In the terrella-experiments, conditions were found that seem to confirm the correctness of this view of the cause of the magnetic perturbations; and to some extent the harmony between the results of the observations and the experiments is striking. The results of the mathematical investigations also give powerful support to this view. In connection with the polar elementary types, for instance, it may be stated that a drawing-in of rays takes place just in a zone answering to the auroral zone; and here the rays descend more or less vertically upon the terrella, and then glance past it as they turn and once more disappear into space. Further, as to the equatoral types a luminous ring is formed under certain conditions in the experiments, this ring consisting of rays that move round the terrella in the plane of its magnetic equator; and there are also found systems of rays that turn round before reaching the terrella, in just such a manner that its effect would correspond to the positive equatorial field.

Two figures representing terrella-experiments are reproduced. One is a series of eight photographs, representing an experiment in which photographs were taken from eight different points of view. The position of the terrella answers to the winter solistice and to 6 a. m. at the magnetic north pole. The photographs have been taken in such a manner as to show successively the afternoon side, the night side, and the morning side of the terrella, the cathode in the discharge-tube being supposed to represent the sun. It will be seen how rings, or rather spirals of light are formed round the magnetic poles of the terrella, and how the rays descend in zones that evidently answer to the auroral zones on the earth.

The second figure shows how the rays move in space round the terrella, and how they are drawn in more or less vertically and concentrated in the polar zones.

Finally, it is shown how the polar systems to some extent follow the sun in its diurnal motion, and how this circumstance varies when the height of the sun above the magnetic equator alters greatly. The most powerful negative polar storms originate, as a rule, on the night side of the earth, the positive polar storms generally on the afternoon side.

A STUDY OF OVERCAST SKIES.

By Prof. E. L. NICHOLS, Cornell University. Dated June, 1908.

[Reprinted from Physical Review, 1908, 28: 122–131.]

In two recent communications I have described the results of certain measurements of the visible spectrum of the light from the sky[1] and have made comparisons between the spectrum of daylight and that of various artificial sources of illumination.[2] In the present paper the spectrum of the light of overcast skies is more particularly considered in its relations to the spectra obtained from the cloudless sky and from skies in intermediate stages.

As in the measurements already described the instrument used was a spectrophotometer of the Lummer-Brodhun type so arranged that one collimator pointed to the zenith while the other, which was horizontal, received the light from a comparison source of nearly constant intensity and composition. This comparison source was an acetylene flame. Measurements were made thruout the visible spectrum from the extreme red at 0.74μ to the extreme violet at 0.38μ, thus including in the observations two regions lying close to the boundaries of the spectrum which had hitherto been comparatively neglected. The results obtained, as in the previous papers just referred to, are presented in the form of curves in which abscissas are wave-lengths and ordinates give the brightness of the spectrum of skylight in terms of the brightness of the corresponding region in the spectrum of the acetylene flame. The scale adopted is entirely arbitrary. The brightness of the comparison spectrum was adjusted to a convenient intensity by the interposition of a diaphragm in front of the flame and of a milk glass screen of neutral tint, the nonselective character of the transmitting power of which had been ascertained by careful observation. Altho many studies of the quality of the light from clear skies have been made, generally for the purpose of testing Rayleigh's theory, but little attention has been given to the light of clouded skies. So far as I am aware, indeed, the only definite spectrophotometric data are those published by Crova in the course of his extended and sytematic observations on the skies at Montpellier in France.[3]

The results to be described in this paper were made during a vacation journey in Europe in 1907.

Measurements of the spectrum of the light from the zenith taken at times when the sky was completely overcast, gave curves notable for their simplicity and for their similarity to one another. The type of these curves is sufficiently represented in fig. 1 where the curve V is for an overcast sky studied in Vienna in June, 1907, and Z represents the character of the

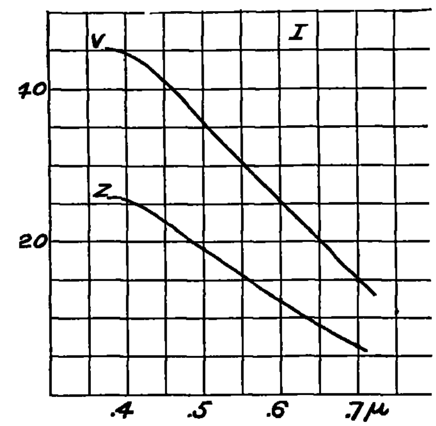

FIG. 1.

light obtained from a similar sky measured at Zell am See, Austria, in July of that year. The former curve was taken just before noon on a rather bright but completely cloudy day, the latter about 6 p. m. when the sky was heavily overcast and threatening rain. While these two skies differ in brightness approximately in the ratio of one to two they indicate remarkable similarity as to the composition of the light coming from the clouds.

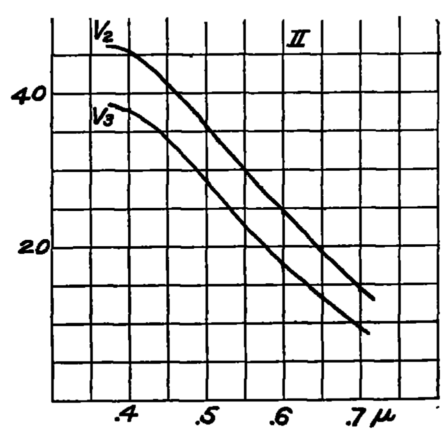

FIG. 2.

It was noted by Crova in the course of his investigation that overcast skies differ but little in composition from many cloudless skies. This observation is verified by a comparison of the

[1] Nichols, Phys. Rev., Vol. XXVI., p. 497. [See above p. 15.]

[2] Nichols, Transactions of the Illuminating Engineering Society, Vol. III., p. 301.

[3] Crova, Annales de Chimie et de Physique (6), XX., p. 480.

curves in fig. 1 with those in fig. 2, which are from measurements made at Vienna on a morning of a cloudless June day. It will be noted that curve V_2, fig. 2, is almost identical with curve V, fig. 1, and that V_3 differs from these but slightly. All of these curves show the same characteristic, namely, a slight droop in the extreme violet. That the light from a cloud in shadow is ever identical in quality with that from blue skies is, I believe, contrary to the common impression; yet it is frequently difficult to tell whether a portion of the sky toward which one is looking is clear or clouded unless one can detect the cloud structure.

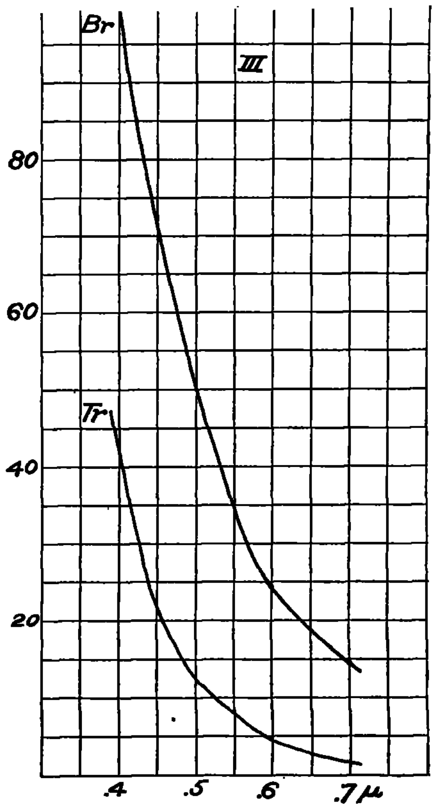

FIG. 3.

While the spectrum of overcast skies is almost identical with that of certain cloudless skies the similarity does not extend by any means to all cases. The intensely blue skies observed in fine weather in regions where the atmosphere is comparatively free from smoke and dust are of quite a different type. Measurements under such conditions give curves of which those in fig. 3 are good examples. The curve *Br* is from measurements made at Brienz, Switzerland, about 8 a. m. on a cloudless morning in August, 1907, while the curve *Tr* was obtained at Trafoi, Tyrol, before sunrise in July of that year. In these curves the relative brightness in the violet as compared with the red is several times as great as in the curves for overcast sky or in the curves for clear sky exhibition in fig. 2. There is moreover no approach to a maximum at the violet end of the spectrum and the yellow and green are relatively very weak so that the curves are strongly concave. Between these extreme types there exist numerous intermediate stages of the atmosphere which depend on the amount of condensed vapor which may be present. On a misty day, for example, when the sun is barely visible another and destinctive type of curve is obtained. Examples of this form are given in fig. 4, the curves in which were taken at Zell am See on a misty day during which clouds were continually gathering and disappearing. Curve *a* was taken at 2:30 p. m. at which time no definite cloud forms were visible but the sky was full of white mist. At 2:45 p. m. the mist cleared and the sky was blue and very bright. Curve *b* represents this condition and it is interesting to compare this curve with those in fig. 2. The intensities are nearly the same as in V_2. The curve *b* is intermediate in type between V_2 and the curves in fig 3 but much closer to V_2 in character. At 3:15 p. m. mist again filled the sky and curve *c* was obtained, the type of which corresponds in all respects with curve *a*. The intensities are the same thruout excepting in the extreme violet where measurements are at best more or less uncertain and both curves have the same characteristic maximum in the blue at 0.42 μ. This maximum is represented in reduced form in the slight drop in the curves from the overcast sky, fig. 1, and is entirely absent in those obtained from cloudless skies of the type depicted in fig. 3.

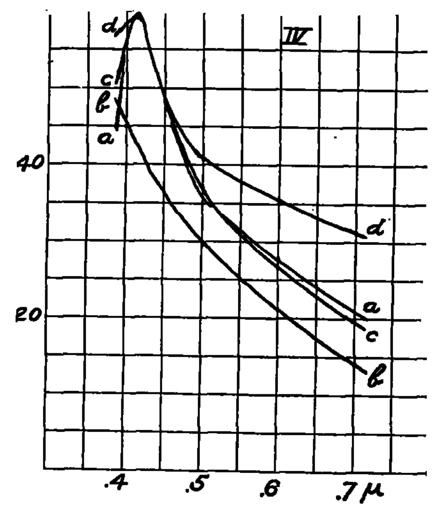

FIG. 4.

At times during the day in question the mists gathered into great masses of sunlit cumulus with patches of clear sky between. At a time when such a cloud mass filled the zenith curve *d* was obtained. In this curve the brightness of the extreme red of the spectrum at 0.7 μ is more than twice that of the spectrum of the clear sky shown in curve *b*. The intensity in the blue at 0.42 μ is the same as in curves *a* and *c* but the peculiar maximum at this region is somewhat less marked.

This maximum in the blue, which is found in all spectrum curves for misty skies which I have observed, appears regularly as the day advances in the mountainous regions of Switzerland during fine summer weather when there is a gradual formation of mist in the upper atmosphere gathering into cloud masses with a tendency toward thundershowers in the afternoon. The change in the curve occurs before the presence of mist is easily observable to the eye. The maximum is commonly well established before noon and frequently persists until toward sunset.

The gradual growth and disappearance of this characteristic may be observed whenever observations are made at intervals thruout the day under weather conditions such as I have described. Fig. 5 shows results obtained at the top of the Brienzer Rothhorn in August, 1907. The curve taken at 10:10 a. m. shows no trace of the maximum in the blue. At 11 a. m. the intensities in the blue and violet had rapidly increased and the approach to a maximum in this region began to manifest itself. At 3:30 p. m. the maximum was well marked; at 4:20 p. m. it had again almost disappeared, the type of curve being almost identical with that obtained at 11 a. m. A much more complete series of observations showing these gradual changes of form during the day was obtained at Sterzing on July 17. Measurements were begun before direct sunlight reached the valley and were continued until after sunset.

The general character of the results are shown in fig. 6, in which the curves drawn in full line are from measurements taken before noon, while the dotted curves give data obtained

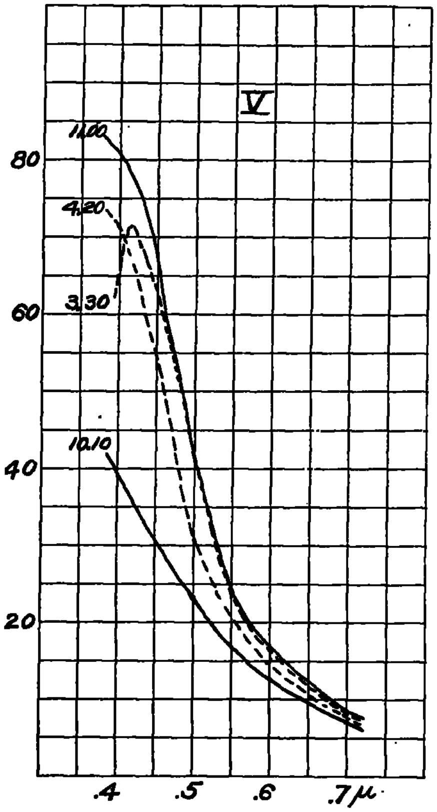

FIG. 5.

in the afternoon. It will be noticed that the curves at 5:20 and 7 a. m. are of the usual early morning type and similar to those of fig. 3. At 10:20 a. m., however, the maximum in the

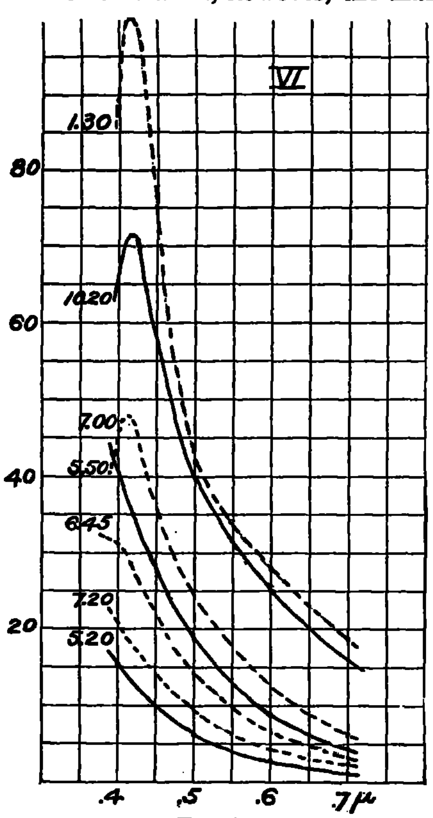

FIG. 6.

blue had developed and it persisted until late in the day. The curves at 1:30 and 5:50 p. m. show the continuance of this feature, but at 6:45 p. m. it had nearly disappeared, and at 7:20 p. m. was entirely gone. The curve at that hour had returned almost exactly to the form obtained before sunrise.

The maximum in the blue seems to occur in its most pronounced form at high altitudes. The best examples of it which I obtained were observed at Samaden in the upper Engadine, and on the upper ice field of the Rhone Glacier.

In curve *S*, fig. 7, which represents the readings taken at Samaden about 9 o'clock on a morning in July, when the sky appeared quite cloudless, the maximum is developed to an unusual degree. It will be noted that the spectrum of the light from the sky was relatively no brighter, compared with that of the acetylene flame, in the extreme violet at 0.38 μ than in the green at 0.50 μ. In the intervening region, however, the ordinates rise to double these values.

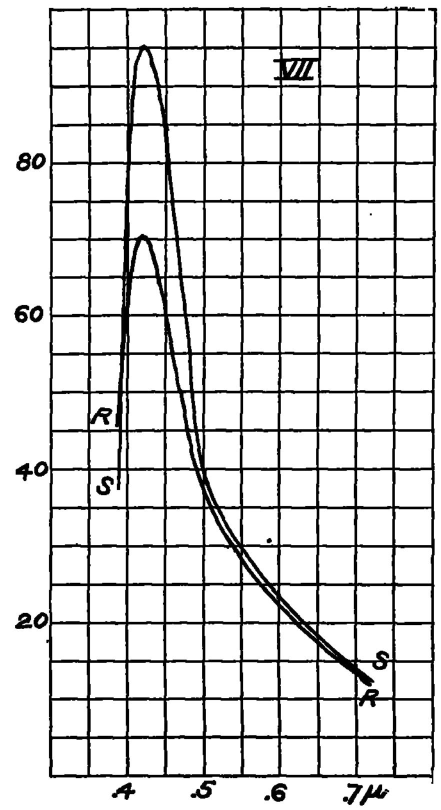

FIG. 7.

Curve *R* in fig. 7 is from measurements made on the ice field of the Rhone Glacier at a point above the ice fall near which crossing is usually made from the Belvidere to the Naegeli Graetli. It was a bright morning but mists were continually forming on the surrounding peaks and melting away so as to leave the sky overhead apparently clear. It will be noted that the intensities of the spectrum thruout the region lying between 0.5 μ and 0.7 μ are almost identical with those obtained at Samaden. The variations lie almost entirely in the blue and violet of the spectrum. Altho in these regions the curves do not coincide, the maximum at 0.42 μ appears in both.

Whether this highly variable band in the blue is an emission band superimposed upon the spectrum of a sky greatly diluted and whitened by the sunlight reflected from particles of condensed vapor, in which case it might be ascribed to the fluorescence of some variable component of the upper atmosphere, possibly ozone, as suggested by Hartley; or whether it is wholly due to selective absorption in the ultraviolet on one side and in the green on the other, as seems much more probable, can not be definitely determined from existing data. In any event, it is a phenomenon absent from the clearest skies and one which is rapidly masked by the presence of considerable thicknesses of cloud materials. Whatever be its nature, it indicates an occasional departure from the distribution of intensities which characterizes the perfect sky of Rayleigh, of a sort which demands further investigation.

It will be seen from the foregoing that there are between the typical curves for the unclouded sky as exhibited in fig. 3 and the curves for completely overcast sky (fig. 1), a number of intermediate forms of considerable complexity. The presence of condensed vapor has the effect of increasing the intensity of the longer wave-lengths of the spectrum so that the ordinates of the curves are raised thruout the red, yellow, and green. At the same time the maximum in the blue is developed and the spectrum of light from the sky shows the phenomenon of selective reflection to a remarkable degree. Light from sun-illumined cloud masses exhibits the further modifications shown in curve *d* of fig. 4, in which the intensities in the red, yellow, and green reach their highest values. The maximum in the blue is in this case still noticeable, altho by no means so marked as in the case of light from a clear sky in the presence of incipient mist.

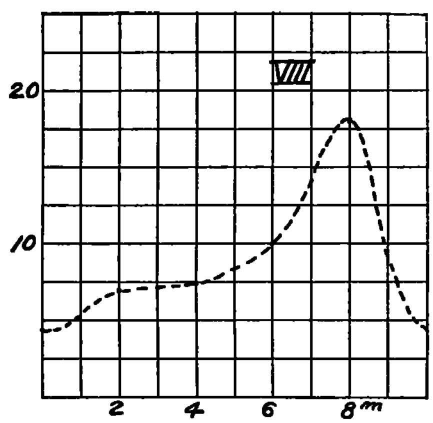

FIG. 8.

That the brightness of the sky increases with the gathering of cloud masses, up to the point where sunlight is completely shut out and the sky becomes thickly overcast, is clearly shown by means of the results graphically recorded in fig. 8. The readings from which this curve was plotted were all made from a single wave-length in the red end of the spectrum. The observations were taken during the rapid gathering of clouds upon a showery day, the initial condition being that of a blue sky with no visible mist. Measurements were made as rapidly as possible during the interval of ten minutes, at the end of which the sky was completely and heavily overcast. The curve which has time as abscissas counting from the first observation and intensities of the wave-lengths in question (0.7 μ), in terms of that of the acetylene flame as ordinates, rises to a well-marked maximum after eight minutes and then falls to a value, after ten minutes, almost identical with the value of the initial reading. The maximum corresponded as nearly as could be observed to the sudden exclusion of direct sunlight from the masses of cloud under observation, and the curve seems to indicate that up to the point where this occurred brightness increased rapidly as the mist gathered. Observations by Basquin[4] and others upon the illumination received from the sky under different conditions are quite in accord with the indications given in this curve. The brightest sky corresponds to a cloudy rather than a clear condition of the heavens, but after a certain density of the cloud masses has been attained the illumination falls off in consequence of the exclusion of direct sunlight from the visible surfaces of the clouds.

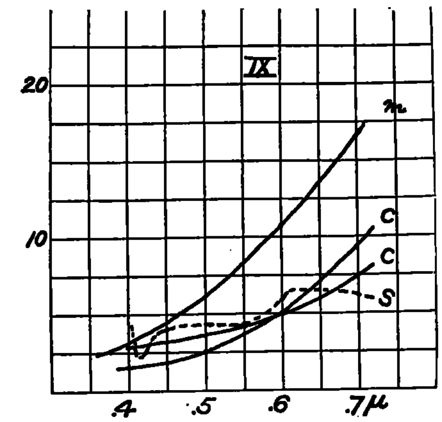

FIG. 9.

In the beginning of this paper I spoke of the curves obtained from overcast skies as being of a simple character, by which is meant that there is less evidence of selective reflection than is the case from the open sky. The distribution of intensities is such as to indicate a composition of light closely related to that of radiation from the carbon in the comparison flame, altho of course of very much higher temperature. Nearly all measurements of light from unclouded skies, particularly at times when the surface of the earth as well as the upper air are in sunlight, show on the other hand more or less well defined selectivity. A comparison of such curves with a curve for light from the sky taken upon a clear morning before sunrise—what I have called the *typical dawn curve* in the first of my previous papers already cited—shows a more or less complicated relationship like that represented in the curve *s* in fig. 9. I have discussed the nature of these ratio curves in the paper in question. When, however, we plot similar curves for the ratios of overcast or mist-filled skies to the typical dawn curve, in cases where the fog is of sufficient density to prevent the direct illumination of the surface of the ground, we get curves of the form *c* and *m* in fig. 9, which are quite free from the irregularities presented by the curve *s*. This would seem to indicate that the selectivity of ordinary skylight is due on the one hand to light reflected from the surface of the ground to the atmosphere, and on the other to selective reflection which takes place in the upper layers of the atmosphere and which is cut out by the intervention of a layer of mist or cloud so that the light from overcast skies is more directly related to sunlight, altho modified as to the distribution of intensities, than is the light commonly observed in the case of unclouded skies.

[4] Basquin, Illuminating Engineer (N. Y.), Vol. I, p. 829.

RAIN WITH LOW TEMPERATURE.

By A. LAWRENCE ROTCH. Dated Blue Hill Meteorological Observatory, January 18, 1909

[Reprinted at author's request from Boston Transcript of January 20, 1909.]

Many persons have been puzzled by observing, in the last two storms, the snow turn to rain while the temperature remained considerably below the freezing point.

The explanation is furnished by the data from kite flights which were made last week at Blue Hill in cooperation with the international series of ascensions of kites and balloons. Kites, carrying recording instruments, were flown on alternate days and entered a warm stratum, whose elevation varied from about 800 feet on the 11th to 3,500 feet on the 15th. Ordinarily, the temperature of these heights is from 3° to 10° lower than at the earth's surface, but during the past week it was actually some 10° warmer than below. Consequently, as