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et Assises du port du futur du Cerema

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Caractériser les actions météo-océaniques sur des durées longues avec le format des Eurocodes

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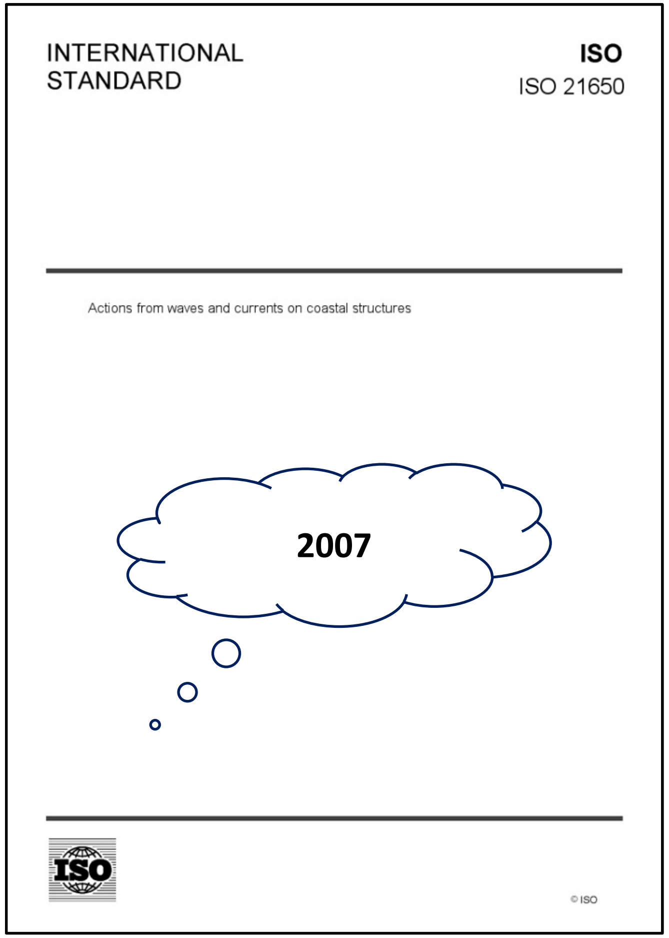
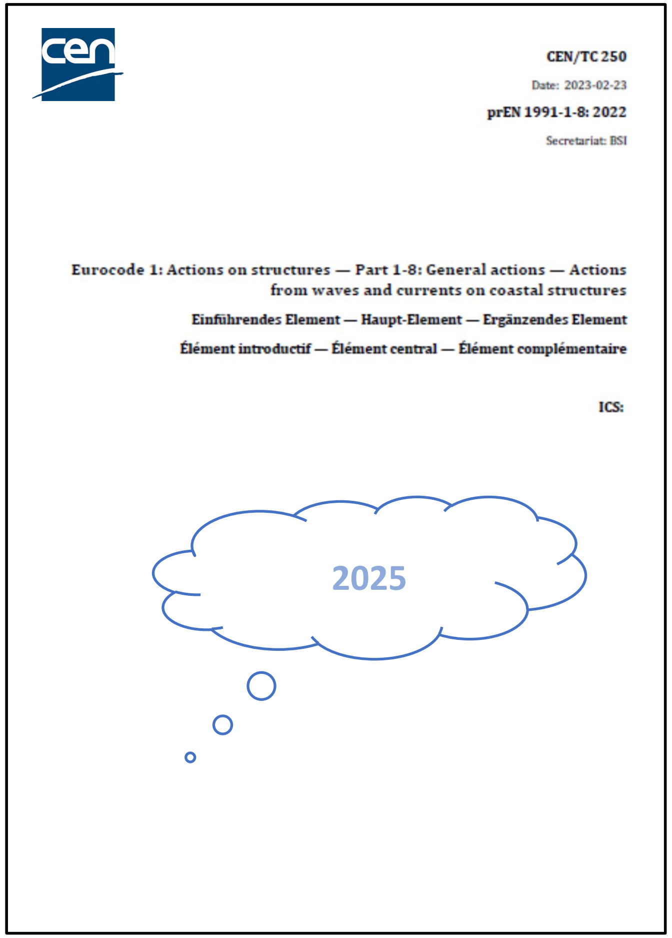
Towards a new European standard



New Work Item Proposal
(NWIP) under Mandate M/515 from European Commission (2016):

"There is a need to incorporate best practice for wave and current actions for designers and to tie those actions to the existing Eurocodes for actions on structures".



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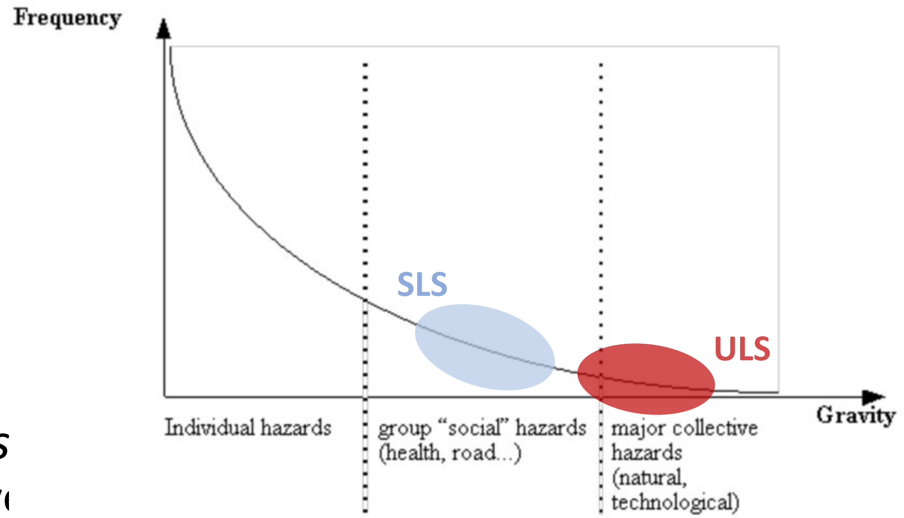
How shall we say if a design criteria refers to a ULS or to a SLS ?

Ultimate limit states (**ULS**) stand for high gravity events, their acceptable frequency of occurrence is therefore *very low*

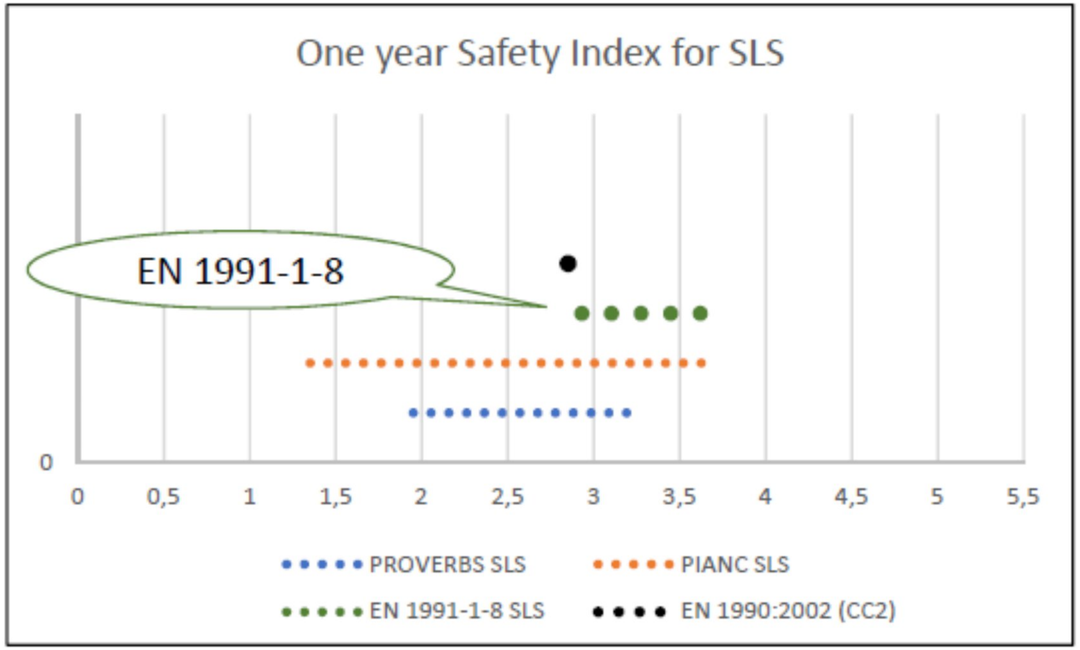
Serviceability limit states (**SLS**) stand for moderate gravity events, their acceptable frequency of occurrence is therefore just *low*

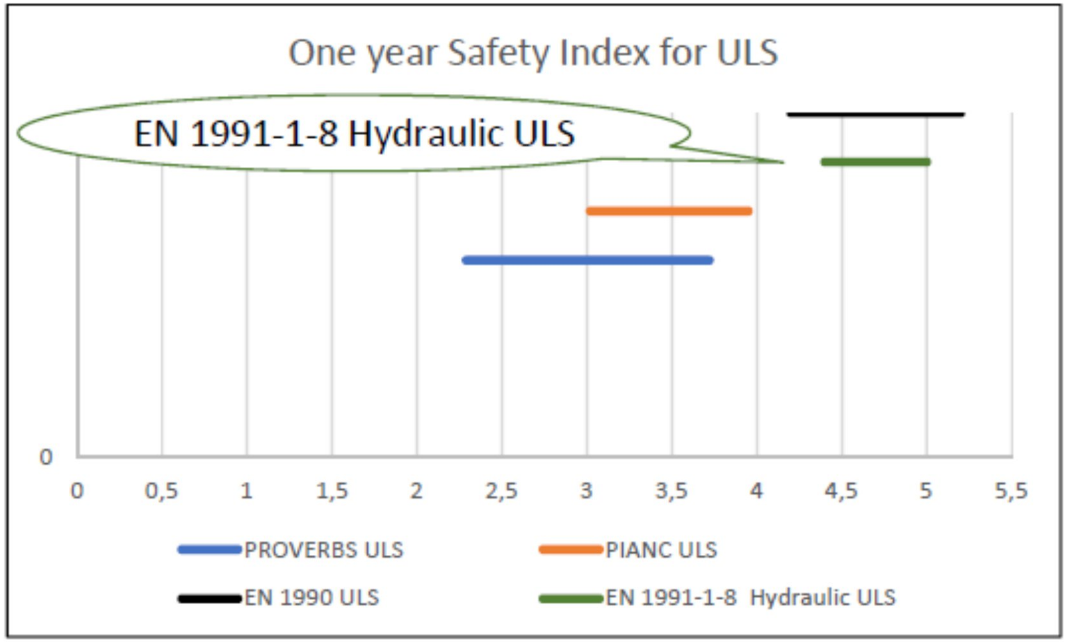
Classification into SLS or ULS does not depend directly on the physics
Nothing prevents a displacement limit-value limit state to be a ULS wheneve
a crossing of this value would be very harmful to the structure. Actually the classification of a failure mechanism into ULS or SLS will depend on the required safety level, not on the type of failure itself, nor on its kinematics (i.e. whether gradual or brittle).



Farmer Curve
Source : *Le risque majeur, Secrétariat d'Etat chargé de l'environnement et de la prévention des risques technologiques et naturels majeurs, Aug 2001.*

Looking for target safety indexes (β values)





Source : *Revised background to EN 1991-1-8 Safety Levels*, CEN/TC 250/SC 1/WG 6 N 241

Characteristic Return Periods (for SLS) and Design Return Periods (for ULS) : result of calibration

Conse-quence class	Importance factor (φ_I)[a]	Characteristic marginal return period (leading metocean parameter)[b]
CC3	2,0	200 y
CC2	1,0	100 y
CC1	0,5	50 y

Conse-quence class	Import-ance factor (φ_I)[a]	Design marginal return period (leading metocean parameter)[b]
CC3	2,0	4 000 y
CC2	1,0	2 000 y
CC1	0,5	1 000 y

Source : pr*EN 1991-1-8*, CEN/TC 250/SC 1/WG 6 N 251

How to consider dependence between metocean parameters ?

- Combining wave heights and water levels has always been a tricky issue for coastal engineering consultancy, that has been solved in a number of *ad hoc* approaches

- Several variants of the hydrodynamic load can be built by combining the *characteristic value* of a “dominant metocean parameter” and the *combination values* of other “accompanying metocean parameters

- The assessment of a *joint return period* of 2+ metocean parameters enables alternative combinations

Marginal Return Periods (RPm) and Joint Return Periods (RPj)

$$RPm\,(x) = \frac{1}{Prob(X>x)} = \frac{1}{1-F_X(x)}$$

$$RPm\,(y) = \frac{1}{Prob(Y>y)} = \frac{1}{1-F_Y(y)}$$

$$RPj\,(x,y) = \frac{1}{Prob(X>x\ \textbf{and}\ Y>y)} = \frac{1}{1+F_{XY}(x,y)-F_X(x)-F_Y(y)}$$

Using a Hougaard-Gumbel copula with dependence parameter « *m* » (for calibration purposes)

$$F_{XY}\,(x,y) = exp\left\{-\left((-ln\,(F_X\,(x)))^m + (-ln\,(F_Y\,(y)))^m\right)^{\frac{1}{m}}\right\}$$

$$\frac{1}{RPj(x,y)} = \frac{1}{RPm(x)} + \frac{1}{RPm(y)} - 1 + exp\left\{-\left(\left(-ln\left(1-\frac{1}{RPm(x)}\right)\right)^m + \left(-ln\left(1-\frac{1}{RPm(y)}\right)\right)^m\right)^{\frac{1}{m}}\right\}$$

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Combination Return Periods and Joint Return Periods (for SLS and ULS) : result of calibration

Conse-quence class	Importance factor (φ_I)[a]	Characteristic marginal return period (leading metocean parameter)[b]	Combination marginal return period (accompanying metocean parameter)[c]		Characteristic joint return period[d]
CC3	2,0	200 y	Very High dependence:	140 y	700 y
			High dependence:	40 y	
			Medium dependence:	13 y	
			Low dependence:	6 y	
CC2	1,0	100 y	Very High dependence:	70 y	350 y
			High dependence:	25 y	
			Medium dependence:	10 y	
			Low dependence:	5 y	
CC1	0,5	50 y	Very High dependence:	40 y	175 y
			High dependence:	15 y	
			Medium dependence:	8 y	
			Low dependence:	4 y	

[a] The importance factor is given in Table 4.4 (NDP).

[b] The characteristic marginal return period is equal to the value given in 4.7.2(1) multiplied by the importance factor.

[c] When the degree of dependence is not known, the "medium dependence" figure can be used.

[d] The characteristic joint return period is equal to the value given in 4.7.2(2) multiplied by the importance factor. Figures are valid for a two-variable joint analysis only.

Conse-quence class	Import-ance factor (φ_I)[a]	Design marginal return period (leading metocean parameter)[b]	Design combination marginal return period (accompanying metocean parameter)[c]		Design joint return period[d]
CC3	2,0	4 000 y	Very High dependence:	1 800 y	12 000 y
			High dependence:	370 y	
			Medium dependence:	45 y	
			Low dependence:	6 y	
CC2	1,0	2 000 y	Very High dependence:	900 y	6 000 y
			High dependence:	190 y	
			Medium dependence:	30 y	
			Low dependence:	6 y	
CC1	0,5	1 000 y	Very High dependence:	450 y	3 000 y
			High dependence:	100 y	
			Medium dependence:	18 y	
			Low dependence:	5 y	

[a] The importance factor φ_I is given in Table 4.4 (NDP).

[b] The design marginal return period is equal to the value given in 7.2.3(1), Note 1 multiplied by the importance factor φ_I.

[c] When the degree of dependence is not known, the "medium dependence" figure can be used

[d] The design joint return period is equal to the value given in 7.2.2(1), Note 2 multiplied by the importance factor φ_I. Figures are valid for a two-variable joint analysis only.

Source : pr*EN 1991-1-8*, CEN/TC 250/SC 1/WG 6 N 251

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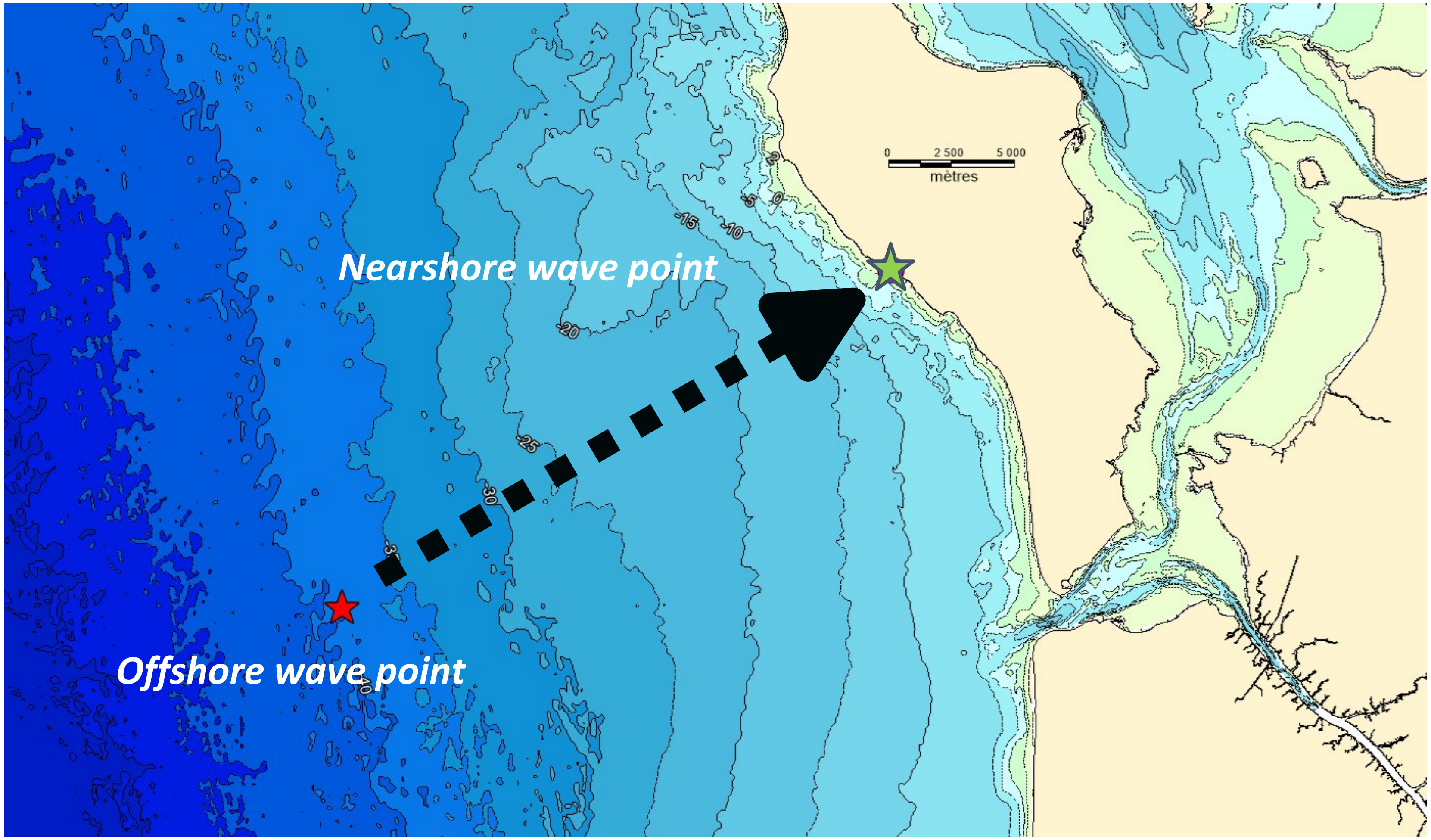
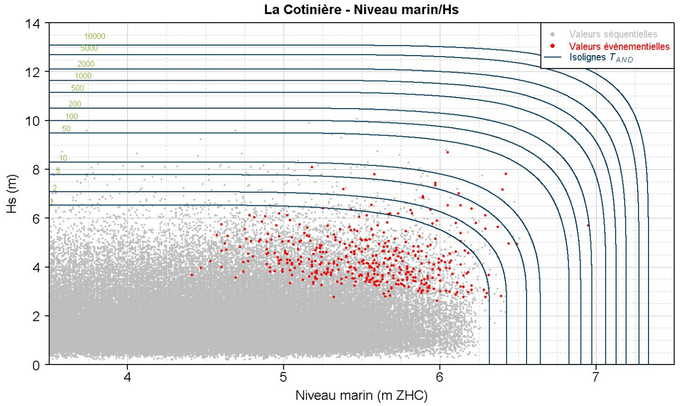
Illustration : Artelia

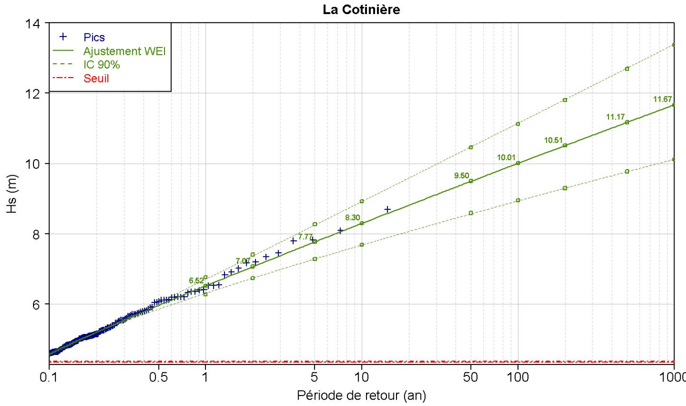
Offshore statistics or nearshore statistics ?



Illustrations : Artelia

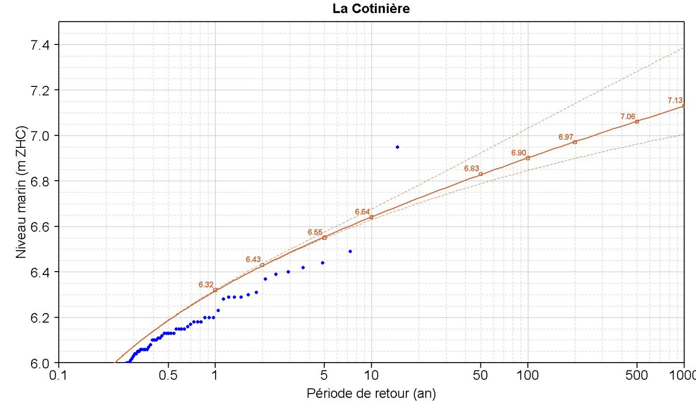
Statistical approaches





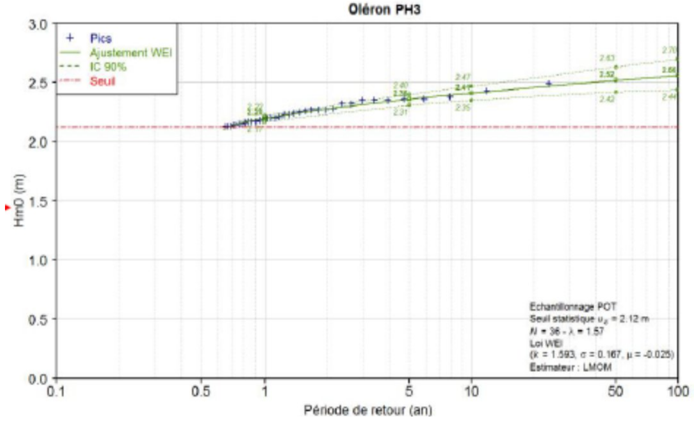
Deep-sea Extremes Method (DsEM)

- A small number of sets of offshore (deep-sea) metocean parameters is selected through a statistical analysis of the metocean parameters (*joint analysis* or *marginal analysis*).
- An offshore set is made of the characteristic or of design value of the dominant metocean parameter, and the combination value of the accompanying ones.
- Different sets correspond to different choices for the dominant metocean parameter.
- These sets are all transferred to the shoreline using a numerical model.
- The hydrodynamic load is the most adverse response of the structure.



Full Transfer Approach (FTA)

- A large set of real or simulated extreme metocean events is transferred to the site of the coastal structure using a numerical model.
- The hydrodynamic load is determined based on the extreme value analysis of the distribution of the responses of the structure and a target return period.



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Partial factor of safety

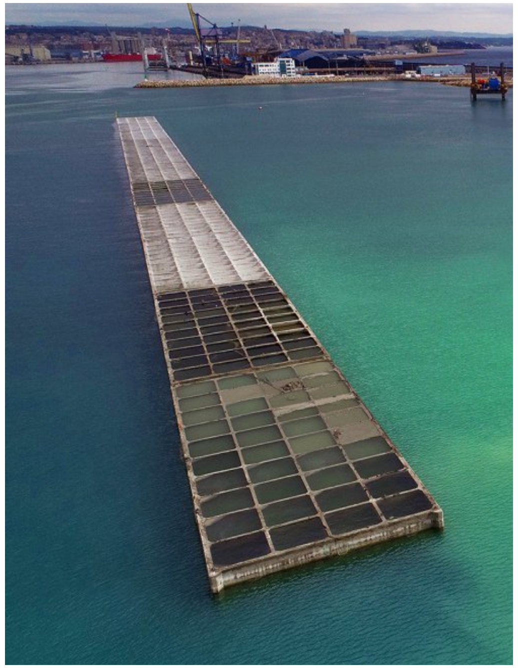
For *structural and geotechnical limit states*

Design value = Characteristic value of hydrodynamic load (or response) (based on the characteristic marginal return period : 100 y for CC2, or characteristic joint return period : 350 y for CC2) x partial factor of safety : γ_F = 1.35 (which is different from the usual Eurocode partial factor for variable actions : γ_F = 1.50)

Subsequentely there is no “consequence factor” allowing for consequence class differentiation : k_f = 1.00

For *hydraulic ultimate limit states*

The design value of the metocean parameters and of the hydrodynamic load (response) is determined according to “design return periods”, i.e. without partial factor : 2 000 y design marginal return period, or 6 000 y design joint return period (CC2)



Source *:* Port Authority of Tarragona

Source : CDR International BV

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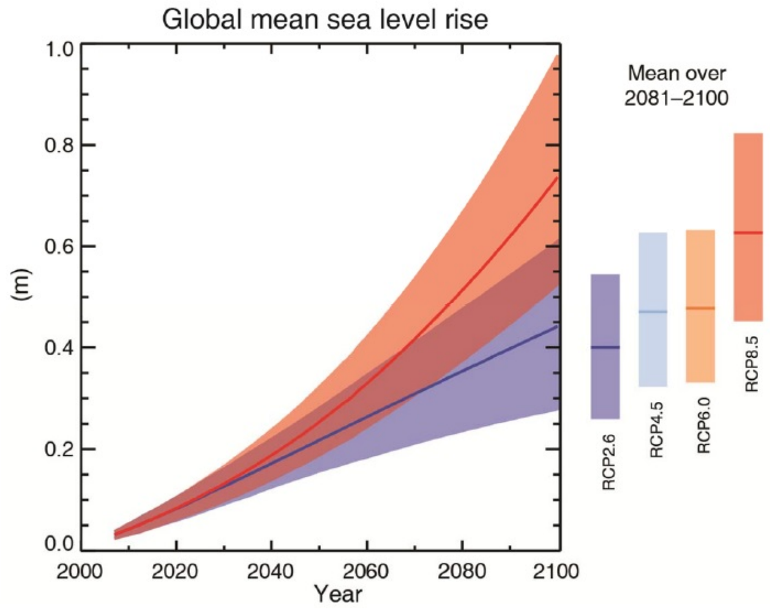
Climate change : what if the random processes are no longer stationary ?

- For **non-adaptable and non-replaceable** structures or parts thereof, the most adverse metocean parameters' random processes during the design service life of the structure are considered, according to the appropriate climate change scenario.

- For **adaptable or replaceable** structures or parts thereof, provided a maintenance and monitoring plan is explicitly addressed, the most adverse climate and sea level until the first major planned maintenance, are considered according to the appropriate climate change scenario.

- In case the maintenance schedule is not known, the most adverse climate change scenario and the marine conditions (waves, currents, winds, water levels, etc.) during the 2/3 of the intended design service life of the structural parts are considered.

- Guidance is given in prEN 1991-1-8 as to the « appropriate climate change scenario ».



Source : IPCC, 2013

Thank you for your attention

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