Introduction

- Research
  - Focus: Resolving/understanding phenomena
  - Tools: Proprietary software, physical models
- Engineering
  - Focus: Wave parameters, time series
  - Tools: Commercial or open source software
  - Traditional Approach:
    - Analytical estimates
    - Modeling initial conditions of the surface elevation
    - Landslide motion modeling

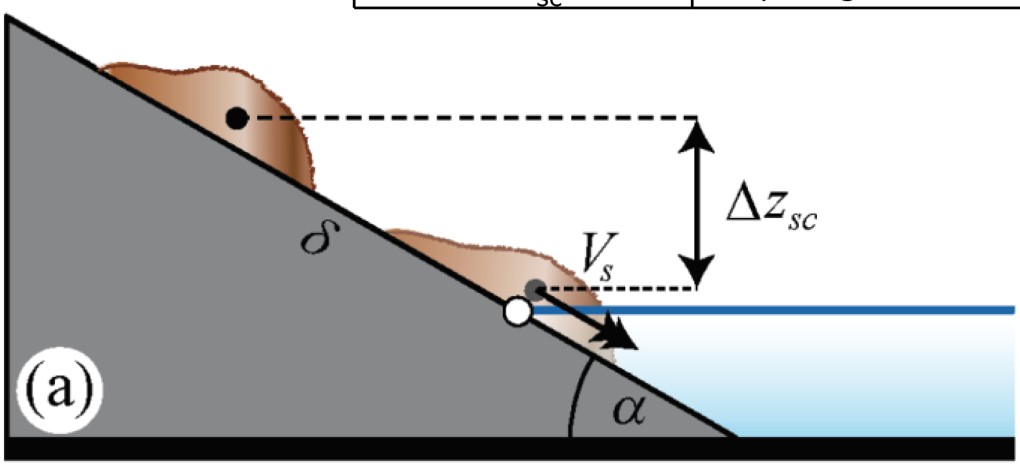
Objective

- Present a practical approach to modeling submarine and subaerial landslide motion for engineering applications
- By describing
  - Theory and implementation
  - Application to historical cases
  - Insight on engineering a slide

Subaerial Motion (Heller et al. 2009)

$$Vs = \sqrt{2g\Delta Z_{sc}(1 - \tan\delta \cot\alpha)}$$

Variable	Description
g	Gravitational acceleration
V_s	Slide center of mass impact velocity
α	Slide impact angle
δ	Dynamic bed friction angle (15°≤δ≤35°)
ΔZ_{sc}	Drop height of the slide center of mass



Submarine Motion (Watts, 1998)

$$\underbrace{(\rho_s + C_m \rho_w) V \frac{d^2 s}{dt^2}}_{m \times a} = \underbrace{(\rho_s - \rho_w) V g \sin\alpha}_{gravity} - \underbrace{\frac{1}{2} C_d \rho_w A \left(\frac{ds}{dt}\right)^2}_{drag}$$

m x a = *gravity* — *drag*

At $t = 0$:

$$a_0 = \frac{(\gamma_s - 1)}{\gamma_s + C_m} g \sin\alpha$$

At $t = \infty$:

$$u_t = \sqrt{\frac{2(\gamma_s - 1) V g \sin\alpha}{C_d A}}$$

Variable	Description	Variable	Description
s	Slide travel distance along slope	ρ_s	Density of slide
a_o	Slide initial acceleration	ρ_w	Density of water
u_t	Slide terminal velocity	γ_s	Specific gravity of slide (ρ_s/ρ_w)
V	Slide volume	α	Submarine bottom slope angle
A	Slide cross-sectional area	C_m	Added-mass coefficient
B	Slide width	C_d	Drag coefficient

Slide Description

- Semi-ellipsoid (Watts, 1998)

$$4\left(\frac{x^2}{W^2}\right) + 4\left(\frac{y^2}{B^2}\right) + \left(\frac{z^2}{T^2}\right) = 1$$

$$A = \frac{\pi}{4} WT \qquad V = \frac{\pi}{6} BWT$$

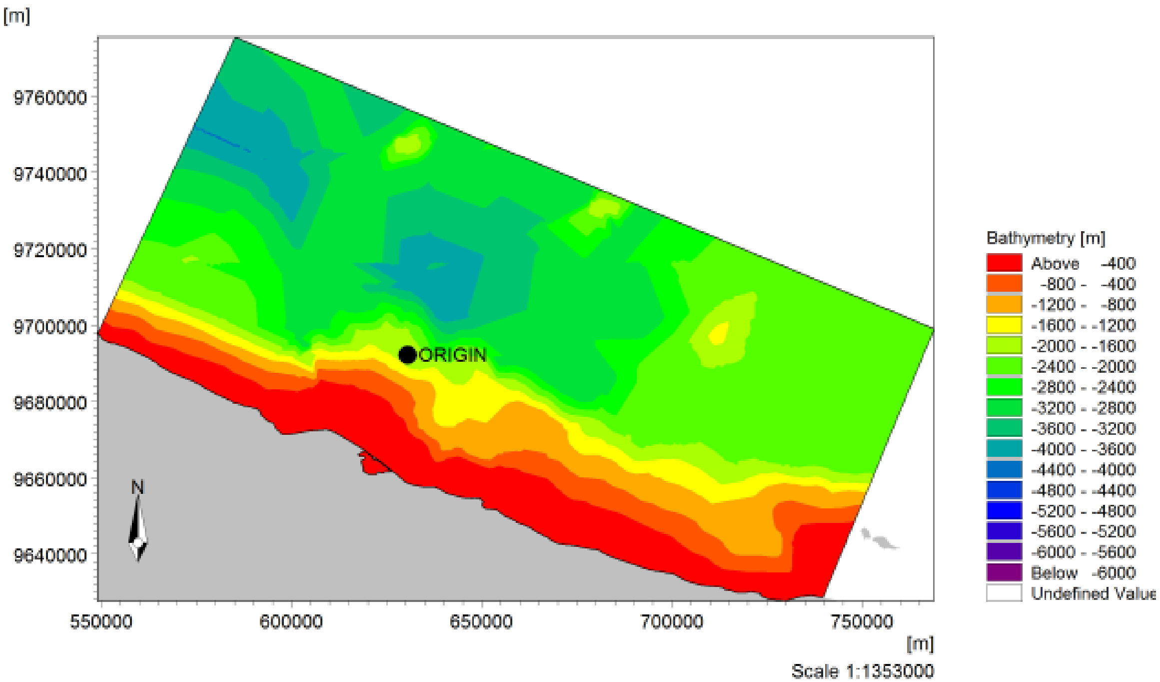
Variable	Description
x,y	Horizontal coordinates
z	Bed level change
W	Slide width across slope
B	Slide length along slope
T	Slide thickness
A	Cross sectional area of semi-ellipsoid
V	Volume of semi-ellipsoid

Implementation

- Matlab script
  - User input
  - Published analytical solutions
  - Output 2D bed level changes
    - MIKE 21 (dfsu/dfs2 file)
- Input
  - Location and direction of motion
  - Width, length and thickness
  - Travel and decelerating distances
  - Added-mass, drag and specific gravity
  - Submarine/subaerial bottom slope

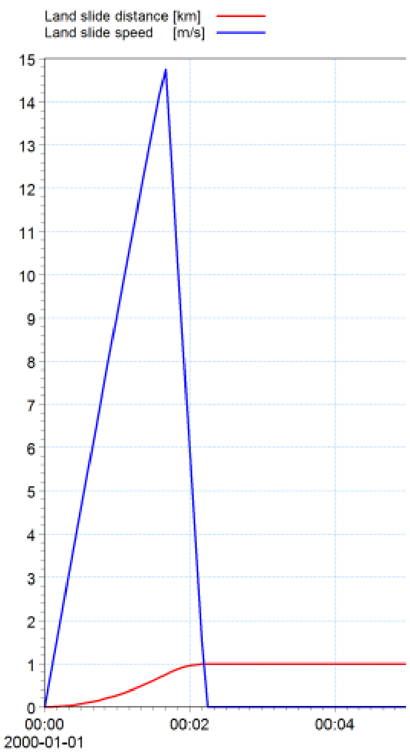
Papua New Guinea (PNG) Slide

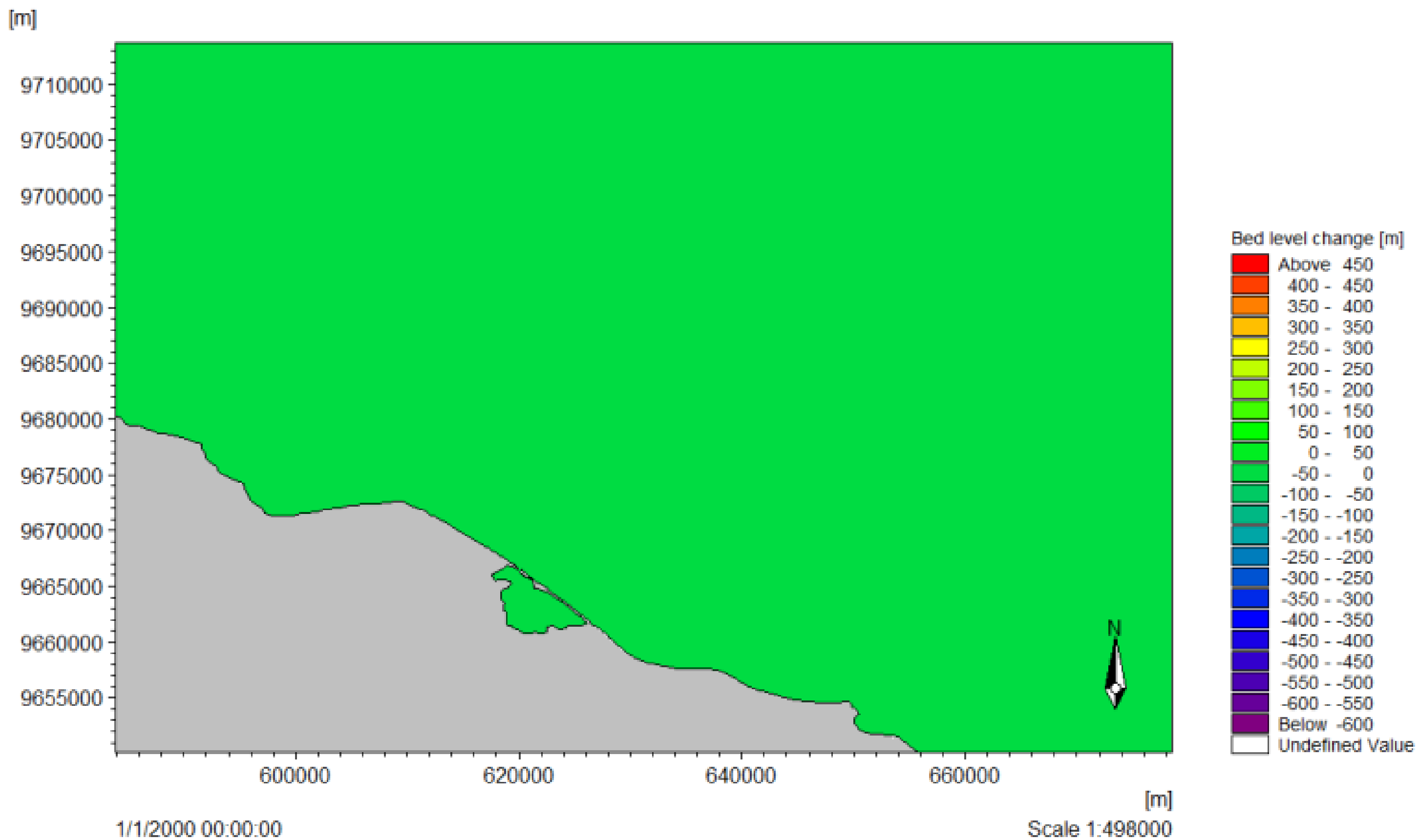
- 17 July 1998
- Offshore of Sissano Lagoon, PNG
- Earthquake-triggered submarine slide



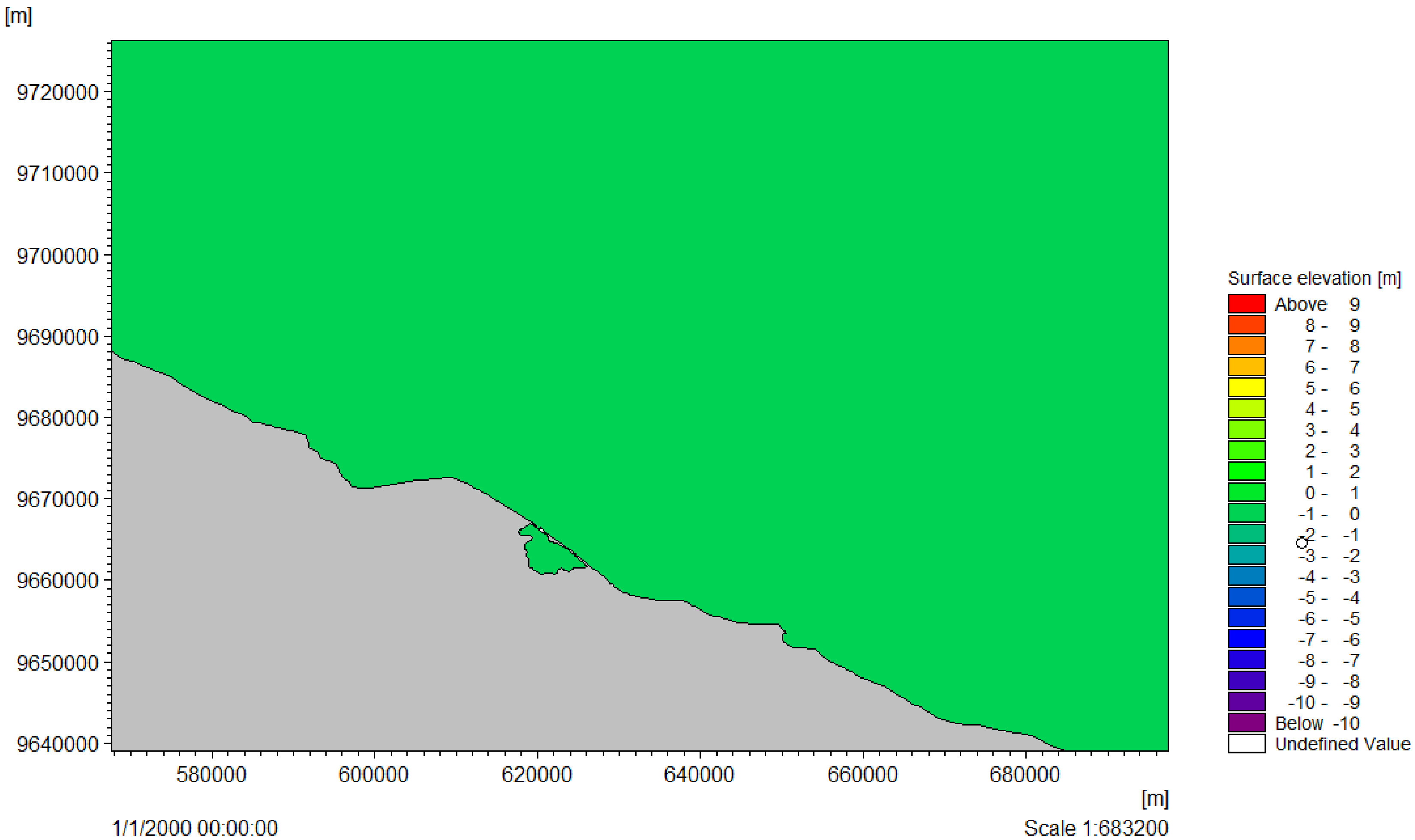
Slide Input (Synalokis et al. 2002)	
Length	4500 m
Width	4000 m
Thickness	600 m
$Dist_{Travel}$	750 m
$Dist_{Decel}$	250 m
Bed slope angle, α	3°
Specific Gravity, γ	1.85
C_m, C_d	1.0

PNG Slide: MIKE 21 Depth Correction





PNG Slide: Results

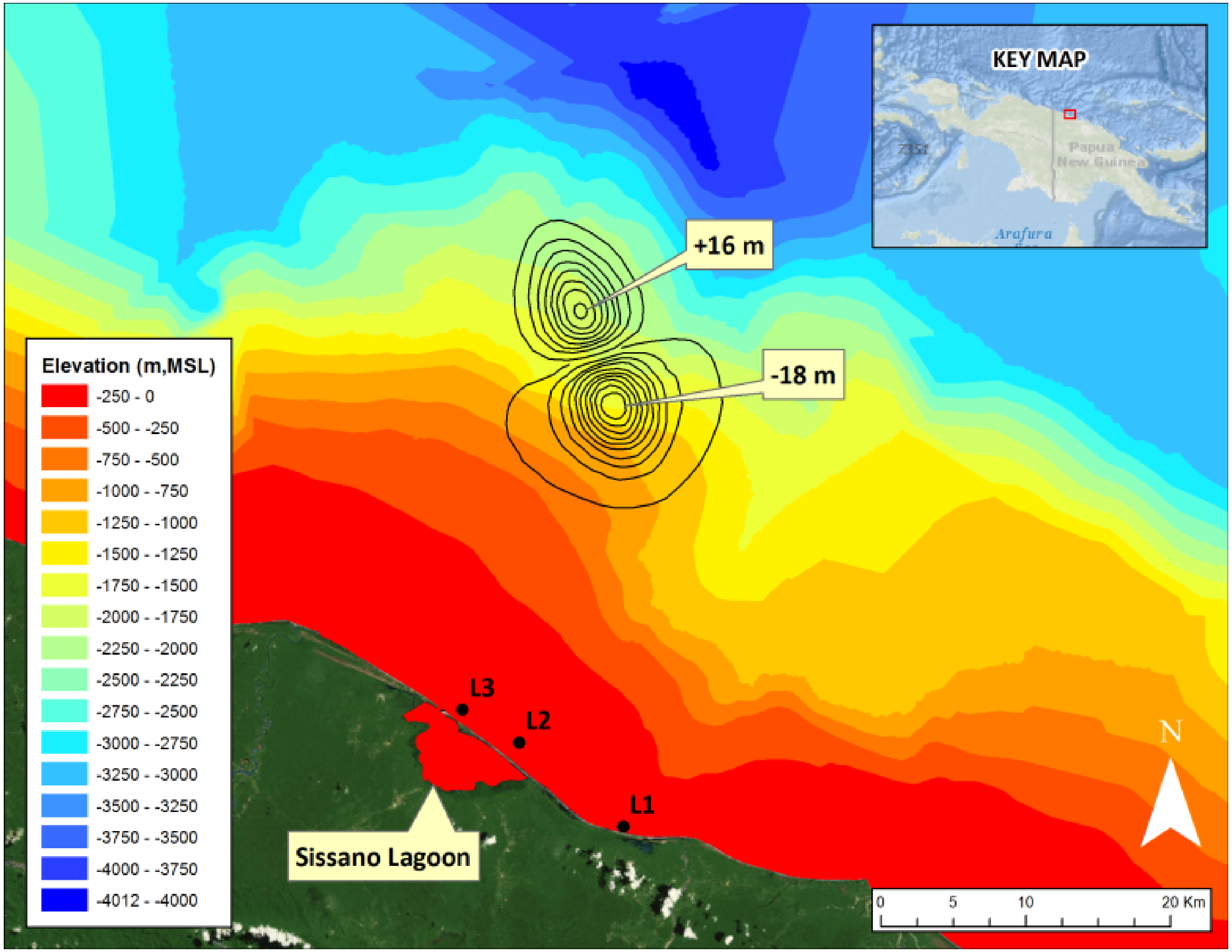


PNG Slide: Results (Cont'd)

Model results using integrated submarine landslide

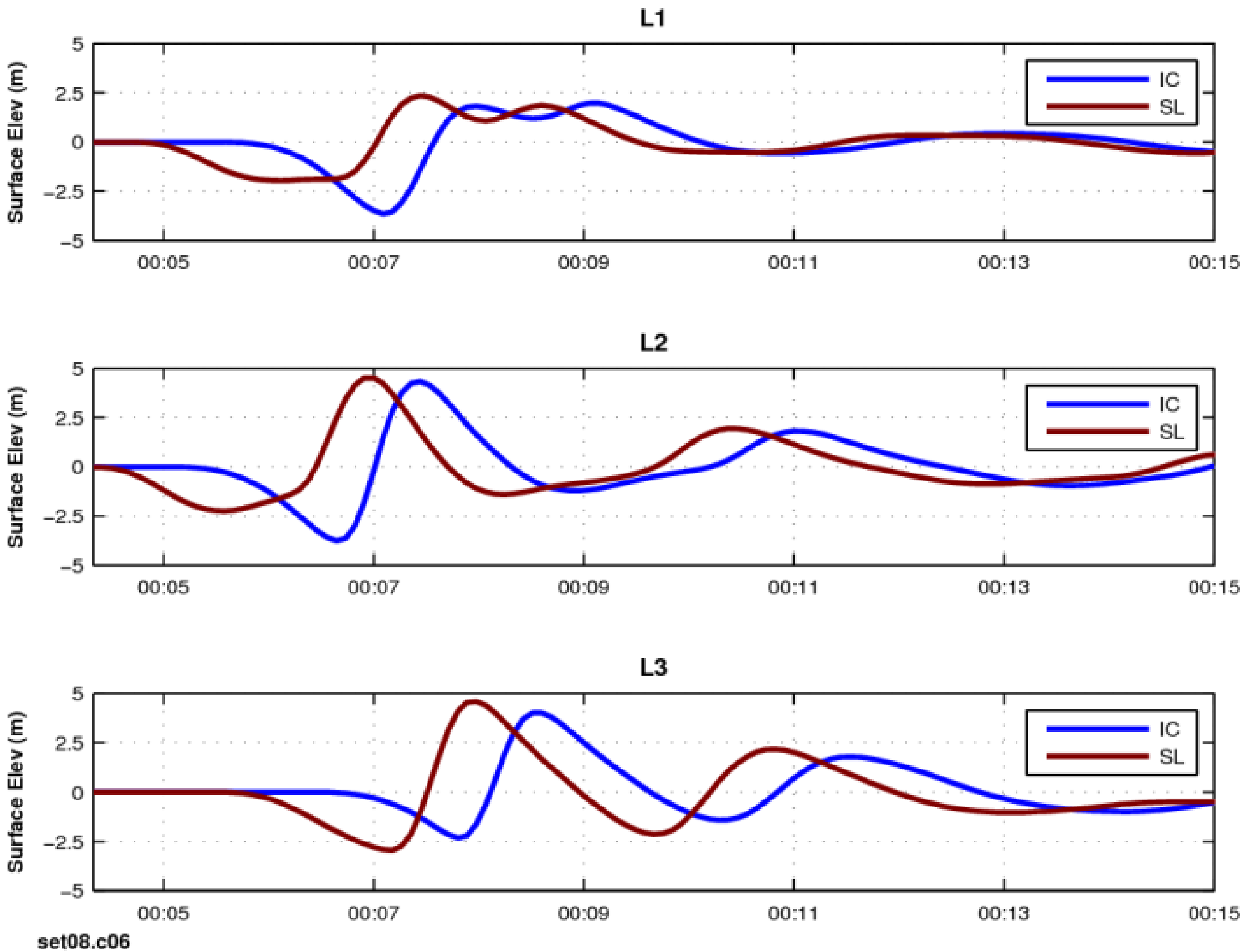
vs.

Model results using imposed initial conditions



PNG Slide: Results (Cont'd)

Legend
IC: Initial Condition
SL: Submarine Landslide



Engineering a Slide

- From regional setting:
  - Triggers (seismic, large tidal range, deltas)
- From ground elevations:
  - Origin and direction of motion
  - Subaerial/submarine slope angle
  - Subaerial/submarine travel distance
- From scientific literature:
  - Origin and dimensions
  - e.g. Width=0.25*Length, Thickness=0.01*Length
- Geotechnical studies

Conclusions

- Submarine/subaerial landslides are often important in engineering
- The described approach uses:
    - Accessible/concise slide input
    - Analytical solutions to integrate slide motion
    - Commercial software
  - To provide:
    - Useful data for engineering/design
    - Advantage over initial conditions approach
- Sensitivity analysis tailored to design

References

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