

REMTECH EXPO



CLIMATE CHANGE AND SEA LEVEL RISE IN THE
MEDITERRANEAN SEA:
RESULTS FROM A *STATE OF THE ART* REGIONAL CLIMATE
MODEL

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Ferrara, September 19th

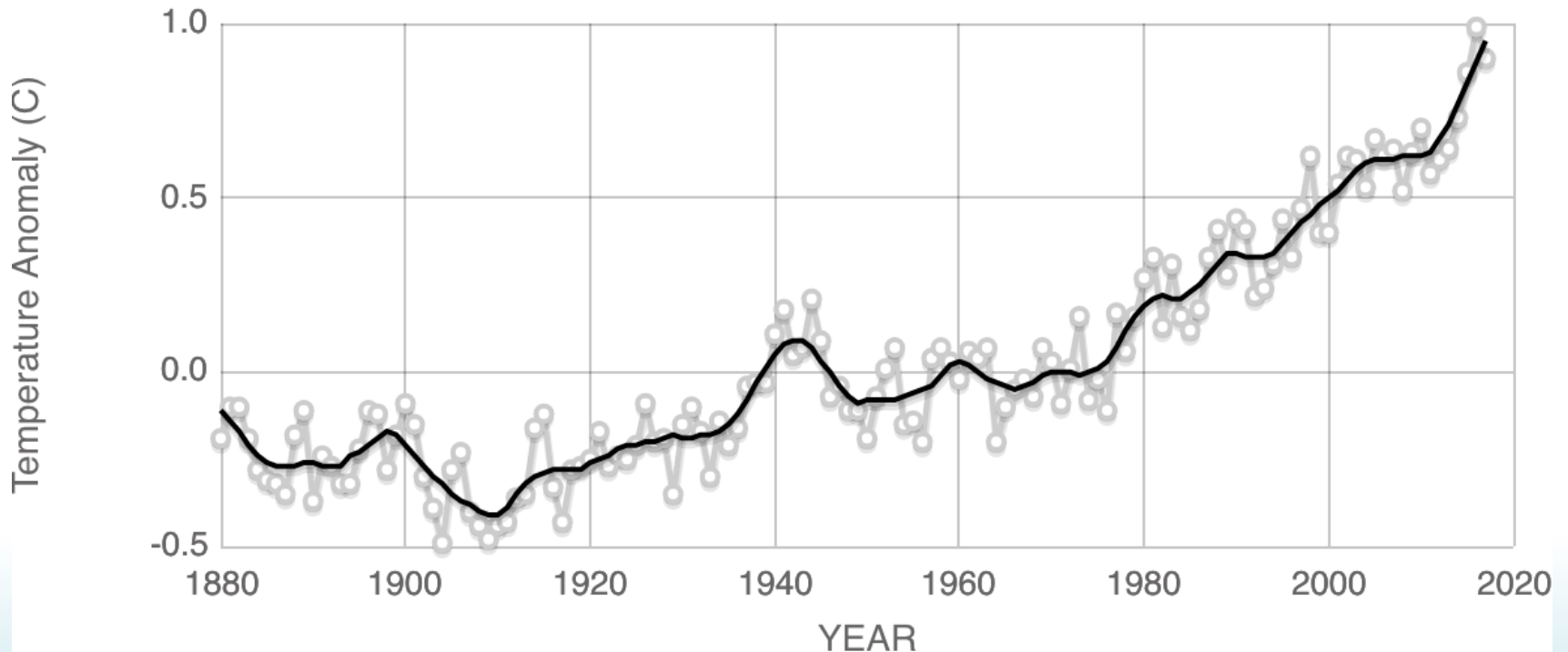
RemTech Expo 2019 (18, 19, 20 Settembre) FerraraFiere

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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

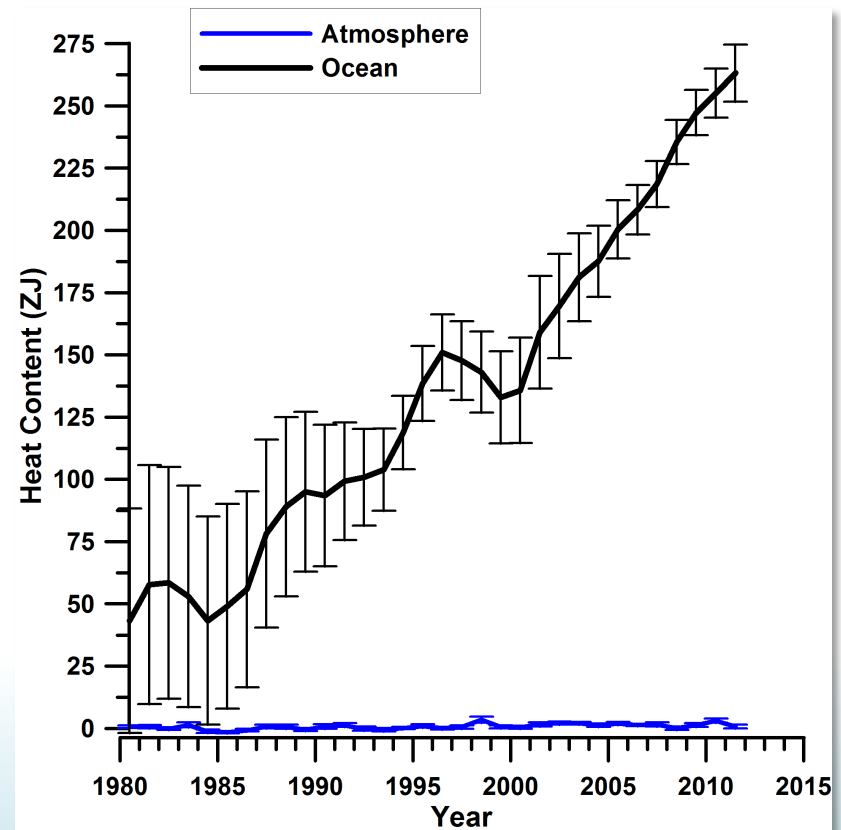
Climate change: some facts

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.



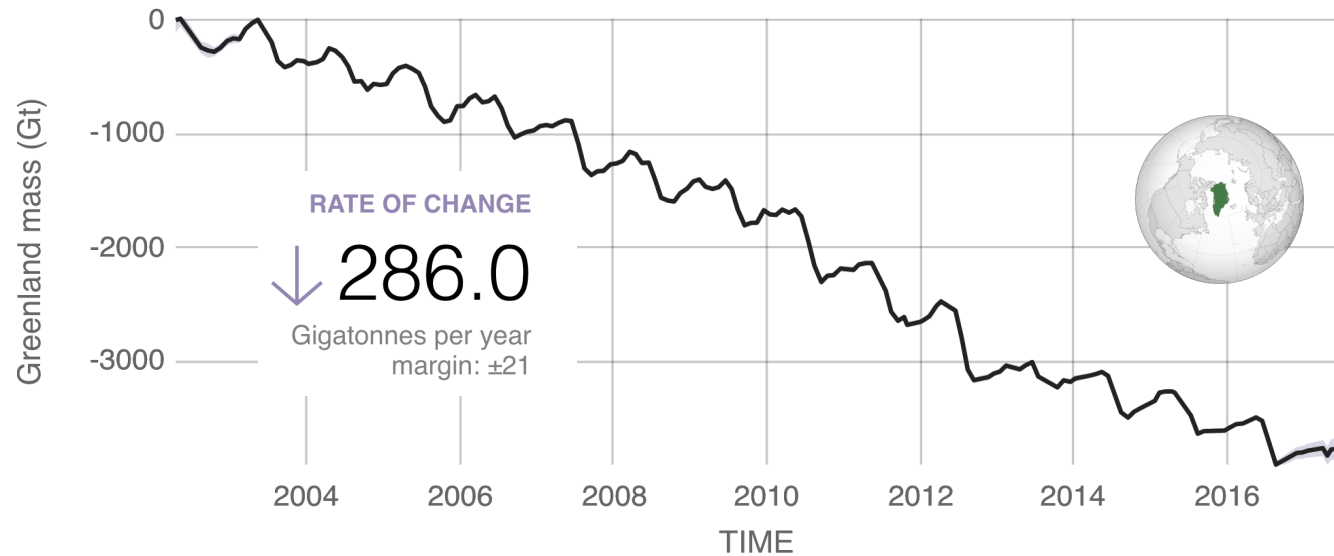
Because of ocean warming and land ice mass loss, **sea level rises**



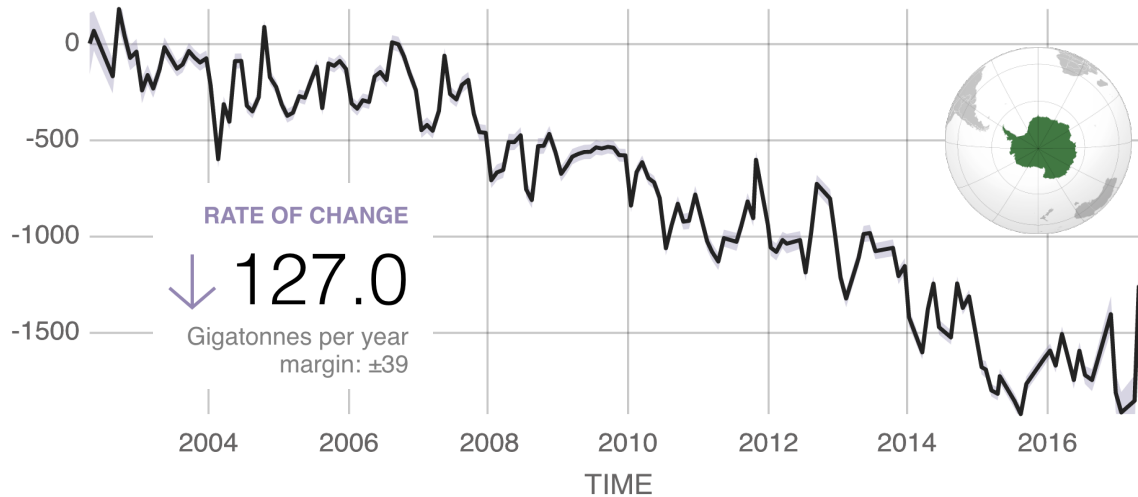
Climate change: some facts

Global Warming effects: land ice melting

Greenland mass variation



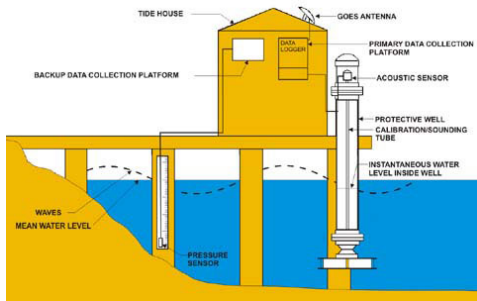
Antarctica mass (Gt)



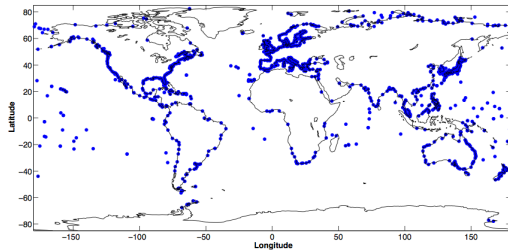
Antarctica mass variation

Climate change: some facts

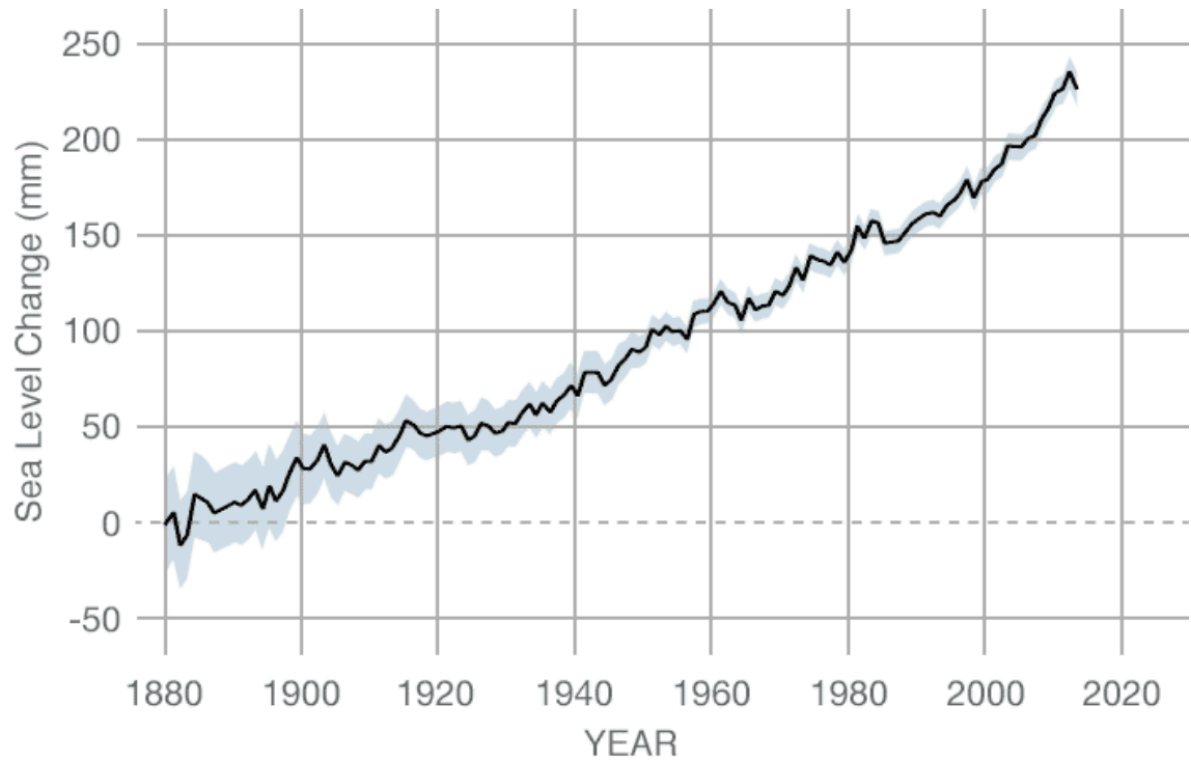
Global sea level since 1880: tide gauge measures



*tide gauge



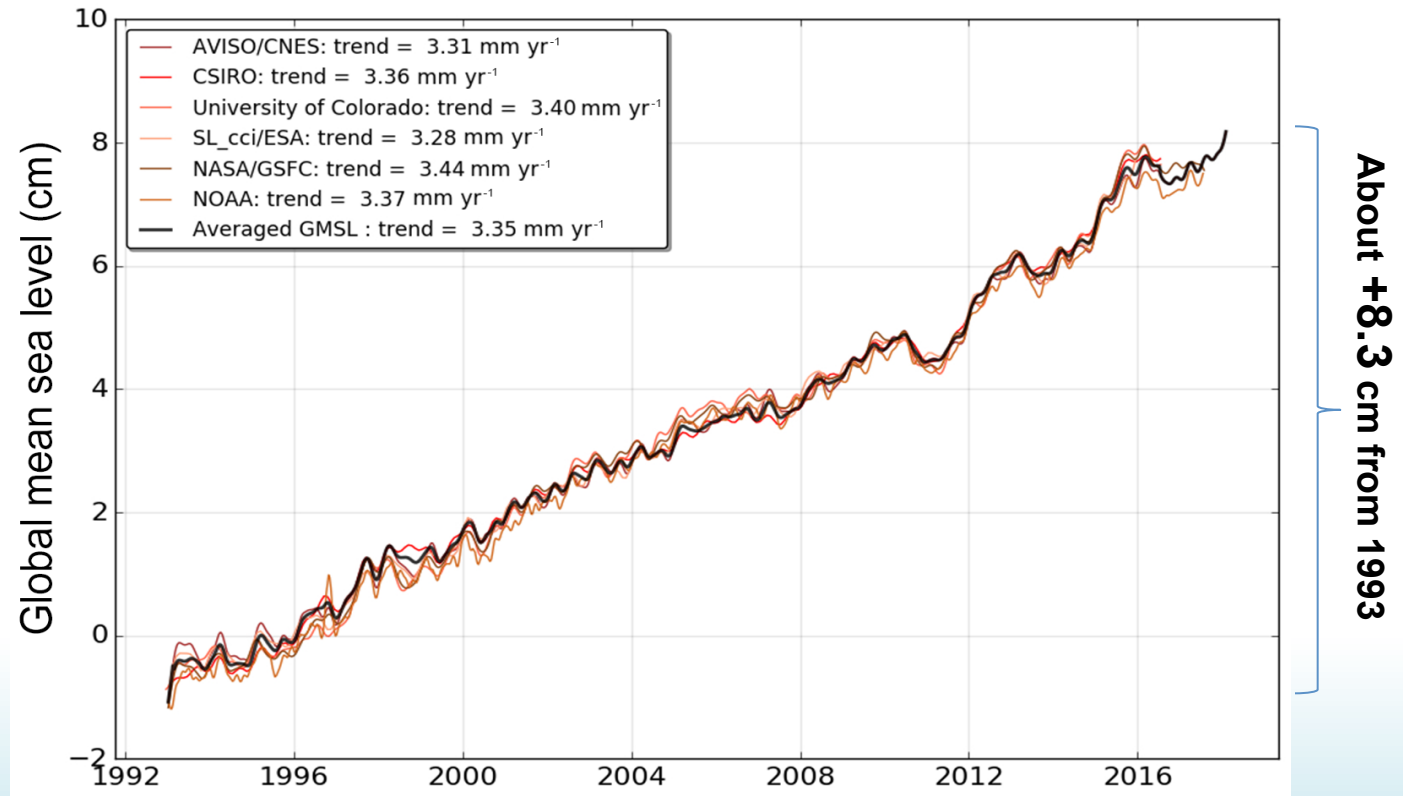
Spatial distribution of the **1420** tide gauges



About **+25 cm** from 1880

Climate change: some facts

Global sea level since 1993: satellite observations



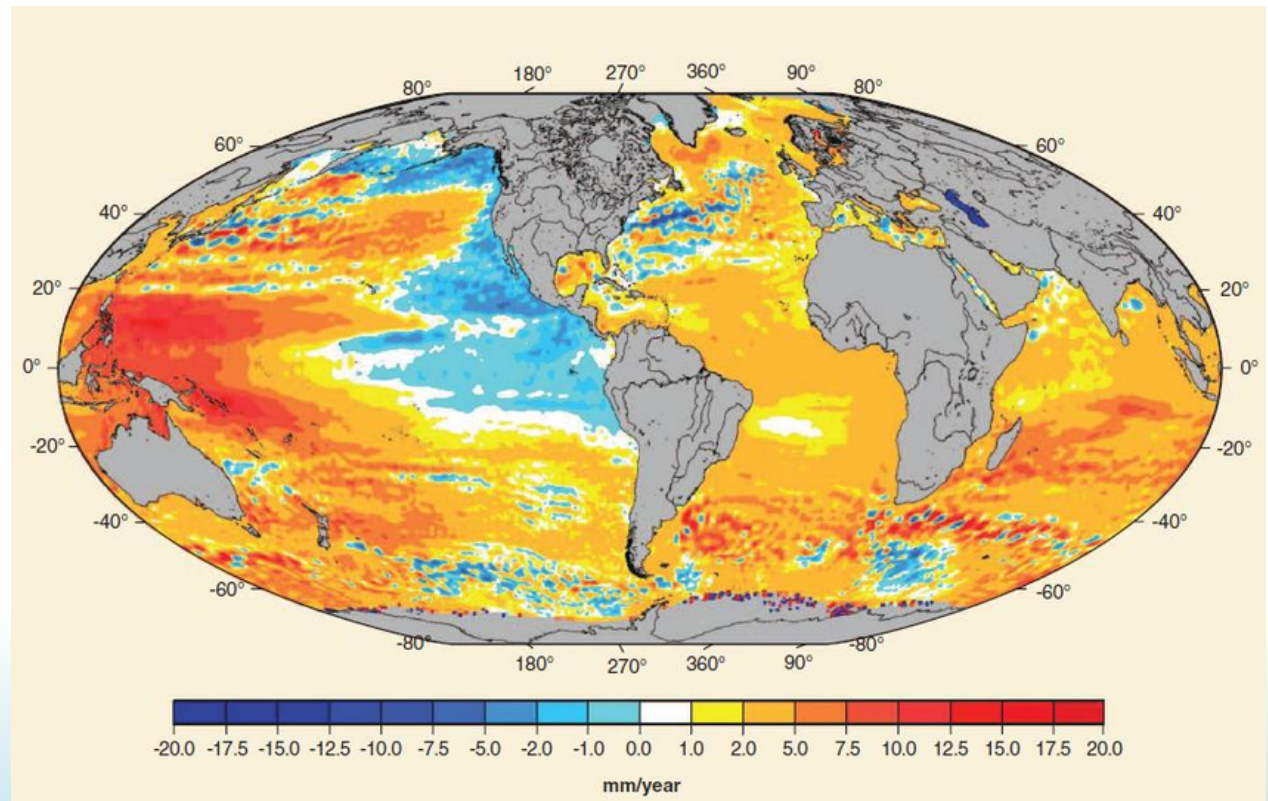
Change in sea level since 1993 as observed by satellites.

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

Spatial differences are due to the steric effect



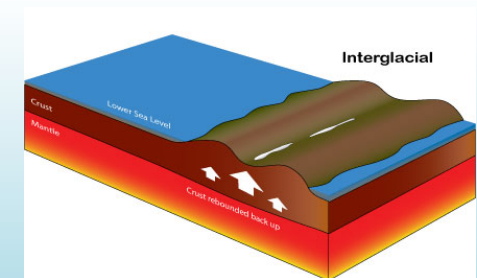
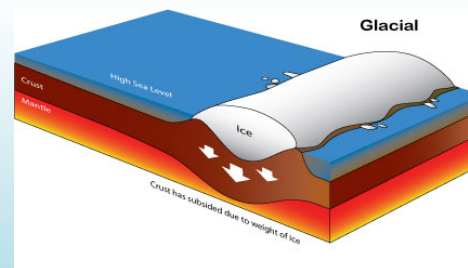
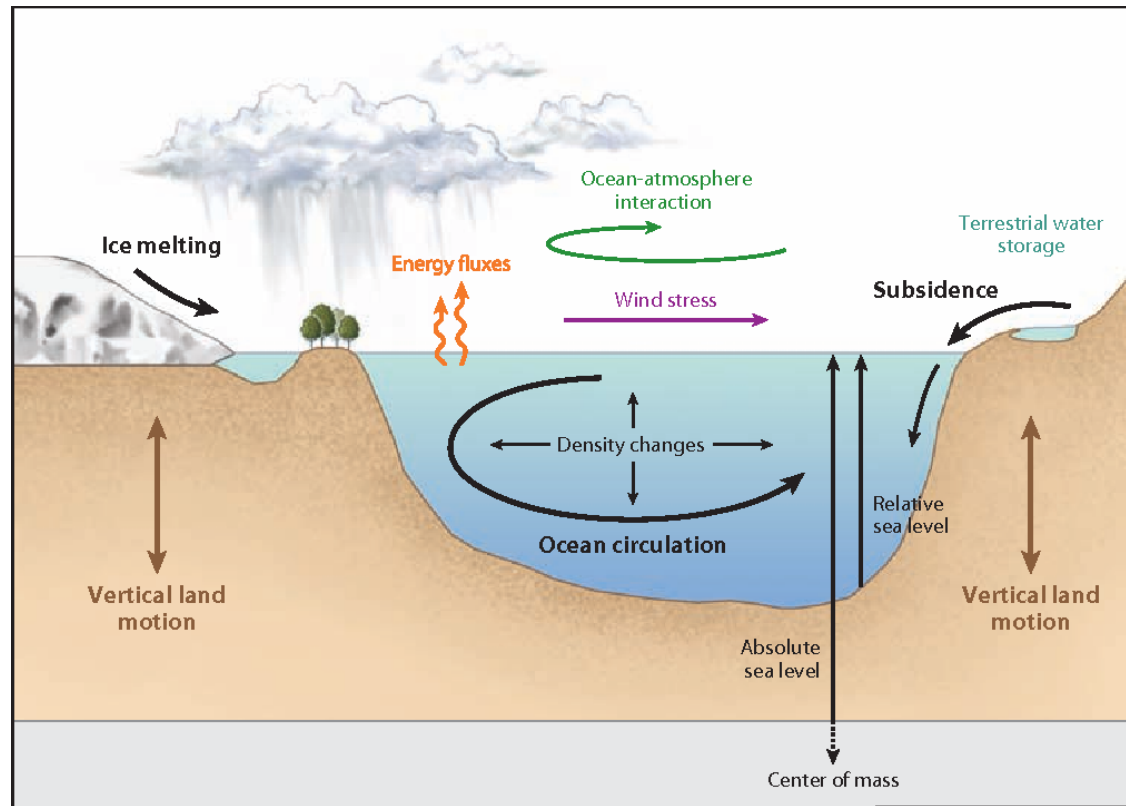
Nicholls & Cazenave, 2010

Causes for SLR at global, regional and local scale

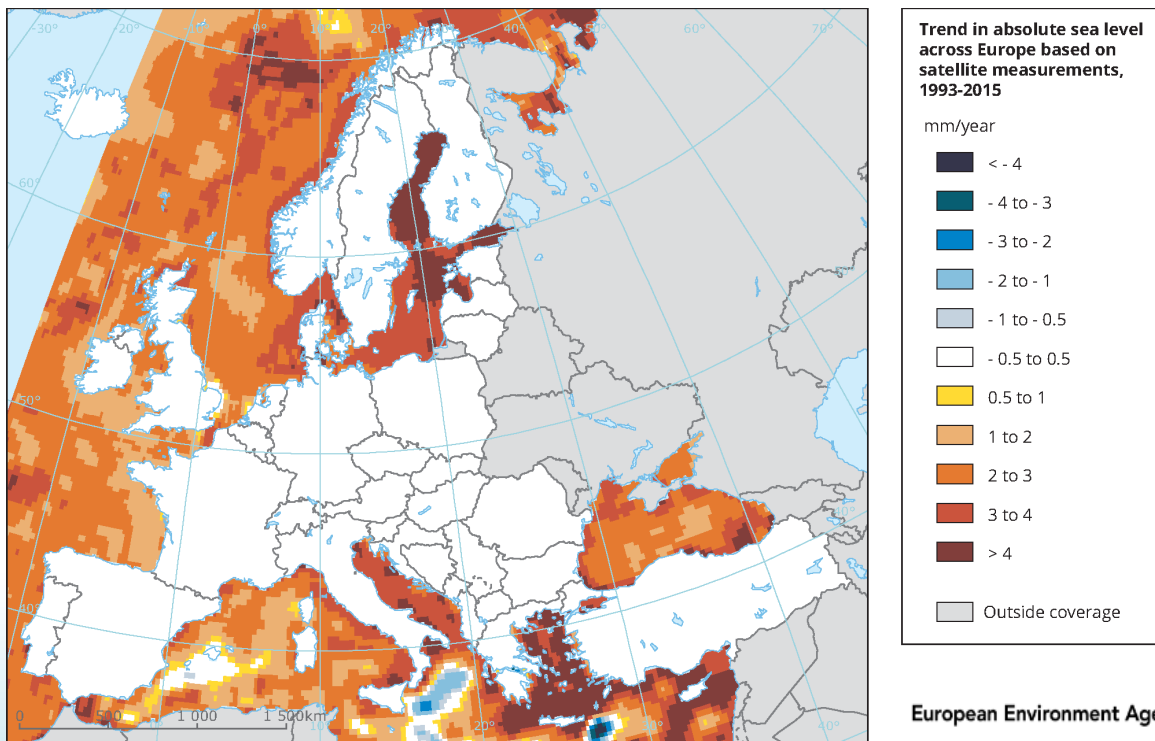
- Melting Greenland and Antarctica
 - Melting Glaciers and ice caps
 - Ocean Thermal expansion
 - Ocean Circulation
 - Postglacial rebound, self-attraction and loading
 - Land Hydrology
 - Tides, Storm surge, Subsidence
- G** **R** **L**

Regional Sea Level Change

Regional sea level changes can deviate substantially from those of the **global mean**, can vary on a broad range of timescales, and in some regions can even lead to a reversal of long-term global mean sea level trends. The underlying causes are associated with dynamic variations in the ocean circulation as part of climate modes of variability and with an **isostatic adjustment** of Earth's crust to past and ongoing changes in polar ice masses and continental water storage. Relative to the coastline, sea level is also affected by processes such as **earthquakes** and **anthropogenically induced subsidence**.



European Seas, Mediterranean and Black Sea



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

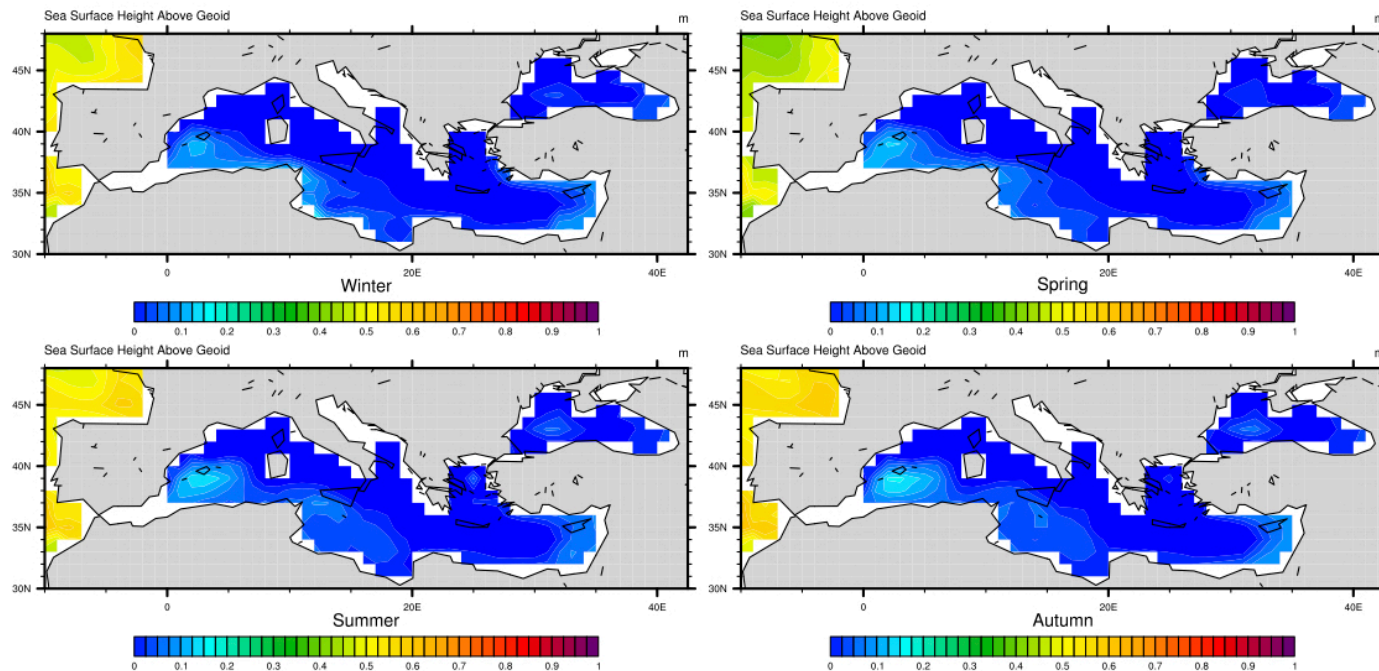
January 1993- December 2015



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 million along the Mediterranean coasts).

Seasonal means



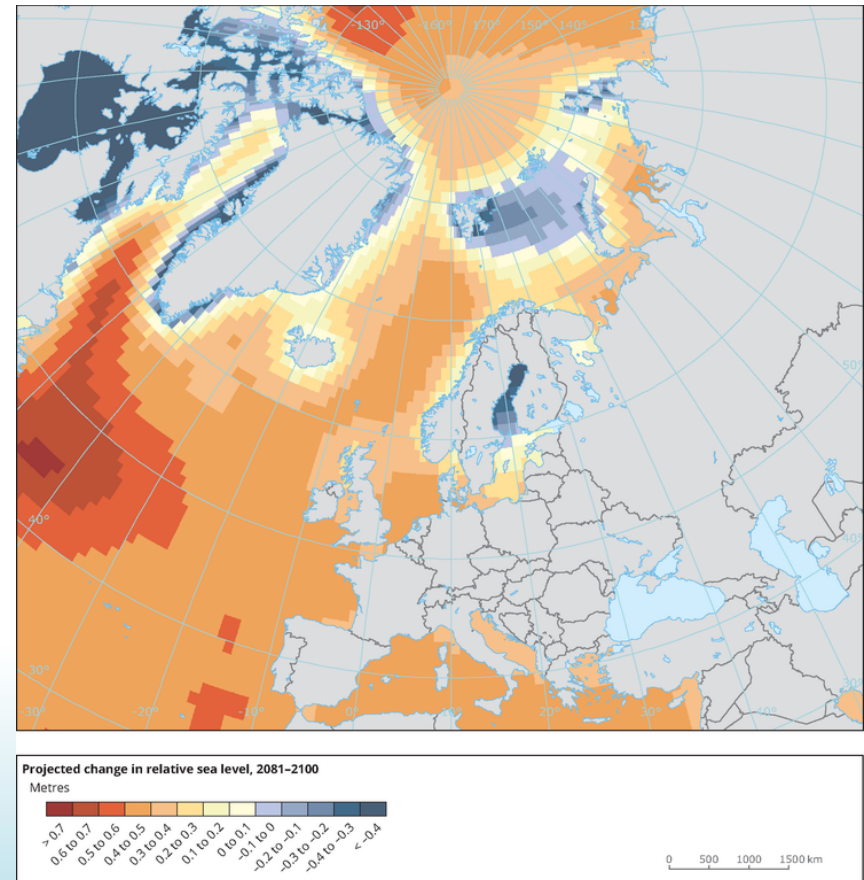
Mediterranean sea level reproduced by CMIP5* global models (present climate)

*Coupled Model Intercomparison Project

What about the future?

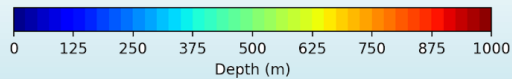
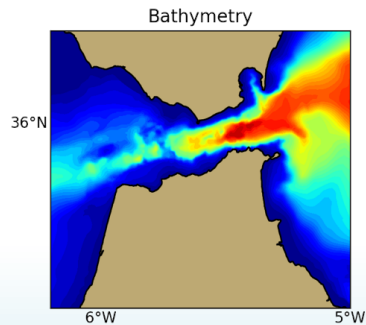
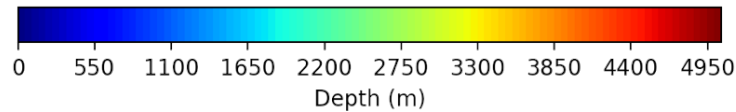
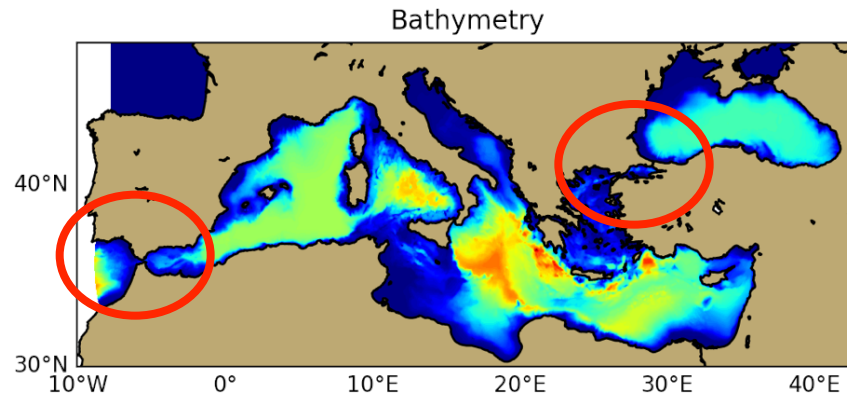
Projected change in relative sea level in **2081-2100** compared to **1986-2005** for the scenario **RCP4.5** based on an ensemble of CMIP5 climate models. Projections consider land movement due to glacial isostatic adjustment but not land subsidence due to human activities and tectonics.

No projections are available for the Black Sea!

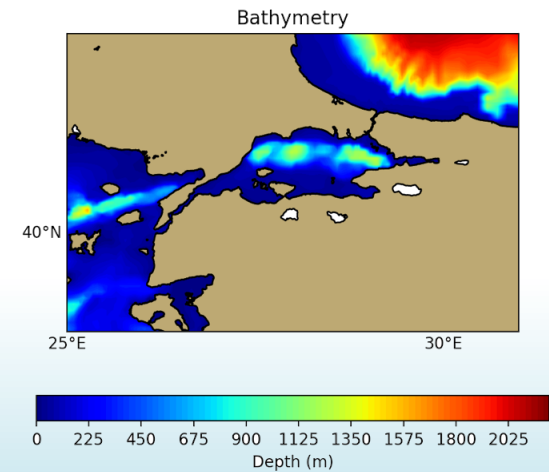


First Black Sea-Mediterranean model with a realistic connection

New modelling efforts are already on the way.

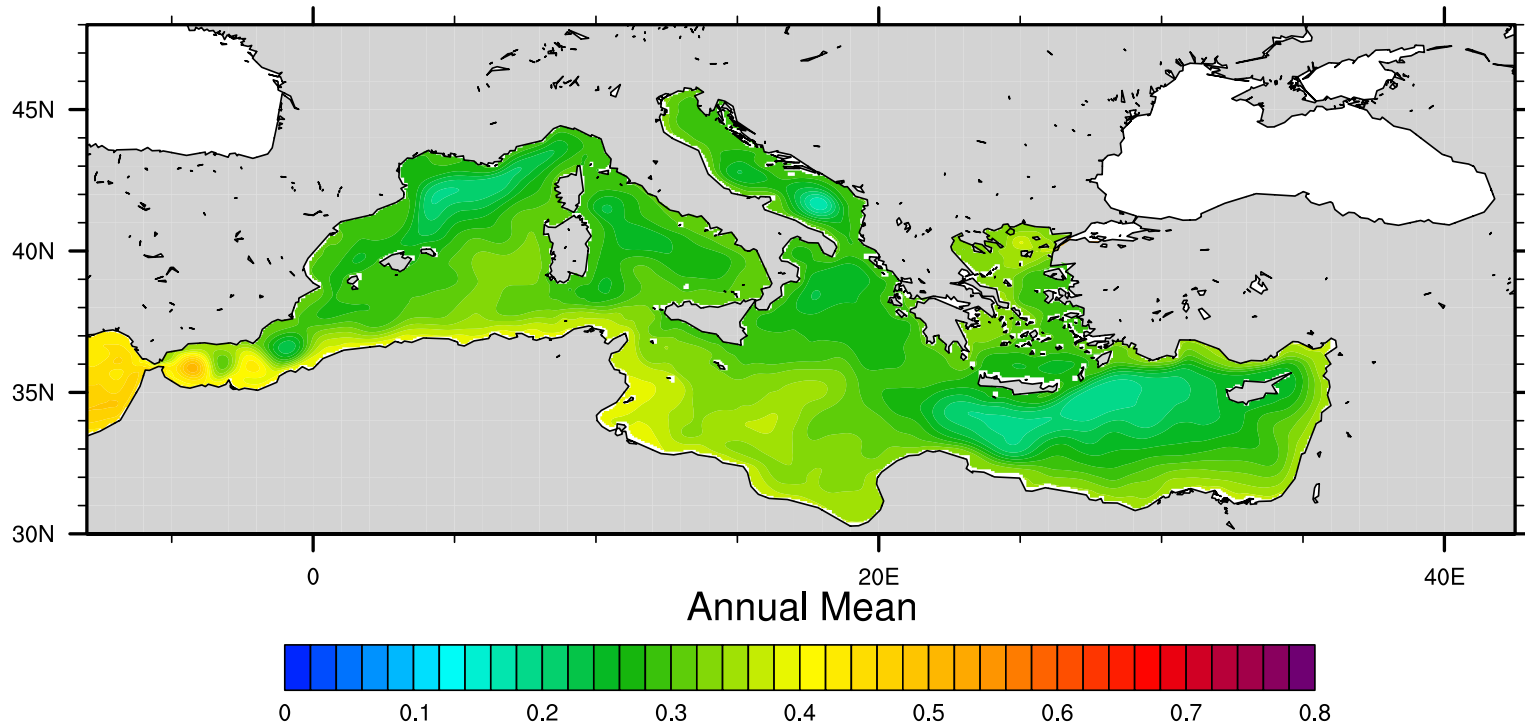


MITgcm – Explicit Tides (M2,S2, K1, O1) –
Lateral Tide + Tidal Potential
Average resolution 1/16° (2.3 Km)
Minimum resolution 230m (Gibraltar and
Turkish Straits)
100 Vertical Levels



Ocean contribution to the Mediterranean sea level change

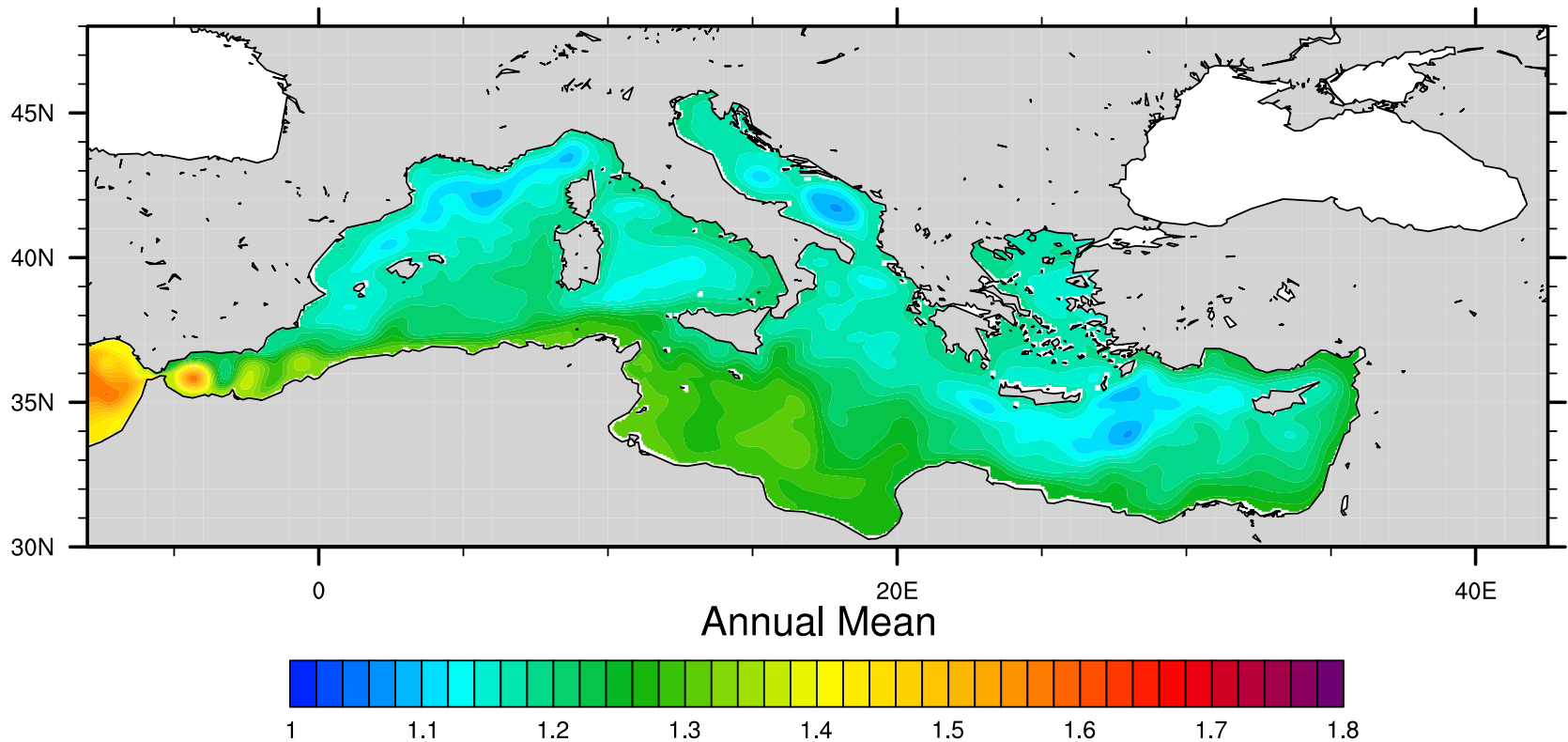
Model forced by: Euro-CORDEX run - MOHC-HadGEM2-ES*-SMHI-historical



Mediterranean sea level (present climate 1970-2005)

Ocean contribution to the Mediterranean sea level change

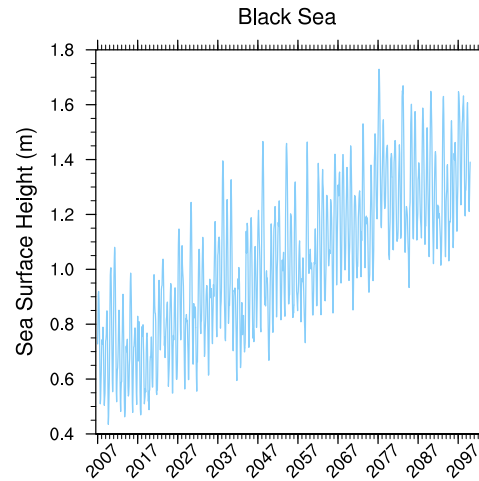
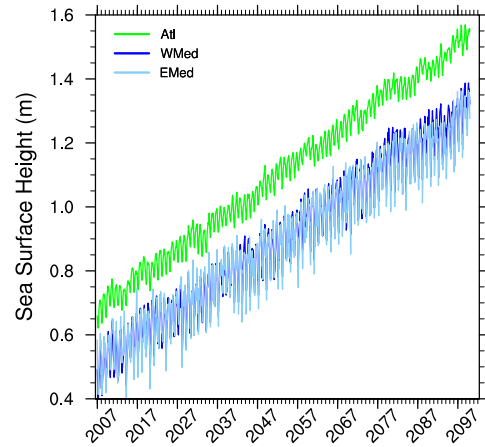
Model forced by: Euro-CORDEX run - MOHC-HadGEM2-ES*-SMHI-rcp85



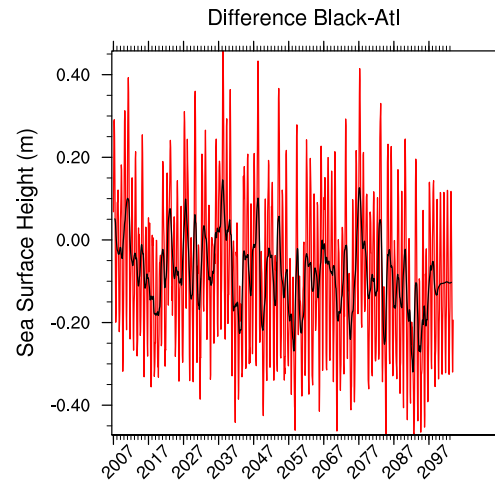
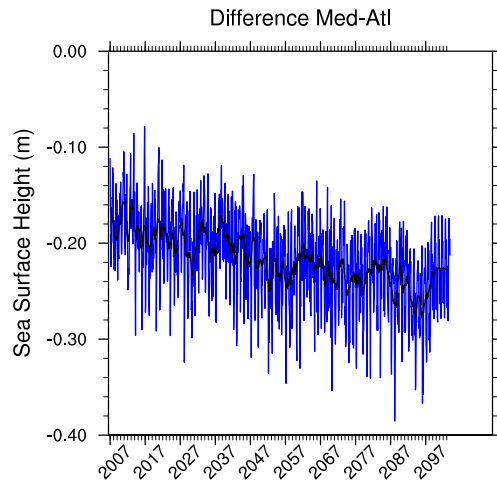
Mediterranean sea level (future climate 2097-2100)

Ocean contribution to the Mediterranean sea level change

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



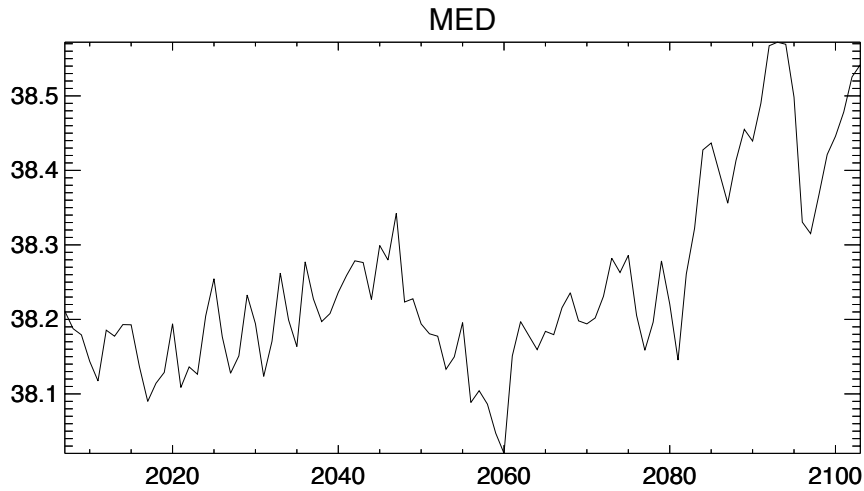
- In the most severe scenario projection Med SLR trend is slightly lower than the global one
- The Med is expected to gain roughly 80 cm
- The difference between Atlantic Ocean and Med Sea increases
- Black Sea SL rises too, gaining almost 70 cm, with a more marked interannual variability



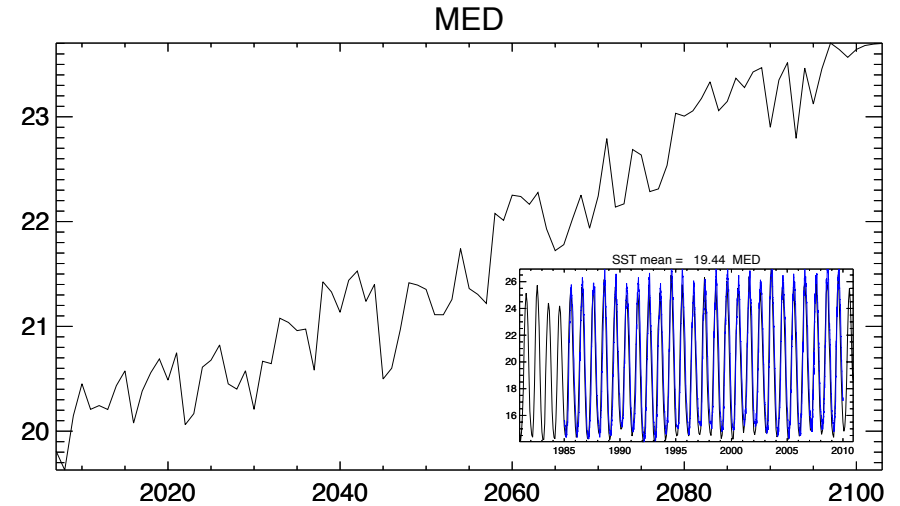
Ocean contribution to the Mediterranean sea level change

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

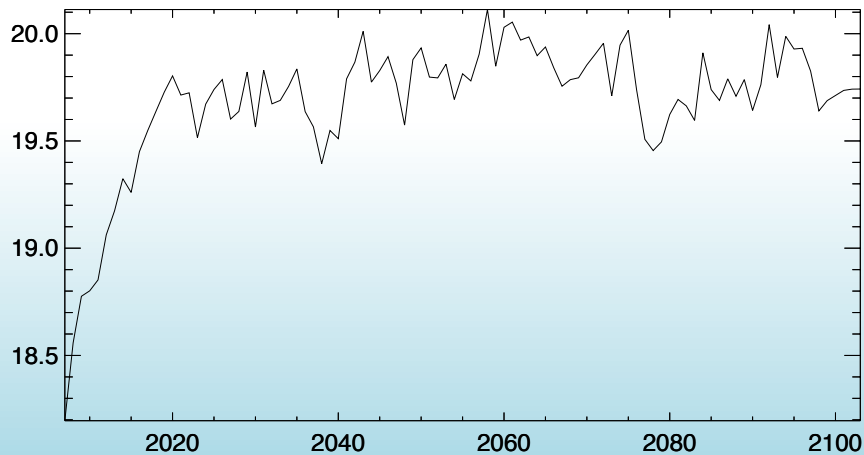
Sea Surface Salinity



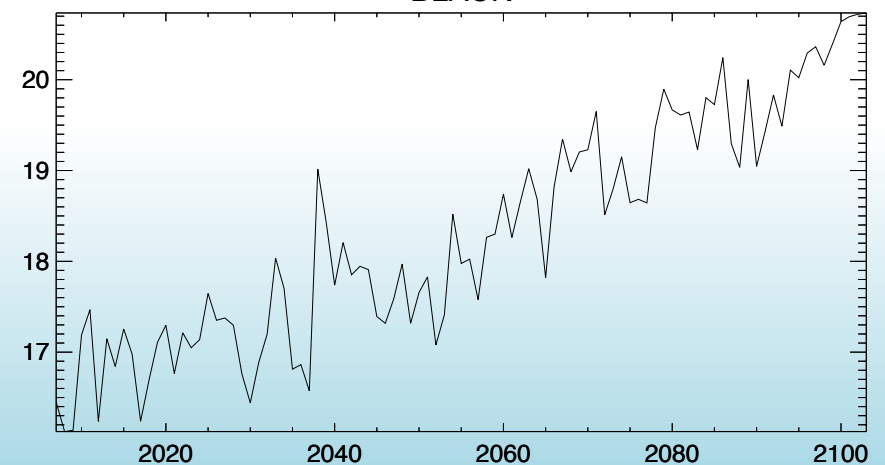
Sea Surface Temperature



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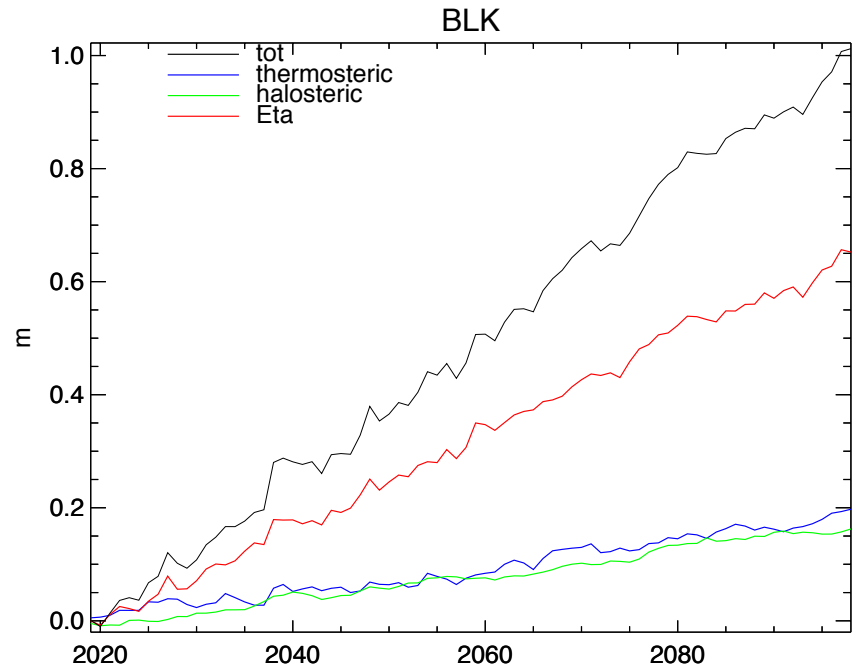
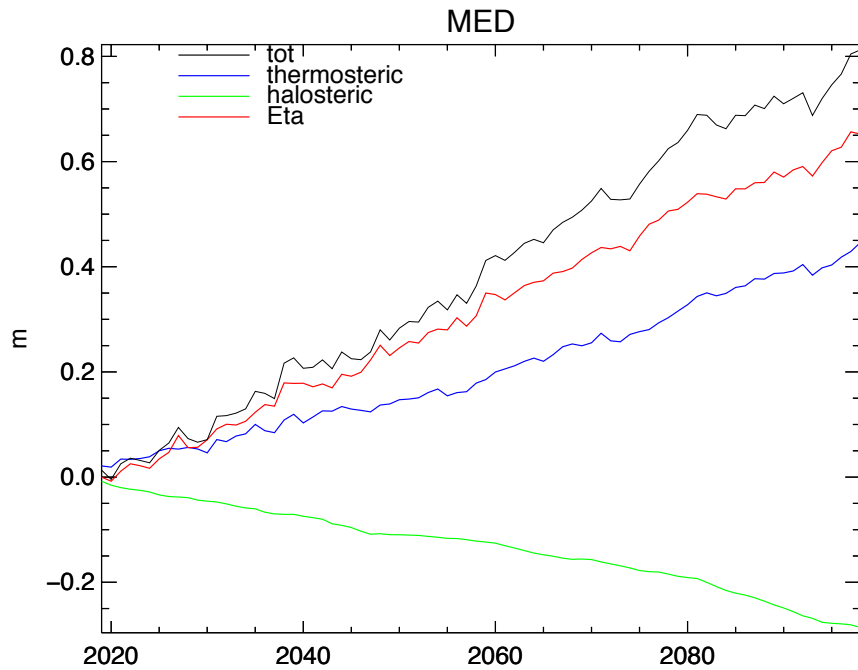


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Ocean contribution to the Mediterranean sea level change: The steric component

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



Concluding remarks

- 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.

GRAZIE PER L'ATTENZIONE,

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