National Research Council
Institute of Marine Sciences

The impact of Climate Change on coastal zones: the example of Venice

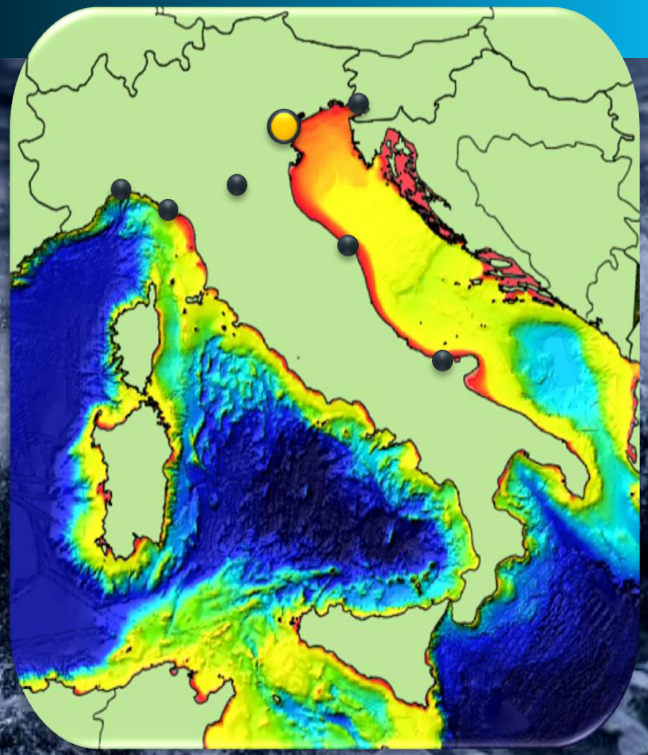
Georg Umgiesser
ISMAR-CNR, Venice, Italy

With contributions from:
Federica Braga, Sandro Carniel, Jacopo Chiggiato, Fabio Raicich, Luigi Tosi

National Research Council

Institute of Marine Sciences

- Pubblic Research Institute
- Headquarter in Venice and 6 regional branches
- About 210 people
- About 60 people in training (PhD, postdoctoral)
- 150 ISI pubblications in 2010



- VENEZIA
- TRIESTE
- GENOVA
- LA SPEZIA
- BOLOGNA
- ANCONA
- LESINA

ISMAR was evaluated as the excellence institute of the Earth and Environment Department of CNR

National Research Council

Institute of Marine Sciences

ISMAR activities

Physical and Chemical Oceanography

(Venezia, Ancona, Bologna, Trieste, La Spezia)

Geology e Geophysics

(Bologna, Venezia)

Coastal Systems And Human Impacts

(All branches)

Climate and Paleoclimate

(Bologna,Venezia, Trieste, La Spezia)

Ecosystems and Biogeochemistry

(Ancona, Venezia, Lesina)

Fisheries and Aquaculture

(Ancona, Lesina)

Technology

(Genova, Ancona, Bologna, La Spezia)

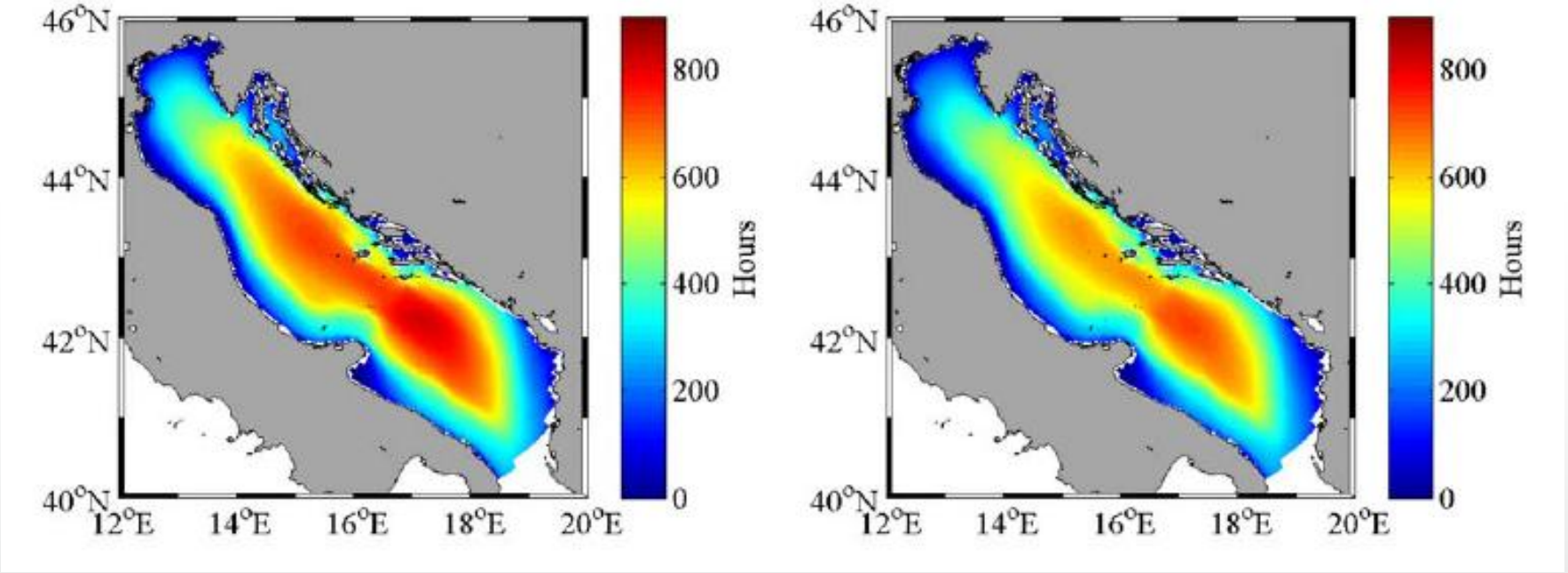
Climate change impact on the coastal zone

- Change in storminess and storm surge occurence
- Coastal erosion
- Subsidence in low lying areas
- Sea level rise
- Venice lagoon: storm surge defense

Sea level extremes

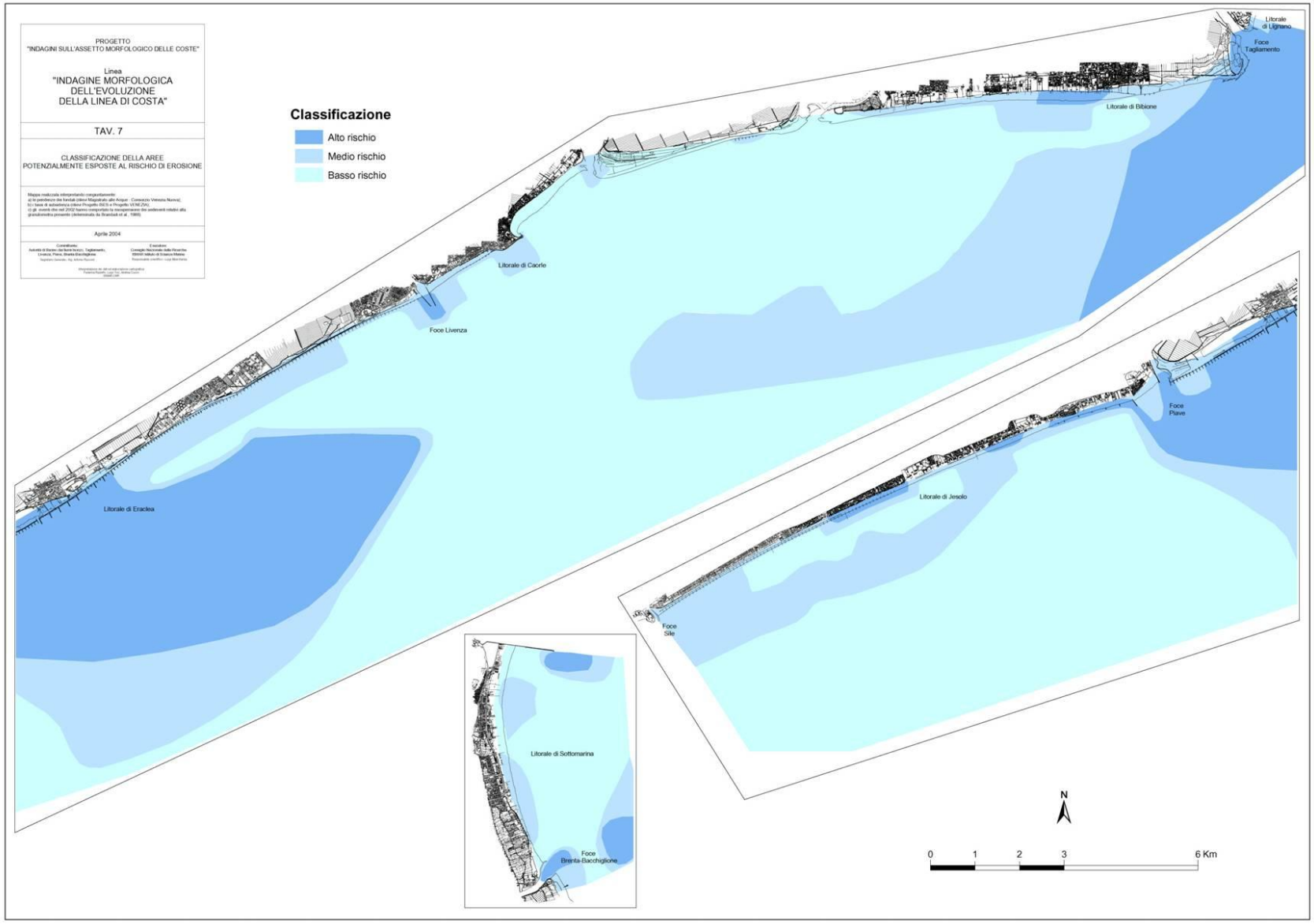
- It is very likely that there will be a significant increase in the occurrence of future sea level extremes in some regions by 2100, with a likely increase in the early 21st century.
- A 8 to 10% increase in the 99th percentile surge heights between 1961–1990 and 2071–2100 was found.
- This increase will primarily be the result of an **increase in mean sea level** (high confidence), with the frequency of a particular sea level extreme increasing by an order of magnitude or more in some regions by the end of the 21st century.
- **Sea level rise** has a greater potential than **meteorological changes** to increase sea level extremes by the end of the 21st century

Changes in significant wave height



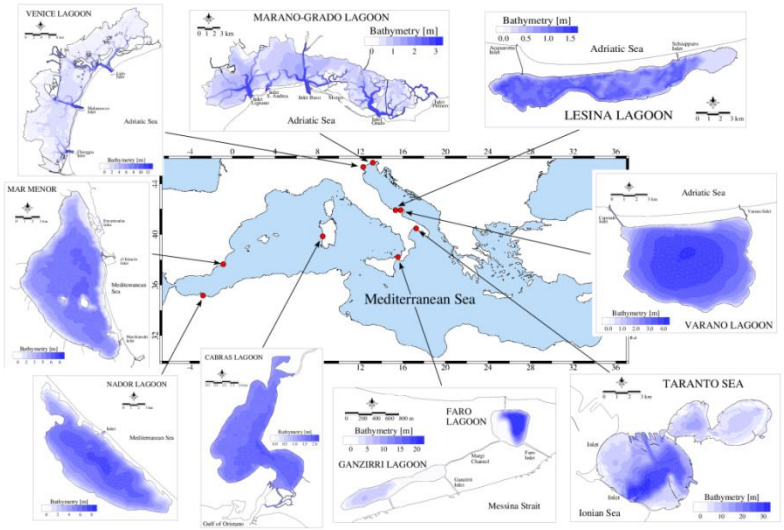
Yearly average number of hours with Hs greater than 2 m. Numerical simulations of the present climate (left) and the future scenario (right) are shown.
Benetazzo et al., NHESS, 2012

Areas vulnerable to erosion



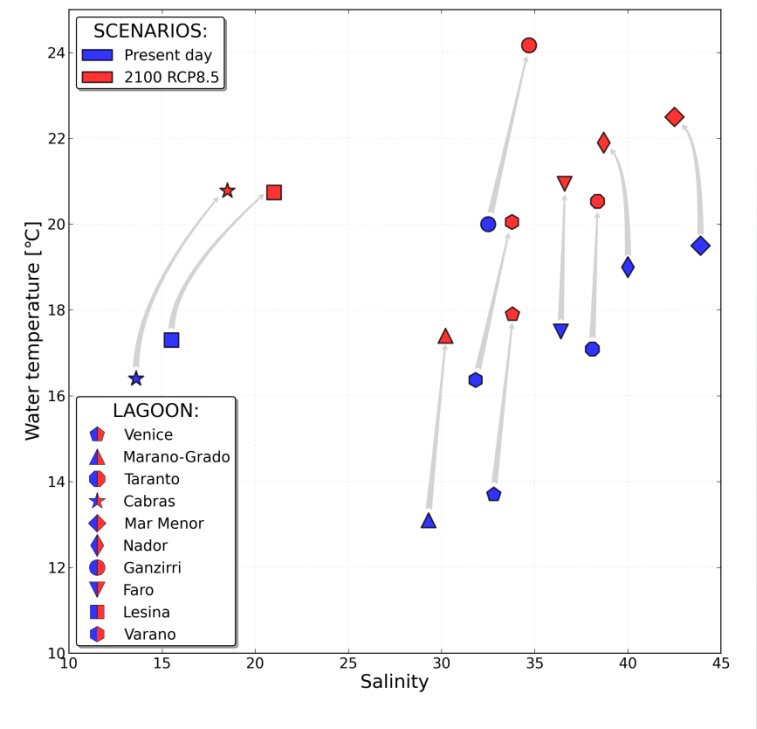
Courtesy: Autorita' di Bacino

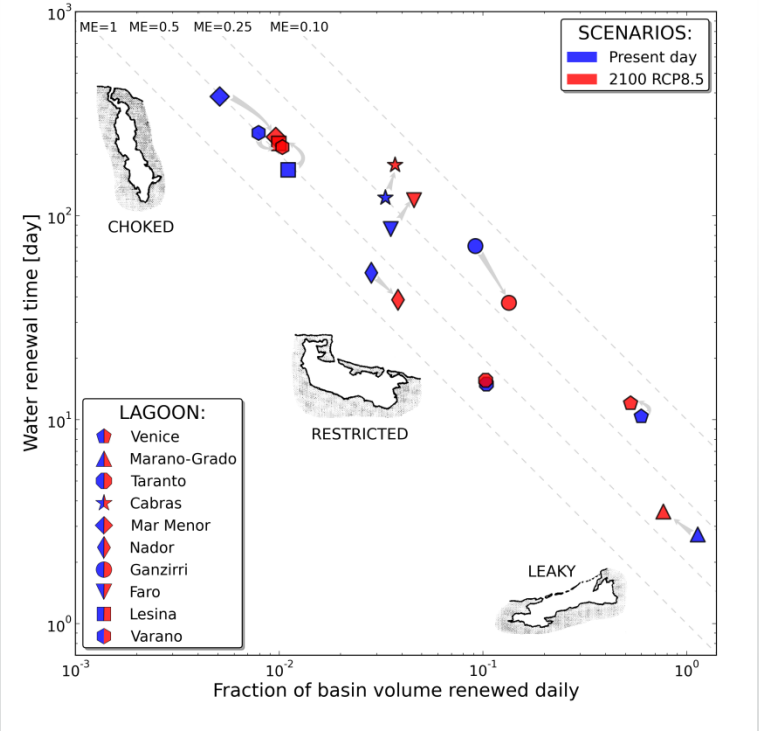
The effect of climate change on lagoons



Application of a finite element hydrodynamic model to investigate the response of Mediterranean lagoons to climate change in terms of:

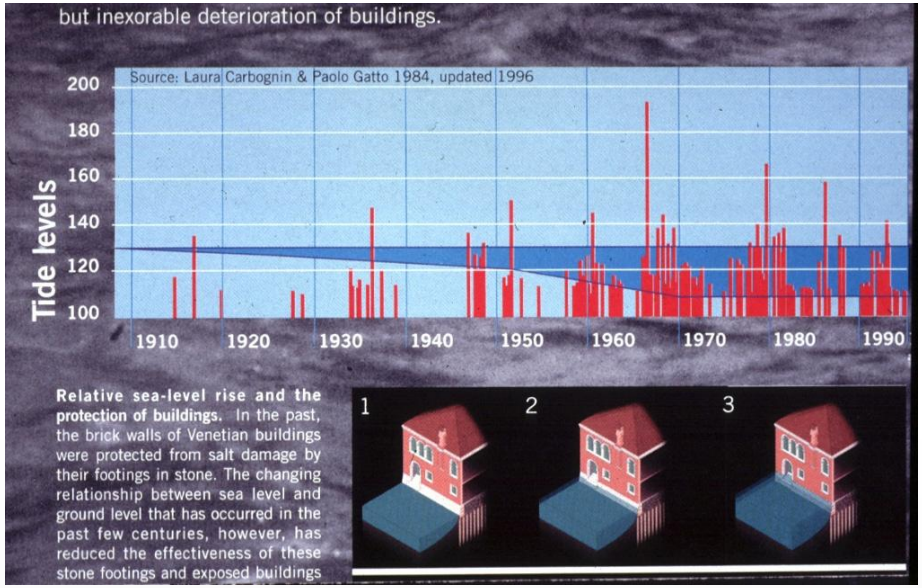
- salinity and temperature
- water renewal time and sea exchange

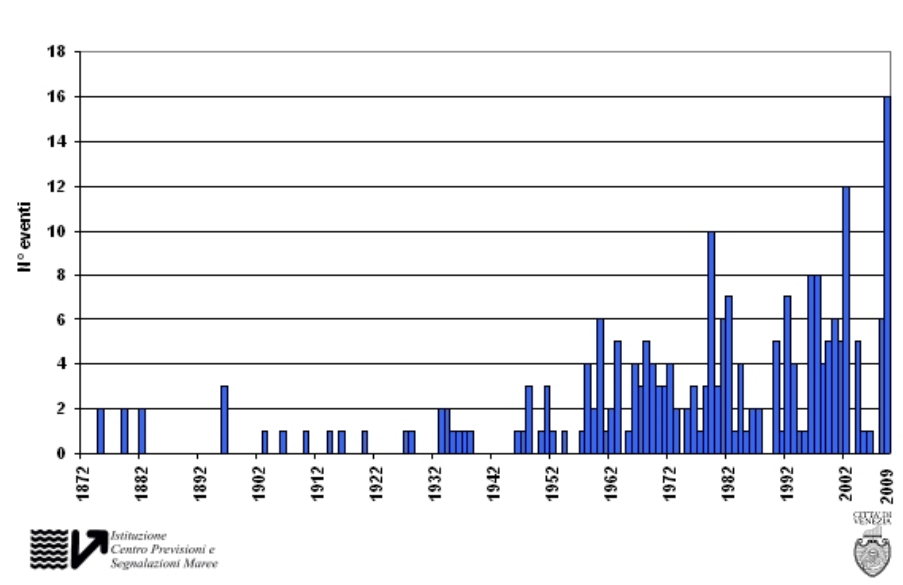




Venice is flooded 20 times a year

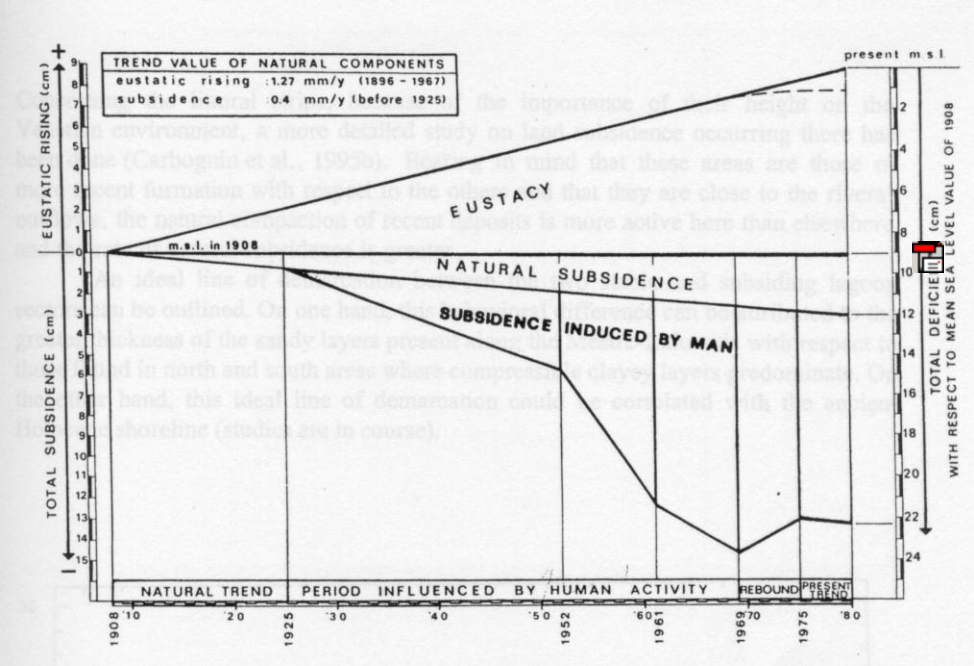
Causes of flooding





- spring tide (1.0 m)
- strong sirroco winds
- low pressure and Adriatic seiches
- rivers and rain
- major flood was on 4 November, 1966

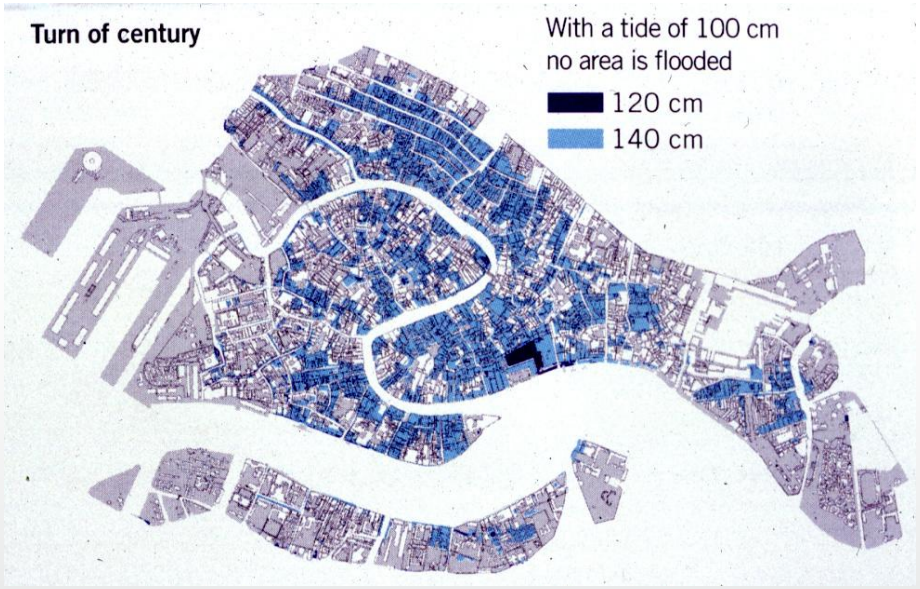
Sea level rise and subsidence



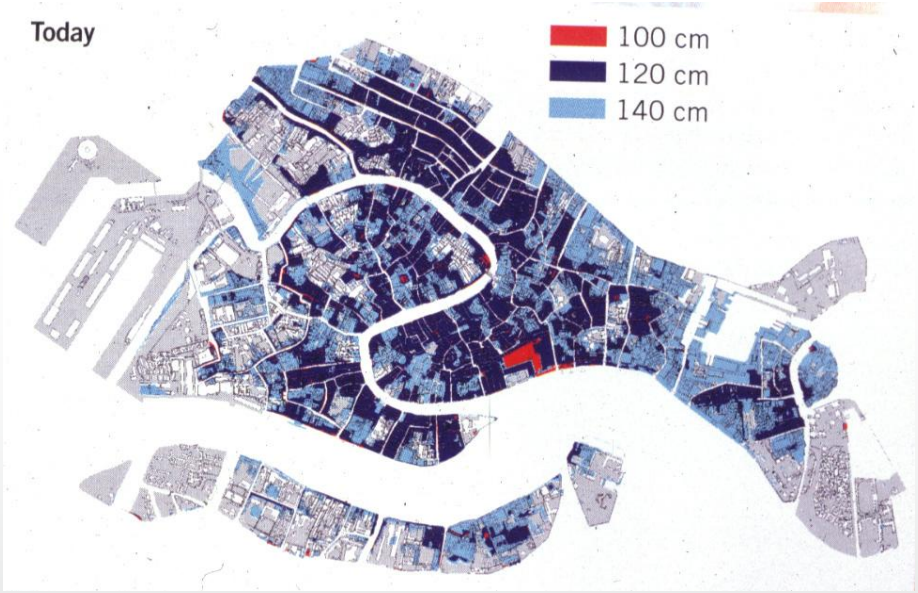
- natural subsidence
  - weight of over-burden
  - isostacy
- man-induced subsidence
  - weight of buildings
  - ground water extraction
- sea level rise

Courtesy of: Laura Carbognin and Paolo Gatto

Flooding in the city of Venice

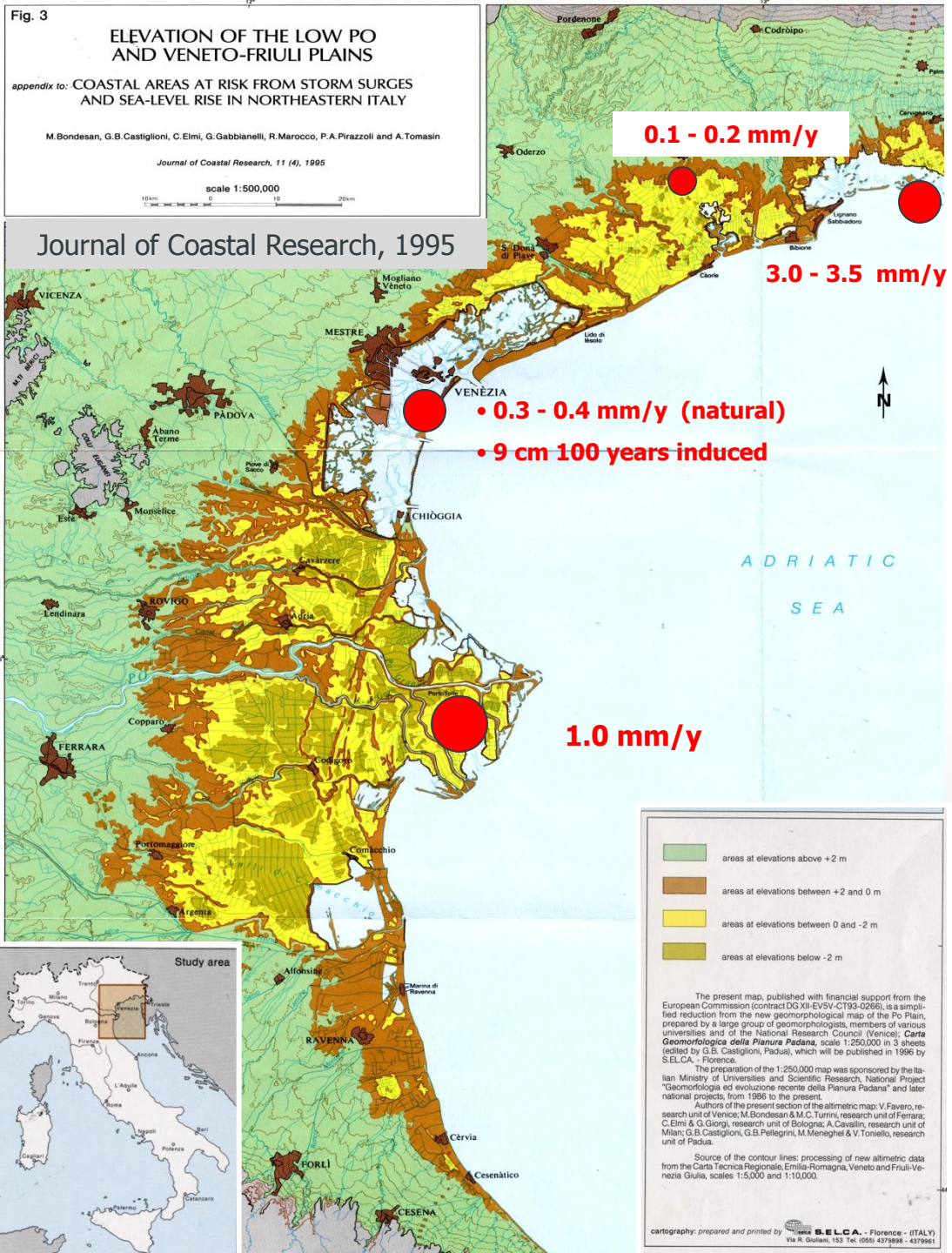


1900



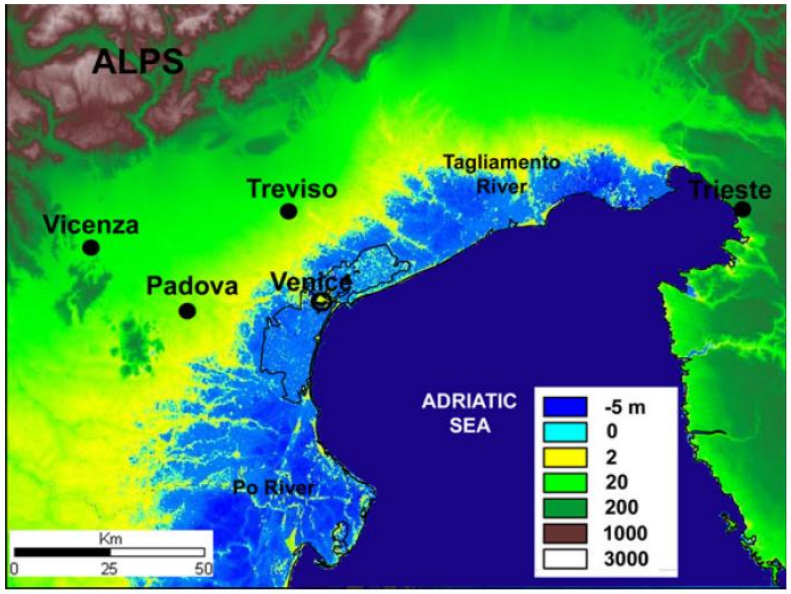
2000

The Po Delta

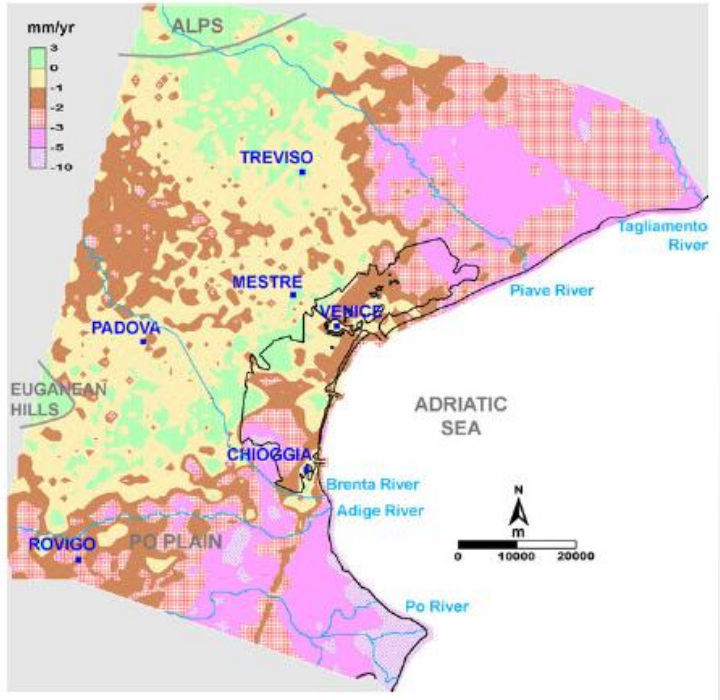


The Veneto region close to the Po Delta and the Venice lagoon is a low lying area threatened by sea level rise

Ground surface dynamics in the northern Adriatic coastland



Digital elevation model (DEM) of the northern Adriatic region
From Tosi et al., Rend. Fis. Acc. Lincei, 2010



Vertical displacement rates g1992–2002 (mm/year) in the Venetian region obtained by the SIMS over the decade 1992–2002
From Tosi et al., Rend. Fis. Acc. Lincei, 2010

Vulnerability of coastal deltas

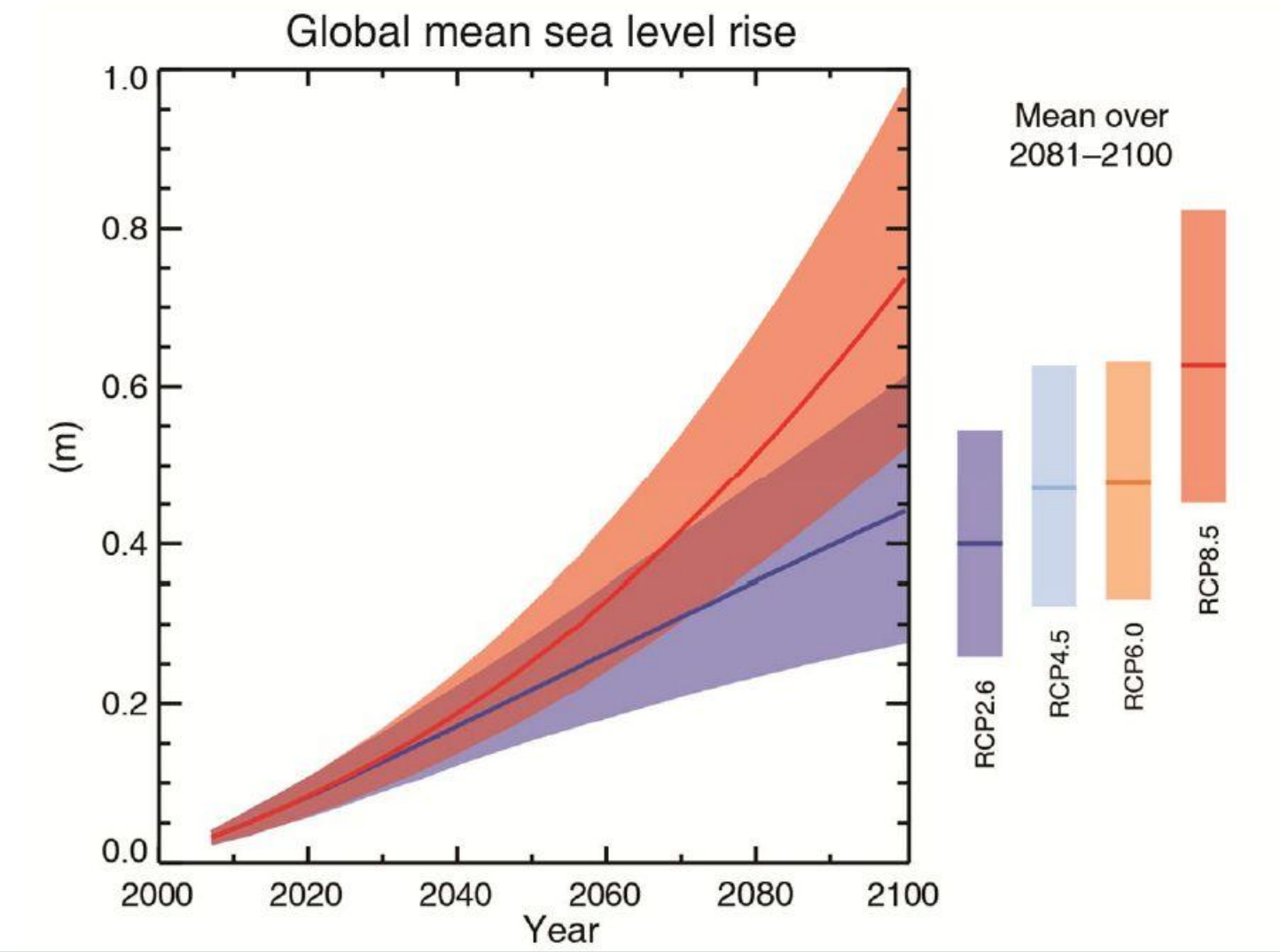
Figure 6.6. *Relative vulnerability of coastal deltas as shown by the indicative population potentially displaced by current sea-level trends to 2050 (Extreme = >1 million; High = 1 million to 50,000; Medium = 50,000 to 5,000; following Ericson et al., 2006).*

Regional Exposure

Table 6.12. *Indicative estimates of regional exposure as a function of elevation and baseline (1995) socio-economics. MER – market exchange rates (after Anthoff et al., 2006).*

Region	Exposure by factor and elevation above mean high water								
	Land area (km²)			Population (millions)			GDP MER (US$ billions)		
	1m	5m	10m	1m	5m	10m	1m	5m	10m
Africa	118	183	271	8	14	22	6	11	19
Asia	875	1548	2342	108	200	294	453	843	1185
Australia	135	198	267	2	3	4	38	51	67
Europe	130	230	331	14	21	30	305	470	635
Latin America	317	509	676	10	17	25	39	71	103
North America	640	1000	1335	4	14	22	103	358	561
Global (Total)	2223	3667	5223	145	268	397	944	1802	2570

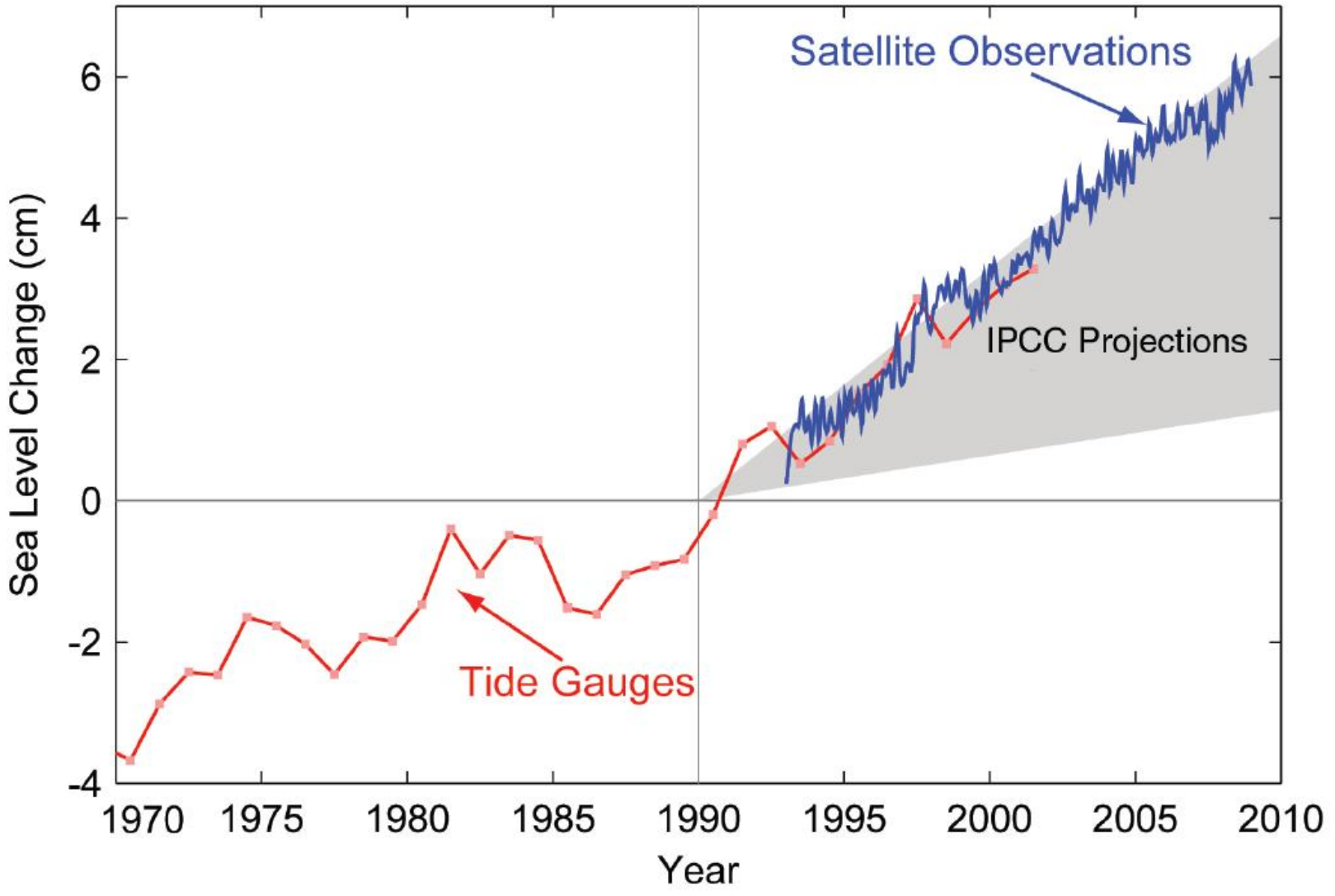
IPCC report 2013 (AR5)



Problems with IPCC estimates

- IPCC in AR4 is only considering the steric effect (volume increase due to higher water temperatures)
- Only in the last AR5 a tentative was made to include mass addition due to ice sheet melting; however, the results are of low confidence
- Global observations through satellite indicate that the rate of rise is already at the maximum end of the IPCC AR4 uncertainty indicating higher than average rise of sea level

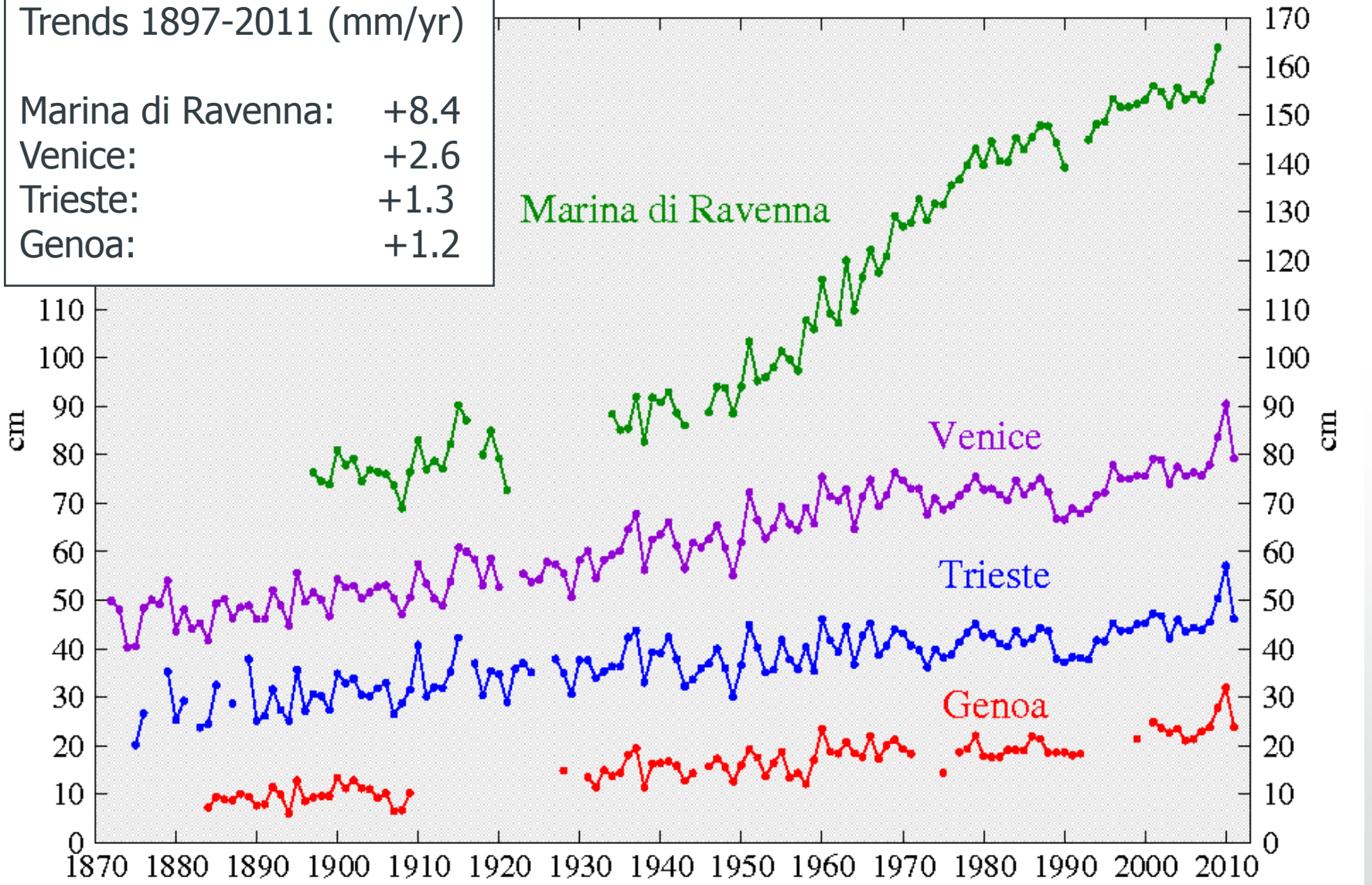
Rise faster than expected



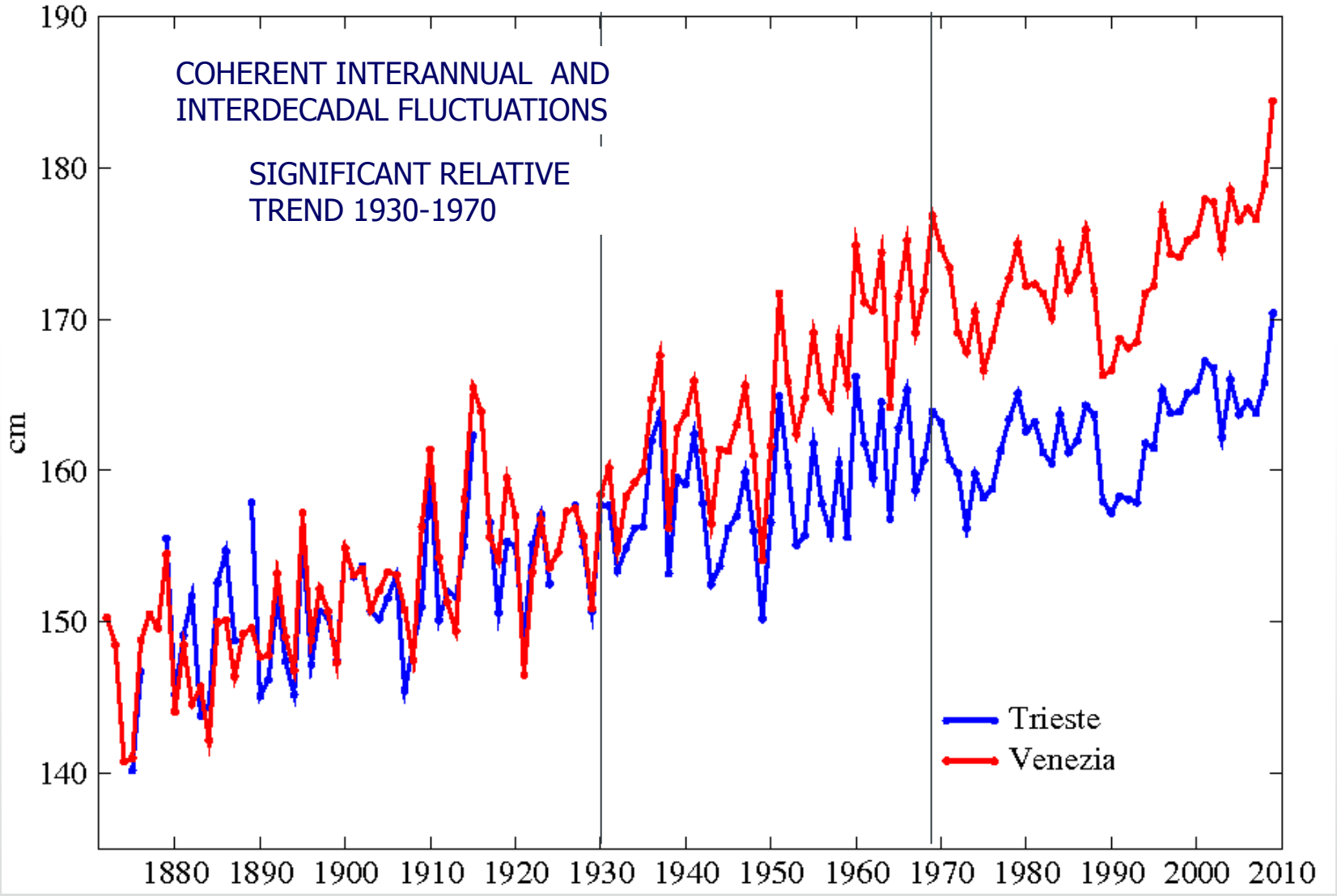
Relative SL – annual means

Trends 1897-2011 (mm/yr)

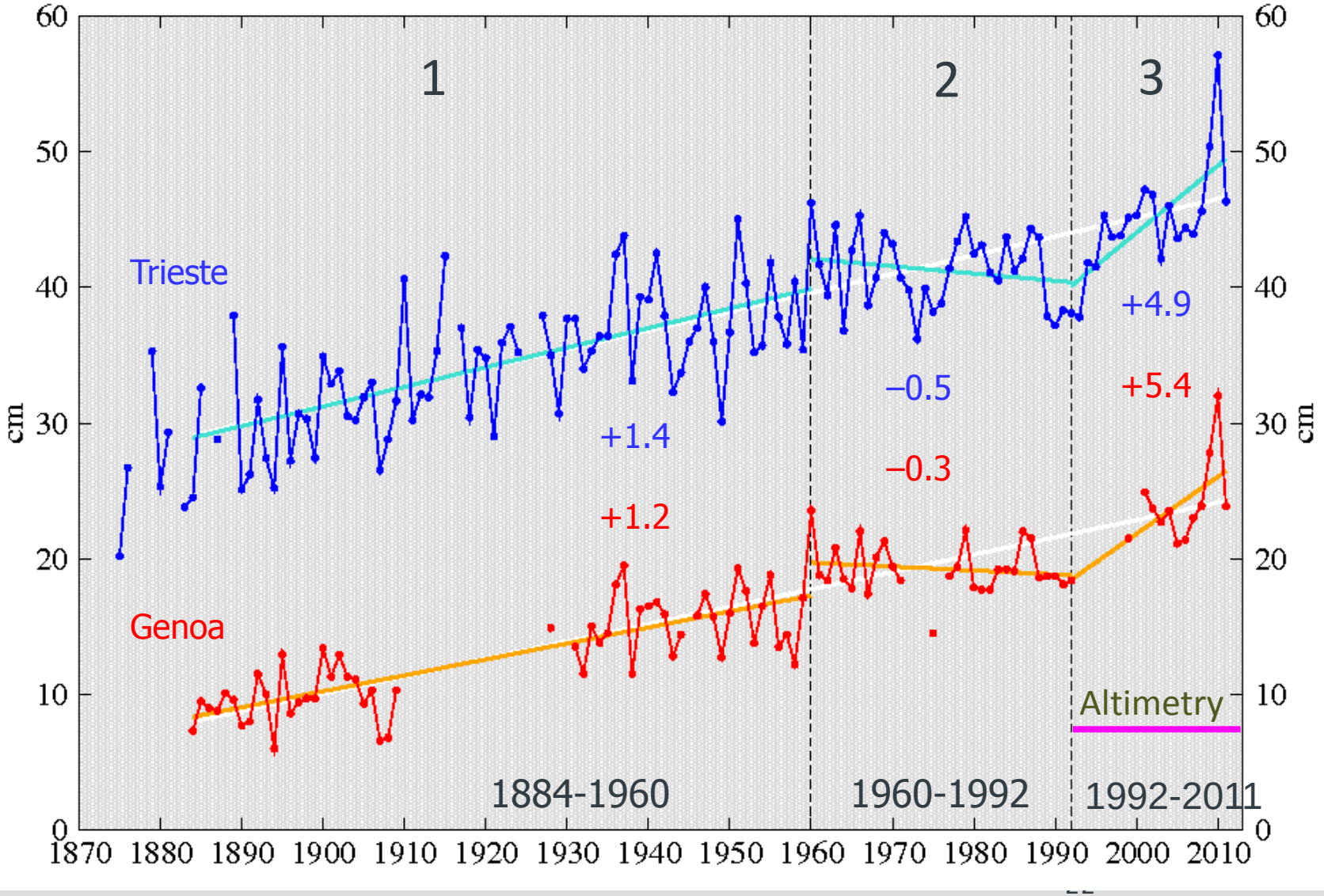
Marina di Ravenna:	+8.4
Venice:	+2.6
Trieste:	+1.3
Genoa:	+1.2



Changes in SLR Trieste-Venezia



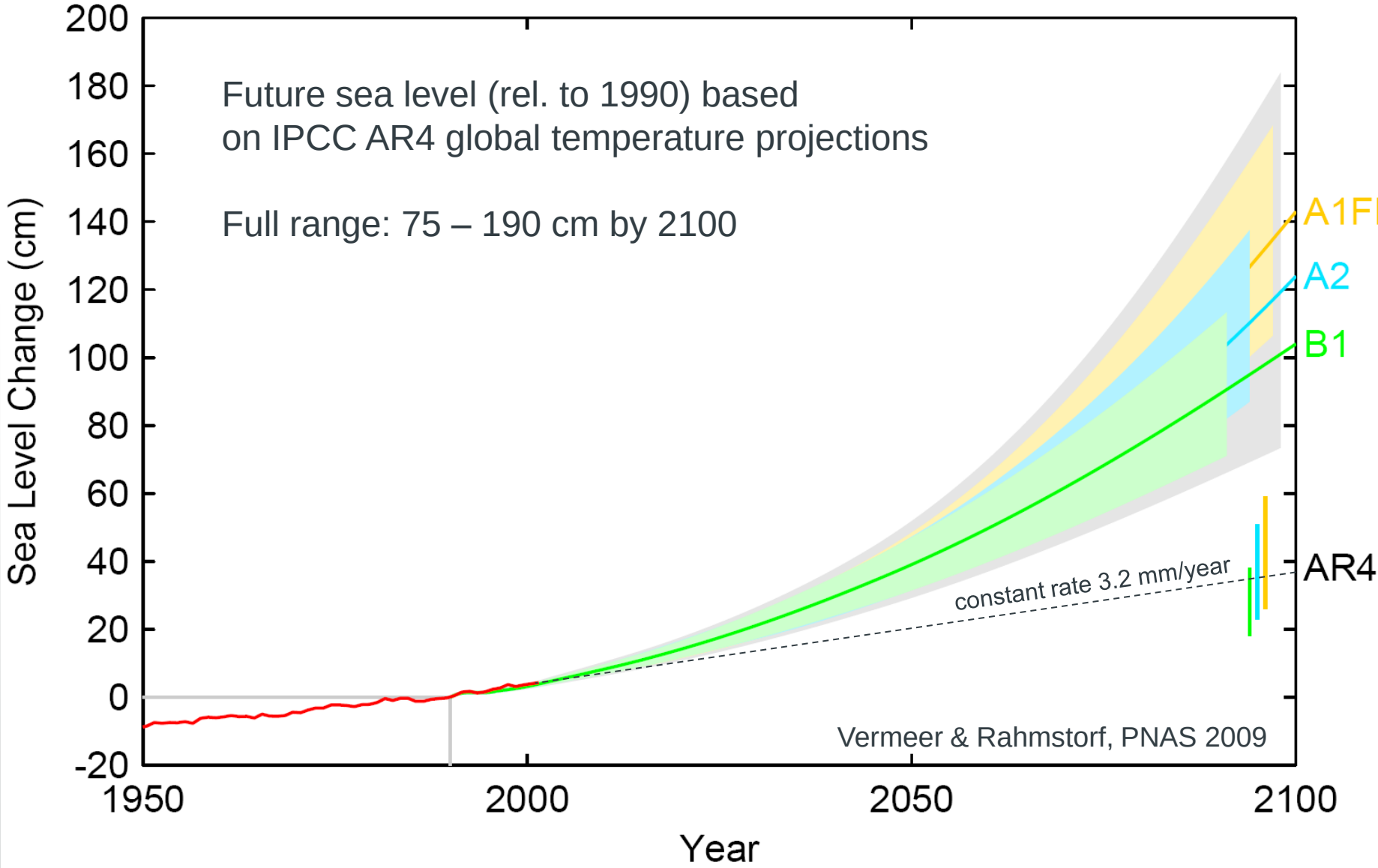
Annual means – trends in mm/yr



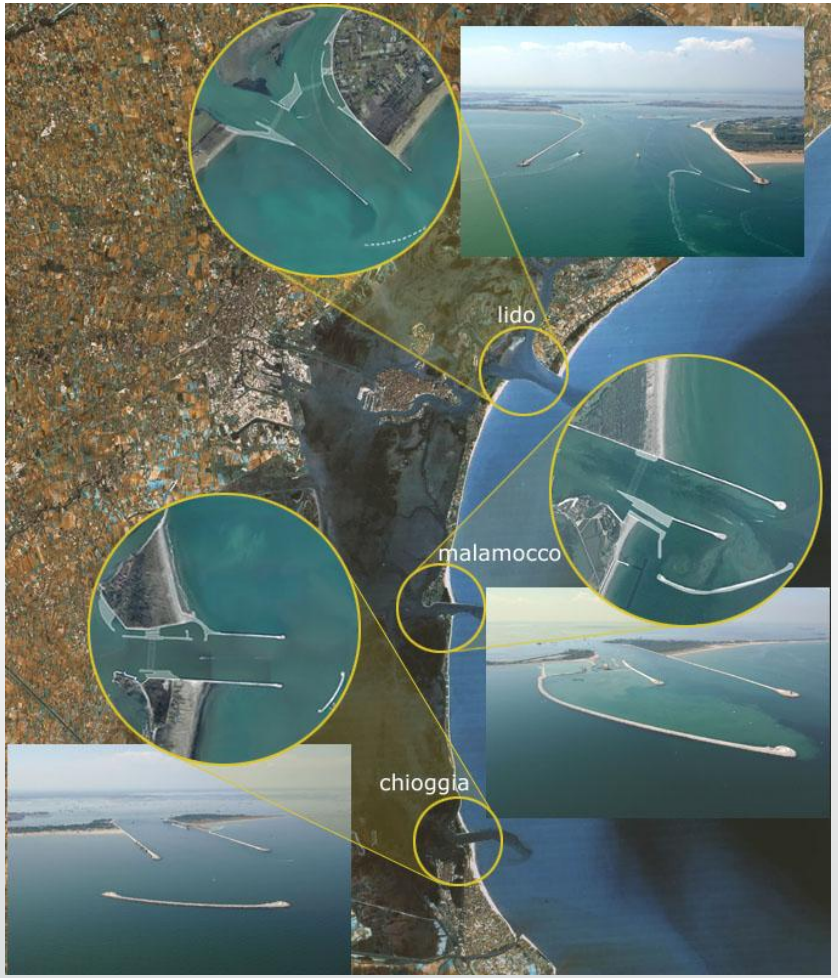
How to include ice melting into the estimates?

- Using past data that give an indication of how fast sea level was rising in the past
  - Current global understanding of ice dynamics allows modern rates of **0.8 to 2.0 m century^{-1}** (Pfeffer et al, *Science* 2008)
- Using semi-empirical models that extrapolate calibrated models to the future
  - Future sea level (rel. to 1990) based on IPCC AR4 global temperature projections show a full range of 75 – 190 cm by 2100 (Vermeer and Rahmstorf, 2009)

Forecasts with semi-empirical models taking into account mass addition



Interventions at the inlets: The MOSE project

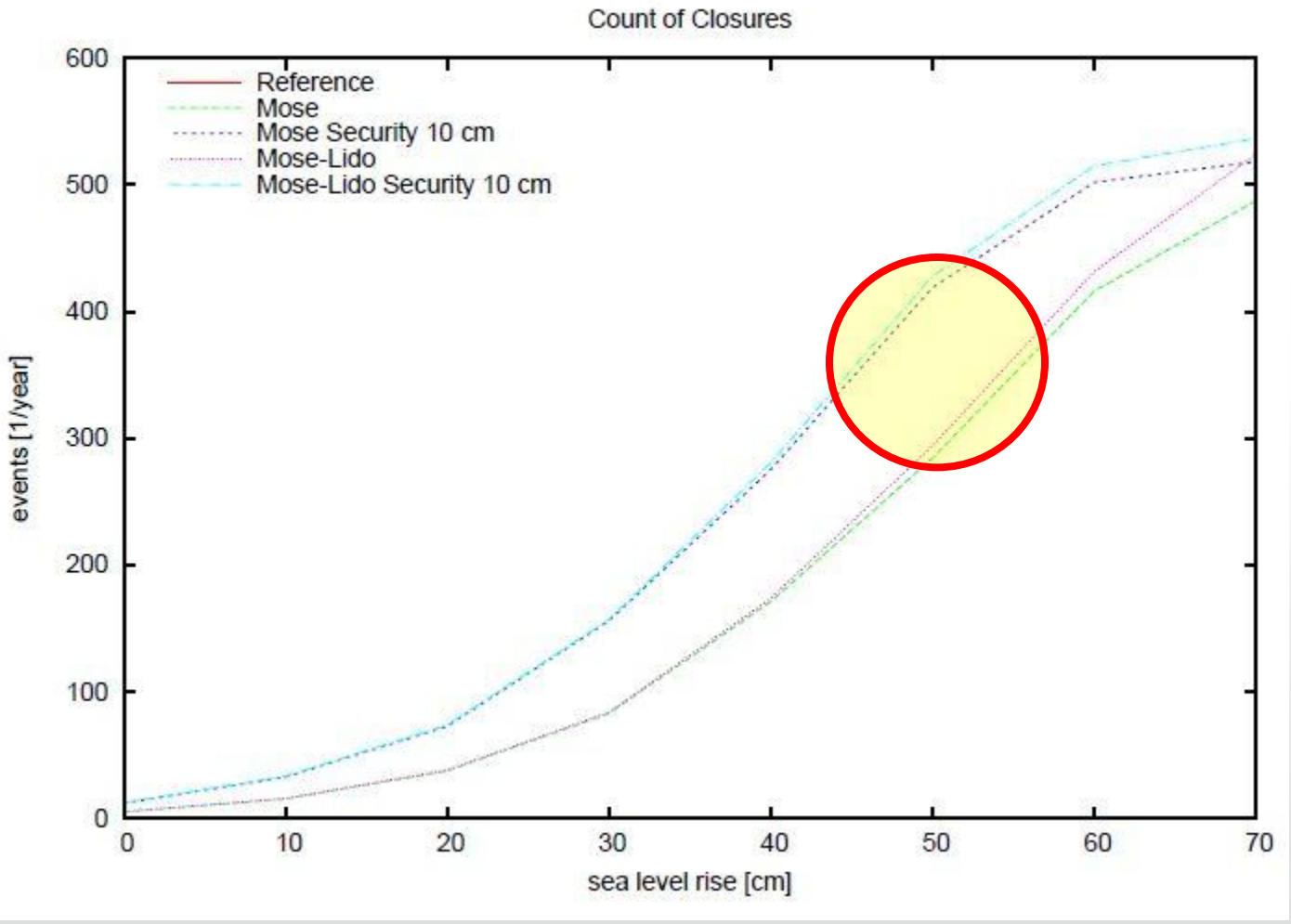


Pros & Cons

- Very efficient for protection
- Work only if needed
- Do not change the water budget of the lagoon
- Can be used to artificially enhance circulation in the lagoon
- Localized interventions

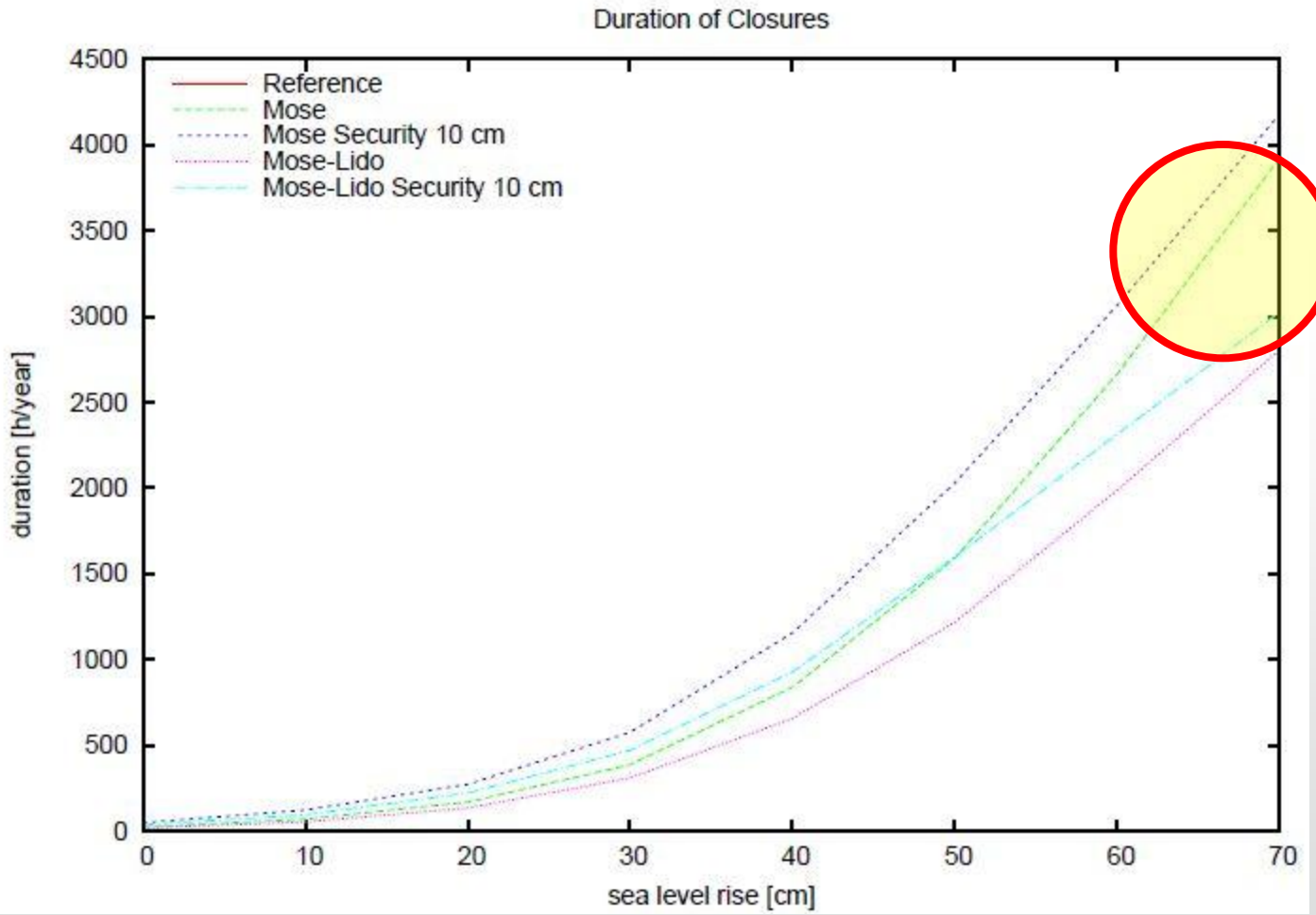
- Very expensive
- Maintenance and management will be difficult
- Sea level rise will question the utility of the barriers
- Strong intervention in the natural equilibrium of the lagoon

Total number of MOSE closures (projection)



approximately 1 closure per day for a SLR of 50 cm

Total time of MOSE closures (projection)



The point where the MOSE will be more often closed than open will happen at around 70 cm SLR

Conclusions

- In the Adriatic Sea levels of storminess in the future will probably be slightly lower than present; also significant wave height will slightly decrease
- Erosion will be an issue for the Italian coastline
- The highest threat in the future will be given by sea level rise
- Depending on the rate of increase local defenses might not be enough to defend the coast and human settlements against sea level rise