Smithsonian Contributions to Knowledge.

268

DISCUSSION AND ANALYSIS

OF

PROFESSOR COFFIN'S TABLES AND CHARTS

OF THE

WINDS OF THE GLOBE.

BY

DR ALEXANDER J. WOEIKOF,

MEMBER OF THE RUSSIAN GEOGRAPHICAL SOCIETY AND OF THE AUSTRIAN METEOROLOGICAL SOCIETY:
FORMER SECRETARY OF THE RUSSIAN METEOROLOGICAL COMMISSION.

REPRINTED FROM THE TWENTIETH VOLUME OF "SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE."

WASHINGTON, D. C.
1876.

DISCUSSION AND ANALYSIS

OF

PROFESSOR COFFIN'S TABLES AND CHARTS

OF THE

WINDS OF THE GLOBE.

BY

DR. ALEXANDER J. WOEIKOF,

MEMBER OF THE RUSSIAN GEOGRAPHICAL SOCIETY AND OF THE AUSTRIAN METEOROLOGICAL SOCIETY:
FORMER SECRETARY OF THE RUSSIAN METEOROLOGICAL COMMISSION.

REPRINTED FROM THE TWENTIETH VOLUME OF "SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE."

WASHINGTON, D. C.
1876.

PHILADELPHIA:
COLLINS, PRINTER, 705 JAYNE STREET.

CONTENTS OF SPECIAL DEDUCTIONS BY A. WOEIKOF.

1. Greenland and vicinity.
2. Arctic Archipelago of America.
3. British America (Continental stations) and Alaska N. of 60°.
4. Southern Alaska, Washington Territory.
5. California.
6. Oregon, Nevada, Utah.
7. Arizona, New Mexico.
8. Texas, Arkansas, Indian Territory, Colorado, Wyoming, Nebraska, Iowa, Kansas, Missouri.
9. Dacota, Manitoba, Minnesota, Wisconsin, N. Michigan.
10. Illinois, Iowa, S. Michigan, Canada, W. Ohio, W. New York, W. Pennsylvania, W. Virginia, Kentucky, Tennessee.
11. Atlantic slope of the U. S., Canada, E. Newfoundland, Nova Scotia, Labrador.
12. Florida, Alabama, Mississippi, Louisiana.
13. Mexico, Central America, West Indies.
14. South America east of the Andes.
15. South America west of the Andes.
16. Atlantic Ocean.
17. Iceland, Faröe Island, Great Britain.
18. Norway, Sweden.
19. Denmark, Germany, Netherlands, Belgium, N. France.
20. Switzerland, Central and S. France, N. Italy, Western Provinces of Austria.
21. Portugal, Spain, S. Italy, Greece, Islands of the Mediterranean.
22. Hungary, Danubian Principalities, S. W. Russia.
23. S. Russia (steppes).
24. N. and Central Russia.
25. W. Siberia and Central Asia.
26. N. E. Siberia.
27. Monsoon region of E. Asia, Amoor Provinces, China, Japan.
28. Sunda Island and Philippine Islands.
29. Northern Indian Ocean.
30. India.
31. Western Asia, Transcaucasia, Persia, Asia Minor.
32. Eastern Africa.
33. Northern and Central Africa.
34. Southern Africa.
35. Southern Indian Ocean.
36. Australia and New Zealand.
37. Pacific Ocean.
38. Antarctic Ocean.

DISCUSSION AND ANALYSIS

OF

PROFESSOR COFFIN'S TABLES AND CHARTS

OF THE

WINDS OF THE GLOBE.

BY

DR. ALEXANDER WOEIKOF,

OF THE IMPERIAL GEOGRAPHICAL SOCIETY OF RUSSIA.

83 July, 1875.

DISCUSSION AND ANALYSIS OF WINDS.

THE aim of Prof. Coffin in this work on the "Winds of the Globe," the reason why he did not write the text, and how I came to take charge of this part of it, has been already explained in the preface.

In what way the ideas of the deceased author would have been modified by the progress of theoretical meteorology in the last twenty years, as well as by the much more extended knowledge of facts we possess now, it is impossible to say. It is very likely, however, that he would have continued to rely principally on the inductive method, would have avoided hasty generalizations, and would have shown the same caution and candor as in his other works, omitting explanations of what our present knowledge did not give sufficient data, rather than mislead his readers.

Before drawing the conclusions which seem to follow from the tables and maps of this work, some explanations are necessary.

The object of this work is to ascertain the movement of the air over different parts of the earth's surface. For this purpose the mean direction and rate of progress of the wind were calculated according to the formula of Lambert. It is easy to see that to accomplish this with precision, we should know the velocity of the wind at all places at which calculations are to be made. Now we know the velocity of the winds in a somewhat accurate manner only for a very small number of stations. For many more the velocity of the wind was merely estimated, and for a majority of places, the direction of the wind alone is known. Now the progressive movement of the air over a certain place, even taking into account the direction only, without considering the number of miles travelled, can be ascertained from the number of observations alone if we make the supposition that all winds have the same velocity; but this is obviously not the case. In nearly all known instances where the velocity of the winds has been ascertained, it has been found to vary considerably; generally, the more accurate observations with self-registering anemometers give a greater difference between the velocities belonging to different directions of the winds than mere estimates have given, the difference being seldom less than 1 to 2, and sometimes even 1 to 4 or 1 to 5.

In considering attentively the observations for the stations where the number of observations, for hours, and the velocity are given, it is seen that generally the most frequent wind is also the strongest, or, comparing the mean direction of the wind calculated from the number of observations only, with that obtained by

taking into account the velocity of the winds, it will be found that in the last case the mean direction generally approaches nearer to the actual direction of the prevailing wind.

Besides it is seen that generally the ratio of resultant is greater in the second case than in the first.

Thus it follows that, when we have the mean direction of the wind at a given place, calculated from the number of observations only, we may infer that, if the velocity was known, it would modify the result in so far as to make the mean direction nearer to that of the prevailing wind, and the ratio of resultant greater.

Unfortunately most of the above deductions apply only to the United States, as it was the only country for which Prof. Coffin made his calculations from the original journals. As to printed meteorological journals, they were very scarce until within a late period, and many of these were not to be had in the United States. Therefore published means and abstracts had to be relied upon, and these gave only the number of observations for each wind. It might be thought that the results of the self-registering anemometers now in use in so many meteorological stations would give abundant material for the answer to this question, but, owing to the recent introduction of these instruments in some cases, and to discontinuity of record in others, comparatively few tabulated records of velocity of winds have been printed.

Yet it seems that the angle between the mean direction calculated, taking into account the number of observations only, and that in which the velocity is considered, seldom exceeds 15°. In case of a very small ratio of resultant it can be much greater, but this small ratio itself shows that the mean direction is not much to be relied upon.

All this leads to the conclusion that it is possible to calculate the mean direction of the wind from the number of observations only without incurring a large error. The map, Plate 13, shows the resultant direction for the number of observations only, as also for velocity, in the United States. I must also explain in what sense I use the words "polar" and "equatorial" winds. Polar designates a wind blowing from a higher latitude towards a lower; and equatorial, a wind blowing from a lower towards a higher latitude. I use these terms in the way which is most generally admitted, to avoid confusion. This agrees also with the manner in which winds are generally designated, so far as we call north wind one that blows from the north towards the south, and not *vice versa*.

It will be remembered that in the "Winds of the Northern Hemisphere" Prof. Coffin used the words "polar" and "equatorial" in the opposite sense.

Another question, to my mind, more difficult to answer, is as to the value of the observations on the motion of clouds. They may serve two ends: 1, to ascertain the motion of an upper current of the air; 2, to observe the lower current, free from the irregularities often found immediately above the surface of the earth.

Naturally enough, in this case all depends on the height of the clouds observed. Very seldom, if ever, in discussing observations from a journal, can even the approximate height of the clouds observed be ascertained. This alone detracts very much from the value of such observations. Besides this, the cases must be taken into account when there were no clouds, or, the clouds being very high, no

appreciable movement could be observed. All this lessens the value of the observations on motion of clouds.

Generally it is seen, that the clouds move from the same direction as the air near the surface of the earth, which would lead to the conclusion that the lower strata of clouds were those observed.

As to the higher clouds, the *cirri*, as far as known, they move generally from the west, except in the polar regions.

Considering all this, as well as the fact that the motion of clouds is recorded in this work for very few places outside of the United States, I shall not consider the subject in the further deductions, leaving to every one interested to draw his own conclusions from the tables and the map, Plate 1.

The most important works in meteorological science in the last twenty-two years are devoted to the proof of the mutual dependence of atmospheric pressure and winds.

It has for a long time been admitted that in the belts of the trade-winds the air moves from the regions where pressure is high (the polar limits of the trades) towards the low pressure of the equatorial regions. The phenomena here were so simple and regular that the explanation was very easy. In the case of the tropical hurricanes it was also generally admitted that the wind blew towards the low pressure in the centre of the storms. The meteorological phenomena of the temperate and polar regions are much more complicated, and the causes of them less easily detected.

It was Prof. Buys-Ballot who proved the general dependence of the winds on the pressure of the air. In its original enunciation, his celebrated *law of the winds* declares that the winds will blow from the region where the barometer is above the mean towards that where it is below, and will be deflected 60° to 80° towards the right, owing to the rotation of the earth. He subjected this law to a severe practical test in using it in the system for prediction of storms which had been established at that time in the Netherlands. Buys-Ballot's law of the winds is now very generally accepted, though in a somewhat modified form, viz.: *the wind blows from a region of high pressure towards one of low pressure, and is deflected to the right owing to the rotation of the earth.* In 1853, Prof. Coffin arrived at a very similar conclusion, saying, "that in the northern hemisphere a wind arriving from its mean direction always finds the point of maximum pressure on its left, and the minimum to its right; while the reverse is true in the southern hemisphere. There seem to be no exceptions to this law." He further states (*Proceedings of American Association*, 1853, p. 88) that the deflection in this case is 65°; that is, very near to that found by Dr. Buys-Ballot. Even before Professor Coffin, Espy expressed similar views, as seen in his "Philosophy of Storms" and "Meteorological Reports." Very likely the views of the American meteorologists were too much in advance of their time to be generally accepted. When Dr. Buys-Ballot published his law of the winds, meteorology had made much more progress, so as to render such views more easy of acceptance.

This law applies to storms as well as gentle winds, to single hours of observations as well as to monthly and yearly means.

Buchan has rendered a great service to meteorology by extending Buys-Ballot's law to the general phenomena of the winds of the globe. He collected a great deal of information as to the mean pressure of the air, and drew *isobaric lines*, *i. e.*, lines of equal pressure of the air reduced to sea-level, and by considering the prevailing winds he proved that they generally followed Buys-Ballot's law. As this work, "Mean Pressure and Prevailing Winds of the Globe," is very important in the discussion of the winds, I make the following extracts from it:—

"*Distribution of Atmospheric Pressure in December, January, and February.*

"In these months the highest pressures are grouped over the land of the Northern Hemisphere, and the larger the extent of land, the greater the pressure. The area of high barometer (thirty inches and upwards) embraces nearly all of Asia, all Europe south of the North and Baltic Seas, the North Atlantic between 15°–45° N., the West Indies, North America except the North and Northwest, and the Northern Pacific between 8° and 24° N. There are also two regions of high pressure of comparatively small extent, the one in the South Atlantic, the other in the South Pacific.

"The regions of low pressure are: the northern part of the North Atlantic and North Pacific, including portions of the continent adjoining; the belt of low pressure in the equatorial region, towards which the trade-winds blow, and the remarkable depression in the Antarctic region which is probably subject to little change throughout the year.

"In *March* the pressure diminishes over Asia, the middle and south of Europe and the United States. Everywhere else except in the tropics it is rising. This rise of pressure is most apparent in the temperate regions of the southern hemisphere. In the north of the Atlantic it is rapidly rising, the average pressure in Iceland now being 29.609 inches, thus showing an increase of 0.34 inch in comparison with January.

"In *April*, the heavy lines indicating a pressure above the average have all but left Asia, Europe, and the United States, and the isobars of 30 inches bound a belt of high pressure, which completely encircles the globe in the south temperate zone. Pressure continues to rise in the north of the Atlantic, and to the north of North America. And it is probable that a space of high pressure (at least 30 inches) completely encircles the north pole. In this month pressure is more equally distributed than in any other month; for, except the Antarctic Ocean, it scarcely rises anywhere above 30.1 inches nor falls below 29.8. In May, in North Europe, in Greenland, and in the north of North America, pressure attains the maximum of the year. Pressure continues to increase in the south temperate zone, and the isobar of 30.1 now nearly encircles the globe. At this time the highest pressure in the southern hemisphere occurs in the S. E. of Australia, where, at Deniliquin, it is 30.185 inches. Pressure is rapidly falling over Asia and the United States.

"In June, July and August, pressure falls in the central regions of Asia to about 29.5. In this season this diminution of pressure, which may be regarded as entirely

determining the summer climate of Asia, reaches its lowest point. Pressure falls also in the interior of North America, where, at Salt Lake City, it is only 29.7 inches. The annual maximum of the south temperate zone is attained in these months. The isobar of 30.1 goes entirely round the globe, and a still higher pressure prevails over South Africa, and the portions of the ocean immediately to the west and east of it. In these months the arrangement of the isobars may be regarded as being, generally speaking, reversed from that of December, January and February, and in this respect a comparison of these two groups of months is very instructive.

"From this period, pressures increase over the continents of the northern hemisphere, and diminish over the south temperate zone, till the distribution of pressure is regained which has been shown to prevail during the winter months.

"In *September* and *October* an interesting feature of these lines is a very rapid diminution of pressure, indicated as taking place in the north of the Atlantic and surrounding regions. This is the season of the year when the first great decrease of temperature takes place, which is accompanied by heavy rains and furious storms. The increase of pressure in Sweden in October, taken in connection with the simultaneous decrease in Greenland, Iceland, the north of Norway, and the British Islands, is interesting as bearing on the transport of masses of the atmosphere from one region into another.

"In November, pressure rises considerably over the continents of the northern hemisphere, and falls in the south temperate zone. And the belt of low pressure in the equatorial regions may be regarded as passing completely around the globe. This belt, towards which the trades on each side of the equator blow, does not occur in the summer months in the Indian Ocean; but, on the contrary, there is a continuous diminution of pressure northward, from Australia and Mauritius to the interior of Asia. It will be seen that in November, as compared with October, the isobars have advanced a little northward from the British Islands to Iceland, and eastward from Baffin's Bay to Iceland, thus indicating a general increase of pressure over the north of the Atlantic and regions adjoining. Coincident with this increase of pressure, there occurs a diminution of pressure to the southeast of it, including Austria, Italy, and countries adjoining the Mediterranean; and in the Atlantic to the south of it, from about latitude 15°–45° N. Probably these extensive oscillations of pressure are part of a general movement of the atmosphere, which, in one of its manifestations, has been generally known to meteorologists as the great November wave, but of which no very satisfactory account has yet been given." (Buchan, p. 577–579.)

WINDS *within, or near, a space of Low Pressure.*—"Of this class, the best example is the low pressure which prevails in the north of the Atlantic and adjoining regions in the winter months. This region of low pressure is bounded to the S. W. by the high pressure of North America, to the S. by the high pressure in the Atlantic, about 30° lat. N., to the S. E. by the high pressure in the interior of Asia. In January, the difference between the average pressure of Iceland and the interior of Asia is fully an inch."

"It is seen from the charts that in Baffin's Bay and east of the Rocky Mountains,

as far south as 40° lat., the winds are N. N. W., N. W., and W. N. W. Crossing the Atlantic, winds in the British Islands, in France, and the north of Germany, from the W. S. W. to S. W.; in Denmark, S. S. W.; near Bergen, in Norway, S.; and at Christiansund and Hammerfest, S. S. E. The relation of these winds to the isobaric lines is the same as that which is illustrated by the winds in storms, in their relation to the isobaric lines of these storms. This has been already stated in a paper by the author, published in the *Transactions of the Royal Society of Edinburgh*, Vol. XXIV. Part I. p. 201, in the following words: 'The wind in storms neither blows round the centre of least pressure in circles, or as tangents to the concentric isobaric curves, nor does it blow directly towards that centre. It takes a direction intermediate, approaching, however, more nearly to the direction and course of the circular curves than of the radii to the centre.' Or, according to Dr. BUYS-BALLOT, the angle is not a right angle, but from about 60° 80°. This relation is usually called 'BUYS-BALLOT'S LAW OF THE WINDS.'[1]

"Another well-marked depression is the low summer pressure in the interior of Asia; with reference to which it is seen from the charts that the winds of Eastern Europe and Western Asia are from N. W. to W. N. W. and W.; at Ceylon, S. W.; at Shanghai, S. E.; and on the Sea of Okhotsk, N. E.; whilst in the interior, calms generally prevail."

"The behavior of the winds, as regards the low pressure of North America, is exactly similar to that of the winds in Asia at this season. In all these cases the wind appears to flow round and in upon the space where pressures are low. Even in those instances where the depression over a limited space is comparatively small, such as in Australia during the summer months, the winds observe the same course with respect to it."

"A well-known and remarkable diminution of pressure is that of the Antarctic regions; and though, except in Tasmania and the south of New Zealand, observations are wanting at particular points for a sufficiently long time to give good averages, yet the concurrent testimony of sailors and the inhabitants of these regions all goes to show that, at least on the outskirts of the region, winds are chiefly N. W. or W. N. W.—that is, they appear to flow in upon the space of low pressure. The low pressure in the equatorial regions, towards which the trades blow, is an illustration of the same principle."

"WINDS *within, or near, a space of High Pressure.*—The most prominent illustration of this is the high pressure in the interior of Asia in winter. It is seen from a single glance at the charts that the winds flow *out of* this space in every direction. The same *outflow* is seen with respect to the less strongly marked, but still very distinct space of high pressure in North America; owing to the large number of stations available here, this principle is amply illustrated.

"The next most noteworthy area of high pressure occurs in summer between Africa and North America, out of which also the charts show the winds blowing in all directions towards and round upon the surrounding low pressures."

"The following mean pressures, in inches, at 32° and sea-level, occur in Australia in June: At Brisbane, Queensland, 30.062; Sydney, 30.116; Melbourne, 30.178; Adelaide, 30.132; Freemantle, 30.121; and at Deniliquin, in the interior, on a

[1] For Prof. Coffin's determination of this angle, as 65°, see page xxv.

branch of the Murray River, 30.217. Hence a higher pressure occurs at this season (winter) in the interior, and it may be inferred that it is greatest in the southern portion of the interior. The prevailing winds are these: At Brisbane, S. S. W.; Sydney, W. by N. W.; Melbourne, N.; Adelaide, N. E. by N.; Freemantle, N. E. by E.; in other words, the winds blow out from this space of high pressure."

"This behavior of the winds with respect to spaces of high pressure differs in no respect from what occurs on particular days on which the isobaric lines present the same conditions of pressure. Mr. FRANCIS GALTON first drew attention to this peculiarity, under the name of *Anticyclones*, by which name he intended to convey the idea that in cases of high pressure occurring over a limited area, the course of the winds is exactly the reverse of what is seen to prevail in cyclones in which the winds blow round and in upon a space of low pressure."

"The *outflow* of the air from a region of high pressure, and the *inflow* upon a region of low pressure, appear to be reducible to a single principle, viz., the principle of gravitation. Given as observed facts the differences of pressure, it might almost be predicted, before calculating the averages, what the prevailing winds are. Indeed, so predominating is the influence of gravitation, that it may be regarded as the sole force immediately concerned in determining the movements of the atmosphere. If there be any other force or forces which set the winds in motion, their influence must be altogether insignificant as compared with gravitation." (Buchan, p. 581 to 583.)

This last passage of Buchan may be more distinctly expressed: in the action of gravity in restoring the equilibrium disturbed by unequal temperature. With a uniform temperature over the whole earth, there would be no wind. In illustration of the dependence of the wind on the difference of pressure, the map of isobars, Plate 14, as well as Plates 2, 4, 5, 6, and others, should be consulted.

Having given the above examples of the manner in which the winds are affected by atmospheric pressure, it is necessary to account for the origin of areas of high pressure, out of which, it is seen, the winds flow.

It must be said that this question is one of the most difficult in meteorology, and far from having received an entire solution.

As the tropical regions present the meteorological phenomena in the simplest form, it is best to begin with them. It has been known for a long time, that above the lower current of the air of the trade winds, flowing in the lower latitudes of the northern hemisphere from N. E. or E. N. E., there exists an upper one from about W. S. W. The existence of this current was proved by the movement of the highest (cirri) clouds always from some westward point, from the strong westerly winds on high mountains in the trade-wind region (the Chimborazo and others in equatorial South America, the peak of Teneriffe, etc.), from the transport eastward of ashes from the eruption of the volcanoes on the island of St. Vincent, (West Indies), and Cosiguina (Central America), and also from the direction of the smoke of very high volcanoes of the tropics. The supposition was then made, that there was a powerful ascending current over the belt of calms and rains near the equator, and that the air thus ascended flowed in the upper regions of the

atmosphere, in a direction contrary to the trade-winds, towards the polar limits of the latter, or to about 30° N. lat. and descended there.

Then the same principle was extended to dry, hot continental areas, where a powerful ascending current must exist on account of the heating by the sun, and this was proved by the great decrease of pressure in summer time.

Buchan extended the idea af ascending and descending currents further, supposing there was an ascending current over every area of low barometer, not only near the equator and on warm continental areas, but also in high latitudes, as on the North Atlantic, the North Pacific, etc. This air, he supposed, descended over areas of high pressure, as for example those existing in winter in Northern Asia and North America. Thus the supposition is, that the air flowing out of areas of high barometers, to a certain extent, comes from above, and again where the barometer is low, air ascends and flows in the higher strata, towards areas of high pressure.

I must repeat here, that this is a supposition, though a very plausible one, and that the actual facts which would prove the existence of such upper currents, with the exception of the so-called *counter-trades* in the region of the trade-winds, are very scarce. To these principles I would refer the direction of the wind at Dodabetta in the Neilghiris, in Southern India (above 8000 feet), which is nearly opposite to that observed in the lower strata in Central India, being from the N. W. in summer, that is, from the heated regions of the Punjab, where pressure is very low. In the lower regions, the winds on the contrary are S. E. and S., that is, the air is flowing towards Punjab. Another remarkable fact is the strong, constant, and warm W. wind observed in winter on some mountains near Lake Baikal. At that time of the year, the air is generally calm in lower regions, the cold intense, and pressure high. This west wind of the higher regions would thus seem to be a compensating current, flowing perhaps from Iceland towards the region of highest pressure of Eastern Siberia.

The observations on two of the highest peaks of the Rocky Mountains, above 14,000 feet, have failed to show an upper current of air blowing in a direction different from the lower one. As we have said before, our information as to upper currents is very scanty, and thus great caution seems yet necessary in drawing conclusions.

On the other hand, the influence of pressure on the winds near the surface of the earth is so well authenticated and reliable that we need not hesitate to base further conclusions on it.

The greater part of the earth being covered with water, we can first consider what would be the case if there were no intervening continents. What in this case would be the normal arrangement of pressure on the oceans? A belt of low pressure near the equator, a belt of high pressure at about 30° north and south, and a belt of low pressure about from 60° to 65°, after which the pressure would rise again towards the pole. This gives us three systems of winds at the surface of the earth, easterly (polar) in the lowest latitudes, westerly (equatorial) in the middle latitudes, and again polar in the highest latitudes, in each hemisphere. A

reference to the maps shows that, in the main, such is the actual arrangement of pressures on the oceans and on parts of the continents.

It is easy to see that this is the general conclusion arrived at by Prof. Coffin in his "Winds of the Northern Hemisphere." The main result is thus the same, the study of the winds, alone having shown that this is the case in a great part of the globe, while what we have said as to the pressure of the air shows at least the proximate cause of the prevailing winds. In how far this normal arrangement of winds is disturbed by geographical features, especially by the influence of the continents, will be shown later.

A further condition is the yearly movements of the belts of high and low pressure with the change of seasons. When the sun is in the zenith over the northern hemisphere, the seas under it will be more heated than the southern seas, and the equatorial belt of low pressure, which is also on the seas, the belt of highest temperature, will move northward. Owing to the great specific heat of the water, and consequently to the longer time it takes to cool, this northward movement will continue nearly to the end of the summer. On the other hand, the belt of low pressure in the higher latitudes will also move northward as the temperature rises near the poles, and the storm-tracks can take a more northerly course. The belt of highest pressure between the two of lowest must also take a more northerly position, as the air flows both north and south out from it. There can be no doubt that it holds an intermediate position between the two.

When the sun is in the zenith over the southern hemisphere, the reverse takes place: the equatorial belt of lowest pressure recedes southward, and also that in higher latitudes of the northern hemisphere, as the polar regions are so much cooled that the condensation of vapor there cannot sustain great barometric depressions. These normal or ideal conditions are realized to some extent on the surface of the present oceans, and are the more striking, the larger the bodies of water are. Generally the southern hemisphere has meteorological conditions which approach more nearly to the normal conditions than the northern. Thus, it will be seen by reference to the map of the isobars that the high pressure in about 30° really encircles the globe in the southern hemisphere, while in the northern, the pressure is highest in January at about latitude from 50° to 53° N. in Asia, and in July the pressure is very low, about 30° L. N. on the same continent. Again the low pressure about from 60° to 65° encircles the globe in the southern hemisphere, the difference of pressure under the different meridians not being great, and further south (especially from 70° to 78°) somewhat higher pressure and easterly winds are found. In the northern hemisphere, on the contrary, the lowest pressure is found on two elliptical spaces, in the Northern Atlantic, about Iceland, and in the Northern Pacific, about the Aleutian Islands, that is, where a great extent of water prevails at about 60°, and the ocean is abnormally heated by currents of warm water.

We thus see that at a distance from the influence of water, the above-stated normal conditions are very much interfered with.

If the earth consisted mainly of continents without intervening oceans, very different conditions would prevail. As continents are more rapidly heated than oceans, temperature would be highest very soon after the passage of the sun

through the zenith of a parallel. The greatest heat in our summer would be about the Tropic of Cancer, in our winter about the Tropic of Capricorn, and this would also be the belt of low pressure at that time. The S. E. trade would cross the equator into the northern hemisphere when the sun has a northern declination, and the N. E. trade follow into the southern hemisphere during the other half of the year, giving a variation of the inner limits of the trades of perhaps 40°, instead of the 10° or 12° which are now observed. Further, as dry continents cool also more rapidly, the cold in the polar region of each hemisphere during the winter would be more intense than now, extending to the whole polar region, and coinciding with a very high pressure.

These hypothetical conditions are much more imperfectly realized than those I have sketched before, as the extent of continents is much less than that of oceans. The nearest approach to realization is on the greatest continent, that of Asia, where the highest pressure of winter is a little north of 50° N. If it is not found further north, it is because the continent does not extend much beyond 73° N. In summer, on the contrary, we find the highest temperature in N. W. India between 30° and 35° N., and also the lowest pressure there and in N. China.

The larger the continent the more it approaches to the ideal conditions I have supposed. In Africa, for example, there is a belt of lowest pressure in summer at about 17° N., and the highest temperature is probably still more to the north.

The narrower continents of North and South America are more under the influence of oceans than Africa.

As already seen, the highest mean pressure on the surface of the globe is found in winter on the Asiatic continent. It is necessary to mention here a feature of the climate of this continent, explained by geographical conditions, which has a great influence on the winds, namely, the steadiness of pressure in winter. Pressure is so constant here that, though the barometrical range generally increases with latitude, it is not greater at Jakutsk in N. E. Siberia, under 62° N. L., than in Vienna in Central Europe, Lat. N. 48°, or even in St. Louis in North America, under 39° N. L. The coldest and heaviest stratum of air over Eastern Siberia is prevented from flowing towards the south and east, where pressure is low, by the intervening mountains and plateaus, from 3000 ft. to 5000 ft. high. So long as the cold of winter continues, pressure must, therefore, be high over the cold region of Northern Asia. As it is low in the Pacific Ocean and the equatorial regions, air will flow there from the region of high pressure above the mountains and plateaus. But, as above said, the coldest and heaviest lowest stratum cannot flow towards the Pacific on account of the intervening heights; the quantity of air moving in this direction will not be great enough to supply the deficiency. Thus pressure being lower the whole winter in the S. and E., the winds should be regular from the N. and W., and this is really the case.

On the whole southern and eastern slope of Asia we see a mutual reaction of continental and oceanic influences—*the great monsoons*. The Europeans were first made acquainted with the regular change of wind and weather in India through the campaigns of Alexander the Great. Not only did the Greeks see this change themselves, but they also learned from the natives with how great a regularity this

change took place; how in all this region the winter was the dry, clear time of the year, and summer the rainy season. The navigators of the sixteenth and seventeenth centuries knew that the monsoons extended much further east than India—to the Indo-Chinese Peninsula, the Sunda Islands, and Southern China.

The cause of the monsoons is this: in our winter the continental regions of Asia are cooler than the surrounding seas, and pressure is higher. The air flows from these towards the equatorial calm-belt in the Indian Ocean, and towards the region of low pressure in the Northern Pacific, as a N. E., N., N. W. or W. wind. As the pressure is continually lower on the seas than on land at this season, this flow of air is very constant. As the air comes from the interior of the continent, and generally also from higher latitudes, *i. e.*, from colder regions, the season when these winds prevail will be a *dry season*, as the vapor contained in the air will be further and further from its point of condensation the further south and east it flows.

In our summer, pressure is very low over a great part of the Asiatic continent, owing to the heat and ascending current produced by it; therefore the air of all surrounding regions will flow towards Asia, and the movement will be especially rapid in and near Southern and Eastern Asia, as the greatest oceans of the world, the Indian and the Pacific, approach Asia in this direction.

Pressure is higher on the oceans in summer on account of the comparatively cool temperature which prevails there. Thus the movement of air will be reversed, and the wind in summer will blow from the S. W., S., S. E. and E. This *summer monsoon* will also be very steady, as the difference of pressure is nearly always in one direction during the whole summer—lower on the land.

Not only is the direction of the movement of air different in summer from that prevailing in winter, the influence on the weather is also different. As the air drawn towards Asia has to pass over a great extent of warm equatorial seas, it is laden with vapor, and this vapor will be deposited in copious showers, especially when it meets a mountain chain, which compels it to rise into higher and cooler regions of the atmosphere. Thus the *summer monsoon* is the time of cloud and rain for all Eastern and Southern Asia, or the *wet monsoon*. There is no doubt that the condensation of vapor, giving out its latent heat, is a new and powerful cause for the continuance of the movement in the same direction.

The influence exerted by the heated continent of Asia is so powerful that there is no equatorial calm-belt in the Indian Ocean during our summer, but pressure decreases steadily from about 25° S. L., the polar limit of the S. E. trade, till about 30° N. L. in Northern India, the S. E. trade crossing the equator, and being thus converted into a S. and S. W. wind. On the eastern coast of Asia the tendency of air to flow towards the continent similarly acts on the N. E. trade of the Pacific Ocean, which is drawn in as an E., S. E. or S. wind. We see here the normal or oceanic conditions very seriously disturbed by the influence of the great continental mass, Asia.

I must correct here an error which is frequently made, *i. e.*, limiting the monsoons to the tropical part of Asia, *i. e.*, India, Indo-China, and Southern China. Even on the new Pilot Chart published by the British Admiralty in 1872, this

error exists. It can be easily explained thus: in the tropical seas adjoining India and Southern China, the direction of the wind is N. E. in winter and S. W. in summer, and seamen were accustomed to consider as monsoon regions those only where winds of this direction were found. The further north we proceed along the coast of Eastern Asia the more the summer winds become S. E. and E., and the winter winds N. W. and W., yet there is good reason to consider Eastern Asia to the 60° N. L. as belonging to the monsoon region, because here also the winds in winter are from the land; in summer, from the sea, they bring dry, clear weather in the first season, and rain in the second; and last, not least, at both seasons they are very constant. (See Maps, Plates 5, 6.)

For these reasons I consider China, Japan, Mantchooria, the basin of the Amoor River, and the western coast of the sea of Ochotsk, as belonging to the monsoon region.

As to the constancy of the winds I would remark, that the inner regions of India, as, for example, the northwest provinces, Oude, Central India, Punjaub, are generally considered as being situated in the monsoon region, yet the winds are not so constant here as in Japan and the Russian Amoor Provinces.

The continent of Australia may also be considered as belonging to the monsoon region, only the periods are reversed, *i. e.*, our winter is the rainy season there, our summer the dry time. At this season regular S. E. winds are experienced in the northern part of Australia; they may be considered as the S. E. trade, strengthened by the comparatively low temperature and high pressure on the continent. They blow towards the Sunda Sea, and, further on, cross the equator, to appear as the S. W. monsoon on the coast of South China. In our winter, on the contrary, pressure being highest in Asia, and very low in the dry, hot interior of Australia, the N. E. monsoon of China crosses the equator and appears as a N. W. monsoon, bringing clouds and rain to the northern coast of Australia. In these meridians the juxtaposition of the continents of Asia and Australia on the north and south of the line, gives additional strength to the monsoons. Here no equatorial calm-belt is found, neither in our summer nor in our winter, while it exists south of India in the Indian Ocean, as there the monsoons can be said to be single, caused by the Asiatic continent alone, while further east they are double, Asia and Australia both exerting an influence.

It may be asked why the whole Asiatic continent, being equally heated in summer and the air rarefied, does not exhibit monsoons of equal magnitude coming from the Arctic and Atlantic Oceans?

The reason is this: on the Arctic Ocean, pressure is also low in summer, though probably not so low as indicated in Buchan's map of isobars, and besides it is not steady, as on the tropical seas. Yet there is a northern wind coming from the Kara Sea, and blowing through Western Siberia to Central Asia, but it is not as steady as the monsoon of India and China. Besides, as this wind comes from a colder region, it does not bring rain, and thus the secondary influence—condensation of vapor, which is instrumental in producing the monsoons of Eastern and Southern Asia—is not effective here. There flows also a current of air, and a very powerful one, from the Atlantic Ocean towards Central Asia; but, as it

is not from the tropical part of the ocean, it cannot bring much rain and produce the secondary areas of low pressure caused by condensation. Besides, the region of high pressure on the Atlantic is far from the low pressure of Central Asia, and near to that about Iceland; so that the movement in the first direction cannot be very constant. As to the air from over the lower latitudes of the Atlantic Ocean and the Western Mediterranean, it is attracted towards Africa, which is highly heated in summer, and open to the winds from the surrounding seas.

The geographical features of the North American continent explain why pressure and winds are so different over it from what is seen in Asia.

The coldest region of America is known to be to the north of the continent, on the islands and ice-bound seas and sounds north of 70°. Ice and snow being bad conductors of heat, the streams of warmer water are thus effectually prevented from having an influence on the air, and the ice-bound seas to the north of America can cool as well as continents.

But, as the coldest space north of the American continent is not separated by mountains and plateaus from the surrounding regions, there cannot be such a constant high pressure there as on the corresponding coldest space of Asia. It will be remembered that the lowest pressure of the northern hemisphere, especially in winter, exists near Iceland, which is partly due to the warm waters of the Gulf Stream. The coldest regions of America are not separated by any natural barrier from this space, and thus air, even from the lowest, heaviest strata, should flow towards Iceland. That this is the case, is shown by the winds in Greenland and on the most northerly stations of the American continent; they are northerly to a very large extent. Probably the easy intercommunication between the coldest region of North America and the region of low pressure near Iceland, explains why the former has not a high mean pressure in winter. Having not a constantly high pressure, the polar regions of America cannot influence the winds in the temperate and tropical regions of this continent as the coldest region of Siberia, with its constantly high pressure, does influence the temperate and tropical regions of Asia. Next, we find a generally high pressure to the south of the United States, on the Gulf of Mexico, as well as on the western highlands and plateaus of the continent, in lat. from 30° to 40° N. Probably, also, pressure is high to about 60° lat. N. on the eastern slope of the Rocky Mountains, where, the winter being cold, the Rocky Mountains in the west not permitting the air in the lower strata to flow towards the Pacific, and the depression about Iceland being far away, there exist all conditions for a high pressure. But barometrical observations from this region are wanting.

Thus, the Mississippi Valley and seaboard of the United States have in winter regions of high pressure to the S. and W. of them; *i. e.* they are exposed to the influence of winds from different directions, of which those that come from the S. are warm and laden with vapor, and thus able to sustain the precipitations necessary to the progress of storm-centres, while the air from the W. and N. W. is cold and dry.

A country generally level, subjected to such different influences, must have a

very variable climate, and this is known to be the case in the United States. Nowhere in the same latitudes are the variations of temperature and pressure so great and sudden as in the Mississippi Valley and in Texas. On the Atlantic sea-board the variation is somewhat less, owing to the slight protection afforded by the Appalachian Chain.

In summer again, there are no parts of North America which are as strongly heated as the interior parts of Asia, none also where pressure is as low, and thus there are no monsoons comparable in strength and constancy to the summer monsoons of Asia. Especially is this the case with the eastern part of the United States, where the land is so much pervaded by the influence of the sea that there is scarcely a summer depression of the barometer. The Gulf of Mexico is situated just in the latitudes where pressure would be lowest on a great continent, and, owing to the relative coolness of the air over great bodies of water, pressure is nearly as high over the Gulf in summer as in winter. Yet, as there is a rarefaction of the air in the interior and western part of North America, there is a monsoon wind drawn in from the Gulf of Mexico to supply the deficiency. The mean direction of the wind is southerly in summer over a great part of the United States east of the Rocky Mountains. It is more S. E. in Texas, and S. and even S. W. in the States north and northeast of it, partly due to the earth's rotation, and partly also to the influence of the lower pressure in the lake regions on the air over the Gulf of Mexico. On the Atlantic coast the winds have some monsoon features (as was shown by Prof. Coffin in 1848) but still the flow of air is much more from the southwest than would be the case in a real monsoon region, the ocean being to the east.

If, aside from disturbing influences, we consider only the mean direction of the wind, the influence of the Gulf of Mexico is seen to be paramount over a large and important region of the United States, extending from the Mississippi to the Appalachian Chain and from 34° to 42° N. L. The mean direction of the wind is about W. S. W. at all seasons, with a ratio of resultant of about 30. The cause of this is, that pressure is highest at all seasons to the S. and lowest to the N. and N. E.

Having now considered the influence of the pressure of the air on the direction of the winds, the influence on force remains to be shown.

It is easy to conceive, that, the influence of pressure once acknowledged, this influence would be the greater, the nearer areas of high pressure approach areas of low pressure, or, in other words, the nearer any given difference of pressure was found to exist. It was to be supposed, that the more this was the case, the greater would be the velocity of the winds. This has been found to be really the case.

This difference of pressure relative to distance was called by Stevenson *barometric gradient.* This term of barometric gradient may be applied to the mean direction of the wind, and the rate of progress, as well as to any given single observation. The more the isobars are crowded together, the steeper is the gradient, and the greater will be the velocity of the wind, all other conditions being the same.

There are conditions well known to science in a general way, although not

measured with accuracy, which prevent all winds from reaching the same velocity even if the relative distance of the isobars be the same.

These conditions must be considered in brief.

In the lowest stratum the velocity is lessened on account of friction on the surface of the earth, while the higher are also more or less affected by the friction of the different strata on each other.

The winds on the ocean will be less affected in this way, because of the smooth surface of the water. The greater velocity of the wind on the sea is well known. The figures published in the "Quarterly Weather Reports" of the Meteorological Office, of London, very clearly show the decrease of velocity in the interior of Great Britain even in level parts of the country.

The following table shows this for the United States. I give the mean velocity of the wind in a group of inland stations (Eastern New York) compared with that of the sea-coast (Cape Cod and adjacent islands) and also with the summit of Mount Washington, the highest peak of the New England States.

MEAN VELOCITY OF THE WIND. MILES PER HOUR.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Eastern New York . .	4.1	2.8	2.4	5.1	5.7	5.4	4.5	5.1	5.8	4.8	3.3	10.4	7.9	5.7	8.7	7.5
Mount Washington[1]. .	19.5	...	...	17.4	21.0	17.3	15.5	**24.3**	50.2	41.7	36.8	38.8	41.8	34.0	44.8	**52.2**
Cape Cod and islands .	7.8	**10.9**	5.3	9.0	6.7	9.6	9.3	6.3	19.9	**20.5**	12.2	16.1	10.6	10.9	10.9	20.0

Mount Washington having the freest position, the strength of the winds there must be considered as more nearly normal than at the other places. The N. W. winds are the strongest, both summer and winter. But in the vicinity of Cape Cod, the N. E. winds coming over the smoother surface of the sea, are the strongest.

It is safe to present the following rules for the velocity of the wind. It is greater:

1. On high isolated peaks, than at low stations.

2. On the seashore, and especially on isolated islands, than in the interior of continents.

3. In level countries than in countries surrounded by mountains.

4. In prairies, and especially desert countries, than in wooded regions.

These rules apply to the local positions only. But we may remark that it is possible to mention some regions where the velocity of the winds is greater, others where it is less, than the average over the whole earth.

To the latter belong the equatorial calm-belt, and the calm-belts at the polar limits of the trade-winds. It would be wrong to imagine that any point on the

[1] One summer and two winters, 1870–71, and January, February, and December, 1872.

surface of the earth has perpetual calms. The calm-belts themselves are not constant, but move in the different seasons, and besides, the calms are more or less frequently disturbed.

In the trade-winds belts also, notwithstanding calms are very rare, the velocity of the wind is probably less than the average of the globe.

Probably the part of the earth where the winds have the greatest velocity, is found between 40° and 60° Lat. S., where very strong westerly winds are prevailing the whole year. The cause of this is the great difference in the pressure of the air at a small distance, or in other words the steep barometric gradient.

The great difference of the mean velocity of the winds blowing over a region, and of the progress of the air in a certain direction, should be borne in mind. Where the winds are weak, but always from one direction, as in the trade-wind region, the total rate of progress measured in miles will be considerable, frequently greater than in regions where strong winds blow from different directions. It is even possible that the winds may be so counterbalanced by one another, that there will be no resultant direction, so that the definite result, as far as progress of the air is concerned, would be the same as if absolute calms had prevailed all the time.

So far as regions are considered, where the mean direction of the wind does not vary, or varies but slightly in the different seasons, the mean annual direction with rate of resultant, gives a tolerably fair idea of the character of winds in such regions.

It is quite different where regions with very great variations in the yearly direction of the wind are considered. Here the annual direction will give but a very imperfect idea of the character of the winds. This is the reason why, as far as possible, I have always placed at least two contrasting seasons, summer and winter, in giving the percentages of the winds and the mean directions in the small tables which follow, and serve to illustrate the winds of different regions of the world. This is also the reason for constructing the two maps, Pl. 5 and 6. The same attention has been given to this subject by Prof. Coffin in his extensive tables arranged in Zones, in Series B of this work, the number of observations being given generally for the four seasons, sometimes even for each month. How far the consideration of the annual result alone would mislead, the following table will show:—

	Year.		Summer.		Winter.	
	Mean direction.	Rate of resultant.	Mean direction.	Rate of resultant.	Mean direction.	Rate of resultant.
57°–58° N. L.—Eastern Scotland .	S. 60° W.	28	S. 65° W.	18½	S. 62° W.	40
Greenwich, England	S. 62° W.	17	S. 61° W.	28	S. 55° W.	25
50°–55° L. N., 0° to 65° long. W.— Atlantic Ocean	S. 53° W.	23	S. 46° W.	23	S. 65° W.	36
N. W. Ohio	S. 65° W.	35	S. 59° W.	39	S. 73° W.	37
Middle Tennessee	S. 64° W.	21	S. 51° W.	22	S. 65° W.	28
Hakodade, N. Japan	S. 79° W.	22	S. 12° E.	42	N. 59° W.	63
Pekin, N. China	S. 64° W.	11	S. 16° E.	18	N. 54° W.	30
Madras, Southern India	S. 30° W.	18	S. 54° W.	85	N. 47° E.	68
Colombo, Ceylon	S. 61° W.	29	S. 58° W.	88	N. 37° E.	59

It is seen from the foregoing that in Western Europe, on the Atlantic Ocean and in a certain region of the United States, the mean direction of the wind in the year, summer and winter, is between S. W. and W. S. W., and the difference between the two seasons very small. If the rate of annual resultant is not greater, it is because at all seasons there are many winds coming from other directions than the prevailing one.

In Pekin and Hakodade the mean annual direction is nearly the same as at the above named places, but the ratio of resultant is small for another reason: the winds of summer and winter being nearly opposite to one another, the resulting annual movement is small. Yet at each of the seasons the winds are very steady. The angle between the mean direction of the wind in winter and summer is 142° at Pekin, and 133° at Hakodade, or more than $\frac{3}{8}$ of a circle, and only from 3° to 20° at the above cited places of Europe and America. Again, the mean annual direction of the wind and ratio of resultant, in Southern India and Ceylon, are very similar to those observed in Europe, but the mean direction of winter and summer nearly opposite to one another, with an extremely great ratio at both seasons, there are conditions as dissimilar as possible to those of Western Europe.

In the pages which follow, the results to be drawn from the observations on the winds are considered by geographical divisions.

SPECIAL DEDUCTIONS.

GREENLAND AND ARCTIC AMERICA.

THE information we have on the winds, as well as on the general climate of Arctic America and the adjacent islands, is more extensive than that on any other Arctic region, Northern Norway excepted. Our knowledge of these regions is mostly due to Arctic explorations. The Arctic Archipelago, north of the American Continent and west of Greenland, was explored almost continuously by British expeditions for more than thirty-five years (1818–1855), in search of a northwestern passage.

The results of these expeditions are of high value to science, especially as the inducements to explorations in this direction can scarcely ever return. The bays and straits between the islands are probably the most ice-bound in the world.

Smith's Sound and Northern Greenland have been explored by the American expeditions of Kane, Hayes, and Hall.

According to the most authentic Arctic authorities, Smith's Sound offers the best route to the Pole, the sea between Spitzbergen and Nova Zembla perhaps alone excepted. It is entirely frozen only a short time, and does not present serious obstacles to navigation in steamers. This gives us reason to expect further knowledge of those regions which were so successfully penetrated by American explorers, with very inadequate means at their disposal.

A German expedition wintered in Eastern Greenland, 75° N. Lat.

We know much less of Western Arctic America; few expeditions having wintered there west of 100°. Our knowledge of the interior of British America is also less than of the Arctic Archipelago, though it is much more easy of access. More information relative to this region is very desirable.

Our knowledge of the climate of Arctic regions generally having been mainly derived from observations made in the Arctic Archipelago of America and in Smith's Sound, it is necessary therefore to inquire into the geographical position of these regions. They are situated from nearly due north to W. N. W. of Iceland, where, as was stated above, exists the lowest pressure of the northern hemisphere, nearly the whole year round, but especially in winter. This must lead to the prevalence of northerly and westerly winds. Accordingly in the stations in Smith's Sound northeasterly winds were found dominant, owing to the influence of the strait, and also to the position, N. N. W. of Iceland. (See Map, Pl. 2.)

There are great discrepancies in the results obtained at the different stations,

but these are easily accounted for, if we remember that the period of observation was short, mostly one year only, and that the climate of the Arctic regions is very changeable; still there are some differences in the direction of the winds which can only be ascribed to their geographical position. Thus Northern Greenland has the greatest prevalence of the true polar winds, northeast, and this is due in no small degree to its proximity to Iceland, as well as to the open water of Smith's Sound near a very cold continental area.

The most northerly stations west of Smith's Sound, as Northumberland Sound and Port Refuge, have the least amount of northern winds. This is, no doubt, owing to their distance from Iceland, and, probably also, to a partly open sea to the northward of them. If there is really an open sea in this direction, the pressure there must be lower in winter than on the ice-bound straits of the Archipelago. This would give rise to southerly winds to equalize the pressure, and thus explain the greater number of these winds in Northumberland Sound and Port Refuge. They do not prevail at these places, because the depression about Iceland is still felt there as well as the depression which must exist on the open waters of Davis' Strait and Smith's Sound. As the other stations of the Archipelago, except Melville and Dealy Island, are much nearer to Davis' Strait, they must feel its influence much more, while a great extent of islands and frozen bays and sounds separate them from the northern partly open Polar Sea.

The prevailing northerly winds in summer can be explained partly by the same cause as those of winter—the low pressure about Iceland. It is true the barometer near Iceland is not as low in summer as in winter. But in the Arctic zone of America the pressure rises also, especially from February to May; in the last-named month it is the highest of the year in most of the stations of this region.

It is probable that the pressure continues to rise in the circum-polar zone till July, thus causing the northerly winds of Arctic America. At this season air is also drawn towards the interior of North America, especially towards the region between the Rocky Mountains and 95° W. Long.

Arctic America is noted for its frequent calms in the colder part of the year—a feature observed by nearly all who wintered in these regions. They are, however, recorded in a very discordant manner in the journals of observations, showing there was a great difference in the meaning of the word "calm." This want of agreement has prevented a more elaborate discussion of this phenomenon, one of the most important in regard to the movements of the atmosphere.

Dr. Bessels has calculated the percentage of what he calls "absolute calms," for the hours when a self-registering wind-vane did not indicate any movement of air whatever, for the second winter-harbor of the U. S. Expedition, under Capt. Hall, at Polaris House or Lifeboat Cove.

Hours of Absolute Calm in 1000.

November, 1872, 74	January, 1873, 298	March, 1873, 188
December, " 47	February, " 79	April, " 179
		May, " 116

Average for seven months, 140.

I should remark, that in many of the stations the proportion of calms increases

towards March and April. In these months the cold is still intense in this region, and the pressure generally higher, so that barometric poles or areas of highest pressure are frequently met with. They are generally accompanied with calms or light winds. On the other hand, the indraught towards Iceland is less, as pressure has also risen there. (See Tables, Zones 2, 3, 4, and 5.)

In cold continental areas of lower latitudes, especially in Siberia, the greatest number of calms will be experienced in mid-winter, the time of lowest temperature and highest pressure. In March and April, when temperature is much higher, pressure decreases, and so also the number of calms.

The following figures give the percentage of winds in Greenland. Winter and summer are chosen as the two contrasting seasons of the year.[1]

Greenland.	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Polaris Bay,[2] No. of obsert'ns	7	20	4	14	9	**31**	8	7	3	35	**38**	5	3	13	0.3	3
" " " miles . .	12	**42**	2	6	4	27	4	4	4	**56**	17	2	2	16	2	2
Lifeboat Cove,[2] observations .									3	**80**	1.5	0.8	6	8	0	0
" " miles									3	**82**	1.7	0.4	5	9	0	0
Port Foulke	3	**45**	3	2	1	**45**	0.7	1.4	4	**73**	1.2	5	0	16	0	0.8
Upernavik	28	7	11	6	5	**36**	5	3	21	15	**40**	3	1	16	3	0
Jacobshavn and Godthaab .	16	13	20	3	5	**32**	7	4	9	16	**42**	8	6	14	2	3
Sabine Island,[3] East. Green'd	**23**	8	13	9	21	7	10	9	**47**	3	6	3	12	6	13	11

	Spring.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Polaris Bay, number of observations	0	**30**	21	18	1	20	4	4
Polaris Bay, number of miles	0	**67**	8	6	0.3	17	1	1
Lifeboat Cove, number of observations	0.8	**64**	3	1	13	18	0	0
Lifeboat Cove, number of miles	0.5	**67**	2	0.4	14	16	0	0
Sabine Island, number of observations	**46**	2	5	5	19	5	12	7

All these stations except Sabine Island are situated on the western shore of the greatest island of the world, an island covered with large sheets of ice, and the temperature of which is much below that of the surrounding seas in winter, spring, and autumn; Smith's Sound is open the greater part of the year, though bearing large floating icebergs. Monsoon winds must be expected in these conditions, and this is really the case.

The winds of Polaris Bay[4] have a peculiar interest, this being the most northerly station at which civilized man has ever wintered.[1] Polar winds prevail largely in spring and winter. Yet there is a great difference between the N. E. and E. winds. The second prevail if the number alone is regarded, but the N. E. prevail

[1] In all cases, except when specified, the percentages are calculated from the winds collected by Prof. Coffin.

[2] From the observations of Dr. Bessels, of Capt. Hall's Expedition.

[3] Observations of the Second German Polar Expedition, under Capt. Koldewey.

[4] I owe this information on the winds of Polaris Bay and Lifeboat Cove to Dr. Bessels, who has kindly permitted the use of his observations.

largely if we take into account the number of miles. And this may be done safely, as the expedition of Capt. Hall had an anemograph of Robinson's plan. The east winds then seem to be a weak local land-wind, caused by the difference of temperature of land and sea. The N. E. winds, on the contrary, are the true polar currents, flowing towards the barometric depression about Iceland.

In summer the S. W. wind prevails as to time, but the excess is on the side of the N. E., if the number of miles is considered, but of much less amount than in winter and spring.

In the second winter station of Capt. Hall's party, Lifeboat Cove or Polaris House, as also in Hayes's Station, Port Foulke, in the vicinity, the N. E. prevail even more than in Polaris Bay in winter and spring. The W. and N. W. are entirely wanting.

In the tables of Professor Coffin, the winds at Rensselaer Harbor, Kane's winter station, were recorded with reference to the magnetic direction. As the magnetic declination is known to be 108° 12′ W., I give below the true mean direction of the wind in this locality, and also that recently calculated by Dr. Bessels for Polaris Bay. In the Map, Pl. 2, the true direction is given.

	Rensselaer Harbor.		Polaris Bay.	
	By Hours.	By Miles.	Mean direction.	Rate of Progress. Miles.
Spring	S. 75° E.	S. 87° E.	N. 38° E.	6279
Summer	S. 1° W.	S. 36° E.	S. 2° W.	1828
Autumn	N. 78° E.	S. 86° E.	N. 26° E.	2685
Winter	N. 65° E.	N. 63° E.	N. 21° E.	4394
Year	S. 86° E.	S. 89° E.	N. 40° E.	11,392

The observations of Rensselaer Bay are thus shown to agree, to a considerable extent, with those of the surrounding stations. The winds are more easterly than at Polaris Bay at all seasons, and do not vary as much as at that station, the difference between winter and summer being only 91° instead of 161°. See Map, Pl. 2.

The Danish settlements of Northern and Southern Greenland (all on the west coast of the island), Upernavik, Jacobshavn, and Godthaab, have largely prevailing east winds (from the land) in winter, and west winds (from the sea) in summer. As the force of the winds has not been accurately ascertained, we cannot say whether the N. E. are much stronger than the East, as in Polaris Bay. In the summer the rocky surface of the interior (as Greenland is not all covered with ice) is highly heated by the sun, it draws in the air from the colder sea, which is cooled by the large number of icebergs floating southward.

We know much less about Eastern Greenland, the country being entirely uninhabited. Yet the 2d German polar expedition having passed a year near Sabine Island, 75° L. N., near the coast, we are able to say that the prevailing winds are N., especially in spring, autumn, and winter, while S. winds are nearly as frequent as N. in summer. The N. prevail here to a less degree than the N. E. at Lifeboat Cove and Port Foulke; but it would be rash to decide from so short a period and so few observations that the polar winds are really less prevailing in the east than in the west of Northern Greenland. The eastern coast of the island

being nearer to Iceland, where pressure is low, we might infer that the contrary should be the case, if all local influences were eliminated. Nearly all the storms near Sabine Island come from the N., and the mean force of this wind is very much greater than that of any other wind.[1]

The constancy of the polar current in Northern Greenland is indirectly proved by the small precipitation of rain and snow. The quantity of snow falling at Polaris Bay and Lifeboat Cove was scarcely measurable, according to Dr. Bessels. He thinks the glaciers of Northern Greenland are the remnant of a former age, when the climate was different. The snow and ice that melt in every summer are not now replaced by new snow, so that the glaciers must be decreasing.

The German expedition did not encounter a heavy snow-fall, and the parties who, in sledges, explored the interior, were quite astonished at the constant brilliancy of the sunshine of the Greenland summer.

In Arctic countries the sea is warmer than the land in the mean of the year; during a very short time only, in summer, are the conditions reversed. The pressure is generally higher on land, so that we must expect to see a prevalence of land-winds in the mean of the year. In looking at the map of the polar regions (Plate 2) an easterly mean direction is seen to prevail in all stations in Greenland, that have the open sea to the westward; and a westerly in the stations of the Arctic Archipelago, which have the sea to the eastward.

By sea, is meant here the more or less open waters of Baffin's Bay and Davis Strait, and not the more ice-bound straits and inlets of the archipelago. Ikogmut and St. Michael in northern Alaska have easterly winds, directed towards Behring Strait. In Ustyansk, in the extreme north of eastern Siberia, the mean yearly direction is nearly due south—as we might infer from the fact that the Arctic Ocean lies to the north of this place. Hammerfest, Vardo, and Bossekop, in extreme northern Norway, have also prevailing southerly winds for a similar reason.

The extreme prevalence of land-bound (Mediterranean) seas, north of the North American continent, greatly affect the character of the region considered in a climatic point of view. As land-bound seas in these latitudes will be also ice-bound, the air over them would cool as over a continent, so that places situated on the shores of such seas will have a cold continental climate in winter, spring, and autumn. This cold will not, however, be followed by a comparatively warm summer, as is the case on polar continents far from the influence of the sea. The melting ice over the sea absorbs the heat of the sun's rays. Thus we have a continental climate during three-quarters of the year, and an oceanic during the remaining summer quarter. This is the case in the Arctic Archipelago. It has one of the coldest climates of the world, the winter being even colder than in northern Greenland, and only a little warmer than in Iakutsk in eastern Siberia, and the summer also extremely cold.

The percentage of winds is as follows:—

---

[1] See "Die Zweite Deutsche Nordpolarfahrt," Leipzig, 1874.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 3, No. 3. Port Refuge	15	10	**28**	18	6	9	6	15	5	1	4	**38**	29	13	5	6
" 3, " 1. Northumberland Sound	4	**28**	3	11	13	12	7	21	7	20	3	20	6	10	4	**30**
" 4, " 4. Melville Island	**28**	5	4	11	13	7	20	12	**46**	0.3	13	6	6	1	8	19
" 4, " 4. Dealy Island	22	14	2	6	9	15	11	**22**	**38**	7	11	6	6	3	5	24
" 4, " 9. S. E. Boothia Felix	**26**	15	5	4	11	10	12	16	**29**	6	4	6	17	12	6	21
" 4, " 10. Port Kennedy, observations	4	25	8	3.5	1.8	5.5	14	**38**	2.4	16	0	0.3	0.1	2	12	**67**
" 4, " 10. " " miles	2.6	21	6	0.4	0.5	4.5	12	**53**	2.4	15	0	0.1	0.1	1.6	13	**68**
" 4, " 11. Port Bowen	16	11	15	8	6	11	**18**	16	12	7	**61**	7	0	1.2	3	9
" 5, " 8. Igloolik	22	7	6	21	4	5	9	**26**	26	8	4	2	2	2	16	**39**
" 5, " 9. Winter Island	16	8	8	10	12	9	13	**23**	27	3	2	5	0.6	2	8	**52**
" 5, " 11. Baffin's Bay	**18**	14	14	10	9	14	8	13								
" 4, " 13. " "	**19**	7	12	18	9	8	11	16	15	7	6	7	6	5	21	**33**

The prevalence of the N. and N. W. winds is here strongly marked, especially in winter. At two of the stations more than half of all the winds come from the N.W. The exception presented by Port Bowen, where E. winds largely prevail in winter, is explained by the large land-mass to the E. The winds of the inland and western stations of Arctic America, as well as the Arctic Ocean in their vicinity, show more irregularities.

Percentages.	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. S.
Zone 6, No. 8. Fort Simpson	7	2	**27**	6	1	10	2	**44**	8	0.7	17	17	2	4	17	**35**
" 6, " 7. Fort Norman									9	1.2	2	**37**	4	0	24	23
" 6, Nos. 10, 11. Forts Enterprise and Reliance									11	**23**	18	2	5	17	16	7
" 5, No. 5. Fort Franklin	0	9	**42**	21	0.9	2	6	18	2	13	20	7	1.2	2	14	**42**
" 5, " 4. Fort Anderson	**37**	6	9	4	18	5	16	4	**29**	6	15	5	15	8	15	7
" 6, " 3. Fort St. Michael's, Alaska	**27**	4	6	2	**28**	16	12	4	**25**	17	7	15	19	13	1.5	3
" 6, " 5. Ikogmut, Alaska	11	19	9	4	4	**22**	14	17	10	**25**	12	7	15	10	7	13
" 6, Behring's Strait, 172°–160° W.	12	15	10	13	**21**	16	7	6								
" 5, " " 177° E.–160° W.	15	8	9	12	**20**	8	12	17								
" 4, W. Arctic Ocean, 155°–175° W.	24	**25**	7	6	8	10	7	13								
" 7, No. 16. York Factory	15	**28**	23	5	18	2	3	5	20	4	11	4	**25**	13	12	12
" 7, " 17. Little Whale River	**28**	7	6	10	2	**28**	9	10	3	3	11	19	**22**	15	19	2

From the foregoing table it appears that in Northern British America (Forts Norman, Simpson, Enterprise, Reliance, Franklin, and Anderson) there is no accordance in the direction of the winds. They seem to vary much according to locality. This is a very cold region, and being continental, calms are much more prevalent in winter than in the Archipelago. We must expect to find here higher pressure in winter than further to the east, because the depression about Iceland is not so near.

The great distance of the Atlantic depression and the mountains which lie between this region and the Pacific depression, also explain the undecided character of the winds in winter.

We have fewer observations in the summer. Among these, Fort Franklin has prevailing E. winds, coming from Great Bear Lake, where the ice does not melt till the end of the summer.

In Alaska monsoon winds are seen to prevail from the N. E. (the land) in winter,

S. W. in summer. In Behring Strait southerly winds are also more numerous in summer, while the Arctic Ocean northward of it has northerly winds at the same season.

In the last two stations lying near Hudson's Bay, a monsoon influence is exhibited in the S. winds of winter. Hudson's Bay does not freeze entirely, and thus the wind will blow towards it from the land. (See Maps, Plates 5, 6, and 14.)

TEMPERATE ZONE OF AMERICA WEST OF THE ROCKY MOUNTAINS.

On the coast of Alaska and further south in Washington Territory, the winds have a monsoon character. The cause of this is the difference of temperature and consequently of pressure on land and sea, producing a current of air from the land in winter, and from the sea in summer.

It is necessary to remember that the warm current of the Kuro-Sivo, the Gulf Stream of the Pacific, passes, in its return to the south, near to this coast, and there must be a diminished pressure over the region, at least in the colder part of the year. The interior of the continent is very cold at that time, and therefore the pressure of the air must be high there.

In the summer there is a narrow cold current passing between the coast and the Kuro-Sivo, while at the same time the interior of the continent has a great excess of temperature over the coast, and, as in other dry and warm continental areas, the pressure must be low.

There is no country of the world where the temperature of the summer increases so much as we go from the coast to the interior as on the Pacific slope of America, from Alaska to Lower California. The summer isotherm of 59° passes near San Francisco on the coast of California, and is supposed to reach the polar circle on the Yukon River, in the interior of Alaska, a difference of 28° in latitude. Fort Miller, in the interior of California, has a summer temperature of 85°.5, and Monterey, on the coast, and in the same latitude, but 59.0; difference 26.5 F. The percentage of winds in Alaska and Washington is given below, and, with the help of the maps, Pl. 5 and 6, will serve to illustrate the winds of this region. Plate 14 gives the atmospheric pressure.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Isl. of St. Paul,[1] Alaska, Behring Sea									11	6	12	9	**25**	16	14	8
Iluluk, Aleutian Islands[1]	7	6	6	17	19	**21**	6	9	**22**	4	12	12	14	9	10	16
Fort Wrangel	5	4	9	8	13	**25**	17	18	12	16	**24**	17	10	7	5	7
Fort Tongass	6	4	2	25	**45**	8	3	6	21	18	13	**24**	15	3	0.3	6
Sitka	5	4	9	8	13	**25**	17	18	12	16	**25**	17	10	7	5	7
N. W. Washington	4	6	3	13	21	**31**	17	4	16	9	11	**24**	12	13	8	6
S. W. Washington	6	4	0	9	3	16	28	**33**	5	17	18	**25**	5	15	3	12

[1] From Report of Chief Signal Officer, 1874.

If, as was said before, the winds of this coast have monsoon features, these monsoon winds do not overpower others, especially in winter. At that season of the year the pressure is high in the latitude from 25° to 35° N. on the coast of California, and in the same latitudes on the Pacific Ocean. Winds from this region are quite frequent, and passing over the warm waters of the Japanese current, give a very warm climate to the whole coast. The winter temperature of Sitka is equal to that of New York, and above that of St. Louis.

It seems to me that the S. E. winds which are so frequent on this coast, are, partly at least, the deflected S. W. winds of the Pacific. The mountain-chains give them a direction from the S. S. E.

The Aleutian islands are very near to the centre of lowest pressure on the Pacific, at least in winter. They occupy a position similar to that of Iceland in the Atlantic; the same may be said of the island of St. Paul in Behring Sea. The storms are frequent and severe, and the winds polar and equatorial in turn, without a marked predominance of either. In summer the centre of depression moves to the northward and inland, and accordingly the winds are principally from the south.

In Washington Territory the winds of the coast-region are very similar to those of Sitka. In the interior of Washington and Oregon the winds have no strongly marked monsoon character. (See also Maps, Pl. 5, 6, 8, and 11.)

Percentages	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
S. E. Washington	3	7	3	20	13	**39**	7	8	4	8	2	23	13	**36**	3	**11**
N. E. Washington . . .	3	7	3	20	13	**39**	7	8	4	8	2	23	13	**36**	3	**11**
N. E. Oregon	3	8	5	3	5	27	**30**	18	3	15	8	6	8	**33**	15	**11**

The S. W. is here the prevailing wind, winter and summer, as in the same latitudes on the oceans and in Europe. We must see in these winds a continuation of the equatorial current of the Pacific, which crosses the coast-ranges and descends into the valleys, while part of it is deflected by these mountains and appears as a S. E. wind at Sitka. The winds of California differ in some respects from those of the northern Pacific coast. They are westerly at all seasons of the year, more S. W. in winter and N. W. in summer. The winds of the summer are very strong and steady, giving to the California coast a peculiar climate—a summer colder than anywhere in the same latitude even in the southern hemisphere. In some places the prevailing winds in summer are S. W., and the mean direction also south of W. This is probably due to the position of the coast, so that the S. W. seems to be a local sea-wind. At San Diego the number of miles was also observed, and I have calculated separately the percentages for the number of observations and for the number of miles, in the three summer months.

San Diego.	Summer.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
No. of Observations	4	10	11	13	7	**29**	19	**7**
No. of Miles	1	2	0.6	8	12	12	9	**55**

Thus the N. W. wind largely prevails if the number of miles is taken into account. The following is the percentage of winds in California, Oregon, and Nevada.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
N. W. Oregon	7	1	3	2	7	34	25	21	4	10	19	18	12	**23**	6	8
W. and S. W. Oregon	11	5	3	6	6	14	14	**42**	10	12	7	14	9	**22**	9	17
N. W. California	**28**	12	3	4	7	11	12	23	12	8	7	14	**19**	16	11	14
California, lat. 39°–40° N.	2	1	1	5	21	19	**42**	8	9	8	15	10	**19**	14	15	9
California, lat. 38°–39° N.	5	1	1	20	**28**	22	16	8	22	6	5	**23**	11	5	4	**24**
California, lat. 37°–38° N.	1	0	1	1	5	32	**48**	13	14	11	6	12	10	**17**	14	15
California, lat. 36°–37° N.	6	3	1	2	4	22	**34**	27	13	4	1	3	9	**30**	21	19
W. Nevada	5	9	8	9	6	17	**37**	10	8	19	11	8	7	19	**21**	7
N. W. Nevada	5	5	15	12	19	14	**26**	4	9	7	10	3	8	14	**44**	5
E. Oregon	7	3	13	5	5	10	**38**	19	3	4	10	**23**	16	18	18	8
N. E. Oregon	3	8	5	3	5	27	**30**	18	3	15	8	7	8	**33**	15	11
S. W. Idaho	8	8	10	7	11	14	**24**	17	**20**	15	8	13	9	7	13	15

The mean direction of the wind in the four seasons is as follows in the same western region of North America.

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
Iluluk, Aleutian Islands	S. 47° W.	.11	S. 27° W.	24½	S. 81° W.	.22½	N. 30° W.	.06
Fort Wrangel	S. 64 E.	.48	S. 36 E.	20	S. 34 E.	.03	N. 46 E.	.15
Sitka	S. 6 W.	.07	S. 61 W.	34	S. 41 E.	.29	N. 88 E.	.32½
N. W. Washington	S 9 W.	.27½	S. 32 W.	44	S. 26 E.	.20	S. 48 E.	.17
S. W. Washington	S. 79 W.	.20	N. 79 W.	53½	S. 64 W.	.19	S. 73 E.	.17
S. W. Oregon	N. 76 W.	.30½	N. 54 W.	56	West.	.17	S. 35 W.	.12
N. W. California	N. 50 W.	.19	N. 32 W.	35	N. 58 W.	.22	S. 36 W.	.16
California, lat. 37°-38°; long. 121°–123°	S. 76 W.	.52½	S. 77 W.	73	S. 75 W.	.47	N. 88 W.	.12½
W. Nevada	N. 88 W.	.26½	S. 81 W.	34½	N. 58 W.	.11	S. 86 W.	.10½

Thus in summer, westerly winds very largely prevail in this region, while in winter the ratio of resultant is much smaller in California and Oregon, and easterly winds prevail further north, as shown also by the map, Plate 8.

The geographical features of the North American continent are such as to exclude a great part of it from the influence of the Pacific Ocean. The mountain-chains are higher in the west than in the east, and, what is more important still, there is a very extensive plateau occupying nearly all the western half of the continent, between 34° and 42° N. L. The eastern part of this plateau, in eastern Wyoming, Colorado, and New Mexico, and in northwestern Texas slopes gradually towards the east—the valley of the Mississippi—and is thus subjected to the influence of the Gulf of Mexico. This influence is especially felt in summer,

when the heated and rarefied air of the plains draws in that of the surrounding regions.

On the west these plateaus are walled in by ranges of mountains, and the indraught of air from the Pacific slope is thus prevented.

We know that there is a depression of the barometer in summer over the plateaus of the interior, but there are yet too few observations to decide as to the region where this depression is greatest. It is, however, most probable that it is in Utah.

There is also a low region, where pressure must be low in summer, that is the valley of the Gila and lower Colorado. The heat is extreme there, Fort Yuma and vicinity having the warmest summer in America, and the ascending current must be very powerful. Air is drawn in towards this hot region, and, owing to its geographical position, principally from the south, from the Gulf of California. (See also Map of Isobars, Pl. 14, and of Winds, Pl. 8 and 11.)

The following table gives the percentage of winds of the region east of the coast:—

Percentages.	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Fort Yuma, Cal.	5	9	10	21	**23**	17	12	4	**21**	14	7	6	7	9	15	20
N W. Arizona	9	6	7	19	**32**	13	7	6	**35**	12	8	8	9	8	9	11
Central Arizona	8	4	3	**24**	**25**	16	14	5	18	10	4	11	15	**18**	14	10
N. E Arizona	11	7	6	7	17	15	**26**	11	13	5	3	5	13	18	**28**	15
Central New Mexico . . .	4	4	4	17	**36**	21	6	8	**22**	15	11	9	13	9	7	15
S. New Mexico	2	4	11	**22**	**22**	20	13	5	11	17	18	6	5	10	**22**	11
N. W. and N. New Mexico .	10	9	12	10	**20**	14	19	6	14	12	9	8	15	12	**16**	14
S. W. Utah	3	1	3	7	21	**31**	23	12	**25**	9	5	3	10	15	**20**	13
N Central Utah	19	11	11	8	16	10	15	10	**25**	14	6	8	14	8	10	14
W. and S. W. Montana . .	5	7	12	5	5	11	**39**	16	7	8	5	14	20	**30**	19	16
N W. Montana	18	6	7	9	5	6	**35**	14	21	7	3	3	10	13	**27**	16
N. Central Dakota . . .	9	6	11	13	**24**	7	19	11	10	8	12	6	17	6	**25**	16

The predominance of southerly winds in summer, as shown by this table, is very great, and it must be remembered that the greatest part of this region is mountainous, and thence great local discrepancies should be expected. The period of observation was short in nearly all cases. Considering this, the agreement between the different regions is very satisfactory. (See Plates 8 and 11.) In Utah there are less southerly winds in summer, and still less in Montana. But this is easily explained. As Montana lies north of 44° N. latitude where there is no extensive plateau, and the mean height of the Rocky Mountains is less than to the south—the westerly winds from the Pacific can therefore readily reach Montana.

We should also expect to see southwesterly winds in winter in Montana, as in California and Oregon. This is really the case. In Arizona and New Mexico, on the contrary, the winds are much more northerly in winter than in summer. I give below the mean direction of the wind in some of the regions here considered. (See also maps, Plates 5, 6, 8, and 11).

	Summer.		Winter.	
	Mean Direction.	Ratio of Resultant.	Mean Direction.	Ratio of Resultant
Fort Yuma, Cal.	S. 36° W.	.35	N. 29° W.	.30½
Central Arizona	S. 8 W.	.39½	S. 79 W.	.15
N. W. Arizona	S. 7 E.	.36½	N. 2 W.	.31
S. New Mexico	S. 3 W.	.43½	N. 9 W.	.15
N. W. New Mexico	S. 26 W.	.18½	N. 63 W.	.25
N. Central New Mexico	S. 29 W.	.23	N. 29 W.	.27
S. W. Utah	S. 52 W.	.51½	N. 56 W.	.29½
N. W. Montana	S. 65 W.	.36½	N. 68 W.	.42½
N. Central Dacotah	S. 20 W.	.17	N. 88 W.	.17½

TEMPERATE ZONE OF NORTH AMERICA, EAST OF THE ROCKY MOUNTAINS.

This region has much in common with Arizona and New Mexico, as to the mean direction and percentage of its winds. In summer a strong current from the south sets in to supply the air which is rising on the interior plateaus. In the winter, on the contrary, the prevailing winds are N. W. and the mean direction generally between N. and W. In winter the winds are more variable than in summer, and even southerly winds are sometimes experienced. The boundaries of this region are the great axis of the continent on the W., the Rio Grande on the S.W., the Gulf of Mexico on the S. E., and the Mississippi on the E. The northern boundary is rather doubtful, but yet, as far as 45° N., winds from the S. E., S., and S. W. prevail in summer. (See also maps, Plates 5, 6, 8 and 11.)

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
E. New Mexico	5	5	7	13	**41**	18	6	4	9	8	11	9	**22**	13	21	7
W. Texas	9	8	15	**16**	15	13	14	9	13	10	7	8	4	11	**25**	22
Rio Grande Valley	1.1	4	13	**61**	19	1.1	0.3	0.9	17	14	9	**24**	11	3	4	**18**
Central Texas	9	7	4	19	**46**	11	2	2	**28**	6	4	8	21	13	8	12
S. Central Texas	5	5	15	**32**	**28**	9	4	2	**31**	13	12	14	12	6	5	8
San Antonio, Texas, No. of ob.	1.2	8	7	**76**	5	2	0.7	0	27	**31**	6	13	4	5	4	10
San Antonio, do., No. of miles	1.3	6	5	**79**	5	3	0.3	0	**50**	15	2	7	4	3	4	15
Forts Brown and Polk with Matamoras	0.7	5	17	**52**	16	8	1	1	16	11	13	**20**	15	5	4	15
S. E. Texas (31°–33° N., 94°–97° W.)	4	5	12	31	**37**	5	2	3	**27**	10	8	12	19	6	6	12
Eastern Central Texas	6	6	12	19	**43**	6	4	3	**30**	4	4	11	23	7	7	14
N. Texas, E. of 98° W. long.	5	2	17	13	**47**	9	6	1	**27**	4	8	6	27	9	9	8
Arkansas, 34°–35° N.	8	9	10	13	18	**20**	13	10	13	10	9	10	9	16	12	**21**
N. E. Arkansas	17	8	11	11	**21**	9	12	11	16	6	10	6	22	11	20	7
S. E. Indian Territory	7	10	18	16	**26**	11	6	6	**22**	11	19	9	11	8	8	12
N. E. Indian Territory	5	7	10	**28**	**27**	13	4	5	18	11	9	20	13	9	5	14
Central and N. E. Kansas	7	5	4	12	**49**	12	6	1	14	6	7	9	20	16	13	16
S. W. and W. Cent. Kansas	7	9	9	23	**26**	14	7	6	**20**	12	6	10	10	11	12	18
S. E. Colorado	4	6	20	**25**	14	8	19	3	7	8	15	10	11	17	**25**	7
Central Colorado	3	4	4	13	4	**37**	21	14	4	7	3	1	4	**40**	21	20
N. E. Colorado	6	9	13	19	**20**	**12**	9	11	4	8	16	12	5	8	23	**24**
N. E. Wyoming	18	5	0.5	10	**24**	21	6	15	13	4	8	9	10	10	19	**27**
S. Central and S. E. Dacotah	10	7	15	**24**	14	6	7	16	19	7	12	10	9	8	12	**23**
N. E. Nebraska	13	5	5	9	**36**	12	8	12	20	5	3	9	17	9	13	**24**
S. and S. E. Nebraska	10	12	7	**23**	**23**	10	5	9	20	5	3	9	14	11	12	**26**
S. Iowa	8	4	11	11	**25**	11	18	12	9	7	10	8	12	9	22	**23**
N. and N. E. Iowa	7	8	5	18	**20**	17	9	16	10	8	4	13	11	12	12	**30**
S. E. Iowa	4	12	4	19	10	**28**	8	16	4	10	4	12	8	20	12	**29**
S. E. Minnesota	9	8	2	**22**	19	16	12	12	8	7	6	16	12	16	14	**21**
W. and Central Missouri	11	10	9	19	**25**	15	4	7	16	11	7	9	15	14	6	**22**
E. and S. E. Missouri	9	10	7	13	**21**	15	11	13	15	9	5	13	16	12	12	**17**

In Texas the winds have nearly the same direction as in Arizona and New Mexico, but the percentage of southerly winds in summer and northerly in winter is much greater. The winds in Texas have very strong monsoon features. This is due in a great measure to the proximity of the Gulf of Mexico. The state, except its extreme western part, is wholly open to the winds from the Gulf, and they must be strongly drawn in towards the land in summer, as the continent is much warmer than the sea. We have seen that there is a monsoon drawn in from the small and narrow Gulf of California to supply the deficiency in the interior. We must expect a much more powerful monsoon from the Gulf of Mexico. Winds in Texas, other than S. and S. E., are all but excluded from April to September.

In winter the winds are more northerly, but not N. E. or E. N. E. as in the trade-wind regions of the same latitudes, but N. and N. W., *i. e.* winds blow from the Staked Plain and other continental areas towards the Gulf of Mexico. Yet the prevalence of these winds, if we take the number of observations only, is not so great as that of the S. E. in summer. But the N. winds are extremely violent in Texas; they are the famous northers so well known and dreaded by seamen navigating the Gulf of Mexico, and also by travellers in Texas, especially because of the suddenness of their appearance. They are especially frequent in Central Southern Texas, about San Antonio, while the north winds east of the Guadalupe River are not so sudden and violent, resembling in fact rather the northwesters of the eastern States.

The cause of the violence of these winds must be sought to the southward in eastern Mexico. This country has not as regular a climate, with small barometrical variations, as other tropical regions of the same latitude. From December to March there are frequent storm-centres, with low barometer, passing there, as also on the eastern coast of Central America. A barometrical depression in Mexico or southward of it must draw in the air from the interior of Texas and New Mexico, where the pressure is high in the winter months. In April and May, when the barometrical variations are less in Mexico, the northers are less frequent, and cease altogether from June to September during the tropical rainy season, when barometrical variation is at minimum in Mexico. To illustrate this I give the mean and extremes of the pressure of the air at Vera Cruz.[1] (See also Plate 14.)

	Mean.	Mean Min.	Mean Max.
January	30.10	29.86	30.36
February	29.99	.68	.26
March	.93	.61	.33
April	.92	.64	.21
May	.86	.64	.09
June	.90	.73	.08
July	.96	.83	.06
August	.98	.85	.13
September	30.00	.85	.12
October	.02	.78	.20
November	.10	.79	.36
December	.11	.78	.43

[1] From the observations by Dr. Berendt, manuscript collection of the Smithsonian Institution.

In the extreme south of Texas, at the mouth and in the valley of the Rio Grande, the S. E. winds are much more frequent, even in winter, than in the rest of the State. This is an intermediate region, partaking of some of the features of the Mexican climate, where easterly winds prevail the whole year. Yet the lower Rio Grande region is subject to violent northers. This seems to lead to the conclusion that in the other regions of Texas, where northerly winds prevail in winter, they are not all northers, there being also north winds of moderate force blowing towards the Gulf.

The mean direction of the winds in the different portions of Texas, is as follows:—

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
Western Texas	N. 81° W.	.29½	S. 7° E.	.15	N. 28° E.	.06	N. 57° W.	.33
Central Texas, N. of 30° N.	S. 3 E.	.24½	S. 12 E.	.52	S. 44 W.	.07	N. 70 W.	.13
N. Texas, E. of 98° W.	S. 23 W.	.27	S. 14 E.	.54½	S. 18 E.	.23	S. 72 W.	.08
Texas, lat. 31°–32° N., long. 94°–97° W.	S. 30 E.	.21½	S. 32 E.	.46½	S. 54 E.	.14	N. 14 W.	.20
S. Central Texas, lat. 29°–30°.	S. 56 E.	.32	S. 33 E.	.53	N. 77 E.	.26	N. 39 E.	.23
S. E. Texas	S. 73 E.	.37	S. 46 E.	.46	N. 66 E.	.28½	N. 24 E.	.32
Rio Grande Valley	S. 60 E.	.56	S. 43 E.	.82	S. 75 E.	.40	N. 62 E.	.19
Forts Brown, Polk andMatamoras	S. 47 E.	.52	S. 44 E.	.70	S. 81 E.	.35½	N. 84 E.	.16½

The summer, as is shown by these tables, and the maps Plates 8 and 11, is the season in which the wind is most constant, the mean direction at all stations being between S. 7° E., and S. 46° E., and the ratio of the resultant very great, except in Western Texas. In the three last regions, nearest to the Gulf, the direction is more S. E., while in the more northern part of the State it is rather S. or S. S. E. The influence of the earth's rotation is here clearly seen. The wind begins as S. E., but soon is deflected to the south, and in its further course passes to the W. of S.

The agreement is not as exact in winter, probably because we have only the number of observations, and not the force of the wind. As the N. and N. W. winds are known to be the strongest, the mean direction would be much nearer each other in the different parts of the State, if we knew the force of the winds. Yet in all cases it would be seen to be more easterly on the lower Rio Grande near the Mexican frontier.

Spring and autumn are transition seasons, and in a country with monsoon winds, as Texas, there is very little to say about them. Generally spring is more analogous to summer, and autumn to winter. (See Plate 8.)

I must further remark as to the S. E. winds of the summer, that it would be an error to consider them merely as sea-winds blowing only during the day. They are stronger in the afternoon, while about sunset there is generally a calm. But about 9 P. M. the S. E. springs up again and blows till morning, when there is a second calm. I had occasion to observe this, in the summer of 1873, in the country between the Nueces and Guadalupe, and old residents of San Antonio informed me this was the regular course. (See the figures showing the number of observations and the force of the wind at 7 A. M., 2 P. M., and 9 P. M., at the last

place for the year 1872. (Zone 13, No. 13.) Even at stations on the Gulf coast, there are scarcely any land winds (N., N. W. and W.) observed in summer, which would be the case if there was a regular alternation of land and sea breezes.

North of Texas, throughout the whole region between 34° and 44° N. and the Rocky Mountains and Mississippi, the winds have also monsoon features, but more subdued. The prevailing winds of this region are N. and N. W. in winter and S. in summer. The cause is the same as in Arizona, New Mexico, and Texas. There are some irregularities in the mountain region (Central Colorado) but east of the mountains, in Nebraska and Iowa, the general character is again strongly marked. It is less the case in S. E. Minnesota, but even there the winds are southerly in summer, and deflected to the S. E. by the direction of the Mississippi Valley. In N. E. Arkansas and in Missouri the difference between winter and summer is still less marked. This is an approach to the character of the region between the Mississippi and the Appalachian chain, where there is no difference whatever between the seasons, the mean direction being about W. S. W. the whole year round. (See Plate 8.)

The tables for this work were printed before the results of observations on two high peaks of the Rocky Mountains could be obtained, both over 14,000 feet high. A meteorological station was established on Pike's Peak in the end of 1873, by the United States Signal Service, and the "Report for 1874" contains the means of observations for the first twelve months. I have given them in percentages, adding the station of Colorado Springs, at the eastern base of Pike's Peak. On Mount Lincoln the observations were made under Professor Hayden's geological survey of the territories, from 21st July, 1871, to the end of January, 1874. Both Pike's Peak and Mount Lincoln are situated in the central part of Colorado.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Colorado Springs	2	4	2	10	**33**	12	7	**31**	**30**	3	2	19	5	6	8	24
Pike's Peak	4	8	6	5	6	**31**	21	8	14	0.4	0.8	1	1	21	**34**	27
Mount Lincoln									**36**	22	1	0.6	0	1	9	30
	Spring.								Autumn.							
Colorado Springs	**31**	8	4	20	16	4	7	10								
Pike's Peak	20	1.5	1.5	2	7	**28**	27	14								
Mount Lincoln									20	15	4	5	0.7	9	14	**32**

The difference between Pike's Peak and Colorado Springs seems to give a much greater proportion of S. W. and W. winds at the higher station, and a smaller amount of N., especially in summer. This agrees with the generally entertained opinion as to the prevailing direction of the upper atmospheric current from the W. S. W. in the middle and northern latitudes. In any case more observations are necessary in this respect.

The mean direction of the wind in the region north of Texas is:—

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
S. E. Indian Territory	S. 74° E.	.20½	S. 34° E.	.32½	N. 70° E.	.22½	N. 37° E.	.18
Arkansas, 34°–35° N. L.	S. 84 W.	.20	S. 25 W.	.21	S. 54 W.	.12	N. 64 W.	.17
N. E. Arkansas	S. 80 W.	.11½	S. 20 W.	.05½	N. 87 W.	.05½	S. 58 W.	.14
N. E. Colorado	N. 35 W.	.02	S. 21 E.	.23	S. 23 W.	.05	N. 65 W.	.16
N. E. Wyoming	N. 68 W.	.16½	S. 57 W.	.22	S. 29 W.	35	N. 66 W.	.27
W. Central Kansas	S. 77 W.	.04	S. 4 E.	.36½	S. 64 W.	.09	N. 46 W.	.20
N. E. Kansas	S. 45 W.	.11	S. 10 E.	.34	S. 44 W.	.13	N. 79 W.	.17½
W. and Central Missouri	N. 46 W.	.05	S. 20 E.	.27	S. 4 W.	.04½	N. 50 W.	.13
E. Missouri	S. 36 W.	.08	S. 3 E.	.15½	S. 54 W.	.11	S. 77 W.	.12½
S. E. Nebraska	N. 12 W.	.13½	S. 24 E.	.22	N. 82 W.	.10	N. 63 W.	.20
N. E. Nebraska	N. 32 W.	.10½	S. 22 W.	.26	S. 75 W.	.21	N. 67 W.	.24
S. E. Dacotah	N. 9 W.	.13	S. 37 W.	.20	N. 53 W.	.10	N. 32 W.	.16
S. E. Minnesota	S. 77 W.	.10	S. 8 W.	.21½	S. 48 W.	.18	S. 67 W.	.18
N. Iowa	N. 37 W.	.13	S. 9 W.	.20½	S. 73 W.	.22	N. 80 W.	.24
S. Iowa	S. 65 W.	.22	S. 32 W.	.24	S. 75 W.	.21½	N. 77 W.	.25

Here, again, as also shown by the maps (Plates 8 and 11), summer is the season which exhibits more regularity, the mean direction being everywhere between S. E. and S. W. The ratio of the resultant is greatest in the Indian Territory and Kansas, *i. e.*, due north of the Gulf coast of Texas, and far from the influence of mountains. It is least in Missouri and N. E. Arkansas.

In winter the winds incline much more to the west than in Texas, being even S. of west, in East Missouri, N. E. Arkansas, and in S. E. Minnesota, *i. e.*, in the extreme east of this region. Except in these regions there is a tolerably good agreement between the other stations.

The greatest difference between this region and Texas is seen in spring, as shown in Plate 8, when the winds are everywhere more or less westerly, except in the Indian Territory. Probably the cause is this: Texas being situated in a lower latitude is earlier heated, and the air from the Gulf of Mexico is sooner drawn in. The region here considered being further to the north, ascending currents are not established as early. Besides, when the lowlands between 34° to 42° N. are already heated, and an ascending current established over them, the deficiency is partly supplied by the cold air from the plateaus lying westward, partly by southerly winds from the Gulf of Mexico, and partly by winds from the polar regions. It is necessary to remember that the distribution of pressure in April and May is not the same as in midsummer. In the region here considered, pressure is lowest in May, while in Utah, and probably also on the lower Colorado, it is lowest in July. In the spring the winds coming from the Gulf of Mexico will be more westerly than in summer, because their point of attraction is more easterly in the former season than in the latter.

To recapitulate: *There is an extensive region in the southwest of the United States which has a common yearly period of winds, different as are its geographical features. It includes the extreme S. E. of California, Arizona, New Mexico, Southern Utah, Texas, Arkansas, the Indian Territory, Eastern Colorado, Eastern Wyoming, Southern Dacotah, Nebraska, Iowa, Kansas, and Missouri. The winds are S. E., S., or S. W. in summ r, with a great ratio of the resultant in the south, diminishing*

towards the north and east. In winter the winds are mostly N. and N. W. This region is equal to more than a million square miles, or about one-third of the United States, without Alaska.

See also Maps, Plates 8, 11, and 14, which clearly show this.

To the north and northeast is a country about which it is difficult to say anything definite. It includes the larger part of Wisconsin and Minnesota, Northern Michigan, Northern Dacotah, and Manitoba.

The percentages of the winds in this region are:—

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Eastern Dacotah	9	11	6	**25**	7	11	7	25	9	7	3	16	8	16	9	**31**
N. W. Minnesota	14	2	9	4	**37**	7	21	6	22	3	6	5	**27**	6	14	17
Central Minnesota	11	9	6	14	**23**	9	13	14	**14**	9	6	9	**20**	8	17	16
Northern Michigan	9	11	3	**20**	13	14	14	16	**25**	15	3	12	10	10	12	16
N. Wisconsin (Lake Superior)	7	**30**	6	6	10	19	12	10	13	14	2	3	5	**28**	22	14
S. W. Wisconsin	8	6	7	14	15	**18**	13	19	11	6	6	11	10	14	18	**24**
E. Wisconsin	8	13	6	10	12	22	14	14	8	9	3	5	10	**29**	17	19
Winnipeg (Manitoba)	16	8	6	12	**24**	5	19	12	**24**	3	3	12	20	9	5	23

In Northern Wisconsin the influence of Lake Superior is clearly seen. The winds are N. E. in summer, or from the lake; S. W. in winter, or from the land. It must be remembered that the five great lakes never entirely freeze over, and that the difference of temperature between the air over the open water and that over the land must be great. On the Canadian shore of Lake Superior (for example, at Michipicoten) the winds are N. E. in winter and S. W. in summer. In Northern Michigan the influence of the lake is not so clearly perceived. One of the stations, Marquette, is situated on a peninsula, having the lake to the east, while others have it to the north.

Yet it seems, on the whole, as shown on Plate 8, that the winds in this belt of country bear a resemblance to the monsoon region lying to the south, especially the prevalence of south winds in summer, which is seen as far as Winnipeg (49° 52′ Lat. North).

The next region we have to consider is that between the Mississippi and the Appalachian range extending southward to the Cumberland range, and northward to Lakes Michigan and Huron, and somewhat beyond Lakes Erie and Ontario. The percentage of the winds is as follows:—

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
S. W. Illinois	6	9	2	12	14	**27**	12	18	8	8	3	12	10	17	16	**26**
W. Kentucky	8	10	4	9	13	**31**	8	17	12	6	6	7	15	**24**	10	19
Middle Tennessee	5	14	9	10	6	**40**	11	5	7	11	5	14	7	**27**	17	12
N. and Central Kentucky	8	14	5	8	10	**31**	13	11	6	8	6	7	11	**28**	19	15
N. W. Indiana	10	7	7	9	10	**24**	18	14	4	8	6	10	7	**28**	24	13
S. E. Michigan	6	10	6	9	9	**26**	11	24	6	11	6	8	6	**27**	12	24
Toronto, Canada W.	13	9	14	8	10	13	14	**19**	12	11	9	4	5	19	**24**	16
N. E. Ohio	8	9	3	6	8	**31**	18	17	4	6	3	10	12	**29**	18	18
W. New York	6	5	5	8	10	**26**	**25**	16	3	6	7	8	10	**27**	**27**	12
W. Pennsylvania	5	2	7	6	7	19	**41**	13	5	4	12	4	5	27	**32**	11
Central New York	4	3	6	10	14	15	**30**	19	5	3	7	11	14	11	**28**	21
N. W. Virginia	7	11	0.1	18	23	**25**	4	11	11	5	0.3	11	17	**29**	5	21
Central Virginia	8	7	5	7	21	21	**22**	7	8	11	3	5	14	**24**	22	13
Middle N. Carolina	8	16	7	5	11	**27**	19	6	10	18	5	4	8	**22**	17	15
E. Tennessee	8	8	18	4	8	**28**	18	8	9	8	9	3	10	**30**	21	10

In the greatest part of this region S. W. and W. winds prevail winter and summer. Looking at the isobar-chart (Plate 14) we see that at all seasons the pressure is higher in the region between the Gulf of Mexico and 35° N. L., and much lower near the lakes; hence there must be a south wind, which is converted into a S. W. by the influence of the earth's rotation. In summer and autumn the pressure is generally higher in the south Atlantic States than in the same latitude further west, and it would seem that S. E. and S. winds should be frequent from this cause. But the Appalachians do not permit an exchange of air in the lower strata, and, as the difference of pressure is but slight, S. E. winds will not often blow over the mountain-chains. In the winter-months pressure is generally higher west of the Alleghanies. Air is, so to say, heaped up by the prevailing S. W. winds. (See also Maps, Pl. 8, 11, and 14.)

The daily weather-maps of the Signal Office show that the centres of storms generally take a course nearly along the northern frontier of the United States, especially in the region of the lakes. The monthly bulletins, in which the tracks of the storm-centres are laid down, show this even more clearly. Besides this, very low barometrical minima are comparatively seldom west of the Mississippi, and the pressure generally diminishes in the centre of a storm the further it advances towards the east. The storm-tracks then lie mostly to the north of the region we are considering now. The winds during the passage of a storm must then be S. W. and W. When the storm-track is more southerly, cold and dry N. W. winds, in the rear of the storm, will be experienced. We see that in this region the N. W. is frequently observed, especially in the winter. The storm-tracks are, however, generally more southerly in winter than in summer.

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
S. E. Michigan	N. 73° W.	.11	S. 65° W.	.17	S. 70° W.	.27	S. 77° W.	.30
N. W. Indiana	S. 72 W.	.27	S. 69 W.	.25	S. 70 W.	.31	S. 67 W.	.34½
N. W. Ohio	S. 88 W.	.18	S. 71 W.	.19	S. 67 W.	.27½	S. 61 W.	.34
N. E. Ohio	S. 84 W.	.24	S. 77 W.	.25	S. 65 W.	.25	S. 63 W.	.34
Toronto, Canada W.	N. 21 W.	.14	N. 68 W.	.05	N. 62 W.	.15	N. 66 W.	.30
Toronto, Motion of Upper Clouds	N. 83 W.	.37	N. 75 W.	.33	N. 81 W.	.40½	N. 78 W.	.30
N. W. Pennsylvania	S. 81 W.	.22½	S. 81 W.	.25⅓	S. 61 W.	.27	S. 61 W.	.33
W. New York	S. 78 W.	.30	S. 76 W.	.39½	S. 68 W.	.37	S. 67 W.	.39
S. W. Illinois	S. 85 W.	.15	S. 42 W.	.20	S. 61 W.	.20½	S. 79 W.	.24
N. and Central Kentucky	S. 65 W.	.22½	S. 61 W.	.21	S. 60 W.	.22	S. 67 W.	.33
E. Tennessee	S. 78 W.	.25	S. 59 W.	.15	S. 87 W.	.15½	S. 71 W.	.27
Central Virginia	S. 78 W.	.34½	S. 51 W.	.31	S. 86 W.	.25½	S. 75 W.	.35
Middle N. Carolina	S. 77 W.	.18	S. 64 W.	.20	N. 59 W.	.20½	N. 76 W.	.21

See maps, Pl. 8 and 11, and for the motion of clouds, and the velocity of the winds, Plates 1 and 13.

The different parts of this region agree very well as to mean direction of the wind and even ratio of resultant: which generally amounts to about .30, which in winter is great enough for middle latitudes. In S. W. Illinois as well as in Kentucky the winds are much more southerly in summer than in the other parts of this region; which is easily accounted for by the proximity of these States to the trans-Mississippi region, where, as was shown before, the mean direction in summer is nearly due south. As there are no mountains separating the two regions, the country on both banks of the Mississippi being generally level, we must expect a gradual merging of one into the other. It was shown above that E. Missouri and N. E. Arkansas are also transition regions between the countries east and west of the Mississippi.

Another exception is Toronto. The winds here were recorded with great care, partly hourly during more than ten years, so that the difference presented cannot be explained by shortness of the period. The ratio of resultant is great only in winter, and it seems that a great part of the then prevailing N. W. are land winds. Lake Ontario is to the S. E. of Toronto For this reason we should expect S. E. winds from the lake in summer, but it seems that they do not prevail to a great extent, and that N. W. winds coming from over the colder waters of Lake Huron also reach Toronto. The motion of upper clouds at this place, as shown on Plate 1, nearly coincides with the course of the lower winds, being somewhat to the west in all seasons, the difference is greatest in spring, 61°, and least in summer, 7°.

The mean direction is more northerly in spring than in other seasons. The influence of the high pressure in the polar regions is seen in this, as also that of the lakes, covered at this season with melting ice. In the other seasons the mean direction is very nearly S. 67° W., or W. S. W. (See Plates 8 and 11.)

To explain the accordance of observations in this region among themselves, it must be remembered that it is comparatively old-settled, and the observations are numerous, especially in New York, Pennsylvania and Ohio, and some of them

long-continued; while in the territories the observations are mostly for short periods and the stations far between.

The lakes do not seem to cause monsoons of any consequence. There are, it is true, day and night winds on their shores, but they do not extend inland to a great distance.[1]

The winds of the Atlantic coast of North America, from Labrador to Florida, have some common features, notwithstanding the great difference in latitude.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Rigolet, Labrador	20	**36**	8	2	1	1	2	30	16	5	8	1	2	1	3	**64**
St. Johns, Newfoundland	5	12	3	13	7	31	15	13	11	13	3	7	7	19	12	**28**
Maine, north of 46°	7	6	18	8	**21**	15	13	10	17	12	6	7	13	10	14	**21**
Montreal and St. Martins, C. E.	4	13	2	10	7	**34**	11	18	4	24	1	6	3	25	13	24
S. Nova Scotia	14	7	4	9	13	**28**	14	13	19	9	3	5	5	19	18	**23**
S. W. Maine	5	9	5	19	12	**23**	7	19	7	23	2	**7**	2	11	9	**39**
S. E. Maine	4	11	3	9	12	**37**	7	17	7	19	2	6	3	16	11	**35**
N. New Hampshire	3	8	13	6	9	13	**31**	16	3	8	11	3	6	9	**41**	19
Mt. Washington, No. of obs.	5	2	2	5	3	13	**17**	**53**	8	2	1	**4**	8	19	**35**	25
Mt. Washington, No. of miles	3	0	0	3	2	13	9	**71**	8	0	0.5	1.4	12	14	27	**36**
W. Massachusetts	3	4	4	16	10	20	11	32	4	6	3	13	6	11	11	**44**
S. E. Massachusetts	4	12	4	7	9	**39**	9	17	9	10	3	4	5	21	13	**35**
Cape Cod and adjacent islands	3	19	3	10	9	**42**	**7**	6	9	9	2	8	4	17	10	**41**
Rhode Island	7	11	4	9	14	**31**	9	14	11	13	4	5	5	16	13	**33**
E. New York	13	4	3	7	**25**	15	19	14	17	6	4	6	17	12	19	**20**
S. E. New York	5	12	6	17	12	**22**	13	14	6	17	2	8	4	19	15	**30**
Central Pennsylvania	1	4	5	15	2	27	12	**34**	2	4	2	11	2	22	9	**48**
E. Pennsylvania	8	7	8	10	10	19	**23**	15	8	12	9	7	4	11	23	**27**
Penna. and S. New Jersey	6	14	5	10	9	**25**	12	18	6	15	4	4	3	16	19	**32**
N. and Central New Jersey	6	12	8	10	7	**26**	15	15	8	15	5	3	3	17	20	28
Easton, Pennsylvania	6	9	3	18	7	20	9	**28**	7	14	3	7	3	15	16	**35**
North Carolina, S. of 35	7	15	9	7	12	**35**	10	4	16	15	7	5	12	**17**	12	**17**
South Carolina, 33°–34°.	6	11	10	15	18	**21**	12	7	10	15	10	7	8	**22**	16	12
Georgia, 33°–34°	3	14	8	16	8	**25**	12	13	6	14	8	9	6	19	15	23
Georgia, 30°–33°	8	10	9	13	**22**	15	14	8	11	14	8	7	12	12	16	22
N. E Virginia	8	8	11	11	12	11	26	13	14	9	6	6	12	11	18	24
S. E. Virginia	7	16	11	12	10	29	8	7	12	17	5	6	8	22	11	19

The general climatic features of the Atlantic slope are somewhat like those of the trans-Mississippi region, the winds of summer being more southerly than those of winter, the N. W. prevailing in winter, the S. W. in summer. The distribution of pressure is here, as elsewhere, instrumental in producing this system of winds. The region we are considering is open to the influence of the Atlantic, and as on other oceans a belt of highest pressure is seen to prevail there about 30° L. N., as shown on Plate 14. This would then cause southerly winds. But in winter this influence is counteracted by the higher pressure to the west, in the interior of the continent. Thus, the N. W. is prevailing in the colder months of the year. In summer there is nothing to check the influence of the higher pressure to the south, on the Atlantic Ocean and in the South Atlantic States. Therefore S. W. winds are seen to prevail in summer. (See Plate 8.)

[1] See the examination of the winds at the Western Reserve College, Ohio, at the different hours of the day, by Prof. Coffin, on p. 299.

Yet there is a difference between the N. and the S. of the Atlantic Coast, which will be best seen if we divide the Atlantic slope of the United States into three parts.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
New England	5	10	8	10	12	**24**	14	16	9	11	4	7	7	14	15	**33**
Middle Atlantic States—New York to N. E. Virginia. .	8	10	6	11	14	**19**	16	15	9	12	5	6	7	14	19	**28**
S. Atlantic States, from S. E. Virginia to Georgia . . .	7	12	8	12	17	**26**	11	8	13	13	7	6	11	**18**	14	**17**

From this table it is seen that in summer the winds are more southerly in the S. Atlantic States than in the middle ones, while in New England the southerly direction is more prevailing. (See Plate 8.) In the case of New England this may be explained by the direction of the coast, which is nearly from W. to E. from Long Island Sound to Cape Cod, so as to have the ocean to the S. Thus the already prevailing southwesterly winds are strengthened by the relative position of land and sea.

In winter the differences are greater between north and south, the N. W. prevailing much more in New England than in the other sections, while in the south the winds are more equally distributed between the different points of the compass. The cause of this decrease of N. W. winds, the further we advance to the S., is the following: The N. W. winds on this coast are a movement of the air, tending to equalize the higher pressure in the interior of the continent with the lower off the coast. They are westerly winds deflected to the N. W. by the rotation of the earth. The difference of pressure in winter is much greater between the coast of Nova Scotia and the interior of New England than between the ocean near the Bermudas and the same latitude in the Southern States. This explains why the N. W. winds are rarer in this last section, in the ordinary course of events. (See Plates 8 and 14.)

During the passing of storms there is yet another cause: the storm-centres in winter pass often over New England from W. to E. In this case the winds to the northward of the storm-track will be in succession E., N. E., N., and N. W., these last appearing in the rear of the storm, being dry and intensely cold. In the Southern States the wind will then veer from S. E. to S. and S. W., sometimes to W., that is, become much more southerly.

This distribution of the winds explains also the extremely rapid increase of temperature from N. to S. on the Atlantic Coast of the United States, which is greater than anywhere else in a level country.

That the prevailing N. W. winds of New England and the middle Atlantic Coast are not merely local, caused by the difference of temperature of the land and sea, is proved by the strength of these winds. The relative prevalence of the N. W. is much greater, if we take into account the number of miles travelled instead of the number of observations only. (See Tables, Zones 9, 10, 11.) I give below the mean velocity, in miles per hour, for the three prevailing winds S. W., W., and N. W. in winter.

	S. W.	W.	N. W.
Eastern Pennsylvania, Smithsonian Stations	5.9	7.0	8.9
Eastern New York " "	5.7	8.7	7.4
S. E. New York " "	6.3	6.7	8.6
Long Island " "	6.6	7.2	9.5
Mt. Washington, N. H.	31.3	43.2	53.2
S. New Hampshire, Smithsonian Stations	6.0	7.9	8.4
N. E. Massachusetts " "	4.5	5.0	7.5
S. E. Massachusetts " "	5.6	7.7	8.2
Cape Cod and adj. isd's " "	10.9	10.9	20.0
S. E. Maine " "	6.9	6.6	11.1

This is also well shown by the map, Plate 13.

The great number and great strength of the N. W. winds at the top of Mount Washington is another proof of the great mass of air which moves in this direction. We have no observations during the winter on so high a mountain in the Southern States, but it is probable that we should not find the N. W. winds as prevalent there; it is more likely that the W. or S. W. would be the most frequent.

The mean direction of the winds in the four seasons is given in the following table, and also in plates 8 and 11:—

	Spring.		Summer.		Autumn.		Winter.	
Rigolet, Labrador . . .	N. 7° W.	.59½	N. 9° E.	.61	N. 24° W.	.58½	N. 31° W.	.70
Maine N. of 46° . . .	S. 81 W.	.12	S. 12 W.	.19	N. 76 W.	.15	N. 51 W.	.21½
Montreal and St. Martins .	N. 77 W.	.20½	S. 67 W.	.32	N. 89 W.	.28	N. 63 W.	.28
St. Johns, Newfoundland .	N. 44 W.	.12	S. 61 W.	.29	N. 62 W.	.16	N. 65 W.	.31
S. W. Maine	N. 65 W.	.14½	S. 54 W.	.24	N. 74 W.	.22	N. 59 W.	.35
N. New Hampshire . . .	N. 77 W.	.26½	S. 86 W.	.25½	N. 82 W.	.30½	N. 80 W.	.37
Rhode Island	N. 78 W.	.17	S. 51 W.	.28½	N. 67 W.	.25	N. 42 W.	.33½
S. Nova Scotia . . .	N. 66 W.	.21½	S. 72 W.	.25	N. 78 W.	.29	N. 60 W.	.33½
W. Massachusetts . . .	N. 63 W.	.28	S. 79 W.	.30	N. 75 W.	.30	N. 63 W.	.36
E. New York	S. 88 W.	.22	S. 70 W.	.31	S. 82 W.	.25½	N. 79 W.	.29
S. E. New York . . .	N. 80 W.	.14	S. 43 W.	.21	N. 77 W.	.19½	N. 60 W.	.29½
N. and Central New Jersey .	N. 55 W.	.19	S. 69 W.	.20	N. 69 W.	.28	N. 58 W.	.39½
E. Pennsylvania . . .	N. 68 W.	.21½	S. 75 W.	.23	N. 72 W.	.24	N. 55 W.	.29½
N. E. Virginia . . .	N. 82 W.	.19	S. 76 W.	.17	N. 82 W.	.16	N. 63 W.	.24
S. E. Virginia	S. 55 W.	.07	S. 10 W.	.15	N. 37 W.	.10½	N. 63 W.	.21
N. Carolina S. of 35° . .	S. 33 W.	.18	S. 25 W.	.29	N. 13 W.	.11	N. 55 W.	.18½
S. Carolina, 33°–34° . .	S. 41 W.	.20	S. 10 W.	.25	N. 14 E.	.12	N. 85 W.	.14½
Georgia, 33°–34° . . .	S. 65 W.	.24½	S. 6 W.	.12	N. 26 W.	.10½	N. 80 W.	.23
Georgia, 30°–33° . . .	S. 55 W.	.13	S. 14 W.	.20½	N. 19 E.	.20	N. 56 W.	.19½

The much more southerly direction of the wind in the five last regions, belonging to the S. Atlantic States, is seen at a first glance, while from New York to N. E. Virginia it is more W. S. W. Everywhere it is between S. and W. in summer, varying from nearly due south to nearly due west. The mean direction in the spring is nearly the same as in the winter, somewhat to the southward. The ratio of resultant is greater in the Middle and New England States than in the south, both winter and summer, but especially in winter.

A noticeable feature is the northerly direction in autumn in the South Atlantic region. It is at least 24° more northerly than in winter. This may be considered as an approach to the trade-wind region. The belt of highest pressure on the ocean has its most northerly position in September. As the indraught of air towards the continent, which produced southerly winds in summer, ceases in the autumn months, the air follows points of attraction further southward; that is,

flows towards the southern parts of the Mexican and Caribbean Seas, where the rainy season is at its height in October. (See also Plates 8 and 14.)

The British Provinces north of the United States have mostly the same system of winds as the latter country. This is especially the case in New Brunswick, Nova Scotia, and Newfoundland. Here we find the same conditions as in New England, that is, prevailing N. W. in winter, spring, and autumn, and S. W. in summer.

In Lower Canada the winds are influenced by the direction of the valley of the St. Lawrence, and therefore the S. W. are more frequent than they would be otherwise. The same is the case in N. E. New York, where most stations along the St. Lawrence show also prevailing S. W. winds. Labrador has N. W. winds, but the mean direction is more northerly in winter than in other parts of the Atlantic coast, and the ratio of resultant is extremely great. In fact, the N. W. wind in Labrador is so constant as to remind us of the winter monsoon of the eastern coast of Asia. As is the case there, this wind is caused by the great difference of pressure between the land to the W. and the ocean to the E., and, as this difference continues nearly all winter in the same direction, the wind is very constant from the N. W.

In summer the winds are from the N. and N. E. in Labrador, coming from the ice-laden seas in this direction. The frequency of N. W. winds, even in summer, seems to indicate that pressure is high in the interior of the continent also at that season. The great number of lakes and morasses, which are full of ice till the middle or end of summer, as also the long continuance of snow in the woods of Labrador, may be the cause of this relatively high pressure. (See Plates 8 and 14.)

A very instructive table, compiled by Prof. Coffin from observations at forty different places in Delaware, Southeastern Pennsylvania, and Southern New Jersey, shows the mean number of days of each month on which every wind blew. (See Table, Zone 11, p. 432.) The mean direction and ratio of resultant for this important region of the Middle States is given below.

January	N. 81°	W. .28	July	S. 83°	W. .41
February	N. 78	W. .38	August	S. 64	W. .26
March	N. 83	W. .30	September	N. 89	W. .31
April	S. 89	W. .20	October	N. 88	W. .37
May	S. 89	W. .33	November	N. 79	W. .39
June	S. 84	W. .33	December	N. 79	W. .44

Here, as generally on the Middle Atlantic coast, the change in the mean direction is slight, the wind being westerly in all months, and the difference but 38° between February, when the winds incline most to the north, and August, when the most southerly direction is reached.

A similar calculation of Prof. Coffin for forty-nine stations in New England, south of 45° L. N., shows the following. (See p. 360.)

January	N. 57° W. .38	July	S. 47° W. .41
February	N. 59 W. .30	August	S. 41 W. .25½
March	N. 65 W. .26	September	S. 76 W. .17½
April	West .14	October	S. 84 W. .26
May	S. 48 W. .21	November	N. 61 W. .34
June	S. 52 W. .32	December	N. 59 W. .39

Here the change during the year is much greater than in the Middle Atlantic States, namely, 82°, the winds being more northerly in winter and more southerly in summer.

The region which is left to complete the temperate zone of North America is one of transition. It partakes of the character of all the surrounding areas. It includes the States of Louisiana, Mississippi, Alabama, and Florida. It is bounded on the west and northwest by the trans-Mississippi region, on the north by that of prevailing W. S. W. winds between the Mississippi and Appalachian chain, on the N. E. by the Atlantic region, and on the S. by the trade wind zone of the Mexican and Caribbean Seas. (See also Plates 5, 6, 8, and 14.)

The winds in the principal subdivisions are as follows:—

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
N. E. Florida	1	19	5	22	5	**38**	5	6	5	24	2	7	3	22	7	**29**
Florida, 29°–30° N. L.	3	16	12	**24**	10	17	11	7	12	**24**	7	10	8	14	8	17
S. E. Florida, S. of 29° N. L.	0.7	13	**34**	**24**	15	4	7	2	13	**20**	17	17	11	4	4	14
W. Florida	8	11	6	14	12	**26**	10	14	**20**	18	9	11	6	9	6	**21**
Florida Keys, 24°–25° N. L.	4	12	**30**	26	12	7	4	4	23	**26**	19	13	6	3	3	6
Northern Bahamas	1	20	20	**46**	7	4	0.4	1	4	**33**	14	22	4	7	2	12
Alabama, 31°–32° N. L.	2	16	8	**23**	8	15	10	19	14	17	5	14	10	11	4	**26**
Alabama, 32°–33° N. L.	9	9	12	**19**	13	14	14	11	16	9	8	16	11	10	12	**19**
Alabama & Miss. S. of 31° N. L.	13	12	8	**16**	**17**	13	12	10	**29**	12	8	11	12	9	6	12
Mississippi, 31°–32° N. L.	11	12	7	15	**17**	**21**	8	9	**17**	10	5	14	**14**	**18**	10	12
N. E. La. & Miss., 33°–34° N. L.	14	12	8	13	**23**	14	6	10	23	9	11	16	**20**	5	3	13
S. E. Louisiana	8	9	15	**20**	15	18	9	8	15	**20**	16	10	10	8	**7**	14

In this region a high pressure is to be found the whole year round, though the different subdivisions participate in it in a somewhat different degree, according to the seasons. It will be seen by reference to the isobar chart that the indraught towards the interior of the continent is so great in summer that the isobar of thirty inches remains east of the mouth of the Mississippi in this season and has even a more southerly position than in the winter, thus showing the great influence of the American continent on the pressure, as it was said before that generally the belt of highest pressure had a more northward position on the ocean in summer.

In the autumn, on the contrary, the isobar of 30 inches is found between 30°–35° L. N., while the interior of the continent has not yet regained the high pressure of winter, though the indraught has already ceased. At this season, as already remarked, about the southern Atlantic States, there is a nearer approach to the condition of the trade-wind region than at other times of the year. In Florida, as also in Alabama, Mississippi and Louisiana, the winds are decidedly north-easterly as far as 33° N. L. The air is drawn in towards the rainy belt of Mexico and Central America.

In winter the pressure is even a little higher in this region than in summer, but it is still higher to the northwest in the interior of the continent, and somewhat lower in the adjoining part of the Atlantic. The mean direction of the wind is then more northerly, or even northwesterly, as shown in the next table, and the maps, Plates 7, 8, and 14.

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
N. E. Florida	S. 62° W.	.18½	S. 2° W.	.27	N. 15° E.	.23	N. 38° W.	.28
Florida, 29°–30° N. L.	N. 87 E.	.03½	S. 33 E.	.23	N. 47 E.	.34	N. 3 E.	.15½
S. W. Florida, S. of 29° N. L.	N. 18 W.	.11½	S. 77 E.	.09	N. 27 E.	.37	N. 19 E.	.25½
S. E. Florida, S. of 29° N. L.	S. 82 E.	.22	S. 64 E.	.54	N. 61 E.	.44	N. 69 E.	.28
Northern Bahamas	N. 78 E.	.42	S. 67 E.	.62	N. 67 E.	.51	N. 73 E.	.37
Florida Keys	N. 76 E.	.31	S. 66 E.	.47	N. 64 E.	.50	N. 52 E.	.46
W. Florida	S. 39 W.	.16	S. 47 W.	.19	N. 32 E.	.15½	N. 10 W.	.23
Alabama, 31°–32° N. L.	S. 16 E.	.05	S. 5 E.	.04½	N. 39 E.	.30½	N. 12 W.	.17½
Alabama, 32°–33° N. L.	S. 51 W.	.11	S. 2 W.	.12	N. 31 E.	.09	N. 54 W.	.09½
Alabama, 33°–34° N. L.	S. 81 W.	.22	S. 51 E.	.12	N. 68 W.	.04	N. 58 W.	.16
Mississippi and Alabama, S. of 31° N. L.	S. 3 E.	.15	S. 3 E.	.08	N. 40 E.	.27	N. 14 E.	.16
Mississippi, 31°–32° N. L.	S. 12 W.	.14½	S. 15 W.	.18	N. 30 E.	.09	S. 41 W.	.02
Mississippi, 33°–34° N. L.	S. 58 W.	.06	S. 11 E.	.01	N. 33 E.	.13	N. 28 E.	.04
Mississippi, 34°–35° N. L.	S. 53 W.	.10½	S. 4 W.	.31½	S. 62 W	.16½	S. 78 W.	.28½
N. E. Louisiana	S. 29 E.	.19	S. 9 E.	.23½	N. 58 E.	.18	N. 61 E.	.15
E. Louisiana, 30°–31° N. L.	S. 51 E.	.16	S. 46 E.	.20½	S. 64 E.	.30½	N. 70 E.	.21
S. E. Louisiana	S. 66 E.	.15	S. 21 E.	.23	N. 53 E.	.31	N. 41 E.	.21

The Florida Keys and the Northern Bahamas belong approximately to the trade-wind region, though, owing to the powerful influence of the continent, the winds are E. S. E. in summer. But this is also the case in the West Indies. In the other seasons the mean direction is nearly E. N. E., and the ratio great, though certainly not so great as further south, in the middle of the ocean, where it often attains from .80 to .90. The same may be said of S. E. Florida, only the winds are less regular, as is seen by the smallness of the ratio of resultant.

On the northern shore of the Gulf of Mexico, and to about 32° N. L., the winds are northeasterly in autumn, but the ratio of resultant is so small as not to warrant the calling of this a region of trade-winds. Pressure is high at this season, and a little lower on the Gulf, but the difference is very small. Besides this, the variations of pressure and temperature are great here in winter. When a belt of low pressure, a storm-centre, reaches the upper Mississippi, air is drawn from the Gulf to supply the deficiency. South winds, with high temperature and abundant precipitation, are the result. In spring and summer the Gulf States have southerly winds from the Atlantic and the Gulf. They then prevail to a greater extent than the northeasterly winds of winter.

I give below the mean direction for the year, and the ratio of resultant, to show how nearly balanced are the different directions, except in the Northern Bahamas, Florida Keys, and S. E. Florida, where the N. E. movement is well marked. (See also Plate 3.)

N. Bahamas	N. 87° E.	.45	S. W. Florida	N. 25° E.	.08½
S. E. Florida	N. 88 E.	.33	E. Louisiana	S. 85 E.	.20
Alabama and Mississippi, S. of 31°	N. 59 E.	.06½	W. Florida	N. 61 W.	.05½
N. E. Louisiana	S. 61 E.	.12	Alabama, 31°–32°	N. 29 E.	.09
N. E. Florida	S. 67 W.	.12	Mississippi, 33°–34°	N. 18 E.	.03
Mississippi, 31°–32°	S. 80 W.	.06½	Alabama, 32°–33°	S. 66 W.	.03
Mississippi, 34°–35°	S. 46 W.	.18½	Alabama, 33°–34°	S. 88 W.	.12
Florida Keys	N. 76 E.	.41½			

Except the last-named areas, we find a ratio of .20 in E. Louisiana, where it is due to the combination of the S. E. winds of summer, spring, and autumn, with the N. E. of winter. Then we have .18½ in the extreme N. of Miss., which belongs approximately to the zone of S. W. winds between the Mississippi and Appalachian chain. All the others have a very small ratio.

TROPICAL NORTH AMERICA AND WEST INDIES.

Mexico, Central America, and the West Indies are in the belt of trade-winds, but these are modified by the land-masses of North and South America. There is a great difference between the east and west shores of the first two countries. In the east, on the Atlantic Ocean, the heating of the continental areas increases the force of the trade-winds, or we may better say, induces monsoons blowing from the sea to the land in a direction but slightly different from that of the trade-wind itself.

On the western shore, on the contrary, the direction of the monsoon would be more or less opposite to that of the trades. If, as is the case near the tropics, the land is not warmer than the sea in winter, we shall have trades in this season near both coasts, the direction of the wind being nearly the same, and very different winds in the summer. This is the case in Mexico. We do not have observations on the western shore of that country, but can supply them by ship-observations taken on the Pacific Ocean, near the Mexican shores. (See Maps, Plates 3, 5, 6, and 7.) The percentage of winds is—

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Pacific Ocean—																
25°–30° N., 105°–125° W.	30	24	0.3	1.2	0.3	0.6	6	**37**	**35**	19	5	4	2	5	10	20
20°–25° N., 105°–115° W.	10	2	4	4	2	11	31	**37**	**33**	11	5	5	6	6	13	24
15°–20° N., 110°–120° W.	**29**	17	6	6	2	11	17	14	26	**53**	11	0.8	0	0	1	7
Vera Cruz	**28**	9	13	23	11	6	9	1.5	**41**	8	16	8	11	2	3	11
City of Mexico	14	**34**	9	11	3	2	6	11	5	4	10	**23**	22	20	15	3

The N. W. winds of summer, the Mexican monsoon, as it is called, are seen to prevail especially between 20°–25° N. The cause of this may be that Northwestern Mexico, as also the adjoining part of the United States on the lower Colorado, is much more heated in summer than the zone between 15°–20°, which has at that time the regular tropical rains. As to Vera Cruz, it seems that the frequency of the N. winds is partly local, at least in summer, as the winds in the Mexican Gulf

are rather E. S. E. at that season. (See Plates 5 and 14.) The mean direction of the wind is given below for the last-named places, as well as for others in Mexico, the West Indies, and Central America.

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
Pacific Ocean—								
Lat. 25°–30° N., long. 105°–125° W.	N. 28° W.	.85	N. 10° W.	.77	N. 25° W.	.67	N. 24° W.	.62
Lat. 20°–25° N., long. 105°–115° W.	N. 56 W.	.70	N. 67 W.	.60	N. 37 W.	.53	N. 23 W.	.48
Lat. 15°–20° N., long. 110°–120° W.	N. 20 E.	.73	N. 20 W.	.39	N. 33 E.	.55	N. 32 E.	.82
Lat. 15°–20° N., long. 90°–110° W.	N. 46 W.	.70	N. 66½ E.	.21	N. 26 W.	.43	N. 16 W.	.34
Monterey, N. E. Mexico	S. 36 E.	.59	S. 41 E.	.82	S. 45 E.	88	N. 33 E.	.33
Cordova, E. Mexico	N. 36 E.	.36½	N. 53 E.	.49	N. 46 E.	.39½	N. 45 E.	.28
Vera Cruz, E. Mexico	N. 87 E.	.25	N. 78 E.	.21	N. 5 E.	.40	N. 22 E.	.37½
N. Coast of Tehuantepec	N. 29 E.	.18½	N. 54 E.	.44	N. 38 E.	.26	N. 53 E.	.32½
West Indies—								
Havana, Cuba	N. 78 E.	.62	N. 80 E.	.70½	N. 79 E.	.69	N. 69 E.	.68
Turk's Island, S. Bahamas	N. 71 E.	.67	S. 64 E.	.52	S. 85 E.	.55½	N. 78 E.	.63½
Jamaica, Porto Rico, San Domingo and Sombrero Island	N. 73 E.	.61	N. 81 E.	.58	N. 83 E.	.67	N. 73 E.	.52
Barbadoes	S. 85 E.	.87½	N. 88 E	.87	S. 86 E.	.85	N. 76 E.	.89
City of Guatemala	N. 69 W.	.03½	N. 32 E.	.41	N. 44 E.	.62	N. 41 E.	.76
Pacific Ocean, 5°–10° N., 75°–90° W.	S. 22 W.	.16	S. 47 W.	.58	S. 42 W.	.43	N. 28 W.	.30
Costa Rica	N. 61 E.	.92	N. 74 E.	.51	N. 58 E.	.38½	N. 60 E.	.82

(See also Plates 5, 6, and 7.)

In the West Indies the direction of the wind is nearly due east, and the ratio of resultant great, especially in Barbadoes. Here we have the real oceanic trade-wind. About Havana the case is different. Cuba is sufficiently large to have monsoons, but as we have observations on the northern coast only, the result of the ascending currents of the summer in the interior of the island is to give additional force to the already prevailing E. N. E. winds. Observations on the south and west coasts of Cuba and San Domingo would show another distribution of winds. It is said by travellers that the Republic of San Domingo, in the eastern part of that island, is subject to the full force of the trade-wind, and the climate less hot, and healthier than could be expected, while Hayti, in the west, has not as regular trades and a hotter climate.

The eastern coast of Mexico has not as regular trades as the West Indies under the same latitude. In winter especially, the barometric range is great, and accordingly the winds variable; the sudden cold *northers* are especially noticeable in winter. They appear when pressure is very low in Mexico and Central America, and high in Texas and New Mexico. The appearance and course of the storm-centres, on which depend the Mexican northers, have not been investigated as have those of the United States. The northers extend far beyond the eastern coast of Mexico. The coast of Honduras, as far as Omoa, is subject to them, and they pass even over the low Isthmus of Tehuantepec to the Pacific coast. (See Map, Plate 6.)

On the north coast of Tehuantepec the mean direction of the wind is more northerly than in the rest of Mexico and the West Indies. This is no doubt due to the relative position of land and sea. In the city of Guatemala southwest winds

are as frequent in spring as northeast. This is the result of the great heat of this region, when, under the influence of the nearly perpendicular rays of the sun, a powerful ascending current is induced. The deficiency is supplied both from the Atlantic and Pacific Oceans, and, in the latter case, probably by air from the S. hemisphere. In the summer Guatemala has its regular rainy season, and the heat decreases. (See Plate 7.) On the Pacific Ocean, between 5°–10° N., near the coast of Central America, the movement of the air is already from the southwest, except in winter, showing the equatorial belt of lowest pressure to be about 10° L. N. In Costa Rica, nearly in the same latitude, in a plateau between the Atlantic and Pacific Oceans, the wind is still N. E.—that is, the regular trade. (See Plates 5, 6, and 7.)

The republic of Nicaragua lying in a depression between the Atlantic and Pacific Oceans, but with its settled part nearer to the latter, is said to have also very regular trade winds, so that its climate is thought to be one of the healthiest in the tropics.[1]

The contrary seems to be the case in San Salvador, which has high mountains to the N. E. It is said to have the hottest climate of Central America. Probably there is a monsoon from the Pacific Ocean the whole year round, as under this low latitude there is little difference between the temperature of winter and summer.

SOUTH AMERICA.

There are very few observations on the winds of tropical South America, and, but for the regularity of the climate of these low latitudes, and the general descriptions given by scientific travellers, we would be at a loss to say anything definite about these countries.

The same may be said relative to barometrical observations, which furnish the key to the winds. They were made nearly exclusively on the coasts, and we do not know how far the extensive plains of South America modify the pressure of the air, if there is a depression there, at all comparable to that existing in the interior of Asia, Africa, and North America.

The want of accurate determination of heights would prevent our knowing it, even were barometrical observations more numerous. When we have barometrical observations from the temperate zone and see the pressure of summer fall much below that of winter, we judge that there must be a depression of some magnitude, even if, the accurate height of the station being unknown, we are unable to reduce the barometrical observations to sea-level. Not so in a tropical country, especially near the equator. The change of seasons can scarcely be said to exist, and, be the pressure higher or lower in the middle of a continent than on the oceans, it will not change perceptibly during the year.

Yet, summing up what we know of the physical geography of South America, we can hardly expect a very low pressure there, especially in the equatorial Amazonian region, as it is covered with dense forests, and the heating by the sun and

[1] See Squier, Nicaragua. Wagner, Naturwissenschaftliche Reisen, etc.

consequent ascending current cannot be much greater than on the ocean. We should rather expect a great barometrical depression in the treeless llanos of the Orinoco, and in the Pampas of the Argentine State, or in the Campos of southern Brazil, as shown on Plate 14. The last two regions being sub-tropical in greater part, the difference of season is well marked. We do not possess a single annual series of observations in the Pampas and Campos, but already Rio Janeiro, Montevideo and Buenos Ayres, as well as the stations of Chili, have a lower pressure in the warm months of the year.

In studying the winds of South America, the physical geography of this continent must be borne in mind. It is separated into two very unequal parts by the chain of the Andes, which runs near to the western coast. The mountains are so high, between 9° N. L. and 40° S. L. as not to permit any interchange of air in the lower strata. The eastern part of South America is generally level, having but two mountain systems of any importance, that of Brazil and that of Guiana, which were not inappropriately compared to the Alleghanies and the Canadian plateau in eastern North America.

These secondary mountain chains of South America have no great influence on the course of the winds, the whole extent of the continent to the eastern slope of the Andes being subject to the trade-winds, and the effect of the continental mass is here rather to intensify them.

This is especially the case on the Amazon, as stated by all travellers who have been there.[1] They say the eastern wind is very regular, especially in the dry season, June to November, blowing at times with the strength of a gale. In the rainy season, especially on the upper Amazon, it is less regular, being frequently interrupted by calms and westerly winds. There can be no doubt as to the general accuracy of these facts, notwithstanding the want of long-continued observations.

We possess, also, an admirable description of the course of the seasons on the llanos (treeless plains) by A. Von Humboldt. The regular blowing of the trades, the clearness of the sky, and want of rain from November to May are particularly noticed there. The appearance of the rainy season is announced by shifting of the wind to S. W. The countries on the lower Orinoco (see Plates 5 and 6) are in the region of the northern trades, while the southern trades are already dominating on the Amazons.

There is a region between 1°–3° N. on the Rio Negro which seems to have prevailing calms and rain in all months, according to Humboldt and Wallace.

We have observations from Venezuela and Guiana, where the winds are as follows.[2]

---

[1] See Hartt's Geol. and Phys. Geogr. of Brazil; Bates, the Naturalist, on the Amazons; Wallace, Amazons and Rio Negro; Martens, Reise nach Brazilien; Herndon and Gibbon, Explorations of the Amazon.

[2] To prevent confusion I give the months of observations for the equatorial regions and the southern hemisphere. In the tables "Winter" always means December, January, and February, and "Summer" June, July, and August.

	June, July, August.								December, January, February.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Northern Venezuela . .	6	17	**32**	22	8	9	4	0.3	2	**45**	23	13	3	6	5	3
Catharina Sophia (Guiana) .	3	**41**	22	24	5	4	0.1	1	4	**68**	13	11	1	0.2	0.1	10

If N. E. and E. are taken as the true representatives of the trade-winds, we see that they amount to 49 per cent. of all winds in the rainy season of Northern Venezuela, and to 68 per cent. in the dry season. In Guiana the trades are more regular, but it seems that it lies somewhat to the S. of the thermal equator; as December, January, and February are rainy months, the proportion of N. E. winds is then greatest. (See Plates 5, 6, and 7.)

In Tropical Brazil we have only the observations in Rio Janeiro, from which we deduct the PERCENTAGES given in the following table. To gain a better insight of the winds of this country, it is necessary to obtain observations made on the Atlantic Ocean near the coast.

	June, July, August.								December, January, February.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Lat. 19°–21° S., long. 37°–39° W. . . .	11	**30**	17	23	12	4	0.6	0.7	24	**37**	12	10	0	0	4	13
long. 35°–37° W. . . .	15	15	24	**34**	4	2	0	5	31	**35**	17	10	3	0.4	0.4	3
Lat. 20°–25° S., long. 37°–39° W. . . .	21	**35**	12	13	8	3	2	6	**40**	**30**	7	6	3	1	3	11
Rio Janeiro	19	19	0	**31**	17	0	2	12	6	11	5	**45**	4	5	8	17

On the Atlantic Ocean, near the coast of Brazil, the winds are more northerly in the rainy season, from December to February, or in the summer of the southern hemisphere. As to Rio Janeiro, the winds are influenced by the locality. The sea-wind (S. E.) generally begins at 9 A. M. and blows till sunset, while land-wind and calms prevail night and morning.

The northerly direction of the winds off the coast of Brazil points to a barometrical minimum in the interior to the west of the Organ Mountains in the campos, as it should do, considering the great heat of the summer of the S. hemisphere, and the sparse covering of trees on the campos. Easterly winds are much more regular and strong in Northern Brazil[1] than on the coast near Rio Janeiro. In the latter region they are to be considered as sea-breezes rather than trade-winds.

In the La Plata States and on the Atlantic Ocean near them, the few observations we have give the following results in PERCENTAGES:—

[1] Burton gives a description of the strength of the E. winds on the lower S. Francisco River in "Highlands of Brazil."

	June, July, August.								December, January, February.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 25 N. 24 Buenos Ayres	17	6	16	15	6	**19**	11	8	**26**	24	11	10	1	16	4	7
" 24 N. 24 Assumption	10	14	**38**	17	11	2	6	2	...	...	...	...	...	...	...	...
" 25 N. 23 Parana	**24**	21	14	15	7	12	6	1	9	18	13	20	**25**	9	1	5
" 25 N. 22 Mendoza	3	3	3	**33**	13	13	13	20	9	15	3	20	**30**	15	1	6
" 26 N. 28 Atlantic Ocean 50°–60° W.	9	29	2	16	16	14	11	2	17	13	**7**	13	8	15	13	14
" 27 N. 19 " " 55°–65° W.	...	...	...	...	...	...	...	..	**17**	10	**4**	4	12	22	14	18

The only observations of a year's duration made in the interior are those at Mendoza and Parana by Burmeister.[1] He remarks as to Mendoza, that calms largely prevail, strong winds are very rare. In Parana, on the contrary, as on the coast of the La Plata States (Buenos Ayres, Montevideo) the winds are violent and atmospheric changes frequent and sudden. In this respect it reminds us of the climate of the Atlantic coast of the United States, though extremes of heat and cold similar to those of North America are never experienced. Two winds are especially noted as strong, the Pampero (S. W.) and the Su-Estada (S. E.). Though Parana is near to Buenos Ayres, the yearly period of the winds is nearly opposite. (See Plates 5, 6, and 7.)

The winds on the Straits of Magellan and on the west coast of S. America are very different from those of the eastern part of this continent, as shown in the following table of PERCENTAGES.

	June, July, August.								December, January, February.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 29 N. 26½ Punta Arenas, Mag. Str.	19	12	7	0	3	12	**31**	16	10	5	4	1	7	13	**41**	19
" 27 Puerto-Montt } Chili	**66**	2	1	5	8	3	3	12	**29**	9	1	17	**28**	1	1	14
" 25 N. 20 Valparaiso } Chili	**35**	13	4	9	17	10	4	8	18	9	3	1	**30**	23	7	9
" 25 N. 21 Santiago } Chili	7	**26**	8	9	11	17	5	16	4	12	5	4	8	**48**	12	8
" 27 Pacific Ocean, 75°–80° W.	12	4	3	5	8	17	**26**	25	11	5	2	3	9	17	**29**	24
" 25 " " 71°–75° W.	22	7	0.4	10	**28**	16	5	12	5	2	0.5	6	**62**	16	4	6
" 24 " " 70°–85° W.	0	0	9	12	**64**	8	3	5	0	0	0	6	**69**	14	4	6
" 23 " " 70°–80° W.	4	1	2	**44**	18	24	3	5	0	0	0	6	**70**	18	5	1
" 22 " " 70°–75° W.	0	0	1	**70**	18	10	1	0	0	0	11	**78**	7	0	4	0
" 21 " " 76°–80° W.	0	0	16	**60**	24	0	0	0	0	0.8	8	**69**	22	0	0	0
" 20 " " 85°–95° W.	0	1	7	**90**	2	0	0	0	0	1	16	**75**	8	0	1	0
" 19 " " 80°–85° W.	0	0	2	**40**	**42**	12	2	1	0.5	0.3	3	**51**	34	7	2	0
" 18 " " 80°–85° W.	0.3	3	2	11	**41**	37	5	0.5	2	0.9	2	17	**37**	30	9	2
" 17 " " 75°–90° W.	3	0	3	14	15	**36**	19	11	16	**20**	6	6	3	11	20	18

The changes of the winds along the W. coast of South America are very regular and gradual; we can follow them for about 60° of latitude. In the extreme south, at Punta Arenas westerly winds are known to prevail especially from December to February, the warm season, while from June to August the number of N. and N. E. winds increases. These are land-winds. The mean direction is found to be northwesterly at all seasons, and the ratio of resultant great (see next page). We are here in the belt of westerly (or northwesterly) winds of the

[1] See his "Klima der Argentinischen Republik."

southern hemisphere, which are very strong and prevail all around the globe, especially from 40° to 60° S. In Puerto Montt these winds also prevail, especially in the cold season, June to August, while the quantity of southerly (cold polar) winds increases in December and February.

In Central Chili (Valparaiso and Santiago) we meet opposing winds in winter and summer. They are northerly in the cold season, southerly in the warm. This is a feature of the sub-tropical belt, which is especially well developed in the southern hemisphere, owing to the great extent of sea. But in Chili the winds are S. and S. W. from December to February, instead of S. E., the direction of the true trades. But this is easily explained by the high chain of the Andes, which does not permit an extensive circulation of air from the S. E. Besides this, air is drawn towards the land from the sea, which is to the westward. The seasons of Central Chili are in keeping with the sub-tropical winds; the summer months are rainless. The further we advance to the N. the greater time the polar winds (S. E., S., S. W.) blow and the longer is the rainless season. About 27° S. the rain ceases altogether, and this belt stretches along the coast of Bolivia and Peru to 5° S.

Santiago has regular sea and land winds, especially from December to March, as is shown by the tri-horary observations of the U. S. expedition under Capt. Wilkes. (See tables, Zone 25.) At midnight, 3, and 6 A. M., the winds are nearly N., from 9 A. M. to 9 P. M. they are nearly S. W. There is no gradual passage of one into the other, but a calm separates them in the morning and evening.

From the latitude of Central Chili to the Isthmus of Panama we can supply the deficiency of land-observations by those made at sea, near the coast. The prevailing wind in zones 25 and 24 (25°–35° S.) is S., especially in the last, where from that quarter more than half of all the winds blow. As we advance towards the north the wind is deflected to the S. E. by the influence of the earth's rotation. Between 5° and 10° S. (Zone 20) 90 per cent. of all the winds blow from the S. E. in the cold months of the year, giving the ratio of resultant 96. This gradual change in the direction of the wind is clearly seen on Plates 5 and 6. There is scarcely any trade-wind region in the southern hemisphere where they are so largely prevailing, and none in the northern hemisphere. Yet it is necessary to remember that the observations between 5° and 10° S. were taken further from the coast (85°–98° W.) than on the other parallels, and thus the proportion of S. E. winds is greater, and of S. less. The nearer to the coast, the less frequent are the S. E. winds, because of the proximity of the Andes on the E., and also because the land is here much warmer than the sea, on account of the extremely cold Peruvian current.

As we approach the equator, the S. winds again increase. Between 0° and 5° S. this increase is probably caused by the position of the cold marine current, which is deflected to the westward. But southerly winds here cross the equator, and are by the earth's rotation deflected to the S. W. Already between 0° and 5° N. there is a great proportion of S. W. winds, though the S. winds still prevail. The mean direction is to the W. of S., as shown on Plates 5 and 6. Between 5° and 10° N., even southerly winds prevail during nine months, especially from June to August. Only in the winter of the northern hemisphere the wind is N. W., and then even with a small ratio of resultant. The equatorial boundary of the northern

trades is thus seen to lie much N. of the equator in the Eastern Pacific. A great body of air is thus drawn in to about 10° L. N., and forms what is called a S. W. monsoon.

In other regions this is also the case; these S. W. monsoons reach a much higher latitude, about 12° N. on the coast of Africa, 17° N. in the interior of this continent, and even 30° N. in India. The following table gives the mean direction of the wind at stations in South America:—

	March to May.		June to August.		Sept. to Nov.		Dec. to Jan.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
Northern Venezuela	.....	...	S. 81° E.	.44½	S. 66° E.	.19	N. 70° E.	.56
Catherina Sophia, Guiana	N. 63° E.	.29	S. 82 E.	.58	N. 77 E.	.55	N. 69 E.	.69
Atlantic Ocean—								
Lat. 19°–21° S., long. 35°–37° W.	S. 60 E.	.47	S. 79 E.	.55	N. 65 E.	.56	N. 55 E.	.63
Lat. 21 –23 S., long. 37 –39 W.	S. 36 E.	.18	N. 86 E.	.40	N. 72 E.	.38	N. 37 E.	.64
Lat. 40 –45 S., long. 55 –65 W.	N. 74 W.	.25	N. 66 W.	.33	N. 55 W.	.25	N. 63 W.	.26
Rio Janeiro	S. 20 E.	.20	N. 86 E.	.22½	S. 69 E.	.21	S. 58 E.	.19
Buenos Ayres	N. 65 E.	.27½	S. 25 E.	.04	N. 87 E.	.38½	N. 27 E.	.33
Assumption, Paraguay	N. 89 E.	.37	S. 86 E.	.50	.....	...	.....	...
Punta Arenas, Magellan Strait	N. 63 W.	41	N. 53 W.	.44	N. 76 W.	.53½	N. 80 W.	.56
Puerto Montt, Chili	N. 18 W.	.36½	N. 7 W.	.63	N. 2 W.	.19	N. 82 E.	.12
Valparaiso, Chili	N. 12 W.	.8½	N. 13 E.	.15	S. 38 W.	.12	S. 48 W.	.21
Santiago, Chili	S. 24 W.	.6½	N. 31 E.	.07	S. 47 W.	.28	S. 57 W.	.32½
Pacific Ocean, Zone 27. 75°–80° W.	N. 81 W.	.52	N. 77 W.	.48	N. 78 W.	.46	S. 78 W.	.52
" " " 25. 71 –75 W.	S. 37 W.	.39	S. 62 W.	.17	S. 22 W.	.57	S. 25 W.	.64
" " " 24. 70 –85 W.	S. 28 W.	.64	S. 8 W.	.75	S. 6 W.	.76	S. 5 E.	.74
" " " 23. 70 –80 W.	S. 17 E.	.81	S. 2 E.	.54	.....	...	S. 27 E.	.84
" " " 22. 70 –75 W.	S. 32 E.	.81	S. 22 E.	.84	.....	...	S. 41 E.	.88
" " " 21. 76 –80 W.	S. 43 E.	.83	S. 40 E.	.86	S. 37 E.	.91	S. 40 E.	.92
" " " 20. 78 –85 W.	S. 43 E.	.96	S. 36 E.	.95	S. 46 E.	.96	S. 42 E.	.88
" " " 19. 80 –85 W.	S. 33 E.	.82	S. 14 E.	.82	S. 17 E.	.79	S. 24 E.	.81
" " " 18. 75 –80 W.	S. 39 W.	.73	S. 32 W.	.75	S. 31 W.	.72	S. 27 W.	.49
" " " 17. 75 –90 W.	S. 22 W.	.16	S. 47 W.	.58	S. 42 W.	.43	N. 28 W.	.30

ATLANTIC OCEAN.

There are four wind-belts stretching across the Atlantic Ocean: the northern belt of westerly winds (principally S. W.); the northern trade-winds (N. E.); the southern trade-winds (S. E.); and the southern belt of westerly winds (principally N. W.). The first and the last of these are also called belts of variable winds in opposition to the constant trade-winds.

As the Atlantic Ocean is the great highway of civilized nations, its meteorology is better known than that of any other ocean. Though narrow when compared to the Pacific and Indian Oceans, the winds have sufficient space on the Atlantic, as it has very few islands, and no mountain-chain in its vicinity at all comparable to the Andes, which exercise so great an influence on the winds of the Pacific. This being the case, the winds of the Atlantic can be regarded as typical for the oceans. (See Plates 5, 6, and 7.)

The most important boundaries of the different systems of winds which occur in the Atlantic are the so-called outer (or polar) and the inner (or equatorial) limits of the trades. We give below these limits, according to the best source of informa-

tion, the "Pilot Chart of the Atlantic Ocean," edited by the Meteorological Office in London.

MEAN POLAR LIMITS OF THE N. E. TRADE.

	MERIDIANS.										
	65° W.	60° W.	55° W.	50° W.	45° W.	40° W.	35° W.	30° W.	25° W.	20° W.	17° W.
January to March	26½° N.	25° N.	23½° N.	23° N.	24½° N.	26° N.	26½° N.	25½° N.	25½° N.	28½° N.	30° N
April to June . .	28 N.	24½ N.	23 N.	25 N.	27 N.	28 N	28 N.	28 N.	28½ N	32 N.	33 N.
Jnly to September	27 N.	27 N.	26½ N.	26 N.	26½ N	27½ N.	27½ N.	28½ N.	31 N.	31½ N.	32½ N.
October to Dec. .	26 N.	24 N.	22½ N.	22 N.	22½ N.	24½ N.	25½ N.	25½ N.	26½ N.	29½ N.	31 N.

EQUATORIAL LIMITS OF THE NORTHERN AND SOUTHERN TRADES.

		MERIDIANS.					
		40° W.	35° W.	30° W.	25° W.	20° W.	17° W.
January	N. E.	3° N.	1½° N.	2° N.	4½° N.	6½° N.	8° N.
	S. E.	1 N.	0½ N.	1 N.	2 N.	3 N.	3 N.
March	N. E.	1½ N.	0	0½ N.	2½ N.	5 N.	6 N.
	S. E.	1 S.	0½ S.	1 S.	0½ N.	0½ N.	1 N.
May	N. E.	3½ N.	3 N.	3½ N.	5½ N.	8½ N.	
	S. E.	0½ N.	0 N.	2 N.	3 N.	3½ N.	
July	N. E.	8½ N.	9 N.	10 N.	12 N.	14 N.	
	S. E.	4 N.	4 N.	3 N.	3 N.	3 N.	
September . . .	N. E.	11½ N.	12 N.	11½ N.	11 N.	12 N.	
	S. E.	6 N.	4 N.	2 N.	2 N.	0	
November . . .	N. E.	6 N.	6 N.	6 N.	6½ N.	9½ N.	
	S. E.	4½ N.	4 N.	3½ N.	3½ N.	4 N.	

MEAN POLAR LIMITS OF S. E. TRADE.

	MERIDIANS.									
	30° W.	25° W.	20° W.	15° W.	10° W.	5° W.	0°	5° E.	10° E.	15° E.
January to March . . .	19° S.	21° S.	24° S	26½° S.	28° S.	29° S.	30° S	31½° S.	32½° S.	33° S
April to June	21½ S.	23 S.	24 S	25 S.	25 S.	27 S.	28½ S	32 S.	33½ S.	
July to September . . .	20½ S.	22½ S.	24 S	24½ S.	27½ S.	28½ S.	29½ S.	29½ S.	30½ S.	
October to December . .	16½ S.	18½ S.	20½ S.	21 S.	22½ S.	28 S.	28½ S.	29 S.	30 S.	

The N. E. trade is much more to the north in the eastern part of the ocean than it is near the coast of America, and on the meridians of 55° to 50° W. its polar limit is still further south. We do not know accurately the equatorial limits of the N. E. trade; on these meridians they must, however, fall on the continent of S. America. The trade-wind belt seems to be more narrow about 40° W. than further eastward, except in the months from July to September.

The equatorial belt of calms and variable winds between the N. E. and S. E. trades is much broader and better marked in the eastern part of the ocean than in the middle. About 20° W. its mean breadth attains 12° in September, and even in January 3½°, while at 35° W. its breadth is only ½° from January to March, so that frequently ships sail from one trade into another without passing through intervening calms. It should be observed that the direction of both trades is much

more easterly in the western than in the eastern part of the ocean. This will be readily seen by a reference to the map. (Plates 3, 5, 6, and 7.)

There are in other places much greater differences in the limits of the S. E. trade. Near the coast of America the winds are so irregular that the seamen do not consider them true trades, thus on the meridian of 30° W. the polar limit is set down at 16½° S. to 21° S. according to the seasons. Near the coast of Africa (10° E.) the polar limit is south of 30° S. at all seasons. The S. E. trade advances much beyond the equator, except in the months of February, March, and April. In September it goes to 6° N. under 40° W.

The narrowing of the ocean in its equatorial part between Cape S. Roque in S. America and Cape Verde in Africa does not allow of a determination of the equatorial limits of the trade east of 17° W. and west of 40° W., as it is known that the trades blow regularly only on the ocean.

The greater breadth, however, of the S. E. trade and its regularity near the equator are well known.

Along the coast of S. Africa there are prevailing S. W. winds the whole year. They exist also on the ocean. This African monsoon is caused by the rarefaction of the air in the interior of the continent, and, in the months from July to September, extends far beyond the equator, and occupies much of the zone between the S. E. and N. E. trade. Violent rains and thunder-storms are experienced at this season in this region of S. W. winds. There is no doubt that the S. E. trade is drawn far beyond the equator and gradually changed into a S. and then a S. W. wind. Having passed over a broad expanse of warm sea it is copiously loaded with vapor.

From January to March the Pilot Charts give the southern boundary of the S. W. winds at 2½° N. and 15° W. It crosses the equator under 10° W.; 7° S. under the meridian of Greenwich; 10° S. under 4° E.; 20° S. under 10° E. Thus the belt of S. W. winds has the greatest breadth opposite the Bay of Biafra, and is much narrower North and south. From April to June the S. W. winds advance to 19° W. opposite Sierra Leone, while the boundary is nearer to the coast of Africa further southward.

From July to September the belt of S. W. winds occupies a great space off the west coast of N. Africa, between 17° and 32° W. and 6°–11½° N. If the boundary were traced for every month, it would be found to coincide much more closely with the inner limits of the N. E. and S. E. trade; as it is, it is near enough, as the southern limit of the N. E. trade is 12° N. in September, near the coast of Africa, while the S. W. monsoons begin about 11½° N.

It is important also to obtain a knowledge of the minor characteristics of the winds of the Atlantic, and this can best be done by studying the percentage of winds in the different regions of the ocean, as presented in the following table:—

	June.			July.		August.			December.			January.		February.		
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 7. N. 20 : 5°–20° W.	5	5	4	11	14	**25**	20	15	0	0	0	0	32	**37**	21	11
" 8. N. 22 : 15 –20 W.	5	3	7	12	**25**	18	22	9	4	4	9	14	16	19	**24**	11
" 8. N. 24 : 0 –20 W.	10	11	10	6	12	19	**25**	8	13	6	7	13	**18**	17	16	9
" 9. N. 94 : 0 –15 W.	13	11	8	3	8	16	**22**	19	11	12	6	7	14	14	**18**	17
" 10. N. 331 : 0 –20 W.	17	11	5	9	6	6	19	**27**	7	6	10	10	17	**25**	17	8
" 11. St. Michael's, Azores	3	**42**	2	12	1	13	7	20	6	24	4	13	7	20	4	22
" 12. N. 150. Bermuda	6	5	8	17	23	27	11	4	18	12	7	5	14	**20**	11	13
" 12. N. 159 : 45 –70 W.	8	9	11	15	**21**	**21**	9	6	11	8	7	8	13	15	**21**	16
" 12. N. 164. Madeira	4	**69**	7	1	0	0	13	7	22	**32**	7	7	2	2	22	6
" 13. N. 64 : 45 –80 W.	2	16	**27**	**28**	2	11	4	1	12	**19**	13	12	10	12	9	13
" 13. N. 65 : 40 –50 W.	6	**37**	33	11	2	3	5	2	9	**25**	22	9	6	13	9	7
" 11. N. 69 : 15 –20 W.	**46**	28	6	3	1	5	3	7	21	**27**	17	9	5	3	8	9
" 13. N. 70 : 15 –45 W.	29	**34**	14	5	4	4	3	7	12	**24**	17	14	11	7	8	6
" 14. N. 28 : 15 –45 W.	13	30	28	8	6	6	**4**	5	24	**51**	17	3	1	1	1	2
" 17. N. 25 : 45 –55 W.	4	**55**	12	16	5	3	6	0.4	11	**67**	20	2	0	0	0	0
" 17. N. 31 : 10 –20 W.	0.5	0.5	2	14	**59**	19	4	1	**23**	21	8	4	6	8	15	16
" 17. N. 32 : 10 –55 W.	3	12	7	18	**39**	12	6	3	14	**48**	19	8	3	2	3	4
" 18. N. 24 : 18 –55 W.	1	3	11	**44**	33	6	2	0.5	8	21	25	**29**	10	4	1	2
" 19. N. 30 : 25 –30 W.	0.2	1	9	**73**	16	1	0.2	0.1	0.8	2	4	**71**	20	2	0.5	0.5
" 19. N. 33 : 11 –15 E.	0	0	8	35	**37**	14	5	0.4	0	0	8	21	**31**	26	13	0
" 20. N. 26. Ascension Is.	0	0	11	**55**	34	0	0	0	0	1	4	34	**57**	2	1	0
" 20. N. 28 : 10 –15 E.	0	1	19	26	**30**	18	4	1	0	0	0	**38**	11	**38**	4	9
" 21. N. 29 : 5 W. 13 E.	3	2	4	**32**	32	19	4	4	0	0	0	**100**	0	0	0	0
" 22. N. 30. St. Helena	1	5	1	**47**	33	9	1	3	3	1	3	**53**	34	5	1	0
" 23. N. 35 : 5 –15 E.	1	2	5	**45**	16	9	12	10	0	2	2	**63**	20	8	1	3
" 24. N. 36 : 5 –11 E.	3	3	4	**35**	19	12	12	11	0.3	0.5	2	**50**	30	10	5	2
" 25. N. 32 : 15 –20 W.	17	14	4	9	7	13	14	**23**	**18**	12	8	10	8	12	10	12
" 25. N. 40 : 15 –20 E.	4	12	20	**21**	11	12	12	8	1	4	14	26	**31**	14	8	3
" 26. N. 41 : 0 – 5 W.	15	5	6	5	11	12	**26**	20	8	3	3	6	13	17	**25**	**25**
" 26. N. 44 : 10 –15 E.	11	2	8	13	**21**	14	19	12	2	1	2	17	15	27	**28**	9
" 27. N. 19 : 55 –65 W.	19	10	2	3	12	23	11	19	17	10	4	4	11	22	14	18
" 27. N. 22 : 45 –50 W.	10	2	2	7	8	25	20	**27**	13	6	4	5	11	**22**	14	**24**
" 27. N. 32 : 10 –15 E.	...	...	...	...	...	...	...	...	17	3	0	3	15	**21**	18	**23**
" 27. N. 33 : 15 –20 E.	...	...	...	...	...	...	...	...	11	5	8	0	8	22	**23**	**24**

North of the regularly-established trades, there is a zone with prevailing northerly winds, especially in summer, in the eastern part of the ocean, as seen on maps, Plates 5, 6, and 7. To this zone the Azores belong.

At Funchal, Madeira, the trade-wind is well established in summer, but northerly winds prevail in winter, though not regular enough to be called trades.

The northerly winds of summer between 30° and 40° N. are N. W. rather than N., showing the influence of the heated surface of Southern Europe and Northern Africa. The African monsoon is to be observed in Z. 17, N. 31, and on Plate 5; the prevailing wind is N. from December to February and S. from June to August.

Under the same latitude in the middle of the ocean the N. E. trade is well established at both seasons. (See Plates 5, 6, and 7.) In zone 18 (0°–5° N.) the S. E. trade begins to prevail.

Along the coast of Africa the S. E. trade is very southerly, especially from June to August in latitude from 5° to 15° S. It must be remembered that a cold marine current flows along this course, and, therefore, the conditions must be like what prevail near the western coast of S. America. (See maps, Pl. 5, 6, and 7.)

The wind blows along this cold current, while on the coast it blows from the cold current to the land; this gives the S.W. winds of South Africa from 0° to 20° S. The only difference from S. America is, that no such high chain of mountains rises here near the coast. The belt of land under the influence of the sea-winds is more

extensive in Africa, and more heated, the ascending current is, therefore, more powerful, and thus the air from over the cold current is attracted with more force.

The mean direction of the wind in the tropical part of the Atlantic is as follows:—

	June to August.		Dec. to Feb.			June to August.		Dec. to Feb.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.		Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
Zone 14. 60°–80° W.	S. 88° E.	.77	N. 73° E.	.51	Zone 23. 40°–45° W.	N. 66° E.	.36	N. 58° E.	.44
" 14. 40 –50 W.	N. 58 E.	.75	N. 63 E.	.55	" 23. 20 –25 W.	S. 65 E.	.46	N. 85 E.	.55
" 14. 15 –25 W.	N. 27 E.	.79	N. 51 E.	.58	" 23. 0 – 5 E.	S. 28 E.	.65	S. 29 E.	.63
" 15. 60 –80 W.	N. 89 E.	.84	N. 66 E.	.80	" 22. 35 –39 W.	S. 61 E.	.67	N. 72 E.	.72
" 15. 45 –50 W.	N. 60 E.	.77	N. 64 E.	.73	" 22. 10 –20 W.	S. 55 E.	.79	S. 61 E.	.80
" 15. 15 –25 W.	N. 42 E.	.91	N. 31 E.	.76	" 22. 0 –12½ E.	S. 26 E.	.84	S. 35 E.	.96
" 16. 45 –50 W.	N. 55 E.	.90	N. 49 E.	.86	" 21. 35 –39 E.	S. 50 E.	.79	S. 87 E.	.83
" 16. 30 –35 W.	N. 72 E.	.55	N. 68 E.	.87	" 21. 15 –25 W.	S. 48 E.	.92	S. 84° E.	.98
" 16. 15 –25 W.	N. 10 E.	.18	N. 37 E.	.77	" 21. 5 W. 13 E.	S. 6 E.	.63	S. 45 E.	.100
" 17. 45 –50 W.	N. 66 E.	.56	N. 50 E.	.91	" 20. 33 –35 W.	S. 46 E.	.89	S. 75 E.	.83
" 17. 30 –35 W.	S. 49 E.	.05	N. 65 E.	.38	" 20. 15 –20 W.	S. 47 E.	.96	S. 45 E.	.96
" 17. 10 –20 W.	S. 4 W.	.88	N. 9 W.	.31	" 20. 15 W. 10 E	S. 11 E.	.68	S. 11 W.	.59
" 18. 40 –55 W.	S. 55 E.	.82	N. 73 E.	.74	" 19. 35 –45 W.	S. 48 E.	.85	S. 62 E.	.88
" 18. 30 –35 W.	S. 62 E.	.70	N. 87 E.	.69	" 19. 20 –25 W.	S. 43 E.	.92	S. 35 E.	.89
" 18. 10 –20 W.	S. 13 E.	.83	S. 29 E.	.34	" 19. 15 W. 11 E.	S. 6 E.	.73	S. 16 W.	.67

(See also Plates 5, 6, and 14.)

This table is so arranged as to show the corresponding latitudes north and south opposite to one another. It will be seen how much more regular are the southern trades, especially between 0°–15°.

In the northern hemisphere the trades are well established between 10°–15° N. in the middle and western part of the ocean; while near the African coast the winds are very variable, or better to say this latitude is divided in summer between the N. E. trade and the S. W. monsoon. In the corresponding latitude south, the S. E. trade is blowing regularly the whole year.

In latitude 5°–10° N. the S. E. trade is already established in the middle of the ocean from June to August and the African monsoon in full force further east. In the corresponding latitude in the southern hemisphere the trade is very regular. It is also blowing between 0°–5° N. with the exception of the months from December to February, when the mean direction is E. N. E. in the western part of the ocean, probably owing to the heating of a part of S. America, towards which the air is drawn from the ocean. (See also Map, Plate 6.)

The more easterly direction of the trades in the western part of the ocean is well marked, especially as concerns the S. E. trade. It is probably due to the rotation of the earth, which gives the winds more easting the further they advance.

There is no doubt that the winds of the Atlantic which blow near the coasts of America have traversed a great part of the ocean, and thus acquired more easting. As to the winds which blow in the eastern part of the ocean, they do not come from so far. The African continent rather attracts the winds than otherwise. It has before been shown that from 5° N. to 20° S. southwesterly winds blow the whole year on the ocean near the coast of Africa, as exhibited on Plate 7. Thus the trade which blows further to the west cannot come from Africa. It originates on the Atlantic Ocean itself, over the cold antarctic current flowing at some distance from the African coast.

Barometric observations are numerous on the Atlantic Ocean, and are important as giving us the key to the winds. (See Plate 14.) Unfortunately their tabulation and reduction is not all that can be desired. They are calculated without regard to longitude, and from 5° to 5° of latitude only. Thus we do not know the difference of pressure in the eastern and western parts of the ocean, although it must be great, especially in latitude from 20° to 35° N. and S. as shown by the great difference in the polar limits of the trades.

The Meteorological Institute of the Netherlands has undertaken the calculation of the barometric means of the Atlantic Ocean for every degree of latitude, distinguishing also, in the southern hemisphere, the outward and homeward voyages. This would give two sets of figures, one for the eastern and one for the middle part of the ocean, as the ships going to the East Indies take a course more to the westward, while on returning they go nearer to the coast of Africa. This expected publication will shed light on many obscure problems.

The most complete barometrical table for the Atlantic we now possess is published in the Pilot Charts. It is calculated from 5° to 5°, for every month. I have calculated from it the pressure of the two contrasting seasons, and have given in the following table the pressure observed on some islands and coast stations reduced to sea-level. (See also Plate 14.) The mean pressure is at 32° Fahr.

	June. July. Aug.	Dec. Jan. Feb.		June. July. Aug.	Dec. Jan. Feb.		June. July. Aug.	Dec. Jan. Feb.
Atlantic Ocean—			Atlantic Ocean—			32° 38′ N. 16° 36′ W.		
35°–40° N. . .	30.18	30.13	10°–15° S. . .	30.05	29.98	Funchal, Madeira .	30.11	30.15
30 –35 N. . .	**30.21**	**30.21**	15 –20 S. . .	30.10	30.03	32° 23′ N. 64° 40′ W.		
25 –30 N. . .	30.20	30.20	20 –25 S. . .	**30.14**	30.06	Bermuda Islands .	29.97	29.93
20 –25 N. . .	30.11	30.07	25 –30 S. . .	30.13	**30.07**	5° 24′ N. 0° 10′ E.		
15 –20 N. . .	30.01	30.03	30 –35 S. . .	30.09	30.03	Christiansb'g, Guinea	30.00	29.91
10 –15 N. . .	**29.93**	29.96	35 –40 S. . .	29.96	30.00	4° 56′ S. 55° 39′ W.		
5 –10 N. . .	29.96	29.92	40 –45 S. . .	29.92	29.94	Cayenne, Fr. Guiana	29.95	29.91
0 – 5 N. . .	29.96	**29.90**	45 –50 S. . .	29.72	29.72	33° 56′ S. 18° 27 E.		
0 – 5 S. . .	29.98	29.91	50 –55 S. . .	29.52	29.43	Cape Town, S. Africa	30.17	30.00
5 –10 S. . .	30.02	29.95	55 –60 S. . .	29.27	29.23	34° 37′ S. 58° 21′ W.		
						Buenos Ayres . .	30.15	30.01

The polar boundaries of the N. E. and S. E. trades are marked by a high pressure (at 30° to 35° N. and at 20° to 30° S.), while the space intervening between the two trades—the belt of equatorial calms and variable winds, has a comparatively low pressure. It should be remarked that this low pressure remains on the northern hemisphere, changing from 10° to 15° N. in our summer and from 0° to 5° in our winter. The air from north and south is attracted towards this belt of low pressure, and, as the conditions of the tropics are very uniform, the winds also are very regular.

A comparison of stations in the west and east of the ocean will show that pressure is generally higher in the east (as in Madeira compared with Bermuda, in Christiansburg compared with Cayenne, and Cape Town compared with Buenos Ayres). This is an additional cause for the easting of the trade-winds near the American continent.

Pressure is extremely low in the higher latitudes of the southern hemisphere.

Between 55° and 60° it is lower than around Iceland, the lowest known in the northern hemisphere. The great permanence and strength of the westerly winds in the southern temperate zone is explained by this. (See Plates 5, 6, and 14.)

NORTHWESTERN EUROPE.

The islands to the N. W. of Europe have still the climate of the Atlantic Ocean. Only one of them, the largest and most northerly, Iceland, has some of the characteristics of the polar zone.

Near Iceland, on account of the heated current of the gulf-stream, is the lowest pressure of the northern hemisphere, and though it is especially marked in autumn and winter it is also conspicuous at the other seasons. As is to be expected from a country in such a position, the winds are very changeable, according to the shifting of the centre of lowest pressure to the north and south. The equatorial winds, S. W., and the polar, N. E., prevail in turn.

The Faröe islands have prevailing S. W. winds at all seasons. This is even more the case at the Shetland islands, and in Great Britain generally, as is shown by percentages in the next table.

		Summer.								Winter.							
		N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone	5. N. 15. Stykkisholm, N. W. Iceland	4	17	**27**	11	13	11	9	9	2	**25**	**25**	15	12	13	6	2
"	6. N. 19. Reikiavik, W. Iceland. .	16	12	9	**21**	16	14	7	5	13	**29**	19	10	2	22	3	2
"	6. N. 21. Thorshavn, Faröe Islands .	11	11	7	10	8	**26**	18	8	10	12	7	13	12	**23**	14	10
"	6. N. 22, 23. Shetland Islands . .	11	11	6	10	12	**20**	**19**	12	12	8	4	12	13	**25**	16	10
"	7. N. 27. W. Scotland, 58°–59° N. .	10	9	11	6	9	**26**	18	11	7	7	8	7	13	**30**	18	10
"	7. N. 29, 31. W. Scotland, 56°–58° N.	5	8	11	7	11	**23**	**23**	12	6	11	8	12	7	**24**	22	9
"	7. N. 33. W. Scotland, 55°–56 N. .	6	9	9	9	9	**23**	**23**	12	5	10	10	10	6	**24**	22	11
"	7. N. 39 and 43. E. Scotland, 56°–58° N.	8	9	11	9	13	**22**	16	12	8	6	5	8	10	**28**	23	12
"	8. N. 39. Ireland, 53°–54° N. . .	8	11	7	9	8	13	**24**	18	7	5	6	10	13	**17**	**24**	18
"	8. N. 44 and 48. Ireland, 51°–53° N. .	8	5	4	7	10	20	20	**25**	8	11	6	11	13	**22**	13	16
"	8. N. 113. Greenwich, S. E. England .	10	13	5	6	9	**36**	13	7	11	11	6	6	12	**32**	12	7

There is little difference between the winds in winter and summer, from Faröe islands to southern England. A very slight one only can be detected in the greater number of W. and N. W. winds in summer. This applies not only to Great Britain, but also to the greatest part of northern and central Europe. It is due to two causes: First, the belt of highest barometer is more northerly in summer than in winter; and second, part of the air is attracted towards the depression of Central Asia.

In Great Britain the influence of the last cause is very small, as Central Asia is too distant, and the depression about Iceland so near, that it must act very powerfully even in summer. But the further we advance eastward the greater is the influence of the depression in Central Asia, and consequently the greater the difference between the direction of the wind in winter and summer. The next table gives the mean direction of the wind in Great Britain and Iceland.

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
Iceland, Stykkisholm	S. 87° E.	.45	S. 74° E.	.23	S. 68° E.	.33	S. 75° E.	.35
" Reikiavik	N. 78 E.	.21	N. 17 E.	.06½	N. 54 E.	.26	N. 80 E.	.19
Thorshavn, Faröe Islands	N. 14 E.	.03	S. 66 W.	.21	N. 77 W.	.13	S. 51 W.	.16
W. Scotland, 58°–59° N.	S. 36 W.	.13	S. 70 W.	.22½	S. 50 W.	.26	S. 55 W.	.34
" 57°–58° N.	S. 58 W.	.28	S. 53 W.	.35¼	S. 51 W.	.36	S. 55 W.	.40
E. Scotland, 57°–58° N.	S. 67 W.	.18	S. 65 W.	.18½	S. 53 W.	.34	S. 62 W.	.40
Ireland, Dublin, Phœnix Park	N. 70 W.	.10½	S. 88 W.	.31	S. 73 W.	.31	S. 61 W.	.36½
" Cork	S. 54 W.	.13	S. 88 W.	.39	S. 70 W.	.19	S. 64 W.	.20½
England, 52°–53° N.	N. 2 W.	.08	N. 81 W.	.29	S. 84 W.	.19	S. 75 W.	.31
Greenwich	N. 57 W.	.02½	S. 61 W.	.28	S. 69 W.	.14½	S. 55 W.	.25
England, 51°–52° N.	N. 45 W.	.08	N. 87 W.	.26½	S. 73 W.	.16½	S. 72 W.	.21

(See also maps, Plates 5, 6, and 9; and map of Isobars, Plate 14.)

The ratio of resultant is less in spring than at other seasons. This is caused by the great increase of pressure in the Polar region, as has been shown before. N. E. winds are oftener experienced in spring than at other seasons.

I must further remark that the character of the winds in Great Britain and the adjoining islands is strictly oceanic *i. e.*, such as would be found in the same latitudes on the oceans. The relative position of the land and sea have scarcely any influence. This is due, first, to the great difference of pressure between north and south, and the great strength of the winds which is the result, so that local causes are comparatively unimportant; second, to the small extent of land, which, being besides pervaded by the influence of the sea, is neither much more heated in summer, nor much more cooled in winter than the surrounding ocean. (See Plates 9 and 12.)

The conditions of the Scandinavian Peninsula are very different. It is by itself a large body of land. Besides this, the high mountain chain rising near its western coast is a great barrier to the influence of the Atlantic Ocean on the interior. The result is a much more continental climate than could be expected from a country so near to the Atlantic Ocean.

In many respects the physical features resemble those of Alaska, where the contrast between the mild, equable climate of the coast and the excessive seasons of the interior is equally great. The winds of the Scandinavian Peninsula are shown in the two following tables; in the first by percentages, and in the second in direction.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 7. N. 56. Christiania, S. Norway	12	16	9	16	**30**	8	**4**	5	**29**	30	6	8	12	4	3	8
" 6. N. 27. Christiansund, W. Norway	**14**	**25**	6	7	3	10	**24**	11	3	4	10	**29**	12	19	17	7
" 6. N. 26. Dovre, Inner Norway	16	4	2	5	**40**	6	4	23	5	2	3	6	**53**	11	6	13
" 5. N. 19. Bossekop, N. Norway	27	40	0	0	7	20	0	7	1	3	30	**42**	10	6	4	3
" 4. N. 18. Hammerfest, N. Norway	10	7	**17**	11	**17**	6	13	17	7	3	9	**31**	28	8	7	7
" 4. N. 19. Vardö, N. Norway	12	15	7	**26**	8	5	2	**24**	5	9	5	11	5	46	8	12
" 3. Mossel Bay, Spitzbergen	...	...	...	...	...	...	...	...	1	1	2	**45**	2	36	3	5
" 3. Ice Fjord, Spitzbergen	...	...	...	...	...	...	...	...	12	13	19	**21**	11	9	8	7
" 3. Hecla Cove, Spitzbergen	15	10	19	15	5	7	14	15								
" 4. N. 16. Bear Island (between Norway and Spitzbergen)	**19**	13	10	9	14	8	15	13	4	13	**31**	17	12	11	5	6
" 5. N. 23, 24, 25. N. Sweden	15	12	13	13	**23**	11	8	5	15	11	5	10	**22**	15	13	8
" 6. N. 35. E. Sweden	9	5	9	7	**31**	17	10	12	14	8	7	8	**20**	18	14	11
" 7. N. 90. S. E. Sweden	12	9	10	10	13	15	**17**	10	13	10	7	8	13	**20**	16	12
" 7. N. 89. S. W. Sweden	9	8	8	8	**20**	19	**20**	18	10	12	14	10	17	**19**	11	10
" 7. N. 68. Lund, S. Sweden	7	7	7	12	12	17	**21**	18	7	8	10	13	14	**22**	14	11

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
Christiania, Southern Norway	N. 57° E.	.24	S. 42° E.	.28	N. 39° E.	.32	N. 31° E.	.41
Sandösund, Southern Norway	N. 8 W.	.05	S. 49 W.	.29	S. 49 W.	.09	N. 39 W.	.08
Christiansund, Western Norway	S. 31 W.	.03	N. 20 W.	.23	S. 13 W.	.24	S. 3 W.	.32
Dovre, Inner Norway	S. 18 W.	.08	S. 48 W.	.08	S. 14 W.	.16	S. 15 W.	.19
Hammerfest, Northern Norway	S. 23 E.	.19	S. 31 E.	.02	S. 12 E.	.24	S. 21 E.	.42½
Vardö, Northern Norway	N. 75 W.	.19	N. 53 E.	.14	S. 53 W.	.25	S. 50 W.	.38
Bossekop, Northern Norway	S. 43 E.	.47	N. 34 E.	.25	S. 60 E.	.24	S. 53 E.	.61
Haparanda, Northern Sweden	S. 25 E.	.12	S. 24 E.	.11½	S. 15 E.	.06	S. 30 E.	.09
Southwestern Sweden	S. 72 W.	.01	S. 57 W.	.25½	S. 6 W.	.15	S. 14 W.	.09½
Southeastern Sweden	N. 5 W.	.06½	S. 71 W.	.14½	S. 66 W.	.12½	S. 83 W.	.10½

In winter the whole coast of Norway has monsoon winds, blowing from the land to the sea, they are N. and N. E. at Christiania, S. E. at Christiansund, Bossekop and Hammerfest, and S. W. at Vardöe. In summer the conditions are reversed.

This was shown some years ago by the best authority in these matters, Prof. H. Mohn.[1] He is of the opinion that the winds are deflected about 90° to the right of the direction they would have if they blew directly from the land in winter and from the sea in summer.

It must, however, be observed that in this result the number of observations alone is taken into account. The storms on the Atlantic coast of Norway are very violent, and the winds during their prevalence mostly S. and W. A south wind should prevail in Norway, taking into account the strength of winds and aside from local influences.

The high station of Dovre, in the interior, has largely prevailing S. winds. In this we see the influence of the high pressure to the S. and in the interior of the continent and of low pressure on the ocean to the W. and N. (See Plates 9 and 14.)

In northern Norway the winds are variable in summer and decidedly from the S. in the winter. In the latter season the general distribution of pressure in the

[1] Oversigt of Norges Klimatologi. See also Norsk Meteorologisk Aarbog.

surrounding countries, and the local monsoon influence, act in the same direction, as the land is to the S., the ocean to the N. In summer they counteract one another. Besides this, the character of the Arctic Ocean must be considered. It is traversed by a warm current, and at no time of the year do icebergs approach the coast of Norway. Even in the summer the temperature of its waters is higher than that of the air on the land. On such a sea a low pressure must prevail, and its monsoon-producing influence in summer cannot be compared with that of an ice-laden sea.

In northern Sweden the wind has also a southerly direction. The Gulf of Bothnia has but very little influence, being a small body of water and frozen to a great extent in winter, otherwise we would have northerly winds in winter, while the Arctic Ocean attracts the air so strongly that no other influence is to be considered in comparison. The S. winds of summer may be partly sea-winds.

In southern Sweden the winds are S. W. in the winter, and W. in summer. The influence of the low pressure in the interior of the continent begins to be felt here at the latter season. (See Plates 5, 6, 9 and 14.)

Bear Island, between Norway and Spitzbergen, lies N. of the warm current of the Gulf-stream. Accordingly the Polar current (E.) is largely prevailing in winter, while the winds of summer are more variable. Bear Island has a position very like that of Iceland, yet it is more clearly north of the warm ocean-current with its low pressure. Besides, at times the island is surrounded by extensive ice-fields, and the temperature sometimes sinks very low over them, and consequently pressure increases.

Iceland and Bear Island are important stations, proving the existence of prevailing polar winds N., N. E., E. in the waters north of Europe, and north of the warm current of the Gulf-stream, while all stations in the extreme north on the continent of Europe still have equatorial winds (S., S. W., W.). Thus, the division line between the two systems of winds is proved to be the belt of low pressure along the warm ocean-current. (See maps, Plates 5, 6 and 7.)

The winds of Spitzbergen seem to be more influenced by the relative position of land and sea than those of Bear Island. In winter they blow from the land, as is seen by the observations of Mossel-Bay, on the N. shore of the principal island, and Ice-Fjord on the S. shore of the same.

CENTRAL EUROPE.

Southwesterly and westerly winds prevail also in the rest of western Europe, that is, Denmark, Germany, the Netherlands, Belgium and Northern France.

This is evident from the following table of percentages:—

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Northern Germany—																
Zone 8. N. 216. Königsberg	8	8	18	7	4	13	**32**	10	4	9	18	9	7	**23**	20	9
" 8. N. 197. Berlin	14	2	15	4	12	6	**42**	4	14	2	19	3	29	8	23	2
" 8. N. 178. Kiel	7	8	10	7	8	**24**	22	15	2	6	13	17	14	**22**	18	8
Denmark—																
Zone 7. N. 57. Tarum	4	4	5	11	12	18	**27**	17	4	12	7	18	13	**26**	14	5
" 7. N. 63. Copenhagen	7	7	7	12	12	17	**21**	18	7	8	10	13	15	**22**	15	11
Zone 8. N. 196. Saxony	8	8	7	7	4	14	**28**	25	4	9	6	14	8	19	**23**	17
" 8. N. 277. Mannheim	10	7	3	11	17	18	13	**21**	9	9	3	16	19	**20**	9	16
" 8. N. 190. Northern Bavaria . . .	5	9	6	12	5	15	**24**	23	6	8	6	19	7	**20**	**20**	13
" 8. N. 312. Hohenpeissenberg . . .	6	13	4	10	4	25	**28**	9	8	17	5	8	4	22	**26**	11
" 9. N. 296. Western Bavaria . . .	9	6	7	6	6	14	**31**	20	6	9	11	10	10	**17**	**26**	10
" 9. N. 126. Eastern France	11	9	4	4	11	**21**	**21**	18	11	9	4	10	**17**	15	**19**	14
" 8. N. 151. Southern Holland . . .	8	11	5	8	8	**32**	12	15	4	14	8	10	12	**29**	13	10
" 9. N. 141. Brussels	8	9	7	5	12	**35**	14	9	4	8	8	7	17	**33**	14	8
" 9. N. 116. Paris[1]	11	10	5	5	11	21	**24**	13	10	11	7	10	17	**19**	16	10
" 9. N. 109. Normandy, Inland Stations	8	10	10	4	13	13	**29**	12	10	10	14	7	13	12	**21**	12
" 9. N. 110. Coast Stations	11	15	8	4	6	17	18	**21**	13	9	12	9	11	**20**	11	14

This is still a region of the undisputed prevalence of westerly winds. What may be noticed in S. Sweden is seen here in nearly all the stations: the winds in summer incline somewhat to the N. W. Kämtz was the first to notice the opposite course taken by the N. W. and the S. E. winds on the continent of Europe, the first being most frequent in summer, the last in the winter.[2] This is caused by the contrasts of temperature and pressure of the interior of the continent, and of the Atlantic Ocean, the influence of the land being conspicuous in winter, that of the ocean in summer.

The S. W. winds are most numerous in Belgium and Holland, while this is less the case in southern Germany, where the W. winds prevail. This is partly caused by the influence of the Alps, which do not give free access to S. W. winds, while those from the west reach Germany without impediment. The direction of the winds in this region is given in the following table:—

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
Denmark—								
Tarum	S. 60° W.	.09	S. 70° W.	.39	S. 11° W.	.26	S. 22° W.	.28
Copenhagen	S. 10 W.	.09	S. 72 W.	.28	S. 27 W.	.25	S. 31 W.	.23½
Brussels	S. 9 W.	.01	S. 62 W.	.32	S. 21 W.	.36	S. 41 W.	.40
S. Holland	N. 55 W.	.11	S. 73 W.	.29	S. 48 W.	.18	S. 40 W.	.28½
N. Holland	N. 60 W.	.12½	S. 85 W.	.32	S. 49 W.	.17	S. 25 W.	.26
Northern Germany—								
Hamburg	N. 78 W.	.12	S. 88 W.	.39	S. 52 W.	.27	S. 39 W.	.24
Kiel	N. 67 E.	.04	S. 79 W.	.30	S. 23 W.	.23	S. 23 W.	.31
Berlin	S. 64 W.	.07	S. 89 W.	.30	S. 70 W.	.20	S. 20 W.	.22
Königsberg	N. 28 W.	.05	N. 83 W.	.20	S. 7 W.	.18	S. 42 W.	.18
Saxony	N. 67 W.	.15½	N. 70 W.	.41	S. 71 W.	.27	S. 73 W.	.30
W. Bavaria	N. 87 W.	.14	N. 80 W.	.40	S. 73 W.	.23	S. 66 W.	.23½
E. France	N. 60 W.	.21	N. 87 W.	.36½	S. 53 W.	.17	S. 76 W.	.20½
Paris	N. 77 W.	.11	S. 81 W.	.33½	S. 42 W.	.23½	S. 41 W.	.22½
Normandy, Inland Stations . . .	N. 61 W.	.11	N. 87 W.	.28	S. 33 W.	.14½	S. 85 W.	.12

[1] Result of forty years' observations, calculated by Haeghens, Annuaire de la Société Météorologique de France.

[2] Repertorium für Meteorologie, v. ii.

(See also Plate 9.)

The N. W. winds of spring in most of the stations of Western Europe must be noticed, especially in stations near the coast of the Atlantic Ocean or the North Sea. The mean direction of the wind in summer is more northerly than in winter.

Central and Southern France, Northern Italy, Switzerland, and the western provinces of Austria are a border-land between two different systems of winds, southerly or westerly prevailing in the N. of this region, and northerly in the S. Still we must expect to find the winds very much influenced by locality in such mountainous countries. The following are the percentages of the winds in the countries mentioned.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 8. N. 362. S. W. France	15	4	4	13	6	8	21	**27**	8	4	5	18	**19**	11	**19**	17
" 9. N. 126. E. France 45°–46° N.	**34**	4	3	3	20	10	11	14	**32**	5	4	5	24	9	8	13
" 10. N. 366. Orange (S. E. France)	**62**	1	1	1	24	4	4	4	**54**	3	2	4	11	4	2	21
" 10. N. 367. Marseilles	0	0	1	12	4	18	**37**	29	0	1	10	16	2	5	11	**55**
" 10. N. 373. Parma	13	16	16	5	3	18	12	17	12	8	14	5	2	9	20	**31**
" 10. N. 374. Bologna	8	8	**22**	9	5	9	**25**	15	3	3	6	2	3	5	**59**	19
Switzerland—																
Zone 9. N. 178. W. Switzerland	**36**	12	2	4	17	18	5	6	23	16	4	4	16	**28**	6	5
" 9. N. 172. Neuchatel	3	**29**	11	5	2	**31**	11	8	2	28	7	1	0	**42**	12	8
" 9. N. 171. Chaumont	14	**26**	9	3	1	12	14	22	6	19	1	0	0	**55**	8	12
" 9. N. 196. Northern Switzerland	11	17	12	5	4	15	**20**	16	3	11	7	5	4	**36**	26	8
" 9. N. 192. Uetliberg	24	1	1	0	0	27	**40**	7	5	0	0	0	0	30	**66**	0
" 9. N. 218. Rigi-Kulm	6	10	9	2	20	1	**40**	13	0	2	6	4	15	4	**63**	6
" 9. N. 228. Lugano	17	**32**	2	20	24	6	0	0	**42**	**43**	0	7	4	2	0	3
" 9. N. 246, 247. Bellinzona / Mendrisio	**52**	14	3	7	11	3	5	4	**60**	13	1	2	4	1	6	12
Zone 9. N. 321. Trieste	12	2	**40**	2	16	2	25	1	18	4	**58**	1	10	1	8	0
" 10. N. 378. Ragusa (Dalmatia)	25	**31**	6	21	0	3	0	14	21	**40**	11	20	1	0	2	5
" 9. N. 320. N. Illyria	10	9	6	10	15	17	**21**	12	15	8	8	7	6	18	**21**	18
" 9. N. 317. Hoch-Obir	10	3	2	6	11	**36**	20	12	16	1	2	6	6	**24**	23	21
" 9. N. 337. Vienna and Schoenthal	8	6	7	9	7	31	2	**35**	7	14	2	19	8	**24**	4	22
" 9. N. 340. Moravia	8	9	6	9	6	10	19	**33**	11	7	4	17	6	8	12	**34**
" 8. N. 204. N. W. Bohemia	5	10	6	8	3	**30**	19	18	3	16	8	13	2	**26**	19	13

In Southern France N. W. and N. winds may be said to predominate, and not only are they the most frequent but also the strongest. They are known under the name of *Mistral*. As early as in 1861[1] Renou traced the isobaric lines of France, and showed that the highest pressure was found in the centre of the country near Limoges. Reduced to sea-level it amounted to 764 millimetres (30.08 inches), to the south it is less. In winter the temperature along the coast from Marseilles to Livorno is much higher than in the surrounding country, this being probably the cause of the lower pressure. (See Plate 14.) In summer the stony, treeless plains on the lower Rhone are so very much heated, as to attract the air of the surrounding country. It comes from the Atlantic, up the valley of the Garonne, as a N. W. wind, and descends towards the Mediterranean near Cette. It will be seen from the table that S. W. France has prevailing N. W. winds only in summer, while in winter southerly winds are frequent.

[1] "Annuaire de la Société Météorologique de France," of that year.

The valley of the Rhone is another outlet for the air flowing towards the Provence. Here nearly all winds take a N. or S. direction, *i. e.*, flow in the direction of the valley; but the first are largely in excess, as is shown by the observations in Eastern France (from 45°–46° N.), and especially at Orange, where 62 per cent. of all the winds in summer and 54 per cent. in winter come from the N.[1] (See Plate 9.)

In the country further east the Alps seems to form a boundary between the prevailing W. and S. W. winds to the north, and N. winds to the south, at least in autumn and winter. This is caused, as has been previously said, by the relatively higher pressure of the country around the Alps, and the relatively low pressure on the Mediterranean. Unfortunately very few results of observations in Northern Italy could be obtained in the libraries of Washington, though many are known to exist. Besides, the observations of Milan and some other stations were reduced to the four components (N., E., S., W.), so that percentages calculated from them would not be immediately comparable to the observations of other places where eight directions are given.

The winds of Parma seem to show what takes place in the lowlands of N. Italy. In winter the prevailing wind is N. W., in summer nearly all directions are represented equally. Bologna seems to have monsoon winds W. (from the land) in winter, and E. (from the Adriatic) in summer. (See Plate 9.)

The stations of Switzerland S. of the Alps (Lugano, Bellinzona, Mendrisio) have largely prevailing N. winds, and a very great number of calms.

The admirable system of meteorological observations begun in Switzerland in 1864 has already given much information as to the winds on mountains and high passes. Of these, the observations on isolated mountains are most valuable, as on high passes the direction is often very much influenced by the surrounding mountains.

The direction on high peaks is generally the same as in the surrounding country, but the character is much more marked, one or two directions prevailing to a greater extent than at the foot of the mountains, and the intervening winds being less numerous.

The Chaumont is situated in the Jura Chain just above Neuchatel. Here we have already a slight prevalence of northerly winds in summer, which is continued in the valley of the Rhone, in Southern France. In the winter S. W. winds prevail to a very great extent on the Chaumont, much more than in Neuchatel and in Western Switzerland generally.

The winds of N. Switzerland are very like those of Germany, that is, westerly at all seasons, as shown on Plate 9, but rather S. W. in winter, and W. N. W. in summer. This is also the case on two isolated mountains of this region, the Uetliberg (near Zurich) and Rigi-Kulm, only the proportion of westerly wind is much greater on the mountains.

Chaumont, Uetliberg, and even Rigi-Kulm, are scarcely high enough to have

[1] Count Gasparin, Fournet, and Ch. Martens were among the first to draw attention to this prevalence of northerly winds in Southern France.

another system of winds than those of the plains and valleys of Switzerland. The winds of these isolated mountains rather give us an idea of what would be the case if local influences were eliminated. The high peaks of the Alps would show us a different system of winds. The following are the winds of Switzerland.

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
W. Switzerland	N. 29° W.	.15	N. 27° W.	.15	N. 15° W.	.09½	S. 78° W.	.09½
Neuchatel	N. 55 E.	.05½	N. 69 W.	.03	N. 46 E.	.07½	S. 80 W.	.14
Chaumont	N. 37 W.	.17½	N. 11 W.	.28	N. 31 W.	.16	S. 73 W.	.31
Geneva	N. 26 W.	.21	N. 24 W.	.20	N. 8 W.	.13	S. 76 W.	.04
Northern Switzerland	N. 76 W.	.09	N. 46 W.	.11	N. 74 W.	.05½	S. 68 W.	.24
Zurich	N. 16 W.	.14	N. 21 W.	.22	N. 22 W.	.17	S. 89 W.	.22
Uetliberg	N. 87 W.	.29	N. 81 W.	.16½	N. 85 W.	.22	S. 79 W.	.43½
Zug	S. 82 W.	.09½	N. 44 W.	.07½	N. 76 W.	.03½	S. 75 W.	.14
Rigi-Kulm	S. 65 W.	.26	S. 89 W.	.18½	S. 55 W.	.27	S. 76 W.	.44
Lugano	N. 63 E.	.14½	S. 84 E.	.08½	N. 42 E.	.07	N. 27 E.	.14
Bellinzona	N. 2 E.	.18	N. 15 E.	.06	N. 24 E.	.08½	N. 7 E.	.16
St. Bernard	N. 45 E.	.32	N. 45 E.	.38	N. 45 E.	.15½	N. 45 E.	.27
Simplon	N. 37 W.	.39½	S. 8 W.	.17	S. 20 W.	.27	S. 46 W.	.24
Julier	S. 28 W.	.17½	S. 52 W.	.40½	South	.19½	S. 5 E.	.16
Bernina	N. 25 E.	.37½	N. 23 E.	.32	N. 2 E.	.33½	N. 31 E.	.45½

How much the winds are influenced by the locality on high mountain-passes, is seen by comparing the Julier and Bernina, both situated in E. Switzerland, but having nearly opposite winds, especially in spring and autumn.

The winds in winter are remarkably like in Northern and Western Switzerland, the extreme difference being only 21°. The ratio of resultant is greatest in the high stations, next in Northern Switzerland, and least at Geneva, where it is only 4. This last place is nearly on the border of the north winds in S. E. France. There are greater differences in summer, yet the mean direction is mostly between the N. and W. (See Plate 9.)

The western provinces of Austria have well-marked westerly winds in the N. (Bohemia, Moravia, Vienna), belonging, in part, to the same zone as those of Germany. This is also the case in the mountainous country (N. Illyria), and, as is the case in Switzerland, the high station of Hoch-Obir, 7016 feet above the sea, has a greater prevalence of westerly winds than the stations in the valleys.

On the Adriatic coast N. E. and E. winds prevail, being, as in S. France, directed from the land towards the sea. As there the prevailing wind is the strongest, so it is here.

The *Bora* of the Dalmatian coast is much feared by the seamen as a strong and cold wind. Another wind often blowing here is the *Sirocco* from the S. or S. E. It is originally a S. W. wind, but it is deflected by the highlands bordering the Adriatic, and takes a course parallel to the shores. The following are the directions of the wind in this region:—

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
N. Illyria	S. 66° W.	.21	S. 68° W.	.23	S. 68° W.	.16½	N. 71° W.	.28½
Hoch-Obir	S. 82 W.	.34	S. 65 W.	.22	S. 81 W.	.33	N. 83 W.	.49
Trieste	S. 83 E.	.25½	S. 74 E.	.16½	S. 80 E.	.38	N. 79 E.	.52
Ragusa	S. 86 E.	.45	N. 38 E.	.43	S. 70 E.	.84	N. 52 E.	.55
S. W. Bohemia	S. 87 W.	.26½	S. 80 W.	.45	S. 83 W.	.47	S. 86 W.	.40
N. E. Bohemia	N. 46 W.	.10½	N. 68 W.	.25	N. 83 W.	.19	S. 71 W.	.08
Moravia	N. 51 W.	.27	N. 61 W.	.34½	N. 79 W.	.21½	N. 51 W.	.25
Vienna	N. 70 W.	.21	N. 70 W.	.38	N. 65 W.	.24	S. 85 W.	.23

(See also Plates 5, 6, and 9.)

SOUTHERN EUROPE.

A belt of high pressure in the summer months is to be found about 40° N. in the Mediterranean. South of it we must expect to find N. and N. E. winds. Yet, as generally the pressure increases towards the W., that is, the eastern part of the Atlantic Ocean, the winds of summer are rather due N. and N. W. The air is attracted towards the Sahara Desert and other hot parts of Africa. The following are the percentages:—

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 11. N. 182. Lisbon	41	22	4	2	2	12	7	11	27	**33**	9	1	6	8	10	6
" 10. N. 335. N. W. Spain	10	**41**	0	0.5	3	23	5	17	10	28	0.4	4	10	**32**	5	11
" 10. N. 343. N. Spain	9	17	4	9	7	3	15	**35**	10	12	7	**23**	10	7	10	**22**
" 11. N. 184. S. W. Spain	14	8	3	6	**26**	**27**	12	4	**22**	12	0	10	**23**	**26**	2	4
" 11. N. 196. S. E. Spain	4	12	20	**30**	10	8	11	6	6	9	5	9	7	17	**28**	19
" 10. N. 375. Rome	14	10	6	4	**21**	**21**	**20**	4	**33**	21	12	6	13	7	5	3
" 11. N. 205. Malta	11	22	7	9	3	11	7	**30**	5	16	8	10	7	**22**	11	**21**
" 11. N. 208. Janina	**30**	15	10	10	3	1	3	**27**	7	7	10	**34**	18	2	10	12
" 11. N. 206. Corfu	**22**	8	9	18	5	5	10	**23**	12	13	15	**31**	5	4	5	15
" 11. N. 208(*a*). Athens	17	**31**	5	2	16	21	3	5	**26**	19	4	5	15	12	11	8

The Mediterranean region S. of 40° L. N. belongs most decidedly to the sub-tropical belt; that is, the summer is nearly or quite rainless, and the more we advance southward, the longer is this rainless period, extending to about six months at Malta and in Algeria, and to nine months in Lower Egypt, while the whole year is nearly rainless in the Sahara S. of 30°, as well as in Upper Egypt. In these conditions, especially when considering a region not deficient in vapor of water, as the shores of the Mediterranean, the absence of rain in summer indicates in our hemisphere very prevailing northerly winds. If even the wind-vane indicates southerly winds, we may be sure that they are merely local sea-winds, or winds deflected from their course by mountain chains, etc., provided that the places where they occur have the rainless summer of the sub-tropical zone. Now this is

the case in S. E. and S. W. Spain, where the winds are southerly in summer, coming from the Mediterranean and the Atlantic Ocean. Yet we know that scarcely any rain falls in summer there; for example, in Gibraltar no rain was observed in July and August, and only 0.1 inch in June, while 27½ inches fall in the winter months. (See Plates 5, 6, and 9.)

In Lisbon, Malta, Corfu, and Athens, we see the extreme prevalence of northerly winds in summer, such as characterize the sub-tropical zone. Rome and Naples again have southwesterly winds in summer, but, according to the yearly period of their rains, they belong to the sub-tropical zone, though not so decidedly as Southern Portugal and Spain, as well as Greece.

The northerly winds of summer were known to the ancient Greeks. Aristotle mentions them under the name of Etesian winds. In their gentle regular flow, they resemble the trades, but their direction is more northerly than those of true trades.

The prevalence of northerly winds is not so decided in winter, though they are more frequent than others in the greater part of this region. They are, however, interrupted from time to time by southerly winds which bring rain.

The northern part of Spain does not belong to the sub-tropical zone, yet the N. E. and N. W. winds prevail in summer. For the northern coast of Spain it is a sea wind coming from the Bay of Biscay.

EASTERN EUROPE.

Northeastward from the Mediterranean region just considered, and southeastward from Germany and the western provinces of Austria, there is a region of prevailing N. W. winds—it comprises Hungary, Transylvania, the Danubian principalities, and S. W. Russia. The following table gives the percentages of winds in this region:—

		Summer.								Winter.							
		N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 9—																	
Hungary, N. 343.	Buda. (Ofen) . . .	23	13	6	5	9	10	6	**29**	**28**	12	5	9	12	13	4	18
N. 346.	Debreczin	**45**	6	8	4	28	1	2	5	**42**	4	9	4	30	5	1	5
N. 347.	Hermannstadt, Transylvania.	12	8	2	21	0	6	8	**42**	9	7	3	22	6	11	6	**36**
S. W. Russia—																	
N. 351.	Kischinev	14	6	2	6	8	9	5	**50**	22	7	2	11	9	12	6	**32**
N. 352.	Dniestrovski Znak . .	**22**	12	11	20	13	7	2	13	**22**	16	16	13	7	8	7	11
N. 353.	Odessa . . .	**25**	5	7	10	**25**	5	10	13	**17**	14	10	9	15	10	13	12

The prevailing winds at both seasons are N. or N. W., and at Debreczin, Hermannstadt and Kischinev, they are very largely prevailing. The mean direction is as follows:—

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
Buda	N. 28° W.	.26	N. 23° W.	.32½	N. 24° W.	.23	N. 14° W.	.21
Hermannstadt	S. 87 W.	.15	N. 34 W.	.30	S. 21 E.	.15	N. 57 W.	.18
Kischinev	N. 61 W.	.25	N. 46 W.	.49½	N. 58 W.	.25	N. 42 W.	.32½
Odessa	S. 37 E.	.17½	N. 71 W,	.06	N. 65 E.	.09	N. 20 W.	.08

The motion of clouds observed at Hermannstadt gives in the summer a wind N. 56° W. mean direction, with a ratio of .39, and N. 59° W. in winter, ratio .39. So that the ratio is greater at both seasons than that of the lower current. At the first four stations, the prevalence of N. and N. W. winds is greater in summer than in winter. Besides in the summer the winds are more westerly, and more northerly in winter. The resultant for each month is as follows at Kischinev:—

	Mean direction.	Ratio of resultant.		Mean direction.	Ratio of resultant.		Mean direction.	Ratio of resultant.
January	N. 30° W.	.30	May	N. 76° W.	.24	September	N. 44° W.	.40
February	N. 58 W.	.33½	June	N. 50 W.	.43½	October	N. 79 W.	.21½
March	N. 61 W.	.29	July	N. 46 W.	.60	November	N. 66 W.	.17
April	N. 46 W.	.24	August	N. 41 W.	.45	December	N. 37 W.	.36

The months of March to May, October and November, have a much smaller amount of N. W. winds than the others. At Odessa and Hermannstadt where the prevalence of N. W. winds is generally less marked, the mean direction is not between N. and W. in spring and autumn. That it should be N. W. in summer in Odessa, though with a small ratio, is a proof of the strength of the N. W. current in these regions. (See Plates 5, 6, 9, and 14.). Odessa is so situated that it should have S. W. monsoon winds in summer, as the Black Sea lies southward, and the steppes around the city are highly heated at this season. Yet this monsoon is but slightly felt, while sea-winds are prevailing in the coast stations of the Crimea and on the shores of the Sea of Azof.

A glance at the map (Plates 5 and 6) will show that the region now considered has a great similarity of position with that of southern France. The relation to the N. W. part of the Mediterranean in the last-named region, and the N. W. part of the Black Sea in this, is the same. The result, prevailing N. and N. W. winds, is also similar.

I have already defined the position of the belt of high pressure which I called the great Axis of the continent, which reaches in winter from Southern Siberia to Central France, through a great part of the Asiatic-European Continent, and also influences to the Caspian, Black and Mediterranean Seas. (See Plate 14.) On these regions the temperature is much higher, and the pressure lower, than on the continents to the north. This gives prevailing easterly winds on the northern shores of the Caspian and Black Seas. Now the regions we are considering are in a

peculiar position towards the southern seas. They are separated from the Mediterranean and Adriatic by some high ranges of mountains. If we suppose a N. E. wind at Kischinev, directed towards the Adriatic, it would have first to pass across the Carpathian mountains, and then, besides others, over the high chains of Dalmatia and Bosnia, towards the Ægean Sea where there are also mountains—the Balkan chain, leaving but the narrow aperture of the Bosphorus, where a N. E. wind prevails during the year.[1] Hungary even, though situated to the S. W. of the Carpathian, has high mountains intervening between it and the Adriatic. Toward the Black Sea the air can arrive more easily along the Danube. There are also some low though narrow passes between Transylvania and Wallachia. Thus we have here a region of high pressure in winter, with a comparatively warm sea lying towards the E. and S. E. The movement of air in this direction is easy. The result is a prevalence of N. and N. W. winds, as shown by the map, Plate 6.

In the summer the pressure is low in the interior of the continent and very high in the western Atlantic, between 30° and 40° N. West winds are the result of this. It was shown that they prevail in Germany and Switzerland, and the further eastward the more this must be the case. Thus we have the air from the Atlantic flowing over the Mediterranean as a north wind towards the depression in Africa, and over the Carpathian region as N.W. towards the Asiatic depression. (See Plate 5.)

In autumn, especially in September and October, the conditions change. Central Asia is already much cooled, pressure has risen there, but in Africa and western Asia there is still a region of low pressure, somewhat to the south of where it was in summer. This causes a more rapid movement of air southward and southwestward, even near the Black Sea, and a greater prevalence of N. E. winds than at other seasons, as shown by the maps, Plates 7 and 9. Pressure is very high in autumn on the northern shore of the Black Sea, and from thence the N. E. winds begin. This is the season when conditions very like to those of the trade-wind region occur here. And it is also a very dry season, the precipitation diminishing very much from June to October. (See Plate 14.)

The cause of the smaller prevalence of the N. W. winds in spring may be found in the low pressure which then prevails in the Mediterranean, while it rises in the Arctic regions. In April especially there is less difference in pressure in the northern hemisphere than in any other month. Thus the winds have a less decided character, and local peculiarities are of comparatively greater influence.

The steppes of south Russia have prevailing easterly winds during about nine months in the year. Only in summer westerly winds take the lead. This region is very different from the rest of Europe in this respect, as well as from the greatest part of the temperate zone of America, where westerly winds are the most frequent.

It was Wesselowski[2] who brought this fact before the scientific world, and proved it so abundantly that no doubt could be entertained as to its correctness. The winds are easterly in this region in winter, spring and autumn, because pressure is higher to the north and in the interior of the continent. The prevalence of easterly winds ceases in summer (or, more accurately, from the middle of May to the middle of

[1] See remarks of Dr. Dwight, p. 369.

[2] In his work on the Climate of Russia.

August), on account of the barometrical depression in central Asia, to which the air is drawn from western Europe and the Atlantic Ocean. (See Plates 7 and 9.)

I give first the percentages and mean direction of the wind as obtained by Kämtz,[1] being the means of 18 stations situated between the Black Sea and 53° N. L.

PERCENTAGES OF WINDS IN THE STEPPES OF SOUTHERN RUSSIA.

	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	Mean direction.	Ratio of resultant.
January	9.4	13.3	21.1	15.0	8.7	10.0	11.4	11.1	N. 89° E.	.15
February	8.3	11.4	19.3	14.4	12.2	11.4	12.2	10.8	S. 56 E.	.11½
March	8.1	11.6	19.6	15.1	11.5	12.7	11.6	9.8	S. 54 E.	.13½
April	8.4	10.6	20.5	16.4	10.8	9.5	13.5	10.3	S. 72 E.	.12½
May	9.2	10.3	17.5	12.3	12.4	11.4	14.6	12.3	S. 29 E.	.04½
June	10.3	9.3	13.3	9.6	10.8	11.7	19.7	15.3	N. 81 W.	.12½
July	10.8	10.1	14.0	10.0	9.5	11.0	19.9	14.7	N. 68 W.	.10½
August	12.4	12.1	19.8	11.5	9.2	9.6	12.7	12.7	N. 54 E.	.10
September	12.0	12.8	19.1	13.7	7.5	9.6	13.3	12.0	N. 59 E.	.11
October	8.9	9.4	19.0	14.2	12.0	11.1	13.9	11.5	S. 43 E.	.07
November	8.3	10.4	18.7	17.2	11.9	12.7	11.5	9.3	S. 46 E.	.15½
December	8.8	10.8	17.6	13.0	11.1	13.2	14.1	11.4	S. 30 E.	.06
Year	...	...	...	...	...	...	...	...	S. 67 E.	.06

The mean direction in June and July is nearly opposite that in December and January, and the prevailing winds are opposite, being W. instead of E. There is no month of the year when the prevailing wind comes from another direction than W. or E.

From November to April the continental influence is seen to prevail, in June and July westerly winds from the Atlantic Ocean, as shown on Plate 5, while August and September have a much larger proportion of northerly winds than the other months, so that the resultant is N. of E. The same is the case in October in the southern part of this region (45°–50° N.) I have already characterized these winds as directed towards Africa and Western Asia, and not towards Central Asia, as in summer.

The small ratio of resultant in all months shows that this is a border region. Especially the stations between 50°–53° N. have this character. The winds are shown in percentages in the next table.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 9. N. 356. Nikolaief	18	17	2	7	18	10	7	**21**	13	**24**	7	10	14	13	5	13
" 10. N. 382. Sevastopol	6	7	**31**	3	4	15	**30**	5	12	**22**	**24**	4	6	12	14	6
" 10. N. 384. Simferopol	1	3	23	20	4	12	**28**	9	17	15	**31**	17	6	6	10	8
" 9. N. 364(*a*). Lougan	11	13	18	6	7	9	**25**	10	6	14	**23**	8	8	12	21	5
" 9. N. 358. Ekaterinoslav	6	5	19	8	10	16	**28**	7	5	10	**20**	16	**21**	13	10	5
" 9. Poltava, Charkov and Woltschansk	6	11	14	9	5	14	**20**	**20**	4	12	**19**	12	7	15	16	15
" 9. N. 363. Taganrog	7	6	23	8	14	11	**24**	9	9	11	**41**	7	11	4	10	7
" 9. N. 366. Astrachan	5	19	10	**23**	6	13	9	15	4	**24**	21	17	3	7	8	16
" 8. N. 235. Samarskaja Ferma	8	17	13	6	8	13	10	**27**	12	13	**15**	11	12	**20**	6	12
" 8. N. 237–239. Orenburg	**20**	16	13	4	7	11	**17**	12	11	**18**	**20**	8	11	18	8	4
Northern Border of the Steppes—																
" 9. N. 356. E. Galicia	14	13	5	9	10	9	**27**	13	16	3	2	13	16	10	**20**	**20**
" 8. N. 231. Southern Central Russia	7	9	10	11	10	17	16	**20**	7	11	12	13	11	**16**	15	14
" 8. N. 233. Pensa	11	10	5	10	6	18	15	**22**	8	4	3	12	13	**27**	11	22
" 8. 325½. Samara	18	20	9	2	5	11	**32**	3	7	15	15	7	16	**27**	11	1

[1] Repertorium f. Meteorologie, v. ii. p. 293.

It is necessary to consider separately the different parts of Southern and Eastern Russia.

In the Crimea there are more easterly winds in summer than elsewhere. It must be remembered that this is a small peninsula, which can receive sea-winds from east and west. The high chain of mountains rising above the southern coast does not permit sea-winds from this direction to reach stations to the northward, as Sevastopol and Simferopol.[1]

The opposition of E. and W. winds is not only observed in the Crimea, but also in all that region of S. Russia between the Dnieper and the Don, and between the Black and Azof seas, and latitude 51° N. This is not the case in the steppes on the lower Volga and further east (Orenburg, Astrachan).

At Astrachan N. E. winds prevail in winter, and S. E. in summer. These last are monsoons from the Caspian Sea.

At Orenburg the prevailing winds are E. and N. E. in winter, and N. and W. in summer. The results of this station are especially valuable, the observations being made during twenty years and carefully discussed.[2] The mean direction in the different months is:—

Jan.	N. 85° E.	.19	May	N. 17° E.	.07½	Sept.	N. 12° W. .10
Feb.	S. 80° E.	.14½	June	N. 10° W.	.22½	Oct.	S. 71° W. .14
March	N 84° E.	.24½	July	N. 6° W.	.24	Nov.	S. 24° E. .03
April	N. 79° E.	.19½	Aug.	N. 29° W.	.19	Dec.	S. 34° E. .08½

Thus in the first four months the direction is nearly due E., the ratio moderately great in March; May to September have northerly winds, with a ratio in July equal to that of March, and S. S. E. in November and December. October stands by itself, having a mean direction from the W. S. W. The percentage of S. W. winds is 20.5, while it is but 18 in winter and 11 in summer. It seems that Orenburg is at this time to the north of the belt of high barometer then existing on the shores of the Black and Caspian seas. Lugan, Astrachan and other more southerly places have prevailing east winds, with little rain and a small amount of clouds. In the winter months Orenburg is then to the S. of the zone of highest pressure, as the winds are E. and N. E. (See Plates 5, 6 and 7.) The division-line runs between Orenburg and Samara, the last named place having prevailing S. W. winds in autumn and winter. The very northerly winds of summer are probably caused by the position of Orenburg just north of the dry and highly heated Kirghiz steppes. They are not found at other stations of Southern Russia nor in Central Asia, while northerly winds are more common in Western Siberia in the summer.

North of 53° in Russia the direction of the wind is about the same as prevails in Western and Central Europe, S. W. in winter, W. and N. W. in summer, as shown on Plate 9. The stations on the northern border of the steppes indicate this. The annexed table gives the percentages of the winds in Northern Russia:—

---

[1] For further details about the winds of the Crimea, see the elaborate memoir of W. Koeppen in the new Repertorium für Meteorol., vol. i.

[2] By A. Ovodof in the Memoirs of the Orenburg Section, Russian Geographical Society, v. i.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 7. N. 222. Gorki[1]	7	9	9	11	9	19	15	**22**	7	12	12	13	10	14	16	14
" 7. N. 101. Dorpat	12	11	9	8	8	16	**18**	**17**	6	7	8	12	11	**22**	**22**	10
" 7. N. 95. Mitau and Riga	**25**	6	7	9	11	10	18	15	12	6	10	19	**22**	11	15	5
" 7. N. 103. St. Petersburg[1]	6	18	10	10	9	18	**25**	4	4	10	10	18	17	**22**	16	4
" 6. Finland, coast stations[1]	**18**	8	13	8	12	13	15	12	11	8	15	16	**21**	12	11	6
" 6. Finland, inland stations[1]	14	8	8	8	**18**	14	16	13	10	7	9	15	**21**	17	11	10
" 6. Aland Islands[1]	**22**	5	2	8	16	21	4	**22**	8	10	3	11	9	**32**	9	17
" 6. N. 61(*a*). Kem, White Sea	12	16	**18**	10	14	11	13	4	12	8	3	7	**21**	**22**	15	12
" 6. N. 63. Archangel,[1] White Sea	**19**	13	14	14	8	9	8	15	6	5	11	18	13	20	21	6
" 7. Gov. Vologda[1]	11	12	10	10	10	**18**	16	14	7	6	6	13	15	**26**	13	13
" 7. N. 107, 111. Moscow and Vladimir[1]	15	8	7	9	11	15	**20**	14	13	6	8	11	17	14	**20**	12
" 7. N. 124. N. E. Russia	4	12	12	14	8	**22**	11	17	4	6	4	11	13	**32**	15	14

At inland stations between 54° and 58° N. (Gorki, Dorpat, Moscow, Vladimir) the direction is very like that which prevails in Germany and further west, that is, a decided prevalence of W. winds, more S. W. in winter, more W. and N. W. in summer. Further north, and aside from the influence of the sea (inner Finland, Government of Vologda, N. E. Russia) the winds are S. W. or S. even in summer. Thus we have the same conditions that prevail in northern Sweden.

At Riga and Mitau there are summer monsoon winds from the N., at the coast stations of Finland they are N. and W., at St. Petersburg W., at Kem on the western shore of the White Sea they are E., while Archangel again has N. winds in summer.

The existence of monsoon winds in so high a latitude is a remarkable fact. Kämtz was the first to show that the winds at Archangel had a monsoon character.[2] The mean direction at this place is:—

Summer, N. 18° E. .16: Winter, S. 25° W. .30.

While at Kem it is:

Summer, N. 87° E. .24: Winter, S. 87° W. .25½.

(See also Plate 9.)

A common trait in nearly all the stations of northern and central Russia is the frequence of S. E. winds in winter. In this the influence of the high pressure in the interior of the continent is seen.

NORTHERN AND CENTRAL ASIA.

The belt of westerly winds extends far into Siberia. Here, as in European Russia, we have a belt of high pressure in winter. North of 53° N. the winds are S. and W. in winter, between 50°–53° N. there is a zone of undecided winds, while S. of 50° N. they are easterly, and N. E. already on the lower Syr-Daria. The further we advance to the S. in this direction the greater is the prevalence of E. and N. E. winds in winter, as well as in spring and autumn. This is well

[1] Calculated by Wesselowski, in his work on the Climate of Russia.

[2] Bulletin Phys. Mat. de l'Acad. de St. Petersburg, vol. v. p. 301.

shown on Plate 7. This is a current of air from the belt of high pressure in S. Siberia towards the Caspian and Black Seas, as well as towards other regions further south, the Persian Gulf for example. Though largely prevailing, these E. and N. E. winds have not the constancy of the trades, as is proved by the rains which fall in central Asia. This may be better called a polar current, as a low temperature is brought by it into southern regions. The summer has prevailing N., N. W., and W. winds in Central Asia, this being the current of air setting towards the heated deserts of these regions with their rarefied air. (See Plate 5.)

North of the division belt from 50° to 53° the air flows towards the Arctic Ocean with its diminished pressure, in spring, autumn and winter. We know now that these winds are still prevailing in the valley of the Jenisei. (See Plates 5 and 6.)

I give below the percentages of the winds in Western Siberia and Central Asia.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 7. Eastern Ural[1]	13	14	7	11	7	14	13	**20**	5	5	1	10	10	24	**27**	17
" 7. N. 130. Kourgan	**17**	11	12	10	12	9	14	13	12	8	9	10	**20**	15	16	9
" 7. N. 131. Tobolsk	14	8	7	15	14	14	10	**21**	4	4	5	**35**	20	11	10	12
" 7. N. 132. Ichim	15	21	8	11	13	17	3	12	7	3	3	5	19	**49**	5	7
" 8. N. 240(*a*). Omsk	15	11	15	15	13	9	12	12	4	13	6	9	10	**24**	17	19
" 8. N. 242. Barnaul	6	**21**	2	16	6	**27**	7	15	8	13	1	5	15	**44**	9	8
" 7. N. 135(*b*). Krasnojar	15	16	3	6	5	22	8	**25**	4	6	2	2	2	**66**	14	5
" 7. N. 135(*a*). Jenisseïsk[2]	8	4	15	8	9	14	17	**26**	1	1	17	**33**	20	16	10	1
" 8. N. 241. Semipalatinsk	7	5	14	8	12	10	**30**	13	1	2	**30**	17	18	11	15	6
" 9. N. 373. Valley of the Syr-Daria	18	15	11	4	4	4	**26**	17	13	**19**	15	15	10	8	10	9
" 10. N. 398(*a*). Taschkent	15	8	7	16	4	13	12	**25**	15	**29**	6	8	7	9	4	22
" 10. N. 397(*a*). Krasnovodsk (E. shore of Caspian)	22	15	16	5	5	9	4	**24**	9	**48**	15	2	0.3	2	4	19

In all stations except the last four, the westerly and southerly current prevails in winter. This is a movement to supply the deficiency existing to the northward, on the Arctic Ocean. Yet it will be seen that the same wind is not the most numerous at all stations. We have S. E., S., S. W., and W. This seems to depend much on local position. Calms are very frequent in the interior parts of the continent, especially in cold winter weather. The winds are generally weak. Thus local influences are very conspicuous.

It seems that the direction of the valley has a great influence, the most frequent wind coming from the upper valley in winter; so, for example in Tobolsk the river coming from the S. E., the prevailing winds are from this direction. At Ichim, Barnaul and Krasnojarsk the rivers come from the S. W., and, as the local influence coincides here with the general conditions, the S. W. winds have an anomalous prevalence.

The only exception is at Omsk, where the rivers come from E. and S. E., and yet the S. W. wind is prevailing. This is probably due to the level position of this city.

---

[1] Mean of Catharinenburg Nijnii-Taguilsk and Bogoslowsk.

[2] The percentage for the winter is taken from older observations, published by Krivoschapkin in his work "Jenisseïski Okrug."

A moderate prevalence of S. W. winds extending also to S. E., S., and W seems to be the real state of the case when local influences are eliminated. (See Plate 7.)

Until within a few years we knew next to nothing in regard to the winds in the basin of the Jenisei. Middendorff had expressed the opinion that the S. W. winds of Europe extended to the lower Jenisei, but there were not facts enough to sustain his opinion. The observations at Krasnojarsk showed that this was the case on the middle part of the river, while Jenisseisk, situated more to the N., has prevailing S. E. winds. This is caused by a change in the direction of the Jenissei from the mouth of the Angara; it flows from S. E., and, as at other points, the winds from the upper part of the river are prevailing.

It will be seen that the winds of the summer are very different from those of winter. The flow of air towards the depression of central Asia is the principal feature at this season. In Siberia we have the influence of the Arctic Ocean, which is principally felt. It is especially the Kara Sea with the Obi Bay, extending further southward than other parts of the Polar Sea, which we must consider. It must be remembered that the steppes and deserts of central Asia are not separated by any barrier from the Arctic Ocean, in the meridian of western Siberia, so that the air of the Arctic flows freely towards those countries with their high temperature and low pressure. In comparing the table given here for western Siberia with that for European Russia, it will be seen that N., N. E., and N. W. winds are much more frequent in the same latitudes in Siberia. In this the influence of the Arctic Ocean is to be seen, although westerly winds from the Atlantic Ocean also extend there. Pressure is not steady on the Arctic Ocean, its fluctuations are great even in summer, and when a storm-centre passes over it, the air from the Atlantic Ocean and southern Europe will be drawn in to supply the deficiency, as a S. W., W. or N. W. wind.

In summer central Asia has the same winds as western Siberia, W. and N. W., while in winter the difference is great. This is clearly shown on Plates 5 and 6. Semipalatinsk, being situated in the division of zone 50°–53°, has a system of winds intermediate between western Siberia and central Asia, the E. being the most frequent in winter, but southerly winds also occur.

Further south, on the lower Syr-Daria, at Taschkent and at Krasnovodsk (on the eastern shore of the Caspian) N. E. winds largely prevail in winter. That this is also the case in other parts of central Asia, where no long-continued observations have been made, is the report of nearly all the scientific travellers who have visited this country.[1]

In the prevalence of easterly winds Central Asia resembles the steppes of Southern Russia, but there are two important differences. First, the winds are more northerly; second, they prevail to a much greater extent. In Central Asia the mean direction in winter is between N. and E., while in southern Russia it is between S. and E., Astrachan and Orenburg excepted, but these places are already on the border of central Asia. The reason of this difference of the two regions seems

[1] I refer, for example, to Khanikof, Basiner, Helmersen, Severtzof.

to be that in central Asia the belt of highest pressure lies clearly north, while it is N. E. from southern Russia, where it is also at a greater distance further and its influence less felt. (See Plate 14.)

It was also Wesselowski who proved the existence of a zone of N. E. winds in Central Asia, though the observations at the time when he published his work (1857) were very few.

Below are the percentages of winds for spring and autumn:—

	Spring.								Autumn.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Eastern Ural	9	10	5	12	10	**20**	18	17	7	7	2	8	8	23	**24**	20
Kourgan	15	9	11	9	15	13	16	11	17	8	10	11	13	11	16	13
Tobolsk	6	5	7	**22**	19	14	9	17	5	3	5	14	17	**24**	17	14
Omsk	6	1	7	17	20	18	**28**	3	9	5	2	8	14	27	**31**	4
Krasnojarsk	...	...	...	...	...	...	...	...	11	10	3	3	4	**43**	19	7
Jenisseïsk	...	...	...	...	...	...	...	...	3	3	13	11	15	10	**32**	12
Valley of the Syr-Daria	17	**24**	17	9	5	6	16	7	13	**28**	15	6	9	7	16	6
Taschkent	16	**29**	4	4	10	14	10	14	7	15	**32**	10	2	4	19	11
Krasnovodsk (E. shore of Caspian)	25	18	2	1	2	5	0	**47**								

The proportion of westerly winds is larger in autumn than in winter, except in Krasnojarsk, where the great frequency of S. W. winds in winter has a local cause. Westerly winds are the most frequent at Jenisseïsk and Tobolsk, which is not the case in winter. The westerly winds in autumn are stronger than in winter, and local conditions not so important.

South of 50° easterly winds prevail largely. Pressure has risen in central Asia in autumn, and the region of high barometer is again found to the northward, yet not so much as in winter, as I have shown in the case of Orenburg. (See Plate 7.)

The Austro-Hungarian polar expedition has given us an insight into the winds of the region between 75°–80° lat. N., between Nova-Zembla and the newly discovered land of Francis Joseph. As the observations have not yet been reduced, I can but mention some remarks about the winds made by Capt. Weyprecht.[1] In the first winter, when they were drifted from near Cape Nassau to about 78½° L. N. and 73° Long. E., they had S. E. and S. W. winds, in the spring the number of N. E. increased. At this time they had drifted to the westward. In the second winter (October, 1873, to May, 1874), they were about 79¾° L. N., and 59° Long. E., not far from Francis Joseph Land, and had largely prevailing E. N. E. winds (more than 50 per cent. of all winds).

It seems that in the polar sea, north of western Siberia, as well as in that north of Europe (Bear Island and Spitzbergen), the polar winds are far from prevailing to such an extent as in the same latitude on the North American continent and the islands north of it.

The observations in northern Nova-Zembla[2] show also a considerable number of

[1] Petermann's Mittheilungen, year 1875, No. 2.

[2] By Capt. Tobiesen, calculated by Prof. H. Mohn, see Petermann's Mitth. 1874, No. 5.

southerly winds in winter. The following are the percentages in winter on the northern coast of Nova-Zembla.

	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
75° 55′ N., 59° 0′ E.	21	17	**20**	11	14	**21**	11	4

Here it seems that the winds blow from the land towards the partially open sea, with its low pressure and high temperature. By winds from the land I mean here local winds from the island itself, as also those from the cold Siberian continent.

We have seen before that prevailing westerly winds extend to the Jenisei. Farther north and east we have but very few observations. It seems that we have here the region of polar calms in winter. The number of calms increases towards the interior and N. E. of Siberia, till at last there can be said to be no prevailing wind. This is the region of highest pressure in winter, as shown on Plate 14, and of also the greatest cold. Here, unlike the American polar regions, the cold of winter is very permanent, and also high pressure. The cold is not brought by winds, but is generated on the spot by radiation.

I give below the percentages of winds as observed at some few stations.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Korennoje Filipovskoje	6	20	**27**	4	2	10	22	8								
Ustjansk	22	14	**40**	6	0	6	6	5	1	0	11	13	**36**	9	22	6
Nijnikolymsk	...	...	...	...	...	...	...	...	6	2	5	**29**	13	7	**25**	12
Yacoutsk	18	7	**20**	8	**20**	4	17	8	**59**	6	3	2	13	2	8	7
Mines of Nertchinsk	6	**15**	11	10	7	12	13	**25**	8	7	5	0.5	0.7	10	23	**48**
	Spring.								**Autumn.**							
Korennoje Filipovskoje	...	...	...	...	...	...	...	...	7	10	21	8	9	14	**26**	4
Yacoutsk	**31**	6	7	4	19	3	17	11	**39**	5	9	**4**	14	4	16	9
Mines of Nertchinsk	5	14	9	3	2	11	18	**36**	5	8	6	4	4	10	17	**46**

In the first three places, situated in the vicinity of the Arctic Ocean, there is a decided prevalence of monsoon winds—from the land in winter, from the sea in summer. The mean direction at Nijnikolymsk[1] is in—

Summer, N. 58° E. .48: Winter, S. 16° W. .48: Year, S. 11° E. .25.

The direction of the winds in autumn and spring is probably nearest to that of winter, as may be expected from so high a latitude, where the land is colder than the sea a great part of the year. Thus the mean yearly direction is nearly S. The direction of winds on the northern coast of Siberia is about the same as on the shores of the White Sea (Archangel and Kem).

It is difficult to determine the reason of the frequent N. winds at Yacoutsk, if the air flows towards the Pacific Ocean and is deflected from its true course by the direction of the valley. At any rate, calms are the prevailing feature in win-

[1] The detailed calculations on the winds at this place were published by Spassky in his "Sibirski Vjestnik," year 1823. I have used here only the figures given by Wesselowski, p. 231, as I could not obtain the original.

ter. In the summer, winds from N., E., S., and W. are about equally frequent. It seems that in September and October, when westerly winds are so prevailing in Western Siberia, warm and moist currents of air from the Atlantic can extend to Yacoutsk. At least westerly winds reach the maximum of their frequency in October (20 per cent.). In this month the flow of air towards Central Asia has ceased, while pressure has not risen high enough at Yacoutsk to prevent westerly winds from the Atlantic. October is also the cloudiest month of the year, the amount of clouds being 6.9, while March has only 2.6. The number of rainy days then is also the greatest in the year.

At the mines of Nertschinsk calms are more prevalent than at any other station we know of. In the winter months 65 to 70 observations out of 100 show no movements of the air, and the recorded winds are generally weak. In spring and summer there are less calms and more strong winds. The basin of the Upper Amoor is thus shown to belong yet to the region of Siberian calms (in winter).

While this is the case in the lowlands and valleys, it seems that the conditions are different in higher regions of the atmosphere. At Mount Alibert, 200 miles west of Irkutsk, and over 7000 feet high, a very constant and strong W. N. W. wind is observed. This place was inhabited some years on account of rich mines of graphite, and it was necessary to erect a wall to protect the inmates from the violence of this wind. The mean temperature was found to be much higher in winter than in the same latitude in lower levels. This wind is probably the upper current flowing towards the Siberian pole of highest pressure. It has been supposed that such upper currents flowed towards all regions of high pressure, but this has been proved only for the polar limits of the trades.

MONSOON REGION OF EASTERN ASIA.

Southeastward from the coldest space of Siberia, towards the Pacific Ocean, we have the region of Asiatic monsoons. I have already explained the cause of the movement of air in this region, and it is only necessary to show how far it extends and how small our knowledge of the northern part of the monsoon region was until the last year. The percentages of the winds in winter and summer are given in the annexed table:—

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 8. N. 246. Nikolaievsk, on the Amoor	5	11	**44**	15	1	2	11	11	9	4	2	0	0	4	**54**	27
" 10. N. 400(*a*). Possiet Bay	0.4	14	8	**43**	5	19	2	8	1	6	1	8	1	6	4	**73**
" 10. N. 400(*b*). Olga Bay	...	...	...	...	...	...	...	...	9	0.1	2	0.6	3	9	**53**	23
N. 401. Hakodade, N. Japan	2	0	11	**39**	11	15	15	6	7	1	5	6	2	1	33	**45**
Zone 11. Yokohama } Japan	5	21	0	3	4	**62**	0	4	**73**	4	0	0	8	4	9	2
" 12. N. 192. Nangasaki } Japan	15	0.5	5	9	**42**	15	6	7	**51**	11	3	3	3	4	5	21
" 10. New Chwang, Mantchooria	8	15	6	**23**	**22**	18	8	1	**28**	24	5	14	9	8	2	9
China—																
Zone 11. N. 227. Pekin	12	12	7	15	**29**	15	2	9	13	8	2	5	11	14	4	**42**
" 11. N. 228. Chefoo	8	5	17	**22**	**22**	8	8	10	25	3	1	3	13	3	13	**39**
" 12. N. 189. Shanghai	6	10	11	**33**	26	7	2	6	**26**	16	9	9	4	4	6	**26**
" 13. Pacific Ocean, 135°–145° E.	6	9	**23**	12	14	**21**	10	4	17	14	13	1	8	4	16	**27**
" 14. N. 42(*a*). Victoria Peak, Hong Kong.	0	0	11	13	**41**	31	2	2	13	19	**60**	5	0	0	1	2
" 14. N. 44(*a*). Pacific Ocean, 120°–130° E.	1	15	17	13	19	**26**	8	2	15	**57**	17	7	1	1	0	1

The mass of air which is drawn towards the Asiatic continent in summer is so great that the ordinary conditions prevailing over extensive areas of the oceans must be disturbed, as shown on Plates 5 and 14. As there is also a great mass of air drawn towards India and Indo-China, we must here consider Eastern and Southern Asia together.

The summer monsoon of Asia is a deflection of air already in motion, that is of part of the S. E. trade of the Indian Ocean and part of the N. E. trade of the Pacific Ocean. It is easy to prove this for the Indian Ocean, as the observations there are numerous and well discussed. This is not the case for the Pacific Ocean. Yet seeing a region of high pressure about 30° N. to the E. of China, it is impossible to conceive how the air from above it should not be drawn towards the heated Asiatic continent with its low pressure. Probably at the beginning of the summer monsoon, only the air over the nearest parts of the ocean is drawn towards Asia, and the circle extends as long as the pressure continues to sink over the continent.

The direction of the winds in summer on the coast of E. Siberia, as well as in China and Japan, shows that they cannot have come from the southern hemisphere, as they otherwise would have a direction from the S. W. as in India, and not E., S. E., or S. It seems that the air from the Pacific supplies the northern part of this region, from about 25° to 60° N. In Southern China the prevailing winds are already S. W., so that this is probably air from the southern hemisphere. (See Plates 5 and 6.)

As in summer the Asiatic continent attracts the winds, so, on the contrary, in winter a continuous stream of cold dry air pours out from it towards the surrounding seas. It takes mostly two directions: towards the depression in the northern part of the Pacific as S. W., W., and N. W. winds, and towards the equatorial region as a N. E. On the coast of E. Siberia, in northern China and northern Japan the winds are mostly N. W., in southern Japan and middle China they are N., and near the tropics they have a direction from the N. E.

The climate of the whole monsoon region is characterized by a great regularity. This is not only the case in the tropics, but also in the temperate zone. The periodicity of the change of monsoons is the leading feature, taking place at more or less fixed periods, with slight changes from year to year. The N. monsoon of winter is the dry time of the year, the summer or S. monsoon the time of clouds and rain. So, for example, at Pekin the amount of clouds is 2.5 in January and 6.3 in July, at Ochotsk, Ajan and Nikolaievsk (Amoor) 2.5 in January and 5.0 in August (an entirely clear sky = 0, an entirely overcast = 10). At Pekin the quantity of rain in July is more than fifty times greater than in January.

As this distribution of rain and clouds is caused by the monsoon, which brings the dry, cold air of the continent in winter, and the vapor-laden air of the sea in summer, thus causing the above-mentioned periodicity, we have means of judging of the character of the climates of this region even without having observations of winds. For a great extent of country, in China and Mantchooria as well as in eastern Siberia, we have no long-continued observations, yet the general character of the climate is known. Thus we must include in the monsoon zone, besides the tropical countries of India and Indo-China, all of China and Japan, Corea,

Mantchooria, the Amoor provinces and the western coast of the sea of Ochotsk, till about 60° N. L. (See Plates 5, 6, 7.)

As this last extension of the monsoon zone is not generally accepted, it is necessary to give some further details. I have already stated that on the last-named coast the cloudiness is double in summer of that of winter. The E. winds of summer and the W. winds which set in September or October lasting all winter are so well known to the inhabitants that they sail in July and August from Kamtschatka to Ajan or Ochotsk and return in September or October, having in each passage favorable winds. The rains have also a marked monsoon character at Ajan, only they are somewhat delayed, the largest amount falling in August and September. This is due to the great masses of ice in the sea of Ochotsk, which disappear only in the end of summer. So long as the sea is colder than the land, precipitation can not be copious, which is the case until August and September when the sea is warmer than the land.

As to the upper Amoor, the small amount of snow falling in winter and the abundant rains of summer also tend to show that this region is under the influence of the monsoons.

I give below the percentage of the prevailing winds of the different months at Hakodade (42° N. L.) and Nikolaievsk (53° N. L.) to show with how much regularity the change takes place in these northern latitudes, which were till now considered as not belonging to the monsoon regions.

	Nikolaievsk.		Hakodade.	
	E., S. E.	W., N. W.	E., S. E., S.	W., N. W.
January	1	**83**	10	**80**
February	5	79	13	72
March	17	52	33	50
April	39	47	43	39
May	50	29	55	25
June	**62**	14	**64**	20
July	**60**	24	**64**	16
August	45	35	54	25
September	28	47	40	45
October	15	60	29	55
November	7	77	21	63
December	**7**	72	15	72

India and adjacent regions have been long known to the Europeans as the classical country of the monsoons, though as we have seen their course is not less regular in China and Japan. There is a reason why the mind is more impressed with their regularity in the Indian Seas; owing to the low latitude, there is scarcely any difference of temperature between winter and summer. The change of the season from wet to dry and vice versa is then the only conspicuous feature in the course of the year. In China and Japan the difference of temperature is greater between the two seasons, and these changes more attract the attention. The inhabitant of a temperate zone finds here the habitual difference between winter and summer, and thus considers this climate as resembling his own, different as it may be in the course of the winds and the period of rains. The atmospheric pressure of the monsoon region is illustrated on Plate 14, the winds on Plates 5, 6 and 7.

SUNDA AND PHILIPPINE ISLANDS.

In the seas south of Indo-China there is a double system of monsoons. The S. E. trade crosses the equator in our summer, and gradually is changed to a S. and S. W. wind, while during our winter the N. E. trade crosses into the southern hemisphere, by and by assuming a direction from N. W. This last movement is caused by the heating and rarefaction of the air over Australia.

The Sunda Islands, being situated near the equator, are under the influence of both monsoons. The one or the other of them can bring rain, and this depends much more on local causes than on the situation north or south of the equator. The direction of the wind in this Archipelago and the surrounding seas is not only governed by the flow of air towards Asia and Australia (the great monsoons), but also by the heating and rarefaction of the air on the islands themselves, especially on the largest, Borneo and Sumatra. Even on the island of Java, narrow as it is, there are great irregularities in the course of the monsoons caused by day and night winds, at least at some seasons.[1]

I give here the mean direction of the winds at Batavia, from the elaborate discussion of the observations made at this place by Dr. Bergsma, director of the Observatory.

	Mean direction.	Ratio of resultant.		Mean direction.	Ratio of resultant.		Mean direction.	Ratio of resultant.
January . . .	N. 87° W.	.64	May	N. 66° E.	.28	September . . .	N. 21° E.	.23
February . . .	N. 83 W.	.61	June	N. 60 E.	.36	October	N. 3 E.	.02
March	N. 27 W.	.14	July	N. 59 E.	.35	November . . .	S. 62 W.	.25
April	N. 85 E.	.11	August	N. 58 E.	.29	December . . .	S. 85 W.	.74

It will be seen that the west monsoon (in our winter) is much more regular than the east monsoon. Besides, in the last season, the mean direction of the wind is to the N. of E., while the S. E. trade should be expected.

This is probably due to sea and land winds, which blow more regularly and strongly, as this is a comparatively dry season.

I give next some percentages from this region, adding the Philippine Islands, where the extreme regularity of both monsoons is remarkable, while the Sunda Islands show more local deflections.

	June to August.								December to February.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 16. Santa Anna, Philippine Islands . .	0	0	0	1	9	**84**	4	2	8	**65**	14	**7**	0	0	0	6
" 18. Celebes Sea	3	6	7	10	**29**	**30**	10	4	**33**	21	6	4	4	6	8	17
" 19. Indian Ocean, 110°–115° E.	5	5	15	**38**	16	10	7	4	22	8	12	5	4	9	13	**26**
" 19. Amboma	2	16	**36**	34	2	3	3	3	16	16	6	**7**	3	12	18	**21**
" 19. Indian Ocean, 105°–110° E.	2	6	30	**39**	14	4	4	1	22	8	4	4	8	14	15	**25**
" 19. Southwestern Sumatra	3	19	**33**	9	7	12	10	7	4	12	18	4	3	13	**33**	14

[1] An excellent sketch of the winds of Java, by Lieut. Jansen, is published in Maury's "Physical Geography of the Sea."

MONSOON REGION OF SOUTHERN ASIA.

Further west, on the Indian Ocean, and the Bay of Bengal, the following table shows the passage of the S. E. trade into the S. W. monsoon. I have given the result of observations on the eastern part of the ocean between 90° and 100° in percentages.

	June to August.								December to February.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Indian Ocean and Bay of Bengal, bet. 90° & 100° E.																
" " " 5 –10 S.	2	8	20	**50**	11	6	2	2	3	4	11	17	10	18	**21**	16
" " " 0 –5 S.	7	8	6	14	17	**20**	14	14	6	4	3	8	11	19	**28**	21
" " " 0 –5 N.	2	1	1	4	18	**50**	18	6	17	**24**	10	4	4	11	13	17
" " " 5 –10 N.	0	2	0.4	4	24	**57**	12	0.8	16	**49**	15	7	3	3	0.7	7
(Port Blair, Andaman Islands) 10 –15 N.	1	0	0	1	7	**84**	4	2	10	**64**	13	7	0	0	0	6
Bay of Bengal 15 –20 N.	1	0	0	0	7	**80**	9	3	**34**	**33**	7	0.6	3	7	4	10

Between 5°–10° S. the S. E. trade prevails yet. From 0–5° S. these S. W. winds are already more frequent, which may be partly caused by the influence of Sumatra, although the S. and S. E. winds are also frequent. Between 0 and 10° N. the prevalence of S. W. is very large, but S. and W. are also well represented. North of 10° N. the S. W. winds prevail nearly to the exclusion of all others. In our winter the N. E. monsoon (or trade) largely prevails between 5° and 15° N. Between 0° and 5° N. the number of N. E. winds has decreased one-half, while N. and N. W. have increased in number, while from 0° to 10° S., west winds are the most numerous.

If we take a more westerly meridian, the result will be more clearly seen, as in the next table, and also on Plates 5 and 6.

	June to August.		December to February.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
Indian Ocean and Bay of Bengal 10°–15° S., 80°–85° E.	S. 52° E.	.85	S. 73½°E.	.38
" " " 5 –10 S., 80 –85 E.	S. 63 E.	.62	S. 58 W.	.16
" " " 0 –5 S., 75 –85 E.	S. 22 E.	.38	N. 56 W.	.24
" " " 0 –5 N., 80 –90 E.	S. 51 W.	.75	N. 30 E.	.43
" " " 5 –10 N., 80 –85 E.	S. 58 W.	.84	N. 45 E.	.59
" " " 10 –15 N., 85 –90 E.	S. 48 W.	.89	N. 50 E.	.66
" " " 15 –20 N., 85 –90 E.	S. 44 W.	.79	N. 34 E.	.53

Here we have from June to August the mean direction of the wind passing from S. 63° E. through S. 22° E. to S. 58° W., while farther north the mean direction becomes a little more southerly, probably owing to the influence of the continent. Still more regular is the passage of the N. E. trade into the N. W. monsoon of the southern hemisphere.

In the western part of the Indian Ocean, towards the coast of Africa, we have the following percentages:—

	June to August.								December to February.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Indian Ocean, 10°–15° S. 40°–45° E.	0.5	0	10	**44**	**43**	2	0.1	0.3	4	1	5	12	**26**	**27**	21	5
" 5 –10 S. 45 –50 E.	0	0.1	2	**57**	37	4	0.5	0.2	**18**	15	15	9	9	7	8	**19**
" 0 –5 S. 45 –55 E.	0.8	0.3	1	15	22	22	**33**	6	10	**41**	22	20	3	0.6	0.6	3
" 0 –5 N. 40 –50 E.	0	0	0	6	23	**62**	2	9	4	**55**	20	18	3	0	0	0
" 5 –10 N. 40 –60 E.	0.3	0.3	0	0.5	7	**76**	14	1	10	**77**	12	1	0	0	0	0
" 10 –15 N. 50 –60 E.	2	3	2	8	22	**60**	3	0.3	4	**38**	**37**	16	5	0	0	0

Here the S. E. trades prevail S. of 5° S.; between 0° and 5° S. there is a zone of variable winds, where S. E., S., S. W. and W. are most frequent, and north of the equator the S. W. monsoon is well established. From December to February the N. E. trades have an easterly direction between 10° and 15° N. They become more N. E. between 0° and 10° N., and between 5° and 10° S, N. W. winds are already prevailing.

Below the percentage of winds at some stations of India is given:—

	June to August.								December to January.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 14. N. 36. Calcutta	5	5	14	17	**36**	15	6	2	**37**	8	7	3	15	7	12	12
" 13. N. 86. N. Central India	4	9	21	**26**	8	8	13	11	7	7	8	11	6	9	**28**	**24**
" 13. N. 84. Bareilly, Central India	7	7	20	**38**	5	5	7	10	8	7	6	11	4	5	19	**41**
" 13. N. 80. Roorkee	2	7	7	**50**	5	6	8	15	2	5	6	17	3	13	13	**43**
N. W. India—																
Zone 12. N. 185(*a*). Moultan	8	11	3	6	17	**50**	0.7	4	**21**	**24**	3	10	4	15	2	**21**
" 12. N. 188(*b*). Lodianah and Dehra Doon	4	7	**18**	17	7	**19**	15	13	2	8	9	4	11	**24**	**22**	20
Zone 15. N. 35. Bombay, number of obs.	0.7	0.9	1	4	6	33	**47**	7	28	19	10	2	0.4	1	6	**43**
number of miles	0.3	0.4	0.8	4	7	36	**47**	5	25	15	7	1.5	0.3	0.7	6	**44**
" 16. N. 36. Madras	1	1	2	14	14	**33**	23	12	11	**45**	20	13	4	2	0.6	4
N. 34. Dodabetta, 8640ft., Neilgherries	9	3	2	1	0	2	17	**66**	11	20	**29**	**29**	9	1	0	1
" 17. N. 38. Colombo, Ceylon	0	0	0	1	3	**63**	32	1	18	58	4	6	2	4	2	6

There is less regularity in the winds of India, taken as a whole, than in Eastern Asia. Especially this is the case if we expect the summer monsoon to be everywhere S. W., and that of winter everywhere N. E. without regard to the position of the station towards the region of lowest pressure, and towards the ocean.[1]

At Calcutta the monsoons must be N. and S., as the region of lowest pressure lies to the N. W. of this place, somewhere in the Punjab, as seen on Plate 14. In the N. W. provinces of India the winds of summer are rather S. E., while N. W. and W. winds prevail in winter. The latter is a current of air from the interior of the peninsula towards the sea, and has much in common with the N. W. winds of Eastern Asia. Farther to the N. W. at Lodianah and Dehra-Doon, we are nearly out of the monsoon region. According to Blanford the winter winds begin on the plains of Northern India, where the pressure is high at that season. They flow towards the seas to the S. W. and S. E.

At Bombay there is a very slight change in the direction of the prevailing wind,

[1] M. Blanford has well discussed the monsoons of Bengal and the adjoining provinces, and their relation to pressure, in "Reports of the Meteorol. Reporter of the Govt. of Bengal."

it being N. N. W. in winter, and W. S. W. in summer. Yet Bombay is known to have very marked monsoon seasons, that is, scarcely any rain falls in winter, while it is profuse from June to September. At Madras the monsoons are from the same direction as on the seas in the same latitude, N. E. in winter, S. W. in summer. The relative position of land and sea has in this case a very small influence, otherwise we should have E. and S. E. winds in summer, W. and N. W. in winter. Madras is nearly due South of the lowest pressure in summer, and the difference is sufficiently great to give the prevalence and regularity of S. W. winds.

The winds at Dodabetta, a high station on the Neilgherries, S. W. of Madras, are peculiar; N. W. winds prevail in summer and S. E. in winter. This shows that the movement of air which is experienced near the sea-level does not extend very high. The mean direction in winter and summer is more than 90° different from that of Madras and other stations of India in low latitudes, and nearly the opposite of that of Calcutta, Central India and the Punjab, as shown by the following table:—

	Spring.		Summer.		Autumn.		Winter.	
	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.	Mean direction.	Ratio of resultant.
Colombo, Ceylon	S. 30° W.	.42	S. 58° W.	.88	S. 63° W.	.43	N. 37° W.	.59
Madras	S. 2 E.	.74	S. 54 W.	.85	N. 51 W.	.24	N. 47 E.	.68
Dodabetta	N 79 E.	.69	N. 47 W.	.81	N. 42 E.	.32	S. 86 E.	.62
Calcutta	S. 1 E.	.55	S. 13 E.	.49½	N. 4 E.	.12½	N. 21 W.	.31½
Bareilly	N. 51 W.	.33	S. 64 E.	.35	N. 11 W.	.12	N. 52 W.	.41
Roorkee	S. 87 W.	.11	S. 42 E.	.29	S. 9 W.	.06	N. 67 W.	.18
Sialkote, near Lahore	N. 86 W.	.22	S. 51 E.	.49	S. 80 W.	.47	N. 85 W.	.34
Bombay	N 58 W.	.62	S. 70 W.	.78	N. 25 W.	.37	N. 5 W.	.64

Thus, on a great part of the continent of India, the motion of air is towards the centre of lowest pressure in the Punjab, as also seen on Plates 5, 6, and 7, while at Dodabetta, 8640 feet high, it is from the Punjab. It seems thus, that the rarefaction of air does not extend to very high regions. In the winter, on the contrary, air moves from N. W. India towards the Bay of Bengal, and in the opposite direction at Dodabetta.

Blanford considers the winds at this high station as somewhat similar to the return-trade or westerly winds blowing over the trades on tropical seas.

At Roorkee the mean pressure in January is 29.15, in June 28.62, difference 0.53 inche, at Dodabetta it is 22.18 in January, 22.09 in June, difference 0.09 in.

It is also seen that the summer monsoon is shorter in the northern part of India, spring and autumn having the same direction of the wind as winter, only the ratio of resultant is smaller. At Calcutta and Madras the S. winds are already established early in spring, while at Colombo, Ceylon, still farther south, spring, summer, and autumn have the same direction of wind. (See Plate 7.)

The dominating winds seem also to be the strongest. So, for example, at Bombay, the greatest mean velocities were distributed as follows: in May S. S. E. 16.5 miles an hour, June S. S. E. 27.5 miles, July W. S. W. 21.4, August S. W. 17.0, December N. N. W. 13.9, January N. N. W. 14.1, and in February N. W. 14.6.

South of the tropic in India the pressure is so much lower on the land than on the sea, that the yearly direction is S. or S. W., with a ratio of resultant, increasing towards the south.

Calcutta S. 2° E. .16½. Madras S. 30° W. .18. Colombo S. 61° W. .29.

Farther to the west, at Bombay, the mean yearly direction is N. 45½° W. .42, thus showing a flow of air from the west, or a much higher pressure on the part of the Indian Ocean between India and North Africa, as also seen on Plates 3 and 14.

As will be shown hereafter, the prevailing winds are also W. and N. W., in Syria and Mesopotamia, especially in summer, but to a less degree in the mean of the year.

WESTERN ASIA.

In Western Asia, that is, in the part of the continent west of India and south of the Caucasus and Black Sea, numerous observations of the winds have not been made. Yet they are needed much more than, for example, in India and eastern Asia, because the latter countries have such a marked climatic type that a very few stations are enough to give us an idea of the whole. Not so western Asia, where there is no regularity and uniformity of climate, and where many local causes have influence on the wind at the few stations established there. The following table gives the PERCENTAGES of winds in this region:—

PERCENTAGES.

	Summer.								Winter.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 13. N. 214. Mosul	25	16	3	2	4	11	12	**26**	12	10	**20**	18	11	3	8	**18**
" 12. N. 183. Bagdad	0	0	0	0	21	27	**52**	0	**31**	0	7	18	3	0	**25**	16
" 12. N. 180. Beirut	8	0.8	0	0	2	27	**34**	27	14	2	0.1	2	12	**29**	**29**	10
" 12. N. 179. Jerusalem	10	3	2	2	2	4	18	**60**	6	15	16	4	5	**22**	17	16
" 13. N. 212. Aleppo	3	0	0.5	0	0	18	**43**	35	11	19	**20**	7	4	15	9	15
" 11. N. 221. Isl. of Ashur-Ade, near Astrabad, S. E. Caspian	11	1	3	1	3	14	**47**	20	14	18	**22**	12	4	9	14	6
" 11. N. 219. Lenkoran	2	15	9	**31**	15	18	5	5	12	18	2	5	4	20	17	**23**
" 11. N. 217. Aralikh	7	7	22	10	3	3	**33**	14	2	9	19	**23**	5	7	19	15
" 10. N. 392. Tiflis	14	3	8	18	10	3	6	**38**	17	4	9	9	5	2	11	**41**
" 10. N. 387(a) & 388. Redout-Kaleh & Poti	0.2	4	13	8	3	**32**	18	22	0.2	3	**59**	15	1	7	7	8
" 10. N. 386. Trebizonde	1.6	1.5	**46**	1.1	1.6	0.5	6	43	3	0	**33**	0	14	5	7	**39**
" 11. N. 213. Erzeroom	4	7	**47**	6	0	3	22	11	14	21	**27**	8	3	3	19	6
" 10. N. 379. Constantinople	0	**76**	0.5	0.5	0	22	0.5	0.3	3	**55**	2	0.3	0.8	37	1.7	0

The first five places have extremely prevailing west and northwest winds in summer—a flow of air towards the depression in Central Asia. At Beirut, Jerusalem and Aleppo, they may be said to be sea-winds, but this is certainly not the case at Mosul and Bagdad, as the Persian Gulf lies to the S. E. of them. Here the winds in the summer are directed from the land to the sea, as also during the same time at Madras. This movement is thus shown not to be local, caused by the difference of temperature between land and sea, but it is part of the general movement towards the depression in Central Asia and India. The meteorological effects of these winds in Syria and Mesopotamia are very different from those of the S. W.

monsoon in India—they bring dry and clear weather. This is easily explained by their origin and direction: in Mesopotamia they come over the land, in Syria from a colder part of the sea.

In all these stations there is a greater number of N., N. E., and E. winds in winter than in summer, Jerusalem alone excepted. In this the influence of the high pressure of the more northerly parts of Asia is clearly seen, and is also shown by Plate 14. Yet it seems that the higher pressure prevailing over northern Africa in that season, and generally about 30° N., has also an influence on the winds: the S. W. in Jerusalem and Beirut, and the W. at Bagdad have probably this origin. Generally the winds are not as constant in winter as they are in summer.

On the Caspian local monsoons prevail. Ashur-Ade, an island in the S. E. corner of the sea, has E. winds in winter and W. in summer. Lenkoran, on the western shore, has prevailing S. E. in summer and N. W. in winter.

At Aralikh at the foot of the Ararat, the prevailing winds are S. E. in winter, that is, from the interior of the continent, and W. in summer.

On the eastern shore of the Black Sea, we see again very strongly marked monsoon winds, from the land (E.) in winter, from the sea (S. W., W.) in summer. The winds here are nearly opposite to those of Lenkoran. It will be noticed that the monsoon character is more marked on the eastern shore of the Black Sea; the reason is, that here the local monsoons correspond to the general movement of the air over this part of Asia, while at Lenkoran they are nearly opposite to it. (See Plates 5 and 6.) The winds of Tiflis are too much influenced by the locality to show the general flow of air over the region.

Trebizonde has prevailing E. and N. W. winds in winter and summer. The country around is very mountainous, and nearly all winds come from one of these two directions. It is very difficult to reach a conclusion on the character of the winds when they are so much influenced by locality.[1]

It seems that the winds at Erzeroom are also much influenced by locality, as it is situated in a rugged mountainous country. It may be that at this elevation, above 6000 feet, the winds are not the same as in the lowlands. E. and N. E. are prevailing here the whole year. I must remark that at all continental stations of western Asia, north, east, and south of Erzeroom the winds are either W. or N. W. in summer (Tiflis, Aralikh, Ooroomiah, Mt. Seir, Bagdad, Mosul, Aleppo). (See Plate 5.) This is with the exception of Alexandropol, which is also a high station (4800 feet) on the plateau of Armenia. At Constantinople the local position is such as to allow scarcely any other wind than N. E. and S. W.; the N. E. are dominant. But it would be rash to conclude that this is the trade-wind. We have seen that to the N. W. of the Black Sea there is a region of prevailing N. W. winds. The country is so walled in by mountains, especially south of the Black Sea, in Asia Minor, that the air must escape through the narrow aperture of the Bosphorus; thence the N. E. winds at Constantinople.

Some meteorologists think that the "trades" are dominant in Western Asia, reaching as far as Constantinople. This idea is founded on the observations at Erze-

[1] See the remarks of the observer at Erzeroom, Rev. N. Benjamin, in the tables, p. 371.

room, Trebizonde and Constantinople, given by Prof. Coffin in his "Winds of the Northern Hemisphere." I have shown that so far as the summer is concerned, we cannot accept this conclusion. At Constantinople and Trebizonde the winds are too strongly influenced by locality, and Erzeroom is too high to warrant an application to the lower regions. Besides this, at other stations, better situated, the winds are westerly. As to the winter, and especially the autumn, I have no difficulty in admitting prevailing N. and E. winds in Trans-Caucasia and Asia Minor, but these are winds which have not the constancy of the trades. (See Plates 6, 7 and 14.)

I should say that the erroneous opinion in regard to the extension of the trades cannot be imputed to Prof. Coffin. The number of stations was so small when he wrote his book (1853), that he wisely refrained from a conclusion.[1]

NORTH AFRICA.

In Africa north of the equator the winds are as given in percentages in the following table:—

	June to August.								December to February.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Eastern Africa—																
Zone 12. Alexandria and Port Said	**34**	5	2	2	3	3	9	**42**	9	9	4	6	10	21	**23**	18
" 12. Cairo and Ismailia	**48**	16	9	1	2	0	1	24	21	16	2	1	5	2	18	**35**
" 13. N. 73(*a*). Suez	**43**	1	0	0	2	4	1	**49**	**33**	3	1	2	6	11	11	**33**
" 13. N. 72. W. Egypt (Oases)	**87**	2	1	0	0	0	9	0	**37**	5	5	2	1	6	**26**	18
" 13. N. 74. Upper Egypt	...	...	...	...	...	...	...	...	**52**	0	4	0	4	8	4	28
" 14. N. 29. N. W. Nubia	...	...	...	...	...	...	...	...	**94**	0	0	0	0	1	1	6
" 16. N. 25. Sennaar, Nubia	0	0	2	4	**71**	14	7	2	**92**	0	0.7	0	4	0	0	3
W. and Central Africa—																
" 12. N. 173. Tripoli	15	**26**	21	20	6	1	2	7								
" 13. N. 71(*a*). Murzonk	...	...	...	...	...	...	...	...	17	6	10	3	5	10	**28**	21
" 11. Northern Algeria[2]	18	20	7	3	5	8	8	**31**	8	11	4	11	4	16	14	**30**
" 16. N. 24(*b*). Goree, Cape Verde	13	12	1	3	6	15	**31**	19	24	**50**	23	1	0	0	0	1
" 16. Kouka, Bornoo	2	3	1	3	11	**55**	22	0	23	**50**	6	0	0	0	0	21
" 17. N. 33(*a*). Christiansborg, Guinea at 7 A. M.	1	0	0	0	0.4	24	19	**54**	6	3	0	0	0	1	0.4	**89**
The same at noon	0	0	0	0.3	0.5	**99**	0.3	0.1	0.4	1.5	1.2	4	1.1	**89**	.2	7.5

To express the general features of the climate of Africa north of the equator, it may be said that N. of 17° N. northerly winds prevail the whole year, especially in the south of this zone, and south of 17° N. the winds are north in the winter and south in the summer. (See Plates 5 and 14.)

The division-line of about 17° is the zone of lowest pressure in summer. From the north air is drawn towards it from the Mediterranean, producing a wind similar to the trade in its constancy and other features. From the S. air is drawn in from the equatorial parts of the Atlantic and Indian oceans, and, coming over a great extent of warm sea, it brings clouds and rain as in the case of the Asiatic monsoon.

[1] For example, p. 137 of the "Winds of the Northern Hemisphere."

[2] Mean of Algiers, Oran, Mostaganem, Setif, Oum-Theboul.

We have seen already that on the Atlantic the division-line between the N. E. trade and the S. W. monsoon of the African coast runs about 12° N., the trade losing its regularity even at 14° N. in July. On the continent this line runs more north. The country to the north, having the whole year N. winds, is rainless, or nearly so; it is the *Sahara* or *Great Desert;* south is the *Soudan*, the country of Agriculture, where vegetation is more and more luxuriant the more we advance southward. This is caused by the longer continuance of the rain They reach in the middle of the summer to about 17°, but in spring and autumn the division-line is more to the south, and south of this line there are southerly winds and rains.

The African traveller Rohlfs remarks that "in the beginning of July we traversed the Titümna or Great Steppe between 16° and 17° where a luxuriant vegetation is found. I noticed a remarkable change in the direction of the wind, instead of the N. E., E. and S. E. we had before, the S. W. was prevailing now. Later, when we came to the country with tropical rains (Kouka) the S. W. was still prevailing, though the rain-clouds came from the S. E."[1] The woodland (Mimosa trees) began at about 15½° N. on the route he traversed. Very similar are the conditions in Nubia. Irregular tropical rains fall as far north as 19° N., further there is a country of prairies or savannah (openings) and still further south the woodland begins. The observations at Sennaar show very well the character of the climate in S. Nubia: N. winds in winter, S. winds in summer, both largely prevailing. (See Plate 7.) The remarkable frequence of calms when the sun passes the zenith is also to be noticed. So, for example, at Schimmedru, 18° 57′ N., there were 37 per cent. of calms in April, 62 per cent. in May, and 47 per cent. in June. At Kouka, 12° 52′, N. Rohlfs observed 46 per cent. of calms in July, 66 per cent. in August, and 51 per cent. in September. The sun is at its zenith at Schimmedru in May and at Kouka in August.

Gorée exhibits the change of monsoon in Western Africa.

Further S., on the coast of Guinea, the winds are from the same direction the whole year; this is the region of the S. W. winds. The daily period is very well marked the whole year, the winds being N. W. in the night and morning, and S. W. in the middle of the day.

On the shores of the Mediterranean the direction of the wind is not the same as in the desert. Especially in Algeria, where the N. W. is most frequent winter and summer. (See Plates 5, 6, and 7.) At the coast stations of Egypt (Alexandria and Port Said) W. and S. W. prevail in winter, and N. and N. W. in summer. There is a belt of highest pressure in winter, and, besides this, there are winds from the land to the sea in the cold season. Farther south, N. W. and N. winds prevail the whole year, as at Cairo, Ismailia, Suez.

---

[1] See Petermann's Mittheilungen, Ergänzungsheft, N. 25.

SOUTH AFRICA.

The winds of South Africa are very little known, except in the British Colonies in the extreme south.

It has been said already that along the west coast of S. Africa there were S. W. winds, that is, from the cold marine current towards the land. On the E. coast of Africa easterly winds prevail, although from December to February they are rather N. E., as the southern hemisphere is much heated then, and the pressure is higher on the north.

The mean direction and amount in percentage are as follows:—

	June to August.		December to February.	
Mozambique Channel, 15°–20° S. . . .	S. 17° E.	.85	N. 31° E.	.28
Indian Ocean, 20°–25° S., 47°–50° E. . .	S. 84° E.	.71	N. 67° E.	.66
Port Louis, Mauritius	S. 61° E.	.66½	N. 83° E.	.47

	June to August.								December to February.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 22. N. 36. Madagascar	4	0	4	21	**52**	18	1	0	11	19	**27**	13	5	6	6	13
Port Louis, Mauritius . .	3	2	**31**	**48**	6	1	3	4	6	16	**36**	21	2	2	6	11
" 24. N. 38. Natal, S. E. Africa . .	10	7	**22**	19	9	9	9	17	5	7	29	**31**	10	6	3	9
" 24. N. 44. Grahamstown, Cape Colony .	1	4	2	4	3	24	18	**43**	3	8	10	**27**	13	**27**	5	6
Graff Reinet, Cape Colony .	**34**	2	2	8	15	7	4	**29**	7	2	1	7	**56**	19	7	**4**
" 25. N. 41. Cape Town, Cape Colony .	**31**	6	6	**32**	14	1	1	9	3	0.3	0.5	9	**67**	9	4	7

In Natal the general character of the winds is tropical, they are still E., but more regular in the summer season of the southern hemisphere (December to February).

In the Cape Colony the winds are regularly sub-tropical: polar (S.) from December to February, and equatorial (N., N. W.) from June to August. The regular yearly movement of the belt of highest pressure which forms the polar limit of the trades is seen here, in the extreme S. of Africa. In the warm season (December to February) it moves southward further towards the pole, so that the Cape Colony has then S. winds. In the winter (June to August) it recedes northward towards the equator. A reference to the map of isobars (Plate 14) will show that in July (midwinter) the pressure is very high in S. Africa, the isobar of 30.2 inches going from the Atlantic to the Indian Ocean, in latitude about 30°. In January, on the contrary, a pressure of 30 inches is found nowhere on the continent of S. Africa, nor on the Indian Ocean, but is restricted to the region of the cold marine current on the Atlantic.

INDIAN OCEAN.

I have given before some figures relating to the northern part of the Indian Ocean. Unfortunately we are far from knowing the winds of this ocean so well as those of the Atlantic. The limits of the trades especially are more uncertain. The position of the Indian Ocean is such, that only the S. E. trade is developed to its full extent, and in our summer, is attracted towards the heated continent of Asia, and, owing to the rotation of the earth, gradually becomes a S. W. wind. There is no equatorial belt of calms at that season, and a reference to the map of isobars, Plate 14, will show that pressure increases then from the polar limits of the S. E. trade, about 25° S. uninterruptedly to the continent of Asia. This is also the explanation of the S. W. Monsoon, which is only the deflected S. E. trade.

Even in our winter (December to February) the winds in the Indian Ocean are under the influence of continents. In the northern part the winds are N. W., that is the N. E. trade crosses the equator, and is drawn towards the heated continent of Australia. Nearer to Africa, the winds are N. E. at this season, also occasioned by a deflection of the trade-wind towards the tropical and sub-tropical part of Africa. Thus, on the whole, the Indian Ocean is more under the influence of the continents than the Atlantic. The following table gives the direction of the winds:—

	June to August.								December to February.							
	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 23. Indian Ocean, 47°– 50° E. . .	6	32	**38**	15	8	1	0	0.5	22	32	28	10	2	1	1	4
" 24. " " 110°–115° E. . .	9	4	**21**	16	12	14	12	10	0	0	1	**49**	44	4	1.5	0.5
" 25. " " 75°– 83° E. . .	11	2	6	6	9	21	**23**	21	10	8	10	13	11	**17**	14	**18**
" 25. " " 25°– 30° E. . .	19	9	3	3	8	**30**	17	11	9	**24**	10	9	15	**23**	8	2
" 26. " " 25°– 30° E. . .	15	8	3	5	9	19	**26**	15	10	10	8	7	13	**22**	21	9
" 26. " " 55°– 60° E. . .	16	4	3	8	13	19	**25**	14	10	5	3	9	11	19	**25**	18
" 26. " " 115°–120° E. . .	8	5	1	1	10	26	**28**	21	3	6	12	12	15	19	**24**	8
" 27. " " 115°–120° E. . .	16	4	0	5	15	**26**	18	17	9	4	2	2	7	20	34	21
" 27. " " 45°– 60° E. . .	20	10	1	1	10	14	22	**23**	13	6	1	3	12	19	20	**25**
" 28. N. 40. Desolation Island . .	16	2	0	1	0	16	32	**34**	5	0	2	0	7	21	**40**	15

There seems not to be a great difference between the limits of the N. E. trades in the eastern and western part of the Indian Ocean at all equal to that in the Atlantic. In Zone 25 (30° to 35° S.) we see a certain predominance of S. W. winds, which in the southern hemisphere correspond to the N. W. in the northern. In the North Atlantic Ocean there is a zone of prevailing northerly winds, rather N. W. than N. E. Thus in the Indian Ocean, especially near the coast of Africa (25° to 30° E.) we are already out of the S. E. trade, while S. and S. W. are yet prevailing. (See Plates 5, 6 and 7.)

Between 35° and 40° S. the westerly winds prevail very largely, and further south the number increases. Besides the large percentage of winds from this direction, they are also very strong, and in all respects prevail more extensively than in the corresponding latitudes of the northern hemisphere. It will be seen that the difference of pressure between north and south is here very great, the pressure being very low in the Antarctic regions, and high at the S. limit of the S. E.

trade. This produces the N. W. and west winds, while the great expanse of sea gives them additional strength. The only part of the northern hemisphere where the isobars are at all as close is the northern part of the Atlantic Ocean between 45° and 65° N. (See Plate 14.) Westerly winds prevail there, and are strong, but they cannot acquire full strength, as they have not so broad an expanse of ocean to blow over.

AUSTRALIA AND NEW ZEALAND.

The winds of Australia and New Zealand are largely modified by the influence of the continent. This is indicated by the following table:—

			June to August.								December to February.							
			N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 21.	N. 39.	Somerset, Cape York .	0	0	25	**66**	7	2	0	0	9	4	17	8	1	8	10	**43**
" 22.		Sween's Island . .	11	10	18	**34**	20	1	3	3	**35**	16	11	6	4	4	8	17
" 24.	N. 54.	Brisbane, Queensland .	2	13	3	10	23	**28**	15	5	10	**41**	9	14	9	6	5	5
" 25.	N. 71.	Sydney, New South Wales .	6	6	3	5	8	10	**36**	27	3	27	**29**	12	21	7	4	4
" 26.	N. 84.	Port Albert, Victoria .	**22**	9	6	9	12	14	10	17	9	3	11	**23**	19	15	10	10
" 26.	N. 78.	Melbourne, " .	**30**	24	4	4	6	8	13	10	10	10	7	15	**25**	16	10	6
" 26.	N. 77.	S. W. Victoria . .	**22**	9	6	9	12	14	10	**17**	9	3	11	**23**	19	15	10	10
" 25.	N. 69.	Adelaide, South Australia .	26	**37**	5	3	5	8	4	11	12	10	5	15	13	**26**	7	11
" 25.	N. 68.	Freemantle, West " .	3	**31**	12	9	8	12	8	17	0	10	17	15	12	**34**	9	4
" 27.	N. 66.	Hobarton, Tasmania .	20	5	3	7	7	10	8	**40**	16	7	6	**29**	8	9	7	19
	N. 68.	Kent's Group, " .	9	11	9	8	4	15	**31**	13	7	14	13	3	2	20	**36**	4
" 26.	N. 90.	Auckland, New Zealand .	4	15	10	13	13	**25**	9	11	11	21	4	6	12	**27**	10	9
" 27.		Hokitika, W. Coast of S. Island, New Zealand .	2	18	20	**24**	3	**25**	3	6	6	**25**	16	4	1	20	3	**23**
" 28.		Southland. E. coast of S. Island, New Zealand .	5	1	17	10	0	2	25	**39**	3	0	9	**29**	1	20	**30**	26

The monsoon character of the winds in Australia is very marked. Somerset, on the N. coast 10° L. S., has still the regular monsoons of the Sunda Islands. From November to February the N. E. monsoon of India and China is drawn towards the southern hemisphere as a N. W. monsoon, and brings with it clouds and rain. In the other months the S. E. trade prevails very strongly, while the N. W. wind is said to be generally weak.

Further, in Queensland we have W. and S. W. from June to August (continental winds) and N. E. and E. from December to February (sea winds). Thus the air is drawn *towards the continent in summer*, when Australia is heated, and in winter, on the contrary, the wind blows from the land towards the sea, as also shown by Plates 5 and 6.

The colonies of Victoria and South Australia being situated on the south coast of the continent, the land and sea winds have not the same direction here as on the eastern coast. They have N. and N. E. winds in the cold season, and S. E., S., and S. W. in the warm. West Australia has decidedly N. E. winds from June to August, and S. W. from December to February.

Tasmania is somewhat under the influence of Australia, but here the winds begin already to assume the normal maritime character, especially on the small islands of Kent's group, near Tasmania.

In New Zealand the influence of the land is far from being as important as in Australia, and westerly winds largely prevailing as on the sea in the same latitudes (36° to 47° S.). There is a difference between the east and the west coast of the south island, separated as they are by the high and steep chain of the New Zealand Alps.

PACIFIC OCEAN.

As in the case of the Indian Ocean, the materials for the study of the winds of the Pacific are the percentage of the winds, as collected by Prof. Coffin, selections from which are given in the following table:—

		June to August.								December to February.							
		N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.
Zone 10.	N. 403 and 404. Pacific Ocean, 120°–150° E.	3	**20**	19	11	19	12	12	4	**23**	2	12	0	7	12	16	**28**
" 14.	Pacific Ocean, 125°–140° W.	**46**	**49**	2	0.4	0.8	0	0	3	12	**51**	23	3	2	3	3	2
" 14.	" 120 –130 E.	0	15	17	13	18	**27**	8	2	15	**57**	17	8	1	1	0	1
" 14.	N. 2. Sandwich Islands	0.3	**47**	34	9	9	0.4	0.2	0.2	12	**26**	4	4	5	**22**	9	17
" 15.	China Sea, 106°–115° E.[1]	3	3	6	17	**37**	27	7	2	19	**55**	15	8	1	0	0	1
" 15.	Pacific Ocean, 135°–150° W.	8	**63**	22	4	0.7	0.8	0.8	1								
" 16.	" 105 –115 W.	19	8	5	5	7	**22**	17	17	9	**54**	28	4	3	1	0	0.5
" 17.	" 90 –100 W.	8	0.6	0	4	**45**	38	8	0	5	**52**	19	8	13	3	0	0
" 17.	" 120 –130 E.	4	8	6	9	**29**	24	7	13	8	**62**	22	5	0.5	0	0	3
" 18.	" 155 –165 W.	0	14	**43**	35	9	0	0	0	2	16	**41**	37	5	0	0	0
" 19.	" 175 –180 W.	5	24	**42**	22	4	0	3	0	**25**	**24**	13	16	3	2	6	12
" 19.	" 145 –160 W.	3	**25**	21	**33**	3	7	0	9	16	**68**	3	4	3	0	3	3
" 19.	" 120 –125 W.	0	4	**46**	44	6	0	0	0	0	0.3	26	**59**	15	0	0	0
" 20.	" 100 –105 W.	0	0	16	**70**	11	2	0.4	0	0	1	11	**84**	4	0	0	0
" 21.	" 150 –155 W.	0	**47**	32	20	0	0	0	0	11	**51**	30	3	0	0	1	3
" 21.	" 175 –180 E.	1	2	**45**	**43**	5	0	4	0	5	**22**	**20**	**20**	**11**	8	6	8
" 21.	" 105 –110 E.	4	7	**47**	30	8	2	0.3	0.3	4	1	5	12	**26**	**27**	21	5
" 22.	" 150 –155 W.	6	8	30	**39**	4	3	8	3	10	**35**	29	12	1	0.5	6	6
" 22.	N. 7. Society Islands	2	13	**27**	14	12	17	8	8	7	24	**31**	2	0	1	14	21
" 22.	Pacific Ocean, 85°–125° W.	1	5	24	**43**	14	1	3	3	3	5	34	**50**	6	0	0	1
" 23.	" 120 –150 W.	16	**28**	11	9	7	3	8	**19**	10	22	**38**	17	3	1	3	5
" 23.	N. 55. Port of France, New Caledonia	1	0	18	**54**	3	4	12	8	0	0.2	5	**79**	13	2	1	0
" 24.	Pacific Ocean, 165°–180° E.	8	14	17	13	13	14	16	4	4	11	**40**	18	6	6	9	4
" 24.	" 175 –180 W.	5	13	**24**	16	8	19	11	4	5	8	**29**	**35**	10	8	4	2
" 25.	" 85 –90 W.	13	13	8	14	5	15	12	**20**	2	5	16	**30**	12	11	15	10
" 25.	" 120 –150 W.	32	**34**	1	3	1	15	21	3	**22**	12	11	14	9	11	10	11
" 25.	" 175 –180 E.	6	14	**23**	15	6	**25**	3	7	4	12	**33**	19	11	7	12	3
" 26.	" 160 –180 E.	**17**	12	4	14	8	16	11	**18**	16	14	11	8	13	14	10	14
" 26.	" 120 –165 W.	**25**	8	7	13	7	13	10	16	11	10	16	13	7	13	17	12
" 26.	" 120 –125 E.	16	3	2	0	11	11	**28**	**30**	12	9	13	8	13	**20**	18	8
" 27.	" 140 –150 E.	11	7	4	7	16	16	**19**	**19**	11	8	8	5	8	13	**27**	19
" 28.	" 100 –120 W.	13	7	0	12	14	12	**34**	6	7	5	5	3	5	23	**35**	15
" 28.	" 85 –90 W.	11	5	4	7	**22**	**22**	15	14	10	2	2	1	6	19	**36**	23

What distinguishes the Pacific Ocean from the Atlantic is a less regular S. E. trade, which seems to be caused by the numerous islands of Polynesia. Many of them are high, volcanic, so as to intercept the wind for a certain distance. Another influence exerted by these islands is the local rains, which are produced by them, partly by condensation of the vapor brought by the trade; partly due to local calms and the ascending current. These condensations of vapor cause a lower pressure, and the movement of the surrounding air to supply the deficiency causes irregular winds.

[1] For the whole year.

Especially in the central and western part of the ocean (between 10°–20° S.), are these irregularities noted. It will be seen that in these parallels the S. E. trade is very regular in the Atlantic Ocean. (Plates 5 and 6.)

The inner boundaries of the S. E. and N. E. trade are given as follows by Kerhallet in his "Considerations Générales sur l'Ocean Pacifique."[1]

Months.	N. E. Trade.	S. E. Trade	Months.	N. E. Trade.	S. E. Trade.
January . . .	6° 30′ N.	5° N.	July	12° 5′ N.	5° 4′ N.
February . . .	4° 11′ N.	2° N.	August . . .	15° N.	2° 30′ N.
March	8° 15′ N.	5° 50′ N.	September . .	13° 56′ N.	8° 11′ N.
April	4° 45′ N.	2° N.	October . . .	12° 20′ N.	3° 32′ N.
May	7° 52′ N.	3° 36′ N.	November . .	———	———
June	9° 56′ N.	2° 30′ N.	December . .	5° 12′ N.	1° 56′ N.

These observations show that the belt of equatorial calms is always north of the equator. It seems that the figures given by Kerhallet are taken from observations in the eastern part of the ocean, near the American coast, where really the S. E. trade crosses the equator. The wide limits between the two trades in summer are caused by the prevalence of the S. W. monsoon on the coasts of Central and South America. (See Plates 5, 6 and 7.)

In other parts of the Pacific Ocean the equatorial calms seem to be nearer to the equator, and partly even south of it. According to the statements of numerous navigators the trades are also more easterly there, and often do not leave any calm-belt between them, so that a ship can sail from the one into the other trade without interruption, as was also stated for the western part of the Atlantic Ocean.

The northern limit of the N. E. trade is also in a comparatively low latitude in these parts, as shown, for example, by the observations at the Sandwich Islands. They seem to be already in the zone of variable winds in the winter, N. E. and S. W., the one being noticed about as frequently as the other. Rains are also frequent in this season, with S. W. winds, thus corroborating the testimony of the wind observations.

The system of winds along the western coast of America has been already discussed.

As to the middle latitudes of the southern hemisphere in the Pacific, the same may be said of them as of the same latitudes of the Atlantic, and Indian Oceans.

ANTARCTIC ZONE.

I give next some calculations from the extreme southern part of the Pacific and Antarctic Oceans, comprising the most southerly latitudes to which man has yet penetrated.

---

[1] See Pilot Chart of Atlantic, Pacific and Indian Ocean, edited by the British Admiralty. Unfortunately I could not obtain it in Washington, and thus have not the possibility of tracing the limits of the trades and monsoons according to the best source, as in the Atlantic.