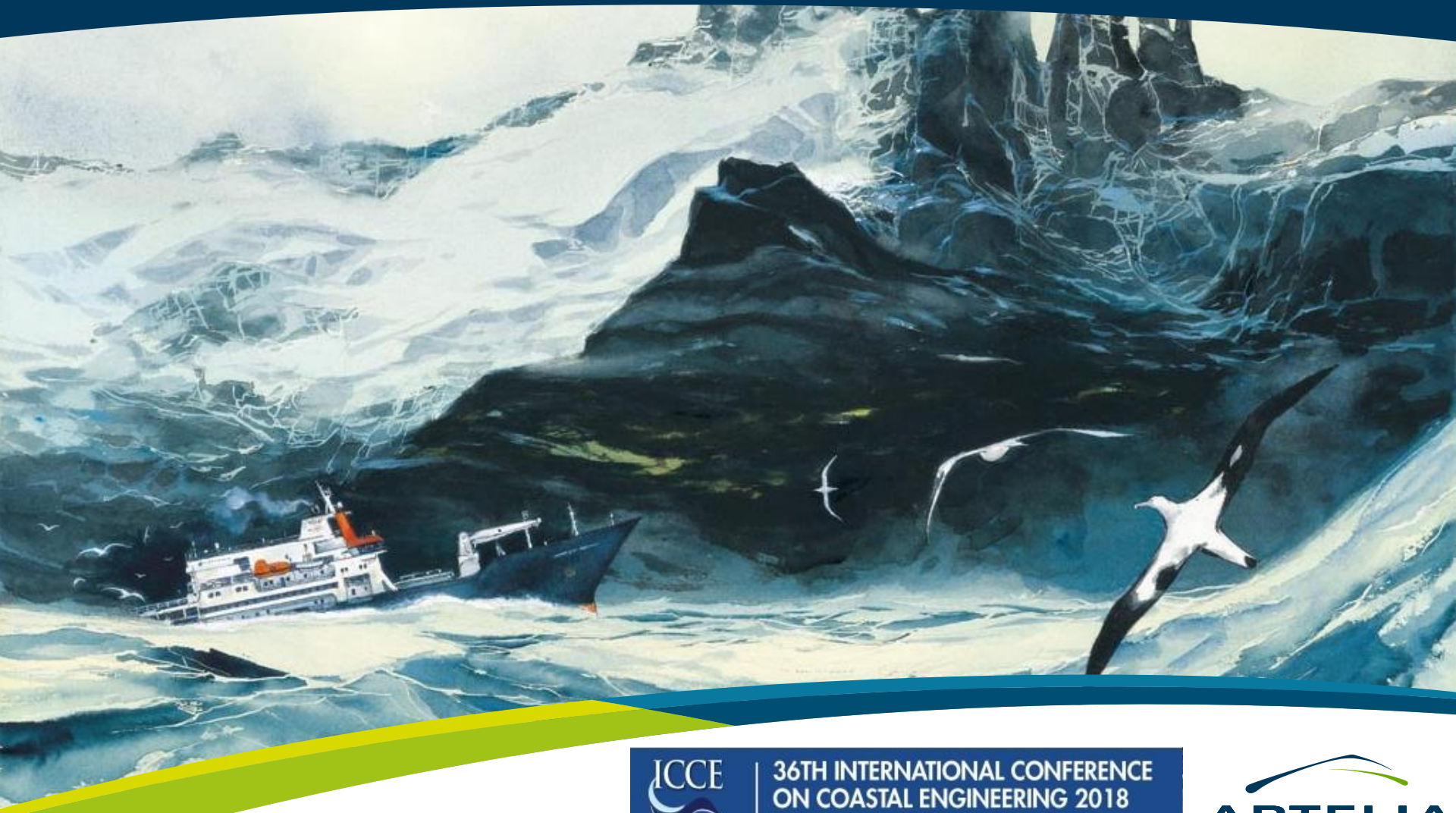
Extreme meteo-oceanographic events

Franck MAZAS, Luc HAMM - ARTELIA



ICCE 2018
36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018
Baltimore, Maryland | July 30 – August 3, 2018

ARTELIA
Passion & Solutions

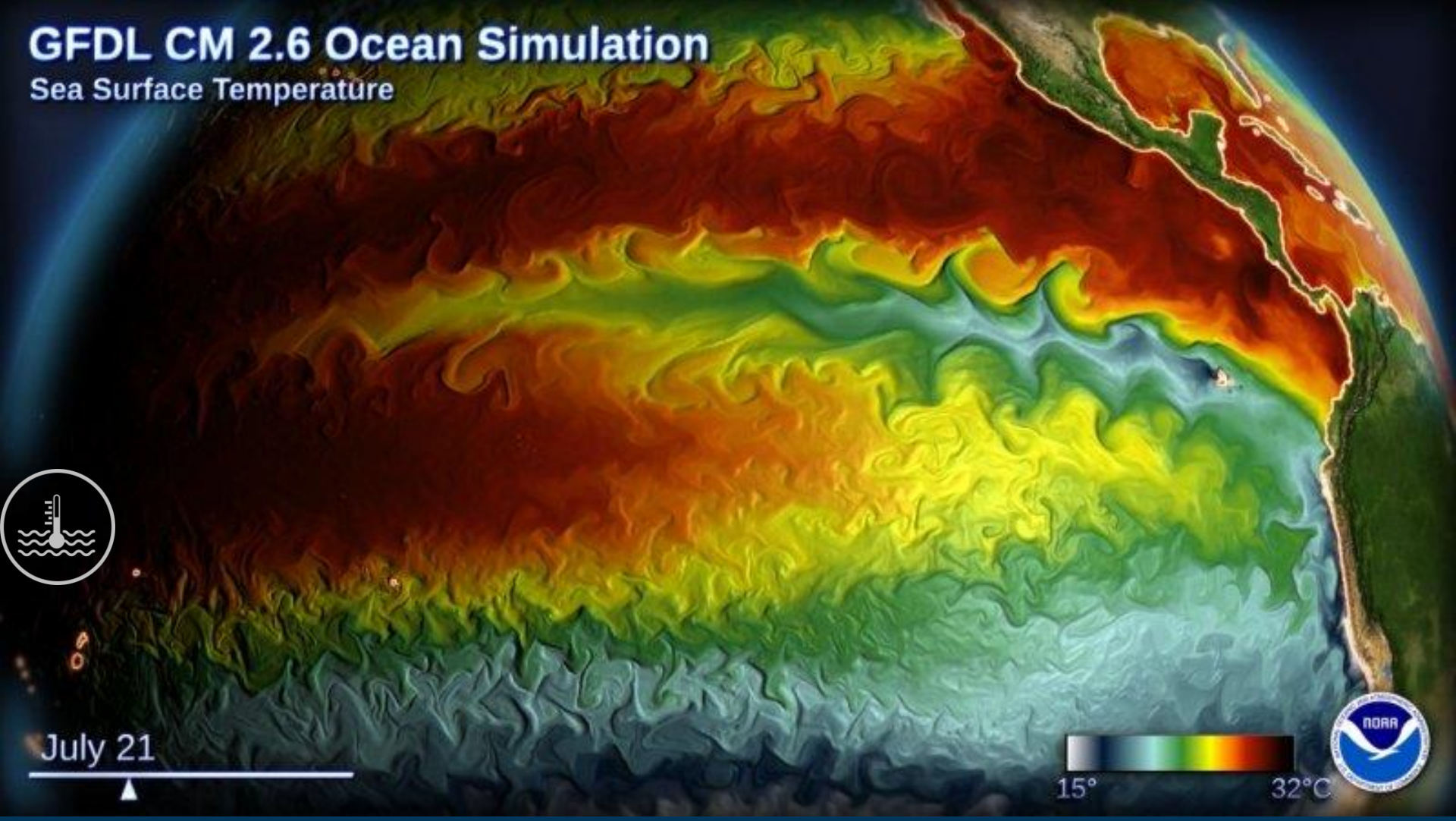
From meteo-oceanography…

Waves

Currents

Sea level

Wind



Sea surface temperature

… to coastal engineering

Coastal structures

Beach erosion

Offshore structures

Coastal flooding

Purpose of the study

Problems

- Link with the physics:
  - ✓ Combination of parameters describing one phenomenon ($H_s/T_p, \dots$)
  - ✓ Combination of components of a broader phenomenon (tide/surge, …)
  - ✓ Combination of parameters describing distinct phenomena ($H_s/Z, \dots$)

- Requests from the clients not always well defined:
  - ✓ Joint occurrence of extreme values of meteo-oceanic variables? → *source variables*
  - ✓ Joint occurrence of values of meteo-oceanic variables causing extreme values of a combination of these? → *response variable*
  - ✓ Probabilities of exceedance or probability of occurrence?

- → need to define a conceptual framework for multivariate analysis

- British Standards 2016: 60 occurrences of "event"… but no definition!

Univariate events: a 2-step framework

Introduction of the concept of event in the univariate case (ICCE 2012)

Autocorrelated time series of observations $Z(t)$

***Sequential variables**:*
temporal evolution of the environmental variable Z

Sampling: Physical Declustering

Definition, identification, description of independent events

X: ***Event-describing random variable***

i.i.d. sample X_i (size N_T)

Statistical Optimization

Setting a threshold for the convergence of the X_i towards the GPD by determining the extreme domain in a statistical meaning

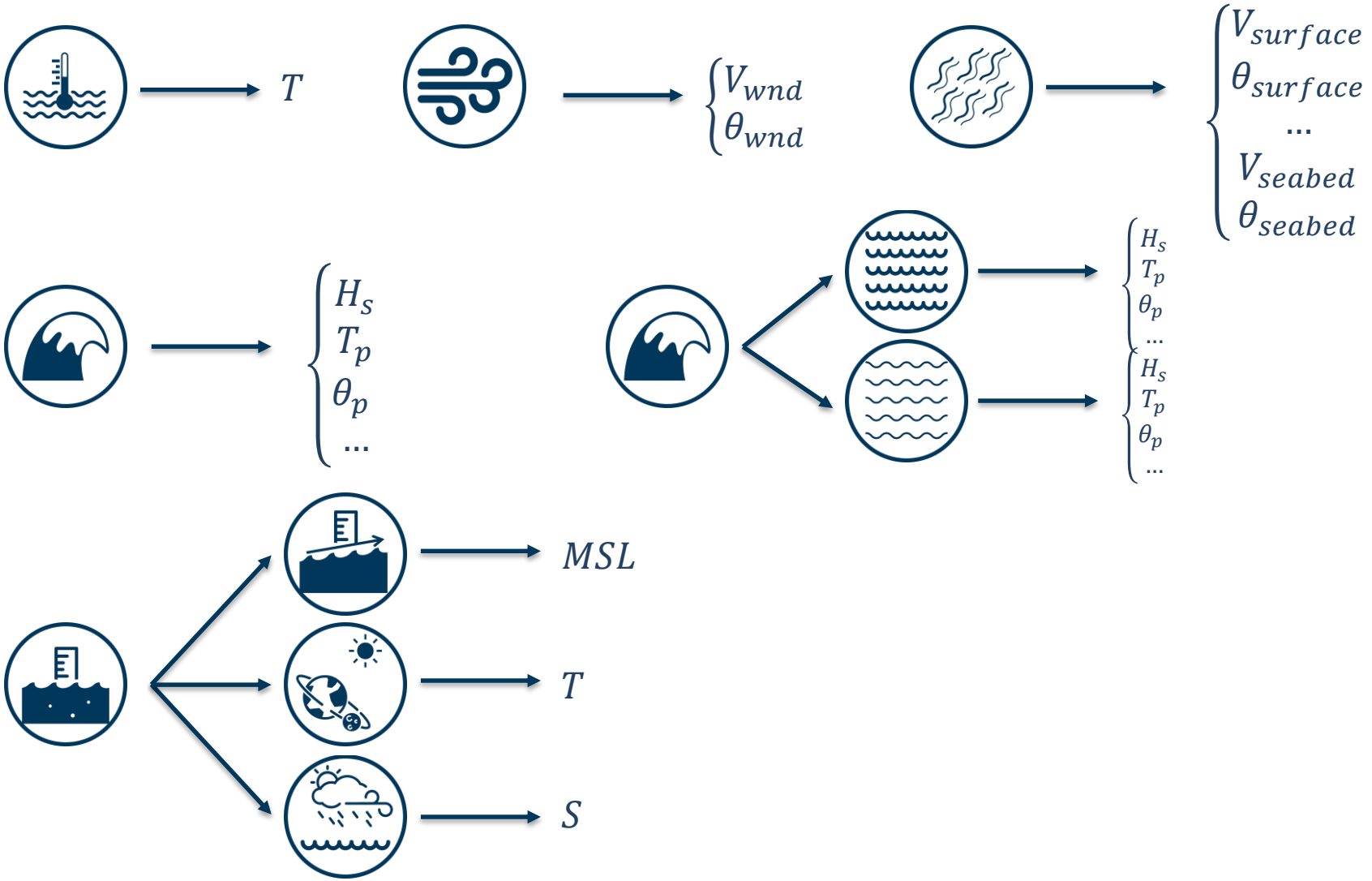
GPD-convergent sample $Y_i = X_i - u_{s|X_i>u_s}$ (size N)

Exceedances over the statistical threshold of the « extreme » X_i

Event =
storm, flood, heat wave, hurricane, flooding…

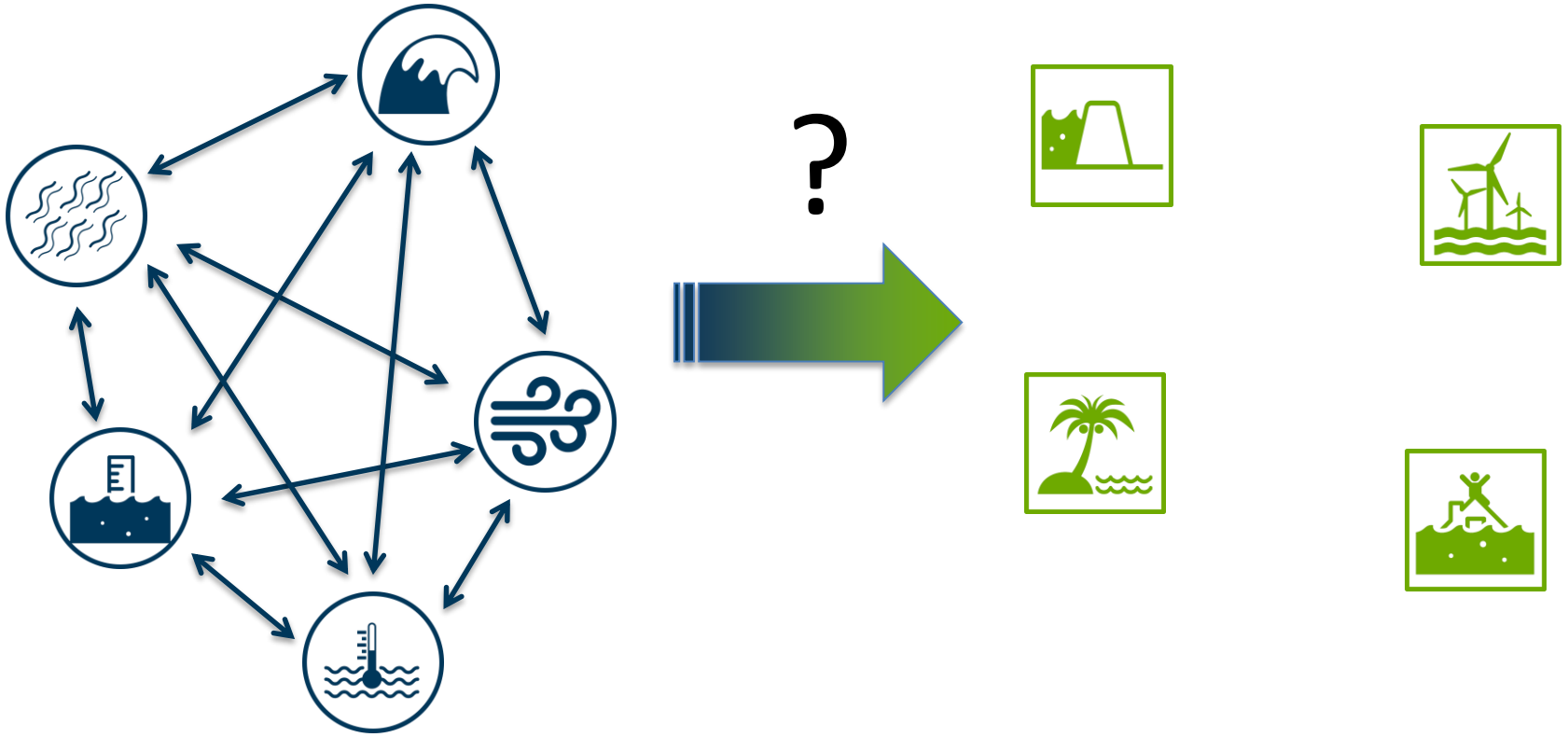
Multivariate events: definition

Meteo-oceanic phenomena: description and components



Multivariate events: definition

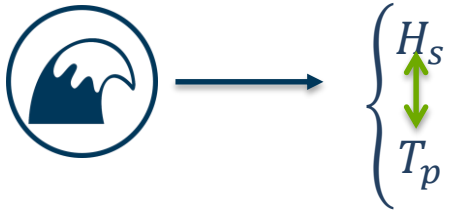
Combinations



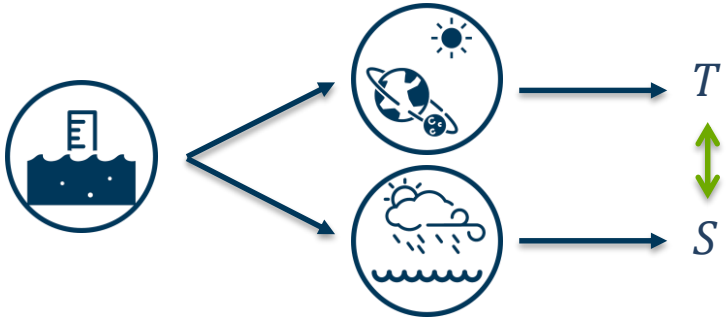
Multivariate events: definition

A classification for multivariate analyses

- **Type A:** a *single phenomenon* described by different *physical quantities* that are *possibly not of the same kind*



- **Type B:** a *phenomenon* made of different *components*, described by *physical quantities of the same kind* between one component and another

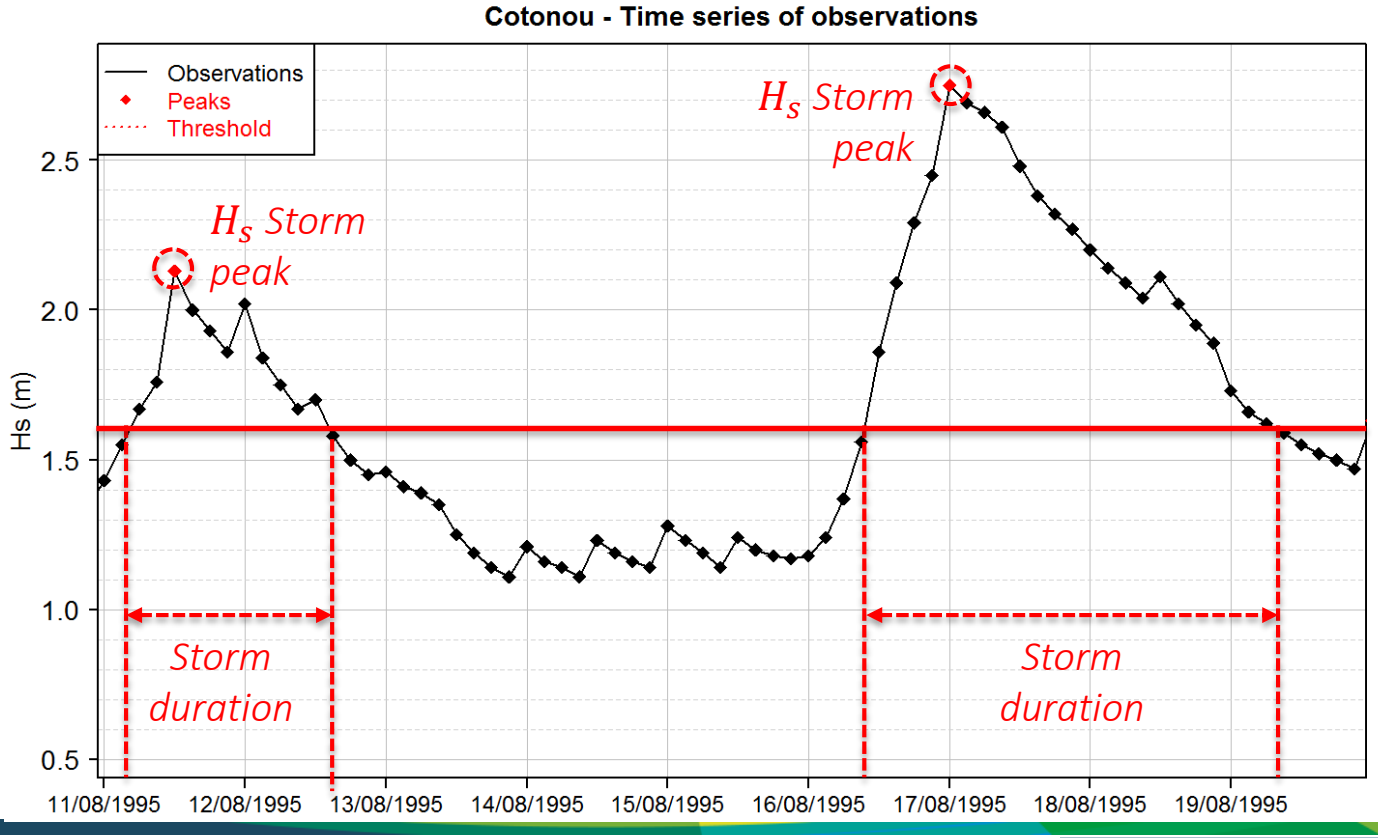


- **Type C:** several *phenomena* described by *physical quantities* that are *possibly not of the same kind*

Event definition and sampling

Type A analyses: choice of an event-defining variable → univariate methods

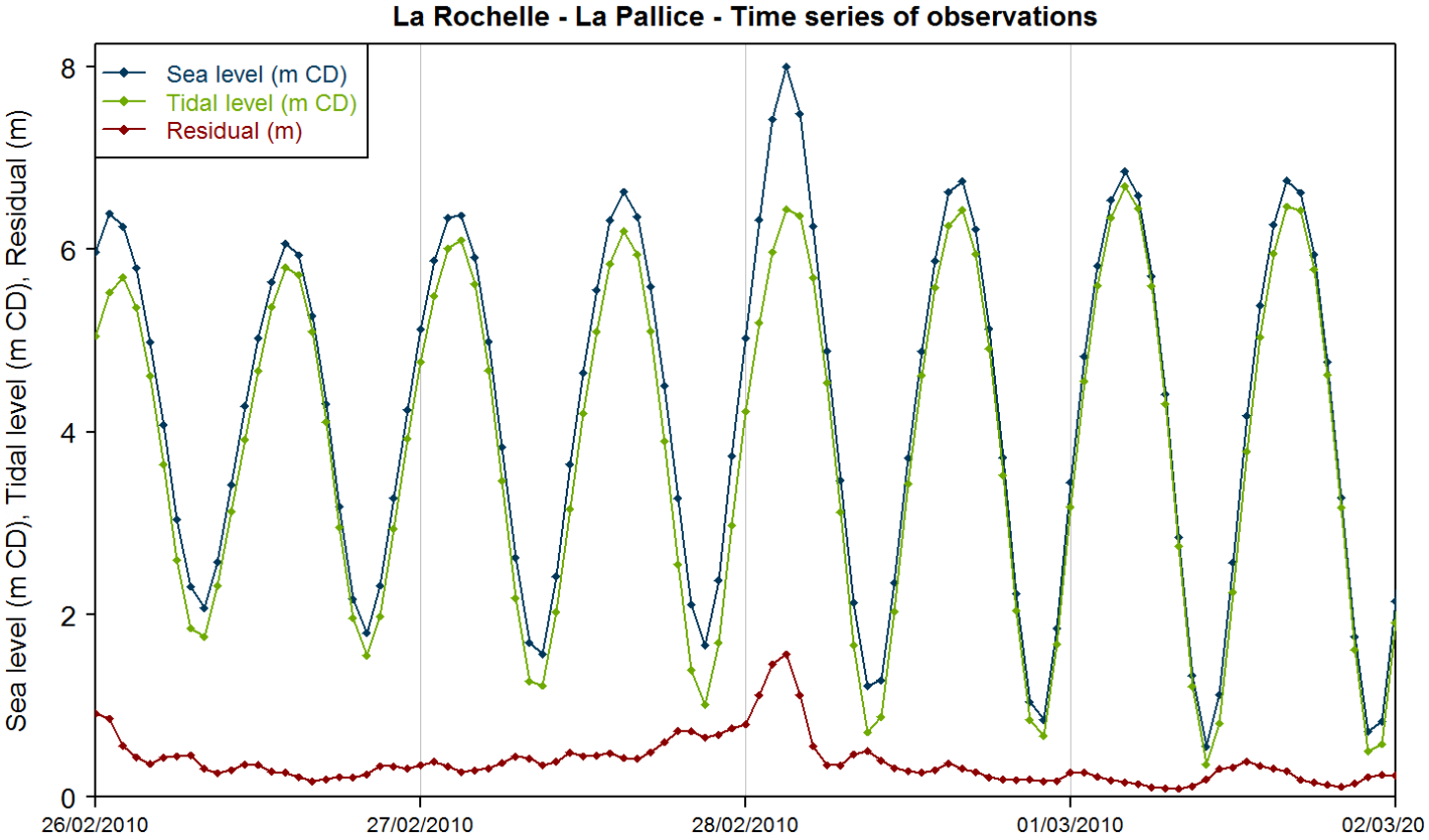
- Sampling = event **definition**, **identification** and **description** – e.g. $H_s/duration$
  - ✓ *Event definition*: large values of wave height H_s
  - ✓ *Event identification*: physical threshold, temporal parameters for independence…
  - ✓ *Event description*: peak H_s, storm duration, wave covariates (T_p, θ_p…) at the peak…



Event definition and sampling

Type B analyses: declustering on a single variable → univariate methods

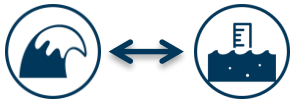
- Case of extreme sea levels = astronomical tide + meteorological surge:
  - ✓ *Astronomical tide*: deterministic variable → no need for sampling
  - ✓ *Meteorological surge*: classical POT declustering

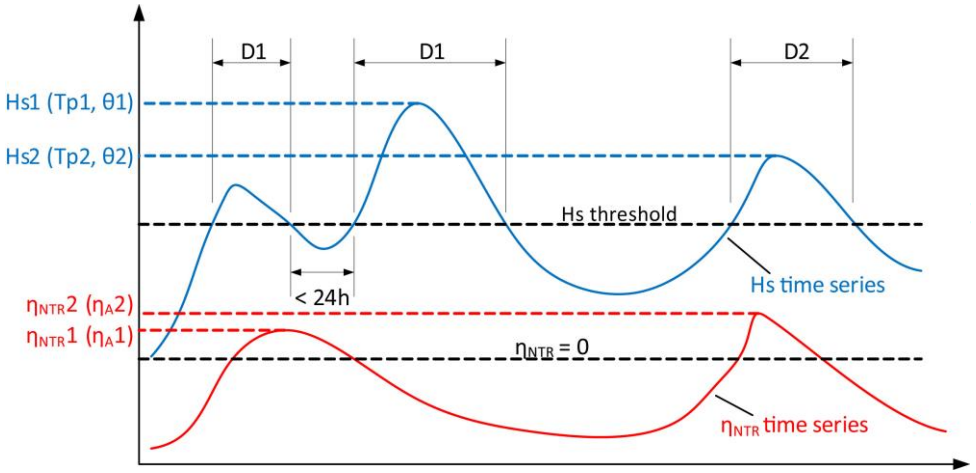


Event definition and sampling

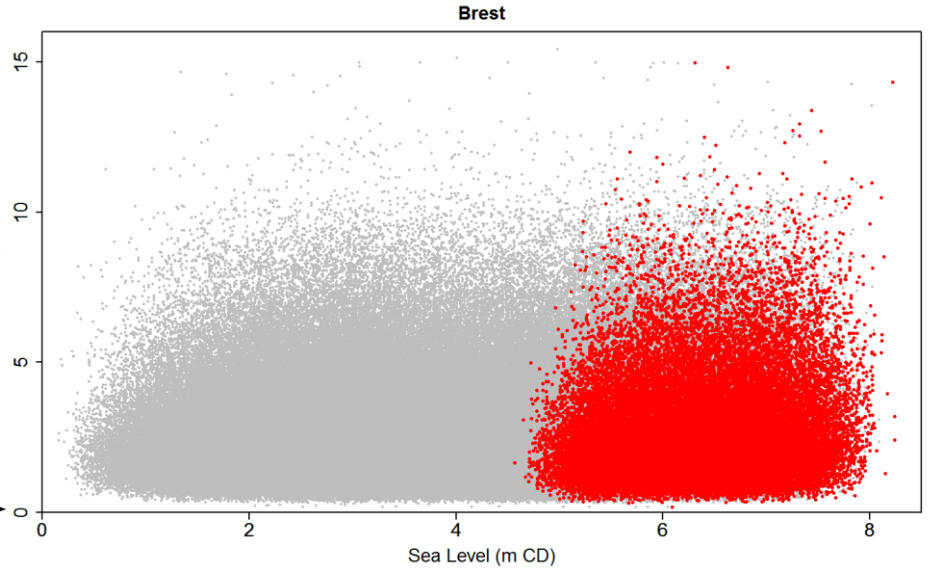
Type C analyses: a choice to be made between the source phenomena and a possible response phenomenon

- Choose an event-defining variable among the source variables





Threshold exceedance by H_s

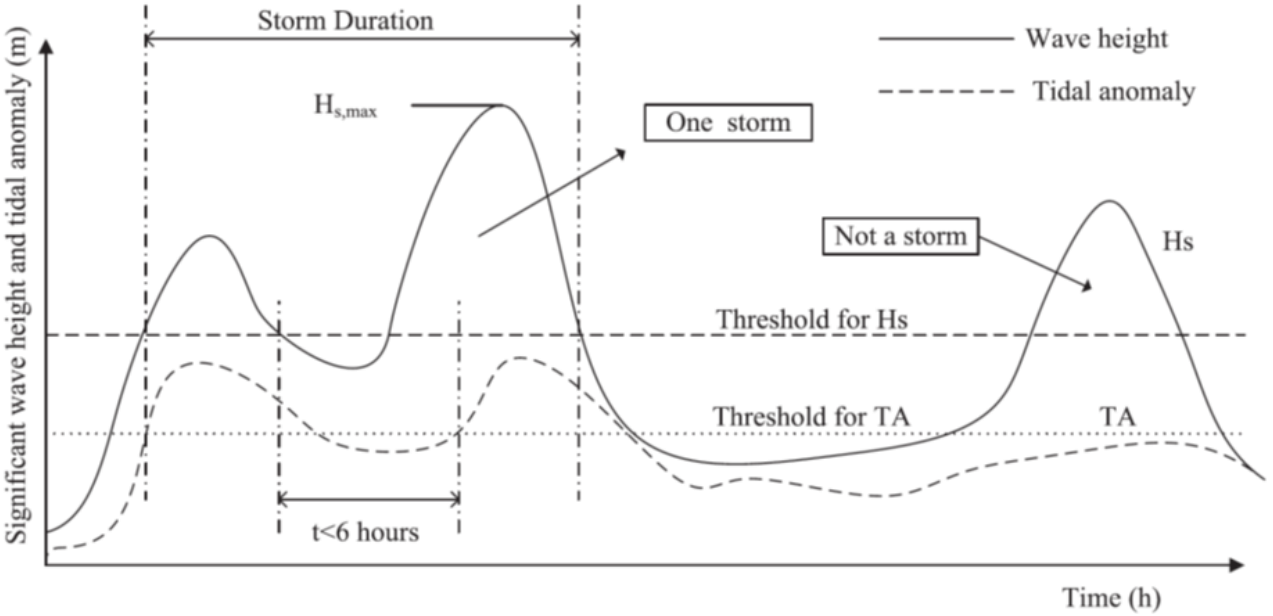


High tide sampling

Event definition and sampling

Type C analyses: a choice to be made between the source phenomena and a possible response phenomenon

- Considering both variables equivalently



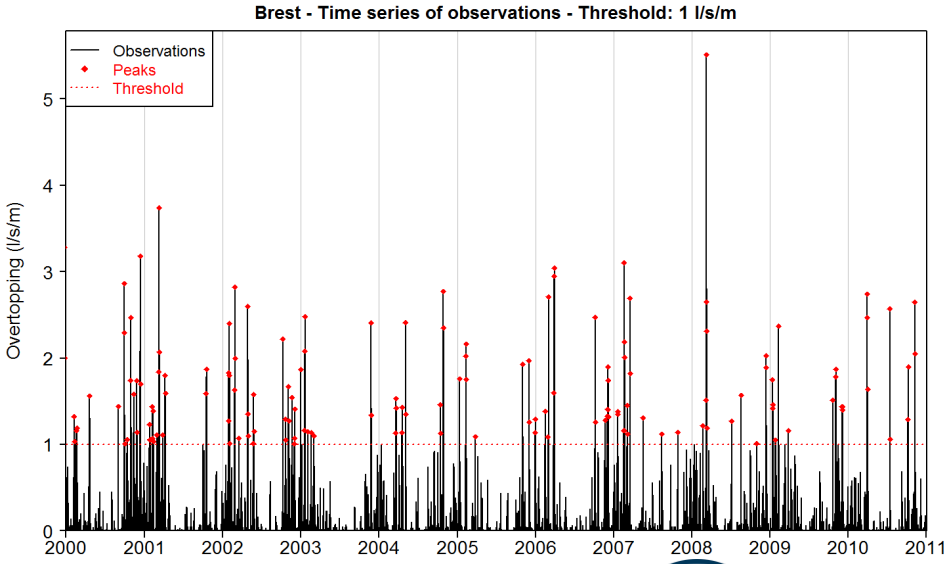
Bivariate threshold

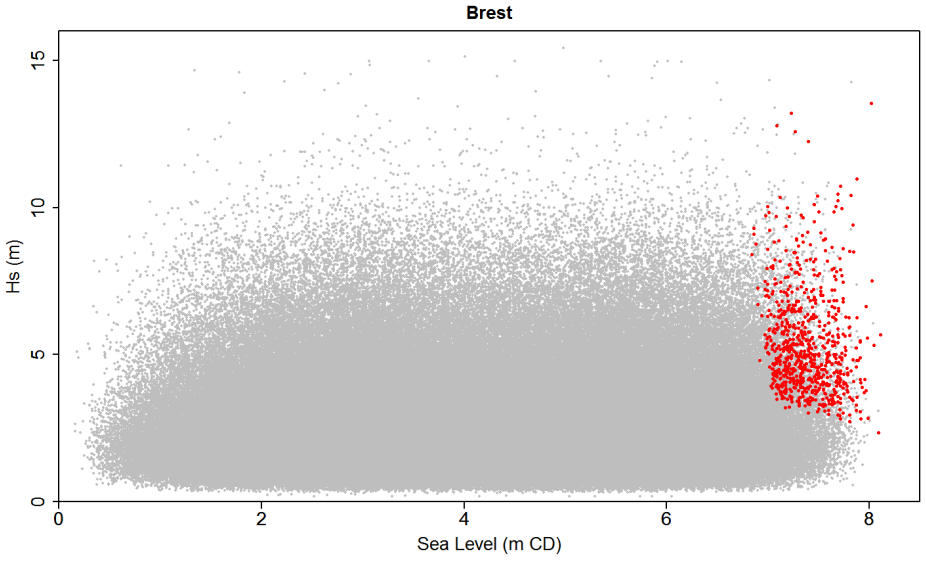
(Li et al., 2014)

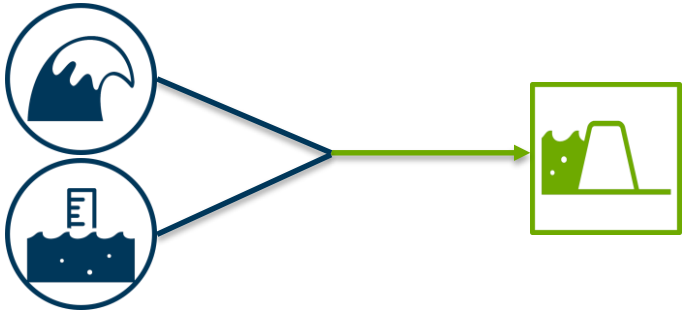
Event definition and sampling

Type C analyses: a choice to be made between the source phenomena and a possible response phenomenon

- Sampling from a univariate response function combining the variables and covariate







Event definition and sampling

A choice to be made according to the aim of the study

- An example of visualisation: Source-Receptor-Pathway approach

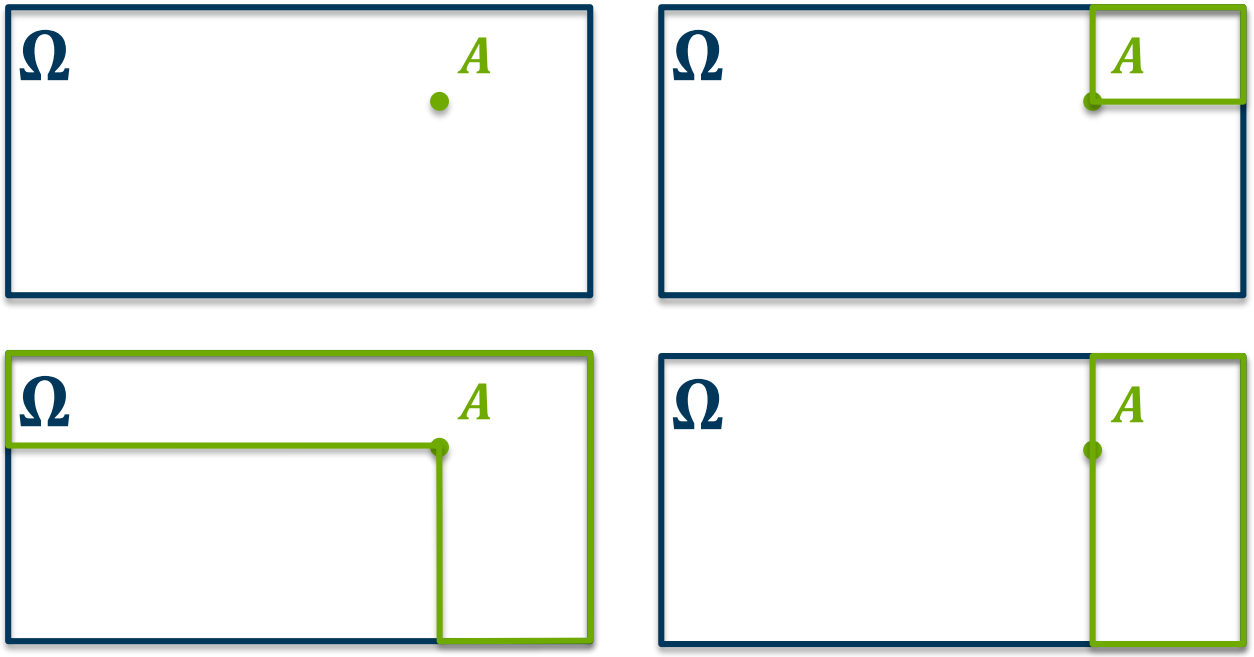
- Event definition driven by the sampling

Event definition

The probabilistic point of view

- **Probability**: measure of the **likelihood** of occurrence of the **event** A, a subset of the possible outcomes Ω
- The event A needs to be defined!
  - ✓ 1D:

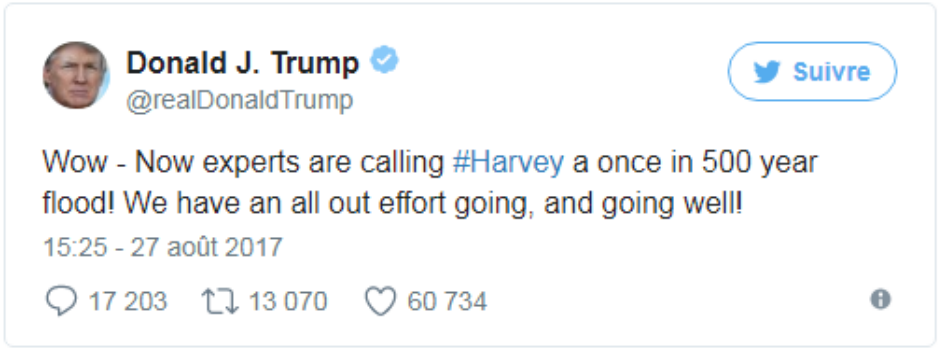
  - ✓ 2D:



Return period

Basic definition… and common misunderstandings

- The "*average period between two occurrences of the event*" ???...



- … or rather a **yearly probability of exceedance**…

$$\mathcal{T} = \frac{1}{\lambda \mathbb{P}_A}$$

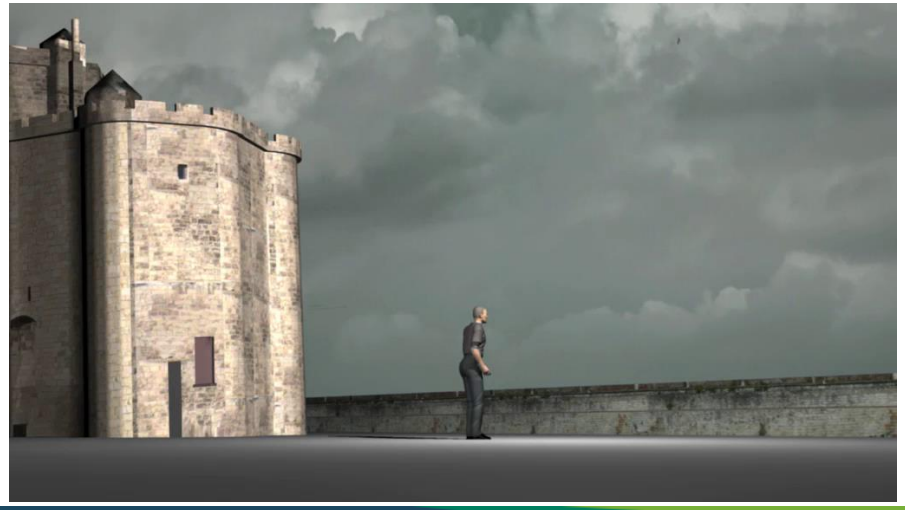
Poisson parameter λ:
number of events / year

Return period

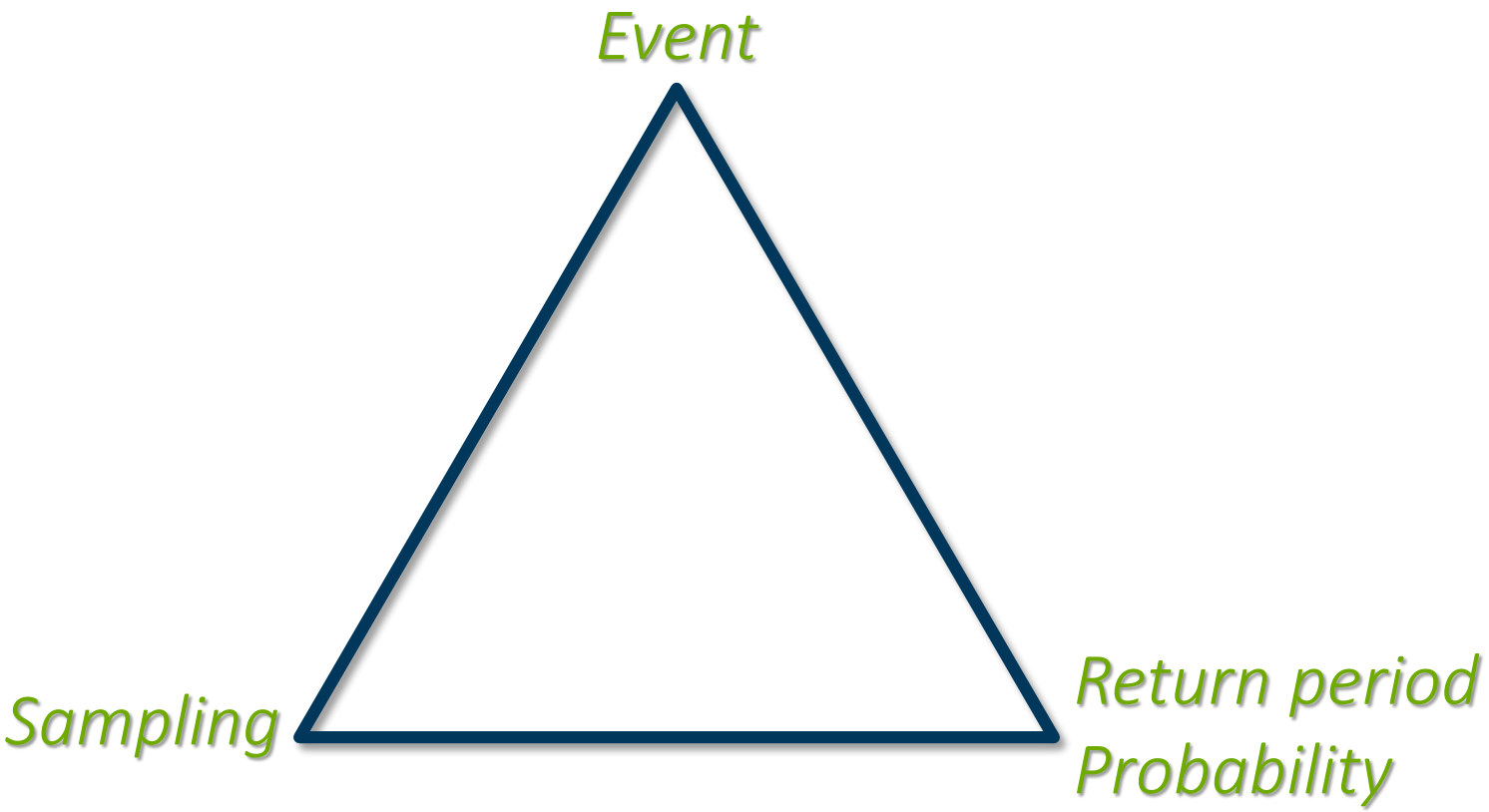
Basic definition… and common misunderstandings

- … to be accounted each and every year over a duration (lifetime)






Entangled concepts



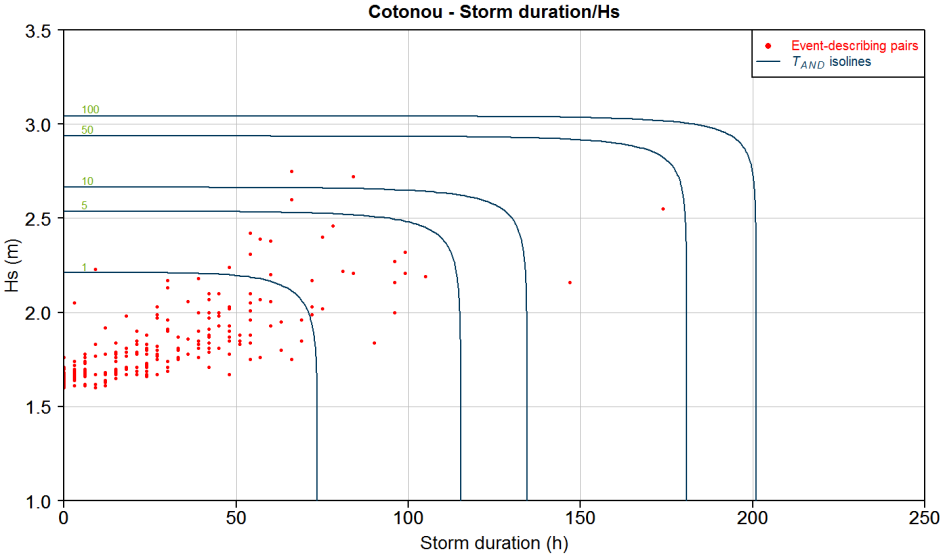
Clarifying the requests in engineering studies

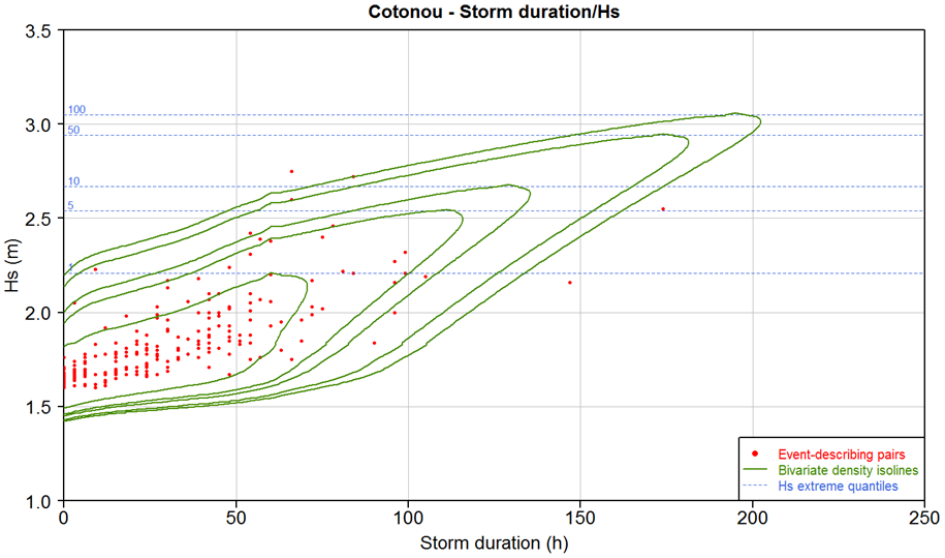
"Please provide the 100-year contours of waves and sea levels."

Extreme bivariate analyses

Examples - Type A: H_s / Storm duration

- Event-describing pairs only (no sequential equivalent for storm duration)





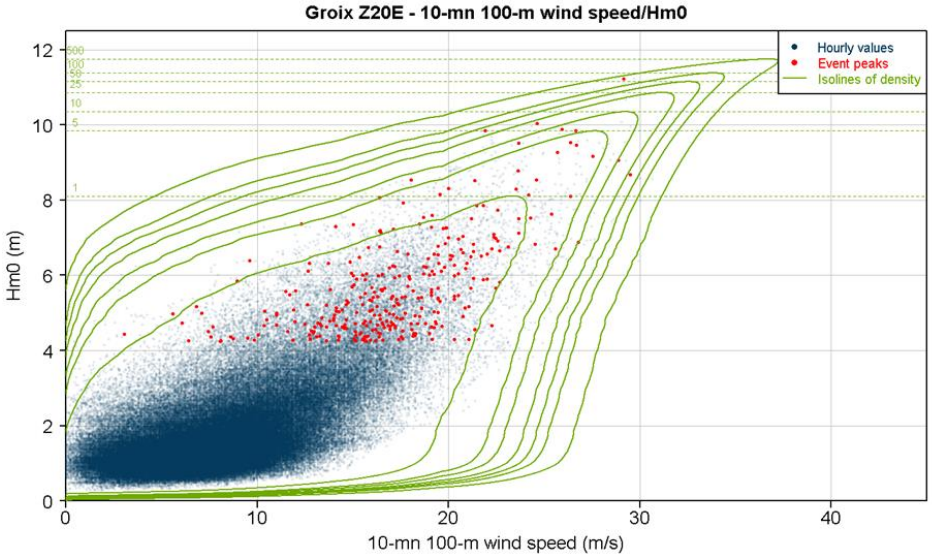
$\mathcal{T}_{AND}$
Probability of joint exceedance

Contours of iso-density from marginal extremes of the reference variable

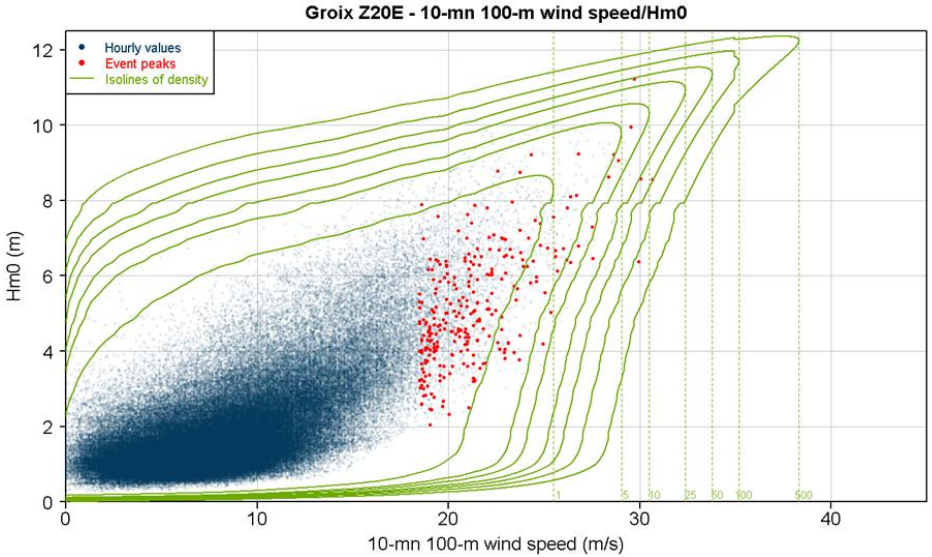
Extreme bivariate analyses

Examples - Type C: H_s / W_s

- Choice of the event-defining variable?



Events defined by H_s peaks
Contours of iso-density from marginal extremes of wave height



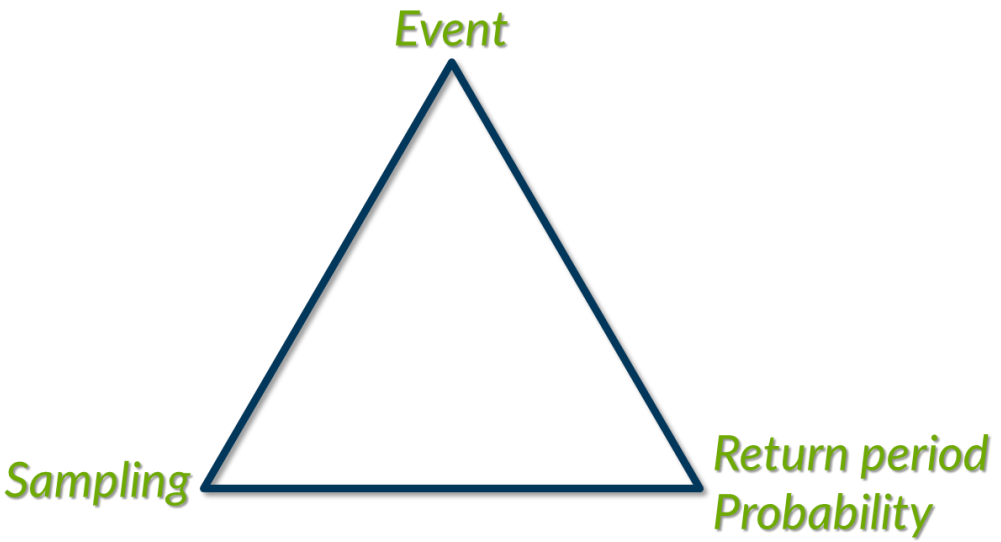
Events defined by W_s peaks
Contours of iso-density from marginal extremes of wind speed

Conclusions

An event-based framework for extreme analyses

- Extension of the event extrapolation framework to the multivariate case with a classification based on physical analysis prior to probabilistic modelling

- Entanglement between event definition, sampling and return period



- Appropriate conceptual framework for complex requests in engineering studies

- Direct applicability to hydrology, environmental extremes… and other (finance)

Thank you for your attention!

ICCE 2018

36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018

Baltimore, Maryland | July 30 – August 3, 2018

ARTELIA

Passion & Solutions