ART. XVIII.—*Brückner's Klimaschwankungen* ; by
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DR. EDWARD BRÜCKNER, the youthful professor of Physical Geography at the University of Berne, has devoted three years to the gathering together and discussion of data concerning oscillations of climate as shown by direct observations

* Neues Jahrbuch für Mineralogie, Beilage-Band. vii, Heft 2, 1890.

† 1. Th. Hiortdahl, Zeitschr. f. Kryst. xii, 413, 1887.

‡ Neues Jahrbuch, Beilage-Band. vii.

instituted by man. His book,* which contains the results of his investigation, is a real contribution to the steady advancement of our knowledge of the subject, and is not merely the working out of a theory based upon an hypothesis which may be at any time overthrown by new discoveries or new ideas. The amount of work necessary to present the matter in the shape given by Dr. Brückner can be judged only by those who have undertaken researches of the same nature, but, as may confidently be said, of less extent. The sub-topics of the book are :

Chapter I. The present condition of the question. Chapt. II. Oscillations of the Caspian Sea. Chapt. III. The secular oscillations of lakes having no outlet. Chapt. IV. The secular oscillations of rivers and lakes with outlets. Chapt. V. Secular oscillations of rain-fall. Chapt. VI. Secular oscillations of air-pressure. Chapt. VII. Secular oscillations of temperature. Chapt. VIII. Periodicity of oscillations of climate, derived from observations of river ice, dates of the grape harvest, and the frequency of severe winters. Chapt. IX. The significance of oscillations of climate for theoretical and practical purposes. Chapt. X. Oscillations of climate of diluvial times. Review of the results obtained. Graphical presentations.

In the general statement of the work that had been previously done, as given in Chapt. I, we obtain a good idea of the extent of the preliminary work done by the author in preparing for his own investigations. The most important literature is certainly embraced in the several hundred titles referred to, and the very condensed summary of the main results of each (pertaining to the question under discussion) shows a good grasp of the matter. In some cases, however, minor and comparatively unimportant contributions are mentioned with the same degree of deference as that given to very exhaustive pieces of work, and without an actual reference to the works themselves the reader may be misled into giving too much weight to the contradictions of the latter by the former.

In carrying out his own work, Dr. Brückner has given most valuable critical opinions of the materials and studies on which he has based his researches ; and his estimates of their individual worth are the results of painstaking and in most cases time-consuming investigations.

As a final table of the oscillations of the surface of the Caspian Sea, Brückner gives :

* *Klimaschwankungen seit 1700 von Dr. Eduard Brückner*, Penck's *Geographische Abhandlungen*, Band IV, Heft 2, Wien, 1890, (Ed. Hölzel.)

Year.	Amount in Meters.	Year.	Amount in Meters.
915/21.....	+ 8·8	1830	+ ·40
12 century.....	— 4·2	1843/46.....	—0·59 under this.
1306/07.....	+ 11·2	1847	+0·22 higher than this,
1638.....	+ 4·9		falling 1809/14—1845
1715/20.....	about + 0·3	1851/55.....	—0·21 falling 1847—1856/60
1715/43.....	rising	1856/60.....	—0·27 rising 1845—1847
1744/66.....	falling	1861/65.....	—0·19
1767/80.....	rising (?)	1866/70.....	+0·19 rising 1866—1878
1815	+ 2·40 at least	1871/75.....	+0·17
		1876/78.....	+0·54
1730/40 to 1809/14, }			
a relatively high level. }			

There are, consequently, maxima about 1743, between 1780—1809 and 1847—1879; and minima about 1715, 1766, 1845 and 1856—60. Brückner places the average duration of an oscillation at about 34 to 36 years. That these oscillations are due to large sectional climatic influences is very evident. A comparison with the oscillations of rainfall and temperature shows that for the period since 1840, these are accompanied by oscillations in this sea level.

For the region west and north of the Caspian Sea, there occurred wet, cold periods about 1745, 1775, 1810, 1845, 1880; and dry, warmer periods about 1715, 1760, 1795, 1825, 1860. These changes affect the inflowing rivers, which in turn change the level of the sea. A comparison with the table of sea levels shows the increase with cold, wet periods and decrease with the dry, warm periods. There are long periods of oscillations in addition to the short period fluctuations.

An investigation of a number of lakes gave the following results:

(1.) The oscillations of the true river-lakes are small and follow without retardation the river oscillations.

(2.) The oscillations of lakes having no outlet are large, and the epochs show a retardation in relation to the corresponding epochs of the inflowing streams: the maximum height of the lake may occur at the time the receding inflowing streams have reached an average height.

(3.) Lakes having no outlets have a slighter retardation in the case where the inflowing streams have large oscillations than for those where the oscillations are small; and the same is true of lakes with low banks in contrast with those having high banks.

(4.) Small secondary oscillations of the influx in lakes having no outlet are without marked effect when the difference of the inflow and diminution still retains the same sign. The only effect is to accelerate or retard the rise or fall of the water.

(5.) In these particulars the partial river-lakes stand somewhere between the true river-lakes and the lakes without outlet.

A list of the times of maxima and minima before 1800 is given for the Alpine glaciers and seven lakes, and for the present century for the Alpine glaciers and 10 lakes in Europe; Caucasian glaciers and 12 lakes in Asia; 10 lakes in N. America; 2 lakes in S. America; 6 lakes in Africa; and 3 lakes in Australia. As a result of a careful study of these data, Brückner finds that there is no law of retardation of epochs (phases) as regards longitude or latitude; but in general the periods of high and low water occur simultaneously over the whole earth. The period from maximum to maximum, or min. to min. oscillates between 30 and 40 years, with an average of 35.6 years. If we are to judge of the climate by these oscillations of lakes without outlet, we obtain the following little table:

Climate Dry or warm or dry and warm.			Climate Wet or cold or wet and cold.		
Before and about 1720		} min. water.	Before and about 1740		} max. water.
"	1760		"	1780	
"	1800		"	1820	
"	1835		"	1850	
"	1865		"	1880	

A similar table of the times of maxima and minima of water in 13 rivers and 13 river-lakes is as follows:

Minima.	Maxima.
About 1760	About 1740
" 1795	" 1775
" 1831/35	" 1820
" 1861/65	" 1850
	" 1876/80

It is seen that these periods are about the same for all three classes of bodies of water, and a common climatic cause must exist on all continents.

But these are in a measure indirect determinations of the oscillations of those factors which go to make up climate. Direct observations of rain-fall, temperature, etc., have been made for a sufficient length of time to furnish material for closer determination of changes of climate than that just mentioned. We will now summarize these.

Rain-fall.—Brückner has made use of observations at 321 points on the earth's surface, and distributed as follows: Europe 198, Asia 39, North America 50, Central and South America 16, Australia 12, Africa 6. It is seen that most of these are in the northern hemisphere, but only those stations could be used where the observations extended over a suffi-

ciently long period. While for most of the stations the data are for the period 1830–1885, yet for many they extend farther back, at Paris beginning in 1691–95. In dealing with such immense masses of data, it would be too burdensome to use single years, and so the averages for five year periods are used; thus 1691–95 refers to the mean for the years 1691–92–93–94–95. The following table contains the average result of these data since 1830.

PERIODS OF RAIN.					
	Deficiency.	Excess.	Deficiency.	Excess.	Deficiency.
Europe	1831–40	1841–55	1856–70	1871–85	
Asia	1831–40	1841–55	1856–70	1871–85	
Australia . .	—45	1846–55	1856–65	1866–75	1876–85
N. America.	1831–40	1841–55	1856–65(71–75)	1866–70(76–85)	
Cent. and } S. Amer. }	1831–45	1846–60	1861–75	1876–85	
<hr/>					
Taken all } together }	1831–40	1846–55	1861–65	1876–85	

The average amplitude of oscillation expressed in per cent. of the total average amount of rain-fall is as follows: Europe 16 per cent, Asia 30 per cent, Australia 22 per cent, North America 26 per cent, Central and South America 28 per cent; the average for all being 24 per cent. That is in the driest period the rain-fall is only $\frac{3}{4}$ of that in the rainiest. It appears also that this oscillation is true for the whole of the land surface and that a deficiency in one section is not counter-balanced by an excess in another section. What takes place on the water surface of the globe we do not know with certainty, as the rain-fall observations at sea are not suitable for such investigations, but the sea-coast stations probably indicate fairly well the results for the open ocean.

It has been suggested that with a shifting towards the eastward a regular retardation of the time of maximum or minimum exists; but Brückner shows that no such relation exists either with change of longitude or latitude. As regards the amplitude of the oscillation, it can be said that while it does not vary very much for the same place, yet for different regions of the earth's surface it is by no means the same. In fact there is found to be the general law that intensity of the oscillations of rain-fall increases with the continentality of the region. The average ratios of maximum : minimum and the average rain-fall at the maximum and minimum for the period 1830–1880 according to the continental distribution, and also arranged for progressive longitudes are as follows:

	Ratio Max : min.	Average min.	Average max.
East part of England.....	1·18	599mm	744
North Germany	1·23	573	705
S. W. Russia	1·26	447	570
S. E. Russia	1·40	273	384
Ural Mt. Region.....	1·36	350	480
W. Siberia	2·31	149	347
E. Siberia	1·59	355	564
Deccan	1·24	---	---
U. S. America, W. Coast	1·38	379	517
“ “ far western interior	1·42	483	684
“ “ Southern part.....	1·36	---	---
“ “ Eastern interior (Ohio, etc.)..	1·20	890	1059

Thus we see that in West Siberia 2·3 times as much rain falls in the rainy period as in the dry period.

The observations along the east coast of the United States, some of the islands of the Atlantic Ocean, and the Irish coast, show minima at about the time of these maxima at the interior; and if these be taken to represent the Atlantic Ocean rain-fall, then there exists in the case of this ocean a compensatory oscillation of rain-fall, the reverse of the oscillations on the land. We have in reality during long periods, a shifting back and forth of the isohyetal lines (lines of equal rain-fall). The amount of this for various isohyets is shown in the following table; in the first columns for the period from the minimum of 1861-65 to the maximum of 1881-85, and in the second column for the average maximum and minimum.

DISPLACEMENT IN KILOMETERS.

Counting + towards inland.

Isohyetals.	Old World.		N. America.	
	West side.	West side.		
1000 ^{mm}	— 1000	— 600	200	700
900	— 500	— 200	300	500
800	+ 300	100	400	600
700	+ 1500	1000	500	500
600	+ 400	1600	1200	1100
500	+ 600	1000	2000	2000
400		800	vanishes	vanishes
300	vanishes	vanishes		

It has been pointed out before what an important factor this displacement becomes in investigating questions concerning any actual increase of rain-fall. There have been found periods of rain-fall with the following maxima and minima; the former being given in large type and the latter in small type:

1691-1715	1806-25
1716-35	1826-40
1736-55	1841-55
1756-70	1856-70
1771-80	1871-85
1781-1805	

For the present century more exact dates can be assigned to the times of actual maximum and minimum of rain-fall and they are as follows:

1815	1861-65
1831-35	1876-80
1846-50	

From this it would appear probable that we are about to enter upon another period of very low rainfall about 1890-95.

Atmospheric Pressure.—The study of synoptic charts, and the theoretical studies of Ferrel, Guldberg and Mohn and others, have shown us the controlling influence of the distribution of air pressure on climate for short periods and the desirability of a comparative investigation for long periods was unquestioned; but the data for such a work were in such a condition that the chance was exceedingly slight for obtaining any results deserving of notice. Brückner has boldly attacked the problem, however, and has deduced some conclusions which the agreement of so many different series of observations forbid our criticizing as being based on deviations within the possibility of errors for single or a few places of observation. These investigations are based mainly on the matter presented by Hann in his recent great work on the "Air Pressure in Europe," and in fact without this work as a basis, Brückner would have been obliged either to forego this investigation or else to spend a year or so in the critical discussion of his preliminary data. As it is, his results refer mainly to Europe, and cannot be made to include other continents until some one has done for the observations of the air pressure on them what Hann spent two years (and many more in preparation) in doing for Europe.

The oscillations of the air pressure are discussed by Brückner under two heads: those of the annual averages and those of the seasons. The table on the following page shows the lustra deviations of the air pressure in millimeters from the average for 1851-1880, and also the rain-fall in per cents.

We see here that for the North Atlantic Ocean a relation exists the reverse of that in Central Europe.

The following arrangement shows the pressure variations in winter and summer for the dry and wet periods:

Relative Pressure.

	North Atlantic.		W. and Central Europe.		E. Europe and N. Asia.	
	Winter.	Summer.	Winter.	Summer.	Winter.	Summer.
Dry period,	Lower.	Higher.	Higher.	Higher.	Higher.	Lower.
Wet period,	Higher.	Lower.	Lower.	Lower.	Lower.	Higher.

The discussion of these oscillations shows that for the dry period as compared with the rainy period there exists: (1) A

deepening of the constant cyclone which the annual means show for the North Atlantic Ocean; (2) an increase of the high pressure which extends from the Azores to the interior of Russia; (3) a deepening of the low pressure in the northern part of the Indian Ocean and China Sea; (4) a decrease of the high pressure which exists, for the yearly means, over Siberia; (5) a general increase of the amplitude of the annual oscillation, which causes in the dry period in winter a relatively high pressure in Europe and Siberia and a relatively low pressure over the North Atlantic Ocean; and in summer a relatively low pressure in Central and Western Europe and on the North Atlantic Ocean.

	1826-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85
Cent. Europe. { Pressure ...	+ '08	'92	'02	— '29	— '19	— '35	'17	'42	— 02	'10	— '33	'34
Rainfall ...	— 1	— 10	— 1	4	1	4	— 4	— 10	0	0	10	6
N. Atlantic. { Pressure ...				— '08	— '18	'54	'51	— '78	— '12	— '13	'32	— '73
Rainfall ...				1	2	0	0	3	5	2	— 6	— 10
W. Siberia. { Pressure ...				— '23	00	— '09	— '04	— '46	— '49	— '08	'09	'24
Rainfall ...				24	31	1	13	— 34	24	14	54	74
E. Siberia. { Pressure ...				—	'45	— '06	— '04	— '10	— '45	'29	'36	'21
Rainfall ...				26	15	0	— 20	— 10	— 5	9	23	28

Each rainy period is, then, accompanied by a smoothing out of all differences of air pressure, and each dry period by a sharpening of them, not only for annual averages from place to place but also for the seasonal averages at the same place. But it is to the amounts and directions of the gradients of air pressure that we owe the general rain-fall conditions, and it is to these long period oscillations of air pressure that we owe the simultaneous long oscillations of rain-fall. We need, however, a similar comparison for other portions of the globe before these relations can be said to be completely proven to have a general applicability.

Temperature.—The much more intimate temporary relations which exists between air pressure and temperature than be-

tween pressure and rainfall leads us to confidently expect that the long period relations of the former will be more readily recognized than those just found for the latter. For the temperature oscillations Brückner has computed lustra means for many places in 22 extended regions, and he has also made use of Köppen's data for 29 regions. The observations used do not extend much back of the beginning of the present century, except for a very limited number of places, and in nearly all cases they are for the northern hemisphere.

These investigations give the following periods of relative heat and cold:

Köppen.		Brückner.	
Warm	1791-1805	Warm	1791-1805
Cold	1806-1820	Cold	1806-1820
Warm	1821-1835	Warm	1821-1835
Cold	1836-1850	Cold	1836-1850
Warm	1851-1870	Warm	1851-1870
		Cold	1871-1885

Only 5 per cent of the material used by Köppen and 8 per cent of that used by Brückner showed the opposite relation to the ones given; but perhaps 15 per cent gave no definite results the one way or the other. The following table shows the amounts of excess (+) and deficiency (−) of temperature referred to the average temperature as determined by many years of observation.

	1821-25.	1836-40.	1866-70.	1821-25.	1836-40.	1866-70.
Tropics	+·34°	−·37°	(−·10°)	+·20°	−·05°	(−·09°)
Sub-tropics	+·66	−·40	+·10	+·59	−·26	(+·03)
Warm temperate ...	+·49	−·56	+·21	+·37	−·35	+·16
Cold temperate	+·47	−·33	+·20	+·40	−·17	+·14
Cold zone or } sub-Arctic }	+·81	−·20	+·37	+·69	−·23	+·19

In the first half of the table are the actual differences of the lustra averages from the mean; and when these maxima and minima are determined by taking into account the values for the lustra on either side, the amounts are somewhat diminished; these are given in the last half of the table. For the average of the whole earth (so far as observed at the various dates) the times and relative amounts of the maxima and minima are:

1736-40	−·43°	1821-25	+·56°
1746-50	+·45	1836-40	−·39
1766-70	−·42	1851-55	+·11
1791-95	+·46	1866-70	+·11
1811-15	−·46	1881-85	−·08

We see, then, that the amount of change in temperature during the 36 years period of oscillation is about 1° C. or nearly

2° Fahrenheit. For Central Europe this would mean a displacement of isotherms by a distance of 3° latitude, or about 200 miles, during the time of oscillation; and this is no inconsiderable climatic change, for it places the temperature of the lowest period at Riga equal to the coldest at Königsberg.

We have next to consider the climatic oscillations as shown for northern Euro-Asia by the duration of time when the waters (rivers) are free from ice, and the dates of their becoming free from ice in the spring; the secular oscillations of the dates of the grape harvest for Central Europe, and the cold winters of which we have records. The following table gives the deviations, at the times of maxima and minima, in days, from the average for 1816-80, of the lustra periods of the days free from ice, the averages being *smoothed out*; the negative sign denoting the colder periods:

1736-40.....	-9.6	1811-15.....	-8.6
1766-70.....	+4.0	1821-25.....	+4.5
1781-85.....	-3.6	1836-40.....	-5.0
1791-95.....	+0.6	1876-80.....	+3.0

These data refer to the average of the observations in Euro-Asia and for a short period for the Hudson River.

Brückner gives the corrections in days to reduce the dates of breaking up of the ice to the average for 1816-1880 for the separate regions, but does not seem to have been able to unite them in an average. Rykatschew's great memoir on the opening and closing of the rivers of Russia and Siberia serves as the chief basis of this research on the ice conditions. On the average the difference in the number of days free from ice between the cold periods and the warm periods amounted to about 16 days for Siberia, 18 days for Central Russia, 25 to 32 days for W. and S. W. Russia respectively, and 24 days for the Hudson River. The dates for breaking up of winter ice varied about half these amounts for these Euro-Asiatic regions.

The record of the dates of the time of the grape harvest in France, South Germany and Switzerland extends back for several hundred years, and the material has been used to determine the forwardness and backwardness of the seasons which are to a certain extent representative of the character of the year. The data used by Brückner extend back to the year 1496. There are regular oscillations from early to late harvests and these periods obtained from smoothed out data are given in the following table:

Early harvest.	Late harvest.	Early harvest.	Late harvest.
1501-05	1511-15	1681-85	1696-1700
1521-25	1546-50	1725-30	1741-45
1555-60	1566-70	1756-60	1766-70
1586-90	1591-95	1781-85	1816-20
1601-05	1626-30	1826-30	1851-55
1636-40	1646-50	1866-70	1886-88
1666-60	1671-75		

While for single years the amount of variation in the time of grape harvest may vary by many days, and for the five years lustra reaches even three weeks, yet for the smoothed out lustra averages the extremes are about a week earlier than the average for the minima and a week later for the maxima times of harvest. A comparison of these periods with similar periods of rain-fall and temperature shows that in general the early harvest period is identical with that of high temperature and small rain-fall, and conversely the times of late harvest and low temperature and excessive rain-fall occur together. By means of the recorded dates of the grape harvest it is possible therefore to trace back to about the year 1400 for Central Europe the periods of warmth and dryness, and cold and excessive wetness. The relation to the glacier changes are still closer.

The occurrences of severe winters have been catalogued still further back, and Brückner commences his list (using that of Pilgram) with the year 800, but thinks that the records before the year 1000 are of little value. He finds finally that for the period 1020 to 1190, there exists a 34 years oscillation; from 1190 to 1370, a 36 years period; from 1370 to 1545, a 35 years period; from 1545 to 1715, a 34 years period; and from 1715 to 1890, a 35 years period.

An average time of about 35 years is, then, found to intervene between one period of excess or deficiency of heat and the next, with the opposite relative condition of moisture accompanying; and this shows itself in all of the various data and methods which have been used in considering the question.

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