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Contents.

(Illustrated articles are marked with an asterisk.)

TABLE OF CONTENTS OF

THE SCIENTIFIC AMERICAN SUPPLEMENT

No. 280,

For the Week ending May 14, 1881.

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TORNADOES, HAILSTORMS, AND WATERSPOUTS.

At this season of the year, when storms of limited area and great violence are apt to occur, we are equally apt to suffer from outbreaks of newspaper meteorology which are sometimes almost as appalling as the phenomena they attempt to explain. We may be excused, therefore, for assuming that the subject is one of popular interest, and for compiling some of the more significant and certain results of observation and scientific deduction with regard to the origin, conditions, and behavior of this class of storms.

A favorable opportunity for doing this is furnished by the recent publication of the 10th appendix to the report of the Superintendent of the United States Coast and Geodetic Survey, for 1878, containing the second part of Mr. William Ferrel's researches on cyclones, tornadoes, and waterspouts, in which the theory of cyclones is mathematically discussed at great length, with a comparison of the results thus obtained with the facts of observation. We may safely draw from this treatise such information as may seem of interest to landsmen at this time, with reasonable confidence that we shall not be misled with respect either to facts or inferences. Although largely similar to cyclones, and governed by the same general principles, tornadoes form a distinct class of meteoric phenomena. The initial temperature conditions which give rise to cyclones generally extend over large areas. The conditions of tornadoes depend rather upon vertical relations of temperature, under which the unstable equilibrium of the atmosphere is liable to be violently disturbed by slight local changes of temperature causing the under strata of air to burst up through the overlying strata. A cyclone is usually a broad, flat, gyrating disk of atmosphere, very many times greater in width than in altitude; a tornado may be regarded as a column of gyrating air in which the altitude is several times greater than its diameter. The enormous velocities of the ascending currents in a tornado appear to be caused by the differences between the gyratory velocities above and those very near the earth's surface. The former largely prevent the air from pressing in to fill up the partial vacuum near the center, while the smaller gyratory velocities near the earth allow it to rush in there to supply the draught. The tendency of friction is constantly to use up the energy of gyration so that the tornado cannot continue very long. The ascending currents carry up an enormous amount of aqueous vapor into the upper regions of the air, where it is condensed and produces the heavy rains observed in connection with tornadoes. An ascending current of 60 meters a second, which cannot be unusual in tornadoes, would furnish, under extreme conditions of air saturation, four inches of rain a minute, if it were to fall directly back. With such an ascending velocity, however, no rain could so fall. It would be thrown outside the vortex, giving an immense though lighter fall of rain over a larger area, especially if the tornado in its irregular progressive motions should remain stationary or nearly so for several minutes. If the velocity of the ascending current is not so great that the water is all carried up to where the currents are outward from the vortex, and yet great enough to prevent its falling back, there may be in the lower part of the cloud a vast accumulation of rain, prevented from falling by the ascending currents and from being dispersed by the inflowing currents from all sides toward the vortex. When the sustaining energy of the tornado is exhausted by friction or by the weight of water accumulated in the cloud, the water is liable to fall in mass, causing what is called a cloud burst. This is especially liable to occur in mountainous regions, for contact with a mountain must greatly interfere with the gyratory motion of the tornado and the inflowing currents below, and tend to break up the system at once and let the whole load of water drop suddenly.

The water in cloud bursts is generally poured down. Long before the ascending currents are reduced so as to allow the water to fall in drops it seems to collect at certain places and force its way in a solid stream down through the ascending air. Having once made an outlet for itself the water is necessarily accelerated in velocity, so that before reaching the earth the stream may be pouring with irresistible force, cutting, when it strikes, the sharply marked and often deep chasms left by cloud bursts, especially on hillsides.

When the ascending current carries the vapor into the region of frost—which is at a lower altitude within the gyrating funnel than outside of it—the condensed vapor is converted into hail. The small hailstones may then be kept suspended near the base of the snow cloud and enlarged by additions of freezing rain. In this way compact homogeneous hailstones of ordinary size are formed. At the height of 7,000 yards the air has lost more than half its density, yet an ascending velocity of twenty yards a second, which must be no unusual one in tornadoes, would sustain even at that altitude hailstones of considerable size. It is not necessary that the hailstones should remain in the freezing region a long time, or remain stationary. They may be carried from this vortex out where the ascending current is small, and, dropping down some distance, may be carried into the vortex by inflowing currents and again thrown up to the region of frost. The nucleus of large hailstones is usually compacted snow. A small ball of snow saturated with rain is carried higher and freezes; and being of less specific gravity than compact hail it is kept where it receives a thick coating of ice from the unfrozen water dashed against it, and afterwards falls to the earth, either at a distance from the vortex where the ascending currents are weak, or near it after the uprush has been sufficiently exhausted. Sometimes, as in the case of the cloud burst, an almost incredible amount of accumulated hail may fall in a short time, when the energy of the system is suddenly spent.

The formation of large hailstones by concentric layers of clear ice and white snow, laid on like the coats of an onion, will be readily understood from the foregoing. As many as thirteen layers have been observed in large hailstones, showing that they must have made half a dozen circuits, being successively thrown out of the froty vortex above and sucked in below by the inflowing currents, each time adding to their coatings of snow and ice before their final fall to earth.

When the tornado is very small in the area covered by the gyratory motion, a land spout or a water spout is formed, as it may happen to occur on land or at sea. In these the gyratory velocity rapidly diminishes with distance from the center. Their destructive effects are sudden and often great, but the area of violence is small. In the center of a waterspout, as in that of a tornado when in full force no rain falls or water descends in any form, though a heavy shower often falls in the vicinity. On land dust and light substances are carried up, and as they are being collected from all sides by inflowing currents toward the vortex below, they assume the form of a cone, which meets the descending spout, falling apparently from the clouds, and thus give the whole phenomenon the appearance of an hour-glass.

The observed diameters of waterspouts range between two and two hundred feet or more, and their heights from thirty to fifteen hundred feet, sometimes very much more; but none of these observations can be regarded as at all exact. With a high temperature and a very low dew point Mr. Ferrel calculates that a water spout might reach a mile in height, but such conditions must occur rarely. Waterspouts are often observed to drop down from a cloud in an incredibly short space of time, and to be drawn up again in the same manner; but this is all an illusion. When the gyrations are such as to not quite reduce the tension and temperature in the center, so as to condense the aqueous vapor and make it visible, a very slight increase at once reduces the temperature sufficiently, and the spout appears from top to bottom almost instantaneously. Just the reverse of this takes place, when the spout breaks, and it seems to be drawn up instantly; it is dissolved, not lifted. Tornadoes and waterspouts originate only in an unstable state of equilibrium of the air, which requires an unusually rapid decrease of temperature with increase of altitude. This can take place only when the strata nearest the earth are unusually heated; accordingly they never occur at night, or in the winter, and but rarely in cloudy weather. If any agitation of the air, such as that arising from the discharge of cannon, tends to break up these meteors, then any considerable disturbance of the air from any cause must tend to prevent their formation. Hence they occur at sea and on the lakes only when there is little or no wind.

White squalls are invisible spouts. In such cases the dew point is so low, and the cloud when formed so high, that the gyrations are invisible. Still the gyrations and the rapidly ascending current in the central part are there, and also the rising and boiling of the sea. Over the boiling sea, high up in the air, is a patch of white cloud, formed by the condensation of the vapor when it reaches the required height. The bulls-eye squalls on the west coast of Africa are of precisely the same nature. In these cases the air is too dry to furnish the cloud necessary to make the spout, or center of the gyratory movement, visible.

In hot dry climates these ascending whirls of air form sand spouts or pillars of sand. Both water spouts and sand spouts are hollow.

HEAT, LIGHT, AND POWER WITHOUT COST.

One of the greatest difficulties that beset the progress of the brave men who venture upon explorations in the Arctic regions is the terrible cold and the deprivation of light. But if we may believe in the theories of Professor Gamgee, as set forth in the remarkable specification of the patent for his new thermo-dynamic engine—date of April 19, 1881—the future Arctic investigator will have no trouble in keeping warm, nor will darkness trouble him, for the harder everything freezes the faster the engine will run.

Says the Professor in his patent: "I utilize heat in this system downward to 0° Centigrade, and below towards absolute zero."

Since both heat and electricity may be produced by means of a rotating wheel, in degrees proportionate to the power of the wheel, it follows that explorers to the north may hereafter make themselves entirely comfortable by taking along a few of Professor Gamgee's self-running engines. These extraordinary machines depend on *cold* for their motive power, the very article that the northerly world supplies in the greatest abundance, and that has heretofore been regarded as a drug in the Greenland market.

If Gamgee and the Patent Office are right, then the owners of coal mines may as well shut up shop. Fuel will no longer be required to produce either motive power, heat, or light. These great factors in human welfare will in future be enjoyed by mankind without labor or cost, all the industries of the world will be revolutionized, and a majority of them discarded for lack of further use.

In view of these considerations we would ask the Commissioner of Patents if he considers that he has done the fair thing in granting a patent to Gamgee, while rejecting the application of poor Keely, the prior inventor?