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Longitudinal wave power as a proxy for coastal change detection

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Information related to the Van Rijn formulation

Table S1. Parameters used for the sediment formulation. [-] indicated non-dimensional and [log] indicated a logical value.

Parameter	Value	Definition
IopSus	0 [log]	Suspended particle diameter determination
Pangle	51 [deg]	Phase lead for bed shear stress
Fpco	1 [-]	Phase lag effect in wave-induced suspended transport
Subiw	51 [-]	Wave period subdivision
EpsPar	0 [log]	Van Rijn's parabolic mixing coefficient
GamTcr	1.5 [-]	Power of the grain size ratio in the critical shear stress expression
SalMax	0 [-]	Salinity for saline settling velocity
BetaM	0 [-]	Exponent used for effect of mud fraction on critical shear stress
Wform	1 [log]	Wave form used

Model set-up.

Table S2. Overview of the Delft3D and SWAN model parameters.

Parameter	Value	Units	Description
General			
Tstart	0	min	Start time
Tstop	525600	min	Stop time
Dt	0.1	min	Timestep
Ag	9.81	ms^{-2}	Gravitational Acceleration
Flow			
Rhow	1000	kgm^{-3}	Water Density
Tempw	15	C	Water Temperature
Salw	31	ppt	Salinity
Rouwav	FR84		Bottom Stress formulation due to wave action
Rhoa	1	kgm^{-3}	Air Density
Ccofu	65	$m^{0.5}s^{-1}$	Chezy roughness u
Ccofv	65	$m^{0.5}s^{-1}$	Chezy roughness v
Vicouv	2		Uniform horizontal eddy viscosity
Dicouv	10		Uniform vertical eddy diffusivity
Irov	0		Wall roughness (slip condition)
Dryflc	0.05	m	Threshold depth for drying and flooding
Tlfsmo	60	s	Time interval to smooth hydrodynamic boundary conditions
North	Neumann		North boundary condition
RettisNorth	0	min	North Thatcher Harlemann return time
East	water level	m	East boundary condition
South	Neumann		South boundary condition
RettisEast	0	min	South Thatcher Harlemann return time
River	discharge	m^3/s	River boundary condition
RettisRiver	0	min	River Thatcher Harlemann return time
Waves			
MinimumDepth	0.05	m	Minimum depth
GenModePhysics	3		Generation mode of physics
Breaking	true		Include wave breaking
BreakAlpha	1		Alpha coefficient for wave breaking
BreakGamma	0.73		Gamma coefficient for wave breaking
BedFriction	jonswap		Bed friction type
BedFricCoef	0.067		Bed friction coefficient
Diffraction	false		Include diffraction
WindGrowth	false		Include wind growth
WhiteCapping	Komen		White capping formulation
Quadruplts	false		Include quadruplets
Refraction	true		Include refraction
FreqShift	true		Include frequency shifting in frequency space
WaveForces	Dissipation 3d		Method of wave force computation
FlowBedLevel 1	0		Use bed level from FLOW in WAVE domain but do not extend
FlowWaterLevel 1	0		Use water level from FLOW and extend across WAVE domain
FlowVelocity 1	0		Use water level from FLOW and extend across WAVE domain
FlowBedLevel 2	use / extend (2)		Use bed level from FLOW and extend across WAVE domain
FlowWaterLevel 2	use / extend (2)		Use water level from FLOW and extend across WAVE domain
FlowVelocity 2	use / extend (2)		Use flow velocity from FLOW and extend across WAVE domain
DirSpace	circle		Default directional space
Ndir	36		Number of directional bins
FreqMin	0.05	s^{-1}	Minimum frequency
FreqMax	1	s^{-1}	Maximum frequency
Nfreq	24		Number of frequencies
SpectrumSpec	parametric		Spectrum type
SpShapeType	jonswap		Spectrum shape
PeriodType	peak		Wave period type
DirSpreadType	power		Directional spreading type
PeakEnhanceFac	3.3		Peak enhancement factor
WaveHeight	var	m	Wave height at boundaries
PeriodType	var	s	Wave period at boundaries
Direction	var	deg	Wave direction at boundaries
DirSpreading	4	deg	Directional spreading
Morphology			
EpsPar	false		Vertical mixing distribution according to van Rijn
MorFac	1		Morphological scale factor
MorStt	720	min	Spin-up interval from TStart to the start of morphological changes
Thresh	0.05	m	Threshold sediment thickness for transport and erosion reduction
MorUpd	true		Update bathymetry during FLOW simulation
EqmBc	true		Equilibrium sand concentration profile at inflow boundaries
DensIn	false		Include effect of sediment concentration on fluid density

Parameter	Value	Units	Description
AksFac	1		van Rijn's reference height
Rwave	2		Wave related roughness. Van Rijn recommends range 1-3
AlfaBs	1		Streamwise bed gradient factor for bed load transport
AlfaBn	1.5		Transverse bed gradient factor for bed load transport
Sus	1		Multiplication factor for suspended sediment ref. concentration
Bed	1		Multiplication factor for bed-load transport vector magnitude
SusW	0.15		Wave-related suspended sed. transport factor
BedW	0.15		Wave-related bed-load sed. transport factor
SedThr	0.1	m	Minimum water depth for sediment computations
ThetSD	1		Factor for erosion of adjacent dry cells
HMaxTH	1.5	m	Max depth for variable THETSD.
FWFac	1		Tuning parameter for wave streaming
Sediment			
Cref	1600	kgm^{-3}	CSoil Reference density for hindered settling calculations
RhoSol	2650	kg/m^3	Specific density
SedDia	0.001	m	Median sediment diameter (D50)
CdryB	1600	kg/m^3	Dry bed density
IniSedThick	10	m	Initial sediment sand layer thickness at bed, updrift sediments
FacDSS	1		FacDss * SedDia = Initial suspended sediment diameter.
IopSus	false		Suspended particle diameter determination
Pangle	51	deg	Phase lead for bed shear stress
Fpco	1		Phase lag effect in wave-induced suspended transport
Subiw	51		Wave period subdivision
EpsPar	false		Van Rijn's parabolic mixing coefficient
GamTcr	1.5		Power of the grain size ratio in the critical shear stress expression
SalMax	0		Salinity for saline settling velocity
BetaM	0		Exponent used for effect of mud fraction on critical shear stress
Wform	true		Wave form used

POT combinations.

Table S3. POT combinations for the morphological and climatic events

Combination number	Percentile	Independence criterion (days)	Minimum event duration (hours)
1	95	2	6
2	95	2	12
3	95	2	18
4	95	2	24
5	95	2	48
6	95	3	6
7 (T-POT)	95	3	12
8	95	3	18
9	95	3	24
10	95	3	48
11	95	4	6
12	95	4	12
13	95	4	18
14	95	4	24
15	95	4	48
16	96	2	6
17	96	2	12
18	96	2	18
19	96	2	24
20	96	2	48
21	96	3	6
22	96	3	12
23	96	3	18
24	96	3	24
25	96	3	48
26	96	4	6
27	96	4	12
28	96	4	18
29	96	4	24
30	96	4	48
31	98	2	6
32	98	2	12
33	98	2	18
34	98	2	24
35	98	2	48
36	98	3	6
37	98	3	12
38	98	3	18
39	98	3	24
40	98	3	48
41	98	4	6
42	98	4	12
43	98	4	18
44	98	4	24
45	98	4	48

Sensitivity analysis

Table S4. Match results obtained for the T-POT (POT(95,3,12)) and the Optimal POT(POT(95,4,6)) combination, including the original simulation and sensitivity analyses of uniform horizontal eddy viscosity (ε) and Chèzy roughness coefficients.

			LWP-ME90		Hs-ME90		LWP-ME95		Hs-ME95	
			NCV	SCV	NCV	SCV	NCV	SCV	NCV	SCV
1980-1981	*T-POT*	**Original**	**49.40**	**55.78**	**34.13**	**32.01**	**65.47**	**82.49**	**53.39**	**55.58**
		ε=1	49.40	55.78	34.13	32.01	65.47	82.49	53.39	55.58
		ε=5	49.40	55.78	34.13	32.01	65.47	82.49	53.39	55.58
		Chèzy=60	49.40	55.78	34.13	32.01	65.47	82.49	53.39	55.58
		Chèzy=70	49.40	55.78	34.13	32.01	65.47	82.49	53.39	55.58
	Optimal POT combination	**Original**	**53.20**	**55.78**	**37.05**	**35.53**	**72.88**	**82.49**	**53.39**	**62.58**
		ε=1	53.20	55.78	37.05	35.53	72.88	82.49	53.39	62.58
		ε=5	53.20	55.78	37.05	35.53	72.88	82.49	53.39	62.58
		Chèzy=60	53.20	55.78	37.05	35.53	72.88	82.49	53.39	62.58
		Chèzy=70	53.20	55.78	37.05	35.53	72.88	82.49	53.39	62.58
1999-2000	T-POT	**Original**	**50.17**	**53.25**	**36.20**	**35.03**	**63.04**	**68.25**	**46.96**	**36.07**
		ε=1	50.17	53.25	36.20	35.03	63.04	68.25	46.96	36.07
		ε=5	50.17	53.25	36.20	35.03	63.04	68.25	46.96	36.07
		Chèzy=60	50.17	53.25	36.20	35.03	63.04	68.25	46.96	36.07
		Chèzy=70	50.17	53.25	36.20	35.03	63.04	68.25	46.96	36.07
	Optimal POT combination	**Original**	**53.52**	**56.72**	**51.06**	**48.05**	**66.52**	**72.35**	**63.26**	**56.37**
		ε=1	53.52	56.72	51.06	48.05	66.52	72.35	63.26	56.37
		ε=5	53.52	56.72	51.06	48.05	66.52	72.35	63.26	56.37
		Chèzy=60	53.52	56.72	51.06	48.05	66.52	72.35	63.26	56.37
		Chèzy=70	53.52	56.72	51.06	48.05	66.52	72.35	63.26	56.37

LvC index

Table S5. LvC index calculated for each CV and for each experiment.

Year (Experiment)	NCV	SCV
1980-1981 (1)	0.25	0.30
1990-1991 (2)	0.18	0.60
1999-2000 (3)	0.85	0.66
2000-2001 (4)	0.38	0.44
2010-2011 (5)	0.01	0.40
2019-2020 (6)	0.17	0.75

Figure S1. Comparison between volume changes, in north (a) and south CV (b), LWP (c) and wave height (d) during the 1990-91 climate for ME90 (90th percentile for volume variation). In (c,d) the CE related to T-POT are marked in red dots.

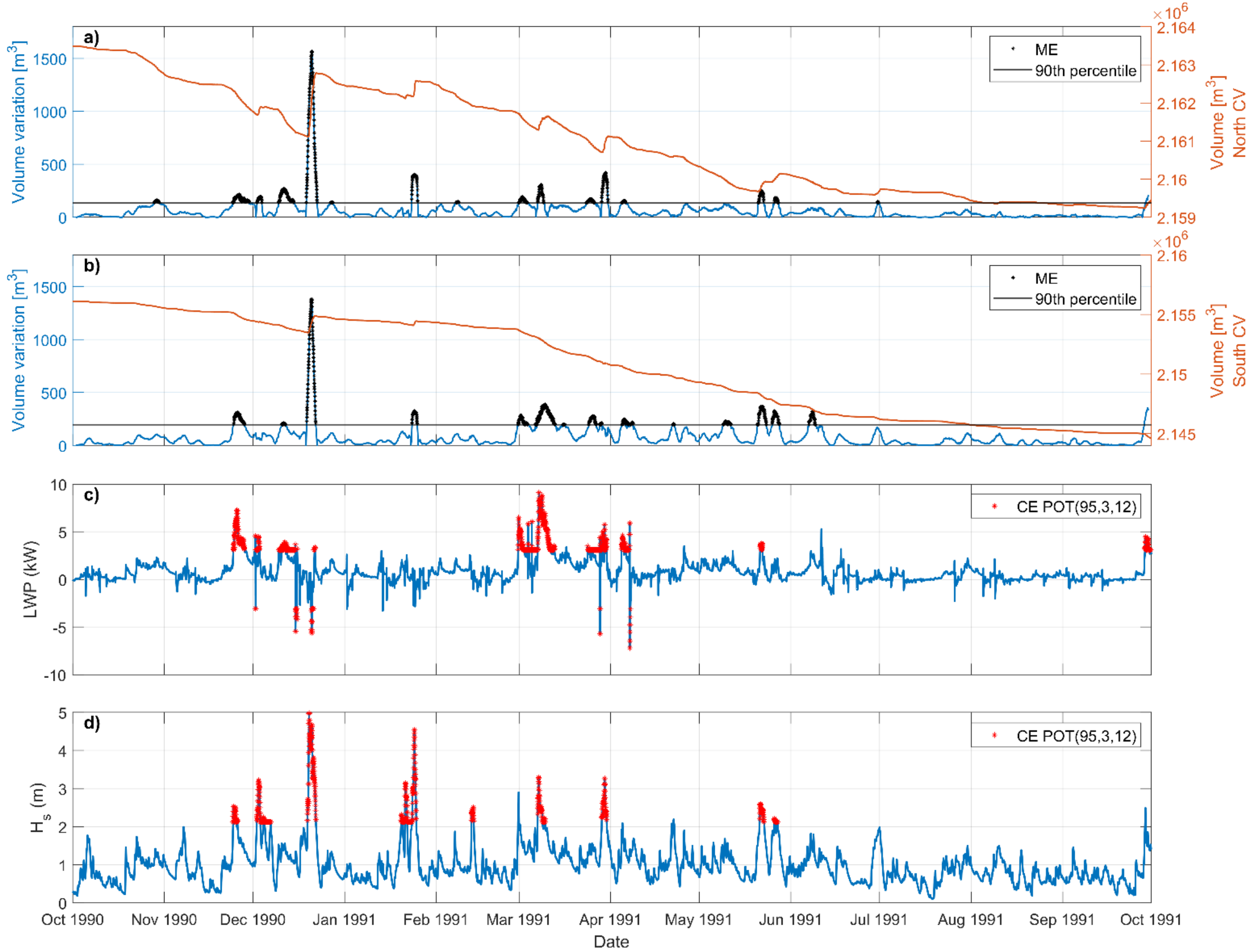

Figure S2. Comparison between volume changes, in north (a) and south CV (b), LWP (c) and wave height (d) during the 1990-91 climate for ME95 (95th percentile for volume variation). In (c,d) the CE related to T-POT are marked in red dots.

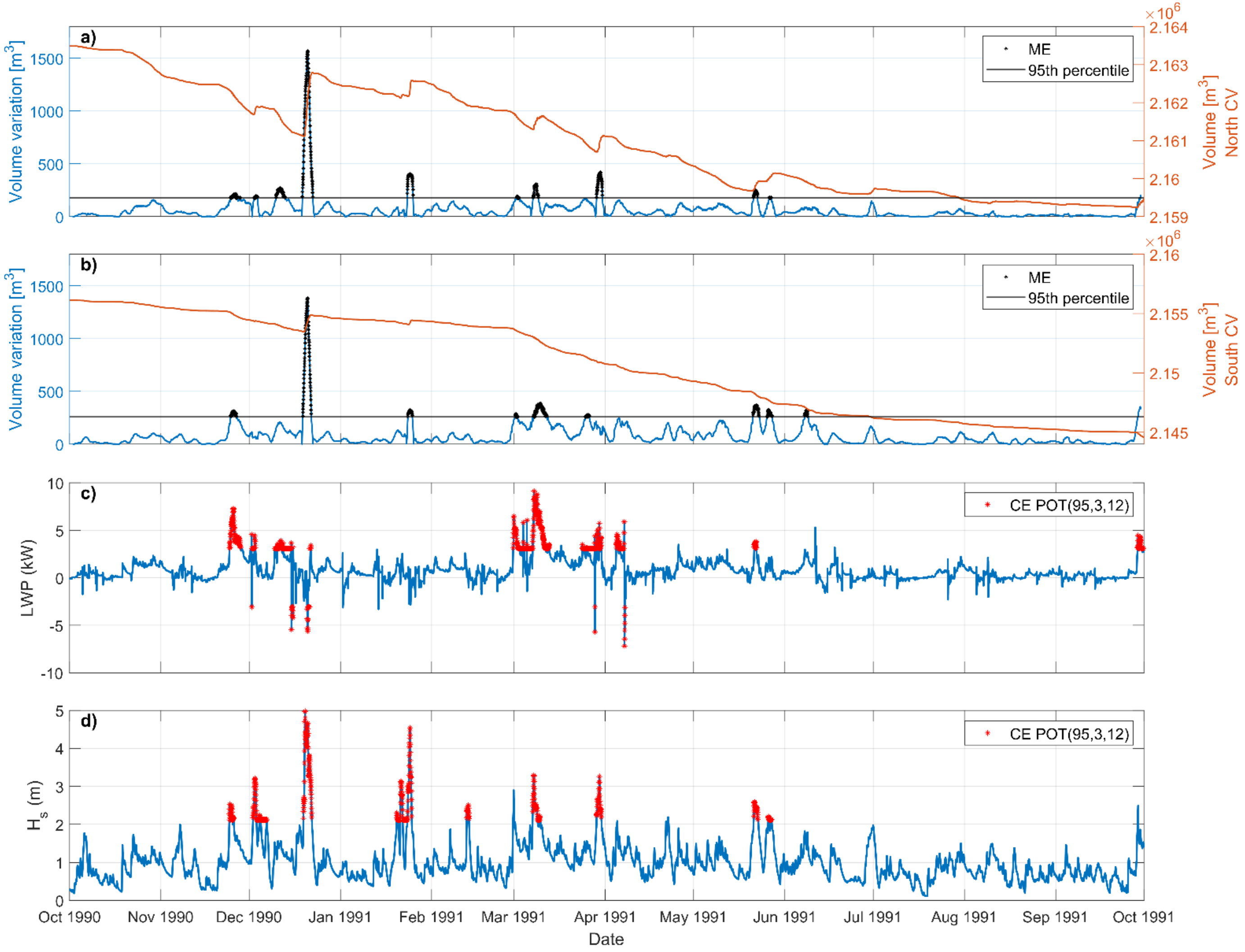

Figure S3. Comparison between volume changes, in north (a) and south CV (b), LWP (c) and wave height (d) during the 1999-2000 climate for ME90 (90th percentile for volume variation). In (c,d) the CE related to T-POT are marked in red dots.

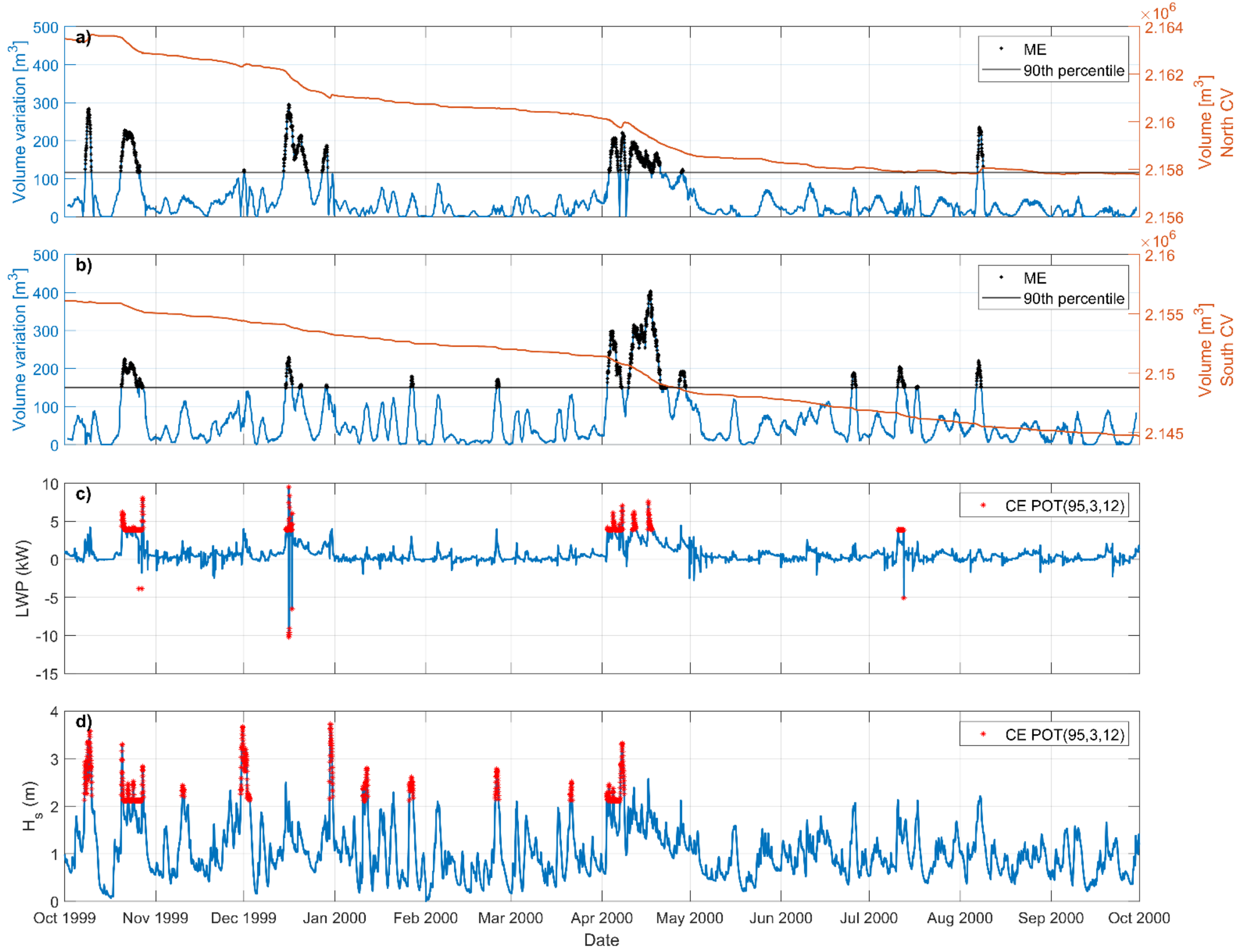

Figure S4. Comparison between volume changes, in north (a) and south CV (b), LWP (c) and wave height (d) during the 1999-2000 climate for ME95 (95th percentile for volume variation). In (c,d) the CE related to T-POT are marked in red dots.

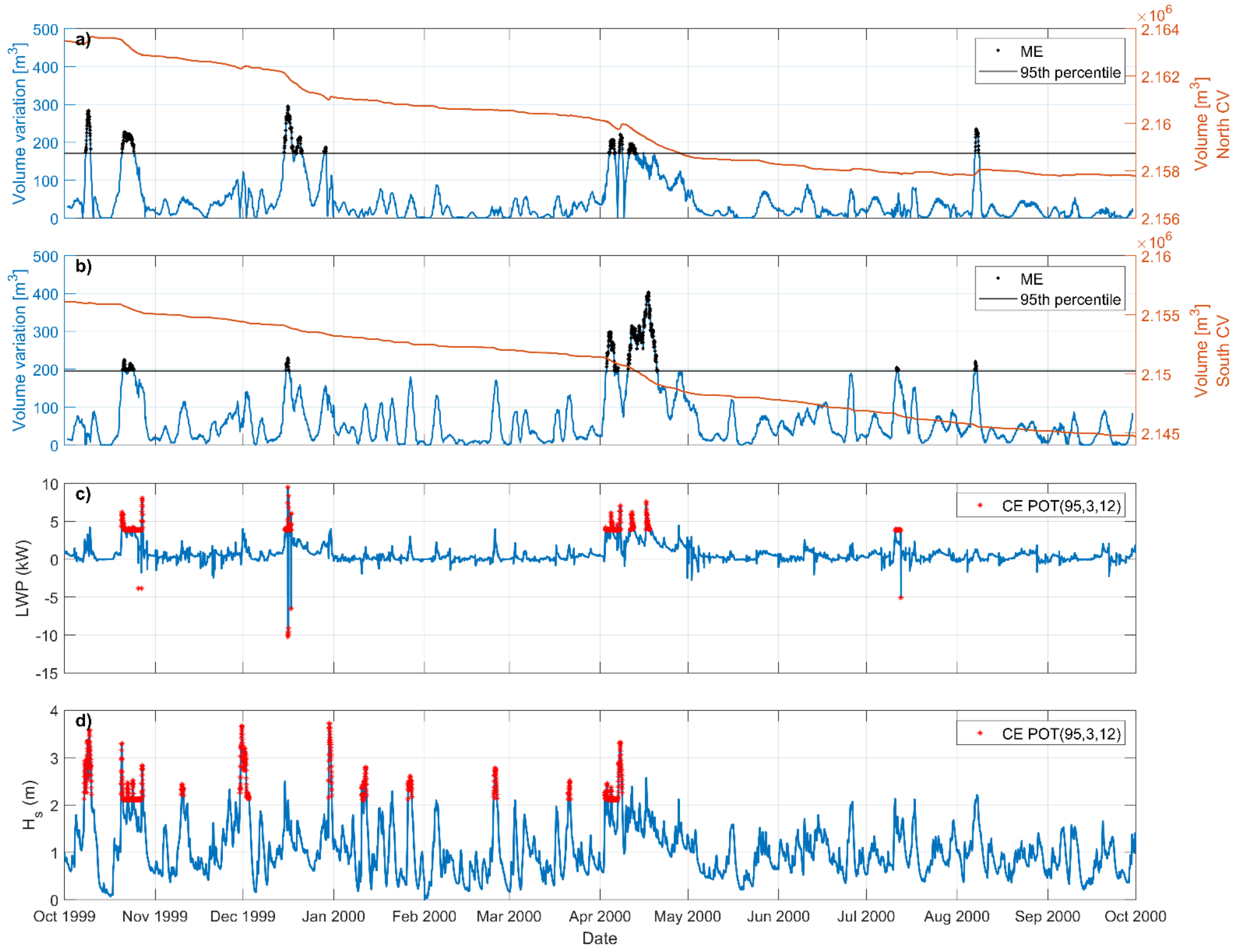

Figure S5. Comparison between volume changes, in north (a) and south CV (b), LWP (c) and wave height (d) during the 2000-2001 climate for ME90 (90th percentile for volume variation). In (c,d) the CE related to T-POT are marked in red dots.

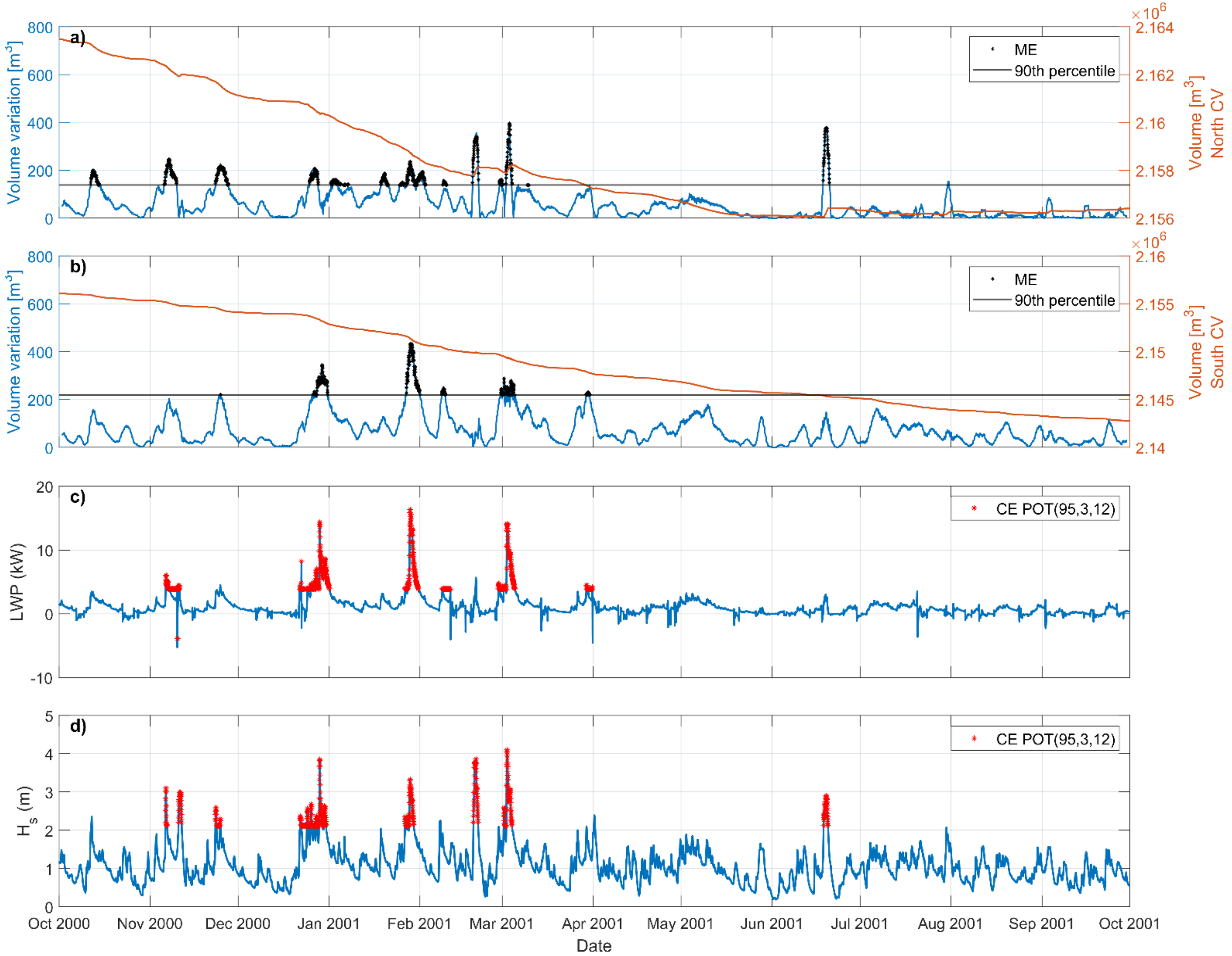

Figure S6. Comparison between volume changes, in north (a) and south CV (b), LWP (c) and wave height (d) during the 2000-2001 climate for ME95 (95th percentile for volume variation). In (c,d) the CE related to T-POT are marked in red dots.

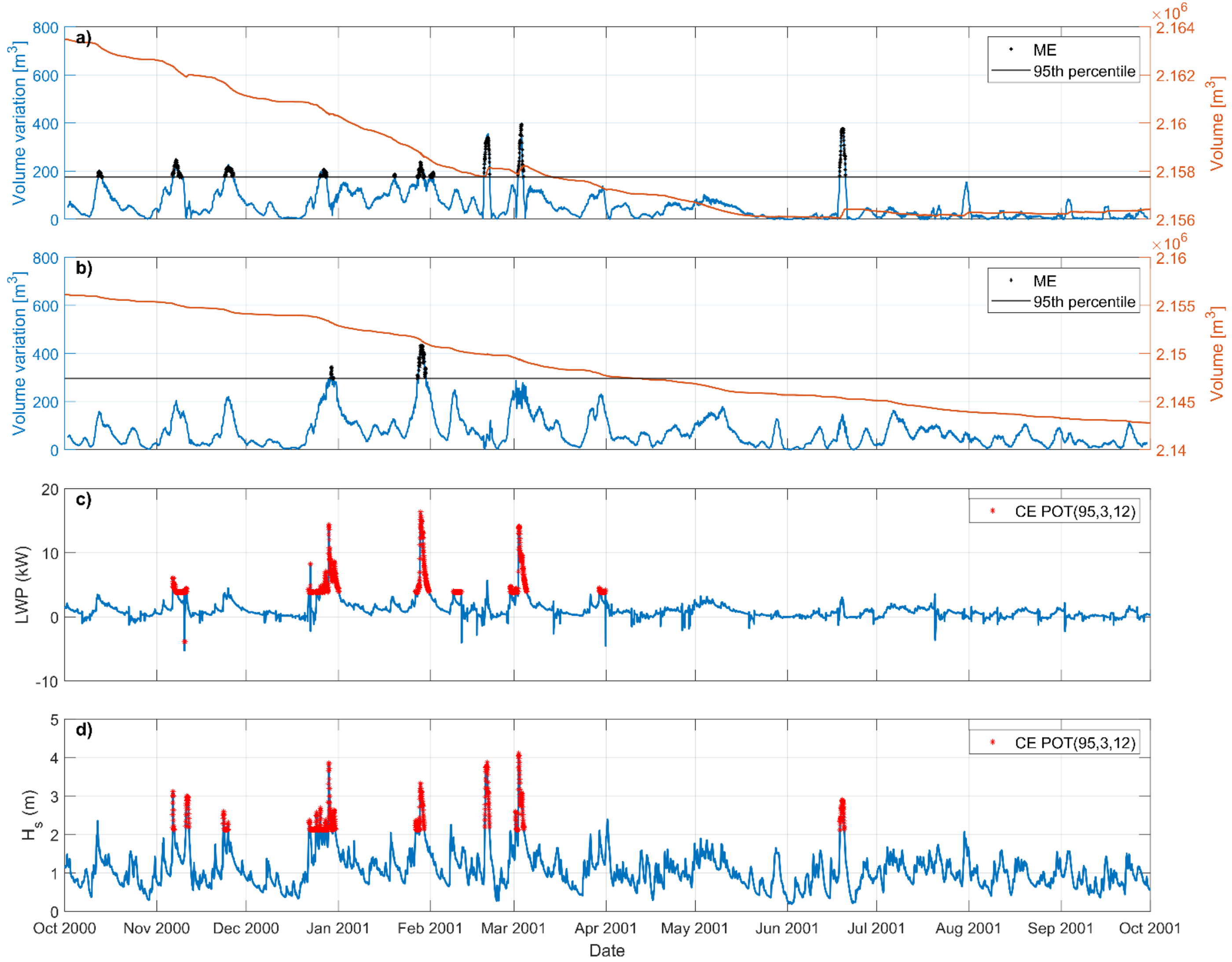

Figure S7. Comparison between volume changes, in north (a) and south CV (b), LWP (c) and wave height (d) during the 2010-11 climate for ME90 (90th percentile for volume variation). In (c,d) the CE related to T-POT are marked in red dots.

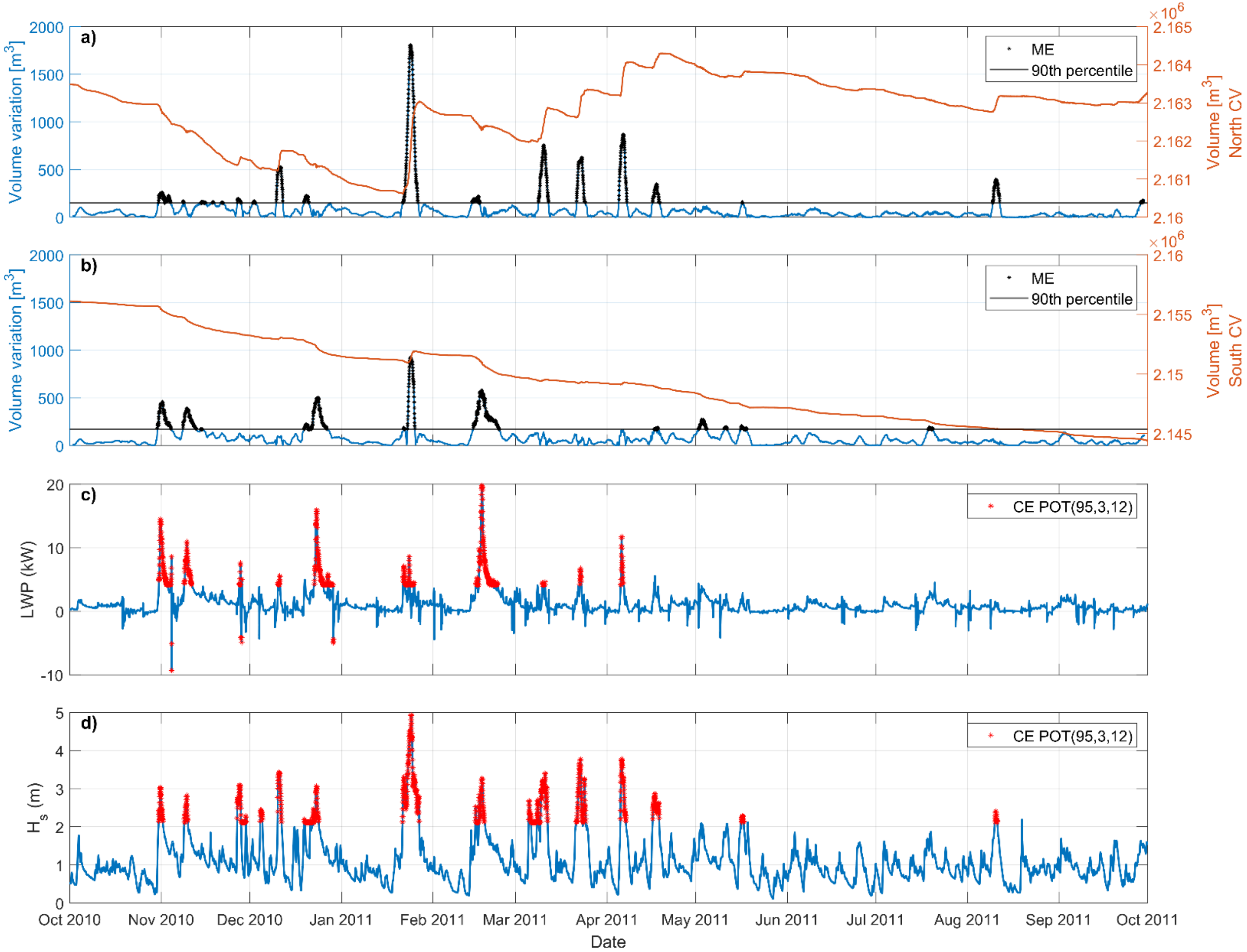

Figure S8. Comparison between volume changes, in north (a) and south CV (b), LWP (c) and wave height (d) during the 2010-11 climate for ME95 (95th percentile for volume variation). In (c,d) the CE related to T-POT are marked in red dots.

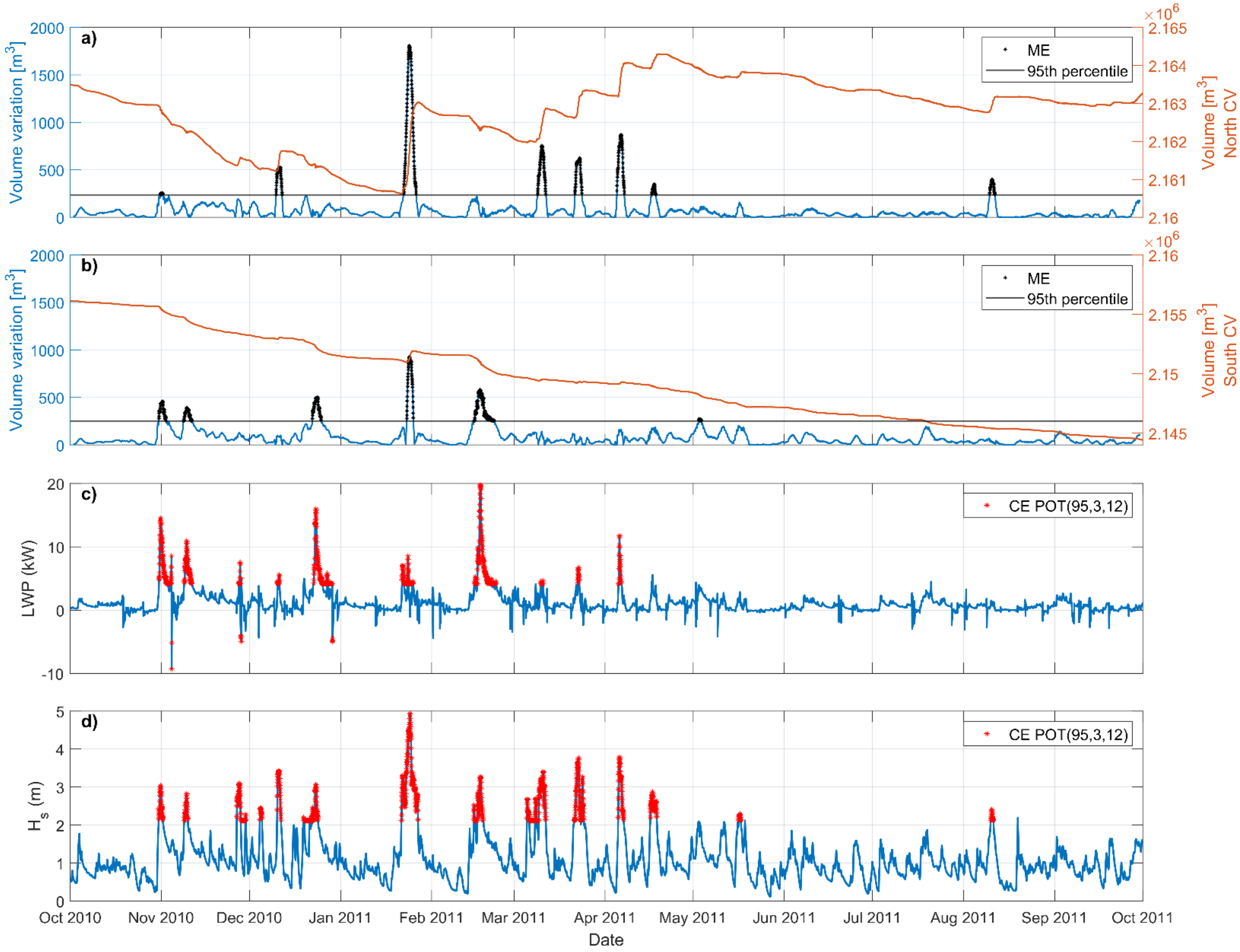

Figure S9. Comparison between volume changes, in north (a) and south CV (b), LWP (c) and wave height (d) during the 2019-20 climate for ME90 (90th percentile for volume variation). In (c,d) the CE related to T-POT are marked in red dots.

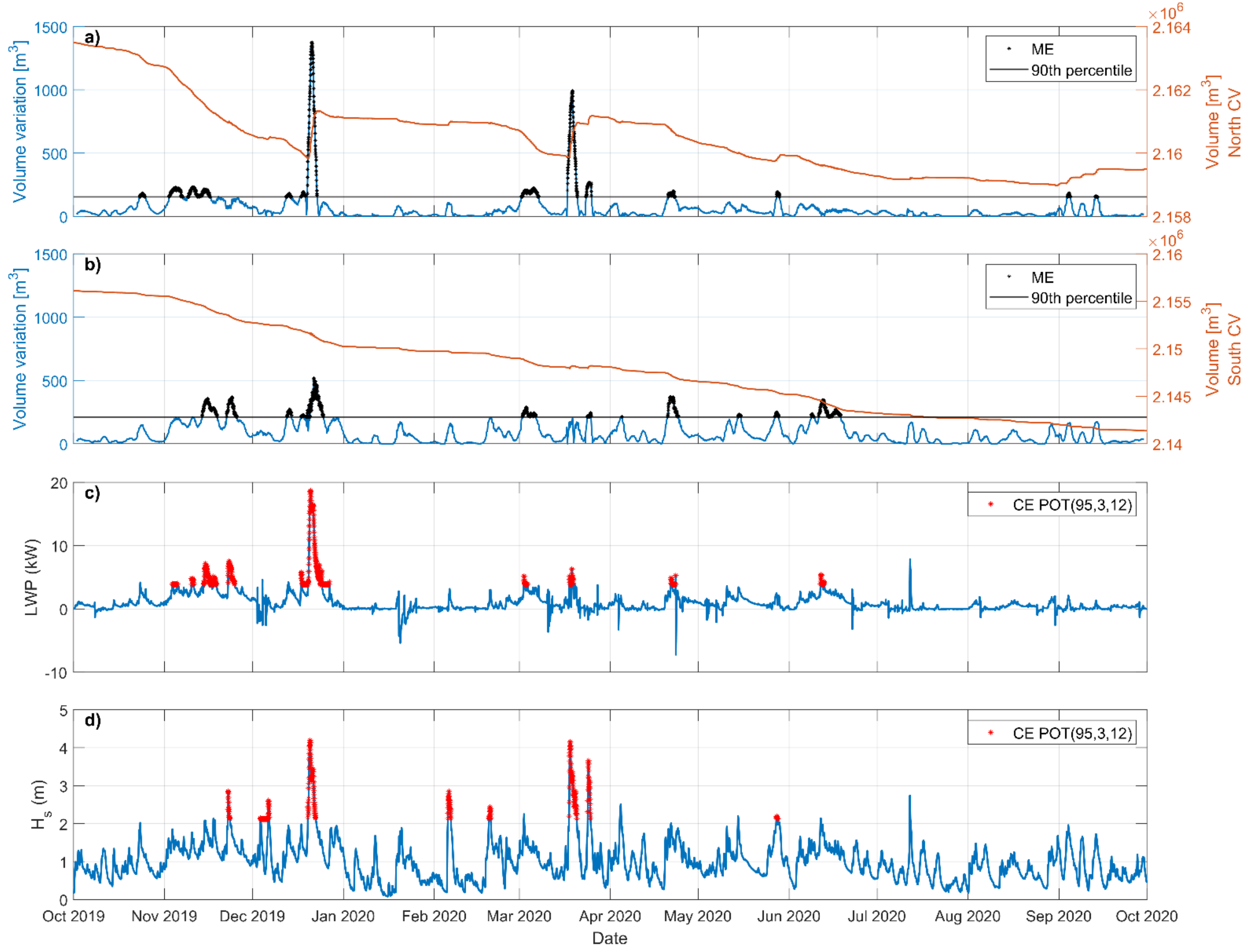

Figure S10. Comparison between volume changes, in north (a) and south CV (b), LWP (c) and wave height (d) during the 2019-20 climate for ME95 (95th percentile for volume variation). In (c,d) the CE related to T-POT are marked in red dots.

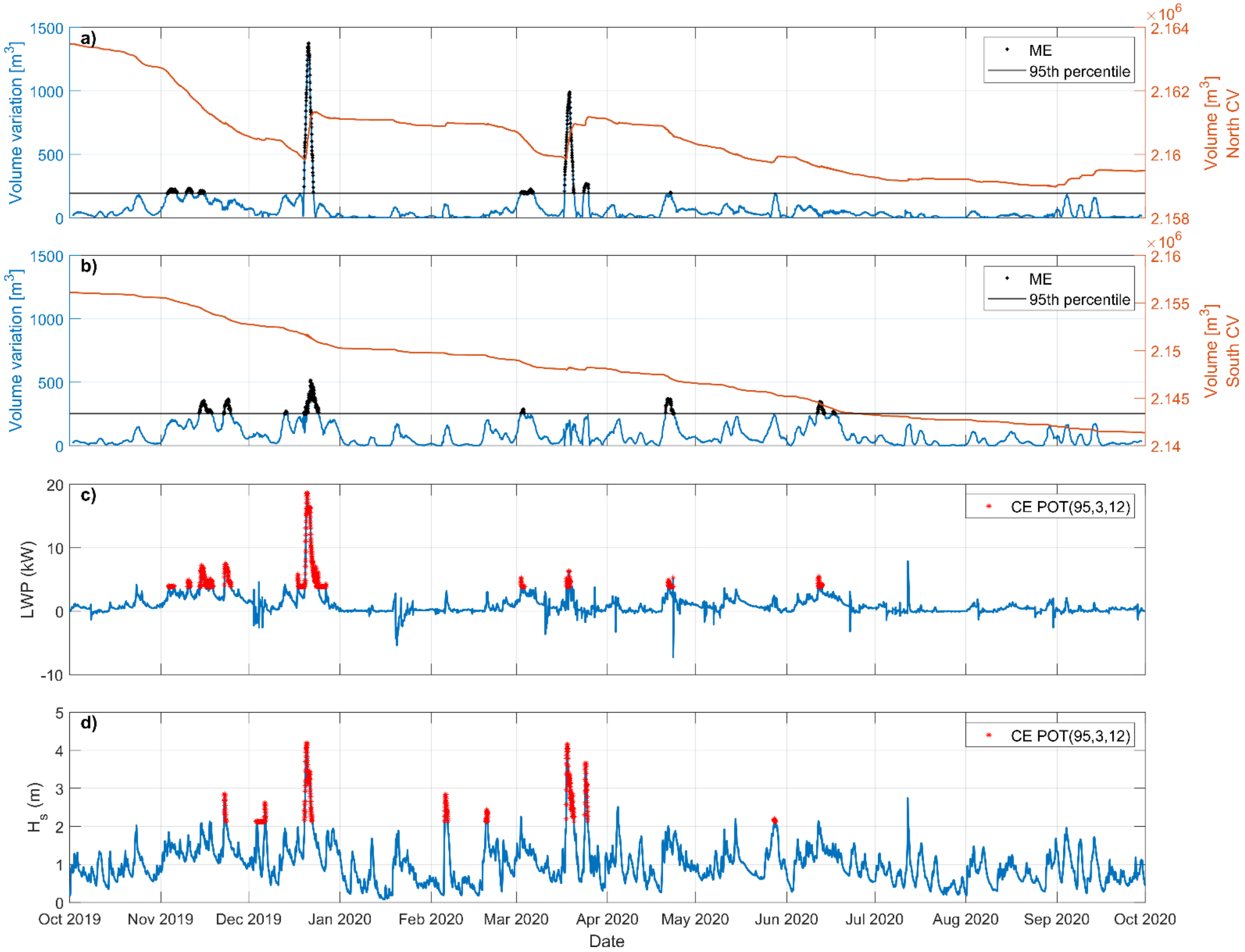

Figure S11. (a) Punta Umbría (study area) location in the Iberian Peninsula. (b) Control volume for the Punta Umbría Inlet shown on the actual bathymetry of the area. Bathymetric contours are represented every 1m, from 0 to -12 m MSL.

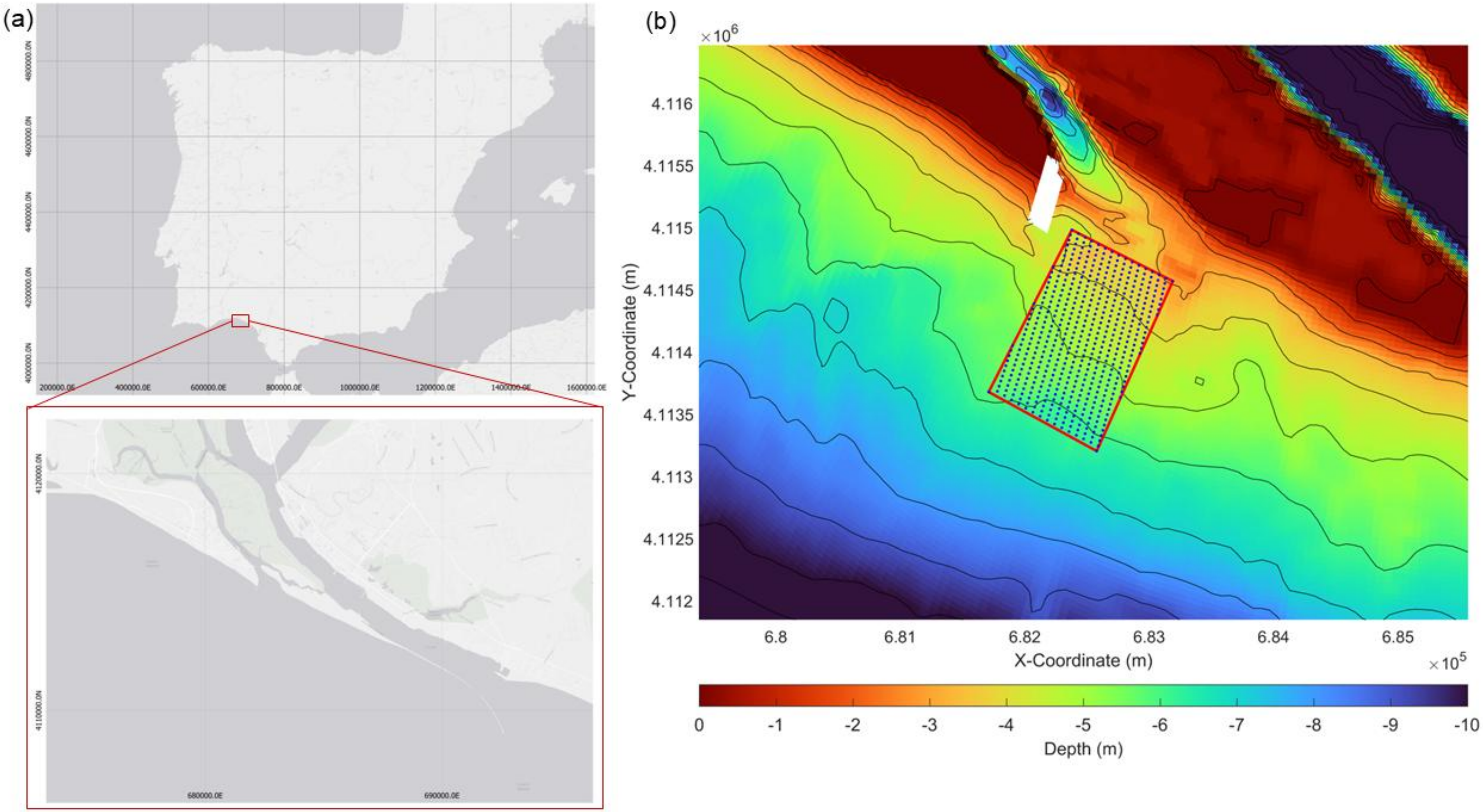

Figure S12. (a) Guadiana Estuary (study area) location in the Iberian Peninsula. (b) Control volume for the Guadiana Estuary shown on the actual bathymetry of the area. Bathymetric contours are represented every 1 m, from 0 to -12 m MSL.