Synergistic Analysis on SSH, SST and Chlorophyll Concentration for Upwelling Region in Arabian Sea

* V.Ashok Subramanian[1],*A.Sethupathy[2],*R.Manikandan[3]

1. Department of Civil Engineering, Indira Institute of Engineering and Technology, India.

2. Department of Civil Engineering, Indira Institute of Engineering and Technology, India.

3. Department of Civil Engineering, Indira Institute of Engineering and Technology, India.

Abstract – Increase in sea surface temperature with global warming has an impact on coastal upwelling. Past two decades (1988 to 2007) of satellite observed sea surface temperatures and sea surface height anomaly provided an insight into the dynamics of coastal upwelling in the Arabian Sea, in the global warming scenario. The Arabian Sea is one of the least studied basins of the world ocean. The altimeter data has been viewed using BRAT software and sea surface temperature data has been converted to raster image using Marine Geospatial ecology Toolbox. These high resolution data products have shown inconsistent variability with a rapid rise in sea surface temperature between 1992 and 1998 and again from 2004 to 2007.

The upwelling regions derived from both sea surface temperature and sea surface height anomaly have shown that there is an increase in the intensity of upwelling during the period 1998 to 2007. A considerable drop in the intensity of upwelling was observed concurrent with these events. Apart from the impact of global warming on the upwelling, the present study also provides an insight into spatial variability of upwelling along the coast.

Index Terms – Upwelling, BRAT, inconsistent, variability, anomaly, concurrent, spatial

1. Introduction

Upwelling is an ascending motion for minimum duration, extend by which, water from subsurface layer is brought into the surface, removing the prevalent waters by horizontal flow. Vertical motions are integral part of ocean circulation, but they are quite insignificant when comparing to horizontal currents. As the temperature decreases and the density increases with depth more energy is required to displace water vertically upwards. Hence, vertical motions are normally inhibited by the density stratification of the ocean. The ocean is also stratified with other properties; for example, nutrient concentration generally increases with depth. Thus, even a weak vertical flow may cause significant effect on biological production due to the advection of

nutrients.

Upwelling regions are therefore, significant for very high levels of primary production in comparison to other areas of the ocean. Approximately 25% of the total global marine fish catches are reported to come from five upwelling systems that occupy only 5% of the total ocean area. Upwelling driven by coastal currents or diverging open ocean currents has the greatest impact on the nutrient enrichment and global fishery yields

The only variable approach to surface circulation of the global ocean with sufficient resolution and consistent sampling is the use of a satellite radar altimeter to measure the height of the sea surface. Satellite altimeter missions such as TOPEX/Poseidon (launched August 1992) and Jason-1(launched December 2001) measure SSH to an accuracy of a few centimeters. These satellites were specifically designed to measure SSH to height possible accuracy.

2. Materials and Methods

The spatial structure and the variability of upwelling were examined by using Sea surface height anomalies data of TOPEX/Poseidon, ERS1/2, Envisat, Jason-1 and Ocean Surface Topography Mission (OSTM)/Jason-2 satellites obtained from PO.DACC website and Sea surface temperature data.

- From October 1995 to August 2002 : TOPEX/Poseidon + ERS-1 or ERS-2
- From August 2002 to June 2003: Jason-1 + ERS-2. Topex Poseidon was replaced by Jason-1 in August 2003 after its orbit change.
- From June 2003 to January 2004: Jason-1 + Envisat. ERS-2 was no longer used since the loss of its Low Bit Recorder (LBR) in June 2003.
- From January 1985 to December 2008 AVHRR pathfinder Sea Surface Temperature (SST) data.

The methodology followed is shown in the Figure 1.

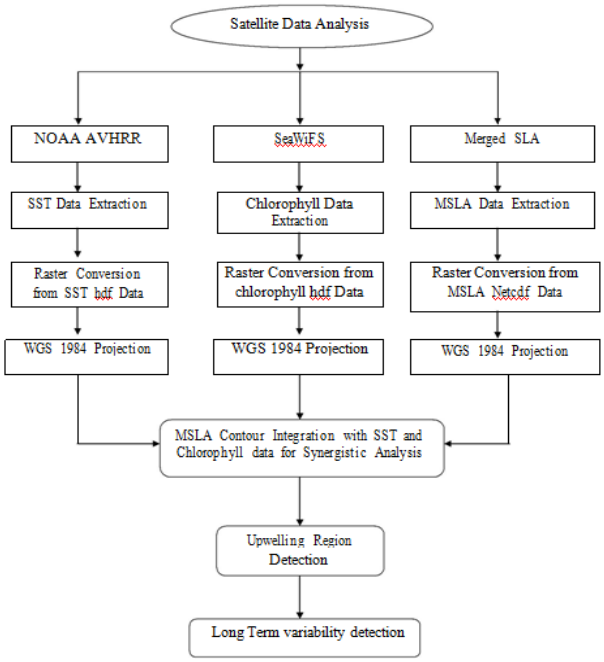

Fig 1: Flowchart for Methodology

3. Results and Discussion

3.1 SST Raster Image from AVHRR Data

The AVHRR data for Sea Surface Temperature has been downloaded in the raw .hdf format. In order to perform the analysis using SST image it has to be converted in to raster. The SST data was converted in to raster using Marine Geospatial Ecology Tool in ArcGIS. The SST raster was obtained for the whole world it has to be clipped to the study area. Clipping tool was used to clip the study area. Then the raster was clipped to the study region by land mask file using the clipping tool in ArcGIS. The raster is classified in to 15 classes to identify the SST variations in the study region. The colored SST image was shown in the Figure 2.

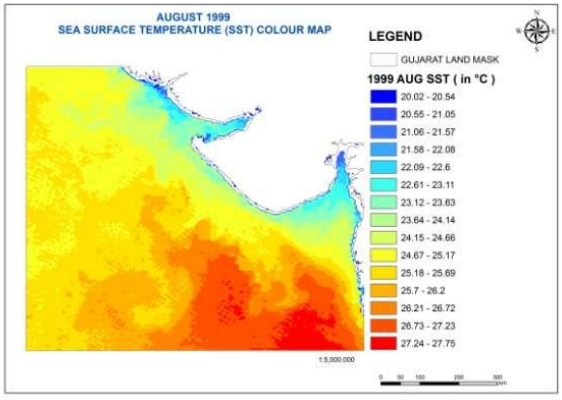

Fig 2: Sea Surface Temperature Color Image

3.2 SLA image from merged sea level anomaly data

The Sea Level Anomaly data that has been downloaded from the AVISO site is in the Netcdf format. It has to be converted initially into ASCII file format using BRAT software. The obtained SLA data in ASCII format has to be converted into raster format to facilitate processing of the data with SST and chlorophyll images in ArcGIS.

The desired raster format can be obtained by first converting the ASCII format data into shape file in ArcGIS. The obtained shape file is finally converted into raster format by using kriging tool. The desired study area was then clipped using clipping tool. The MSLA colour image thus obtained in raster format was classified into fifteen classes. The classified MSLA colour image is shown in the Figure 3.

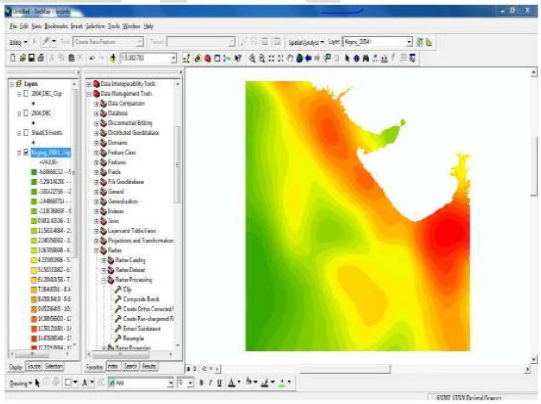

Fig 3: Sea Level Anomaly Color Image

3.3 MSLA contour generation

Contours were generated for the above obtained MSLA raster image by using contour generation tool in ArcGIS. The contour interval that has been specified

for this purpose is 0.5cm. The generated contour for MSLA colour image is overlaid with the corresponding MSLA image as shown in the Figure 4. This is for the purpose of facilitating the overlay of the generated MSLA contour image with SST image and chlorophyll image separately.

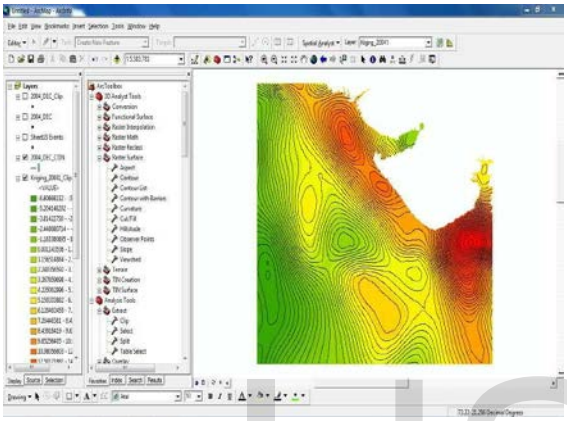

Fig 4: MSLA Contour overlaid with MSLA color image

3.4 Chlorophyll raster image from SEAWIFS data

The SeaWiFS data for Chlorophyll has been downloaded in the raw.hdf format. In order to perform the analysis using Chlorophyll image it has to be converted in to raster. The Chlorophyll data was converted in to raster using Marine Geospatial Ecology Tool in ArcGIS. The Chlorophyll raster was obtained for the whole world, it has to be clipped to the study area. Clipping tool was used to clip the study area. Then the raster was clipped to the study region by land mask file using the clipping tool in ArcGIS. The raster is classified in to 15 classes to identify the Chlorophyll concentration variations in the study region. The colored Chlorophyll image was shown in the Figure 5.

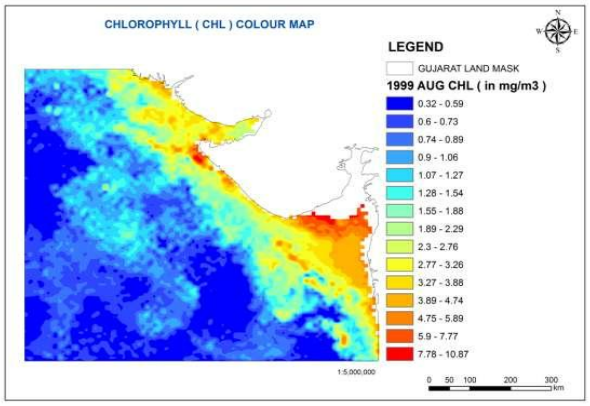

Fig 5: Chlorophyll Concentration Color Image

3.5 Upwelling region detection and long term variability analysis

The upwelling region has been detected from the MSLA contours for each of the year mentioned above. This upwelling region from the MSLA data is compared with the SST data and chlorophyll data for the corresponding years and analysis is performed. As per the above conducted study, it is found that the upwelling regions found in the SST data coincide with the corresponding year's upwelling regions found in the chlorophyll data.

In the detected upwelling region, the Sea Level Anomaly for the year 1998 was found to be varying from -18 cm

to -10 cm as shown in the below figure . Similarly, the corresponding upwelling regions in the SST data for the year 1998 was found to be varying from 22.5 °C to 25 °C as shown in the below figure. This can be validated through the chlorophyll image for the corresponding year, whose concentration was found to be varying from 2.5 mg/m^3 to 4.3 mg/m^3 as shown in the Figure 6.

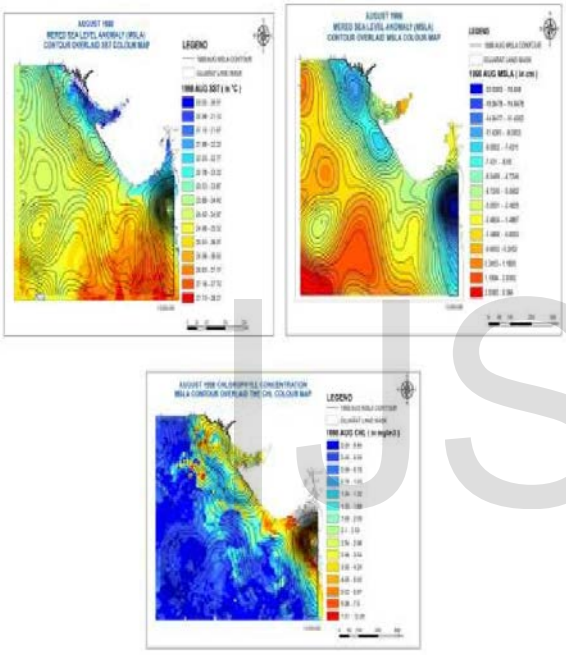

Fig 6: Upwelling region in MSLA and SST validated with chlorophyll during the year 1998

In the detected upwelling region, the Sea Level Anomaly for the year 2007 was found to be varying from -19 cm to -11 cm as shown in the below figure. Similarly, the corresponding upwelling regions in the SST data for the year 2007 was found to be varying from 22°C to 25°C as shown in the below figure. This can be validated through the chlorophyll image for the corresponding year, whose concentration was found to be varying from 2.8 mg/m^3 to 4.9 mg/m^3 as shown in the Figure 7.

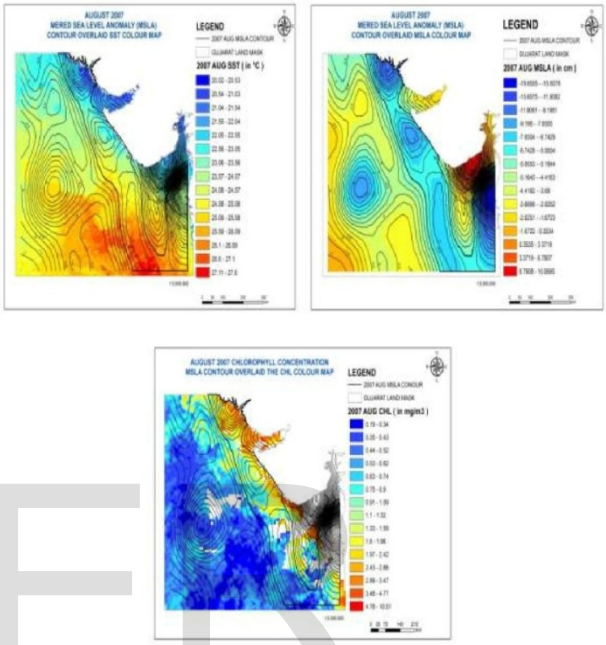

Fig 7: Upwelling region in MSLA and SST validated with chlorophyll during the year 2007

4. Conclusion

The upwelling region detection has been carried out using the MSLA and SST data for the Gujarat coat region in Arabian Sea. Using the ten years (1998-2007) of merged altimetry data, from different missions (TOPEX/Poseidon, ERS1/2, Jason-1 and Envisat) and AVHRR data, upwelling region has been studied for the Gujarat coast region in Arabian Sea. This stud uses synergetic analysis technique

for detecting the upwelling region in the study area. Mainly the upwelling region is occurred during august, mid of the southwest monsoon season over the ten years.

In the upwelling region SLA varies from -24 cm to -10 cm and SST varies from 22 °C to 26 °C. The detected upwelling regions were validated through chlorophyll concentration. From the analysis that has been done, the Sea Level Anomaly is found to be directly correlated with Sea Surface Temperature and negatively correlated with Chlorophyll content. This infers that Sea Surface Temperature is negatively correlated with Chlorophyll content.

Acknowledgements

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