Tsunami Modeling Achievements at Alfred Wegener Institute

Claudia Wekerle
Tsunami Modeling Group at AWI

DEWS Midterm Conference

Potsdam, 7th & 8th july 2009

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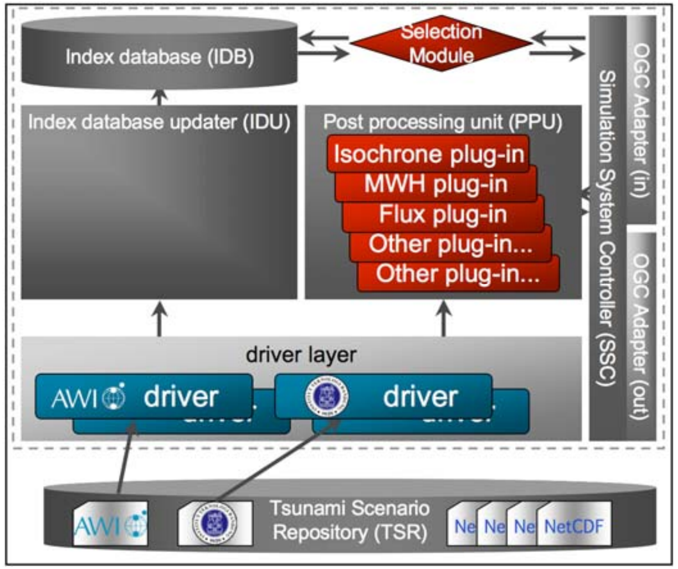
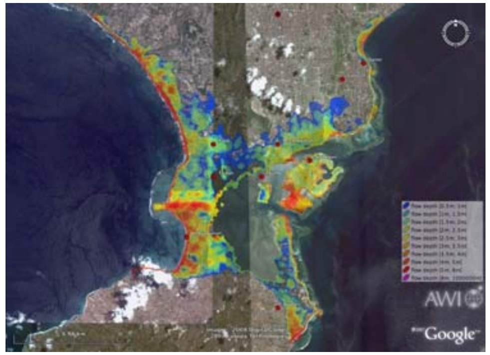
GITEWS Simulation System (SIM)

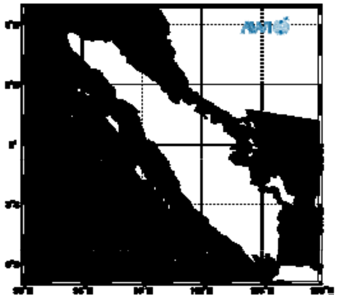
Robust Multi-Sensor Selection



Advanced Simulation Products



TSUNAWI



- Unstructured mesh
- Finite elements
- Non-linear shallow water equation
- With run-up/inundation

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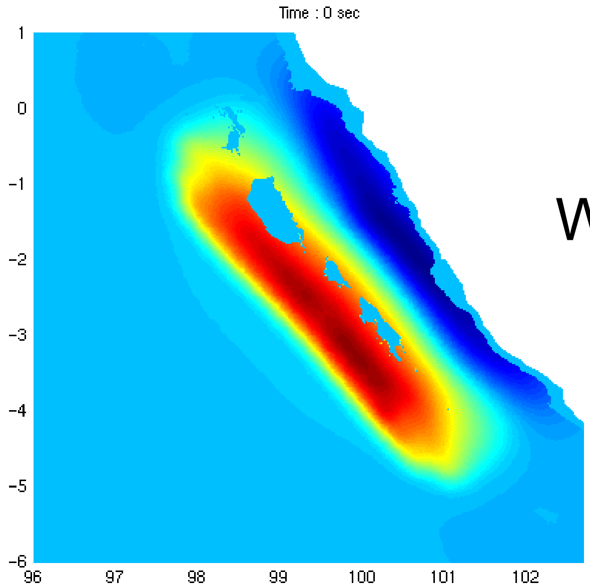
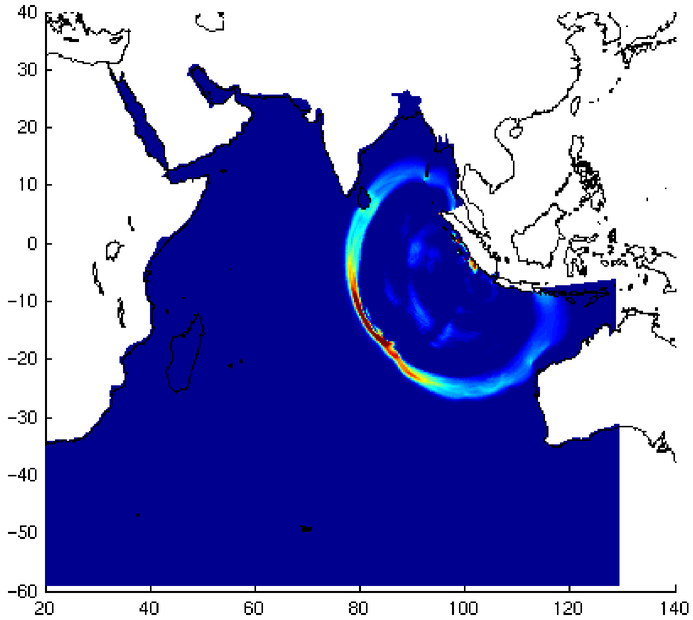
Simulation overview

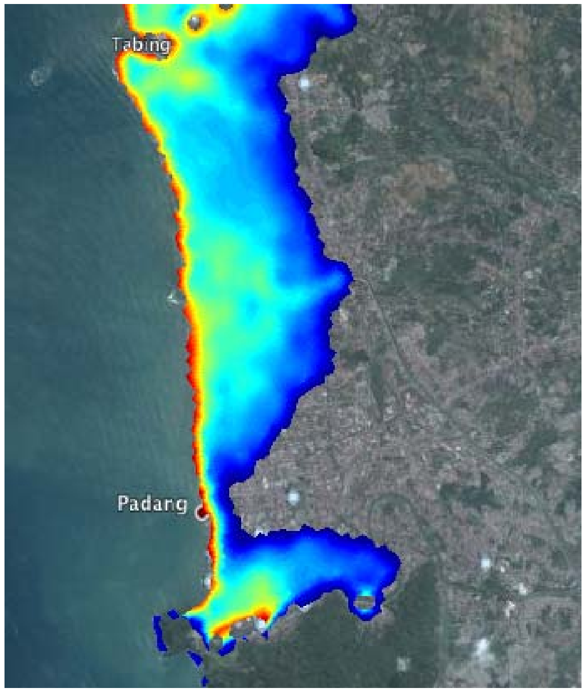
Source



Wave propagation



Inundation



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Mesh Generation

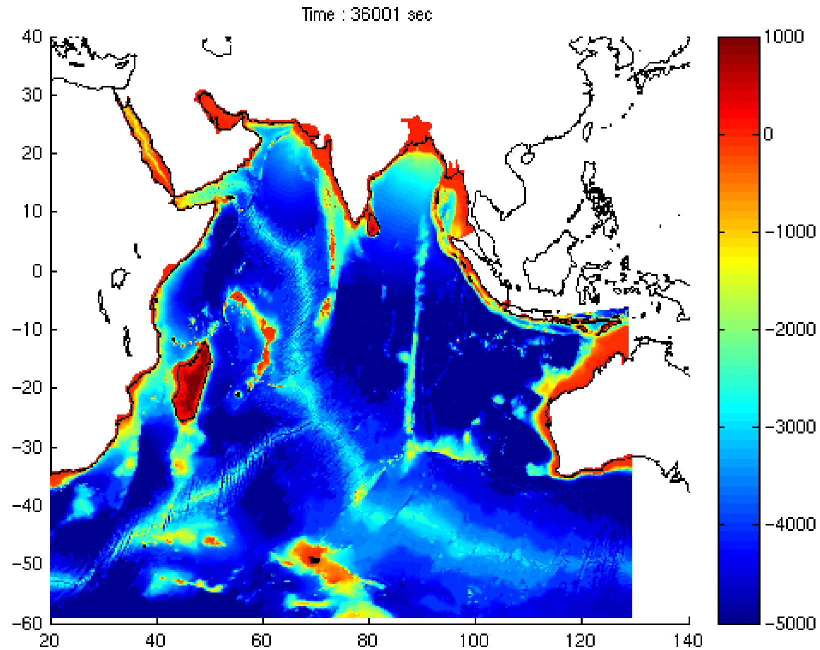
Input:

- Topography
- Bathymetry
- Coastline
- Domain boundary
  (open or solid boundary)

Refinement criteria:

$$\Delta \mathbf{x} \leq \min \left\{ c_t \sqrt{gH}, c_g \frac{h}{\nabla h} \right\}$$

Coarse resolution in deep ocean, fine resolution in shallow water.



Bathymetry of mesh indian_hi

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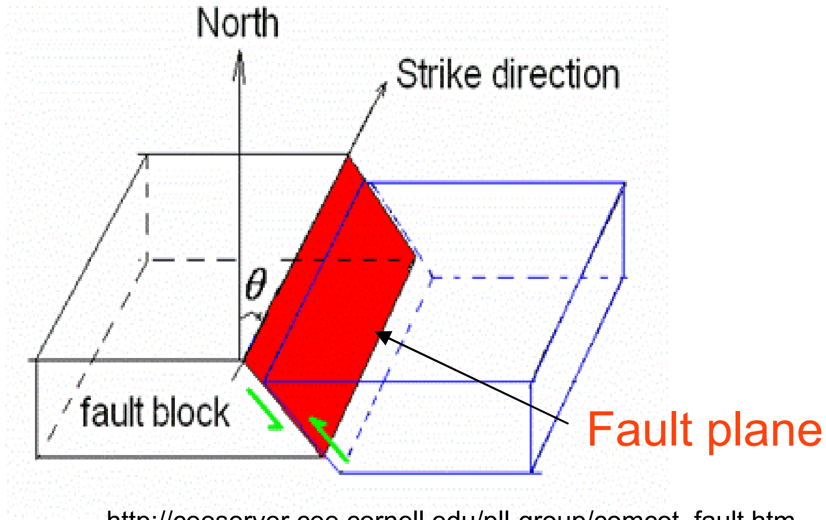
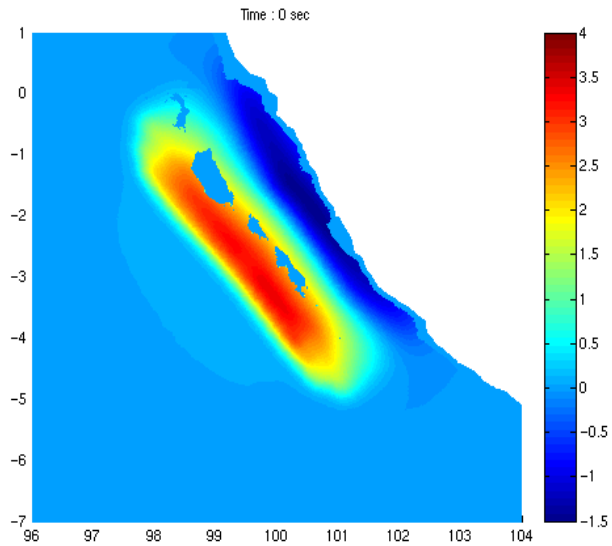
Source generation (1): Okada's method

Input parameters:

- latitude / longitude of epicenter
- depth
- length/width of fault plane
- amount of slip
- strike/dip/rake angle



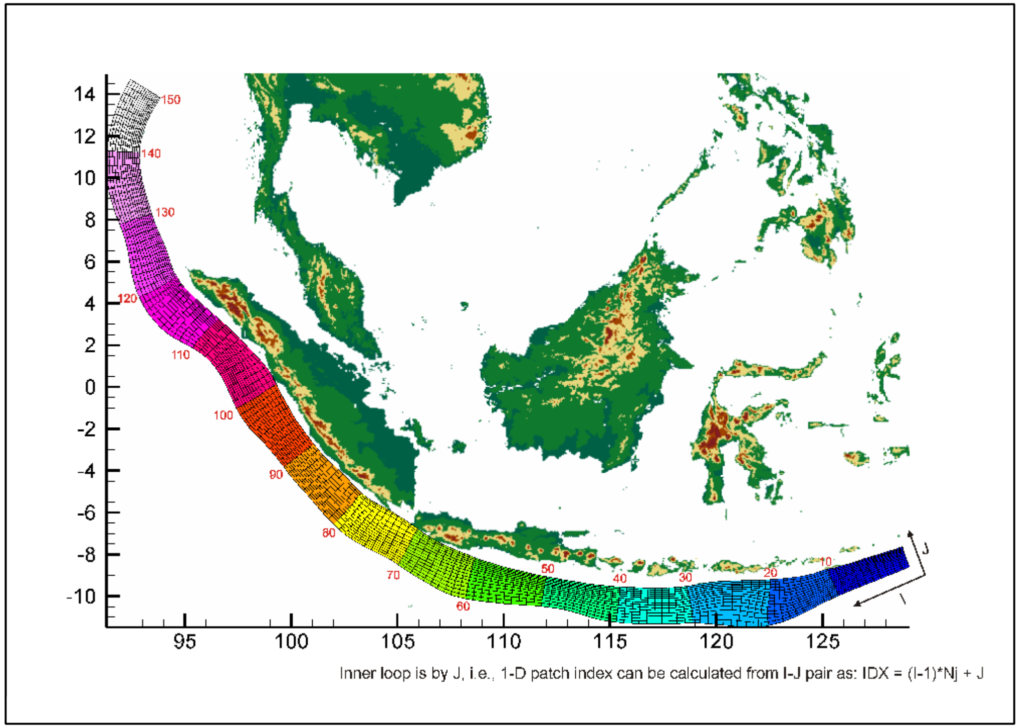
http://ceeserver.cee.cornell.edu/pll-group/comcot_fault.htm



Initial condition

Source generation (2): RuptGen

- Calculates sea floor deformation at the Sunda trench
- Plate interface divided into regular mesh of patches: 2250 patches with dimensions about 40 x 15 km
- Using Green's function method
- Includes crust deformation



Sunda trench, devided into patches

by A. Babeyko (GFZ)

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Wave propagation: Shallow water equations

Continuity equation:

$$\frac{\partial h}{\partial t} + \nabla \cdot (\vec{v}(h+H)) = 0$$

h - surface elevation
H - reference depth
$\vec{v}$ - velocity
f - Coriolis parameter
g - gravitational acceleration
C_d - friction parameter
A_h - viscosity parameter

Momentum equation:

$$\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla)\vec{v} + f \times \vec{v} + g\nabla h + \frac{C_d \vec{v}|\vec{v}|}{\rho(h+H)} - \nabla \cdot (A_h \nabla \vec{v}) = 0$$

Advection term

Coriolis term

“Pressure gradient”

Bottom friction

Viscosity term

Boundary conditions:

open boundary: $\vec{v} \cdot \vec{n} = \sqrt{\frac{g}{h+H}}h$ solid boundary: $\vec{v} \cdot \vec{n} = 0$

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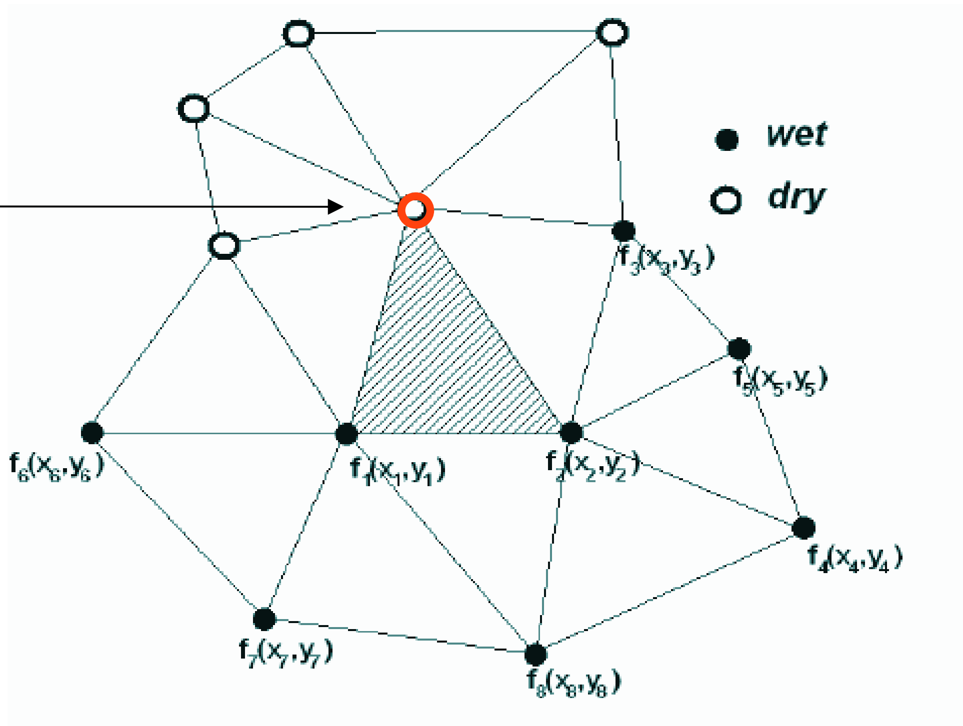
Wave runup

- Moving boundary technique (Lynett, 2002)
- Linear extrapolation through the wet-dry boundary
- boundary exists in between nodal points

Extrapolate elevation
to dry nodes
from wet neighbors



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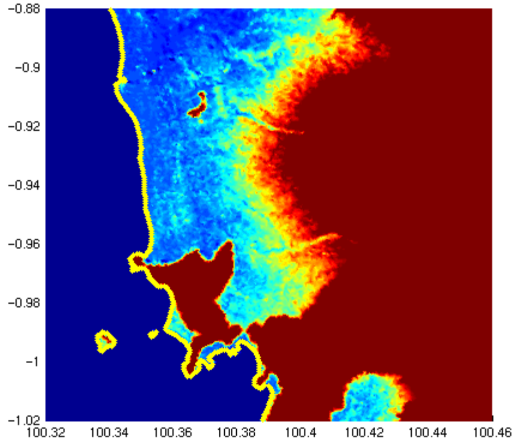
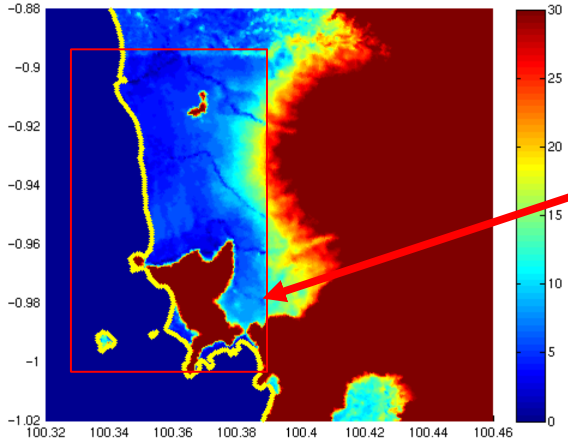
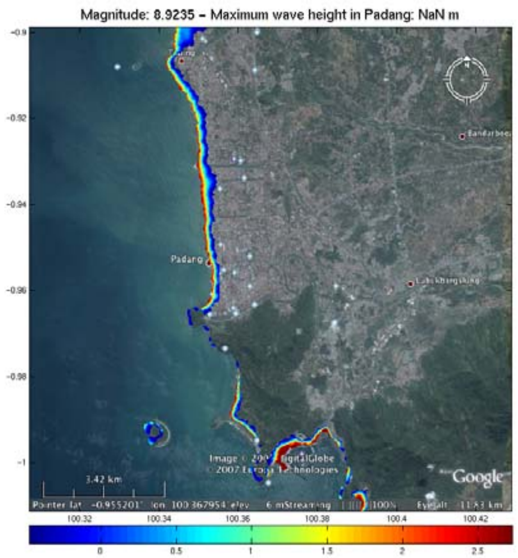
Critical Point: Data Quality

SRTM topography

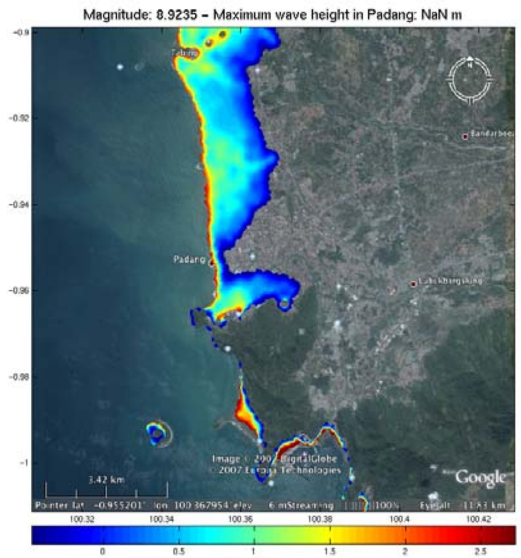




SRTM and HRSC topography



Inundation of Padang region



Bad topography data leads to unreliable results in inundation!

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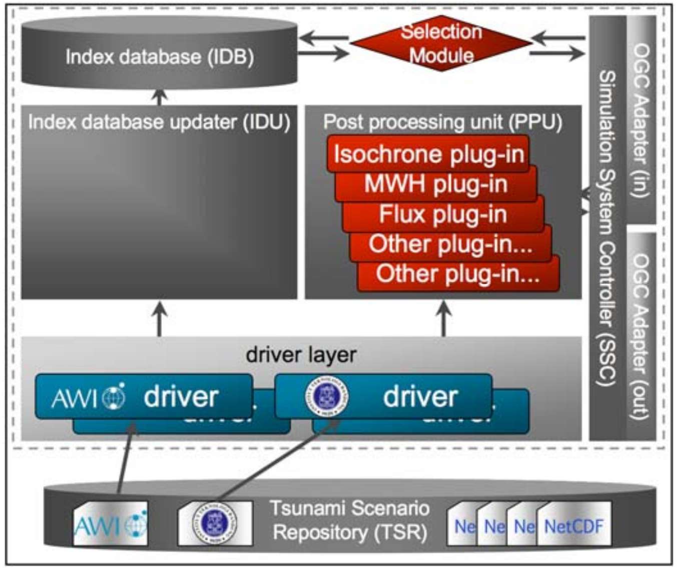

Advanced Simulation Products

TsunAWI

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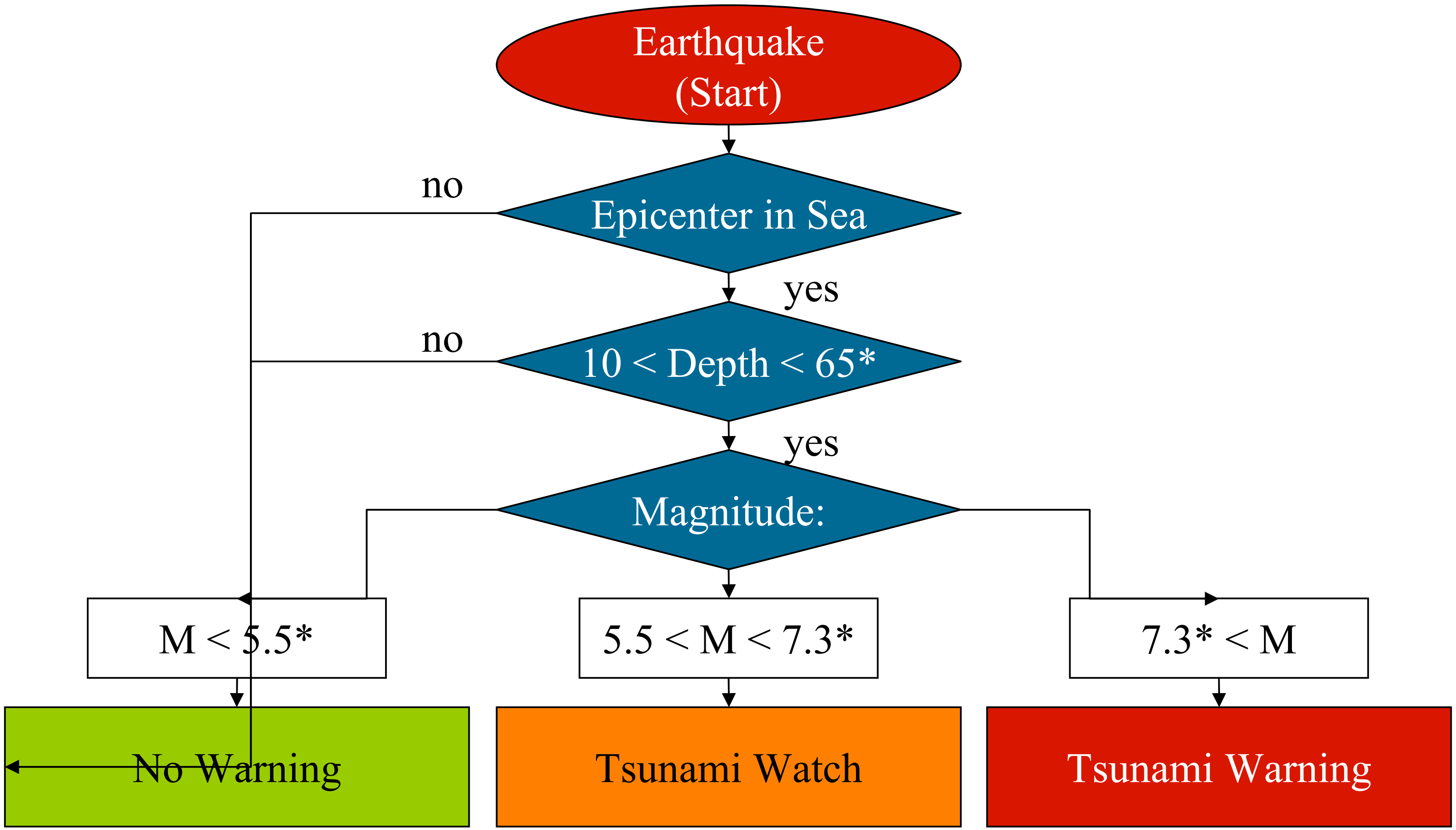
Traditional Approach: Decision Matrix



*) Values not realistic!

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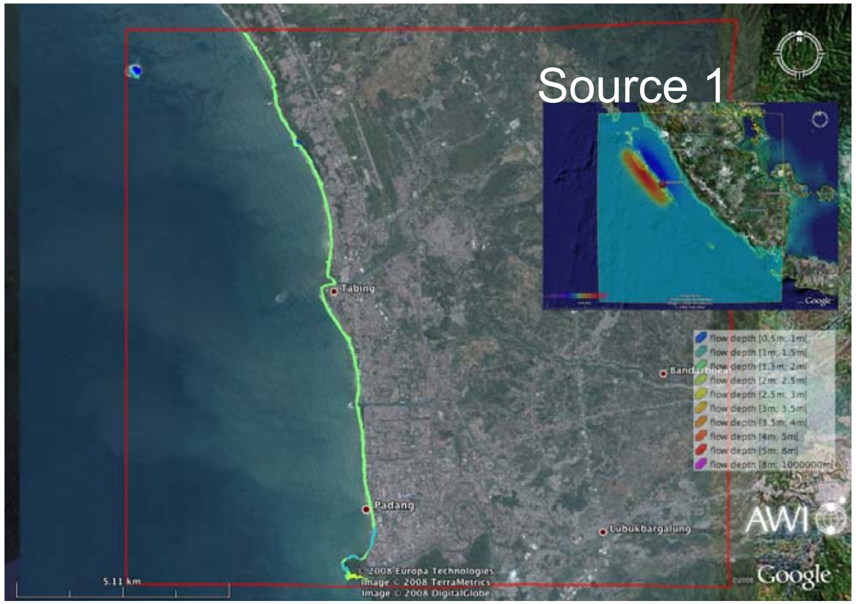
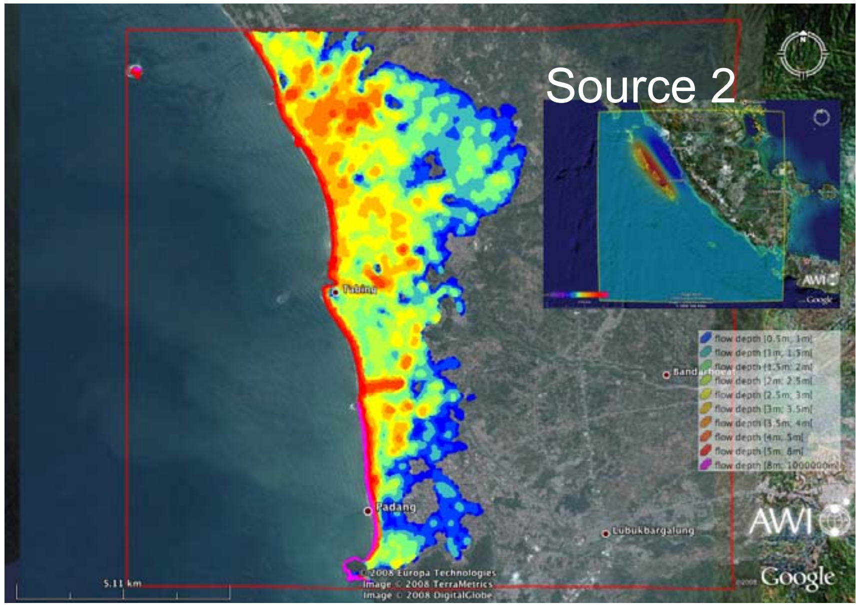
Uncertainty in Tsunami Early Warning I

Uncertainty from

- measurement
- situation (incompleteness in sensor observations)
- procedures used (incompleteness in precomputed scenarios)
- physics





Same epicenter, different rupture zone leads to completely different inundation!!!

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Uncertainty in Tsunami Early Warning II

Uncertainty in tsunami source inversion from epicenter...

...pose no problems

- in far-field tsunami
- if infrastructure is good and a false warning can be canceled

In Indonesia / Thailand: near-field tsunamis!

How to handle uncertainties?

- By use of large amount of sensor observations
- By use of multiple types of sensors at once
- By taking uncertainty into assessment

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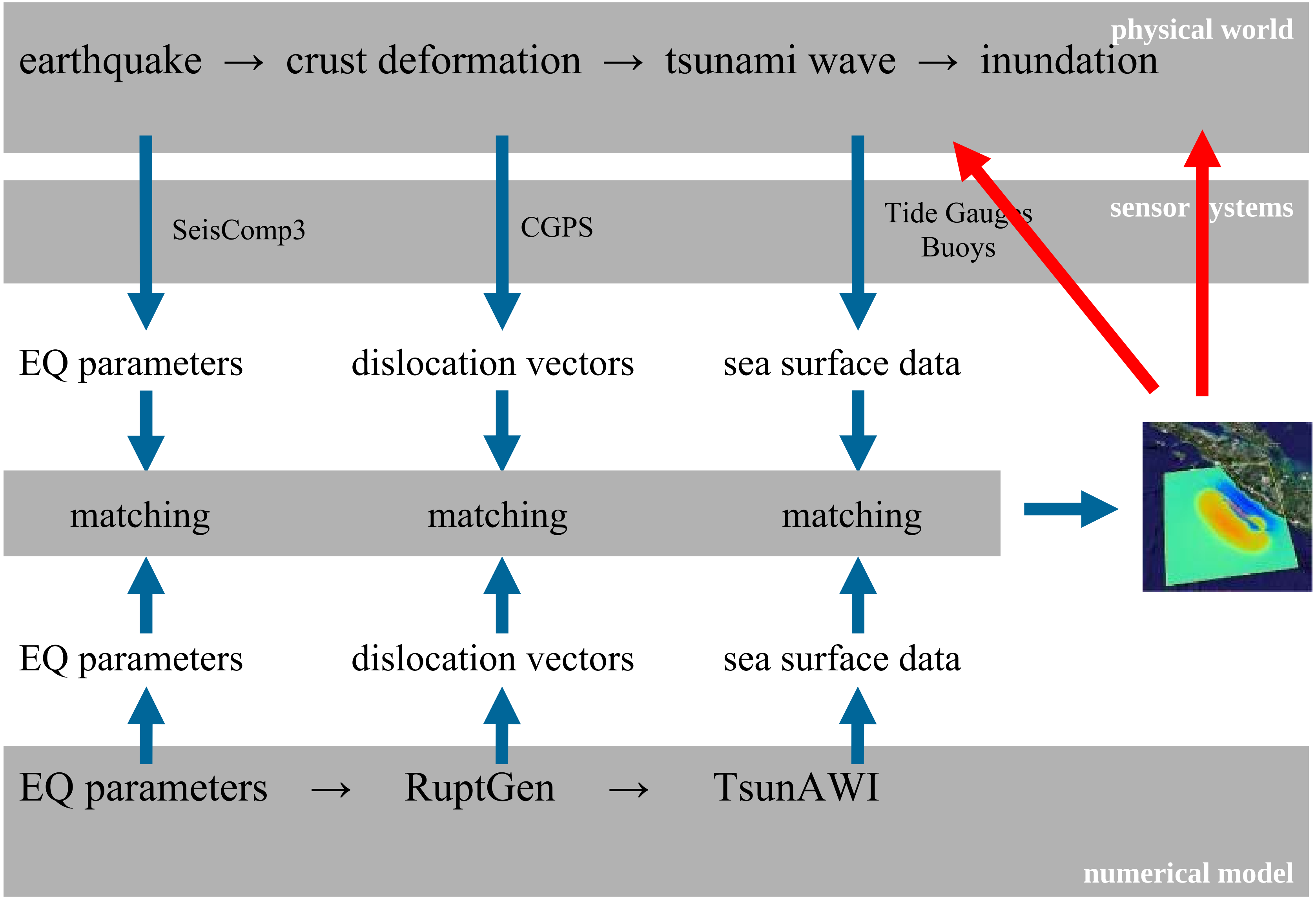
Multi Sensor Scenario Selection



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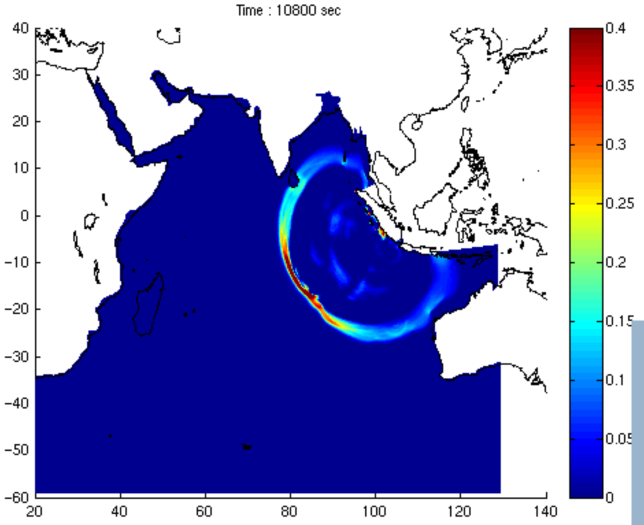
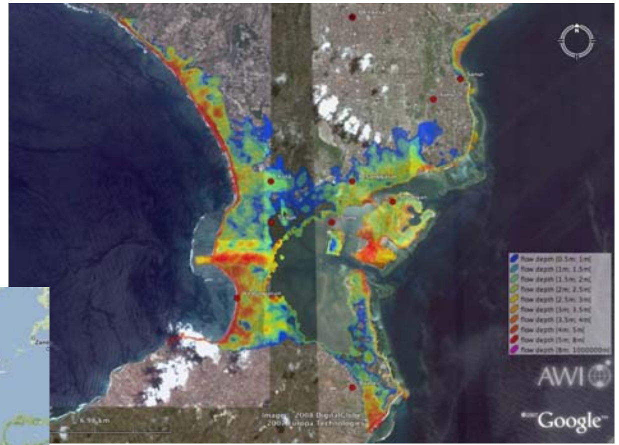
Simulation Results

ssh time series

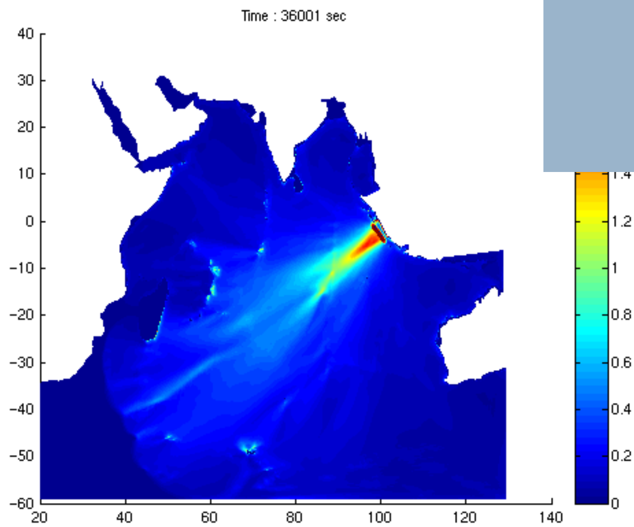


inundation

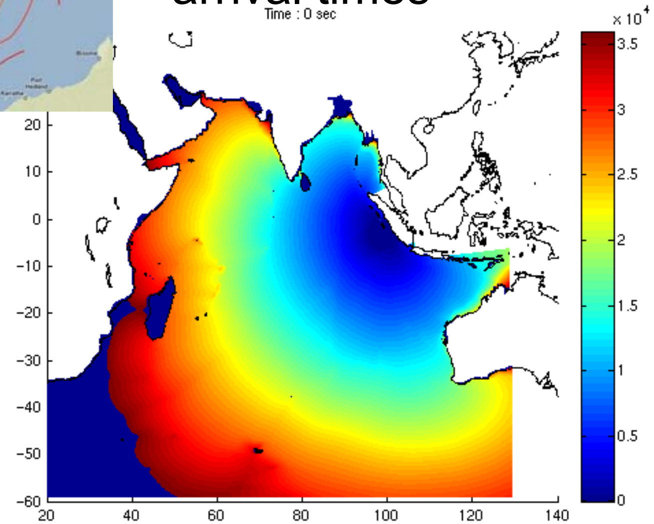


isochrones

maximum ssh



arrival times



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Summary

- Advanced Tsunami Propagation and Inundation Model
- Uncertainty in Tsunami Early Warning
- Multi Sensor Approach
- Simulation Results

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Thank you!

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