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Importance of non-stationary analysis for assessing extreme sea levels under sea level rise

Damiano Baldan et al.

Correspondence to: Sara Morucci (sara.morucci@isprambiente.it) and Andrea Bonometto (andrea.bonometto@isprambiente.it)

Figure S1 – Tide and Surge distribution for Marseille and Venice. Both distributions are calculated from data spanning 30 years.

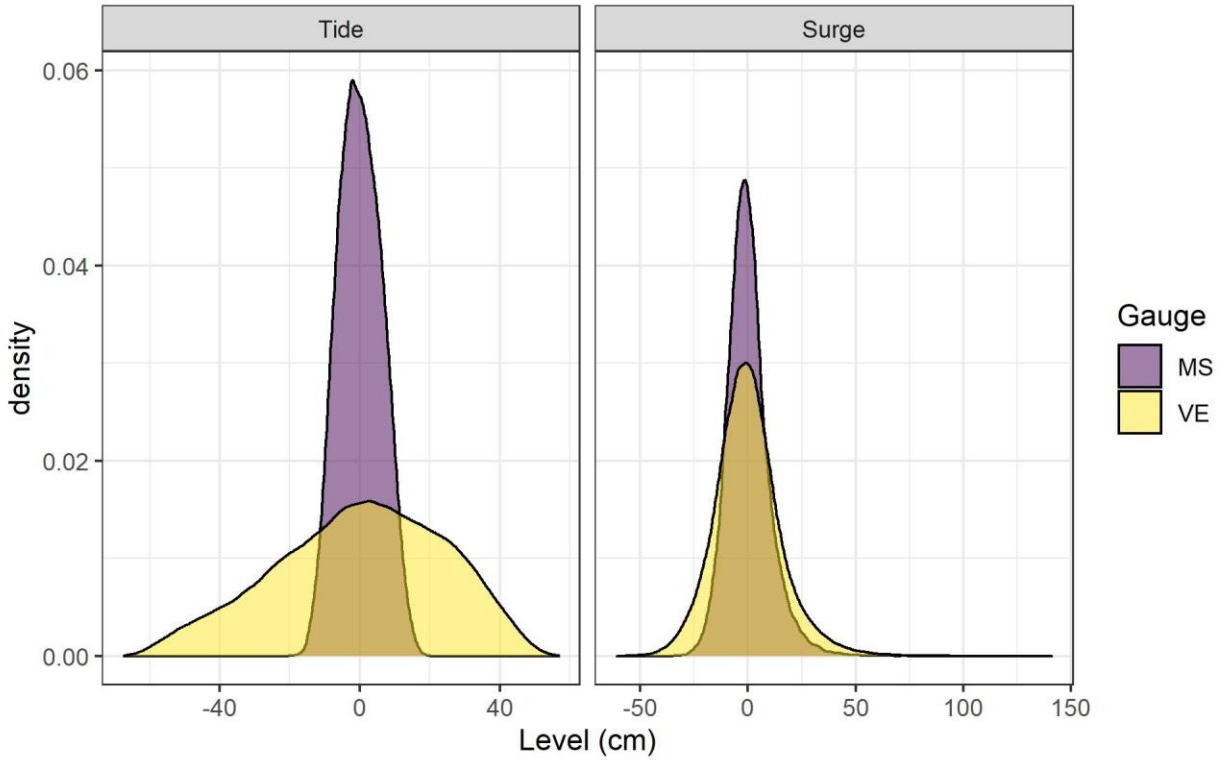

Figure S2 – Marseille data used to fit the models. Plots are grouped vertically according to the detrending method (MSL: mean sea level, MSL_L: long term mean sea level, NDT: non detrended), and horizontally according to the maxima typology (BM: block maxima, POT: peak over threshold). The text in the label on the top-left corner of each plot shows the significance level of the Mann-Kendall trend test (n.s.: non significant; .: $p < 0.1$; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$). The continuous line represents the mean sea level value; the dashed line represents the long-term mean sea level.

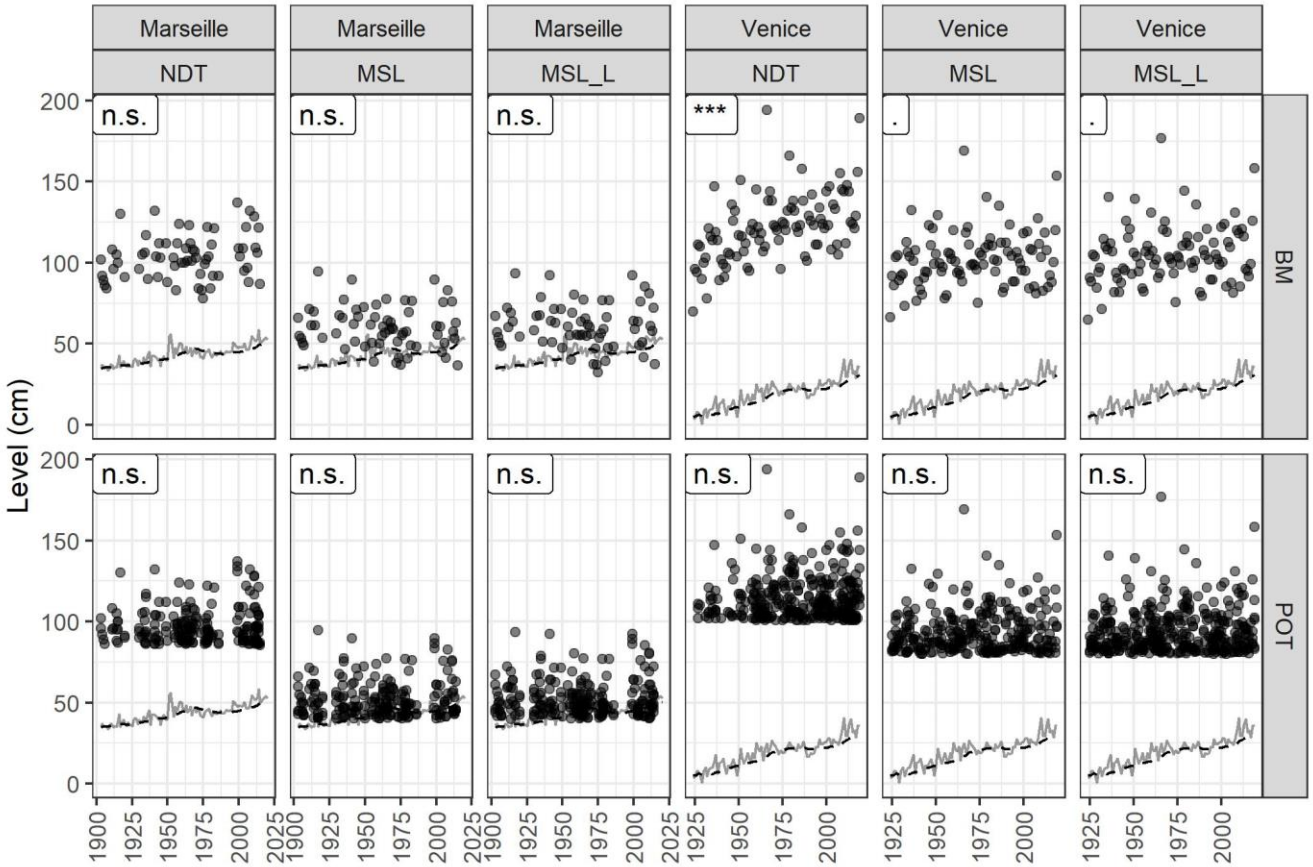

Figure S3 – Comparison between the parameters estimated in the time window analysis (dashed line; the grey envelope represents the uncertainty of the parameters from the time window analysis) and the parameters estimated by different models configurations over the full data length. Parameters from all the configurations of GEV, GPD and PP that do not include covariates are showed. Parameters from models with covariates are showed only if models improve significantly the fit (see Table 2 for the likelihood test). The shape ξ is included in the figure, but no covariates dependence was tested for this parameter. The horizontal axis represents the final year of the time window. Plots are grouped vertically according to the detrending method, and horizontally according to the distribution function. The text in the label on the top-left corner of each plot shows the significance level of the Mann-Kendall trend test on the parameters from the time-window analysis

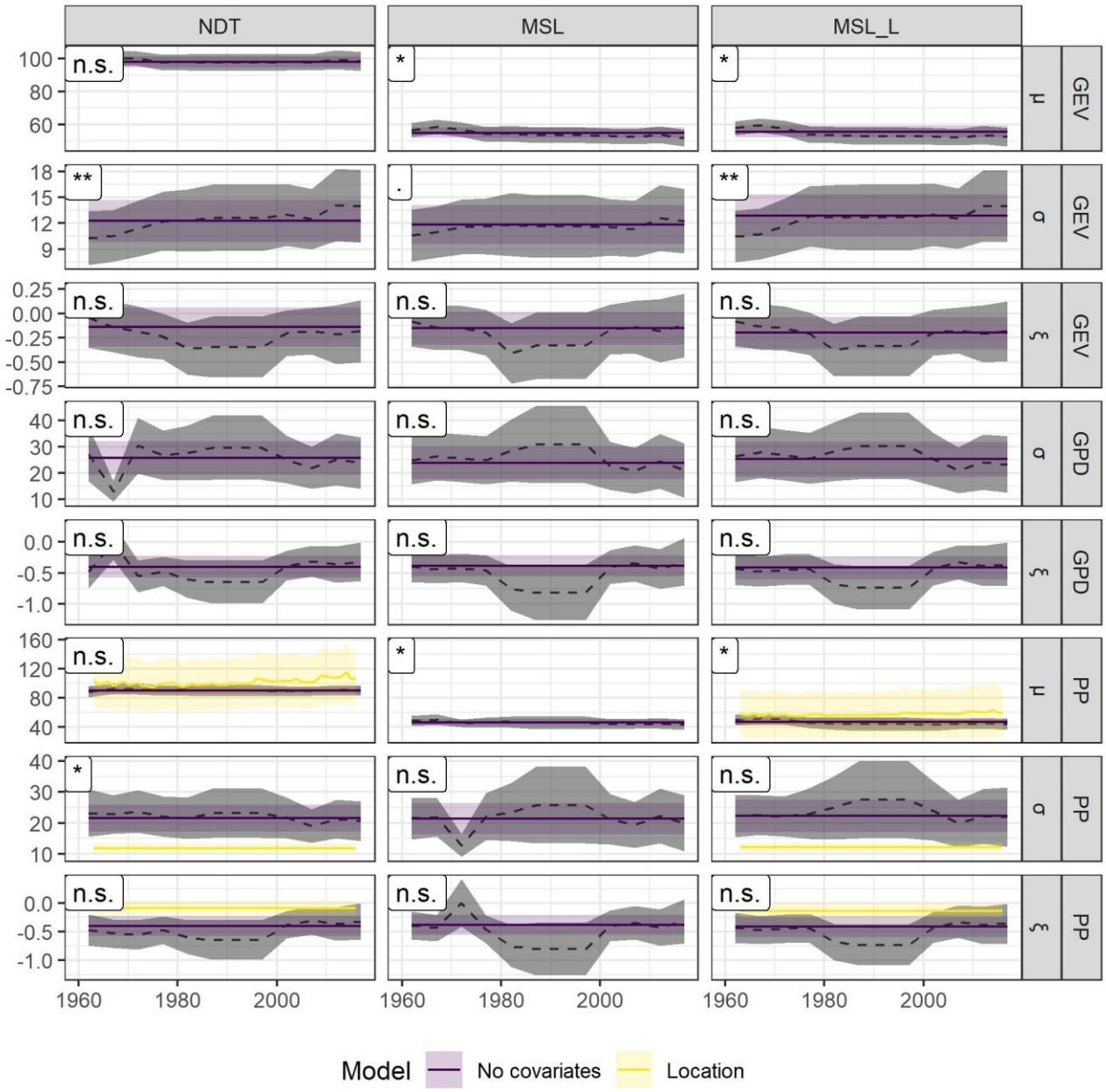

Figure S4 – Return level plot actualized to 2019 for Venice and Marseille. Plots are grouped vertically according to the detrending method (MSL: mean sea level, MSL_L: long term mean sea level, NDT: non detrended), and horizontally according to the distribution function (GEV: generalized extreme values, GPD: generalized pareto, PP: point process). The dashed line is the empirical return level for the joint probability method (JPM). Curves are color-coded based on the model configuration. Note: horizontal axis is logarithmic. Return level curves for direct models with covariates are reported only if the addition of the covariate improves the fit significantly ($p < 0.01$; see Table 2).

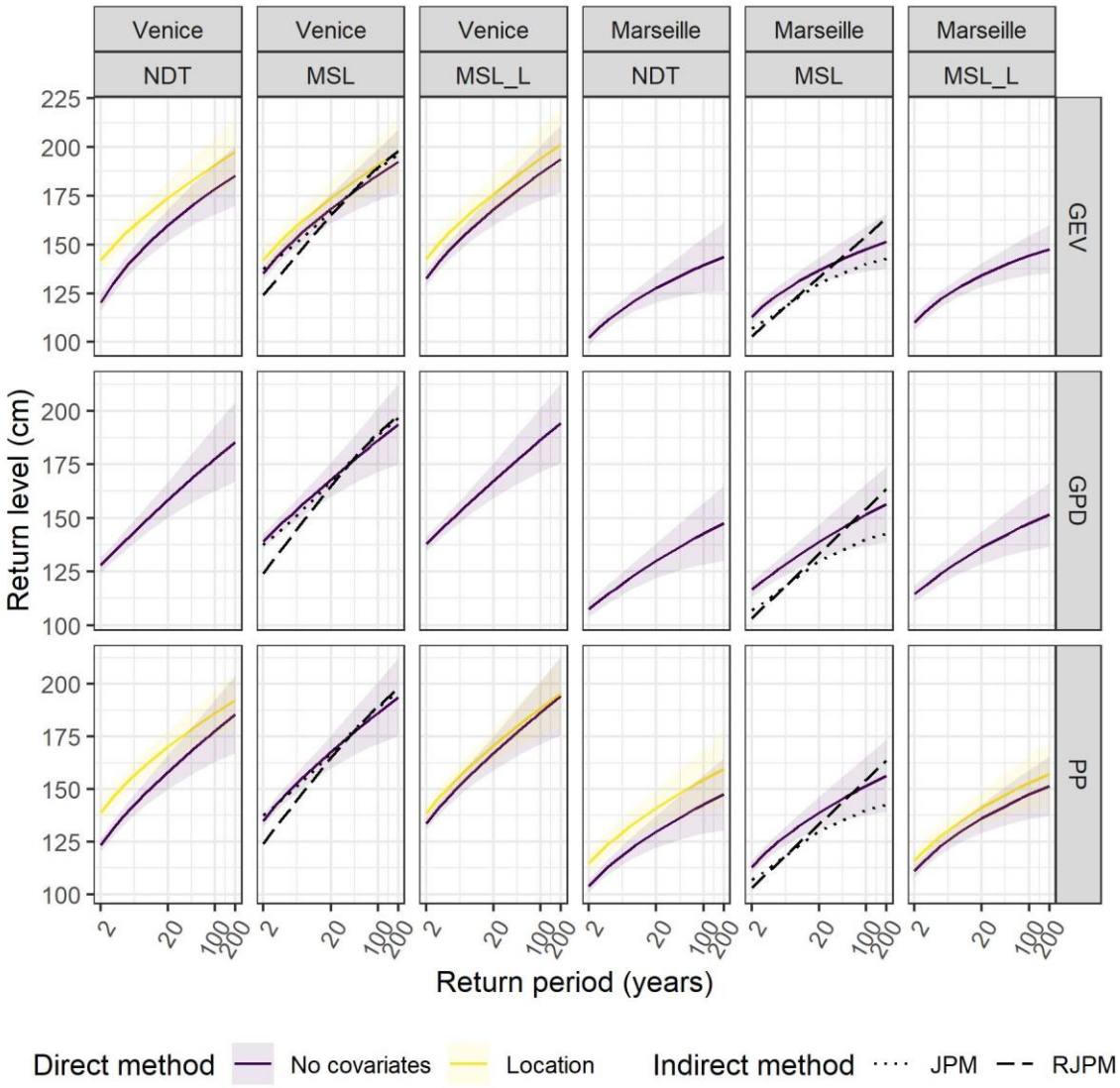

Figure S5 – Comparison of direct and indirect methods fitted to data that are 30 years long (for VE, models are fitted for 1990-2019, for MS, models are fitted to 1968-2019). Only Models obtained from MSL detrending strategy without covariates are reported.

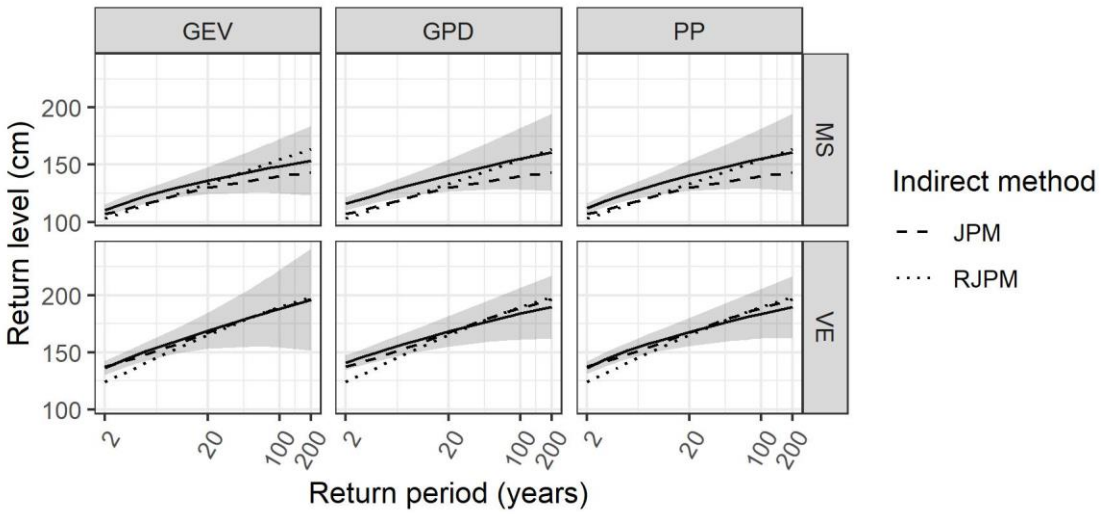

Table S1 – Return level estimates for Venice data. Numbers in brackets are the standard estimates.

Return period	Detrend	GEV			GPD		PP			JPM	RJPM
		No covariates	Location	Scale	No covariates	Scale	No covariates	Location	Scale		
2-years	MSL	136(132,139)	143(137,149)	145(137,153)	140(137,143)	146(141,151)	136(133,138)	138(134,143)	142(136,149)	138	124
2-years	MSL_L	134(130,137)	144(138,150)	146(138,154)	139(136,142)	146(141,152)	134(132,137)	140(135,144)	144(138,150)		-
2-years	NDT	120(116,125)	143(137,149)	145(137,153)	128(125,131)	133(128,138)	123(120,126)	139(134,145)	142(136,148)		-
20-years	MSL	169(161,176)	175(166,183)	181(165,197)	169(160,177)	182(165,199)	168(160,176)	170(162,178)	179(165,194)	167	165
20-years	MSL_L	169(161,177)	177(168,186)	184(167,201)	168(160,176)	184(165,202)	168(160,176)	172(164,179)	182(168,195)	-	-
20-years	NDT	160(152,168)	175(166,183)	181(165,197)	159(150,167)	169(155,184)	158(150,166)	171(163,178)	179(166,192)	-	-
100-years	MSL	186(173,200)	192(178,206)	199(178,221)	187(172,202)	205(171,238)	187(172,202)	188(174,202)	199(178,220)	189	189
100-years	MSL_L	187(174,201)	195(180,210)	203(180,226)	187(172,202)	208(173,243)	187(172,202)	190(177,203)	203(182,223)	-	-
100-years	NDT	179(166,191)	192(178,206)	199(178,221)	178(163,193)	192(165,219)	178(163,193)	187(176,198)	198(178,219)	-	-
200-years	MSL	193(177,210)	198(181,216)	206(182,231)	194(176,213)	214(172,256)	194(176,213)	195(178,213)	207(182,232)	197	198
200-years	MSL_L	195(178,212)	202(184,221)	211(184,237)	195(176,214)	218(174,262)	195(176,214)	197(181,213)	211(186,235)	-	-
200-years	NDT	185(170,201)	198(181,216)	206(182,231)	186(167,204)	201(167,235)	186(167,204)	193(180,206)	206(182,230)	-	-

Table S2 – Return level estimates for Marseille data. Numbers in brackets are the standard estimates.

Return period	**Detrend**	**GEV**			**GPD**		**PP**			**JPM**	**RJPM**
		No covariates	Location	Scale	No covariates	Scale	No covariates	Location	Scale		
2-years	MSL	111(108,115)	110(103,116)	110(103,116)	115(111,119)	115(112,119)	111(108,114)	112(108,116)	112(107,117)	107	103
2-years	MSL_L	110(107,114)	111(104,118)	111(104,118)	115(111,119)	115(111,119)	111(108,114)	115(111,120)	114(109,119)	-	-
2-years	NDT	102(99,106)	110(103,116)	110(103,116)	108(104,111)	108(104,112)	104(101,107)	113(108,117)	112(107,117)	-	-
20-years	MSL	135(129,142)	134(125,142)	135(122,148)	137(129,145)	138(129,146)	137(130,145)	138(130,146)	138(126,149)	130	133
20-years	MSL_L	135(129,141)	136(127,144)	137(125,149)	137(129,144)	137(129,145)	136(130,143)	141(133,148)	138(128,148)	-	-
20-years	NDT	128(120,135)	134(125,142)	135(122,148)	130(122,138)	132(122,141)	130(122,137)	139(131,148)	136(125,148)	-	-
100-years	MSL	146(135,158)	144(132,157)	147(126,168)	150(136,164)	150(136,165)	150(136,164)	150(136,165)	150(132,168)	140	154
100-years	MSL_L	145(134,155)	146(134,157)	147(130,165)	148(135,160)	148(135,161)	148(136,160)	153(140,165)	149(134,163)	-	-
100-years	NDT	139(125,153)	144(132,157)	147(126,167)	143(128,157)	145(128,161)	143(129,157)	153(138,167)	148(130,166)	-	-
200-years	MSL	150(136,164)	148(133,164)	151(127,175)	155(137,172)	155(137,173)	155(137,172)	155(138,173)	155(134,176)	143	164
200-years	MSL_L	148(136,160)	149(135,163)	151(130,172)	152(137,167)	152(137,168)	152(138,166)	157(142,172)	152(136,169)	-	-
200-years	NDT	144(126,161)	148(133,164)	151(127,175)	148(130,165)	150(129,170)	147(130,165)	158(140,175)	153(132,174)	-	-