

INDIA METEOROLOGICAL DEPARTMENT.

WINDS, WEATHER & CURRENTS
ON
THE COASTS OF INDIA
AND
THE LAWS OF STORMS

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CHAPTER I.

PREVAILING WINDS IN THE INDIAN SEAS.—THE MONSOONS. SEA AND LAND BREEZES.

Monsoons.—The outstanding feature of the wind system in the Indian Seas is the seasonal reversal known as the “ monsoons ”. During the winter third of the year the general flow of the lower air layers is from India and Burma over the Arabian Sea and Bay of Bengal towards the equator as a *northeast monsoon*. January is the month in which this air movement is best exemplified. In the summer third of the year 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 month representative of the weather conditions of the southwest monsoon season. In illustration of the two monsoons, charts of winds and pressure for January and July are reproduced in *Plate 1*. In the January chart the seat of high pressure is in northern India and the pressure decreases steadily southwards to the areas at the bottom of the chart where pressure is lowest. In the July chart the regions of highest and lowest barometer are reversed. The high pressure is now at the bottom of the chart over the equatorial sea and the low pressure is over northwest India. In the interval between January and July this change is brought about by changes of temperature. In both charts the region of lowest pressure is also the region of greatest heat and that of highest pressure is the region where the atmosphere is coolest. 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. No atmospheric motion, however, is as simple as this. There are other controls. For example, 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, being deflected towards the right, 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. There are other controlling and disturbing influences, such as mountain ranges, which may deflect air currents, and coast lines, which give rise to land and sea breezes. The result is that the wind is not everywhere southwest in the southwest monsoon, nor is it everywhere northeast in the northeast monsoon. The terms "southwest" and "northeast" are indeed truly descriptive 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 area. 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—(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.—This is a season of winds of land origin and thus of generally dry weather, of clear, or lightly clouded skies and of 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. It curves 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 Persia to northern India and cause considerable

snowfall on the Himalayas. These depressions sometimes give rise to squally weather in the north Arabian Sea and off the Bengal coast.

Hot Weather.—During this period temperature rises in northern India, more especially over the land area, the rise of temperature being accompanied by a fairly continuous fall of pressure. Winds become light in the centre and south of the Arabian Sea. Off the west coast and Gujarat, the winds strengthen and back to northwest. In the Bay of Bengal southwest winds spring up, though unsteadily, being 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 ” are experienced.

Southwest Monsoon.—The summer monsoon is a season of winds of oceanic origin, of high humidity and of 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. Within two or three weeks, it takes possession of the Bay of Bengal and the Arabian Sea up to their northern coasts. It invades India from these seas in two main currents. The Bombay current from the Arabian Sea blows on the west coast from directions between west and southwest and prevails exclusively 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 Tenneserim hills or passes up the Irrawadi valley ; 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, then towards the northwest up the Gangetic plain. A number of cyclonic storms form in this period at the head of the Bay of Bengal and, after crossing the Bengal or Orissa coasts, move 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 northwestern India.

The Retreating Monsoon.—The transition from the wet to the dry monsoon begins in the latter part of September and is usually not completed 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 action. 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. The southwest winds persist for some time in the extreme south of the Bay, while the northerly winds are developing in the north of the Bay and are extending 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 of 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 variation in the winds described above, there are local and seasonal variations in the winds along the coasts. The most important of these local variations is the daily variation due to 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. Generally at about sunset, the sea breeze is followed by a calm which continues till the land breeze commences between 20 hrs. and 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, in fact practically non-existent, 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 for sailing vessels if they are to benefit by them to the full extent. In the morning and before noon, it is advisable to edge more out 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 inshore, if the wind admit it without tacking, for it is stronger and steadier there than farther out.

CHAPTER II.

LOCAL WINDS AND WEATHER ON THE COASTS OF INDIA.

Mekran Coast.—From October to February land and sea breezes prevail. They begin to weaken in March and vanish by April, the predominating winds during these two months being light to moderate west to southwesterly winds. 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 winds are light and variable. The weather is generally fine and the sea smooth throughout these months except when affected by cyclonic storms in the Arabian Sea or the winter storms, also known as the western disturbances. Towards the beginning and end of this period, *i.e.*, in October and November and in May, cyclonic storms in the Arabian Sea moving northwestwards may at rare intervals affect this coast and cause cloudy and thundery weather with gales, rainsqualls and rough seas. During the winter months, December, January and February, gales or squalls with rough sea and heavy swell 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 duststorm or thick dust haze; they are often the precursors of strong cold northwesterly wind known as "*Shamals*". Dust haze may sometimes last a few days, even after the subsidence of the strong winds associated with duststorms.

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 over the western half of the coast) continues throughout July. The wind and swell diminish in August, when small craft 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 duststorms. Visibility is decidedly poorest 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 in the atmosphere continues during 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 Coasts.—Weather is generally fine and seas smooth in the cold weather months, when however local gales and squalls sometimes occur in association with the eastward passage of western depressions from Persia 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 southwesterly sea breezes become gradually more pronounced and from April onwards they blow by night as well as by day, being strongest in the afternoons. The southwest monsoon sets in in June, attended with overcast skies, occasional 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 Coast.—Throughout the cold weather 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, blowing from the northeast in the mornings and 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 eye 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.

During the period of change before the southwest monsoon has set in, the small coasting vessels run in the afternoon into the nearest river or place of shelter south of Bombay; but large vessels should have sea-room.

At evening in May and in early June heavy clouds sometimes collect and hard squalls occur with rain at night. The south-west monsoon normally sets in at the end of the first week of June and up to the middle of August weather is generally very unsettled with hard squalls, much rain, dark cloudy weather and a heavy southwesterly swell. The monsoon begins to weaken in August and finishes in September. A period of light variable winds and frequent calms with cloudy weather and occasional showers intervenes. Late in October or early in November there is frequent thunder and lightning associated at times with a storm from southwards. After this period the northerly winds of the winter months are established.

Visibility.—During the season of northwest winds (February to May) the atmosphere is generally hazy southward of Bombay along the Konkan and Kanara coasts; this is particularly marked in March and April. Owing to the haze the land and trees along the coast appear to be at a much smaller distance than they really are.

During the period from April to October the Western Ghats are usually enveloped in a dense mist or haze, which hides the mountains from view. These mists however occasionally disperse for short intervals after heavy falls of rain. In October early morning fogs occur obscuring from the view the low-lands and projecting headlands up to about sunrise or a little later.

Malabar Coast.—The daily variation of morning land breeze and evening sea breeze is a marked feature of the winds on the Malabar coast during the northeast monsoon season. In October the wind is generally weak and mostly off the sea, the land breezes as yet being only occasional, light and uncertain. The land breezes are strongest and most regular in December and January but are also fairly well marked in November and February; even in these months the afternoon sea breeze remains a regular feature, despite the opposing influence of the northeast monsoon winds in the upper air. From March onwards, the land breezes decrease in strength and duration and are not always regular. Thus the navigator may calculate on sea breezes for nearly all the year, but on regular land winds for only about four months.

Opposite gaps in the mountain chain, as at Palghat on the south of the Nilgiri hills, the land winds in December and January, being helped by the northeast monsoon, sometimes continue to blow for more than a day without any intervening sea breeze. This also occurs, but in a lesser degree, off Karwar where the valley of the Sadasivgad river assumes a straight funnel shape eastward towards the interior of the Peninsula.

South of the Palghat gap the southwest monsoon sets in late in May. It frequently commences with a gale from southeast veering to south and southwest where it ultimately remains; at other times it commences with squalls from southwest, and a heavy long swell rolling in upon the shore. In June the wind keeps mostly between southwest and west by south, with much rain, high sea and severe squalls at times. In July the weather becomes a little more settled and the squalls veer sometimes to the west and westnorthwest. The sky is mostly obscured by heavy clouds during the southwest monsoon season, but considerable intervals of fine weather are occasionally experienced. In August the squalls have veered pronouncedly to the west and westnorthwest and winds become northwesterly or westnorthwesterly.

In September the weather moderates. West and westnorthwest winds are the most prevalent while calms are experienced off Cape Comorin. Severe squalls are rare although the weather is often cloudy and threatening with heavy showers. A swell often rolls in from westsouthwest in this month, particularly during unsettled, squally weather. After some weeks of mostly fine weather, but frequent showers, the Malabar Coast is usually visited, in the end of September or the beginning of October, by strong easterly squalls, rain and thunder which finally closes the southwest monsoon season.

The navigation southwards along the west coast of India, for sailing vessels, during October and a great part of November, is usually tedious and uncertain; for there is no dependence on the winds till late in November. But the light winds are not unfavourable for sailing down the coast as the drain of the current is still generally to the southwards.

Gulf of Manar.—On the west coast of Ceylon land and sea breezes occur from December to March (*i.e.*, the northeast monsoon season) and the weather is generally fine, but the winds along the Indian shore of the gulf do not assume the character of land and sea breezes until February. The sea breezes gradually become of longer duration after February and increase in force till about the middle of May.

Towards the end of April, at night the wind becomes light and variable and squalls and showers of rain may occur while a swell is experienced from the westward. The sky becomes overcast in May, banks of clouds rising over the ocean; and winds begin to blow continuously from the southwest. The southwest monsoon gains strength in June, and the fishermen seldom go out to sea in this month. Showers become less frequent in July, but the weather is cloudy and hazy with generally a fresh breeze; the wind moderates near the head of the gulf in the mornings and blows strong again in the afternoons. Fresh southwesterly to westsouthwesterly winds continue in August and September but the weather is generally fine; in the afternoon the breezes are strengthened and are accompanied with occasional squall and rain. The atmosphere often remains hazy in September.

October has more unsettled weather and at times there are heavy squalls with rain towards the end of the month. During November the winds are light and variable between northeast and westnorthwest; weather is very unsettled with frequent heavy squalls and rain. About the middle of the month the northeast monsoon is ushered in by lightning, thunder and heavy rain. The northeast monsoon lasts till the end of January and blows steadily from northnortheast along the Indian coast; but in the northwest part of Ceylon it is modified into land and sea breezes and is attended with generally fine weather except for occasional showers and hazy atmosphere.

The East Ceylon Coast.—Weather is almost invariably fine from February to April with occasional light squalls accompanied by thunder and lightning, at the end of this period. In May winds become southwesterly with cloudy skies and the southwest monsoon sets in towards the end of the month. The island of Ceylon shields

the east coast from the full force of the southwest monsoon, but at some distance off the coast, as well as on the south coast, isolated rain squalls are of frequent occurrence. The monsoon weakens generally in September and October but the force of the south-westerly winds in these months is very variable; the winds are feeble when fine weather prevails but invariably strengthen when squally or stormy weather prevails in the centre of the Bay of Bengal. After a period of light variable and unsteady winds the northeast monsoon sets in during November, and continues in strength until January; November and December are the two rainiest months of the year on this coast.

Coromandel Coast.—Weather is generally calm during the first half of October, but later, northerly to easterly winds set in and prevail till about the middle of February. Land and sea breezes remain only very weak throughout this period, being at their minimum in November. Rain is general over the southern part of the coast in November which is the rainiest month and also the month when the coast is most liable to be affected by severe cyclonic storms travelling west or northwestwards from the south of the Bay of Bengal and causing spells of strong winds, severe rain squalls and rough seas. The weather improves in December and is generally fine in January with much clearer sky and very little rain. Winds are less steady or strong in February when the normal direction at Madras is easterly. Hereafter land and sea breezes strengthen; they increase rapidly in March and April and are most strongly in evidence during the period May to September except on those days on which the southwest monsoon is strong. The land wind blows in the morning hours after sunrise, the sea breeze commencing in the early afternoon hours. In March and April southeasterly winds predominate and become very strong during the day. They veer towards south as the season advances, sometimes blowing as “longshore winds” directly or nearly directly from the south. The average wind direction in Madras is southwesterly in May, but it undergoes greater variations in direction and strength during the twentyfour hours each day in this month than at any other period of the year; occasionally indeed, a westerly wind prevails in this month throughout the day so that the sea breeze which usually sets in about midday does

not appear at all. Weather is generally fine during March to May interrupted occasionally by thunderstorms. Depressions sometimes form in the centre or south of the Bay and during the first half of May they may move in a westerly direction towards the Madras Coast, and for a time establish weather similar to those of November. In June southwesterly winds prevail, but only occasional showers and rain squalls occur in this month. On days when the southwest monsoon is strong, the sea breeze either does not set in on the Madras Coast at all or lasts for a very short time. During July, August and September, the southwesterly wind becomes weaker and rain squalls become more and more frequent, and showers increase on the Madras Coast. Sometimes very heavy and sudden showers of 2 to 4 inches are received in September, calms being frequent towards the end of the month.

The Circars Coast.—The dry season sets in by the end of November and lasts till early May. The mean winds are generally northeasterly during November and December, veer round to east during January, and become eastsoutheast to southsoutheasterly in February and first half of March. Land and sea breezes are well marked during the cold weather months, December to February. There is a pronounced shift of the predominating winds by the end of March when they are southerly to southwesterly, the weather remaining fine throughout. In May and June cyclonic storms originating in the Bay of Bengal approach this coast and affect the weather; in May the storms generally curve northeastwards towards the head of the Bay but in June they mostly pass inland through the Orissa Ganjam coast. Steady southwesterly winds predominate during July to end of August which is the rainiest period on this coast. During the withdrawal of the southwest monsoon, in September, October and November, this coast continues to get rain and squally weather in association with cyclonic storms of severe intensity. These storms generally form in the central Bay of Bengal about Lat. 16°N. in September and further south in October and November, and may move towards the coast causing much damage to life and property. In October the winds shift to a northerly direction and gradually the northeasterly winds of the cold season appear and hold steadily. By the end of October or

early November the rain slackens and feeble land and sea breezes set in and gradually gain strength thereafter.

Orissa and Bengal Coast.—In the middle of October the southwest monsoon winds are replaced by light unsteady northerly winds usually with more or less easting, calms being met with on the Chittagong Coast. As the season advances these northerly winds increase in steadiness and velocity, and in November and December blow as dry land winds from the northnorthwest to northwest, with the variation that they may be northeasterly winds in the mornings on the Chittagong Coast. From the beginning of October to the middle of December, cyclonic storms occur at irregular intervals in the Bay and occasionally advance northwards, curving sometimes northeastwards towards the Chittagong Coast. They are sometimes of excessive violence and a great majority of them affect the winds and weather on the Orissa-Bengal Coast. Dry northerly land winds with fine weather prevail as a rule in January and the greater part of February except during the brief periods when cold weather depressions cross northeast India. Winds during these disturbances shift round to southerly directions, and the weather becomes cloudy with occasional squalls. On the Chittagong Coast marked land and sea breezes prevail from the end of October to the middle of March.

There is a feeble indraught of local sea winds across the Bengal coast by early March. These southerly winds gradually strengthen, are vigorous and steady in April and May and continue unchanged in general character until the first or second week of June being sometimes of exceptional strength. These sea winds advance chiefly into eastern and northern Bengal and into Assam across the Assam hills and give rise to frequent afternoon and evening thunderstorms and much rain in those areas. Similar storms of considerable intensity occur in west Bengal, but not so frequently as in east Bengal. They usually advance from the northwest, and hence they are known as "*nor'westers*". They occasionally pass seawards across the Bengal or Orissa coasts, during April, May and June and may be felt up to distances of 70—80 miles from land.

The following is a brief description of a typical *nor'wester* storm :—

"The first sign of these storms is a low bank of dark clouds in the northwest, the upper outline of which has the appearance of an

arch. It approaches at first slowly, and then more and more rapidly and arrives with a strong gust or squall. There is frequently thunder and lightning followed by downpours of rain, and sometimes hail, which is driven by the strong wind. On some occasions the wind blows with almost hurricane force. The greatest velocity of the wind recorded in one of these storms (if the record can be relied upon) was 115 miles per hour. These storms commence generally in the afternoon, rarely last more than three or four hours and are usually followed by cool and clear weather during the remainder of the night."

Throughout the southwest monsoon period the predominating winds are southwesterly on the Orissa coast and southerly to southeasterly on the Bengal coast. July and August are the rainiest months. The transformation from the local southerly winds to the winds of the southwest monsoon proper usually occurs in the second or third week of June and is generally ushered in by the advance of a cyclonic storm of moderate intensity in the rear of which the monsoon currents are carried. These storms may occasionally reach excessive violence. From the commencement of the southwest monsoon in June to the end of September or middle of October there is a rapid succession of cyclonic storms or depressions which form at the head of the Bay. Advancing westwards these depressions cross the coast generally between False Point and Barisal. Hence the weather in this period alternates between periods of stormy conditions with showers and rain squalls during the inception and early stages of the advance landwards of these storms, and periods of light unsteady winds after their passage inland. The southwest monsoon usually withdraws in the first half of October.

Arakan Coast.—The dry season lasts from the end of November to April. Light northerly winds with generally a slight westing prevail till the end of February. During the hot season, March to May marked land and sea breezes are experienced. In the months October-December and also April and May cyclonic storms sometimes form in the Bay of Bengal near and to the west or northwest of the Andamans and pass by a curved path to the Arakan Coast giving rise to rain and squally weather. During the rainy