He remarks upon the significance of the close agreement between this equation and one found by the reviewer to apply to Washington, namely.

$$Q_S = Q_O(0.22 + 0.78\ S)$$

With his equation Ångström computed monthly totals for the period January, 1905–June, 1922. The annual radiation curves thus computed agree well with the curve based upon observed values. He points out, however, that the probable error of monthly totals thus computed, and especially for winter months, is large, but is small for annual totals. Annual totals thus computed have therefore been employed to show variations in the annual radiation receipt over the period 1905–1926.

From the measured monthly totals of solar radiation and computations by Westman of the total radiation received on a horizontal surface directly from the sun, Ångström has computed the percentage of the total radiation that is included in the diffuse radiation. For the year he finds it to average 30 per cent, but in different months it varies from 87 per cent in December to 19 per cent in July. For clear-sky conditions, for the year the percentage is 12.5; for December, 46; for July, 1.1; and for June 2.7 per cent. These percentages appear to be entirely too low. (See MONTHLY WEATHER REVIEW, October, 1924, 52:475, Table 1.)

The author shows that the annual variation in the total radiation receipt may be expressed by a Fourier series. He develops the series for nine stations at which records of the total radiation receipt were available to him. They vary in latitude from Stockholm, 59° 21′ N. to Lourenco Marques, 25° 58′ S.; and in altitude from 37 meters for South Kensington, England, to 1,600 meters for Davos, Switzerland. The term representing the average monthly value for the year varies from about 5,700 at South Kensington to over 12,000 at Lourenco Marques and Davos. The first periodic or average annual term varies from about 2,800 at Lourenco Marques to 7,100 at Davos, and the second periodic or semiannual term varies from 375 at Toronto to 1,360 at Davos. The maximum monthly value occurs at about the time of the summer solstice at all stations in the Northern Hemisphere, and shortly before our winter solstice in the Southern Hemisphere.

Under "Concluding Remarks" the author refers to the significance of marked departures from the normal in individual records, and suggests the following problems as of special interest:

1. Influence of different forms of clouds on the radiation exchange. Studies of the regular and diffuse reflection from clouds. Influence of clouds on different rays.
2. The records of the diffused radiation from perfectly overcast skies give possibility to follow the variations in the density and mass of clouds. A study of the relation to the synoptic situation seems desirable.
3. A study of the relation between the rapid fluctuations in radiation caused by cumulus clouds and the variations in temperature resulting herefrom.
4. Structure of clouds in the neighborhood of lines of discontinuity.
5. Studies of the diffused radiation from overcast skies for various wave lengths at the moment when rain begins to fall.

We have to thank Doctor Ångström for pointing the way in which radiation studies may be directed. As he truly states, cooperation on the part of many workers will be necessary for the complete solution of some of the problems presented. International commissions are already in existence to facilitate such cooperation.

C. E. P. BROOKS AND W. QUENNEL ON THE INFLUENCE OF ARCTIC ICE ON THE SUBSEQUENT DISTRIBUTION OF PRESSURE OVER THE EASTERN NORTH ATLANTIC AND WESTERN EUROPE [1]

551.467 (98): 551.54 (4) (261.2)

By ALFRED J. HENRY

[Weather Bureau, Washington]

In a previous publication an attempt was made (2) 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 later changes in the pressure distribution of the eastern North Atlantic. Some definite though small effects were noted; since, however, the Gulf Stream is not the only oceanic factor that may be expected to influence the weather of the British Isles, it seemed desirable to investigate the effects which reasonably may be attributed to variations in the temperature and ice distribution in the Arctic Ocean, the Greenland Sea, and the neighborhood of Newfoundland.

Figure 1 shows the area considered, the meteorological stations whose records were utilized and a sketch of the ocean currents.

Ice appears to be formed chiefly in two parts of the north Polar Basin, viz, the area of open ocean north of Asia and the channels among the islands of the American Arctic Archipelago; the inland ice sheet of Greenland also is an important auxiliary source.

The first step in the investigation is a discussion of the tracks and average speeds of the ocean currents which carry the ice from one part in the basin to another and eventually into lower latitudes.

It has been pointed out by Wiese (3) that 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."

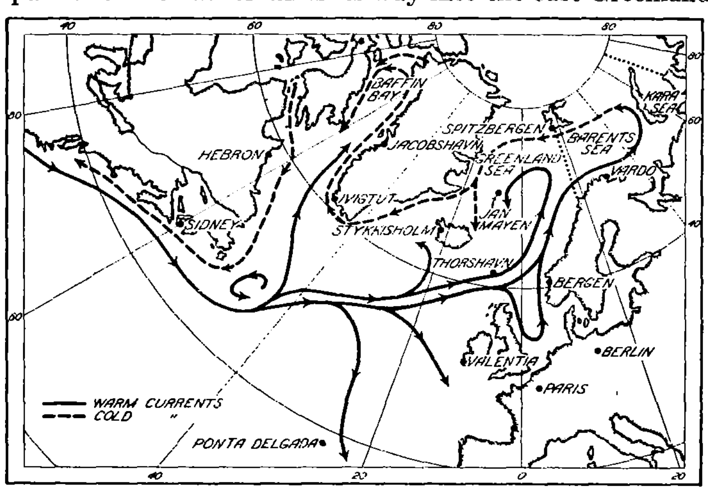

FIGURE 1.—North Atlantic and Arctic showing divisions, stations, and ocean currents

[1] Air Ministry, Meteorological Office, Geophysical Memoir No. 41 (first number of Vol. V), by C. E. P. Brooks, D. Sc., and Winifred Quennel, London, 1928. Pressure distribution over the Greenland-Iceland region is at times an important factor in determining the course followed and speed of movement of cyclones that reach northeast United States and Canada. For that reason the memoir here under review is especially welcome.—ED.

From the "factory" the ice drifts westward passing mainly south of Spitzbergen, where a great deal of ice formation goes on among the islands and continues towards the east coast of Greenland. The distance is about 2,000 miles and at the average rate of 1.2 miles per day (based on a barrel drift from Point Barrow to the north coast of Iceland) the journey would take just over four and one-half years. Wiese regards the temperature of the autumn, months of September to November, at Obdorsk and Touroukhansk in northern Siberia as the best available criterion of the ice-forming activity in the "factory" (a low temperature giving much ice and a high temperature little ice) and he finds that the correlation coefficient between the mean of the autumn temperatures at those places (1877–1910) and the ice-covered area in the Greenland Sea four and one-half years later has the high value of -0.83 ± 0.05 which he regards as confirmation of the theory. Sir Gilbert Walker has informed the authors, 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 connection found by Wiese may be dependent upon the remarkable periodicity of four and three-fourths years in the Greenland Sea and Iceland conditions to be referred to later.

THE LABRADOR CURRENT

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 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 to the westward and then southward along 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.

THE RATE OF ICE DRIFT

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

TABLE 1.—*Speeds and times of Arctic circulation*

Current	From—	To—	Distance (nautical miles)	Mean velocity (miles per day)	Mean time (months)
Arctic Ocean drift	75° N., 75° W	75° N., 0°	2,000	1.2	55
Greenland current	75° N., 0°	69° N., 53° W	2,150	7.5	10
Labrador current	69° N	47° N., 55° W	1,600	12	4
Gulf Stream drift	47° N., 55° W	60° N., 5° W	1,800	12	5

The distances and velocities as given above are, of course, only the roughest 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 to be propogated along the currents and thus affect the conditions in other parts.

THE PALÆOCRYSTIC ICE

The areas for which ice data are available—Greenland Sea, Barents Sea, and Kara Sea—(see fig. 1), include only the fringe of the great ice area of the Arctic Ocean, which persists from one year to another and has been termed palæocrystic ice. The fringe is important in 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 cocean between Greenland and Scandinavia, but the main ice mass would be expected to play a greater part in causing variations in the general atmospheric circulation of the globe. Unfortunately there are no measurements of the whole ice-covered area, but results obtained by other authors show that even indirect measures may have considerable significance. The authors conclude that 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 Paleochrystic Ice. (See Table 2 (original Table XXIII).)

THE GREENLAND SEA AND ICELAND REGION

The effect of variations in the ice conditions in the Greenland Sea and off Iceland has been studied by W. Wiese (**4**), W. Brennecke (**5**), and W. Meinardus (**7**). Wiese found that years with heavy ice in the Greenland Sea in spring and summer (April–July) were characterized in autumn (September to November) by a higher pressure in the neighborhood of Iceland, Greenland, and the White Sea, and a lower pressure over the British Isles. This distribution is associated with a southerly movement of the tracks of depressions. Brennicke 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 in Iceland was given by a study of the deviation of pressure from normal at Stykkisholm, during the presence of ice, days with the presence of ice off Iceland, had pressure that averaged 6.7 mb. above the mean pressure for the corresponding months (**6**). Meinardus, also investigated the variations of ice in the neighborhood of Iceland. He pointed out that there was a very clearly marked periodicity of four and one-half years; a further investigation shows that this period is more nearly four and three-fourths years (**8**).

In the second part of his work Meinardus investigates the cause 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 clear 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. 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. C. E. P. Brooks investigated the 4¾-year periodicity in Iceland ice but without significant results.

SUMMARY OF PART I

The preceding discussion has shown 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 areas 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.

PART II. THE EFFECT OF ARCTIC ICE

In this part of the memoir the effect of the variates named below is investigated by means of correlation coefficients. The variates are as follows:

(*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 Barents Sea.
(*g*) The area of ice in Kara Sea.
(*h*) The temperature of Obdorsk and Touroukhansk in September to November.
(*k*) Pressure and temperature at Spitsbergen.

The correlation coefficients among the variates given above are set forth in a series of tables, Nos. II to XIX, and these are followed by a consideration of partial correlation coefficients as indicated in section 21 as follows:

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, viz, 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 centers—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 crude correlation coefficients between the different ice data are shown in the table below:

Ice	Greenland Sea	Barents Sea	Kara Sea
Iceland	+0.43	+0.32	+0.25
Greenland Sea		+.20	+.32
Barents Sea			+.28

The discussion in sections 22 and 23 is reproduced verbatim.

THE ANNUAL VARIATION OF THE EFFECTS OF ARCTIC ICE

In sections 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:

(1) 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.

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

(3) 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 toward 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 section 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 (3) 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 (1) 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 (2) 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 (1) and (2) 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, (3) 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 overlying 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 (1) and (2) on the one hand and factor (3) 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 palæocrystic ice which persists 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 palæocrystic 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 +0.57; hence we should expect the correlation between the first and third years to be $(0.57)^2$ or 0.32, and between the first and fourth years $(0.57)^3$ or 0.19. Actually we find between the first and third years +0.22 and between the first and fourth years −0.01, the differences from +0.32 and +0.19 indicating some systematic variation of the order of 8 to 12 years, which we identify as a variation with the sun-spot cycle (there is a correlation of −0.51 between Barents Sea ice and the sun spot 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 centers reach their maximum 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.

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 2 (ORIGINAL 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					

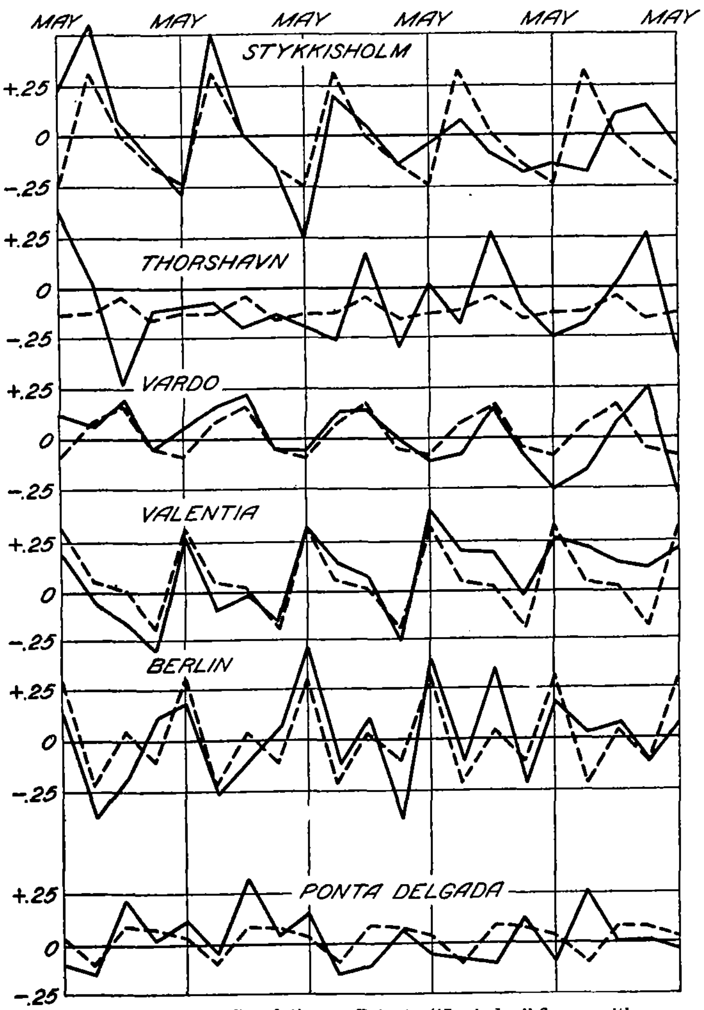

FIGURE 2 (14 in original).—Correlation coefficients, "Ice index" figures with pressure in succeeding years. Broken lines represent the average coefficients for the first four years.

For convenience of workers wishing to utilize 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 +0.66, appreciably higher than that for the Barents Sea ice alone.

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 Figure 2. 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.

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 northwestern 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.

LITERATURE CITED

(1) BROOKS, C. E. P., and QUENNEL, WINIFRED.
1928. Geophysical Memoir No. 41.

(2) C. E. P. BROOKS, D. Sc.
1926. Geophysical Memoirs No. 34. The effect of fluctuations of the Gulf Stream on the distribution of pressure over the eastern North Atlantic and western Europe.

(3) WEISE, W.
1922. Die Einwirkung des Polareises im Grönlandischen Meere auf die Nordatlantische zyclonal Tätigkeit. Ann. Hydrogr. Berlin 50: 271.

(4) WEISE, W.
1924. Polareis und atmosphärische Schwankungen. Stockholm Geog. Ann. 6: 273.

(5) BRENNECKE, W.
1923. Beziehungen zwischen der Luftdruckverteilung und den Eisverhältnisse des Ostgrönlandischen Meeres. Ann. Hydrogr. Berlin 32: 186.

(6) BROOKS, C. E. P.
1923. Weather influences in the British Isles. London Nature 112: 386.

(7) MEINARDUS, W.
1906. Periodische Schwankungen der Eistrift bei Island. Ann. Hydrogr. Berlin 34: 148.

(8) BROOKS, C. E. P., and J. GLASSPOOLE.
1922. The drought in 1921. London Q. J. R. Met. Soc. 48: 139.

[17] See: Walker, Sir Gilbert, and E. W. Bliss "On Correlation Coefficients, their Calculation and Use." London, Q. J. R. Meteor. Soc., 52, 926, p. 73.