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Oil spill trajectory forecast with the aid of gnome

J.R. Rajapriyadharshini* **and K. Sudaliamani**
Thiagarajar College of Engineering, Madurai, TN – 625015, India
rajapiryadharshinir@gmail.com

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Abstract

Oil spills have the potential to cause serious harm to the marine environment in which they occur. They are capable of causing widespread economic and environmental damage. An examination into the dangers of oil slicks in a region and the techniques that can be taken to maintain a strategic distance from, or on the off chance that they happen, battle the spill would be important in limiting the degree to which oil can obliterate a biological system. The GNOME might be tedious and defenseless to client input errors which are burdens for crisis response. Oil slick reaction systems must be quick, solid and exact. Guaranteeing the accessibility of such forecast requires skill in model input sources and yields, data formats for multiple models and the GNOME interface. This study builds up a robotized way to deal with coupling after effects of the hydrodynamic model MIKE21 to GNOME. This is a numerical report that quantitatively and subjectively characterizes the development of oil spill amid spill. The 2010 Mumbai oil spill is taken for this investigation. Oil spill trajectories are anticipated by contributing wind and water ebb and flow constrains on an underlying spill in a committed spill trajectory model (say GNOME model). The wave currents are obtained by simulation of flow model in MIKE21 and the wind data from ASCAT. Both the wave currents and wind are converted into the GNOME file format using MATLAB and these outcomes should then be coupled with GNOME. At long last, mapping of the influenced locale is finished utilizing ArcGIS. The validation of the model shows that if the contributions to the model were given with high accuracy, at that point the yield will likewise be acquired with high precision.

Keywords: Trajectory model, GNOME, Simulation, ADIOS, Flow model, Particle tracking.

Introduction

India involves a significant part of South Asian subcontinent and the Indian territory extends eastbound from Pakistan in the west to Bangladesh and Burma in the east. Length of coastline of India including the coastlines of all Islands in the Bay of Bengal and the Arabian Sea is 7517 km. The long drift line of India is spotted with a few noteworthy ports, for example, Kandla, Mumbai, Navasheva, Mangalore, Cochin, Chennai, Tuticorin, Vishakapatnam and Paradip. Every year, 568,000 tons of oil enters the marine condition because of shipping. Substantial quantities of related research on dispersion, spread and stretch out of oil spill have already been carried out. It was closed to broaden recipe considering the part of dissemination, spread and decay[1] and furthermore estimating the relationship between oil, water and wave. The hydrodynamic modeling forms the base for oil spill mathematical model which in turn is connected to real ventures[2].

The oil spill is the release of liquid petroleum hydrocarbon into the sea (say ship collision). Oil enters the marine condition from multiple points of view viz., refinery outflow, dispatch cleaning operations, coincidental spills and so on. Oil slicks regularly result in both quick and long haul natural harm. A portion of the natural harm caused by an oil slick can keep going for a considerable length of time after the spill happens. The oil spill hazard is measured by the scale of harms caused by amount of oil, density and type of oil, area of the spill, the biotic life in the spilled zone, the breeding cycles and occasional relocations and also the climatic adrift amid after the spill. Be that as it may, one thing which never changes is that oil spills are always terrible news for the nature.

Oil spill models: Oil spill modeling is on a awfully basic 3 – organized methods. The primary stage is computer input file preparation, the second stage is hydrodynamic modeling, and the third stage is spill flight modeling[3]. Computer input file preparation needs distinctive all the operational parameters of the two models, as well as the model space and matrices, tidal flow conditions, inflows, wind/rain and alternative weather information and initial hydrodynamic conditions[4]. The hydrodynamic model is answerable of predicting the currents supported the forcings from the computer input file, whereas the spill trajectory model is answerable for applying these anticipated ebb and flows and additionally another pertinent forcings simulate the oil particles' fate and transport. An extensive range of oil slick models are being used on the earth nowadays.

These ranges in ability from simple trajectory, or particle – chase models, to three-dimensional flight and fate models that incorporate simulation of response actions and estimation of biological impacts. A major range of those models and their synopses are said.

The SPILOR model is created out of some sub-models[5] like behavior of oil spill portrayed by a temperature change – diffusion equation with processes of floating, sinking, entrainment, emulsification, evaporation and biodegradation. Bond's equation is employed for floating process and Stoke's formula for sinking process. The conditions are fathomed by utilizing finite difference methodology[6]. SELFE may be a semi – implicit eulerian lagrangian finite-element model. It is a 3-dimensional horizontally unstructured grid matrix with hybrid S-Z vertical coordinates.

It utilizes the Generic Length Scale turbulence closure models and this mathematics blends turbulent wind energy through the free surface. Testing of this wind forcing rule against already existing rule determined that the foremost large impacts are seen on the surface currents[7], the most significant current to oil spill trajectory modeling.

DMI had run an operational oil drift forecasting service for the North Sea – Baltic Sea. Later it's been reached out by utilization of an oil drift and fate model (DMOD), additionally to passive temperature change, reenacts varied compound procedures altogether named 'oil weathering'. The model applies surface winds and three – dimensional ocean motion (horizontal and vertical current) so as to calculate drift and spreading of the oil. SIMAP, a programming application created by Applied Science Associates (ASA) Inc., which estimates physical and biological effects due to oil spill, in 3-dimension.

The model outputs are then imported to a topographical data framework (GIS) that contains environmental and biological data and then they are overlayed to a model that contains physical – chemical properties and biological plenitude. In practice, the foremost common forcings applied by the oil spill model are currents, winds, diffusion and weathering / decay[1]. One outstanding case is GNOME, an oil spill model which has an amazing visualization process[1]. GNOME is the trajectory model used throughout this work.

Study area: Oil spill modeling research has been as of now in advance for Kandla and Mandla port by NIO, Goa. This part incorporates the outline characteristics of Mumbai territory around Jawaharlal Port Trust. Mumbai, India's most populous city is located on Salsette Island off the coast of Maharashtra. In the 18th century, the seven islands were consolidated to shape one vast Salsette island. Back Bay is the largest bay in the city. Nhava Sheva, located south of Mumbai, the Port on the Arabian Sea is accessed via Thane creek.

The Port spreads more than 10 square kilometer and was developed to relieve pressure on Mumbai Port. The geographical coordinates of Nhava Sheva is 18º57'N 72º57'E. Mumbai has numerous creeks with near 71 square kilometer of creek and mangroves along its coastline. The Vasai creek toward the north and Thane creek toward the east isolates Salsette Island from the terrain.

The study area has mudflats and a mix of mangroves and support coastal biodiversity. Vulnerability assessment[8] suggests that a heap of stresses like Mumbai's flat topography, geography, wetlands and floor prone areas, projected sea-level rise, poor sanitation creates high probability of vulnerability for the city. It has a tropical atmosphere, particularly tropical wet and dry climate, with seven months of dryness and pinnacle of downpours in July. The investigation range is inclined to cyclones and gusty winds.

Considering the hydrodynamic regimes, Shamal (hot and dry, dusty wind from the north or northwest in Iraq, Iran and the Arabian Peninsula) winds typically occur in the Arabian Peninsula amid winter and summer. The onset, duration and strength of shamal wind differ contingent upon the dynamic interaction of upper air jet streams and distribution of lower tropospheric pressure zones[9]. Variations in swell statures related with shamal occasions demonstrate that Kochi, Mangalore, Goa, Ratnagiri, Mumbai and Dwarka along the west shoreline of India are impacted by shamal swells, however there are changes in patterns and statures as indicated by the fore and length of the occasion[10]. The shamal swell effects high degree on the Gujarat coast and Mumbai coast stands second. The seaside currents around India alter direction with season[11].

Methodology

GNOME, version 1.3.5, is an explicit oil spill simulation system intended for the quick modeling of oil particle tracking in the sea condition. The GNOME might be time consuming and susceptible to user input error, which are impediments for crisis response. Oil spill response techniques must be fast and based on reliable and accurate forecasts to keep spills from reaching ecologically sensitive shorelines. Guaranteeing the accessibility of such forecasts requires someone whose primary job is to be conversant in model inputs and outputs, data formats for multiple models, and the GNOME interface. This investigation builds up a computerized way to deal with coupling aftereffects of the hydrodynamic model MIKE21 to GNOME.

The overall design is that of modular and integrated software. GNOME model output will be in the format of data files and graphics for post-processing in a secondary platform, say geographical information system (GIS) tool or can also be processed by GNOME analyst tool which is in-built in NOAA Emergency Response Division. GNOME model is built-up in C++ platform which make is easier to update and improve in future. GNOME is an Eulerian / Lagrangian two-dimensional model (2D) for solving trajectory problems. The accuracy of the model output depends on the data used for calculation of trajectory problem and the physical processes which are modeled. The grid and the boundary conditions are based on Eulerian approach whereas the particle tracking was based on Lagrangian approach. The shoreline maps prepared using GIS tool shall be given as area that is modeled. The model by default detects the coordinate system of mapping.

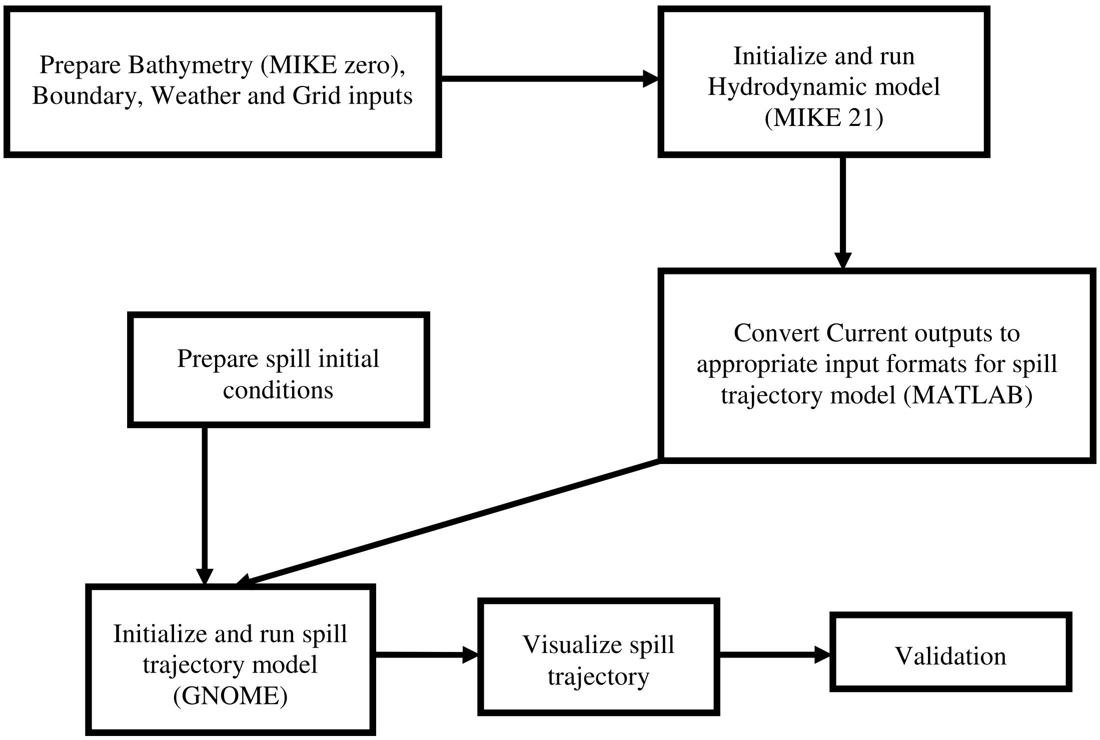

Figure-1: Workflow process for oil spill model.

Movers are the term that is used to denote the movement of any particle (say pollutant) in the medium (say water) due to currents or winds or diffusion or combination of all. For 2-dimensional model (only u and v component), at each time step (say i), the trajectory position are calculated from both the u and v velocity components using Forward Euler scheme with Range-Kutta 1st order interpolation. The trajectory positions of the movers (x, y, z, t) and the displacement (Δx, Δy, Δz, t) are given below in the equation:

$$\Delta x = \frac{\frac{u}{111{,}120.00024} \times \Delta t}{\cos y} \quad (1)$$

$$\Delta y = \frac{v}{111{,}120.00024} \times \Delta t \quad (2)$$

$$\Delta z = 0 \quad (3)$$

Where: y = latitude (radians); 1° of latitude = 111,120.00024 meters, Δx, Δy = 2D longitude and latitude respectively at a depth z.

The currents data of different grid types can be given as input in GNOME. Current Analysis for Trajectory Simulations (CATS) is an in-built hydrodynamic model designed by NOAA for US coast scenario. CATS model is based on 2-D depth averaged steady-state equation using finite element approach. The output of CATS model are made time-dependent in GNOME platform using time-series like tidal coefficients. DAG tree algorithm is used for particle tracking around the grids of finite element mesh.

At each time step, each particle will be considered as a Lagrangian Element (LE) along with their moving positions (say latitude and longitude). Using DAG tree algorithm, we can identify at what grid cell each element is in, and using nearest neighbor approximation, the closest velocity node is being identified along with the updated value of latitude and longitude. More computational time will be taken for particle tracking using DAG tree algorithm as each particle at every time step is calculated by nearest neighbor approximation scheme.

The wind movers for GNOME can be given as constant or time-dependent or time and space dependent. The wind file contains all the details including date, time, speed and direction and their corresponding units are loaded. The spatially varying wind either constant or variable should be in ASCII or NetCDF format. The variable wind i.e., time dependent wind are then interpolated using hermite polynomial fit. The spatially varying wind should be projected on a rectangular or curvilinear grid.

MIKE21 Flow Model is a 2-dimensional model for simulating free-surface flows which numerically solves depth integrated shallow water equations for incompressible Reynolds averaged Navier-Stokes (RANS) equations. The model includes various formulations like continuity equation, momentum equation, temperature equation, salinity and density equations. MIKE Zero Mesh Generator is a tool used for generating unstructured meshes along with boundary conditions. The mesh file for Mumbai region is first generated using MIKE Zero Mesh Generator. The mesh file is an ASCII file and this .xyz file is imported to MIKE Zero grid. The file also includes location specific information of the node-connectivity in the grid. The bathymetry data for the study area are obtained from C-map and GEBCO and are used for creation of Bathymetry in MIKE Zero. Using this bathymetry as input and other parameters like bed resistance, eddy viscosity, tidal potential (from World annual tide), structures etc for the Mumbai region are given as input in MIKE21 Flow model and it is simulated. The current data are obtained as output which is in ASCII format. These ASCII format are then need to be converted to gridcur format using MATLAB.

Geospatial Information System (GIS), a computer based platform is a mapping tool for analyzing features on earth. Using GIS we can project the output from various models on the basis of location and it also helps for analysis of the statistical results. Here, Land Use and Land Cover (LULC) map has been prepared for the study. LULC map is used to demarcate the affected region due to spill using the output from spill trajectory simulation. 2010 LANDSAT satellite data has been used for mapping.

Results and discussion

The oil spill particle tracking are done for variable wind scenario for the 2010 Mumbai spill. Finally, mapping of the affected region is done using ArcGIS. The original Advanced Scatterometer (ASCAT) sea-surface wind data, provided through EUMETSAT's Ocean and Sea Ice Satellite Application Facility (OSI SAF) project are very accurate. In ASCAT, winds near the coast look consistent and they are of good quality. In Mumbai, the wind direction varies with season but in general it is from the North to the West quarter. Monsoon or any other such factor influence the currents in the harbor rather they are caused only by the tides and winds. The peak tide which occurs in Mumbai Harbor is a Semi-diurnal tide (period 12 hours and 40 minutes). The bathymetry was first created using MIKE zero. Using this bathymetry, the circulation characteristics for Mumbai region is being studied using MIKE21 Flow model with a grid size of 50m×50m.

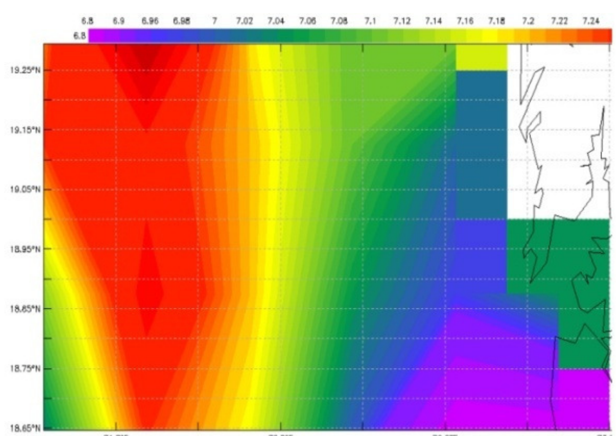

Figure-2: ECMWF wind regime for Mumbai coast during August 2010.

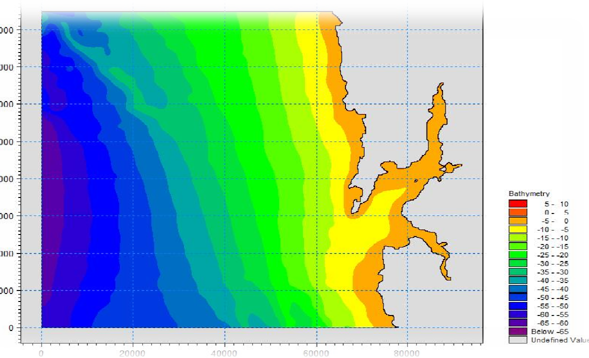

Figure-3: Bathymetry generated using Mike Zero.

The spill particle released in the Mumbai coast is significantly influenced by wind forcing, as it appears this phenomenon is the only force capable of producing and maintaining the currents observed in the coast. The particle is considered neutrally buoyant and highlights the possible path of oil particles released in the location. The particle tracks will vary with changes in the seasonal wind record. The output from the spill trajectory model is given below in the images.

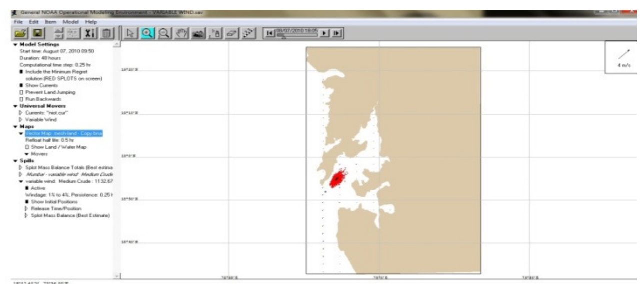

Figure-4: Particle trajectories after 8 hours of initial release.

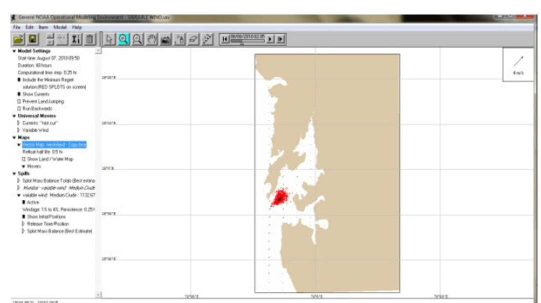

Figure-5: Particle trajectories after 16 hours of initial release.

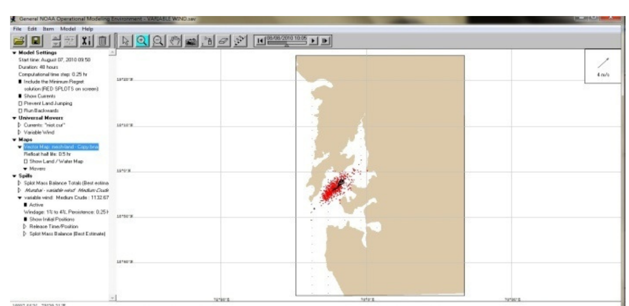

Figure-6: Particle trajectories after 24 hours of initial release.

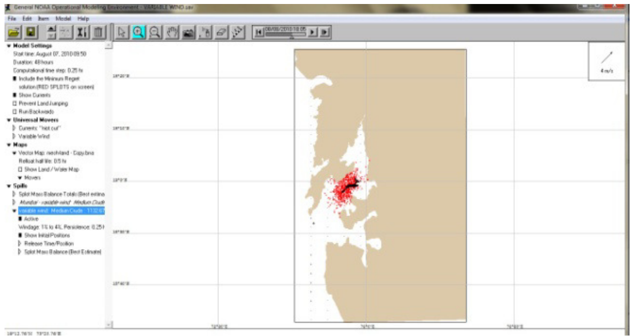

Figure-7: Particle trajectories after 32 hours of initial release.

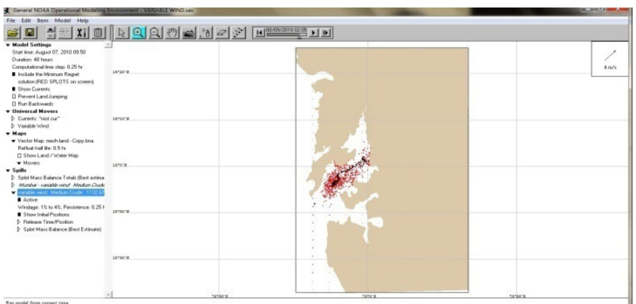

Figure-8: Particle trajectories after 40 hours of initial release.

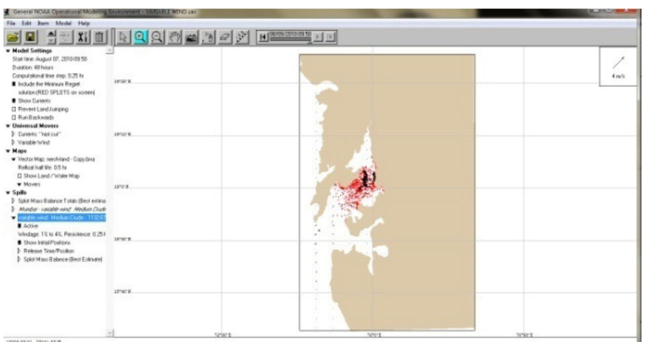

Figure-9: Particle trajectories after 48 hours of initial release.

A Land Use Land Cover map has been prepared from LANDSAT 2010 satellite image. The output from GNOME is obtained in NOAA standard splot files (GIS) format and then the oil spill affected region is marked in black splots. The image showing the affected region is given:

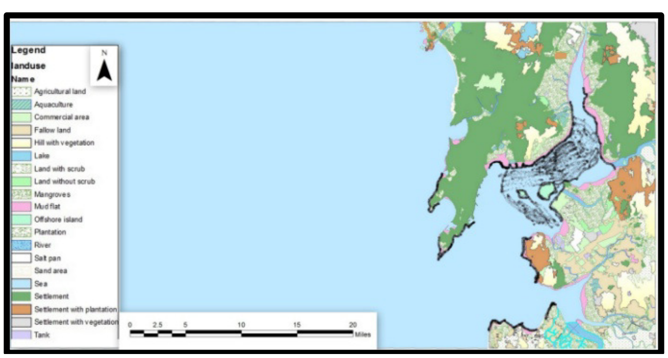

Figure-10: LULC map showing the spill affected region.

Table-1: Affected Coastal L-USE features and affected areas.

Land Use name	Area (in sq.km)
Mudflat	13.209
Settlement	10.451
Plantation	1.104
Settlement with plantation	0.360
Aquaculture	0.416
Mangroves	2.433
Offshore island	3.292
River	0.527
Sea (Affected by oil spill)	84.756
Sandy beach	1.545
Commercial area	2.271

Conclusion

This is a numerical study that quantitatively defines the movement of oil slicks throughout the Mumbai coast. The following conclusions have arisen through the course of this thesis: i. Summer prevails on this area during August, when the spill occurred. The oil is generally weathered enough to have less of an effect. ii. The losses due to evaporation were substantial in summer months. iii. In Elephanta Island, oil spill contaminants were heavily dispersed in sediments in the south, west and east direction than the north. iv. Uran, which has industries like JNPT, P&O, GTI and other shipping companies are moderately affected due to oil spill. v. In Uran beach, the sediments were affected with tar balls of less density and Margove cover was contaminated with thinly dispersed oil particles. vi. Mandva, which has sandy and rocky beach, also show traces of tar balls.

In conclusion, the bathymetry of the Mumbai is such that it is a semi-enclosed basin. The oil can only escape to the ocean through the western passage of the coast. The circulation through the Mumbai is key to determine how the oil remaining at each time interval, after losses have been removed, will behave. The winds were confirmed as the most important driving force for the circulation patterns within the coast. The validation of the model shows that if the inputs to the model were given with high accuracy, then the output will also be obtained with high accuracy.

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