INSIGHTS FROM ASTARTE PROJECT

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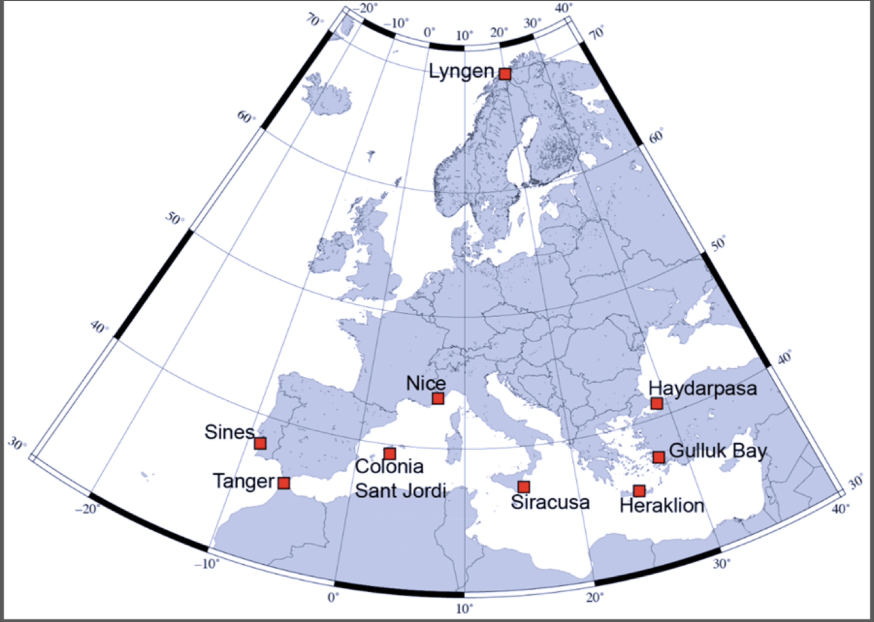
ASTARTE - ASSESSMENT STRATEGY AND RISK REDUCTION FOR TSUNAMIS IN EUROPE

6M€ EU, 16 countries and 20 institutions

ASTARTE : a holistic approach to assess tsunami hazard and mitigate risk



ASTARTE test sites are vulnerable to tsunami impact generated by different source mechanisms: earthquakes, landslides and volcanic eruptions. They cover a broad range of values at risk namely: buildings and other infrastructure, industrial facilities, harbors, road network, fisheries, aquaculture and tourist areas. Test sites provide the possibility to test most of the approaches developed during the project, thus providing a “test bench”, where the different methodologies are tested in a diversity of geological and social environments.

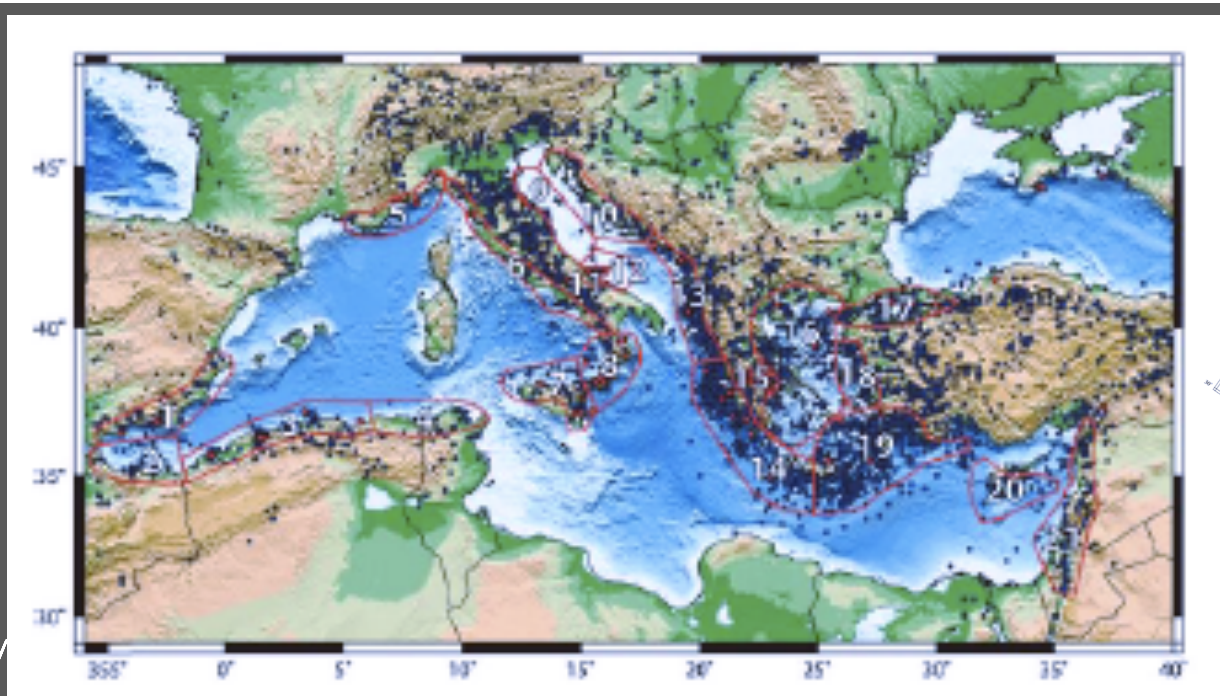
MARIA ANA BAPTISTA

SOURCE – MEDITERRANEAN

NEAM is the IOC terminology for this area North East Atlantic and Mediterranean

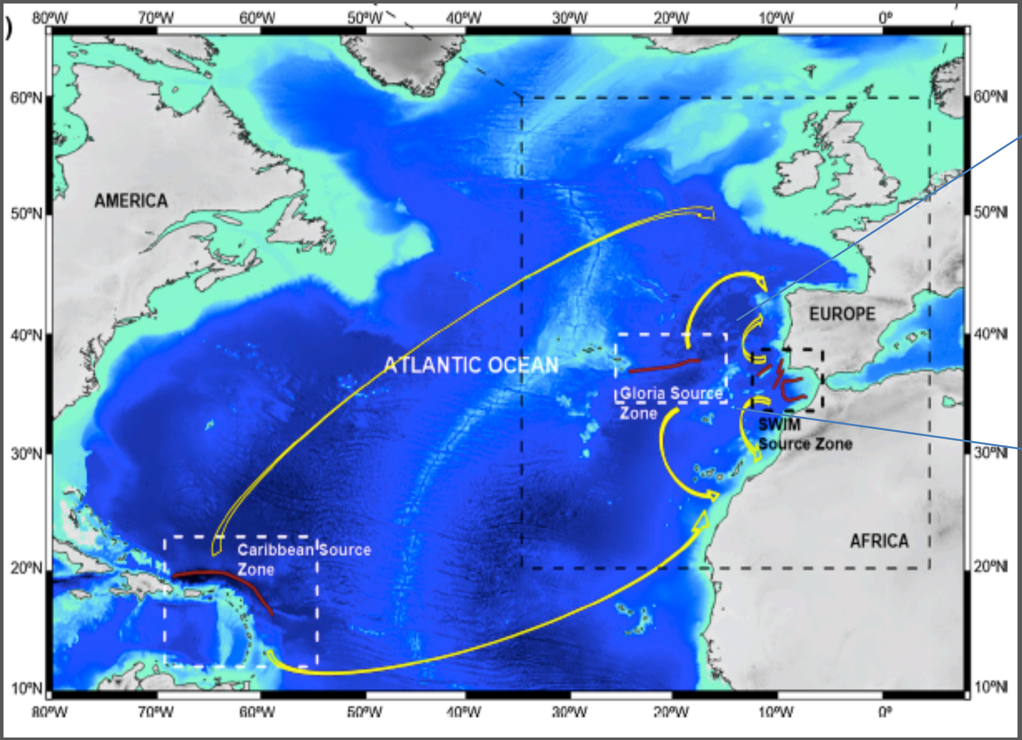
NEAM includes 2 main basins the North East Atlantic and the Mediterranean & Connected seas

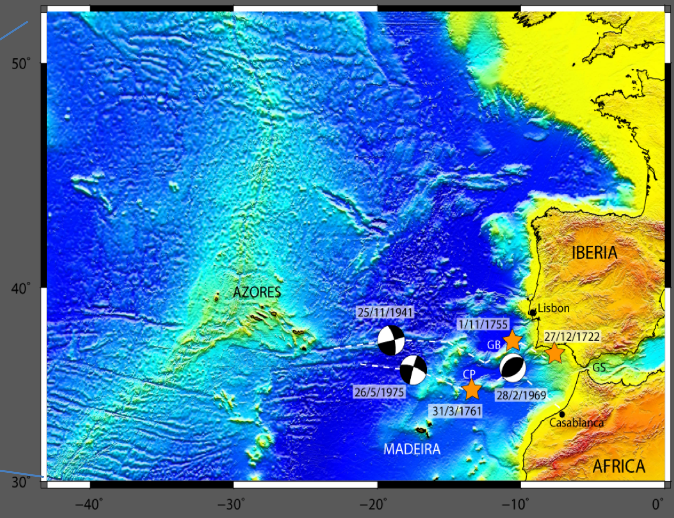
While seismic sources are the most important tsunamigenic structures for all southern sites (Sines, Tangier, Nice, Gullen, Siracusa and Haydarpasa), because of the **complex Eurasia-Africa plate boundary**, non-seismic sources, particularly landslides and rockslides, are relevant in specific environments and have a critical role in the northern European coasts. In the eastern Mediterranean volcanic tsunami sources must also be considered.



SOURCES – NE ATLANTIC

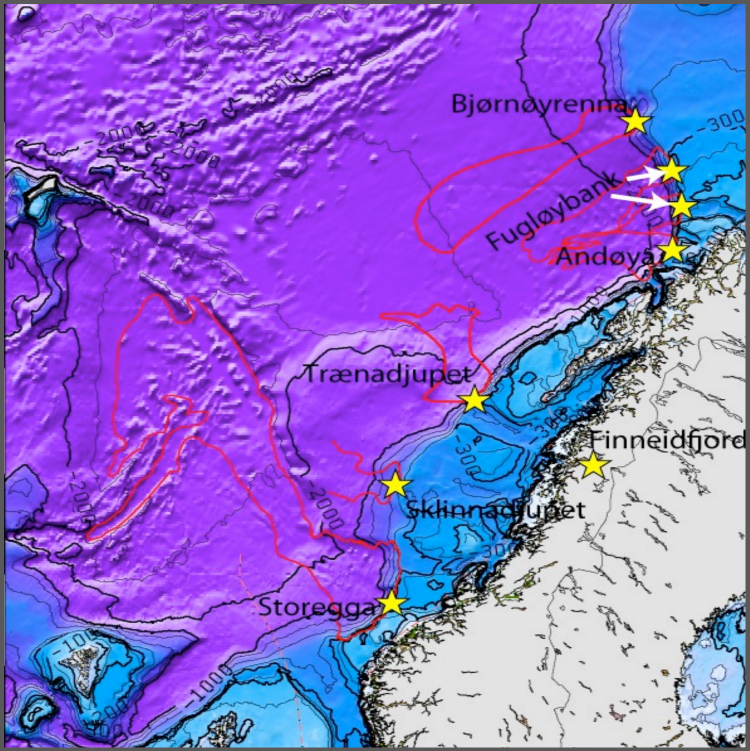
The tsunamigenic earthquakes of the South West Iberian Margin are the primary source of hazard for the North East Atlantic coasts The November 1st, 1755 tsunami was the most devastating event in the history of the NE Atlantic, in terms of loss of live and destruction. However, it was not the unique great tsunami in this region. Distant sources include tsunamigenic earthquakes on the Gloria Fault and in the Caribbean subduction arc





SOURCES ASSESSMENT– NE ATLANTIC

Submarine landslides off the Norwegian continental margin, rockslides in Northern Norway constitute an important source of hazard;



ASTARTE assessed the generation of landslide tsunamis due to both basic block slides and retrogressive landslides are investigated through sensitivity tests.

SOURCES ASSESSMENT– NE ATLANTIC

ASTARTE completed a general assessment of tsunami triggered by earthquakes, showing that:

- an **important percentage of submarine earthquakes may be tsunamigenic** (70% for magnitudes greater than 8.0, 25% for magnitudes greater than 7 and 7% for magnitudes greater than 6.0
- **Large earthquakes in oceanic transpressive fault zones may be tsunamigenic** (in the thrust systems of the Gulf of Cadiz and along the Algerian coastline).
- In the Mediterranean off Algeria results indicate **clustering** for large earthquakes and related tsunamis.
- For central and eastern Mediterranean the major source of hazard comes from **the Western Hellenic Arc**
- The Eastern Mediterranean is mainly affected by local and regional earthquakes; The analysis of historical events does not reveal earthquakes of magnitude higher than 7.5 in this part of the basin. However, for hazard determinations, this upper limit should be used with caution
- **ASTARTE completed** an assessment of volcanic sources in the eastern Mediterranean and Canary Islands in the Atlantic and assessed the possibility of landslide induced tsunamis in Norway and Ireland

METHODOLOGIES: PROBABILISTIC VS SCENARIO BASED

- ASTARTE performed Deterministic and Probabilistic Hazard assessments. Deterministic or Scenario Based Tsunami Hazard Assessment (SBTHA) was performed for most of the test sites. In two test sites both methodologies were performed and compared.

- PTHA predicts the **probability of flooding for an exposure time** while SBTHA produces mainly **inundation maps with flow depths and inundation limits for a specific scenario** or a set of scenarios (even with a priori probability of each scenario)

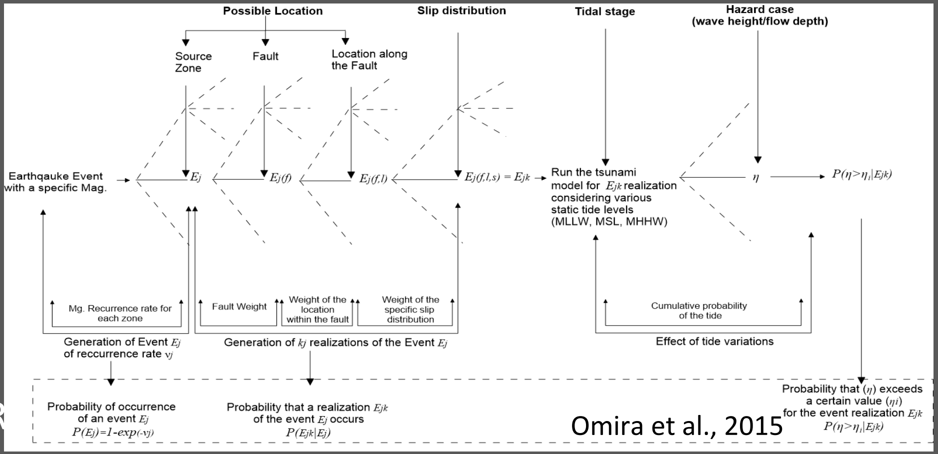
METHODOLOGIES: PTHA EARTHQUAKE INDUCED TSUNAMIS

LOGIC TREE – IPMA METHOD

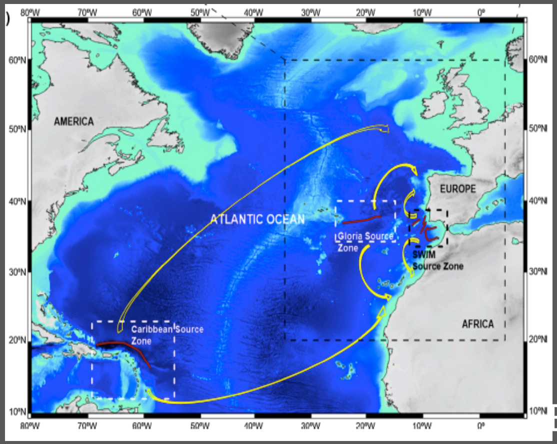
The Logic tree approach considered earthquake scenarios with magnitudes between 7.5 and 9.0 and results computed for 50% probability of tsunami flooding for 500 and 1000-year return periods

The logic tree branches correspond to:

- possible source zones and magnitude recurrence within each zone;
- possible faults where the rupture can take place;
- earthquake source location within the fault;
- earthquake slip distribution;
- tidal stage.



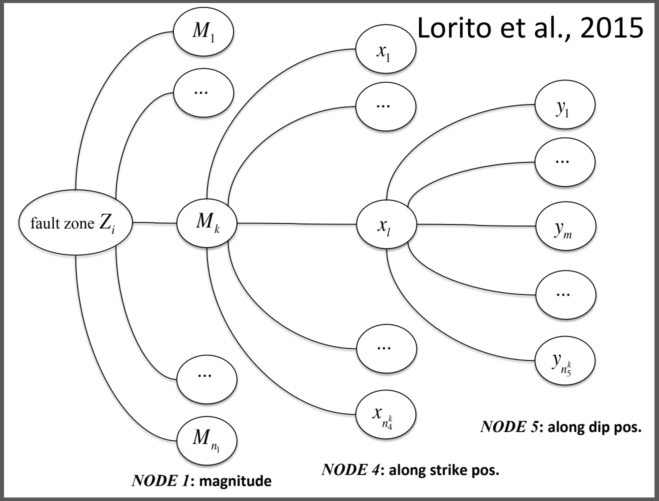
Omira et al., 2015



METHODOLOGIES: PTHA EARTHQUAKE INDUCED TSUNAMIS

Earthquake uncertainty on mapped faults + 'background' seismicity in unmapped faults - INGV method

- dividing all the potential source area in a number of statistically independent seismic regions;
- explore the source variability within each zone making use of an Event Tree approach;
- propagating each individual source to assess maximum water elevation offshore at the target area;
- performing a 2-stage filtering process in order to individuate clusters of similar tsunami events at site;
- evaluate the inundation from this reduced number of scenarios;
- recombining the output of such inundation simulations in order to produce a final cumulated hazard assessment.



METHODOLOGIES: PTHA EARTHQUAKE INDUCED TSUNAMIS

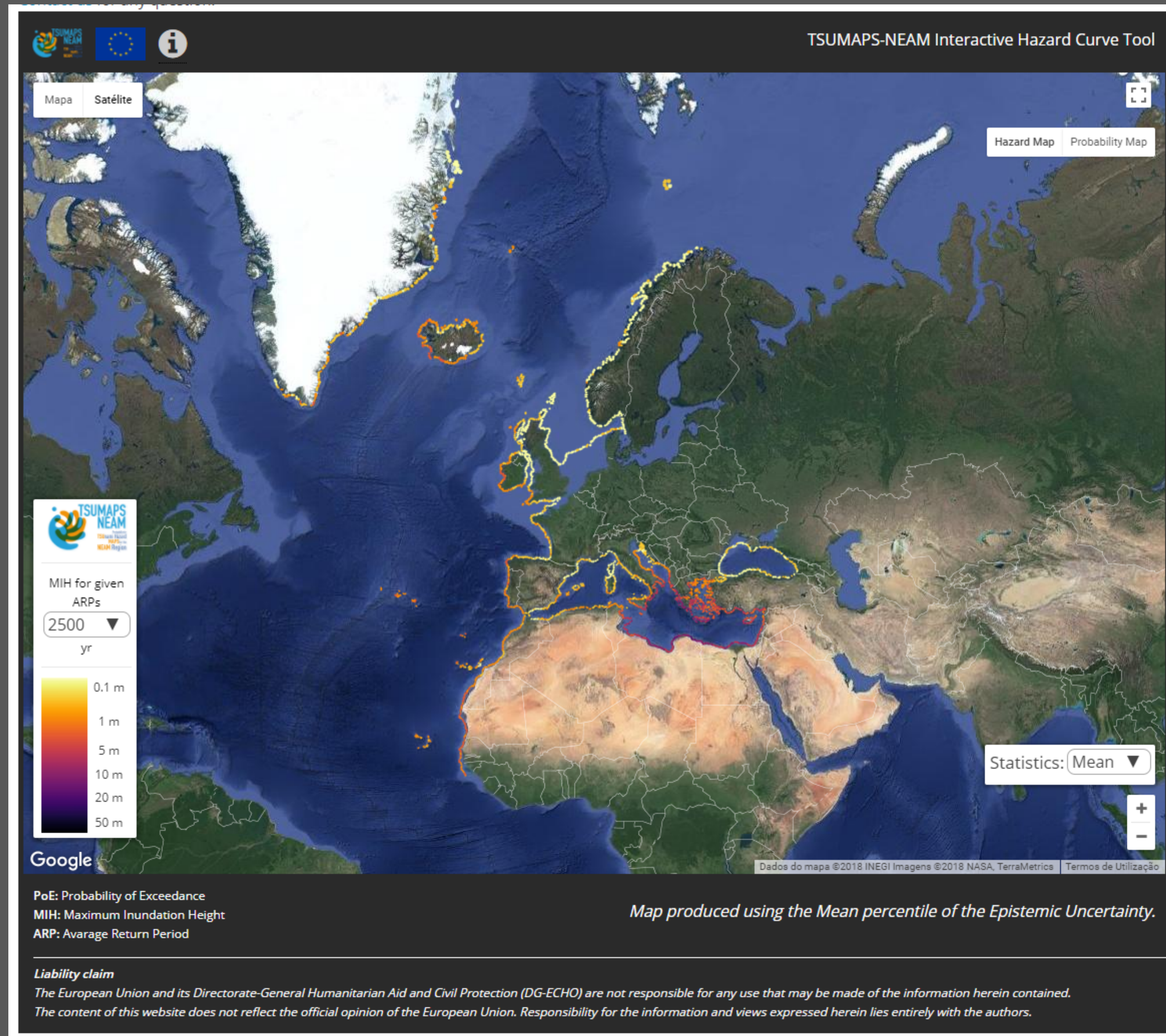
- The computationally-based methods of ASTARTE are for earthquake induced tsunamis. They don't deal with tsunamis generated by other sources, landslides or volcanoes.
- However, **these methods are suitable for an extension to these types of sources, provided that enough data are available for their probabilistic treatment**.
- The empirical method by NOA is based on the completeness of earthquake catalogues but (by the end of ASTARTE) still **needed extensive tes**ts for validating the completeness catalogue; The tsunamigenic earthquakes that occurred worldwide in the last ten years showed us that there might be a wide range of events with very specific features that may be **under-represented, at least locally, in available catalogues**.

METHODOLOGIES: PROBABILISTIC VS SCENARIO BASED – CONCLUSIONS

- In **Scenario Based THA**, the choice in ASTARTE was to use the **realistic worst-case earthquake** scenario that was based on **maximum historical tsunami events** (Heraklion, Sines, Tangier).
- **The main conclusion of our PTHA and SBTHA is that both methods produce similar inundation zones** for values less than 10% of probability of inundation during 1000-year return period.
- However, the inundation areas produced by the aggregate scenario in deterministic approach and probabilistic approach were found different for a return period of 1000-year; To obtain the same inundation area produced with the aggregate scenario with 100% probability of occurrence we need **to consider much longer return times**. **This fact may be explained by the rareness of extreme earthquake events (Mw=9.0) and the use of a Gaussian distribution.**

ASTARTE FOSTERED THE GROUND FOR TSUMAPS NEAM

Project leader: Roberto Basili
Map produced to DG-ECHO EU



AGITHAR - KoM

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TSUNAMI HAZARD ASSESSMENT FOR LANDSLIDE SCENARIOS AND VOLCANIC SCENARIOS

Landslide scenarios were computed considering the past millennia, and not considering potential future landslides, **due to the huge epistemic uncertainty in landslide forecasting.**

Modelling **past landslide-generated tsunamis** yields only a general idea of the tsunami height range that might reach the impacted area

Even through this approach, **epistemic uncertainty exists in the exact source description of past landslides (in terms of sediment volume, initial velocity, maximum velocity and rheology of the landslide masses)**.

However, even if it is impossible to rigorously quantify the exact amount of uncertainty, **an upper bound for wave height can be determined**.

In the case of **volcanic explosions**, expert geological evaluation was found to be the best approach to select the scenario – e.g. the Minoan eruption tested for Heraklion.

VULNERABILITY ASSESSMENT OF BUILDINGS

The methods used in ASTARTE for **assessment of the vulnerability of buildings to tsunami impact were** qualitative and quantitative approaches.

The qualitative methods characterize the exposure of structures to the hazard by means of attributes from territorial element inventories. This is done by assigning scores to some subjective criteria which are then combined using weighted averages or sums to determine the vulnerability class of each structure.

The quantitative methodologies are based on **the use of fragility cur**ves (for buildings/structures) and mortality curves (for individuals), that link damage and losses to values of the tsunami parameters.

VULNERABILITY ASSESSMENT OF BUILDINGS

Vulnerability assessment in Sines and Tangier was computed for probabilities of occurrence of 20%, 50%, and 80% using fragility curves (based on the 2011 Japanese post-tsunami survey) and adapted to local construction types; Tsunami damage was divided in 6 levels (D1-Minor, D2- Moderate, D3-Major, D4-Complete, D5- Collapse, and D6-Washed away) and results depicted in vulnerability maps. Results show that **construction material and the structure elevation play an important role in controlling the tsunami vulnerability**.

For Colònia San Jordi, in the Balearic island of Mallorca, both SCHEMA project and PTVA-3 models were used and compared . Here, the **damage scenarios** were calculated for tsunami wave heights of 2 m, 4 m, 8 m and 10 m. **Both models indicate that moderate tsunami heights >2 m**) could produce light to important damage to buildings located in the first and second lines in the port and urban beach front area.

In Siracusa and Augusta in Italy, the results showed that **SCHEMA model tends to underestimate the damage level with respect to PTVA-3**.

RISK ASSESSMENT OF BUILDINGS

For tsunami risk assessment, the study made for Heraklion test site shows the need to **compute separately risk to buildings and risk to population**.

- To compute the risk to buildings NOA partners made an ex-ante calculation of the absolute economic (**monetary) losses needed for building replacement, either reparation or reconstruction.**
- An additional assumption made for reasons of simplicity is that in **each individual building damage occurred only in the ground floor without any involvement in the calculations of the rest building floors**.
- The computation of the risk for the population was found more complex because population is not directly described in terms of geolocation. In Heraklion, it was concluded **that Census data should be used as a reference**, and the population geographical density might be used as metric of the population exposure, using a simple mathematical spatial distribution model

In summary,

AGITHAR can use:

- ASTARTE made good progress Methods for tsunami hazard assessment while Vulnerability and Risk were only moderately addressed… (input WG1)
- ASTARTE assessed the impact of small tsunamis on harbours, due to resonance effects - Boumerdés 2013 impact in the Balearic ports but did not complete any risk assessment.

- New numerical models and real time computation and produced

new benchmarks for model validation based on laboratory experiments; assessment on grid resolution versus computational time (inputs for WG3)

- Last but not least, ASTARTE concluded more than 1000 interviews in NEAM region and concluded that local citizens and occasional tourists **reveal a low level of tsunami awareness** and do not recognize the natural signs of an approaching tsunami – The case of the 2017 event between Turkey and Greece is an example

In AGITHAR,

- Still room to improve methods for THA

- Include all types of tsunami generation mechanisms

- Go from hazard to risk assessment

- The world's highly populated shoreline with the continuous growth of tourism and economic activity increases the potential losses caused by tsunamis.

- Climate change with scenarios of sea level rise will increase the potential losses caused by tsunamis.

- Improve hazard and risk maps, but we need to address how to use these maps and how to communicate uncertainties to authorities and land-use managers?

- THANK YOU!!! (on behalf of all ASTARTE partners)