curve has been corrected for losses in the apparatus, must be proportional to the total heating effect of all the sun's rays combined, as these might be observed with the pyrheliometer. Accordingly, in standardizing the bolometric work we read the pyrheliometer at the time when each of the six curves is made, and by dividing the reading of the pyrheliometer by the area of the corresponding bolographic curve a constant is obtained from which the sensitiveness of the bolometer is determined. This constant is applicable not only to the curves as they actually stand at the earth's surface, but also to the curve outside the atmosphere as corrected for atmospheric transmission, as the latter is determined by the dependence of the intensities at different wave lengths on the thickness of the atmosphere traversed.

We employ to measure the total heat of the sun the standardized silver disk pyrheliometer, of which the institution has furnished about 30 copies to various governmental and private institutions in different parts of the world. Two copies of this instrument are employed at Calama. They are mounted upon the same equatorial stand, and the observer reads them successively, so that during the taking of each spectro-bolometric curve he gets the reading of the two pyrheliometers.

The air mass corresponding to the observation is determined by means of a theodolite which gives the zenith distance of the sun. A table has been prepared giving the air mass corrected according to Bemporad, corresponding to the zenith distance observed. This procedure saves the determinations of time and the computation of the air mass in the manner still employed at Mount Wilson.

In reducing the observations of the spectro-bolometer, we measure the heights of the six successive curves at about 40 points, corresponding to the different wave lengths in the spectrum. The determination of the corresponding intensities in the solar spectrum outside the atmosphere we determine by a graphical method instead of the logarithmic computations which we have hitherto used in Washington.

For the purpose of this graphical extrapolation we have constructed a special slide-rule machine. An accurate steel frame with a horizontal scale of distances in centimeters has upon it six slide rules whose positions may be adjusted along the horizontal scale according to the air mass at which observations were made. We then set off upon the sliders vertically the observed intensities of solar radiations at a single wave length as read from the six curves. As these values are logarithmically plotted in the slide rule they fall upon a straight line, which produced to the abscissa of zero air mass gives the intensity which would be found outside the atmosphere, as on the moon for example. The numerical value is read off on a seventh slide rule situated at the zero of air mass.

In order to make extrapolation easier, a taut wire attached to the slider of the rule located at zero air mass and to a slidable reel at the other extremity of the steel frame is adjusted until it falls as closely as possible upon the six points determined by the six slide rules. In this way quick and accurate extrapolations of the data to the zero of air mass may be made.

The observers are so skillful and zealous in the reduction of the observations that, thanks also to these special devices, they are able to complete the determination of the solar constant of radiation on the same day that the observations are made, although in our former practice at Washington the computation required amounted to 25 hours. Thus it is possible for two observers to determine in a single day the solar constant of radiation so as to be in a position to telegraph the result, if it was desirable, within 10 hours of the beginning of the observations. However, so grinding an occupation as the observation and computation of solar constant values day after day would soon wear out so small a staff, and we expect in the immediate future to add another person to it.

Messrs. Moore and Abbot are in communication with Dr. H. H. Clayton, of the meterological service of Argentina, who is making studies of the relations of temperature of Argentina to the solar constant values they determine. Dr. Clayton speaks very enthusiastically of the apparent connection of the two variables and even mentions that correlations as high as 68 per cent are being found between them.

If this state of affairs should be confirmed, if it is found in future that the temperature of any station upon the earth's surface may be predicted for some time in advance on the basis of the values of the solar constant of radiation, it will seem to be indicated that a sufficient number of solar radiation stations should be established to observe not merely 70 per cent of the days, but all days, for the use of meteorologists. For such a purpose three or four more stations ought to be equipped in the most widely separated cloudless regions of the earth—let us say Australia, South Africa, India, and Egypt. While it would no doubt be advantageous if all these stations could be under a single management, as, for instance, that of the Smithsonian Institution, yet the institution has not at present the means available for the establishment and continuation of them. About $50,000 for the establishment and $50,000 annually for maintenance would be needed. Very probably it might be easier to secure the necessary funds if the various governments of the regions indicated should themselves establish and support their observing stations. Possibly no defect of homogeneousness in the results would arise from such a divided control. At all events the matter of the establishment of additional stations may well be delayed for at least a year, until the results of Dr. Clayton on the correlation of solar radiation with terrestrial temperatures shall be further advanced.

TERRESTRIAL WEATHER AND SOLAR ACTIVITIES.

By CHARLES F. MARVIN, Chief of Weather Bureau.

[Dated: Washington, Feb. 21, 1919.]

Meteorologists have long been accustomed to ascribe practically all atmospheric motions, both local and general, to the gravitational flow resulting from the local and general contrasts of temperature over the surface of the earth. The atmosphere derives its heat, not directly from the sun, except to a small extent, but chiefly from the surface of the earth itself. The daily sequence of sunshine and darkness; the varied distribution of clear and cloudy skies; diversities of surface cover added to contrasts of land and water areas, including the phenomena of evaporation, condensation, and precipitation; the cycle of the seasons, and above all the fluctuating but nevertheless perpetual contrasts of surface temperatures, ranging all the way from the heat of the Tropics to the intense cold of the polar zones constitute a complex series of varied and changeable influences seemingly abundantly adequate to cause and explain every feature of our weather conditions, however changeable we may find them.

These differences and contrasts on the one hand perpetually disturb the orderly arrangement of air densities

and pressures demanded by gravity. The latter, on the other hand, as perpetually and continuously sets portions of the air in motion, in order to establish and maintain a state of equilibrium, which, however, is never attained, or rather we must clearly recognize that *the ceaseless complex changes in and motions of our atmosphere represent in fact the only state of equilibrium possible between gravity on the one hand and solar heating of the earth on the other.*

Seemingly with little regard for the considerations just mentioned, many have sought and still seek to ascribe terrestrial weather—that is to say, *all* the characteristic features of atmospheric variations—to *minor* features of solar activity, as, for example, to the spots and faculae of the sun or to its magnetic manifestations, or to the relatively small and irregular fluctuations in the intensity of its thermal radiations, or to some of these variously in combination, etc.

Even suppose these solar phenomena directly influence terrestrial weather in some way yet to be proved, is it not plainly most essential in detecting and analyzing cause and effect relations that we adequately segregate and make due allowance for the complex phenomena which clearly must result if solar insolation were perfectly constant and if the other manifestations of solar activity were entirely absent?

Those who have been most ready to find convincing evidence of definite relations between terrestrial weather and minor features of solar activity have seemingly disregarded the obligation devolving upon them to make the segregation, we have mentioned as necessary, between the major and the minor influences, or have tacitly inferred that such a result has been automatically attained merely as an indirect consequence of involved processes of combinations and analyses of data, quite, however, inadequate in themselves.

Variations in the intensity of thermal radiations from the sun must, of course, be reflected in terrestrial weather phenomena, but such reflected effects must stand in appropriate relation quantitatively to the variations themselves. The advocates of definite relations are generally too prone to follow a line of thought which, pushed to an issue, leads to the conclusion that "variations of terrestrial weather," "deviations from the average," or whatever unit or term may be employed to express weather features, are ascribable directly to solar variations. The fallacy or doubt of the correctness of such a view is brought out if we ask, would the "deviations," "variations," "departures," etc., be *nil* or nonexistent if the intensity of solar radiation were perfectly constant? We think this question can be answered only in the negative, which is very largely at least a refutation of many of the conclusions thus far advocated, or at least questions the quantitative correctness of such results.

Meteorologists must hail with approval the action of the astrophysical observatory of the Smithsonian Institution in establishing a permanent station for continuous observations of solar radiation at Calama, Chile, in South America, the objects and equipment of which are so well described by the director of the observatory, Dr. Charles G. Abbot, in the preceding note in the REVIEW. The collection of a prolonged series of nearly continuous measurements of solar radiation intensities, even from a single observatory, will supply meteorologists with much needed material for refining their studies of close relations between terrestrial weather and solar activity. It is greatly to be hoped that a few other like observatories may be established at distant points over the earth in order to bridge the inevitable gaps in the series of observations and to confirm and verify the general correctness of the results obtainable at a single station.

SOLAR AND SKY RADIATION MEASUREMENTS.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Weather Bureau, Washington, Mar. 1, 1919.]

INSTRUMENTS AND EXPOSURES.

In the REVIEW for January, 1916, **44**:2, will be found descriptions of the exposures of the Marvin pyrheliometer at the various stations and an account of the methods of obtaining and reducing the radiation measurements. These still apply, except as amended in the REVIEW for January, 1917, **45**:2. The increased amount of local smoke in the atmosphere at the American University, Washington, D. C., referred to in the REVIEW for January, 1918, **46**:2, was eliminated with the discontinuance of the activities of the experiment station of the Chemical Warfare Service at the end of 1918.

On May 21 and June 14, 1918, respectively, the Marvin pyrheliometers of the spiral ribbon type in use at Lincoln, Nebr., and Madison, Wis., were replaced by Marvin silver block pyrheliometers. The factors for reducing the readings of these latter instruments to heat units were determined by comparison with simultaneous readings of Smithsonian silver disk pyrheliometer No. 1, the factors of the Marvin instruments having been first approximately determined by the electrical heating process described by Foote.[1]

In the REVIEW for January and April, 1916, **44**:4, 179–180, will be found descriptions of the exposures of the Callendar recording pyrheliometer at the different stations and an account of the method by which these records are reduced to heat units. These still apply, except as modified in the REVIEW for January, 1917, **45**:2.

The statements in the REVIEW for January, 1916 and 1917, **44**:2 and **45**:2, relative to skylight polarization measurements, and in the REVIEW for January, 1917, **45**:2, relative to radiation normals and the extrapolation of pyrheliometric readings to air mass 1, also still apply.

OBSERVATIONS DURING JANUARY, 1919.

Table 1 is a summary of the measurements made at the different stations with the Marvin pyrheliometer. The departures from normal values indicate that direct solar radiation intensities were very close to normal at Madison, slightly below normal at Lincoln, and slightly above at Washington. A noon reading of 1.42 calories obtained at Washington on the 27th equals the highest January reading heretofore obtained at Washington.

No measurements were obtained at Santa Fe, N. Mex., on account of a defect in the galvanometer.

Table 3 shows close to normal radiation for the month at Washington, a deficiency at Madison during the second and third decades, and an excess at Lincoln during the first and second decades.

Skylight polarization measurements at Washington on five days give a mean of 55 per cent, with a maximum of 60 per cent on the 27th. These are below the average values for Washington. At Madison measurements on the last three days of the month, when the ground was bare of snow but ice covered Lake Mendota, give a mean of 58 per cent, with a maximum of 70 per cent on the 30th.

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[1] See abstract in this REVIEW for November, 1918, 46: 499–500.