LONG TIME FORECASTS OF OHIO RIVER FLOODS

E. L. MOSELEY,
Bowling Green State University
Bowling Green, Ohio

Had we known ten years ago what we know now about cycles of precipitation we could have predicted heavy rain for the Ohio valley in the winter of 1936–'37. That the most disastrous flood in its entire history would come at that time we could not have foreseen.

The amount of destruction wrought by a flood depends on many things besides the amount of rain at the time. Nevertheless, major floods in the Ohio River have probably rarely, if ever, occurred without more than the average amount of rain over the drainage area of some of its tributaries not very long prior to the flood. Heavy precipitation is a major factor in flood production.

Twenty-nine times in the past eighty years the gauge at Cincinnati has shown the river to be more than 55 feet above the zero mark. This occurred once in August and once in December, but 27 of these 29 floods occurred in the first third of the year—6 in January, 9 in February, 8 in March, 4 in April. In predicting major floods a knowledge of prospective rainfall in spring and summer is of less importance than that of winter. If heavy summer rains keep the ground wet until late fall, less rain will be needed later to start the water flowing in drain tile and ditches, but the amount of precipitation in late fall and in winter is of more importance in flood production.

There have been periods of several years without great floods and periods of similar duration with several great floods. The Annual Meterological Summary for Cincinnati gives the highest stage of the river for every year from 1867–1937. Within this time the river was above 55 feet 24 times, but only eight times in isolated years. The other 16 floods occurred in years that were just before or just after a flood year. Thus there was a major flood in 1882, in 1883, and in 1884, also in 1897, 1898, and 1899. The Pittsburgh record shows the same thing; major floods occurring singly were much less numerous than those occurring in successive years.

We have good reason to believe that variations in the emission of solar energy, both in total quantity and in the proportional amount of ultraviolet rays, are in some way responsible for at least a part of those changes in the terrestrial atmosphere which we commonly speak of as weather. How they influence weather is not yet well understood. Quite likely the sunspots themselves do not play an important part, but their presence in large numbers indicates increased activity in the solar atmosphere, accompanied by emission of more heat. Strange to say our thermometers at such times register lower temperatures. This paradox is not so easily explained as the fact that our winter comes when the earth is nearest the sun, for the lowering of temperature at times of sunspot maxima is not confined to either hemisphere. The increased heat from the sun causes more storms with attendant clouds that intercept part of the sun's rays before they reach the solid earth. These storms also cause an overturning of the atmosphere resulting in a mingling of cool air from above with the air near the earth's surface.

Just as a violin string vibrates as a whole and at the same time in parts, so the curve representing the sunspot numbers shows a fundamental period and other periods which may be called harmonics. The fundamental, although variable, averages more than eleven years. Corresponding to this period I have found variations in rainfall in the Ohio valley. In arid regions of the Southwest, where rain is the all-important factor in tree growth, Professor Douglass of the University of Arizona has found that not only the fundamental but also the harmonics in the curve of sunspot numbers show in the tree rings.

Each of these short periods in the sunspot curve probably has some influence on our weather. Their combined effect at any particular time depends on the phases which come together at that time. This changes from year to year, but since the fundamental and the harmonics are all submultiples of about ninety years they combine again after this interval in the same phase as at the beginning.

Professor Kullmer of Syracuse University has found that the centers of greatest storminess over the United States and Canada shift in both latitude and longitude. After moving east for a number of years the location of these centers returns abruptly to a position much farther west. It may be that after ninety years the storm centers return to very nearly the same place which they had at the beginning. The data available for his charts do not cover a long enough period yet to tell whether there is a basis of fact in this hypothesis.

My early work with tree rings consisted mainly in laying off 46-year periods, later changed to 45-year periods, and measuring the radial growth increment during each of these periods. The period starting with 1891 I called Period 1, the preceding 45 years Period 2, and so on. I found that in Period 2 a majority of trees made more growth than in Period 1 or 3, and that all even numbered periods were wet ones, odd numbered periods, with one exception, dry ones. Consequently twice 45 years takes us from the beginning of one wet period to the beginning of another wet period, and likewise from any part of any period to the corresponding part of another similar period.

Thus there are some theoretical grounds for the idea that precipitation in any given region in this part of North America comes in ninety-year cycles. That there actually is a repetition of drought and flood after the lapse of about ninety years we have abundant evidence. It comes from four sources: Great Lakes levels, tree rings, high and low water in rivers, and actual records of rainfall. Early records of unusually high or low water in the Great Lakes are scanty. More of them relate to Lake Ontario than to any other lake, for on its shores there were settlements earlier than about the lakes farther west. Since it receives most of its water from the other lakes its level is an index of rainfall over a large area. When it was unusually high this was noticed and in some cases a record made of it. About ninety years after each of these early years of high water in the Great Lakes there was high water again.

On the terminal portion of the Cedar Point peninsula, which lies between Sandusky Bay and Lake Erie, are long parallel ridges formed of gravel and sand. Each ridge was built by a great northeast storm occurring at a time when Lake Erie was unusually high. Only at such times was it possible for the wind to drive the waves far back on the land and throw up ridges which would not be demolished by a later storm. Early in the present century, accompanied by boys from the Sandusky High School, I made many trips to Cedar Point for the purpose of determining when these ridges were formed. The methods we employed and the dates which we finally assigned as a result of this research were made known to the Ohio Academy of Science at its annual meeting in Cleveland in 1904.[1] Two of the ridges were formed in the nineteenth

[1]Thirteenth Annual Report, Ohio Academy of Science, pp. 223–231.

century, one in the eighteenth, one in the seventeenth, two in the sixteenth and one in the fifteenth.

The dates which we assigned to the ridges that were built in the nineteenth century we had reason to believe were correct within two or three years. We did not suppose that such close approximation was true also of the dates of ridges formed in the earlier centuries. Not until recently did I know anything about cycles of precipitation. In view of this fact it is significant that a succession of ninety-year intervals is clearly shown by these dates. Three of the dates are 1504, 1594 and 1684. Ninety years later no permanent ridge was formed, but 180 years later, 1864, is very close to the time that ridge 6 B was formed, 1861 or 1862. The date assigned to the oldest ridge is 1429. Five times 90 (450) years later is 1879. The date assigned to the latest of these permanent ridges is 1878.

A living tree forms a new ring of wood each year just beneath the bark. These annual rings, as they are called, show by their thickness whether the tree was getting more or less than the usual amount of moisture at the time the ring was formed. A study of these rings after the tree is cut down makes it possible to learn about the rainfall during the life of the tree. I have made measurements on the tops of stumps, the ends of logs, or on cross sections taken from them, representing more than four hundred large trees that grew from southern Michigan to central Tennessee. A large part of these trees were between 200 and 370 years old, a few were still older and so afford information about the rainfall each year for the past four centuries. They show plainly a tendency to repeat after about ninety years.

The dates when the trees formed rings which were obviously wider or narrower than neighboring rings were recorded for about 125 trees, of which a large majority were oaks. These records form the basis for the table of wide and narrow rings. (See Table I.)

Records of Ohio River floods at Pittsburgh go back to 1762, which is 26 years before there was any permanent settlement in Ohio. Until after 1832 there were only seven floods so important that they are shown on this record. Each of these was followed by a flood approximately ninety years later, the water usually reaching a height similar to that of the earlier flood. There were six floods in the years 1846–'52; no other comparable period in the nineteenth century had so many floods when the Ohio River reached such high levels. This corresponds to the period 1936–1942, which has already given three major floods.

TABLE I

YEARS WHEN A MAJORITY OF THE TREES IN THE REGION EXTENDING FROM SOUTHERN MICHIGAN TO TENNESSEE FORMED WIDE OR NARROW RINGS

Wide				Narrow			
	1852	1761	1671	1936	1845	1755	1665
	1850	1760	1669	1934	1843	1753	1663
1939 (?)	1849	1759	1668	1931–2	1841	1751	1660
1938	1848	1758		1930	1839	1748–9	1658
1937	1847	1756		1925	1834	1743–4	1652–3
1928	1837	1747	1657	1911	1821	1730	1640
1927	1836			1910	1820	1729(?)	1639 (?)
1922	1832	1741		1907	1816	1726	1636
				1901	1811	1721	1630
	1887	1797	1707	1900	1810	1720	1629 (?)
	1886	1796	1706	1898–9	1808–9	1718	1628
	1885	1795	1705	1895	1804	1714	1624
	1884	1794	1704	1894	1802–3	1712–3	1622–3
	1883	1793	1703	1891	1801	1711	1620
	1881	1791		1890	1799–0	1709–0	1618–9
	1878	1788	1697 (?)	1874	1784	1693	1603
	1877	1787	1696	1871	1781	1691	1600
	1876	1786	1695	1870	1780	1690	1599
	1869	1779(?)	1688	1868	1778	1687	1597
	1859	1769	1678	1867	1777	1686	1596 (?)
	1858	1768	1677	1864	1774	1683	1592
				1857	1767	1676	1585
				1856	1766	1675	1584

The table shows that each wet year was followed after an interval of 90 or 91 years by another wet year, likewise each dry year by a dry year. If the precipitation cycle were as long as ninety and one-half years, the 91-year interval would appear as often as the 90-year interval, but it does not. If the cycle were just ninety and one-third years, then after three such intervals the difference between dates would be 271 years, as it usually is, but in some cases it is 272 years, which implies that the cycle is a little more than ninety and one-third years.

By using records of rainfall prior to 1848 many attempts have been made to correlate months of excessive or deficient rain with months between 90 and 91 years later. The best correlations were found by using the months ninety years and five months later, the next best by using an interval of ninety years and four months. This result is in good agreement with the table of dates of wet and dry years shown by the width of tree rings. Both methods lead to the conclusion that the length of the cycle is not far from 90.4 years.

The first two floods recorded at Pittsburgh, 1762 and 1763, were among the greatest in the entire record. Ninety years after 1762, that is in 1852, the river at Pittsburgh rose to 35.1 feet, almost as high as in the great flood of 1884, and higher than at any other time in the century preceding 1936. It lacked only one foot of attaining the same height a few months earlier, September, 1851. This is the only time that two such

Bur oak stump 47″ × 52″, 30″ high, Allen county, Indiana, May 2, 1939. It shows 283 annual rings.
Photo by O. E. Ehrhart, Antwerp, Ohio.

high floods have occurred there within so short a period in the entire 175 years of the Pittsburgh record. Ninety years after 1852—twice ninety years after 1762—will be 1942. Farther on we will consider the probability of a great flood then.

Tree rings show that there were copious rains over a wide area in the years 1846–'52, also in 1756–'62, and 1666–'72, that is at intervals of ninety years.

These great floods of course affected the river also along the West Virginia, Kentucky, and Ohio border, where there are records of a few other early floods. At Cincinnati the highest water that old residents could remember prior to the flood of 1937 came in 1883 and '84. Each of these great floods followed ninety-one years after a great flood; that of 1792 reached a height of about 63 feet, that of 1793, 57 feet. Tree rings for all four of these great flood years have been observed on stumps and logs in seven states; they all show heavy rainfall. Ninety years earlier still, 1702 and '03, a majority of the trees produced wide rings.

We are now ready to see how this tendency of heavy precipitation to repeat itself after 90.4 years might have been used in predicting recent floods. Let us consider first the rainfall 90.4 years prior to the terrible flood in January, 1937. This takes us back to the summer of 1846. That year the rainfall at Cincinnati and Dayton was above normal every month from April to August; in some of these months it was very much above normal, double or nearly double. Marietta had over 19 inches of rain in three months, June, July, and August. Steubenville, still farther up the river, had 22.79 inches in four months, May to August. Pittsburgh had double the normal amount, July and August. Portsmouth, Ohio, and Springdale, near Louisville, Kentucky, also had heavy rain at that time. Such rain in the summer of 1846 would have justified predicting a serious flood in the Ohio River in the winter of 1936–'37.

The great flood of 1936, which at Pittsburgh was even greater than that of 1937, came two months later in the year than that of 1937, as might have been expected from the fact that heavy rain in 1845 started later and continued later. That year Cincinnati had 11½ inches of rain in June and 14.39 inches in the two months August and September.

In 1847 there was a surplus of rain along the Ohio River from Pittsburgh to Louisville in June and July, likewise 90.4

years later, October and December, 1937. There would have been a flood in January or February, 1938, if heavy rains had continued, but in August, 1847, rainfall was below normal, likewise in January, 1938, it was below normal. So 1938 did not, like the preceding years, give a major flood.

The year 1848, like the years before and after, gave more than the usual amount of rain in the Ohio valley. There was a large surplus in May and a very large one in July, followed by a surplus of one inch in August. 90.4 years later came the winter of 1938–'39, with a flood which drove many thousands of people from their homes.

Every major flood which has occurred from 1913 to the present was preceded by heavy precipitation about 90.4 years before. Marietta is the only Ohio River station whose record goes back 90 years earlier than 1913. It had almost double the usual amount of rain in September, October and November, 1822. The tree rings formed in 1822 and 1823 indicate that more rain fell in those years than in any two previous years in the century.

In September, 1848, rainfall in the Ohio valley was below normal, in October and November it was about normal. The corresponding part of 1939 is from February, or a little before, to about the present time. December, 1848, brought heavy rains all along the Ohio River, also in western New York, central Pennsylvania, eastern Missouri and Iowa. At Cincinnati and Springdale there was more than ten inches. The following month the rainfall was not so great but, nevertheless, was double the normal at Cincinnati, Dayton, and St. Louis, and above normal at most places. We may expect heavy rains in the next two months.

In February, 1849, at a majority of places in this part of the country rainfall was below normal, in March it was well above, in April, May and June it was near normal. Accordingly we may look for about the average amount of rain in the five months, July to November, taken as a whole.

July, 1849, gave a very heavy rain—on an average more than nine inches at Dayton, Cincinnati, Portsmouth and at St. Louis, Missouri; but in eastern Ohio, Pennsylvania and New York rain that month was below normal. About December, 1939, rain should be heavy from Cincinnati to St. Louis. In August, 1849, rain averaged about normal along the Ohio River, in September rain was light at all stations, in October it was about double the normal at some stations, in November it was below. Judging from these data I think there will not be a major flood in the Ohio River in the early part of 1940. The Mississippi River will be unusually high above St. Louis and perhaps also farther south, throughout much of the winter of 1939–'40.

In 1850 the rainfall at Cincinnati was 54.56 inches, exceeding that of any year since. Portsmouth had 57.20 inches, which is more than in any other year in its entire record of over a century. Springdale, Kentucky, had still more rain that year, 67.10 inches, which was also its maximum. 1850 was a wet year also in the Eastern States. All along the Ohio River there were excessive rains the last month of 1849 and the first part of 1850, continuing through March at most places. So we may expect copious rains, May to August, 1940. If great floods in this river were not so rare in summer, I would expect one in the summer of 1940.

In the summer of 1850 rainfall was heavy at Cincinnati and Springdale, but not along the upper course of the river. There is not likely to be a major flood in 1941.

Rainfall was double the normal in December, 1850, at four of the six stations along the Ohio River, but in nearly every month of 1851 it was below normal at all stations. Therefore we may expect less rain from June, 1941, to May, 1942, than in any other twelve month period in the seven wet years which began late in the summer of 1936. This does not mean, however, that there will be a drought at that time.

In 1942 the river should rise in July and August and become high in September. During the remainder of the year rainfall should not average much, if any, above normal.

Since there was a great flood in 1762 and another in 1852, we might expect another about 1943. Let us consider the probability of it on the basis of rainfall in 1852. In July it was below normal at all Ohio River stations, in August and September about normal, in October below normal at all stations. Hence December, 1942, and the first three months of 1943, taken as a whole, should not have precipitation above normal.

November precipitation in 1852 was well above average in four places on the river and at Richmond, Indiana, whose record started with that year. In the following month Richmond had 11.20 inches, or four times the normal. At other places the average was about double the normal. Hence the river should rise in April, 1943, and in May become unusually high for that month.

In 1853 average precipitation was low at Ohio River stations, also in 1854 in part of them, in summer low at all of them. It was also rather low in the first four months of 1855. Hence there should be no very high water after the spring of 1943 until late in 1945.

In the summer of 1855 rainfall was excessive all along the river from June to September, at some places also in May. This implies high water from November, 1945, to February, 1946. If much of the precipitation in early winter falls as snow that remains long on the ground, there will be a flood when it melts if a large amount melts in a short time.

There will be high water at this time also in Pennsylvania, New York, and northern Ohio, resulting in floods, especially if much snow melts quickly.

After the spring of 1946 until late in the following year we think there will be no great floods in large streams in southern Wisconsin, eastern Iowa, Illinois, Indiana, Ohio, Kentucky, Pennsylvania, or New York.

In the spring of 1946 there should be abundant rain for crops that mature before mid-summer, but after that we may expect a drought that will continue until late in 1947. This drought will be of wide extent, in this part of the continent, but will not be felt everywhere. Tree rings show that the growing season of 1856 was dry from Michigan to Tennessee, in many places very dry. Weather records at those places in this area where the year 1856 is included show the same thing. Nearly all the trees show a narrow ring also in 1766, which was ninety years earlier. Ninety and ninety-one years before that, the growing seasons of both 1675 and '76 were dry. In 1584 and '85 the trees formed rings that were very narrow.

In 1856, which over a large area was one of the driest years of the nineteenth century, New Orleans and Baton Rouge each had 67 inches of rain. More than usual fell also at St. Louis, Missouri, Fort Madison and Monticello, Iowa, Kearney, Nebraska, Leavenworth, Kansas, and Fort Gibson, Oklahoma. Rainfall was below normal at other places in Iowa and much below in southeastern Texas, Pennsylvania and parts of New York State.

There will be plentiful rain again in 1948, 1949, and indeed in a majority of the years until the last quarter of the century.

In summary, nearly all of the great floods of the Ohio River have occurred in the first third of the year. Excessive precipitation 90.4 years later falls in summer. Nevertheless floods early in the year are likely to recur after ninety or ninety-one years, because precipitation oftentimes is high not only at the time of the flood but also in the summers preceding and following the flood. Wet years, like the floods themselves, show a tendency to occur in groups.

There will be high water in the river several times before the middle of 1943. These include May and June of the present year, the summer of next year, the latter part of summer in 1942, and the spring of 1943. In the five years following the spring of 1943, if a great flood occurs, it will probably be in the winter of 1945 to '46.