number of mistakes made, in each addition. All observations and suggestions relating to the subject will be most gratefully received.

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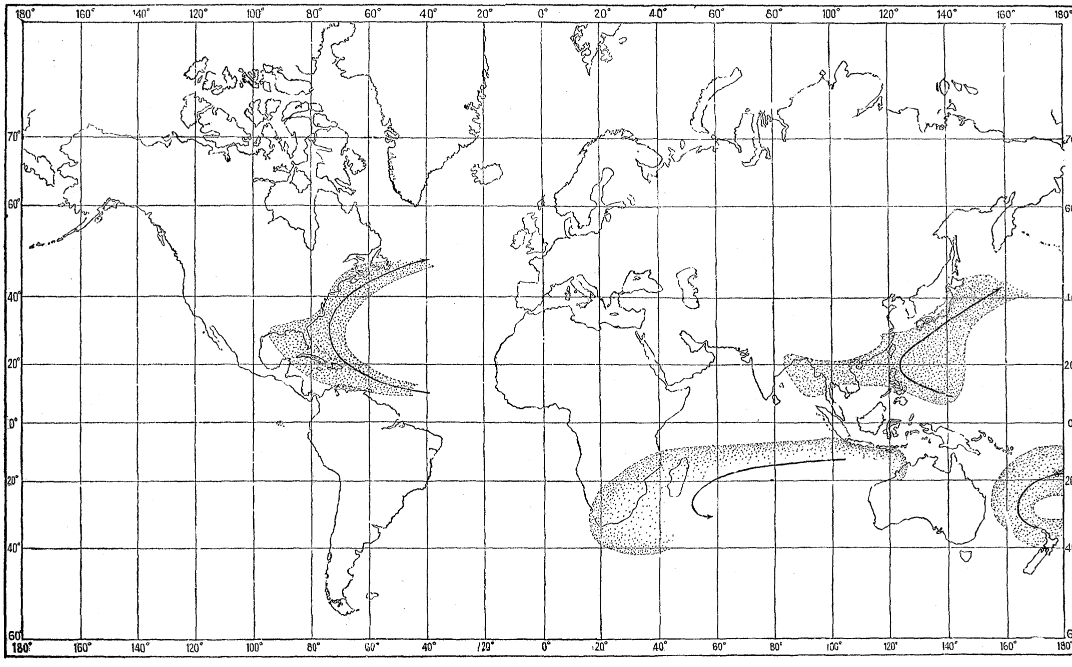
WHIRLWINDS, CYCLONES, AND TORNADOES.[1] — VI.

Having seen how storms arise, and examined the general motions of their spiral winds, we must next consider their progression from place to place. It is now a familiar fact, that storms do not remain stationary, but advance forth. The apparently lawless winds of a storm could be reduced to system if they were supposed to blow around a centre which itself has a progressive motion. In nearing the centre, the barometer falls, and the winds increase their strength. The manner and cause of the progressive motion must now be examined.

The four regions where tropical storms move into temperate latitudes — the seas south and east of India and China, and south-east of the United States, in the northern hemisphere; and those east of Madagascar and (probably) of Australia, in the southern hemisphere — are



THE REGIONS OF TROPICAL CYCLONES. (TAKEN FROM STIELER'S ATLAS.)

at a velocity of from five to fifty miles an hour along a line known as their track. Although perceived by Franklin about 1750, this, as well as their whirling motion, first found full and satisfactory proof at the hands of Dove of Berlin (1828), and Redfield of New York (1831). The latter gave the more numerous examples, and was the first to explain the motions of storm-winds at sea. The method of his discovery was simple enough. Information concerning the storm was gathered from all attainable records, and the condition of the winds and weather was plotted for certain hours. At once the result stood clearly all crossed by storm-tracks, running first westward near the equator, then turning toward the pole, and passing around the apex of a parabolic curve near latitude 30°, into an obliquely eastward course. The more numerous storms of temperate latitudes have less regular tracks, but are nearly always characterized by a strong eastward element in their motion; their chief variations to the right or left being dependent on thermal changes with the seasons, and on the configuration of land and water which they traverse. There have been four causes suggested to determine the progression of the storm-centre: namely, the general winds of the region, and especially the stronger and less

[1] Continued from No. 44.

variable upper currents; the supply of warm, moist air, and consequent occurrence of heavy rain; the relative strength of the inblowing winds; and a certain effect of the earth's rotation. All these causes of progression are variable in amount, and in relation to one another; and it is therefore natural to find their resultant inconstant.

The first-named cause is the most evident, the most powerful, and was the first recognized. The general or planetary circulation of the winds will require that any disturbance in the moving atmosphere shall partake of its motion, and be carried along in the direction of the current within which it is generated. Thus a storm arising in the equatorial calms is carried westward as soon as it attains sufficient height to reach the upper current, which must there move from east to west. No equatorial cyclone has ever been observed moving eastward. On approaching the western shores of the ocean, a part, at least, of the general winds, turns toward the poles, as may be seen on any wind-chart, and in latitude 25° or 30° passes from the region of the tropical winds into the system of the prevailing westerly winds of temperate latitudes. The storms have a strikingly similar course, and, on the western side of the oceans in these latitudes, never move towards the equator. Their further progress, and that of the many storms of the temperate zones, is easterly, with a leaning towards the pole while crossing the oceans, and a variable north-easterly or south-easterly advance on the continents. No storm has been found crossing the North Atlantic from east to west, or moving from our Atlantic coast to the plains beyond the Mississippi. Additional evidence of this style of bodily transference of storms will be given in considering the relative strength and the direction of their spiral winds on different sides of the centre.

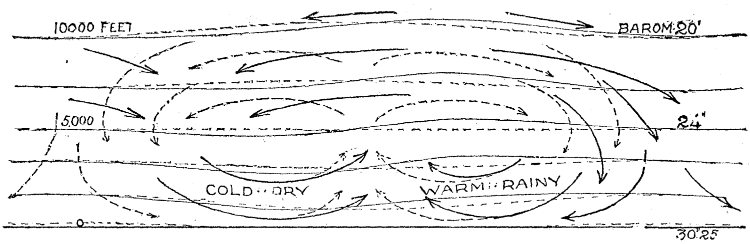


FIG. 12.

The importance of the condensation of vapor and consequent rainfall in decreasing the cooling of the central up-draught, and so increasing its strength, has already been shown. In the explanation of this process, it was tacitly assumed that all the surface-indraught was equally warm and moist, so that condensation and rain would occur symmetrically about the centre of low pressure. It will now be seen, that, when a storm-centre is supplied from areas of unequal warmth and moisture, symmetrical cloud-forming and rain-falling on all sides will be impossible; there will be more rain, and hence less cooling, on one side than on the other; and just as the liberation of 'latent heat' aided in the formation of the first central barometric depression, so it will now tend to displace this centre to the side where the greatest amount of rain falls. If no other cause but this acted, the storm would advance regularly toward the region of heaviest precipitation: but this advance will not be like the bodily transference of the rotating winds effected by the general atmospheric currents; it will be rather the abandoning of one centre of attraction as a stronger one is created beside it, — the continual filling-up of one depression, and production of another. This may be illustrated by a modification of fig. 8, given here in fig. 12, in which the dotted lines show the gradients and winds established at a certain period of the storm. Let it be supposed that warmer, moister winds enter on the right, and cooler, drier winds, on the left. Where cooler, the air will be contracted, and the isobaric surfaces depressed: where warmer, from its own warmth, as well as from that of the condensing vapor, the air will be expanded, and the isobars elevated, as shown in full lines in the figure. The gradients will then be unsymmetrical about the original centre; and the previous motion of the winds will be accelerated at some points, retarded or reversed at others. As a result, the pressures at the surface will be changed from their previous arrangement to a new one, shown in fig. 13, in which the region of least pressure has moved to the side of the warmer winds and heavier rains. Any further inflow of the surrounding air must now be to the new low-pressure centre: in other words, the storm has advanced to the right. The process will be continuous as long as the winds on opposite sides of the storm are unlike.[1] Having thus

[1] Fig. 12 may serve further to explain the retarded arrival of the centre of low pressure at altitudes of a mile or more above

seen the general action of this cause of motion, it must now be applied more directly. There are two causes of rain in a cyclonic storm, — one from the expansion and cooling of the moist air as it enters the district of low pressure, and rises in the central up-draught; the other from the advance of the wind from a warmer into a cooler region. The first of these will generally be nearly symmetrical about the storm-centre, and hence not productive of any progressive motion: the second will as generally be unsymmetrical. In fig. 14, for the northern hemisphere, the parallel lines represent normal east and west isotherms, showing the usual decrease of temperature to the north. Of the several winds blowing inward to the storm-centre, *A* and *B*, which advance almost along the same isotherm, will not be seriously changed in temperature by their change of place; *C*, which comes from a cooler to a

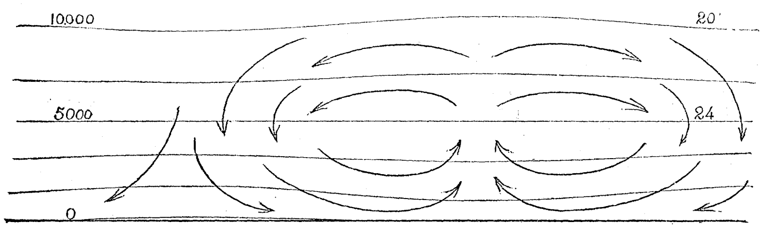


FIG. 13.

warmer district, will consequently increase its capacity for moisture, and be a clear, cold, drying wind; but *D* will be chilled, and must produce heavy clouds and strong rain somewhere about the shaded part of the figure; and the storm-centre will then be transferred toward the middle of this rainy district.

Standing on the warm side of the storm, the centre will appear to move nearly along the isotherms to the right. Actual isotherms seldom follow lines of latitude, and always vary their position with the seasons, especially along continental borders. Thus, over western Europe and the eastern margin of the Atlantic, the summer isotherms run to the north-east: so do the storms. In winter the isotherms run south-eastward, and the storms turn in the same direction. Figs. 15 and 16, illustrating this change, are based on diagrams in the 'Laws of the winds,' by Ley, who first, some fifteen years ago, called attention to the control of rain over storm-tracks. It should be noted that the change in the

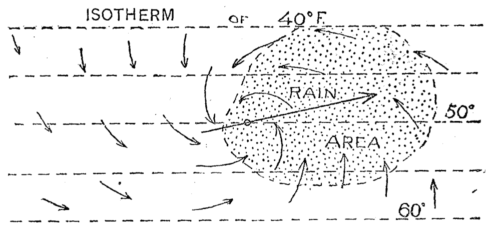


FIG. 14.

winter and summer prevalent winds would have a similar effect on the courses of European storms. In the United States, Professor Loomis has shown that the velocity, as well as the direction of advance, is closely dependent on the position and amount of the rain. In tropical storms the action of this cause of progression is not so clearly marked; for all the winds are moist, and almost equally warm. It is reported that the rainy area often extends farthest ahead of the storm; but it is not at once apparent why it should, for the front of the storm is occupied by winds from the north, which come from a slightly cooler latitude. It may be suggested, that, as their source in a region of high pressure (the 'horse latitudes') causes them to move faster, it also, probably, allows them a greater expansion and cooling, on entering the storm-area, than is permitted in the winds that come more slowly from the equatorial region of low pressure; but tropical storms probably de-

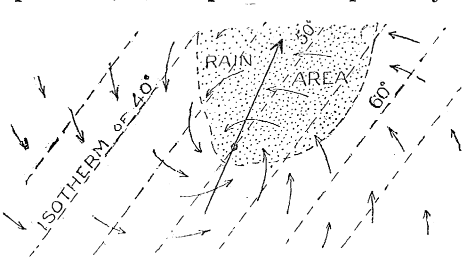


FIG. 15.

pend chiefly on the prevalent winds for their direction and rate of advance. In Austria none of the winds are very moist, and the rainy area has no definite relation to the advance of the

the surface. Observations on Mount Washington have shown the centre of low pressure there to be about two hundred miles behind that at sea-level (Loomis), and a similar retardation has been inferred in England from observations of cirrus-clouds (Ley). Fig. 12 shows this to be directly connected with rainfall; for, in this unsymmetrical storm, the former horizontal neutral plane is distorted, so that the centre of low pressure in the upper air is clearly behind, instead of vertically above, the centre on the surface of the earth.

storm: hence here, also, other causes than rain determine the general easterly progression. Whatever effect rain would have is overcome by stronger causes. The separation of a cyclone into two independent storms is probably aided by the irregular distribution of rain.

Inequality in the strength of the inblowing winds is a result of irregular distribution of barometric pressure in the regions around the storm; and the stronger indraught will come from the higher pressure, because the gradients will be steepest on that side. Thus, in the case of the West India hurricanes, the higher pressure is to the north or north-east in the 'horse latitudes' above named, and the lower pressure to the south, near the equator; and the northerly winds will therefore be stronger than the southerly. The stronger the wind, the greater its centrifugal force;

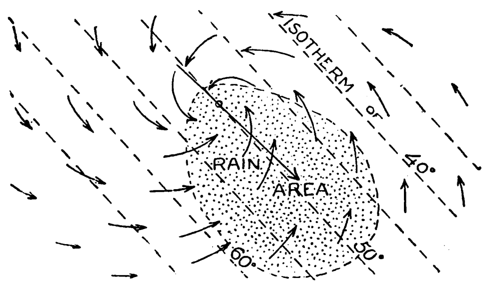


FIG. 16.

and, if this is not equal on all sides, the centre of lowest pressure will be drawn toward the point where it is strongest. This will be where it has to bend sharply around from its original direction, and may average about 135° from the source of the wind: hence, if the stronger wind come from the north-east, the storm-centre will move west; if from the east, north-west, as in fig. 17; and so on. Consequently, this cause will aid the first named in requiring the storm to describe a curved track in passing from the torrid to the temperate zone. It will also aid the coalescing of two neighboring storms, which has not unfrequently been observed; but, as a rule, it plays a subordinate part in determining the direction of advance. The slower advance of such of our storms as have extra strong winds on their western side (Loomis) is probably also due to this cause.

The fourth cause of a storm's advance is a peculiar effect of the deflective force arising from the earth's rotation. It has already been shown that this force increases toward the poles: it will therefore be greatest on the polar side of a cyclone; and the greater the

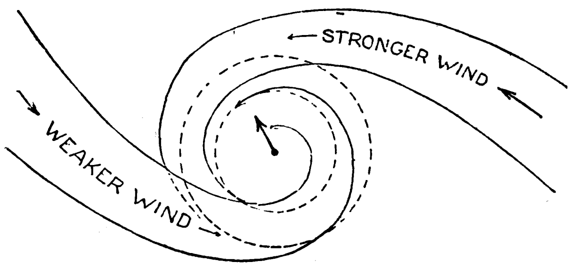


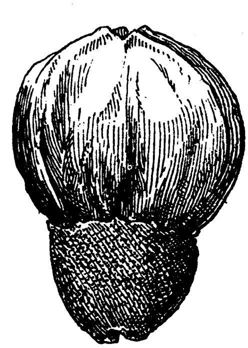
FIG. 17.

storm's diameter, the more marked the difference between the two sides. Its effect will be to make the centrifugal force on the two sides unequal, as in the previous cause; but the resultant motion will here be always from the equator. In the absence of other causes of motion, cyclones would therefore move along meridians: as it is, they nearly always have a more or less pronounced polar tendency; and their failure to move directly from the equator is due to the other causes of progression already mentioned.

(To be continued.)

A COMBINATION WALNUT.

A PECULIAR nut has recently been sent to me from Mr. S. L. Bingaman, Pughtown, Chester county, Penn. It was found on his lawn under a black-walnut tree (Juglans nigra). Mr. Bingaman says, "There is a pecan about sixty feet from it [the walnut-tree], and a shellbark some three hundred yards off." The nut is divided into two parts, as viewed upon the outside. There is a small portion at the base end, which has a covering similar to that of a black walnut. The upper and larger part of the nut has a covering closely resembling that of a shellbark (Carya alba). This exocarp is four-valved, and a partial separation has taken place at the upper end.



In its texture and adherence to the shell this covering is much like that of the ordinary black walnut. Upon cutting the nut in two, the shell