LIFE08 ENV/IT/436

PROJECT ACT

ADAPTING TO CLIMATE CHANGE IN TIME

PROJECTIONS OF RELATIVE SEA-LEVEL RISE OVER THE NEXT CENTURY

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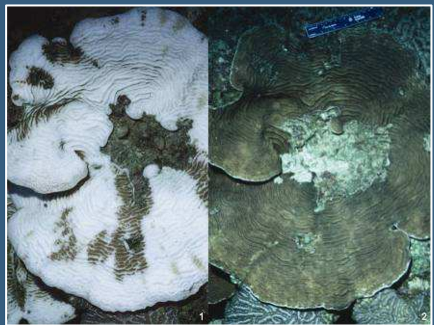
ISPRA

Istituto Superiore per la Protezione
e la Ricerca Ambientale

Climate change effects on the Mediterranean Sea

Marine ecosystems

- Habitats reduction
- Tropicalization phenomena (alien species)
- Meridionalization phenomena
- Implications for fisheries and aquaculture



Ocean waters

- Algal blooms (mucillagini)
- Ocean acidification
- Coral bleaching

<u>Coastal systems</u>

- Increase in extreme events
- **Sea-level change** (beaches erosion, coastal flooding)

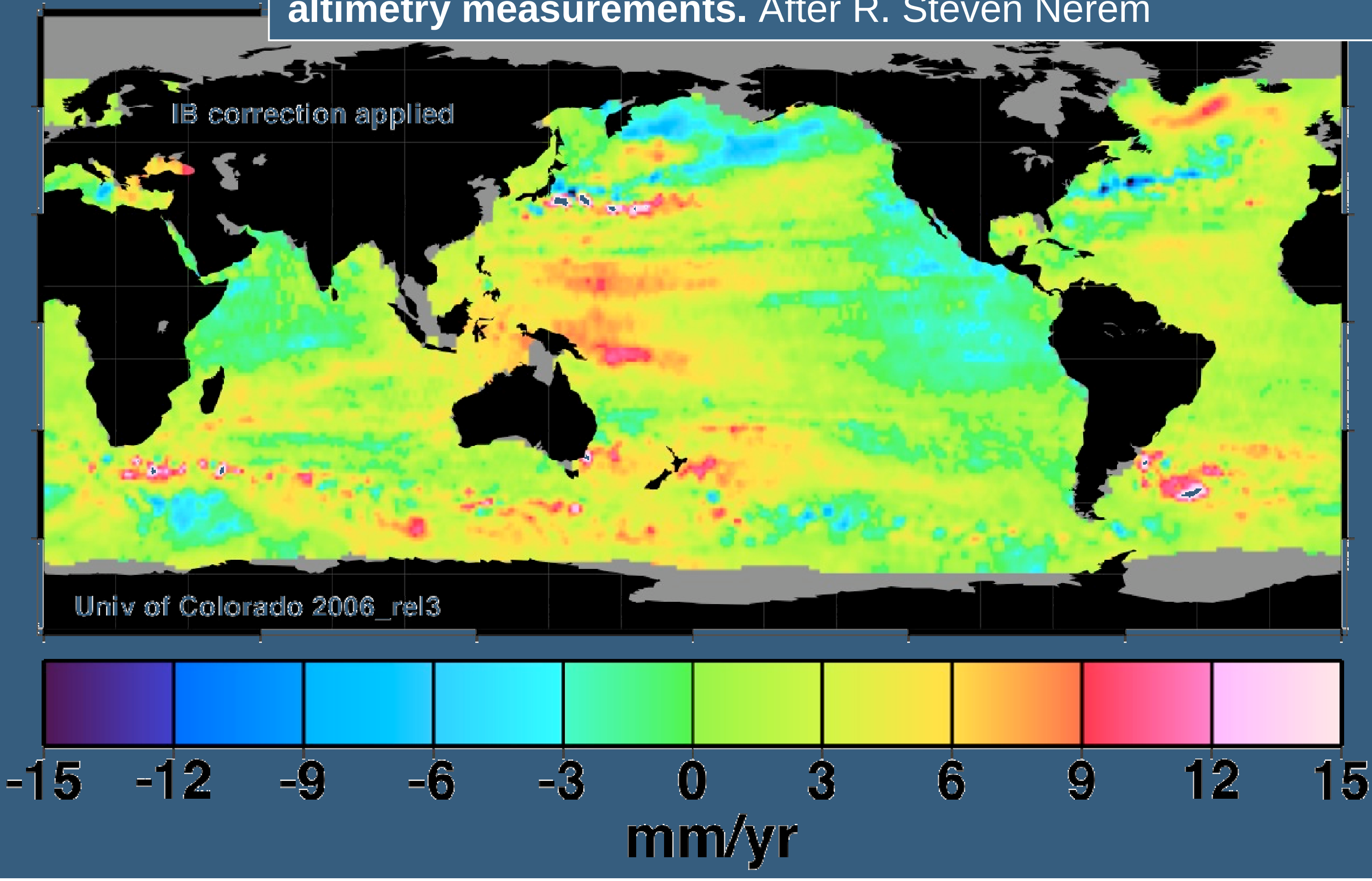
What is Global Mean Sea Level Change?

Global Mean Sea Level Change is the change in the average height of the oceans over the entire globe at a single point in time.

Sea level change at a specific location in the ocean may be higher or lower than the global mean because of differences in ocean temperature and other effects.

Does not include ocean tides, storm surge.

Average Sea Level Rise over 1993-2006 determined from satellite altimetry measurements. After R. Steven Nerem



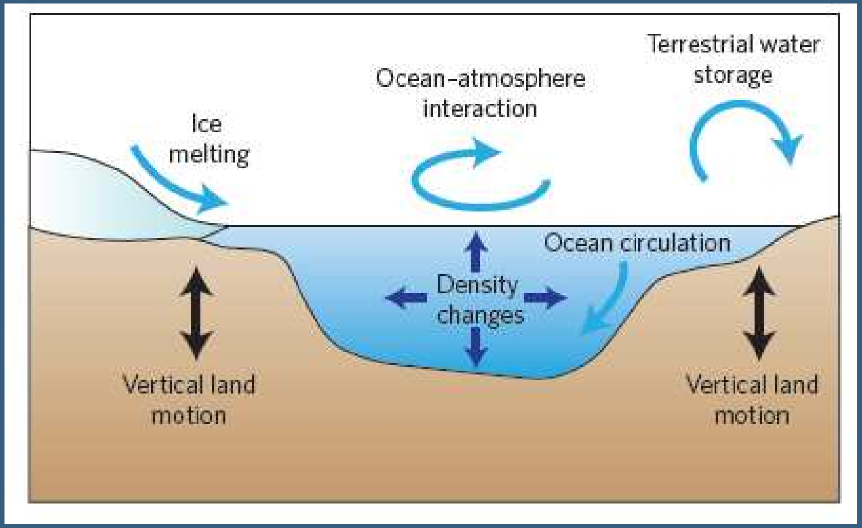
What causes relative sea-level change?

- **Change in ocean volume (thermal expansion, addition/removal of water)**

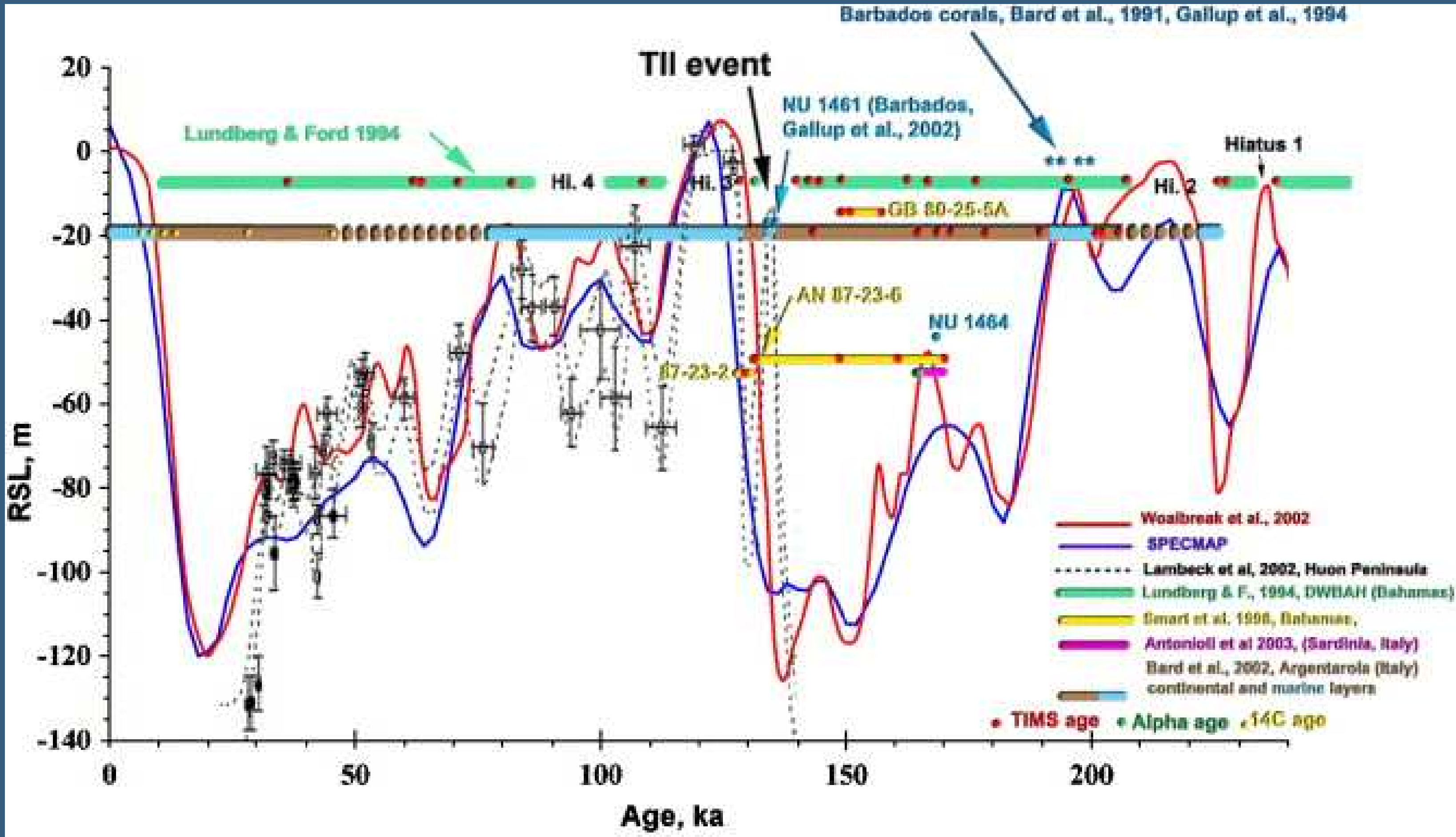
- **Change in shape of basin holding a constant volume of water (ocean ridge formation)**

- **Change in gravity field (ocean surface as an equipotential surface, e.g. change in rotation.)**

- **Land movement, tectonic uplift and subsidence along the coastal zone.**



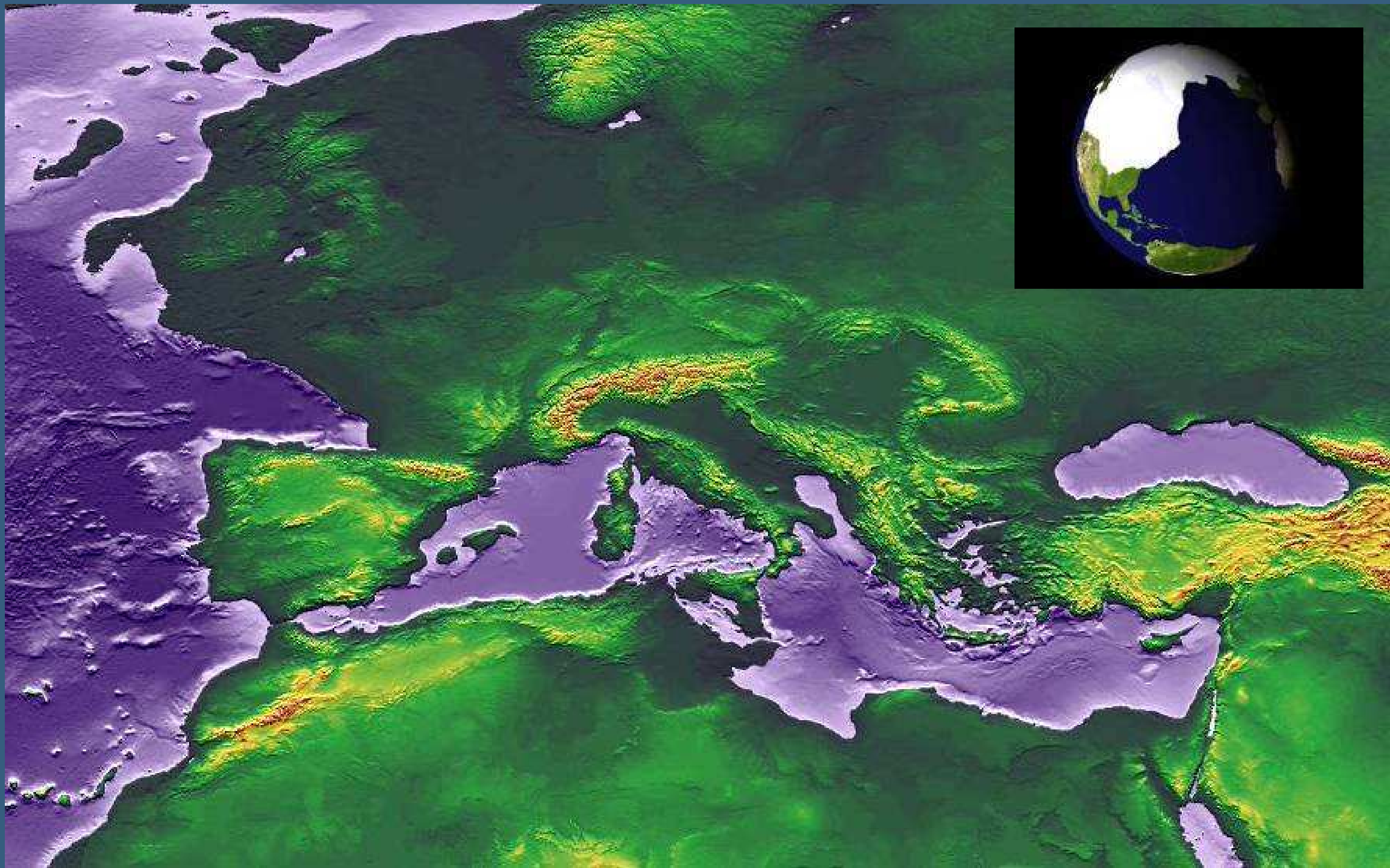
Global sea-level variations over the last 240 ka



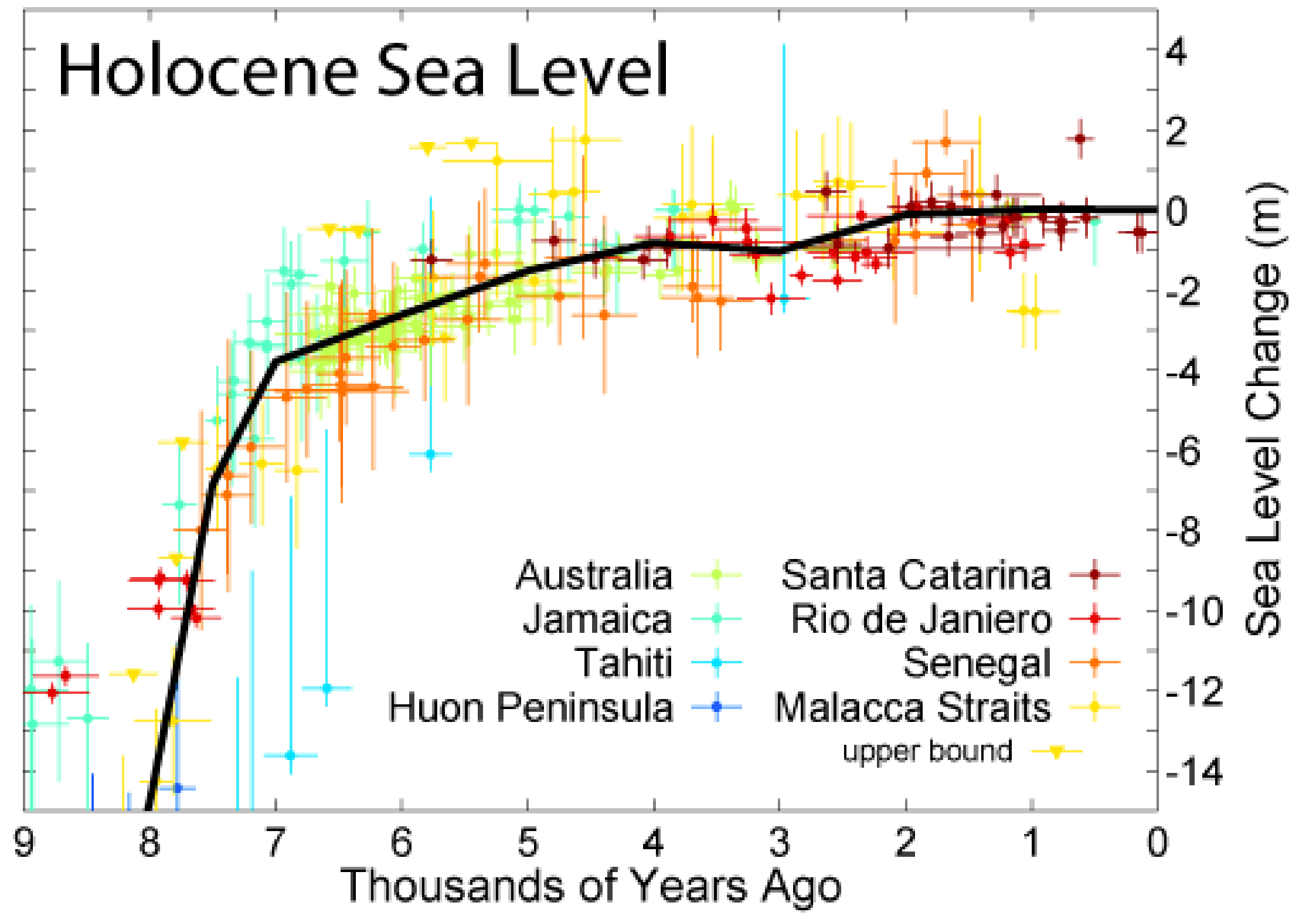
• DWBAH flowstone in green Lundberg, 1990, Li et al., 1989, Lundberg and Ford, 1994 and Richards et al., 1994;• Argentarola stalagmites in brown (Bard et al., 2002a; this paper);• speleothems sampled at South Andros cave, Bahamas (Smart et al., 1998) in yellow;• Grotta Verde stalagmite (Antonioli et al., 2003) in violet;• corals from Barbados in blue circle Gallup et al., 2002 and Bard et al., 1990;• in black, the (Lambeck et al., 2002) sea-level curve from Papua, New Guinea.

After Antonioli et al., 2004

Global sea-level variations during the Last Glacial Maximum (20 ka BP)



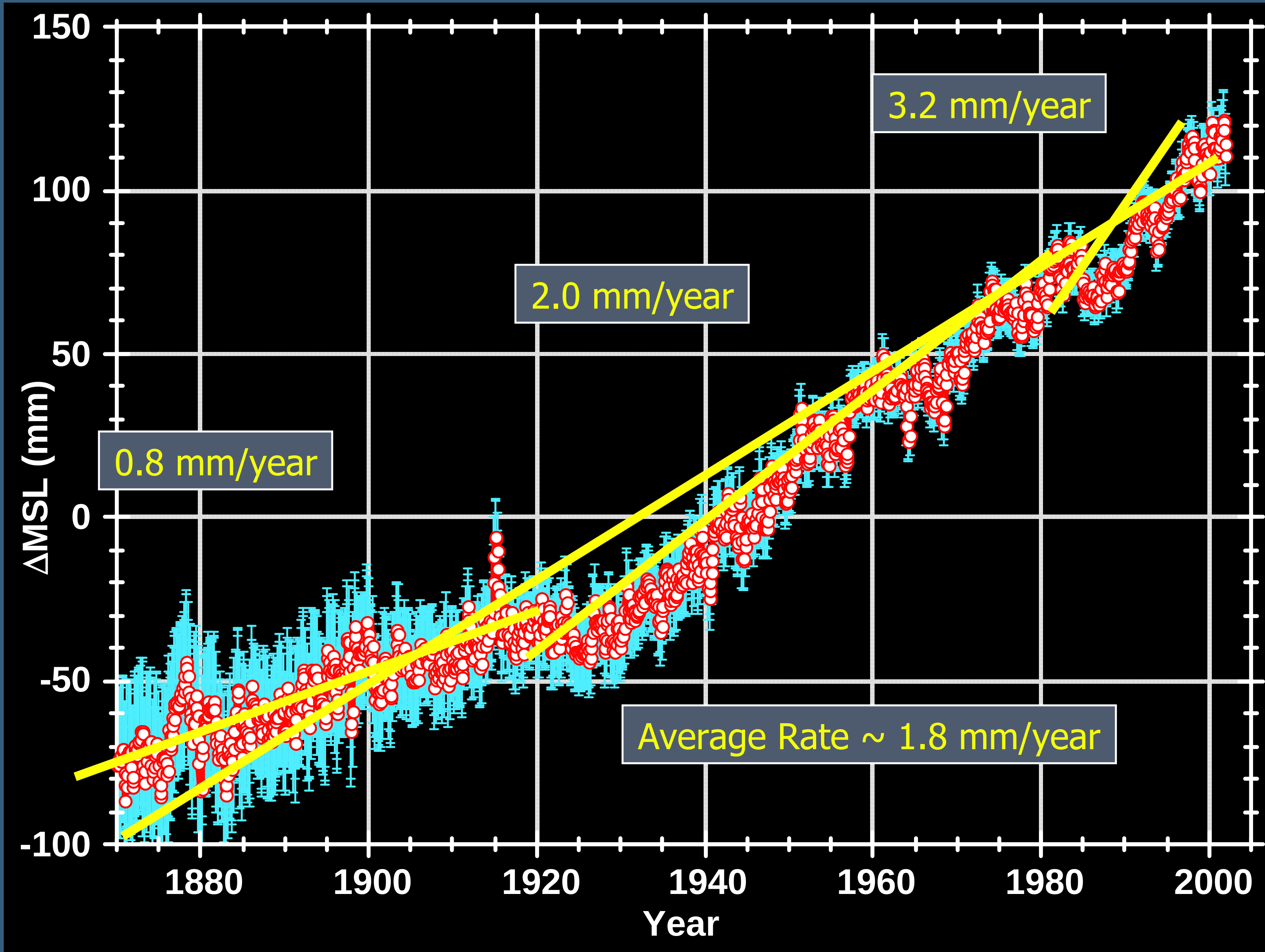
Global sea-level variations during the Holocene



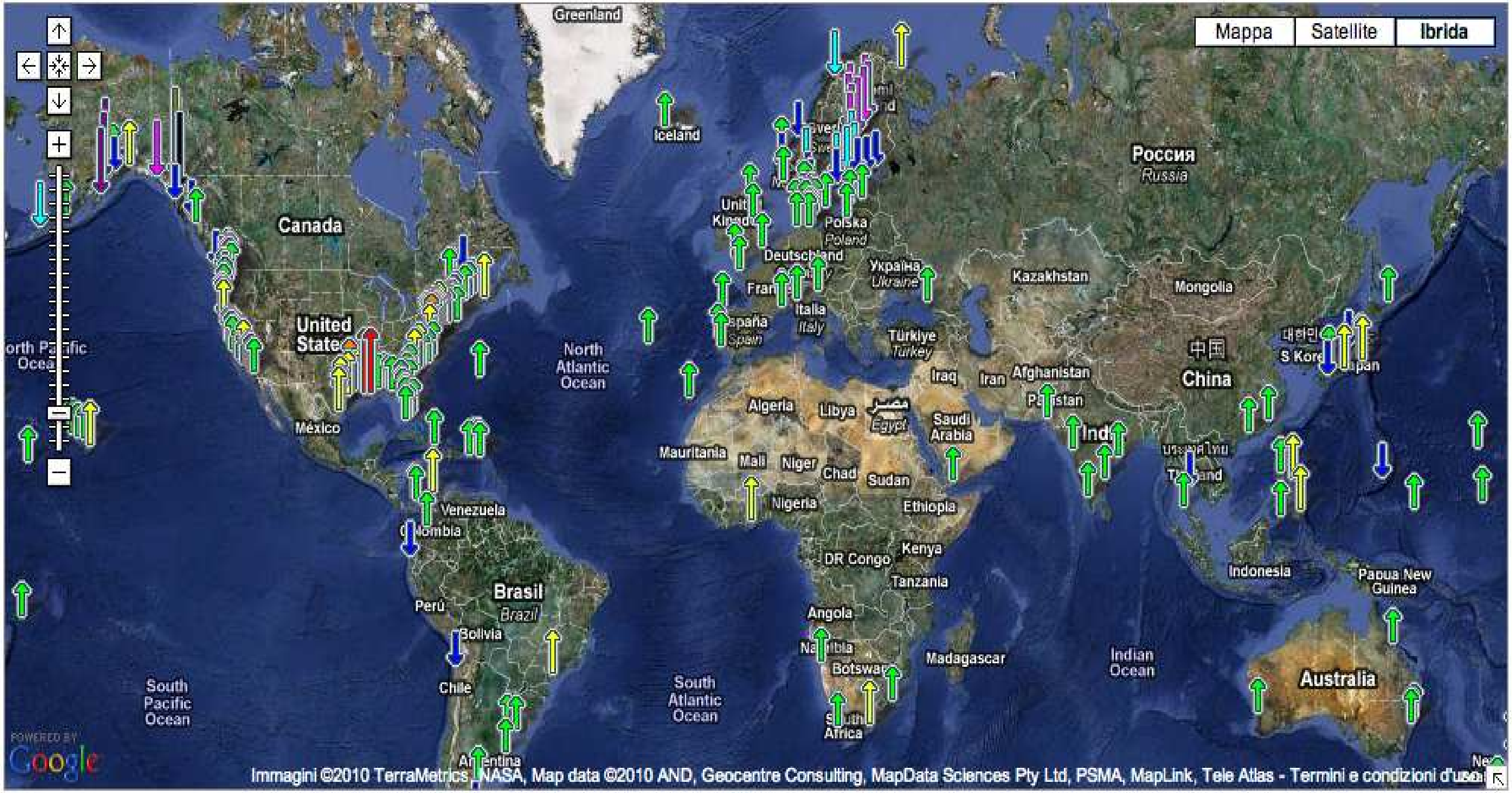
After Robert A. Rohde

Global sea-level variations during the Last Century

After Church and White, 2006



Changes in Sea Level over the last 150-100 years: the importance of local factors



The map above illustrates regional trends in sea level, with arrows representing the direction and magnitude of change. Click on an arrow to access additional information about that station.

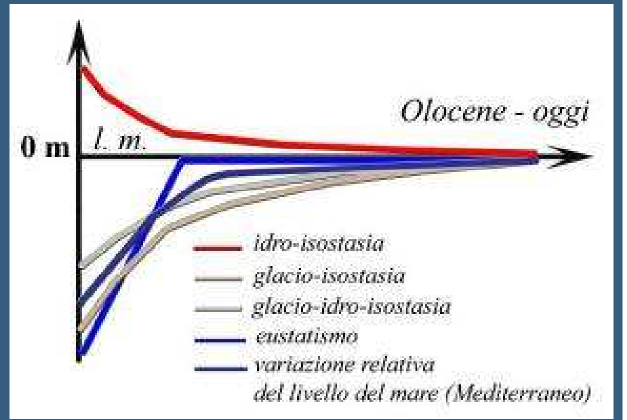
Sea Level Trends
mm/yr (feet/century)

9 to 12 (3 to 4)	3 to 6 (1 to 2)	-3 to 0 (-1 to 0)	-9 to -6 (-3 to -2)	-15 to -12 (-5 to -4)
6 to 9 (2 to 3)	0 to 3 (0 to 1)	-6 to -3 (-2 to -1)	-12 to -9 (-4 to -3)	-18 to -15 (-6 to -5)

NOAA data

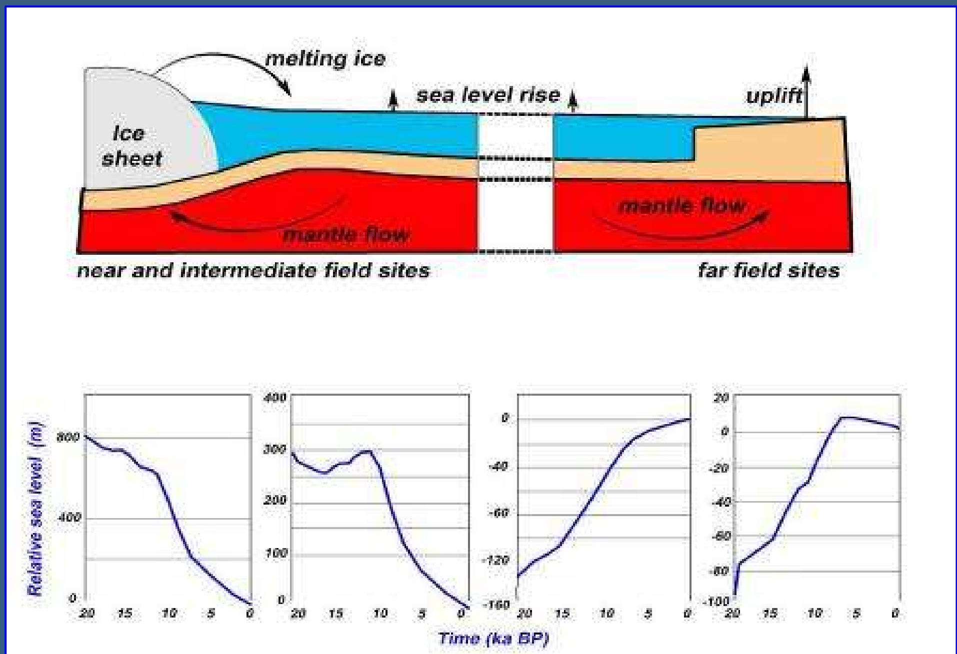
Glacio-hydro-isostasy

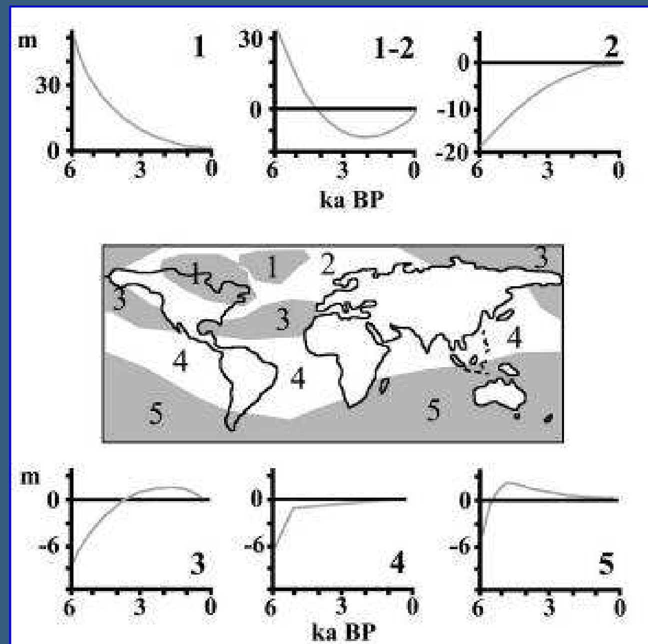
$$\Delta\zeta_{rsl}(\varphi,t) = \Delta\zeta_{esl}(t) + \Delta\zeta_{G}(\varphi,t) + \Delta\zeta_{T}(\varphi,t) + \Delta\zeta_{\square}(\varphi,t) + \Delta\zeta_{O}(\varphi,t)$$



When ice sheet melts:

- Ocean volume increases $\Delta\zeta(t)_{esl}$
- Gravitational attraction between ice and water changes; geoid change.
- Earth deforms under changing ice load; subsidence beneath ice broad peripheral zone of uplift.
- Mass redistribution within Earth and change in shape of Earth causes further geoid change.
- Ocean basin shape changes and water is redistributed within basins.
- Differential loading of sea floor cause further deformation of surface and gravity/geoid.

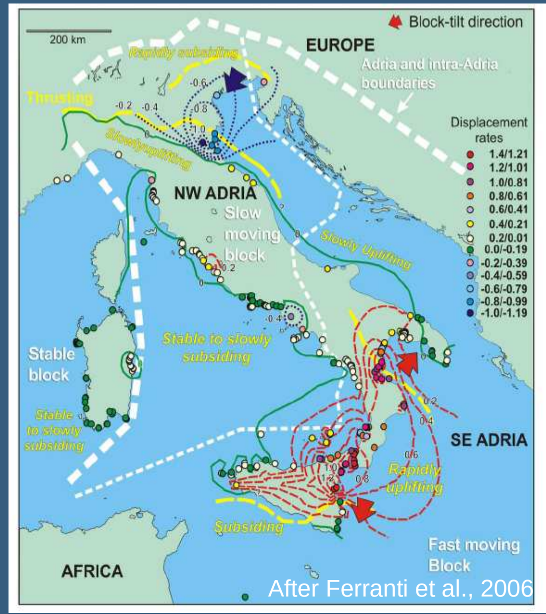




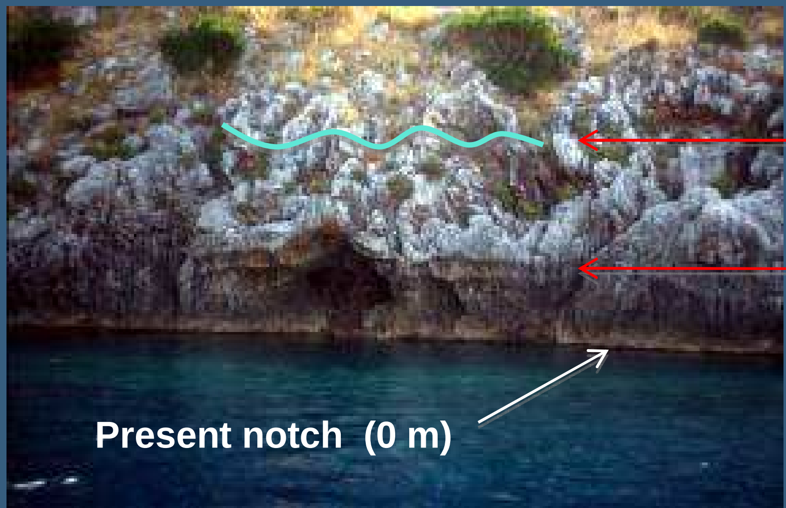
Vertical movements (Tectonic): the example of Palinuro (Italy)

The Mediterranean area is characterized by active tectonic deformations.
The vertical component of every deformation is an addendum in the relative sea-level rise computation: the amount of this component can be different for every coastal location.
However, by comparing paleosea-level markers (tidal notches, marine terraces, beach deposits, archeological remains) with the present elevation, is possible to determine the vertical displacements during long- and short-periods.

Two examples: Palinuro(Italy) and Falasarna (Crete, Greece)



After Ferranti et al., 2006



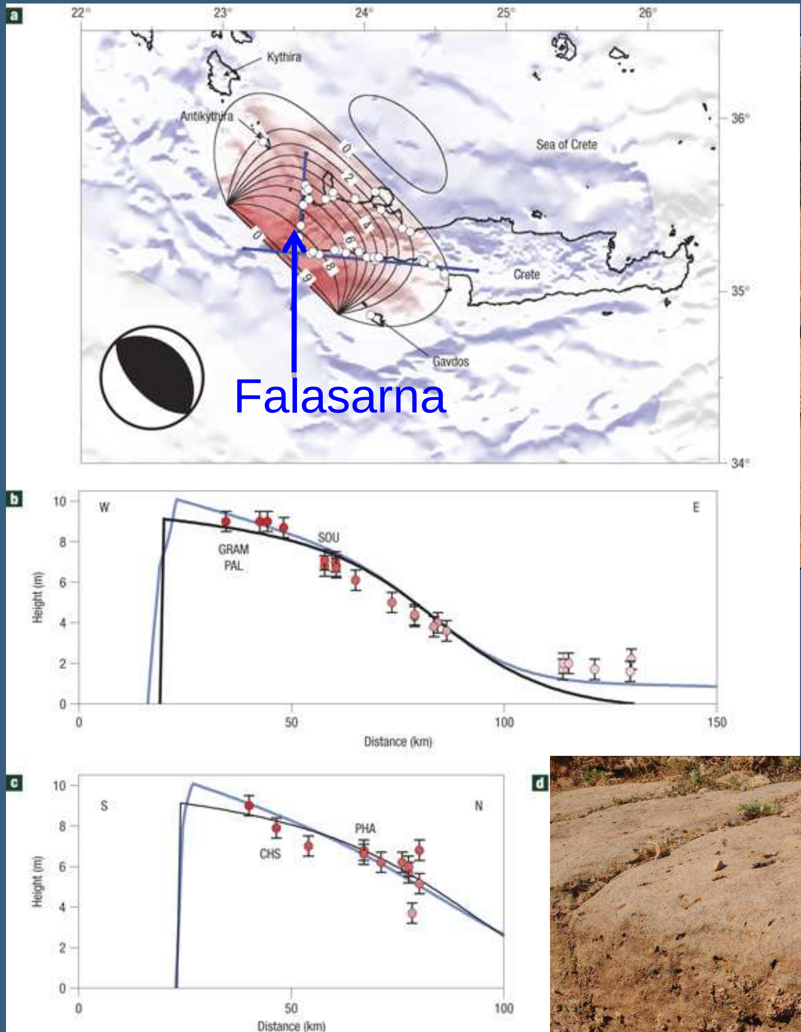
SL elevation during the Last Interglacial + 7±1 m

Long-term vertical displacement

Present height of the the Last Interglacial notch + 2.2 m

Vertical movement: 7-2.2=-4.8m in 125000 yrs => 0.04 mm/yr

Vertical movements (Tectonic): the example of Falasarna (Crete earthquake 365 DC)

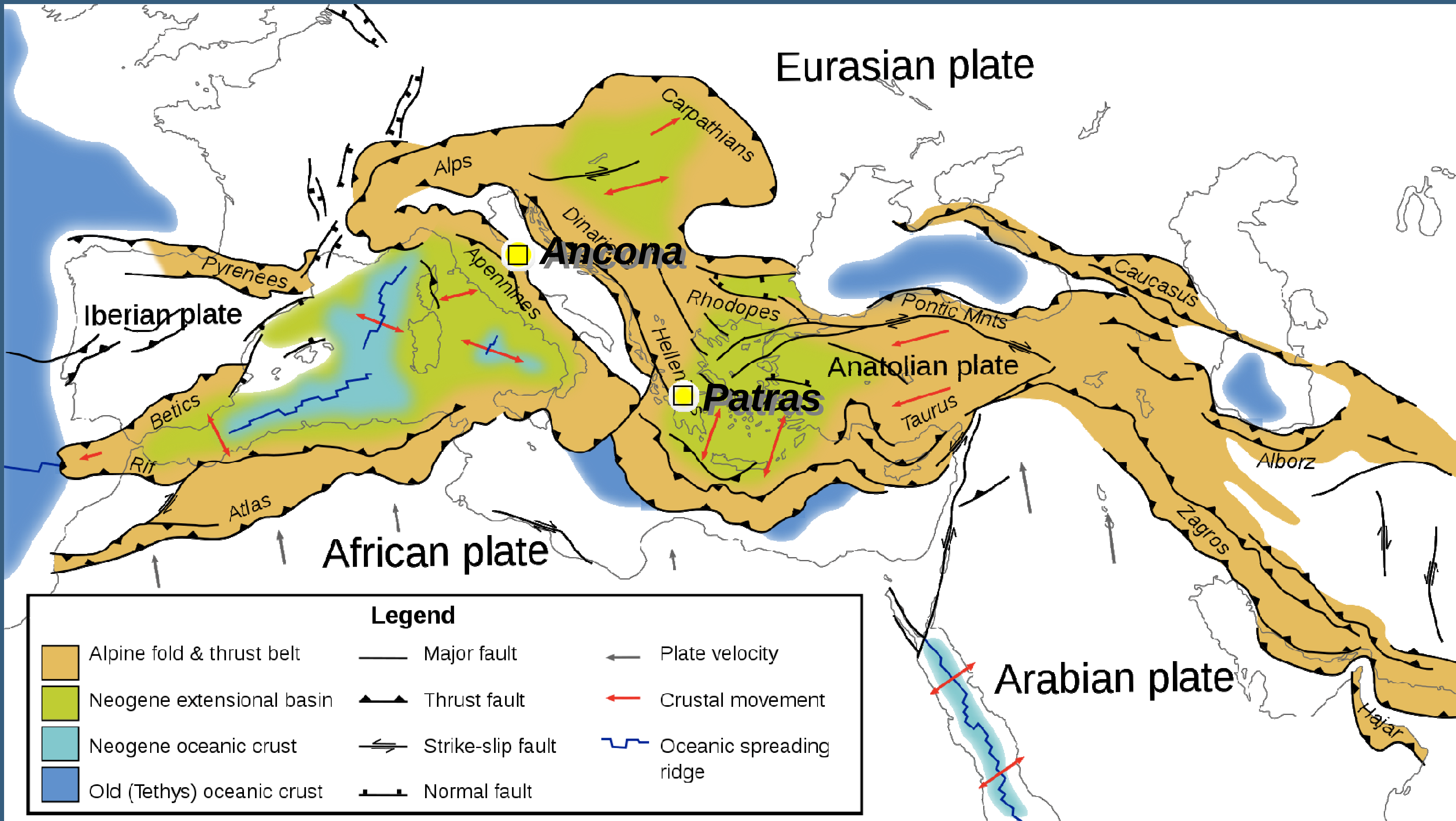


After Shaw et al., 2008

The ancient harbor of Falasarna

Shells and bitts

Life ACT studied areas



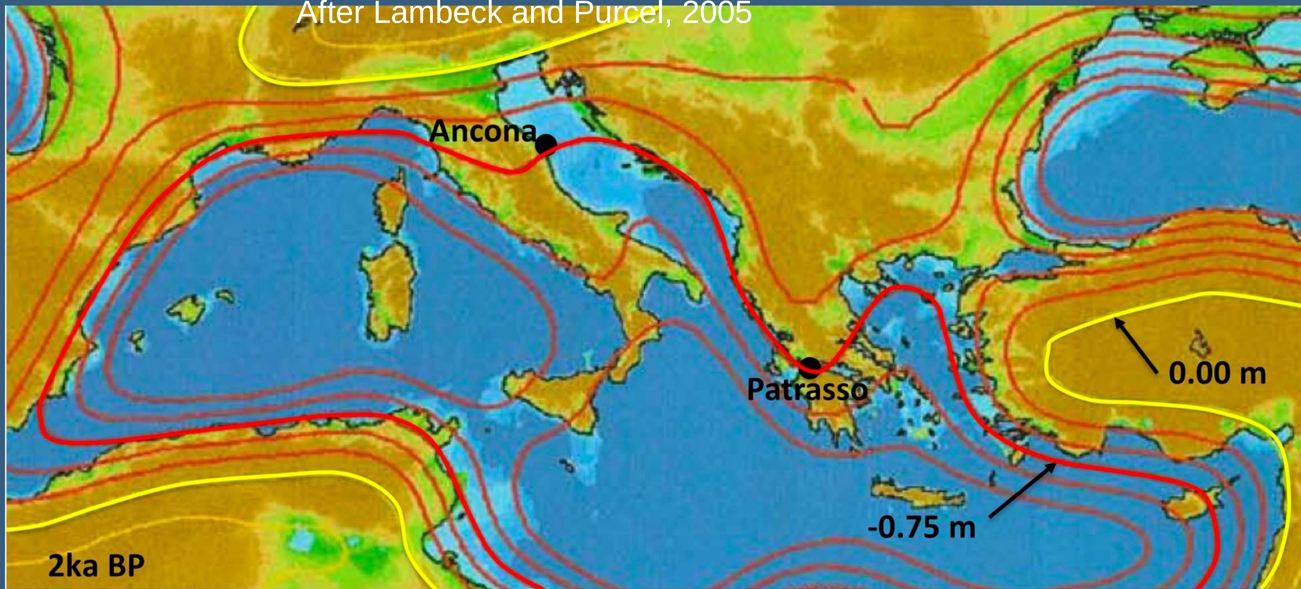
Sketch by Woudloper

Local Isostasy: Ancona and Patras

Predicted relative sea-levels and shorelines across the Mediterranean region, 2 ka BP.

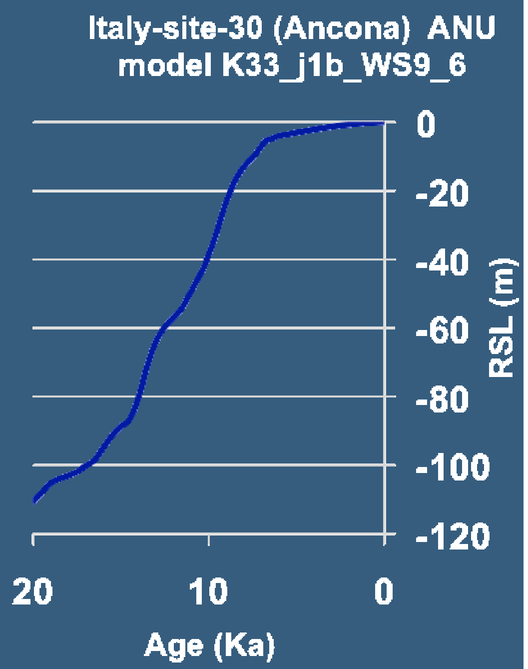
The red contours denote negative values, the orange contours denote positive values, and the yellow contour corresponds to zero change. The contour intervals is 0.25 m.

After Lambeck and Purcel, 2005

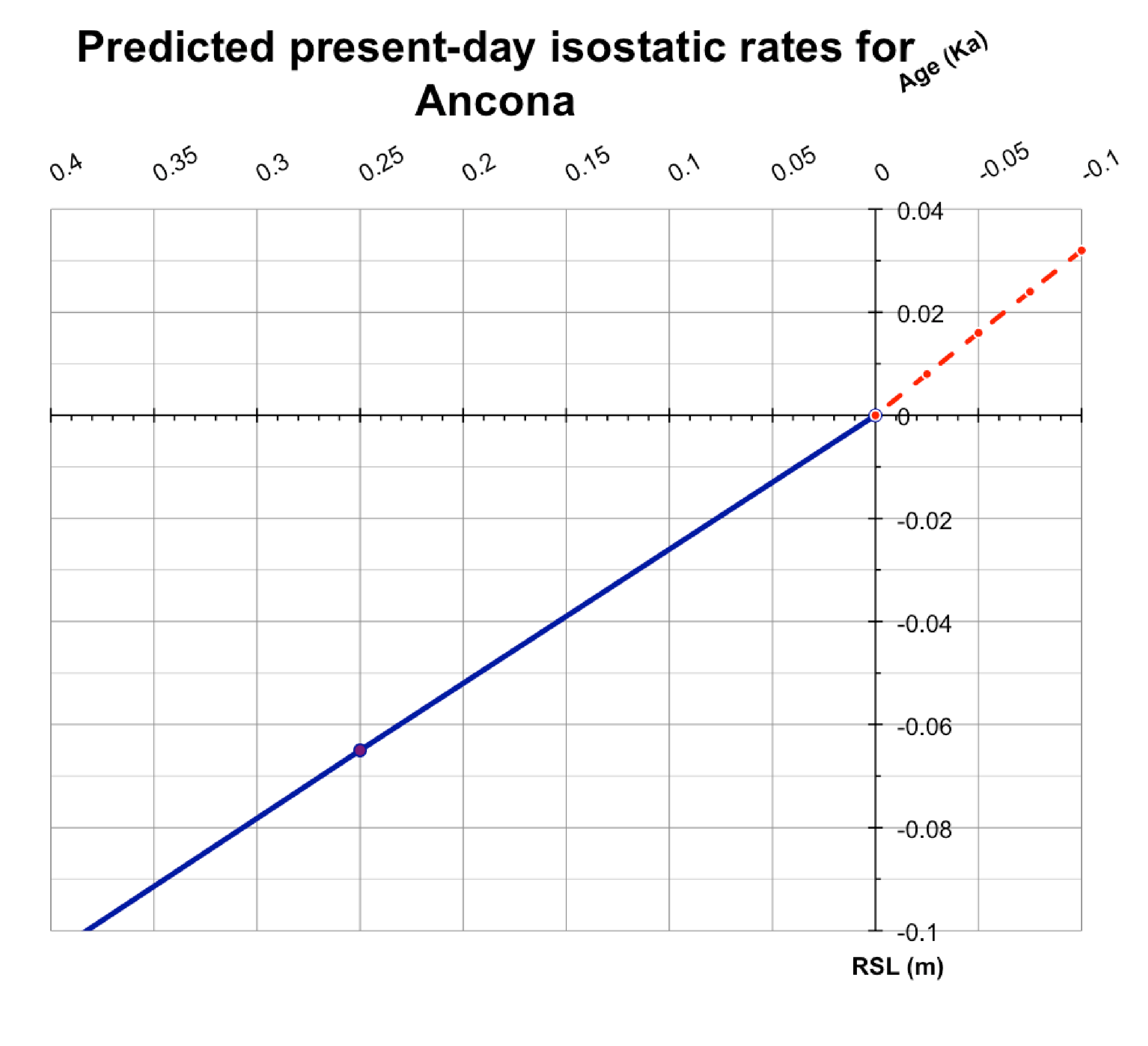


Over the next century, the isostatic contribution to the RSLR will be the same for both Ancona and Patras areas.

Local Isostasy: Ancona and Patras

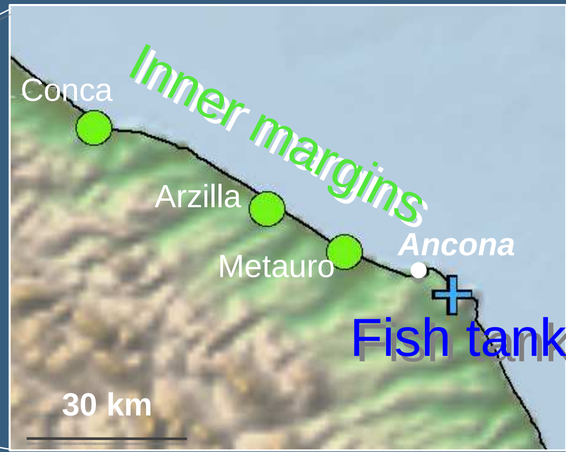


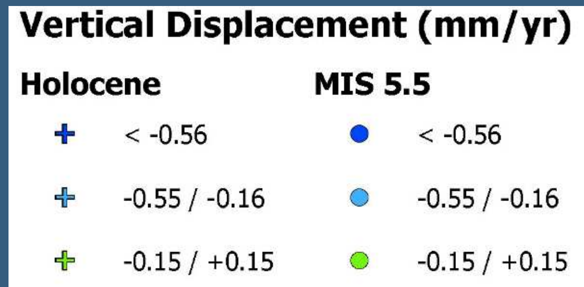
After Lambeck et al., 2010



Isostatic rebound for the Yr 2100 AD = 3.2 cm

Local tectonic data: Ancona

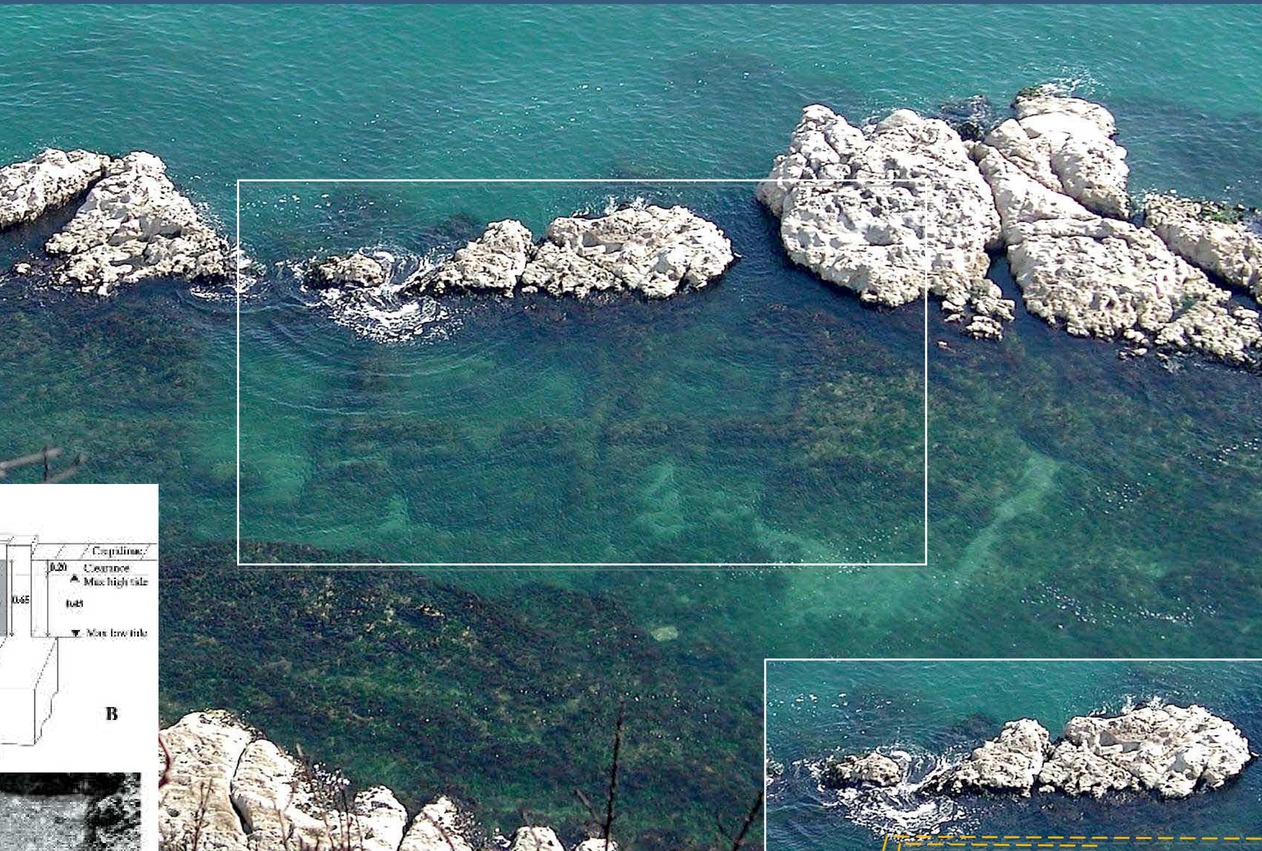


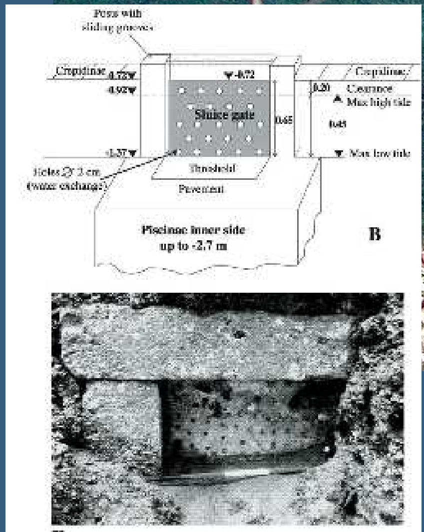


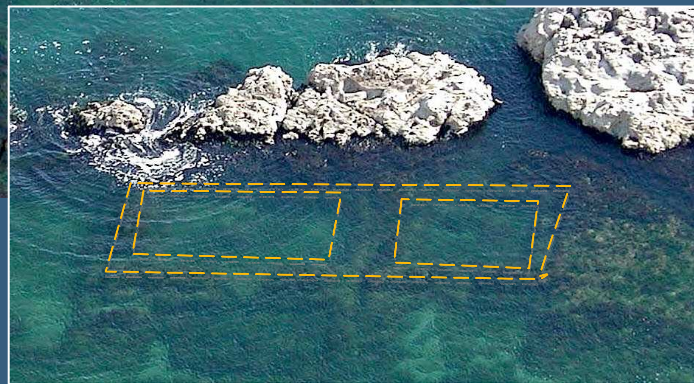
Rate of vertical movements in Italy averaged for the Holocene and for the Last Interglacial

Metauro River: 0.01 mm/a
Arzilla River: 0.07 mm/a
Conca River: 0.08 mm/a

Local tectonic data: Ancona

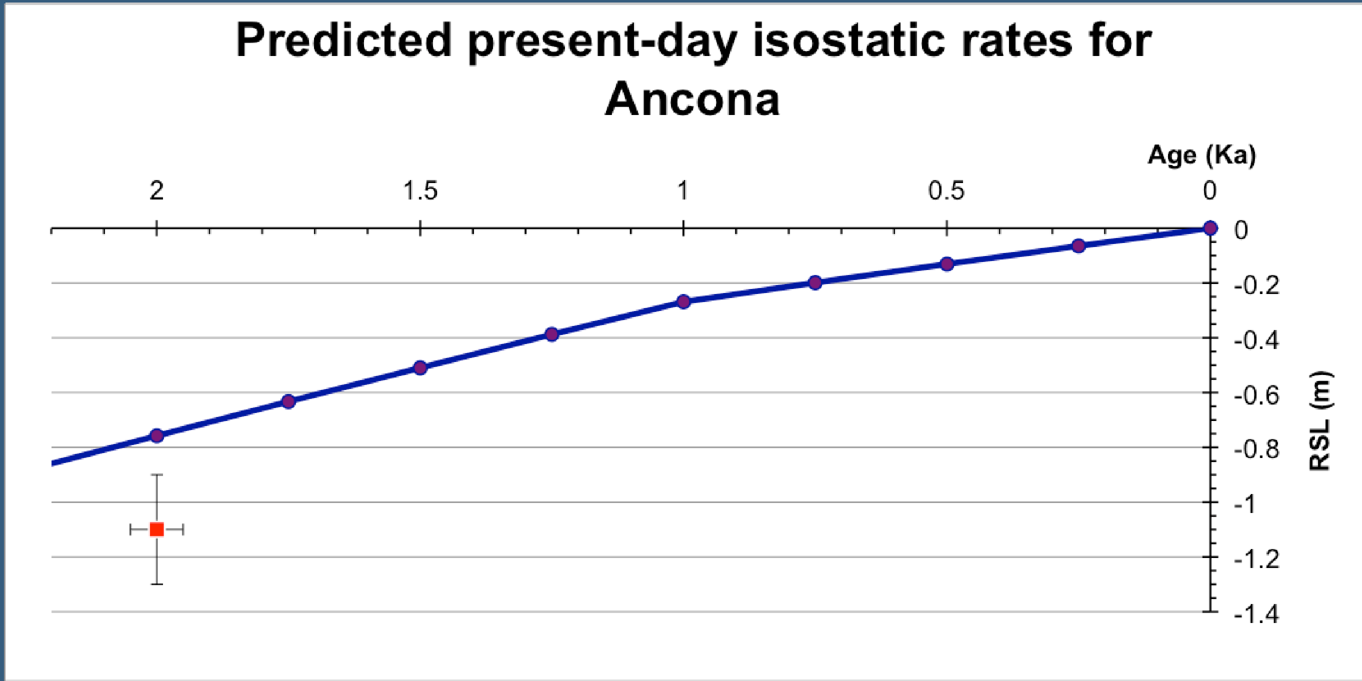






Ancona fish tank - Present height: -1.1 m basl

Local tectonic data: Ancona



Site name	Kind of marker, stratigraphy	Centesimal Coordinates Lat °N	Centesimal Coordinates Long °E	Age Cal BP 1σ Archaeological	Corrected height (m a.s.l.)	Corrected height error +- (m a.s.l.)	Predicted values ANU model (Lambeck et al., 2010)	Vertical tectonic movements (mm\yr) *Mean*	Reference
Ancona	Fish tank	43.56670	13.56667	1950±50	-1.1	0.2	-0.76	**-0.17**	Profumo 2007

Local tectonic adopted for Ancona: -0.17 mm/a

Local tectonic data: Patras

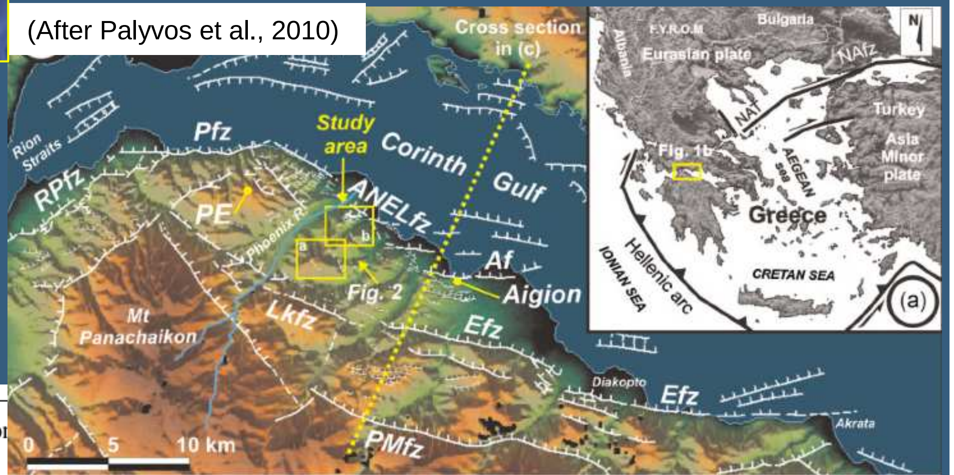
1) Peracora Peninsula: 1.4 mm/a (Lambeck et al., 2006)

2) Central Corinth Gulf: 1.74 ÷1.85 mm/a (Palyvos et al., 2010)

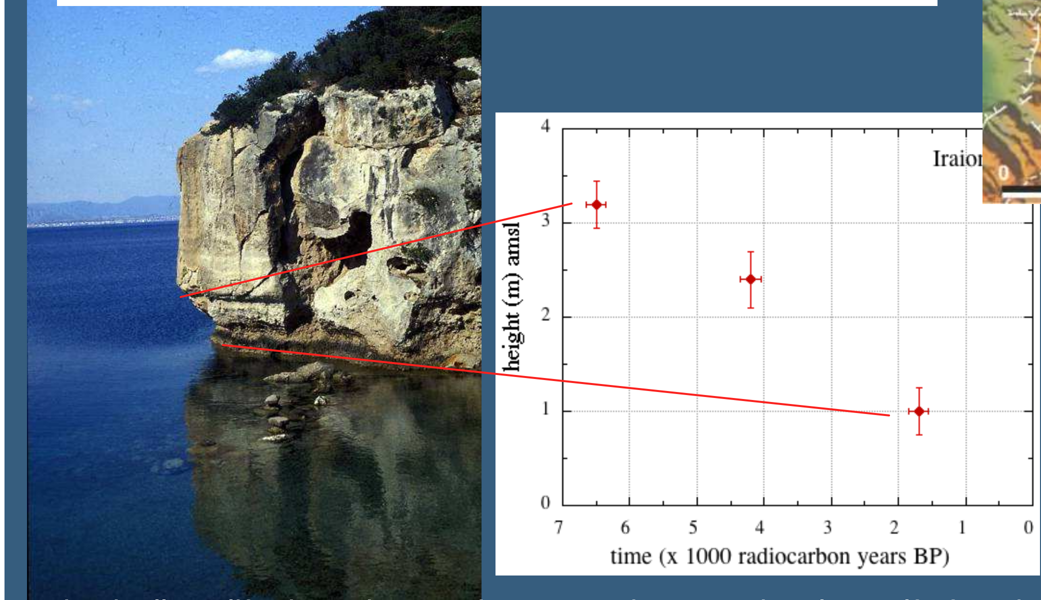
3) N Gulf of Patras: 1÷ 2 mm/a (Chonis et al., 1991)

4) Elis: 1.8 mm/a (Vott, 2007)

(After Palyvos et al., 2010)

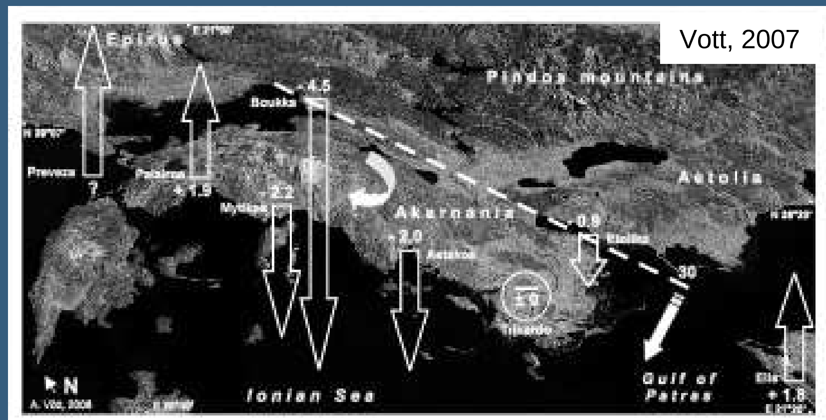


Local tectonic adopted for Patras: 1.5 mm/a

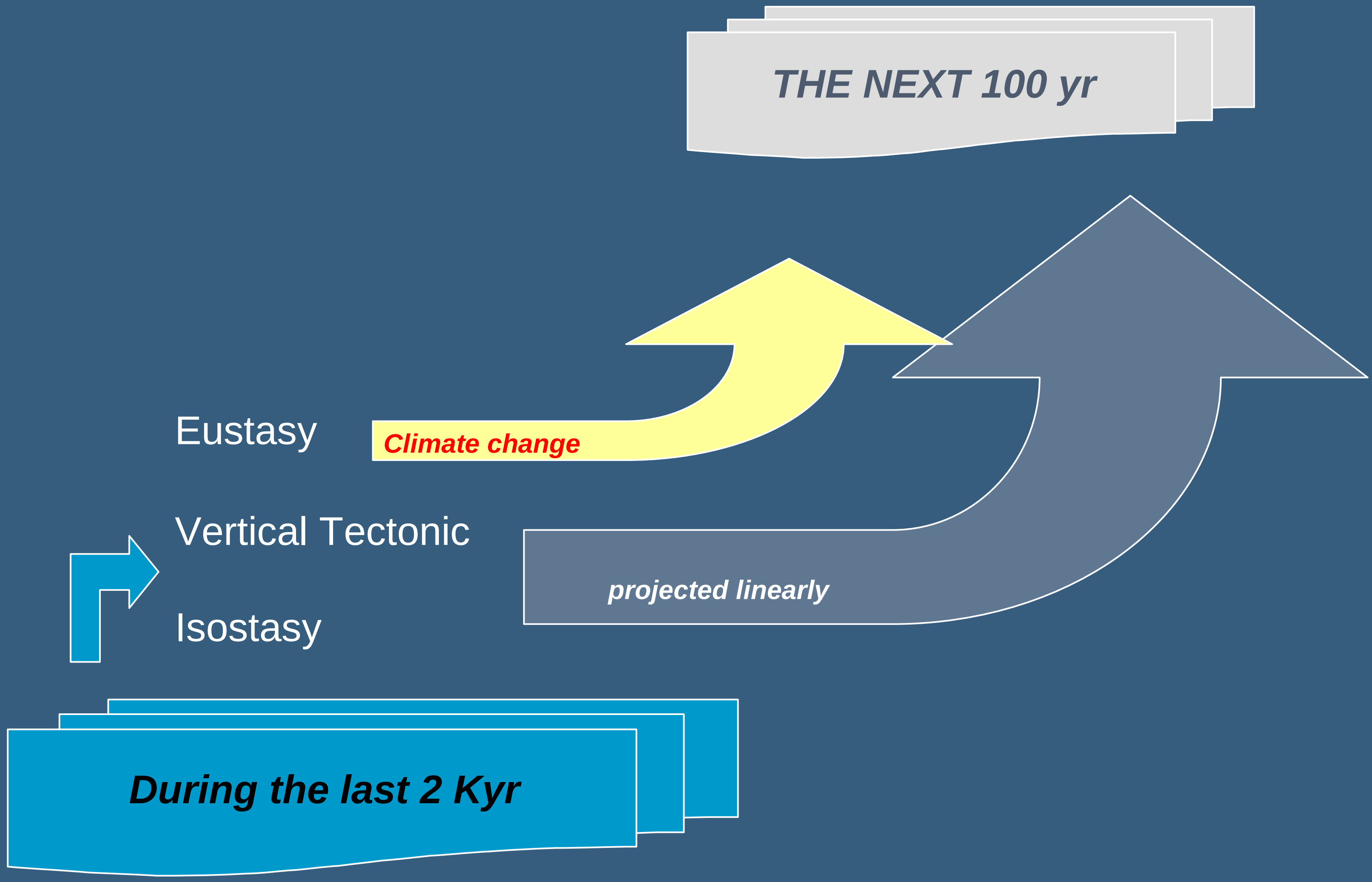


Seismically uplifted erosion notches, Perachora Peninsula, Gulf of Corinth, (After Lambeck, 2006)

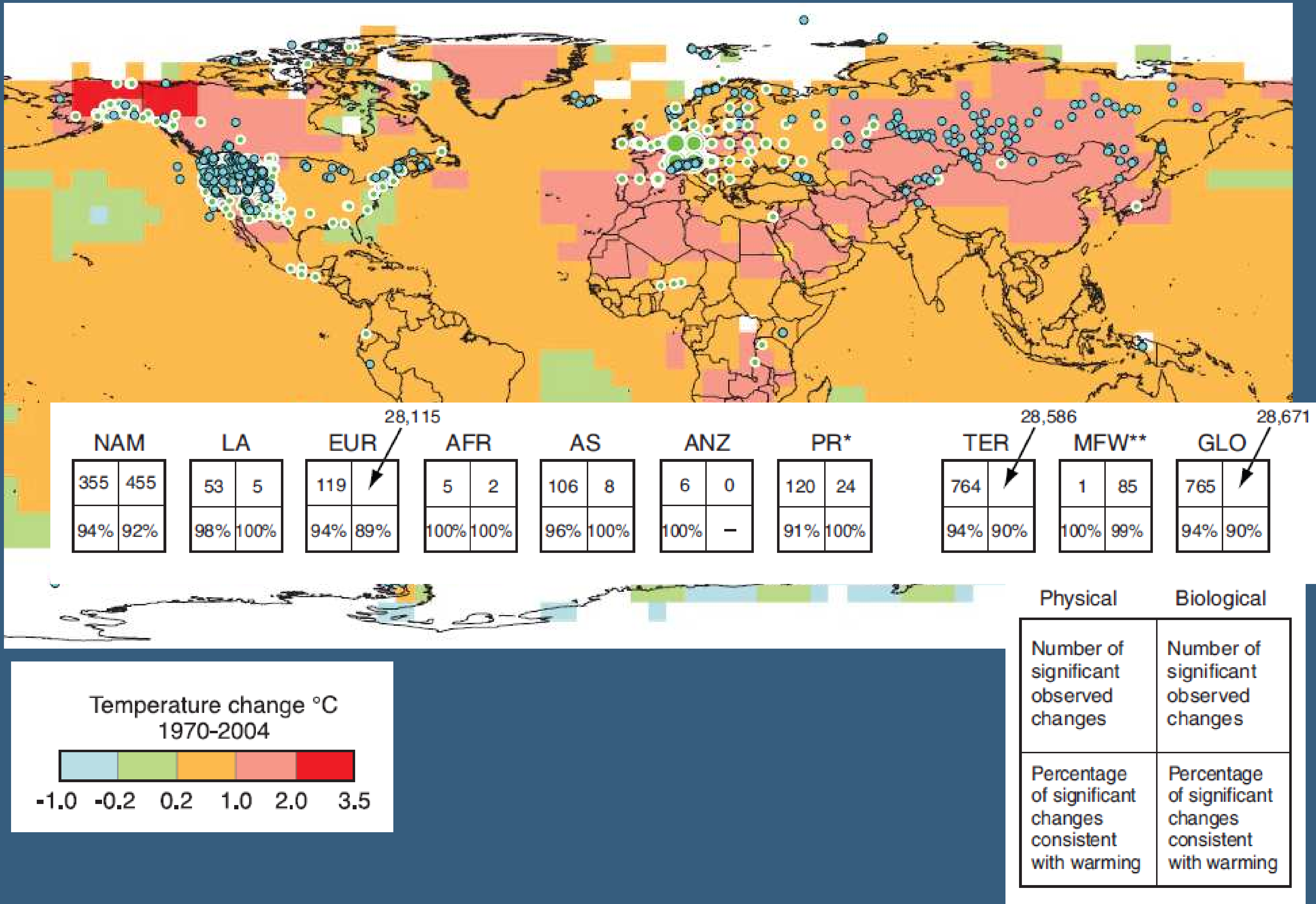
Vott, 2007



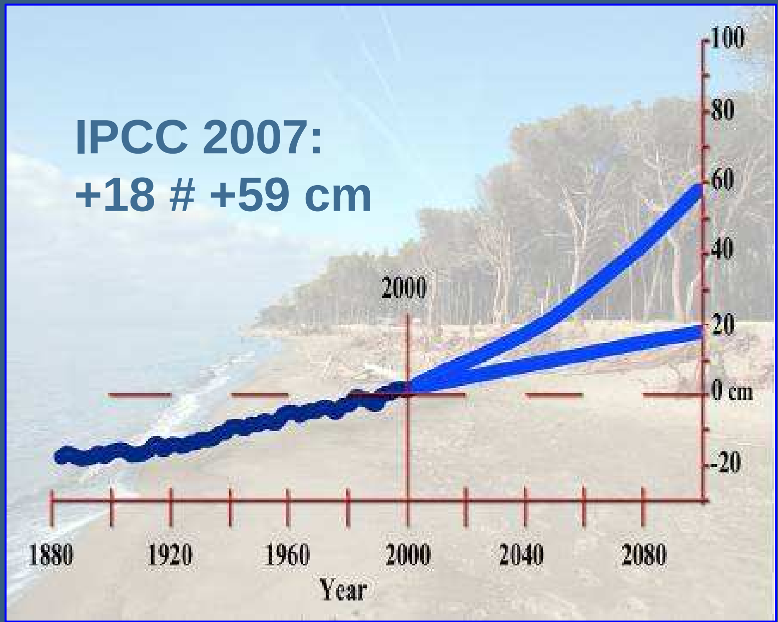
RSLR in the next century

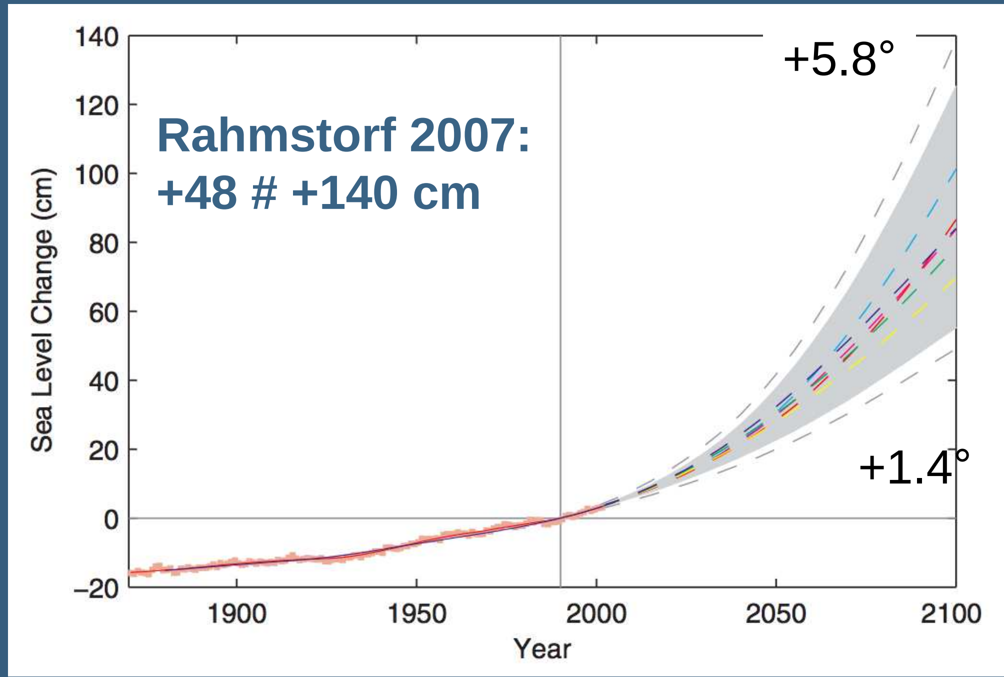


Global Changes in Mean Sea Level over the next 100 years: the IPCC data

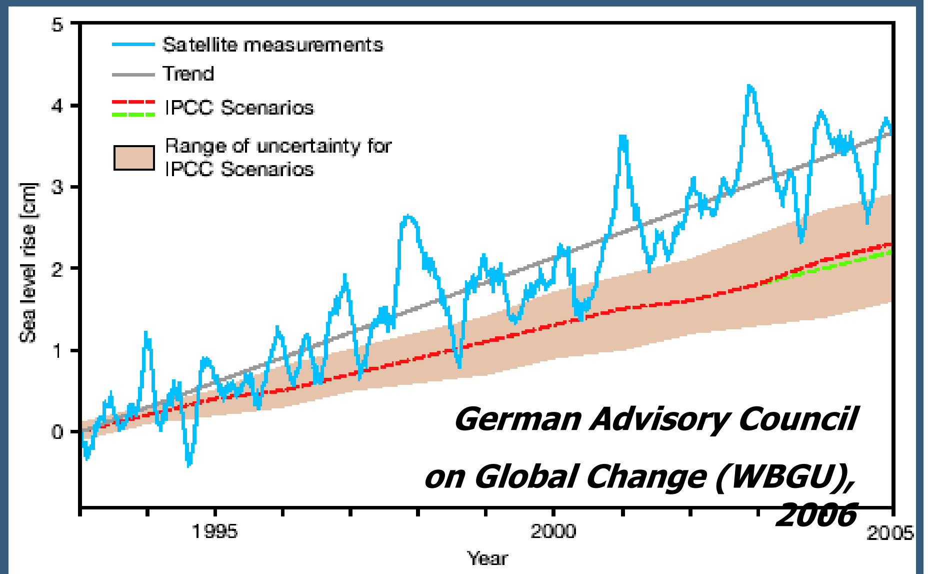


Global Changes in Mean Sea Level over the next 100 years





Scenario	SLR Yr 2050 (mm)		SLR Yr 2100 (mm)	
	Min	Max	Min	Max
AR4-B1	92	194	182	384
R. 2007	200	420	480	1400



Ancona and Patras - Aspected sea-level changes over the next 100 years

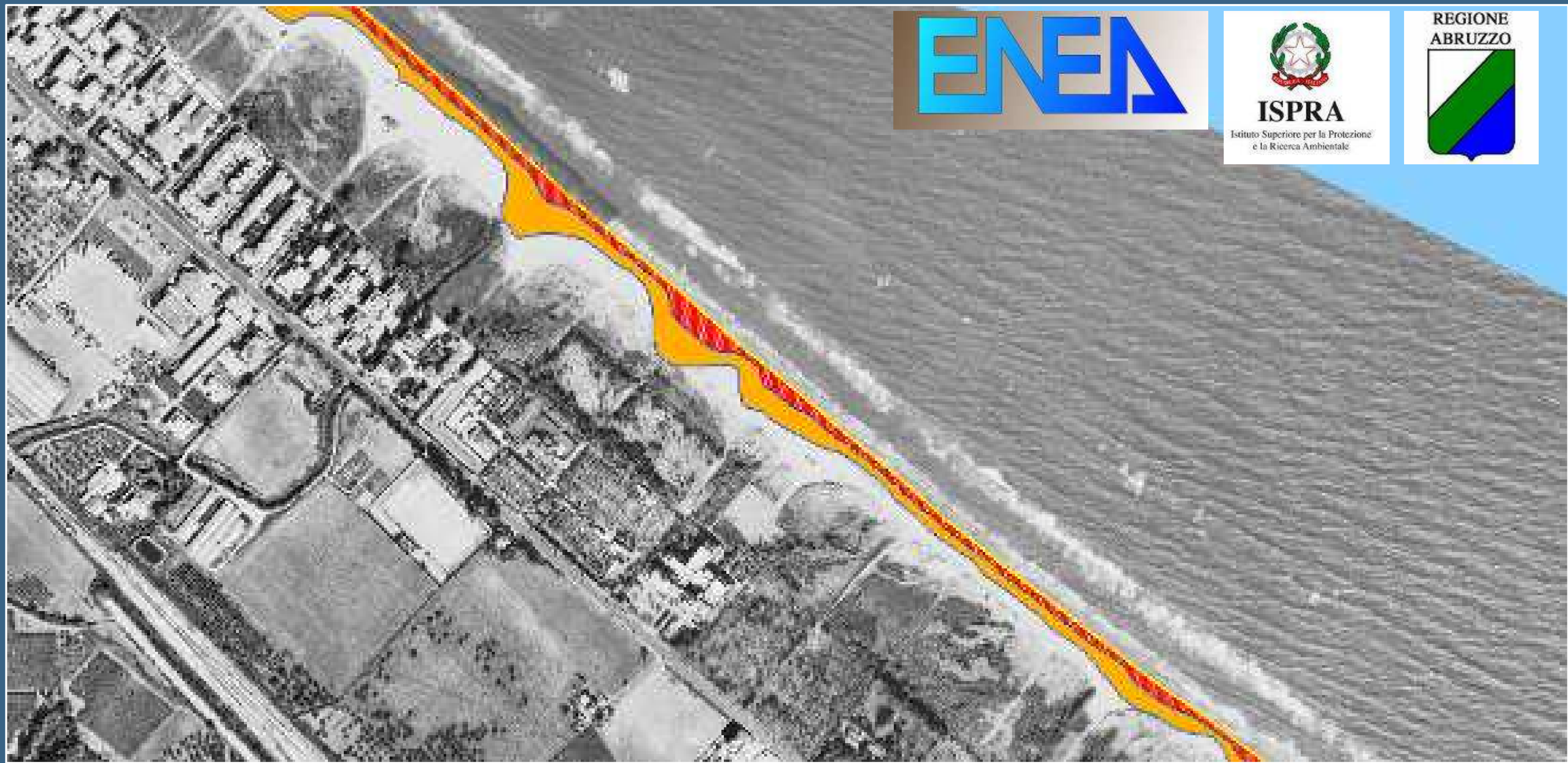
RSLR = Eustatism ± Tectonic ± Isostasy

Site	Global and local components							
	Global SLR Yr 2050 (mm)		Global SLR Yr 2100 (mm)		Tectonic (mm)		Glacio-Hydro-Isostasy (mm)	
	Min	**Max**	**Min**	**Max**	**2050**	**2100**	**2050**	**2100**
Ancona (Italy)	92	420	182	1400	-8.5	-17	-16	-32
Patrasso (Greece)	92	420	182	1400	75	150	-16	-32

Site	RSLR Predicted scenarios (mm)			
	Yr 2050 (mm)		Yr 2100 (mm)	
	Min	Max	Min	Max
Ancona (Italy)	116.5	206.5	469	1449
Patras (Greece)	33	123	302	1282

Some spatial application of the 2010 RSLR estimates

Percentages of coastal areas potentially vulnerable to RSLR:
the case of the Abruzzo Region



Thank you!