THE INDIA DIRECTORY

For Guidance of Commanders of

STEAMERS AND SAILING VESSELS

COMPILED FROM LATEST BRITISH OFFICIAL PUBLICATIONS

PART THE FIRST

FROM ENGLAND TO

THE EAST INDIES

WITH INTERJACENT PORTS IN

AFRICA AND SOUTH AMERICA

ALSO BY THE MEDITERRANEAN AND SUEZ CANAL

ILLUSTRATED BY

CHARTS OF WINDS, CURRENTS, TIDES, PASSAGES
AND COMPASS VARIATION

Revised Edition, with Supplementary Chapter

BY

COMMANDER ALFRED DUNDAS TAYLOR, INDIAN NAVY
LATE SUPERINTENDENT OF MARINE SURVEYS TO THE GOVERNMENT OF INDIA

LONDON
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1891

TO THE

RIGHT HONOURABLE

THE SECRETARY OF STATE FOR INDIA IN COUNCIL,

THIS WORK

Is, with Permission, Respectfully Inscribed by

THE AUTHOR.

WATERLOO PLACE, S.W., *November*, 1873.

PREFACE TO REVISED EDITION.

In presenting an amended edition of Part I. of my *East India Directory*, let me explain that revision became necessary after that convulsion of nature in Sunda Strait in the year 1883, whereby the northern half of Krakatoa Island was blown into the air, several populous towns and villages along the Java and Sumatra shores were submerged by the tidal wave, and some useful lighthouses were thrown down. As this volume of the Directory only describes the Strait of Sunda as a gateway from the Indian Ocean into the Java and China Seas, the value of the work became much diminished, whilst other books (speedily revised by their authors) came prominently forward and took the wind out of our sails.

To remedy this imperfection, the twelve pages (from p. 632 to 643) have been re-written. And for the purpose of introducing much new information of importance to all navigators of the Indian Ocean, and in the interest of students in meteorological science, a Supplementary Chapter has been drawn up. This chapter, besides giving some results of half-a-century's meditation upon the winds of our globe, does not confine its remarks to Asia only, but introduces the reader to the Polar winds at the two solstitial periods, when the sun (lord of the winds) is in Cancer and in Capricorn alternately.

In the Preface to the first edition, I have commented most favourably upon the Wind and Current Charts brought out by the British Admiralty in 1883, after my book had been in print. Such portions of these charts as covered the Indian Ocean were reproduced by me as a convenient basis upon which the various passages for sailing vessels were sketched out upon the four Wind Charts, while those for steamers were shown upon the two Current Charts. With reference to the Wind Charts, it seems proper to call the attention of navigators to what is an arbitrary and utterly unfair chopping up of the year into four quarters, as follows:—January—March; April—June; July—September; October—December. Such a *quartering* presents a most fallacious view of the winds. Those of January in the Tropics (and indeed everywhere) differ much from March, while those of April come from nearly opposite quarters to those of June. The solstitial winds of December differ also greatly from those experienced in October. Then, again, half November would run better on all fours with December, January, and February, but March should be left out. April would represent the centre of a season embracing part of March and the early half of May. Likewise, if the winds of June, July, and August had been charted together, such a chart would indicate far better the general winds for those months. October, again, would represent the centre of another season, coupled with the fag end of September and a moiety of November. Having myself laid down the winds in this fashion, for not only the Indian Ocean and China Seas, but for all the world (and, moreover, taking them out of the excellent books published by the Admiralty), it has been a labour of love to place what I have gleaned before the nautical world—and not for their consideration only, but for the scientific public—in the Supplementary Chapter of this volume, as well as in Part II., wherever the subject embraces the China Sea and Asiatic Archipelago.

Primary belts of winds are thus introduced, not indeed as a novelty, because brief allusion to them had previously been made at p. 299, in the General Remarks upon the winds of India, as well as in the Introduction at p. xvi, concerning monsoons or periodical winds. My ambition is, if spared, and encouraged by public approval, to bring out an Atlas of the universal winds in their seasons, and therein to enlarge more fully upon the Northern and Southern Overflows, which I have merely sketched in outline in this new edition at Chapter XXI. That brief allusion—adopting the language of Arnold Guyot—to the *primary* belts of winds "should bring out in strong relief, even by venturing a dash of the pencil somewh[illegible] essential t[illegible] subject, in order to fix and deepen the [illegible]

PREFACE.

have no fear or hesitation in saying that the Admiralty have made a false start by improperly grouping the months together. What trouble might have been saved by at once charting the winds for each month separately; and this will have to be done sooner or later. Only the Admiralty, with the Meteorological Department of the Board of Trade, possess materials for a better system, with numerous young and intelligent naval officers as useful agents for carrying it out. It is too much to expect the public (whose servants they are) to wait patiently much longer for the compilation of more useful charts on a better chosen basis, even if wind charts be not produced for *every month* of the year.

Similarly, navigators and physical geographers have been led astray by the publication of a very pretty General Chart of the Currents for Atlantic, Pacific, and Indian Oceans. It is surely most unreasonable to expect identical currents in January and July. The attempt to group them thus together only tends to irreverently exhibit a Creator God as the author of confusion; in which character, neither a right-minded seaman, like Maury, nor a really earnest physical geographer, such as Arnold Guyot, could contemplate the God who made the worlds, the Omniscient One, who has been revealed to us in the Holy Scriptures.

These brief remarks upon the winds of the universe, the author hopes, may be—again to use the words of Arnold Guyot—"the forerunner of a more complete work, the materials of which, gradually collected during long years of study, and still daily accumulating, he hopes to arrange, and work out more at leisure," in an "essay towards a first approximation to charts of co-existing winds." It can only be called a first attempt, because we have made a false start, and must retrace our steps and begin again; and the result will only be a first approximation whereon many blanks exist; but hundreds of navigators may carry with them into every ocean this framework and scaffolding, and build thereon and therewith for the ultimate improvement of a structure which shall furnish the rising generation of mariners with graphic pictures of the winds in their seasons.

The class of useful men, who make provision for our merchant ships in stores of all kinds and navigating appliances, are known as *ship's husbands*. As an "old salt," with half a century's experience of what a vessel needs, I appeal to those of London, Liverpool, Cardiff, Glasgow, and other large ports, to patronise my *India Directory*, the child of my old age. As was said in my earlier Preface, "Such a book as this is necessarily a collation from the remarks of one or two centuries of sailor-pioneers." Individuals can only add thereto, each his mite, and all we can truly say is, in the words of our adorable Redeemer—"Other men laboured, and ye have entered into their labours."

A. DUNDAS TAYLOR.

LONDON, 30*th August*, 1891.

PREFACE TO FIRST EDITION.

HYDROGRAPHY is a progressive science and might take for her motto "Line upon line, line upon line; here a little, and there a little." One man's life-time suffices not to accumulate notes of his own experience; therefore such a book as this is necessarily a collation from the remarks of one or two centuries of sailor-pioneers. Those compilers, who cater now-a-days for the nautical public, must be up and doing to provide such food as may satisfy the great and increasing demand. The author's object therefore has been to make as complete an "India Directory" as the present knowledge of Indian Ocean navigation will permit.

The opening of the Suez Canal having completely revolutionised the Ocean traffic of the East Indies, it became necessary to make the First Section of this Book descriptive of the steamer highway through the Mediterranean and Red Seas. This section is brief, but Horsburgh's very useful plan of giving the latitudes and longitudes of places with the description of lights and other landmarks in their geographical sequence, that the mariner may find at a glance all the useful information he needs on his outward bound voyage, has been maintained. Having furnished this missing link to the navigation of our Ocean highway towards the East Indies, the author has made provision for sailing vessels as well as Steamers going out by the Cape of Good Hope Route, being persuaded that sailing vessels are not about to be entirely superseded by steamers in these days of dear coal; persuaded also that an accurate knowledge of Indian monsoons will enable sailing ships to compete successfully on many lines of highway with all but full-powered steamers.

Some description of the entire contour of Africa is given in the Second Section for the first time; that of the East Coast from the Cape of Good Hope to Suez is the most elaborate, but we have yet much to learn of the coast between Natal and Guardafui. For that end we must look to the intelligent officers of the mercantile marine who may commence those trade operations along that coast which are soon likely to follow the abolition of the infamous slave trade. The description of the coasts of Arabia, Persia, and British India, is gleaned from the writings of Captains Haines, Albany, Grieve, and Constable, I.N., of Commanders Ward and Heathcote, I.N., and from the author's own West Coast of Hindostan Pilot.

The projection of the Iceberg Chart is novel in a book of this kind, but it shows so much better than Mercator's projection what is the space of sea available for ship traffic to the South of the Cape and Australia.

The author has endeavoured to show the best tracks for steamers in opposite monsoons on two separate charts, which also define the prevailing ocean currents. These charts and the various remarks on "Passages" throughout the book (giving the author's personal experience and that gathered from analysis of many ships' logs) should tend to shorten steamer voyages considerably, or at any rate to give navigators greater confidence in adopting any particular route. We hope to see one or more coaling stations established in the central portion of the Indian Ocean, and then the breaking down of a steamer will be a less disastrous affair than hitherto.

Four other charts exhibit the probably best tracks for sailing vessels throughout the Indian Ocean during four different periods of the year. These will supply a desideratum to mariners. In the construction of these wind and passage charts the author has had the most opportune aid of the excellent wind and current Atlas, recently published by the Admiralty. The tracks which have been delineated are what may be called "studding-sail tracks," that is to say allowing generally for the wind being *abeam*, or *abaft the beam*. Consideration of the vexatious delays endured by ships—in crossing certain portions of the Indian Ocean—has led to a new system advocated in this book, which may be explained as follows:—Different belts of wind have ... according as the sun is north or south of the Equator. For instance, after roundi[ng] onsoon. It is obvious then that if she fall to *leeward* in one belt of wind, she will be all the to *windward* as she enters the adjoining belt. Again:—at the opposite season of the year, S.E. Trade blows nearly up to the Equator, and ample *Westing* must be made, whilst in the ade-wind region, to enable her to fetch the desired goal.

It will be observed that no attempt is made to retain on the passage charts those names by ich the tracks adopted by former navigators were known to the world. They were not the result of perience, but merely tentative tracks; nor were our ancestors acquainted with the (now well-fined) belts of wind which are exhibited on these Wind and Passage Charts.

He assumes a great responsibility who would perform the functions of "Indian Ocean Pilot," and nobody should undertake such a task without considerable personal experience of Eastern seas. An uninterrupted service (during which he was accumulating "Notes"), of 19 years in those seas, entitles the author of this "India Directory" to a hearing from his brother mariners, and in the patience of hope he looks forward to receiving many fresh hints from them—as the ramifications of our ocean highways become better known—which may enable him to improve future editions of his book. Warnings (based on the experience of former navigators), of those localities where exceptionally bad weather may be found, should have the beneficial effect of shortening passages and rendering Oceanic navigation less perilous than heretofore. A so-called *scientific* nomenclature has stepped in and altered thousands of well-known names upon Admiralty Charts, to the utter bewilderment of the poor seaman. Many years must elapse before existing "Directories" can be so altered as to correspond with the latest charts. Fortunately, the author has been able to give in the "Index" (in brackets) these new-fangled names.

With gratitude the Author puts on record the names of those who have helped him in his labours. Firstly he would mention the late Mr. Richard Green, who (twelve years ago) kindly permitted access to all the valuable logs of his Blackwall Liners, the *personnel* and *materiel* of which are well known to have been second to none of their kind. To the officers of the Hydrographic Department of the Admiralty, especially to Captains Davis and Hoskyn (the latter recently deceased) and to Staff-Commander Hull, the present Superintendent of Charts, he is indebted for ready help at all times in affording him access to the latest issues of Admiralty Charts and Sailing Directions. The general public is little aware of the patient, peaceful labours of these intelligent gentlemen who belong to the navigating class of the Royal Navy. The author's earnest hope is that still further advantage may ere long be taken of the world-wide experience of officers of their stamp, by employing double the present number in the Hydrographic Department of the British Navy.

At the India Office there is no Marine Department; but the author is much indebted to Mr. Clements Markham, C.B., and to Mr. Trelawny Saunders, the Geographer, for access to all existing documents saved from the hands of the destroyer, when the poor old Indian Navy fell a victim to imaginary political and financial necessities.

He is also much indebted to Lieut. C. R. Low, late of the Indian Navy, for completing and bringing through the press the "Index" to this "India Directory"; and to Mr. W. Parkes, the eminent harbour-engineer, for observations on Tides.

A. DUNDAS TAYLOR,
Commander, late Indian Navy.

February, 1874.

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INTRODUCTION.

WINDS AND CURRENTS, MAGNETISM, VARIATION OF COMPASS, TIDES.

Particular, or Local Winds, Weather, and Currents, are described in the different parts of this work, to which the reader is referred. Winds may be arranged under three distinct heads *Constant, Periodical*, and *Variable.* Constant winds are those which blow always in the same direction, and are called Trade Winds. Periodical Winds, or those which blow one part of the year in one direction and the other part in a contrary one, are generally called Monsoons. Variable Winds are those which are not subject to any determinate periods or uniformity.

TRADE WINDS seem to be occasioned by the rotatory motion of the earth on its axis, combined with the influence of the sun in rarefying the atmosphere between the tropics. The cold dense air at the poles would naturally move along the surface of the globe to take the place of the hot rarefied air at the Equator; but the earth's rotatory motion, and the gradually increasing velocity of this motion at its surface from the poles to the Equator, oblige these polar currents of air to diverge from their meridians on their route to the Equator. The points of greatest rarefaction are those in the *Thermal Girdle*, or *Heat Belt,* under the sun; and, as the earth revolves, these places pass under the sun from E. to the W.; thus the denser air must move towards them, and occasion a constant Easterly wind in the ocean remote from land between the tropics.

As the earth revolves on its axis, each point on its surface has a rotatory E. velocity proportional to the radius of its circle of latitude. A wind from N. in the N. tropic, becomes a N.E. wind, and a S. wind, in the S. tropic, becomes a S.E. wind. The earth is also continually acting on the air by *friction*, and communicating to it a rotatory velocity, which counteracts the Westerly tendency, or (in other words) deprives the wind of its Easting as it nears the Equator; but as the wind (say the S.E. Trade) passes the Line towards the N. Solstice, or Heat Belt,—that is to say, goes from a place of greatest velocity to one of a less—it becomes a S. by W. wind, owing to this friction.

By the dense air proceeding from both polar regions in a N. and S. direction towards Cancer and Capricorn, and afterwards more Westerly towards the points of greatest rarefaction, a N.E. wind is produced on the N. side, and a S.E. wind on the S. side of the Equator. These are called trade winds, and in their direction incline towards the Thermal Girdle. When the sun is near the Tropic of Cancer, or returning from it (after *tarrying* there, almost vertical for two months), having greatly heated the N. hemisphere, the S.E. trade wind blows with strength, and its N. limit reaches to, and in some places nearly 10° beyond, the Equator. The N.E. trade wind, at the same time, blows with less strength, becoming contracted in its limits; the S limit then receding several degrees to the N. of the Equator; and between the two, we find in the open ocean a broad belt of light airs and calms. And again, in the opposite season, when the S. hemisphere is greatly heated by the sun, the N.E. trade wind blows stronger, and approaches nearer to the Equator; the strength of the S.E. trade wind, at the same time, being diminished considerably by the sun's influence. When these N. and S. currents of air meet about the Equator, they destroy each other, producing a calm, and become deflected upwards, forming an ascending current.

As there is a perpetual current of air proceeding from the polar regions to the Equator, where it is rarefied, while the superior gravity of the cold makes the heated air ascend to the upper regions of the atmosphere, whence it returns to the poles, to preserve the equilibrium, the upper current of air must proceed from the parts in which the heat is greatest, so that by a kind of atmospherical circulation, admirably adapted to the preservation of animal life, the N.E. trade wind below will be attended by a S.W. wind above, and the S.E. trade wind below with a N.W. wind above. This opinion is corroborated by the clouds in the upper part of the atmosphere being frequently seen to move in a direction contrary to the trade winds, and by an instantaneous change of wind often experienced when the limits of the trade winds are passed.

Trade winds are only constant in the ocean at a considerable distance from land; for large islands and continents obstruct the regular currents of the atmosphere, and thereby produce either periodical or variable winds. When land is heated by the sun's influence, the atmosphere over it becomes rarefied, the air acquires motion, and a wind is produced, blowing from the ocean towards the land. This may be exemplified by the winds on the African coasts, within the limits of the N.E. trade, blowing often from North and N.W. about Cape de Verde; and from S.W. and S.S.W. betwixt the Coast of Guinea and the Cape of Good Hope, within the limits of the S.E. trade, instead of N.E. and S.E., as is experienced when well out from the land, in the open ocean.

When the land of Australia is heated by the presence of the sun in the S. hemisphere, the wind blows generally from the N.W. upon the N.W. coast; from the S.W. upon the W. coast; from the S.W. the S., and S.E., upon the S. coast: and from S.E. and E. upon the E. coast of that extensive tract of land. Winds, indeed, blow nearly always from the sea by day, towards the heated atmosphere over the land; but contiguous to shores, land breezes are often experienced, coming off dry and parching.

High land obstructs the regular progress of winds. A steady trade wind will pass over a considerable tract of low level land without being much changed in its direction or velocity; particularly if that land be barren and destitute of moisture. But if the wind come in contact with high land or mountains, it is compressed in passing over their summits; as the atmosphere, being heated by the sun's rays according to its density, is much warmer at the bottom than at the top of mountains; consequently the air is cooled in its ascent, and being frequently condensed into humid clouds or fog, is discharged in wet misty vapour, or in small rain, upon the tops of mountains. This may be often seen on Table Mountain at the Cape of Good Hope, or on high islands between the tropics, when the sun shines bright below, with clear weather around.

The presence of the sun in either hemisphere obstructs considerably the regularity and strength of the trade wind in that hemisphere, and *vice versâ*.

The Trade Winds extend generally to about 28° on each side of the Equator, and there is usually a considerable space between them, in which light variable winds prevail mostly from the W., a *counter-current* of air, forming in several parts of the globe, near the Equator, a kind of monsoon, and carrying in some parts a current of water *with* it.

The N.E. and S.E. trade winds prevail in the open sea in the Atlantic and Pacific Oceans; and from the great extent of the latter, they generally blow more steadily in it than in the former; and the S.E. trade wind in the S. Atlantic Ocean blows more steadily than the N.E. trade wind to the N. of the Equator, where the ocean becomes contracted between Cape de Verde and the N. extremity of the coast of Brazil; but towards the West India Islands, the N.E. trade wind generally blows steadily between E. and E.N.E.

The S.E. trade wind prevails also in the Indian Ocean, from within a few degrees of the E. side of Madagascar nearly to the coast of Australia, between the parallels of 10° and 28° S.

MONSOONS, or PERIODICAL WINDS, are those which blow half of the year from one quarter, and the other half-year from the opposite direction. They blow more steadily in the East-Indian Seas than in any other place, particularly to the N. of the Equator, from the coast of Africa to the E. side of the Bay of Bengal; also in the China Sea, but with somewhat less regularity in the N. part of it.

The Thermal Girdle under the sun, where the atmosphere becomes rarefied, and the heated air ascends, is nature's suction-pump, and the principal cause of these winds, as well as of the trade winds. The situation of the land, as connected with the course of the sun, has not so much influence as formerly imagined. Surely Africa is heated enough between April and Sept.; yet the S.E. Trade, having blown towards it in the direction of Zanzibar, then turns (*short* of it) towards the N.E., and becomes the S.W. monsoon of the Arabian Sea: the extensive coasts of India being greatly heated when the sun is vertical to them, a S.W. wind blows from the ocean towards the land to restore the equilibrium. The current of air proceeding from the ocean, being highly charged with moisture, is gradually condensed into rain, which descends in great quantities upon the coasts of India where high land fronts the ocean to the S.W., or W.S.W.

When the sun returns into the S. hemisphere, the atmosphere there becomes greatly rarefied around the Thermal Girdle, or that belt immediately under the sun, and a N.E. wind or monsoon is then produced in N. latitude, blowing towards the heated parts about the Equator. This is the dry season on the coasts of India, for the wind blowing from the land brings fair weather: and the rainy season is produced by wind blowing from the ocean towards the land, which is generally the case on both sides of the tropics.

The S.W. Monsoon prevails from April to Oct., between the Equator and the Tropic of Cancer, and it reaches from the East coast of Africa to the coasts of India, China, and the Philippine Islands; its influence extends sometimes into the Pacific Ocean as far as the Marian Islands, or to about lon. 145° E.; and it reaches as far N. as the Japan Islands. In the same season, a S.S.W. monsoon prevails to the S. of the Equator in the Mozambique Channel, changing a few points in direction, owing to the conformation of lands on each side of that channel.

The S.W. Monsoon, of the Arabian Sea and Bay of Bengal, is merely a prolongation of the S.E. Trade, blowing towards the earth's Thermal Girdle; and we must remember that that girdle lies to the N. of the latitude of Bombay, from mid-May to the end of July. For more than three-score and ten days, the suction-pump has there been at full work. But why should the wind, thus drawn in along the surface of the sea, prefer to fall upon India as a S.W. and a W. wind, rather than upon Arabia and Africa as a S.E. wind? We accept Dove's explanation, that the S.E. Trade is (in crossing the Equator) a volume of air moving from a lower to a higher latitude: thus carrying with it into those higher latitudes, the equatorial velocity, and appearing consequently as a South wind with Westing in it. Sir John Herschel also says that the earth acts upon the air by *friction*, communicating to it a rotatory velocity. Thus, the S.E. Trade wind, as it approaches the Equator, loses its *Easting;* and, as it passes to the N. of the Equator, acquires *Westing*, becoming a S.W. monsoon.

We may understand this better if we reflect that at the parallel of Mauritius (being as much to the S. of the Equator as Maseira Island on the Arabian Coast is to the N.), the rotatory velocity of the earth is considerably less than at the Equator. Passing then from that Capricorn region of a less rotatory velocity to the Equator, where the greatest velocity is found, the wind acquires Easting; but passing on beyond the Equator towards the Cancer region (one of less velocity), it acquires Westing, and developes itself as the S.W. Monsoon.

The N.E. monsoon prevails from Oct. to March throughout nearly the same space as that mentioned above; but the monsoons are subject to great obstructions from the land; and in contracted places, such as Malacca Strait, they are changed into variable winds. Their limits are not everywhere the same, nor do they always shift *exactly* at the same period. The N.E. monsoon of India and the China Sea is no other than the undisturbed N.E. Trade-wind. The N.W. winds below the Equator are simply an extension of the N.E. Trade, blowing towards the Heat-Belt; whilst the sun is near the Tropic of Capricorn, and daily passing over the Australian deserts.

The N.W. monsoon prevails between the N.E. part of Madagascar and the W. coast of Australia from Oct. to April, and it is generally confined between the Equator and 10° or 11° of S. latitude, but subject to irregularities. This monsoon seldom blows steadily in the open sea, although in Dec. and Jan. it generally prevails, and in these months sometimes extends from lat. 10° or 12° S. across the Equator to lat. 2° or 3° N. This is the rainy monsoon to the S.-ward of the Equator, and the S.E. monsoon is the dry season.

The S.E. monsoon predominates from April to Oct. in the Java Sea and whole Asiatic Mediterranean, as far as and beyond Papua, (New Guinea), and in some places reaches the Equator, when the sun is near the northern tropic; but this monsoon may be considered as an extension of the Pacific S.E. trade following the sun; and when that luminary returns to the S. tropic, this monsoon recedes to lat 10° or 12° S., *backing down* like the S.E. Trade near the Chagos Group.

The parts where the N.W. and S.E. monsoons prevail with greatest strength and regularity are in the Java Sea, and from thence E.-ward to Timor, amongst the Molucca and Banda Islands, and onward to New Guinea. The Westerly monsoon blows as steadily, strongly, and regularly along the N. side of New Guinea, at New Britain, New Ireland, and all contiguous islands S. of the Equator, as far E. as Malanta and the N. part of the New Hebrides, as in any part of the Indian Ocean whatever, and extending in a wind of gradually decreasing constancy and continuation, from hence, far E. to the Society and Marquesas Islands. The limits in latitude appear similar to the Indian Ocean, from 1° N. to 15° S., and occasionally to 19° S., and the period from the beginning of Jan. to the end of March.

Westerly winds are sometimes experienced near the Equator, in the Pacific Ocean, a great way to the E. of New Guinea; and also in the Atlantic Ocean, westerly winds at times occur near, or a little to the N. of the Equator, forming a counter current to the regular N.E. and S.E. trade winds which prevail on each side of it.

INTER-TROPICAL HEAT-BELTS of the Indian Ocean. Some brief explanation of the sun's passage over the broad zone between the Tropics seems highly necessary in order that the seaman may understand what we mean by the expression—Thermal Girdle, or Heat-Belt—applied in the foregoing remarks concerning the Monsoons. Thermal Maps have been from time to time produced by Berghaus, Dove, and their copyists. In all these examples the Equator is recognised as the seat of the normal *isotherm* of greatest heat; that line or band being diverted northward or southward, according as observation has proved the idea to be inconsistent with ascertained facts. Thus, there has appeared (in many a physical atlas) an imaginary waving line round the globe, which has been styled the "*Warmth-Equator*," and corresponding lines of equal annual temperature, called "*Isotherms*," girdle the higher latitudes. Of course such a plan would be a necessity on any single map which should attempt to show at one glance the *mean* direction of winds and currents and the *means* of heat throughout the air and the sea. But to the seaman it is worse than useless—it is positively misleading. However, we do not object to "*Isotheres*," or lines of equal *summer* temperature; nor to "*Isochimenes*," or lines of equal *winter* temperature.

The notions on tropical climate which *were* current twenty years ago—and *even now* are entertained by many physical geographers—were well reviewed in a little treatise on "The Asiatic Mediterranean," by Trelawny Saunders, now Geographer at the India Office, as follows :—

"It is admitted that the sun is the paramount source of atmospheric heat. But his influence on the earth is referred to his *apparent* path in the ecliptic; and the *real* motion of the earth in her path around the sun has been lost sight of, in the consideration of thermal and climatological questions. Now it is clear that whatever influence the sun exerts on the earth must be attributed to the *actual* and not to the *apparent* motions.

"But the motion of the earth around the sun, as described by astronomers, and in the accepted theory of the seasons, is inconsistent with the facts which geography demonstrates. The astronomers and climatologists say that the earth moves round the sun in an elliptical orbit, and on a single plane, which is regarded as passing through the centre of the sun and the centre of the earth; the axis of the earth round which she revolves daily, being at an angle of nearly 66° 32′ to the plane of her orbit. This doctrine is inconsistent with the *fact* that the sun is vertical day by day to successive points between the tropics, producing spiral lines on the earth's surface nearly parallel to the Equator. In fact, the sun's solstitial motion is in the parallel of 23° 28′ nearly, N. and S. of the Equator alternately, at intervals of six months; and his equinoctial motion is on the line of the Equator nearly, instead of in lines parallel to the ecliptic.

"**Five distinct Zones in the Tropics.** It is maintained, therefore, that the earth moves around the sun in a spiral path between two planes, which are respectively coincident with the vertical action of the sun on the two tropics, at his nearest approach to either pole, severally and separately, at intervals of about six months. The interval between the spiral lines of the sun's vertical action, on each daily revolution of the earth, is about 15′ of latitude, subject to variation.

"**Two bands of greatest heat** therefore exist (though they do not co-exist) on the earth's surface, arising from the continuous vertical action of the sun at each tropic; each parched up with heat for a period of 62 successive days, during which time he is passing from lat. 20° to the tropic in 23° 28′, and then back to 20° again. He is vertical for less than one-sixth of that time, over a similar extent of latitude in any other part of his apparent course. The result is a band of deserts under each tropic around the earth. **The tropic of Cancer** traverses the 'tierras calientes,' or desert regions of Mexico; the Sahara of N. Africa, and the Arabian desert; while the desert of Mekran on the *Coast* of Beloochistan, and that of Thurr, to the E. of the Indus, are close to it on the north. **The tropic of Capricorn** traverses the desert of Atacama on the Pacific, in Bolivia; the desert of El Gran Chaco in La Plata; the desert of Kalihari, between the lake Nyassi and the Orange River in South Africa; and the great desert region of Australia, so well described by Sturt. The tropical region appears, therefore, to be burnt up and desert, with trifling exceptions, arising from local causes, which preponderate over the sun's continuous vertical action.

"**The Equatorial region,** or the zone within 10° of the Equator, also presents special characteristics of an excessive kind. The temperature is high, and scarcely varies; the rain falls in torrents during several months; vegetation is rank and luxurious; and animal life revels in its most impressive and abundant varieties. The closer juxtaposition of the sun to this culminating portion of the sphere, may partly account for its preponderating influence there.

"**The zones halfway between Equator and Tropics,** (or between 10° and 20° on both sides of the Equator) are equally remarkable, and peculiarly interesting on account of their remarkable fitness for the occupation of man. All around the earth within those latitudes the country abounds with lakes, rivers, and fertility, but the vegetation is not excessive. The climate also partakes of the qualities prevailing in the temperate zones."

FURTHER REMARKS about Monsoon Winds will be found at pages indicated below.

For Winds and Weather off Cape of Good Hope, *see* page 76. For Algoa Bay, page 83.

For Winds and Currents in Mozambique Channel, *see* page 560.

For Winds and Weather at Mauritius and Rodrigue, *see* page 525. Between Zanzibar and Aden, *see* page 116.

For Winds at the S. extreme of the Maldives, *see* page 571. At Ceylon, page 306.

For Navigation and Winds of the Arabian Coast, *see* page 233. For Persian Gulf, page 279.

For Winds and Weather on the Malabar Coast, *see* pages 299 to 307.

For Monsoons and Gales in the Gulf of Bengal, *see* pages 317 to 321.

For Monsoons on the West Coast of Sumatra, *see* page 624.

The SURFACE CURRENTS of the OCEAN flow in harmony with the Trade winds, and the Anti-trades. They are properly distinguished by the different and significant names, *Drift* and *Stream*. **The Drift** is merely the wind's effect on the surface of the ocean. **The Stream** is an accumulation of the parts of the Drift into a collective mass, by the intervention of some obstacle; and onwards it goes because pressed on by fresh drift in its rear. Deep submarine currents may be the effort of nature restoring the equilibrium which surface currents have disturbed; and in this process the rotation of the earth is an active agent.

In the Pacific Ocean, a fair field, and where they suffer no divergence through interposition of a continent, the Trade-drifts flow towards the West, inclining towards the Equator. But, unable to escape through channels of the Asiatic Archipelago into the Indian Ocean (except in a very partial manner at one season of the year), and aided by the peculiar positions of great islands, the two Westerly streams coalesce and produce an Equatorial* Counter-current flowing towards the East. Besides this method of preserving equilibrium, nature has established the Japan current in the North, which is identical in character and origin to the Gulf Stream. Some have ventured to dispute the correctness of Sir John Herschel's conclusions as to the relation of the trade winds to the Gulf Stream. We venture to think that time will vindicate the sound arguments of that eminent man; we only find him wrong when misled by wrong data, and sailors are to be blamed for supplying men of science with that. He says in one place, "the North Pacific currents are as yet far from well understood." We wish to endorse the following remarks from his "*Physical Geography*."—"From meteorology we learn to refer the great system of aquatic circulation (which transfers the waters of every one region of the ocean, in the course of time, to every other), to the action of our Trade winds, and their compensating currents, the Anti-trades; themselves the results of solar action in combination with the earth's rotation on its axis."

VARIABLE WINDS prevail in both hemispheres from lat. 28° or 30° to the poles, but those from W. and W.S.W. generally predominate in N. latitudes; and those from W. and W.N.W. predominate in S. latitudes.

The prevalence of Westerly winds in high latitudes has been thus accounted for. The upper parts of the atmosphere having a motion towards the poles, contrary to the trade winds, and becoming condensed beyond their limits, descend to the surface of the earth or sea; thus producing the motion from the W. towards the E., to restore the equilibrium which has been destroyed by the trade winds. Immediately beyond the limits of the trade winds, the Westerly winds are generally found to prevail.

These Westerly winds, in high latitudes, are liable to obstructions and changes, from various causes, the influence of the sun being mutable and uncertain in the Temperate Zones; but beyond the Arctic and Antarctic Circles, where a settled frost and cold atmosphere constantly prevail, strong gales and sudden shifts of wind are not so liable to happen as at a greater distance from the poles.

The sun's presence in either hemisphere has great influence upon the prevailing Westerly winds in high latitudes; in the N. Atlantic Ocean the wind generally inclines to W.S.W. in the summer months; and in winter, almost constantly to W.N.W., between the coasts of Newfoundland and Ireland. In the British Channel, Easterly winds often prevail in Feb., March, April, and part of May; during the other months, Westerly winds prevail greatly.

On the N.W. coast of America, S.W. winds prevail in the summer months, and Northerly winds during winter.

* It is to be desired that Physical Geographers would alter the nomenclature of Ocean Currents. The *proper* Equatorial Current of the Pacific is a counter-current to the E., between the Trade Drifts forced along by the N.E. and S.E. winds. These Trade-Drifts are *now* called respectively the N. Equatorial and S. Equatorial currents; which names were given before the *proper* Equatorial E. current was known. (*See* also Currents in Chapter XX.)

In the S. hemisphere, during the summer months, when the sun is near the Tropic of Capricorn, the winds are sometimes very variable, but prevail at W. and W.N.W. In the winter months they blow mostly from W.S.W. and W., and sometimes from S. or S.E. Westerly winds prevail off the Cape of Good Hope, Cape Horn, and Cape Van Diemen, particularly when the sun is near the Tropic of Cancer; but on the W. coasts which form these promontories, the wind frequently prevails from the Southward, when it is blowing strong from the Westward off their extremities. And S.E. or Southerly winds are *generally* found to prevail more than any other, in Feb., March, and part of April, in the vicinity of those head-lands.

LAND and SEA BREEZES may be considered as a kind of alternating winds, which are generally experienced in settled weather upon coasts or islands between the tropics. They arise from the circumstance of land being a better conductor of heat than water, and consequently being susceptible of a higher degree of temperature by the action of the sun than the sea: this increase of temperature during the day rarefies the incumbent atmosphere, and a current of colder air rushes in from the sea to supply the deficiency, and forms what is called a *sea-breeze*. The progress of this breeze is *regressive* upon the sea, as it commences close to the shore where the motion of the air first inclines to the land, and then gradually extends out to sea; so that vessels close in with the shore get the regular breeze sooner than those which are in the offing. After sunset the atmosphere over the land becomes cool by evaporation; and at whatever time of the night it exceeds in density that over the sea, the air takes a motion from the land towards the more rarefied parts over the sea, producing what is called the *land-breeze*. This is a *progressive* breeze upon the sea, as it begins on the shore, and gradually extends to seaward; and its approach may be sometimes known by an increased noise of the surf.

These land and sea-breezes extend in some places only to a small distance from the shore; but on the Malabar Coast, in the fair season, where they prevail *probably* with greater regularity than in any other part of the globe, their influence is perceptible at the distance of 20 leagues from the land. When the land is greatly heated, and the evaporation not sufficient to cool the atmosphere over it below that of the adjoining sea, there will be no land-breeze, and in such case the wind blows mostly from seaward: this may be observed in the temperate as well as in the torrid zone.

During summer in England, when the weather is settled and serene, a gentle breeze from the sea frequently rises, and increases with the altitude of the sun; it is strongest after noon, when the air over the land is greatly rarefied, and it declines with the setting sun. The evaporation from the land during the night being in this country not sufficient to cool the atmosphere over it below that of the adjoining sea, a land-breeze is consequently seldom experienced in the night. The temperature of the atmosphere being nearly the same over the land and sea, calms generally prevail in the night, until the sea-breeze returns, when the atmosphere over the land becomes heated by the sun in its diurnal course.

SQUALLS are generally of *three* kinds; that called the **Arched Squall** is frequently experienced, and is usually distinguished by the arched form of the clouds near the horizon; but sometimes it assumes the appearance of a dense black cloud, particularly when highly charged with rain or electric matter. From the time that the arch or cloud is first seen above the horizon, its motion is sometimes very quick to the zenith, the interval being scarcely sufficient to allow a ship to reduce the necessary sail before the wind reaches her, which happens when the cloud has approached to the zenith. At other times, the motion of the cloud is very slow, and not unfrequently it disappears, or is dispersed, the impulse of the wind being then not sufficient to reach a ship. As a general rule, it may be observed, that if there be rain in these squalls preceding the wind, the latter will probably follow the rain in sudden severe gusts; whereas, if the wind precedes the rain, the squalls are seldom so furious, and terminate in moderate showers of rain. This general rule, however, is often interrupted by the operation of local causes. **The Descending Squall** is not so easily discerned as the former because it issues from clouds which are formed in the lower parts of the atmosphere near the observer; and when clouds are thus formed, they generally produce showers of rain and successive squalls of wind **The White Squall** is not often experienced; but it sometimes happens near or within the tropics, particularly in the vicinity of mountainous land. This squall generally blows very violently for a short time, and as it is liable to happen when the weather is clear, without any appearance in the atmosphere to indicate its approach, it is consequently very dangerous. The only mark that accompanies it is the white broken water on the sea surface, which is torn up by the force of the wind. Squalls, and also storms, are sometimes *progressive*, at other times *regressive*, when obstructed by an opposite wind, or according as the point of greatest rarefaction is situated, as may be seen in the description of the sea-breeze. When a squall comes up against an opposite wind, its motion is greatly retarded thereby, and a ship sometimes in this case outruns the squall, and overtakes other ships which are within the limits of the opposite wind. Progressive winds, when they have an opposite wind to subdue, are frequently preceded many hours by a swell, which extends a great way before them.

In Straits or Channels formed between high lands, strong winds generally blow directly through them: this is experienced in many parts of the Eastern seas, such as the Straits of Shadwan in the Red Sea, the Mozambique Channel, Straits of Macassar and Lombock; also in the entrance of the river St. Lawrence in North America, and frequently in the Frith of Forth in Scotland, although the latter is not bounded by *very* high land.

In many places between the tropics, where shoal coral banks shoot up out of deep water, a decrease of the prevailing wind is frequently experienced upon them; for when a steady wind is blowing over the surface of the deep water, no sooner does a ship get upon the verge of a shoal coral bank, than a sudden decrease of wind is often perceived. This is probably occasioned by the atmosphere over these banks being less rarefied, and cooler by the increased evaporation, than that over the deep water; consequently not requiring so great a supply of air to restore the equilibrium, as the circumjacent parts which are more rarefied and heated. Water, in small quantities, parts quickly with its heat, but retains it when in large quantities; in other words, the quantity of water evaporated and the cold generated in a given time is always in proportion to the extent of surface and the depth of the evaporating mass: the evaporation, therefore, over shoal banks is always greater than over deep parts of the sea, and the atmosphere, as well as the surface of the water, proportionally cooler over the former than over the latter.

The changes of the Moon are more likely to be accompanied by stormy weather than the full moon. The Nautical Almanack gives all the lunar points. When her semi-diameter and horizontal parallax are *greatest*, she is in that part of her orbit nearest the earth, called *Perigee*. When the semi-diameter and horizontal parallax are *least*, she is farthest from the earth, or in *Apogee*. The Perigee of the Moon is likely to be accompanied by the greatest changes which happen from a *single* lunar point. The new moon, next to Perigee, is likely to be attended by great changes of weather. At new moon coinciding with Perigee, the greatest changes may be expected; and at the equinox, the chances of a change must be great.

STORMS may be classed under three heads: **Gales of Wind, Hurricanes, and Whirlwinds.**

GALES generally happen beyond the tropics, outside of the limits of Trade winds; for in high latitudes, gales of wind, or storms, blow sometimes from one direction several days together, particularly during winter. These strong gales prevail mostly from the Westward, and they are not so liable to shift round suddenly as the storms near the tropics; this, however, sometimes happens, and has occasioned the loss of many ships in the Atlantic Ocean, having their square sails set, and consequently not prepared for a sudden change.

The gales of wind which happen near and within the tropics are generally of short duration, and liable to veer round suddenly to an opposite direction.

HURRICANES or CYCLONES are seldom experienced beyond the tropics, nor nearer to the Equator than lat. 9° or 10° N. or S.: they rage with greatest fury near the tropics in the vicinity of the main-land or islands: far out in the open ocean, they rarely occur; and when they happen within 10° of the Equator, they generally are less violent than nearer to the tropics.

These are dreadful tempests, in which (when the centre passes over the ship) the wind shifts sometimes suddenly from one direction to the opposite, raising the sea in pyramids; its violence is frequently so great as to overcome all resistance, carrying away the masts of ships, and tearing up trees by the roots. The velocity of the wind in some violent hurricanes has been estimated at about 80 or 90 m. an hour: in a pleasant brisk gale it is about 20 m. an hour. In some places, hurricanes are occasionally accompanied by an earthquake.

Cyclones* happen near the E. coast of Madagascar, near the Islands of Mauritius and Reunion, and to the E. of these islands, within the limits of the S.E. Trade: they are also liable to happen near the coasts of India, particularly in the Bay of Bengal at the changing of the monsoons.

They are called Ty-foongs by the Chinese, and frequently happen on and near the coast of China, extending from thence to the E.-ward of Luconia, and to the N.E.-ward as far as the Japan Islands. A description of them will be found in Volume Second of this Work, under the title "China Sea;" and the hurricanes which happen near the islands of Mauritius and Bourbon are described at page 525; and also in Chapter XX. on Passages.

Admiral Sir Francis Beaufort, R.N., for many years Hydrographer of the Admiralty, drew up for the edification of seamen the following remarks on Revolving Storms:—

The nature of Hurricanes, with propriety called **Revolving Storms (Cyclones),** has of late

* Piddington's Sailor's Horn-Book of Storms should be in the library of every Master Mariner. Colonel Capper, H.E.I.C.S., was about the first to notice the revolving tendency of these storms.

years much engaged the attention of meteorologists and philosophers; but it is a subject of more immediate importance and of far deeper interest to practical seamen, who would therefore find their time amply repaid by a careful perusal of the several works of Redfield, Piddington, Thom, Meldrum, and Sir William Reid. With a zeal worthy of all praise, these gentlemen have collected the facts and endeavoured to develop the laws by which such storms are governed, and have thereby entitled themselves to the lasting thanks of the whole maritime community for having, not only demonstrated the dangerous consequences of neglecting the indications by which those storms are invariably preceded, but for having pointed out the means by which they may generally be avoided.

The joint labours of these authors have indeed so forced the subject on the attention of the public, that to suppose any commanders altogether ignorant of it would now be a severe reproach. Yet there are many who, from want of opportunities to study those works, are so imperfectly acquainted with the peculiar phenomena which distinguish these storms, that they are unable to act in the hour of need with decision and firmness. For their use, therefore, the following pages have been drawn up; the object being to show the seaman the necessity of seeking more diligently for full information on these important matters, and, in the meantime, to furnish him with a few brief and general rules by which he can determine whether it be only a common gale that is approaching, or whether it is likely to be one of these revolving storms; and, if the latter, to show him how it may be eluded, or, if too late for that, how to prevent his being drawn into its vortex.

Gyration. The space over which these storms have been known to expand themselves varies from twenty or thirty to some hundreds of miles; blowing continually round and round a centre or vortex, but with an ever varying force, now lulling into little more than a strong breeze, and then again suddenly swelling up into a blast of uncontrollable fury. But the peculiar characteristic of their revolving action is, that in each hemisphere of the world the gyration invariably takes place in one direction, and that direction *contrary* to the apparent course of the sun; so that in north latitudes these storms revolve from right to left, and in south latitudes from left to right. The knowledge of this law is the more especially important, as it not only supplies the seaman with direct means of distinguishing them from common gales, but it reveals to him the actual position of the centre or vortex with respect to the place of his vessel, and therefore points out with unerring certainty the way to escape from them.

Progress. But besides the above circular motion of the wind round a centre, these storms have a bodily progressive movement—rolling onwards, if it may be so expressed, along their desolating tracks, sometimes with great velocity, and sometimes appearing to pause or scarcely to advance more than a few miles in the hour, although the impetuosity of the wind itself round the circle may continue undiminished.

Regions. These storms occur commonly in the three great oceans, the Atlantic, Indian, and Pacific, but they are seldom found within less than 5° or 6° of the Equator, and have not yet been traced into very high latitudes. They appear to be most frequent and most severe in the West India, Madagascar, and China Seas; and the season in which they are most prevalent is during the sun's return from the summer solstice; or, in other words, from July to Oct. in the northern hemisphere, and in southern regions from Jan. to April.

Path. Though these storms in traversing the ocean do not always adopt exactly the same path, nor ever travel with any uniform velocity, yet there is so much apparent similarity in their movements as to show that they are ruled by one general law. To endeavour to trace this law, the log books of a great number of vessels in all parts of the sea have been examined, as well as the meteorologic registers of numerous places on shore; and from them the movements of these storms have been reduced into comparative tables, their separate tracks graphically represented on charts, and their several characteristics analysed with great labour and zeal by the before-mentioned authors. The general result may be thus briefly stated:—In all cases, within the tropics, they commence to the E.; for some days they travel along a path not exactly W., but inclining a point or two towards the pole of that hemisphere which they are crossing: their rate of movement, though very variable, may be averaged at from 10 to 30 m. in the hour; and as they advance they seem to be the more inclined to curve away from the Equator. When they reach the 25th degree of latitude they generally curve still more until they move to the N.E. in the N. hemisphere, and to the S.E in the S. hemisphere. Occasionally they are found to cross the line of the shore, and to sweep over the land that opposes their progress, as appears to be generally the case in the East Indies; but by far the greater number seem to be repelled by any continental coast, so as to be deflected back to the N.E. in the N. hemisphere, and to the S.E. on the other side of the Equator. The Atlantic storms, for instance, almost always wheel round to the N. in the Mexican Gulf, and follow the sea-board of North America.

Vortex. Another remarkable feature of these storms is their increasing violence in the neighbourhood of their centre or vortex; and yet there, they are so much the more fitful and uncertain as to render a vessel absolutely helpless and unmanageable. Besides which, as she approaches the vortex (unless on the direct line of its own progressive motion), the more rapid become the changes of the wind till at length, instead of veering point by point, as she had found when entering the storm-field, it now flies round at once to the opposite point—the vessel is taken aback, or brought by the lee, in an irresistible squall—and forced into sternway against an overpowering sea, the destructive consequences of which need not be enlarged upon here.

Those who have dearly bought this experience, by having passed through the centre of one of these storms, describe the cross confused sea there as being tremendous—raised by gusts from every point of the compass into pyramidal heaps, which strike the vessel on either side, and with a force similar to that of a heavy surf beating over a reef. And yet, on the other hand, there are instances on record of the wind suddenly failing in the very vortex, and the clouds dispersing for a short and delusive interval, though soon, as if the wind had acquired fresh power from the transient calm, resuming its violence with tenfold fury. It may be added, that few vessels ever went through the ordeal of the vortex without losing either masts or rudder, or meeting with some worse disaster; and, therefore, at whatever cost of time, trouble, or loss of ground, the central part of the storm-field will be avoided by every man in his senses.

A few simple rules are given here, by which Cyclones may be either wholly avoided; or by which, if the vessel be already too near to prevent the collision altogether, she may place herself so as to receive them in the least disadvantageous position and to extricate herself speedily.

Prognostics. With that threatening aspect of the sky which generally precedes all storms,—such as the greasy halo round the sun or moon, the rolled and tufted forms of the clouds, with their lurid streams of light and extraordinary colours, and the heavy bank clinging to the horizon with its darting forks and threads of pale lightning,—every seaman is acquainted. The best and surest of all warnings will, however, be found in that invaluable and seldom-failing monitor, **the barometer;** the language of which, in the torrid zone, is unmistakeable, because there, it is usually so tranquil and undisturbed. When any such warning symptoms are observed in *any* quarter of the world it may be supposed that no time will be lost in making all due preparation, and especially if to such menacing appearances be added the confused and troubled agitation of the sea which often precedes these revolving storms, and always shows that they are at no great distance. But, if these combined prognostics should occur, within the limits of *those regions* which have been pointed out as the hot-bed of Cyclones, let the seaman immediately consider the possibility at least of his being about to encounter a storm of that revolving type of which we have been treating.

Revolution. Acting under this anticipation, his first care should be to discover the position of the storm with respect to the vessel, or, in other words, to ascertain its bearing. Fortunately this is a problem of extreme facility, for, as we have already stated, it is one of the remarkable laws of these storms that in opposite hemispheres they revolve in opposite directions—in *North* latitudes against the course of the sun, that is to say, from right to left, or in a direction *contrary* to the movement of the hands of a watch, and in *South* latitudes from left to right; and secondly, it is known that, no matter how great, or how little may be the size of the storm-field, the wind continually blows in a circular course round and round a centre or vortex. It therefore follows that this centre must nearly be at right angles to that circular course; or, in other words, that the bearing of the centre is 10 points of the compass from the direction of the wind. Now, these two considerations are quite enough for our purpose, for they enable us to answer the question instantly and certainly by the following general rule:—

Rule. Look to the wind's eye,—set its bearing by the compass,—take the 10th point to the **right** thereof—and that will be the bearing of the centre of the storm if in N. latitude; or if in S. latitude, a 10th point to the **left** of the direction of the wind. For example: suppose the vessel to be in 14° N. latitude, the wind from E.S.E., and the barometer and sky indicating a coming gale,—then, look at the compass, take a 10th point to the right of E.S.E., and S.W. will very nearly be the bearing of the brewing storm, *if it be* of a revolving type. Or, under similar appearances of the weather in 14° S. latitude, with the wind S.W., take 10 points to the left of S.W., and E.S.E. is approximately the direction of the centre of the impending gale. In the former case, the vessel will be on the N. edge of the storm-field; and in the latter, she will be somewhere in its N.W. segment. Nothing can be more unambiguous than the above rule—requiring no diagrams nor any puzzling considerations to lead to a distinct and immediate conclusion: nevertheless, as the mind, when somewhat excited by the approach of such an unwelcome visitor as one of these storms, might possibly apply the ten points on the wrong side, we have added two tables, one for N. latitude, and one for S. latitude, in which the seaman will at once see the question solved without the trouble of any reflection whatever.

TABLE 1.—BEARING OF THE VORTEX IN NORTH LATITUDES.*

If the Wind be	The Vortex of the Storm will bear from the Ship,
North.	E.S.E.
N. by E.	S.E. by E.
N.N.E.	S.E.
N.E. by N.	S.E. by S
N.E.	S.S.E.
N.E. by E.	S. by E.
E.N.E.	South.
E. by N	S. by W.
East.	S.S.W.
E. by S.	S. W. by S.
E.S.E.	S.W.
S.E. by E.	S.W. by W.
S.E.	W.S.W.
S.E. by S.	W. by S.
S.S.E.	West.
S. by E.	W. by N.
South.	W.N.W.
S. by W.	N.W. by W.
S.S.W.	N.W.
S.W. by S.	N.W. by N.
S.W.	N.N.W.
S.W. by W.	N. by W.
W.S.W.	North.
W. by S.	N. by E.
West.	N.N.E.
W. by N.	N.E. by N
W.N.W.	N.E.
N.W. by W.	N.E. by E.
N.W.	E.N.E.
N.W. by N.	E. by N.
N.N.W.	East.
N. by W.	E. by S.

TABLE 2.—BEARING OF THE VORTEX IN SOUTH LATITUDES

If the Wind be,	The vortex of the Storm will bear from the Ship,
North.	W.S.W.
N. by E.	W. by S.
N.N.E.	West.
N.E. by N.	W. by N.
N.E.	W.N.W.
N.E. by E.	N.W. by W.
E.N.E.	N.W.
E. by N.	N.W. by N.
East.	N.N.W.
E. by S.	N. by W.
E.S.E.	North.
S.E. by E.	N. by E.
S.E.	N.N.E.
S.E. by S.	N.E. by N.
S.S.E.	N.E.
S. by E.	N.E. by E.
South.	E.N.E.
S. by W.	E. by N.
S.S.W.	East.
S.W. by S.	E. by S.
S.W.	E.S.E.
S.W. by W.	S.E. by E.
W.S.W.	S.E.
W. by S.	S.E. by S.
West.	S.S.E.
W. by N.	S. by E.
W.N.W.	South.
N.W. by W.	S. by W.
N.W.	S.S.W.
N.W. by N.	S.W. by S.
N.N.W.	S.W.
N. by W.	S.W. by W.

* This table is more amplified in the Introduction to Part II.

The bearing of the storm from the vessel having thus been determined, it would no doubt be very desirable to ascertain, at the same time, its distance from her; but for this no very clear rules have yet been suggested. A good guess may however be made from the quickness or slowness with which the storm appears to develop itself,—from the increasing severity of its squalls,—from the faster veering of the wind,—from the rising confusion of a cross swell,—and especially from the sudden fluctuations of the barometer, which should be carefully noted every quarter of an hour whenever there is reason to suspect that a revolving storm is in the neighbourhood.

It is necessary that the seaman should clearly perceive that the changes of wind which occur to him in any part of the storm-field entirely depend on the relative position of his ship to the vortex; and moreover that they may be correctly foreseen, and ought to be well considered before he can determine on what measures to adopt,—whether to lie-to, or to fly from the danger,—whether to avoid further entanglement with its vicious circles, or to endeavour to render them subservient to the progress of her voyage.

The General Rule for all vessels, in all cases, except when controlled by land or shoals, is this. Let them immediately steer in that direction which will most quickly increase their distance from the vortex, or centre of the storm-field. But then let it be remembered, that the whole storm-field is itself in motion; that it is travelling with certainty to the westward, while within the tropics, though with very uncertain velocity; and that it has a tendency to curve round to the N. in N. latitudes, or to the S. in S. latitudes when leaving the tropics. The situation of the vessel must therefore be considered, not only with respect to the present position of the vortex, but also with respect to the place to which it will have advanced by the time she may have executed any projected run; for otherwise, though going at her best speed, she might be overtaken by a following, and probably an expanding, storm. When the progressive velocity of a storm is slow, a vessel may overtake and plunge into it; in which case the cross sea that follows in the "*wake*" of the storm may serve as a warning.

As the latter half of a storm-field is often pregnant with far greater mischief than the preceding half, and as it is generally attended by a much more turbulent sea, so a prudent commander (in the N. hemisphere) would have led her off, with the wind on the *starboard* quarter, so that she might go to the N., although perhaps she were bound to the S. Or, if the wind or sea were not quite intolerable, he might possibly lie-to on the *starboard* tack; being certain that, as the vortex was going off to the W.N.W., it would bear from him more and more Westerly, and consequently that his vessel would keep *coming up* to the wind without any danger of being taken aback in some of its sudden changes: this being a very material consideration in dealing with these changeful storms.

In the S. hemisphere, she should run with the wind on the *port* quarter, or lie-to on the *port* tack; thus also she would *come up* to the wind.

The Southern Indian Ocean, which includes the Mauritius, and stretches from Madagascar to about 110° of E. longitude, is prolific of revolving storms. So frequent and numerous are they in this region, that it is upon record that three separate ones have been blowing in different parts of it at the same time. Their tracks also are variable, as well as the rate at which they travel, but generally their line of movement is from E.N.E. to W.S.W. Let us then imagine two vessels, A and B, in company, homeward-bound, to be crossing that zone with the wind from E.S.E., and that both are startled some evening by those threatening appearances in the sky which, with a rapidly falling barometer and a growing agitation of the sea, too surely indicate the approach of bad weather. Looking towards the E.S.E., and taking ten points to the *left* thereof (being in *South* latitude, *see* Table 2), they both quickly infer that the vortex of the coming storm bears North; but A, anxious to profit by the freshening gale, persists in her course, and before morning is taken aback in a crushing gust of wind, with a mountainous sea, and discovers too late the truth of the old proverb that "most haste makes worst speed." Whereas B, warned by experience, and alarmed by the continued depression of the barometer, hauls out to the S. by W., keeping as much way on the ship as the snug sail (to which she has been wisely reduced) will permit; and when about sunrise she receives a pretty severe brush of the gale she quietly heaves-to, knowing by the direction of the wind, which had drawn *aft* to E.N.E., that the main body of the storm having already passed her is then bearing N.N.W.; and that, owing to her prudent Southern board, she had so considerably increased her distance from it, that there was then no immediate danger. In time, the barometer looks upward, the wind moderates, the sea gradually subsides, and she pursues her voyage.

Anomalies in all these laws. We have thus given a sketch of the general laws by which revolving storms appear to be guided, as well as of the general principles on which they may be avoided; and we have endeavoured to do this with the utmost brevity, because our principal object has been to awaken the seaman to the extreme importance of the subject, and to show the nature of the resources which prudence and foresight will place in his hands. But it is our duty to warn him that he must acquire a much more efficient knowledge than can be gathered from this little Abstract of the leading phenomena which distinguish these storms; and he must also study their various anomalies and exceptions, for they have been known suddenly to intermit, and even to back round again in a contrary direction to their usual course; and sometimes to be followed by a second storm, leaving a narrow intermediate space between their two circular areas, where a vessel has been alternately affected by each of them. These, and other highly interesting facts, he will find narrated and classed in the books which we have mentioned, which we again therefore recommend to his careful study.

WHIRLWINDS are sometimes occasioned by high uneven land: when the wind is blowing strong, gusts from the mountains descend sometimes with a spiral or whirling motion upon the surface of the contiguous sea. But the phenomenon usually known by the name of **Whirlwind** when seen upon land, and called a **Water-spout** when it happens at sea, is generally attributed to electrical causes; as it occurs mostly in warm climates, when black dense clouds appear low in the atmosphere, which, being highly charged with electric fluid, thunder or lightning is mostly experienced with a whirlwind; and at sea, it is almost invariably accompanied by rain and hail.

When a water-spout is forming at a small distance, a portion of a dense cloud is observed to descend and stretch itself towards the sea in a conical shape; at the same time the surface of the sea immediately under it is agitated, and ascends a little way, in the form of steam, or white vapour, from the centre of which a small cone proceeding upwards unites with that projected from the cloud; the water-spout is then formed; frequently, however, the acting cause is not adequate to its completion; in which case the half-formed water-spout soon disperses.

There is in the middle of the cone that forms a water-spout a white transparent tube or column, which, when viewed at a distance, seems like a stream of water ascending, and gives it a very threatening aspect; but when closely approached, this partly vanishes. I have passed close to several water-spouts, and through the vortex of some that were forming, and was enabled to make the following observations:

By an electrical force, or *ascending* whirlwind, a circular motion is given to a small part of the surface of the sea, in which the water breaks, and afterwards acquires a whirling motion with a velocity of 2, 3, to 4 or 5 knots. At the same time a considerable portion of the water in the whirlpool is separated from the surface in minute particles, resembling smoke or vapour, accompanied by a hissing noise, from the strength of the whirlwind: these particles continue to ascend with a spiral motion to the impending cloud. In the centre of the water spout there is probably a calm, in which none of the small particles of water ascend; and in this, as well as around the outer edges of the water-spout, large drops of rain fall, because in those places the power of the whirlwind is not sufficient to support the ascending particles.

The vacant space in the centre of the water-spout seems, when viewed at a distance, to be that which has a white transparent appearance, like a column of water, or a hollow glass tube. In calm weather, water-spouts are generally perpendicular, but occasionally they have an oblique or curved direction, according to the progressive motion given them by the prevailing winds. Sometimes they disperse suddenly, at other times they move rapidly along the surface of the sea, and continue a quarter of an hour or more before they disappear.

Water-spouts are seldom seen in the night; yet I once passed near to a large one in a cloudy dark night. The danger from water-spouts is not so great as many persons apprehend; for it has been said, that when they break, a large body of water descends, sufficient to sink any ship. This does not appear to be the case, for the water descends only in the form of heavy rain, where it is broken from the ascending whirlwind; but there is danger of boats being swamped, or in small vessels of being overset when carrying much sail; and large ships, if their top-sails are not clewed up, and the yards secured, may be liable to have them carried up to the mast-heads by the force of the whirlwind, and thereby lose their masts. It is sometimes thought that the firing of a gun when near a water-spout will break it, and effect a dispersion; the concussion produced in the atmosphere by the explosion destroying in such case the cohesive force of the whirlwind. In the vicinity of water-spouts the wind is subject to fly all round in sudden gusts, rendering it prudent for ships to take in their square sails.

When a whirlwind happens on land, all the light substances on the surface of the earth within its course are carried up in a spiral motion by it. I have observed one pass over Canton River, in which the water ascended like a water-spout at sea, and some of the ships that were moored near its path were suddenly turned round by its influence. After passing over the river, it was observed to strip many trees of their leaves, which, with the light covering of some of the houses or sheds, it carried up a considerable way into the atmosphere.

THE MARINE BAROMETER is a very useful instrument, especially in high latitudes, in assisting navigators to anticipate approaching storms. Previous to a hard gale of wind, there is generally a great fall of the mercury, and even near the tropics, the fall of it before a storm or hurricane is usually considerable. Within 9° or 10° of the Equator, there seldom or never is a hurricane or storm of long duration; but whirlwinds, and hard squalls of a few hours' continuance, are sometimes experienced within these parallels, without any fall of the mercury. Indeed, the barometer is of little use as a guide in prognosticating storms which may happen within the tropics; except that before a severe hurricane there is often a considerable fall of the mercury, when the latitude is not less than 14° or 15° N. or S.

In high latitudes, the motion of the mercury in the barometer, like the winds, is mutable and uncertain; but previous to a storm or gale of wind, there is commonly a great fall, and the mercury begins to rise before the conclusion of the gale, sometimes even at its commencement, as the equilibrium in the atmosphere begins to be restored.

Although the mercury sinks lowest before high winds, it frequently sinks considerably before a heavy fall of rain; and when the mercury stands low, the air is light, and deprived of expansibility or elasticity, therefore not capable of supporting much gaseous moisture: at such periods, consequently, rain generally falls. The mercury also sinks on the approach of thunder and lightning, or when the atmosphere is highly charged with electric matter.

In serene settled weather, the mercury commonly stands high, also in clear frosty weather. The mercury, in the open sea, is generally inclined to rise with Easterly, and fall with Westerly winds. It is likewise necessary to remember, that in the N. hemisphere, in the open sea, the mercury rises with Northerly and falls with Southerly winds; because the former, coming from the frozen parts near the pole, are more dense than the latter, which blow from the equatorial regions. In the S. hemisphere, the contrary takes place, for there the mercury rises with the cold Southerly winds, and falls with Northerly winds. These effects are more particularly observed in high latitudes in the ocean, for obstructions and irregularities will always happen near land; because there, the rarefaction and expansibility of the atmosphere are not so equal as over the ocean. After very warm and calm weather, in winter particularly, a storm is likely to follow; or at any time that the atmosphere is greatly heated above the medium temperature.

It is proper to observe, that in the open ocean between the tropics, in settled weather, there is a *flux* and *reflux* in the atmosphere *twice* every 24 hours, resembling the tides of the sea; but these atmospheric tides depend upon the sun's influence and the rotation of the earth, and do not follow the motion of the moon. The rise and fall of the mercury, in consequence of these tides, is about 6 or 7 hundredths of an inch, in settled weather, near the Equator; the high station happening about 10 o'clock in the morning and 10 o'clock at night, and the low station about 4 o'clock in the morning and evening. The regularity of this flux and reflux of the atmosphere is obstructed by land, but in the ocean it prevails to lat. 26° North and South; and in fine steady weather it may be perceived as far as lat. 30° or 32° North or South.

By proper attention to the barometer, the experienced navigator may often be enabled to anticipate changes of weather; and, in some seas, he may by its indications even take in or let out reefs in the night.

The LUMINOUS APPEARANCE of the SEA, which frequently happens, more particularly between the tropics, or near them, in different parts of the globe, is produced from various causes, not generally known to navigators; although it has been noticed by Aristotle and Pliny, and by several naturalists in different ages since their time. Various kinds of marine animals emit light, but although the luminous appearance of the sea is generally produced by living animals, nevertheless some kinds of dead matter seem to give it a similar aspect at times; such as the exuviæ of fishes, or putrefactions. I have sometimes carefully examined the water of the sea when it was luminous, and could not discern any animation, but it appeared only to contain small particles of matter of a *dusky straw-colour*, which dissolved with the slightest touch of the finger; at other times the sea was evidently illuminated by small sparkling animals.

A peculiar phenomenon is sometimes seen in the Banda Sea, and other parts of the Eastern seas; and particularly in the Arabian Sea, between the east coast of Africa and the coast of Malabar, during the rainy monsoon. This I had an opportunity of observing at midnight, when the weather was cloudy, and the sea particularly dark; but it suddenly changed to a white flaming colour all round. This phenomenon bore no resemblance to the sparkling or glowing appearance, observed on other occasions in seas near the Equator, but the sea was of a splendid colour, white as milk, which did not continue more than ten minutes, when it resumed its former darkness. This singular phenomenon has been also observed by several persons near the Malabar Coast, and in other parts, and it appears to be in a great degree elucidated by the observations of Mr. Langstaff, made in a passage from Port Jackson toward China. About half an hour after sunset, the sea changed to milky appearance, and the ship seemed to be surrounded by ice covered with snow. A bucket of water being hauled up, and examined in the dark, a great number of globular bodies were discovered, *linked together*, each about the size of a pin's head, the chains thus formed did not exceed three inches in length, and emitted a pale phosphoric light. This extraordinary appearance of the sea was visible two nights: but as soon as the moon exerted her influence, the sea resumed its natural dark colour, and exhibited *distinct glittering spots*, as at other times. Mr. Langstaff's observations seem to show that the diffused light of the sea is produced by an assemblage of minute medusæ on the surface of the water.

The surface of the sea is usually more subject to be luminous after long calms and sultry weather than at any other time; for then it abounds with minute medusæ and small marine animals, generated in calm weather, which render it foetid both to the smell and taste. At such times the sea becomes easily illuminated by the least disturbance of a squall, or anything that produces agitation or friction on its surface. The porpoise, dolphin, dorado, and other fishes, therefore, often reflect a vivid light when swimming near the surface, which has induced some persons to ascribe the property of emitting light to several fishes; but upon close examination, the bodies of those fishes were found to be covered with minute spherical particles, which adhere to their surface, apparently the same that illuminated the whole of the sea at the time, and in all probability were a minute kind of medusæ.

A beautiful illumination of the surface of the sea is sometimes reflected from the broken water or waves at the head of a ship, occasioned by her velocity through the fluid, when it abounds with those animals which emit light. Once I perceived a splendid instance of this kind near the Equator, when the quantity of gleaming light reflected from the waves under the weather bow of the ship, against the white fore-sail, was sufficient to enable me to read any pages of a book, if not printed with a very small type, although the night was otherwise dark at the time.

The TEMPERATURE of the SEA is a phenomenon hitherto but little investigated, although it appears to be closely connected with the improvement of nautical science. It used to be thought that the temperature of the ocean was subject to little variation, particularly between the tropics; the temperature of its surface, however, is affected by changes of the superincumbent atmosphere, as well as by other local or adventitious causes.

1st. When the atmosphere has a low temperature, a portion of its cold is imparted to the surface of the ocean, by which the temperature of the water is diminished.

2nd. Tempestuous weather raises the temperature of the sea: an effect which is *probably* produced by the agitation or friction of the broken waves, the particles of water rubbing against each other.

3rd. Currents have a more powerful influence than any other cause in changing the temperature of the surface of the ocean; and it may be here observed, that the same rule is applicable in this case as that already stated in regard to winds, under the articles *Trade Winds* and *Marine Barometer*; viz., That in either hemisphere a current proceeding from the cold polar regions towards the Equator, diminishes the temperature of the sea; whereas a current running from the inter-tropical regions towards either pole, raises its temperature. It is surprising how long the great bodies of currents preserve their original temperature: that known by the name of the Gulf Stream loses only two degrees of its original warmth in running 1,300 miles into a cooler climate, it being 81° in summer in lat. 39° N.; and in passing the bank of Newfoundland, it is several degrees warmer than the sea in its vicinity; *thus* the experienced navigator is enabled to ascertain when he gets into the Gulf Stream, merely by drawing a bucket of water and feeling its temperature.

In calm and settled weather, the temperature of the sea was found by Dr. John Davy to reach its maximum about one or two hours after noon, and its minimum about sunrise. Were the temperature of the sea, as well as that of the atmosphere, conjointly registered in the journals of navigators, several times every twenty-four hours, it would assist greatly the improvement of nautical science; and the proximity of land or shoal banks might *probably* be ascertained by carefully observing the temperature of the sea.

The late Captain J. P. Wilson, of the Company's ship *Hythe*, a very scientific officer, ascertained by careful observation, that the temperature of the *central* part of the stream of Westerly current which prevails along the verge of Cape Agulhas Bank, is about 8° or 9° higher than that of the sea beyond the limits of the stream of current; and as the maximum of temperature is in the middle of the stream of current, a ship may be kept in it, by attending to changes of temperature in the surface water, and thereby be enabled to accelerate her progress to the westward during adverse winds.

TERRESTRIAL MAGNETISM.

Terrestrial Magnetism is one of the phenomena of nature that for a considerable time has received much and deserved attention at the hands of science; and although the time appears distant at which the true physical theory may be established, still the mass of observations accumulated during the last quarter of a century have laid a secure foundation for this great object. The magnetic condition of our globe is manifested at its surface by the three elements known as the *Variation, Dip*, and *Intensity*:—the two former terms are, however, seldom used in scientific discussions, having given way to the modern appellations of *Magnetic Declination* and *Inclination*. The original and more simple names, which are familiar to every sailor, are retained in this brief treatise.

Magnetic Variation is the amount by which the pointing of the compass needle varies horizontally from the true geographical North. The **Magnetic Dip** is the angle of inclination to the horizon of a freely suspended needle, not limited in motion only to the horizontal plane, as is the compass needle. The **Intensity** is the amount of magnetic force acting on the freely suspended needle, and giving it its direction:—for convenience, this element may be resolved into two components, one acting in the horizontal, the other in a vertical direction. The forces are then distinguished as the Total or Absolute, Horizontal and Vertical.

The changes to which the earth's magnetism is subject, are classed as *periodical*, *secular*, and *irregular*. The **periodical changes** are denoted by certain regular movements of the needle occurring in short intervals; as, for example, the diurnal changes of the Variation, amounting in Europe to 12′ or 15′, and apparently governed by the sun whilst above the horizon at any place. The **secular changes** are either slowly progressive, or run through a certain course, the elements returning finally to their former values, in periods of great and uncertain magnitude; thus, between the years 1657 and 1660, the compass needle at London did not sensibly deviate from the true meridian; in 1665 the direction was about 1½° W. of the meridian, and this Westerly Variation went on increasing to the year 1818, when the maximum, 24° 21′ was attained, since which time the needle has been gradually approaching the true meridian, and was in the year 1863, about 20° 50′ W. The **irregular changes** are such as *apparently* follow no uniform course, and are uncontrolled by any law. The most remarkable of these changes are known as "*magnetic disturbances*, or *storms*," during which the needle is affected by a shivering motion, and oscillates largely on either side of its mean position. These perturbations manifest themselves often simultaneously over land and sea, embracing vast areas: one of the most remarkable (Sept. 25th, 1841) was observed at Toronto in Canada, at Prague, the Cape of Good Hope, and at Van Diemen's Land.

Our countryman Halley was the first person who appears to have taken a correct view of the system of terrestrial magnetism; he considered that the variation and dip of the needle could not be consistently accounted for on the supposition of the earth having only one magnetic axis and two magnetic poles, and inferred that two magnetic poles must exist in each hemisphere of the globe,—the one fixed and the other in motion,—in order to account for the discordant magnetic changes. To Halley we are also indebted for the earliest variation chart, published in 1701, on his return from a voyage in the Atlantic Ocean in a ship of war furnished by William III. Collecting a large number of observations, he marked on a chart of the world all those places where the magnetic and true meridians coincided, and connecting them by a line, obtained the curve, or line of no variation; pursuing a similar course for those places where the angular differences between the magnetic and true meridians were equal in amount, the courses and system of the variation lines were clearly traced out. Halley's variation chart underwent revision in 1744 and 1756-7, and since that time various others have been contributed by men of science; later productions comprehend also the Dip and Intensity, and are therefore, properly, general magnetic charts.

A variation chart of the world for the epoch 1858, by Frederick J. Evans, Master R.N., F.R.S., was published by the Hydrographic Office, and revised editions have followed to the present year; it has no equal. This chart is especially used for the navigation of iron-built ships, as the seaman, by observing azimuths of the sun, or other heavenly body, and comparing the variation of his compass so determined, with the known variation of the chart, can detect any changes in the deviation of the compass. The Admiralty Manual of the Deviation of the Compass* comprises charts of the lines of equal dip and equal horizontal intensity.

The Variation of the Needle, as before alluded to, is in most parts of the globe undergoing continual change, partaking of an *annual* as well as a *diurnal* variation. The latter follows a general law in either hemisphere: in the N., the movement of the N. pole of the needle from about 8 A.M. to 1 P.M. is from E. to W.; it then becomes stationary, and with a slow motion retrogrades to the E., arriving at the original point about 10 P.M., a smaller oscillation being observed during the night; the movement in the S. hemisphere is reversed in direction. The amount in angular value varies in different latitudes, and according to the seasons; in Northern Europe it attains 15′ or 17′. **The annual change** varies in different regions; at the present time in Great Britain the average decrease is about 7′. On the E. coasts of America, nearly in the same parallel, it appears to be increasing by a similar amount. At Bombay, Madras, and in Eastern India generally, the annual changes are remarkably small, whilst in the Red Sea the annual decrease during the present century has averaged 4 to 5 minutes.

* As an introduction and companion to the Admiralty Manual, we strongly recommend Staff-Captain Evans' Elementary Manual for the Deviations of the Compass in Iron Ships. Published by J. D. Potter, 31, Poultry, and at 11, King Street, Tower Hill, London.

TABLE

Of the Variation of Compass at different epochs, for a few places within the limits of this work, appended as an instructive example of secular changes.

Place	Year	°	′
London	1580	11	17 E.
	1622	6	12 E.
	1662	0	0
	1720	13	0 W.
	1760	19	30 W.
	1806	24	8 W.
	1818	24	41 W. Max.
	1831	24	0 W.
	1845	22	55 W.
	1863	20	50 W.
St. Helena	1691	1	0 W.
	1793	15	28 W.
	1815	17	30 W.
	1824	19	34 W.
	1845	23	28 W.
Cape of Good Hope	1609	0	12 W.
	1702	12	50 W.
	1724	16	27 W.
	1792	24	30 W.
	1841	29	7 W.
	1850	29	20 W.
	1857	29	34 W.
Mauritius	1805	11	42 W.
	1813	16	40 W.
	1824	13	46 W.
	1836	11	18 W.
	1858	9	45 W.
Bombay	1722	5	7 W.
	1751	5	12 W.
	1817	0	0
	1859	0	20 E.
Maskat	1728	10	30 W.
	1785	6	0 W.
	1824	2	7 W.
	1858	0	40 W.
Bushire	1765	7	30 W.
	1786	7	15 W.
	1827	4	12 W.
	1857	1	15 W.
Aden	1723	13	50 W.
	1800	8	49 W.
	1857	4	20 W.
Macao	1616	1	30 W.
	1779	0	32 W.
	1841	0	35 E.
Sydney, New South Wales	1793	8	46 E.
	1813	8	47 E.
	1824	8	56 E.
	1843	9	44 E.
	1849	10	9 E.

The Dip of the Needle engages but little the attention of seamen, though it is familiar to them that the compass needle does not retain its horizontality on great changes of latitude, excepting through the medium of *adjusting weights*. As the dip is an important element in the consideration of the changes of the magnetic condition of all vessels, whether wood or iron built, a brief account of its nature and distribution is added. It has been already observed that the term **magnetic poles** is applied to those positions on the surface of the earth where the horizontal force disappears and a freely suspended needle becomes vertical; the end of the needle which points downward in one hemisphere pointing upward in the other. In like manner the term **magnetic equator** is applied to those places where the needle has no inclination or dip, but rests in a horizontal direction; this line of no dip is irregular, cutting the geographical Equator in two points, one on the meridian of Greenwich, and the other in about 170° E. longitude.

The dip increases gradually on either side of the magnetic Equator, and the lines of equal amount are nearly parallel to it till within the vicinity of the magnetic poles. A ship sailing along one of the lines of equal dip, is said to remain in the same magnetic latitude, and she changes her magnetic latitude most rapidly when her course is at right angles to those lines.

The dip, like the variation, is subject to secular change; the annual decrease in the British Islands, and over a great part of Europe, has averaged for several years past, about 3′; in the South Atlantic Ocean it is increasing 6′ annually; the hourly variation is very small.

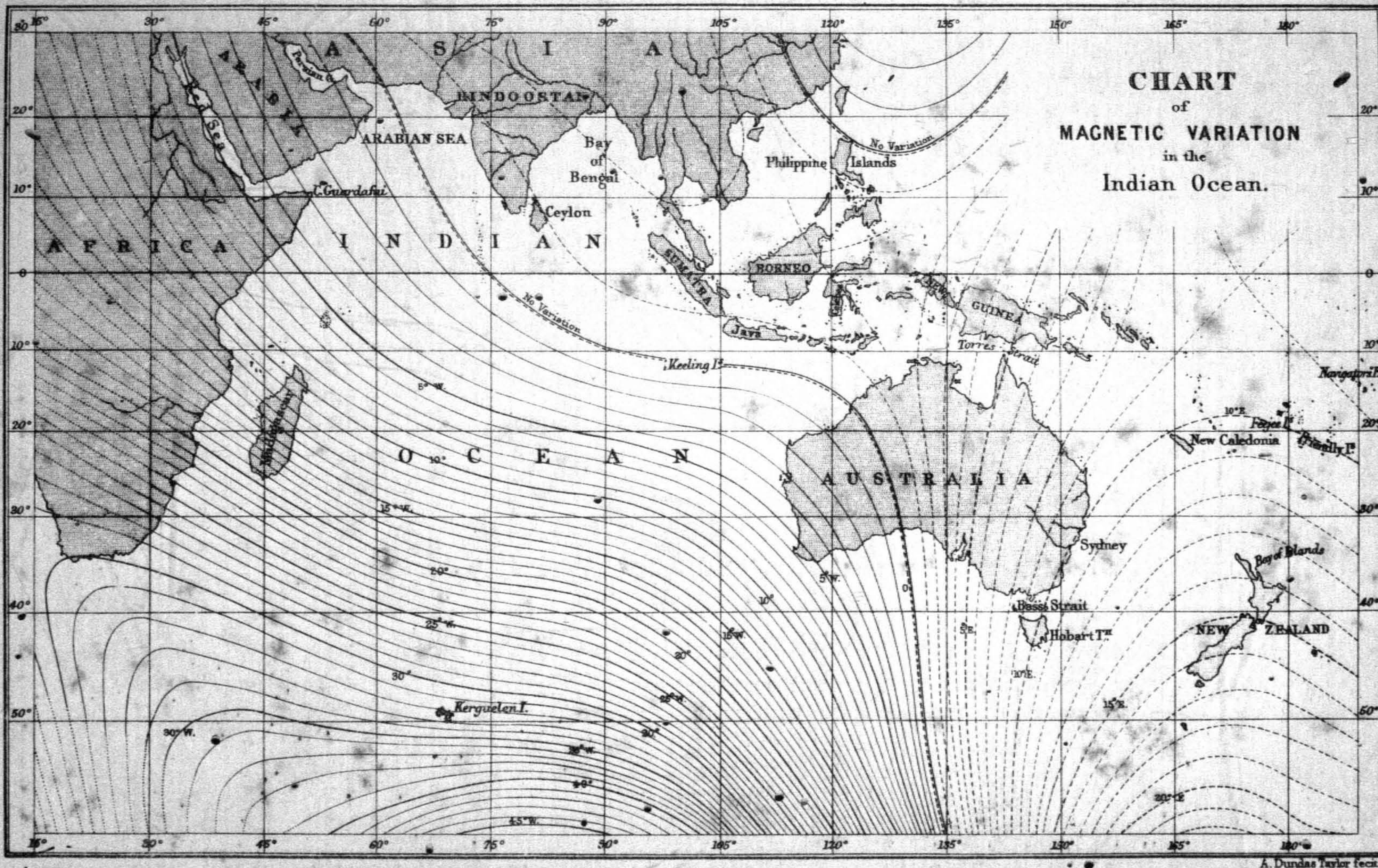
CHART
of
MAGNETIC VARIATION
in the
Indian Ocean.
ASIA
ARABIA
Persian G.
Red Sea
HINDOOSTAN
ARABIAN SEA
Bay of Bengal
C. Guardafui
Ceylon
Philippine Islands
No Variation
AFRICA
INDIAN
OCEAN
SUMATRA
BORNEO
NEW GUINEA
Java
Torres Strait
Keeling I.
Madagascar
AUSTRALIA
New Caledonia
Feejee I.
Friendly I.
Navigators I.
Sydney
Bay of Islands
Bass Strait
Hobart T.
NEW ZEALAND
Kerguelen I.
A. Dundas Taylor fecit.

Subjoined is the amount of dip (1859) at several stations within the limits of this work:—

	° ′		° ′		° ′
London...............	68 35 N.	St. Helena	23 17 S.	Singapore	13 18 S.
Cape de Verde Islands	45 0 N.	Cape of Good Hope	54 30 S.	Sydney, N. S. W..	62 45 S.
Ascension...........	1 30 N.	Mauritius	54 0 S.	Hobarton	70 36 S.
Rio de Janeiro......	12 30 S.	Bombay	19 15 S.		

Having thus briefly noticed those principles and elements of terrestrial magnetism necessary for a correct appreciation of so important a branch of knowledge, it will be necessary to direct the seaman's attention to the immediate practical subject of the *local attraction*, or, in other words, the deviation of the compass caused by the iron in a ship.

The DEVIATION of the COMPASS is a subject which of late years has received ample attention from our most celebrated navigators, mathematicians, and men of science: of the former, Flinders, Parry, James Ross, Fitzroy, and Scoresby, must be especially noted; whilst the labours of Airy, Sabine, Harris, Johnson, and A. Smith, in the field of theory, have given the subject a popular and practical direction.

The uncertainty of the amount of local deviation in a ship, and the necessity of determining or making compensation for its amount, are facts now so universally admitted, that it is unnecessary to adduce proofs, or to direct attention to the disastrous consequences of its neglect. But before giving the best practical methods for determining the amount and its application, it is well to offer a few general propositions, based on observation and experiment, and to explain the varying character of local deviation, and its dependence on certain magnetic laws.

1st. That the compasses of all ships, whether built of wood or iron, are liable to a greater or less degree of deviation; but that, in iron ships generally, larger deviations and more variable conditions exist. The most remarkable of these conditions are, that in iron built ships the neutral points approximate to those points of the compass to which the ship's head and stern were directed in building, the deviation being Easterly when *the part of the ship which was S. in building* is E., and Westerly when it is W. It follows from this that in an iron ship built head North, the deviations will be *Westerly* when the ship's head is to the E., and *Easterly* when the ship's head is to the W. This being opposite to what is generally found in wood-built ships in N. latitudes is often a source of perplexity to the seaman.

2nd. That the amount of deviation in one ship is no guide to the amount in another vessel.

3rd. That these errors are subject to change, on a change of geographic position, but especially of magnetic latitude; and may change, from extraneous circumstances, without a change of latitude.

4th. The changes which the deviations undergo on a change of geographic position differ according to the structure of the vessel. In wooden vessels the deviations are dependent on the amount of the magnetic dip (varying directly as its *tangent*), diminishing as the magnetic Equator is approached, and change their direction on attaining a S. magnetic latitude; the deviations do not however vanish in changing from the one direction to the other, but near the magnetic Equator have four zero points when the ship's head is on or near the magnetic cardinal points, two Easterly maxima when on or near N.E. or S.W., and two Westerly maxima when on or near S.E. and N.W. In iron vessels, where the standard or azimuth compass is in a position removed from vertical bars or masses of iron, the change is dependent on the changes of the earth's magnetic *horizontal* force (varying *inversely* as the horizontal force), in addition to the dip; as the influence, however, of the first of these elements preponderates in most vessels, the deviations generally retain the same direction in both hemispheres, though varying in amount.

5th. Experience has also shown that the deviations in iron vessels are affected by the *heeling* of the ship; the magnitude of the error so resulting depending on the amount of heel, and to some extent on the value of the deviations observed while the ship was on an even keel, as also on the original direction of the ship's head in building; but in general the *maximum* disturbance (or *List-deviation*) when heeling will be found when the ship's head is *North* or *South* by the observing compass, the disturbance vanishing when the ship's head is *East* or *West* by the observing compass.

Explanation.—The iron entering into the composition of a vessel and her fittings varies between the two conditions of hard and soft: in wooden vessels the soft predominates; in iron ships we have hard iron in the rolled and hammered plates forming the hull.

Soft iron becomes instantly magnetic by *induction*, (or is *induced* to become magnetic), when exposed to the influence of the earth or any other magnetic body, and as quickly loses its magnetism when the influence is removed. Hard iron does not, under ordinary circumstances, become magnetic by induction; but when magnetized, it *retains* the magnetic power even after the influencing body is removed: its magnetism has therefore received the term "*permanent*," whilst that of soft iron has received the term "*induced*."*

It will be readily conceived that much of the iron of a ship must be in an intermediate state, between the two extremes of "hard" and "soft;" the magnetism of this portion has been named "*sub-permanent*," or "*retentive*," and the condition of this magnetism appears to be that it is liable to change from blows, or straining of the vessel, as also slowly and gradually when the vessel changes her magnetic latitude.

The nature of the change in the deviation produced by the *permanent* and *induced* magnetism respectively, on a change of magnetic latitude, is this:—"The first varies inversely as the horizontal force; the second varies as the tangent of the dip; their changes in different magnetic latitudes may be thus described: at a magnetic pole of the earth, when the dip is 90°, and the horizontal force zero, each part becomes infinite:—this indicates that there is then no directive force.

"For some distance from the magnetic pole, the two parts change nearly at the same rate, and therefore the whole varies nearly as the tangent of the dip. But as we approach the magnetic equator, the part which arises from the soft iron diminishes the most rapidly. It becomes zero at the Equator, and in S. magnetic latitudes has the *same* value as in corresponding N. magnetic latitudes, but the *opposite* sign. The part which arises from the hard iron does not become zero at the magnetic equator, but becomes a minimum at that line, nearly coincident with the magnetic equator, at which the horizontal force is a maximum, and in S. magnetic latitudes it has the same sign and nearly the same value as in N. latitudes.

"If the hypothesis that all the iron is perfectly hard or perfectly soft were strictly true, it would be possible by observations made in any two magnetic latitudes to determine the values of the two parts separately. But, in fact, this is impossible. The *sub-permanent* or *retentive* magnetism, causes the changes in the magnetism of a ship to depend not only on the place at which the ship is, but on the places in which she has been for some preceding days or weeks; her magnetism being thus in arrear of its theoretical amount, to an extent which there appears to be no means of estimating."

It has been established by recent investigations, that a change takes place in a newly-launched iron vessel, even without a change of magnetic latitude; but generally that after a few months' sea service, no further change of any importance takes place without a change of magnetic latitude.

Mechanical Correction. From the preceding details it is evident that the question of the deviation of the compass is very complicated, and hence the unceasing experiments and investigations to neutralize its causes by *mechanical correction*, or (in other words) employing an antagonistic influence to the iron of the ship. The general method now adopted in the mercantile navy is that introduced by the Astronomer Royal, G. B. Airy, who, from the year 1838 to the present time, has been engaged in its discussion. He considers that the deviation of the compass may be accurately corrected by placing a magnet in an *athwart-ship* direction, fixed at a distance determined by trial, for correcting the deviation when the ship's head is N. or S; by a magnet in a *fore-and-aft* direction, also at a distance determined by trial, for correcting the deviation when the ship's head is E. or W.; and by a mass of *unmagnetized iron*, at the same level as the compass, in the athwart-ship line, or in the fore-and-aft line, according to circumstances (usually in the former), also at a distance determined by trial, for correcting the deviation when the ship's head is N.E., S.E., S.W., or N.W.

The Magnets are here employed to correct that portion of the error known as the "polar-magnet," or "semicircular" deviation (or that arising from the *permanent* magnetism of the hard iron, and that *induced* by the vertical part of the earth's force in the soft iron), and the unmagnetized iron to correct the "quadrantal" deviation, or that due alone to the transient magnetism *induced* in the soft iron by the horizontal part of the earth's force.

* To render this term clear, we subjoin the following description from the *Admiralty Manual*:—The action of the earth on the N. end of the needle, is exerted in the direction called the *line of force*. This is the direction of the dipping-needle, viz., towards the magnetic N., but inclined to the horizon at an angle equal to the magnetic dip at the place—in England about 70° below the horizon.—A rod of soft iron held in the direction of the dip becomes instantly magnetic. Its S. (in England the *upper*) end becomes a S. pole, and attracts the N. end of the compass needle; its N. (in England the *lower*) end becomes a N. pole, and repels it. If the rod be inclined to the line of force, its magnetism diminishes, and when at right angles to the line of force the bar ceases to be magnetic. If the inclination of the bar to the line of force be still further increased, the end which was a N. pole, and which then repelled the N. end of the needle, becomes a S. pole, and attracts it. It follows from this, that if a rod of soft iron be in a vertical position, its upper end will in N. magnetic latitude attract the N. end of the compass needle. At the magnetic equator, the line of force of the earth is horizontal, and there a vertical rod of soft iron will not be magnetic. In S. magnetic latitudes, the line of force of the earth is inclined upwards; and in these latitudes the upper end of a vertical bar of soft iron will repel the N. end of a compass needle, and attract the S. end.

The unmagnetized iron, when adjusted, produces its due effect at all parts of the world, without ever requiring change, and the quadrantal deviation is considered thus permanently corrected. The elements of polar-magnet deviation are of course liable to changes on a change of magnetic latitude, as already noticed; but these changes may be corrected by *re-adjusting* the position of the magnets, *leaving the unmagnetized iron undisturbed*, and that the change (if there is any) in the intensity of the correcting magnets will also be corrected as to its effect on the compass by the same re-adjustment of position. For more complete detail on the subject of compensation, we must refer to Mr. Airy's valuable discussions, given in the *Philosophical Transactions* for 1839 and 1855, as also to the Reports of the Liverpool Compass Committee, 1857-61.

Many practical authorities are averse to the correction (by magnets and soft iron) of the *Standard* compass of the ship; but, from the great amount of disturbing force to which *steering* compasses are from their position generally exposed, this mechanical correction is, doubtless, for them very desirable; compasses so corrected should however never be considered as entirely compensated, but that their deviations require verification as frequently as practicable.

RULES FOR ASCERTAINING AND APPLYING THE DEVIATIONS OF COMPASS CAUSED BY THE IRON IN A SHIP.

1. Every ship should be provided with a good azimuth compass, which may be called the *Standard* compass. It should be fixed on a permanent pillar, and at such a height as to permit amplitudes and bearings to be observed with it over the bulwarks; and be also carefully placed on the mid-ship line of the quarter-deck or poop, as convenient, and as far as possible from any considerable mass of iron, such as the spindle of the capstan, chain-rigging, iron davits, &c.; and care also observed in placing the *lubber-line* directly in a fore-and-aft line of the ship.

2. In iron-built vessels, it is desirable that all the compasses, but more especially the Standard compass, should be raised much higher than usual above the deck; and the latter fitted so as to be readily consulted.

3. When the ship is ready for sea, with all her iron stores on board, and stowed in their proper places, as well as the moveable iron-work secured in the positions in which it is intended to remain at sea, then the deviation of the Standard compass from the correct magnetic meridian is to be ascertained by either of the following means: viz., by the bearing of a distant and well-defined object, or by a series of reciprocal observations. In general the former is most convenient, as requiring only one observer; and advantage can be taken of the ship *tending* to tides or winds, where time will permit, instead of employing hawsers.

To ascertain the deviations by bearing of a distant object. 1. The object selected for that purpose, should be at such a distance from the ship that the diameter of the space through which she swings shall make no sensible difference in its real bearing: thus, if at an anchor with a long scope of cable, a distance not less than from 6 to 8 m. would suffice; if at moorings or in a basin, half that distance would be sufficient.

2. If warps are employed, the ship is to be gradually swung, so as to bring her head successively on *each point* of the compass; and when steady, and after a gentle tapping of the compass-bowl to insure free action of the needle, the bearing of the selected object is to be observed and registered. If time presses, 16, or even 8 points, will suffice; but in the latter case, it is advisable to obtain the cardinal and intermediate points.

3. The real or correct magnetic bearing of the selected object from the ship must then be determined. By the term "real or *correct* magnetic bearing" is meant, that which the compass would have given on every point, had it not been disturbed by the local attraction of the ship. This may be generally effected by taking a mean of all the bearings: but a surer result will be obtained by carrying the Standard compass to the adjacent shore, in a position in a direct line between the ship (that part where the compass stood) and the distant object; the bearing of the latter will evidently be the same as its correct magnetic bearing from the ship.

Care however must be taken that the compass is not placed on *trap* (volcanic and igneous) rocks, or exposed to the influence of masses of iron, such as buried anchors, gas-pipes, or any collection of iron articles in adjoining storehouses.

The *correct* magnetic bearing of the distant object may also be determined by obtaining from the ship its astronomical bearing, and applying the variation to it,—that element being deduced from a variation chart, or else determined on shore in the neighbourhood of the ship's position.

4. The difference between the correct magnetic bearing of the distant object, and the successive bearings of it which were observed with the Standard compass on board, when the ship's head was

on each of the several points, will show the error at each of those points which was caused by the ship's iron; or, in other words, the *deviation* of the Standard compass.

5. The deviation thus found is named *East* when the N. end of the needle is drawn to the E., or *right* hand, and *West* when it is drawn to the W., or *left* hand of the magnetic meridian. As every seaman is familiar with the terms *East* and *West Variation*, it appears only necessary to point out that the terms *East* and *West* deviations are precisely analagous, and may be thus illustrated. A ship is off the Lizard, where the variation is 24° W.; with her head W.S.W., she has a *West deviation* of 6°; and with her head E.N.E., an *East deviation* of 7°; in the former case, with her head W.S.W., the variation and deviation being of the *same* name, may be treated as an actual variation on board of 30° W.; and in the latter case, with her head E.N.E., the variation and deviation being of *different* names, may be treated as a variation of only 17° W. Were seamen to consider the similarity of the terms deviation and variation, and the simplicity in using them combined, when convenient to do so, much of the misapprehension and mistakes which frequently occur in practice would be obviated.

To ascertain deviations by reciprocal bearings. 1. A careful observer must go on shore with a second compass, and place it on its stand or tripod in some open spot, under the conditions of being free from local influences as before noticed, and where it may be distinctly seen from the compass on board.

2. By means of *preconcerted* signals, the mutual bearings of the shore and ship's Standard compass from each other are to be observed at the moment the ship's head is steadily on each of the successive points of the compass. The observations should be *simultaneously* made as strictly as possible; and to guard against signals being misinterpreted, the time at which each bearing is taken should be noted, both on shore and on board, by compared watches.

3. Before, if convenient, or after the process is completed, the Standard compass should be carried on shore, in order to be compared with the compass which had been employed there, by means of the bearing of some distant object; and the difference (if any) is to be recorded, in order to correct or reduce the shore bearings to what they would have been had the ship's Standard compass been so employed. And in all cases when compasses are compared, the caps, pivots, &c., should first be carefully examined.

The following forms will be found convenient for registering the two processes of ascertaining the deviations:—

FORM 1.—BY BEARING OF A DISTANT OBJECT.

Observations to determine the effect of Ship's Iron on the Standard Compass of Ship "Perseverance," in the River Thames, 1st June, 1863. The correct Magnetic Bearing of a Church Steeple from the Ship, being N. 50° E. 8 *miles distant.*

Ship's Head by the Standard Compass.	Bearing of Steeple by the Standard Compass.	Deviation of the Standard Compass.	Ship's Head by the Standard Compass.	Bearing of Steeple by the Standard Compass.	Deviation of the Standard Compass.
	° ′	° ′		° ′	° ′
North.	N. 45 10 E.	4 50 E.	South.	N. 55 10 E.	5 10 W.
N. by E.	42 25	7 35 ,,	S. by W.	58 0	8 0 ,,
N.N.E.	40 25	9 35 ,,	S.S.W.	60 40	10 40 ,,
N.E. by N.	39 30	10 30 ,,	S.W. by S.	62 20	12 20 ,,
N.E.	38 50	11 10 ,,	S.W.	63 15	13 15 ,,
N.E. by E.	38 20	11 40 ,,	S.W. by W.	64 40	14 40 ,,
E.N.E.	36 45	13 15 ,,	W.S.W.	64 35	14 35 ,,
E. by N.	35 50	14 10 ,,	W. by S.	63 45	13 45 ,,
East.	35 30	14 30 ,,	West.	63 15	13 15 ,,
E. by S.	37 45	12 15 ,,	W. by N.	60 30	10 30 ,,
E.S.E.	40 0	10 0 ,,	W.N.W.	59 55	9 55 ,,
S.E. by E.	41 25	8 35 ,,	N.W. by W.	58 0	8 0 ,,
S.E.	44 40	5 20 ,,	N.W.	56 20	6 20 ,,
S.E. by S.	47 25	2 35 ,,	N.W. by N.	55 10	5 10 ,,
S.S.E	50 15	0 15 W.	N.N.W.	52 40	2 40 ,,
S. by E.	54 50	4 50 ,,	N. by W.	49 20	0 40 E.

FORM 2.—BY RECIPROCAL BEARINGS.

Observations to determine the effects of Ship's Iron on the Standard Compass of Ship "Perseverance," made at Greenhithe, River Thames, 1st June, 1863.

[*Note.*—The Standard, and an azimuth compass were taken on shore, and compared by observing the bearing of a distant object with each compass, the two compasses being twelve feet apart, in order to prevent their having influence on each other. The bearings, by the means of several repetitions, were found to agree. The azimuth compass was retained on shore, and the Standard compass replaced on board.]

Time.		Ship's Head by the Standard Compass.	Bearing of the Shore Compass from the Standard Compass.			Bearing of the Standard Compass from the Compass on Shore.			Deviation of the Standard Compass.		
A.	M.		°	′		°	′		°	′	
9	20	E.S.E.	N. 76	0	W.	S. 66	0	E.	10	0	E.
9	24	S.E. by E.	75	10		66	35		8	35	„
9	30	S.E.	73	0		67	40		5	20	„
9	40	S.E. by S.	71	10		68	35		2	35	„
9	45	S.S.E.	69	0		69	15		0	15	W.
9	48	S. by E.	64	50		69	40		4	50	„
9	51	South.	64	30		69	40		5	10	„
9	55	S. by W.	61	50		69	50		8	0	„
10	0	S.S.W.	58	20		69	0		10	40	„
		*									

* And in like manner at all the points of the Compass.

It has been already stated that the terms *East and West deviation* are precisely analogous to that of *East and West variation*, and therefore, in applying the correction for the deviation to any course or bearing, the seaman must adopt the same method exactly as in the case of applying the variation; that is to say, he is to suppose his eye in the centre of the card, from whence, looking along the point in question, he is to apply the East deviaton to the *right* hand, and the West deviation to the *left* hand.

Example 1.—If ship's head by Standard compass be E.N.E., and deviation (see Table) be 13° 15′ E., then the correct magnetic direction of her head will be 13° 15′ to the *right* hand of E.N.E., or about E ¾ N.

Example 2.—If with the ship's head on the same point as in the foregoing example, the bearings of two islands be S.E. and W. by S. by the Standard compass, then by applying the same correction, 13° 15′ E., and in the same way, the correct magnetic bearing of those two islands will be S. 31° 45′ E., and N. 88° 0′ W., or, roughly, S.S.E. ¾ E., and W. ¼ N.

[This example is instructive as to the *necessity* of stating the direction of the ship's head when bearings are inserted in the log book uncorrected.]

Example 3.—If it be required to steer the vessel on a certain correct magnetic course, and for that purpose to determine what will be the corresponding course by the Standard compass, the above rule must be *reversed.*

Let the proposed correct magnetic course be S.E. The deviation for that point by the Standard compass is 5° 20′ E., which now being applied reversely, or to the *left* of S.E., gives S. 50° 20′ E., or S.E. ½ E. for the *approximate* course to be steered; but to determine the course accurately, the deviation due to this partly corrected course must be employed, instead of that belonging to the proposed course. Referring to the Table, with the approximate course S.E. ½ E., and taking the proportional difference from the half-point, the proper deviation to be allowed will be 7° 0′, which, applied to the left of S.E., gives S. 52° E., or nearly S.E. ¾ E. for the desired course.

[In vessels with a large amount of deviation, where a change of from 3 to 5° between consecutive points is not uncommon, it is necessary to pay due attention to the foregoing example.]

To prevent, however, any mistake in shaping a proper course by the Standard compass, it will be found useful to prepare a Table like the following, where the corrections for deviation have been applied *reversely*, as stated in Example 3, and with the corrections due to the approximate courses; in other words, the proper courses to be steered.

TABLE OF STANDARD COMPASS COURSES,

For Ship "Perseverance," determined in River Thames, England.

Correct Magnetic course proposed to be made.	Course therefore to be steered by Standard Compass in order to make good the proposed correct magnetic course.	Correct Magnetic course proposed to be made.	Course therefore to be steered by Standard Compass in order to make good the proposed correct magnetic course.
	° ′		° ′
North.	N. 3 20 W., or nearly N. ¼ W.	South.	S. 6 50 W., or nearly S. ⅝ W.
N. by E.	5 0 E. „ N. ½ E.	S. by W.	21 35 „ S. by W. ⅞ W
N.N.E.	14 30 „ N. by E. ¼ E.	S.S.W.	34 55 „ S.W. ¾ S.
N.E. by N.	24 5 „ N.N.E. ⅛ E.	S.W. by S.	47 20 „ S.W. ¼ W.
N.E.	34 20 „ N.E. by N.	S.W.	59 40 „ S.W. by W. ¼ W.
N.E. by E.	45 5 „ N.E.	S.W. by W.	70 35 „ W. by S. ¾ S.
E.N.E.	55 50 „ N.E. by E.	W.S.W.	81 0 „ W. ¾ S.
E. by N.	65 50 „ N.E. by E. ⅞ E.	W. by S.	N. 88 25 „ W. ⅛ N.
East.	76 10 „ E. by N. ¼ N.	West.	79 10 „ W. by N.
E. by S.	86 55 „ E. ¼ N.	W. by N.	68 45 „ W. by N. ⅞ N.
E.S.E.	S. 80 5 „ E. ⅞ S.	W.N.W.	59 0 „ N.W. by W. ¼ W.
S.E. by E.	66 5 „ S.E. by E. ⅞ E.	N.W. by W.	49 10 „ N.W. ⅝ W.
S.E.	52 20 „ S.E. ⅝ E.	N.W.	39 15 „ N.W. ½ N.
S.E. by S.	36 55 „ S.E. ¾ S.	N.W. by N.	29 45 „ N.N.W. ⅝ W.
S.S.E.	22 45 „ S.S.E.	N.N.W.	20 30 „ N. by W. ¾ W.
S. by E.	6 15 „ S. ½ E.	N. by W.	11 45 „ N. by W.

This Table should be hung in a convenient and public place, in order that the pilot or officer of the watch may make immediate use of it; but it must be remembered that whenever, by shifting guns or cargo, or by great change of latitude, the deviation of the standard compass is found to vary, a new Table should be immediately constructed. This may be effected at sea by a series of azimuths taken with the ship's head successively on different points, and comparing the variations so determined with the known variation at the place of observation. In any cursory examination, the points of most importance to determine will be those of no deviation, of greatest deviation, and at a few of the intermediate points.

In an iron ship especially, it is always desirable to determine the compass variation by actual observation of the sun's *azimuth* and *amplitude* frequently during the day, whilst at sea; for it must be remembered, that by these means the TWO corrections, viz., for deviation and variation combined, are obtained, and ample warning afforded for any necessity of the reconstruction of the Deviation Table. (*See* Practical Hints about Compasses, page 328.)

It now only remains to add, that the mariner must remember that the corrections found for the Standard compass belong to that compass alone—and to that compass only while in its proper place; and that those corrections will furnish no guide whatever to the effect of the ship's iron on a compass placed in any other part of the ship.

It is essential, therefore, that the ship's course should not only be invariably directed by the Standard compass, but that all the courses and bearings inserted in the log-book should be those shown by that compass alone; the binnacle compass or compasses being regarded solely as a guide to the helmsman: thus, when a ship has been placed on her proper course by Standard compass, the helmsman will notice the point shown by the binnacle compass as being that to which *he* has to attend; and a comparison of the two compasses should be frequently made by the officer of the watch, especially whenever any alteration occurs in the direction of the course.

Graphic Methods. The deviations of the Standard compass are admirably illustrated by graphic methods for their determination and application, published by order of the Lords of the Admiralty, and also by the Board of Trade. Mr. A. Smith's straight-line method will be found a simple and convenient plan for tabulating the results of the observations, and of making the "course" corrections.

We recommend to seamen the adoption of these ingenious aids to the practice of navigation; they are obtainable of J. D. Potter, Admiralty Chart Agent.

REMARKS ON THE TESTING OF COMPASSES.

Accidents happening to steamers plying between England and the East Indies, and generally with a fatal result, have caused the navigation of eastern waters to be looked upon as abnormally dangerous on account of conflicting currents, the charts of these seas to become sadly depreciated, and the compasses, together with the absence of lights, here, there, and almost everywhere, to be spoken of as certain causes of disaster. But is this all the truth? Time was when with inferior compasses and meagre charts, before we knew much of the vagaries of surface-currents, and with never a light-house between Bombay and Suez, the per-centage of casualties was a hundred-fold less than at present. And when we can point to a line of steamers whose career during a quarter of a century has been a great success, and whose officers acknowledge that such success is due to a watchful care over the ship's compasses, we claim to be heard when we affirm that the primary cause of iron steamers getting out of their reckoning is not the mariner's compass merely, but **inattention** on the part of master mariners to the compasses placed in their ships.

Since this volume was made over to the printer's hands, it has been my good fortune to be passenger in more than one steamer under a careful commander. In vessels ably commanded, the compasses receive due attention. *There* nothing is left to chance. but (as already pointed out at page 329), if a considerable change in the vessel's course be imminent, a test is taken of the *existing* deviation on the course about to be steered. Thus all uncertainty will be set aside. It must be remembered, too, that when a ship changes her geographical position *considerably*, and especially when she has passed from one hemisphere to the other, all old tables will be found useless for present purposes, and it becomes indispensable, therefore, that an early opportunity should be taken of forming new tables, by again swinging the ship and ascertaining the actual deviation.

Some short practical examples, as being of most value and the best for ready reference, are here given, to encourage young officers not to neglect their compasses, for neglect is sure to embarrass them in doubt. The careful navigator will never relax his attention, nor suffer his subordinates to do so. When in sight of land the same careful "sights" of all kinds should be taken—to test the chronometer, the compass, and the chart—as are an absolute necessity when out of sight of land, to ascertain the vessel's position. It was said of old that the three essentials to safe navigation were, *Lead*, *Latitude*, and *Look-out*. In these fast days may we not insist upon equal attention being paid to these other three, *Chart*, *Compass*, and *Chronometer?*

The officers of the P. and O. Company have had a longer and more varied experience in the navigation of eastern seas than any other body of seamen, and it is noteworthy that their precautions* against accident are more numerous. The question of "*distance off*," when passing islands, capes, or other landmarks, is not allowed to become a matter of mere guess-work. In their ships the officer of the watch is encouraged to determine distances by the changes of bearing in a certain time. This method—designated the **"four-point bearing"**—consists in noting the exact time when the object is four points on the bow, and again when right abeam. The distance run by the steamer in the interval will be the distance of the object at the second observation, assuming that one course has been maintained during that interval.

The system pursued in the P. and O. vessels with regard to compasses, which is well worthy of being followed by other navigators, is as follows:—

The vagaries of the compass are duly recorded in a form somewhat like that given below. Thus, on each successive voyage, as the vessel (on about the same course) reaches the neighbourhood of her former recorded azimuthal observations, these are repeated and similarly noted in the book. Discrepancies are thus found out, and if there be a doubt of the correctness of the last-taken azimuths, the observations are multiplied.† Thus may the deviations be at any time examined at sea, and their correspondence or otherwise with the tables be ascertained, by a few careful azimuths, with the ship's head successively on different points, and especially on that point or degree which is to be the **next course** she will have to steer.

The secret of the successful navigation of the P. and O. steamers is this—**steering to the degree,**—instead of (as formerly) to *the quarter.point*, by which very rough method you could not *fetch* the exact position required to be reached within a "handful of miles." Quartermasters and helmsmen, both British and Chinese, readily learn and appreciate this new system, to which the monster compass-cards of the present day are admirably adapted.

* To Captain Coleman, of the P. and O. steamer *Mongolia*, I am indebted for much valuable information on all questions touching the navigation of the Indian Ocean, and for ready access to the records of his ship, from which my examples are taken.

† As causes which will be found to produce irregularities, we may mention—the *inertia* of the compass needle on its centre, and the *list* or "heeling" of the ship.

Short Practical Examples.—The P. and O. steamer "*Mongolia*," from India towards England, during March and April, before entering the Red Sea, tested her compasses by placing the ship's head successively on the different courses she would have to steer in the Red Sea. Again, between Aden and Suez, before entering the Mediterranean Sea; a third test between Alexandria and Malta; and lastly, between Gibraltar and Southampton. These examples represent merely a few of those actually taken. The results are tabulated as follows:—

P. AND O. STEAM SHIP, "MONGOLIA," A. COLEMAN, COMMANDER.

Bombay to Aden.

Date and Time.	Lat.	Lon.	Variation of Compass.	Ship's Head, True.	How ascertained.	Ship's Head by Standard Compass.	Difference between True Head and Compass.	Total Deviation.	Remarks.
	N.	E.	W.						
1874. March 27th, A.M.	13° 0′	50° 20′	2° 30′	S. 54° 00 W.	Sun's Azimuth.	S. 60° W.	6° 00′ W.	3° 30′ W.	Ship steady and upright.
				" 62 20 "		" 70 "	7 40 "	5 10 "	
				" 70 24 "		" 80 "	9 36 "	7 6 "	
				" 79 35 "		West.	10 25 "	7 55 "	
				" 87 7 "		N. 80 W.	12 53 "	10 23 "	
				N. 84 5 W.		" 70 "	14 5 "	11 35 "	
				" 73 55 "		" 60 "	13 55 "	11 25 "	

Same Voyage Continued.—Aden to Suez.

Date and Time.	Lat.	Lon.	Variation of Compass.	Ship's Head, True.	How ascertained.	Ship's Head by Standard Compass.	Difference between True Head and Compass.	Total Deviation.	Remarks.
	N.	E.	W.						
1874. March 31st. A.M.	19° 0′	39° 10′	4° 45′	N. 6° 30′ E.	Sun's Azimuth.	N. 10° E.	3° 30′ W.	1° 15′ E.	Ship steady and upright.
				N. 6 20 W.		North	6 20 "	1 35 W.	
				" 18 50 "		N. 10 W.	8 50 "	4 5 "	
				" 30 55 "		" 20 "	10 55 "	6 10 "	
				" 43 15 "		" 30 "	13 15 "	8 30 "	
				" 54 15 "		" 40 "	14 15 "	9 30 "	

Same Homeward Voyage.—Alexandria to Malta.

Date and Time.	Lat.	Lon.	Variation of Compass.	Ship's Head, True.	How ascertained.	Ship's Head by Standard Compass.	Difference between True Head and Compass.	Total Deviation.	Remarks.
	N.	E.	W.						
1874. April 8th. A.M.	32° 40′	26° 20′	7° 30′	N. 79° 45′ W.	Sun's Azimuth.	N. 60° W.	19° 45′ W.	12° 15′ W.	Ship steady.
				" 70 0 "		" 50 "	20 0 "	12 30 "	
				" 59 0 "		" 40 "	19 0 "	11 30 "	
				" 47 15 "		" 30 "	17 15 "	9 45 "	
				" 34 45 "		" 20 "	14 45 "	7 15 "	
				" 21 45 "		" 10 "	11 45 "	4 15 "	
				" 8 15 "		North	8 15 "	0 45 "	

Same Homeward Voyage.—Gibraltar to England.

Date and Time.	Lat.	Lon.	Variation of Compass.	Ship's Head, True.	How ascertained.	Ship's Head by Standard Compass.	Difference between True Head and Compass.	Total Deviation.	Remarks.
	N.	W.	W.						
1874. April 17th. A.M.	36° 25′	7° 30′	19° 30′	N. 62° 0′ W.	Sun's Azimuth.	N. 30° W.	32° 0′ W.	12° 30′ W.	Ship pitching compass rather unsteady.
				" 50 15 "		" 20 "	30 15 "	10 45 "	
				" 37 45 "		" 10 "	27 45 "	8 15 "	
				" 22 30 "		North.	22 30 "	3 0 "	
April 18th. A.M.	39 20	9 45	21 0	" 8 30 "		N. 10 E.	18 30 "	2 30 E.	
				N. 5 15 E.		" 20 "	14 45 "	6 15 "	
				" 17 15 "		" 30 "	12 45 "	8 15 "	
				" 31 0 "		" 40 "	9 0 "	12 0 "	
				" 42 30 "		" 50 "	7 30 "	13 30 "	

Comparison of the foregoing with the following tabulated statement—and it will be noticed that the observations in nearly the same locality, but on different voyages, are placed *abreast* of each other—will show that occasionally the deviation on one course differs 3° or 4° in two successive voyages. It is clear, therefore that old **Deviation Cards** must not be trusted, and that the compasses cannot be too frequently tested.

P. & O. STEAMER "MONGOLIA," A. COLEMAN—COMMANDER.

Bombay to Aden.

Date and Time.	Lat.	Lon.	Variation of Compass	Ship's Head, True.	How ascertained.	Ship's Head by Standard Compass.	Difference between True Head and Compass.	Total Deviation.	Remarks.
	N. ° '	E. ° '	W. ° '	° '		°	°	° '	
1874. June 28th. A.M.	13 50	49 40	2 30	S. 54 30 W.	Sun's Azimuth.	S. 60 W.	5 30 W.	3 0 W.	Ship tolerably steady.
				„ 64 00 „		„ 70 „	6 00 „	3 30 „	
				„ 70 45 „		„ 80 „	9 15 „	6 45 „	
				„ 77 45 „		West	12 15 „	9 45 „	
				„ 86 30 „		N. 80 W.	13 30 „	11 0 „	
				N. 85 30 W.		„ 70 „	15 30 „	13 0 „	
				„ 76 45 „		„ 60 „	16 45 „	14 15 „	

Same Voyage (Continued).—Aden to Suez.

Date and Time.	Lat.	Lon.	Variation of Compass	Ship's Head, True.	How ascertained.	Ship's Head by Standard Compass.	Difference between True Head and Compass.	Total Deviation.	Remarks.
	N. ° '	E. ° '	W. ° '	° '		°	° '	° '	
1874. July 2nd. A.M.	19 30	39 00	5 0	N. 45 0 W.	Sun's Azimuth.	N. 30 W.	15 0 W.	10 0 W.	Ship steady and upright.
				„ 33 15 „		„ 20 „	13 15 „	8 15 „	
				„ 21 45 „		„ 10 „	11 45 „	6 45 „	
				„ 8 30 „		North	8 30 „	3 30 „	
				N. 4 15 E.		N. 10 E.	5 45 „	0 45 „	

Same Homeward Voyage.—Alexandria to Malta.

Date and Time.	Lat.	Lon.	Variation of Compass	Ship's Head, True.	How ascertained.	Ship's Head by Standard Compass.	Difference between True Head and Compass.	Total Deviation.	Remarks.
	N. ° '	E. ° '	W. ° '	° '		°	° '	° '	
1874. July 14th. A.M.	32 30	26 20	7 15	N. 89 45 W.	Sun's Azimuth.	N. 70 W.	19 45 W.	12 30 W.	Ship steady with a slight list to port.
				„ 80 45 „		„ 60 „	20 45 „	13 30 „	
				„ 71 00 „		„ 50 „	21 0 „	13 45 „	
				„ 60 30 „		„ 40 „	20 30 „	13 15 „	
				„ 49 30 „		„ 30 „	19 30 „	12 15 „	
				„ 37 30 „		„ 20 „	17 30 „	10 15 „	
				„ 24 15 „		„ 10 „	14 15 „	7 0 „	
				„ 11 45 „		North	11 45 „	4 30 „	

Same Homeward Voyage, as above."—Gibraltar to England.

Date and Time.	Lat.	Lon.	Variation of Compass	Ship's Head, True.	How ascertained.	Ship's Head by Standard Compass.	Difference between True Head and Compass.	Total Deviation.	Remarks.
	N. ° '	W. ° '	W. ° '	° '		°	° '	° '	
1874. July 22nd. A.M.	36 47	8 33	19 50	N. 63 0 W.	Sun's Azimuth.	N. 30 W.	33 0 W.	13 10 W.	Ship upright and steady.
				„ 50 40 „		„ 20 „	30 40 „	10 50 „	
				„ 36 45 „		„ 10 „	26 45 „	6 55 „	
	° '			„ 23 30 „		North	23 30 „	3 40 „	
		° '	° '	„ 9 49 „		N. 10 E.	19 49 „	0 1 E.	
July 23rd. A.M.	40 0	9 40	21 0	N. 3 50 E.		„ 20 „	16 10 „	4 50 „	Ship with a list to starboard, and unsteady compass.
				„ 16 36 „		„ 30 „	13 24 „	7 36 „	
				„ 28 45 „		„ 40 „	11 15 „	9 45 „	
				„ 40 30 „		„ 50 „	9 30 „	11 30 „	

The examples on the two preceding pages clearly show that a considerable difference in the amount of deviation must be expected on consecutive voyages, even in well-found vessels, and under the most careful management.

The Standard Compass has been called* the heart of a ship, and demands (as we have endeavoured to show in the preceding pages) the constant attention of the commander and officers of all steamers plying between England and the East Indies through the Suez Canal. We have already mentioned the standard books which treat of the compass and magnetism generally. Any book of ready reference, which may save the time of the officer of the watch (who cannot conveniently be spared from his other manifold duties, for oft-repeated *calculations* of the sun's true azimuth), is an invaluable addition to the seaman's library. Therefore we call attention to a new book of **Azimuth Tables,** for computing the **Sun's true bearing**†—the want of which has long been felt—affecting, as it does, so large a portion of the Atlantic, Pacific and Indian Oceans, the West Indies, the Red Sea, the Arabian and China Seas, and the Bay of Bengal, as well as the increasingly-important passages between Australia and China and Japan, which we shall describe in "Part Second" of this work.

* "Practical Nautical Surveying," by Commander Thomas Hull, R.N. This little book gives many useful hints to seamen—"how to construct a plan of a bay or harbour, how to detect errors in the chart of a piece of coast-line, or frame a report on a newly-discovered island, rock, or shoal."

† "Sun's True Bearing, or Azimuth Tables," computed for intervals of four minutes, between the Equator and the parallel of 30° Latitude—being a completion to the Equator of the late Captain Birdwood's Azimuth Tables between 30° and 60° Latitude—by Captain Davis, R.N., F.R.G.S., and published by J. D. Potter, Agent for Admiralty Charts, 31, Poultry, and 11, King Street, Tower Hill, London.

THE TIDES OF THE INDIAN OCEAN.

The rise and fall of the tide twice a day, or nearly so, is quite familiar to every one, and it will be taken for granted that this is due to the attractions of the sun and moon; for, although the planets exercise a certain amount of attraction, still their distances are so enormous that the effect thereof in the tides is quite inappreciable.

Now the moon (supposed to be on one side of the earth) tends to draw up the water nearest to it, and produces high water. Every part of the earth feels the moon's influence, but not all equally; those parts nearest to it necessarily feel it the most, and those furthest feel it the least, so that the water nearest to the moon is heaped up most; but at the same time that the moon is effecting this, it tends to draw the earth away from the water on the opposite side, so that there would be a rise of the water there relatively to the earth's surface. We see, then, that at any moment there are two high waters from the attractive forces, and, of course, there will be two low waters at the intermediate points of the surface between them. The sun again influences the water in the same way.

Now the moon makes her apparent circuit in 24 hours and 48 minutes: therefore the moon's wave will recur twice in that period, or at every 12 hours and 24 minutes; thus we see there is a semi-diurnal lunar tide, and also another solar tide. It is evident that if these two waves follow the same direction nearly (as indeed they do), on the surface of the earth, they must produce the effect of one wave recurring nearly at the periods of the greater of the two, but modified in its height by the smaller wave. Thus, when the summits of the two happen to coincide, the summit of the combined wave will be at its highest. When the hollow of the smaller wave coincides with the summit of the larger, the summit of the combined wave will be at its lowest.

Now, as the sun's wave recurs every 12 hours, and the moon's wave every 12 hours 24 minutes, the sun makes thirty waves in about the same time that the moon makes 29 waves; and if at the first of these 29, the summits of the two coincide, at the 15th the summit of the moon's will coincide with the hollow of the sun's, and at the 29th the summits of the two will again nearly coincide. The height of the first and last will be the sum of the two, and that of the middle one will be the difference. These are in fact the *spring tides*, or great tides which occur every fortnight, at or soon after new and full moon; and the neaps or small tides occur in the intermediate weeks. The amount of the lunar tide is more than double that of the solar tide.

Diurnal inequality. At spring tides the effects of sun and moon are the same throughout the year. At neaps, in summer and winter, the moon makes the circuit of the Equator, and in spring and autumn that of the tropical zones. At new and full moon, during summer and winter, the sun and moon exert their attractive forces together upon alternate belts of the earth's surface, so that the consecutive waves (caused by these attractions) although recurring at the regular times, or nearly so, will be in themselves different. In spring and autumn, the attractions are exerted upon the Equator each time, consequently the consecutive waves will be nearly similar.

At the quarters of the moon, when the sun and moon are at right angles to one another, in spring and autumn the moon will be on the tropics and the sun on the Equator; and in summer and winter the moon will be in the Equator and the sun in the tropics. The effect of these varying causes is that, in summer and winter, alternate spring tides are high and low, and neap tides are nearly regular. In spring and autumn, the spring tides are regular, and neap tides alternately vary. Thus we see that there are diurnal and semi-diurnal tides, both lunar and solar, which are called the **short period tides,** and the difference in the alternate superior and inferior high waters produced by them represents what is called the diurnal inequality.

Long period tides. Besides the above tides, we must consider that the moon, according as she is in the Equator, or further and further from it in either N. or S. declination, will cause a fortnightly tide, consisting of rise at the Equator and fall at the poles, on the average of 24 hours when the moon is crossing the Equator, and fall at the Equator and rise at the poles when the moon is in greatest N. or S. declination. And for a similar reason there will be a semi annual tide for solar declination. We shall thus understand also that the tide wave, whose summit is in the Equator, is greater than one whose summit is on one or the other side of the Equator—that the height of the tide depends in fact upon the *declination* of the sun and moon; being greatest when the declination is zero, and least when the declination (whether N. or S.) is greatest. Now Equinoctial tides are well known to be the highest. At the Equinoxes, the sun and moon act in concert upon the *Equator*, when they have the greatest effect.

Again:—according as the moon is in apogee or perigee, there will be a lesser or a greater heaping up of water round the Equator and a sinking at the poles, and this is the cause of a monthly lunar tide. And for similar reasons there is an annual solar tide.

Summary. The above is a brief explanation of the principal inequalities in the tide-generating forces; the other minor ones, depending on the moon's perturbations, need not be taken into consideration in our brief account of the tides. But the intelligent mariner must remember the *four following* chief tidal constituents (as explained above) that are found in most localities:—

Firstly.—Lunar and solar semi-diurnal tides.

Secondly.—Lunar and solar diurnal tides.

Thirdly.—Lunar fortnightly and solar semi-annual tides.

Fourthly.—Lunar monthly and solar annual tides.

In the Gulf of Cambay there is a diurnal inequality of 7 or 8 feet in the height, but the two tides arrive at their regular intervals: there is no inequality of time. But at many localities, there is more or less diurnal inequality, both in height and time, and a want of due attention to this fact has doubtless introduced confusion into the records of local observations. It so happens that the diurnal inequality here (on the coasts of England) is so small, that it is considered a comparatively unimportant matter. Taking their knowledge from British tides, our navigators in distant seas are often unprepared for the above phenomenon. Thus observed facts, which are really of great importance, have sometimes been set down as merely accidental irregularities due to local causes. It is well known that the night high tide is higher than the day high tide, both at Calcutta and Bombay, in the winter season or N.E. monsoon, when the sun is in Capricorn. But in the S.W monsoon, with the sun in Cancer, the day high water is higher than that of the night. This phenomenon also occurs in the Gulf of Cutch.

The Admiralty publish Tide Tables for many British Ports, and it is to be hoped that such tables may eventually be drawn up for the Ports of British India. Then the mariner would benefit by the predicted height of the tide for any day—the exact height due to the attraction of sun and moon, but still liable to differ on any day owing to **two causes** which are not calculable beforehand; firstly, the weight of the atmosphere as indicated by the barometer; and secondly, the effect of the wind, which when from one direction may *raise*, and in others may *lower* the tide, affecting both time and height.

The Tide-Wave. After the graphic method, adopted by Dr. Whewell in his "First approximation towards drawing a map of *Co-tidal Lines*," we have given a chart of the Indian Ocean, showing roughly the **Co-tidal Lines,** or the progress of the Wave of High Water in hours of Greenwich time. Mr. William Parkes, the eminent harbour engineer—who has deeply studied the tides of Karachi, Bombay, and Calcutta, and to whose writings concerning "the Tides" we are indebted for much of the above brief explanations—does not think this mode of illustration the most correct, but we adopt it as the most graphic to engage the attention and interest of seamen. Mr. Parkes publishes Annual "Tide Tables" for Bombay and Karáchi, by authority of the Secretary of State in Council of India. From these we take a Table and *two examples* (in the next pages) to show their utility and what benefit we should derive from similar "Tide-Tables" for Calcutta and other great Indian ports.

The Age of the Tide. Dr. Whewell's collated observations showed that a greater number of high waters occurred between 6 and 7 hours after the passage of the moon. It will be seen that the lines at the Chagos and Seychelle groups, and at Mauritius, differ little from this. But in its progress the Tide-wave suffers great retardations and impediments which cause variations to the amount of several hours. If they extend to 12 hours, it becomes a question whether the tide which we see is due to one transit of the moon or another. It may be either a very quick, comparatively unimpeded tide, formed by a late passage, or a much retarded tide formed by an earlier one. If we can trace the impediments, we can at once decide; but if not, we must compare the heights of several successive tides with the changing relative positions of the heavenly bodies. We know what variations in the tides the changes in the positions of the heavenly bodies will cause, and we must see *how long after* such changes of position the variations in the tides actually occur. This interval is called the **age of the tide,** and it simply represents the time that has elapsed since the sun and moon were in the position to form it, and includes both the time occupied in forming and the time during which it has since been rolling about upon the sea. Thus the tide on the West coast of Ireland is two days old, whilst that on the East coast of England is two and a-half days old, and the highest spring tides occur respectively two days and two and a-half days after the new and full moon.

Tidal Currents. The tide-wave in the deep sea is merely an undulation; but, when shallow seas or bays are reached, the movement of the water is discernible. The general principle is, that in the deep sea there is a quick movement of the wave, and a slow movement of the water; in the shallow sea there is a slow movement of the wave, and a quick movement of the water, which is called the tidal current. These currents are frequently spoken of as the *flood* and *ebb* tides; but the terms (although sanctioned by usage) are not correct, because *flood* and *ebb* are applied to the rising and falling of the water, which is quite a different thing. The flood current in a channel supplies water for the wave, but the wave requires water after its summit has passed any particular point, so that at that point *flood current* continues, although *ebb tide* may have commenced. Similarly *ebb current* may continue, after *flood tide* has commenced. In the Gulf of Cambay the ebb current frequently runs for an hour and a half after actual low water; and in the Persian Gulf, the tidal current has been observed to run on for nearly three hours at some places after the water has begun to rise or fall.

Tidal currents have also much to do with the formation of *bars* at the mouths of Indian rivers. Therefore, unless the harbour engineer has a full knowledge of their set and force, and whether they act in conjunction with or in opposition to the ocean currents, his plans for improvement may be rendered nugatory.

The Tide-Wave of the Indian Ocean. Of course it is mere hypothesis that a great wave passes (as on the chart) to the Westward, round the S.W. extremity of Australia into the Indian Ocean. Yet certain anomalies in the tides at King George's Sound—where there sometimes appears to be only one tide in the day—seem to indicate a second wave as coming some hours after a first wave, and thus adding to the first high water and producing a prolonged tide. The second wave (if we may so call it for distinction) must be also hypothetical, but it might be confirmed by accurate observations at the Keelings Islands and at the Chagos group, in conjunction with others at Sunda Strait, at the E. end of Java, and along the N.W. coast of Australia.

The tides of the Asiatic Archipelago have yet to be investigated, but our conviction is (as the chart represents) that the wave down Malacca Strait, and that which flows to Eastward between Java and Australia (till it meets the Pacific wave which has come through Torres Strait) are a backward undulation from the wave which the moon has formed under herself as she passes over the deep sea near the Keelings Islands, where high water occurs about two hours sooner than at Sunda Strait, or about four hours after the passage of the moon; whereas at Torres Strait the high water is about 9 hours after the moon. We assume that the moon does thus *pick up*, as it were, a fresh wave; and, as the tide follows the moon, the first effect close to the W. shore of Australia and the S. coast of Java, must be to draw the water away from the land, in order to form a tide-wave to the W. of that land. A certain space of water behind the moon is required to form a wave; this wave then, when brought to a head, as it were, may be easily supposed to fall back upon the coast of W. Australia, causing high water at Swan River at a later hour than at the N.W. Cape, and later still at King George's Sound, where (we are told) the flood current comes in from the Westward, and the diurnal inequality of the times is very great, so that sometimes the two tides come close together, and the water falls so little between them, as if there were only one tide in the day.

In the Gulf of Carpentaria, Flinders found great inequalities, and was induced to believe that there was only one tide in the day *there* also. This might be due to the great inequality of time bringing the two tides together, or to the great inequality of height causing the smaller tide to be overlooked, but recorded facts are too few to determine by. We must leave to the rising generation of scientific mariners the task of elucidating the progress of the tide-wave in those Eastern seas, and of showing to their fellow seamen how the tidal currents are interfered with by the periodical ocean currents and prevailing winds. Mr. Parkes has given a sketch of the tides in the seas between the Pacific and Indian Oceans, and thus remarks. "High water occurs at every hour of the twelve, at some part or other. The two tides of the day differ from one another in all or almost all parts; but in some cases the difference is in the height of high water, in some in the level of low water; in some in the time at which the summit of the wave arrives; in others, in the time at which the hollow of the wave passes; but each passes through its regular series of changes from fortnight to fortnight, from year to year, and from era to era; each change following the influence of the different positions of the heavenly bodies. The *diurnal inequality* (so marked a feature in these tides, arises from the fact that the two waves, formed in different parts of the ocean, travel by routes differing in length, direction and conformation. The meetings or the crossings of two waves may present great modifications. Where the summit of one comes near the summit of another, we shall have a wave of double height. Where the summit of one coincides with the hollow of another, we shall have both obliterated."

A method of finding the height of tide* at any hour, for the principal ports which have "Tide Tables" prepared for them—such as Bombay and Karáchi,—is given in the next page.

* To Mr. W. Parkes, C.E., we are indebted for this table and examples. Much of the foregoing information has been gleaned from Mr. Parkes' little book on "The Tides," and from Colonel Walker's "Notes on the harmonic analysis of Tidal Observations."

TABLE

For finding the Height of the Tide at any intermediate period of flood or ebb,—the amount of rise and the times of low and high water being known.

Total Rise from Low to High Water.	Tide above Low Water level.					
	One-sixth Flood.	One-third Flood.	Half-flood.	Two-thirds Flood.	Five-sixths Flood.	High Water.
Feet.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
4	0 3½	1 0	2 0	3 0	3 8½	4 0
5	0 5	1 2½	2 6	3 8½	4 7	5 0
6	0 6	1 6	3 0	4 6	5 6	6 0
7	0 7	1 9½	3 6	5 3½	6 5	7 0
8	0 8½	2 0	4 0	6 0	7 3½	8 0
9	0 9	2 3½	4 6	6 8½	8 2½	9 0
10	0 9½	2 7	5 0	7 5	9 2½	10 0
11	0 11	2 9½	5 6	8 2½	10 1	11 0
12	1 0	3 1	6 0	8 11	11 0	12 0
13	1 0	3 3½	6 6	9 8½	12 0	13 0
14	1 1¼	3 7	7 0	10 5	12 11	14 0
15	1 2½	3 9½	7 6	11 2½	13 9½	15 0
16	1 3	4 1	8 0	11 11	14 8½	16 0
17	1 3½	4 3½	8 6	12 8½	15 8½	17 0
18	1 5	4 7	9 0	13 5	16 7	18 0
19	1 6	4 9½	9 6	14 2½	17 6	19 0
20	1 7	5 1	10 0	14 11	18 5	20 0

For the corresponding periods of ebb tide use the same figures, but consider them as the amounts of *fall* from *High Water* level.

EXAMPLE I.—To find the height of the water at Bombay at 5 P.M. on Sept. 13th, 1873.

Previous High Water .	3h. 14m. (from Tide Table)	2ft. 8in.	Height above Zero.
Next Low Water . .	10h. 2m. ,, ,,	4ft. 11in.	Depth below Zero.
Duration of ebb . .	6h. 48m.	7ft. 7in.	Fall of Tide.

One-sixth of duration of ebb is 6h. 48m. ÷ 6 = 1h. 8m. Therefore one-sixth ebb occurs at 3h. 14m. + 1h. 8m. = 4h. 22m., and one-third ebb at 3h. 14m. + 2h. 16m. = 5h. 30m.

Fall (from Table) at one-sixth ebb for tide of 7ft. 7in. = 0ft. 8in.
,, ,, one-third ebb ,, ,, = 1ft. 11in.
Whence height of water at 4h. 22m. is 2ft. 8in. — 0ft. 8in. = 2ft. 0in.
,, ,, ,, 5h. 30m. is 2ft. 8in. — 1ft. 11in. = 0ft. 9in.
or, (according to proportion), at 5h. 0m. the height of the water is about 1ft. 5in. *above* Zero.

EXAMPLE II.—To find the height of the water at Bombay at 4 A.M. on Sept. 16th, 1873.

Previous Low Water .	0h. 28m. (from Tide Table)	3ft. 5in.	Depth below Zero.
Next High Water . .	8h. 0m. ,, ,,	2ft. 11in.	Height above Zero.
Duration of flood . .	7h. 32m.	6ft. 4in.	Rise of Tide.

Therefore, one-sixth flood = 1h. 15m.; one-third flood = 2h. 3m.; one-half flood = 3h 46m.
Previous L. W. + one-sixth flood = 0h. 28m. + 1h. 15m. = 1h. 43m.
,, L. W. + one-third ,, = 0h. 28m. + 2h. 31m. = 2h. 59m.
,, L. W. + one-half ,, = 0h. 28m. + 3h. 46m. = 4h. 14m.
Rise at half flood (from Table) for tide of 6ft. 4in. = ... 3ft. 2in.
Proportional rise in 14m. (from Table; one-fifth of diff. between 1ft. 6in. and 3ft. 2in.) = 0ft. 4in.

Rise up to 4 A.M. . . . . 2ft. 10in.

Therefore, 2h. 10m. deducted from 3ft. 5in. leaves 0ft. 7in. *below* Zero, as required height of water.

GENERAL REMARKS ON TIDES.

Until late years only, few seamen have noticed the real distinction between high water or full sea, and the turn of the stream;—which may take place sooner or later than high, or low water, by a quarter, or half a tide (more or less), but seldom with it, except at the head, or end of a tidal inlet, estuary, or harbour.

Example.—From the Atlantic, for example, a gradual elevation of the ocean, an excessively broad flat wave, impinges on the western shores of the British Islands and swells around them, by the north and south. After raising the water, everywhere, successively, or simultaneously (according to the coast line and other circumstances) these two north and south waves meet near the Strait of Dover.

The tide wave that travels northward, and right round the British Isles, is longer on its course, and meets near Dover the swell of a tide nearly two days younger (or later) which has passed up the British Channel. Winds, either Northerly or S.W., must retard the one and hasten the other; thus making an alteration, by several miles, in the meeting place of the two tides.

Local Peculiarities of the tides vary in all imaginable ways; but their main principles or features are everywhere similar, only differing in degree. The ocean is slightly influenced by gravitation, and very small movements of so vast a mass suffice to impel secondary waves against shores, and these again send off their derivatives, in great variety, according to the conformation of coasts and the depth or shallowness of the waters adjacent to them.

Sometimes these derivative tide-waves succeed at equal intervals, sometimes they combine and accumulate; at others they follow in such exact succession as completely to neutralise one another, and thus cause an appearance of **no tide at all.** Between such extreme cases there is every variety found, in various parts of the world; and they may all be illustrated by reference to a wave advancing against a cluster of rocks, on any sea shore, which may be observed to circle around, fill cavities more or less gradually, form every kind of eddy, with streams chasing each other without rising, or meeting in accumulation;—exemplifying in miniature, what takes place, on a great scale, but very much more gradually, throughout the world.

Precaution.—Whenever a coast is approached from an open ocean, the tidal stream, or current of tide near the shore, should be carefully considered. In some places there is a set of many miles, perhaps 20 m., or 30 m., along shore, or towards the land, **in one tide;** but, happily, on most sea-boards there are no such extreme dangers.

Tides of the Indian Ocean.—Of the tides in Australian and Chinese seas, we have much to learn. We have a fair knowledge of the tides of the Indian Ocean, northward of Mauritius, but some anomalies require to be cleared up. We shall learn more of the Arabian Sea and Gulf of Bengal tides, when the scientific observations, now under charge of the Surveyor-General of India, along her shores, become published and multiplied.

Anomalies present themselves in the Gulf of Manar and the Red Sea. In the former region, it has been noticed that sometimes four slight tidal risings and corresponding falls occur in one day. The tidal chart may partly account for this, as it shows that a direct wave may come up the Indian Ocean causing the first high water, and that this is afterwards followed by another wave thrown back down the Malabar coast. In the Red Sea, tidal notes have been gathered at the wreck of many a vessel, as well as by the talented surveyors of the Royal Navy, who, of late years, have been employed there. Thus we are enabled to draw up the following remarks.

TIDES IN THE RED SEA.

The Gulf of Suez seems to have a tidal influence of its own, which is not a continuation of the Indian Ocean wave that enters the Red Sea. The latter seems to reach the Dhalac Bank; thence merely faint indications of any tide are found till northward of Kosair. Distinct tidal currents are found between the mouth of the Gulf of Ahkaba, and Shadwan and the Jafatain Islands.

Rise.—There is at springs, a rise at Suez of 7 ft., and at Ras Gharib of 2 ft.; but (the Royal Navy surveyors state) there is no tidal rise and fall at Toor, nor yet at Cape Zeitee. They also state that it is H. W. in the bay to the west of the islands Shadwan and Jubal when it is L. W. at Suez, and *vice versâ*.

The tidal current, throughout the length of the Gulf of Suez above Toor and Zeitee, is said to run to the northward, whilst the water is rising at Suez; and again, to set to the southward when the water is falling at Suez. The maximum spring tide rate is 1½ m. per hour.

The attentive reader of all the foregoing brief remarks on "Tides," will easily understand that the moon must *pick up* a wave to form H. W. at Suez; and, in doing so, the effect must be to draw away water from some distant point. Observations indicate *that point* to be between Toor and

Zeitee; that the source of her supply is the broad Red Sea below the Sinai peninsula, and that the Strait of Jubal is her feeding channel. Thus we have some little clue to certain (apparently) anomalies in the tidal currents of that strait, which are said to run longer to the Northward than to Southward. Exact observations of tidal phenomena in the Gulf of Suez were not initiated until the maritime canal was opened. We cannot therefore tell how much of this extra Northward flow may be due to the demand caused by evaporation from the broad surface of the Bitter lakes. A flood stream of seven hours, contrasted with an ebb stream of only five hours (*see* further on), indicates the effect of evaporation. This, however, is a question more for the physical geographer than for the seaman. But it is for the latter especially that these remarks on the tides are introduced.

A vessel's course is sensibly affected by the tidal currents in Jubal Straits. Some few remarks about them will be found at page 161. The ebb current sets a vessel to the west, and the flood to the east. If the set be at its maximum, *i.e.*, about 2 m. per hour, and directly *athwart* her course, a steamer going 10 knots in the hour, may find that the course made good differs **one entire point** from that attempted or intended. Such deviation in narrow channels may be productive of disaster during foggy weather. The fatal accident to the Peninsular and Oriental Steamer *Carnatic*, in December, 1869, may partly have arisen from these currents. The diving operations at her wreck fully established this fact, that, at that season of the year, the current ran more frequently to the N.W. in the vicinity than to the South.

Suez Canal Tides. There is no perceptible tide or current in Lake Timsah nor yet in the Great Bitter Lake. The tidal influence in the southern portion of the canal, extends from Suez to about 4 m. within the south end of the Little Bitter Lake, and it is at the latter position that the demarcation of the salt lake water from the Red Sea water occurs.

The tidal stream between Suez and Chalouf (the latter being 11 m. from the canal's S. entrance) turns to the Northward about two hours before H. W. at Suez; thus the canal flood-current runs for 7 hours. The stream commences at Chalouf to run Southward about one hour before it is L. W. at Suez, and continues little more than 5 hours. At the F. and C. of moon the tidal stream runs Northward from 9h. 30m. to 4h. 30m., and Southward from about 5h. to 10h. It is said that the time occupied by the North and South tidal streams is different, in consequence of the unvarying height of the water in the Bitter lakes; but surely much of the difference is due to evaporation there. The current cannot run Northward until the flood tide at Suez has risen above the level of the lakes, which is about two hours before H. W., at which time it turns to run up, and continues running during the latter part of the Suez flood and throughout two-thirds of the ebb tide at Suez, or until the water there has again fallen to the mean level. The canal stream then turns to run Southward about one hour before L. W., and continues to run out till the flood tide has again raised the water above the level of the Bitter lakes.

Velocity. In this tidal part of the canal, between Chalouf and Suez, spring tides run at the rate of 2½ knots an hour, and occasionally much stronger. The strength of the stream increases from Chalouf to near Madama, where it is strongest. Off the mouth of Suez creek, precaution is necessary, and allowance must be made for the strong tidal current (either *into* or *out of* the creek, according to flood or ebb) setting sometimes across the axis of the canal, and frequently in the contrary direction of the canal current.

Rise and Fall. A spring tide rises half a foot at the S. entrance of the Little Bitter Lake; about 1½ feet at Chalouf; 2 ft. at Madama, and 7 ft. at Suez. At the latter place with a strong Southerly wind in the Gulf of Suez, the water rises from 8 to 9 ft. at the head of the Gulf, and must then affect the water in the canal to some small extent.

SECTION I.

ENGLAND TO MALTA, SUEZ AND ADEN.

CHAPTER I.

ENGLAND TO GIBRALTAR.

FERROL—CORUNNA—CAPE FINISTERRE—AROSA BAY—VIGO—TAGUS—LAGOS BAY—CAPE ST. MARY—CADIZ—CAPE TRAFALGAR—TARIFA—GIBRALTAR BAY—AFRICAN COAST—TANGIER—CEUTA—WINDS, TIDES, CURRENTS, RACES, IN GIBRALTAR STRAIT—PASSAGES—WINDS AND CURRENTS.

(Variation of Compass at Falmouth, 23° W.; at Gibraltar, 19° W.)

In accordance with the plan laid down, a description of the land and ports likely to be approached, either in outward or homeward-bound vessels, will be given, and then general directions for making the passage, to ensure the safety of the ship and a quick voyage.

So exceptional is the necessity for approaching the coast or making any harbour in the Bay of Biscay, that we need only describe one or two ports which, in case of not weathering Cape Finisterre, it may be necessary to bear up for. Further information will be found in the Section, from England to Cape of Good Hope (pp 33 to 37).

FERROL HARBOUR. The bay formed by Cape Priorino and Hermino Point may be called the entrance to the three inlets of Ferrol, Betanzos and Corunna: the distance between the two points being 5 m. Ferrol, the northen inlet, is the best, as it is enclosed by high land, and shelters from all winds; the entrance between Priorino Light and Coitelada Point is nearly 1¼ m. broad; but, as you go in, it narrows to a channel, which, in some parts, is not more than 2 cables wide, though it is 1½ m. in length; having passed this channel the harbour is spacious.

There is no danger in making Ferrol. Either point of the entrance can be rounded at 3 cables. La Muela Rock, which lies off Segano Point, is now marked by a Red buoy. Having passed this, a mid-channel course must be kept until within the harbour, when you must haul to the N.E. for anchorage.

Light. The N. point of entrance, Priorino Chico, has a light, *fixed*, White, giving a Red flash every two minutes; visible 12 m.; elevated 90 ft. Lat. 43° 28′ N., lon. 8° 20′ W.

Cape Prior, 6 m. to N.N.E. of Chico Priorino, has a bright *fixed* light, 450 ft. high.

CORUNNA BAY. The Southern inlet is not so clear of danger as Ferrol. A rocky bank, **Jacentes,** a mile in extent, lies immediately before the port, 1½ m. to N.E. of the light; in fine weather it may be crossed, but it breaks heavily in bad weather, and must be avoided. As the shore is bold on both sides, and can be approached to 3 or 4 cables, you should keep either shore abroad until within this bank, when the Bay may be said to be entered: this entrance, between Herminio Point and Mera Point, is 1½ m wide

Lights. If coming from the W., the light-house of the Torre de Hercules, 330 ft. above the sea, is conspicuous, and will lead up to the Bay. Hercules Light is *fixed*, White, flashing every three minutes; visible 16 m. After rounding Herminio Point, which is ¾ m. E.S.E. of the light, steer about S.E. by S. until San Diego Castle opens to E. of San Antonio Castle; being then clear of the Cabanes rocky shoal, which breaks when there is much sea, steer for the light on San Antonio Castle, and, having rounded it at a cable distance, you may anchor. Vessels above 50 tons are bound to employ a pilot.

Between Corunna and Finisterre there are two lights. Sisargas Light is *fixed*, White; but flashes Red every four minutes, lat. 43° 22′ N., lon. 8° 50′ W. Cape Villano Light is *fixed;* visible 10 m.; lat. 43° 10′ N., lon. 9° 13′ W. **African Rock** lies half a league off Cape Torinana, 8 m. W.S.W. from Villano, and 12 m. to N. of Finisterre. (See also p. 34.)

CAPE FINISTERRE. The land to the N. of this cape, is high, with a flat top. The Cape itself is not high, but easily recognised by the light-house, nearly 470 ft above the sea.

Finisterre Light is *revolving* every 30 seconds; visible 20 m.; lat. 42° 53′ N., lon. 9° 15′ W.

The coast from Cape Finisterre to Cape Silleiro, 50 m., is broken by a series of deep inlets, the headlands between which are rugged. As many dangers lie off the shore, it should not be approached at night or in thick weather.

Arosa Bay is an extensive inlet with good shelter, and may be resorted to in case of emergency with a leading wind and by daylight. The entrance is 2 m. wide. The W. side of it, Salvora Island, is distinguished by a light-house. A mid channel course, after rounding Brisan Point, leads safely in, when the Rua Light-house will be seen. Passing between the Rua Light-house, and that on the N.W. end of Arosa Island, you can haul to the W. into Puebla Bay.

Ons Island, 5 m. to the S. of Arosa Bay, affords safe anchorage on its E. side in W. winds, at 3 cables from the shore. A light-house is on the summit of the island, which is 400 ft. high. In rounding Ons Island, give a berth to the rocks off the S. end.

VIGO BAY, a deep and safe inlet, is fronted by the Cies or Bayona islands. The middle island, Faro, has a *revolving* light, 595 ft. high. Under the lee of the islands, there is safe anchorage in 9 or 10 fathoms in W. gales. Vigo Bay can be entered either to the N. or S. of those islands, according to the wind. Entering by the N. channel, care must be taken to avoid a reef of rocks, which extend 1¼ m. N. from Caballo Point; by keeping Cape Hombre in a line with the hill of Na. Senora del Alba about S S.E. ½ E., until Monte Ferro bears S. ½ W. Then steer for the latter until the centre of the Bay opens.

By the S. passage, Cape Mar in line with the light house of Monte de la Guia, bearing E. by N., will lead in mid-channel between the dangers off St. Martin Island and those off the main. When Faro Light-house opens to the E. of St. Martin, haul to the N.E., towards the centre of the Bay. By keeping midway between the shores all dangers are avoided until the town of Vigo is past, then anchor in from 6 to 9 fathoms.

Between Vigo and Lisbon there is no port that a vessel might run for without a pilot.

Burlings and Farilhoes are a remarkable cluster of islets, between 300 and 400 ft. high, off Cape Carvoeiro. Burlings Light *revolves* every three minutes; 365 ft. above sea. The channel between them and the main is clear. In foggy weather keep well to the W.

TAGUS RIVER. The approach to the Tagus, from the N., is well marked by the Cintra mountains, 1,700 ft. high, and also by Cape Roca (Rock of Lisbon), a cliff about 550 ft. high, with a light-house on the summit. Cape Razo is 4 m. S. of Roca, and from thence the coast trends to S.E. 4½ m. to Guia Light, then to the E. to Cascaes Bay; where, during summer months, when N. winds prevail, anchorage may be sought in 10 to 12 fathoms with Fort St. Martha in a line with Guia Light-house, N.W. ½ W., and the town of Cascaes nearly open to N. of Cascaes Fort.

The entrance to the Tagus, between forts St. Julian and Bugio, is 1½ m. wide. Off both forts there are dangerous sandy shoals extending to the W., and having between them a deep channel nearly a mile broad. These sand-banks are the N. and S. Cachopo. Between N. Cachopo and Fort St. Julian is the narrow North channel, which can only be taken with a fair wind.

Belem Castle, on the N. side of the Tagus, 5 m. above Fort San Julian, and about 2 m. below Lisbon, is prominent in entering the river; it stands on a projecting point, nearly insulated at high water; near it is the quarantine station. Here are the health and customs offices, and of it all vessels are boarded on entering. Belem is almost connected with Lisbon.

Cachopo Shoals. The N. shoal extends from Fort St Julian about W. by S. ½ S. 3½ m. and has a shoal patch of 6 ft. The S. shoal extends from Bugio Fort W.S.W. 1½ m.: this shoal has a like depth, and is marked by White buoys.

The Bar, between the outer extremes of the two shoals, has 6 and 7 fathoms over it at L. W. springs; the channel within soon deepens to 9 fathoms: between the two forts there is 19 fathoms In S.W. gales the sea frequently breaks heavy on the Bar; in winter, when the freshes are strong this break continues for days together, and at such times the Bar is impassable.

LIGHTS. Cape Roca has a *revolving* light, alternating Red and White every 100 seconds, elevated 600 ft.; visible 20 m.; lat. 38° 46′ N., lon. 9° 30′ W. **Guia Light** is *fixed;* 210 ft high; visible 12 m. Lights are exhibited from Forts Julian (*fixed*) and Bugio (*revolving*). For Bon Success, near Belem Castle, has a small *Red* light.

The Tides of the Tagus are dangerous. Off Lisbon City, the ebb sometimes runs 6 or 7 knots, when freshes come down after rain. Flood is generally much weaker than ebb The current sets directly through the S. channel and over the Bar; on flood 3 m., and on ebb 4 m. an hour. To enter during ebb you must have a strong breeze. H. W. at F. and C., on the Bar, at 2½ h.; rise 16 ft.

Winds. Within the river the wind comes irregularly down the valleys on either side, excepting when it blows up or down river, when it is pretty steady.

Pilots are usually found off the entrance, or at Cascaes town. Their boats have a Blue flag at the yard-arm of their lateen sails.

DIRECTIONS.—**The North Channel** into the Tagus requires a knowledge of the tides, and in a sailing vessel a commanding breeze. Having passed Guia and Cascaes, bring Cassilhas Point (the E. termination of the S. shore) in line with the S. face of Fort San Julian bearing E. by S. ½ S.,—or if wishing to borrow on the Cachopo, Belem Tower on with the S.E. extreme of San Julian Point;—steer in with either of the above marks until Guia Light-house is in one with the angle or centre of the high part of Santa Martha Fort, N.W. ½ W.; then keep this latter mark on, and it will lead in mid-channel, in not less than 6 fathoms at low water.

When the centre of Mount Cordova (on the S. shore) comes in one with Bugio Tower, bearing about S.E. ¾ S., steer for Bugio until San Thomas Fort (which is white and a long half mile N.E. of San Julian) opens to E. of the yellow fort of Catelazete; then haul into the river, but carefully allowing for tides, as the flood sets right on the shoal extending from San Julian, while the ebb sets directly on the N. Cachopo.

Mount Cordova is 12 m. from San Julian Fort, and may not be visible; in this case, having entered the N channel, as soon as the rocks at Catelazete Point are open of the S E. angle of Fort San Julian, steer for Bugio Fort till the battery at Catelazete Point, San Thomas Fort (the next to it), and the outer windmill, are in line bearing N.E. by E., and then haul more to E. into the river. With Rana Church in one with Quinta Nova, and Cassilhas Point in one with the S. face of Fort San Julian, a vessel will be in the centre of the fairway, and have Guia Light-house in one with the bastion of Santa Martha Fort.

The South Channel is the principal one into the river. Entering with a fair wind, and rounding the S. extreme of N. Cachopo, keep the Peninha (or W. part of the mountains of Cintra) bearing N. ½ E., and open to W. of Cascaes Fort, until Bugio Fort comes in one with Estrélla Dome, E. ¾ N. Then steer towards Bugio, keeping it in one with Estrélla Dome, in which line the Bar connecting the N. and S. Cachopos will be crossed in the deepest water, not less than 6½ fathoms; and when the Paps are in one with Jacob's Ladder. E. by N. ¾ N., a vessel will be inside the Bar, and in deeper water. Now run up with the Paps in one with Jacob's Ladder, or if the wind hangs to the N., borrow as far as the N. turning mark (Paps in one with Caxias, E. by N. ½ N.) If the wind be from S.E., borrow towards the S. turning mark (Paps in line with the cypress tree,) bearing about E.N.E., but avoid going too near Bugio, as the tides there are strong and irregular, and the shoal steep-to.

Having passed between Bugio and San Julian, keep to the N., so as to clear the sandy flat inside Bugio, till Belem Castle is in line with the S. part of the city of Lisbon, bearing E. ¾ S. Pass Belem Castle at 2 or 3 cables off; and then proceed to the anchorage, keeping Fort San Julian and all its outworks open to the S. of the parapet of Belem Castle. This will clear the shoals of Alcantara, until the vessel arrives off the Packet Stairs, where there is anchorage in from 10 to 14 fathoms, or farther up in 12 to 16 fathoms mud.

Turning through the South Channel. A vessel standing S.E. towards the W. tail of N. Cachopo, should keep Peninha Peak bearing N. ½ E., open to W. of Cascaes Fort, and in not less than 12 fathoms water, until the S. part of the city of Lisbon is in line with Bugio Fort, E. ½ S.; then haul to the wind. The turning mark for the N. side of the channel is the Paps in line with the Mirante or Turret of Caxias E by N. ½ N,; and the turning mark for the S side of the channel is the Paps in line with the cypress tree (which stands a third of a mile E. of Jacob's Ladder,) E.N.E.

The N. turning mark is safe and prudent, as a vessel will not approach any part of the N. Cachopo nearer than ½ m. The S. turning mark carries a vessel within 1½ cables of S. Cachopo, and as the tides here are uncertain, the shoal should be approached with caution.

Rana Church open W. of Quinta, bearing N. by E. ½ E., clears the tail of the S. Cachopo, and a vessel working in, need not go to the E. of this line until well in the channel. A mill on a height 1¾ m. N.E. of Fort San Julian, open to E. of Fort San Thomas, bearing N.E. by E., clears the E. edge of the N. Cachopo, and is a good, near, fairway mark in running out through the S. channel. The shallow ground around San Julian extends a short distance from the fort, but deepens immediately to 5 and 6 fathoms; San Thomas Fort well open E. of the small battery of Catelazete, clears the S. extremity of this shoal.

Having passed Forts San Julian and Bugio, stand to either shore into 12 fathoms; a good mark for clearing the shoulder of the sands, inside of Bugio, is Belem Castle in one with the citadel of Lisbon, which stands on the first rise of the land from the S. point of the city. Between Medao Point and the village of Trafaria, the S. shore is bordered by a bank of the latter name, which extends off full a third of a mile, with deep water close to it. To clear this bank, the houses at Torre Velha must be to N. of Trafaria cliffs. Above Trafaria the S. shore of the river is clear, with deep water as far as Cassilhas Point

Between Fort San Julian and Belem Castle the N. shore is bordered by a narrow bank, but W. of the castle it extends off a ¼ m. The shore on the S. side of the castle is steep; thence it is again bordered by a bank, which in places extends nearly 2 cables off, with 5 fathoms on its edge, and deep water close-to.

When nearing Alcantara bank, the mark (for clearing it in 7 fathoms,) is San Julian Castle and outworks open of the parapet of Belem Castle, until Alcantara, which appears like the angle of a fort with a watch-tower, bears N. ½ W. The bank will then be passed, and the shore may be approached until the tower of San Julian is in one with the parapet of Belem Castle; and this is a good mark for anchoring in an in-shore berth in 7 or 8 fathoms water, off the Packet stairs. A ship of heavy draught will be far enough out in 12 or 14 fathoms, good holding ground of stiff mud, and out of the strength of the tides.

At night. If coming from the N., bring Guia Light to bear N., and run for it until Bugio Light bear E ; then steer for Bugio until San Julian Light bears N.E.; when an E.N.E. course will lead between the two lights. When Belem Light is seen, bring it to bear E. by S , as the vessel will be nearly in mid channel, and then run up the river.

In entering from the S., bring San Julian Light to bear N.E., and run on that bearing until the Bugio Light bears E., then proceed as directed above. San Julian Light N.N.E. just clears the S. Cachopo in 4 fathoms.

When Cape Roca Light is shut in with Guia a vessel will be nearing the shoals, and within the influence of the river tides, and therefore a cautious and constant reference to the bearings will be necessary. Should the ebb tide be running, be careful not to be set too near Bugio, and if in any doubt, steer more to the N.

CAPE ESPICHEL TO CAPE ST. VINCENT. Cape Espichel Light-house is 625 feet above the sea. The coast from this cape to Riberia river is generally low and sandy; onwards to Cape St. Vincent it gradually rises, with steep rocky cliffs The Sierra de Monchique (its highest part, Foya, elevated 3,830 feet) is remarkable, 8 leagues E.N.E. of St. Vincent Cape.

CAPE ST. VINCENT is about 200 ft. high, having a convent, light-house, and other buildings on the summit. A good offing should be kept off this Cape, as the currents generally set strong along shore, with a tendency towards the Cape.

Light. Cape St. Vincent Light *revolves* every 2 minutes; 220 ft. high; visible 20 m. Lat 37° 3′ N., lon. 9° 0′ W.

Sagres Point. Shelter from N. winds can be found E. of this point in 11 fathoms, about ½ m. from the shore; but, directly the wind changes, vessels should leave.

Lagos Bay also affords anchorage during N. winds Large vessels should anchor to E. of Piedade Point in 12 to 15 fathoms. Springs rise 13 ft.; H. W. F. and C. at 2 h.

CAPE ST. MARY is the S. island of several, low and sandy. A light-house stands on it. Vessels in the vicinity of the Cape should not approach the coast in thick weather, as the water rapidly shallows towards the Cape

There is no port between Cape St. Mary and Cadiz that a vessel of any size can take without a pilot, and anchorage off them can only be obtained in fine weather. The bay between these two places is to be avoided.

Guadalquivir River has a light on its S. side. *flashing* every minute; elevated 220 ft.; visible 22 m. It is 12 m. to N. of Cadiz, and a good landmark for that port.

CADIZ BAY, between Rota and Cadiz, is 5½ m wide, and between Cadiz and Sta. Catalina 3 m., but rocks and shoals make it much narrower for navigation. In approaching from W., the first land seen will probably be the mountains of Ronda, Ulrique, and Medina. Ronda is the highest of an extensive chain 24 m. inland. Ulrique is not so distant, but less conspicuous. Medina, a pyramid hill, is lowest, but near its summit has a remarkable tower. The houses of Medina on the W. slope of the mountain appear as a white patch. Beva tower, 6 m. to N. of Rota, is also a good mark on this coast, as it can be seen far off.

Rota is a small fortified town, with a *fixed* White light on the mole. A reef extends from the point and shoal water to **Rota Reef,** a patch with 3¼ fathoms. A *Red* buoy is on its S. point, S.S.E. 1¼ m. from Rota. A rocky shoal also extends 1¼ m. to the W.