On the use of Paleo DEMS for Simulation of historical Tsunami Events

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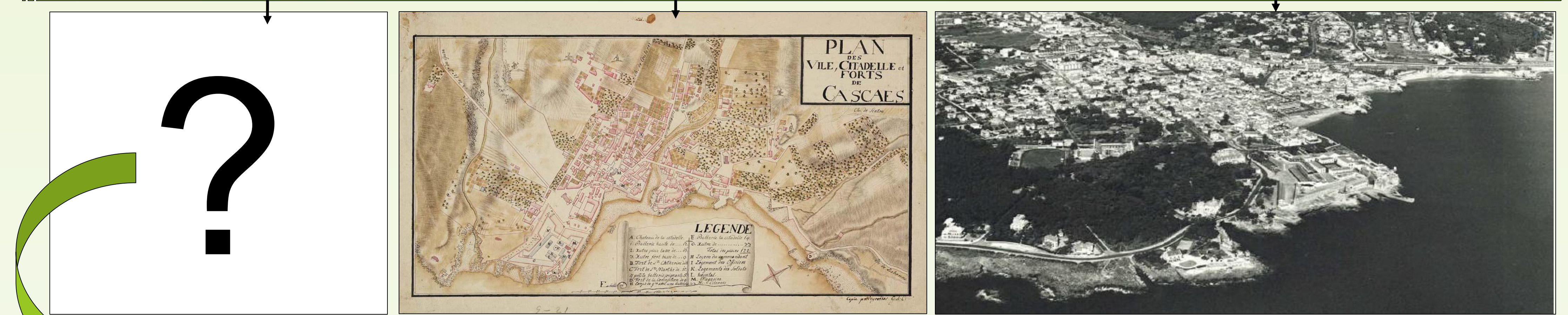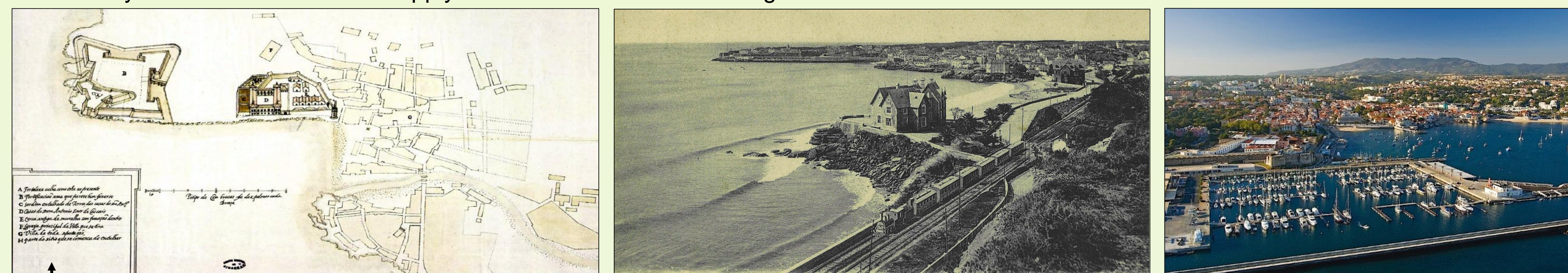
Introduction – The Problem

Tsunamis devastated coastlines in different historical contexts, but the evaluation regarding coastal impact in most of the cases is difficult. For present day Tsunami Hazard Assessment, highly accurate Digital Elevation Models (DEMs) of specific study areas are used. They are built from actual precise LIDAR data and bathymetric data from hydrographic surveys. In the case of historical tsunamis, the past or paleo DEM is hard to build. To obtain a reliable Paleo DEM a lot of effort is needed to convert the information contained in antique documents. Until recently, old maps and other documents have been disregarded for use in quantitative geophysical modelling due to difficulties in their interpretation. But for the reconstruction of an ancient urban landscape, these documents are indispensable. Nowadays, digital tools allow easier access to ancient documents and facilitate their analysis and interpretation. We apply a new methodology to reconstruct a recent Holocene Paleo-DEM for the coastal city of Cascais in 1755 and apply numerical Tsunami modelling.

Timeline

1594 | 1755 (Paleo Period) | 181? | *Urbanization* | 1889 | 1970 | 2000 (Present Day)

Method – The Solution

The reconstruction process starts from a known or given reference. This is commonly the todays outline of a given test site. This method focus on a large cartographic scale reconstruction of local and mainly urbanized areas. Topographic and bathymetric data is available for big parts of coastal areas but with varying quality. Depending on the spatial extent of the test-site, the study purpose and the features in the study area that should be represented a certain resolution is necessary to obtain reliable results. We use actual LIDAR Data with 2 m resolution and digital hydrographic dataset with 100 m resolution as starting point. We used the following procedure to identify and quantify differences and remodelled topographic and bathymetric on basis of historic maps and developed slope models.

- We investigate in **historical documents** like coeval descriptions, pictures, paintings and maps.
- We **identify the differences** of comparing the conclusions taken from the historical documents to the actual outline
- We **geo-reference the old maps** to actual satellite images to localize the differences.
- We **classify the main areas** in the study area the suffered under anthropogenic influences.
- We **establish models to reproduce the slopes** in the identified areas for each of the following classes.
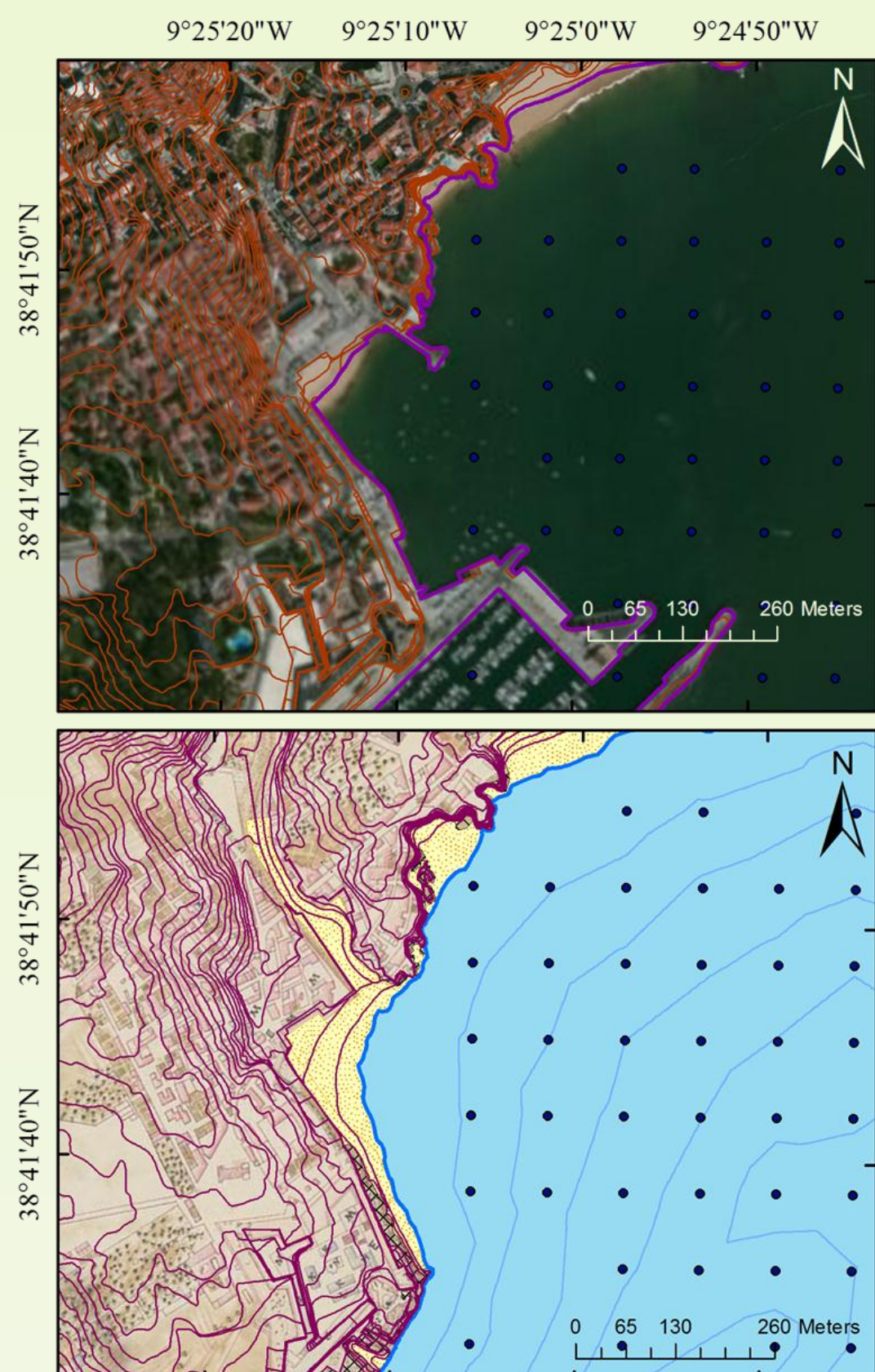
The cliffs
Slope is obtained from a typical Cross-section applied according to the shadings of the antique map
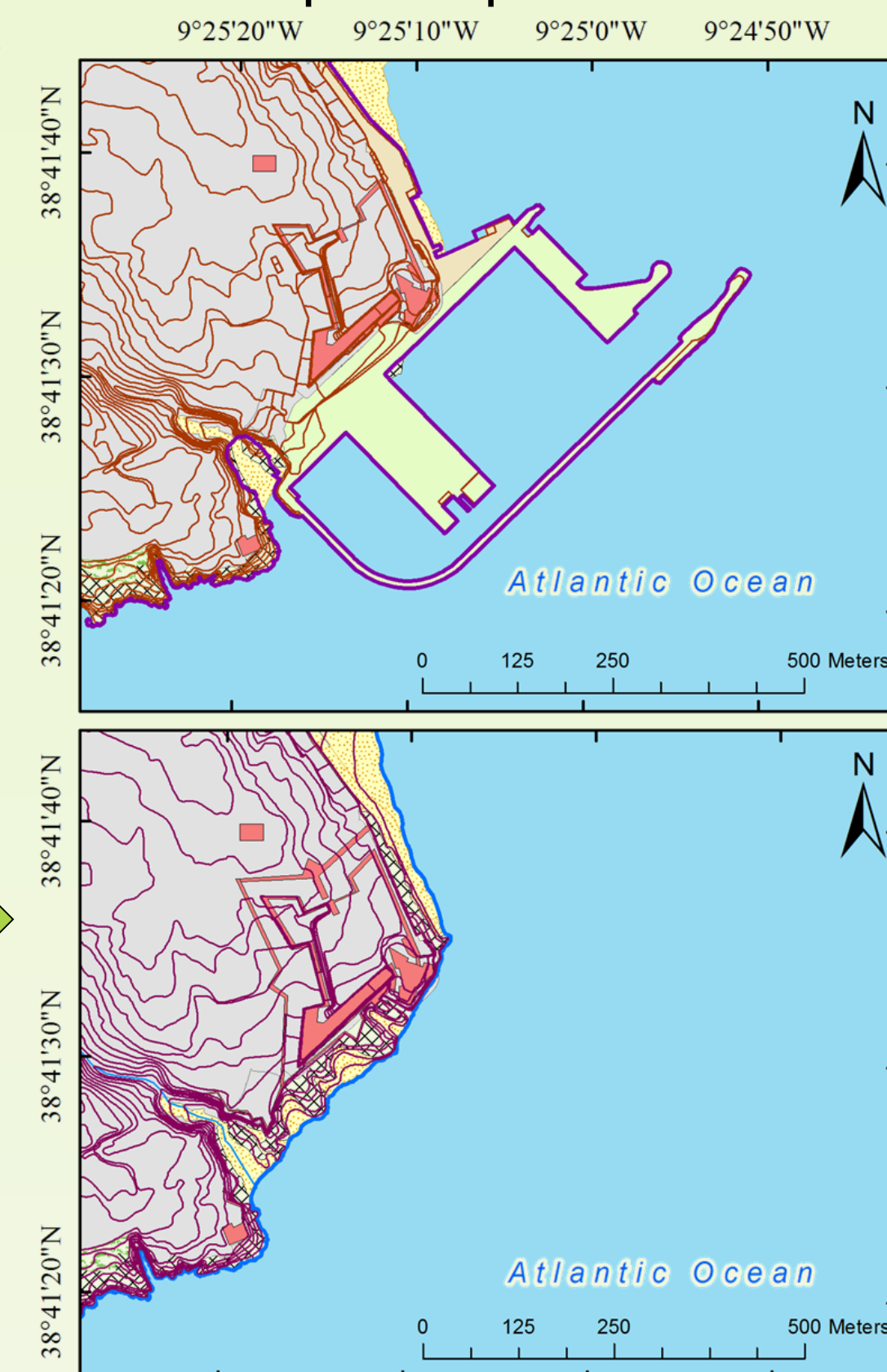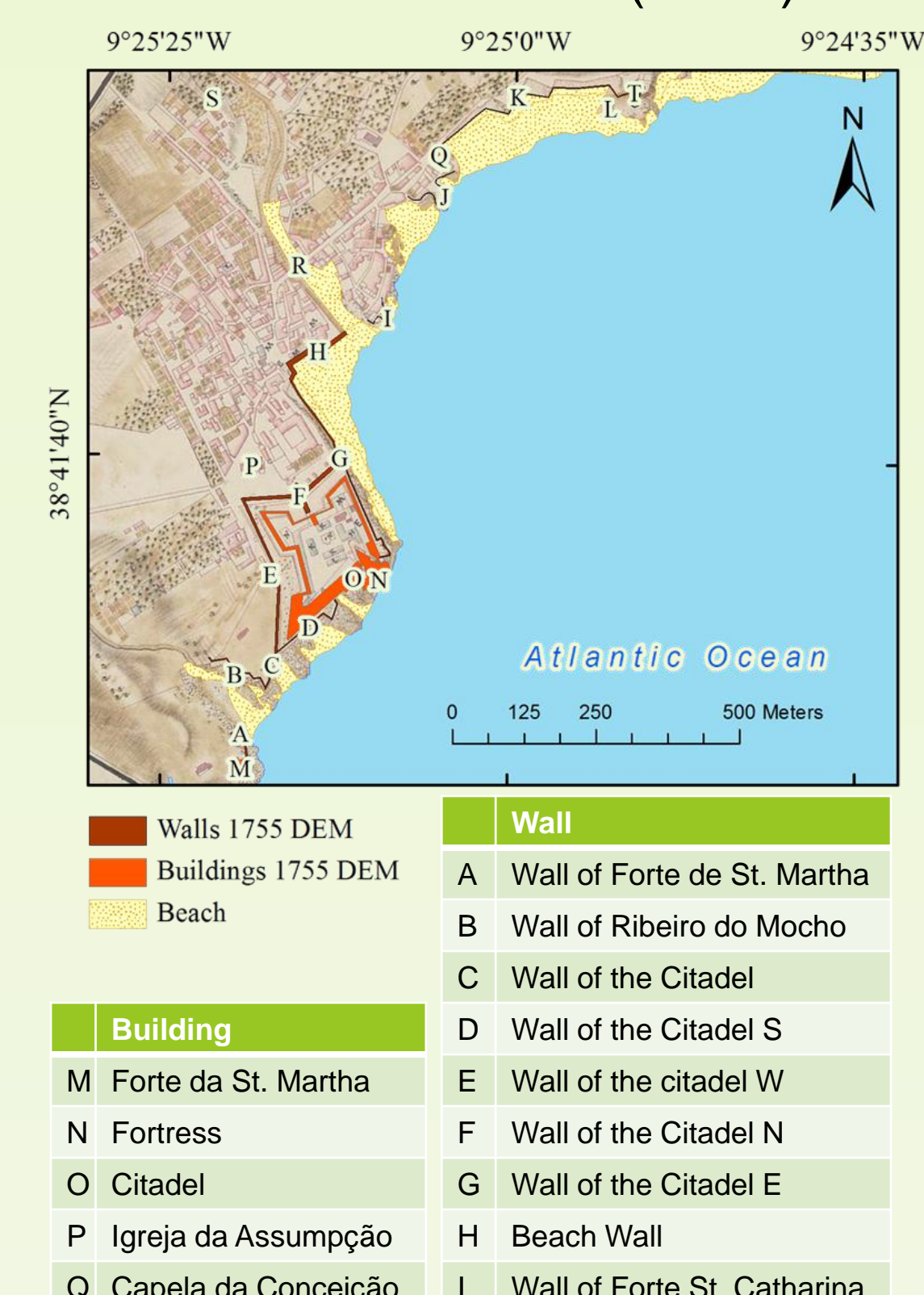
The beaches
Slope is obtained by the intertidal regime depicted in the antique map
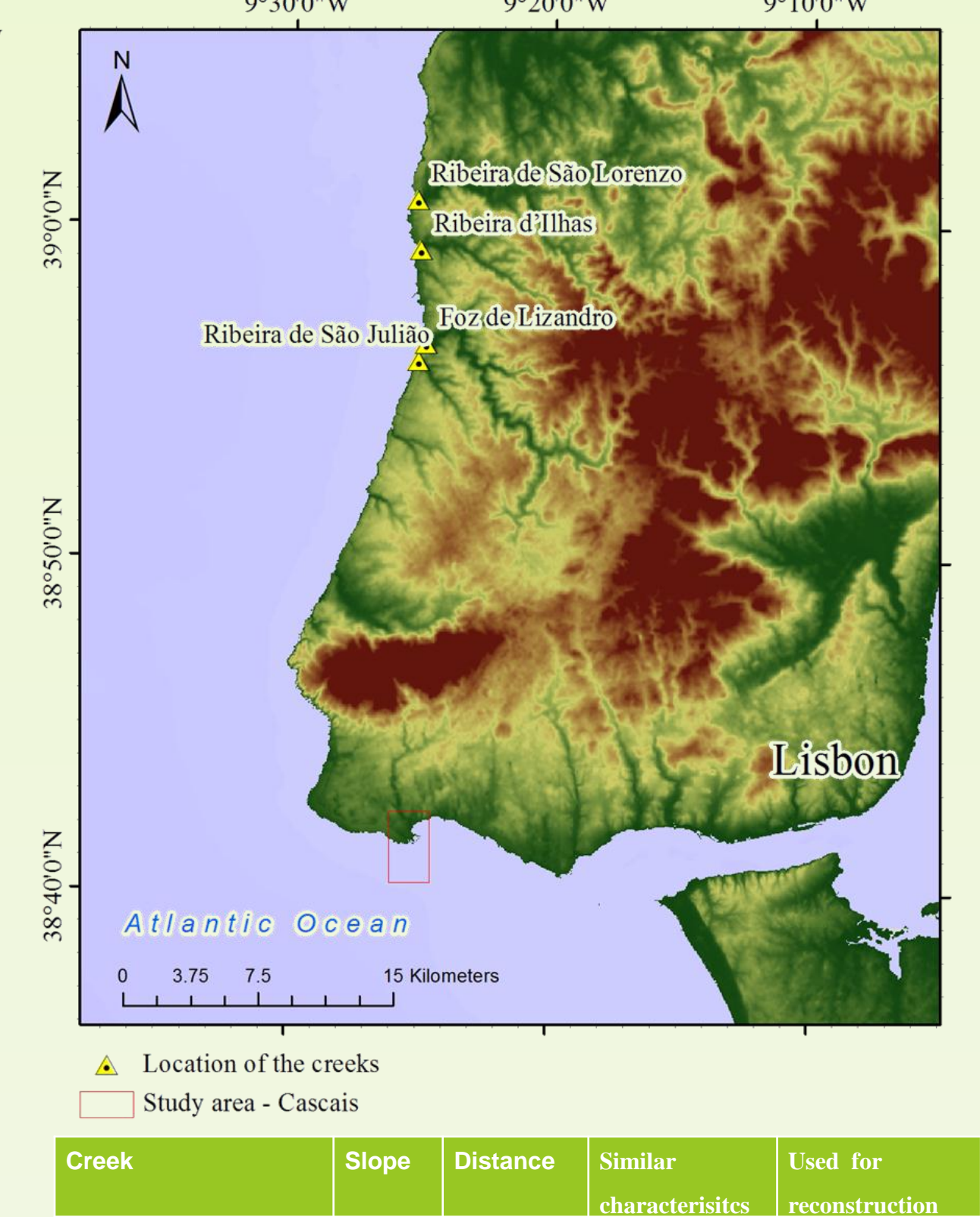
The constructions
Information on constructions derived from old images and descriptions Ferreira Boiça et al., (2001), Carita (2003) & Câmara de Cascais (2005)

Wall	
A	Wall of Forte de St. Martha
B	Wall of Ribeiro do Mocho
C	Wall of the Citadel
D	Wall of the Citadel S
E	Wall of the citadel W
F	Wall of the Citadel N
G	Wall of the Citadel E
H	Beach Wall
I	Wall of Forte St. Catharina
J	Wall of Praia da Rainha
K	Wall of Praia da Conceição
L	Wall of Forte de Conceição

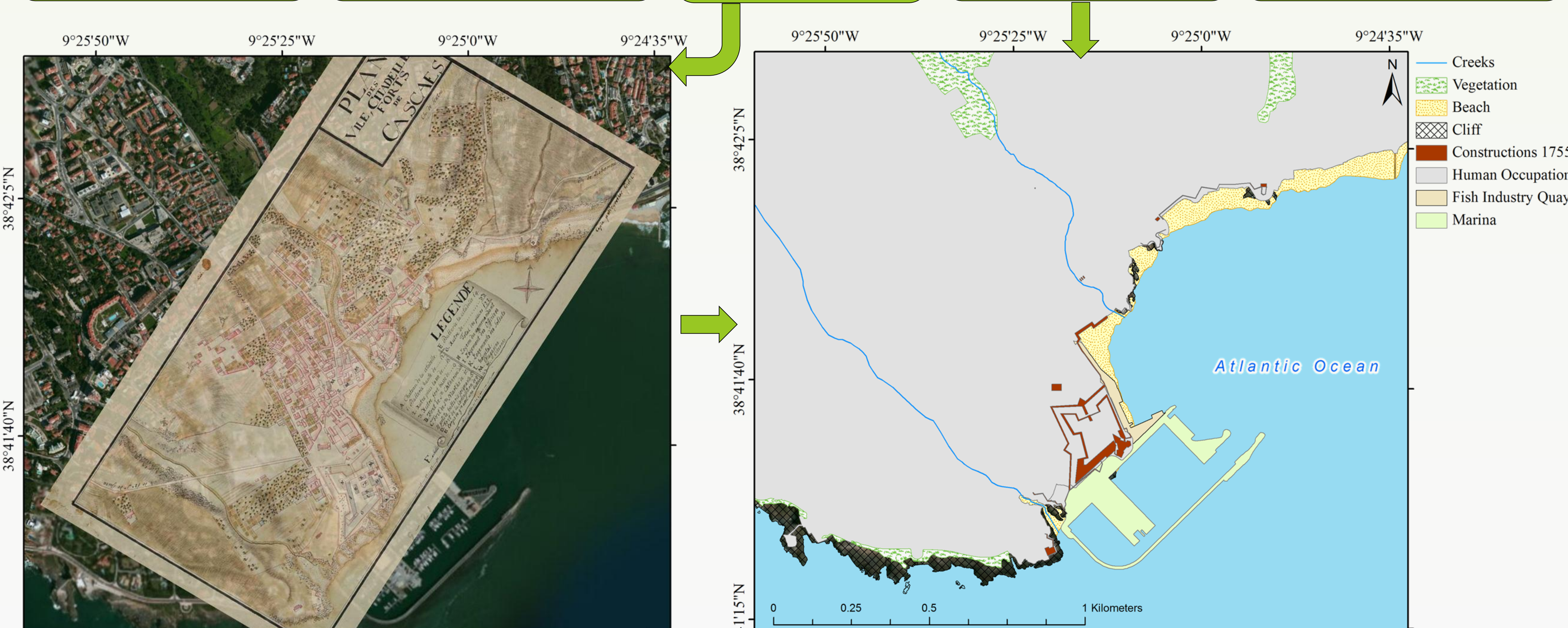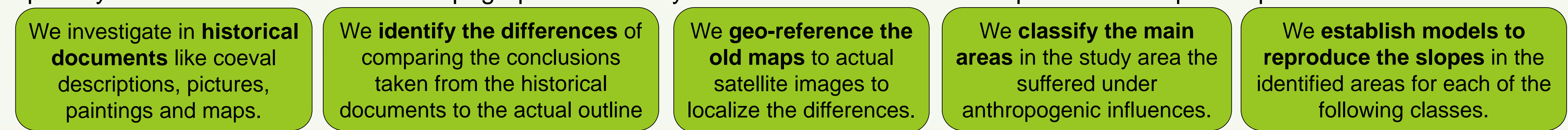| Building	
M	Forte da St. Martha
N	Fortress
O	Citadel
P	Igreja da Assumpção
Q	Capela da Conceição
R	Columns of the bridge
S	Poço velho
T	Forte da Conceição

The creeks
This reconstruction model is based on a GPS-RTK survey at creeks in similar hydrologic and geologic environment. The obtained values are than transferred to the test site.

Creek	Slope	Distance	Similar characteristics	Used for reconstruction
Rib. de São Julião	−1.5%	330 m	Yes	no
Rib. d'Ilhas	−0.24%	410 m	yes	yes
Foz de Lizandro	−0.05%	800 m	no	no
Rib. de São Lorenzo	−0.08%	800 m	no	yes

## The Result & Application

The 1755 Cascais Paleo-DEM

Finally we tested our result and applied the numerical tsunami modelling tool COMCOT (Liu et al., 1998 & Wang, 2009). We built 4 layer nested grids and incorporate the Paleo-DEM with 2 m final resolution as finest grid. We used the 1755-like scenario as proposed by Baptista et al. (2011). Initial condition was calculated using the Horseshoe fault based on the elastic half-space theory (Okada 1985).

Fault Parameter:

Fault	Length [km]	Width [km]	Slip [m]	Strike [°]	Dip [°]	Rake [°]	Magnitude
HSF	165	70	15	42.1	35	90	8.4
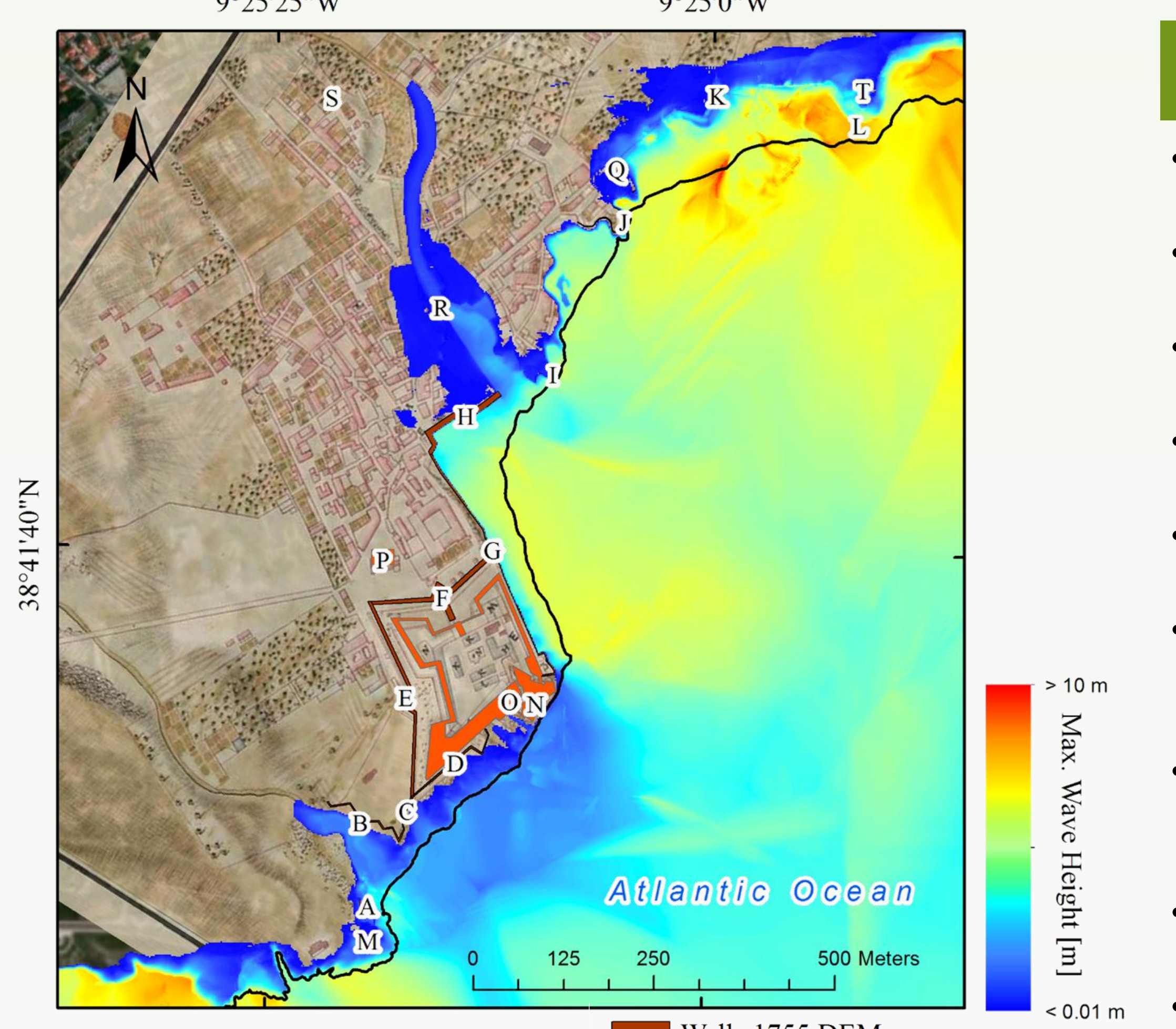
Conclusions

- We built a Paleo-DEM for Cascais, Portugal to simulate a tsunami impact of a 1755-like scenario for the same Paleo period.
- The results of the tsunami simulation show max. flow depth values above 10 m.
- The tsunami entered through the creek Ribeira das vinhas and inundated the village.
- The beach wall acted as an obstacle to the incoming tsunami and was not overtopped.
- The tsunami penetrated approximately 520 m inland and reached as far as the Quinta da Santa Clara.
- The entrance Capela da Conceição was inundated with values of 0.4 m, according to brother António the waves did not enter the chapel and the people in the chapel survived
- The wave inundated a part of the the garden of the cloister Nossa Senhora da Piedade, according to discriptions the fence of the cloister was overtopped.
- The results are in good agreement of the observations at the time described by brother António.
- Paleo-DEM are useful tool to re-evaluate tsunami impact of historic events. Their use also allows the verification of proposed Sources regarding historic events.