Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

CONFCOMMERCIO
IMPRESE PER L'ITALIA

"PERICOLO" MEDITERRANEO PER L'ECONOMIA DEL MARE

L'impatto dell'innalzamento delle acque per le attività turistico-balneari e marittimo-portuali

ENEA - Casaccia Laboratorio Modellistica Climatica e Impatti
Fabrizio.antonioli@enea.it

Sardegna, Golfo di Orosei

Solco di battente fossile, 125.000 anni fa:

+ 8 m, 290 parti per milione di CO^2

Il Mare è destinato a salire…

CAUSE

Solco di battente : OGGI

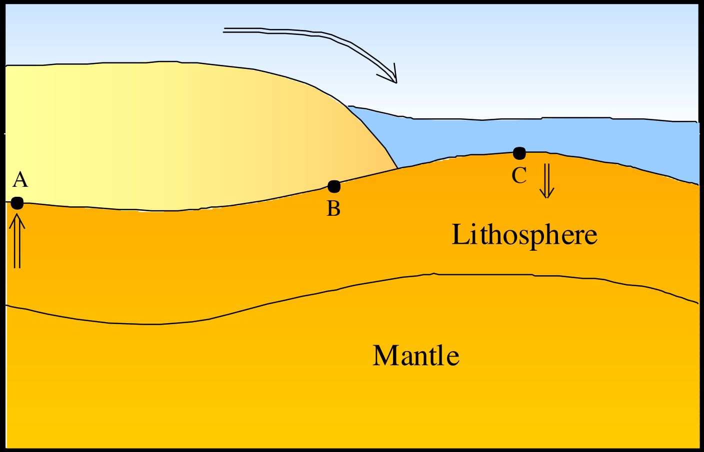
411 parti per milione di CO^2

Le variazioni relative livello del mare

costituiscono la sommatoria di:

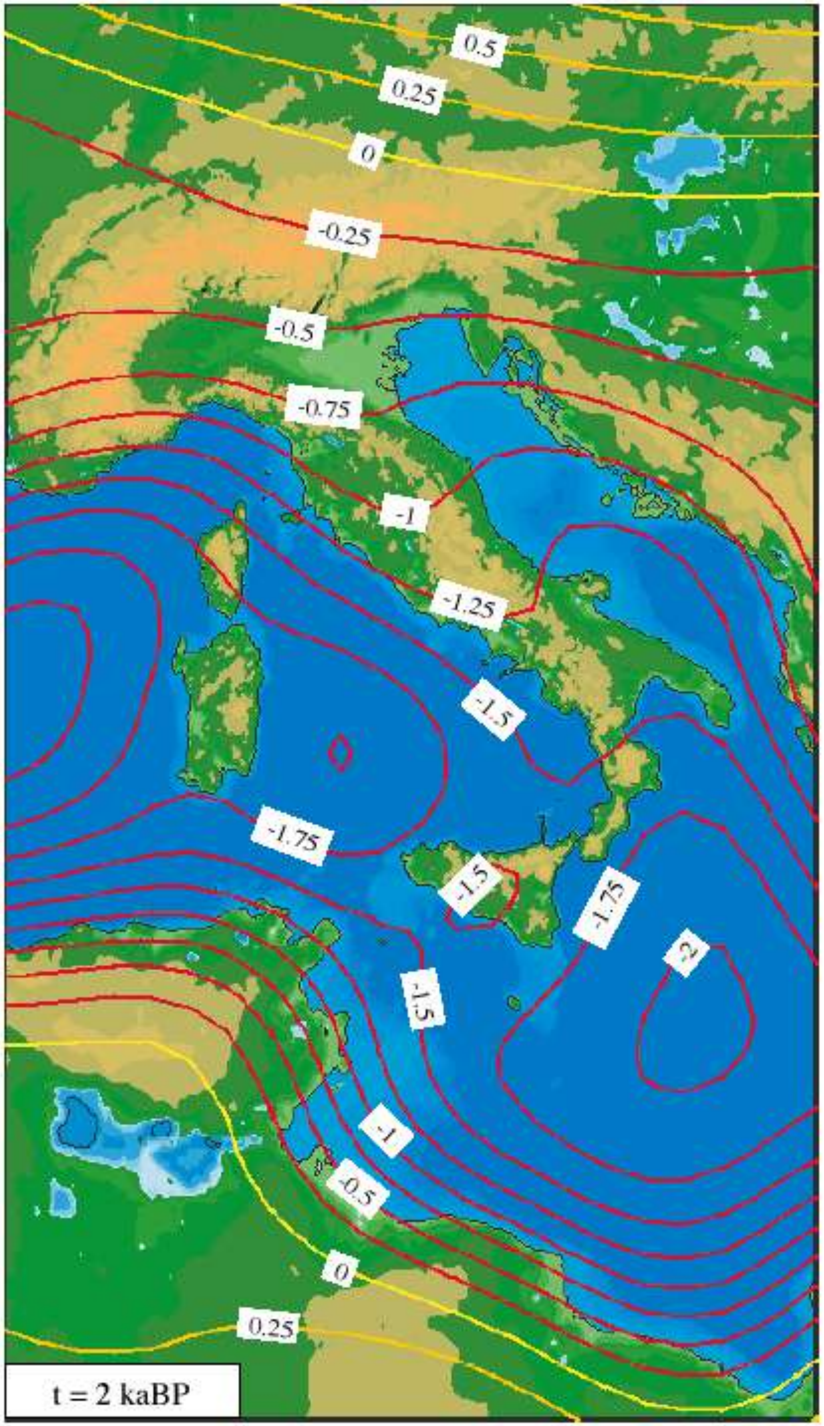
Eustatismo (Scioglim. Ghiacci + dilatazione termica) **+ isostasia + tettonica**

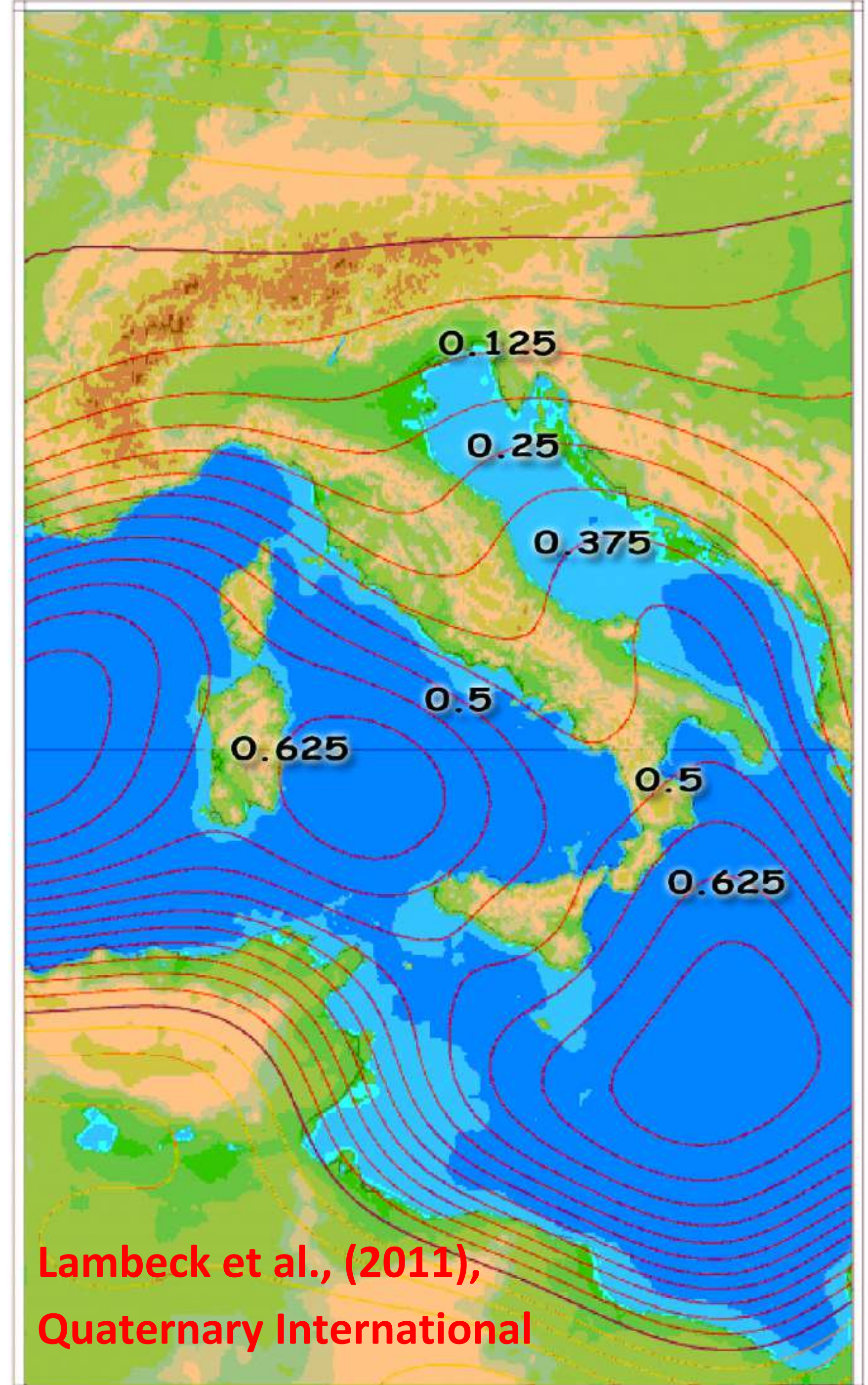
Scioglimento dei ghiacci e dilatazione termica



Isostasia

Tettonica e compattazione


0.5
0.25
0
-0.25
-0.5
-0.75
-1
-1.25
-1.5
-1.75
-1.5
-1.75
-2
-1.5
-1
-0.5
0
0.25
t = 2 kaBP


0.125
0.25
0.375
0.5
0.625
0.5
0.625
Lambeck et al., (2011),
Quaternary International

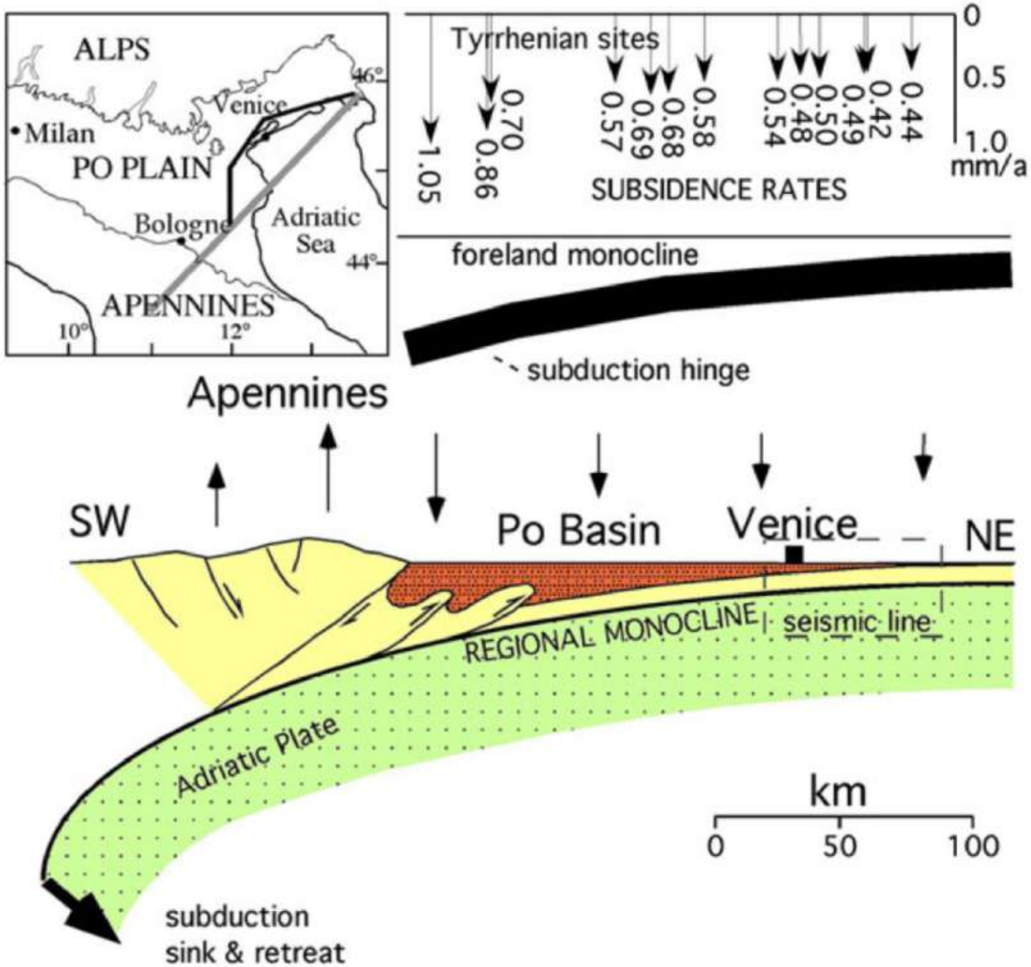
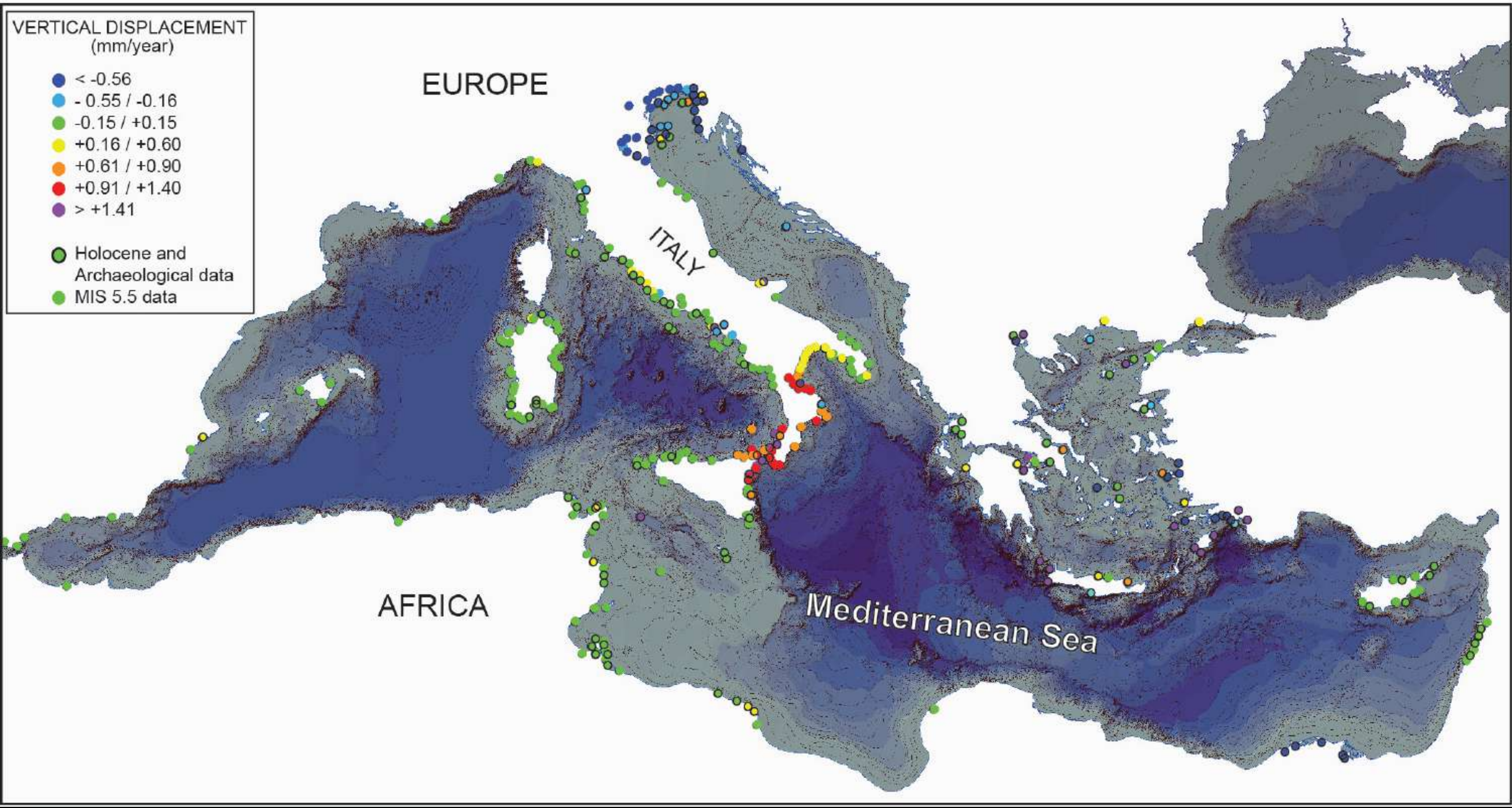
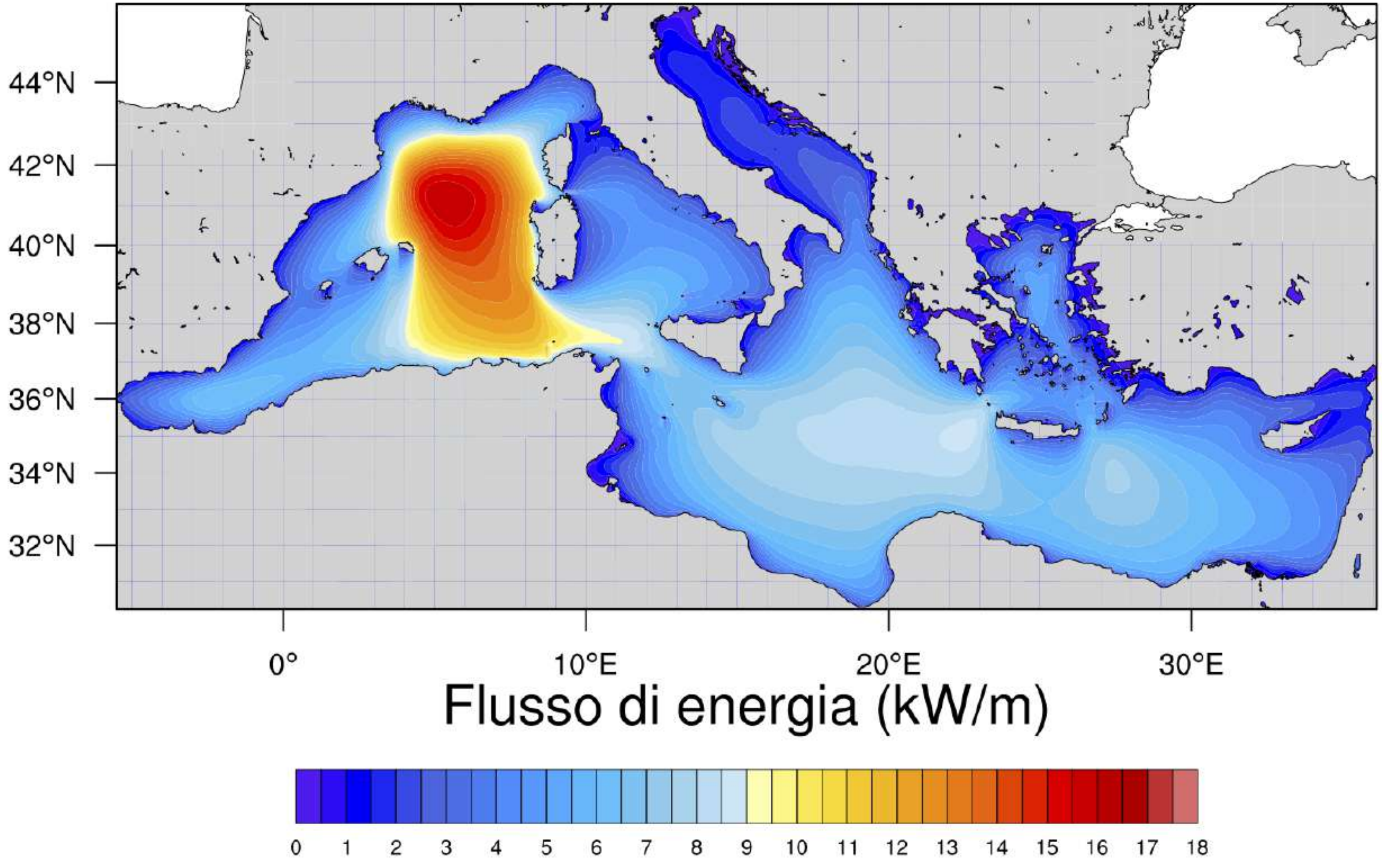


Fig. 10 Subsidence rates determined by the depth of the Tyrrhenian (MIS 5.5) layer cored mostly along the gray line running on the coast are displayed in the top panel (data after Antonioli et al. 2009). These rates indicate faster subsidence in the southwestern part of the profile, i.e., an asymmetric active subsidence, coherently with the independent data of the previous figure. The dip of the regional monocline in the northern Adriatic Sea recorded the faster subsidence to the southwest and it can be explained by the northeastward slab retreat of the Adriatic slab. The *dashed box* labeled as "seismic line" shows the position in this profile of the cross-section shown as Fig. 9

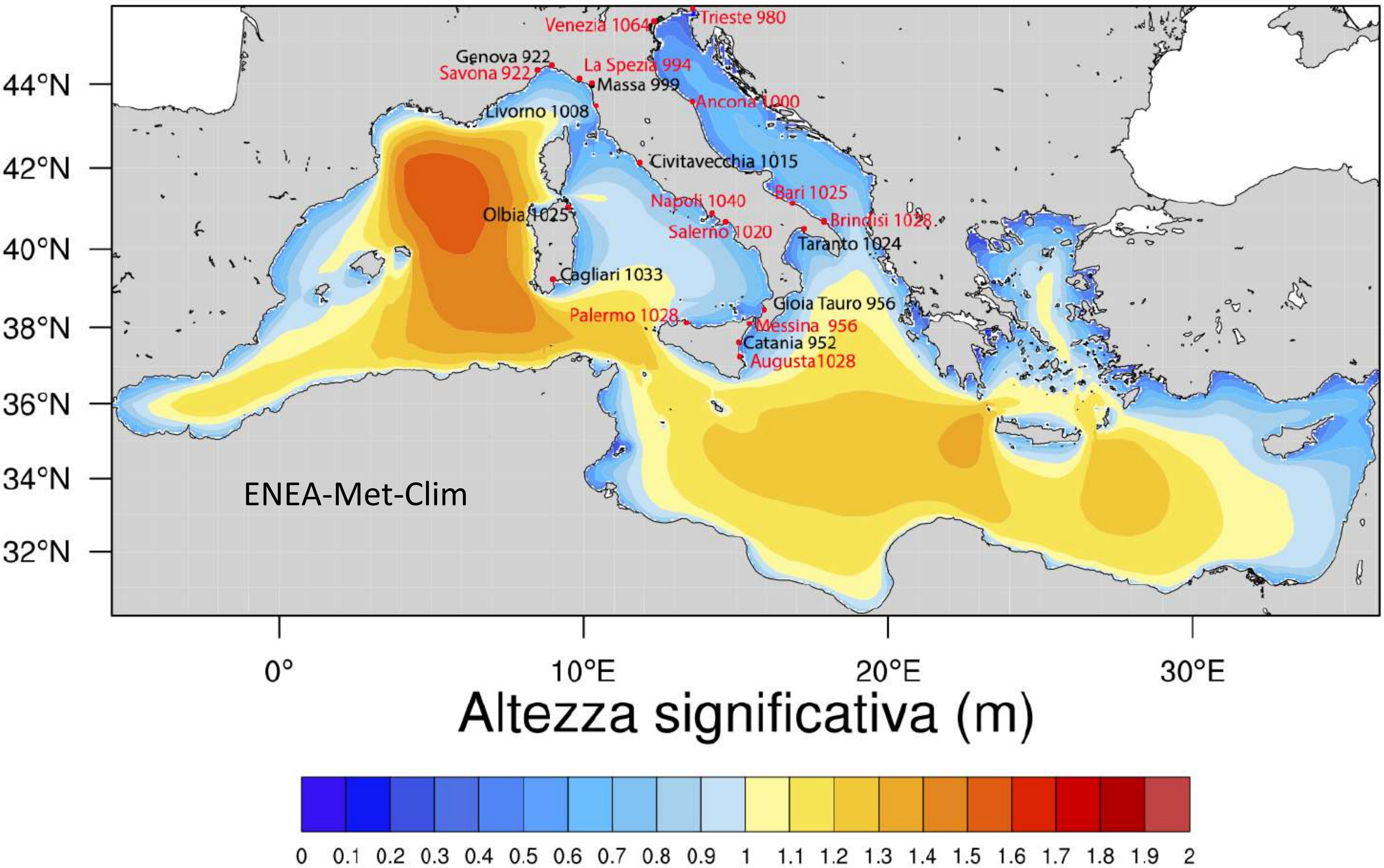


VERTICAL DISPLACEMENT
(mm/year)
< -0.56
- 0.55 / -0.16
-0.15 / +0.15
+0.16 / +0.60
+0.61 / +0.90
+0.91 / +1.40
> +1.41
Holocene and Archaeological data
MIS 5.5 data
EUROPE
ITALY
AFRICA
Mediterranean Sea

ONDE

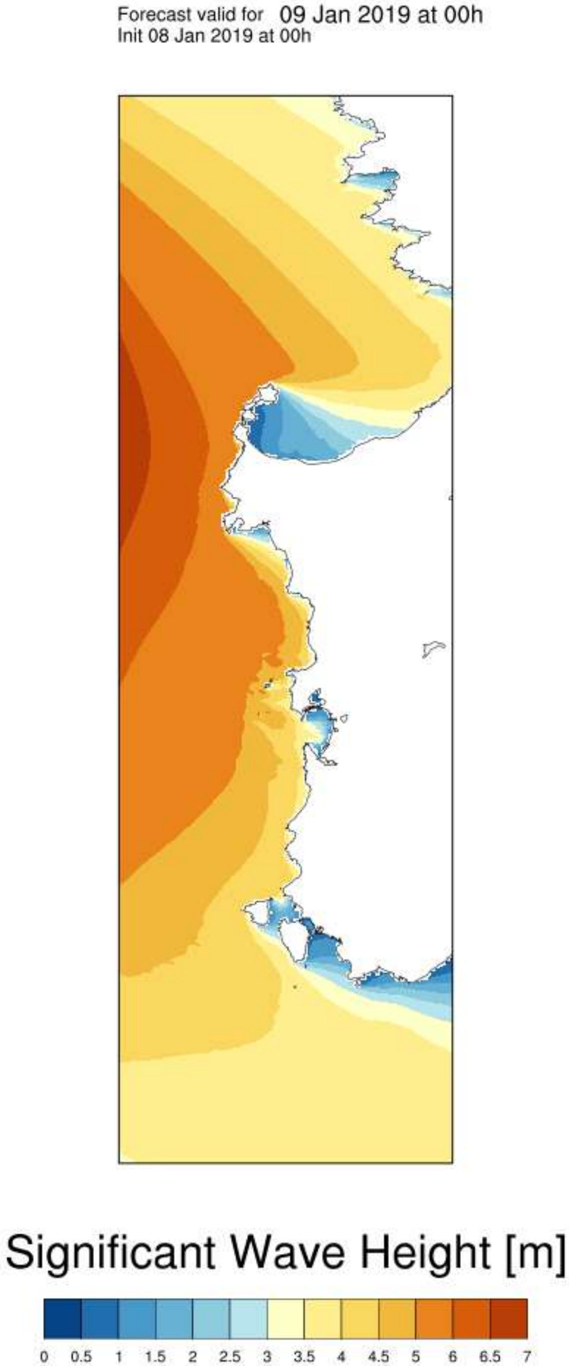


44°N
42°N
40°N
38°N
36°N
34°N
32°N
0°
10°E
20°E
30°E
Flusso di energia (kW/m)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18



Trieste 980
Venezia 1064
Genova 922
Savona 922
La Spezia 994
Massa 999
Ancona 1000
Livorno 1008
Civitavecchia 1015
Bari 1025
Napoli 1040
Olbia 1025
Salerno 1020
Brindisi 1028
Taranto 1024
Cagliari 1033
Gioia Tauro 956
Palermo 1028
Messina 956
Catania 952
Augusta1028
ENEA-Met-Clim
44°N
42°N
40°N
38°N
36°N
34°N
32°N
0°
10°E
20°E
30°E
Altezza significativa (m)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2

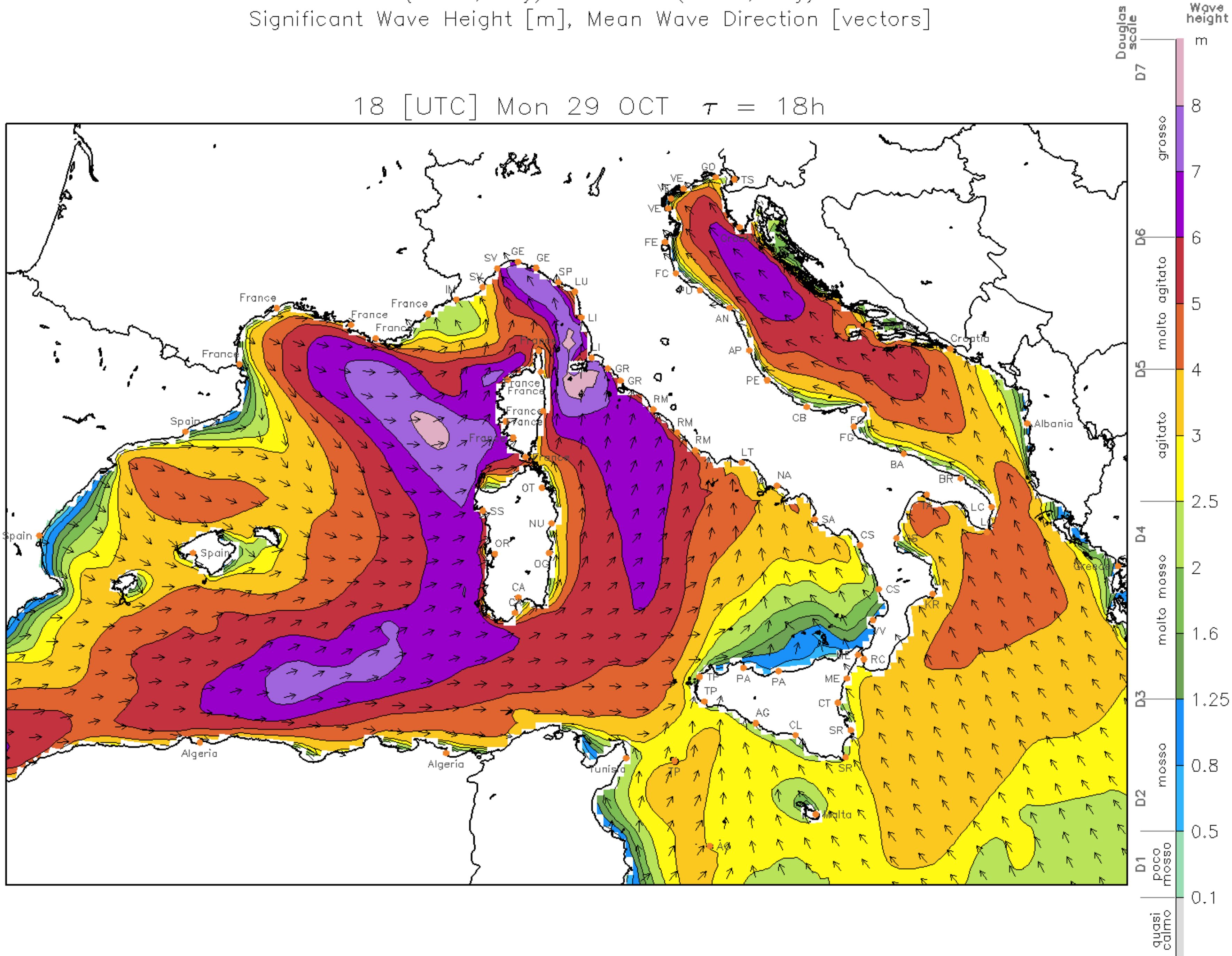
ENEA-Met-Clim



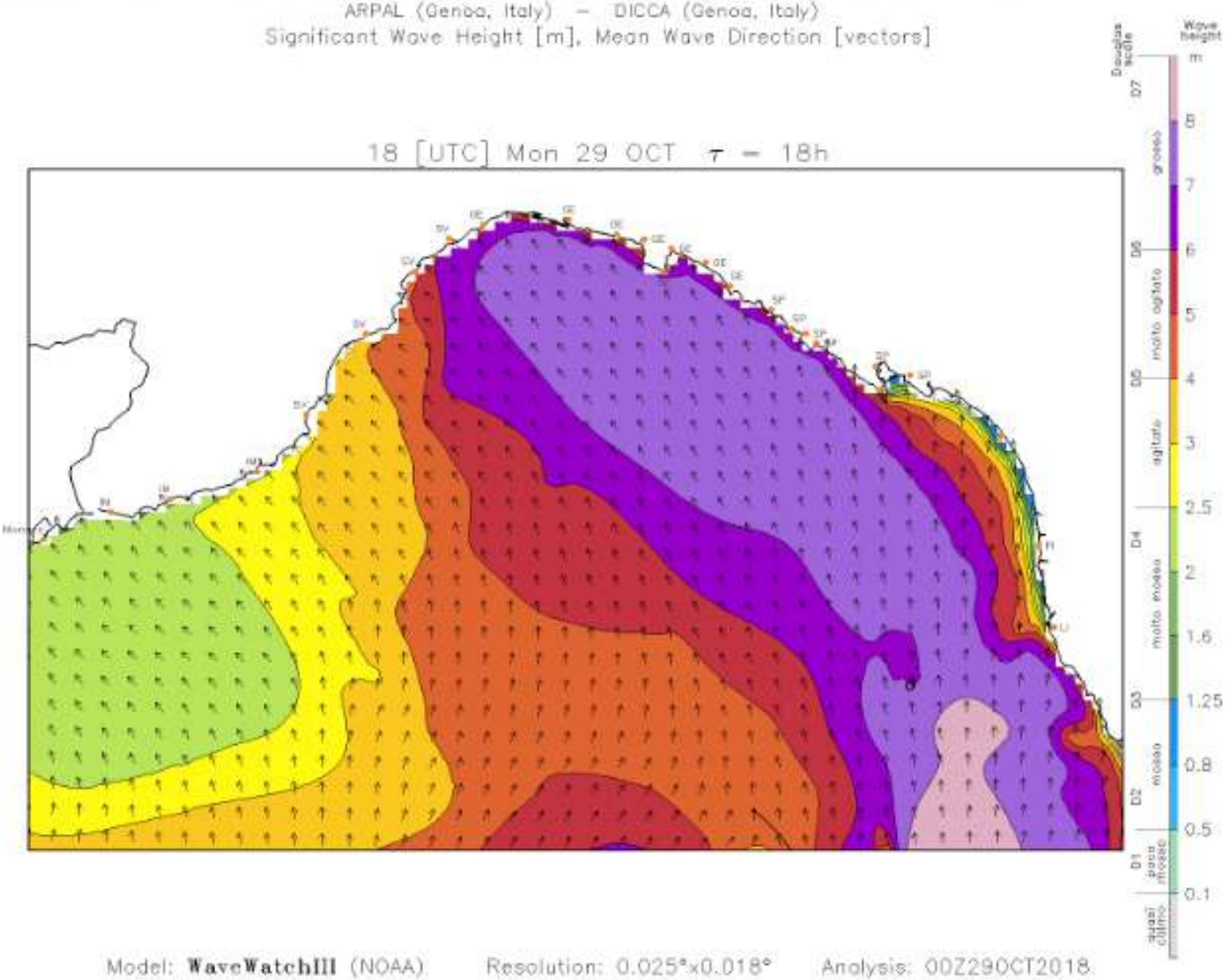
ARPAL (Genoa, Italy) — DICCA (Genoa, Italy)

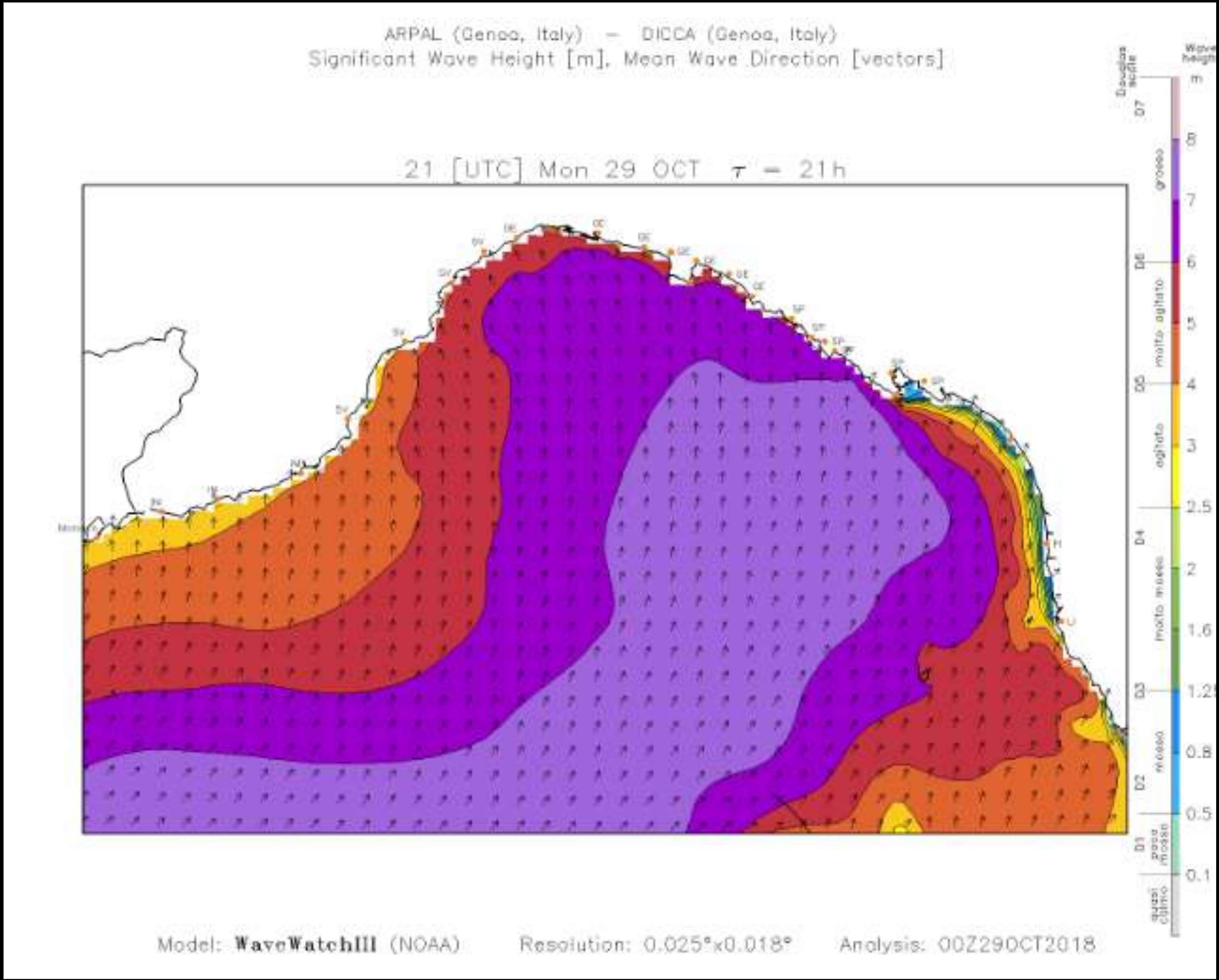
Significant Wave Height [m], Mean Wave Direction [vectors]

18 [UTC] Mon 29 OCT τ = 18h



Model: **WaveWatchIII** (NOAA)   Resolution: 0.127°x0.090°   Analysis: 00Z29OCT2018 unendosi sono state in grado di amplificare l'effetto finale sulla costa.





ARPAL (Genoa, Italy) - DICCA (Genoa, Italy)
Significant Wave Height [m], Mean Wave Direction [vectors]
21 [UTC] Mon 29 OCT τ = 21h
Model: WaveWatchIII (NOAA)
Resolution: 0.025°x0.018°
Analysis: 00Z29OCT2018
Douglas scale
Wave height
m
D7
D6
D5
D4
D3
D2
D1
grosso
molto agitato
agitato
molto mosso
mosso
poco mosso
quasi calmo
8
7
6
5
4
3
2.5
2
1.6
1.25
0.8
0.5
0.1


HYUNDAI


GENOVATODAY

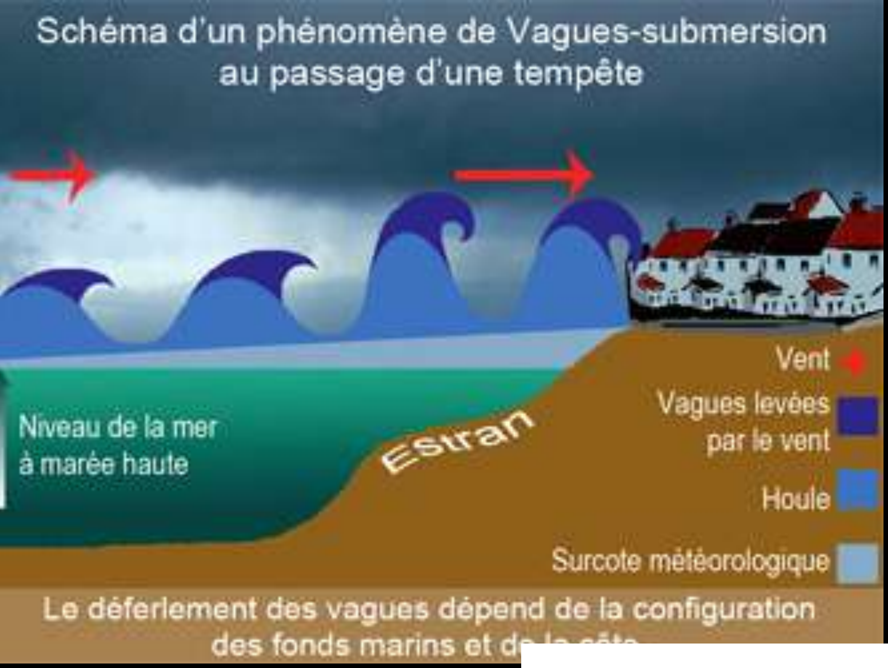
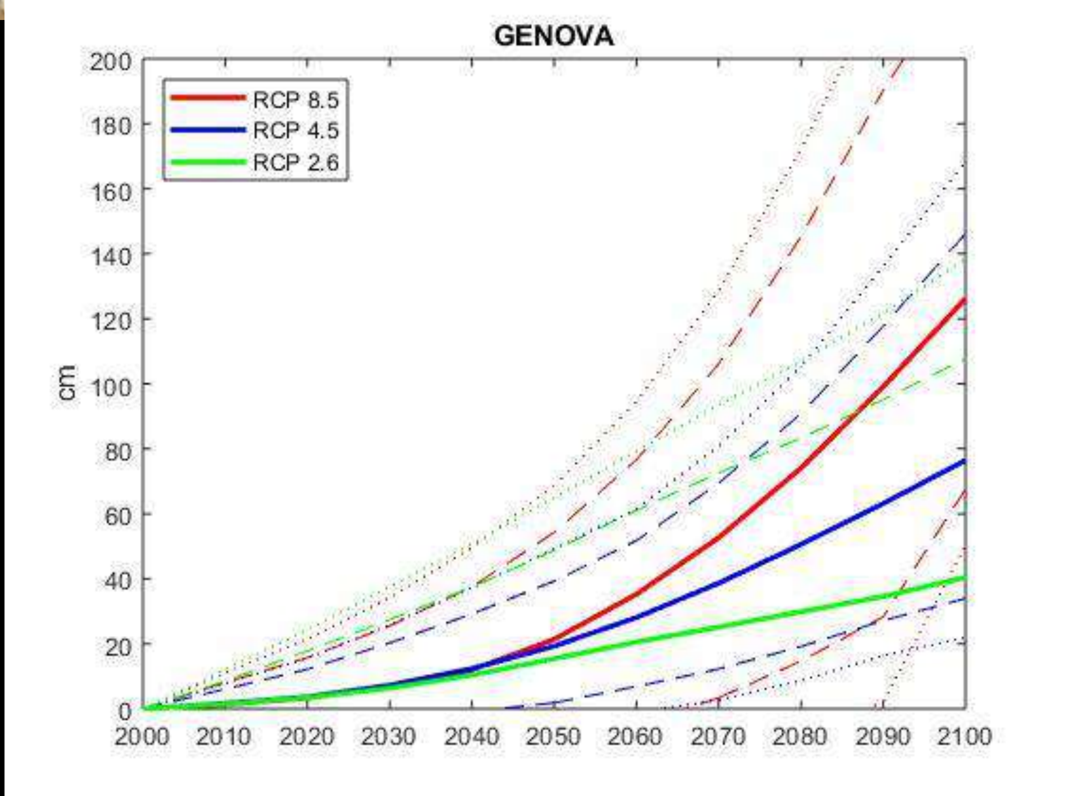
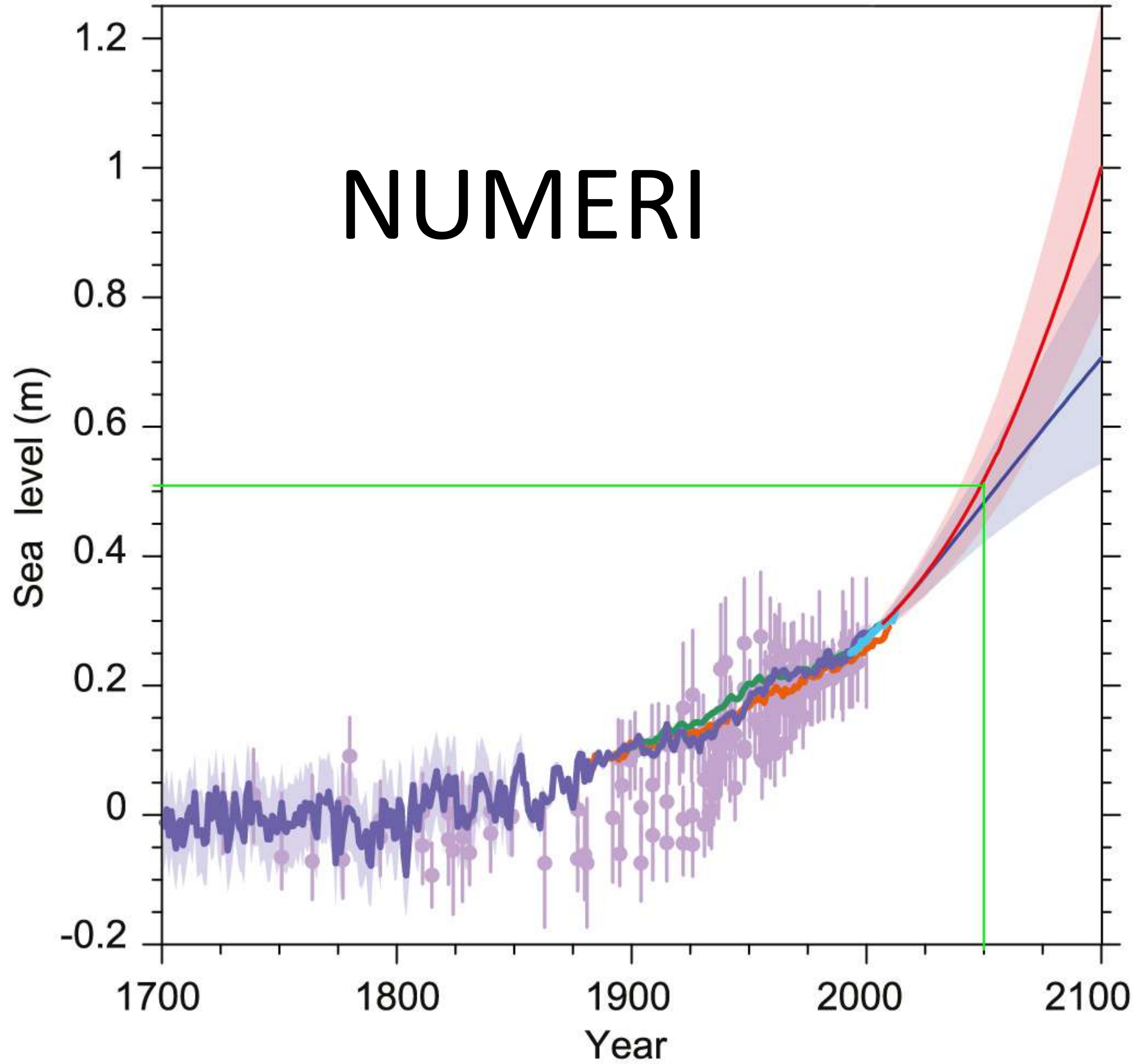


Schéma d'un phénomène de Vagues-submersion
au passage d'une tempête
Niveau de la mer
à marée haute
Estran
Vent
Vagues levées
par le vent
Houle
Surcote météorologique
Le déferlement des vagues dépend de la configuration
des fonds marins et de la côte


Wind
Sea
wall
Storm Surge
Mean high tide
Mean sea level
Mean low tide
Tropical storms and hurricanes generate storm surge from the drag of wind over the water and low barometric pressure. The height of storm surge relates to storm size, strength, forward speed, and path, as well as tidal heights and cycles and coastal geography.


GENOVA
RCP 8.5
RCP 4.5
RCP 2.6
cm
0
20
40
60
80
100
120
140
160
180
200
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100


NUMERI
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
Sea level (m)
1700
1800
1900
2000
2100
Year

I numeri…

Table 2

1) Investigates area (see maps on supplementary material S1, 2,3,4). 2) Long term tectonic rates for the investigated areas. Isostatic rates (GIA). 4) the epoch of the LIDAR campaigns. 5, 6) Relative sea-level rise projections for the investigated regions at 2100 for the IPCC 8.5 scenarios minimum and maximum (with GIA and tectonic). 7) Maximum relative sea level rise projections for the investigated regions at 2100 (with GIA and tectonic) for the Rahmstorf (2007) model.

1) Area	2) Tectonic Vertical Movements mm/yr	3) Isostatic rates mm/yr	4) Base Map (year)	5) RSLR 2100 IPCC 8.5 min mm	6) RSLR 2100 IPCC 8.5 max mm	7) RSLR 2100 Rahmstorf max mm
North Adriatic - 1	−0.40	−0.12	2003	565	992	1409
North Adriatic - 2	−0.60	−0.13	2003	584	1011	1428
North Adriatic - 3	−0.95	−0.21	2008	594	999	1395
North Adriatic - 4	−0.78	−0.21	2008	579	983	1379
Gulf of Taranto	+0.14	−0.45	2008	516	921	1317
Gulf of Cagliari	0.00	−0.58	2007	547	956	1356
Gulf of Oristano	0.00	−0.62	2008	545	949	1345

Proiezioni di sollevamento del mare			
AREA	**IPCC 2013 8.5 min scenario (cm)**	**IPCC 2013 8.5 max scenario (cm)**	**Rahmstorf 2007 max scenario (cm)**
North Adriatic - area 2	58,4	101,1	142,8
Gulf of Oristano	54,5	94,9	134,5
Gulf of Taranto	51,6	92,1	131,7
Gulf of Cagliari	54,7	95,6	135,6

Tabella 2: proiezione in centimetri della risalita del livello del mare attesa nelle diverse aree in studio, da Antonioli et al., 2016.

Area	**IPCC 2013 scenario 8.5 700 PPM CO^2**		**Rahmstorf 2007 scenario**	
	km^2	**distance (m)**	**km^2**	**distance (m)**
a) Nord Adriatico	4957,6	59132,1	5451,7	61280,4
b) Golfo di Taranto	2,26	903,6	4,2	1730,6
c) Golfo di Oristano	104,20	9787,3	124,5	10374,5
d) Golfo Cagliari	54,00	9137,5	61,2	12358,2

Tabella 3 : previsione dei Km^2 allagati nelle 4 aree studiate da ENEA e RITMARE e distanza della linea di riva prevista nel 2100 rispetto a quella attuale, da Antonioli et al., 2016.

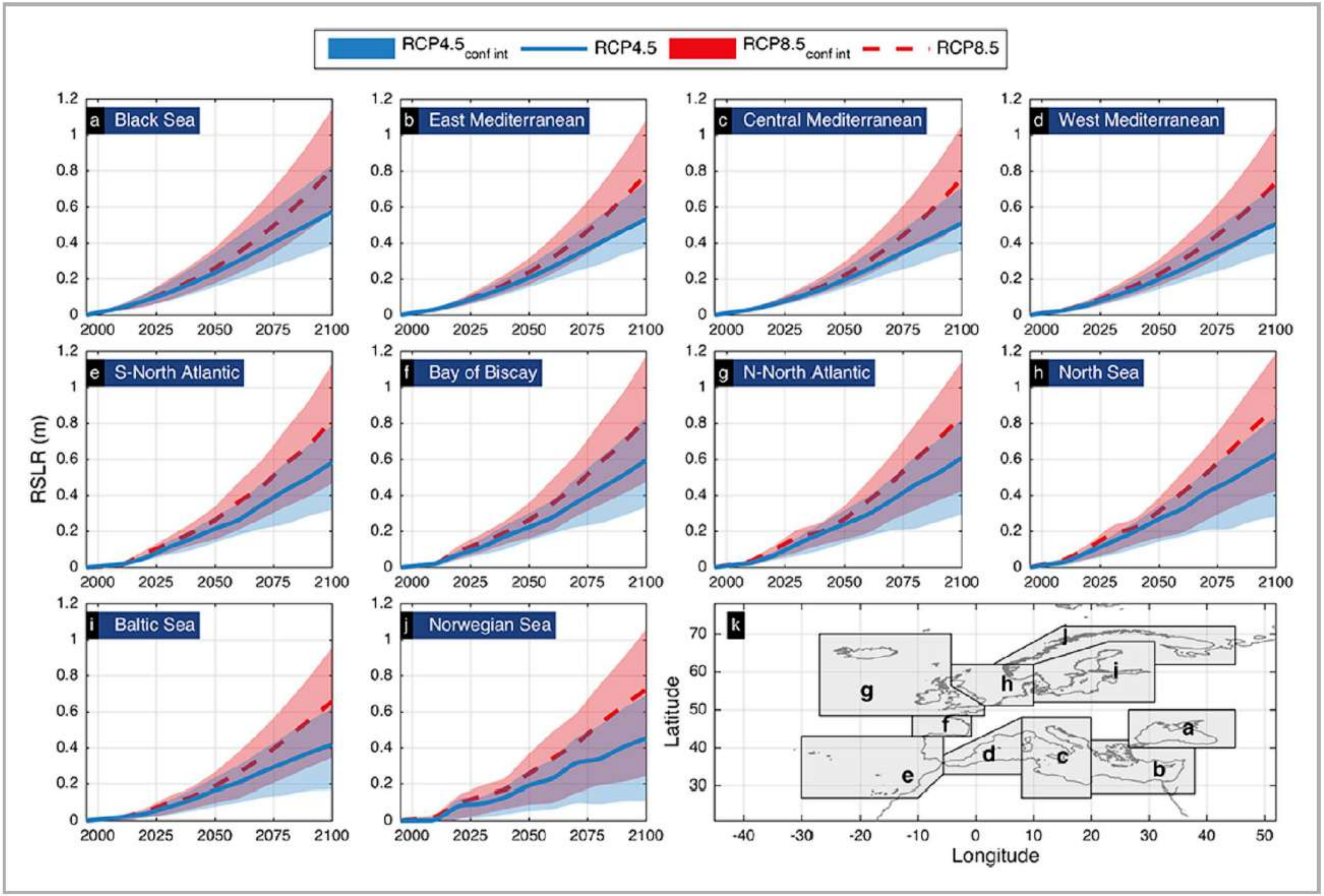

RCP4.5 conf int
RCP4.5
RCP8.5 conf int
RCP8.5
a Black Sea
b East Mediterranean
c Central Mediterranean
d West Mediterranean
e S-North Atlantic
f Bay of Biscay
g N-North Atlantic
h North Sea
i Baltic Sea
j Norwegian Sea
k
RSLR (m)
Latitude
Longitude

Figure 2

40 aree costiere a rischio Mappe finite Mappe da completare

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Sea-level rise and potential drowning of the Italian coastal plains: Flooding risk scenarios for 2100

F. Antonioli [a, *], M. Anzidei [b], A. Amorosi [c], V. Lo Presti [a], G. Mastronuzzi [d], G. Deiana [e], G. De Falco [f], A. Fontana [g], G. Fontolan [h], S. Lisco [d], A. Marsico [d], M. Moretti [d], P.E. Orrù [e], G.M. Sannino [a], E. Serpelloni [b], A. Vecchio [i]

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[g] Dipartimento di Geoscienze, University of Padova, Padova, Italy
[h] Dipartimento di Matematica e Geoscienze, University of Trieste, CONISMA, Italy
[i] Lesia Observatoire de Paris, Section de Meudon 5, France

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Marine flooding
Climate change
2100 Coastline scenario

ABSTRACT

We depict the relative sea-level rise scenarios for the year 2100 from four areas of the Italian peninsula. Our estimates are based on the Rahmstorf (2007) and IPCC-AR5 reports 2013 for the RCP-8.5 scenarios (www.ipcc.ch) of climate change, adjusted for the rates of vertical land movements (isostasy and tectonics). These latter are inferred from the elevation of MIS 5.5 deposits and from late Holocene sea-level indicators, matched against sea-level predictions for the same periods using the glacio-hydro-isostatic model of Lambeck et al. (2011). We focus on a variety of tectonic settings: the subsiding North Adriatic coast (including the Venice lagoon), two tectonically stable Sardinia coastal plains (Oristano and Cagliari), and the slightly uplifting Taranto coastal plain, in Apulia. Maps of flooding scenarios are shown on high-resolution Digital Terrain Models mostly based on Lidar data. The expected relative sea-level rise by 2100 will change dramatically the present-day morphology, potentially flooding up to about 5500 km^2 of coastal plains at elevations close to present-day sea level.

The subsequent loss of land will impact the environment and local infrastructures, suggesting land planners and decision makers to take into account these scenarios for a cognizant coastal management. Our method developed for the Italian coast can be applied worldwide in other coastal areas expected to be affected by marine ingression due to global climate change.

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1. Introduction

Instrumental and observational data show that in the past two

The recent report on global climate change (Church et al., 2013) warned countries on the risk induced by sea-level rise (Fig. 1). This warning must be seriously considered for the assessment of coastal

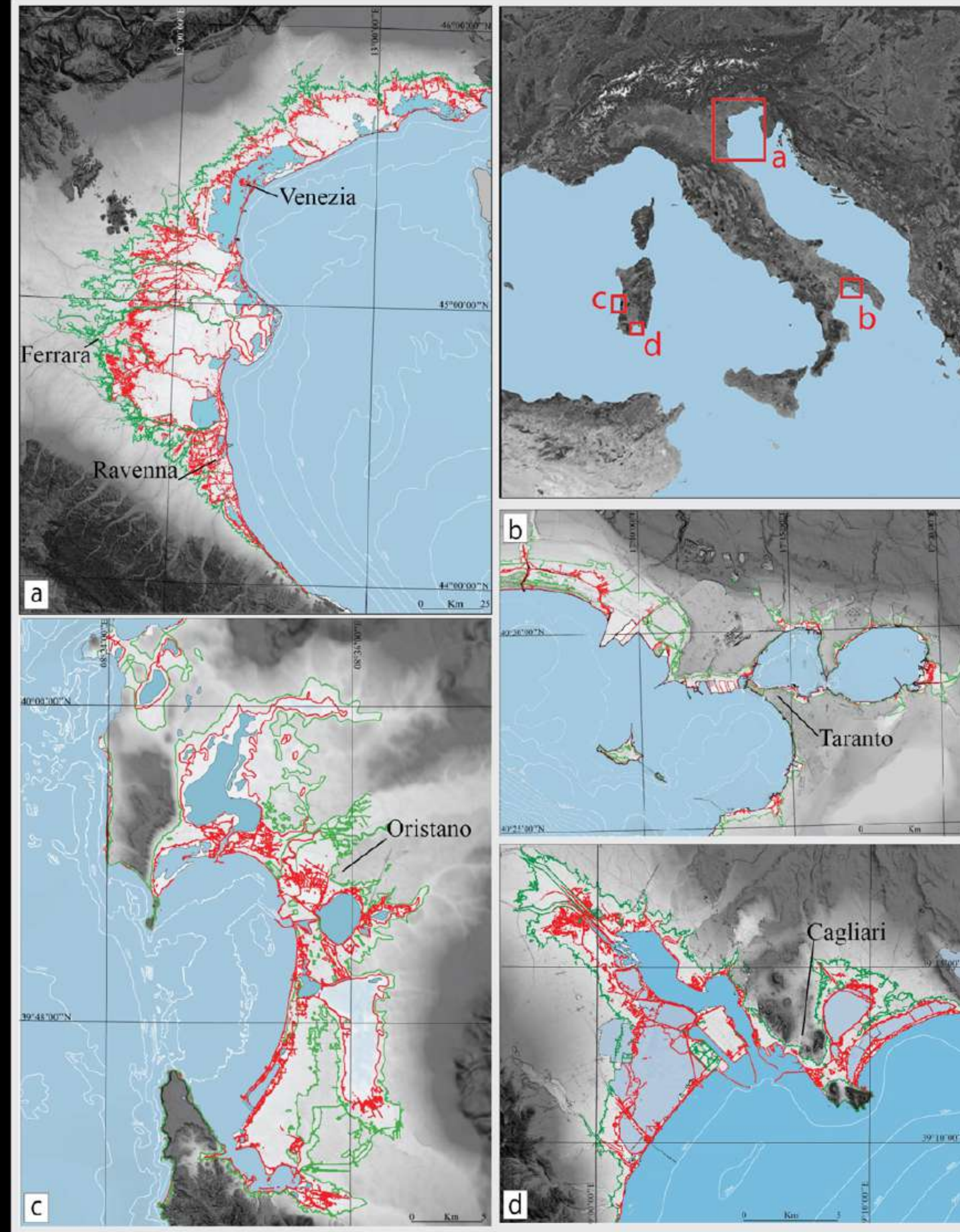
Journal of Coastal Conservation

Integrating multidisciplinary instruments for assessing coastal vulnerability to erosion and sea level rise: lessons and challenges from the Adriatic Sea, Italy

D. Bonaldo · F. Antonioli · R. Archetti · A. Bezzi · A. Correggiari · S. Davolio · G. De Falco · M. Fantini · G. Fontolan · S. Furlani · M. G. Gaeta · G. Leoni · V. Lo Presti · G. Mastronuzzi · S. Pillon · A. Ricchi · P. Stocchi · A. G. Samaras · G. Scicchitano · S. Carniel

Abstract

The evolution of coastal and transitional environments depends upon the interplay of human activities and natural drivers, two factors that are strongly connected and many times conflicting. The urge for efficient tools for characterizing and predicting the behaviour of such systems is nowadays particularly pressing, especially under the effects of a changing climate, and requires a deeper understanding of the connections among different drivers and different scales. To this aim, the present paper reviews the results of a set of interdisciplinary and coordinated experiences carried out in the Adriatic Sea (north-eastern Mediterranean region), discussing state-of-the art methods for coastal dynamics assessment and monitoring, and suggests strategies towards a more efficient coastal management. Coupled with detailed geomorphological information, the methodologies currently available for evaluating the different components of relative sea level rise facilitate a first identification of the flooding hazard in coastal areas, providing a fundamental element for the prioritization and identification of the sustainability of possible interventions and policies. In addition, hydro- and morpho-dynamic models are achieving significant advances in terms of spatial resolution and physical insight, also in a climatological context, improving the description of the interactions between meteo-oceanographic processes at the regional scale to coastal dynamics at the local scale. We point out that a coordinated use of the described tools should be promptly promoted in the design of survey and monitoring activities as well as in the exploitation of already collected data. Moreover, expected benefits from this strategy include the production of services and infrastructures for coastal protection with a focus on short-term forecast and rapid response, enabling the implementation of an event-oriented sampling strategy.



FLOODING SCENARIO AT FOUR ITALIAN COASTAL PLAINS USING THREE RELATIVE SEA LEVEL RISE MODELS: THE NORTH ADRIATIC AREA

A. Marsico[1], S. Lisco[1], V. Lo Presti[2], F. Antonioli[2], A. Amorosi[3], M. Anzidei[4], G. Deiana[5], G. De Falco[6], A. Fontana[7], G. Fontolan[8], M. Moretti[1], P. Orru[5], G. Sannino[2], E. Serpelloni[4], A. Vecchio[9], G. Mastronuzzi[1]

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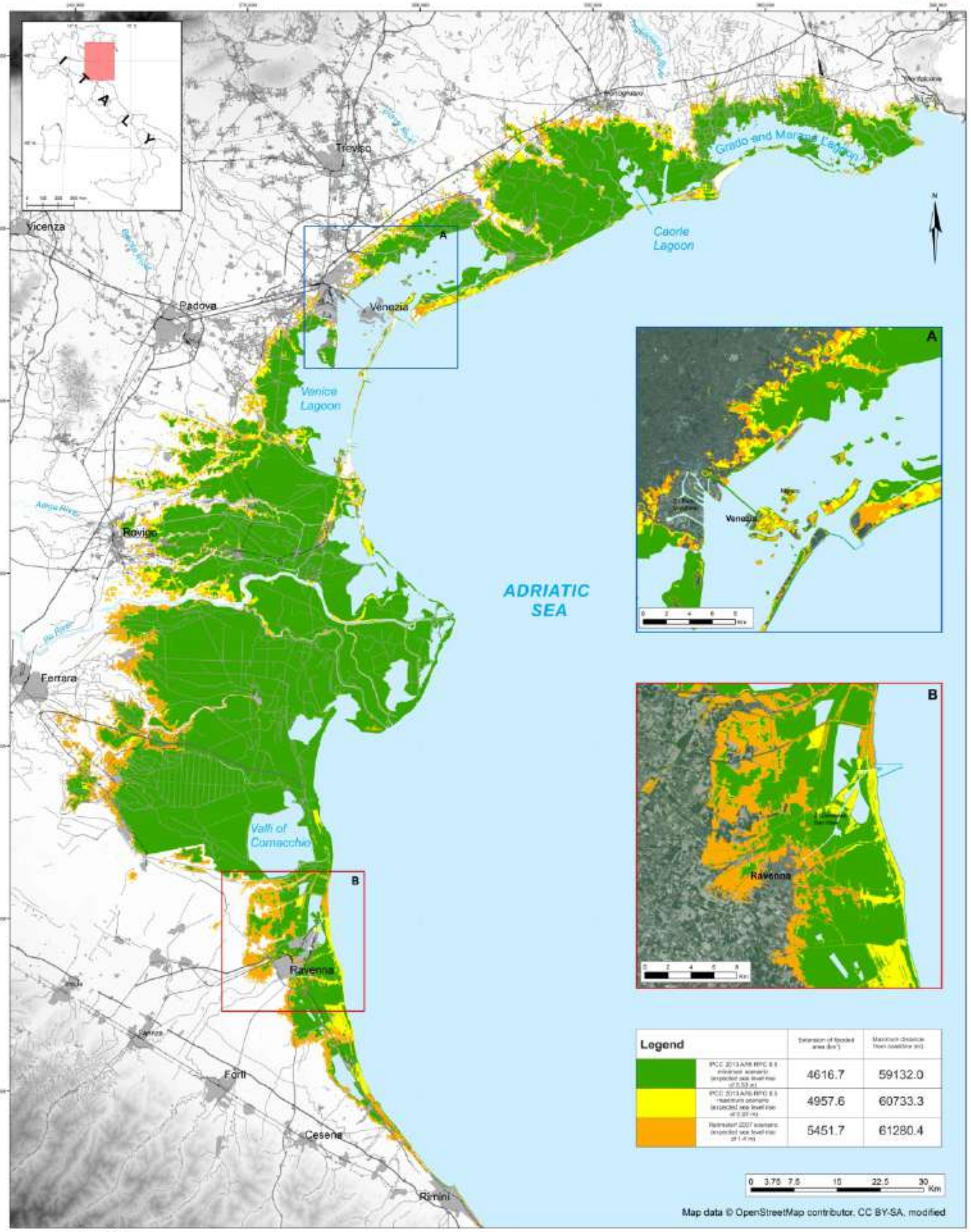
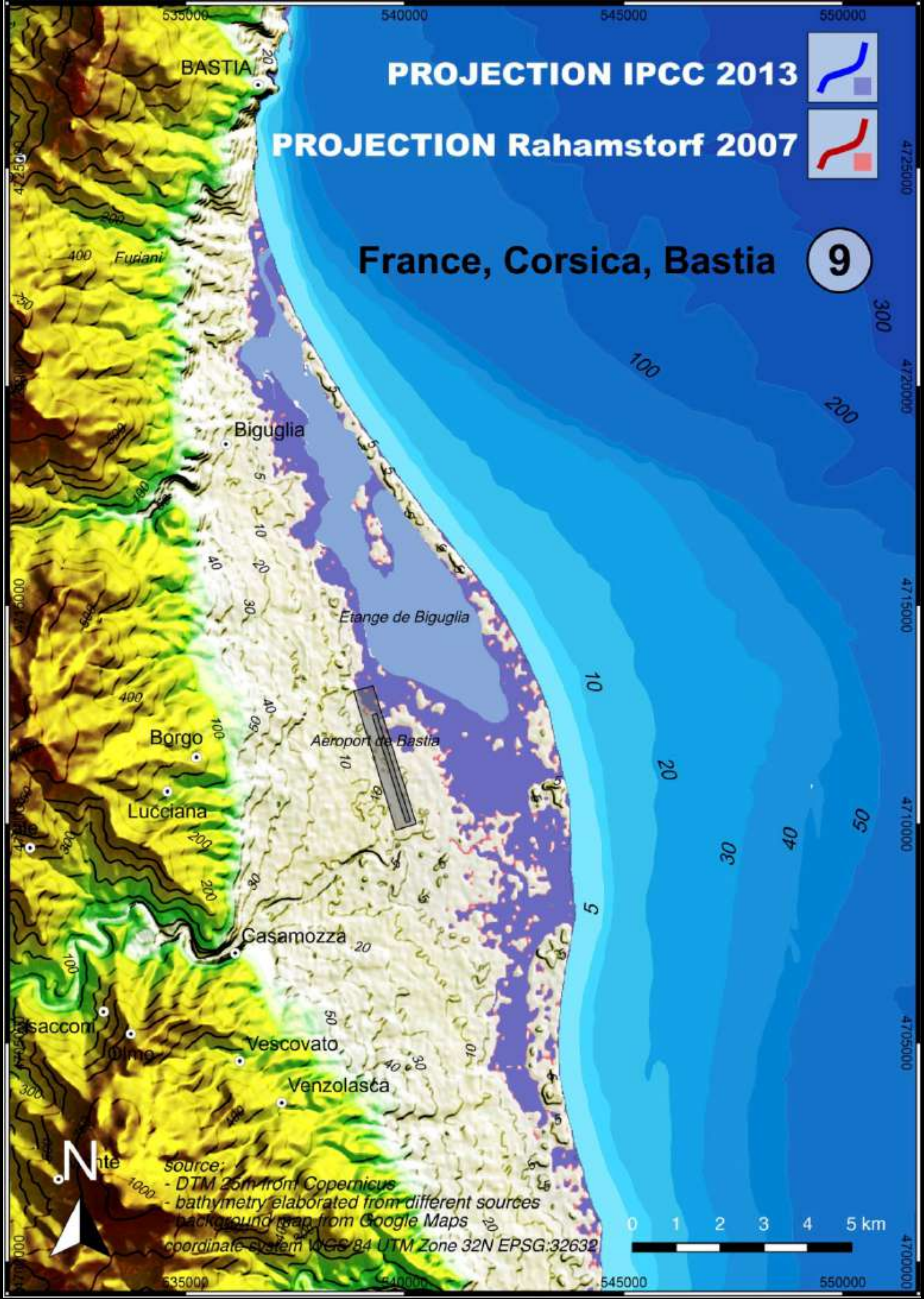
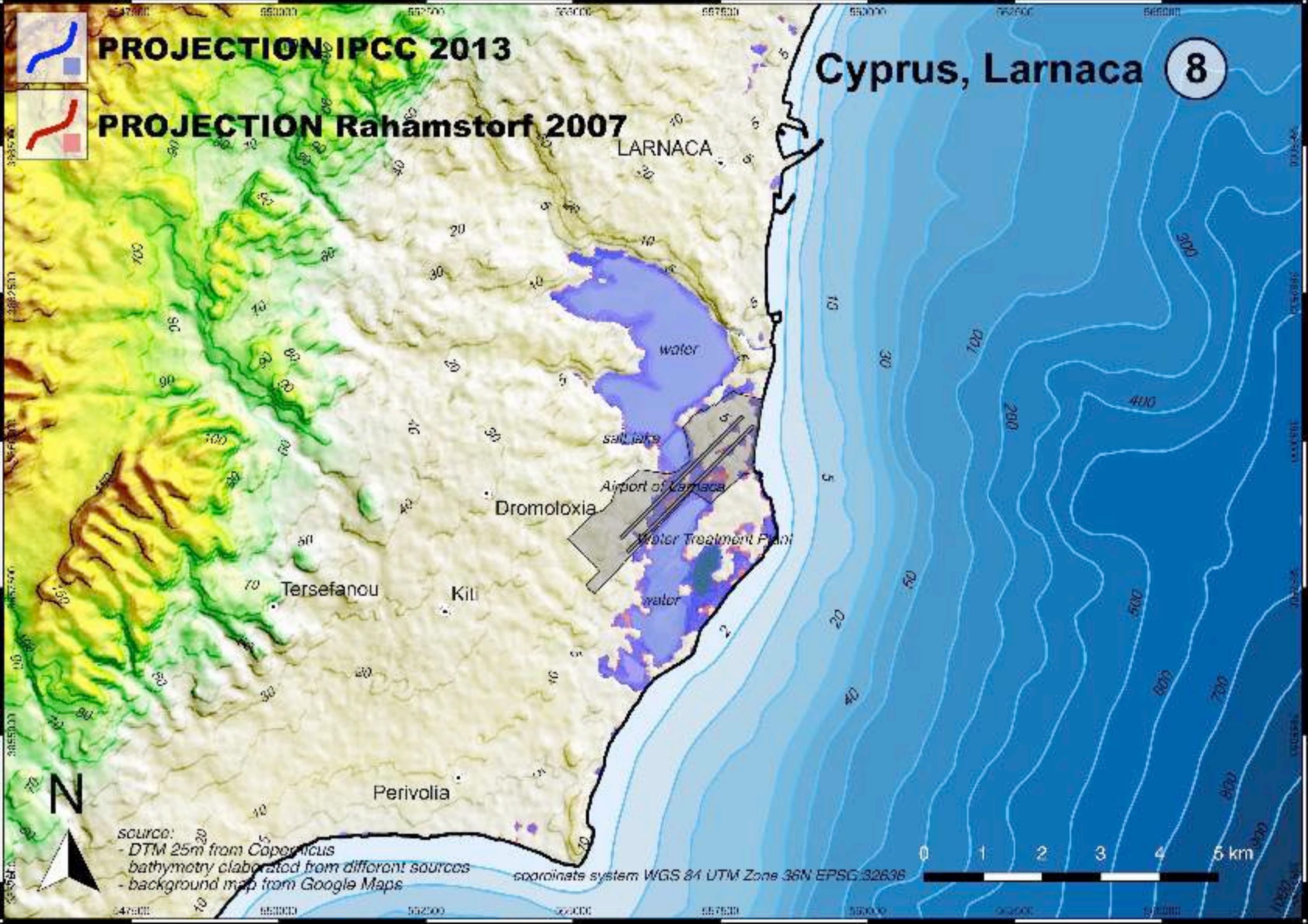
[3]Dipartimento di Scienze Biologiche, Geologiche e Ambientali, University of Bologna, Italy; [4]Istituto Nazionale di Geofisica e Vulcanologia, Italy;
[5]Dipartimento di Scienze Chimiche e Geologiche, University of Cagliari, CONISMA Italy; [6]CNR Oristano; [7]Dipartimento di Geoscienze, University of Padova, CONISMA Italy;
[8]Dipartimento di Matematica e Geoscienze, University of Trieste, CONISMA Italy; [9]Lesia Observatoire de Paris, Section de Meudon 5, France



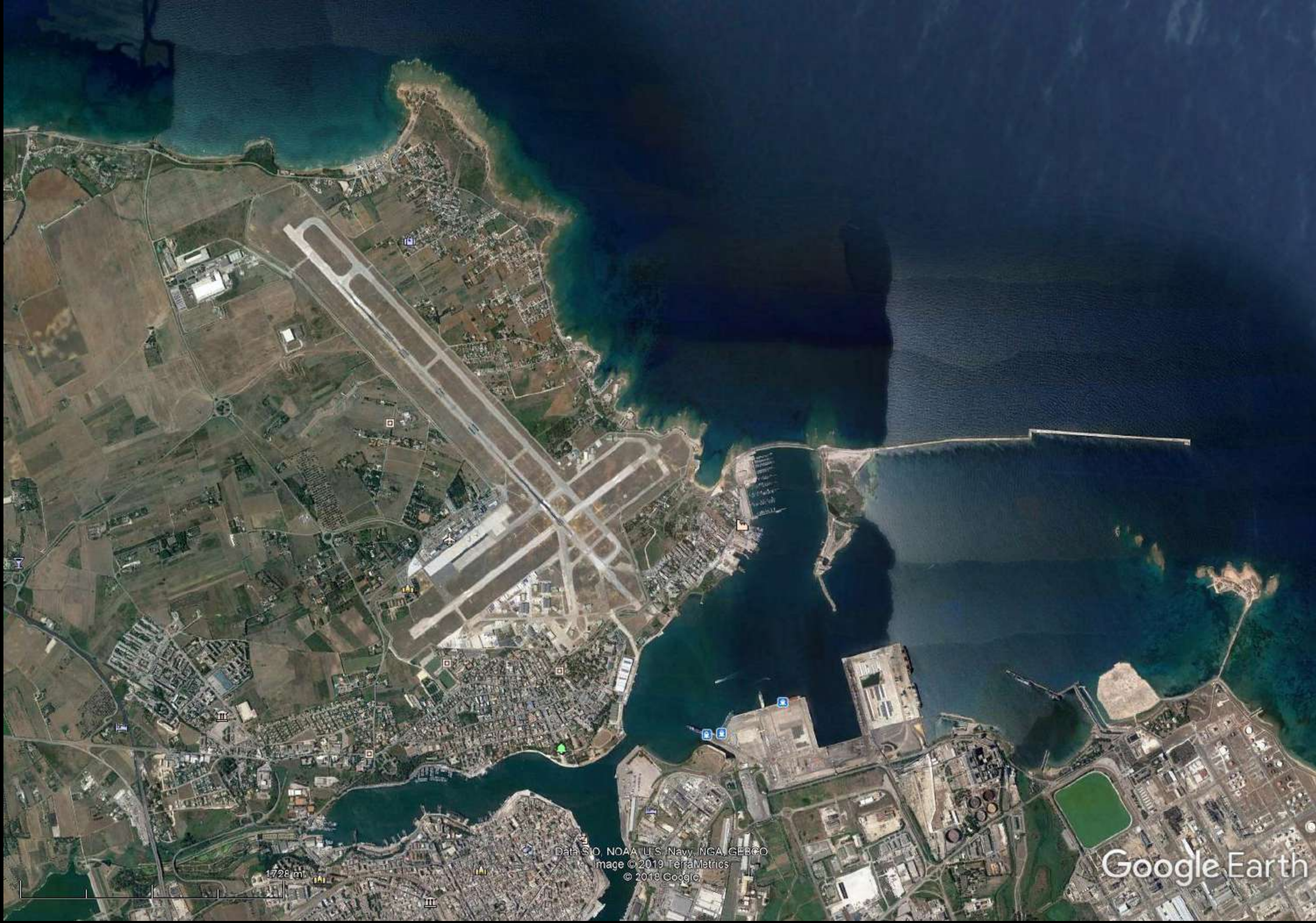
DATUM: WGS 1984 - Projection: Transverse Mercator ZONE 33, Northern Hemisphere - EPSG: 32633



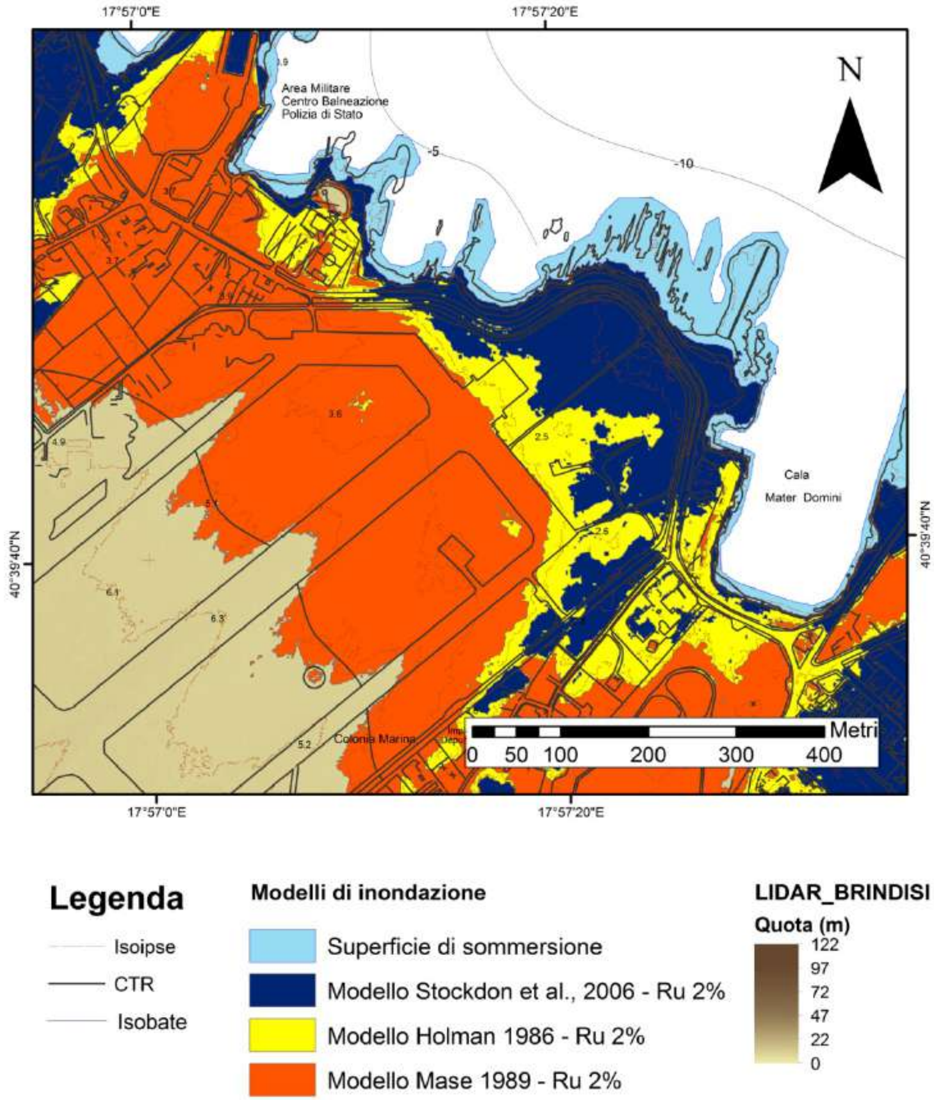
PROJECTION IPCC 2013
PROJECTION Rahamstorf 2007
France, Corsica, Bastia
9
BASTIA
Furiani
Biguglia
Etange de Biguglia
Aeroport de Bastia
Borgo
Lucciana
Casamozza
Vescovato
Venzolasca
N
source:
- DTM 25m from Copernicus
- bathymetry elaborated from different sources
- background map from Google Maps
coordinate system WGS 84 UTM Zone 32N EPSG:32632
0 1 2 3 4 5 km
535000
540000
545000
550000



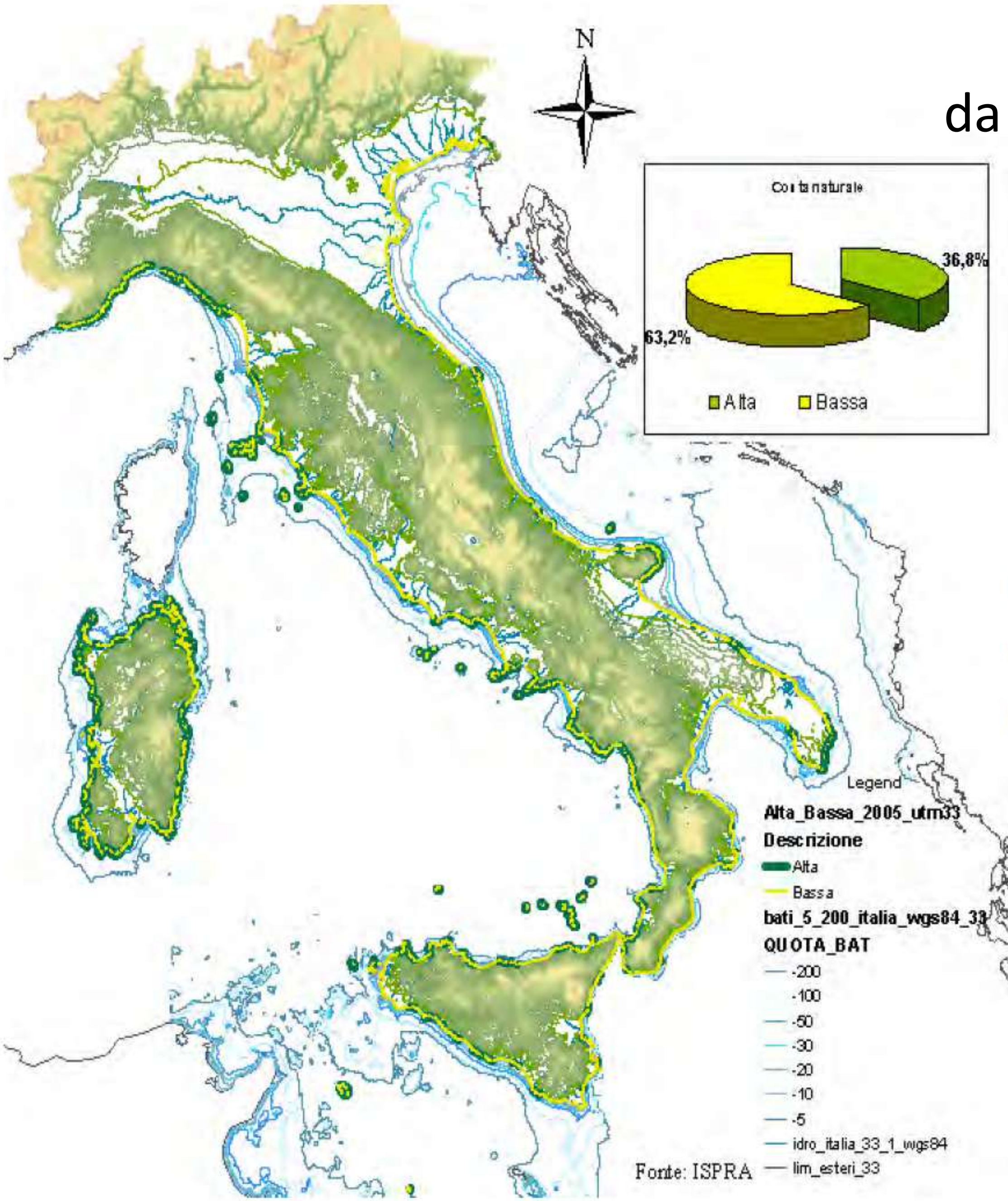
PROJECTION IPCC 2013
PROJECTION Rahamstorf 2007
Cyprus, Larnaca
8
LARNACA
water
salt lake
Airport of Larnaca
Dromolaxia
Water Treatment Plant
water
Tersefanou
Kiti
Perivolia
N
source:
- DTM 25m from Copernicus
bathymetry elaborated from different sources
- background map from Google Maps
coordinate system WGS 84 UTM Zone 36N EPSG:32636
0 1 2 3 4 5 km


1728 m
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2019 TerraMetrics
© 2018 Google
Google Earth

Livello del mare = 1.0 m
Ampiezza di marea = 0.2 m
Surge = 0.3 m
Altezza d'onda = 4.5 m



Erosione
da report ISPRA 2017



CAPITOLO 5

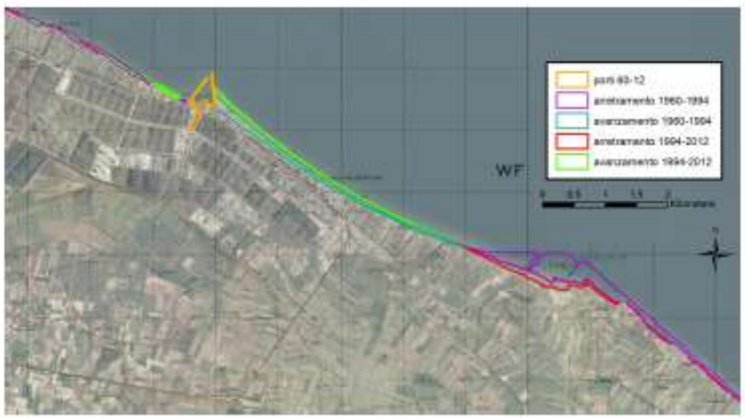
MARE E AMBIENTE COSTIERO

Introduzione

Direzione generale per la salvaguardia del territorio e delle acque

L'EROSIONE COSTIERA IN ITALIA

LE VARIAZIONI DELLA LINEA DI COSTA DAL 1960 AL 2012



Elaborazione nazionale dei dati sulle superfici e sui tratti di spiaggia in avanzamento e in arretramento della costa dell'Italia peninsulare, della Sicilia e della Sardegna dal 1960 al 1994 e al 2012. *Agg. Mar2017.*

SOGESID

VARIAZIONE DELLA LINEA DI COSTA DELL'ITALIA PENINSULARE DAL 1960 AL 2012

regione	superfici (kmq)		tratti costieri (km)		bilancio delle superfici (kmq)
	arretramento	avanzamento	arretramento	avanzamento	
ABRUZZO	1,3	1,9	39,9	58,0	0,6
BASILICATA	2,0	1,5	20,0	19,8	-0,5
CALABRIA	12,3	9,1	342,2	237,6	-3,2
CAMPANIA	3,7	2,0	86,0	61,5	-1,7
EMILIA R	20,0*	6,2	65,6	62,3	-13,8
FRIULI VG	1,1	3,2	32,1	50,5	2,1
LAZIO	2,4	4,9	77,3	131,4	2,5
LIGURIA	1,3	1,8	46,5	67,6	0,5
MARCHE	3,2	1,9	67,1	60,0	-1,3
MOLISE	1,5	0,7	14,5	19,5	-0,8
PUGLIA	4,3	3,7	128,2	121,7	-0,5
SARDEGNA	1,5	0,9	90,3	61,0	-0,5
SICILIA	13,4	5,9	365,9	187,9	-7,5
TOSCANA	6,1	5,2	88,7	87,0	-0,8
VENETO	17,9**	7,5***	70,0	80,7	-10,3
Totale complessivo	**91,9**	**56,6**	**1534,4**	**1306,4**	**-35,3**

** di cui arretramento Delta F. Po EMR 10.7 kmq*

***di cui arretramento Delta F. Po VEN 16.2 kmq*

**** di cui avanzamento Delta F. Po VEN 3.1kmq*

Bilancio cmplessivo superfici Km2: -35,3%

Ministero dell'Ambiente e della Tutela del Territorio e del Mare
Direzione Generale per la Salvaguardia del Territorio e delle Acque

LE VARIAZIONI DELLA LINEA DI COSTA ITALIANA 1960-2012

I PRINCIPALI RIPASCIMENTI CON SABBIE PRELEVATE IN MARE DAL 1997 AL 2011

Ministero dell'Ambiente e della Tutela del Territorio e del Mare
Direzione Generale per la Salvaguardia del Territorio e delle Acque

LE VARIAZIONI DELLA LINEA DI COSTA ITALIANA 1960-2012

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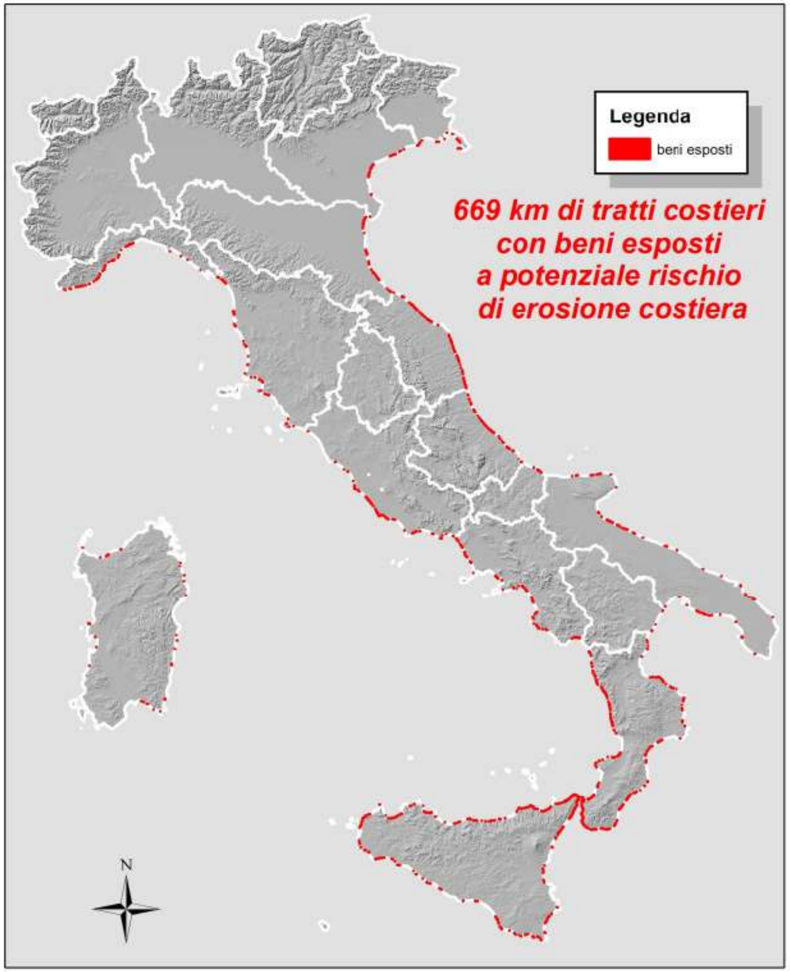
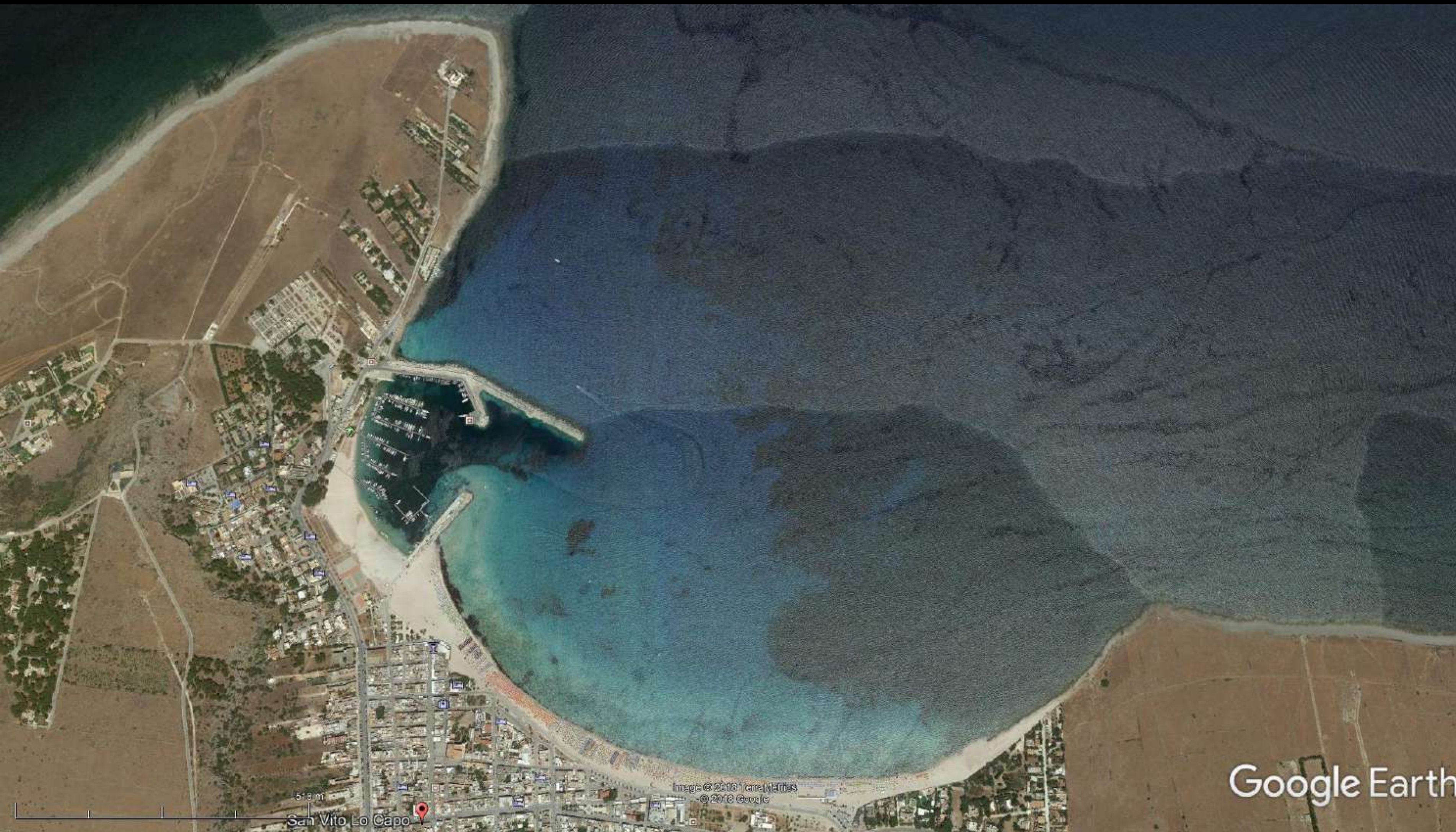
TRATTI COSTIERI CON BENI ESPOSTI A POTENZIALE RISCHIO DI EROSIONE



Il caso di San Vito lo Capo, non c’è erosione , e pur in assenza di fiumi la spiaggia non si erode **perche?**


518 m
San Vito Lo Capo
Image © 2018 TerraMetrics
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Trottire a Vermetidi, scogliere vive
che forniscono carbonato organico

Ferrovie


= LINEE PRINCIPALI
= LINEE SOPPRESSE
= LINEE NUOVE
(1985) = ANNO Soppressione Totale
(1985) = ANNO Soppr. Serv. Passeg.
= LINEE SECONDARIE
= Rete Fondamentale Odierna
PALERMO
Palermo Maritt.
TRAPANI
Marsala
Castelvetrano
Salemi
Roccapalumba
Fiumetorto
MESSINA
Caltanissetta
CALTANISSETTA C.
ENNA
CATANIA C.
Bicocca
Valsavoia
SIRACUSA
AGRIGENTO C.
Porto Empedocle
Porto Empedocle Succursale
Canicattì
Licata
Taormina G.
Alcantara
Randazzo
Regalbuto
REGGIO CAL.
Reggio C. Lido
Catanzaro Lido
CATANZARO
COSENZA
Crotone
Paola
Castiglione Cosentino
Sibari
Lagonegro
POTENZA
TARANTO
Metaponto
Villa S.Giovanni
(1981)
(1959)
(2013)
(1968)
(1979)
(1991)
(1986)
(1994)
(1971)
(1987)
(1916)
(1939)
(2008)
(2011)
Roberto Troiano A.T.

L’esempio dell’Olanda

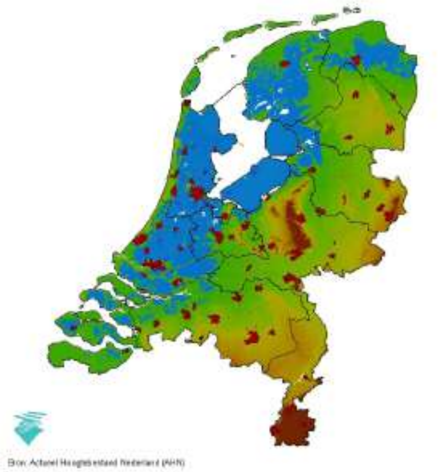

Figure 2.1: The Netherlands below sea level (in blue)

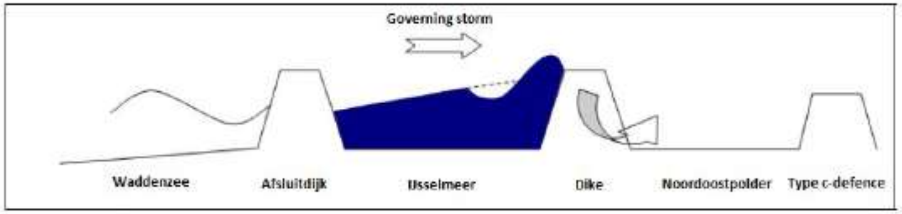

Figure 2.9: Schematistation of the IJsselmeer water system during a storm on the IJsselmeer dikes (source: [14])

However, as wind speeds (and direction) influence both possibilities of failure it can happen that failure of the Afsluitdijk also influences failure of the IJsselmeer dikes (see figure 2.10). This amount of influence is investigated in this thesis (see section 5.4).

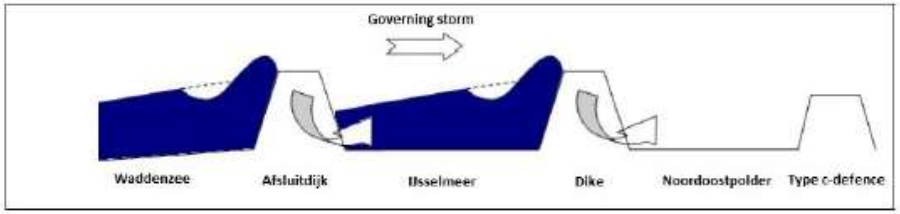

Figure 2.10: Schematistation of the IJsselmeer water system during a breach in the Afsluitdijk

If the dikes around the IJsselmeer fail, water will flow into the hinterland. In the case of a still intact Afsluitdijk the water level of the IJsselmeer will go down and water in the polder will rise to arrive at a new equilibrium (see figure 2.11).

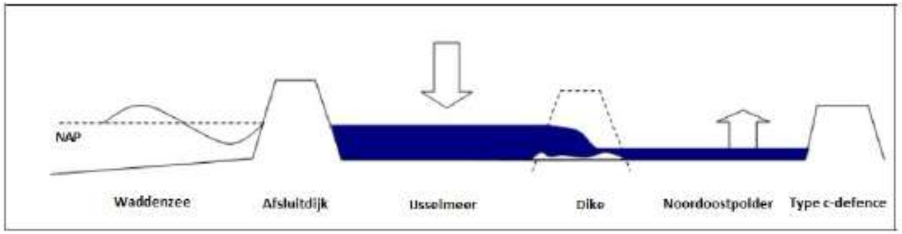

Figure 2.11: Schematistation of the IJsselmeer water system during a breach in the IJsselmeer dikes (source: [14])

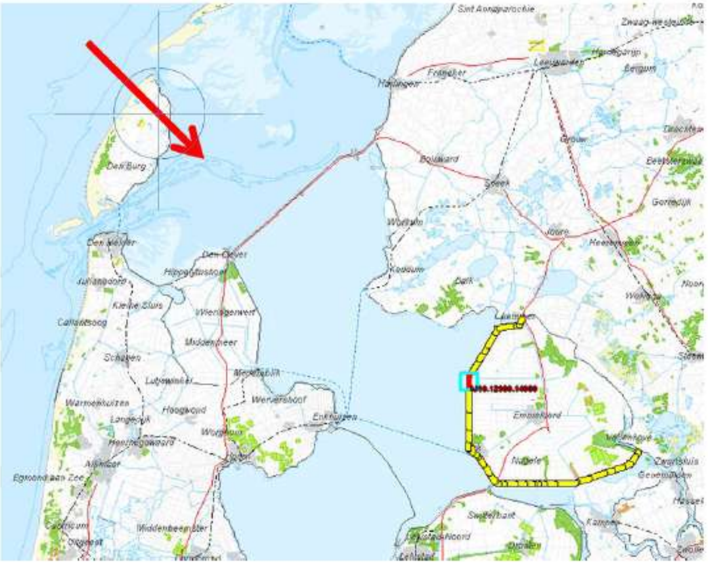

Figure 5.6: Dike ring area 7 in the Southwestern side of the IJsselmeer

Il sollevamento del mare atteso per le coste Italiane nel 2100 sarà compreso tra e 940 e 1035 mm con il modello più cautelativo, tra 1310 e 1450 mm con un modello meno cautelativo. A questi valori bisogna aggiungere un valore di storm surge variabile da zona a zona che saltuariamente, in particolari condizioni di vento, onde e bassa pressione può arrivare a superare 1100 mm