# OIL SPILL TRAJECTORY PREDICTION SYSTEM

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**ITCOOcean**

**11-12 JULY 2023**

# OUTLINE OF THE PRESENTATION

- Oil spill and its impact on marine environment
- Need for an oil spill advisory system
- INCOIS Operational set up in predicting the oil drift pattern
- Case studies
- Detecting oil slicks in SAR data
- Extending research towards the benefit of marine stakeholders
- Online oil spill advisory system
- Demonstration

# OIL SPILL

**Release of liquid petroleum hydrocarbon into the marine environment**

| | |
|---|---|
| Carbon | 83-87 wt % |
| Hydrogen | 10-14 wt % |
| Nitrogen | 0.1-2 wt % |
| Oxygen | 0.1-1.5 wt % |
| Sulfur | 0.5-6 wt % |
| Metals | < 0.1 wt % |

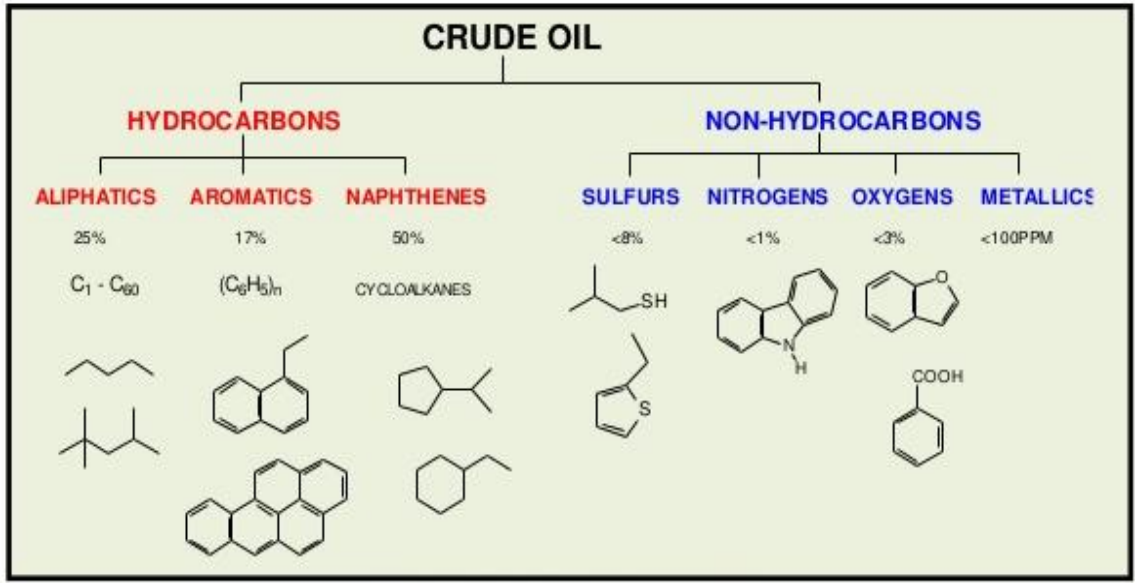
**Elemental composition of petroleum crude oil**

**Based on the quantity (ICG Norms)**

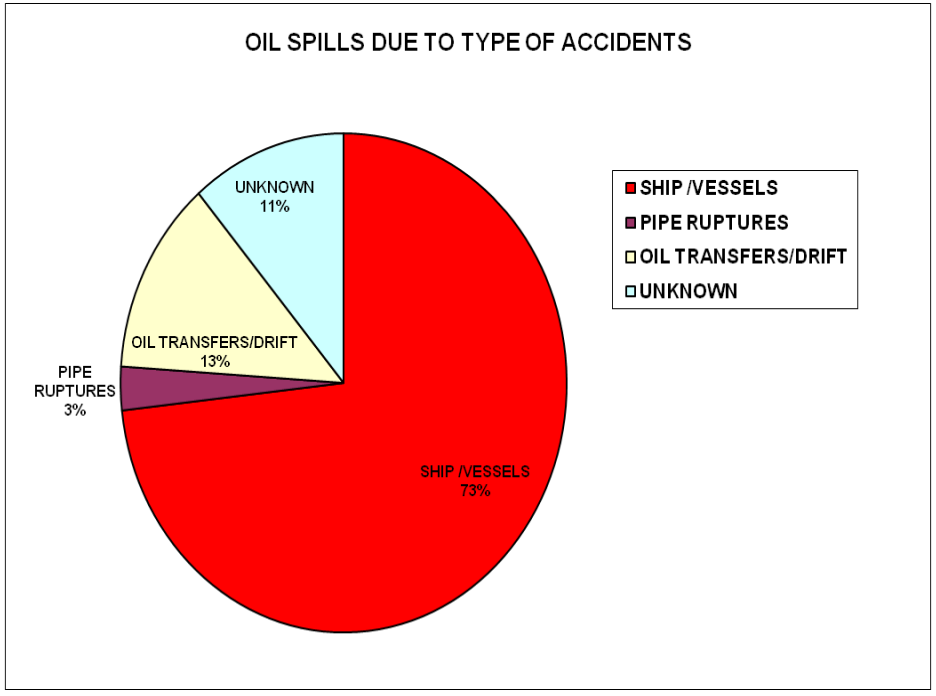
Tier -1 < 700 Tons

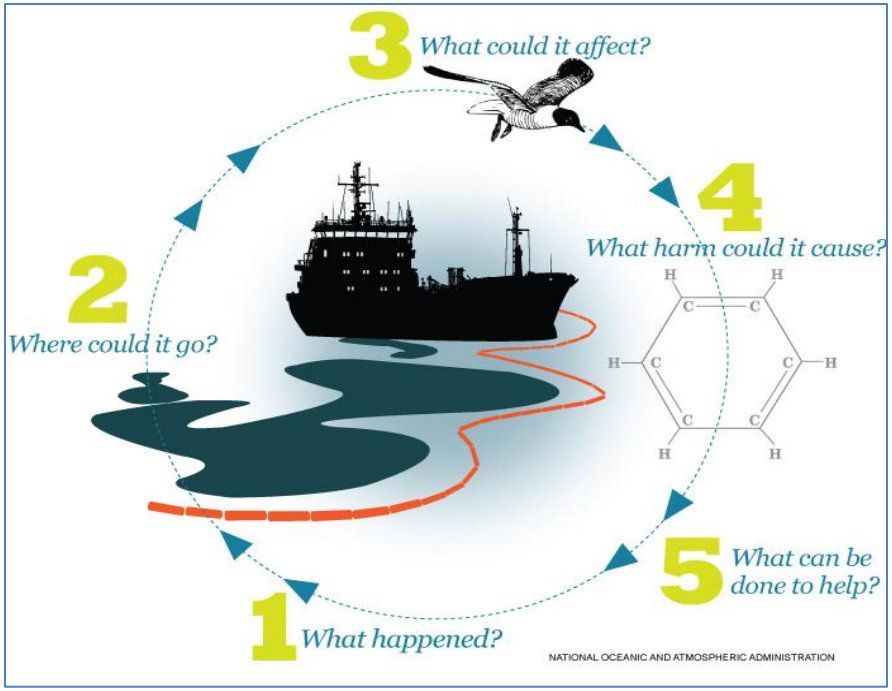
Tier -2 > 700 and <10000 Tons

Tier - 3 > 10000 Tons



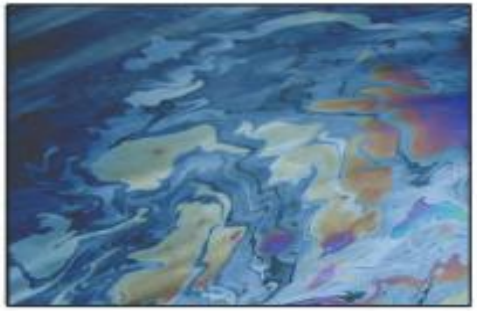
# SOURCES OF OIL SPILLS AND RESPONSE

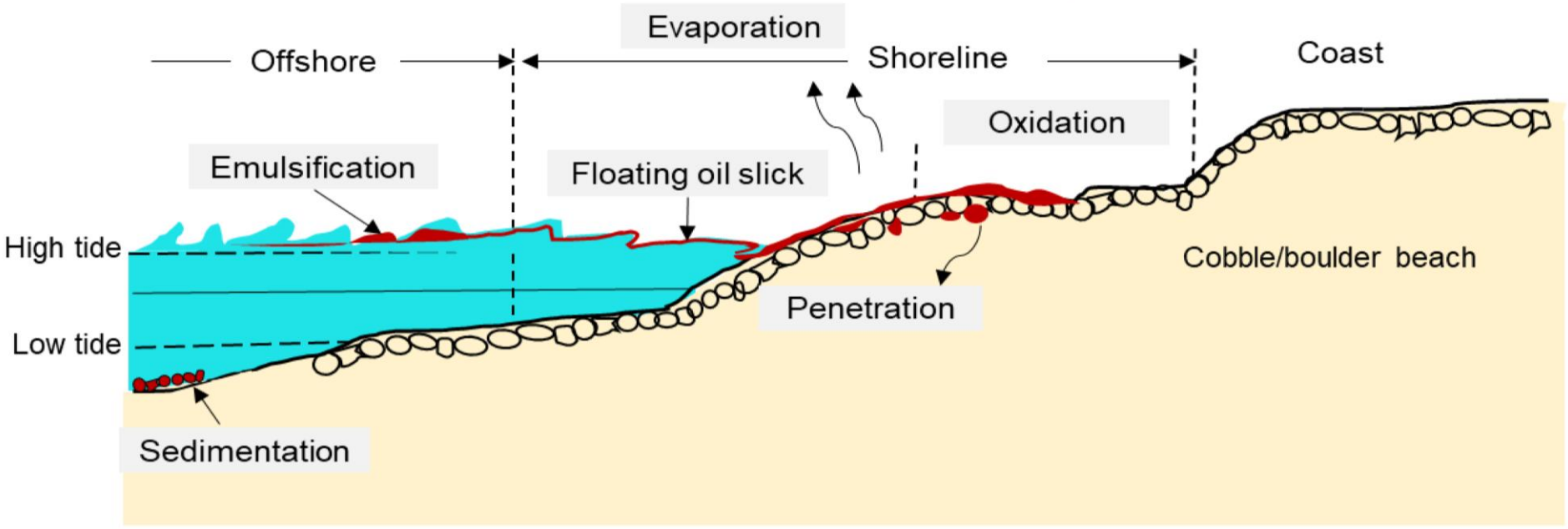




*Source : Indian coast Guard*

# TYPES OF OIL AND WEATHERING PROCESS




Light – API > 31.1, Medium – API between 22.3 and 31.1, Heavy – API < 22.3,
Extra Heavy – API < 10.0, API gravity = (141.5/Specific Gravity) – 131.5



# HABITATS AND THE RECOVERY PERIOD

| Habitat | Recovery period |
|---|---|
| Plankton | Weeks/months |
| Sand beaches | 1 – 2 years |
| Exposed rocky shores | 1 – 3 years |
| Sheltered rocky shores | 1 – 5 years |
| Saltmarsh | 3 – 5 years |
| Mangroves | 10 years and greater |

*Figure 10a: Intrusive clean-up of the marsh has caused additional damage over and above that caused by the oil.*

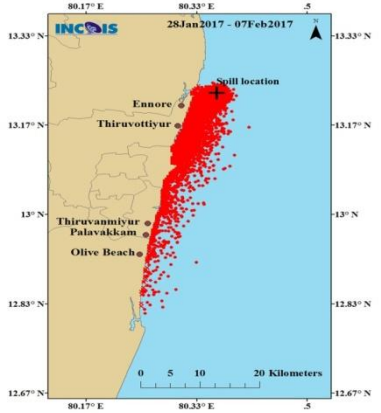
*Figure 10d: After three years, the marsh has returned to full species diversity.*

# NEED FOR AN OIL SPILL TRAJECTORY PREDICTION SYSTEM

## DISSEMINATION OF OIL SPILL ADVISORY TO THE USERS


**Oil Spill Advisory - INCOIS Bulletin**

As per the information obtained from Indian Coast Guard, On 28.01.2017 04.00 hrs MT Maple and MT Dawn vessels collided at 13.228166° N, 80.363333° E. INCOIS set its own oil spill trajectory model with the necessary forcings and predicted the HFO (196 MT) drift. The extent of affected coastline is also estimated.




| Date/time | Predicted length of the affected coastline(km) | Landmark |
|---|---|---|
| Spill on 28.01.2017,04.00 hrs | - | Ennore |
| 28.01.2017,14.00 hrs | 7 | North of Thiruvottiyur |
| 29.01.2017,04.00 hrs | 13 | Ennore Fishing Harbour |
| 30.01.2017,04.00 hrs | 18 | Sathya Nagar |
| 31.01.2017,04.00 hrs | 24 | North of Adyar river mouth |
| 02.02.2017,23.00 hrs | 30 | Thiruvanmiyur |
| 04.02.2017,23.00 hrs | 36 | Palavakkam |
| 06.02.2017,23.00 hrs | 45 | South east of VGP Beach |
| 07.02.2017,23.00 hrs | 51 | Kovalam Beach |
| 08.02.2017,23.00 hrs | 52 | AMET university |

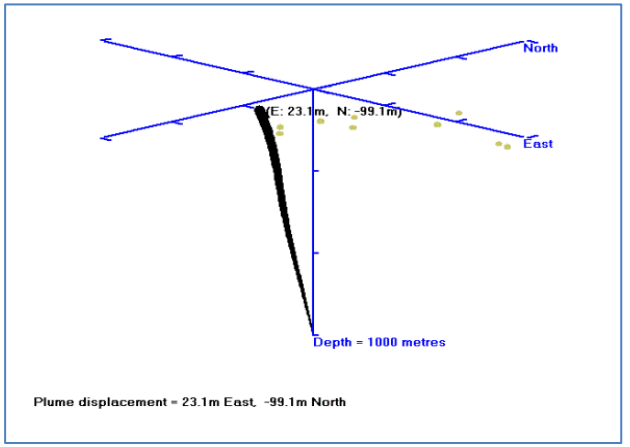
## SIGNIFICANCE OF OIL SPILL TRAJECTORY PREDICTION

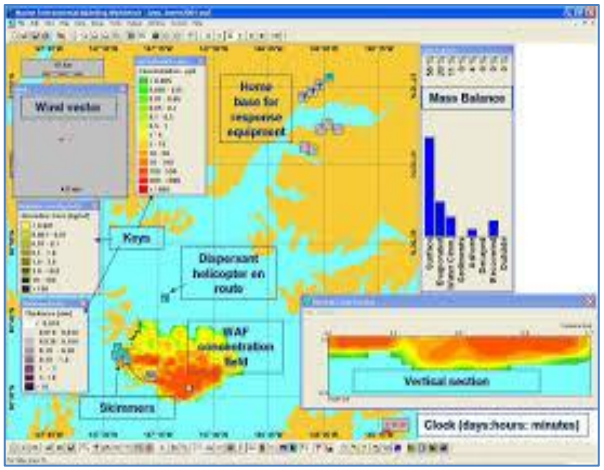
India possessing sensitive ecosystems and aquatic organisms along its coastline known for its coastal and Marine biodiversity. The marine habitats are being affected due to the oil spills caused due to vessel collisions and illegal discharges. In order to prevent the impact of oil spills on the marine environment an oil spill trajectory prediction system is required, to provide the trajectory of an oil spill thereby protecting the Marine habitats. In the event of oil spill, the direction and movement of the oil will be predicted in advance in our system and will be disseminated to the Regulatory Authority. The clean up and control measures will be planned and carried out accordingly.

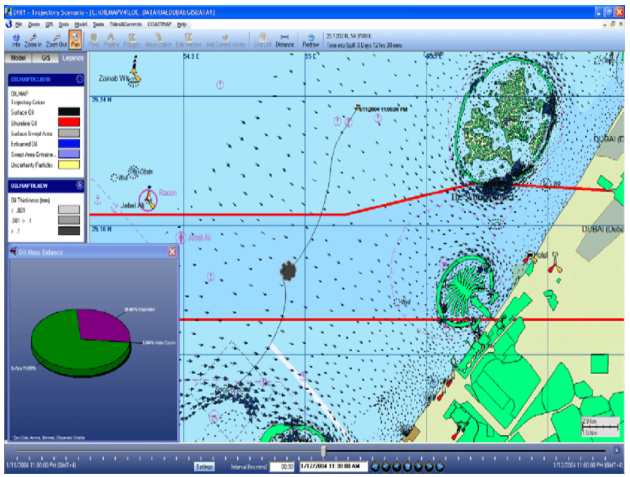
# OIL SPILL MODELS

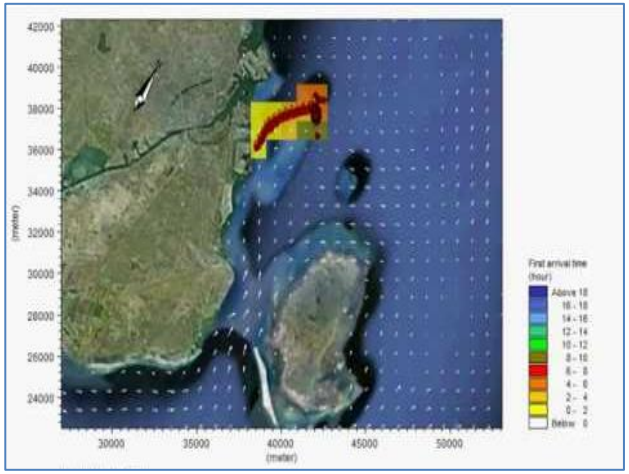
# TYPES OF OIL SPILL MODELS

- Probability model (Impact at defined time),OSCAR, OILMAP
- Weathering models (DHI module, ADIOS2, MEDSLICK)
- Back-Track models (Reverse model run) OILMAP
- Subsea Models (OSCAR, OILMAP)
- Oil Spill Trajectory Model (GNOME)
- HDFM & OS MODULE (MIKE3)



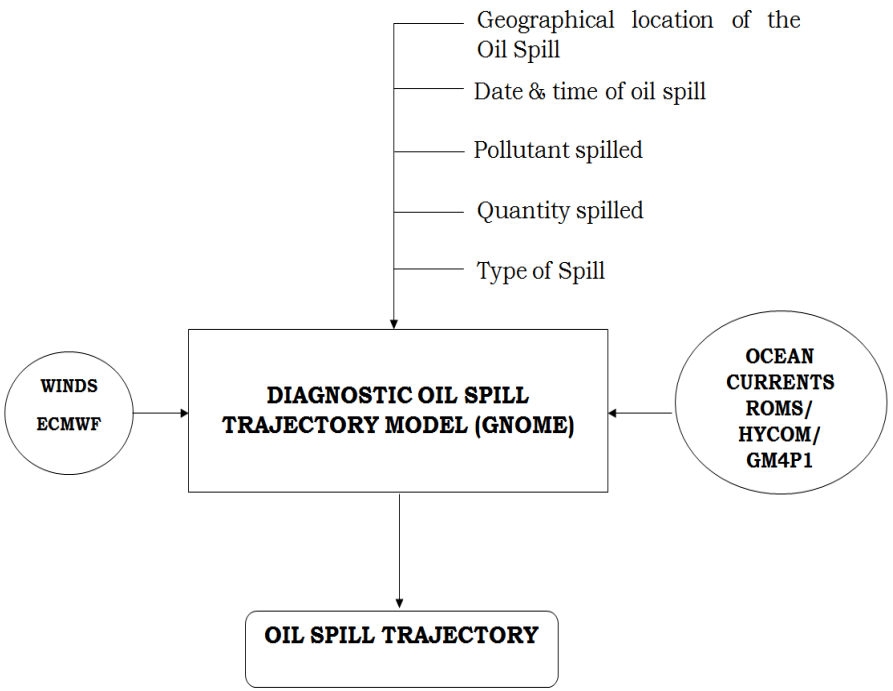



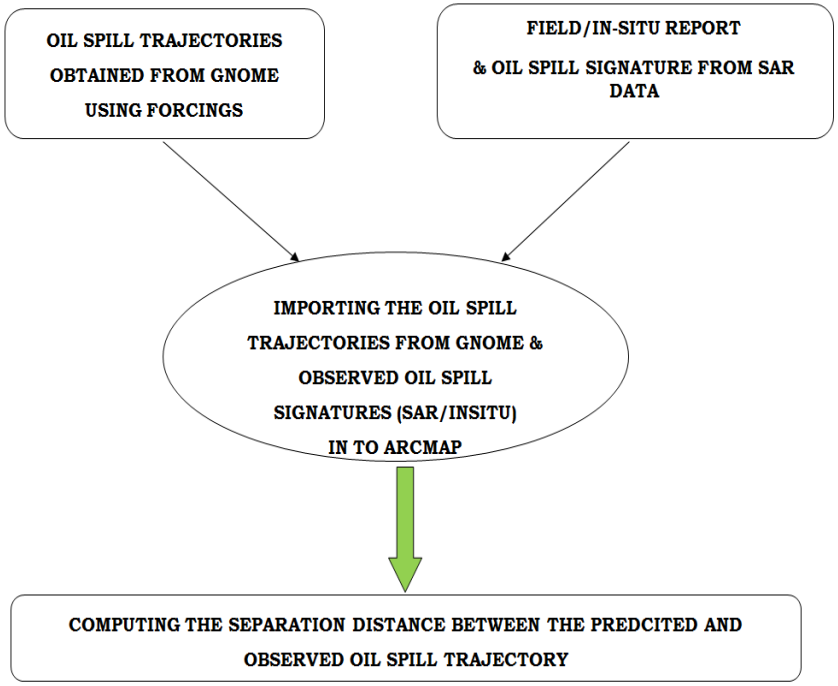





# OPERATIONAL OIL SPILL TRAJECTORY PREDICTION SET UP AT INCOIS

# OIL SPILL TRAJECTORY PREDICTION & VALIDATION SET UP



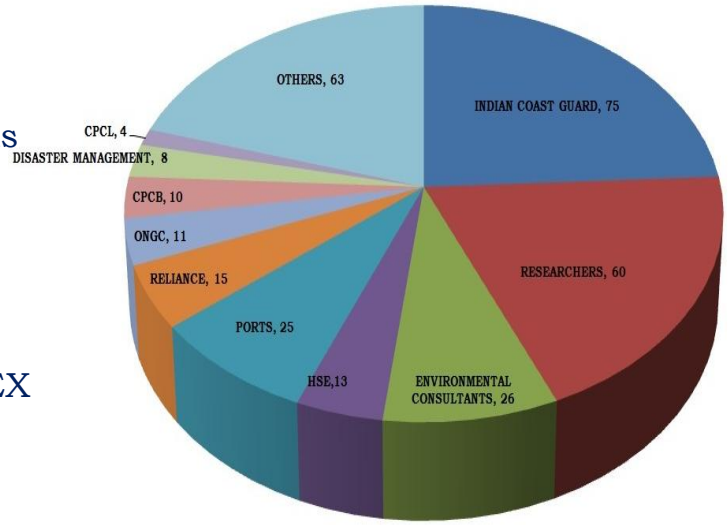




## OPERATIONAL ONLINE OIL SPILL ADVISORY SYSTEM LAUNCH – 21 NOSDCP MEET AUGUST 2016


## OOSA UTILISATION

- Real oil spills
- Hypothetical spills
- Marine mock drills/Field exps
- NAT/REG POLREX
- Research

## OOSA USERS (ICG & STAKEHOLDERS)



## Governing equations

GNOME follows the forward Euler scheme, to get the displacement of an oil particle from the initial location over time.

### A. Displacement of oil parcels

Equation 1 represents the displacement of an oil particle in x and y directions from their initial spill location

$$x_{(i+1)} = x_i + \Delta x, \; , y_{(i+1)} = y_i + \Delta y \qquad \text{----------1}$$

where

$x_{(i+1)}$ is the longitude of oil particle at time $t_{(i+1)}$

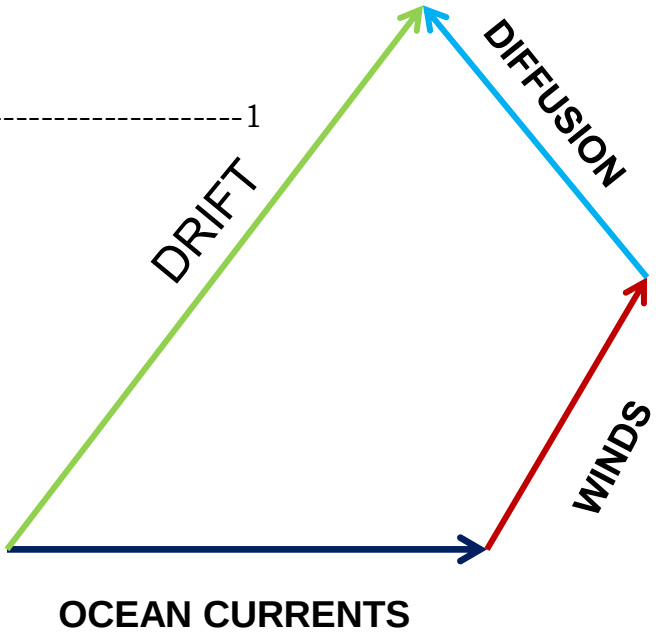
$y_{(i+1)}$ is the latitude of oil particle at time $t_{(i+1)}$

$x_i$ is the longitude of oil particle at time $t_i$

$y_i$ is the latitude of oil particle at time $t_i$

$\Delta x$ is the displacement of the oil particle due to forcings in x -direction

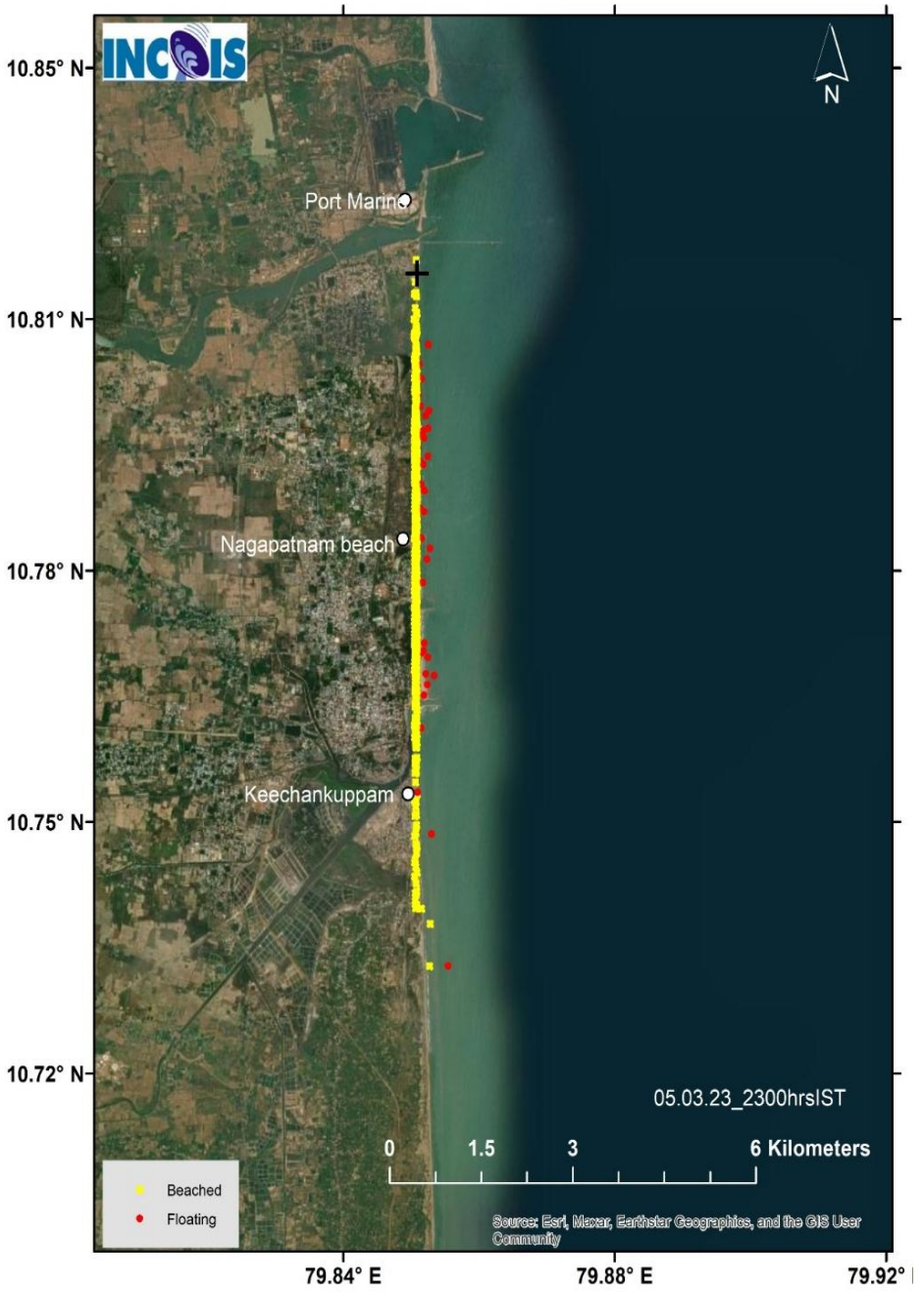
$\Delta y$ is the displacement of the oil particle due to forcings in y -direction



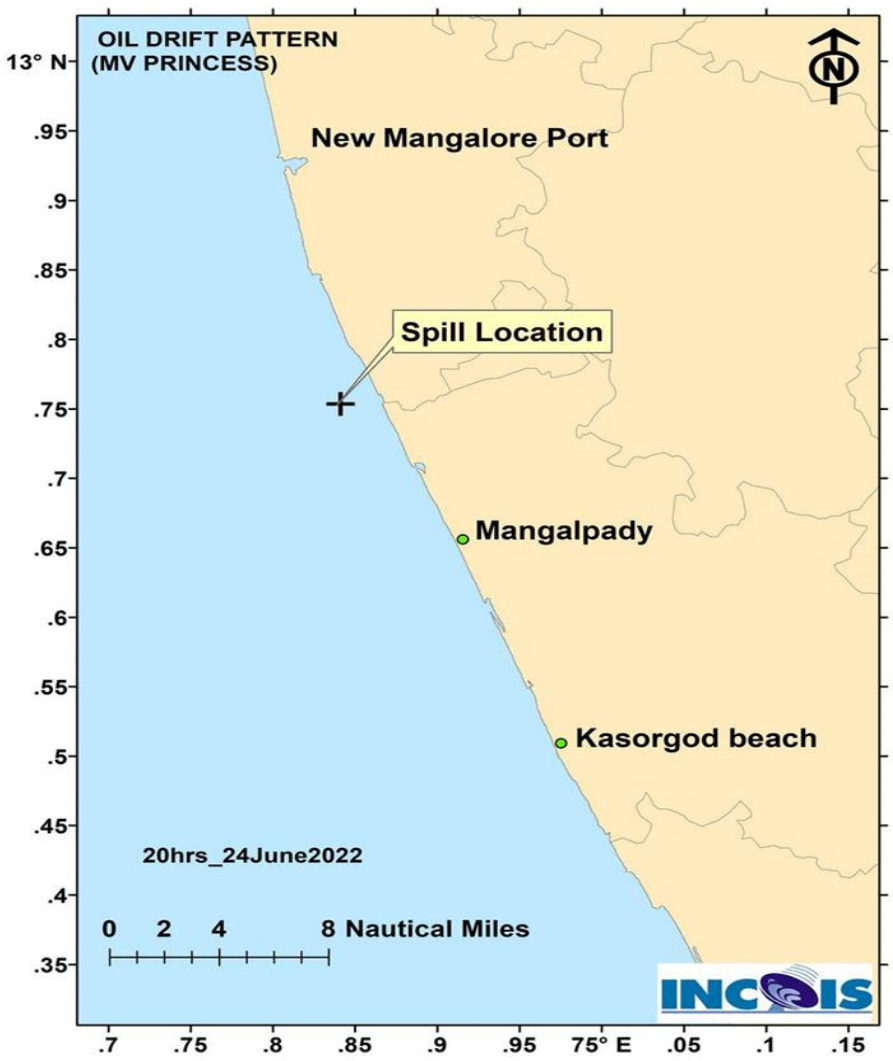

Densities g/cc
gasoline = .75
Jetfuels = .81
Diesel = .87
Fuel oil 4 = .90
crude = .90
bunker 6= .99

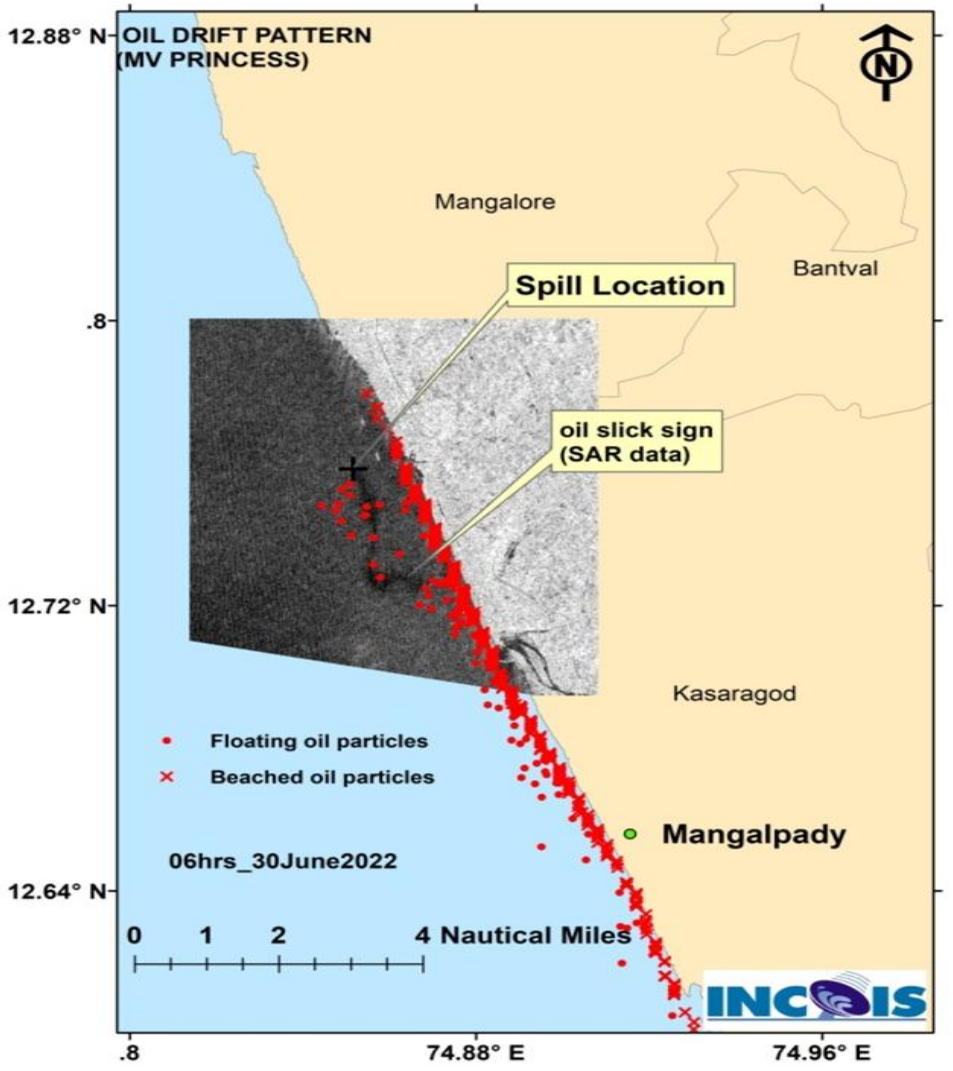
# NAGORE BEACH - PIPELINE OIL SPILL – ADVISORIES ISSUED

Indian National Centre for Ocean Information Services (INCOIS) have generated oil spill trajectory patterns on forecast basis for the spill reported due to pipeline rupture at Nagore Beach, Nagapattinam. On 02 Mar 2023 (Thursday) night, oil leak was noticed by the local community. The spilled crude oil has reached the shore on the same day. Later it was noticed to spread along the coast. INCOIS generated oil drift patterns to advise the coastal community, on further spread of the pollutant. As per the simulations, it was noticed that the pollutant will spread further south on the forthcoming days. On 03 March 2023, it would have affected ~ 8.5 km of shoreline. The next day, the pollutant would have reached ~10.76 Km. On 05 March, ~10.33 km of coastline would have got affected. 10.91 km, 11.40 km, and 12.00 Km of coastline will get affected on 06, 07 and 08 March 2023 respectively. This spill conditions are monitored on forecast basis, However INCOIS will disseminate the report/ Bulletins on periodical basis.



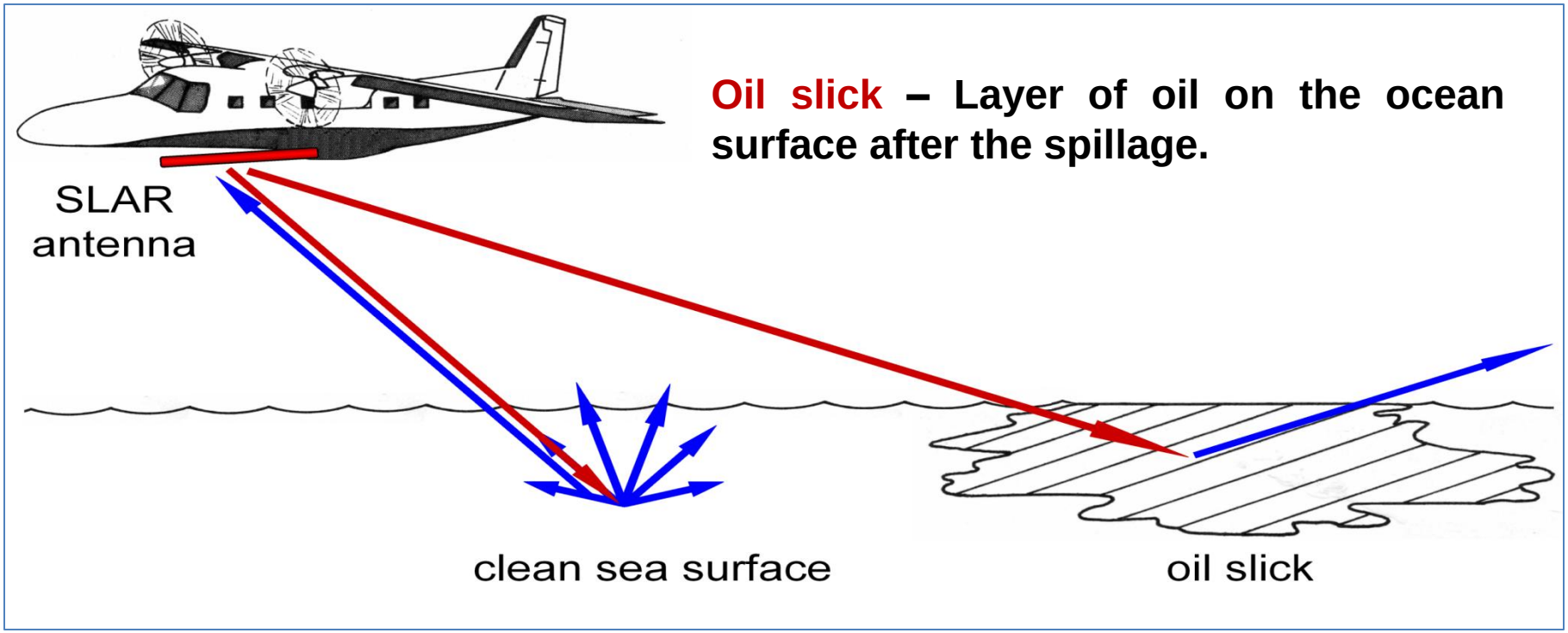
# VALIDATING THE SIMULATED OIL DRIFT PATTERNS USING SAR DATA




- Oil drift patterns were simulated on regular intervals from the spill location 12º 45.5'N, 74º 51.1'E of the wrecked vessel MV Princess which had 220 Tons of Fuel oil on board, from 21.06.2022 to 04.07.2022.
- Synthetic Aperture Radar (SAR) data was acquired on 30.06.2022 from European Space Agency. The simulated drift pattern was validated with the oil slick signature obtained from the SAR dataset as shown in the right panel.
- Advisories of INCOIS helped ICG, Disaster Management Authority etc., in deploying their response and clean up operations.

# PRINCIPLE OF OIL SLICK DETECTION

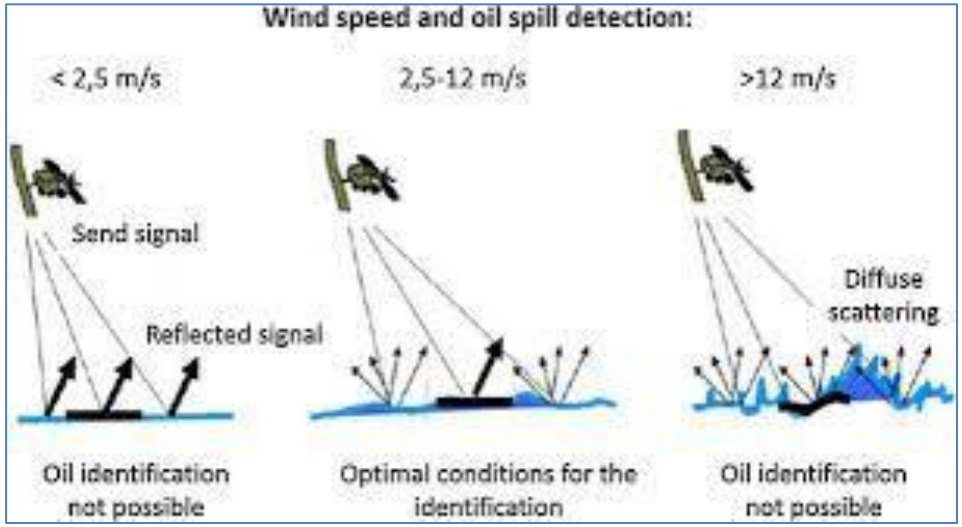



**Oil slick – Layer of oil on the ocean surface after the spillage.**

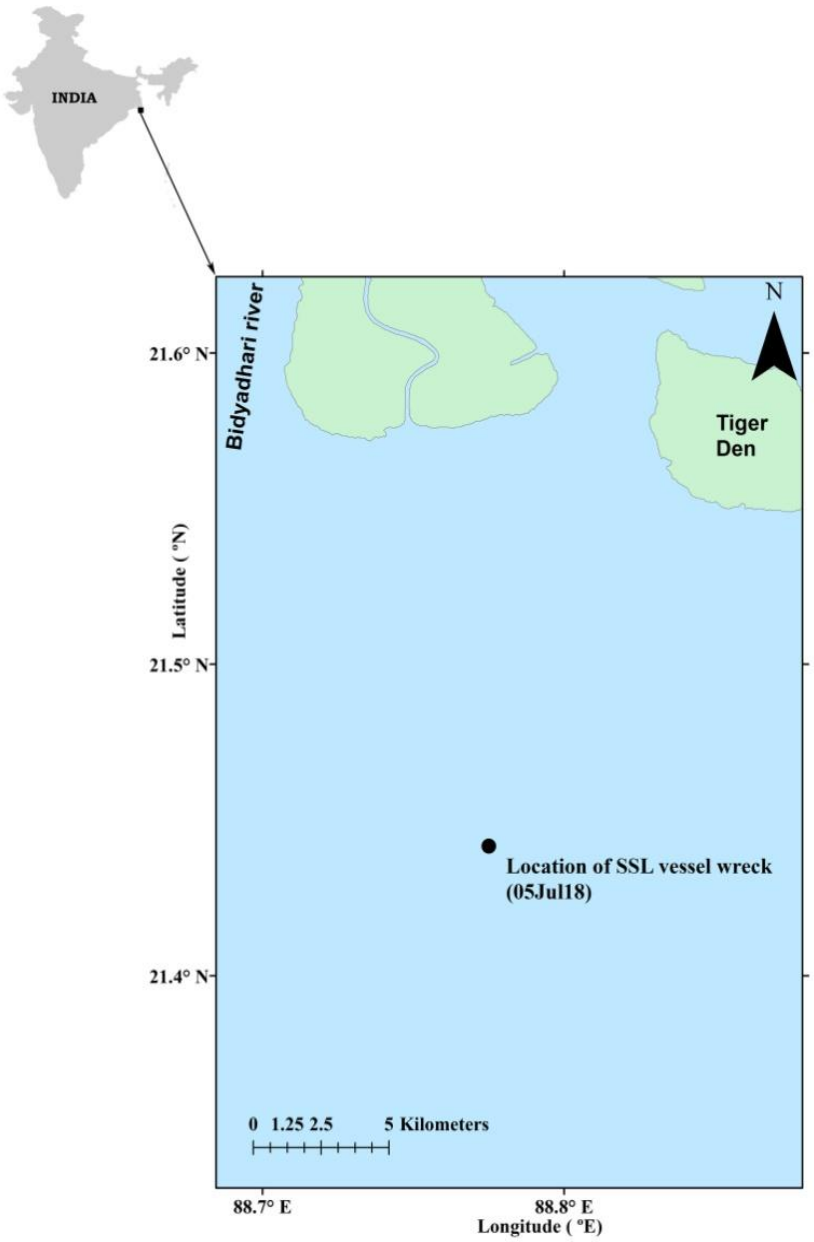
**Principle** : Dampening of sea surface roughness by oil slicks causes reduced backscatter in the radar image.

The reduced backscatter (dB) corresponds to the pixels of oil slicks/dark spots.

Slick pixels are exported for further processing



# SSL VESEL WRECKAGE – 05 JULY 2018

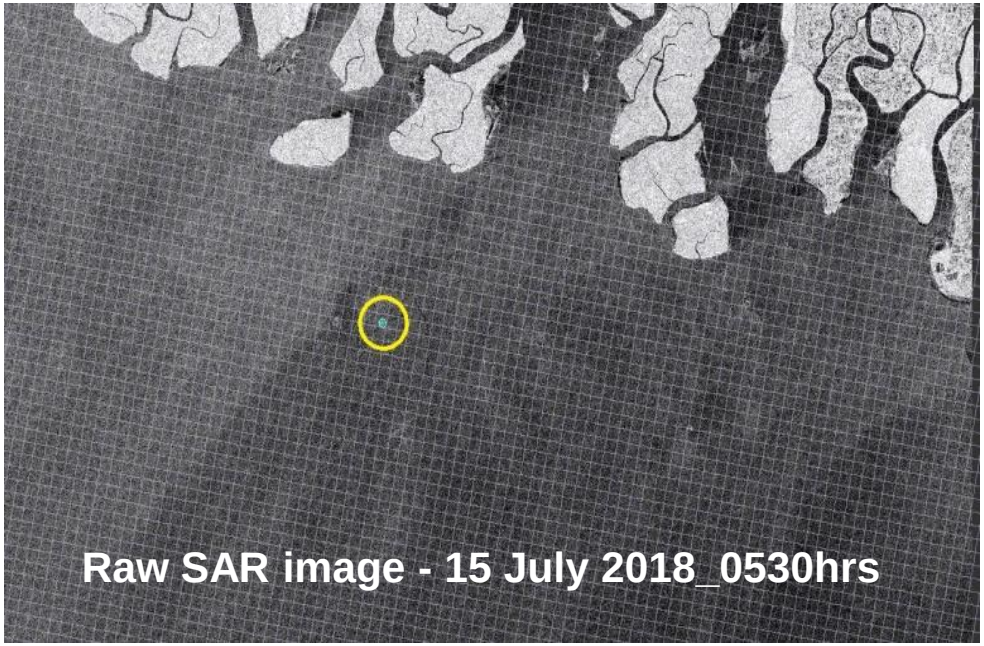


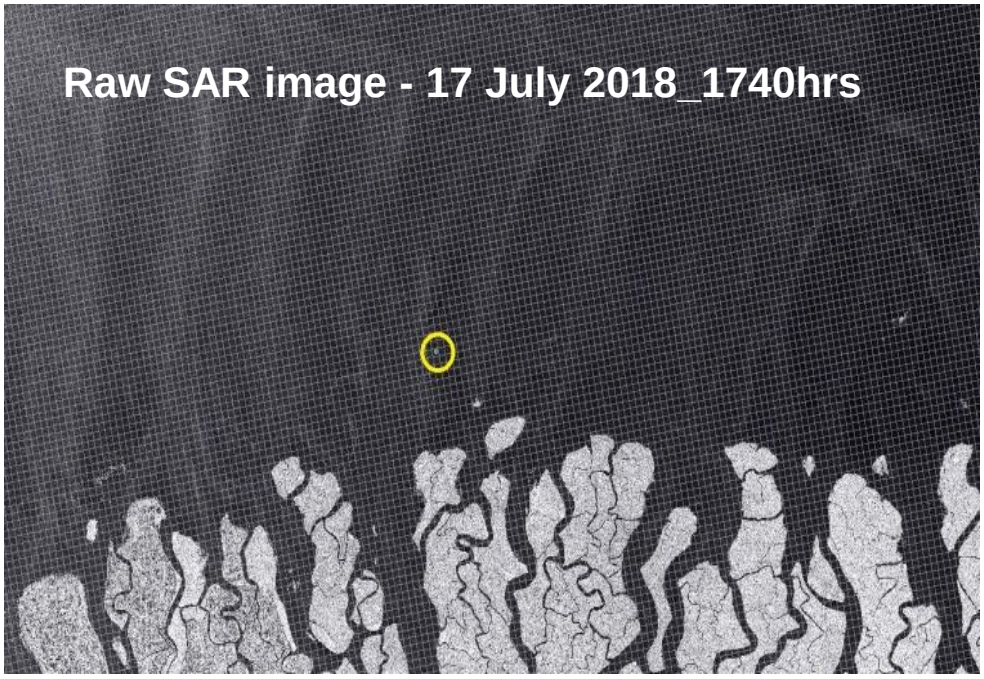


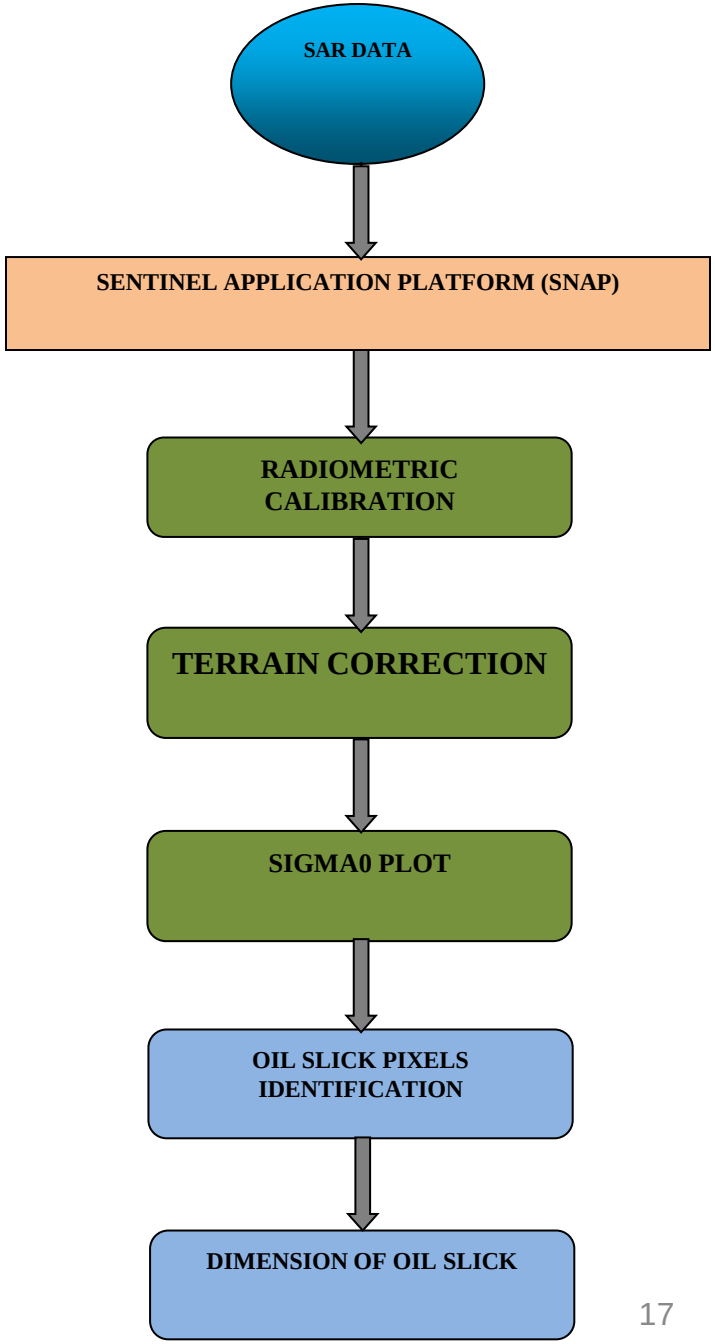
**Objective : To detect and analyze the oil slicks using radar datasets of Sentinel -1 A mission during the wreckage of SSL Kolkata vessel off Bidhyadhari river, West Bengal during July 2018.**

**SSL Kolkata vessel, caught fire - 05 July 2018- 88.775º E, 21.4416º N off Tiger Den island, West Bengal.**

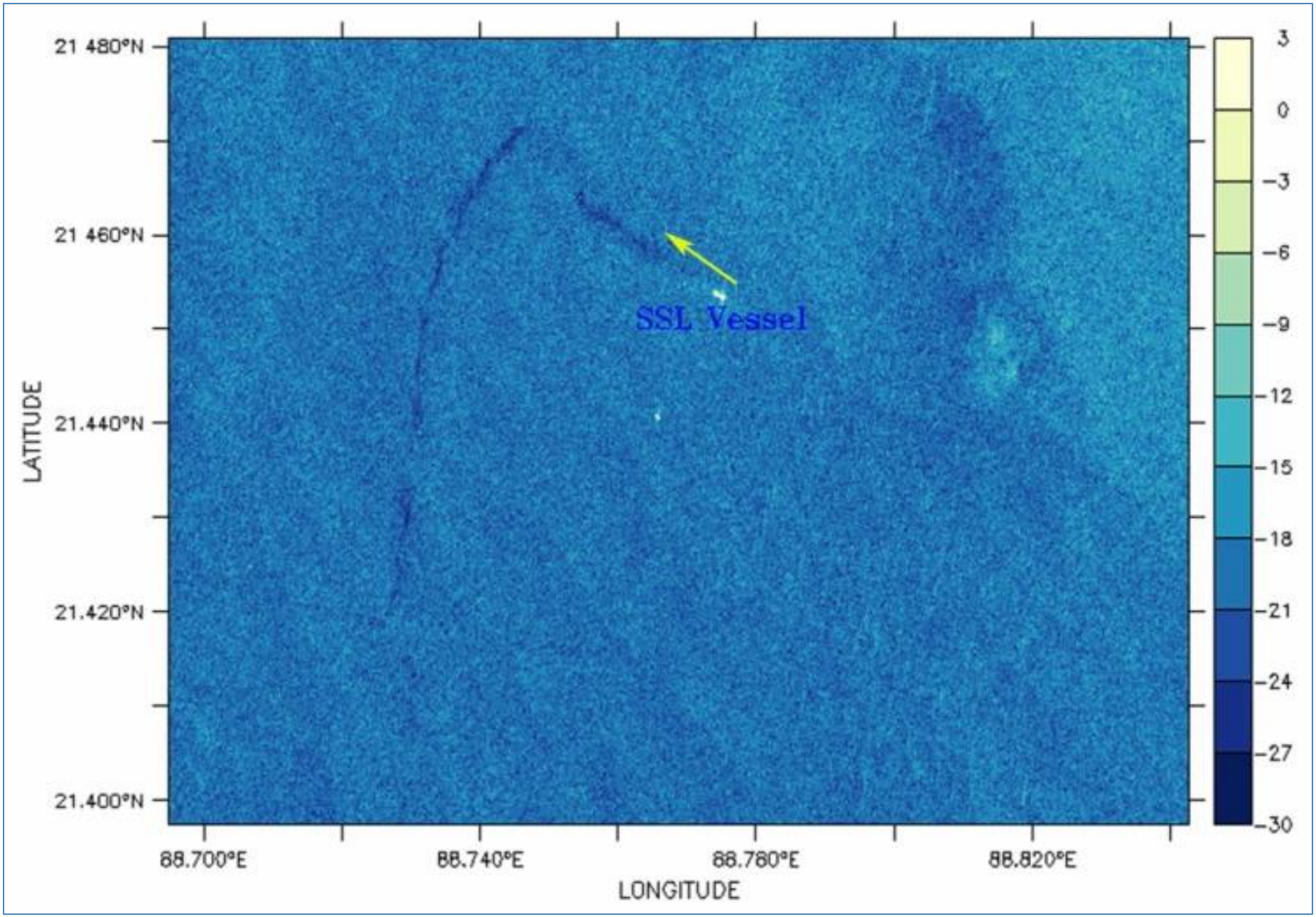
# METHOD FOR PROCESSING SENTINEL - 1A SAR DATASET



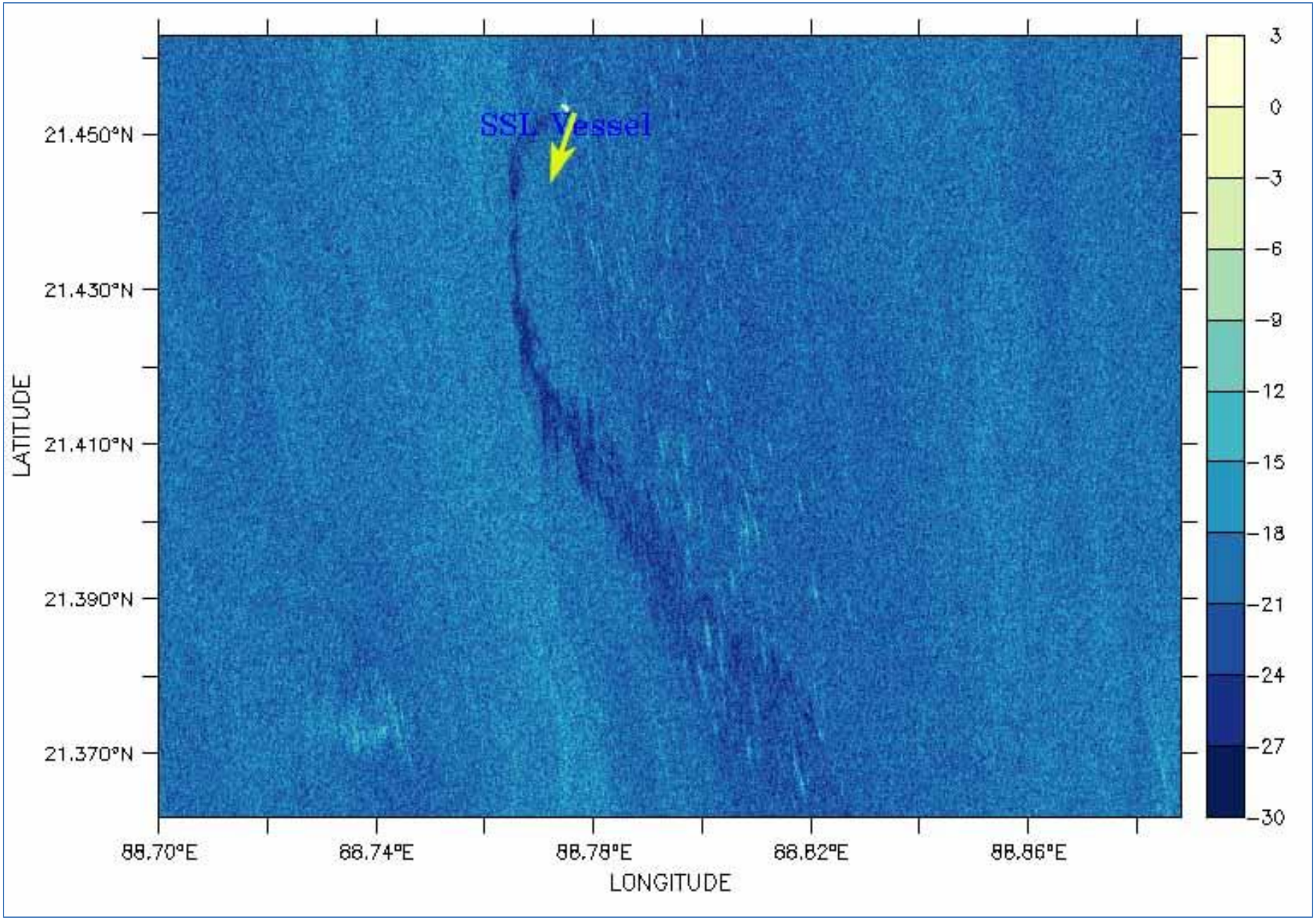



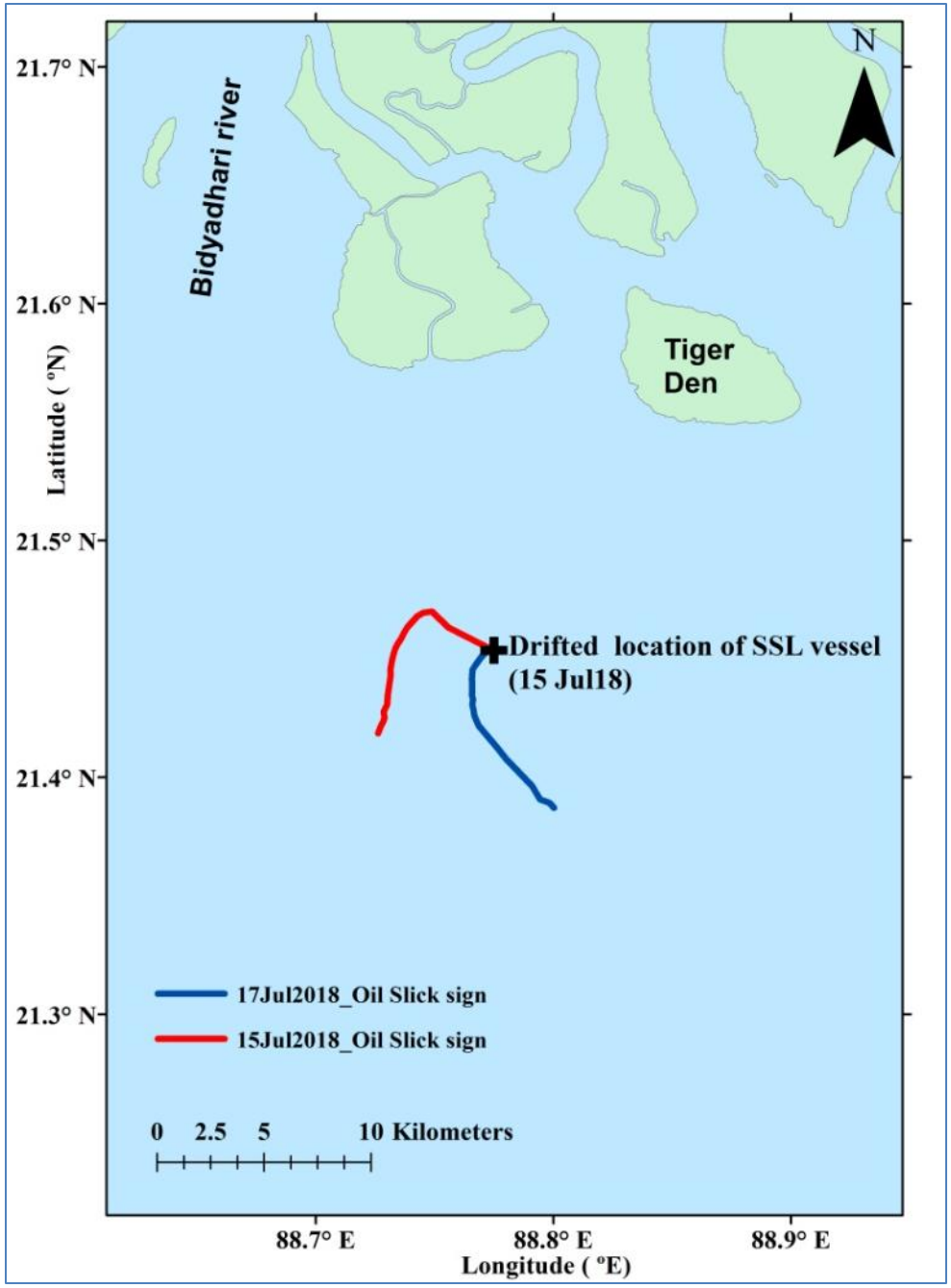
# PROCESSED SAR DATA IN dB SCALE ON 15 JULY 2018_0530HRS



# PROCESSED SAR DATA IN dB SCALE ON 17 JULY 2018_1740 HRS

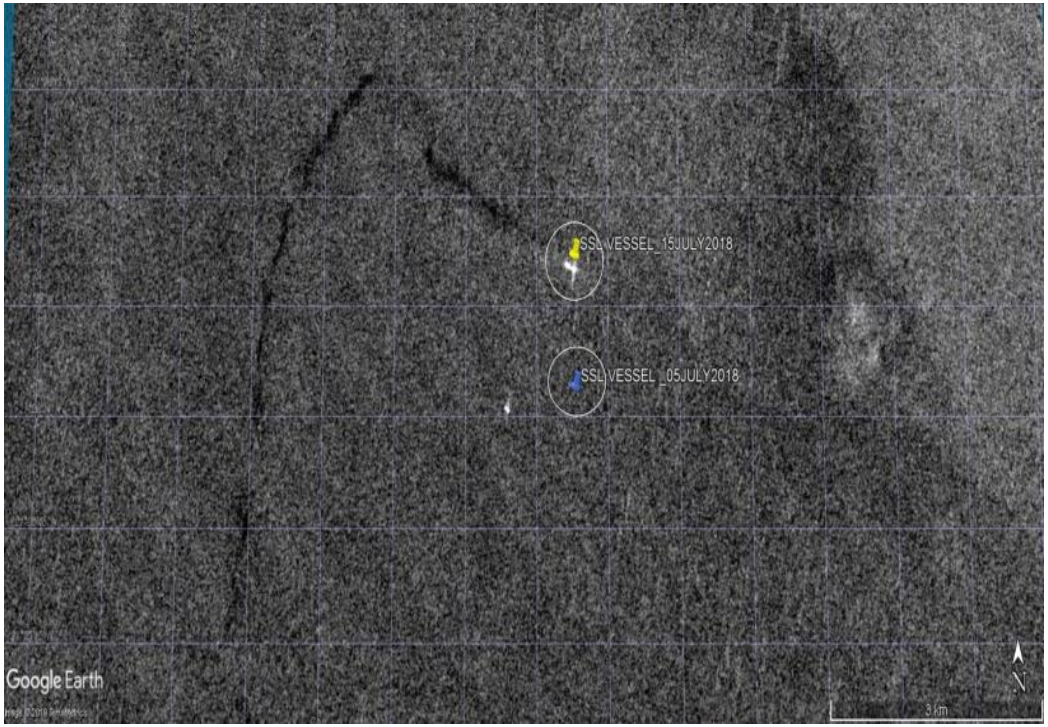


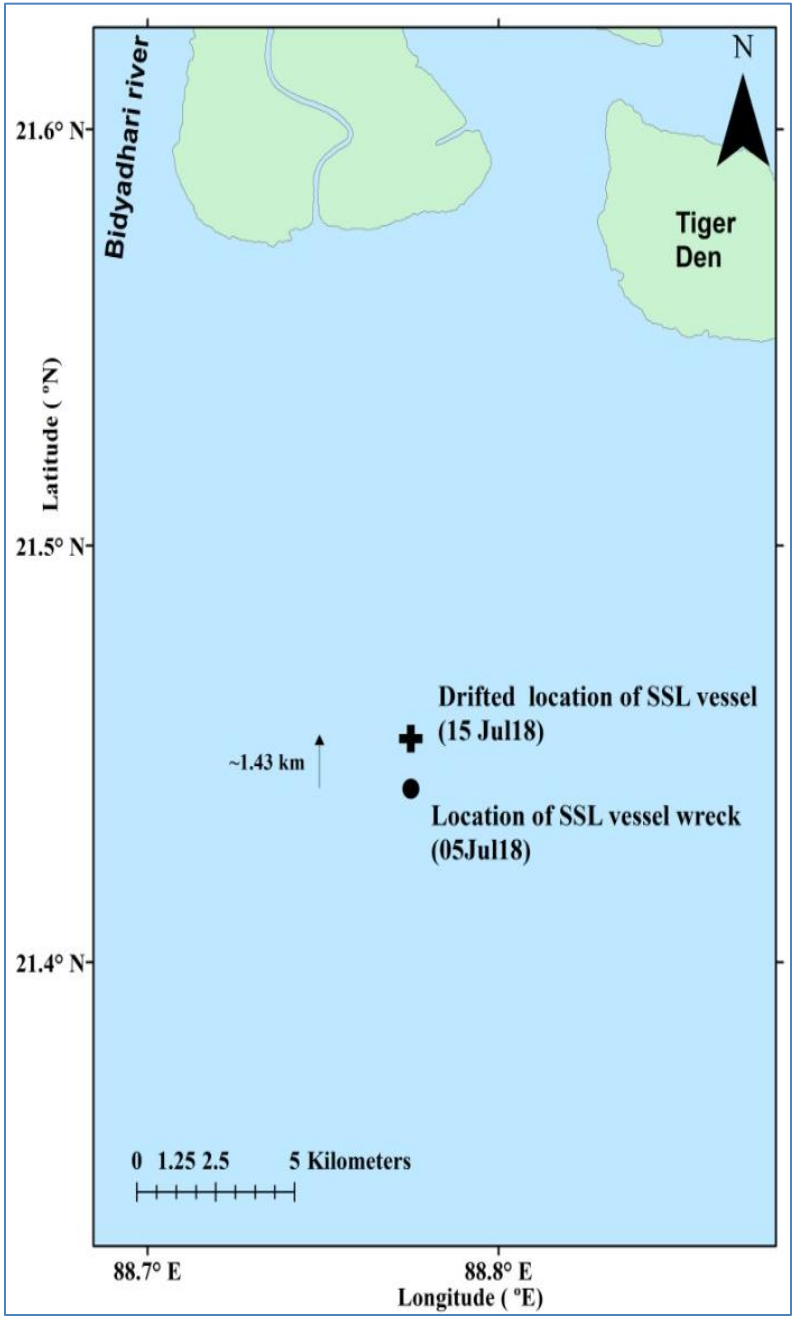
# ESTIMATING THE DIMENSIONS OIL SLICK




- 15 July 2018, a snacking oil slick of ~9.84 km was found from the vessel datum and
- 17 July 2018, ~9.09 Km, snacking slick of oil was detected.
- The Oil slicks from the SSL vessel datum on 15 and 17 July 2018 are shown in Fig . The red polyline is the oil slick signature obtained on 15 July 2018 and the blue line denotes the oil slick signature on 17 July 2018

# ESTIMATING THE VESSEL SHIFT FROM DATUM

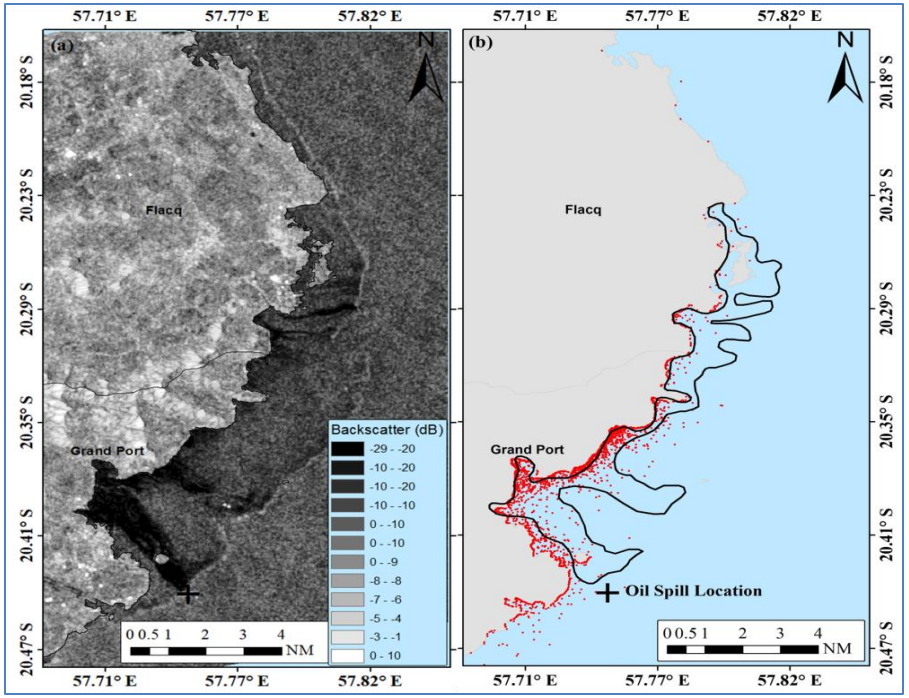


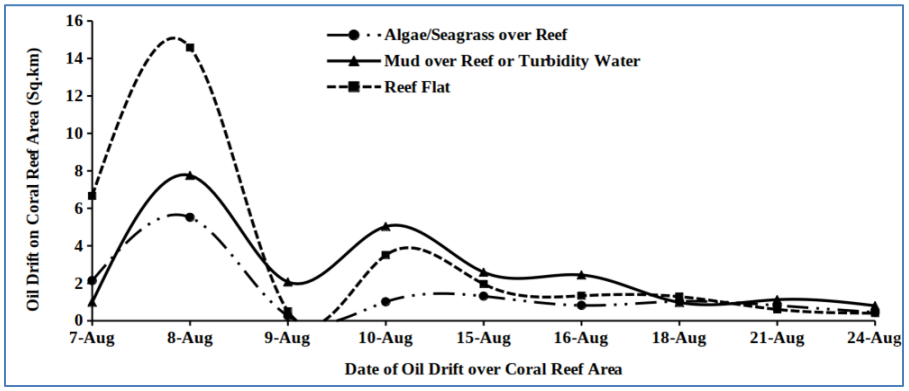

- SSL Kolkata vessel at 88.775º E, 21.4416º N drifted Northwards. The blue pin denotes the initial position of the vessel. The yellow pin shows the drifted position (88.775º E, 21.4537º N) on 15 July 2018.
- Black dot - SSL vessel - 05 July 2018, Black plus - drifted position - 15 July 2018.
- A drift ~1.43 Km was noticed

# EXTENDED RESEARCH TOWARDS THE BENEFIT OF MARINE STAKEHOLDERS

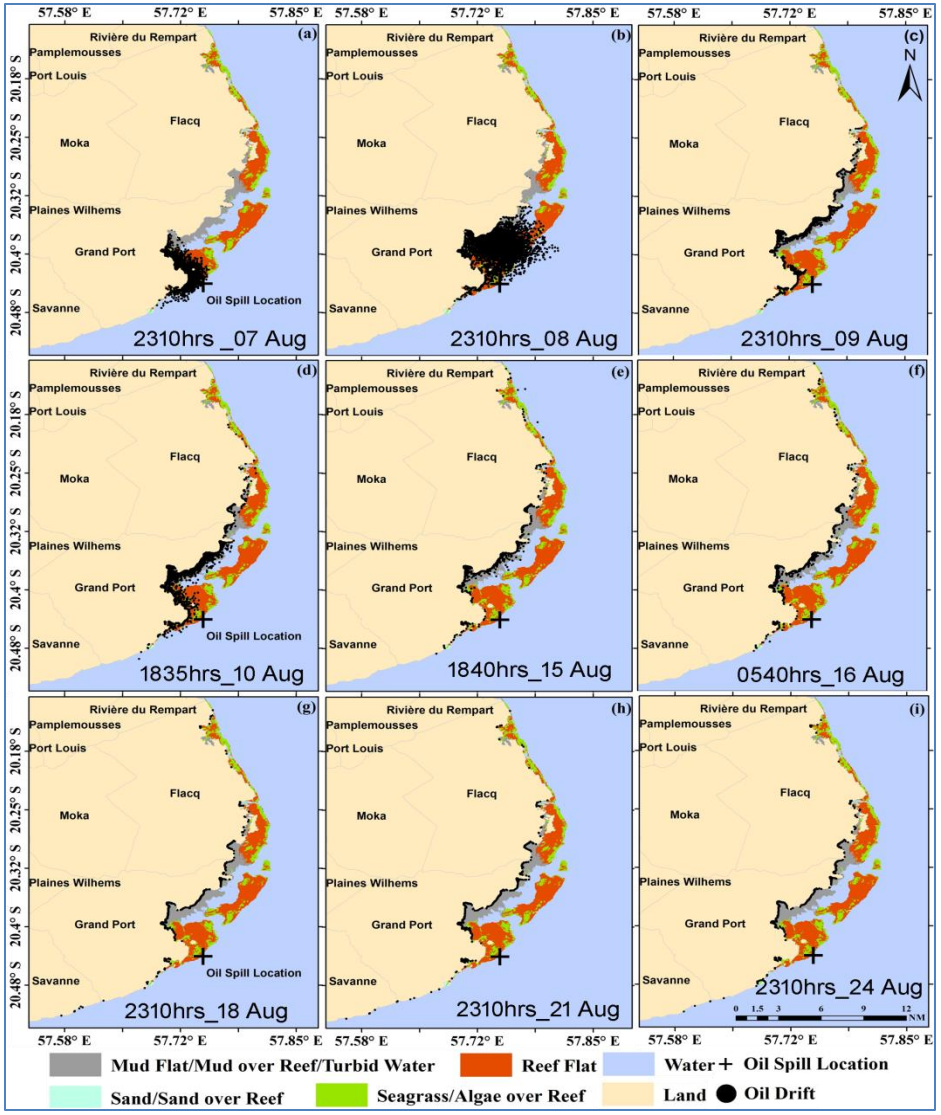
# MAURITIUS OIL SPILL – ESTIMATING EXTENT OF AFFECTED CORAL REEF ZONES DUE TO OIL SPILL




OIL DRIFT SIMULATION/ VALIDATION ON 10 AUG 20




EXTENT OF AFFECTED CORAL REEFS



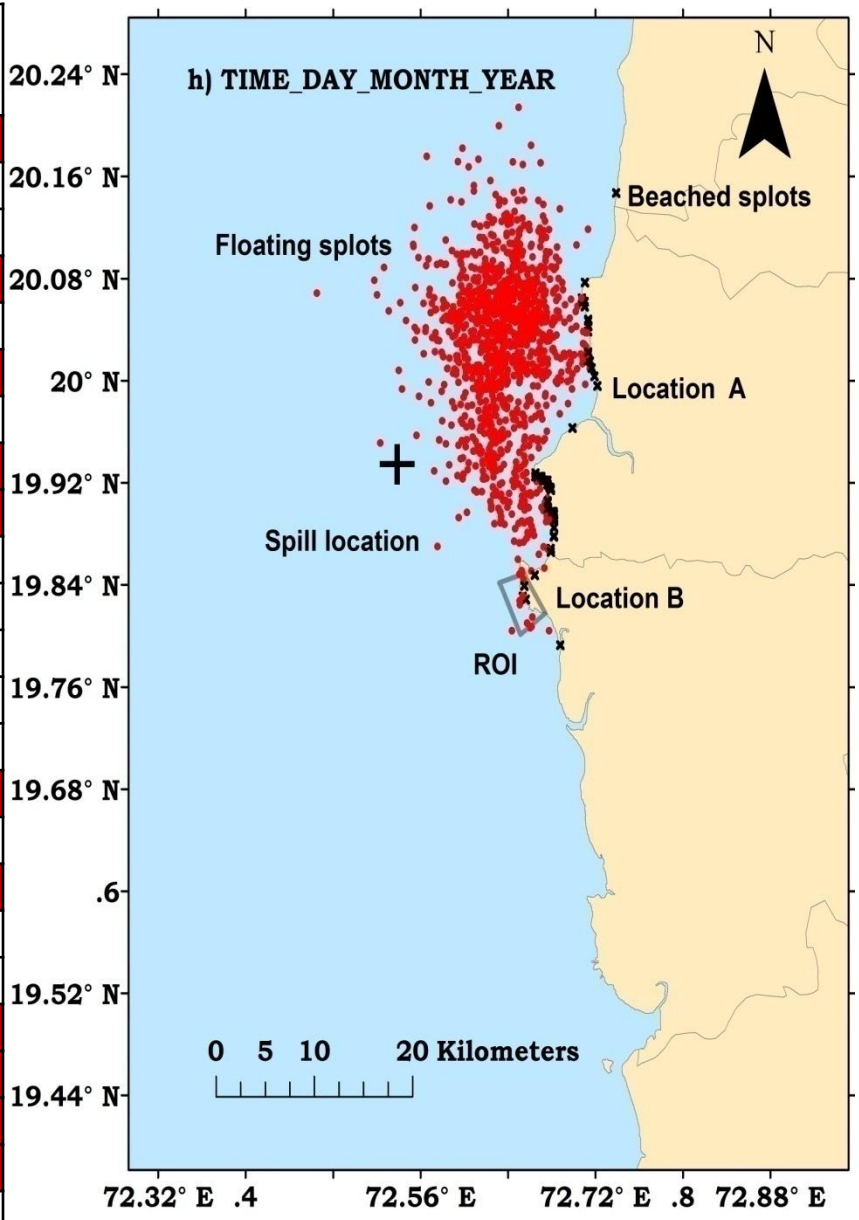

OIL DRIFT OVER CORAL REEFS

- On 06 Aug 2020, MV Wakashio spilled ~1000 tons of Fuel oil at 20°26'17.2"S 57°44'40.7"E off Mauritius.
- The extent of affected coral reef affected due to oil spill was estimated by superimposing oil drift over coral reefs.
- On 08 Aug 2020, It was found that, the reef flats were highly affected.

***Prasad, S. J.,*** *Nair, T. M., Joseph, S., & Mohanty, P. C*. (2022). Simulating the spatial and temporal distribution of oil spill over the coral reef environs along the southeast coast of Mauritius: A case study on MV Wakashio vessel wreckage, August 2020. Journal of Earth System Science, 131(1), 1-10.*

# ESTIMATING THE IMPACT BY OIL SPILL MODELING IN CONTINGENCY PLANING

| S. No | Mon | Type of tide | Date/time (0000hrs to 2400 hrs) | 18 th Hr | 36 th Hr | 54 th Hr | 72 nd Hr |
|---|---|---|---|---|---|---|---|
| 01 | Jan | spring | 12 to 14 Jan (2017) | N | Y | Y | Y |
| 02 | | neap | 20 to 22 Jan (2017) | N | N | N | N |
| 03 | Feb | spring | 11 to 14 Feb (2017) | N | N | N | N |
| 04 | | neap | 19 to 21 Feb (2017) | N | Y | Y | Y |
| 05 | Mar | spring | 12 to 14 Mar (2017) | N | N | N | N |
| 06 | | neap | 20 to 22 Mar (2017) | N | N | Y | Y |
| 07 | Apr | spring | 11 to 13 Apr (2017) | N | N | N | N |
| 08 | | neap | 19 to 21 Apr (2017) | N | Y | Y | Y |
| 09 | May | spring | 11 to 13 May (2017) | N | N | Y | Y |
| 10 | | neap | 19 to 21 May (2017) | N | N | N | N |
| 11 | Jun | spring | 09 to 11 Jun (2017) | N | N | N | N |
| 12 | | neap | 17 to 19 Jun (2017) | N | N | N | N |
| 13 | Jul | spring | 09 to 11 Jul (2017) | N | N | N | N |
| 14 | | neap | 17 to 19 Jul (2017) | N | N | N | N |
| 15 | Aug | spring | 07 to 09 Aug (2017) | N | Y | Y | Y |
| 16 | | neap | 15 to 17 Aug (2017) | N | N | N | N |
| 17 | Sep | spring | 06 to 08 Sep (2017) | N | N | N | Y |
| 18 | | neap | 13 to 15 Sep (2017) | N | N | N | N |
| 19 | Oct | spring | 06 to 08 Oct (2017) | N | N | N | N |
| 20 | | neap | 12 to 14 Oct (2017) | N | Y | Y | Y |
| 21 | Nov | spring | 04 to 06 Nov (2017) | N | Y | Y | Y |
| 22 | | neap | 11 to 13 Nov (2017) | N | Y | Y | Y |
| 23 | Dec | spring | 03 to 05 Dec (2017) | N | Y | Y | Y |
| 24 | | neap | 10 to 12 Dec (2017) | N | N | N | N |




**SJ Prasad*,** Alakes Samanta, K.Srinivas, Jithin Abraham, Yatin Grover and T.M.Balakrishnan Nair "Oil spill trajectory prediction and assessing the probable spread and drift towards zone of interest on hypothetical basis" (January 2019).

# ONLINE OIL SPILL ADVISORY (OOSA)

# DEMONSTRATION

# OOSA- SOP & ARCHITECTURE

OPERATOR /USER

Registration

OOSA HOME/DIRECTORY
ENTER :SPILL INFORMATION

Continuous (Enter : Start date/time End date/time)

OR

Instantaneous (Enter :Start date/time Run duration)

Select :Region Map
Enter :spill location
Feed : pollutant/quantity/units

Submit

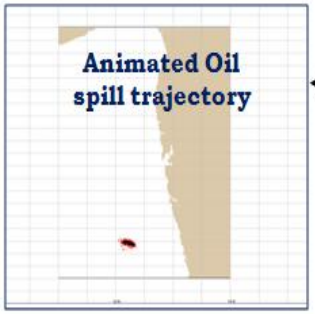
Oil spill trajectory (.mov,.nc,.kml,webmap)

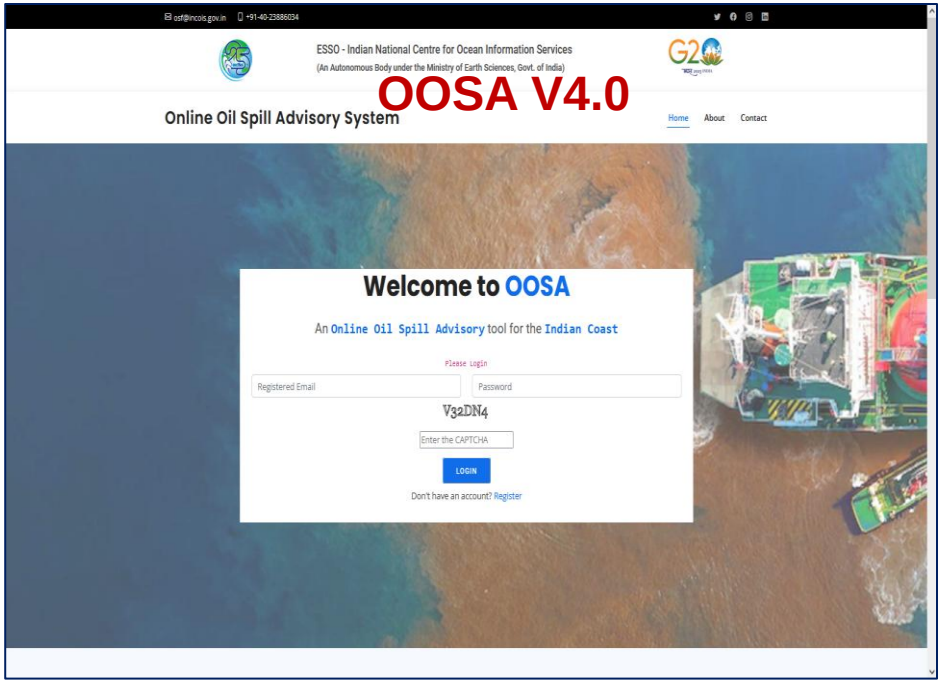


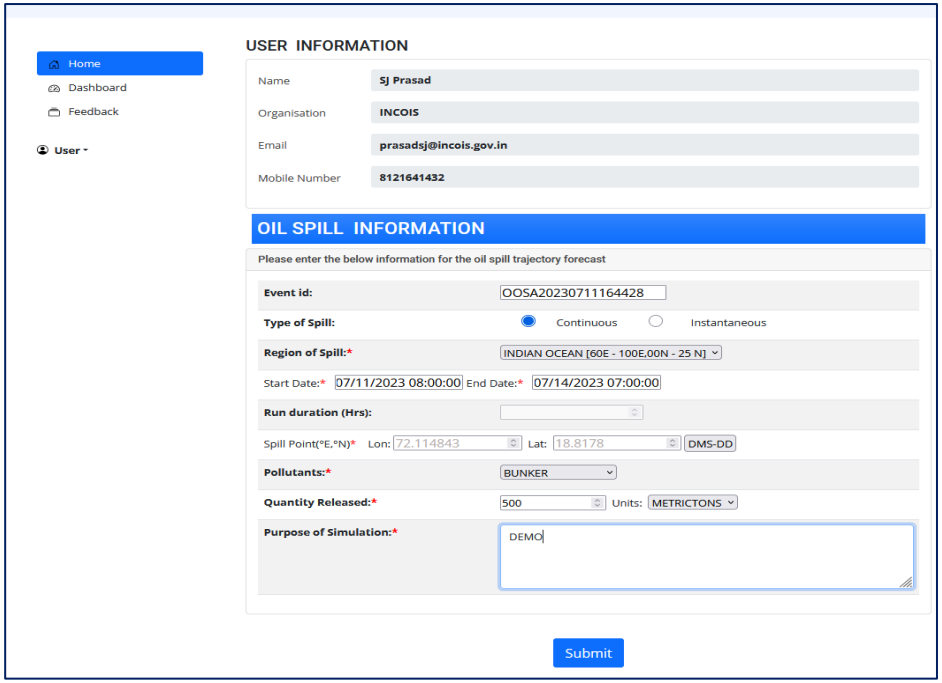
WINDS ECMWF

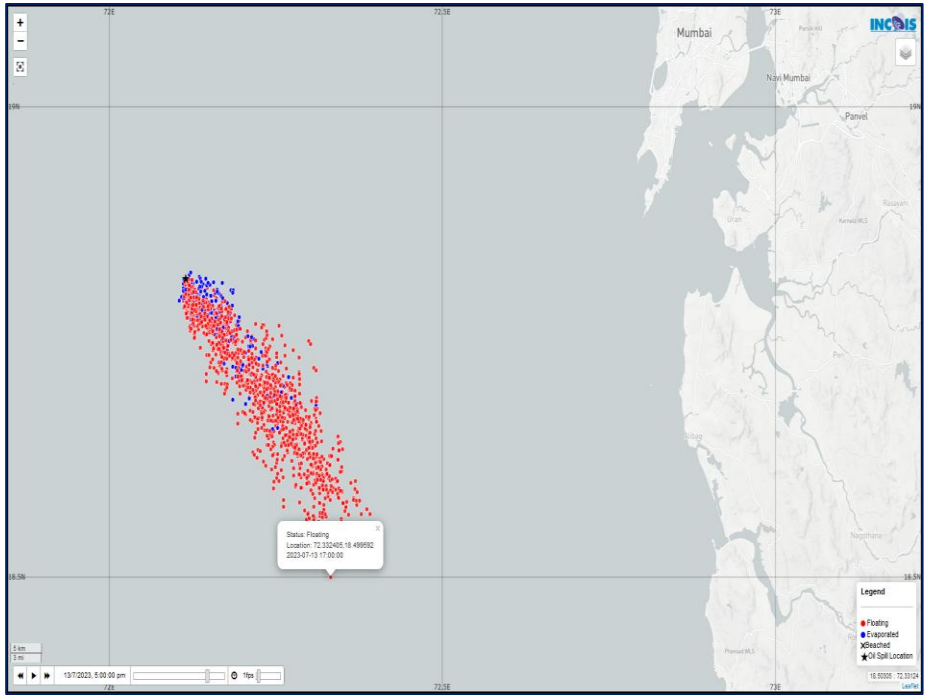
OCEAN CURRENTS

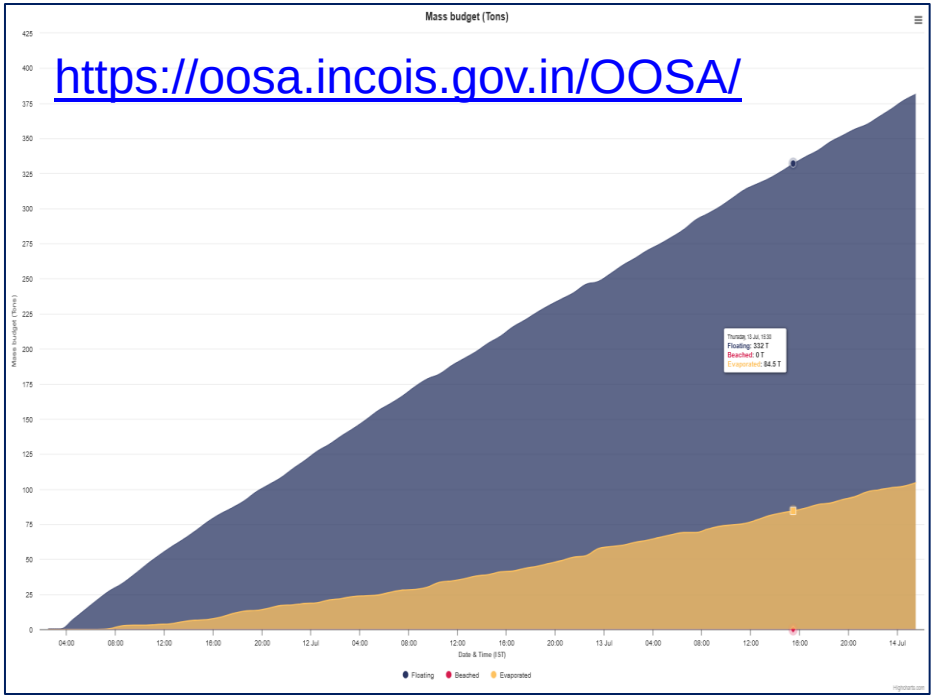
AUTOMATIC TRIGGER OF BATCH GNOME TO GENERATE TRAJECTORY





ESSO - Indian National Centre for Ocean Information Services
(An Autonomous Body under the Ministry of Earth Sciences, Govt. of India)
OOSA V4.0
Online Oil Spill Advisory System
Home
About
Contact
Welcome to OOSA
An Online Oil Spill Advisory tool for the Indian Coast
Please Login
Registered Email
Password
V32DN4
Enter the CAPTCHA
LOGIN
Don't have an account? Register


Home
Dashboard
Feedback
User
USER INFORMATION
Name
SJ Prasad
Organisation
INCOIS
Email
prasadsj@incois.gov.in
Mobile Number
8121641432
OIL SPILL INFORMATION
Please enter the below information for the oil spill trajectory forecast
Event id:
OOSA20230711164428
Type of Spill:
Continuous
Instantaneous
Region of Spill:*
INDIAN OCEAN [60E - 100E,00N - 25 N]
Start Date:*
07/11/2023 08:00:00
End Date:*
07/14/2023 07:00:00
Run duration (Hrs):
Spill Point(°E,°N)*
Lon:
72.114843
Lat:
18.8178
DMS-DD
Pollutants:*
BUNKER
Quantity Released:*
500
Units:
METRICTONS
Purpose of Simulation:*
DEMO
Submit


Mumbai
Navi Mumbai
Panvel
INCOIS
Legend
Floating
Evaporated
Beached
Oil Spill Location


Mass budget (Tons)
https://oosa.incois.gov.in/OOSA/
Floating
Beached
Evaporated

# SUMMARY

- oil spill modeling enhances the preparedness and response capabilities in dealing with oil spills by providing crucial information on spill behavior and its impacts.
- oil spill surveillance plays a critical role in marine oil spill response operations by providing essential information for early detection, monitoring, and tracking of spills.

# WAY FORWARD

- INCOIS is now extending its research in treating different types of oil pollutants by coupling the trajectory model with a weathering module.
- We are into the estimation of particle density of the spilled pollutant in a GIS map and including the response strategies in oil spill modeling
- Improved data representation, enhanced resolution of the input forcings are being carried out. Also Interacting with the research labs in carrying out the tar sand analysis during the oil spill events

# LIST OF PUBLICATIONS/REPORTS

1. **Prasad SJ ***, Balakrishnan Nair TM and Balaji B “Improved prediction of oil drift pattern using ensemble ocean currents” published in “Journal of Operational Oceanography” (Nov 2022)
2. **Prasad SJ***, Balakrishnan Nair TM, Sudheer Joseph and P.C. Mohanty. Simulating the spatial and temporal distribution of oil spill over the coral reef environs along the south-east coast of Mauritius: A case study on MV Wakashio vessel wreckage, August 2020 " published (Feb 2022) at "Journal of Earth System Sciences", Springer Nature.
3. **S. J. Prasad**, P. A. Francis, T. M. Balakrishnan Nair, S. S. C. Shenoi & T. Vijayalakshmi (2019) Oil spill trajectory prediction with high-resolution ocean currents, Journal of Operational Oceanography, DOI: 10.1080/1755876X.2019.1606691
4. **Prasad SJ*,** Balakrishnan Nair TM, Hasibur Rahaman, Shenoi SSC, Vijayalakshmi T, (2018), An assessment on oil spill trajectory prediction - Case study on oil spill off Ennore Port, "Journal of Earth System Sciences", Springer Nature.
5. **Prasad SJ ***, Balakrishnan Nair TM and Vijayalakshmi T. Oil spill trajectory prediction assessment using multi model ocean currents - case study of MT Dawn Oil spill 2017. Proceedings of International Oil spill conference (IOSC 2021) (Scopus indexed).
6. **Prasad SJ *** and Balakrishnan Nair TM “Quantification of oil lost from tanker vessel using space borne radar datasets - Case study of Haldia port oil spill, July 2018” Proceedings of International Oil spill conference (IOSC 2021).
7. **Prasad SJ*,** Balakrishnan Nair T.M, Francis P.A, Vijayalaksmi T (2017) Marine mock drills to combat oil spills - aid to coastal zone management, 3rd International Conference on Environmental Management, 2017.
8. **Prasad SJ***, Balakrishnan Nair T.M, Krishna Prasad B, Kaviyazhahu K, Vijayalakshmi T (2017) An Online Tool for Predicting the Trajectory of the Spilled Marine Pollutant, International Journal of Latest Technology in Engineering, Management & Applied Science-IJLTEMAS vol.6 issue 8s, pp.115-120.
9. **Prasad SJ***, Balakrishnan Nair T.M, Francis P.A and Vijayalaksmi T, Hindcasting and validation of Mumbai oil spills using GNOME, Int. Res. J. Environment Sci., 3(12),(2014).
10. **Prasad, S.J***, Balakrishnan Nair, T.M., Rahaman, H., Joseph, S., Yatin, G., Evaluation of oil spill trajectory model with the observed SVP drifter track. Report No.: ESSO- INCOIS-ISG-MOG-TR-03 (2017), pp. 1-14.
11. **S.J. Prasad***, T.M. Balakrishnan Nair, P.A. Francis & S.S.C Shenoi "Oil Spill Trajectory Prediction System" Blue Waters, Jan 2016,Vol XVII.
12. **Prasad S.J***, Alakes S, Srinivas K, Jithin A, Yatin G, Balakrishnan Nair T.M, Oil spill trajectory prediction for Proposed Vadhavan Port. Report No.: ESSO-INCOIS-ISG- MDG-TR-01 (2019), pp.23- 80.
13. **Prasad S.J***, Balakrishnan Nair T.M and Vijayalakshmi T, Oil slick detection in the marine Environment using space borne synthetic aperture radar sensor, Maritime International Conference 2019.
14. **Prasad S.J***, Pavan Kumar J, Kiran Kumar K and Balakrishnan Nair T.M, Spatial representation of the mass balance of spilled Marine Oil pollutant, Maritime International Conference 2019.

# THANK YOU