ence low temperature may be expected to have on the indications of an instrument whose action depends on a steel helical spring. The effect of temperature on such instruments is often ascertained more conveniently by trial than by calculation; but when the instrument is to be used at temperatures outside of the limits between which it has been tested, recourse must be had to calculation, usually by extrapolation from the temperatures at which tests have been made. It is always a question how far it is justifiable to carry such extrapolation; for the rate of change with temperature may be very different outside the limits within which tests have been made from what it is inside of them. The writer's experiments show that at low temperatures no very great change takes place in the manner in which the elasticity of steel depends on temperature; and that, therefore, in allowing for the effect of low temperature on an instrument whose indications depend on the action of a steel spring, it is possible to extrapolate from the results of tests at higher temperatures.

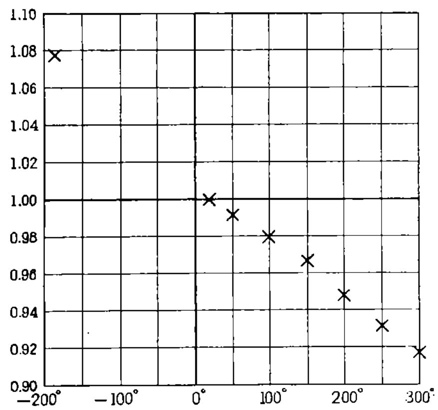

FIG. 4.—Rigidity modulus for steel, in terms of its value at 20° C. Pisati's results for high temperatures. My result for −186° C.

THERMOMETRIC OBSERVATIONS AT SANTA FE, ON THE ISLE OF PINES.

Communicated by E. W. KELLOGG, M. D.

Isle of Pines temperatures during December, 1902.

[Observed with a spirit thermometer.*]

December.	6 a. m.	Noon.	9 p. m.	Weather.	December.	6 a. m.	Noon.	9 p. m.	Weather.
	°	°	°			°	°	°	
1..	74	86	76	Clear.	17..	74	83	75	Clear.
2..	74	87	76	Clear.	18..	72	80	72	Clear.
3..	74	86	76	Clear.	19..	70	79	69	Clear.
4..	76	88	78	Light showers.	20..	71	80	72	Clear.
5..	76	81	76	Partly cloudy.	21..	70	80	72	Clear.
6..	74	82	76	Clear.	22..	65	80	74	Clear.
7..	76	82	76	Clear.	23..	65	75	70	Clear.
8..	72	78	72	Clear.	24..	65	71	68	Clear.
9..	76	80	74	Partly cloudy and clear.	25..	64	70	70	Partly cloudy.
10..	72	81	76	Clear.	26..	69	72	68	Clear.
11..	74	80	76	Light thundershower.	27..	60	73	66	Clear.
12..	72	83	78	Clear.	28..	58	72	67	Clear.
13..	76	85	76	Clear.	29..	67	78	71	Clear.
14..	76	83	76	Clear.	30..	70	78	71	Shower and clear.
15..	75	82	74	Clear.	31..	72	82	72	Clear.
16..	74	83	76	Clear.					

* Nothing is at present known of the accuracy of this spirit thermometer, but it is hoped that the observer will eventually provide a reliable mercurial thermometer and make the necessary comparative readings.—*C. A.*

VIOLENT WIND IN SOUTH DAKOTA.

By S. W. GLENN, Local Forecast Official, dated Huron, January 15, 1903.

The wind, which was from the northwest, attained a maximum velocity of 48 miles per hour; a special observation was taken at 2:40 p. m. of the 6th and sent to the district forecast center. Because of an increase in pressure of .12 inch in two hours, another was taken at 5:20 p. m. and sent; and at 6:20 p. m. another was sent because of a 64-mile per hour wind and a possibility of no wires being available for the regular p. m. report. It was only through the courtesy of the train dispatcher of the Chicago & Northwestern Railway, who had an outlet for about five minutes, that the p. m. report got off.

The a. m. report of the 7th was promptly filed, but it was later learned that it did not get off in time for the St. Paul circuit, so was sent by mail with an explanation relative thereto. There was practically no outlet by wire from the time that the p. m. report of the 6th was sent until the late afternoon of the 7th, due to the wires being down, or in trouble.

On the 7th as soon as a wire was available, a special observation was taken and sent to Chicago, showing the conditions from 8 a. m. up to that time.

After 2:20 p. m. of the 6th the wind steadily increased, with occasionally some abatement for short periods, until about 10:45 p. m. when it attained a maximum velocity of 72 miles per hour, after which time it very slowly diminished, though it continued high most of the 7th.

A number of clippings relative to the storm have already been forwarded, but those applying to Huron and the vicinity are somewhat exaggerated. A portion of the flat tin roof of the Presbyterian College, a four-story structure, was torn away about two hours before the maximum wind velocity occurred, taking with it a portion of the brick coping that was in poor repair, and a portion of the débris knocked down a chimney of a near-by church and also of a residence. Several out-of-repair chimneys were blown down or damaged, and some loose and exposed outhouses were blown over. The south gable of an old one-story building was blown out, due to a draft from an opening on the north side. The roof of the college was a weak affair, and I am informed the wind had access below and under the roof from a broken window.

Farmers in the county report some wind mills with old wooden supports blown down, and hay stacks uncovered.

The Chicago & Northwestern Railway train service was greatly interrupted by the storm, due to snow blowing into the cuts.

In the county adjoining on the east, two men and some animals were reported killed by a shelter being blown in.

The Weather Bureau instrument shelter is fully exposed to the force of the wind from all directions, but the thermograph trace during the storm does not show a very marked vibration.

Fortunately, there was no snow during the storm of any consequence, and the temperature was comparatively moderate during the gale.

The maximum velocity during the storm exceeded by three miles the highest ever before recorded at the station, which was 69 miles per hour in June, 1894, but the wind has equaled or exceeded 60 miles per hour in 21 previous storms.

The total movement from noon of the 6th to noon of the 7th was 1000 miles, or an average of 41.7 miles per hour.

THE VERTICAL COMPONENT OF THE MOVEMENT OF CLOUDS MEASURED BY THE NEPHOSCOPE.

By LOUIS BESSON, translated from the Annuaire, Societé, Météorologique de France, 1902, pp. 180-185.

In order to determine by means of a nephoscope the movement of a layer of clouds, it is usually considered sufficient to observe the direction of these from a point in the sky chosen arbitrarily. This is to admit implicitly that—omitting all accidental deviations—the same result would be found at any other point in the sky.

This, however, is not the case. The observations made at Montsouris show that in general the apparent direction of the motion of the clouds varies from one point in the sky to another and that the differences frequently attain a rhumb (22.5°), and even much more. In the great majority of cases the clouds seem to vary from one side to the other of their mean direction.

As an example I give an extract from our observations for the 20th and 21st of May, 1902. Each direction here given is the mean of 3 or 4 determinations made successively at the same point in the heavens. The directions are counted from 0° to 360° from north to west.

Year.	Time.	Kinds of clouds.	Location.	Altitude.	Movement.	Location.	Altitude.	Movement.	Difference.
1902.	H. M.			°	°		°	°	°
May 20	9 25	Nimbus	e.	35	27	w.	35	5	22
Do	15 30	Cirrus	ese.	35	39	wnw.	35	346	53
Do	18 20	Cirro-stratus	e.	30	355	w.	30	335	20
May 21	18 20	Alto-cumulus	e.	20	17	w.	20	350	27

If the cirrus only are considered, our observations show that in fifty cases the differences of the observed directions at two opposite points in the heavens were:

Cases.	Difference.	Cases.	Difference.
	°		°
1	55	10	15
2	30	13	8
7	25	9	5
5	20	3	0

This phenomenon is not peculiar to the Montsouris station. Thanks to the kind cooperation of M. Teisserenc de Bort, I have been able to ascertain that it exists also at Trappes. On March 20 simultaneous measurements were made at the observatory of dynamic meteorology at Trappes and at Montsouris using two identical nephoscopic diaphragms and following the same methods, as will be explained further on; these showed quite uniform differences of direction. The following is the résumé of these observations:

Hour.	Kinds of clouds.	Mean direction of movement.		Difference of movement.	
		Trappes.	Montsouris.	Trappes.	Montsouris.
		°	°	°	°
10 a. m.	Alto-cumulus	116	115	14	10
11 a. m.	..do	122	117	8	8
Do.	Fracto-cumulus.	120	114	11	8
12 m.	Strato-cumulus.	122	114	5	6

What is the cause of these differences? The most natural hypothesis is that the movement of the clouds instead of being horizontal, as is usually supposed, has a vertical component, or in other words it is along an inclination. By this hypothesis the apparent direction, as given by the nephoscope, forms with the true direction of the horizontal component an angle, ε, which depends on the inclination, i, of the movement of the clouds, on the angular height, h, of the observed point above the horizon, and on the angle, a, made by the azimuth at bearing of this point with the true direction. The value of the angle, ε, which we call deviation, is given by the formula:

(1) $$\tan \varepsilon = \frac{\sin a}{\cos a - \cot i \tan h}$$

The deviation is always zero at the zenith. For the same altitude it is maximum when the azimuth of observation is perpendicular to the apparent direction. At the same azimuth it increases with the zenithal distance. At points of the sky symmetrical as regards the perpendicular to the apparent direction, the deviations are equal in absolute values, but are in opposite directions.

In order to define in a general way the direction of these apparent deviations, it may be said that the clouds seem to converge when they have an ascending movement and diverge when they have a descending one.

Conversely from the relation (1) there may be found the amount of the inclination, i, of the movement of the clouds as a function of the deviation observed at a point of the sky whose coordinates are a and h.

This gives:

(2) $$\tan i = -\frac{\sin \varepsilon \tan h}{\sin (a - \varepsilon)}.$$

The deviation, ε, may be considered as given directly by the observation. According to the remarks made above, ε is equal to the difference of the apparent direction of movement at a point whose coordinates are a and h and the movement at the zenith, or again to the half difference of the apparent directions at the two points whose coordinates are a and h, $-a$ and h.

If the azimuth of observation is perpendicular to the true direction of the clouds, the formula (2) becomes simpler.

(3) For $a = \pm 90°$, one has $\tan i = \pm \tan \varepsilon \tan h$.

Finally, if also $h = 45°$, we have simply $i = \pm \varepsilon$.

From this last remark a very simple method is deduced for determining by means of a nephoscope[1] the inclination of the motions of the clouds; it suffices to observe their apparent directions of motion at two points whose azimuths are perpendicular to the movement and whose altitudes are 45°. The angle of inclination may be obtained by taking the difference of the two observed directions of movement and dividing by 2.

In practise it is often impossible or disadvantageous to make observations at the height of 45° on both sides. It may, in fact, happen that the clouds under consideration are absent from that part of the sky or that the points of the clouds are not sufficiently distinct. In general, it may be necessary at each measurement, to make observations at different heights on each side. The simple formula $i = \pm \varepsilon$ will, therefore, not be always applicable, and it will often be necessary to make use of the more general formula (3).

We may here remark that tan i, as given directly by this formula, is nothing more than the ratio of the vertical and horizontal components of velocity, or $\tan i = \frac{H}{V}$. It is more useful to know this ratio than the angle i itself, because it lends itself more conveniently to the calculation of mean values and allows the vertical velocity to be learned as soon as the horizontal velocity is known.

It is therefore very useful to compute once for all a table of double entry giving tan i as a function of ε and of h according to formula (3). The variations of ε should be by half degrees and of h by five degrees. This table will also be useful in cases where the observations may not have been made on the two sides at the same height. Starting then from the tabular line of numbers corresponding to the half difference of the observed directions, we move away the same number of lines, in opposite directions, but still in the columns corresponding to the two observed altitudes, until we arrive at the same number, or nearly so, which will be the value of tan i, that is sought.

It may be useful to enter into some details of the technical part of these observations. On account of the irregular motion of the clouds, it is necessary to make several successive observations at each point of the sky where the apparent direction of movement is to be determined. By taking the mean of the observed values the accidental errors of observation and the variations of the two components of cloud motions will be more or less eliminated. Moreover, during the necessarily long duration of the observations the movement of the clouds may vary perceptibly. In order to avoid the error that would thus result in the value of ε, it will suffice to interchange the order of succession in making the measurements. For instance, if the clouds come from the north the

[1] For the description of this instrument, see the Annales of the Municipal Observatory of Paris, Vol. II, 1901.

observation will be made first in the east, then in the west, then again in the east.[3]

The azimuth of the points of observation will be determined without difficulty and with sufficient accuracy by comparing with the surrounding terrestrial objects whose azimuth have been determined once for all. As regards the altitudes above the horizon a more precise determination is necessary. We measure these at Montsouris in the following manner: As the ground surrounding the nephoscopic network is sloping, we have from the first used a small liquid level in order to determine the slope by the eye, and correct the relative velocity. This level is composed of a glass tube recurved four times at right angles, forming a rectangle, and containing a certain quantity of mercury; the two extremities, brought close together, are joined by a piece of rubber tube in order that the mercury may not escape. This little instrument, very portable and easy to make, enables one to measure the slope to within one or two centimeters at 20 meters distance. It can also show the angular heights within 1°. For this purpose the glass of the mercury level is graduated on the two opposing branches for a certain position of the instrument in the vertical plane, then it is made to turn in this plane successively 5°, 10°, or 15°, and at each turn it is marked to show the level of the mercury. The instrument being thus graduated, then in order to obtain the angular height of any object whatever, it suffices to sight at this object, making use of the two marks corresponding to the initial position and to note at which degree of the graduation the level of the mercury stands.

Together with the direction of movement it is indispensable to determine the relative velocity of the clouds. The knowledge of this fact assures us that the respective points observed are really of the same nature and enables us to avoid confounding different layers of clouds. Besides, if the movement is inclined, the relative velocity is affected, like the direction, by an apparent modification, the law of which may be established theoretically. This question, however, we will not now consider.

Are the differences of direction observed at Montsouris to be attributed entirely to an inclination of the trajectory of the clouds? In order to examine into this subject we have for some time past, and as often as possible, made measurements at two different heights, generally at 20° or 25°, and at 40° or 50° from the horizon.

The following is a series of measurements made on the 15th of March, 1902, from 5:30 to 5:50 p. m. on a sheet of cirro-stratus cloud.

Coordinates.		Direction of movement.	$\frac{H}{V}$	Coordinates.		Direction of movement.	$\frac{H}{V}$
Azimuth.	Altitude.			Azimuth.	Altitude.		
	°	°			°	°	
Southwest	20	22	206	Northeast	40	39	212
Southwest	40	25	205	Northeast	20	50	205
Northeast	40	36	213	Northeast	40	40	223
Northeast	20	43	198	Southwest	40	28	181
Northeast	40	40	213	Southwest	20	31	206
Southwest	40	32	200	Southwest	40	28	195
Southwest	20	26	217	Northeast	50	39	227
Southwest	40	27	202	Northeast	20	39	205

Summary.

Azimuth.	Altitude.	Direction of movement.	$\frac{H}{V}$
	°	°	
Northeast	20	44	210
Northeast	40	39	197
Southwest	40	28	218
Southwest	20	26	203
Mean	......	34	207

[3] So in the original text, but the best order is E-W-W-E.—*C. A.*

From the deviations observed, respectively at 20° and at 40°, there are deduced two values of *tan i*, which should be equal at least on the average, if the hypothesis of inclined movement suffices to account for the phenomenon.

We have not yet been able to make a very great number of determinations of this kind; in order that they should be practicable, it is necessary that the clouds should present over the whole heavens a homogeneity and a stability of form which is very seldom attained. At all events the results obtained up to the present time appear to me sufficiently clear to enable us to consider the question as about settled.

Out of 21 cases of fracto-cumulus and fracto-stratus 11 show a value of tan i greater at 45° than at 20°, if the descending movement be taken as the positive direction. If the algebraic mean of the 21 values of tan i be taken, we find at 20° tan $i=$ 0.23; at 45° tan $i=0.31$.

The difference which is 0.008 represents an excess of deviation of 0.5° at 45°. The mean deviation at this altitude is about 2°.

Out of 13 cases of alto-cumulus clouds 9 show a greater value of tan i at 45° than at 25°. The mean values are, at 25° tan $i=0.043$; at 45° tan $i=0.073$.

The difference of 0.030 represents an excess of deviation of about 1.5°: the mean is 4° at 45° of altitude.

Out of 16 cases of high cirrus, cirro-stratus, and cirro-cumulus 12 show a value of tan i greater at 45° than at 20°. The mean value of the tangent is, at 20°, 0.046; at 45°, 0.080.

The difference, 0.034, represents an excess of deviation of 2°; the mean is 4.5° at an elevation of 45°.

It will thus be seen that the deviations observed at Montsouris accord very nearly with the law of inclined movement for the lower clouds, but depart more and more from it if we pass to the medium clouds and then to the elevated ones. For these last particularly is the disagreement striking and unanswerable. The occurrences take place as if there were superposed over the action of a general cause, a disturbing element the effect of which seems to be to increase the apparent deviation in the neighborhood of 45° of elevation, and which affects either the vertical component of motion, or the horizontal component, or even the two together; this influence is more apparent in proportion as the clouds are more elevated.

There are reasons for thinking that the greater part, if not the whole of this disturbance, consists in a real variation of the direction of movement of the clouds. Many zenithal observations made simultaneously during several years at the Tour Saint-Jacques and at Montsouris show that the clouds above these two stations generally have perceptibly different directions. In particular, if we consider the cases where the movement of clouds is nearly perpendicular to the straight line which unites the two stations we find that there is, in general, a divergence for all kinds of clouds. Nevertheless, for the cumulus clouds in summer convergent directions are most frequently observed in the warmest hours of the day.

A long time ago M. Renou pointed out the existence of systematic differences in the direction of the lower wind around Paris; differences that Teisserenc de Bort has attributed to the influence of the population of Paris. Our observations tend to prove that this influence, probably of calorific origin, extends up to a considerable height and on the average manifests itself in the cloud regions by an expansion of the currents of air.

I will not dilate further at present on this phenomenon, the data which we possess being still too incomplete.

It is very desirable that observations with the nephoscope should be made at various stations, according to the method explained by us. In the open country, or generally outside of every disturbing cause, there is no doubt but that the deviations vary with the zenithal distance, according to the inclined movement.