

Chapter 2

Hydrodynamics of Lakshadweep Sea

Abstract The winds in the Lakshadweep are predominantly northwest throughout the year with higher speeds in the range 5–8 m/s during June through August, the southwest monsoon season. The wave climate of the Lakshadweep Sea is dominated by the southwest monsoon. The highest wave heights are observed during the period from June to August with the dominant values of maximum wave heights around 5 m. During the rest of the period it was around 1.4 m. Higher wave periods are observed in February and April and the lower ones during June–August. The dominant zero-crossing period during the southwest monsoon is in the range 7–8 s and in the rest of the months it varies from 5 to 10 s. South-southwesterly waves dominate during most of the periods except during the peak southwest monsoon when west-southwest to westerly waves dominate. The inner-shelf currents are generally weak with northeast to southwest directions. The tide in the Lakshadweep Sea is mixed, semidiurnal and micro-tidal type.

Keywords Lakshadweep Sea • Waves • Currents and tides • Wind • Significant wave height • Wave direction • Wave climate

2.1 Introduction

Hydrodynamics generally refers to the study of the dynamics of fluids. It deals with the flow as well as the characteristics of the fluid in motion, in this case the sea water. Thus the characteristics of the wind, waves, currents and tide in the coastal waters of the Lakshadweep are explained here. They are interlinked in one way or other. For example, the waves are generated mainly due to the action of wind blowing over the sea surface. The dynamic energy is transferred to the sea surface nonlinearly by the wind. The wind is one among the driving force for the ocean currents also. On the other hand, the sea is transferring energy to the wind, as in the case of storms/cyclones moving above the sea. Finally, it is by the action of the waves and currents the sediment transport is taking place.

2.2 Waves

Centre for Earth Science Studies (CESS) under the financial assistance from the Department of Ocean Development, Government of India carried out wave measurements in the sea off Kavaratti [1] by deploying a directional wave rider buoy during March 1991–March 1992 [2, 3]. The buoy was deployed off Kavaratti on the southern side at a depth of 30 m. Due to the very steep bathymetry of the shelf the shoaling effects at this point is negligible when compared to the deep water waves. Hence, the waves recorded at this point can be taken as deep water waves for all practical purposes. In this section, the characteristics of the waves are presented.

2.2.1 Wave Heights

The parameters of wave height presented in this section are the maximum value of wave heights in each recording period, usually known as the maximum wave height (H_{\max}) and the average of the highest one-third of the wave heights in each recording period, known as the significant wave height (H_s). The H_s is mostly used in engineering applications since it reflects the energy content of the wave group.

The maximum wave height (H_{\max}) during each recording period ranged from 0.56 to 8.95 m, with the lowest values observed in February and the highest in August. Percentage occurrence of H_{\max} during the different months are presented in Fig. 2.1 which shows that H_{\max} is generally less than 5.0 m during November–March. During the above period the predominant H_{\max} is in the range 1.2–1.6 m, which constitutes nearly half of the cases. From June onwards the wave intensity increases and higher waves persist for 3 months. During June–August (monsoon season) the wave heights reach its maximum as expected and the distribution is flatty kurtic. The highest occurrences are in the range 4.8–5.2 m which contributes 21 % and the range 4.0–5.2 m constitutes 51 % during June–August.

The monthly average H_{\max} in each month is given in Fig. 2.2. The highest wave activity is observed during June–August, as seen in the monthly distributions. The average H_{\max} during these months are in the range 4.1–5.0 m, the highest occurring in July. During the other months the average values range from 1.3 to 2.7 m. During the months of November–March, lower values of less than 2 m are observed.

The significant wave height ranged in the year from 0.4 to 4.7 m, the lowest being observed in February and the highest in August as in the case of H_{\max} . The monthly distributions of H_s are depicted in Fig. 2.3 as percentage occurrences. The maximum values of H_s are observed during June–August with ranges 2.4–2.6, 3.0–3.2 and 2.0–2.2 m contributing about one-fifth each of the total occurrence. The wave activity decreases since then and the peak of the distribution of H_s during September and October are in the range 1.4–1.6 m. The wave activity is still less intense during November–March. Maximum occurrences of H_s during these months are in the range 0.8–1.0 m with contributions between 40 and 50 %. During March, November and December the wave activity is slightly more intense compared to January and February with H_s in the range 0.8–1.2 m contributing about 65–70 % of the occurrence. During April and May the

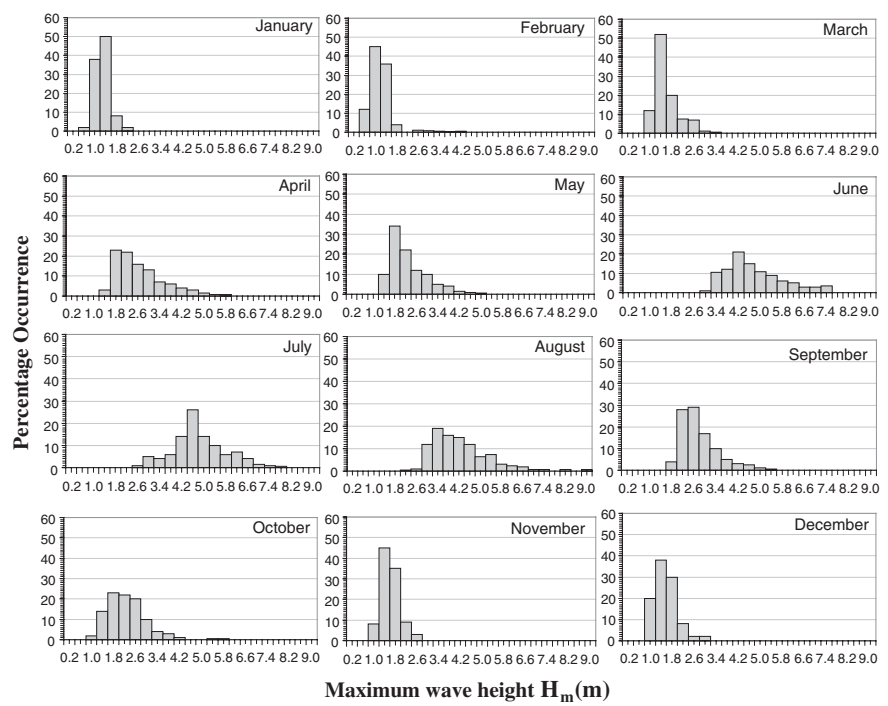
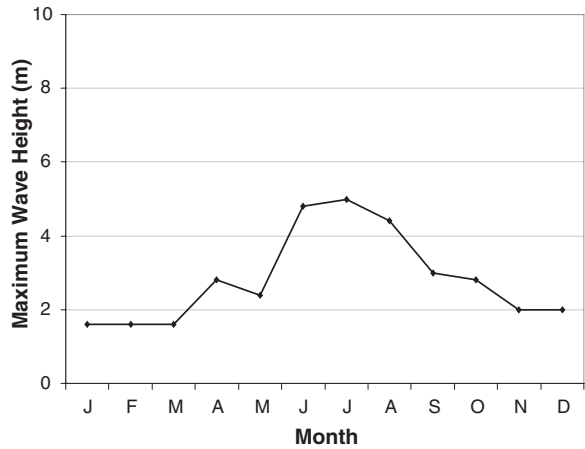


Fig. 2.1 Monthly distributions of maximum wave height (after Baba et al. [1])

Fig. 2.2 Monthly average of maximum wave height (after Baba et al. [1])



waves are slightly higher. The monthly mean H_s in each month is given in Fig. 2.4. High values of H_s are observed, as expected, during the months of June, July and August. During these months the monthly mean value of H_s varied from 2.5 to 3.0 m. During the other months mean H_s are in the range 0.8–1.7 m. The lowest wave heights are observed during November–March. During these months, the mean H_s ranged from 0.8 to 1.2 m.

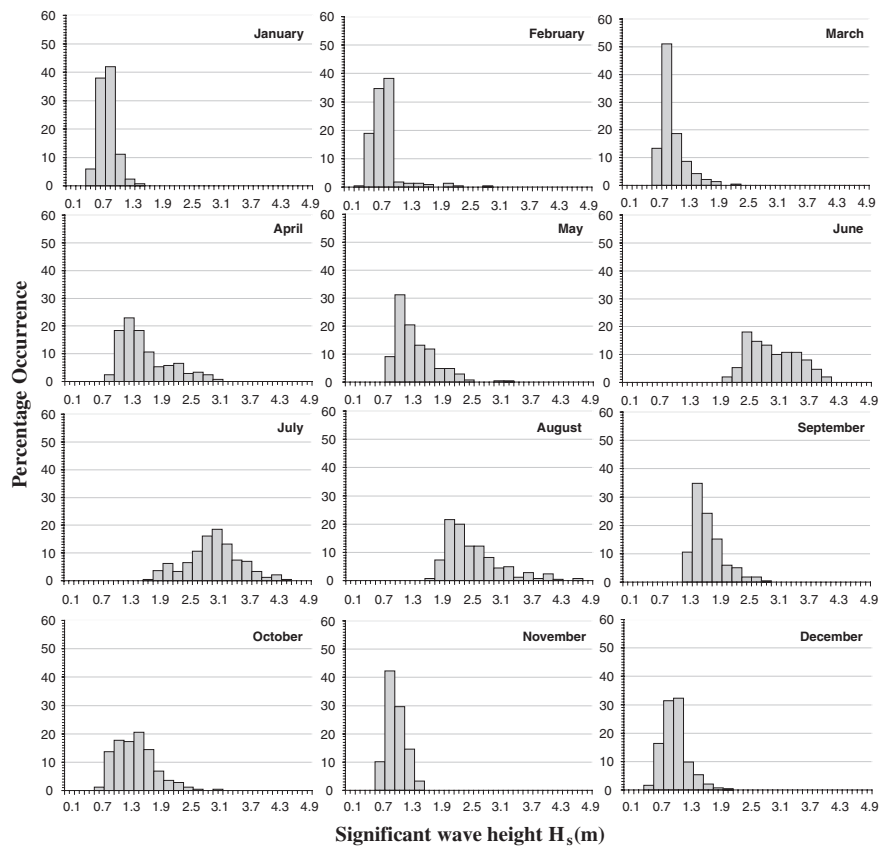
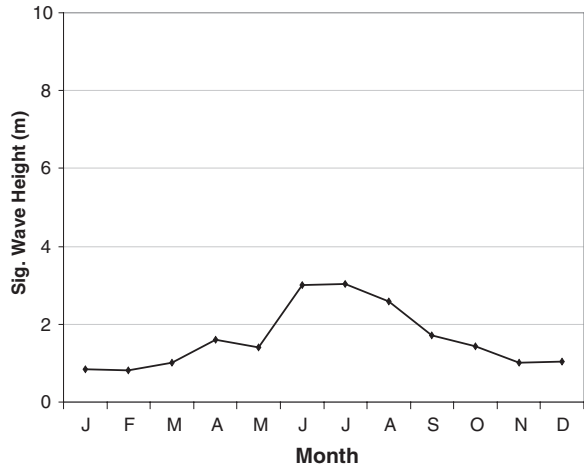


Fig. 2.3 Monthly distributions of significant wave height (after Baba et al. [1])

Fig. 2.4 Monthly average of significant wave height (after Baba et al. [1])



2.2.2 Wave Periods

The usually referred wave period parameters are the zero-crossing period and the peak period. The zero-crossing period (T_z) is the time taken by two successive crests to cross the zero or mean water level. It represents the average period of the waves in a wave train. Similarly, the period corresponding to the maximum wave energy spectrum is referred as peak period (T_p). It is mostly used in engineering applications at it represents the peak energy of the wave train.

The zero-crossing period vary from 3.5 to 13.3 s annually. The maximum range is observed in February and April and the minimum during the monsoon period of June–August. The monthly percentage occurrence of T_z (Fig. 2.5) shows that during January and February T_z in the range 5.0–6.5 s constitute more than half of the distributions. During March and April the waves are poorly sorted. During March there are two peaks in the distribution of T_z with nearly equal occurrences in the ranges

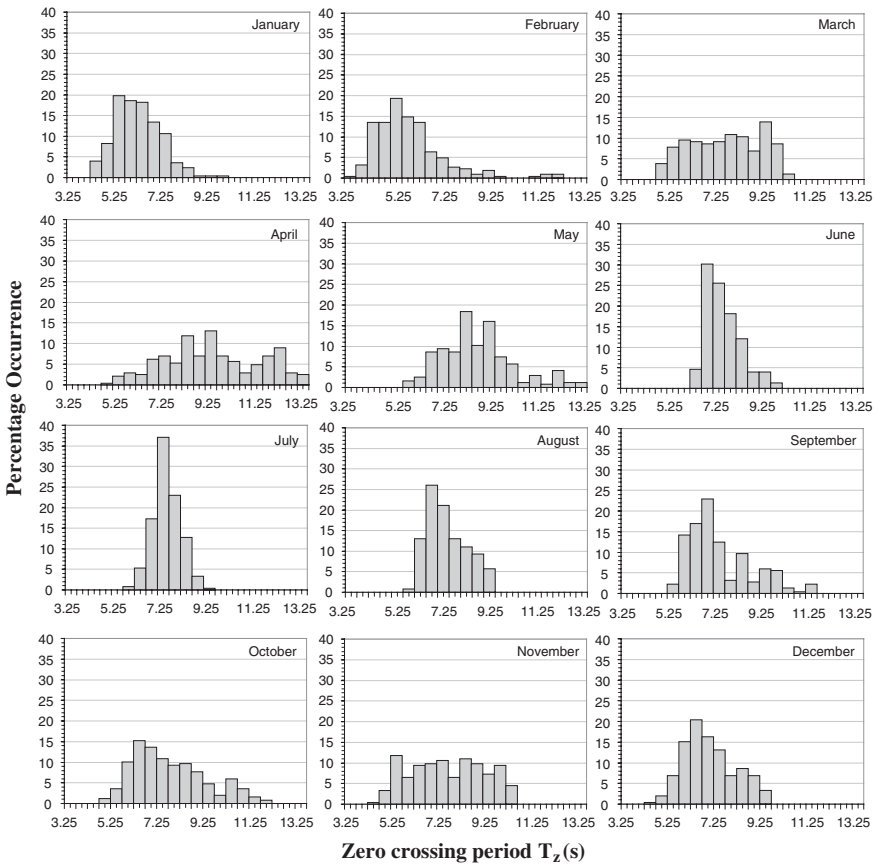
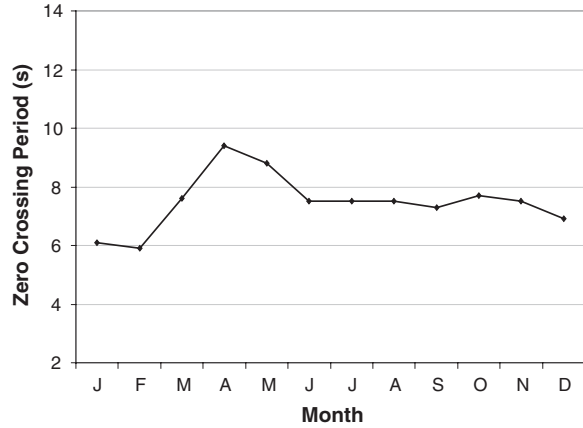


Fig. 2.5 Monthly distributions of zero crossing period

Fig. 2.6 Monthly average of zero crossing period (after Baba et al. [1])



of 5.0–6.5 s and 8.0–9.5 s. During April the peak of the distribution is in the range 8.5–9.5 s with about one-fourth of the occurrence. During May the wave periods are comparatively higher with about half in the range 8.0–9.5 s. During June–August waves are comparatively better sorted with the peak distribution falling in the range 7.0–7.5 s constituting about one-fourth to one-third of the distributions. During June T_z in the range 6.5–7.5 s constitutes more than half of the cases. During July and August more than three-fourth of the distribution is confined to the range 7.0–8.5 s and 6.0–8.0 s respectively. From September onwards the range of the distribution is widened. During September T_z in the range 5.5–7.5 s constitutes about three-fourth during this month. During October and November the distributions become more flatty-kurtic. During October T_z in the range 6.0–7.0 s represents one-fourth and that in the range 5.5–9.0 s represents three-fourth of the distribution. During November one-fourth of the distribution is in the range 8.0–9.0 s whereas during December 60 % of the distribution is in the range 5.5–7.5 s.

The monthly average values of T_z are depicted in Fig. 2.6. The monthly mean T_z ranged from 5.9 to 9.4 s. During June–November the values are almost uniform and are around 7.6 s. However, during September–November the range of occurrence are more compared to June–August. The lower range and better sorting during the monsoon season confirms the proximity of the generating zone.

The peak period (T_p) ranged from 8.4 to 26.0 s during the year, the lowest being observed in November and the highest in February. Generally, T_p is lower during June–August with small variations. The monthly distributions of T_p (Fig. 2.7) show that the distributions are somewhat similar in pattern, to the distribution of T_z . The maximum spread with lower percentage occurrence of T_p is observed in January and February. During January T_p in the range 11–18 s constitutes nearly 80 % of the distribution, whereas during February, T_p in the range 14–21 s represents three-fourth of the distribution. During March the peak is in the range 14–15 s contributing to one-fourth of the distribution and T_p in the range 14–18 s represents nearly three-fourth of the distribution. During April T_p values are slightly higher with nearly half the cases in the range 15–17 s. During May, more than 80 % of

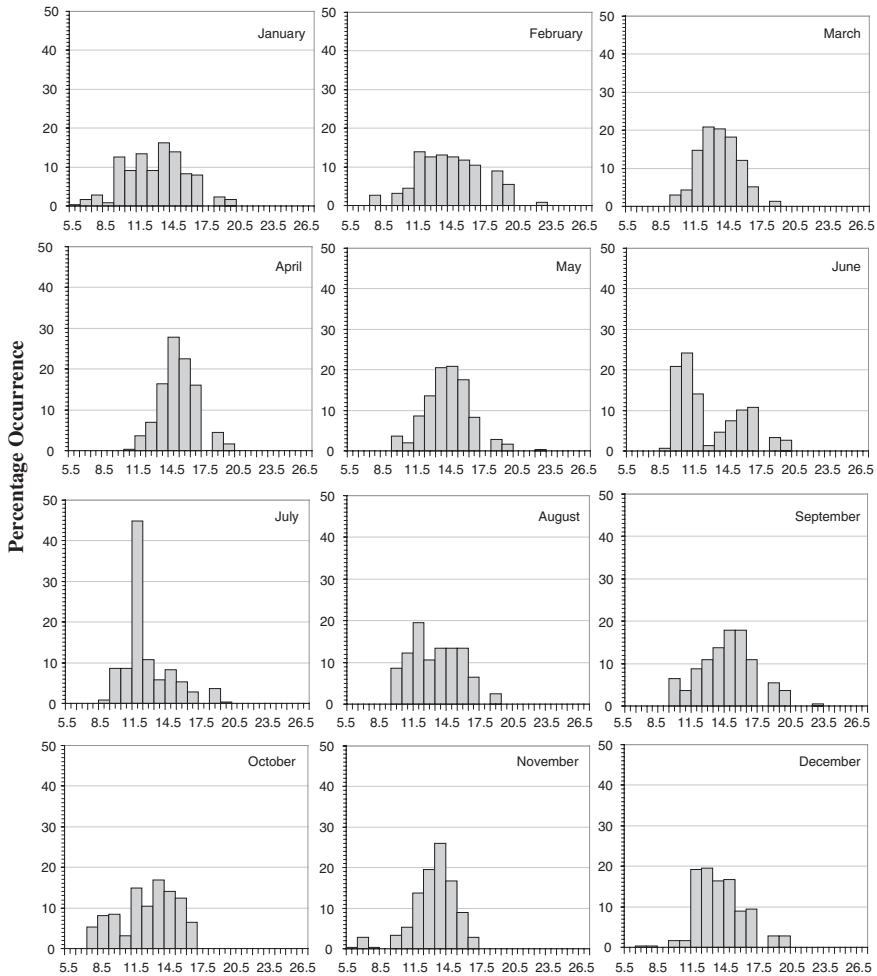
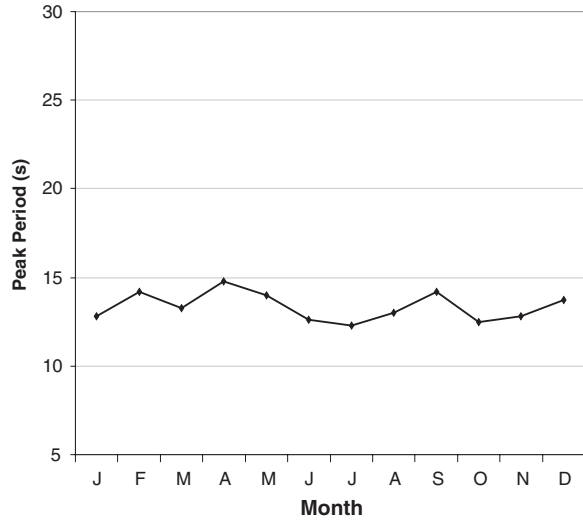


Fig. 2.7 Monthly distributions of peak period (after Baba et al. [1])

the T_p values fall in the range 14–18 s. By June, the values become lower with lower spread, with the onset of the southwest monsoon, when the waves are better sorted. During June, July and August the peaks of the distributions are in the ranges 11–12 s, 12–13 s and 14–15 s with about one-fourth of the contributions (24, 29 and 30 % respectively). During June T_p in the range 11–15 s represents more than two-third of the distribution. During July and August more than half of T_p fall in the range 12–14 s and 13–15 s respectively. The increase in T_p is continued in September with the shifting of the peak in the range 15–16 s. During September the distribution is widened and nearly half of the values fall in the range 14–17 s. During October and December the peaks of the distributions lie in the range 14–15 s with nearly one-fifth of the values falling in this range. During

Fig. 2.8 Monthly average of peak wave period (after Baba et al. [1])



October the distribution is further widened with nearly three-fourth of the values falling in the range 13–17 s and during November the ranges 13–14 s and 14–15 s have equal frequencies, both together constituting about 40 % in the distribution. During December about two-third of the values are found in the range 13–17 s.

The monthly mean values of T_p are depicted in Fig. 2.8. The values range from 13.6 s in June to 17.9 s in February. The lowest values are observed during June, July and August, as expected. The characteristics during June–August, as observed from the distributions of T_z is confirmed from the distribution of T_p also. During these months the average values vary between 13.6 and 14.3 s only. During February–May and September the mean T_p is between 16 and 17 s.

2.3 Wave Direction

The wave direction corresponding to the peak spectral density during each recording period (D_p) is dealt here because it corresponds to the direction of the major part of the wave energy. It is seen that D_p ranges from 106 to 316°N during the year. The monthly distributions of wave directions (D_p) are presented in Fig. 2.9. During most of the months, except during the monsoon months, the peaks of the distributions are around 200°–210°. The dominance of the peak varies with months. While the peak at 200°–210° represents one-fourth the cases in January, it is nearly half in February, April and May, one-third in March and about two-fifth in September, November and December. During June–August the distribution give a different pattern. During June the peak of the distribution is in the range 250°–260° with 20 % contribution followed by a secondary peak with 15 % occurrence in the range 200°–210°. During this month directions in the ranges 230°–270° and 190°–220°

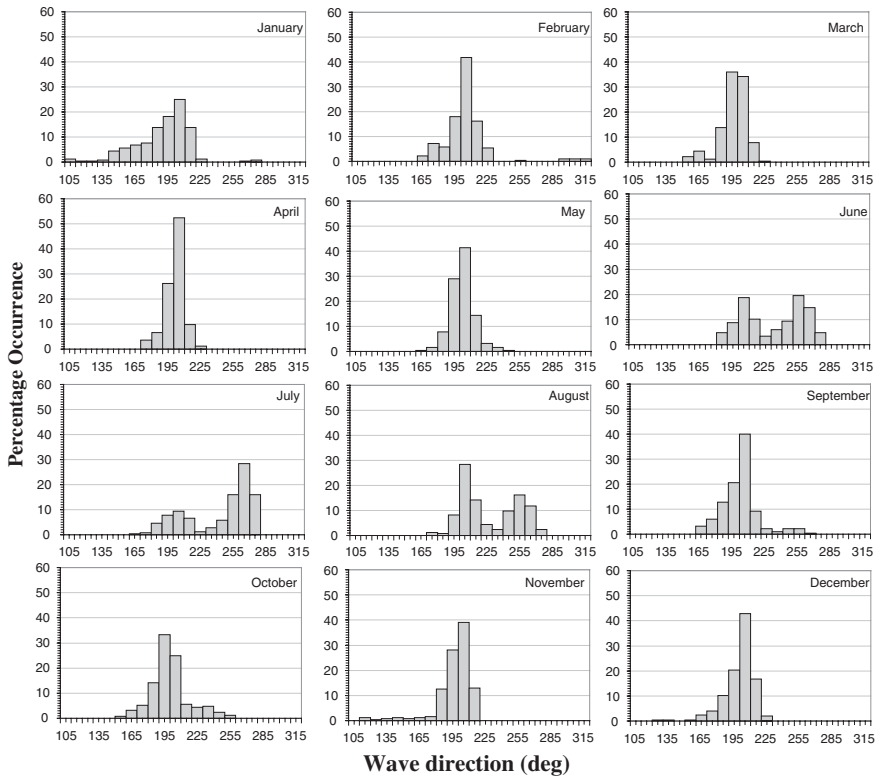
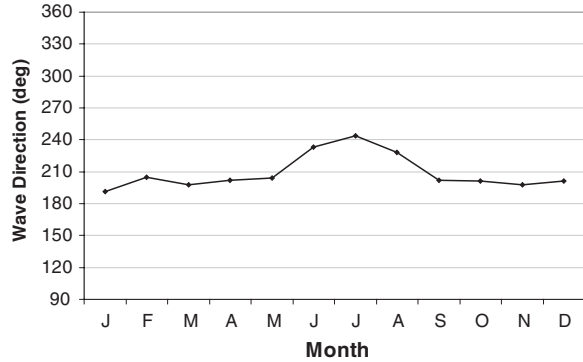


Fig. 2.9 Monthly distributions of wave direction (after Baba et al. [1])

represents more than half and one-third respectively in the distribution. During the month of July the dominant direction is near to west and the peak is at 260° – 270° with 30 % contribution. During this month about two-third of the distribution is in the range 250° – 280° . During August the distribution shows a pattern similar to that observed in June, but with more prominence to the direction in the range 200° – 210° with more than one-fourth of the cases. Directions in the ranges 200° – 220° and 240° – 270° represents nearly half and one-third of the distribution during this month. By September the westerly components are still reduced and the southerly directions become prominent, as noted in the beginning of this section. During October the peak lies in the range 190° – 200° with nearly one-third of the contribution and those in the range 190° – 210° represent 60 % of the distribution. Thus, it follows that the southerly-southwesterly waves are persistent in the Lakshadweep throughout the year and the westerly waves dominate only when the monsoon is very intensive. Similar observations are also reported [4] for the southwest coast of India.

The monthly mean wave directions are presented in Fig. 2.10. The mean wave directions range from 191° to 246° N. The waves are least persistent in the direction during January and February. Few easterly directions are observed during the period

Fig. 2.10 Monthly average of wave direction (after Baba et al. [1])



November–January. During the other months from March to October the directions vary from 152 to 281°N. The westerly components are dominant during the southwest monsoon period of June–August, the range being 227–246°N. During the other months the mean wave directions are more persistent in the range of 191–205°N.

2.4 Currents

2.4.1 In the Open Sea

For studying the offshore current, the data available from the NIOT DS2 (<http://www.niot.res.in>) buoy was used. The rose plots show the monthly variation of offshore current for the months of January–May and October–December (Fig. 2.11). The mean direction of offshore current is predominantly towards southwest during the months of January, February, March and October. The current speeds vary between 0 and 0.7 m/s with an average value of around 0.2 m/s during March–May and October–November and around 0.3 m/s during January, February and December. During the months of April and May the current direction varies between NW and NE. The current direction is mostly towards NW in November with some scattering in the northerly and westerly directions. NE direction is also equally dominant during December.

2.4.2 Inside Lagoon

Currents near the entrance channel was measured during the period February–March, 2008. The measured current and its progressive vector plots are presented in Fig. 2.12. The progressive vector plot indicates net southerly movement. The drift was towards southeast during the first half of the recording period, followed by south-southwest movement in the subsequent periods.

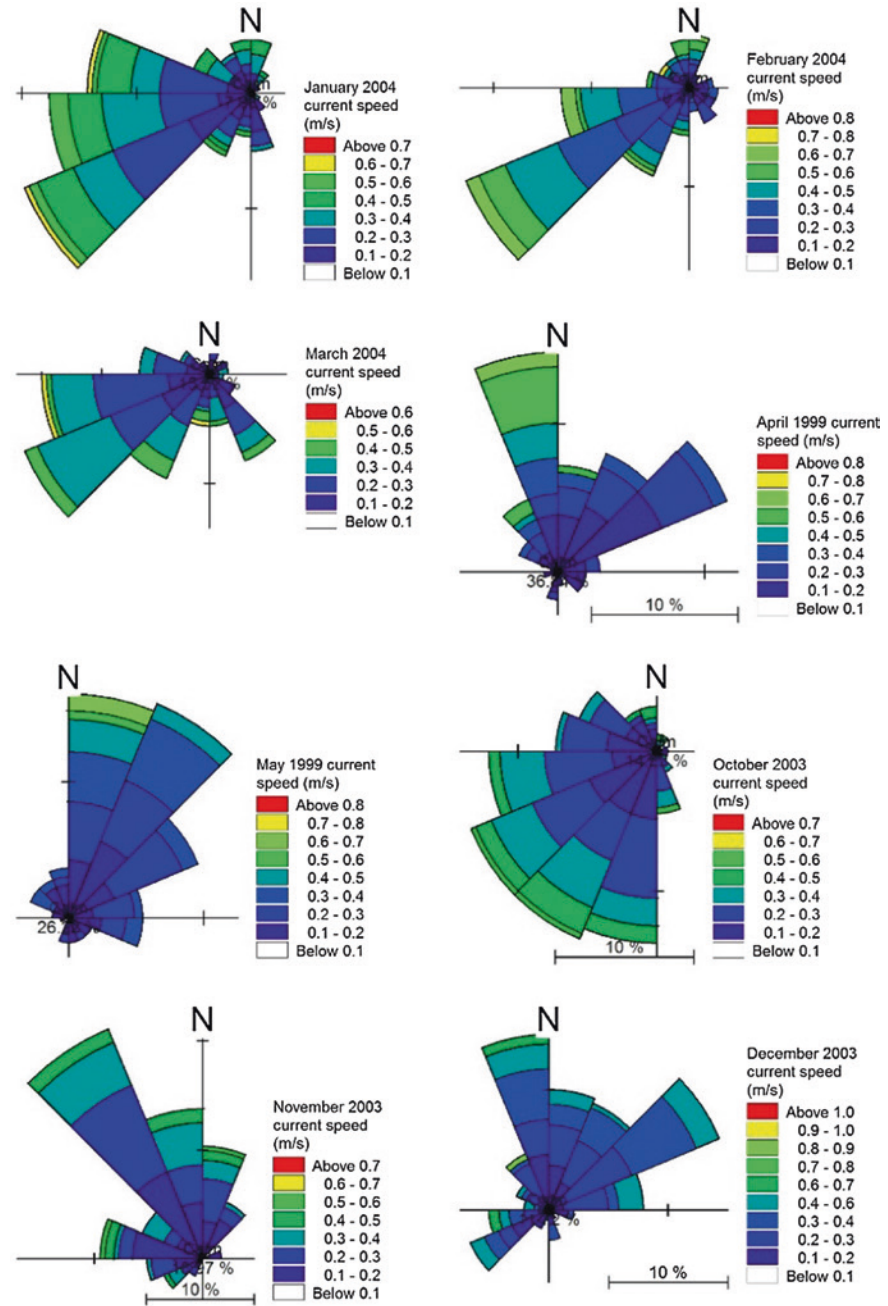
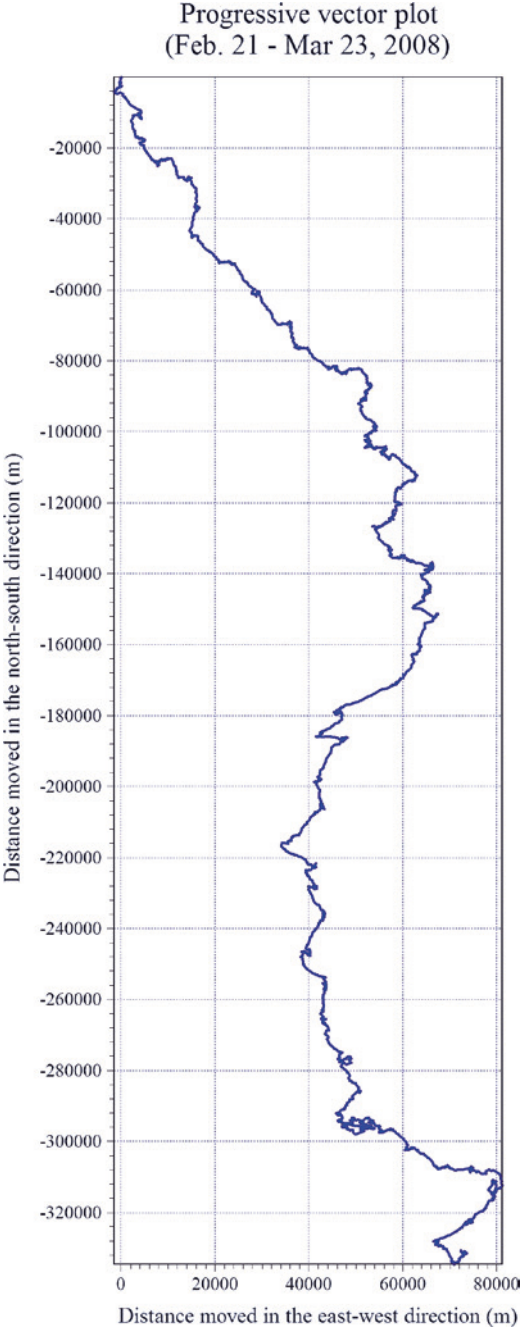


Fig. 2.11 Monthly offshore current rose (Source NIOT Buoy-DS2)

Fig. 2.12 Progressive vector plot of current near the entrance channel during February–March, 2008



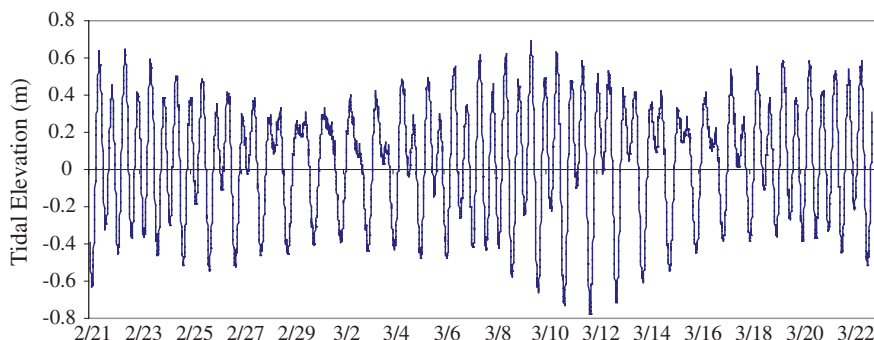


Fig. 2.13 Water level variations inside the lagoon during February–March, 2008

2.5 Tide

Tide is measured using a Wave and Tide Recorder (MIDAS, Valeport, UK) deployed at Kachery jetty of Kavaratti Island at a water depth of 2.5 m [5]. The tides are of the mixed semidiurnal type with a maximum tidal range of 1.4 m. Figure 2.13 shows the water level variation during the period 21st February to 23rd March 2008. As seen in the figure, the tide is found to form a kind of groupings, as seen in the case of waves, with fortnightly lunar cycle, which is indicative of the influence of the constituent MF in the tide.

2.6 Wind

The offshore data from the NIOT buoy DS2 deployed approximately 25 km to the northwest of the Kavaratti Island have been used in this analysis. Figure 2.14 gives the wind rose plots showing the variation of wind during each month. The wind direction is predominantly north-westerly followed by westerly, northerly and northeasterly. During February–March and November–December period, the presence of winds from northeasterly direction is noticeable. During the period January–April and December the wind speed varies between 0 and 8 m/s with a monthly average value of less than 4 m/s with February having the minimum average value of 2.3 m/s. The wind is moderate during the period May–September with average speeds in the range 5.5–8.3 m/s with the minimum in May and the maximum in July. In the month of May the wind speed ranges up to 18 m/s whereas it is up to 14 m/s for June–November.

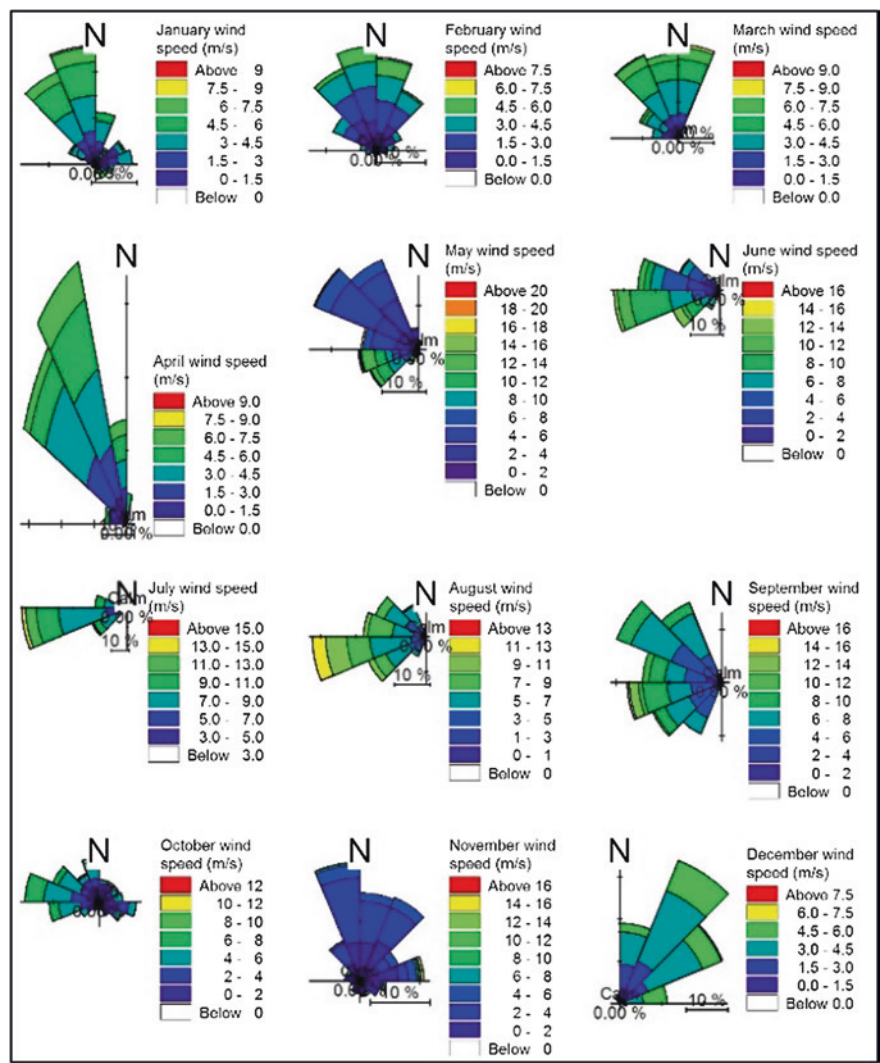


Fig. 2.14 Offshore wind data rose (Source NIOT Buoy-DS2)

2.7 Summary

The wave, current, tide and wind characteristics are interlinked in one way or other. The wave characteristics in the coastal waters of the Lakshadweep is derived from the data collected round the year with a directional wave rider buoy. The data reveal that the wave climate of the Lakshadweep Sea is influenced by the south-west monsoon. The period from June to August is the roughest season.

The highest wave height observed during the period is 8.95 m in August. Waves generally do not exceed the height of 5 m during November–March. During the

southwest monsoon the dominant values of H_{\max} is around 5 m and during the non-monsoon season it is around 1.4 m. Generally H_s are higher during June, July and August when the range is 1.75–4.70 m and are lower during November–March.

The zero-crossing periods (T_z) range from 3.5 to 13.3 s with maximum in February and April and the lowest in June–August. The dominant T_z during the southwest monsoon is in the range of 7–8 s and during the non-monsoon it is 5–7 s. The peak periods (T_p) range from 8.4 to 26.0 s during the year, the lowest being observed in November and the highest in February. Generally, T_p is lower during June–August, as in the case of T_z .

The wave directions ranged from 106 to 316°N during the year. S-SW directions persist throughout the year and these directions dominate during most of the periods except when the southwest monsoon is intense with dominance of westerly waves. Easterly components are observed during November–January.

The mean current direction in the offshore is towards southwest during the measurement periods of January, February, March and October while it is north-northeasterly in April and December. The current speeds ranged up to 0.7 m/s. Net current near the entrance channel is southerly to the lagoon during the month of measurements. The drift is towards southeast during the first fortnight, followed by southwest movement in the subsequent fortnight.

Tide in the Lakshadweep nearshore waters is of the mixed semidiurnal type, with a maximum tidal range of 1.4 m. The tide is fortnightly lunar, which is indicative of the influence of the constituent MF in the tide.

The wind direction is predominantly north-westerly followed by westerly, northerly and northeasterly. During the period January–April and December the wind speed varies between 0 and 8 m/s with a monthly average value of less than 4 m/s. The wind has moderate speed during the months of May, June, July, August and September with average speeds of 5.5–8.3 m/s.

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