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SEA LEVEL RISE ISSUES: North Adriatic case study

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Target groups

- **Local/Regional Authorities**
- **Private Stakeholders**
- **Regional met offices**

Relevance to the case-study requirements

Since the early stages of CLIM-RUN, most of the stakeholders involved in the North Adriatic case study, especially local authorities, asked for climate information about sea-level rise, especially when relative to those extreme events that cause flooding ('acqua alta' in Venice Lagoon) or other damages. However, not all the factors that can determine changes in sea level height can be accurately quantified in the available climate simulations. We report some results about the capability of state-of-the art numerical models in reproducing the observed sea level anomalies in the North Adriatic sub-basin. Moreover, as requested by local stakeholders, climate projections for sea level rise in the Mediterranean basin, taking into account some of the most relevant factors potentially affecting the sea level, are here shown. However, more research dedicated to this topics seems to be needed in order to compute all the key components of regional sea level on Mediterranean coasts and to provide reliable climate information and projections at local scale. To achieve this goal, several research initiatives at European and International level are focused on sea level.

The approach

To elaborate the present information sheet we inspect regional climate projection experiments performed within the framework of the EU CIRCE project (*Gualdi et al 2012*) and MED-CORDEX (www.medcordex.eu) experiment.
The sea level changes at regional/local scale is a rather complex issue not completely solved and understood, yet. Here we report some of the major factors affecting of sea level changes in the Mediterranean basin:

1.Thermosteric effect: Thermal expansion of sea. This effect should be considered at the Mediterranean basin-scale
2.Halosteric effect: changes in salinity of sea
3.Mass addition: It's due to changes in mass budget of the Mediterranean Sea (the salt-related mass addiction is almost compensated by **2,** see Jordà and Gomis, 2013)
4.Dynamical effect: due to local changes in oceanic circulation
5.Atmospheric pressure effect
6.Change of near-Atlantic sea level due to all the processes including ice melting (glaciers or ice sheets)
7.Changes in sea floor
8.Storm surges (local and snapshot effect)
9.Tides (periodic effect)

Not all the factors determining sea level changes are so far reproduced in the climate models, in particular at regional scale. To provide information about sea level rise in the North Adriatic from regional climate simulations we can take into account the thermosteric effect **(1)** and, secondarily, changes in oceanic circulation **(4)** where it is available. In the state-of the art regional climatic simulations the effects of ice melting **(6)** and changes of sea floor **(7)** cannot be so far taken into account. The potential contribution to global mean sea level rise in future scenario for ice melting for continental glaciers **(6)** (Antarctica, Greenland) has been estimated in the IPCC AR4 in terms of about *15-30cm* for the second half of XXI century. Out of effect of ice melting, the most relevant effect at climatic time scale should be the thermal expansion **(1)** with a global contribution of the same order magnitude**.**
At global scale the IPCC AR4 report estimates a projected sea level ranging between *35-70cm* for the second half of XXI century.

References:
Artale et al., 2010. An atmosphere-ocean regional climate model for the Mediterranean area: assessment of a present climate simulation Clim. Dyn. doi:10.1007/s00382-009-0691-8
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Jordà, G., and D. Gomis, 2013: On the interpretation of the steric and mass components of sea level variability: The case of the Mediterranean basin, J. Geophys. Res.: Oceans, 118, doi:10.1002/jgrc.20060

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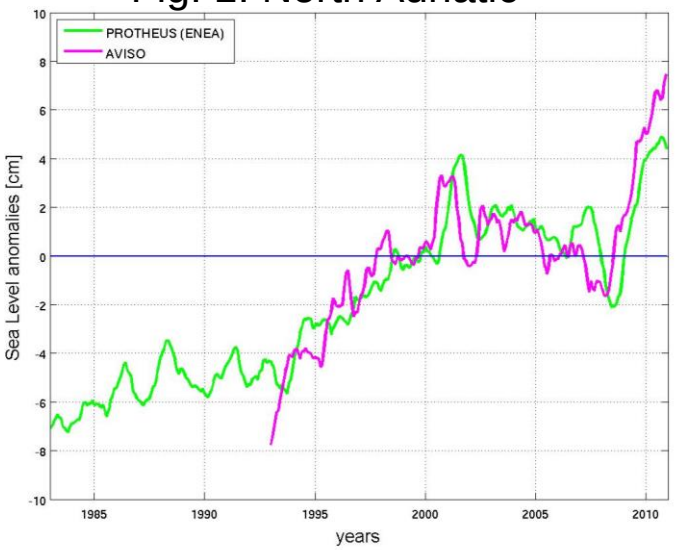
CLIM-RUN

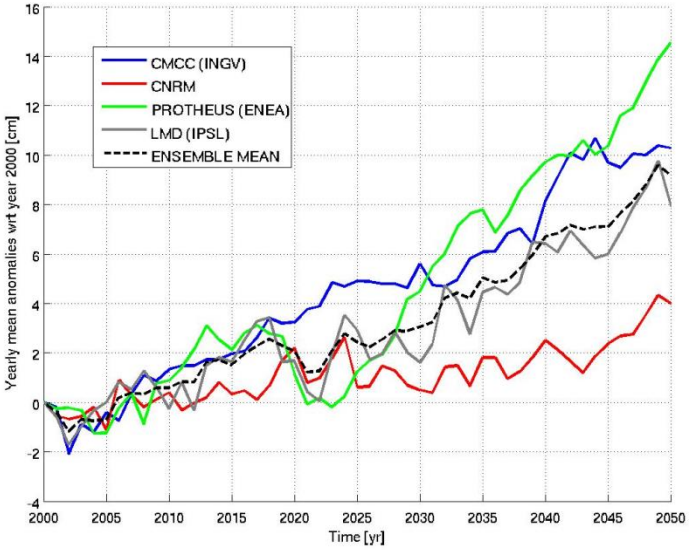
The product

Fig. 1: North Adriatic



Reproducing the observed features:
In Fig.1 sea level anomalies for North-Adriatic sub-basin (Lon=12-19E; Lat=42-45N) from ENEA-PROTHEUS (Artale et al 2010) validation simulation driven by global Reanalysis Era-Interim (green line) against AVISO altimeter satellite data (purple line) are reported for period 1982-2010. For the climate simulation we consider only the sea level anomalies due to thermal expansion of sea **(1)** + local changes in circulation **(4).** The other factors affecting the sea level changes (see 'The Approach' section) cannot be taken into account in the simulation. Even if not all the factors can be represented, this validation simulation closely follows the overall behaviour of satellite observations

Fig. 2: Mediterranean basin



Projecting sea level changes:
Fig.2 shows the time series of the annual sea level anomalies in the Mediterranean basin due to the effect of thermal expansion of sea **(1)** for the period 1951-2050 in CIRCE Atmosphere-Ocean coupled SRES A1B scenario simulations. Anomalies are computed as incremental differences with respect to year 2000 [SLR(t)-SLR(t=2000)].
The models produce a rather broad range of trends ranging between 0.3 and 0.08 cm/yr. The ensemble mean projected change for the 2001-2050 displays an upward trend 0.18±0.1 cm/yr amplitude. Let us remark that the effect of continental glaciers is not here taken into account and should be potentially added.

Making the product usable

Even if not all the factors determining sea level changes are considered in the climate simulations for the Mediterranean basin, the models seem to be able to overall reproduce the main features of observed sea level changes in the North Adriatic at sub-basin scale (Fig.1). However, in the future climate projections (Fig.2) other factors (mainly the ice melting of continental glaciers) should be included. The models so far produce a rather broad range of trends. However, for the near future a projected increase of mean sea level in the Mediterranean basin could be expected potentially meaning that, all other things being equal, storm surges and extremes of sea level could have a greater impact. These results highlight the necessity to develop flexible and adaptive policies and strategies in the matter of sea level changes in the context of North Adriatic. More in general, areas for other potential improvements of the climate product can include:

- Research needed to provide more reliable climate projections regarding sea level issues at regional/local scale taking into account more factors (circulation, ice melting effect…),
- Inclusion of new climate simulations from recent initiatives (Med-CORDEX, HYMEX..)
- Interaction with regional authorities to build up impact scenarios (response of critical infrastructures, changes in the lagoon ecosystems…).

This information sheet was developed in the framework of the CLIM-RUN FP7 EU project. The product it describes should not be used without acknowledging the project and, particularly for any operational use, interaction with the authors is welcome and strongly encouraged.

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