−·10	−**·27**	+·14	−·15	+·03
Mean	−·14	+·05	+·14	+·11	+·08	−·16	−·03	−·07	−·03	−·10	+·08
Thorshavn—											
January–March ..	−·20	+·05	+**·22**	+·13	+**·27**	−·01	−·01	−·02	+·09	+·07	−·10
April–June	+·16	−·04	+·09	+·14	+**·21**	+·06	+·11	−**·27**	−**·33**	+·07	+·09
July–September ..	+·22	+·09	+·19	+·13	+**·23**	+·14	−·05	+·05	+·13	+**·31**	+**·31**
October–December	−·11	+·04	+·12	+·11	−·09	−**·50**	−·18	+·06	−·06	−**·26**	−**·20**
Mean	+·02	+·04	+·15	+·13	+·15	−·08	−·03	−·05	·04	+·05	+·03
Ponta Delgada—											
January–March ..	+·23	−·18	−·11	+·02	+**·29**	+**·25**	+·16	−·06	+**·35**	+·14	−·01
April–June	+·13	+**·37**	+**·27**	+·14	+·17	+·01	+·04	+**·56**	+**·24**	+**·44**	+**·38**
July–September ..	+·04	+**·26**	+·10	+·15	+·11	+·07	−·12	+·09	+**·27**	−·19	+·17
October–December	+·32	−·06	−·07	·00	+·05	+**·23**	·14	−·02	−·07	+**·20**	−**·24**
Mean	+·18	+·10	+·05	+·08	+·15	+·14	·02	+·14	+**·20**	+·15	+·08
Valencia—											
January–March ..	−·12	−·12	−·15	−·06	+**·30**	+**·21**	−·16	−**·31**	+·08	−·08	−**·20**
April–June	−·09	−**·33**	−·17	+·03	−·01	+·09	+·09	+·07	−·08	+·02	+·13
July–September ..	+·28	+·02	+·15	+·14	+**·22**	+**·26**	+**·21**	+**·26**	+**·19**	+**·22**	+**·33**
October–December	−·12	−·16	−**·27**	−**·21**	−·17	−**·23**	−·03	−**·23**	−**·24**	−**·29**	−**·39**
Mean	−·01	−·15	−·11	−·03	+·08	+·08	+·03	−·05	−·01	−·03	−·03
Paris—											
January–March ..	+·20	−·17	−·14	−·02	+·12	+·11	−**·20**	−**·46**	+**·22**	+·05	−·18
April–June	−·09	−**·33**	−**·23**	+·03	+·14	+·06	−·09	+**·27**	−·05	+·04	·00
July–September ..	+·22	−·17	−·08	−·13	−·04	−·19	+**·42**	−·16	+**·36**	−·09	−**·24**
October–December	+·08	−·17	−**·36**	−**·29**	−·17	+·04	+·04	−·13	−**·42**	−**·30**	−**·38**
Mean	+·10	−**·21**	−**·20**	−·10	−·01	·00	+·04	−·12	+·03	−·07	−**·20**
Berlin—											
January–March ..	+·36	−·06	−·04	−·03	−·07	+·14	−·03	−**·38**	+**·25**	+·08	−·14
April–June	+·11	−**·33**	−·15	+·18	+**·24**	+**·24**	+**·24**	+**·32**	−·10	−·06	+·05
July–September ..	+·16	−·19	−·04	−**·29**	−·10	−·15	+**·34**	−·10	+**·31**	−·19	−**·33**
October–December	+·37	−·03	−·18	−·16	−·11	−·01	+·04	+·13	−**·38**	−**·42**	−**·24**
Mean	+·25	−·15	−·10	−·07	−·01	+·06	+·13	−·01	+·02	−·15	−·16
Bergen—											
January–March ..	−·01	−·05	+·19	+·09	+**·23**	+·10	+·11	−·15	−·03	−·07	−·19
April–June	+·13	−·15	+·03	+**·27**	+**·34**	+·11	+**·29**	−·04	−**·24**	−·07	+·11
July–September ..	+·24	−·17	+·15	+·09	+·14	+·09	+·05	+·15	+**·41**	+·03	+·06
October–December	+·16	+·05	−·04	−·04	−·12	−**·25**	−·14	+·15	+·04	−**·37**	−·02
Mean	+·13	−·08	+·08	+·06	+·15	+·01	+·08	+·03	+·04	−·12	−·01
Vardo—											
January–March ..	−·34	−·06	+**·21**	+·01	+·16	−**·21**	−·03	+**·34**	−·06	−·07	−·02
April–June	−·17	−·06	−·19	−·17	+·06	−**·49**	−·14	−**·53**	·00	−·04	−·12
July–September ..	+·14	−·17	+·03	+·09	+·17	−·09	−·05	+**·20**	+·16	+·14	+·17
October–December	+·21	+·08	+**·28**	+**·42**	+·17	−·08	+·05	+**·26**	+·05	−·04	+·05
Mean	−·04	−·05	+·08	+·04	+·14	−**·22**	−·04	+·07	+·04	·00	+·02

The mean values and standard deviations of the pressures at the selected stations in western Europe, etc., have been given in Table II.

From Figure 9 we see that following a high value of the pressure difference Bermuda-Charleston we have :—

After an interval of three months, low pressure at Valencia, Paris and Berlin ;

After an interval of four to six months, high pressure at Stykkisholm, Thorshavn, Bergen and Vardo, low pressure at Paris, Berlin and Ponta Delgada ;

After an interval of nine months, high pressure at Ponta Delgada, low pressure at Jacobshavn, Stykkisholm and Vardo ;

After an interval of eighteen months, high pressure at Ponta Delgada.

The correlation between the Bermuda-Charleston pressure gradient and the subsequent surface temperature of the North Atlantic (1902 to 1906 quarterly means) is as follows (Table XVI) :—

TABLE XVI.—CORRELATION BETWEEN BERMUDA-CHARLESTON PRESSURE—DIFFERENCE AND SUBSEQUENT SEA TEMPERATURE.

Interval in months	3	4	5	6	9	12	15	18
Coefficient	$+$ **·44**	$+$ **·44**	$+$ **·39**	**·33**	$+$ **·20**	·18	$+$ **·44**	$+$ **·32**

The maximum effect is shown after 3-4 months and again with equal intensity after 15 months, a large pressure difference resulting in high surface temperatures in the Atlantic. The three stations at which the effect of the Bermuda-Charleston pressure difference on the pressure distribution three months later is largest, are Valencia, Paris and Berlin, which give a mean coefficient of $-$·14, and it is interesting to note that all three show a repetition of the effect after 15 months. The correlation at these three stations with a lag of three months was repeated for the years 1916-23 at Valencia, 1916-20 at Paris, and 1916-18 at Berlin, subsequent years not then being available at the two latter stations.

The 64 quarterly means gave a correlation coefficient of $-$·10 with the Bermuda-Charleston pressure difference three months before. This, though of the same sign, is considerably smaller than the mean coefficient for the three stations for the period 1891-1915 ($-$·17), and a further check seemed required. The quarterly values of the Bermuda-Charleston pressure difference for the 17 years 1874 to 1890 were accordingly correlated with the pressures at Valencia, Paris and Berlin 3, 4, 5, 6, 9, 12, 15 and 18 months later. These 68 quarterly values at each station gave the following coefficients :—

TABLE XVII.—CORRELATION OF BERMUDA-CHARLESTON PRESSURE—DIFFERENCE WITH SUBSEQUENT PRESSURE, VALENCIA, PARIS AND BERLIN.

LAG (months) 1874–1890.	3	4	5	6	9	12	15	18
Valencia	$+$ ·16	$-$ ·01	$-$ ·03	$-$ ·01	·00	$-$ **·29**	$-$ ·08	$-$ ·07
Paris	$+$ ·11	·00	·00	·00	·00	$-$ **·21**	$-$ ·09	$-$ ·13
Berlin	$+$ ·02	$-$ ·10	$-$ ·02	$+$ ·09	$+$ ·01	$-$ ·02	$-$ ·02	$-$ ·13
Mean (1874–1890) ..	$+$ ·10	$-$ ·04	$-$ ·02	$+$ ·03	·00	$-$ ·17	$-$ ·06	$-$ ·11
Mean (1891–1915) ..	$-$ ·17	$-$ ·14	$-$ ·07	$+$ ·03	$+$ ·05	$+$ **·20**	$-$ ·06	$+$ ·01
Mean (1874–1915) ..	$-$ ·06	$-$ ·10	$-$ ·05	$+$ ·03	$+$ ·03	$+$ ·05	$-$ ·06	$-$ ·04

The two sets of coefficients for the periods 1874 to 1890 and 1891 to 1915 are quite different, and the weighted means of the two give very small values. It therefore seems probable that the large negative coefficients at these three stations for the period 1891 to 1915 are spurious, and that the effect of variations of the Bermuda-Charleston pressure difference on the subsequent pressures over western Europe is negligible.

In view of this result sets of coefficients for the period 1874 to 1890 were also calculated for Ponta Delgada and Stykkisholm. The results are as follows :—

TABLE XVIII.—CORRELATION OF BERMUDA-CHARLESTON PRESSURE—DIFFERENCE WITH SUBSEQUENT PRESSURE, PONTA DELGADA AND STYKKISHOLM.

LAG (months).	3	4	5	6	9	12	15	18
Ponta Delgada—								
1874–1890	+ ·11	+ ·18	+ ·09	+ ·08	+ ·04	·14	+ ·02	+ ·10
1891–1915	+ ·10	+ ·05	+ ·08	+ ·15	+ ·14	·02	+ ·14	+ **·20**
Mean	+ ·10	+ ·10	+ ·08	+ ·12	+ ·10	·07	+ ·09	+ ·16
Stykkisholm—								
1874–1890	·00	+ ·02	— ·14	+ ·03	— ·02	·00	·10	+ ·03
1891–1915	+ ·05	+ ·14	+ ·11	+ ·08	·16	·03	·07	– ·03
Mean	+ ·03	+ ·09	+ ·01	+ ·06	— ·10	·02	·08	— ·01

The figures for Ponta Delgada for the period 1874 to 1890 are in good agreement with those for 1891 to 1915, the signs of the corresponding pairs of coefficients being the same in all eight instances. At Stykkisholm the agreement is not good. The final result of the test therefore appears to be that while the pressure difference Bermuda-Charleston has some effect on the subsequent pressure at Ponta Delgada, its influence on the pressure of the more northerly stations is negligible.

§ 9. THE WESTERLY DRIFT IN THE NORTH ATLANTIC.

Off Cape Hatteras the Gulf Stream splits up into several branches, this part of the ocean being known as the " Delta of the Gulf Stream." Under the influence of the prevailing south-westerly winds the greater part of the warm water drifts eastward and influences the temperature of the whole eastern part of the North Atlantic from the Azores to the Arctic Ocean. The drift is influenced not only by variations of the pressure gradient from south to north, but also by variations in the pressure gradient from east to west. In order to determine the most suitable points for further attack, a preliminary investigation was made, based on the pressure values published in the *Réseau Mondial* for the years 1910 to 1916. The deviations of pressure from normal in each month at Ponta Delgada, Stykkisholm, Valencia and Berlin, were correlated with the pressure differences 0,1......6 months earlier between the following places :—

Bermuda-St. John's (Newfoundland).
Horta (Azores)-St. John's.
St. John's-Ivigtut (South Greenland).
Horta-Vestmanno (Iceland).
50° N. 20° W.—Vestmanno.
40° N. 20° W.—50° N. 20° W.
Stornoway-Vestmanno.
Ivigtut-Vestmanno.

The deviations from normal at the points 50° N., 20° W. and 40° N., 20° W. were interpolated from the *Réseau Mondial* charts. The coefficients were calculated separately for the half-years October to March, and April to September ; the mean values only are given in Table XIX.

Discussion of the pressure differences between St. John's and Ivigtut and between Ivigtut and Vestmanno is postponed to a later paper, since they presumably owe their influence to the ice and cold water which they drive from the north into the Atlantic circulation. The remaining pressure gradients are discussed below. In an attempt to test relationships suggested by Table XIX a large number of correlation coefficients were calculated, but for the most part the results were negligible, and only a few connexions emerged which could be regarded as being possibly real.

Bermuda-St. John's.—As no long series of reliable observations of pressure at St. John's was available, the pressure difference Bermuda-Sydney was substituted. There is some evidence for a definite annual variation in the correlation between this pressure difference and the pressure at the selected stations in the following month. The coefficients are shown in Table XX and also graphically in Figure 10, in which the full lines represent the observed coefficients and the broken lines the values

TABLE XIX.—CORRELATION BETWEEN VARIOUS PRESSURE GRADIENTS AND SUBSEQUENT PRESSURE AT PONTA DELGADA, STYKKISHOLM, VALENCIA AND BERLIN, 1910-1916. (MONTHLY VALUES.)

PRESSURE DIFFERENCE	STATION	LAG IN MONTHS						
		0	1	2	3	4	5	6
Bermuda–St. John's ..	Ponta Delgada	+ ·11	+ **·20**	+ ·15	+ ·06	+ ·01	+ ·10	+ ·10
	Stykkisholm ..	— ·04	— ·15	— ·09	— ·13	— ·02	— ·08	+ ·01
	Valencia ..	+ ·07	+ ·03	— ·03	— ·09	— ·15	— ·03	+ ·05
	Berlin	+ ·16	+ ·07	+ ·15	+ ·11	— ·12	— ·04	+ ·10
Horta–St. John's	Ponta Delgada	+ ·59	+ ·05	·00	+ ·13	+ ·01	+ ·11	+ **·21**
	Stykkisholm ..	— ·29	+ ·01	— ·07	— ·19	— ·09	— ·11	— **·21**
	Valencia ..	+ ·17	+ ·10	— ·04	+ ·07	+ ·06	— ·09	+ ·07
	Berlin	+ ·06	+ ·07	+ ·17	+ ·12	— ·06	— ·03	+ ·03
St. John's–Ivigtut ..	Ponta Delgada	+ ·59	+ ·05	— ·05	+ ·10	+ ·03	— ·13	— ·15
	Stykkisholm ..	— ·69	— ·05	— ·08	— ·11	— ·17	+ ·03	+ ·01
	Valencia ..	+ ·15	— ·05	— **·24**	— **·20**	+ ·13	+ ·09	+ ·03
	Berlin	+ ·37	+ ·03	— ·07	+ ·03	+ ·13	+ ·03	— ·04
Horta–Vestmanno ..	Ponta Delgada	+ ·89	+ ·09	— ·15	+ ·19	— ·01	— ·03	+ ·11
	Stykkisholm ..	— ·85	+ ·09	·00	— **·33**	— ·07	+ ·01	— ·16
	Valencia ..	— ·09	+ ·06	— ·07	— ·11	+ ·15	— ·15	— ·03
	Berlin	+ ·04	·00	+ ·06	+ ·05	— ·03	— ·13	— ·03
50° N., 20° W.–Vestmanno	Ponta Delgada	+ ·68	+ ·09	— **·21**	+ ·17	+ ·07	— ·07	+ ·11
	Stykkisholm ..	— ·73	+ ·05	+ ·07	— **·33**	— **·23**	+ ·03	— ·13
	[Thorshavn ..	— ·32	+ ·09	+ ·01	— **·43**	·00	+ ·05	— ·05]
	Valencia ..	+ ·51	+ ·13	— **·23**	— **·29**	+ ·10	+ ·11	— ·01
	Berlin	+ ·39	+ ·03	+ ·03	+ ·03	— ·02	— ·15	+ ·03
	[Bergen ..	+ ·08	+ ·06	+ ·06	— ·17	+ ·05	+ ·04	+ ·07]
40°N., 20°W.–50°N., 20°W.	Ponta Delgada	+ ·43	+ ·03	— ·03	+ ·04	+ ·04	+ ·07	— ·01
	Stykkisholm ..	— ·41	+ ·03	— ·06	+ ·01	+ ·01	— ·05	— ·04
	Valencia ..	— ·75	— ·01	+ ·14	+ ·11	·00	— **·37**	— ·03
	Berlin	— ·28	+ ·06	+ ·09	+ ·05	— ·05	— ·18	— ·03
Stornoway–Vestmanno ..	Ponta Delgada	+ ·29	— ·03	+ ·01	+ **·23**	+ ·17	+ ·05	+ ·15
	Stykkisholm ..	— ·44	+ ·03	·00	— **·40**	— **·20**	+ ·07	— ·11
	Valencia ..	+ ·74	+ ·01	— **·25**	— **·25**	+ ·13	+ **·21**	+ ·01
	Berlin	+ ·71	+ ·03	— ·03	+ ·09	+ ·07	+ ·05	+ ·05
Ivigtut–Vestmanno ..	Ponta Delgada	+ ·05	+ ·01	— **·23**	+ ·07	+ ·04	— ·09	+ ·01
	Stykkisholm ..	— ·07	+ ·17	+ ·17	— ·10	+ ·19	— ·01	— ·05
	Valencia ..	— ·42	+ ·07	+ **·21**	+ ·12	+ ·03	— **·25**	— ·17
	Berlin	— ·47	— ·04	+ ·02	— ·03	— ·13	— ·05	— ·03

TABLE XX.—CORRELATION BETWEEN MEAN MONTHLY PRESSURE AT SELECTED STATIONS AND BERMUDA-SYDNEY PRESSURE—DIFFERENCE IN PRECEDING MONTH (1891-1915).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Jacobshavn	−**·20**	−**·25**	−**·28**	−·13	−·18	−**·28**	+·13	+·15	−·10	+·16	+·04	−**·26**	−·10
Stykkisholm	−·08	−**·32**	−·11	−·14	+·05	−·03	+**·34**	+·03	+**·42**	+·16	+·05	−**·32**	·00
Thorshavn	−·02	−**·36**	+·02	−**·38**	−·11	+**·31**	+·19	+**·25**	+**·30**	−·04	+·03	−**·39**	−·02
Ponta Delgada ...	−**·20**	+·15	+**·21**	−**·21**	+**·25**	+**·31**	+·12	−·09	−**·31**	−·11	−·01	−·08	+·04
Valencia	+·08	−**·24**	+**·24**	−·10	−**·25**	+**·20**	+·16	+**·53**	·00	−·19	−·10	−·04	+·01
Paris	+**·24**	−·05	+**·23**	+·12	−·07	−·11	+**·28**	+**·50**	−·11	−**·25**	−·01	+·04	+·07
Berlin	+·17	+·05	+**·30**	·00	−**·22**	−·02	+·05	+**·41**	−·10	−·18	+·14	+·16	+·06
Bergen	−·02	−**·27**	+·01	−**·22**	−·15	+**·22**	+·02	+**·33**	+·10	−·11	+·08	−·17	−·01
Vardo	−**·30**	−**·24**	−**·34**	−**·36**	−·09	−·01	−**·25**	−**·24**	−·05	+**·34**	+·08	−·12	−·13

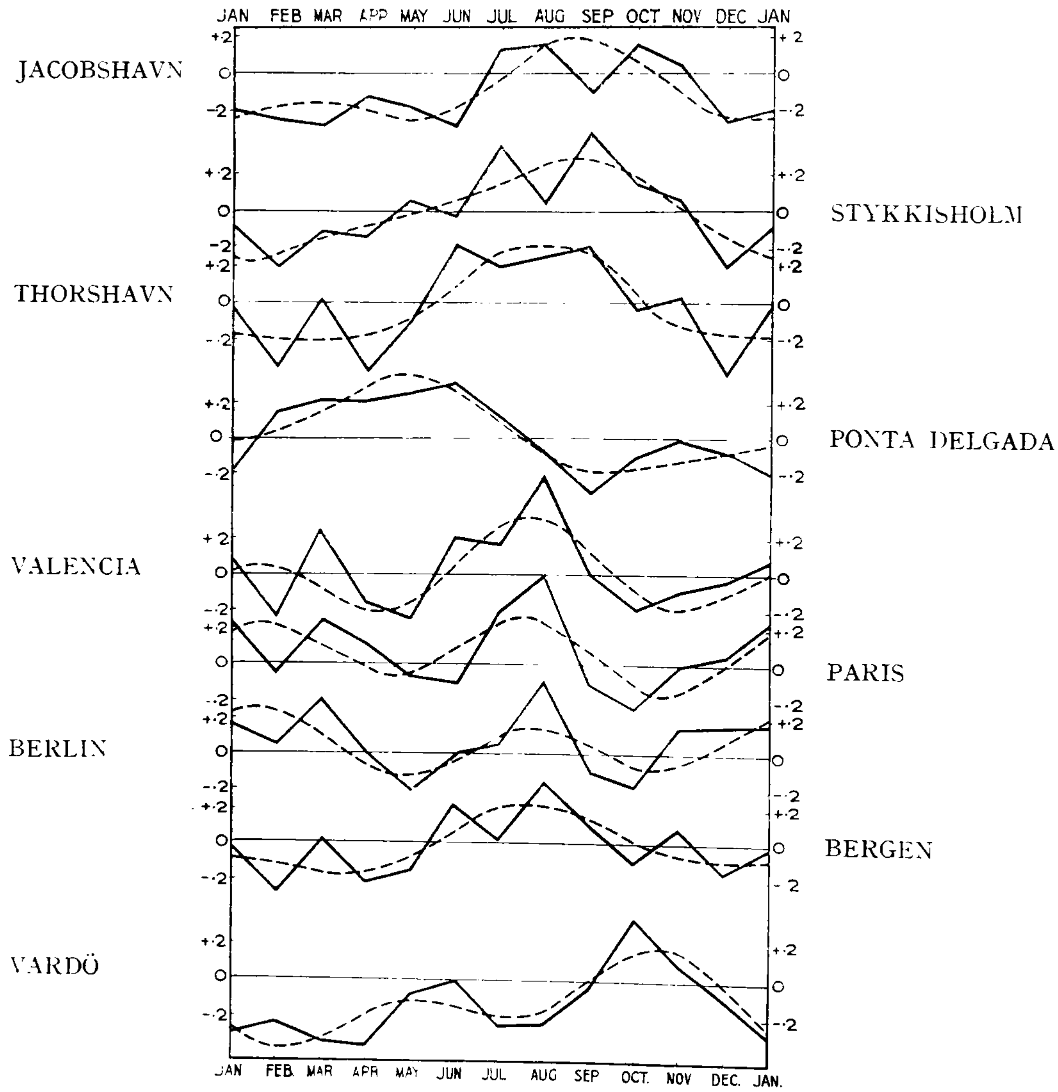

FIG. 10.—CORRELATION BETWEEN BERMUDA—SYDNEY PRESSURE DIFFERENCE AND PRESSURE AT VARIOUS STATIONS ONE MONTH LATER.

smoothed by means of the first two terms of a Fourier series. The annual variation is shown best at the northern stations and at Ponta Delgada ; at the intermediate stations of Valencia, Paris and Berlin, it is less clearly marked and tends to be double.

The correlation of the pressure difference Bermuda-Sydney with the pressures at the selected stations 2, 3, 4, 5 and 6 months later shows very little trace of this regular annual variation, and it is not clear to what cause the correlations with a lag of one month are due. The time interval appears to be too short for action to take place through the medium of ocean currents. The annual variation of the coefficients may be connected with the annual variation in the difference of temperature between land and sea ; possibly a large pressure difference between Bermuda and Sydney, by causing a large eastward transference of air which is relatively cold in winter and warm in summer, may affect the pressure distribution in the eastern North Atlantic and Europe in the following month, but the mechanism is not obvious. At any rate, the regularity in the annual variation of the coefficients at the northern stations and at Ponta Delgada seems too great to be due to chance. This regularity is not due to the persistence of pressure deviations of the same sign at the same station over several months, since the correlation between the pressure of one month and that of the next at the same station is very small.

The quarterly means of the pressure difference Bermuda-Sydney were also correlated with the means of pressure at the selected stations in the following quarter and in the second following quarter. The results are shown in Table XXI. At Jacobshavn, Stykkisholm, Thorshavn, Vardo and Ponta Delgada the coefficients are insignificant, but at Paris, Berlin and to a less extent at Valencia and Bergen, the individual coefficients are appreciable, though the annual means are small. At these stations high pressure in summer follows a small pressure difference between Bermuda and Sydney three months earlier, or a large pressure difference six months earlier ; high pressure in winter follows a small pressure difference six months earlier. The effect of a large pressure difference in spring on the pressure at the selected stations in the following summer (lag of three months) is very similar to the effect of the Bermuda-Charleston pressure difference throughout the year. The reversal of this effect after six months is probably due to the effect of a strong off-shore wind in bringing cold bottom water to the surface after it has driven away the warm surface water. The cause of the annual variation is not clear.

Horta-St. John's.—The correlations shown in Table XIX between this pressure difference and the subsequent pressures present no points of interest, and the effect of this pressure difference was not investigated further.

Horta-Vestmanno.—This represents a well-known variable, the pressure difference between the Azores anticyclone and the Icelandic low. For the purpose of a further investigation, the pressure difference Ponta Delgada-Stykkisholm was employed. Correlation coefficients were calculated between the values of this pressure difference in each month and the pressure at the selected stations 1, 2, 3, 4 and 5 months later. The results were disappointing ; the coefficients were extremely irregular and the annual means were small. The only result which can be regarded as having any significance is that, three months after a large pressure difference between the Azores and Iceland, pressure tends to be low at Stykkisholm and Thorshavn. Out of the 24 coefficients (those for the 12 months at each station), 19 are negative and five are positive (Table XXII). The validity of this result is borne out by the comparatively high negative coefficients between the pressure difference Horta-Vestmanno and pressure at Stykkisholm three months later during the period 1910 to 1916.

In Table XIX the pressure difference between the point 50° N., 20° W and Vestmanno gives higher correlation with subsequent pressure at most stations than does the pressure difference between Horta and Vestmanno. This correlation was accordingly investigated for the remaining stations for the period 1910 to 1916. The full results are shown in Table XXIII.

TABLE XXI.—CORRELATION BETWEEN PRESSURES AT VARIOUS STATIONS AND THE BERMUDA-SYDNEY PRESSURE—DIFFERENCE ONE AND TWO QUARTERS EARLIER.

	LAG OF ONE QUARTER					LAG OF TWO QUARTERS				
	Jan.-Mar.	April-June.	July-Sept.	Oct.-Dec.	Year.	Jan.-Mar.	April-June.	July-Sept.	Oct.-Dec.	Year.
Jacobshavn ..	— **·25**	— ·05	— ·03	— **·30**	— ·16	— ·01	— **·21**	— ·08	+ ·08	— ·05
Stykkisholm ..	— ·06	+ ·09	+ ·01	— ·06	— ·01	+ ·04	— **·27**	— ·03	— ·01	— ·07
Thorshavn ..	+ ·16	+ ·04	+ ·01	+ ·07	+ ·07	+ ·12	— ·11	+ **·25**	— ·07	+ ·05
Ponta Delgada ..	+ **·24**	+ **·27**	+ ·03	·00	+ ·13	+ **·21**	+ ·01	+ ·10	·00	+ ·08
Valencia	+ ·07	+ **·32**	— **·31**	— ·02	+ ·01	— ·13	— ·03	+ **·36**	— ·13	+ ·02
Paris	+ ·11	— ·12	— **·38**	— ·02	— ·10	— **·50**	+ ·05	+ **·32**	— ·10	— ·06
Berlin	+ ·11	— ·18	— **·26**	+ ·08	— ·06	— **·32**	+ ·19	+ ·19	+ ·04	+ ·03
Bergen	+ ·13	— ·15	— ·18	+ ·08	— ·03	— ·01	+ ·01	+ **·31**	+ ·07	+ ·09
Vardo	+ ·08	— ·21	+ ·05	— ·07	— ·03	+ **·27**	+ ·10	+ ·03	+ ·16	+ ·14

TABLE XXII.—CORRELATION BETWEEN PRESSURES AT STYKKISHOLM AND THORSHAVN AND THE AZORES-ICELAND GRADIENT THREE MONTHS EARLIER (MONTHLY MEANS).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Stykkisholm— 1891–1915	— ·06	— ·14	— **·23**	— ·16	— ·05	+ ·12	— ·03	— **·24**	— ·13	— **·41**	+ **·33**	— **·21**	— ·10
1910–1916	Oct.-Mar. — **·26**		...	...	...	...	Apr.-Sept. — **·39**		...	...	...	...	— **·33**
Thorshavn— 1891–1915	— **·36**	— ·03	— **·31**	— ·02	— ·08	+ **·20**	— **·20**	+ ·01	— ·02	— **·50**	+ **·22**	— **·24**	— ·11

Excluding the first column, the total number of coefficients of ·20 or over is :—

Lag in months	1	2	3	4	5	6
No. of coefficients exceeding ·2 —						
Positive	2	1	1	1	1	1
Negative	1	5	8	3	2	0
Total..	3	6	9	4	3	1

With the exception of Ponta Delgada and Berlin, the whole of the coefficients of pressure with the pressure difference 50° N., 20° W.-Vestmanno three months earlier are negative, the mean values being: October-March —·19, April-September —**·21**. There seems to be no doubt that this effect is real. The maximum correlation occurs after two months at Ponta Delgada and at 50° N., 20° W.; two to three months at Valencia and Paris; three months at Thorshavn; three to four months at Stykkisholm;

TABLE XXIII.—CORRELATION BETWEEN PRESSURE—DIFFERENCE 50° N. 20° W.-VESTMANNO AND SUBSEQUENT PRESSURES AT SELECTED STATIONS (MONTHLY MEANS).

LAG IN MONTHS		0	1	2	3	4	5	6
Jacobshavn,	October–March	−·58	−·18	+·16	−·05	−·11	−·14	−·17
	April–September	−·61	−·17	−·08	−·12	−·13	+·03	−·10
Stykkisholm,	October–March	−·75	−·06	+·13	**−·33**	**−·25**	−·08	−·12
	April–September	−·72	+·16	+·01	**−·34**	**−·20**	+·15	−·15
Thorshavn,	October–March	−·39	+·11	−·03	**−·45**	−·08	+·02	+·01
	April–September	−·25	+·06	+·04	**−·40**	+·08	+·07	−·10
Ponta Delgada,	October–March	+·81	**+·23**	**−·30**	**+·21**	**+·33**	+·07	+·15
	April–September	+·55	−·06	−·13	+·12	−·18	**−·22**	+·08
50° N., 20° W.,	October–March	+·50	+·19	**−·28**	−·13	+·16	+·17	+·08
	April–September	+·57	+·09	−·14	**−·20**	+·06	−·09	−·04
Valencia,	October–March	+·39	**+·20**	**−·27**	**−·24**	+·04	**+·22**	+·13
	April–September	+·64	+·05	**−·20**	**−·34**	+·16	−·01	−·15
Paris,	October–March	+·67	+·10	**−·26**	−·01	+·08	+·14	**+·24**
	April–September	+·48	−·07	−·13	−·13	−·01	−·05	−·12
Berlin,	October–March	+·44	+·12	−·13	·00	+·05	+·10	+·16
	April–September	+·35	−·06	+·08	+·07	−·09	**−·39**	−·10
Bergen,	October–March	−·11	+·17	−·08	**−·22**	+·02	+·08	+·19
	April–September	+·27	−·05	**+·20**	−·13	+·07	−·02	−·04
Vardo,	October–March	−·54	−·12	+·08	−·12	−·11	−·04	+·04
	April–September	−·08	**−·27**	−·10	−·01	**−·21**	−·14	−·03

and four months at Jacobshavn and Vardo, the sequence of values suggesting a gradual progress from south to north.

Stornoway-Vestmanno.—As would be expected, the relationships between the pressure difference between Scotland and Iceland and subsequent pressures at the selected stations are similar to those between the point 50° N., 20° W. and Iceland. For the period 1910-1916 there are maximum negative correlation coefficients with a lag of two to three months at Valencia and three to four months at Stykkisholm, and maximum positive coefficients with a lag of three months at Ponta Delgada. The coefficients are greater in winter (W) than in summer (S) :—

TABLE XXIV.—CORRELATION BETWEEN PRESSURE DIFFERENCE STORNOWAY-VESTMANNO AND SUBSEQUENT PRESSURE (MONTHLY MEANS).

LAG	Two months		Three months		Four months	
Season.	W.	S.	W.	S.	W.	S.
Valencia	**−·43**	−·07	**−·26**	**·25**	+·05	**+·22**
Stykkisholm	−·13	+·13	**−·47**	**·33**	**−·35**	−·05
Ponta Delgada	·00	+·01	**+·36**	+·11	**+·38**	−·03

§ 10. Discussion of the Results.

The results which have been presented have been obtained by the calculation of more than a thousand correlation coefficients. So large an amount of material is apt to be confusing; it is difficult to see the wood for the trees, and some form of simplification seems to be required.

The initial assumption was that the effect of the various factors—trade winds, Bermuda-Charleston pressure difference, etc.—takes place *mainly* through temperature variations propagated along the course of the Gulf Stream and the Gulf Stream Drift. We should not expect the effect of an abnormally warm or abnormally cold North Atlantic on the contemporaneous pressure to be the same in all parts of the North Atlantic, and the first step is to examine the correlation between the quarterly means of surface temperature of the North Atlantic and the pressure at the selected stations in the same quarters. For this purpose Hepworth's figures of sea temperature for the years 1903 to 1907 were employed. The coefficients obtained are set out in Table XXV and in Figure 11.

Table XXV.—Correlation Coefficients, Sea Temperature with Contemporaneous Pressure (Quarterly Means).

Jacobshavn	− ·39	Paris	+ ·32
Stykkisholm	− ·21	Berlin	+ ·32
Thorshavn	+ ·22	Bergen	+ ·25
Ponta Delgada	+ ·32	Vardo	+ ·03
Valencia	·37		

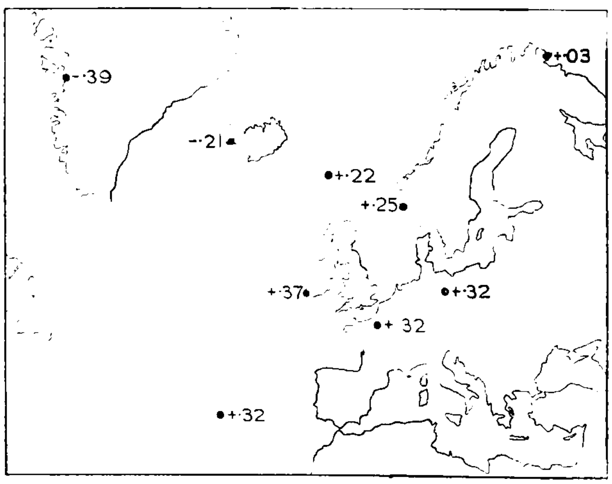

Fig. 11.—Correlation between Sea Temperature and Contemporaneous Pressure (Quarterly Means).

The coefficients indicate that high surface temperature in the North Atlantic tends to be associated with high pressure in the area between the Azores in the south and Thorshavn and Bergen in the north, the maximum correlation occurring at Valencia, while at the same time low pressure develops in the north-west of the area, at Jacobshavn and Stykkisholm. Hence, at the southern stations the correlations between the trade winds, etc., and the subsequent pressure should be similar to those between the trade winds, etc., and the subsequent North Atlantic temperature. At the north-western stations, Jacobshavn and Stykkisholm, on the other hand, the correlations between the trade winds, etc., and subsequent pressure should be the reverse of those with the subsequent North Atlantic temperature. A comparison of Tables IV and V with Table VI or an examination of Figure 5, shows that this expectation is justified by the results for the NE. and SE. trade winds. A comparison of Table XVI with Tables XV, XVII and XVIII, shows that the correlations between the Bermuda-Charleston pressure difference and subsequent sea temperature are similar to those between the Bermuda-Charleston pressure difference and subsequent pressure at Ponta Delgada, and the reverse of those between this pressure difference and subsequent pressure at Jacobshavn. On the other hand, the correlation coefficients between the Bermuda-Charleston pressure difference and subsequent pressures at the remaining stations are insignificant and irregular.

For the remaining factors in the North Atlantic (pressure differences Bermuda-Sydney, Azores-Iceland, and Stornoway-Iceland) we can compare the correlation coefficients between these factors and the sea temperature one quarter later with the coefficients between the same factors and the pressure one quarter or three months later. This comparison is shown in Table XXVI.

TABLE XXVI.—CORRELATION COEFFICIENTS—PRESSURE DIFFERENCES WITH TEMPERATURE AND PRESSURE THREE MONTHS LATER.

Correlation with	PRESSURE DIFFERENCE		
	Bermuda-Sydney	Azores-Iceland	Stornoway-Iceland
Temperature of North Atlantic ..	+ ·34	+ ·12	+ ·11
Pressure—			
Jacobshavn	— ·16	— ·02	— ·01
Stykkisholm	— ·01	— ·10	— ·09
Thorshavn	+ ·07	— ·11	— ·06
Ponta Delgada	+ ·13	+ ·03	·00
Valencia..	+ ·01	·00	— ·05
Paris	— ·10	+ ·01	— ·13
Berlin	— ·06	+ ·02	— ·14
Bergen	— ·03	— ·06	— ·10
Vardo	— ·03	— ·04	·00

The pressure difference Bermuda-Sydney has a fairly good positive correlation with the North Atlantic surface temperature one quarter afterwards, but the corresponding correlations with subsequent pressure are insignficant. The highest values, —·16 at Jacobshavn and +·13 at Ponta Delgada, show agreement between sea temperature and pressure in the south, and opposition between sea temperature and pressure in the north-west, the result which we should expect. As previously remarked, the coefficients with the Azores-Iceland pressure difference are insignificant. The coefficients with the Stornoway-Iceland pressure difference are not much better; they seem to indicate a tendency for a high value of this pressure difference to be followed one quarter later by low pressure in western Europe, but the coefficients are too small for the matter to be worth pursuing further. Thus these auxiliary factors along the course of the Gulf Stream Drift are shown to be of little importance in modifying the effects due to the trade winds and the Gulf Stream proper.

The results of the investigation may be summarized as follows :—

(1) The surface temperature of the North Atlantic Ocean between Florida and Valencia has a positive correlation with synchronous pressure over the area Valencia, Bergen, Berlin and Azores, but a negative correlation with pressure at Jacobshavn and Stykkisholm.

(2) The pressure at Jacobshavn and Stykkisholm has a positive correlation with the NE. trade wind four months before, this relationship not being due to the influence of the Gulf Stream.

(3) The surface temperature of the North Atlantic has a positive correlation with the NE. trade wind 12 months before, this relationship being due to the influence of the Gulf Stream.

(4) The surface temperature has a negative correlation with the NE. trade wind 15 to 21 months before.

(5) The correlation between the pressure in western Europe and the North Atlantic and the strength of the NE. trade wind 12 to 21 months before is generally small, but the coefficients usually have the signs to be expected from relationships (1), (3) and (4); that is, pressure at stations in the area Valencia, Bergen, Berlin and Azores tends to have a positive correlation with the NE. trade wind 12 months before, and a negative correlation with the trade wind 15 to 21 months before.

(6) The surface temperature of the North Atlantic has a positive correlation with the velocity of the SE. trade wind 15 to 21 months before, this relationship being due to the influence of the Gulf Stream.

(7) Pressure at Valencia, Paris, Berlin and Ponta Delgada has a positive correlation with the velocity of the SE. trade wind 15 to 21 months before; pressure at Jacobshavn, Stykkisholm and Vardo has a negative correlation with the velocity of the SE. trade wind 15 to 21 months before.

(8) The surface temperature of the North Atlantic, and the pressure at Ponta Delgada, have a positive correlation with the Bermuda-Charleston pressure difference 3 to 9 months before and 15 to 18 months before.

(9) The surface temperature of the North Atlantic has a positive correlation with the Bermuda-Sydney (Nova Scotia) pressure difference three months before; the pressure at Ponta Delgada has a small positive correlation, and pressure at Jacobshavn a small negative correlation with the Bermuda-Sydney pressure difference three months before.

(10) The pressure in western Europe and the North Atlantic (except the Azores) has a negative correlation with the pressure difference three months before between the point 50° N., 20° W. and Vestmanno (Iceland). At the Azores the correlation is positive.

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