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RESEARCH ARTICLE

MARINE ENVIRONMENT POLLUTION HAZARDS OFF NORTH WEST COAST OF INDIA OBSERVED BY SAR IMAGERY: STORM WATER PLUMES, PETROLEUM HYDROCARBONS

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ABSTRACT

Stormwater runoff, Petroleum Hydrocarbon plumes are found abundantly near big cities and heavy coastal population settlements. These hazards cause deleterious effects on the population in many ways directly or indirectly. Hence these pollution hazards are important and the coastal administrations and population need to be aware of such a danger lurking very close to them. These hazards due to their small size, dynamic and episodic in nature are difficult to be visualized or to sample using in-situ traditional scientific methods. Natural obstructions like cloud cover and complex coastal circulations can hinder to detect and monitor such occurrences in the selected areas chosen for observations. This study takes recourse to Synthetic Aperture Radar (SAR) imagery because the pollution hazards are easily detectable as surfactants are deposited on the sea surface, smoothing capillary and small gravity waves to produce areas of reduced backscatter compared with surrounding ocean. Therefore we are suggesting that SAR imagery, that delivers useful data regardless of darkness or cloud cover, should be made as an important observational tool for assessment and monitoring marine pollution hazards in the areas close to big cities and other developed coastal regions.

INTRODUCTION

The rich marine environment in the region is subjected to great pressure through over- extraction of resources, enhanced pollution and physical alterations in coastal ecosystems. According to SAARC report, Petroleum hydrocarbons and stormwater runoffs threatens the marine ecosystems, where boating activities for tourism and fishing are unregulated. Most of the shallow water coral reef habitats of Sri Lanka, Maldives and India were severely damaged as result of bleaching. Mangroves have been exploited for timber, fuel wood and other purposes, while large areas have been cleared for agricultural activities and for shrimp farming. Freshwater interceptions for agricultural schemes have severely affected mangroves and other coastal habitats. Marine-based tourism also leads to environment degradation through the construction of hotels, beach clubs and marinas involving infilling, dredging and resuspension of contaminated silts. Sediment loads in the coastal zones of South Asia is high mainly arising from soil erosion due to poor land use practices. Major industrial cities and towns are situated on or near to the coastline and they discharge large amounts of untreated effluents daily. Limited institutional capacity and resources continue to be the major impediments to the implementation of coastal environmental management plans. The levels of urbanization and infrastructure buildings of these areas are constantly on the rise. This affects increase in impervious surfaces for the river runoffs (Schiff *et al.,* 2000). Increase in the number of sources, types of constituents, and concentrations of pollutants in stormwater runoff accompany the rising population of this region. South west monsoon typically occurring till end August; contribute to a large extent the runoff volume and pollutant load in the study area. These inputs modify the physical and biogeochemical state of coastal waters. Stormwater runoff changes density stratification and coastal circulation processes, nutrient distributions, suspended sediment concentrations, phytoplankton biomass, and primary productivity. A study in Santa Monica Bay, California found that runoff plumes from single rainfall events of ~2cm total precipitation have cross-shelf length scales of 4-7 km, alongshore scales of at least 10km, and vertical scales of about 10m (Washburn et al., 2003). Elevated nutrient concentrations in stormwater runoff in California promote rapid phytoplankton growth yielding chlorophyll concentrations in excess of 20 mg m^{-3} (Jones et al., 2002), a result suggesting that stormwater runoff might increase the incidence of harmful algal blooms. Urban stormwater runoff is also a health hazard to human health (Noble et. al., 2003). Stormwater runoff plumes also exhibit toxicity when freshwater concentrations of the plumes are high (Bay et al., 1999).

INDIAN SCENARIO

The population according to census 2011 is 1.21 billion which is about 18% of the world of which 25% live along the coastal plains and river deltas of the east and west coasts of India. The chemistry and biology of coastal waters are very vulnerable to additions of biodegradable and stable compounds from land through stormwater and river runoff. It is estimated (Qasim and Sen Gupta, 1983) that in 1984, 5 million tonnes of

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fertilizers, 55 000 tonnes of pesticides, and 125000 tonnes of synthetic detergents were used in India. Roughly about 25% of all these can be expected to ultimately end up in the sea every year. Their cumulative effect over a long period could be quite harmful to the coastal marine environment. Thanks to the summer monsoon which blows winds for nearly a quarter of an year to blow pollutants away. How far this phenomenon cleans up our coastal waters is a research problem? But near a few big cities and industrial conglomerates the effects are, indeed, becoming near disastrous. Gujrat has 41 Urban Agglomerations (UA) and 242 towns most of them in Gulf of Khambat (CAMBAY) and Maharashtra has 15 UA's and 378 towns. In the 15 years from 1959 to 1974 phosphate-phosphorous concentration in the near shore waters of Mumbai increased from 0.82 to 1.13 µmol/l, i.e. by about 40% (Sen Gupta and Sankaranarayanan, 1975). In 1984 the concentration was around 2 µmol/l (Zingde, 1985). The dissolved oxygen concentration decreased from 4.71 ml/l to near zero in 1983 (Parulekar et al., 1986). The total volume of all discharges from environs of Mumbai is around 365 million tonnes per year (Sabnis, 1984).

The details of Mahim River Bay, Mumbai enumerated below throws light on past pollution levels (Sabnis, 1984). The bay occupies an area of 64 km^2 and is semi diurnal tide with a maximum height of 3m. It once had good fisheries and an oyster bed, and its fringing mangroves used to be visited by migratory birds. Today it is one of the most industrialized and densely populated areas of Mumbai. Birds hardly flock there and the fisheries are dead, as no fauna can survive the toxic environment. The bay used to receive 64 million tonnes of domestic sewage and 0.9 million tonnes of industrial effluents every year. These discharges were initially untreated, but now are partially treated. The resulting concentration of H_2S-S in waters of the Bay ranges from 1.5 to 98.4 µmol/l, depending on the stages of the tide. The release of effluents of hydrocarbon origin has so heavily contaminated the creek that it has become common practice to recover the oil by soaking sorbents. Geochronology of sediments using ^{210}Pb gave the maximum period since deterioration started as 54 years, which is roughly about the time when pumping untreated sewage into the river started. Similarly Sabarmati and Narmada rivers from gulf of Cambay also pump marine pollutants through stormwater runoff into the Arabian Sea. The petroleum hydrocarbons presence as oil slicks, dissolved/dispersed form, floating residues (tar balls) and tar on beaches is well known in the Arabian Sea. A total of 6689 observations on oil slicks and other floating pollutants revealed positive results for oil slicks on 5582 or 83% of the total (Sen Gupta and Kureishy, 1981). In the near shore areas of Mumbai high concentrations of dissolved/dispersed hydrocarbons ranged from 2 to 46µg/l in water and from 4 to 32µg/g dry weight in sediments. In Mumbai habour region the concentrations, after a tanker fire accident, ranged from 27 to 105 µg/l at the surface and from 36 to 59 µg/l at 5m. The concentrations in sediments increased from 1-26 µg/g to 40-512 µg/g after the accident. In a polluted creek in Mumbai concentrations in sediments were in the high range of 142-393 µg/g.

ATA ACQUSITION

Marine pollution hazards are typically not daily events and features localized to the areas where they occur at random or after the event like summer monsoons. Acquiring the data about this phenomenon can be challenging using either in situ or remote sensing approaches because of their uncertainty in occurrence and extent of their spatial distribution. Ship or aircraft based is a time consuming, expensive ordeal, requires advance planning, and is difficult to conduct in poor weather. Time series data is hard to come by and requires heavy resources. Buoys, on the other hand, are well suited to single point time series measurements, but at high establishment costs and their vulnerability limit their use. Satellite remote sensing, particularly those sensors using visible, near – and thermal infrared portions of the electromagnetic spectrum, is valuable in the coastal regions since it can provide daily, synoptic time-series data. However, these sensors have only moderate ground resolution (e.g., 0.3-1km) and viewing is frequently limited by cloud cover. Active microwave remote sensing approaches overcome some of these limitations.

SUITABILITY OF SYNTHETIC APERTURE RADAR DATA

A valuable, but still under-used active remote sensing approach for coastal water quality applications, is satellite-borne synthetic aperture radar (SAR) (e.g., Holt, 2004). SAR imagery provides high-resolution (*6*100m ground resolution) active microwave observations of sea-surface roughness that are independent of weather and availability of light. Factors modulating surface roughness include wind, interactions of waves and currents, and the presence of surfactants on the ocean surface. Observed surface roughness variability can distinguish surface manifestations of the pollution hazards described above from the ambient ocean because they all contain surfactants. The surfactants smooth capillary and small gravity waves, which reduces surface roughness and thus radar backscatter. The smoothed surfactant-covered areas appear darker on SAR imagery compared with the usually wind-roughened surrounding ocean, which has higher backscatter and thus appears brighter on SAR imagery. SAR imagery also visualizes complex, small-scale oceanographic processes, such as coastal eddies (e.g., Munk et al., 2000; DiGiacomo and Holt, 2001), which are likely important in controlling the transport, near shore residence times, and fates of pollutants associated with these hazards. SAR imagery has been used to identify significant, and often illegal, discharges from ships (e.g., Gade and Alpers, 1999; Lu, 2003; Pavlakis et al., 2001), to examine natural seeps in the Gulf of Mexico (De Beukelaer et al., 2003), and to observe stormwater and sewage runoff in southern California (Svejkovsky and Jones, 2001). SAR has also been used for monitoring oil spills from ships and platforms (e.g., Fingas and Brown, 1997; Espedal and Johannessen, 2000; Jones, 2001).

The ability of SAR to detect pollution hazards is limited by environmental conditions, particularly wind and waves (Gade et al., 1998; Trivero et al., 1998; DiGiacomo and Holt, 2001; Svejkovsky and Jones, 2001). Successful imaging of oil slicks using SAR requires that surface wind speeds fall in a fairly narrow range. At very low wind speeds (less than 2–3ms^{-1}), little microwave energy transmitted to the sea surface is backscattered toward the SAR, resulting in dark areas, broadly distributed over a SAR image. Under these conditions oil slicks cannot be differentiated from smooth ambient waters. At high wind speeds increased surface roughness results in dispersal and mixing of the oil into the upper ocean. Petrogenic hydrocarbons may be detectable on SAR imagery until winds exceed 10–14ms^{-1}, depending on sea state and heaviness of oil (e.g., Espedal et al., 1998; Espedal et al., 1999; Wismann et al., 1998). Biogenic oils (e.g., phytoplankton exudates) are generally not detectable when winds exceed 7–8ms_1 (DiGiacomo and Holt, 2001). Sorting out ambiguous surface slick signatures is an area of active research, requiring repeat imaging, analysis of wind time series, and knowledge of sources (Espedal and Wahl, 1999; Solberg et al., 1999). Perhaps the most significant constraint on the routine use of SAR for coastal pollution monitoring is the inconsistent temporal coverage afforded by all SAR platforms to date. From a single sensor, with swath widths from 100– 500km, SAR observation frequency is variable, ranging from a best of twice-per-day to several observations per week.

PURPOSE OF THIS STUDY

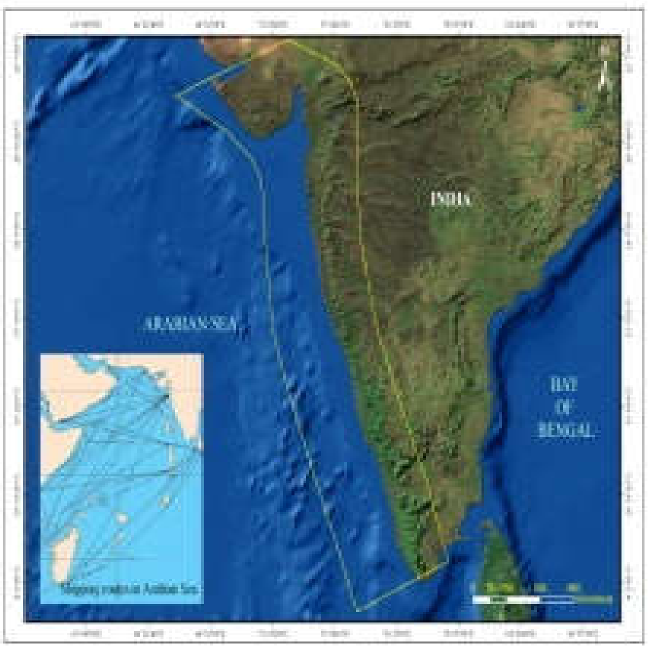
The purpose of this study is to bring out the extent of pollution in the coastal waters due to human activity on the land and identify sources of pollution. Also this study demonstrates the importance of SAR to monitor the storm water runoff and petroleum hydrocarbons in the coastal waters of India. The study is regional analysis of SAR imagery supported by comparisons with satellite imagery of Noaa-18 satellite and Modis from Terra.

STUDY AREA

The study area chosen is Gujarat and Maharashtra Coasts where numerous UA's exist. The river runoff is predominant with considerable number of rivers and their tributaries discharge water into the Arabian Sea.

METHODS

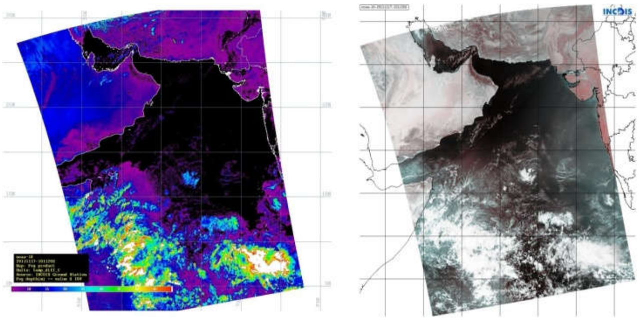
An Advanced Synthetic Aperture Radar (ASAR), operating at C-band, ASAR ensures continuity with the image mode (SAR) and the wave mode of the ERS-1/2 AMI. It features enhanced capability in terms of coverage, range of incidence angles, polarisation, and modes of operation. This enhanced capability is provided by significant differences in the instrument design: a full active array antenna equipped with distributed transmit/receive modules which provides distinct transmit and receive beams, a digital waveform generation for pulse "chirp" generation, a block adaptive quantisation scheme, and a ScanSAR mode of operation by beam scanning in elevation. Radiometric resolution in range: 1.5-3.5 dB. Spatial Resolution in Image, Wave and Alternating Polarisation modes: approx 30m x 30m. Wide Swath mode: approx 150m x 150m. Global Monitoring mode: approx 1000m x 1000m. Swath Width is Image and alternating polarisation modes: up to 100km, Wave mode: 5km, Wide swath and global monitoring modes: 400km or more. Wave Band can be Microwave: C-band, with choice of 5 polarisation modes (VV, HH, VV/HH, HV/HH, or VH/VV). To date, the only operational Level-1B data product offered by ESA from the ASAR Wide-Swath Mode (WSM) has been the multi-look detected product (ASA_WSM_1P), intended to support applications that exploit intensity data. Two images of wide swath mode obtained in November 2011 of the study area are used in this study.



IN SITU DATA

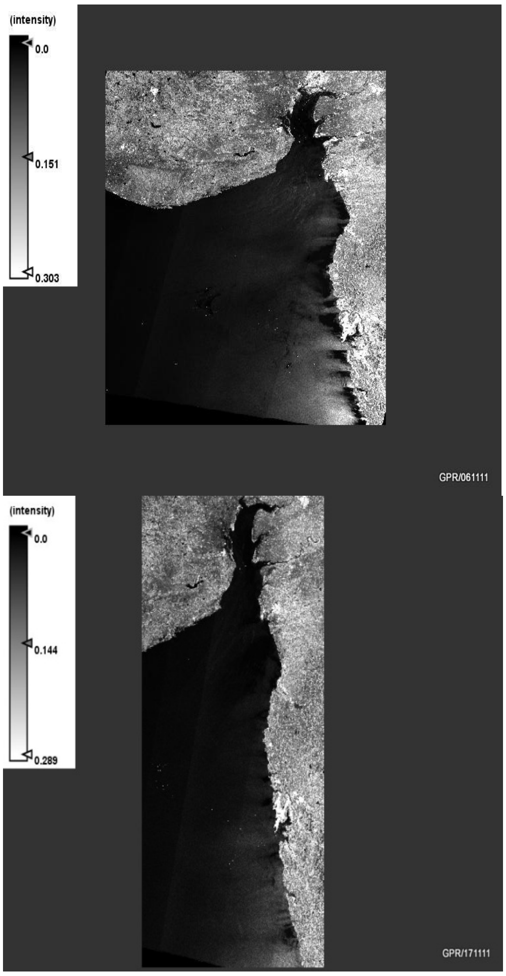
A number of field measurements are required to help interpret this data. The river discharge rate is required to measure the intensity of the storm water runoff. Even if the precipitation data in the catchment area is absent the rise and fall of tide also brings in the pollutants in to the Arabian Sea. The other parameters are winds, SST, Tides, Tidal current, surface currents of the area and knowledge of the sources of petroleum hydrocarbons entering in the area. Satellite data from Noaa-18, Modis Terra are used to correlate the event and analyse the data. On 06 November 2011 the tidal High and Low water height and timings used by Mariners from Admiralty tide tables gives us a fair idea of flow and ebb at that specific location. The Table reads at Mumbai as 06 Sunday, IST 02 46 1.93 mtrs, 08 52 3.42 mtrs, 15 29 1.27 mtrs and 21 52 3.59 mtrs (Lat 18^{o} 56' N/ Lon 72^{o} 50' E). At Dahej 01 52 7.50 mtrs, 07 57 2.80 mtrs, 13 44 7.20 mtrs and 20 18 1.70 mtrs (Lat 21^{o} 43'N/ Lon 72^{o} 35'E). At Bhavnagar 01 39 7.90 mtrs, 0735

4.40 mtrs, 13 07 8.20 mtrs and 21 05 3.20 mtrs (Lat 21° 47'N/ Lon 72° 16'E). On 17 November 2011 the Thurday at Mumbai the Tide Table reads 03 50 3.88 mtrs, 10 08 1.69 mtrs, 15 40 3.19 mtrs and 21 19 1.35 mtrs. At Dahej it reads 02 07 1.90 mtrs, 08 13 8.50 mtrs, 15 06 2.00 mtrs and 20 50 7.00 mtrs. At Bhavnagar it reads 03 19 2.40 mtrs, 08 37 10.50, 16 15 2.80 mtrs and 21 06 8.10 mtrs. The exact data at the time of image can be interpolated from these values. The wind field data derived from the image itself is used. Some satellite data of the same day are shown below:



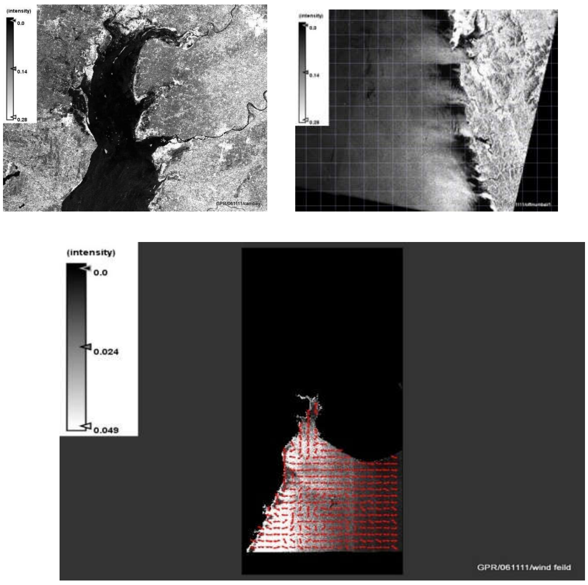
RESULTS AND DISCUSSION

The study area is Gulf of Khambat, Gujarat and Maharashtra coasts and two images on06 November 2011and 17 November were chosen.

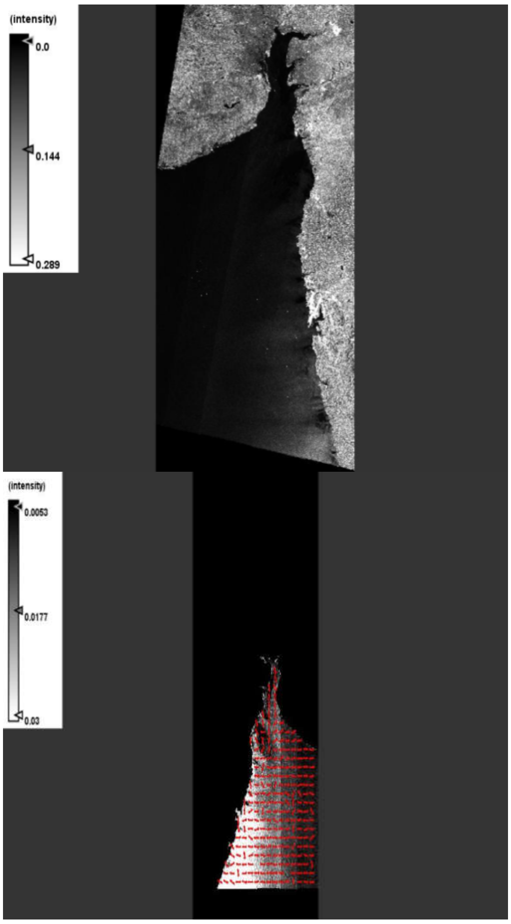


06112011-0514 i.e. 10 44 IST 17112011-0511 i.e. 10 41 IST

The image sub sets are enumerated below to depict the pollution:



Sub sets of 061111 image



Sub set of 171111 images

The wind field estimation results are obtained on processing with the following information given for each window of 20 km in which wind estimation is read:

A. Lat: Latitude of the central point of window.
B. Long: Longitude of the central point of window.

C. Speed: Estimated wind speed in m/s.
D. dX; X component of the estimated wind vector.
E. dY: Y component of the estimated wind vector.
F. ratio: In estimating wind direction, the spectrum of a given window is matched with a 2D polynomial (like f (x, y) = ax_^{2}+bxy+cy_^{2}+dx+ey+f). The ratio in the report is the ratio of the minor semi axes over the major semi axes of the 2D polynomial. Generally speaking, the smaller the ratio value, the more reliable the estimated wind direction.
Sample wind field Info ratio is:
“<windFieldInfo ratio=”0.91“ dy=’0.94” dx=”-87.99” speed=”3.4” lon=:69.84” lat=”18.42”/>

The analysis of 06 Nov 2011 image, the wind field info results reveal winds above 3 m/s i.e. the threshold level to detect oil spills and pollution less chances for dark spots due to low wind area. The tidal observations at Mumbai at the time of the image was ebb tide for 80 minutes duration creating an ebb flow into the sea which is clear in the picture. The tides at Dahej and Bhavnagar were also in ebbing mode after the high water. The tidal flows / currents are seen in the image clearly flowing south.The wind velocity average was 7 m/s and direction west/ east direction in the sea area and South / North direction in the Gulf of Khambat. A black spot of 63x 21 km wide light black patch observed in the Gulf of Khambat and thirteen light black patches of various sizes total area amounting to 3900 km^2. The dark spot out of thirteen observed in Mumbai harbour is a confirmed patch of low wind area as per the wind field info results. This is not a healthy state of marine environment. The image shows stratified black spots probably with oil, surfactants along with fresh water or stormwater runoff around the ebb stream at most of the river outlets. The analysis of 17 Nov 2011 image, the wind field info results shows low wind in 10 results out of 219 results of total image. The wind was of the same order as in the earlier image with not much of a change. The tidal conditions were also similar i.e. ebbing just commenced in Mumbai harbour and well in to the ebb flow at Dahej and Bhavnagar. In this image a total of twelve patches were observed with total area of 3773 km^2. This figure is very close to the earlier image figure of 3900 km^2. This time the patches seemed darker. There was a moving ship spill in each image, the length of oil spill in this image was 25 km.

CONCLUSION

SAR imagery can be used to track oil in the coastal ocean such as might occur in an accidental oil spill. A significant research issue that must be addressed is the nature and composition of the surfactants detected by SAR. The composition of oil slicks from natural hydrocarbon seepage and the grease and oils from sewage outfalls is fairly well understood. In contrast, the composition of surfactants in stormwater runoff is poorly understood, as are the connections between surfactants and distributions of toxic constituents and pathogens. If connections can be established, then SAR imagery might usefully predict the extent and duration of the negative effects due to stormwater plumes on beaches and near shore recreational waters. As part of this effort, detailed assessments are required to examine how surfactant composition and loading vary with watershed characteristics such as land use (e.g., urban, agricultural, mixed-use) and land cover (e.g., percent impervious surface). SAR imagery has several advantages compared with other satellite approaches for use in marine pollution studies. Among the advantages are its high spatial resolution (order 25–100m), its sensitivity to the presence of surfactants as illustrated in this study, and its ability to obtain useful information regardless of cloud cover or darkness. The latter point is particularly relevant here given that stormwater discharge events occur during storms, when clouds often prevent observation by optical satellite sensors. The high spatial resolution of SAR imagery enables detection of small-scale hazards (e.g., IMAGES), as well as interactions between these hazards and small-scale ocean features such as eddies. The occurrence and interaction of these hazards and features would not be readily detected with most optical sensors. As an additional benefit, nearly all current and future SAR platforms include wide swath coverage (>250km) that improves the synoptic view of coastal regions.

Limitations of SAR include its inability to distinguish slicks from low wind or other low backscatter regions. At high wind speeds, another limitation of SAR is that it cannot determine the thickness of oil slicks, which is of particular importance for tracking oil spills (Fingas and Brown, 1997) and determining spill volumes. At present, however, the major limitations of SAR for detecting coastal pollution hazards are infrequent temporal coverage and restricted access to realtime and archived data. Improving temporal coverage to daily, for example, is only currently possible by using multiple SAR platforms (Holt and Hilland, 2000). Much SAR data exists, but each international agency managing SAR programs has different scientific and programmatic objectives as well as inconsistent data access policies which complicate use and increase costs of data from multiple platforms. This severely limits use of existing SAR platforms and data sets as coastal management tools. Improved management of existing SAR programs could quickly remove these limitations.

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REFERENCES

Allen, A.A., Schlueter, R.S., Mikolag, P.G., 1970. Natural oil seepage at Coal Oil Point, Santa Barbara, California. Science 170, 974-977.

Bay, S., Jones, B.H., Schiff, K.C., 1999. Study of the impact of stormwater discharge on Santa Monica Bay. Executive Summary Report prepared for the Los Angeles County Department of Public Works, Alhambra, C A. USC Sea Grant Program, Los Angeles, CA (USCSG-TR-02-99).

DiGiacomo, P.M., Holt, B., 2001. Satellite observations of small coastal eddies in the Southern California Bight, J. Geophys. Res. 106 (C10), 22521-22544.

Espedal, H.A., Johannessen, O.M., Knulst, J., 1999. Satellite detection of natural films on the ocean surface. Geophys. Res. Lett. 23, 3151-3154.

H.Hersbach, CMOD5,” An Improved Geophysical Model Function for ERS C-Band Scatterometry”, Report of the

European Centre Medium Range Weather Forecasts (ECMWF), 2003.

Paul M. DiaGiacomo, Libe Washburn, Benjamin Holt, Burton H. Jones. “Coastal Pollution hazards in southern California observed by SAR imagery: stormwater plumes, wastewater plumes, and natural hydrocarbon seeps”.

Pavlakis, Tarchi, P.D., Sieber, A.J., 2001. On the monitoring of illicit vessel discharges using spaceborne SAR remote sensing-a reconnaissance study in the Mediterranean sea. Ann. Telecommun. 56 (11-12), 700-718.

Sengupta, R., Sugandhini Naik,and V V R Varadachari “ Environmennntal Pollution in Coastal Areas of India

Wackerman, C.C., W G Pichel, P. Clemente-Colon, “ Automated Estimation of wind Vectors from SAR”, 12 Conf. on Interactions of the Sea and Atmosphere, 2003.

Wu, Y. L., Washburn, L., Jones, B.H., 1994. Buoyant plume dispersion in a coastal environment; observations of plume structure and dynamics. Cont. Shelf Res. 14 (9), 1001-1023.

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