Impact of the ocean-atmosphere coupling on high-resolution future projections for the Mediterranean sea and surrounding climate from the Med-CORDEX ensemble

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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

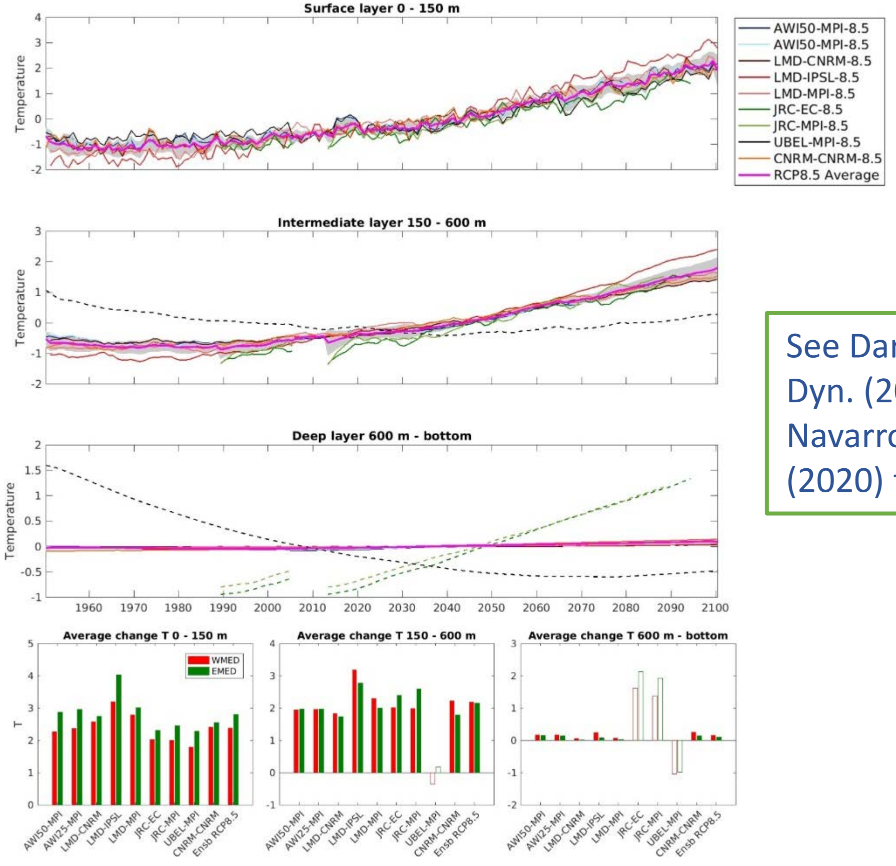
- CMCC
- CNRM
- ENEA
- GERICS-AWI
- GUF
- LMD
- U. Belgrade

Baseline atm – ocean coupled simulations

26 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: 14 simulations (7 historical, 7 scenario runs)

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
ENEA	ENEA-PROTHEUS		CNRM-CM5	RCP 4.5	ENEA-CNRM
LMD	LMD-LMDZNEMOMED8		IPSL-CM5A-MR	RCP 8.5	LMD-IPSL
U. Belgrade	EBU-POM2	EBU	MPI-ESM-LR	RCP 8.5	UBEL-MPI

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In this presentation: 14 simulations (7 historical, 7 scenario runs)

- 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)

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Models CC response

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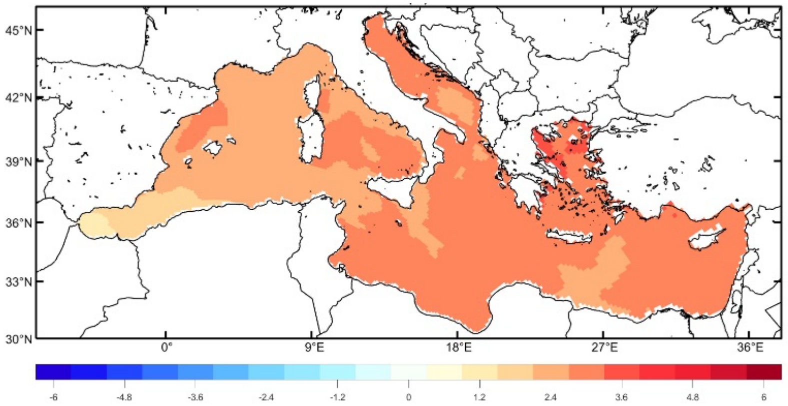
Instituto de Ingeniería Oceánica

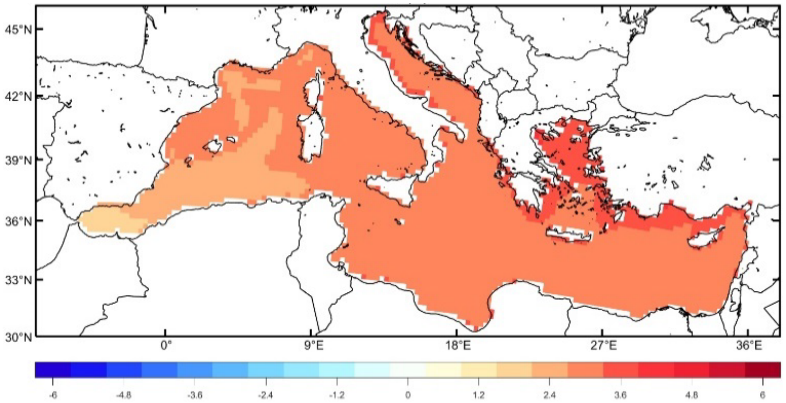
UNIVERSIDAD DE MÁLAGA

SST and Air temperature increase

AWI-25-MPI SST CC signal (ºC)



AWI-25-MPI Air T CC signal (ºC)

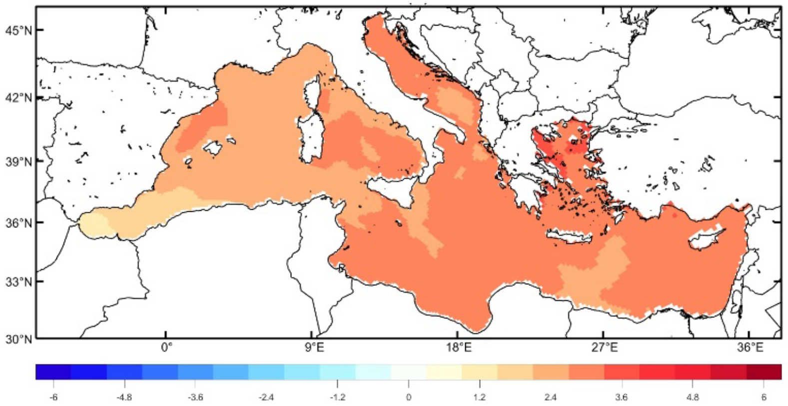


- All the simulations show a warming of the sea surface between 2.5 and 4 ºC on average (1.2-1.5 ºC for RCP 4.5)
- The Air T average increase is around 30% higher than for the SST

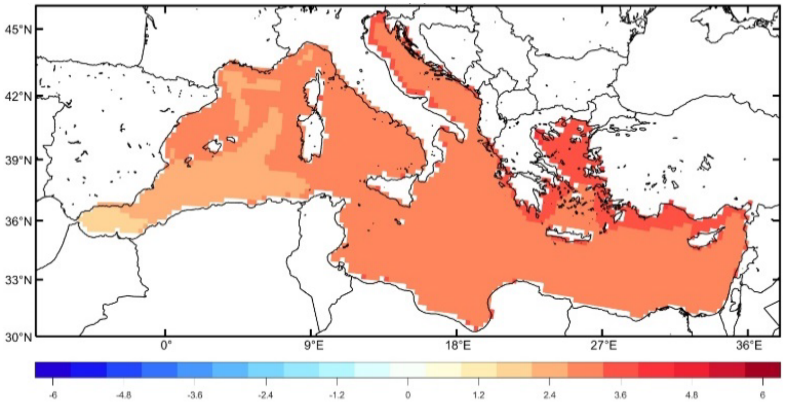
Models CC response

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

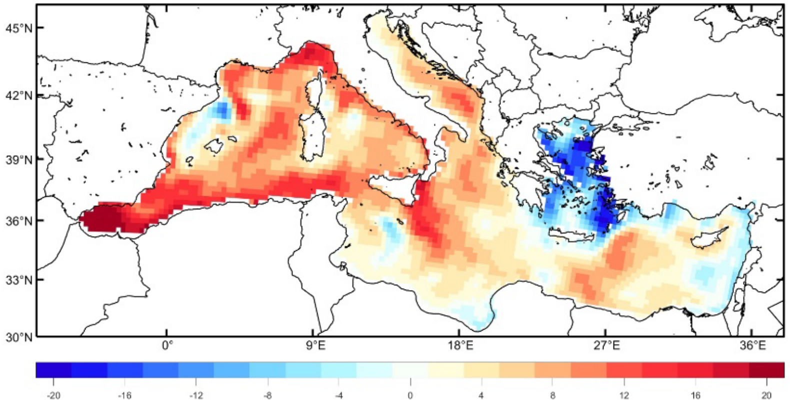
AWI-25-MPI SST CC signal (ºC)



AWI-25-MPI Air T CC signal (ºC)



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



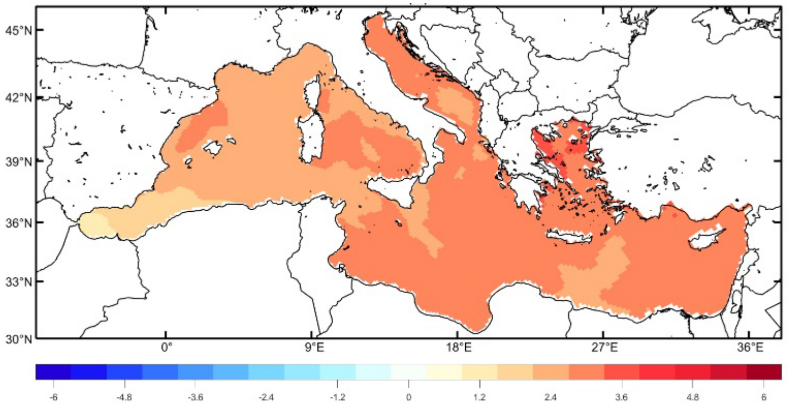
Heat flux positive downwards (towards the ocean)

- 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

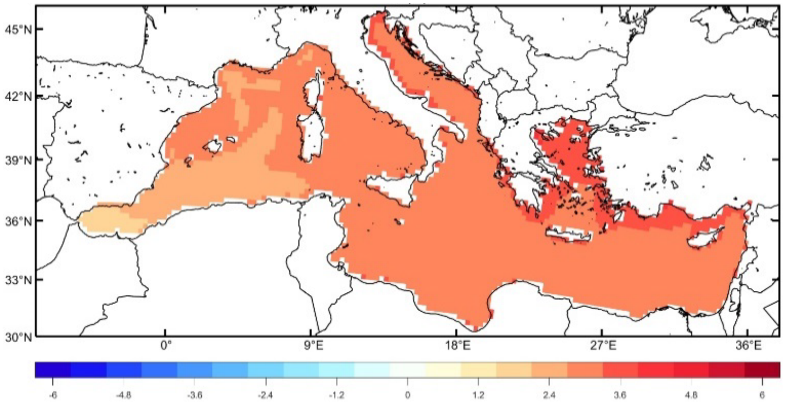
Models CC response

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

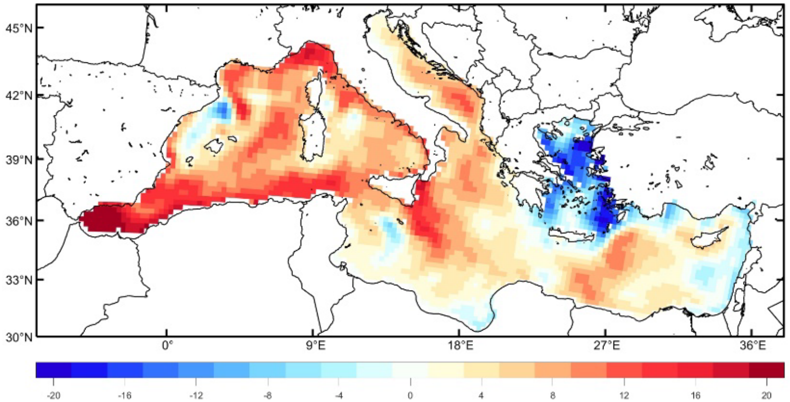
AWI-25-MPI SST CC signal (ºC)



AWI-25-MPI Air T CC signal (ºC)



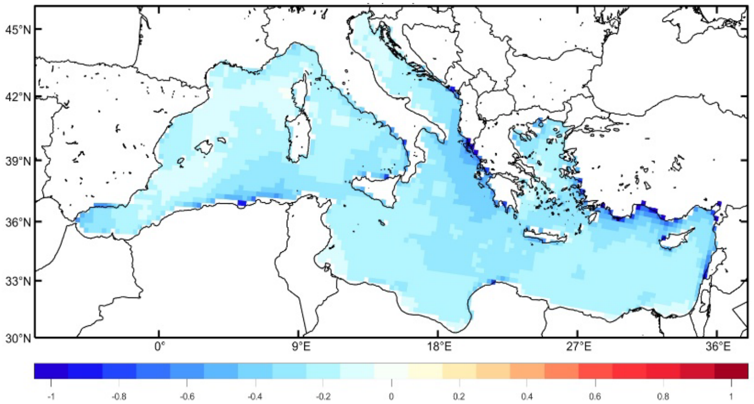
AWI-25-MPI Net Surface Heat Flux CC signal (W/m^2)



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

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



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

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Models CC response

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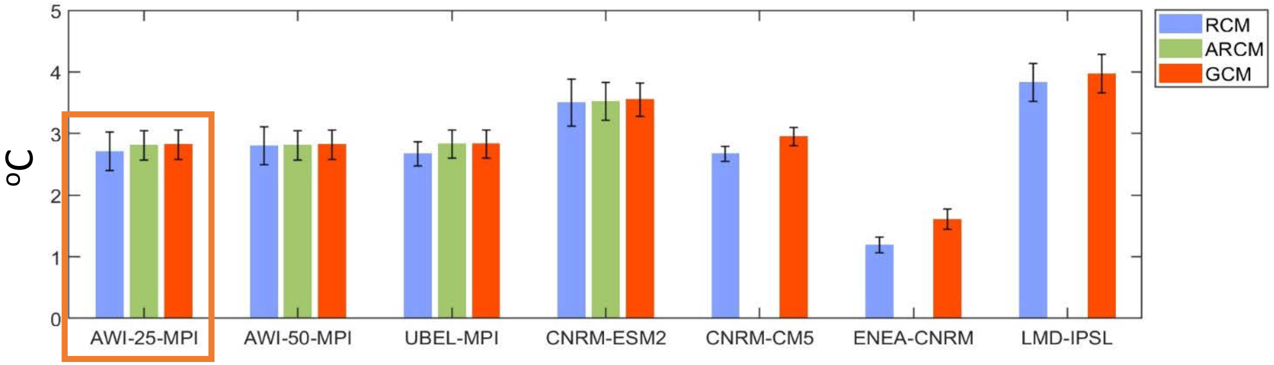
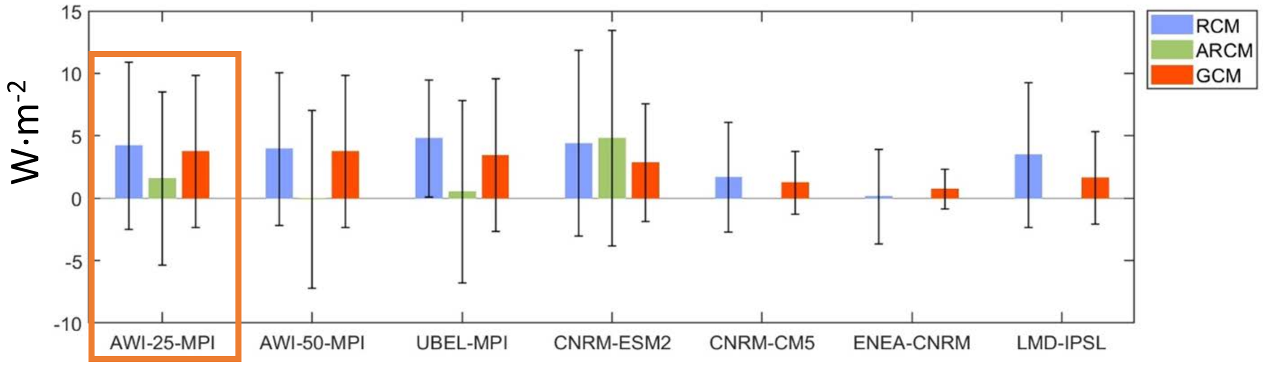
Consistency among all the models

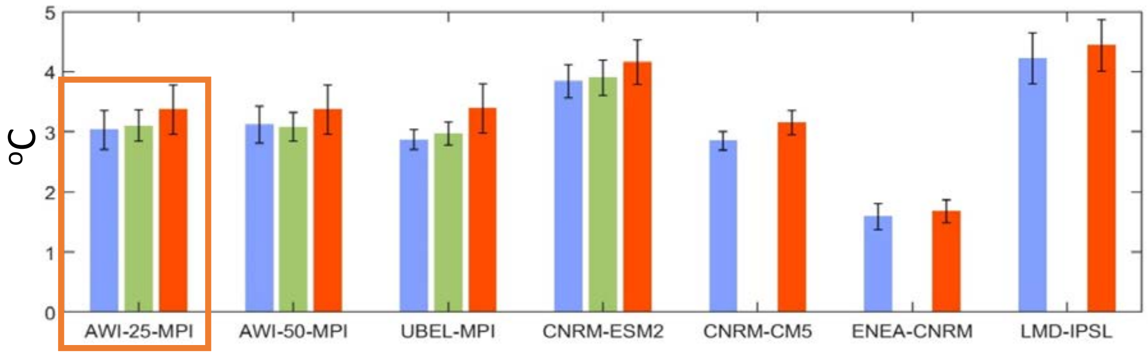
SST CC signal



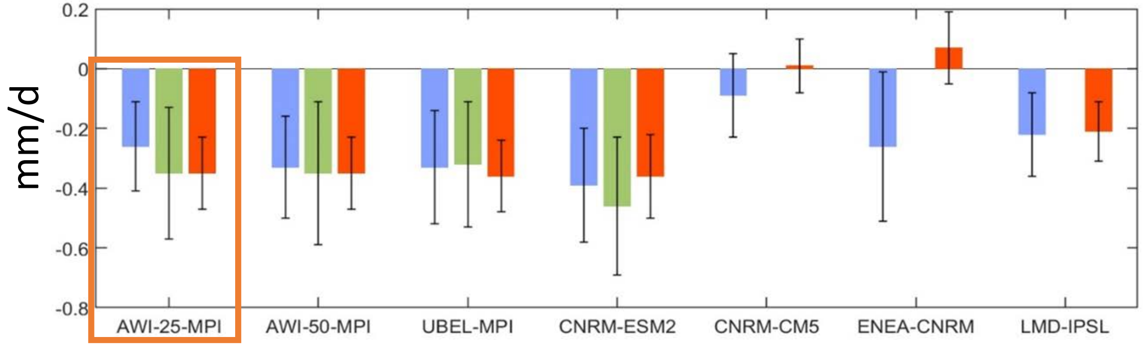
Net Surface Heat Flux CC signal



Air T CC signal



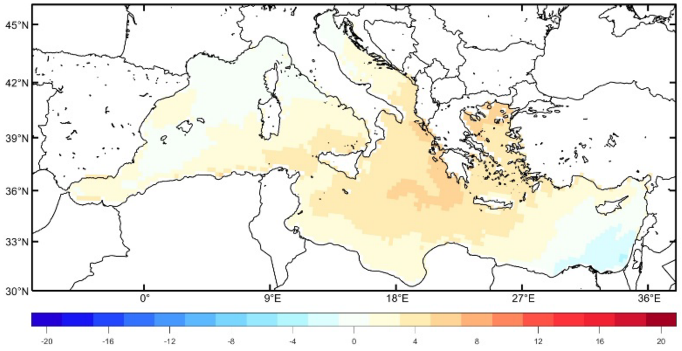
Precipitation CC signal



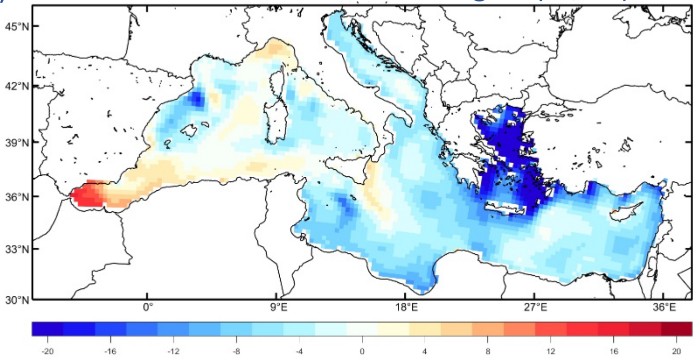
Models CC response

Surface heat flux components

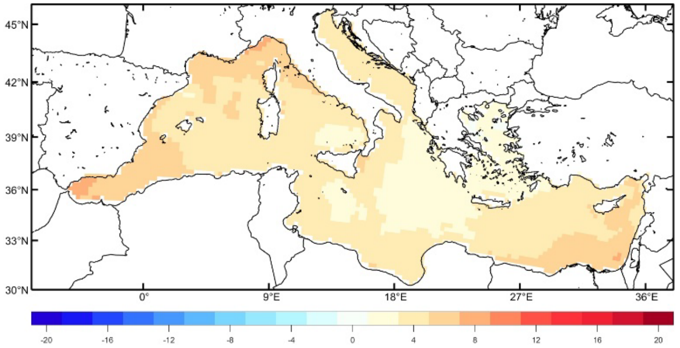
AWI-25-MPI **Net Shortwave Radiation** CC signal (W/m^2)



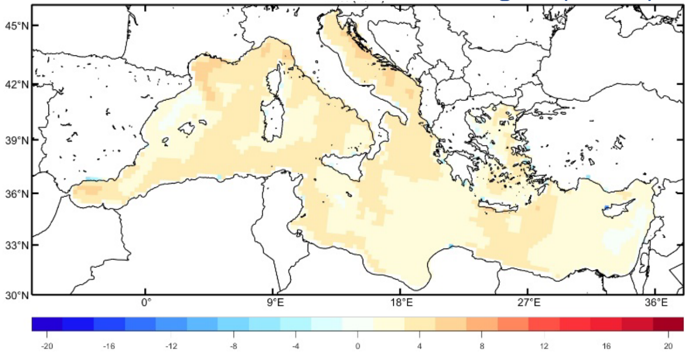
AWI-25-MPI **Latent Heat Flux** CC signal (W/m^2)



AWI-25-MPI **Net Longwave Radiation** CC signal (W/m^2)



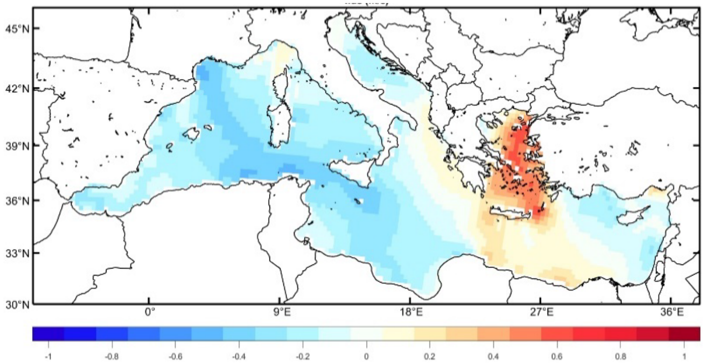
AWI-25-MPI **Sensible Heat Flux** CC signal (W/m^2)



Heat flux positive downwards (towards the ocean)

- **Increase** of the net **shortwave** radiation → reduction in the cloud cover and aerosol concentration
- **Increase** of the net **longwave** radiation → atmospheric warming due to GHG (among other factors)
- **Increase** of the **sensible** heat flux → due to the increase in the difference between the Air and Sea Temp
- **Decrease** of the **latent** heat flux, meaning an **increase** in the heat loss due to **evaporation** → the only negative term (tend compensate). **Modulated by wind**

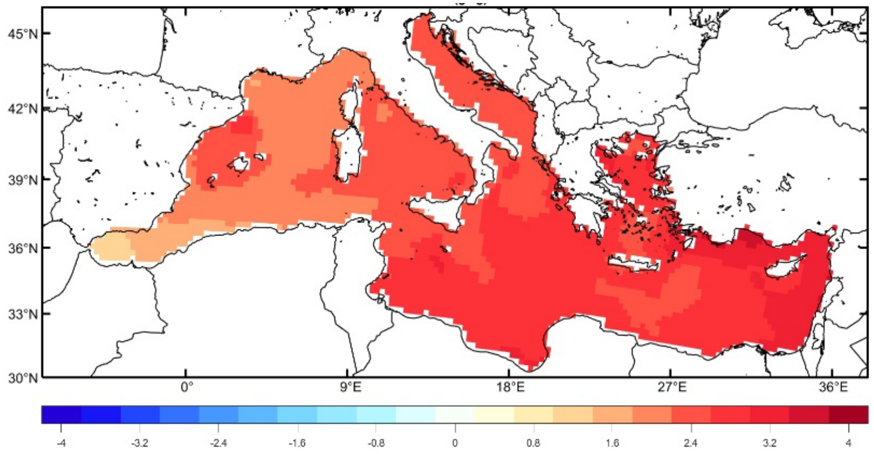
AWI-25-MPI Wind Intensity CC signal (m/s)



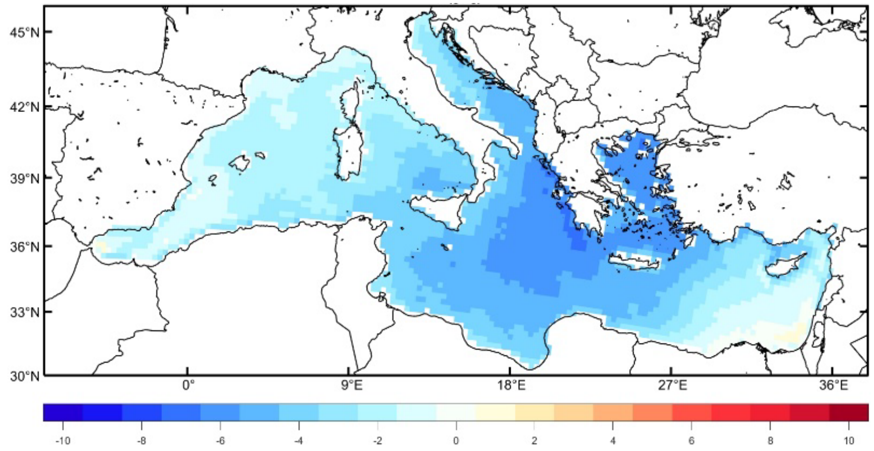
Models CC response

Humidity and clouds cover

AWI-25-MPI Specific Humidity CC signal (g/kg)



AWI-25-MPI Clouds cover CC signal (%)

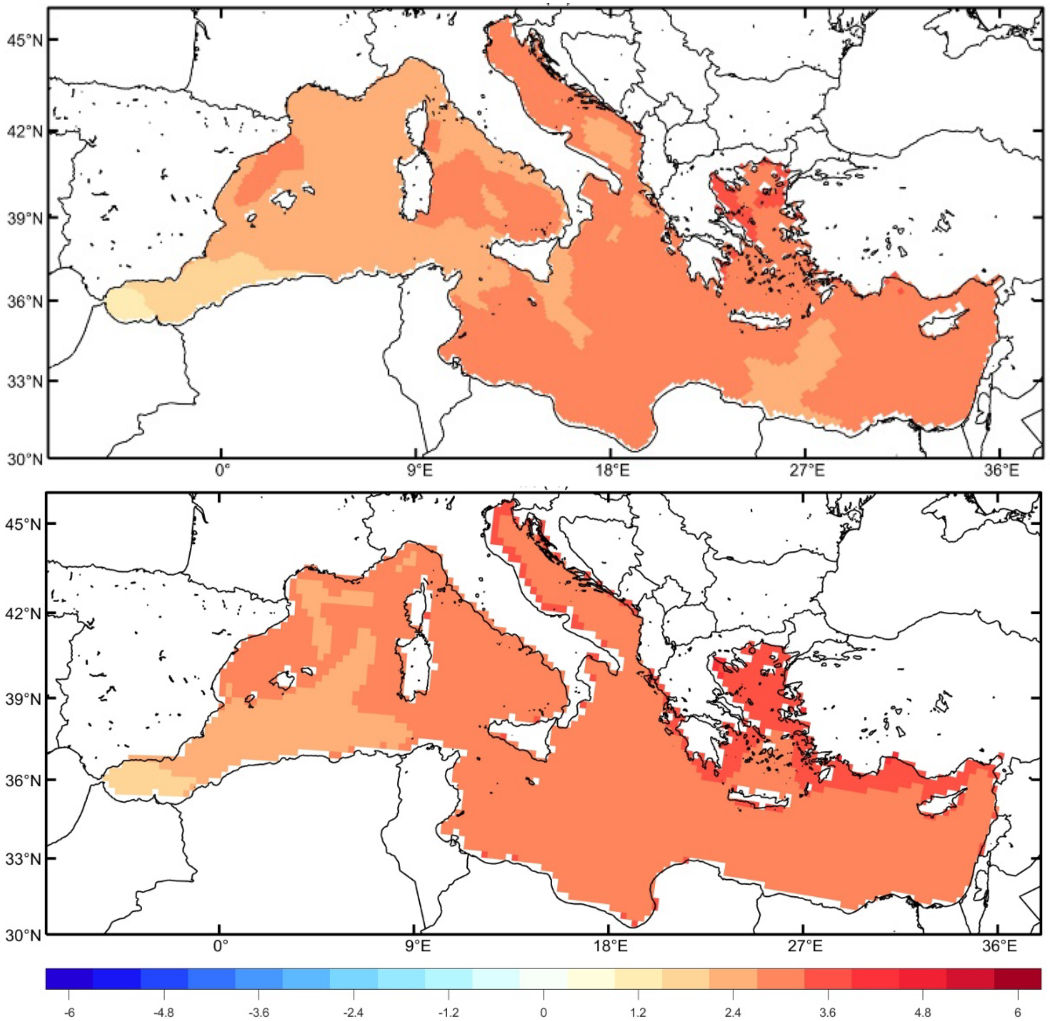


- Increase of the specific humidity due to the increase of the evaporation and atmospheric warming (Clausius-Clapeyron)
- General decrease in the cloud cover → Med climate is less prone to convection in the future

Impact of the resolution

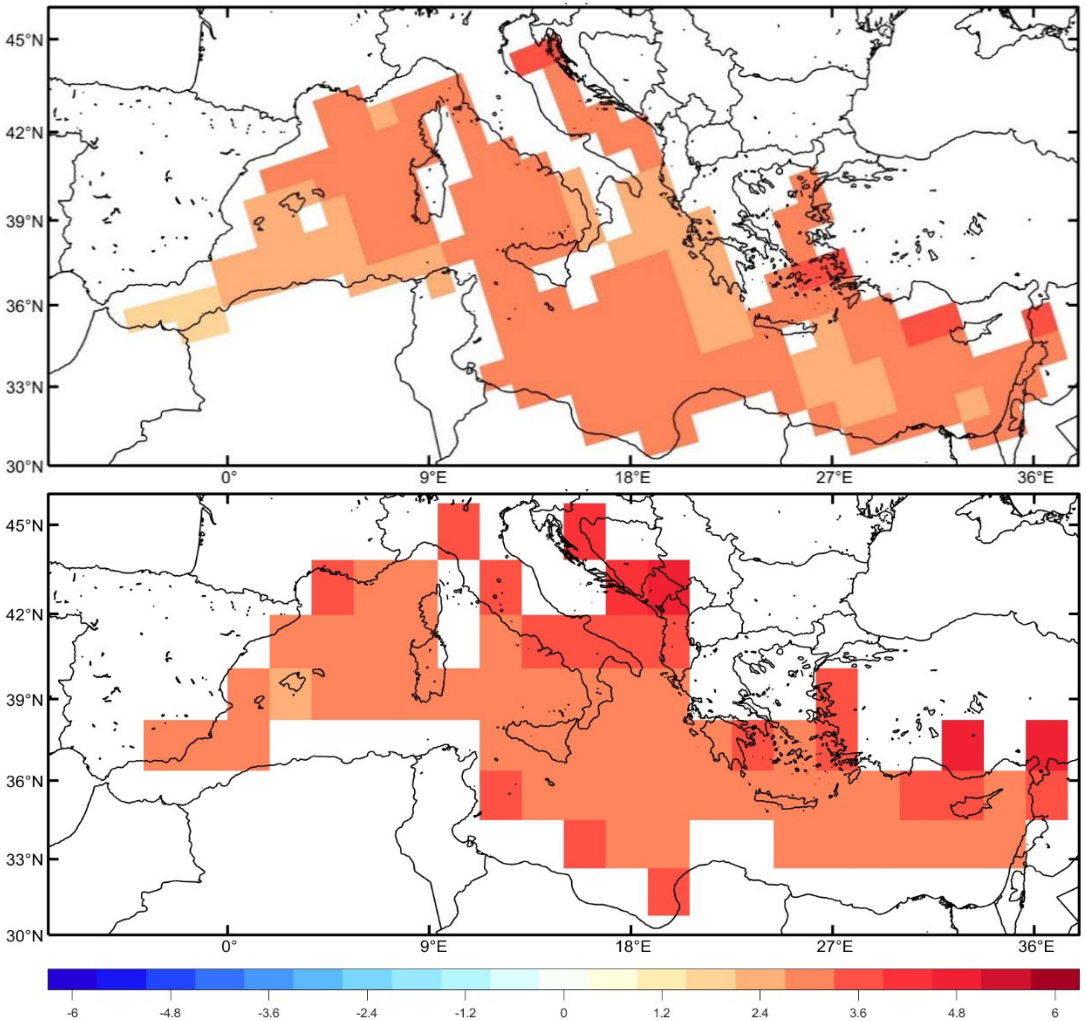
RCM

AWI-ROM25 SST & Air T CC signal (ºC)



GCM

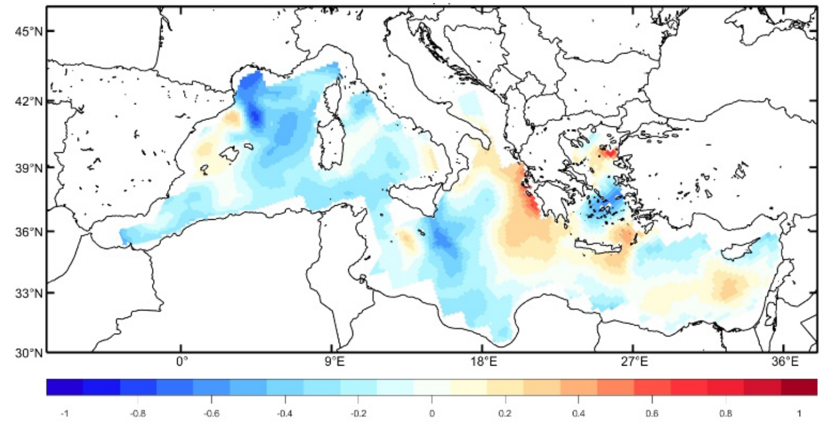
MPI-ESM-LR SST & Air T CC signal (ºC)



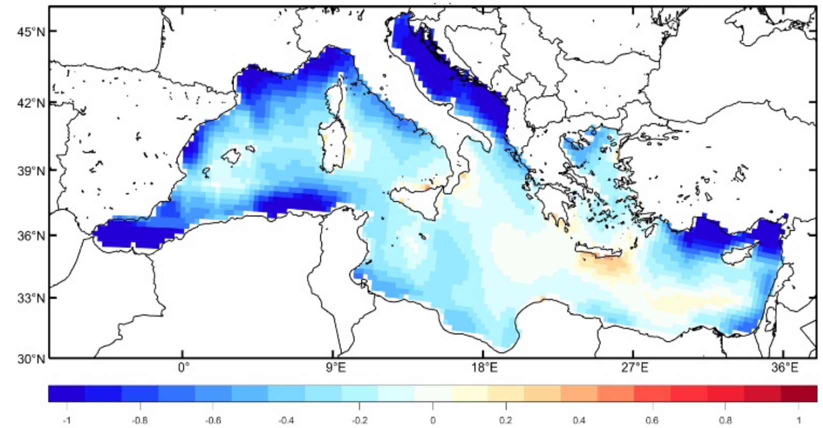
Impact of the resolution

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)

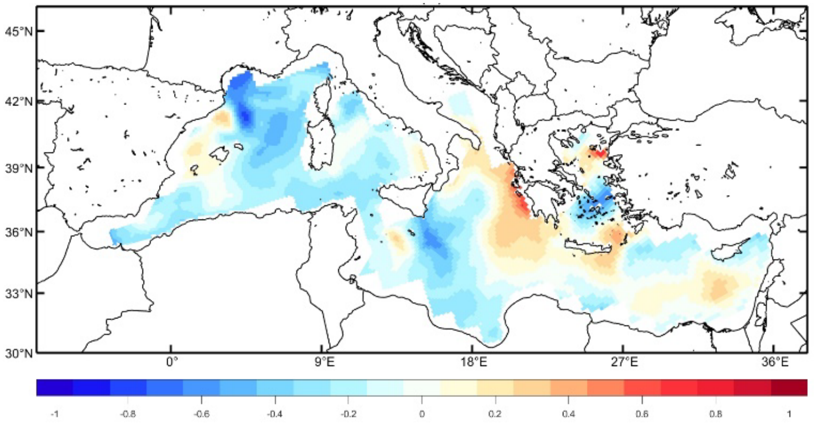


- The average SST CC signal is slightly stronger in the GCMs in general
- Significant changes in the spatial structures
- The air T signal is clearly stronger in the GCMs

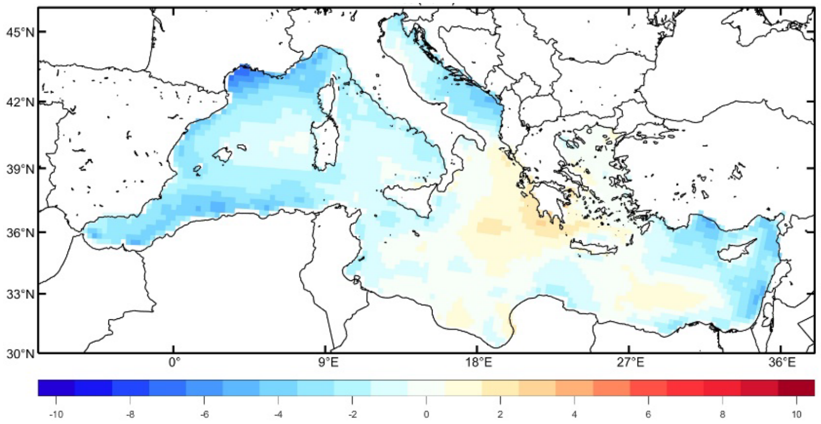
Impact of the resolution

Differences between the RCMs and GCMs CC signals

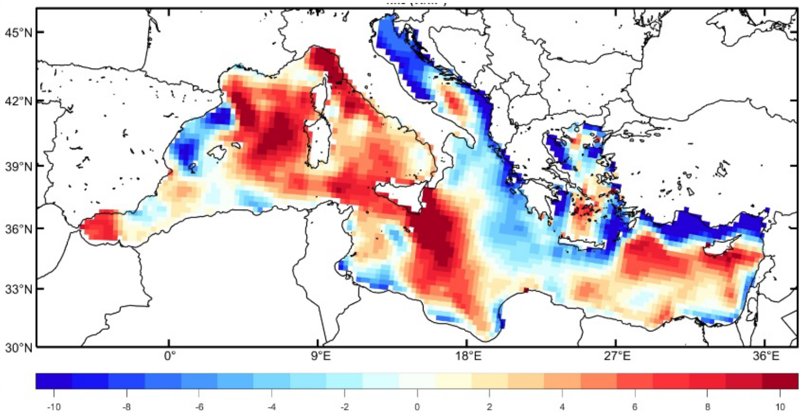
AWI-ROM25 vs MPI-ESM-LR SST dCC signals (ºC)



AWI-ROM25 vs MPI-ESM-LR NSWR dCC signals (W/m²)

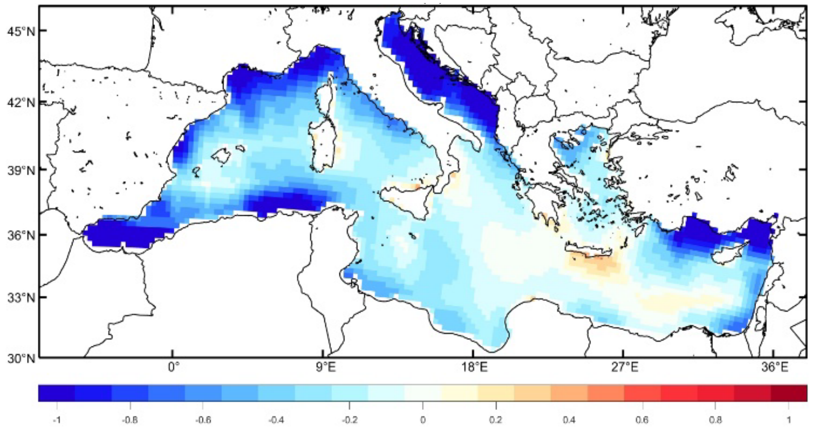


AWI-ROM25 vs MPI-ESM-LR HFLS dCC signals (w/m²)



Heat flux positive downwards (towards the ocean)

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

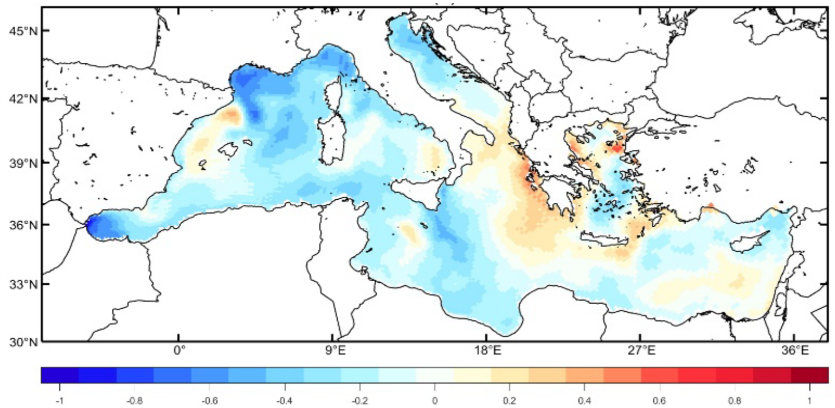


- **RCMs signals weaker than GCMs for shortwave rad →** higher reduction of the cloud cover in the GCMs and not inclusion of aerosols in all RCMs
- **RCMs signal weaker than GCMs for latent heat flux →** more evaporation in the GCMs due to higher SST increase
- **RCMs sensible heat flux signals are stronger than for the GCMs** in 5 of the 7 simulations (not shown) → stronger gradient between SST and Air-T in RCMs
- **No consistent** difference between RCMs and GCMs in **Precipitation**

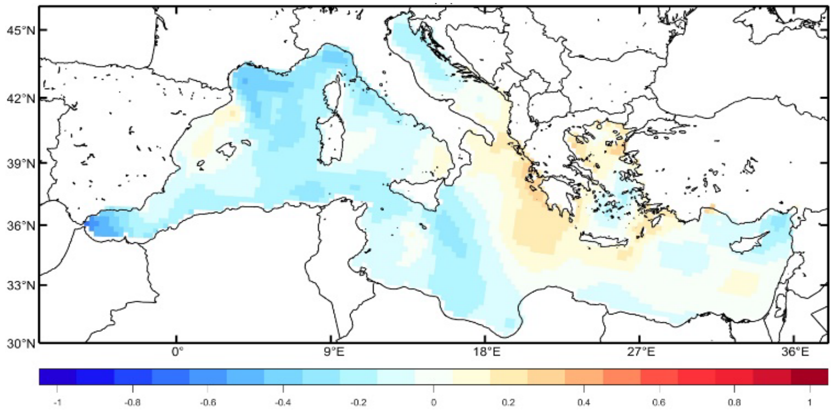
Impact of the coupling

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)

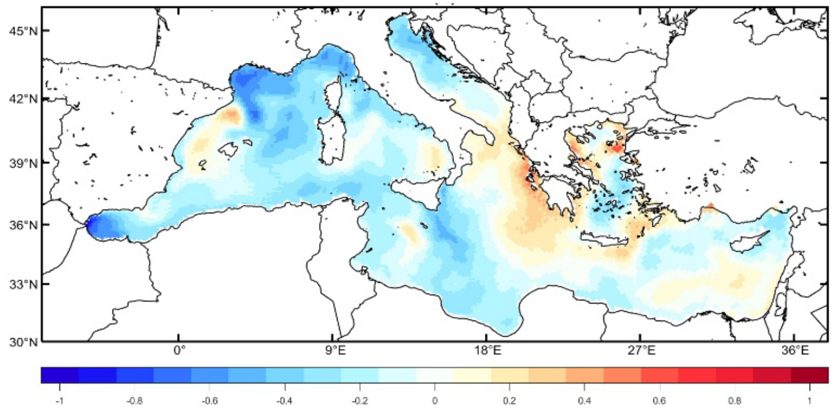


- The average SST CC differences are very close to the differences with the GCMs, as expected because the ARCMs use GCMs as boundary layer
- Significant changes in the spatial structures
- The air T signal differences are not as pronounce as with the GCMs, but still significant for the spatial structures

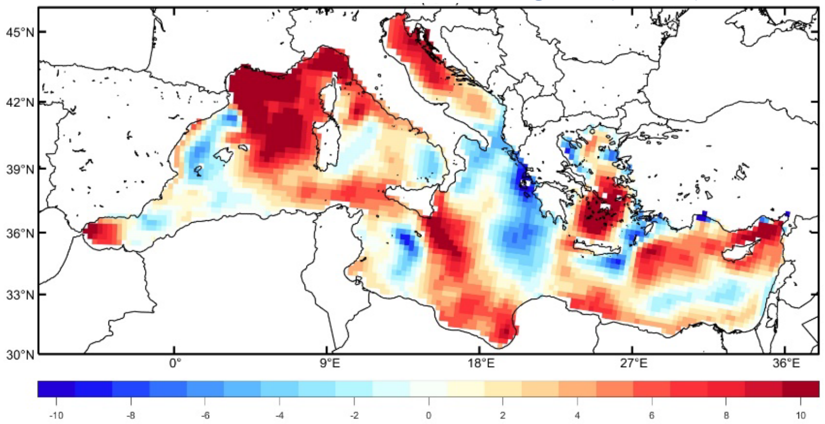
Impact of the coupling

Differences between the RCMs and ARCMs CC signals

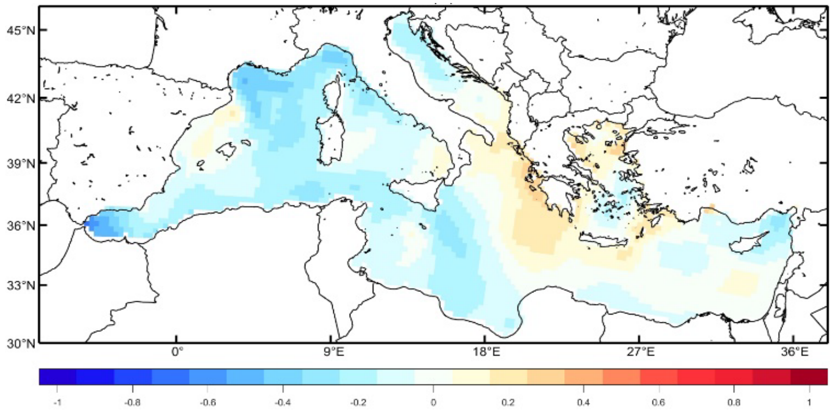
AWI-ROM25 vs REMO25 SST dCC signals (ºC)



AWI-ROM25 vs REMO25 HFLS dCC signals (W/m²)



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



- **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
- **No consistent** difference between RCMs and ARCMs in **Precipitation**

Summary

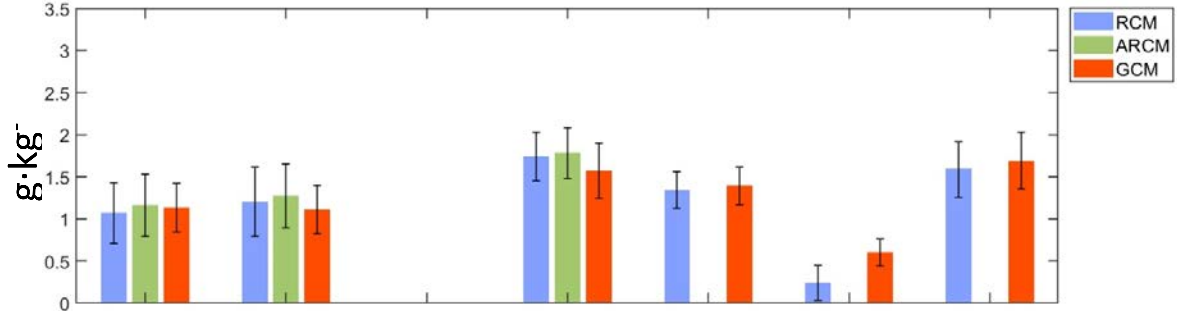
- There is consistency in the CC respond of all the simulations for the variables analyzed.
- The warming of the sea surface and the air results in a reduction of the net heat loss by the sea. The only component of the surface net heat flux that tends to counter this effect is the latent heat flux (increase of the ocean heat loss by evaporation).
- Despite the evaporation and humidity increase, the average cloud cover and precipitation decrease over the Mediterranean.
- Similar general behavior over land, but with much larger spatial variability.
- The main differences between RCMs and GCMs CC response are the SST and Air T signals, which in turn condition the ocean-atmosphere net heat flux.
- The RCMs dump this difference by the ocean-atmosphere interaction while in the ARCMs increase the latent heat flux losses (more evaporation) to compensate the extra sea surface warming from the GCMs boundary condition.
- Therefore, there is a significant impact of both the high resolution and the coupling in the models response to the climate change forcing.

Extra slides

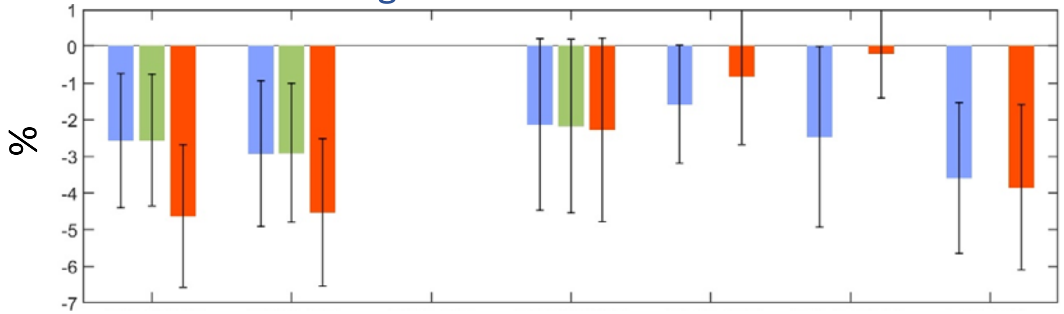
Impact over land

Spatial averages of the CC signal over land

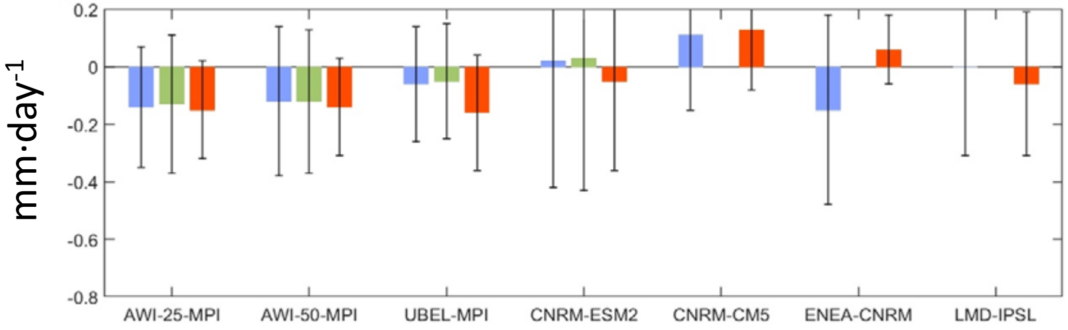
Specific humidity CC signal

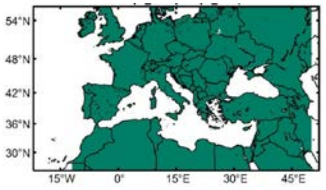


Cloud cover CC signal



Precipitation CC signal





- As for the Med, general increase of humidity over land, but of lower magnitude. Higher in the RCMs and even more in the ARMs becaouse of the HFSL differences
- Again, general decrease in the clouds cover, lower than over sea.
- Over land 3 of the 4 GCMs show a stronger decrease of the clouds cover. The differences between RCMs and ARCMs are no significant.
- The precipitation behavior is not as clear over land than over sea.
- All models show a very small average signal, but very high spatial variability.
- Clear diff between GCM response and RCM/ARCM.
- RCM seem to be drier than ARCM → change in land-sea contrast

The land region is too large and affected by different and complex processes on each region. More accurate results will be obtained when analyzing the land-sea interaction over specific land regions instead of the whole domain.