two widely separated objects are much more accurate than micrometer (excluding double image or heliometer) observations with the same instrument, because the former are affected alike, the same time element being common to each.

PROPERTIES AND STRUCTURE OF ICE.

AN interesting account of a number of experiments by Prof. R. S. Tarr and Dr. J. L. Rich, of Cornell University, appears in the *Zeitschrift für Gletscherkunde* (Band vi., p. 225). The results agree mainly with those obtained by Mügge and MacConnell, and show that, as urged in 1869 by W. Mathews, those of Prof. Tyndall and Canon Moseley were inconclusive, through not taking sufficient account of the time-element in the problem. These recent experiments, which were both numerous and designed to test the various properties of ice, show that it welds readily at a temperature of 0° C.; that when a block of ice has been cut through by a wire and regelation has occurred, optical continuity is re-established, the new-forming crystals being controlled by those previously in existence, and that the welding, at temperatures well below the freezing point, to some extent resembles what has been observed in marble after being crushed.

The authors tentatively advance four propositions; the first, that the observed deformation is of the nature of plasticity, *i.e.* it is not initiated until a certain strain is reached, the plastic yield-point lying near the breaking point of the ice; the second, that the ease with which deformation may be produced varies with the direction in the crystal; the third, that the optical properties of a crystal are affected by such deformation, the effect being dependent upon the direction in the crystal in which the deformation takes place; and the fourth that granular ice, composed of interlocking crystals, is subject to deformation equally with a single ice-crystal. Pond-ice was mostly used in the experiments, but granular snow- and glacier-ice were also employed. The authors notice a suggestive fact in regard to the first, that in a cake 30 cm. thick, about 10 cm. at the top consisted of finely granular ice; the next 15 cm. of coarse prismatic crystals of ice, standing perpendicular to the water surface, and the remainder of finely granular ice with diversely oriented crystals.

THE WINDS IN THE FREE AIR.[1]

IT was noticed in very early times that the wind in the upper air may be very different from what it is on the surface. Lucretius says: "See you not too that clouds from contrary winds pass in contrary directions; the upper in contrary way to the lower." Bacon advocated the use of kites in studying the winds; but it is only in quite recent years that any systematic attempt has been made to investigate the free air above the surface of the earth. Kites have been flown to a height of four miles, but it is a matter of some delicacy to get even so high as two miles.

The temperature of the free air may be recorded by a meteorograph attached to a small rubber balloon, which continues to ascend until the pressure of the gas inside bursts the envelope, and the instrument descends again to the surface. The beautiful instrument constructed by Mr. W. H. Dines, F.R.S., the pioneer of upper air research in this country, is so light that the torn fabric of the balloon is sufficient to act as a parachute and check the speed of descent.

[1] Discourse delivered at the Royal Institution on Friday, April 11, by Mr. Charles J. P. Cave.

The general result of the observations has been to show that the temperature of the air decreases with height up to a certain point, above which the temperature distribution is nearly isothermal; however much higher the balloon may ascend, there is little further change of temperature. This upper layer, discovered by M. Teisserenc de Bort, whose recent death meteorologists of every country lament, is called the stratosphere; the lower part of the atmosphere is the part that is churned up by ascending and descending convection currents, and is called the troposphere. The height at which the stratosphere is reached, as well as the temperature of the layer, varies from day to day and from place to place. In these latitudes it is met with at heights varying from about 8 to 14 km., with temperatures varying from −40° to −80° C.

It is not, however, with temperatures that I am chiefly concerned to-night, but with the wind currents in the different layers of the atmosphere. If one of the balloons carrying instruments, or a smaller pilot-balloon, is observed with a theodolite, its position from minute to minute can be determined, and from its trajectory, or its path, as it ascends, the winds that it encounters can be calculated.

The theodolite used is constructed specially for the purpose; a prism in the telescope reflects the light at right angles, so that the observer is always looking in a horizontal direction, even if the balloon is overhead. It is important that the observer should be in as comfortable a position as possible, for an ascent sometimes lasts more than an hour and a half, during which time the observer can only take his eye from the telescope for a few seconds at a time, otherwise he may lose sight of the balloon and be unable to find it again.

The balloon having been started from one end of the base, observations are taken from both ends at exactly the same times, usually every minute. From the positions of the balloon at each successive minute, which are plotted on a diagram, the run of the balloon during the minute can be measured, and hence the wind velocity during that minute can be obtained. After the wind velocities have been measured off, and the wind directions obtained from the directions of the lines on the diagram, another diagram is constructed showing the relation of the wind velocity and direction to the height.

It is not necessary, however, to have two observers if the rate of ascent of the balloon is known; in such a case, the complete path of the balloon can be calculated from the observations of one theodolite. It is not, however, possible to know the rate of ascent with complete accuracy, as up and down currents in the air will affect the normal rate. In practice, especially in clear weather, the method is fairly satisfactory. The method of one theodolite requires less preparation, and the subsequent calculations of the path of the balloon are less laborious, than in the case of observations taken with two theodolites from opposite ends of a base line.

The best time for observations is towards sunset, so that the balloon reaches its greatest height after the sun has set on the surface of the earth; at such times the balloon, still illuminated by the sun, shines like a planet, and on one occasion I should have found it impossible to tell which was the balloon and which was Venus, except for the movement of the balloon. The distances at which balloons may be seen through the telescope of the theodolite are remarkable. A striking instance was when the flash of the sun on the small meteorograph was seen, not once, but repeatedly, when the balloon was about nine miles above the sea and at a horizontal distance of about thirty miles.