An Online Tool for Predicting the Trajectory of the Spilled Marine Pollutant

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***Abstract* - An online oil spill advisory(OOSA) system was developed for the first time in India, at Indian National Centre for Ocean Information Services (INCOIS) to serve the coastal community, regulatory authority and oil spill responders. It is achieved by triggering the oil spill trajectory model through web-interface. OOSA receives the inputs from the users in html feeds. Once after the submission of inputs, it automatically triggers the oil spill trajectory model and delivers the drift pattern of the pollutant at regular intervals, without the support from modeling community or officials of INCOIS. It is completely an automated set up. The system comprised the diagnostic mode of General National Oceanic and Atmospheric Administration (NOAA) Operational Modeling Environment(GNOME) in batch, which is triggered through web interface with the details such as, location, date & time of the spill, quantity, type of the oil spilled. The forecasted wind forcing and the current forcing obtained from our ocean state forecast(OSF)laboratory, were tuned and set in the prescribed format on daily operational basis. The generated trajectory is layered automatically on a webmap, so that the zones that are likely to get affected are known. Trajectory predictions were made online for the oil spill occured at Sundarbans delta during 09.12.2014 to 15.12.2014. The oil slicks were noticed within 1.3 km from the predicted locations. This paper explains the simulation of an oil spill trajectory model for getting the drift pattern of the pollutant at sundarbans delta, through web interface. The method of interpreting the results are also explained. This OOSA system is made available online, so that the users can utilize this during oil spills, mock drills and for preparing the local contingency plans. This system will also guide the oil spill responders, to manage and plan the response activities during the event of an actual or a hypothetical oil spill.**

***Keywords* - GNOME, Modeling, oil spill trajectory, web user interface, validation, online.**

I. INTRODUCTION

Indian coastline is sensitive to oil spills, due to various natural and man -made causes. Indian coast is well known for its marine biodiversity. More than 13,000 species were found from the synthesis [1]. The significance of coral reefs is vital in treatment of human illnesses and in surgical interventions [2]. Higher concentration of Bombay high crude oil will impact the growth, protein and nucleic acid content of the phytoplanktons [3].The assessment of the nature and distribution of the poly aromatic hydrocarbons after an oil spill is necessary in oil spill management [4].In order to prevent the impact of oil spills on the ecosystem and on the aquatic organisms, an oil spill trajectory prediction system is required. After validating several case studies, Indian National Centre for Ocean Information Services (INCOIS) have developed & launched an experimental set up of Online Oil Spill Advisory(OOSA) System during May 2014, for issuing the oil spill advisory to the coastal community, regulatory authority and the spill responders. In the event of oil spills, the direction and movement of the oil or pollutant will be predicted in advance in this system and the advisory will be made available to the users. The clean up and control measures will be planned and carried out accordingly. Offline simulation for the Mumbai oil spills, using an oil spill trajectory model, General National Oceanic and Atmospheric Administration (NOAA) Operational Modeling Environment(GNOME) and its validation were carried out and explained [5]. Eventhough publications, citations are rare, as far as web based oil spill trajectory forecast systems are concerned, few organizations such as Applied Science Associates, Met ocean solutions Ltd, have experimented such web based forecasts for Ireland and New Zealand respectively. In this paper, the methodology adopted to do online prediction of the drifted Furnace oil at Sundarban delta is explained. The method of interpreting the outputs in open -layers is also explained.

II. ONLINE OIL SPILL ADVISORY(OOSA) SYSTEM

A. Need for the online simulation

Once after obtaining the necessary information about the oil spilled, it is required to feed the spatially varying met-ocean parameters such as forecasted wind and ocean currents as per the prescribed format of the trajectory model, GNOME. It is typically difficult for the coastal community, regulatory authority to feed such spatially varying Met-Ocean parameters and to run a local model during an emergency response, especially, soon after an oil spill. Considering the benefit towards the oil spill responders, it was decided to develop an online tool for decision support. Spatially varying met ocean parameters were tuned as per the format of the trajectory model and made available in server for the model run. Now, the user can trigger the trajectory model at any time, without the support of the modeling community, through the web interface, which can deliver them the predicted trajectory or the drift pattern.

B. Details of the OOSA system

The online execution is experimented with the diagnostic mode of GNOME. The difference exists between diagnostic mode and other modes [6]. A web interface is used to get the user inputs on the details of the spill with which the user can directly run the trajectory model. Once after submitting the request, the trajectory model will run on INCOIS server and a report will be generated based on the inputs. If error exists, then those have to be rectified by the user. An user manual is enclosed in the webpage for guiding the users in feeding the inputs. The batch version of GNOME will run in the background by taking the inputs fed by the user through web interface. The major processes involved in predicting the trajectory of spilled oil are advection, spreading and diffusion turbulence. The oil movement can be estimated as the vector sum of the wind speed, current speed and diffusion turbulence. The resultant of this forcings at each and every time step gives the oil drift and direction in which the oil parcels move. GNOME uses three phase algorithm, in which the pollutant is treated as three component substance with independent half lives[7]. This system will do the trajectory prediction for two types of spills: (i) Continuous spills, are those spills, in which the pollutant will be released continuously from source at a point location for a period of time. spills resulting from vessel collision are said to be continuous. (ii)Instantaneous spills, are those, in which the entire mass of the pollutant will be released instantly (from source). It is an onetime release such as, dumping the pollutant in sea or dumping of rice husks during mock drills. This OOSA system delivers two formats of outputs: (i) Movement of the trajectory in animation (video) with respect to time. The user can also make the time wise movement of the spill that can be forwarded/reversed with the help of the radio buttons of the video file. (ii) Trajectory positions at regular intervals are obtained through open layers webmap. Overlays of best estimate and regret estimates will be layered. Open layers is a pure JavaScript library for displaying map data in most modern web browsers, with no server-side dependencies. Open Layers implements JavaScript for building rich web-based geographic applications, similar to the Google Maps and MSN Virtual Earth APIs. With the help of webmap services it is easy to share the trajectory of the spill spatially, over web. Using open layers, the drift of the oil will be displayed in web map as layers. The user can view the drift of the predicted trajectory with respect to time. The layout of OOSA system is shown (Fig. 1**)**. The layout explains the flow starting from the user inputs. The inputs are received through the feed form. The submission will trigger the batch version of GNOME. The forcings parameters of the respective dates will be taken from the INCOIS server automatically and the trajectory will be generated in video animation and Webmap format. The users can view the respective links to download the trajectory.

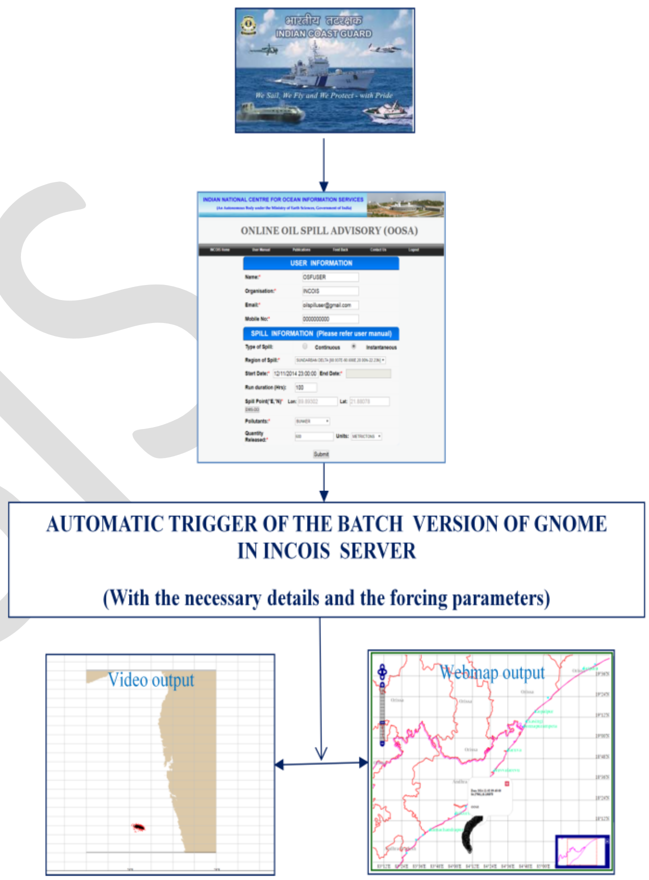


Fig. 1 Layout of OOSA showing the input submission and the generated outputs

III. REQUIREMENTS FOR ONLINE TRAJECTORY PREDICTION

Information on the spilled oil such as its type, quantity, time of occurrence and the geographic location have to be fed by user through web interface. Wind drifts are obtained from European Centre for Medium- range Weather Forecasts (ECMWF).The model derived fields from ECMWF are compared and validated with I-RAWS and in situ data. The Root Mean Square Error (RMSE) was found to be 2.5 m/s [8]. OOSA set up considers the wind drift, ranging from 1-4%. This factor is considered, as it can simulate the drift of objects with greater wind effects like drifting ships, floating debris etc., Current pattern is obtained from Regional Ocean Modeling System (ROMS) of INCOIS. Both the wind and current forcings are made to the unique resolution of 3km x 3km and fed into the server on daily basis. INCOIS has set up a state-of-the-art ocean general circulation model that issues six-hourly forecasts of the sea-surface currents up to five-days of lead time. The surface current predictions were fairly accurate at almost all the locations [9]. The spilled oil in water is subjected to turbulence due to bulk movement of water. This will split the oil slicks into smaller patches that are distributed over a wider area. The diffusion will occur in the horizontal direction. The horizontal diffusion of the ocean surface water ranges from 100 to 10,00,000 cm^2/s [7]. Uncertainty is associated with each forcing parameter. In the current movers, the uncertainty of down current and cross current is assumed to be 10%. For the wind movers, the uncertainty is assumed to be 2 for the speed scale and 0.4 radians for the angle scale [7]. The uncertainty will exist for the user specified duration. This can also be modified. OOSA uses these data, to run 1,000 splots. Each splot is considered as a lagrangian element. The trajectories of these uncertainty splots will map the domain for the spill trajectory with uncertainty, which is said to be the minimum regret solution.

IV.REQUIREMENTS FOR VALIDATING THE PREDICTED SPILL TRAJECTORY

Spill trajectories obtained from the trajectory model is compared with either observed oil spill signatures from the satellite imagery or from the report of observation provided by the observer. The availability of the satellite pass favours the comparison. The limitations of the optical sensors have overcome by the radar sensors. Radar sensors are capable of viewing the sea surface in all weather conditions. Air borne and space borne radar sensors are widely used in oil spill surveillance [10]. Envisat from European space agency and Radarsat from Canadian space agency were found to be appropriate for oil spill detection [11]. Wind speed in the range of 3-10m/s is favourable for oil spill detection [12]. Oil spills can be discriminated from the look alikes by its homogenity,contrast and dissimilarities [13]. Selection of the optimal classifiers and configuring them with feature construction techniques plays a vital role in Radarsat data processing [14]. In addition to this, the observation reports are also obtained from the regulatory authorities during the oil spill events.

V. DETAILS OF THE SUNDARBAN OIL SPILL

The Location map of spill is shown (Fig. 2)

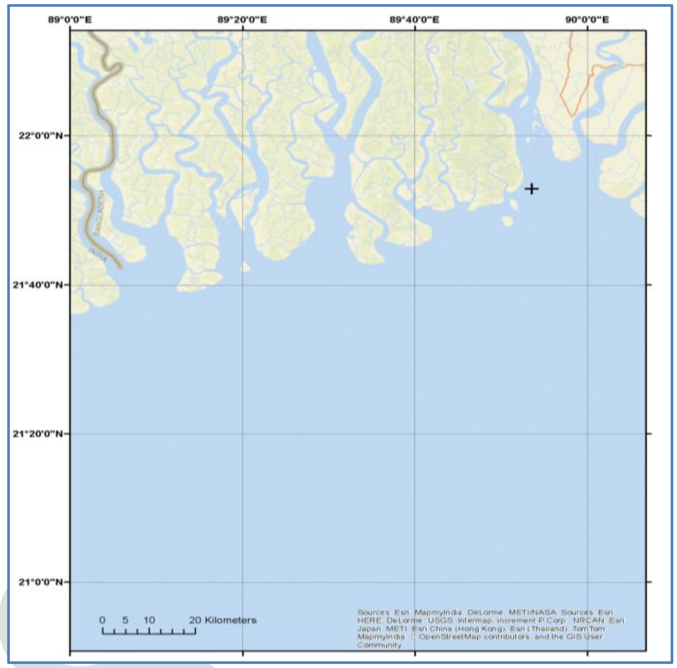


Fig. 2 Location map of Sundarban oil spill. (+) symbol denotes the location of the oil spill on 11.12.2014,23.00 hrs

OT Southern Star 7 was anchored in Sela river at 22.355614° N, 89.672696° E, which was struck behind by another vessel on 09.12.2014, 05.00 hrs.The spilled Furnace oil has covered the upstream and entered Pasur river. On 11.12.2014, 23.00 hrs, spill signatures were noticed near sundarbans delta, which is the northern bay of Bengal. With respect to the Landsat data on 11.12.2014,23.00 hrs, it was suspected to reach the river mouth of Sundarban delta at 89.89302° E, 21.88078° N [15]. A quantity of 240 Metric Tons, was spilled. Bunker type pollutant is considered, as furnace oil belongs to such category.

VI. ONLINE EXECUTION - SUNDARBAN OIL SPILL TRAJECTORY PREDICTION

A.Model execution (on 11.12.2014, 23.00 hrs)

The details of the spill were fed into the system through web interface and submitted for the execution. The layout that has received the inputs from the user is shown (Fig 3). It displays the input fed by the user. The details of the registered user can be found from the user information section. Before feeding the spill information, the users are requested to refer the manual. After selecting the type of spill, the region was selected. In this case Sundarban delta was selected. Then the start date & time of the spill with run duration was fed, followed by the location and the type of pollutant with its quantity. Once after the submission, the system has validated the inputs for error and triggered the batch version. The batch version of the trajectory model GNOME was triggered from the river mouth location (89.89302° E, 21.88078° N) at 11.12.2014, 23.00 hrs for a duration of 100 hrs. The trajectory is generated from the river mouth of the Sundarban delta by assuming the spill type as instantaneous. The execution was completed successfully without any error and the output is ready to download. The status of the model run is shown (Fig. 4). The report on the model run has the spill type, start date & time, the geographical location of the spill, pollutant and the quantity released and the duration of the trajectory prediction fed by the user. It also delivers the message of successful execution with respective links to download and view the trajectory. By clicking on the respective links, user can view the predicted trajectory.

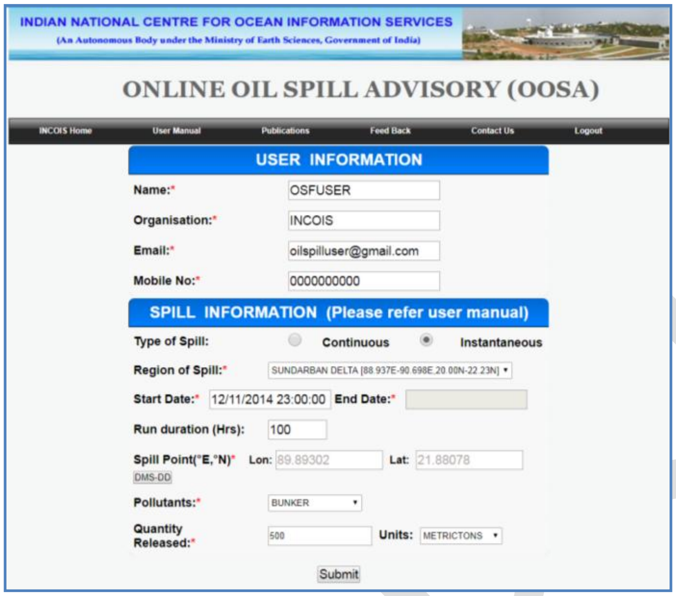
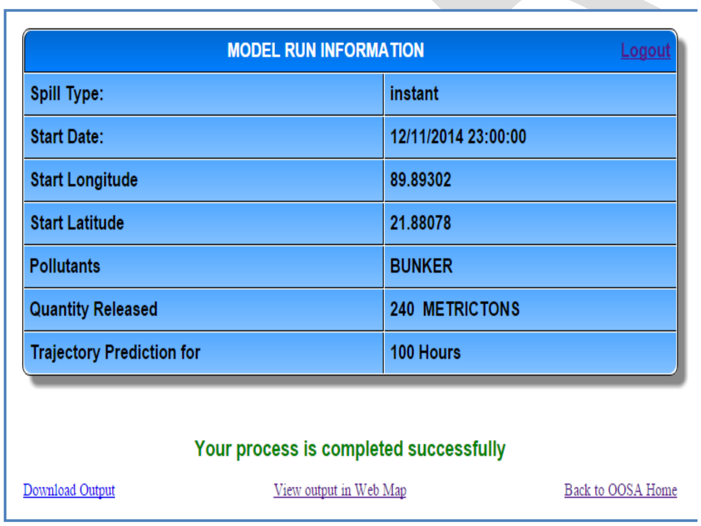


Fig. 3 Layout of the interface for Sundarban oil spill.



MODEL RUN INFORMATION	Logout
Spill Type:	instant
Start Date:	12/11/2014 23:00:00
Start Longitude	89.89302
Start Latitude	21.88078
Pollutants	BUNKER
Quantity Released	240 METRICTONS
Trajectory Prediction for	100 Hours

Your process is completed successfully

Download Output | View output in Web Map | Back to OOSA Home

Fig. 4 Status of the model run.

B. Met-Ocean conditions

The rose plot of the wind & current forcings in the spill location are shown (Fig. 5-6). At the spill location, the predominant wind speed was in the range 4.2m/s to 5.6m/s from North.Current pattern was found predominantly towards NorthWest ranged in between 0.04 m/s to 0.08 m/s.The resultant trajectory movement was found to move southwest wards and finally southwards.

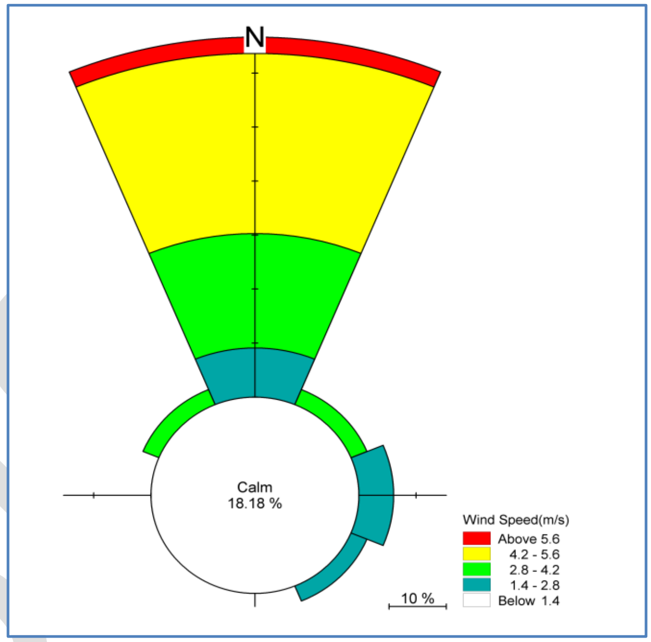


Fig. 5 Wind rose at the spill location.

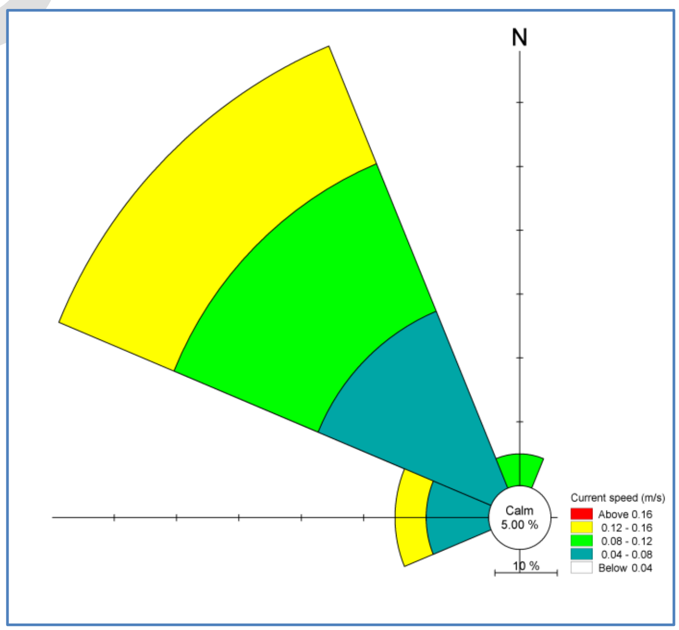


Fig. 6 Current rose at the spill location.

C. Output Interpretation

The delivered trajectory is superimposed on the webmap open layers. The layers of the best estimate and the uncertainty can be enabled for the required time. In this case, the layers of 3hourly output is stacked. Best estimates are obtained assuming that the input forcing was accurate. The regret estimates are obtained by giving 10% uncertainty in the input forcings. The status of each particle is computed at every time step and displays only, if the splot floats or beaches. The evaporated particle will not be displayed in the webGIS map. In this case, all the splots were floating. The splots indicate the movement of the trajectory at the time. The splots of best estimate are shown in black color and the red splots are obtained from regret estimate. The snapshots of the obtained drifts are shown (Fig. 7-8). In Fig 7, the plus symbol encircled is the spill location from which the trajectory is generated. The black splots of best estimate denotes, the predicted movement or the drift of the pollutant(furnace oil), on 15.12.2014,17.00 hrs. The enabled or ticked layer of 90th hour in the best estimate, can also be noticed. In Fig 8, the plus symbol encircled is the spill location from which the trajectory is generated. The red splots of uncertainty estimate denotes, the predicted movement or the drift of the pollutant (furnace oil) on 15.12.2014,17.00 hrs. The enabled or ticked layer of 90th hour in the uncertainty estimate, can be noticed. The pop-up (by click) on the splots will intimate the date, time and geographical location. Apart from this Webmap representation of output, a video format of the animated trajectory can also be viewed as explained in the layout of OOSA system. For the purpose of illustration and interpretation, webmap output is considered.

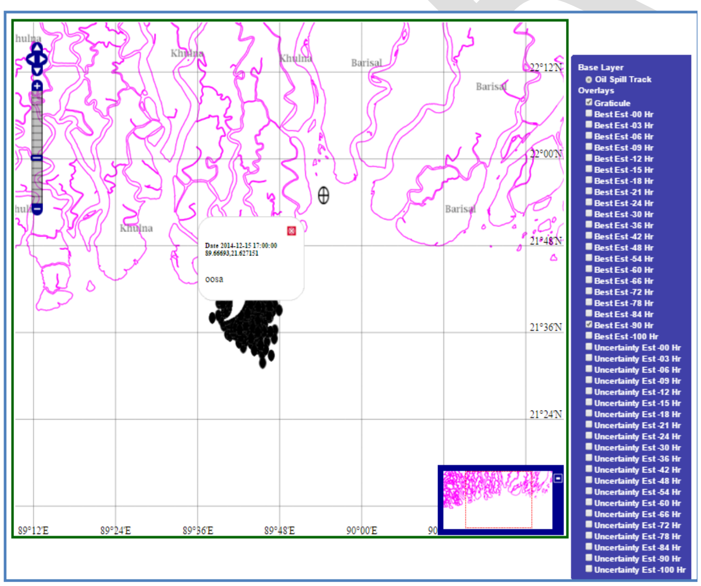


Fig. 7 Trajectory of the best estimate during 90th hr,15-12.2014,17.00 hrs.

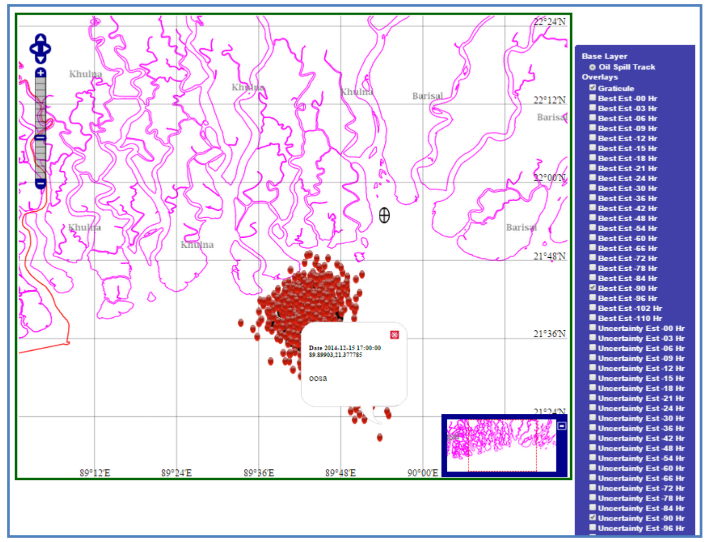


Fig. 8 Trajectory of the regret estimate during 90th hr, 15-12.2014, 17.00 hrs.

VII COMPARING THE PREDICTED DRIFT WITH OBSERVATION

The information on the updates of Bangladesh oil spill pertaining to the observed oil slick signatures on 15.12.2017,17.00 hrs in radar datasets were obtained from National Remote Sensing Centre, Hyderabad. The positions of the predicted trajectory and the observed oil slicks during 15.12.2014, 17.00 hrs, were plotted in the ArcMap as shown (Fig. 9). (.) denotes the floating splots. Black splots are obtained from best estimate, Red splots are obtained from Regret estimate. Blue circle shows the location of the observed oil slicks. The observed oil slicks were found within 1.3 km from the predicted best estimate trajectory, but the trajectory of regret estimate was well in agreement, i.e. it contained the spill signature within its predicted range.

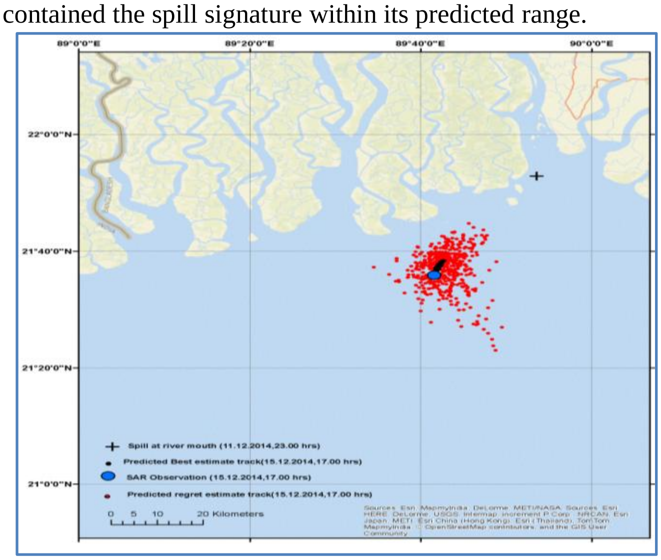


Fig. 9 Sundarbans oil spill _ comparison between the prediction and observation

VIII. CONCLUSIONS

An experimental execution of spill trajectory model through web interface was made for Sundarbans oil spill. The trajectory obtained was automatically superimposed in the open layers webmap. The comparison on the predicted drift locations of the pollutant and the locations of observed oil slicks were made. The oil slick were noticed within the distance of 1.3 km from the best estimate trajectory prediction. However the regret estimates were well within the agreement, thereby indicating the likely areas to get affected. So the users were advised to consider both the estimates before making a decision. The batch version of OOSA computes the evaporation with a rudimentary three phase algorithm. Several case studies were executed in offline mode for estimating the performance of OOSA system. The results were encouraging. Hence the system is operationalised made available for the coastal community and regulatory authority. The same system can be used for preparing the contingency plan, mock drill exercises, oil spill response operations. The future scope includes the execution of multiple spill scenarios, plume dispersion and detailed weathering impact. The system is made available at http://www.incois.gov.in/portal/osf/oosa.jsp.

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