ISRO project

NEW PROJECT PROPOSAL "Determination of marine ecosystem health in BoB using physical-biogeochemical models and ANN"

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1.Title of the research proposal

"Determination of marine ecosystem health in BoB using physical-biogeochemical models and ANN".

2. Summary of the proposed research

The aim of the project is to monitor the health of marine ecosystems in Northern Bay of Bengal (BoB) using a combination of biogeochemical models and Artificial Neural Network. This will incorporate the following satellite and insitu data - SST (from AVHRR satellite), SSS (Aquarius satellite), velocities (OSCAR dataset), light (from irradiance data of MODIS aqua and terra satellite), pH (from modeling), pCO2 and pO2 (from modeling), chl-a (from MODIS satellite) all linked together using an Artificial Neural Network to determine the health of the ecosystem. In carrying out the project, we will be modeling biogeochemical parameters using a ROMS (Regional Ocean Modeling System) coupled to PISCES model. The annual variation of the above 8 parameters will be looked at in the effort to predict the ecosystem health in the continental shelf of Northern Bay of Bengal.

For the ANN, 9 hidden layers varying from 30 to 50 neurons, with ReLU activation function and 0.001 as the learning rate, and 2 output layers having 2 neurons with linear activation function will be employed for the network.

3. Objectives

Collection of phytoplankton data from satellites, partial pressure of CO2 and O2 from various datasets, temperature and salinity from AVHRR and Aquarius satellites.
Use these data to calibrate the PISCES-ROMS model to get a continuous time series of the above parameters for a complete year. Numerical simulations using PISCES-ROMS to determine the physical (velocities), chemical (pH) and biological variables (chl-a) as a time series at a location.
Calibate an ANN using the above time series datasests as input variables and marine ecosystem health as the output variable. Validate using known values of Marine Health Index.
Predict for any further year.
Ecosystem health is important in the socio-economic context in terms of fisheries, marine pollution and climate change. Predicting the marine health is very important for fishermen/climate scientists at a national and international level. The application of numerical modeling and ANN in the same is being applied in many countries.

4. Major Scientific fields of Interest

International scenario: The marine resource provides one of the primary sources of animal protein consumed worldwide, and income, especially for people in developing countries (Allan et al., 2005; Welcomme et al., 2010). In developing countries, fish protein sources are mainly derived from the harvest of natural fish stocks, while those in developed countries are produced by recreational fisheries or aquaculture (Allan et al., 2005; Welcomme et al., 2010). Poor people in developing countries depend on food mainly from marine sources (McIntyre et al., 2016). Harvesting natural marine stock has rapidly increased in developing countries but decreased in developed countries (Allan et al., 2005). Overall, the global mairne catch is reported to have increased because of an increase in the exploitation in Asia and Africa (FAO, 2014) and an increase in human population density (McIntyre et al., 2016). In the longer time-scale, climate-related declines in marine healths are projected to render over 10% of the global population vulnerable to malnutrition . This raises significant health equity concerns, as the majority of countries which are highly seafood-dependent (FAO, 2014) are also low-income, food-deficient, countries,like India.

Deterination of marine health is therefore an important topic nowadays not only due to the importance of marine phyto and zooplankton in the daily diet of all communities (including India) but also because of the destruction of many species due to climatic variations associated with this field.

National scenario: India has about 8118 Km. of coastal line and nearly 2 million Sq Km of Exclusive Economic Zone (EEZ) and half a million Sq Km. of Continental Shelf.

From these marine resources, India has an estimated fisheries potential of 4.41 million tonnes. Similarly, we have 3.15 million hectares of reservoirs, 2.5 million hectares of ponds and tanks, 1.25 million hectares of brackish water area, cold water resources of hilly states and all other inland marine resources offer a production potential of about 15 million tonnes. Against this potential, the production of seafood from marine sector was mere 7.77 million tonnes during 2016-17. In this context, optimum utilization of resources has become pivotal to achieve the targeted production. It is against this backdrop that the Govt of India wants to harness all possibilities for intensive and integrated development of marine life sector. This can only be achieeved through a thorough investigation and scientific practise to predict the marine yield by any means.

Importance of the proposed project: In the recent past, Indian fisheries has witnessed a paradigm shift from marine dominated fisheries to inland fisheries, with the latter emerging as a major contributor of fish production from 36% in the mid-1980 to 70% in the recent past. (https://dof.gov.in/marine-fisheries).

Within this marine foods sector, a shift from capture to culture-based fisheries has paved the way for a slightly differentiated blue economy. The main reason why Indian community has made this shift to culture-based fisheries is due to lack of proper scientific investigation into marine production and marine capture where countries like Japan and US lead the way.

We intend to fill this gap for the North Bay of Bengal and prepare a dataset that scientists and marine biologists can use to determine the marine health which can also help the fisheries department to increase their marine food catchments.

Justification for support: In the new government policy, it has been decided to make all the knowledge-base, technology and applications as 'Make in India' so that we become an 'Atmanirbhar Bharat'.This proposal has been framed in that spirit such that the seafood consumption of India becomes not only self-reliant but we can export to other countries as well.

5. Linkages to Space Programme/Deliverables to ISRO on successful completion of the project

Deliverables:

1) Determination of the factors affecting the ecosystem health of the continental shelf of Bay of Bengal.
2) Yearly and seasonal variations of parameters like SST, SSS, pH, pCO2, pO2, light and chl-a using a combination of satellite data and a physical combined to biogeochemical model (ROMS-PISCES).
2) An ANN that combines and synthesizes these factors and predicts the marine health.
3) Effect of climate variations to the ecosystem health..
4) Best marine catchment areas in BoB for various seasons.

Relevance to ISRO goals:

The above project is one of the 'Research Areas in Space 2021' put forward by ISRO (Section I2.23).

6. Approach

BoB is known to be a unique geographical setting due to its enclosed nature with only an opening into Indian Ocean, and the high amounts of freshwater that flow into it (Murty et al., 1992). The region experiences fresh water input with various chemical constituents (Sarma et al, 2012) from rivers such as Ganga, Brahmaputra, Mahanadi, Krishna etc.(UNESCO 1969). This fresh water discharge peaks during summer monsoon (JJA) and the fresh water that comes in then spreads far during (SOND). The implications of this fresh water spread (FWP) have been investigated by many scientists (Murty et al, 1992, Shetye et al., 1996, Vinayachandran et al., 2007). Very recently Sandeep and Pant (2019) showed using idealized numerical simulations that the NorthEasterly and SouthEasterly winds channel the FWP towards the coast while the SouthWest winds push the low saline waters to the central Bay.
The river water inflow is alkaline not only due to its low salt content, but also due to the total alkalinity in it. The change in pH in the Bay over the last few decades or the phenomenon of ocean acidification, has been a topic of great interest to scientists. A decrease in the river input in recent decades coupled with the increased DIC in those waters is slowly increasing the acidity of Bay. The ocean acidification prediction for BoB region, as reported by Feely et al., 2009, puts the pH of the Bay below 8.0 by 2050 and 7.8 by the year 2095. BoB being a vast reservoir of marine life, like corals and shelled fishes, this scenario predicted by Feely concerns scientists and policy makers alike. Joshi et al, (2020, 2021 and unpublished manuscript) have teased out the various factors that affect pH using numerical modeling using the biogeochemical model PISCES combined with the ocean model ROMS. These factors come out to be SST, SSS, DIC and total alkalinity of which SSS is the primary driver in the Bay.

The current study aims to study the marine health in the continental shelf of Northern Bay in the area near West Bengal and Orissa. This shelf is complicated due to the interplay of many factors there like the tides, local winds, the monsoonal wind circulation andthe freshwater plume dynamics. The large freshwater input into the Bay from various rivers makes the ocean dynamics more complicated (Sumangala et al 2020). We believe a complete study of the marine life in such area can only be produced by a complicated ANN which takes into accout many factors.

Artificial Neural Network is a data-driven pattern developing method used here to study the flow in the continental shelf. Since its conception, numerous models have been developed having improved execution techniques and architecture. Wasserman (1993) and Jain and Deo 2006 provide the history of ANN in elaborate details. In Oceanography and coastal engineering, scientists primarily use 9 hidden layers varying from 30 to 50 neurons, with ReLU activation function, and 2 output layers having 2 neurons with linear activation function. Here the input data is run through hidden nodes transforming the results using a sigmoid transfer function (Sumangala et al., 2020).

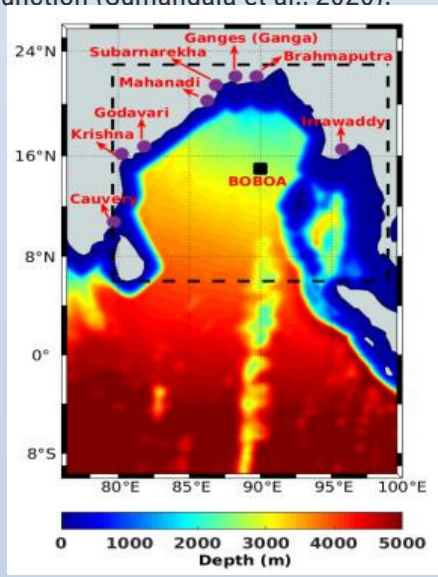

Fig 1: Bay of Bengal basin with major rivers flowing into it

6.2. Material and Methods

Site Specification: Region of study is given in Fig 1. The domain of simulation is 20o N to 23o N; 87o E to 91o E which is a subset of the Figure 1.

6.3 Models used:

A) Delt3D is a hydrodynamic code that can be run in 2D or 3D that calculates the flow resulting from tidal and meteorological forcings on a well-defined grid. In our study here, the model will be run for January-October 2018. We choose 120 min as the time interval and include major tidal constituents taken from the global tidal model TPXO 7.1. The bathymetric chart is taken from GEBCO 08 grid of Reynolds and Smith. Horizontal resolution is 0.015o while the vertical resolution is 2 m. The total matrix of grids is 500 X 405.

B) For studying the pH, the present study couples the Regional Oceanic Modeling System (ROMS) (physical model) (Shchepetkin and McWilliams, 2005, 2009) to the Pelagic Interaction Scheme for Carbon and Ecosystem Studies (PISCES) (biogeochemical model) (Aumont et al., 2003; Aumont and Bopp, 2006). Details of the model used can be seen in Joshi et al., (2020), (2021). The climatological river discharge data is included in the coupled model from Dai et al. (2013). The horizontal resolution is 1/7o with 32 sigma layers as vertical resolution. The Comprehensive Ocean-Atmospheric Data Set (COADS) (Worley et al., 2005) is used to provide the heat fluxes, temperature, humidity (both relative and specific), and density of air. The E-P and shortwave radiations are also provided from the COADS data set. The monthly climatology of winds and wind stresses are used from the QuikSCAT satellite scatterometer from 1999-2009 (Risien and Chelton, 2008).

6.4 Validation dataset

OSCAR contains near-surface ocean current estimates directly calculated from sea surface height, surface wind vectors and sea surface temperature. This is the combined data from various satellites like the TOPEX-POSEIDON altimeters, JASON, Poseidon 2 altimeter, DMSP F-8, 10,11, special sensor microwave imager (SSMI), Seawinds from QUICKSAT scatterometer and Reynolds Smith sea surface temperature data and other insitu instruments. Data are on a 1/3 o grid with a 5 day resolution and is generated by Earth Space Research. (https://www.esr.org/research/oscar/oscar-surface-currents).

The Sea Surface Salinity in our study will be derived from the Aquarius satellite. NASA's Aquarius was the primary instrument on the SAC-D spacecraft. It consisted of three passive microwave radiometers to detect the surface emission that was used to obtain salinity and an active scatterometer. While salinity levels in the open ocean generally range from 32 to 37 psu, the Aquarius sensor was able to detect changes in salinity as small as 0.2 psu.

6.5 Artificial Neural Network

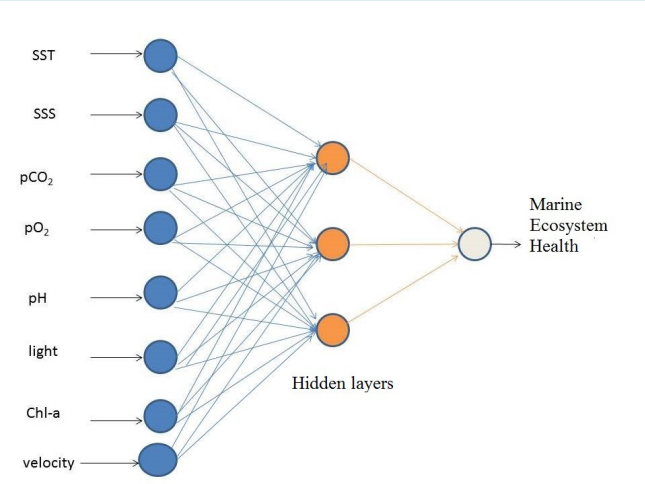

Fig 2: Input and output parameters of the ANN used.

The inputs to the ANN are the SST, SSSS, pCO2, pO2, pH, light, chl-a and the flow velocities.The data having the inputs and target data, will be divided into training and testing by using the train-test split from scikit-learn library (Pedregosa et al.,2011). 80% of the data to be used for training and 20% for testing. Random Search class from Keras tuner (Omalley et al., 2019) is to be employed for hyperparameter tuning for ANN. 9 hidden layers varying from 30 to 50 neurons, with ReLU activation function and 0.001 as the learning rate, and 2 output layers having 2 neurons with linear activation function is to be employed for the network. The training set to be divided into 10 kfolds and is to be trained for 1000 epochs. The average loss function, here the mean square error, will be plotted for trained and validation set. An MLR (Multiple Linear Regression) model can also also set up with the same dataset.

Fig 3 shows the results from PISCES-ROMS coupled model runs with sensitivity to various drivers carried out for a point on the continental shelf. As can be seen, the pH starts increasing from the period of SouthWest monsoon (JJAS). The pH reaches a maximum by October and then starts decreasing. The alkaline water spreads in the Bay in post-monsoon period. Fig 3 is also from this model output which shows how the alkaline water spreads in the Bay over various months. The decrease in the river inflow in recent decades and an increased DIC concentration in the river water in recent years makes the Bay more acidic, a cause for concern.

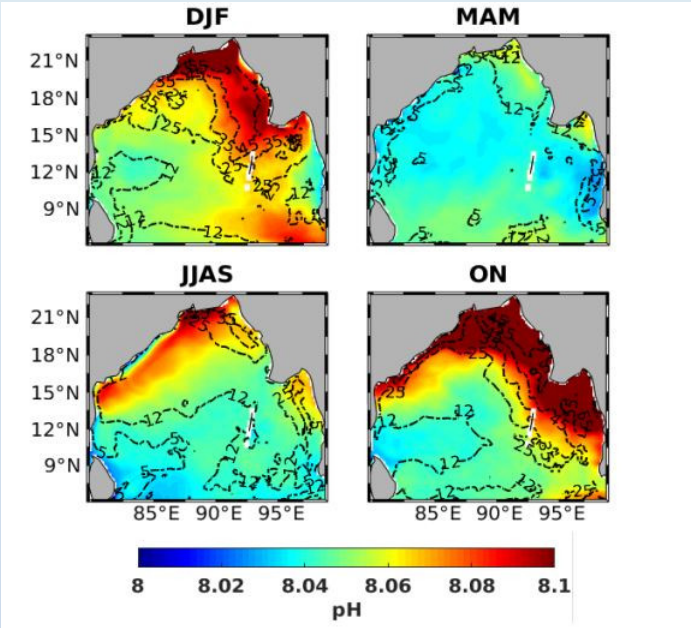

Fig3: Spread of pH over the year in BoB

From these various models, we can collect the data needed for determining the marine ecosystem health. SST can be taken from the AVHRR satellite data, while the SSS can be taken from Aquarius stellite data. The units of pCO2, pO2 and pH can be derived by running the PISCES-ROMS code for a climatological data set. The chla and irradiance data can be taken from MODIS terra and aqua sensors. MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites.

Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths (see MODIS Technical Specifications). The flow velocities can be taken either from the Delft3D or from ROMS. Once the entire dataset is collected, we can put it into the ANN to determine the ecosystem health at various locations of BoB shelf.

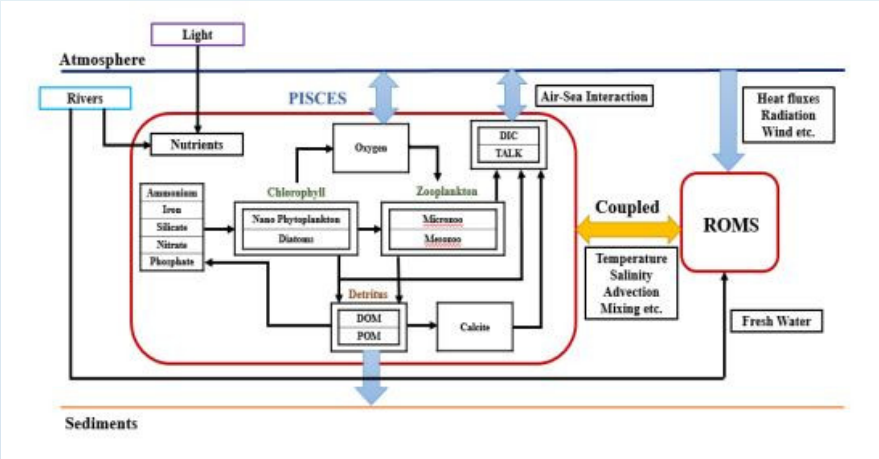

Fig 4: Schematic of the total setup

Figure 4 above shows a schematic of the entire bio-geochemical setup linked to the physical model ROMS. With this coupled model runs, we can get the required yearly variation of all the biogeochemical factors that affect the marine health. We thus use these factors to input to the ANN as described before.

The marine total catch contributes around 20% of fish production in India. Hilsa (Tenualosa ilisha) as a single species accounts for more than half of the total marine catches. In quantitative terms, Hilsa catch is 12% of the total fish production in BoB and 2% of entire population engaged with this fishery.

The major species in BoB are finfish, shrimp, crabs, lobster, mollusks, starfish, cuttlefish, squid, snakes, turtles, crocodile and mammals. The most abundant groups are catfishes (Ariidae) which account for 11.99%, croakers (Sciaenidae) for 10.37% and threadfin bream (Nemipteridae) for 9%. The marine catch is subdivided into industrial and artisanal fisheries. The industrial fishery is based on trawl (shrimp trawl and fish trawl) fishery. Out of the total 127 trawlers, 45 are shrimp trawlers and the remaining are finfish trawlers DOF (Department of Fisheries).

The fish species-wise catch production and % compositions are shown in Fig.5

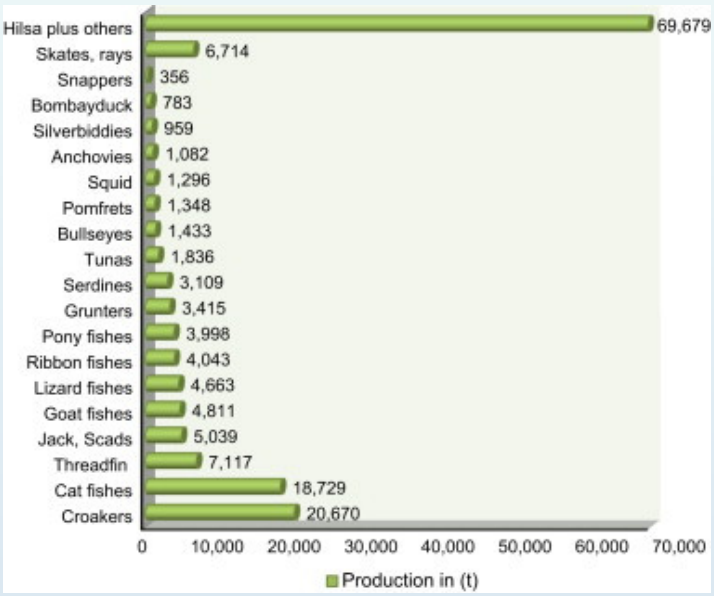

Fig 5: Fish yields in BoB

In the BoB within the territorial waters of Bangladesh there are four major fishing grounds which include: (i) South patches, (ii) South of south patches that lies between 20°50'N to 21°40'N latitude and 91°00'E to 91°50'E longitude covering an area of about 6200 km, (iii) The Middle Fishing Ground is situated between 20°50'N to 21°20'N latitude and 90°00'E to 91°00'E longitude that covers an area about 4600 km, (iv) Swatch of No Ground that lies between 21°00'N to 21°21'N latitude and 89°00'E to 90°00'E longitude which covers an area of about 3800 km.

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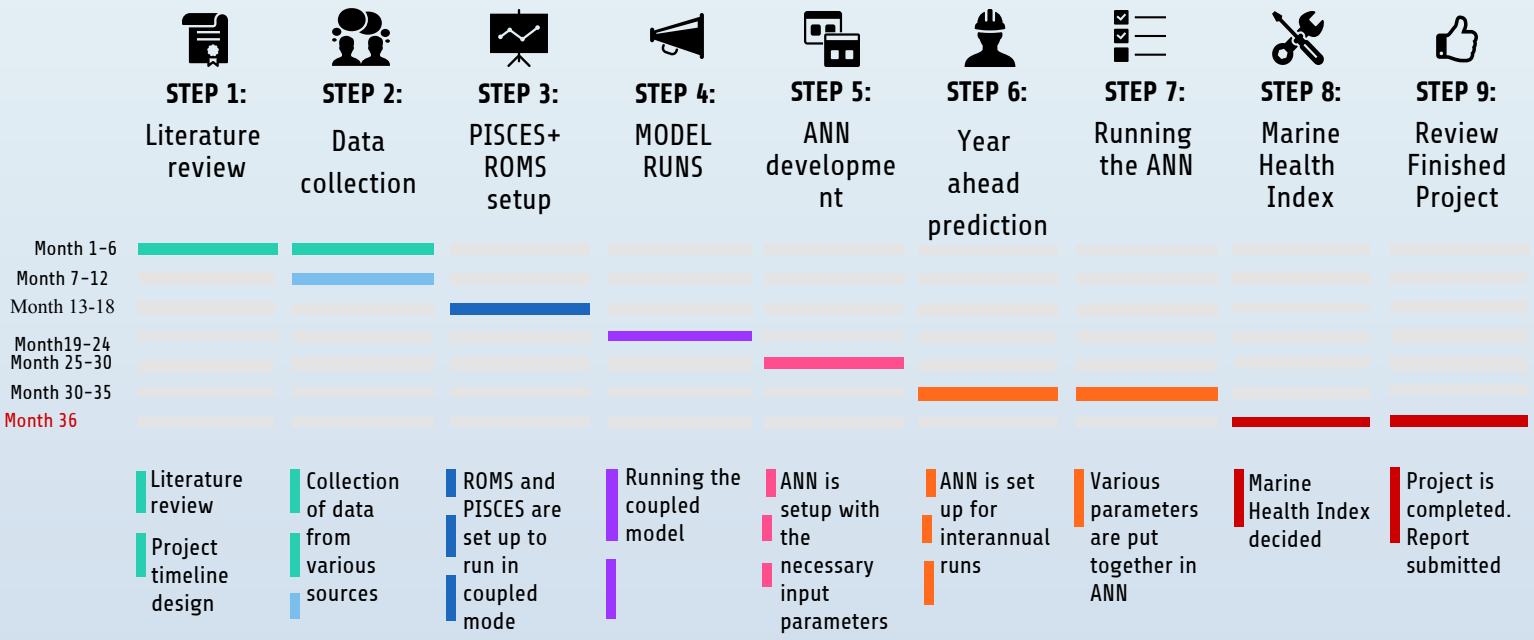
7. Data base and analysis

Please see section 6.

PROJ. WORK PLAN

Red Pill Studio



8. Available Institutional facilities

a) The PI has two workstations of 8 cores each.
b) Delft3D is installed in them.
c)ROMS and PISCES are also installed.
d) The department has a circulating water tank that can be used for experiments.
e) ADV instrument for measuring velocities is available.

9) Fund Requirement

SN	Item	1st Year	2nd Year	3rd Year	total
1	RA at 47k/month*	564000	564000	564000	
2	Satellite data	70000	70000	70000	
3	Contingency	50000	50000	50000	
4	Consummables	190000	130000	130000	
5	IIT Overhead (at 20%) or 5 L whichever is less	174800	162800	162800	
6	Total	1048800	976800	976800	30,02,400

Item	Justification
RA	A post-doc with expertise in ANN and in ROMS is required to be hired
Contingency/Consummables	For expendables like cartridges and other stationaries; There are some routine experiments to be conducted to validate certain parameters and some expenses are to be kept for this.

10. Whether the same or similar proposal has been submitted to other funding agencies of Government of India.
No