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

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

Physical and Chemical Oceanography
(Bologn, 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 occurrence
- 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

Classificazione
- Alto rischio
- Medio rischio
- Basso rischio

Courtesy: Autorita’ di Bacino
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

The effect of climate change on lagoons...
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

Turn of century
With a tide of 100 cm
no area is flooded

120 cm
140 cm

Today

2000

100 cm
120 cm
140 cm
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>
<thead>
<tr>
<th>Region</th>
<th>Land area (km$^2$)</th>
<th>Exposure by factor and elevation above mean high water</th>
<th>Population (millions)</th>
<th>GDP MER (US$ billions)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1m</td>
<td>5m</td>
<td>10m</td>
<td>1m</td>
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<tr>
<td>Africa</td>
<td>118</td>
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<td>North America</td>
<td>640</td>
<td>1000</td>
<td>1335</td>
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<tr>
<td>Global (Total)</td>
<td>2223</td>
<td>3687</td>
<td>5223</td>
<td>145</td>
</tr>
</tbody>
</table>
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

COHERENT INTERANNUAL AND INTERDECADAL FLUCTUATIONS

SIGNIFICANT RELATIVE TREND 1930-1970

Changes in SLR Trieste-Venezia

COHERENT INTERANNUAL AND INTERDECADAL FLUCTUATIONS

SIGNIFICANT RELATIVE TREND 1930-1970

Changes in SLR Trieste-Venezia

COHERENT INTERANNUAL AND INTERDECADAL FLUCTUATIONS

SIGNIFICANT RELATIVE TREND 1930-1970
Annual means – trends in mm/yr

Trieste
1884-1960 +1.4
1960-1992 -0.5
1992-2011 +4.9

Genoa
1884-1960 +1.2
1960-1992 -0.3
1992-2011 +5.4

Altimetry
1870-1920
1920-1990
1990-2010
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

Future sea level (rel. to 1990) based on IPCC AR4 global temperature projections

Full range: 75 – 190 cm by 2100

Vermeer & Rahmstorf, PNAS 2009
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