



Università
di Genova

DICCA DIPARTIMENTO
DI INGEGNERIA CIVILE, CHIMICA
E AMBIENTALE

CENNI DI MORFODINAMICA COSTIERA: CAUSE E POSSIBILI INTERVENTI DI MITIGAZIONE

Francesco De Leo

francesco.deleo@unige.it

<https://meteocean.science/>

Sestri Levante, 20/09/2024



Barcellona Pozzo di
Gotto (ME)

linea ferroviaria
in Cataluña



Un problema articolato



Morfologia della costa
Forzanti meteo-marine



fattori coinvolti



fenomeni a larga scala
fenomeni puntuali



diverse scale spazio-temporali



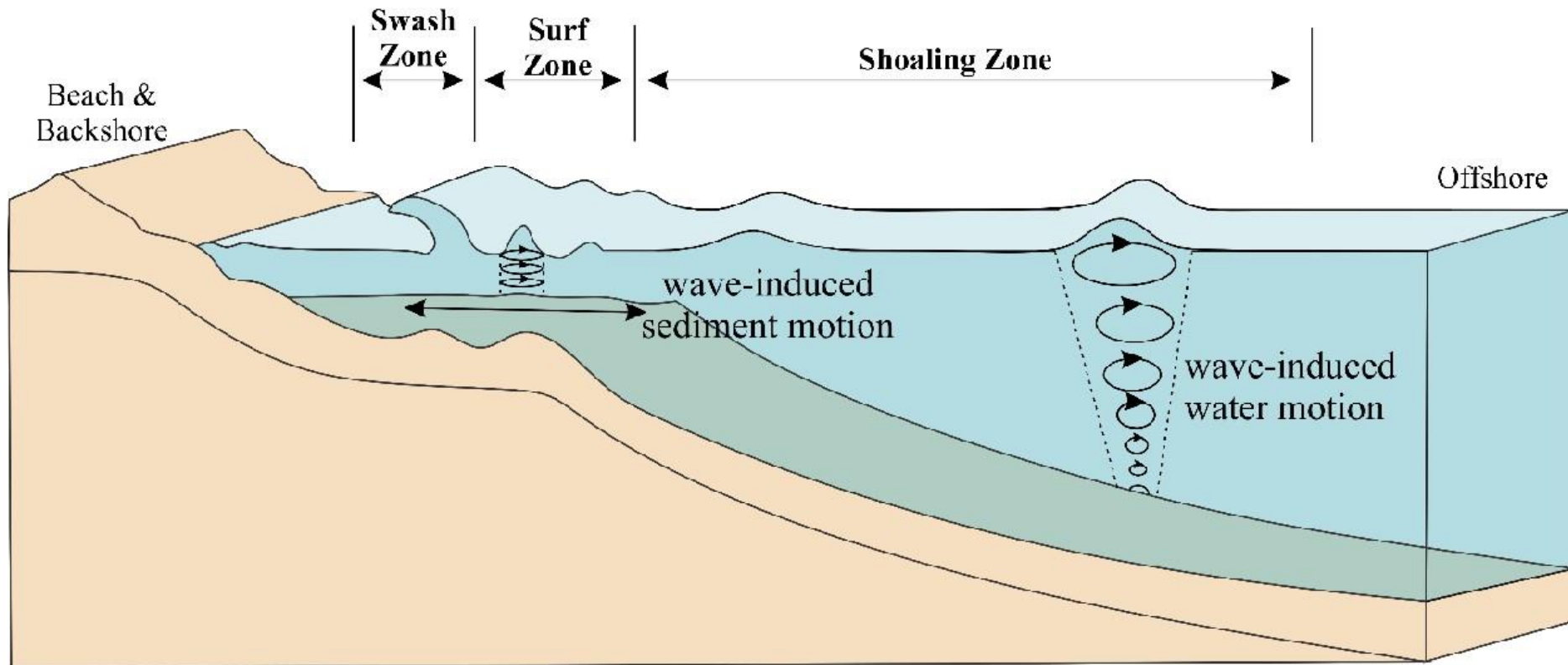
“soft engineering”
“hard engineering”



possibili interventi mitigativi

I diversi «corpi» di una costa

Shanganiali (2007)

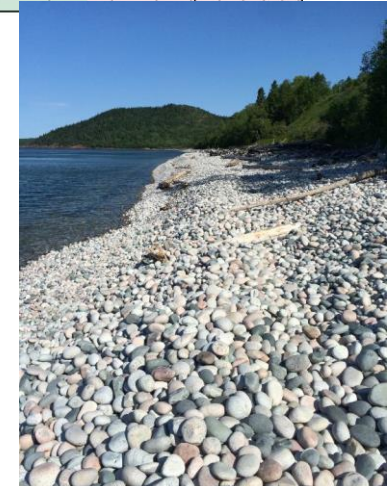
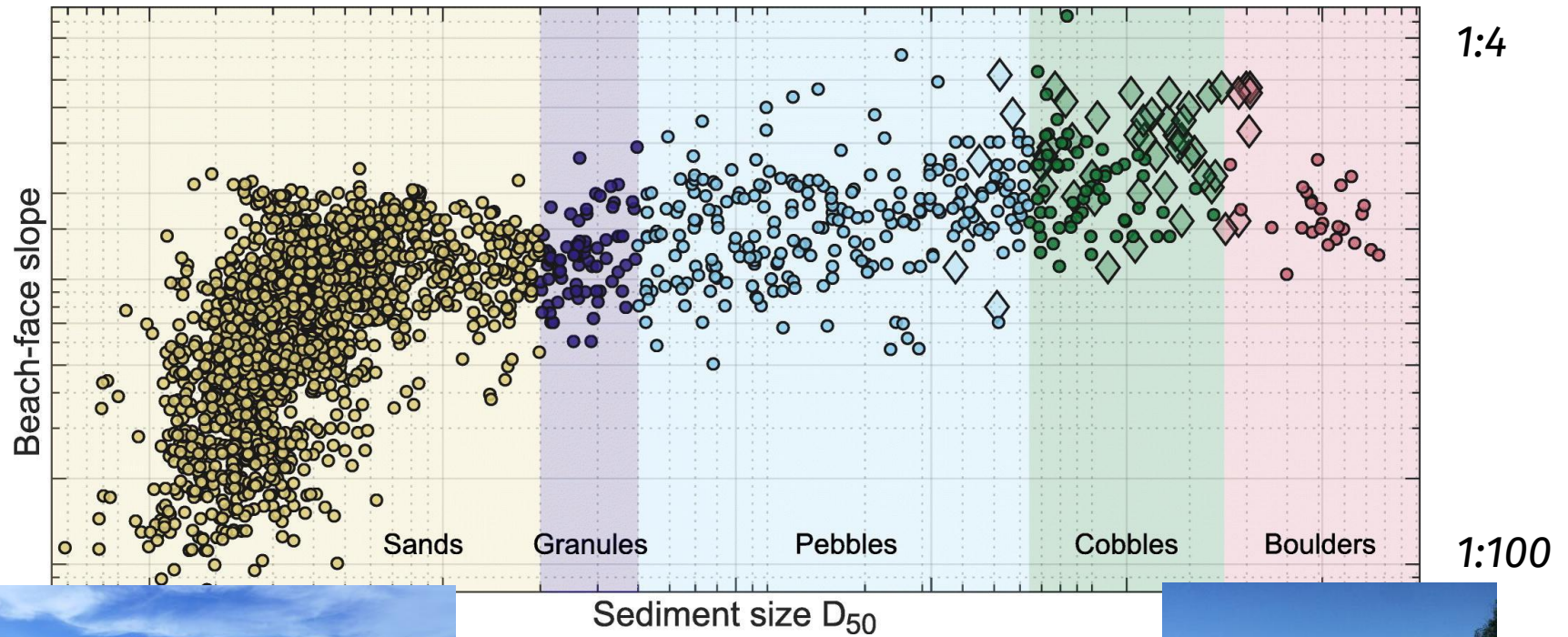


«Dune-Beach utopia»

Kamphuis – Introduction to Coastal Engineering and Management

Morfologia della costa

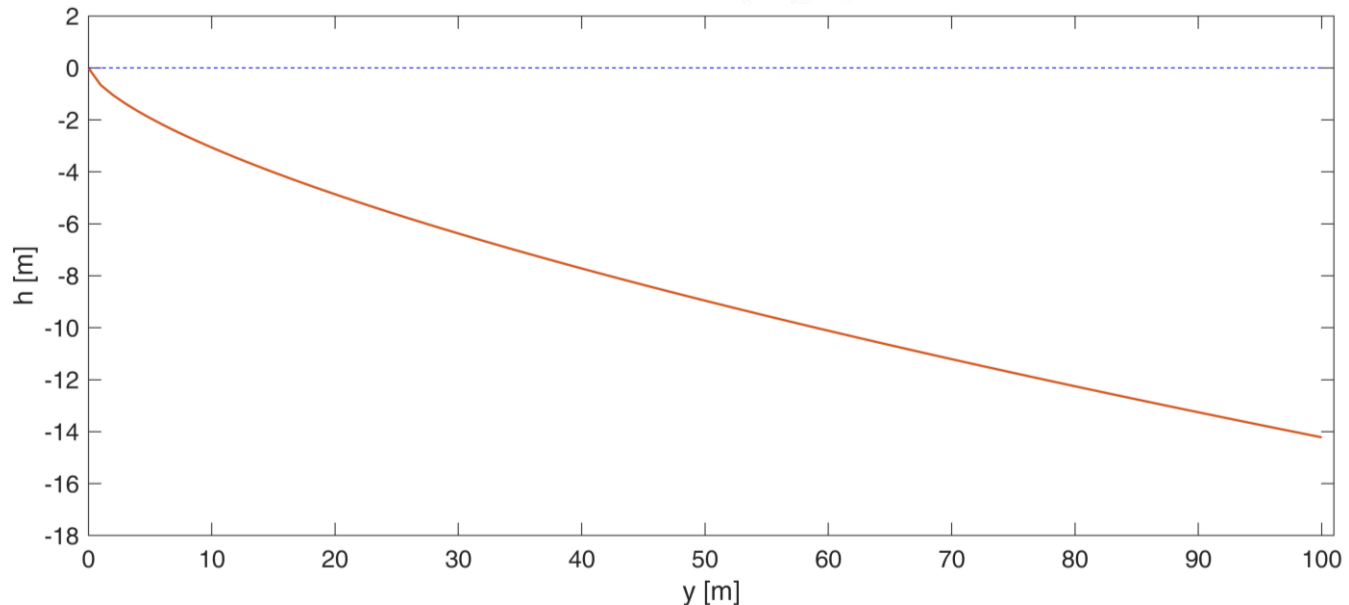
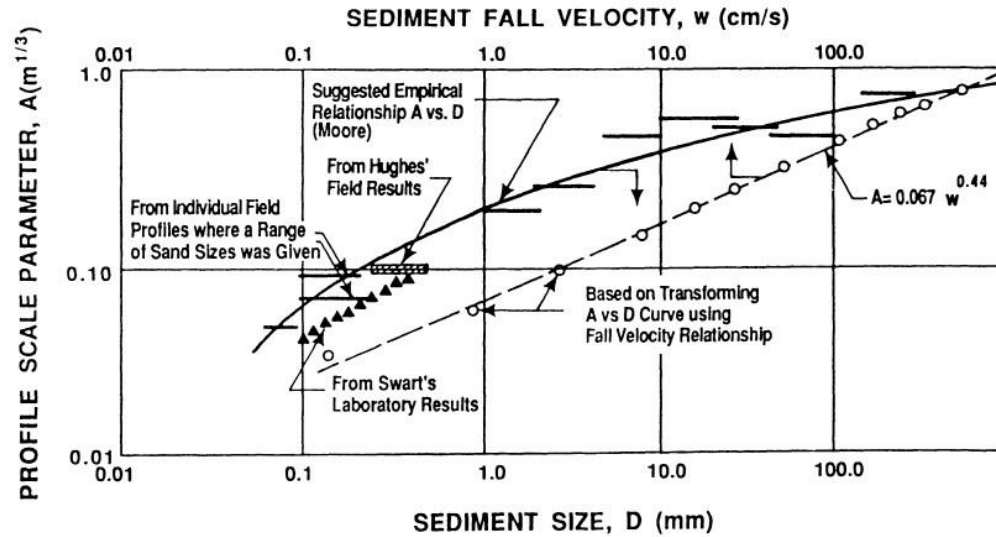
Bujan et al., (2019)



Morfologia della costa

$$h = Ay^{2/3}$$

Dean (1977)

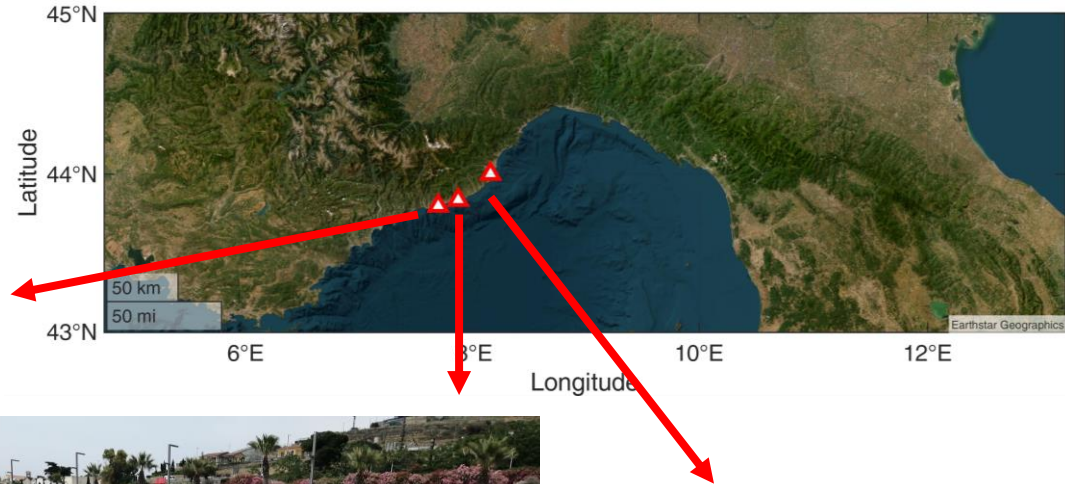


Morfologia della costa

Le spiagge liguri



Ospedaletti (IM)



Santo Stefano (IM)

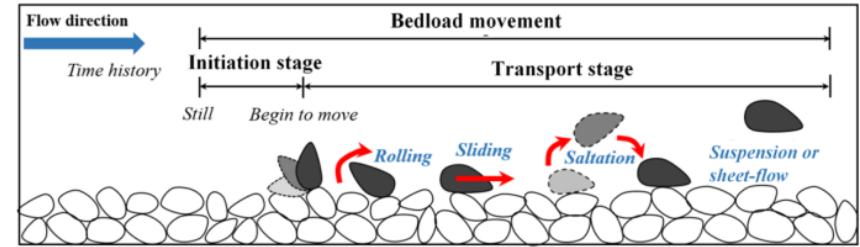


Alassio (SV)

per gentile
concessione di
Geoscape



Morfologia della costa



Tensione critica per diversi tipi di materiale solido

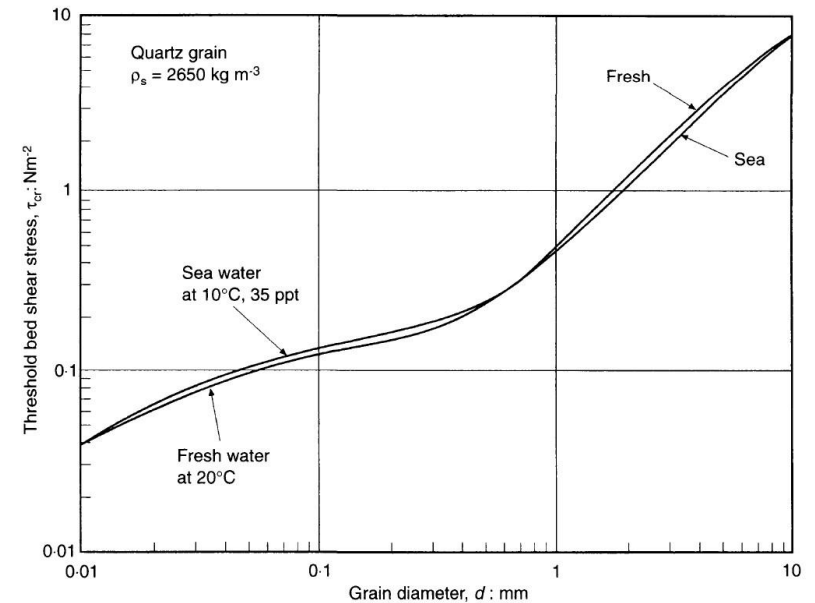
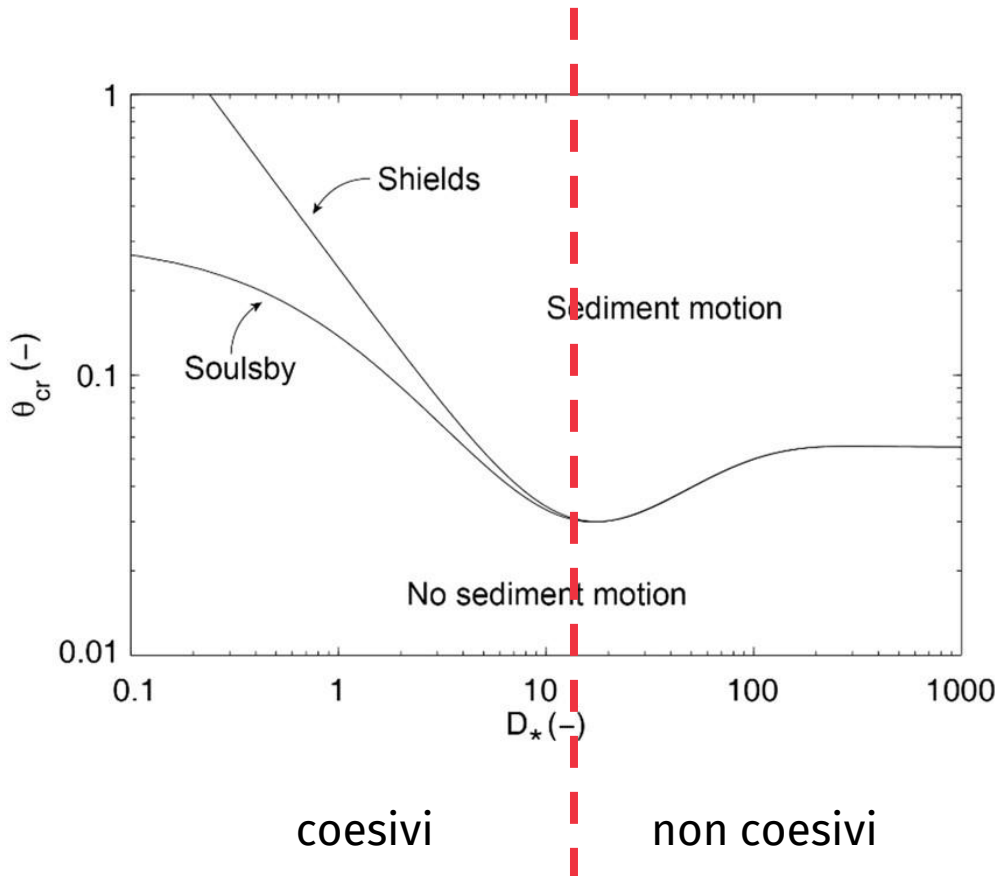


Figure 21. Threshold bed shear-stress for motion of quartz grains of sieve diameter d

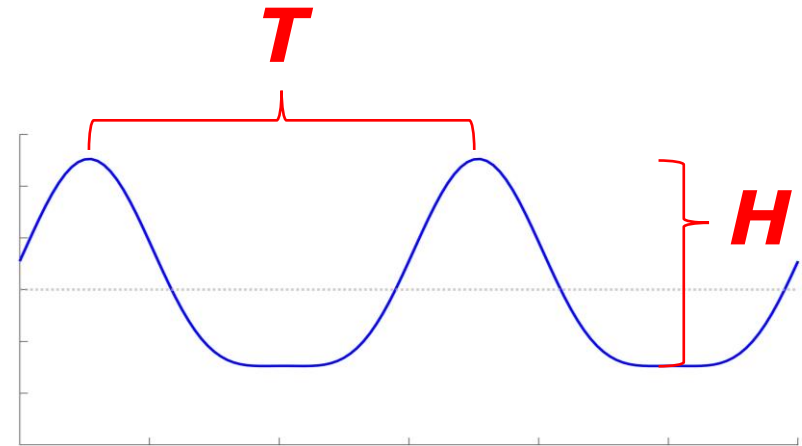
Soulsby (1997)

Le forzanti ambientali

onde di mare

I parametri principali

sup. libera



tempo



Le forzanti ambientali

onde di mare

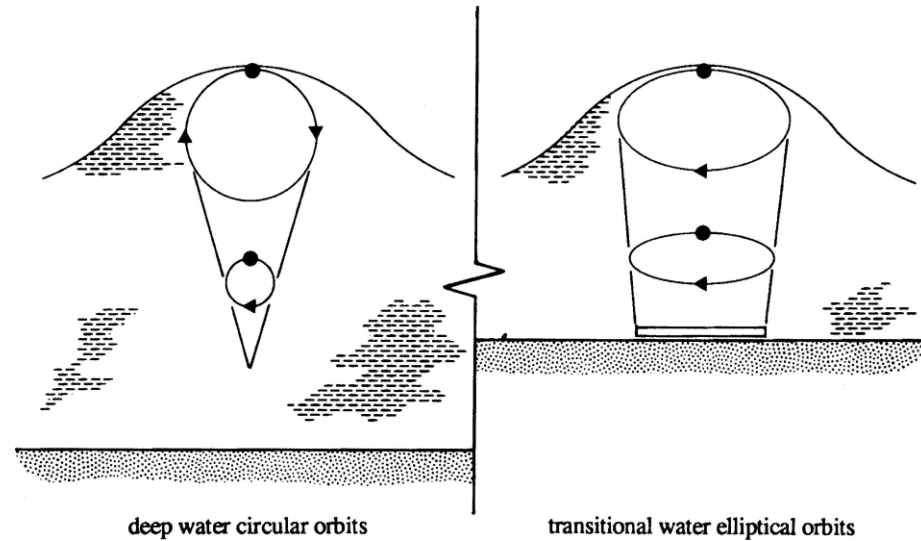
I moti indotti

elevate
profondità



direction of wave propagation →

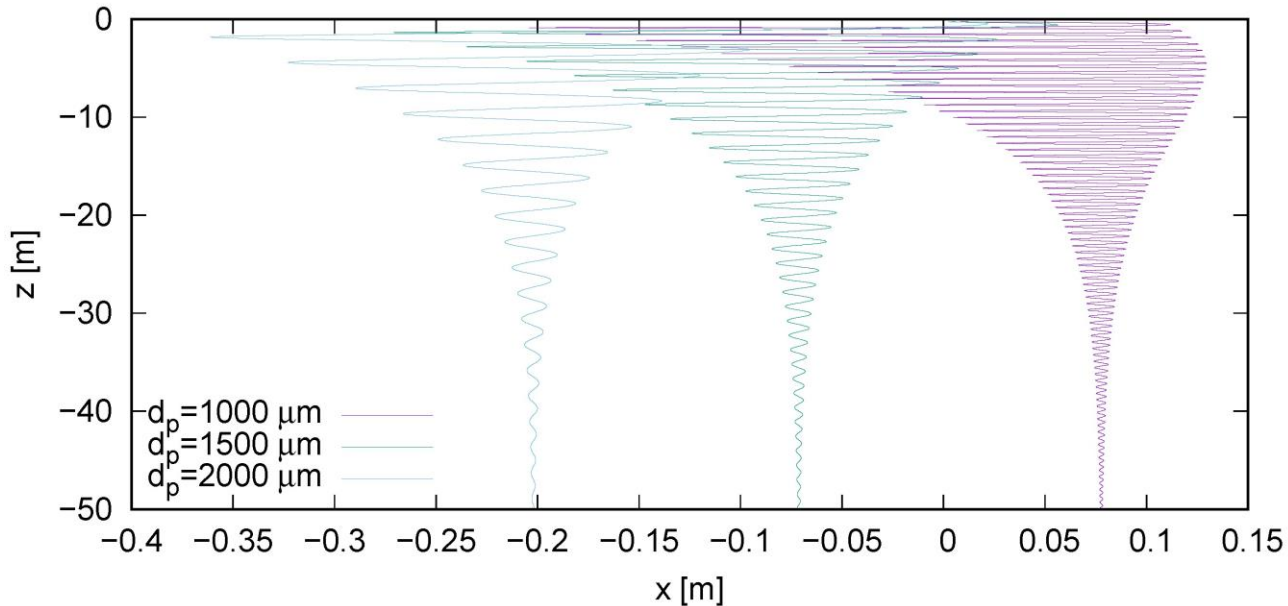
Sorensen (1993)



basse
profondità



RUN 12

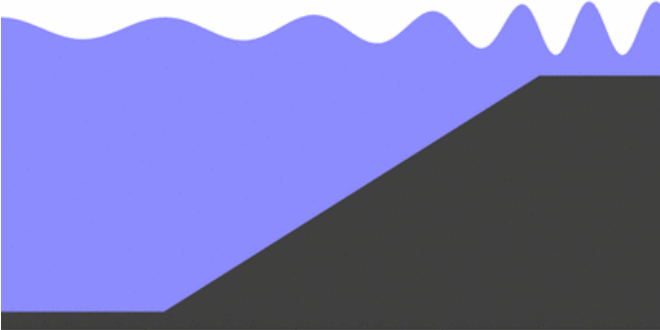


Stocchino et al., (2019)

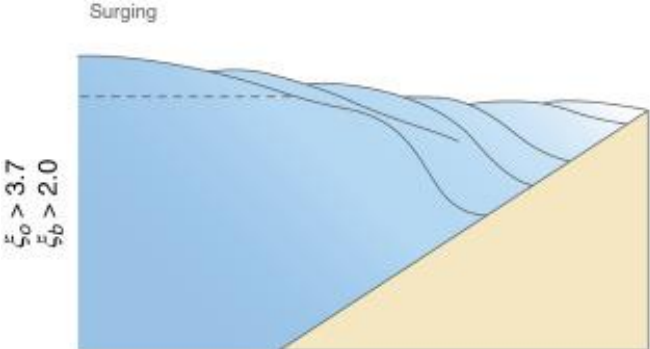
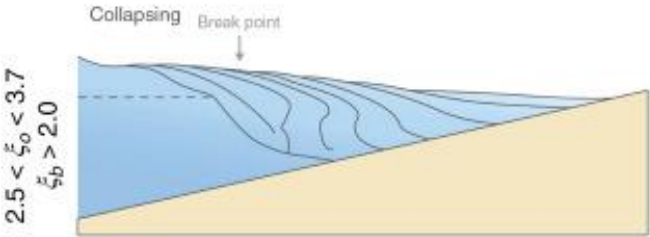
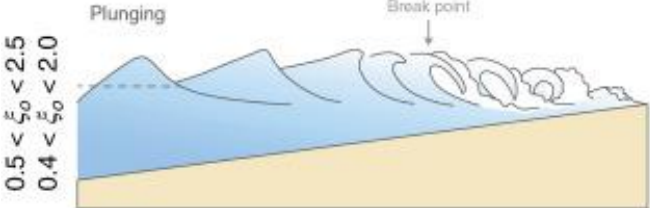
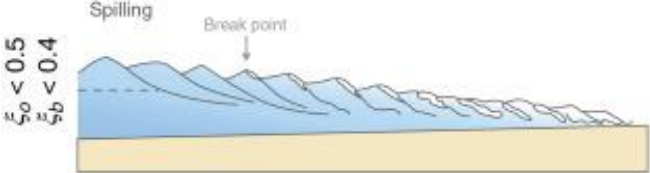
Le forzanti ambientali

onde di mare

Wave shoaling



Frangimento

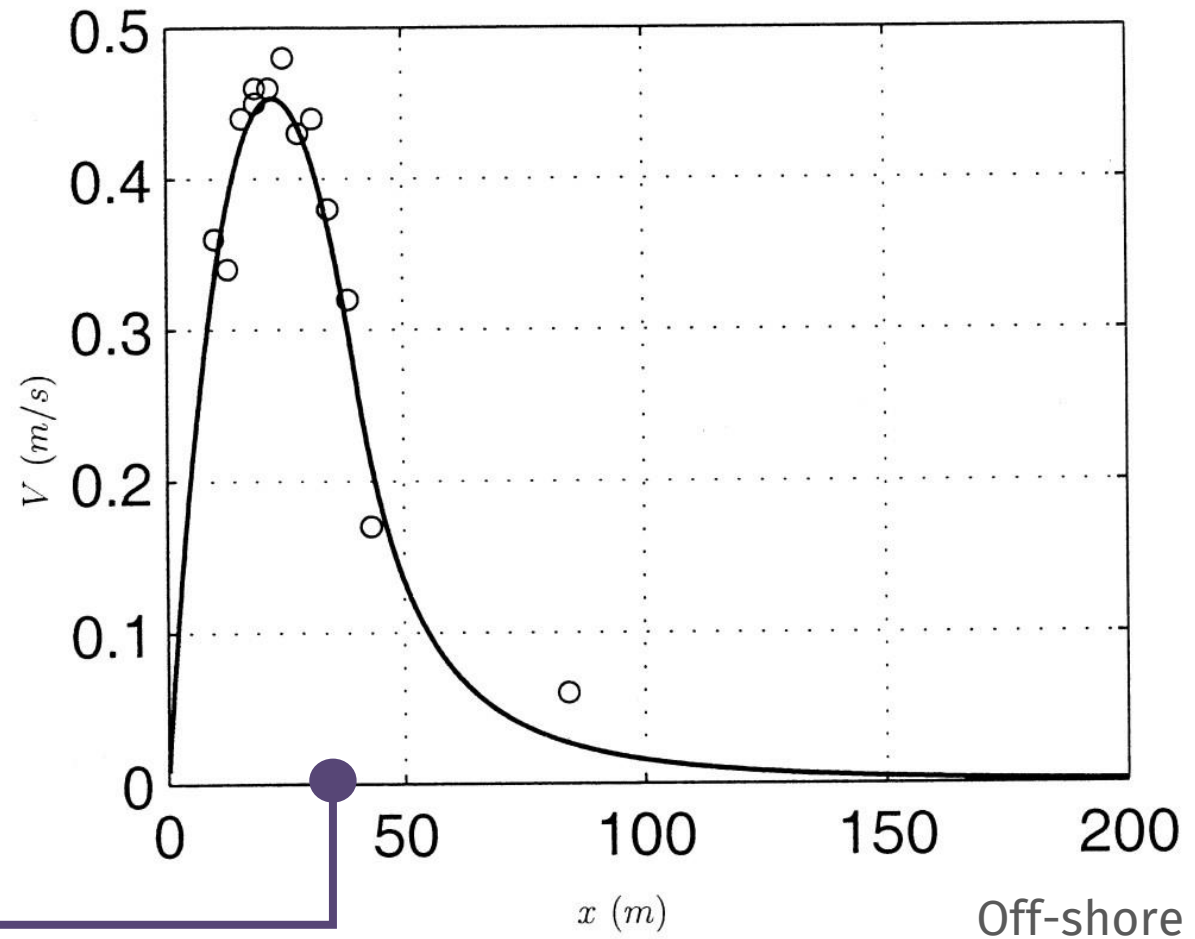


Power (2020)

Le forzanti ambientali

Haller & Dalrymple (1999)

onde di mare



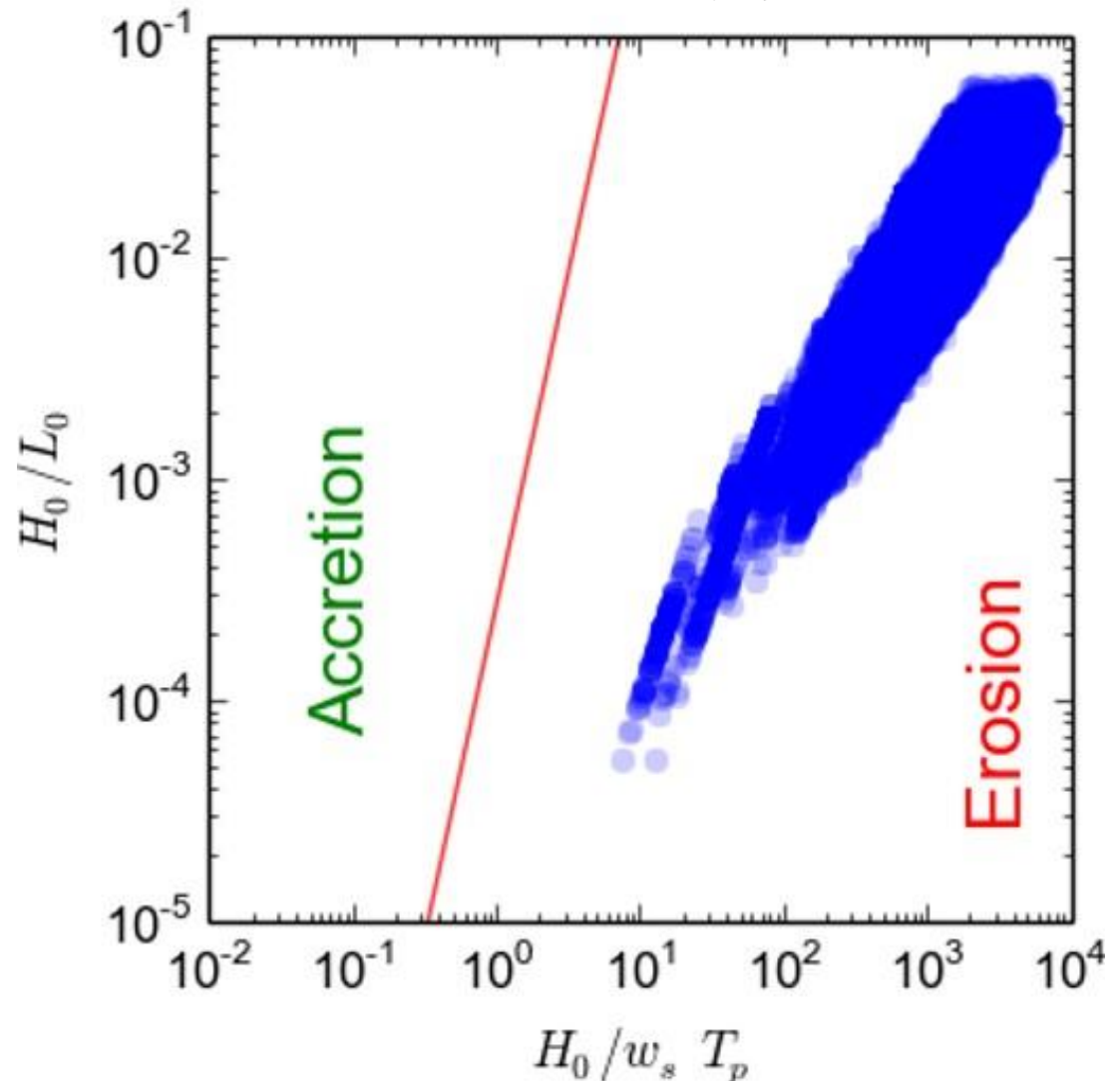
Sezione al
frangimento

Le forzanti ambientali

onde di mare

- $H_o \rightarrow$ altezza d'onda
- $L_o \rightarrow$ lunghezza d'onda
- $T_p \rightarrow$ periodo d'onda
- $w_s \rightarrow$ velocità di caduta dei sedimenti

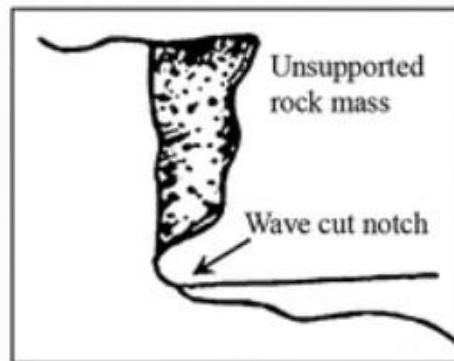
Dean & Dalrymple (2004)



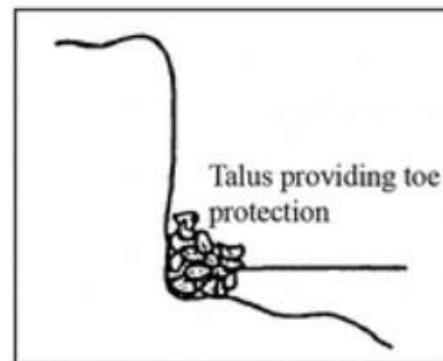
Le forzanti ambientali

onde di mare

*adattato da:
Kumar et al., (2009)*



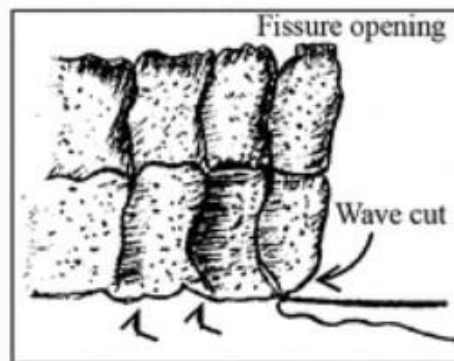
1. Before Rockfall



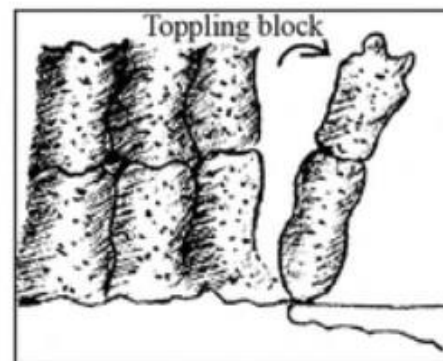
After Rockfall



Cliff fall; Wave cut notches at Kadalai.



2. Before Toppling Failure



After Toppling Failure



Toppling failure at Varkala.

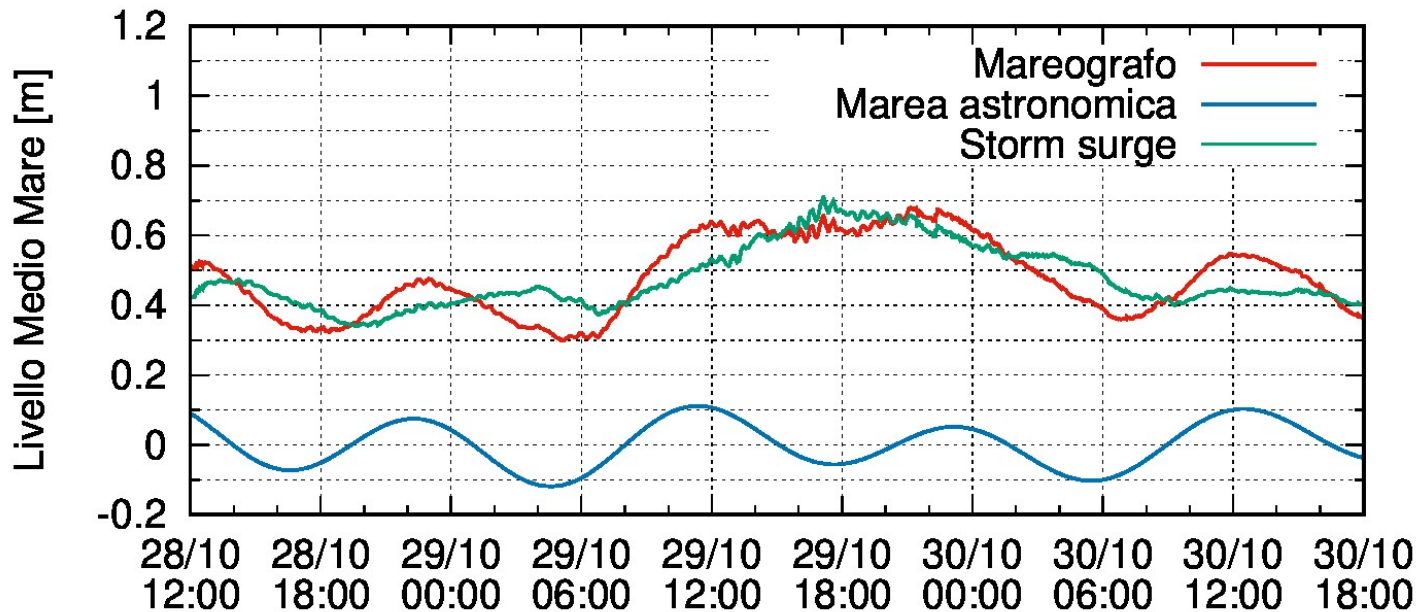
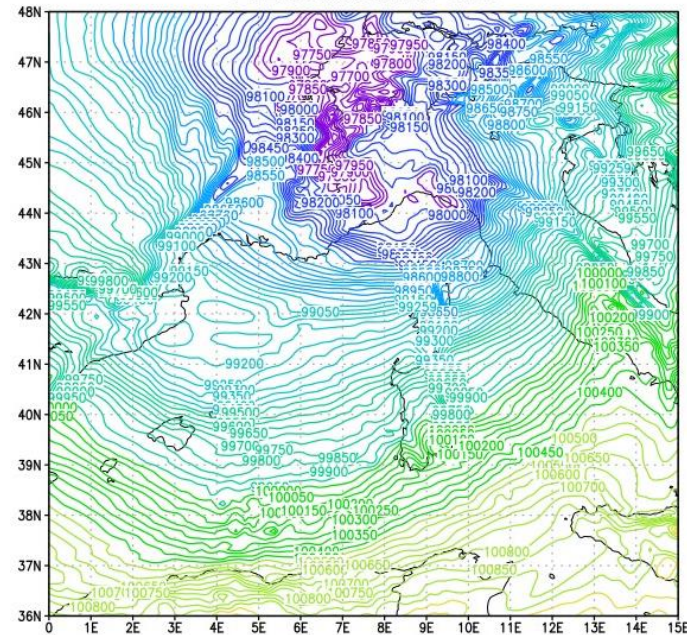
Le forzanti ambientali

Storm surge

$$\Delta p = \rho g \Delta h$$

“la mareggiata del secolo”

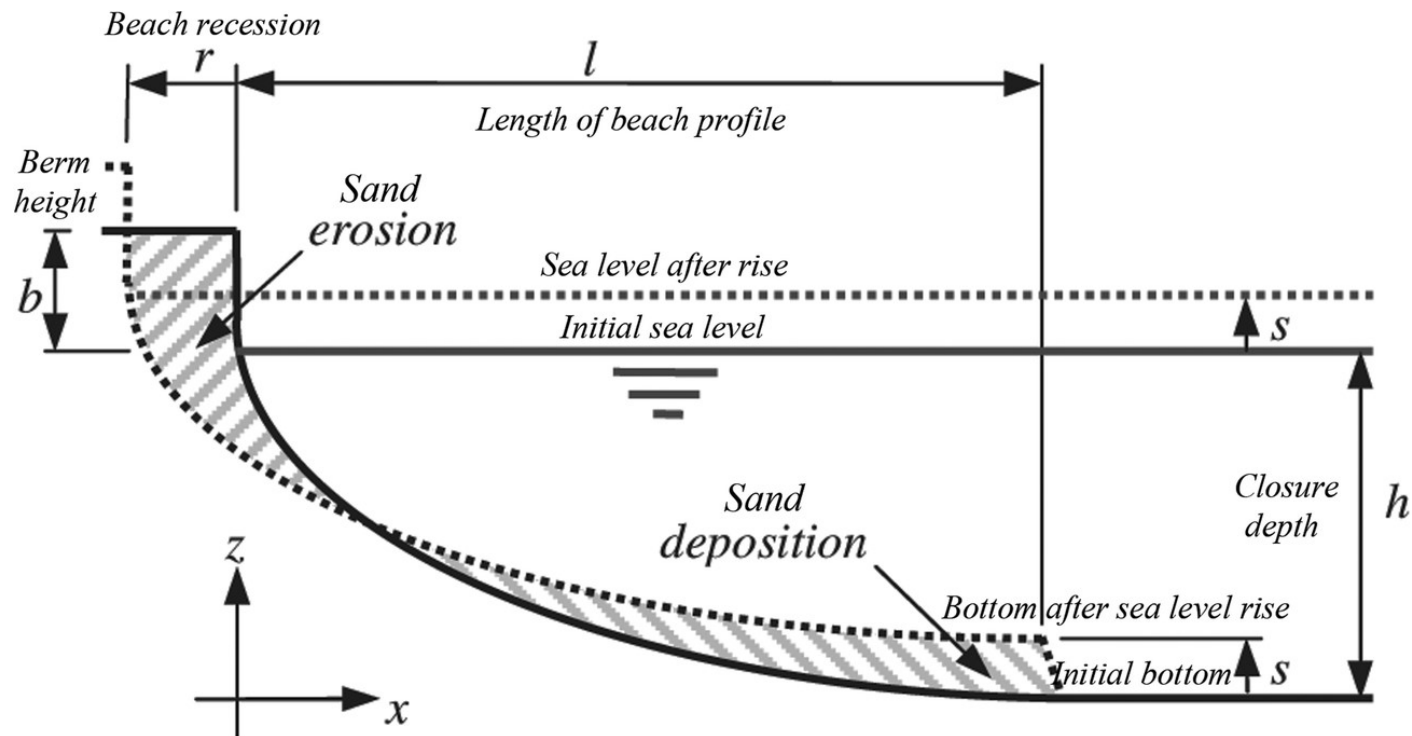
19Z29OCT2018 UTC



per gentile
concessione di
Giovanni Besio e
Francesco Ferrari

Le forzanti ambientali

SLR
$$r = \frac{s \times l}{h + b} \quad \text{Brunn (1962)}$$

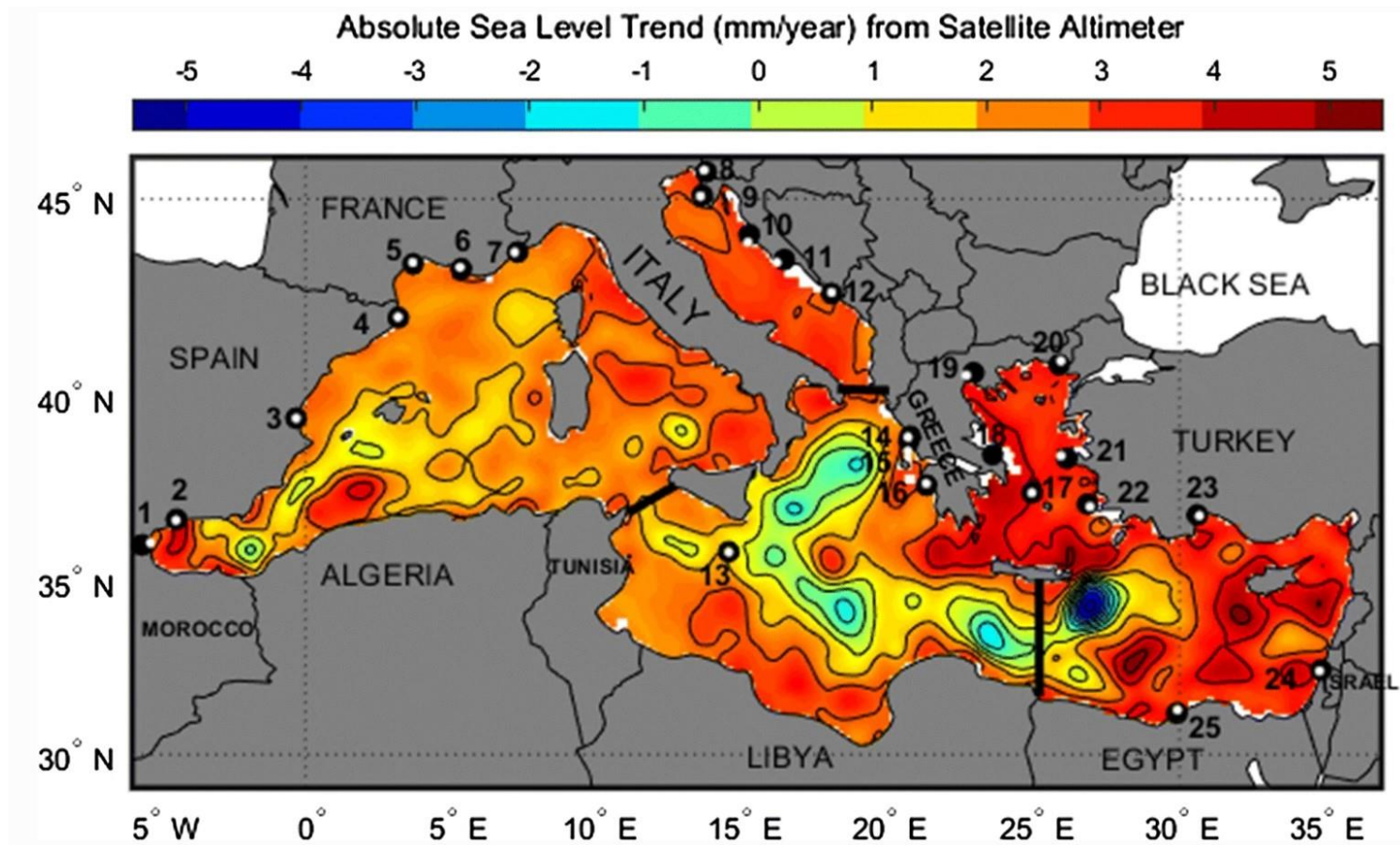


Cooper, J. A. G., & Pilkey, O. H. (2004). Sea-level rise and shoreline retreat: time to abandon the Bruun Rule. *Global and planetary change*, 43(3-4), 157-171.

Le forzanti ambientali

SLR

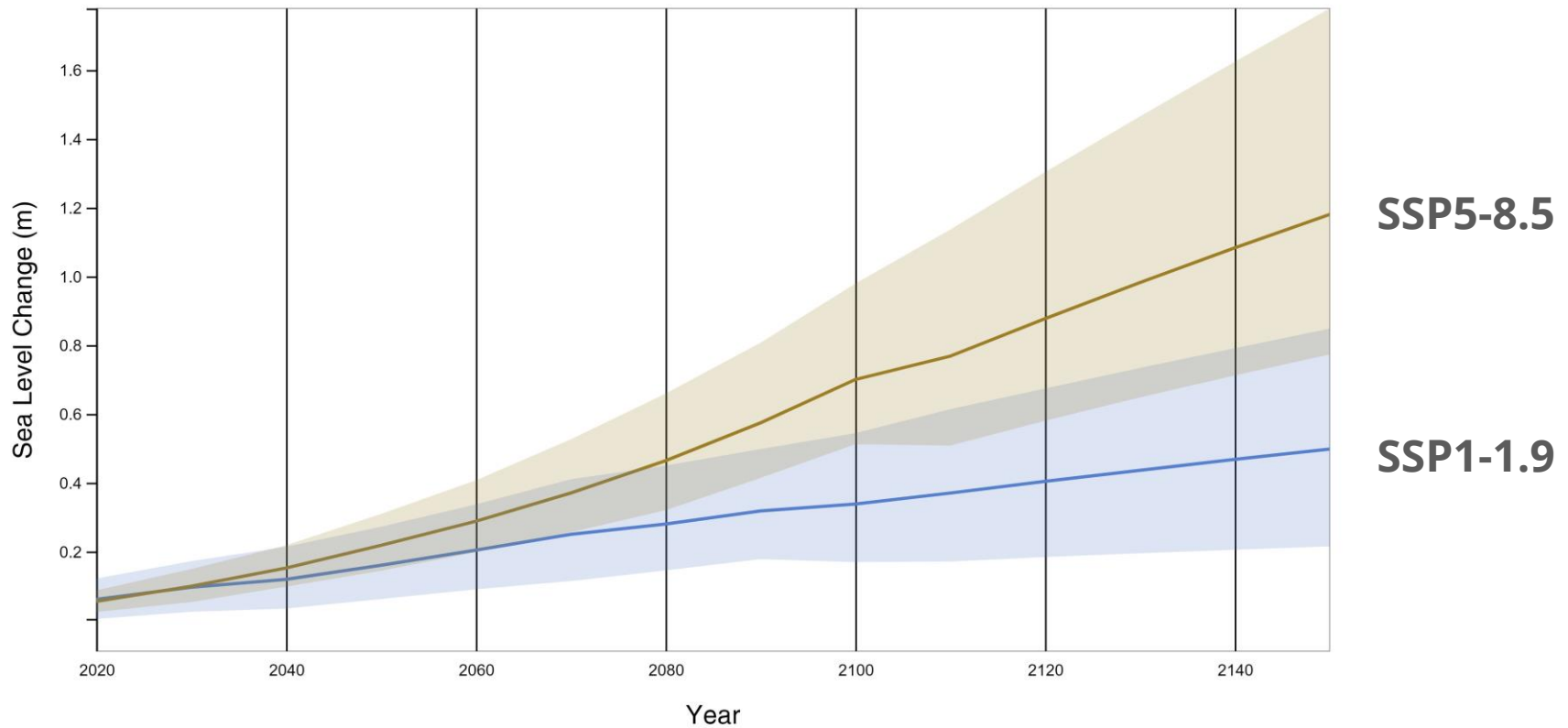
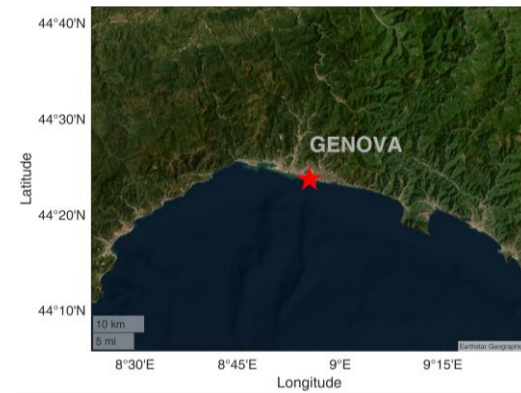
Mohamed et al., (2019)



tendenze nel periodo 1993-2017

Le forzanti ambientali

SLR



<https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool>

Le forzanti ambientali

Le escursioni mareali

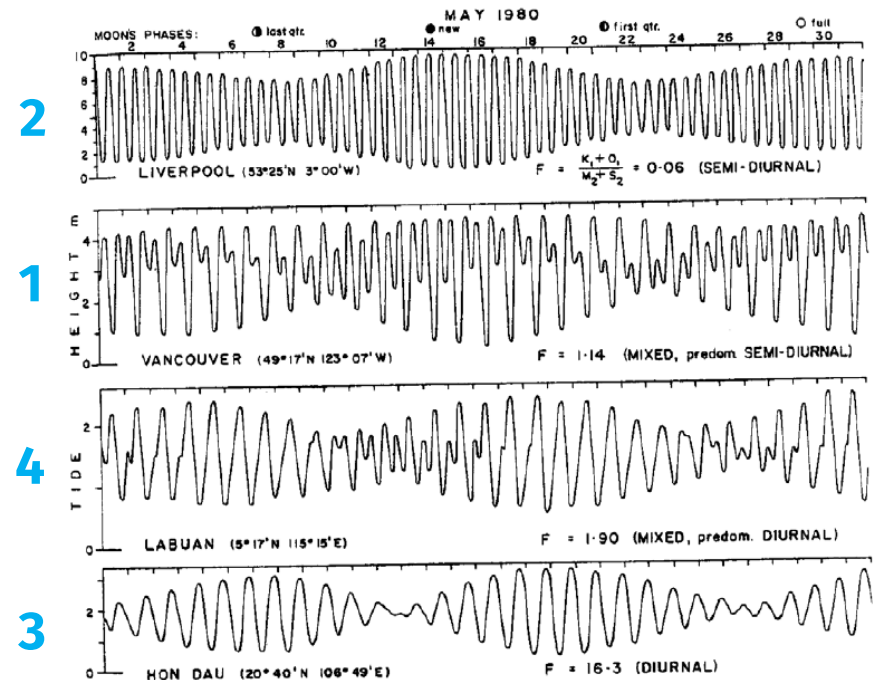
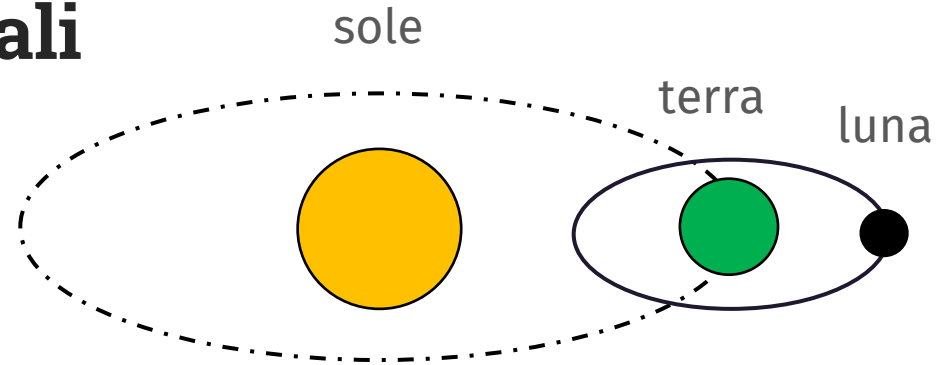


FIG. 13.1 Tide curves for May 1980 (data from Admiralty Tide Tables) showing four types in terms of the "form ratio" $F = (K_1 + O_1)/(M_2 + S_2)$ of major diurnal to semi-diurnal constituents.

Le forzanti ambientali

Le escursioni mareali

Staithes, Yorkshire

©Marten



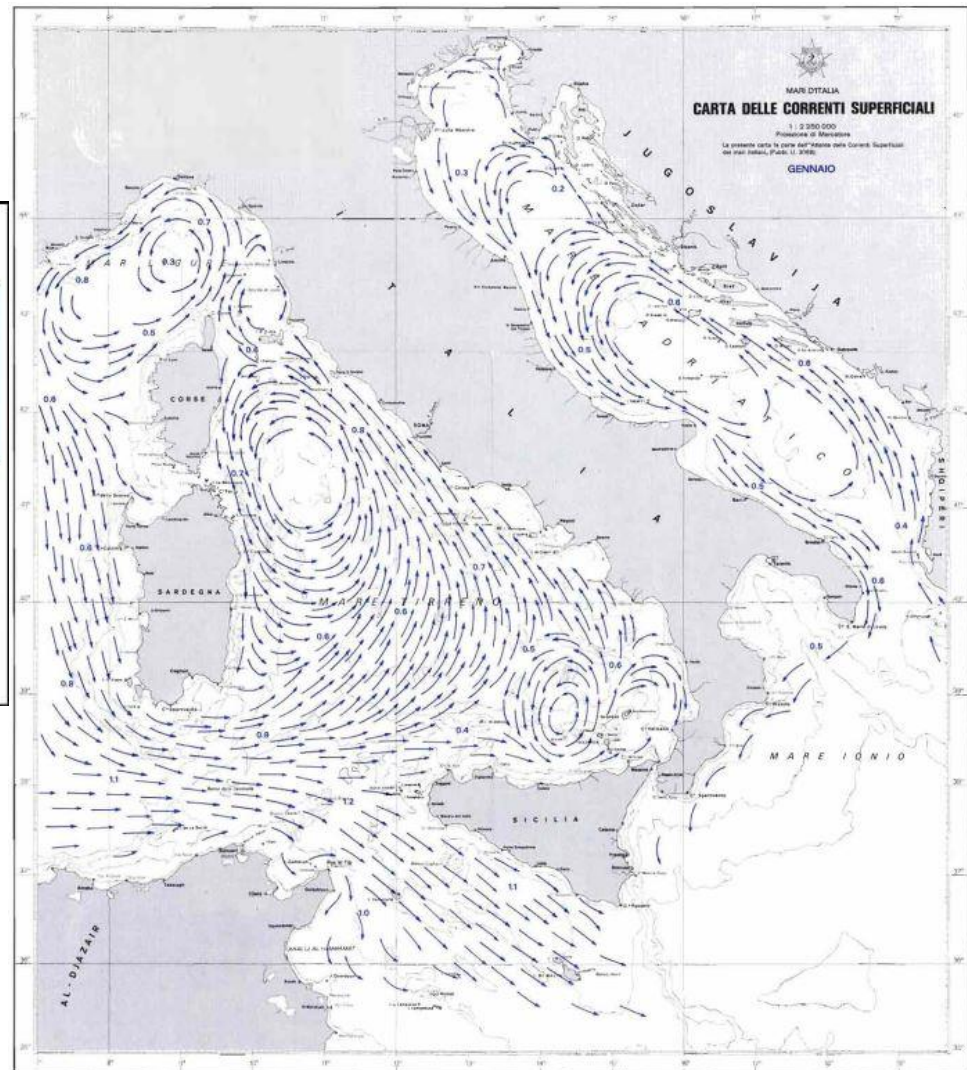
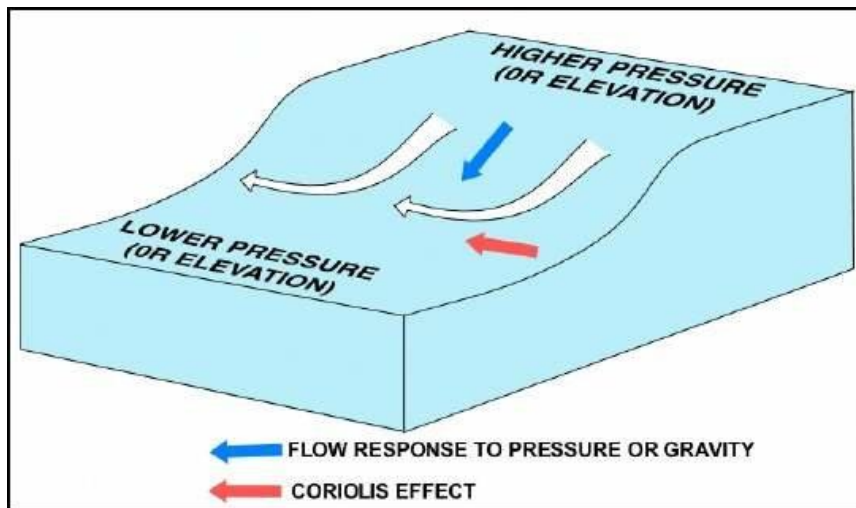
corrente



corrente

Le forzanti ambientali

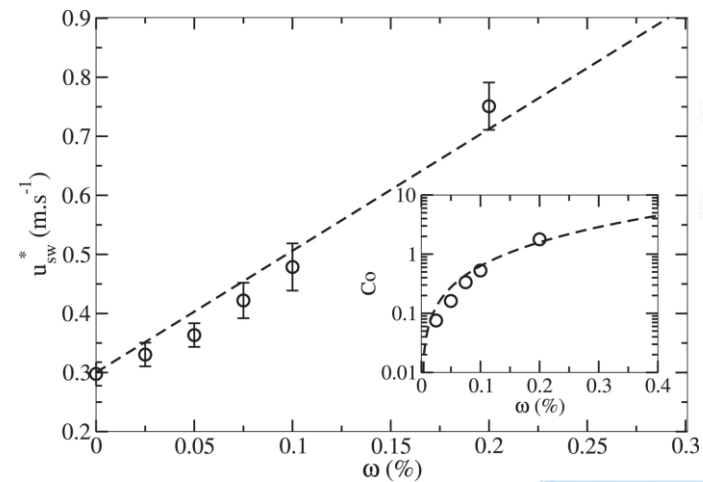
Correnti oceaniche



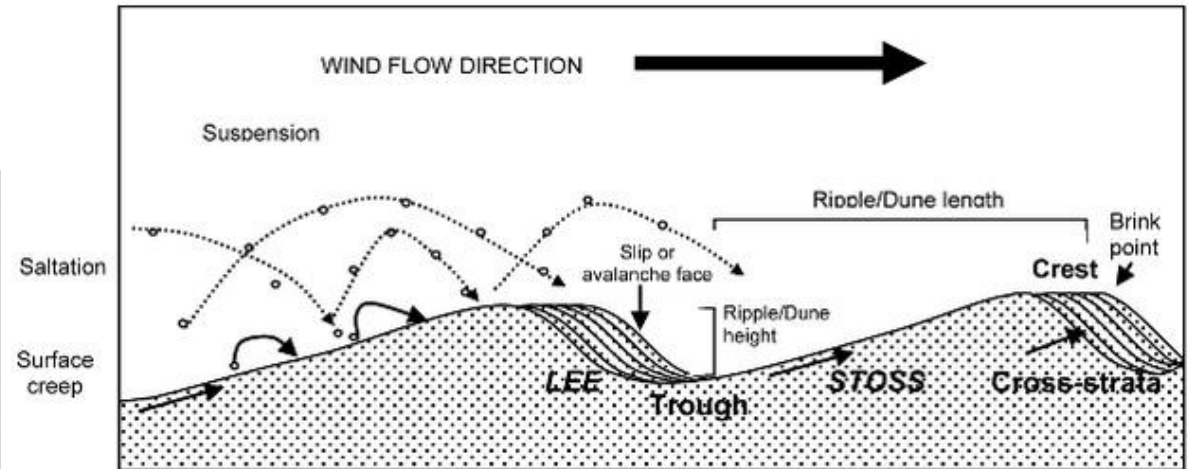
Le forzanti ambientali

Vento

Besnard et al., (2022)



©Nature communication (2012)



Strypsteen et al., (2021)



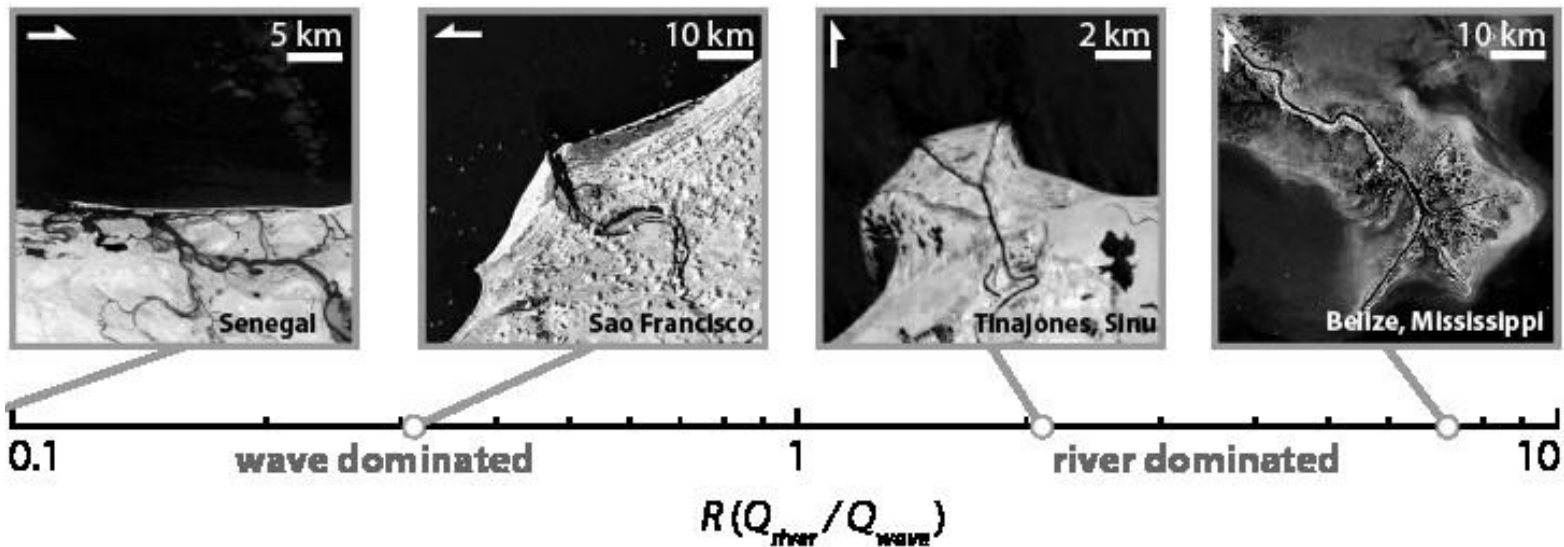
Le forzanti ambientali

Fiumi

Galloway, (1975)



<https://www.coastalwiki.org>



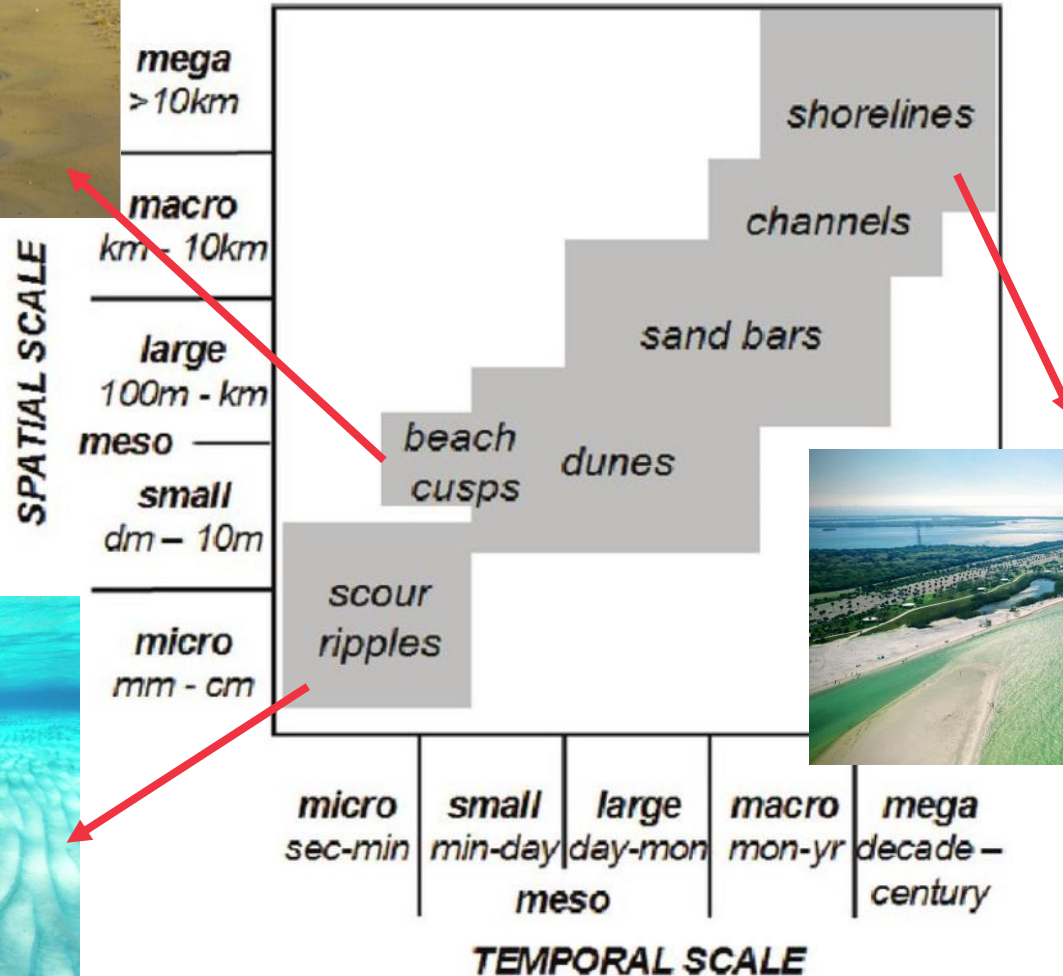
I fattori decorrono su diverse scale spazio/temporali



Ortega (2016)



Winter (2012)



Tampa Bay (FL)

scale «macro/mega»

$\approx [10^3; 10^4]m / \approx [10^0; 10^3]y$



©Marli Miller



San Diego (CA)

<https://www.geocaching.com/geocache/GC20FPC>

scale «macro/mega»

$\approx [10^3; 10^4]m$ / $\approx [10^0; 10^3]y$



Durdle door (UK)

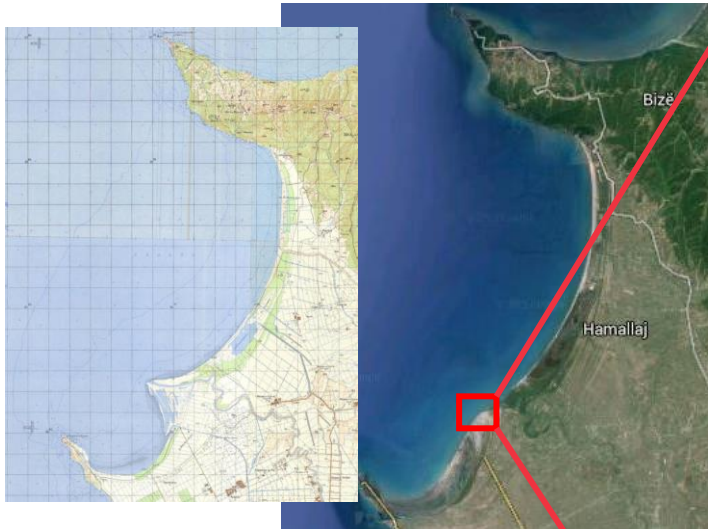
L'arche et l'aiguille d'Etretat (FR)



e-education.psu.edu

scale «large/macro»

$\approx [10^0; 10^3]m$ / $\approx [10^0; 10^3]d$



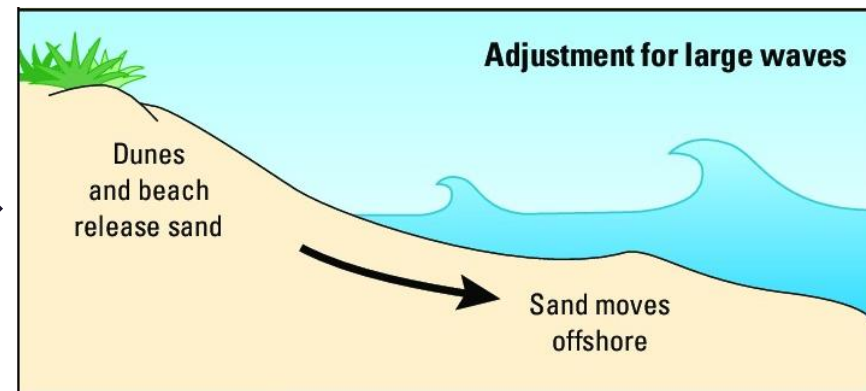
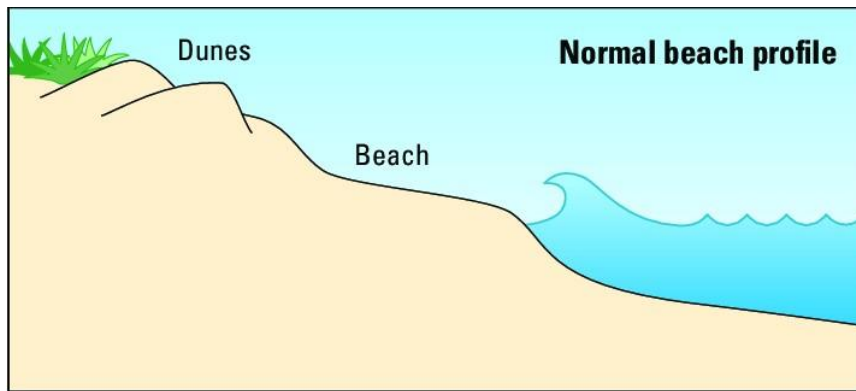
De Leo et al., (2017)



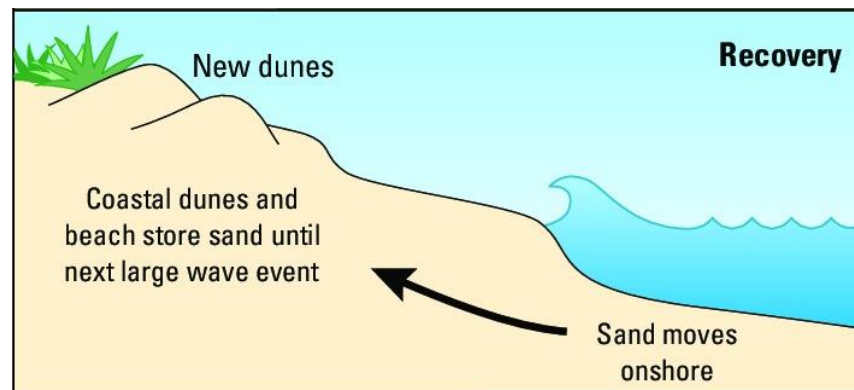
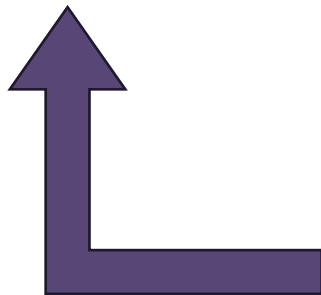
scale «small/large»

$\approx [10^0; 10^3]m$ / $\approx [10^0; 10^3]d$

PROFILO INVERNALE



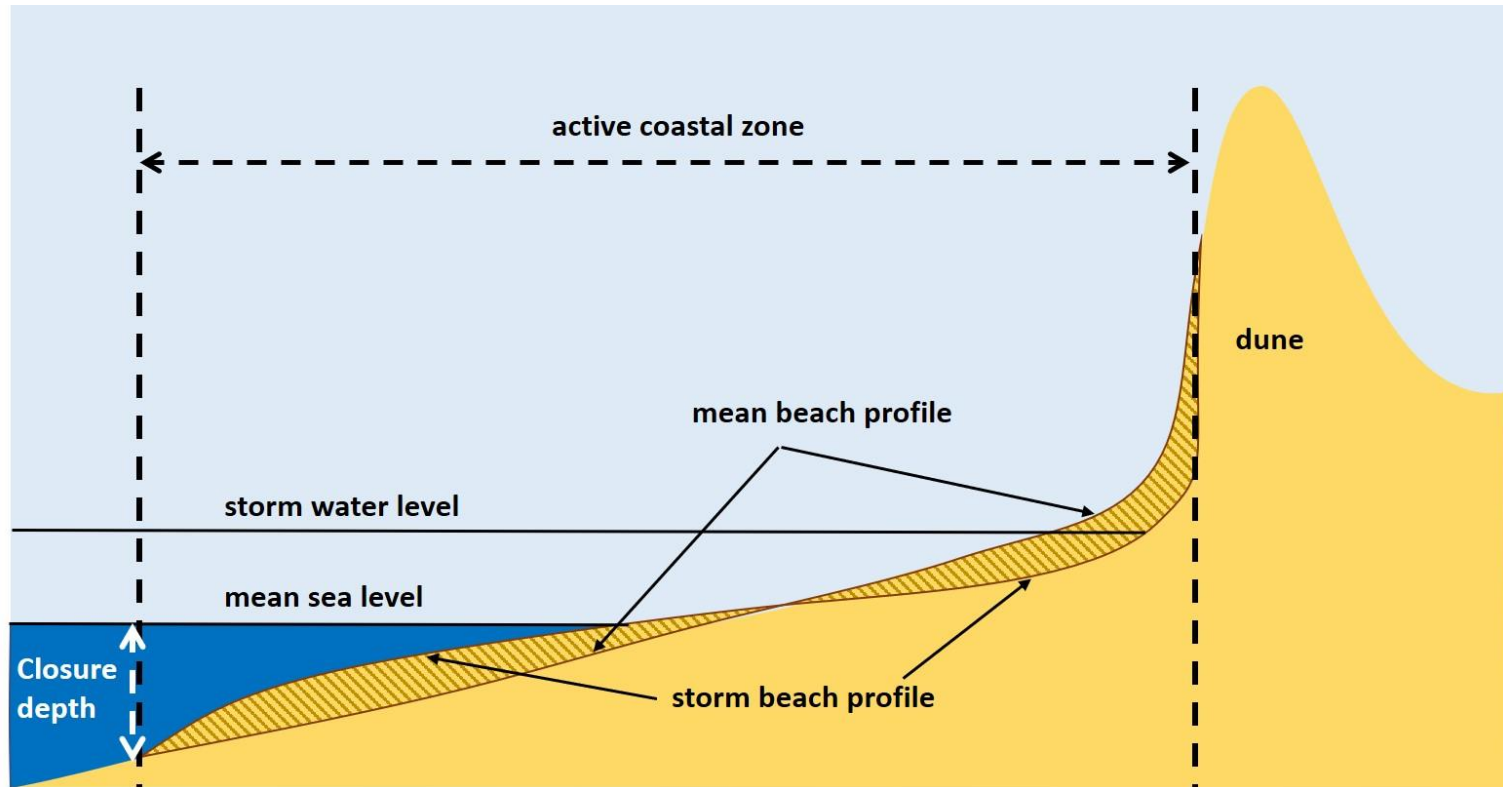
Fletcher et al., (2012)



scale «small/large»

profondità di chiusura

Hallermeier (1981)

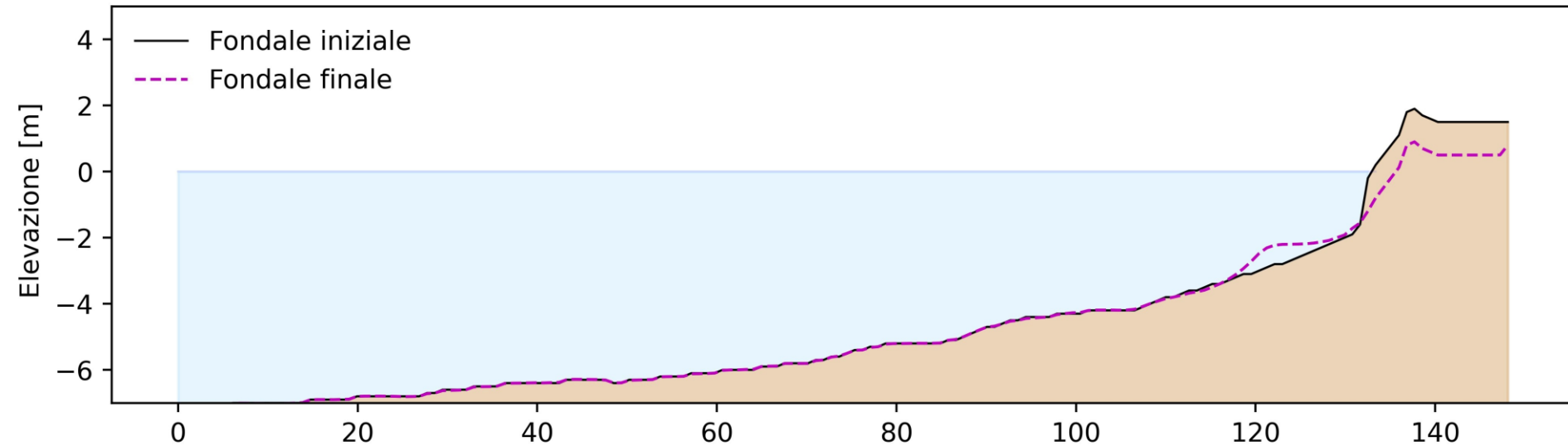


$$d_c \propto (H_{12}, T_{12})$$

scale «small/large»

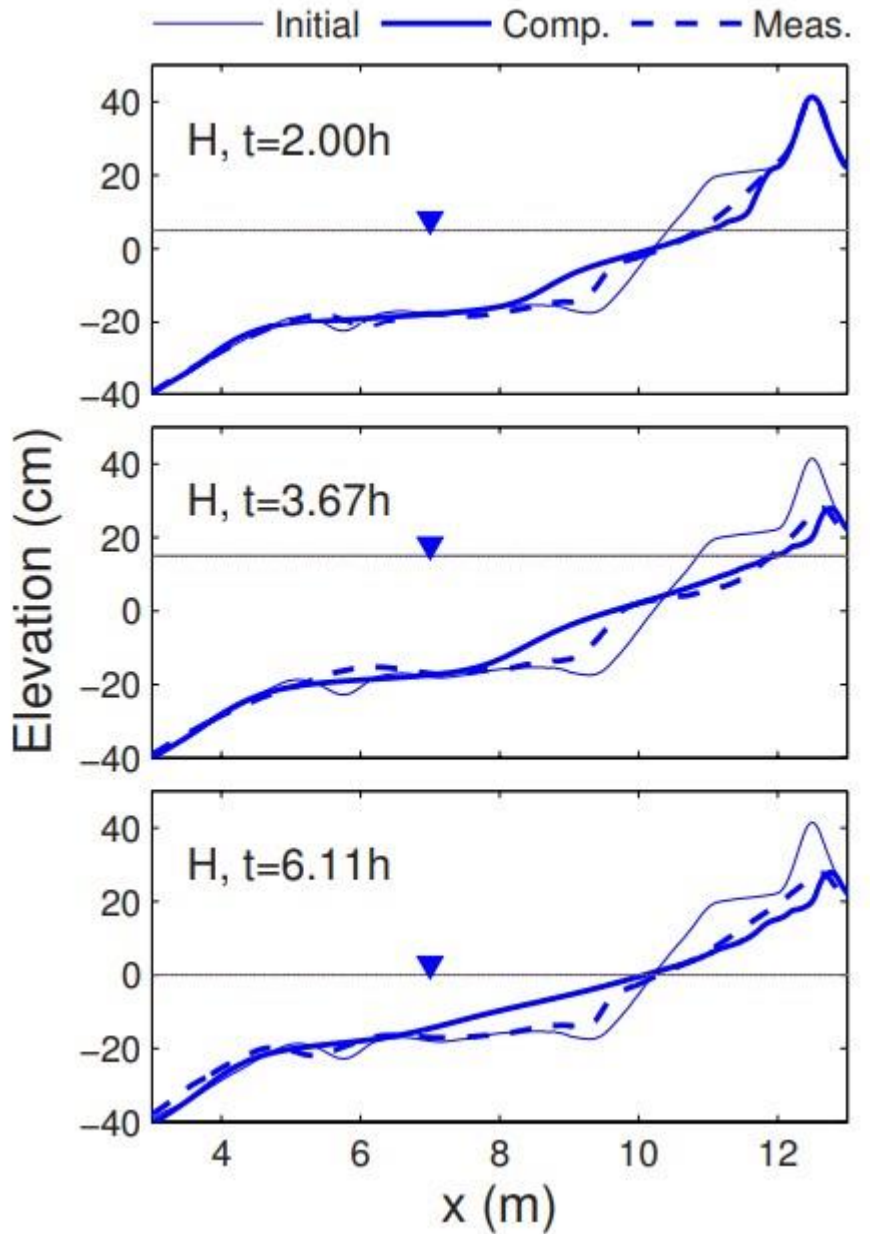
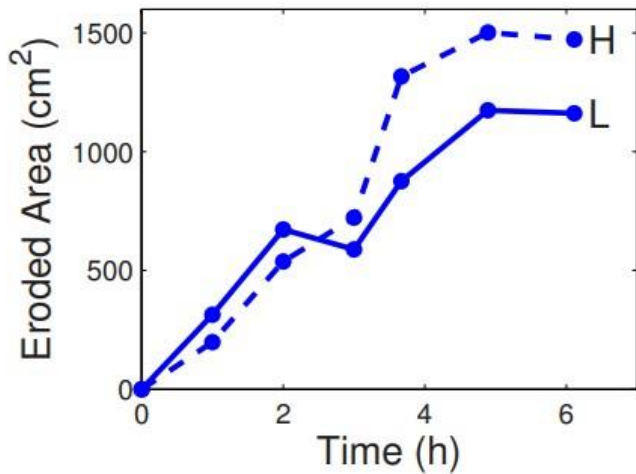
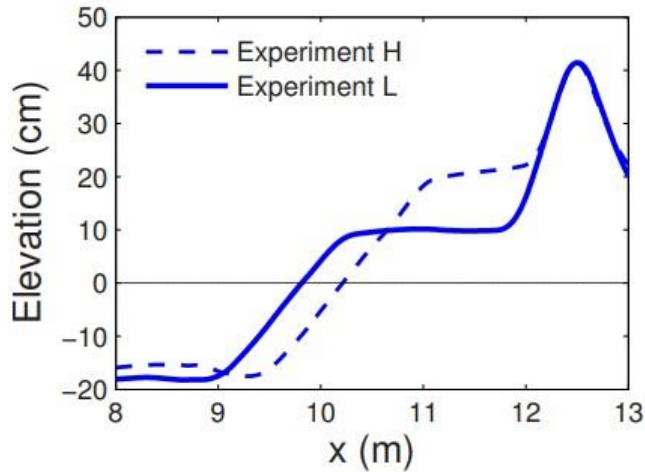
$$\approx [10^0; 10^3]m / \approx [10^0; 10^3]d$$

Erosione di un profilo trasversale a Sturla (GE)



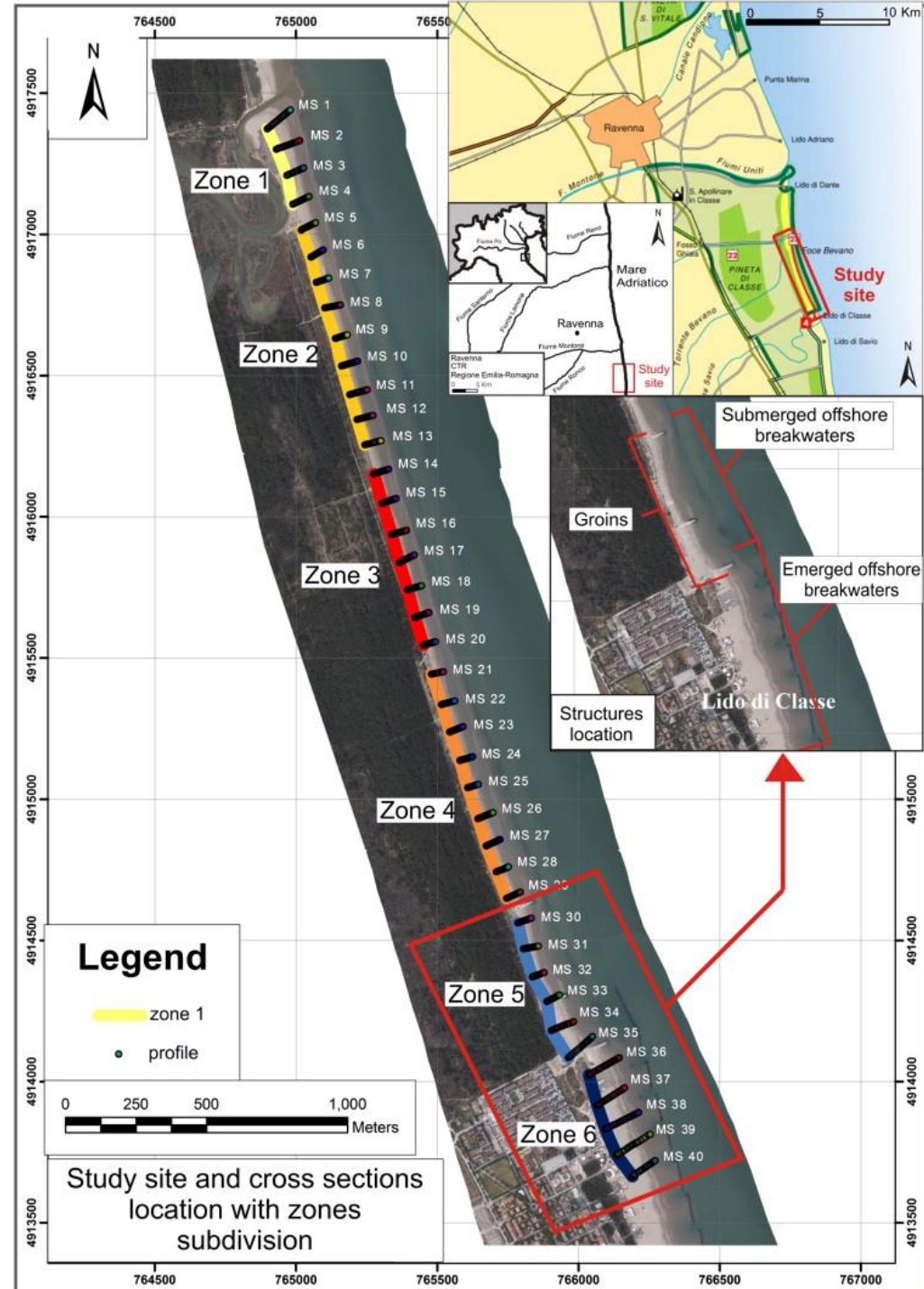
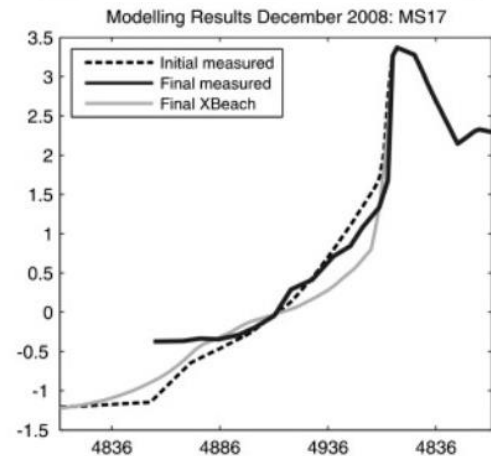
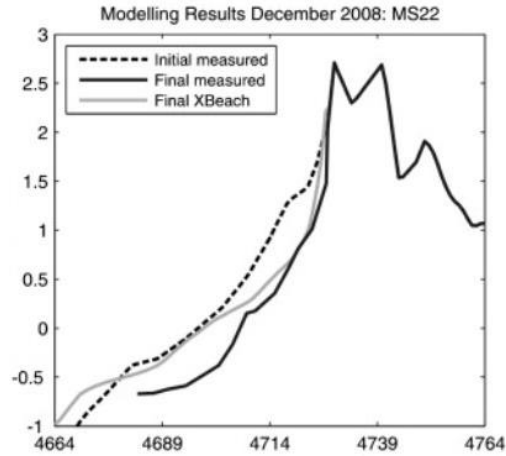
scale «small/large»

$\approx [10^0; 10^3]m / \approx [10^0; 10^3]d$



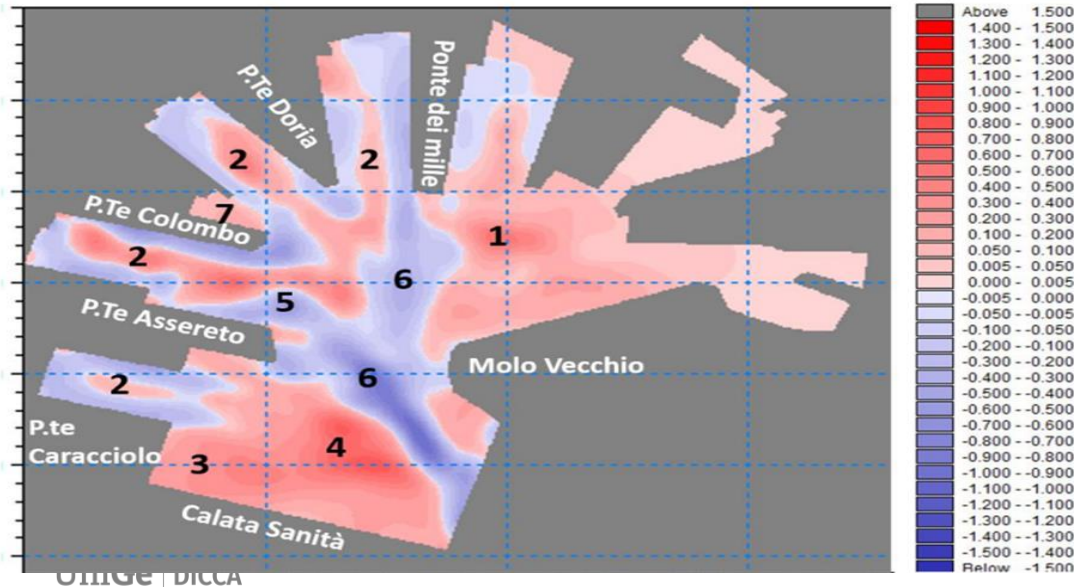
scale «small/large»

$$\approx [10^0; 10^3]m / \approx [10^0; 10^3]d$$



scale «small/large»

$$\approx [10^0; 10^3]m / \approx [10^0; 10^3]d$$



Deposito/Erosione nel
Porto di Genova (anno: 2017)

scale «small/large»

$$\approx [10^0; 10^3]m / \approx [10^0; 10^3]d$$



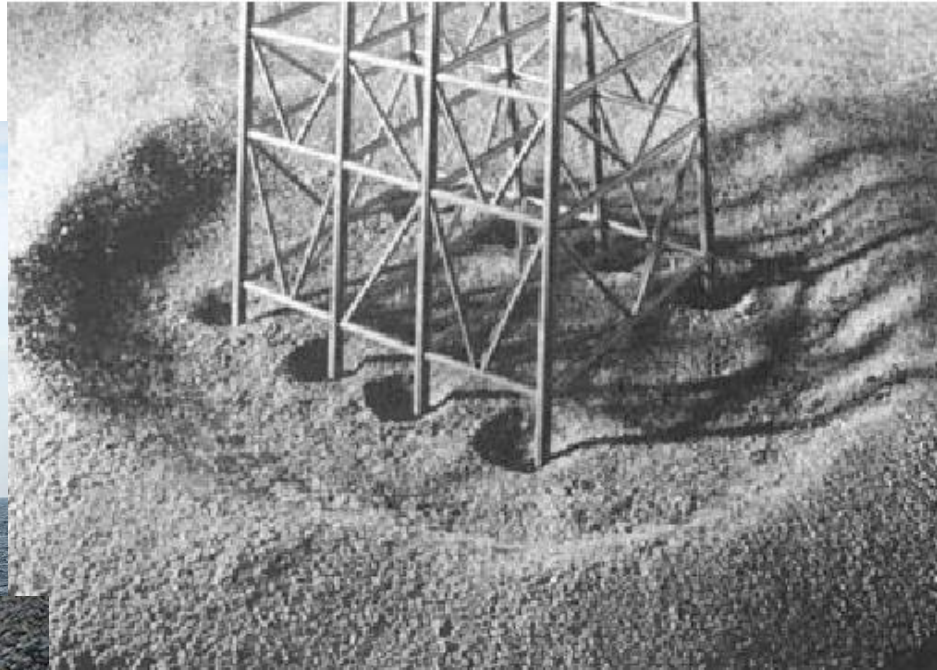
scavi in prossimità di strutture
monopile & jacket



(a) single pile scour (b) dunes appear (c) dunes move backward (d) pile groups scour as whole

scale «small/large»

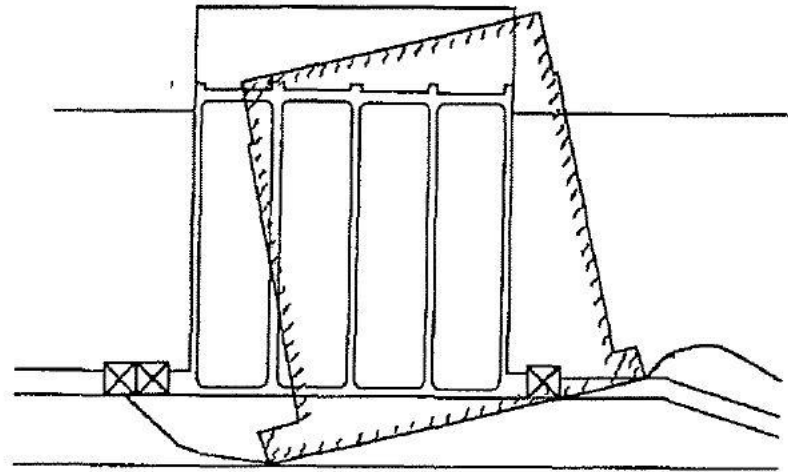
$\approx [10^0; 10^3]m / \approx [10^0; 10^3]d$



protezione del fondale tramite
massi guardiani

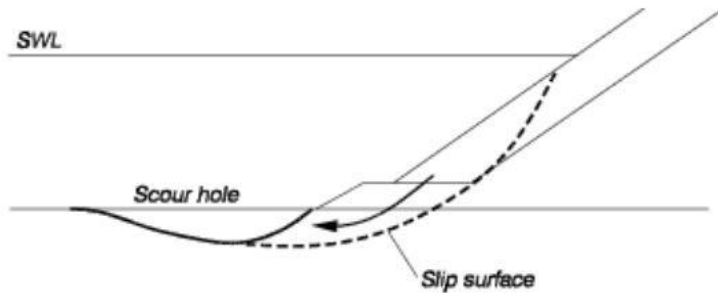
scale «small/large»

$\approx [10^0; 10^3]m$ / $\approx [10^0; 10^3]d$



scale «small/large»

$$\approx [10^0; 10^3] \text{m} / \approx [10^0; 10^3] d$$



Esteban et al., (2012)

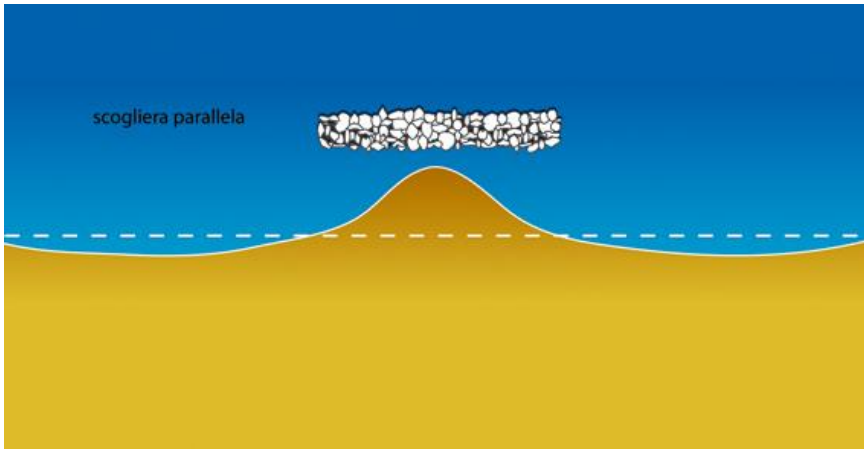


Figure 1. Damaged Sea-Block Armour Units at Ooya Port



Interventi di mitigazione

Strutture Rigide → scogliere parallele

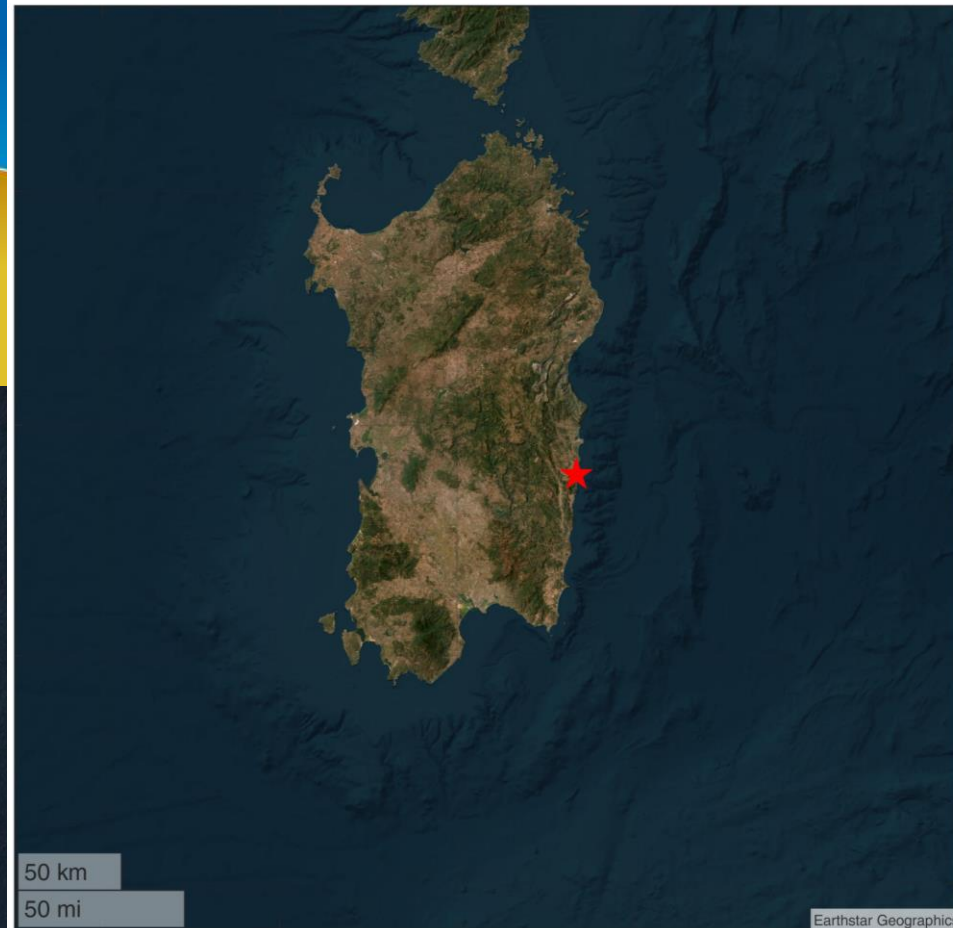
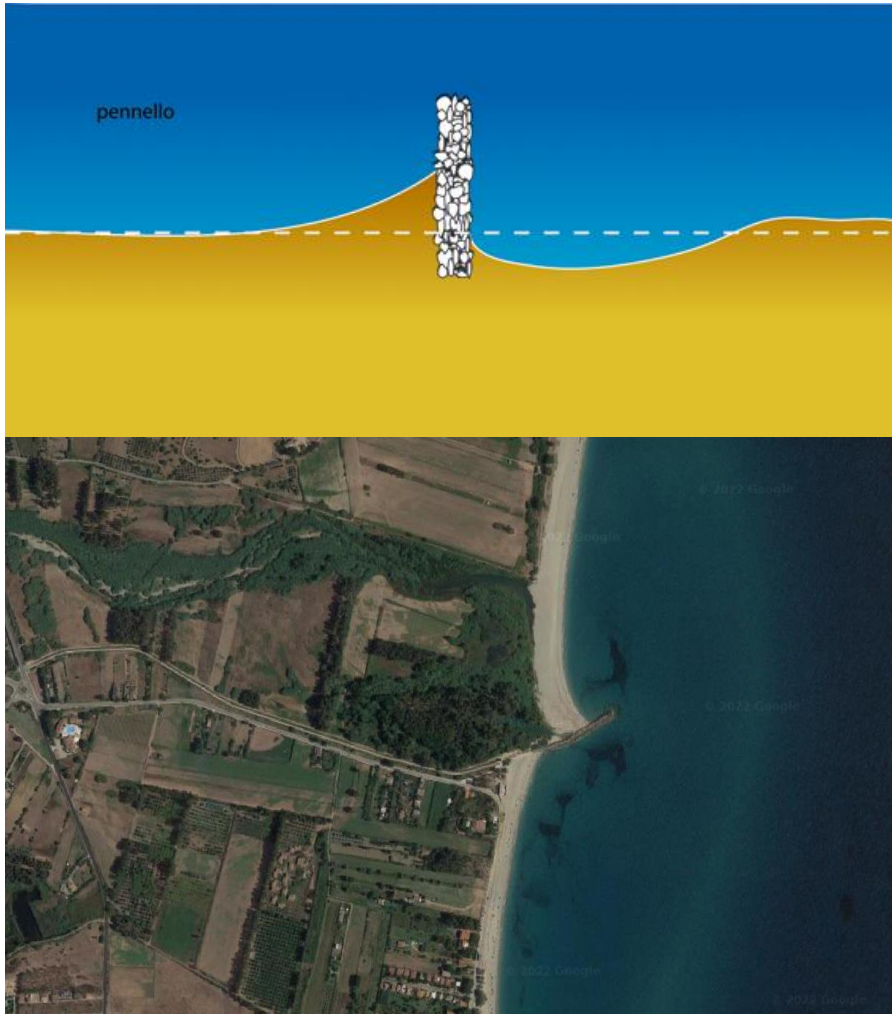


Chiavari,
Liguria

Interventi di mitigazione

Strutture Rigide → pennelli trasversali

Cardedu, Sardegna



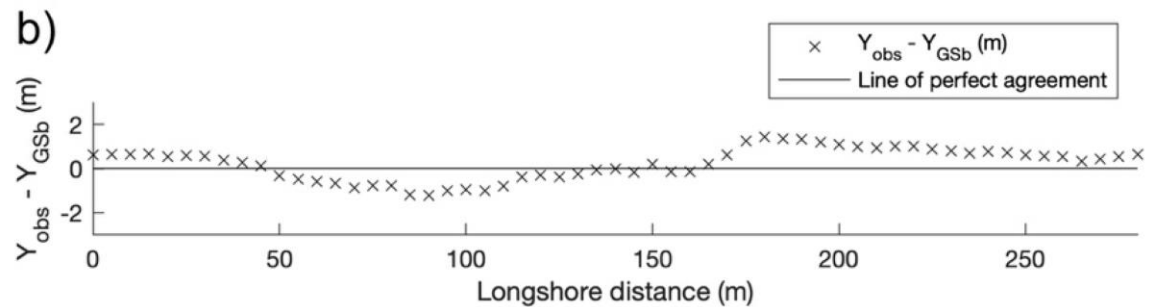
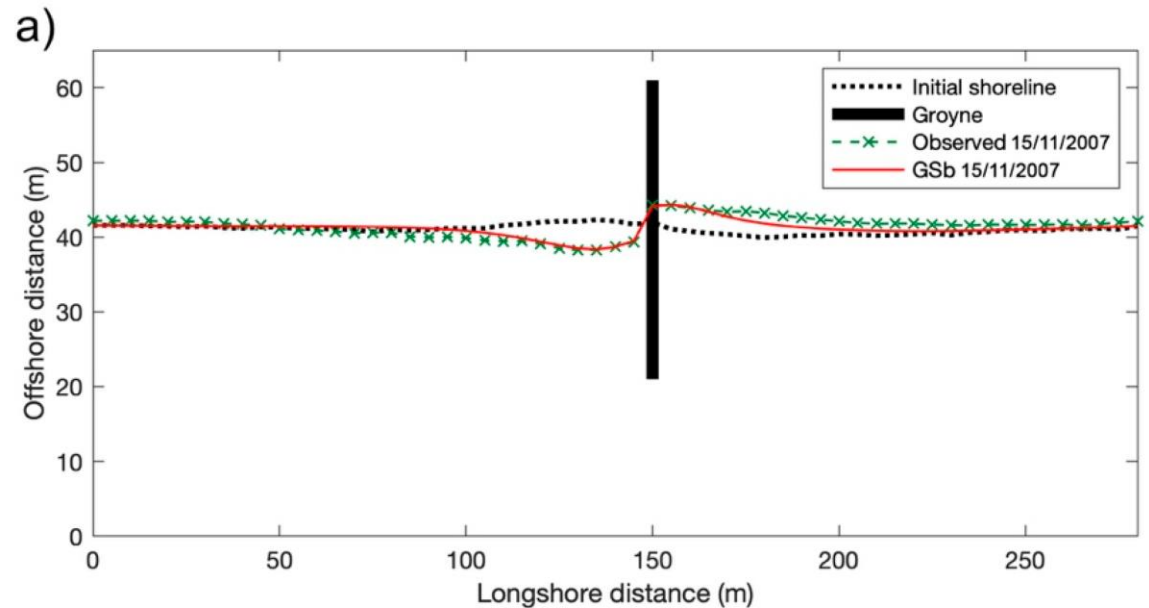
Interventi di mitigazione

Strutture Rigide → pennelli trasversali



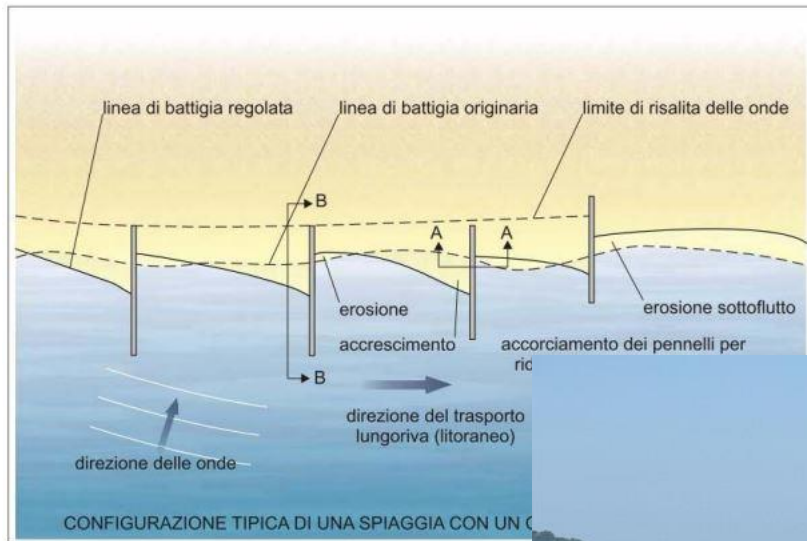
(a)

Tomasicchio et al., (2020)



Interventi di mitigazione

Strutture Rigide → pennelli trasversali



APAT (2007)

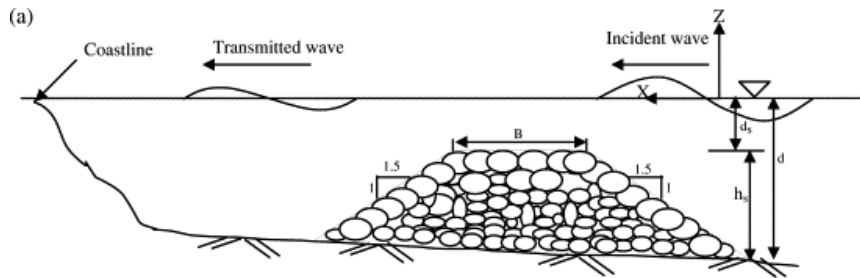
*Spiaggia di Misano
(Rimini)*



Interventi di mitigazione

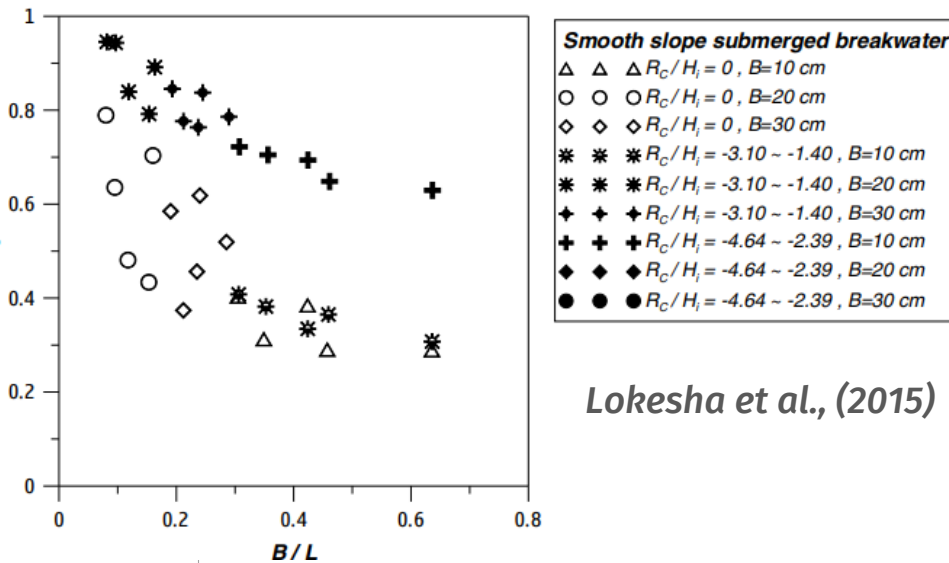
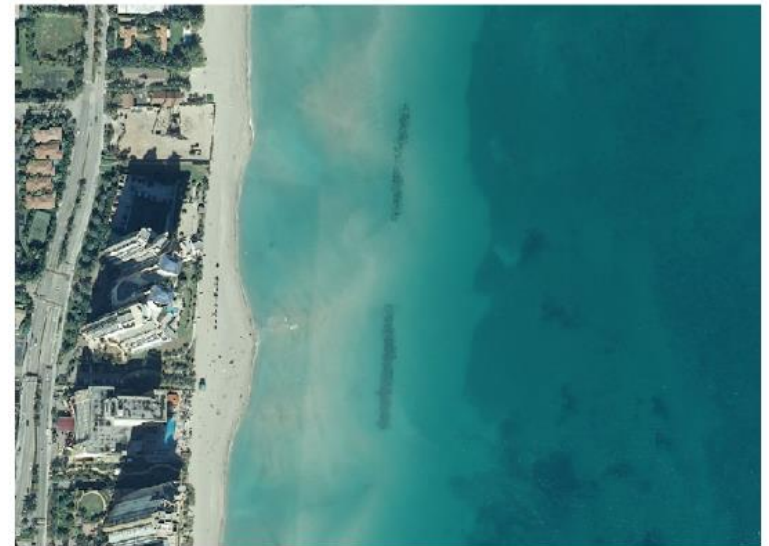
Strutture Rigide → dighe soffolte

Rambabu & Mani (2005)



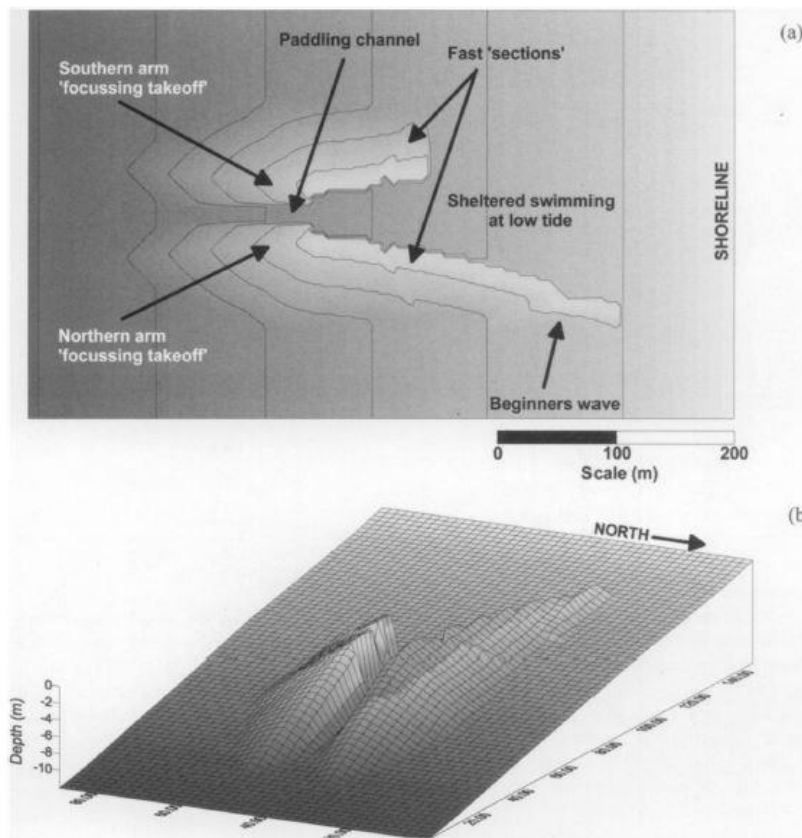
Sunny Isles (FL)

U.S. Geological Survey

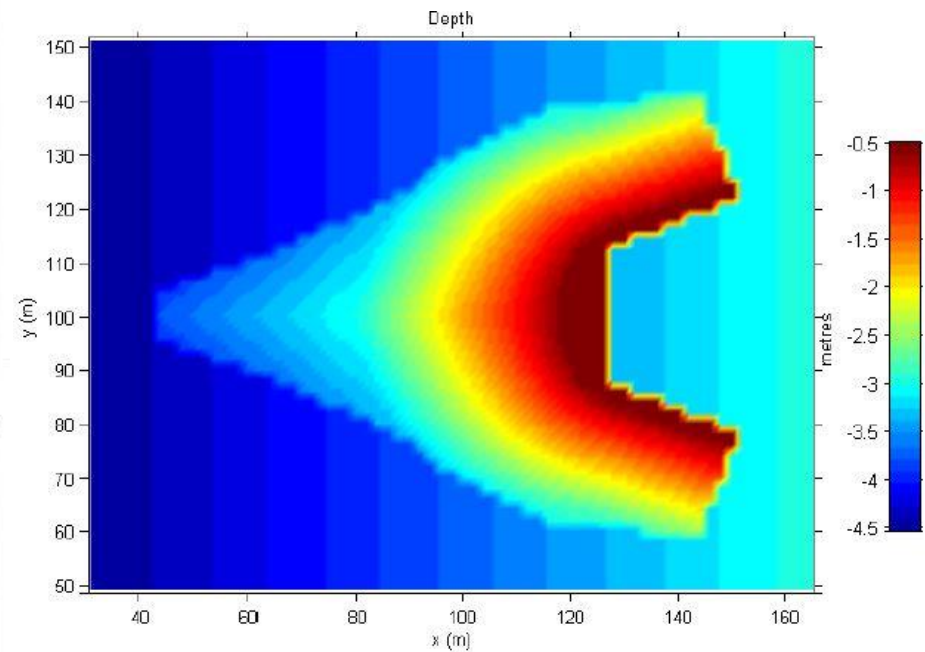


Interventi di mitigazione

Strutture Rigide → Artificial Surf Reef



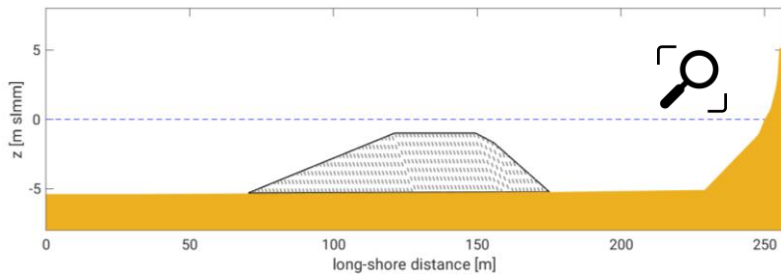
*Goald coast artificial reef
Black (2001)*



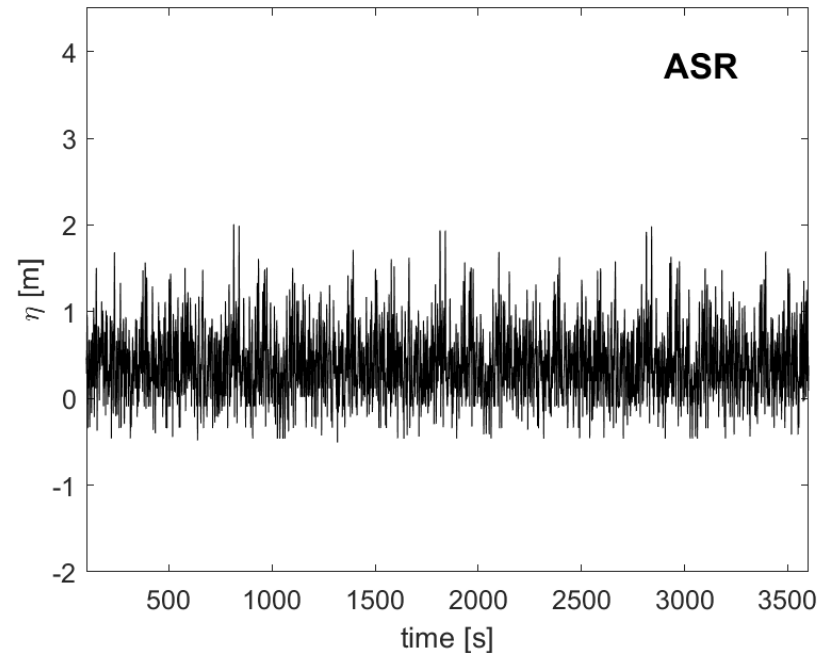
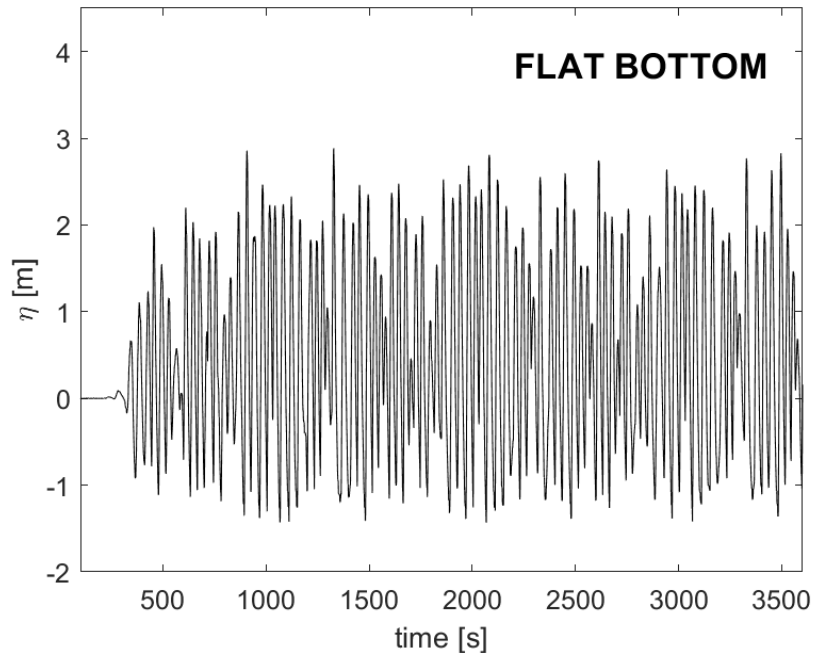
*Mount Maunganui Multi-level Reef
Black & Mead (2001)*

Interventi di mitigazione

Strutture Rigide \rightarrow Artificial Surf Reef



modellazione numerica di possibile intervento per la spiaggia di Sturla (DICCA, UniGE)



Interventi di mitigazione

Strutture Rigide → barriere aderenti («revetment»)



www.venturariver.org



©Evelyn Simak, CC BY-SA 2.0

Interventi di mitigazione

Strutture Rigide → sand fences



Cape Cod National Seashore, Massachusetts.



Mascarenhas (2008)

Interventi di mitigazione

Soft Engineering → interventi di ripascimento

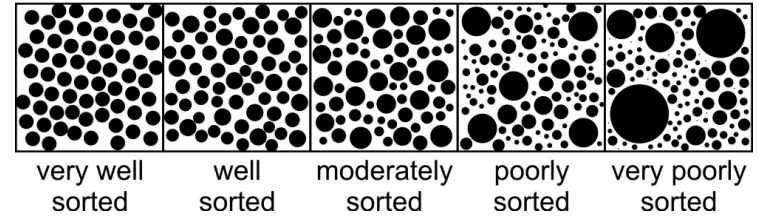


Laigueglia

Sori

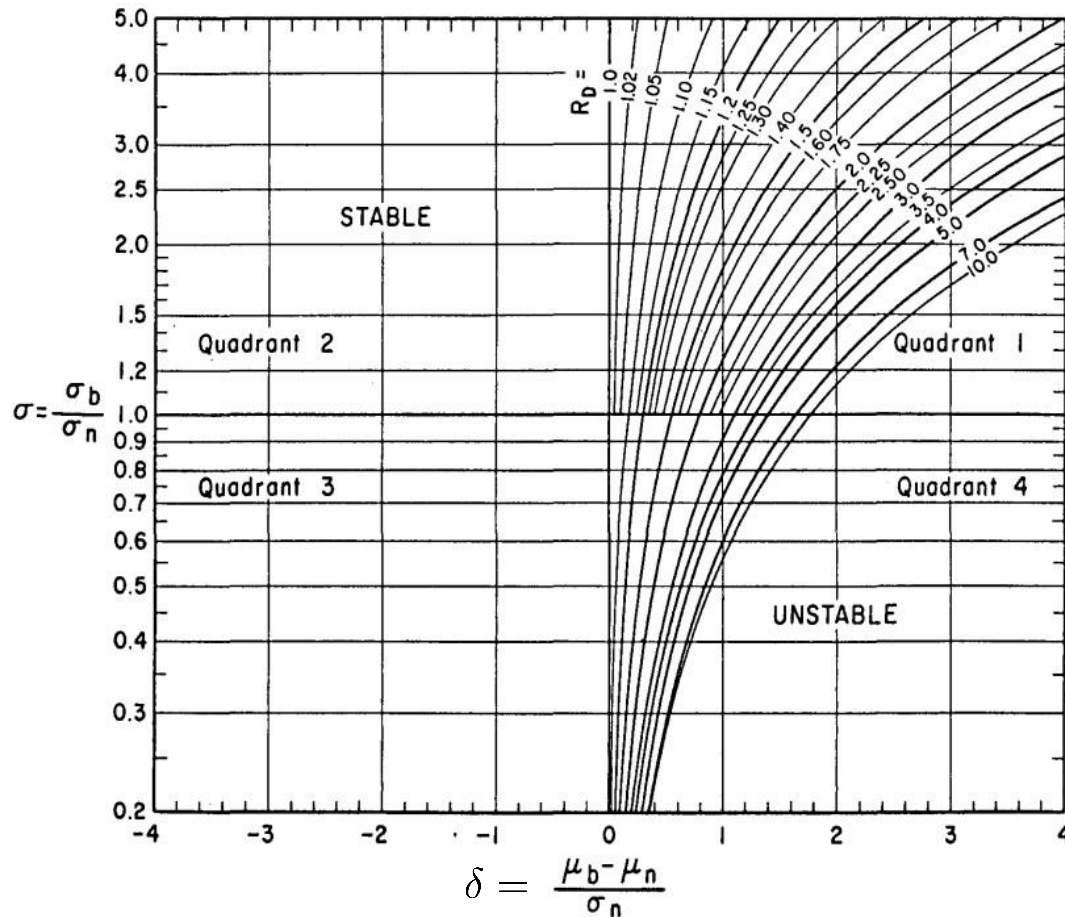


Interventi di mitigazione



Soft Engineering → interventi di ripascimento

James (1975)



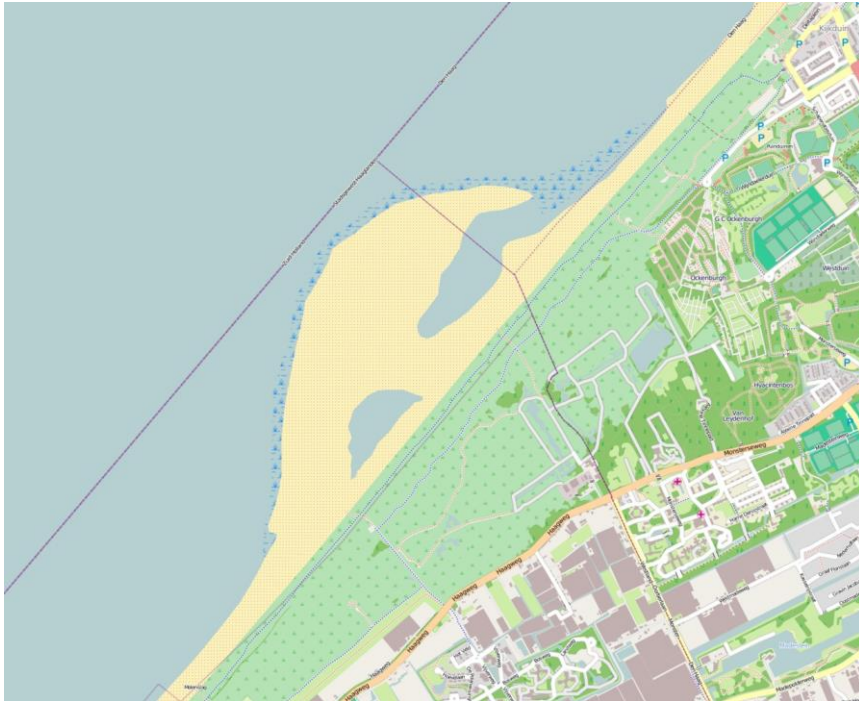
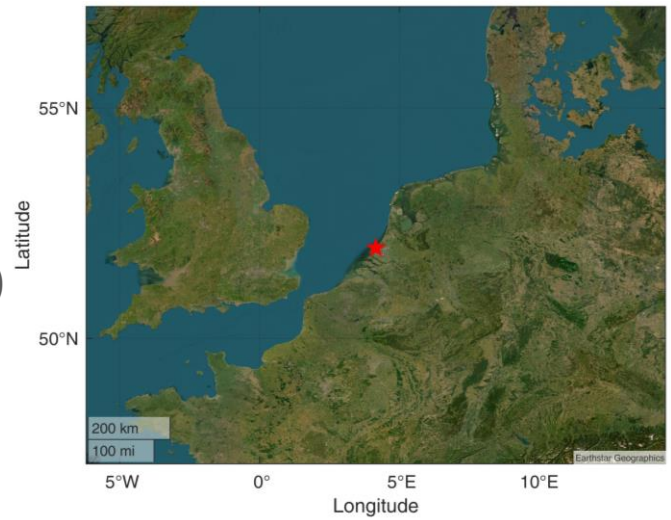
$\sigma \begin{cases} > 1 & \text{borrow more poorly sorted} \\ < 1 & \text{borrow less poorly sorted} \end{cases}$

$\delta \begin{cases} > 0 & \text{borrow finer than native} \\ < 0 & \text{borrow coarser than native} \end{cases}$

Interventi di mitigazione

Soft Engineering → sand engine (o sand motor)

Ter Heijde (NL)



UniGe

DICCA