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Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 09, No. 03

June 2016, P.P.84-92

RS - GIS based Operational Monitoring of Indian Maritime and Environs

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Abstract: The prestigious Sagarmala concept announced during the first Maritime India Summit, Mumbai in April 2016, shows the great economic importance of the 7500 km long coastline as the number of major / minor ports in the near future are expected to increase significantly to boost sea trade and increase the prosperity of the nation. The increase in number of trading ships passing through Indian Maritime environs also raises the probability of oil spills that give rise to environmental alarms. Indian Maritime zone, includes the clusters of islands in the western and eastern seas, major oil installations along the coast line, growing international maritime trade across the ports, proximity to the International trade sea routes and some prominent choke points, tends to be a highly potential zone for oils spills. For marine safety and environmental concerns oil spill monitoring and management on operational basis, becomes an imperative national requirement. Additionally the ship clogging at Strait Malacca choke-point near Andaman sea affirms the vital need for oil spill monitoring in Indian Maritime. This calls for a Techno-Managerial Framework based on RS and GIS. The Government of India realizing the importance of oil spill management, has already identified the roadmap for Oil Spill Management by forming Oil Spill India (OSI) and by conceiving and revising the National Oil Spill – Disaster Contingency Plan (NOS-DCP) in 2015. Some of the international success stories on the Remote Sensing and GIS based marine oil spill monitoring are PROMED in Mediterranean, EMSA which has achieved Clean-seas / Safe-seas in Europe, I-STOP in Canada, North Caspian Sea Scan-Ex RDC etc. Hence, there is an emerging requirement for a space based, RS-GIS supported Oil spill monitoring over the Indian Maritime Zone and its vicinity. The availability of Remote Sensing Technology in Microwave (Hybrid Polarimetric SAR) / Optical / NIR Bands, data from Microwave radiometers, scatter meters, Sea state Geo Physical data records, Processing Algorithms, Models, GIS and web services put together has the potential to offer a scope for an operational frame work and thus improving the turn-around efficiency of oil spill management. In addition, the recent realization of IRNSS ensures availability of position information. The broad reasons for the requirement, the feasibility through an integrated approach of oil spill response schemes, resources and advanced technologies like Remote Sensing from RISAT/Oceansat, ISRO GeoPortals Bhuvan / NICES, INCOIS web portal and similar services is discussed in this paper.

Keywords: *Oil Slicks Monitoring, Remote Sensing, Polarimetry SAR, Bhuvan Geo-Portal*

1. Introduction

Oil spills are a global concern and are often referred to as marine oil spills, where oil gets released into the ocean. Table 1 gives a list of major oil spills. Marine oil pollution is undesirable for survival of global living creatures. The probability of occurrence of oil spills raises with increase in the number of ships passing through. Observed oil spills correlate with the major shipping routes and also with offshore installations. Around Sixty three percent of the world's oil production moves on maritime routes and these ship routes are in general relatively smooth, except at a few choke points across the world seas. World maritime routes are shown Figures 1.

Nevertheless, even a single oil release incident from a large oil trading ship could be a disaster to the marine environment. The cargo ship routes that transit through the Indian ocean waters near Indira Point will flock at the Strait of Malacca before they diverge and sail to their destinations at pacific that increases the probability of ship collision [1]. The Strait of Malacca is part of a major trade route for global seaborne oil transportation and this strait is the world's most important strategic chokepoint by volume of oil transit that connects Indian ocean with Pacific ocean [2,3]. Seven oil transit Choke points are listed across the world as per published reports namely, Panama Canal, Danish straits, Turkish straits, Suez canal, Babel Mandeb, Strait of Hormuz and Strait of Malacca [4] as shown in Figure 2.

Out of these, Strait of Malacca is the busiest world oil chokepoints located near to India’s Indira point, having a width of only 2.7 km at its narrow point in the Phillips Channel of the Singapore Strait. This

Strait of Malacca links the north of Indian Ocean and the western Pacific Ocean and cut shorts the sea route between the Middle East and growing Asian markets. It connects the Indian Ocean with the South China Sea and is close to the Andaman Sea. Oil bound for Japan, South Korea, China and other nearby countries passes through this strait. This makes The Strait of Malacca, a ship dense nerve centre and has high potential for unexpected ship collisions, and therefore for unwanted oils spills [5].

Figure 1 *World Maritime route (The Huffington post, China US focus, 2015)*

The world oil demand hovers around 70 to 90 million barrels per day (~159 lit/barrel) as per Organization for Economic Co-operation and Development / International Energy Agency (OECD/IEA) oil market 2013 reports. By the year 2025, the world oil demand is estimated to be around 5500 Million Metric Tons Per Annum (MMTPA) out of which around 70% is anticipated to be sailed through Indian waters. Even though the modern crude oil tankers are built to state-of-the art design with safety features and the oil spill numbers have shown a decreasing trend (as per (ITOPF) in the last decade, a normal oil ship accident involving even one tanker can spill about 7000 to 10000 tons of oil. With the present trend in the deployment of larger tankers, even a single oil release incident from such a large oil trading ship could be hazardous to the marine environment.

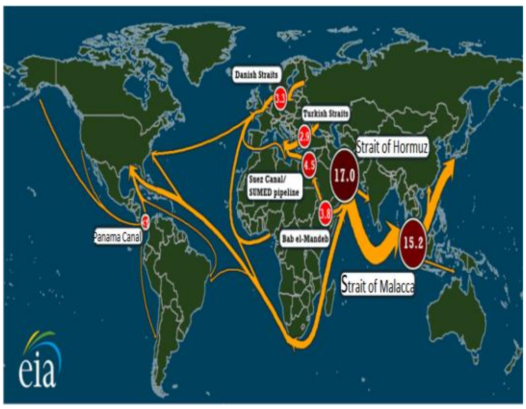

Figure 2: *Oil Choke points across the world*

Table 1 *Major Oil spills*

SN	Ship / Pipeline Name	year	Location	Oil lost in tons
1	OT Southern Star 7	Dec2014	Bangladesh	350
2	Napocor	Nov 2013	Philippines	1200
3	Taylor Energy wells	Sep 2004	Gulf of Mexico	
4	Trans-Israel Pipeline	Dec 2014	Israel	1948
5	Mid-Valley Pipeline	Oct 2014	United States	546
6	North Dakota Pipeline	Mar 2014	United States	110
7	Mumbai Oil spill (MSC Chitra and MV Khalijia)	Aug-2010	India	800
8	Exxon Valdez	1989	United States	37000
9	Wafra	1971	South Africa	40000
10	Sea Express	1996	UK	72000

Source: www.en.m.wikipedia.org and International Tanker's Owners Pollution Federation Limited (ITOPF)

Figure 3 and Figure 4 show oil spills which made headlines. Table 2 shows the growing awareness for oil spill management in India. Different kinds of economic losses due to oil spill include:

- Loss of oil
- Cost of Cleaning
- Loss of tourism and local business
- Loss of sea food and associated jobs
- Cost of waste management
- Damage to the environment
- Insurance claims and protracted legal disputes

Delayed or non-detection of oil spill events will have severe impacts on marine ecology and climatic environment.

It is essential to observe the ocean area continuously and early-detect the potentially hazardous ocean zones in order to minimize the impact of environmental disaster and economical losses due to oil spills in the ocean.

The strait Malacca and ship traffic density between Mozambique and Arabian Sea draw attention to the imperative need for a well-organized, suitable operational system for Indian Maritime with adequate technical infrastructure, capabilities, expertise to routinely monitor the oceans and use the information to deal with any situation arising out of oil spills and thus to minimize the damage to the Indian Maritime.

Though technology based services are in place to keep track of individual ships, similar techno-managerial frame work is yet to be formed to identify the oil slicks using remote sensing technology and associated GIS services.

Figure 3: *The BURMAH AGATE collided with freighter MIMOSA southeast of Galveston Entrance in the Gulf of Mexico on November 1, 1979. An estimated 2.6 million gallons of oil were released into the environment, another 7.8 million gallons consumed by the fire on board (Source: www.noaa.gov)*

Figure 4: *The IXTOC 1 exploratory well blew on June 3 1979 in the Bay of Campeche off ciudad del Carmen Mexico (Source: www.noaa.gov)*

Table 2: *Growing awareness for Oil spill Management in India*

2003	Road Map for Oil Spill Management for India by GOI / PSA
2008	Oil spill response exercise conducted since OCT 08 by ICG
2010	Mumbai Oil Spill : Ship collision involving MV MSC Chitra and MV Khalijia- III
2011	Oil Spill India formed / 1st Oil Spill India Conference
2012	2nd Oil Spoil India Conference
	RISAT-1 with Hybrid polarimetric SAR launched (First for Earth Observation)
2014	Oil Spill in Sunderbans, 3rd Oil Spill India Conference
2015	NOS-DCP : Indian Coast Guard is part of it
	India's First Tier-I OSR Center inaugurated @ Mumbai
	On-Line Oil Spill Advisory established by INCOIS
2016	First India Maritime Summit
	4th Oil Spill India Conference

India has operational remote sensing satellite systems for observations of land cover and ocean surfaces on the earth. Among several currently operational IRS satellites of ISRO, Oceansat and RISAT series of satellites with their variety of remote sensing instruments on board, have potential for offering oil slick monitoring services on operational basis. Oceansat satellites have wide field optical and infrared ocean monitoring sensors, scatter meters, radio meters, whereas RISAT satellite has Hybrid Polarimetry Synthetic Aperture Radar with high degree of potential to detect marine oil slicks.

It is aimed in this paper to bring out the imperative need for space based Operational monitoring of India's Maritime Zone and Environs and discuss RS-GIS based techno-managerial frame work to address the solution to the requirement.

Section 2 gives the description of a few global case studies on the application of Remote Sensing and GIS for oil spill management. Section 3 describes the present Oil Spill Response and present status in Indian maritime zone. Section 4 gives an overview of the space based Ocean Surface Monitoring in India. Section 5 describes the proposed space based techno-managerial framework for our maritime zone. Section 6 gives the conclusion.

2. RS - GIS based Oil spill Management: A few Global case studies

Across the globe, there have been major initiatives in employing RS & GIS for oil spill monitoring and detection using SAR data. Some of the international success stories on the satellite based marine oil spill monitoring are Operational System for Monitoring Oil Spills in the Mediterranean Seas (PROMED), European Maritime Safety Agency (EMSA) which has achieved Clean-seas / Safe-seas in Europe, Integrated Satellite Tracking of Oil Polluters (I-STOP) in Canada, North Caspian Sea Scan-Ex Research and Development Centre (Scan-Ex RDC) etc,. European Maritime Safety Agency goes a step ahead and generates near real time alerts for oil spills and has been successful in identifying the polluting vessels. A few case studies are given below:

A) North Caspian Sea Oil Spill Radar Satellite Monitoring

In 2007, Scan Ex R&D Center together with NGO Transparent World launched the on-line project, aimed at the monitoring of oil spills in the Caspian Sea. The project's goal is to collect operational data on the Northern Caspian Sea water area pollution by oil and oil products and to provide this data to a wide range of users via an open Internet-resource. Monitoring is based on all-weather near real-time radar imaging from ENVISAT and RADARSAT satellites, arranged by Scan Ex R&D Center. A geo-information approach is applied to get a better understanding of the oil sources and to perform a comprehensive analysis of radar data used in the project as the main information source of sea oil pollutions.

B) Kongsberg Satellite Services (KSAT) and "Clean-Sea-Net" in European waters

KSAT provides maritime monitoring services to oil companies, pollution control authorities and coastguards. Information derived from analyzing SAR images provides early detection of pollution incidents introduced by off shore oil activities as well as accidental or illegal discharges from vessel traffic. The service is available to oil companies across the world and all 24 European coastal states through Maritime Safety Agency (EMSA) Clean-Sea-Net Service. Near Real-Time oil spill detection system for European countries is being provided by the "Clean-Sea-Net" service. It uses ENVISAT, RADARSAT-1 and 2 and SENTINEL-1 satellites for oil spill detection. The setup is operated by EMSA since April 2007. KSAT is owned 50 % by Kongsberg Group and 50 % by Norwegian Space Agency Properties, and the head office is located in Tromso.

C) Operational Satellite Monitoring and Detection for oil spill in offshore of UAE

The Japan Oil Development Co., Ltd. (JODCO) in collaboration with Japanese Information Centre for Petroleum Exploration and Production (ICEP) created and supported Satellite Image Processing Project (SIPP) for "Environmental Protection System in Oil Producing Offshore Areas of Abu Dhabi" in the United Arab Emirates University for environmental protection.

D) An Operational System For Monitoring Oil Spills In The Mediterranean Sea: The PROMED System

The Mediterranean Sea is a frequented sea route allowing access to Southern Europe, North Africa, the Middle East and the Black Sea. The result of this extensive marine traffic is a high risk of oil pollution. Hence, an operational system for managing oil spill events, namely the PROMED system, has been developed to monitor areas under surveillance for oil spill emergencies using satellite SAR imagery, and to provide quantitative assessment of accident consequences, help users evaluate the available options and effectively implement their decisions [6].

3. Oil Spill Response status in Indian Maritime

There are various sources of oil spills; natural seepage from seabed, ship-borne (Accidental or Incidental), oil exploration, processing, refining and production etc. Incidence of spills is by operations involving loading /discharging, bunkering, illegal oil release and oil spills by accidents are due to ship collisions, groundings, hull failures, fires, explosions etc.

Oceans cover 70% of earth's surface and that is why maritime trade is important. Indian peninsula has a natural gift of a long coastline of over 7500 km (including Andaman, Nicobar and Lakshadweep Islands). The contiguous oceans around India, forming Sagarmala, will open up vast investment opportunities in future. India's coastline can become engine of growth [7].

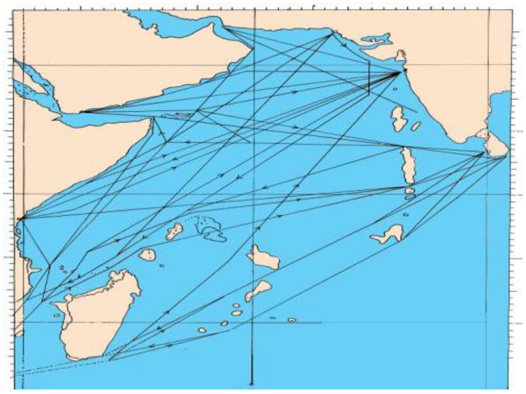

Figure 5a: *Principal Routes from Mocambique to Western Indian maritime*

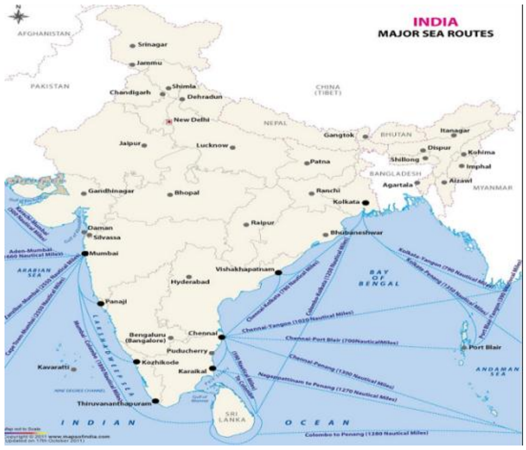

Figure 5b: *Major sea routes around India Channel and Arabian Sea (Source: Road map for Oil Spill Management for India 2003; www.mapsofindia.com)*

Monitoring of the sea around India to locate oil slicks is yet to take an operational form. It is necessary not only for environmental balancing but also for energy security and marine bio-safety reasons. Oil spill management process detects oil spills, initiates quick response to risk mitigation, minimizes any damage by advising and assisting all parties on the most appropriate clean-up techniques, organizes the cleanup schemes, investigates damage to the marine environment and fisheries and advices on methods to mitigate environmental and economic losses including restoration options etc. This requires attention from Government, shipping industry, oil companies, port authorities, spill management agencies, national research organizations and information dissemination agencies.

Oil spill contingency management plans and procedures needed for response actions are documented and are in place in India. The response agencies are the Indian coast guard, Ministry of Shipping / the Directorate General of Shipping, State Government Maritime Board, Ministry of Petroleum and Natural Gas, Ministry of Environment and Forests, Ministry of Defense, Department of Fisheries, Major Port Authorities, Emergency organizations for oil spill disaster, Emergency Response units, Emergency control centers, Marine response centers, salvage monitoring and control units, off shore control units, etc.

At present, ESSO-INCOIS, Hyderabad is providing forecast information derived from satellites and ocean in-situ sensors for the coastal Indian Ocean in near real time to the public organizations such as fisher / coastal populations, Maritime Boards, Indian Navy, Indian Coast Guard, Shipping sector, Energy Sector, Oil & offshore exploration industries, Port Authorities, Pollution Control Boards, Disaster Management Agencies, NGOs and other research organizations.

Nansen Environmental Research Centre India recognized by DSIR, in collaboration with INCOIS aims to provide ocean information and advisory services to the society, industry, government and scientific community through sustained ocean observations and continual improvement through systematic and concentrated research efforts. Earth System Science Organization (ESSO) with Indian National Centre for Ocean Information Services (INCOIS) has established the integrated INDian Ocean FOrecasting System (INDOFOS), capable of predicting the weekly surface and subsurface features of the Indian Ocean. Currently, INCOIS provides forecasts of several ocean parameters including Oil-spill trajectory. The forecast is available separately for Arabian Sea, Bay of Bengal, Northern Indian Ocean, Southern Indian Ocean, Red Sea, Persian Gulf and South China Sea. The OOSA system, developed by INCOIS, has developed an online platform for characterizing and guessing the movement of oil spills.

Regarding oil spills response, India has initiated the framework in 1993, known as the National Oil Spill Disaster Contingency Plan (NOSDCP) to convene oil spill disasters. Ministry of Defense is the nodal authority to implement this. NOSDCP provides the basic framework and guidelines for a national response to a significant spill at sea and is intended to demarcate functions of concerned units for the operational responsibility in an integrated manner on the marine oil spills. The Central Coordinating Authority (CCA) / Director General Coast Guard implement the plan, and coordinates response activities in the event of oil spill at sea. The comprehensively revised, 2015 edition of the NOSDCP reflects current international norms and best practices, key relevant national regulation, experience gained since publication of the first edition in July, 1996, and valuable inputs received from stakeholders to the national plan. While the earlier editions of NOSDCP covered only oil spills, the revised edition initiates national preparedness and response to Hazardous and Noxious Substance (HNS) incidents as well [8]. Tier-I Oil Spill Response Centre for Mumbai & JNPT Harbors (Jawaharlal Nehru Port Trust) (OSRC) has 24/7 operational readiness to combating oil spill up to 700 tons. The Ministry of Environment Oil Spill Response (OSR) Tier system deal with the contingencies arising out of oil spill in the marine area. The required equipment and the types of dispersants are identified and OISD advises all the concerned oil companies (IOCL RIL, Essar, BORL, Cairn, Niko, BPCL, GSPC, ONGC, Hardy, HOEC, and HPCL) to prepare for pooling of oil spill resources. The Directorate of Hydrocarbons, the Oil Industrial Safety Directorate, the Ministry of Petroleum and Natural Gas, and the Ministry of Environment and Forests all exercise some control over procedural safety, risk assessment and mitigation, and impact assessment in any such accident. International conferences & exhibitions conducted once in two years by Oil Spill India (OSI) for oil spill professionals and researchers' aims to focus on the prime causes of oil spill create awareness, alleviation methods, regulations, and guidelines, technological innovations in equipments & training needs to the people for damage control in time [9].

ITOPF-Oil Spill Response Ltd (OSRL) coordinates through seminars and attempts to bring out implementation aspects of the new National Oil Spill Disaster Contingency plan (NOSDCP).

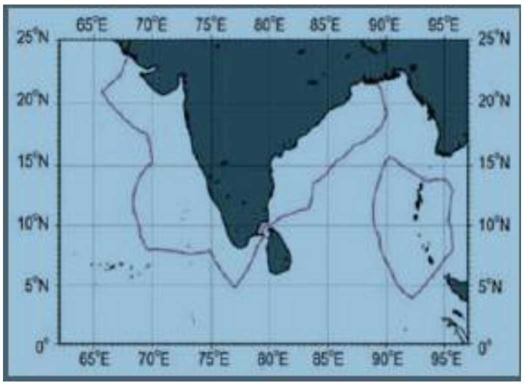

Figure 6: *National Pollution Response area (Source: Internet)*

As per International Tanker Owners Pollution Federation Limited (ITOPF), Spill notification points in India are located at Northern, Eastern, North-Western, National Centre, and at Andaman Nicobar Islands. The charted out oil spill response arrangements happen through Indian Coast Guard. India has already set off the needed technologies and promulgated global good practices for oil spill monitoring, cleaning processes, meeting environmental contingencies etc.[10]. The Road Map for India deals with all relevant aspects of oil spills, including sources of oil spills, contingency planning, mitigation strategy, need for review of different existing legislation for oil spill management, need for training and re-training [11].

National ocean monitoring satellite systems of Indian Remote Sensing program are currently in operational orbits with advanced and diversified imaging systems for detecting sea surface oil spills in optical and microwave frequency bands. ISRO has deployed Polarimetric Radar imaging satellites which have very high potential to detect the oil spill in Indian marine seas. However, an integrated operational infrastructure, if in place, would immensely add to the existing sporadic services to address the oil spill detection and implementation of contingency response measures.

4. Space based Ocean Surface Monitoring in India

ISRO has launched series of ocean monitoring satellites in optical and microwave bands with sensors that provide ocean data in various swaths and resolutions, at all times and weather conditions. This data is made available to access by various National agencies like BHUVAN, MOSDAC / SAC, IMD, INCOIS. Remote sensing data from satellites have been successfully used in identifying the oil slicks [12, 13]. Since oil normally exhibits a lower temperature than sea water, thermal infrared scanners mounted on satellites, could also be deployed in the surveillance of oil spills besides optical sensors. Similarly, sea surface roughness and oil slick surface roughness will be different and this variation could be detected by scatter measurement microwave sensors.

ISRO's Oceansat2, intended to capture ocean dynamics, had captured images of the slick covering overall area of 1,420 km in breadth around the slick, the rig and US coastlines of Louisiana and New Orleans. The images were made use of by US scientists for analysis of spread and extent of oil spill. ISRO Satellite images were used to map the area of Gulf of Mexico oil spill. Besides, Scatter meter at 13.3 GHz frequency has been used for detecting oil spills [14]. Optical/infrared radiometers, imaging spectrometers, seaWifs sensors, SAR systems in multi polarization modes with variable swaths and resolutions were used as oil slick data acquisition systems [15].

Figure 7: *RISAT-1 Spacecraft with Hybrid Polarimetric SAR launched on April 2012*

Figure 7 shows India's RISAT-1 and Figure 8 shows IRNSS which is expected to become operational in 2016. This improves the scope for self-reliance towards oil spill detection and monitoring system as SAR images and location information is now available along with optical images. India has operational remote sensing system for land cover and ocean surfaces on the earth. Among several currently operational IRS satellites of ISRO and other international satellites in orbit, Oceansat and RISAT series of satellites have potential for offering oil slick monitoring services on operational basis. Oceansat satellites have wide field optical and infrared ocean monitoring sensors, scatter meters, radio meters, while RISAT satellites have Hybrid Polarimetry Synthetic Aperture Radar with high degree of potential to detect marine oil slicks. Realization of near real time operational services for Oil spill monitoring could become possible with the integration of the remote sensing processed images data, in-situ measurements from multi-sensor ocean geophysical data, oil spill identification methods, high resolution numerical ocean models, GIS support etc. [16]. However this will be operationally possible when the Indian Satellite series are clustered or put in constellations with improved revisit capabilities.

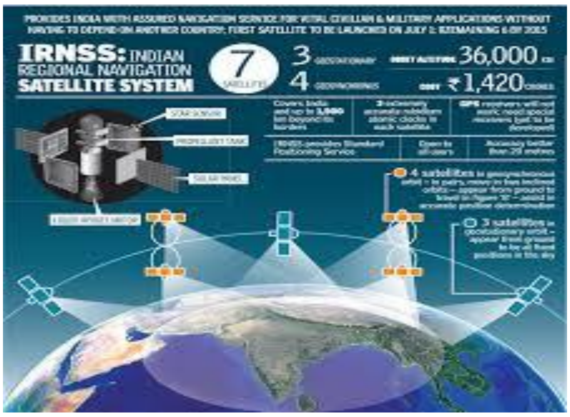

Figure 8: *IRNSS Constellation across India*

Though Oil spill contingency management plans and procedures needed for response actions are well documented and are in place in India for Tier-1 level, techno managerial frame work for operational detection of severe oil slicks, and information dissemination through web sites, adequate contingency response plans are yet to take a proper shape for providing the Tier-3 or higher level oil slick purification services.

5. Proposed Techno-Managerial Framework

Oil slick observations from National or International space platforms have the capability to provide required input data for oil spill detection and characterization. Such Microwave imaging radars with multi polarization configurability have recently been found to be very useful in oil slick observations in all weather conditions and were demonstrated to map the area of Gulf of Mexico oil spill successfully. Space-borne SAR imagery can provide valuable information in monitoring and keep watch on the marine pollution problems and this was demonstrated by International agencies [17, 18, 19]. It is stated that satellites with Synthetic Aperture Radar (SAR) are the main data sources to detect the oil spills with sufficient accuracies using several methods [20]. Across the globe, there have been major initiatives in employing RS & GIS for oil spill detection and monitoring using SAR data.

The architecture of the proposed oil slick detection system involves the synergy of multifarious functions such as use of oceanographic physical parameters (prior to and post events), local meteorology parameters, the local marine water characteristics, atmosphere and surrounding sediments, advanced technologies like Hybrid prolarimetric images from RISAT, Remote Sensing images from Oceansat, GIS services from Bhuvan / NICES GeoPortals of ISRO, network communication services, INCOIS web portal, as well as individual software modules and tools that perform all necessary numerical calculations and reporting tasks related to the specific management of an oil spill emergency.

5.1 Advantage due to RISAT-1 & IRNSS

Though oil slicks are detectable from satellites, the discrimination between oil slicks and look alikes require more information and different approach. A new class of remote sensing satellite, different from the established Indian Remote Sensing (IRS) class, has been put into orbit by ISRO on 26-Apr-2012 onboard the PSLV launch vehicle [21]. It is designed for operations from a sun-synchronous orbit of 536 km altitude. RISAT-1 is having a multimode Synthetic Aperture Radar (SAR) as the sole payload which is aimed to cater primarily the oceanographic and agriculture sectors using C-band frequency (5.35 GHz) [21]. The Synthetic Aperture Radar (SAR) in RISAT-1 with its hybrid-polarimetric architecture transmitting circular polarization, and receiving in orthogonal linear polarizations along with their relative phase, provides this needed additional information to discriminate the look alikes. Oil slick image scenes acquired using RISAT-1 in MRS/FRS-1 mode at favorable look angles are processed to SLC level. Novel decomposition technique could be used in which the computed four Stokes parameters from SLC images are used to formulate m-chi and m-delta decompositions of the RISAT scene to discriminate oil spill and look alikes [22, 23]. RISAT-1 SAR images acquired in hybrid-polarimetric FRS-1 mode are found to be useful for oil spill detection and look alike segregation [24].

Existing oil spill detection methods have certain limitations. The main disadvantage is in the difficulty to distinguish between oil spill and look alikes which affects accuracy of oil spill detection. Additionally, feature extraction, involvement of human intervention, supervised classification techniques etc., make it difficult to implement automatic oil spill detection system. In order to overcome above limitations and to improve oil spill detection, research was done using hybrid polarimetric data of RISAT-1 and decomposition algorithms. The advantage of the decomposition algorithm based on polarization response, gives different colour combination for each object in the scene. This depends on the received polarization parameter responses due to permittivity (or dielectric constant), magnetic permeability, and conductivity of the target surface. Using this characteristic of decomposition algorithm, it is possible to directly detect oil spills and also distinguish oil spills from look alikes which further improves the accuracy of classification. In the hybrid polarimetric SAR image, polarization parameters will change depeding upon target object characteristics. The polarization parameter changes will be captured by the Stokes parameters and it will be used for decomposition methods. Since oil spill characteristics are different from lookalikes, it is possible to discriminate the oil spill and look alike based on decomposition methods. The proposed decomposition methods avoid the manual intervention for feature extraction used in many traditional SAR as well as earlier polarimetric SAR approaches for oil spill detection systems. It also has less computational complexity since it does not require any training process. Hence it simplifies the process of automating the oil spill detection system realized as a Geo Information System GIS.

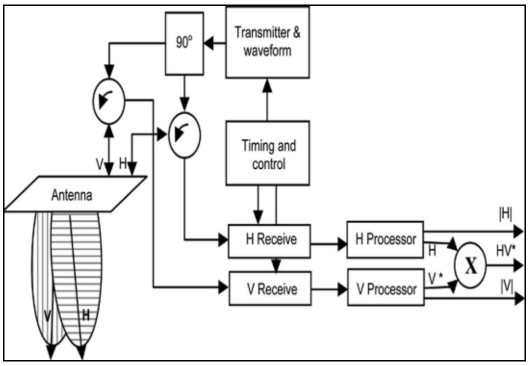

***Fig 9:** Hybrid polarity SAR architecture of RISAT -1 (First EO Spacecraft)*

After acquiring image from RISAT-1 in MRS/FRS-1 mode with circular transmission and linear reception, receive the Single Look Complex image of MRS/FRS-1 mode. Apply the decomposition algorithms on acquired MRS/FRS-1 images. Identify the Oil spill from look alikes using decomposition algorithm. If possible, supplementary information from other satellites can also be added. Tag the oil spill location with positional information of longitude and latitude in the image using image auxiliary data and IRNSS data. Based on the output of the system whether an oil spill is detected or not, information is conveyed to the end user about current status of the situation. The information also indicates the spread of the oil spill and other vital information. The results obtained by implementing the four decomposition methods on RISAT-1 oil slick and look alike images are analyzed for detecting the oil slicks and separating the look alikes spread out on the ocean surface. Parameters such as Orientation, Polarization angle, Relative Phase, Ellipticity and total polarized power parameters will be used for further recognizing and confirming the presence of oil slicks using microwave radar data. Initial identification RISAT-1 SAR images acquired in hybrid-polarimetric FRS-1 mode are found to be useful for oil spill detection and look alike segregation. India has a long coast line from Gujarat to Bengal and hundreds of ports. The increase in shipping also increases the risk of oil spills in our maritime zone. The availability of RISAT-1 SAR images and IRNSS enhances the scope to monitor oil spills, shipping routes, oil spill exploration structures and develop a GIS along with position information on NICES / Bhuvan which can be accessed by the users, such as ships, coast guard, environmentalists and oil spill response centers etc.,. However, due to the unpredictability of the disasters and high impact on the environment, they need to be monitored constantly. Such monitoring requires the availability of data on demand which calls for a constellation of multiple satellites. Currently, the services may not meet operational requirements in total due to such constraints. Still, there can be multiple solutions in terms of increasing number of Indian satellites and collaborating with international satellite operators / agencies providing complementary data. Additional resources in this context could also be deployment of UAVs. India has various optical remote sensing based operational earth observation satellite constellations in orbit.

5.2 Oil Spill monitoring Operational Input Data

For continuous monitoring of entire sea surface around India including the ship routes, foremost requirement is the acquisition of the data on oil slick area using Remote sensing satellites. The existing Oceansat satellites, Resource sat satellites, SARAL, RISAT satellites, MODIS, NOAA and similar available foreign satellites have the capabilities to observe the oil spill area with their onboard sensor. Quick Revisit by the satellites is needed to reliably detect the oil slicks by contiguous coverage of the sea surface. Image Data is processed to SLC level and archived into the BHUVAN GIS information system. Subsequently the Hybrid polarized image data will be subjected to decomposition methods. After identification and localization of oil slick, further value addition could be carried out for dissemination of information to various agencies concerned such as Central Pollution Control Board, Delhi & several Pollution Control boards at State level; Indian Coast Guard, MOD, New Delhi & the regional Coast Guards at Mumbai, Chennai and Port Blair. The availability of RISAT-1 SAR images and IRNSS enhances the scope to monitor oil spills, shipping routes, oil spill exploration. However, due to the unpredictability of the disasters and high impact on the environment, they need to be monitored constantly. Such monitoring needs the availability of data on demand which requires a constellation of multiple satellites. Currently, the services may not meet operational requirements in total due to such constraints. Still, there can be multiple solutions in terms of increasing number of Indian satellites and collaborating with international satellite operators / agencies providing complementary data.

5.3 Data Integration and Dissemination

Bhuvan is a Geoportal of ISRO, a platform to host various services including visualization, thematic map display, analysis, free data download, timely information on disaster and project specific GIS applications since August 2009 and is available in English, Hindi, Tamil and Telugu. Bhuvan is a gateway to explore and discover virtual earth in 2D and 3D space. Bhuvan is of vital use for planners, decision makers, social groups, village community and even to common man. Bhuvan is very high potential web based GIS and it's features are utilized by engineers, farmers, forest departments, environmentalists, ONGC, Coast Guards etc., Bhuvan platform can be utilized for providing information about oil spillage in the ocean. Geographic information systems (GIS) like BHUVAN has very high scope to significantly contribute to oil spill management which can be accessed by all the users, such as ships, coast guard, environmentalists etc., The oil spill exploration structures and their locations can be identified on BHUVAN along with all the shipping routes. The information from other satellite images can also be added to increase accuracy.

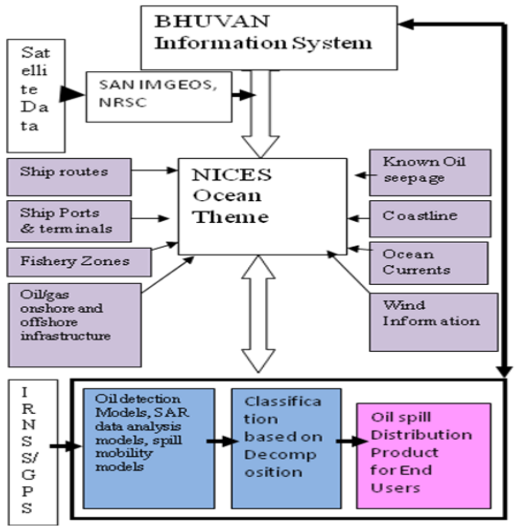

Figure 10: *Geo-information and NICES/ Bhuvan/ INCOIS information system approach to oil spill mapping based on SAR images*

This can be used to develop oil spill distribution maps in our maritime zone in Arabian Sea, Bay of Bengal and Indian Ocean. NICES aims to build an archive for climate and environmental data with access and visualization to various ministries, academia and research institutions in the country. Bhuvan/NICES, INCOIS, GPS/IRNSS, IRS / RISAT, MODIS and similar systems in integrated mode could derive the synergetic advantage of regular, monitoring and safe guarding the interests of ocean surfaces around Indian peninsula.

6. Conclusion

A Techno managerial frame work for oil spill management is presented. A new approach towards feasibility of an operational frame work for an integrated Oil Spill Detection & Management based on Optical Remote Sensing satellites, Microwave Radiometers, latest RISAT-1 Hybrid Polarimetric SAR and Polarization decomposition techniques with dissemination via BHUVAN / NICES, and INCOIS is proposed. Importance of such oil slick monitoring on operational basis is discussed in the context of surrounding choke points in the Indian Ocean. The approach of decomposition methods for oil spill detection based on Hybrid Polarimetric SAR images can aid in simplifying the oil spill detection and monitoring systems with reliability. GIS based approach also helps in Media Management and social outreach to assure the affected parties as well as to gather additional information through crowd sourcing. It can help various oil spill response centers across the nation and maintain the archival of such environmental disasters in the marine archives of India using ISRO’s Geo-portal BHUVAN’s services. The derived oil spill distribution maps can be hosted as part of National Information System for Climate and Environment Studies (NICES).

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