Training/Workshop on

Tsunami Evacuation Maps, Plans, and Procedures and the UNESCO-IOC Tsunami Ready Recognition Programme for the Indian Ocean Member States

Hyderabad - India, 15-23 April 2025

Tsunami Inundation Modelling and MAP

TIMM #: Inundation Mapping Modeling Requirements: Earthquake Tsunami Sources, Parameterization

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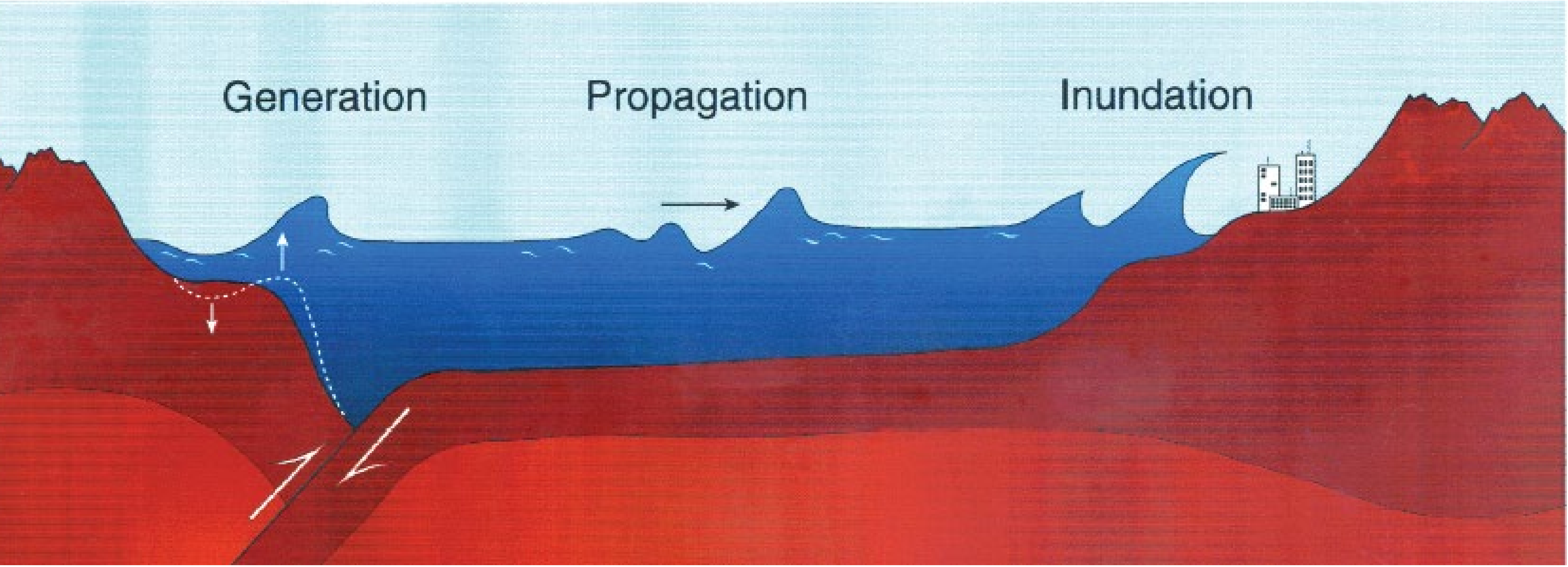
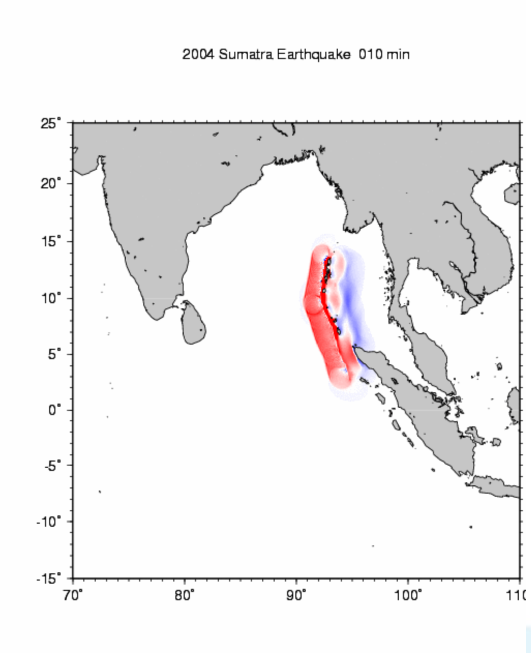
Tsunami Modelling and Forecasting



Tsunami Modelling and Forecasting

What are the required inputs to modelling software and outputs from modelling software?

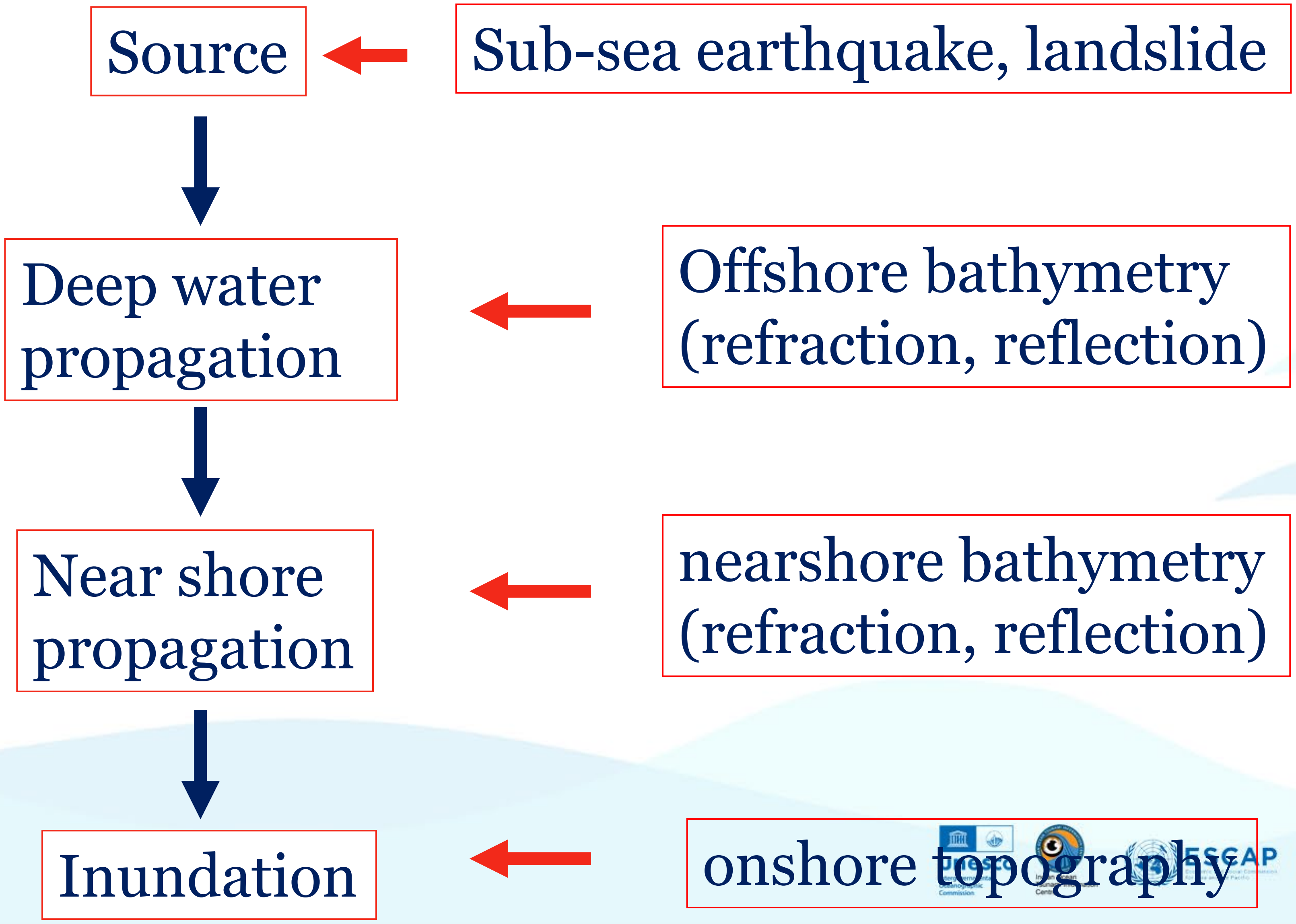


inputs:
- source
- deepwater bathymetry
- nearshore bathymetry (50m resolution)
- onshore topography

outputs:
- distribution of wave heights
- run-up heights

given locations

Tsunami modelling framework



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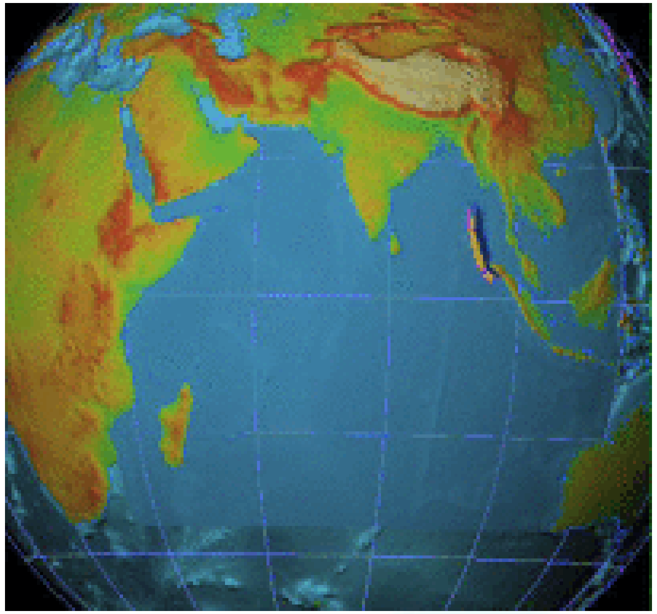
ICG/IOTWS Working Group 2

Modelling, Forecasting and Scenario Development



- Provide benchmarked and validated numerical modelling methods and software applicable for use in the Indian Ocean
- Develop and sustain national and regional capacity to apply numerical modelling for tsunami source generation, wave propagation, and coastal inundation in the Indian Ocean

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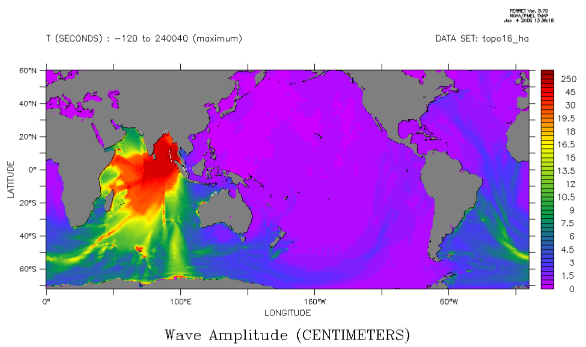
unesco Intergovernmental Oceanographic Commission | Indian Ocean Tsunami Information Centre | ESCAP | INCOIS | BMKG | Tsunami Ready

ICG/IOTWS Working Group 2

Facilitate the development of a web-based Community Model Interface for Tsunami (ComMIT)

(developed by NOAA/PMEL through USAID funding)

- ComMIT provides propagation and inundation mapping capability to countries of the Indian Ocean region.
- The model system includes access to pre-computed deep water propagation scenarios.



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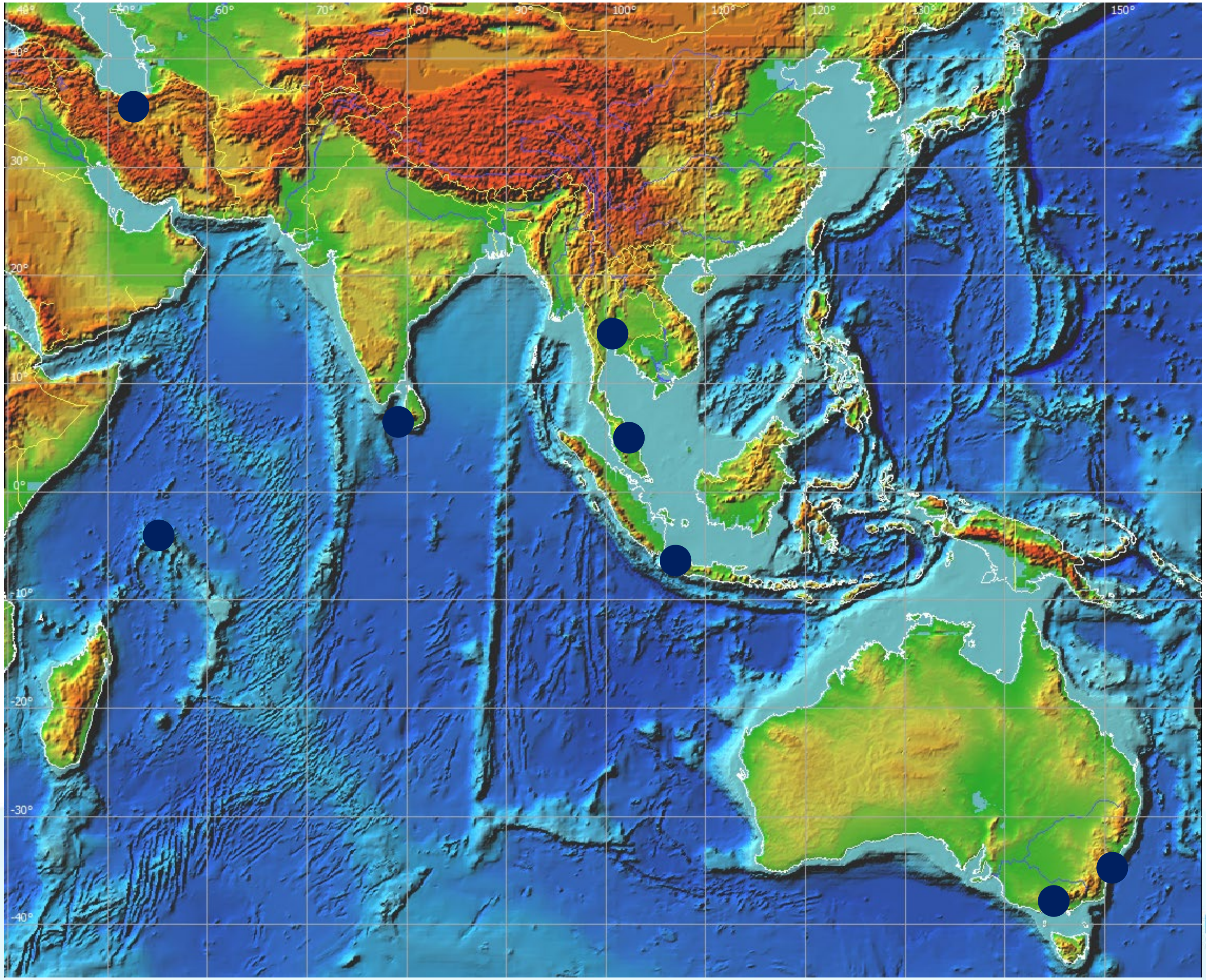
ComMIT Training Courses



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ESCAP

INCOIS

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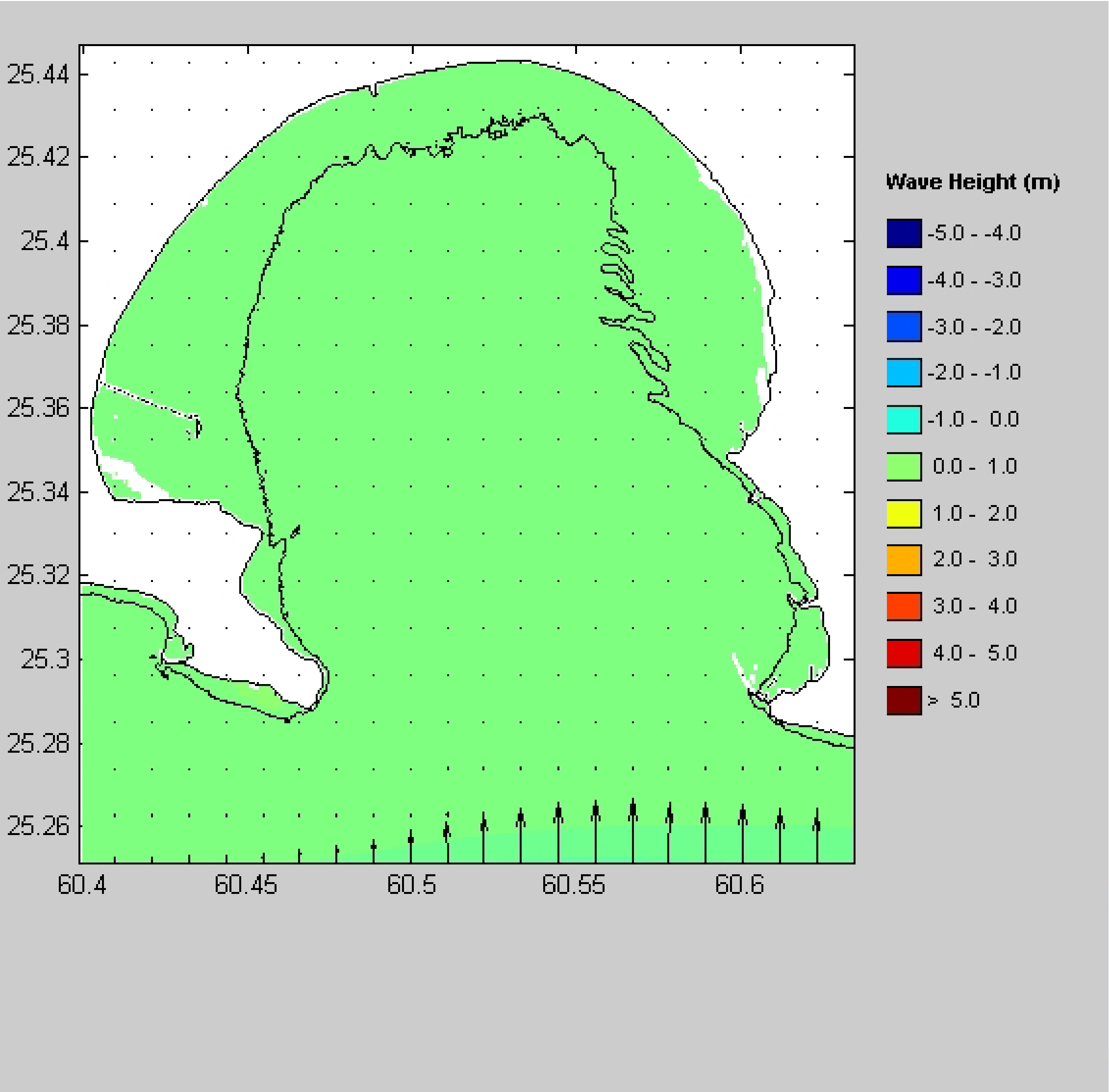
Tsunami Ready

ComMIT Training Courses



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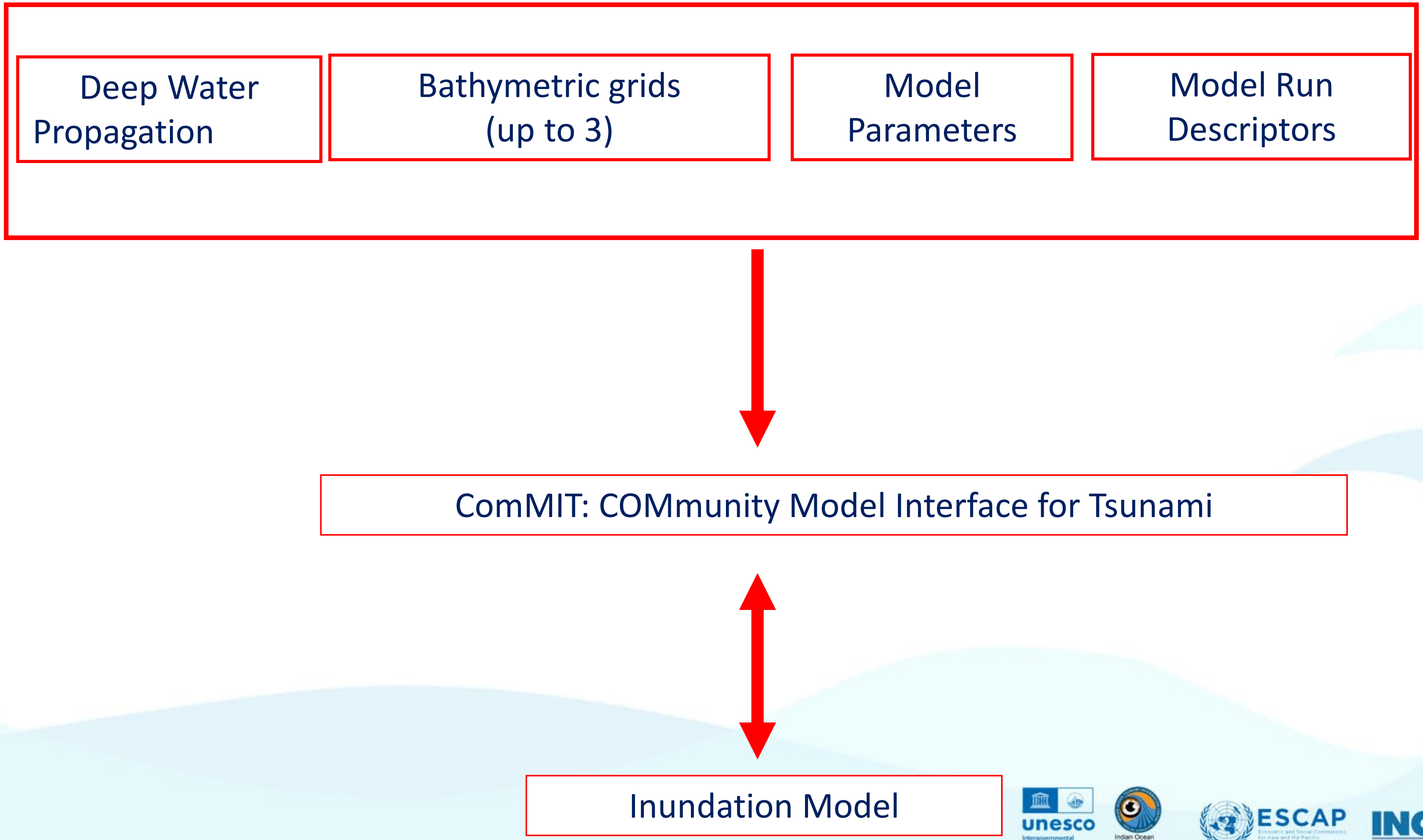
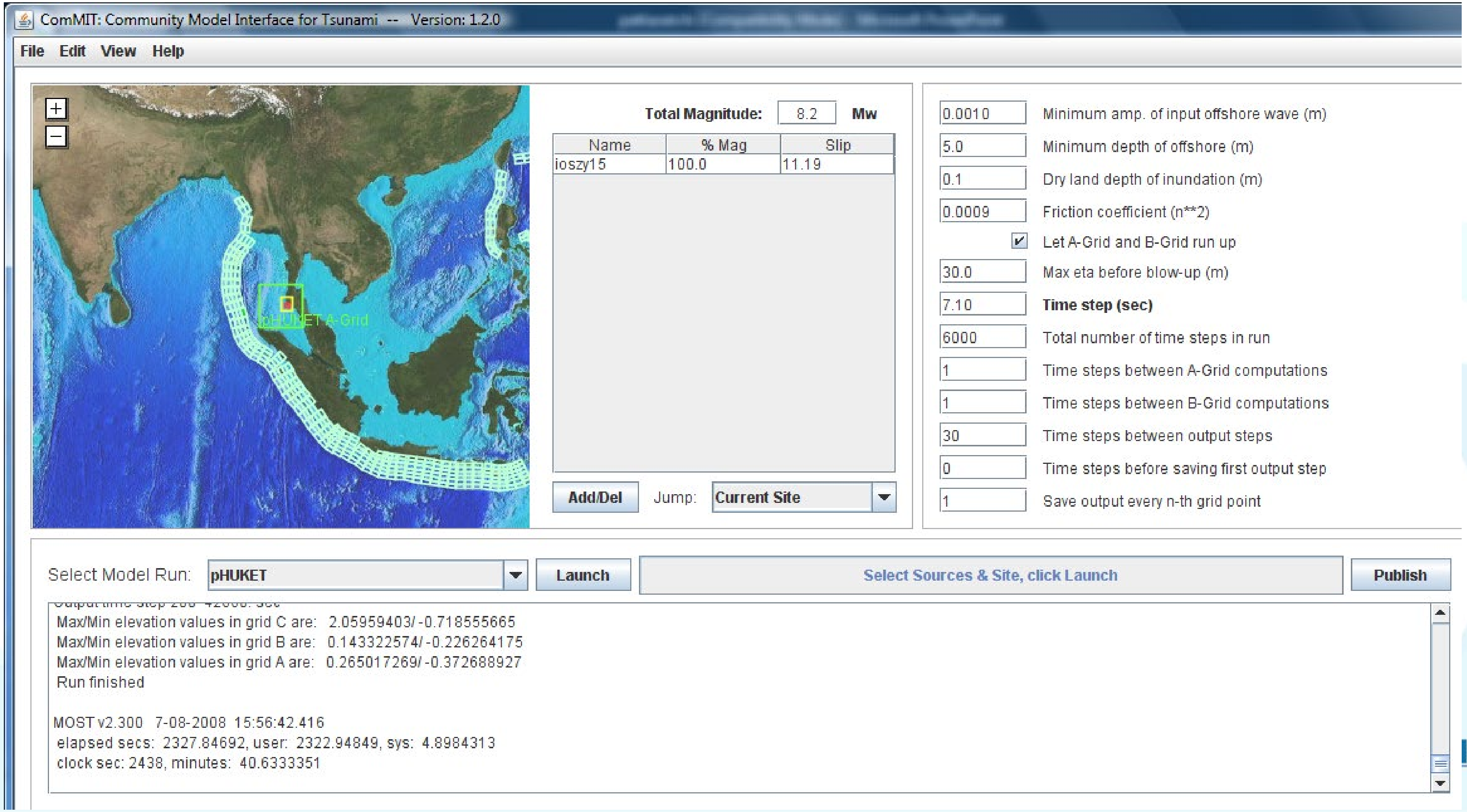
ESCAP INCOIS BMKG

ComMIT


Deep Water Propagation
Bathymetric grids (up to 3)
Model Parameters
Model Run Descriptors
ComMIT: COMmunity Model Interface for Tsunami
Inundation Model

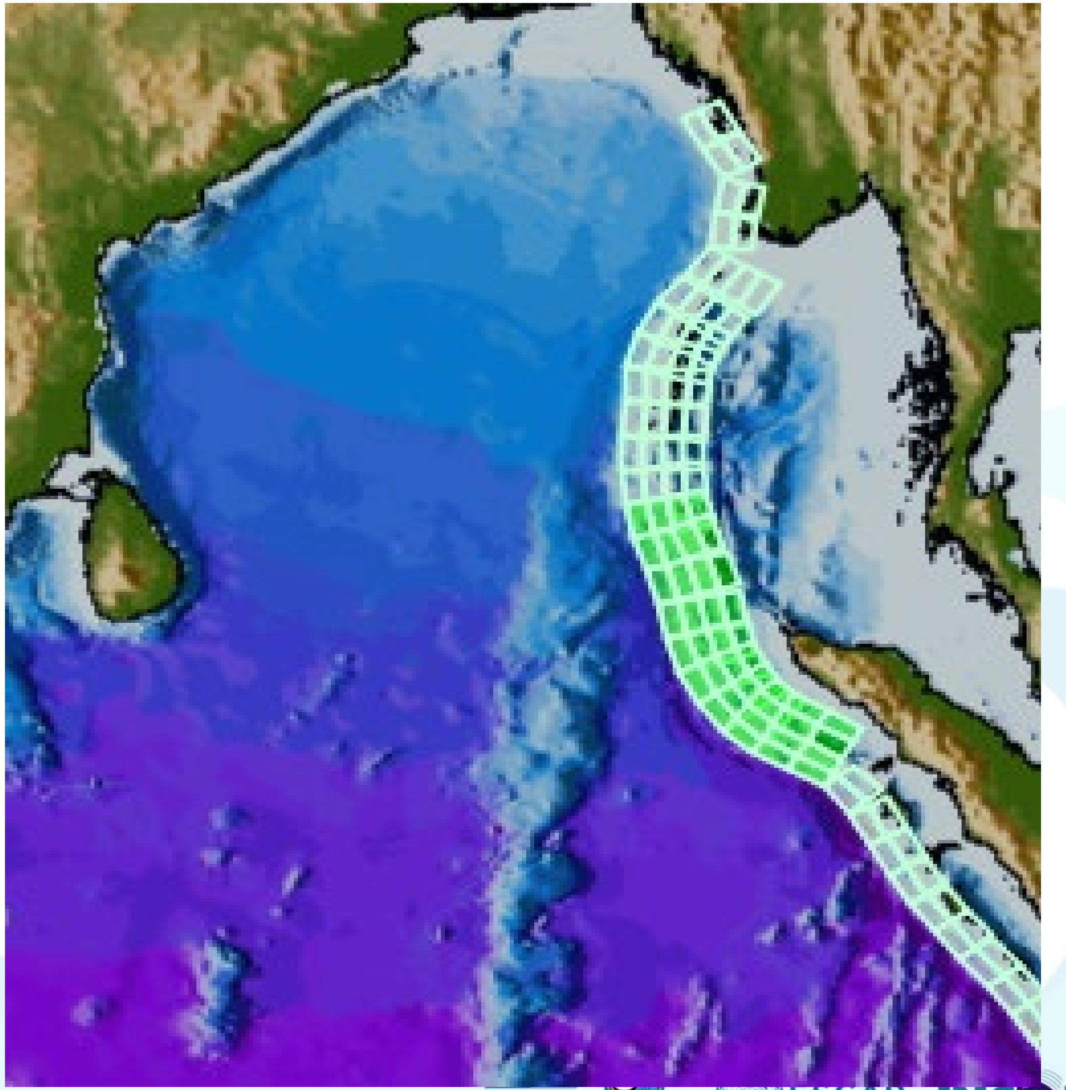
ComMIT
Community Model Interface for Tsunami



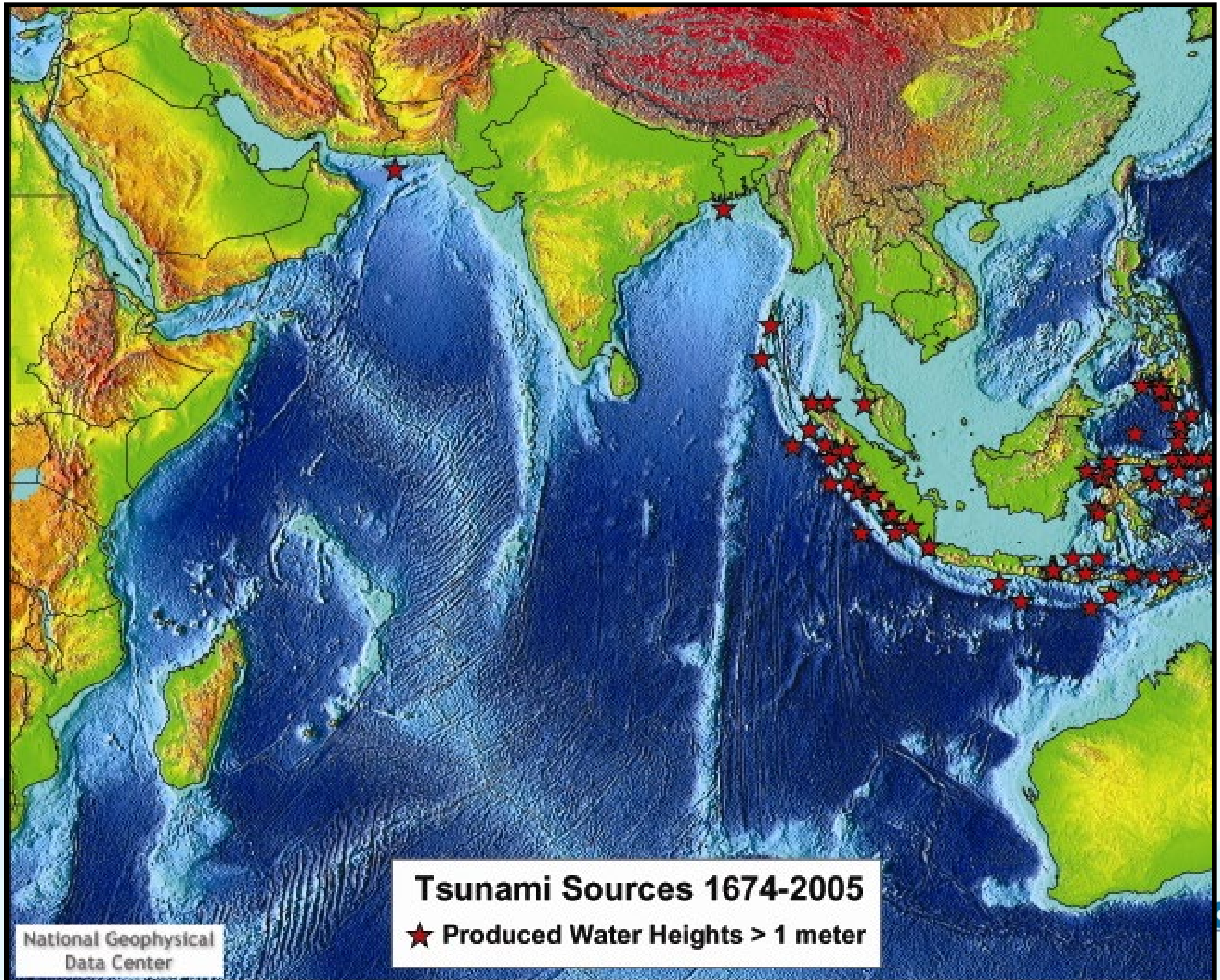
Model Sources

Seismic forcing:

Epicentre location
Length (*L*)
Width (*W*)
depth
Strike, dip, rake (deg)
Magnitude (M_w) or slip (u_o):



Indian Ocean region: Tsunami sources



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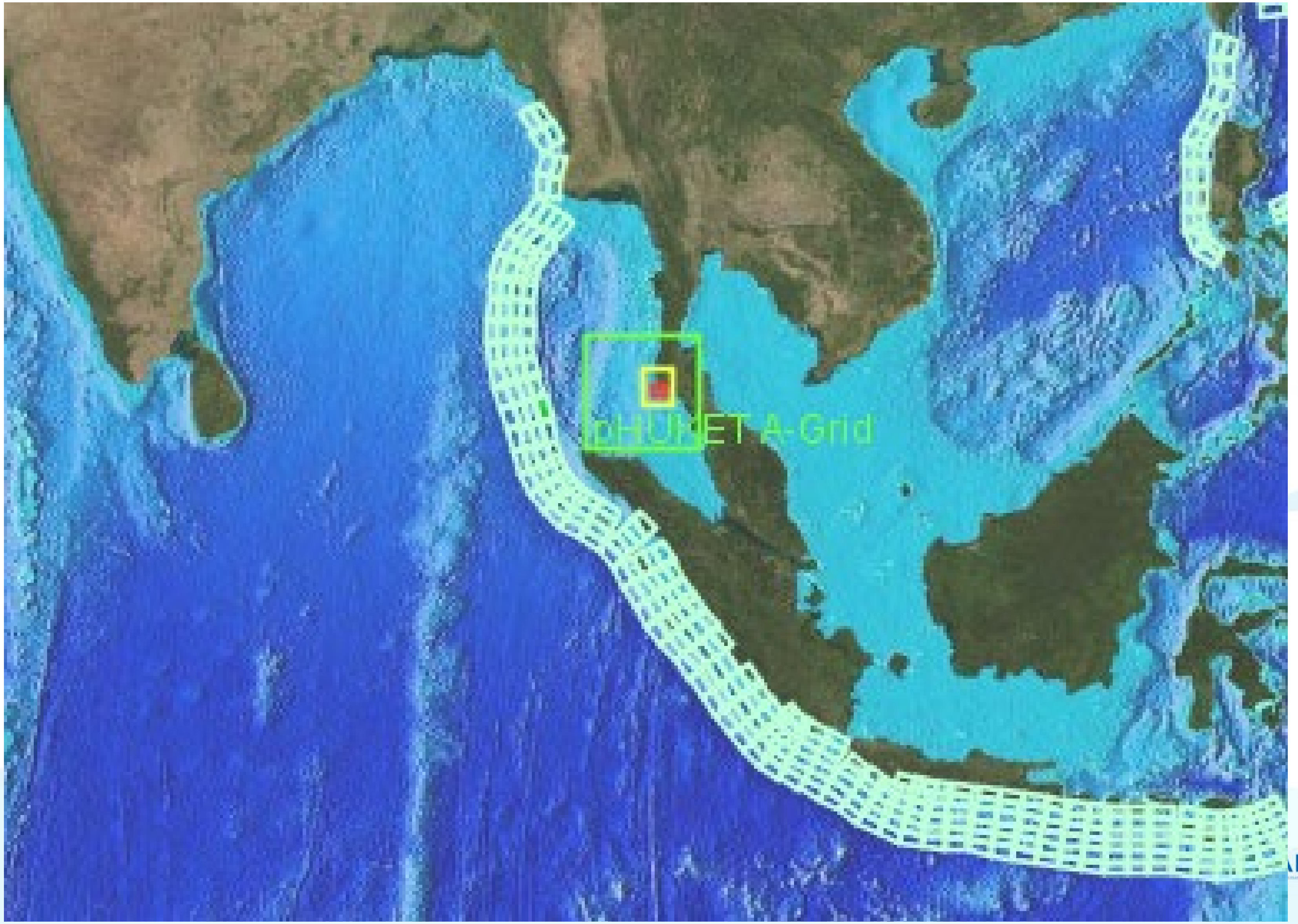
Indian Ocean region: Tsunami sources



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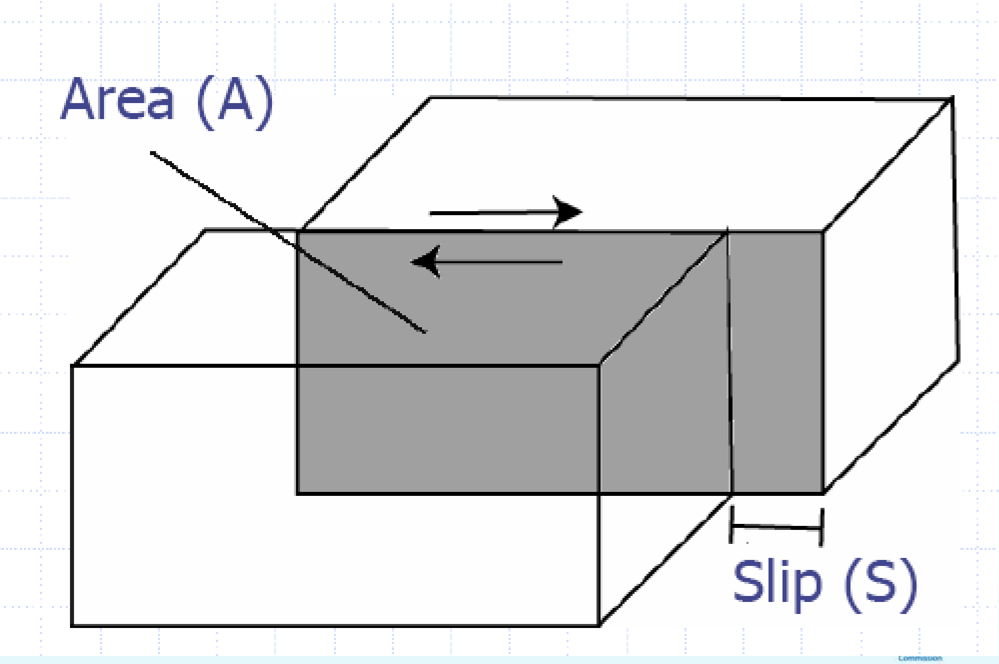
Source Characterisation:
Unit sources

Seismic moment = rigidity x fault area x slip

$$M_0 = \mu L W u_0 \quad \text{(Nm)}$$



Source Characterisation: Unit sources

Seismic moment = rigidity x fault area x slip

$$M_0 = \mu L W u_0$$ (Nm)

Rigidity (shear modulus) = ~2 x 10^{10} Pa

$$\mu = \rho V_s^2$$

$V_s = 3.6$ km s^{-1}

$$M_W = \frac{2}{3}(\log_{10}(M_0) - 9.1)$$

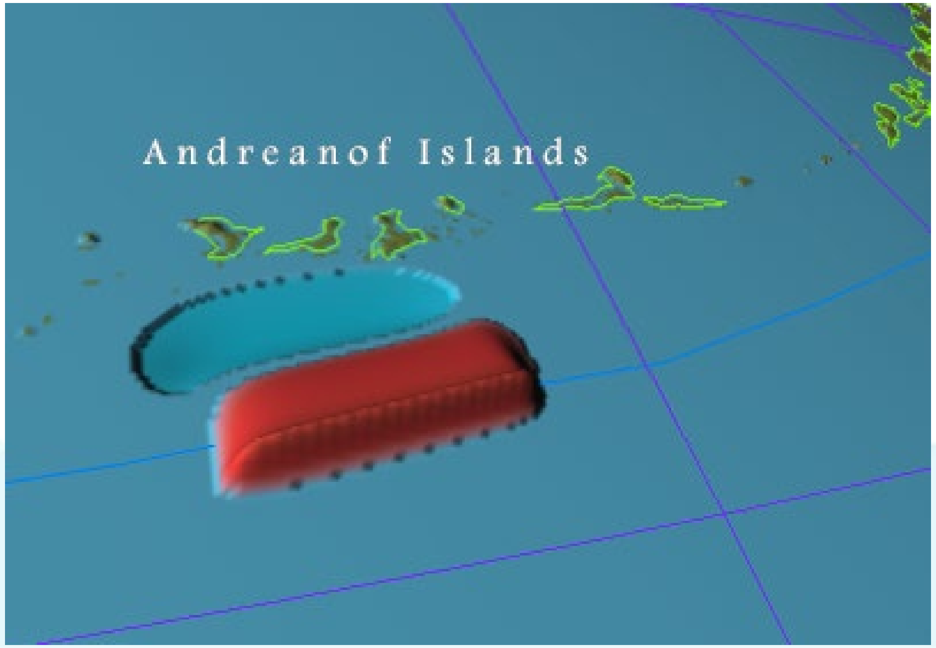
M_o in dyne cm

Source Characterisation: Unit sources

$$M_0 = \mu L W u_0$$

ComMIT uses unit sources L= 100 km   W=50 km

Moment magnitude is dependent only on slip



For a given unit source there is a max moment magnitude

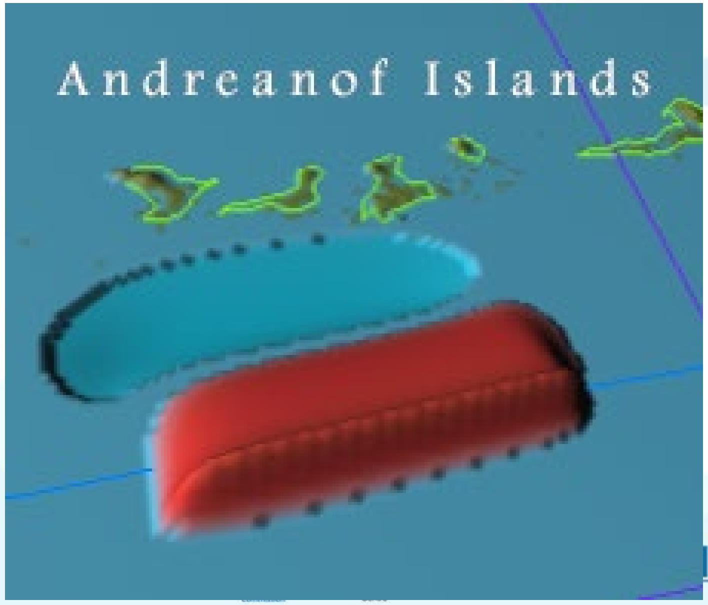
Source Characterisation: Unit sources

Guidelines for maximum moment magnitude (M_w)

Maximum slip ~30m (2004 was 20 m)

1 unit = 100x50 km

1 unit	8.5
2 units	8.7
4 units	8.9
6 units	9.0
10 units	9.2



Unit sources: Examples

1 unit

Total Magnitude: 9.20 Mw

Name	% Mag	Slip
ioszb13	100.0	353.97

2 units

Total Magnitude: 9.2 Mw

Name	% Mag	Slip
ioszb12	50.0	176.99
ioszb13	50.0	176.99

4 units

Total Magnitude: 9.2 Mw

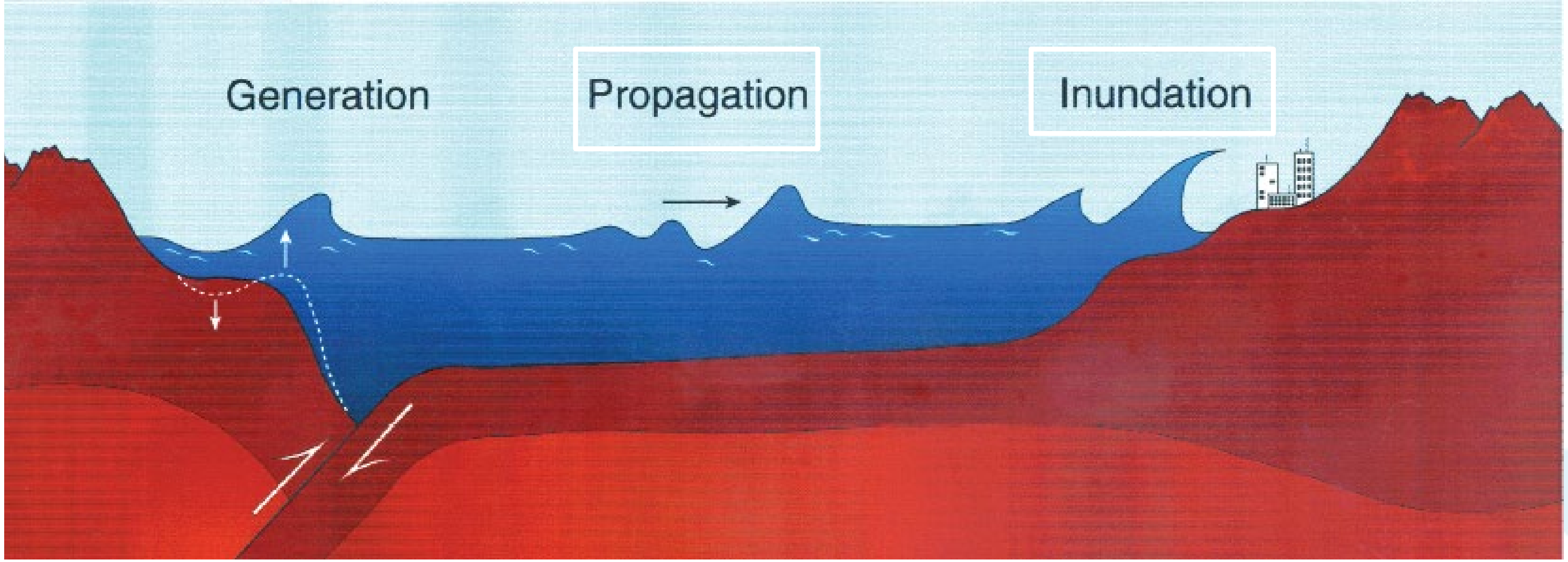
Name	% Mag	Slip
ioszb10	25.0	88.49
ioszb11	25.0	88.49
ioszb12	25.0	88.49
ioszb13	25.0	88.49

10 units

Total Magnitude: 9.2 Mw

Name	% Mag	Slip
iosza9	10.0	35.40
ioszb9	10.0	35.40
iosza10	10.0	35.40
ioszb10	10.0	35.40
iosza11	10.0	35.40
ioszb11	10.0	35.40
iosza12	10.0	35.40
ioszb12	10.0	35.40
iosza13	10.0	35.40
ioszb13	10.0	35.40

Tsunami Models



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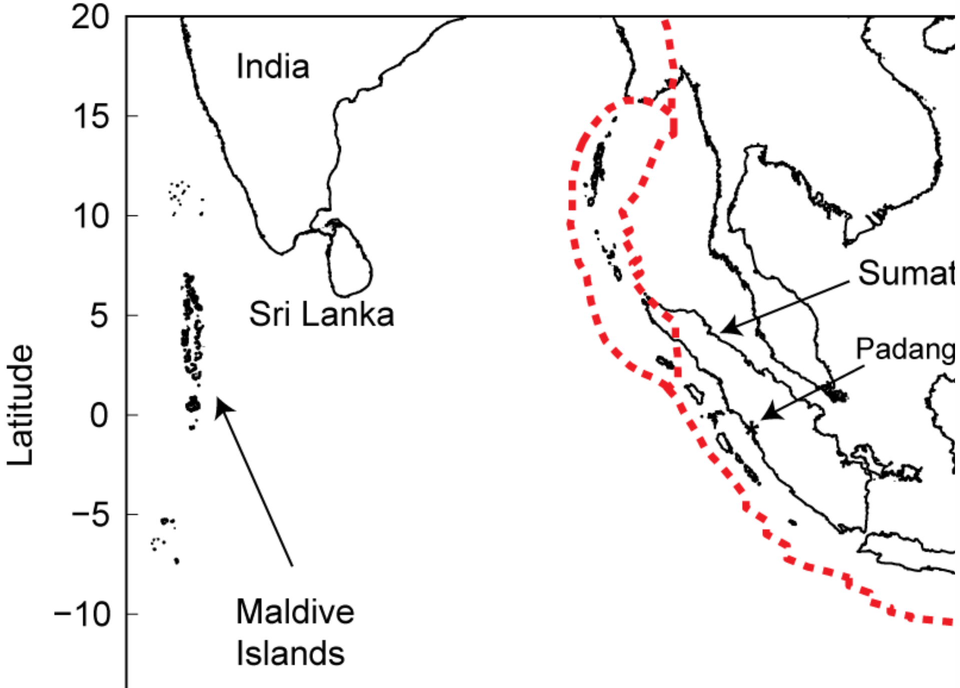
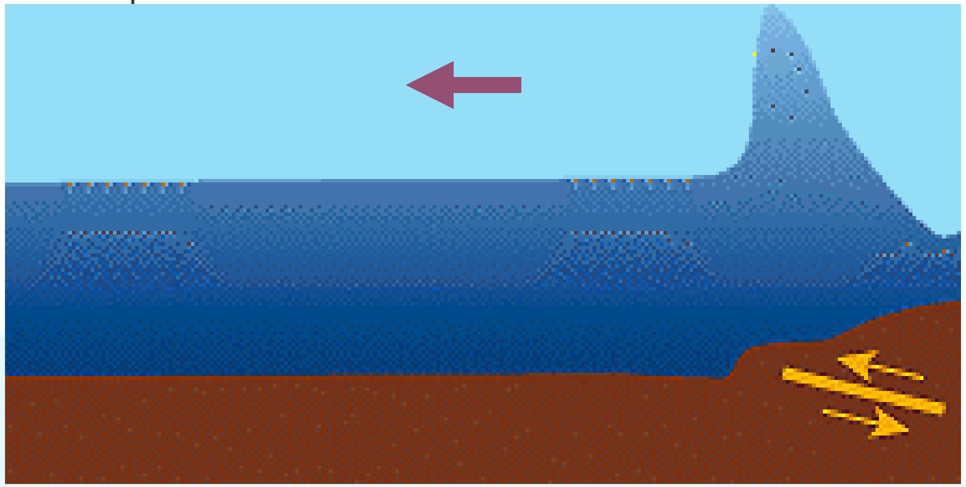
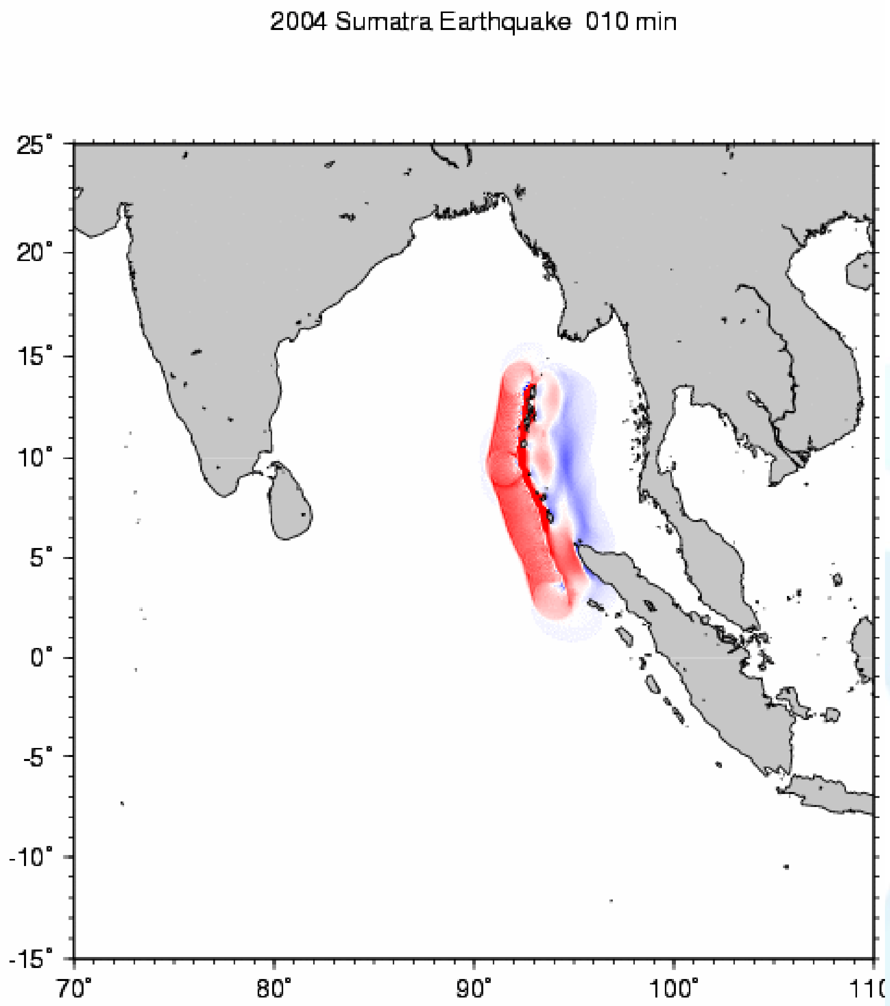
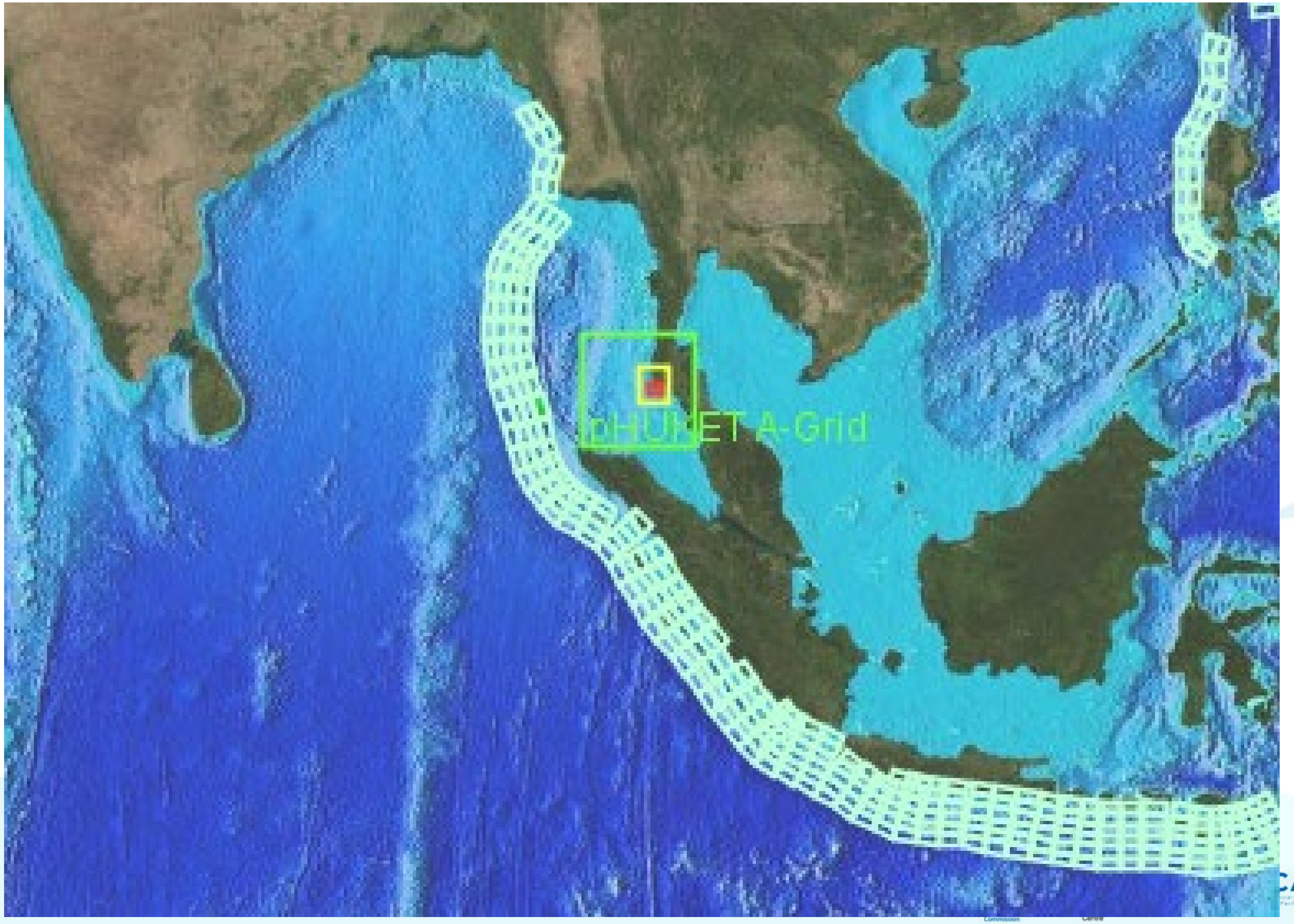
Tsunami Propagation



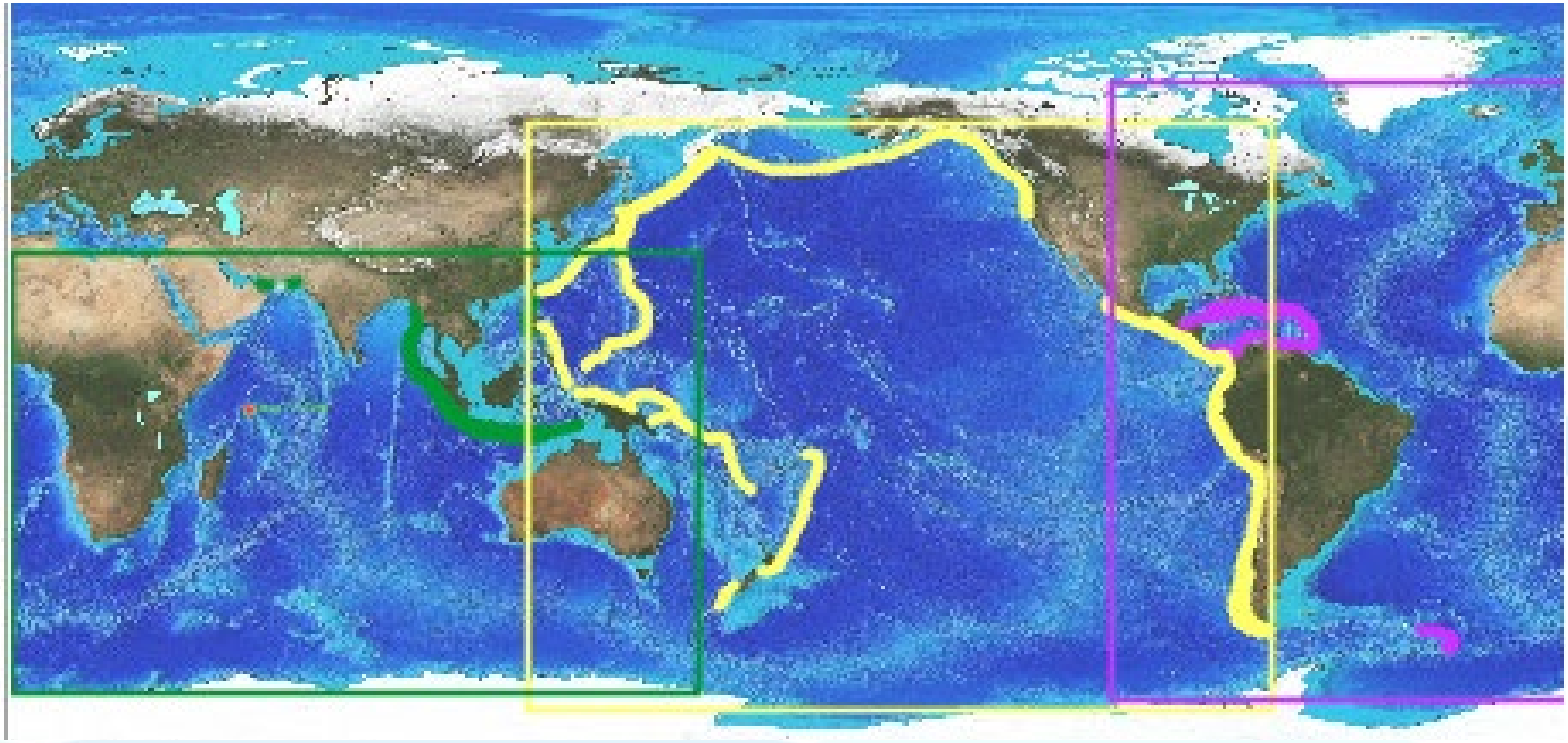




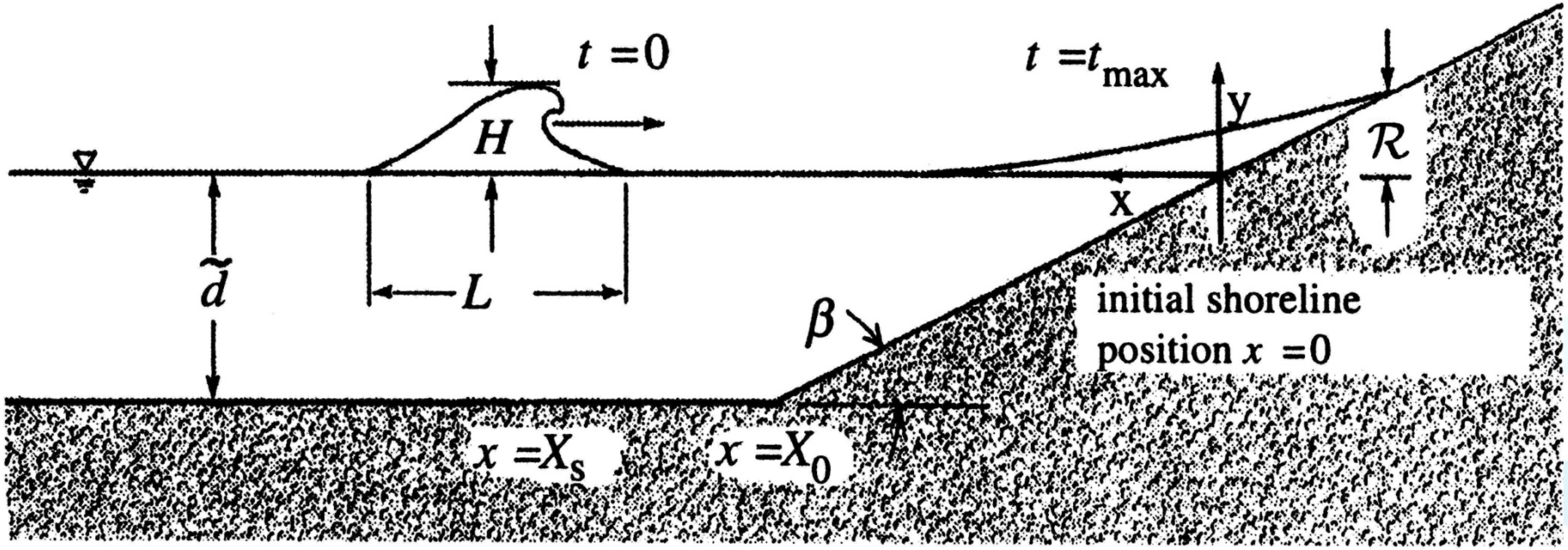
Deep water propagation scenarios pre-run



Tsunami Propagation model data base



Tsunami Propagation - Nomenclature



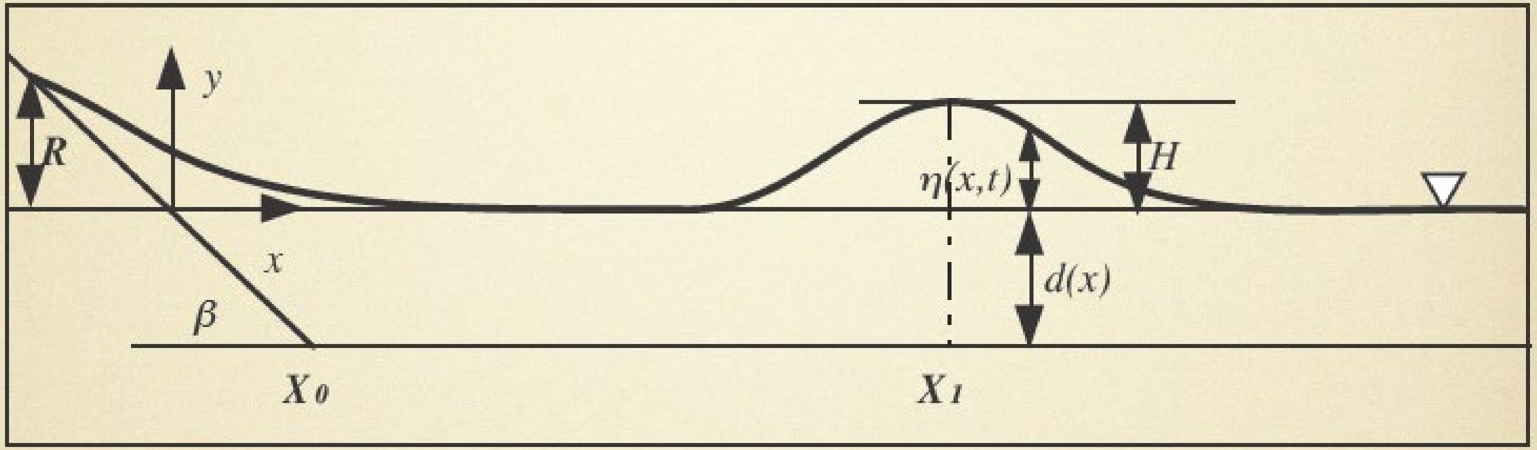
H is the wave height

L is the wave wavelength

R is the maximum runup

d is the charateristic length scale for normalization

MOST – Method of Splitting Tsunami



$$h_t + (uh)_x + (vh)_y = 0$$
$$u_t + uu_x + vu_y + gh_x = gd_x$$
$$v_t + uv_x + vv_y + gh_y = gd_y$$

$$d(x, y, t) = d_0(x, y, t),\ t \le t_0$$
$$d(x, y, t) = d_0(x, y, t_0),\ t \le t_0$$

where $h = \eta\,(x,y,t) + d(x,y,t)$, $\eta\,(x,y,t)$ is the amplitude, $d(x,y,t)$ is the undisturbed water depth, $u(x,y,t)$, $v(x,y,t)$ are the depth-averaged velocities in the x and y directions respectively, g is the acceleration of gravity.

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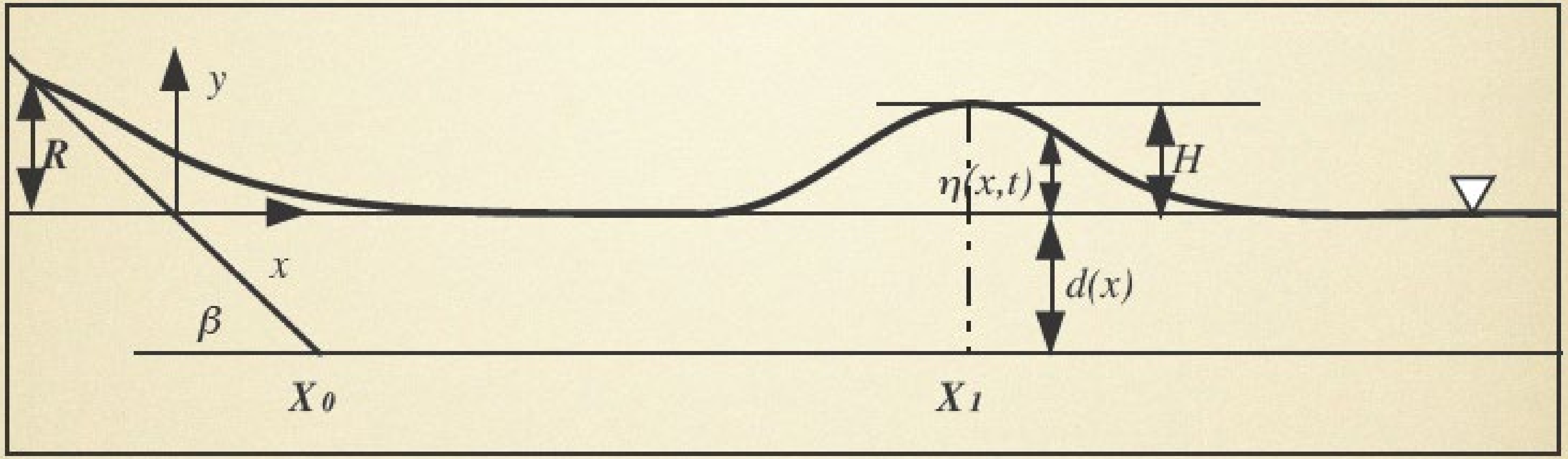
MOST – Method of Splitting Tsunami



$$
\begin{aligned}
h_t + (uh)_x + (vh)_y &= 0 \\
u_t + uu_x + vu_y + gh_x &= gd_x \\
v_t + uv_x + vv_y + gh_y &= gd_y
\end{aligned}
$$

$$
\begin{aligned}
d(x, y, t) &= d_0(x, y, t),\ t \leq t_0 \\
d(x, y, t) &= d_0(x, y, t_0),\ t \leq t_0
\end{aligned}
$$

where $h = \eta\,(x,y,t) + d(x,y,t)$, $\eta\,(x,y,t)$ is the amplitude, $d(x,y,t)$ is the undisturbed water depth, $u(x,y,t)$, $v(x,y,t)$ are the depth-averaged velocities in the x and y directions respectively, g is the acceleration of gravity.

Titov

MOST – Method of Splitting Tsunami

Splitting Technique (Method of fractional steps)

The method (Yanenko, 1971) reduces the numerical solution of the two-dimensional problem into consecutive solution of two instantaneous one-dimensional problems. This is achieved by splitting the governing system of equations into a pair of systems, each containing only one space variable.

$$\begin{Bmatrix} h_t + (uh)_x = 0 \\ u_t + uu_x + gh_x = gd_x \\ v_t + uv_x = 0 \end{Bmatrix} \text{ and } \begin{Bmatrix} h_t + vh_y = 0 \\ v_t + vv_y + gh_y = gd_y \\ u_t + vu_y = 0 \end{Bmatrix}$$

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MOST – Method of Splitting Tsunami

Finite-difference scheme

$$\frac{\Delta_t p_i^n}{\Delta t} + \frac{1}{2\Delta x}\left[\lambda_i^n(\Delta_{-x}+\Delta_x)p_i^n - \frac{\Delta t}{\Delta x}\lambda_i^n\Delta_x\left(\lambda_i^n\Delta_{-x}p_i^n\right)\right] = \frac{g}{2\Delta x}\left[(\Delta_{-x}+\Delta_x)d_i^n - \frac{\Delta t}{\Delta x}\lambda_i^n\Delta_x\Delta_{-x}d_i^n\right]$$

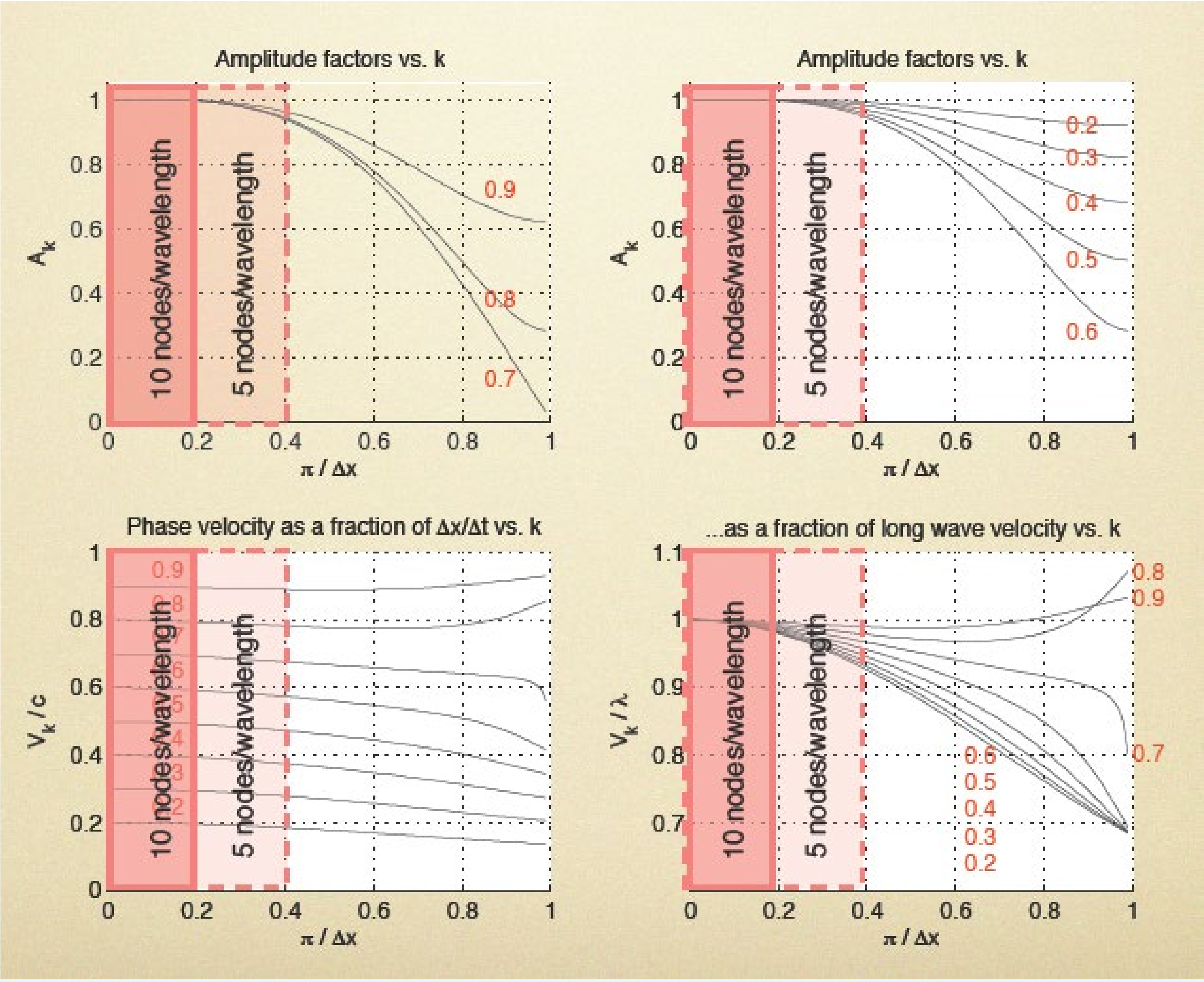
On boundary: $p_b^{n+1} = p_b^n - \frac{\Delta t}{\Delta x}[\lambda_1^n(\Delta_{-x} p_b^n) - g(\Delta_{-x} d_b^n)]$

Stability criteria: $\Delta t \le min \frac{\Delta x_i}{|u_i| + \sqrt{g h_i}}$

Titov

MOST – Method of Splitting Tsunami

Numerical dispersion and diffusion



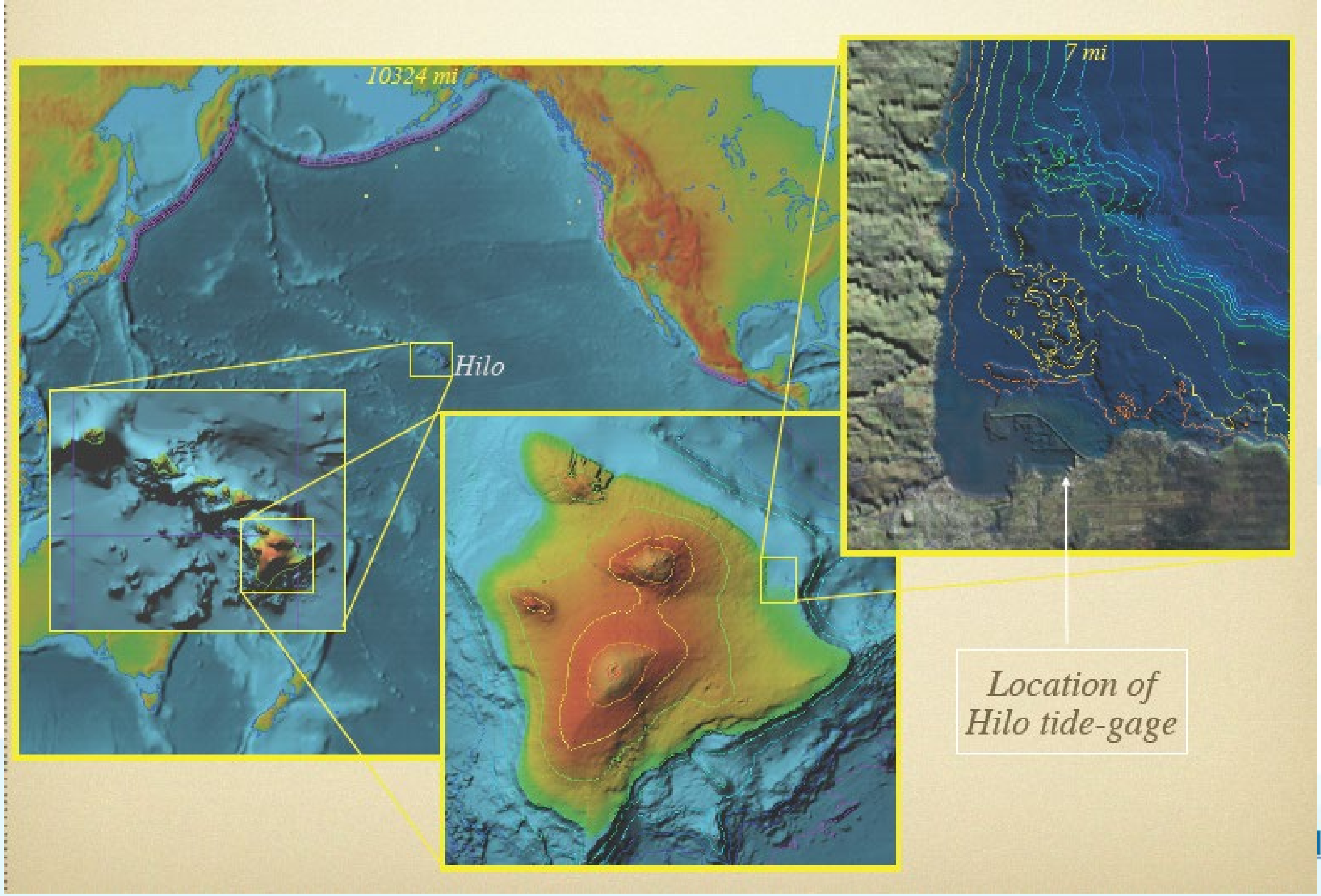
MOST – Method of Splitting Tsunami

Tips:

- 10 nodes (grid boxes) per wave length
- Use time step as close (or less) then CFL (Courant-Friedrich-Lewy) condition

$$\Delta t \leq min \frac{\Delta x_i}{|u_i| + \sqrt{g h_i}}$$

ComMIT Grids: A, B, C at different scales



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ComMIT Grids: A, B, C at different scales

MOST Stage	Recommended Resolution	Lowest Required Resolution*
Deformation/Propagation	1 arcminute (~1800 m)	4 arcminutes (~7300 m)
Inundation: Grid A (Outer)	36 arcseconds (~1080 m)	2 arcminutes (~3600 m)
Grid B (Intermediate)	6 arcseconds (~180 m)	18 arcseconds (~500 m)
Grid C (Inner)	≤ 1 arcsecond (≤ 30 m)	2 arcseconds (60 m)

*Note: Equivalent meter value on the Equator.

Notes:

- Ideally grids should have ratio 1:6 (1:10 maximum)
- Boundaries should not intersect

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ComMIT Common Grid Format (text file)

Coordinate system: Latitude/Longitude

Nx Ny (max400x400) Size of Array

Nx lines of longitude

Ny lines of latitude lines

Matrix of bathymetry/topography data (size: Nx by Ny)

Note: depths are negative land is positive

ComMIT Common Grid Format (text file)

Alternative

ARC ASCII Grid

ncols	249
nrows	190
xllcorner	79.77292048
yllcorner	6.955485971
cellsize	0.000449943
nodata_value	-9999

23.441 23.302 23.2 23.306 23.193 23.106 ....Matrix

Note: depths are negative land is positive

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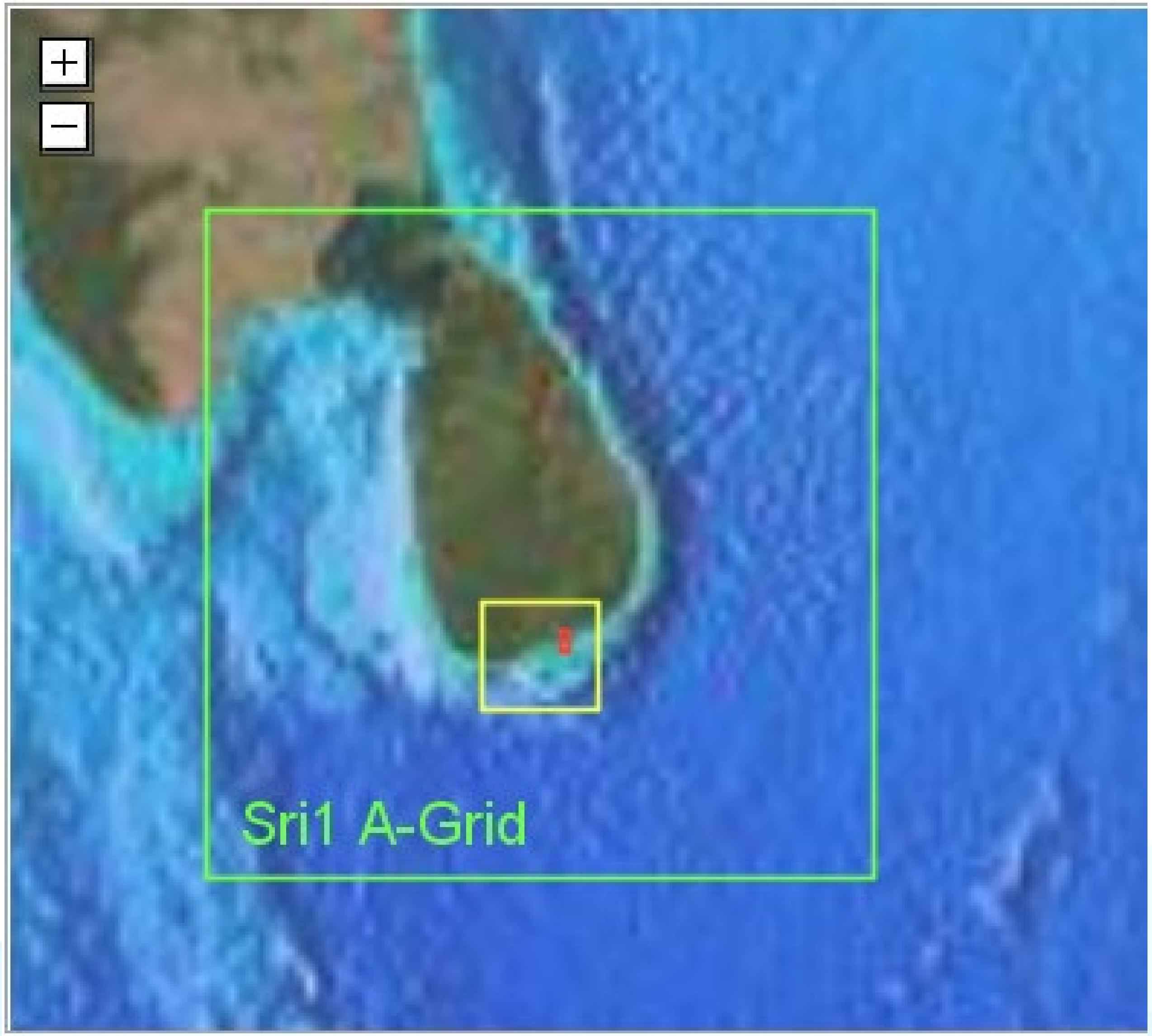
ComMIT Grids: A, B and C



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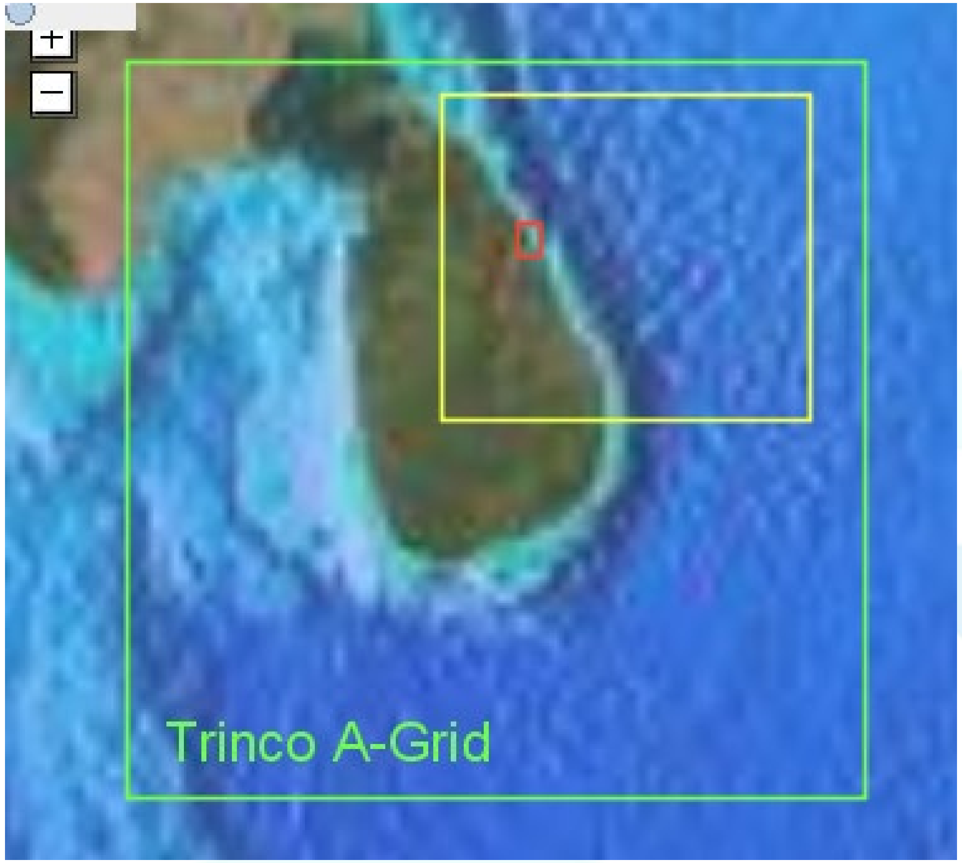
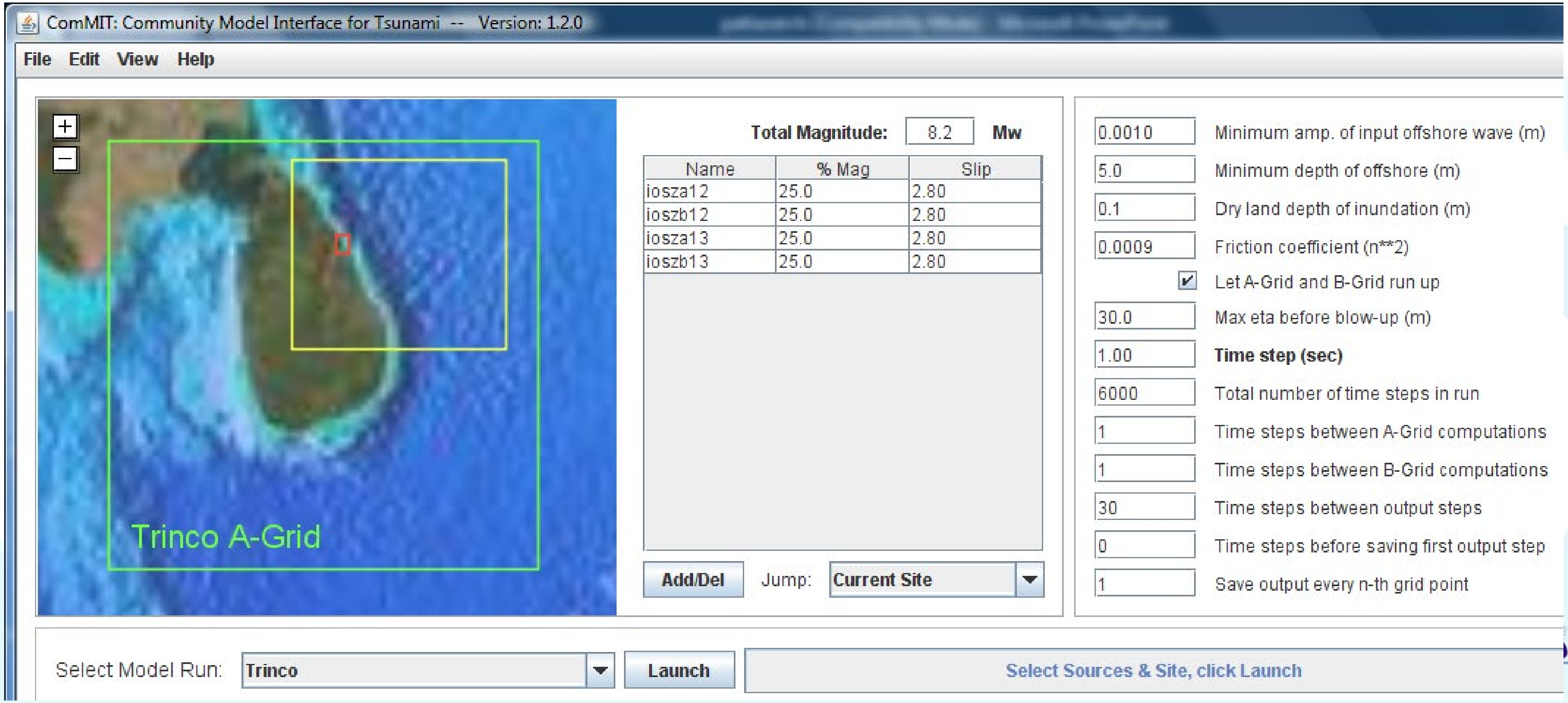
ComMIT Grids: A, B and C



ComMIT – Model run

- Create/Select Model Run
- Select Sources
- Launch



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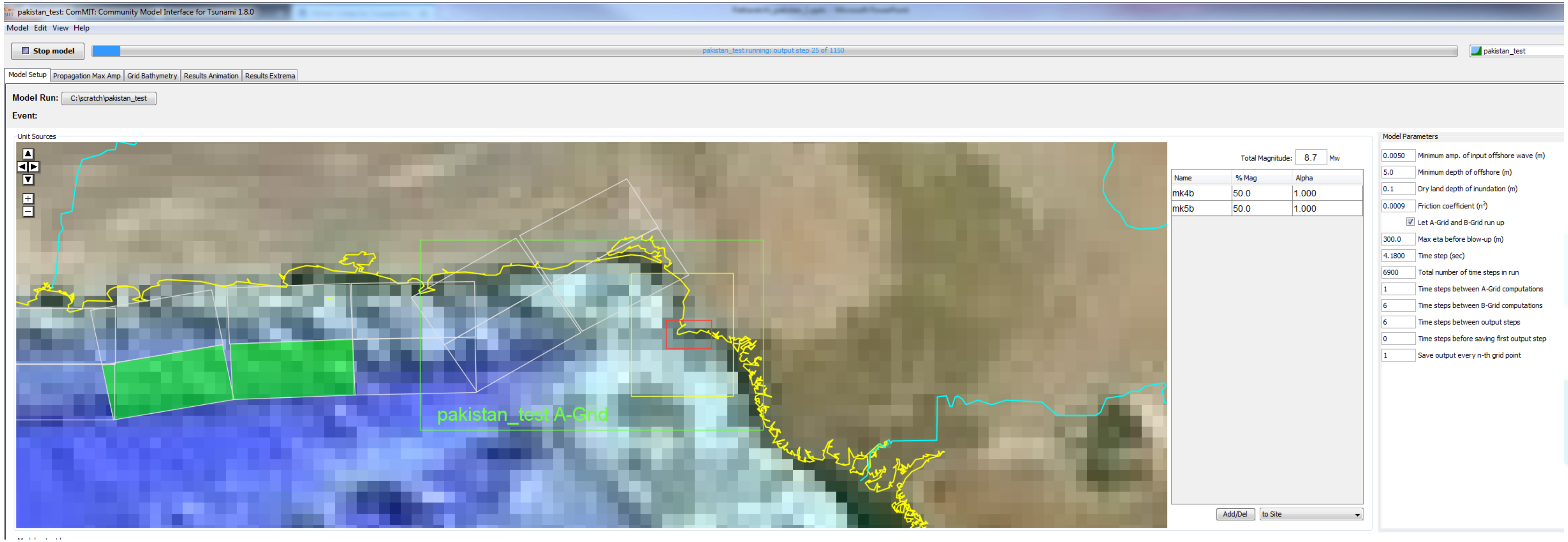
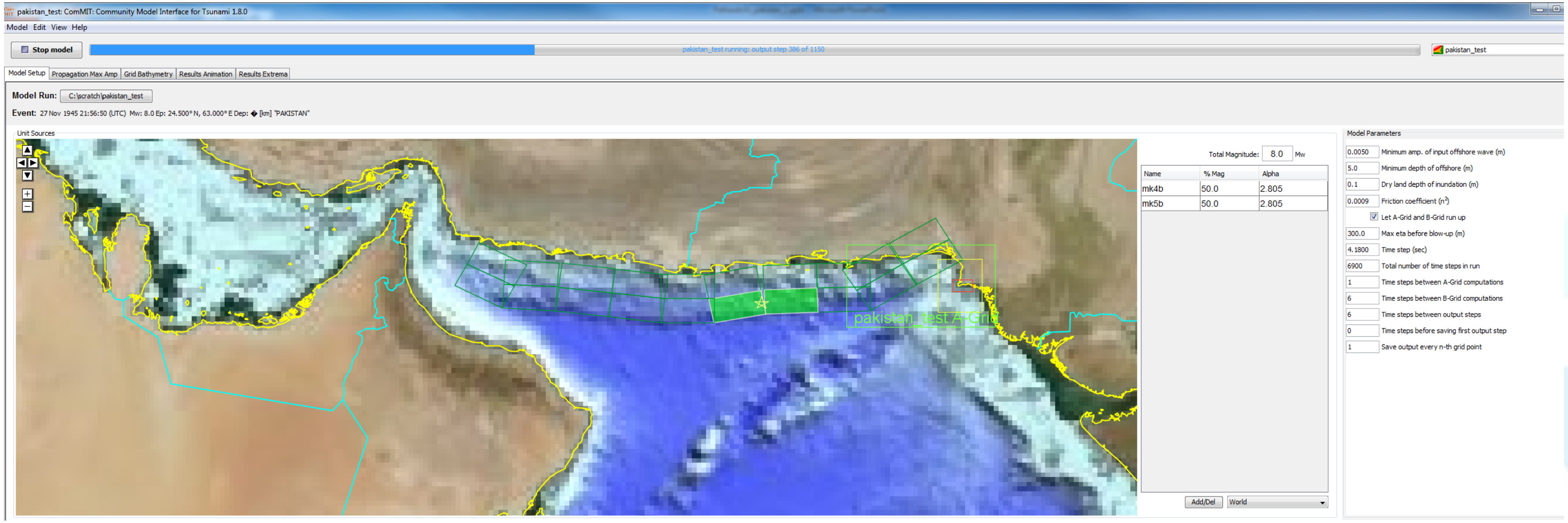
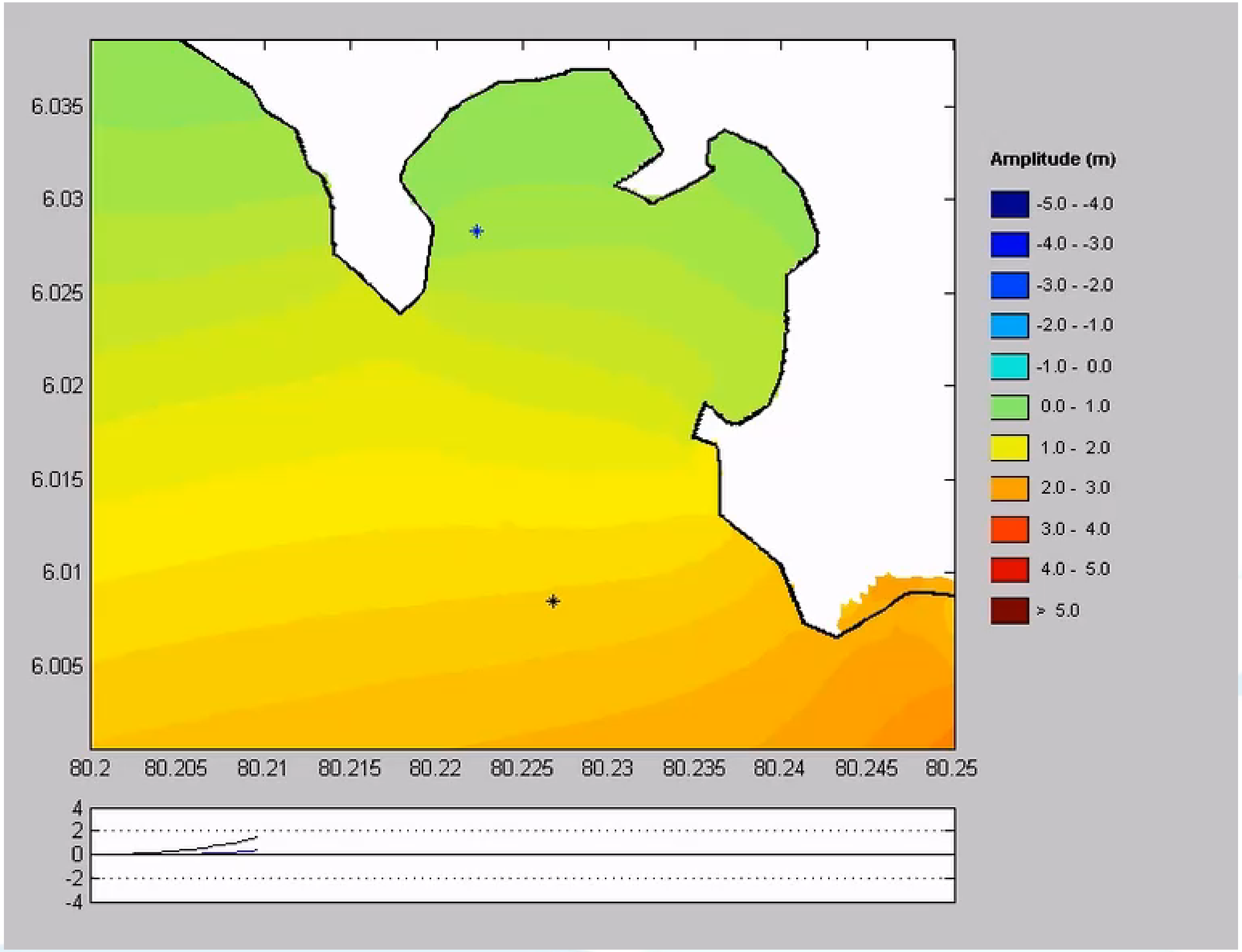
ComMIT – Model run

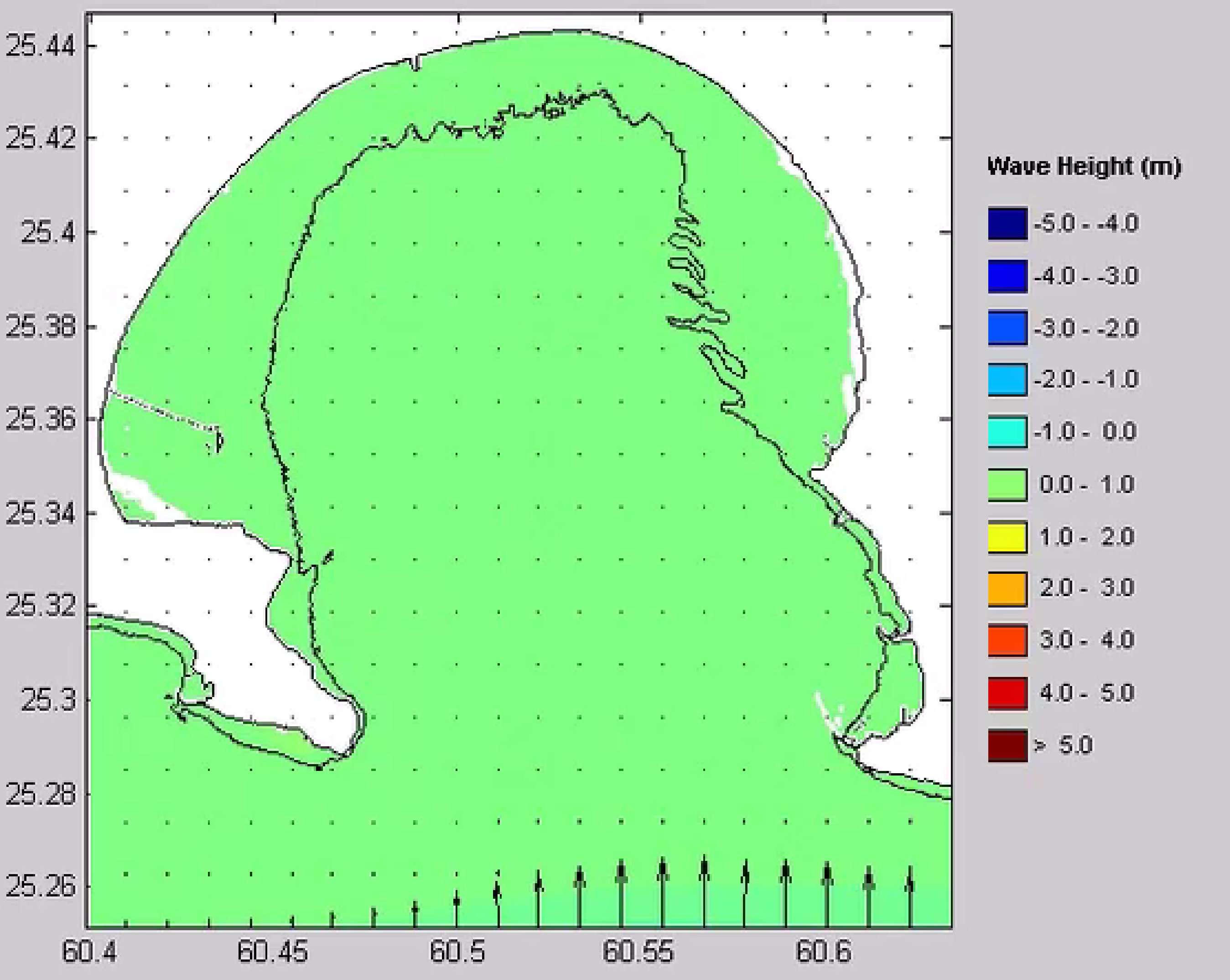


ComMIT – Model run

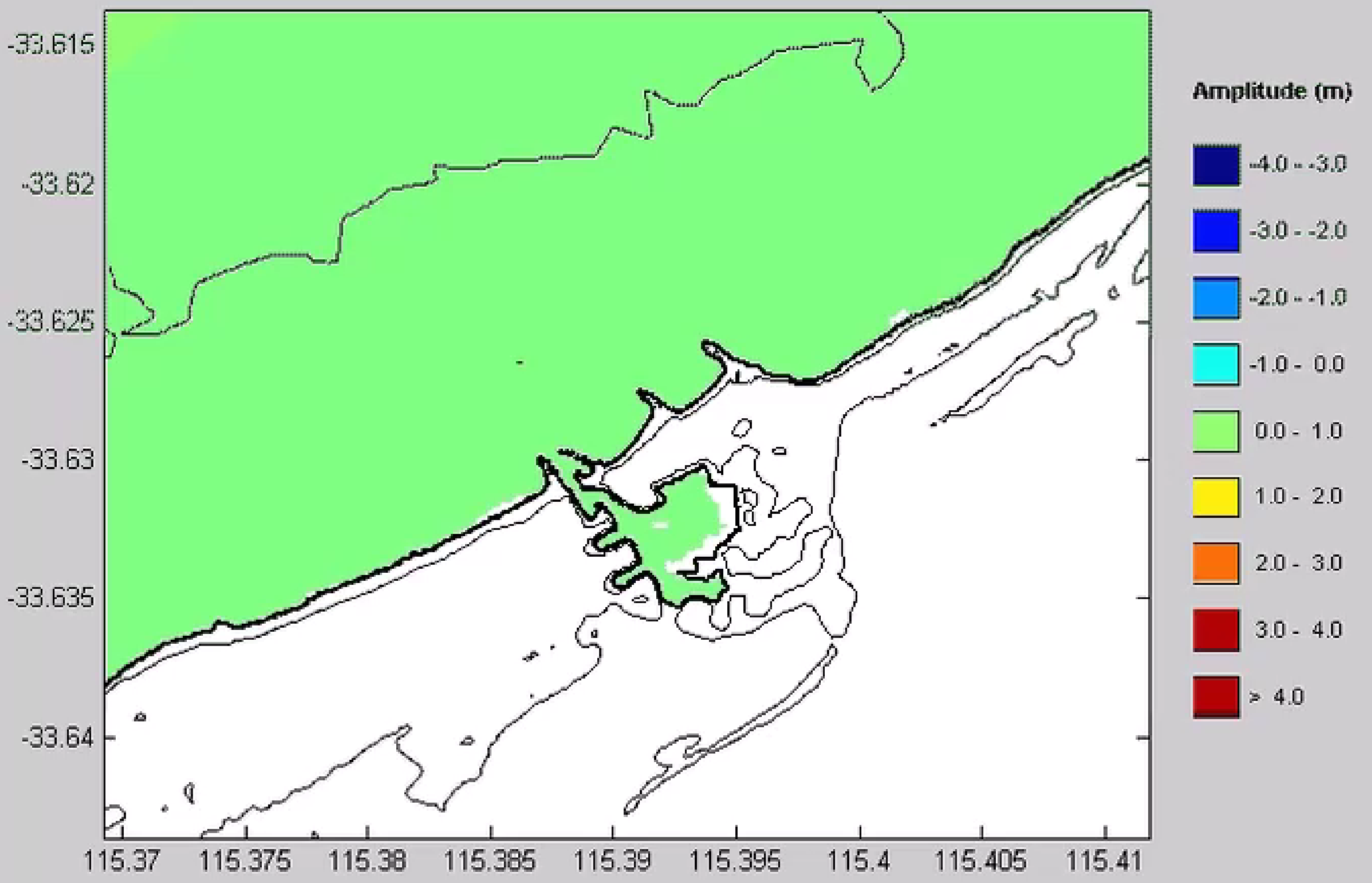




6.035
6.03
6.025
6.02
6.015
6.01
6.005
80.2
80.205
80.21
80.215
80.22
80.225
80.23
80.235
80.24
80.245
80.25
Amplitude (m)
-5.0 - -4.0
-4.0 - -3.0
-3.0 - -2.0
-2.0 - -1.0
-1.0 - 0.0
0.0 - 1.0
1.0 - 2.0
2.0 - 3.0
3.0 - 4.0
4.0 - 5.0
> 5.0
4
2
0
-2
-4



25.44
25.42
25.4
25.38
25.36
25.34
25.32
25.3
25.28
25.26
60.4
60.45
60.5
60.55
60.6
Wave Height (m)
-5.0 - -4.0
-4.0 - -3.0
-3.0 - -2.0
-2.0 - -1.0
-1.0 - 0.0
0.0 - 1.0
1.0 - 2.0
2.0 - 3.0
3.0 - 4.0
4.0 - 5.0
> 5.0



-33.615
-33.62
-33.625
-33.63
-33.635
-33.64
115.37
115.375
115.38
115.385
115.39
115.395
115.4
115.405
115.41
Amplitude (m)
-4.0 - -3.0
-3.0 - -2.0
-2.0 - -1.0
-1.0 - 0.0
0.0 - 1.0
1.0 - 2.0
2.0 - 3.0
3.0 - 4.0
> 4.0

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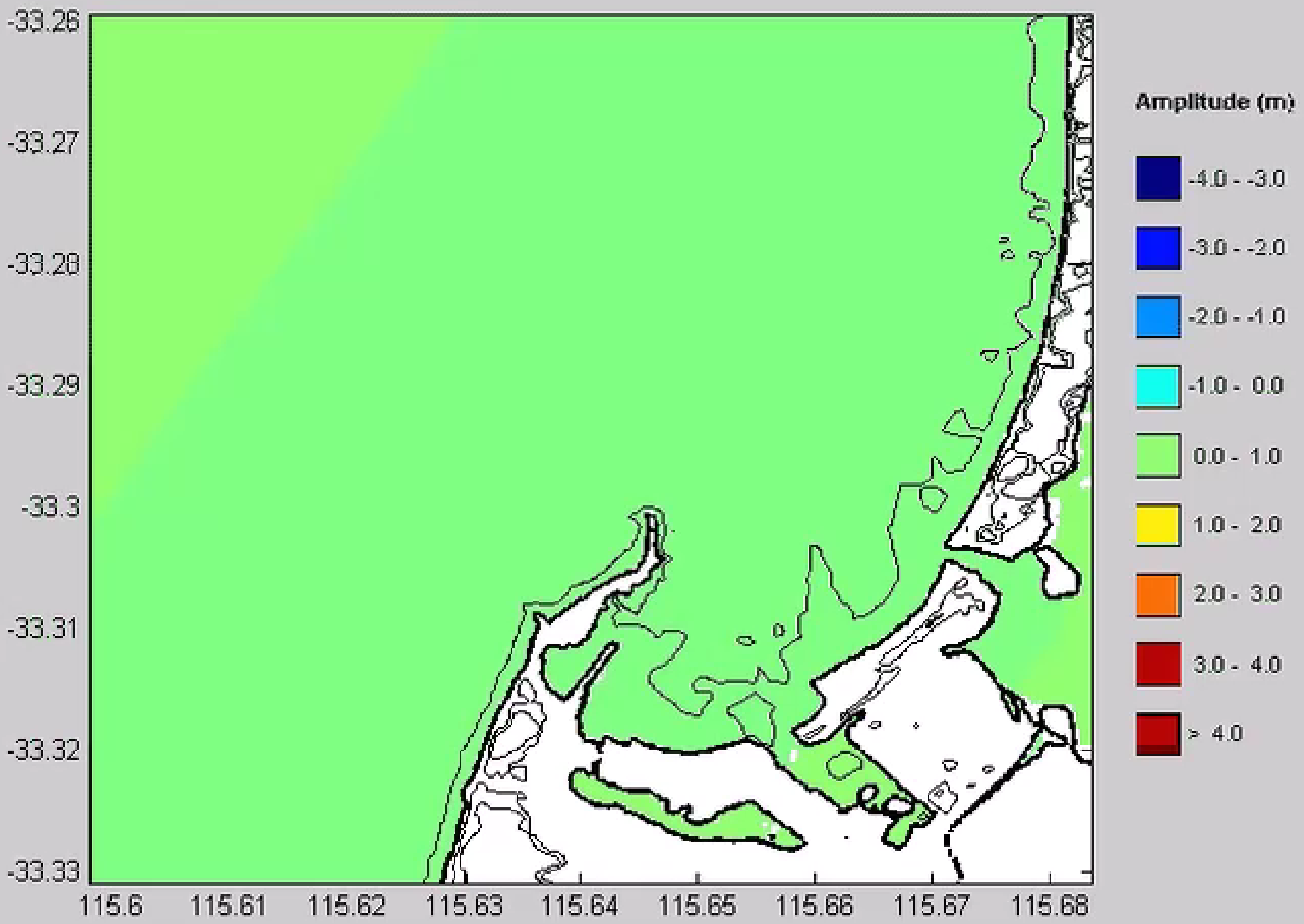

Amplitude (m)
-4.0 - -3.0
-3.0 - -2.0
-2.0 - -1.0
-1.0 - 0.0
0.0 - 1.0
1.0 - 2.0
2.0 - 3.0
3.0 - 4.0
> 4.0
-33.26
-33.27
-33.28
-33.29
-33.3
-33.31
-33.32
-33.33
115.6
115.61
115.62
115.63
115.64
115.65
115.66
115.67
115.68

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Thank you