IDENTIFICATION OF CLOUD TYPES WITH THE SPHERICAL SUNSHINE RECORDER

by

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ACKNOWLEDGMENT

To Dr. L. F. Miller of the University of Minnesota and Dr. E. H. Warner of the University of Arizona, the writer expresses his sincere appreciation for the assistanse and courtesies extended him during this study.

CHAPTER I.

INTRODUCTION

Since November 15, 1935 the Physics Departments of the Universities of Arizona and Minnesota have jointly carried on a solar radiation project at the University of Arizona in Tucson. A sunshine recorder having a spherical absorber has been operated continually since November 15, 1935.

Each day a trace on photostat paper is made which is a record of the sun's radiation plus any sky radiation. Any fluctuation of radiation is reflected by a drop or rise in the trace. Clouds passing over or near the sun produce a very noticeable effect on the trace. This suggested the possibility of classification of clouds by means of the recorder's trace. As study along the line of cloud classification progressed, as mentioned above, a very noticeable effect was noted on the trace during apparently clear days. This tended to expand the study and at the same time to complicate the matter of cloud classification. The writer has found the injection of the invisible into this study to be very interesting and thinks perhaps that it will be very important.

CHAPTER II.

CLOUDS VISIBLE AND INVISIBLE

Clouds and cloud forms no doubt have fascinated man for ages, but it was not until 1801 that any attempt was made to classify them. Humphrey[1] sums up the situation pretty well when he says:

> "It is passing strange that the ancient Arabs, Greeks, and others should have given a name to every portion of the heavens, and to numerous individual stars, and yet have failed to name any one of the many kinds of clouds that are ever more conspicuous in the sky than the stars themselves or their constellations."

Lamarck, the French naturalist, made the first attempt to classify clouds in 1801. This, however, received scant attention. Another classification was proposed in 1803 by the English chemist, Luke Howard. Howard's classification was similar to Lamarck's in that it was based on appearance alone.

Howard recognized three main types of cloud structure which he called Cirrus, Stratus, and Cumulus. Cirrus included all forms which are built up of delicate threads, like the fibers in a fragment of wool. Stratus was the name applied to all clouds which lie in level sheets. Cumulus was the name used to designate the lumpy form of clouds. By a combination of these terms other clouds were described, such as strato-cumulus, cirro-cumulus, and cirro-stratus.

To obtain uniformity in the cloud reports of professional meteorologists and others, the International Meteorological Committee published in 1910 a report with definitions, illustrations, and descriptions of cloud forms. In 1929 at Copenhagen, Denmark, the International Meteoro-

1. W. J. Humphreys, Fogs and Clouds, p. 31.

logical Organization adopted code specifications for clouds including upper, middle, lower, and predominating clouds. Clouds are now classified according to form and appearance, but consideration is also given to the physical processes producing them.

There is a general relationship between the form of clouds and their heights as shown by actual measurements. The temperature, moisture, and movements of the air differ characteristically at the various levels above the earth's surface, and hence there are significant differences in the apparent effects of distance or height above the observer.

About 75 different types of clouds and sky are internationally recognized. In the international system there are 4 families and 10 genera, and in addition certain species, varieties, and special features. The ten genera and their heights as given by the International Cloud Atlas are shown in Table I.

TABLE I.

Families	Mean Heights (feet)	Stratiform Clouds	Cumuliform Clouds
High	Top, 40,000 Base, 20,000	Cirrus (I) Cirrostratus (I)	Cirrocumulus (I)
Middle	Top, 20,000 Base, 6,500	Altostratus (I) Nimbostratus (I)	Altocumulus (I+W)*
Low	Top, 6,500 Base, Near Surface	Stratocumulus (W) Stratus (W)	Stratocumulus (W)
Clouds with Vertical Development	Top, Cirrus level Base, 1,600		Cumulus (W) Cumulonimbus (I+W)

*I represents ice clouds
W represents water clouds
I+W represents ice and water clouds.

Some clouds existing at heights much greater than the usual common clouds have been observed. These rare clouds are usually called invisible since they cannot be seen at all times.

Articles have been written describing in detail why clouds cannot exist beyond our troposphere. Each year additional evidence is produced that there exist some types of clouds above our troposphere.

The invisible or high altitude clouds have been observed and their heights measured. These clouds exist at two different heights of 80 kilometers and 25 kilometers, approximately. The 80-kilometer clouds are called Noctilucent, and those at 25 kilometers are called Nacreous.

The Noctilucent, luminous night clouds, as they are sometimes called, were first observed by T. W. Backhouse[2] in England in 1885. Mr. O. Jesse has made many reports on them. These clouds seem to be sort of a cirrus cloud, silvery and bluish white in appearance. Dr. Carl Stormer of the University of Oslo, and others, have observed and measured their heights and found it to be 80 kilometers.

The Nacreous, or Mother of Pearl clouds, were first reported by Professor H. Mohn in 1871. Since then Mohn, Stormer, and others have reported seeing them in England, Norway, and Germany. From the many photographs of the Nacreous clouds taken by Dr. Carl Stormer, one would conclude that they resemble in places altocumulus lenticularis or alto-stratus lenticularis, all of which are brightly colored. Stormer[3] between 1926 and 1934 measured the heights of the Nacreous clouds that appeared during that period and found that the maximum height was 27.7 kilometers and the lowest was 20 kilometers. Stormer also reports that a measurement

2. Backhouse, T.W., Nature, vol. 33, pp. 194, 486.
3. Stormer, Carl, Nature, vol. 145, p. 221.

of the cloud particles reveals that the diameter of the cloud particles does not exceed .0025 mm. It should be remembered that ordinary cloud particles have a diameter of 0.0021 mm.

CHAPTER III.

APPARATUS AND PROCEDURE

A spherical sunshine recorder, devised by Dr. L. F. Miller[4] of the Physics Department of the University of Minnesota, was used. This instrument is illustrated by Figures 1(a), 1(b), below and Figure 2, page 8.

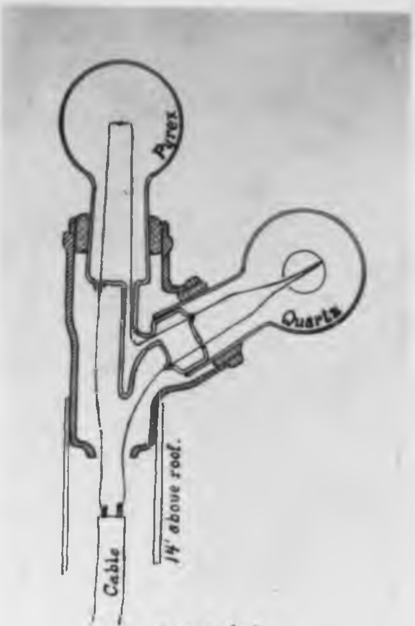


Fig. 1. (a)

Fig 1. (b)

The evacuated bulbs of Figure 1 (a) are mounted on a tower—Figure 1 (b)—on the south side of the Physics and Chemistry Building at the University of Arizona. The photographic recorder of Figure 2 is located

4. Miller, L. F., Bulletin of the American Meteorological Society, vol. 18, pp. 213-220.

on the third floor of the Physics and Chemistry Building.

The device here employed consists of two highly evacuated quartz bulbs arranged in Y form on a pyrex base as illustrated in Figure 1. Inside of one bulb is contained a very thin, seamless, hollow spun-silver sphere, blackened externally and having a small opening on the under side. Through this small hole pass the fine wires of a previously calibrated thermocouple which is very lightly soldered to the inside of the sphere. As solar radiations pass through the quartz to the blackened sphere, they are absorbed and converted into heat, raising the temperature of the sphere and its attached junction as much as 250° above the other junction which is bare and located in the other bulb. The bulb containing the blackened sphere is pointed to the south midway between sunrise and sunset. At all positions of the sun the solar radiations fall in a hemisphere. Consequently the bulbs do not need to be turned by a clock mechanism; the instrument exhibits the same degree of sensitiveness for all positions of the sun; with convection and conduction of air removed, the device operates almost entirely by radiation and according to the Stefan-Boltzmann law; the deflections of the galvanometer receiving this thermoelectric current are very closely proportional to the intensity of solar radiation coming to the bulbs and the areas under the charts traced photographically at the recorder are proportional to the total number of calories received. The abscissae on these charts represent time and the ordinates, intensity of solar radiation. (e.g., see Figure 3, page 11.)

Figure 2, page 8, represents the recorder. A vertical fine line of light from the light source L is reflected by the galvanometer mirror at G back upon a long narrow horizontal slit S mounted in front of a clock

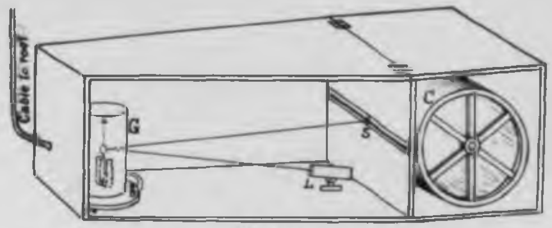


Fig. 2.

driven cylinder C. On the cylinder is mounted photographic paper. As the thermoelectric current passes through the galvanometer, the spot of light at S is moved from its zero position at one end of the cylinder so that the deflections and consequently the ordinate values traced on the chart are proportional to the intensity of solar radiation (gr. cal. per min. per cm.^{2}) absorbed by the blackened sphere. The abscissae values run off by the uniform rotation of the cylinder are proportional to the time. It is the area underneath this curve which may be measured by a planimeter and which is found proportional to the total number of calories received at the instrument in a day. Figure 3 shows a chart for an apparently very clear day. The total radiation received by the bulb is that direct from the sun plus the diffuse sky radiation.

Each chart which comes from the recorder has its base line drawn as in the abscissae of Figure 3 (page 11). A vertical line is drawn through each hour of the day according to the markings of an electric time marker connected in the circuit. These furnish the ordinate values. A vertical line is also erected at the time of sunrise and of sunset. From the abscissae the number of minutes during which solar energy has been received can be determined.

Each hour during daylight a cloud or sky observation is made. If clouds are present, they are classified as to genera, and occasionally into species, varieties, and special features. Any smoke, haze, dust, or unusual phenomena is recorded during the day. The hourly cloud or sky information is written on the vertical lines down through each hour of the day on the charts after they come from the recorder.

For this particular study dark glasses and filters were used by the writer to aid in observing and classifying clouds. These were valuable aids in bringing out many cloud forms, detecting halos, coronas, and bringing into view iridescence, all of which are aids in classifying clouds. Also, photographs were taken of clouds on days when certain well defined cloud types were present. These photographs were taken with a Wratten, K-3 filter on 35 mm. panchromatic film.

CHAPTER IV.

DISCUSSION OF RESULTS

Fourteen representative charts from the recorder of various cloud traces were photographed and placed in this chapter. These 14 charts represent a period of 18 months dating from January, 1942 to June, 1943.

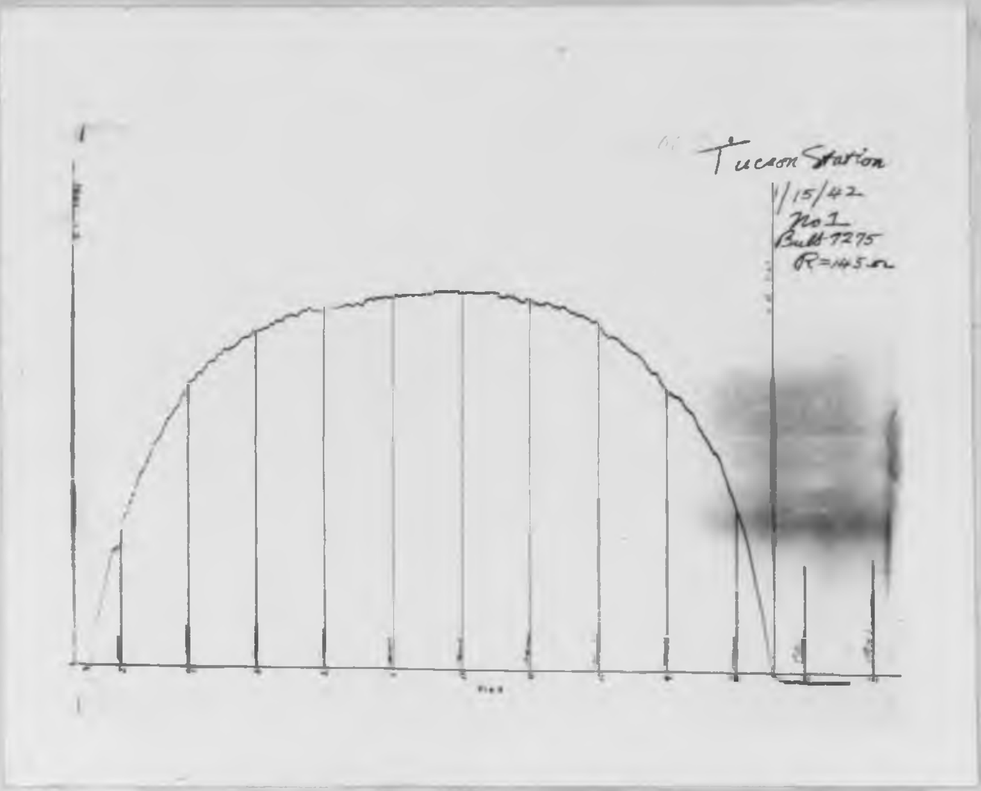
The following abbreviations of cloud forms were used in describing the hourly cloud data on the charts:

Cirrus	Ci.
Cirrocumulus	Cc.
Cirrostratus	Cs.
Altocumulus	Ac.
Altostratus	As.
Stratocumulus	Sc.
Stratus	St.
Nimbostratus	Ns.
Cumulus	Cu.
Cumulonimbus	Cb.
Fractostratus	Fs.
Fractocumulus	Fc.

The word "same" was used if the cloud form or condition of the sky was the same as the preceding hour.

Figure 3 (page 11) is the trace of a clear day on January 15, 1942. No clouds were visible in the entire sky throughout the day. The trace is relatively smooth and very symmetrical, which would indicate very little, if any, disturbance. This trace is used as a criterion for study in the remaining figures.

The trace of Figure 4 (page 11) was for January 5, 1943. Cirrus was scattered in patches over the sky at sunrise. In some places it was more dense than others. This condition existed until 10 A. M. From 10 A. M. until 1 P. M. the sky was clear. At 2 P. M. the cirrus reappeared and remained until after sunset, being quite dense in spots. At 2:20 P.M.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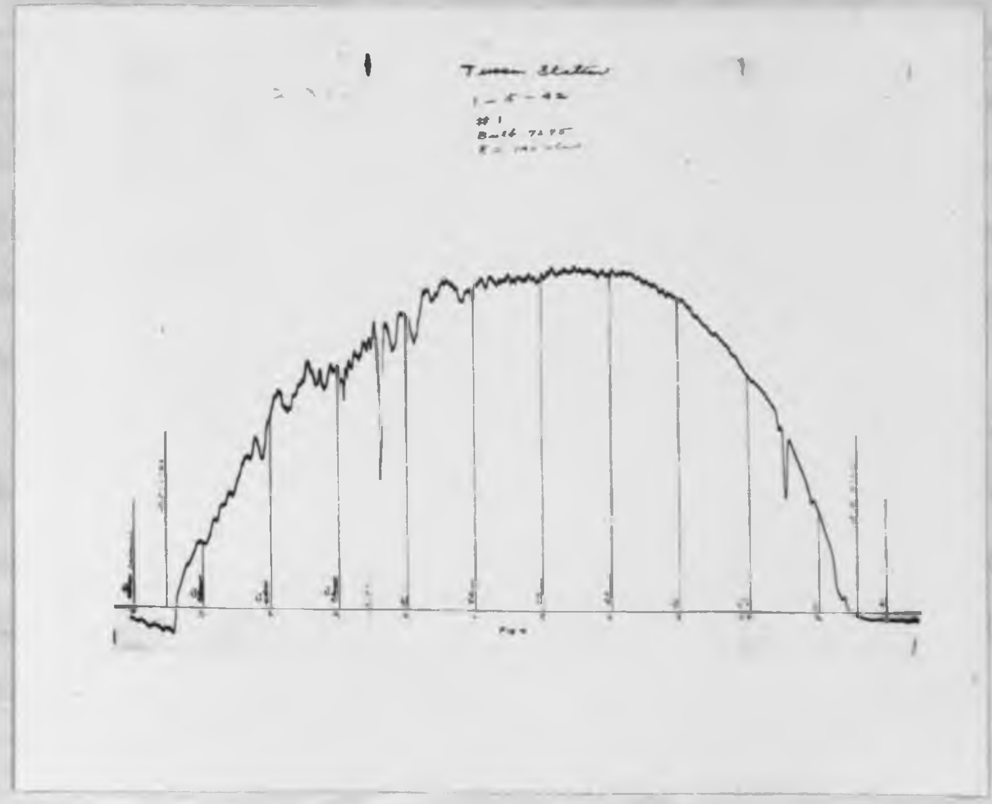
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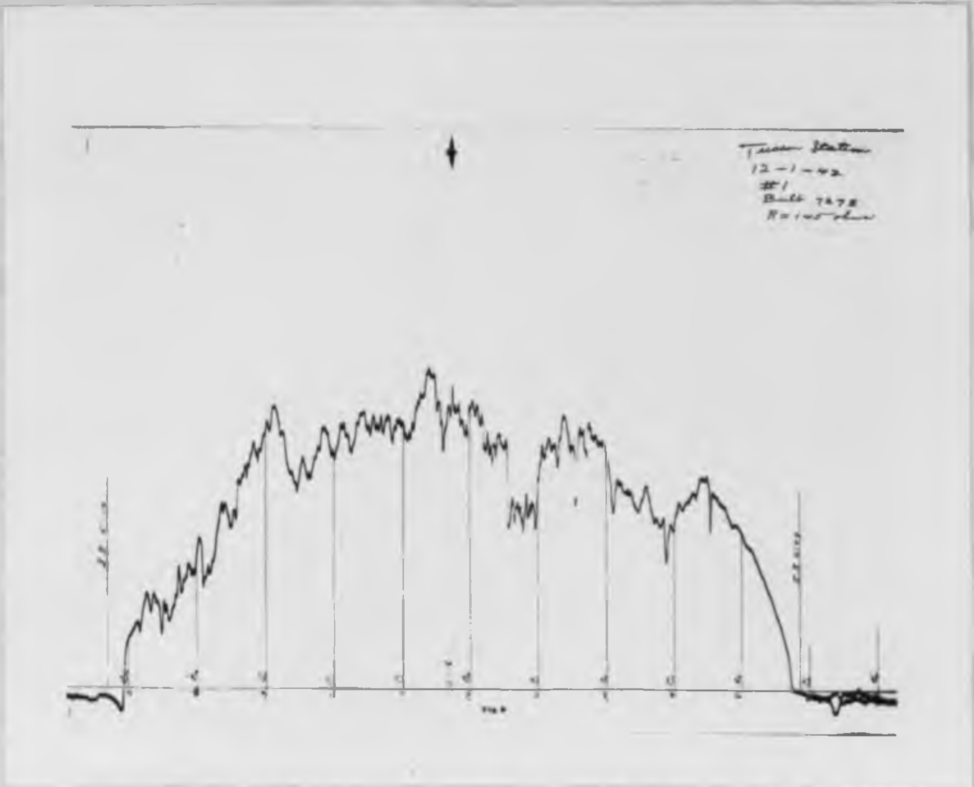
a photograph (Figure 5) was taken of the cirrus near the sun which produced the dip in the trace at 2:20 P. M. This cloud could not be called cirrus densus or cirrostratus.

Fig 5

Figure 5 is a picture of a rather dense cirrus cloud. It, however, could not be called cirrus densus or cirrostratus. This photograph was taken to one side of the sun. The sun is in the lower left corner of the picture. This photograph was taken at 2:20 P. M. Mountain Standard Time, January 5, 1943, on panchromatic film with a Wratten K-3 filter, a stop of 18, and an exposure of 1/200 seconds.

Figure 6 (page 13) is a typical cirrus trace. This trace was made on December 1, 1942, a day on which cirrus was present the entire day. The cirrus was uniform throughout the sky, and this is reflected in the trace, which is in contrast with Figure 4. Figure 4 shows the effect of cirrus that was not of uniform thickness.

On December 2, 1942, a band of cirrus moved across the sun's path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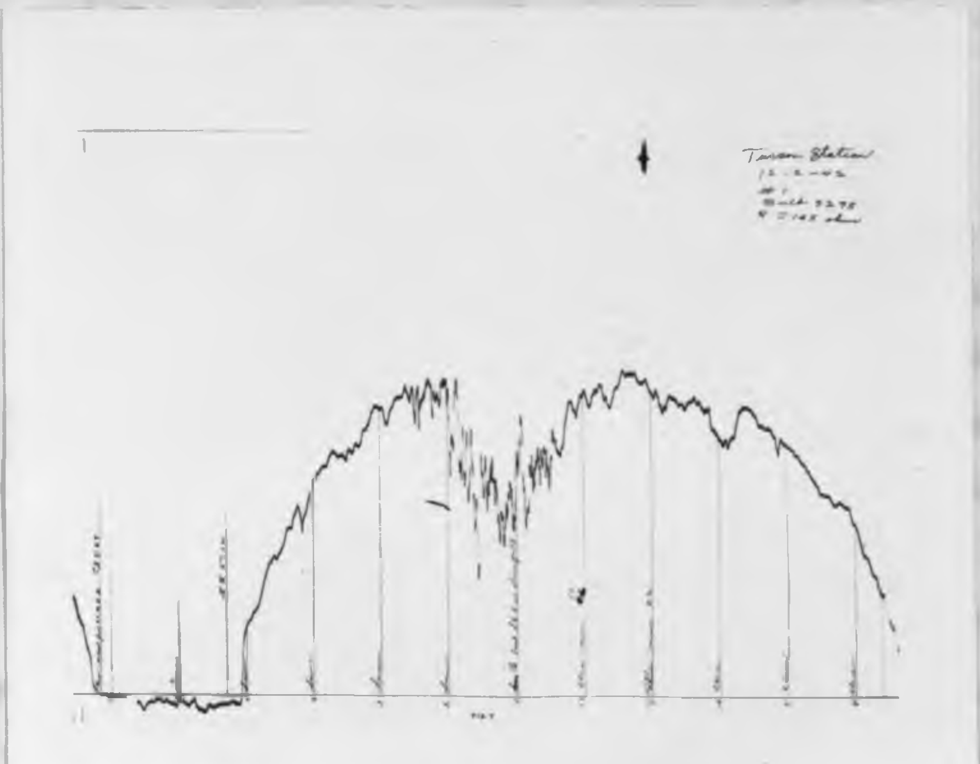
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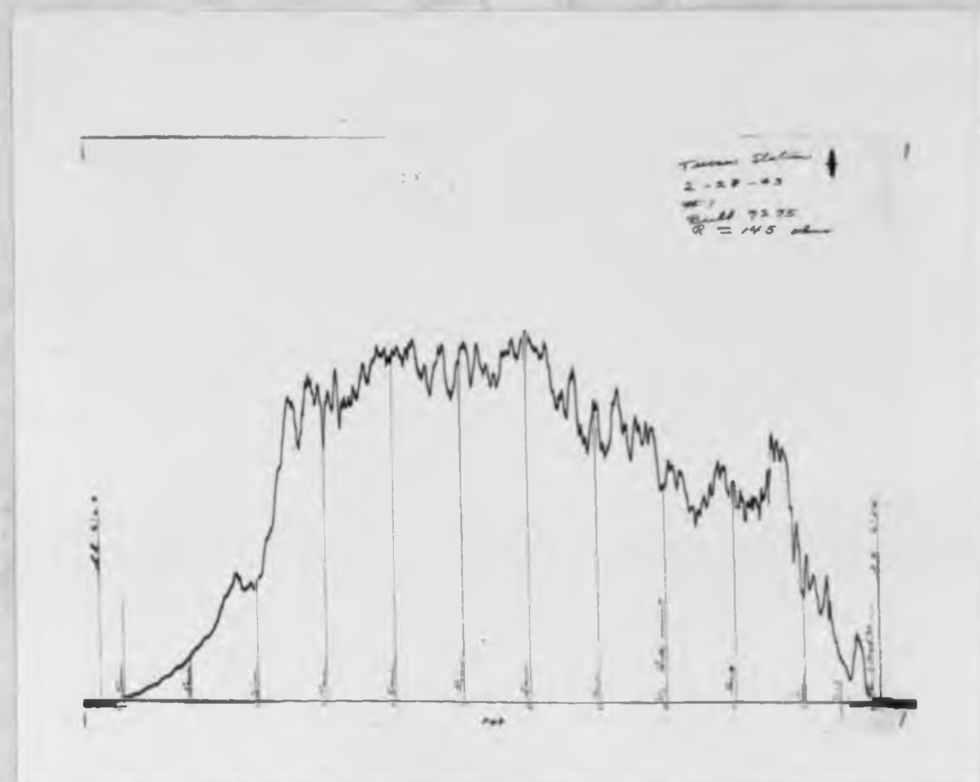
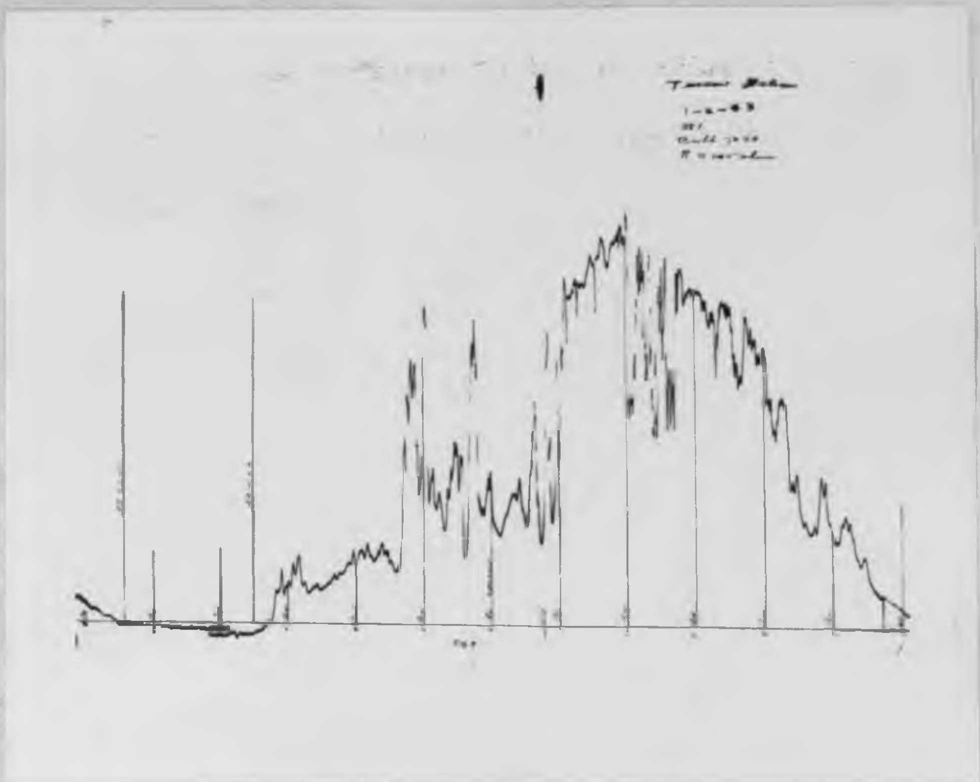
from south to north. This is illustrated in Figure 7 (page 13). The sun rose clear on this day. Some cirrocumulus was present from 11 A. M. to 12 noon. Thin cirrus continued in the sky after the band of cirrus had moved across. The trace shows clearly when the band first crossed the sun and when it had passed.



The trace of Figure 8 is for the 28th of February, 1943. On this day a cirrostratus sheet, that covered the entire sky from 10 A. M. until after sunset, was present. From sunrise until 10 A. M. cirrus densus was scattered over the sky. A 22° halo about the sun was visible from 10 A. M. until sunset.

Figure 9 (page 15) is the trace of an altostratus and altocumulus overcast. Thin altostratus was present from sunrise until 11 A. M. At 11 A. M. the altostratus changed to altocumulus until approximately 3 P. M.



From 1 P. M. until 3 P. M. the altocumulus became quite dense and was recorded as altocumulus opacus. Considerable irisation was noticeable.

Figure 10 (page 16) is a photograph taken at 1:08 P. M. when altocumulus covered the sun. Figure 11 (page 16) is altostratus taken at 2:45 P. M. when most of the altocumulus had changed into altostratus. The altocumulus trace shows considerable vertical fluctuation as is indicated between 11 and 12 P. M. The altostratus tends to push the trace down and shows less fluctuation except where more dense portion of the strata moved across the sun.

Figure 10 shows a mixture of altocumulus and altostratus clouds, taken at 1:08 P. M. Mountain Standard Time on January 2, 1943. The sun, which is in the lower right corner of the picture, was entirely covered with altocumulus. This picture was taken on panchromatic film with a

Fig 10

Fig 11

Wratten K-3 filter, a stop of 18, and an exposure of 1/200 second.

Figure 11 is a picture which shows a typical altostratus cloud.

The sun, which shows vaguely with a faint gleam as though through ground glass, is in the center of the picture. Panchromatic film with a Wratten K-3 filter, a stop of 18, and an exposure of 1/200 second was used to take this picture at 2:45 P. M. on January 2, 1943.

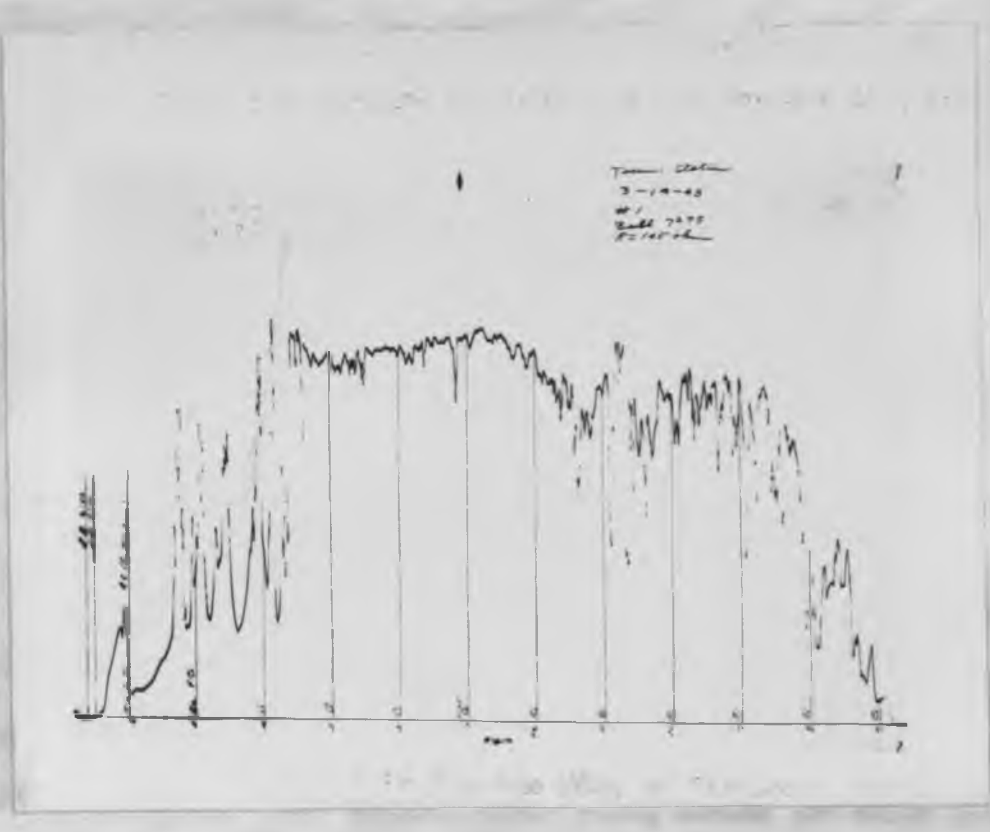


Figure 12 is a trace of a sky that had both cirrus and altocumulus. From observation, thin cirrus was present in the sky all day. From 4 P. M. until sunset, altocumulus lenticularis was present. The section of the trace from 4 P. M. until 5 P. M. shows the thickness and width of the cloud. The thickness is shown by the fluctuation of the ordinate value, while the width is shown by the width of the trough of the depression.

Rolls of stratocumulus which moved across the sky from the northwest to the southeast on January 17, 1943 produced the chart of Figure 13 (page 18).

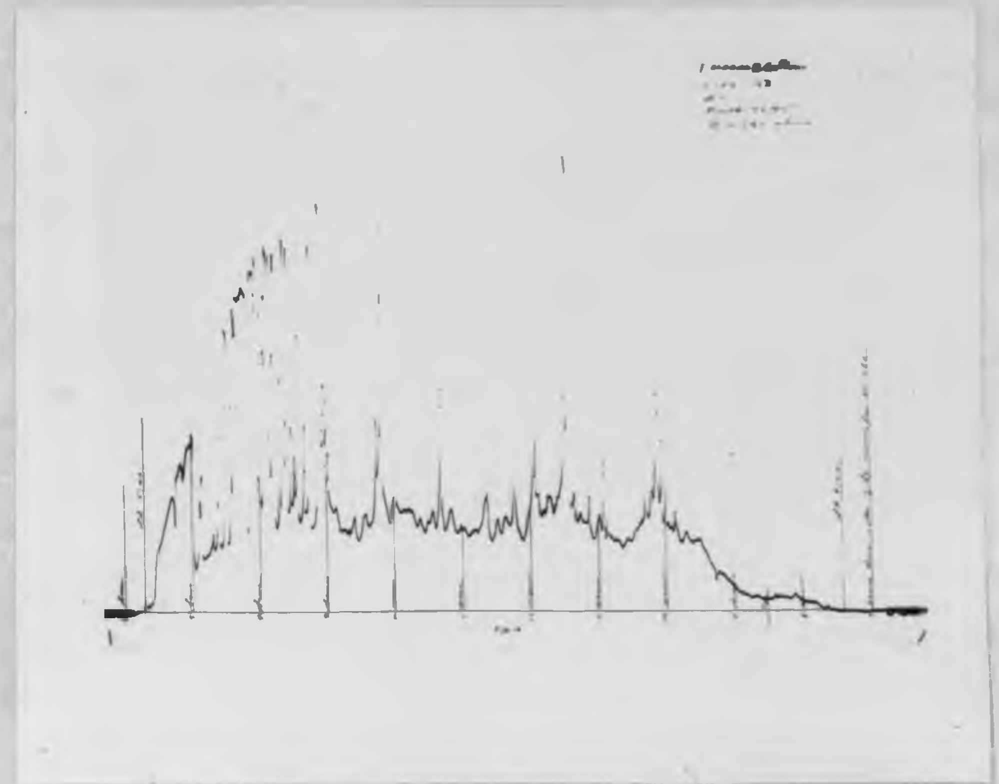


Figure 14 (page 19) is a picture of the stratocumulus of January 17, 1943. The denseness and nearness to the earth produced the tremendous depression of the trace of Figure 13. When the sun would shine through the interstices for a few minutes after being behind the dense cloud, the trace would move with considerable speed upward, as is indicated by the faintness of the trace.

Figure 14 is a picture of stratocumulus opacus clouds in rolls that entirely covered the sky throughout the day of January 17, 1943. The sun can be partially seen at the interstices near the center of the picture. The reflections of the sun may be seen coming from behind and above the clouds near the top of the picture. This photograph was taken on panchromatic film with a K-3 filter, a stop of 18, and an exposure of 1/20 second. This picture was taken at 8:20 Mountain Standard Time.

Fig. 14

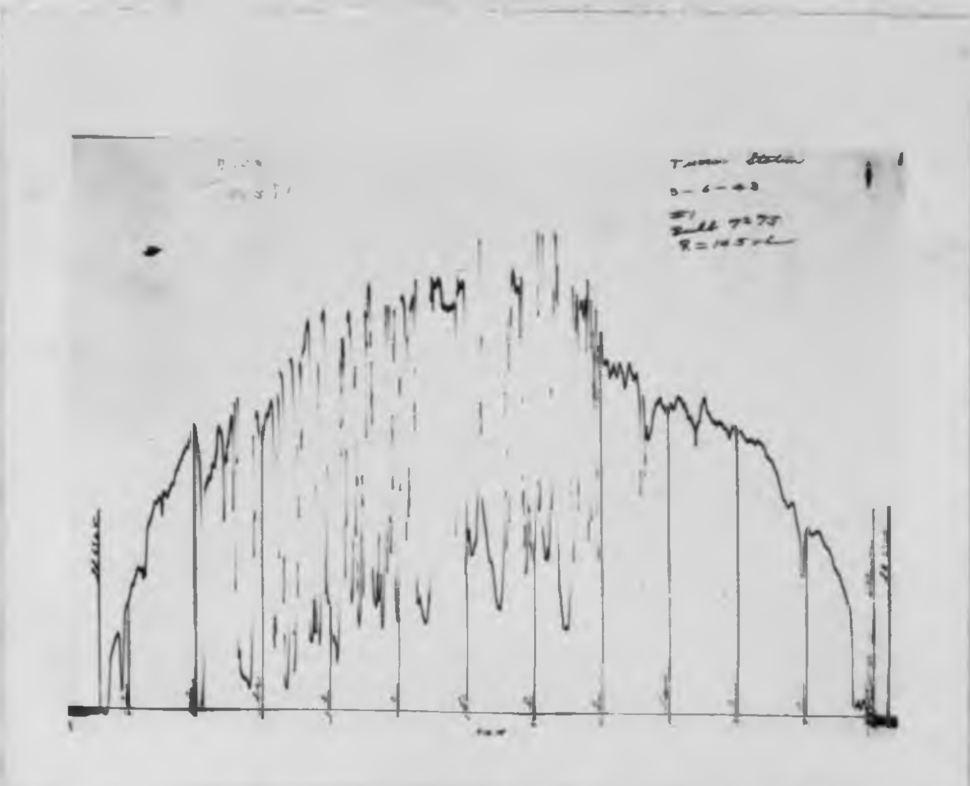
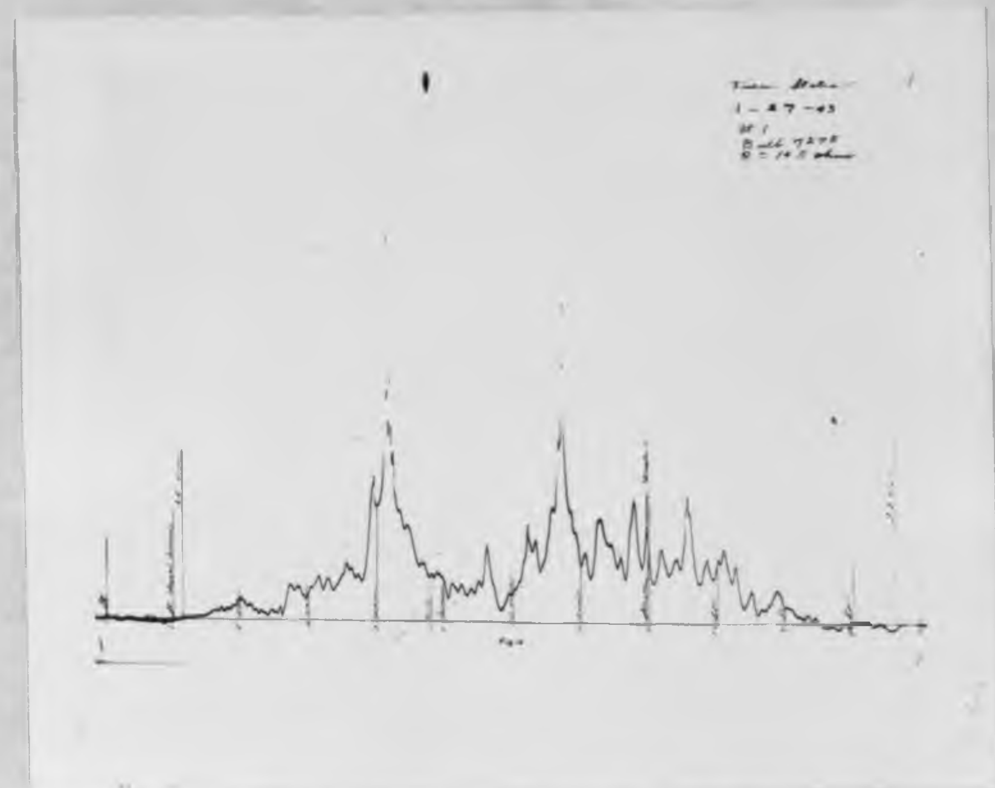


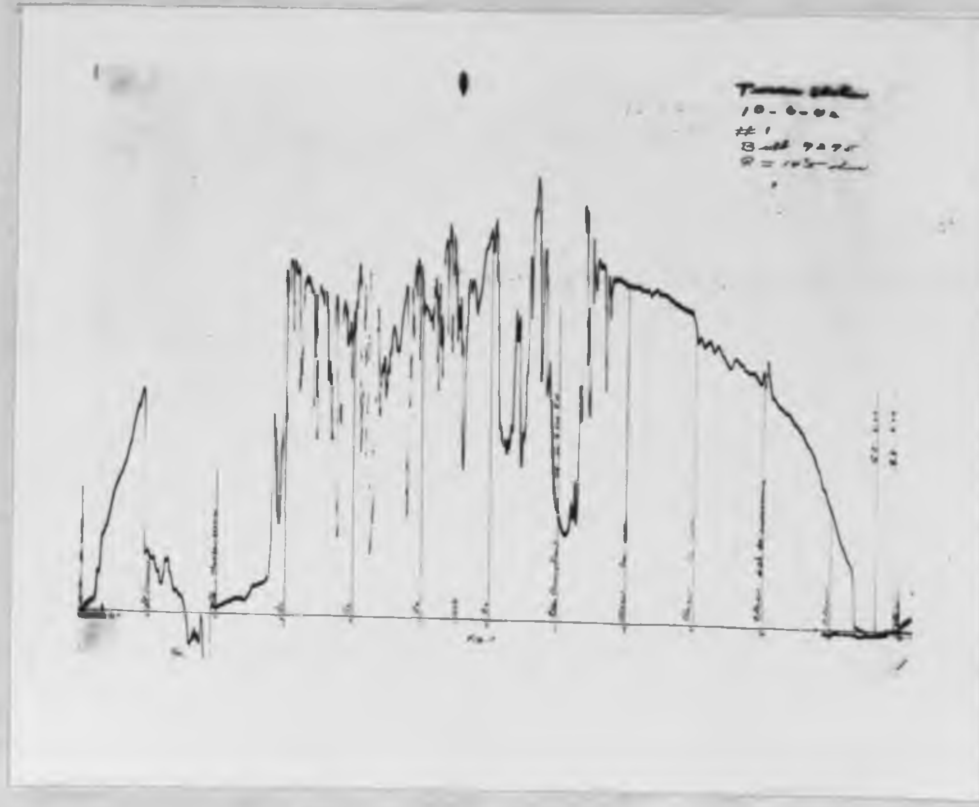
Figure 15 (page 19) is a trace of a typical stratocumulus as compared to the overcast of Figure 13. The trace seems to divide at 11 A. M. and form two traces, one lower and one upper. The tremendous fluctuation is typical of stratocumulus.



The trace of Figure 16 is a typical trace for a day on which there is a stratus overcast with an occasional drizzle of rain.

Figure 17 (page 21) shows the formation and approach of a thunderstorm with a climax of rain and subsequent clearing just before sunset.

The day of September 29, 1942, the chart of which is shown in Figure 18 (page 21) was observed to be clear until 5 P. M. when altocumulus clouds were observed on the western horizon in the path of the sun. These clouds produced the depression shown between 5 P. M. and 6 P. M. From sunrise until 1 P. M. the trace is similar to Figure 1. From 1 P. M. until 5 P. M.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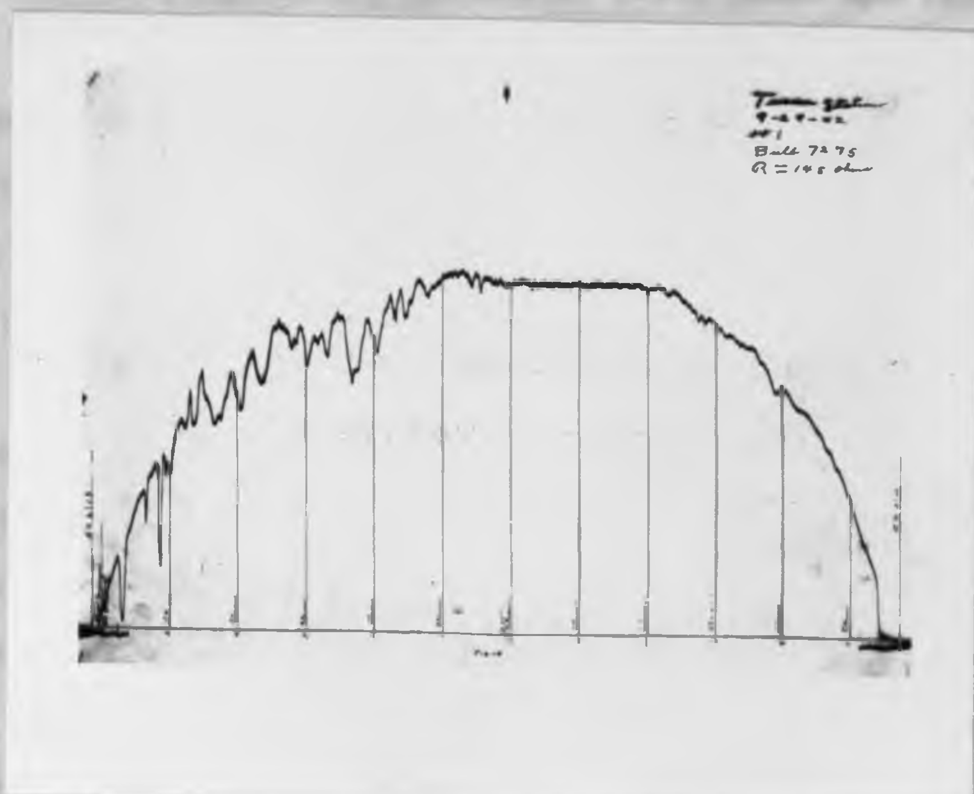
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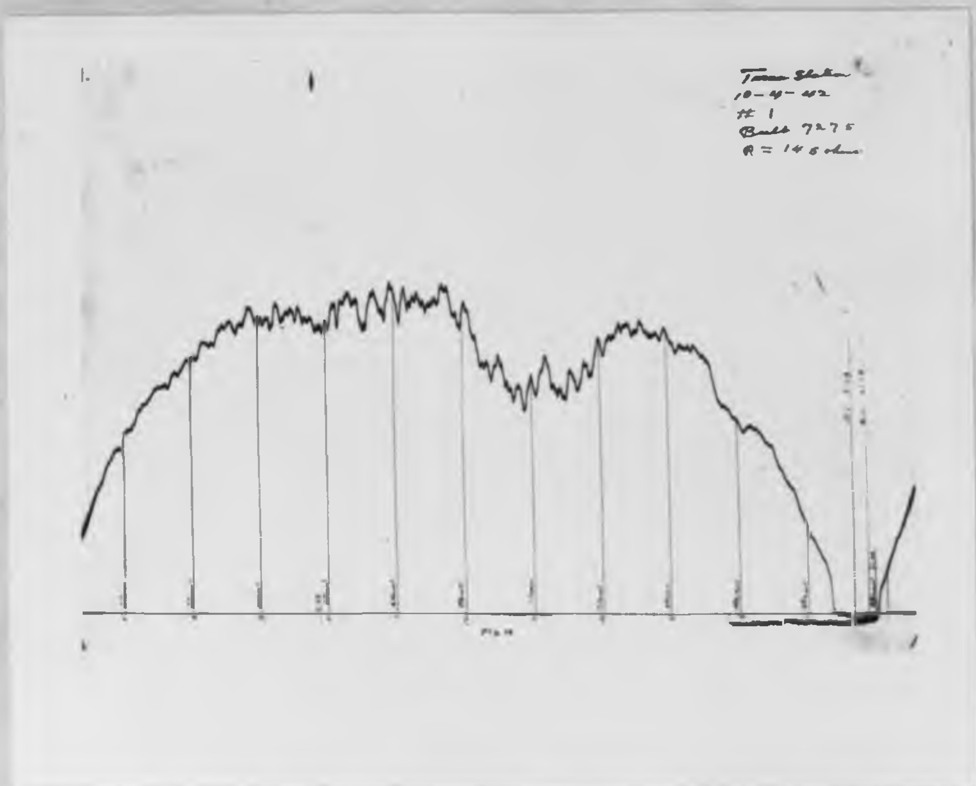
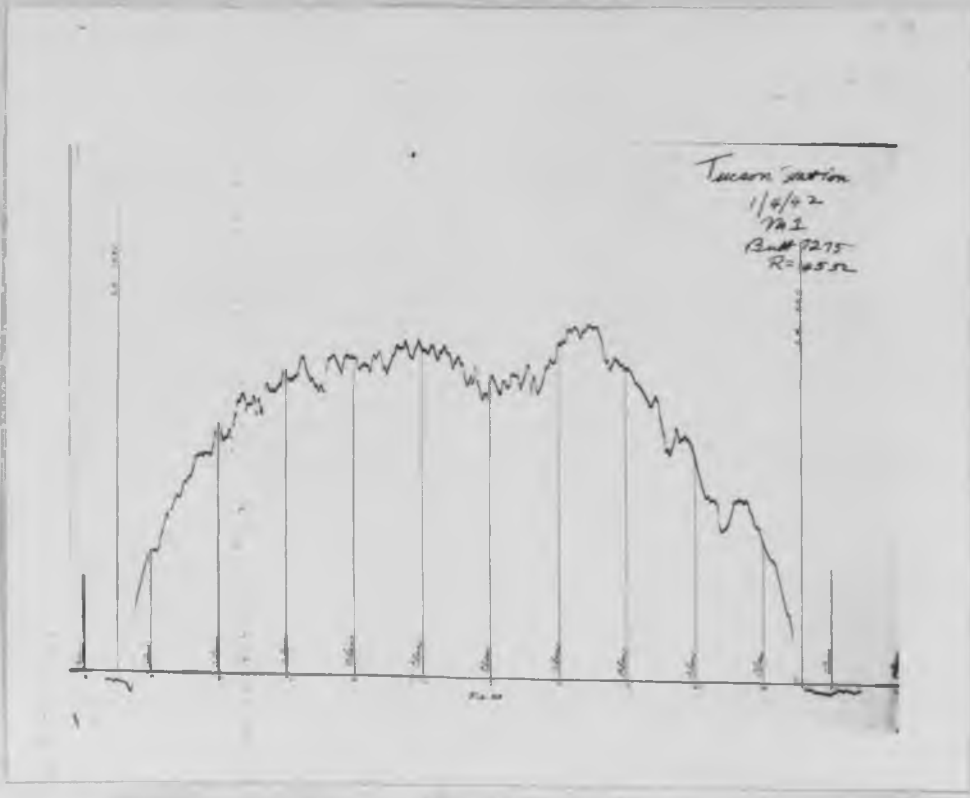


the trace shows considerable flustuation, yet no clouds were visible.

Figure 19 is the trace for an apparently clear day. No clouds were visible the entire day near the horizon or higher in the sky. This chart produced by the writer on October 4, 1942, and the one produced by Mr. John Phillips, shown by Figure 20 (page 23), is typical of 112 of the 114 days observed as apparently clear days.

From January 1, 1942, until June 30, 1943, there were 114 days during which absolutely no clouds whatsoever appeared on or near the horizon or higher in the sky. Of these 114 days, only two days, January 14 and 15, 1942 showed traces such as Figure 3. The remaining 112 days had traces similar to Figures 19 and 20.

In addition to the above-mentioned days, there were many days that could be termed "clear," since only a few clouds would develop over the



mountains, never come near the sun, and then evaporate before late afternoon.

CHAPTER V.

SUMMARY

Conclusions:

1. Upper Clouds

Cirrus, cirrocumulus, and cirrostratus cannot be classified with any degree of certainty by means of the chart trace. Although Figures 6 and 8 (pages 13 and 14, respectively) are typical of cirrus and cirrostratus, respectively; the traces of Figures 19 and 20 (pages 22 and 23, respectively) for apparently clear or cloudless days are similar.

2. Middle Clouds

Altostratus can be identified with the chart trace.

Altocumulus can be identified in most cases. The magnitude of the dip in the trace, when the clouds move over the sun, is approximately one-third of the maximum ordinate for the day. However, relatively high altocumulus cannot be distinguished from low cirrus densus by the trace.

3. Lower Clouds

Stratocumulus is the most easily identified of all clouds by the chart trace. The magnitude of the dip of the trace, when a stratocumulus cloud covers the sun, is approximately two-thirds of the amplitude of the maximum ordinate of the trace.

Stratus is easily identified. However, nimbostratus cannot easily be distinguished from stratus.

4. Clouds with Vertical Development

Cumulus can easily be identified by the very large depression in the trace and the very wide trough in the depression, which indicates the height and size of the cloud. Cumulonimbus produces a trace similar to that of cumulus.

5. Invisible Factors

It is quite obvious that the factors producing the disturbance on the clear days were also present and contributed to the trace on cloudy days. This effect would not be so noticeable on a trace of stratocumulus as it would on traces of clouds like cirrus.

6. The Stratosphere Effect

The effect evident in Figures 19 and 20 might briefly be called the stratosphere effect. The stratosphere effect could be due to many factors such as Nacreous and Noctilucent clouds, atmospheric Ozone, and/or the ion layers.

Davis and McCarthy[5] state in their article, "Twenty-Nine Months of Solar Radiation at Tucson, Arizona;"

> "Although no data on the effect of invisible cloud films is at hand, it is probable that such films over the sun may effectively reduce the solar radiation, accounting partially for some of the low values observed under an apparently unclouded sun."

It is obvious from Figures 19 and 20 that: (1) there are some very noticeable disturbances, and (2) during the past 18 months these chart disturbances were frequent.

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5. Davis, George E. and McCarthy, Joseph L., Monthly Weather Review, Vol. 60, pp. 237-242.

Recommendations:

1. Attempts should be made to photograph the high altitude or invisible clouds on clear days when the record shows fluctuation of the trace.
2. To facilitate further study, additional stations with the spherical recorder should be located in the southwestern part of the United States, where a greater percent of the days are cloudless. These stations should be placed 200-300 miles apart, and similar records kept to observe any similarities on cloudless days.

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