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Satellite oceanography- A review

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Abstract

Ocean information is collected using different types of remote sensing techniques such as optical, thermal, microwave and so on. This paper gives a review of various remote sensors used for the estimation of coastal hazards, Sea Surface Temperature (SST), bathymetry, coastal vulnerability, Suspended Sediment Concentration (SSC), ship routing, chlorophyll etc. Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 are the widely used satellite data products for the bathymetry. Ocean color and hence the derived parameters like chlorophyll, suspended particulates and bathymetry are determined by visible wave band sensors. The same sensors are also used for determining the surface roughness, surface winds, wave height, wave spectra, internal waves and surface slicks. Active radar instruments are also used for this. Microwave sensors are useful for observing sea surface temperature, salinity and surface roughness. Infrared sensors are used for determining sea surface temperature. Surface slopes can be determined using active radar instruments.

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1. Introduction

The use of remote sensing satellites as platforms for sensors to view ocean have several advantages such as the opportunity to get a wide synoptic coverage at fine spatial detail, and repeated regular sampling to produce time series many years long. It is these capabilities that differentiate satellite remote sensing from all other oceanographic observing techniques. The details of different remote sensing system are distributed among various websites of the data producer and manufacturer. In order to choose a data product for a given project, a remote sensing data user must be aware of the different products and their applications.

The ocean properties can measure using the different parts of electromagnetic spectrum. Generally 2 sensors classes namely passive and active sensors are used. Visible wave band sensors, infrared sensors and microwave sensors are comes under active type sensors.

Ocean color and hence the derived parameters like chlorophyll, suspended particulates and bathymetry are determined by visible wave band sensors. The same sensors are also used for determining the surface roughness, surface winds, wave height, wave spectra, internal waves and surface slicks. Active radar instruments are also used for this. Microwave sensors are useful for observing sea surface temperature, salinity and surface roughness. Infrared sensors are used for determining sea surface temperature. Surface slopes can be determined using active radar instruments.

2. Review

Literature review of the various remote sensing methods used for the estimation of coastal hazards, SST, bathymetry, SSC, ship routing, chlorophyll, coastal vulnerability and wave parameters have been done and discussed in the following paragraphs.

Coastal hazards are both natural and manmade disasters that happen along the coast line. The location, size, intensity of the affected area are interpreted and calculated using visible and thermal IR imageries. NIR spectral bands are used for discriminating inundated urban or natural areas from dry ones. Victor V Kelmas (2009). Flooding is a particular hazard in urban areas worldwide due to the increased risks for life and property in these regions. Synthetic Aperture Radar (SAR) sensors are often used to image flooding because of their all weather day night capability and now possess sufficient resolution to image urban flooding. The flood and landslide hazard monitoring data are provided by the remote sensors like InSAR, GPS (Malet et al (2002) ; Gili et al (2000)), visible and near infrared/ thermal infrared (VNIR/TIR) imaging, multi-parameter SAR, laser altimetry, and microwave imaging. The TOPEX/POSEIDON altimetry satellite , Jason-1, and the planned NASA Ocean Surface Topography Mission (each a collaborative mission between the US and French space agencies), as well as ERS-1 and -2, and recently ENVISAT are giving accurate data of sea surface topography. Estimation of sea level rise is important because the variation in level trigger coastal hazards .D.M. Tralli et al (2005).

Sea surface temperature (SST) is the water temperature close to the ocean's surface. The exact meaning of surface varies according the measurement method used, but it is between 1mm and 20 meter below the sea surface. Weather satellite have been available to determine the SST since 1967.The satellite measurement is made by sensing the ocean radiation in 2 or more wavelengths within the infrared part of the electromagnetic spectrum. Multisensor SST level 3 data(L3S data) and level 4 are built from all available GHRSST L2P infrared measurements(which include the SST measurements on the original swath as some auxiliary information) B.Buongiorno Nardelli (2013).Visible and Infrared (IR) sensors monitor SST, currents, eddies and ocean color. The AVHRR MCSST data set provides weekly values of SST available in (approximately) 19 x 19-km grids for the entire globe (NASA/NOAA, 1995). SSTs are calculated using data from the AHVRR instrument aboard the National Oceanic and Atmospheric Administration (NOAA) series of polar-orbiting environmental satellites McClain et al. (1985). Passive microwave radio meters like Advanced Microwave Scanning Radio meter, AMSR) can provide estimates of SST in cloudy conditions. M.D. Sumner et al (2003). Microwave and infrared remote sensing provided SST data were used by Miller, (2009) for his work.

Bathymetry is the study of the under water depth of lake or ocean floors. In other words bathymetry is the under Water equivalent to topography. Originally bathymetry involved the measurement of ocean depth through depth sounding. Satellites are used to measure bathymetry. Satellite radar maps deep sea topography by detecting the subtle variations in sea level caused by the gravitational pull of under Sea Mountains, ridges and other masses. On average sea level is higher over mountains and ridges than over abyssal plains and trenches. Using digital globe quick bird and landsat 7 ETM+ multispectral images of different dates and spatial resolution to determine water depth for the Belium estuary China Zhouwei Deng et al.The visible light has a good ability to penetrate water. The light radiation intensity transmitting to the water is gradually weekend become of the absorption and reflection effect of the water. So the water depth can be derived from the visible radiation intensity received by satellite.

Vulnerability can be defined as the degree to which a person, community or a system is likely to experience harm due to an exposure to an external stress. Generally vulnerability is a set of condition and processes resulting from, physical, economical and environmental factors that increases the susceptibility of a community to the impact of hazards vulnerability also encompasses the idea of response and coping since it is determined by the potential of a community to react and withstand a disaster Kumpulainen (2006).Coastal vulnerability is estimated and interpreted by remote sensing imageries. The LULC database is prepared by visual interpretation. SLCR information obtained from global sea level observing system. Orthorectified Landsat MSS & TM images used for calculation of share line change rate. Near IR band is must suitable for the demarcation of the land water boundary has been used to extract shoreline R S Mahander et al (2011).

MODIS space born sensors were used to analyze the suspended sediment transport processes along the main stem of the madeire river. Field measurements of suspended sediment concentration, spectral radiometry and granulometry were performed by during 10 cruises from 2007 to 2011.Relation ship between spectral reflectance and surface suspended sediment concentration analyzed using both field radiometric measurements and satellite data. Light scattering by inorganic particle s varies little as function of wavelength. Light absorption decreases exponentially towards higher wavelength. Here they computed ratio between the Near Infrared and red MODIS bands for the entire data set. One of the application of visible and near infrared remote sensing in oceanography is to relate the measured wavelength signal to the constituents of water body(e.g. Phytoplankton, dissolved organic matter mineral particles).The empirical relationship based reflectance ratio between nearer(850 nm) and visible (550nm) wavelength allows the accurate estimation of suspended particulate matter concentrations D.Doxaran et al (2008) .

For ship route planning synthetic aperture radar (SAR) data is transmitted to ships in real time. SAR systems provide long range high resolution images using extensive electronic processing of data and monitor the ocean surface and detect wave height and movement. Scatterometrs, high frequency microwave radar sensors designed to sense ocean surface condition are used to measure wind speed and direction at the surface. Combined data from these sensors provide reliable information on ocean activity and facilitate efficient route planning. Ships also rely on radar weather prediction and sea ice detection for save navigation .Both wind speed and direction is essential for sea state prediction. Hence the MSMR (Multi Frequency Scanning Microwave Radiometer) winds over 150x150 km are merged with medium range weather forecast by NMRWF along with various other available data including Global Telemetric system data J.K Panigrahi and J K tripathy (2008).Technological advances in satellite altimetry offer the potential for providing timely ocean current information which could be used when optimizing strategies ship routes Hong K Lo et al (1998).

Chlorophyll is a green pigment found in cyanobacteria and the chloroplasts of algae and plants. Chlorophyll is an extremely important biomolecule critical in photosynthesis which allows plants to absorb energy from light .Chlorophyll absorbs light most strongly in the blue portion of the electromagnetic spectrum followed by the red portion. Chlorophyll concentration can be estimated from shallow water using optical remote sensing . Global distribution of chlorophyll is the direct proxy of phytoplankton biomass .The spatial and temporal variability of sea surface chlorophyll-a concentration in the Bohai and Yellow seas were analyzed using satellite derived Chl-a products from SeaWifs and Modis sensors Dongyen Lin et al. Processing and validation of oceanic optical property retrieved from the sea viewing wide field of view sensor (SeaWiFs) and moderate resolution imaging spectroradiometer MODIS. SeaWIFS views earth in 8 spectral bands covering the visible and NIR range from 400-900nm . Hyperspectral remote sensing with high spatial resolution can be used for estimating chlorophyll content Xiguang Yang et al .It is a microwave remote sensing technique.

Coastal zones are most vulnerable for land use changes in this rapid industrialization and urbanization epoch. It is necessary to evaluate land use land cover changes to develop efficient management strategies. Remote sensing satellite data provides a synoptic view of the coastal zones Green et al (1998), Robinson (1994), Sathyendranath et al (2004).The modern scientific technologies of remote sensing and digital image processing are extremely useful in periodic assessment of the coastal LULC changes and analyze them to formulate better management (Klemas 1986,Spectar and Gayle 1990). Landsat TM data were used .one visible red band, a near infrared band and a mid IR band were extracted from original TM data sets because of their vegetation/land cover characteristics W.Muttianon et al.

The two measurements systems that have so far been directly used for wave measurements are the satellite radar altimeter (RA) and the synthetic Aperture Radar (SAR).SAR is currently only satellite instrument which can measure directional characteristics of ocean waves Harald E. Krogstad et al (1999). Remote sensing technology is a promising tool because instrumentation does not directly contact the water or interfere with wave propagation Adam J. Bechle (2011). For example, high-frequency surface wave radars Wyatt et al (1999) ; Dankert and Rosenthal (2004) and Light Detection and Ranging (LiDAR) systems Hwang et al (2000) ; Irish et al (2006) deployed from ground, airplane, and satellite-based configurations have been used to measure wave climate. A. TURIEL et al. could be shown that coherent wave fronts on the tropical ocean surface can monitor by using an advanced detection algorithm applied to visible sunglint affected imagery from geostationary satellites. Visible spectrum of electromagnetic radiation is used here.

To evaluate and quantify Abu Dhabi coastal zone LULC changes from 1972 to 2000 using multi-temporal LANDSAT satellite data and digital change detection techniques M.M. Yagoub et al (2006) were used. Optical and infrared bands of electromagnetic spectrum is useful for LULC change detection. Multi-temporal LANDSAT satellite data and digital change detection techniques are very useful for LULC change detection M.M. Yagoub et al (2006).Through thorough visual interpretation techniques the change can be detected. This study has given good insight into Abu Dhabi coastal zone changes during last 3 decades. Table 1.1 shows the recent and current sensors used in ocean remote sensing.

Table 1.1. Details of various sensors used in satellite oceanography

Type of sensors	Sensors used
Microwave radiometers	SSM/I (Special Sensor Microwave Imager), TMI (TRMM Microwave Imager), AMSR-E (Advanced Microwave Scanning Radiometer)
Infrared radiometers	Advanced very high resolution radiometers AVHRR version 2 and 3,Along track scanning radiometer, MODIS
Altimeters	TOPEX/Poseidon, Poseidon-2 on Jason-1, Poseidon-3 on Jason-2, Radar altimeter on ERS-1 and ERS-2, Radar Altimeter 2 on Envisat
Ocean color sensors	Coastal zone color scanner CZCS, Ocean color and thermal sensor OCTS, Sea-viewing wide-field-of-view sensor SeaWiFs, Moderate-resolution imaging spectrometer MODIS, Medium-resolution imaging spectrometer MERIS,
Synthetic aperture radars	ERS-1 SAR, Radarsat, ERS-2 SAR, Envisat ASAR, Radarsat-2

3. Discussions

Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and the Moderate Resolution Imaging Spectroradiometer (MODIS) are used for the retrieval of oceanic optical property and ocean color data. A major goal of this activity is the production of a continuous ocean color time-series spanning.. Bryan A. Franz et al. A serious Harmful Algal Blooms (HAB) occurred in the Bohai Sea during autumn 1998, causing the largest fisheries economic loss. Satellite SeaWiFS ocean color data is used for the analyzes of the formation, distribution, and advection of HAB.. DanLing Tang et al (2006).

Technological advances in satellite altimetry offer the potential for providing timely ocean current information which could be used when optimizing strategic ship routes. However, the time to collect and process the raw data and deliver the processed information to the end user makes the information an inaccurate description of the actual current patterns that would be encountered by a ship in areas of dynamic current activity. Hong K. Lo and Mark R. McCord (1998). Hong K. Lo et al developed an optimization approach that explicitly addresses the uncertainty that results from these time lag. New research could formulated the optimal fuel routing problem as a dynamic program that allows the ship to choose both heading and power setting (H&P) and developed two heuristics (H/P and HA) that reduce the complexity of this formulation by decomposing the optimal heading selection from the power setting selection. To improve computational efficiency a ship is used and ocean current dynamics to introduce three boundaries to the feasible region: directional, geographical ellipse, and arrival time boundaries. These approaches were effective in reducing the feasible region- the first two approaches each reduced the geographical feasible region by one third, and the third approach reduced the temporal feasible region by over 70%. Hongk.Lo and Mark R. McCord (1995).

For the bathymetric survey a method for data reduction is developed by Paul A. Work et al (1998) to account for vertical errors. This study shows that the variation of water composition and chlorophyll concentration have direct influence on the bathymetric results. The problem is this method can use only in oligotrophic periods and regions where the chlorophyll concentration is low (<1 mg.m-3) and constant (<10% of variation in the image) to limit the error of bathymetric estimation all over the image(Audrey MINGHELLI-ROMAN et al). The suggested method P. Bailly du Bois (2011) facilitates the updating of bathymetry data and optimizes their use. It enables automatic execution of all the tasks and building of new digital bathymetry models in a few hours, without action from the operator. The method has been tested many times on the continental shelf of North-West Europe. The bathymetric data so generated do not require corrections, and the hydrodynamic models on which these data are based could be very precise .The paper has demonstrated that the recent development of a green laser with narrow footprint and short repetition rate is able to provide topographic data of both land surfaces and shallow water zones Michael Doneus et al (2013).

Colleen M Long et al explains that the remote sensing models developed in one location can be transferred to another location to qualitatively predict SSCs without the need for in situ data .The first criterion we identify for making such a transfer (i.e., that a near infrared band and a visible band used in combination are more effective than a single band used alone or another sort of combination) is supported by previous work also suggesting that multispectral models are preferable for remotely sensing SSC e.g. Holyer (1978) ; Schiebe et al (1992). Some previous studies e.g. Doxaran et al (2002) ; Holyer (1978) ; Novo et al (1989) have more specifically suggested that the best models use a combination of a near infrared and a red band.A simple mathematical model to predict suspended sediment concentration due to wave agitation is formulated using the diffusional approach. the present formulation predicts the concentration distribution reasonably well. However, this does not mean that the method is applicable for the whole range of the parameter. More experimental data are required to test the above hypothesis and also to extend the range of applicability of the present formulation Michael G. Skafel (1984). A methodology is presented which enables estimation of the advective transport probabilities from a coastal wastewater discharge based on information that can be obtained from current measurements. From these, shoreline impact can be assessed. While these produce only approximate estimations, the methodologies allow estimates to be improved with acquisition of progressively more data Robert C. Y. Koh (1988).A simple method to identify turbid, sediment-loaded, waters within satellite ocean color imageries was recently proposed A.Morel and S. Bélanger (2006). In this paper an improved technique was proposed to detect “turbid” waters within satellite color imageries. It is simply based on the enhancement of irradiance reflectance, R, in the green part of the spectrum resulting from the presence of sediments in suspension.

The results obtained in the work done by Vanda Brotas et al (2013). indicate that the estimation of cell abundances from remotely-sensed chlorophyll-a seems to be a promising avenue. Long time-series of remote sensing derived information on size structure offer the possibility to detect shifts in phytoplankton communities as a response to global changes. Moreover, in the context of global change, we have to consider that the ecosystem response to the change may also include changes to the relationship between total chlorophyll and phytoplankton size structure.

The phytoplankton size structure and size classes are associated with phytoplankton functional types in the oceans. Methods that use the optical properties of phytoplankton to retrieve their size structure could contribute to our understanding of its time-evolution on a global scale, when applied to ocean-colour imagery. The presented method that uses phytoplankton absorption in the red band to retrieve quantitative information on phytoplankton size structure. The method provides a new tool to compute these quantities directly from in situ measurements or from remotely-sensed ocean-colour data Shovonlal Roy et al (2013).

The shelf edge is a site of elevated surface chlorophyll, previous work has suggested that the periodic mixing generated by an internal tide at the shelf edge alters the size– structure of the phytoplankton community which fish larvae from the spawning stocks along the shelf edge are able to exploit. Satellite imagery of sea surface temperature and chlorophyll correlates with fishing activity in some regions, though such correlation does not provide insight into the primary causes underlying the distribution of fishing Jonathan Sharples et al (2012).

According to Satoshi Nakada et al. a new combination of in situ, high-density observations gathered by fishermen, and a real-time, high-resolution (approx. 1.5 km) prediction model developed toward more efficient fishing. Flow field data can be successfully collected by observations from acoustic Doppler current profilers installed on commercial fishing boats, which uncover sub-mesoscale structures such as small (approx. 10 km) eddies in the eastern boundary current region of the Japan/East Sea. Frequent vertical temperature profiles observed by sensors attached to casting trawl nets indicate fine feature of summertime upwelling area associated with fishing grounds. Our prediction system is automated with high-end computers and enables better understanding of sub mesoscale phenomena for more accurate determination of fishing conditions Satoshi Nakada et al (2014).

The earth observation satellite ENVISAT (ESA) carry several instruments that provide new opportunities to measure oceanographic variables. Together, they represent the main measurement techniques of satellite oceanography, and complement each other in an ideal manner. To prepare the oceanographic community to make best use of the ENVISAT sensors in the pre-launch phase, existing algorithms to derive marine parameters are used and validated using data from the ERS SAR, the ERS RA, SeaWiFS and IRS MOS sensors now in operation. Derived products are used to address problems that can best be tackled using the synergy of radar and optical data, such as the effect of surface slicks on radar wind measurements, of sea state on ocean color, of wind and waves on the resuspension of suspended matter, and of wind and waves on sea ice variables S. Lehner et al (2002)

The spatial and temporal variability of sea surface chlorophyll-a (Chl-a) concentrations in the Bohai and Yellow Seas were analyzed, using satellite-derived Chl-a products from SeaWiFS and MODIS sensors over the period of September 1997–September 2011. A set of monthly and cloud-free Chl-a data was produced by the Data Interpolating Empirical Orthogonal Function (DINEOF) method (Dongyan Liu and Yueqi Wang).The effect of the leaf chlorophyll content inversion model was very robust, and the precision achieved 88.74% (Xiguang Yang et al)**.**

Rivers that form deltas often carry large amounts of suspended sediment, but floodplain lakes and wetlands usually have little sediment in suspension. Remote observation of high sediment water in lakes and wetlands therefore often indicates connectivity with the river network. In this study, we use daily 250-m MODIS imagery in band 1 (620–670 nm) and band 2 (841–876 nm) to monitor suspended sediment transport and, by proxy, hydrologic recharge in the Peace–Athabasca Delta, Canada. To identify an appropriate suspended sediment concentration (SSC)-reflectance model, we compare 31 published empirical equations using a field dataset containing 147 observations of SSC and in situ spectral reflectance. Results suggest potential for spatial transferability of such models, but success is contingent on the equation meeting certain criteria: 1) use of a near infrared band in combination with at least one visible band, 2) development based on SSCs similar to those in the observed region, and 3) a nonlinear form.

4. Conclusions

From the literature review it can be seen that remote sensing technology has improved a lot and varieties of new techniques have been using for the estimation of different ocean parameters.

Thus we can conclude that remote sensing has wide varieties of applications in oceanography for the estimation of various ocean parameters and numerous new works are going on in this field for the improvement of accuracy of the estimation. All thermal, optical and microwave remote sensors are used for these works. Combined techniques are also have been used by some researchers.

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