

INDIA METEOROLOGICAL DEPARTMENT

WINDS, WEATHER AND CURRENTS

**ON THE COASTS OF INDIA
AND
THE LAWS OF STORMS**

SECOND EDITION

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PREFACE TO SECOND EDITION

After the amendment in 1928 by the Government of India of the rules for examination of candidates for certificates of competency as Masters and Mates of Steamships, the need was felt of a text-book to enable Indian seamen to study the laws of storms and the prevailing winds, weather and currents in Indian Waters. To meet this need the preparation of this pamphlet on "Winds, Weather and Currents on the Coasts of India and the Laws of Storms" was undertaken by the India Meteorological Department. The first edition of the pamphlet was compiled by Mr. S. Basu in the Marine Section of the Poona Meteorological Office from sources of information available in the department. It has now been revised with alterations and additions. The chapter on Currents and Tides has been re-written. The following are the main additions :—

- (1) A short preliminary chapter on Wind and Pressure;
- (2) Tables of climatological data of 14 coastal stations ; and
- (3) A glossary of important meteorological terms occurring in the pamphlet.

The attention of seamen is invited to the following two publications of the India Meteorological Department :—

- (1) Weather Codes for Ships in Indian Waters,
Part 1—Weather Reports from Ships (1936) ; and
Part 2—Weather Broadcasts to Ships (1939).
- (2) Code of Storm Warning Signals for use at Indian Maritime Ports (1936).

The India Meteorological Department will welcome suggestions for increasing the usefulness of this publication in future editions.

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Director General of Observatories.

POONA,
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CHAPTER I

WIND AND PRESSURE

Wind

Wind is air in movement. To specify a wind, one must mention both its direction and speed. The direction of a wind is taken to be that from which it blows and is usually given in 8, 16 or 32 points of the compass. When the wind direction is given as NNW, it means that the wind is coming from the northnorthwest and when it is given as N/W, the meaning is that the wind blows from between N and NNW. The speed of a wind is expressed in miles per hour, or among sailors, in knots.

1 knot=1.152 miles per hour.

Wind Force and its estimate.—Beaufort scale.—Before the days of instrumental meteorology, the speed of wind was estimated by its effects. In 1805, Admiral Beaufort of the British Navy devised a scale of wind force which is still used widely both at sea and on land. The scale has 13 figures, 0 to 12, and the higher the figure, the greater is the corresponding wind speed. The Beaufort scale of wind force, the mode of estimating it on sea and land and the corresponding wind speeds are given in *Table I*.

The steamship mariner of to-day estimates the force of wind at sea by its effect on the surface of the sea. In a calm, the sea-surface is glassy, with a light wind it is smooth but with small wavelets, with a moderate gale it becomes rough, and with a strong gale blowing, the sea becomes very high. The state of the sea surface corresponding to different wind forces is given in the sixth column of *Table I*.

TABLE I
Beaufort Scale of Wind Force

Beaufort Number.	Brief description of wind.	Limits of speed in miles per hour.	Specification of Beaufort Scale.			Approximate Equivalent Sea Disturbance Scale in Open Sea.	
			For use inland.	For use on coast.	Corresponding state of open sea.	Code Figure.	Probable Mean Height of Waves in ft.
0	Calm ..	0-1	Smoke rises vertically ..	Calm	Calm ; glassy	0	..
1	Light air ..	2-3	Wind direction shown by smoke drift but not by wind vanes.	Fishing smack just has steerage way.	Calm ; ripples without foam crests.	1	$\frac{1}{2}$
2	Light breeze	4-7	Wind felt on face, leaves rustle ; ordinary vane moved by wind.	Wind fills the sails of smacks which then move at 1-2 m.p.h.	Smooth ; with small wavelets.	2	1
3	Gentle breeze ..	8-11	Leaves and small twigs in constant motion ; wind extends light flag.	Smacks travel at 3-4 m.p.h.	Smooth ; crests of wavelets begin to break.	2	$2\frac{1}{2}$
4	Moderate breeze ..	12-16	Raises dust and loose paper ; small branches are moved.	Good working breeze ; smacks carry all canvas with good list.	Slight ; with white horses	3	5

6	Fresh breeze	..	17—21	Small trees in leaf begin to sway.	Smacks shorten sail	..	Moderate ; many white hor- ses.	4	9
6	Strong breeze	..	22—27	Large branches in motion ; whistling in telegraph wires.	Smacks have double reef in main sail.	..	Rough ; large waves begin to form ; extensive white foam crests.	5	14
7	Moderate gale	..	28—33	Whole trees in motion	Smacks at sea lie to	..	Very rough ; white foam from waves begins to be blown in streaks along wind.	6	19
8	Fresh gale	..	34—40	Breaks twigs off trees ; generally impedes progress.	All smacks make for harbour.	..	High ; edges of crests break into spindrift ; well marked streaks of foam along wind.	7	25
	Strong gale	..	41—48	Slight structural damage occurs.	}	Very high ; long overhanging crests of waves ; heavy rolling of sea ; Visibility affected.	8	31
10	Whole gale	..	49—56	Trees uprooted, considerable structural damage.		..	Exceptionally high ; small and medium sized ships lost for a time to view behind waves ; Sea completely covered with white foam.	..	37
11	Storm	..	57—65	Widespread damage		..	Phenomenal ; sea white with driving spray. Visibility very seriously affected.	9	45 or more.
12	Hurricane	..	> 65			

Pressure

Wind is caused by differences of atmospheric pressure at the same level. The pressure at any place is the weight of the atmosphere on a unit of area and is equal to the weight of a column of mercury of unit area of cross-section and height equal to the height of mercury in a barometric tube. If the pressure is measured at a number of places at sea level and plotted on a map, we can draw a series of lines, each passing through points having the same pressure. These lines are called *isobars*. Isobars are generally drawn with constant difference of pressure. Thus we can have isobars corresponding to 29.85, 29.90, 29.95, 30.0, etc., inches of pressure. If some of the places at which the barometers are read are not at sea level, their readings should, before plotting, be reduced to what they would be at sea level. Similarly if the mercury in the different barometers is at different temperatures, the readings of the barometers should be reduced to the same standard temperature. A correction is also required for the variation of gravity with latitude.

If a number of isobars on a map enclose an area of low pressure, the region of lowest pressure is called a *barometric low* or *depression* or cyclonic storm depending on the strength of the winds, and if they enclose an area of high pressure, the region of highest pressure is called a *barometric high* or anticyclone. If we examine a series of maps showing isobars and winds, it is found that there are certain simple rules governing the relation between them.

(1) The winds are strongest where isobars are closest and *vice versa*. The rate at which pressure decreases in a direction at right angles to the isobars is called the barometric gradient. In the same latitude the greater the barometric gradient, the greater is the speed of wind.

(2) The wind blows roughly parallel to the isobars, but with a definite tendency to flow from the region of high pressure, into that of low pressure. The angle between isobars and wind is generally 10° to 30° at sea and 20° to 50° on land.

(3) When we face the wind the lowest barometer is towards the right hand side in the northern hemisphere, and towards the left in the southern. (Buys Ballot's Law.)

CHAPTER II

WIND SYSTEMS IN THE INDIAN SEAS—THE MONSOONS—SEA AND LAND BREEZES

Monsoons.—The outstanding feature of the wind system in the Indian Seas is a seasonal reversal of direction known as the “ monsoons ”. During the winter third of the year, December to March, the general flow of air is from Iran, India and Burma to the Arabian Sea and Bay of Bengal and thence towards the equator. Over the Indian Seas, the winds in this season have mainly a northeasterly direction, and are therefore called the *northeast monsoon* winds. January is the month in which this air movement is best seen. In the summer third of the year, June to September, the flow is almost completely reversed and the winds blow from the southwest over the sea towards India and Burma in the great current known as the *southwest monsoon*. July is a representative month of the southwest monsoon season. In illustration of the two monsoons, charts of winds and pressure for January and July are reproduced in *Figs. 1 and 2*. In January the seat of high pressure is in Central Asia and the pressure decreases steadily from the north of our area to the south. In July the region of lowest pressure is over northwest India and the high pressures in our chart are over the equatorial sea. This change between January and July is mainly caused by changes of temperature. In both charts, the region of lowest pressure is near the region of highest temperature and that of highest pressure near the region of lowest temperature. Air tends to flow from a region of high pressure to one of low pressure ; hence, looking at the January chart, we would expect winds to blow, roughly, from north to south, and on the July chart from south to north. Atmospheric motion, however, is not as simple as this. There is another important control. The rotation of the earth causes a current in the northern hemisphere always to curve towards the right hand side. A current trying to move from north to south, is deflected towards the right and becomes a northeast current as in the northeast monsoon. A current moving from south to north is also deflected towards the right

and thus becomes a southwest current as in the southwest monsoon. If there were no friction, the deflection of the current due to the earth's rotation would make it flow round the low pressure area along the lines of equal pressure. Mountain ranges and coast lines produce localised deflections of air currents.

The terms " southwest " and " northeast " applied to the two monsoons are truly descriptive of them only in the Bay of Bengal and the western half of the Arabian Sea.

Between the two main monsoon seasons are two transition periods, making in all four seasons, into which the year may be divided for the purpose of describing the prevailing winds in the Indian Seas. The four seasons are :—

- (1) The Northeast Monsoon Season—(December to March)
—when northeast winds of land origin prevail over the greater part of the Indian Seas ;
- (2) The Hot Weather Period—(April and May)—the transitional period of preparation for the southwest monsoon ;
- (3) The Southwest Monsoon Season—(June to September)
—when southwest winds of oceanic origin blow steadily ; and
- (4) The Transition Monsoon Period—(October and November)—when southwest winds of oceanic origin retreat southwards and are replaced by northerly winds of land origin.

Northeast Monsoon (December to March).—This is a season of winds of land origin and thus of clear or lightly clouded skies and little rain. Over the land this is the season of lightest winds. Air movement in northern and central India is from the west down the Gangetic plain. The stream-lines of airflow curve through northwest to north across Bengal and to northeast in the Bay of Bengal. Across the Indian Peninsula the air moves from the east and passes out into the Arabian Sea

where winds are light northerly near the Indian coast but become stronger and steadier further west, blowing from north-northeast or northeast. A feature of this period is the succession of cold weather storms, or winter depressions, which pass from the west through Iraq and Iran to northern India and cause considerable snowfall on the western Himalayas and rainfall in the neighbouring plains. These depressions sometimes give rise to squally weather in the north Arabian Sea and off the Bengal coast.

Hot weather period (April and May).—During this period temperature rises in central and northern India, the rise of temperature being accompanied by a fall of pressure. Winds become light in the centre and south of the Arabian Sea. Off the west coast of the Peninsula the winds strengthen and back to northwest, and off the east coast they become southerly to southwesterly. In middle and south Bay of Bengal the winds are variable and are sometimes interrupted by calms. It is a season in which severe tropical storms may develop in either of these seas (see later chapters) and in which some coastal districts are liable to be visited by thunderstorms or severe local storms, especially the Bengal coast, where the local storms known as "*Nor'westers*" or "*Kalbaisakhis*" are experienced.

Southwest Monsoon (June to September).—The summer monsoon is a season of winds of oceanic origin with high humidity and frequent and heavy rain over nearly the whole area. It sets in on the Travancore coast at the end of May or early in June and on the south Burma coast sometime in May. The monsoon invades India in two main currents. Within two or three weeks, it takes possession of the whole Bay of Bengal and the Arabian Sea up to their northern coasts. The current from the Arabian Sea blows on the west coast from directions between west and southwest and spreads over the Peninsula, Central Provinces and Gujarat. The Bay current sweeps from southwest over the Bay towards Burma. The southern portion is either forced across the Tennasserim hills or passes up the Irrawadi valley and the remaining portion advances up the Bay and is deflected by the Arakan hills and the Himalayas.

first towards the north across the Bengal coast, and then towards the northwest up the Gangetic plain. A number of cyclonic storms forms in this period at the head of the Bay of Bengal and, after crossing the Bengal or Orissa coasts, moves in a northwesterly direction over the Indian land regions. These are times of strong monsoon in both seas. At other times both branches of the monsoon may relax their strength for a spell and fair weather with moderate wind may prevail for days or even for weeks. In September, conditions rapidly change and the rain-bearing winds cease to penetrate to north-western India.

The Retreating Monsoon (October and November).—

The transition from the wet to the dry monsoon begins in the latter part of September and is usually not complete until the middle of December. It is thus a transitional period of considerable length and differs in this respect from the transitional period at the beginning of the southwest monsoon, which is usually established rapidly over the whole Indian area and extends over the greater part of India in the course of a fortnight or so. The advancing monsoon current is a vigorous movement; but the retreat or withdrawal is a much more gradual and intermittent process. Before the end of October, the southwest winds weaken and then disappear in the Arabian Sea off the west coast and in the centre of the Bay of Bengal, but they persist for some time in the extreme south of the Bay. In the meantime, northerly winds develop in the north of the Bay and extend as a northeast current towards the south Madras coast. The inter-play between these two currents gives rise to alternate periods of fine dry weather and boisterous wet weather. Each period of wet weather is, as a rule, associated with the development and progress of a cyclonic storm. This indeed is the most favourable season of the year for the formation of severe cyclones in the Bay of Bengal.

Sea and Land Breezes.—Besides the seasonal winds described above, there are local and seasonal winds along the coasts. The most important of these local winds are the sea and land breezes. By day, the air over the land near any coast

becomes, as a rule, warmer and therefore lighter than the air over the sea with its more equable temperature ; the heavier air from the sea flows in as a cool "*sea breeze*" displacing the warm lighter air over the land. At night, on the other hand, the land cools by radiation faster than the sea and so the air over the land becomes cooler and heavier than the air over the sea ; hence the heavier land air slides out over the sea as a "*land breeze*" and displaces the warm lighter air that rests over it. When these breezes are regular, the land breeze begins to weaken after about 9 hrs. in the morning and decreases to a calm about midday. Soon afterwards, the sea breeze sets in, increasing in strength as the evening advances. Some time after sunset, the sea breeze dies down and is followed by a calm which continues till the land breeze commences. The time of onset of the land breeze varies with the month and the place, but is generally after 22 hrs. At first the land breeze comes as a fluctuating gentle wind ; it soon becomes steady and continues so till 9 hrs. or 10 hrs. next morning.

Sea and land breezes are very pronounced along the Indian coasts during the bright sunny weather of the northeast monsoon season. They are least pronounced during the southwest monsoon when cloudy weather prevents the land from heating up by day or cooling by night, and when, in any case, the regular strong winds of the season overcome the daily land and sea reversal.

Sea and land breezes deserve attention from sailing vessels if they are to take advantage of them. In the morning and before noon, it is advisable to edge more out from the coast to get an offing of 15 or 20 miles and be ready for the sea breeze. In the evening it is desirable to be near the shore before the land breeze comes on ; if close in prior to the commencement of the land breeze, short tacks are made near the shore until the breeze comes off. With the land breeze during the night it is prudent to keep well in shore if the wind admit it without tacking, for it is stronger and steadier there than farther out.

CHAPTER III

LOCAL WINDS AND WEATHER ON THE COASTS OF INDIA.

In this chapter, a brief description is given of the winds and weather prevailing in each season in the different coastal zones of India and Burma from Gwador on the Mekran Coast to Victoria Point in S. Tenasserim. The coastal strips occurring in the following descriptions are marked on the map shown in *Fig. 21*.

Mekran Coast (Long. 60° E to 67° E).— From October to February, land and sea breezes prevail. They begin to weaken in March and merge into the general wind circulation in April; the predominant winds during these two months are light to moderate from west or southwest. May is the most windy month on the eastern half of this coast where moderate to strong west to southwesterly winds are met with, while in the western half, the winds are light and variable. The weather is generally fine and the sea smooth throughout the months October to May, except when affected by cyclonic storms in the Arabian Sea or by western disturbances. Cyclonic storms in the Arabian Sea moving northwestwards affect the coast at rare intervals in the beginning and end of this period, *i.e.*, in October and November, and in May. They cause cloudy and, thundery weather with gales, rainsqualls and rough seas. During the winter months, December, January and February, gales or squalls with rough seas and heavy swells are sometimes experienced in association with the eastward passage of winter depressions over Baluchistan. The squalls behind these winter depressions may raise clouds of dust and produce a dust-storm or thick dust haze; they are often the precursors of strong cold northwesterly winds known as "*Shamals*".

The dust haze may sometimes persist for a few days after the strong winds associated with the dust storms have subsided.

A period of threatening weather, which may sometimes be associated with the northwestward movement of a cyclonic storm in the Arabian Sea in early June, is usually followed later in the month by a moderate monsoon gale from westsouthwest which lasts from a few days to a fortnight and is preceded or accompanied by a heavy swell and rough sea. A westsouthwest monsoon breeze and swell (southerly to easterly winds

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over the western half of the coast) continue throughout July. The wind and swell diminish in August, when small crafts go out to sea again, and by the beginning of September the monsoon is generally at an end. Between mid-July and September, depressions move westwards over northern India and occasionally reach the north Arabian Sea when they may cause rain squalls and thunderstorms on the Mekran coast with moderate to rough seas.

Visibility.—The early part of mornings, from an hour before to an hour after sunrise, the atmosphere remains foggy or misty in March, and towards the latter half of the month dust begins to be blown about during the day causing loss of visibility. In April, the air sometimes remains hazy following dust storms. Visibility is decidedly poor along this coast in May on account of dust haze everywhere and, in addition, occasional morning fog in the eastern parts of the coast. The poor visibility due to dust continues in June. In July the atmosphere begins to clear, though along the coast misty and hazy conditions may prevail in the early morning. The visibility remains generally good thereafter, except for occasional morning fog in October and November.

Sind and Kathiawar Coast (Karachi to Gulf of Cambay).—Weather is generally fine and seas smooth in the cold weather months; occasionally, however, local gales and squalls occur in association with the eastward passage of western depressions from Iran to northwest India. The characteristic cold weather months are December and January, when moderate morning land breezes generally alternate with weak afternoon sea breezes; the land breeze is the predominating feature and at times blows continuously for two days or more on end. After calm nights in the cold weather banks of fog may be seen on this coast at early dawn, which drift out to sea with the land breezes. Mirages are of frequent occurrence. From February onwards the westerly and south-westerly sea breezes become gradually more pronounced in the afternoons, and from April onwards they blow by night as well as by day, being strongest in the afternoons. The south-west monsoon sets in June, attended with overcast skies,

showers and strong winds at times rising to a fresh gale. It remains vigorous throughout July and August and weakens rapidly in September. The rainy spells on this coast during the monsoon are generally associated with depressions which advance westwards from the Central Provinces or the Gangetic plain; winds on the coast are then variable in direction and the rain may be accompanied by thunderstorms. A heavy swell begins in the middle of May (when coasting steam vessels and small craft cease to put to sea) and continues with varying intensity until the end of the monsoon.

The Konkan and Kanara Coasts (Gulf of Cambay to south of Mangalore).—Throughout the cold weather period the wind blows on the average from some northerly direction, in October from northwest, in November, December and January from north and in February from northnorthwest. The daily land and sea breezes are well marked, the former blowing from the northeast in the mornings and the latter from the northwest in the afternoons and evenings. From March to May the average wind direction backs from northwest to westnorthwest and the land breezes become very uncertain, seldom coming off till morning; they continue for so short a time that they are of little advantage to sailing vessels. It is therefore necessary to keep an offing to be ready for the sea breeze, which in this season sets in at about noon. A feeble land breeze sometimes follows; but more frequently light airs from northward or calms may be expected from nearly midnight to about noon on the following day when the northwest sea wind again sets in. Sometimes these northwest winds are particularly strong, producing a short choppy sea and a drain of lee current; so that when it falls to a calm, it is necessary to anchor at times with a light anchor to avoid being driven southward.

The northwesterly winds continue, but are often variable and uncertain in May. The weather is cloudy with showers and lightning, which come at times from the southeast. In this month a gale from southwest may occur; and it is prudent therefore to keep well out from the land and be prepared for bad weather, in order to avoid being driven on a lee shore if a storm should set in from westward.