the error will at some future time be found to fall within this limit. The law of probabilities requires this, if the maximum limit falls within 1″. But who is prepared to select a particular star and say that the absolute position of this star in space cannot be more than 0·2″ in error?

e. At present an arbitrary hypothesis is necessary in the discussion of the problem. Airy assumed that the relative distances of the stars are proportional to their magnitudes; and he found slightly different results according to different modes of treatment. Safford assumed that the distances are, at least approximately, in inverse proportion to the magnitude of the proper motions. The general result of his investigations up to this point is that there is some hope of using the solar motion as a base to advance our knowledge of stellar distances. Later investigations have been made by De Ball, but the details have not yet come to hand. It is understood, however, that his results coincide in a general way with those previously obtained.

It is clear from this brief review that we have here a field of investigation worthy of the highest powers of the astronomer. The first step has been taken in the survey of the heavens carried on under the auspices of the *Gesellschaft*. It remains for the astronomers of the present generation to solve the difficulties which now environ the problem, and prepare the way for a more perfect scheme of observation in the next century.

INDIAN METEOROLOGY[1]

III.

THE next paper we shall notice is No. IX., by Fred. Chambers, on "The Winds of Kurrachee." The station dealt with is not only a representative one of the Arabian sea current, but is remarkable for exhibiting the highest average monthly wind velocity of any place in India. The observations used were furnished by a Beckley's anemograph for 1873, 1874, and 1875.[2]

In discussing the annual variation, Mr. Chambers adopts a plan which has been followed out with much success by his brother in his great work on the meteorology of the Bombay Presidency, viz. its separation into *normal* and *abnormal* north and east components.

It is thence found that the former are closely related to the corresponding barometric variations, and represent that part of the grand monsoon system which affects Kurrachee, while the latter are found to be connected with a system of local convection currents, due to (relatively) local temperature variations. These latter, though subordinate to the former in point of magnitude, are still sufficiently large to mask the true nature of the regular monsoon currents which obey the barometric law. This is more especially the case in Bengal, where, as it appears both from evidence furnished in this paper and elsewhere, the activity of the monsoon currents is far less than on the west coast of India, while the absolute efficiency of the *local* variations is about the same.[3]

Another important result deduced, is that the causes which produce the abnormal variations in the wind and pressure components, are similar to those which produce the annual variations. Thus, when the barometer rises abnormally a tenth of an inch, it is accompanied by an abnormal wind of 4·4 miles per hour from N. 55° E., while a similar rise in the barometer from summer to winter gives rise to a wind of 4·7 miles per hour from N. 57° E.

This principle, which, though *a priori* probable, has not hitherto been supported by direct evidence, is without doubt destined to play an important part in the meteorology of the future, and to form one of the few channels by which we may hope to arrive at a correct knowledge of the effects of the suspected intrinsic variation of solar radiation on terrestrial meteorology. Thus Mr. Chambers says: "If the sun's heat is itself subject to fluctuations, either periodical or irregular, corresponding meteorological effects similar to those which are produced by the sun's change of position must result;" and he adds: "The relation at Kurrachee ppears to be one of the kind that would be anticipated on the supposition of the sun's heat being variable, and in itself affords a reason for suspecting, if it does not tend to prove, such variability."

In discussing the diurnal variations, Mr. Chambers divides the winds into two great classes, *convection* or ordinary currents, in which the air moves from relatively cool to relatively warm regions, and *anti-convection* currents, or "winds of elastic expansion" as Blanford calls them, which blow outwards from regions of high temperature. Each of these classes is again divisible into two sub-classes, (1) general and (2) local.[1]

If each of these systems is possible, as Mr. Chambers infers, the resultant variation is evidently a very complex one, and the main difficulty in discussing it, evidently consists in being able to adequately separate each component in turn from the rest. For this purpose Mr. Chambers employs Bessel's formula, and though he admits that the components derived by this method, do not necessarily represent physically distinct variations, its use in this case, as well as in others throughout this work, is attended with such favourable results, as to constitute a plea in favour of its more general adoption by English meteorologists.

To follow all the details of the investigation would be beyond our scope. It may therefore be briefly noted that the greater part of the variation of the north component, is due to the alternate land and sea breeze (convection currents), while a portion at any rate of the variation of the east component, is due to local anti-convection currents which prevail only in the drier months. Further, the direction of the local anti-convection currents varies with the varying position of the centre of maximum temperature range in the peninsula, while that of the coast convection currents is nearly constant.

By an ingenious plan for eliminating the variations due to coast convection currents, and by choosing the months so as to reduce the local anti-convection currents to a minimum, the existence is further proved of a system of general anti-convection currents, which, it may be remarked, were first noticed by Mr. Laughton in 1871, consisting of a double diurnal oscillation of the east component, which in the case of Kurrachee reaches its maxima at 10 a.m. and 9 p.m. and its minima at 4 p.m. and 2 a.m. respectively. These general anti-convection currents have been likewise proved by Mr. Chambers to exist at Calcutta, Belgaum, Bermuda, and Falmouth, *i.e.* in places where the ordinary convection currents differ completely both in character and intensity.

A comparison of the rainfall with the wind at the end of this paper leads to a conclusion similar to that drawn by Mr. Blanford, viz., that rain seldom falls as long as the summer monsoon continues to blow steadily, and Mr. Chambers hence infers, that a strong, damp wind from the seaward, is not the only condition required to produce rain. If this rule is only meant to apply to the place where the wind prevails, it is doubtless correct; but it seems open to misinterpretation if taken in a more general sense, since the laws of cyclonic systems and experience, both tell us that the reason why there is little rain on the coast when the sea wind is blowing strongly, is because the area of lowest pressure towards which the wind is spirally blowing is situated in the interior of the country, and that when there is *least* rain on the coast there is probably *most* inland.

Paper X. "Some Results of the Meteorological Observations taken at Allahabad during the Ten Years 1870-79," by S. A. Hill.—This paper, which represents the most complete discussion of the climatic elements at a single station in the interior of India that has ever been published, contains much that is valuable and highly suggestive to the physical meteorologist. To the climatologist it is especially interesting, owing to the inland as well as tropical position of the station. In May and June, Allahabad is one of the hottest places in India, the maximum temperature in the shade often rising above 115° Fahr., while in that terribly hot year, 1878, the temperature actually rose up to 119°·8 on June 19.

Nearly all the elements are discussed by the aid of Bessel's formula, and as it is a paper which cannot readily be reviewed in detail, we propose merely noticing one or two of the most salient conclusions deduced by the author.

One remarkable feature that comes out from the discussion of the diurnal barometric oscillation, is its "continental" character. Like Yarkand and other typically continental stations, the fall of the night tide is very small, and the ratio of the amplitude of the semi-diurnal to the diurnal component, is not only smaller than

[1] Continued from p. 430.

[2] The small elevation of the anemograph (only 15·6 feet above the ground) is open to some objection, but this is a good deal compensated for by its unusually free exposure.

[3] The resultant ranges of the wind variations obeying the barometric law are as follows:—

Kurrachee	26·6
Bombay	20·5
Calcutta	6·2

[1] These latter are dealt with in detail in those papers of Mr. Chambers's which have already been alluded to.

that at marine stations like Bombay, but reaches its minimum value in the hottest part of the year, when the ratio at the latter stations is rising towards its maximum.

When discussing the vapour tension, Prof. Hill remarks that, "while the diurnal variations of vapour tension and atmospheric pressure are connected with each other in so far as they are both effects of the diurnal inequality of temperature, it is doubtful whether there is any other connection between them except in an indirect way. At a dry station like Allahabad, where the range of the inequality of vapour tension is less than one-fourth of the range of pressure, it could never be supposed that the observed variation of the barometer is *caused* by the variation of the quantity of aqueous vapour in the air."

In explaining the afternoon minimum of vapour tension which is so distinctly marked at Allahabad during the dry hot months, a suggestion of Mr. Blanford's is noticed referring it to the semi-diurnal interchange between the lower and upper currents (which is supposed by Dr. Köppen to account for the diurnal increase in the velocity of the wind), supplemented perhaps by diffusion. The occurrence of a maximum of cloud nearly simultaneously, lends countenance to this view.

The clouds and rain are found to manifest similar diurnal variations, reaching their maxima nearly (1) when the temperature is lowest; and (2) when the vapour in the air reaches a maximum, either by diffusion from below or intermixture with the lower strata.

The heaviest fall recorded in one day during the ten years of observation was 15·48 inches between July 29 and 30, 1875, which has only been approached in the plains by the rainfall at Purneah in Bengal on September 13, 1879, and the rainfalls on September 17 and 18, 1880, when the disastrous land-slip at Naini Tal took place. These abnormal falls are found to be due to the passage of small cyclones (secondaries, as they are generally termed in European weather bureaux) which strike the land on the coast of Orissa, and move northwards along a line separating the westerly winds of Southern India from the easterly winds of the northern plain—the axis as it were of the entire monsoon system.[1] The occurrence of the fall so far west as Naini Tal, together with its exceptional character in 1880, appears to the writer to have been due to the preponderance in that year of the eastern over the western monsoon system.

In regard to wind, Allahabad conforms to the general rule deduced by Dr. Hann for stations near sea-level in every part of the world, viz. that the velocity of the wind in every season is greatest about the hottest hour of the day.

The double diurnal rotation of the wind, exhibits a peculiarity which is of considerable interest in relation to Mr. Chambers's hypothesis of the connection between it and the diurnal variation of the barometric pressure. It is that in the dry hot months, the loop in the diagram representing the nocturnal variation is almost invisible, while in the rainy season it is much more pronounced, in correspondence with the nocturnal barometric tide which undergoes similar changes. In the marine climate of Bermuda, as Mr. Chambers has shown, both the nocturnal wind and barometer variations are nearly equal to those which occur during the day, and, in proportion as the climate of Allahabad becomes moister and therefore more maritime, so the variations in these elements appear to approximate in character to those at marine stations.

Paper XII. "The Meteorology of the North-West Himalaya," by S. A. Hill.—In this paper, which was originally compiled for a gazeteer and afterwards expanded, the author gives one of the most lucid and exhaustive accounts of the meteorology of a single district that we have ever had the good fortune to meet with. Not only is the region, one of peculiar interest, owing to the extraordinary facilities it presents for the observation of atmospheric changes, in vertical as well as horizontal range, but the manner in which the data are discussed is so eminently exhaustive, and withal attractive, that it virtually forms an almost complete epitome in miniature of meteorological science. In a preliminary description of the climate, and while noticing the great heat of the Punjab and North-West Provinces as compared with regions further south, Prof. Hill alludes to the investigations of Poisson, Meech, and Wiener, as showing that the total heating effect of the sun is a function of *the time during which he is above the horizon of a place*, as well as his altitude. The region where, according to their calculations, most heat falls from May 7 to August 7, lies about latitude 41°, and it is to this circumstance, together with the dryness of the air and absence of cloud, that Prof. Hill ascribes the excessively high temperature of June and July in the extreme north of the Punjab, and in the plains of Yarkand and Kashgar still farther north.

In fact (and this is a point which we think has been a good deal overlooked by climatologists) the annual range of temperature, is not merely dependent on the sea distance of a place, but also on its latitude; the further it is from the equator, *cæteris paribus*, the greater the amount of heat that falls in the summer months. On the other hand, since the summer season diminishes in length as the latitude increases, the region where the effect upon the temperature reaches its *maximum for the longest period* is probably about lat. 25½°, where the greatest amount of heat falls from equinox to equinox.

With respect to the other factor, humidity, the North-Western Himalaya are found to differ very markedly from what may be termed the South-Eastern Himalaya. Thus Darjeeling, though higher, has very nearly the same temperature in January as Simla, Chakrata, or Mussoorie, where the winter rains are more prevalent; while in May and June, owing to its coming in for a much more copious share of the summer monsoon, it is seven or eight degrees cooler.[1]

The vertical variation in the annual and diurnal ranges of temperature is found to be dependent chiefly on differences in the relative humidity of the air, the ranges being greater at the surface than at 6000 feet, where the lower cloud strata prevail, and greater again at the most elevated stations, where the radiation is excessive.

Another important element—the vertical decrement of temperature—is found to vary considerably in amount and rate at different seasons, being on the whole greater in the summer than in the winter up to 6000 feet. Above this height, especially in the inner ranges, the temperature diminishes very slowly, partly owing to the greater latitude, and partly to the absence of *cloud*, and it is to these circumstances, quite as much as to the small amount of precipitation, that the well-known fact of the snow-line being higher on the northern than on the southern side of the Himalaya, must be attributed. After working out the decrements in detail by the help of the method of least squares, Prof. Hill finds that on the mean of the year the temperature diminishes on the mean latitude 32°, at the rate of 2°·8 per 1000 feet, or 1° in every 357 feet of ascent. In the Eastern Himalaya, it is more rapid, being 1° for 320 feet.

It is interesting to observe, as Prof. Hill says, that, assuming the rate of decrement to be uniform over the southern slope of the North-West Himalaya, "a mean temperature of 50° Fahr., equal to that of London, would be attained at a height of 9600 feet, and the annual range of temperature would probably differ little from that observed in England. The hill sanitaria, at heights of 6000 to 7000 feet, possess climates comparable as regards temperature to those of Nice, Mentone, and other health resorts on the Riviera," only they appear to be somewhat superior to these in having a much smaller annual temperature range.

Prof. Hill calculates the height of the perpetual snow-line on the south slope of the North-West Himalaya to be 17,800 feet, which is a good deal higher than the measurements given hitherto. It seems probable, however, that a good many of these, by mistaking glaciers for snow, erred in making it too low. On the inner ranges bordering on Thibet, for reasons already noticed, the snow-line is about 2000 feet higher.

The diurnal variation of pressure—that hitherto unsolved problem for meteorologists—is discussed, though briefly, yet in a masterly manner, and the analogy of the mountain type by vertical exchange of air between their summits and the valleys, to the coast type caused by lateral exchange of air between the sea and the land, is noticed in connection with the corresponding system of mountain winds.

It is evident, from a perusal of this as well as other facts in connection with the diurnal range, that a complete explanation of it can only be attained by discussing data embracing a wide area, in order to eliminate all such local variations of the normal type.

The annual variation of pressure, is also very well described and explained, and we cordially commend it to the perusal of teachers of physical geography out of text-books, in which the old

[1] Mascart, in his "Météorologie appliquée à la Prévision du Temps," has noticed a similar tendency in European storms to move "vers la région des vents faibles."

[1] This explains why Darjeeling is such a healthy place for children, to whom a high summer temperature is so fatal.

stock notions of how the monsoons are caused in India are so prevalent. The explanations of many of the text-books are in fact a libel on the intelligence of both teacher and pupil.

It is usually said that the air is heated over the land expands, and rises (presumably in a courant ascendant). The air from the sea then rushes in to supply the tendency to vacuum, and this constitutes the monsoon.

The true state of the case is, however, quite different. The way in which the air is removed from North India is not by ascending, but by lateral currents which constitute the "hot winds." The vertical expansion by which a larger portion of the whole atmosphere is lifted above the level of the hill-stations would indeed rather tend to *raise* than *lower* the isobaric planes towards the north, and as no true "courant ascendant" can exist until the air is rendered moist by the monsoon rains, the lateral winds are the only means by which the isobaric planes are caused to slope northwards prior to their arrival.

The annual variation of pressure at the level of Leh, which is 11,538 feet above sea-level, shows us that at a still higher elevation the phases of annual barometric variation are exactly contrary to those which occur on the plains, the minimum occurring in mid-winter, and the maximum in midsummer.

It is further shown by Prof. Hill that the peculiar double oscillation at the hill-stations, which in correspondence with their position is intermediate in character to those in the two extreme cases, is due to exactly the same causes as the single oscillation on the plains—a fact which will prove of much utility in further research on this complicated question.

The winds for the most part correspond to the barometric variations. The constant south-westerly direction of the wind at the elevation of the hill-stations is, the result of two independent circumstances, viz. (1) the small depth of the winter (north-east) monsoon, above which the south-west anti-monsoon blows, and (2) the great height to which the summer (south-west) monsoon reaches. Above the latter monsoon it is not known how the wind blows, but in accordance with cyclonic laws it should be *north-west*. Perhaps future research will verify this inference.

The discussion of the humidity observations, leads to results which corroborate some previously obtained from somewhat meagre data by General Strachey. On the assumption that Hann's empirical formula with the value of the constant as given by Hill is correct, viz.—

$$\log p = \log P - \frac{h}{23058},$$ [1]

it is found that "at an elevation of 23,000 feet, or about the average height of the snowy peaks, the quantity of vapour in the air is only one-tenth of that at sea-level. *The extreme dryness of Thibet and Ladakh is thus easily accounted for.*"

The relative humidity depending on the temperature, obeys quite different laws, and undergoes variations very similar to those in the amount of cloud.

The average height at which cloud would be formed in the rainy season, is calculated by Prof. Hill to be about 4000 feet, and it is interesting to note that this elevation agrees with that of the zone on which the greatest amount of rain falls in the Himalaya, the exact height of which is found to be 4240 feet above sea-level. Above this height the rainfall decreases rapidly owing to the exhaustion of vapour, but in the case of the Himalaya this decrease is rendered more prominent owing to the outer ranges cutting off the supply of vapour to those more in the interior by promoting abnormal precipitation in their own vicinity.

E. DOUGLAS ARCHIBALD

MULTIPLEX CAMERA BACK

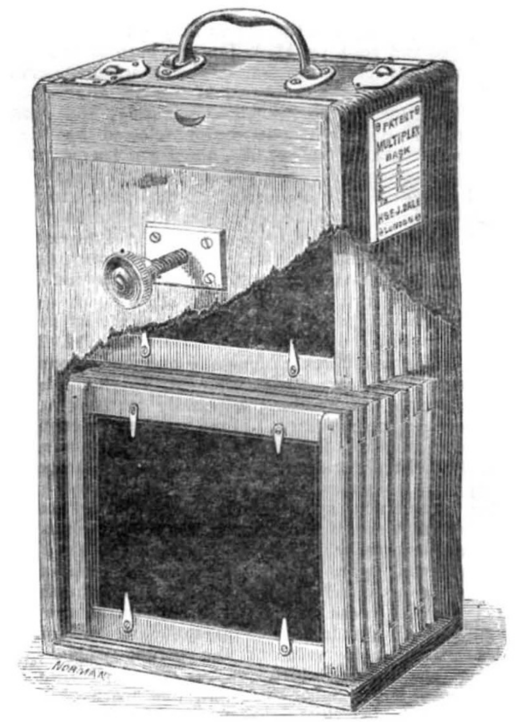
THE great advance in tourist photography by reason of the production of the more sensitive and rapid gelatine dry plates now used in such large numbers has led to continued improvements in the construction of portable photographic apparatus.

Considerable difficulty has always been experienced in carrying a sufficient supply of sensitive plates for a day's tour.

To meet this want not only are large numbers of double backs carried but the changing box has also been devised. The latter consists of a cabinet arranged to carry twelve sensitive plates and a specially constructed dark back for the camera. When a plate is required to be changed, the dark back is attached to the changing cabinet, and by the action of springs and shutters a sensitive plate is transferred from the cabinet to the dark back, which is then removed and exposed in the camera as desired. The changing box is complicated and expensive, besides adding another piece of apparatus to the tourist's luggage. The greatest difficulty, however, arises from the very merits of the gelatine plates themselves.

They are so sensitive that the utmost care is required to keep every trace of light from the plate, and double backs that appear perfect to the eye, yet by the action of the sensitive plates themselves are found to be imperfect. It is obvious that the multiplication of double backs and the shutters forming part of them, adds to the liability of access of light and consequent fogging of plates. With the use of a changing box the same trouble is experienced, with occasionally further difficulties, caused by variations in thickness or sizes of sensitive plates, the latter sometimes refusing to pass from the changing box to the back or *vice versâ*, very often causing loss of time, temper, and plate as well.

We give illustration and description of an improved apparatus that, by its simplicity of action, appears to obviate the



difficulties before mentioned, and to possess merits of its own that will insure the success desired by the inventors. The apparatus combines in one cabinet the dark back and the changing box, and is the invention of Messrs. J. H. Hare and H. J. Dale.

The woodcut (which shows part of the outer cabinet cut away to give a view of the interior construction) will immediately explain its action.

The cabinet or multiplex back is made large enough to contain thirteen plates in two tiers, the lower tier containing seven and the upper tier six plates. The plates are secured in holders or carriers, with a thin metal back to each to prevent the light passing through the plate which may be exposed to those behind it. In the front of the cabinet is the usual sliding shutter, which draws up half way for exposure of the front plate of the lower tier.

At the back of the cabinet is a shutter which can be entirely removed when required to refill the back with plates. In the front shutter a small window of non-actinic glass is provided, through which the number of the sensitive plate ready to be exposed can be seen. In the back shutter two quick-running three-thread screws are provided, the lower one to bring the plates of the lower tier up to focus, and the

[1] Where p P are the vapour tensions at the given elevation and sea level respectively, and h is the height in feet.