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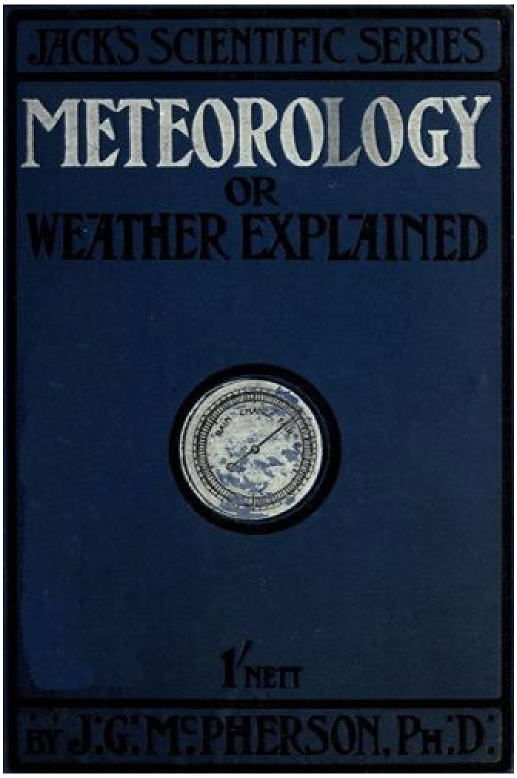

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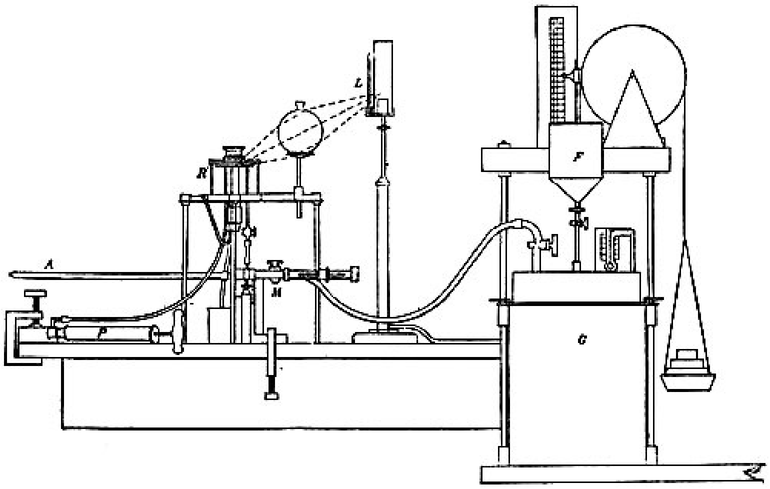

DR. AITKEN'S DUST-COUNTER.

R is the test-receiver; P the air-pump; M the measuring apparatus; L the illuminating arrangements; G the Gasometer; A the pipe through which the tested air is drawn.

METEOROLOGY; OR, WEATHER EXPLAINED.

BY

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PREFATORY NOTE

I am very much indebted to Dr. John Aitken, F.R.S., for his great kindness in carefully revising the proof sheets, and giving me most valuable suggestions. This is a sufficient guarantee that accuracy has not been sacrificed to popular explanation.

J. G. M'P.

Ruthven Manse,
June 10, 1905.

METEOROLOGY

[Pg 9]

CHAPTER I

INTRODUCTION

Though by familiarity made commonplace, the "weather" is one of the most important topics of conversation, and has constant bearings upon the work and prospects of business-men and men of pleasure. The state of the weather is the password when people meet on the country road: we could not do without the humble talisman. "A fine day" comes spontaneously to the lips, whatever be the state of the atmosphere, unless it is peculiarly and strikingly repulsive; then "A bitter day" would take the place of the expression. Yet I have heard "*Terrible* guid wither" as often as "*Terrible* bad day" among country people.

Scarcely a friendly letter is penned without a reference to the weather, as to what has been, is, or may be. It is a new stimulus to a lagging conversation at any dinner-table. All are so dependent on the weather, especially those getting up in years or of delicate health.

I remember, when at Strathpeffer, the great health-resort in the North of Scotland, in 1885, an anxious invalid at "The Pump" asking a weather-beaten, rheumatic old gamekeeper what [Pg 10] sort of a day it was to be, considering that it had been wet for some time. The keeper crippled to the barometer outside the doorway, and returned with the matter-of-fact answer: "She's faurer doon ta tay nur she wass up yestreen." The barometer had evidently fallen during the night. "And what are we to expect?" sadly inquired the invalid. "It'll pe aither ferry wat, or mohr rain"—a poor consolation!

Most men who are bent on business or pleasure, and all dwellers in the country who have the instruments, make a first call at the barometer in the lobby, or the aneroid in the breakfast-parlour, to "see what she says." A good rise of the black needle (that is, to the right) above the yellow needle is a source of rejoicing, as it will likely be clear, dry, and hard weather. A slight fall (that is, to the left) causes anxiety as to coming rain, and a big depression forebodes much rain or a violent storm of wind. In either case of "fall," the shutters come over the eyes of the observer. Next, even before breakfast, a move is made to the self-registering thermometer (set the night before) on a stone, a couple of feet above the grass. A good reading, above the freezing-point in winter and much above it in summer, indicates the absence of killing rimes, that are generally followed by rain. A very low register accounts for the feeling of cold during the night, though the fires were not out; and predicts precarious weather. Ordinarily careful observers—as I, who have been in one place for more than thirty years—can, with the morning indications of these two instruments, [Pg 11] come pretty sure of their prognostics of the day's weather. Of course, the morning newspaper is carefully scanned as to the weather-forecasts from the London Meteorological Office—direction of wind; warm, mild, or cold; rain or fair, and so on—and in general these indications are wonderfully accurate for twenty-four hours; though the "three days'" prognostics seem to stretch a point. We are hardly up to that yet.

The lower animals are very sensitive as to the state of approaching extremes of weather. "Thae sea beass," referring to sea-gulls over the inland leas during ploughing, are ordinary indicators of stormy weather. Wind is sure to follow violent wheelings of crows. "Beware of rain" when the sheep are restive, rubbing themselves on tree stumps. But all are familiar with Jenner's prognostics of rain.

Science has come to the aid of ordinary weather-lore during the last twenty years, by leaps and bounds. Time-honoured notions and revered fictions, around which the hallowed associations of our early training fondly and firmly cling, must now yield to the exact handling of modern science; and with reluctance we have to part with them. Yet there is in all a fascination to account for certain ordinary phenomena. "The man in the street," as well as the strong reading man, wishes to know the "why" and the "how" of weather-forecasting. They are anxious to have weather-phenomena explained in a plain, interesting, but accurate way.

The freshness of the marvellous results has an irresistible charm for the open mind, keen for useful information. The discoveries often seem so simple that one wonders why they were not made before. [Pg 12]

Until about twenty years ago, Meteorology was comparatively far back as a science; and in one important branch of it, no one has done more to put weather-lore on a scientific basis than Dr. John Aitken, F.R.S., who has very kindly given me his full permission to popularise what I like of his numerous and very valuable scientific papers in the *Transactions of the Royal Society of Edinburgh*. This I have done my best to carry out in the following pages. "The way of putting it" is my only claim.

Many scientific men are decoyed on in the search for truth with a spell unknown to others: the anticipation of the results sometimes amounts to a passion. Many wrong tracks do they take, yet they start afresh, just as the detective has to take several courses before he hits upon the correct scent. When they succeed, they experience a pleasure which is indescribable; to them fame is more than a mere "fancied life in others' breath."

Dr. Aitken's continued experiments, often of rare ingenuity and brilliancy, show that no truth is altogether barren; and even that which looks at first sight the very simplest and most trivial may turn out fruitful in precious results. Small things must not be overlooked, for great discoveries are sometimes at a man's very door. Dr. Aitken has shown us this in many of his discoveries which have revolutionised a branch of meteorology. Prudence, patience, observing power, and perseverance in scientific research will do much to bring about unexpected results, and not more so in any science than in accounting for weather-lore on a rational basis, which it is in the power of all my readers to further. [Pg 13]

"The old order changeth, giving place to new." With kaleidoscopic variety Nature's face changes to the touch of the anxious and reverent observer. And some of these curious weather-views will be disclosed in these pages, so as, in a brief but readable way, to explain the weather, and lay a safe basis for probable forecastings, which will be of great benefit to the man of business as well as the man of pleasure.

> "Felix, qui potuit rerum cognoscere causas."
> —VIRGIL.

CHAPTER II

THE FORMATION OF DEW

The writer of the Book of Job gravely asked the important question, "Who hath begotten the drops of dew?" We repeat the question in another form, "Whence comes the real dew? Does it fall from the heavens above, or does it rise from the earth beneath?"

Until about the beginning of the seventeenth century, scientific men held the opinion of ordinary observers that dew fell from the atmosphere. But there was then a reaction from this theory, for Nardius defined it as an exhalation from the earth. Of course, it was well known that dew was formed by the precipitation of the vapour of the air upon a colder body. You can see that any day for yourself by bringing a glass of very cold water into a warm room; the outer surface of the glass is dimmed at once by the moisture from the air. M. Picket was puzzled when he saw that a thermometer, suspended five feet above the ground, marked a lower temperature on clear nights than one suspended at the height of seventy-five feet; because it was always supposed that the cold of evening descended from above. Again he was puzzled when he observed that a buried thermometer read higher than one on the surface of the ground. Until recently the greatest authority on dew was Dr. Wells, who carefully converged all the rays of scientific light upon the subject. He came to the conclusion that dew was condensed out of the air. [Pg 14]

But the discovery of the true theory was left to Dr. John Aitken, F.R.S., a distinguished observer and a practical physicist, of whom Scotland has reason to be proud. About twenty years ago he made the discovery, and it is now accepted by all scientific men on the Continent as well as in Great Britain. What first caused him to doubt Dr. Wells' theory, so universally accepted, that dew is formed of vapour existing at the time in the air, and to suppose that dew is mostly formed of vapour rising from the ground, was the result of some observations made in summer on the temperature of the soil at a small depth under the surface, and of the air over it, after sunset and at night. He was struck with the unvarying fact that the ground, a little below the surface, was warmer than the air over it. By placing a thermometer among stems below the surface, he found that it registered 18° Fahr. higher than one on the surface. So long, then, as the surface of the ground is above the dew-point (*i.e.* the temperature when dew begins to be formed), vapour must rise from the ground; this [Pg 15] moist air will mingle with the air which it enters, and its moisture will be condensed and form dew, whenever it comes in contact with a surface cooled below the dew-point.

You can verify this by simple experiments. Take a thin, shallow, metal tray, painted black, and place it over the ground after sunset. On dewy nights the *inside* of the tray is dewed, and the grass inside is wetter than that outside. On some nights there is no dew outside the tray, and on all nights the deposit on the inner is heavier than that on the outside. If wool is used in the experiments, we are reminded of one of the forms of the dewing of Gideon's fleece—the fleece was bedewed when all outside was dry.

You therefore naturally and rightly come to the conclusion that far more vapour rises out of the ground during the night than condenses as dew on the grass, and that this vapour from the ground is trapped by the tray. Much of the rising vapour is generally carried away by the passing wind, however gentle; hence we have it condensed as dew on the roofs of houses, and other places, where you would think that it had fallen from above. The vapour rising under the tray is not diluted by the mixture with the drier air which is occasioned by the passing wind; therefore, though only cooled to the same extent as the air outside, it yields a heavier deposit of dew.

If you place the tray on bare ground, you will find on a dewy night that the inside of the tray is quite wet. On a dewy night you will observe that the under part of the gravel of the road is dripping wet when the top is dry. You will find, too, that around pieces of iron and old implements in the field, there is a very marked increase of grass, owing to the deposit of moisture on these articles—moisture which has been condensed by the cold metal from the vapour-charged air, which has risen from the ground on dewy nights.

But all doubt upon this important matter is removed by a most successful experiment with a fine balance, which weighs to a quarter of a grain. If vapour rises from the ground for any length of time during dewy nights, the soil which gives off the vapour must lose weight. To test this, cut from the lawn a piece of turf six inches square and a quarter of an inch thick. Place this in a shallow pan, and carefully note the weight of both turf and pan with the sensitive balance. To prevent loss by evaporation, the weighing should be done in an open shed. Then place the pan and turf at sunset in the open cut. Five hours afterwards remove and weigh them, and it will be found that the turf has lost a part of its weight. The vapour which rose from the ground during the formation of the dew accounts for the difference of weight. This weighing-test will also succeed on bare ground.

When dealing with hoar-frost, which is just frozen dew, we shall find visible evidence of the rising of dew from the ground.

You know the beautiful song, "Annie Laurie," which begins with—

"Maxwelton's braes are bonnie,
Where early fa's the dew"—

well, you can no longer say that the dew "falls," for it rises from the ground. The song, however, will be sung as sweetly as ever; for the spirit of true poetry defies the cold letter of science.

CHAPTER III

TRUE AND FALSE DEW

Ever since men could observe and think, they have admired the diamond globules sparkling in the rising sun. These "dew-drops" were considered to be shed from the bosom of the morn into the blooming flowers and rich grass-leaves. Ballantine's beautiful song of Providential care tells us that "Ilka blade o' grass keps it's ain drap o' dew."

But, alas! we have to bid "good-bye" to the appellation "dew-drop." What was popularly and poetically called dew *is not dew at all*. Then what is it?

On what we have been accustomed to call a "dewy" night, after the brilliant summer sun has set, and the stars begin to peep out of the almost cloudless sky, let us take a look at the produce of our vegetable garden. On the broccoli are found glistening drops; but on the peas, growing next them, we find nothing.

A closer examination shows us that the moisture on the plants is not arranged as would be expected from the ordinary laws of radiation and condensation. There is no generally filmy appearance over the leaves; the moisture is collected in little drops placed at short distances apart, along the edges of the leaves all round.

Now place a lighted lantern below one of the blades of the broccoli, and a revelation will be made. The brilliant diamond-drops that fringe the edge of the blade are all placed at the points where the nearly colourless veins of the blade come to the outer edge. The drops are not dew at all, but the exudation of the healthy plant, which has been conveyed up these veins by strong root-pressure.

The fact is that the root acts as a kind of force-pump, and keeps up a constant pressure inside the tissues of the plant. One of the simplest experiments suggested by Dr. Aitken is to lift a single grass-plant, with a clod of moist earth attached to it, and place it on a plate with an inverted tumbler over it. In about an hour, drops will begin to exude, and the tip of nearly every blade will be found to be studded with a diamond-like drop.

Next substitute water-pressure. Remove a blade of broccoli and connect it by means of an india-rubber tube with a head of water of about forty inches. Place a glass receiver over it, so as to check evaporation, and leave it for an hour. The plant will be found to have excreted water freely, some parts of the leaves being quite wet, while drops are collected at the places where they appeared at night.

If the water pressed into the leaf is coloured with aniline blue, the drops when they first appear are colourless; but before they grow to any size, the blue appears, showing that little water was held in the veins. The whole leaf soon gets coloured of a fine deep blue-green, like that seen when vegetation is rank; this shows that the injected liquid has penetrated through the whole leaf. [Pg 19]

Again, the surfaces of the leaves of these drop-exuding plants never seem to be wetted by the water. It is because of the rejection of water by the leaf-surface that the exuded moisture from the veins remains as a drop.

These observations and experiments establish the fact that the drops which first make their appearance on grass on dewy nights are not dew-drops at all, but the exuded watery juices of the plants.

If now we look at dead leaves we shall find a difference of formation of the moisture on a dewy night: the moisture is spread equally over, where equally exposed. The moisture exuded by the healthy grass is always found at a *point* situated near the tip of the blade, forming a drop of some size; but the true dew collects later on *evenly* all over the blade. The false dew forms a large glistening diamond-drop, whereas the true dew coats the blade with a fine pearly lustre. Brilliant globules are produced by the vital action of the plant, especially beautiful when the deep-red setting sun makes them glisten, all a-tremble, with gold light; while an infinite number of minute but shining opal-like particles of moisture bedecks the blade-surfaces, in the form of the gentle dew—

> "Like that which kept the heart of Eden green
> Before the useful trouble of the rain."

CHAPTER IV [Pg 20]

HOAR-FROST

All in this country are familiar with the beauty of hoar-frost. The children are delighted with the funny figures on the glass of the bedroom window on a cold winter morning. Frost is a wonderful artist; during the night he has been dipping his brush into something like diluted schist, and laying it gracefully on the smooth panes.

And, as you walk over the meadows, you observe the thin white films of ice on the green pasture; and the clear, slender blades seem like crystal spears, or the "lashes of light that trim the stars."

You all know what hoar-frost is, though most in the country give it the expressive name of "rime." But you are not all aware of how it is formed. Hoar-frost is just frozen dew. In a learned paper, written in 1784, Professor Wilson of Glasgow made this significant remark: "This is a subject which, besides its entire novelty, seems, upon other accounts, to have a claim to some attention." He observed, in that exceptionally cold winter, that, when sheets of paper and plates of metal were laid out, all began to attract hoar-frost as soon as they had time to cool down to the temperature of the air. He was struck with the fact that, while the thermometer indicated 36 degrees of frost a few feet above the ground and 44 degrees of frost at the surface of the snow, there were only 8 degrees of frost at a point 3 inches below [Pg 21] the surface of the snow. If he had only thought of placing the thermometer on the grass, under the snow, he would have found it to register the freezing-point only. And had he inserted the instrument below the ground, he would have found it registering a still higher temperature. That fact would have suggested to him the formation of hoar-frost; that the water-vapour from the warm soil was trapped by a cold stratum of air and frozen when in the form of dew.

One of the most interesting experiments, without apparatus, which you can make is in connection with the formation of hoar-frost, when there is no snow on the ground, in very cold weather. If it has been a bright, clear, sunny day in January, the effect can be better observed. Look over the garden, grass, and walks on the morning after the intense cold of the night; big plane-tree leaves may be found scattered over the place. You see little or no hoar-frost on the *upper* surface of the leaves. But turn up the surface next the earth, or the road, or the grass, and what do you see? You have only to handle the leaf in this way to be brightly astonished. A thick white coating of hoar-frost, as thick as a layer of snow, is on the *under* surface. If a number of leaves have been overlapping each other, there will be no coating of hoar-frost under the top leaves; but when you reach the lowest layer, next the bare ground, you will find the hoar-frost on the under surface of the leaves. Now that is positive proof that the hoar-frost has not fallen from the air, but has risen from the earth.

The sun’s heat on the previous day warmed the earth. This heat the earth retained till evening. As the air chilled, the water-vapour from the warmer earth rose from its surface, and was arrested by the cold surface of the leaves. So cold was that surface that it froze the water-vapour when rising from the earth, and formed hoar-frost in very large quantities. When this happens later on in the season, one may be almost sure of having rain in the forenoon. [Pg 22]

As hoar-frost is just frozen dew, I can even more surely convince you of the formation of hoar-frost as rising from the ground by observations made by me at my manse in Strathmore, in June 1892. I mention this particularly because then was the most favourable testing-time that has *ever* occurred during meteorological observations. June 9th was the warmest June day (with one exception) for twenty years. The thermometer reached 83° Fahr. in the shade. Next day was the coldest June day (with one exception) for twenty years, when the thermometer was as low as 51° in the shade. But during the night my thermometer on the grass registered 32°—the freezing point. On the evening of the sultry day I examined the soil at 10 o’clock. It was damp, and the grass round it was filmy moist. The leaves of the trees were crackling dry, and all above was void of moisture. The air became gradually chilly; and as gradually the moisture rose in height on the shrubs and lower branches of small trees. The moon shone bright, and the stars showed their clear, chilly eyes. The soil soon became quite wet, the low grass was dripping with moisture, and the longer grass was becoming dewed. This gave the best natural evidence of the rising of the dew that I ever witnessed. But everything was favourable for the observation—the cold air incumbent on the rising, warm, moist vapour from the soil fixing the dew-point, when the projecting blades seized the moisture greedily and formed dew. Had the temperature been a little below the freezing-point, hoar-frost would have been beautifully formed. [Pg 23]

CHAPTER V

FOG

To many nothing is more troublesome than a dense fog in a large town. It paralyses traffic, it is dangerous to pedestrians, it encourages theft, it chokes the asthmatic, and chills the weak-lunged.

In the country it is disagreeable enough; but never so intensely raw and dense as in the city. On the sea, too, the fog is disagreeable and fraught with danger. The fog-horn is heard, in its deep, sombre note, from the lighthouse tower, when the strong artificial light is almost useless.

But a peculiar sense of stagnation possesses the dweller of the large town, when enveloped in a dense fog. Sometimes during the day, through a thinner portion, the sun will be dimly seen in copper hue, like the moon under an eclipse. The smoke-impregnated mass assumes a peculiar “pea-soup” colour.

Now, what is this fog? How is it formed? It has been ascertained that fogs are dependent upon *dust* for their formation. Without dust there could be no fogs, there would be only dew on the grass and road. Instead of the dust-impregnated air that irritates the housekeeper, there would be the constant dripping of moisture on the walls, which would annoy her more. [Pg 24]

Ocular demonstration can testify to this. If two closed glass receivers be placed beside each other, the one containing ordinary air, and the other filtered air (*i.e.* air deprived of its dust by being driven through cotton wool), and if jets of steam be successively introduced into these, a strange effect is noticed. In the vessel containing common air the steam will be seen rising in a dense cloud; then a beautiful white foggy cloud will be formed, so dense that it cannot be seen through. But in the vessel containing the filtered air, the steam is not seen at all; there is not the slightest appearance of cloudiness. In the one case, where there was the ordinary atmospheric dust, fog at once appeared; in the other case, where there was no dust in suspension, the air remained clear and destitute of fog. Invisible dust, then, is necessary in the air for the formation of fogs.

The reason of this is that a free-surface must exist for the condensation of the vapour-particles. The fine particles of dust in the air act as free-surfaces, on which the fog is formed. Where there is abundance of dust in the air and little water-vapour present, there is an over-proportion of dust-particles; and the fog-particles are, in consequence, closely packed, but light in form and small in size, and take the lighter appearance of fog. Accordingly, if the dust is increased in the air, there is a proportionate increase of fog. Every [Pg 25] fog-particle, then, has embosomed in it an invisible dust-particle.

But whence comes the dust? From many sources. It is organic and inorganic. So very fine is the inorganic dust in the atmosphere that, if the two-thousandth part of a grain of fine iron be heated, and the dust be driven off and carried into a glass receiver of filtered air, the introduction of a jet of steam into that receiver would at once occasion an appreciable cloudiness.

This is why fogs are so prevalent in large towns. Next the minute brine-particles, driven into the air as fog forms above the ocean surface, are the burnt sulphur-particles emanating from the chimneys in towns. The brilliant flame, as well as the smoky flame, is a fog-producer. If gas is burnt in filtered air, intense fog is produced when water-vapour is introduced. Products of combustion from a clear fire and from a smoky one produce equal fogging. The fogs that densely fill our large towns are generally less bearable than those that veil the hills and overhang the rivers.

It is the sulphur, however, from the consumed coals, which is the active producer of the fogs of a large town. The burnt sulphur condenses in the air to very fine particles, and the quantity of burnt sulphur is enormous. No less than seven and a half millions of tons of coals are consumed in London. Now, the average amount of sulphur in English coal is one and a quarter per cent. That would give no less than 93,750 tons of sulphur burned every year in London fires. Now, if we reckon that on an average twice the quantity of coals is consumed there on a winter day that is consumed on a summer day, no less than 347 tons of the [Pg 26] products of combustion (in extremely fine particles) are driven into the superincumbent air of London every winter day. This is an enormous quantity, quite sufficient to account for the density of the fogs in that city.

CHAPTER VI

THE NUMBERING OF THE DUST

If the shutters be all but closed in a room, when the sun is shining in, myriads of floating particles can be seen glistening in the stream of light. Their number seems inexhaustible. According to Milton, the follies of life are—

> "Thick and numberless,
> As the gay motes that people the sunbeams."

Can these, then, be counted? Yes, Dr. Aitken has numbered the dust of the air. I shall never forget my rapt astonishment the day I first numbered the dust in the lecture-room of the Royal Society of Edinburgh, with his instrument and under his direction.

This wonderfully ingenious instrument was devised on this principle, that every fog-particle has entombed in it an invisible dust-particle. A definite small quantity of common air is diluted with a fixed large quantity of dustless air (*i.e.* air that has been filtered through cotton-wool). The mixture is allowed to be saturated with water-vapour. Then the few particles of dust seize the moisture, become visible in fine drops, fall on a divided plate, and [Pg 27] are there counted by means of a magnifying glass. That is the secret!

I shall now give you a general idea of the apparatus. Into a common glass flask of carafe shape, and flat-bottomed, of 30 cubic inches capacity, are passed two small tubes, at the end of one of which is attached a small square silver table, 1 inch in length. A little water having been inserted, the flask is inverted, and the table is placed exactly 1 inch from the inverted bottom, so that the contents of air right above the table are 1 cubic inch. This observing table is divided into 100 equal squares, and is highly polished, with the burnishing all in one direction, so that during the observations it appears dark, when the fine mist-particles glisten opal-like with the reflected light in order that they may be more easily counted. The tube to which the silver table is attached is connected with two stop-cocks, one of which can admit a small measured portion of the air to be examined. The other tube in the flask is connected with an air-pump of 10 cubic inches capacity. Over the flask is placed a covering, coloured black in the inside. In the top of this cover is inserted a powerful magnifying glass, through which the particles on the silver table can be easily counted. A little to the side of this magnifier is an opening in the cover, through which light is concentrated on the table.

To perform the experiment, the air in the flask is exhausted by the air-pump. The flask is then filled with filtered air. One-tenth of a cubic inch of the air to be examined is then introduced into the flask, and mixed with the 30 cubic inches of dustless air. After one stroke of the air-pump, this mixed air is made to occupy an additional space of 10 cubic inches; and this rarefying of the air so chills it that condensation of the water-vapour takes place on the dust-particles. The observer, looking through the magnifying-glass upon the silver table, sees the mist-particles fall like an opal shower on the table. He counts the number on a single square in two or three places, striking an average in his mind. Suppose the average number upon a single square were five, then on the whole table there would be 500; and these 500 particles of dust are those which floated invisibly in the cubic inch of mixed air right above the table. But, as there are 40 cubic inches of mixed air in the flask and barrel, the number of dust-particles in the whole is 20,000. That is, there are 20,000 dust-particles in the same quantity of common air (one-tenth of a cubic inch) which was introduced for examination. In other words, a cubic inch of the air contained 200,000 dust-particles—nearly a quarter of a million. [Pg 28]

The day I used the instrument we counted 4,000,000 of dust-particles in a cubic inch of the air outside of the room, due to the quantity of smoke from the passing trains. Dr. Aitken has counted in 1 cubic inch of air immediately above a Bunsen flame the fabulous number of 489,000,000 of dust-particles.

A small instrument has been constructed which can bring about results sufficiently accurate for ordinary purposes. It is so constructed that, when the different parts are unscrewed, they fit into a case 4½ inches by 2½ by 1¼ deep—about the size of an ordinary cigar-case.

After knowing this, we are apt to wonder why our lungs do not get clogged up with the enormous number of dust-particles. In ordinary breathing, 30 cubic inches of air pass in and out at every breath, and adults breathe about fifteen times every minute. But the warm lung-surface repels the colder dust-particles, and the continuous evaporation of moisture from the surface of the air-tubes prevents the dust from alighting or clinging to the surface at all. [Pg 29]

CHAPTER VII

DUST AND ATMOSPHERIC PHENOMENA

Dr. Aitken has devoted a vast amount of attention to the enumeration of dust-particles in the air, on the Continent as well as in Scotland, to determine the effects of their variation in number.

On his first visit to Hyères, in 1890, he counted with the instrument 12,000 dust-particles in a cubic inch of the air: whereas in the following year he counted 250,000. He observed, however, that where there was least dust, the air was very clear; whereas with the maximum of dust, there was a very thick haze.

At Mentone, the corresponding number was 13,000, when the wind was blowing from the mountains; but increased to 430,000, when the wind was blowing from the populous town.

On his first visit to the Rigi Kulm, in Switzerland, the air was remarkably clear and brilliant, and the corresponding number never exceeded 33,000; but, on his second visit, he counted no less than 166,000. This was accounted for by a thick haze, which rendered the lower Alps scarcely visible. The upper limit of the haze was well defined; and though the sky was cloudless, the sun looked like a harvest moon, and required no eagle’s eye to keep fixed on it. [Pg 30]

Next day there was a violent thunder-storm. At 6 P.M. the storm commenced, and 60,000 dust-particles to the cubic inch of air were registered; but in the middle of the storm he counted only 13,000. There was a heavy fall of hail at this time, and he accounts for the diminution of dust-particles by the down-rush of purer upper air, which displaced the contaminated lower air.

At the Lake of Lucerne there was an exceptional diminution of the number in the course of an hour, viz. from 171,000 to 28,000 in a cubic inch. On looking about, he found that the direction of the wind had changed, bringing down the purer upper air to the place of observation. The bending downwards of the trees by the strong wind showed that it was coming from the upper air.

Returning to Scotland, he continued his observations at Ben Nevis and at Kingairloch, opposite Appin, Mr. Rankin using the instrument at the top of the mountain. These observations showed in general that on the mountain southerly, south-easterly, and easterly winds were more impregnated with dust-particles, sometimes containing 133,000 per cubic inch. Northerly winds brought pure air. The observations at sea-level showed a certain parallelism to those on the summit of the mountain. With a north-westerly wind the dust-particles reached the low number of 300 per cubic inch, the lowest recorded at any low-level station. [Pg 31]

The general deductions which he made from his numerous observations during these two years are that (1) air coming from inhabited districts is always impure; (2) dust is carried by the wind to enormous distances; (3) dust rises to the tops of mountains during the day; (4) with much dust there is much haze; (5) high humidity causes great thickness of the atmosphere, if accompanied by a great amount of dust, whereas there is no evidence that humidity alone has any effect in producing thickness; (6) and there is generally a high amount of dust with high temperature, and a low amount of dust with low temperature.

CHAPTER VIII

A FOG-COUNTER

Next to the enumeration of the dust-particles in the atmosphere is the marvellous accuracy of counting the number of particles in a fog. The same ingenious inventor has constructed a fog-counter for the purpose; and the number of fog-particles in a cubic inch can be ascertained. This instrument consists of a glass micrometer divided into squares of a known size, and a strong microscope for observing the drops on the stage. The space between the micrometer and the microscope is open, so that the air passes freely over the stage; and the drops that fall on its surface are easily seen. These drops are very small; many of them when spread on the glass are no more than the five-hundredth of an inch in diameter. [Pg 32]

In observing these drops, the attention requires to be confined to a limited area of the stage, as many of the drops rapidly evaporate, some almost as soon as they touch the glass, whilst the large ones remain a few seconds.

In one set of Dr. Aitken’s observations, in February 1891, the fog was so thick that objects beyond a hundred yards were quite invisible. The number of drops falling per second varied greatly from time to time. The greatest number was 323 drops per square inch in one second. The high number never lasted for long, and in the intervals the number fell as low as 32, or to one-tenth.

If we knew the size of these drops, we might be able to calculate the velocity of their fall, and from that obtain the number in a cubic inch.

An ingenious addition is put to the instrument in order to ascertain this directly. It is constructed so as to ascertain the number of particles that fall from a known height. Under a low-power microscope, and concentric with it, is mounted a tube 2 inches long and 1½ inch in diameter, with a bottom and a cover, which are fixed to an axis parallel with the axis of the tube, so that, by turning a handle, these can be slid sideways, closing or opening the tube at both ends when required. In the top is a small opening, corresponding to the lens of the microscope, and in the centre of the bottom is placed the observing-stage illumined by a spot-mirror. The handle is turned, and the ends are open to admit the foggy air. The handle is quickly reversed, and the ends are closed, enabling the observer to count on the stage all the fog-particles in the two inches of air over it. [Pg 33]

The number of dust-particles in the air which become centres of condensation depends on the rate at which the condensation is taking place. The most recent observations show that quick condensation causes a large number of particles to become active, whereas slow condensation causes a small number. After the condensation has ceased, a process of differentiation takes place, the larger particles robbing the smaller ones of their moisture, owing to the vapour-pressure at the surface of the drops of large curvature being less than at the surface of drops of smaller curvature.

By this process the particles in a cloud are reduced in number; the remaining ones, becoming larger, fall quicker. The cloud thus becomes thinner for a time. A strong wind, suddenly arising, will cause the cloud-particles to be rapidly formed: these will be very numerous, but very small—so small that they are just visible with great care under a strong magnifying lens used in the instrument. But in slowly formed clouds the particles are larger, and therefore more easily visible to the naked eye.

Though the particles in a fog are slightly finer, the number is about the same as in a cloud—that is, generally. As clouds vary in density, the number of particles varies. Sometimes in a cloud one cannot see farther than 30 yards; whereas in a few minutes it clears up a little, so [Pg 34] that we can see 100 yards. Of course, the denser the cloud the greater the number of water-particles falling on the calculating-stage of the instrument.

Very heavy falls of cloud-particles seldom last more than a few seconds, the average being about 325 on the square inch per second, the maximum reaching to 1290. This is about four times the number counted in a fog. Yet the particles are so very small that they evaporate instantly when they reach a slight increase of temperature.

CHAPTER IX

FORMATION OF CLOUDS

In our ordinary atmosphere there can be no clouds without dust. A dust-particle is the nucleus that at a certain humidity becomes the centre of condensation of the water-vapour so as to form a cloud-particle; and a collection of these forms a cloud.

This condensation of vapour round a number of dust-particles in visible form gives rise to a vast variety of cloud-shapes. There are two distinct ways in which the formation of clouds generally takes place. Either a layer of air is cooled in a body below the dew-point; or a mass of warm and moist air rises into a mass which is cold and dry. The first forms a cloud, called, from being a layer, *stratus*; the second forms a cloud, called, from its heap appearance, *cumulus*. The first is widely extended and horizontal, averaging 1800 feet in height; the [Pg 35] second is convex or conical, like the head of a sheaf, increasing upward from a level base, averaging from 4500 feet to 6000 feet in height.

There are endless combinations of these two; but at the height of 27,000 feet, where the cloud-particles are frozen, the structure of the cloud is finer, like “mares’ tails,” receiving the name *cirrus*. When the cirrus and cumulus are combined, in well-defined roundish masses, what is familiarly described as a “mackerel sky” is beautifully presented. The dark mass of cloud, called *nimbus*, is the threatening rain-cloud, about 4500 feet in height.

At the International Meteorological Conference at Munich, in 1892, twelve varieties of clouds were classified, but those named above are the principal. In a beautiful sunset one can sometimes notice two or three distances of clouds, the sun shedding its gold light on the full front of one set, and only fringing with vivid light the nearer range.

Although no man has wrought so hard as Dr. Aitken to establish the principle that clouds are mainly due to the existence of dust-particles which attract moisture on certain conditions, yet even twenty years ago he said that it was probable that sunshine might cause the formation of nuclei and allow cloudy condensation to take place where there was no dust.

Under certain conditions the sun gives rise to a great increase in the number of nuclei. Accordingly, he has carefully tested a few of the ordinary constituents and impurities in our atmosphere to see if sunshine acted on them in such a way as to make them probable formers of cloud-particles.

He tested various gases, with more or less success. He found that ordinary air, after being [Pg 36] deprived of its dust-particles and exposed to sunshine, does not show any cloudy condensation on expansion; but, when certain gases are in the dustless air, a very different result is obtained.

He first used ammonia, putting one drop into six cubic inches of water in a flask, and sunning this for one minute; the result was a considerable quantity of condensation, even with such a weak solution. When the flask was exposed for five minutes, the condensation by the action of the sunshine was made more dense.

Hydrogen peroxide was tested in the same way, and it was found to be a powerful generator of nuclei. Curious is it that sulphurous acid is puzzling to the experimentalist for cloud formation. It gives rise to condensation in the dark; but sunshine very conclusively increases the condensation.

Chlorine causes condensation to take place without supersaturation; sulphuretted hydrogen (which one always associates with the smell of rotten eggs) gives dense condensation after being exposed to sunshine.

Though the most of these nuclei, due to the action of sunshine in the gases, remain active for cloudy condensation for a comparatively short space of time—fifteen minutes to half-an-hour—yet the experiments show that it is possible for the cloudy condensation to take place in certain circumstances in the absence of dust. This seems paradoxical in the light of the former beautiful experiments; but, in ordinary circumstances, dust is needed for the [Pg 37] formation of clouds. However, supposing there is any part of the upper air free from dust, it is now found possible, when any of these gases experimented on be present, for the sun to convert them into nuclei of condensation, and permit of clouds being formed in dustless air, miles above the surface of the earth.

In the lower atmosphere there are always plenty of dust-particles to form cloudy condensation, whether the sun shines or not. These are produced by the waste from the millions of meteors that daily fall into the air.

But in the higher atmosphere, clouds can be formed by the action of the sun's rays on certain gases. This is a great boon to us on the earth; for it assures us of clouds being ever existing to defend us from the sun's extra-powerful rays, even when our atmosphere is fairly clear. This is surely of some meteorological importance.

CHAPTER X

DECAY OF CLOUDS

From the earliest ages clouds have attracted the attention of observers. Varied are their forms and colours, yet in our atmosphere there is one law in their formation. Cloud-particles are formed by the condensation of water-vapour on the dust-particles invisibly floating in the atmosphere, up to thousands—and even millions—in the cubic inch of air.

But observers have not directed their attention so much to the decay of clouds—in fact, the [Pg 38]
subject is quite new. And yet how suggestive is the subject!

The process of decay in clouds takes place in various ways. A careful observer may witness the gradual wasting away and dilution into thin air of even great stretches of cloud, when circumstances are favourable. In May 1896 my attention was particularly drawn to this at my manse in Strathmore. In the middle of that exceptionally sultry month, I was arrested by a remarkable transformation scene. It was the hottest May for seventy-two years, and the driest for twenty-five years. The whole parched earth was thirsting for rain. All the morning my eyes were turned to the clouds in the hope that the much-desired shower should fall. Till ten o'clock the sun was not seen, and there was no blue in the sky. Nor was there any haze or fog.

But suddenly the sun shone through a thinner portion of the enveloping clouds, and, to the north, the sky began to open. As if by some magic spell there was, in a quarter of an hour, more blue to be seen than clouds. At the same time, near the horizon, a haze was forming, gradually becoming denser as time wore on. In an hour the whole clouds were gone, and the glorious orb of day dispelled the moisture to its thin-air form.

This was a pointed and rapid illustration of the decay from cloud-form to haze, and then to the pure vapoury sky. It was an instance of the *reverse* process. As the sun cleared through, the temperature in the cloud-land rose and evaporation took place on the surface of the
cloud-particles, until by an untraceable, but still a gradual process through fog, the haze was [Pg 39]
formed. Even then the heat was too great for a definite haze, and the water-vapour returned to the air, leaving the dust-particles in invisible suspension.

But clouds decay in another way. This I will illustrate in the next chapter on "It always rains."

What strikes a close observer is the difference of structure in clouds which are in the process of formation and those which are in the process of decay. In the former the water-particles are much smaller and far more numerous than in the latter. While the particles in clouds in decay are large enough to be seen with the unaided eye, when they fall on a properly lighted measuring table, they are so small in clouds in rapid formation that the particles cannot be seen without the aid of a strong magnifying glass.

Observers have assumed that the whole explanation of the fantastic shapes taken by clouds is founded on the process of formation; but Dr. Aitken has pointed out that ripple-marked clouds, for instance, have been clouds of decay. When what is called a cirro-stratus cloud—mackerel-like against the blue sky—is carefully observed in fine weather, it will be found that it frequently changes the ripple-marked cirrus in the process of decay to vanishing. Where the cloud is thin enough to be broken through by the clear air that is drawn in between the eddies, the ripple markings get nearer and nearer the centre, as the cloud decays. And, at last, when nearly dissolved, these markings are extended quite across the cloud.

Whether, then, we consider the cases of clouds gradually melting away back into their [Pg 40]
original state of blue water-vapour, or the constant fine raining from clouds and re-formation by evaporation, or the transformation of such clouds as the cirro-stratus into the ripple-marked cirrus, we are forced to the conclusion that in clouds there is not always

development, but sometimes degeneration; not always formation, but sometimes decay.

CHAPTER XI

IT ALWAYS RAINS

All are familiar with the answer given by the native of Skye to the irate tourist on that island, who, for the sixth day drenched, asked the question: "Does it always rain here?" "Na!" answered the workman, without at all understanding the joke; "feiles it snaas" (sometimes it snows). Yet, strange to say, the tourist's question has been answered in the affirmative in every place where a cloud is overhead, visible or invisible.

Whenever a cloud is formed, it begins to rain; and the drops shower down in immense numbers, though most minute in size—"the playful fancies of the mighty sky."

No doubt it is only in certain circumstances that these drops are attracted together so as to form large drops, which fall to the earth in genial showers to refresh the thirsty soil, or in a terrible deluge to cause great destruction. But when the temperature and pressure are not [Pg 41] suitable for the formation of what we commonly know as the rain, the fine drops fall into the air under the cloud, where they immediately evaporate from their dust free-surfaces, if the air is dry and warm. This is, in other words, the decay of clouds.

It is a curious fact that objects in a fog may not be wetted, when the number of water-particles is great. It seems that these water-particles all evaporate so quickly that even one's hand or face is not sensible of being wetted. The particles are minutely small; and they may evaporate even before reaching the warm skin, by reason of the heated air over the skin.

There is a peculiarly warm sensation in the centre of a cumulus cloud, especially when it is not dense. A glow of heat seems to radiate from all points. Yet the face and hands are quite dry, and exposed objects are not wetted; but it is really *always raining*. That is a curious discovery.

It is radiant heat that is the cause of the remarkable result. The rays of the sun, which strike the upper part of the cloud, not only heat that surface but also penetrate the cloud and fall on the surface of bodies within, generating heat there. These heated surfaces again radiate heat into the air attached to them. This warm air receives the fine raindrops in the cloud, and dissolves the moisture from the dust-particles before the moisture can reach the surfaces exposed. That a vast amount of radiant heat rushes through a cloud is clearly shown by exposing a thermometer with black bulb *in vacuo*. On some occasions, a thermometer would indicate from 40° to 50° above the temperature of the air, thus proving [Pg 42] the surface to be quite dry.

These observations have been corroborated on Mount Pilatus, near Lucerne—1000 feet higher and more isolated than the Rigi. The summit was quite enveloped in cloud, and, though one might naturally conclude that the air was dense with moisture, yet the wooden seats, walls, and all exposed surfaces were quite dry. Strange to say, however, the thermometers hung up got wet rapidly, and the pins driven into the wooden post to support them rapidly became moist. A thermometer lying on a wooden seat stood at 60°, while one hung up read only 48°. This difference was caused by radiant heat.

It is well known that, when bodies are exposed to radiant heat, they are heated in proportion to their size; the smaller, then, may be moist, when the larger are dry by radiation. The effect of the sun's penetrating heat through the cloud is to heat exposed objects above the temperature of the air; and if the objects are of any size they are considerably heated, and retain their heat more, while at the same time around them is a layer of warm air which is quite sufficient to force the water-vapour to leave the dust-particles in the fine rain.

Hence seats, walls, posts, &c., are quite dry, though they are in the middle of a cloud. They are large enough to throw off the moisture by the retained heat, or by the large amount of surrounding heat; whereas, small bodies, which are not heated to the same degree and cannot therefore retain their heat so easily, have not heat-power sufficient to withstand the moisture, and they become wetted. Hence, by the radiant heat, the large exposed objects [Pg 43] are dry in the cloud; whereas small objects are damp, and, in some cases, dripping with wet.

The fact is, then, that whenever a cloud overhangs, *rain is falling*, though it may not reach the earth on account of the dryness of the stratum of air below the cloud, and the heat of the air over the earth. So that on a summer day, with the gold-fringed, fleecy clouds sailing overhead, it is really raining; but the drops, being very small, evaporate long before reaching the earth. As Ariel sings at the end of "The Tempest" of Shakespeare, "The rain, it raineth every day." It rains, but much of the melting of the clouds is reproduced by a wonderful circularity—the moisture evaporating, seizing other dust-particles, forming cloud-particles, falling again, and so on *ad infinitum*, during the existing circumstances.

CHAPTER XII

HAZE

What is haze? The dictionary says, “a fog.” Well, haze is *not* a fog. In a fog, the dust-particles in the air have been fully clothed with water-vapour; in a haze, the process of condensation has been arrested.

Cloudy condensation is changed to haze by the reduction of its humidity. Dr. Aitken invented a simple apparatus for testing the condensing power of dust, and observing if water-vapour condensed on the deposited dust in unsaturated air.

The dust from the air has first to be collected. This is done by placing a glass plate vertically, and in close contact with one of the panes of glass in the window, by means of a little india-rubber solution. The plate being thus rendered colder than the air in the room, the dust is deposited on it. [Pg 44]

Construct a rectangular box, with a square bottom, 1½ inches a side and ¾ inch deep, and open at the top. Cover the top edge of the box with a thickness of india-rubber. Place the dusty plate—a square glass mirror, 4 inches a side—on the top of the india-rubber, and hold it down by spring catches, so as to make the box water-tight. The box has been provided with two pipes, one for taking in water and the other for taking away the overflow, with the bulb of a thermometer in the centre. Clean the dust carefully off one half of the mirror, so that one half of the glass covering the box is clean and the other half dusty. Pour cold water through the pipe into the box, so as to lower the temperature of the mirror, and carefully observe when condensation begins on the clean part and on the dusty part, taking a note of the difference of temperature. The condensation of the water-vapour will appear on the dust-particles before coming down to the natural dew-point temperature of the clean glass. And the difference between the two temperatures indicates the temperature above the dew-point at which the dust has condensed the water-vapour.

Magnesia dust has small affinity for water-vapour; accordingly, it condenses at almost exactly the same temperature as the glass. But gunpowder has great condensing power. All have noticed that the smoke from exploded gunpowder is far more dense in damp than in dry weather. In the experiment it will be found that the dust from gunpowder smoke begins to show signs of condensing the vapour at a temperature of 9° Fahr. above the dew-point. In the case of sodium dust, the vapour is condensed from the air at a temperature of 30° above the dew-point. [Pg 45]

Dust collected in a smoking-room shows a decidedly greater condensing power than that from the outer air.

We can now understand why the glass in picture frames and other places sometimes appears damp when the air is not saturated. When in winter the windows are not often cleaned, a damp deposit may be frequently seen on the glass. Any one can try the experiment. Clean one half of a dusty pane of glass in cold weather, and the clean part will remain undewed and clear, while the dusty part is damp to the eye and greasy to the touch.

These observations indicate that moisture is deposited on the dust-particles from air, which is not saturated, and that the condensation takes place while the air is comparatively dry, *before* the temperature is lowered to the dew-point. There is, then, no definite demarcation between what seems to us clear air and thick haze. The clearest air has some haze, and, as the humidity increases, the thickness of the air increases.

In all haze the temperature is above the dew-point. The dust-particles have only condensed a very small amount of the moisture so as to form haze, before the fuller condensation takes place at the dew-point.

At the Italian lakes, on many occasions when the air is damp and still, every stage of condensation may be observed in close proximity, not separated by a hard and fast line, but when no one could determine where the clear air ended and the cloud began. Sometimes in the sky overhead a gradual change can be observed from perfect clearness to thick air, and then the cloud. [Pg 46]

A thick haze may be occasioned by an increased number of dust-particles with little moisture, or of a diminished number of dust-particles with much moisture, above the point of saturation. The haze is cleared by this temperature rising, so as to allow the moisture to evaporate from the dust-particles.

Whenever the air is dry and hazy, much dust is found in it; as the dust decreases the haze also decreases. For example, Dr. Aitken, at Kingairloch, in one of the clearest districts of Argyleshire, on a clear July afternoon, counted 4000 dust-particles in a cubic inch of the air; whereas, two days before, in thick haze, he counted no fewer than 64,000 in the cubic inch. At Dumfries the number counted on a very hazy day in October increased twenty-fold over the number counted the day before, when it was clear.

All know that thick haze is usual in very sultry weather. The wavy, will-o'-the-wisp ripples near the horizon indicate its presence very plainly. During the intense heat there is generally much dust in the atmosphere; this dust, by the high temperature, attracts moisture from the apparently dry air, though above the saturation point. In all circumstances, then, the haze can be accounted for by the condensing power of the dust-particles in the atmosphere, at a higher temperature than that required for the formation of fogs, or mists, or rain.

CHAPTER XIII [Pg 47]

HAZING EFFECTS OF ATMOSPHERIC DUST

The transparency of the atmosphere is very much destroyed by the impurities communicated to it while passing over the inhabited areas of the country. Dr. Aitken devoted eighteen months to compare the amount of dusty impurities in different masses of air, or of different airs brought in by winds from different directions.

He took Falkirk for his centre of observations. This town lies a little to the north of a line drawn between Edinburgh and Glasgow, and is nearly midway between them. If we draw a line due west from it, and another due north, we find that, in the north-west quadrant so enclosed, the population of that part of Scotland is extremely thin, the country over that area being chiefly mountainous. In all other directions, the conditions are quite different. In the north-east quadrant are the fairly well-populated areas of Aberdeenshire, Forfarshire, and the thickly populated county of Fife. In the south-east quadrant are situated Edinburgh and the well-populated districts of the south-east of Scotland. And in the south-west quadrant are Glasgow and the large manufacturing towns which surround it. The winds from three of these quadrants bring air polluted in its passage over populated areas, whereas the winds from the north-west come comparatively pure.

The general plan of estimating the amount of haze is to note the most distant hill that can be seen through the haze. The distance in miles of the farthest away hill visible is then called "the limit of visibility" of the air at the time. For the observations made at Falkirk, only three hills are available, one about four miles distant, the Ochils about fifteen miles distant, and Ben Ledi about twenty-five miles distant—all in the north-west quadrant. When the air is thick, only the near hill can be seen; then the Ochils become visible as the air clears; and at last Ben Ledi is seen, when the haze becomes still less. After Ben Ledi is visible, it then becomes necessary to estimate the amount of haze on it, in order to get the limit of visibility of the air at the time. Thus, if Ben Ledi be half-hazed, then the limit of visibility will be fifty miles. In this way all the estimates of haze have been reduced to one scale for comparison. [Pg 48]

As the result of all the observations it was found that, as the dryness of the air increases, the limit of visibility also increases. A very marked difference in the transparency of the air was found with winds from the different directions. In the north-west quadrant the winds made the air very clear, whereas winds from all other directions made the air very much hazed. The winds in the other three areas are nearly ten times more hazed than those from the north-west quadrant. That is very striking.

The conclusion come to is that the air from densely inhabited districts is so polluted that it is fully nine times more hazed than the air that comes from the thinly inhabited districts; in other words, the atmosphere at Falkirk is about ten times thicker when the wind is east or south than it would be if there were no fires and no inhabitants. [Pg 49]

It is interesting to notice that the limit varies considerably for the same wind at the same humidity. This is what might have been expected, because from the observations made by the dust-counter the number of particles varied greatly in winds from the same directions, but at different times. This depends upon the rise and fall of the wind, changes in the state of trade, season of the year, and other causes. During a strike, the dearth of coal will make a considerable diminution in the number of dust-particles in the air of large towns. With a north wind, the extreme limits of visibility are 120 to 200 miles; and with a north-west wind, from 70 to 250 miles. An east wind has as limits 4 to 50 miles, and a south-east wind 2 to 60 miles.

One interesting fact to be noticed, after wading through these tables, is this—that, as a general result, the transparency of the air increases about 3·7 times for any increase in dryness from 2° to 8° of wet-bulb depression. That is, the clearness of the air is inversely proportional to the relative humidity; or, put another way, if the air is four times drier it is about four times clearer.

CHAPTER XIV

THUNDER CLEARS THE AIR

The phrase “thunder clears the air” is familiar to all. It contains a very vital truth, yet even scientific men did not know its full meaning until just the other day. It came by experience to people who had been for ages observing the weather; and it is one of the most pointed of the “weather-lore” expressions. Folks got to know, by a sort of rule-of-thumb, truths which scientifically they were unable to learn. And this is one. [Pg 50]

Perhaps, therefore, we should respect a little more what is called “folk-lore,” or ordinary people’s sayings. Experience has taught men many wonderful things. In olden times they were keener natural observers. They had few books, but they had plenty of time. They studied the habits of animals and moods of nature, and they came wonderfully near to reaching the full truth, though they could not give a reason for it. The awe-inspiring in nature has especially riveted the attention of man.

And no appearance in nature joins more powerfully the elements of grandeur and awe than a heavy thunder-storm. When, suddenly, from the breast of a dark thunder-cloud a brilliant flash of light darts zigzag to the earth, followed by a loud crackling noise which softens in the distance into weaker volumes of sound, terror seizes the birds of the air and the cattle in the field. The man who is born to rule the storm rejoices in the powerful display; but kings have trembled at the sight.

Byron thus pictures a storm in the Alps:—

“Far along
From peak to peak, the rattling crags among
Leaps the live thunder! Not from one lone cloud,
But every mountain now hath found a tongue,
And Jura answers, through her misty shroud,
Back to the joyous Alps, who call to her aloud!”

Franklin found that lightning is just a kind of electricity. No one can tell how it is produced; [Pg 51] yet a flash has been photographed. When the flash is from one cloud to another there is sheet-lightning, which is beautiful but not dangerous; but, when the electricity passes from a cloud to the earth in a forked form, it is very dangerous indeed. The flash is instantaneous, but the sound of the thunder takes some time to travel. Roughly speaking, the sound takes five seconds or six beats of the pulse to the mile.

All are now taught at school that it is the oxygen in the air which is necessary to keep us in life. If mice are put into a glass jar of pure oxygen gas, they will at once dance with exhilarating joy. It occurred to Sir Benjamin Richardson, some time ago, that it would be interesting to continue some experiments with animals and oxygen. He put a number of mice into a jar of pure oxygen for a time; they breathed in the gas, and breathed out water-vapour and carbonic acid. After the mice had continued this for some time, he removed them by an arrangement. By chemical means he removed the water-vapour and carbonic acid from the mixed air in the vessel. When a blown-out taper was inserted, it at once burst into flame, showing that the remaining gas was oxygen.

Again, the mice were put into this vessel to breathe away. But, strange to say, the animals soon became drowsy; the smartness of the oxygen was gone. At last they died; there was nothing in the gas to keep them in life; yet, by the ordinary chemical tests, it was still oxygen. It had repeatedly passed through the lungs of the mice, and during this passage [Pg 52] there had been an action in the air-cells which absorbed the life-giving element of the gas. It is oxygen, so far as chemistry is concerned, but it has no life-giving power. It has been *devitalised*.

But the startling discovery still remains. Sir Benjamin had previously fitted up the vessel with two short wires, opposite each other in the sides—part outside and part inside. Two wires are fastened to the outside knobs. These wires are attached to an electric machine, and a flash of electricity is made to pass between the inner points of the vessel. The wires are again removed; nothing strange is seen in the vessel. But, when living mice are put into the vessel, they dance as joyfully as if pure oxygen were in it. The oxygen in which the first mice died has now been quite refreshed by the electricity. The bad air has been cleared and made life-supporting by the electric discharge. It has been again vitalised.

Now, to apply this: before a thunder-storm, everything has been so still for days that the oxygen in the air has been to some extent robbed of its life-sustaining power. The air feels “close,” a feeling of drowsiness comes over all. But, after the air has been pierced by several flashes of lightning, the life-force in the air is restored. Your spirits revive; you feel restored; your breathing is far freer; your drowsiness is gone. Then there is a burst of heavenly music from the exhilarated birds. Thus a thunder-storm “clears the air.”

After the passage of lightning through the air ozone is produced—the gas that is produced after a flash of electricity. It is a kind of oxygen, with fine exciting effects on the body. If, then, the life-sustaining power of oxygen depends on a trace of ozone, and this is being made by lightning’s work, how pleased should we be at the occasional thunder-storm! [Pg 53]

CHAPTER XV

DISEASE-GERMS IN THE AIR

The gay motes that dance in the sunbeams are not all harmless. All are annoying to the tidy housekeeper; but some are dangerous. There are living particles that float in the air as the messengers of disease and death. Some, falling on fresh wounds, find there a suitable feeding-place; and, if not destroyed, generate the deadly influence. Others are drawn in with the breath; and, unless the lungs can withstand them, they seize hold and spread some sickness or disease. From stagnant pools, common sewers, and filthy rooms, disease-germs are constantly contaminating the air. Yet these can be counted.

The simplest method is that of Professor Frankland. It depends on this principle: a certain quantity of air is drawn through some cotton-wool; this wool seizes the organisms as the air passes through; these organisms are afterwards allowed to feed upon a suitable nutritive medium until they reach maturity; they are then counted easily.

About an inch from each end of a glass tube (5 inches long and 1 inch bore), the glass is pressed in during the process of blowing. Some cotton-wool is squeezed in to form a plug at the farther constricted part of the glass. The important plug is now inserted at the same open end, but is not allowed to go beyond the constricted part at its end. A piece of long lead tubing is attached to the former end by an india-rubber tube. The other end of the lead tubing is connected with an exhausting syringe. Sixty strokes of the 18 cubic inches syringe will draw 1080 cubic inches of the air to be examined through the plugs, the first retaining the organisms. [Pg 54]

The impregnated plug is then put into a flask containing in solution some gelatine-peptone. The flask is made to revolve horizontally until an almost perfectly even film of gelatine and the organisms from the broken-up plug cover its inner surface.

The flask is allowed to remain for an hour in a cool place, and is then placed under a bell-jar, at a temperature of 70° Fahr. There it remains, to allow the germs to incubate, for four or five days. The surface of the flask having been previously divided into equal parts by ink lines, the counting is now commenced. If the average be taken for each segment, the number of the whole is easily ascertained. A simple arithmetical calculation then determines the number of organisms in a cubic foot, since the number is known for the 1080 cubic inches. That is the process for determining the number of living organisms in a fixed quantity of air.

No less than thirty colonies of organisms were counted in a cubic foot of air taken from the Golden Gallery of St. Paul’s Cathedral, London, and 140 from the air of the churchyard. An ordinary man would breathe there thirty-six micro-organisms every minute. [Pg 55]

Electricity has a powerful effect in destroying these organisms. Ozone is generated in the air by lightning, and it is detrimental to them. In fine ozoned Highland air scarcely a disease-germ can be detected. Open sea air contains about one germ in two cubic feet. It has been found that in Paris the average in summer is about 140 per cubic foot of air, but in bedrooms the number is double. During the twenty-four hours of the day the number of germs is highest about 6 A.M., and lowest about mid-day.

Raindrops carry the germs to the ground. Hence the advantage of a thunder plout in a sanitary way. A cubic foot of rain has been found to contain 5500 organic dust-germs, besides 7,000,000,000 of inorganic dust-particles. In a dirty town the rain will bring down in a year, upon a square foot of surface, no less than 3,000,000 of bacteria, many of them being disease-bearing and death-bearing. No wonder, then, that scientific men are using every endeavour to protect the human frame, as well as the frame of the lower animals, from the baneful inroads of these floating nuclei of disease and death.

CHAPTER XVI

A CHANGE OF AIR

For weakness of body and fatigue of mind a very common and essentially serviceable recommendation is “a change of air.” Of course, the change of scene from coast to country, [Pg 56] or from town to hillside, may help much the depressed in body or mind; and this is very commendable. But, strange to say, there is a healing virtue in breathing different air.

At first one is apt to think that air is the same all over, as he thinks water is—especially outside smoky towns; but both have varied qualities in different parts. You have only to be assured that in a cubic inch of bedroom air in the denser parts of a large town there are about 20,000,000 of dust-particles, and in the open air of a heathery mountain-side there are only some hundreds, to see that there is something after all on the face of it in the “old wives’ saw.”

Not that the dust-particles are all injurious; for most of them are inorganic, and many of the organic particles are quite wholesome; yet there is a change wrought, often very marked, in going from one place to another for different air.

Even in the country, especially in summer-time, one distinctly notices the great difference in the air of lowland and highland localities. The ten miles change from Strathmore to Glenisla shows a marked difference in the air. Below, it is close, weakening, enervating; above, it is exhilarating, invigorating, and strong.

So people must have a change—at least those who can afford it—for health must be seen to first of all, if one has means to do so. Oh! the blessing of good health! How many who enjoy it never think of the misery of its loss! In fact, health is the soul that animates all enjoyments of life; for without it those would soon be tasteless. A man starves at the best-spread table, [Pg 57] and is poor in the midst of the greatest treasures without health.

In these days half of our diseases come from the neglect of the body in the overwork of the brain. The wear and tear of labour and intellect go on without pause or self-pity. Men may live as long as their forefathers, but they suffer more from a thousand artificial anxieties and cares. The men of old fatigued only the muscles, we exhaust the finer strength of the nerves. Even more so now, then, do we require a change of air to soothe our overwrought nervous system.

And when that magic power, concealed from mortal view, works such wonders on the health, surely it is one’s duty to save up and have it, when it is within one’s means. For is not health the greatest of all possessions? What a rich colour clothes the countenance of the young after a month’s outing in the hill country! How fine and pure has the blood become! All stagnant humours, accumulated in winter town life, have been dispelled by the ozone-brightening charm. The weary looking office or shop man is now transfigured into a sprightly youth once more, ready with strongly recuperated power for another winter’s labours. The pale wife, who has been stifled for months in close-aired rooms, has now a healthy flush on her becoming countenance that speaks of gladly restored health. And all this has been brought about by a “change of air”!

For a thorough change to a town man, he should make for the Highlands. There he is never tired of walking, for the air which he breathes is full of ozone. This revivifying element in the air is produced by the lightning-bursts from hill to hill. There is in the Highlands a continual [Pg 58] rush of electricity, whether seen or not. Hence the air is very pure, free from organic germs, intensely exhilarating and buoyant.

Sportsmen are livingly aware of the recuperative power of the Highland air. Perhaps these city men do not benefit so much by the easy walking exercise on the grouse moors as in breathing the splendidly delight-inspiring air. What a change one feels there in a very few hours!

“A change of air” is an old wives’ adage. But much of the weather-lore of our forefathers was based on real scientific principles only now coming to light. Nature is ever true, but it requires patience to unravel her secrets. We therefore advocate an occasional “change of air” to improve the health—

“The chiefest good,
Bestow’d by Heaven, but seldom understood.”

CHAPTER XVII

THE OLD MOON IN THE NEW MOON'S ARMS

After the sun's broad beams have tired the sight, the moon with more sober light charms us to descry her beauty, as she shines sublimely in her virgin modesty. There is always a most fascinating freshness in the first sight of the new moon. The superstition of centuries adds to this charm. Why boys and girls like to turn over a coin in their pocket at this sight one cannot tell: yet it is done. No young lady likes to look at the new moon through a pane of [Pg 59] glass. And farmers are always confident of a change of weather with a new moon: at least in bad weather they earnestly hope for it.

But, banishing all superstition, we welcome the pale silver sickle in the heavens, once more appearing from the bosom of the azure. And no language can equal these beautiful words of the youthful Shelley:—

"Like the young moon,
When on the sunlit limits of the night
Her white shell trembles amid crimson air,
And while the sleeping tempest gathers might,
Doth, as the herald of his coming, bear
The ghost of its dead mother, whose dim form
Bends in dark ether from her infant's chair."

That is a more charming way of putting the ordinary expression, "the old moon in the new moon's arms." We are regularly accustomed to the moonshine, but only occasionally is the *earthshine* on the moon so regulated that the shadowed part is visible. This is not seen at the appearance of every new moon. It depends upon the positions of the sun and moon, the state of the atmosphere, and the absence of heavy clouds. I never in my life saw the phenomenon so marvellously beautiful as on May 7th, 1894, at my manse in Strathmore. I took particular note of it, as some exceedingly curious things were connected with it.

At nine o'clock in the evening, the new moon issued from some clouds in the western heavens, the sun having set, about an hour before. The crescent was thin and silvery, and the outline of the shadowed part was just visible. The sky near the horizon was clear and [Pg 60] greenish-hued. As the night advanced the moon descended, and at ten o'clock she was approaching a purple stratum of clouds that stretched over the hills, while the position of the sun was only known a little to the east, by the back-thrown light upon the dim sky. Through the moisture-laden air the sun's rays, reflected by the moon, threw a golden stream from the crescent moon, for the silvery shell became more golden-hued.

The horns of the moon now seemed to project, and the shadowed part became more distinct, though the circle appeared smaller. By means of a field-glass I noticed that this was extra lighted, with points here and there quite golden-tinged. The darker spots showed the deep caverns; the brighter points brought into relief the mountain peaks.

Why was the surface brighter than usual? I cannot go into detail about the phases of the moon; but, in a word, I may say that, while the sun can illuminate the side of the moon turned towards it, it is unable to throw any light on the shadow, seeing that there is no atmosphere around the moon to refract the light.

If we, in imagination, looked from the moon upon the earth, we should see the same phases as are now noticed in the moon; and when it is just before new moon on the earth, the earth will appear fully illuminated from the moon. We would also observe (from the moon) that the brightness of the illuminated part of the earth would vary from time to time, according to the changes in the earth's atmosphere. More light would be reflected to the moon from the clouds in our atmosphere than from the bare earth or cloudless sea, since clouds reflect [Pg 61] more light than either land or sea. Accordingly, we arrive at this curious fact—that the extra brightness of the *dark* body of the moon is mainly determined by the amount of *cloud in our atmosphere*.

Accordingly, I concluded that there must be clouds to the west, though I could not see them, which reflected rays of light and faintly illuminated the shadowed part of the moon. It had become much colder, and I concluded that during the night the cloud-particles, if driven near by the wind, would condense into rain. And, assuredly, next morning I was gratified to find that rain had fallen in large quantities, substantiating the theory.

There is much pleasure in verifying such an interesting problem. The dark body of the moon being more than usually visible is one of our well-known and oldest indications of coming bad weather. And at once came to my memory the lines of Sir Patrick Spens, as he foreboded rain for his crossing the North Sea:—

"I saw the new moon late yestreen
Wi' the auld moon in her arm;
And if we gang to sea, master,
I fear we'll come to harm."

This lunar indication, then, has a sound physical basis, showing that near the observer there are vast areas of clouds, which are reflecting light upon the moon at the time, before they condense into rain by the chilling of the air. According to the old Greek poet, Aratus: “If the new moon is ruddy, and you can trace the shadow of the complete circle, a storm is approaching.”

CHAPTER XVIII [Pg 62]

AN AUTUMN AFTERGLOW

A brilliant afterglow is welcomed for its surpassing beauty and a precursor of fine fixed weather.

A glorious sunset has always had a charm for the lover of nature’s beauties. The zenith spreads its canopy of sapphire, and not a breath creeps through the rosy air. A magnificent array of clouds of numberless shapes come smartly into view. Some, far off, are voyaging their sun-bright paths in silvery folds; others float in golden groups. Some masses are embroidered with burning crimson; others are like “islands all lovely in an emerald sea.” Over the glowing sky are splendid colourings. The flood of rosy light looks as if a great conflagration were below the horizon.

I remember witnessing an especially brilliant sunset last autumn on the high-road between Kirriemuir and Blairgowrie. The setting sun shone upon the back of certain long trailing clouds which were much nearer me than a range behind. The fringes of the front range were brilliantly golden, while the face of those behind was sparklingly bright. Then the sun disappeared over the western hills, and his place was full of spokes of living light.

Looking eastward, I observed on the horizon the base of the northern line of a beautiful rainbow—“the shepherd’s delight” for fine weather.

Soon in the west the light faded; but there came out of the east a lovely flush, and the general sky was presently flamboyant with afterglow. The front set of clouds was darker except on the edges, the red being on the clouds behind; and the horizon in the east was particularly rich with dark red hues. [Pg 63]

Gradually the eastern glow rose and reddened all the clouds, but the front clouds were still grey. The effect was very fine in contrast. The fleecy clouds overhead became transparently light red, as they stretched over to reach the silver-streaked west. The new moon was just appearing upright against a slightly less bright opening in the sky, betokening the firm hardness of autumn.

Soon the colouring melted away, and the peaceful reign of the later twilight possessed the land.

Now why that brilliancy of the east, when the west was colourless? Most of all you note the immense variety and wealth of reds. These are due to dust in the atmosphere. We are the more convinced of this by the very remarkable and beautiful sunsets which occurred after the tremendous eruption at Krakatoa, in the Straits of Sunda, thirty years ago. There was then ejected an enormous quantity of fine dust, which spread over the whole world’s atmosphere. So long as that vast amount of dust remained in the air did the sunsets and afterglows display an exceptional wealth of colouring. All observers were struck with the vividly brilliant red colours in all shades and tints.

The minute particles of dust in the atmosphere arrest the sun’s rays and scatter them in all directions; they are so small, however, that they cannot reflect and scatter all; their power is limited to the scattering of the rays at the blue end of the spectrum, while the red rays pass [Pg 64] on unarrested. The display of the colours of the blue end are found in numberless shades, from the full deep blue in the zenith to the greenish-blue near the horizon.

If there were no fine dust-particles in the upper strata, the sunset effect would be whiter; if there were no large dust-particles, there would be no colouring at all. If there were no dust-particles in the air at all, the light would simply pass through into space without revealing itself, and the moment the sun disappeared there would be total darkness. The very existence of our twilight depends on the dust in the air; and its length depends on the amount and extension upwards of the dust-particles.

But how have the particles been increased in size in the east? Because, as the sun was sinking, but before its rays failed to illumine the heavens, the temperature of the air began to fall. This cooling made the dust-particles seize the water-vapour to form haze-particles of a larger size. The particles in the east first lose the sun’s heat, and first become cool; and the rays of light are then best sifted, producing a more distinct and darker red. As the sun dipped lower, the particles overhead became a turn larger, and thereby better reflected the red rays. Accordingly, the roseate bands in the east spread over to the zenith, and passed over to the west, producing in a few minutes a universal transformation glow.

To produce the full effect often witnessed, there must be, besides the ordinary dust-particles, small crystals floating in the air, which increase the reflection from their surfaces and enhance the glow effects. In autumn, after sunset, the water-covered dust-particles [Pg 65] become frozen and the red light streams with rare brilliancy, causing all reddish and coloured objects to glow with a rare brightness. Then the air glows with a strange light as of the northern dawn. From all this it is clear that, though the colouring of sunset is produced by the direct rays of the sun, the afterglow is produced by reflection, or, rather, radiation from the illuminated particles near the horizon.

The effect in autumn is a stream of red light, of varied tones, and rare brilliancy in all quarters, unseen during the warmer summer. We have to witness the sunsets at Ballachulish to be assured that Waller Paton really imitated nature in the characteristic bronze tints of his richly painted landscapes.

CHAPTER XIX

A WINTER FOREGLOW

Little attention has been paid to foreglows compared with afterglows, either with regard to their natural beauty or their weather forecasting. But either the ordinary red-cloud surroundings at sunrise, or the western foreglow at rarer intervals, betokens to the weather-prophet wet and gloomy weather. The farmer and the sailor do not like the sight, they depend so much on favourable weather conditions.

Of course, sunrise to the æsthetic observer has always its charms. The powerful king of day rejoices “as a bridegroom coming out of his chamber” as he steps upon the earth over the [Pg 66] dewy mountain tops, bathing all in light, and spreading gladness and deep joy before him. The lessening cloud, the kindling azure, and the mountain’s brow illumined with golden streaks, mark his approach; he is encompassed with bright beams, as he throws his unutterable love upon the clouds, “the beauteous robes of heaven.” Aslant the dew-bright earth and coloured air he looks in boundless majesty abroad, touching the green leaves all a-tremble with gold light.

But glorious, and educating, and inspiring as is the sunrise in itself in many cases, there is occasionally something very remarkable that is connected with it. Rare is it, but how charming when witnessed, though till very recently it was all but unexplained. This is the *foreglow*.

It is in no respect so splendid as the afterglow succeeding sunset; but, because of its comparative rarity, its beauty is enhanced. I remember a foreglow most vividly which was seen at my manse, in Strathmore, in January 1893. My bedroom window looked due west; I slept with the blind up. On that morning I was struck, just after the darkness was fading away, with a slight colouring all along the western horizon. The skeleton branches of the trees stood out strongly against it. The colouring gradually increased, and the roseate hue stretched higher. The old well-known faces that I used to conjure up out of the thin blended boughs became more life-like, as the cheeks flushed. There was rare warmth on a winter morning to cheer a half-despairing soul, tired out with the long hours of oil reading, and [Pg 67] pierced to the heart by the never-ceasing rimes; yet I could not understand it.

I went to the room opposite to watch the sunrise, for I had observed in the diary that the appearance of the sun would not be for a few minutes. There were streaks of light in the east above the horizon, but no colour was visible. That hectic flush—slight, yet well marked—which was deepening in the western heavens, had no counterpart in the east, except the colourless light which marked the wintry sun’s near approach. As soon as the sun’s rays shot up into the eastern clouds, and his orb appeared above the horizon, the western sky paled, the colour left it, as if ashamed of its assumed glory. A foreglow like that I have very rarely seen, and its existence was a puzzle to me till I studied Dr. Aitken’s explanation of the afterglows after sunset. I had never come across any description of a foreglow; and, of course, across no explanation of the curious phenomenon. The western heavens were coloured with fairly bright roseate hues, while the eastern horizon was only silvery bright before the sun rose; whereas, after the sun appeared and coloured the eastern hills and clouds, the western sky resumed its leaden grey and colourless appearance. Why was that? What is the explanation?

I have not space enough to repeat the explanation given already in the last chapter of the glorious phenomenon of the afterglow. But the explanation is similar. Before sunrise, the rays of the sun are reflected by dust-particles in the zenith to the western clouds. The colouring is intensified by the frozen water-vapour on these particles in the west.

One thing I carefully noted. Ere mid-day, snow began to fall, and for some days a severe [Pg 68]
snow-storm kept us indoors. Then, at any rate, the foreglow betokened a coming storm. It was, like a rainbow in a summer morning, a decided warning of the approaching wet weather.

CHAPTER XX

THE RAINBOW

The poet Wordsworth rapturously exclaimed—

> “My heart leaps up when I behold
> A rainbow in the sky.”

And old and young have always been enchanted with the beautiful phenomenon. How glorious is the parti-coloured girdle which, on an April morning or September evening, is cast o’er mountain, tower, and town, or even mirrored in the ocean’s depths! No colours are so vividly bright as when this triumphal arch bespans a dark nimbus: then it unfolds them in due prismatic proportion, “running from the red to where the violet fades into the sky.”

A plain description of the formation of the rainbow is not very easily given, but a short sketch may be useful. Beautiful as is the ethereal bow, “born of the shower and colour’d by the sun,” yet the marvellous effect is more exquisitely intensified in its gorgeous display
when the hand of science points out the path in which the sun’s rays, from above the [Pg 69]
western horizon, fall on the watery cloud, indicating fine weather—“the shepherd’s delight.”

One law of reflection is that, when a ray of light falls on a plane or spherical surface, it goes off at the same angle to the surface as it fell. One law of refraction is that, when a ray of light passes through one medium and enters a denser medium (as from air to water), it is bent back a little. By refraction you see the sun’s rays long after the sun has set; when the sun is just below the horizon, an observer, on the surface of the earth, will see it raised by an amount which is generally equal to its apparent diameter.

The rays of different colours are bent back (when passing through the water) at different rates, some slightly, others more, from the red to the violet end. The rainbow, then, is produced by refraction and reflection of the several coloured rays of sunlight in the drops of water which make up falling rain.

The sun is behind the observer, and its rays fall in a parallel direction upon the drops of rain before him. In each drop the light is dispersively refracted, and then reflected from the farther face of the drop; it travels back through the drop, and comes out with dispersing colours.

According to the height of the sun, or the slope of its rays, a higher or lower rainbow will be formed. And, strange, no two people can see the very same bow; in fact the rainbow, as seen by the one eye, is not formed by the same water-drops as the rainbow seen by the other eye.

When the primary bow is seen in most vivid colours on a dark cloud, a second arch, larger [Pg 70]
and fainter, is often seen. But the order of the colours is quite reversed. At a greater elevation, the sun’s ray enters the lower side of a drop of rain-water, is refracted, reflected *twice*, and then refracted again before being sent out to the observer’s eye. That is why the colours are reversed.

A one-coloured rainbow is a curious and rare phenomenon. It is a strange paradox, for the very idea of a rainbow brings up the seven colours—red, orange, yellow, green, blue, indigo, and violet. Yet Dr. Aitken tells us of a rainbow with one colour which he observed on Christmas Day, in 1888.

He was taking his walk on the high ground south of Falkirk. In the east he observed a strange pillar-like cloud, lit up with the light of the setting sun. Then the red pillar extended, curved over, and formed a perfect arch across the north-eastern sky. When fully developed, this rainbow was the most extraordinary one which he had ever seen. There was no colour in it but red. It consisted simply of a red arch, and even the red had a sameness about it.

Outside the rainbow there was part of a secondary bow. The Ochil Hills were north of his point of observation. These hills were covered with snow, and the setting sun was glowing with rosy light. Never had he seen such a depth of colour as was on them on this occasion. It was a deep, furnacy red. The sun’s light was shorn of all the rays of short-wave length on its passage through the atmosphere, and only the red rays reached the earth. The reason why
the Ochils glowed with so deep a red was owing to their being overhung by a dense curtain [Pg 71]

of clouds, which screened off the light of the sky. The illumination was thus principally that of the direct softer light of the sun.

CHAPTER XXI

THE AURORA BOREALIS

He must be a very careless observer who has not been struck with the appearance of the streamers which occasionally light up the northern heavens, and which farmers consider to be indicators of strong wind or broken weather.

The time was when the phenomenon was considered to be supernatural and portentous, as the chroniclers of spectral battles, when "fierce, fiery warriors fought upon the clouds, in ranks and squadrons, and right form of war." And even in the rural districts of Britain, the blood-coloured aurora, of October 24th, 1870, was considered to be the reflection of an enormous Prussian bonfire, fed by the beleaguered French capital.

In joyful spirit, the Shetlanders call the beautiful natural phenomenon, "Merry Dancers." Burns associated their evanescence with the transitoriness of sensuous gratification:—"they flit ere you can point their place." And Tennyson spoke of his cousin's face lit up with the colour and light of love, "as I have seen the rosy red flushing in the northern night."

Yet this phenomenon is to a great extent under the control of cosmical laws. One of the most difficult problems of our day has been to disentangle the irregular webwork of auroræ, and [Pg 72] bring them under a law of periodicity, which depends upon the fluctuations of the sun's photosphere and the variations on the earth's magnetism, and which have such an important influence upon the fluctuations of the weather.

The name "Aurora Borealis" was given to it by Gassendi in 1621. Afterwards, the old almanacs described it as the "Great Amazing Light in the North." In the Lowlands of Scotland, the name it long went by, of "Lord Derwentwater's Lights," was given because it suddenly appeared on the night before the execution of the rebel lord. In Ceylon auroræ were called "Buddha Lights."

The first symptom of an aurora borealis is commonly a low arch of pale, greenish-yellow light, placed at right angles to the magnetic meridian. Sometimes rays cover the whole sky, frequently showing tremulous motion from end to end; and sometimes they appear to hang from the sky like the fringes of a mantle. They are among the most capricious of natural phenomena, so full of individualities and vagaries. To the glitter of rapid movement they add the charm of vivid colouring. It is strongly asserted that auroræ are preceded by the same general phenomena as thunder-storms. This was borne out by Piazzi Smith (late Astronomer-Royal for Scotland), who observed that their monthly frequency varies inversely with that of thunder-storms—both being safety-valves for the discharge of surplus electricity.

[Pg 73] Careful observers have, moreover, noticed a remarkable coincidence between the display of auroræ and the maxima of the sun's spots and of the earth's magnetic disturbances. Some have supposed that the light of the aurora is caused by clouds of meteoric dust, composed of iron, which is ignited by friction with the atmosphere. But there is this difficulty in the way, shooting stars are more frequent in the morning, while the reverse is the case with the aurora. The highest authorities have concluded, pretty uniformly, that auroræ are electric discharges through highly rarefied air, taking place in a magnetic field, and under the sway of the earth's magnetic induction. They are not inappropriately called "Polar lightnings," for when electricity misses the one channel it must traverse the other.

The natives of the Arctic regions of North America pretend to foretell wind by the rapidity of the motions of the streamers. When they spread over the whole sky, in a uniform sheet of light, fine weather ensues. Fitzroy believed that auroræ in northern latitudes indicated and accompanied stormy weather at a distance. The same idea is still current among many farmers and fishermen in Scotland.

Is there any audible accompaniment to the brilliant spectacle? The natives of some parts, with subtle hearing-power, speak of the "whizzing" sound which is often heard during auroral displays. Burns tells of their "hissing, eerie din," as echoes of the far-off songs of the Valkyries. Perhaps the most striking incident which corroborates this opinion occurred during the Franco-Prussian War. Rolier, a practised aëronaut, left Paris in a balloon, on his mission of city defence, and fourteen hours afterwards landed in Norway. He had reached [Pg 74] the height of two and a half miles. When descending, he passed through a peculiar cloud of sulphurous odour, which emitted flashed light and a slight scratching or rustling noise. On landing, he witnessed a splendid aurora borealis. He must, therefore, have passed through a cloud in which an electrical discharge of an auroral nature was proceeding, accompanied with an audible sound. There is, moreover, no improbability of such sounds being occasionally heard, since a somewhat similar phenomenon accompanies the brush discharge of the electric machinery, to which the aurora bears considerable resemblance.

Though no fixed conclusions are yet established about the causes of the brilliant auroral display, yet, as the results of laborious observations, we are assured that the stabler centre of our solar system holds in its powerful sway the several planets at their respective distances, supplying them all with their seasonable light and heat, vibrating sympathetic chords in all, and even controlling under certain—though to us still unknown—laws the electric streamers that flit, apparently lawlessly, in the distant earth's atmosphere.

CHAPTER XXII

THE BLUE SKY

If we look at the sky overhead, when cloudless in the sunshine, we wonder what gives the air such a deep-blue colour. We are not looking, as children seem to do, into vacancy, away into the far unknown. And even, if that were the case, would not the space be quite colourless? What, then, produces the blueness?

Some of the very fine dust-particles, even when clothed with an exceedingly thin coating of water-vapour, are carried very high; and, looking through a vast accumulation of these, we find the effect of a deep-blue colour.

Why so? Because these particles are so small that they can only reflect the rays of the blue end of the spectrum; and the higher we ascend, the smaller are the particles and the deeper is the blue. But it is also because water, even in its very finest and purest form, is blue in colour. For long this was disputed. Even Sir Robert Christison concluded, after years of experimenting on Highland streams, that water was colourless.

Of course, he admitted that the water in the Indian and Pacific Oceans has frequent patches of red, brown, or white colour, from the myriads of animalcules suspended in the water. Ehrenberg found that it was vegetable matter which gave to the Red Sea its characteristic name. But these, and similar waters, are not pure.

It is to Dr. Aitken that the final discovery of the real colour of water is due. When on a visit to several towns on the shores of the Mediterranean, he set about making some very interesting experiments, which the reader will follow with pleasure.

It is a well-known fact that colour transmitted through different bodies differs considerably from colour reflected by them. In his first experiment he took a long empty metal tube, open at one end, and closed at the other end by a clear-glass plate. This was let down vertically into the water, near to a fixed object, which appeared of most beautiful deep and delicate blue at a depth of 20 feet. Scientific men know that, if the colour of water is due to the light reflected by extremely small particles of matter suspended in the water, then the object looked at through it would have been illuminated with yellow (the complementary colour of blue). A blackened tube was then filled with water (which had a clear-glass plate fixed to the bottom), and white, red, yellow, and purple objects were sunk in the water, and these colours were found to change in the same way as if they were looked at through a piece of pale-blue glass. The white object appeared blue, the red darkened very rapidly as it sank, and soon lost its colour; at the depth of seven feet a very brilliant red was so darkened as to appear dark brick-red. The yellow object changed to green, and the purple to dark blue.

But, still further to satisfy himself that water is really blue in itself, even without any particles suspended in it, he tested the colour of *distilled* water. He filled a darkened tube with this water (clear-glass plates being at the ends of the tube), and looked through it at a white surface. The effect was the same as before, the colour was blue, almost exactly of the same hue as a solution of Prussian blue.

This is corroborated by the fact that, the purer the water is in nature, the bluer is the tint when a large quantity is looked through. Some Highland lochs have crystal waters of the most extraordinary blue. Of course, some cling to the old idea that this is accounted for by the reflected blue of the clear heavens above. No doubt, if the sky be deep blue, then this blue light, when reflected by the surface of the water, will enrich and deepen the hue. But the water itself is *really* blue.

At the same time, the dust-particles suspended in the water have a great effect in making the water appear more beautiful, brilliant, and varied in its colouring; because little or no light is reflected by the interior of a mass of water itself. If a dark metal vessel be filled with a weak solution of Prussian blue, the liquid will appear quite dark and void of colour. But throw in some fine white powder, and the liquid will at once become of a brilliant blue colour. This accounts for the change of depth and brilliancy of colour in the several shores of the Mediterranean.

When, then, you look at the face of a deep-blue lake on a summer evening—the heavens all aglow with the unrivalled display of colour from the zenith, stretching in lighter hues of glory to the horizon—though to you the calm water appears like a lake of molten metal glowing with sky-reflected light, so powerful and brilliant as entirely to overpower the light which is internally reflected, yet blue is the normal colour of the water: *blueness is its inherent hue*.

Looking upwards, we observe three distinct kinds of blue in the sky from the horizon to the zenith. All painters in water-colours know that. Newton thought that the colour of the sky was produced in the same way as the colours in thin plates, the order of succession of the colours gradually increasing in intensity.

CHAPTER XXIII [Pg 78]

A SANITARY DETECTIVE

The impure state of the air in the rooms of a house can now be determined by means of colour alone. Dr. Aitken has invented a very simple instrument for that purpose; and this ought to be of great service to sanitary officers. It is called the koniscope—or dust-detective.

The instrument consists of an air-pump and a metal tube with glass ends. Near one end of the test-tube is a passage by which it communicates with the air-pump, and near the other end is attached a stop-cock for admitting the air to be tested. It is not nearly so accurate as the dust-counter; but it is cheaper, more easily wrought, and more handy for quick work. All the grades of blue, from what is scarcely visible to deep, dark blue, may be attached alongside the tube on pieces of coloured glass; and opposite these colours are the numbers of dust-particles in the cubic inch of the similar air, as determined by the dust-counter.

While the number of particles was counted by means of the dust-counter, the depth of blue given by the koniscope was noted; and the piece of glass of that exact depth of blue attached. A metal tube was fitted up vertically in the room, in such a way that it could be raised to any desired height into the impure air near the ceiling, so that supplies of air of different degrees of impurity might be obtained. To produce the impurity, the gas was lit [Pg 79] and kept burning during the experiments. The air was drawn down through the pipe by means of the air-pump of the koniscope, and it passed through the measuring apparatus of the dust-counter on its way to the koniscope. It may be remarked that, by a stroke of the air-pump, the air within the test-tube is rarefied and the dust-particles seize the moisture in the super-saturated air to form fog-particles; through this fog the colour is observed, and the shade of colour determines the number of dust-particles in the air. These colours are named “just visible,” “very pale blue,” “pale blue,” “fine blue,” “deep blue,” and “very deep blue.”

When making a sanitary inspection, the pure air should be examined first, and the colour corresponding to that should be considered as the normal health colour. Any increase from the depth would indicate that the air was being gradually contaminated; and the amount of increase in the depth of colour would indicate the amount of increase of pollution.

As an illustration of what this instrument can detect, a room of 24 by 17 by 13 feet was selected. The air was examined before the gas was lighted, and the colour in the test-tube was very faint, indicating a clear atmosphere. In all parts of the room this was found the same. A small tube was attached to the test-tube, open at the other end, for taking air from different parts of the room. Three jets of gas were then lit in the centre of the room, and observations at once begun with the koniscope.

Within thirty-five seconds of striking the match to light the gas, the products of combustion [Pg 80] had extended near the ceiling to the end of the room; this was indicated by the colour in the koniscope suddenly becoming a deep blue. In four minutes the deep-blue-producing air was got at a distance of two feet from the ceiling. In ten minutes there was strong evidence of the pollution all through the room. In half-an-hour the impurity at nine feet from the floor was very great, the colour being an intensely deep blue.

The wide range of the indications of the instrument, from pure clearness to nearly black blue, makes the estimate of the impurity very easily taken with it; and, as there are few parts to get out of order, it is hoped it may come into general use for sanitary work.

CHAPTER XXIV

FOG AND SMOKE

Just two hundred and forty years ago, Mr. John Evelyn, F.R.S., a well-known writer on meteorology, sent a curious tract to King Charles II., which was ordered to be printed by his Majesty. It was entitled “Fumifugium,” and dealt with the great smoke nuisance in London. I find from the thesis that he had a very hazy idea of the connection between fog and smoke; and no wonder, for it is only lately that the connection has been fully explained.

We know that without dust-particles there can be no fog, and that smoke supplies a vast [Pg 81] amount of such particles. Therefore, in certain states of the atmosphere, the more smoke the more fog. In Mr. Evelyn’s day the fog, which he called “presumptuous smoake,” was at times so dense that men could hardly discern each other for the “clowd.” His Majesty’s only sister had complained of the damage done to her lungs by the contamination, and Mr. Evelyn was disgusted at the apathy of the people to do anything to remedy the nuisance. He deplored that that glorious and ancient city of London should wrap her stately head in “clowds of smoake, so full of stink and darknesse.” He was of opinion that a method of charring coal so as to divest it of its smoke, while leaving it serviceable for many purposes, should be made the object of a very strict inquiry. And he was right. For it is now known that fog in a town is intensified by much smoke.

In a city like London or Glasgow, where a great river, fed by warm streams of water from gigantic works, passes through its centre, fogs can never be entirely obliterated, for the dust-particles in the air (often four millions and upwards in the cubic inch) will seize with terrible avidity the warm vapour rising from the river. That is the main reason why fogs cannot there be put down. Smoke is being consumed to a great extent; yet we find particles of sulphur remaining, which seize the warm vapour and form fogs dense enough to check all traffic. The worst form of city fogs seems to be produced when the air, after first flowing slowly in one direction, then turns on its tracks and flows back over the city, bringing with it [Pg 82] a black pall, the accumulated products of previous days, to which gets added the smoke and other impurities produced at the time.

What irritated Mr. Evelyn was that, outside of London, the air was clear when passengers could not walk in safety within the city. So vexed was he about the contamination, that he made it the occasion of all the “cathars, phthisicks, coughs, and consumption in the city.” He appealed to common sense to testify that those who repair to London soon take some serious illness. “I know a man,” he said, “who came up to London and took a great cold, which he could never afterwards claw off again.”

Mr. Evelyn proposed that, by an Act of Parliament, the nuisance be removed; enjoining that all breweries, dye-works, soap and salt boilers, lime-burners, and the like, be removed five or six miles distant from London below the river Thames. That would have materially helped his cause.

But there is more difficulty in the purification than he anticipated. Yet there was pluck in the old man pointing out the killing contamination and suggesting a possible remedy. He had the fond idea that thereby a certain charm, “or innocent magick,” would make a transformation scene like Arabia, which is therefore “styl’d the Happy, attracting all with its gums and precious spices.” In purer air fogs would be less dense, breathing would be easier, business would be livelier, life would be happier.

Few, I suppose, have laid their hands on this curious Latin thesis, or its quaint translation, directing the King’s attention to the fogs that were ruining London. Since that time the city [Pg 83] has increased, from little more than a village, to be the dwelling-place of six millions of human beings, yet too little improvement has been made in the removal of this fog nuisance. King Edward’s drive through London would be even more dangerous on a muggy, frosty day than was Charles II.’s, when science was little known.

CHAPTER XXV

ELECTRICAL DEPOSITION OF SMOKE

A good deal of scientific work is being done in the way of clearing away fog and smoke; and this, through time, may have some practical results in removing a great source of annoyance, illness, and danger in large towns. Sir Oliver Lodge and Dr. Aitken have been throwing light upon the deposition of smoke in the air by means of electricity.

If an electric discharge be passed through a jar containing the smoke from burnt magnesium wire, tobacco, brown paper, and other substances, the dust will be deposited so as to make the air clear. Brush discharge, or anything that electrifies the air itself, is the most expeditious.

If water be forced upwards through a vertical tube (with a nozzle one-twentieth of an inch in diameter), it will fall to the ground in a fine rain; but, if a piece of rubbed (electrified) sealing-wax be held a yard distant from the place where the jet breaks into drops, they at once fall in large spots as in a thunder-shower. If paper be put on the ground during the experiment, the sound of pattering will be observed to be quite different. If a kite be flown into a cloud, and made to give off electricity for some time, that cloud will begin to condense into rain. [Pg 84]

Experiments with Lord Kelvin's recorder show that variations in the electrical state of the atmosphere precede a change of weather. Then, with a very large voltaic battery, a tremendous quantity of electricity could be poured into the atmosphere, and its electrical condition could be certainly disturbed. If this could be made practically available, how useful it would be to farmers when the crops were suffering from excessive drought! It might be more powerfully available than the imagined condensation of a cloud into rain by the reverberation caused by the firing of a range of cannon.

But what is the practical benefit of this information? If electricity deposits smoke, it might be made available in many ways. The fumes from chemical works might be condensed; and the air in large cities, otherwise polluted, might be purified and rendered innocuous. The smoke of chimneys in manufacturing works might be prevented from entering the atmosphere at all. In flour-mills and coal-mines the fine dust is dangerously explosive. In lead, copper, and arsenic works, it is both poisonous and valuable.

Lead smelters labour under this difficulty of condensing the fume which escapes along with the smoke from red-lead smelting furnaces; and it was considered that an electrical process of condensation might be made serviceable for the purpose. At Bagillt, the method used for collecting or condensing the lead fume is a large flue two miles long; much is retained in this flue, but still a visible cloud of white-lead fume continually escapes from the top of the chimney. There is a difficulty in the way of depositing fumes in the flue by means of a sufficient discharge of electricity, viz. the violent draught which is liable to exist there, and which would mechanically blow away any deposited dust. [Pg 85]

But Dr. Aitken suggests that regenerators might be used along with the electricity. The warm fumes might be taken to a cold depositor, where (by the ordinary law of cold surfaces attracting warm dust-particles) the impurities would be removed, and, when purified, the air would again be taken through a hot regenerator before being sent up the chimney. By a succession of these chambers, with the assistance of electric currents, the air, impregnated with the most deleterious particles, or valuable dust, could be rendered innocuous.

The sewage of our towns must be cleaned of its deleterious parts before being run into the streams which give drink to the lower animals, because an Act of Parliament enforces the process. Why, then, ought we not to have similar compulsion for making the smoke from chemical and other noxious works quite harmless before being thrown into the air which contains the oxygen necessary for the life of human beings?

There seems to be a good field before electricians to catch the smoke on the wing and deposit its dust on a large scale. This seems to be a matter beyond our reach at present, except in the scientist's laboratory; but certainly it is a "consummation devoutly to be wished."

CHAPTER XXVI [Pg 86]

RADIATION FROM SNOW

One night a most interesting paper by Dr. Aitken, on "Radiation from Snow," was read by Professor Tait to the Fellows of the Royal Society of Edinburgh. I remember that Dr. Alex. Buchan—the greatest meteorologist living—spoke afterwards in the very highest terms of the subject-matter of the paper. This was corroborated by Lord Kelvin, Lord MacLaren, and Professor Chrystal.

Dr. Aitken had been testing the radiating powers of different substances. Snow in the shade on a bright day at noon is 7° Fahr. colder than the air that floats upon it, whereas a black surface at the same is only 4° colder. This difference diminishes as the sun gets lower; and at night both radiate almost equally well.

I select, among the careful and numerous observations, the notes on January 19, 1886; for I took note of the cold of that day in my diary. It was the coldest day of the whole of that winter. The barometer was 28·8 inches, and the thermometer 4°—that is, 28° of frost. According to Dr. Buchan, that January had only two equal in average cold for fifty years.

On January 19, at 10 A.M., when the air was at 20° and the sky clear, a black surface registered 16° and the upper layer of snow 12°, showing a difference of 4° when both surfaces were colder than the superincumbent air. It is curious to note that, on February 5 [Pg 87] of the same year, at the same hour, when the sky was overcast, the air was at 23°, the black surface registered 29°, and the snow 25°, showing again the difference of 4°; but, in this case, both surfaces were warmer than the air. In both cases the radiation at night was equal.

This small absorbing power of snow for heat reflected and radiated from the sky during the day must have a most important effect on the temperature of the air. The temperature of lands when covered with snow must be much lower than when free from it. And, when once a country has become covered with snow, there will be a tendency towards glacial conditions.

But, besides being a bad absorber of heat from the sky, snow is also a very poor conductor of heat. On that very cold night (January 18), when there was a depth of 5½ inches of snow on the ground, and the night clear, with strong radiation, the temperature of the surface of the snow was 3° Fahr., and a minimum thermometer on the snow showed that it had been down to zero some time before. A thermometer, plunged into the snow down to the grass, gave the most remarkable register of 32°. Through the depth of 5½ inches of snow there was a difference of temperature of 29°. This was confirmed by removing the snow, and finding that the grass was unfrozen. As the ground was frozen when the snow fell, it would appear that the earth's heat slowly thawed it under the protection of the snow.

The protection afforded by the bad-conducting power of snow is of great importance in the economy of nature. How vegetation would suffer, were it exposed to a low temperature, [Pg 88] unprotected by the snow-mantle! So that, though the continued snow cools the air for animals that can look after their own heating, it keeps warm the soil; and vegetation prospers under the genial covering. The fine rich look of the young wheat-blades, after a continued snow has melted, must strike the most careless observer. Instead of the half-blackened tips and semi-sickly blades, which we see in a field of young wheat after a considerable course of dry frost without snow, we have a rich, healthy green which shows the vital energy at work in the plants. Or even in the town gardens, after a continued snow has been melted away by a soft, western breeze, we are struck with the white, peeping buds of the snowdrop and the finely springing grass in the sward.

Yet the snow-covering gives durability to cold weather. This has been demonstrated by Dr. Wœikof, the distinguished Russian meteorologist. On this account the spring months of Russia and Siberia are intensely cold. The plants, then, which in winter are unable by locomotion to keep themselves in health, are protected by the snow-mantle which chills the air for animals that can keep themselves in heat by exercise. What a grand compensating power is here!

CHAPTER XXVII

MOUNTAIN GIANTS

Some mysterious physical phenomena can be clearly explained by the aid of science. The mountain giants that at times haunt the lonely valleys, and strike with fear the superstitious [Pg 89] dwellers there, are only the enlarged shadows of living human beings cast upon a dense mist.

The two most startling of these "eerie" phenomena are the spectres of Adam's Peak and the Brocken.

The phenomena sometimes to be observed at Adam's Peak, in Ceylon, are very remarkable. Many travellers have given vivid accounts of these. On one occasion the Hon. Ralph Abercromby, in his praiseworthy enthusiasm for meteorological research, went there with two scientific friends to witness the strange appearance. The conical peak, a mile and a half high, overlooks a gorge west of it. When, then, the north-east monsoon blows the morning mist up the valley, light wreaths of condensed vapour pass to the right of the Peak, and catch the shadows at sunrise.

This party reached the summit early one morning in February. The foreglow began to brighten the under-surface of the stratus-cloud with orange, and patches of white mist filled the hollows. Soon the sun peeped through a chink in the clouds, and they saw the pointed shadow of the Peak lying on the misty land. Then a prismatic circle, with the red inside, formed round the shadow. The meteorologist waved his arms about, and immediately he found giant shadowy arms moving in the centre of the rainbow.

Soon they saw a brighter and sharper shadow of the Peak, encircled by a double bow, and their own spectral arms more clearly visible. The shadow, the double bow, and the giant forms, combined to make this phenomenon the most marked in the whole world. [Pg 90]

The question has been frequently asked: Why are such aërial effects not more widely observed? There are not many mountains of this height and of a conical shape; and still fewer can there be where a steady wind, for months together, blows up a valley so as to project the rising morning mist at a suitable height and distance on the western side, to catch the shadow of the peak at sunrise.

The most famous place in Europe for witnessing the awe-inspiring phenomenon is the Brocken, in Germany—3740 feet in height. The only great disappointment there is that the conditions rarely combine at sunrise or sunset to have "the spectre" successful.

In July 1892, my daughter and I were spending some weeks at Harzburg, and, of course, we had to visit the Brocken and take stock of the world-known phenomenon. At mid-day, the air at the flat summit was cold, clear, and hard. The boulders are of enormous size; and near the "Noah's Ark" Hotel and Observatory many are piled up in a mass, on which the observers stand at the appointed time for having their shadows projected on the misty air in the valleys.

At five o'clock in the afternoon the sky was brilliantly clear on the summit of the Brocken; but the wind was rising from the sun's direction, and the mist was filling up the wide-spread eastern valley. We stood on the "spectre" boulders, and our shadows were thrown on the grass, just as at home. However, they fell upon large patches of white heather, which there is very plentiful. [Pg 91]

At six o'clock the sun was still shining beautifully, and we anxiously waited for the time when it would be low enough to raise our shadows to the misty wall. An hour afterwards, a hundred visitors were out, and many of us were on the "spectre" stones. There was great excitement in anticipation of the weird appearances, which had attracted us from such a distance.

But, almost at the moment of success, the sun descended behind a belt of purple cloud, and all we saw was part of a rainbow on the misty hollow. For the sun never appeared again. This was intensely saddening, seeing that, but for that stratum of cloud above the horizon, the phenomenon would have been graphically displayed.

The cold became suddenly intense, and we had to sleep with a freezing mist enveloping the hotel. In vain did we wait for the wakening call, to tell us of sunrise; for the sun could not pierce the mist, and we had to return home disappointed.

Sometimes the rainbow colours assume the shapes of crosses instead of circles. Occasionally a bright halo will be seen above the shadow-head of the observer, concentric rainbows enclosing all. In some recorded cases the grand effect must have been simply glorious.

Scientific observation has done much to dispel the superstition which has clung so tenaciously to the Highland mind. The lonely grandeur of the weird mountain giants has been clearly explained as perfectly natural, yet the awe-striking feeling cannot be entirely driven off.

CHAPTER XXVIII [Pg 92]

THE WIND

Once was the remark pointedly made: "The wind bloweth where it listeth." And that is nearly true still. The leading winds are under the calculation of the meteorologist, but the others will not be bound by laws.

Yet there are instruments for measuring the velocity and force of the wind, after it is on; but "whence it comes" is a different matter. A gentle air moves at the rate of 7 miles an hour; a hurricane from 80 to 150 miles, pressing with 50 lbs. on the square foot exposed to its fury. Some of the gusts of the Tay Bridge storm, in 1879, had a velocity of 150 miles an hour, with a pressure of 80 to 90 lbs. to the square foot.

Before steamers supplanted so many sailing vessels, seamen required to be always on the alert as to the direction and strength of the wind, and the likelihood of any sudden change; and they chronicled twelve different strengths from "faint air" to a "storm."

In general, the wind may be considered to be the result of a change of pressure and temperature in the atmosphere at the same level. The air of a warmer region, being lighter, ascends, and gives place to a current of wind from a colder region. These two currents—the higher and the lower—will continue to blow until there is equilibrium.

The trade winds are regular and constant. These were much followed in the days of old. A [Pg 93]
vast amount of air in the tropics gets heated and ascends, being lighter, and travels to the colder north. A strong current rushes in from the north to take its place. But the earth rotates round its axis from west to east, and the combined motions make two slant wind directions, which are called the "trade winds," because they were so important in trade navigation.

Among the periodical winds are the "land and sea breezes." During the day, the land on the sea coast is warmer than the sea; accordingly, the air over the land becomes heated and ascends, the fine cool breeze from the sea taking its place. Towards evening there is the equilibrium of temperature which produces a temporary calm. Soon the earth chills, and the sea is counterbalancingly warm—as sea-water is steadier as to temperature than is land—the air over the sea becomes warmer, and ascends, the current from the land rushing in to take its place. Hence during the night the wind is reversed, until in the morning again the equilibrium is restored and there is a calm, so far as these are concerned. These are therefore called the "land and sea breezes." Of course, it is within the tropics that these breezes are most marked. By the assistance of other winds, a hurricane will there occasionally destroy towns and bring about much damage and loss of life; but better that hundreds should perish by a hurricane than thousands by the pestilence which, but for the storm, would have done its dire work.

In countries where the differences of pressure are more marked than the differences of
temperature, in the surrounding regions the strength of the wind thereby occasioned is far [Pg 94]
stronger than the land and sea breezes.

The variable winds are more conflicting. These depend on purely local causes for a time, such as "the nature of the ground, covered with vegetation or bare; the physical configuration of the surface, level or mountainous; the vicinity of the sea or lakes, and the passage of storms." Among these winds are the simoom and sirocco.

The *east* winds, which one does not care about in the British Islands during the spring time, are occasioned by the powerful northern current which rushes south from the northern regions in Europe. Dr. Buchan points out a very common mistake among even intelligent observers who shudder at the hard east winds. It is generally held that these winds are damp. They are unhealthy, but they are dry. It is quite true that many easterly winds are peculiarly moist; all that precede storms are so far damp and rainy; and it is owing to this circumstance that, on the east coast of Scotland, the east winds are searching and carry most of the annual rainfall there. But all of these moist easterly winds, however, soon turn to some westerly point. The real east wind, so much feared by invalids, does not turn to the west; it is exceeding dry. Curious is it that brain diseases, as well as consumption, reach their height in Britain while east winds prevail. Once in Edinburgh, during the early spring, I had rheumatic fever, and during my convalescence my medical adviser, Dr. Menzies, would
not let me have a short drive until the wind changed to the west. The first thing I anxiously [Pg 95]
watched in the morning was the flag on the Castle; and for nearly two months it always waved from the east. How heart-depressing!

Creatures are we in the hands of nature's messengers. We so much depend upon the weather for our happiness. Joyful are we when the honey-laden zephyr waves the long grass in June, or when

> "The gentle wind, a sweet and passionate wooer,
> Kisses the blushing leaf."

Compared with this, how terrible is Shakespeare's allusion to the appalling aspects of the storm:—

> "I have seen tempests, when the scolding winds
> Have rived the knotty oaks; and I have seen
> The ambitious ocean swell, and rage and foam,
> To be exalted with the threat'ning clouds;
> But never till to-night, never till now,
> Did I go through a tempest dropping fire."

CHAPTER XXIX

CYCLONES AND ANTI-CYCLONES

The criticism of the weather in the meteorological column of our daily newspapers invariably speaks of "cyclones." It is, therefore, advisable to give as plain an explanation of these as possible. Cyclones are "storm-winds." Their nature has to be carefully studied by meteorologists, who are industriously at work to ascertain some scientific basis for the atmospheric movements.

What is the cause of the spiral movement in storm-winds? In their centre the depression of the barometer is lowest, because the atmosphere there is lightest. As the walls of the spiral are approached, the barometer rises. [Pg 96]

Dr. Aitken has ingeniously hit upon an experiment to illustrate a spiral in air. All that is necessary is a good fire, a free-going chimney, and a wet cloth. The cloth is hung up in front of the fire, and pretty near it, so that steam rises readily from its surface; and, when there are no air-currents in the room, the steam will rise vertically, keeping close to the cloth. But if the room has a window in the wall, at right angles to the fireplace, so as to cause the air coming from it to make a cross-current past the fire, then a cyclone will be formed, and the vapour from the cloth will be seen circling round. When the cyclone is well formed, all the vapour is collected into the centre of the cyclone, and forms a white pillar extending from the cloth to the chimney. This experiment shows that no cyclone can form without some tangential motion in the air entering the area of low-pressure.

Now to illustrate the spiral approach. Fill with water a cylindrical glass vessel, say 15 inches in diameter and 6 inches deep. Have an orifice with a plug a little from the centre of the bottom. Remove the plug, the water runs out, passing round the vessel in a vortex form. But, as the passage between the orifice (or centre of the cyclone) and the temporary division is narrower than in any other place, the water has to pass this part much more quickly than at any other place. And this curious result is observed: the top of the cyclone no longer remains [Pg 97] over the orifice, but *travels* in the direction of the water which is moving most speedily. Similar to this is the cyclone in the atmosphere; its centre also moves in the direction of the quickest flowing wind that enters it.

Dr. Aitken is of opinion that, in forecasting storms, too little attention has been paid to the *anti-cyclones*. They do more than simply follow and fill up the depression made by the cyclones. They initiate and keep up their own circulation, and collect the materials with which the cyclones produce their effect. Neither could work efficiently without the other.

Suppose a large area on the earth over which the air is still in bright sunshine. After a time, when the air gets heated and charged with vapour, columns of air would begin to ascend in a disorderly fashion. But suppose an anti-cyclone is blowing at one side of this area. When the upper air descends to the earth, it spreads outwards in all directions; but the earth's rotation interferes and changes the radial into a spiral motion. The anti-cyclonic winds will prevent the formation of local cyclones, and drive all the moist, hot air to its circumference, just above the earth. The anti-cyclone forces its air tangentially into the cyclone, and gives it its direction and velocity of rotation, also the direction and rate of travel of the centre of depression. The earth's rotation is the original source of the rotatory movements, but both intensify the initial motion.

Accordingly, the cyclone must travel in the direction of the strongest winds blowing into it, just as the vortex in the vessel with the eccentric orifice travelled in the direction of the [Pg 98] quickest moving water. This is verified by a study of the synoptic charts of the Meteorological Office.

The sun's heat has always been looked upon as the main source of the energy of our winds, but some account must also be taken of the effects of cold. It is well known that the mean pressure over Continental areas is high during winter and low during summer. As the sun's rays during summer give rise to the cyclonic conditions, so the cooling of the earth during winter gives rise to anti-cyclonic conditions. It is found during the winter months in several parts of the Continent that as the temperature falls the pressure rises, producing anti-cyclones over the cold area; whereas, when the temperature begins to rise, the pressure falls, and cyclones are attracted to the warming area.

Small natural cyclones are often seen on dusty roads, the whirling column having a core of dusty air, and the centre of the vortex travelling along the road, tossing up the dust in a very disagreeable way to pedestrians. Sometimes such a cyclone will toss up dry leaves to a height of four or five feet. They are very common; but it is only when dust, leaves, or other light material is present that they are visible to the eye.

CHAPTER XXX

RAIN PHENOMENA

The soft rain on a genial evening, or the heavy thunder-showers on a broiling day, are too well known to be written about. Sometimes rain is earnestly wished for, at other times it is [Pg 99] dreaded, according to the season, seed-time or harvest. Some years, like 1826, are very deficient in rainfall, when the corn is stunted and everything is being burnt up; other years, like 1903, there is an over-supply, causing great damage to agriculture. The year 1903 will long be remembered for its continuous rainfall; it is the record year; no year comes near it for the total rainfall all over the kingdom.

Rain is caused by anything that lowers the temperature of the air below the dew-point, but especially by winds. When a wind has blown over a considerable area of ocean on to the land, there is a likelihood of rain. When this wind is carried on to higher latitudes, or colder parts, there is a certainty of rain. Of course, in the latter case the rain will fall heavier on the wind side than on the lee side.

For short periods, the heaviest falls or "plouts" of rain are during thunder-storms. When the raindrops fall through a broad, cold stratum of air, they are frozen into hail, the particles of which sometimes reach a large size, like stones. Of course, water-spouts now and again are of terrible violence.

One of the heaviest rainfalls yet recorded in Great Britain was about 2¼ inches in forty minutes at Lednathie, Forfarshire, in 1887. Now 1 inch deep of rain means 100 tons on an imperial acre; so the amount of water falling on a field during that short time is simply startling. The heaviest fall for one day was at Ben Nevis Observatory, being fully 7¼ inches in 1890. In other parts of the world this is far exceeded. In one day at Brownsville, Texas, [Pg 100] nearly 13 inches fell in 1886. On the Khasi hills, India, 30 inches on each of five successive days were registered. At Gibraltar, 33 inches were recorded in twenty-six hours.

The heaviest rainfalls of the globe are occasioned by the winds that have swept over the most extensive ocean-areas in the tropics. On the summer winds the rainfall of India mainly depends; when this fails, there is most distressing drought. Reservoirs are being erected to meet emergencies.

From Dr. Buchan's statistics it is found that the annual rainfall at Mahabaleshwar is 263 inches; at Sandoway 214; and at Cherra-pungi 472 inches, the largest known rainfall anywhere on the globe. Over a large part of the Highlands of Scotland more than 80 inches fall annually, while in some of the best agricultural districts there it does not exceed 30 inches.

Of all meteorological phenomena, rainfall is the most variable and uncertain. Symons gives as tentative results from twenty years' observations in London—(1) In winter, the nights are wetter than the days; (2) in spring and autumn, there is not much difference; (3) in summer, nearly half as much again by day as by night.

The wearisomeness of statistics may be here relieved by a short consideration of the *splash* of a drop of rain. Watching the drop-splashes on a rainy day in the outskirts of the city, when unable to get out, I brought to my recollection the marvellous series of experiments made by Professor A. M. Worthington in connection with these phenomena. Of course, I could not see to proper advantage the formation of the splashes, as the heavy raindrops fell into these tiny [Pg 101] lakes on the quiet road. There is not the effect of the huge thunder-drops in a stream or pool. The building up of the bubbles is not here perfect, for the domes fail to close, nor are the emergent columns visible to the naked eye. It is a pity; for R. L. Stevenson once wrote of them in his delightful "Inland Voyage," when he canoed in the Belgian canals, as thrown up by the rain into "an infinity of little crystal fountains."

Beautiful is this effect if one is under shelter, every dome seeming quite different in contour and individuality from all the rest. But terrible is it when out fishing on Loch Earn, even with the good-humoured old Admiral, when the heavy thunder-drops splash up the crystal water, and one gets soaked to the skin, sportsman-like despising an umbrella.

There is, however, a scientific interest about the splash of a drop. The phenomenon can be best seen indoors by letting a drop of ink fall upon the surface of pure water in a tumbler, which stands on white paper. It is an exquisitely regulated phenomenon, which very ideally illustrates some of the fundamental properties of fluids.

When a drop of milk is let fall upon water coloured with aniline dye, the centre column of the splash is nearly cylindrical, and breaks up into drops before or during its subsequent descent into the liquid. As it disappears below the surface, the outward and downward flow causes a hollow to be again formed, up the sides of which a ring of milk is carried; while the remainder descends to be torn a second time into a beautiful vortex ring. This shell or dome [Pg 102] is a characteristic of all splashes made by large drops falling from a considerable height, and is extremely pretty. Sometimes the dome closes permanently over the imprisoned air, and forms a large bubble floating upon the water. The most successful experiments, however, have been carried through by means of instantaneous photography, with the aid of a Leyden-jar spark, whose duration was less than the ten-millionth of a second. But the simple experiments, without the use of the apparatus, will while away a few hours on a rainy afternoon, when condemned to the penance of keeping within doors.

CHAPTER XXXI

THE METEOROLOGY OF BEN NEVIS

Several large and very important volumes of the Royal Society of Edinburgh are devoted to statistics connected with the meteorology of Ben Nevis. Most of the abstracts have been arranged by Dr. Buchan; while Messrs. Buchanan, Omond, and Rankine have taken a fair share of the work.

This Observatory, as Mr. Buchanan remarks, is unique, for it is established in the clouds; and the observations made in it furnish a record of the meteorology of the clouds. It is 4406 feet above the level of the sea; and as there is a corresponding Observatory at Fort William, at the base of the mountain, it is peculiarly well fitted for important observations and weather forecasting. The mountain, too, is on the west sea-coast of Scotland, exposed [Pg 103] immediately to the winds from the Atlantic, catching them at first hand. It is lamentable to think that, when the importance of the observations made at the two Observatories was becoming world known, funds could not be got to carry them on. Ben Nevis is the highest mountain in the British Islands, best fitted for meteorological observations; yet these have been stopped for want of money.

Dr. Buchan's valuable papers were published before any one dreamed of the stoppage of the work, which had such an important bearing on men engaged in business or taken up with open-air sport. From these I shall sift out a few facts that even "mute, inglorious" meteorologists may be interested in knowing.

For a considerable time the importance of the study of the changes of the weather has come gradually to be recognised, and an additional impetus was given to the prosecution of this branch of meteorology when it was seen that the subject had intimate relations to the practical question of weather forecasts, including storm warnings. Weather maps, showing the state of the weather over an extensive part of the surface of the globe, began to be constructed; but these were only indicators from places at the level of the sea.

The singular advantages of a high-level observatory occurred to Mr. Milne Home in 1877; and Ben Nevis was considered to be in every respect the most suitable in this country. The Meteorological Council of the Royal Society of London offered in 1880, unsolicited, £100 annually to the Scottish Meteorological Society, to aid in the support of an Observatory, the [Pg 104] only stipulation being that the Council be supplied with copies of the observations.

From June to October, in 1881, Mr. Wragge made daily observations at the top of the Ben; and simultaneous observations were made, by Mrs. Wragge, at Fort William. A second series, on a much more extended scale, was made in the following summer.

Funds were secured to build an Observatory; and, in November 1883, the regular work commenced, consisting of hourly observations by night as well as by day. Until a short time ago, these were carried on uninterruptedly. Telegraphic communications of each day's observations were sent to the morning newspapers; and now we are disappointed at not seeing them for comparison.

The whole of the observations of temperature and humidity were of necessity eye-observations. For self-registering thermometers were comparatively useless when the wind was sometimes blowing at the rate of 100 miles an hour. Saturation was so complete in the atmosphere that everything exposed to it was dripping wet. Every object exposed to the outside frosts of winter soon became thickly incrusted with ice. Snowdrifts blocked up exposed instruments. Accordingly, the observers had to use their own eyes, often at great risks.

The instruments in the Ben Nevis Observatory, and in the Observing Station at Fort William, were of the best description. Both stations were in positions where the effects of solar and terrestrial radiation were minimised. No other pair of meteorological stations anywhere in the world are so favourably situated as these two stations, for supplying the necessary [Pg 105] observations for investigating the vertical changes of the atmosphere. It is to be earnestly hoped, therefore, that funds will be secured to resume the valuable work.

The rate of the decrease of temperature with height there is 1° Fahr. for every 275 feet of ascent, on the mean of the year. The rate is most rapid in April and May, when it is 1° for each 247 feet; and least rapid in November and December, when it is 1° for 307 feet. This rate agrees closely with the results of the most carefully conducted balloon ascents. The departures from the normal differences of temperature, but more especially the inversions of temperature, and the extraordinarily rapid rates of diminution with height, are intimately connected with the cyclones and anti-cyclones of North-Western Europe; and form data, as valuable as they are unique, in forecasting storms.

The most striking feature of the climate of Ben Nevis is the repeated occurrence of excessive droughts. For instance, in the summer and early autumn of 1885, low humidities and dew-points frequently occurred. Corresponding notes were observed at sea-level. During nights

when temperature falls through the effects of terrestrial radiation, those parts of the country suffer most from frosts over which very dry states of the air pass or rest; whereas, those districts, over which a more humid atmosphere hangs, will escape. On the night of August 31 of that year, the potato crop on Speyside was totally destroyed by the frost; whereas at Dalnaspidal, in the district immediately adjoining, potatoes were scarcely—if at all— [Pg 106]
blackened.

The mean annual pressure at Ben Nevis was 25·3 inches, and at Fort William 29·8, the difference being 4½ inches for the 4400 feet.

For the whole year, the difference between the mean coldest hour, 5 A.M., and the warmest hour, 2 P.M., is 2°. For the five months, from October to February, the mean daily range of temperature varied only from O·6 to 1·5. This is the time of the year when storms are most frequent; and this small range in the diurnal march of the temperature is an important feature in the climatology of Ben Nevis; for it presents, in nearly their simple form, the great changes of temperature accompanying storms and other weather changes, which it is so essential to know in forecasting weather.

The daily maximum velocity of the wind occurs during the night, the daily differences being greatest in summer and least in winter. A blazing sun in the summer daily pours its rays on the atmosphere, and a thick envelope of cloud has apparently but little influence on the effect of the sun’s rays. Thunder-storms are essentially autumn and winter phenomena, being rare in summer.

According to Mr. Buchanan, the weather on Ben Nevis is characterised by great prevalence of fog or mist. In continuously clear weather it practically never rains on the mountain at all. In continuously foggy weather, on the other hand, the average daily rainfall is 1 inch. There is a large and continuous excess of pressure in clear weather over that of foggy weather. The mean temperature of the year is 3½ degrees higher in clear than in foggy weather. In [Pg 107]
June the excess is 10 degrees. The nocturnal heating in the winter is very clearly observed. This has been noticed before in balloons as well as on mountains. The fog and mist in winter are much denser than in summer. Whether wet or dry, the fog which characterises the climate of the mountain is nothing but *cloud* under another name.

CHAPTER XXXII

THE WEATHER AND INFLUENZA

Some remarkable facts have been deduced by the late Dr. L. Gillespie, Medical Registrar, from the records of the Royal Infirmary of Edinburgh. He considered that it might lead to interesting results if the admissions into the medical wards were contrasted with the varying states of the atmosphere. The repeated attacks of influenza made him pay particular attention to the influence of the weather on that disease.

The meteorological facts taken comprise the weekly type of weather, *i.e.* cyclonic or anti-cyclonic, the extremes of temperature for the district for each week, and the mean weekly rainfall for the same district. More use is made of the extremes than of the mean, for rapid changes of temperature have a greater influence on disease than the actual mean.

The period which he took up comprises the seven years 1888-1895. There was a yearly average of admissions of 3938; so that he had a good field for observation. Six distinct [Pg 108]
epidemics of influenza, varying in intensity, occurred during that period; yet there had been only twenty-three attacks between 1510 and 1890. Accordingly, these six epidemics must have had a great influence on the incidence of disease in the same period, knowing the vigorous action of the poison on the respiratory, the circulatory, and the nervous systems. The epidemics of influenza recorded in this country have usually occurred during the winter months.

The first epidemic, which began on the 15th of December 1889 and continued for nine weeks, was preceded by six weeks of cyclonic weather, which was not, however, accompanied by a heavy rainfall. Throughout the course of the disease, the type continued to be almost exclusively cyclonic, with a heavy rainfall, a high temperature, and a great deficiency of sunshine. The four weeks immediately following were also chiefly cyclonic, but with a smaller rainfall.

The summer epidemic of 1891 followed a fine winter and spring, during which anti-cyclonic conditions were largely prevalent. But the epidemic was immediately preceded by wet weather and a low barometer. It took place in dry weather, and was followed by wet, cyclonic weather in turn.

The great winter epidemic of 1891 followed an extremely wet and broken autumn.

Simultaneously with the establishment of an anti-cyclone, with east wind, practically no rain, and a lowering temperature, the influenza commenced. Great extremes in the temperature followed, the advent of warmer weather and more equable days witnessing the [Pg 109] disappearance of the disease.

The fourth epidemic was preceded by a wet period, ushered in by dry weather, accompanied by great heat; and its close occurred in slightly wetter weather, but under anti-cyclonic conditions. The fifth outbreak began after a short anti-cyclone had become established over our islands, continued during a long spell of cyclonic weather with a considerable rainfall, but was drowned out by heavy rains. The last appearance of the modern plague, of which Dr. Gillespie's paper treats, commenced after cold and wet weather, continued in very cold but drier weather, and subsided in warmth with a moderate rainfall.

The conditions of these six epidemics were very variable in some respects, and regular in others. The most constant condition was the decreased rainfall at the time, when the disease was becoming epidemic. Anti-cyclonic weather prevailed at the time.

According to Dr. Gillespie, the tables seem to suggest that a type of weather, which is liable to cause catarrhs and other affections of the respiratory tract, precedes the attacks of influenza; but that the occurrence of influenza in *epidemic form* does not appear to take place until another and drier type has been established. As the weather changes, the affected patients increase with a rush.

He is of opinion that the supposed rapid spread of influenza on the establishment of anti-cyclonic conditions may be explained in this way. The air in the cyclonic vortex, drawn chiefly from the atmosphere over the ocean, is moist, and contains none of the contagion; [Pg 110] the air of the anti-cyclone, derived from the higher strata, and thus from distant cyclones, descending, blows gently over the land to the nearest cyclone, and, being drier, is more able to carry suspended particles with it. He considers that temperature has nothing to do with the problem, except in so far as the different types of weather may modify it. The Infirmary records point to the occurrence of similar phenomena, recorded on previous occasions. Accordingly, if such meteorological conditions are not indispensable to the spread of influenza in epidemic form, they at least afford favourable facilities for it.

CHAPTER XXXIII

CLIMATE

One is not far up in years, in Scotland at any rate, without practically realising what climate means. He may not be able to put it in words, but easterly haars, chilling rimes, drizzling mists, dagging fogs, and soddening rains speak eloquently to him of the meaning of climate.

Climate is an expression for the conditions of a district with regard to temperature, and its influence on the health of animals and plants. The sun is the great source of heat, and when its rays are nearly perpendicular—as at the Tropics—the heat is greater on the earth than when the slanted rays are gradually cooled in their passage. As one passes to a higher level, he feels the air colder, until he reaches the fluctuating snow-line that marks perpetual snow. [Pg 111]

The temperature of the atmosphere also depends upon the radiation from the earth. Heat is quite differently radiated from a long stretch of sand, a dense forest, and a wide breadth of water. Strange is it that a newly ploughed field absorbs and radiates more heat than an open lea. The equable temperature of the sea-water has an influence on coast towns. The Gulf Stream, from the Gulf of Mexico, heats the ocean on to the west coast of Britain, and mellows the climate there.

The rainfall of a district has a telling effect on the climate. Boggy land produces a deleterious climate, if not malaria. Over the world, generally, the prevailing winds are grand regulators of the climate in the distinctive districts. A wooded valley—like the greatest in Britain, Strathmore—has a health-invigorating power: what a calamity it is, then, that so many extensive woods, destroyed by the awful hurricane twelve years ago, are not replanted!

Some people can stand with impunity any climate; their "leather lungs" cannot be touched by extremes of temperature; but ordinary mortals are mere puppets in the hands of the goddess climate. Hence health-resorts are munificently got up, and splendidly patronised by people of means. The poor, fortunately, have been successful in the struggle for existence, by innate hardiness, otherwise they would have had a bad chance without ready cash for purchasing health.

It may look ludicrous at first sight, but it seems none the less true, that the variation of the spots on the sun have something to do with climate, even to the produce of the fields. On [Pg 112] close examination, with a proper instrument, the disc of the sun is found to be here and there studded with dark spots. These vary in size and position day after day. They always make their first appearance on the same side of the sun, they travel across it in about fourteen days, and then they disappear on the other side. There is a great difference in the number of spots visible from time to time; indeed, there is what is called the minimum period, when none are seen for weeks together, and a maximum period, when more are seen than at any other time. The interval between two maximum periods of sun-spots is about eleven years. This is a very important fact, which has wonderful coincidences in the varied economy of nature.

Kirchhoff has shown, by means of the spectroscope, that the temperature of a sun-spot must be lower than that of the remainder of the solar surface. As we must get less heat from the sun when it is covered with spots than when there are none, it may be considered a variable star, with a period of eleven years. Balfour Stewart and Lockyer have shown that this period is in some way connected with the action of the planets on the photosphere. As we have already mentioned, the variations of the magnetic needle have a period of the same length, its greatest variations occurring when there are most sun-spots. Auroræ, and the currents of electricity which traverse the earth's surface, follow the same law. This remarkable coincidence set men a-thinking. Can the varying condition of the sun exert any influences upon terrestrial affairs? Is it connected with the variation of rainfall, the temperature and pressure of the atmosphere, and the frequency of storms? Has the regular periodicity of eleven years in the sun-spots no effect upon climate and agricultural produce? [Pg 113]

Mr. F. Chambers, of Bombay, has taken great trouble to strike, as far as possible, a connection between the recurring eleven years of sun-spots and the variation of grain prices. He arranged the years from 1783 to 1882 in nine groups of eleven years; and, from an examination of his tables, we find that there is a decided tendency for high prices to recur at more or less regular intervals of about eleven years, and a similar tendency for low prices. An occasional slight difference can be accounted for by some abnormal cause, as war or famine.

Amid all the apparently irregular fluctuations of the yearly prices, there is in every one of the ten provinces of India a periodical rise and fall of prices once every eleven years, corresponding to the regular variation which takes place in the number of sun-spots during the same period. If it were possible to obtain statistics to show the actual out-turn of the crops each year, the eleven yearly variations calculated therefrom might reasonably correspond with the sun-spot variations even more closely than do the price variations.

This is a remarkable coincidence, if nothing more. What if it were yet possible to predict the variations of prices in the coming sun-spot cycle? Such a power would be of immense service. By its aid it could be predicted that, as the present period of low prices has followed the last maximum of sun-spots, which was in the year 1904, it will not last much longer, but that prices must gradually keep rising for the next five years. Could science really predict this, it would be studied by many and blessed by more. Yet the strange coincidence of a century's observations renders the conclusions not only possible, but to some extent probable. [Pg 114]

CHAPTER XXXIV

THE "CHALLENGER" WEATHER REPORTS

The *Challenger* Expedition, commenced by Sir Wyville Thomson, and after his death continued by Sir John Murray, with an able staff of assistants for the several departments, was one of the splendid exceptions to the ordinary British Government stinginess in the furtherance of science. The results of the Expedition were printed in a great number of very handsome volumes at the expense of the Government.

And the valuable deductions from the *Challenger's* Weather Reports by Dr. Alex. Buchan, in his "Atmospheric Circulation," have thrown considerable light upon oceanic weather phenomena. For some of his matured opinions on these, I am here much indebted to him.

Humboldt, in 1817, published a treatise on "Isothermal Lines," which initiated a fresh line for the study of atmospheric phenomena. An isotherm is an imaginary line on the earth's surface, passing through places having a corresponding temperature either throughout the year or at any particular period. An isobar is an imaginary line on the earth's surface, connecting places at which the mean height of the barometer at sea-level is the same. To isobars, as well as to isotherms, Dr. Buchan has devoted considerable attention. In 1868, he published an important series of charts containing these, with arrows for prevailing winds over the earth for the months of the year. In this way what are called synoptic charts were established. [Pg 115]

In the *Challenger* Report are shown the various movements of the atmosphere, with their corresponding causes. It is thus observed that the prevailing winds are produced by the inequality of the mass of air at different places. The air flows from a region of higher to a region of lower pressure, *i.e.* from where there is an excessive mass of air to fill up some deficiency. And this is the great principle on which the science of meteorology rests, not only as to winds, but as to weather changes.

Of the sun's rays which reach the earth, those that fall on the land are absorbed by the surface layer of about 4 feet in thickness. But those that fall on the surface of the ocean penetrate, as shown by the observations of the *Challenger* Expedition, to a depth of about 500 feet. Hence, in deep waters the temperature of the surface is only partially heated by the direct rays of the sun. In mid-ocean the temperature of the surface scarcely differs 1° Fahr. during the whole day, while the daily variation of the surface layer of land is sometimes 50°. The temperature of the air over the ocean is about three times greater than that of the surface of the open sea over which it lies; but, near land, this increases to five times.

The elastic force of vapour is seen in its simplest form on the open sea, as disclosed by these Reports. It is lowest at 4 A.M. and highest at 2 P.M. The relative humidity is just the reverse. When the temperature is highest, the saturation of the air is lowest, and *vice versâ*. So on land when the air, by radiation of heat from the earth, is cooled below the dew-point, dew is produced, and, at the freezing-point, hoar-frost. [Pg 116]

The *Challenger* Reports, too, show that the force of the winds on the open sea is subject to no distinct and uniform daily variation, but that on nearing land the force of the wind gives a curve as distinctly marked as the ordinary curve of temperature. That force is lowest from 2 to 4 A.M., and highest from 2 to 4 P.M. Each of the five great oceans gives the same result. At Ben Nevis, on the other hand, these forces are just reversed in strength.

It is also shown by the *Challenger* observations that on the open sea the greatest number of thunder-storms occur from 10 P.M. to 8 A.M. And, from this, Dr. Buchan concludes that over the ocean terrestrial radiation is more powerful than solar radiation in causing those vertical disturbances in the equilibrium of the atmosphere which give rise to the thunder-storm.

CHAPTER XXXV

WEATHER-FORECASTING

To foretell with any degree of certainty the state of the weather for twenty-four hours is of immense advantage to business men, tourists, fishermen, and many others. The weather is everybody's business. And the probabilities of accurate forecasts are so improving that all are more or less giving attention to the morning meteorological reports. [Pg 117]

Weather-forecasting depends on the principle from vast experience that, if one event happens, a second is likely to follow. According to the extent and accuracy of the data, will be the strength of the probability of correct forecasts. And the great end of popular meteorology is to demonstrate this.

We have given some explanations of the weather in some respects unique; and a careful consideration of these explanations will the more convince the reader of the importance of the subject. No doubt the changes of the weather are extremely complex, at times baffling; and the wonder is that forecasts come so near the truth.

For instance, the year 1903 almost defied the ordinary rules of weather, for it broke the record for rainfall. And, last year, so repulsive and unseasonable was the spring, that there seemed to be a virtual "withdrawal" of the season. I wrote on it as "The Recession of Spring." Speak about Borrowing Days! We had the equinoctial gales of March about the middle of April. On very few days had we "clear shining to cheer us after rain," for the bitter cold dried up any genial moisture. An old farmer remarked that "We're gaun ower faur North." No one could account for the backwardness of the season. Unless for the cheering songs of the grove-charmers, one would have forgotten the time of the year.

In March of this year, at Strathmore, the barometer fell from 30·5 inches (the highest for years) to 28·65 in five days without unfavourable weather following. It again rose to 30·05, then fell to 28·45, followed by a rise to 28·7 without any peculiar change. But in two days it fell to 28·4 (the lowest for years), followed by a deluge of rain and a perfect hurricane for several hours, while the temperature was fortunately mild. It was only evident at the end that this universal storm had been "brewing" some days before. [Pg 118]

All are familiar with the ordinary prognostics of good and bad weather. A "broch" round the moon, in her troubled heaven, indicates a storm of rain or wind. When the dark crimson sun in the evening throws a brilliant bronzed light on the gables and dead leaves, we are sure that there is an intense radiation from the earth to form dew, or even hoar-frost.

According to the meteorological folk-lore, the weather of the summer season is indicated by the foliation of the oak and ash trees. If the oak comes first into leaf, the summer will be hot and dry, if the ash has the precedence it will be wet and cold. Looking over the observations of the budding of these two trees for half a century, I find that the weather-lore adage has been pretty correct. The ash was out before the oak a full month in the years 1816, ’17, ’21, ’23, ’28, ’29, ’30, ’38, ’40, ’45, ’50, and ’59; and the summer and autumn in these years were unfavourable. Again, the oak was out before the ash several weeks in the years 1818, ’19, ’20, ’22, ’24, ’25, ’26, ’27, ’33, ’34, ’35, ’36, ’37, ’42, ’46, ’54, ’68, and ’69; the summers during these years were dry and warm, and the harvests were abundant. One can never [Pg 119] think of this weather prognostic from nature without recalling the Swallow Song of Tennyson’s “Princess”:—

> “Why lingereth she to clothe her heart with love,
> Delaying, as the tender ash delays
> To clothe herself, when all the woods are green?”

On a muggy morning a sudden clearness in the south “drowns the ploughman.” And yet enough blue in the sky “tae mak’ a pair o’ breeks” cheers one with the assurance of coming dry and sunny weather. The low flying of the swallows betokens rain, as well as any unseasonable dancing of midges in the evening. Sore corns on the feet, and rheumatism in the joints, are direful precursors. The leaves are all a-tremble before the approach of thunder. But throughout this volume I have given many illustrations.

But one of the largest and most important practical problems of meteorology is to ascertain the course which storms follow, and the causes by which that course is determined, so that a forecast may thereby be made, not only of the certain approach of a storm, but the particular direction and force of the storm. The method of conducting this large inquiry most effectively was devised by the French astronomer, Le Verrier—the great aspirant, with our own Couch Adams, for the discovery of the planet Neptune. He began to carry this out in 1858 by the daily publication of weather data, followed by a synchronous weather map, which showed graphically for the morning of the day of publication the atmospheric pressure and the direction and force of the wind, together with tables of temperature, [Pg 120] rainfall, cloud, and sea disturbances from a large number of places in all parts of Europe. It is from similar maps that forecasts of storms are still framed, and suitable warnings issued; and a mass of information is being collected by telegraph from sixty stations in the British Islands, &c., of the state of the weather at eight o’clock every morning, and analysed and arranged at the Meteorological Office in London for the evening’s forecasts over the different districts of the country. A juster knowledge is being now acquired of those great atmospheric movements, and other changes, which form the groundwork of weather-forecasting.

The Meteorological Office, Westminster (entirely distinct from the Royal Meteorological Society), is administered by a Council (Chairman, Sir R. Strachey; Scottish member, Dr. Buchan), selected by the Royal Society. It employs a staff of over forty. The chief departments relate to: (1) Ocean Meteorology, including the collection, tabulation, and discussion of meteorological data from British ships, the preparation of ocean weather charts, and the issue of meteorological instruments to the Royal Navy and Mercantile Marine; (2) Weather Telegraphy, including the reception of telegrams thrice a day from selected stations for the preparation of the daily reports and weather forecasts. Representatives of newspapers, &c., receive copies of the 11 A.M. forecast based on the 8 A.M. observations; and also of the 8.30 P.M. forecasts based on the observations received earlier in the day. In summer and autumn harvest forecasts are issued by telegraph to individuals who will defray the cost. The Office also collects climatological data from a [Pg 121] number of voluntary and some subsidised stations. The “first order” stations include Valentia, Falmouth, Kew, and Aberdeen. These have self-recording instruments of high precision, giving a continuous record of the meteorological elements.

A Government Commission which sat last year, under the Rt. Hon. Sir Herbert Maxwell, Bart., have issued a Report, recommending a number of changes in the management and constitution of the Meteorological Office; and considerable modifications are not unlikely to take place in the near future. In his evidence before that Commission, the Chairman of the Council acknowledged that the great function of meteorologists is the collection of facts; but the interpretation of those collected facts, in a scientific manner, is still in a very immature condition. Dr. Buchan, in his evidence, confessed that forecasting by the Council is purely “by rule of thumb.” It is not possible to lay down hard and fast rules for forecasting.

With regard to the storm-warning telegrams, as a rule, the earliest trustworthy indication of the approach of a dangerous storm to the coasts of the British Isles precedes the storm by only a few hours. Delays are therefore very serious.

It is admitted by the best British meteorologists that the observations of the United States are better conducted, although the best instruments in the world are set and registered at Kew, in England. The work of weather forecasts and storm warnings is carried on with the highest degree of promptitude and efficiency at the Washington Central Office. This is [Pg 122] because the work of predictions has been hitherto the chief work of the Office: the entire time of the observers, on whose telegraphic reports the forecasts are based, is controlled by the United States Weather Bureau; and the right of precedence in the use of wires is maintained.

Professor Brückner, of Berne, has devoted a lifetime to the comparatively new treatment of climatic oscillations, based upon observations made at 321 points on the earth's surface, distributed as follows: Europe, 198; Asia, 39; N. America, 50; Cen. and S. America, 16; Australia, 12; Africa, 6. One of his conclusions is that an average time of about thirty-five years is found to intervene between one period of excess or deficiency of warmth and the next, accompanied by the opposite relative condition of moisture.

All are familiar with the hoisting of cone-warning as indication of a coming storm. This work is exceedingly important, especially for those connected with the sea by business or pleasure. On the known approach of a cyclone of dangerous intensity, special messages are sent from the London Meteorological Office, warning the coasts likely to be affected. When the cone is hoisted with its apex downwards, it means that strong south or south-west winds are to be looked for. When the cone is hoisted with its apex upwards, it indicates that strong winds from the north or north-east are expected. Of course they are merely useful precautions; but they are universally attended to by people on the sea-coast.

Though one may have reasonable doubts about the use that can be made of weather forecasts for three days, such as are now regularly issued, on account of the finical, coy, spasmodic interludes on short notice, yet there is a wonderful certainty in the daily prognostics of the direction and strength of the wind, the temperature of the air, and the likelihood of rainy or fair weather, dependent on the broad uniformity of nature. This is very serviceable for people who have now to live at high pressure in business, in the enthralling days of keen competition. And it is a great boon to those who are in search of health by travelling, or who, in innocent pleasure, desire to live as much as possible in the open air. Very little credit is given to the "gas" of the isolated "weather prophet"; but those who have confidence in the usual weather forecasts from the Meteorological Office are satisfied in their belief; and those who, in self-confidence, ignore all weather prognostics, are still weak enough to read them and act up to them. [Pg 123]

In practical meteorology, in the scientific explanation of popular weather-lore, and in the study of atmospheric phenomena, which so powerfully influence us, for gladness or discomfort, we may, as with other branches of science, even all our days, cheerfully go on in "the noiseless tenor of our way,"

"Nourishing a youth sublime,
With the fairy tales of science and the long results of time."

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