gent to the solar halo at its upper point between the sun and the zenith and a mock sun appeared at the point of tangency. The most beautiful formation of all was directly in the zenith. This was a halo of 4° radius surrounding the zenith; the half circle toward the sun was composed of the most intense colors and tints which delicately shaded to the northern half and gradually merged into a bright semicircumference. The colors were distinct and brilliant, being more intense than those of the rainbow, and so dazzling that satisfactory inspection could only be made through smoked glasses. In the arrangement of colors the red was on the side toward the sun.

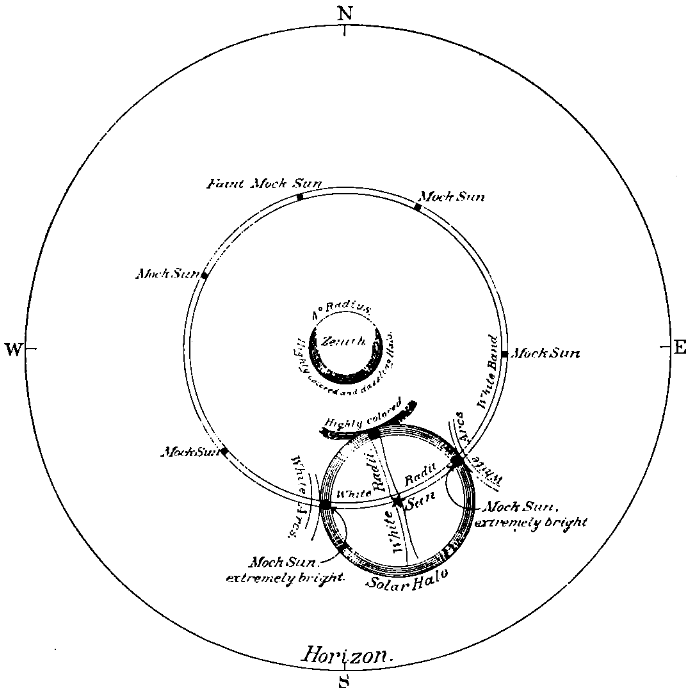

FIG. 1.—Solar halo at Milwaukee, Wis., February 2, 1904.

In a subsequent communication, Mr. Schaeffer adds the following items:

The sun rose February 2 at 7:13, sun time (latitude 43° 2′), and set at 5:13 p. m., making the sun ten hours above the horizon for the entire day. The solar halo was first observed at 9:10 a. m., and was judged to be the ordinary 22° halo. At 9:30 a. m. (or 10:30 a. m., seventy-fifth meridian time), the entire phenomenon was first observed, and continued with unabated distinctness until 12 noon, local time (ninetieth meridian time), then occupied about one-half hour in fading, becoming invisible at about 12:40 p. m. The zenithal halo waned slowly, or occupied about one-half hour, disappearing with the remainder of the phenomenon. The bright spots on either side of the extreme northern parhelion were judged to be about one-sixteenth of a circumference [or 22.5°] from the north point.

A BRIEF DISCUSSION OF CONDITIONS CONTRIBUTING TO FRESHETS IN THE JAMES RIVER WATERSHED.

By EDWARD A. EVANS, Section Director, Richmond, Va., dated July 10, 1903.

No one who has given serious thought to the subject of precipitation and resulting run-off can have failed to perceive that the relationship between them is a variable one; that practically equal quantities of rainfall over the same areas do not always produce equal or even approximately equal flood heights.

In considering the freshets of the James River watershed there are found to be always present certain conditions that affect the run-off. These conditions are divided into two groups, one of which may be designated as permanent, the other changing.

The permanent group comprises:
- Basin topography.
- Immediate stream environments.
- Soil structure.

The changing group consists of:
- Differences in air temperature and moisture.
- Differences in soil temperature and moisture.

The first group represents conditions, the value of which would always be fixed, definite, and unvarying with equal amounts of precipitation were it not for the operations of the factors contained in the second group. These, though permanent in the sense that they are always present, are termed "changing," because they vary constantly in the degree of their application, both with and in the seasons. They prevent a fixed ratio of run-off to precipitation, and for this reason assume a position of high importance in any consideration of questions relating to flood causation or control.

The purpose of this article is to present briefly some information bearing upon each of these groups.

BASIN TOPOGRAPHY.

Beginning with basin topography, a glance at the map of Virginia will show that that part of the James River watershed subject to overflow, and for which flood warnings are issued, fig. 1, extends from the Allegheny Mountains in the central-western portion of the State generally eastward to the head of tidewater at Richmond, a distance of about 263 miles. The greatest width of the watershed is approximately 80 miles, and the least about 5 miles. It consists of two distinct catchment basins which may conveniently be called the upper or mountain, and the lower or middle drainage areas.

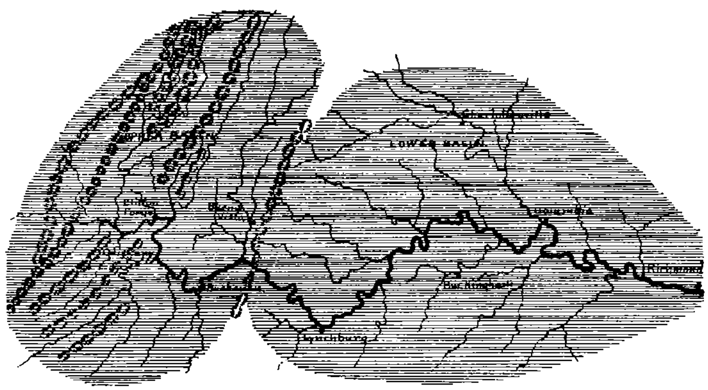

Fig. 1.—James River watershed—Covington to Richmond, Va.

Of these, the upper basin is an oval-shaped depression, the rim of which is composed of the Blue Ridge and the Allegheny mountains on the east and west, respectively, and high intervening uplift of valley lands on the north and south. Its trend is northeast and southwest along the line of its greatest diameter. It has an area of 2058 square miles, and its elevation above sea varies from 706 feet at Balcony Falls, where the James River breaks through the Blue Ridge on its way to the ocean, to about 4000 feet along the western crest of the watershed. In its western parts the surface is broken by numerous ranges of mountains, which lie parallel to the trend of the basin, and as they enter it gradually decrease in elevation until they merge into the high rolling lands of the Shenandoah Valley. These in turn sweep up to the Blue Ridge on the east. A network of branches, creeks, and rivers drain the Shenandoah Valley and the narrow valleys lying between the mountain ranges. Their combined waters enter the James River (which nearly equally bisects the upper basin) either from the northeast on its north side or from the southwest on its south side. These streams are all shallow, rocky, and swift flowing, falling rapidly from their headwaters to their point of junction with the main stream, and having many sinuosities.

The more important of these tributaries, with approximate figures of their greatest and least elevation above sea level, are given in the following table:

Principal tributary streams of the upper basin.

Tributary.	Elevation at source.	Elevation at mouth.
	Feet.	*Feet.*
Jackson	2,000	1,245
Cowpasture	2,000	980
Craigs Creek	1,400	960
North	1,300	730

The lower basin is of much the same outline as the upper basin, but in its surface characteristics it differs decidedly, being not nearly so rugged, except in its Blue Ridge portions. Its area is considerably greater, being about 4528 square miles, and its mean and extreme elevations are much less, while its greatest diameter bears east and west. Its boundaries are marked by the James-South Anna and the James-Chickahominy divides on the north side; by the James-Appomattox divide on the south; by the hill country on the edge of the marine plateau or coastal plain on the east; by the eastern face of the Blue Ridge on the west. Its maximum elevation, 2700 feet, occurs in the Rocky Row Mountains near Balcony Falls, while the minimum is zero, or mean tide at Richmond.

Seven principal tributary streams drain this basin, five of which originate in that part of the Blue Ridge which forms the northwestern boundary, and flow thence southeastwardly until their waters unite with the James River; the remaining two rise in isolated mountain spurs on the southwest edge of the basin, and flow to the northeast.

Approximate figures of greatest and least elevation above sea level for these tributaries follow:

Principal tributary streams of the lower basin.

Tributary.	Elevation at source.	Elevation at mouth.
	Feet.	*Feet.*
Pedlar	1,500	580
Tye	1,500	382
Rockfish	1,450	320
Slate	800	279
Rivanna	1,260	220
Willis	650	205
Hardware	1,000	285

A general survey of the watershed, fig. 1, discloses outlines that may be likened to a figure eight, placed on a horizontal plane with its left half flattened and its right half elongated. The crossing of the curves at the center would then indicate the water gap at Balcony Falls, where the two basins are united; the extreme right-hand end is at the falls of the James River at Richmond; the remaining curves would fairly correspond with the rim of hills and mountains that forms the crest of the divide between this and neighboring watersheds.

The diagram, fig. 5, gives the profiles separately of James River and James River watershed from Covington eastward to Richmond. Crossing the two basins on a nearly median line, and forming the backbone of the system of tributary streams, is the James River. In all its parts above tidewater this river is generally shallow. Especially is this true of its upper waters. Its bed is narrow, well-defined, and rocky, rising occasionally and forming boulder-strewn rapids of limited extent. Outcropping ledges of stratified rock cross it at frequent intervals until well into the lower basin, then disappear not to be seen again until within a few miles of Richmond when they again occur, forming rapids about 9 miles in length, having a fall of about 123 feet. The head of tidewater is at the foot of these rapids, which constitute what is known as the falls of the James River and furnish a magnificent and unfailing power. At the point where the rapids begin the river is first broken by large, isolated boulders. The number of these increases rapidly. Many of them attain the proportions of small rocky islets and have a dense growth of vines, underbrush, and small trees. Two rather large islands close the group, one, Belle Isle, lying about one-fourth of a mile above tidewater, and rising domelike from the river bed to a height of 60 or 70 feet; the other, Mayos Island, low, flat, projecting into tidewater, and formed apparently by sedimentation upon the rocky shelf that crops out at this point. From Richmond eastward the river is navigable for sea-going vessels, is not seriously affected by freshet water, and therefore is not considered in this article.

STREAM ENVIRONMENT.

For the most part the immediate stream environment of the upper basin consists of precipitous slopes from mountain tops to valleys. This is especially true of those streams having their sources well up on the eastern flank of the Alleghenies, but, as the Shenandoah Valley is entered, the basin opens out to some extent and the slope of the surface of the land is not so sharp. However, in all cases it is steep enough to cause it to assume importance in its relation to floods by accelerating the rate of movement of the run-off resulting from precipitation.

In the Blue Ridge and Piedmont portions of the lower basin, stream environment does not differ greatly from that of the more rugged portions of the upper basin, the slopes from the crest of the mountains and hills to the river beds in the valleys being very sharp; but advancing eastward into the more open portions of the basin, the rolling character of the surface presents less abrupt descents and greater drainage areas for individual streams. The fall of the river beds also is less and the normal rate of water travel is diminished. In general the streams are deeper and the rocky bottoms and banks that mark the region of their source disappear. Four of the streams mentioned above, viz: Pedlar, Tye, Rockfish, and Slate, are true mountain streams, being swift flowing, rocky, and turbulent. The Hardware, Willis, and Rivanna rivers, throughout the greater portion of their course, pass through a relatively open country, drain more of the basin, and move less swiftly on their way to the main stream.

SOIL STRUCTURE.

The soil of the watershed varies decidedly in structure and in depth. With the exception of the humus it is derived, as is all soil, from rock, and is, therefore, coarse or fine in grain according to the character of the rock from which it came. Thus, in the case of coarsely crystalline rock, as some kinds of granite and limestone, the eroded particles are relatively large, and form a loose, sandy, porous soil, while fine grained rock, as argillite, will yield relatively small particles and form compact soils, as clay-loams and clay. Coarse granite and limestone, together with argillite, are commonly found in the mountainous portions of the James River watershed, and the local soils are derived therefrom, each kind occupying a situation appropriate to its origin.

The soils of the watershed are considered in fig. 2 with respect to their relative capacity for absorption of precipitation, as it is this aspect that determines their importance in assisting to produce flood water. In general, throughout the watershed, three characteristic types of soil structure are found; one of them is porous enough to be designated and considered as water absorbing, while another, by reason of its compactness, may be fitly termed water resisting.[1] It will be evident upon even cursory examination of the subject that these qualities must have an important bearing on the matter of run-off. Over areas where the soil is light, porous, and sandy, surface drainage must be nearly *nil* until a condition of saturation is reached, and as to this the quantity and rate of rainfall and the depth of soil would be the determining factors. On the other hand, where the soil is compact, dense, and fine grained, absorption would be so greatly re-

[1] The action of these soils in absorbing or shedding rainfall is referred to; not their capacity for holding a quantity of water.

duced that practically all rainfall in excess of that required to wet the surface would be realized as run-off. This is, of course, subject to such modifying conditions of soil and air temperature and moisture, and of wind movement as may obtain in any season.

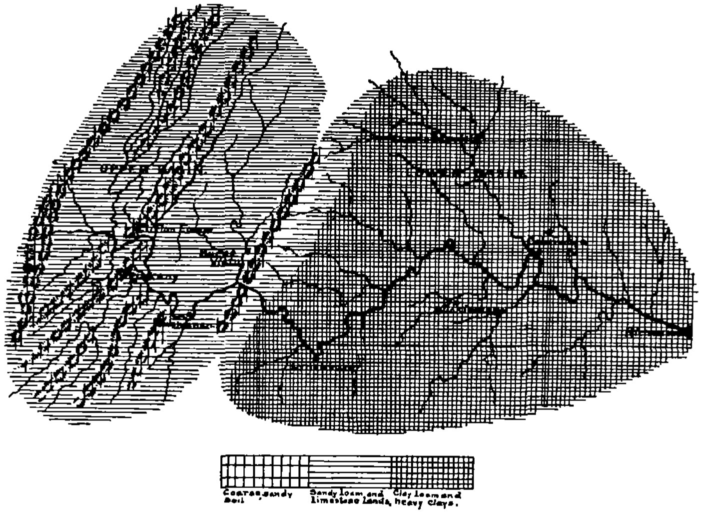

Fig. 2.—Soils of James River watershed—Covington to Richmond, Va.

The mountain soil of both the upper and lower basins of the watershed is loose, sandy, and shallow, forming nothing more than a thin covering for the rock of the region; it is spongy, permeable soil, receptive, but not retentive. In the small elevated valleys, the soil is similar, but deeper, in rather more compact form, and with a greater proportion of humus.

In the Shenandoah watershed of the upper basin the character of the soil changes to sandy loam and limestone lands. The soil particles are finer, and hence, in structural order, the soil is more compact than that of the mountains. It overlies rock, is relatively deeper compared with that of the mountains, and is more retentive, but not so receptive of water. Over the greater part of the lower basin clay-loams and dense, heavy clays obtain. Soils of these types, particularly the latter, are characterized by a great storage capacity for water if time be allowed for absorption, but they are so impermeable, so water-resisting, by reason of their density, that in ordinary cases of precipitation occurring as rain the amount absorbed would be trifling in comparison with that shed. This fact will be the first to attract attention when the cause of the greater frequency of freshets in the lower basin is considered.

The importance of the degree of compactness of the soil as governing the movement of surface and ground waters is generally mentioned by all authorities. Storer, in Agriculture, volume 1, p. 72, touching this, says: "In the case of clayey soils special regard must be had to the impermeable character of the clay." Again, on page 80, he mentions a test made by Gasparin of the rate of percolation through wet soils, in which "a layer of water 20 inches deep passed through a layer of soil 12 inches thick" in a specified number of hours. Quoting from this the tests of the soils nearest approaching those of the James River watershed, we have:

	Hours.
Coarse sand somewhat calcareous	1.54
Limestone soil with 11 per cent humus	7.94
Refractory clay from a field	168.00

The first of these soils would approximate the mountain soils, the second the Shenandoah Valley soils, and the third a large portion of the soil of the lower basin. While this test relates to a rate of percolation, it inversely shows what the proportion of surface drainage for soils would be. Let us suppose the conditions of the test to be changed so that the water, instead of being compelled to pass through the soil, is free to run off. How much of it in such a case would be absorbed by the refractory clay that required a period of a week, in the test, before percolation was complete?

On the other hand, in the coarse soil percolation was complete in less than two hours, that is to say, in one-eighty-fourth of the time required for the heavy clay. In the case of rain, the clay should, then, almost immediately begin to furnish run-off, while the sandy soils would accumulate water, except for seepage over shelving lands, until subsoil or rock was reached, when its action, as described by King, in Irrigation and Drainage, p. 330, would be to "* * * travel sideways by capillarity fastest * * * for the same reason that it flows downward fastest, namely, because the pores are largest and offer less resistance to the flow."

VARIATIONS IN TEMPERATURE AND MOISTURE OF AIR AND SOIL.

Every fall of temperature below the dew-point is accompanied necessarily by condensation, and every rise of temperature is accompanied necessarily by evaporation. It is the application of this law in nature that keeps water vapor constantly hesitating between the visible and invisible states.

When a given mass of air is increased in temperature by an access of heat, its capacity for water vapor increases. If a fall of temperature follows, the capacity is decreased, and, if the fall of temperature be sufficient, precipitation must occur.

In those latitudes where, during the winter months, the temperatures are ordinarily low, the capacity for moisture at that season must be considerably less than at other seasons. The winter season may, therefore, be considered as one in which the process of evaporation is being sluggishly carried on. Moreover, with the approach of winter the soil becomes chilled, and the evaporation of its moisture content is thus greatly retarded. Again, if the soil should become frozen, absorption would in great part cease. It seems reasonable, therefore, that these conditions can not help but greatly increase the percentage of run-off that may be had during the winter season in cases of precipitation occurring as rain.

On the other hand, during the summer, when the air is most warmed and its capacity for water vapor is greatest, and when the surface soil becomes hot and dry and precipitation is local and less frequent, the proportion of rain that is lost by evaporation and absorption becomes very great and the amount available to produce flood water is correspondingly diminished; so much so, indeed, that it may, and often does, happen that a fall of rain sufficient to cause a flood if it occurred in the winter, spring, or fall, fails to do so in summer under the conditions noted. Summer freshets, as compared with those occurring at other times of the year, are, therefore, infrequent and usually unimportant, but the rainfall producing them is generally much greater than that required to cause a flood rise in the fall, winter, and spring. The opinion seems popularly to prevail that the rarity of freshets in summer is due to the local nature of the precipitation. There can be no doubt that this fact has some bearing on the matter, but, as compared with the effects of evaporation and absorption, it is relatively unimportant. The quantity of water that may be taken up by even one of these processes is enormous. On page 88, Storer, in Agriculture, referring to this matter, says: "Stockbridge observed during seven growing months of the year that out of a total of 25.70 inches of rainfall, 20.56 inches evaporated," or about 84 per cent. The circumstances of this test were such as to make its application in the present instance hardly suitable, but it is mentioned as showing how important a factor in flood control evaporation may become.

If it were possible to have a uniform condition of temperature of the air and soil and a uniform condition of physical structure of the soil, in the watershed, there would seem to be no good reason why equal or nearly equal amounts of precipitation should not produce equal or nearly equal flood heights, but such heights rarely result under prevailing conditions, and as we find constant changes in the temperature and moisture of the atmosphere and of the surface soil, as well as differences in soil structure, it seems that to them must be attributed the variable relationship between precipitation and run-off.

Turning to the record of precipitation that has produced floods in the James River watershed, and going as far back as reliable reports of one can be coordinated with the other, that is from 1895 to 1902, inclusive, it is found, first of all, that there is only one recorded instance of a summer freshet, that of July 10–11, 1896. The rains producing this rise averaged 3.40 inches for the watershed and the maximum river gage reading at Richmond during the flood condition consequent thereon was 12.5 feet. Comparing this with winter, spring, and fall freshets the record is as follows:

1895.—One rise each in January, March, and April, giving maximum stages of 18.2, 12.7, and 16.2 feet from an average precipitation for the watershed of 3.50, 1.14, and 1.92 inches, respectively.

1897.—Two February rises with maximum stages of 11.9 and 15.0 feet from an average precipitation of 1.76 and 2.01 inches, respectively.

1898.—One rise in October, reaching a maximum of 11.6 feet from an average precipitation of 2.47 inches.

1899.—One rise in January and two in March (February rise due to ice jam and omitted), reaching maximum stages of 13.5, 20.5, and 15.2 feet from an average precipitation of 1.31, 1.82, and 1.94 inches, respectively.

1901.—April and May each one rise, having maximum gage readings of 14.5 and 19.3 feet from an average precipitation of 2.25 and 2.40 inches, respectively, and two rises in December, giving maximum stages of 12.3 and 23.3 feet from an average precipitation of 2.25 and 3.40 inches, respectively.

1902.—One rise each in February and March, having maximum stages of 17.0 and 18.0 feet from an average precipitation 1.46 and 1.64 inches, respectively, and one rise in October of 12.0 feet, maximum, from an average precipitation of 4.45 inches.

The number of stations from which these data were compiled was about the same for each year, and the results have been put into tabular form.

Two prominent conditions appear therein:

1. A large percentage of run-off in the winter from relatively moderate amounts of rainfall.

2. A small percentage of run-off in summer from relatively large amounts of rainfall.

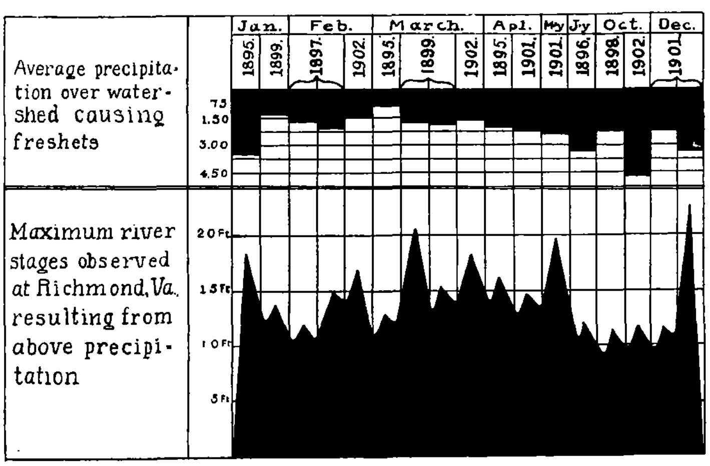

Fig. 3.—Precipitation and freshets resulting therefrom in James River watershed (1895 to 1902, inclusive).

A very instructive example of the difference between summer and winter run-off may be found in the freshets of July, 1896, and December, 1901. In each case the average precipitation for the watershed was 3.40 inches, but while in July the resulting run-off gave a maximum stage of 12.5 feet, in December it gave 23.3 feet, or very nearly double the quantity. On the other hand, some of the data appear inconsistent with this conclusion, as in the Octobers of 1898 and 1902, when large amounts of rainfall produced very moderate freshet stages. In these cases, however, the inconsistency is only apparent. It so happened that the monthly temperatures, especially in the watershed, were above normal (and in one case had been above normal for two months preceding), also that the precipitation for the preceding four months was quite considerably below normal. Under these circumstances the soil would have become more than normally warm and so thoroughly dried that both evaporation and absorption would have been greatly increased in their effects and the run-off correspondingly lessened. In the diagram referred to, fig. 3, precipitation causing floods for the years given and the maximum river stages resulting therefrom at Richmond, Va., have been coordinated.

Taken in connection with fig. 4, a very interesting example

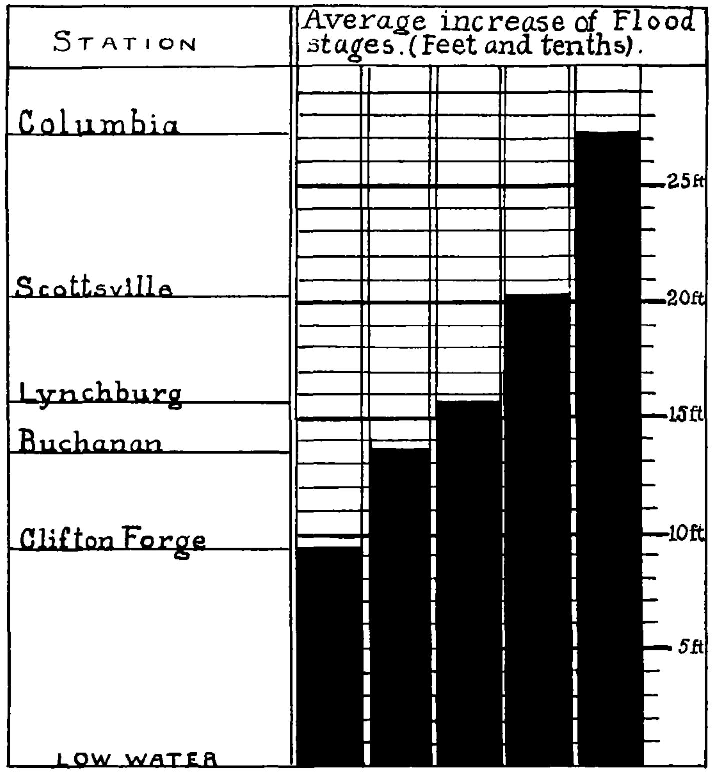

Fig. 4.—Average increase of flood heights in James River during general precipitation.

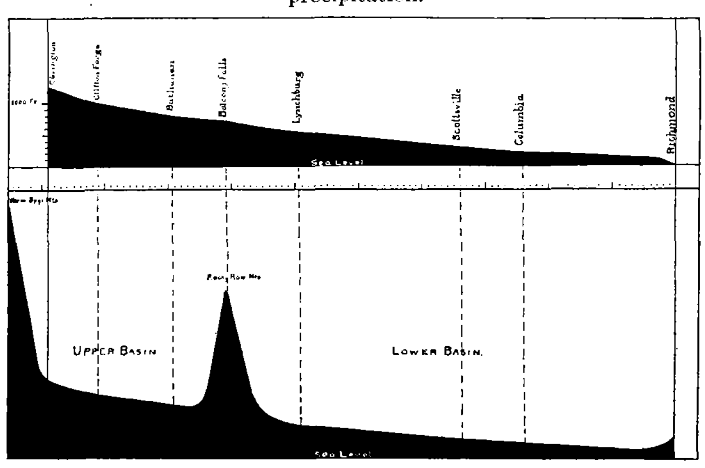

Fig. 5.—Profile of James River and James River watershed—Covington to Richmond, Va.

of the cumulative effect of rainfall is discovered. Assuming rainfall to be general over the watershed, each tributary in contributing its waters should serve to swell, by so much surplus as it carried, the total volume of the main stream, and this augmentation would, in turn, be shown by river gage readings made at or immediately below the point where it joined the main stream. Figuring on this basis and using maximum freshet data of from six to seventeen years, the average increase of freshet water carried by the James River would result, indicating what might be termed the discharge value of single or grouped tributaries. Thus, an average freshet height of 9.5 feet, representing the discharge of Dunlops Creek and Jackson River, is increased to 13.7 feet at Buchanan from the outflow of the Cowpasture River and Craigs and Catawba creeks; to 15.7 feet at Lynchburg from the waters of North River and smaller streams; to 18.9 feet at Scottsville by the Pedlar, Tye, and Rockfish rivers and smaller streams; and to 27.3 feet at Columbia by the State and Rivanna rivers. It is to be noted, however, that the local conditions at Columbia are such as to prevent a true increase or discharge value from being observed. The Rivanna River, the main tributary of the lower basin, here enters the James River at right angles, and the latter being narrow and shallow at this point becomes congested and a piled up condition of the water results that gives the local reading a value in excess of what it actually should be. Making allowance for this condition, it is probable that the ratio of increase at Columbia would be but slightly greater than that for Scottsville.

STUDIES ON THE CIRCULATION OF THE ATMOSPHERES OF THE SUN AND OF THE EARTH.

By Prof. FRANK H. BIGELOW.

IV.—VALUES OF CERTAIN METEOROLOGICAL QUANTITIES FOR THE SUN.

THE IMPORTANCE OF THESE VALUES TO TERRESTRIAL METEOROLOGY.

The most important data needed for use in studies in solar physics are the correct values of the pressure, the temperature, the density, the gas constant, and their many derived relations, at the surface of the sun, within its mass, and throughout the gaseous envelope. In the present uncertain state of our knowledge of these quantities, even an approximate derivation of these data is important, and this forms the justification for the studies contained in this paper. The problems of the circulation within the sun's photosphere, the transitions and the transformations in the atmospheric envelope with the attendant radiations and absorptions, the heat and light received at the outer surface of the earth's atmosphere, the resulting absorption and transmission of energy in the air, and the dependent circulation, are all languishing for the lack of a sound footing for our computations and deductions. The computations for the surface temperature of the sun give results ranging from 5000° to 10,000°; using Ritter's Law, Professor Schuster computes the temperature at the center of the sun as 12,000,000°, assuming that it is composed of hydrogen split up into monatomic elements. But it is evident that any such range of temperature would simply explode the sun, whereas it now circulates in a moderate manner. Unless some value for the temperature of the solar photosphere can be found, it will be impossible to determine what percentage of the total solar radiation is absorbed in the solar envelope, even though the radiant heat be computed successfully on the outer surface of the earth's atmosphere from radiation measurements at the ground. Should the following remarks prove to be merely suggestive it will be proper to make them as a contribution to the problems in solar physics.

I have been interested in the paper by Prof. F. E. Nipher, on the "Law of contraction of gaseous nebulæ,"[25] because it seems to offer a way of escape from the impossible results which follow from Ritter's equations, where the exponent in $P v^n = B$ is $1.33+$. Nipher makes the value of $n = 1.10$, and from this exponent the entire system of relations seems to be more probable. I will recapitulate Nipher's equations, after making the following changes in his notation to reduce them to the symbols used in my papers:

		Nipher.		Bigelow.
Gas constant	change	C	to	R
Density	"	δ	"	ρ
Distance from center	"	R	"	r
Mechanical equivalent of heat	"	J	"	$A' = \frac{1}{A}$
Heat equivalent of work	"	$\frac{1}{J}$	"	$A = \frac{1}{A'}$
Constant	"	A	"	B
Ratio	"	ρ	"	b
Constant	"	k	"	k^2

NIPHER'S EQUATIONS.

Adiabatic law for perfect gases:

$$(41)\quad P v = R T.$$

Heat relation:

$$(42)\quad dQ = c_v dT + P\, dv.$$

Assumed laws for non-perfect gases:

$$(43)\quad P v^n = P_0 v_0^n = B.$$

$$(44)\quad T v^{n-1} = \frac{B}{R}.$$

$$(45)\quad \frac{T^n}{P^{n-1}} = \frac{B}{R^n}.$$

Specific heat:

$$(46)\quad \left(\frac{dQ}{dT}\right)_n = c_v + \frac{AR}{1-n} \qquad A = \frac{1}{4.19 \times 10^7}.$$

Gravitation:

$$(47)\quad \frac{dP}{dr} = -k^2 \frac{M}{r^2} \rho = -k^2 \frac{M}{r^2} \left(\frac{P}{B}\right)^{\frac{1}{n}} \qquad k^2 = \frac{1}{1.5173 \times 10^7}.$$

Pressure:

$$(48)\quad P = \left[\frac{4n-3n^2}{(2-n)^2} \cdot \frac{B^{\frac{2}{n}}}{2\pi k^2 r^2}\right]^{\frac{n}{2-n}} = \left[\frac{0.95 B^{1.82}}{2\pi k^2 r^2}\right]^{1.22}$$

$$= \frac{0.95 R^2 T^2}{2\pi k^2 r^2} = \frac{0.636}{8\pi} \frac{M^2 k^2}{r^4}.$$

Density:

$$(49)\quad \rho = \left[\frac{4n-3n^2}{(2-n)^2} \cdot \frac{B}{2\pi k^2 r^2}\right]^{\frac{1}{2-n}} = \left[\frac{0.95 B}{2\pi k^2 r^2}\right]^{1.11}$$

$$= 0.95 \frac{R T}{2\pi k^2 r^2} = \frac{0.78}{4\pi} \frac{M}{r^3}.$$

Temperature:

$$(50)\quad T = \frac{B^{\frac{1}{2-n}}}{R}\left[\frac{4n-3n^2}{(2-n)^2} \cdot \frac{1}{2\pi k^2 r^2}\right]^{\frac{n-1}{2-n}} = \frac{B^{1.11}}{R}\left(\frac{0.95}{2\pi k^2 r^2}\right)^{0.111}$$

$$= 0.818 \frac{M k^2}{2 R r}.$$

Mass:

$$(51)\quad M = 4\pi \left(\frac{2-n}{4-3n}\right)\left[\frac{B(4n-3n^2)}{2\pi k^2 (2-n)^2}\right]^{\frac{1}{2-n}} r^{\frac{4-3n}{2-n}}$$

$$= 5.14\pi \left(\frac{0.95 B}{2\pi k^2}\right)^{1.11} r^{0.77}$$

$$= \frac{n}{2-n} \cdot \frac{2r R T}{k^2} = 1.22 \frac{2R T r}{k^2}.$$

[25] Transactions Academy of Science, St. Louis, October 1, 1903.