REMOTE SENSING TECHNIQUES FOR OCEAN-RELATED STUDIES

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ABSTRACT

Ocean resources have gained a lot of importance owing to the rapid growth in population leading to large demands on resources. Effective management and exploitation of ocean resources need a thorough understanding of the various oceanic processes. Study of the ocean encompasses several aspects, including physical and chemical properties, as well as the interaction of the ocean with the land and the atmosphere. Biological productivity and marine resources potential are another important aspect. Studies related to the ocean have been hampered in the past by lack of data. The conventional methods of data collection are costly and time-consuming. With the advent of remote sensing techniques through satellite and aerial survey, there is better data coverage and availability. Satellites, in particular, have the advantage of providing spatially contiguous data over large areas. Several studies using remotely sensed data have proved their usefulness in oceanography. In this paper, the current status of the use of remote sensing for the study of various ocean-related parameters is presented.

INTRODUCTION

THE ever increasing demand for new resources has made exploitation of ocean resources highly important. Optimum exploitation of ocean resources is possible only if we have a detailed knowledge of the physical, dynamic and other aspects of the ocean. Physical oceanography is defined by various parameters such as winds, waves, temperature and salinity, while biological oceanography relates to primary and secondary productivity.

Ocean-related studies have been affected to a great extent in the past by lack of data. Collection of data over oceans by conventional methods such as sample collection and *in situ* measurements by ships is costly and time-consuming. A satellite platform with its synoptic view and capability to give spatially continuous data is ideal for the study of oceans. The availability of satellite data has led to several studies and also to the design of sensors specific to ocean remote sensing[1]. In the following sections the role of remote sensing in ocean-related studies is reviewed.

PHYSICAL OCEANOGRAPHY

Ocean colour

The colour of the ocean is an indicator of several processes that take place in the ocean. With remote sensed data from satellite/aircraft, it has been possible to study ocean colour in detail. The coastal zone colour scanner (CZCS) carried by the Nimbus-7 satellite has four narrow bands centred at 443 nm (blue), 520 nm (blue/green), 550 nm (green) and 670 nm (red), and has been found to be well-suited for ocean colour studies. By carrying out appropriate atmospheric corrections, meaningful correlations have been obtained between CZCS data and oceanic features like (i) sediment transport/pollution discharge, (ii) boundaries of streams, and (iii) location of greenish, biological matter, etc[2–5].

Sea surface temperature

Sea surface temperature (SST) plays an important role in many oceanic processes, the most important among which are:

(i) horizontal temperature gradients which affect cyclone development and movement, (ii) the transfer of energy in the boundary layer, (iii) the role of horizontal advection in distributing the excess thermal energy in the 0–20° latitudes, and (iv) day-to-day and seasonal weather changes.

Several sensors have been qualified for SST mapping from satellites[6]. Thermal infrared sensors with multiple channels are capable of giving accuracies of up to 1 K. Improved atmospheric correction models can yield better accuracy. Over persistently cloudy areas, microwave radiometers are found to be advantageous[7]. However the satellite-derived SST requires validation by extensive sea truth.

Sea-ice features

Sea-ice is an important feature which affects the radiation budget and influences climatic conditions over a region. Sea-ice covers approximately 7% of the world's oceans and significantly reduces the amount of solar radiation absorbed by the Earth's surface, greatly restricts the transfer of heat from the ocean to the atmosphere, and influences global atmospheric and oceanic circulation.

Microwave radiometry is highly useful in distinguishing sea-ice features. The electrically scanning microwave radiometer (ESMR) of Nimbus-5 was used to map sea-ice areas. It could give quantitative estimates of concentrations of sea-ice and also information regarding their age.

Ocean pollution

Several natural and man-made processes affect ocean waters and cause pollution. The most important pollutants are those that result from oil spills and sedimentation. Monitoring of ocean pollution is important from the point of view of marine resources as well as various ocean-atmospheric interactions. Data obtained by remote sensing using satellites have been found to be advantageous in ocean pollution monitoring. Albuisson *et al*[8] showed that large-scale monitoring of oil spills is possible using Landsat data. Earlier studies[9,10] have shown that ocean waste and water quality can be assessed using remotely sensed data.

DYNAMIC ASPECTS OF THE OCEAN

Ocean circulation/currents

Ocean circulation is controlled by winds, density structure, bottom topography and coastal boundaries. A knowledge of the circulation features is important in climatic studies. Satellite data which provide large area coverage have been of great help in this regard.

The microwave altimeter carried by SEASAT (during 1978) was capable of giving data on the elevation of sea surface with an accuracy of 10 cm allowing determination of topography and roughness of sea surface. Another important satellite sensor is the microwave scatterometer[11] designed to measure windspeeds to an accuracy of 2 m/s and wind direction to 20°. Scatterometry can give wind data over a wide area but requires careful validation with *in situ* data from ocean buoys, ships, etc.

Another method is to use heat transport measurements to derive circulation patterns indirectly[11,12]. This is possible since the main heat transport mechanism in the ocean the quasi-geostrophic large-scale current systems, which extend to a depth of up to 1000 m. Infrared radiometry is capable of giving data on the thermal front, cold wall of streams, etc[13], which are indirectly correlated with the strength of the streams/currents.

Ocean waves

The surface waves are generated by surface winds. The waves are responsible for downward mixing of heat thereby increasing the thickness of the heat storage layer. In air-sea interaction also, waves play a crucial role.

The wave data obtained from *in situ* measurements and from data buoys are quite meagre and insufficient for any climatic study. The satellite data available by way of wave scatterometry and altimetry appear to be promising[14,15]. The altimeter is capable of giving wave heights of the order of 20 cm.

The synthetic aperture radar (SAR) on board SEASAT was capable of producing good images of wave patterns. The radar return is influenced by the short-wavelength gravity or capillary waves. It has been found that the directional wave spectra can be determined from SAR data by appropriate modelling[16]. However, to extract information from SAR data large-scale computations are required and corrections have to be incorporated for speckle, motion effects, etc.

State of the sea

The state of the sea is defined by the conditions of the ocean surface winds and waves. Weather conditions prevailing over a given area cause changes in the state of the sea in that area. Monitoring the state of the sea has practical applications. Various weather phenomena cause high winds and swell-waves.

Data from microwave sensors like scatterometer and altimeter are useful in this regard. In addition, the cloud imagery obtained from NOAA and INSAT satellites is highly useful in detecting areas of cyclogenesis and rough weather.

Air-sea interaction

The most important aspect is the exchange of heat energy between ocean and atmosphere at the boundary layer. Important parameters affecting this exchange are the surface winds and SST. Studies of air-sea interaction need a large amount of data on

surface winds, temperature, radiation etc. Satellite-derived data are ideal in this regard.

COASTAL STUDIES

Coastal morphology

The interaction between different elements like lithology, structure, climate, etc., plays a vital role, in the geomorphic evolution of the coast. The Landsat data have been found to be useful in identifying many geomorphic features[17]. The various geomorphic units originating from (i) structural processes, (ii) denudation, (iii) fluvial processes, and (iv) marine processes could be located from data available from Earth Resources satellites[18,19]. The different bands are sensitive to specific features.

Littoral processes

The littoral zone is defined as the zone extending from the shoreline to the tidal zone (generally up to a depth of 100 fathoms). The transport of sediments in this zone by waves and currents is of importance in coastal engineering applications and estimation of erosion and accretion rates along the shore. Under ideal conditions, the nearshore profiles can be utilized in determining longshore transport rates. In this respect the remotely sensed data have been found to be highly useful[20]. Landsat MSS data when used in conjunction with *in situ* optical data and navigational charts could give nearshore profiles with some accuracy[21]. In this respect the different bands have different sensitivities to different features. While MSS-7 (infrared) is suitable for delineation of the land-water boundary, MSS-4 and MSS-5 give good penetration and are useful for evaluation of depth contours in the nearshore region. Though the Landsat sensors are not optimized for ocean studies, they have been found to be useful in the study of coastal processes.

Sedimentation

The main sources of suspended matter in sea water are river runoff, biological productivity and coastal erosion. The amount of suspended sediment load is an important factor in deciding the dynamics of the ocean-bottom flow. Several studies have indicated that a good correlation exists between the visible and near-IR reflectance values of water bodies and the sediment load[22,23]. The studies using Landsat-MSS[24] indicate that a good correlation exists between suspended load and the inverse of sunlight penetration depth as measured in the field. The 600–700 nm channel is found to give the sharpest definition of coastal waters of varying turbidity. Extensive atmospheric corrections have to be applied to the data to get more accurate results.

Nearshore bathymetry

The interaction of the waves and the beach causes changes in the beach profile from time to time affecting the nearshore bathymetry. With a knowledge of the sediment load in the surface

Table 1 *Remote sensing capabilities*

Satellite/ Sensor	Temperature	Salinity	Chlorophyll	Colour	Suspended Sediment	Sea State	Fronts	Patchiness	Oil
Landsat-MSS	–	–	C	B	A	C	B	B	B
Nimbus-7 (CZCS)	–	–	B	A	A	C	B	C	C
NOAA-7 (AVHRR)	A	–	–	–	–	C	A	C	C
HCMM (heat capacity mapping mission)	A	–	–	–	–	–	B	C	C
SEASAT (microwave sensors)	A	C	–	–	–	A	B	B	B
IRS-1A (LISS I & II optical sensors)	–	–	C	C	C	C	C	C	C
Aircraft (OCS)	–	–	B	A	A	C	B	C	C
Aircraft (thermal IR)	A	–	–	–	–	C	A	B	B
Aircraft (microwave)	B	B	–	–	–	A	B	C	B

A – Operational; B – Needs more validation; C – Future possibility.

layers, it is possible to correlate satellite radiance values with ocean depth[18]. A sensor of importance in this respect is SAR which is sensitive to land-ocean features[25].

Estuarine siltation

One important aspect of the physiology of the coast is the study of river mouths and sediment transport near the coast. Landsat data have been found to be sensitive to turbidity of coastal waters. By collecting water samples during the satellite pass, correlation between suspended matter and patchiness as inferred from satellite imagery can be established.

Coastal vegetation

Information on coastal vegetation is important from the economic point of view. Remote sensing techniques have been found to be useful in inventorying coastal vegetation[26,27]. The visible and near-IR reflectance characteristics can be utilized to distinguish canopies. *In situ* measurements using radiometry can be used in conjunction with satellite data to determine reflectance signatures with respect to vegetation canopies.

MARINE RESOURCES

Phytoplankton concentration

The primary productivity of the ocean is linked to the phytoplankton availability. Optical remote sensing offers great promise in mapping phytoplankton concentration. The CZCS carried by Nimbus-7 gave encouraging results[3,28,29]. It has been proved that with extensive validation, CZCS type of data can be used on an operational basis[30].

Fishery resources

Correlation has been established between certain characteristics of water masses, such as upwelling and fishery resources. Many studies carried out by aerial survey have shown promising results[5].

CONCLUSION

Remote sensing techniques offer a wide range of possibilities in the study of various ocean-related parameters. Many of the studies have reached a near-operational level and suitable sensors have been identified. Systematic studies using remotely sensed data and *in situ* measurement campaigns can lead to the development of suitable methods for ocean parameter retrieval. The present capabilities of satellite/aircraft sensors in oceanography are given in table 1.

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NEWS

HOMOGENEOUS SUPERCONDUCTING FILMS MADE AT WESTINGHOUSE

Scientists have discovered a way to make films of oxide materials that are uniformly superconducting right to their surface layers—a property vital to the development of practical electronic devices using the new "warm" ceramic superconductors. Oxide superconductors have become notorious for their tendency to degrade at any surface exposed to the atmosphere, making it difficult to connect them to insulators. The Josephson junction is a basic building block of circuitry in superconductor electronics as the transistor is in semiconductor electronics.

To make yttrium-barium-copper oxide (YBCO) thin films homogeneous to their surfaces, the Westinghouse researchers devised a way of processing the films without exposing them to the atmosphere.

"The major significance of this work is that we now know we can create a well defined interface between superconducting YBCO and an insulator. This has been for some time a critical hurdle in efforts to develop a Josephson device with the oxide materials and the industry has now finally overcome this hurdle."

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