gical Department. The weather under which a ship enters a division may be of any description whatever, except that of an absolute calm in a sea without a current, and therefore has no bearing on the present question. It must further be observed that the error he had pointed out not only affects the winds, but all the meteorological elements so far as they are correlated with the winds; the temperature and dampness are especially affected by it. The method he proposed by which this error might be obviated, was to impose a limitation to the observations in respect to interval in distance, in addition to the existing eight-hourly interval in respect to time. He proposed that observations should not be included in the groups, unless the places where they were made were at least as far asunder, measuring in the direction of the ship's general course (and not along her tacks) as she could traverse with a favourable wind in eight hours. Then on an average not more than three observations would be accepted from a single log-book in any 5-degree ocean square. He did not possess data to show how far the accuracy of the existing wind charts is impaired by the neglect of this cause of error. He presumed that it would only be in certain parts of the ocean that it would exercise considerable influence on the computed proportions of the winds, but that the ratio of the calms would be everywhere exaggerated. It was sufficient that he should point out the error as one to be guarded against for the future, for he trusted that the whole of the work in the Meteorological Office would be submitted to recomputation, and that an improved method of handling and grouping the observations would be adopted, in accordance with the recommendation of that Report to which he had already alluded.

On the Conversion of Wind-charts into Passage-charts. *By* FRANCIS GALTON, *F.R.S.*

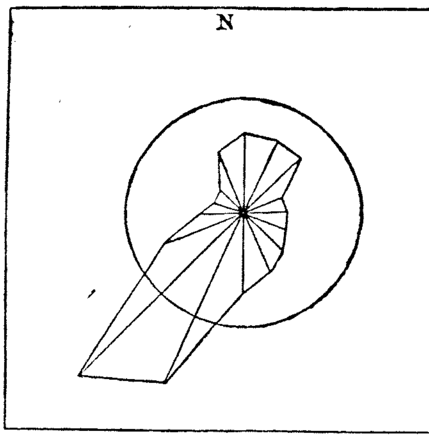
The most direct line between two points of the ocean is seldom the quickest route for sailing-vessels. A compromise has always to be made between directness of route on the one hand, and the best chance of propitious winds and currents on the other. Hence it is justly argued that an inquiry into the distribution of the winds over all parts of the ocean is of high national importance to a seafaring people like ourselves. A knowledge of the distribution of the winds would clearly enable a calculation to be made which would show the most suitable passage in any given case.

But as a matter of fact, no calculations have yet been made upon this basis; much less have charts been contrived to enable a navigator to estimate by simple measurements the probable duration of a proposed passage. The wind-charts compiled by the Meteorological Department of the Board of Trade are seldom used by navigators; for they do not afford the results that seamen principally require; they only give data from which those results might be calculated by some hitherto unexplained process, which, we can easily foresee, must be an exceedingly tedious one.

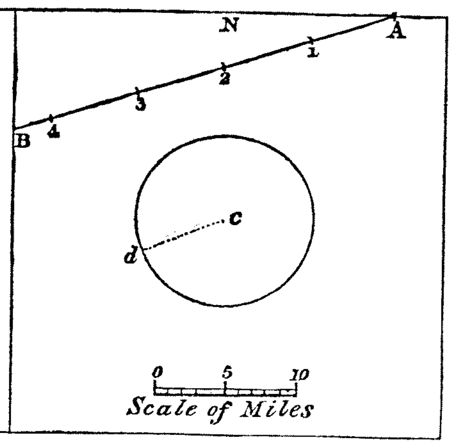
To convert wind-charts, or the tables of wind-direction from which the wind-charts have been compiled, into passage-charts, we must ascertain the distances that ships of different classes would attain in an hour, if they made the best of their way under the same wind towards different points of the compass. With a moderate wind, a merchantman of the class that usually navigates the Atlantic will, by beating to windward, make $2\frac{1}{3}$ miles an hour, right in the wind's eye. At two points off the wind it will make 3 miles; at four, 4 miles; at six, 7 miles; at eight, $8\frac{1}{2}$ miles: at ten, 9 miles; at twelve, $9\frac{1}{2}$ miles; at fourteen, $8\frac{3}{4}$ miles; and at sixteen, or with the wind right astern, it will make $7\frac{1}{2}$ miles. We must next turn to the wind-charts, or to the Tables from which they were compiled, to ascertain the proportion of the winds that blow from different points of the compass, in the region we are investigating. Thus in one particular case we find, out of one hundred observations, that six referred to N. winds, fourteen to N.N.E., seventeen to N.E., six to E.N.E., three to E., two to E.S.E., two to S.E., five to S.S.E., six to S., six to S.S.W., six to S.W., three to W.S.W., three to W., three to W.N.W., four to N.W., five to N.N.W., and nine calms. The force of the winds was not recorded in this instance; we must therefore, for want of better information, assume them to be moderate. We have now to calculate the progress that ships could make towards each point of the compass, under the several influences of each of these winds. In the example taken, the N. wind will be reckoned as lasting 6 per cent. of an hour, and therefore ships would be able to sail during its prevalence, ·014 mile to the N., ·018 to the N.N.E., and so on. The N.N.E. wind lasting 14 per cent. of an hour will enable ships to sail ·042 mile to the N., ·033 mile to N.N.E., and so on. The N.E., E.N.E., and all the other winds would have their influence similarly calculated. We thus obtain a Table of sixteen lines (not reckoning the line of zeros that correspond to "calms") and of sixteen columns, whose addition gives the total progress of one particular class of ships, in one hour, to all points of the compass, under the influence of the winds that blow in the ocean-district under consideration.

The bottom line of the Table gives the results that we seek. In the case we have taken, the diagram in the Wind-chart and that in the Passage-chart would be of the following shapes respectively:—

Wind-chart Diagram.



Passage-chart Diagram, calculated from that of the Wind-chart.



The proportion of winds from the neighbourhood of each of sixteen points of the compass is shown by the length of the corresponding lines drawn to the leeward of the centre. The radius of the circle represents the proportion of calms.

The force of the winds is not given in this diagram. It must therefore be reckoned as "moderate" throughout.

The probable length of an hour's sail in any direction from *c*, the centre of the diagram, is shown by the length of its radius in that direction. This gives a scale to be used throughout the ocean area to which the diagram refers.

Example.—Since A B is $4\frac{1}{4}$ times the length of the parallel radius *c d*, therefore the passage from A to B will occupy on an average $4\frac{1}{4}$ hours.

We should not be justified in usually adopting an "average force" for the winds, though, for simplicity of explanation, we selected the foregoing example, in which we were obliged to do so. If we confined our computation to the effect of simple averages, then an alternation of squalls and calms would be improperly reckoned as moderate weather. We must therefore group the winds, not necessarily to each degree of force, but, it may be, in two or perhaps three groups. The Tables would therefore consist not of sixteen lines, but of twice or thrice that number. For the rapid performance of these calculations we should tabulate the passages of various classes of ships to each of the sixteen points of the compass, under the influence of winds of, say, thirty different degrees of duration, and six of force, making a total of 180 lines for each class of ships. In each line the figures should be repeated, so as to sweep not only once but twice round the compass. If these are printed on separate slips of paper, the labour of copying them would be wholly avoided; for the same slips could be used over again. An *extract* from the foregoing Table will suffice for an example of what is meant; where, in order to save space, the figures that refer to the eight principal points of the compass are alone inserted.

Method of Calculating Data for the Construction of a Passage-chart.

Hours of wind.	Direction of wind.	Corresponding passages in various directions (in nautical miles).															
		N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
9	Calms.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	N.	14	18	24	42	51	54	57	52	45	52	57	54	51	42	24	18
14	N.N.E.	42	33	42	56	98	119	126	133	121	105	121	133	126	119	98	56
17	N.E.	68	51	40	51	68	119	144	153	161	149	127	149	161	153	144	119
6	E.N.E.	42	24	18	14	18	24	42	51	54	57	52	45	52	57	54	51
3	E.	25	21	12	9	7	9	12	21	25	27	28	26	22	26	28	27
2	E.S.E.	18	17	14	8	6	5	6	8	14	17	18	19	17	15	17	19
2	S.E.	19	18	17	14	8	6	5	6	8	14	17	18	19	17	15	17
5	S.S.E.	44	47	45	42	35	20	15	12	15	20	35	42	45	47	44	37
6	S.	45	52	57	54	51	42	24	18	14	18	24	42	51	54	57	52
6	S.S.W.	52	45	52	57	54	51	42	24	18	14	18	24	42	51	54	57
6	S.W.	57	52	45	52	57	54	51	42	24	18	14	18	24	42	51	54
3	W.S.W.	27	28	26	22	26	28	27	25	21	12	9	7	9	12	21	25
3	W.	25	27	28	26	22	26	28	27	25	21	12	9	7	9	12	21
3	W.N.W.	21	25	27	28	26	22	26	28	27	25	21	12	9	7	9	12
4	N.W.	16	28	34	36	38	35	30	35	38	36	34	28	16	2	9	12
5	N.N.W.	15	20	35	42	45	47	44	37	44	47	45	42	35	20	15	12
Total hours 100	All winds.	530	506	516	553	610	661	679	672	654	632	632	668	686	683	652	589
Or, in one hour.	All winds.	5·3	5·1	5·2	5·5	6·1	6·6	6·8	6·7	6·5	6·3	6·3	6·7	6·9	6·8	6·5	5·9

N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.

N.	Hours 6	Force mod.	14	24	51	57	45	57	51	24	14	24	51	57	45	57	51	2
N.E.	Hours 17	Force mod.	40	68	144	161	127	161	144	68	40	68	144	161	127	161	144	68
E. ...	Hours 3	Force mod.	7	12	25	28	22	28	25	12	7	12	25	28	22	28	25	12
S.E.....	Hours 2	Force mod.	5	8	17	19	15	19	17	8	5	8	17	19	15	19	17	8
S.......	Hours 6	Force mod.	14	24	51	57	45	57	51	24	14	24	51	57	45	57	51	24
S.W.	Hours 6	Force mod.	14	24	51	57	45	57	51	24	14	24	51	57	45	57	51	24
W..........	Hours 3	Force mod.	7	12	25	28	22	28	25	12	7	12	25	28	22	28	25	12
N.W..............	Hours 4	Force mod.	9	16	34	38	30	38	34	16	9	16	34	38	30	38	34	16

Total.

If the slips were of sufficient length to include the data for every class of ship, a single operation would simultaneously build up Tables for all.

A navigator wishing to find the probable duration of his intended voyage, would refer to a chart on which the results of these calculations had been protracted in the form of diagrams. He must set his compasses to the radius of the diagram nearest to the commencement of his intended route, measuring it in a direction parallel to the route. He will thereby obtain a scale of probable distance for one hour's sail during that part of his voyage, and he will prick out his passage accordingly. When he has come within the range of another diagram he will set his compasses afresh. Continuing on this principle, he will dot out the probable duration of the whole of a proposed passage in the simplest possible manner. He will thus be able to select the quickest out of any number of routes that may be suggested to him, and to determine, on the most trustworthy of existing data, what is the best course to adopt in sailing from any one part of the ocean to another.

The method of altering a diagram so as to include the effect of a current, is too simple to require explanation.

On the Heat attained by the Moon under Solar Radiation. *By* J. Park Harrison, *M.A.*

When the author brought forward the subject of lunar insolation a year ago, he showed by a simple diagram that the surplus, or accumulated heat in the moon, beyond what it radiates off to other matter into space, or owing to the long-continued action of the sun's rays upon her crust, would necessarily reach its maximum several days after the date of complete illumination. The mean duration of solar radiation for the two periods of first and third quarters is in fact in the proportion of 4·25 : 11·25; and, consequently, the days on which the moon's surface opposite to us is longest withdrawn from, or exposed to, the sun's heat (in other words, the days on which the moon completes her first and third quarters) would be not far removed from the days of her maximum and minimum temperature. He has since learnt that Herr Althaus, some few years back, approximately estimated a maximum temperature of 840° F. on the 22nd day of the lunation, seven days after the day of full moon. Althaus, it appears, measured the sun's radiation by the pyrheliometer, and then applying the results to the moon, deduced from the extent of her area the amount of heat intercepted; his measure of the moon's capacity for heat was that of quartz*. Assuming his deduction to be correct, the heat occasionally attained by the moon would approach very closely the temperature at which iron appears red in twilight, and it exceeds the fusing-points of tin and lead. Unfortunately the estimate cannot be compared with that made by Sir John Herschel which applies to the moon's heat at the period of complete illumination, at which time he states that it must be far in excess of boiling water. But

* Pogg. Ann. vol. xc. p. 551.