On the Job Training on

Tsunami Inundation Modelling and Mapping and Development of Tsunami Hazards Maps for Implementation of UNESCO-IOC Tsunami Ready Pilot Sites in Madagascar, Maldives, Seychelles and Sri Lanka

Hyderabad – India, 16–21 March 2026

Tsunami Inundation Modelling and Mapping

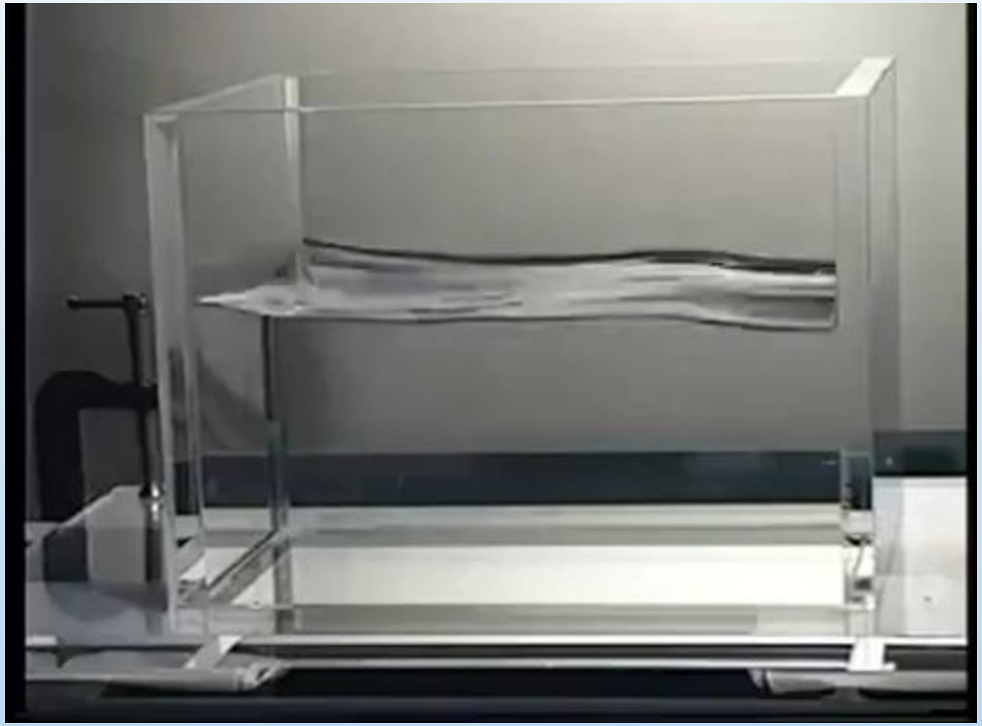
TIMM: Tsunami Science, Numerical Modelling and Forecasting

Siva Srinivas Kolukula (PhD), PLN Murty (PhD), C. Patanjali Kumar (PhD)

INCOIS

sivasrinivas.k@incois.gov.in

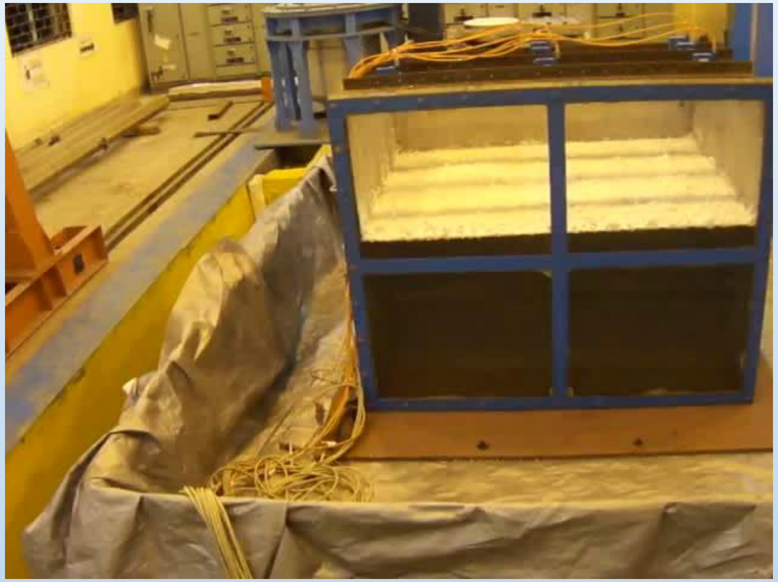
Sloshing

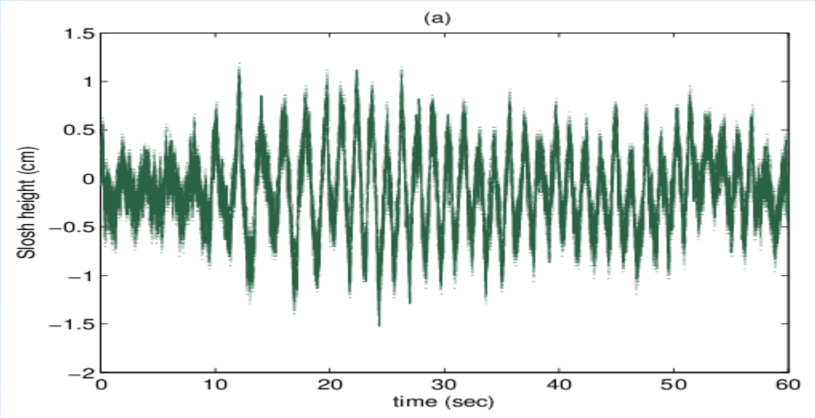


Violent or noisy movement of liquid inside a partially filled container, such as tanks in ships, trucks, or rockets.

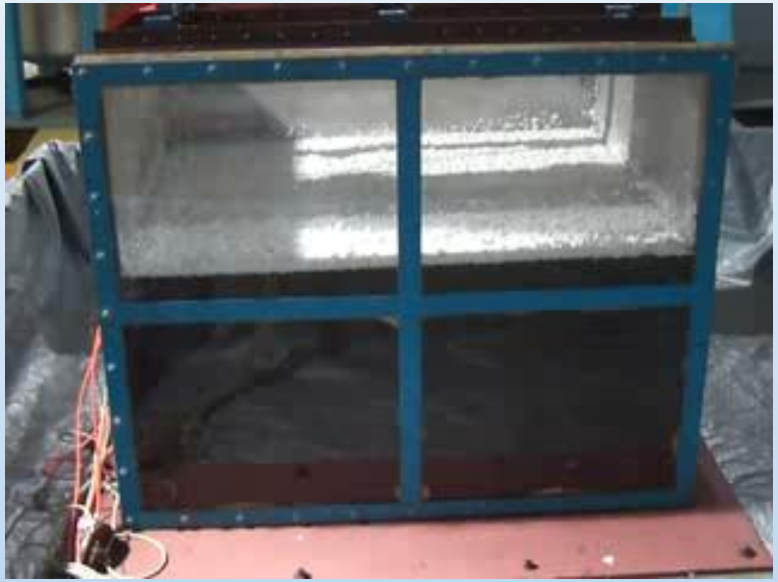
Instability on the free surface of fluid under external excitations (Tsunami Basic)

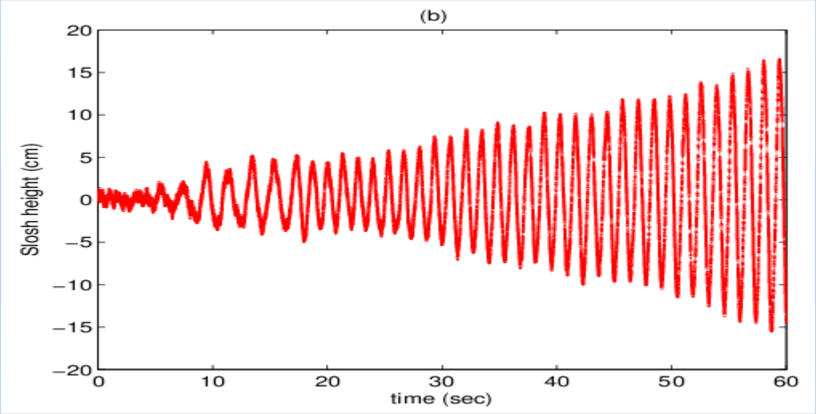
Stability on free-surface



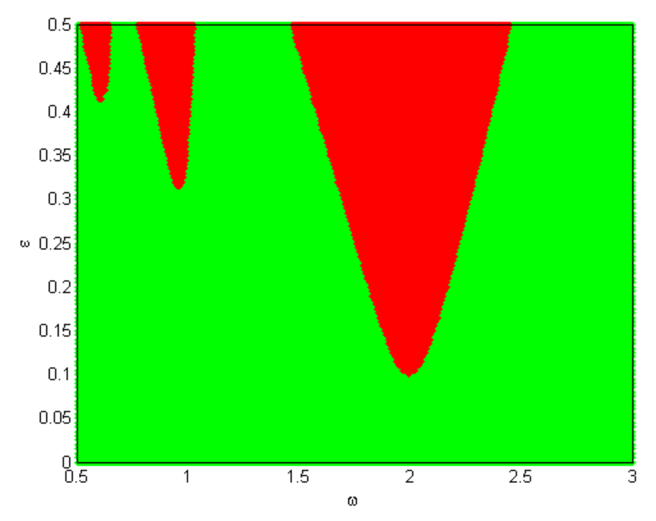


Instability on free-surface

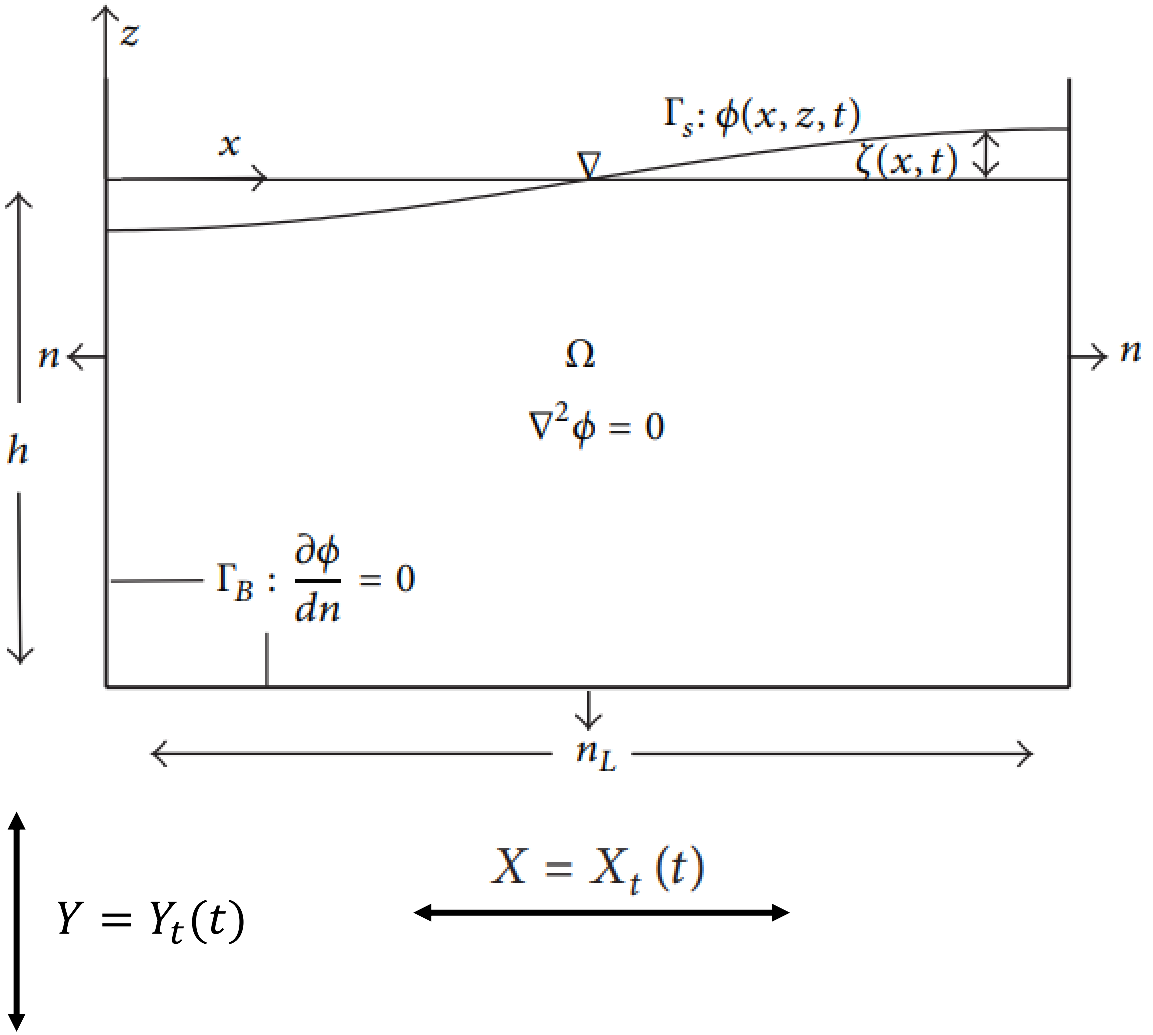




Instability Chart



Sloshing Governing Equations



$$\nabla^2\phi = 0.$$

$$\left.\frac{\partial\phi}{\partial n}\right|_{x=0,L} = 0, \qquad \left.\frac{\partial\phi}{\partial n}\right|_{z=-h} = 0.$$

$$\left.\frac{\partial\phi}{\partial t}\right|_{z=\zeta} + \frac{1}{2}\nabla\phi\cdot\nabla\phi + g\zeta + xX_t'',$$

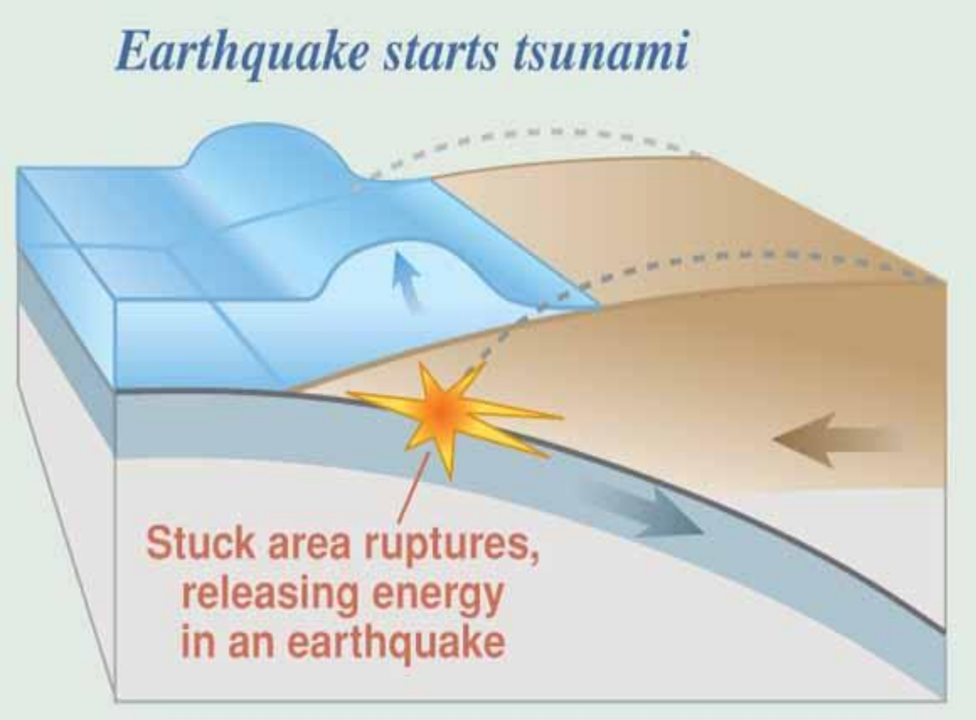
$$\frac{\partial\zeta}{\partial t} + \frac{\partial\phi}{\partial x}\frac{\partial\zeta}{\partial x} - \frac{\partial\phi}{\partial z} = 0.$$

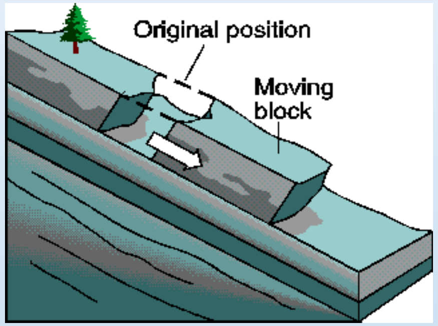
$$\phi(x,0,0) = -x\frac{dX_t(t)}{dt},$$

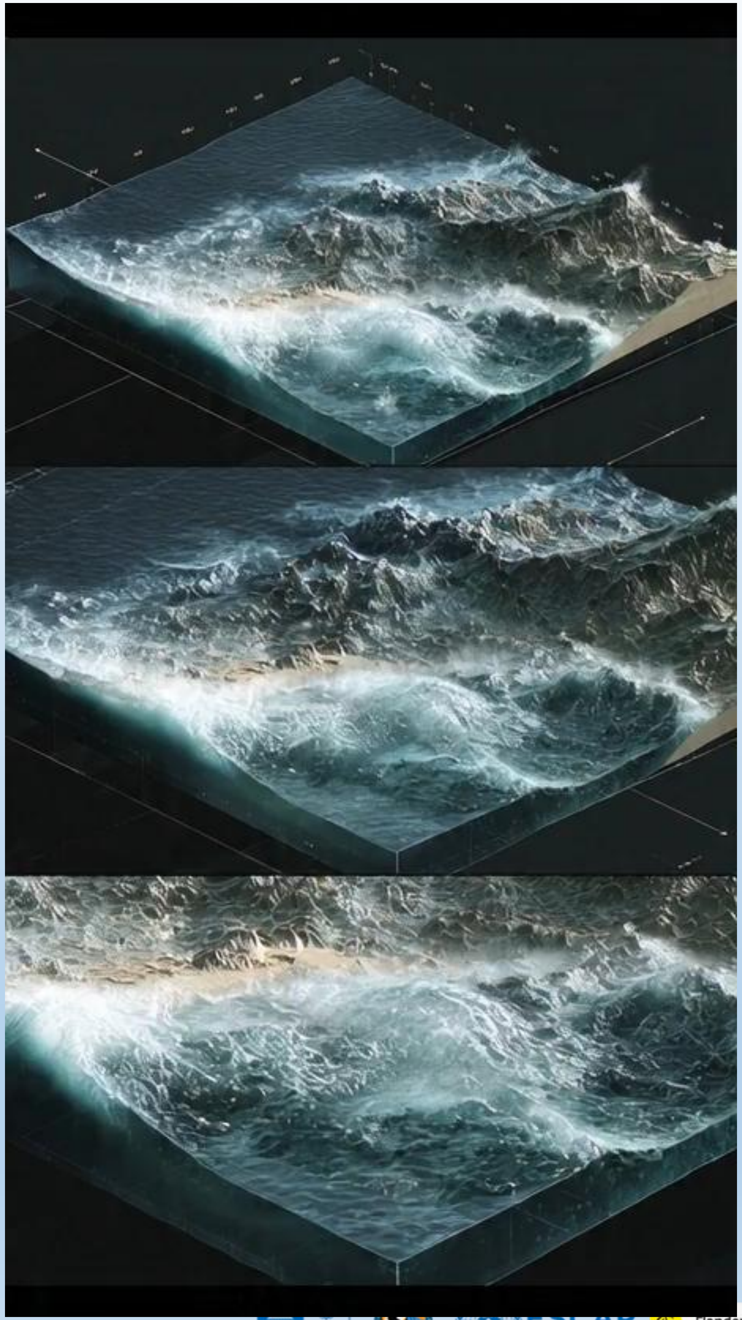
$$\zeta(x,0) = 0.$$

Any impulse may cause large-scale displacement of the sea surface.

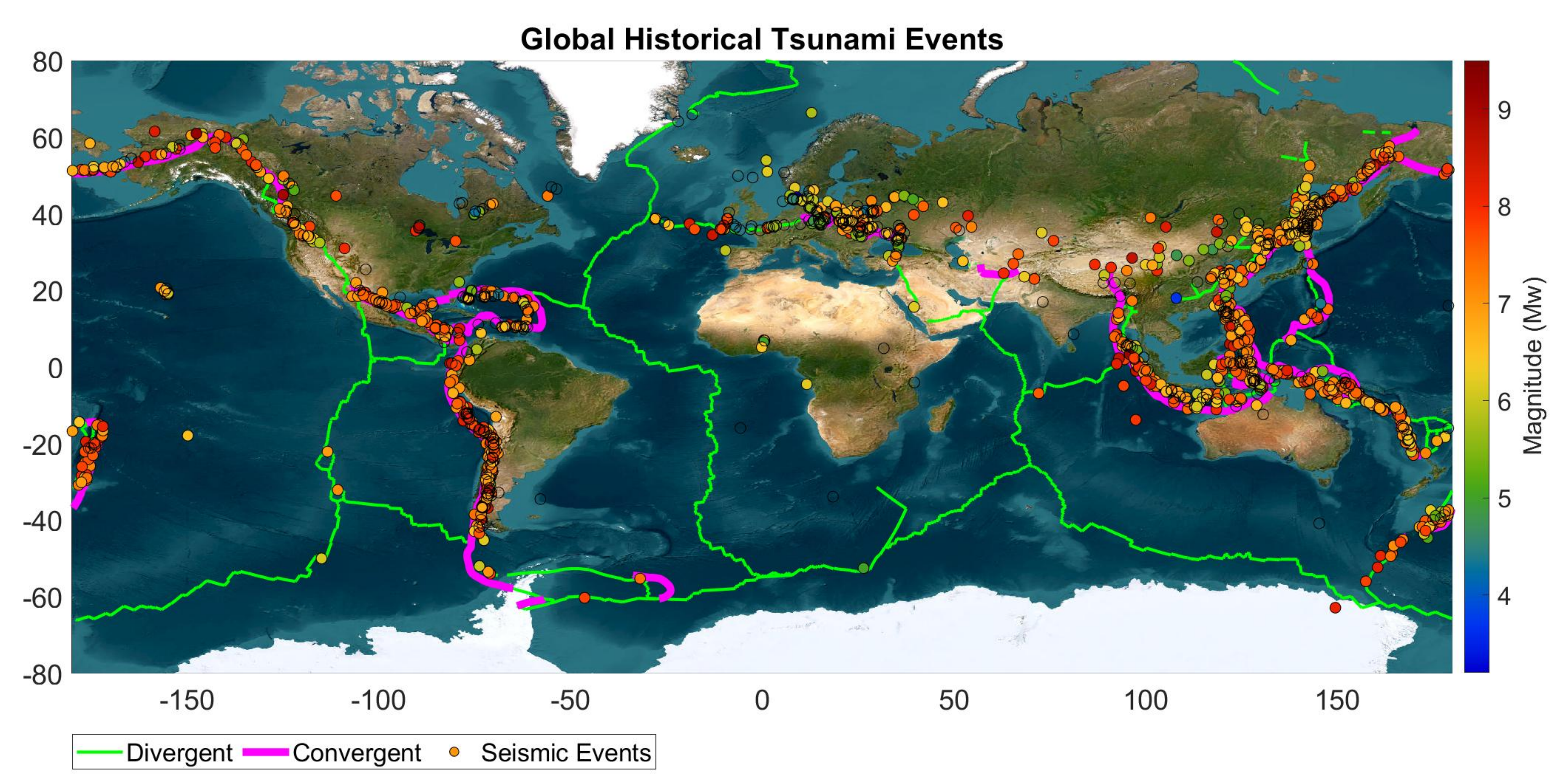
- Earthquakes
- Landslide
- Volcanic eruptions
- Meteoroids Impact







How does a tsunami occur?



Reference: doi:10.7289/V5PN93H7

Tsunami

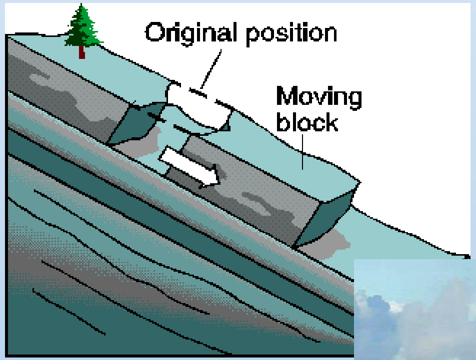
Propagation of disturbance on the ocean free surface under gravitational force from source to coast.

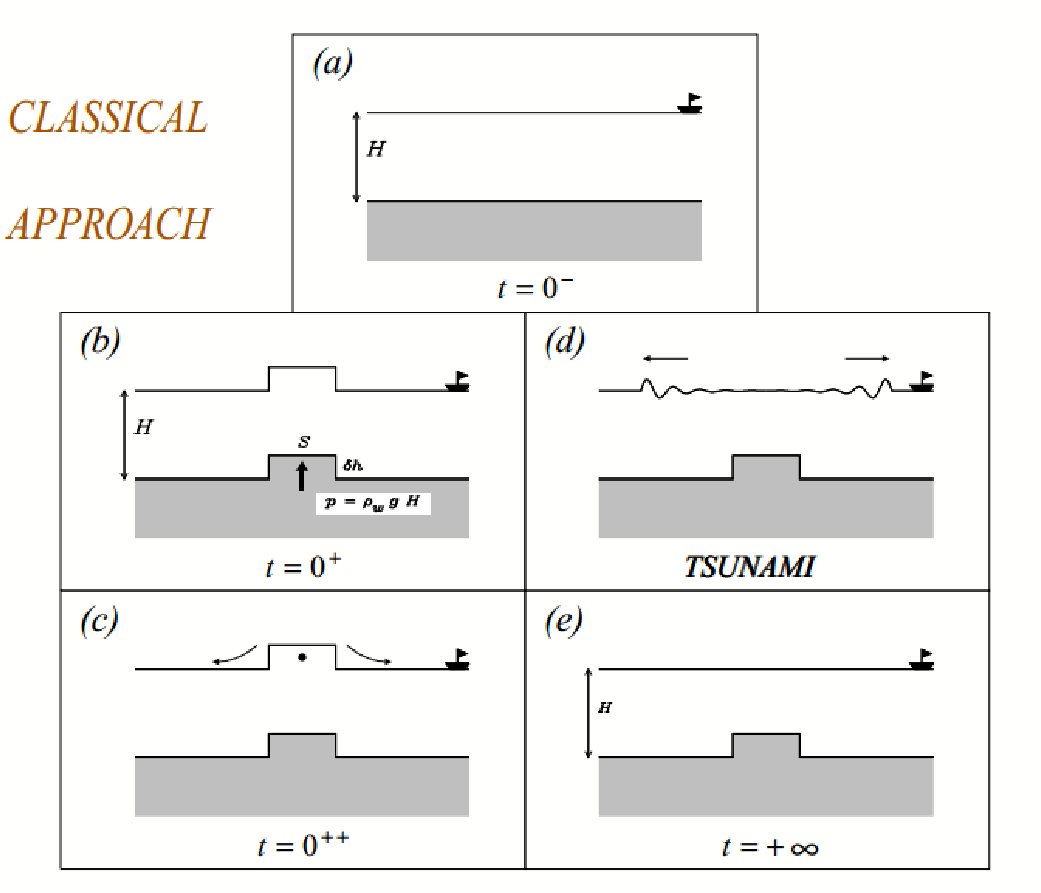
TSUNAMIS GENERATED BY

- ❖**Earthquakes**
- ❖**Landslides**
- ❖**Volcanic Explosions**
- ❑**Meteo – Tsunamis**

Tsunami Simulation Steps

1. Generation
2. Propagation
3. Run Up/ Inundation

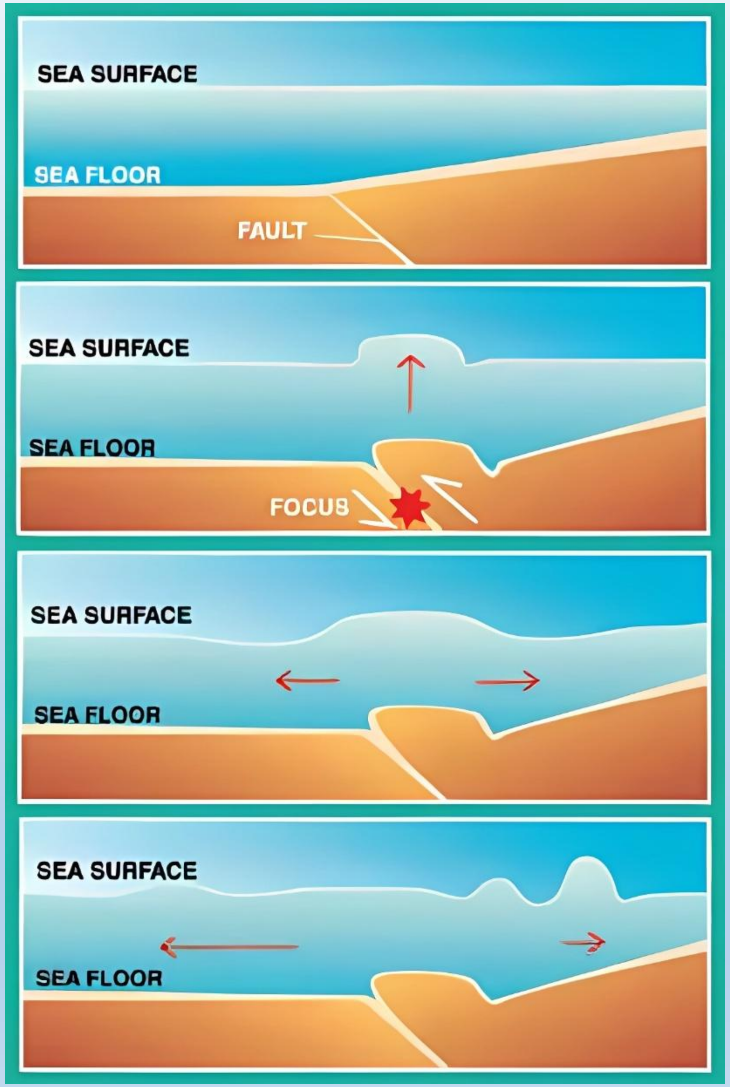




Classical Approach: Source – Prof. Emile A. Okal, Northwestern University, 2017.

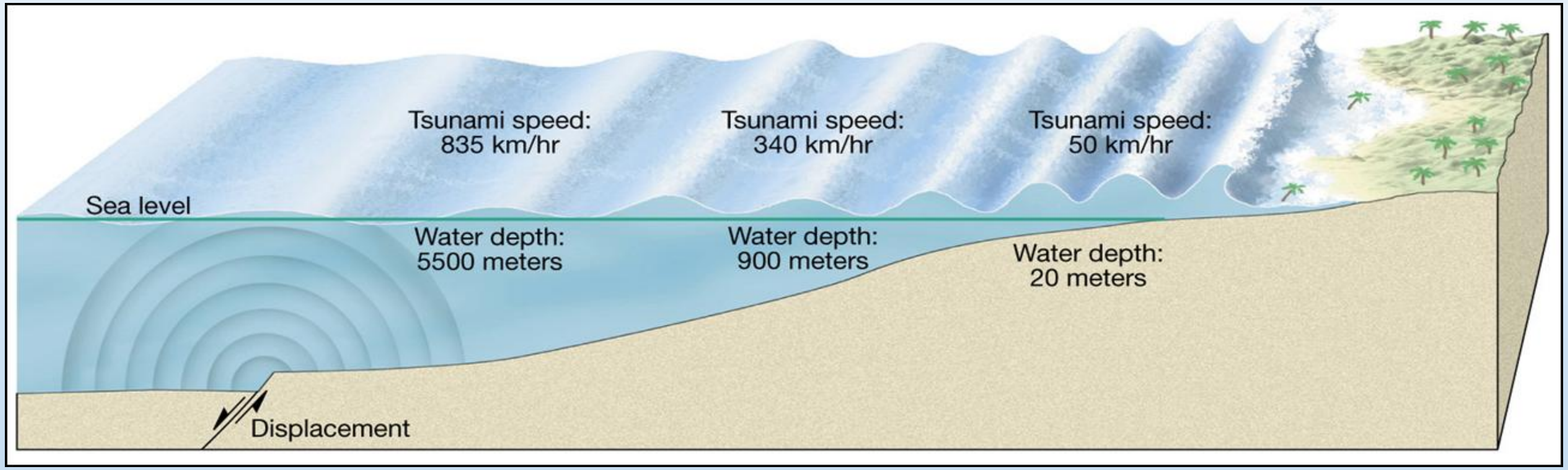
Tsunami

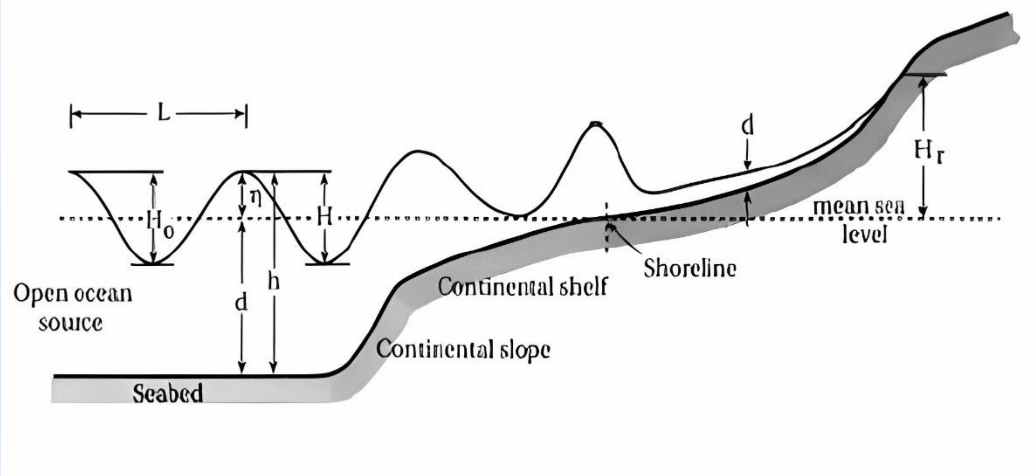
Propagation of disturbance on the ocean-free surface under gravitational force from source to coast.



Classical approach

←Generation→ ← Propagation → ←Inundation→





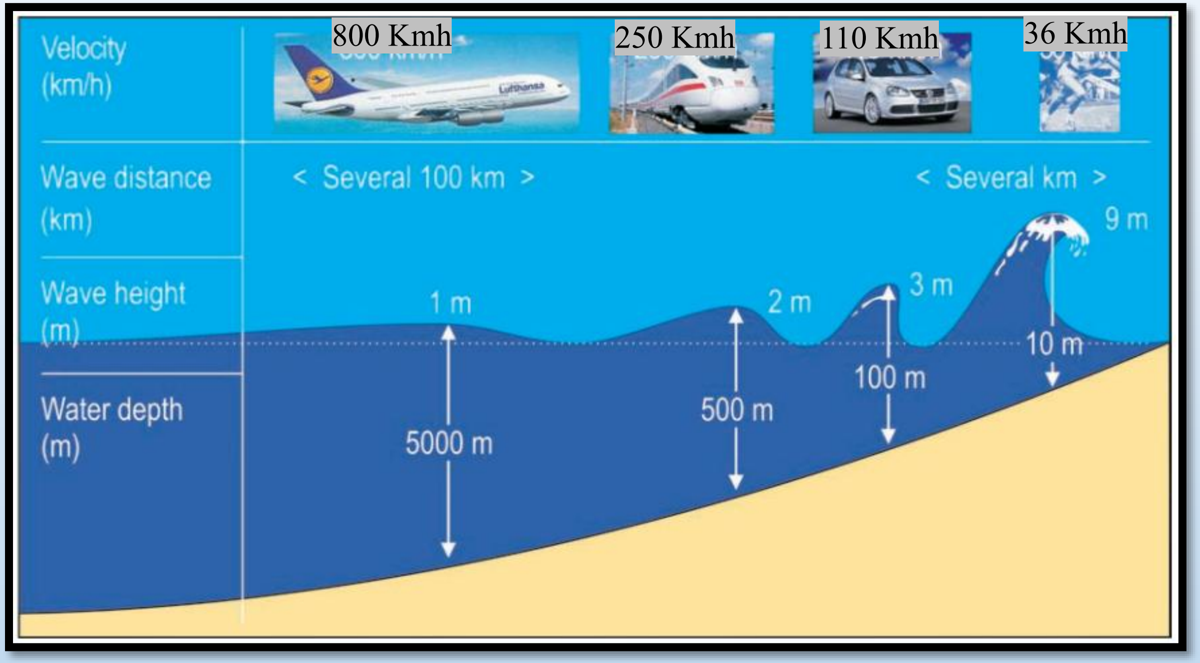
L	:	wavelength (m)
H_0	:	wave height at deep water (m)
d	:	water depth (m)
η	:	wave elevation (m)
h	:	water elevation (m)
H	:	wave height (m)
H_r	:	wave run-up (m)

Tsunami characteristics and definitions

Tsunami Characteristics

- Length and Time Period
  - Long wavelength (of several 100 km)
  - Periods of a few minutes to about an hour
- Speed proportional to the square root of water depth

  (Speed = $\sqrt{gh}$)
  - 500 to 1000 km per hour in Deep Ocean
  - About 30 km per hour near the shore
- Height of Tsunami Wave
  - Less than a meter in the Deep Ocean
  - Grows to Tens of meters near the shore



Propagation

IN THE DEEP OCEAN tsunami has a long wavelength, travels fast, and has a small amplitude

As it approaches the shore, it slows. Since energy is conserved, amplitude builds up.

Governing Equations for tsunami

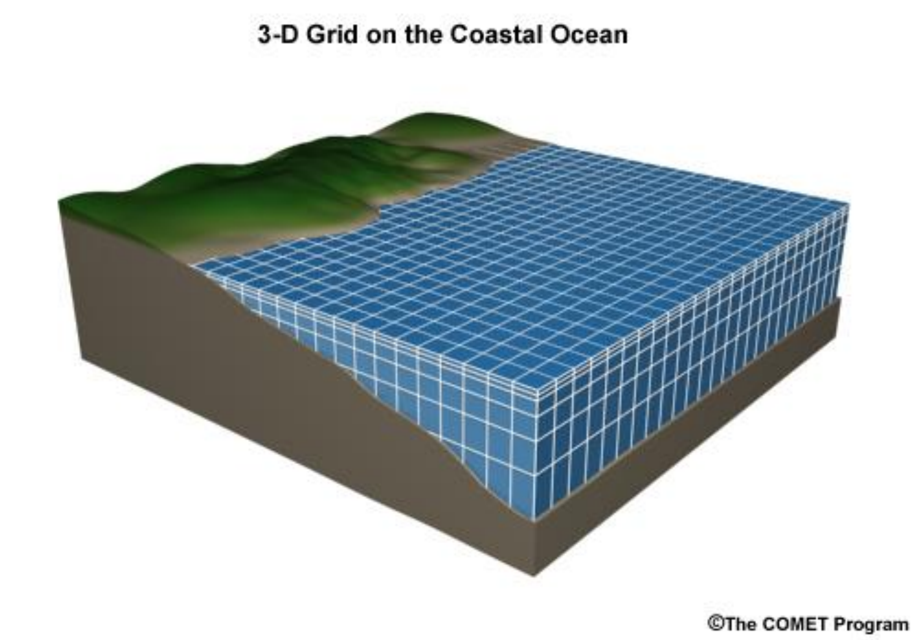
The Navier-Stokes Equations

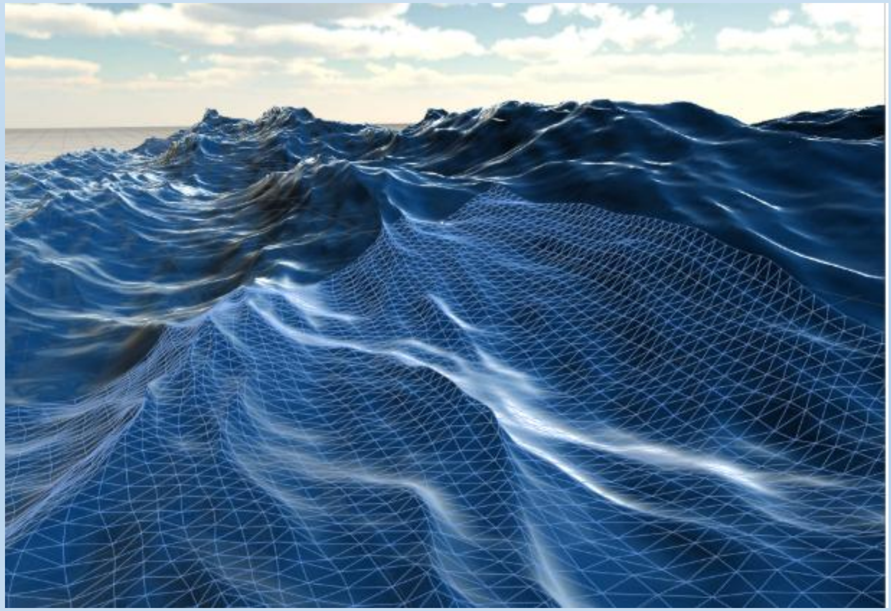
$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

$$\frac{\partial(\rho u)}{\partial t}+\frac{\partial(\rho u^2)}{\partial x}+\frac{\partial(\rho uv)}{\partial y}+\frac{\partial(\rho uw)}{\partial z}=\frac{\partial(\tau_{xx}-p)}{\partial x}+\frac{\partial\tau_{xy}}{\partial y}+\frac{\partial\tau_{xz}}{\partial z}$$

$$\frac{\partial(\rho v)}{\partial t}+\frac{\partial(\rho uv)}{\partial x}+\frac{\partial(\rho v^2)}{\partial y}+\frac{\partial(\rho vw)}{\partial z}=\frac{\partial\tau_x y}{\partial x}+\frac{\partial(\tau_{yy}-p)}{\partial y}+\frac{\partial\tau_{yz}}{\partial z}$$

$$\frac{\partial(\rho w)}{\partial t}+\frac{\partial(\rho uw)}{\partial x}+\frac{\partial(\rho vw)}{\partial y}+\frac{\partial(\rho w^2)}{\partial z}=-\rho g+\frac{\partial\tau_{xz}}{\partial x}+\frac{\partial\tau_{yz}}{\partial y}+\frac{\partial(\tau_{zz}-p)}{\partial z}$$





The Shallow Water Equations

$$\frac{\partial H}{\partial t}+\frac{\partial}{\partial x}(H\bar{u})+\frac{\partial}{\partial y}(H\bar{v})=0$$

$$\frac{\partial}{\partial t}(H\bar{u})+\frac{\partial}{\partial x}(H\bar{u}^2)+\frac{\partial}{\partial y}(H\bar{u}\bar{v})=-gH\frac{\partial\zeta}{\partial x}+\frac{1}{\rho}[\tau_{sx}-\tau_{bx}+F_x]$$

$$\frac{\partial}{\partial t}(H\bar{v})+\frac{\partial}{\partial x}(H\bar{u}\bar{v})+\frac{\partial}{\partial y}(H\bar{v}^2)=-gH\frac{\partial\zeta}{\partial y}+\frac{1}{\rho}[\tau_{sy}-\tau_{by}+F_y]$$

The Shallow water Equations

$$\frac{\partial \eta}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0$$

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{D}\right)+\frac{\partial}{\partial y}\left(\frac{MN}{D}\right)+gD\frac{\partial \eta}{\partial x}+\frac{gn^2}{D^{7/3}}M\sqrt{M^2+N^2}=0$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}\left(\frac{MN}{D}\right)+\frac{\partial}{\partial y}\left(\frac{N^2}{D}\right)+gD\frac{\partial \eta}{\partial y}+\frac{gn^2}{D^{7/3}}N\sqrt{M^2+N^2}=0$$

$$\frac{\partial \eta}{\partial t}+\frac{1}{R\cos\theta}\left[\frac{\partial M}{\partial \lambda}+\frac{\partial}{\partial \theta}(N\cos\theta)\right]=0$$

$$\frac{\partial M}{\partial t}+\frac{gh}{R\cos\theta}\frac{\partial \eta}{\partial \lambda}=fN$$

$$\frac{\partial N}{\partial t}+\frac{gh}{R}\frac{\partial \eta}{\partial \theta}=-fM$$

$$H_t+(uH)_x+(vH)_y=0,$$

$$u_t+uu_x+vu_y+gH_x=gD_x$$

$$v_t+uv_x+vv_y+gH_y=gD_y$$

$$\frac{\partial \zeta}{\partial t}+\frac{\partial UH}{\partial x}+\frac{\partial VH}{\partial y}=0$$

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}-fV=-\frac{\partial}{\partial x}\left[\frac{p_s}{\rho_0}+g\zeta-g(\eta+\gamma)\right]+\frac{\tau_{sx}}{\rho_0 H}-\frac{\tau_{bx}}{\rho_0 H}$$

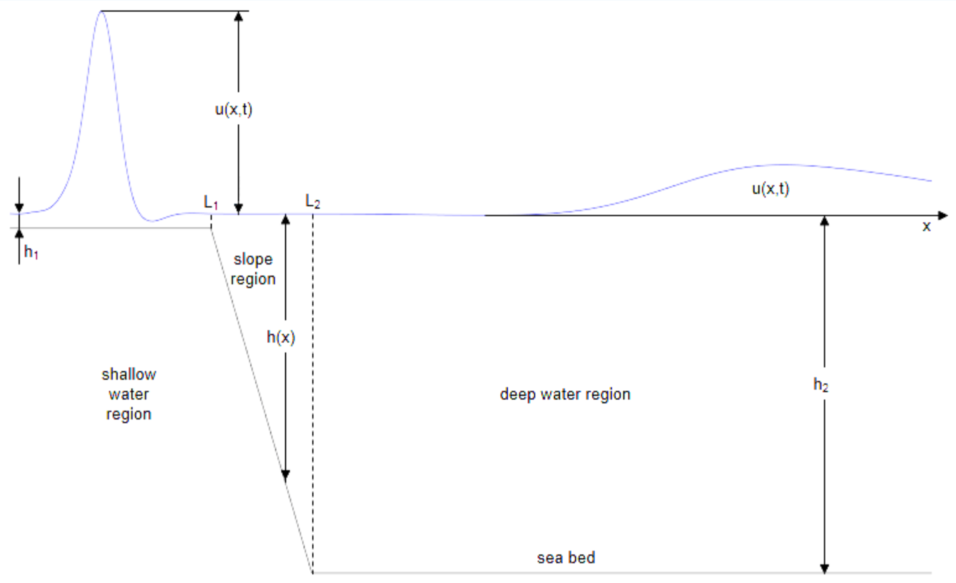
$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}+fU=-\frac{\partial}{\partial y}\left[\frac{p_s}{\rho_0}+g\zeta-g(\eta+\gamma)\right]+\frac{\tau_{sy}}{\rho_0 H}-\frac{\tau_{by}}{\rho_0 H}$$

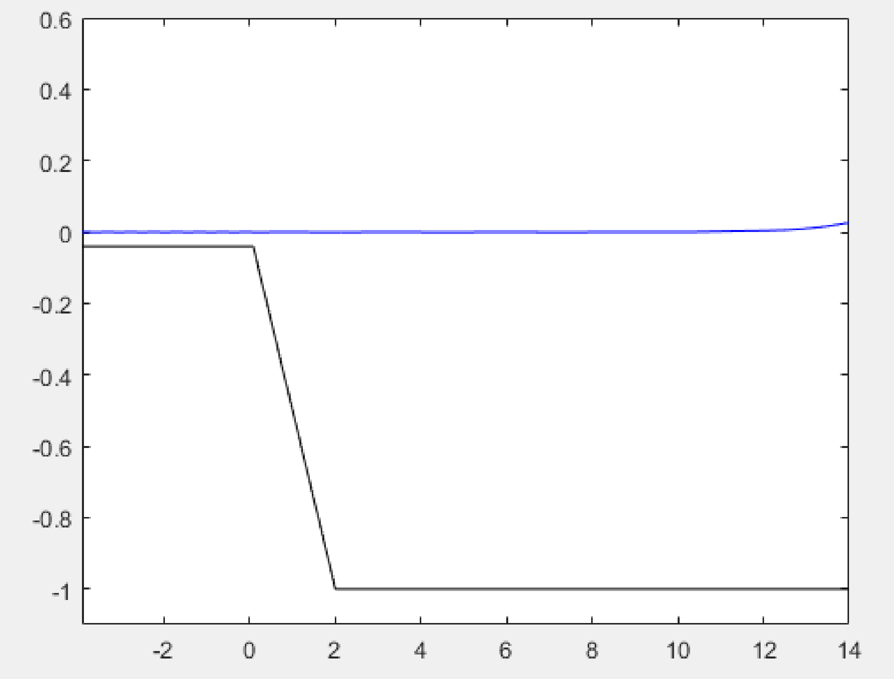
$$h_t+\frac{(uh)_\lambda+(vh\cos\phi)_\phi}{R\cos\phi}=0$$

$$u_t+\frac{uu_\lambda}{R\cos\phi}+\frac{vu_\phi}{R}+\frac{gh_\lambda}{R\cos\phi}=\frac{gd_\lambda}{R\cos\phi}+fv$$

$$v_t+\frac{uv_\lambda}{R\cos\phi}+\frac{vv_\phi}{R}+\frac{gh_\phi}{R}=\frac{gd_\phi}{R}-fu$$

Analytical 1D PDE of Tsunami Model





Tsunami Model: Wave Equation Solution
Governing PDE (linear 1D water theory)

$$u_{tt} = g\,(h(x)\,u_x)_x$$

- $u(x,t)$: free surface elevation - $g = 9.81\,\mathrm{m/s}^2$: gravity - $h(x)$: water depth

Depth Profile (slope region $L_1 \le x \le L_2$)

$$h(x) = \frac{H}{L}x, \quad h_1 = \text{depthratio} \cdot H, \quad h_2 = H$$

- H: deep water depth - L: slope length - depthratio $= h_1/h_2$: shallow/deep depth ratio

Fourier Mode Decomposition ($u(x,t) = U(x,\omega)\,e^{i\omega t}$)

Deep water ($h = h_2$):

$$u_2(x,t) = e^{i\omega(t+x/c_2)} + R(\omega)\,e^{i\omega(t-x/c_2)}, \quad c_2 = \sqrt{gh_2}$$

Shallow water ($h = h_1$):

$$u_1(x,t) = T(\omega)\,e^{i\omega(t+x/c_1)}, \quad c_1 = \sqrt{gh_1}$$

Slope region:

$$U(x,\omega) = C_1 J_0\left(2\omega\sqrt{\frac{Lx}{gH}}\right) + C_2 Y_0\left(2\omega\sqrt{\frac{Lx}{gH}}\right)$$

J_0, Y_0: Bessel functions of order zero.

Boundary Matching (continuity of u and u_x at $x = L_1, L_2$) determines constants $C_1, C_2, R(\omega), T(\omega)$.

Low Frequency Limits (dominant tsunami energy)

$$\lim_{\omega\to 0} R = \frac{1-\sqrt{\text{depthratio}}}{1+\sqrt{\text{depthratio}}}, \qquad \lim_{\omega\to 0} T = \frac{2}{1+\sqrt{\text{depthratio}}}$$

Full Wave Field obtained via inverse FFT of frequency domain solutions.

Real-world Problems

Structural Analysis, Thermal Analysis, Fluid Analysis

ODE/ PDE/ Matrices

3. Numerical Methods/ Numerical Simulations

- Finite Difference Method (FDM)
- Finite Element Method (FEM)
- Finite Volume Method (FVM)
- Boundary Element Method (BEM)
- Meshless Method (SPH)
- Finite Particle Method (FPM)
- Monte Carlo Methods (MC)

2. Experimental Analysis

1. Analytical Solutions

A General Procedure of Numerical Methods

Preprocessing

- ❑ Define the geometric domain of the problem of interest
- ❑ Define the element type based on the deformation
- ❑ Define the geometric properties of the elements
- ❑ Define the material properties
- ❑ Define the nodal connectivity (constitutes a mesh)
- ❑ Define the boundary conditions

Mathematical solution

- ❑ Compute the unknown variables

Postprocessing

- ❑ Visualizing the results
- ❑ Sorting, plotting, printing

Programming/ Coding/ Packages

C, C++
Fortran
Python
R
Julia
Mathematica
MATLAB
Octave
Scilab

ABAQUS
ANSYS
Cast3M
Fluent
Open Foam

Methods to solve the Shallow water Equations

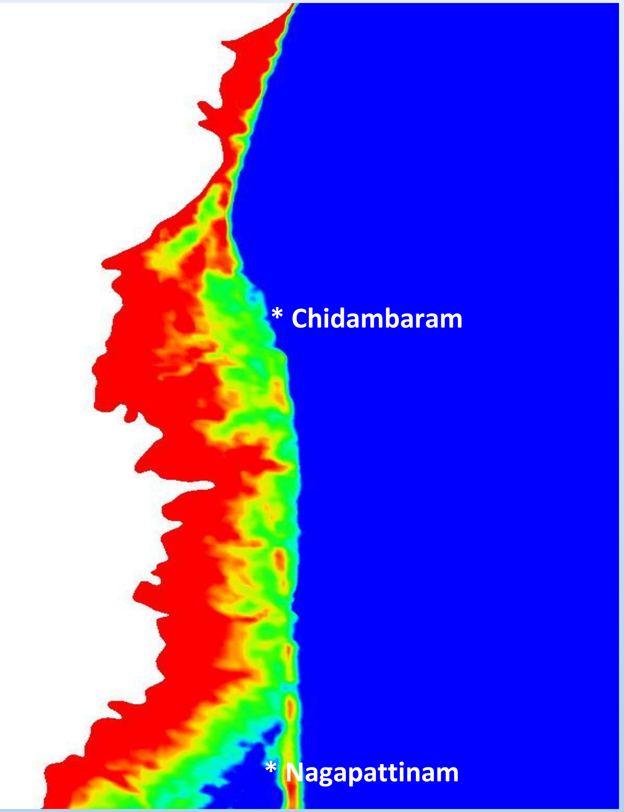
1	**Analytical solutions** **Closed form solution. Not possible for all the cases.**
2	Finite Difference Method (FDM) Differential Equations are discretized using Taylors series and time integrated Ex: comMIT, TUNAMI, COMCOT, MOST
3	Finite Element Method (FEM) Subdivides domain into smaller parts called finite elements and are then assembled into the main domain Ex: ADCIRC, CAST3M, (ABAQUS, ANSYS, COMSOL)
4	Finite Volume Method (FVM) Volume integrals with a divergence term are converted to surface integrals, using the divergence theorem, and fluxes are evaluated at the surfaces Ex: ANUGA, CLAWPACK, FVCOM, HySEA, OPEN-FOAM, (FLUENT)
5	Meshfree Methods The differentials in are converted into a summation formula using kernel functions which operates on nearby data points Ex: Smoothed Particle Hydrodynamics (SPH)

Tsunami Modelling and Coastal Inundation Requirements

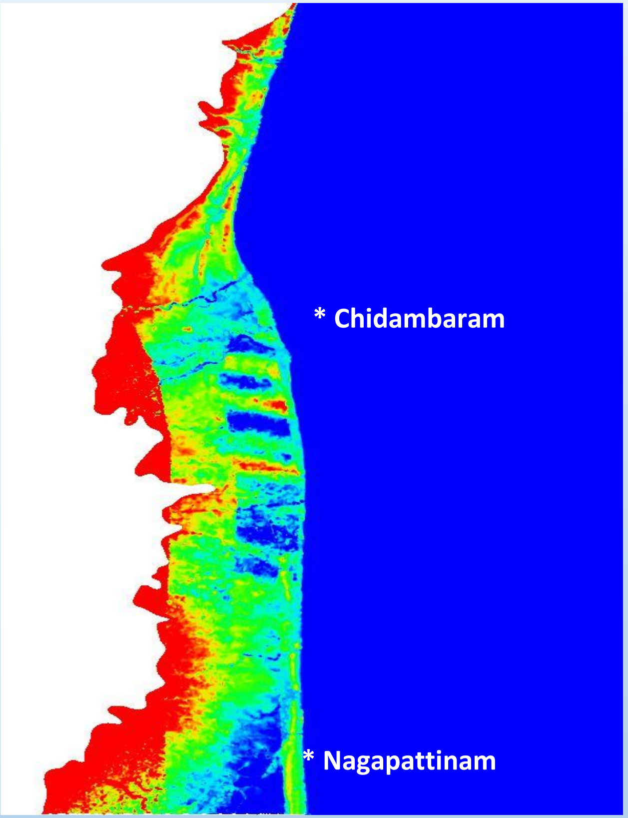
Model	**A high-resolution, physics-based SWE solver with flooding and drying capabilities** **Supports parallel computing**
Preprocessing	
	High resolution mesh/ grid of region of interest
Generation	Seismic fault parameters Accurate Initial deformation Mansinha and Smiley; Okada model
Solving	
Propagation	A high-resolution water depth (bathymetry)
Inundation	A high-resolution land elevation (topography) elevation
Postprocessing	
Analysis	Wave heights, travel times, inundated area (Plotting tools) (Observations)

Propagation and Coastal Inundation Requirements (preprocessing)

Importance of bathymetry and inland topography

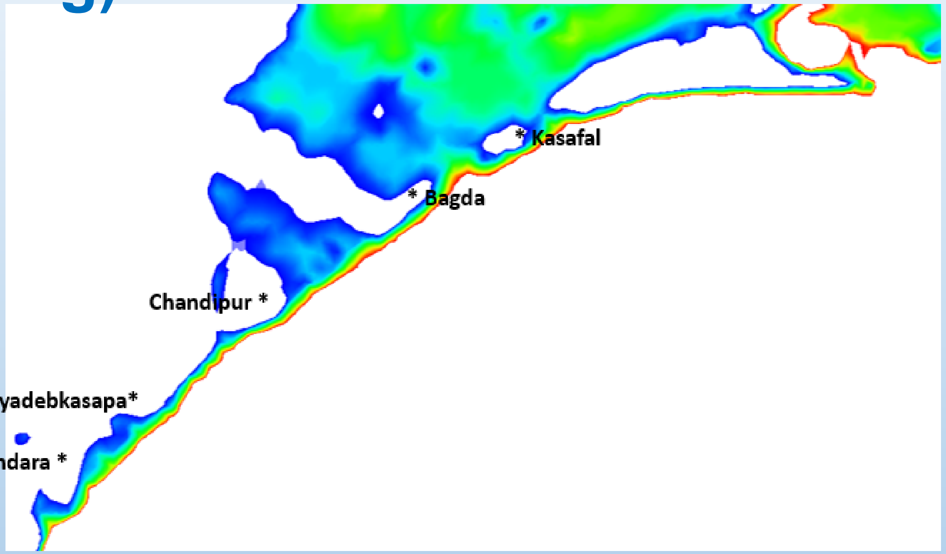


GEBCO 30 arc sec

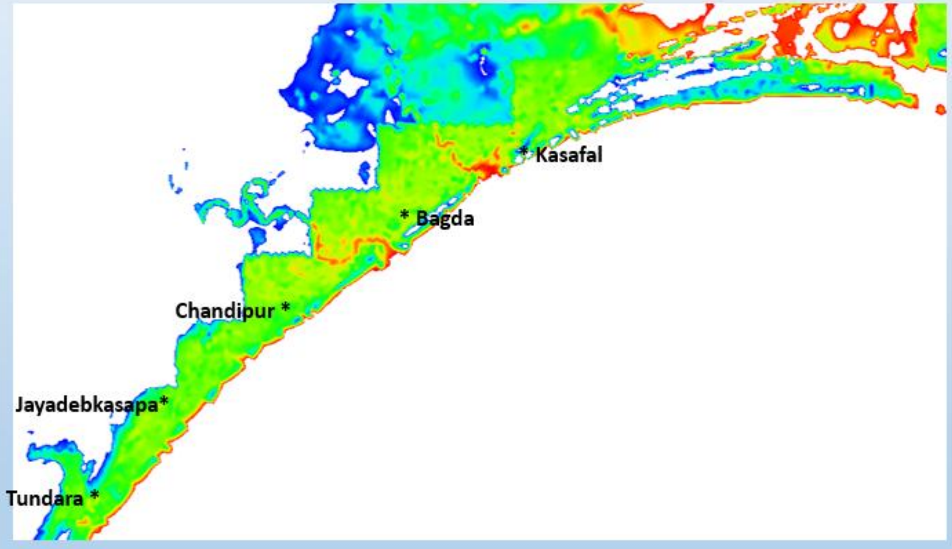


ALTM+CARTOSAT+SRTM

GEBCO 30 arc sec topography



SRTM+CARTOSAT+ALTM topography



 # GEBCO (General Bathymetric Chart of the Oceans)
 # SRTM (Shuttle Radar Topography Mission)

Tsunami Generation

1. **Formation of an initial disturbance of the ocean surface due to the earthquake-triggered deformation of the sea floor**
2. **Initial water surface disturbance - A long gravity wave radiating from the earthquake source**
3. **The basic parameters required to generate initial deformation:**

Earthquake Hypocenter	
1	Moment magnitude of the Earthquake (Mw)
2	Location (Latitude, Longitude) in degrees
3	Focal depth (km)
Focal Mechanism	
4	Strike angle (0° to 360°)
5	Dip angle (0° to 90°)
6	Slip/ Rake angle (0° to ±180°)
Fault geometry	
7	Slip (m)
8	Fault Length (km)
9	Fault Width (km)

$$\log_{10}(M_0) = 1.5M_w + 9.05$$

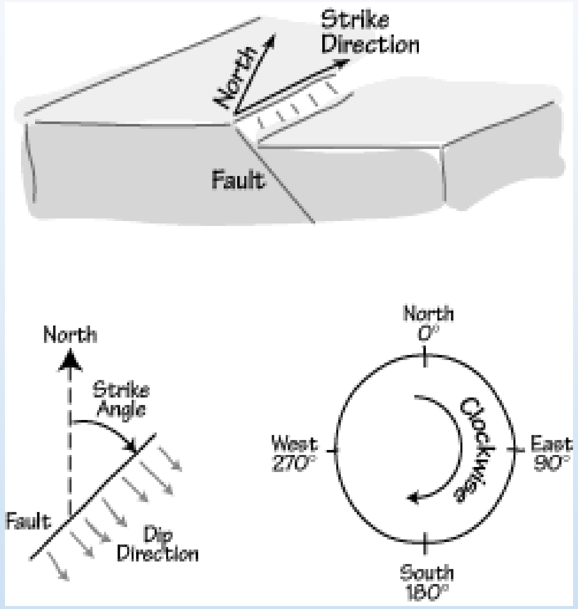
Strike- Along the plate boundary or parallel to the coast, Dip 45 degrees, Rake 90 degrees

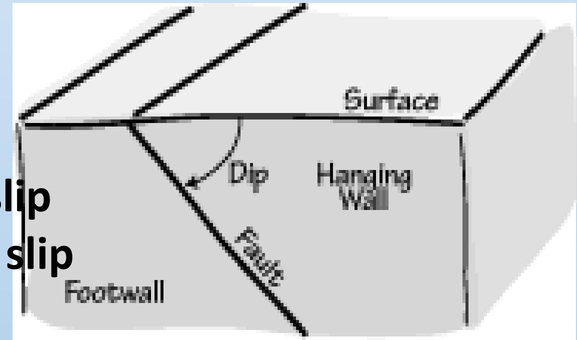
Dip = 90° Rake = 0° :: left-lateral strike-slip
Dip = 90° Rake = 180° :: right lateral strike slip
Dip = 45° Rake = 90° :: reverse fault
Dip = 45° Rake = -90° :: normal fault

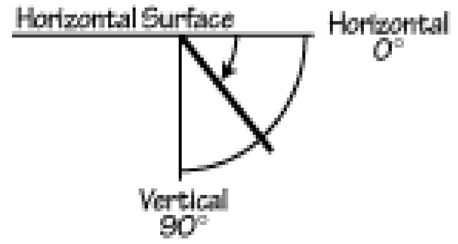
$$M_0 = \mu AD$$

$$\log_{10} L = a + bM_w$$

$$\log_{10} W = a + bM_w$$







Governing Equations

Non-linear Shallow water equations

$$\frac{\partial \eta}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0$$

$$\frac{\partial M}{\partial t} + \frac{\partial}{\partial x}\left(\frac{M^2}{D}\right) + \frac{\partial}{\partial y}\left(\frac{MN}{D}\right) + gD\frac{\partial \eta}{\partial x} + \frac{gn^2}{D^{7/3}} M\sqrt{M^2+N^2} = 0$$

$$\frac{\partial N}{\partial t} + \frac{\partial}{\partial x}\left(\frac{MN}{D}\right) + \frac{\partial}{\partial y}\left(\frac{N^2}{D}\right) + gD\frac{\partial \eta}{\partial y} + \frac{gn^2}{D^{7/3}} N\sqrt{M^2+N^2} = 0$$

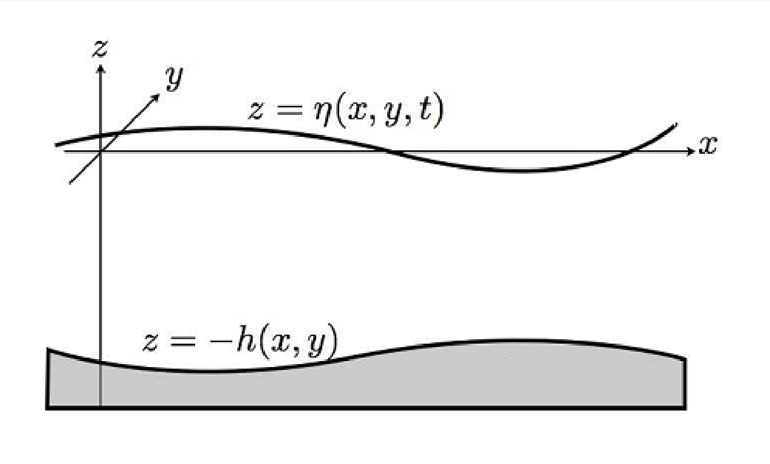
Linear Shallow water equations

$$\frac{\partial \eta}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0$$

$$\frac{\partial M}{\partial t} + gD\frac{\partial \eta}{\partial x} = 0$$

$$\frac{\partial N}{\partial t} + gD\frac{\partial \eta}{\partial y} = 0$$

λ >> h



$\eta \rightarrow$ Wave height

$M, N \rightarrow$ discharge fluxes in x and y directions

$D \rightarrow$ Total water depth

$n \rightarrow$ Mannings roughness coefficient

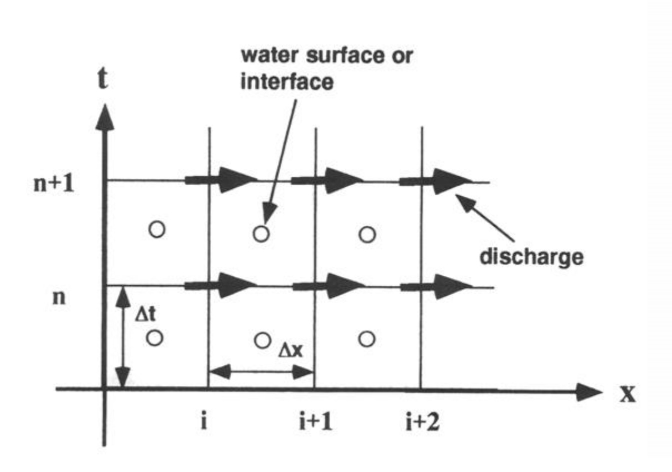
$M = u(h+\eta) = uD \quad N = v(h+\eta) = vD$

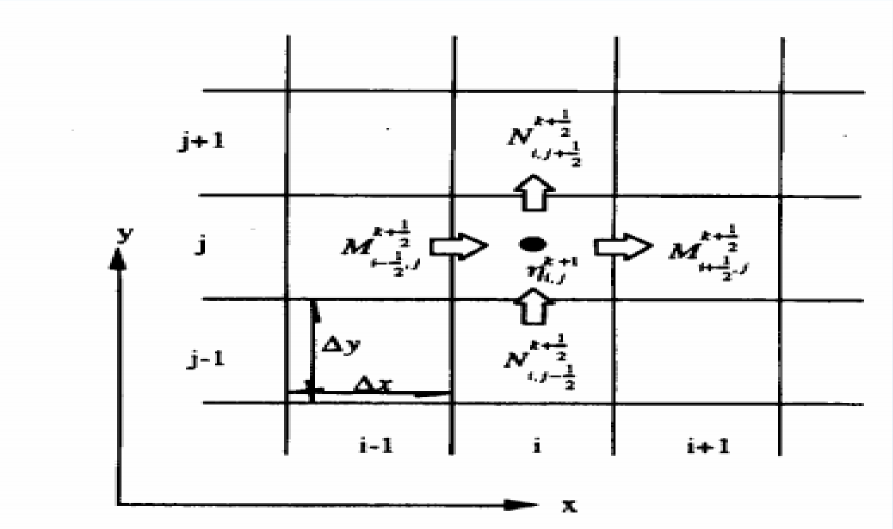
$n = \sqrt{\frac{fD^{1/3}}{2g}}$

$u, v \rightarrow$ velocity in x and y directions

$f \rightarrow$ friction coefficient

Numerical Methodology





1. Initial boundary value problem
2. Equations are solved by employing finite difference method (FDM)
3. The staggered leap-frog scheme (Shuto, Goto, Imamura, (1990)) is used to solve the governing equations.
4. At every time step, wave is propagated by calculating the water surface elevations and water velocities throughout the domain.
5. For stability the time step and grid size should be selected properly and they should obey CFL condition

$$\frac{\nabla x}{\nabla t} = \sqrt{2gh_{\max}}$$

Finite Difference Scheme

$$\frac{\partial \eta}{\partial t} = \frac{1}{\Delta t}\left[\eta_{i,j}^{k+1} - \eta_{i,j}^{k}\right]; \frac{\partial M}{\partial x} = \frac{1}{\Delta x}\left[M_{i+\frac{1}{2},j}^{k+\frac{1}{2}} - M_{i-\frac{1}{2},j}^{k+\frac{1}{2}}\right]; \frac{\partial N}{\partial y} = \frac{1}{\Delta y}\left[N_{i,j+\frac{1}{2}}^{k+\frac{1}{2}} - N_{i,j-\frac{1}{2}}^{k+\frac{1}{2}}\right]$$

$$\eta_{i,j}^{k+1} = \eta_{i,j}^{k} - \frac{\Delta t}{\Delta x}\left[M_{i+\frac{1}{2},j}^{k+\frac{1}{2}} - M_{i-\frac{1}{2},j}^{k+\frac{1}{2}}\right] - \frac{\Delta t}{\Delta y}\left[N_{i,j+\frac{1}{2}}^{k+\frac{1}{2}} - N_{i,j-\frac{1}{2}}^{k+\frac{1}{2}}\right]$$

Wave height

$$M_{i+\frac{1}{2},j}^{k+\frac{1}{2}} = M_{i+\frac{1}{2},j}^{k-\frac{1}{2}} - gD_{i+\frac{1}{2},j}^{k}\frac{\Delta t}{\Delta x}\left[\eta_{i+1,j}^{k} - \eta_{i,j}^{k}\right]$$

$$D_{i+\frac{1}{2},j}^{k} = h_{i+\frac{1}{2},j} - \eta_{i+\frac{1}{2},j}^{k} = h_{i+\frac{1}{2},j} + \frac{1}{2}\left[\eta_{i+1,j}^{k} + \eta_{i,j}^{k}\right]$$

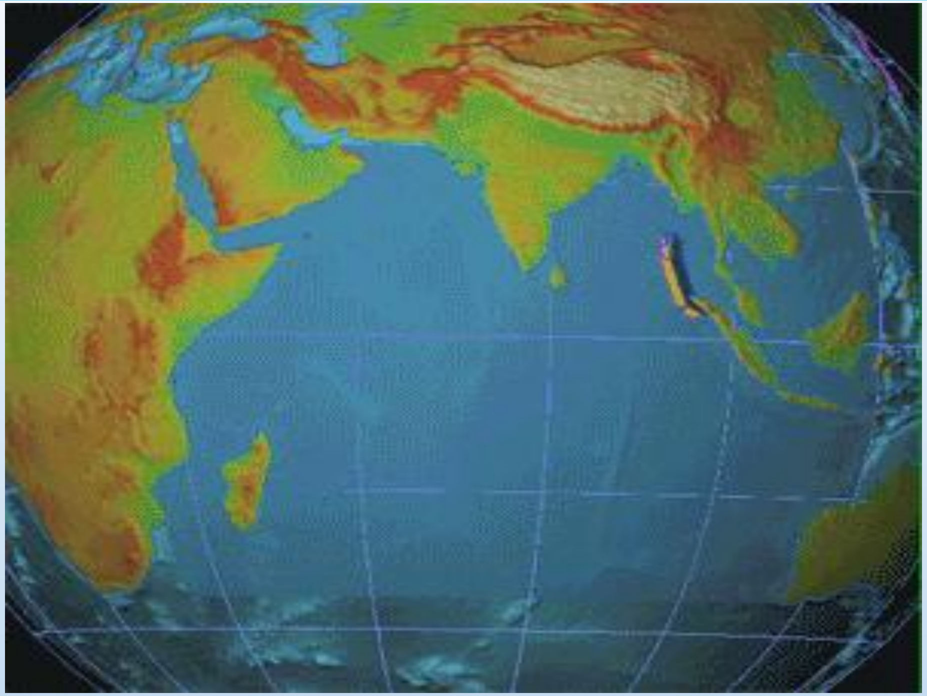
Discharge flux along x

$$N_{i,j+\frac{1}{2}}^{k+\frac{1}{2}} = N_{i,j+\frac{1}{2}}^{k-\frac{1}{2}} - gD_{i,j-\frac{1}{2}}^{k}\frac{\Delta t}{\Delta y}\left[\eta_{i,j+1}^{k} + \eta_{i,j}^{k}\right]$$

$$D_{i,j+\frac{1}{2}}^{k} = h_{i,j+\frac{1}{2}} + \eta_{i,j+\frac{1}{2}}^{k} = h_{i,j+\frac{1}{2}} + \frac{1}{2}\left[\eta_{i,j+1}^{k} + \eta_{i,j}^{k}\right]$$

Discharge flux along y

Indian Ocean Tsunami of December 26, 2004

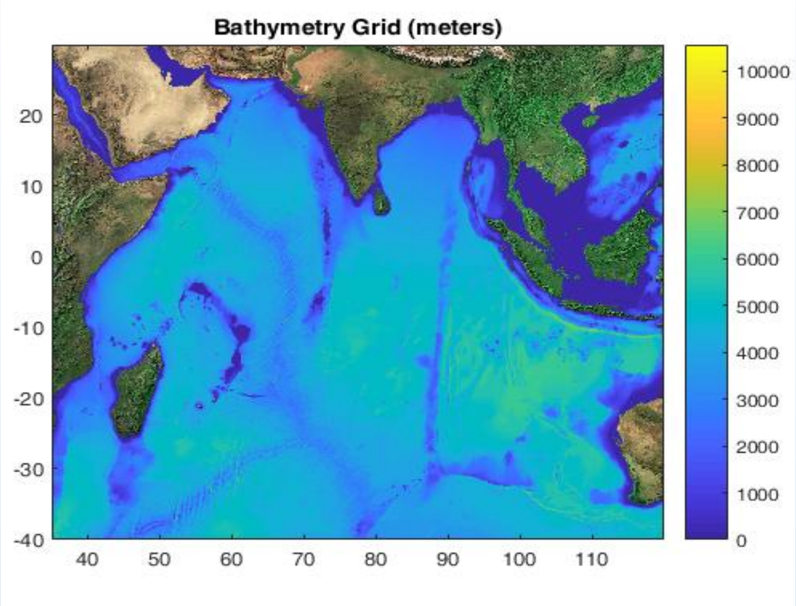


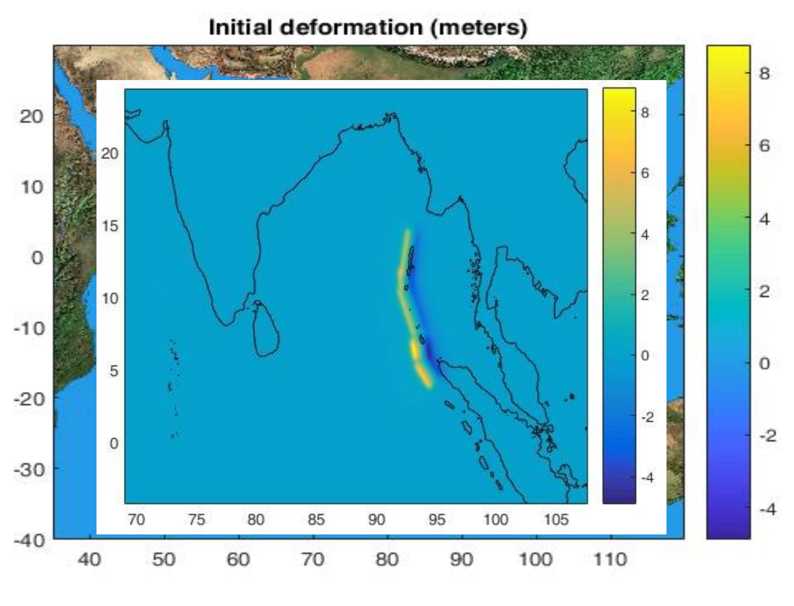
- The worst tsunami in recorded history on December 26, 2004
- Magnitude 9.3 (second strongest earthquake ever recorded on a seismograph)
- Lasted 10 minutes (longest lasting earthquake in history)
- 229,866 confirmed dead, which includes 42,883 missing and never accounted for
- More than $7 billion dollars damage

Reasons for huge loss…..

- Many nations in the Indian Ocean did not even recognize the word “tsunami”
- None had tsunami preparedness programs in place
- Absence of a Tsunami Early Warning System (TEWS) in India
- Ignorance of the natural signs of a tsunami led to inappropriate actions

Generation/Initial deformation



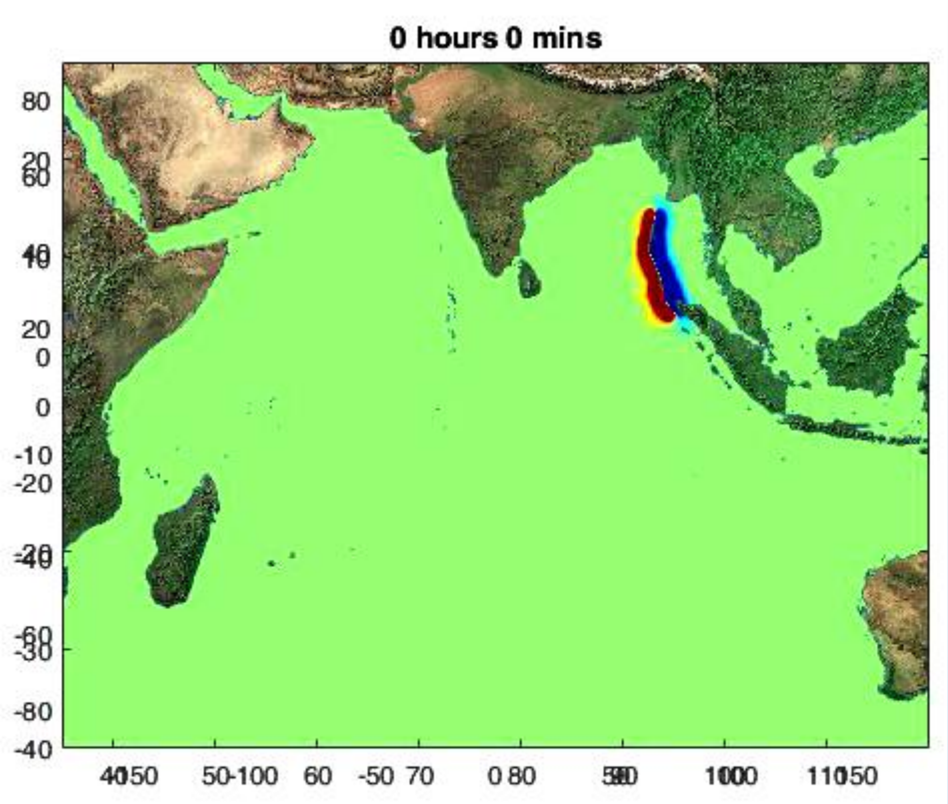


Computed initial deformation due to December 26, 2004, Great Sumatra Earthquake

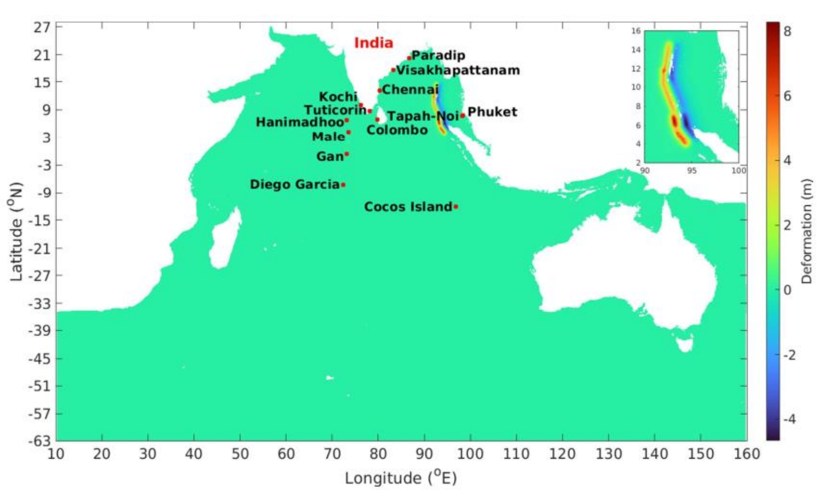
Parameters	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
x_o (longitude)	94.57	93.90	93.21	92.60	92.87
y_o(latitude)	3.83	5.22	7.41	9.70	11.70
d (km)	25	25	25	25	25
φ (degrees)	323	348	338	356	10
λ (degrees)	90	90	90	90	90
δ (degrees)	12	12	12	12	12
Δ (m)	18	23	12	12	12
L (km)	220	150	390	150	350
W (km)	130	130	120	95	95

Earthquake fault parameters of the December 26, 2004, Great Sumatra Earthquake were used to compute initial deformation (Source: Grilli et al., 2007)

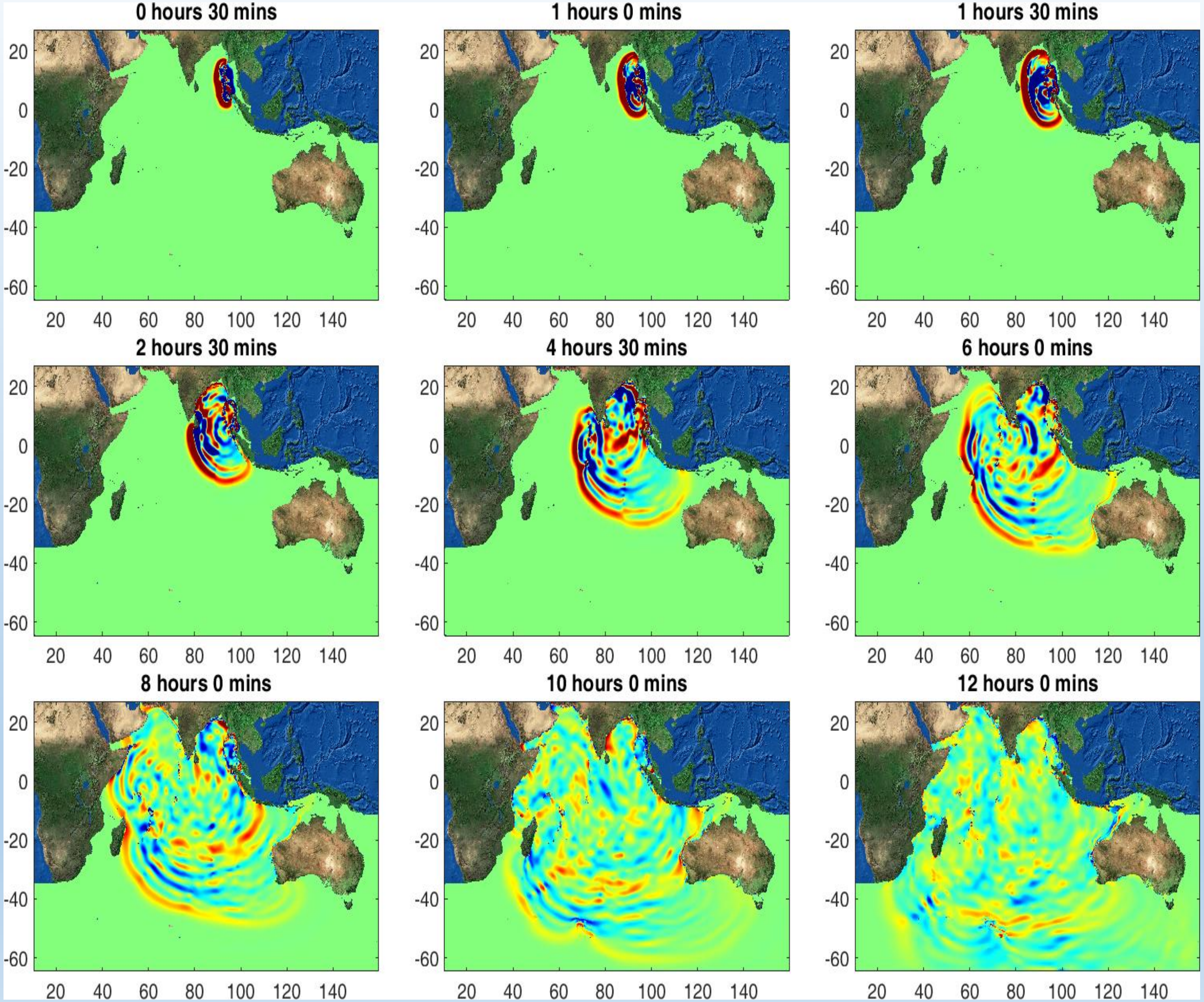
http://equake-rc.info/srcmod/

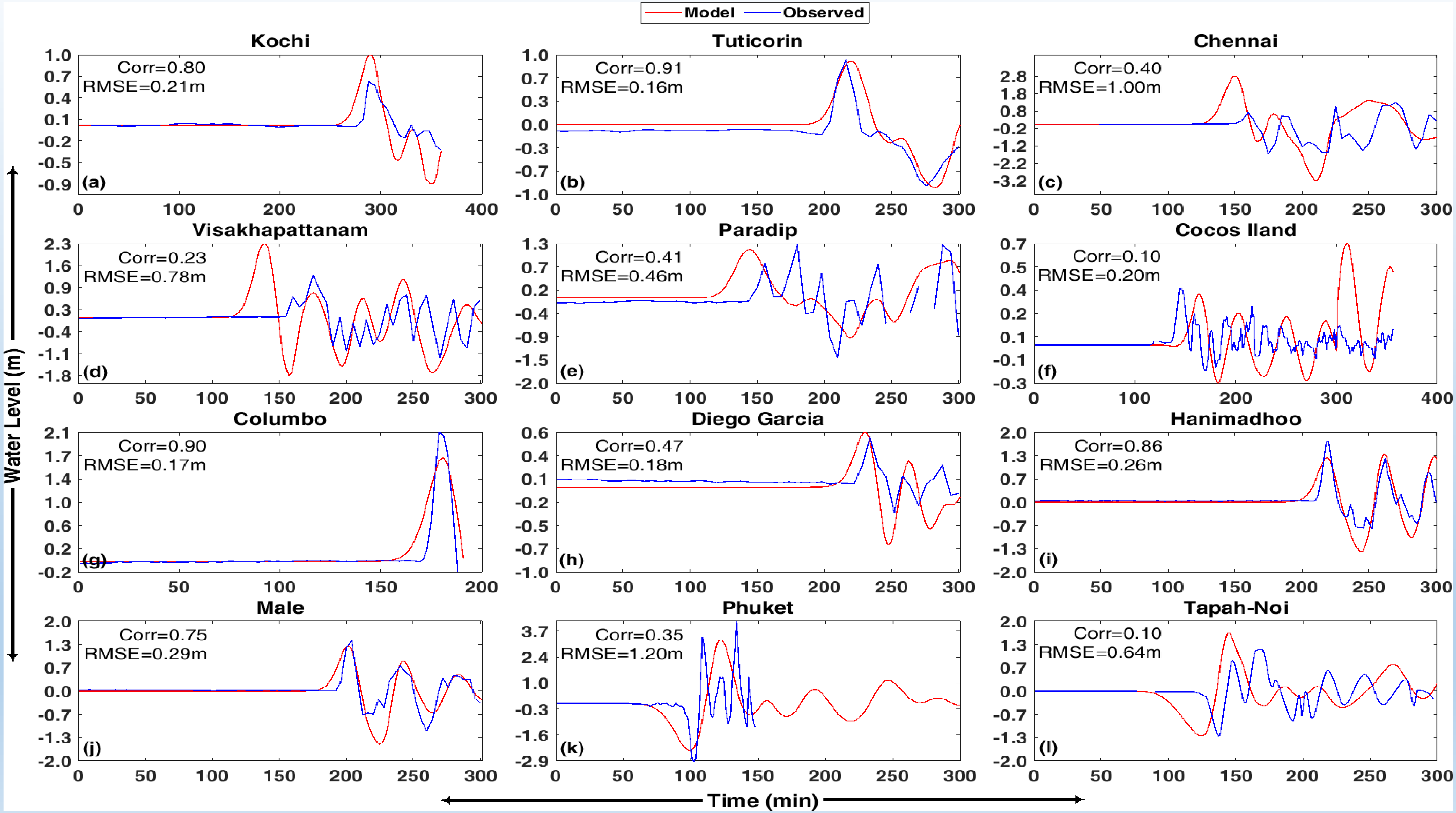


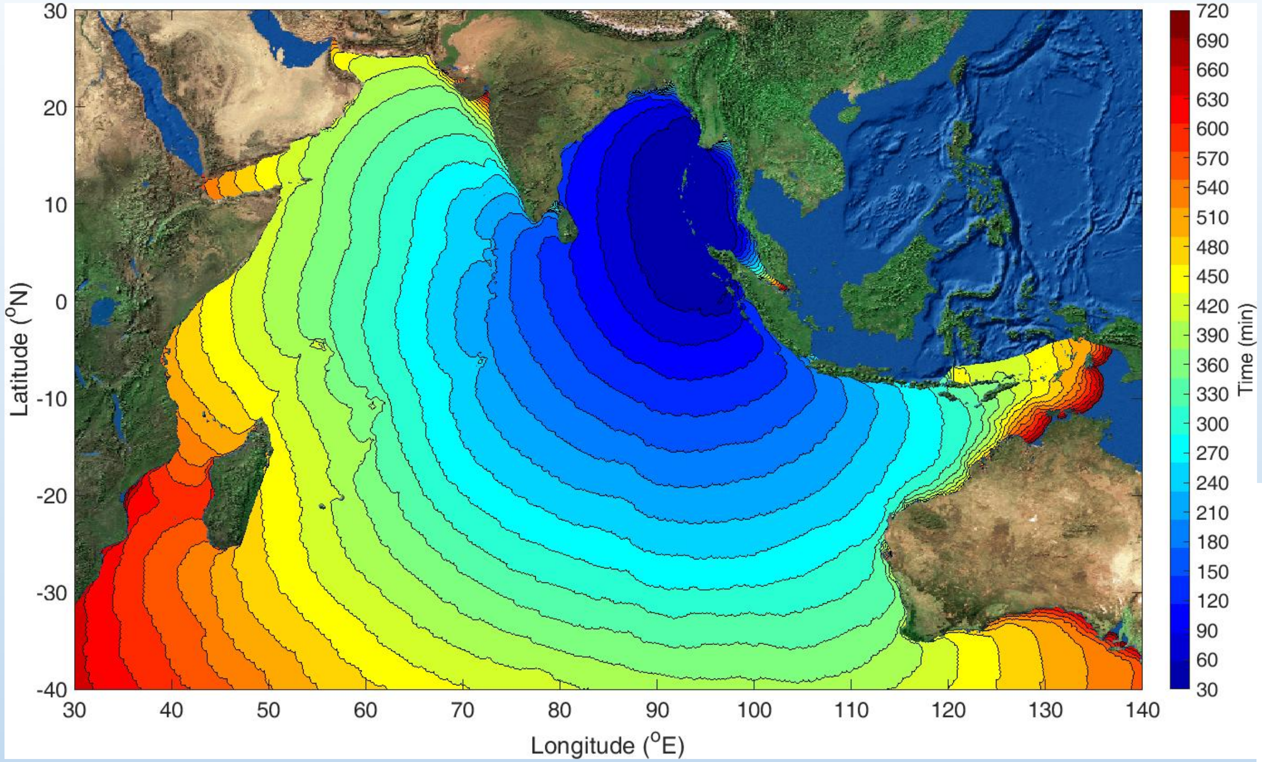
Wave propagation Animation



Propagation

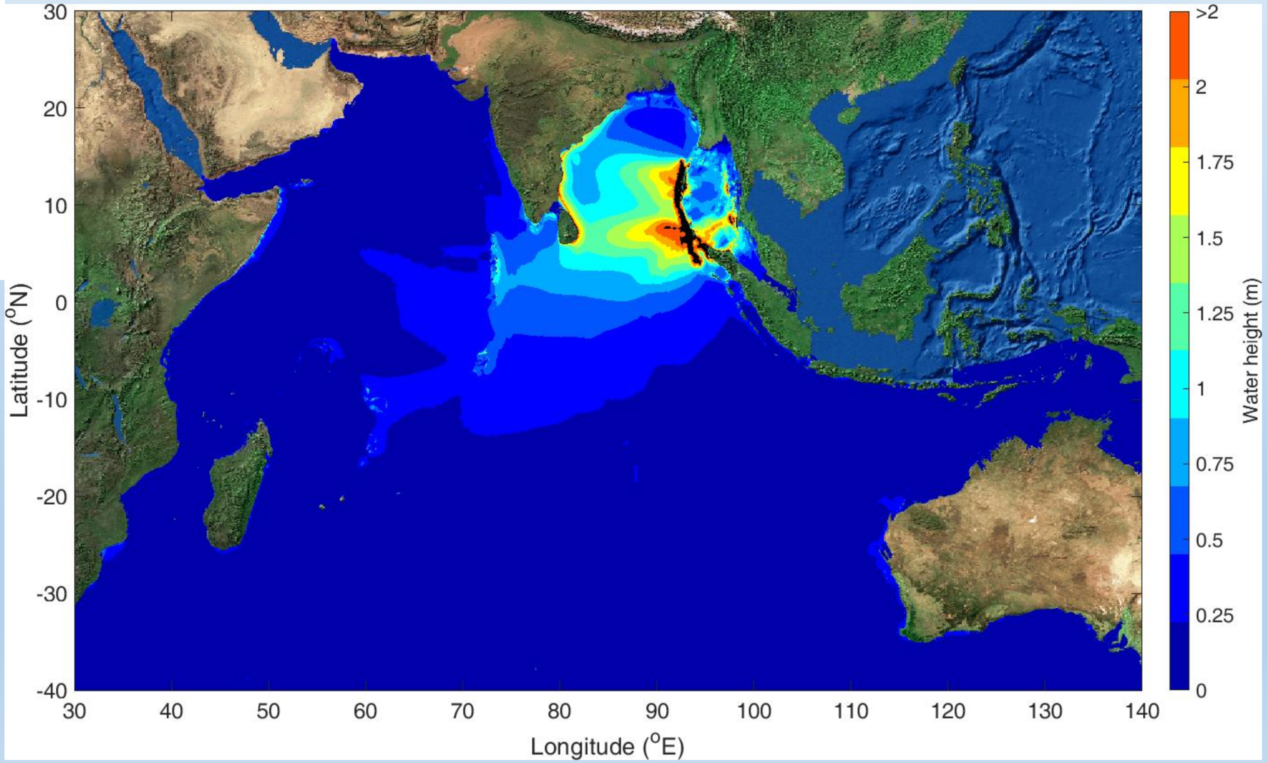


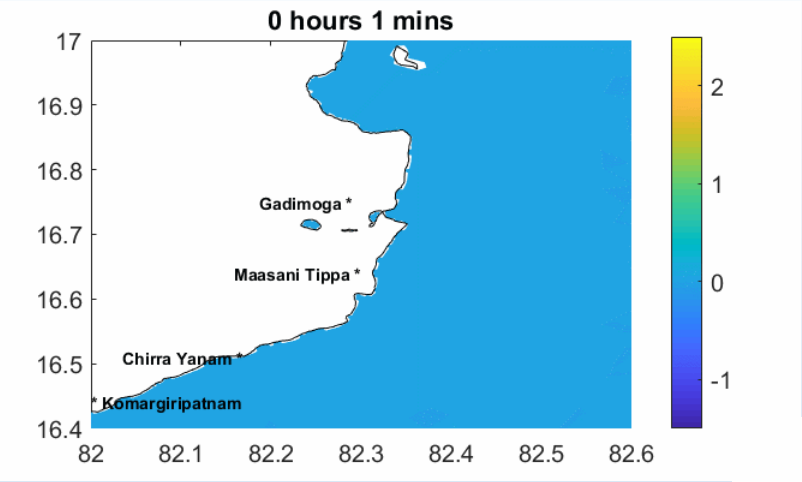

Model
Observed
Water Level (m)
Time (min)
Kochi
Corr=0.80
RMSE=0.21m
(a)
Tuticorin
Corr=0.91
RMSE=0.16m
(b)
Chennai
Corr=0.40
RMSE=1.00m
(c)
Visakhapattanam
Corr=0.23
RMSE=0.78m
(d)
Paradip
Corr=0.41
RMSE=0.46m
(e)
Cocos Iland
Corr=0.10
RMSE=0.20m
(f)
Columbo
Corr=0.90
RMSE=0.17m
(g)
Diego Garcia
Corr=0.47
RMSE=0.18m
(h)
Hanimadhoo
Corr=0.86
RMSE=0.26m
(i)
Male
Corr=0.75
RMSE=0.29m
(j)
Phuket
Corr=0.35
RMSE=1.20m
(k)
Tapah-Noi
Corr=0.10
RMSE=0.64m
(l)

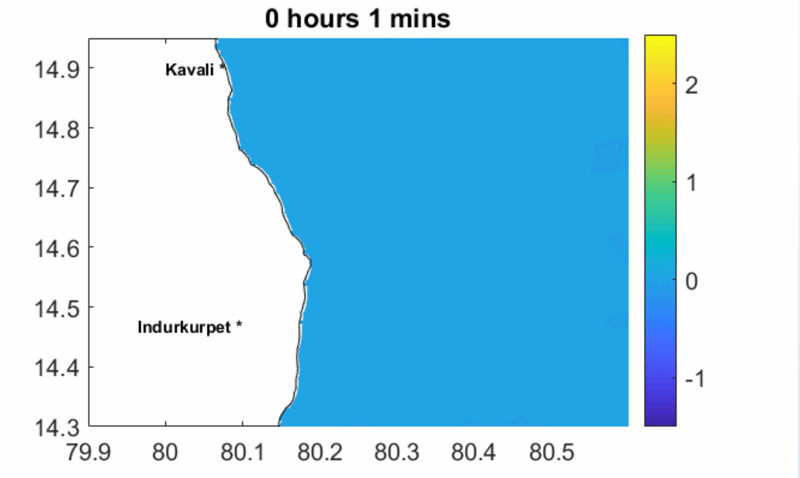


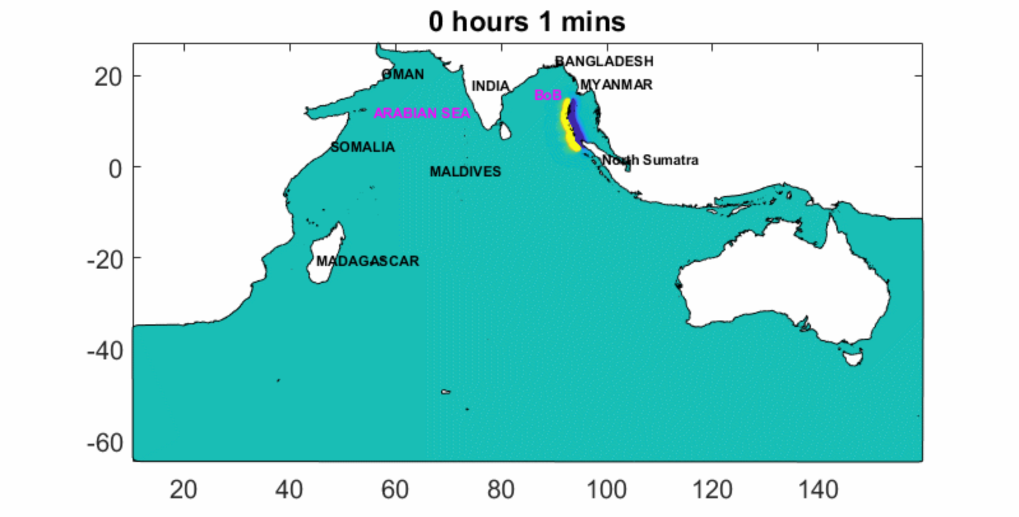
Travel time contours of the tsunami wave associated with 26th December 2004 Sumatra Earthquake.

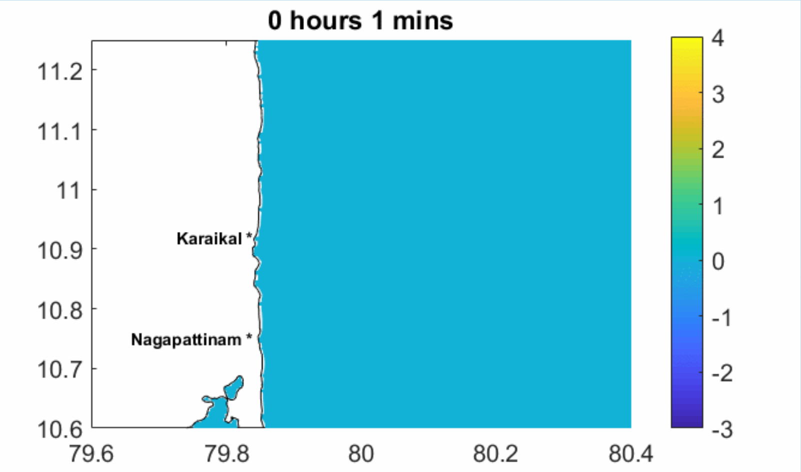
Directivity Plot (Wave height in meters)

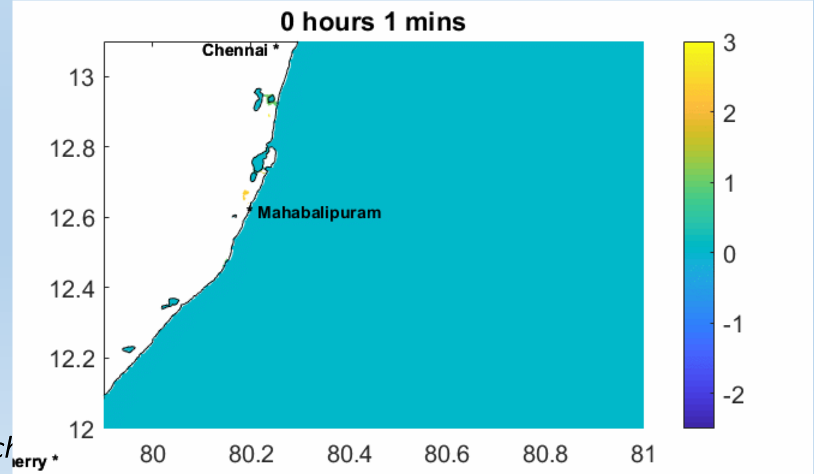


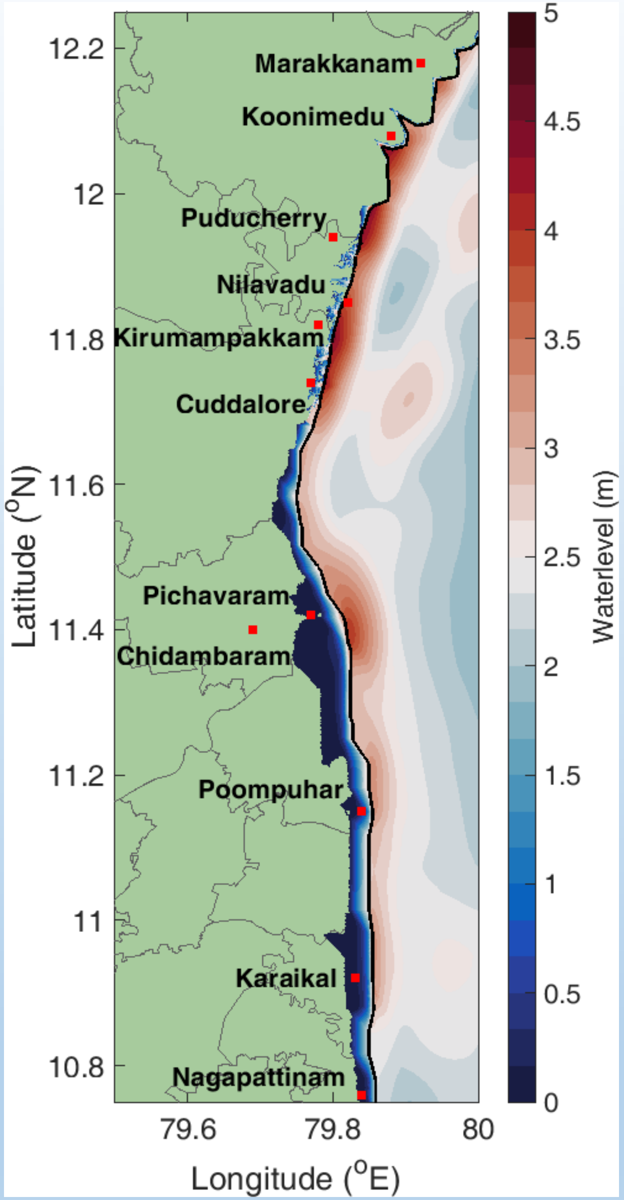

0 hours 1 mins
Gadimoga *
Maasani Tippa *
Chirra Yanam *
* Komargiripatnam
17
16.9
16.8
16.7
16.6
16.5
16.4
82
82.1
82.2
82.3
82.4
82.5
82.6
2
1
0
-1


0 hours 1 mins
Kavali *
Indurkurpet *
14.9
14.8
14.7
14.6
14.5
14.4
14.3
79.9
80
80.1
80.2
80.3
80.4
80.5
2
1
0
-1

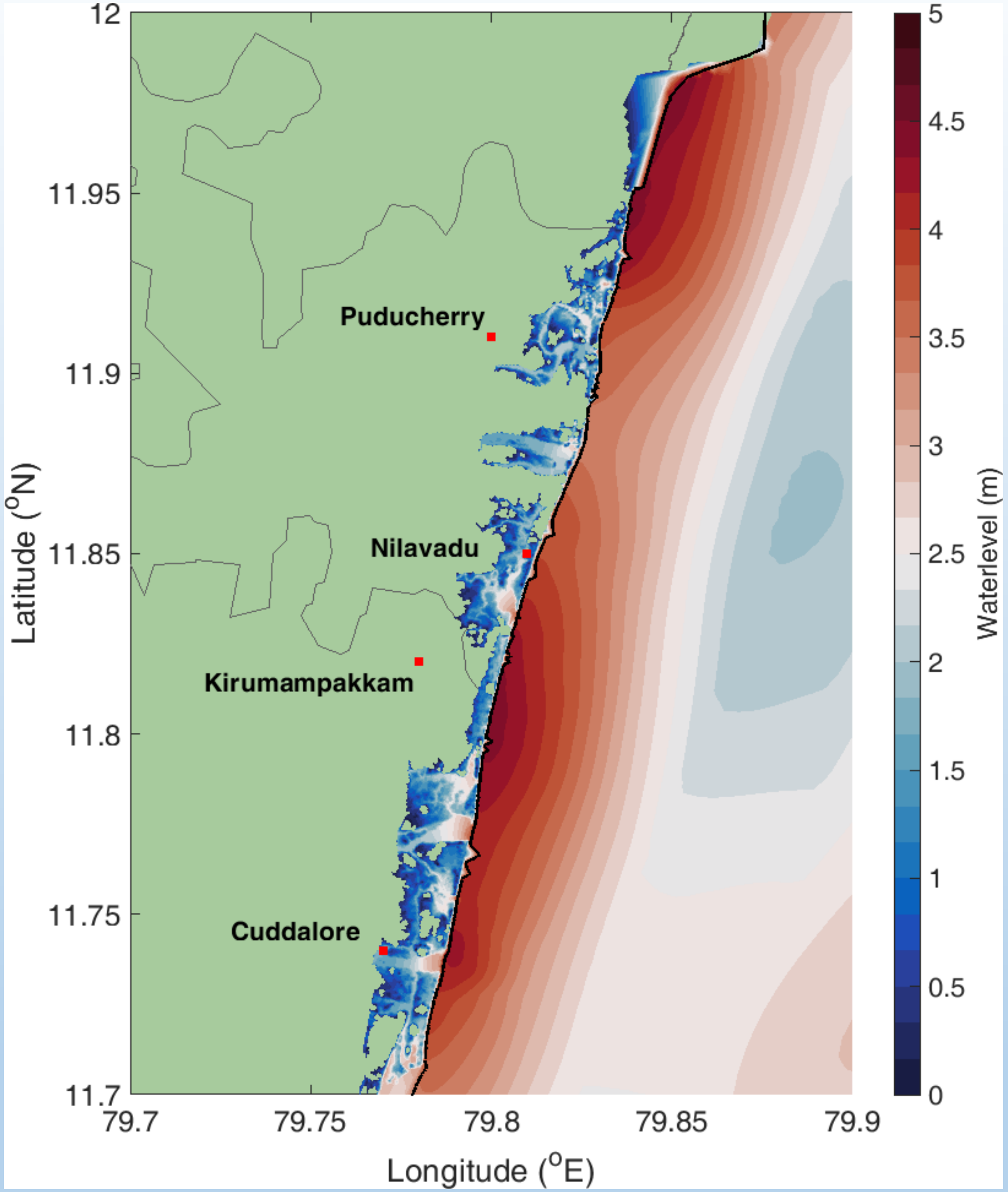

0 hours 1 mins
OMAN
INDIA
BANGLADESH
MYANMAR
BoB
ARABIAN SEA
SOMALIA
MALDIVES
North Sumatra
MADAGASCAR
20
0
-20
-40
-60
20
40
60
80
100
120
140


0 hours 1 mins
Karaikal *
Nagapattinam *
11.2
11.1
11
10.9
10.8
10.7
10.6
79.6
79.8
80
80.2
80.4
4
3
2
1
0
-1
-2
-3


0 hours 1 mins
Chennai *
Mahabalipuram
13
12.8
12.6
12.4
12.2
12
80
80.2
80.4
80.6
80.8
81
3
2
1
0
-1
-2

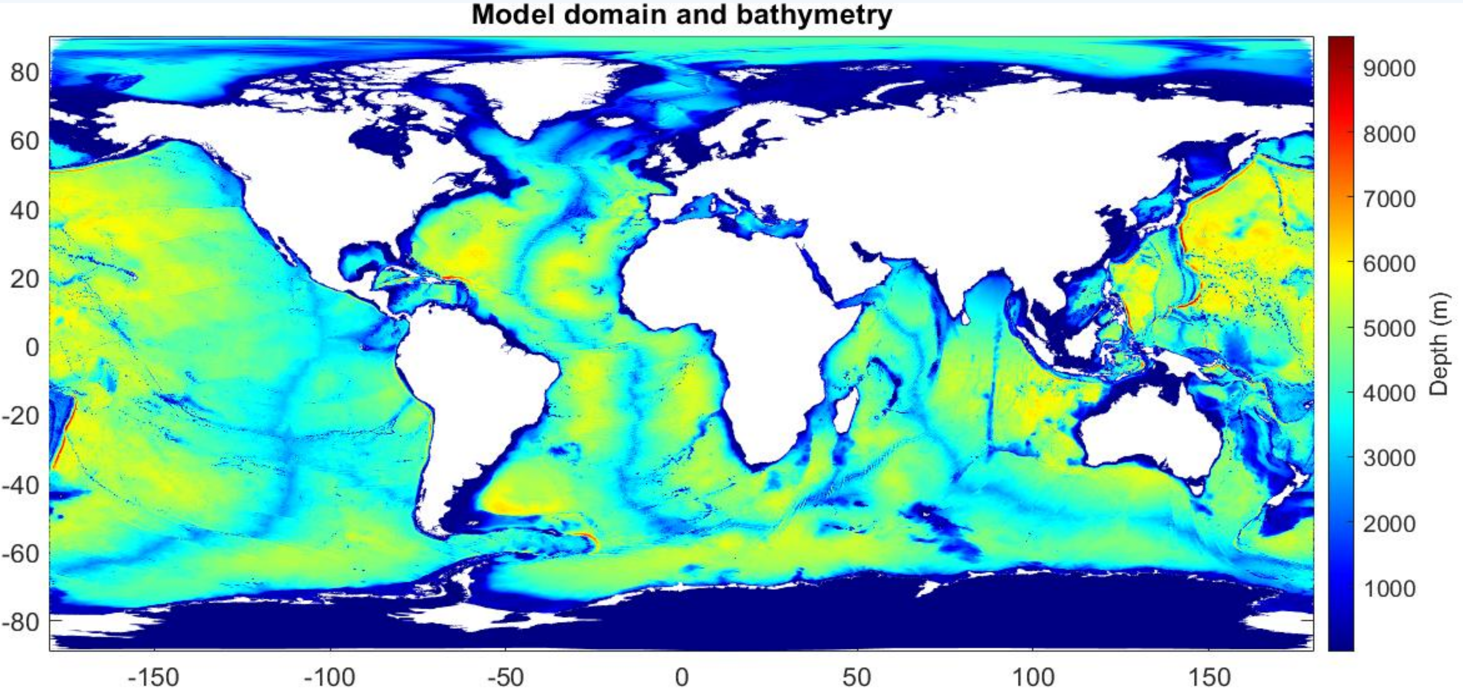


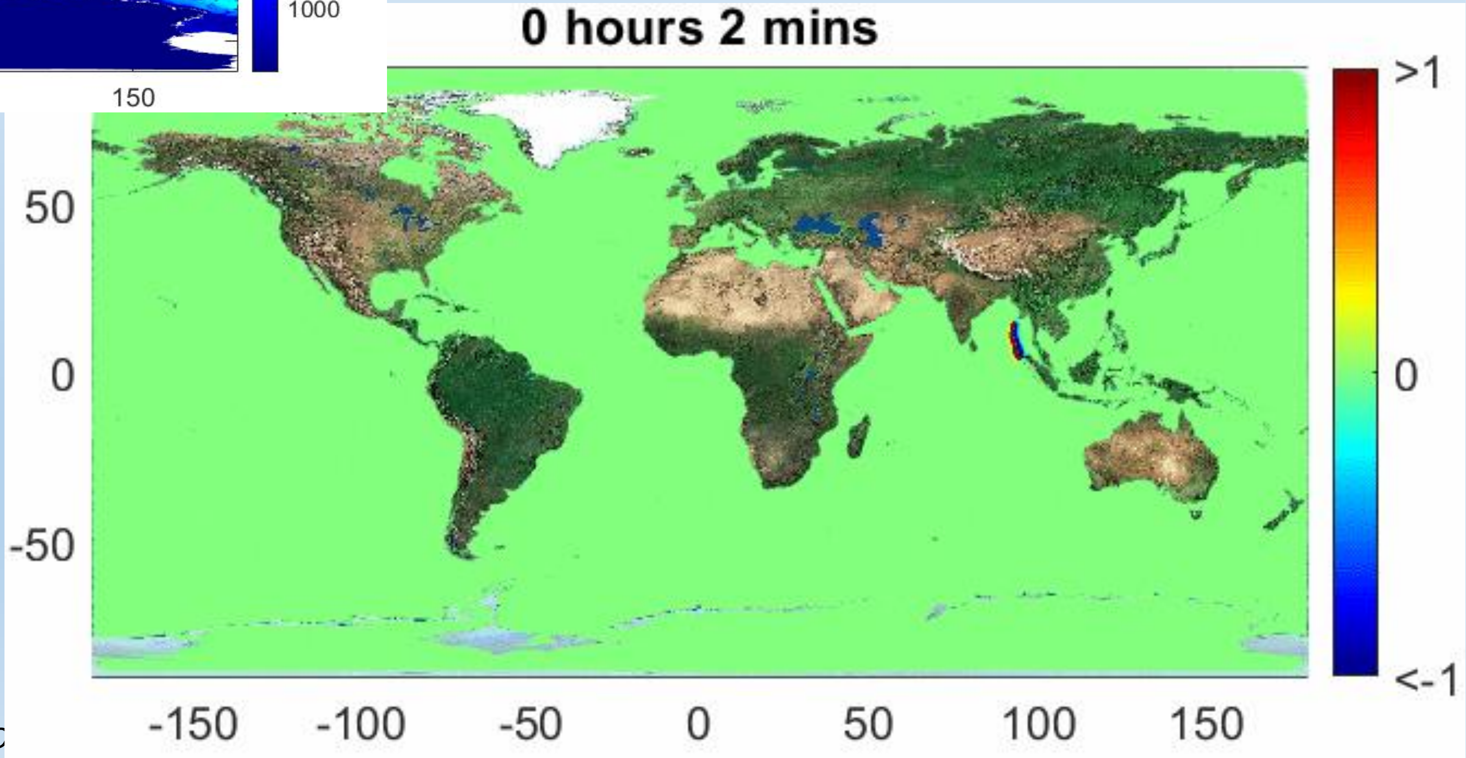
Spatial depiction of inundation extent along the coastal region of southern Tamil Nadu



Enlarged portion of depicting inundation where the merged bathymetry and topography data were used

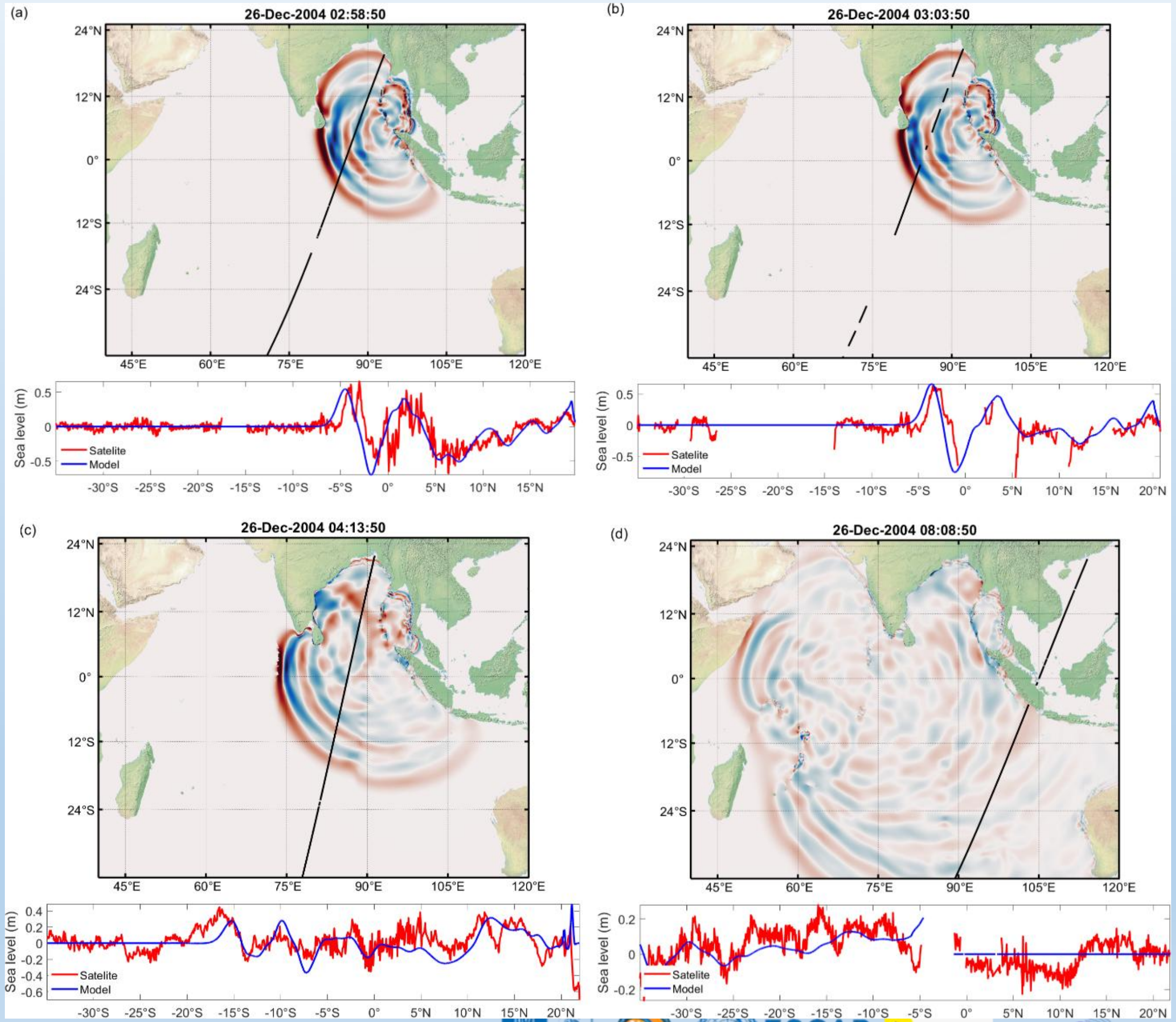
Tsunami modelling over global oceans





Tsunami Inundation Modelling and Mapping, INCO


blueb: Mauritius, Blue Bay
chenn: India, Chennai
chit: New Zealand, Owenga, Chatham Island
cocb: Australia, Cocos Island
coch: India, Cochin
colo: Sri Lanka, Colombo
ganm: Maldive Islands, Gan
garc: UK, Diego Garcia
hani: Maldive Islands, Hanimadhoo
jack: New Zealand, Jackson Bay
lamu: Kenya, Lamu
laru2: Seychelles, Pt.LaRue
male: Maldive Islands, Male
marm: India, Marmagao
okha: India, Okha
parad: India, Paradip
rich: South Africa, Richards Bay
sala: Oman, Salalah
syow: Antarctica, Syowa
tuti: India, Tuticorin
vish: India, Visakhapatnam
zanz: Tanzania, Zanzibar
6:00 AM
12:00 PM
6:00 PM
12:00 AM
6:00 AM


(a)
26-Dec-2004 02:58:50
(b)
26-Dec-2004 03:03:50
(c)
26-Dec-2004 04:13:50
(d)
26-Dec-2004 08:08:50
24°N
12°N
0°
12°S
24°S
45°E
60°E
75°E
90°E
105°E
120°E
Sea level (m)
Satelite
Model
-30°S
-25°S
-20°S
-15°S
-10°S
-5°S
0°
5°N
10°N
15°N
20°N

Thank you