Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

Stato dell'arte delle proiezioni di *Sea Level Rise* nel Mar Mediterraneo

A brief review and new perspectives

MAREGOT - GESTIONE E PREVENZIONE DEL RISCHIO COSTIERO DI UN TERRITORIO IN EVOLUZIONE

Scuola Normale Superiore di Pisa, 8 Ottobre 2019

Maria Vittoria Struglia, G. Sannino, A. Carillo, R. Iacono, E. Napolitano, G. Pisacane / Climate Modelling Lab/ SSPT-MET-CLIM

SSPT – MET – CLIM

The motivation

Climate change will amplify existing risks and create new risks for natural and human systems.

Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development.

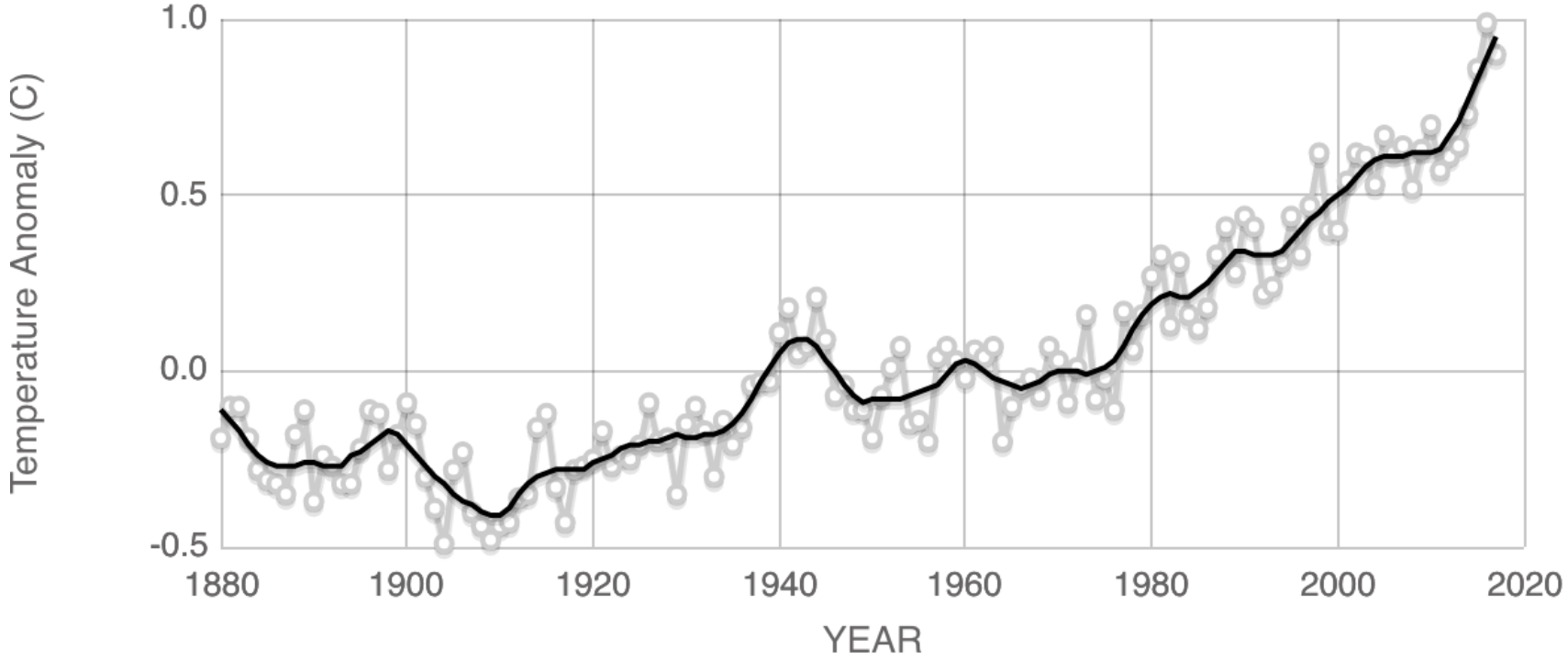
- Coastal systems and low-lying areas are at risk from sea level rise, which will continue for centuries even if the global mean temperature is stabilized (**high confidence**).
- The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (**high confidence**)

IPCC - CLIMATE CHANGE 2014 Synthesis Report

Climate change: some facts

Global Warming: current status (T °C)

Change in global surface temperature relative to 1951-1980 average temperatures.



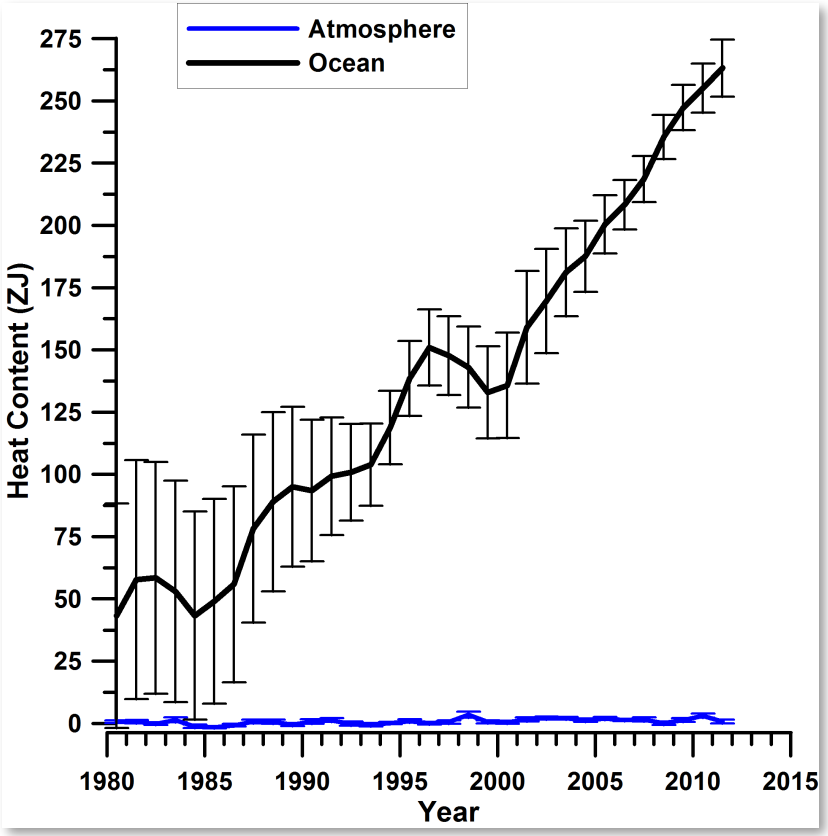
Source: climate.nasa.gov

Climate change: some facts

Heat Content distribution

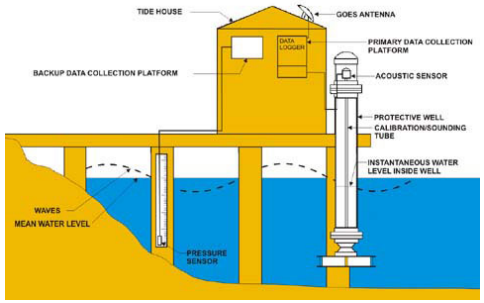
In the last 65 years, about **93%** of the excess heat accumulated in the climate system - due to greenhouse gas emissions - has been **stored in the oceans**, while the remaining 7% has warmed the atmosphere and the continents, melting sea and land ice.

Because of **ocean warming** and **land ice mass loss**, **sea level rises**

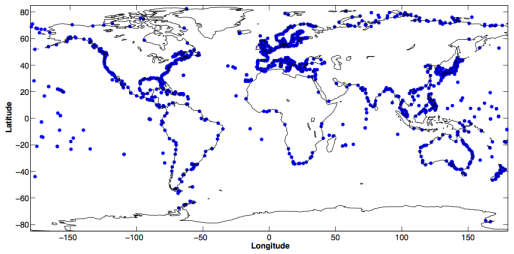


Climate change: some facts

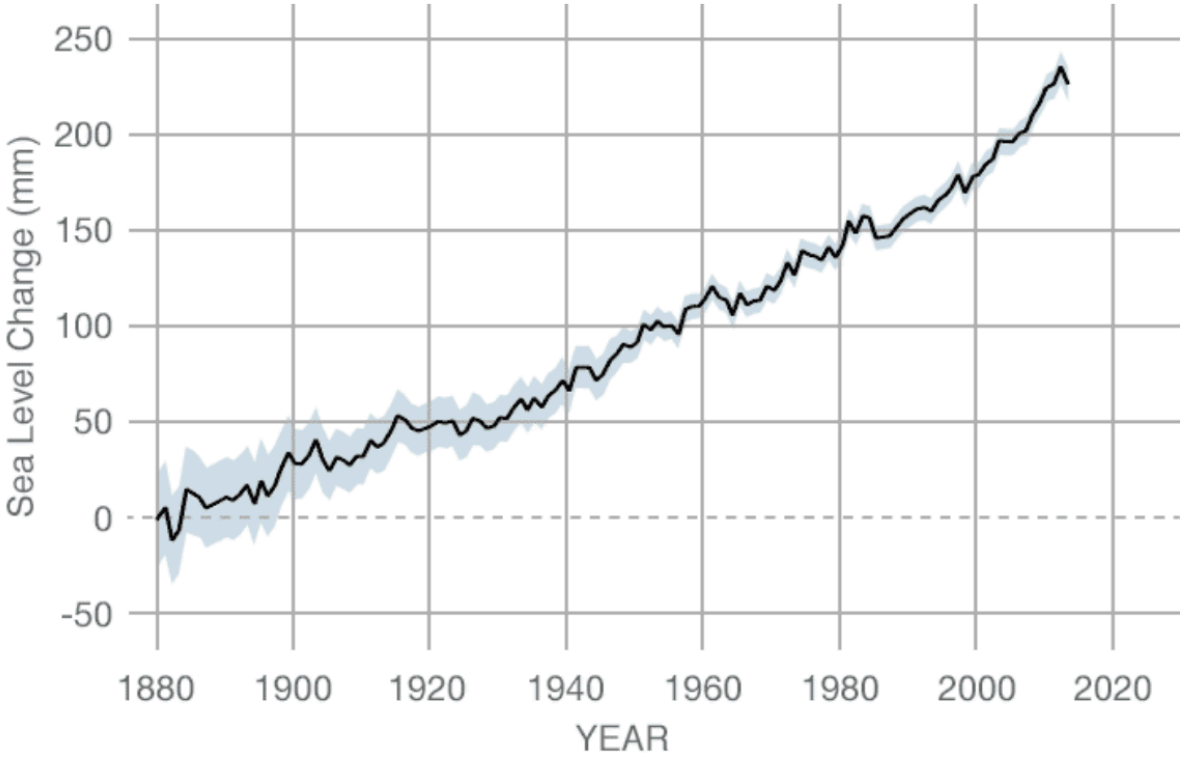
Global sea level since 1880: tide gauge measures



*tide gauge



Spatial distribution of the **1420** tide gauges



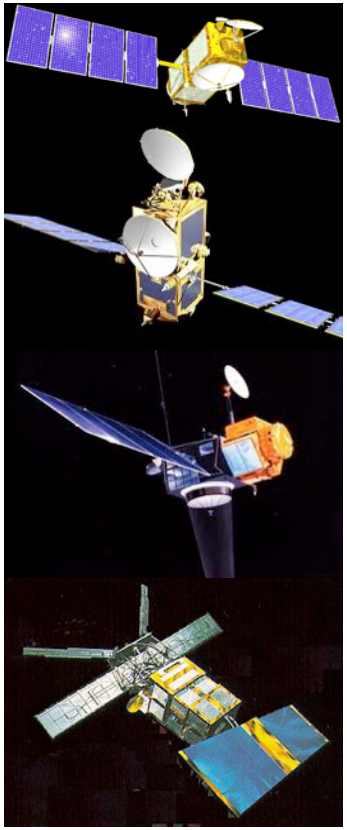
About +25 cm from 1880

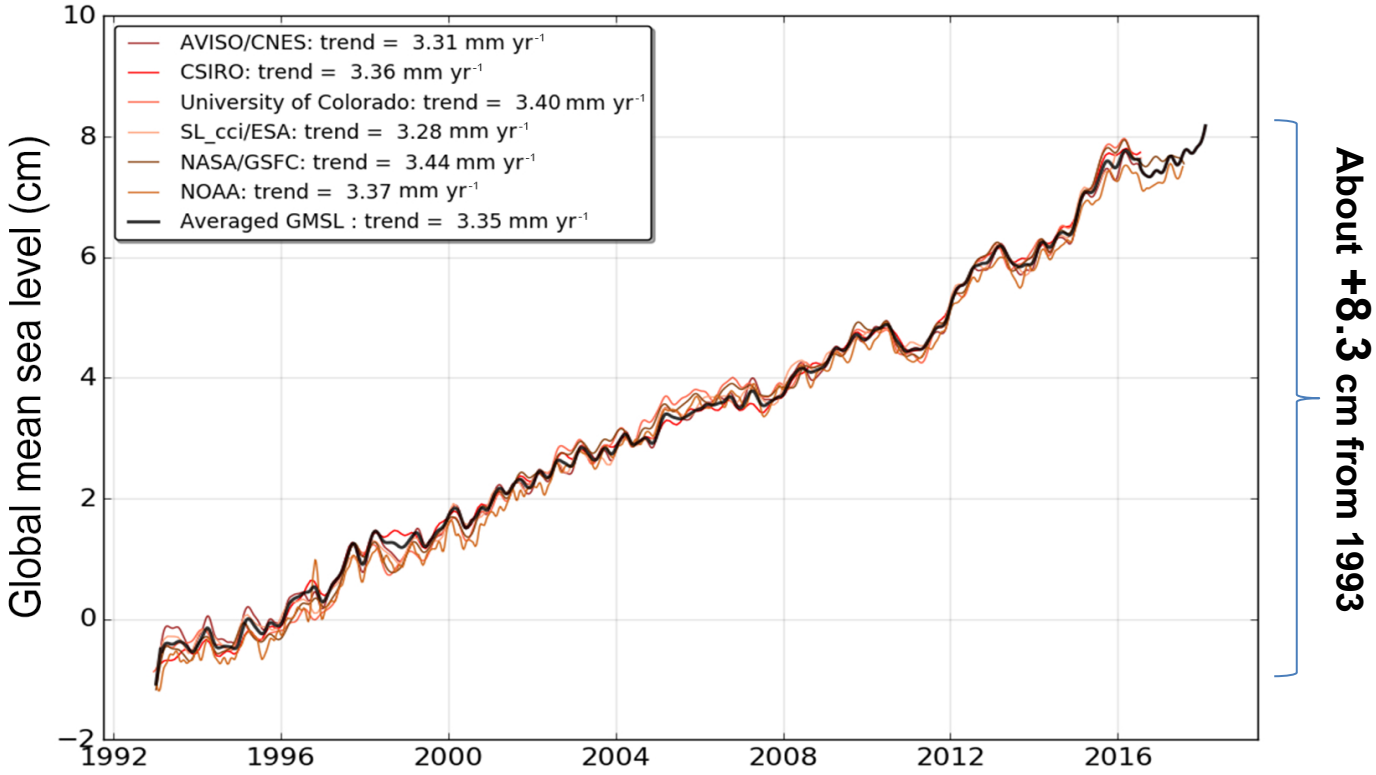
1.7 ± 0.3 mm/year since 1950

Church & White Geophys. Res. Lett. 33, L01602 (2006)

Climate change: some facts

Global sea level since 1993: satellite observations





Change in sea level since **1993** as observed by satellites.

3.3 ± 0.4 mm/year (1993 – 2009)

Nicholls & Cazenave, 2010 SCIENCE VOL 328 18 JUNE 2010

Climate change: some facts

The spatial distribution as observed by altimeters

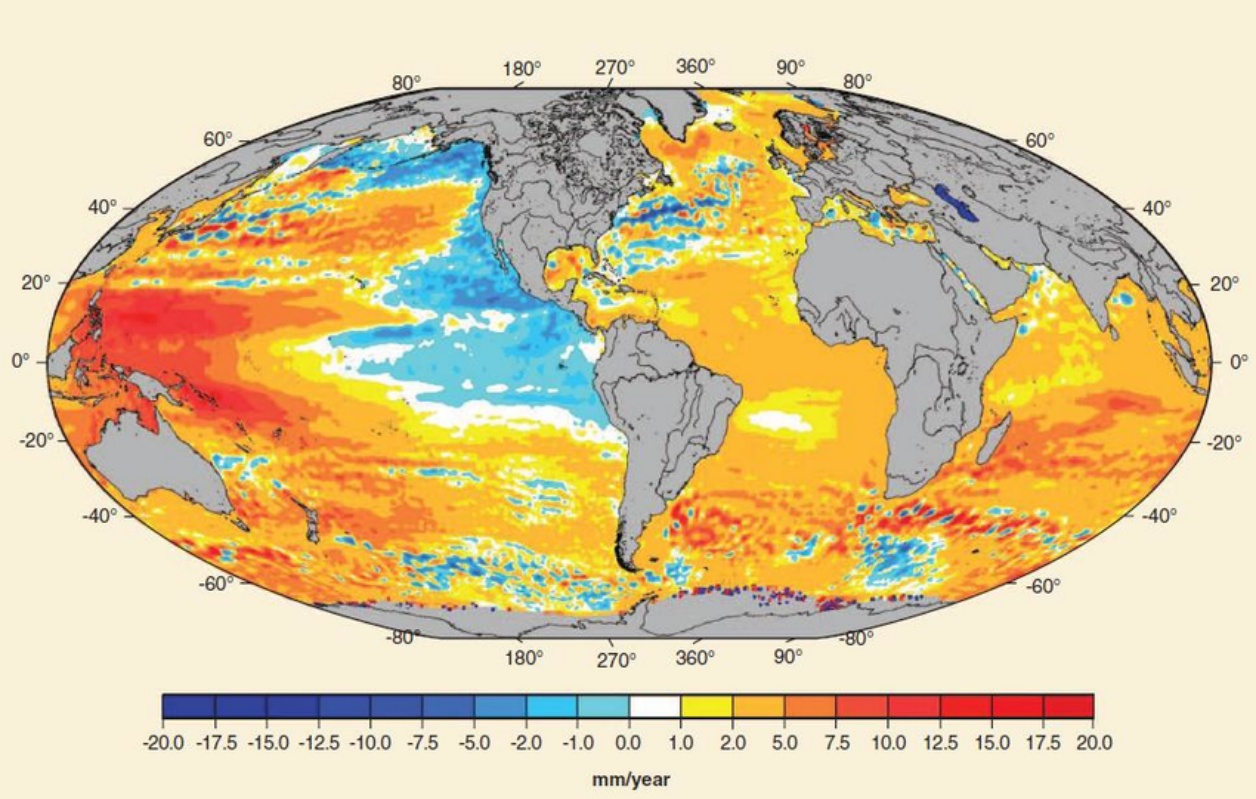
Regional sea-level trends from satellite altimetry for the period:

October 1992 to July 2009

(Topex/Poseidon, Jason-1&2, GFO, ERS-1&2, and Envisat missions)

Spatial differences are due to the halosteric effect, Glacial Isostatic Adjustment (GIA), changes in ocean circulation.

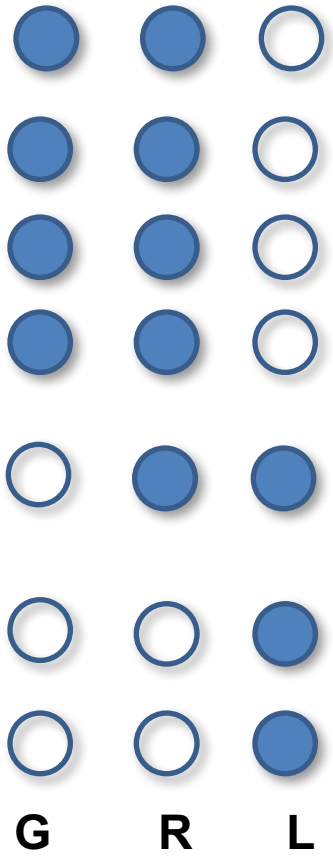
Oscillations on multidecadal time scales are expected in the SL change spatial patterns



Nicholls & Cazenave, 2010 SCIENCE VOL 328 18 JUNE 2010

Causes for SLR at global, regional and local scale

- Melting Greenland and Antarctica
- Melting Glaciers and ice caps
- Ocean Thermal expansion
- Ocean Circulation
- Postglacial rebound, self-attraction and loading
- Land Hydrology
- Tides, Storm surge, Subsidence



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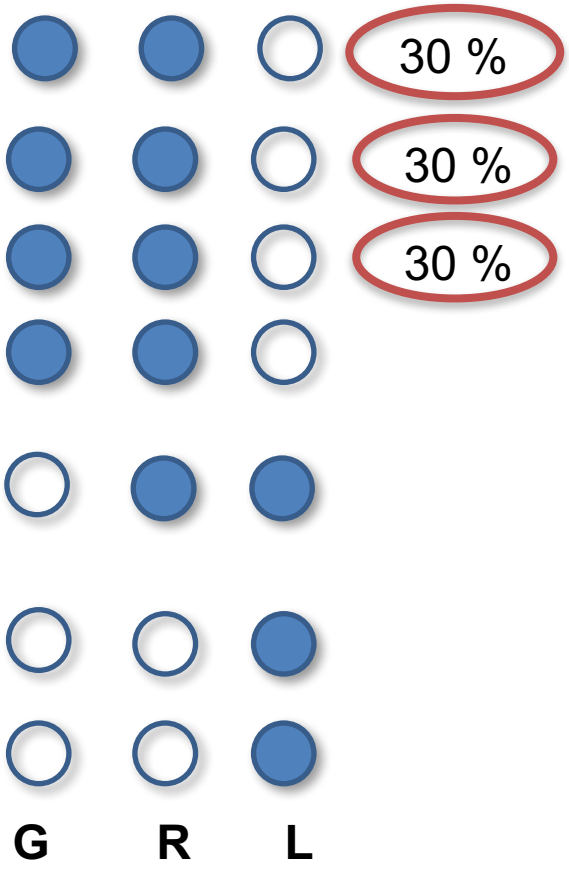
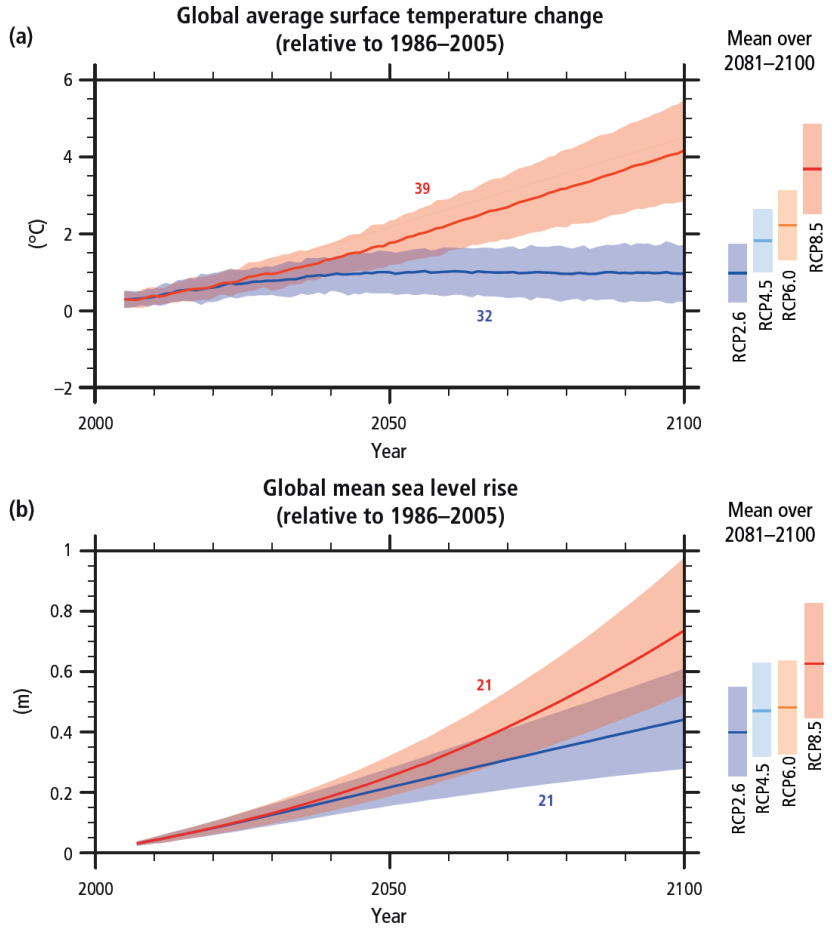


Average estimates over 1993-2009 period from Nicholls & Cazenave, 2010 SCIENCE VOL 328

Global SLR projections according IPCC AR5 – CMIP5



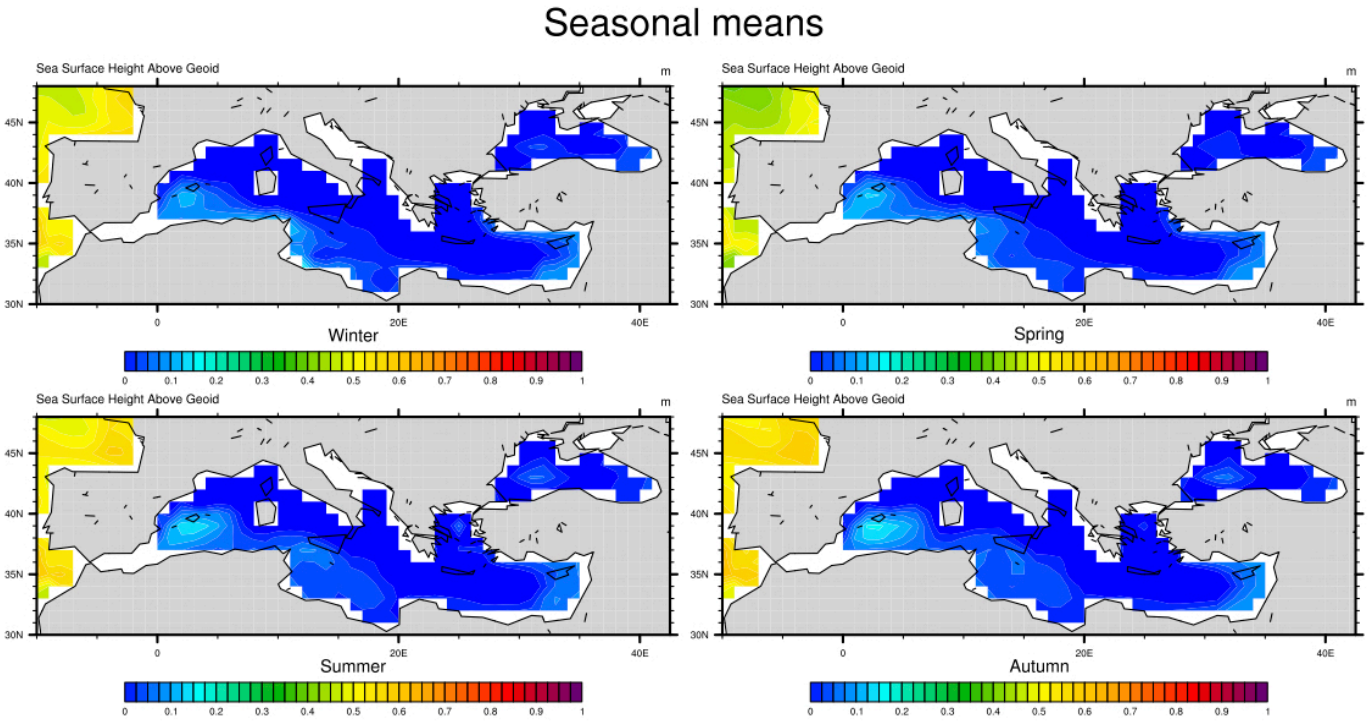
IPCC AR5

Global average surface temperature change (a) and global mean sea level rise10 (b) from 2006 to 2100 as determined by multi-model simulations.
All changes are relative to 1986–2005. Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). The mean and associated uncertainties averaged over 2081–2100 are given for all RCP scenarios as coloured vertical bars at the right hand side of each panel. The number of Coupled Model Intercomparison Project Phase 5 (CMIP5) models used to calculate the multi-model mean is indicated.

26 – 97 cm range up to 2100
40 – 62 cm mean 2081-2100

CMIP5 and the Mediterranean and Black Lakes!

The total population of the Mediterranean countries grew from 276 million in 1970 to 412 million in 2000 (a 1,35 % increase per year) and to 466 million in 2010. The population is predicted to reach **529 million by 2025** (176 milion along the Mediterranean coasts)

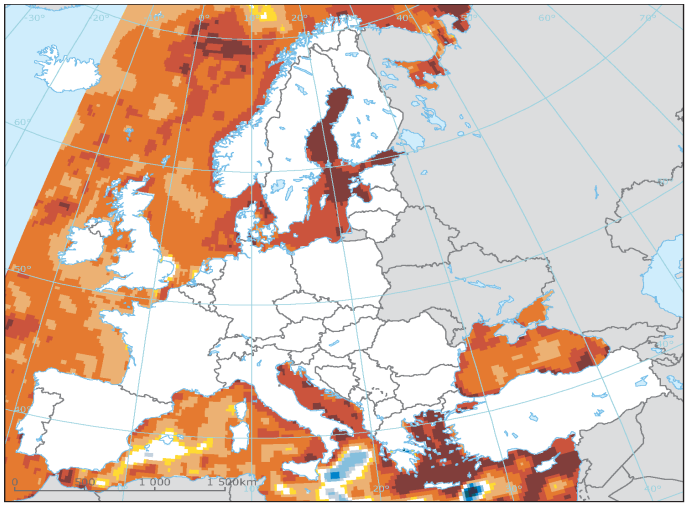


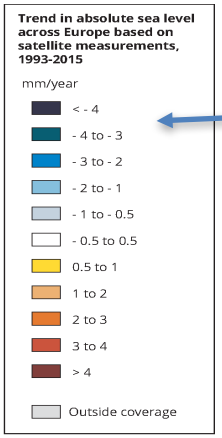
Mediterranean sea level reproduced by CMIP5* global models (present climate)

*Coupled Model Intercomparison Project

The Mediterranean realm

Current observations vs global projections





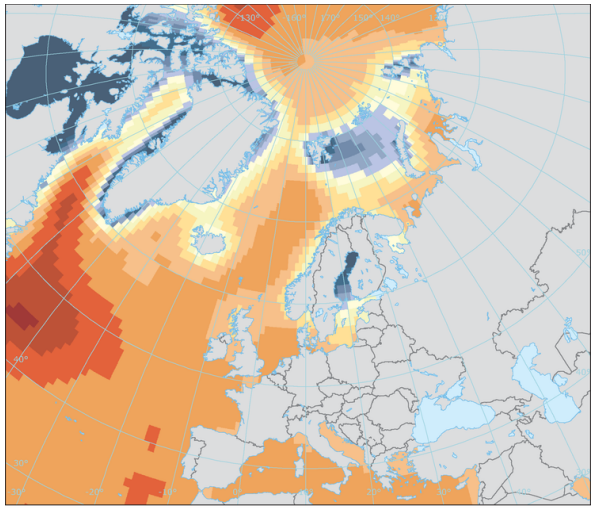
European Environment Agency

Horizontal spatial distribution of mean sea level trend in European Seas based on satellite observations from

January 1993- December 2015

Projected change in relative sea level in **2081-2100** compared to **1986-2005** for the scenario **RCP4.5** based on an ensemble of CMIP5 climate models. Projections consider land movement due to glacial isostatic adjustment but not land subsidence due to human activities and tectonics.

No projections are available for the Black Sea!

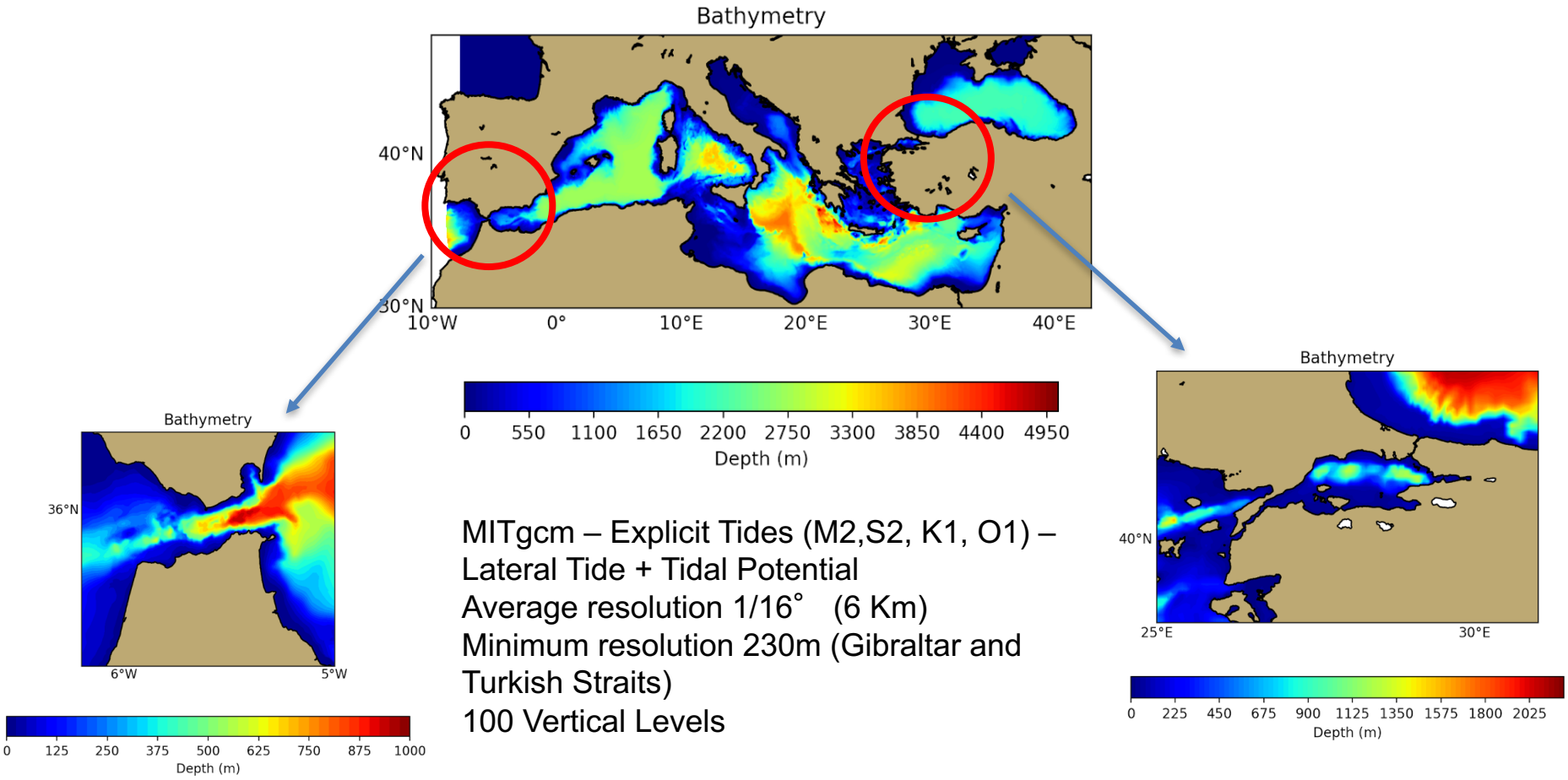


Regional projections: a brief history

- Marcos & Tsimplis, 2008: 12 AR4 global models with different scenarios, thermosteric (+3 cm ÷ +61cm), halosteric (-22 cm ÷ +31cm)
- Tsimplis et al, 2008: IPCC AR4, single AORCM downscaling of A2scenario(extreme) to 2100, 1/8° (12 km), rivers, no Black Sea, rigid lid, no ice melting, dynamic variations (±6cm), atmospheric pressure (-2cm) & steric contribution ex-post (+25 cm ÷ +5cm, mean +13cm)
- Carillo et al., 2012: IPCC AR4, 2 (different LBC) AORCM downscaling of SRESA1B(intermediate) to 2050, 1/8° (12 km), steric variations (2cm or 7cm depending on LBC)
- Jordà & Gomis, 2013: Quantification of the Different Sea Level Components in Mediterranean Sea & regional models, application to similar run of Tsimplis 2008, +50 cm at 2100
- Meyssignac et al. 2017: Evaluation of CMIP5 models for regional projections, "the Mediterranean basin is excluded from the sea level simulations based on climate models here"
- Adloff et al., 2018: 4 ORCM hindcast simulations differing mainly in LBC (variable SSH, ice sheet mass loss, glaciers ice melt, changes in land water storage, as well as global thermal expansion), "Mediterranean mean sea level is strongly influenced by the Atlantic conditions and thus the quality of the information in the LBCs is crucial for the good modelling of Mediterranean sea level", "regional differences inside the basin that are induced by circulation changes, we find that,are model dependent"

First Black Sea-Mediterranean model with a realistic connection

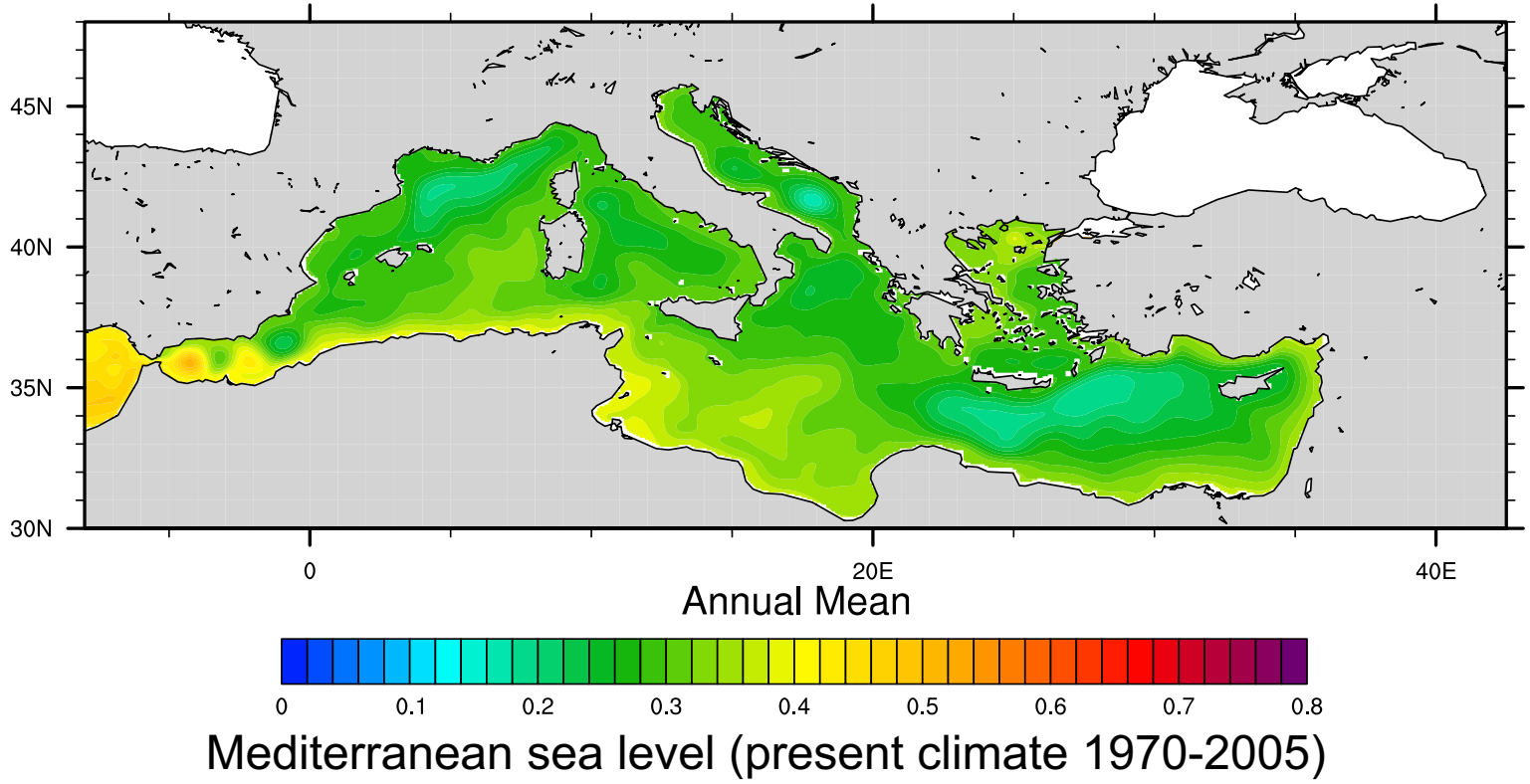
New modelling efforts are already on the way.



MITgcm – Explicit Tides (M2,S2, K1, O1) – Lateral Tide + Tidal Potential
Average resolution 1/16° (6 Km)
Minimum resolution 230m (Gibraltar and Turkish Straits)
100 Vertical Levels

Ocean dynamics contribution to the Mediterranean SL change

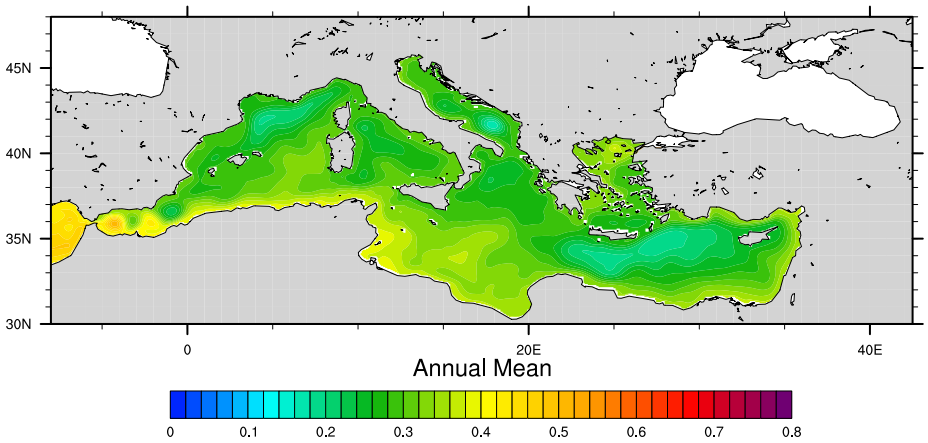
Model forced by: Euro-CORDEX run - MOHC-HadGEM2-ES*-SMHI-historical

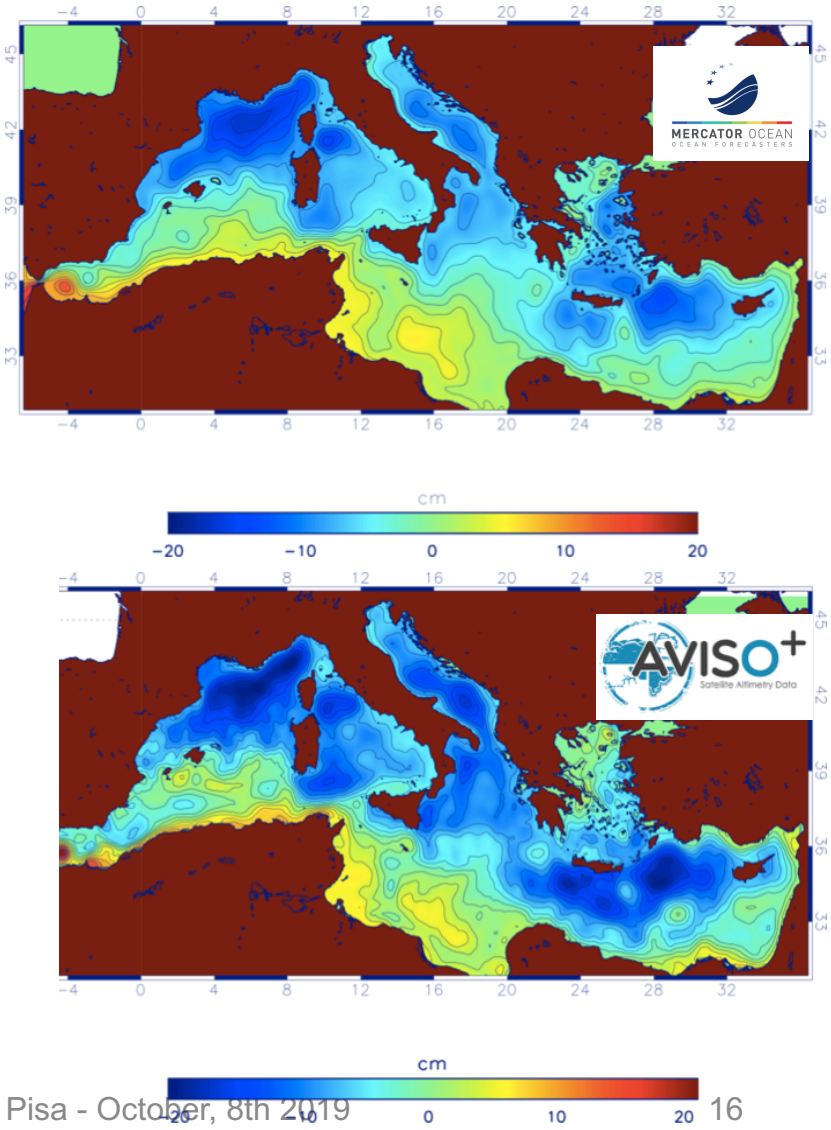


Validation of the model: mean ocean circulation

Right: Sea surface height 1990 – 2013 from reference datasets.
Upper panel: Ocean reanalysis by Mercator
Lower panel: Satellite observations from AVISO dataset

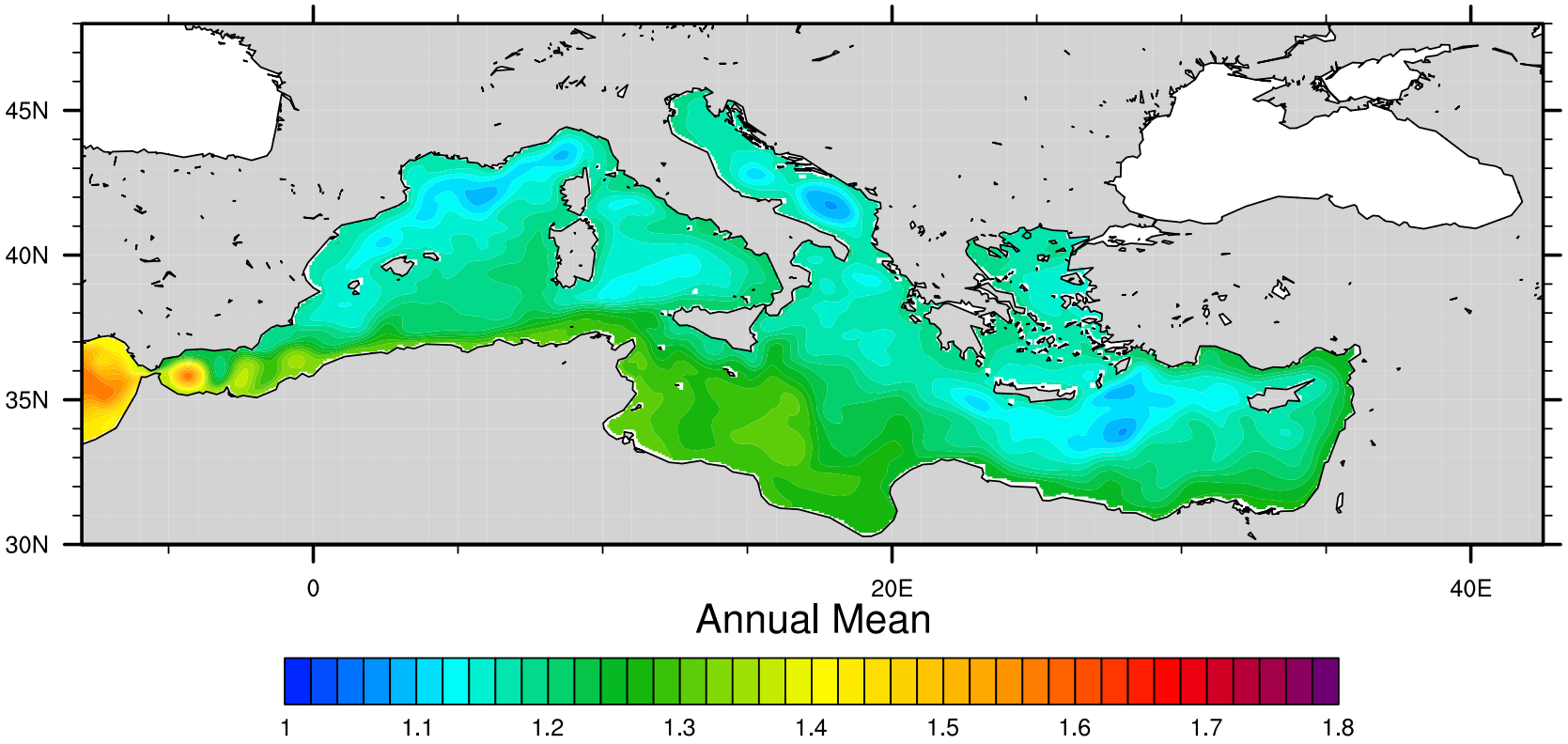
Left: present climate simulation 1970 -2005





Ocean contribution to the Mediterranean sea level change

Model forced by: Euro-CORDEX run - MOHC-HadGEM2-ES*-SMHI-rcp85



Mediterranean sea level (future climate 2097-2100)

Ocean contribution to the Mediterranean sea level change

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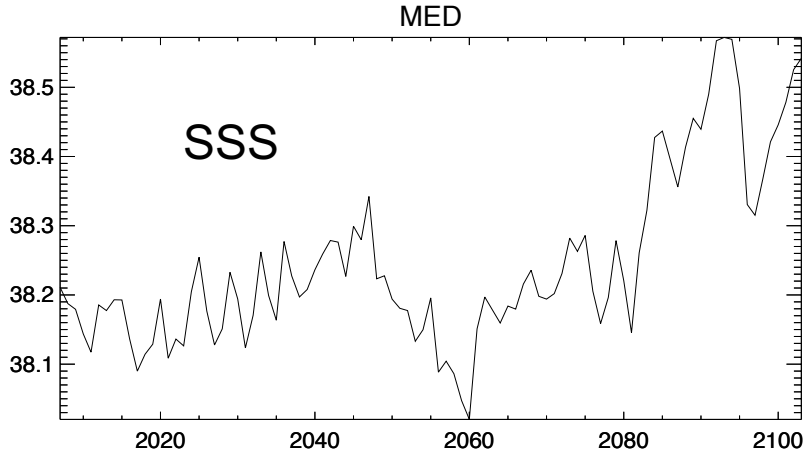
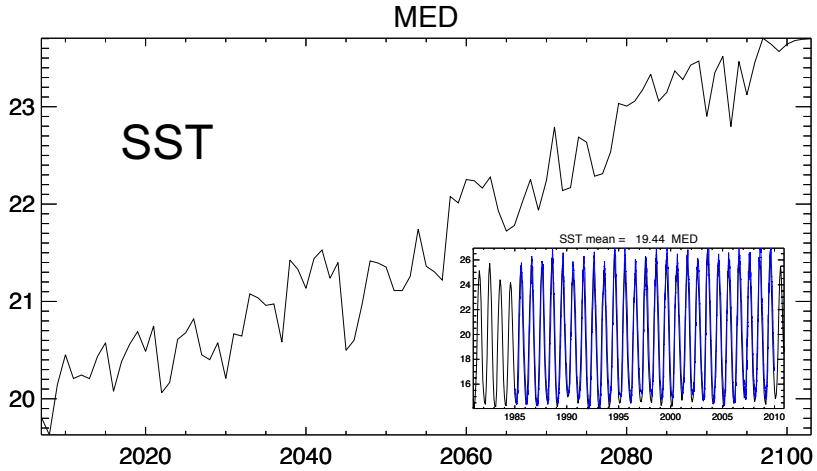
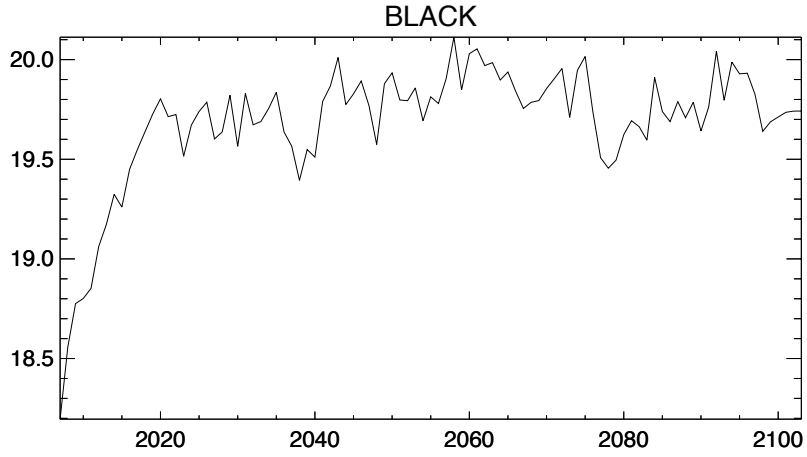
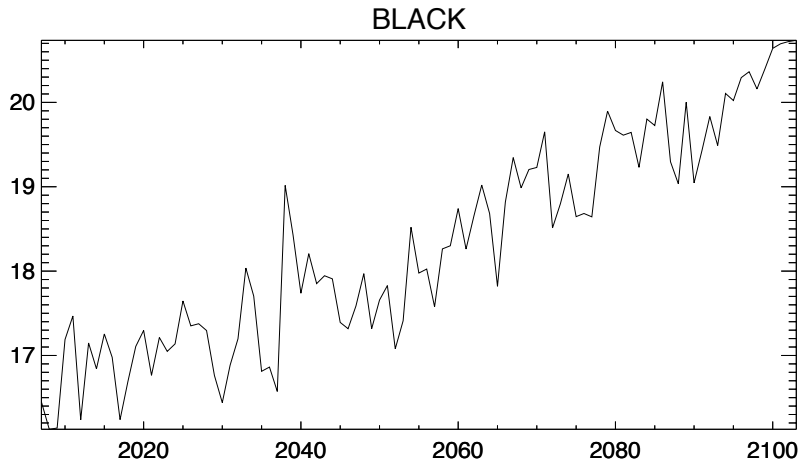


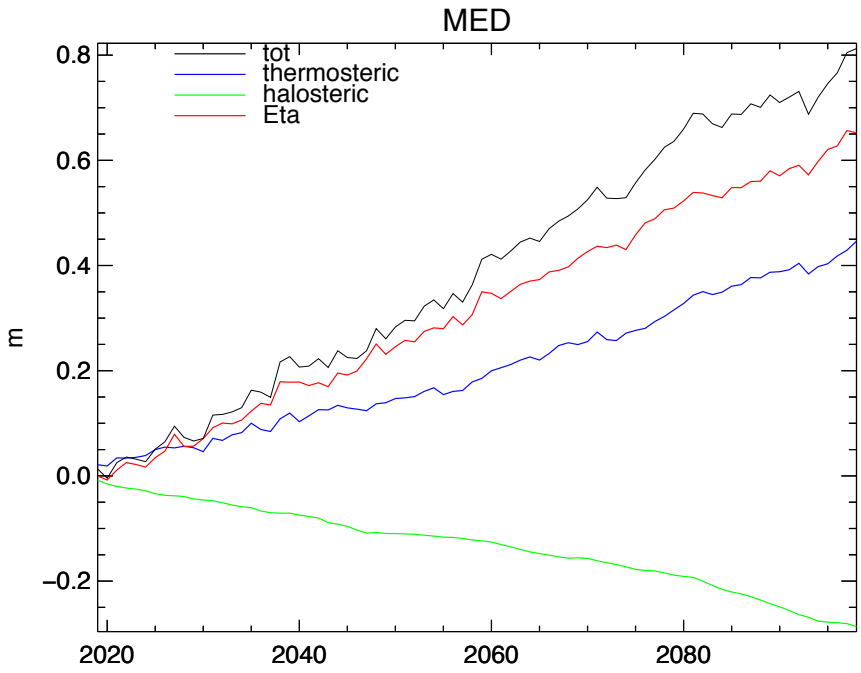


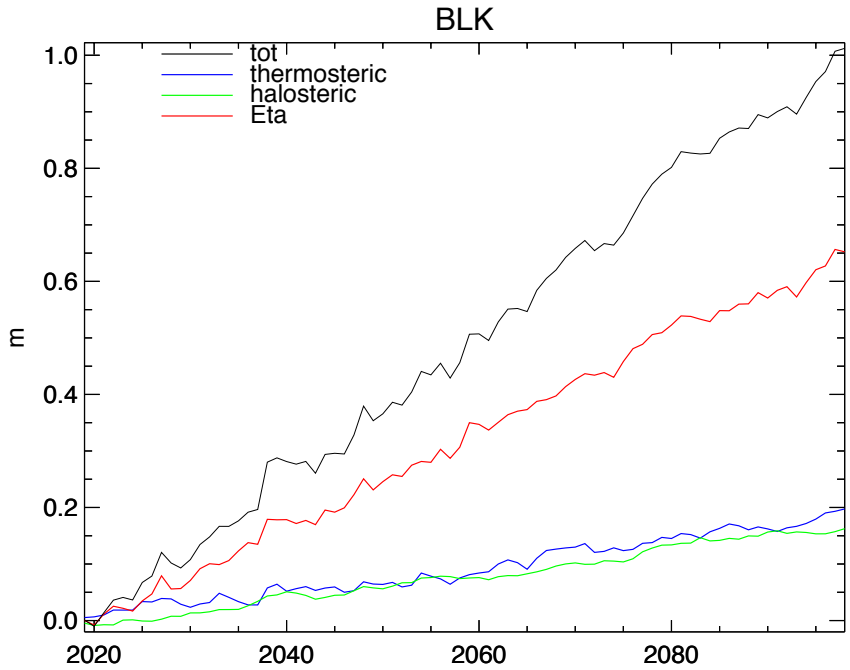




Ocean contribution to the Mediterranean sea level change: The steric component

Model forced by: Euro-CORDEX run - MOHC-HadGEM2-ES*-SMHI-rcp85





Conclusions

- SLR Impacts for coastal management policy must consider all relevant climate and non climate coastal drivers
- Regional ocean models, solving the Strait dynamics (Gibraltar, Bosphorus, Dardanelles) and including the local tidal forcing, can give reliable result of SLR also for those regions for which the result is currently unavailable.
- Relying upon a long modelling experience, we performed the very first climatic simulations (historical and scenario) for the connected system Mediterranean – Black Sea
- Preliminary results show that the trend inside the Mediterranean can differ from the global one.
- More investigation and more simulations will be performed to assess the robustness of the results.

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