CLIVAR 2023: TOWARDS AN INTEGRATED VIEW OF CLIMATE

The MED-CORDEX ensemble future climate projections for the Mediterranean Sea: impacts of the high resolution and ocean-atmosphere coupling

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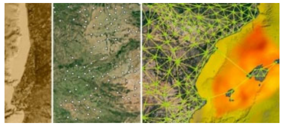


Med-CORDEX

International initiative that aims at developing **fully coupled high resolution Regional Climate Models (RCMs) for the Mediterranean basin**, as part of the global **CORDEX** initiative.

Institutions

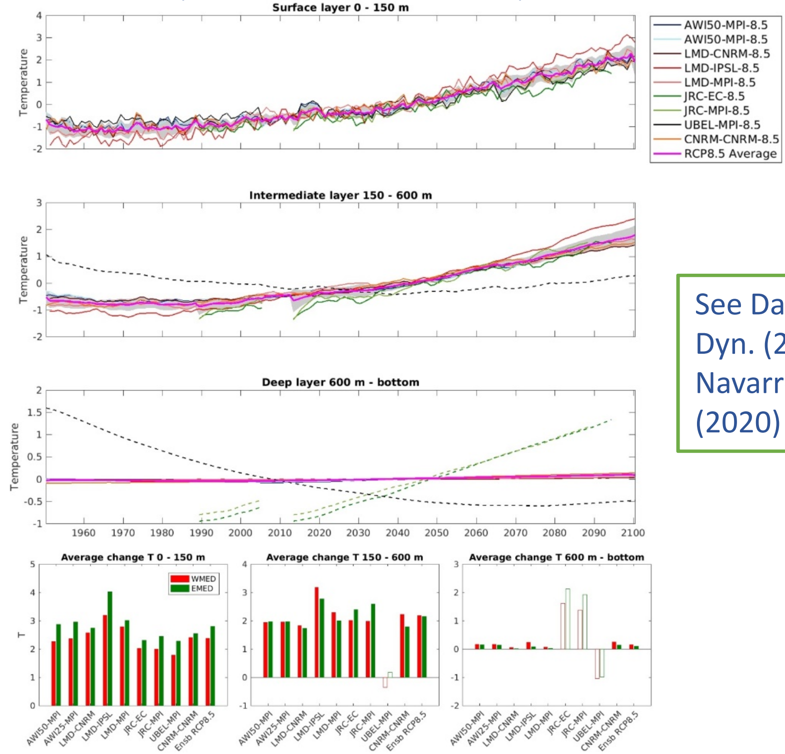
- CMCC
- CNRM
- ENEA
- GERICS-AWI
- GUF
- LMD
- U. Belgrade

Baseline atm – ocean coupled simulations

33 historical and multi-scenario simulations

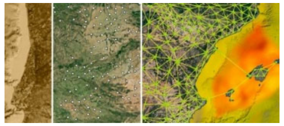
Climate change studies in the Mediterranean basin

Temperature anomalies of the water column from 1950 to 2100 (ºC)
(from Soto-Navarro et al 2020)



See Darmaraki et al., Clim. Dyn. (2019) and Soto-Navarro et al., Clim. Dyn. (2020) for details

www.medcordex.eu

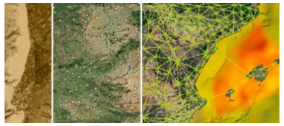


Objectives:

- Is the climate change response consistent in all the models?
- Is there a significant impact of the higher resolution in the RCMs?
- Is there a significant impact of the ocean-atmosphere coupling?

In this presentation: 28 simulations. 14 historical (10 RCM, 4 ARCM), 14 RCP 8.5 scenario runs (10 RCM, 4 ARCM).

Institution	RCM	ARCM	GCM	Scenario	Short Name
CNRM	CNRM-RCSM4		CNRM-CM5	RCP 8.5	CNRM-CM5
	CNRM-RCSM6	CNRM-ALADIN63	CNRM-ESM2-1	SSP 5-85	CNRM-ESM2
GERICS-AWI	GERICS-AWI-ROM25	REMO25	MPI-ESM-LR	RCP 8.5	AWI-25-MPI
	GERICS-AWI-ROM50	REMO50	MPI-ESM-LR	RCP 8.5	AWI-50-MPI
LMD	LMD-LMDZNEMOMED8		IPSL-CM5A-MR	RCP 8.5	LMD-IPSL
			MPI-ESM-MR	RCP 8.5	LMD-MPI
			CNRM-CM5	RCP 8.5	LMD-CNRM
U. Belgrade	EBU-POM2	EBU	MPI-ESM-LR	RCP 8.5	UBEL-MPI
CMCC	CMCC-CCLM4		CMCC-CM	RCP 8.5	CMCC-CMCC
GUF	CLMcom-GUF-CCLM5		EC-EARTH	RCP 8.5	GUF-ECEARTH



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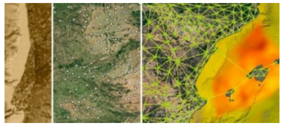
- Analysis of the climate change signal of SST and atmospheric variables at the surface level

Climate Change (CC) signal computed as the difference between the averages of the last 30 years of the projection (2070-2100) and the last 30 years of the historical period (1976-2005).

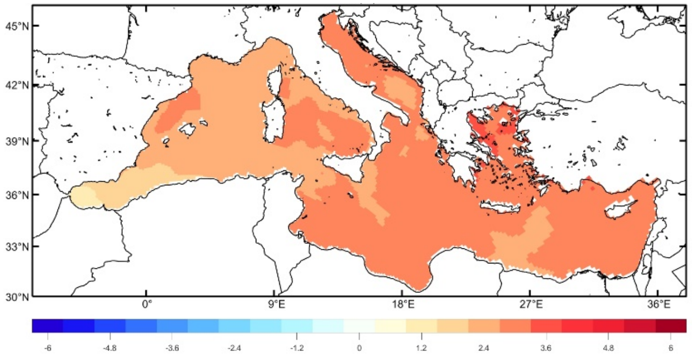
CC signal = average(2070-2100) – average(1976-2005)



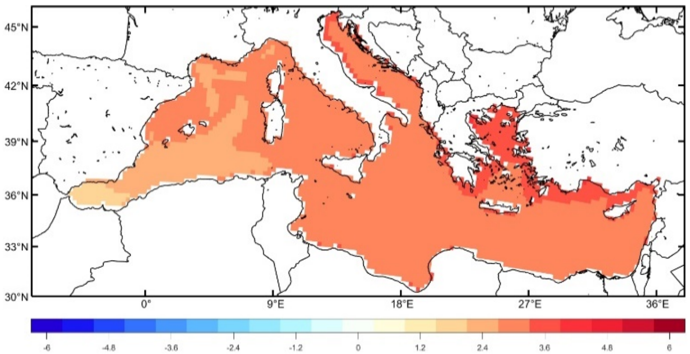
Models CC response

SST and Air temperature increase

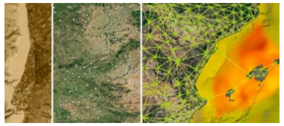
AWI-25-MPI **SST CC signal (ºC)**



AWI-25-MPI **Air T CC signal (ºC)**



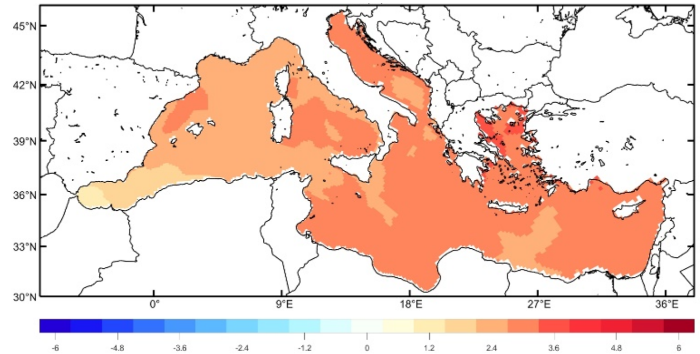
- All the simulations show a warming of the sea surface **between 2.5 and 4 ºC** on average.
- The Air T average increase is around **30% higher** than for the SST.



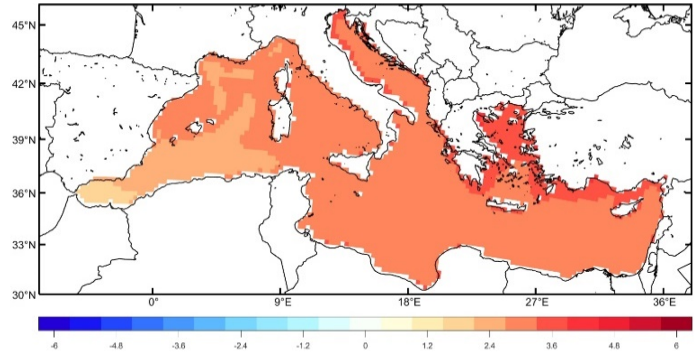
Models CC response

SST and Air temperature increase → Decrease of the net heat losses towards the atmosphere (heat gain)

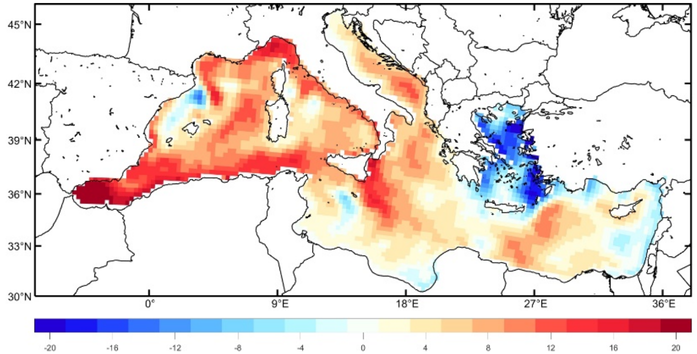
AWI-25-MPI **SST CC signal (ºC)**



AWI-25-MPI **Air T CC signal (ºC)**

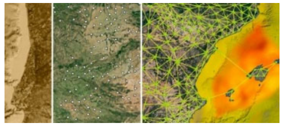


AWI-25-MPI **Net Surface Heat Flux CC signal (W/m^2)**



Heat flux positive downwards (towards the ocean)

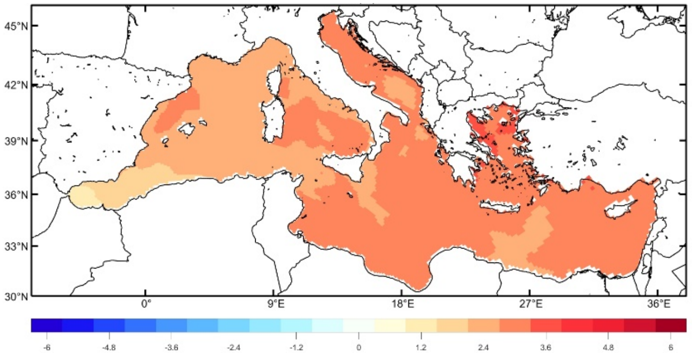
- Decrease in the net heat loss (average **0.2 – 4.3 W/m^2**) with high spatial variability → the **atmosphere is cooling less the sea** and even starting to warm it for some models.



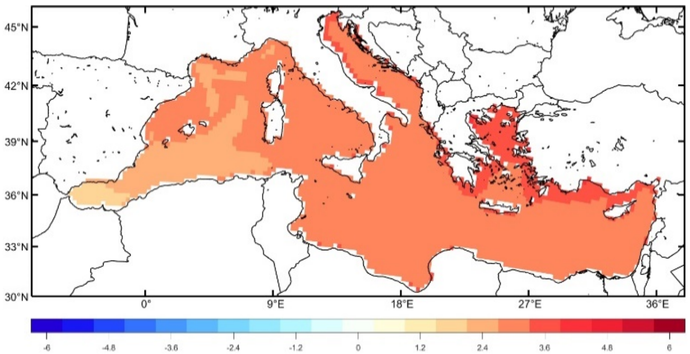
Models CC response

SST and Air temperature increase → Decrease of the net heat losses towards the atmosphere (heat gain) → Decrease of Precipitation

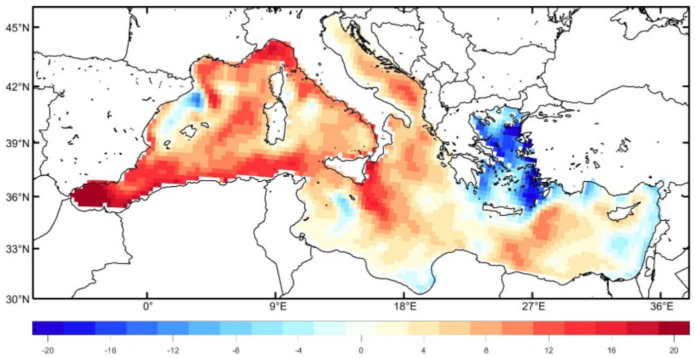
AWI-25-MPI **SST CC signal (ºC)**



AWI-25-MPI **Air T CC signal (ºC)**



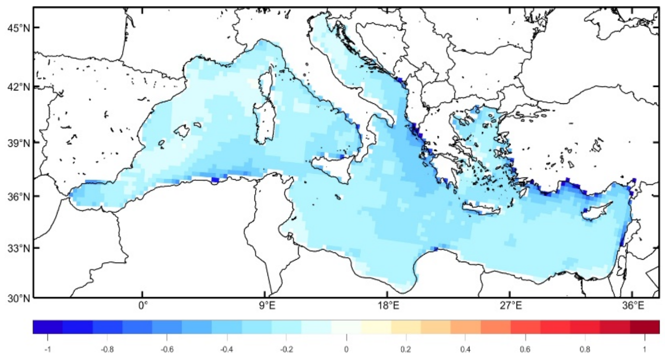
AWI-25-MPI **Net Surface Heat Flux CC signal (W/m²)**



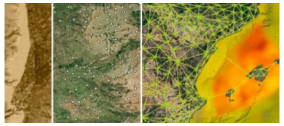
Heat flux positive downwards (towards the ocean)

- Decrease in the net heat loss (average 0.2 – 4.3 W/m²) with high spatial variability → the **atmosphere is cooling less the sea** and even starting to warm it for some models.

AWI-25-MPI **Precipitation CC signal (mm/d)**



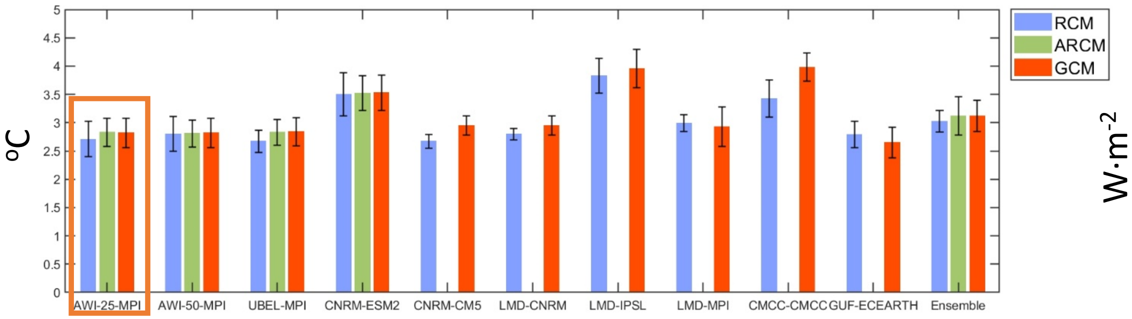
- Precipitation decreases in all RCMs (average -0.1 – -0.4 mm/d).



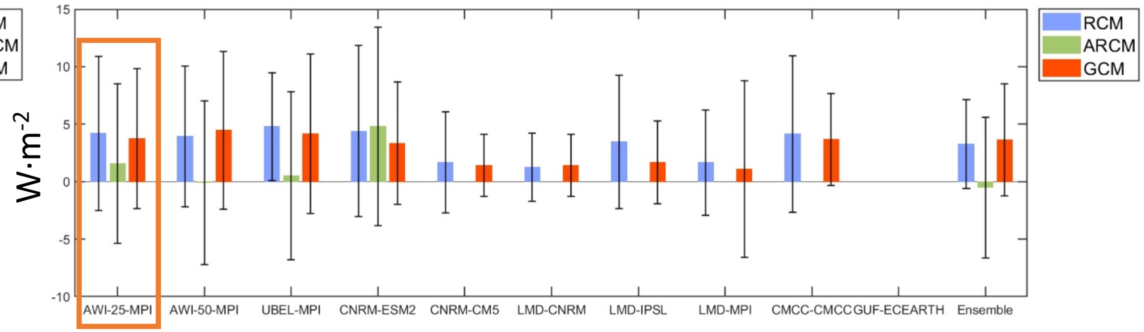
Models CC response

Consistency among all the models

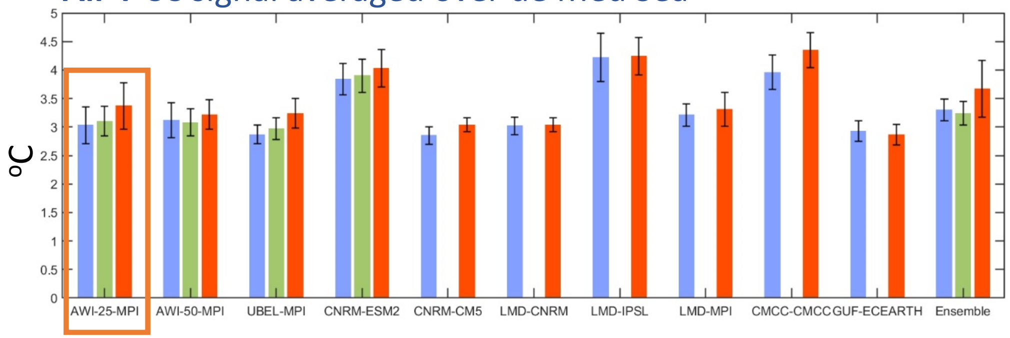
SST CC signal averaged over de Med Sea



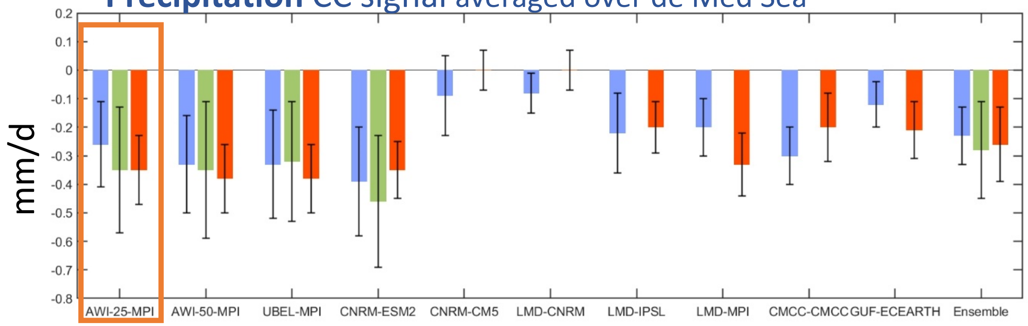
Net Surface Heat Flux CC signal averaged over de Med Sea



Air T CC signal averaged over de Med Sea



Precipitation CC signal averaged over de Med Sea



Impact of the resolution

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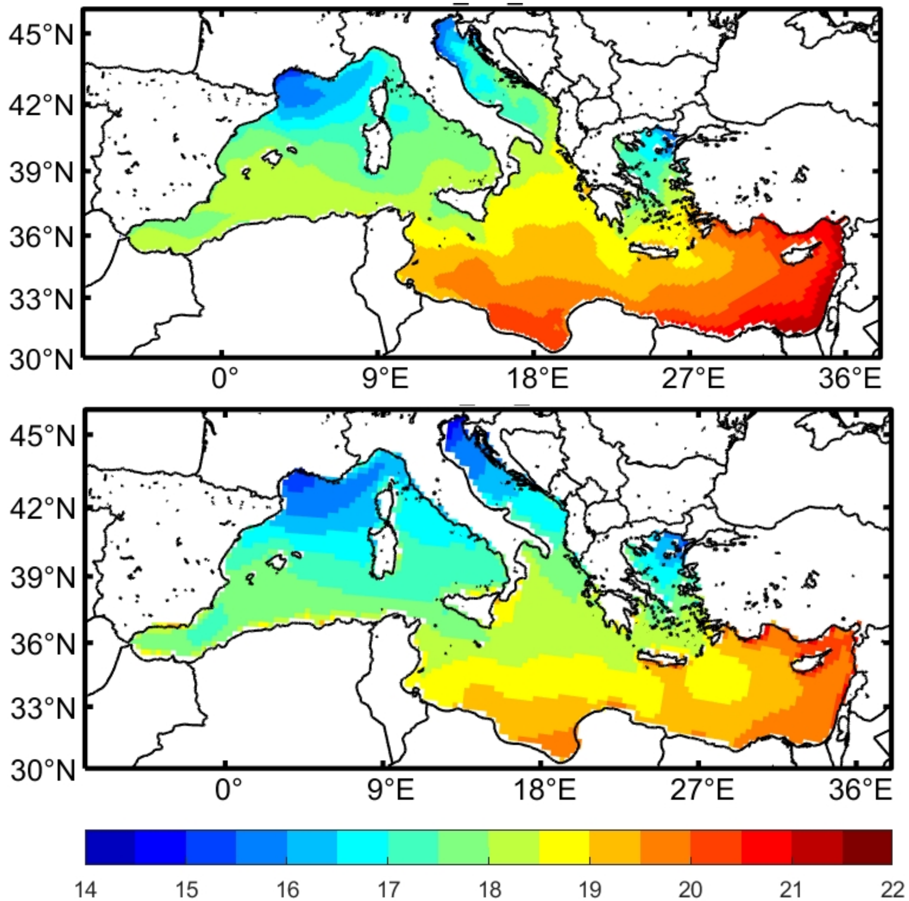
RCM

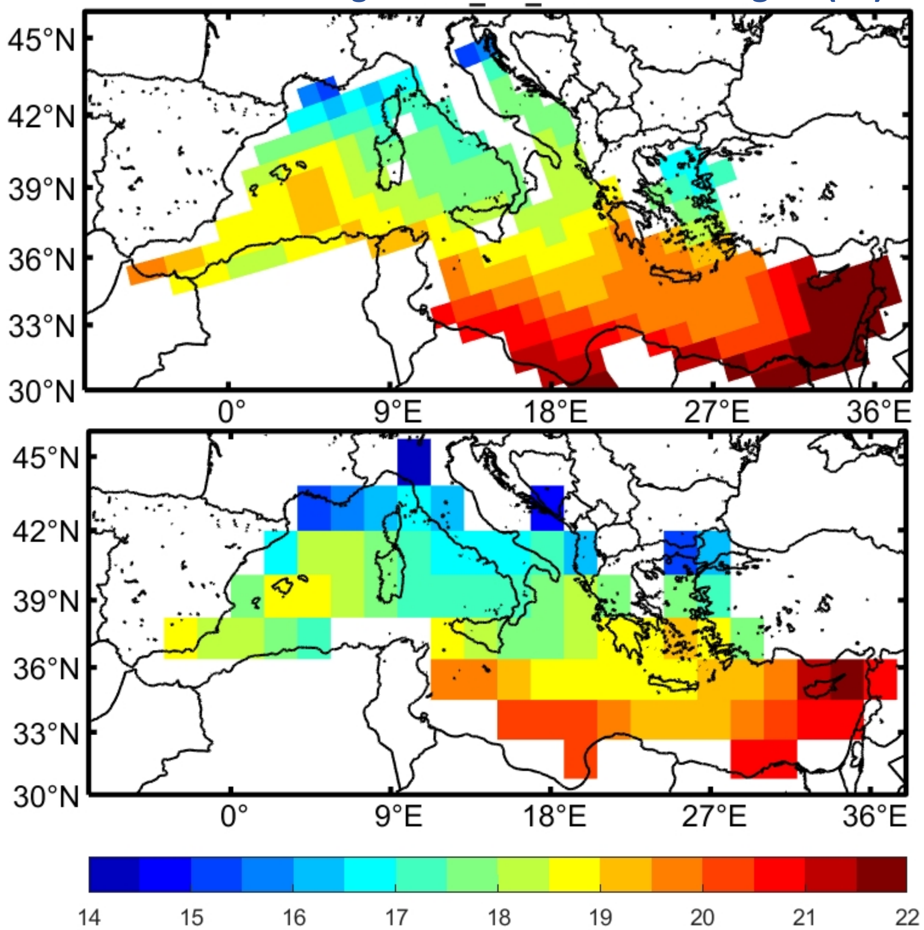
AWI-ROM25 average historical **SST & Air T signal (ºC)**

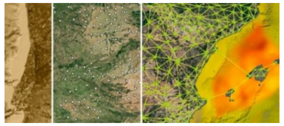


Vs

GCM

MPI-ESM-LR average historical **SST & Air T signal (ºC)**

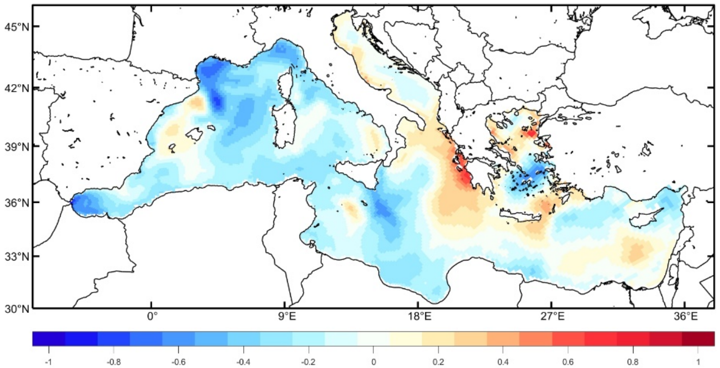




Impact of the resolution

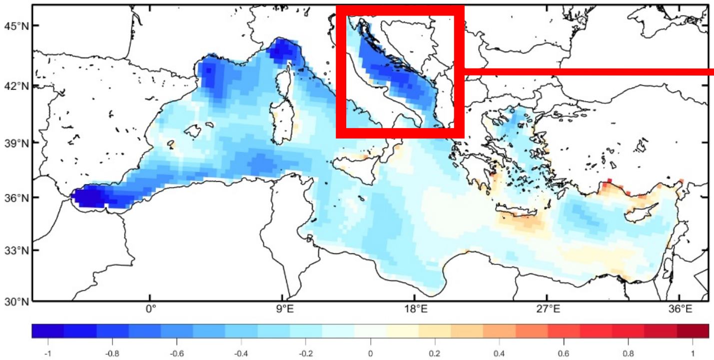
Differences between the RCMs and GCMs CC signals

AWI-ROM25 vs MPI-ESM-LR **SST dCC signals (ºC)**

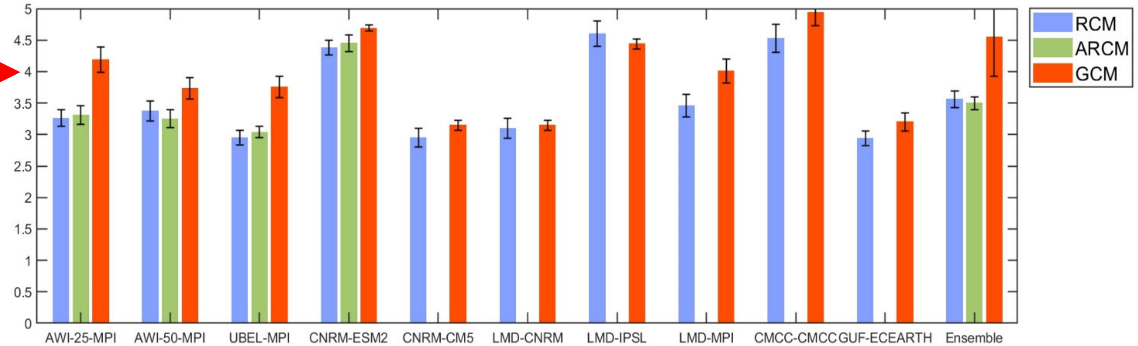


- The average **SST** CC signal is slightly stronger in the GCMs (**+ 0.2 ºC on average**).
- Significant differences between RCM and GCM SST in the **spatial structures**.
- The **air T** signal is clearly stronger in the GCMs (**+ 0.4 ºC on average**).
- More **pronounced differences in specific regions** as the Adriatic or the Gulf of Lions, reaching 1 ºC on average in these sub-basins.

AWI-ROM25 vs MPI-ESM-LR **Air T dCC signals (ºC)**



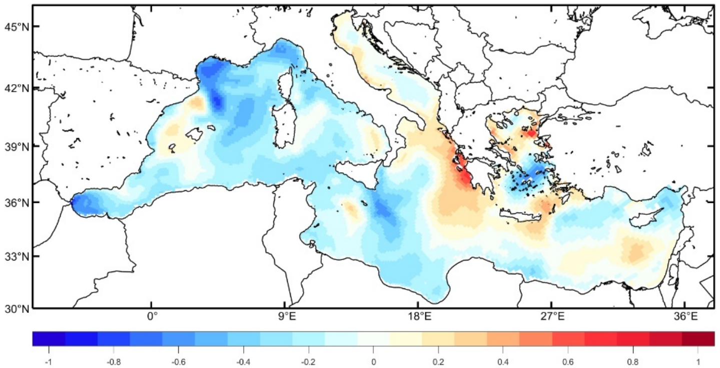
Air T CC signal averaged over the **Adriatic Sea**



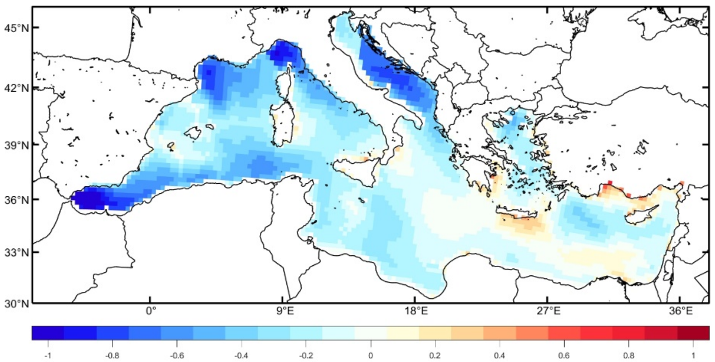
Impact of the resolution

Differences between the RCMs and GCMs CC signals

AWI-ROM25 vs MPI-ESM-LR **SST dCC signals (ºC)**

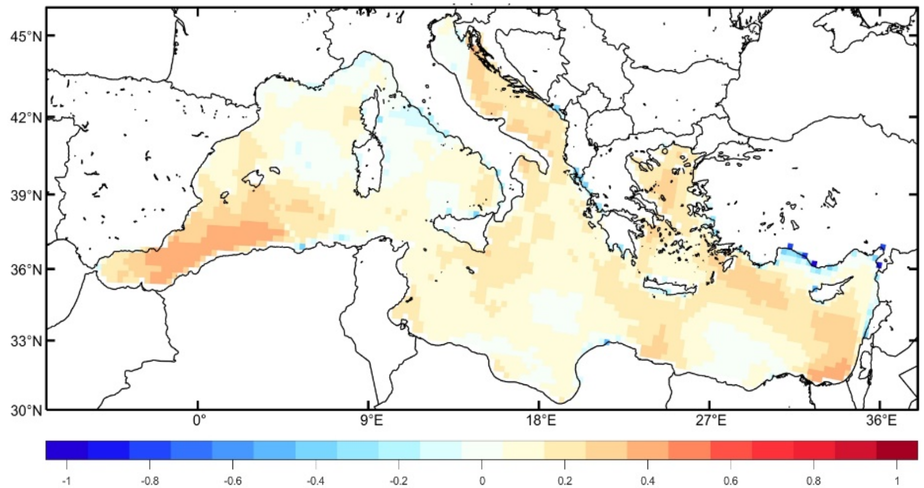


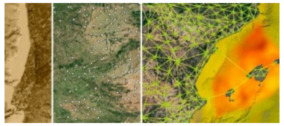
AWI-ROM25 vs MPI-ESM-LR **Air T dCC signals (ºC)**



- The higher SST, air temperature and the consequent increase in the heat gain in the GCMs are translated in **a generalized higher reduction of the precipitation over the basin (+0.2 mm/d on average, although very dependent on the model).**

AWI-ROM25 vs MPI-ESM-LR **Precipitation dCC signals (mm/d)**

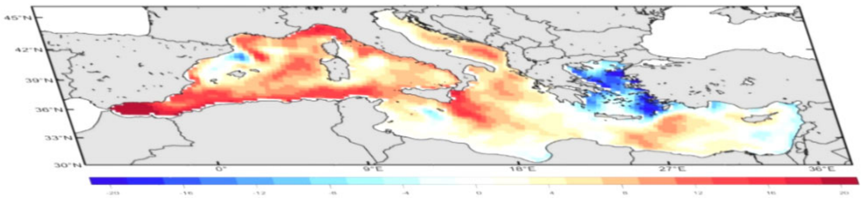




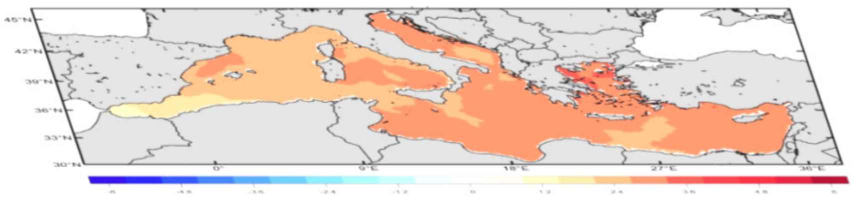
Impact of the coupling

RCM

High resolution atmospheric model



Feedback between ocean and atmosphere

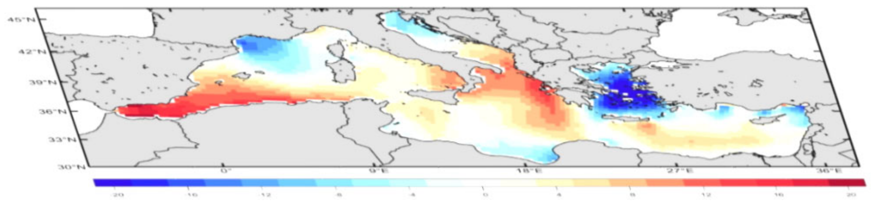


High resolution ocean model

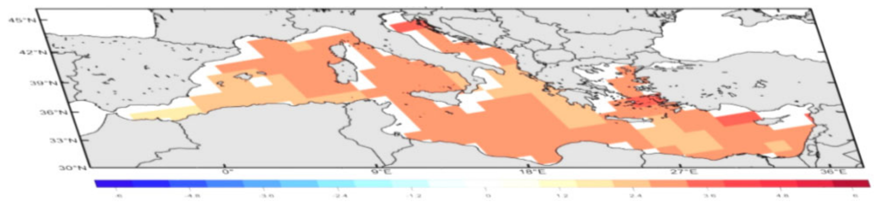
Vs

ARCM

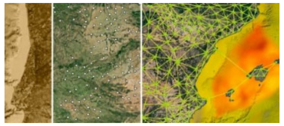
High resolution atmospheric model



SST boundary condition from GCM, no feedback



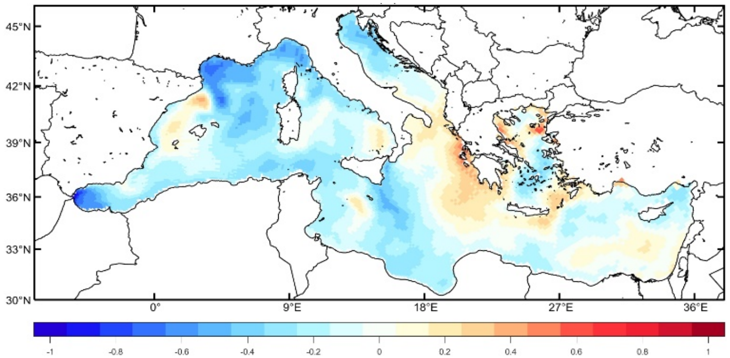
Low resolution SST from GCM



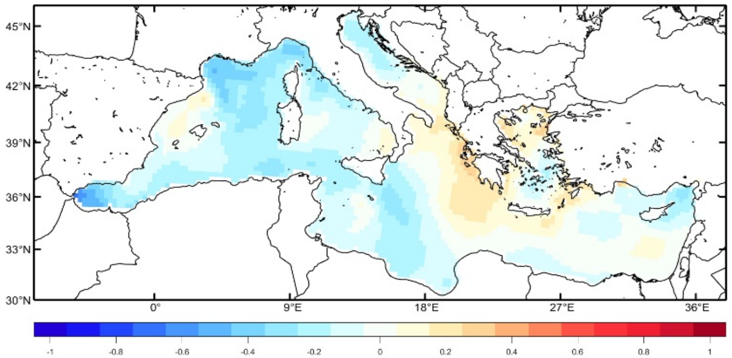
Impact of the coupling

Differences between the RCMs and ARCMs CC signals

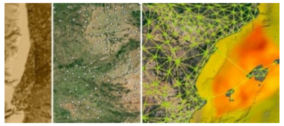
AWI-ROM25 vs REMO25 **SST dCC signals (ºC)**



AWI-ROM25 vs REMO25 **Air T dCC signals (ºC)**



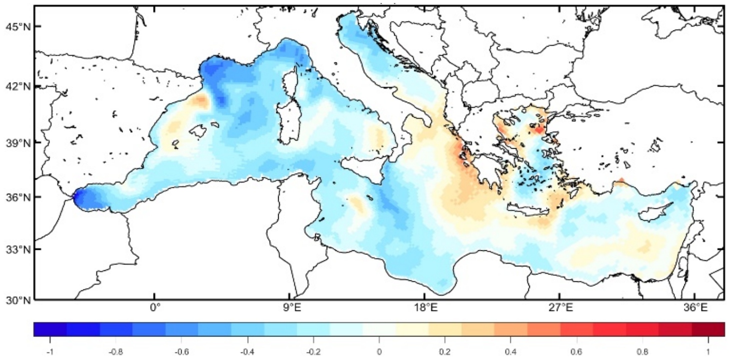
- The average **SST CC differences are similar to the differences with the GCMs**, as expected because the ARCMs use GCMs as boundary condition.
- Significant changes in the **spatial structures.**
- The **air T signal differences are not as pronounce as with the GCMs**, but still significant for the spatial structures.



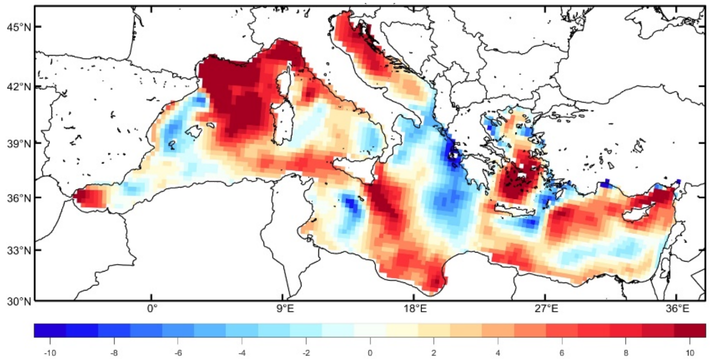
Impact of the coupling

Differences between the RCMs and ARCMs CC signals

AWI-ROM25 vs REMO25 SST dCC signals (ºC)

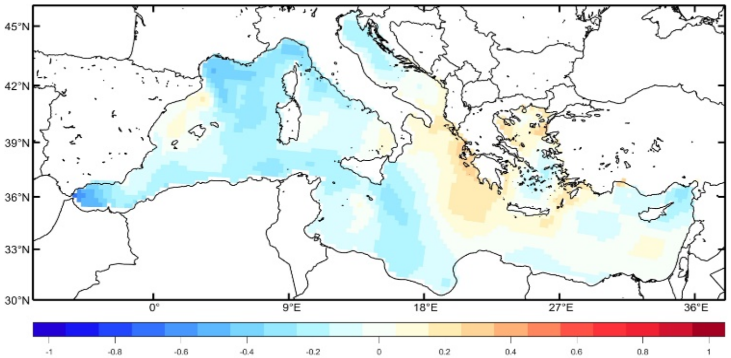


AWI-ROM25 vs REMO25 HFLS dCC signals (W/m^2)

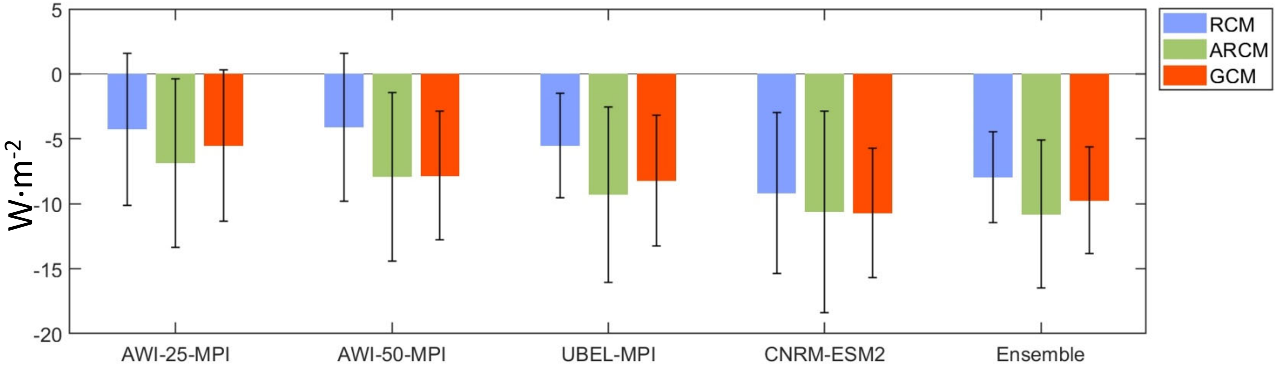


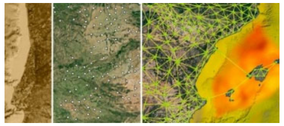
- ARCMs show **stronger latent HF signals** than both RCMs and GCMs → **more evaporation** to compensate the higher SST increase from the GCMs boundary condition at the sea surface.
- Also **higher humidity increase in the ARCMs** (not shown) → SST – Air -T gradient and latent heat flux differences.

AWI-ROM25 vs REMO25 Air T dCC signals (ºC)



Latent Heat Flux CC signal averaged over the Med Sea

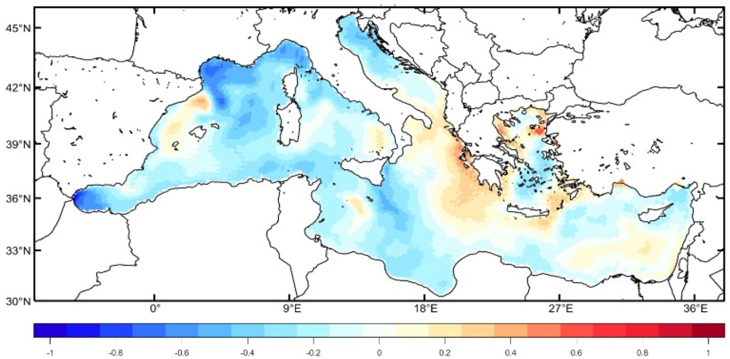




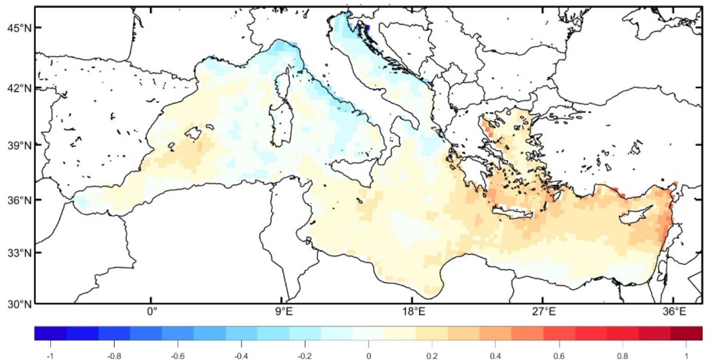
Impact of the coupling

Differences between the RCMs and ARCMs CC signals

AWI-ROM25 vs REMO25 SST dCC signals (ºC)

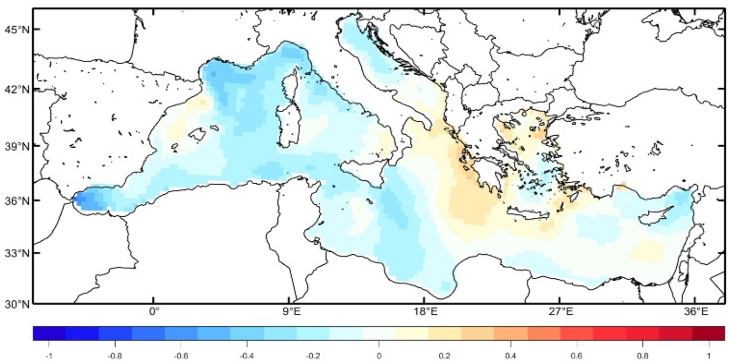


AWI-ROM25 vs REMO25 precipitation dCC signals (mm/d)

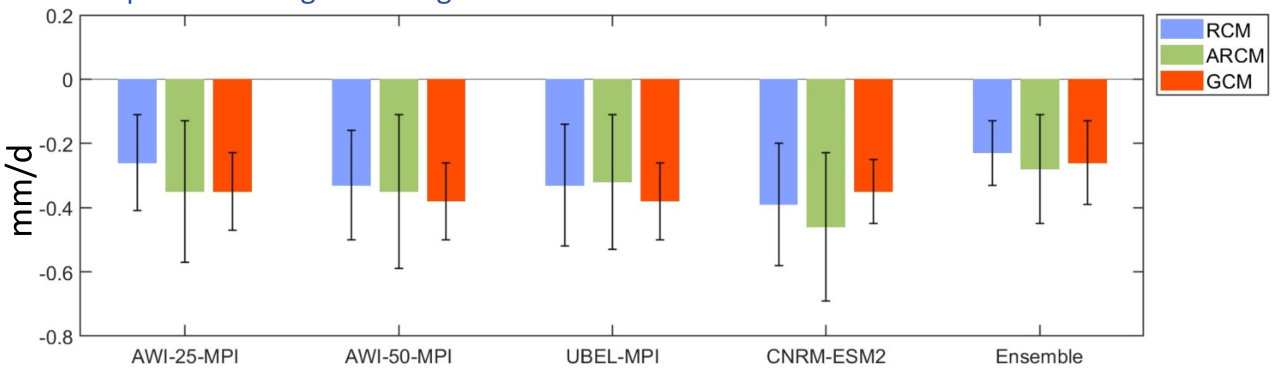


- **Stronger precipitation decrease** in ARCM. As a consequence of the differences in the heat gain.

AWI-ROM25 vs REMO25 Air T dCC signals (ºC)



Precipitation CC signal averaged over the Med Sea



Summary

Consistency in the CC respond of all the simulations for the variables analyzed. ⇨ Increase in the SST and the Air T ⇨ Decrease of the net heat losses towards the atmosphere (heat gain) ⇨ Decrease of Precipitation

Impact of the high resolution **RCM vs GCM** ⇨ Lower SST and Air T CC signals in the RCM ⇨ Very significant impact on the spatial structures ⇨ Higher reduction of precipitation in the GCMs (model dependent)

Impact of ocean-atmosphere coupling **RCM vs ARCM** ⇨ SST CC signals differences similar to GCM. Smaller differences in the Air T. ⇨ Very significant impact on the evaporative heat losses (higher in ARCMs) ⇨ Higher reduction of precipitation in the ARCMs