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A MULTIVARIATE STATISTICAL MODEL TO SIMULATE STORM EVOLUTION

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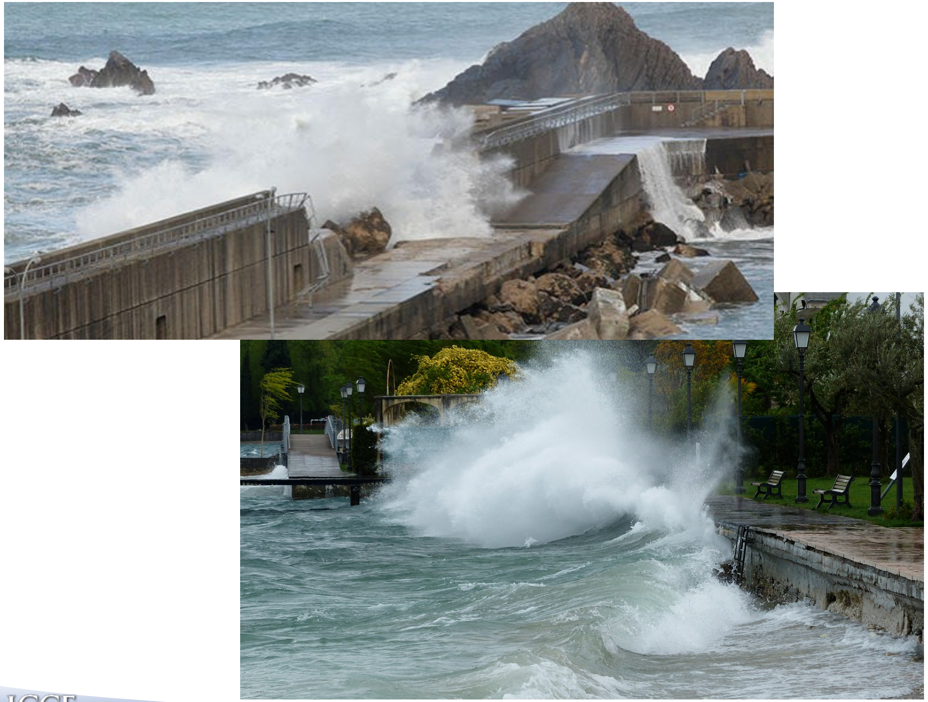
Motivation

Probabilistic design and risk assessment:

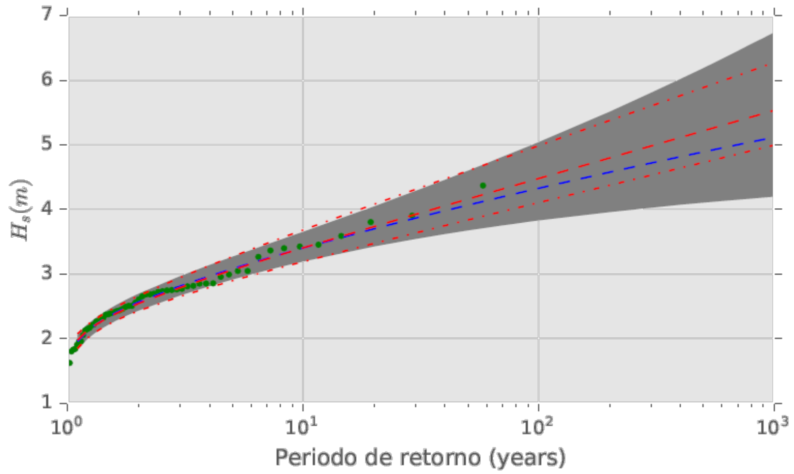
Coastal structures → progressive failure

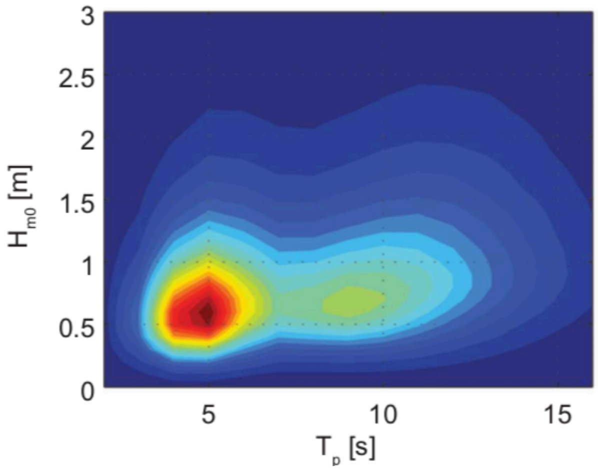
Flooding and beach erosion → resilience



State of Art – Extreme analysis

- Statistical characterization → Return period
- Need to consider different variables and their dependence → joint distributions and temporal dependence
- Consideration of the storm's evolution



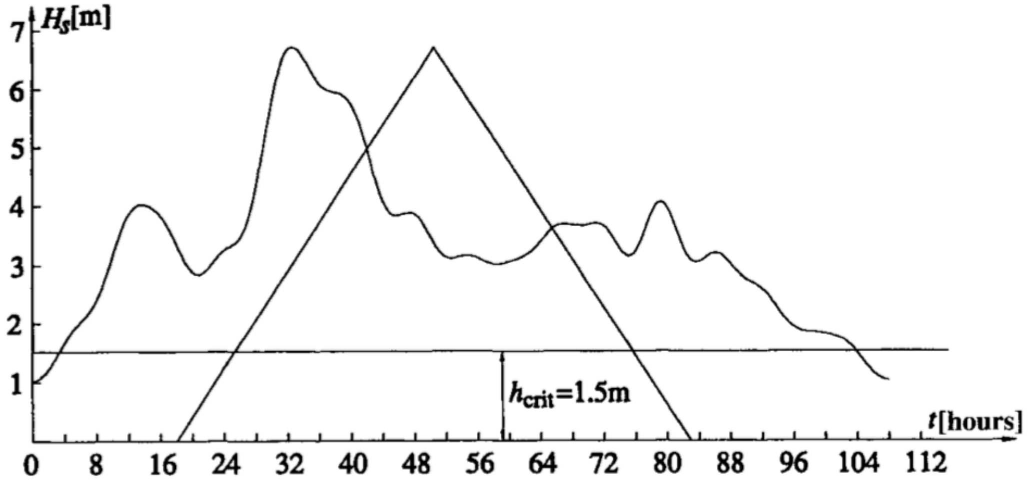


Solari & van Gelder (2011)

State of Art – Storm Evolution

Borgman (1969) – Need to take into account the different maritime variables and their *evolution*

- Equivalent Triangular Storm ETS (Boccotti; 2000)



State of Art – Storm Evolution

Borgman (1969) – Need to take into account the different maritime variables and their *evolution*

- Equivalent Triangular Storm ETS (Boccotti; 2000)
- Equivalent Power Storm EPS (Fedele & Arena; 2010)
- Equivalent Magnitude Storm EMS & Equivalent Number of Waves Storm EWS (Martin-Hidalgo *et al.*; 2014)
- Other geometric shapes (ROM 1.0-09 Recommendations for the Project Design and Construction of Breakwaters; 2009)

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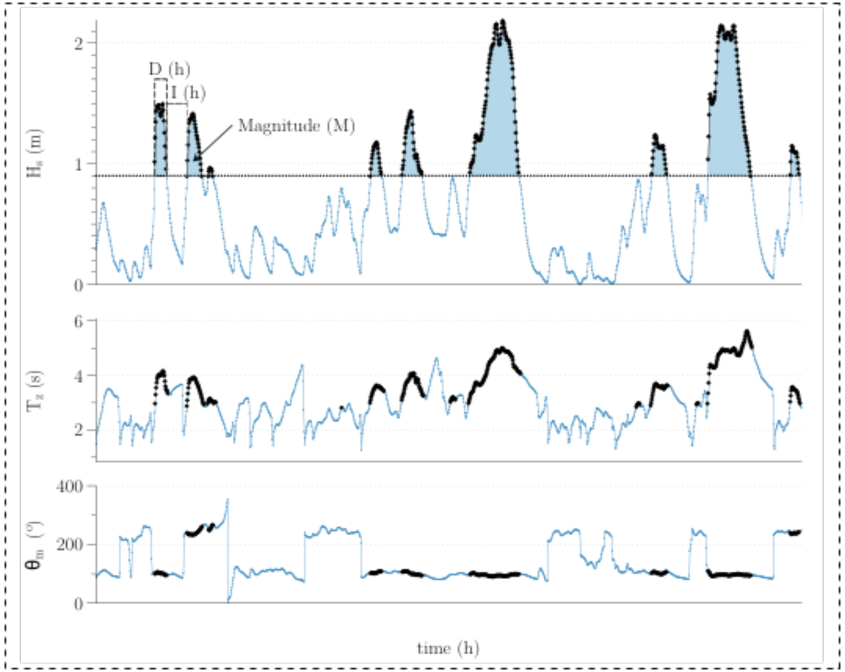
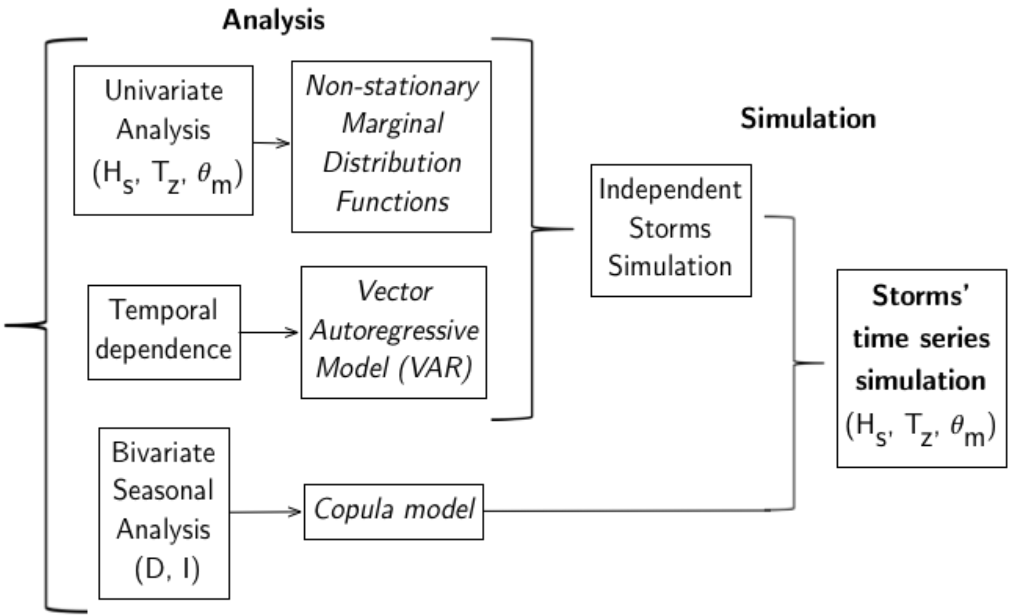
Need to develop methodologies for storms' simulation and their evolution (HUMOR 2001-2003; Solari & Losada, 2018)

Methodology to simulate long time series of extreme events including several maritime variables and their evolution reproducing real and irregular storms

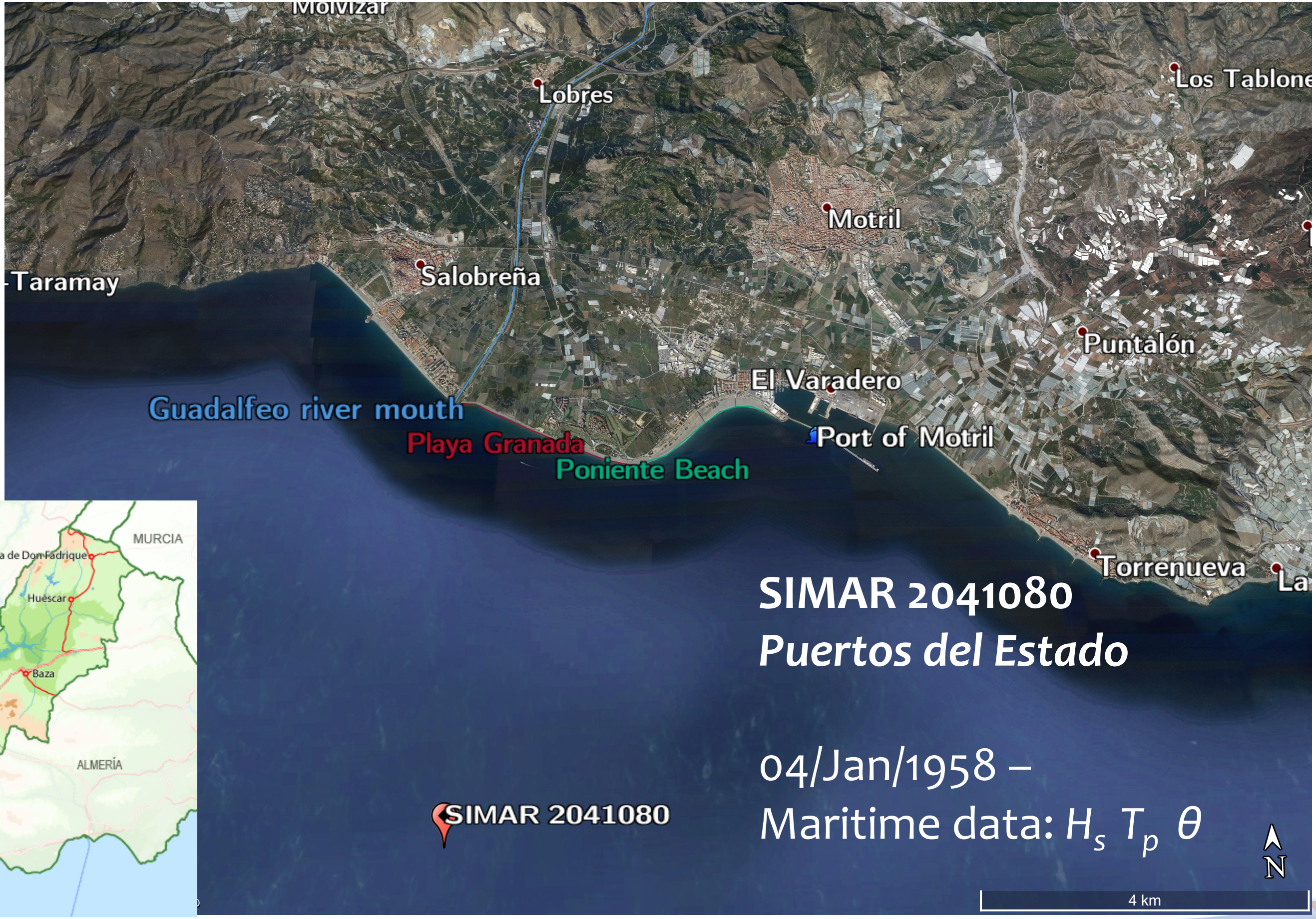
Methodology

Storm identification: $(H_s, T_z, \theta_m, D, I)$



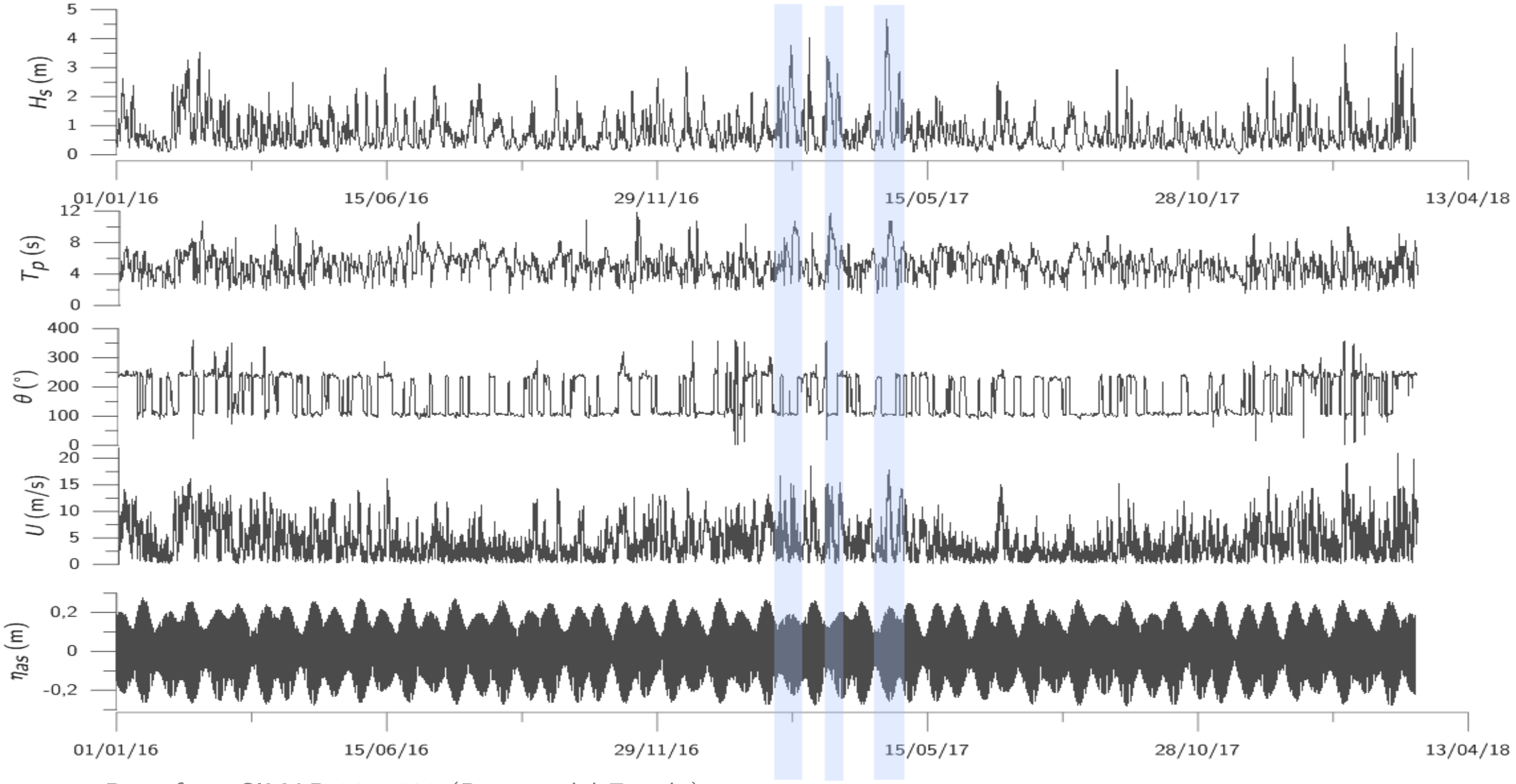


Case study



SIMAR 2041080
Puertos del Estado

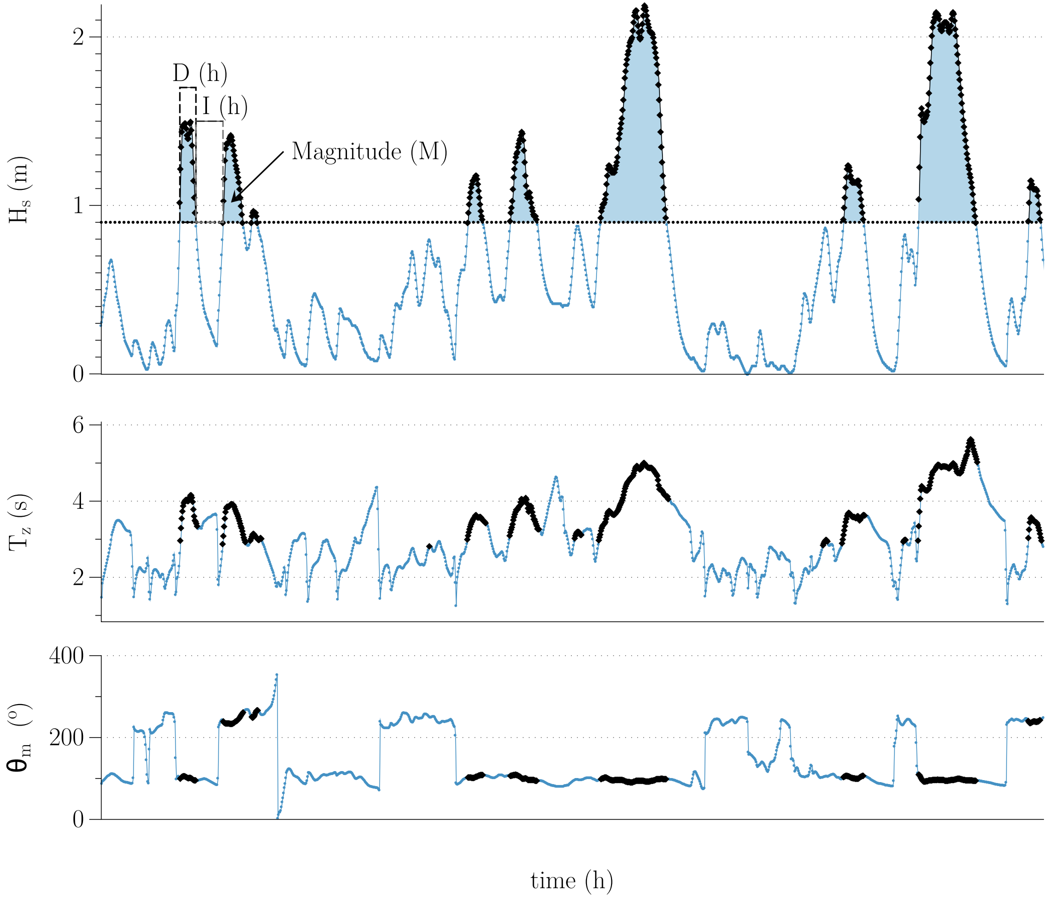
04/Jan/1958 –
Maritime data: H_s T_p θ



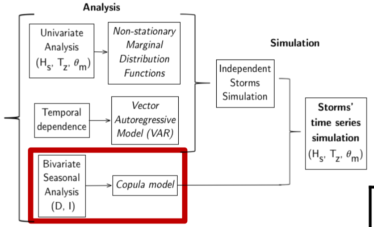
Data from SIMAR 2041080 (Puertos del Estado)


Motril
Salobreña
El Varadero
Guadalfeo river mouth
Playa Granada
Poniente Beach
Port of Motril

a) Storm definition



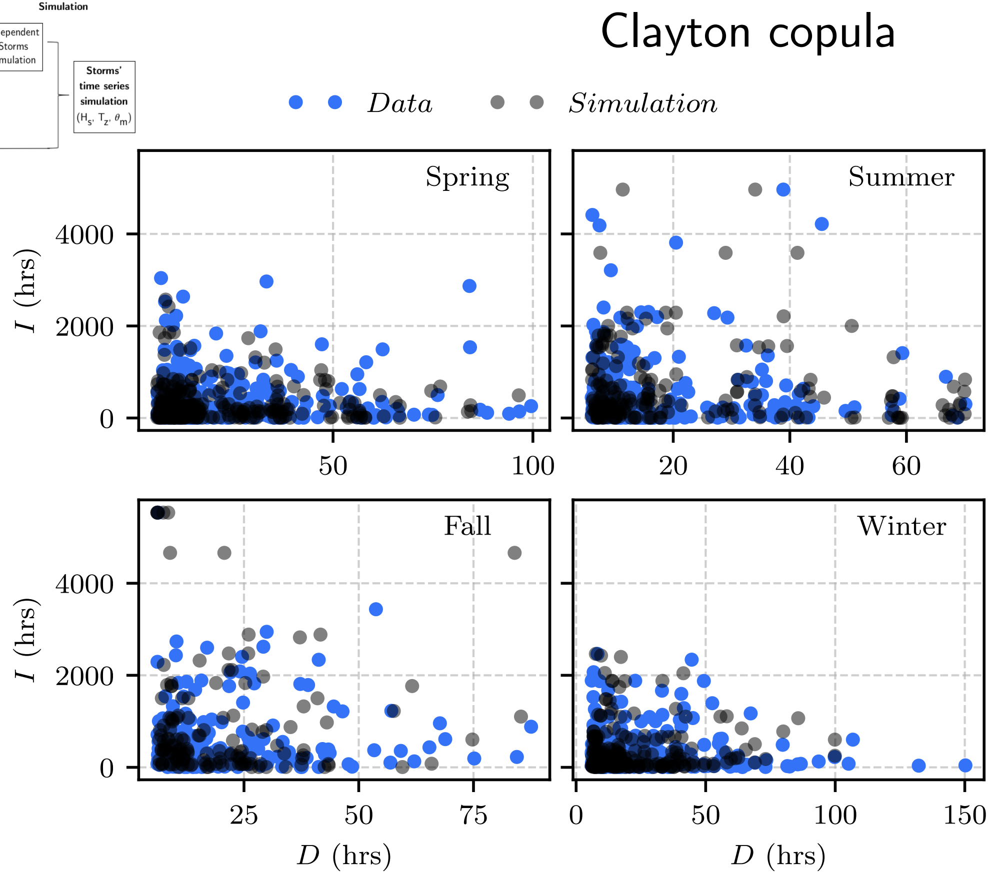
- Significant wave height $H_s > H_{s,u}$
- Peak period T_p
- Mean wave direction θ
- Duration D
- Interarrival times I

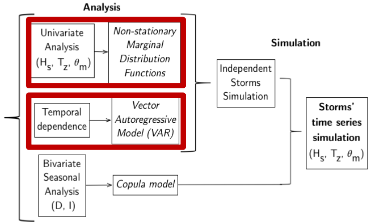


a) Storm definition

b) Distribution functions

i. Copula model: *D*, *I*





a) Storm definition

b) Distribution functions

   i. Copula model: *D, I*

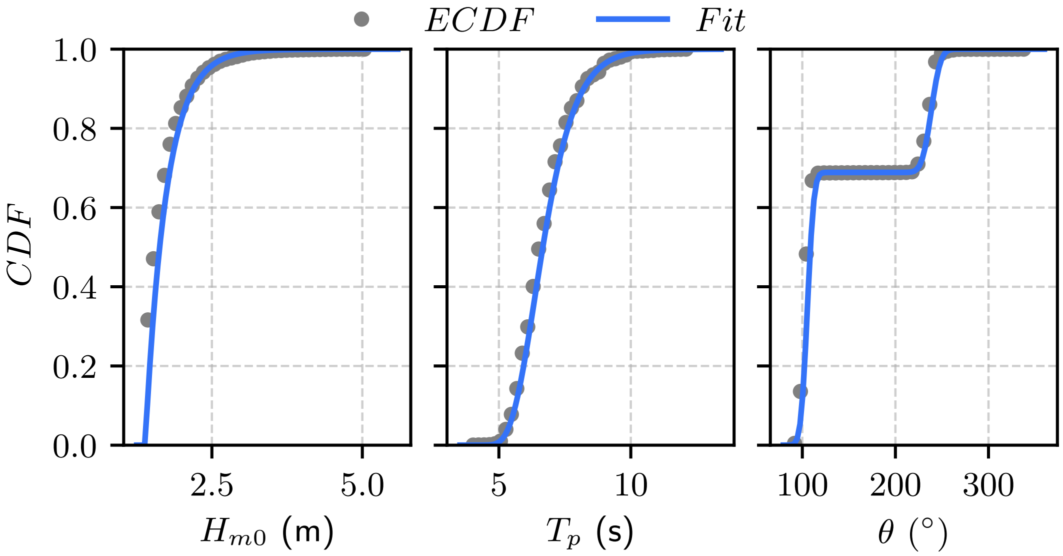
   ii. Marginal distributions: H_s, T_p, θ

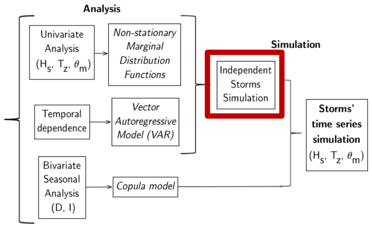
c) Temporal dependence: VAR model

H_s - Exponential distribution

T_p - Lognormal distribution

θ - Truncated Normal distributions





- Non-stationary marginal distributions
- VAR model

→ Simulation of continuous events

a) Storm definition

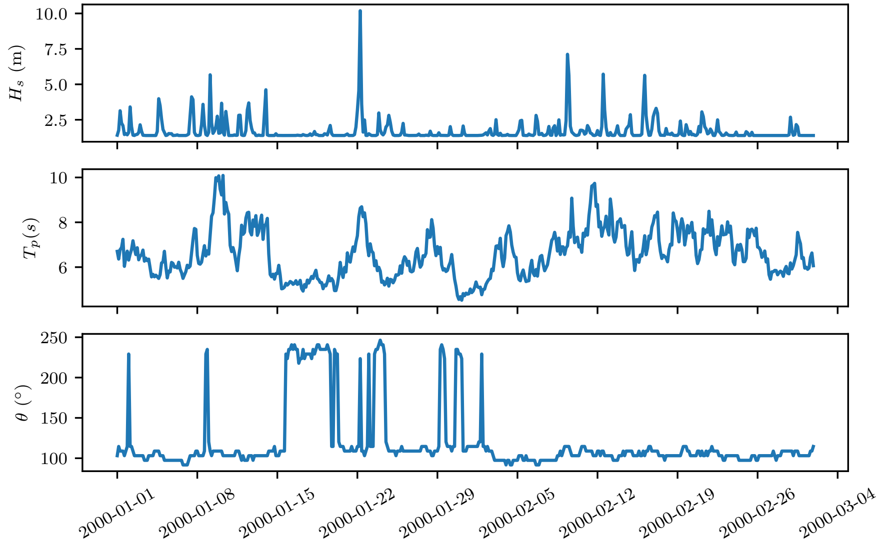
b) Distribution functions

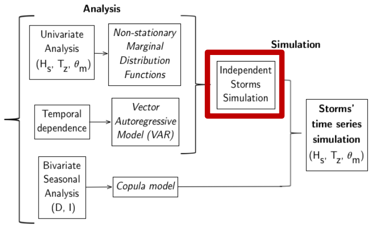
   i. Copula model: *D*, *I*

   ii. Marginal distributions: H_s, T_p, θ

c) Temporal dependence: VAR model

d) Independent storms simulation





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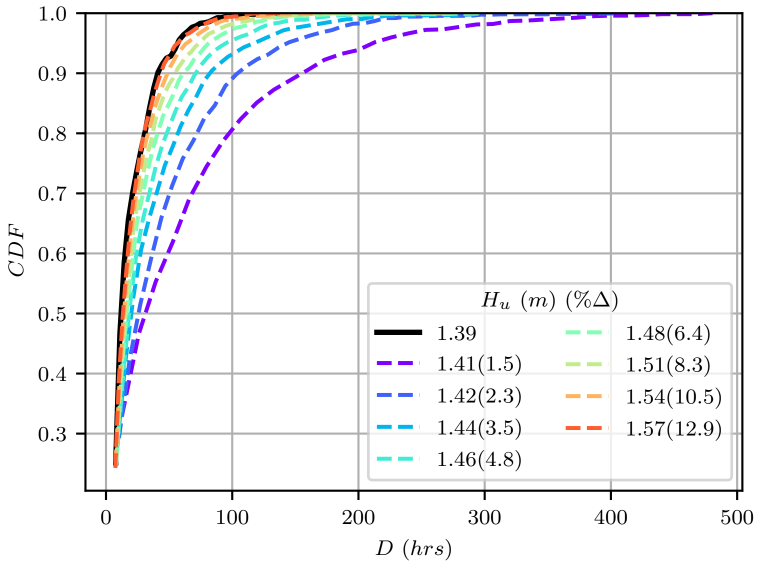
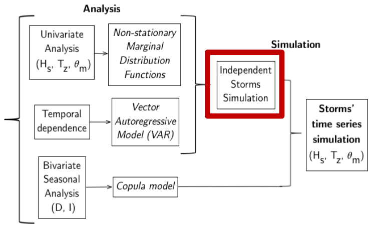
→ Simulation of continuous events

→ Threshold definition $H_{s,u}$'





a) Storm definition

b) Distribution functions

   i. Copula model: *D*, *I*

   ii. Marginal distributions: $H_{s,}$ $T_{p,}$ θ

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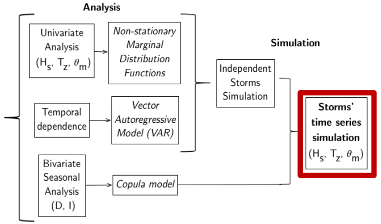
- Non-stationary marginal distributions
- VAR model

→ Simulation of continuous events

→ Threshold definition $H_{s,u}$'

Simulation of independent storms



a) Storm definition

b) Distribution functions

i. Copula model: *D, I*

ii. Marginal distributions: H_s, T_p, θ

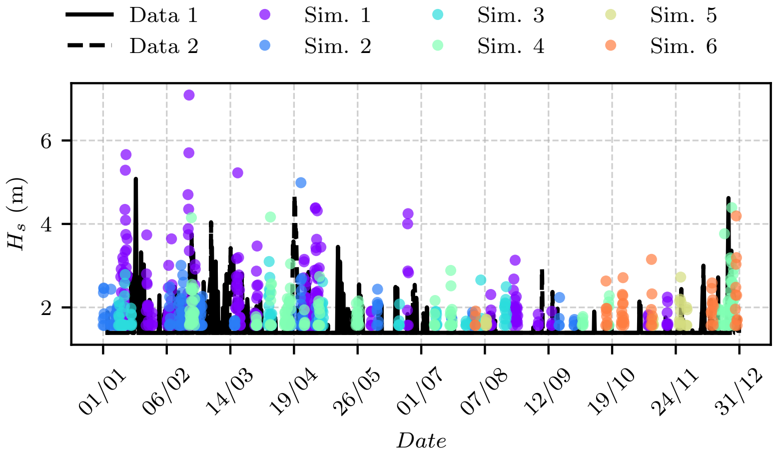
c) Temporal dependence: VAR model

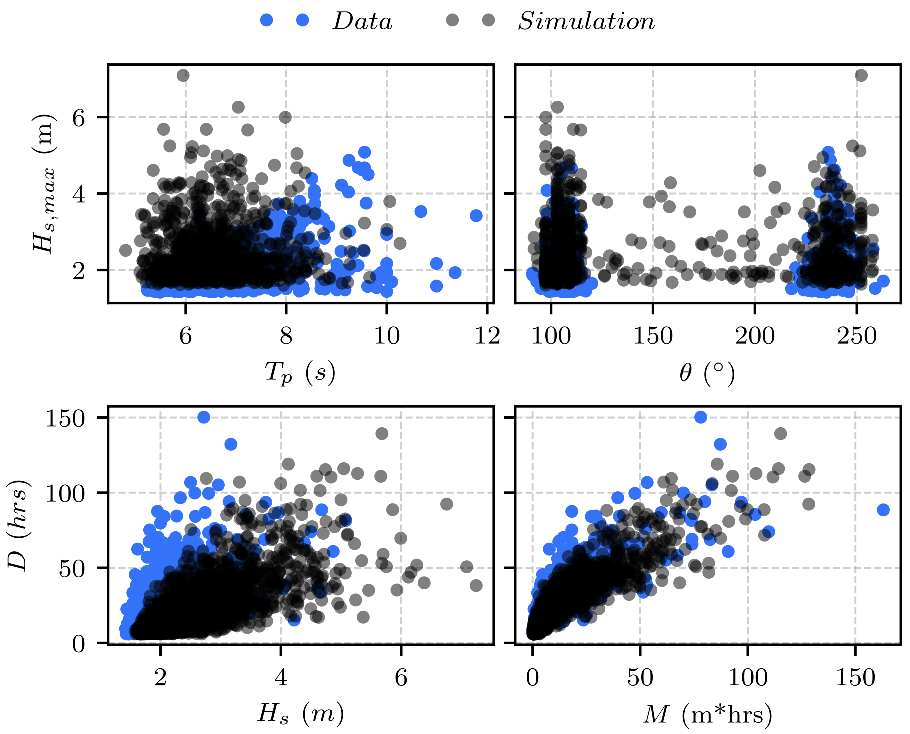
d) Independent storms simulation

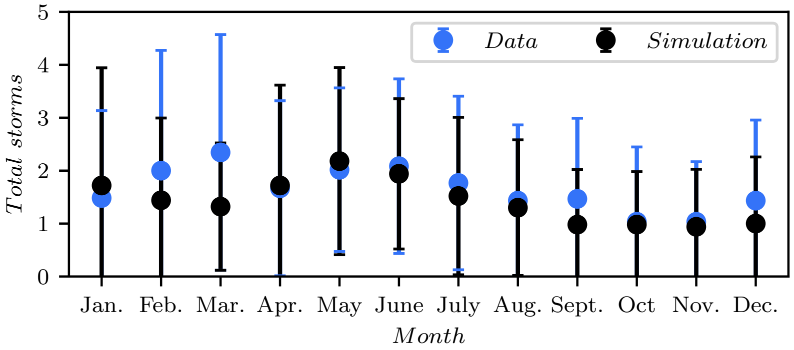
e) Storm's time series simulation

- Simulation of independent events
- Copula model *D-I*

→ Storms' time series simulation




Data
Simulation
$H_{s,max}$ (m)
T_p (s)
θ (°)
D (hrs)
H_s (m)
M (m*hrs)


Data
Simulation
Total storms
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct
Nov.
Dec.
Month

- ✓ Goodness of fit of the non-stationary distribution functions → improved with the use of mixed distribution functions
- ✓ Includes the temporal dependence and inter-dependence of different maritime variables
- ✓ Improved reproduction of the storm evolution
- ✓ Efficient methodology to perform long time series simulations of extreme events → Uncertainty analysis
- ✓ Enables a probabilistic approach for structure design and damage evolution → Folgueras *et al, 2018.*
- ✓ Future work: use of climate change projections data and introduce SLR

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Thank you for your attention

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