RAPSODI
Risk Assessment and design of Prevention Structures for enhanced tsunami Disaster resilience

Possible NGI contributions related to tsunami modelling activities

Finn Løvholt and Carl B. Harbitz
Numerical simulations – the standard approach

1. Seabed displacement due to earthquake in subduction zone (or due to landslide)
2. Seabed displacement slightly smoothed ⇒ initial wave for tsunami simulation
3. Numerical oceanic scenario tsunami simulation using a dispersive oceanic wave model. Data extracted from time series in specific locations
4. Run-up / inundation by rough regional “approximate” linear methods or detailed local nonlinear inundation models
Possible contributions I - Model coupling and nesting (tsunami propagation and run-up)

**GloBouss**: Includes effects of frequency dispersion
- Important for shorter waves, particularly landslide tsunamis
- Also for seismic scenarios, smaller events and over long distances

**ComMIT/MOST**: Developed by NOAA for earthquake tsunamis –
- high number of precomputed events

At NGI/ICG this model is applied for run-up calculations with input from nonlinear dispersive models

Shock capturing →
- handling steep wave fronts - bores
Possible contributions II – earthquake source modeling

Simplified Okada model

Heterogeneous models, random slip, stochastic modeling superimposing Okadas solution (overlap with EU-ASTARTE project)

Source realisations for Tohoku event or similar – forecasting and hazard assessment

Numerical models $\rightarrow$ FEM or FDM (would require further development)
Possible contributions III – landslide source modelling

Depth averaged models, e.g. BING

Fully compressible, fully non-linear multi material models, including the generation phase

Benefit from other projects

1: Landslide induced tsunamis in ASTARTE (NGI WP leader)

2: At the University of Oslo, modelling of rock slide evolution and landslide impact
The Åknes-Tafjord project – western Norway

- Largest volume > 50 Mm$^3$
- Unstable rock slope 150 - 900 m.a.s.l
- Large movements / deformations
- Advanced computational tools needed
- A large number of computations and hazard assessments performed

Inundation Hellesylt

Regional tsunami hazard map

Maximum elevation, 1C

7-20 cm/ year

3-4 cm/ year
3D laboratory experiments

SINTEF Coast and Harbour Research Laboratory, Trondheim

Scale 1:500

Instrumentation and setup is based on numerical simulations and the 2D laboratory experiments at UiO Hydrodynamics Laboratory

Input to and validation of numerical tsunami models
Modeling a complex problem

Large volume and high impact velocity
Nonlinear and dispersive effects

Generation phase important for the resulting waves
Deforming (retrogressive) slide or one big block?
Shape of the slide when hitting the water
Interaction with water during submerged run-out?

Large bathymetric gradients (ria coasts and fjords)

Laboratory experiments and numerical simulations

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1 - Courtesy "National Land Image Information (Color Aerial Photographs), Ministry of Land, Infrastructure, Transport and Tourism".
Possible contribution IV – two way coupling - primitive solvers in impact region – long wave solvers for propagation

- Near field – primitive models
  - Nested with long wave solver in the far field

- Propagation, necessary factors
  - Dispersion important
  - Non-linearity, sometimes strong
  - Inundation during fjord propagation
  - Rugged terrain, steep slopes

- Boussinesq type models with inundation needed
  - Models must handle steep slopes, rugged terrain and be robust

- Other models may be considered for local inundation (e.g. NLSW)
Possible contribution V - Modeling near shore processes with non-hydstatic models

Modelling combined run-up and propagation in rugged terrain

Non hydrostatic response and undular bore propagation

Effect of mitigating structures

Overcoming spurious effects

Validation of performance

NLSW models

3D models

Cooperation with USC
Counter measures and land use planning

Building measures

Land use planning

Assessment of dykes / sea walls with overtopping / openings

NIBR

B. Heyerdahl
sivilarkitekter as

NTNU
Possible contributions VI – run-up and impact of mitigation structures using depth averaged models
Final remarks – suggested NGI contributions

Literature review of available models *(WP1, D.1)*

Source models – needed in hazard assessment

   Need for **some joint source models** in the present project, but perhaps not extensive *(WP2, D.2, D.5, or D.6)*

   Landslide models considered less relevant here

Near shore processes and impact on structures using depth averaged models *(WP2, D.5, or D.6)*

   **NLSW** – relatively robust, fast, least general

   **Boussinesq** – less robust, handles undular bores

3D models would need adaptation from NGIs side to be employed for run-up and damage calculations

Utilization of results from other projects *(ASTARTE, UiO project, and possible other projects)*
Source modelling

Earthquakes

Simplified analytical (Okada, 1985) \(\rightarrow\) homogenous
Numerical models \(\rightarrow\) FEM or FDM
Heterogeneous models, random slip, stochastic modeling

Landslides and rock slides

Depth averaged models, e.g. BING \(\rightarrow\) suitable for landslides, debris flows and some rock slides
Fully compressible, fully non-linear multi material models, including the generation phase \(\rightarrow\) rock slides and volcanoes
La Palma simulation

Coupled model

SAGE (hydrocode) for landslide and wave generation

"GloBouss" dispersive tsunami model

Thorough study of

Wave evolution and asymptotics

*Importance of dispersion*

*Undular bore evolution*
Effects of frequency dispersion

- Non-uniform slip distribution, dip angle 25°
- Minor effect of dispersion close to earthquake
- Clear effect of dispersion for trans-oceanic propagation
  - $T=14$ hrs, $L=11000$ km, $\tau \sim 10^{-1}$
Thank you!