about 15° nearer the equator. This latter feature gives it soil temperatures and monsoon influences similar to those that prevail in northern Africa, so that it may itself produce an appreciable disturbance of the general circulation in the southern half of our atmosphere. But the principal cause of the droughts in Australia and India is undoubtedly to be found in the changes going on periodically in the relation between the general atmospheric pressure and resultant circulation in the south and in the north, or between Cape Colony and Australia, China and eastern Siberia. In this large portion of the globe a system of circulation prevails that is affected but comparatively little by what goes on to the west of it and north of it. A large quantity of air enters into this region from the Antarctic Ocean and passes out of it as the southwest monsoon of southern Asia to eventually become the westerly winds of the North Pacific. We may, therefore, look for some connection by this roundabout way between the droughts and rains of Australia, or southeastern Asia, and those of northwestern America.—*C. A.*

SHADOW BANDS; SCINTILLATION; INTERFERENCE BANDS.

Among the optical phenomena observed in the atmosphere the shadow bands seen on the ground during total solar eclipses just before the beginning and just after the end of totality have excited considerable attention. During the total eclipse of May 28, 1900, they were made the special subject of investigation in connection with Weather Bureau work, as it is highly probable that they originate in the earth's atmosphere. It is very rare that there do not exist in the atmosphere ascending and descending currents of air, which may be on a very minute scale as well as on a large scale. We conceive of the atmosphere as filled with minute masses of smaller density slowly ascending amidst equally minute descending masses of greater density. This mixture of rarer and denser portions produces in general a loss of light and a diminution of sound, which we know under the familiar name of heat-haze and acoustic opacity, respectively. Another effect is perceived when one views a minute source of light, such as a fixed star, and notices that it is apparently wobbling in all directions irregularly. This is undoubtedly due to the irregular refractions of the ray of light, which is bent out of its course by having to pass through so many curved surfaces separating the masses of warm air from those of cold air. In addition to refraction, the ray of light is also subject to prismatic dispersion, and the star is seen to oscillate in color from blue, through green and yellow, to red, especially when it is low down in the horizon. The existence of this mixture of small masses of air having different degrees of refracting power is also very prettily shown when we look at a white surface illuminated by a bright point, such as the electric light. In this case we see the white surface, not of a uniform tint, but spotted all over with dark and bright patches, which are in constant motion corresponding to the movements of the mixed cold and warm currents.

During the progress of a total eclipse the sun's disk is for a few minutes before and after the totality reduced to an exceedingly thin, bright circular arc, whose light throws upon a bright wall, or a white sheet laid upon the ground, visible shadows perfectly analogous to those just referred to as cast by the electric light; the principal differences arise from the fact that the eclipse happens during the warmer daytime and that the sunlight comes from a considerable angular altitude, whereas in the electric light we observe during the cooler night-time, and the beam of light is nearly horizontal and passes through only a small thickness of the lower air. If there were minute waves on a horizontal surface separating two strata of air at some distance above us, then the sunlight refracted at this wave surface would produce simple bands of shadow on the ground analogous to the shadows of the ascending warm air. This is a possible phenomenon, but not one that is likely to occur without being combined with the more important phenomena due to ascending currents analogous to waves in a vertical plane. To these combined horizontal and vertical waves we owe the phenomena of scintillation that have been most patiently observed by Montigny, in the hope of deriving therefrom some additional knowledge of the conditions prevailing in the upper air. But the investigations made, by means of the scintillometer, and especially the complete explanation by Exner and Pernter, of the origin and nature of scintillation have shown that but little of any value to dynamic meteorology can be expected to be derived from this study, although it is important to astronomy. The eclipse of May, 1900, added considerably to the observational data on the shadow bands or the dark fringes, as they are sometimes called. Among the articles written on the subject we note one by G. Johnstone Stoney in the Monthly Notices of the Royal Astronomical Society, vol. 60, p. 586. A memoir by Señor V. Ventosa, Astronomer at the Madrid Observatory, is summarized on page 86, vol. 62, 1900, of the English journal Nature, as follows:

> The examination of the observed facts appears to support the view that these shadow phenomena are not diffraction fringes bordering the actual shadow of the moon, but are produced in the body of our own atmosphere and are affected by the direction of the wind.
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> Señor Ventosa has been occupied for some time in studying the currents in the higher regions of our atmosphere by observing the undulations round the sun and stars with a telescope, and thinks that these upper atmospheric currents may possibly have some bearing on the question of the eclipse shadow bands; the movement of these higher portions showing through the quieter lower strata, and being rendered visible on account of different refractive powers. He thinks it would be useful to determine the velocity of these currents by anemometers at various altitudes, and also to observe the undulations round the limb of the sun at the time of eclipse, comparing them with the shadow bands in direction and velocity of movement. To ascertain if any experimental illustration of this hypothesis could be presented, he states that bands may be produced by passing diffused light reflected from a sheet of corrugated glass through a circular aperture representing the sun, over which an opaque disk, representing the moon, is made to slide. When the segment left uncovered is about 5 mm. in width, alternate bright and dark bands can be observed on a white screen held near, if the length of the segmental opening is approximately parallel to the undulations of the glass; but if at right angles they entirely disappear. * * * This hypothesis shows the advisability of recording the direction and velocity of the wind during eclipses.

The subject of the shadow bands has been especially considered by Prof. F. H. Bigelow in the third chapter of his Eclipse Meteorology and Allied Problems. On page 57, after the collation of observations at many stations, he says:

> The direction of the cusps of the visible arc of the sun and the direction of the shadow bands are generally parallel to each other, and this direction varies distinctly between the center of the path of totality and the edge of the path, yet, keeping up the same parallelism. These two geometric facts are practically decisive in regard to the origin of the bands * * *. We, therefore, dismiss the diffraction theory from further consideration. We are, therefore, brought to conceive of the umbra [or central blackest portion of the moon's shadow] as surrounded by semiopaque rings * * * of such a character that the crescents of the sun's disk will cast down images upon the ground through a flickering and wavy medium. The width of the bands was found to be on the average 1.37 inches before totality, and 1.21 inches after totality; the widths of the bright spaces were 2.15 inches before and 2.24 inches after totality.

Owing to the irregular refractions of sunlight passing through a mixture of small masses of warm and cold or dry and moist air, the air must contain an immense number of small beams of light slightly inclined to each other and some of these produce what are known as optical interference. This subject is explained fully in all treatise on physical optics (see also Watson's text-book of physics). Interference is the cause of numerous well-known phenomena, such as the colors seen on irridescent mother of pearl and the magnificent ruled gratings of Rowland; also the so-called colors of thin plates seen in soap bubbles or between plates of glass when pressed together and in films of oil on water. The diffraction rings seen about a bright light when viewed through a dusty atmosphere, or through a very narrow slit are also cases of optical interference.

In general we may say that when a wave of light has just arrived at any surface every atom of that surface is at that moment just beginning its minute vibration that produces in the human eye the effect called light. Each of these atoms not only oscillates to and fro, but also sets in motion the atom next in front of it, with, however, an appreciable lag in time. From each atom there proceeds a series of oscillations such that all atoms at the same distance from the initial one just begin to move at the same moment. The distance between two atoms that are in the same phase of motion is the length of a wave of light. The atoms that are just beginning to move in the same direction at the same moment make up a wave front. The vibrations proceeding from the atoms in a wave front often interfere with each other. Two beams of light inclined at a small angle to each other may produce brightness in some portions of the region where they interfere with each other and darkness in another portion, so that the whole space may be filled with alternating bright and dark regions. If the beams are stationary, then, these bright and dark patches will also be so, but if the beams are moving or flickering the dark patches will have corresponding motions. Analogous quiet patches are observed when waves of water or of sound interfere with each other.

If we look through a very perfect telescope at a bright star we shall see the flickering movements peculiar to the beams of light passing through the earth's atmosphere. If we pull the eye piece of the telescope forward, so as to convert the sharp image of the star into a large circular blurr, we shall obtain virtually a small image of the condition of affairs. If the glass is imperfect, we shall see its imperfections. If the air, either of the atmosphere beyond the glass or within the tube of the telescope, has any imperfection as to homogeneity, we shall see its effect, since it will produce slightly convergent rays of light, and resulting interferences, and we shall see bright and dark spots or bright and dark bands covering the surface of the lens. As these atmospheric imperfections are usually in motion, either horizontally with the wind, or vertically, because of temperature or irregular eddies, therefore, the bands and spots will appear in motion across the lens. It would not be fair to consider this motion as an indication of the direction of the wind unless we are sure that it is caused by the wind only and is not affected by any vertical convection.

The frequency of the oscillations of the beams of light is best studied by the use of the scintillometer, which is a simple device by means of which the sharp well defined image of the star is made to move around the field of view rapidly in a circle. We at once perceive this circle broken up into parts or bright lines separated by dark spaces: if the image of the star is made to rotate rapidly enough, we may easily count the number of alternations of brightness and darkness per second, corresponding, therefore, to the number of small masses of warm and cold air that have passed across the line of sight in that time.

The character of the interference phenomena may also be studied by photographing the diffuse image of the star, as has been done by A. E. Douglass, at the Lowell Observatory, Flagstaff, Arizona, a report on which was published by him in the American Meteorological Journal, March, 1895, Vol. XI, pp. 395–413. He states that his first observation at that observatory, September 28, 1894, showed that a swift northeast and a slow north or northwest current were present. The distance between the bands as they crossed the objective he called the "breadth of the wave;" but this "wave" is simply the optical appearance on the object glass and has no known connection with the waves of the atmosphere. It is a resulting optical effect, and it would be a mistake to hastily adopt the conclusion that we are observing waves in the upper air due to the wind; we observe only the "interference bands." When the sun shines through a basin of water whose surface is in wavy motion, lines or spots of brightness and darkness are seen at the bottom of the vessel, and these do have some simple relation to the wave surfaces, but this is not the case with the interference bands observed by Mr. Douglass's method. It is possible that by long-continued study of these telescopic phenomena one may be able to deduce important information with regard to the condition of the atmosphere, and there is reason to hope that Mr. Douglass's observations at Flagstaff will be repeated in other localities. He himself has stated that his "waves" change their size in the presence of clouds and that their motions have some connection with the lower isobars. The method of determining the distance or location of the atmospheric disturbances devised by Mr. Douglass seems to us to need revision. We are simply observing one set of interference bands out of the myriads that must exist between the eye and the source of disturbance.

In an article in the Monthly Notices of the Royal Astronomical Society for November, 1902, Mr. Percival Lowell, Proprietor and Director of the late Flagstaff Observatory, announces that expeditions should be sent to various portions of the globe in order to ascertain where atmospheric conditions are most favorable for the best astronomical work. Speaking of what constitutes satisfactory or unsatisfactory vision of the celestial bodies, he says:

> Studies directed to that end have resulted in a knowledge of the conditions which constitute good or bad seeing. * * * The basis of the matter lies in the discovery that systems of waves traverse the air, several of these systems being present at once at various levels above the earth's surface. The waves composing any given system are constant in size and differ for the different currents all the way from a fraction of an inch to several feet in length. If the wave be less than the diameter of the object glass from crest to crest, the image is confused by the unequal refraction from the different phases of the wave; if the wave be longer than this, a bodily oscillation of the whole image results. The first is fatal to good definition, the second to accurate micrometric measurement.
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> It is possible to see these waves by taking out the eyepiece and putting one's eye in the focus of the instrument when the tube is pointed at some sufficiently bright light. It is further possible to measure their effect by carefully noting the character of the spurious disk and rings made by a star and the extent of the swing of the image in the field of view. By combining the amount of confusion with the degree of bodily motion of the resulting image the definition at any time and place can be accurately and absolutely recorded.
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> The increasing perfection of the optical image of a star testifies to the increasing lack of damaging currents with reference to the object glass used. It records all the waves below a certain wave length. Similarly the amount of bodily motion registers all those above that length. The two taken together give account of all the currents independent of the glass.—*C. A.*

METEOROLOGICAL STATIONS IN AFRICA.

We take pleasure in announcing that, in connection with the work of the Georgetown College Observatory, in charge of Rev. J. G. Hagen, S. J., an auxiliary observatory is to be established by Rev. Edmund Goetz, S. J., at Buluwayo, Rhodesia, South Africa. This new station will attend to meteorology as well as to astronomy, and will be in latitude 20.5° south, longitude 29° east. The meteorological observatory at Kimberley, in charge of J. R. Sutton, and known as the Kenilworth Observatory, is in latitude 26.5° south, and longitude 25° east. The station Zomba in British Central Africa is in latitude 15° 22′ south, and longitude 35° 18′ east, or a few degrees south of Lake Nyassa, at an altitude of 2,948 feet. These few stations are but samples of the hundreds that are now being occupied throughout those portions of Africa that are accessible to modern civilization.—*C. A.*