SECTION I.—AEROLOGY.

THE DIURNAL PERIOD OF THE WIND VELOCITY.

During 1912 and 1913 Prof. G. Hellmann (1) has studied the vertical change in wind velocity in winds up to moderate distances above the earth's surface. These studies have helped to reach the following conclusions concerning the diurnal periods of the velocity at different levels.—C. A., jr.

When one reviews all the facts heretofore learned concerning the diurnal period of the wind velocity, supplementing them with those brought out [in (1)], one comes to hold the view that the principal wind phenomenon of the higher levels of the atmosphere demanding explanation is the diurnal period.

In our region of the globe, viz, that of the prevailing westerlies, the diurnal period in the wind velocity, characterized by a nocturnal maximum and a daytime minimum, dominates the greater mass of the atmosphere. Throughout the year this diurnal period extends down to the surface of the ocean; but over the lands it extends only to within about 50 meters of their surface during the cold season and to within about 100 meters during the warm season, and with weak air movements down to within a few meters of the ground. Inversely, that diurnal period of the wind velocity characterized by a daylight maximum and a nocturnal minimum, is restricted to the corresponding lowermost atmospheric layers and in fact is found in all the wind districts of the land regions of the earth.

The Espy-Köppen theory, which is the most widely known, seeks to explain both types of the diurnal periodicity in the wind velocity by the effect of the ascending and descending air currents that develop over the continents during the day. The ascending currents weaken the higher lying air currents; the descending currents bring down from above more rapidly moving air and thereby increase the wind velocity of the lower strata.

Such convection currents are indeed adequate to explain the processes taking place in the lower air layers. It has, however, long been recognized as a fault in this theory that the daytime minimum in the wind velocity which occurs even during the winter at great altitudes, could scarcely be due to ascending air currents. To be sure, our knowledge of these upper air conditions is almost wholly due to observations at mountain stations, that is, at points on the earth's surface. A. Peppler's recent effort to use wind-velocity observations made by means of kites in deducing the period for the free-air winds has taught us, however, that here also the velocity minimum seems to occur during the daytime. The conclusion is still somewhat uncertain, since the measurements are numerically few and very unequally distributed among the different hours. On the other hand, the records secured from the summit of the Eiffel Tower (305 meters) are altogether in favor of the conclusion that the general character of the diurnal period of the wind velocity is the same for mountain summits as for the upper strata of the free air (2).

The writer finds that the cause of the diurnal period in the air currents of the main portion of the atmosphere, lies in the thermal wave which passes around the earth from east to west every 24 hours; a phenomenon which has already been pointed out, sometimes in quite different connections, by Kelvin, Margules, Gold, Möller, and others. In the morning the air of the more easterly regions is more strongly heated, thereby the isobaric surfaces in the east suffer elevation so that an overhead pressure gradient from east to west arises. The prevailing west wind must thereby be weakened, while after the thermal wave has crossed a given local meridian both the causes have the same sign and therefore tend to strengthen the wind velocity. For a locality in the Northern Hemisphere the region of maximum heating and the summit of the resultant great air wave, lies to the southeast in the morning, to the south at noon, and to the southwest in the afternoon, so that the resultant of the two effective forces must vary according as the general westerly drift of the air of the higher atmosphere inclines to come from the northwest, west, or southwest.

Is this view correct, then it may be expected that districts having predominantly east winds will have a diurnal period the opposite of the above, i. e., a daytime maximum. This is in fact the case. We have for some time known the remarkable fact that on the summits of the mountains of the southern East Indies the diurnal period of the wind velocity during the dominance of the southwest monsoon is similar to that of our own mountains (3); but that during the northeast monsoon the diurnal period is inverted, showing a daytime maximum. In these cases then, both the upper and the lower strata have the same hourly changes in wind velocity.

Our hypothesis gives, at the same time, an explanation of the fact that in the portion of the region of the northeast trades lying over the continents (northern Africa, northern South America), there is such a pronounced daily period to the wind velocity that the wind becomes almost stormy soon after noon while in the evening it sinks to a complete calm.

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(2) **Hann, J.** Der tägliche Gang der Windstärke auf dem Gipfel von Ben Nevis und seine Bedeutung für die Theorie. Met. Ztschr., 1912, **29**: 462.

(3) **Hann, J.** Die täglich Variation der Windstärke auf den Berggipfeln in Südindien. Met. Ztschr., 1898, **15**: 220. See also his Lehrbuch der Meteorologie. Leipzig, 1915. 3d. ed., p. 410.

THE ASCENT OF AIR ABOVE ACTIVE VOLCANOES.

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Besides the alarming eruption of glowing or hot lava fragments that accompanies a volcanic eruption, there is a second phenomenon that often is not less striking in external splendor and always furnishes an effective background for the former display, and that is the columns of steam rising above the crater and frequently sending down lightning, thunder, and rain.

So far as I am able properly to understand the portion of vulcanological literature known to me, students are to-day inclined to regard the enormous masses of water carried up into the air to descend again as rain, as being in whole or in part "juvenile water," that is water which was united with the glowing lava and had separated out as vapor as the lava cooled.

Delkeskamp [1] has found it probable that glowing lava quiescent at a depth within the earth's crust has a water-content of 10 per cent. According to this I had expected a volcano or a lava spring would develop a quantity of vapor proportionate to the amount of lava extruded and cooled.

In near-by Savaii (Samoa) an overflowing lava spring formed a lava field about 40 km² in extent and of an average depth of 5 meters. Hence in 1906 and 1907 about 200,000,000 cubic meters of lava were poured out, which would have brought 20,000,000 cubic meters of water vapor into the air, assuming a water content of 10 per cent. This would be a large volume as compared with that delivered by other known volcanoes, yet the columns of steam and "smoke" in Savaii were actually rather slight as is the case with many lava lakes. According to the reports of those living near the Savaii lake the steam and "smoke" columns were best developed during the first year of the eruption, viz, 1905. But at that time no noteworthy volume of lava overflowed at all, there being but explosions which tossed the lava into the air.

These experiences seem to me to justify one in doubting whether the steam cloud consists altogether or even largely of juvenile water.

On the other hand one can not immediately deny the presence of juvenile water in the lava, due either to water primarily in the lava or to water from the earth's surface which has in some way penetrated to the liquid lava. Only scattered students seem to hold the latter view. It seems thus to be of interest to consider whether and to what extent the juvenile water is necessary in order to explain the development of the vapor column, as also what rôle purely meteorological processes might play here.

When the air resting upon the margins of a crater (Kraterrand) becomes heated it expands, thereby becomes (specifically) lighter than its surroundings and ascends. The cooling due to ascension and expansion (1° C. per 100 meters for dry air) will sooner or later cause condensation and thunderstorms in proportion to the moisture content of the air, which varies between 4 grams per cubic meter in temperate latitudes and 18 grams per cubic meter in the Tropics. For the sake of simplicity suppose that the crater has an altitude of several hundred meters so that 1 kilogram of air has the volume of 1 cubic meter of air. Assume that the temperature of the air is 20° C., which is approximately that of tropical and subtropical latitudes. Further take the amount of water contained in 1 kilogram of air as being 14 grams; at saturation it would be 16 grams.

Now the pronounced stratification of our atmosphere will prevent the warmed air rising to very great altitudes, in individual cases, unless there were very strong heating at the volcano. The degree of heating at the volcano will, however, rarely exceed a certain normal amount since a definite ascensional force, *alias* heating, of the air would carry it away from the further influence of the volcano. Thus the altitudes to which ascending air may attain and accordingly the intensity of the thunderstorm concomitantly developed, will both depend upon the atmospheric conditions as will also the general effect made by the erupting crater. Many craters will not be able to develop their clouds beyond altitudes of 3,000 to 4,000 meters where the steam cloud will have to spread out along the boundary of the limiting stratum that generally lies at that altitude. Most ascending currents over volcanoes will have ceased to ascend when they have attained an altitude of from 10,000 to 15,000 meters, where begins a third meteorologically important stratum whose temperature is relatively notably higher than that of the currents beneath it. It is in rare cases only, including particularly the recent explosion of Krakatoa, that the ascending air masses with their accompanying load of gas, lava, and dust particles are able to effect a notable penetration into this third stratum.

The temperature of a volume of air ascending adiabatically, i. e., without receiving heat from its surroundings, decreases at rates lying between 1°C. and 0.5°C. per 100 meters. Hence the separation from it of its water content. In general the temperature of the free-air strata decreases upward at the same rate of 0.5° to 1.0°C. per 100 meters. At the boundaries of the air layers, however—and the meteorologically most important lie at about 4,000 and 10,000 meters—there is often a sudden change in temperature such that, on the average, the overlying stratum is *relatively warmer* than the underlying stratum. Such a stratification wherein warmer, hence lighter air, overlies colder air is mechanically stable and opposes the further ascent of the rising air.

If it be assumed that the air ascends to an altitude of 10 or 15 kilometers then the dynamic cooling must have caused the liquefaction of practically all its content of water vapor. It would be followed by other air masses ascending and cooling under the same conditions. If the ascensional velocity of the air is 1 meter per second then over an area of 1 square meter of the earth's surface there will be set free every second 14 grams = 0.014 kilogram of moisture, or 0.84 kilogram every minute.

Balloon observations have shown us that an ascensional velocity of 10 meters per second is no rarity for the air over the sun-warmed portion of the earth. It is certain that the air over craters is much more strongly heated than elsewhere and acquires a greater upward tendency.

However, we may stick to the above ascensional velocity for the present and regard a velocity of 10 meters per second as the lower limiting value. The resulting production of rainwater would be 8.4 kilograms per minute per square meter of the crater surface $\left(=8.4\frac{\text{kg.}}{\text{min.m}^2}\right)$.

Hellmann's well-known work on the rainfall of the river basins of northern Germany (vol. 1, p. 157) gives the absolute maximum rainfall for a brief interval as $4\frac{\text{mm.}}{\text{minute}}=\frac{4\text{ kg.}}{\text{min. m}^2}$ for Germany. In the Tropics the water vapor content of the atmosphere is about four or five times as great as it is in Germany; so that a measured rainfall of $\frac{8.4\text{ kg.}}{\text{min. m}^2}$ would not be extraordinary. As a matter of fact, however, the actually measured rainfall can be but a fraction of the water produced. A larger and perhaps the greater portion of the water produced remains as clouds floating in or very slowly falling through the air. Further that portion of the produced water which reaches our gages will be spread over a many times larger area [than that from within which it originated].

[1] Der Umschau, May 26, 1906.

Thus a comparison with Hellmann's averages leads us to the conclusion that our assumptions as to ascensional velocity and moisture content are close to the lower limits of the probable ones; and that meteorological processes alone would be adequate to explain the amount of water that occurs as rain or cloud.

When the air has an ascensional velocity of 10 meters per second even thick raindrops[2] can no longer approach the earth. If they are pushed aside then it would seem as though, by reason of the sorting action of the ascending air, the mass of the drops must increase until their weight overcomes the kinetic energy of the ascending air and a violent outbreak follows. Perhaps this is the procedure in the case of the mud-flows which are reported as accompanying some volcanic eruptions.

Take for example a volcano having a chimney aperture of 10 square meters, according to the above assumptions it would yield water to the amount of $8.4 \times 100 \times 100 = 84{,}000$ liters = 84 cubic meters per minute. This would amount to:

5×10^3 cubic meters per hour.
121×10^3 cubic meters per day.
44×10^6 cubic meters per year.

The chimney aperture of the lava lake on Savaii is approximately ten times as great as the above, hence would produce 440×10^6 cubic meters of rainwater per year while its product in juvenile water for the same period, and under the most favorable conditions, would be but 10×10^6 cubic meters or 1/44 of the total water produced—an insignificant fraction. This contrast becomes yet more striking when the extensive spread and surface of the extruded lava in Savaii are considered. For one must consider that the air ascends from over the hot lava-flow as well as from the lava lake; and that while the quantity of juvenile water exhaled remains constant, being merely spread over a greater surface, the ascending air current secures thereby an extraordinarily larger base. It would be much nearer the truth, therefore, if the amount of water brought to condensation merely as the result of warming the air, or by meteorological processes, over the Savaii lava lake were set at ten times the above-assumed quantity.[3]

As a result of the warming of the air it becomes more receptive for water vapor, and the juvenile water evaporates into it there to play a role similar to that of the natural water-vapor content of the air. The existence of the juvenile water vapor may not be denied, but the above discussion shows that it can form so small a factor in the meteorological processes involved as to be unrecognizable, and its existence is not seen to be probable except after studying other considerations. The juvenile water vapor can not appear independently. Meteorologically it can only have the significance that its presence shifts the level of condensation or the level of development of "visible" water vapor somewhat lower, at the very most bringing this level down into the chimney itself.

The occurrence of electric discharges needs no special explanation when they accompany heavy formation of cloud and has nothing to do with the crater as such.

The significance of the general weather conditions and particularly of the temporarily prevailing atmospheric stratification, has already been pointed out. The same volcano that, under well-developed stable stratification, and perhaps dry air, can drive up its cap of steam cloud, rain, or thunderstorm to an altitude of only 3,000 to 4,000 meters—thereby precipitating only about one-half of the water present as vapor—can make an extraordinarily greater impression of its activities when an almost indifferent atmospheric equilibrium permits it to drive its cloud masses to altitudes of 10,000 to 15,000 meters, whence the blue-black cap pours down a heavy, rattling rain of water, ashes, and lava fragments. In the latter case it is difficult to avoid blaming the volcanic eruption for the flash and flare of the lightning among the cloud masses, the roar of the thunder, and even the trembling of the thunder-shaken ground; as a matter of fact the relation between the volcano and the meteorological phenomena is a very loose and indirect one.

[2] There is a limit to the diameter and the speed of descent of raindrops. When their fall exceeds a certain speed they split up.

[3] So that the proportion would better read,

Juvenile water: Meteorological water :: 1 : 440.

COMMENTS.

In connection with the subject of the foregoing paper by Dr. Wegener it is instructive to recall that the Carnegie Institution of Washington has recently conducted experiments on much the same phenomena as they develop at the volcanoes of Hawaii. There is good reason for believing that the character of the activity and the nature of the volcanic products are closely similar in Hawaii and Savaii (the larger of the two islands of German Samoa). Dr. Arthur L. Day, who has been in charge of recent studies in Hawaii, finds that there the volcano cloud consists chiefly of finely divided sulphur, not of water particles, and if the same is true of the cloud at Savaii it will be necessary to modify the conclusions reached by Wegener.

At Hawaii, says Dr. Day,[4] the volatile products escape in two ways: (1) From the hot lava; and (2) from cracks in the adjacent cold lava forming the basin of the pool. When escaping from the hot lava the gases have its temperature and they burn to transparency on coming into contact with the air, so that the hydrogen forms water, the sulphur forms SO_2, and so on. When the gases are escaping from the adjacent, comparatively cold cracks, however, they are cooled before they reach the atmospheric oxygen and do not react with it, so that the hydrogen then escapes as hydrogen, and the sulphur as sulphur. During diminished activity and consequent low stages of the liquid lava, a maximum number of cracks in the cold lava are exposed so that the gases of the liquid lava mostly escape in the relatively cold condition and the visible cloud *increases*. In Hawaii this cloud appears, in fact, to be mostly free sulphur. During periods of considerable activity, on the other hand the liquid lava rises and overflows, thereby closing the cracks in the cold lava rim, and consequently reducing the volume of the visible cloud which may indeed *cease entirely*. Thus the apparent magnitude of the volcano cloud over the Hawaiian lava lakes is, roughly, in inverse proportion to the volcanic activity and so to the amount of volatile matter given off by the liquid lava. This is probably not true for explosive volcanoes, but it may hold for the Samoan localities referred to by Wegener. If there is this similarity with the Hawaiian volcanoes, then it may be necessary to modify the conclusions drawn in Wegener's paper.—[C. A. jr.]

[4] Letter to the editor, dated Washington, D. C., Mar. 27, 1915.