MARINE DEBRIS TRAJECTORY SIMULATION
"Case Study in Bali"

I GEDE HENDRAWAN*

*Faculty of Marine Sciences and Fisheries
Universitas Udayana

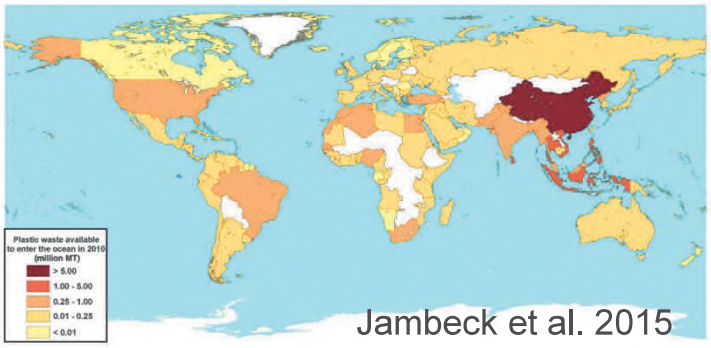
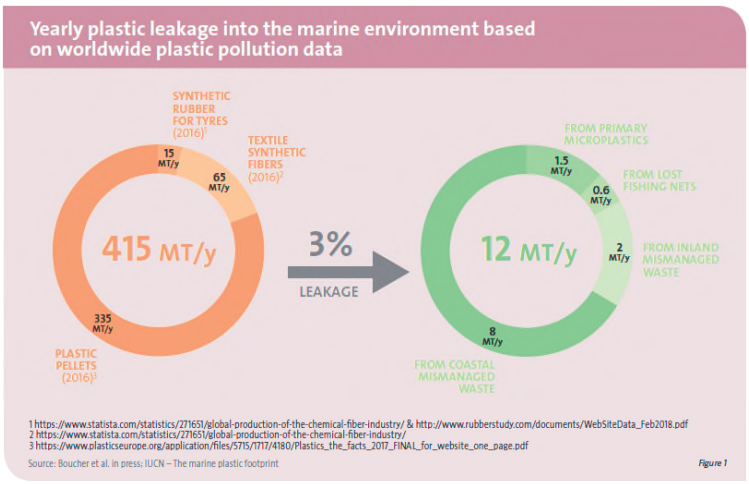
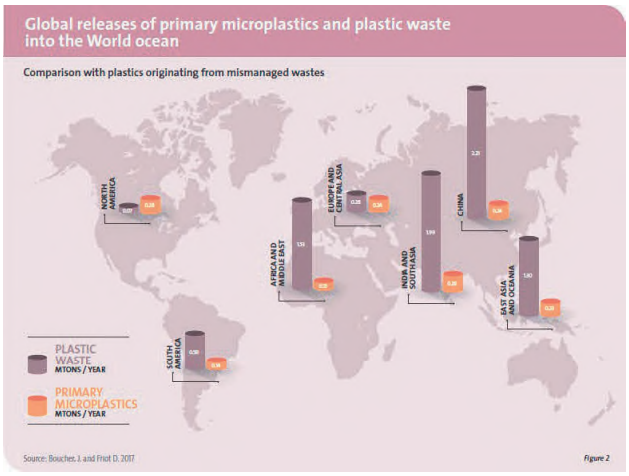


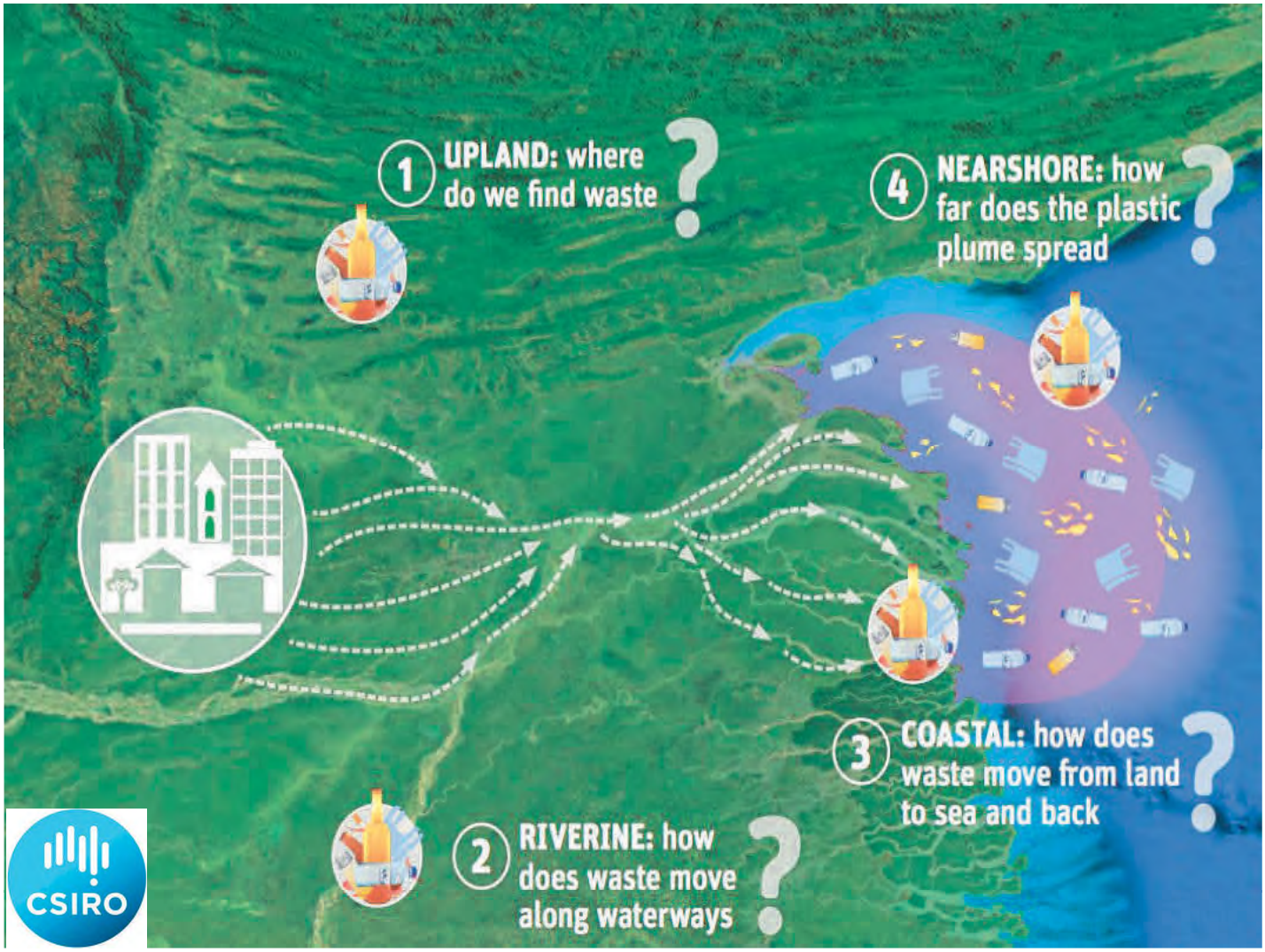
Fig. 1. Global map with each country shaded according to the estimated mass of mismanaged plastic waste [millions of metric tons (MT)] generated in 2010 by populations living within 50 km of the coast. We considered 192 countries. Countries not included in the study are shaded white.

80% comes from land with and estimated 8 Million metric tons of plastic dumped into the ocean each year

Asia: Largest Contributor for Marine Plastics



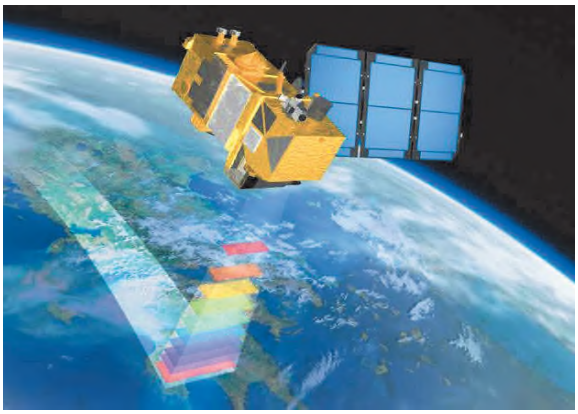




Marine Ecosystem with Plastic

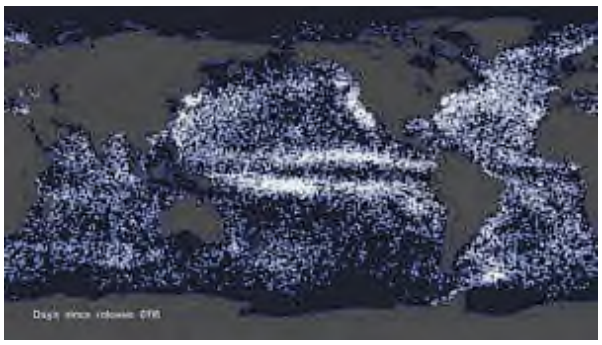
HOW DOES THE PLASTIC TRANSPORT IN THE OCEAN?

Satellite



Observation

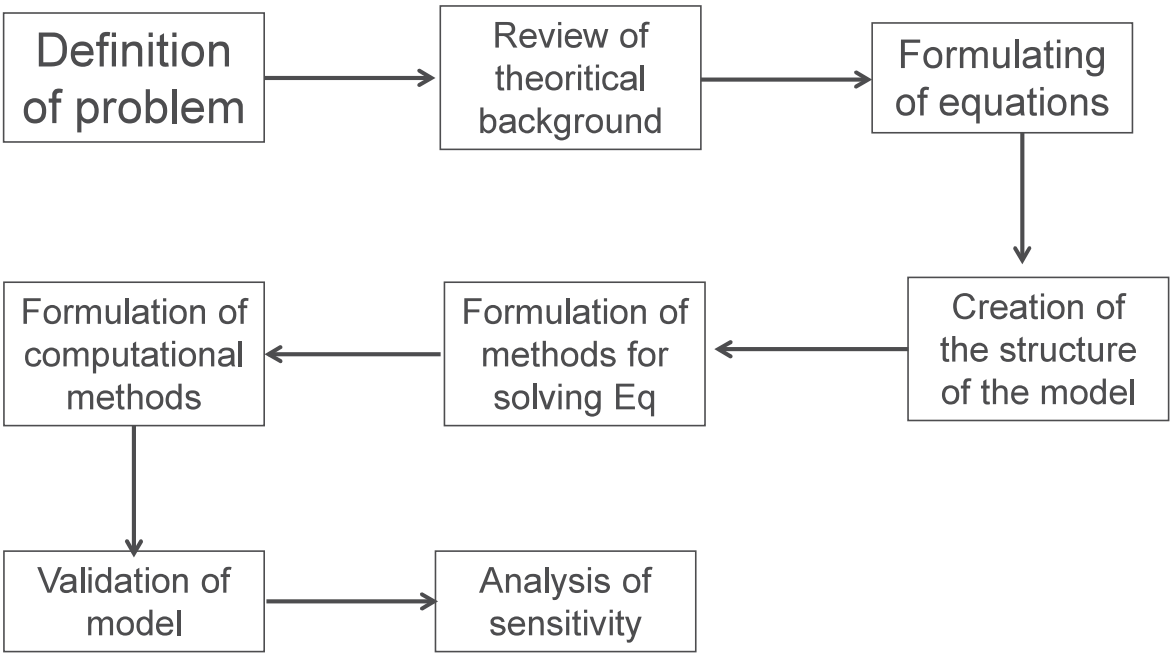
Model Simulation



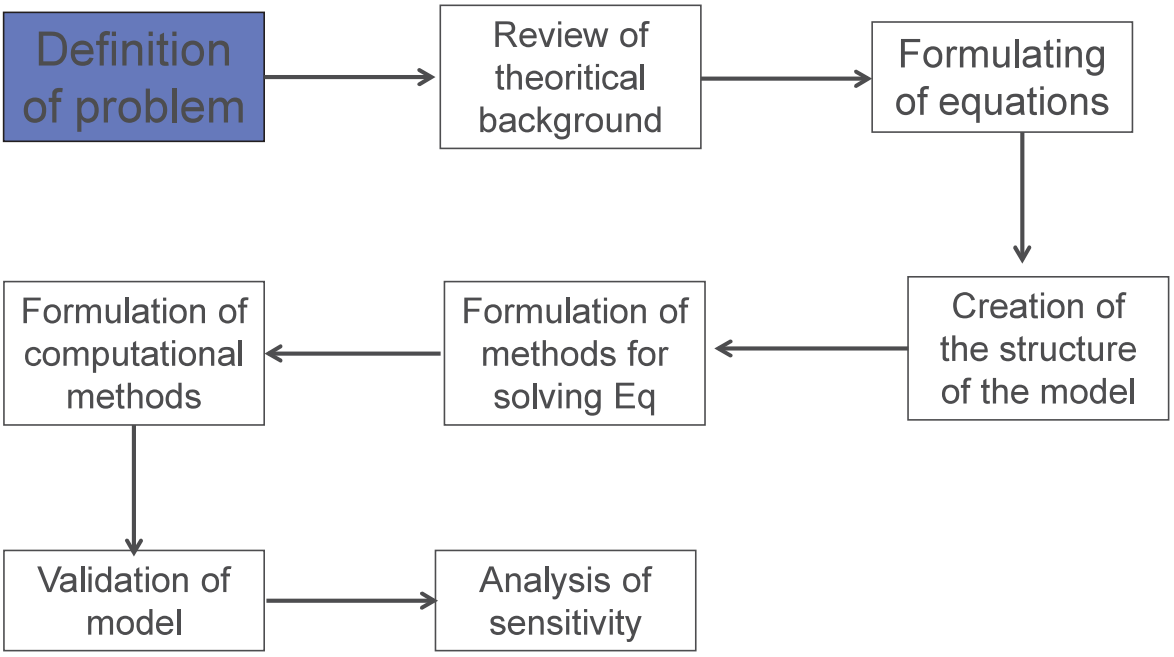
WHY SHOULD USE NUMERICAL MODEL?

They simulate flows in realistic ocean basins with a realistic sea floor.
They include the influence of viscosity and non-linear dynamics.
They can calculate possible future flows in the ocean.
Perhaps, most important, they interpolate between sparse observations of the ocean produced by ships, drifters, and satellites.

STEP IN CREATING A SIMULATION



STEP IN CREATING A SIMULATION



Definition of The Problem: These need to be stated as precisely as possible, preferably in quantitative terms.

Why the plastic memenuhi sebuah kawasan perairan?

what the amount of plastics are?

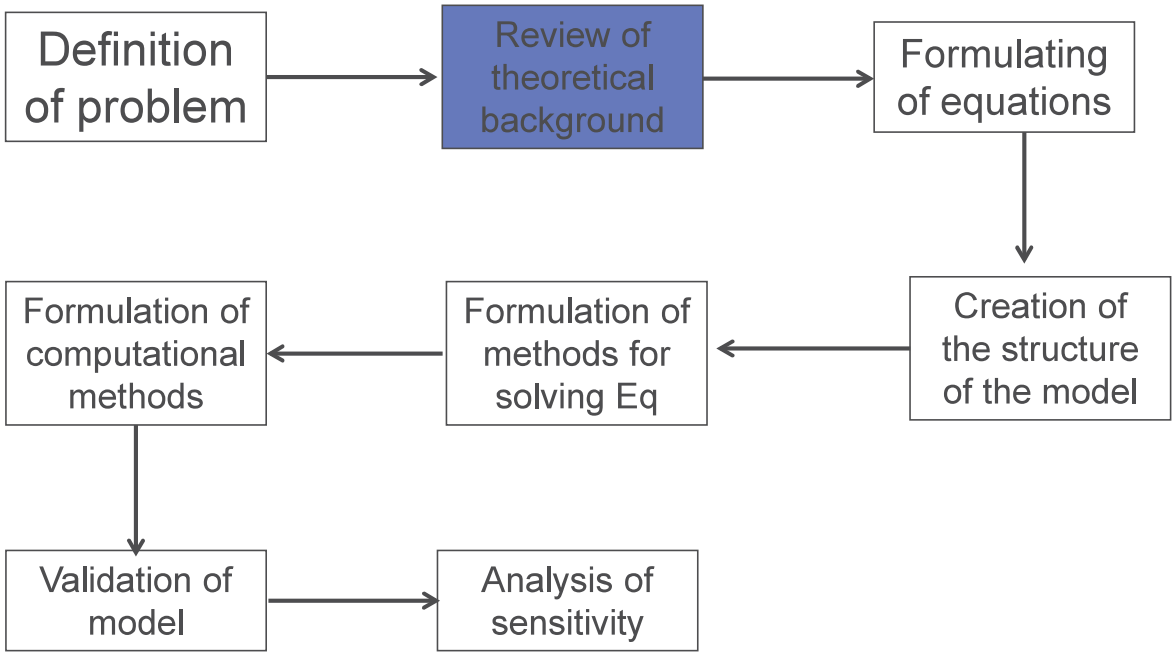
What kind of plastics are pollute?

From where does the plastics coming from?

How the plastics transported into the certain area?

What the mechanism were driven?

STEP IN CREATING A SIMULATION



Review of Theory: The amount of plastic in the area may be influences by various factors, notably:

The source of plastic

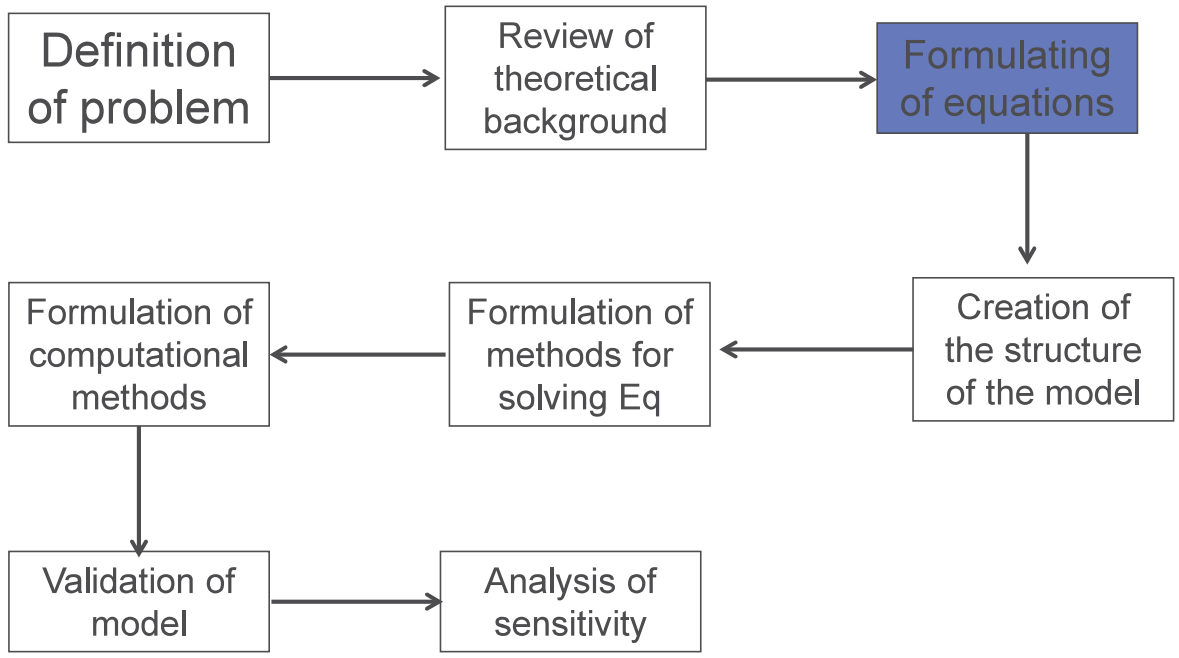
The Ocean mechanism: wind, tide, density current, etc.

Global and local driven

kind of plastic material

Could we simplify it?

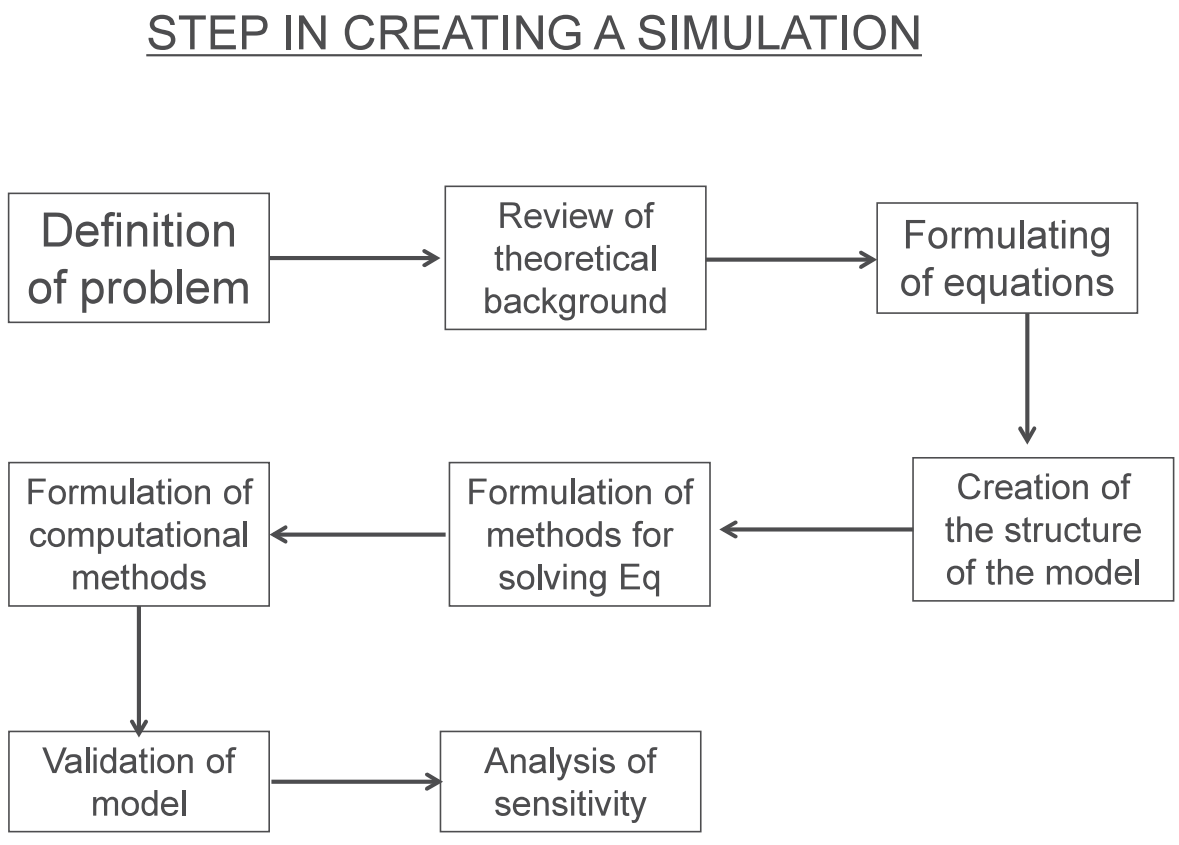
STEP IN CREATING A SIMULATION



Formulation of equation: need to be expressed in some mathematical or statistical format:

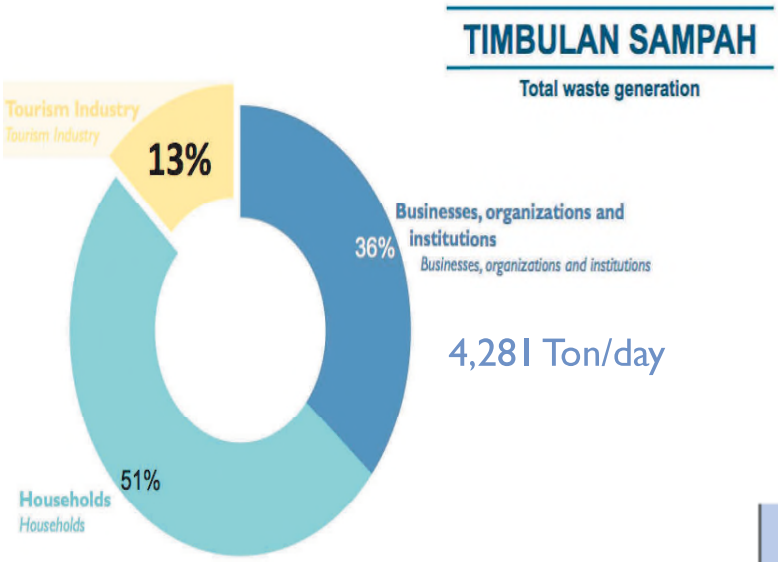
Hydrodynamic Eq: Momentum Eq, Continuity Eq,

Lagrangian Eq



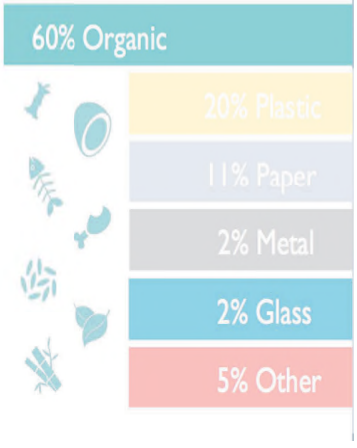
CASE STUDY IN BALI

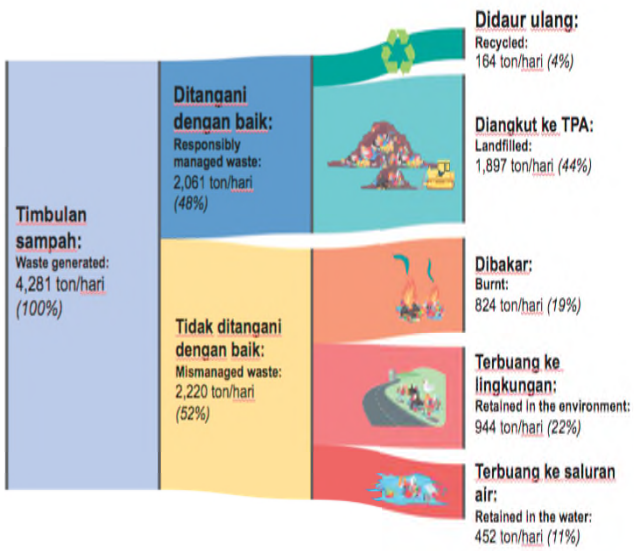
Preliminary Study of Plastic Transport



4,281 Ton/day

WASTE CHARACERISTCS IN BALI PROVINCE (2019)





Sampah Plastik di lingkungan

Plastic Litter in the environment

PANTAI

BEACH

3.9 Ton plastik per km²

SUNGAI

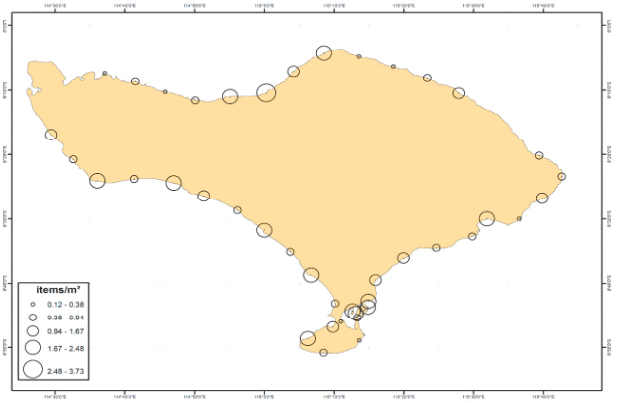
RIVER

20.7 Ton plastik per km²

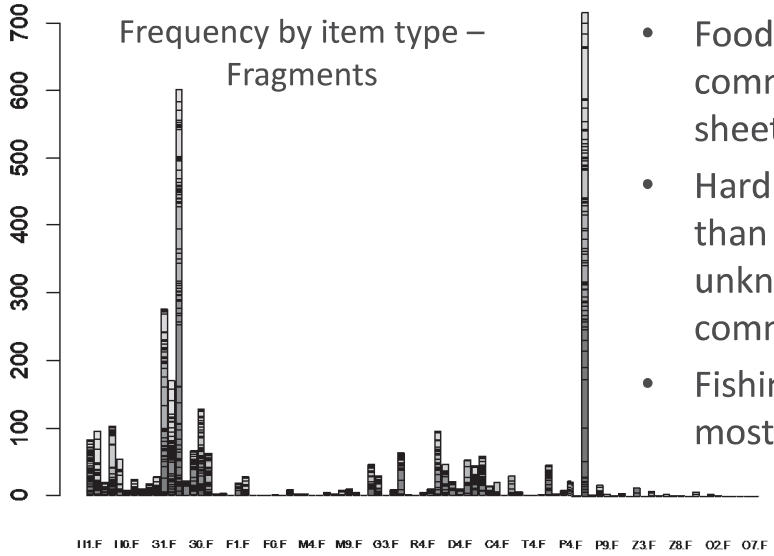
DARATAN

INLAND

2.1 Ton plastik per km²



Marine Debris Distribution in Bali (METODE CSIRO)

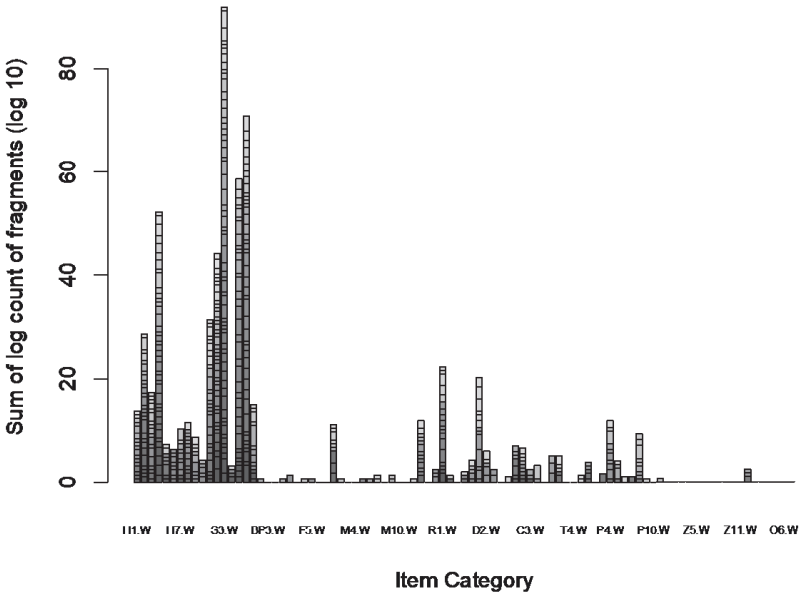


- Food wrappers (PF.6) are the most common item, followed by plastic sheeting and carry bags
- Hard plastic items is less common than elsewhere, eg H10 – hard unknown fragments are usually very common
- Fishing items do not appear in top 10 most common fragments

P6.F	S3.F	S1.F	S2.F	S6.F	H4.F	H2.F	D1.F	H1.F	S5.F
715	602	276	170	128	103	96	95	83	67

Frequency by item type – Whole Items

- Some items are very common (S3-sheeting, S6 – unknown soft plastic)
- Food related items common (H4 – bottle tops, S5 – straws, D1 – foam food container, S1 – thin film carry bag).
- Glass is relatively rare



S3.W	S6.W	S5.W	H4.W	S2.W	D1.W	S1.W	BP1.W	H2.W	R1.W
314	262	218	132	100	81	77	69	66	56

Hydrodynamic Model

Finite Volume Coastal Ocean Model (FVCOM)

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} - fv = -\frac{1}{\rho}\frac{\partial P}{\partial x} + \frac{\partial}{\partial z}\left(K_m\frac{\partial u}{\partial z}\right) + F_u$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} + fu = -\frac{1}{\rho}\frac{\partial P}{\partial y} + \frac{\partial}{\partial z}\left(K_m\frac{\partial v}{\partial z}\right) + F_v$$

$$\frac{\partial P}{\partial z} = -\rho g$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = \frac{\partial}{\partial z}\left(K_h\frac{\partial T}{\partial z}\right) + F_T$$

$$\frac{\partial s}{\partial t} + u\frac{\partial s}{\partial x} + v\frac{\partial s}{\partial y} + w\frac{\partial s}{\partial z} = \frac{\partial}{\partial z}\left(K_h\frac{\partial s}{\partial z}\right) + F_s$$

$$\rho = \rho(T, S)$$

$$\zeta_0 = \bar{\zeta} + \sum_{i=1}^{N_0}\hat{\zeta}_i \cos(\omega_i t - \theta_i)$$

(III.1) (III.2) (III.3) Momentum

(III.4) Continuity

(III.5) Temperature

(III.6) Salinity

(III.7) Density

(III.8) Tidal Elevation

Version 2.5

FVCOM

3D Lagrangian Particle Tracking

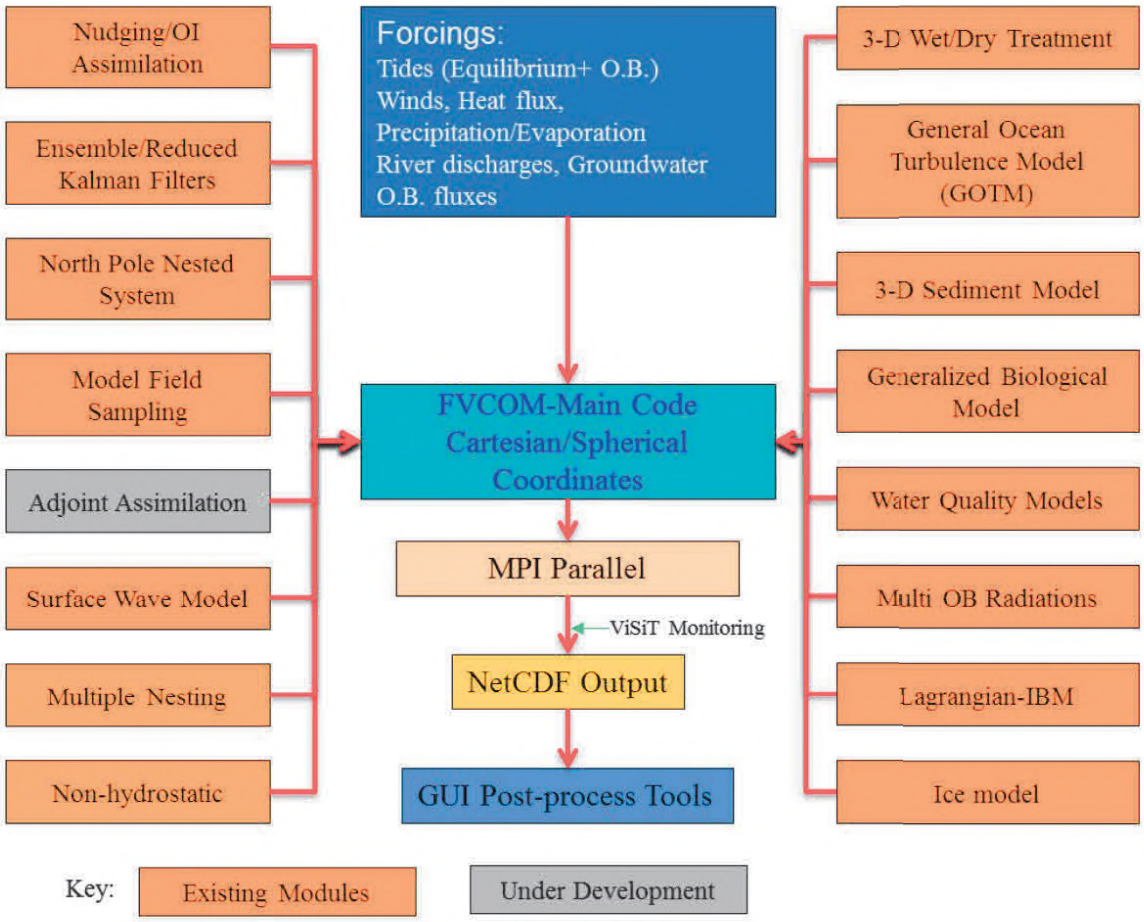
Finite Volume Coastal Ocean Model (FVCOM)

Ordinary Differential Equations (ODE)

$$\frac{dx}{dt} = v(x(t),t) \qquad \text{(III.9)}$$

- x particle position at time t.
- $v(x(t),t)$ velocity on 3-D (x,y,z) from hydrodynamic model

Modules of FVCOM

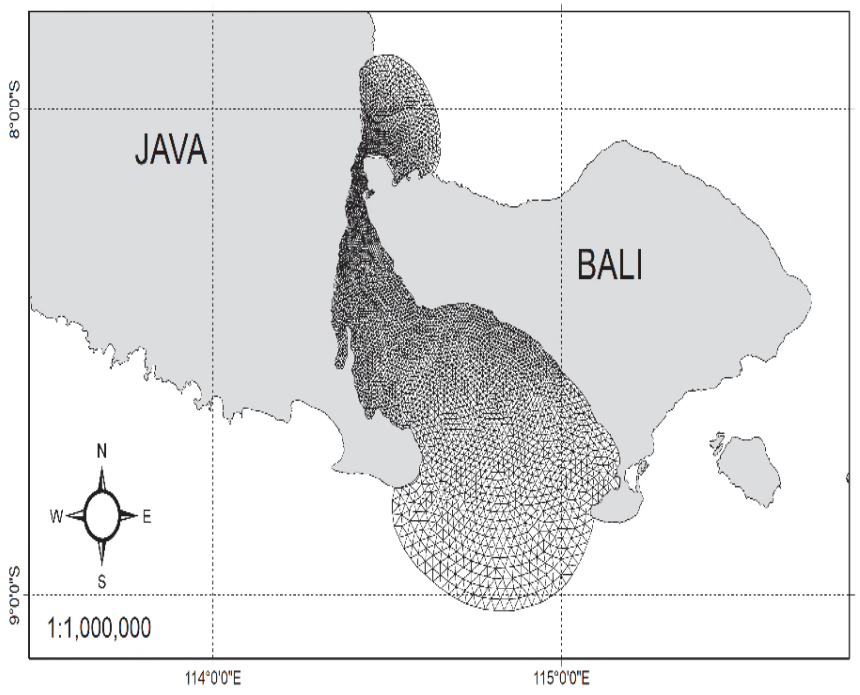


Data Input Model

- DISHIDROS TNI-AL 2006 → Bathymetry
- European Centre for Medium-Range Weather Forecasts (ECMWF) → Wind (3 hours)
- Hybrid Coordinate Ocean Model (HYCOM) → Temperature, Salinity
- Ocean Research Institute (ORI) → Tide Elevation

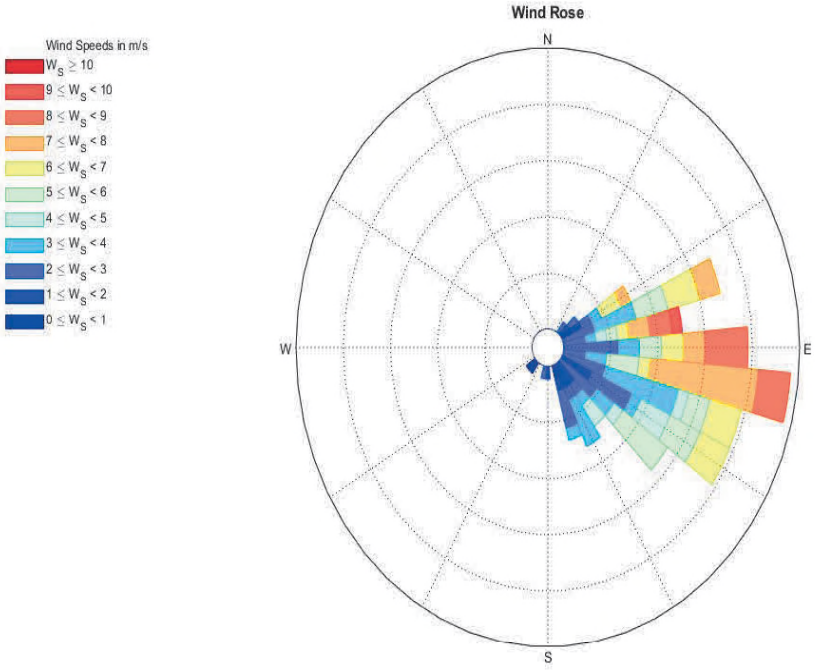
METHODS

Grid Model

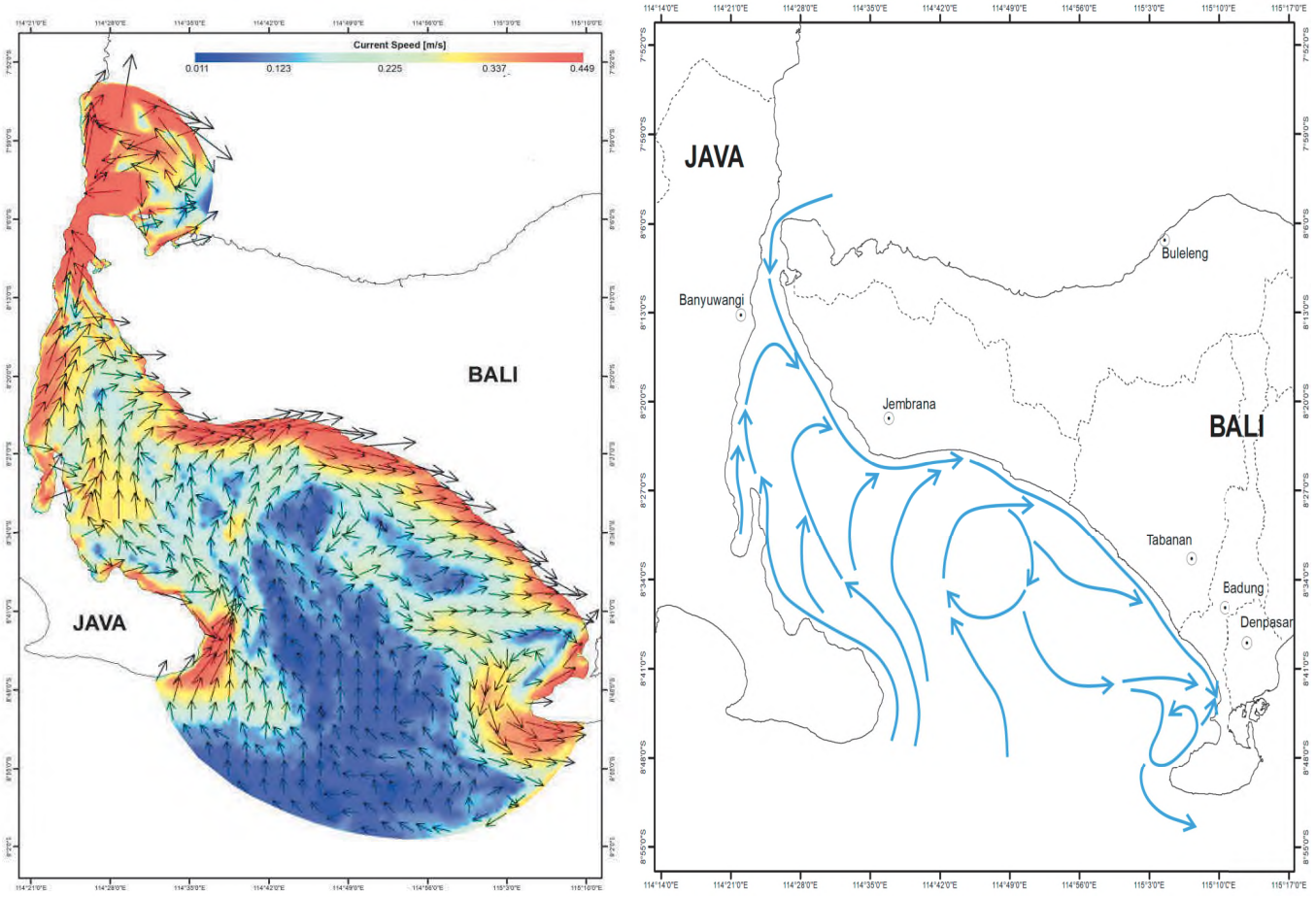


- *Unstructural triangular grid*
- Spatial resolution of 500 up to 1000 m.
- Time step 10 second
- Uniform layer with 20 sigma layer

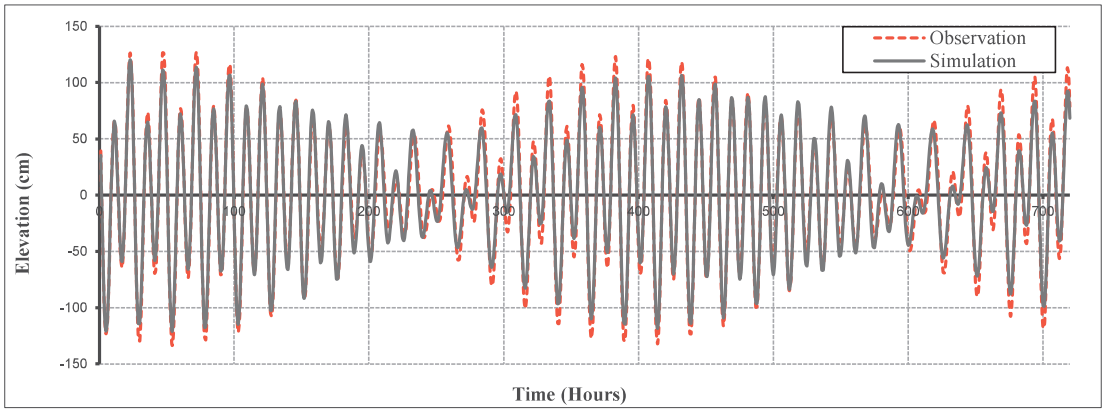
Wind Rose (blowing to)

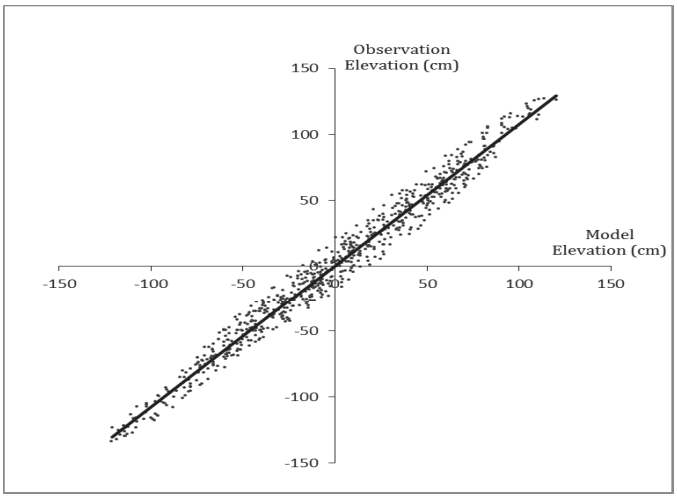


Transport Mechanism Using Numerical Model (Case: Wind + Tide)



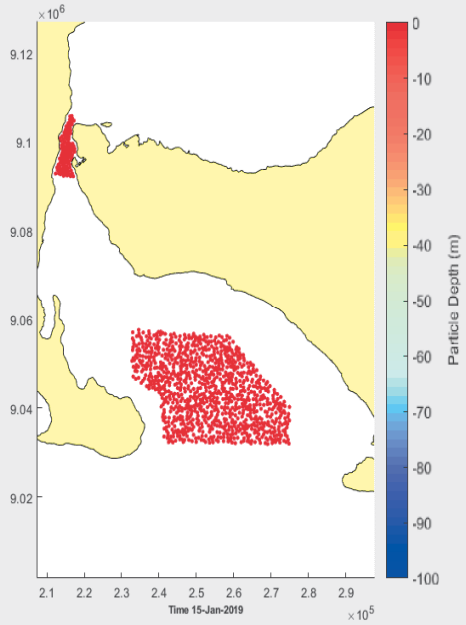
MODEL VALIDATION



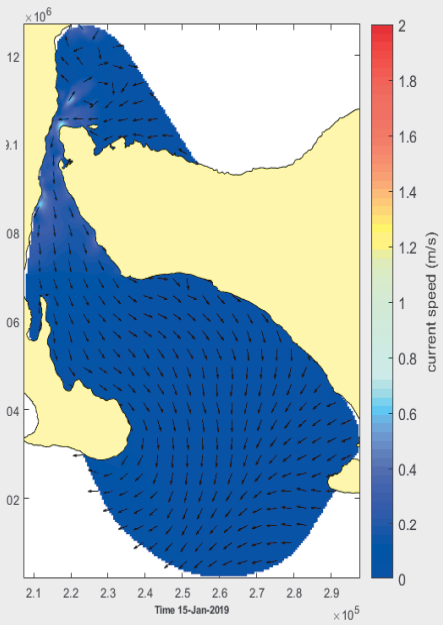


Barotropic Model Tide

Particle Transport

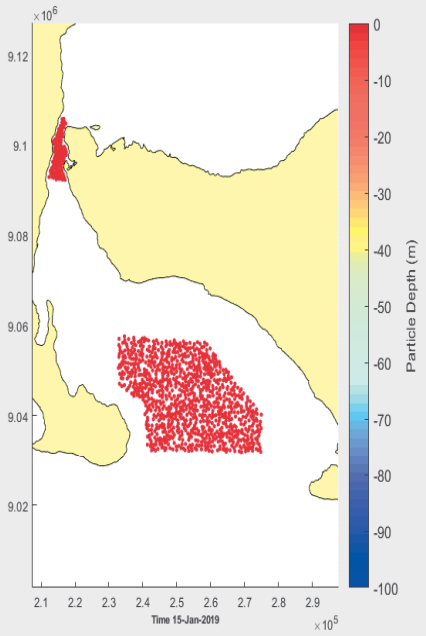


Depth Average current



Barotropic Model Tide+ Wind

Particle Transport



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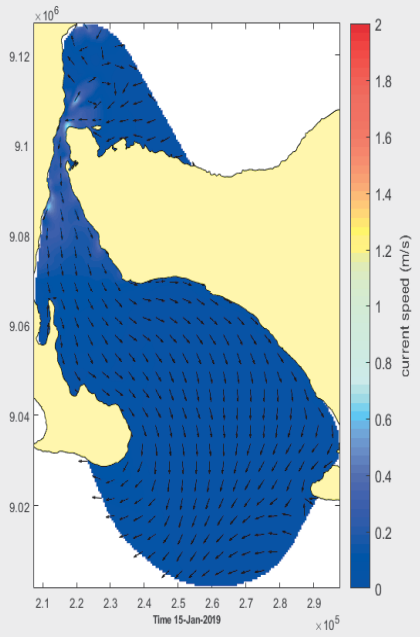
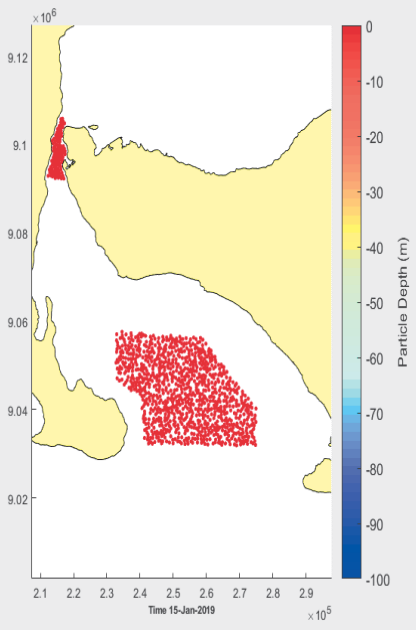


Baroclinic Model Tide

Particle Transport



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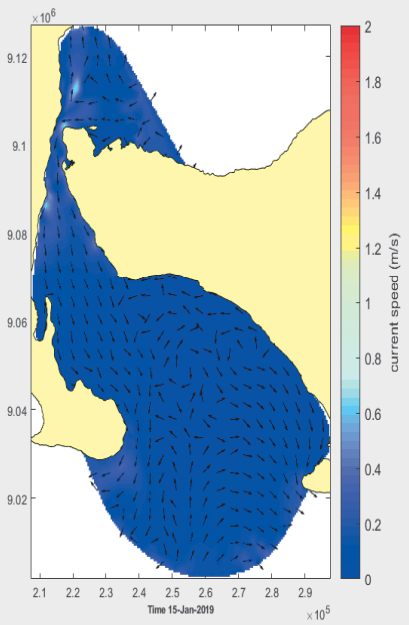
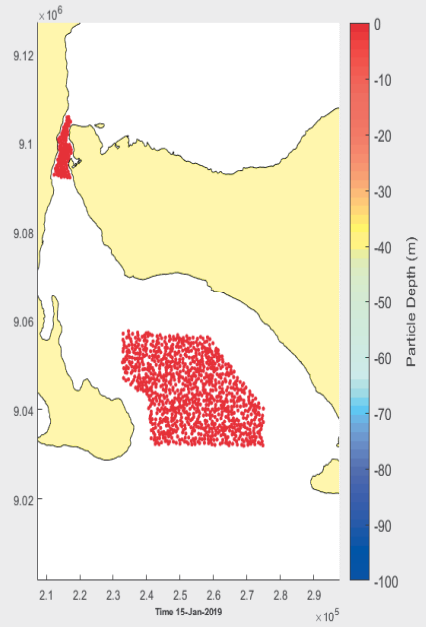


Baroclinic Model
Tide + Wind

Particle Transport



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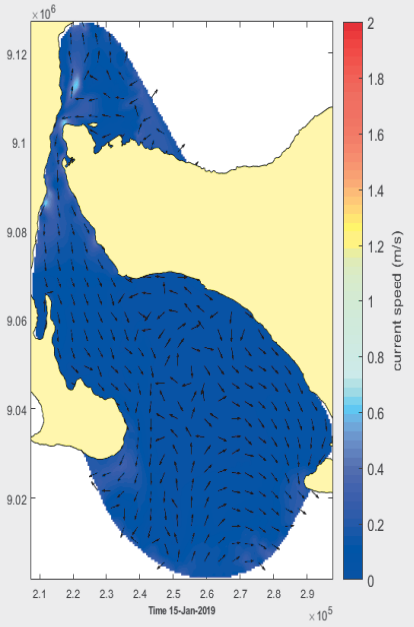
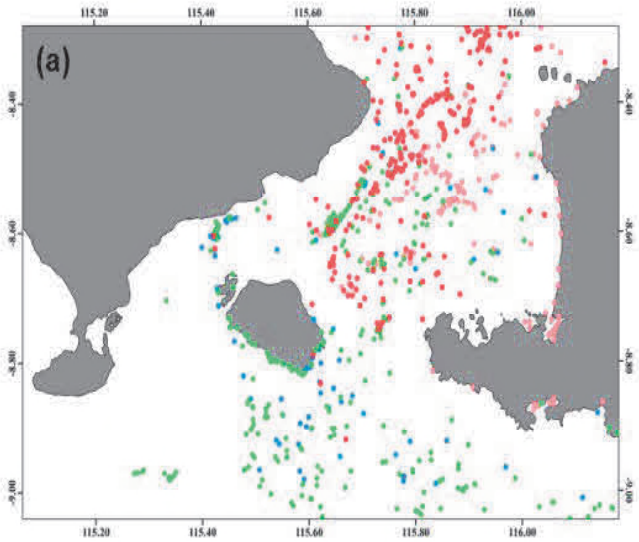
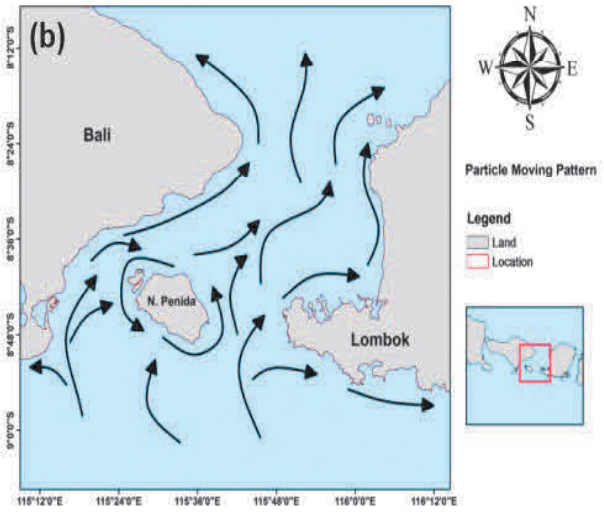


Particle Transport in Nusa Penida MPA and its Adjacent Area





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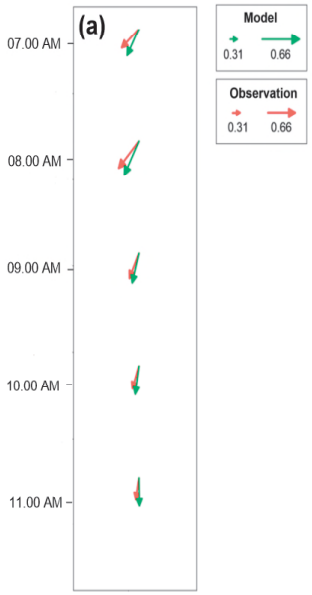

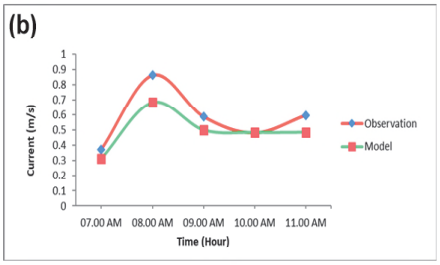

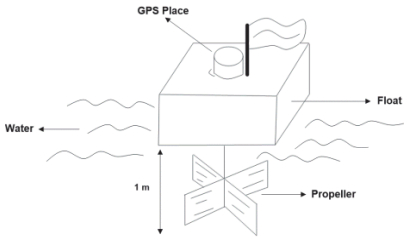

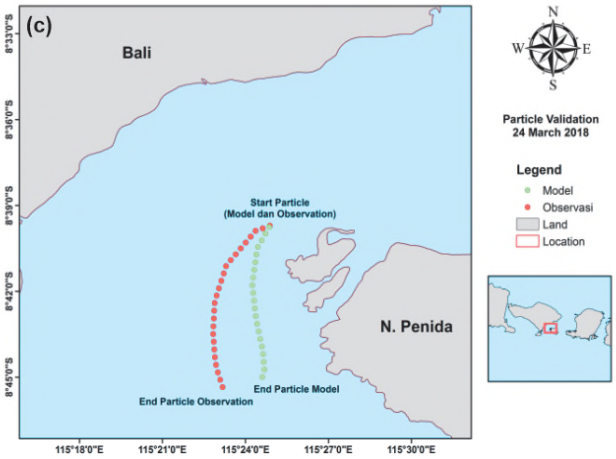

Training and Survey on Marine Debris


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