Carnegie Institution of Washington

CONTRIBUTIONS FROM THE SOLAR OBSERVATORY
MT. WILSON, CALIFORNIA

NO. 1

A STUDY OF THE CONDITIONS FOR SOLAR RESEARCH AT MT. WILSON, CALIFORNIA

BY

GEORGE E. HALE

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A STUDY OF THE CONDITIONS FOR SOLAR RESEARCH AT MOUNT WILSON, CALIFORNIA[1]

By GEORGE E. HALE, Director

In 1902, Dr. S. P. Langley addressed a communication to the Carnegie Institution recommending the establishment of an observatory at a very high altitude for the special purpose of measuring the solar radiation. In this communication Dr. Langley offered reasons for his belief that the solar radiation may undergo changes of intensity corresponding with those great changes of solar activity which are so strikingly illustrated in the sun-spot cycle. This communication was referred to an advisory committee appointed by the Carnegie Institution to report on various astronomical projects which had been submitted. The committee consisted of Professor E. C. Pickering, chairman; Professor Lewis Boss, Dr. S. P. Langley, Professor Simon Newcomb, and the writer. In its report to the Carnegie Institution, the committee expressed its approval of Dr. Langley's proposal and recommended, in case the Institution felt inclined to pursue the matter further, that a special committee be appointed to make a detailed report on the requirements of a complete solar observatory. It was also recommended that a project for an observatory in the southern hemisphere be investigated and reported upon by the same committee.

As a result of this recommendation, a committee, consisting of Professor Lewis Boss, chairman; Professor W. W. Campbell, and the writer, was appointed in December 1902 to report upon the proposed southern and solar observatories. The report of this committee may be found in *Year Book* No. 2 of the Carnegie Institution. This report also includes a detailed account by Professor W. J. Hussey of his telescopic tests of atmospheric conditions at sites in southern California and Arizona, where he had been sent by the committee. Professor Hussey strongly recommended, as the result of his tests, that Mount Wilson, near Pasadena, Cal., be chosen as the site of the proposed solar observatory, in case the Carnegie Institution decided to establish it.

[1] *Year Book No. 3 of the Carnegie Institution of Washington.*

PERPUSTAKAAN NASIONAL RI.

My first visit to Mount Wilson was made in company with Professor Campbell in June 1903. Professor Hussey had practically completed his tests and desired that we should see for ourselves the conditions he had found. Previous observations of the Sun at Pike's Peak, Mount Etna, and Mount Hamilton had in no wise prepared me for my experience on Mount Wilson. On certain occasions, it is true, I had seen the solar image sharply defined on Mount Etna in the very early morning hours. On Mount Hamilton, also, the solar image is sometimes good; but the testimony of those who have observed the Sun there was decidedly unfavorable. It was therefore with intense satisfaction that on each of the four days of my stay on Mount Wilson I found the definition of the solar image almost perfect, to be rated at from 8 to 9 on a scale of 10.

This visit was necessarily a hurried one, and it was evident that before Mount Wilson could be determined upon as the best available site for an observatory, observations extending over a long period of time would be necessary. As circumstances required that my family should spend the winter of 1903–4 in southern California, I decided to take this opportunity to make a more complete test of atmospheric conditions on Mount Wilson. Before arrangements had been made for living upon the mountain, I made frequent trips from Pasadena to Mount Wilson during the months of December, January, and February, observing the Sun on each occasion with a telescope of $3\frac{1}{4}$ inches aperture, and noting the prevailing weather conditions. The extraordinary absence of wind, which had seemed so characteristic a feature of the mountain during Professor Hussey's visit, could not be said to continue throughout the winter months. High gales sometimes occur at this season, and the average wind velocity is greater than during the summer. Nevertheless, the wind during the day was usually very light, and on many occasions the quiet days of the previous June seemed to be almost exactly duplicated, except that the temperature was lower. For weeks together not a cloud would be seen in the sky, and the summer serenity was in some measure retained until well into January. Later it was broken by storms, but these practically ended with April.

As the solar definition proved to be surprisingly good for this season of the year, I was soon convinced that Mount Wilson offered

exceptional opportunities for both solar and stellar work and that a systematic test of conditions should be inaugurated at the earliest possible moment. Accordingly, I commenced on March 1 to render habitable an old log cabin on the mountain that had been in a state of partial ruin for many years. The cabin, known locally as the "Casino," became our headquarters, where we have lived throughout our work on Mount Wilson. Tests of the solar definition were made as often as possible with the telescope already mentioned, and on April 15 several meteorological instruments provided by the Carnegie Institution were installed. Since that time, with only such interruptions as have been made necessary by the enforced absence of the observers, the instruments have been read at stated hours by Mr. Ferdinand Ellerman or Mr. W. S. Adams, who have also made regular tests of the seeing with the telescope mentioned above.

Through important financial assistance rendered by Mr. Arthur Orr, of Evanston, Ill., and Mr. John D. Hooker, of Los Angeles, and the exceptional facilities kindly granted by the Atchison, Topeka & Santa Fé Railway Co., through President Ripley, it became possible to bring from the Yerkes Observatory the small cœlostat which had previously been sent to the eclipses of 1900 (North Carolina) and 1901 (Sumatra). It had been my purpose to bring out the Snow telescope, but lack of sufficient funds prevented me from doing so. The smaller cœlostat was accordingly erected on the mountain, where it yielded excellent photographs of the Sun, amply sufficient to give objective evidence of the high quality of the observational conditions.

During my first visit to Mount Wilson the only unfavorable feature was the presence of fine dust in the air, which was conspicuous not only in the valley below, but also seemed to extend to a considerable altitude above the mountain. This was by no means sufficient to affect greatly the transparency of the sky, except very near the horizon. Nevertheless, the Milky Way did not stand out with the degree of contrast which one expects to see in a very transparent atmosphere. On my return trip to Chicago through the San Gabriel Valley the dust seemed so conspicuous that I feared it might prove an important objection to Mount Wilson as a site for an observatory. In most classes of solar observation dust does not play a very important part, and the great steadiness of the image would far outweigh any objec-

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Tanggal : 28-6-2010
Nomor Induk : 287/1N-Mus
BIB - ID : 0010-27286760
ITEM - ID : 100803032g
Asal : Museum Pusat

tions which might result from this cause. But in other classes of work which were contemplated for the proposed observatory, this dust, if persistent, would inevitably prove a serious obstacle. For example, in determinations of the value of the solar constant and in the photography of faint nebulæ, the absorption and scattering of light produced by dust in the atmosphere may interfere greatly with the work. It accordingly seemed that special attention should be given to the question of dust in the atmosphere above Mount Wilson. It has fortunately turned out, as will be shown later, that the presence of any appreciable amount of dust in the air above the mountain is so exceptional a phenomenon as to constitute no important objection to Mount Wilson as an observatory site.

After a brief statement regarding the conditions found at Mount Wilson had been presented to the Executive Committee of the Carnegie Institution, in April 1904, they decided to make a grant of a sum sufficient to provide for the erection and use of the Snow telescope on the mountain. The Yerkes Observatory loaned the telescope, and the University of Chicago provided the salaries of some of the observers. The work accomplished on the mountain since this grant was made has been sufficient to serve as a reliable basis for estimates on the cost of a large solar observatory, besides giving valuable experience regarding the necessary methods and cost of construction under the unusual conditions existing at the summit of a mountain nearly 6,000 feet in height. In view of their bearing on the question of a solar observatory, I have accordingly included in my report some remarks on the principal obstacles encountered and overcome in the construction of buildings and the transportation of instruments and materials.

REQUIREMENTS OF A SITE FOR A SOLAR OBSERVATORY

It is desirable to recapitulate here the purposes and plans for a solar observatory which were given at some length in *Year Book* No. 2 of the Carnegie Institution. At the outset, it should be stated that the term "solar observatory" is used here in a broad sense, since it is not intended to exclude from the program certain investigations of stars which are of fundamental importance in any general study of the problem of stellar evolution. For the Sun is a star, comparable in almost every respect with many other stars in the heavens, and

rendering possible, through an intimate knowledge of its own phenomena, the solution of some of the most puzzling questions in the general problem of stellar evolution. Conversely, however, the stars are suns, and if we would know the past and future conditions of the Sun, we must examine into the physical condition of stars which represent earlier and later stages of development. It will be seen that there is ample ground for the inclusion in the equipment of a solar observatory of certain instruments especially designed for the study of stellar problems.

The plan of work proposed for the observatory, as outlined in *Year Book* No. 2, includes the following classes of observations:

1. Frequent measurements of the heat radiation of the Sun, to determine whether there may be changes during the sun-spot cycle in the amount of heat received from the Sun by the Earth and in the relative radiation of the various portions of the solar surface.

2. Studies of various solar phenomena, particularly through the use of powerful spectroscopes and spectroheliographs.

3. Photographic and spectroscopic investigations of the stars and nebulæ with a very powerful reflecting telescope, for the principal purpose of throwing light on the problem of stellar evolution.

The present opportunity for important advances in these three departments of research is very unusual. Since the publication of *Year Book* No. 2, Dr. Langley has offered reasons to believe that an actual change in the amount of heat emitted by the Sun occurred in March 1903. It is hardly necessary to say that a change in the intensity of the Sun's heat, if actually established, might have a most important bearing upon many questions relating to the Earth, and, at the same time, be of capital interest in its relationship to the problem of the solar constitution. Through the force of circumstances, Dr. Langley's observations have been made under the very unfavorable conditions which obtain at Washington. If they could be continued at a considerable altitude, at a point above the denser and more fluctuating region of the Earth's atmosphere, the question as to what changes actually occur in the solar radiation could doubtless be answered in a thoroughly satisfactory manner.

In the study of the phenomena of the Sun's surface and atmosphere we again enter a remarkably fruitful field of research. Within the

past few years the instruments available for work in this field have been greatly developed, and now only await application on a large scale in order to secure a great number of new results which have hitherto been entirely out of reach. But even if the means were available for supplying the necessary instruments to existing observatories, they could not be successfully employed without atmospheric conditions much superior to those at present available. In work of this nature, success depends upon the perfect definition of the solar image and the absence of those disturbances from which the amosphere at existing observatories is almost never free. For this work, therefore, an elevated station in a region of great atmospheric calm is absolutely essential. Furthermore, the site must be free from the disturbing factors which frequently prevent good observations from being obtained on mountain summits.

In the third class of investigations required to complete the program of a properly equipped solar observatory, similar possibilities of advance exist. Within the past few years the remarkable advantages of the reflecting telescope have been demonstrated. It now only remains to construct a large and powerful instrument of the type shown by these experiments to promise success. With such an instrument, immense new fields of investigation of the highest importance in their bearing on the problem of stellar evolution could be immediately occupied. Here again, however, the unfavorable atmospheric conditions at almost all existing observatories would render the construction of a large telescope almost useless. To be successful, such an instrument must be erected at a site where the night-seeing is nearly perfect, the sky clear and transparent, and the average wind velocity very low. Under such conditions, a properly constructed telescope of large aperture would undoubtedly yield results greatly surpassing those hitherto obtained.

These considerations are sufficient to define the general character of a site suitable for a well-equipped solar observatory. There are other points, however, which must be taken into account. A solar observatory provided with an outfit of instruments, and then left to do its work without the possibility of improvement or change, could never attain the best results. On the contrary, it must have the means of producing new types of instruments and modifying old ones, as

the development of the work may suggest. In other words, a shop completely equipped with all appliances necessary for the most refined construction of both the mechanical and optical parts of instruments should form an integral part of a solar observatory. A shop of this kind cannot be conducted without great difficulty and expense, if far removed from large cities and other sources of supply. This is only one of many reasons which would render it desirable to select an observatory site within easy reach of the facilities afforded by a large city.

In his recommendation for the establishment of an observatory for the purpose of determining whether the heat radiation of the Sun undergoes change, Dr. Langley pointed out the desirabliity of making the observations at a height of some 20,000 feet above sea-level. Apart from the excessive difficulty and expense of conducting an observatory at such an elevation, which are best appreciated by those who have worked at great altitudes, the inaccessibility of high mountain peaks would stand in the way of such an undertaking. But it nevertheless might have been carried out, at a somewhat lower altitude, if the recent development of Dr. Langley's work at Washington had not indicated that the great mass of observations could undoubtedly be made to good advantage at a much lower station. The increasing perfection of the observational method has, indeed, permitted fairly good results to be obtained under the very unfavorable conditions which exist at Washington. Nevertheless, it by no means follows that Dr. Langley's purpose could be accomplished at such a point. The humidity of our atmosphere is a most serious obstacle in this particular work, since the solar heat is very subject to absorption by water vapor. It is therefore desirable to establish the instruments a least a mile above the dense and disturbed layers of the atmosphere which lie near the sea-level. Certain problems connected with the investigation may render it desirable to make some of the observations at a higher altitude, reaching from 12,000 to 15,000 feet. We conclude, therefore, that the principal work should be done at a station having an elevation of 5,000 to 6,000 feet, in a dry climate, where the weather is continuously clear over long periods of time. The work at higher altitudes, if needed at all, could in all probability be completed in two or three summers by expeditions equipped with

a portable outfit erected at an altitude of from 12,000 to 15,000 feet It would thus be convenient to have the principal station at a lower altitude, not far removed from accessible mountains of this considerable elevation. It would be inadvisable, for reasons which it is hardly necessary to specify, to establish the principal station at an altitude much greater than 6,000 feet.

POSITION AND NATURAL RESOURCES OF MOUNT WILSON

From a meteorological standpoint, the state of California may naturally be divided into three parts. In the northern region the rainfall is very considerable, much cloudiness prevails, and in almost all respects the conditions are very unfavorable for astronomical work. The central region, which may be considered to extend as far south as Point Concepcion, is favored with much better weather conditions, best exemplified at the Lick Observatory, on Mount Hamilton, where a high average of night-seeing is maintained during a large part of the year. Except for the frequent winds at night, which interfere with some classes of work, Mount Hamilton might be regarded as an almost ideal observatory site, at least for night observations. For solar work it may not be superior to certain stations in the eastern part of the United States, because of the excessive radiation from the heated slopes of the mountain, which is almost devoid of trees near the summit.

In the southern part of California the climatic conditions are decidedly different from those which prevail in the two other sections of the state. The much lighter rainfall is naturally associated with fewer clouds, a remarkably steady barometer, and very light winds. During a part of the year the fog rolls in from the ocean and covers much of the San Gabriel Valley during the night. But these fog-clouds rarely attain elevations exceeding 3000 feet, except when storm conditions prevail during the winter months. The mountains of the Sierra Madre range rise high above the fog, and during a great proportion of the year they enjoy practically continuous sunshine. During the summer months the sea breeze blows for a large part of the day, but it attains only a low velocity, which decreases in passing from the valley to the mountain tops and in going inward from the coast.

Mount Wilson is one of many mountains that form the southern boundary of the Sierra Madre range. Standing at a distance of thirty miles from the ocean, it rises abruptly from the valley floor, flanked only by a few spurs of lesser elevation, of which Mount Harvard is the highest. Except for a narrow saddle, Mount Wilson is separated from Mount Harvard by a deep cañon, the walls of which are very precipitous. Farther to the west, beyond the saddle leading to Mount Harvard, the ridge of Mount Wilson forms the upper extremity of Eaton Cañon, which leads directly to the San Gabriel Valley. East and north of Mount Wilson lies the deep cañon through which flows the west fork of the San Gabriel River, and beyond this rises a constant succession of mountains, most of them higher than Mount Wilson, which extend in a broken mass to the Mojave Desert. The Sierra Madre range forms the northern boundary of the San Gabriel Valley, which is further protected toward the east from the desert by the high peaks of the San Bernardino range. Through the Cajon Pass, where the Atchison, Topeka & Santa Fé Railroad enters the valley, winds from the desert frequently blow, bringing vast quantities of dust, which sometimes diffuses through the lower air over the entire valley. This dust but rarely reaches an elevation as great as that of Mount Wilson, though I have seen a few windstorms that carried the dust of the desert directly over the Sierra Madre range and into the valley below.

For the most part, the readily accessible mountains on the southern boundary of the Sierra Madre range have few trees near the summit, and enjoy but small supplies of water. Mount Wilson is remarkable in having a fine growth of trees covering its summit, and in possessing within easy reach of its highest point several large springs of water, which afford a good supply even during very dry seasons.

In a dry country the question of a pure and permanent supply of water is of paramount importance. It is therefore desirable to give more definite information of the springs near the summit of Mount Wilson. Some of these are located at Strain's Camp, where, for many years, they have supplied the necessities of summer visitors, who frequently occupy tents here for considerable periods of time. Two wells have been dug at Strain's Camp, and these are regarded as excellent sources of pure water.

In accordance with the terms of the lease of the property at present occupied as an observatory site on Mount Wilson, the water rights on the mountain are to be equally divided between the owners of the property and the occupants of the observatory site. It seems probable that the wells at Strain's Camp, if properly developed, would supply the purposes of a large observatory. If not, more water could easily be developed on the mountain; it may appear desirable to obtain water from a stream in one of the neighboring cañons, about 1000 feet below. The expense of pumping to this height would be great, and the stream can be relied upon as a never-failing source of water. A water-tunnel on the south face of the mountain has been reserved by the owners of the property for the purpose of supplying Martin's Camp, and is not included in the equal division of the remaining water rights. A method of securing more water, which could undoubtedly be employed with advantage, would be through the use of large storage tanks, in which water could be collected during the rainy season, either by pumping from the overflowing wells or by catching the rain as it falls on roofs or other large surfaces provided for the purpose.

TRANSPORTATION AND CONSTRUCTION

Much granite is available on Mount Wilson for the purpose of construction, but in the portion of the mountain selected for the observatory site it is not so easily obtained as might be wished. This is due to the fact that much of the granite is decomposed, and consequently too soft for building purposes. The hard and the decomposed granites occur together, so that if a quarry is started at a point where plenty of hard granite seems to be present, it sometimes happens that the supply is soon exhausted, leaving only decomposed granite below. Men experienced in matters of this kind have been quite unable to judge whether selected spots could be relied upon to furnish a good supply of hard granite. This fact greatly increases the expense of constructing stone piers, since quarries may have to be abandoned after having been opened at considerable cost. However, some abundant sources of excellent stone can be rendered easily accessible by the extension of roads constructed for work now in progress.

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Numerous fallen trees on Mount Wilson, which are not yet greatly decayed, will furnish an abundant supply of firewood for many years to come. They cannot be depended upon, however, to yield any wood for building purposes, and as the living trees may not be destroyed, all lumber must be taken to the summit of the mountain from Pasadena. This raises the question of transportation over the mountain trail—a matter of vital importance in constructing an observatory. The "Toll Road" or "New Trail," which extends from the summit of the mountain to the foot of Eaton Cañon, is well adapted for all ordinary packing with animals, though it is much too narrow to permit wagons to pass over it. At present, all except the heaviest articles are taken to the summit of the mountain by means of burros and pack-mules, each of which can carry a load ranging from 80 to 200 pounds. It is evident that transportation of building materials by this means must be very slow and expensive, since the trail is nine miles in length to the foot of Eaton Cañon, six and one-half miles distant by road from Pasadena. But, as compared with most mountains, Mount Wilson is unusually accessible from cities, Pasadena being so close at hand, and Los Angeles, with its large sources of supply, being only nine miles farther away.

For transporting heavy castings and other similar articles, we have found it necessary to construct a special four-wheel carriage, two feet in width. On this loads of a thousand pounds have been taken to the summit without difficulty. By widening the trail to six feet, the heaviest castings required for a solar observatory probably could be transported.

WEATHER

So far as cloudiness is concerned, the records of the Weather Bureau at Los Angeles are of comparatively little value for our present purposes. The fog rolls in from the ocean night after night, and sometimes hangs over Los Angeles throughout the day during the winter season. But Mount Wilson reaches far above this layer of clouds, and thus frequently enjoys sunshine when the valley below is completely covered. Our daily percentage record of cloudiness, beginning on April 18, 1904, may be found in the following table. A dash signifies that no observation was made.

There were many days which were cloudy at the time of observation, but nevertheless suitable at other hours for solar work. Adding these to the record, it may be said that the actual number of days on

CLOUDINESS

Day of Month	April		May		June		July		August	
	8 A. M.	6 P. M.	8 A. M.	6 P. M.	8 A. M.	6 P. M.	8 A. M.	6 P. M.	8 A. M.	6 P. M.
1	...	...	100	20	75	75	0	0	0	0
2	...	...	0	5	5	0	0	0	0	0
3	...	...	0	0	0	0	0	0	90	10
4	...	...	0	0	0	0	0	0	5	25
5	...	...	0	0	0	0	0	0	0	0
6	...	...	0	0	0	0	0	0	30	100
7	...	...	0	0	0	0	0	—	40	60
8	...	...	0	0	0	0	0	10	50	40
9	...	...	70	85	0	0	0	—	0	0
10	...	...	5	5	0	0	—	—	0	0
11	...	...	0	0	0	0	0	0	0	0
12	...	...	0	0	0	0	0	0	30	50
13	...	...	0	0	0	0	0	0	20	20
14	...	...	0	0	0	0	0	0	80	80
15	...	...	0	0	0	25	0	0	0	0
16	...	...	0	0	5	0	0	—	0	5
17	..	...	0	0	0	0	—	—	0	0
18	...	...	0	0	0	10	—	0	10	5
19	100	100	0	0	0	0	0	0	0	0
20	50	5	0	75	0	0	5	5	0	0
21	0	0	25	5	0	0	—	50	0	5
22	70	100	0	50	0	0	45	5	75	80
23	0	0	5	5	0	0	35	5	20	30
24	0	5	0	0	0	0	5	10	60	5
25	75	0	100	100	0	0	35	15	5	5
26	100	100	100	0	0	0	20	15	5	5
27	0	100	0	0	0	0	12	7	0	5
28	80	100	0	0	0	0	15	5	0	5
29	0	0	10	75	0	0	10	5	0	5
30	0	—	0	0	0	0	5	—	5	80
31	...	...	0	0	...	...	—	—	80	5

which observations could be made amount to 132 out of 135. The long periods of perfectly clear weather, permitting observations of the Sun to be made without interruption from day to day, should prove of the greatest importance in the study of many solar problems which require daily observations for their solution. From the records so far obtained, it seems probable that observations of the Sun could be made at Mount Wilson on more than 300 days in a year. In Los Angeles, during the past twenty-three years, the average number of "clear" days in the year is 317.

CLOUDINESS

Day of Month	September		October		November		December	
	8 A. M.	6 P. M.	8 A. M.	6 P. M.	8 A. M.	6 P. M.	8 A. M.	6 P. M.
1	0	0	15	10	80	90	100	100
2	0	0	0	0	0	0	100	100
3	0	5	15	60	0	0	0	5
4	0	60	80	50	5	40	80	25
5	0	40	0	50	3	60	5	3
6	5	0	100	100	20	20	0	0
7	0	0	100	100	0	30	5	3
8	0	5	100	—	30	0	5	3
9	10	60	—	—	0	5	5	95
10	0	0	—	10	15	5	0	0
11	0	5	60	40	3	0	10	25
12	0	60	0	0	80	70	—	0
13	0	5	0	0	80	5	10	70
14	0	0	0	0	7	75	20	50
15	3	15	20	10	95	50	40	40
16	60	3	0	0	5	0	5	0
17	50	40	0	0	0	0	10	3
18	20	5	0	0	15	0	5	0
19	40	50	0	0	5	0	0	5
20	70	40	0	0	3	10	15	50
21	75	95	0	0	60	15	90	95
22	100	30	0	0	10	3	100	10
23	100	100	0	0	0	5	90	5
24	100	100	0	0	—	—	100	100
25	100	100	0	3	—	15	5	5
26	100	98	0	0	50	30	—	—
27	—	—	0	0	70	10	—	—
28	—	0	0	3	5	5	0	5
29	0	40	0	15	0	3	60	0
30	0	3	50	3	20	40	3	95
31	..	..	0	0	..	..	100	30

The cloudiness in July and August was due almost entirely to thunderstorms over the desert to the north and east. The clouds rarely reached our zenith and almost never interfered with the regular solar observations (cf. table of Seeing).

HUMIDITY

The question of humidity is of special importance in connection with the measurement of the solar constant, since water-vapor in the atmosphere absorbs very strongly the solar heat. The results obtained with a standard sling psychrometer, Weather Bureau pattern, are given in the following table:

RELATIVE HUMIDITY AT MOUNT WILSON

Day of Month	April		May		June		July		August	
	8 A. M.	6 P. M.	8 A. M.	6 P. M.	8 A. M.	6 P. M.	8 A. M.	6 P. M.	8 A. M.	6 P. M.
1	..	..	100	80	40	36	34	24	22	27
2	..	..	57	80	39	39	23	38	22	33
3	..	..	34	66	39	41	30	32	29	30
4	..	..	46	49	24	25	38	56	32	40
5	..	..	38	38	20	24	34	42	40	43
6	..	..	29	40	27	42	45	43	34	43
7	..	..	36	31	29	41	49	—	—	76
8	..	..	18	22	23	29	33	18	64	58
9	..	..	15	24	20	34	42	—	41	46
10	..	..	22	41	21	21	—	—	28	35
11	..	..	36	38	19	17	57	24	30	33
12	..	..	36	54	—	—	29	40	53	65
13	..	..	41	40	—	43	46	22	61	64
14	..	..	32	64	52	42	25	25	67	72
15	..	..	23	29	32	30	30	44	54	45
16	..	..	27	19	34	30	50	—	37	36
17	..	..	34	38	33	24	—	—	40	30
18	—	85	25	66	32	41	—	16	34	45
19	100	100	46	64	31	42	22	24	32	46
20	96	73	41	100	56	72	21	19	23	40
21	60	79	42	45	45	53	—	42	37	33
22	92	98	28	43	40	43	24	34	58	85
23	63	65	37	32	44	54	35	35	79	79
24	60	50	38	50	42	32	31	26	77	56
25	29	68	100	100	30	27	33	50	69	58
26	100	100	100	48	28	25	38	27	67	37
27	100	100	37	38	27	36	31	50	40	43
28	100	100	38	33	42	35	30	32	43	33
29	46	36	23	15	35	30	50	46	21	29
30	58	71	14	47	30	37	38	—	27	14
31	..	..	30	35	..	..	—	—	14	31
Means...	77		43		34		33		43	

The marked dryness of the atmosphere on Mount Wilson during the summer months may be best appreciated by comparing these results with those obtained by the Weather Bureau at Washington during the corresponding period.

RELATIVE HUMIDITY AT WASHINGTON

Month	Mean	Maximum[1]	Minimum[1]
April	63.0	100	30
May	65.6	97	41
June	77.8	98	54
July	60.6	99	51
August	78.0	95	59

[1] Mean maximum and mean minimum humidity not determined.

RELATIVE HUMIDITY AT MOUNT WILSON

Day of Month	September		October		November		December	
	8 A. M.	6 P. M.	8 A. M.	6 P. M.	8 A. M.	6 P. M.	8 A. M.	6 P. M.
1	26	29	47	38	62	46	100	100
2	38	24	49	48	84	89	100	100
3	31	38	42	37	72	83	70	57
4	43	43	60	63	71	53	63	49
5	31	22	69	100	49	53	58	52
6	22	25	100	100	63	57	53	47
7	20	18	100	100	38	57	59	43
8	30	40	100	—	52	35	47	59
9	41	39	—	—	37	51	57	51
10	53	48	—	86	56	61	12	14
11	48	45	100	100	54	26	12	17
12	60	63	53	56	48	44	19	42
13	57	63	53	47	61	30	48	43
14	51	28	56	60	22	21	33	30
15	37	43	67	77	28	56	18	—
16	41	27	67	55	57	50	—	21
17	32	66	49	54	72	41	20	30
18	54	78	44	52	71	81	26	35
19	60	37	59	66	59	35	42	28
20	46	49	67	68	60	34	29	34
21	32	67	33	31	69	29	42	65
22	93	93	20	27	59	57	100	84
23	94	100	22	34	55	47	91	95
24	100	100	24	28	—	—	100	100
25	100	100	23	27	—	32	81	81
26	100	80	26	34	65	41	—	—
27	—	—	29	47	31	29	—	—
28	—	64	46	71	53	50	56	45
29	60	52	41	66	36	40	50	56
30	57	47	66	81	49	62	38	90
31	..	.	78	40	..	..	100	83
Means	52		57		51		55	

The chief of the Weather Bureau has also kindly sent the following data as to the mean relative humidity at Washington for the remainder of the year. The two values refer to the results for 8 A. M. and 8 P. M., respectively. September, 84.8, 78.2; October, 80.8, 71.7; November, 76.2, 66.9; December, 77.8, 70.6.

TEMPERATURE

From March 25 to April 15 the temperature was recorded on a self-registering thermometer. After April 15 this record was supplemented by observations of maximum and minimum thermometers.

The results are given (in degrees Fahrenheit) in the following table. As bearing upon certain classes of night observations, the range of temperature between 8 P. M. and 4 A. M. is also included.

TEMPERATURE

Day of Month	April			May			June			July			August		
	Maximum	Minimum	Range 8 P. M. to 4 A. M.	Maximum	Minimum	Range 8 P. M. to 4 A. M.	Maximum	Minimum	Range 8 P. M. to 4 A. M.	Maximum	Minimum	Range 8 P. M. to 4 A. M.	Maximum	Minimum	Range 8 P. M. to 4 A. M.
1	..	..	..	49	32	8	76	46	4	93	57	5	83	57	3
2	..	..	..	56	27	4	82	53	1	81	58	5	90	63	5
3	..	..	..	64	39	4	89	55	2	79	56	8	91	66	3
4	..	..	..	70	42	5	80	56	7	80	56	3	89	66	5
5	..	..	..	79	45	7	81	59	5	77	54	6	91	66	2
6	..	..	..	80	55	2	78	57	6	75	55	6	92	68	2
7	..	.	..	84	51	8	75	48	9	—	—	5	—	—	6
8	..	..	..	84	55	7	79	52	3	76	52	6	83	64	3
9	..	..	..	85	57	5	83	57	4	—	—	2	87	60	6
10	.	..	..	86	57	5	82	61	5	—	—	2	86	64	4
11	..	..	.	79	57	2	87	60	4	82	57	5	87	63	4
12	..	..	.	85	54	2	—	—	5	86	56	4	88	62	5
13	..	..	..	75	56	4	—	—	5	89	59	3	85	64	3
14	..	..	..	79	50	6	77	57	6	83	63	7	83	60	3
15	..	.	..	85	53	4	80	54	4	75	57	4	86	60	2
16	..	..	..	82	57	4	79	53	5	72	50	4	87	60	5
17	..	..	..	79	56	5	81	56	5	84	63	6	87	62	5
18	53	37	6	75	49	4	83	55	8	93	61	1	88	63	4
19	42	35	3	56	36	8	79	59	5	95	66	3	93	64	5
20	41	23	6	74	45	1	73	51	7	91	69	1	90	65	5
21	49	34	1	78	50	5	86	50	1	—	—	2	86	59	8
22	46	32	5	81	51	4	83	55	2	82	62	4	77	60	2
23	49	25	9	78	56	3	78	55	6	89	62	2	78	56	2
24	63	36	3	69	54	4	78	53	6	91	66	3	81	56	0
25	64	40	4	52	38	10	87	56	3	88	68	4	85	61	2
26	43	29	8	53	35	3	88	62	1	82	66	3	89	62	3
27	43	23	4	69	41	0	85	63	5	88	62	2	87	64	2
28	44	31	0	75	49	5	79	57	4	83	68	5	87	62	2
29	63	36	2	71	50	5	79	55	3	83	62	7	87	62	2
30	65	41	5	70	46	6	78	53	5	—	—	3	81	59	4
31	—	—	—	77	45	4	—	—	—	—	—	4	82	59	3
Means	51.2	32.7	4.3	73.5	48.0	4.7	80.9	55.3	4.5	84.0	60.2	4.0	86.2	61.9	3.5
Daily r'ge	18.5		....	25.5		....	25.6		...	23.8		....	24.3		....

TEMPERATURE

Day of Month	September			October			November			December		
	Maximum	Minimum	Range 8 P. M. to 4 A. M.	Maximum	Minimum	Range 8 P. M. to 4 A. M.	Maximum	Minimum	Range 8 P. M. to 4 A. M.	Maximum	Minimum	Range 8 P. M. to 4 A. M.
1	87	60	3	79	60	5	75	48	2	60	38	4
2	90	66	2	83	54	5	63	42	7	48	36	4
3	91	66	3	84	55	4	78	40	3	59	33	4
4	89	63	5	87	59	2	71	46	3	64	35	2
5	93	65	5	66	47	3	70	45	2	60	29	7
6	97	67	4	56	37	8	72	46	1	63	31	3
7	97	69	4	49	39	2	80	49	3	64	33	2
8	87	68	5	—	—	0	84	49	2	61	37	1
9	87	63	7	—	—	2	82	51	2	66	37	2
10	83	59	7	67	—	2	82	52	3	74	41	1
11	83	59	3	56	43	7	76	47	5	72	42	4
12	86	57	3	72	36	4	69	49	7	68	37	5
13	85	58	4	74	45	4	72	42	3	70	36	4
14	87	58	1	71	48	5	72	48	1	66	44	1
15	83	59	2	67	43	5	64	44	3	—	44	5
16	81	59	3	75	43	4	74	38	6	66	52	—
17	74	50	4	75	39	6	73	47	2	65	41	2
18	71	44	5	77	42	2	67	45	3	67	49	2
19	78	49	2	82	46	3	76	42	5	69	42	3
20	76	50	3	84	46	4	78	47	2	67	50	2
21	72	52	3	81	50	4	80	50	3	60	39	3
22	51	41	7	83	53	4	73	50	3	44	32	5
23	51	39	4	79	54	4	72	49	2	45	33	2
24	54	41	2	82	54	2	—	—	1	41	35	2
25	52	43	1	82	54	3	72	—	1	50	31	5
26	52	36	6	78	52	3	77	51	3	—	—	3
27	—	—	2	74	47	6	73	52	2	—	—	3
28	75	—	3	72	47	3	73	50	3	56	34	5
29	82	50	3	67	47	1	75	49	2	59	44	3
30	81	52	5	67	46	2	72	45	2	54	38	4
31	..	..	..	75	43	3	..	..	..	43	33	4
Means	78.4	55.1	3.7	73.9	47.5	3.6	74.0	46.9	2.9	60.0	38.1	3.1
Daily range	23.3			26.4			27.1			21.9		

ATMOSPHERIC PRESSURE

No complete barometric record has been kept, since this did not seem of special importance in connection with the work. Nevertheless, an aneroid barometer has been read twice daily since July 13. The maximum and minimum readings recorded up to September 1 differed by only 0.22 inch.

WIND MOVEMENT

With such uniformity of atmospheric pressure, it might naturally be anticipated that the wind movement would be low. The results of anemometer readings (in miles), made with an instrument of the standard Weather Bureau pattern, are shown in the following table. The "day" results give the total movement from 8 A. M. to 6 P. M.; the "night" results give the total movement from 6 P. M. to 8 A. M.

Day of Month	April		May		June		July		August	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
1	...	...	99	75	120	175	55	145	43	95
2	...	...	49	165	71	141	71	102	50	72
3	...	...	52	118	44	185	47	71	45	61
4	...	...	29	88	44	114	34	41	46	48
5	...	...	43	91	61	47	30	54	60	41
6	...	...	30	62	78	108	43	78	43	49
7	...	...	34	128	59	155	40	44	47	80
8	...	...	43	106	55	146	49	85	33	63
9	...	...	38	44	50	66	44	83	43	60
10	...	...	44	133	52	86	43	77	62	78
11	...	...	54	110	43	49	49	93	49	81
12	...	...	35	101	32	75	31	74	58	122
13	...	...	41	80	30	95	42	81	59	71
14	..	...	39	95	23	133	42	59	44	73
15	...	...	72	114	49	61	39	68	44	55
16	...	. .	42	110	56	80	33	50	45	80
17	...	...	46	81	40	58	40	70	44	60
18	. .	...	50	56	37	56	32	62	26	55
19	140	188	105	136	30	47	38	78	37	58
20	62	70	45	48	36	74	63	91	36	100
21	35	144	63	71	56	90	37	60	39	55
22	40	42	66	82	37	56	43	37	63	104
23	47	120	67	97	74	103	44	85	63	113
24	32	109	69	79	44	86	60	64	55	101
25	70	63	63	136	52	51	44	56	50	64
26	91	191	33	60	55	59	39	71	35	66
27	44	51	50	58	75	51	47	80	56	84
28	33	34	21	101	42	52	41	57	54	107
29	50	101	62	73	37	60	56	65	55	56
30	47	63	51	80	56	46	57	131	57	69
31	...	. .	57	151	...	...	53	97	38	54
Total	691	1,176	1,592	2,929	1,538	2,605	1,386	2,309	1,479	2,275
Means	57.6	96.0	51.3	94.5	51.3	86.6	44.7	74.5	47.7	73.4
Hourly means	5.8	6.8	5.1	6.7	5.1	6.2	4.5	5.3	4.8	5.2

It appears from these results that the average wind movement is exceptionally low. The importance of this fact in its indication of a uniform atmosphere, and in connection with astronomical photog-

WIND MOVEMENT

Day of Month	September		October		November		December	
	Day	Night	Day	Night	Day	Night	Day	Night
1	34	76	43	60	61	71	27	81
2	51	30	39	32	42	123	36	70
3	52	67	38	58	44	130	34	82
4	40	70	50	81	55	47	42	137
5	49	71	58	100	38	88	80	120
6	50	97	44	125	41	95	40	141
7	51	48	85	56	38	64	42	78
8	50	88	—	129	48	97	36	62
9	47	68	—	—	41	144	38	66
10	35	54	—	—	36	151	66	106
11	37	53	68	86	32	45	37	59
12	42	44	40	102	35	148	65	165
13	46	73	41	52	25	53	38	154
14	47	71	53	83	49	46	38	56
15	66	86	40	117	35	105	53	69
16	73	81	50	79	37	71	39	68
17	51	101	89	207	56	93	31	56
18	33	91	50	139	44	92	31	53
19	38	83	65	128	39	48	33	64
20	36	71	47	194	29	51	37	51
21	80	52	37	125	39	73	85	74
22	37	110	46	45	59	110	64	101
23	83	84	45	44	65	141	36	46
24	72	161	36	74	—	—	82	113
25	70	163	38	66	—	—	66	142
26	64	101	36	55	53	91	—	—
27	—	—	42	49	46	91	—	—
28	—	—	53	62	45	47	37	69
29	64	158	64	94	47	73	57	48
30	58	53	39	66	65	165	122	146
31	..	..	42	73	..	..	60	200
Means	52.0	82.3	49.2	89.0	44.4	91.2	50.1	92.3
Hourly means	5.2	5.9	4.9	6.4	4.4	6.5	5.0	6.6

raphy, will be appreciated by astronomers. The shaking of a large instrument by the wind is frequently so serious as to reduce greatly the quality of astronomical photographs obtained in windy weather. At Mount Wilson, where a dead calm is an exceedingly common occurrence, all of the most exacting requirements of astronomical photography are completely realized.

TRANSPARENCY OF THE ATMOSPHERE

I have previously alluded to the dust-storms which sometimes enter the San Gabriel Valley through the Cajon Pass from the Mojave Desert, and those much rarer storms in which the dust is carried by

the wind completely over the Sierra Madre Mountains. In the more common form of dust-storm (the so-called "Santa Ana") the dust enters the valley in a fairly well-defined mass and proceeds westward along the cañon of the Santa Aña River. In approaching the coast it spreads over a large area and diffuses itself with tolerable uniformity through the lower atmosphere. I have seen from Mount Wilson a dust-storm in the region of Riverside, which in twenty-four hours had spread itself over Los Angeles and Pasadena. When it reached this part of the valley there was almost no wind, and the dust seemed to diffuse itself through the air. Such storms sometimes completely hide the Sierra Madre Mountains from observers in Pasadena. Fortunately they are almost always confined to the lower atmosphere, and do not appreciably affect the transparency of the sky above Mount Wilson, where daily observations show that the transparency of the day and night sky are very satisfactory.

SEEING

Systematic tests of the definition of the solar image have been made on Mount Wilson with a telescope of $3\frac{1}{4}$ inches aperture, with an eyepiece giving a power of about 100 diameters. At first the character of the seeing was rated on a scale of 5; but it soon appeared that a scale of 10 would be preferable under the existing conditions. Accordingly, the seeing as recorded in the following table is given on a scale of 10. Seeing 8, which is so frequently obtained during the early morning hours, represents a sharply defined image of the Sun, showing the granulation and the details of the spots with great distinctness, and indicating practically no trembling at the limb. Such seeing occurs at the Yerkes Observatory only occasionally, although that observatory seems to be better situated than many other institutions for work on the Sun.

An examination of the table will show that the seeing is best during the early morning hours, although the image is frequently very good in the late afternoon. Shortly after sunrise the Sun's limb is serrated, but this effect becomes less and less marked as the Sun's altitude increases. Usually, at this time in the morning, the atmosphere is almost perfectly calm and cloudless. The seeing usually improves and reaches a maximum, where it remains for some time. The effect

SEEING

April	Hour of Observation								
	6	7	8	9	10-2	3	4	5	6
1...	–	5	5	4	4	4	5	4	–
2...	–	–	5	6	5	5	4	4	–
3...	–	5	6	7	6	–	–	–	–
4...	–	5	6	7	6	3	5	–	–
5...	–	8	8	8	7	–	8	8	6
6...	–	6	7	6	4	7	7	5	–
7...	–	9	8	7	7	6	7	7	5
8...	–	–	7	–	–	–	–	–	–
9...	–	5	5	4	4	4	5	4	–
10...	6	7	7	6	6	7	–	–	–
11...	7	9	7	6	6	7	–	–	–
12...	–	7	7	6	–	–	–	–	–
13...	–	8	8	7	–	–	7	8	7
14...	–	6	6	6	5	5	4	–	–
15...	–	–	–	–	–	–	–	–	–

April	Hour of Observation								
	6	7	8	9	10-2	3	4	5	6
16...	–	5	–	5	–	–	–	4	–
17...	–	–	5	4	4	6	6	–	–
18...	–	6	7	–	–	–	–	–	–
19[1]..	–	–	–	–	–	–	–	–	–
20...	–	6	5	–	–	–	–	–	–
21...	–	6	7	6	5	4	6	6	–
22[1]..	–	–	–	–	4	–	–	–	–
23...	–	–	5	4	4	4	4	–	–
24...	–	–	7	6	5	5	6	6	7
25...	–	–	–	–	4	4	4	4	–
26[2]..	–	–	–	–	–	–	–	–	–
27[1]..	–	6	4	–	–	–	–	–	–
28[1]..	–	6	–	–	–	–	–	–	–
29...	–	7	6	6	4	5	6	–	–
30...	6	7	4	4	4	4	6	–	–

May	Hour of Observation								
	6	7	8	9	10-2	3	4	5	6
1[2]..	–	–	–	–	–	–	–	–	–
2...	–	5	4	4	3	2	2	2	–
3...	–	7	6	7	5	4	6	–	–
4...	–	6	6	5	4	5	5	–	–
5...	–	7	–	–	4	5	5	4	–
6...	7	8	6	–	–	–	–	–	–
7...	5	4	4	4	4	4	4	4	–
8...	–	7	7	5	–	–	–	–	–
9[3]..	–	–	5	–	–	–	–	–	–
10...	–	5	6	5	5	–	–	–	–
11...	–	6	5	5	4	–	–	–	–
12...	–	–	–	–	–	–	–	–	–
13...	–	–	–	–	–	–	–	–	–
14...	–	–	–	–	–	–	–	–	–
15...	–	5	6	5	–	–	–	–	–
16...	6	–	–	7	7	–	6	6	–
17...	–	–	–	–	–	–	–	–	–
18...	–	–	–	–	–	–	–	–	–
19...	–	–	–	–	–	–	–	–	–
20...	–	–	–	–	–	–	–	–	–
21...	–	–	–	–	–	–	5	–	–
22...	–	6	7	8	–	4	–	–	–
23...	–	6	–	6	5	–	6	–	–
24...	–	8	–	6	6	–	5	–	–
25[1]..	–	–	–	–	–	–	–	–	–
26[1]..	–	–	–	–	–	–	–	8	–
27...	–	8	7	6	6	7	7	8	–
28...	–	8	8	–	7	–	8	–	7
29...	–	9	8	8	8	–	–	–	–
30...	–	7	8	8	7	6	6	7	–
31...	–	6	7	–	6	6	7	–	–

June	Hour of Observation								
	6	7	8	9	10-2	3	4	5	6
13...	–	–	–	–	–	–	6	–	–
2...	–	–	7	6	6	6	6	6	–
3...	–	6	6	6	6	6	6	6	–
4...	–	6	–	7	5	–	–	–	–
5...	–	8	8	–	7	–	6	–	4
6...	–	9	9	8	7	7	–	–	–
7...	–	7	–	–	4	4	6	–	7
8...	–	8	8	–	6	–	–	7	6
9...	–	9	8	6	6	–	6	7	–
10...	–	9	8	–	7	–	–	7	–
11...	–	9	8	–	6	–	8	7	9
12...	–	9	–	–	–	–	–	–	–
13...	–	–	–	–	–	–	–	–	–
14...	–	–	–	–	–	–	–	8	–
15...	–	9	8	7	6	–	7	7	–
16...	–	9	8	–	7	–	8	7	8
17...	–	9	9	7	7	5	–	7	8
18...	–	8	7	–	5	–	7	8	7
19...	–	9	6	6	4	–	–	7	–
20...	6	6	–	6	5	7	7	–	6
21...	–	6	6	–	5	–	6	–	6
22...	8	–	8	6	6	6	7	8	8
23...	–	8	7	–	7	–	7	8	–
24...	–	9	8	–	6	–	7	8	–
25...	8	9	7	–	7	–	7	7	–
26...	–	9	8	8	6	–	6	6	–
27...	–	8	8	7	7	–	–	5	6
28...	8	8	–	–	6	–	6	6	–
29...	8	9	–	6	6	–	–	8	–
30...	8	9	–	8	8	8	8	8	7

[1] Rain. [2] Snow. [3] Cloudy.

July	Hour of Observation									August	Hour of Observation								
	6	7	8	9	10-2	3	4	5	6		6	7	8	9	10-2	3	4	5	6
1...	–	5	–	6	–	–	6	6	–	1...	–	–	–	6	5	6	7	8	–
2...	–	8	–	–	4	–	–	–	–	2...	6	6	6	–	4	6	7	6	–
3...	–	8	7	–	6	–	–	–	4	3...	–	7	–	–	5	–	7	7	–
4...	–	6	–	7	5	–	–	–	–	4...	–	6	7	7	6	6	6	7	–
5...	8	8	–	–	5	–	7	–	6	5...	–	8	8	–	5	5	–	–	–
6...	–	8	8	–	7	–	–	8	8	6...	8	8	7	6	–	–	–	–	–
7...	–	8	7	–	–	–	–	–	–	7...	–	8	–	–	–	–	–	–	–
8...	8	8	7	–	7	–	–	8	8	8...	–	8	–	–	5	6	6	6	–
9...	8	9	–	–	6	–	–	–	–	9...	6	7	–	6	4	–	7	8	8
10...	–	–	–	–	–	–	–	–	–	10...	6	7	7	–	5	6	–	6	–
11...	–	8	6	–	5	–	7	8	6	11...	7	7	6	–	5	6	–	6	–
12...	8	9	8	–	5	6	7	7	7	12...	6	5	–	–	5	6	–	6	–
13...	8	8	7	7	6	–	–	8	7	13[4]....	6	–	–	–	–	–	4	–	
14...	8	8	7	–	6	–	7	7	7	14[4]..	–	7	–	–	–	–	–	–	–
15...	–	7	6	5	4	4	6	7	–	15...	–	7	–	–	–	–	8	–	6
16...	–	5	4	4	–	–	–	–	–	16...	8	7	–	–	4	–	8	–	7
17...	–	–	–	–	–	–	–	–	–	17...	–	8	7	–	7	–	7	7	–
18...	8	8	8	7	6	–	–	–	–	18...	8	7	6	–	5	–	7	7	–
19...	6	8	7	7	6	–	–	–	–	19...	7	8	–	–	6	–	7	7	–
20...	7	8	7	6	4	–	6	8	7	20...	5	6	6	–	6	–	6	6	–
21...	–	–	–	–	–	–	–	–	–	21...	–	8	8	–	6	–	7	–	6
22...	–	7	–	6	5	–	6	7	–	22[1] ..	–	–	–	6	–	–	–	–	–
23...	–	7	–	6	5	–	6	7	–	23...	–	–	8	–	–	–	–	7	–
24...	–	7	–	–	–	–	–	–	–	24...	–	6	–	–	5	–	–	6	–
25...	–	6	5	4	4	4	5	–	–	25...	8	7	6	–	5	–	6	–	6
26...	–	–	6	5	4	5	6	7	–	26...	–	9	7	–	5	–	7	–	6
27...	–	6	5	4	4	5	6	7	–	27...	8	8	7	–	6	–	7	–	6
28...	7	8	7	–	4	–	–	4	–	28...	–	8	7	6	5	–	7	6	–
29...	–	7	6	–	4	–	8	7	–	29...	–	8	7	–	5	–	–	–	7
30...	–	8	7	6	6	–	–	–	–	30...	–	8	7	–	5	–	–	–	7
31...	–	–	–	–	–	–	–	–	–	31[3] ..	–	3	–	–	–	8	–	6	–

of the heating of the mountain then becomes apparent and the definition deteriorates. The disturbances at the Sun's limb under these conditions do not resemble those seen immediately after sunrise, but have a fluttering appearance, which we are accustomed to speak of as the "heating effect." In the late afternoon the seeing usually improves, but it is rarely very good at midday. This is not a rule without exceptions, however, as we have sometimes recorded nearly perfect definition during the hottest hours of the day.

Everyone who has noted the heated air above the surface of the ground will wonder, in considering the effect of such disturbances upon solar observations, whether these disturbances rise to a great height. A casual observation is sufficient to show that the disturb-

[1] Rain [2] Snow [3] Cloudy [4] Storm.

SEEING

September	Hour of Observation							October	Hour of Observation						
	7	8	9	10-2	3	4	5		7	8	9	10-2	3	4	5
1	8	6	–	5	–	7	7	1	7	6	–	5	–	7	6
2	7	8	6	5	–	7	6	2	8	7	–	5	–	–	–
3	8	6	6	5	–	–	7	3	8	7	6	5	–	7	–
4[3]	8	7	–	–	–	–	6	4[3]	–	–	–	–	–	6	–
5[3]	7	6	–	–	6	–	–	5[5]	8	–	–	–	–	–	–
6	8	7	6	5	–	–	7	6[9]	–	–	–	–	–	–	–
7	8	7	6	5	6	–	–	7[9]	–	–	–	–	–	–	–
8	8	7	–	5	–	7	7	8[9]	–	–	–	–	–	–	–
9	8	7	6	5	6	–	–	9[9]	–	–	–	–	–	–	–
10	8	–	6	5	–	7	6	10[9]	–	–	–	–	–	6	–
11	7	7	6	5	–	7	7	11[5]	7	6	–	–	–	–	–
12[3]	8	7	–	–	–	–	–	12	7	8	7	5	–	6	–
13	8	6	–	5	5	–	–	13	6	8	6	6	–	6	–
14	7	6	–	5	–	–	4	14	7	8	7	6	–	7	–
15	8	7	–	5	–	–	6	15	7	7	–	5	–	6	–
16	7	6	–	5	–	7	6	16	6	7	–	6	–	–	–
17[3]	7	6	–	–	–	–	–	17	6	6	–	5	–	6	–
18[5]	7	6	–	–	–	–	–	18	6	6	–	6	–	6	–
19	7	7	–	5	–	–	7	19	6	7	–	6	–	6	–
20[3]	7	6	–	–	–	–	–	20[6]	3	–	6	5	–	–	5
21[3]	–	–	–	–	–	–	–	21	6	6	–	5	–	6	–
22[9]	–	–	–	–	–	–	–	22	7	8	7	5	–	6	–
23[9]	–	–	–	–	–	–	–	23	7	7	7	5	–	6	–
24[9]	–	–	–	–	–	–	–	24	8	8	–	6	7	6	–
25[9]	–	–	–	–	–	–	–	25	7	8	–	6	6	8	–
26[9]	–	–	–	–	–	–	–	26	7	8	–	6	6	–	–
27	–	–	–	–	–	–	–	27	6	7	–	5	6	–	–
28	–	–	–	–	–	–	–	28	6	8	–	5	–	–	–
29	7	–	6	5	–	7	–	29	8	8	6	5	–	–	–
30	7	6	–	5	–	6	–	30[3]	–	–	5	5	8	7	–
								31	8	7	–	5	7	–	–

ance decreases rapidly in passing upward from the ground, but it is, of course, quite impossible to determine by means of the unaided eye the probable effect of this disturbance on telescopic observations. We have accordingly made many observations of the Sun with the $3\frac{1}{4}$-inch telescope supported in a pine tree at heights above the ground ranging from 20 to 80 feet. The results of these observations clearly indicate that a telescope employed in solar work should be mounted as high above the ground as circumstances warrant. At the lower elevations in the tree the advantage over positions still nearer to the ground was sometimes not appreciable; but at a height of 80 feet above the ground the improvement in definition was very distinct. Probably

3 Cloudy. 5 Fog. 6 High wind. 9 Fog and rain.

SEEING

November	Hour of Observation							December	Hour of Observation						
	7	8	9	10-2	3	4	5		7	8	9	10-2	3	4	5
13.....	–	–	–	6	6	6	–	15.....	–	–	–	–	–	–	–
23.....	5	–	–	–	6	–	–	25.....	–	–	–	–	–	–	–
3.....	6	6	–	5	6	–	–	37.....	6	–	–	–	–	–	–
43.....	8	7	–	5	–	–	–	43.....	–	–	–	–	–	–	–
5.....	7	7	–	5	–	–	–	58.....	–	5	–	–	–	–	–
6.....	–	8	7	5	6	–	–	6.....	5	6	–	5	5	–	–
7.....	7	7	–	6	6	–	–	7.....	–	6	–	6	6	–	–
8.....	7	–	–	5	6	–	–	8.....	–	6	–	5	6	–	–
9.....	6	–	–	5	6	–	–	9.....	–	7	–	6	6	–	–
10.....	5	6	–	5	5	–	–	10.....	–	–	–	–	–	–	–
11.....	6	8	–	5	5	–	–	11.....	–	–	–	–	–	–	–
123.....	–	–	–	–	–	–	–	12.....	–	–	–	–	–	–	–
133.....	–	–	–	–	6	–	–	13.....	–	6	6	5	6	–	–
14.....	6	6	–	5	–	–	–	14.....	–	7	–	5	6	5	–
15.....	–	–	–	–	6	–	–	15.....	–	6	–	5	5	–	–
16.....	7	7	–	5	6	–	–	16.....	–	8	7	6	6	–	–
17.....	8	7	–	6	6	–	–	17.....	–	8	–	6	6	–	–
18.....	7	7	–	5	6	–	–	18.....	–	8	–	6	7	–	–
19.....	7	8	–	6	–	–	–	19.....	–	8	7	5	6	–	–
20.....	–	7	6	6	6	–	–	203.....	–	7	–	–	–	–	–
21.....	7	7	–	6	–	–	–	213.....	–	–	–	–	–	–	–
22.....	7	8	–	6	7	–	–	229.....	–	–	–	–	–	–	–
23.....	7	7	–	6	7	–	–	239.....	–	–	–	–	–	–	–
24.....	–	–	–	–	–	–	–	249.....	–	–	–	–	–	–	–
25.....	–	–	–	–	–	–	–	25.....	–	–	6	–	6	–	–
26.....	6	7	–	5	–	–	–	26.....	–	–	–	–	–	–	–
273.....	–	–	–	5	6	–	–	27.....	–	–	–	–	–	–	–
28.....	7	7	–	5	7	–	–	28.....	–	7	6	5	6	–	–
29.....	7	7	7	6	5	–	–	29.....	–	8	7	6	6	–	–
303.....	–	6	–	–	–	–	–	303.....	–	–	7	–	–	–	–
								319.....	–	–	–	–	–	–	–

this is one of the reasons why the solar definition with the 40-inch Yerkes telescope averages considerably better than we expected it would, for with this telescope the object-glass is over 70 feet above the ground.

OBSERVATIONS WITH THE FIFTEEN-INCH CŒLOSTAT TELESCOPE

In March 1904 a cœlostat of 15 inches aperture was sent to Mount Wilson from the Yerkes Observatory. This instrument had previously been employed by Professors Barnard and Ritchey, of the Yerkes Observatory party, at the solar eclipse of May 28, 1900, in Wadesboro, N. C., and by Professor Barnard at the Sumatra eclipse

3 Cloudy. 5 Fog. 7 Partly cloudy. 8 Cold and windy. 9 Fog and rain.

in 1901. As used at Mount Wilson, it is supplied with a second plane mirror, mounted south of the cœlostat, and arranged to slide on a north-and-south track in such a way as to receive the solar rays corresponding to any declination of the Sun.

The rays are reflected from this mirror toward the north to a 6-inch photographic objective of 61½ feet focal length, mounted on the extension of the stone pier just above the cœlostat. After passing through this lens the rays traverse a long tube built of wooden framework and covered with paper. The solar image is formed within a small house which terminates this tube at its north end. In the house a photographic plate-holder is mounted, in conjunction with a slide containing a narrow slit, which can be shot at high speed across the solar image by means of a spring. In this way the very short exposure required for direct photography of the Sun can be obtained.

One of the chief points of interest connected with this instrument is the effect of the heating of the air within the tube upon the definition of the solar image. In the first experiments with this apparatus, the skeleton tube was covered on all sides with tar-paper, just as it had been used in the eclipse work. Above the tube, and separated from it by a considerable air-space, was a canvas fly for the purpose of shielding the tube from the direct rays of the Sun. It was found that in the early morning, before the tube had become heated, the definition of the solar image was excellent. In a short time, however, heated air within the tube completely spoiled the definition, and the Sun's image became so blurred and indistinct that no observations of value could be made with it. These circumstances led us to question what the effect would be if no tube were employed. The 6-inch lens was therefore mounted in such a position as to throw the beam horizontally through the air toward the north, outside of the tube and over that portion of the ground which was in shadow. The image observed under these circumstances was found to be much better defined than that seen through the heated air of the tube. We accordingly decided to try the experiment of taking off all of the paper on the two sides which formed the upper half of the tube. It also seemed advisable to stretch the canvas fly at a much greater distance from the tube and to provide means of exit at the top for any heated air which might be found under the fly. As soon as the tube and fly had been re-arranged

in this manner, a great improvement was immediately noticed. The definition of the image became much better and the deterioration observed in the previous instance was no longer seen. The air in the tube remained cool, whereas before it had become greatly heated.

These experiments would seem to throw some light on the question of designing suitable tubes and shelters for telescopes used in a horizontal, or nearly horizontal, position. It seems likely that if the cœlostat and the instruments used with it could be mounted on piers at a height of 70 feet or more above the ground, it would be unnecessary to use any tube, particularly if the ground below the path of the beam were shielded from the Sun by a light canvas cover, stretched at a height of several feet above the surface and suitably ventilated. Of course, the practical difficulties in such a construction are very considerable, on account of the great cost and the lack of stability of high piers. For the Snow telescope it therefore seemed advisable to design a special form of house, in the hope of securing good definition with a solar beam at a moderate height above the ground. Experiments made with the 15-inch cœlostat seem to show that this latter instrument is too near the ground for the best results, although it gives excellent definition in the early morning, before the heating of the soil is very great.

The design of the house now under construction for the Snow telescope will be described in a subsequent report. It may be said here, however, that it consists of a skeleton frame of light steel construction, provided with a ventilated roof. The floor is to be of canvas, tightly stretched at a height of one foot above the ground and permitting a free circulation of air below. The inner walls of the house (which is 10 feet wide at its narrowest point) are to be of light canvas, so arranged that they can be raised or lowered at will. The outer walls of the house are to be covered by canvas louvres, so arranged as to shield the entire house from the direct rays of the Sun, and permitting a free circulation of air. The stone pier, 27 feet high, on which the cœlostat will stand, is also to be shielded from the Sun by canvas louvres. The ground surrounding the instrument is fairly well covered with bushes, and the few bare spots can be covered with stretched canvas, if necessary.

Spectroscopic observations.—The spectroscope used with the

cœlostat telescope is of the Littrow form: a single lens, of 4 inches aperture and 18 feet focal length, serves at once as collimator and camera lens. After passing through the slit, which is mounted in the focal plane of the photographic objective employed with the cœlostat, the rays pass to the 4-inch objective, by which they are rendered parallel. They then meet the 4-inch Rowland plane grating, having 14,438 lines to the inch, from which they are returned through the 4-inch objective. The image of the spectrum is formed on a photographic plate, mounted in the focal plane and a little to one side of the slit. This apparatus is giving excellent definition, surpassing that of any spectroscope employed at the Yerkes Observatory.

The character of the results obtained with this spectroscope, and its convenience of manipulation, illustrate one of the arguments in favor of fixed telescopes of the cœlostat type, as contrasted with moving equatorial telescopes. At the Yerkes Observatory it has never been possible to attach a sufficiently long and powerful spectroscope to the moving tube of the 40-inch refractor. Such a spectroscope must be mounted in a fixed position on substantial piers, and the telescope must be so constructed as to permit a sharp and well-defined image of the Sun to be maintained in a fixed position on the slit. This can readily be accomplished with the aid of a cœlostat, provided only that the difficulties peculiar to this type of telescope can be overcome. From the experiments so far made, we believe that the difficulties can be surmounted and that the fixed telescope is certain to become an instrument of great importance in the future.

CONCLUSION

From the observations given in this paper, it appears that Mount Wilson meets in a very remarkable degree the requirements of a site for a solar observatory. Indeed, I know of no other site that compares at all favorably with it. If a large solar observatory were established there, it might be expected to yield many important results, not to be obtained under less favorable conditions.

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