

WAVES

IN THE SEAS

Crashing waves are a sight to watch.

M. J. VARKEY sheds light on how these waves are formed

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YOU are on a seashore on a windless day. Watch the sea for some time and you will see regular, long waves running towards the land, steepening and heightening as they near the coast and finally breaking up on the beaches or a little away from the beaches. In the same place, on a windy day, one can see high and low waves, both short and long; all mixed up.

The scene is chaotic indeed. In the first case the waves are formed in the far away windy open ocean and in the second case they are formed in the nearby coastal sea itself. Now go to a small beach-side stall. When the tea is brought pour it into the saucer and blow air in puffs and see how small waves are formed. In the same way sea waves are also caused by wind.

Waves are in integral part of life. Life itself proceeds in waves — in the march of time from dawn to dusk and again to dawn; on the variations of consumer price index and share prices. The study of wind waves in the sea is a wide and interesting field with applications in marine exploration activities, underwater pipe laying, pollution control, ports and shipping involving billions of dollars worth of transactions.

Not all sea waves look alike in form. Scientists, in fact, classify all waves into definite groups, which can be simulated on a computer using specific models. Thus there are many types of wave forms on the sea surface like regular sinusoidal waves, steep nonsymmetric cnoidal waves, solitons and random waves. They have different properties too. Any wave form has a wave period (T), wave height (H) and speed (C) which depends on T . Still another type of waves are breaking waves near a coast. They are steep with breaking frothy crests. This is the type which are often seen on beaches and near sea walls.

Why does anything thrown into the seas take so long to reach the shore even when there are huge waves? It would be interesting for a nonspecial-

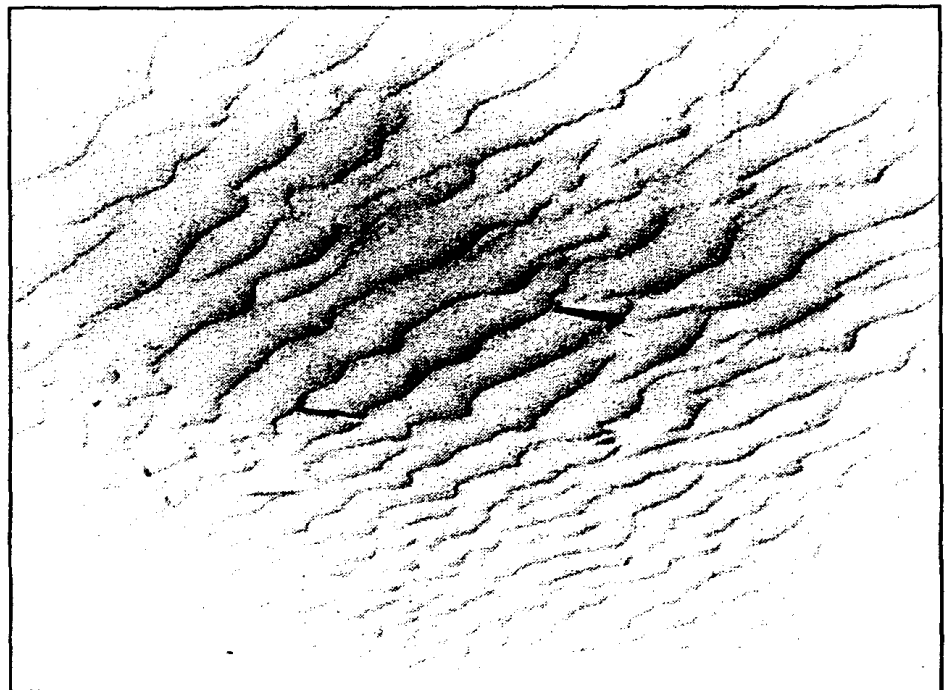
ist to know that the surface water does not flow forward as the waves move forward. Do a simple experiment. Go to a small pond, jetty or a bridge over a river or bay. Throw some pieces of paper or any floating thing in the surface water. As the waves pass by the floats just move up (with crest) and down (with trough) only if there is no current. This is because the waves are formed by revolving water particles.

There are different theories about water waves airy waves — (linear), stokes waves, cnoidal waves and random or stochastic waves. Airy waves are ideal waves of sinusoidal shape (- shape) and of very low steepness. This theory provides some of the basic ideas used in other topics in waves and for practical applications. One can never see an airy wave on a sea surface. Other nonsinusoidal wave theories are used to simulate steep waves going to break or approaching a shore. The crests are very steep. Crests and troughs are not of equal lengths or similar shapes. One can never see these ideal nonlinear waves also on the sea surface but only approximately similar ones.

Stochastic or random theory simu-

lates the sea surface more close to reality. Here it is assumed that the unimaginably chaotic sea surface is formed by superimposition of indefinite number of component waves of various periods and heights. This is the most commonly used theory for practical applications like design of ships, oil rigs and coastal structures such as jetties, ports, and sea walls. This theory also provides sufficient intellectual stimulation and excitement since it has much complexity and scope for further developments. The recently developed wonder-tool of mathematics, 'fractals' can also be used to model sea surfaces.

Generation of waves on the sea surface is a very complex process, the whys and hows of which are not yet fully understood. It can be considered as one of the most complex of all natural phenomena. Waves are caused by wind. As the winds grow in strength, its 'blowing' or 'wave causing' properties also increase or change. If initially, only a thin layer of air close to the water surface matters in the momentum transfer from wind to water, afterwards with strong winds, a layer of air upto say 15 to 30 metres comes

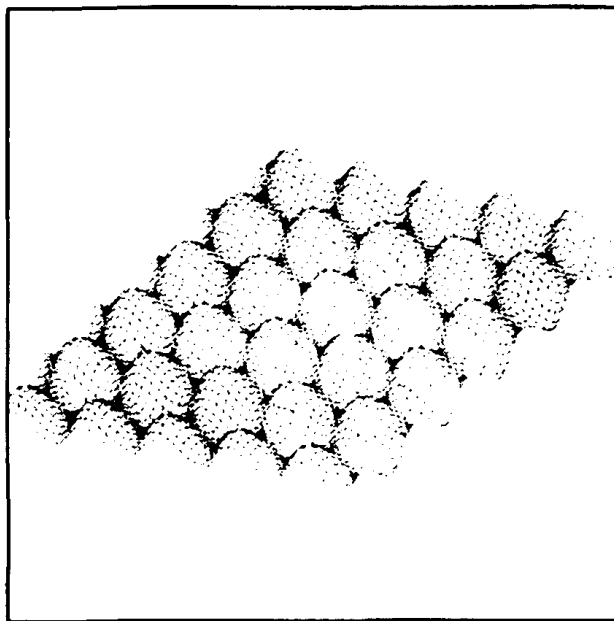


Small sand waves formed on a seashore due to special sand and wind structures

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into active role. For a clear understanding of the mechanisms of wave formation it is necessary to know some basic aspects of wind as it blows over the water with low or high velocities.

When wind blows over the sea surface it exerts a force, 'a push' (blowing) or a 'pull' (suction) of small impact initially, but of high impact later as winds become strong. As the wind strengthens not only the intensity of action ('push' or 'pull') increases but also the duration of action increases causing bigger waves making the initial small ones (called ripples), more and more insignificant. Now, once a wave is formed it goes on moving unattenuated (in ideal situations, until it breaks with a heading wind or on a beach). Consider an open sea of say 1000 square kilometres wherein billions of 'pushes' and 'pulls' happen over tens of hours, causing uncountable number of waves and wave groups of various types moving in different directions, colliding, breaking, passing by and overtaking, exchanging and dissipating energy by



Two swell systems passing each other

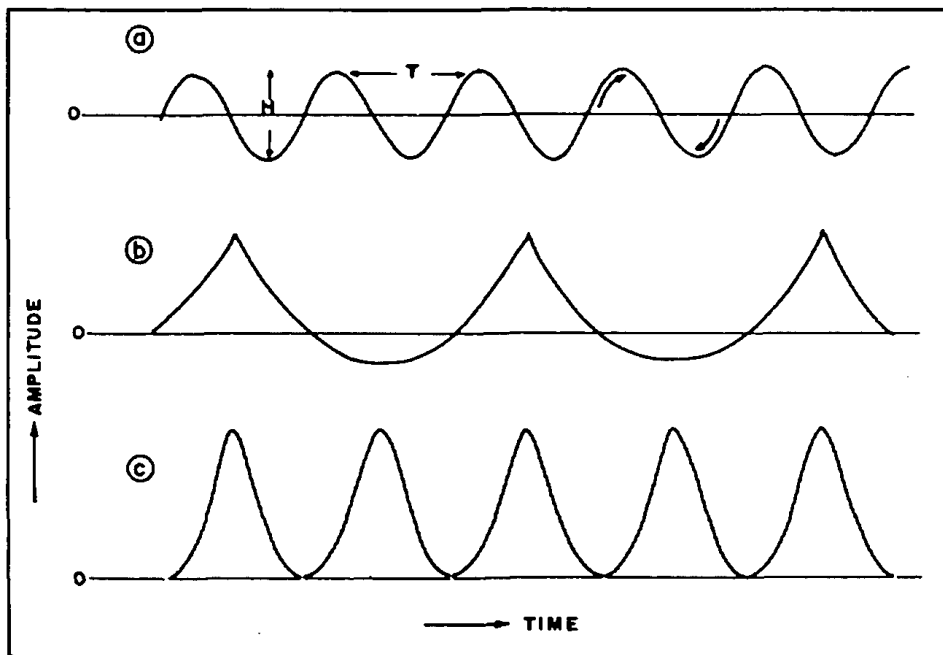
various ways. Mathematically the whole scene is difficult to understand or theorize. Hence the whole phenomenon is studied in parts, that is, wind action over water, small waves, long waves, propagation, breaking, and beaching.

The way waves of different periods and wavelengths travel out from the generating area is interesting. This is due to the fact that wave velocity de-

pends on period as $C = 1.5 T$. In the generating area the sea surface is totally chaotic consisting of waves of various periods, heights and directions. Consider a sea at the centre of an ideal generating area of 1000 km² outside of which no winds blow. The periods range from 2 to 20 seconds with different energy contents. Maximum wave height is for the wave with period 14 sees. After 200 minutes at a distance of 72 kms where no wind exists, the sea surface would be chaotic almost to the same extent as in the generating area, only the waves with 2 second periods would be missing here. At the same time, at a distance of 252 kms only waves with periods greater than or equal

to 14 seconds would be present. All other waves of smaller periods and low-speeds die away before they reach the spot. The sea surface therefore, would be less chaotic here. Similarly at a distance of 362 kms, waves would be very regular in nature with 20 second periods only. This property of waves is called frequency dispersion and the popular meaning is 'the longer waves run faster'.

Prediction of waves finds many uses these days. In some marine operations like surveys, drilling and pipe laying, advance information on wave conditions is required to plan works ahead. Prediction of waves in the sea is possible if the causal factor (wind) is known over the sea. In wave prediction the main inputs required are (1) direct wind energy input to the sea surface which depends upon the wind speed, (2) dissipation of wave energy by breaking, (3) energy exchange between the innumerable component waves while moving liither and thither and (4) the changes while travelling from one point to another. All the inputs are integrated in a computer and suitably computed to get the prediction. Wave predictions are now routinely done by a few institutes (e.g. Japanese Meteorological Agency) for



Different waveforms — (a) sinusoidal, (b) cnoidal, and (c) solitons

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Breaking waves near a sea wall (above); and on a beach (below)



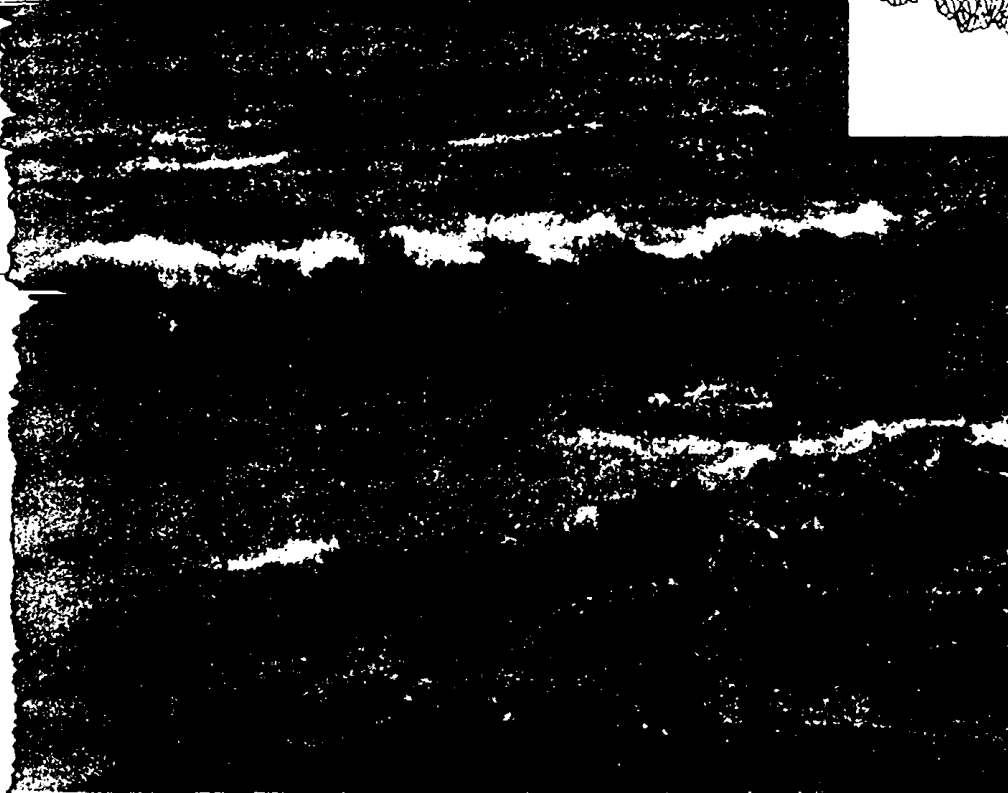
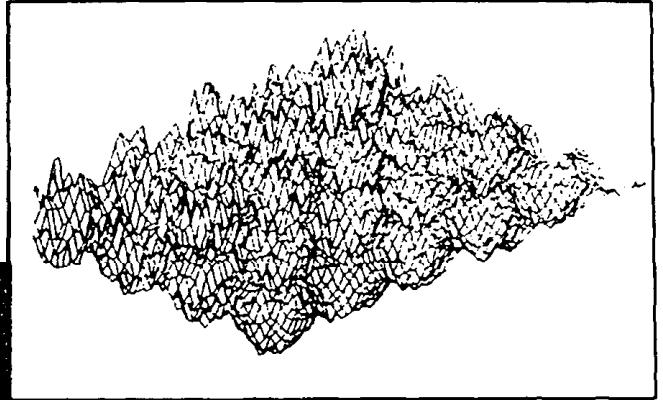
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global use. Wind data required for this purpose are now available from many satellites.

This kind of studies are also important in another area — the harnessing of wave-energy for generation of electricity. Wind while blowing over

the sea surface transfers huge amounts of energy into the sea by imparting oscillatory motion to the surface. This includes both kinetic and potential



Chaotic sea surface; (inset) a computer simulation

forms of energy. Along the coasts of India, both in the Arabian Sea and Bay of Bengal, wave heights vary with seasons. During fair weather, wave heights are less than 3 m and during the rough summer monsoon the height variations are between 2 and 4.7. m. this offers a good situation for utilising this enormous, nonpolluting and everlasting source of energy. Along the west coast, the area around Goa is thought to be of maximum wave energy potential during July (82.3 KW/m). Along the east coast, the area around the head of Bay of Bengal is of maximum potential during July (50.2 KW/m). Engineers and wave specialists in different countries are working on different methods of using this enormous source of energy.

Japan, Norway, England and U.S.A. are the prominent nations engaged in these studies. The Indian Institute of Technology, Madras made some studies and prototype testing at a place near Vizhinjam over the southern Kerala coast. The investigations showed promising results. The device could generate a peak power of 15 KW. At present the system is run only periodically for experiments. In future they plan to change the device by incorporating a multimodular design with peripheral benefits like a jetty.

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Breaking waves provide a wonderful sight