Session 1: Introduction to Beach Morphodynamics

Session 1: Introduction au Morphodynamisme Côtier

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Synopsis

1.1 Coastal Erosion: A major hazard for the coastal zone ecosystems and socio-economic activity/assets

1.2 Coastal (beach) erosion: Causes

1.3 Monitoring and forecasting of beach erosion

1.4 Sea level rise and coastal erosion

1. 5 Erosion costs and adaptation and relevant regulation

1.1 Coastal Erosion: A major hazard

Coastal (beach) erosion, i.e. the shoreline retreat is a global phenomenon

Beaches (i.e. the low lying coasts built on unconsolidated sediments), are the most erosion sensitive coastal environments

Beaches are themselves valuable ecosystems; they also, front/protect various other important back-barrier environments/ecosystems

Beaches are very important economic resources; they also protect very expensive assets/infrastructure and activities

Beach erosion, which may or may not be accompanied by coastal sediment volume reduction, can be differentiated into:

- Long term erosion, i.e. non-reversible coastline retreat (and/or drowning), occurring in long (in engineering terms) temporal scales and

- Short term erosion, i.e. reversible or non-reversible retreat, occurring in short (in engineering terms) temporal scales

Tabel 1.1 Examples of beach erosion

	Erosion				Causes	Reference
	Long-term		*Short-term*			
	%	*rate*	*%*	*rate*		
St.Lawrence, Canada		up to 1.5m/y			Storm waves/surges	Forbes et al, 2004
S. Carolina (US)	70%	1.4 m/yr	59%	1.8 m/y	Storm waves and surges, SLR	Morton & Miller, 2005
Louisiana	91%	8.2±4.4 m/yr	88%	12.0 m/y	Subsidence,storm waves and surges, SLR, sediment supply reduction, coastal works	Morton et al, 2004
Texas (US)	64%	1.8±1.3 m/yr	48%	2.6 m/y	Subsidence,storm waves and surges, SLR, sediment supply reduction, coastal works	Morton et al, 2004
C. California (US)	53%	0.3±0.1 m/yr	79%	0.8±0.4 m/y	El Niño, storm waves and surges, SLR, sediment supply reduction, coastal works	Hapke et al, 2006
E. China	44%			420 m/y (delta)	Subsidence, storms, SLR, sediment supply reduction, coastal works, sand abstraction	Cai et al, 2009
Provence, France	40%	0.1±0.03 m/yr			60% of erosion due to SLR	Brunel and Sabatier, 2009
Cies Islands (Spain)		0.44 m/yr		1.7 - 3.2 m/y	NAO Storm waves and surges, SLR, sand abstraction	Costas & Alejo, 2007
E. UK			67%		Storm waves and surges, SLR,	Taylor et al., 2004
Romania,Black Sea	> 50%	5- 25 m/yr			Storm waves and surges, SLR, sediment supply reduction, coastal works	Stanica & Panin, 2009
Nigeria				3 m/y	Storm waves and surges, SLR sediment supply reduction	Okude & Ademiluyi, 2006
Negril (Jamaica)	> 80%	Up to 1.4 m/yr			Storm waves and surges, SLR, sediment supply and seagrass reduction,	RiVAMP, 2010

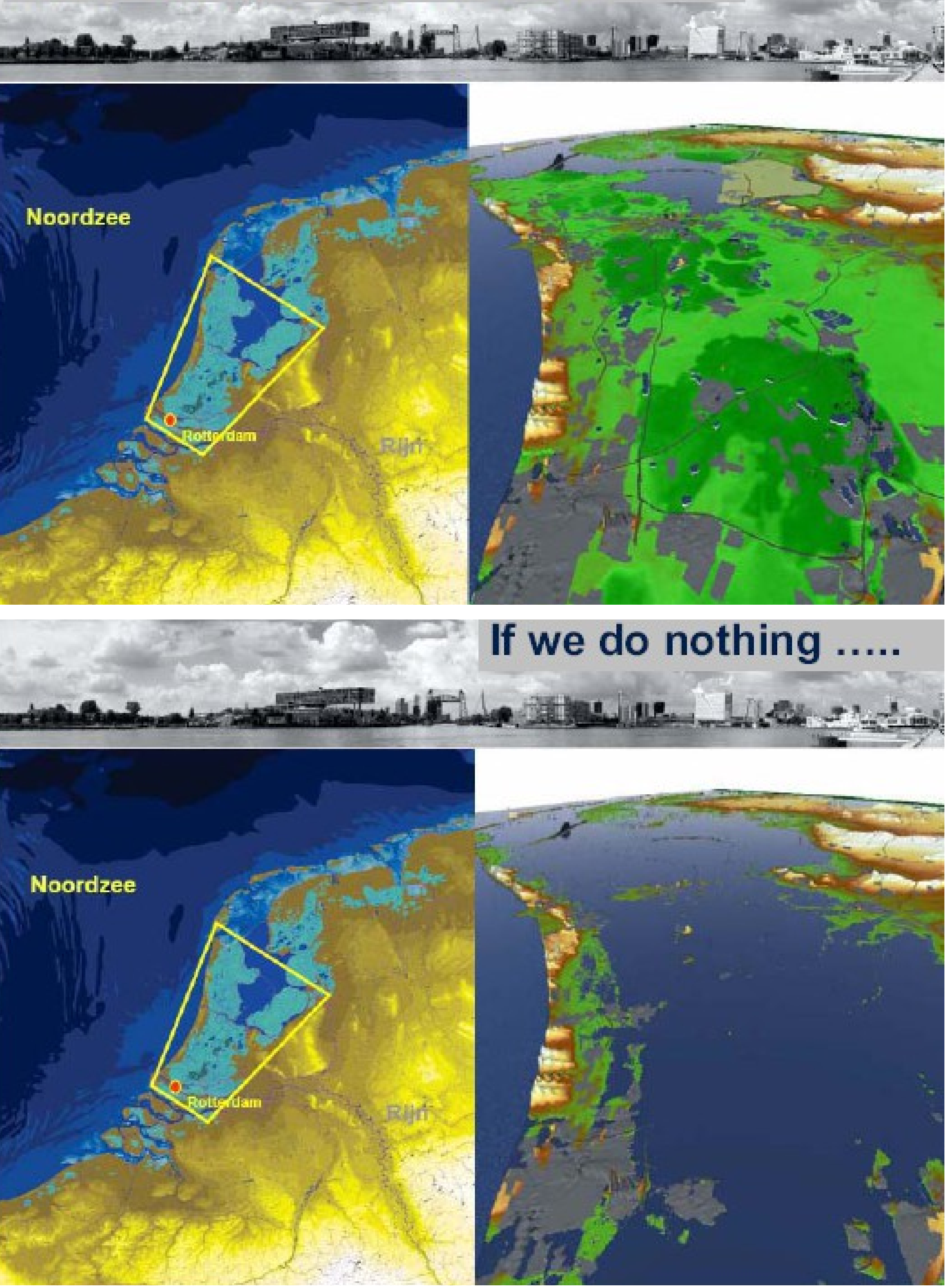


Fig. 1.1 The Netherlands case (Mollema, 2009).

If the fronting beaches (and/or coastal defenses) are breached, then the back-barrier ecosystems (e.g. wetlands and saltmarshes) will be flooded

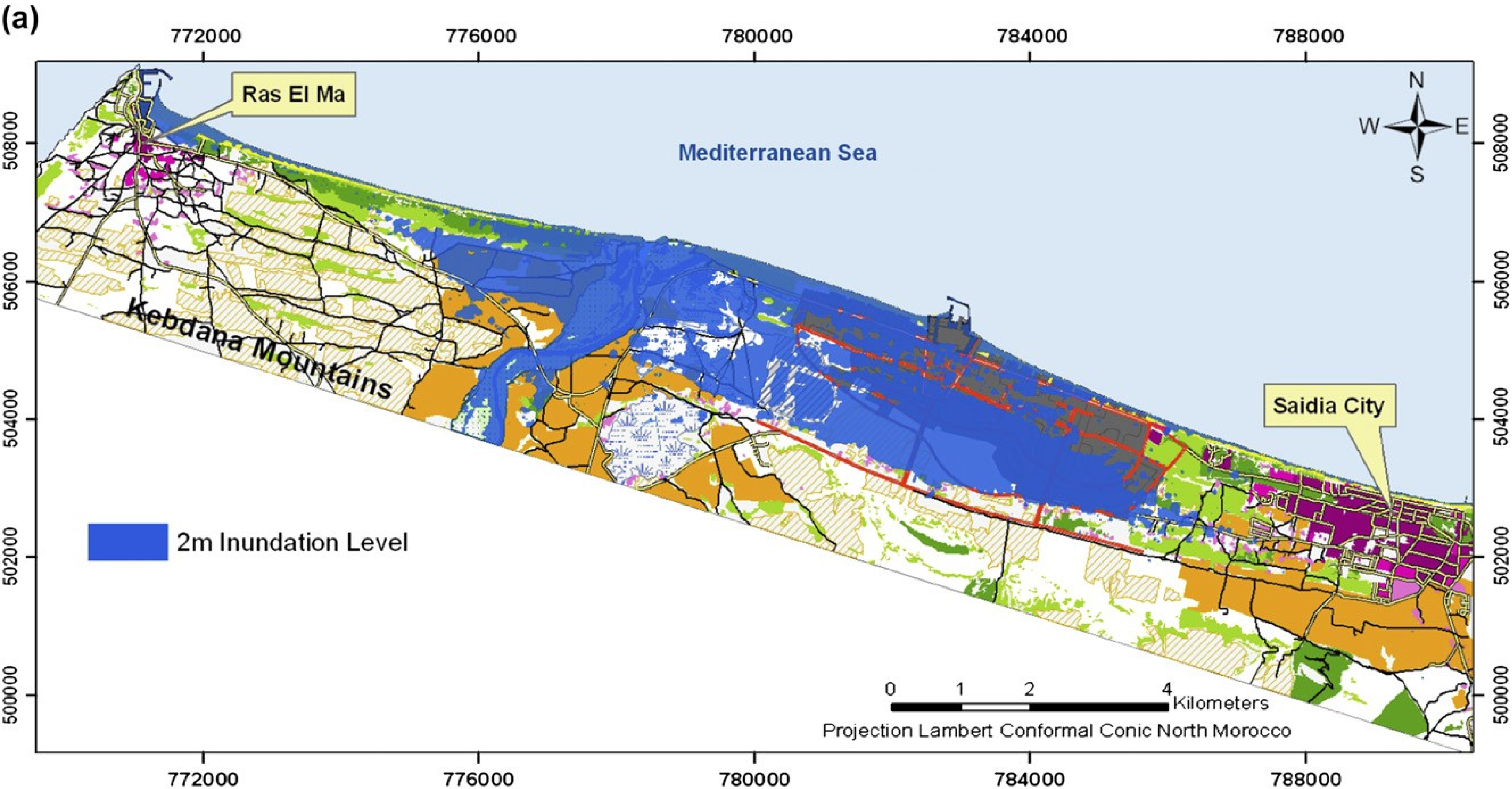


Fig. 1.2 Morocco Med coastline Land area vulnerable to flooding minimum inundation level of 2 m (Snoussi et al., 2008);

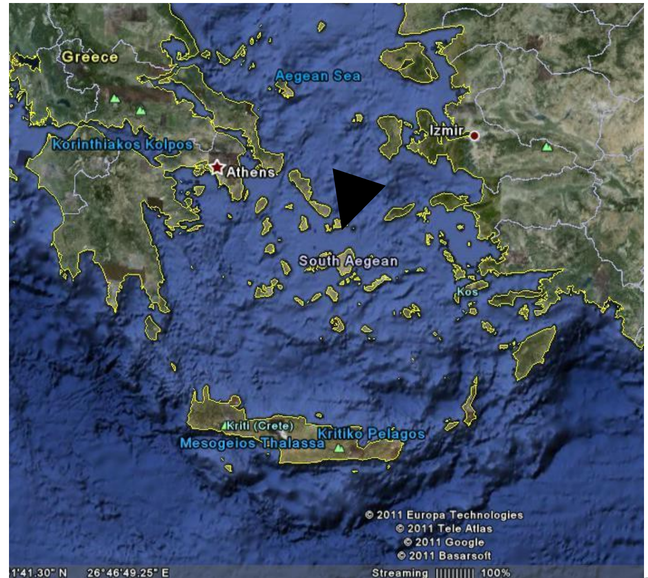


Fig. 1.3. Super Paradise (Mykonos). A pocket beach with very large economic potential. Economic value of Greek beaches min €1400/m/yr. This beach, €60000/m/yr.

Coastal housing destruction, following short-term (catastrophic) beach erosion

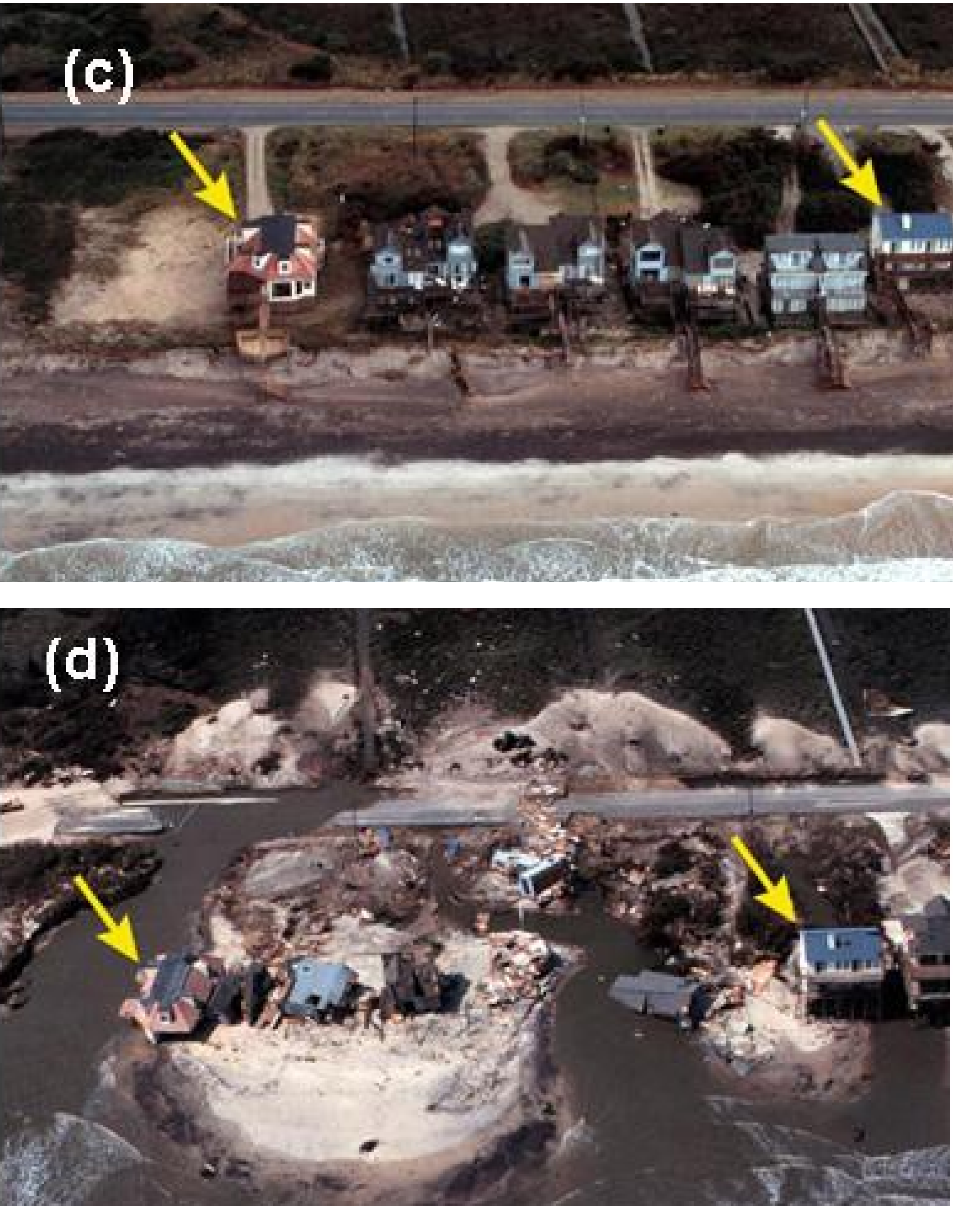
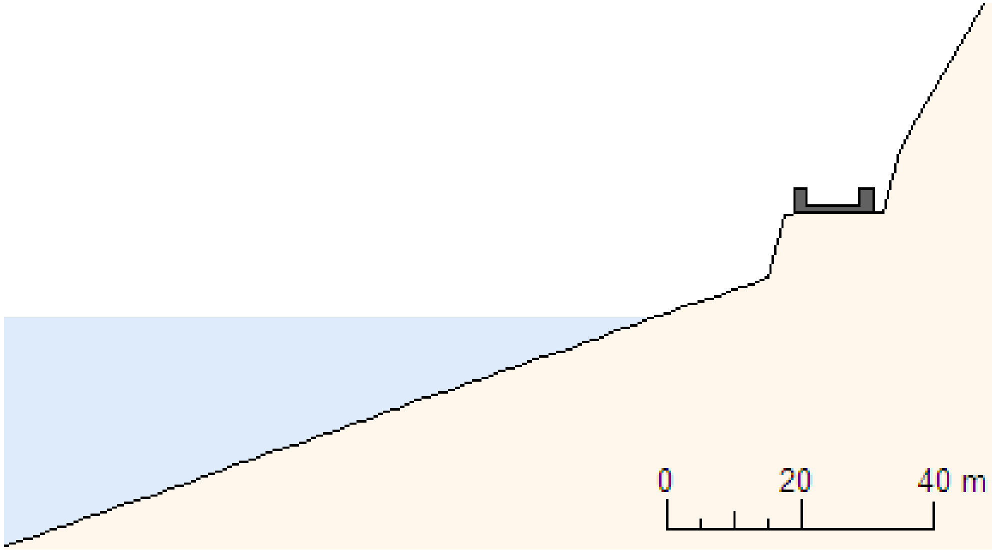


Fig. 1.4 S. Carolina (US) beach (c) before and (d) after a storm event in September 1996 (USGS, 1996)

Coastal transport infrastructure

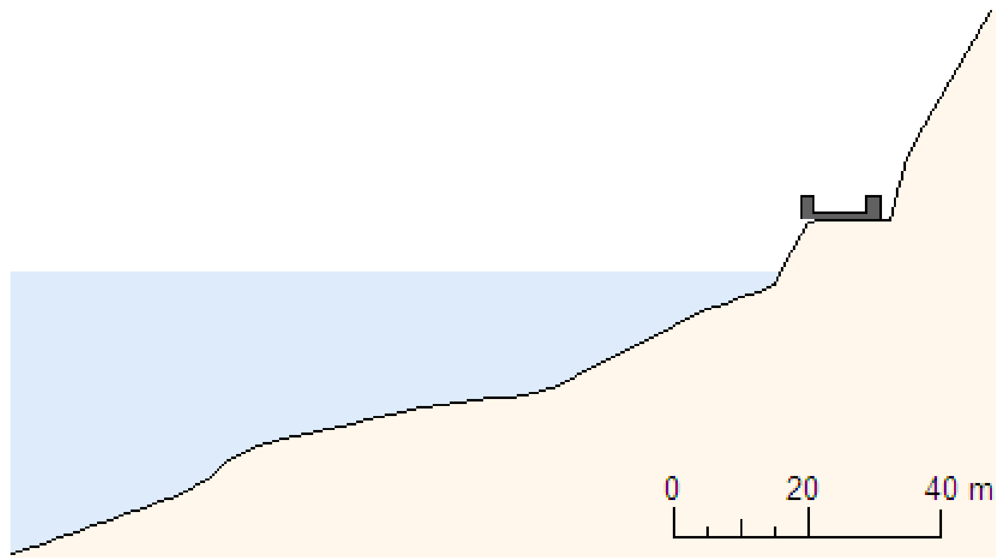
Fig. 1.5 The main railway line to Sochi in Black Sea will be in jeopardy, if the fronting beach would be eroded – which, will be (red line) under 1 m storm surge and offshore waves with height (H) = 4 m and period (T) = 7.9 sec.

Leont' yev Model



Present normal conditions

Storm surge 1 m



US Gulf Coast inundation risk

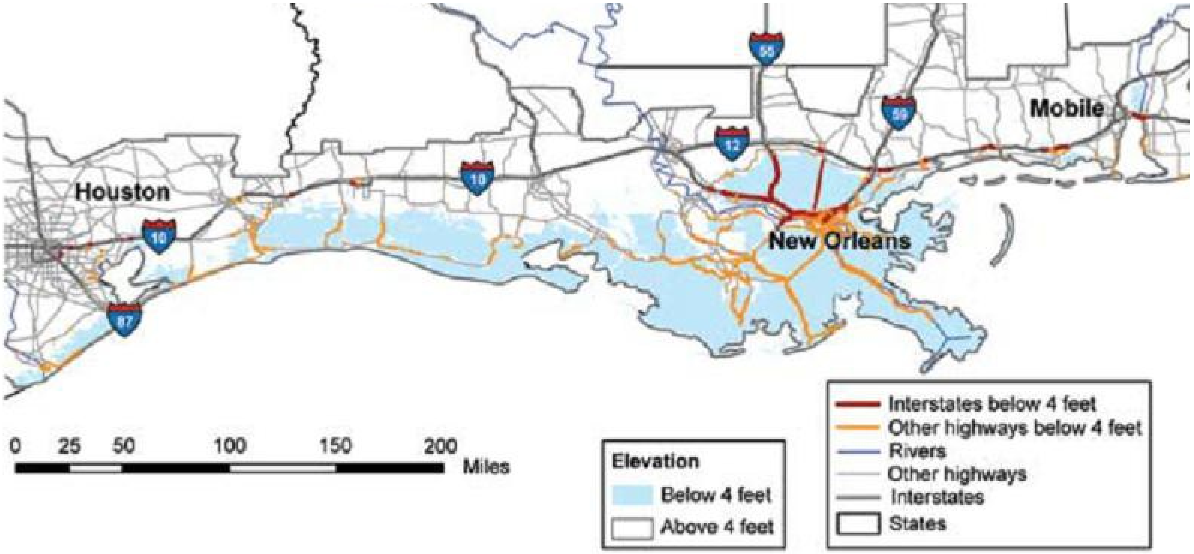
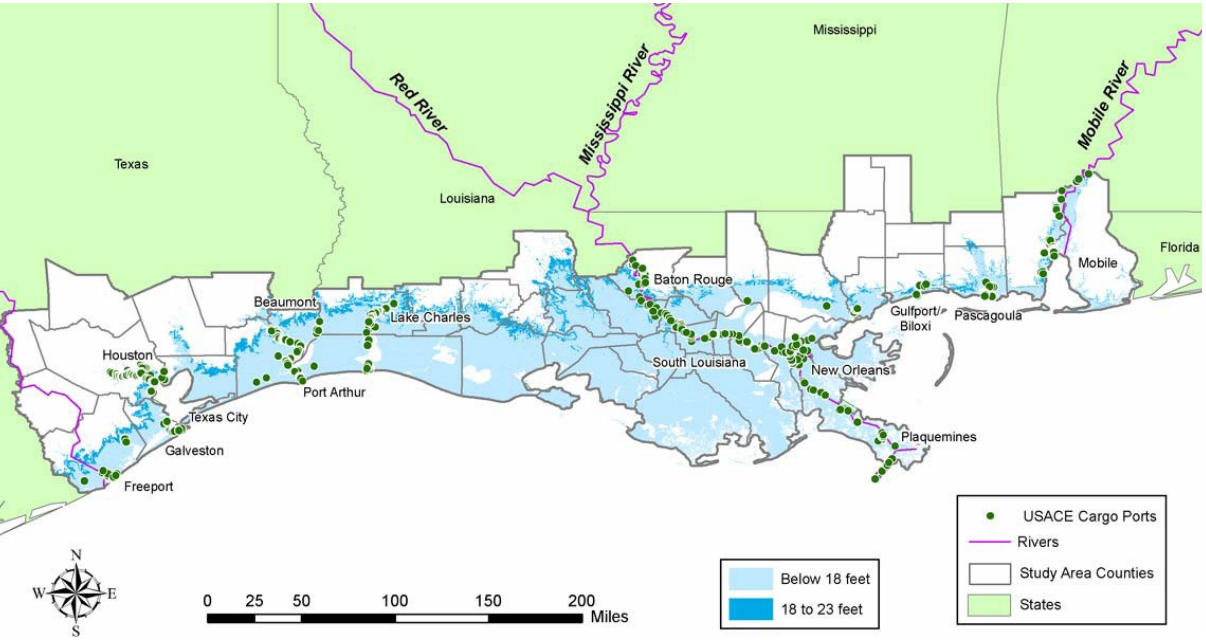


Fig.1.7 (a) Flood risk at US Gulf coast under sea level rise of 0-6-1.2 m (MSL+ storm surge); such rise could inundate > 2400 miles of roads, > 70% of the existing port facilities, 9% of the rail lines and 3 airports.



(b) In the case of a ~5.4-7 m rise (MSL+ storm surge), > 50% of interstate and arterial roads, 98% of port facilities, 33% of railways and 22 airports could be affected (CCSP, 2008).

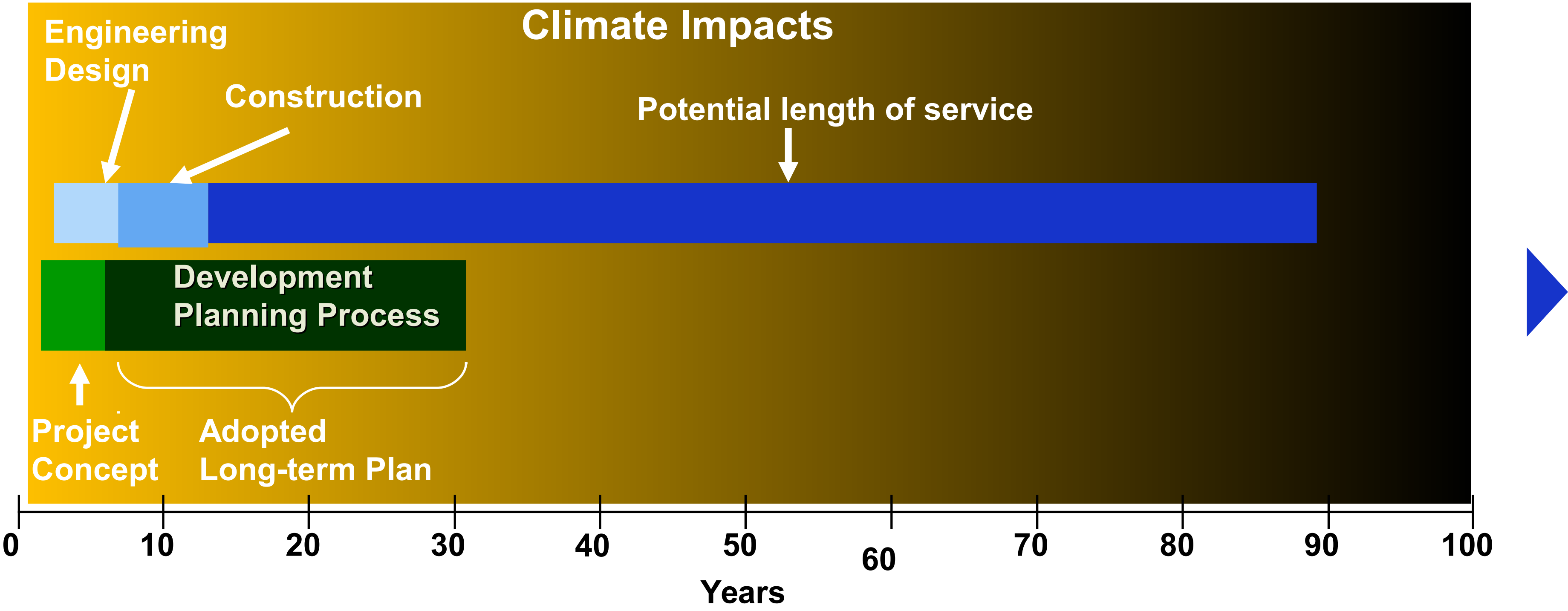


Fig. 1. 8 Coastal development planning/engineering time scales must take into account future environmental changes (after Savonis, 2011)

Long-term beach erosion

Fig. 1.9 Beach erosion since the 1945 in Morris Island, S. Carolina, US (SEPM, 1996)

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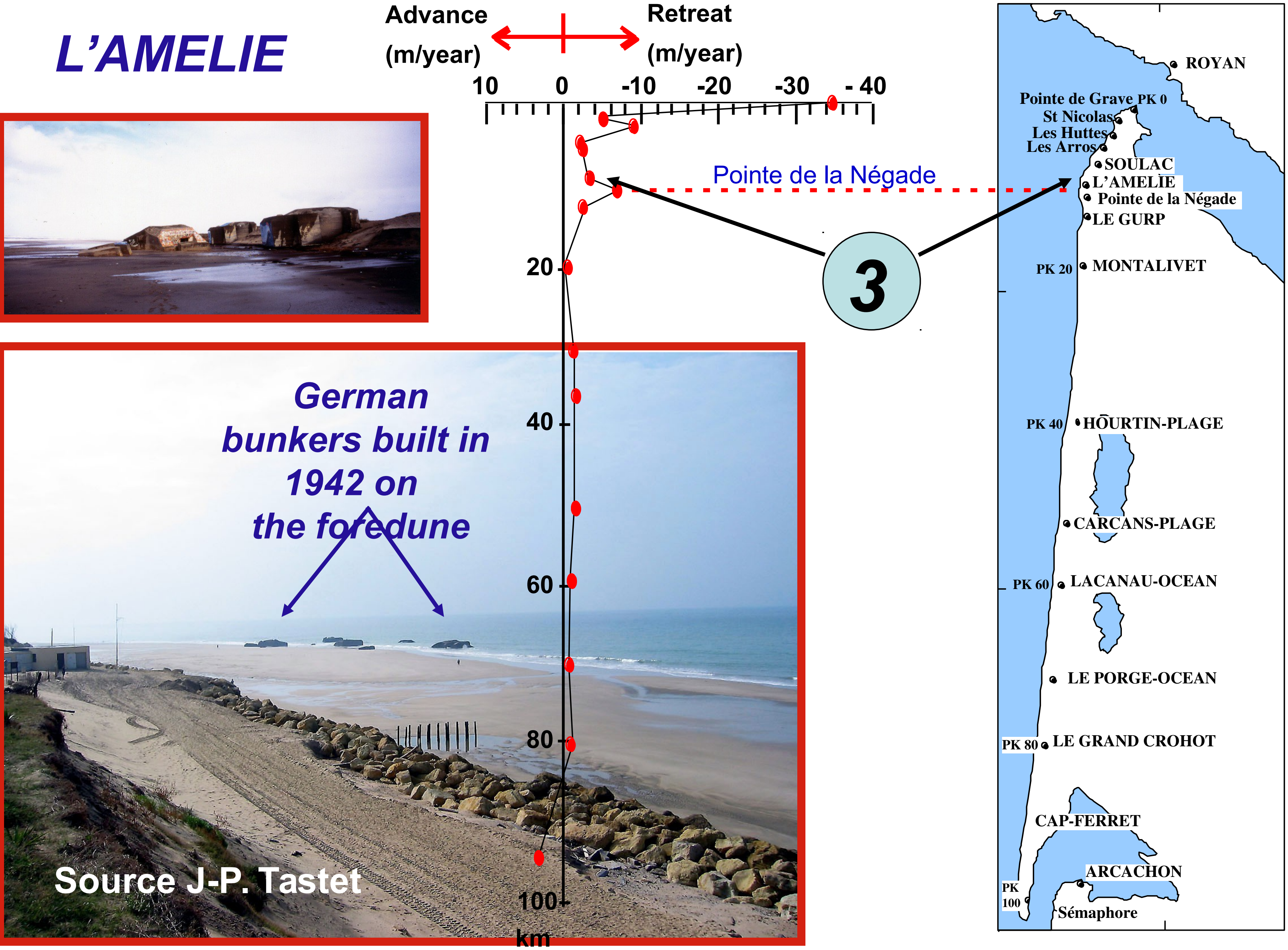

Advance (m/year)
Retreat (m/year)
10
0
-10
-20
-30
- 40
20
40
60
80
100
km
Pointe de la Négade
3
German bunkers built in 1942 on the foredune
Source J-P. Tastet
ROYAN
Pointe de Grave PK 0
St Nicolas
Les Huttes
Les Arros
SOULAC
L'AMELIE
Pointe de la Négade
LE GURP
PK 20
MONTALIVET
PK 40
HOURTIN-PLAGE
CARCANS-PLAGE
PK 60
LACANAU-OCEAN
LE PORGE-OCEAN
PK 80
LE GRAND CROHOT
CAP-FERRET
ARCACHON
PK 100
Sémaphore

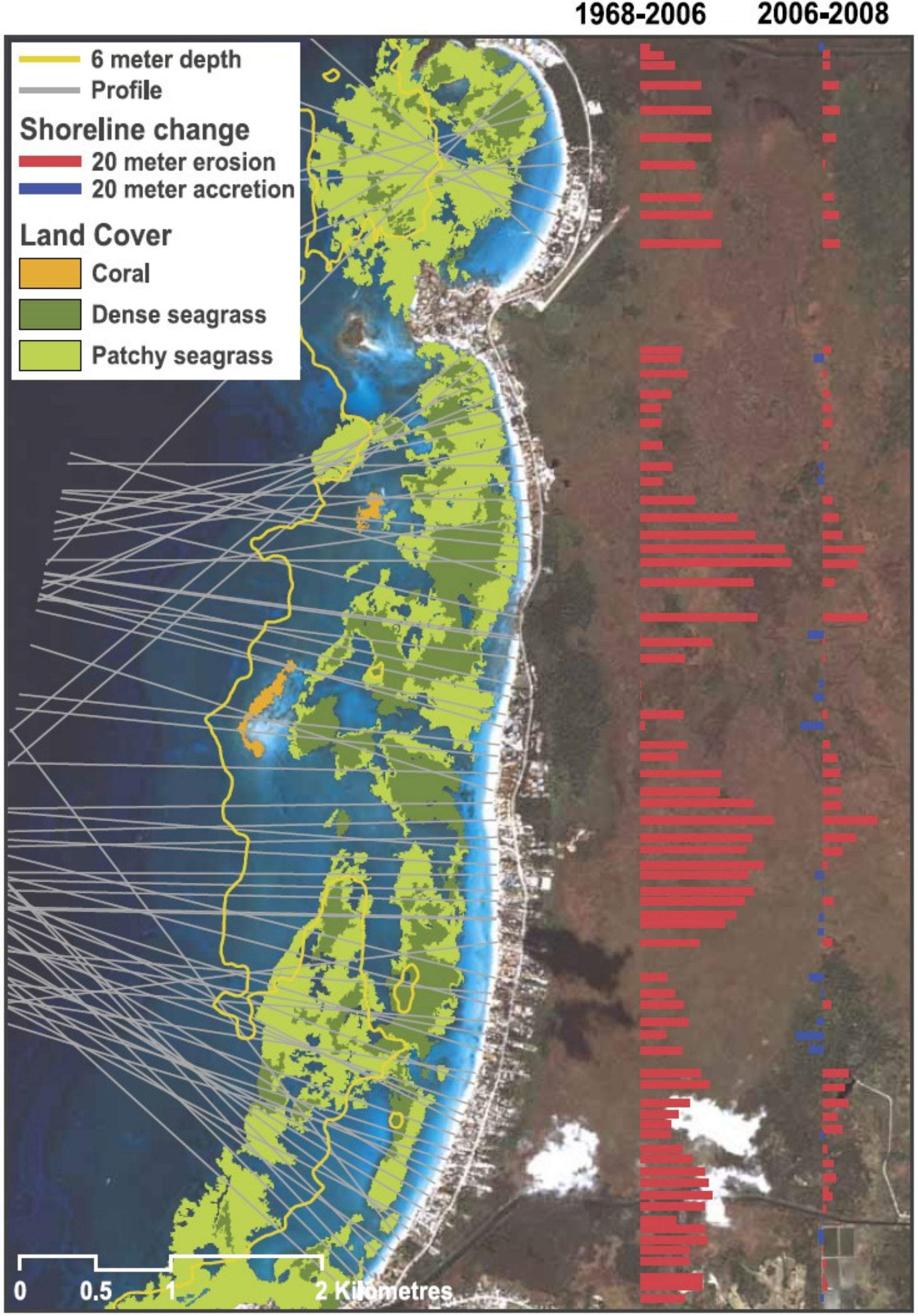


Fig. 1.11 Nearshore bed cover and shoreline changes along Negril (Jamaica) beaches (at the location of the 74 used beach profiles (RiVAMP, 2010)

Fig.1.12 Long-term and short-term (catastrophic beach erosion, Eresos beach E. Mediterranean

1.2 Coastal (beach) erosion: Causes

Climatic changes (mean sea level rise, reduction in precipitation/river sediment discharges fluxes, changes in the frequency/intensity and destructiveness of storms/storm surges

Reduction in coastal sediment supply-negative sediment budgets due to e.g. river management schemes, destruction of coastal seagrasses that provide marine biogenic sediments and badly designed coastal works

Isostatic and tectonic movements

Natural or human–induced subsidence of coastal deltas/estuaries where most of the large coastal cities are built (Erikson et al., 2005)

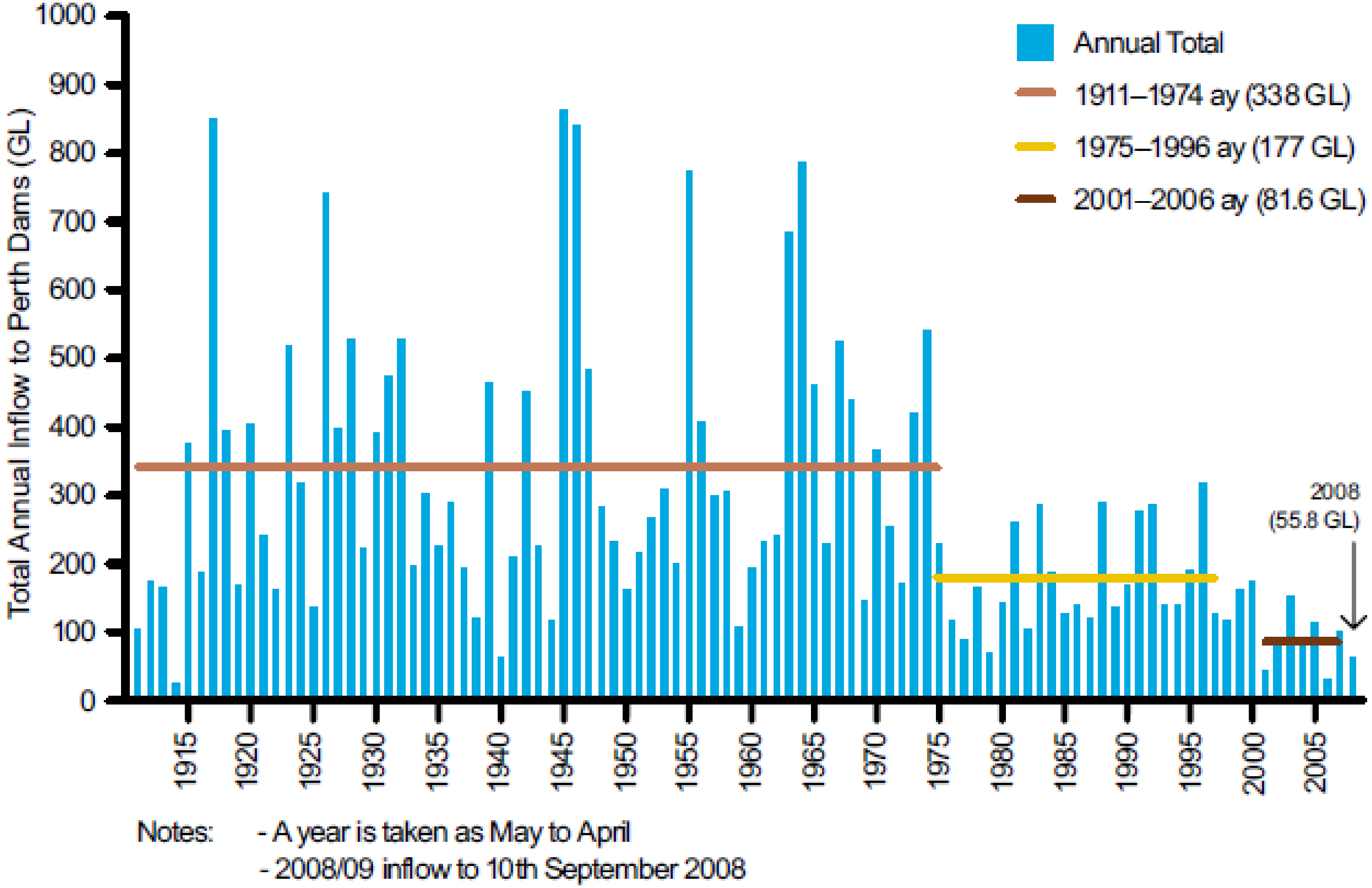


Fig. 1.13 Trends in total annual stream flow into Perth dams 1911–2008. (Steffen, 2009)

Current trends: More energetic extreme waves

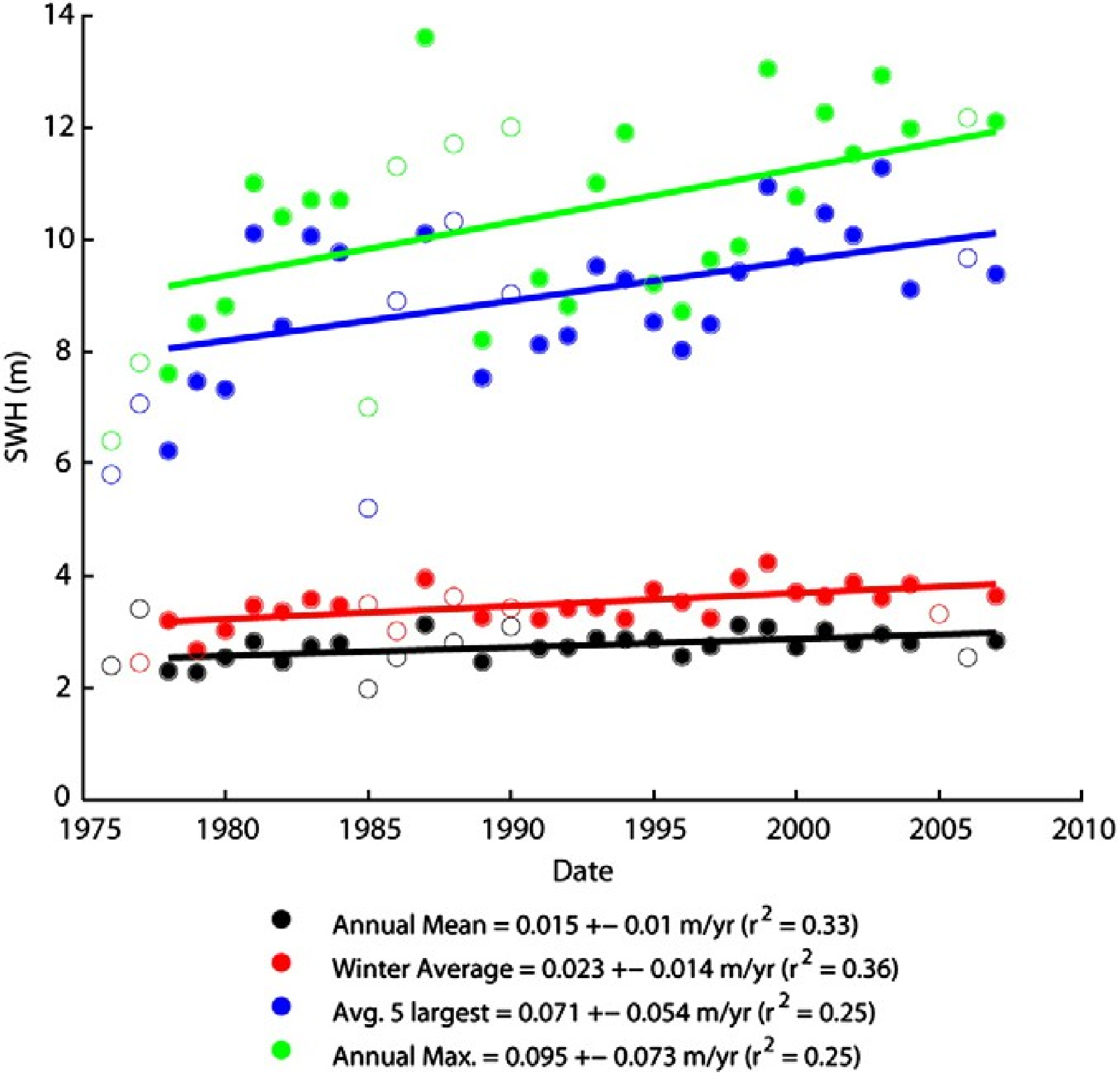


Fig. 1.14 Increases in the annual mean, winter averages, mean of the highest annual waves and annual maxima significant wave heights at the NDBC #46005 platform (NE Pacific). The annual maximum significant wave height has increased 2.4 m! in the last 25 years. (Ruggiero et al., 2010).

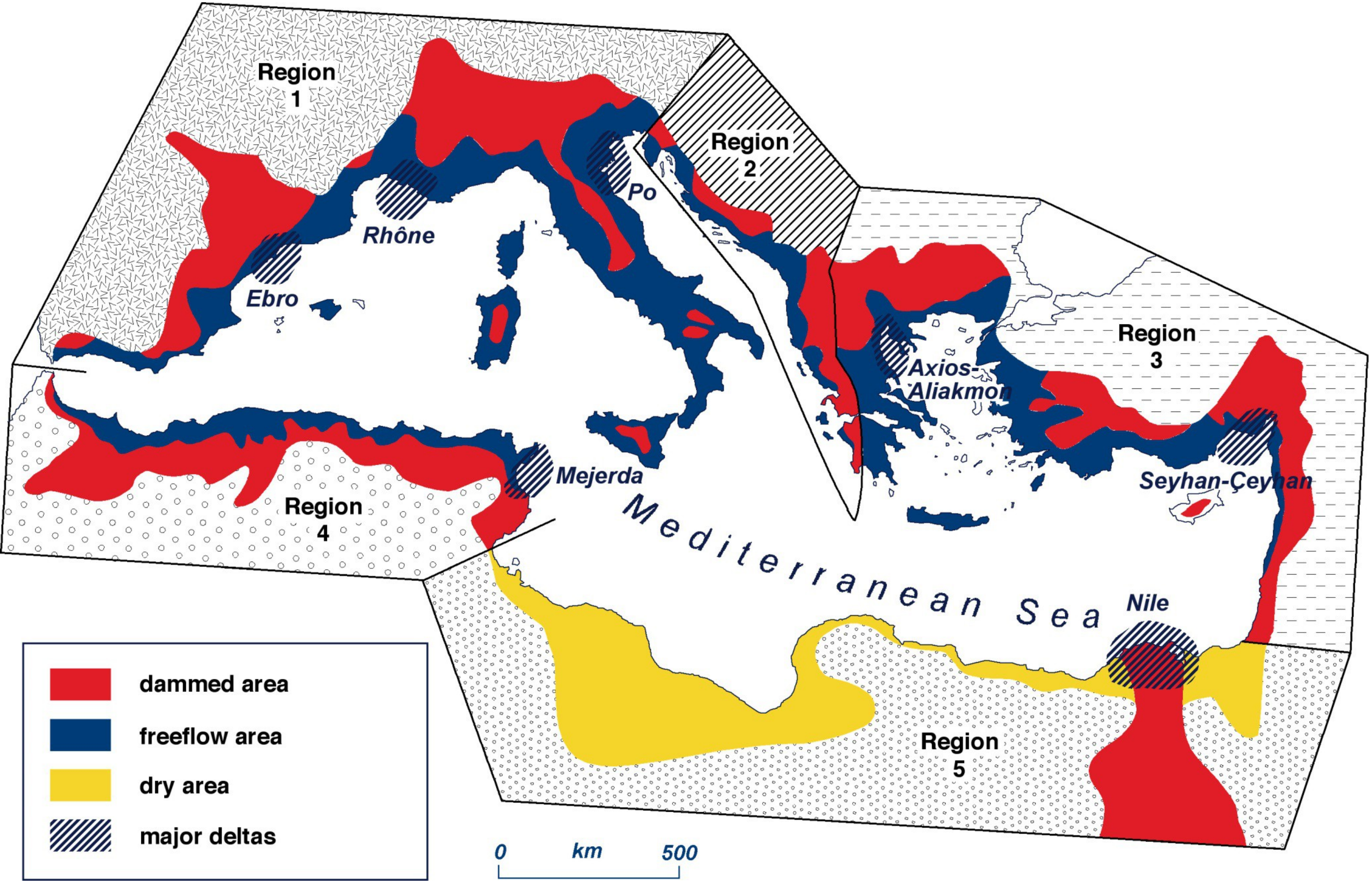
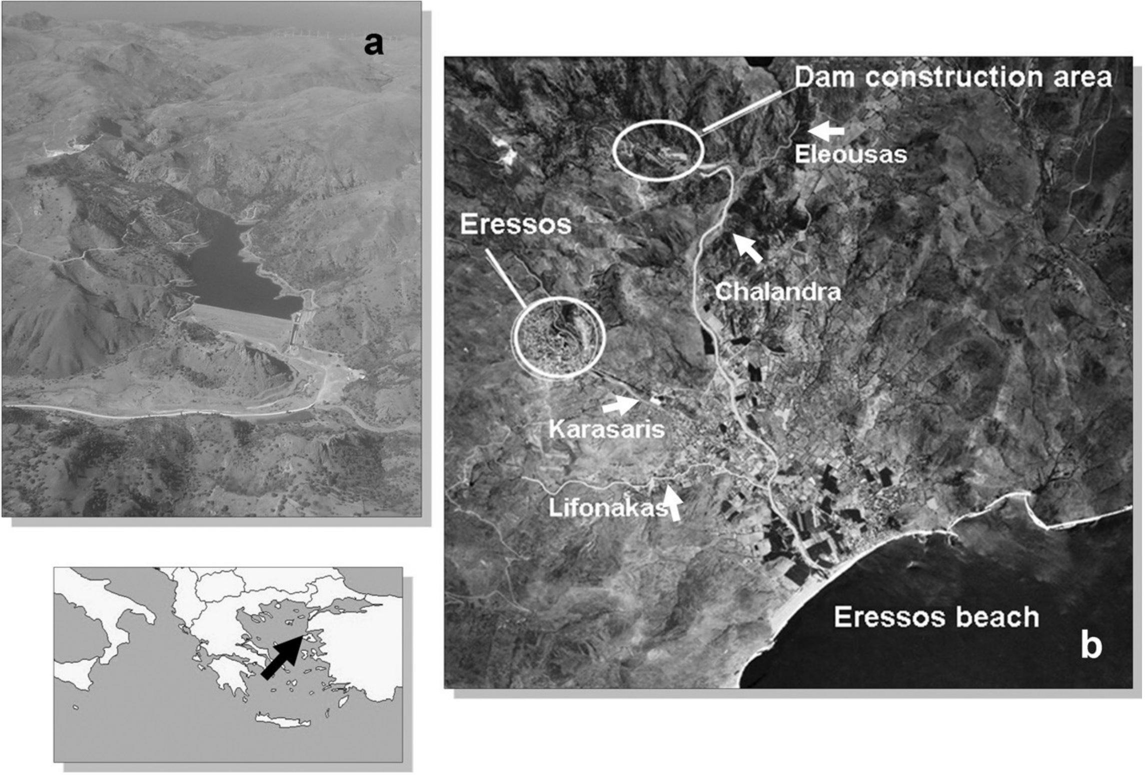


Fig. 1.15 Coastal sediment supply in the Med has been reduced from 1012 x 10^6 σε 355 x10^6 tons/yr during the second half of the 20th century due to the presence of about 3500 dams, 84% of which have been constructed during this period (Poulos and Collins, 2002).



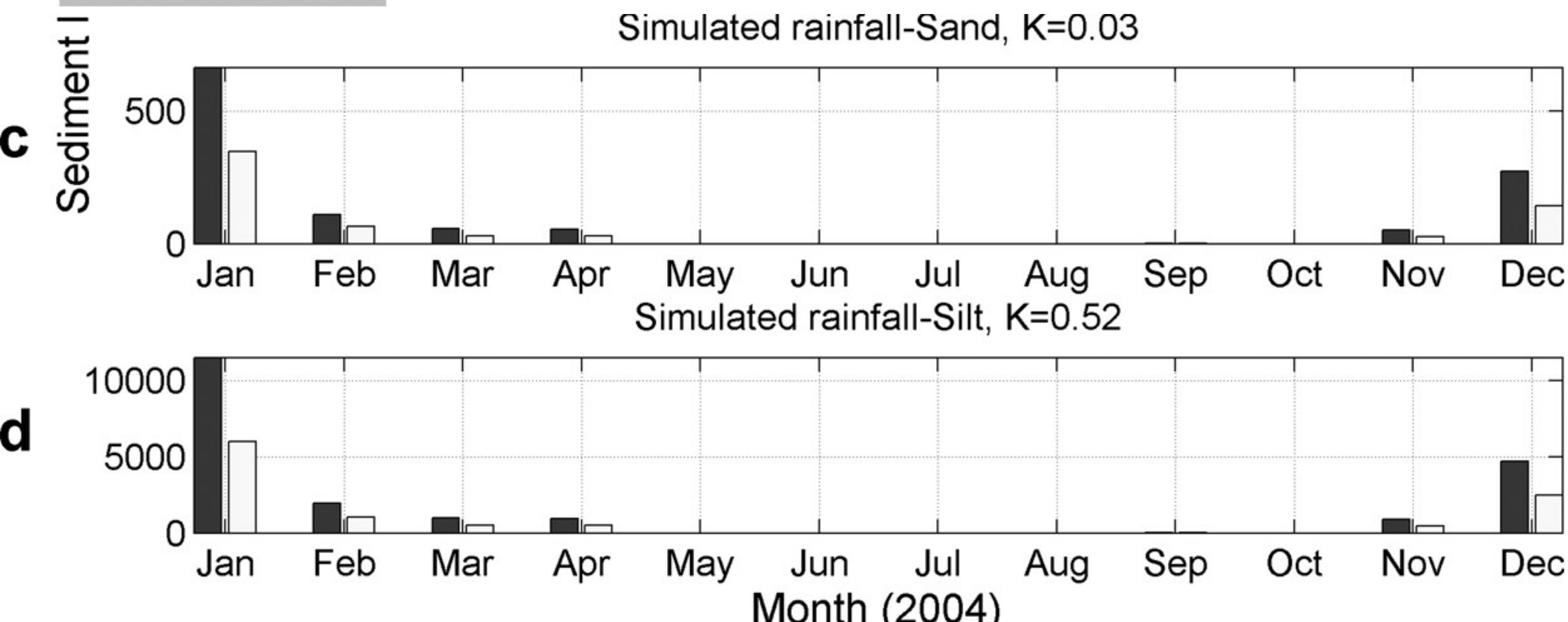


Fig. 1.16 (a) The dam and the Eresos drainage basin/beach, (c) monthly time series (2004) of (potential) sediment load (in tons) of the Eresos basin (black) and the sub-basin of the dam (white), for steady and high intensity (simulated) rainfall for 2 soil cases (i) sand soil (K=0.03) and (ii) silt soil (K=0.52). The dam keeps 52-55% of the sediments produced in the drainage basin

Fig. 1.17 Eresos, Lesbos, E. Med 27-2-2004. The beach, the river and the dam

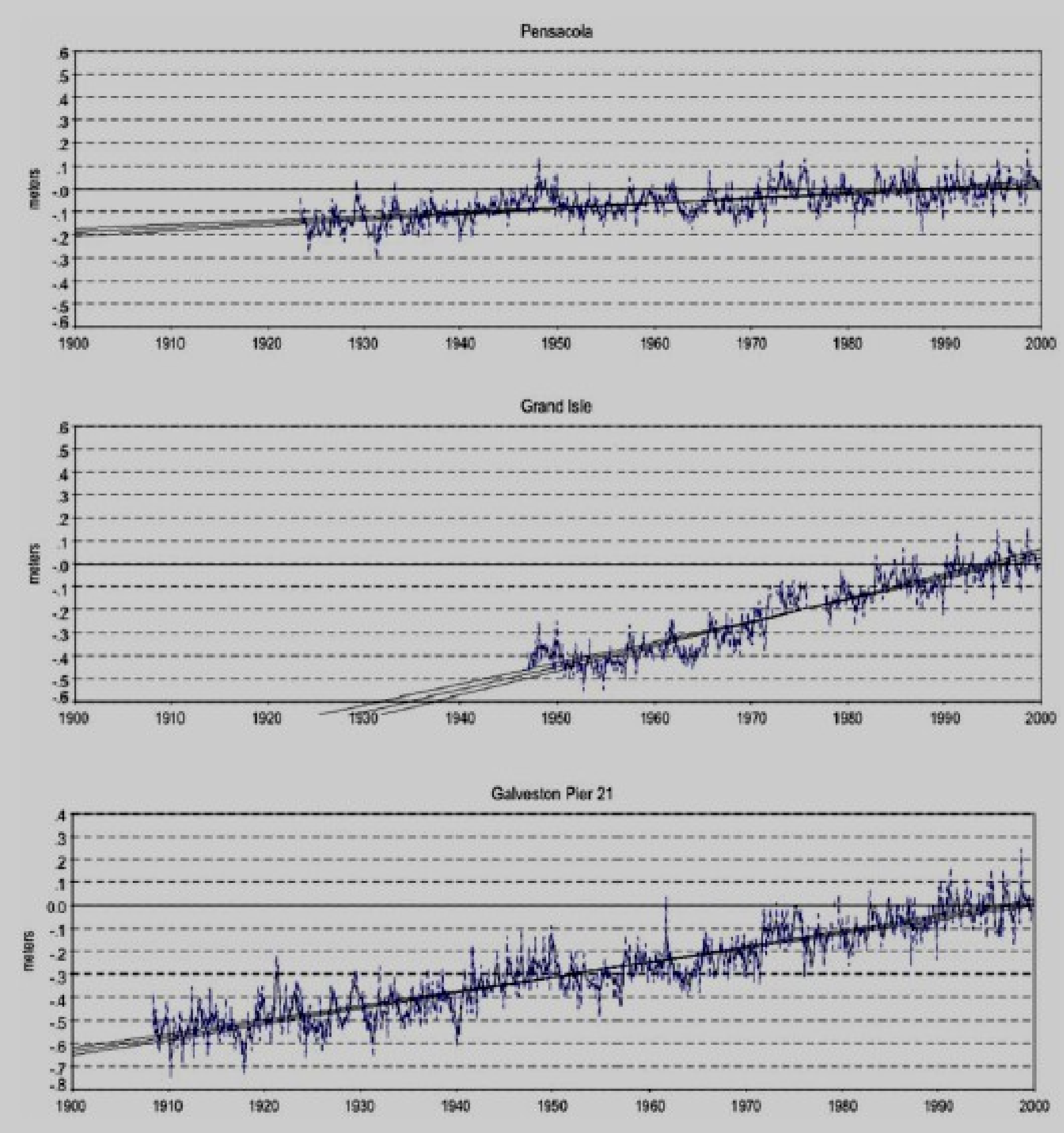


Fig. 1.18 Sea level rise at Pensacola (FL) 2.14 mm/yr, Grand Isle (LA)- 9.85 mm/yr, and Galveston (TX)- 6.5 mm/yr. These trends show the high rates of local subsidence in Louisiana and Texas relative to the more stable geology of Florida (Savonis et al., 2008)

1.3 Monitoring and forecasting of beach erosion

In order to predict/manage coastal change, reasonable forecasts of beach retreat are required

Such forecasts could be based on

- past trends (if available) and
- beach morphodynamic modeling, the predictions of which are validated by experiments

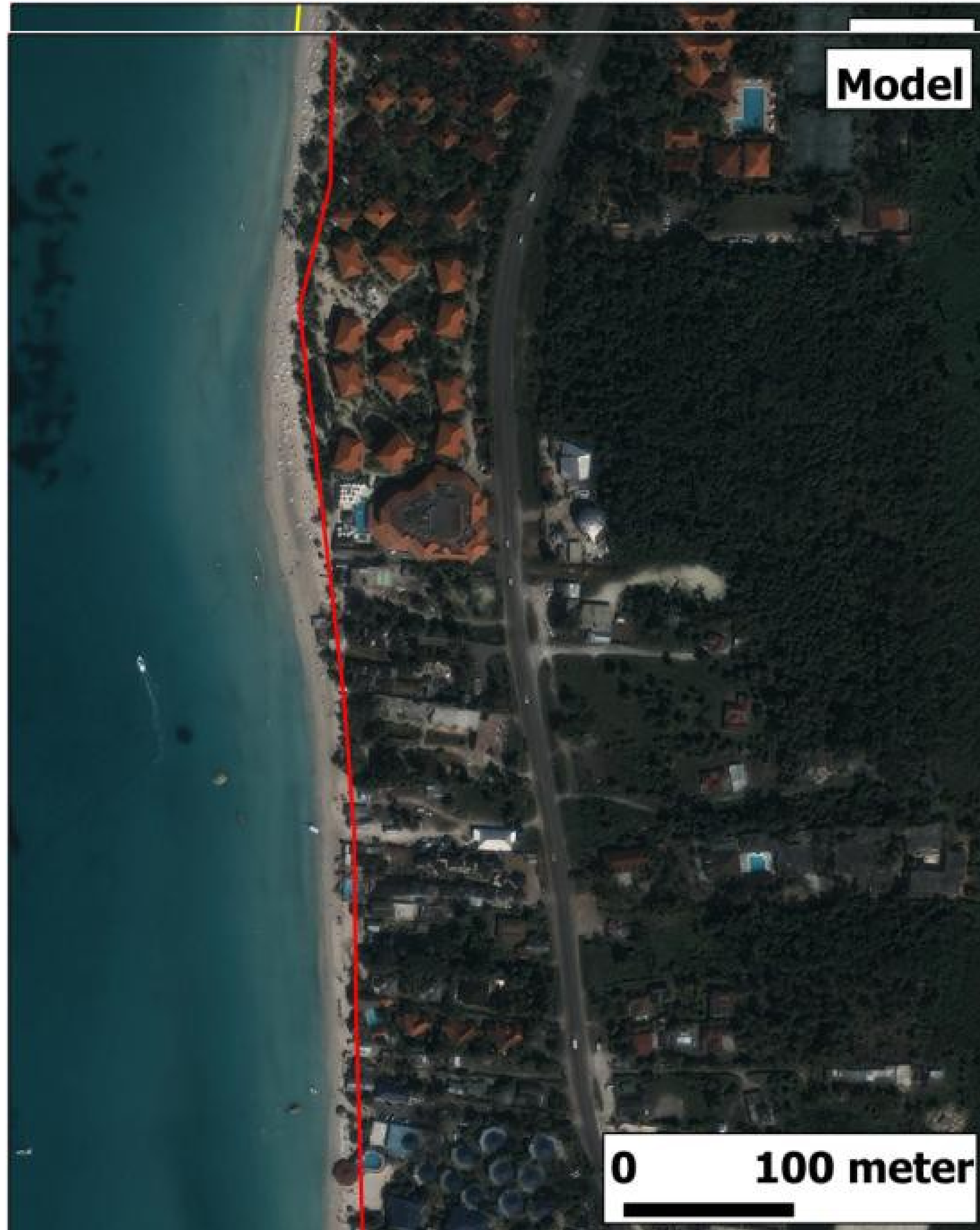


Fig. 1.19 Technical Analysis Beach erosion trends and projections Negril beach (Jamaica) (Peduzzi, 2011)

Predictions of beach retreat under storm surges: Model validation

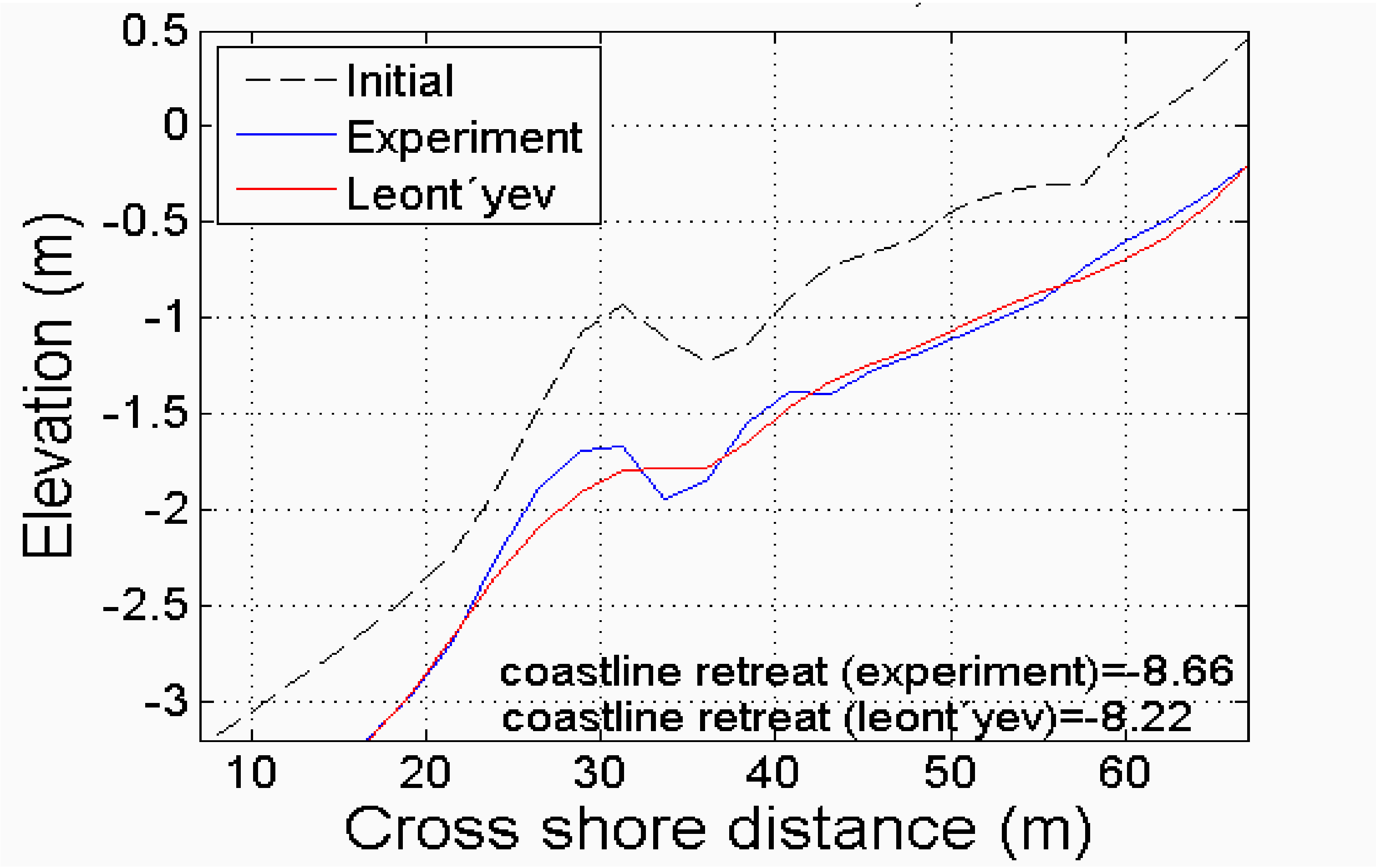


Fig. 1.20 Validation of the Leon'yev model by physical experiments in HYDRALAB (Monioudi et al., 2014 (submitted). Conditions: Offshore wave height (H) 1m, Period (T) 5.1 s, sea level rise 0.6 m. Simulation time 3000 s.

1.4 Sea level rise and coastal erosion

One the most potent drivers of coastal erosion is the sea level rise

Coastal response to sea level rise is a non-linear process, depending:

- **the sea level rise**
- **the coastal slope/morphology**
- **the wave energy and**
- **the nature of coastal sediments**

Our knowledge on coastal erosion processes are still incomplete and predictions are characterised by uncertainty

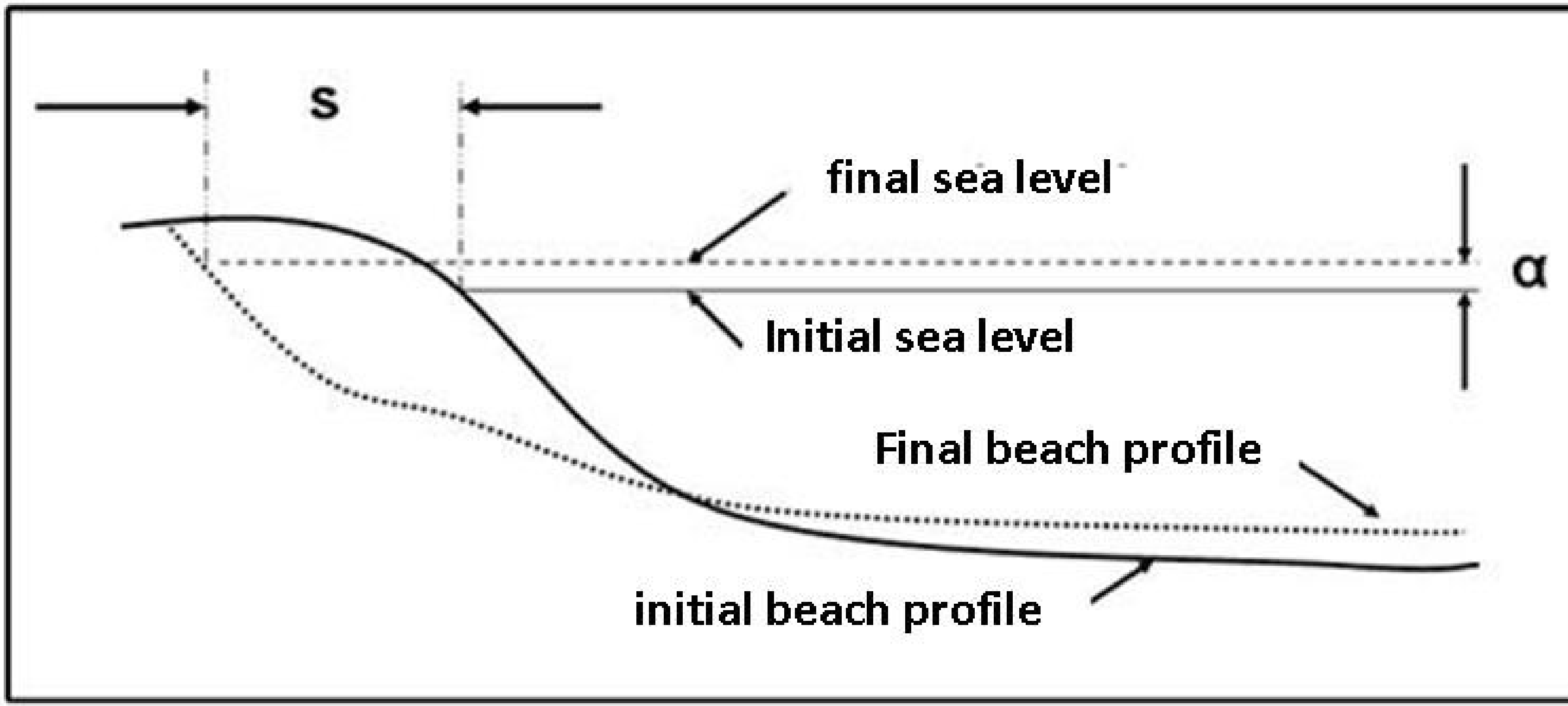


Fig. 1.21 Sketch showing the beach response to sea level rise. If the sea level rises by α, beach face sediments are eroded and transported offshore to be deposited at the seabed, resulting to a shoreline retreat of s.

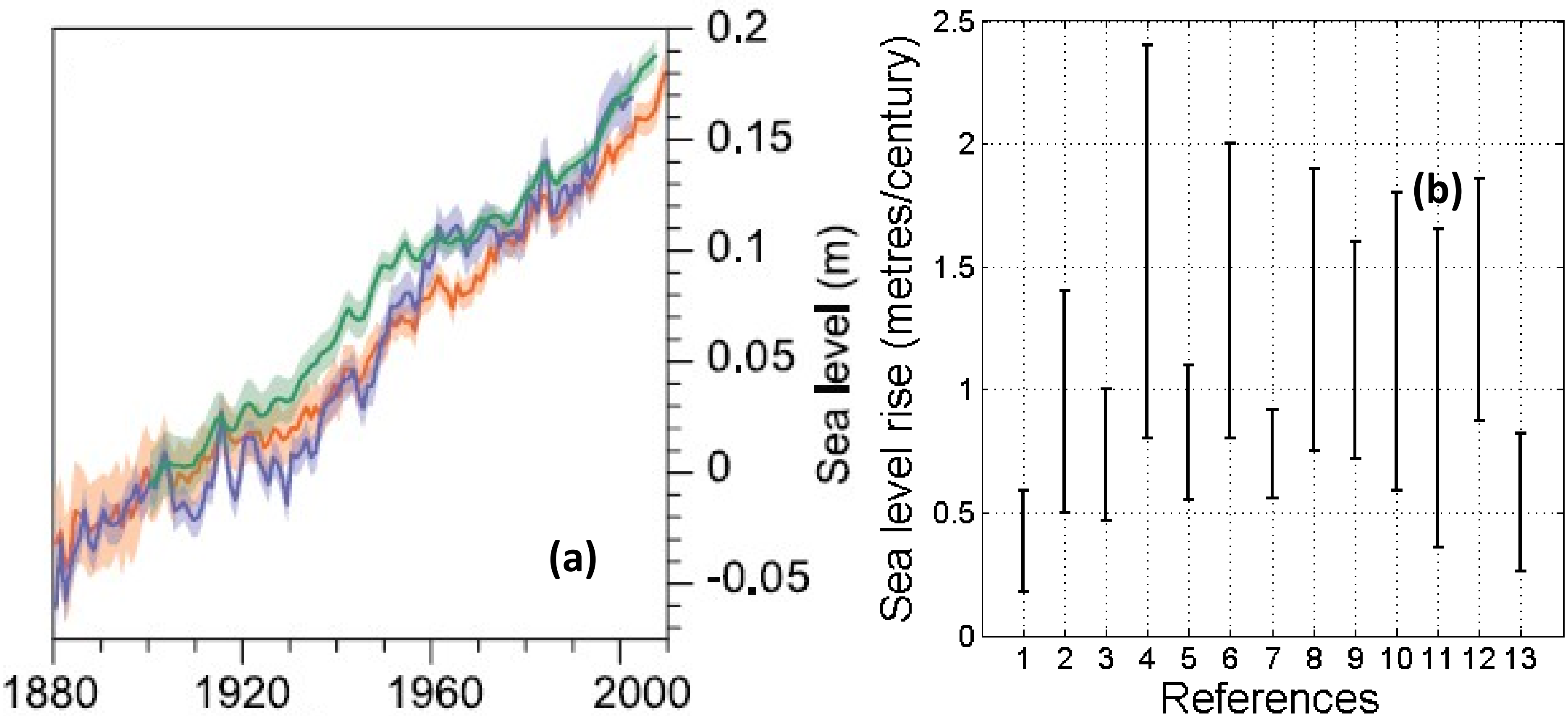


Fig. 1.22 (a) Yearly average global mean sea level (GMSL) reconstructed from tide gauges. Orange (Church and White,(2011), blue (evrejeva et al. (2008), green (Ray and Douglas, 2011) IPCC, 2013 (b) 1 Recent sea level rise projections for 2100 compared to that of IPCC (2007a). Key: 1, IPCC (2007a), 0.18-0.59 m; 2, Rahmstorf et al. (2007); 3, Horton et al. (2008); 4, Rohling et al. (2008); 5, Vellinga et al. (2008); 6, Pfeffer et al. (2008); 7, Kopp et al. (2009); 8, Vermeer and Rahmstorf (2009); 9, Grinsted et al. (2010); 10, Jevrejeva et al. (2010); 11, Jevrejeva et al. (2012); 12, Mori et al. (2013); and 13, IPCC (2013).

Observed storm surge heights (cm) along the Mediterranean coast

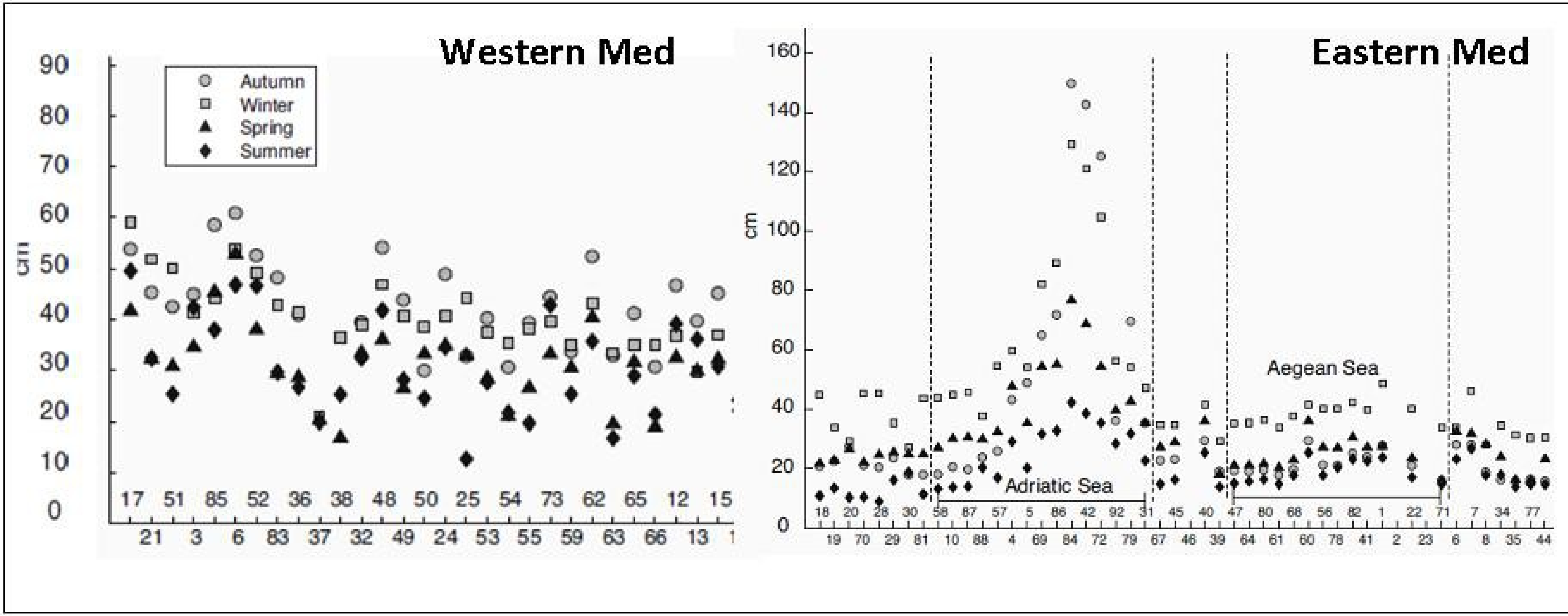


Fig. 1.23 Maximum seasonal extreme sea level values (tidal residuals) in the western and Eastern Mediterranean (Tsimplis and Shaw, 2010). For location of stations, see the original publication.

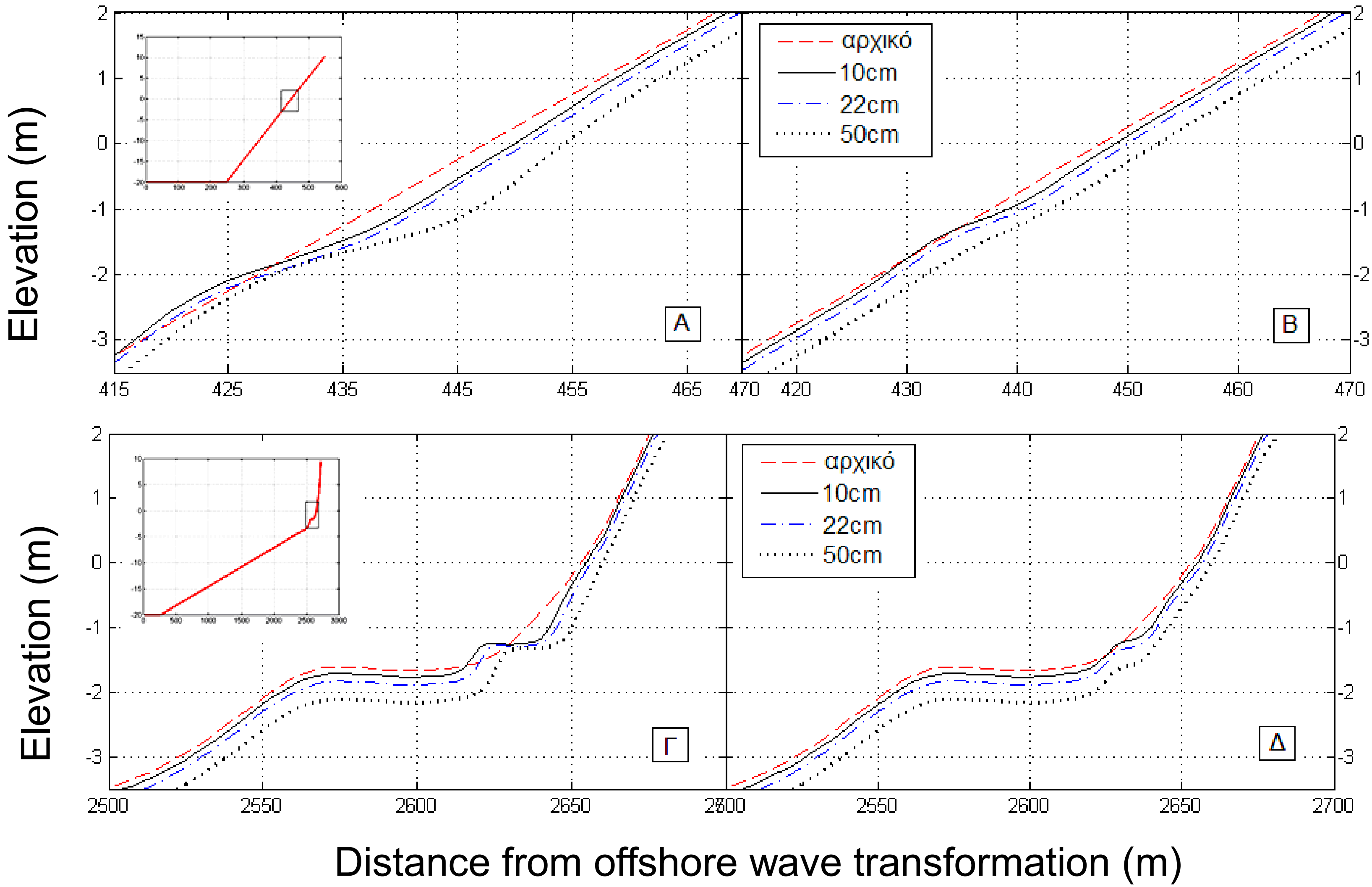


Fig. 1.24 Morphodynamic model (Leont'yev and SBEACH) results for the upper part of a linear and a natural cross-section ('mean' section of Delilah experiment, US Army Corps of Engineers) for 3 m waves and sediments with d50 = 0.2 mm and sea level rise of 0.10, 0.22 και 0.50 m. (A) Leont'yev (linear profile, slope 1/10), (B) SBEACH model (linear profile, slope 1/10) (Γ) Leont'yev model ('mean' profile Delilah) και (Δ) SBEACH model ('mean' profile Delilah) (Monioudi 2011).

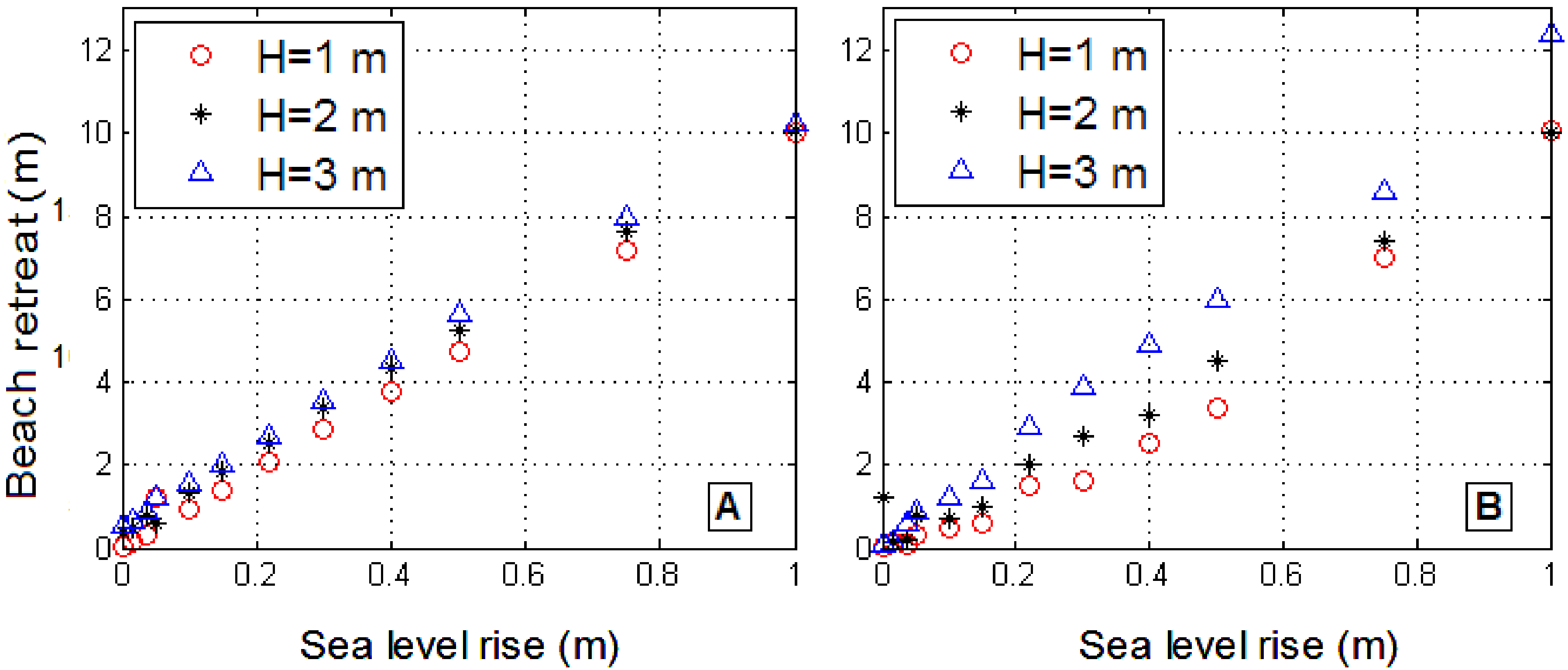


Fig. 1.25 Wave height effects on the relationship between sea level rise and coastal retreat for a linear profile (slope 1/10) and coarse sediments (d50 = 0.8mm): (A) Leont'yev (1996) model (B) SBEACH model

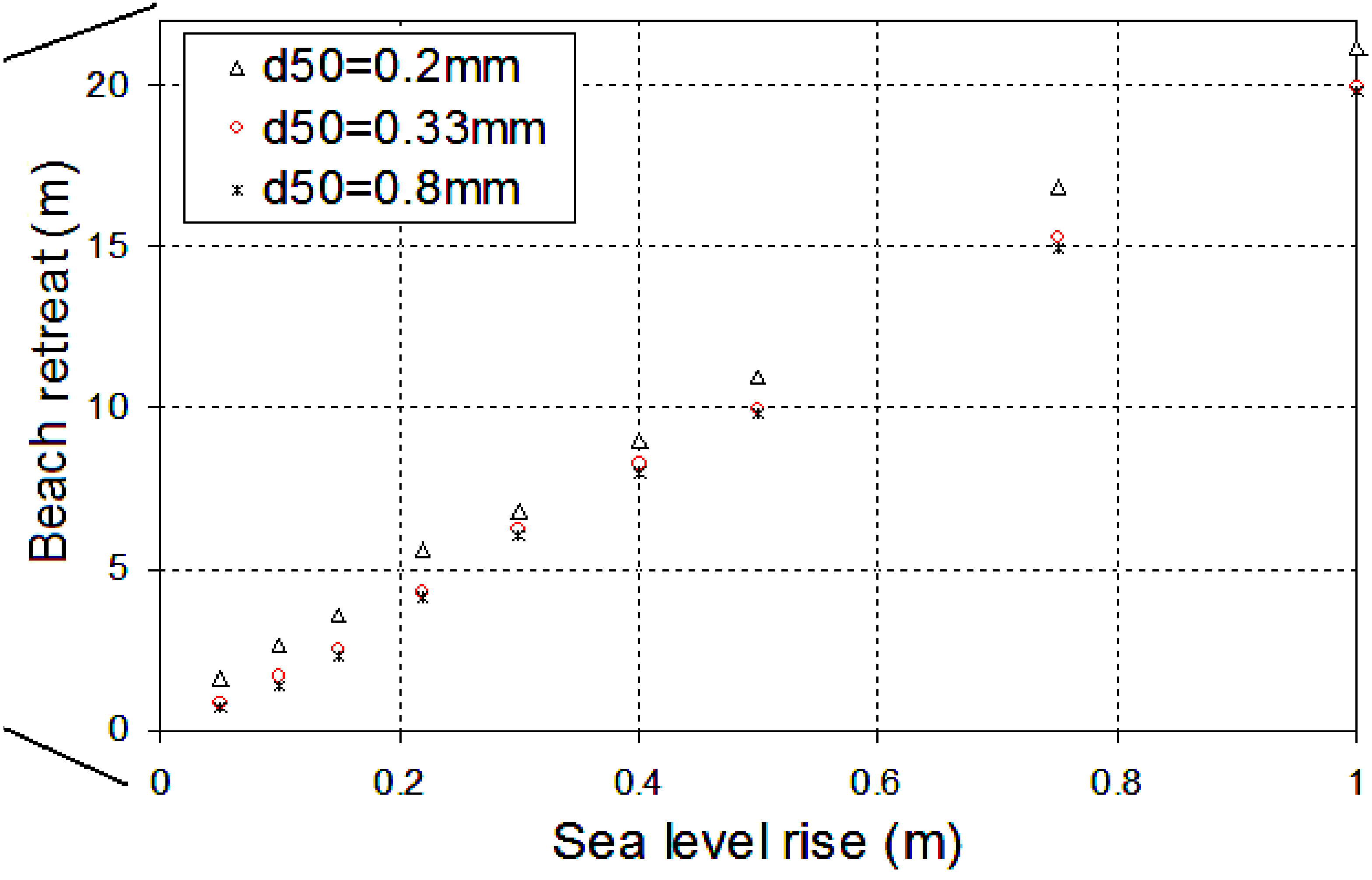


Fig. 1.26 Beach grain size effects on the on the relationship between sea level rise and coastal retreat for a linear profile (slope 1/20) and offshore waves H=1m, and T=5sec) from a Boussinesq model (Monioudi 2011)

1.5 Aims and content

To present a user friendly, integrated software toolbox (comprising a suite of components) allowing an initial assessment of the beach retreat/erosion risk (the inshore displacement of the winter waterline) under sea level rise

It is based on the use of different cross-shore analytical and numerical morphodynamic models of varied complexity, which can be used either individually or in combination.

Initial beach morphology to set up the models can be either

- linear (beach profiles are represented by a single bed slope (set by the user), ,
- or ‘natural (actual beach profiles can be used being either a single observation or the ‘mean’ of a time series of beach profiles).

The models can be forced either by

- waves with user-set wave heights, periods and directions or
- waves estimated from wind records and wave hindcasting

Table 1.2 Summary of the components of the toolbox (presented as user-friendly Guide User Interfaces-GUIs). For detailed information on the toolbox components, see the relevant Sections

Component	Purpose	Input	Output
C1: Beach profile analysis (for details see Section 2)	To identify the 'mean' beach profile from a time-series of beach profiles, using Empirical Orthogonal Functions (EOFs).	Time series of beach profiles	'Mean' beach profile (the most significant spatial eigenvector (first spatial EOF Mode)
C2: Wind record analysis (for details see Section 3)	To identify the wind characteristics that can generate waves that may affect a beach (wind speed, frequency and duration) from the different (direction) sectors, on the basis of time series of wind records.	Time series of wind records (speed and direction)	Files of wind characteristics and windroses
C3: Wave estimations (for details see Section 4)	To estimate open sea wave conditions from wind characteristics (speed, frequency and duration) and the fetch (i.e. the maximum distance between two obstructions e.g. coasts, Islands) along which the wind can flow unhindered)	The output of C2 and the fetch (estimated using maps)	Open sea significant and equivalent* wave heights and periods
C4: Beach retreat assessment by analytical models (for details see Section 5)	To estimate beach retreat *s* under (long-term) sea level rise α using analytical models for linear (C4a) and 'natural' (C4b) profiles	C4a: wave characteristics (user-set or the output of C3); bed slope and sediment size C4b: wave characteristics (user-set or the output of C3); mean beach profile (output of C1) and sediment size	Beach retreat estimations either by individual models or by a several models (ensemble)
C5: Beach retreat assessment by numerical models (for details see Section 6)	To estimate beach retreat *s* under (short-term) sea level rise α using dynamic (numerical) models	C5a: wave characteristics (user-set or the output of C3); bed slope and sediment size C4b: wave characteristics (user-set or the output of C3); mean beach profile (output of C1) and sediment size	Beach retreat estimations either by individual models or by a several models (ensemble)