Tsunami Hazard at the Spanish Coasts

UTE PROES PRINCIPIA

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Introduction

- RD 1053/2015 approved Basic Directive of Protección Civil planning against Tsunami risk
  - *Section 3.1. (Tsunami Hazard Assessment)*
  - It is necessary to develop Tsunami hazard maps *"in order to determine the territorial areas where it is essential, advisable or unnecessary for the Autonomous Regions to draft civil protection plans to face this risk*

- Protección Civil commissioned UTE PROES-PRINCIPIA to produce the required maps

Introduction

- Current status:
  - Answers given to comments from Working Group following up the tasks of the Basic Directive
    - The results are available at:

      http://www.proteccioncivil.es/riesgos/maremotos/documentacion
    - A summary was published in the electronic Journal of Protección Civil

      http://www.proteccioncivil.es/revistadigital/revistaNoticia.php?page=1&n=76
  - National Council of Civil Protection
    - Permanent Commission has already been informed
    - Still pending to be presented to the Plenary Session

Object

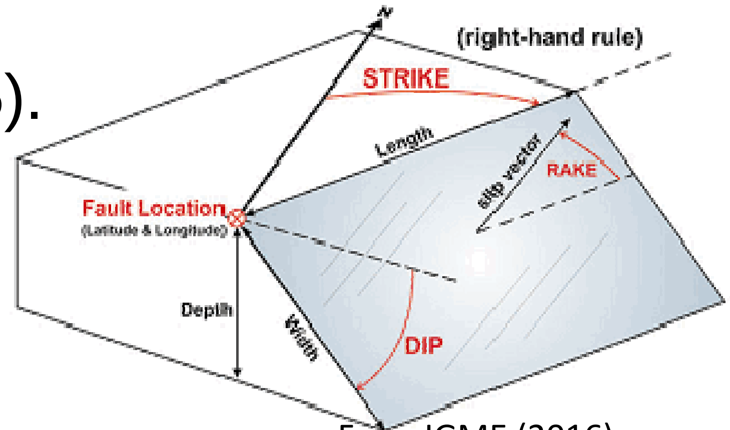
- To determine the Tsunami hazard at the Spanish coasts following a deterministic approach. Two final outcomes:
  - Map of maximum sea level elevations and arrival times
  - Final report and presentation of results, conclusions and recommendations

Scope

- Tasks:
  - Identification of tsunami sources
  - Gathering of the required bathymetry and topography data and integration in a common data base
  - Numerical simulations associating each identified source with the corresponding consequences at the coast
  - Analysis of the results, derivation of conclusions and recommendations
  - Documentation of the work performed

Methodology

- Characterisation of seismic sources
  - Identification of faults with al least half of their trace offshore
  - Parameters required Okada (1985).
    - Length
    - Dip
    - Width
    - Rake
    - Displacement D ➔ To be calculated
  - Evaluation of the maximum Magnitude
    - Correlations from technical literature
    - Contrast with magnitudes from the seismic catalogue
    - M_w ➔ Seismic Moment ➔ D



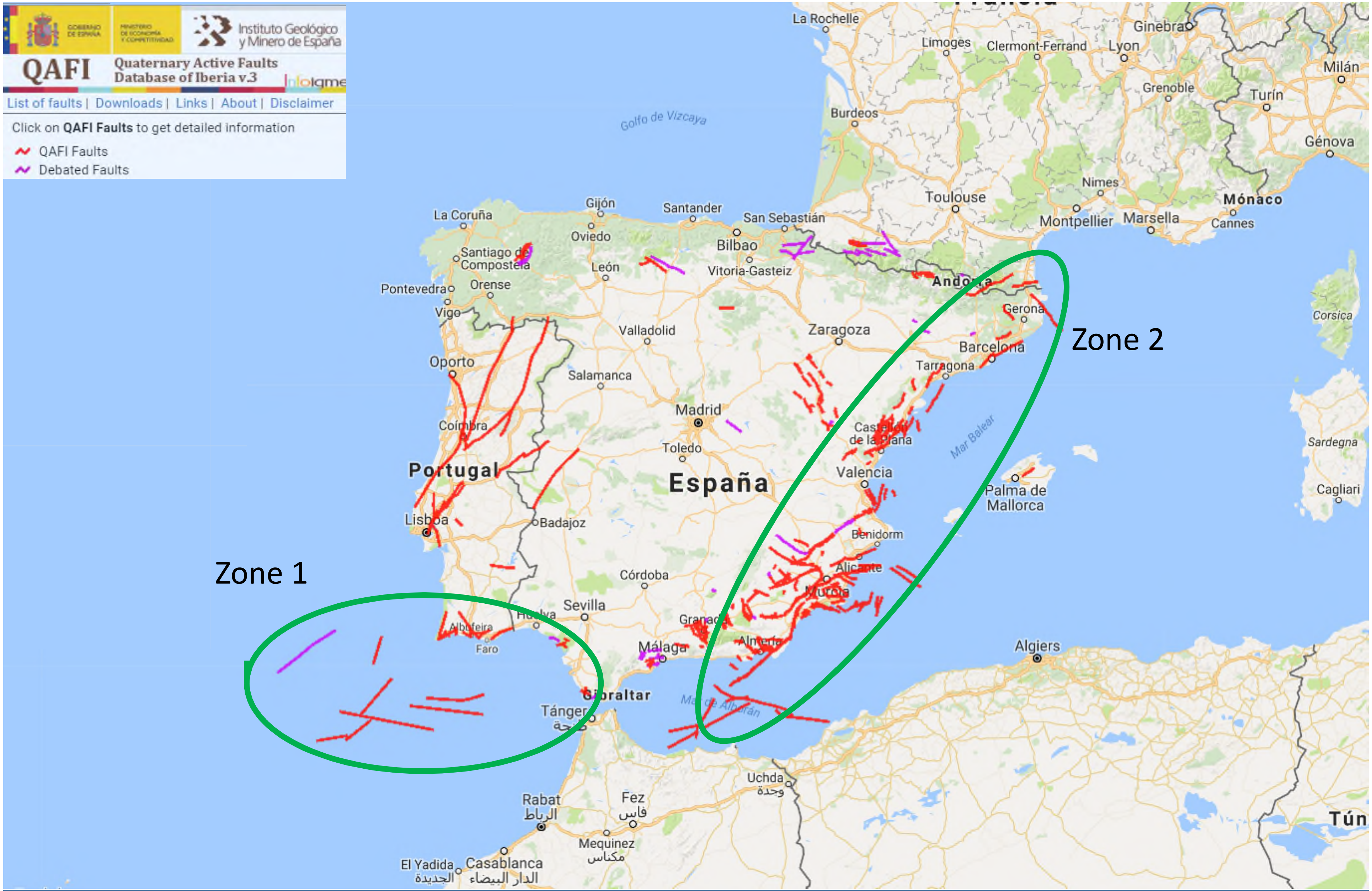
From IGME (2016)

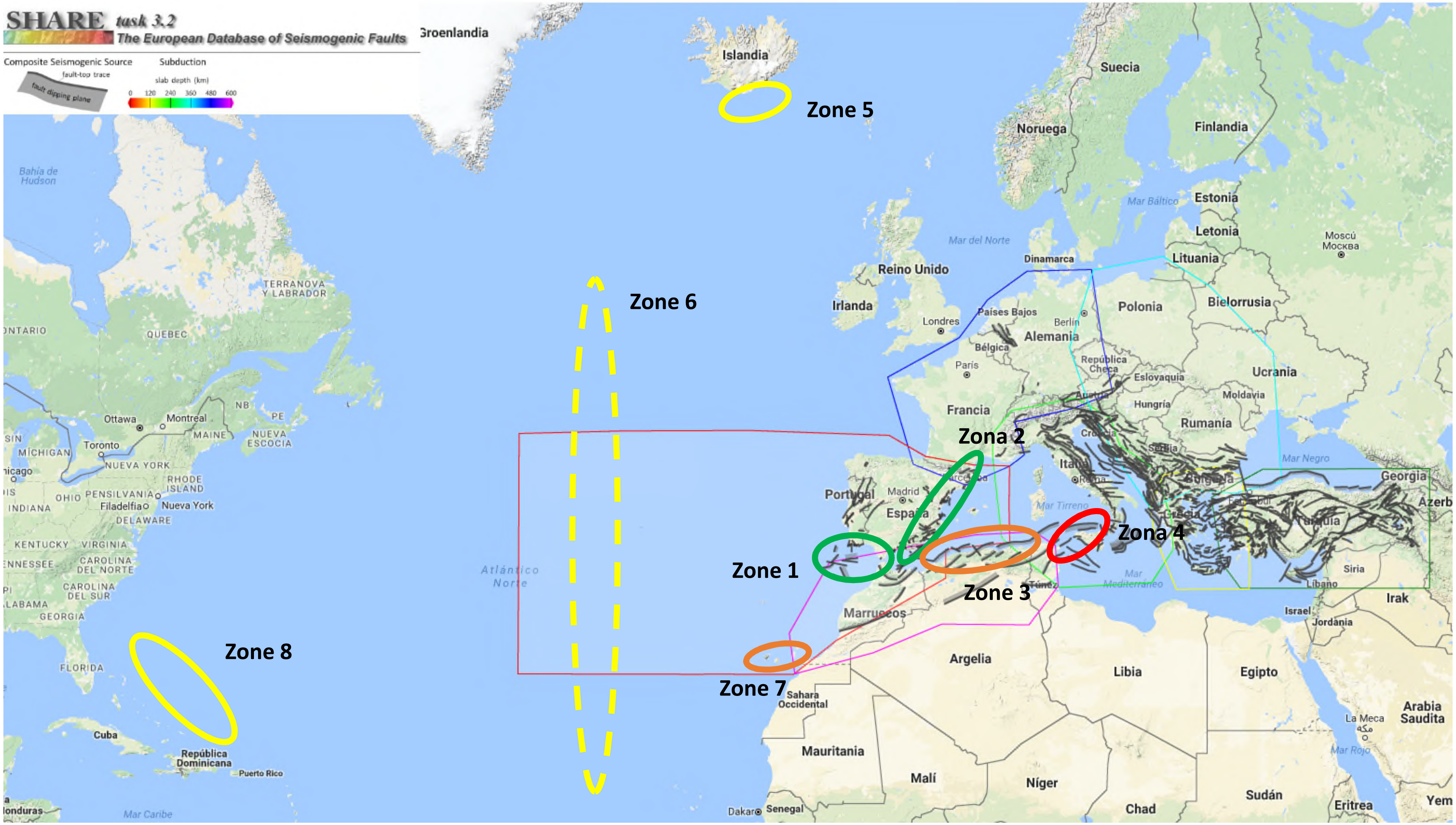
Methodology

- Numerical simulations
  - Compilation of topographic and bathymetric data
  - Homogenisation of compiled information
  - Hydrodynamic propagation: Delft3D-FLOW
  - Pre-processing: initial (Okada, 1985) and boundary conditions with Delft-Dashboard
  - Post-processing: generation of maps from the results with arcGIS

Source characterisation

- Faults databases:
  - QAFI - Quaternary Active Faults Database of Iberia
    - Faults with more at least half of their trace offshore recalculated with updated correlations (Stirling & Goded, 2012)
  - European Database of Seismogenic Faults (SHARE task 3.2)
    - Maximum assigned Magnitude: criteria indicated (correlation or observed seismicity) ➔ recalculated (Stirling & Goded, 2012)
- Technical literature
- Total: 66 faults


Instituto Geológico y Minero de España
QAFI
Quaternary Active Faults Database of Iberia v.3
List of faults | Downloads | Links | About | Disclaimer
Click on QAFI Faults to get detailed information
QAFI Faults
Debated Faults
Zone 1
Zone 2
Golfo de Vizcaya
La Rochelle
Limoges
Clermont-Ferrand
Lyon
Ginebra
Milán
Grenoble
Turín
Burdeos
Génova
Toulouse
Nimes
Mónaco
Montpellier
Marsella
Cannes
La Coruña
Gijón
Santander
San Sebastián
Oviedo
Bilbao
Santiago de Compostela
León
Vitoria-Gasteiz
Andorra
Pontevedra
Orense
Vigo
Gerona
Corsica
Valladolid
Zaragoza
Oporto
Barcelona
Tarragona
Salamanca
Madrid
Coímbra
Castellón de la Plana
Toledo
Mar Balear
Sardegna
Portugal
España
Valencia
Palma de Mallorca
Cagliari
Lisboa
Badajoz
Benidorm
Córdoba
Alicante
Murcia
Sevilla
Huelva
Albufeira
Faro
Granada
Málaga
Almería
Algiers
Gibraltar
Mar de Alborán
Tánger
Uchda
Rabat
Fez
Mequinez
El Yadida
Casablanca
Tún


SHARE task 3.2
The European Database of Seismogenic Faults
Composite Seismogenic Source
fault-top trace
fault dipping plane
Subduction
slab depth (km)
0 120 240 360 480 600
Zone 5
Zone 6
Zona 2
Zone 1
Zone 3
Zona 4
Zone 7
Zone 8
Islandia
Groenlandia
Noruega
Suecia
Finlandia
Reino Unido
Irlanda
Francia
Portugal
España
Marruecos
Argelia
Libia
Egipto
Atlántico Norte
Mar Mediterráneo
Cuba
República Dominicana
Puerto Rico

Bathymetry and topography

- Information adopted for the Digital Terrain Model (DTM):
    - Dirección General de Sostenibilidad de la Costa y del Mar
    - Puertos de Estado
    - Instituto Español de Oceanografía
    - Instituto Geográfico Nacional
    - Instituto Hidrográfico de la Marina
    - GEBCO data

Different scales

Bathymetry and topography

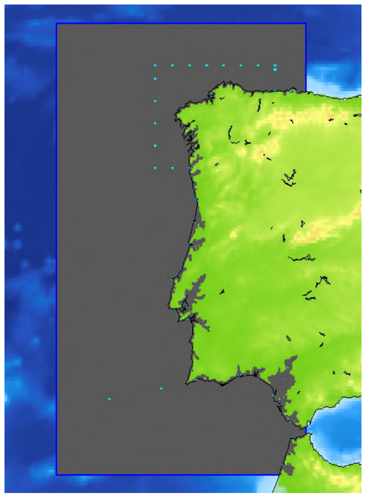
- DTM preparation:
  - GIS homogenisation of topography and bathimetry to a common coordinate system and reference level
    - Bathymetry: EMODnet and GEBCO
    - Topography: IGN information

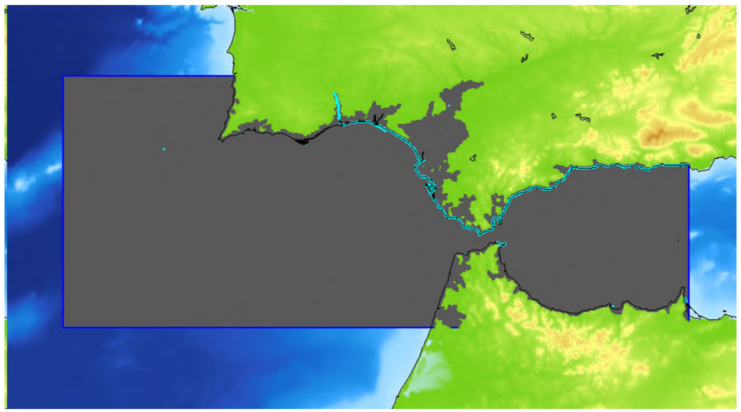
WGS84 (geographic coordinates).

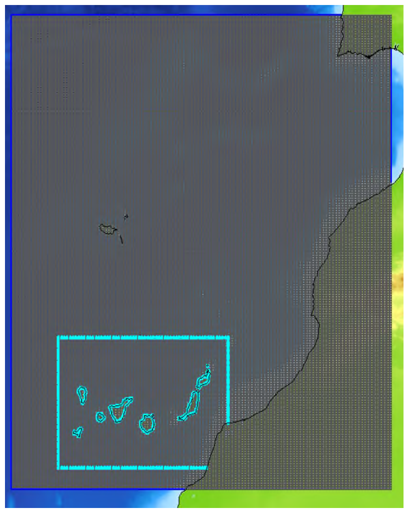
Elevations referred to Mean Sea Level (MSL).

Numerical simulations

- Definition of zones where tsunamigenic faults are located: 8 Zones
- Calculation grids:
  - Caribbean, Canary Islands, Algeria, Italy, and Iceland: 3km x 3km + nested of 500m x 500m
  - Gulf of Cadiz and Levante: 500m x 500m







Numerical simulations

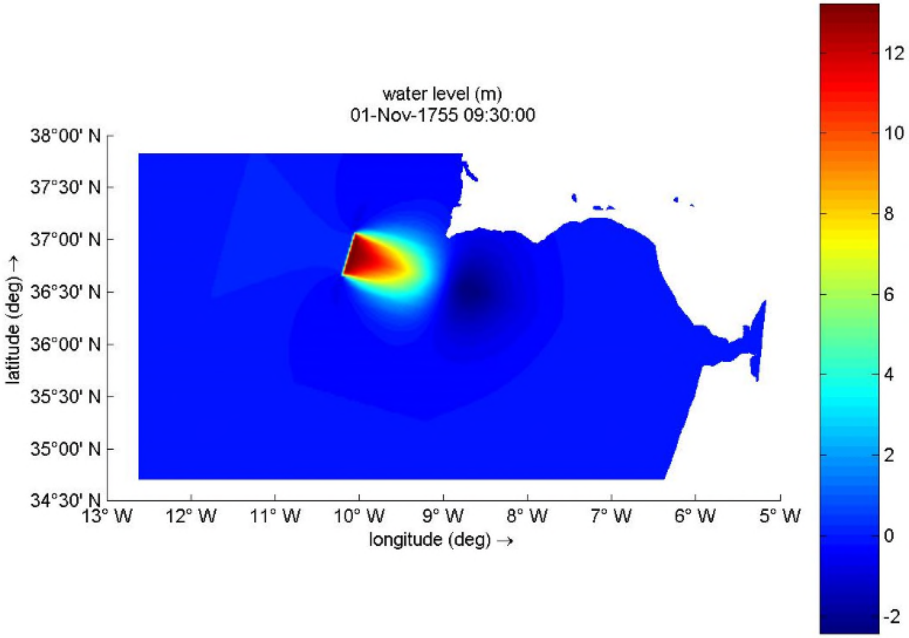
- General results with 500 m x 500 m grids
- Determination of critical zones and the associated tsunami generating faults
- Detailed study with 50 m x 50 m meshes or 25 m x 25 m meshes in critical zones, only for the governing tsunamis
- Total cases: 66

Zone	1	2	3	4	5	6	7	8
# cases	8	43	10	2	1	0	1	1

Numerical simulations

- Boundary conditions:
  - Riemann (initial mesh)→ non-reflecting boundaries
  - Time series of elevations extracted from previous simulations (nested meshes)
- Initial conditions:

  Initial elevation of the sea surface as a consequence of the vertical displacement of the fault at the sea bottom



Numerical simulations

- Sensitivity analyses:
  - Mesh size
    - Maximum differences around 0.5 m
  - Tide
    - The results of applying simultaneously tide and tsunami are approximately equal to the sum of their individual effects
  - Source parameters from Gulf of Cadiz zone
    - Earthquake magnitude
    - Fault trace
- Model validation
  - Results consistent with observations at the Gulf of Cadiz during the 1755 Lisbon earthquake

Results

- For each fault at least one simulation has been performed
- Each simulation produces the following results:
  - Sea surface elevation contours at different times
  - Sea surface elevation history at coastal control points
- The final results for the Spanish coasts are:
  - Maximum sea surface elevations maps along the coast
  - Maps of source faults that generate maximum sea surface elevations
  - Maps showing the areas where the maximum sea elevation exceeds 0.5m, including arrival time and the causal fault

Results: Maximum sea surface elevation

Results: faults that generate the maximum sea surface elevations

Results: Maximum sea surface elevations > 0.5 m

Conclusions

- The tsunami hazard at the Spanish coasts has been deterministically studied in terms of maximum sea elevation. A state-of-the-art methodology has been adopted for source characterisation and hydrodynamic modelling.

- Arrival times have also been calculated for the critical scenarios.

Conclusions

- The hazard is highest at the SW coasts: Huelva, Cadiz, Canary Islands
  - Sea surface elevations higher than 8 m
  - Arrival times for maximum sea elevations: 1 hour Huelva – 1.5 hour Canary Islands
  - Minimum arrival time: 30 min (Huelva)
- Relevant maximum elevations (> 0.5 m) along the Mediterranean coast and Galicia
- Elevations are very moderate in the Gulf of Biscay

Recommendations

- More detailed studies should be conducted for the areas where the maximum sea levels exceed 50 cm.
- Those studies should use a probabilistic approach.
- Detailed studies are also warranted for governing faults to quantify their uncertainties in parameters and use them in a probabilistic approach.
- Hazard is only the first step:

Risk = Hazard * Vulnerability

incorporating the consequences later on