exact reasons for this increased productivity in terms of oceanographic conditions still remain to be elucidated. Many former observers have conjectured the possibility of nutrient laden deep waters coming to the surface through the influence of (*a*) bottom drifts striking against sub-marine ridges; (b) upwelling of water associated with the prevailing current systems; (c) large-scale turbulence caused by strong monsoon winds which pile the water against the west coast of India; and (*d*) coastal eddies resulting from the local wind effects.

Recent studies made by researchers of the Central Marine Fisheries Institute and of the Indo-Norwegian Project have clearly shown that deep water of low temperature and low oxygen content occur considerably higher up near the surface on the west coast of India. Indications of low temperature water in coastal regions are also available from surface temperature and salinity charts for the Arabian Sea published by the Dutch Meteorological Institute. A number of observations showing high values of phosphates for the Arabian Sea coastal waters of the west coast have been reported as against the Bay of Bengal coastal waters. Intensive studies on the standing crop of plankton have also shown substantially high organic production off the Malabar coast. The correct understanding of the forces responsible for this upwelling and indeed whether it is upwelling in the classical sense or a combined effect of several factors will be one of the problems whose solution will be sought by Indian workers because of the very close relation which these phenomena have on the movements and shoaling of the sardines and the mackerel which form the backbone of Indian Marine Fisheries. Valuable data in this direction have already been obtained by the work of R. V. VARUNA. Oceanography team working at the Andhra University has shown upwelling in the Waltair Coast but its relation to fisheries of the Bay of Bengal remains to be investigated. Indian ships and the U.S. Research Vessel ANTON BRUUN will be devoting some time to this problem.

Oceanography is a very young science in India. Pioneer work was accomplished by the "INVESTIGATOR" during the beginning of this century and in the series of later investigations on surface temperature and salinities by Col. Seymour Sewell who led the John Murray Expedition to the Arabian Sea in 1933-34. Some of the earliest observations on the optical properties of sea-water were made by Sir C. V. Raman during 1920. In recent years the notable advances have been the growth of two schools of oceanography since 1950, one associated with the Central Marine Fisheries Institute at Mandapam and its Substations and the other associated with the Andhra University under the leadership of the late Prof. Mahadevan and Prof. E. C. LaFond. The Naval Physical Laboratory at Cochin has come to the fore recently in certain aspects of physical oceanography and many other institutions are newly entering this field. Inadequacy of research vessels for work which cramped earlier efforts has now been overcome. It is hoped that Indian participation in this expedition will result in substantial advancement to oceanological studies in the country and the development of applied marine sciences based on a solid foundation of fundamental work. A country with over three thousand miles coastline and a pre-eminent geographical situation in the Indian Ocean will require a number of trained oceanographers and a vigorous marine sciences programme towards which Indian participation in this Expedition can only be just a beginning.

PROBLEMS OF OPERATING RESEARCH SHIPS*

C. S. RAMAGE

THIRTY or forty years ago, when few oceanographic cruises were undertaken, planning, execution, research and publication were expertly and exhaustively carried out by first-class scientists. Today, although the number of research ships has greatly increased, the number of interested scientists has not increased proportionately. Consequently the data from many voyages have not been analysed nor disseminated, wasteful duplication occurs and oceanographers are so busy planning and participating in new voyages that they have little time to conduct research on the results. No oceanographic cruise should be undertaken unless competent scientists make themselves available for all aspects of data collection and processing, research and publication. Since the supply of

* Abstract of contribution to symposium on "Oceanographic Research and Related Topics" presented at the 28th Annual Meeting of the Indian Academy of Sciences, Bombay, December 1962.

oceanographers is limited, international collaboration should be invited for each voyage.

The recent tendency to build ever larger oceanographic vessels has some merit, particularly since these ships with their long cruising ranges can explore remote ocean areas. However, the cost of operating a large ship is high. Regions such as the South Indian or East Pacific Oceans might be more suitably explored by an adaptation of the naval task force or whaling fleet concepts. A scientific "mother ship", ideally a light aircraft carrier, would act as a mid-ocean base, providing refuelling, repair, hospital, recreation and scientific processing services to a group of small, relatively short range oceanographic vessels. Not only would the observations cost less than comparable observations made by large oceanographic vessels, but entirely new and valuable oceanic and atmospheric measurements could be made from the aircraft carrier.

OCEAN-WAVES*

P. R. PISHAROTY

OCEAN-WAVES generated by wind form the most conspicuous interaction between the atmosphere and the ocean. The formation of breakers, foam and spray may perhaps change the quantities like evaporation and heat exchange by an order of magnitude and also provide the giant nuclei for the initiation of precipitation. Knowledge about wind generated ocean-waves can be broadly classified as under :—

(*i*) The precise physical processes responsible for the transference of energy from the wind to the water waves ;

(*ii*) A correct description of the waves so generated ;

(*iii*) Forecasting of the ocean-waves from the antecedent wind conditions.

Wave Generation.—According to Jeffreys (1925) a *uniform* wind passing over a set of already existing waves induces a deficit of pressure on the leeward side of the crests and an excess on the windward. The component of this variable pressure distribution in-phase with the wave-slope supplies energy for the wave development. The consequences of this theory are not fully borne out by the empirical facts of observations.

According to Phillips (1957, 1958) a random variation of normal pressure associated with the onset of a *turbulent* wind produces waves which then develop most rapidly through a resonance mechanism occurring when a component of the surface pressure distribution moves at the same speed as the free surface wave with the same wave number.

Miles (1957) has developed a theory based on a *laminar flow* of the wind with a *logarithmic shear* and is an improvement on the Kelvin-Helmholtz theory of instability of an interface with a density-discontinuity and a velocity-discontinuity.

Apparently, there is a transition frequency (Phillips, 1961), depending on the fetch and duration; below which waves develop according to the resonance-mechanism of Phillips and above which according to the shear-instability-mechanism of Miles. Much work remains to be done in the theoretical as well as in the experimental field. We do not know the exact wind distribution in the first ten metres above the surface of a large water body, let alone the ocean. Are there eddies ? Is the flow laminar ? What are the variations of wind with height when the surface is unruffled and when it is violently agitated ? These are questions for which we do not have definite answers. Let us hope that the Indian Ocean Expedition will provide some of the answers.

Description of an Ocean Surface Agitated by Wind.—The best description of an ocean surface under the action of a strong wind acting over a sufficiently long fetch for a sufficiently long time, appears to be given by a 'stationary gaussian surface'. There appears to be a spectrum of simple-harmonic waves with the individual wave-fronts having all possible orientations and random phases, the total energy remaining finite. The mathematical expression for such a state is :

$$\eta(x, y, t) = \int_0^{\infty} \int_{-\pi}^{\pi} \cos\left[\frac{\mu^2}{g}(x\cos\theta + y\sin\theta) - \mu t + \epsilon(\mu, \theta)\right] \sqrt{[A(\mu, \theta)]^2 d\mu d\theta}.$$

The total energy is proportional to :

$$E = \int_0^{\infty} \int_{-\infty}^{\pi} [A(\mu, \theta)]^2 \, d\mu d\theta = \int_0^{\infty} [A(\mu)]^2 d\mu$$

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