SOLAR RADIATION INTENSITIES AND TERRESTRIAL WEATHER.

By CHARLES F. MARVIN.

[Weather Bureau, Washington, D. C., May 12, 1923.]

All meteorologists are deeply interested in the ultimate significance of, and conclusions to be drawn from, the measurements of intensity of solar radiation being made by the Astrophysical Observatory of the Smithsonian Institution under the able leadership of Dr. C. G. Abbot.

These measurements are the more remarkable because of the relatively high accuracy of the results and also because of the extreme difficulties attending observations and the personal hardships which must be endured by the observing staff. The only stations suitable for these investigations are those located in the most arid and cloudless regions of the globe, preferably near the Equator and at high altitudes above the sea and surrounding terrain, and consequently desolate and remote from all pleasing human habitations. Here, day after day, under torrid suns the elaborate schedule of observations and computations must be carried on to get, for the day, the supposed value of intensity of radiation *outside the earth's atmosphere.*

During the years 1905–1920 observations were made at Mount Wilson, Calif., during only the summer months. A new station making observations the year round was set up at Calama, Chile, in 1918. In 1920 the latter was moved to a better site near by, known as Montezuma; and an additional station was started at an arid station in Arizona, known as Harqua Hala.

The Weather Bureau [1] has just published Doctor Abbot's own account of his work at these two stations and all the observations up to September, 1922.

The most conspicuous feature of these observations is a seeming steady decline in solar intensity which set in during January, 1922, and continued downward until September of that year. Commenting on this notable feature Doctor Abbot says:

> Unpublished observations at Arizona and Chile since September, 1922, indicate that the low solar values continued and perhaps became still more pronounced. Whether this has an important bearing on the unusual weather conditions of recent months will be for meteorologists to decide.
>
> We reserve further comment on the results. We hope they will prove valuable to meteorologists. As we have intimated already, the present outlook warrants the hope that more numerous and more concordant observations will be available from January 1, 1923. Arrangements have been made to continue daily observations at both stations until July, 1925, when it will be earnestly considered whether they should continue, and if so, under what auspices.

Other meteorologists will heartily join me, I believe, in subscribing to this conservative statement as to solar and terrestrial weather influences and will gladly accept the challenge to work out the correlations when the body of observational data is sufficient.

In the meantime it may be worth while to take stock, so to speak, of how the matter now stands and to request that in the future Doctor Abbot continue to publish certain data which are now omitted but are necessary to a proper investigation of solar and terrestrial relations.

Large fluctuations appear from day to day in all the observed values of the solar constant, and prior to 1920 these were generally regarded by Doctor Abbot himself and others as indicating actual changes from day to day in intensity of solar radiation as it reached the outer limits of the earth's atmosphere.

Mr. H. H. Clayton, then attached as forecaster to the Argentine Weather Service, claimed in a paper published in 1919 by the Smithsonian Institution to have established remarkable weather correlations between the Mount Wilson and Calama observations of solar radiation and the weather of Argentina.

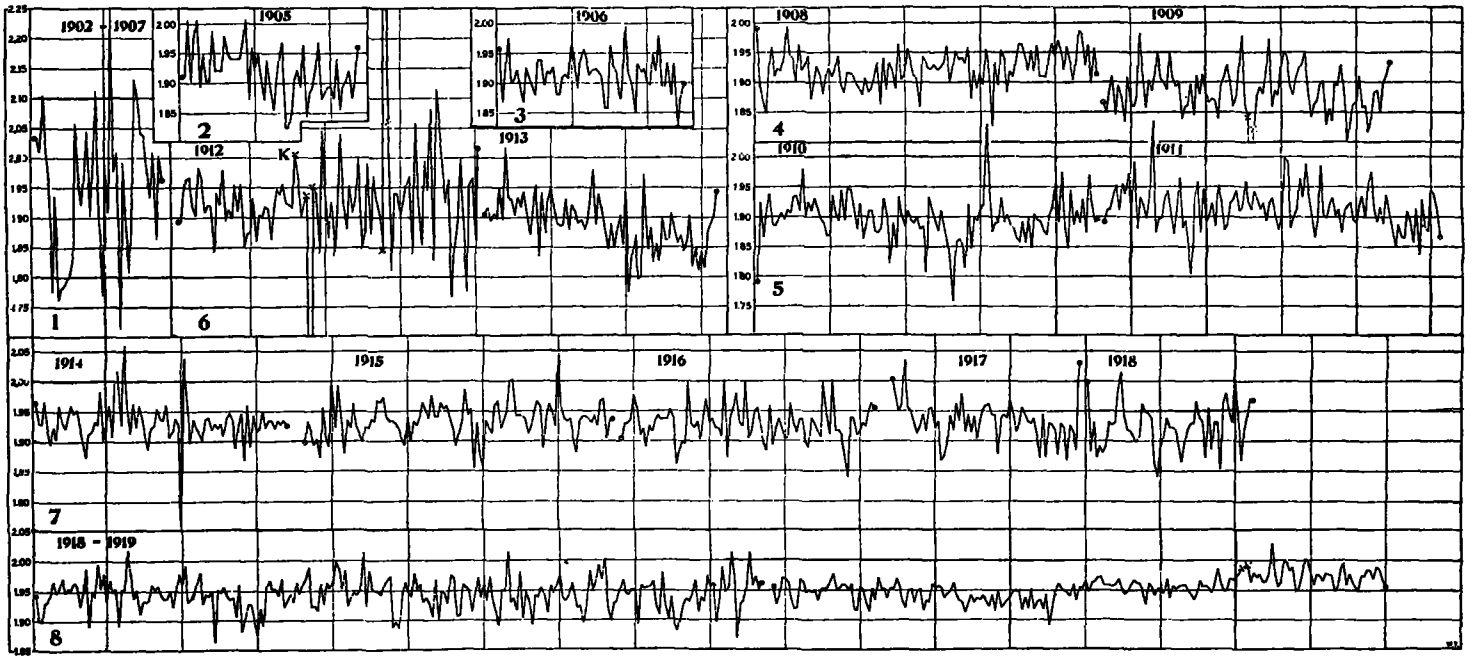

FIG. 1.—Diagram of nearly 2,000 observed values of "solar constant" as determined by the Smithsonian Institution from the beginning of observations in 1902 to the end of 1919 at stations Washington, D. C., Mount Wilson, Calif., and Calama, Chile.

[1] MO. WEATHER REV. February, 1923, p. 71.

The present writer seriously questioned [2] not only the soundness of Mr. Clayton's investigations and conclusions, but gave evidence on a statistical basis tending very strongly to show that the day-to-day apparent changes in intensity of solar radiation are really largely errors of observations due to the turbidity of the earth's atmosphere for which no allowance whatever was made by Mr. Clayton. If there is on the average any appreciable day-to-day change of intensity of radiation reaching the outer atmosphere of the earth it can not be more than a small fraction of 1 per cent, since statistically examined we find the probable day-to-day variation has grown smaller and smaller as improvements have been made in instruments and methods and stations have been better located for making such observations. (See figs. 1 and 2.)

Figure 1 tells a very important story with great force and plainness. Great variations in consecutive values of intensity mark the early observations in Washington

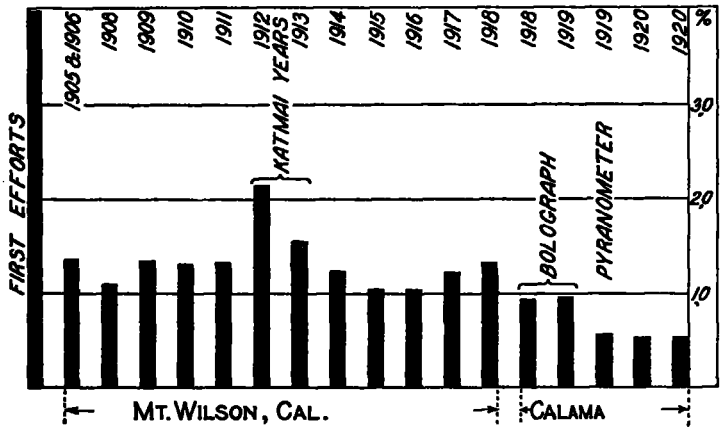

FIG. 2.—Height of bars shows probable error of an observation for a single day of the intensity of solar radiation as measured by the Astrophysical Observatory of the Smithsonian Institution at Washington, D. C., Mount Wilson, Calif., and Calama, Chile.

with imperfect equipment and poor atmospheric conditions.

Observations at Mount Wilson from 1905 to 1912 show far more nearly constant values of radiation until the arrival of the atmospheric dust from the Katmai volcanic eruption, after which day-to-day or consecutive values showed great variations. Everyone probably ascribes these increased variations not to increased solar activity, but to inaccuracies of measurement due to atmospheric dust. The large variations disappeared with the dust. Furthermore, some increased accuracy (smaller variations) characterized the observations at the station at Calama, Chile, either because of the better instrumentation, greater observational experience, or better observing conditions, or all of these in combination.

Finally, it is most striking that a further marked reduction in day-to-day variability immediately resulted from the introduction in 1919 of the pyranometer method of observation.

The percentage *probable error of a single value* has been carefully computed for each group of observations and the results are shown graphically in Figure 2.

Entirely terrestrial causes easily explain the great changes and gradual diminution in variability shown by the observations, the accuracy of which has been wonderfully increased by improvements in instruments, methods, and location of stations. What are now regarded as good observations *for a single day's work* show a probable error as low as five-tenths or six-tenths of 1 per cent. This is remarkable precision. This analysis of the whole body of radiation data brings one face to face with the important question:

Is all of this five-tenths to six-tenths of 1 per cent of day-to-day variation in solar radiation intensities real error of measurement only? Or is part of it error of measurement and part real solar change? If the latter, what are the respective amounts of each variation?

That the writer is not alone in the opinion that the day-to-day changes in observed values of the so-called "solar constant" are best explained by the changing transmission of the earth's atmosphere is shown by the following citations:

> It is not claimed that the solar constant does not vary, but that its variations are marked by changes in the atmospheric transmission, when the observations are made through different air masses.[3]
>
> *Solar Constant.*—Their investigations lead the authors to believe that strong reasons can be raised against the reality of the interdiurnal variation of the solar constant; and that the apparent variations are due to changes in atmospheric turbidity.[4]

From the evidence now available the writer holds to the conclusion that the day-to-day up-and-down fluctuations of observed intensity of solar radiation are largely due to the uncorrected effect of atmospheric transmission, and if there is any real day-to-day fluctuation of actual intensity of radiation it must be but a small part of the apparent fluctuation.

Slow progressive and long-time changes in solar constant.—Doctor Abbot's paper in the February REVIEW places emphasis upon the striking decline in solar constant values throughout the year 1922. It would be decidedly premature to venture any opinion whatsoever concerning such a feature of the observations or its influence on the present or future weather conditions. It is well known the sun is approaching a state of minimum spottedness, and Doctor Abbot's solar observations are of very great interest and importance. Obviously, we must patiently await the complete passage of the minimum and at least the partial return toward the next maximum of spottedness. Doctor Abbot assures the continuance of his present stations until July, 1925, which at best may be only slightly beyond the present sunspot minimum. It is difficult to overemphasize the unusual importance of the solar observations at this particular period of time.

The values for the next five years or more constitute the climax to the long series which have gone before and promise to furnish data which may help to a better understanding of both sunspot phenomena and the influence of slow progressive changes in radiation intensities on the weather.

Suggestions and requests.—Recognizing the extreme importance of the observations now in progress at the two observatories and the fact that the fundamental Langley or so-called complete long method is employed only infrequently, we venture to express the hope that the entire homogeneity of the ultimate body of data be preserved by *making and publishing the greatest practicable number of measurements by the long method at both stations.* Those for Harqua Hala are omitted entirely from the data in the MONTHLY WEATHER REVIEW for

[2] MO. WEATHER REV., March, 1920, p. 149.

[3] H. Knox-Shaw: Observations of Solar Radiation, 1915-1921. *Bulletin No. 23, Helwan Observatory, Ministry of Public Works, Egypt, Physical Dept.*, p. 256.

[4] *Science Abstracts, Physics.* F. Linke and K. Boda. *Meteorologische Zeitschrift.* 39, June, 1922, pp. 161-166.

February. Of these Doctor Abbot says (p. 74, second column):

> We have made no use of "long-method" values at Harqua Hala, except for determining "function transmission curves." We consider them individually so much less accurate than "short-method" values, because they are influenced by clearing up or hazing up of the atmosphere, while short-method values are not, that to include them in the mean values would injure the work. The observers at Montezuma have been accustomed to give "long-method" values half weight. We have thought it best not to alter their "weighted mean" values already published in the MONTHLY WEATHER REVIEW, but have modified the grade assigned.

The seeming discredit cast by Doctor Abbot himself upon these long-method results is a surprise to the writer because that method is fundamental and one whose average values must be more accurate and dependable than those by the empirical or short method. The case is somewhat analogous to adopting aneroid barometers for measurements of air pressure to replace fundamental mercurial standards. It is very difficult to properly appraise the real value of the so-called short method which requires for the *evaluation* of its indications a whole train of complicated "function" values of a highly arbitrary and empirical character. The "short-method values" are acceptable only when they follow closely in step with long-method values under good observing conditions.

The writer recognizes that the so-called short method may possibly give truer indications of short-time fluctuations of apparent solar intensity, but it is difficult to believe that in the long run short-method observations can be of superior accuracy to the long method, which must be relied upon for evaluating the long train of complicated "function" values required in the use of the short method. It is again hoped and urged that frequent long-method observations be made and published for each station. It seems highly important also that the observations at the Arizona and Chile stations be made *absolutely independent of each other*, without the application of coordinating corrections that are designed to bring about some imaginary agreement between these two stations. The Weather Bureau fully recognizes that outstanding constant differences may arise, but it seems premature to attempt to evaluate these differences and apply arbitrary corrections to these observations at this early time in the history of the two stations. That is to say, the writer believes the observations should be made as absolutely independent of each other as possible and all outstanding differences harmonized when a large body of observational material is available for dicsussion. Various corrections have been applied to the records in the past which might perhaps better have been left to be determined and evaluated in a final discussion of the material.

Annual period.—Figure 8 of Doctor Abbot's article in this REVIEW for February shows a well-defined 12-month period with maxima values about January. A tendency toward a similar period but opposite in phase can be shown in the Mount Wilson data. Observations at the latter station, however, especially after 1916, extended over such a short portion of the year that a periodic tendency can not be conclusively evaluated.

The logical inference is that any annual period of this character must be due to changes in atmospheric absorption and that the effect of the latter is not as yet completely eliminated. The opposition of phase between Mount Wilson and Chile allows the inference that the feature is a summer and winter influence in the two hemispheres. This, however, is refuted, because seemingly the Harqua Hala and Montezuma annual periods (only a little over one year of record is available) are in the same phase. This raises the question whether the seasonal changes at Montezuma (so-called corrections to constant sun) have not been impressed upon the Harqua Hala results by the empirical corrections required by the short-period method. (See column 2, et seq., p. 73, this REVIEW for February, 1923.)

If the annual period is truly solar, must we not also expect to find other periods corresponding to the inner and outer planets? It seems far better to allow a small apparent error of this kind to remain to be finally evaluated when the body of data is large enough to permit the error to be most assuredly evaluated by rigorous statistical methods.

Placing the highest valuation on long method observations, it is hoped the results of all such for both Harqua Hala and Montezuma may be included in the observations which are submitted for publication in the MONTHLY WEATHER REVIEW from time to time.

WEATHER FORECASTING FROM SHIPS AT SEA.

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[Weather Bureau, Washington, D. C., May 23, 1923.]

With the development of radio transmission in the early years of the twentieth century, one of the very first practical applications of the new method of transmission was in the issue of warnings of dangerous storms to vessels at sea.

As early as 1906, therefore, arrangements had been made by the United States Weather Bureau to dispatch weather forecasts and warnings to all vessels within the zone of communication that were equipped with radio apparatus.

At that time the idea of a central floating weather station had not developed, but it was thought that perhaps the accuracy of the forecasts might be improved by extending the field of observations from land to water areas, hence arrangements were made whenever possible to transmit ships' observations to shore stations. As it turned out, the extension and development of radio transmission found its fullest expression in eastern United States and northwestern Europe so that vessels navigating the north Atlantic lanes of travel were first to be in a position to communicate with shore stations. For a short time, ships' observations from the north Atlantic were collected by the United States Weather Bureau, but the collection was suspended in the last half of 1907. In the next year, 1908, the outstanding event was the test of the feasibility of the plan of constructing a weather chart on board ships navigating the high seas. This test became possible through the generosity of the Hamburg-American Line in cooperation with Dr. P. Polis, director of the Aachen Meteorological Observatory.[1]

Doctor Polis made the trip, Cherbourg to New York and return, in 1908. The plan followed was to arrange for the transmission of a few reports from European land stations and to supplement these daily by such ships' reports as could be collected. At that time radio transmission from European stations was not effective beyond about 1,800 miles from the British coast; reports from the eastern portion of the United States were

[1] Polis, P.: Wireless telegraphy in the service of meteorology, MO. WEATHER REV. 36: 407.