SHORT-TERM EXTRAPOLATION OF EXTREME SEA LEVEL STATISTICAL DISTRIBUTIONS

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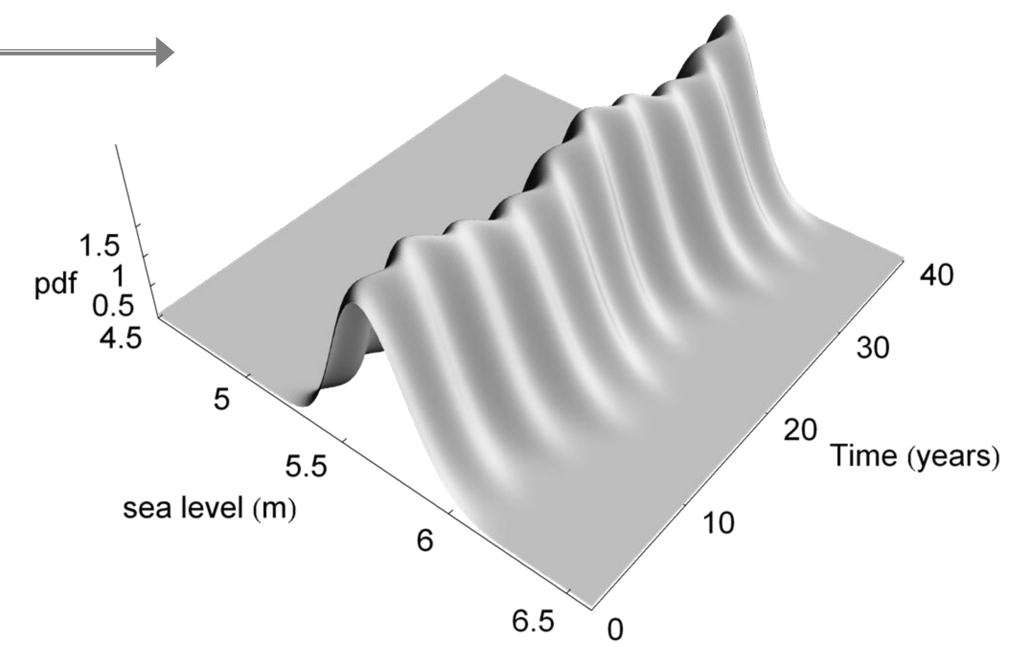
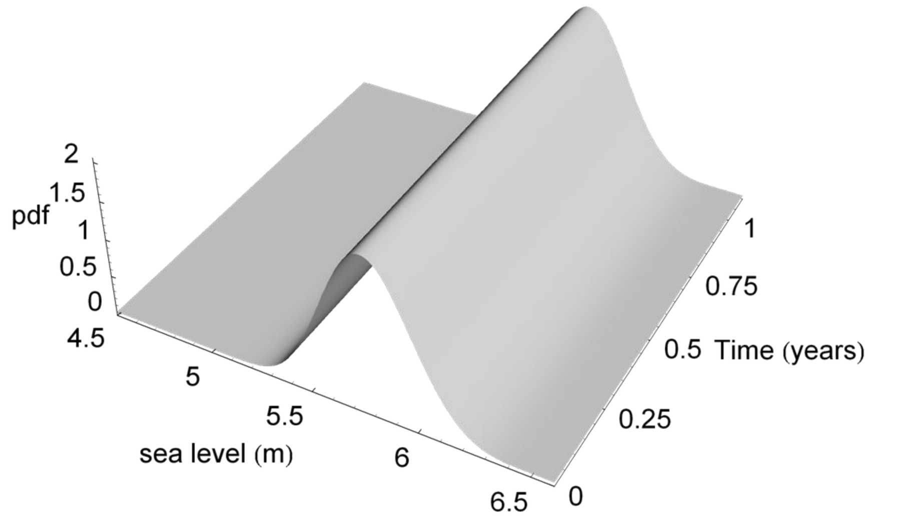
Importance of extreme high water level events:

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?

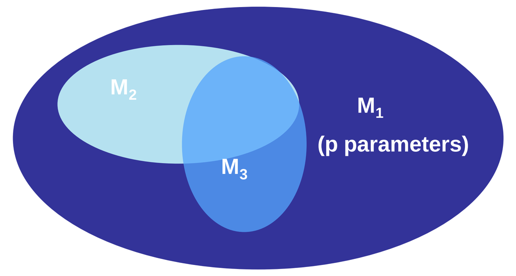




Model Selection:

Including only significant factors..

Models: {M_1, M_2,...}



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

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

Regression model (parameters):

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

For example..

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

1 | 0 On/Off   1 | 0 On/Off   1 | 0 On/Off

A possible Final model:

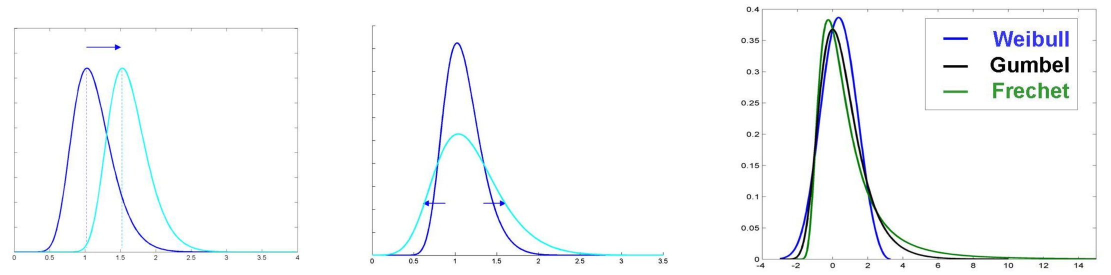
[1 1 1 0 0 0 1 0 1 0]

- 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:

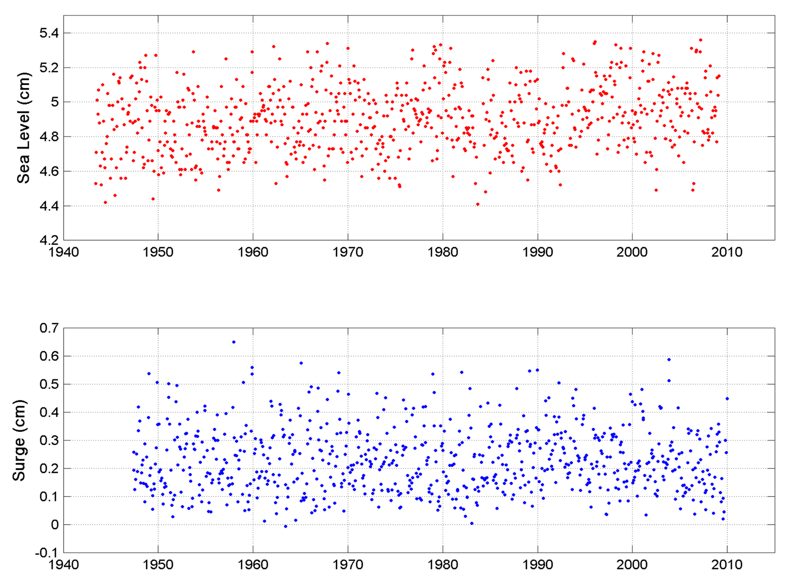
$$F(x;\theta) = \exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\psi}\right)\right]^{-1/\xi}\right\} \qquad \begin{pmatrix}\mu = \mu_t = f(time)\\ \psi = \psi_t = f(time)\\ \xi = \xi_t = f(time)\end{pmatrix}$$

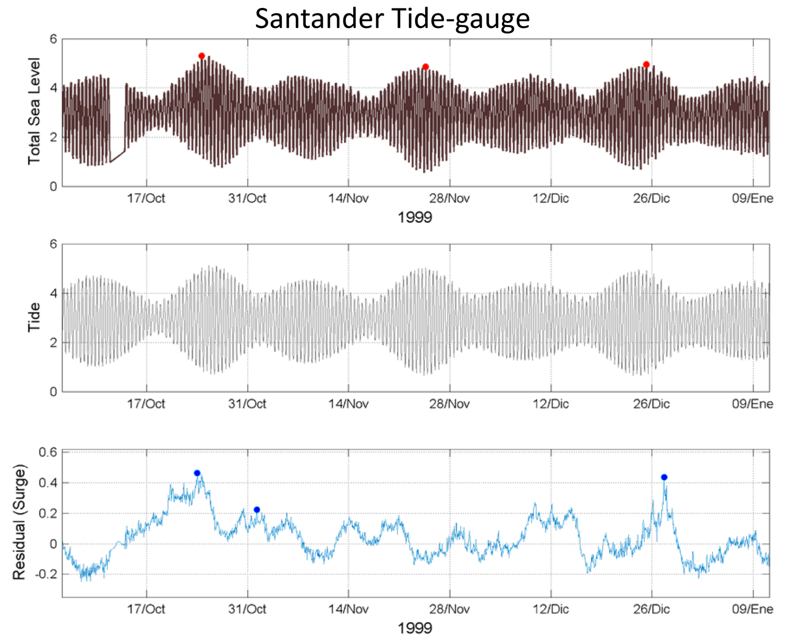


$\mu \rightarrow location$ $\psi \rightarrow scale$ $\xi \rightarrow shape$

Selection of extreme values: MONTHLY MAXIMA (MM)

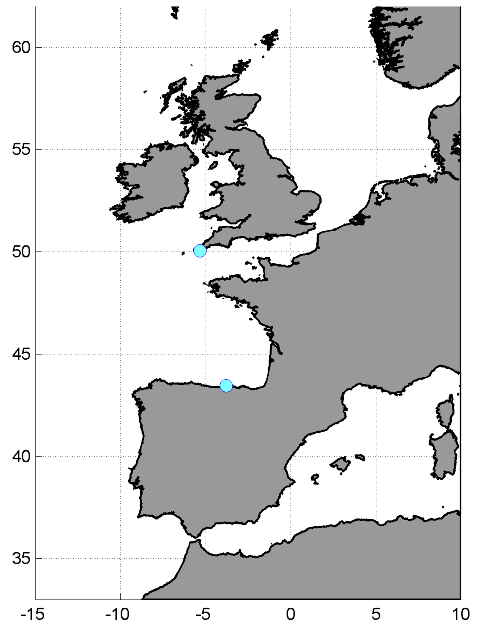
- Total Elevation
- Surge (non-tidal residual)





Data examples (tide-gauges):

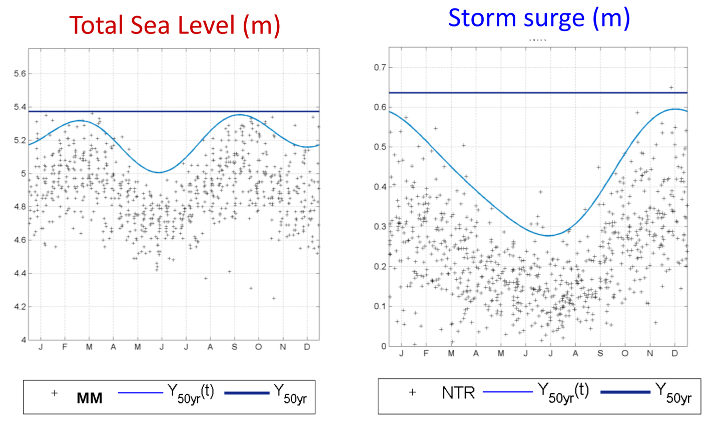
Newlyn (1915-2010)
Santander (1943-2010)

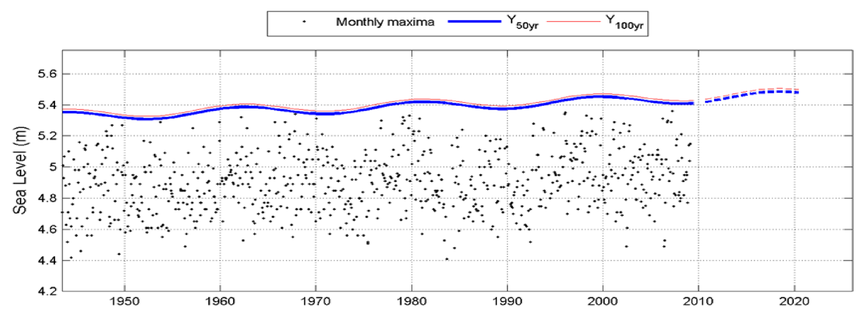


SANTANDER		Parameter	Total Sea Level: Priority order	Total Sea Level: Parameter estimated	Surge: Priority order	Surge: Parameter estimated
	Averaged Location parameter	β_0		4.785		0.181
	Averaged scale parameter	α_0		0.162		0.097
	Averaged shape parameter	γ_0		-0.334		-0.089
μ_S	Annual modulation	β_1	2	0.069	1	-0.002
		β_2		-0.018		0.024
	Semiannual modulation	β_3	1	-0.098		
		β_4		0.072		
ψ_S	Annual modulation	α_1	4	0.030	2	-0.005
		α_2		-0.014		0.011
	Semiannual modulation	α_3				
		α_4				
ξ_S	Annual modulation	γ_1			3	0.083
		γ_2				-0.066
	Semiannual modulation	γ_3				
		γ_4				
μ_{LT}	Trend on magnitude	β_{LT}	3	0.0018		
ψ_{LT}	Trend on dispersion	α_{LT}				
μ_N	Nodal Cycle	β_{N1}	5	0.030		
		β_{N2}		0.004		
μ_P	Perigean influence	β_{P1}	6	-0.017		
		β_{P2}		0.007		

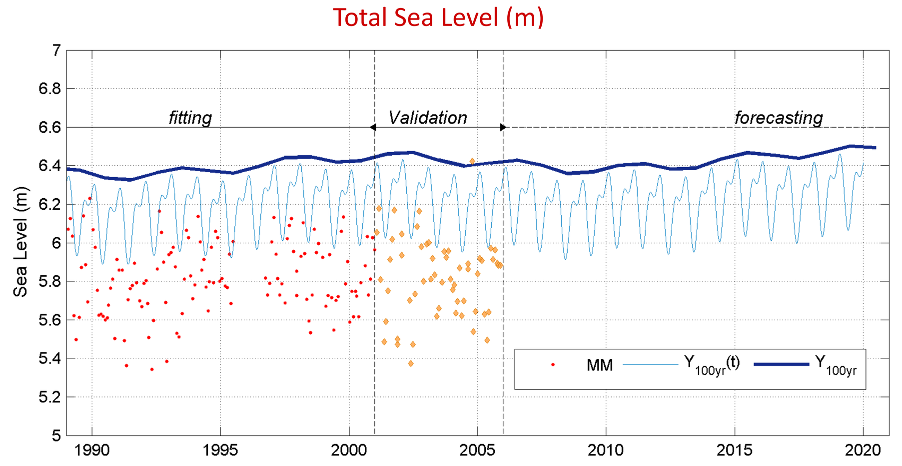
Extreme seasonal pattern:

Santander





Newlyn



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