ON

THE MODIFICATIONS

OF

CLOUDS, &c.

LONDON:

PRINTED BY J. TAYLOR,

BLACK-HORSE-COURT, FLEET-STREET.

Contains also
Meteorological journals 1807-1810
by W. Scoresby, jun.

ON THE

MODIFICATIONS OF CLOUDS,

AND ON

THE PRINCIPLES OF THEIR PRODUCTION, SUSPENSION, AND DESTRUCTION:

Being the Substance of an Essay read before the Askesian Society in the Session 1802-3.

By LUKE HOWARD, *Esq.*

SINCE the increased attention which has been given to meteorology, the study of the various appearances of water suspended in the atmosphere is become an interesting and even necessary branch of that pursuit.

If clouds were the mere result of the condensation of vapour in the masses of atmosphere which they occupy, if their variations were produced by the movements of the atmosphere alone, then indeed might the study of them be deemed an useless pursuit of shadows, an attempt to describe forms which, being the sport of winds, must be ever varying, and therefore not to be defined.

But however the erroneous admission of this opinion may have operated to prevent attention to them, the case is not so with clouds. They are subject to certain distinct modifications, produced by the general causes which effect all the variations of the atmosphere: they are commonly as good visible indications of the operation of these causes, as is the countenance of the state of a person's mind or body.

It is the frequent observation of the countenance of the sky, and of its connection with the present and ensuing phænomena, that constitutes the antient and popular meteorology. The want of this branch of knowledge renders the predictions of the philosopher (who in attending only to his instruments may be said only to examine the pulse of the atmosphere) less generally successful than those of the weather-wise mariner or husbandman.

With the latter, the dependence of their labours on the state of the atmosphere, and the direction of its currents, creates a necessity of frequent observation, which in its turn produces experience.

But as this experience is usually consigned only to the memory of the possessor, in a confused mass of simple aphorisms, the skill resulting from it is in a manner incommunicable; for, however valuable these links when in connection with the rest of the chain, they often serve, when taken singly, only to mislead; and the power of connecting them, in order to form a judgment upon occasion, resides only in the mind before which their relations have passed, though perhaps imperceptibly, in review. In order to enable the meteorologist to apply the key of analysis to the experience of others, as well as to record his own with brevity and precision, it may perhaps be allowable to introduce a methodical nomenclature, applicable to the various forms of suspended water, or, in other words, to the modifications of cloud.

By modification is to be understood simply the structure or manner of aggregation, not the precise form or magnitude; which indeed varies every moment in most clouds. The principal modifications are commonly as distinguishable from each other as a tree from a hill, or the latter from a lake; although clouds in the same modification, considered with respect to each other, have often only the common resemblances which exist among trees, hills, or lakes, taken generally.

The nomenclature is drawn from the Latin. The reasons for having recourse to a dead language for terms to be adopted by the learned of different nations are obvious. If it should be asked why the Greek was not preferred, after the example of chemistry, the author answers, that the objects being to be defined by visible characters, as in natural history, it was desirable that the terms adopted should at once convey the idea of these, and render a recourse to definitions needless to such as understand the literal sense, which many more would, it is concluded, in Latin than in Greek words.

There are three simple and distinct modifications, in any one of which the aggregate of minute drops called a cloud may be formed, increase to its greatest extent, and finally decrease and disappear.

But the same aggregate which has been formed in one modification, upon a change in the attendant circumstances, may pass into another.

Or it may continue a considerable time in an intermediate state, partaking of the characters of two modifications; and it may also disappear in this stage, or return to the first modification.

Lastly, aggregates separately formed in different modifications may unite and pass into one, exhibiting different characters in different parts, or a portion of a simple aggregate may pass into another modification without separating from the remainder of the mass.

Hence, together with the simple, it becomes necessary to admit intermediate and compound modifications, and to impose names on such of them as are worthy of notice.

The simple modifications are thus named and defined:

1. CIRRUS. *Def.* Nubes cirrata, tenuissima, quæ undique crescat.

Parallel, flexuous, or diverging fibres, extensible in any or in all directions.

2. CUMULUS. *Def.* Nubes cumulata, densa, sursum crescens.

Convex or conical heaps, increasing upward from a horizontal base.

3. STRATUS. *Def.* Nubes strata, aquæ modo expansa, deorsum crescens.

A widely extended, continuous, horizontal sheet, increasing from below.

This application of the Latin word *stratus* is a little forced. But the substantive, *stratum*, did not agree in its termination with the other two, and is besides already used in a different sense even on this subject, e. g. *a stratum of clouds*; yet it was desirable to keep the derivation from the verb *sterno*, as its significations agree so well with the circumstances of this cloud.

The intermediate modifications which require to be noticed are:

4. CIRRO-CUMULUS. *Def.* Nubeculæ densiores subrotundæ et quasi in agmine appositæ.

Small, well defined roundish masses, in close horizontal arrangement.

5. CIRRO-STRATUS. *Def.* Nubes extenuata sub-concava vel undulata. Nubeculæ hujus modi appositæ.

Horizontal or slightly inclined masses, attenuated towards a part or the whole of their circumference, bent downward, or undulated, separate, or in groups consisting of small clouds having these characters.

The compound modifications are:

6. CUMULO-STRATUS. *Def.* Nubes densa, basim planam undique supercrescens, vel cujus moles longinqua videtur partim plana partim cumulata.

The cirro-stratus blended with the cumulus, and either appearing intermixed with the heaps of the latter, or superadding a wide-spread structure to its base.

7. CUMULO-CIRRO-STRATUS vel NIMBUS. *Def.* Nubes vel nubium congeries pluviam effundens.

The rain cloud. A cloud or system of clouds from which rain is falling. It is a horizontal sheet, above which the cirrus spreads, while the cumulus enters it laterally and from beneath.

Of the Cirrus.

Clouds in this modification appear to have the least density, the greatest elevation, and the greatest variety of extent and direction. They are the earliest appearance after serene weather. They are first indicated by a few threads pencilled, as it were, on the sky. These increase in length, and new ones are in the mean time added laterally. Often the first-formed threads serve as stems to support numerous branches, which in their turn give rise to others.

The increase is sometimes perfectly indeterminate, at others it has a very decided direction. Thus the first few threads being once formed, the remainder shall be propagated either in one, two, or more directions laterally, or obliquely upward or downward, the direction being often the same in a great number of clouds visible at the same time: for the oblique descending tufts shall appear to converge towards a point in the horizon, and the long straight streaks to meet in opposite points therein; which is the optical effect of parallel extension.

Their duration is uncertain, varying from a few minutes after the first appearance to an extent of many hours. It is long when they appear alone and at great heights, and shorter when they are formed lower and in the vicinity of other clouds.

This modification, although in appearance almost motionless, is intimately connected with the variable motions of the atmosphere. Considering that clouds of this kind have long been deemed a prognostic of wind, it is extraordinary that the nature of this connection should not have been more studied, as the knowledge of it might have been productive of useful results.

In fair weather, with light variable breezes, the sky is seldom quite clear of small groups of the oblique cirrus, which frequently come on from the leeward, and the direction of their increase is to windward. Continued wet weather is attended with horizontal sheets of this cloud, which subside quickly and pass to the cirro-stratus.

Before storms they appear lower and denser, and usually in the quarter opposite to that from which the storm arises. Steady high winds are also preceded and attended by streaks running quite across the sky in the direction they blow in.

The relations of this modification with the state of the barometer, thermometer, hygrometer, and electrometer, have not yet been attended to.

Of the Cumulus.

Clouds in this modification are commonly of the most dense structure: they are formed in the lower atmosphere, and move along with the current which is next the earth.

A small irregular spot first appears, and is, as it were, the nucleus on which they increase. The lower surface continues irregularly plane, while the upper rises into conical or hemispherical heaps; which may afterwards continue long nearly of the same bulk, or rapidly rise to mountains.

In the former case they are usually numerous and near together, in the latter few and distant; but whether there are few or many, their bases always lie nearly in one horizontal plane, and their increase upward is somewhat proportionate to the extent of base, and nearly alike in many that appear at once.

Their appearance, increase, and disappearance, in fair weather, are often periodical, and keep pace with the temperature of the day. Thus they will begin to form some hours after sun-rise, arrive at their maximum in the hottest part of the afternoon, then go on diminishing, and totally disperse about sun-set.

But in changeable weather they partake of the vicissitudes of the atmosphere; sometimes evaporating almost as soon as formed, at others suddenly forming and as quickly passing to the compound modifications.

The cumulus of fair weather has a moderate elevation and extent, and a well defined rounded surface. Previous to rain it increases more rapidly, appears lower in the atmosphere, and with its surface full of loose fleeces or protuberances.

The formation of large cumuli to leeward in a strong wind, indicates the approach of a calm with rain. When they do not disappear or subside about sun-set, but continue to rise, thunder is to be expected in the night.

Independently of the beauty and magnificence it adds to the face of nature, the cumulus serves to skreen the earth from the direct rays of the sun, by its multiplied reflections to diffuse, and, as it were, economize the light, and also to convey the product of evaporation to a distance from the place of its origin. The relations of the cumulus with the state of the barometer, &c. have not yet been enough attended to.

Of the Stratus.

This modification has a mean degree of density.

It is the lowest of clouds, since its inferior surface commonly rests on the earth or water.

Contrary to the last, which may be considered as belonging to the day, this is properly the cloud of night; the time of its first appearance being about sun-set. It comprehends all those creeping mists which in calm evening ascend in spreading sheets (like an inundation of water) from the bottom of valleys and the surface of lakes, rivers, &c.

Its duration is frequently through the night.

On the return of the sun the level surface of this cloud begins to put on the appearance of cumulus, the whole at the same time separating from the ground. The continuity is next destroyed, and the cloud ascends and evaporates, or passes off with the appearance of the nascent cumulus.

This has been long experienced as a prognostic of fair weather *, and indeed there is none more serene than that which is ushered in by it. The relation of the stratus to the state of the atmosphere as indicated by the barometer, &c. appears notwithstanding to have passed hitherto without due attention.

Of the Cirro-cumulus.

The cirrus having continued for some time increasing or stationary, usually passes either to the cirro-cumulus or the cirro-stratus, at the same time descending to a lower station in the atmosphere.

The cirro-cumulus is formed from a cirrus, or from a number of small separate cirri, by the fibres collapsing, as it were, and passing into small roundish masses, in which the texture of the cirrus is no longer discernible, although they still retain somewhat of the same relative arrangement. This change takes place either throughout the whole mass at once, or progressively from one extremity to the other. In either case, the same effect is produced on a number of adjacent cirri at the same time and in the same order. It appears in some instances to be accelerated by the approach of other clouds.

This modification forms a very beautiful sky, sometimes

* At nebulæ magis ima petunt, campoque recumbunt.
Virgil. Georg. lib. i.

exhibiting

exhibiting numerous distinct beds of these small connected clouds, floating at different altitudes.

The cirro-cumulus is frequent in summer, and is attendant on warm and dry weather. It is also occasionally and more sparingly seen in the intervals of showers, and in winter*. It may either evaporate, or pass to the cirrus or cirro-stratus.

Of the Cirro-stratus.

This cloud appears to result from the subsidence of the fibres of the cirrus to a horizontal position, at the same time that they approach towards each other laterally. The form and relative position, when seen in the distance, frequently give the idea of shoals of fish. Yet in this, as in other instances, the structure must be attended to rather than the form, which varies much, presenting at other times the appearance of parallel bars, interwoven streaks like the grain of polished wood, &c. It is always thickest in the middle, or at one extremity, and extenuated towards the edge. The distinct appearance of a cirrus does not always precede the production of this and the last modification.

The cirro-stratus precedes wind and rain, the near or distant approach of which may sometimes be estimated from its greater or less abundance and permanence. It is almost always to be seen in the intervals of storms. Sometimes this and the cirro-cumulus appear together in the sky, and even alternate with each other in the same cloud, when the different evolutions which ensue are a curious spectacle, and a judgment may be formed of the weather likely to ensue by observing which modification prevails at last. The cirro-stratus is the modification which most frequently and completely exhibits the phænomena of the solar and lunar halo, and (as supposed from a few observations) the parhelion and paraselene also. Hence the reason of the prognostic for foul weather, commonly drawn from the appearance of halo †.

This

* The following passage is beautifully descriptive of the appearance of this modification by moonlight:

For yet above these wafted clouds are seen
(In a remoter sky, still more serene)
Others, detached in ranges through the air,
Spotless as snow, and countless as they're fair,
Scatter'd immensely wide from east to west,
The beauteous semblance of a flock at rest.
These to the raptur'd mind aloud proclaim
Their mighty Shepherd's everlasting name.

Bloomfield's Farmer's Boy, Winter.

† The frequent appearance of halo in this cloud may be attributed to its

This modification is on this account more peculiarly worthy of investigation. Little is yet ascertained of the relations of this and the last modification with the barometer, &c. although, as may be readily supposed, they have been found to accord with opposite indications of those instruments.

Of the Cumulo-stratus.

The different modifications which have been just treated of sometimes give place to each other, at other times two or more appear in the same sky; but in this case the clouds in the same modification lie mostly in the same plane of elevation, those which are more elevated appearing through the intervals of the lower, or the latter showing dark against the lighter ones above them. When the cumulus increases rapidly, a cirro-stratus is frequently seen to form around its summit, reposing thereon as on a mountain, while the former cloud continues discernible in some degree through it. This state continues but a short time. The cirro-stratus speedily becomes denser and spreads, while the superior part of the cumulus extends itself and passes into it, the base continuing as before, and the convex protuberances changing their position till they present themselves laterally and downward. More rarely the cumulus alone performs this evolution, and its superior part constitutes the incumbent cirro-stratus.

In either case a large lofty dense cloud is formed, which may be compared to a mushroom with a very thick short stem. But when a whole sky is crowded with this modification, the appearances are more indistinct. The cumulus rises through the interstices of the superior clouds, and the whole, seen as it passes off in the distant horizon, presents to the fancy mountains covered with snow, intersected with darker ridges and lakes of water, rocks and towers, &c. The distinct cumulo-stratus is formed in the interval between the first appearance of the fleecy cumulus and the

its possessing great extent, at such times, with little perpendicular depth, and that degree of continuity of substance which seems requisite to the phænomenon. There is also probably some additional peculiarity of structure in it not yet attended to.

The following lines of Virgil seem to relate to an effect of the cirro-stratus, which in this country is more often to be observed on the *setting* sun:

> Ille ubi nascentem *maculis* variaverit ortum
> Conditus in nubem, *medioque refugerit orbe*,
> Suspecti tibi sint *imbres:* namque urget ab alto
> Arboribusque satisque *Notus*, pecorique sinister.
>
> *Georgic.* lib. i.

commencement

commencement of rain, while the lower atmosphere is yet too dry; also during the approach of thunder storms: the indistinct appearance of it is chiefly in the longer or shorter intervals of showers of rain, snow, or hail.

The cumulo-stratus chiefly affects a mean state of the atmosphere as to pressure and temperature; but in this respect, like the other modifications, it affords much room for future observation.

Of the Nimbus, or Cumulo-cirro-stratus.

Clouds in any one of the preceding modifications, at the same degree of elevation, or in two or more of them at different elevations, may increase so as completely to obscure the sky, and at times put on an appearance of density which to the inexperienced observer indicates the speedy commencement of rain. It is nevertheless extremely probable, as well from attentive observation as from a consideration of the several modes of their production, that the clouds while in any one of these states do not at any time let fall rain.

Before this effect takes place they have been uniformly found to undergo a change, attended with appearances sufficiently remarkable to constitute a distinct modification. These appearances, when the rain happens over our heads, are but imperfectly seen. We can then only observe, before the arrival of the denser and lower clouds, or through their interstices, that there exists *at a greater altitude* a thin light veil, or at least a hazy turbidness. When this has considerably increased, we see the lower clouds spread themselves till they unite in all points and form one uniform sheet. The rain then commences, and the lower clouds, arriving from the windward, move under this sheet and are successively lost in it. When the latter cease to arrive, or when the sheet breaks, every one's experience teaches him to expect an abatement or cessation of rain.

But there often follows, what seems hitherto to have been unnoticed, an immediate and great addition to the quantity of cloud. At the same time the actual *obscurity* is lessened, because the arrangement, which now returns, gives freer passage to the rays of light: for on the cessation of rain the lower broken clouds which remain rise into cumuli, and the superior sheet puts on the various forms of the cirro-stratus, sometimes passing to the cirro-cumulus.

If the interval be long before the next shower, the cumulo-stratus usually makes its appearance, which it also does sometimes very suddenly after the first cessation.

But we see the nature of this process more perfectly in viewing a distant shower in profile.

If the cumulus be the only cloud present at such a time, we may observe its superior part to become tufted with nascent cirri. Several adjacent clouds also approach and unite laterally by subsidence.

The cirri increase, extending themselves upward and laterally; after which the shower is seen to commence. At other times the converse takes place of what has been described relative to the cessation of rain. The cirro-stratus is previously formed above the cumulus, and their sudden union is attended with the production of cirri and rain.

In either case the cirri *vegetate*, as it were, in proportion to the quantity of rain falling, and give the cloud a character by which it is easily known at great distances, and to which, in the language of meteorology, we may appropriate the nimbus of the Latins*.

When one of these arrives hastily *with the wind* it brings but little rain, and frequently some hail or driven snow.

In heavy showers, the central sheet once formed, is, as it were, warped to windward, the cirri being propagated above and against the lower current, while the cumuli arriving with the latter are successively *brought to* and contribute to reinforce it.

Such are the phænomena of showers. In continued gentle rains it does not appear necessary for the resolution of the clouds that the different modifications should come into actual contact.

It is sufficient that there exist two strata of clouds, one passing beneath the other, and each continually tending to horizontal uniform diffusion. It will rain during this state of the two strata, although they should be separated by an interval of many hundred feet in elevation. See an instance in De Luc, *Idées sur la Météorologie*, tom. ii. p. 52, &c.

As the masses of cloud are always blended and their arrangement destroyed before rain comes on, so the reappearance of these is the signal for its cessation. The thin sheets of cloud which pass over during a wet day, certainly receive from the humid atmosphere a supply proportionate to their consumption, while the latter prevents their increase in bulk. Hence a seeming paradox, which yet accords strictly with observation, that for any given hour of a wet day, or any given day of a wet season, *the more cloud the less rain.*

* Qualis ubi ad terras abrupto sydere *nimbus*
It mare per medium, miseris heu *prescia longe*
Horrescunt corda agricolis.

Hence

Hence also arise some further reflections on the purpose answered by clouds in the œconomy of nature. Since rain may be produced by, and continue to fall from, the slightest obscuration of the sky by the nimbus (that is, by *two sheets* in different states), while the cumulus or cumulo-stratus, with the most dark and threatening aspect, shall pass over without letting fall a drop, until their change of state commences; it should seem that the latter are reservoirs in which the water is collected from a large space of atmosphere for occasional and local irrigation in dry seasons, and by means of which it is also arrested at times in its descent in the midst of wet ones *. In which so evident provision for the sustenance of all animal and vegetable life, as well as for the success of mankind in that pursuit so essential to their welfare, in temperate climates, of cultivating the earth, we may discover the wisdom and goodness of the Creator and Preserver of all things †.

The nimbus, although in itself one of the least beautiful clouds, is yet now and then superbly decorated with its attendant the rainbow; which can only be seen in perfection when backed by the widely extended uniform gloom of this modification ‡.

The relations of rain, and of periodical showers more especially, with the varying temperature, density, and electricity of the atmosphere, will probably now obtain a fuller investigation, and with a better prospect of success, than heretofore.

Plate VI. *a,a*, represents different appearances of the cirrus: *b*, a regular cumulus: *c*, a stratus occupying a valley at sun-set, in the midst of which is supposed a spot of higher ground, with trees, &c.

Plate VII. *a,a*, exhibits the character of the cirro-cumulus, as also its appearance in the distance. *b,b*, a light and a dark cirro-stratus; the former taken just before the commencement of wet weather, the latter in the twilight of the evening, when dew was falling: the smaller ones show its appearance in the distance. *c,c*, the mixed and the distinct cumulo-stratus; the latter in its most regular state, as sometimes seen at the approach of thunder storms and after showers.

Plate VIII. A distant shower coming from behind an ele-

* Nulla dies adeo est Australibus humida nimbis
Non intermissis ut fluat imber aquis.

† See on this subject, Job, chap. xxxvii. and xxxviii.

‡ *Bibit* INGENS *arcus*, says Virgil, in enumerating the prognostics of continued rain.

vated

vated point of land, in which are represented the superior sheet stretching in different parts to windward, and cumuli advancing towards and entering the mass, the whole of which constitutes the nimbus.

As the establishing distinctive characters for clouds has been heretofore deemed a desirable object, and it is consequently probable that the author's modifications will begin to be noted in meteorological registers as they occur, a practice which may be productive of considerable advantage to science, the following system of abbreviations may, perhaps, be found of some use in this respect. They will save room and the labour of writing, and types may be easily formed for printing them. These are advantages not to be despised, when observations are to be noted once or oftener in the day. It is only necessary that they be inserted in a column headed *Clouds*; that the modifications which appear together be placed side by side, and those which succeed to each other in the usual succession of the column, but separated by a line or space from the preceding and succeeding day's notations.

\ Cirrus.
∩ Cumulus.
— Stratus.
\∩ Cirro-cumulus.
_ Cirro-stratus.
∩_ Cumulo-stratus.
\∩_ Cumulo-cirro-stratus, or Nimbus.

In tracing the various appearances of clouds, we have only adverted to their connection with the different states of the atmosphere (on which, indeed, their diversity in a great measure depends), having purposely avoided mixing difficult and doubtful explanation with a simple descriptive arrangement.

Of Evaporation.

On the remote and universal origin of clouds there can be but one opinion—that the water of which they consist has been carried into the atmosphere by evaporation. It is on the nature of this process, the state in which the vapour subsists for a time, and the means by which the water becomes again visible, that the greatest diversity of opinion has prevailed.

The chemical philosopher, seduced by analogy, and accustomed more to the action of liquids on solids, naturally

regards

regards evaporation as a solution of water in the atmosphere, and the appearance of cloud as the first indication of its precipitation; which becoming afterwards (under favourable circumstances) more abundant, produces rain. The theory of Dr. Hutton goes a step further, assumes a certain rate of solution differing from that of the advance of temperature by which it is effected, and deduces a general explanation of clouds and rain from the precipitation which, according to his rule, should result from every mixture of different portions of saturated air. The fundamental principle of this theory has been disproved in an essay heretofore presented to the society*, and which was written under the opinion, at present generally adopted by chemists, that evaporation depends on a solvent power in the atmosphere, and follows the general rules of chemical solution.

The author has since espoused a theory of evaporation which altogether excludes the above-mentioned opinion (and consequently Dr. Hutton's also), and considers himself in a considerable degree indebted to it for the origin of the explanation he is about to offer. It will be proper, therefore, to state the fundamental propositions of this theory, with such other parts as appear immediately necessary, referring for mathematical demonstrations and detail of experiments to the work itself, which is entitled "Experimental Essays on the Constitution of mixed Gases; on the Force of Steam or Vapour from Water and other Liquids in different Temperatures, both in a Torricellian Vacuum and in Air; on Evaporation; and on the Expansion of Elastic Fluids by Heat. By John Dalton."—See Memoirs of the Literary and Philosophical Society of Manchester, vol. v. part 2.—The propositions are as follow:

"1. When two elastic fluids, denoted by *A* and *B*, are mixed together, there is no mutual repulsion amongst their particles; that is, the particles of *A* do not repel those of *B*, as they do one another. Consequently, the pressure or whole weight upon any one particle arises solely from those of its own kind.

"2. The force of steam from all liquids is the same at equal distances above or below the several temperatures at which they boil in the open air; and that force is the same under any pressure of another elastic fluid as it is *in vacuo*. Thus the force of aqueous vapour of 212° is equal to 30 inches of mercury; at 30° below, or 182°, it is of half that force; and at 40° above, or 252°, it is of double the force: so like-

* See Phil. Mag. vol. xiv. p. 55.

wise

wise the vapour from sulphuric ether which boils at 102°, then supporting 30 inches of mercury, at 30° below that temperature it has half the force, and at 40° above it, double the force: and so in other liquids. Moreover, the force of aqueous vapour of 60° is nearly equal to half an inch of mercury when admitted into a Torricellian vacuum; and water of the same temperature, confined with perfectly dry air, increases the elasticity to just the same amount.

"3. The quantity of any liquid evaporated in the open air is directly as the force of steam from such liquid at its temperature, all other circumstances being the same."

The following is part of the Essay on Evaporation:

"When a liquid is exposed to the air, it becomes gradually dissipated in it: the process by which this effect is produced we call *evaporation*.

"Many philosophers concur in the theory of chemical solution: atmospheric air, it is said, has an affinity for water; it is a menstruum in which water is soluble to a certain degree. It is allowed notwithstanding by all, that each liquid is convertible into an elastic vapour *in vacuo*, which can subsist independently in any temperature; but as the utmost forces of these vapours are inferior to the pressure of the atmosphere in ordinary temperatures, they are supposed to be incapable of existing in it in the same way as they do in a Torricellian vacuum: hence the notion of affinity is induced. According to this theory of evaporation, atmospheric air (and every other species of air for aught that appears) dissolves water, alcohol, ether, acids, and even metals. Water below 212° is chemically combined with the gases; above 212° it assumes a new form, and becomes a distinct elastic fluid, called *steam*: whether water first chemically combined with air, and then heated above 212°, is detached from the air or remains with it, the advocates of the theory have not determined. This theory has always been considered as complex, and attended with difficulties; so much that M. Pictet and others have rejected it, and adopted that which admits of distinct elastic vapours in the atmosphere at all temperatures, uncombined with either of the principal constituent gases, as being much more simple and easy of explication than the other; though they do not remove the grand objection to it, arising from atmospheric pressure."

"*On the Evaporation of Water below* 212°.

"I have frequently tried the evaporation at all the temperatures below 212: it would be tedious to enter into detail of all the experiments, but shall give the results at some

 remarkable

remarkable points. In all the high temperatures I used the vessel above mentioned*, keeping a thermometer in it, by which I could secure a constant heat, or at least keep it oscillating within narrow limits.

" The evaporation from water of 180° was from 18 to 22 grains per minute, according to circumstances; or about one-half of that at 212°.

" At 164° it was about one-third of the quantity at the boiling temperature, or from 10 to 16 grains per minute.

" At 152° it was only one-fourth of that at boiling, or from 8 to 12 grains, according to circumstances.

" The temperature of 144° affords one-fifth of the effect at boiling; 138° gave one-sixth, &c.

" Having previously to these experiments determined the force of aqueous vapour at all the temperatures under 212°, I was naturally led to examine whether the quantity of water evaporated in a given time bore any proportion to the force of vapour of the same temperature, and was agreeably surprised to find that they exactly corresponded in every part of the thermometric scale: thus the forces of vapour at 212°, 180°, 164°, 152°, 144°, and 138°, are equal to 30, 15, 10, $7\frac{1}{2}$, 6, and 5 inches of mercury respectively; and the grains of water evaporated per minute in those temperatures were 30, 15, 10, $7\frac{1}{2}$, 6, and 5, also; or numbers proportional to these. Indeed it should be so from the established law of mechanics, that all effects are proportional to the causes producing them. The atmosphere, it should seem, obstructs the diffusion of vapour, which would otherwise be almost instantaneous, as *in vacuo*; but this obstruction is overcome in proportion to the force of the vapour. The obstruction, however, cannot arise from the weight of the atmosphere, as has till now been supposed; for then it would effectually prevent any vapour from arising under 212°: but it is caused by the *vis inertiæ* of the particles of air, and is similar to that which a stream of water meets with in descending amongst pebbles.

" The theory of evaporation being thus manifested from experiments in high temperatures, I found that if it was to be verified by experiments in low temperatures regard must be had to the force of vapour actually existing in the atmosphere at the time. For instance, if water of 59° were the subject, the force of vapour of that temperature is 1-60th of the force at 212°, and one might expect the quantity

* This refers to experiments on the evaporation of water at 212°; for which see the Essay.

of evaporation 1-60th also; but if it should happen, as it sometimes does in summer, that an aqueous atmosphere to that amount does already exist, the evaporation, instead of being 1-60th of that from boiling water, would be nothing at all. On the other hand, if the aqueous atmosphere were less than that, suppose one-half of it, corresponding to 39° of heat, then the effective evaporating force would be 1-120th of that from boiling water: in short, the evaporating force must be universally equal to that of the temperature of the water, diminished by that already existing in the atmosphere. In order to find the force of the aqueous atmosphere I usually take a tall cylindrical glass jar, dry on the outside, and fill it with cold spring water fresh from the well: if dew be immediately formed on the outside, I pour the water out, let it stand a while to increase in heat, dry the outside of the glass well with a linen cloth, and then pour the water in again: this operation is to be continued till dew ceases to be formed, and then the temperature of the water must be observed; and opposite to it in the table will be found the force of vapour in the atmosphere. This must be done in the open air, or at a window; because the air within is generally more humid than that without. Spring water is generally about 50°, and will mostly answer the purpose the three hottest months in the year; in other seasons an artificial cold mixture is required. The accuracy of the result obtained this way I think scarcely needs to be insisted upon. Glass, and all other hard, smooth substances I have tried, when cooled to a degree below what the surrounding aqueous vapour can support, cause it to be condensed on their surfaces into water. The degree of cold is usually from 1 to 10 below the mean heat of the 24 hours; in summer I have often observed the point as high as 58° or 59°, corresponding to half an inch of mercury in force; and once or twice have seen it at 62°: in changeable and windy weather it is liable to considerable fluctuation: but this is not the place to enlarge upon it.

" For the purpose of observing the evaporation in atmospheric temperatures I got two light tin vessels, the one six inches in diameter and half an inch deep, the other eight inches diameter and three-fourths of an inch deep, and made to be suspended from a balance. When any experiment, designed as a test of the theory, was made, a quantity of water was put into one of these (generally the six-inch one, which I preferred), the whole was weighed to a grain; then it was placed in an open window or other exposed situation for 10 or 15 minutes, and again weighed

to

to ascertain the loss by evaporation; at the same time the temperature of the water was observed, the force of the aqueous atmosphere ascertained as above, and the strength of the current of air noticed. From a great variety of experiments made both in the winter and summer, and when the evaporating force was strong and weak, I have found the results entirely conformable with the above theory. The same quantity is evaporated with the same evaporating force thus determined, whatever be the temperature of the air, as near as can be judged; but with the same evaporating force, a strong wind will double the effect produced in a still atmosphere. Thus, if the aqueous atmosphere be correspondent to 40° of temperature and the air be 60°, the evaporation is the same as if the aqueous atmosphere were at 60° of temperature and the air 72°; and in a calm air the evaporation from a vessel of six inches in diameter in such circumstances would be about ·9 of a grain per minute, and about 1·8 grain per minute in a very strong wind; the different intermediate quantities being regulated solely by the force of the wind."

Of the Aqueous Atmosphere.

Having quoted so much of this essay as may suffice to exhibit the principles on which we shall proceed, it may be useful, before we do this, to recapitulate the following circumstances respecting the atmosphere of aqueous gas, or (for brevity) the aqueous atmosphere.

1st, It is supplied by the process of evaporation, which by this theory appears to be reduced to the immediate union of water with caloric into a binary compound, *aqueous gas*.

2dly, The supply of vapour (by which term, for the purposes of meteorology, we may denote aqueous gas,) is regulated by the following circumstances:—1. Temperature of the evaporating water, being greater as this is higher, and *vice versâ*. 2. Quantity of surface exposed. Since it is from the surface only of the mass that the vapour in common cases can escape, the supply is in direct proportion thereto. 3. Quantity of vapour already subsisting in the atmosphere: the evaporation being less (with equal temperature and surface) in proportion as this is greater, and *vice versâ*.

3dly, The vapour thus thrown into the atmosphere is diffusible therein by its own elasticity, which suffices for its ascent to any height in a perfect calm. Yet, as in this case the *inertia* of the particles of air considerably resists its diffusion, so in the opposite one of a brisk current, the vapour, by the same rule, must in some measure be drawn along with the mass into which it enters.

4thly, The quantity of vapour which, under equal pressure, can subsist in a given mass of air, will be greater as the common temperature is higher, and *vice versâ* *.

Aqueous vapour is the only gas contained in the atmosphere which is subject to very sensible variations in quantity. These variations arise from its attraction for caloric being inferior to that of all the others. Hence when a cold body, such as the glass of water in the experiment above quoted, is presented to the atmosphere, the other gases, composing the latter, will only be cooled by it (and that at all known temperatures); but the vapour, after being more or less cooled, will begin to be decomposed, its caloric entering the body while the water is left on the surface.

The formation of cloud is in all cases the *remote* consequence of a decomposition thus effected, except that the caloric escapes, not into a solid or liquid, but into the surrounding gases.

Of the Formation of Dew.

Dew is the *immediate* result of this decomposition. The particles of water constituting it are, singly, invisible, on account of their extreme minuteness. The approach of dew is, nevertheless, discoverable by a dark hazy appearance, verging from purple to faint red, extending from the horizon to a small distance upwards, and most conspicuous over valleys and large pieces of water.

The theory of dew seems to be simply this:—During the heat of the day a great quantity of vapour is thrown into the atmosphere from the surface of the earth and waters. When the evening returns, if the vapour has not been carried off in part by currents, it will often happen that more remains diffused in the general atmosphere than the temperature of the night will permit to subsist under the full pressure of the

* "The aqueous vapour atmosphere is variable in quantity according to temperature: in the torrid zone its pressure on the surface of the earth is equal to the force of ·6, and from that to one inch of mercury. In these parts it rarely amounts to the pressure of ·6, but I have frequently observed it above half an inch in summer: in winter it is sometimes so low as to be of no more force than ·1 of an inch of mercury, or even half a tenth, in this latitude, and consequently much less where the cold is more severe. This want of equilibrium in the aqueous vapour atmosphere is a principal cause of that constant inundation of it into the temperate and frigid zones, where it becomes in part condensed in its progress by the cold, like the vapour of distillation in the worm of a refrigeratory, and supplies the earth with rain and dew." See the Essays above quoted.

the aqueous atmosphere. A decomposition of the latter then commences, and is continued until the general temperature and aqueous pressure arrive at an equilibrium, or until the returning sun puts an end to the process. The caloric of the decomposed vapour goes to maintain the general temperature; while the water is separated in drops, which, minute as they are, arrive successively at the earth in the space of a few hours. That the ordinary production of dew is by a real *descent* of water from the atmosphere, and not by decomposition of vapour on surfaces previously cooled (as in the experiment already mentioned), any one may readily be convinced by observing in what abundance it is collected by substances which are wholly unfit to carry off the requisite quantity of caloric for the latter effect.

Of the Formation of the Stratus.

The case which has been just stated, *of the decomposition of vapour by the atmosphere in which it is already diffused*, goes but a little way in explanation of the production of a cloud consisting of visible drops, and confined to a certain space in the atmosphere: much less does it enable us to account for the diversity of its situations and appearances. In attempting this we will begin with the stratus, as the most simple in structure, and the next step, as it were, in the progress of *nubification*.

When dew falls upon a surface the temperature of which is superior to that of the atmosphere, it is plain that it will not continue there, but will be evaporated again: and a body so circumstanced will continue to refund into the atmosphere the whole of the water thus *gradually* deposited on it, so long as its substance can supply the requisite temperature to the surface. Moreover, water either in mass, or diffused among sand, clay, vegetable earth, &c. will continue to be evaporated therefrom with a force proportioned to its temperature, so long as the latter continues above that point which counterbalances the pressure of the aqueous atmosphere.

From these causes it happens, that after the earth has been superficially dried by a continuance of sunshine, and heated, together with the lakes and rivers, to a considerable depth, there is an almost continual emission of vapour into the atmosphere by night.

This nocturnal evaporation is usually most powerful in the autumn, about the time that the temperature of the nights undergoes a considerable and sometimes pretty sudden depression attended with a calm.

In this state of things the vapour arising from the heated earth is condensed *in the act of diffusing itself* (if we may be allowed the expression): the cold particles of water thus formed, in *descending* meet the ascending stream of vapour, and condense a portion on their surfaces: if they touch the earth they are again evaporated, which is not necessarily the case if they alight on the herbage. In this way an aggregate of visible drops is sooner or later formed*; and as from the temperature thus communicated to the air next the earth the vapour has still further and further to rise in order to be condensed, the cloud will be propagated upward in proportion.

Hence the stratus most usually makes its appearance in the evening succeeding a clear warm day, and in that quiescent state of the atmosphere which attends a succession of them. Hence also the frequency of it during the penetration of the autumnal rains into the earth; while in spring, when the latter is *acquiring* temperature together with the atmosphere, it is rarely seen.

Of the Formation of the Cumulus.

When the sun's rays traverse a clear space of atmosphere, it is well known that they communicate no sensible increase of temperature thereto. It is by the contact, and what may be termed the *radiation*, of opake substances exposed to the light, that caloric is thrown into the atmosphere.

This effect is first produced on the air adjacent to the earth's surface, and proceeds upward, more or less rapidly, according to the season and other attendant circumstances. In the morning, therefore, evaporation usually prevails again; and the vapour which continues to be thrown into air, now increasing in temperature, is no longer condensed: on the contrary, it exerts its elastic force on that which the nocturnal temperature had not been able to decompose, and which consequently remained universally diffused. The latter, in rising *through the atmosphere* to give place to the supply from below, must necessarily change its climate, quit the lower air of equal temperature, and arrive among more elevated and colder air, the pressure from above still continuing unabated. The consequence is a partial decomposition, extending through the portion thus thrown up, and, in short, a recommencement in the superior region, of the same process which in the vicinity of the earth furnished the dew of the night. In this case, however, the particles

* A plentiful dew may often be found on the grass after a stratus.

of water cannot arrive at the earth, as they are necessarily evaporated again in their descent.

It appears that this second evaporation takes place precisely at that elevation where the temperature derived from the action of the sun's rays upon the earth, and decreasing upward, becomes just sufficient to counterbalance the pressure of the superior vapour.

Here is formed a sort of boundary between the region of cloud and the region of permanent vapour, which for the present purpose, and until we are furnished with a nomenclature for the whole science of meteorology, may be denominated the evaporating plane, or, more simply, the vapour plane *.

Immediately above the vapour plane, then, the formation of the cumulus commences (as soon as a sufficient quantity of vapour has been thrown up) by the mixture of descending minute drops of water with vapour newly formed, and just diffusing itself, as in the case of the stratus before described.

A continuance of this process might be expected to produce a uniform sheet of cloud, in short a stratus, only differing in situation from the true one. Instead of which we see the first-formed small masses become so many centres, towards which all the water afterwards precipitated appears to be attracted from the space surrounding them ; and this attraction becomes more powerful as the cloud increases in magnitude, insomuch that the small clouds previously formed disappear when a large one approaches them in its increase, and seem to vanish instead of joining it. This is probably owing to the small drops composing them having passed in a loose manner, and successively, into the large one, and consequently so as not to be traced in their passage.

Are the distinct masses into which the drops form themselves, in this case, due to the attraction of aggregation alone, or is the operation of any other cause to be admitted?

A rigid mathematician would perhaps answer the latter clause in the negative ; and with such a conclusion we should have great reason to remain satisfied, as cutting short much of the inquiry that is to follow, were it not that it leaves us quite in the dark, both as to the cause of the variety so readily observable in clouds, and their long suspension, not to insist on several facts contained in the former part of this paper, which would then remain unaccounted for.

* We use the word *plane* here in the same sense in which we apply it to a surface of water. Strictly speaking, it is a portion of a sphere.

 The

The operation of one simple principle would produce an effect at all times *uniform*, and varying only in degree. We should then see no diversity in clouds but in their magnitude, and the same attraction that could bring minute drops of water together through a considerable space of atmosphere in a few minutes, ought not to end there, but to effect their perfect union into larger, and finally into rain.

In admitting the constant operation of electricity, which is sometimes so manifestly accumulated in clouds, upon their forms and arrangement, we shall not much overstep the limits of experimental inquiry, since it has been ascertained by several eminent philosophers, that "clouds, as well as rain, snow, and hail, that fall from them, are almost always electrified *."

An insulated conductor formed of solid matter retains the charge given to it so much the longer, as it is more nearly spherical, and free from points and projecting parts. The particles of water, when charged, appear to make an effort to separate from each other, or, in other words, become mutually repulsive. Moreover, when a small conducting substance is brought within the reach of a large one similarly electrified, the latter, instead of repelling, will throw the small one into an opposite state, and then attract it. From these and other well-known facts in electricity it would not be difficult to demonstrate, that an assemblage of particles of water floating in the atmosphere, and similarly electrified, ought to arrange themselves in a spherical aggregate, into which all the surrounding particles of water should be attracted (within a certain distance) at the same time that the drops composing such aggregate should be absolutely prevented from uniting with each other *during the equilibrium of their electricity*.

To apply this reasoning to the formation of the cumulus, we may, in the first place, admit that the commencement of distinct aggregation, in the descending particles of water, is due to their mutual attraction, by virtue of which small bodies, floating in any medium, tend to coalesce. The masses thus formed, however, often increase more rapidly than could be expected from the effect of simple attraction exercised at great distances; and when the cloud has arrived at a considerable size, its protuberances are seen to form, and successively sink down into the mass, in a manner which forces one to suppose a shower of invisible drops rushing upon it from all parts.

* Cavallo. Complete Treatise on Electricity, vol. i. p. 74.

In unsettled weather the rapid formation of large cumuli has been observed to clear the sky of a considerable hazy whiteness, which on the other hand has been found to ensue upon their *dispersion* *.

On these considerations we are obliged to admit as a co-operating cause of the increase of this cloud, that sort of attraction which large insulated conducting masses exercise, when charged, on the smaller ones which lie within their influence. Instead of a *spherical* aggregate, however, we have only a sort of hemisphere, because that part of the cloud which presents itself towards the earth can receive no addition from beneath, there being no condensed water. On the contrary, the mass must be continually suffering a diminution there by the tendency of the cloud to subside, and of the vapour plane to rise during the increase of the diurnal temperature. It is this evaporation that cuts off all the cumuli visible at one time in the same plane, and it is reasonable to conclude that much of the vapour thus produced is again condensed without quitting the cloud, as its course would naturally be mostly upward. Thus the drops of which a cumulus consists may become larger the longer it is suspended, and the electricity stronger from the comparative diminution of surface.

Such is probably the manner in which this curious structure is raised, while the base is continually escaping from beneath it. That we may not however be accused of building such a castle in the air by attempting further conjecture, we may leave the present modification, after recapitulating some of its circumstances which appear to be accounted for.

The cumulus appears only in the day time, because the direct action of the sun's rays upon the earth can alone put the atmosphere into that state of inequality of temperature which has been described. It evaporates in the evening from the cessation of this inequality, the superior atmosphere having become warmer, the inferior colder: attended with a decrease of the superficial evaporation. It begins to form some hours after sun-rise, because the vapour requires that space of time to become elevated by the gra-

* That clouds are not always evaporated when they disappear, but sometimes dispersed so as to become invisible as distinct aggregates, is a fact pretty well ascertained by observations. This happens sometimes by the approach of other clouds; at others, the evaporation of part of a cumulus is followed by the dispersion of the remainder. The criterion used was the speedy production of transparency in the one case, and of hazy turbidness in the other.

dual accession from below. When a stratus covers the ground at sun-rise, however, we often see it collect into cumuli upon the evaporation of that part of it which is immediately contiguous to the earth: and this effect ought to happen; for the cloud is then insulated, the *vapour plane* is established, and every thing in the same state, except in point of elevation, as in the ordinary mode of production of the cumulus.

Lastly, the cumulus, however dense it becomes, does not afford rain, because it consists of drops *similarly* electrified and repelling each other, and is moreover continually evaporating from the plane of its base. The change of form which comes on before it falls in rain, and which indicates a disturbance of its electrical state, will be noticed hereafter.

It must have been owing entirely to the want of distinctive characters for clouds, and the consequent neglect of observing their changes, that the nature of this modification more especially has not engaged the attention of electricians. The attraction of aggregation operating on solid particles diffused in fluids does indeed produce a great variety of ramifications in the process of crystallization: but these are either uniform in each substance, or have a limited number of changes; and in no instance do we see the same substance separating from the same medium, and, unconfined in its movements, rival the numerous metamorphoses of the cirrus.

The great elevation of these clouds in their ordinary mode of appearance has been ascertained both by geometrical observations* and by viewing them from the summits of the highest mountains, when they appear as if seen from the plain. A more easy and not less convincing proof may be had by noting the time during which they continue to reflect the different coloured rays after sunset, which they do incomparably longer than any others. The same configuration of cirrus has been observed in the same quarter of the sky for two successive days, during which a smart breeze from the opposite quarter prevailed below.

It is therefore probable that this modification collects its water in a comparatively calm region, which is sometimes incumbent on the current next the earth, and almost out of the reach of its *daily* variations in temperature and quantity of vapour; but at other times is interposed between the

* "The small white streaks of condensed vapour which appear on the face of the sky in serene weather I have, by several careful observations, found to be from three to five miles above the earth's surface." —Dalton.

latter

latter and a supervening current from another climate, in which case it may be affected by both currents.

The cumulus has been just now considered as an insulated body, consisting of perfectly moveable parts which accommodate themselves to the state of *retaining* electricity. We shall attempt to explain the nature of the cirrus by comparing it to those imperfect conductors, which being interposed between electrics and conductors, or between the latter in different states, serve to restore by degrees the equilibrium of the electric fluid.

If a lock of hair be properly fixed on the prime conductor and electrified *plus*, the hairs will be separately extended at as great a distance from each other as possible; in which state they will continue some time. The reason appears to be, that the contiguous air is then *minus*; and consequently these two moveable substances put themselves into the state most favourable to a communication which is but slowly effected between bad conductors.

The same appearances will take place if the lock be electrified *minus*, the contiguous air being *plus*; and in each case the hairs will move *from* a body similarly electrified and brought near them, and *towards* one contrariwise electrified, &c. Moreover, if we could insulate such a charged lock in the midst of a perfectly tranquil atmosphere of sufficient extent, in which particles of conducting matter were suspended, the latter would be attracted by it so long as the charge continued; after which they would be at large as before.

Dry air being an electric, and moist air but an indifferent conductor, it is reasonable to suppose that an immediate communication of electricity between masses of air differently charged can scarcely happen to any great extent, except by the intimate mixture of such masses; an occurrence which may possibly result in some such cases, and occasion strong winds and commotions in the atmosphere. If we consider how frequently, and to what an extent, the electricity of the air is disturbed (as appears from numerous experiments) by evaporation, by the formation and passage of clouds, by elevation or depression of temperature, (by friction upon surfaces of ice?) it seems probable that the particles of water floating in a calm space may be frequently converted into conductors, by which the equilibrium is in part restored after such disturbance.

Viewing the cirrus in this light, it becomes important for those who are well versed in electricity to study its appearances, and compare them with the changes that ensue in the

the atmosphere. A number of observations, made hitherto chiefly in one place, and without system or aid from concurrent ones in other places, have furnished the preceding data (see vol. xvi. p. 100), which may serve as hints for future investigation.

At present we can only conjecture that the local detached cirri which ramify *in all directions* are collecting particles of water from the surrounding space, and at the same time equalizing their own electricity with that of the air or vapour.

That when numerous oblique short tufts appear, they are conducting between the air above and that below them.

That a decided direction of the extremities of pendent or erected cirri from the mass they join towards any quarter, is occasioned by the different electricity of a current of air which is pressing upon the space they are contained in from thence. This is the most important point to attend to, as these *tails* sometimes veer half round the compass in the course of a few hours; and many observations have confirmed the fact that they point *towards the coming wind*, and are larger and lower as this is about to be stronger.

Lastly, that cirri in parallel lines stretching from horizon to horizon denote a communication of electricity carried on through these clouds *over* the place of observation; the two predisposing masses of atmosphere being very distant, and the intermediate lower atmosphere not in a state to conduct it. It is at least a circumstance well deserving inquiry, by what means the clouds in stormy seasons become arranged in these elevated parallel bars, which must be at least 60 miles long, and are probably much more, considering their elevation, and that both extremities are often invisible.

Of the Nature of the intermediate Modifications.

The conversion of the cirrus into the cirro-cumulus is a phænomenon which at some seasons may be daily traced, and serves to confirm the opinion that there exists somewhat of the same difference between the cumulus and the cirrus, as between a *charged* and a *transmitting* or an influenced conductor among solid bodies. On this supposition, the orbicular arrangement of the particles ought to take place as soon as the mass has ceased to conduct from particle to particle, or to be so acted on by a contiguous conductor as to have a *plus* and *minus* state within itself at the same time: and as this sort of communication in a cloud may be as slow as in other imperfect conductors, the equilibrium among the particles may be restored at one extremity

mity some time before the other has ceased to transmit; whence a visible progress of the change which may be traced in a cirrus of sufficient length.

That an extensive horizontal cirrus should become divided across its ramifications, and that these divided parts should assume more or less of a round form, is also consistent with the idea of a change of this sort*. It is not so easy to give a reason why these small orbicular masses should remain in close arrangement, or even in contact, for several hours, forming a system of small clouds which yet do not interfere with each other or run together into one, but remain as it were in readiness to reform the cirrus, which sometimes happens very suddenly, though they more frequently evaporate by degrees.

The same remark must be applied to the curious and as it were capricious divisions and subdivisions, both longitudinal and transverse, which happen in the cirro-stratus when this cloud is verging towards the cirro-cumulus. In general, nevertheless, its appearance is sufficiently distinct from that of the cirrus and cirro-cumulus. The cirrus by its great extent in proportion to its mass, its distinct lines and angular flexures in all directions, and the cirro-cumulus by the roundness and softness of its forms, indicates an essential difference in the state of the containing atmosphere. The cirro-stratus appears to be always in a subsiding state, slowly diminishing by evaporation or dispersion, and at the same time more feebly acted upon by electricity than the preceding modifications. Indeed, the lower atmosphere is usually pretty much charged with dew or haze at the time of its appearance, and therefore in a state to conduct it to the earth.

Of the Nature of the Compound Modifications, and of the Resolution of Clouds into Rain, &c.

From the theory of evaporation it appears that no permanent cloud can be formed in the atmosphere, however low the temperature, without a sufficient pressure from vapour previously diffused. Hence, although in cold weather the breath and perspiration of animals, as also water at a certain excess of temperature, occasion a visible cloud, and,

* A quickly evaporating cumulus sometimes leaves a regular cirrus behind, formed out of the remnant of the cloud which in the intermediate state, and just when it begins to show the sky through it, exactly represents the pores and fibre of sponge. This may be attributed to the quantity of electricity passing into or from the cloud at that time.

 in

in fact, from the same cause as heretofore stated, (the water first condensed being followed by undiffused vapour;) yet this cloud speedily evaporates again at all times, except when precipitation is actually going on at large in the atmosphere next the ground; when it is only *dispersed* therein. By comparing the different effects of a clear frosty air, and of a misty though much warmer one, on the perspiration and breath of horses warmed by labour, we may be assisted in reasoning on the great case of evaporation, which, in some sense, is the *perspiration* of the earth.

The most powerful predisposing cause of evaporation appears to be a superior current in the atmosphere coming from a region where the low temperature of the surface, or its dry state, occasions a comparative deficiency of vapour. Hence, after heavy rain in winter, we see the sudden evaporation, first of the remaining clouds, then of the water on the ground, followed by a brisk northerly wind and sharp frost.

The very snow which had fallen on its arrival is sometimes totally evaporated again during the prevalence of such a wind. On the contrary, the first appearance of clouds forming in cold weather gives us to expect a speedy remission of the frost, although the cause is not generally known to be a change to a southerly direction already begun in the superior atmosphere, which consequently brings on an excess of vapour.

This excess of vapour, coming with a superior current, may be placed next to depression of temperature among the causes of rain. The simultaneous decomposition of the higher *imported* vapour, and of that which is formed on the spot, or already diffused in the inferior current, would necessarily produce two orders of cloud, differing more or less in electricity as well as in other respects. To the slow action of these upon each other, while evaporation continues below, may be attributed the singular union which constitutes the cumulo-stratus. It is too early in the present state of the subject to attempt to define the precise mode of this action, or to say by what change of state a cumulus already formed is thrown into this modification. That the latter phænomenon is an electrical effect, no one who has had opportunity to see its rapid progress during the approach of a thunder storm can reasonably doubt.

To assert that rain is in almost every instance the result of the electrical action of clouds upon each other, might appear to many too speculative, were we even to bring the authority of Kirwan for it, which is decidedly in favour of this

this idea: yet it is in a great measure confirmed by observations made in various ways upon the electrical state of clouds and of rain, not to insist on the probability that a thunder storm is only a more sudden and sensible display of those energies which, according to the order observable in the creation in other respects, ought to be incessantly and silently operating for more general and beneficial purposes.

In the formation of the nimbus, two circumstances claim particular attention: the spreading of the superior masses of cloud in all directions until they become, like the stratus, one uniform sheet; and the rapid motion and visible decrease of the cumulus when brought under the latter. The cirri, also, which so frequently stretch from the superior sheet upward, and resemble erected hairs, carry so much the appearance of temporary conductors for the electricity, extricated by the sudden union of its minute drops into the vastly larger ones which form the rain, that one is in a manner compelled, when viewing this phænomenon, to indulge a little in electrical speculations. By one experiment of Cavallo's, with a kite carrying three hundred and sixty feet of conducting string, in an interval between two showers, and kept up during rain, it seems that the superior clouds possessed a positive electricity before the rain, which on the arrival of a large cumulus gave place to a very strong negative, continuing as long as it was over the kite. We are not, however, warranted from this to conclude the cumulus which brings on rain always negative, as the same effect might ensue from a positive cumulus uniting with a negative stratus. Yet the general negative state of the lower atmosphere during rain, and the positive indications commonly given by the true stratus, render this the more probable opinion. It is not, however, absolutely necessary to determine the several states of the clouds which appear during rain, since there is sufficient evidence in favour of the conclusion, that clouds formed in different parts of the atmosphere operate on each other, when brought near enough, so as to occasion their partial or entire destruction; an effect which can only be attributed to their possessing beforehand, or acquiring at the moment, the opposite electricities.

It may be objected that this explanation is better suited to the case of a shower than to that of continued rain, for which it does not seem sufficient. If it should appear, nevertheless, that the supply of each kind of cloud is by any means kept up in proportion to the consumption, the objection

objection will be answered. Now, it is a well-known fact, that evaporation from the surface of the earth and waters often returns and continues during rain, and consequently affords the lower clouds, while the upper are recruited from the quantity of vapour brought by the superior current, and continually subsiding in the form of dew; as is evident both from the turbidness of the atmosphere in rainy seasons, and the plentiful deposition of dew in the nocturnal intervals of rain. Neither is it pretended that electricity is any further concerned in the production of rain than as a secondary agent, which modifies the effect of the two grand predisposing causes—a falling temperature and the influx of vapour.

The theory of rain, however, was not intended to be discussed in the present essay, which has already been extended to the usual limits. We may therefore conclude with requesting, that those who possess the means, and have acquired the habit of experimental observation, will take suitable opportunities to submit to this test the preceding conjectures on the nature of several clouds. These might have been extended further, but that the author was unwilling to go beyond the line which the experiments of several eminent philosophers, and a few of his own, seemed to point out as safe in the present state of the subject.

The author thinks he cannot more properly terminate this essay than in publicly acknowledging the obligation he lies under to his friend Silvanus Bevan jun. for his frequent and zealous aid in his observations and drawings.

FINIS.

Taylor, Printer, Black-Horse-Court, Fleet-street.

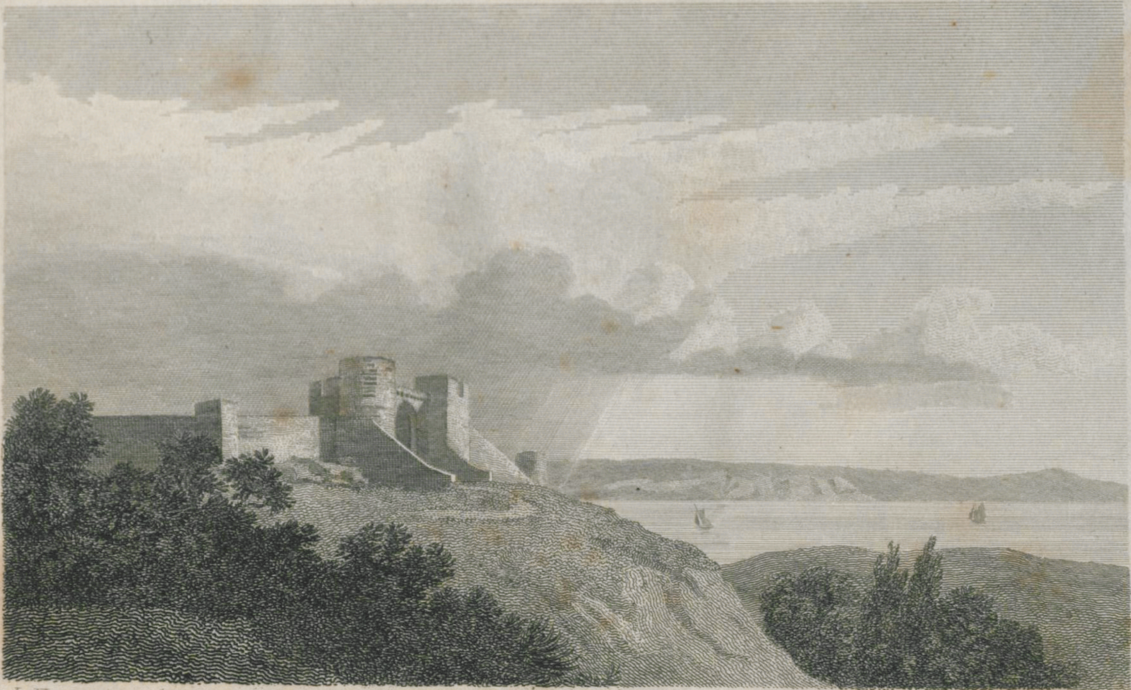
Lewis, sculp

Reduce to 4" width

Lewis sculp

Reduce 6" in width

Philo. Mag. Pl. VIII Vol. XVI.



L. Howard del. *Lowry direxit*

Same day