

# Robust assessment of the Mediterranean Sea future evolution using the Med-CORDEX RCM multi-model ensemble:

## illustration for the Marine Heat Waves

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V. Djurdjevic, W. Cabos, D. Sein, G. Sannino*

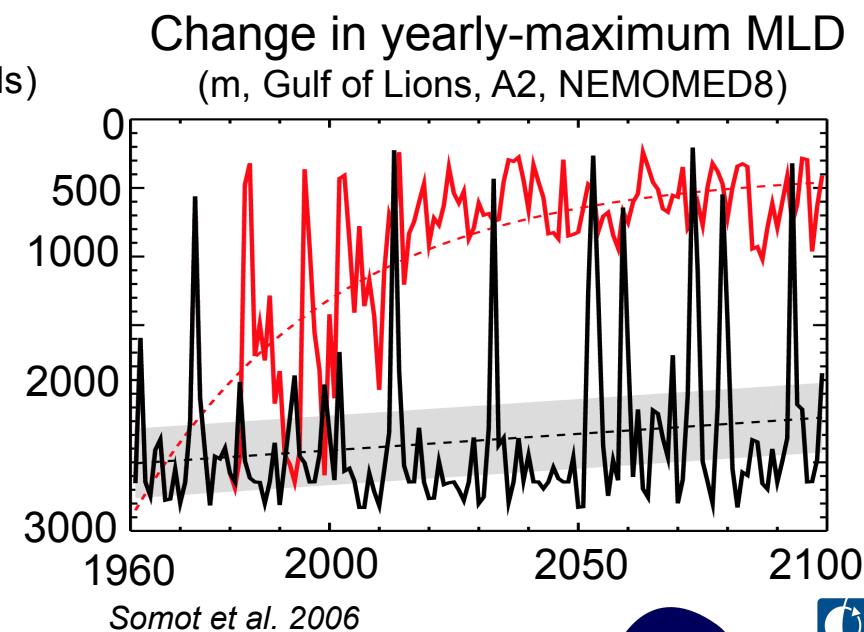
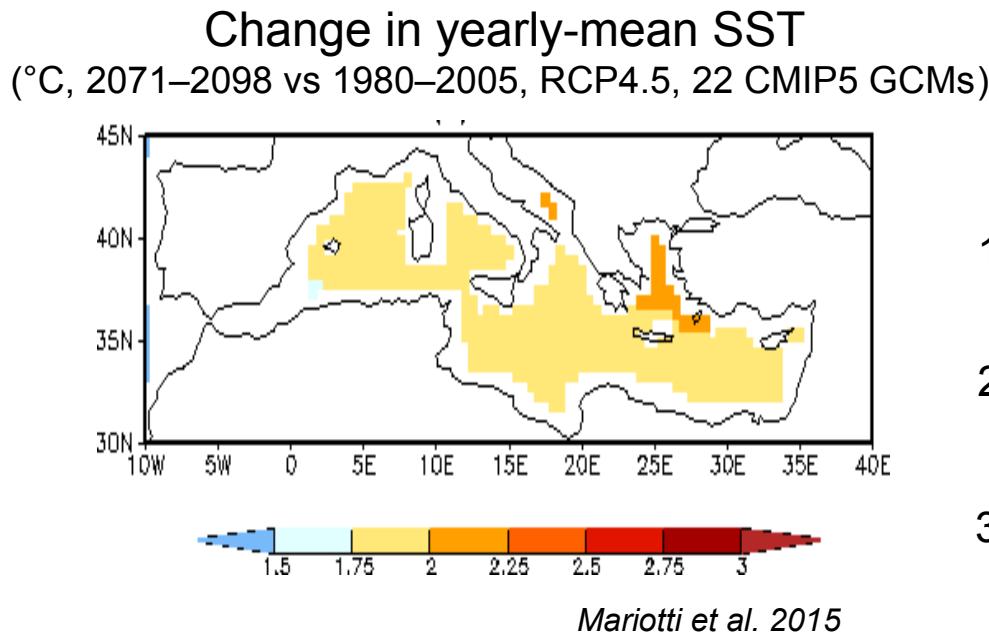
*CNRM, Météo-France/CNRS, Toulouse, France*

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# Current limitations to study future climate change effects on Mediterranean marine ecosystems

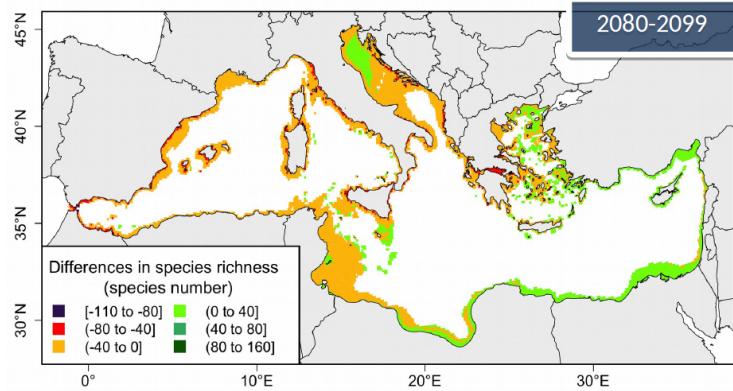
- ⇒ Options to get Mediterranean Sea future projections :
  - Low-resolution GCM ensemble from CMIP → Bad representation of the sea physics
  - Single high-resolution regional ocean/coupled simulation → No uncertainty assessment  
→ No user-friendly database
- ⇒ Multi-model studies are rare, recent and underestimate the spread (*Adloff et al. 2015, Maciàs et al. 2015*)



# Current limitations to study future climate change effects on Mediterranean marine ecosystems

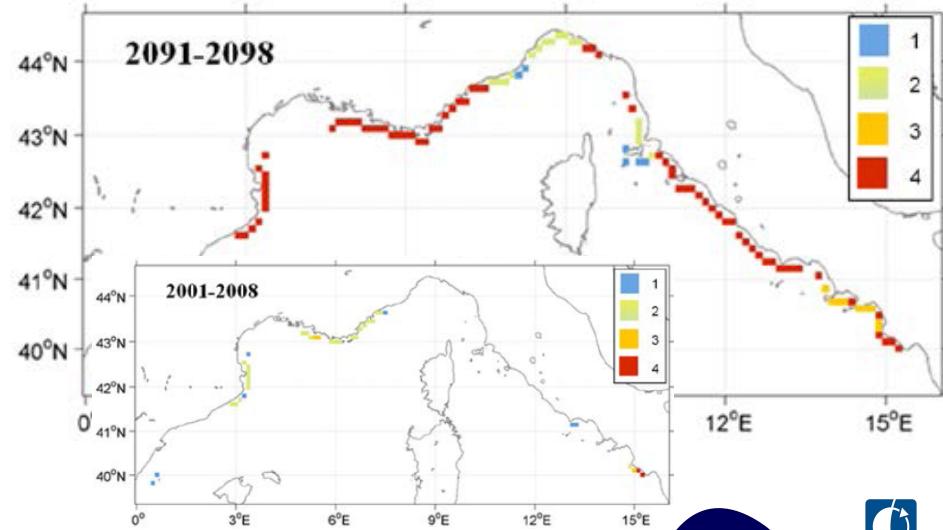
- Consequently, future climate change impact studies on marine ecosystems can not deliver robust messages (*Ben Rais Lasram et al. 2010, Alouy et al. 2013, 2015, Lazzari et al. 2013, Bensoussan et al. 2013, Jordà et al. 2013, Maciàs et al. 2013, Hattab et al. 2014, Andrello et al. 2015*)
- Studies taking into account uncertainties are rare, recent and still underestimating the spread (*Herrmann et al. 2014, Maciàs et al. 2015, Benedetti et al. 2017*)

Change in species richness  
(species number, A2, NEMOMED8)



Alouy et al. 2013

Risk level of mortality outbreak  
(Red gorgonian *Paramuricea clavata*, A2, NEMOMED8)

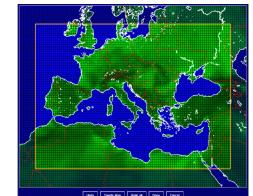


Bensoussan et al. 2013

# The Med-CORDEX scenario runs

- ⇒ The Med-CORDEX initiative targets to solve the previously identified issues by
  - Developing an ensemble of fully coupled Regional Climate System Models
  - Developing a shared protocol for running Med. Sea projection simulations
  - Developing a multi-model, multi-scenario ensemble of high-resolution simulations
- ⇒ Since 2009, Med-CORDEX is an open and voluntary-based initiative with regular meetings are financially supported by MISTRALS (mostly HyMeX)

[www.medcordex.eu](http://www.medcordex.eu)



INSTITUTE	RCSM name	Driving GCM	Resol. Ocean	Historical	RCP8.5	RCP4.5	RCP2.6	Contact
CNRM	CNRM-RCSM4	CNRM-CM5	9-12km	1950-2005	2006-2100	2006-2100	2006-2100	S. Somot
LMD	LMDZ/NEMOMED8	IPSL-CM5	9-12km	1950-2005	2006-2100	2006-2100		L. Li
CMCC	COSMOMED	CMCC-CM	1/16°	1950-2005	2006-2100	2006-2100		L. Cavicchia
AWI/GERICS	ROM	MPI-ESM-LR	25km	1950-2005	2006-2100	2006-2100		W. Cabos, D. Sein
U. Belgrade	EBU-POM	MPI-ESM-LR	0.2°	1950-2005	2006-2100			V. Djurdjevic
ENEA	PROTHEUS	CNRM-CM5	1/8°	1978-2005		2006-2095		G. Sannino

(6)

(5)

(5)

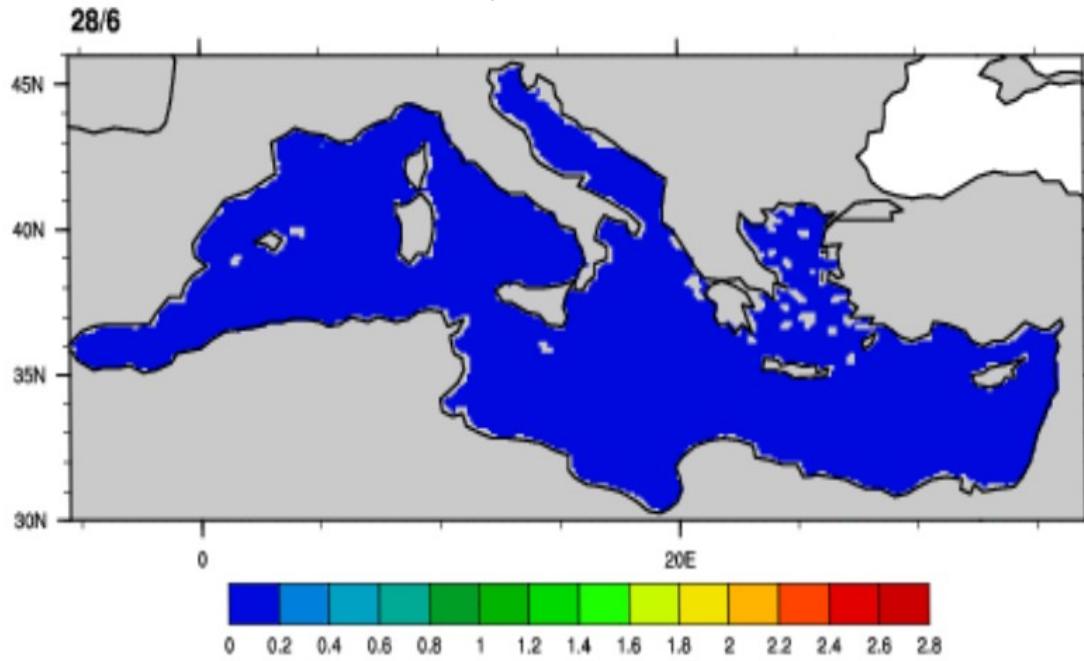
(1)



# Marine Heat Waves : motivations

- ⇒ Marine Heat Waves (MHW) are the oceanic counterpart of atmospheric heat waves
- ⇒ Already recorded in the Mediterranean Sea (but also Pacific, Australia, ...)
- ⇒ They are responsible for ecosystem mass mortality events (MHW2003, Garrabou *et al.* 2009)
- ⇒ They are currently largely unknown (driving factors, distribution in time-space-depth, future evolution, related impacts)

Example : daily SST anomalies during a MHW  
(°C, 28 june → 18 sept)



# Marine Heat Waves : definition

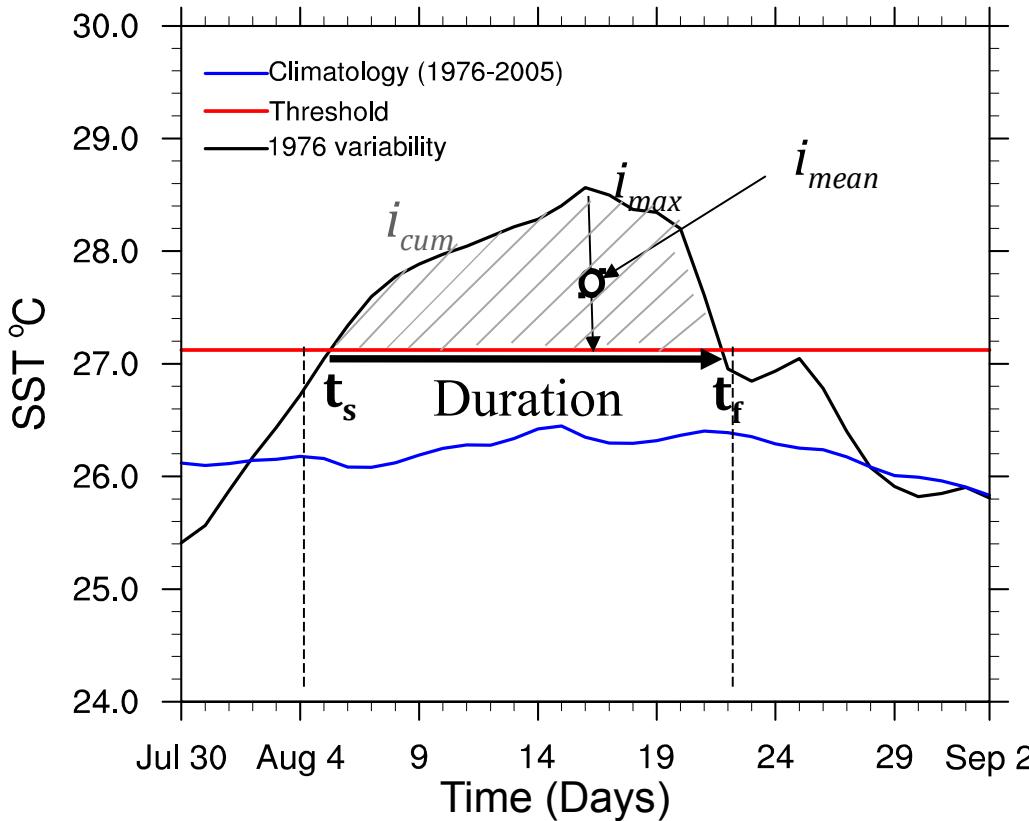
- Generic definition (from Hobday et al. 2016) :

« A discrete, prolonged anomalously warm water event in a particular location »

- Summer MHW with threshold constant in time but model-dependant & space-varying

Threshold:  $SST_T = \langle Q99^{\text{yr}}[\text{SST}(\text{day})] \rangle_{1976-2005}$

Minimum duration of 5 consecutive days (gap days not allowed)

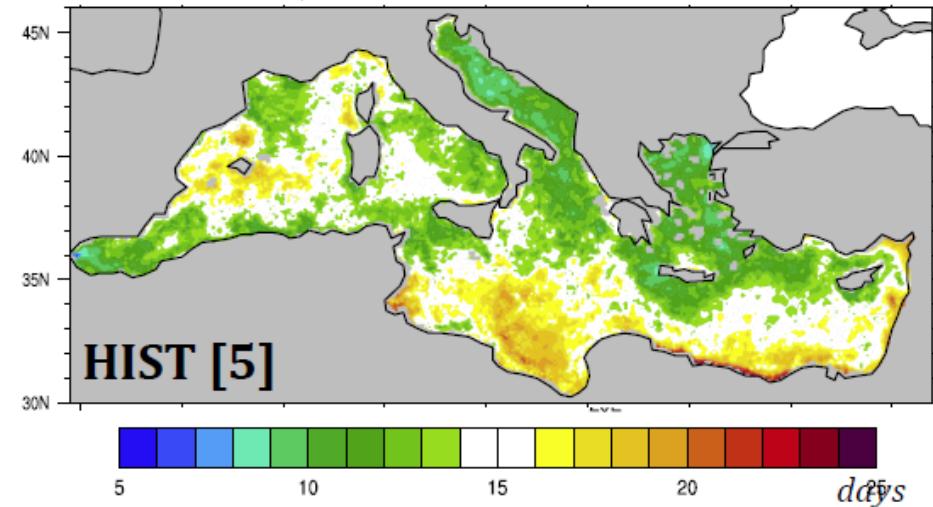


## Various MHW metrics:

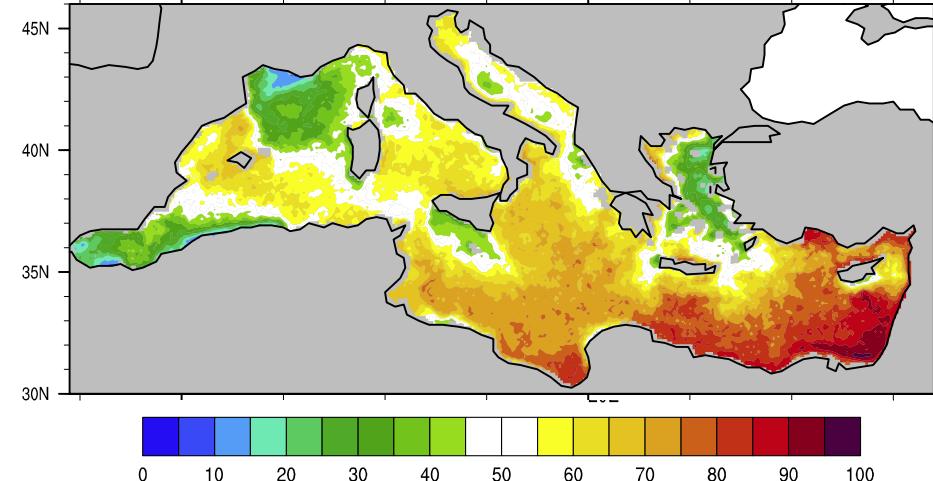
- Number of MHW
- Duration (days), starting/ending dates
- Intensity: mean, maximum (°C)
- Severity: cumulative intensity (°C.days)

# Marine Heat Waves : future evolution

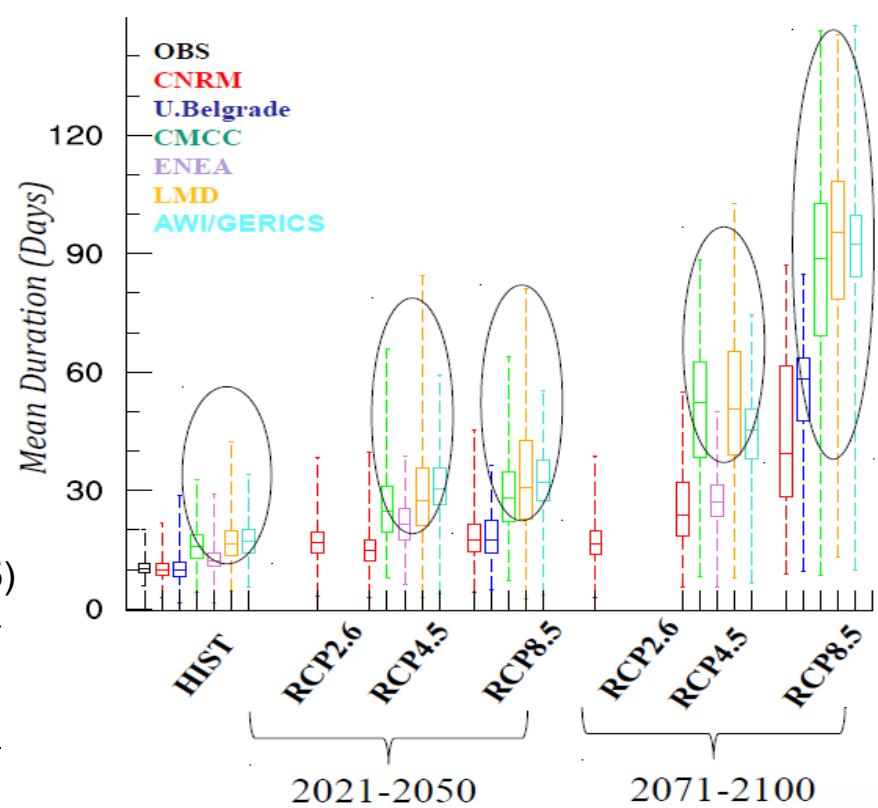
Multi-Model Ensemble Mean Duration  
(days, 5 HIST runs, 1976-2005)



MMEM Duration Anomaly  
(days, 5 runs, RCP8.5 (2071-2100) – HIST (1976-2005))



Duration  
(days, Med Sea average, 1976-2005)

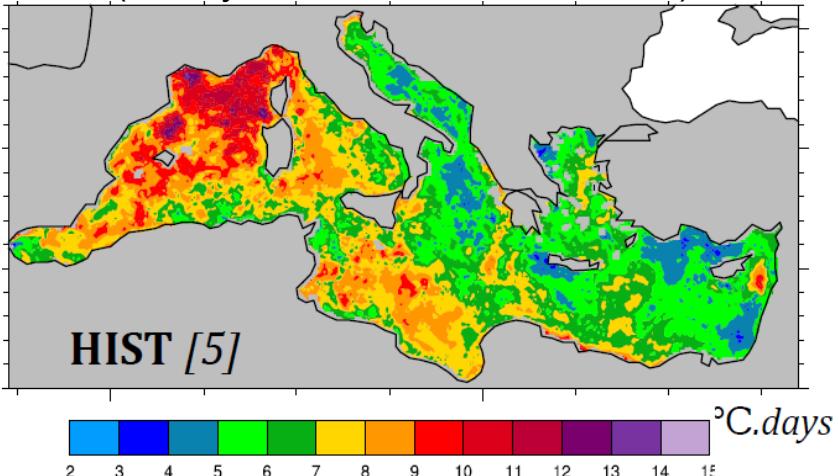


- Increased duration even in RCP2.6
- Duration is multiplied by 4 in RCP8.5 at the end of the 21<sup>st</sup> century
- Spatial pattern in the expected changes
- MHW lasting 5 months are simulated

# Marine Heat Waves : future evolution

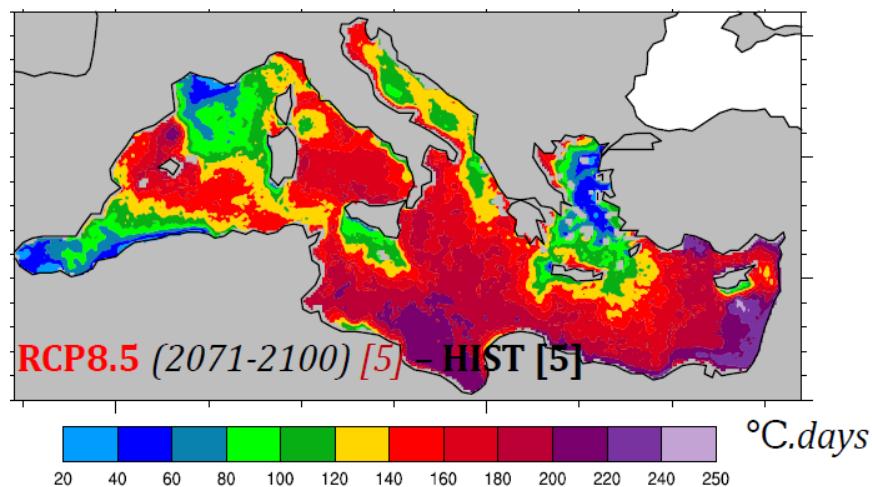
MMEM Severity (cumulative intensity  $I_{cum}$ )

(°C.days, 5 HIST runs, 1976-2005)

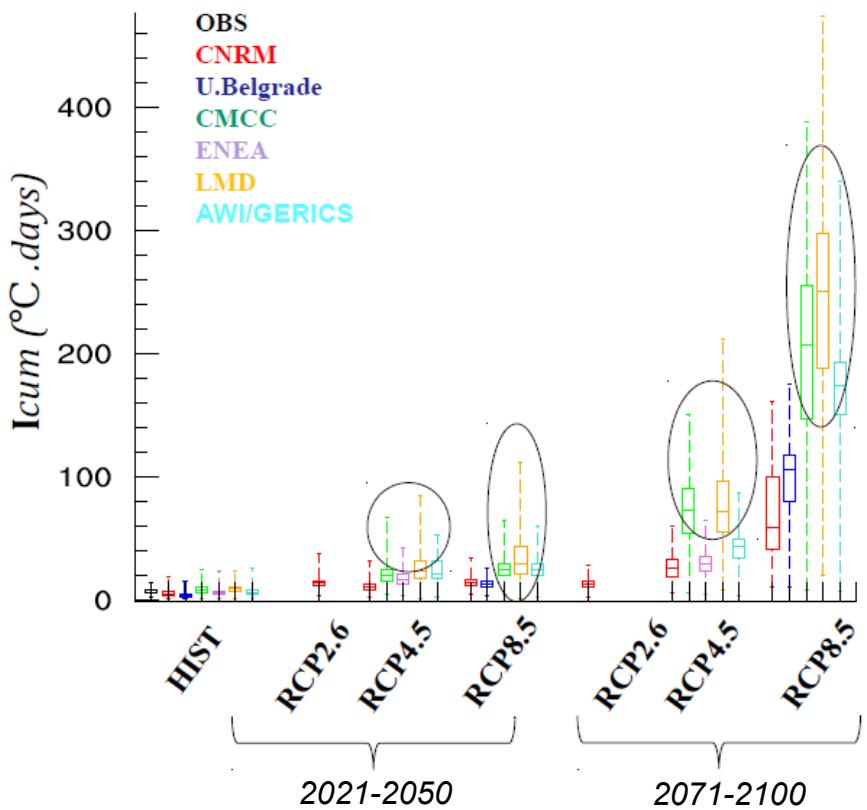


MMEM Severity Anomaly

(days, 5 runs, RCP8.5 (2071-2100) – HIST (1976-2005))



Severity  
(°C.days, Med Sea average, 1976-2005)



- Increased severity even in RCP2.6
- Severity is multiplied by 10 (MMEM, RCP8.5, 2071-2100)
- Strong spatial pattern
- Large model uncertainty

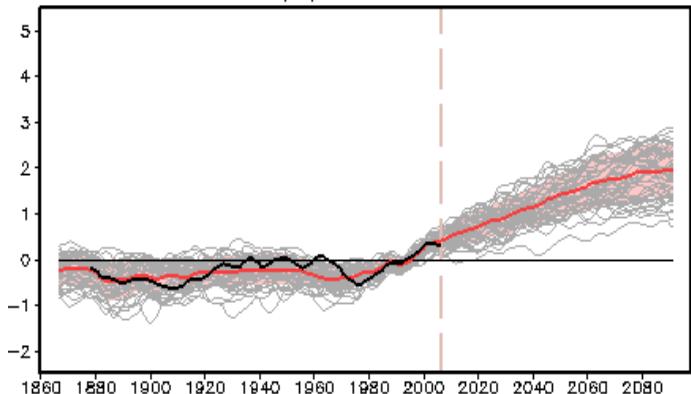
# Conclusions

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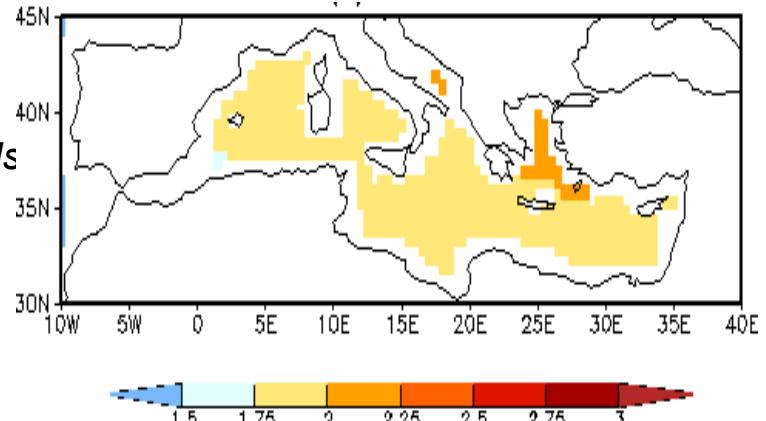
- ⇒ Quantitative and reproducible definition of Marine Heat Waves for the Medit. Sea
  - ⇒ First (robust) assessment of their future evolution using Med-CORDEX simulations
  - ⇒ MHW become longer, more intense and more severe (even in RCP2.6)
  - ⇒ Strong spatial pattern in the response, due to local atmospheric/oceanic phenomena
  - ⇒ In the RCP8.5 and at the end of 21st century, the duration (resp. severity) increases by a factor 4 (resp. 10) in average among the models
  - ⇒ Large model uncertainty (esp. at the end of the 21st century)
- 
- ⇒ Med-CORDEX is an on-going effort with more runs to come thanks to the start of phase 2 (now becoming a Transverse Action with MISTRALS)
  - ⇒ Full documentation of the multi-model ensemble sea scenarios is still missing
  - ⇒ On going work to provide standardized outputs in the Med-CORDEX database

# Mediterranean Sea projections : GCM vs RCSM

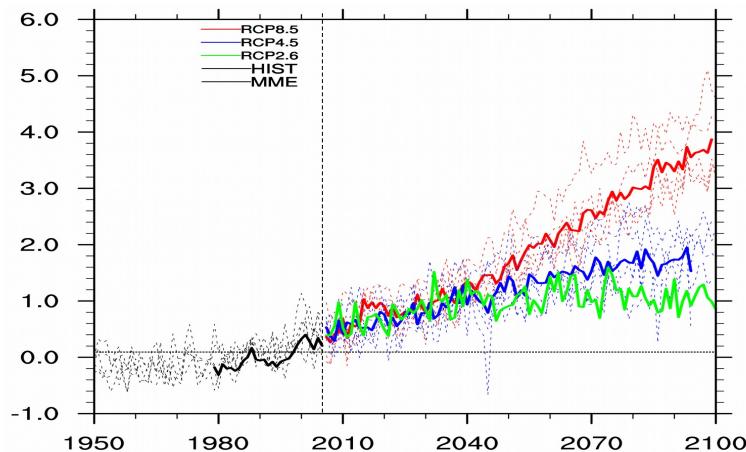
Yearly-mean SST anomalies  
(°C, Med Sea spatial average, wrt 1980–2005, 10-year filter)



Yearly-mean SST change  
(°C, 2071–2098 vs 1980–2005, RCP4.5)

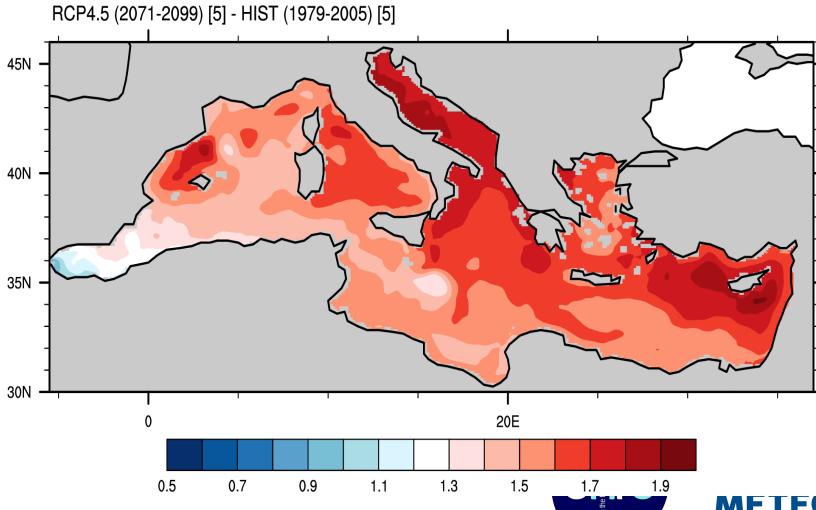


Yearly-mean SST anomalies  
(°C, Med Sea spatial average, wrt 1979–2005)



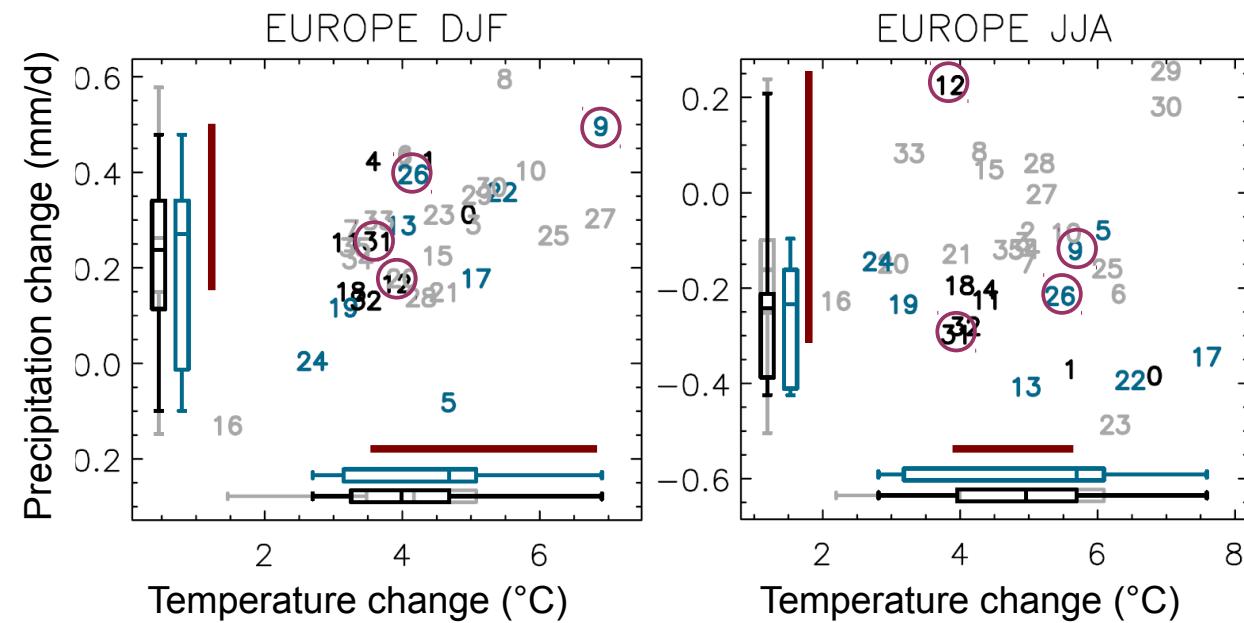
Based on  
Med-CORDEX  
RCSM runs  
(Darmaraki et al.,  
in prep.)

Yearly-mean SST change  
(°C, 2071–2099 vs 1979–2005, RCP4.5)



# Med-CORDEX RCSM simulations

Selection criteria among CMIP5 GCMs over Euro-Mediterranean following *McSweeney et al. (2015)*  
(also see *Brands et al. 2013* ; *Cattiaux et al. 2013* ; *Van den Hurk et al. 2014* ; *Jury et al. 2015*)

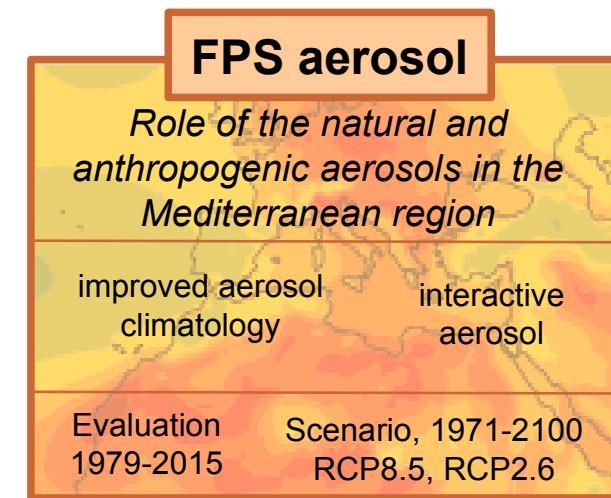
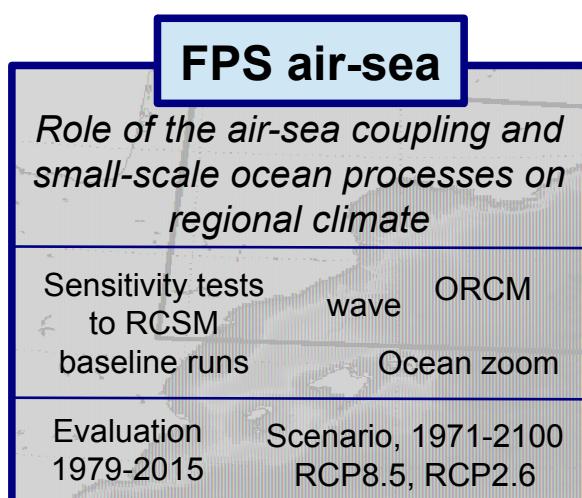
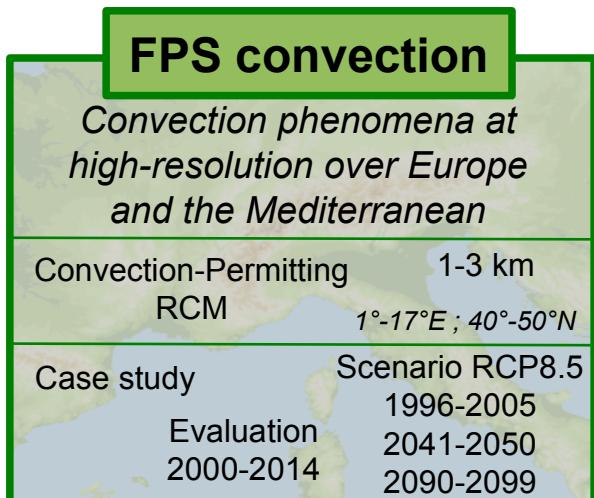
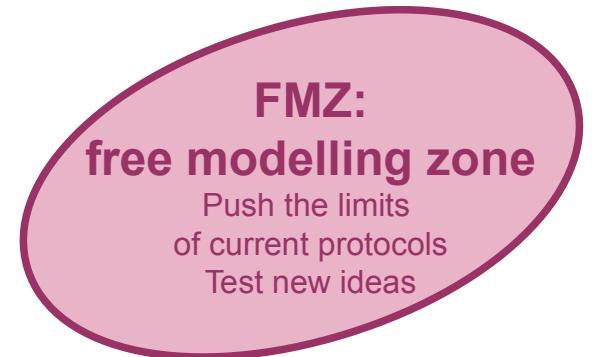
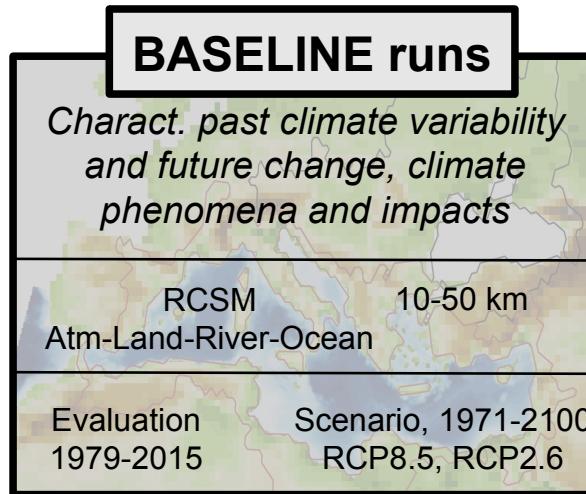


CMCC-CM (9)  
CNRM-CM5 (12)  
IPSL-CM5A-MR (26)  
MPI-ESM-LR (31)

	South East Asia	Europe	Africa	Overall
	North-east Monsoon Annual Cycles of T and P Summer Monsoon	TIP Annual Cycles of T and P Circulation Storm tracks	Summer Cycles of T and P Tele- Connections (Rowell, 2013)	
ACCESS1-0				ACCESS1-0
ACCESS1-3				ACCESS1-3
bcc-csm1-1				bcc-csm1-1
bcc-csm1-1-m				bcc-csm1-1-m
BNU-ESM				BNU-ESM
CanESM2				CanESM2
CNRM-CM5				CNRM-CM5
CGCM3A-MR				CGCM3A-MR
EC-EARTH				EC-EARTH*
FGOALS-g2				FGOALS-g2
GFDL-CM3				GFDL-CM3
GFDL-ESM2G				GFDL-ESM2G
GFDL-ESM2M				GFDL-ESM2M
HadGEM2-CC				HadGEM2-CC
HadGEM2-ES				HadGEM2-ES
inmcm4				inmcm4
IPSL-CM5A-LP				IPSL-CM5A-LP
IPSL-CM5A-MR				IPSL-CM5A-MR
IPSL-CM5B-LR				IPSL-CM5B-LR
LR				LR
MIROC5				MIROC5
MIROC-ESM				MIROC-ESM
MIROC-ESM-				MIROC-
MRI-ESM1				MRI-ESM1
MPI-ESM-LR				MPI-ESM-LR
MPI-ESM-MR				MPI-ESM-MR
MRI-CGCM3				MRI-CGCM3
Nor-ESM1-M				Nor-ESM1-M

# Med-CORDEX, phase 2 (2016-...)

## the main modelling exercises



# Med-CORDEX, baseline runs, phase 2

## The participating groups and models

- ⇒ 11 (12) participating modelling groups so far :

CNRM (France, S. Somot) : CNRM-RCSM6 (ALADINv6-12km, SURFEXv8-12km, CTRIPv2-50km, NEMOv3.6-MED12)

ENEA (Italy, G. Sannino) : PROTHEUS or RegCM-ES (RegCM4/MITgcm/HD)

GUF (Germany, B. Ahrens) : CCLM/TRIP/NEMOMED12

LMD (France, L. Li) : LMDZ/river/NEMOMED8

IPSL (France, T. Arsouze) : MORCE-MED (WRF/ORCHIDEE/NEMOMED12)

CMCC-UnivSalento (Italy, if funding, D. Conte - P. Lionello) : COSMOMED

Univ of Belgrade (Serbia, V. Djurdjevic) : EBU/POM

ITU (Turkey, U. Turungoglu) : RegESM1.2 (RegCM or WRF ; MITgcm or ROMS)

AWI-GERICS (Germany, D. Sein – W. Cabos) : REMO/MPIOM

UCLM\* (Spain, M. Gaertner) : PROMES/NEMOMED12

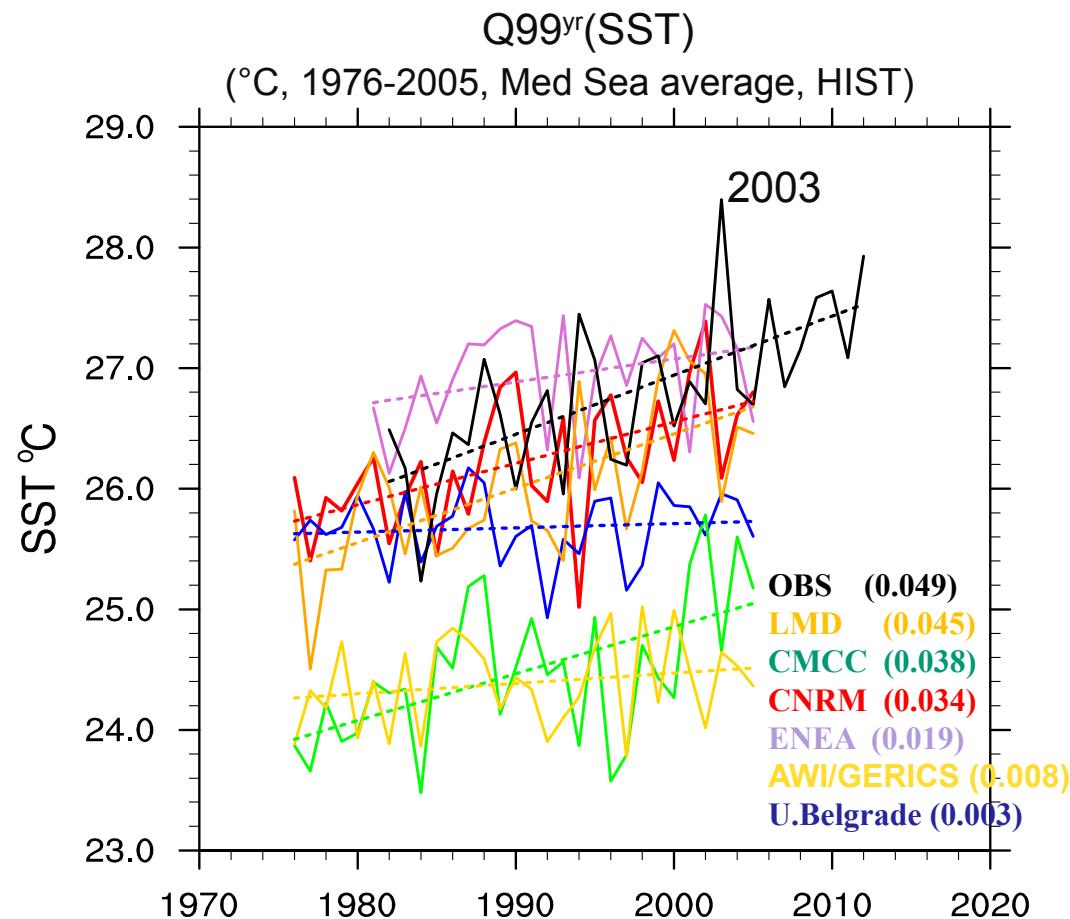
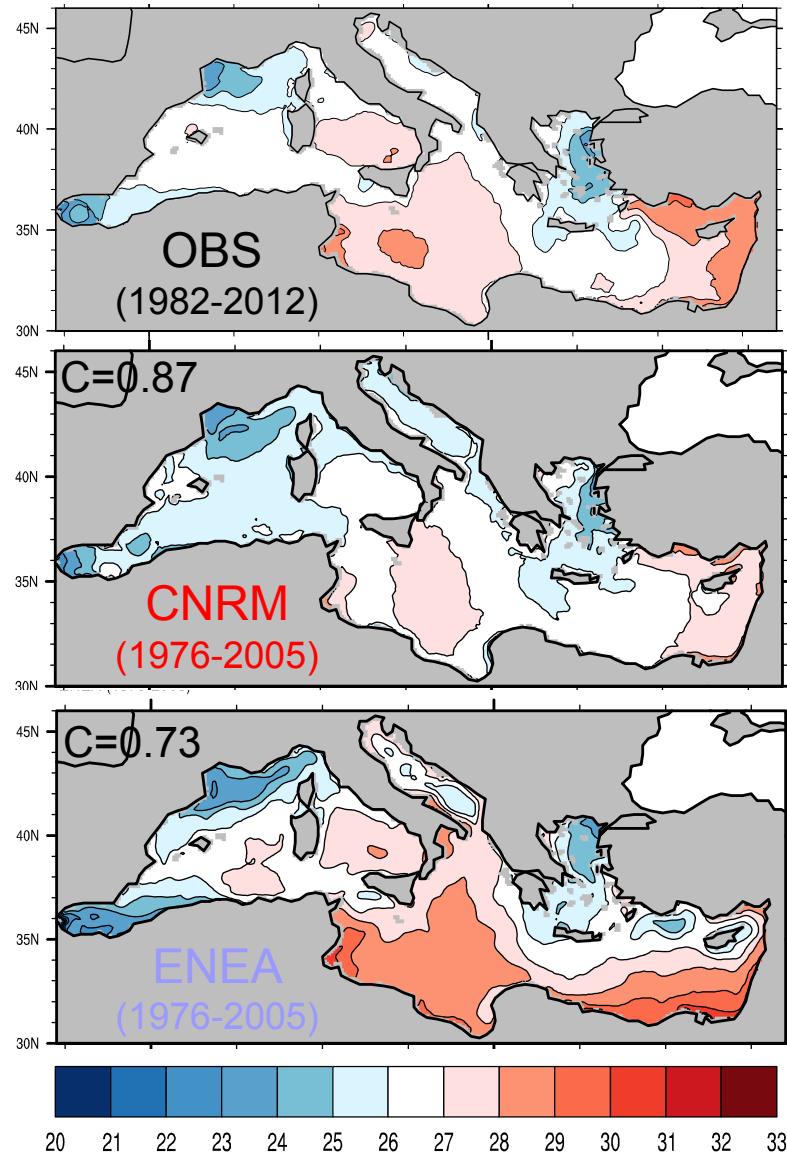
ICTP\* (Italy, R. Farneti – E. Coppola) : RegCM-ES (RegCM4/MITgcm)

?? BSC\* (Spain, M. Goncalves Ageitos) : NMMB/ROMS ??

(\* : no RCSM in phase 1)

# Marine Heat Waves : threshold evaluation

Threshold maps ( $^{\circ}\text{C}$ , 30 years)



Good spatial pattern (despite mean biases)  
Underestimation of the observed trends  
Exceptionnal 2003 MHW



# Marine Heat Waves : future evolution

➤ To summarise :

