« Vulnerability of coastal ecosystems to global change and extreme events »
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Extreme waves generated by debris avalanches in oceanic islands and their consequences on the coasts : study case of La Palma case, Canary Islands

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1. Background

• Several large debris avalanche deposits underwater (~100 km3) [Masson *et al.*, 2003]
• Marine conglomerate found on Gran Canaria [Perez-Torrado *et al.*, 2006] =ancient tsunami prints ?
• Cumbre Vieja= fastest growing volcano on La Palma...

Fig. 1 : View of La Palma Island (Canary, Spain) with the main towns and the study area in black

Questions :
• is the West flank of Cumbre Vieja stable ?
• What kind of waves can be expected in case of a large debris avalanche in this area ?
• What would be the consequences of such waves in the region ?

2. Numerical Model

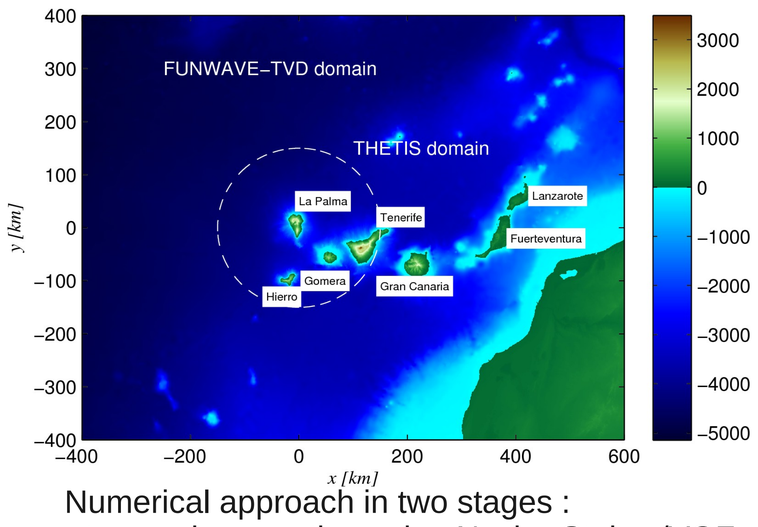

Fig. 2 : View of the Canarian archipelago with numerical domains :
• Cylindrical domain (Inside circle) used for tsunami generation computations
• Whole domain used for Boussinesq computations of tsunami propagation

Numerical approach in two stages :
• tsunami generation using Navier-Stokes/VOF model THETIS [Abadie *et al.*, 2010]
• tsunami propagation based on Boussinesq model FUNWAVE-TVD [Shi et *al.* , 2011]; initial solution given by THETIS

Several slide scenarios based on geotechnical numerical results [Fabre *et al.*, in revision]. Volume considered : 20, 40, 80, 450 km^3. Slide simulated as a Newtonian fluid of basalt density (behavior of fragmented rocks in water ?).

3. Tsunami génération

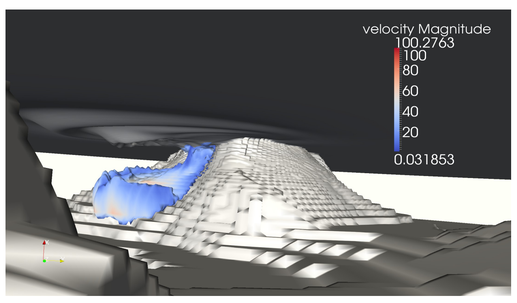

Fig. 3 : Navier-Stokes simulation; results at t~4min for the 80 km^3 case. Underwater view.

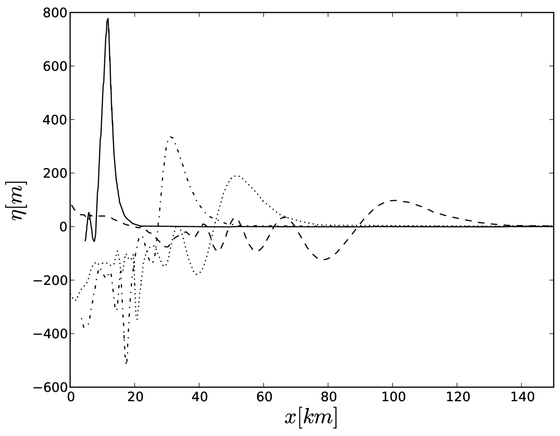

Fig. 4 : Free surface elevation in a vertical plane 20° anti-clockwise with respect to West (see Fig. 5), at t = (solid line) 101 s; (dash-dotted line) 232 s; (dotted line) 340 s ; (dashed line) 558 s.

•Slide Froude number close to 1 : critical regime (optimal generation)
• Waves start as a huge positive free surface deformation (few hundred meters)
• Then fast decrease of the first wave, with dispersion generating a few waves of comparable amplitudes
• Most energy is directed South-West/West, but significant waves still propagate eastwards

4. Near field effects

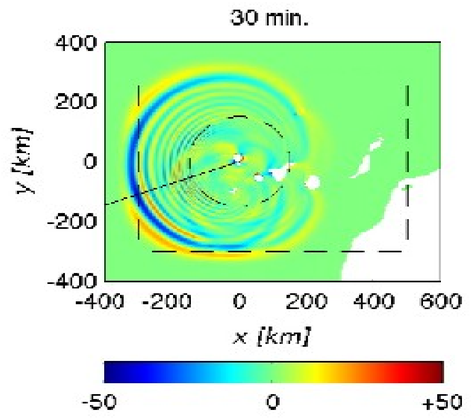

Fig. 5 : Example of tsunami propagation results obtained with Boussinesq model FUNWAVE-TVD for the 80 km^3 case. Dashed black lines indicate the boundary of the sponge layer in the model grid and the size of the initial THETIS grid. Solid black line indicates location of transect.of Fig. 4.

Station	Location	Arrival time	20 km^3	40 km^3	80 km^3	450 km^3
			Gran Canaria			
Las Palmas	28.128 N 15.385 W	37-38 min.	0.92 m	1.75 m	5.34 m	13.8 m
Telde	28.000 N 15.340 W	39-40 min.	2.96 m	5.73 m	7.93 m	20.1 m
Santa Lucia	27.820 N 15.370 W	36-38 min.	3.26 m	6.35 m	8.57 m	17.8 m
			Tenerife			
Santa Cruz	28.450 N 16.230 W	28-30 min.	3.27 m	6.72 m	9.36 m	20.5 m
Arona	28.060 N 16.760 W	17-18 min.	8.95 m	17.3 m	23.2 m	54.8 m
			Lazarote			
Arrecife	28.930 N 13.420 W	65-67 min.	0.70 m	1.38 m	1.97 m	4.98 m
			Fuerteventura			
Puerto del Rosario	28.490 N 13.820 W	59-60 min.	0.74 m	1.49 m	2.07 m	4.88 m

Table 1 : Maximum wave height at seven stations around the Canary Islands; the arrival time for the peak wave was essentially the same between the four test cases.

Conclusions:

• Coupling of Navier-Stokes code Thetis with Boussinesq model FUNWAVE-TVD validated.
• Several slide scenarios : waves sharing the same features but significantly variable amplitudes.
• Higher waves as compared to Lovholt et al. (2008)
• Dramatic effects on La Palma. Significant effects on the surrounding islands for every scenario considered.
• But very low probability scenario (~1/100000) and effects may be drastically reduced is slide doesn't fall in one-go

References

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