THE SUN'S RADIATION AND ITS STUDY.

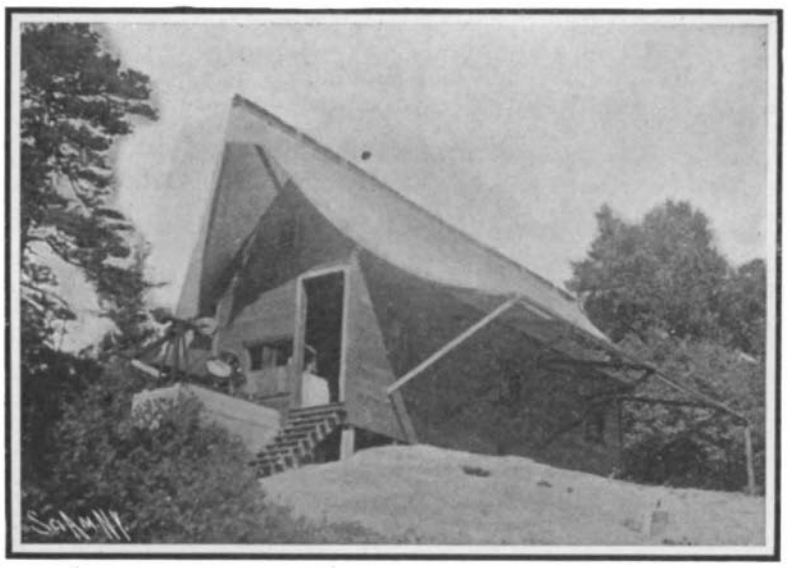
BY HERBERT T. WADE.

The late Dr. S. P. Langley, who was secretary of the Smithsonian Institution and the founder and first director of its Astrophysical Observatory, as a result of his study of the radiation from the sun believed that investigations in this field would eventually lead to the discovery of means of forecasting the weather, or more accurately, the climatic conditions of the earth, for some time in advance. The brilliant studies carried on at this observatory since its foundation in 1890 have done much toward realizing this promise and toward establishing evidences of the relations of the sun to climate and life upon the earth. The work so auspiciously begun at the Astrophysical Observatory was not interrupted by the death of Dr. Langley in 1906, and since that time it has been carried on with marked progress. Recently there has been published Volume II of the Annals of the Astrophysical Observatory, which gives a detailed account by C. G. Abbot, director, and F. E. Fowle, Jr., aid, of the investigations made in the period 1900-1906. During this time the principal problems that have attracted the attention of the observatory have been the "solar constant" of radiation, the relation of radiation to terrestrial temperature, and the radiation of different parts of the sun's disk, together with many incidental matters naturally involved in these investigations.

Now, by the term "solar constant" is meant the amount of radiation or heat emitted by the sun, as it would be found if measured outside of the earth's atmosphere at mean solar distance, and as a unit of measurement there is taken that intensity of radiation which when fully absorbed for one minute over a square centimeter of area placed at right angles to the ray would produce heat enough to raise the temperature of a gramme of water 1 deg. C., or expressed in C. G. S. units, one calorie.

This determination of the amount of heat transmitted to the earth by the sun is one of the most difficult as well as the most important in astronomical physics, and it has been termed by Dr. Langley the fundamental problem of meteorology; for if once it is possible to know the original quantity and kind of this heat, its effect on the constituents of the atmosphere on its journey to the earth, how much of it reaches the soil, how through the aid of the atmosphere it maintains the surface temperature of our globe, and finally how in diminished quantity and altered kind, it is finally returned to outer space, it will be possible to predict nearly all of the phenomena of meteorology.

The question of climate depending on the amount of radiation received was first clearly indicated in examining the records made late in March in 1903. At this time there was observed a decline in the intensity of the solar radiation and this was followed by a marked and general decline in the temperature of the North Temperate Zone as compared with the mean temperature for the same month for many years.

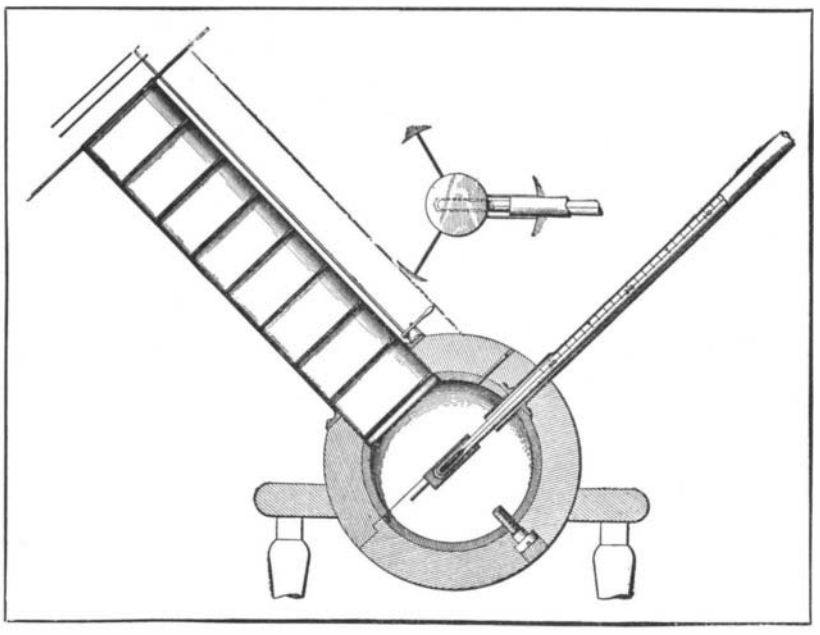


The Shelter for the Bolometer.

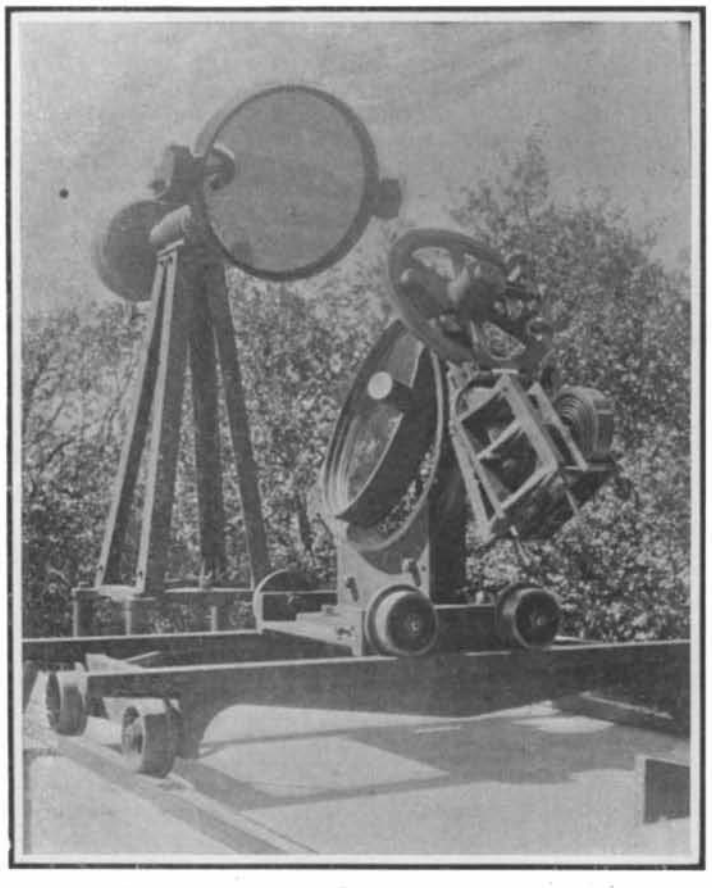
When computed and critically studied the observations seem to show that the decline in temperature was in remarkably close agreement with that which should follow a real decrease of the solar radiation. This, therefore, seemed to indicate not only the variation of the solar radiation but also its effect upon climate and its applicability to forecasting weather conditions.

Various theories as to the amount and nature of the solar radiation have been advanced, based on more or less experimental matter, but at best very little positive or satisfactory information had been secured, and it was not known whether the radiation sent to the earth by the sun was a constant quantity or varied considerably. Consequently, not only the intensity of the sun's radiation which reaches the earth must be determined, but how and why it varies, and especially its alteration in quality and quantity during its passage through the atmosphere, apart from its obstruction by visible clouds. Now for such measurements it would be desirable first to start at sea-level and then make other observations at various altitudes, rising if possible to the extreme heights only reached by unmanned balloons. But such is obviously impossible, as the work requires all the adjuncts of the most refined instrumental work and a laboratory, and accordingly two stations were selected for observations, one the Astrophysical Observatory on the grounds of the Smithsonian Institution at Washington, D. C., practically at sea-level, and the other some 3,000 miles away at the Carnegie Institution's solar observatory on Mount Wilson, Cal., at an altitude of 6,000 feet. The observations involved two main tasks—the measuring of the total intensity of the radiation at the earth's surface, using the pyrheliometer, and secondly, the measuring of the energy in different parts of the solar spectrum using the spectrobolometer. The necessity for ascertaining the intensity of radiation in different parts of the spectrum is due to the fact that the various wave-lengths of light in their passage through the atmosphere from the sun to the earth are affected differently, so it is necessary to consider the different spectral rays separately. For making observations it is of course desirable to select a day free from cloudiness, and occasionally simultaneous observations could be made at Washington and at Mount Wilson, the latter station being more than a mile above sea-level. Now the intensity of radiation actually observed at Washington was only about three-fourths as great as that observed on Mount Wilson, so that the difference furnishes data for determining the effect of the denser and lower atmosphere on the transmission of the solar radiation and with this as a basis determining the total effect of the atmosphere.

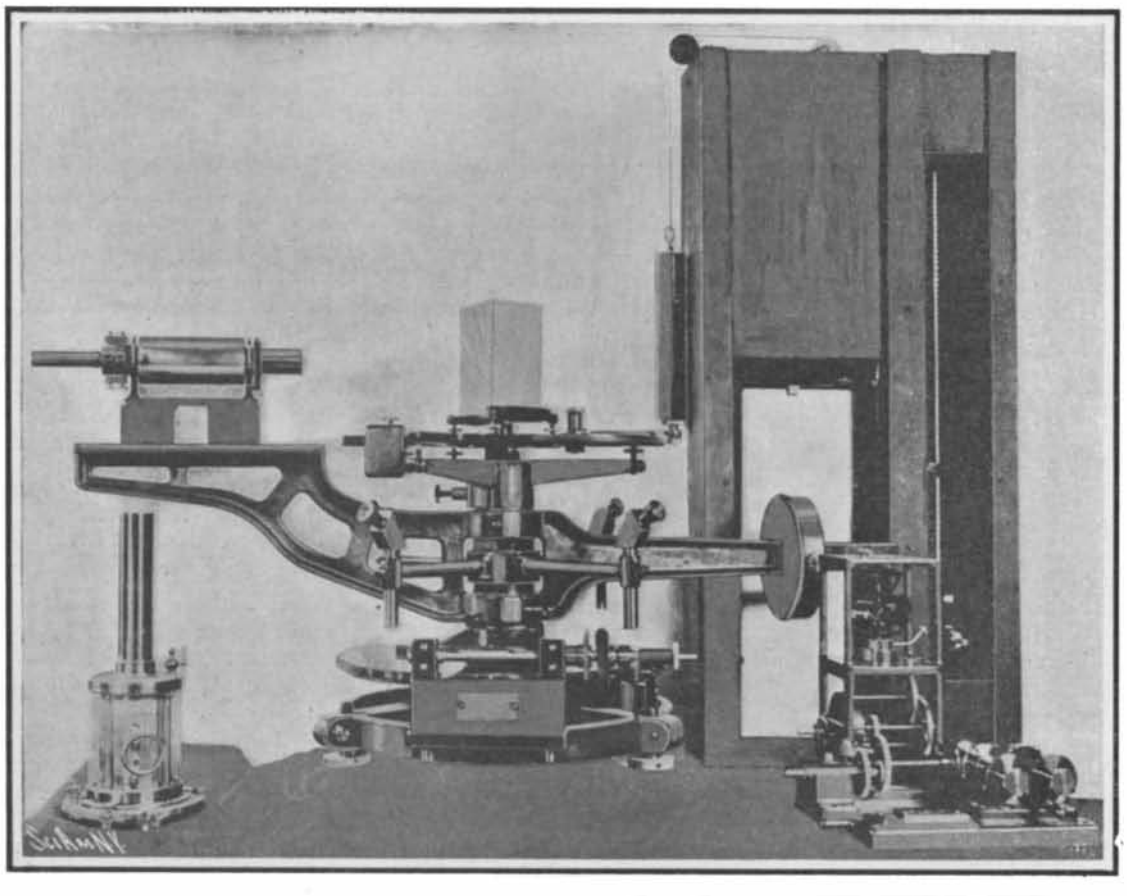
The observations with the pyrheliometer and the bolometer are made during the day simultaneously at various altitudes of the sun, as at different times obviously the solar rays will pass through varying amounts of atmosphere, from a minimum at noon, when the direction of the radiation is practically perpendicular to the surface of the earth, to that occurring at other altitudes of the sun when the path is through a much greater length of the dense atmo-



Details of the Pyrheliometer.



The Cœlostat Reflecting the Solar Rays to the Bolometer.



The Spectrobolometer, an Instrument that Measures the Energy in Various Parts of the Solar Spectrum.

sphere near the earth's surface. Now the bolometer is simply a most delicate form of thermometer adapted to measuring the energy heat in the various parts of the spectrum, not only in the visible portion, but wave lengths extending considerably beyond into the ultra-violet at the short end or to wave length 0.37μ, and to 2.5μ in the infra-red part of the spectrum where the long or heat waves proper are found. It consists of a fine wire of blackened platinum on which the radiation falls after passing through a prism to be separated into its component rays. The rays are received from the sun by a cœlostat, consisting of two adjustable plane mirrors, one of which is so mounted and operated by clockwork that it follows the motion of the sun and reflects its rays to the second or fixed mirror, from which they pass to the slit of the spectroscope after being reflected from a concave cylindric collimating mirror, which renders the rays parallel before they are passed through a flint glass prism for dispersion. After reflection from two plane mirrors the rays pass to the bolometer, and any variation in the resistance of the platinum wire which serves one arm of a Wheatstone bridge is indicated by a reflecting galvanometer. The galvanometer used for this work is a 16-coil reflecting galvanometer, modified from the familiar Thomson type, and with it is employed the usual beam of light and a photographic dry plate moved by clockwork on which the movements of the galvanometer needle are recorded. When in operation the prism is rotated by clockwork so as to bring successively the radiation peculiar to the different parts of the spectrum on the platinum wires of the bolometer, whose resistance naturally varies with the intensity of the radiation received, causing the movements of the needle to make a record in the form of an irregular curve on the sensitized plate. The bolometer does not determine the total amount of radiation received in terms of an absolute or known and invariable scale of energy, but by studying and standardizing its relative measurements, results are obtained which can be used to determine either the absolute magnitude or the changes of the solar radiation outside the atmosphere.

As the bolometer is used in connection with the pyrheliometer, it is necessary to understand the essential operation of this instrument. It, too, is a thermometric device, but it measures the total quantity of heat received. Various forms of pyrheliometer have been devised and tried in these experiments. Of the older types the most useful is one where the bulb of the thermometer was immersed in mercury, placed in a small hole in a blackened copper disk at the center of the copper sphere. The copper disk was exposed to the direct radiation of the sun and accordingly the thermometer received and indicated the total heat energy received. This form of instrument had various shortcomings, as did also the other pyrheliometers and actinometers tested, so that it was found necessary to devise a new and standard pyrheliometer. In this instrument the solar beam was received in a blackened chamber, around which water at a constant temperature was permitted to pass. Now it was possible to measure the increase of heat received by this water in flowing around this chamber by means of a platinum resistance thermometer with the usual arrangement of galvanometer and Wheatstone bridge. Then by heating the chamber from a platinum resistance wire, it could be ascertained how much heat must be introduced to produce the same effect. In this way the total heat energy falling on the standard pyrheliometer could be determined. This instrument was tested thoroughly by itself and with other pyrheliometers so that it was possible to determine with high precision the relative accuracy of the measurements, but there was some uncertainty amounting to a little more than one per cent of the absolute value of the measurement made with the standard instrument. Nevertheless when the pyrheliometer and the bolometer were used together, a most satisfactory determination of the heat energy received at the earth's surface could be obtained.

The mean result of 130 measurements made with such apparatus in the summer and autumn of 1905-6 on Mount Wilson, fixes the intensity of the solar radiation outside the atmosphere at mean solar distances at 2.023 calories per square centimeter per minute. The mean result of forty-one similar measurements at Washington extending over the period from 1902 to 1907 is 2.061 calories. A critical study of the measurements makes it probable that if they were conducted for a long term of years the mean value would be higher, and accordingly 2.1 calories per square centimeter is estimated as the probable mean value of the "solar constant." In other words the heat sent out to the earth from the sun in the course of the year is capable of melting an ice shell 35 meters (114 feet) thick over the whole surface of the earth.

This new value for the "solar constant" is somewhat less than that obtained by Langley from his Mt. Whitney observations, 3 calories, but the investigators in charge of the more recent work have been able to trace certain errors in Langley's conclusions and have discussed his observations in the light of further developments so that the value of the "solar constant" they obtain from his observations agrees very closely with that from their own observations. This is particularly interesting, as it enables observations made on a high mountain, Mt. Whitney, whose height is 3,500 meters (11,483 feet), to be compared with the Mount Wilson and Washington observations. It has been proved that the solar radiation is not a constant quantity but that it varies with the decrease in the solar distance and this may amount to 3½ per cent from August to October. Other changes occur from month to month and from year to year, though the mean value represents the average condition of the sun. It is, however, also proved that the variation in the solar radiation is due to changes in the source of radiation rather than to the effects of the atmosphere or external causes.

With the assumed value of the "solar constant," 2.1 calories, it is possible to study and explain the temperature of the earth, and it was found that the actual temperature was in close agreement with that which would follow from the assumed value. The amount of reflection or the albedo of the earth for light and heat from the sun was determined at 37 per cent, and on this basis the "solar constant" could not exceed 2.33 calories, or otherwise the earth would be a perfect radiator and better than the "absolute black body" which is taken as a standard of radiation. Now the surface of the earth is covered with clouds and water vapor which interfere with terrestrial radiation, and its temperature is maintained very nearly constant by means of the water vapor layer at an elevation of four to five thousand meters. The earth as a planet reflects 37 per cent of the radiation that it receives, and of the 63 per cent absorbed, 45 per cent is absorbed either at the earth's solid and liquid surface or in the atmosphere within a mile of sea-level.

For purposes of comparison the investigators have considered the radiation that would act on a "hypothetical earth," assuming for it the same dimensions and motions as the real earth but making it hollow and like a soap-bubble in thickness of wall, making it absorb solar radiation perfectly and also radiate perfectly the long waves in addition to conducting perfectly heat along parallels of latitude and being a perfect non-conductor for meridians of longitude. For such an earth was calculated a temperature at all latitudes and at all times of year, making use of the known value of the "solar constant" and the laws of radiation of perfect radiators. The discussion of this "hypothetical earth" afforded an explanation for many meteorological phenomena, and a comparison extending over thirty years of the temperatures at 47 stations at different points on the land surface of the globe seems to indicate that changes of solar radiation often do produce well-marked and recognizable changes of temperature with considerable certainty. In the course of these rather elaborate investigations many incidental observations of great value were made. For example, by measuring the distribution of brightness over the sun's disk, considering especially the difference between the center and the edge, it was found that changes in the solar radiation were attended by a variation in the transparency of the outer envelope of the sun and are possibly due to fluctuations in this transparency. Of course such results of observations as the transparency of the upper and lower strata of air, the reflective power of the clouds, the probable temperature of the sun and the quality of the radiation of its sunspots were all valuable incidents to this work, and the relation of the sun to climate and life on the earth is one that now stands in a fair way to be determined and understood with much greater accuracy and on a much more intelligent basis than ever previously.

The Tuberculosis Congress Proceedings.

That tuberculosis in its early stages can be cured has been announced more than once in late years. The statement was reiterated in more than one paper read before the Sixth International Tuberculosis Congress at Washington. Among those who spoke on this subject were Prof. M. A. Barber of the University of Kansas, who spoke for himself, and Dr. Gerald Buell and Dr. W. S. Williams of Colorado Springs, Prof. A. Calmette of the Pasteur Institute, Lille, France, and Dr. Edward R. Baldwin of Saranac Lake, N. Y.

Dr. Ishigami, director of the Ishigami Institute, at Osaka, Japan, declared positively that by the use of a serum tuberculosis patients can be almost without exception completely cured in from three to six months. He said:

"After continuous investigations for more than ten years I have succeeded in getting two remedies of comparatively great efficacy and free from any detrimental reaction.

"1. The one is a chemical preparation from tubercle bacilli and is applicable to incipient and feverless patients.

"2. The other is an immunization serum and is applicable chiefly to patients in an advanced stage of the disease.

"Tuberculo toxoidin, the first, is a preparation made by chemically dissolving the tubercle bacilli and transforming the toxic property, thus getting rid of the reaction which is the common detriment of all the other preparations from tubercle bacilli.

"The incipient and feverless tuberculosis patients can be, almost without exception, completely cured within from three to six months by the injection of this preparation.

"In patients in more or less advanced stage, if the nutrition is in good order, similar results can be obtained. In feverish patients a satisfactory result is often obtained by means of the injection used side by side with antipyretics. In more serious cases, beyond a certain degree, it is quite useless.

"Out of the total of 772 tuberculosis patients, each of whom has received more than fifteen injections of tuberculo toxoidin in my clinic within the last few years, there were 274 who were completely cured and 258 who were partially cured. These last two figures added together made 532, being 68.91 per cent of the total number of patients. Those who discontinued the treatment on various reasons numbered 107. Those who died numbered 29, and the remnant numbered 104.

"Satisfactory immunity to tuberculosis has only been obtained experimentally by the use of living bacilli. Any successful method of producing freedom from tuberculosis must be sought through the use of the living germ.

"The idea was first carried out by mice and anthrax germs. Encouraged by results, guinea pigs, animals very easily rendered victims of tuberculosis, were inoculated with the germ of tuberculosis. About forty guinea pigs have received inoculations, beginning with one live tubercle bacillus and increasing up to thousands; so far none, as proved by post-mortem examinations, have become victims of tuberculosis."

Benjamin C. Marsh, executive secretary of the committee on congestion of population in New York city, read a paper on "Town Planning in Relation to the Anti-Tuberculosis Campaign." He said in part:

"Town planning involves the determination by the city of the lines of its development. It means that the city sets a standard for density of population which, while recognizing the values which the inner sections have acquired through the unrestricted and hence too intensive use of land, grades the use to which land may be put to secure as near as possible to the city center a requisite standard of living and work for its population.

"Fresh air, rest and good food is the standard emphasized over and over again in this tuberculosis exhibit, and they are essential to the prevention of tuberculosis. It is difficult to inject fresh air into tenement house blocks with a density of 500 to the acre. New York has many blocks with a density of 1,000, which cover from 65 to 75 per cent of the site.

"No effective warfare can be waged against tuberculosis without a systematic plan for the development of every city and could adopt a standard of the number of cubic feet of air space and admit that natural light should be provided for all workers in factories, stores and offices."

Washington, despite its beauty, was branded as a disgrace; and Paris is even worse.

Mr. Jacob H. Schiff made a strong plea for the compulsory treatment of advanced consumption by the State or municipality. Mr. Schiff summarized his conclusions as follows:

"That the private hospital and sanatoria exclude from admission advanced and incurable consumptive patients.

"That the State make ample and adequate provision for the proper care of sufferers from advanced and incurable consumption, and that the isolation of phthisis sufferers in advanced stage be made compulsory by law, though in a manner which shall accomplish this with the greatest possible consideration for the sensibility of the patient.

"That ample provision be made in sanatoria and otherwise for the scientific treatment of the consumptive in the early and curable stage of the disease, both through private philanthropy and by the State.

"That a thorough system be organized through which can be disclosed the existence of cases of weakened constitutions and anæmic conditions in children and young persons, especially in families afflicted with consumption."

It is interesting to note that the slide rule, which but lately has become universally used for calculations, was invented nearly 300 years ago. An article in Zeitschrift für Vermessungswesen calls attention to the fact that Gunter, shortly after his bringing out the trigonometric logarithm tables in 1620, placed logarithmic scales on wooden rules, and used a pair of dividers to add or subtract the logarithms. In 1627 these logarithmic scales were drawn by Wingate on two separate wooden rules, sliding against each other, so as to render the use of dividers unnecessary, and in 1657, or over 250 years ago, Partridge brought out the slide rule in its present form.