SHORT-TERM EXTRAPOLATION OF EXTREME SEA LEVEL STATISTICAL DISTRIBUTIONS

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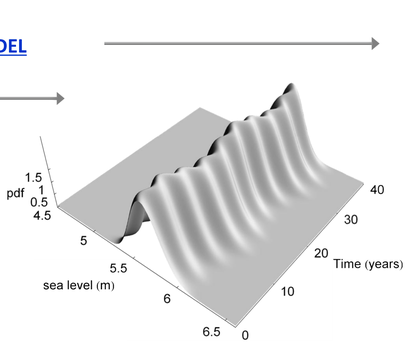
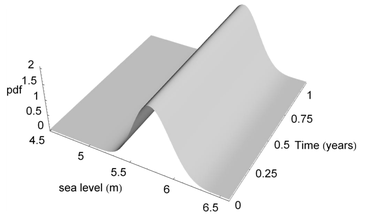
Importance of extreme high water level events:

How can we characterize from a probabilistic point of view the extreme sea level events? **EXTREME VALUE STATISTICAL MODEL**

How can we identify and quantify the climate variability of extreme high waters? **NON-STATIONARY APPROACH**

- Are extreme sea levels being affected by climate change ?
  Is there any evidence for recent increases over and above the MSL change?
- What is the within a year variation pattern?
- What is the influence of regional atmospheric patterns?
- What is the influence of astronomical modulations?
- Is it possible to extrapolate the PDF of extreme sea leves?

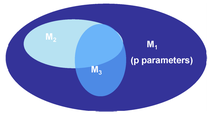




Model Selection:

Including only significant factors..

Models: {M1, M2,...}



Codification:

[1/0 1/0 1/0 1/0 1/0 1/0 1/0 1/0 1/0 1/0]

To find the optimal model between the possible combinations:

Forward procedure

[0 0 0 0 0 0 0 0 0 0]
[1 0 0 0 0 0 0 0 0 0]
[1 0 1 0 0 0 0 0 0 0]
: : :
[1 1 1 0 0 0 1 0 1 0]

Checking the improvement by

Likelihood ratio test (minimum significant level of 0.1)

Each particular model is fitted by

Maximum Likelihood Estimation

$$l(\theta \mid t_i, z_i) = -\sum_{i=1}^{m} \left\{ \log \psi(t_i) + (1 + 1/\xi(t_i)) \log \left[1 + \xi(t_i) \left(\frac{z_i - \mu(t_i)}{\psi(t_i)} \right) \right] + \left[1 + \xi(t_i) \left(\frac{z_i - \mu(t_i)}{\psi(t_i)} \right) \right]^{-1/\xi(t_i)} \right\}$$

Regression model (parameters):

$$\begin{cases} \mu(t) = \mu_S(t) + \mu_N(t) + \mu_P(t) + \mu_{CLI}(t) + \mu_{LTI}(t) \\ \psi(t) = \psi_S(t) + \psi_{...}(t) + \psi_{...}(t) + \psi_{CLI}(t) + \psi_{LTI}(t) \\ \xi(t) = \xi_S(t) + \xi_{LTI}(t) \end{cases}$$

For example..

$$\mu_{Season}(t) \qquad \mu_{LTI}(t)$$

$$\mu(t) = \beta_0 + \underbrace{\beta_1 \cos(2\pi t) + \beta_2 \sin(2\pi t)}_{\text{Annual cycle}} + \underbrace{\beta_3 \cos(4\pi t) + \beta_4 \sin(4\pi t)}_{\text{Semiannual cycle}} + \underbrace{\beta_{LTI} t}_{\text{Trend}}$$

On/Off On/Off On/Off

A possible Final model:

[1 1 1 0 0 0 1 0 1 0]

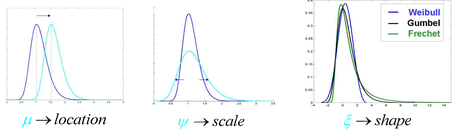
- Annual cycle & Semiannual cycle on location parameter
- Annual cycle & Semiannual cycle on scale parameter
- Annual cycle & Semiannual cycle on shape parameter
- Perigean influence on location parameter
- Nodal cycle on location parameter
- Long-term Trend on location parameter
- Long-term Trend on scale parameter

Long-term extreme value distribution:

Generalized Extreme Value distribution, GEV:

$$F(x;\theta) = \exp\left\{ -\left[1 + \xi \left(\frac{x - \mu}{\psi} \right) \right]^{-1/\xi} \right\}$$

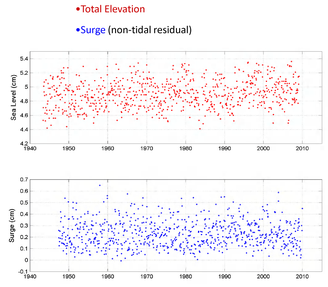
$$\begin{pmatrix} \mu = \mu_t = f(time) \\ \psi = \psi_t = f(time) \\ \xi = \xi_t = f(time) \end{pmatrix}$$

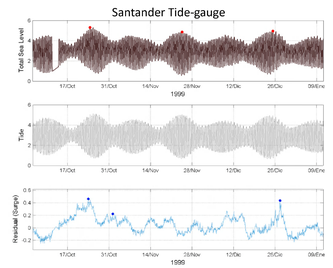


$\mu \rightarrow location$ $\psi \rightarrow scale$ $\xi \rightarrow shape$

Selection of extreme values:

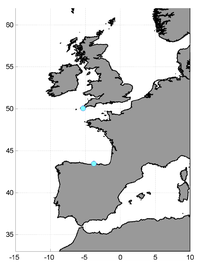
MONTHLY MAXIMA (MM)





Data examples (tide-gauges):

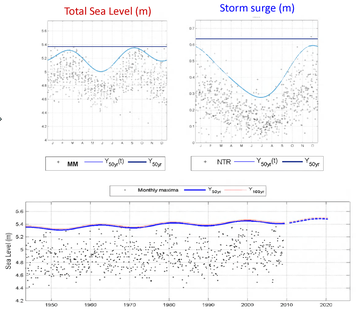
Newlyn (1915-2010)
Santander (1943-2010)



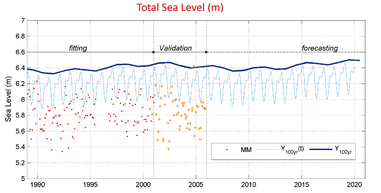
SANTANDER		Total Sea Level		Surge	
Parameter		Priority order	Parameter estimated	Priority order	Parameter estimated
Averaged Location parameter	β_0		4.765		0.181
Averaged scale parameter	α_0		0.162		0.097
Averaged shape parameter	γ_0		-0.334		-0.089
Annual modulation	β_1	2	0.089	1	-0.002
	β_2		-0.018		0.024
Semiannual modulation	β_3	1	-0.098		
	β_4		0.072		
Annual modulation	α_1	4	0.030	2	-0.005
	α_2		-0.014		0.011
Semiannual modulation	α_3				
	α_4				
Annual modulation	γ_1			3	0.003
	γ_2				-0.066
Semiannual modulation	γ_3				
	γ_4				
Trend on magnitude	β_{LTI}	3	0.0018		
Trend on dispersion	α_{LTI}				
Nodal Cycle	β_{N1}	5	0.030		
	β_{N2}		0.004		
Perigean influence	β_{P1}	6	-0.017		
	β_{P2}		0.007		

Extreme seasonal pattern:

Santander



Newlyn



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