M.O. 307a

FOR OFFICIAL USE

AIR MINISTRY

METEOROLOGICAL OFFICE

GEOPHYSICAL MEMOIRS No. 41

(*First Number of Volume V*).

The Influence of Arctic Ice on the Subsequent Distribution of Pressure over the Eastern North Atlantic and Western Europe

By C. E. P. BROOKS, D.Sc., and WINIFRED A. QUENNELL

Published by Authority of the Meteorological Committee

LONDON :
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses :
Adastral House, Kingsway, London, W.C.2 ; 120, George Street, Edinburgh ;
York Street, Manchester ; 1, St. Andrew's Crescent, Cardiff ;
15, Donegall Square West, Belfast ;
or through any Bookseller.

1928

Price 2s. 6d. Net.

40—27—41.

TABLE OF CONTENTS

PART I—THE CONDITIONS OF THE PROBLEM

PART II—THE EFFECT OF ARCTIC ICE

PART III—THE EFFECT OF ICE IN THE WESTERN NORTH ATLANTIC

LIST OF ILLUSTRATIONS

(65) Wt. 27878—1568/1986. 625. 7/28. T.S. 66.

THE INFLUENCE OF ARCTIC ICE ON THE SUBSEQUENT DISTRIBUTION OF PRESSURE OVER THE EASTERN NORTH ATLANTIC AND WESTERN EUROPE

PART I—THE CONDITIONS OF THE PROBLEM

§ 1—The Birthplace of Arctic Ice

In a preceding paper[1] an attempt was made to discover whether small changes in the temperature and volume of the Gulf Stream, due to variations in the strength of the trade winds and other factors, were reflected in subsequent changes of the pressure distribution in the region affected by the eastern North Atlantic. As a result of this investigation some definite, though small, effects were traced. The Gulf Stream, however, is not the only oceanic factor which may be expected to influence the weather of the British Isles, and it seemed desirable to investigate the effects due to variations in the temperature and ice conditions in the Arctic Ocean, the Greenland Sea and the neighbourhood of Newfoundland. The area considered, with the geographical divisions adopted and the meteorological stations whose records were utilised in this paper, and a sketch of the ocean currents, are shown in Figure 1.

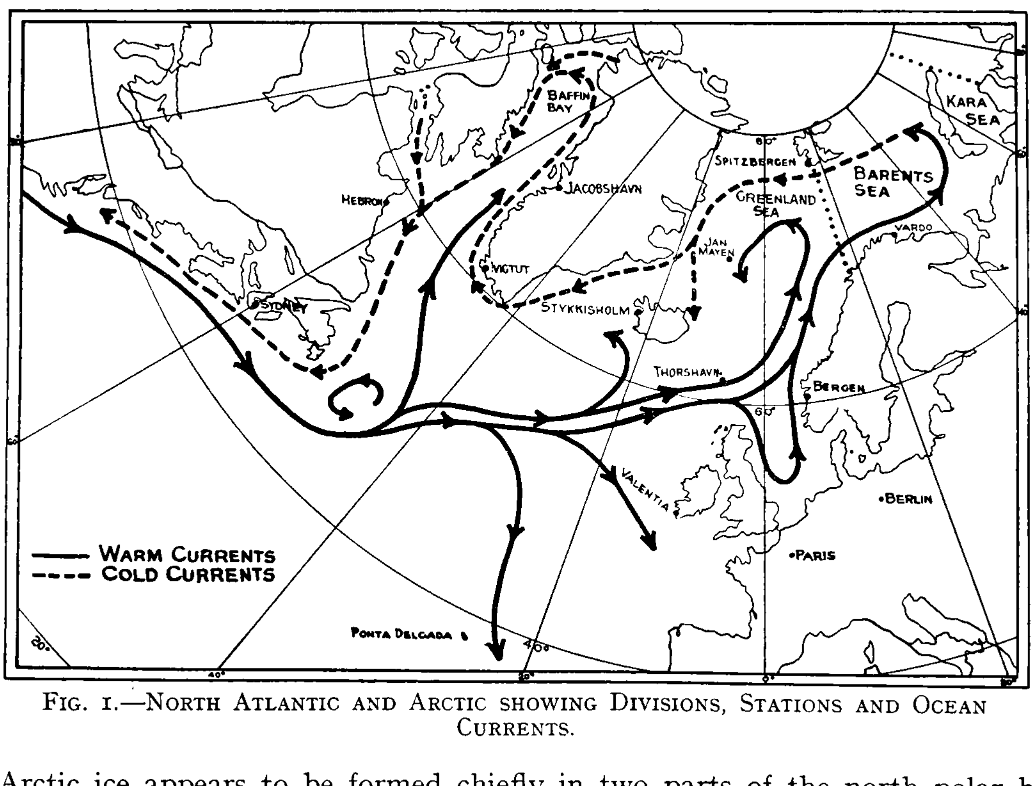


Fig. 1.—North Atlantic and Arctic showing Divisions, Stations and Ocean Currents.

Arctic ice appears to be formed chiefly in two parts of the north polar basin, namely, the area of open ocean north of Asia and the channels among the islands of

[1] *Geophysical Memoirs* No. 34, 1926. The effect of fluctuations of the Gulf Stream on the distribution of pressure over the Eastern North Atlantic and Western Europe.

the American Arctic Archipelago ; the inland ice sheet of Greenland is an important auxiliary source. This ice is distributed by the prevailing ocean currents, and the first step must be a discussion of the tracks and average speeds of these currents. Over the greater part of the Arctic Ocean the currents appear to set very slowly from the Bering Sea towards Greenland, as exemplified by the drift of the " Jeannette " from Wrangel Island to De Long Island (September, 1880, to June, 1881) and of the " Fram " from the New Siberian Islands to Spitsbergen (September, 1893 to July, 1896). Wreckage from the " Jeannette " reached Julianehaab in south-west Greenland in 1884. A barrel dropped on the ice at Cape Barrow, Alaska, on September 13th, 1899, was found on the north coast of Iceland on June 7th, 1905, after travelling at least 2,500 miles at the rate of 1·2 miles a day. It is not probable, however, that any appreciable amount of ice makes a whole journey from the Bering Straits to the south of Greenland ; as W. Wiese[2] points out, the greater part of the ice which finds its way into the East Greenland Current is formed by the freezing of the layer of fresh water north of the mouths of the great Siberian rivers, and Wiese terms this region the " Factory of Northern Polar Ice."

From the " Factory " the ice drifts westward, passing mainly south of Spitsbergen, where a great deal of ice formation goes on among the islands, and continues towards the east coast of Greenland, where it turns south as the East Greenland Current. The distance is about 2,000 miles, and at the average rate of 1·2 miles per day given by the barrel drift referred to above, the journey would take just over 4½ years. Wiese regards the autumn (September–November) air temperature at Obdorsk and Touroukhansk as the best available criterion of the ice-forming activity in the "Factory" (a low temperature giving much ice, a high temperature little ice) and he finds that the correlation coefficient between the mean of the autumn temperatures at these places (1877–1910) and the ice-covered area in the Greenland Sea 4½ years later has the high value of $-{\cdot}83 \pm {\cdot}05$, which he regards as confirmation of the theory. Sir Gilbert Walker informs me, however, that there is an equally high correlation between the Greenland Sea ice and the conditions in the " Factory " three months later, and that the connexion found by Wiese may be dependent on the remarkable periodicity of 4¾ years in the Greenland Sea and Iceland ice conditions, to be referred to later.

§ 2—The Labrador Current

The East Greenland Current sends out a small arm to the south-east (due to the westerly winds from Greenland) which passes a short distance north of Iceland and sometimes brings much ice to that island, but the main mass of the Arctic water follows the coast of Greenland, bearing great quantities of ice. This current moves with a velocity of 5 to 10 miles a day, and it is banked up against the coast by the earth's rotation, so that there is very little scattering. Rounding Cape Farewell, the current passes up the west coast of Greenland as far as Disco Island, picking up icebergs from the Greenland ice sheet on its way. Under the influence of easterly winds caused by the secondary barometric minimum in Davis Strait, the current turns westward and then southward along the east coast of Baffin Land, receiving tributary currents from the channels between the islands of the North American archipelago, and from the Arctic Ocean by way of Smith, Jones and Lancaster Sounds. This is the beginning of the Labrador Current ; between 74° and 69° N. the velocity was found by Hall's Polar Expedition to be 6·3 miles a day, but this may have been in a weak part of the current. Between 69° and 53° N. the velocity averaged 11·8 miles a day. Off the Newfoundland Banks the Labrador Current meets the Gulf Stream, interdigitating with it in a series of whirls and partly sinking under it, while the northern edge turns eastward and travels on the northern side of the Gulf Stream Drift. The icebergs carried by the Labrador Current become spread out over a considerable area of the North Atlantic and may lower the temperature appreciably.

[2] Wiese, W. Die Einwirkung des Polareises im Grönlandischen Meere auf die nordatlantische zyklonale Tätigkeit. *Ann. Hydrogr., Berlin*, **50** 1922, p. 271.

§ 3—The Rate of Ice Drift

The distances and velocities of the various currents may be tabulated roughly as follows :—

Table I—Speeds and Times of Arctic Circulation

Current	From	To	Distance (nautical miles)	Mean Velocity (mi./day)	Mean Time (months)
Arctic Ocean Drift	75° N. 75° W.	75° N. 0°	2000	1·2	55
Greenland Current	75° N. 0°	69° N. 53° W.	2150	7·5	10
Labrador Current	69° N.	47° N. 55° W.	1600	12	4
Gulf Stream Drift	47° N. 55° W.	60° N. 5° W.	1800	12	5

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 ice conditions in one part of the Arctic Ocean to be propagated along the currents and so affect conditions in other parts.

§ 4—The Palaeocrystic Ice

The areas for which ice data are available—Greenland Sea, Barents Sea and Kara Sea—include only the fringe of the great ice area of the Arctic Ocean, which persists from one year to another and has been termed the Palaeocrystic Ice. The fringe is important as supplying the scattered ice which reaches Iceland or rounds Cape Farewell, and the cold thaw water which probably has an appreciable effect on the temperature of the ocean between Greenland and Scandinavia, but the main ice mass would be expected to play a greater part in causing variations in the general circulation of the globe. Unfortunately we have no measurements of the whole ice-covered area, but results obtained by other authors show that even indirect measures may have considerable significance. Thus F.M. Exner[3] found a correlation of +·57 between the temperature difference 20° N. (mean of Aden and Honolulu) minus 70° N. (mean of Markovo and Gjesvaer), and the corresponding pressure difference. Similarly W. Wiese[4] has suggested various relationships between the area of ice in the Barents Sea and certain quantities which depend on the general circulation. Evidently one of the objects of this study must be to devise some numerical index which can be employed as a measure of the area of the Palaeocrystic Ice.

§ 5—The Greenland Sea and Iceland

The effect of variations in the ice conditions in the Greenland Sea and off Iceland has been studied by W. Wiese, W. Brennecke and W. Meinardus. Wiese found[5] that years with heavy ice in the Greenland Sea in spring and summer (April to July)

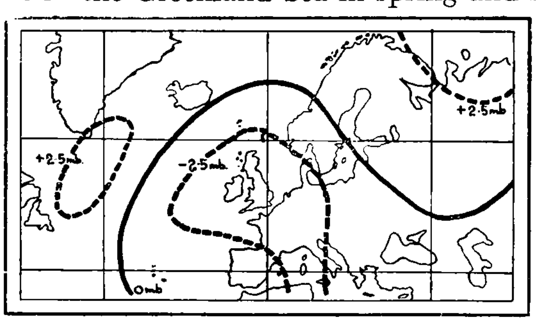


Fig. 2.—Pressure difference (September to November), years of much ice in the Greenland Sea in April to July minus years of little ice.

were characterised in autumn (September to November) by a higher pressure in the neighbourhood of Iceland, Greenland, and the White Sea, and a lower pressure over

[3] Uber monatliche Witterungsanomalien auf der nördlichen Erdhalfte im Winter. *Wien, Sitzungsber. Ak. Wiss.*, **123**, 1913, Abt. 2A, p. 1165.
[4] *J. Geophys., Leningrad*, **1**, 1924 ; *Bull. Hydrol. Inst., Russia*. No. 13, 1925.
[5] Wiese, W. Polareis und atmosphärische Schwankungen. *Stockholm, Geogr. Ann.*, **6**, 1924, p. 273.

the British Isles. This distribution is associated with a southerly movement of the tracks of depressions. From Wiese's data Figure 2 has been constructed, showing the difference of the pressure distribution in September to November between years with much ice and years with little ice in the Greenland Sea in April to July.

W. Brennecke[6] investigated the variations of ice off Iceland and found that years with little ice tend to be associated with an abnormally large pressure difference between Iceland and Scandinavia in spring (March to May), while years with much ice tend to be associated with a small pressure difference between Iceland and Scandinavia. Thus, generally speaking, in the spring of ice-poor years pressure is abnormally low in Iceland and high in Scandinavia, in ice-rich years high in Iceland and low in Scandinavia.

A similar result as regards pressure at Iceland was given by a study of the deviation of pressure from normal at Stykkisholm during the presence of ice.[7] From 1901 to 1919 there were 701 days during which ice lay off Iceland and the pressure at Stykkisholm during these days averaged 6·7 mb. above the mean pressure for the corresponding months.

W. Meinardus[8] investigated the variations of ice in the neighbourhood of Iceland. He gave a table of the duration and severity of the ice from 1801 to 1904 and pointed out that there was a very clearly marked periodicity of 4½ years ; a further investigation shows that this period is more nearly 4¾ years.[9] In the second part of his work (p. 234 ff.) Meinardus investigates the causes of these variations. He points out that the quantity of ice in the East Greenland Current is least in autumn, when the eastern boundary of the ice is so near the Greenland coast that Iceland is almost invariably quite free of ice. But the advancing masses of polar ice are already beginning to reach the northern part of the Greenland Sea by the end of summer, forming a swelling of the ice which advances southwards during the autumn. The beginning of the ice season at Iceland is determined by the arrival of this swelling in Denmark Strait, but in many years the amount of ice is insufficient to fill the strait and Iceland remains free. In normal years the ice reaches its maximum in April and May.

The 4¾-year periodicity in Iceland ice was investigated further in the hope that it would prove sufficiently regular to aid in forecasting, but without result. The exact length of this periodicity as determined by a periodogram analysis is 4·76 years and the mean amplitude is about half the standard deviation. When we correlate the Iceland ice figures with the corresponding figures 1, 2 to 6 years later, however, we obtain insignificant results :—

Years later ..	1	2	3	4	5	6
Coefficient ..	+·01	–·16	–·09	+·04	+·06	+·01

This appears to be due mainly to the great variations in the intensity of successive maxima and minima. A slight improvement is obtained by calculating partial coefficients, thus calling r_{12} the correlation coefficient between ice in two successive years, and r_{13} the coefficient between ice in one year and in the next year but one, we obtain—

$$r_{12\cdot 3} = +\cdot 11 \qquad r_{13\cdot 2} = -\cdot 17$$

Values calculated from these two partial coefficients would have a correlation of ·21 with the observed values, but this is useless for forecasting purposes.

Variations from year to year of the incidence of ice at Iceland are determined largely by variations of the ocean currents. In the absence of direct measurements, Meinardus determines these by variations in the winds due to variations in the pressure gradients. Thus, if the winds along the current are unusually strong in any winter, we should expect heavy ice off Iceland in the following spring, and in the table on p. 280 Meinardus shows that the pressure difference Stykkisholm minus Vardo in November to January is greater before years of much ice than before years

6 Brennecke, W. Beziehungen zwischen der Luftdruckverteilung und den Eisverhältnisse des Ostgrönlandischen Meeres. *Ann. Hydrogr., Berlin*, **32**, 1904, p. 49.

7 Brooks, C. E. P. Weather influences in the British Isles. *Nature, London*, **112**, 1923, p. 836.

8 Meinardus, W. Periodische Schwankungen der Eistrift bei Island. *Ann. Hydrogr., Berlin*, **34**, 1906, pp. 148, 227, 278.

9 Brooks, C. E. P. and J. Glasspoole. The drought of 1921. *London, Q. J. R. Meteor. Soc.*, **48**, 1922, p. 139.

of little ice, the difference averaging 6 mb. If we accept the view that the Iceland ice is a factor in the synchronous and subsequent pressure distribution over the north-eastern Atlantic, this pressure difference should also be a factor.

The same conclusion results from studies of the incidence of drought in the British Isles[9], in which it was found that seasons with abnormally high pressure over the British Isles and abnormally low pressure over the Arctic Ocean are almost invariably followed by heavy ice off Iceland in the following spring.

§ 6—Ice off Newfoundland

The cold waters of the Labrador Current, and the amount of ice which that current carries to the Newfoundland Banks, probably affect the temperature of the surface waters to some extent. Hence the Newfoundland ice may be an important factor in the general pressure distribution. We may employ this amount directly, or we may go back a stage further, and examine the variations of the factors underlying variations of the Newfoundland ice itself. These factors have been investigated by E. H. Smith,[10] who obtained correlation coefficients between the following variates :—

(A) Number of bergs (scale 0–10).

(B) Amount of field ice (scale 0–10).

(C) Pressure difference (mb.) Belle Isle minus Ivigtut in December to March (4 × Dec. + 3 × Jan. + 2 × Feb. + 2 × March) / 11 + one-sixth of pressure deviation at Stykkisholm.

(D) Pressure difference Bergen minus Stykkisholm, October to January, December being given double weight.

These four variates gave :—

Between (A) and (B) +·87
Between (A) and (C)[11] +·62
Between (A) and (D) +·60

For our purposes it is unnecessary to discriminate between bergs and field ice ; the correlation between them is so high that the one will serve as an index of the other. Obviously we should expect similar relationships with the subsequent pressure distribution to be given by—

(1) Number of bergs, April to June.

(2) Pressure difference, Belle Isle minus Ivigtut, December to March.

(3) Pressure difference, Bergen minus Stykkisholm, October to January.

§ 7—Summary of Part I

The preceding discussion shows that at least three effects have to be considered :—

(*a*) The effect of variations in the ice-covered area in the Arctic basin on the general circulation of the globe.

(*b*) The effect of variations in the ice-covered area in the Greenland Sea and near Iceland on the pressure distribution over the North Atlantic Ocean and Western Europe.

(*c*) The effect of variations in the supply of ice and cold water introduced into the North Atlantic by the Labrador Current.

Of these (*c*) can be isolated from the other two, but (*a*) and (*b*) are inter-related and must be considered together. The discussion which follows therefore falls into two parts, first the effect of Arctic and Greenland Sea ice, and secondly, the effect of the Labrador Current.

---

[9] *Loc. cit.*

[10] Smith, Edward H. The International Ice Patrol. *Meteor. Mag., London*, 60, 1925, p. 236.

[11] E. H. Smith gives this coefficient as —·62, but this appears to be a misprint.

PART II—THE EFFECT OF ARCTIC ICE

§ 8—THE VARIATES TO BE INVESTIGATED

As a result of the discussion in Part I it was considered desirable to investigate the effect of the following variates, beginning with those near at hand and proceeding to the more remote :—

(*a*) The duration and severity of the ice off Iceland.
(*b*) Temperature at Stykkisholm (as a check on (*a*)).
(*c*) The pressure difference, Stykkisholm minus Vardo, in November to January.
(*d*) The area of ice in the Greenland Sea.
(*e*) Temperature at Jan Mayen (as a check on (*d*)).
(*f*) The area of ice in the Barents Sea.
(*g*) The area of ice in the Kara Sea.
(*h*) The temperature of Obdorsk and Touroukhansk in September to November.
(*k*) Pressure and temperature at Spitsbergen.

§ 9—CORRELATIONS WITH ICELAND ICE

The amount of ice off Iceland is represented by an index of "duration and severity," which was designed by Meinardus.[12] A day on which ice was observed

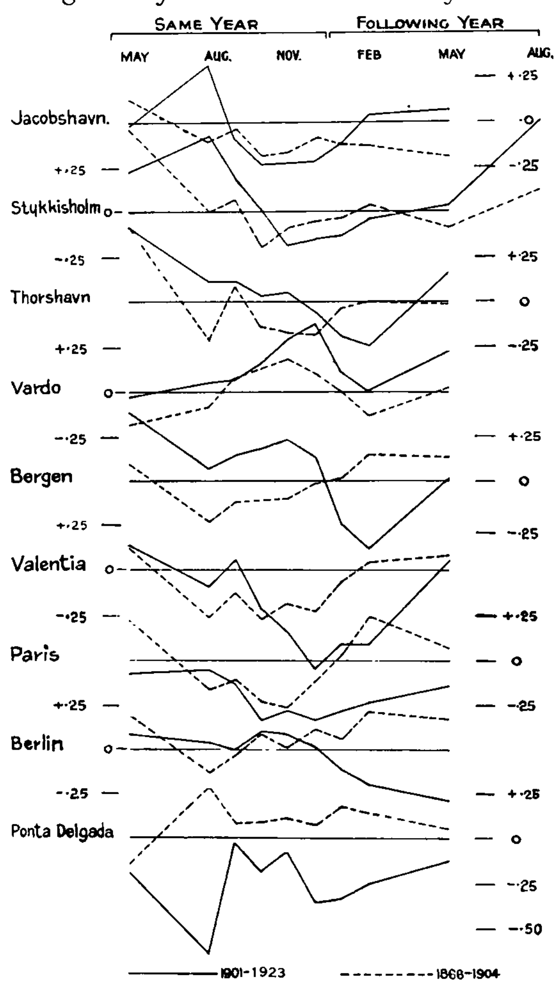


FIG. 3.—CORRELATION COEFFICIENTS, ICE OFF ICELAND WITH PRESSURE AT SELECTED STATIONS.

counts as one, but if the ice was especially heavy, it counts as two. Meinardus' table extends from 1801 to 1904, but gives annual values only. We constructed a similar table extending from 1901 to 1924, and giving the data for each month, from

[12] *Ann. Hydrogr., Berlin*, 43, 1906, p. 154.

the information published annually by the Danish Meteorological Institute.[13] For these years the annual variation was as follows :—

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
4·0	4·3	8·2	7·5	7·3	7·3	3·8	1·0	0·0	0·2	0·1	0·2

Generally speaking the ice season extends from January to July, but occasionally it continues into August and rarely it begins in December. If the ice conditions are to be employed for forecasting autumn pressures, it is hardly practicable to include any months later than June. Hence the figures which were taken for purposes of correlation were those for December to June ; these were correlated with pressures at the following stations : Jacobshavn (West Greenland), Stykkisholm (Iceland), Thorshavn (Farœs), Vardo and Bergen (Norway), Valentia, Paris, Berlin, and Ponta Delgada (Azores), which for convenient reference are termed the " selected stations." Quarterly means of pressure were employed for the periods April to June, July to September and so on. The results are shown on the lines marked A in Table[14] II and by the full lines in Figure 3. As the period utilised was rather short, a corresponding set of coefficients was calculated using Meinardus' data for 1866 to 1904 ; these are shown in the lines marked B in Table II, and by the broken lines in Figure 3. Both sets of coefficients agree with the results of Part I in showing positive coefficients with pressure in April to June at Stykkisholm and Thorshavn and with pressure in October to January at Vardo, and negative coefficients with pressure in September to January at Valentia and Paris. Apart from these points, however, the agreement is not good ; in particular the two sets of coefficients at Ponta Delgada are almost directly opposed, and the large coefficient of −·64 between ice in 1902 to 1923 and pressure in April to July of the same years becomes +·28 when the data for 1866 to 1904 are employed.

TABLE II—CORRELATION COEFFICIENTS, ICE OFF ICELAND AND PRESSURE

A—Ice, December to June. B—Ice, whole year.

		Same year							Following year	
		April to June	July to Sept.	Aug. to Oct.	Sept. to Nov.	Oct. to Dec.	Nov. to Jan.	Dec. to Feb.	Jan. to Mar.	April to June
Jacobshavn ..	A 1902–1923	−·02	+**·32**	−·09	−**·23**	−**·22**	−**·21**	−·11	+·03	+·06
	B 1866–1905	+·12	−·10	−·04	−·19	−·16	−·08	−·11	−·13	−·19
Stykkisholm ..	A 1902–1924	+·23	+**·43**	+·19	+·01	−·19	−·15	−·13	−·04	+·03
	B 1866–1905	+·47	·00	+·06	−·20	−·09	−·05	−·03	+·03	−·08
Thorshavn ..	A 1902–1922	+·42	+·12	+·12	+·03	+·05	−·06	−·19	−**·24**	+·16
	B 1873–1905	+·42	−·21	+·08	−·14	−·17	−·18	−·04	·00	−·01
Vardo	A 1902–1924	−·02	+·05	+·07	+·16	+**·29**	+**·38**	+·11	+·01	+**·23**
	B 1874–1905	−·18	−·08	+·08	+·13	+·18	+·10	+·01	−·13	+·02
Bergen ..	A 1902–1924	+·39	+·07	+·14	+·18	+**·23**	+·13	−**·25**	−**·38**	+·01
	B 1868–1905	+·10	−·23	−·12	−·11	−·10	−·01	+·02	+·15	+·14
Valentia ..	A 1902–1924	+·13	−·09	+·05	−**·21**	−**·34**	−**·54**	−**·41**	−**·41**	+·04
	B 1866–1905	+·11	−·26	−·13	−·27	−·18	−·22	−·06	+·04	+·08
Paris	A 1902–1920	−·07	−·05	−·13	−**·33**	−**·28**	−**·33**	−**·28**	−**·24**	−·14
	B 1874–1905	+·23	−·16	−·10	−·22	−·26	−·12	+·04	+**·25**	+·07
Berlin	A 1902–1923	+·09	+·04	·00	+·10	+·08	+·02	−·11	−**·20**	−**·29**
	B 1873–1905	+·20	−·13	−·03	+·09	+·01	+·11	+·06	+**·21**	+·17
Ponta Delgada	A 1902–1924	−·18	−**·64**	−·02	−·18	−·07	−**·35**	−**·33**	−**·25**	−·12
	B 1866–1905	−·14	+·28	+·09	+·09	+·11	+·08	+·18	+·14	+·05

The following additional coefficients were calculated with pressure at Stykkisholm : July–September of following year, A +**·50** ; B +·13.

13 Isforholdene i de Arktiske Have. *Kjobenhavn, Danske Meteor. inst., Naut-meteor. Aarbog.*

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

§ 10—Correlations with Temperature at Stykkisholm

The definition of "Iceland ice" being rather vague, some other variate was sought which would serve as a criterion of the ice conditions on the Icelandic coasts and which could be determined exactly. For this purpose the temperature at Stykkisholm was tried, but the results, which are shown in Table III, proved to be disappointing, the annual means, at the bottom of the table, being all less than ·20. The largest coefficient of −·18 with contemporary Stykkisholm pressure agrees with the result that much ice and therefore presumably low temperature give high pressure, but here the possibility is not excluded that the temperature may be the result of the pressure distribution instead of *vice versâ*. The ice season at Iceland may be considered as including the quarters January to March and April to June; temperatures during both these quarters show positive correlation with pressure at Valentia during October to December. The results for Stykkisholm temperature may therefore be regarded as confirming the two salient points derived from the Iceland ice data, but as of little use as an independent criterion of the pressure distribution.

Table III—Correlation Coefficients, Stykkisholm Temperature (1874-1923) and Pressure

		Same Year				Following Year				
		Jan. to Mar.	April to June	July to Sept.	Oct. to Dec.	Jan. to Mar.	April to June	July to Sept.	Oct. to Dec.	Jan. to Mar.
Stykkisholm ..	Jan.-Mar. ..	−·19	−·17	−·06	+**·24**	+·16	−·03			
	Apr.-June ..		−·34	+·02	−·14	+·02	−·01	−·17		
	July-Sept. ..			+·21	−·04	+·18	+**·25**	−·09	+·08	
	Oct.-Dec. ..				−·39	−**·27**	+·17	+·02	−·04	−·05
Valentia ..	Jan.-Mar. ..	+·01	+·02	+·03	+·13	−·18	+·06			
	Apr.-June ..		+·09	+·06	+**·22**	−·14	+·03	+·18		
	July-Sept. ..			+·31	+·14	+·04	−·15	−·03	−·17	
	Oct.-Dec. ..				−·18	−·08	−·06	+·08	−·19	−·14
Berlin	Jan.-Mar. ..	+·07	−·05	+·10	−**·26**	−**·32**	−·06			
	Apr.-June ..		+·12	+·06	+·13	−·10	−·02	−·05		
	July-Sept. ..			−·02	+·11	−·10	−·16	+·04	−·07	
	Oct.-Dec. ..				+·39	−·02	−**·21**	+·05	−·12	−**·23**
Ponta Delgada	Jan.-Mar. ..	+·22	+·03	−·01	−·10	−**·23**	+·13			
	Apr.-June ..		+·08	−·14	+·04	−·17	+**·36**	+·17		
	July-Sept. ..			−·39	−·15	−·17	−·10	−·11	−·12	
	Oct.-Dec. ..				−·02	+**·20**	+·02	−·12	·00	−·07
Mean Values— Lag in months		0	3	6	9	12	15			
Stykkisholm		−·18	−·11	+·04	+·13	+·01	−·04			
Valentia		+·06	+·03	+·06	−·02	−·09	−·02			
Berlin		+·14	+·03	−·02	−·12	−·11	−·10			
Ponta Delgada		−·03	−·01	−·03	−·12	+·01	+·03			

§ 11—The Pressure Difference Stykkisholm minus Vardo in November to January

This variate would be expected to give similar results to Iceland ice in December to June, but with smaller coefficients, as it is only one of the causes governing the ice conditions. The results for four stations are shown in Table IV. The positive coefficients with pressure at Stykkisholm from March to August agree with expectations, as do the negative coefficients with Valentia in June to November.

TABLE IV—CORRELATION COEFFICIENTS, PRESSURE DIFFERENCE STYKKISHOLM MINUS VARDO (NOV.–JAN.) AND SUBSEQUENT PRESSURE

Lag in months	4	5	6	7	8	9	10	11	12	13
Months	Mar. to May	April to June	May to July	June to Aug.	July to Sept.	Aug. to Oct.	Sept. to Nov.	Oct. to Dec.	Nov. to Jan.	Dec. to Feb.
Stykkisholm (1892-1924)	+ **·23**	+ **·29**	+ **·22**	+ **·28**	+ ·18	+ ·04	− ·06	− ·01	+ ·18	+ ·17
Valentia (1892-1925) ..	+ ·18	+ ·03	+ ·03	− **·22**	− **·26**	− ·17	− **·24**	− ·01	− **·23**	+ ·03
Berlin (1892-1923) ..	+ ·10	− ·08	− ·03	− ·11	− **·27**	− **·47**	− **·26**	·00	+ ·13	+ ·19
Ponta Delgada (1892-1925)	− **·24**	− **·35**	− **·22**	− **·26**	− ·14	+ **·31**	+ **·28**	+ ·15	− **·32**	− **·26**

§ 12—THE PRESSURE DIFFERENCE IVIGTUT MINUS STYKKISHOLM

In this connexion it seemed desirable to consider also the effect of the pressure gradient west of Iceland. The quarterly means of pressures at the selected stations during the period 1891 to 1915 were correlated with the pressure difference Ivigtut minus Stykkisholm in the preceding quarter, and these coefficients are shown in Table V.

TABLE V—CORRELATION COEFFICIENTS BETWEEN PRESSURE AT SELECTED STATIONS AND PRESSURE DIFFERENCE IVIGTUT MINUS STYKKISHOLM ONE QUARTER EARLIER

Pressure during	Jan.–Mar.	April–June	July–Sept.	Oct.-Dec.
Jacobshavn	+ **·31**	+ ·16	+ ·05	+ **·23**
Stykkisholm	+ ·06	+ **·24**	+ ·08	+ ·10
Thorshavn	− ·13	+ **·30**	− ·09	+ ·18
Vardo	+ ·12	+ **·28**	− ·09	+ ·01
Bergen	− **·30**	+ **·20**	− ·06	+ **·20**
Valentia	− ·14	+ ·03*	− ·04	+ ·04
Paris	− **·37**	·00	+ ·01	+ ·14
Berlin	− **·52**	− ·05	+ ·09	+ ·03
Ponta Delgada	− ·08	− ·08	− **·23**	− ·10

The only coefficients which appear to possess any significance at all are those for Jacobshavn (mean value +·19) and possibly Stykkisholm (mean value +·12) and Ponta Delgada (mean value − ·12). At Stykkisholm the effect is appreciable only during April to June, the months which give the largest correlation with the pressure difference Stykkisholm minus Vardo during the preceding December to February. An examination of the data for individual months shows that at both Jacobshavn and Stykkisholm the effect persists for only two months. Thus correlating the 300 monthly means of pressure difference Ivigtut minus Stykkisholm with pressure in the succeeding month, we obtain : Jacobshavn + ·16, Stykkisholm + ·12 ; with pressure two months later : Jacobshavn + ·14, Stykkisholm + ·13, the probable error of all four coefficients being ± ·04. Hence it seems probable that an unusually large pressure difference between Ivigtut and Stykkisholm, by causing an increase in the strength of the East Greenland Current between Iceland and Greenland, lowers the temperature and raises the pressure slightly. The effect is not shown in the monthly means at Ponta Delgada.

§ 13—CORRELATIONS WITH GREENLAND SEA ICE

This is the most definite of all the ice areas in the Arctic. The duration and severity of ice off Iceland is a rather vague term, while the Barents Sea and Kara Sea are not sufficiently frequented to provide really reliable estimates of the ice-covered area. Hence it is with this variate, if any, that we may expect significant correlation coefficients. The term Greenland Sea is defined by the Danish Meteorological Institute as "the area between the meridian of Cape Farewell, the east coast of Greenland, 80° N., west coast of Spitzbergen until the meridian of South Cape."[15]

The data available extend from April to August, 1877 to 1892 and 1895 to 1924. It was thought best to deal with these two periods separately, and also to distinguish between the ice conditions in April to June and in July to August, in order to discriminate between summer effects due to the preceding spring ice and those due to the contemporary summer ice. The data for August 1877 to 1892 were not sufficiently complete for discussion. The results are shown in Tables VI and VII ; in the former

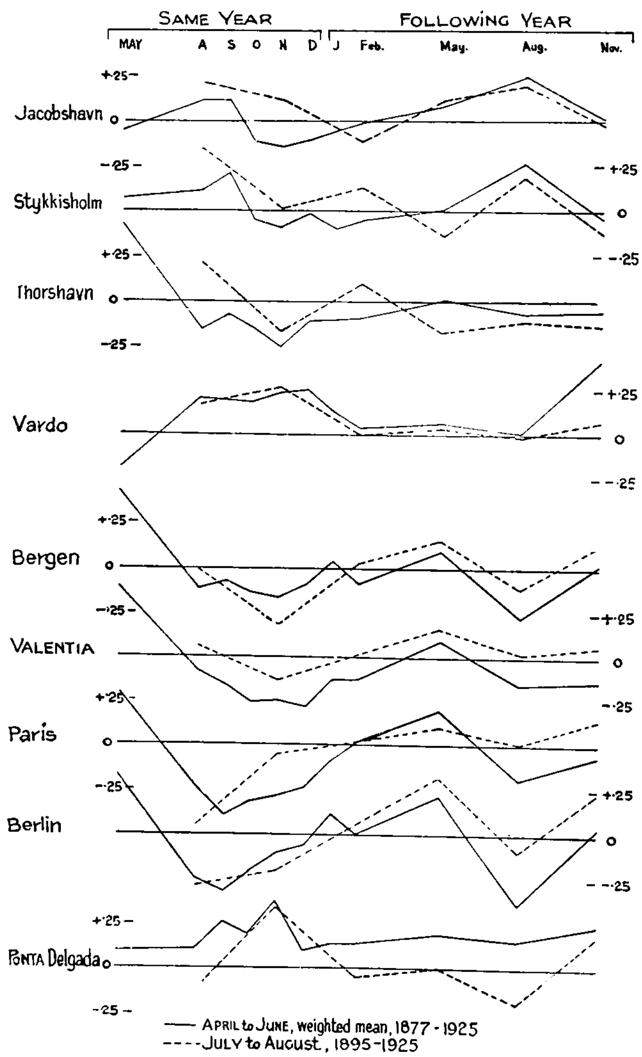


FIG. 4.—CORRELATION COEFFICIENTS, GREENLAND SEA ICE WITH PRESSURE AT SELECTED STATIONS.

the lines marked "weighted means" are simply the means of the two preceding lines weighted according to the number of years included. In Figure 4, the continuous lines represent the weighted means of the correlations with the ice conditions in April to June and the broken lines those with the ice conditions in July to August. The two sets of coefficients are similar, and an analysis of the "weighted means" in Table VI shows that the coefficients are generally larger than would be expected to

[15] Isforholdene i de Arktiske Have. Almindelig Oversigt. Kjobenhavn, 1917, p. 23.

arise by chance. Taking the coefficients with lags of 0, 3, 6, 9, 12, 15 and 18 months, and omitting those for 4, 5, 7 and 8 months which cannot be regarded as independent, we have 63 coefficients, of which 21 exceed twice the probable error, compared with an expectancy of 11, while eight coefficients reach or exceed ·30, compared with an expectancy of less than three. It must be remarked however that of these eight, five are with contemporary pressure.

The individual values indicate that a large amount of ice in the Greenland Sea, whether in April to June or in July to August, tends to be accompanied by pressure above normal at Stykkisholm and Thorshavn, and to be followed in September to January by pressure above normal at Vardo and Ponta Delgada but below normal at Thorshavn, Bergen, Valentia, Paris and Berlin. These coefficients agree generally with the results obtained for Iceland ice, to a greater extent than can be attributed to the parallelism between the two sets of ice conditions, the correlation between Iceland ice in December to June and Greenland Sea ice in April to June being only + ·22.

TABLE VI—CORRELATION COEFFICIENTS, GREENLAND SEA ICE (APRIL TO JUNE) AND PRESSURE

Lag in months	0	3	4	5	6	7	8	9	12	15	18
Months	April to June	July to Sept.	Aug. to Oct.	Sept. to Nov.	Oct. to Dec.	Nov. to Jan.	Dec. to Feb.	Jan. to Mar.	April to June	July to Sept.	Oct. to Dec.
Jacobshavn—											
1877–1892 ..	+·09	**−·25**	**−·28**	**−·51**	**−·35**	**−·25**	−·14	−·12	**+·44**	−·14	−·01
1895–1923 ..	−·12	**+·30**	**+·32**	+·09	−·04	−·02	−·01	+·04	−·08	**+·45**	+·03
Weighted mean ..	−·05	+·12	+·12	−·11	−·14	−·10	−·05	−·01	+·09	**+·25**	+·02
Stykkisholm—											
1877–1892 ..	+·21	−·16	−·04	**−·39**	**−·37**	**−·43**	**−·31**	**−·23**	**+·34**	−·17	**−·22**
1895–1924 ..	−·05	**+·25**	**+·33**	+·14	+·06	+·18	+·02	+·04	−·15	**+·49**	+·06
Weighted mean ..	+·07	+·11	**+·21**	−·04	−·08	−·02	−·09	−·05	+·01	**+·27**	−·03
Thorshavn—											
1877–1892 ..	+·48	**−·20**	+·16	−·11	**−·40**	**−·48**	**−·25**	**−·21**	+·04	**−·27**	**−·30**
1895–1922 ..	+·40	−·12	−·19	−·17	−·18	+·07	−·03	−·03	−·01	+·05	+·08
Weighted mean ..	+·43	−·15	−·07	−·15	**−·25**	−·11	−·10	−·09	+·01	−·06	−·05
Vardo—											
1877–1892 ..	−·10	−·01	**+·62**	**+·58**	**+·49**	·00	**−·20**	**−·44**	**+·34**	−·02	**+·56**
1895–1924 ..	−·24	**+·30**	−·02	−·02	+·10	**+·38**	**+·29**	**+·28**	−·07	+·03	**+·35**
Weighted mean ..	−·19	**+·20**	+·19	+·18	**+·23**	**+·25**	+·13	+·04	+·07	+·01	**+·42**
Bergen—											
1877–1892 ..	+·41	**−·22**	**+·22**	**+·24**	+·05	−·19	−·04	**−·22**	+·10	**−·40**	−·07
1895–1924 ..	+·44	−·06	**−·21**	**−·31**	**−·27**	−·02	+·07	−·01	+·08	**−·20**	+·07
Weighted mean ..	+·43	−·11	−·07	−·13	−·16	−·08	+·03	−·08	+·09	**−·27**	+·02
Valentia—											
1877–1892 ..	+·13	**−·23**	**−·22**	**−·45**	**−·56**	**−·47**	−·08	+·19	−·03	**−·35**	**−·29**
1895–1924 ..	+·53	−·01	−·13	−·16	−·09	−·19	−·16	**−·29**	+·15	−·07	−·06
Weighted mean ..	+·40	−·08	−·16	**−·26**	**−·25**	**−·28**	−·13	−·13	+·09	−·16	−·14
Paris—											
1877–1892 ..	+·33	−·16	−·15	−·16	−·18	−·03	**+·20**	**+·30**	+·17	**−·39**	**−·31**
1895–1920 ..	+·30	**−·27**	**−·50**	**−·40**	**−·35**	**−·34**	**−·23**	−·13	**+·20**	−·09	+·07
Weighted mean ..	+·31	**−·23**	**−·38**	**−·32**	**−·29**	**−·24**	−·09	+·01	+·19	−·19	−·06
Berlin—											
1877–1892 ..	+·45	**−·26**	−·03	+·10	**+·22**	**+·23**	**+·49**	**+·21**	**+·26**	**−·57**	−·09
1895–1923 ..	+·27	**−·25**	**−·47**	**−·36**	**−·28**	**−·21**	−·08	−·10	+·18	**−·30**	+·10
Weighted mean ..	+·33	**−·25**	**−·32**	**−·21**	−·11	−·06	+·11	·00	**+·21**	**−·39**	+·04
Ponta Delgada—											
1877–1892 ..	+·11	+·15	+·07	+·08	**+·28**	**+·33**	**+·35**	**+·26**	+·19	**+·53**	**+·30**
1895–1925 ..	+·09	+·09	**+·36**	**+·26**	**+·41**	−·02	+·04	+·08	**+·21**	−·01	**+·23**
Weighted mean ..	+·10	+·11	**+·26**	**+·20**	**+·37**	+·10	+·14	+·14	**+·20**	+·17	**+·25**

TABLE VII—CORRELATION COEFFICIENTS, GREENLAND SEA ICE (JULY TO AUGUST AND PRESSURE

Lag in Months	0	3	6	9	12	15
Months	July to Sept.	Oct. to Dec.	Jan. to Mar.	April to June	July to Sept.	Oct. to Dec.
Jacobshavn	+·22	+·12	−·11	+·12	+·19	−·02
Stykkisholm	+·35	+·02	+·13	−·13	+·19	−·12
Thorshavn	+·22	−·17	+·09	−·17	−·11	−·13
Vardo	+·17	**+·27**	·00	+·03	−·01	+·07
Bergen	−·01	**−·32**	+·02	+·15	−·11	+·13
Valentia	+·06	−·13	+·02	+·16	+·02	+·06
Paris	−·44	−·06	+·02	+·10	+·01	+·14
Berlin	−·28	**−·20**	+·06	**+·32**	−·09	**+·23**
Ponta Delgada	−·13	**+·33**	−·05	·00	−·19	+·19

§ 14—TEMPERATURE AT JAN MAYEN

In 1921 a meteorological station was established at Jan Mayen, which lies within the East Greenland Current. The 20 monthly values of temperature during April to August, 1922 to 1925, corrected for annual variation, give a correlation of −·67 with the areas of ice in the Greenland Sea during the same months similarly corrected. Hence any effects which are given by the Greenland Sea ice should also be given by Jan Mayen temperature, the signs of the deviations being reversed. Unfortunately the Jan Mayen series is too short for the four quarters to be considered separately, so the quarterly means of temperature irrespective of season were correlated with the synchronous and subsequent pressure at Stykkisholm, Valentia and Ponta Delgada. The results, which are shown in Table VIII, do not fit in well with those for the Greenland Sea ice.

TABLE VIII—CORRELATION COEFFICIENTS OF GREENLAND SEA ICE AND PRESSURE COMPARED WITH THOSE OF JAN MAYEN TEMPERATURE

Lag in months	0	3	6	9	12
Stykkisholm—					
Ice, April to June	+·07	+·11	−·08	−·05	+·01
Ice, July to August	+·35	+·02	+·13	−·13	+·19
Temperature (reversed)	+·23	**−·22**	**+·44**	**−·41**	−·13
Valentia—					
Ice, April to June	+·40	−·08	**−·25**	−·13	+·09
Ice, July to August	+·06	−·13	+·02	+·16	+·02
Temperature (reversed)	+·32	**−·28**	**+·57**	**−·43**	+·09
Ponta Delgada—					
Ice, April to June	+·10	+·11	**+·37**	+·14	**+·20**
Ice, July to August	−·13	**+·33**	−·05	·00	−·19
Temperature (reversed)	−·22	−·06	−·09	+·12	**+·27**

Probably there is a well-marked seasonal effect, as a result of which the sequence of events following much ice or a low temperature in April to June differs from the sequence following a low temperature in say October to December. This was foreshadowed in Fig. 4, in which the best comparison between the effect of ice in April to June and in July to August was obtained by plotting the coefficients against the season to which the pressure data referred rather than against the lag in months. It would also be expected from the positive correlation (·51) between the Greenland Sea ice in April to June and in July to August. Hence until the series of observations at Jan Mayen becomes long enough to treat each season separately, only the temperatures for April to August can be utilized, and even those only as an index of ice conditions.

§ 15—Ice in the Barents Sea

The limits of the Barents Sea are defined by the Danish Meteorological Institute[16] as "the meridian of South Cape, east coast of Spitzbergen, 80° N., 70° E., the coast of Nowaya Zemlya and the continent." The data available extend from April to August, 1895 to 1924. These were divided into two sets, April to June and July to August, as were the data for the Greenland Sea, but

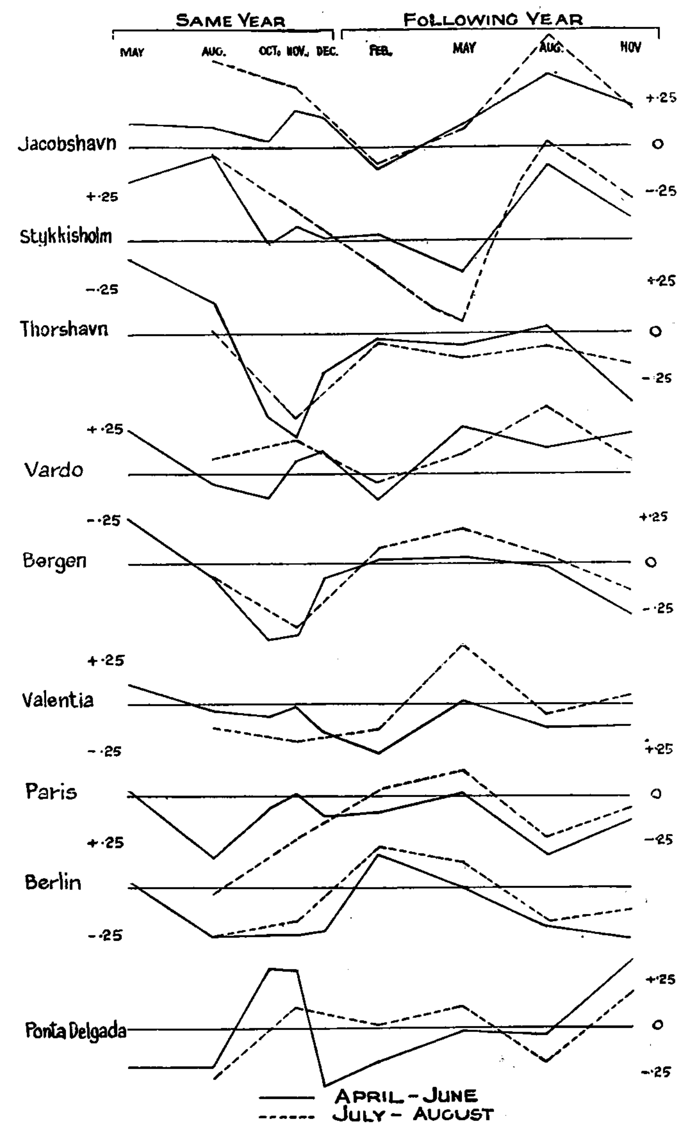


Fig. 5.—Correlation coefficients, Barents Sea Ice with pressure at selected stations.

there is a correlation of +·70 between the area of Barents Sea ice in April to June and that in July to August, and the two sets of coefficients, which are set out in Tables VIII and IX and in Fig. 5, run closely parallel if we refer them to the months to which the pressure data belong, and not the lag after the ice conditions. The results are generally similar to those for the Greenland Sea. The chief difference is that the largest negative correlations with pressure in the following autumn occur at Thorshavn and Bergen instead of at Paris and Berlin, while the curve for Vardo is almost entirely reversed compared with that for the Greenland Sea ice. There is also a well-marked series of negative coefficients between Barents Sea ice in July to August and pressure at Stykkisholm in March to June of the succeeding year,

[16] *Loc. cit.*

which is only faintly indicated by the corresponding coefficients with Barents Sea ice in April to June and by Greenland Sea ice in July to August. It is supported however by the negative correlation between Kara Sea ice in August and pressure at Stykkisholm in April to June (*see* below). These negative coefficients are followed by well-marked positive coefficients between Barents Sea ice in July to August and

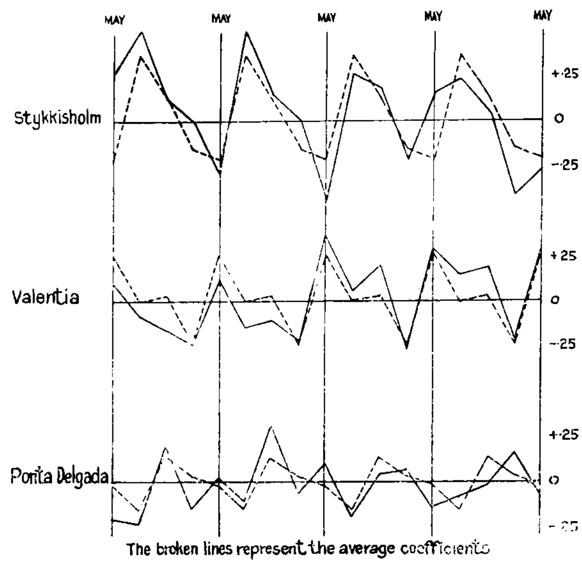


FIG. 6.—CORRELATION COEFFICIENTS, BARENTS SEA ICE (APRIL TO AUGUST) WITH PRESSURE IN SUCCEEDING YEARS.

Stykkisholm pressure in June to September of the following year, which are supported by the correlations of the same pressure with Barents Sea ice in April to June, and less markedly by those with Greenland Sea ice in both April to June and July to August. These positive coefficients extend to Jacobshavn but not to Thorshavn.

The recurrence of positive coefficients at Stykkisholm in July to September of the same year as the ice, and in the following year, suggested the possibility of a more or less regular annual variation, which was investigated further for the three stations Stykkisholm, Valentia and Ponta Delgada. The results are shown in Table XI and Fig. 6. The average values of the coefficients for the various quarters beginning with July to September and ending with April to June four years later are shown in Table XII.

TABLE IX—CORRELATION COEFFICIENTS, BARENTS SEA ICE (APRIL TO JUNE) AND PRESSURE

Pressure in	April to June	July to Sept.	Sept. to Nov.	Oct. to Dec.	Nov. to Jan.	Jan. to Mar.	April to June	July to Sept.	Oct. to Dec.
Lag in months ..	0	3	5	6	7	9	12	15	18
Jacobshavn (1895–1923) ..	+·23	+**·21**	+·04	+**·20**	—·16	·11	+·12	+**·39**	+**·22**
Stykkisholm (1895–1924) ..	+·32	+**·46**	—·01	+·07	+**·26**	+·03	—·17	+**·40**	+·11
Thorshavn (1895–1922)	+·40	+·17	—**·45**	—**·55**	—·15	·04	—·06	+·03	**·36**
Vardo (1895–1924)	+·24	—·06	—·14	+·06	+·12	—·14	+**·25**	+·13	**·21**
Bergen (1895–1924)	+·26	—·07	—**·39**	—**·38**	—·09	—·02	+·03	—·02	**·27**
Valentia (1895–1925)	+·11	—·03	—·06	—·02	—·15	**·27**	+·01	—·13	·12
Paris (1895–1920)	+·05	—**·34**	—·06	+·02	—·11	—·09	+·02	—**·32**	·14
Berlin (1895–1923)	+·04	—**·26**	—**·25**	—**·25**	—**·23**	+·17	·00	—**·21**	**·27**
Ponta Delgada (1895–1925) ..	—·21	—**·21**	+**·31**	+**·30**	—**·32**	—·19	—·02	—·04	—**·35**

Table X—Correlation Coefficients, Barents Sea Ice (July to August) and Pressure

Pressure in	July to Sept.	Oct. to Dec.	Jan. to March	April to June	July to Sept.	Oct. to Dec.
Jacobshavn (1895–1923)	+·47	+**·32**	−·09	+·09	+**·57**	+**·20**
Stykkisholm (1895–1924)	+·47	+·16	−·14	−**·44**	+**·52**	+**·22**
Thorshavn (1895–1922)	+·01	−**·45**	−·05	−·14	−·08	−·17
Vardo (1895–1924)	+·08	+·18	−·05	+·10	+**·35**	+·07
Bergen (1895–1924)	−·07	−**·28**	+·08	+·19	+·04	−·15
Valentia (1895–1925)	−·13	−**·20**	−·14	+**·32**	−·05	+·05
Paris (1895–1920)	−·53	−**·24**	+·03	+·13	−**·23**	−·06
Berlin (1895–1923)	−·26	−·18	+**·22**	+·14	−·18	−·11
Ponta Delgada (1895–1925)	−·27	+·11	+·02	+·11	−·19	+·19

The following additional coefficients were calculated for Stykkisholm:—March to May, −**·36**; May to July, −·05; June to August, +**·30**; August to October, +**·43**.

Table XI—Correlation Coefficients, Barents Sea Ice (April to August) and Pressure in succeeding years

Months after April to June of ice year.	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
Stykkisholm	+·27	+·51	+·13	·00	−**·28**	+**·50**	+·15	+·01	−**·44**	+**·26**	+·18	−**·21**	+·15	+**·23**	+·06	−**·40**	−**·27**
Valentia	+·10	−·08	−·16	−**·24**	+·12	−·14	−·11	−**·22**	+**·37**	+·06	+**·21**	−**·27**	+**·29**	+·15	+·19	−**·22**	+**·27**
Ponta Delgada	−·21	−·23	+·18	−·14	+·02	−·10	+**·31**	−·06	+·09	−·18	+·04	+·06	−·14	−·08	−·02	+**·25**	−·06

Table XII—Average Values of Coefficients between Barents Sea Ice (April to August) and Pressure in succeeding Four Years

	July–Sept.	Oct.–Dec.	Jan.–March	April–June
Stykkisholm	+**·37**	+·13	−·15	−**·21**
Valentia	·00	+·03	−**·24**	+**·26**
Ponta Delgada	−·15	+·13	+·03	−·02

These figures are indicated by the broken lines in Fig. 6 and serve to bring out the great regularity with which similar coefficients recur with lags of n, $n+12$, $n+24$ and $n+36$ months. This annual variation is discussed further in § 22.

§ 16—Ice in the Kara Sea

The Kara Sea which lies between Nowaya Zemlya and 70° E., is generally almost entirely frozen over until July, and it is only in August that the variation from year to year is sufficient to give figures suitable for correlation. It was not considered necessary to work out completely the relations of the ice conditions in this month with all the nine selected stations, the latter being limited to contemporary relationships (pressure July to September) and those in the following November to January. These are shown in Table XIII.

TABLE XIII—CORRELATION COEFFICIENTS, KARA SEA ICE (AUGUST) WITH PRESSURE

Pressure in	July to Sept.	Nov. to Jan.	Pressure in	July to Sept.	Nov. to Jan.
Jacobshavn	+·27	—·17	Valentia	+·06	—·18
Stykkisholm	+·41	+·01	Paris	—·35	—·19
Thorshavn	—·09	—**·22**	Berlin	—·22	+·01
Vardo	·00	+·14	Ponta Delgada	—·12	—**·20**
Bergen	—·11	+·04			

The "contemporary" coefficients show the usual positive values at Jacobshavn and Stykkisholm and the usual negative value at Ponta Delgada. The coefficients with the following November to January show an area of negative correlation including Thorshavn, Valentia, Paris and Ponta Delgada; this is discussed further in § 20.

TABLE XIV—AVERAGE VALUES OF COEFFICIENTS BETWEEN KARA SEA ICE (AUGUST) AND PRESSURE IN SUCCEEDING FOUR YEARS

	July–Sept.	Oct.–Dec.	Jan.–Mar.	April–June
Stykkisholm	+**·21**	+·09	—**·21**	—·09
Valentia	+·07	+·08	—·10	+**·21**
Berlin	—·10	+·05	—·04	+**·22**
Ponta Delgada	+·05	+·06	+·19	+·15

Secondly, having regard to the well-marked annual recurrence of similar coefficients found with the Barents Sea ice, the Kara Sea ice for August was correlated with the quarterly means of pressure at Stykkisholm, Valentia, Berlin and Ponta

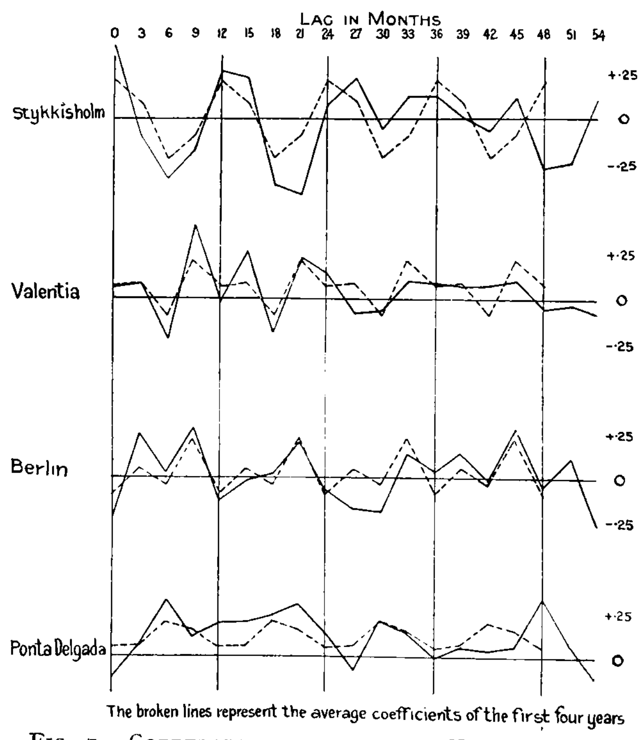


FIG. 7.—CORRELATION COEFFICIENTS, KARA SEA ICE (AUGUST) WITH PRESSURE IN SUCCEEDING YEARS.

Delgada over a period of $4\frac{1}{2}$ years. The results are shown in Table XV and Fig. 7. The curve for Stykkisholm strongly suggests an annual variation, but this is not so clear at the other stations. The means of the separate quarters for the first four years are shown in Table XIV.

This annual variation is shown by the broken lines in Fig. 7. It is discussed further in § 22.

Although the coefficients with Ponta Delgada are mainly small, they show a considerable preponderance of positive values. The distribution is as follows :—

> +·24	+·24 to +·15	+·14 to +·05	+·04 to −·04	−·05 to −·14
3	4	7	2	3

Only two values exceed −·10, one of which is with "contemporary" pressure, while ten exceed +·10. The preponderance of positive values seems to indicate that much ice in the Kara Sea is followed by a persistent though slight tendency for pressure to be above normal at the Azores. The series of coefficients from 6 to 21 months seems to be especially significant. No particular meaning can be assigned to the correlations with pressure at Valentia and Berlin.

TABLE XV—CORRELATION COEFFICIENTS, KARA SEA ICE (AUGUST) AND PRESSURE IN SUCCEEDING YEARS

Lag in months	0	3	6	9	12	15	18	21
Stykkisholm (1895–1924)	+·41	−·08	**−·34**	−·17	**+·26**	**+·23**	**−·37**	**−·42**
Valentia (1895–1925)	+·06	+·09	**−·22**	**+·41**	−·01	**+·26**	−·19	**+·23**
Berlin (1895–1923)	−·22	**+·25**	+·03	**+·27**	−·13	−·02	+·01	**+·20**
Ponta Delgada (1895–1925)	−·12	+·06	**+·31**	+·11	+·19	+·19	**+·23**	**+·29**

Lag in months	24	27	30	33	36	39	42	45	48	51	54
Stykkisholm (1895–1924) ..	+·07	**+·22**	−·05	+·11	+·12	+·01	−·06	+·11	**−·27**	**−·24**	+·10
Valentia (1895–1925) ..	+·14	−·08	−·07	+·09	+·08	+·06	+·07	+·10	−·06	−·04	−·08
Berlin (1895–1923)	−·07	−·18	**−·20**	+·13	+·03	+·14	−·01	**+·27**	−·05	+·11	**−·27**
Ponta Delgada (1895–1925)	+·13	−·07	**+·20**	+·14	·00	+·05	+·04	+·06	**+·33**	+·08	−·12

§ 17—SIBERIAN AUTUMN TEMPERATURES

From Wiese's theory that the main "ice factory" of the Arctic Ocean is situated north of western Siberia (§1), we should expect that a high Siberian autumn temperature would be followed by a period of little ice extending over several years, and finally reaching the Greenland Sea $4\frac{1}{2}$ years later.

Correlation coefficients were calculated between the mean autumn temperature at Touroukhansk and Obdorsk and pressures during the following $5\frac{1}{2}$ years at Stykkisholm, Valentia, Berlin and Ponta Delgada ; these coefficients are shown in Table XVI and Fig. 8, but the results are disappointing. Supposing that there is no real

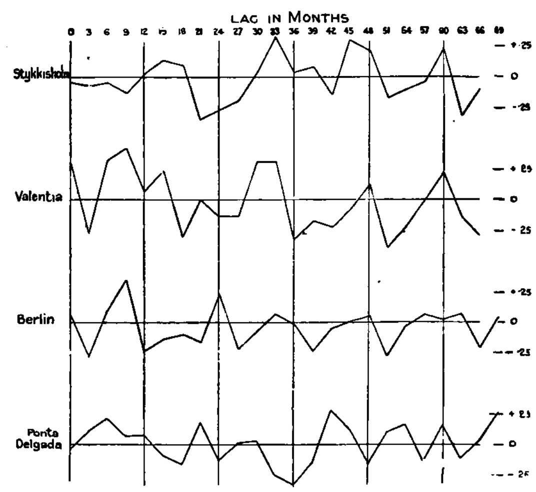


FIG. 8.—CORRELATION COEFFICIENTS, SIBERIAN TEMPERATURES (SEPTEMBER TO NOVEMBER) WITH PRESSURE IN SUCCEEDING YEARS.

connexion, we should expect 47 of the 94 coefficients to exceed the probable error (± ·13), while actually we find that 48 exceed this value; similarly we should expect 16 or 17 to exceed twice this value (± ·26) while actually we find 18. At each of the four stations the highest coefficient which would be expected on a basis of pure chance is ·43, and this value is not once exceeded.

From a comparison with the results for Greenland Sea ice (Tables VI and VII and Fig. 4) we should expect:—

Negative coefficients with Valentia and Berlin 4½ years later. The values found are −·21 and −·03.

Positive coefficients with Valentia and Berlin five years later. The values found are +·22 and +·02.

A negative coefficient with Ponta Delgada five years later. The value found is however +·15.

The results of the correlations with Siberian autumn temperatures therefore confirm those with Greenland Sea ice in the case of pressure at Valentia, but not in the case of Berlin or Ponta Delgada, while the coefficients are too small to have any appreciable independent value.

From the results found with ice in the Barents Sea and Kara Sea, we should expect an annual variation in the coefficients with pressure at Stykkisholm, but this is not confirmed by an examination of Table XVI.

TABLE XVI—CORRELATION COEFFICIENTS, SIBERIAN TEMPERATURE AND PRESSURE IN SUCCEEDING YEARS

½ (Obdorsk + Touroukhansk), September–November, 1883–1908.

Lag in Months	0	3	6	9	12	15	18	21	24	27	30	33
Stykkisholm ..	−·03	−·06	−·04	−·12	+·03	+·14	+·10	−**·33**	−**·26**	−·19	+·04	+**·33**
Valentia	+·31	−**·26**	+**·33**	+**·43**	+·07	+**·24**	−**·29**	·00	−·13	−·13	+**·31**	+**·32**
Berlin	+·07	−**·28**	+·10	+**·36**	−**·23**	−·14	−·10	−·16	+**·23**	−**·21**	−·07	−·07
Ponta Delgada ..	−·03	+·11	+**·22**	+·07	+·08	−·08	−·16	+·19	−·12	+·01	+·03	−**·25**

Lag in Months	36	39	42	45	48	51	54	57	60	63	66	69
Stykkisholm.. ..	+·04	+·08	−·13	+**·30**	+**·22**	−·16	−·10	−·04	+**·23**	−**·31**	−·09	
Valentia	−**·31**	−·17	−**·21**	−·09	+·11	−**·38**	−**·21**	·00	+**·22**	−·15	−**·29**	
Berlin	−·01	−**·24**	−·05	−·12	+·05	−**·28**	−·03	+·06	+·02	+·07	−**·21**	+·05
Ponta Delgada ..	−**·33**	−·15	+**·28**	+·13	−·16	+·10	+·16	−·14	+·15	−·11	+·03	+**·26**

§ 18—PRESSURE AND TEMPERATURE AT SPITSBERGEN

Since the ice conditions in the Arctic Ocean must react to some extent on the meteorological conditions over that ocean, the short series of observations at Spitsbergen was examined. In particular temperature at Spitsbergen may be expected to show a fairly close negative relation to the amount of ice in the Barents Sea which lies to the eastward. This point was examined first by correlating the mean temperature at Green Harbour during April to August with the average ice area in the Barents Sea during the same months over the period 1912 to 1924; this gave a coefficient of −·77 ± ·076. The coefficients for the individual months were as follows:—

April	May	June	July	August	Mean
−·59	−·40	−·32	−·55	−·88	−·55

Evidently the inverse temperature at Spitsbergen during these months may be used with fair accuracy to represent ice conditions in the Barents Sea. In addition it was considered desirable to investigate directly the relations between pressure and temperature at Spitsbergen and subsequent pressure at the selected stations. Pressure data were available from October, 1911, to September, 1923, temperature from January, 1912, to June, 1924, so that the data were not sufficient to discriminate between the different seasons. The results are shown in Table XVII. There is negative correlation (−·43) between contemporary pressure and temperature at Spitsbergen, so that the pairs of corresponding coefficients (pressure at one of the selected stations with pressure and with temperature at Spitsbergen) are generally of opposite signs.

Pressure at Spitsbergen has, as would be expected, generally high correlation with contemporary pressure in the North Atlantic region, reaching +·75 at Vardo and +·63 at Stykkisholm. The line of zero correlation passes just south of Bergen and high negative correlation is found at Paris (−·69) and Ponta Delgada (−·60). Correlation of pressure at the selected stations with contemporary temperature at Spitsbergen is generally smaller, but the coefficients reach −·42 at Stykkisholm and +·42 at Paris.

The coefficients with subsequent pressures at the selected stations are generally small and without apparent significance, except perhaps the coefficients of +·48 at Jacobshavn and +·30 at Stykkisholm six months after Spitsbergen pressure. Leaving aside the contemporary coefficients, Table XVII contains 36 figures for both pressure and temperature, and the highest coefficients which would be expected to arise on a chance basis are ·34 with pressure and ·33 with temperature. There is, therefore, no intrinsic evidence of the reality of any of the coefficients between Spitsbergen temperature and subsequent pressure, but in this connexion it must be remarked that the coefficients refer to the whole year, and that a different result might have been obtained had it been possible to utilise the spring months only.

Table XVII—Correlation Coefficients, Spitsbergen Pressure and Temperature and Pressure

Spitsbergen Pressure, 1911 (4th qr.) to 1923 (3rd qr.).
,, Temperature, 1912 (1st qr.) to 1924 (2nd qr.).

Lag in Months		0	3	6	9	12
Jacobshavn (1912–1923)	P	+·56	−·02	**+·48**	−·11	−·08
	T	−·35	−·12	**−·33**	−·05	**−·33**
Stykkisholm (1912–1924)	P	+·63	+·09	**+·30**	+·02	−·06
	T	−·42	−·11	−·18	·00	−·14
Thorshavn (1912–1922)	P	+·29	+·09	−·04	−·02	−·16
	T	−·21	−·19	+·09	**+·27**	+·02
Vardo (1912–1924)	P	+·75	+·02	**+·22**	−·06	+·04
	T	−·11	−·07	−·08	−·12	−·17
Bergen (1912–1924)	P	+·03	+·04	−·11	−·06	·00
	T	−·01	−·18	+·03	+·15	+·04
Valentia (1912–1925)	P	−·51	+·13	−·16	**+·26**	−·01
	T	+·14	−·14	−·02	−·05	+·16
Paris (1912–1920)	P	−·41	−·01	−·09	+·19	**+·21**
	T	+·13	−·03	+·05	−·11	−·03
Berlin (1912–1923)	P	−·69	−·03	−·10	−·05	+·14
	T	+·42	−·09	+·07	+·04	+·01
Ponta Delgada (1912–1925)	P	−·60	+·04	−·16	+·13	+·04
	T	+·34	+·05	+·10	−·12	+·17

TABLE XVIII—CORRELATION OF ARCTIC ICE, ETC., WITH "CONTEMPORARY" PRESSURE

	Jacobs-havn	Stykkis-holm	Thors-havn	Vardo	Bergen	Valen-tia	Paris	Berlin	Ponta Delgada
Iceland Ice (with P. April–June)—									
1902–1923*	−·02	+·23	+·42	−·02	+·39	+·13	−·07	+·09	−·18
Meinardus'data*	+·12	+·47	+·42	−·18	+·10	+·11	+·23	+·20	−·14
Stykkisholm-Vardo P. diff. Nov.–Jan. with P. Apr.–June	—	+·29	—	—	—	+·03	—	−·08	−·35
Stykkisholm T. (reversed)—									
All quarters	—	+·18	—	—	—	−·06	—	−·14	+·03
Jan.–June	—	+·27	—	—	—	−·05	—	−·09	−·15
Greenland Sea Ice—									
Ice in April–June*	−·05	+·07	+·43	−·19	+·43	+·40	+·31	+·33	+·10
Ice in July–August* .. .. .. (With P. July–Sept.)	+·22	+·35	+·22	+·17	−·01	+·06	−·44	−·28	−·13
Jan Mayen T. (reversed)	—	+·23	—	—	—	+·32	—	—	−·22
Barents Sea Ice—									
Ice in April–June*	+·23	+·32	+·40	+·24	+·26	+·11	+·05	+·04	−·21
Ice in July–August* .. .. .. (with P. July–Sept.)	+·47	+·47	+·01	+·08	−·07	−·13	−·53	−·26	−·27
Kara Sea Ice, August (with P. July–Sept.) ..	+·27	+·41	−·09	·00	−·11	+·06	−·35	−·22	−·12
Siberian autumn T. 4½ years before (reversed)	—	+·10	—	—	—	+·21	—	+·03	−·16
Spitsbergen T.* (reversed)	+·35	+·42	+·21	+·11	+·01	−·14	−·42	−·13	−·34
*MEANS OF STARRED VALUES	+·20	+·34	+·25	+·03	+·13	+·07	−·15	−·03	−·16

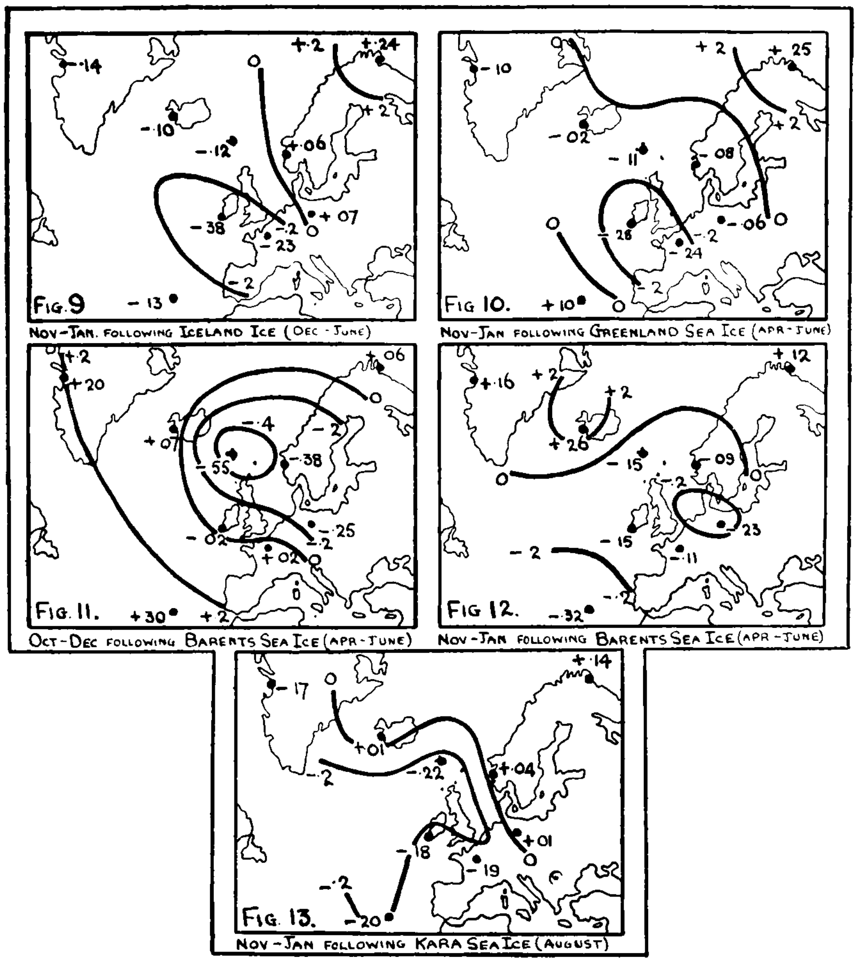
§ 19—THE INFLUENCE OF ARCTIC ICE ON CONTEMPORARY PRESSURE

The correlation coefficients listed in Tables II to XV have generally indicated a fairly definite parallelism between the amount of ice in different parts of the Arctic and the contemporary pressure at northern stations. The coefficients with the different variates are collected in Table XVIII. In this table the factors to which we have been led to attach the greatest importance are distinguished by a star (*), and the means of these starred values are given at the foot of the table.

This table shows quite clearly that an abnormally large amount of ice off Iceland, or in the Greenland Sea, Barents Sea or Kara Sea, or an abnormally low temperature in these regions, is associated with pressure above normal at Stykkisholm and Thorshavn, and not quite so definitely with pressure below normal at Ponta Delgada. At Vardo the relationship is much slighter, even with ice in the Barents Sea or with temperature at Spitsbergen, in spite of the much closer proximity of Vardo than of Stykkisholm to the Barents Sea and Spitsbergen. This suggests that the effect is exercised most strongly in the Icelandic minimum of pressure, but the sign of the relationship is not what we should expect from the usual theories of the circulation of the atmosphere, according to which an increase in the amount of Arctic ice, by lowering the temperature in high latitudes, and thereby increasing the thermal gradient between low and high latitudes, should increase the strength of the atmospheric circulation and therefore accentuate the Icelandic low and the Azores high. It seems probable that the positive correlations with pressure at Jacobshavn, Stykkisholm and Thorshavn are mainly density effects due to the variations in the temperature of the air associated with the ice, but that this effect is not operative at Vardo presumably because the latter station is generally in the region of equatorial air brought by the south-west winds. The negative correlations with pressure at Ponta Delgada are presumably a reflection of the well-known negative correlation between pressures in Iceland and the Azores ; the value of this correlation is about −·5, and the mean of the different correlations with Ponta Delgada in Table XVIII is about half the mean of the correlations with Stykkisholm.

§ 20—THE NEGATIVE CORRELATIONS OF ICE CONDITIONS WITH PRESSURE IN THE FOLLOWING AUTUMN AND WINTER

The most interesting of all the phenomena associated with Arctic ice is the way in which, as pointed out by Wiese and illustrated in Fig. 2, heavy ice conditions tend to be followed in autumn and early winter by pressure below normal in the storm regions of north-west Europe. The coefficients following ice off Iceland, and ice in the Greenland Sea, the Barents Sea and the Kara Sea, respectively, are shown in Table XIX and in Figs. 9 to 13, in which isocorrelates have been sketched in to aid the eye. Fig. 9 shows the means of coefficients A and B in Table II, the period selected, November to January, being that for which the coefficient is largest at Valentia. The area of negative correlation extends from Jacobshavn in the north to Ponta Delgada in the south and Paris in the east, but does not include Berlin or Bergen, while Vardo has a fairly high positive coefficient. The effect apparently lasts from September to January, and from the figures it appears to begin earlier at Paris than at Valentia, but this may be accidental.



FIGS. 9–13.—MAPS SHOWING DISTRIBUTION OF CORRELATION COEFFICIENTS BETWEEN ARCTIC ICE AND SUBSEQUENT PRESSURE.

Fig. 10 shows the corresponding relationships between Greenland Sea ice in April to June and pressure in November to January following. The figures are the "weighted means" of Table VI. The largest negative coefficient is still at Valentia, but Ponta Delgada has become positive, and the negative area has extended north-eastwards to include Berlin and Bergen.

Figs. 11 and 12, representing the coefficients of Barents Sea ice in April to June with pressure in the following October to December and in November to January, are of interest. The coefficients for October to December show large negative coefficients at Thorshavn (−·55) and Bergen (−·38), and a positive coefficient of +·30 at Ponta Delgada. The figures for September to November are very similar. In November to January, however, the distribution of coefficients is quite different; Thorshavn has decreased to −·15 and Bergen to −·09, while Ponta Delgada has changed to −·32. The distribution is in fact not very different from that of Fig. 9. Consideration shows that the large coefficients with October to December must be mainly due to October, and the pressure data for this single month were found to have the following correlation coefficients with Barents Sea ice in April to June: Thorshavn, −·46; Ponta Delgada, +·51. Unfortunately the series of data employed covers only 31 years, and these high values, which depart considerably from those for the ice conditions in the other areas, must be regarded as probably accidental. The much smaller values for November to January, on the other hand, which agree with the corresponding results for other ice centres, are probably real.

The coefficients of pressure in November to January with Kara Sea ice in the preceding August are shown in Fig. 13, which is generally similar to Figs. 9, 10 and 12.

It must be remarked here that the similarity of Figs. 9, 10, 12 and 13 cannot be accounted for by close correlation between simultaneous conditions in the different ice centres, since the relationships between the latter are in general small, with the exception of Iceland and Greenland Sea ice which have a coefficient of +·43 (*see* Table XX). This point is dealt with more fully in § 21.

The cause of the series of negative relationships shown in Figs. 9–13 is not entirely clear, but a tentative hypothesis may be fashioned somewhat as follows: after a heavy ice season, the thaw of late summer and autumn liberates a large amount of cold but relatively fresh thaw water, which finds its way southward and penetrates into the warm waters of the Gulf Stream Drift. This sets up large differences of temperature in short distances, which are believed to be favourable to the development of depressions. Hence the greater the amount of ice in spring and summer the greater the storminess and the lower the pressure in the following autumn and winter.

TABLE XIX—CORRELATION BETWEEN ICE CONDITIONS AND PRESSURE IN THE FOLLOWING NOVEMBER TO JANUARY

	Jacobs-havn	Stykkis-holm	Thors-havn	Vardo	Bergen	Valentia	Paris	Berlin	Ponta Delgada
Iceland Ice (Dec.–June)	−·14	−·10	−·12	+**·24**	+·06	−**·38**	−**·23**	+·07	−·13
Greenland Sea Ice (Apr.–June)	−·10	−·02	−·11	+**·25**	−·08	−**·28**	−**·24**	−·06	+·10
Barents Sea Ice (Apr.–June)	+·16	+**·26**	−·15	+·12	−·09	−·15	−·11	−**·23**	−**·32**
Kara Sea Ice (August)	−·17	+·01	−**·22**	+·14	+·04	−·18	−·19	+·01	−**·20**
Mean ..	−·06	+·04	−·15	+·19	−·02	−**·25**	−·19	−·05	−·14

§ 21—PARTIAL CORRELATION

The preceding discussion has brought out two periods in which pressure in western Europe and the North Atlantic probably has real relationships with ice conditions in the Arctic, namely, April to June contemporaneous with the ice, and the following November to January. In order to examine these relationships more closely, partial correlations were calculated between the ice conditions in the four centres—Iceland (December to June), Greenland Sea (April to June), Barents Sea (April to June) and Kara Sea (August) on the one hand, and the four stations Stykkisholm, Vardo, Valentia and Ponta Delgada on the other hand. The uniform period 1895 to 1923 was employed throughout, the Iceland data for the years 1895 to 1900 being completed from Meinardus' figures.

The crude correlation coefficients between the different ice data are shown in Table XX.

TABLE XX—CORRELATION BETWEEN ICE IN DIFFERENT CENTRES

Ice	Greenland Sea	Barents Sea	Kara Sea
Iceland	+·43	+·32	+·25
Greenland Sea	—	+·20	+·32
Barents Sea	—	—	+·28

The partial correlation coefficients of the third order are shown in Tables XXI and XXII.

TABLE XXI—PARTIAL COEFFICIENTS (r) AND REGRESSION COEFFICIENTS (b) WITH PRESSURE IN APRIL TO JUNE

	Stykkisholm		Vardo		Valentia		Ponta Delgada	
	r	b	r	b	r	b	r	b
Iceland Ice (Dec.–June)	+·14	+·012	−·20	−·015	+·01	+·001	−·05	−·002
Greenland Sea Ice (Apr.–June)	−·17	− ·44	−·21	− ·46	+·48	+1·20	+·14	+ ·20
Barents Sea Ice (Apr.–June)	+·30	+ ·54	+·35	+ ·53	·00	·00	−·21	− ·20

TABLE XXII—PARTIAL COEFFICIENTS (r) AND REGRESSION COEFFICIENTS (b) WITH PRESSURE IN NOVEMBER TO JANUARY

	Stykkisholm		Vardo		Valentia		Ponta Delgada	
	r	b	r	b	r	b	r	b
Iceland Ice (Dec.–June)	−·21	−·028	+·28	+·033	−·51	−·062	−·05	−·004
Greenland Sea Ice (Apr.–June)	+·23	+ ·97	+·25	+ ·92	+·08	+ ·27	+·10	+ ·23
Barents Sea Ice (Apr.–June)	+·29	+ ·82	−·02	− ·05	+·04	+ ·08	+·27	+ ·41
Kara Sea Ice (August)	−·10	− ·63	−·02	− ·10	−·08	− ·41	−·13	− ·46

From Table XXII we can deduce equations for forecasting average pressures during November to January. The various quantities are expressed in the following units :—

P = Pressure in millibars at mean sea level, reduced to mean of 24 hours.

I = Duration and severity of ice off Iceland in December to June (total number of days, days with heavy ice counting double).

G = Area of ice in Greenland Sea in April to June, unit one thousand square kilometres.

B = Area of ice in Barents Sea in April to June, unit as for G.

K = Area of ice in Kara Sea in August, unit as for G.

Stykkisholm $P = 979{\cdot}8 - {\cdot}028\, I + {\cdot}97\, (G - 600) + {\cdot}82\, (B - 400) - {\cdot}63\, (K - 100)$.
Vardo $P = 971{\cdot}9 + {\cdot}033\, I + {\cdot}92\, (G - 600) - {\cdot}05\, (B - 400) - {\cdot}10\, (K - 100)$.
Valentia $P = 1021{\cdot}4 - {\cdot}062\, I + {\cdot}27\, (G - 600) + {\cdot}08\, (B - 400) - {\cdot}41\, (K - 100)$.
Ponta Delgada $P = 1027{\cdot}7 - {\cdot}004\, I + {\cdot}23\, (G - 600) + {\cdot}41\, (B - 400) - {\cdot}46\, (K - 100)$.

Although of no use for forecasting purposes, it may be of interest to give the regression equations connecting pressures in April to June with ice conditions. The notation is the same as above, but the ice area in the Kara Sea is omitted from consideration.

Stykkisholm $P = 1022{\cdot}3 + {\cdot}012\, I - {\cdot}44\, (G - 600) + {\cdot}54\, (B - 400)$.
Vardo $P = 1026{\cdot}0 - {\cdot}015\, I - {\cdot}46\, (G - 600) + {\cdot}53\, (B - 400)$.
Valentia $P = 967{\cdot}4 + {\cdot}001\, I + 1{\cdot}20\, (G - 600)$.
Ponta Delgada $P = 1016{\cdot}2 - {\cdot}002\, I + {\cdot}20\, (G - 600) - {\cdot}20\, (B - 400)$.

§ 22—The Annual Variation of the Effects of Arctic Ice

In §§ 15 and 16 we found evidence that the effects of a heavy or light ice season persist for several years, but go through an annual variation so that they differ in different seasons. There are indications of this annual variation in the case of the Greenland Sea ice, the positive coefficients with pressure in July to September of the same year recurring in the same months of the following year, and the same recurrence is indicated with Iceland ice, especially by the figures for 1902 to 1923. We may take Stykkisholm as typical of the northern stations ; here the general sequence is—positive coefficients in July to September, small coefficients in October to December, negative coefficients in January to March and small negative coefficients in April to June. There are two problems here, first the change from positive to negative, and secondly the repetition in successive years.

The annual variation of the coefficients may plausibly be referred to the annual variation of three other quantities :—

(i.) The area and solidity of the Arctic ice, which reaches a maximum in January to March and a minimum in July to September. As there is a high correlation between the area of ice in, say, the Barents Sea in April to August of one year and in the same months of the following year, it is a plausible assumption that there is also a high correlation between the area of ice in summer and that in the following winter.

(ii.) The intensity of the Icelandic minimum of pressure which is greatest in winter and least in summer.

(iii.) The cooling of the surface waters of the North Atlantic by thaw water from the ice in the East Greenland Current, which is greatest in summer, and is practically negligible in winter. The main reason for this is that in these regions very little scattering and melting of ice takes place in winter, but a great deal in summer. A secondary factor is the annual variation of the Gulf Stream Drift towards the Arctic Ocean, which owing to the annual variation in the direction and velocity of the winds, is strongest and most regular in winter, weakest and least regular in summer.

In § 19 it was suggested that there are two opposing tendencies in the effect of Arctic ice on pressure at Stykkisholm, namely, (*a*) a tendency for a large temperature difference between the equator and the north pole to bring about a dynamic intensification of the Icelandic low, and (*b*) a tendency for much ice to give high pressure owing to the direct effect of the cold surface on air temperature and density. With this latter tendency we may include the effect of the Gulf Stream Drift referred to under (iii) above, a weakening of the Gulf Stream being presumed to have the same effect as an increase in the area of ice. Not only are (i) the area and solidity of the Arctic ice cap greatest in January to March, but the cooling power of ice on the air above it also appears to be greatest in winter. Hence it is reasonable to suppose that the effect of this ice cap on the general atmospheric circulation is greatest about January to March and least about July to September. The relation between (ii) the general circulation of the atmosphere and pressure in the Icelandic low should be closest when that low is best developed, *i.e.* in winter. Both (i) and (ii) would therefore lead us to anticipate a stronger tendency in winter than in summer for negative correlation between the area of Arctic ice and pressure at Stykkisholm. (iii) the cooling of the surface of the North Atlantic near Iceland by thaw water being greatest in summer, we should expect the cooling of the over-lying air, and consequently the direct rise of pressure near Iceland, to be greatest at this season. This would give a tendency for positive correlation between the area of ice and the pressure at Stykkisholm in summer but not in winter. The annual variation actually found would then represent the balance between factors (i) and (ii) on the one hand and factor (iii) on the other hand. The annual variations of the coefficients at the remaining stations—Valentia, Berlin and Ponta Delgada—are less marked and may be regarded as mainly secondary effects due to the dynamical relations of pressures at these stations with those in Iceland and the Arctic.

The second problem is the persistence of similar coefficients at the same seasons over a period of several years. The Barents Sea and the Kara Sea are on the fringe of the great mass of Palaeocrystic ice which persists for year after year. Hence the variations of the ice area in these seas may be regarded as to some extent an indication of the variations in the main mass of Palaeocrystic ice, and consequently as rather persistent from year to year. The correlation between the areas of Barents Sea ice (April to August) in successive years is +·57 ; hence we should expect the correlation between the first and third years to be $(·57)^2$ or ·32, and between the first and fourth years $(·57)^3$ or ·19. Actually we find between the first and third years +·22 and between the first and fourth years −·01, the differences from +·32 and +·19 indicating some systematic variation of the order of eight to twelve years, which we identify as a variation with the sunspot cycle (there is a correlation of −·51 between Barents Sea ice and the sunspot relative number of the preceding year). These coefficients account for the persistence over one year but not over four years. Without going into the question fully, however, it may be remarked that there is some evidence that the various centres reach their maxima in successive years, the Greenland Sea one year after the Barents Sea and Iceland one year after the Greenland Sea. This is also to be expected from the slow drift of the ice across the Arctic Ocean. Hence, if we could obtain a measure of the total ice-covered area of the Arctic, we should probably find that the correlation between successive years was much higher than for the Barents Sea ice alone.

§ 23—The Index of Arctic Ice

A measure of the total ice-covered area is at present outside practical politics, we have to do the best we can with the data for the fringe of the ice which are actually available. Here we are faced with the difficulty that the ice conditions at Iceland and in the Greenland Sea, which are nearest to the western European region, have the greatest temporary effect on pressure there, but being outposts, are probably less representative of the persistent conditions of the central Arctic Ocean than are the Barents and Kara Seas. After some discussion, taking as a basis the partial correlation coefficients in Tables XX—XXII, we arrived at the following expression for a figure which we call the index figure of Arctic ice :—

5 [Greenland Sea Ice, April to August] + 7 [Barents Sea Ice, April to August] + 2 [3 (Kara Sea Ice, August) + Kara Sea Ice, April to August].

The values of the " Ice Index " obtained in this way are given in Table XXIII.

Table XXIII—Values of " Ice Index " for Arctic Ocean

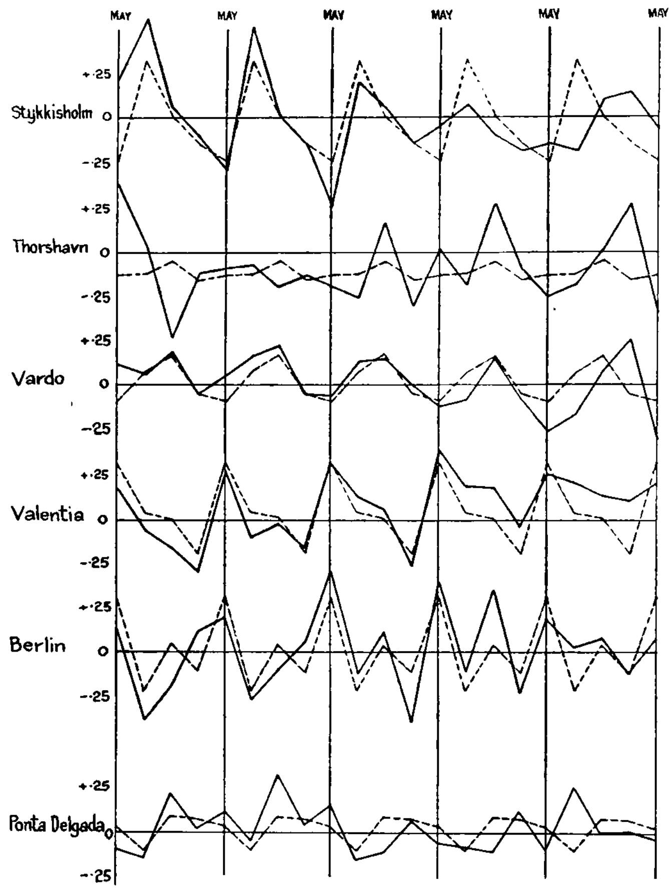
	0	1	2	3	4	5	6	7	8	9
1890	—	—	—	—	—	115	111	101	81	101
1900	97	104	127	113	89	107	105	107	103	119
1910	112	123	135	125	116	114	133	145	137	112
1920	101	104	86	94	88	—	—	—	—	—

For convenience of workers wishing to utilise these figures for obtaining other correlation coefficients it may be remarked that their variance[17] is approximately 20.

The correlation of the " ice index " for one year with that of the next gives a coefficient of +·66, appreciably higher than that for the Barents Sea ice alone.

[17] *See* : Walker, Sir Gilbert & E. W. Bliss. " On correlation coefficients, their calculation and use." *London, Q.J.R. Meteor. Soc.*, **52**, 1926, p. 73.

These figures were then correlated with the means of pressure for each quarter from April to June of the same year to April to June five years later. The results are shown in Table XXIV and Fig. 14. The coefficients for Stykkisholm, Vardo and Valentia show the annual variation very clearly, those for Berlin and Ponta Delgada less clearly, Thorshavn not at all. The average coefficients of each season during the first four years (commencing with July to September) are shown in Table XXV.



The broken line represent the average coefficients for the first four years.

FIG. 14.—CORRELATION COEFFICIENTS, "ICE INDEX" FIGURES WITH PRESSURE IN SUCCEEDING YEARS.

TABLE XXIV—CORRELATION COEFFICIENTS, ICE INDEX FIGURE WITH PRESSURE

	Same Year			One Year Later				Two Years Later			
	Apr. to June	July to Sept.	Oct. to Dec.	Jan. to Mar.	Apr. to June	July to Sept.	Oct. to Dec.	Jan. to Mar.	Apr. to June	July to Sept.	Oct. to Dec.
Stykkisholm .. (1895–1924)	+·21	+·56	+·06	−·09	**−·28**	**+·51**	+·02	−·14	**−·49**	**+·20**	+·05
Thorshavn .. (1895–1922)	+·38	+·04	**−·48**	−·12	−·09	−·07	−·19	−·13	**−·20**	**−·26**	+·17
Vardo .. .. (1895–1924)	+·12	+·06	+·18	−·05	+·05	+·16	**+·22**	−·05	−·06	+·13	+·15
Valentia .. (1895–1924)	+·18	−·06	−·16	**−·29**	**+·27**	−·10	−·02	−·16	**+·31**	+·13	+·06
Berlin .. .. (1895–1923)	+·13	−·37	−·19	+·12	**+·20**	**−·26**	−·10	+·06	**+·46**	−·12	+·11
Ponta Delgada (1895–1924)	−·09	−·14	**+·21**	+·02	+·11	−·04	**+·32**	+·09	+·15	−·15	−·11

TABLE XXIV—*continued*

	Three Years Later				Four Years Later				Five Years Later	
	Jan. to Mar.	Apr. to June	July to Sept.	Oct. to Dec.	Jan. to Mar.	Apr. to June	July to Sept.	Oct. to Dec.	Jan. to Mar.	Apr. to June
Stykkisholm .. .. (1895–1924)	−·14	−·04	+·07	−·09	−·18	−·14	−·18	+·10	+·14	−·06
Thorshavn .. .. (1895–1922)	**−·30**	+·02	−·18	**+·28**	−·09	**−·25**	−·18	+·02	**+·27**	**−·33**
Vardo .. .. .. (1895–1924)	−·01	**−·22**	−·08	+·15	−·08	**−·26**	−·17	+·07	**+·25**	**−·30**
Valentia .. .. (1895–1924)	**−·27**	**+·38**	+·19	+·18	−·03	**+·26**	**+·21**	+·14	+·11	**+·21**
Berlin .. .. .. (1895–1923)	**−·38**	**+·40**	−·10	**+·35**	**−·22**	+·19	+·03	+·08	−·11	+·08
Ponta Delgada.. .. (1895–1924)	+·06	−·05	−·08	−·10	+·12	−·08	**+·25**	·00	+·01	−·03

Additional coefficients with Stykkisholm were calculated as follows :—
Same Year : Nov.–Jan., **+·27**.
One Year Later : May–July, +·10 ; June–Aug., **+·33** ; Aug.–Oct., **+·27**.
Two Years Later : Mar.–May, **−·35** ; See also section 24.

TABLE XXV—AVERAGE VALUES OF COEFFICIENTS BETWEEN ICE INDEX AND PRESSURE IN SUCCEEDING FOUR YEARS

	July–Sept.	Oct.–Dec.	Jan.–Mar.	April–June
Stykkisholm	**+·33**	+·01	−·14	**−·24**
Thorshavn	−·12	−·05	−·16	−·13
Vardo	+·07	+·17	−·05	−·09
Valentia	+·04	+·01	−·19	**+·31**
Berlin	**−·21**	+·04	−·11	**+·31**
Ponta Delgada	−·10	+·08	+·07	+·03

These values are shown by the broken lines in Fig. 14. It is to be remarked that the coefficients in this table do not differ greatly from those in Table XII. The highest coefficient for Stykkisholm is +·33 instead of +·37, but on the other hand the highest coefficient for Valentia is +·31 instead of +·26.

§ 24—CORRELATION BETWEEN ICE INDEX AND PRESSURE IN FOLLOWING NOVEMBER TO JANUARY

For comparison with Table XIX and Figs. 9–13, the ice index figures were correlated with the pressure values for the following November to January at all nine stations. The results are shown in Table XXVI and Fig. 15.

TABLE XXVI—CORRELATION COEFFICIENTS, ICE INDEX FIGURES WITH PRESSURE IN THE FOLLOWING NOVEMBER TO JANUARY

	Jacobshavn	Stykkisholm	Thorshavn	Vardo	Bergen	Valentia	Paris	Berlin	Ponta Delgada
Coefficients with Ice Index ..	+·11	**+·27**	−·13	**+·28**	−·08	**−·28**	**−·28**	**−·20**	**−·35**
Mean from Table XIX	−·06	+·04	−·15	+·19	−·02	**−·25**	−·19	−·05	−·14
Highest individual value from Table XIX	−·17 } +·16 }	**+·26**	**−·22**	**+·25**	−·09	**−·38**	**−·24**	**−·23**	**−·32**

The distribution of the coefficients is more regular than those of Figs. 9, 10, 12 and 13, and the coefficients are, on the whole, larger. The coefficients for the northern stations Vardo and Stykkisholm have higher positive values than the highest in Table XIX, while the coefficients for the two southern stations, Ponta Delgada and Paris, have higher negative values. At intermediate stations, however, the coefficients of Fig. 15 are exceeded by the highest of Table XIX.

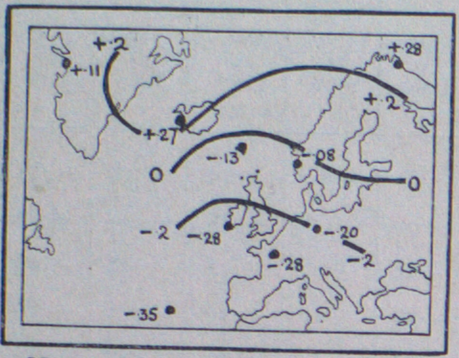


FIG. 15.—MAP SHOWING CORRELATION COEFFICIENTS BETWEEN "ICE INDEX" FIGURES AND PRESSURE IN FOLLOWING NOVEMBER TO JANUARY.

PART III—THE EFFECT OF ICE IN THE WESTERN NORTH ATLANTIC

§ 25—THE ICE SEASON OFF NEWFOUNDLAND

In Part I (§ 6) the possible effect of ice off Newfoundland on the general pressure distribution over the eastern North Atlantic and western Europe was considered and the factors which it was desirable to investigate were set out.

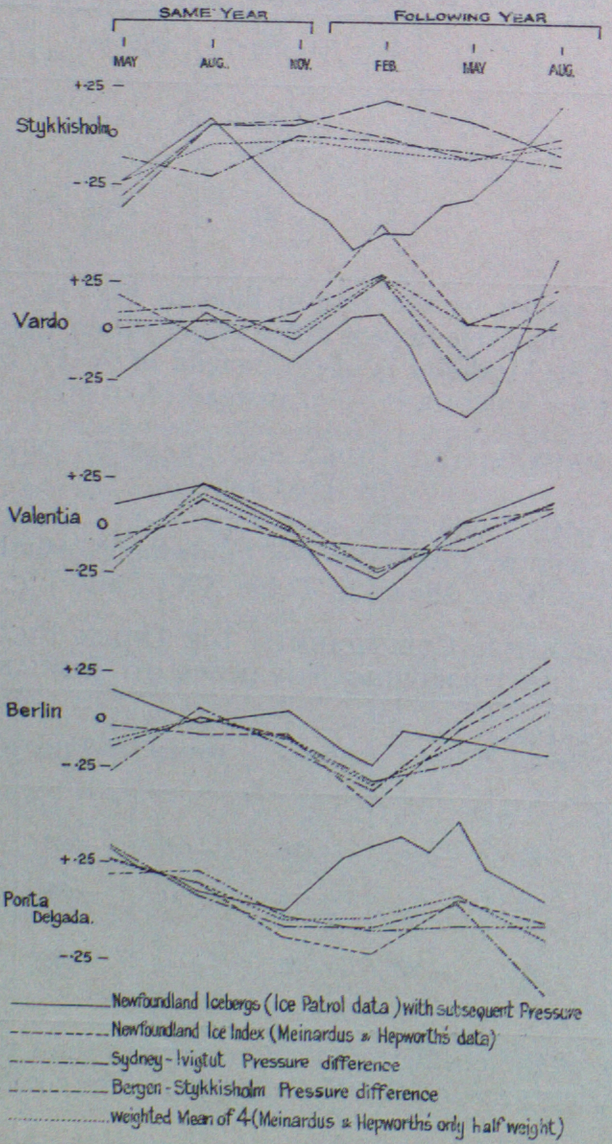


FIG. 16.—CORRELATION COEFFICIENTS, NEWFOUNDLAND ICE AND ITS FACTORS WITH PRESSURE.

The ice season off Newfoundland extends from February to May for field ice and from the middle of March to the middle of July for icebergs. In the following discussion ice conditions during April to June have been used, and no attempt has been made to discriminate between field ice and bergs.

§ 26—Icebergs off Newfoundland

The actual number of bergs south of Newfoundland (48th parallel) is observed by the Ice Patrol and a table of the numbers from 1900 to 1925 has been published by the U.S. Coast Guard.[18] The number of bergs, April to June, was correlated with the pressure at the selected stations during April to June, July to September and so on up to July to September in the following year. The results for all stations are shown in the lines marked A in Table XXVII. The full lines in Fig. 16 show the results for the five representative stations, Stykkisholm, Vardo, Valentia, Berlin and Ponta Delgada.

As a check on the results so obtained we utilized a series of index figures of ice conditions off Newfoundland for the years 1860 to 1902, compiled by W. Meinardus[19] on a scale of + 2 (much ice) to − 2 (little ice). These were completed up to 1905 by means of the data given by the late Campbell Hepworth[20] reduced to the same scale. The results are given in the lines marked B in Table XXVII and by the broken lines in Fig. 16. Although they agree on the whole with the results obtained from the Ice Patrol figures, the correlation coefficients obtained with Meinardus' data are less regular, a result which may be due to a smaller degree of accuracy in Meinardus' figures. The large coefficients with the Ice Patrol data shown by pressure at Stykkis-

Table XXVII—Correlation Coefficients, Ice off Newfoundland (April to June) and Pressure

A = Bergs (U.S. Ice Patrol). B = Index (Meinardus and Hepworth).

	0	3	6	7	8	9	10	11	12	13	15
	April to June	July to Sept.	Oct. to Dec.	Nov. to Jan.	Dec. to Feb.	Jan. to Mar.	Feb. to April	Mar. to May	April to June	May to July	July to Sept.
Jacobshavn—											
A. 1900–23	−·43	+·18	**−·39**	**−·49**	**−·43**	−·18	—	—	**−·26**	—	−·10
B. 1866–1905	—	−·08	**+·29**	—	—	**+·22**	—	—	−·03	—	−·06
Stykkisholm—											
A. 1900–25	−·23	+·09	**−·33**	**−·47**	**−·56**	**−·48**	**−·48**	**−·34**	**−·30**	−·17	+·17
B. 1860–1905	−·37	+·05	+·07	—	—	+·19	—	—	+·09	—	−·07
Thorshavn—											
A. 1900–22	+·11	+·07	−·02	**−·36**	**−·56**	**−·45**	**−·38**	**−·26**	**−·36**	**−·30**	**+·59**
B. 1873–1905	—	+·06	**+·24**	—	—	+·11	—	—	−·03	—	−·14
Vardo—											
A. 1900–24	−·24	+·10	−·14	—	+·09	+·11	−·05	**−·33**	**−·40**	**−·27**	**+·41**
B. 1874–1905	+·01	+·06	+·07	—	—	**+·56**	—	—	+·07	—	+·05
Bergen—											
A. 1900–24	+·08	**+·24**	−·07	−·19	**−·40**	**−·37**	**−·26**	−·18	**−·32**	—	**+·39**
B. 1868–1905	—	+·09	−·03	—	—	+·07	—	—	+·02	—	+·04
Valentia—											
A. 1900–25	+·11	**+·22**	+·01	—	**−·33**	**−·36**	**−·23**	—	+·06	—	**+·25**
B. 1866–1905	−·06	+·04	−·06	—	—	**−·25**	—	—	+·05	—	+·14
Paris—											
A. 1900–20	+·11	−·13	−·02	—	**−·21**	**−·24**	−·11	—	−·04	—	−·04
B. 1874–1905	—	−·03	−·09	—	—	**−·55**	—	—	−·03	—	**+·33**
Berlin—											
A. 1900–23	+·15	−·01	+·06	—	−·14	**−·21**	−·03	—	−·07	—	−·14
B. 1874–1905	−·03	−·07	−·06	—	—	**−·42**	—	—	−·02	—	**+·25**
Ponta Delgada—											
A. 1900–25	+·32	+·10	+·02	—	**+·29**	**+·36**	**+·42**	**+·34**	**+·50**	**+·25**	+·09
B. 1865–1905	+·27	+·15	−·12	—	—	**−·20**	—	—	+·09	—	−·02

The following additional coefficients were calculated between bergs (U.S. Ice Patrol) and pressure:—

Jacobshavn, Sept.-Nov. of the same year −·12; Thorshavn, June-Aug. of following year +·**20**; Ponta Delgada, May-July, June-Aug. of same year, +·22, +·18.

[18] Washington, Treasury Dept., *United States Coast Guard. Bulletin* No. 15. International ice observation and ice patrol service in the North Atlantic Ocean, 1926. Washington, 1927.

[19] *Meteor. Zs., Wien*, 22, 1905, p. 405.

[20] *London, Meteorological Office, Geophysical Memoirs*, Nos. 1 and 10.

holm 6 to 12 months later and at Ponta Delgada 9 to 12 months later, which are not confirmed by Meinardus' figures, must be regarded as accidental and due to the shortness of the period. The results are discussed more fully in § 30.

§ 27—Pressure Difference, Sydney minus Ivigtut

The pressure gradient between Nova Scotia and Greenland determines the direction and strength of the winds blowing down from Baffin Bay along the coast of Labrador. The work of E. H. Smith (*see* § 6) has shown that this is the main factor which influences the amount of ice off Newfoundland. The pressure differences between Sydney (Nova Scotia) and Ivigtut (Greenland) were calculated according to Smith's earlier[21] formula :

(4 × December + 3 × January + 2 × February + 2 × March.)

Sydney being used in place of Belle Isle as the records for the former station were more complete. The results are given in Table XXVIII and Fig. 16, and are discussed in § 30.

Table XXVIII—Correlation Coefficients, Sydney minus Ivigtut Pressure Gradient (Smith's Formula) and subsequent Pressure (1880–1918)

Lag in Months	3	6	9	12	15	18
Months	April to June	July to Sept.	Oct. to Dec.	Jan. to Mar.	April to June	July to Sept.
Stykkisholm	−**·31**	+·05	+·08	+·01	−·09	+·01
Vardo	+·09	+·14	−·03	+**·29**	−**·22**	+·08
Valentia	−**·23**	+**·23**	+·06	−**·22**	−·03	+·17
Berlin	−**·27**	+·06	−·13	−**·34**	+·03	+**·36**
Ponta Delgada	+**·33**	+·08	−·06	−·06	+·07	−**·38**

§ 28—Pressure Difference Bergen minus Stykkisholm

E. H. Smith found a correlation of +·60 between the pressure difference, Bergen minus Stykkisholm, in October to January (December being given double weight) and the number of bergs off Newfoundland in the following spring. This pressure difference was accordingly correlated with the pressure at the selected stations for January to March, April to June and so on. The results are given in Table XXIX and Fig. 16 and are discussed in the § 30.

Table XXIX—Correlation Coefficients, Bergen minus Stykkisholm Pressure Gradient (Smith's Formula) and Pressure

Lag in Months	0	3	6	9	12	15	18
Months	Jan. to Mar.	April to June	July to Sept.	Oct. to Dec.	Jan. to Mar.	April to June	July to Sept.
Stykkisholm, 1869–1924	−·38	−·11	−**·20**	+·01	−·01	−·06	−·12
Vardo, 1874–1924	−·25	+·18	−·04	+·07	+**·31**	+·06	+**·25**
Valentia, 1869–1924	+·08	−·18	+·14	−·06	−·09	−·10	+·12
Berlin, 1873–1923	+·12	−·14	+·01	−·12	−**·29**	−·18	+·09
Ponta Delgada, 1869–1924	+·33	+·18	+**·21**	−·01	−·07	−·04	−·03

§ 29—Temperature at Hebron

A further check was sought by making use of mean temperatures at Hebron on the coast of Labrador, it being supposed that this temperature would be low

21 In *U.S. Coast Guard Bulletin* No. 15 the formula employed is 2 × December + 2 × January + February + March.

when there was much ice in the Labrador Current. It was only possible to make use of the thirteen years 1901–13, and in order to find the months whose temperatures best represented the ice conditions during April to June, the latter were correlated successively with the mean temperatures of February to April, March to May and so on, with the following results :—

Correlation of Newfoundland Icebergs (April to June) with Temperature at Hebron ;

Feb.–Apr.	March–May	Apr.–June	May–July	June–Aug.	July–Sept.
−·33	−·36	−·50	−·50	−·65	−·25

The period is too short for correlation coefficients of temperature with subsequent pressures to have much value, but a few coefficients were calculated between temperature in June to August and subsequent pressure and it is interesting to note that the relationships in Fig. 16 which seem to have the greatest steadiness—those with pressure at Vardo, Valentia and Berlin in the following January to March—are supported also by the Hebron temperatures, the figures being :—

January–March	Vardo	Valentia	Berlin
Mean Values from Fig. 16	+ **·30** ..	− **·20** ..	− **·31**
Hebron temp. (reversed)	+ **·25** ..	− **·23** ..	− ·16

TABLE XXX—WEIGHTED MEAN VALUES OF CORRELATION COEFFICIENTS BETWEEN ICE OFF NEWFOUNDLAND (APRIL TO JUNE) AND PRESSURE

	Apr.–June	July–Sept.	Oct.–Dec.	Jan.–Mar.	Apr.–June	July–Sept.
Stykkisholm	−·23	−·04	−·02	−·06	−·09	−·02
Vardo	+·05	+·05	·00	+**·30**	−·11	+**·21**
Valentia	−·12	+·17	−·01	−**·20**	−·03	+·16
Berlin	−·11	+·01	−·08	−**·31**	−·08	+·16
Ponta Delgada	+·26	+·15	−·03	−·01	+·11	−·10
Jacobshavn	—	—	—	−·09	—	—
Thorshavn	—	—	—	−·19	—	—
Bergen	—	—	—	−·14	—	—
Paris	—	—	—	−·12	—	—

§ 30—SUMMARY

The results of the various measures which have been adopted of the amount of ice off Newfoundland are combined in one diagram in Fig. 16. Mean values were obtained by weighting the various coefficients according to the number of years employed in their calculation, but only half weight was assigned to those obtained from Meinardus' values, their reliability being probably less than that of the other measures. These mean values are shown in Table XXX, and by the dotted lines in Fig. 16. The reliability of the different results is indicated to some extent by the "scatter" of the lines. Only three groups of figures seem to have any significance :—

(1) Much ice in April to June tends to be associated with low pressure in the same months at Stykkisholm and high pressure at Ponta Delgada, the average coefficients being −·23 and +·26, respectively.

(2) Much ice in April to June tends to be followed in the succeeding January to March by high pressure at Vardo (average coefficient +·30) and low pressure at Valentia (−·20) and Berlin (−·31).

(3) Much ice in April to June tends to be followed 15 months later (July to September of the succeeding year) by high pressure at Vardo and Valentia (average coefficients +·21 and +·16).

The distribution of the correlation coefficients between Newfoundland ice and pressure in the following January to March is remarkably similar to the distribution of the coefficients between Arctic or Greenland Sea ice and pressure in the following November to January (*see* Figs. 9, 10, 12, 13). The coefficients were accordingly calculated for the remaining four stations ; the results are shown in Table XXX and the isocorrelates of the average values, weighted as in Table XXX, in Fig. 17. The explanation of the effect is probably the same as that which was put forward tentatively in § 20, but the cause of the retardation by two months compared with Arctic ice is not clear. We are also unable to offer any explanation of the positive correlations at Vardo and Valentia in the following August.

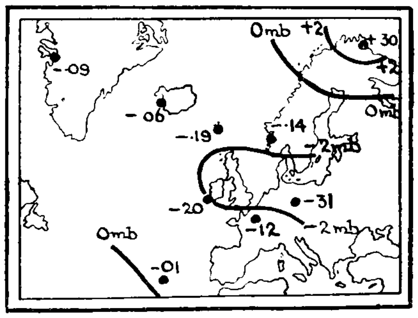


FIG. 17.—CORRELATION COEFFICIENTS, ICE OFF NEWFOUNDLAND (APRIL TO JUNE) AND PRESSURE (JANUARY TO MARCH, FOLLOWING).

At Valentia there are indications of an annual variation similar to that found with Arctic ice (Table XXIV); this, if real—and it is shown by all four of the individual curves in Fig. 16—may originate in the persistence of ice conditions from one year to the next in Baffin Bay.

§ 31—FORECASTING

The three relations set out in § 30 appear to have some small value for forecasting purposes.

(1) Pressure at Stykkisholm and Ponta Delgada in April to June. Since this is contemporaneous with the Newfoundland bergs the latter cannot be employed as a basis, but the relationships between bergs and preceding pressure differences Sydney minus Ivigtut and Bergen minus Stykkisholm may be so used.

If Y = pressure difference in mb. between Sydney and Ivigtut calculated from the expression $(4 \times \text{Dec.} + 3 \times \text{Jan.} + 2 \times \text{Feb.} + 2 \times \text{March})/11$.

Z = pressure difference in mb. between Bergen and Stykkisholm from the expression $(\text{Oct.} + \text{Nov.} + 2 \times \text{Dec.} + \text{Jan.})/5$.

P_1 = mean pressure of April to June in mb.

Then : P_1 (Stykkisholm) $= 1014{\cdot}2 - {\cdot}17Y - {\cdot}05Z$.

P_1 (Ponta Delgada) $= 1020{\cdot}0 + {\cdot}10Y + {\cdot}05Z$.

(2) In calculating pressures for the following January to March the number of bergs off Newfoundland can also be included. Owing to the shortness of the period for which data of bergs were available, it was not satisfactory to calculate regression equations from the partial correlation coefficients in the ordinary way, and the following equations have been calculated on the assumption that the weighted average coefficients of Table XXX represented the relationships between subsequent pressure and each of the separate elements X, Y and Z, where Y and Z have the significance given above and

X = number of bergs off Newfoundland in April to June.

P_2 = mean pressure of January to March in mb.

P_2 (Jacobshavn) $= 1008{\cdot}6 - {\cdot}002\,X - {\cdot}08\,Y - {\cdot}07\,Z$

P_2 (Stykkisholm) $= 1003{\cdot}2 - {\cdot}002\,X - {\cdot}07\,Y - {\cdot}06\,Z$

P_2 (Thorshavn) $= 1011{\cdot}7 - {\cdot}005\,X - {\cdot}24\,Y \quad {\cdot}21\,Z$

P_2 (Vardo) $= 998{\cdot}9 + {\cdot}005\,X + {\cdot}24\,Y + {\cdot}22\,Z$

P_2 (Bergen) $= 1012{\cdot}9 - {\cdot}002\,X - {\cdot}08\,Y - {\cdot}07\,Z$

P_2 (Valentia) $= 1019{\cdot}3 - {\cdot}004\,X - {\cdot}18\,Y - {\cdot}16\,Z$

P_2 (Paris) $= 1019{\cdot}7 - {\cdot}002\,X - {\cdot}09\,Y - {\cdot}08\,Z$

P_2 (Berlin) $= 1021{\cdot}3 - {\cdot}004\,X - {\cdot}20\,Y - {\cdot}18\,Z$

P_2 (Ponta Delgada) $= 1021{\cdot}3 \quad - {\cdot}01\,Y - {\cdot}01\,Z$

(3) The pressures (P_3) at Vardo and Valentia in July to September, 15 months after the ice conditions were calculated in the same way :—

P_3 (Vardo) $= 1008{\cdot}1 + {\cdot}002\ X + {\cdot}09\ Y + {\cdot}08\ Z$

P_3 (Valentia) $= 1013{\cdot}5 + {\cdot}001\ X + {\cdot}06\ Y + {\cdot}05\ Z$

§ 32—Earlier Work on Pressure Difference Sydney minus Ivigtut

Reference may be made here to some correlation coefficients between the pressure difference Sydney minus Ivigtut and subsequent pressure which were calculated several years ago but have not hitherto been published. The pressure differences for the quarters January to March, April to June, July to September and October to December were correlated with the pressures three months later. The results are shown in Table XXXI. The coefficients with the pressure difference during the quarter January to March agree with those in Table XXVIII, but the figures for the remaining quarters are generally smaller and often of opposite sign. In order to discover the limits of this winter effect, the monthly values of pressure difference Sydney minus Ivigtut were correlated with the monthly pressures three months later. The results are shown in Table XXXII and Fig. 18 ; in the latter the full lines represent the

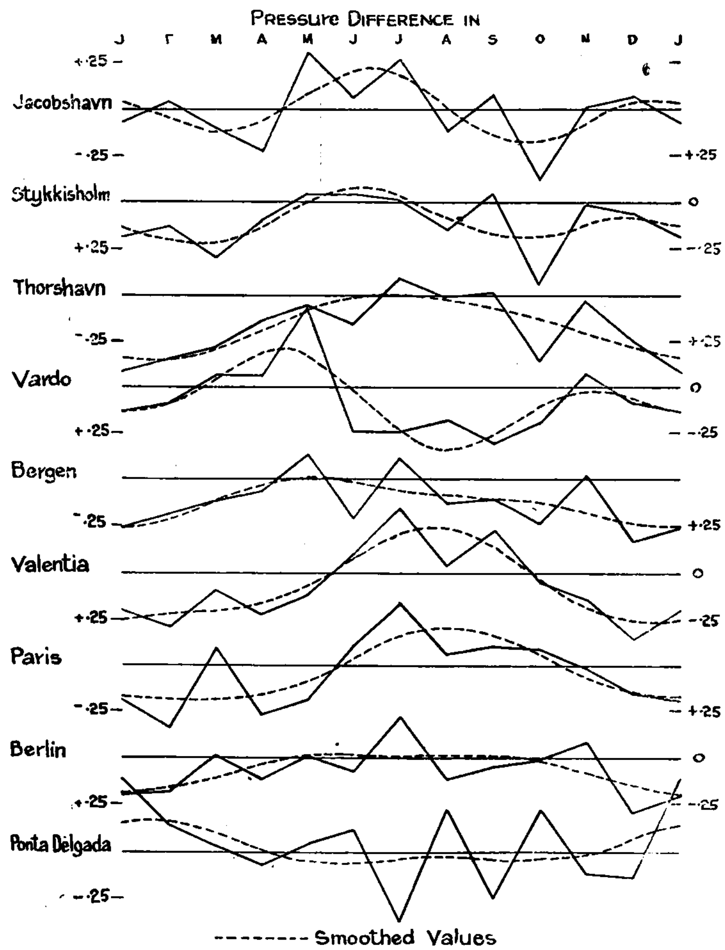


Fig. 18.—Correlation coefficients, pressure difference Sydney minus Ivigtut with pressure three months later.

actual coefficients and the broken curved lines the values smoothed by the first two terms of a Fourier series. The curves indicate that the effect lasts practically from November to April ; the correlation is negative at Stykkisholm, Thorshavn, Bergen, Paris and Berlin, and positive, but small, at Ponta Delgada. At Vardo the distribution of the coefficients is peculiar. The annual variation at Thorshavn and Valentia at least appears to be real.

TABLE XXXI—CORRELATION COEFFICIENTS, PRESSURE DIFFERENCE SYDNEY MINUS IVIGTUT (QUARTERLY) AND PRESSURE THREE MONTHS LATER

	Sydney Ivigtut pressure difference (1891-1915.)			
	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.
Jacobshavn	**−·35**	+·01	+·07	+·07
Stykkisholm	**−·35**	−·15	−·04	+·02
Thorshavn	**−·38**	+·08	−·04	−·12
Vardo	−·05	**+·29**	**−·28**	+·05
Bergen	**−·31**	**+·43**	+·07	−·16
Valentia	**−·26**	−·14	**+·27**	**−·35**
Paris	**−·24**	**+·20**	**+·22**	**−·26**
Berlin	**−·34**	**+·36**	+·11	−·16
Ponta Delgada	**+·43**	−·15	−·17	**−·23**

TABLE XXXII—CORRELATION COEFFICIENTS, PRESSURE DIFFERENCE SYDNEY MINUS IVIGTUT (MONTHLY) AND PRESSURE THREE MONTHS LATER

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Jacobshavn	−·06	+·04	−·10	**−·22**	**+·30**	+·06	**+·26**	−·11	+·07	**−·37**	+·02	+·07
Stykkisholm ..	−·19	−·13	**−·30**	−·10	+·04	+·04	+·02	−·15	+·04	**−·45**	−·01	−·07
Thorshavn	**−·42**	**−·35**	**−·28**	−·14	−·05	−·15	+·09	−·01	+·01	**−·36**	−·03	**−·25**
Vardo	−·13	−·09	+·06	+·06	**+·44**	**−·25**	**−·25**	−·18	**−·31**	**−·20**	+·07	−·09
Bergen	**−·27**	−·19	−·12	−·07	+·13	**−·21**	+·11	−·13	−·11	**−·25**	+·01	**−·34**
Valentia	**−·20**	**−·28**	−·09	**−·22**	−·12	+·09	**+·34**	+·03	**+·22**	−·05	−·14	**−·35**
Paris	−·19	**−·34**	+·09	**−·27**	−·19	+·10	**+·33**	+·06	+·11	+·09	−·01	−·16
Berlin	**−·20**	−·18	+·01	−·11	+·01	−·07	**+·22**	−·11	−·05	−·01	+·08	**−·29**
Ponta Delgada ..	**+·39**	+·14	+·03	−·07	+·04	+·12	**−·38**	**+·22**	**−·25**	**+·22**	−·12	−·13

§ 33—CONCLUSIONS

The general result of this investigation of the effect of ice conditions on subsequent pressure in the eastern North Atlantic and western Europe is that Arctic ice is an appreciable factor in the weather of the British Isles. Much ice in the spring and summer tends to be associated with high pressure in the same months at the north-western stations Jacobshavn, Stykkisholm and Thorshavn, and with low pressure at the southern stations Paris and Ponta Delgada, the relationships being shown by well-supported correlation coefficients which range up to 0·5. Again, much ice in spring or summer tends to be followed in November to January by low pressure over the British Isles, this relation being very definite and regular whatever index of Arctic ice conditions is employed. The ice conditions in various parts of the Arctic have been combined into a series of "ice index" figures, which have the following well-supported correlation coefficients with pressure in the following November to January—Ponta Delgada −·35, Stykkisholm +·27, Ponta Delgada minus Stykkisholm, −·37. These relationships appear to recur in the following two years, thus giving rise to a rather regular annual variation of the correlation coefficients. At Stykkisholm and Valentia the effect of Arctic ice on the pressure appears to outweigh the effect of the warm Gulf Stream very considerably, but at Ponta Delgada the latter is the more important factor. The effect of the ice off Newfoundland on pressure over western Europe is generally similar to that of Arctic ice, but is much less pronounced.

Printed under the Authority of His Majesty's Stationery Office,
By JAS. TRUSCOTT & SON, Ltd., Suffolk Lane, E.C. 4.