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AND
THE DISTRIBUTION OF PRESSURE
OVER
WESTERN EUROPE

BY

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SUNSPOTS AND THE DISTRIBUTION OF PRESSURE OVER WESTERN EUROPE

By C. E. P. Brooks, D.Sc.

The following paper gives the results of an investigation into the relations between the position of any month, quarter or year in the eleven-year sunspot cycle and the distribution of pressure over western Europe and the eastern North Atlantic. Two aspects of the question were considered :—

(1) whether there is any relation between the position of a month in the sunspot cycle and the type of pressure distribution over the area as a whole ;

(2) whether there is any relation between the position of a quarter or year in the sunspot cycle and the actual pressure at certain individual stations.

1. The sequence of pressure types during the sunspot cycle.— The first inquiry is concerned not so much with the actual numerical values of the pressures as with the positions of the areas with highest and lowest pressure relative to normal, i.e. the " type " of pressure distribution. For this purpose the classified list of monthly charts of pressure anomaly* was employed, the classification being extended to include 1921. The position of years in the sunspot cycle was based on the scheme given in Table I ; actually only the 40 years, 1873 to 1900 and 1910 to 1921, were employed in this instance, but the full table is given here as it will be required for reference later.

The frequencies of different pressure types are shown in Table II. For full descriptions of the types reference must be made to the original work, but the following summary gives the salient points : Group I (IA, IB, etc.) includes all charts with pressure above normal at Thorshavn, in the Faroe Islands, Group II all those with pressure below normal at Thorshavn. The centres of maximum deviation, positive in Group I, negative in Group II, are :—A, Scandinavia ; B, Western Europe ; C, British Isles ; D, Iceland ; E, Arctic. The figures given in italics are the expectations on the assumption that the numbers of each type are distributed at random through the sunspot cycle. It will be seen that the numbers actually found agree closely enough with this random distribution, and do not suggest any systematic variation of pressure type through the sunspot cycle. The only cases which may possibly be exceptions are ID and IID ; one to three years after spot minimum the frequency of ID exceeds expectation by 4, or 33 per cent, that of IID falls short of expectation by 4, or 31 per cent, while two to four years after spot

* *London, Meteorological Office, Geophysical Memoirs, No.* 31. Classification of Monthly Charts of Pressure Anomaly, 1926.

maximum this distribution is reversed, ID falling short of expectation by 22 per cent and IID exceeding expectation by 52 per cent.

TABLE I.—POSITION OF YEARS IN THE SUNSPOT CYCLE.

Minimum.				Rising.		Maximum.			Falling.			
	1843	*1844*		1845	1846	1847	**1848**	1849	1850	1851	1852	1853
	1854	1855	*1856*	1857	1858	1859	**1860**	1861	1862	1863	1864	
	1865	1866	*1867*	1868	1869	**1870**	1871	1872	1873	1874	1875	
1876	1877	*1878*	1879	1880	1881	1882	**1883**	1884	1885	1886	1887	
	1888	*1889*	1890	1891	1892	**1893**	1894		1895	1896	1897	1898
1899	1900	*1901*	1902	1903	1904	**1905**	1906	1907	1908	1909	1910	
1911	1912	*1913*	1914	1915	1916	**1917**	1918		1919	1920	1921	
	1922	*1923*	1924	1925	1926							

Years of spot min., italics ; years of spot max., heavy type.

TABLE II.—FREQUENCIES (F) OF VARIOUS TYPES OF PRESSURE DISTRIBUTION, COMPARED WITH EXPECTATION (E).

		IA	IB	IC	ID	IE	IIA	IIB	IIC	IID	IIE
Spot min. 13 years	F	12	15	19	24	4	18	16	15	26	7
	E	*14*	*10*	*21*	*25*	*5*	*17*	*10*	*16*	*28*	*8*
Rising 6 years ..	F	9	3	7	16	3	6	7	7	9	5
	E	*7*	*5*	*10*	*12*	*3*	*8*	*5*	*7*	*13*	*4*
Spot max. 7 years	F	8	3	7	17	5	11	1	8	18	6
	E	*8*	*5*	*11*	*14*	*3*	*9*	*6*	*9*	*15*	*5*
Falling 14 years	F	15	9	32	21	5	18	8	20	32	8
	E	*15*	*11*	*23*	*27*	*6*	*19*	*11*	*17*	*21*	*9*

This means that when sunspots are increasing in number pressure tends to be high over Iceland, while when sunspots are decreasing pressure tends to be low over Iceland. The odds against the distribution in Table II arising by chance are, however, only seven to one, so that this result is of little significance. A second count was made weighting the different months according to the numerical value of the maximum pressure deviation, but this gave no additional information.

2. Deviations of Pressure from Normal during the Sunspot cycle.—The second aspect of the problem was investigated by tabulating the actual deviations of pressure from normal over as long a period as possible.

Results for four stations are given in Table III, the periods employed being :—Stykkisholm 1846–1926, Berlin 1848–1923, Valentia 1866–1926, Ponta Delgada 1865–1926.

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TABLE III.—DEVIATIONS OF PRESSURE FROM NORMAL IN DIFFERENT PARTS OF THE SUNSPOT CYCLE, AND CORRESPONDING STANDARD ERRORS (S.E.).

	Number of Years	Jan.–March		April–June		July–Sept.		Oct.–Dec.		Year	
		Dev. mb.	S.E. mb.	Dev. mb.	S.E. mb.	Dev. mb.	S.E. mb.	Dev. mb.	S.E. mb.	Dev. mb.	S.E. mb.
Stykkisholm—											
Spot minimum	24	+1·92	1·18	−0·31	0·55	+0·12	0·53	−0·16	1·02	+0·39	0·46
Rising	14	−0·54	1·73	+0·45	1·01	+0·15	0·53	+0·08	1·28	+0·03	0·65
Spot maximum	19	−1·57	1·16	−0·85	0·58	+0·05	0·50	+0·11	0·97	−0·14	0·46
Falling	23	−0·39	1·12	−0·65	0·52	−0·21	0·46	+0·04	0·82	−0·30	0·44
Valentia—											
Spot minimum	20	−1·08	0·70	−1·17	0·37	−0·38	0·34	+0·59	0·65	−0·51	0·34
Rising	12	−0·40	1·10	+0·13	0·46	+0·08	0·46	−1·84	1·09	−0·51	0·37
Spot maximum	13	+1·06	1·36	+0·43	0·26	−0·23	0·19	+0·58	1·36	+0·46	0·56
Falling	16	+0·77	1·03	+1·00	0·73	+0·61	0·48	+0·19	0·60	+0·64	0·44
Berlin—											
Spot minimum	23	−1·39	0·52	−0·35	0·36	−0·13	0·33	−0·22	0·58	−0·52	0·19
Rising	12	0·00	1·23	+0·17	0·50	−0·04	0·31	−0·04	1·10	+0·02	0·39
Spot maximum	18	+0·95	0·67	+0·05	0·43	−0·29	0·36	−0·23	0·48	+0·12	0·25
Falling	23	+0·63	0·65	+0·18	0·31	+0·37	0·22	+0·43	0·67	+0·40	0·28
Ponta Delgada—											
Spot minimum	21	−0·67	0·75	+0·27	0·50	+0·19	0·30	+0·01	0·74	−0·05	0·33
Rising	12	−0·07	1·29	−0·15	0·48	−0·42	0·34	−0·80	0·77	−0·36	0·41
Spot maximum	13	+0·22	1·02	−0·24	0·48	+0·15	0·27	+1·76	0·51	+0·47	0·32
Falling	16	+0·74	0·88	−0·02	0·35	−0·06	0·28	−0·84	0·53	−0·05	0·37

A preliminary test showed that little information was to be expected from the use of monthly values, but it seemed possible that a longer interval might give significant results. The work was accordingly repeated using quarterly and annual means. The results are shown in Table III, where against each mean value of pressure is shown the standard error (S.E.) of the figures composing it; this S.E. is obtained from the expression $\sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$ where x_1, x_2 . . . are the deviations in individual years or seasons, $\bar{x}$ the average deviation and n the number of observations. Thus, for Stykkisholm, spot minimum, January to March, $\bar{x} = +1 \cdot 92$mb. and n is 24.

Considering first the sixteen annual means, if there were no relation between pressure and position in the sunspot cycle, we should expect on the theory of probability that the deviations would exceed 0·67 times their standard error on eight occasions, 1·15 times their S.E. on four occasions, and so on. The relations between expectation and observation are as follows :—

TABLE IV.—RELATION OF MEAN ANNUAL PRESSURES AT DIFFERENT PARTS OF THE SUNSPOT CYCLE TO THEIR STANDARD ERRORS

Ratio of Deviation to S.E. greater than	·67	1·15	1·53	1·86	2·15	2·56
Frequency expected	8	4	2	1	½	¼
Frequency observed	10	6	1	1	1	1

It is evident that the ratios of the deviations to their standard errors are not systematically greater than would be expected by chance. There is one outstanding ratio of 2·74 at spot minimum at Berlin, and the odds against chance figures giving a ratio of this amount once in 16 tries are about nine to one, but considering the general run of the figures the results must be held to be without significance.

Considering next the 64 quarterly values, the comparison between expectation and observation is made in Table V.

TABLE V.—RELATION OF MEAN QUARTERLY PRESSURES AT DIFFERENT PARTS OF THE SUNSPOT CYCLE TO THEIR STANDARD ERRORS.

Ratio of deviation to S.E. greater than	·67	1·15	1·53	1·86	2·15	2·56
Frequency expected	32	16	8	4	2	1
Frequency observed	27	16	9	3	3	3

The three highest ratios are 3·45 at spot maximum, October to December, at Ponta Delgada ; 3·17 at spot minimum, April to June, at Valentia ; and 2·67 at spot minimum, January to March, at Berlin. The odds against a ratio of 3·45 occurring once in 64 tries are about 30 to 1, but considering the general run of the figures, the results, like those for the annual means, are probably without significance. It appears, therefore, that at present the variations of sunspots in the eleven-year cycle cannot be taken into account in predicting quarterly mean deviations of pressure in the eastern North Atlantic or western Europe.

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