in which clouds are conveniently placed in five levels: Level 1, Cirrus, 9000 metres; level 2, cirro-cumulus, 7000; level 3, alto-cumulus, 2000 to 4000; level 4, cumulus, 1200 to 1600; level 5, stratus, 500 or lower, these data being from observations at Blue Hill. The correctness of this estimate was apparent as light increased, for the sheet of clouds gradually assumed the appearance of a very thin A-Cu. mixed with A-St., one and sometimes the other predominating. Between 8.17 and 8.50, through openings in the A-Cu., were seen well-defined Ci or Ci-St. moving with nearly the same velocity and direction as the A-Cu.; it is possible that these Ci really were streamers from the A-Cu-A-St. and should be assigned to the same level. Possibly, from appearance alone the prevailing clouds should be placed in Level 2, or between Levels 2 and 3; but they were changing continually and rapidly, partly because

Observations of Clouds at Middletown Connecticut, During the Total Solar Eclipse of 1925

Time A.M.	Level (1—5)	Kind and Density (0—4)	Amt. (0-10)	Azimuth From Degrees	Velocity		Posi-tion	Remarks
					Rela-tive mm	Abso-lute m/s		
7.00	3?	A-Cu^3	9	W.NW.			W^d	
7.30	3	A-Cu^3	7	W.N.W.			NW^d	
8.17	2?3?	A-Cu^3	3	131	76	15		Scattered
8.30	1?	Ci	?	134	60	35?		Partly hidden by
8.33	1?	Ci-Ci-St^4	5	134	54	30?	NE	A-Cu
8.35	3?2?	A-Cu^2	5	129	70	14	W^d	
8.47	1?	Ci^3?	2	131	60	35?	NE	
8.47	2?	A-Cu$^{1-2}$	3	128	54	11		
9.00	2–3	A-Cu^1-A-St^2	3	145	74	15		
9.01	2–3	A-Cu-A-St	3	134	69	13	E^d	
9.06	3	A-Cu-A-St	2?	140	72	14	E^d	
9.30	3	A-St-A-Cu^1	2	147	84	17	E^d	
9.32	3	A-St-A-Cu	2	140	80	16	E^d	
9.38	3	A-St-A-Cu	2	138	84	17	E	Very low; only 8°
9.41	3	A-St-A-Cu$^{3-1}$	2	139	78	16	E	above horizon
9.56	3	A-Cu-A-St$^{1-2}$	3	138	66	13	E	
10.05	3	A-Cu-A-St$^{3-2}$	3	136	64	13	E	
10.07	3	A-Cu-A-St^3	2	128	90?	18?	E	Same cloud obser-
10.09	3	A-Cu-A-St	2	138	74	15		ved at 10.05
10.10	3	A-Cu-A-St	2	132	80	17	E	
10.12	3	A-Cu-A-St	2	130	78	16	E	Clouds higher and
10.13	3	A-Cu-A-St	2	130	82	17	E	observations bet-
10.45	3	A-Cu-A-St^2	2	125	80	17	E	ter than those
10.48	3	A-Cu^1	2	123	74	15	E	between 9.01 and
10.49	3	A-Cu^1	2	126	80	17	E	10.05

Note—When two kinds of clouds are mixed or in the same level the prevailing kind and its density are entered first. The column headed "Position" indicates the position of clouds with reference to the observer or that of greatest density or number, indicated by the exponent *d*.

of evaporation and of changes in illumination as the eclipse progressed and had other characteristics of a low A-Cu. The changes of outline or form impaired the accuracy of the individual measurements and doubtless account for the differences between consecutive measurements at 10.05 to 10.07 A. M. and elsewhere.

The actual velocities in Figure 1 were computed from observed relative velocities, assuming that the Ci. were 6500 and the A-Cu. 2000 metres above sea-level. Relative velocity is the distance in millimetres traveled by the cloud-image in one minute when the observer's eye is 167 mm above the reflecting surface of the nephoscope, and is convertible into actual velocity in metres a second by multiplying it by the height of the cloud, in metres and dividing by 10,000—an operation performed mentally.

Mr. Clayton, who was at Westerly, suggests that the apparent clearing of the sky, observed at Middletown, New London and Westerly, was probably due to the shadow.

Shadow-bands. The methods of observation followed were suggested by Upton and Rotch for the eclipse of 1889 and described in the *Annals of Harvard College Observatory*, XXIX, 1. The "lie" and direction of motion at each appearance were marked by colored sticks laid on the snow-covered ground and afterward measured by means of the alt-azimuth. The conditions for observations were excellent although better results might have been secured by two observers, one measuring the "lie" and the other the direction of motion.

On first appearance the bands were a faint mass of interlacing bright lines, rapidly and continually changing in length and having an indefinite rapid lengthwise motion as well as a slower general movement from the W.N.W. The visual effect was that of a layer of transparent liquid some 15 centimetres deep into which has been poured another liquid having a different density. Precise measurements were impossible. The bright lines apparently were about one centimetre wide and 3 to 4 centimetres apart. During the second appearance these bands were more definite, and better measurements were secured, the "lie" being about 45°—225°, the azimuth of motion from about 110°, and the velocity 1 to 2 metres a second. As nearly as could be determined, the width and distance apart were about 3 to 4 centimetres. Azimuths are from south (0°), through west (90°), north (180°), east (270°) to south.

By reason of their irregularity and indefiniteness the bands observed by the writer at Middletown (and by others) were very unlike those accompanying earlier eclipses, particularly those observed at Washington, Georgia, in 1900, which were sharply outlined and retained a definite form and dimensions throughout the two periods of visibility. The most probable reason for the difference is that the atmosphere, on the 24th of January, 1925, was unusually quiescent or homogeneous, a state to be expected at so early an hour in midwinter in this region, but, in this instance, intensified by anti-cyclonic conditions, and by clouds. The attempt to photograph the bands failed.

General agreement regarding the cause of shadow-bands has not yet been reached. Neither convection near the earth's surface, nor changes in refraction when sunlight passes through strata differing in temperature are considered sufficient, themselves, for shadow-bands have been observed on a sheet suspended from a balloon at a height of 3800 metres, far above convection from the ground, and stratification is a persistent if not a normal state of the atmosphere, at all heights. Information accumulated since 1900, indicates that these bands probably occur chiefly, perhaps only, during the mixing of masses of air having different densities or temperatures, as do the familiar artificial shadow-bands or waves that form over chimneys, heated roofs or when air from a warm room escapes through a window. These contrasts of density or temperature in the free atmosphere are maintained to an appreciable degree only during the rapid decrease and increase of temperature before and following totality, and the motions of the bands or waves probably are more closely related to those of the eclipse wind than to the normal wind prevailing at the time. At Middletown, the velocity of the shadow-bands was 1 to 2 metres a second, and that of the A-Cu., 15, while a calm prevailed at the ground.

The Meteorology of Future Eclipses

If worth-while contributions to meteorology are accomplished by the collection of data during future eclipses, methods and equipment must be given first consideration. The need of this was clearly evident from an examination of many records obtained during the eclipse of 1925, some of which, although made by conscientious observers, were of small value because of the lack of information concerning the conditions or requirements of such work. Studies of former eclipses show clearly that the methods of the ordinary climatological station (where temperatures are read to whole degrees, pressures to 0.3 mb and the directions of wind and clouds to eight points) are hopelessly inadequate, for the probability of a calm day when eclipse-effects are large is usually too small to be depended upon. Sensitive recording instruments are preferable to instruments that must be read frequently, for not only can readings of record-sheets be made much oftener and pressures and winds determined more accurately, but the valuable time of observers can be devoted to observations of clouds and other phenomena. A ventilated meteorograph of the Assmann type, having a time-scale of at least 10 mm an hour, and whose pressure-pen moves 3 mm for a change in pressure of 1mb, exposed in an open shelter of the French type should be very satisfactory; pressures recorded on such a wide scale are more accurate than readings of the ordinary portable mercurial barometer, and the temperatures will not be affected by the nearness of the observer as might be the case if frequent readings of thermometers were depended upon. For data of the wind, the portable Draper anemoscope and anemometer, employed during eclipses since 1889, is most satisfactory; the direction should be read to degrees and velocity to half-metres a second. To facilitate reading when the direction is very variable this instrument should have two time-scales, one of about 10 mm and one of 40 to 60 mm an hour, the former for use during the period before the eclipse when the local characteristics of the station are determined, and the latter only during the eclipse. If recording instruments are not available an Assmann ventilated psychrometer can be submitted for the thermograph, a wide-scale aneroid for the barograph, and the direction of the wind can be determined from observations of a vane reflected in a nephoscope, as was done during the eclipse of 1918; but, to allow for errors and accidental variations, observations must be made very frequently—every two or three minutes if possible—and a full program will require at least two, and preferably three observers, one of whom should give his entire time to clouds, which have received little attention heretofore.

Concerning exposures of instruments, stations should be placed where there are no hills, trees, buildings, etc., likely to obstruct or deflect the normal wind in any direction; obviously, the more first-class stations, well-distributed, the better. Since temperatures in closed shelters lag appreciably, particularly during calms, a small, open shed having a double roof and suitable boards on three sides to exclude direct sunlight and heat radiated or reflected from surrounding objects, will be best for the thermometers and can easily be improvised from inexpensive materials. It should be erected over grass in an open space freely exposed to the wind.

To summarize, adequate observations and records during solar eclipses are no more difficult to secure than are data of uncertain quality and do not necessarily require elaborate or very costly apparatus; the chief requisites are instruments with wide scales permitting frequent readings, proper exposures and care, information concerning which is available in recent pupblications.

The meteorology of solar eclipses may not be of the highest importance, but, viewing a program of study simply as an experiment or an exercise in the measurement of very small quantities, the results of which may have an incidental value in astronomy or physics, it is believed that the small effort required is worth while.

Washington, D. C.,
12th August, 1925.

Cause of Shadow Bands

Plates exposed here (Middletown, Conn.) during the period of shadow bands in the total eclipse of the sun have been developed at Wesleyan University and prove beyond any doubt, it is said, that the bands were caused by irregularities in the density of the atmosphere. This is the theory that has been held for years, but is the first time that it has been proved by actual photographs. The plates were forwarded by Dr. A. E. Douglass, director of the Steward Observatory at Tucson, Ariz., who designed the camera. The conditions under which the photographs were taken were perfect. Dr. Douglass says that the same effects witnessed