COASTAL FLOODING PREDICTION THROUGH AN ARTIFICIAL NEURAL NETWORK BASED APPROACH

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Malta, 29th november 2019

Coastal flooding risk

Coastal zones are:

- more densely populated than the hinterland. In particular, the population in the world living in low elevation coastal zone (<10 m) is more than 600 million.
- exposed to several natural hazards.

Marzamemi (Sicily) - 09 28 2018

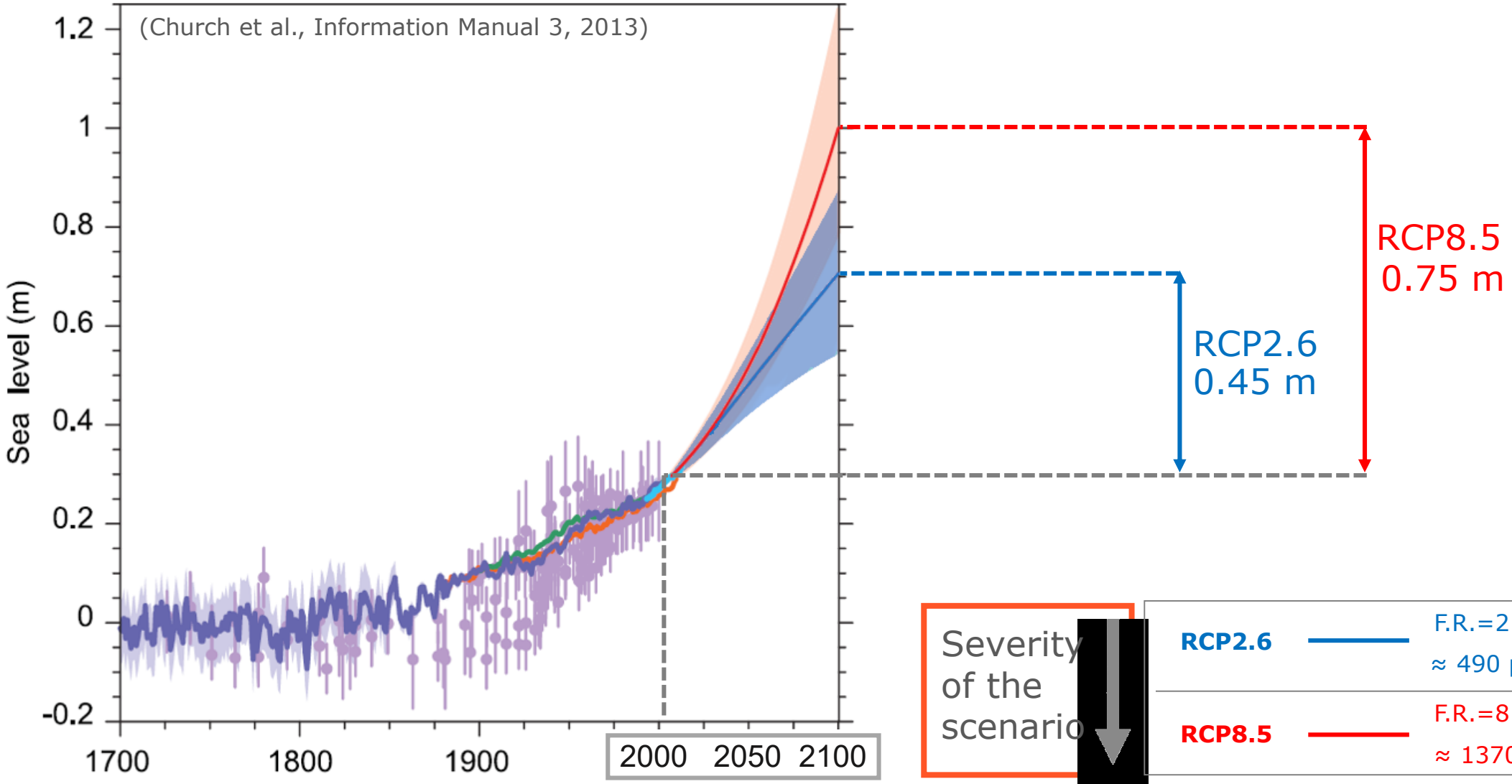
Coastal zones are characterized by a high risk related to flooding

Coastal flooding risk

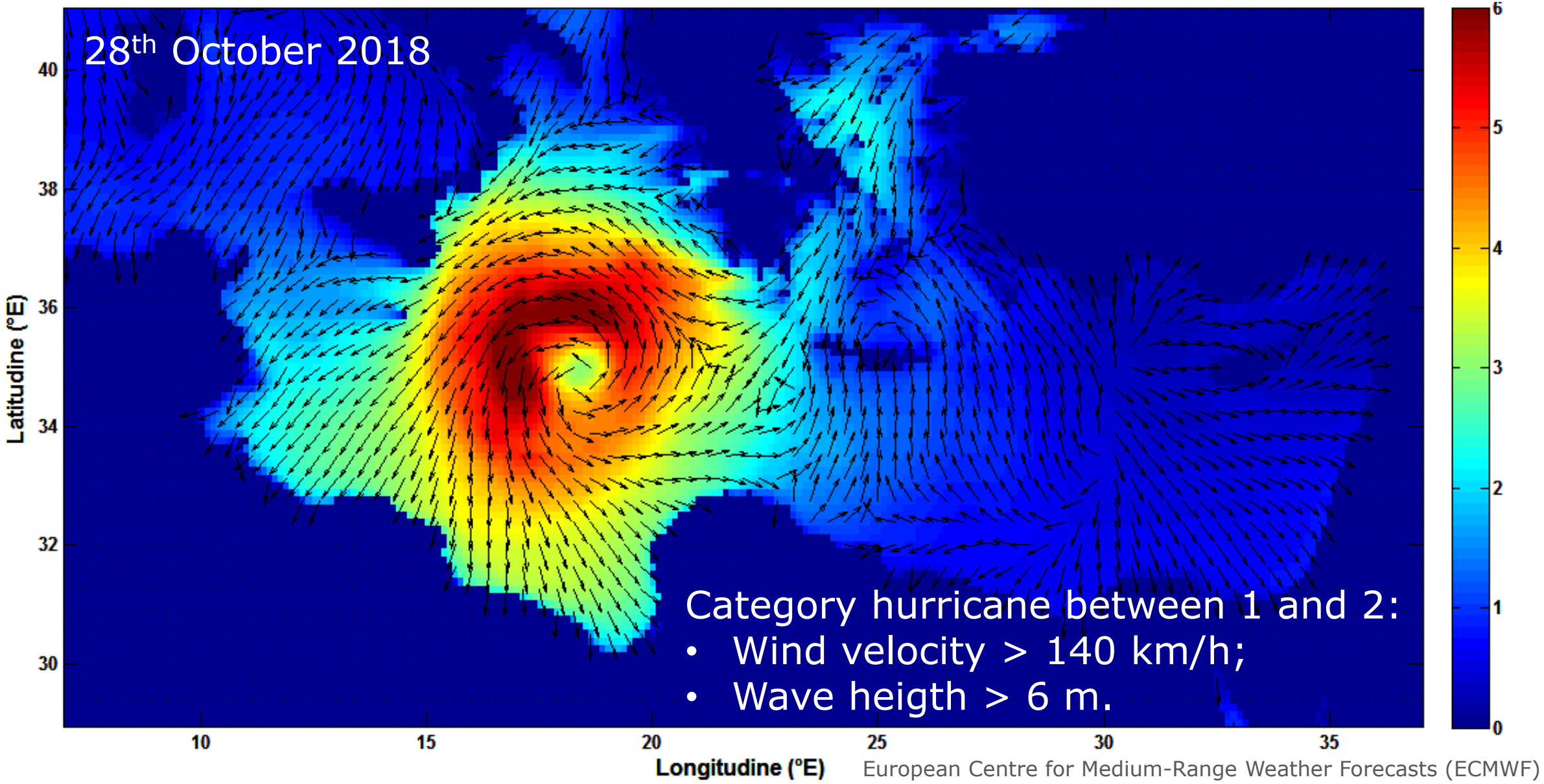
Malta
24th February 2019

Coastal flooding risk

Global mean sea level rise: IPCC projections



Coastal flooding risk

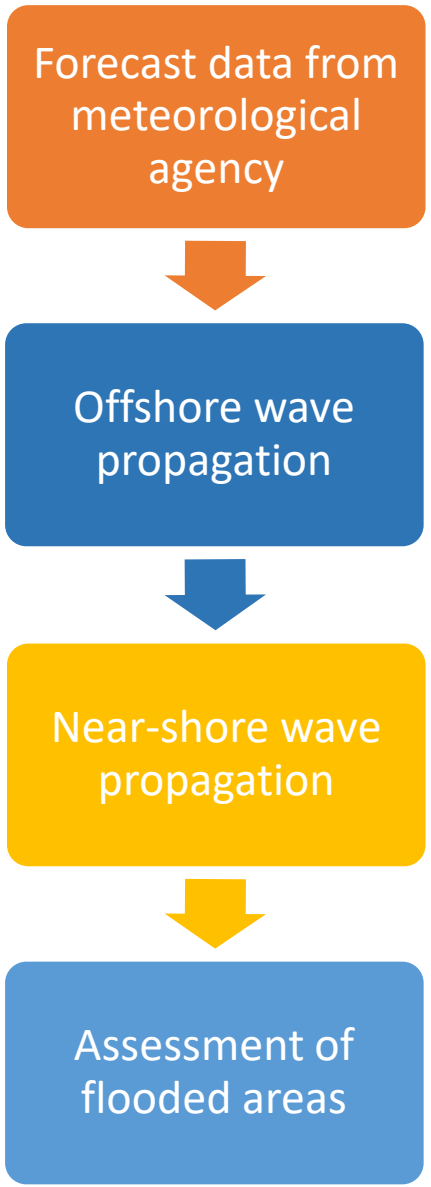


European Centre for Medium-Range Weather Forecasts (ECMWF)

Coastal flooding risk

- Coastal floods extend over an area which is easily controlled.
- The use of effective early warning systems can substantially reduce the risks to the population associated with coastal flooding.

Coastal flooding forecast



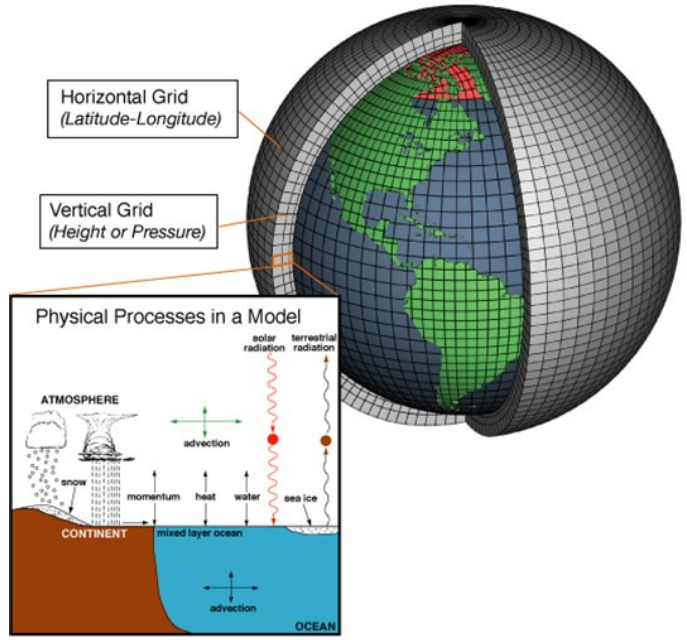
Coastal flooding forecast

Forecast data from meteorological agency

Metereological Agency (i.e. ECMWF and NOAA) provided offshore wave data.

The adopted numerical model (WAM, WAVEWATCHIII) do not allow to evaluate the wave propagation within the nearshore area.

It is therefore necessary to adopt additional detailed models.

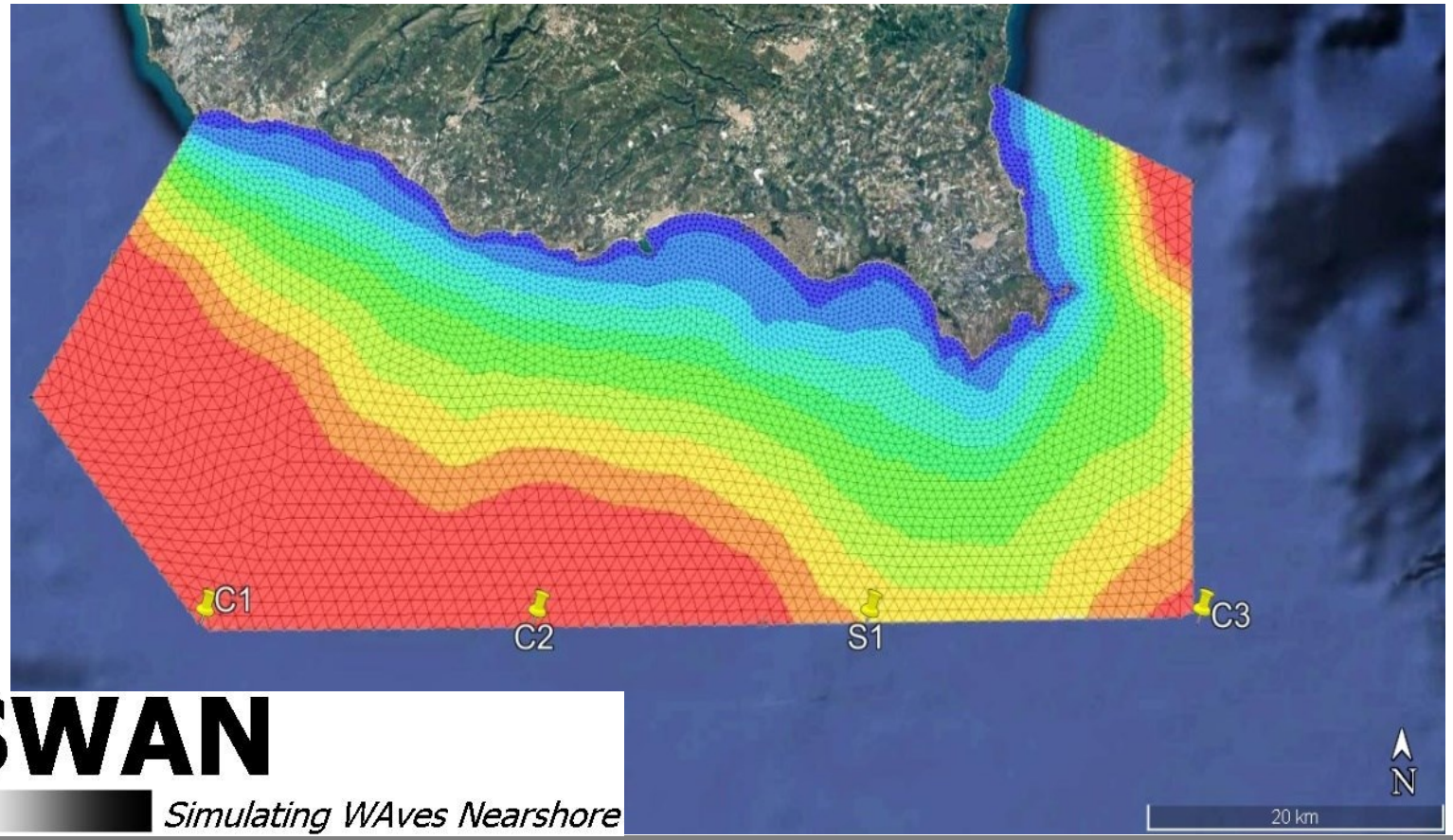


Coastal flooding forecast

Offshore wave propagation

The transformation of the wave motion towards the shore must be carried out with models that allow to simulate phenomena such as:

- ❑ Generation from wind
- ❑ Energy dissipation



SWAN
Simulating WAves Nearshore

Coastal flooding forecast

Near-shore wave propagation

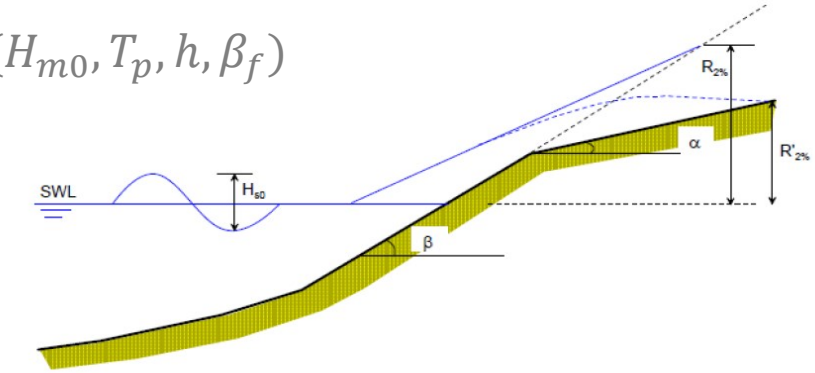
Assessment of flooded areas

The wave run-up on beaches and structures can be carried out by means of:

- Empirical model

$$R_{2\%} = f(H_{m0}, T_p, h, \beta_f)$$

H_{m0}: wave heigth
T_p: peak wave period
h: depth
β_f: beach slope



- Numerical model

CFD model
2DV e 3D

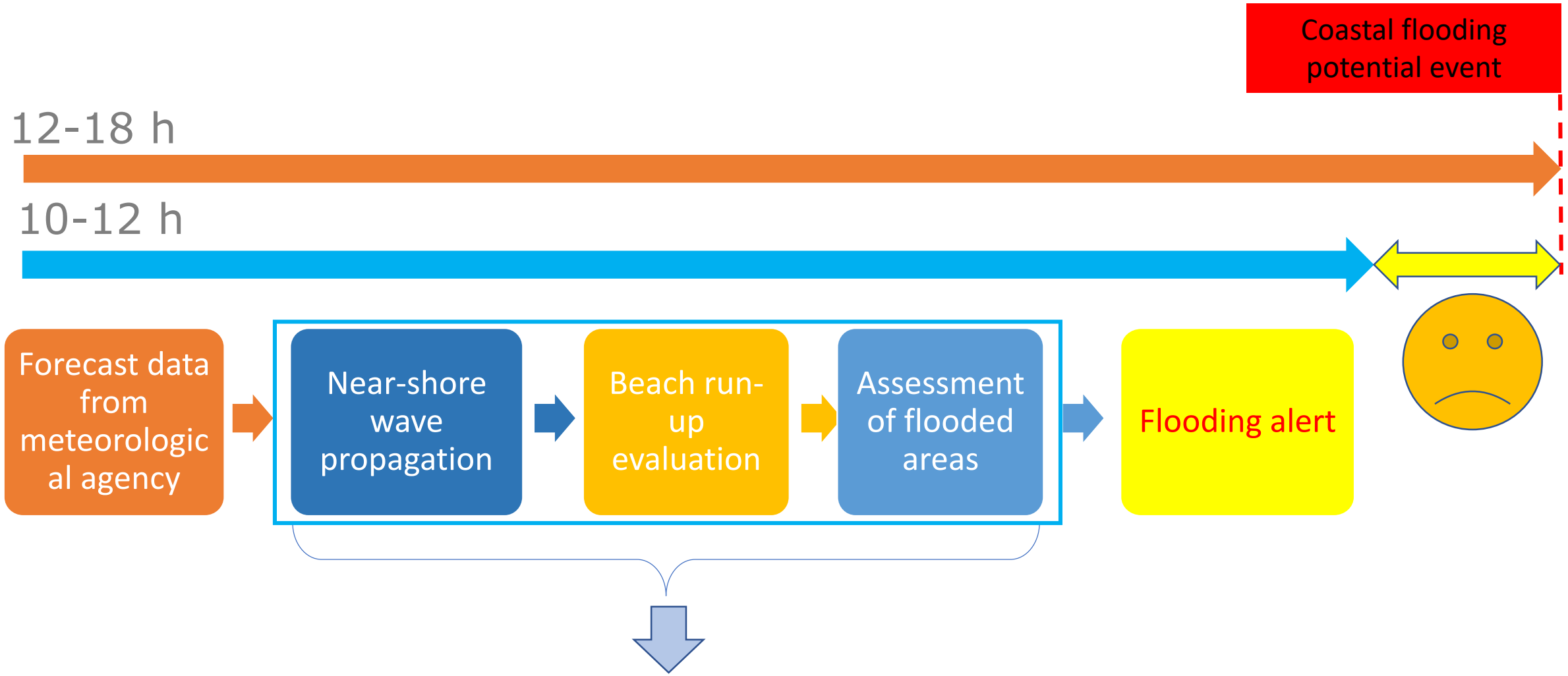
FLOW Science

OpenFOAM

2DHModel

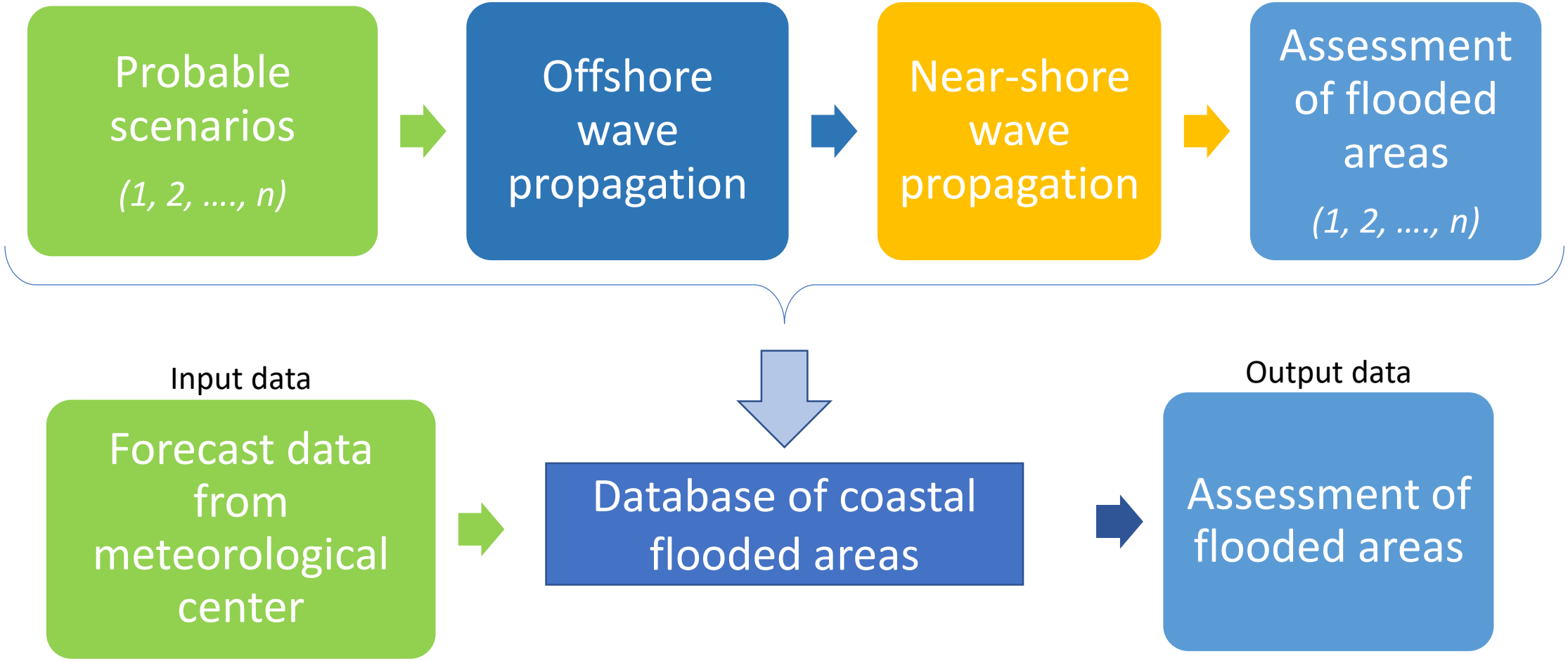
XB

Coastal flooding prediction: Alert time



The evaluation of flooded areas through numerical models requires computational times of the order of 10-12 hours.

Proposed approach for the prediction of coastal flooding



Proposed approach for the prediction of coastal flooding

Coastal flooding potential event

12-24 h

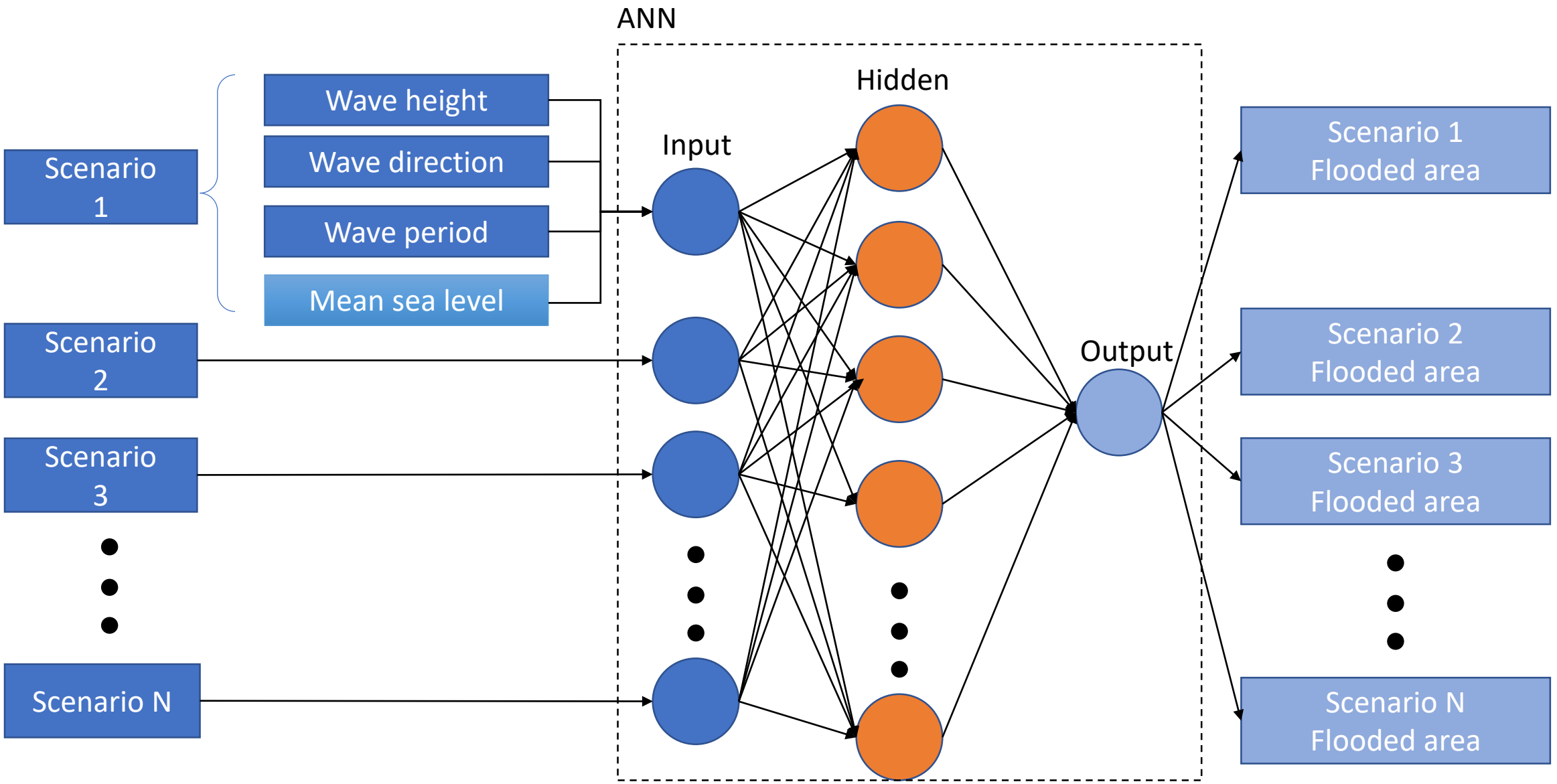
Few seconds

Forecast data from meteorological agency

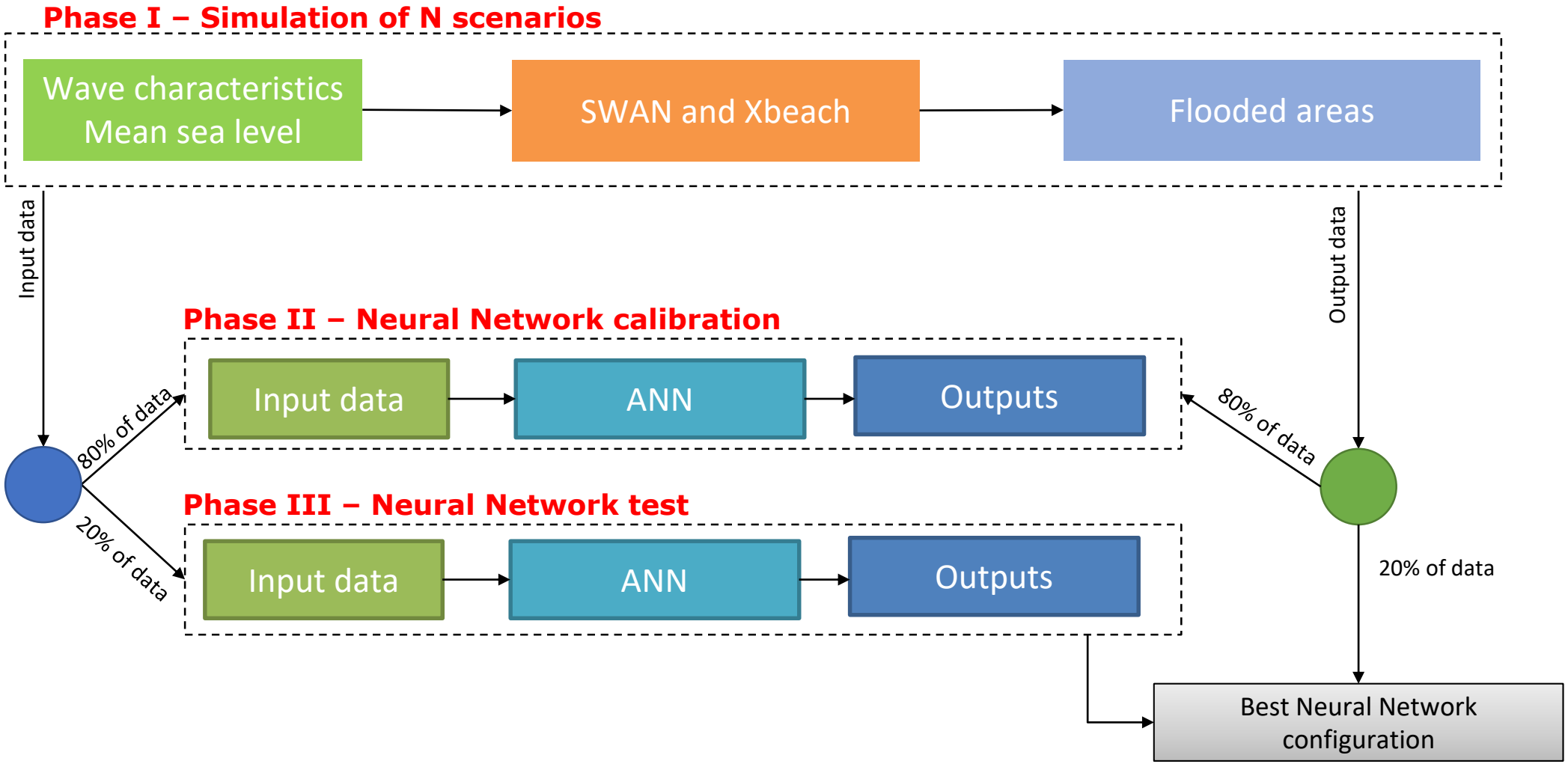
Assessment of flooded areas by querying the database

Flooding alert

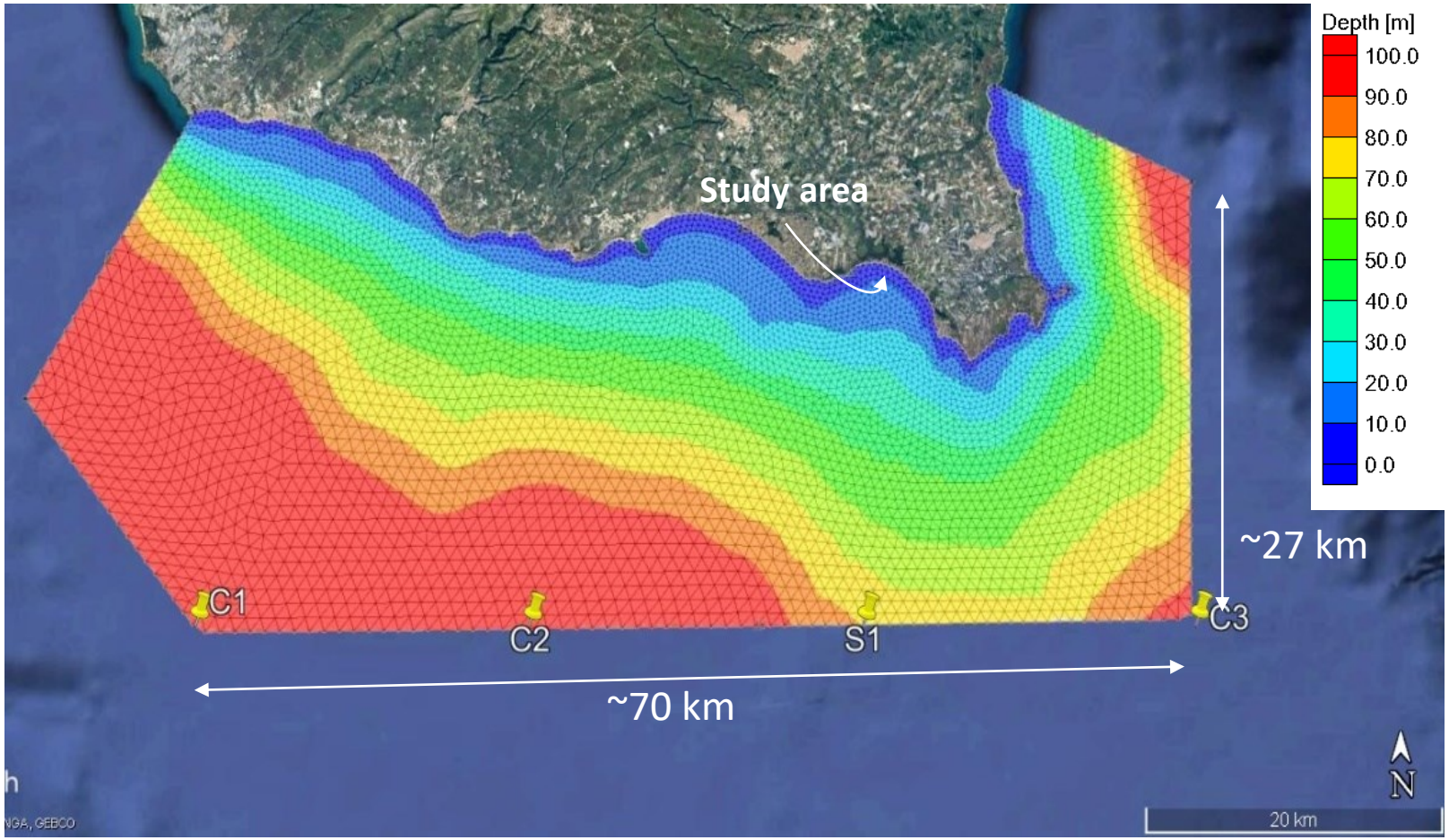
Adopted structure of the Artificial Neural Network (ANN)

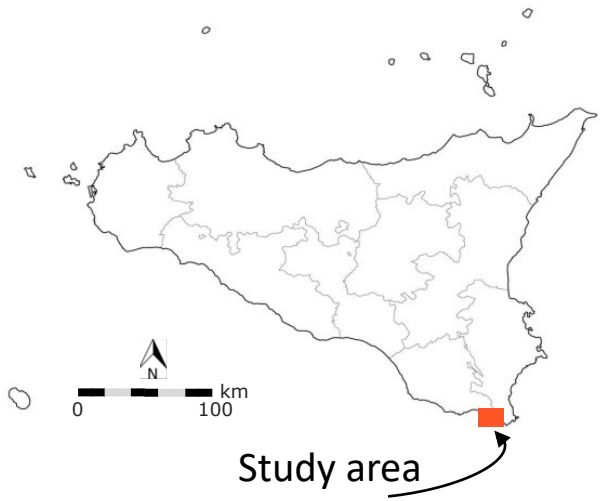


Flooded area database and Artificial Neural Network (ANN)



Case study: offshore wave propagation (SWAN)

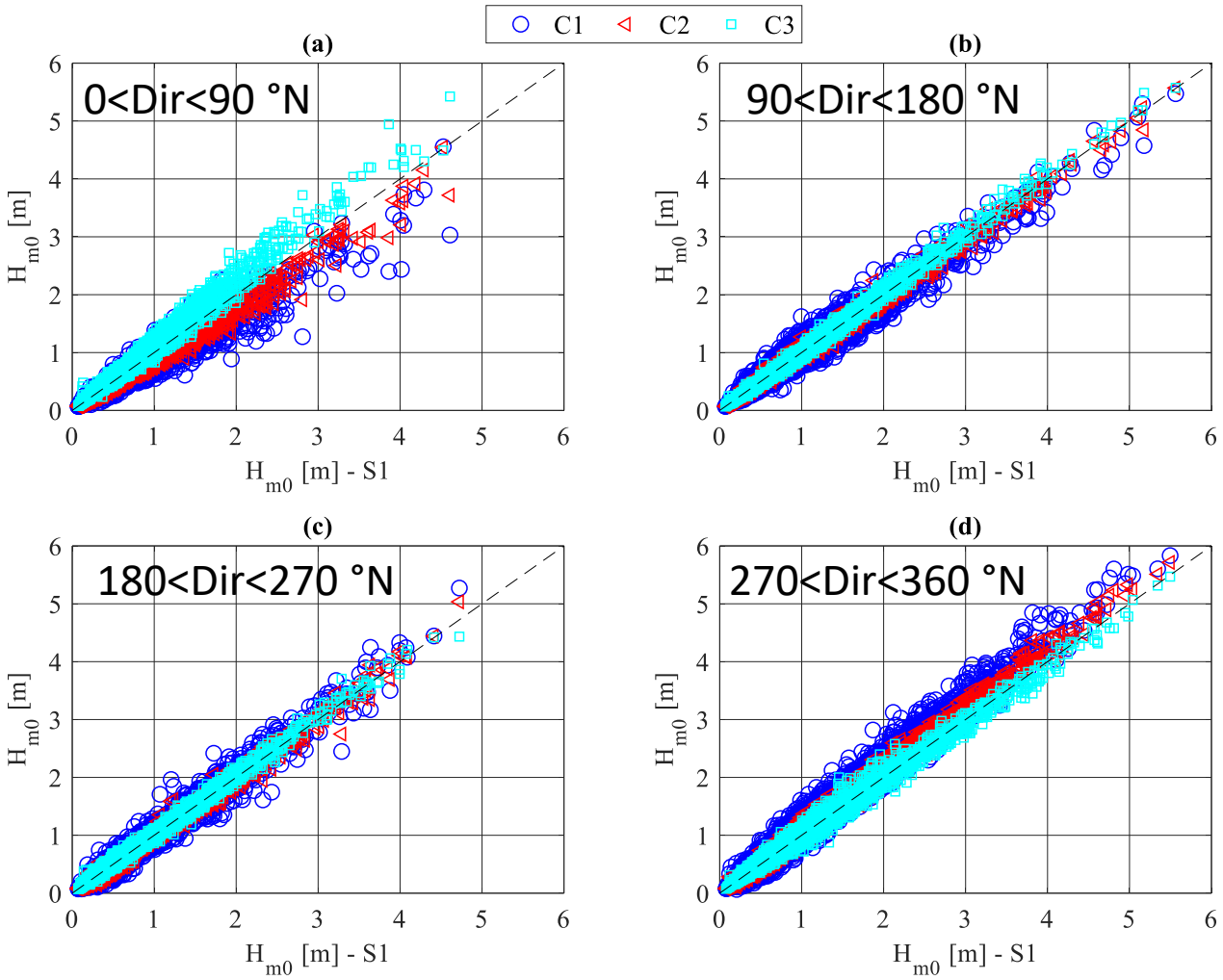


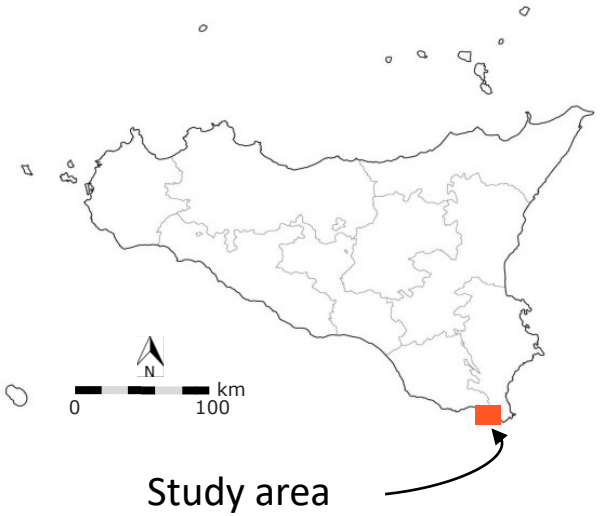


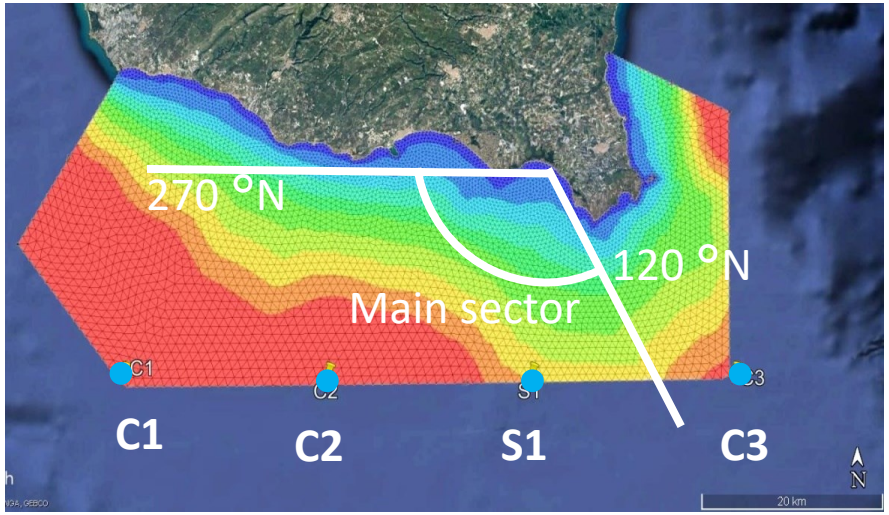
Scenarios		
Parameters	Range	Resolution
Wave height	2-8 m	0.5 m
Wave direction	120-170 °N	10 °N
Wave period	2.5-12 s	2.5 s
Mean sea level	0.0-0.5 m	0.25 m

Unstructured grid containing 12743 triangular elements and 6598 nodes

Case study: offshore wave characteristics



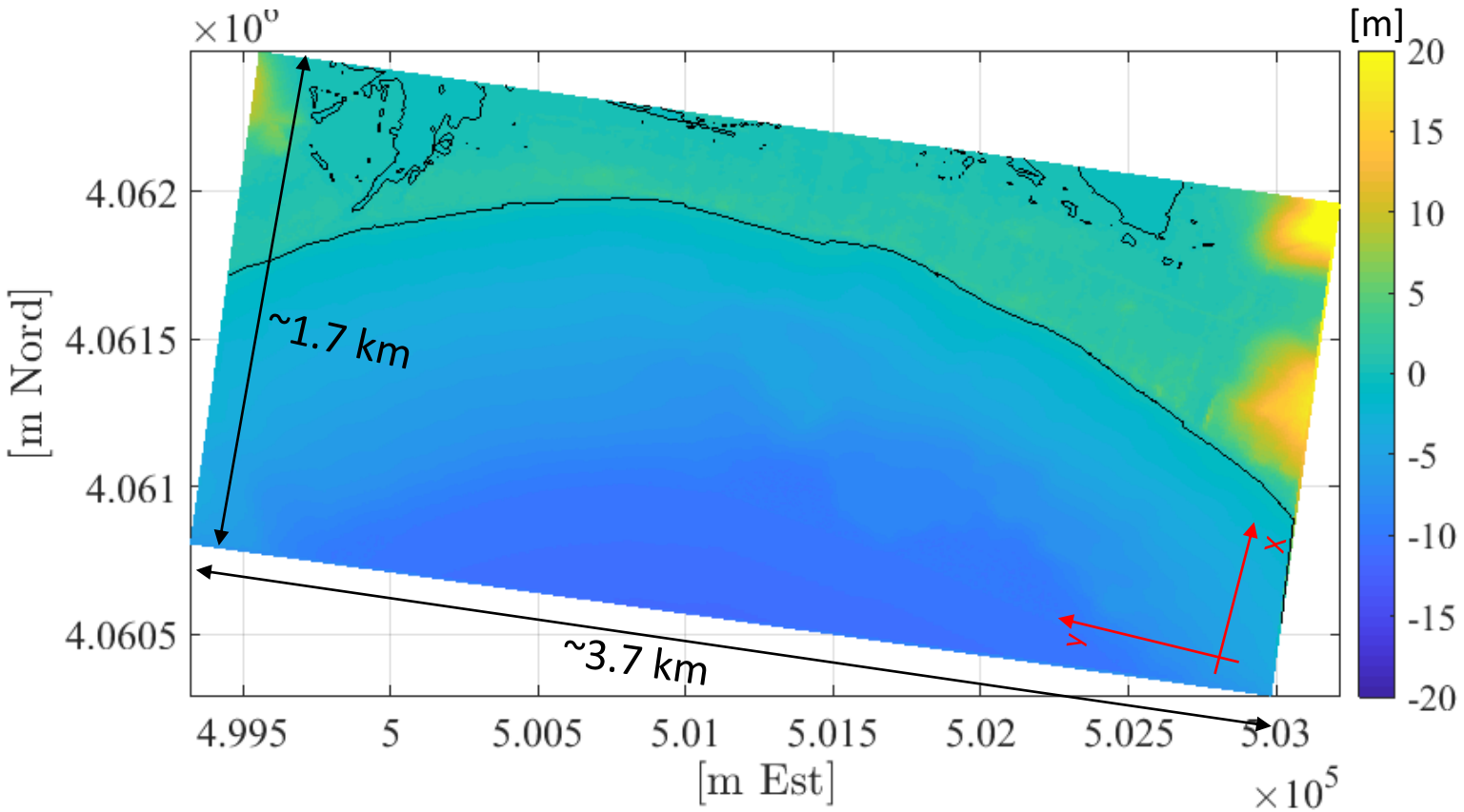


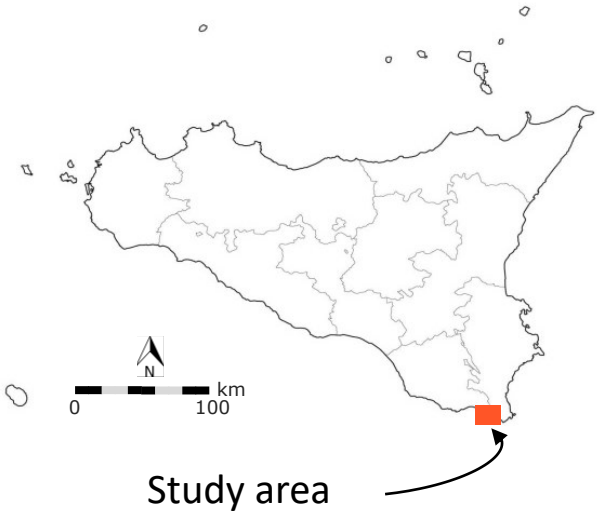


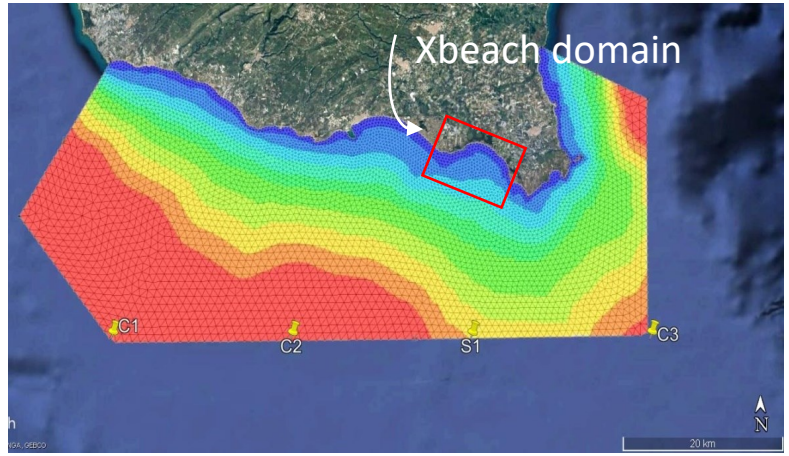
Data from European Center Medium Weather Forecast

ECMWF

Case study: near-shore wave propagation (Xbeach)

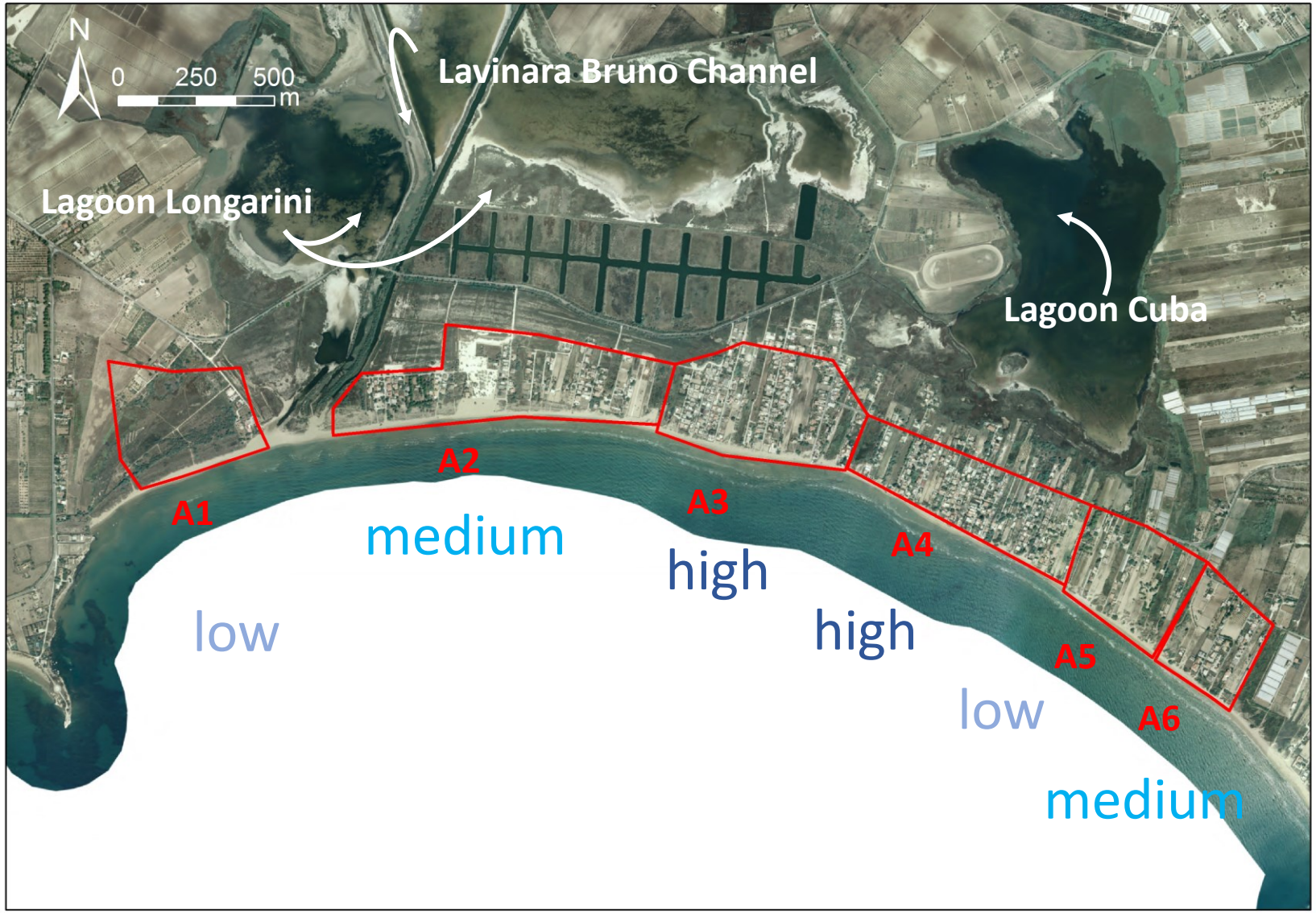


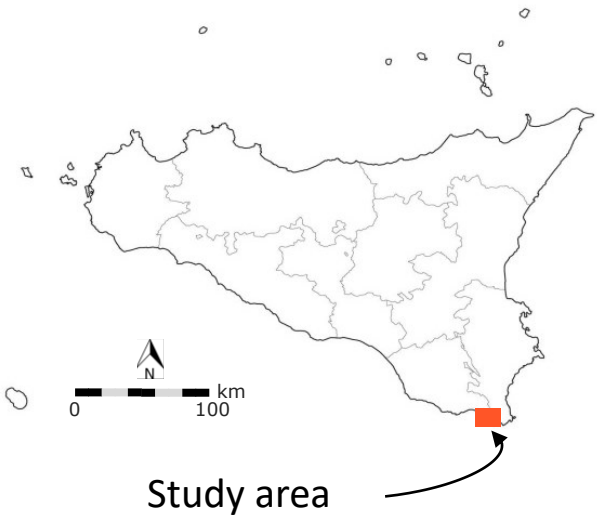




Rectilinear grid containing 207940 cells

Case study: flooded area analysis by the ANN





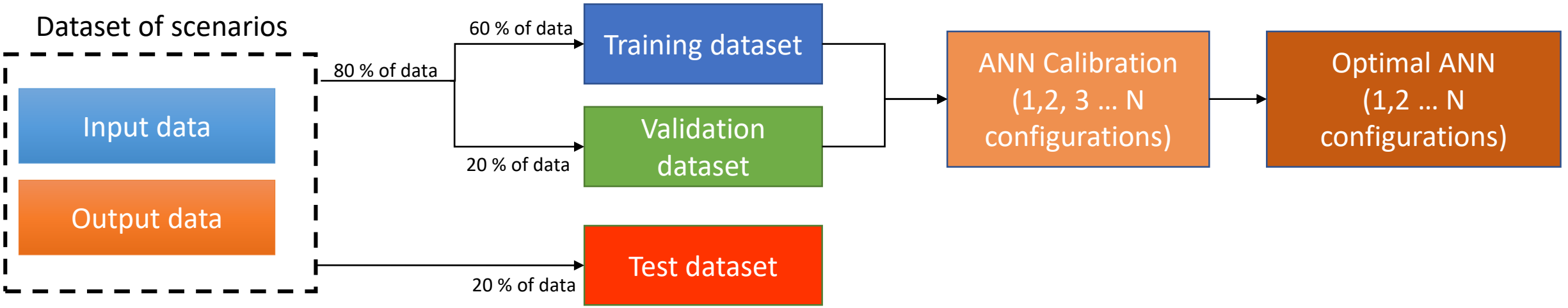
Population density

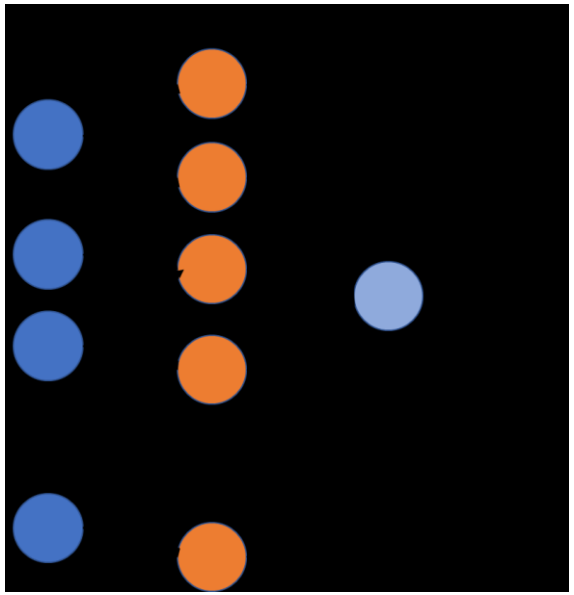
high

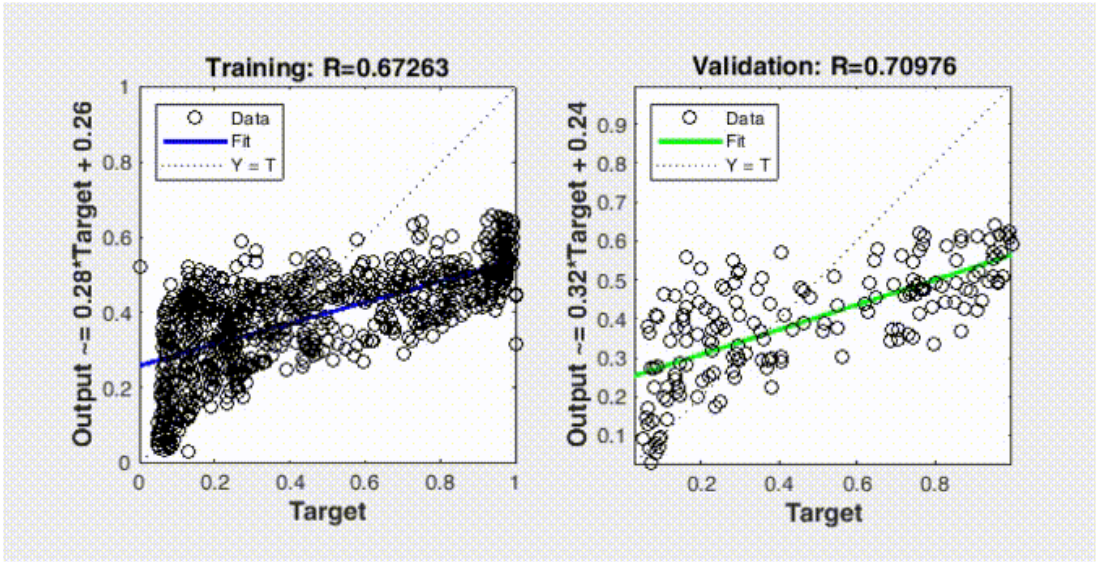
medium

low

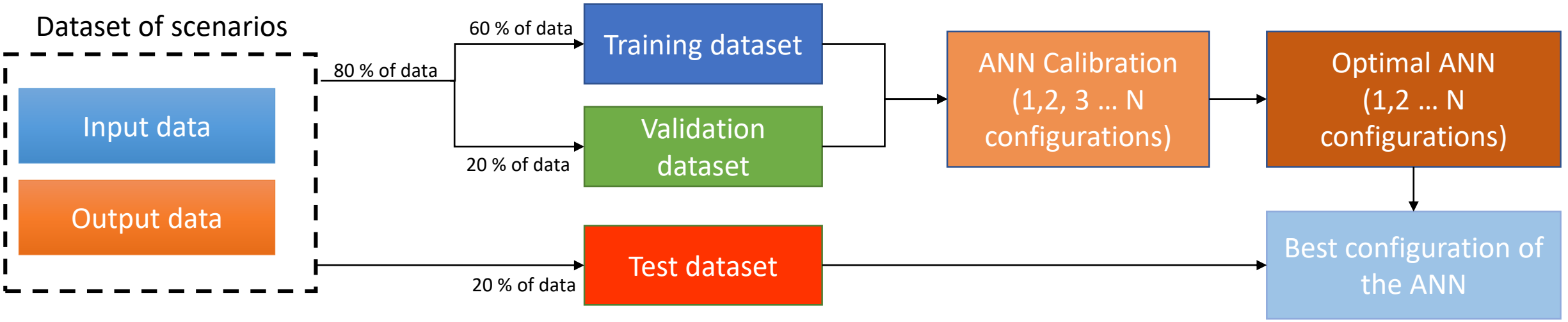
Case study: ANN calibration

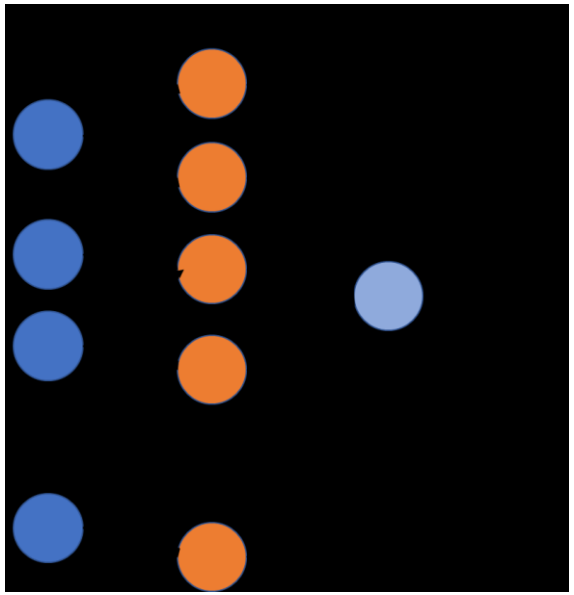


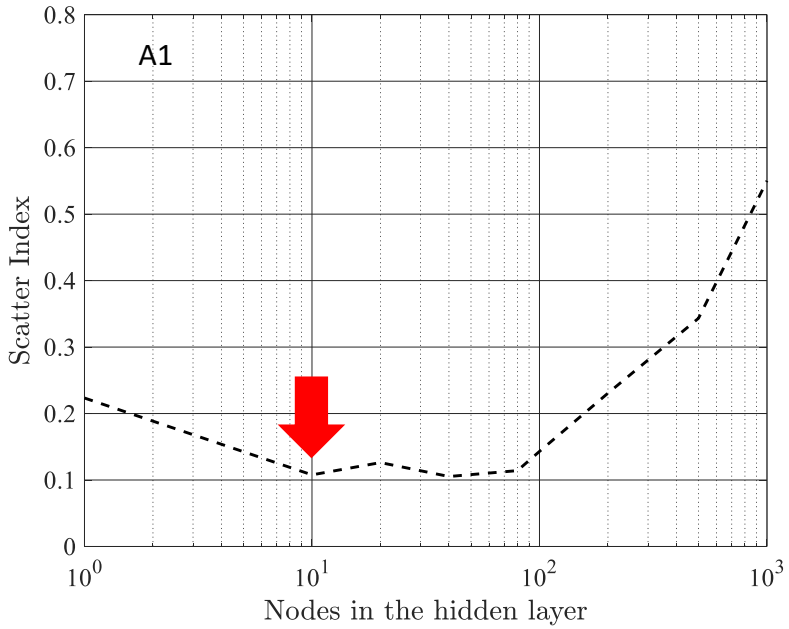




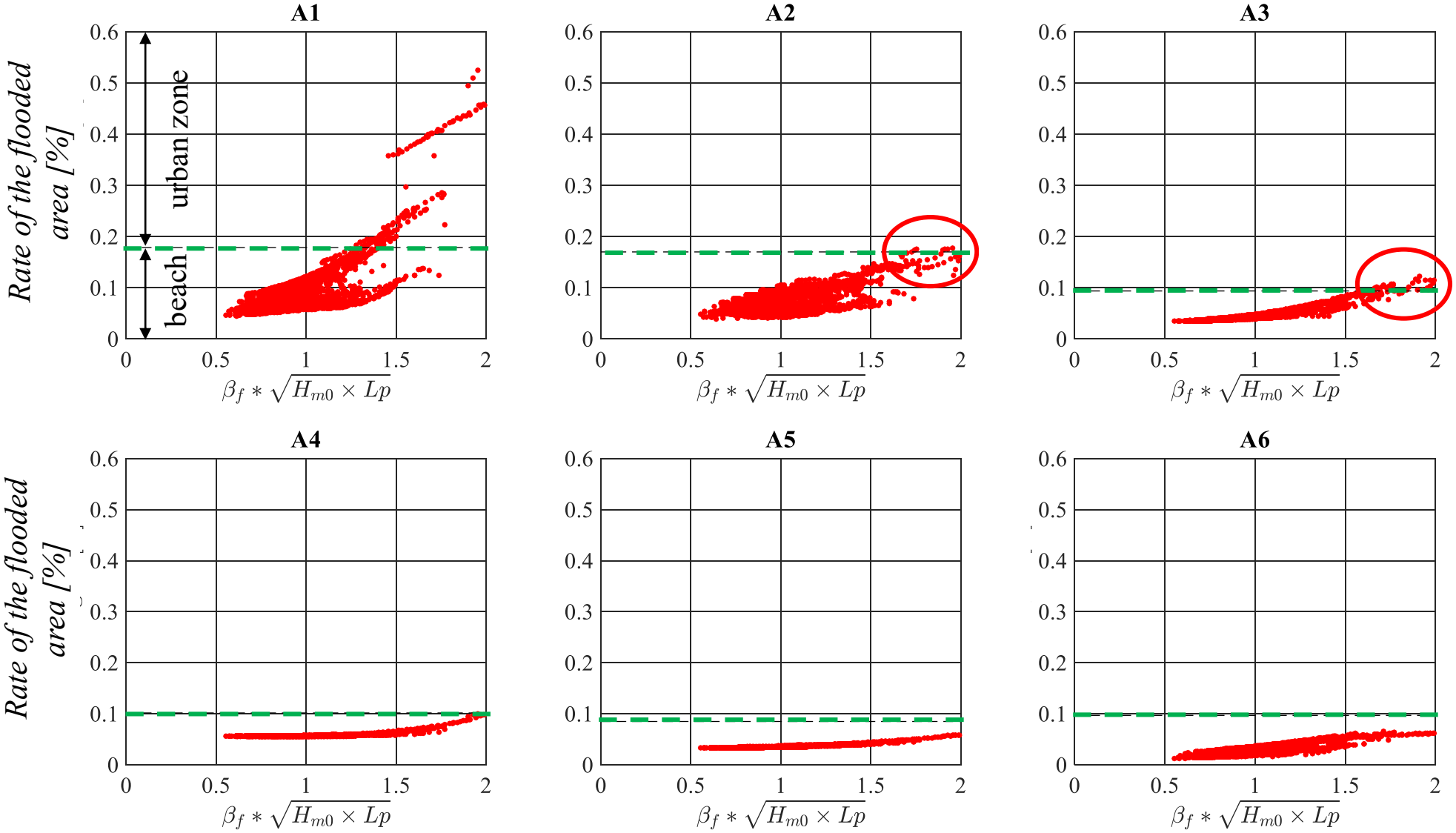
Case study: ANN test







Coastal flooding risk assessment through the ANN



Limit between the beach and urban zone

H_{m0} significant wave height

L_p wavelength

β_f beach slope

Period between 2006 and 2017

Risk assessment | Event of 13 January 2009

Offshore wave characteristics:

Wave height = 5.5÷6 m
Wave direction = 124 °N
Peak period = 10÷12 s

Legend
Water level [m]

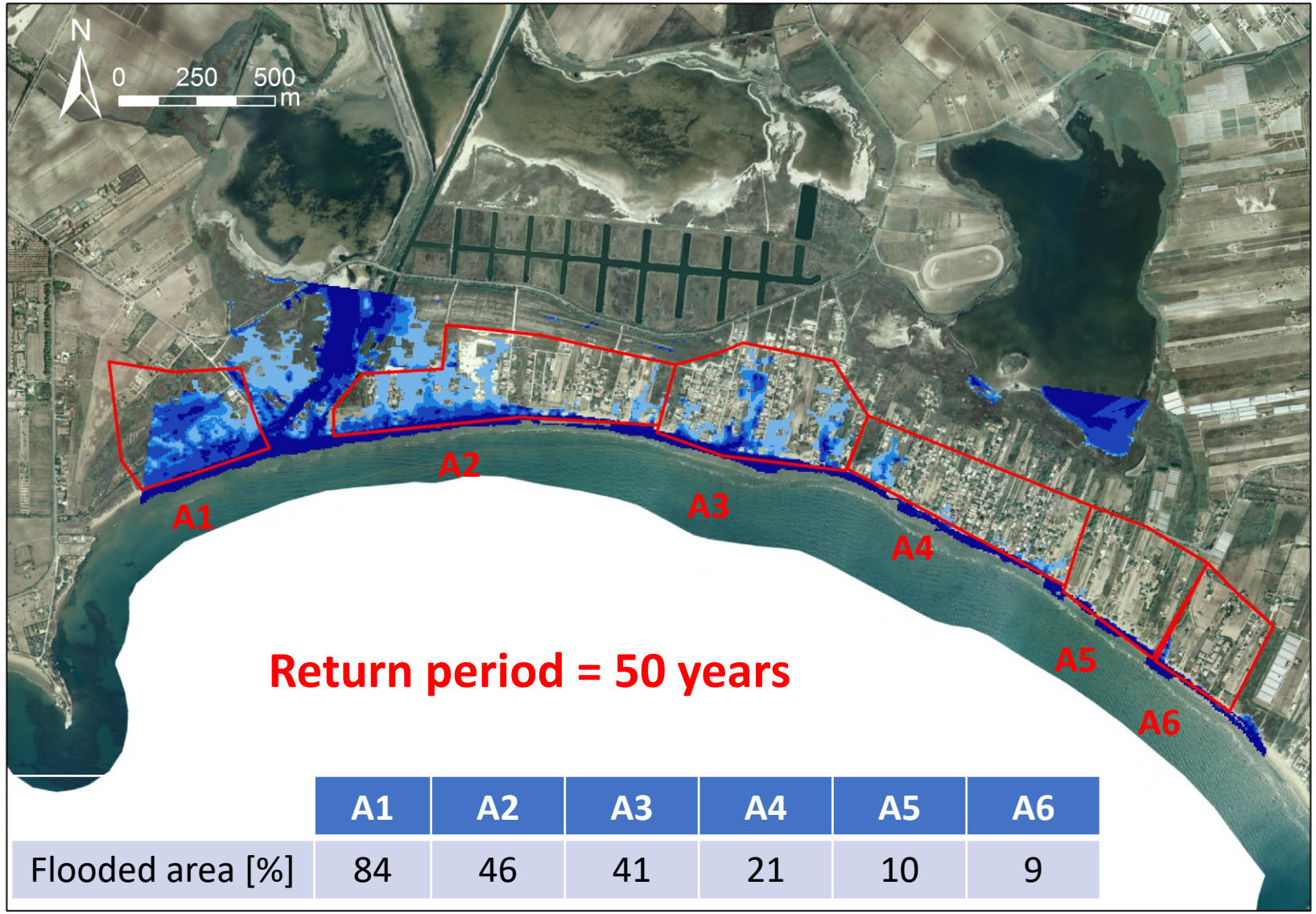
- 0.00 - 0.10
- 0.10 - 0.20
- 0.20 - 0.40
- >0.40

	A1	A2	A3	A4	A5	A6
Flooded area [%]	57	18	10	9	6	7

Risk assessment | Probable event

Offshore wave characteristics:

Wave height = 5 m
Wave direction = 180 °N
Peak period = 10 s



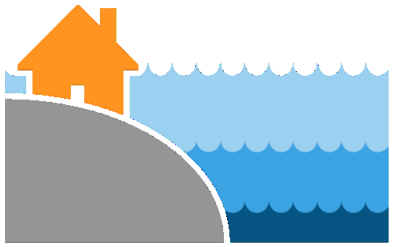
Legend
Water level [m]

- 0.00 - 0.10
- 0.10 - 0.20
- 0.20 - 0.40
- >0.40

	A1	A2	A3	A4	A5	A6
Flooded area [%]	84	46	41	21	10	9

Conclusions

- An early warning system approach is often essential to mitigate the coastal flooding risk



- The typical prediction method of coastal flooding requires too high computational costs, which are incompatible for an early system approach

- The proposed strategy, which couples a database of coastal flooding areas and ANN, allows for an instantaneous estimate of coastal flooding which, in turn, permits a timely decision of the Authorities for the preparedness of population