

Ocean climate modelling in the Mediterranean: The MedCORDEX initiative

Gabriel Jordà

gabriel.jorda@uib.cat



HyMeX



Unión Europea

Fondo Europeo
de Desarrollo Regional
"Una manera de hacer Europa"



GOBIERNO
DE ESPAÑA

MINISTERIO
DE ECONOMÍA
Y COMPETITIVIDAD



People participating

Ufuk Turuncoglu, Jonathan Beuvier, Jose C. Sanchez-Garrido, Ali Harzallah, Bodo Ahrens, Ricardo Farneti, Alba de la Vara, Enrique Sánchez, Diego Macías, Gabriel Jordà, Gianmaria Sannino, Samuel Somot, Robin Waldman, Claudia Pasquero, Agostino Meroni, Thomas Arsouze, Vladimir Djurjevic, Antonio Parodi, Piero Lionello, Sofianos Sarantis, Vassilios Vervatis, Miguel Angel Gaertner, Roland Aznar, Pedro Galan, Laurent Li



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The Mediterranean Sea

- **150 M people live along its coasts**
- **Historical economic importance (linked to climate conditions)**
- **In the Balearic Islands: 45% of the GDP linked to tourism**
- **Large biodiversity (0.8% of**

(UN-DESA, 2015)

Why do we focus on Mediterranean Climate?

What is climate?

AMS Glossary::

“The slowly varying aspects of the atmosphere-hydrosphere-land surface system”

· Also ...

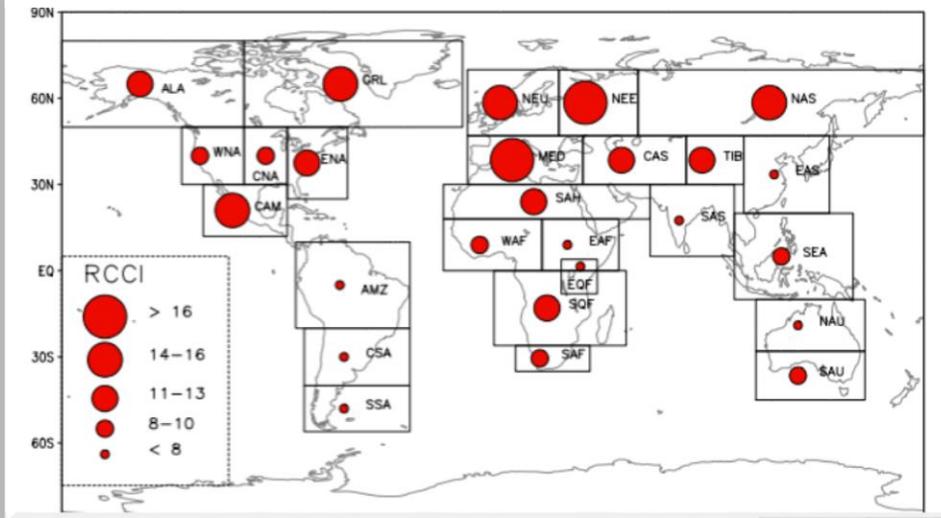
“Climate is the statistical description of weather”

Climate shapes the structure and functioning of ecosystems, societies and economy. Thus, variations on the climate will have impact on all those elements

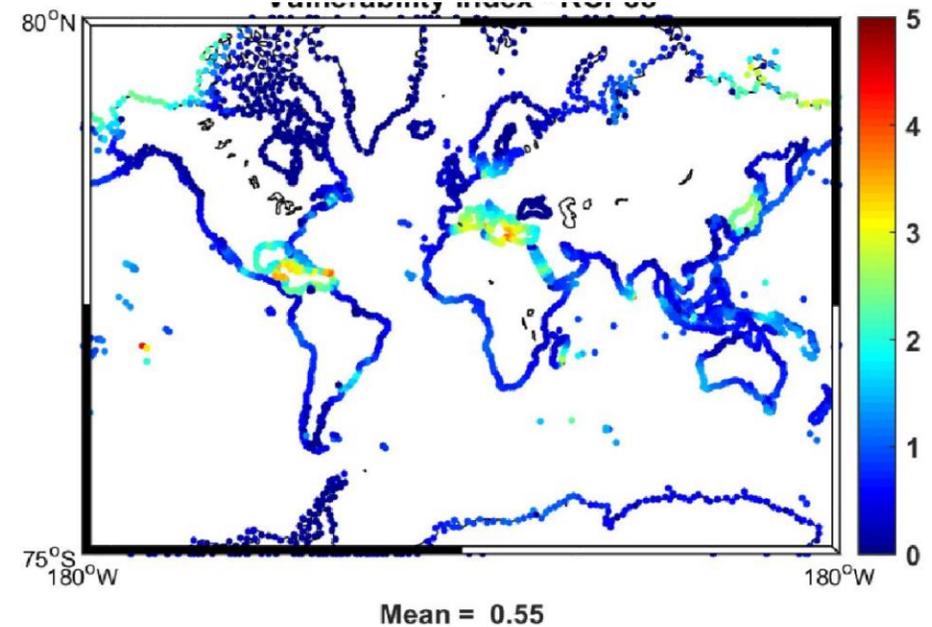
Why do we focus on Mediterranean Climate?

The Mediterranean is one of the hot-spots for climate change, being specially vulnerable due to migrations of climate-type boundaries (i.e. large changes in T/P) and sea level rise.

Regional Climate Change Index (*Giorgi, 2006*)



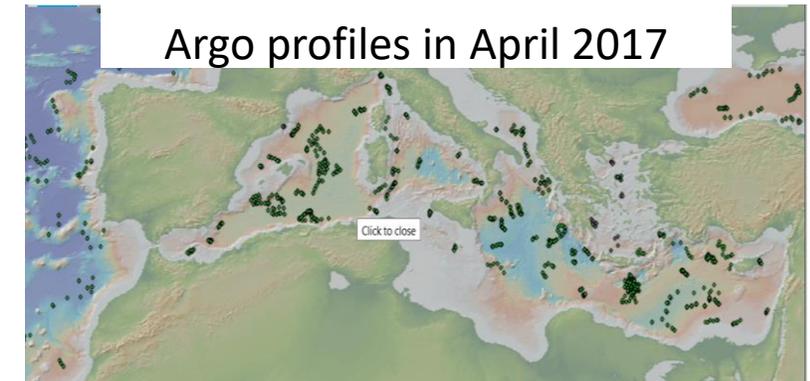
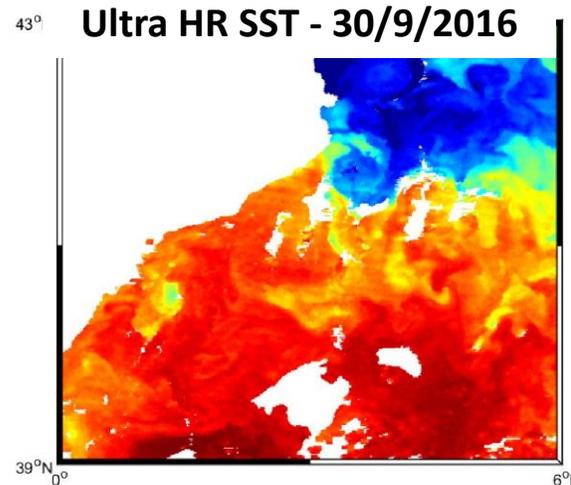
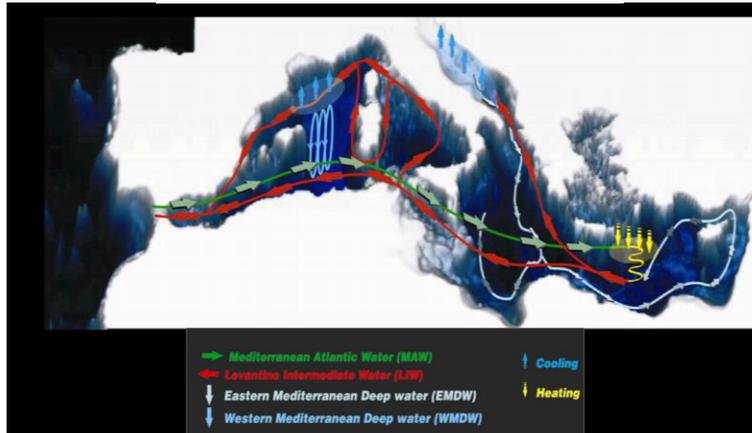
Vulnerability Index to Sea Level Rise (*Jordà et al., 2017*)



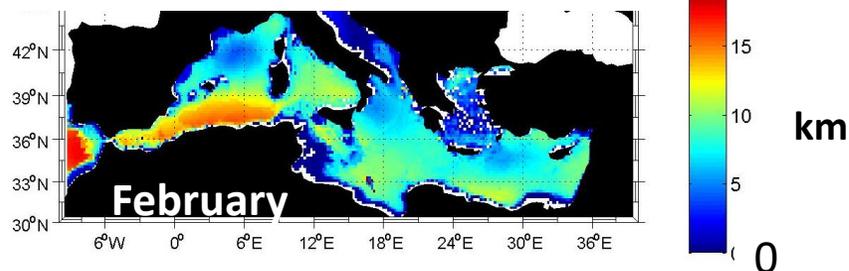
The Mediterranean, an appealing case study

The Mediterranean Sea is one of the few places in the world where **water masses are formed** and an **overturning thermohaline circulation** appears. Also the deformation radius is small (from 2-20 km) and presents a very **active mesoscale field** which plays a key role in the air-sea interactions. Also, it is **one of the best observed oceanic regions** in the world.

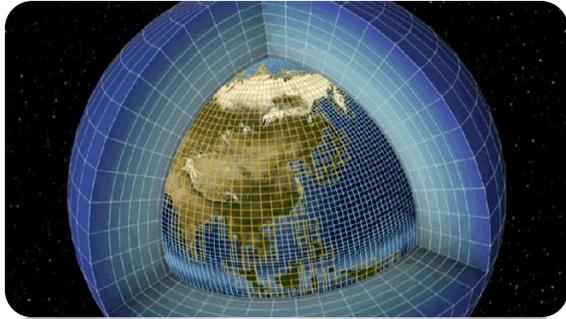
Mediterranean THC



Rossby Radius of Deformation

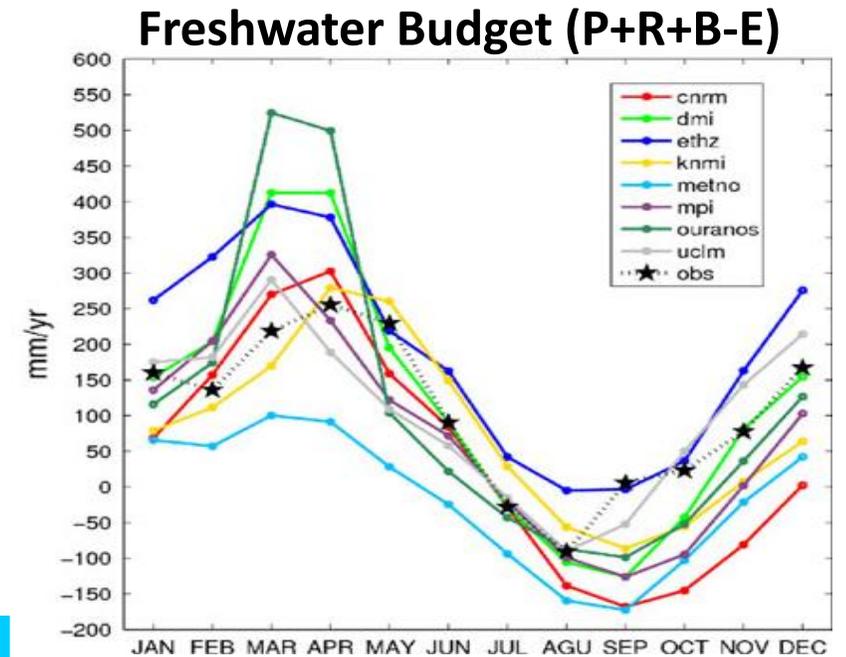
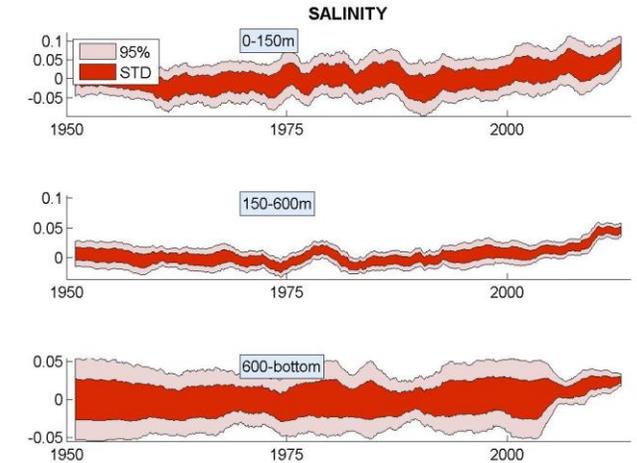


Modelling the regional climate, a risky business



Initial conditions
Atlantic information
Surface forcing
River data
Black Sea

Resolution
Parametrizations
Surface boundary conditions
Lateral boundary conditions
Initialization strategy



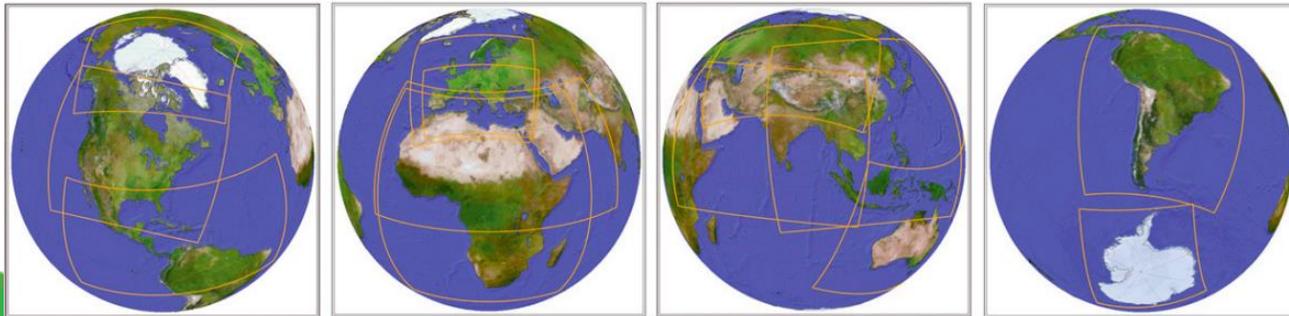
Joining efforts, the multimodel initiatives



The CORDEX vision is to advance and coordinate the science and application of regional climate downscaling through global partnerships.

The Coordinated Regional Downscaling Experiment (**CORDEX**) is a project of the World Climate Research Program.

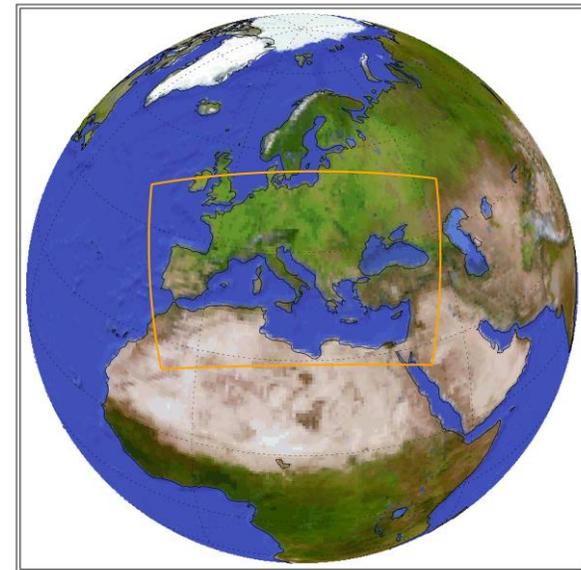
MedCORDEX is one of the 14 regional domains. It has been proposed as the follow-up of previous and existing initiatives and is supported by HyMEX and MedCLIVAR. At present it is the **largest effort in terms of regional coupled models** (23 modelling teams from 9 countries).



The MedCORDEX initiative

www.medcordex.eu

Ruti et al., BAMS, 2015



Med-CORDEX, 2010-2015

Main Achievements

www.medcordex.eu
medcordex@hymex.org

- **23 different modelling groups** (ENEA, CNRM, LMD, MPI, IPSL, UCLM, ENSTA, MERCATOR, INSTM, GUF, ICTP, CMCC, Puertos de l'Estado, Univ. of Athens, Univ. Belgrade, UPM, KIT, ITU, UAH, Eotvos Lorand U, IC3, BSC, JRC) from **9 countries** (France, Italy, Spain, Serbia, Greece, Turkey, Tunisia, Germany, Hungary) in **Europe, Middle-East** and **North-Africa**
- **87 individual members** in the Med-CORDEX Science Team
- 9 atmosphere RCMs (minimal resol. 50 km), 4 atmosphere RCMs running at 12 km, 10 ocean models (min. resol. 25 km), 5 surface models and **12 fully-coupled RCSMs** (3 including river coupling) and a total of **106 climate simulations**. Historical and scenario runs use **6 different GCMs from CMIP5**
- Database : Upload (March 2016): 116.000 files, 4.4 To / **Download: 412.000 files, 13.5 To** by **125 users** (incl. 39 HyMeX users)
- **Ruti et al. 2015 (BAMS) + 43 published articles** since 2011 + **28 articles to appear in a special issue in Clim. Dyn.** (France, Italy, Germany, Spain, Tunisia, Greece, Croatia)

Med-CORDEX is the largest coordinated multi-model effort ever for Mediterranean climate simulations

Med-CORDEX is the largest coordinated effort using coupled regional climate models

Med-CORDEX provides for the first time long-term regional ocean simulations in a standardized and open way

Med-CORDEX II , 2016-2020

Common baseline runs and targeted Flagship Pilot Studies (FPS)

Baseline runs :

Characterization of the Regional climate variability and future change , of the relevant Mediterranean climate phenomena and of the Mediterranean climate impacts

FPS3:

Role of the air-sea coupling and small-scale ocean processes on regional climate

FPS2:

Convection phenomena at high-resolution over Europe and the Mediterranean

FPS1:

Role of the natural and anthropogenic aerosols in the Mediterranean region

SIMED



HPC in MedCORDEX

All activities of MedCORDEX teams rely on HPC resources, although with different approaches. Some teams can use their own HPC resources (e.g. MétéoFrance), others use small clusters for small applications while rely on PRACE/RES for the demanding experiments. *This may pose problems to ensure results for certain projects with rigid deadlines !*

Experiments require intensive use for a limited period of time (ie. few but demanding experiments)

An example, the ENEA experience

Cluster USED

2 sockets with 8 cores Intel E5-2670 2.6 GHz 64 GB/RAM (4 GB per core)

One interface IB QDR 40 Gb/s

Two interfaces GbE

Resources needed

MITgcm 1/12° Ocean forced model.

312 cores - 5 years/day

MITgcm 1/12° Atmosphere/Ocean coupled model.

252 cores - 1 years/day

MITgcm very high resolution for the Turkish Straits Systems

252 cores 1.5 month/day

Climate runs require o(100 yrs) runs (0.2 - 1. Millions of core hours per exp.)

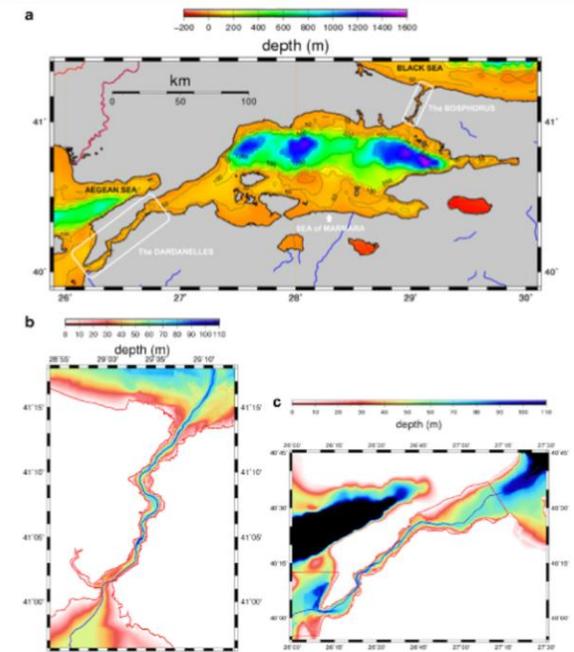
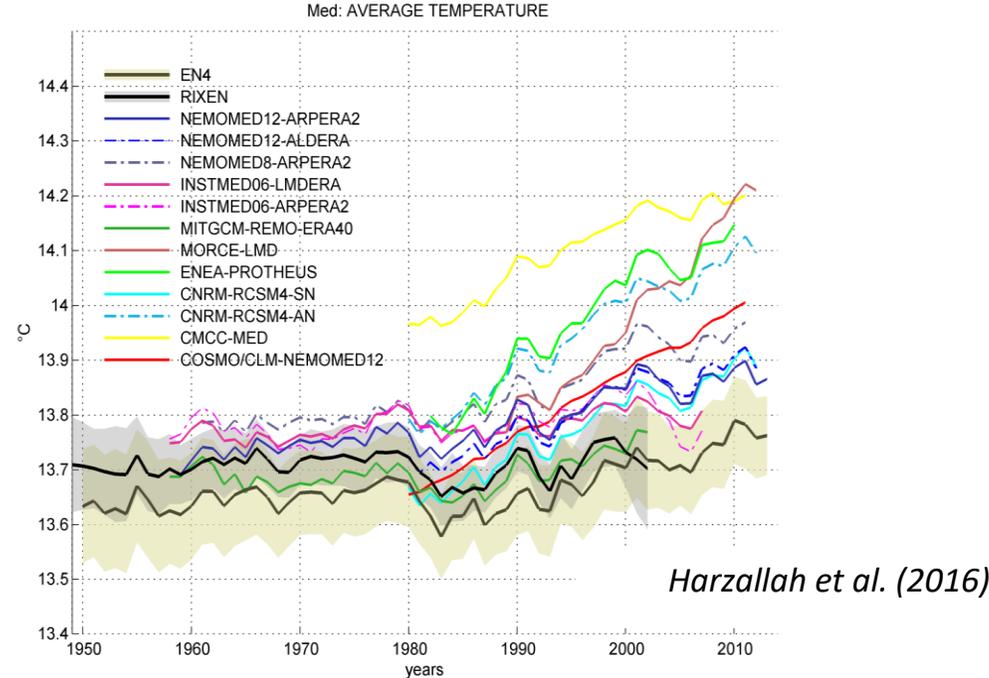


Fig. 1 Location and bottom topography maps for a Turkish Straits System (TSS) including b Dardanelles and c Bosphorus Straits. The blue line denotes the thalweg along the strait channels

Sannino et al., 2017

Results : *Mediterranean Heat Content*

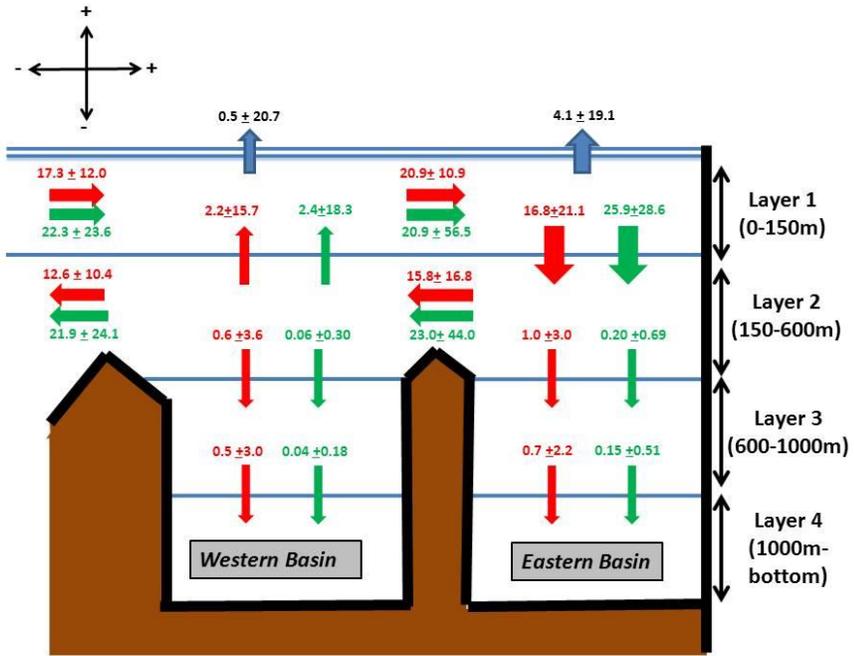


Most RCMs reproduce quite well the interannual variability of Med Heat Content thanks to the good quality of the surface forcing and the relative low influence of Gibraltar at those scales.

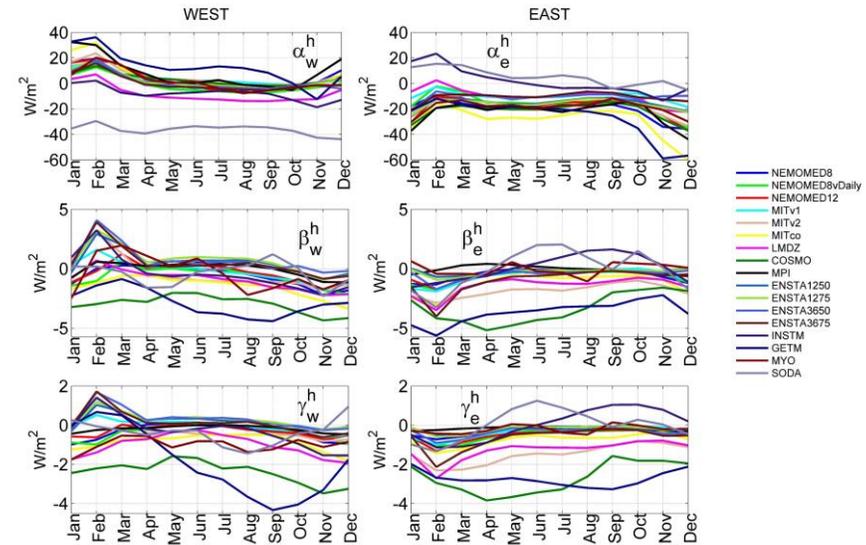
Some of them show unrealistic trends due to initialization problems (spin up)

Biases are due to the initialization dataset - Note of caution with the observational limitations!!

Results : Mediterranean Heat and Salt redistribution



Seasonal cycle of heat transfer between layers



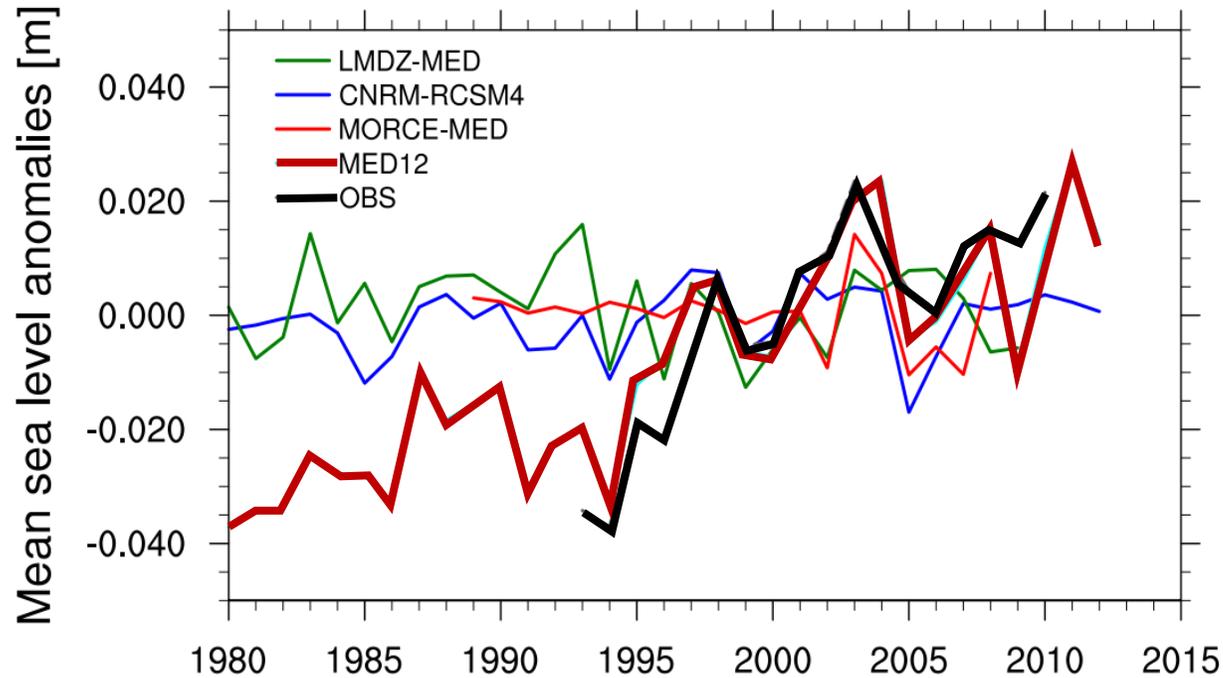
Most of the heat and salt is transferred in a loop in the upper 600m with heat losses in the Eastern basin. Only ~5% is transferred to the layers below

But the ensemble of models show discrepancies.

No observations reliable enough to estimate heat and salt redistribution.

We can discard some of the models based on knowledge of the region (e.g SODA) but it is very difficult to determine which of the other RCMs is better: We have to work with uncertainties

Results : Sea Level representation in Med RCMs



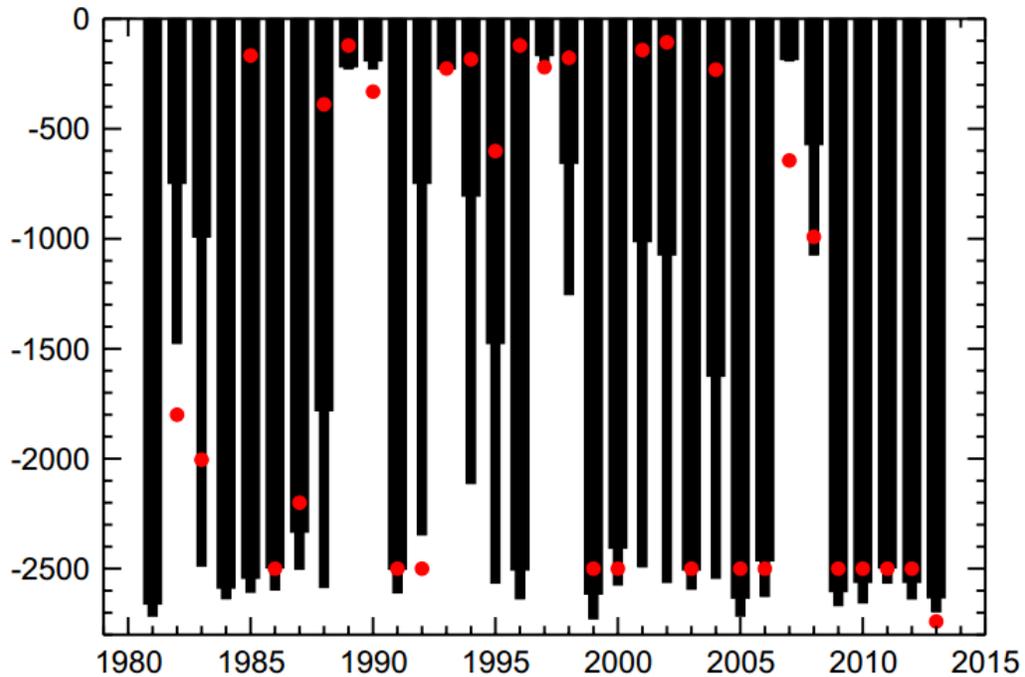
LMDZ - Fixed Atlantic
CNRM - Atlantic from GCM
MORCE - Atlantic from reanalysis
MED12 - Corrected Atlantic
OBS - Altimetry

Adloff et al., (2016)

Basin averaged sea level can be properly reproduced but ONLY if a proper treatment for the Atlantic boundary conditions is applied.

Results : *Western Mediterranean DW formation*

*Interannual time series of the yearly maximum Mixed Layer Depth (in m).
Black bars - model, red dots - observational indicators*

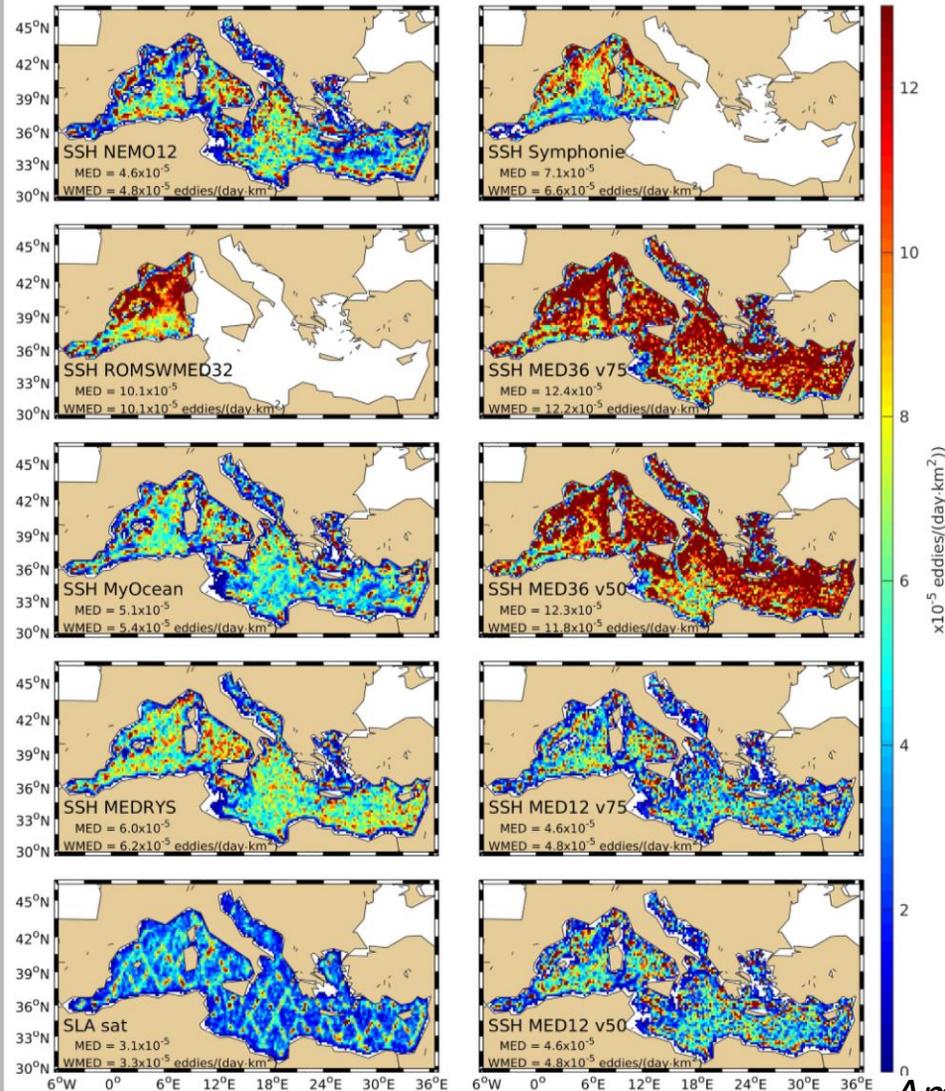


Somot et al. (2016)

Some of the ORCMs show good skills reproducing the chronology and intensity of the DW formation events.

Results : Eddy field statistics

Density of eddies in an ensemble of models (eddies/(day km²))



The analysis of the ensemble of climate models highlights the impact of model resolution, differences on model physics and more important, the strong limitations of observational estimates

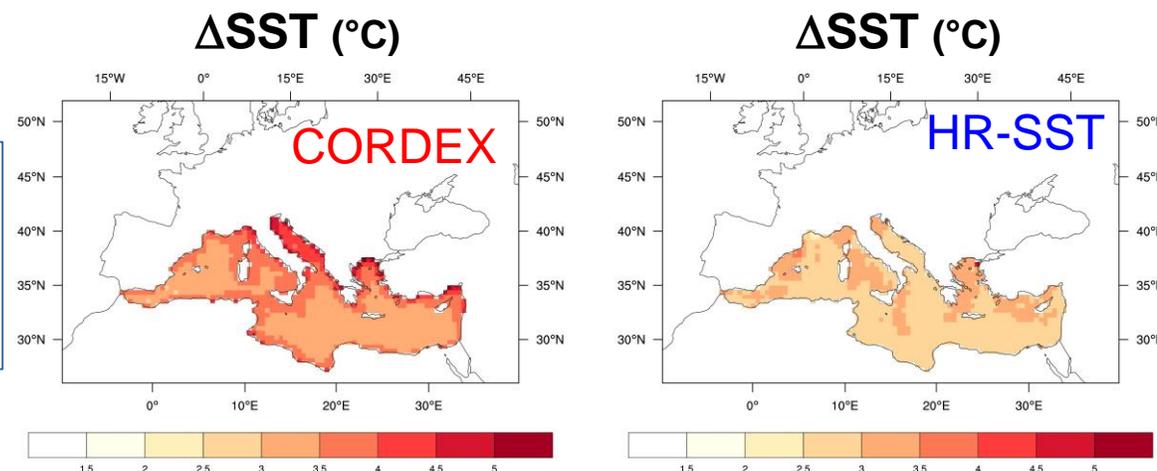
Amores and Jordà , 2017

Results : *Impact of the high-resolution SST representation*

1- What is the role of the air-sea coupling in both regional climate variability and future projections?

Example: Comparing an Atmosphere only with a twin Atmosphere-ocean coupled simulation (CNRM, Somot et al., 2016)

**Climate change signal
in Summer**
(RCP8.5, JJA,
2071-2100 vs 1976-2005)



- SST warms less in HR-SST run than in CORDEX run
- Spatial pattern of the warming is different (Balearic Sea, Adriatic Sea)

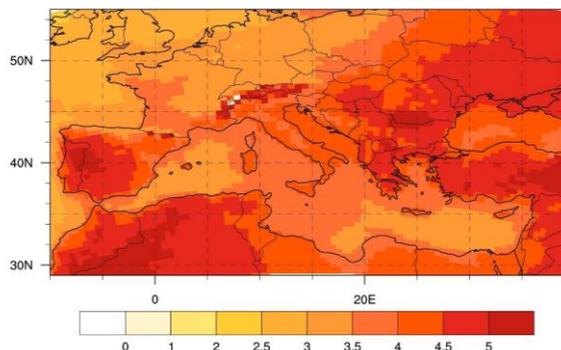
* Here CORDEX means the GCM ocean model and
HR-SST means the high-resolution Mediterranean Sea model

Results : *Impact of the high-resolution SST representation*

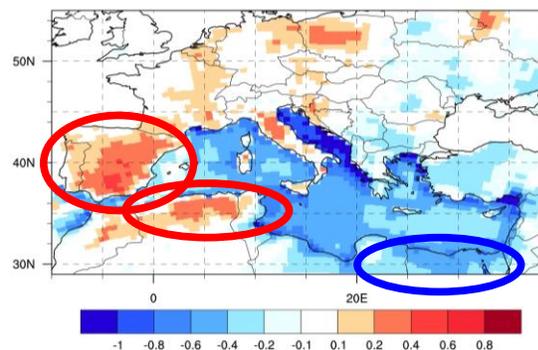
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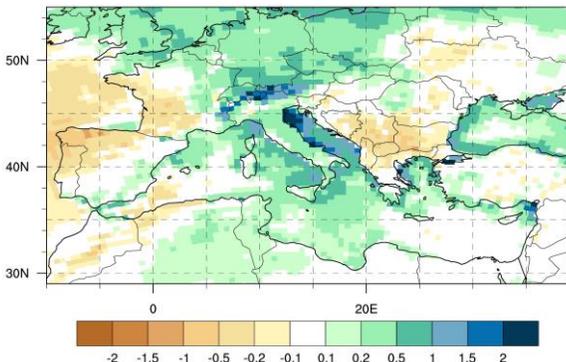
ΔT_{2m} (°C)



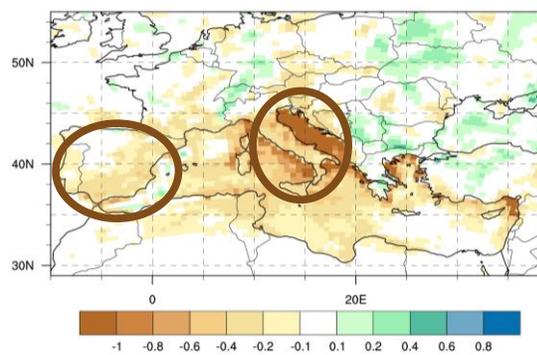
$\Delta\Delta T_{2m}$ (°C)



$\Delta Prec$ (mm/d)



$\Delta\Delta Prec$ (mm/d)



- T2m climate change signal is modified over sea and surrounding lands
- Enhanced drying over sea and surrounding lands in HR-SST
- Land-sea contrast and dynamical modifications explain the West Europe signal

Climate change signal in Summer
(RCP8.5, 2071-2100 vs 1976-2005, JJA)

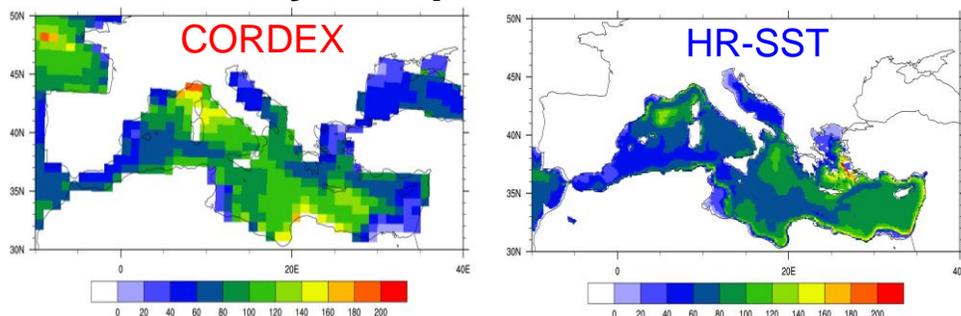
Difference of Summer climate change signal between HR-SST and CORDEX

Results : *Impact of the high-resolution SST representation*

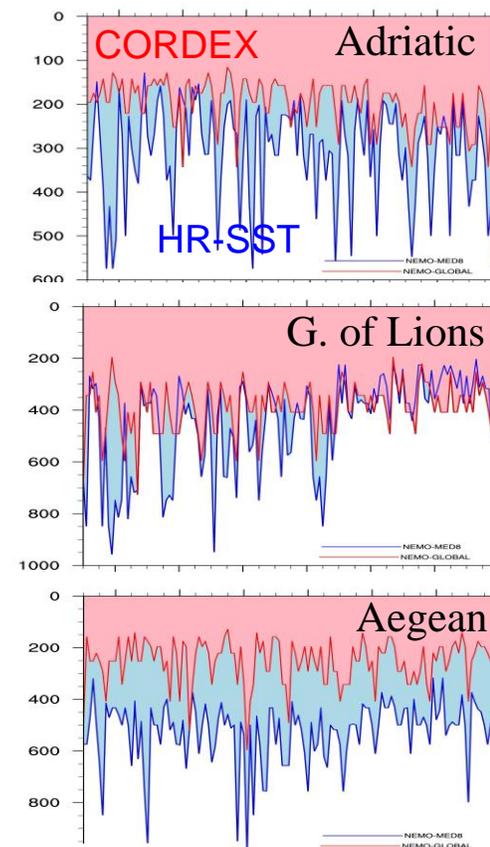
2-What is the role of small scale oceanic processes in both regional climate variability and future projections?

Example: Comparing an Atmosphere only with a twin Atmosphere-ocean coupled simulation (CNRM, Somot et al., 2016)

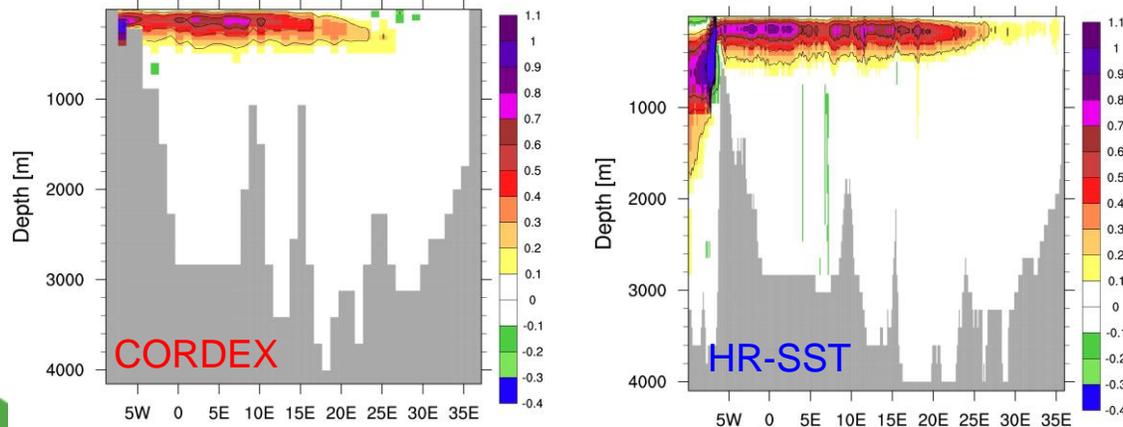
Mixed layer depth (m, DJF, 1976-2005)



Yearly maximum MLD (m)



Zonal overturning streamfunction (S_v , 1976-2005)



* Here CORDEX means the GCM ocean model and HR-SST means the high-resolution Mediterranean Sea model

Future challenges on HPC from the MedCORDEX perspective

Servicios marinos y supercomputación: experiencias y retos futuros



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CESGA
Centro de Supercomputación de Galicia

Seminario científico - 27 SEP 2017 - Santiago de Compostela

Esta jornada científica se celebra el 27 de septiembre en Santiago de Compostela, un día antes de la Jornada de Usuarios de la RES, en la que habrá una sesión de interés para los participantes relacionada con las ciencias de la tierra. Está financiada por la Red Española de Supercomputación, el Instituto Español de Oceanografía y la Rede Galega HPC.

The MedCORDEX community has discussed several times about the next challenges on HPC. Future improvements in computing speed are not a pressing priority (*need more research time to really take advantage of it!*).

Conversely, storage and the processing of huge amounts of data start to be a serious concern. Local storage usually necessary.

Also, it is worth noting that in MedCORDEX there are no code developers that could design computational solutions to optimize the problems. Problems consolidating know-how to exploit/optimize HPC applications (*the publish-or-perish Damocles' sword*)

Shared or Cloud computing, are there a real alternative for climate simulations?

Thanks for your attention

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