A 15-year history of coupled regional climate modelling for the Mediterranean: success stories and current challenges

Samuel Somot

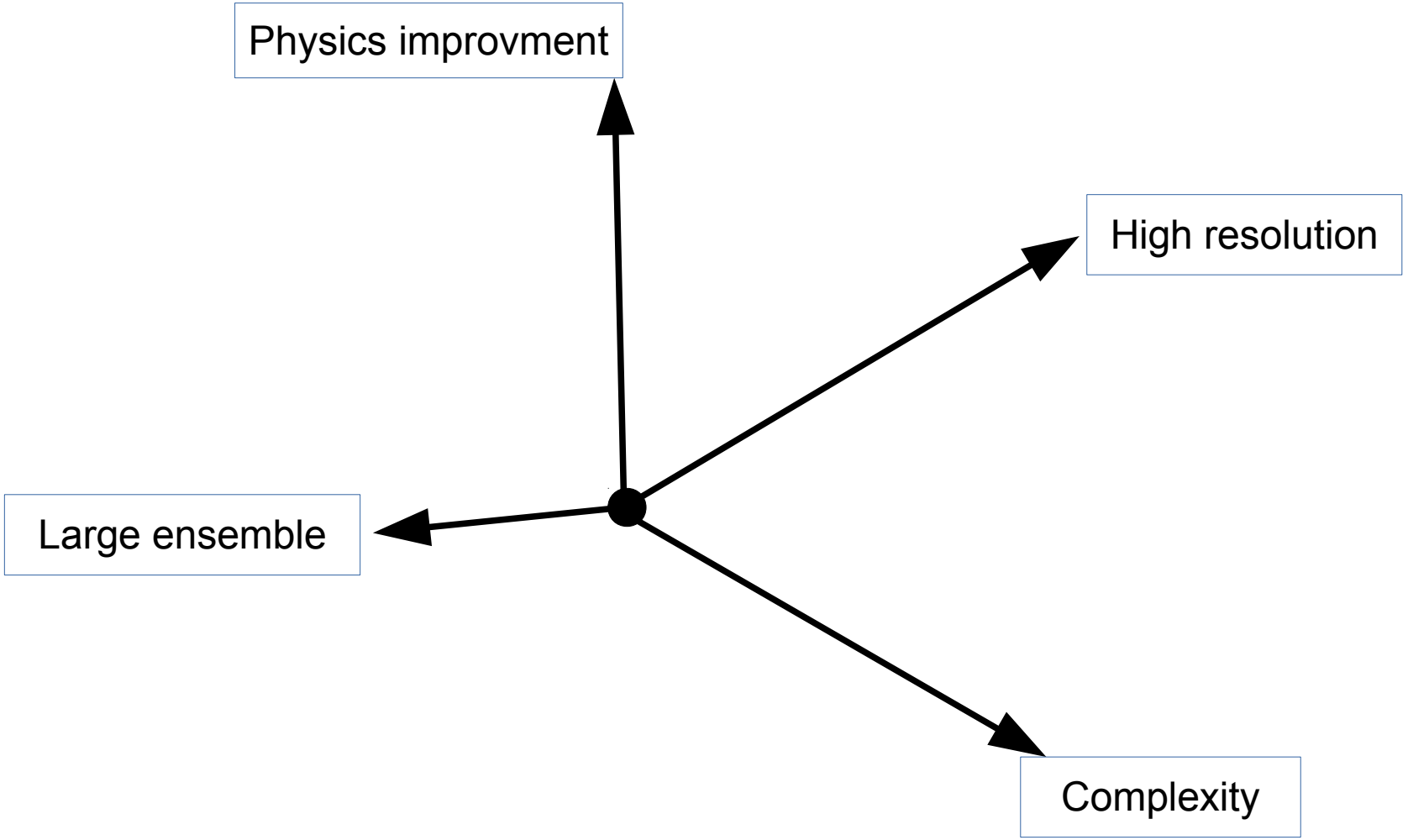
with many contributions from the Med-CORDEX community

CNRM, University of Toulouse, Meteo-France, CNRS

Regional Climate System Modelling for the European Seas Regions
Med-CORDEX Baltic Earth COST Workshop, Majorca, March 2018

Where are coupled RCMs in the climate model family ?

Multi-axes of the climate model developement world



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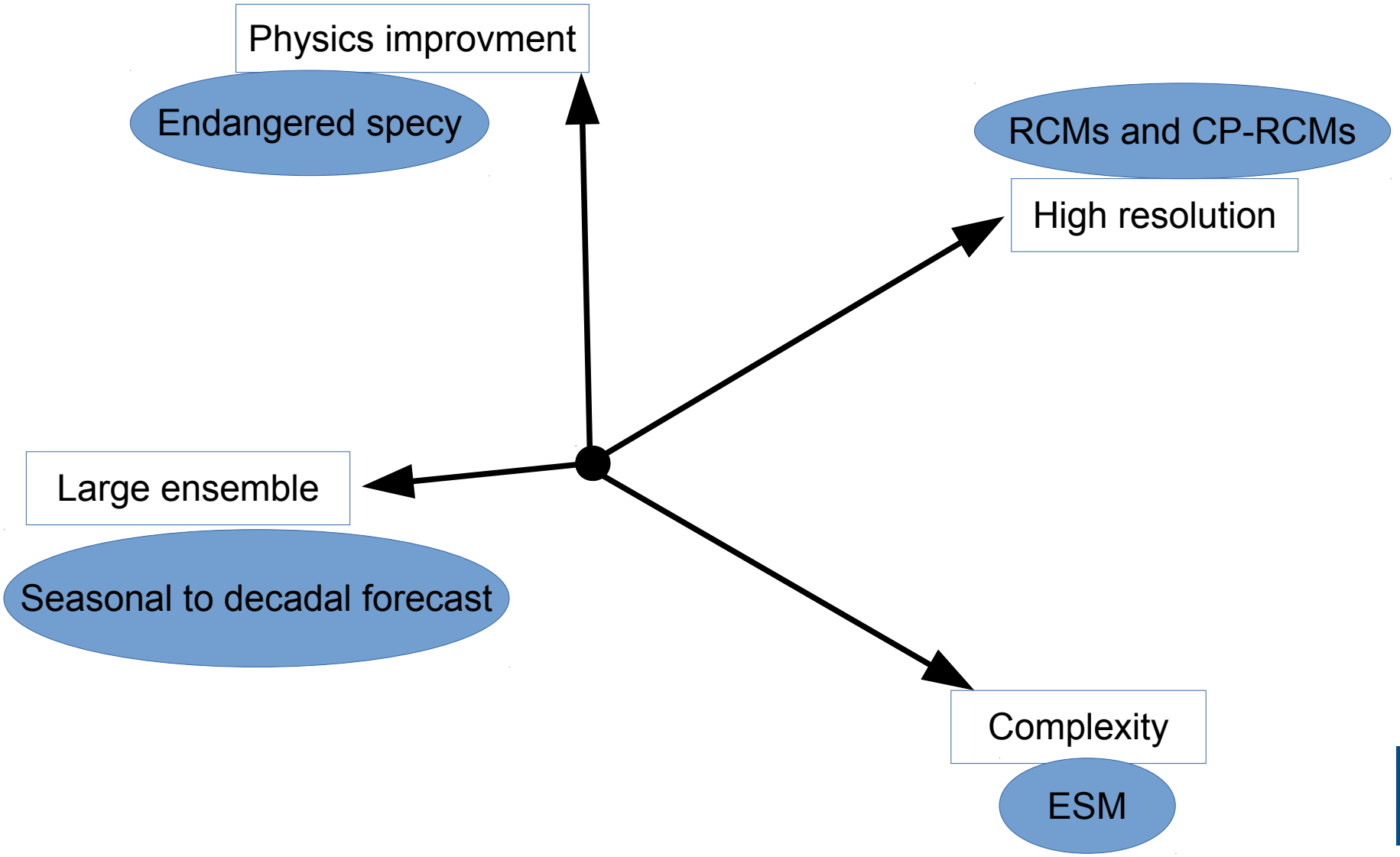

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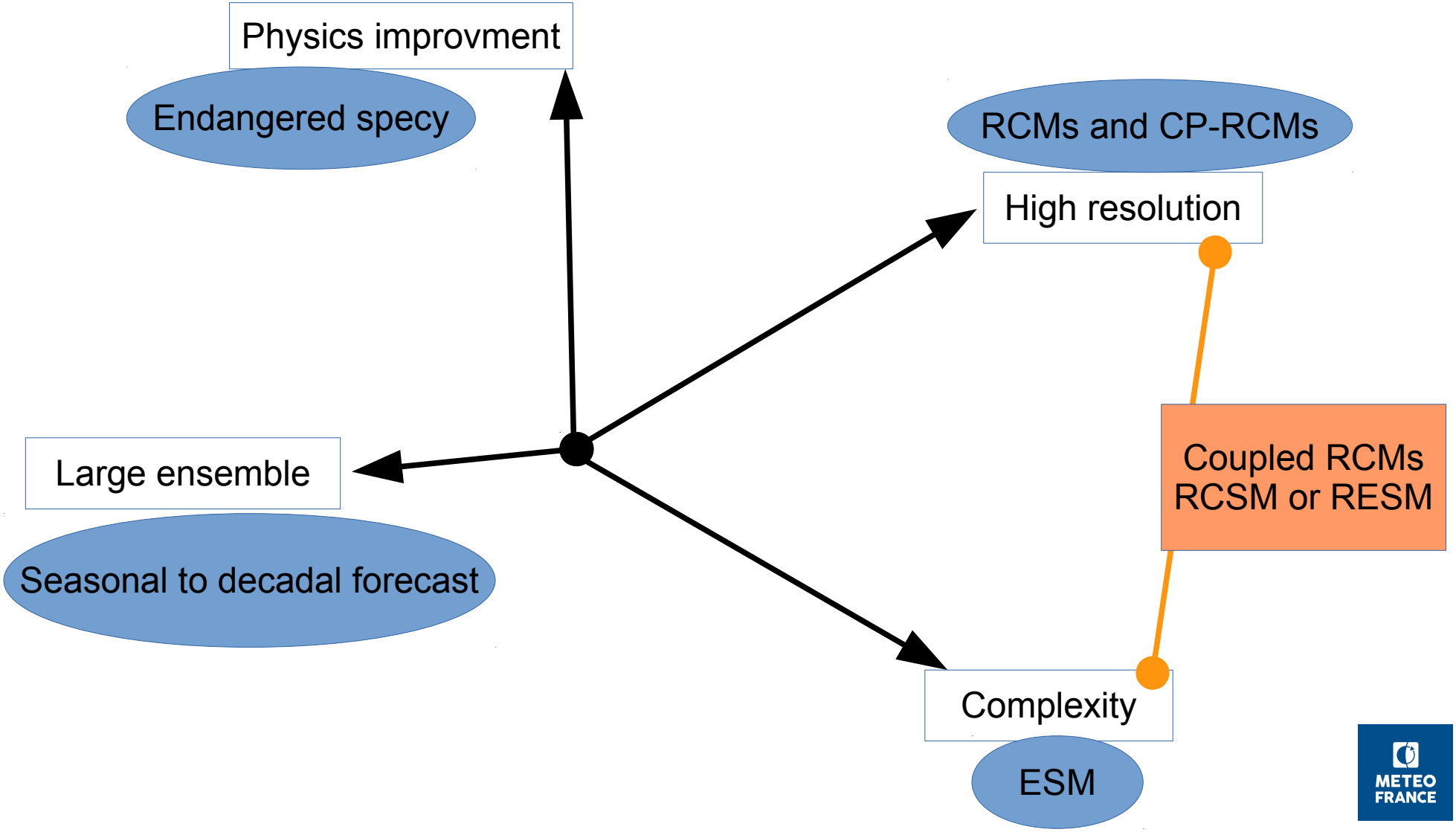
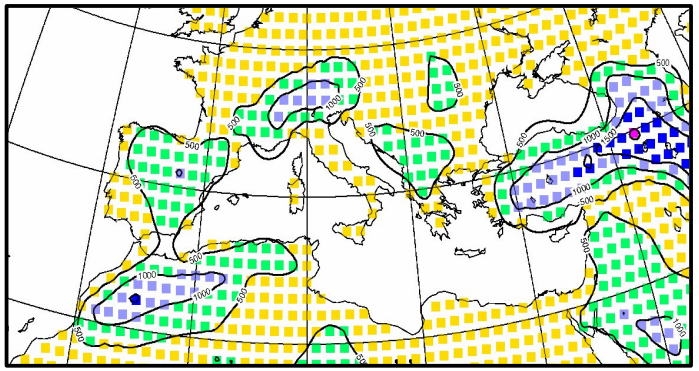


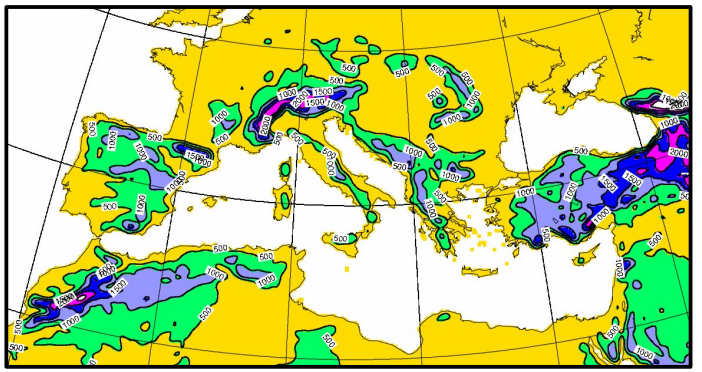
Motivations to develop RCSM : the resolution issue

Low-resolution models poorly represent the physical constrains

Topography and land-sea mask

GCM
CMIP
125km

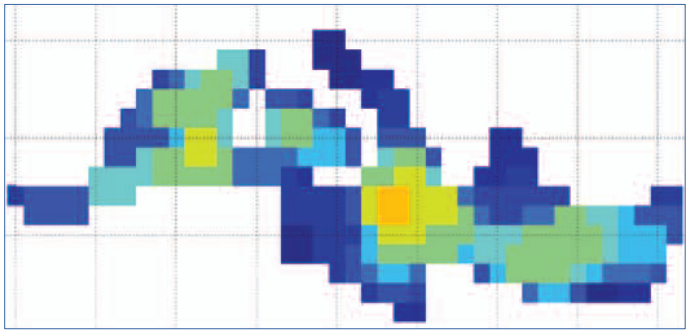


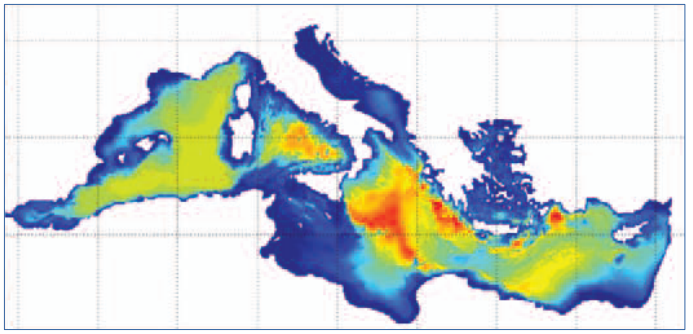


RCM
CORDEX
12km

Bathymetry and land-sea mask

GCM
110km





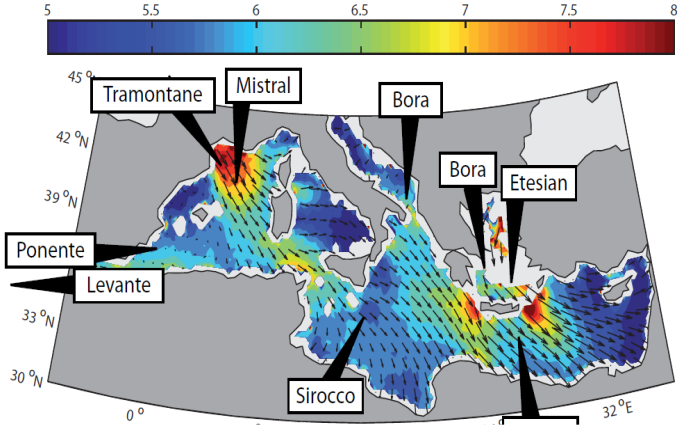
RCSM
10km

S. Somot (pers. comm.), Gualdi et al. 2013, BAMS

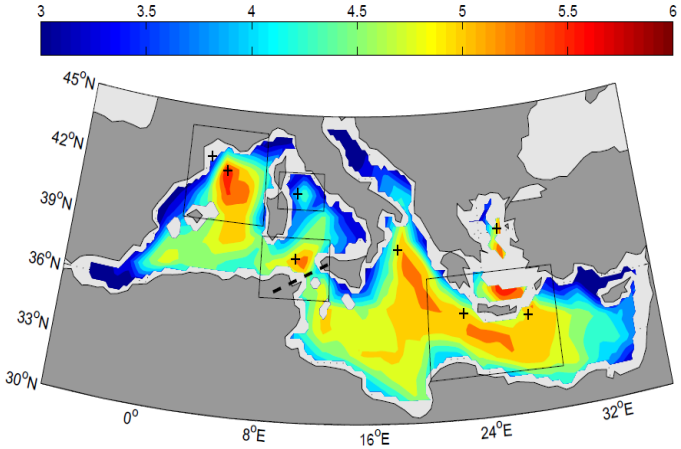
Motivations to develop RCSM : the resolution issue

Low-resolution atmosphere models poorly represent the Mediterranean climate and associated regional sea winds

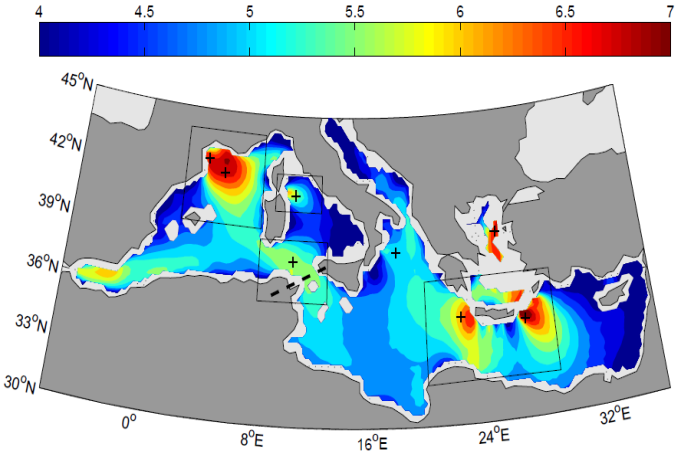
Mean wind speed (m/s, 2000-2001)



OBS : QuikSCAT

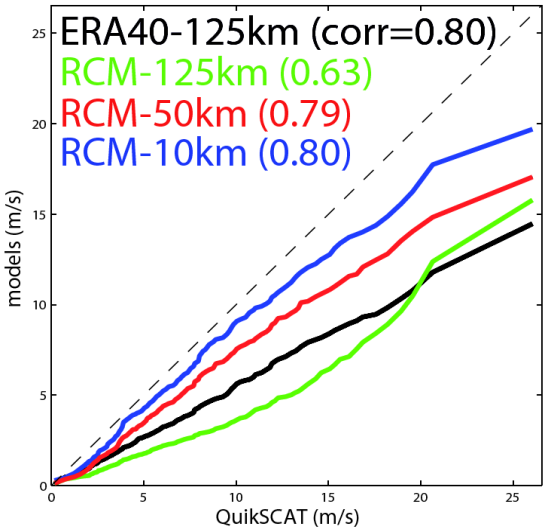


RCM, 125 km



RCM, 10 km

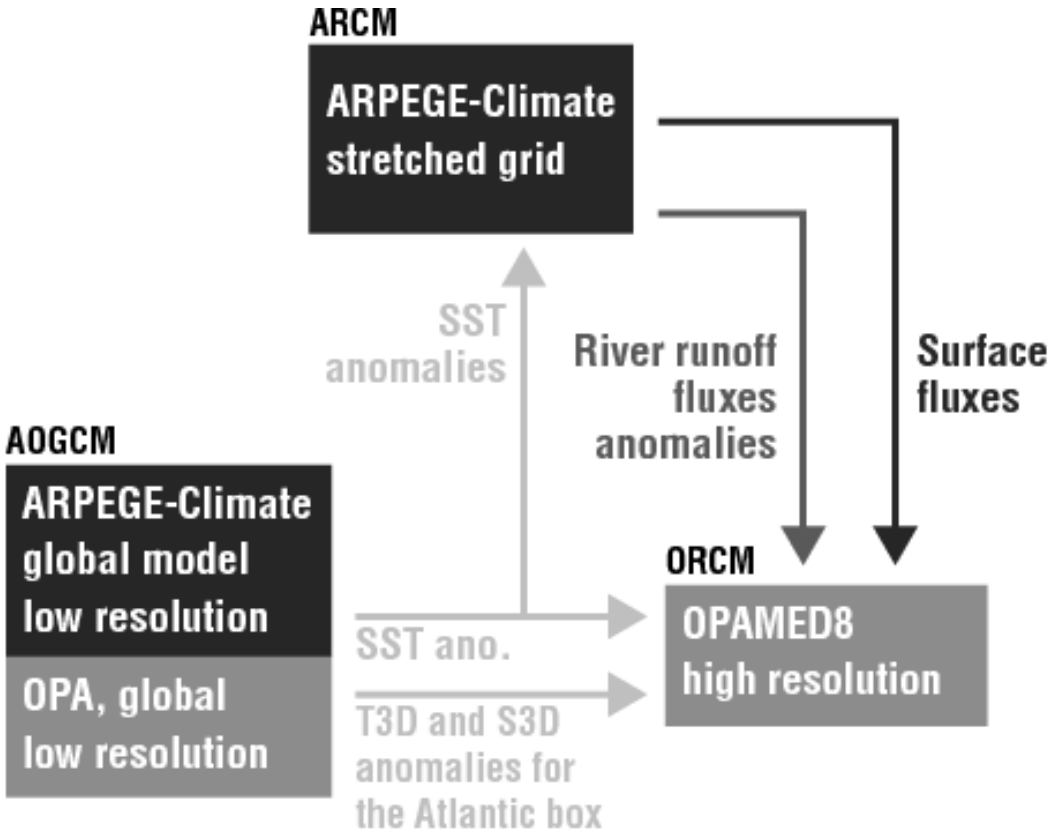
Quantile-Quantile plot for daily wind speed (G. of Lions, 2000-2001, m/s)



Herrmann et al. 2011

Motivations to develop RCSM : the coupling issue

Non-coupled climate model is an ill-posed problem, specially in scenario mode



Somot et al. 2006

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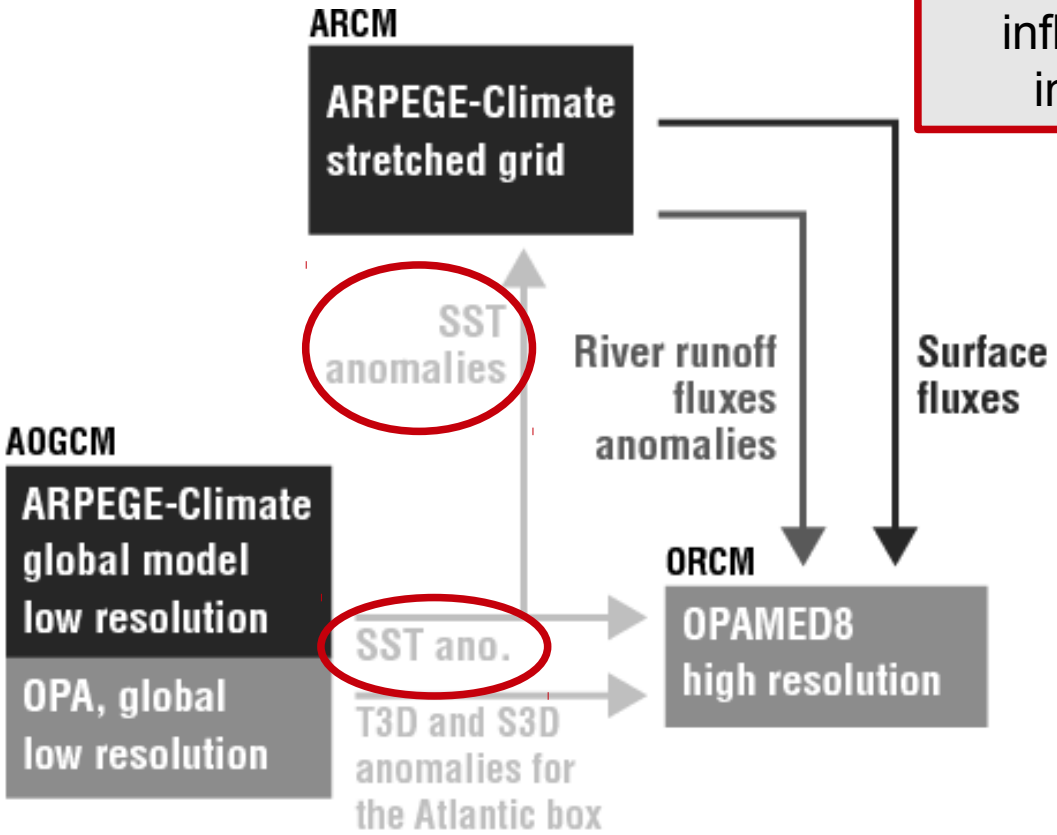
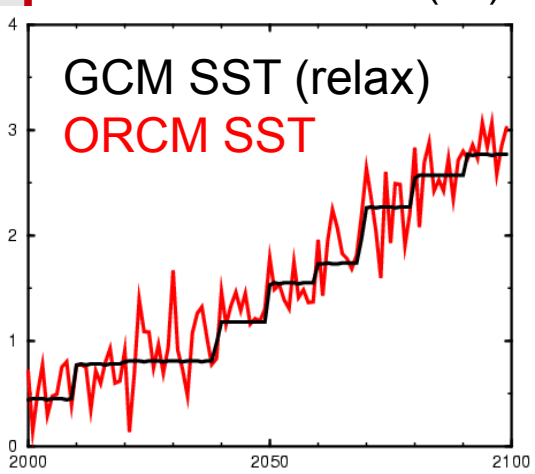
Low-resolution information from the GCM does influence the results inside the domain



SST anomalies (°C)



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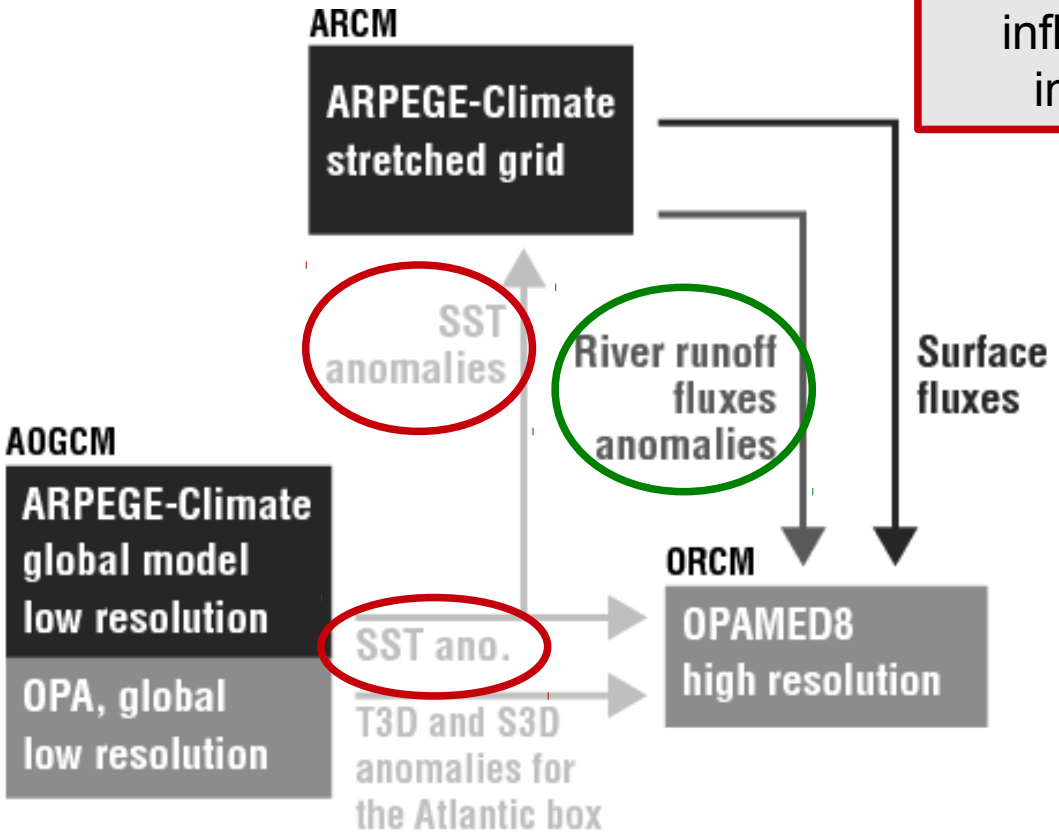

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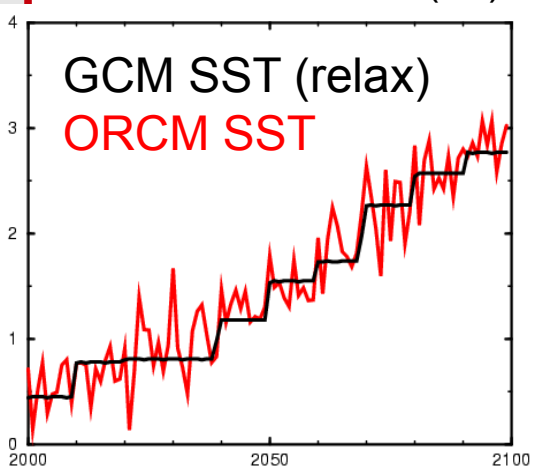
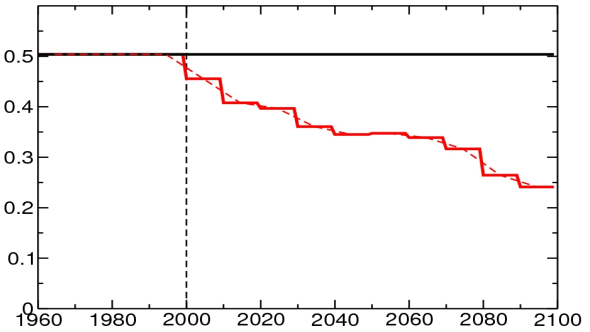


Imposing consistent river flow changes is a big issue

River and Black Sea anomalies (mm/d)



Somot et al. 2006

History of the Mediterranean RCSM

1995

Atmosphere + Surface = (A)RCM

(Déqué & Piedelievre 1995, Jones et al. 1995)

time

RCM : Regional Climate Model

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2008 + Ocean = AORCM
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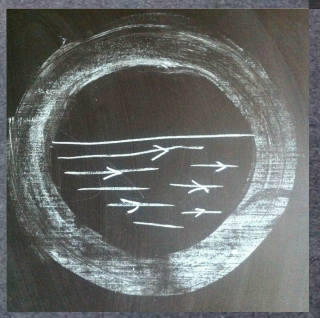

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AORCM : Atmosphere-Ocean Regional Climate Model

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+ Natural & Anthropogenic aerosols = RCSM
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(Sein et al. 2015)
+ Natural & Anthropogenic aerosols = RCSM
(Nabat et al. 2015)

2017 + Lake, Aquifers, Flood plains = RCSM
(Voldoire al. 2017)

When ? What ? Why ? Who ?

time

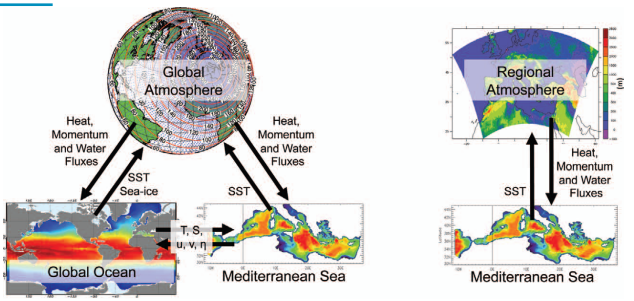
RCM : Regional Climate Model

AORCM : Atmosphere-Ocean Regional Climate Model

RCSM : Regional Climate System Model

Coordinated multi-model initiatives to date

- **The EU CIRCE project *(Gualdi et al. 2013)***
  - 6 AORCMs (ENEA, LMDZx2, MPI, CNRM, INGV)
  - Scenario runs for the 1950-2050 period, A1B
  - Very few multi-model scientific articles *(Dubois et al. 2012, Gualdi et al. 2013)*
  - Contribution to the RACCM and Med-CLIVAR book



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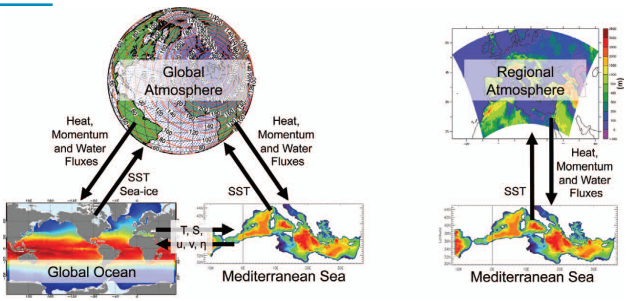
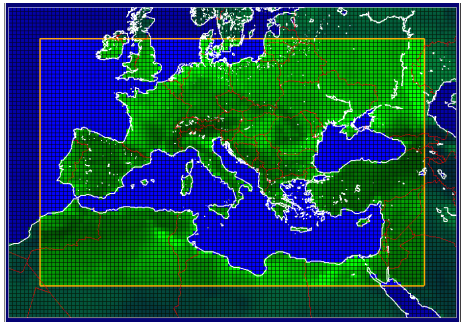




- **The Med-CORDEX initiative *(Ruti et al. 2016)***
  - Endorsed by WCRP CORDEX and Med-CLIVAR
  - Financially supported by MISTRALS/HyMeX since 2009
  - 12 RCSMs : evaluation runs (1979-2013) and scenario runs (1950-2100, RCP8.5, RCP4.5, RCP2.6)
  - Improved models wrt CIRCE
  - Growing number of multi-model articles
  - Phase 2 starting with Baseline runs and FPS air-sea
  - Contribution to the MedECC, IPCC-SROCC, IPCC-AR6 reports

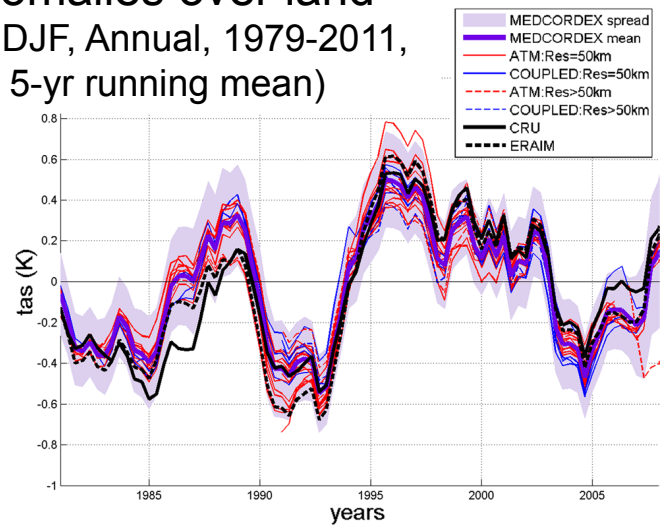
MedCORDEX – TIER1 simulations RCSM (same atm as corresponding ARCM)				ERAI	HIST	RCP8.5	RCP4.5	RCP2.6
	institute	model	comp.	1979-now	1950-2005	2006-2100	2006-2100	2006-2100
RUN	ENEA	PROTHEUS	ALRO	1982-2010	1971-2005		2006-2100	
	MPI	REMO/MPI-OM	ALRO					
	CNRM	RCSM4 v1	ALRO	1980-2013	1950-2005	2006-2100	2006-2100	2006-2100
	LMD	LMDZ4NEMOMED8	ALO	1979-2009	1950-2005	2006-2100	2006-2100	
	Univ. Belg.	EBU/POM	ALO	1958-2008				
	IPSL	WRF311NEMO-20km	ALO	1989-2013				
	UCLM/UPM	PROMES/NEMOMED12	ALO					
	INSTM	LMDZ/ROMS-MED	ALO	1979-2009				
	UAH-AWI-ROM	REMO/MITgcm	ALROB					
	GUF	CCLM-NEMO	ALO	1965-2012				
	CMCC / U. of Salento	CCLM4-21-NEMOMFS	ALO	1950-2011	1950-2005	2006-2100	2006-2100	
	ITU	RegCM4/ROMS	ALO					

METEO FRANCE

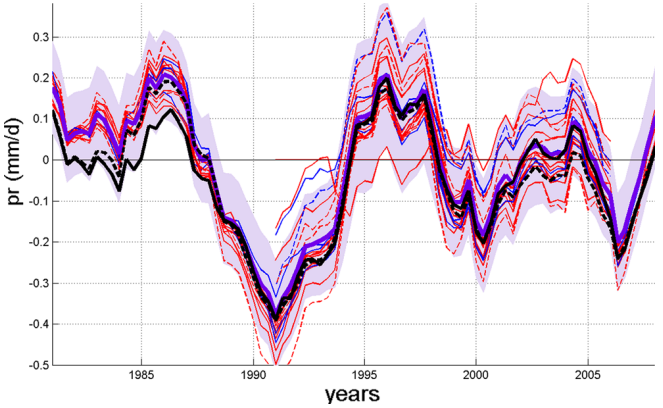
Evaluation : atmosphere, river, air-sea fluxes

Surface temperature anomalies over land

(°C, DJF, Annual, 1979-2011, 5-yr running mean)

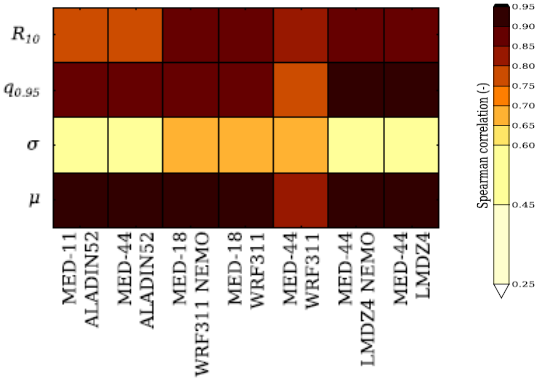


Precipitation anomalies over land (mm/d, DJF, Annual, 1979-2011, 5-yr running mean)



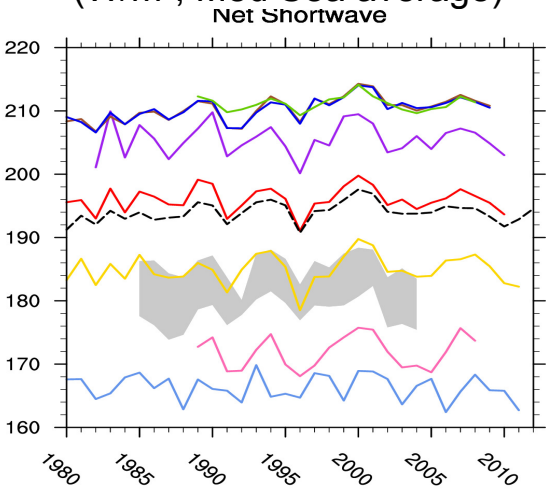
Spatial correlation for temperature indicators

(mean, std, Q95, 10-yr return level, ref: E-OBS)



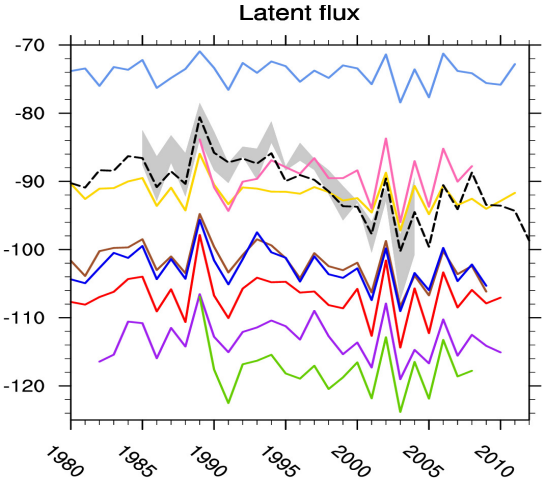
Net Shortwave radiation interannual time series

(W/m², Med Sea average)

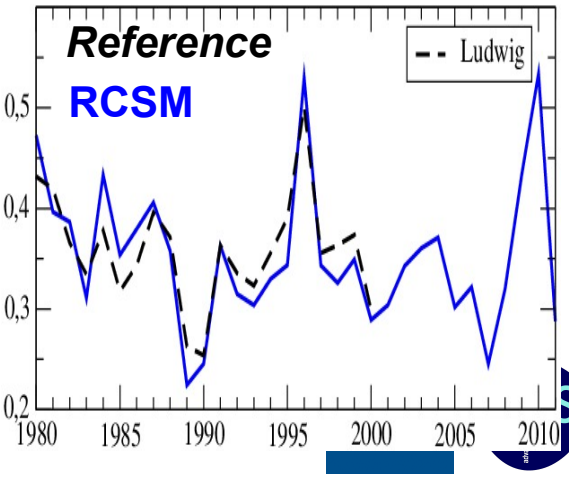


Latent heat loss interannual time series

(W/m², Med Sea average)



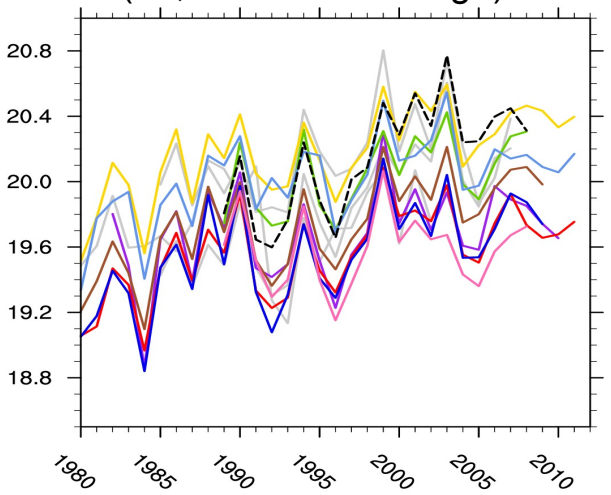
Interannual variability of Mediterranean river discharges (mm/d)



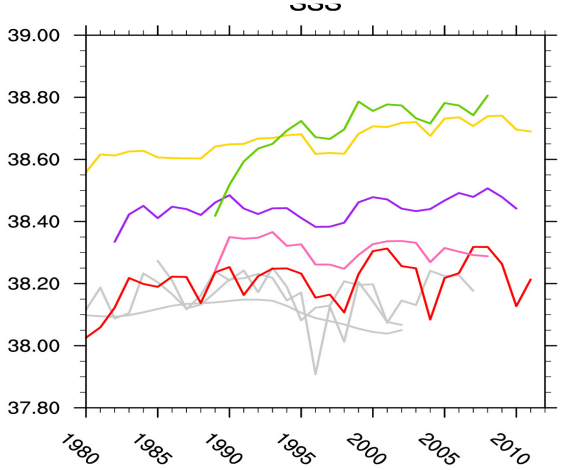
Dell'Aquila et al. 2016, Panthou et al. 2016, C. Dubois, pers. comm., Sevault et al. 2014

Evaluation : ocean

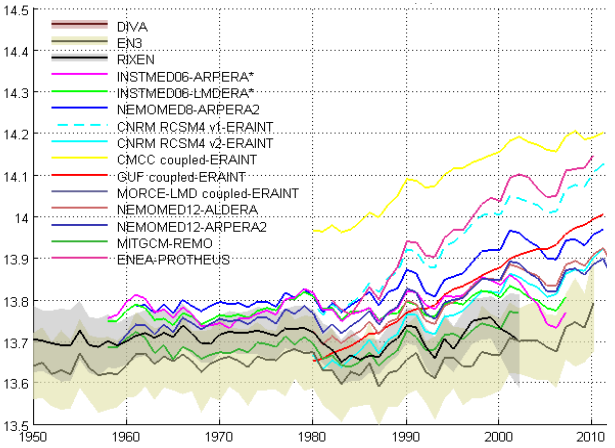
Interannual SST
(°C, Med Sea average)



Interannual SSS
(psu, Med Sea average)

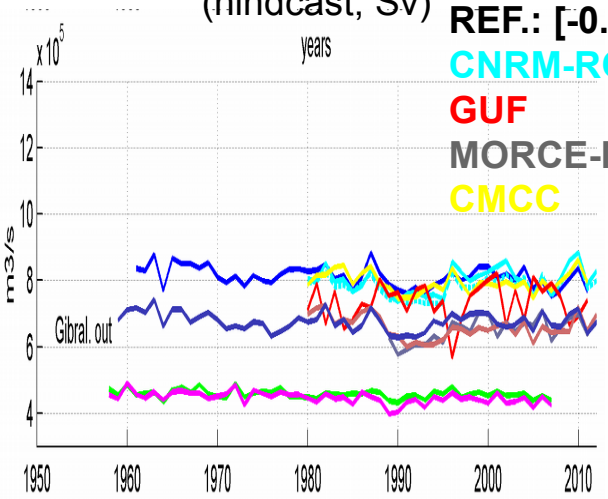


Interannual heat content
(°C,1960-2013, Med Sea average)

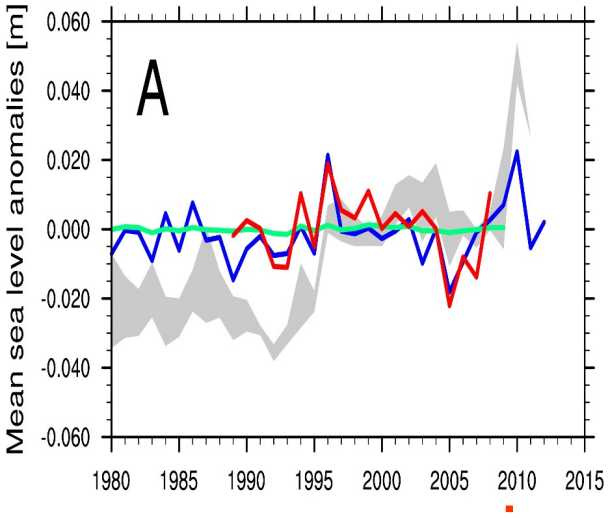


Gibraltar Strait Outflow
(hindcast, Sv)

REF.: [-0.78 ± 0.06] Sv
CNRM-RCSM4
GUF
MORCE-MED
CMCC



Interannual sea level anomaly
(m, hindcast, 1980-2012, Med Sea average)



REFERENCE
CNRM-RCSM4
LMDZ-MED
MORCE-MED

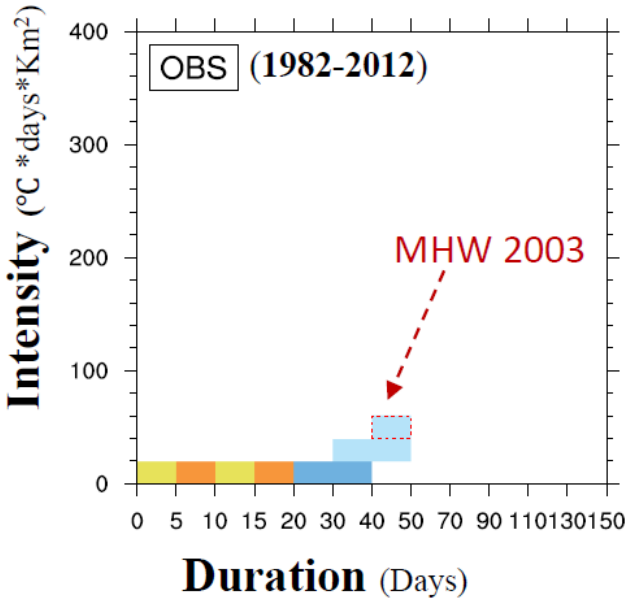
C. Dubois, pers. comm., Ruti et al. 2016, Harzallah et al. 2016, Adloff et al. 2017

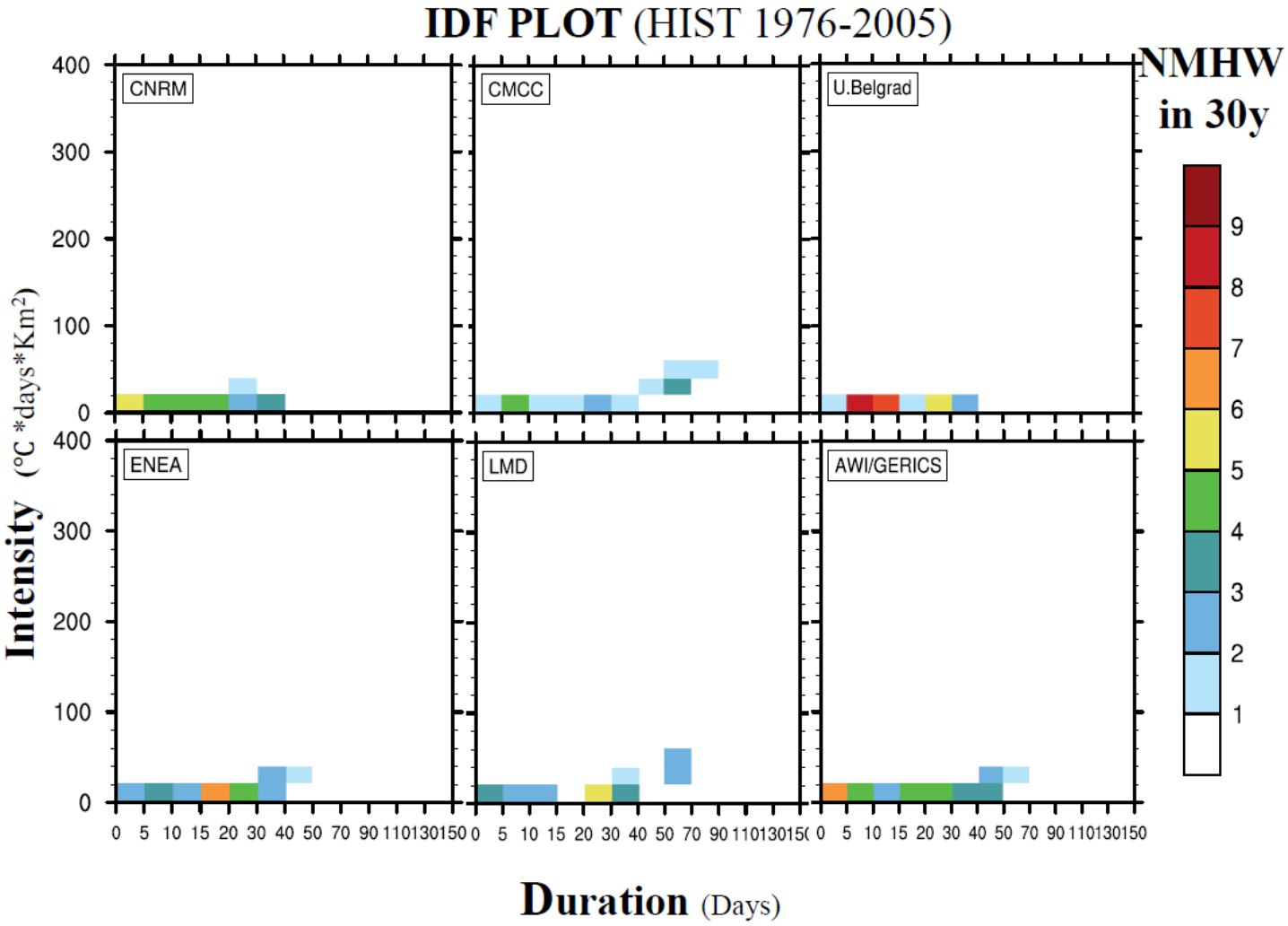
Evaluation : phenomena-oriented

Marine Heat Waves

- Reference: CMEMS L4 satellite product (0.04°, CNR-ISAC-ROME)
- Detection: 2D threshold wrt local Q99-SST, 5- days min. duration, max 3 gap days, min. 20% surface
- RCSM: CNRM, ENEA, LMD, CMCC, AWI-GERICS, Uni. Belgrade / Historical period / 1976-2005

Intensity-Duration-Frequency plots





Darmaraki et al. (in prep.)

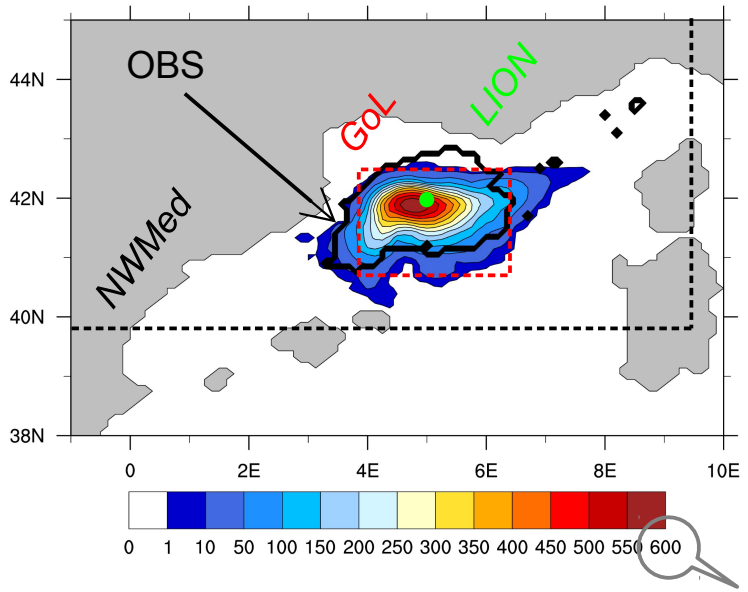
Evaluation : phenomena-oriented

Deep Water Formation in the North-Western Med. Sea

- Reference: LION weather buoy and deep mooring + HYDROCHANGES, CTD field campaigns (MOOSE, DeWeX), re-assessment of past observations
- Model: CNRM-RCSM4, ERA-Int driven + spectral nudging, 1980-2013
- Method: spatial and temporal evaluation of the maximum mixed layer depth

Occurence of daily MLD>1000m

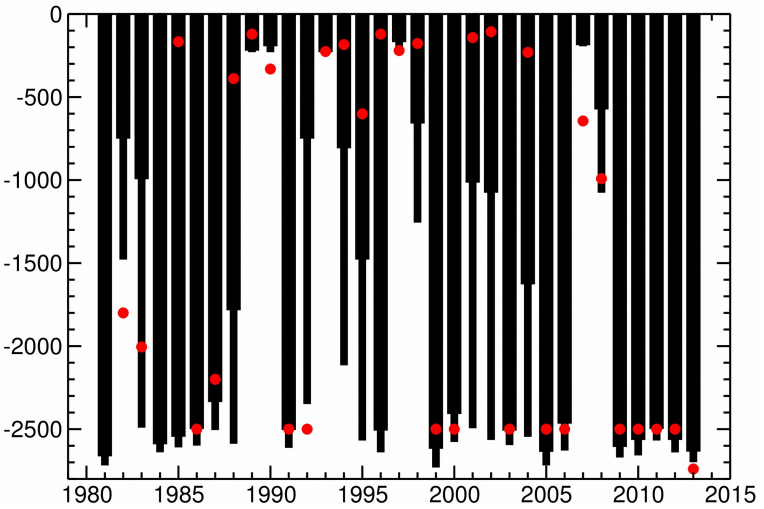
(Nb of day, 1980-2013)



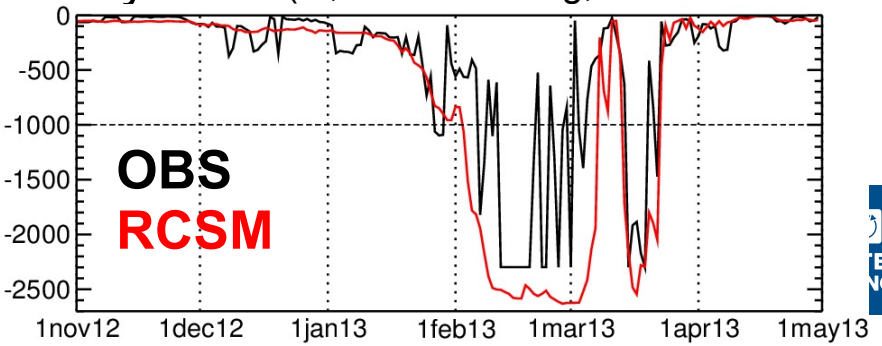
20 days/yr

Yearly spatio-temporal maximum MLD

(m, GoL, daily data)



Daily MLD (m, LION mooring, Winter 2012-2013)

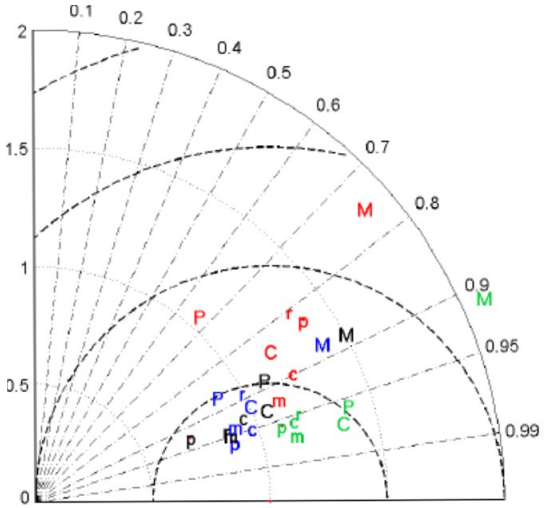


Adapted from Somot et al. 2016, using additionnal observations from Houpert et al. 2016, Waldman et al. 2018 (also see L'Hévéder et al. 2013)

Added-value : RCSM vs AOGCM

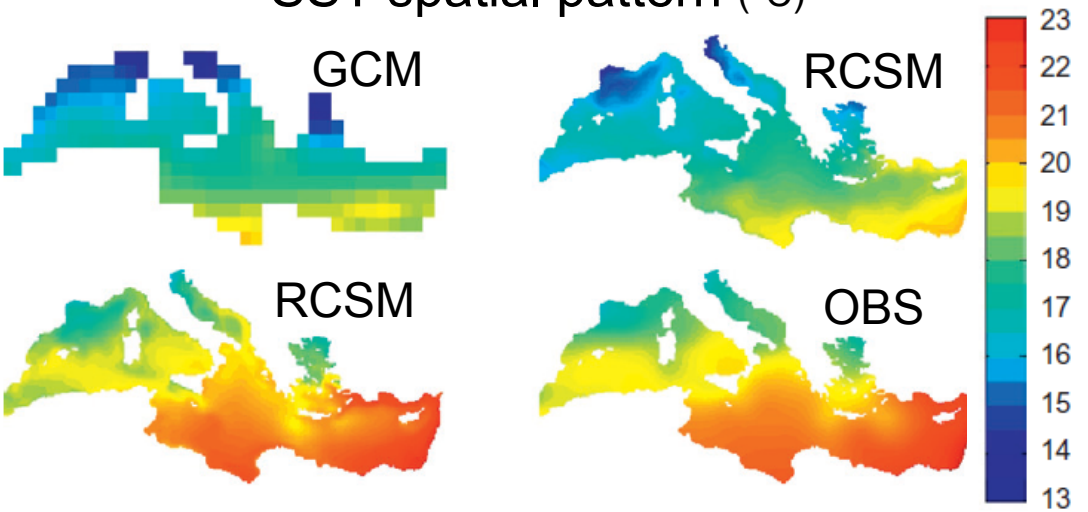
If any, related to a better representation of SST at small-scale and high-frequency

SST spatial Taylor diagram (ref : Marullo et al. 2007 dataset, 1985-2010, Mediterranean Sea)

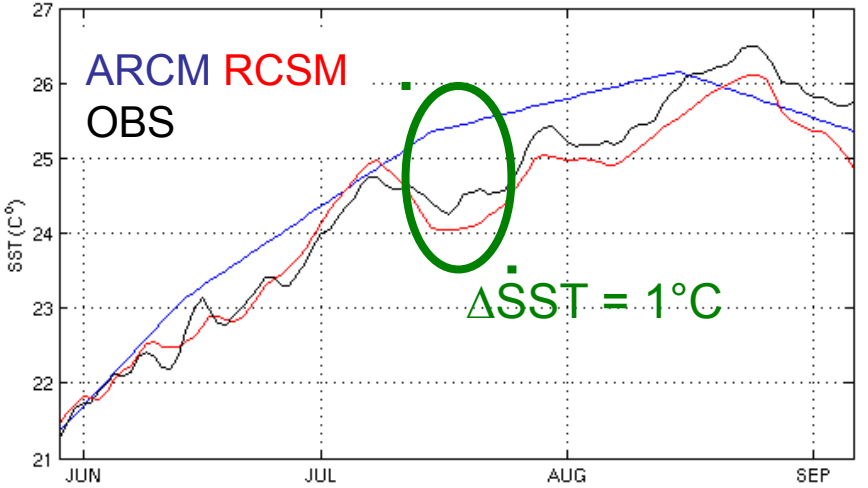


Comparison between GCM (capital letters) and AORCM (small letters) for DJF (black), MAM (green), JJA (red), SON (blue)

SST spatial pattern (°C)



SST daily time series (°C, July 2000, RegCM vs PROTHEUS, ref : Marullo et al. 2007)



RCSMs better capture SST spatial pattern and high-frequency variability than GCM or ARCM

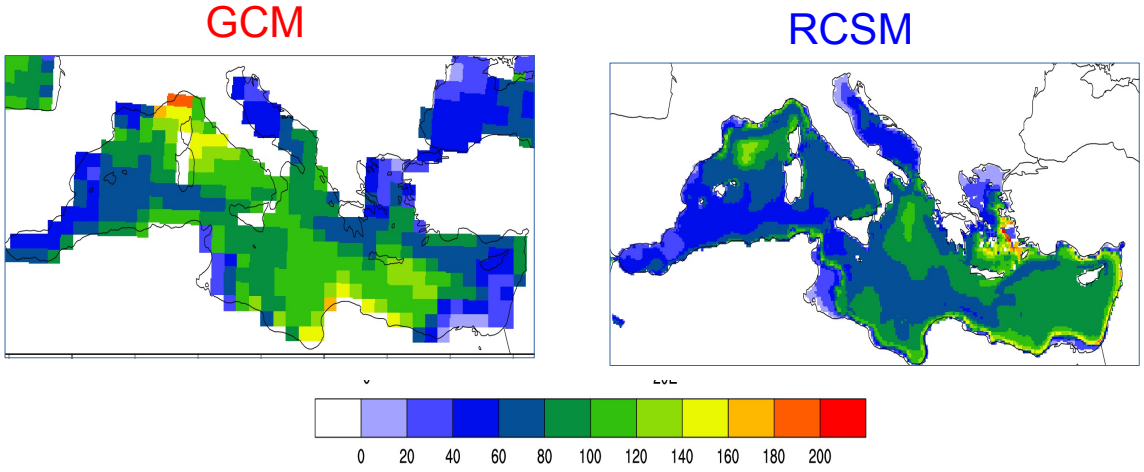
This potentially leads to improve air-sea fluxes, moisture and heat transports and finally may influence the surrounding land areas

S. Calmanti, pers. comm., CIRCE project, Li et al. 2012, adapted from Artale et al. 2010, M. Herrmann, pers. comm.

Added-value : RCSM vs AOGCM

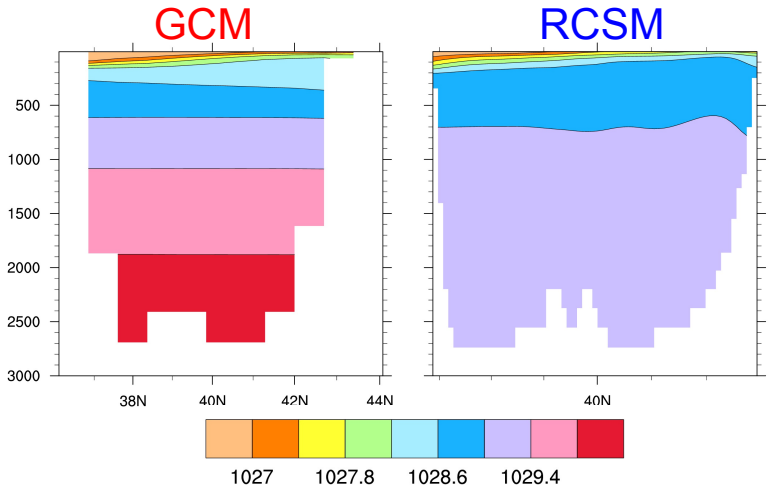
RCSM improves the representation of DWF and MTHC wrt GCM

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

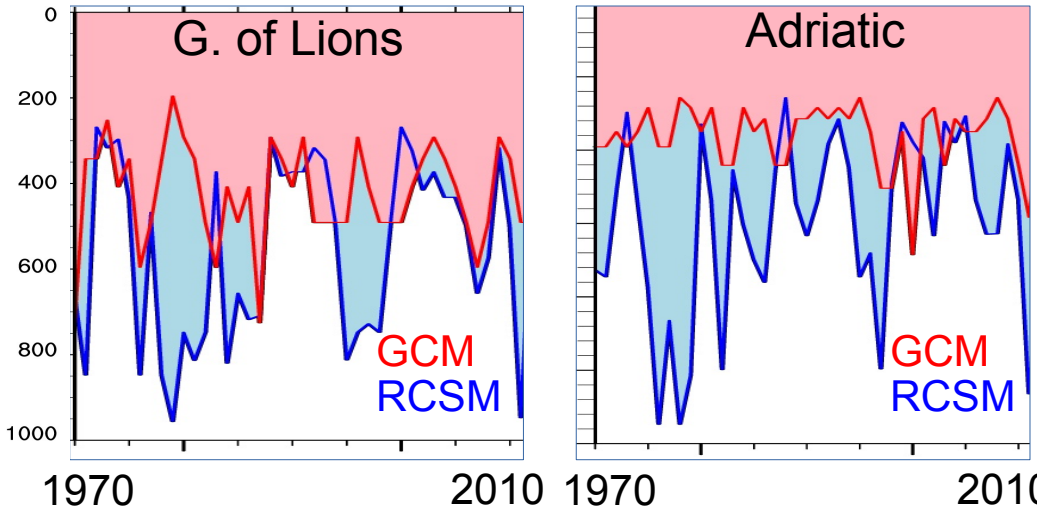


Potential density vertical section

(G. of Lions, 5°E, kg/m3)

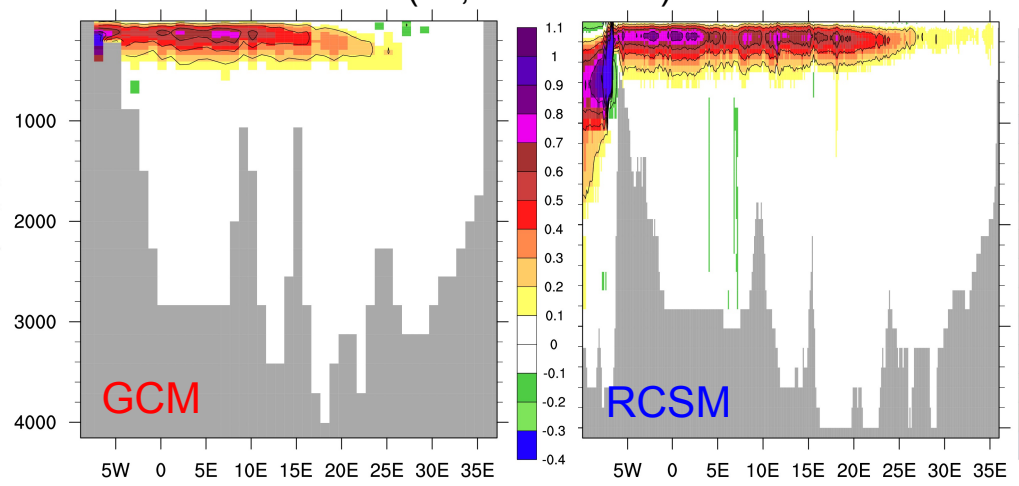


Yearly maximum MLD (m)



Zonal overturning streamfunction

(Sv, 1976-2005)



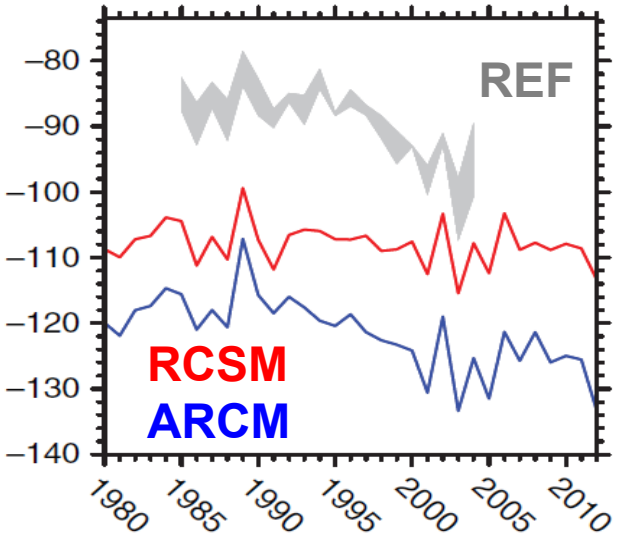
C. Dubois (CNRM), pers. comm.

Added-value : RCSM vs ARCM

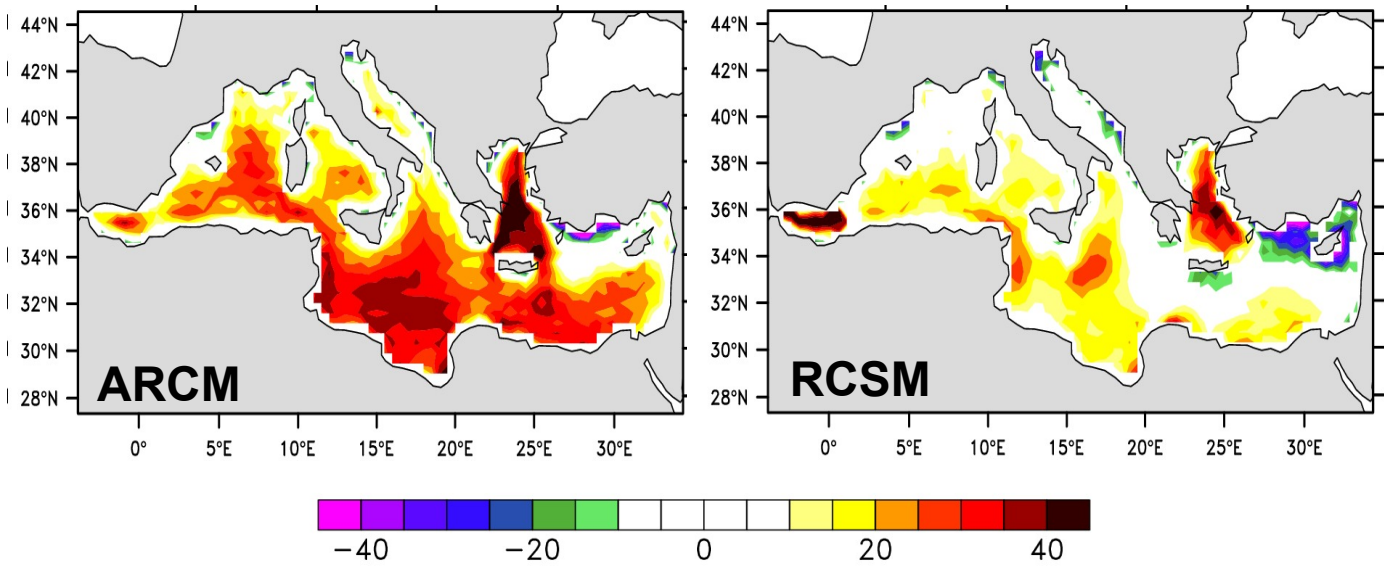
Latent heat flux and net heat flux

- Reference: OAFLUX satellite product
- Model: CNRM-RCSM4 and corresponding ALADIN simulation, ERA-Int driven + spectral nudging, 1980-2013

Latent heat loss interannual time series (W/m², Med Sea average)



Latent Heat flux bias wrt OAFLUX (W/m²)



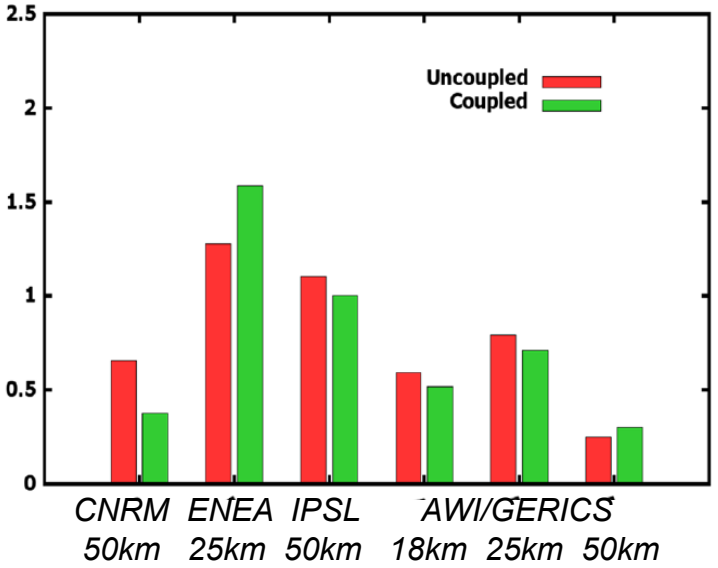
RCSM generally improves latent heat flux and net heat flux wrt ARCM
However, this often leads to SST bias wrt observations

Sevault et al. 2014, Nabat et al. 2015a
Other relevant studies : Dubois et al. 2012, Lebeaupin-Brossier et al. 2015, Cavicchia et al. 2015, Akhtar et al. 2017

Added-value : RCSM vs ARCM

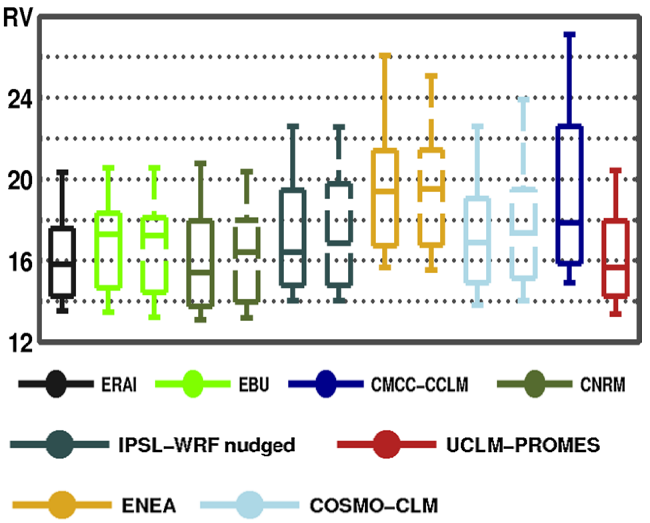
Mediterranean cyclones and medicanes

Medicane frequency
(Number/year)



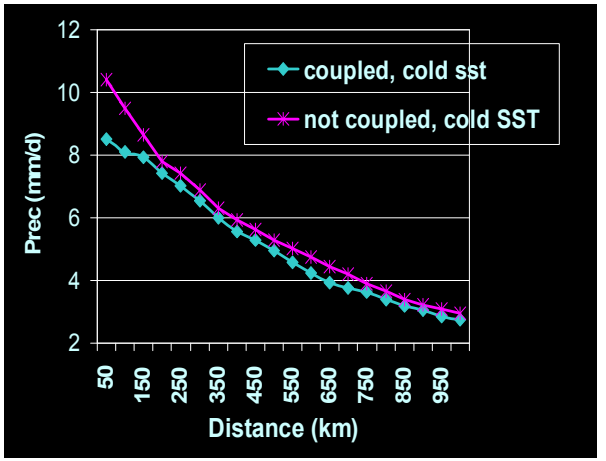
Detection based on Picornell et al. 2001 for tracking, Hart (2003) for cyclone phase space method and Miglietta et al. 2013 for threshold (17.5 m/s)

Maximum intensity for the most intense cyclones
(West Med, 10^{-5} s^{-1})



Maximum relative vorticity of the 500 most intense Mediterranean cyclones, 1989-2008.
Using 5 ARCM/RCSM pairs
Using 2 tracking methods.
Coupled models in dashed lines.

Precipitation composite wrt to cyclone center distance
(mm/d, G. of Genoa, > 10^{-5} s^{-1})



Coupling has a limited impact on Medicanes (frequency, intensity)

Coupling has a weak impact on Mediterranean cyclones (number, geography, intensity)

Coupling leads to negative feedback on precipitation close to cyclone center

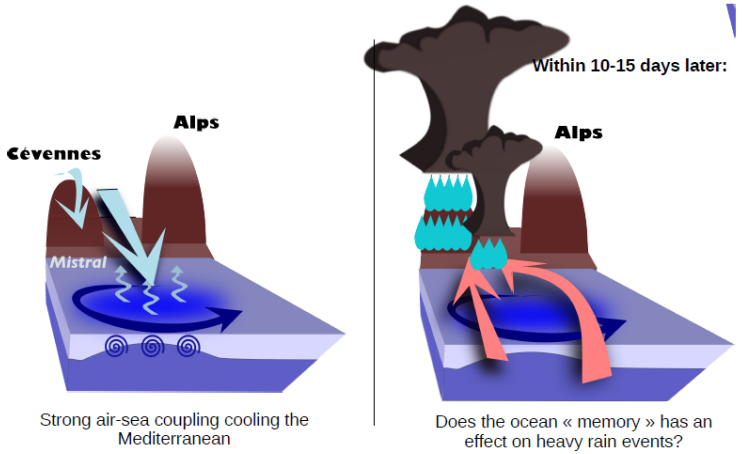
Gartner et al. 2016, Flaounas et al. 2016, Somot 2005 (see also Sanna et al. 2013, Akhtar et al. 2014)

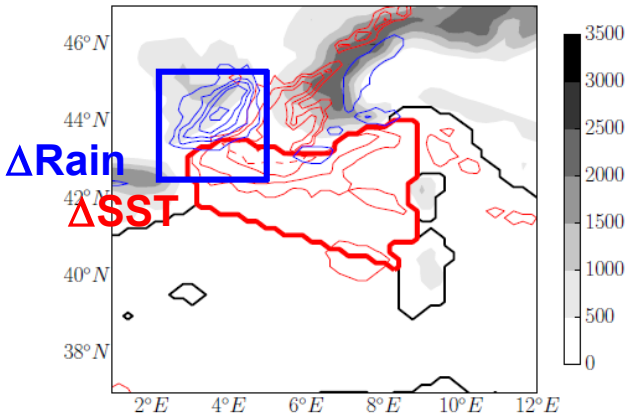
RCSM as a tool to answer scientific questions

Ocean short-term memory effect on Mediterranean Heavy Precipitation Events

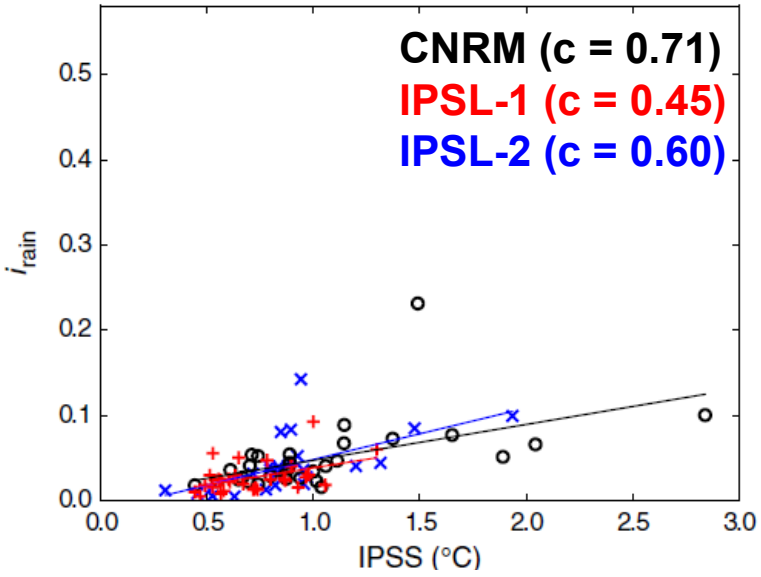
Statistically, HPE intensity is influenced by regional high-frequency ocean-atmosphere interactions
A SST-HPE relationship is obtained comparing RCSM and ARCM negative (multi-model, multi-site)

Schematic view of a Mistral event followed by an HPE event





Relationship between an HPE indice (i_rain) and a SST indice (IPSS, °C) for the Cevennes area



$$IPSS = \sqrt{\overline{\delta SST^2}^{\,\mathrm{Reg_{SST}}}}$$

$$I_{rain} = \sqrt{\overline{\delta P^2}^{\,\mathrm{Reg_{Precip}}}} \,/\, Pmax$$

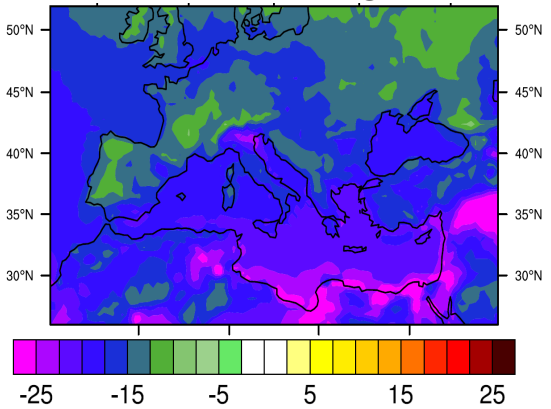
Berthou et al. 2016 (see also Lebeaupin-brossier et al. 2012, Berthou et al. 2014, 2015, 2016)

RCSM as a tool to answer scientific questions

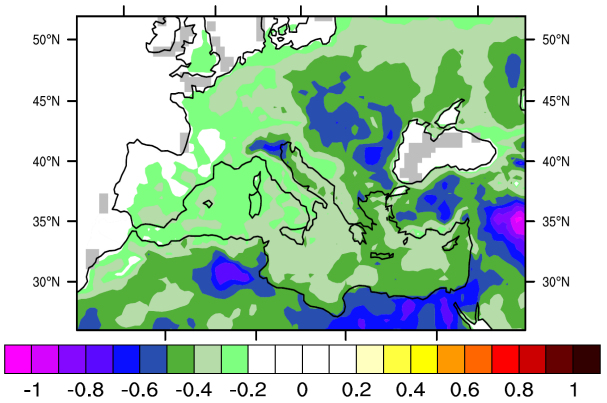
Aerosol impact on Mediterranean climate

- Most of the CORDEX RCMs do not take aerosol variability into account
- Sentivity tests with and without aerosols in CNRM-RCSM4 (2003-2009)

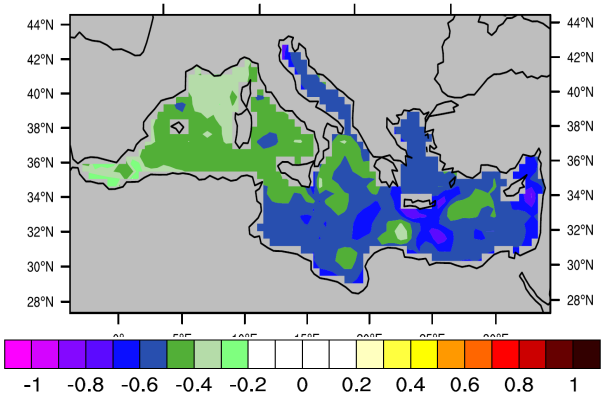
Direct aerosol SW radiative forcing (W/m2)



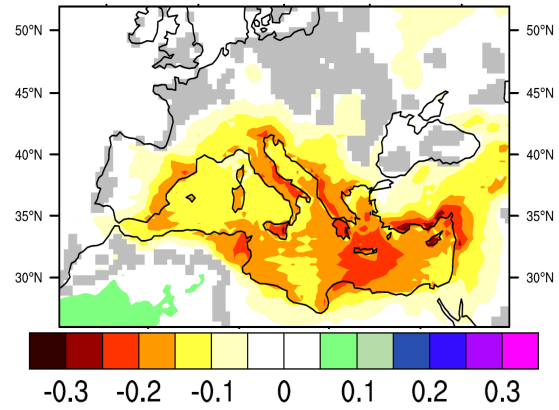
Effect on T2m (°C)



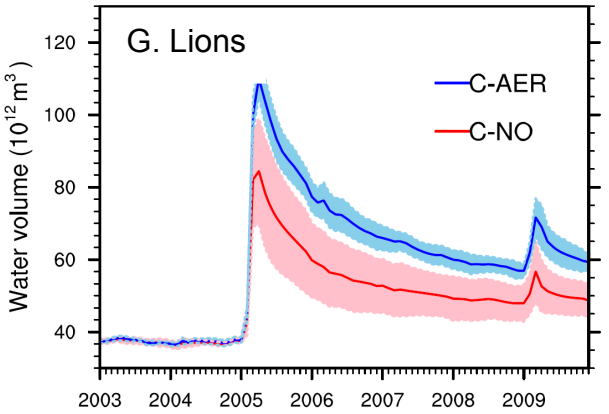
Effect on SST (°C)



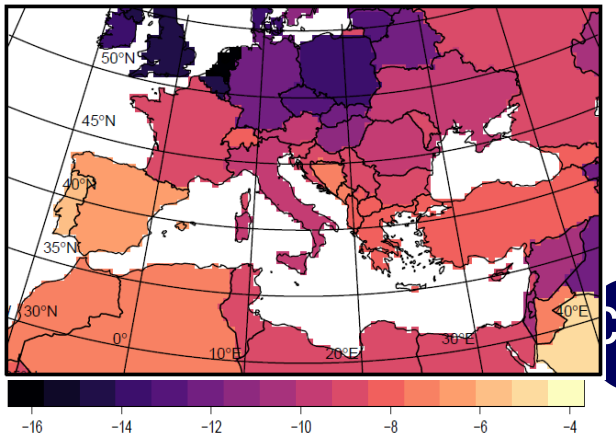
Effect on specific humidity (g/kg)



Effect on dense water volume (10^12 m3)



Effect on photovoltaique production (%, 2-axes panels)



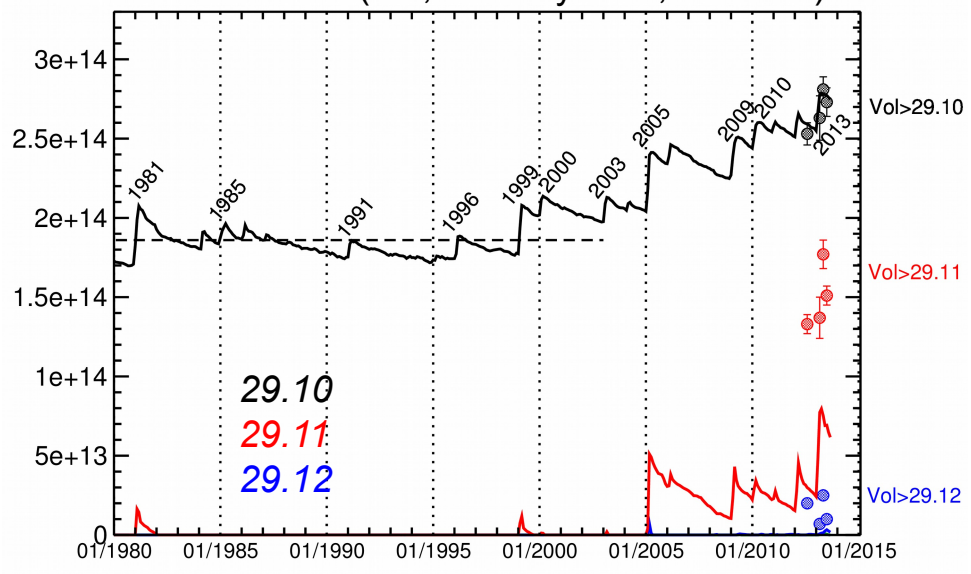
Nabat et al. 2015a (see also Nabat et al. 2012, 2014, 2015b, Cavicchia et al. 2016)

RCSM as a tool to answer scientific questions

Trend in North-Western Mediterranean Deep Water Masses

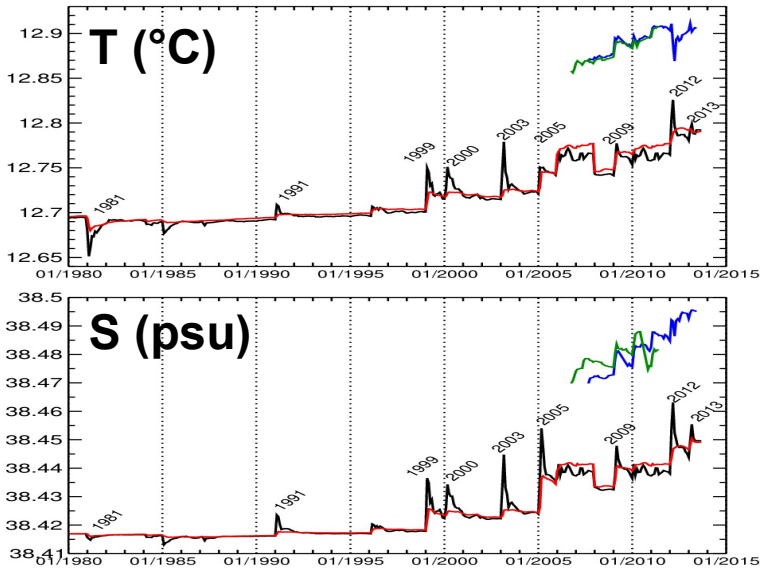
- Reference: LION deep mooring + HYDROCHANGES, CTD field campaigns (MOOSE, DeWeX), re-assessment of past observations
- Model: CNRM-RCSM4, ERA-Int driven + spectral nudging, 1980-2013

Monthly-mean deep water volume (m3, monthly data, NWMed)



Monthly-mean deep water characteristics

(2300m, LION or Gulf of Lions)



HYDROCHANGES mooring, LION mooring

Deep water mass trends (warming, saltening, densening) is reproduced though underestimated

Trend is a stepwise phenomena, not explained by trends in the buoyancy forcing or in the water stratification but by significant trends in the surface and intermediate water characteristics, initially linked to a near-Atlantic salinity trend

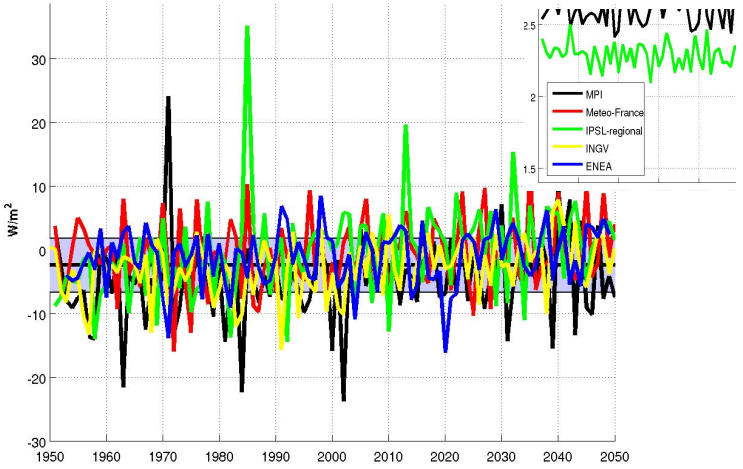
Somot et al. (2016)

Regional future climate change : air-sea flux

Future evolution of the Med Sea Heat Budget (MSHB) terms

- ARCMs give physically inconsistent results (ENSEMBLES runs)
- AORCMs allow a consistent estimation for the first time. They give qualitatively similar responses (5 CIRCE runs: A1B, 1950-2050)
- Surface net heat loss decreases during the 21st century leading to a weaker cooling of the sea by the atmosphere or even a warming

Net heat flux evolution (W/m2)



Difference 2021-2050 vs 1961-1990, A1B	SW	LW	SH	LH	MSHB
CIRCE Ensemble Mean	**+2.2**	**+1.9**	**+1.5**	**-2.5**	**+3.1**
CIRCE Ensemble Range	[+0.8 ; +2.6]	[+1.2 ; + 2.8]	[+0.7 ; +2.9]	[-0.8 ; -3.4]	[+1.6 ;+5.5]

More warming (less cloud)

Less cooling (GHG effect > SST warming)

Less cooling (air-sea gradient, wind decrease)

More cooling (warmer sea, dryer atm)

Less cooling or even warming for some models

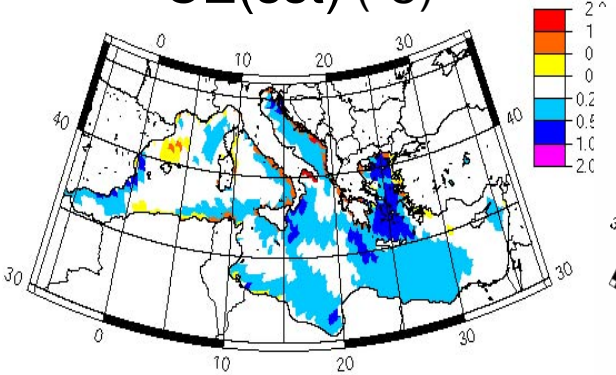
Dubois et al. 2012

Regional future climate change : coupling impact

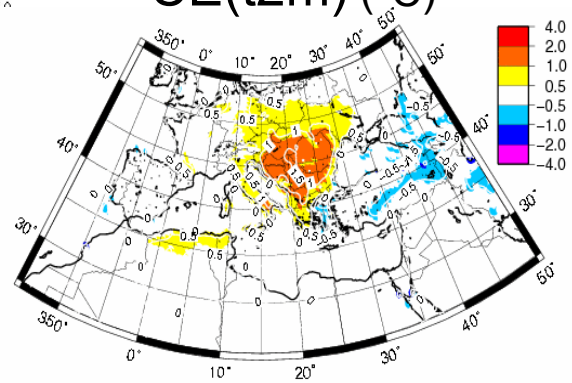
RCSM can modify regional climate change signal of ARCM

Summer Coupling Effect (CE) on regional climate change (CC) : **CE=CC(RCSM)-CC(ARCM)**

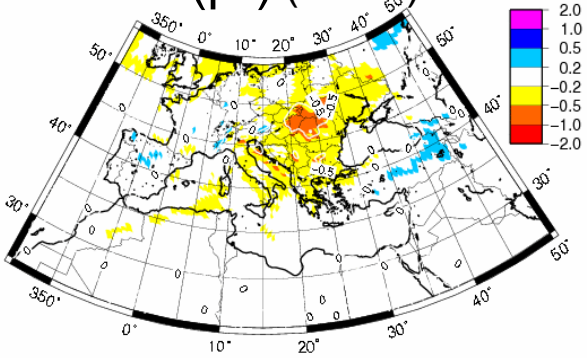
CE(sst) (°C)



CE(t2m) (°C)

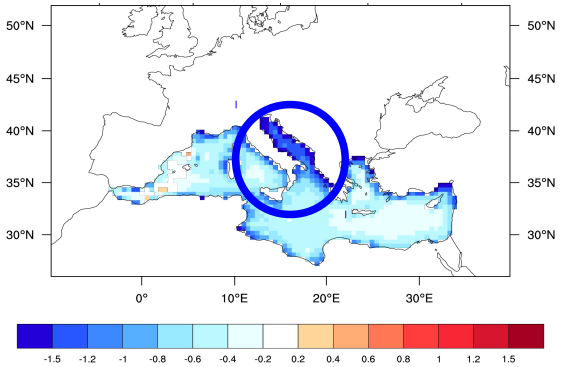


CE(pr) (mm/d)

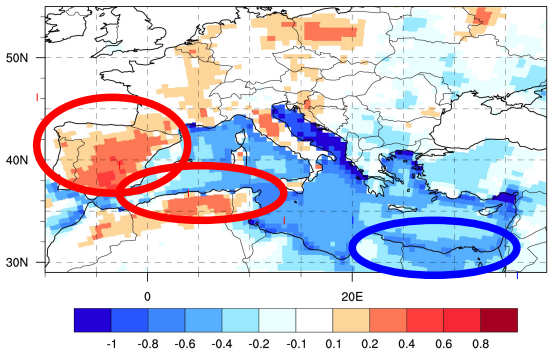


AORCM vs ARCM, GCM=CNRM-CM, 2070-2099 vs 1961-1990, SRES-A2, JJA

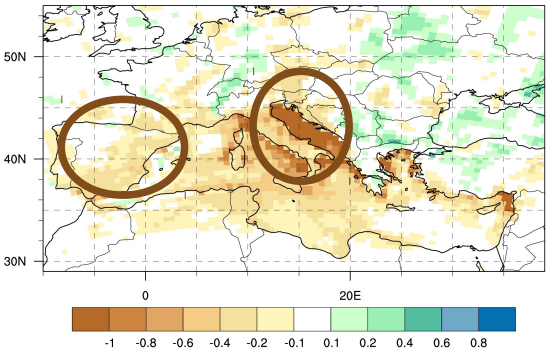
CE(sst) (°C)



CE(t2m) (°C)



CE(pr) (mm/d)



CNRM-RCSM4 vs CNRM-ALADIN, GCM=CNRM-CM5, 2071-2100 vs 1976-2005, RCP8.5, JJA

Somot et al. 2008, Somot, Dubois, pers. comm.

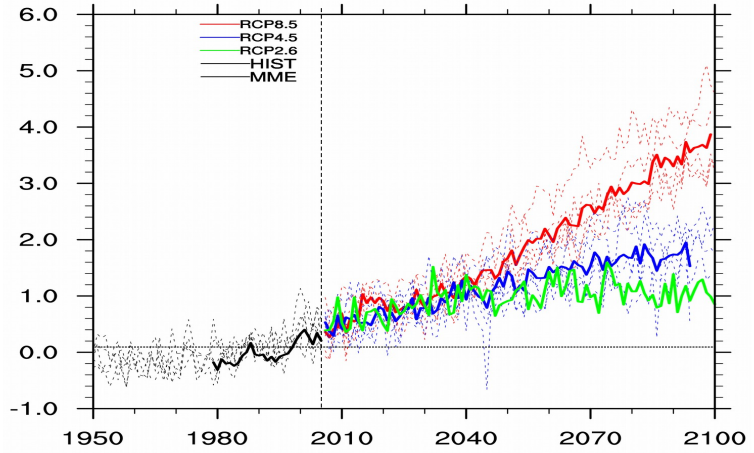
Regional future climate change: Med-CORDEX

RCSM can deliver spatial information for the SST change

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)	

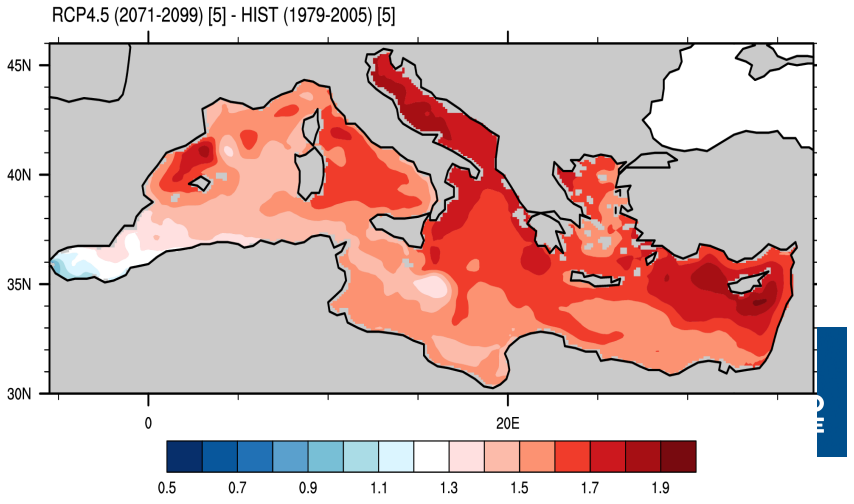
Yearly-mean SST anomalies

(°C, Med Sea spatial average, wrt 1979-2005)



Yearly-mean SST change

(°C, 2071–2099 vs 1979–2005, RCP4.5)



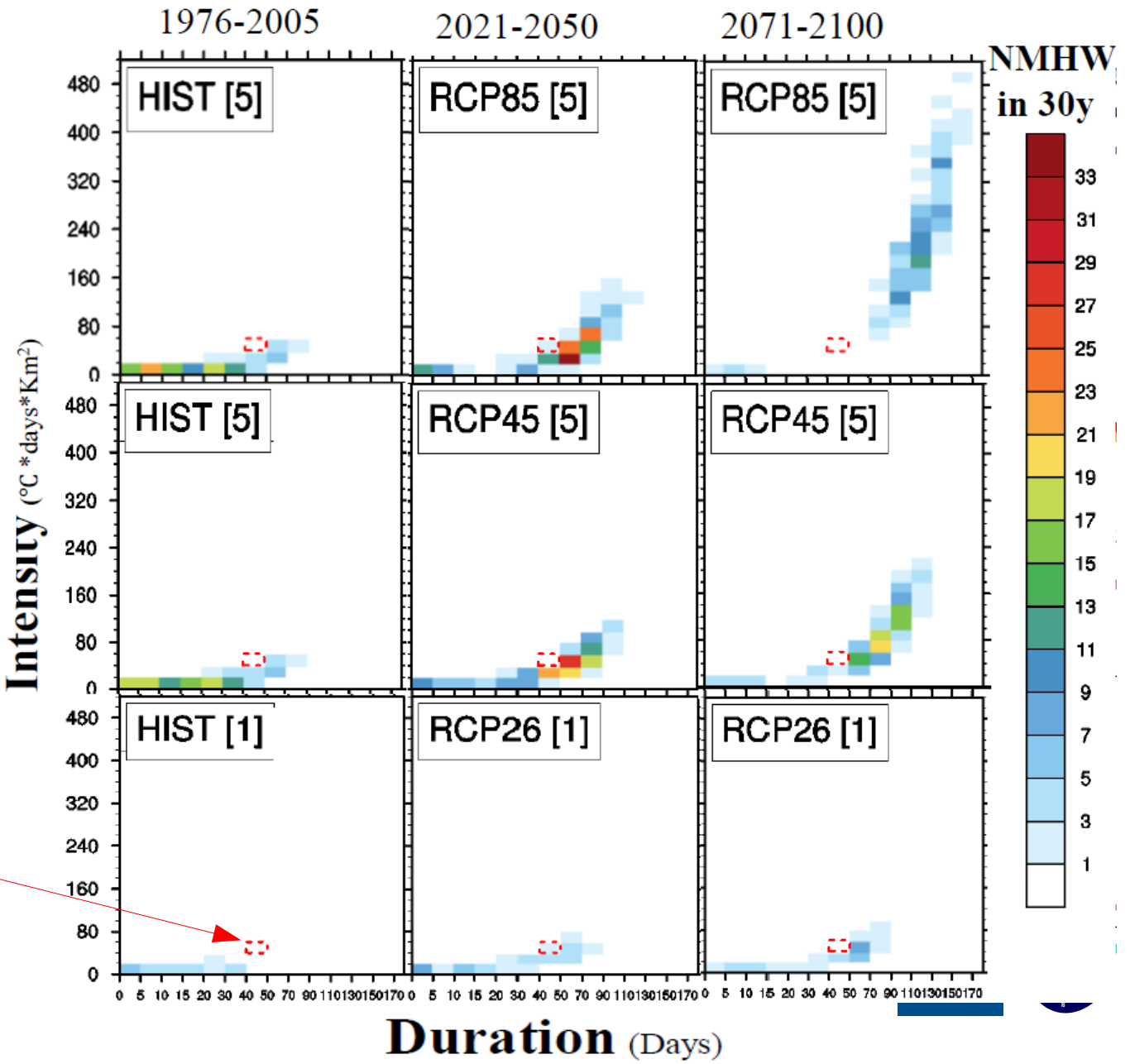
List available on www.medcordex.eu , Darmaraki et al. (in prep.)

Regional future climate change: Marine Heat Waves

RCP8.5, 2071-2100 vs 1976-2005:

- Extended MHW favourable time
- At least one MHW per year
- Duration increases by a factor 2
- Severity increases by a factor 8
- MHW may cover 100% of Med Sea surface for a given day
- MHW-2003 becomes a cold MHW

Intensity-Duration-Frequency plots



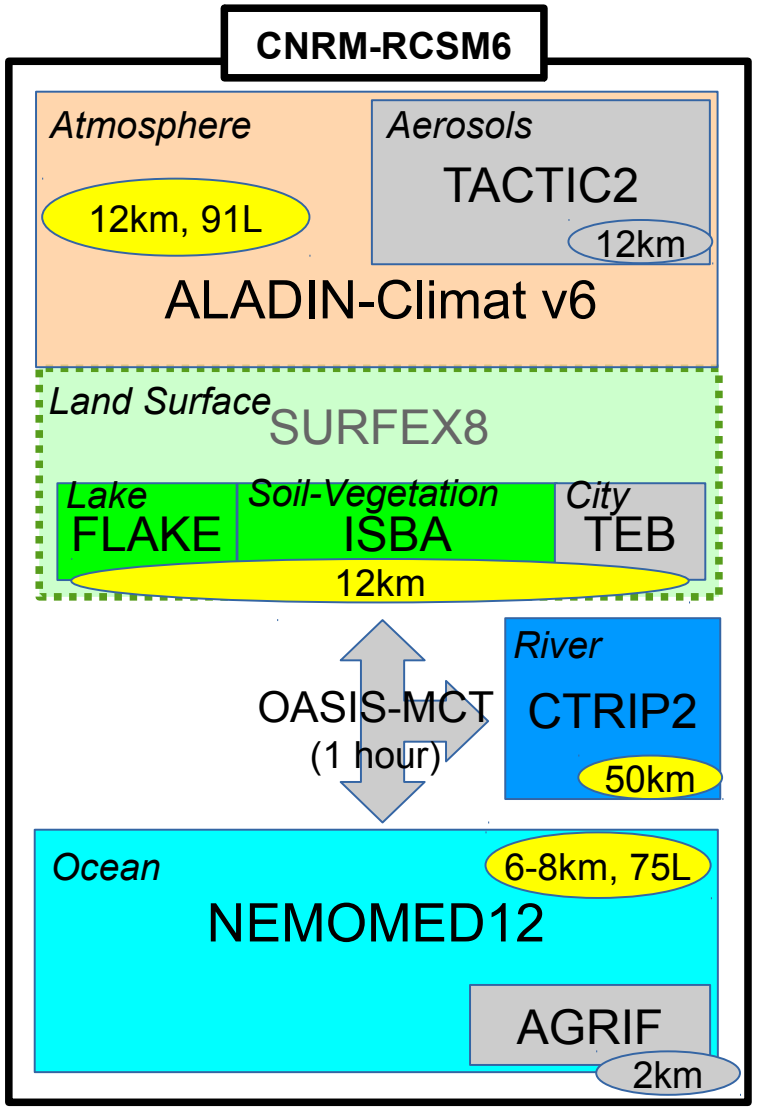
Darmaraki et al. in prep.

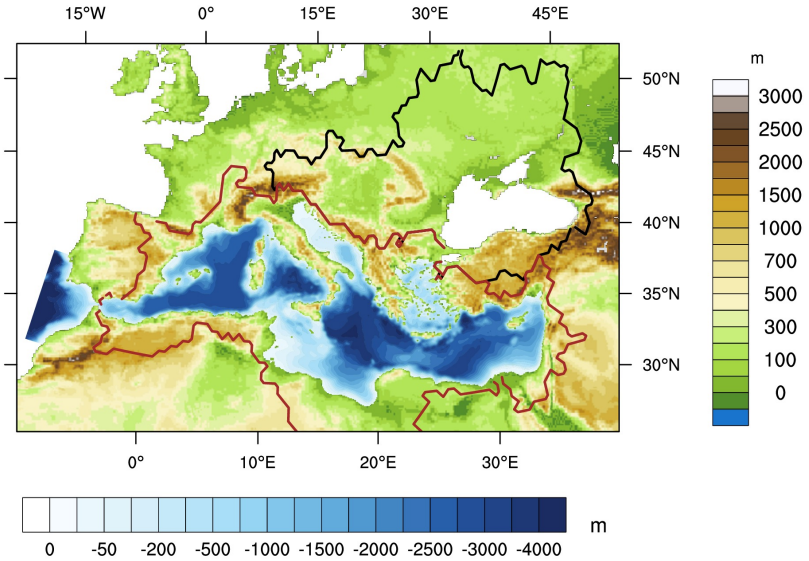
Conclusions

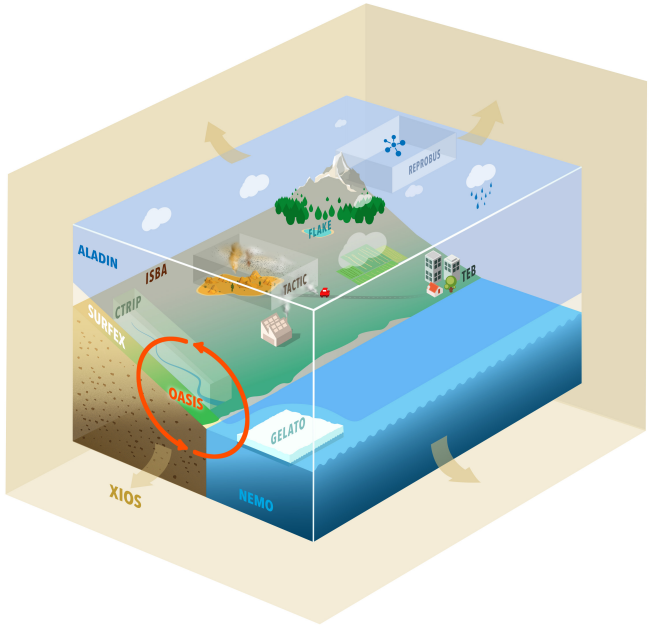
- **Success stories**
  - Model development : very good (numerous and diverse modelling plateforms, new model versions, new coupled components, regularly new modelling centers)
  - Coordination : currently good in Med-CORDEX
  - Evaluation : good (individual models well documented, evaluation of the interfaces, first multi-model studies)
  - Added-value : limited (RCSM are not worse than ARCM and ORCM but added-value is often hidden by SST biases, air-sea flux and ocean reference dataset are rare)
  - Answering scientific questions : very encouraging results (heavy precip, cyclones, medicanes, deep water formation, marine heat waves, aerosol-climate interactions, winds, sea level, trend understanding, sea breeze)
  - Scenarios : not bad (11 Med-CORDEX runs by 6 RCSMs, driven by 4 GCMs for 3 RCPs, coordination, data partly available on open database)

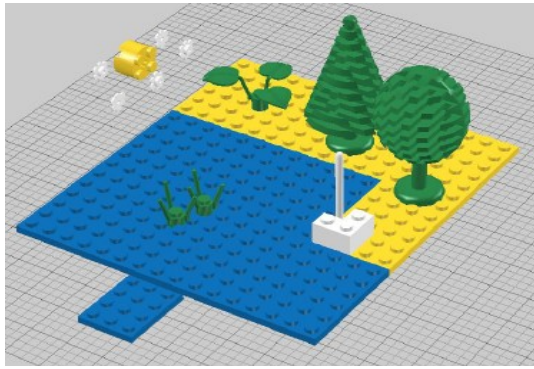
- **Current challenges**
  - Model development: work on bias reduction (Med Sea heat budget terms), challenge of the long-term sustainability of model quality and diversity, adding the humans in the system
  - Coordination: lack of EU-scale funding after CIRCE ends
  - Evaluation: need for more phenomena-oriented multi-model evaluation, need for spreading good practices and reference datasets
  - Added-value: need for persuasive and multi-model proofs (How to convince Euro-CORDEX & C3S ?)
  - Answering scientific questions: « stop developing and evaluating, use your wonderful tools »
  - Scenarios : need for more runs, for more multi-model studies, for easier model output access

Illustrations of Mediterranean RCSM







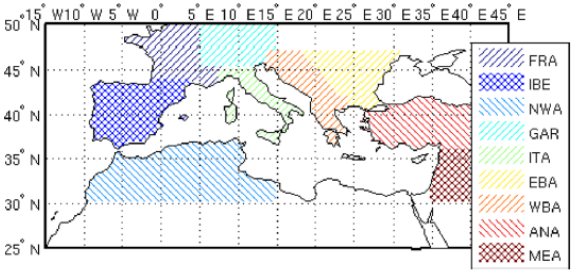


CNRM-RCSM

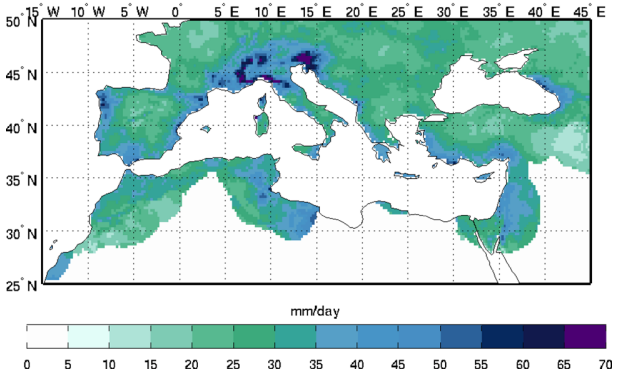
Evaluation : phenomena-oriented

Extreme precipitations

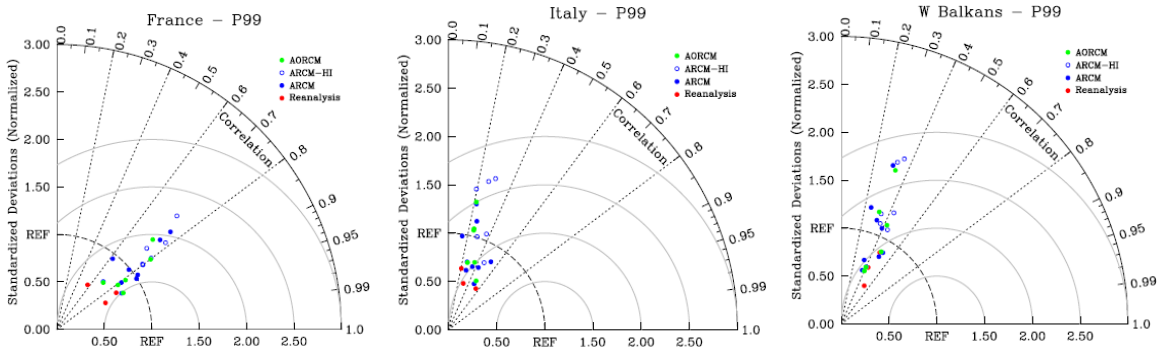
- Reference: E-OBS
- Model: Med-CORDEX ARCM, High-resol ARCM, Coupled AORCM



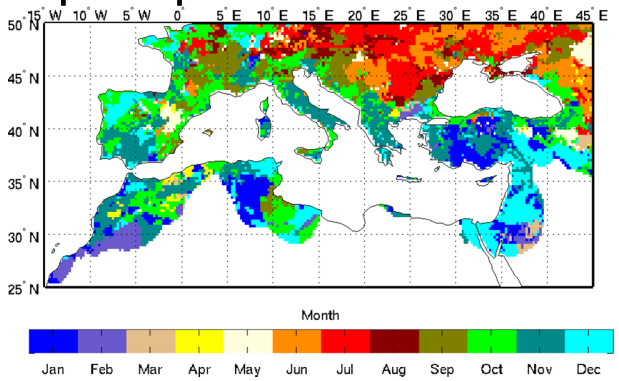
Wet days 99th percentile of daily precip. in E-OBS



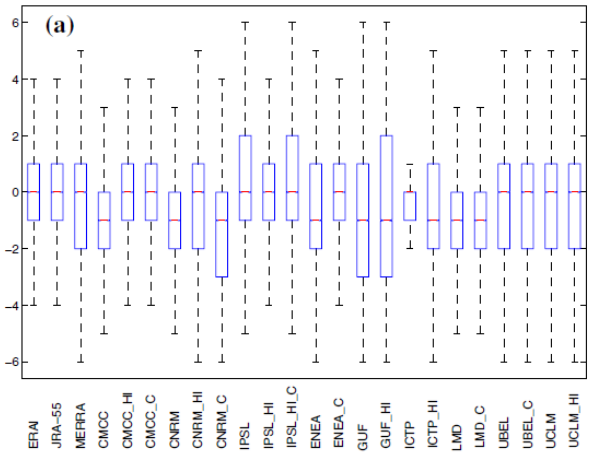
Taylor diagram for 99th percentile for various regions



Timing of extreme precipitations in E-OBS



Box plot of timing difference in models



Cavicchia et al. 2016

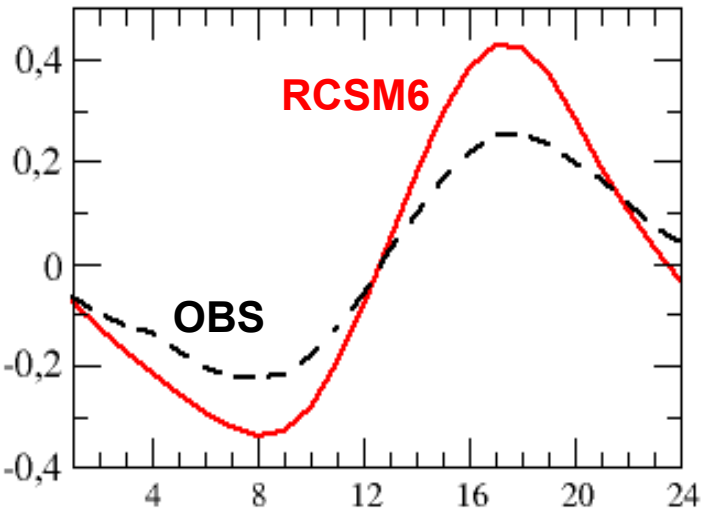
Evaluation : phenomena-oriented

SST diurnal cycle in the North-Western Med Sea

- Reference: LION weather buoy, hourly SST data (2006-2012) at 0.5m, HyMeX dataset
- Model: CNRM-RCSM6, ERA-Int driven + spectral nudging, 1-hour coupling frequency, 1-meter thick first model level, 2D monthly Chlorophyll climatology (ESA-CCI) for the solar radiation penetration
- Method: SSTmax(9h-17h)-SSTmin(18h at J-1 - 8h), day kept if no missing data at the buoy (88%) and if amplitude>0.1°C

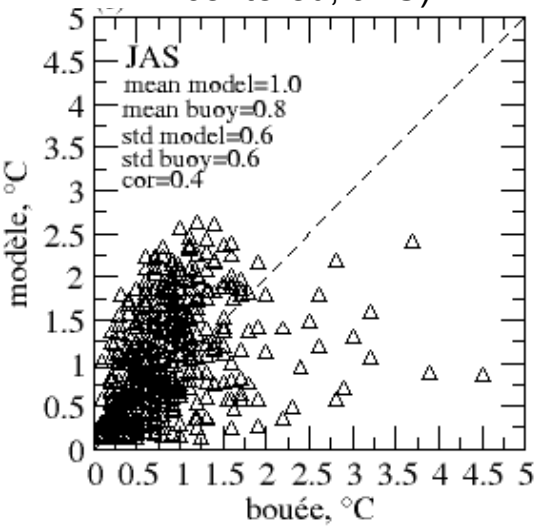
SST diurnal cycle composite

(°C, 2006-2012, LION, ampl.>0.1°C, centered, JAS)



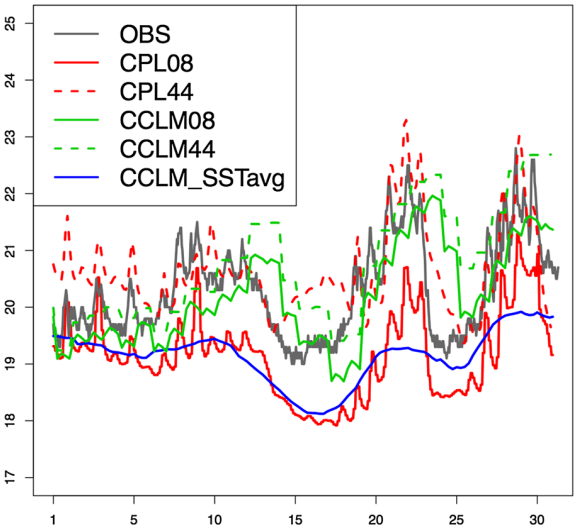
Scatter-plot of the SST diurnal cycle amplitude

(°C, 2006-2012, LION, ampl.>0.1°C, centered, JAS)



RCSM6 statistics (JAS) :
Freq.: 81 % (buoy: 91%)
Mean ampl: 1.0°C (buoy: 0.8°C)
Std : 0.6°C (buoy : 0.6°C)
Daily correlation of amplitude : 0.4

Sub-daily SST LION buoy (July 2002, °C)



Akhtar et al. (2017), Voldoire et al. (2017, F. Sevault, ANR REMEMBER)

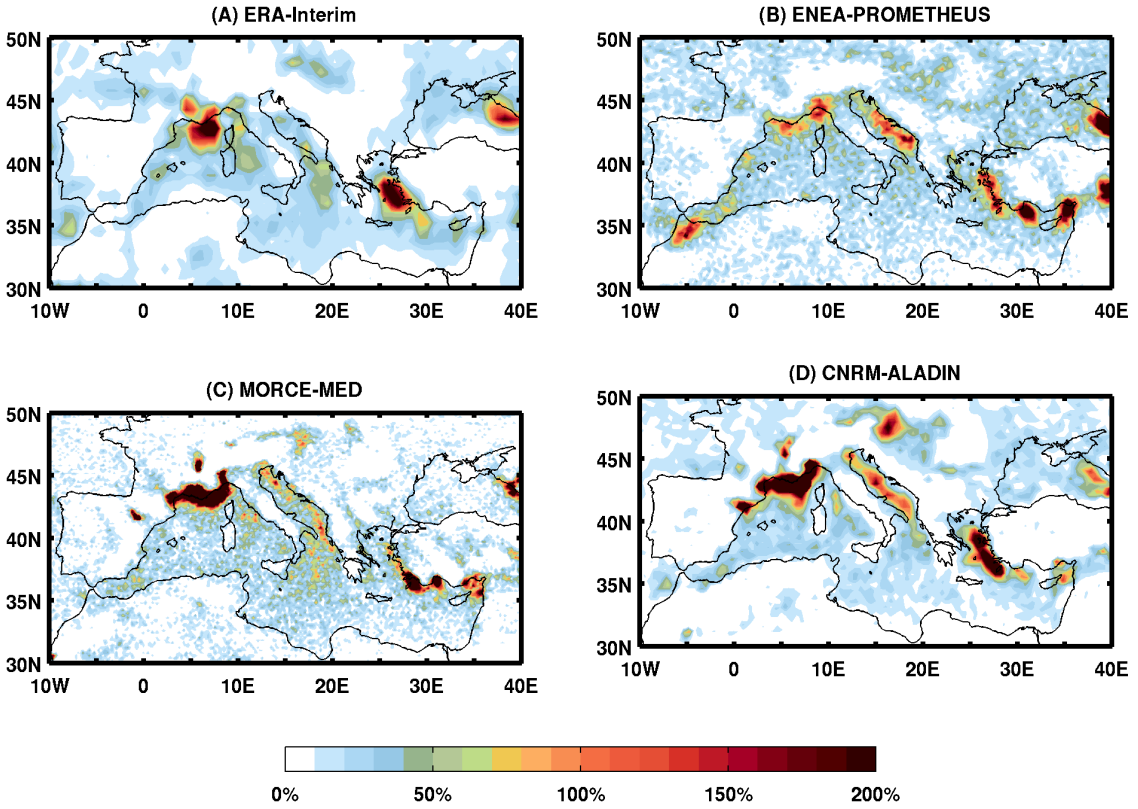
Evaluation : phenomena-oriented

Mediterranean cyclones

- Reference: ERA-interim
- Model: CNRM-RCSM4, ENEA-PROTHEUS, MORCE-MED
- Method: cyclone tracking algorithm

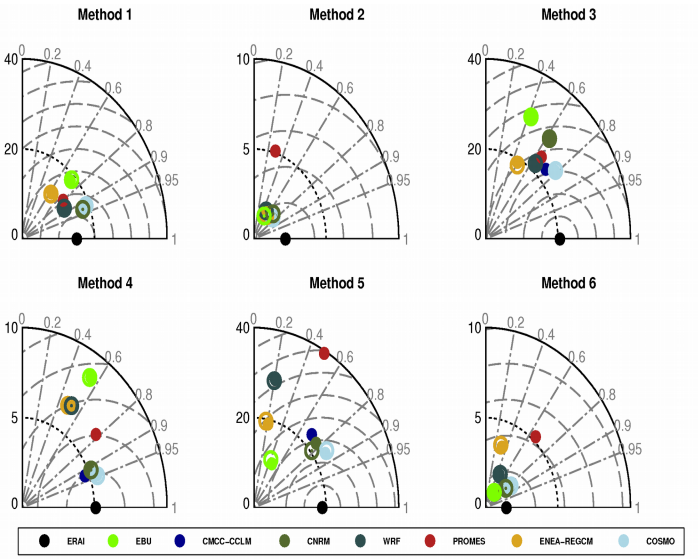
Frequency of cyclone occurrence

(per 1000km² per 25 days for autumns and winters, 1989-2008)



Taylor diagram for cyclone center density

(1989-2008)



Ruti et al. (2016), Flaounas et al. (2016)

RCSM as a tool to answer scientific questions

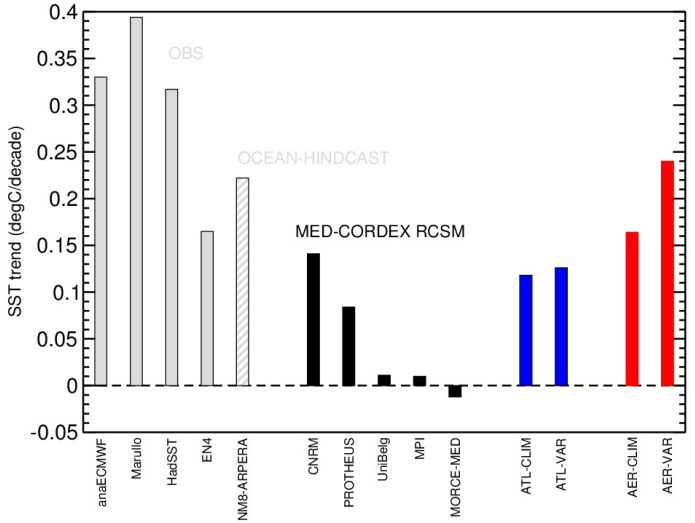
Driving factors of the Mediterranean SST trend

Med-CORDEX RCSMs underestimate the SST trend

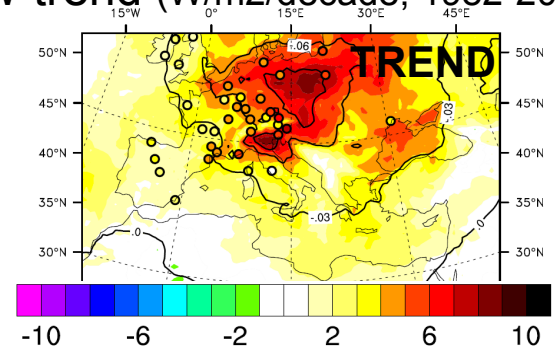
Trend in the Near-Atlantic Ocean characteristics has a small impact

Aerosol brightening effect explains part of the missing signal

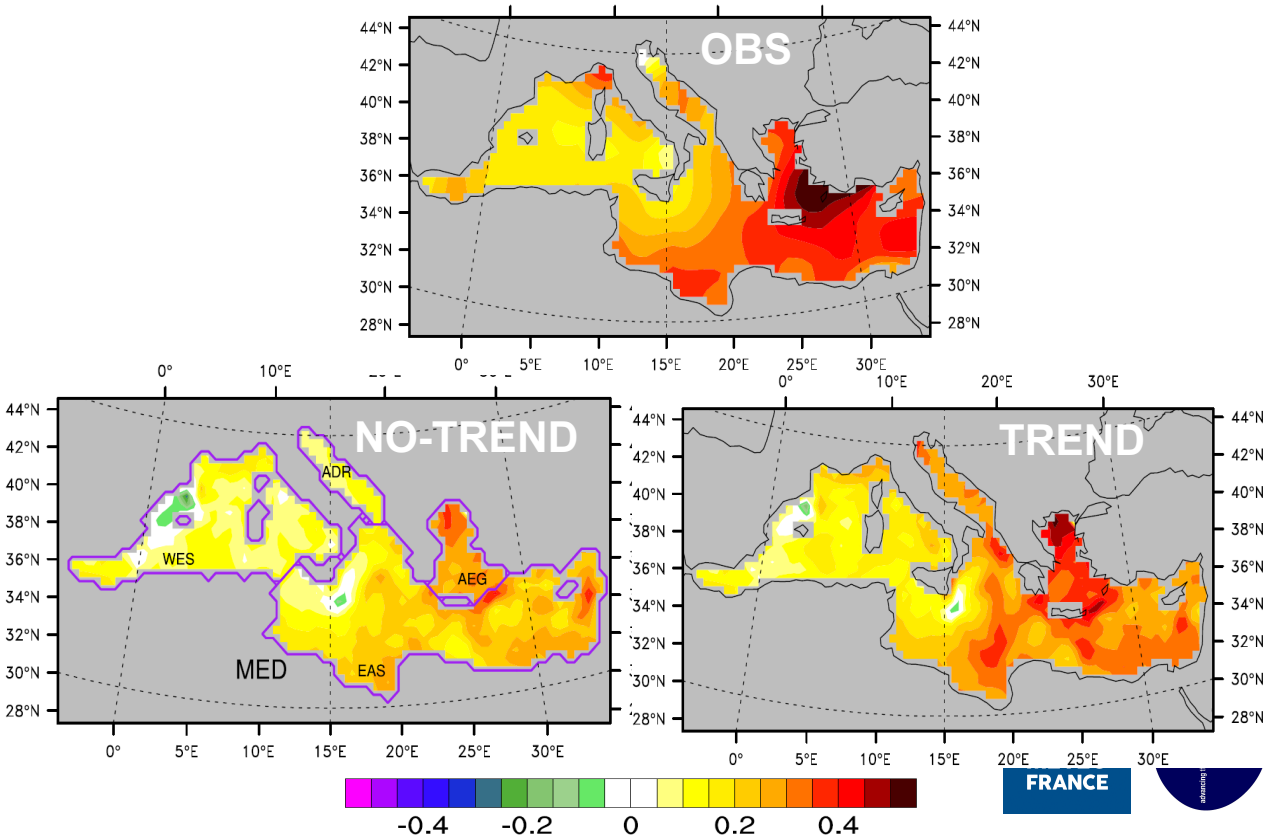
SST trend (°C/decade, 1982-2012)



SW trend (W/m2/decade, 1982-2012)



Effect of aerosol trend on SST trend (°C/decade, 1982-2012)

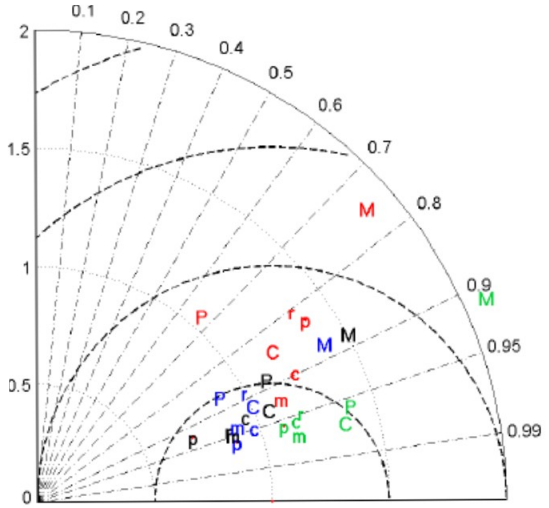


Somot S. (pers. comm.), Nabat et 2014 (see also Dell'Aquila et al. 2016, Nabat et al. 2015a)

Added-value : RCSM vs AOGCM

If any, related to a better OML-SST-flux consistency at small-scale and high-frequency

SST spatial Taylor diagram (ref : Marullo et al. 2007 dataset, 1985-2010, Mediterranean Sea)

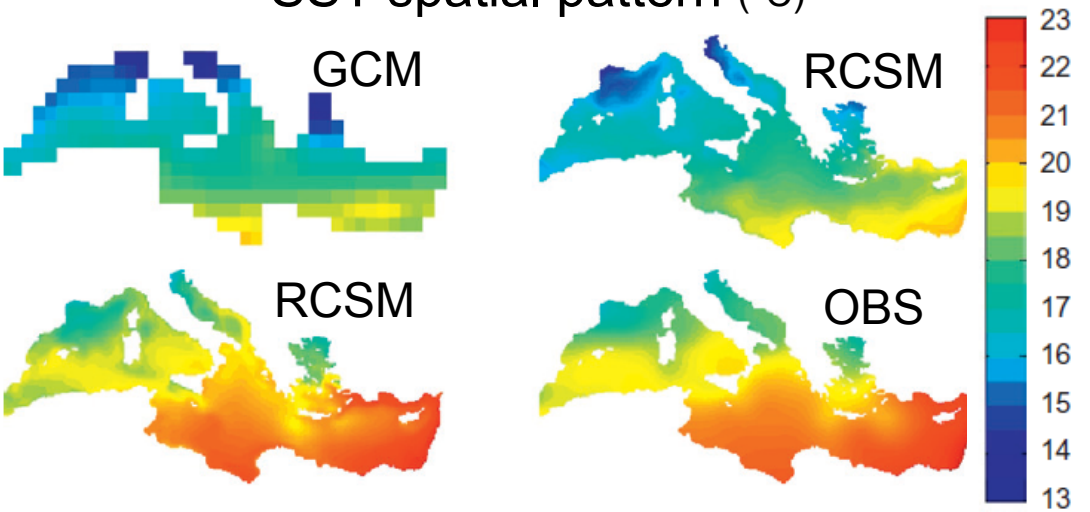


Comparison between GCM (capital letters) and AORCM (small letters) for DJF (black), MAM (green), JJA (red), SON (blue)

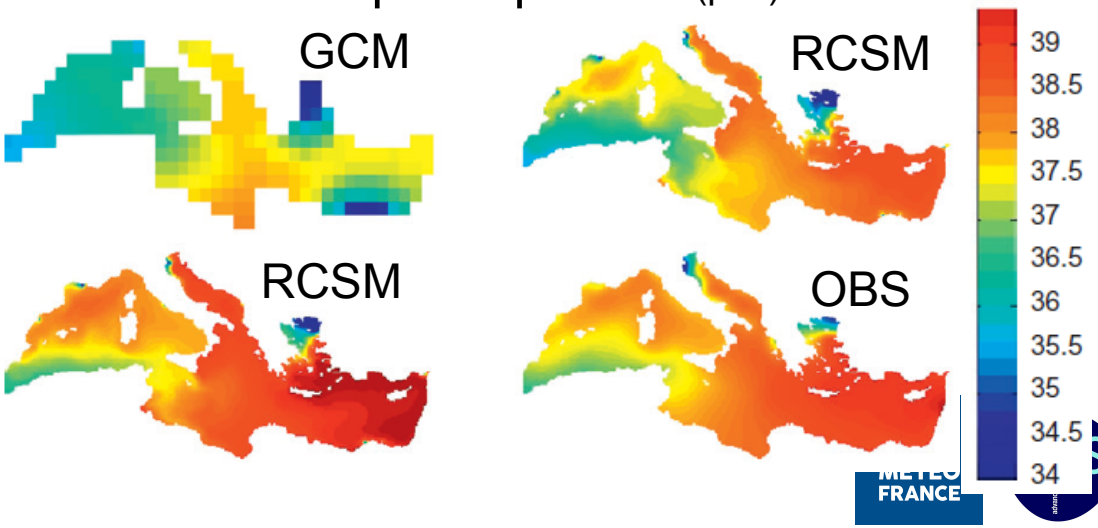
RCSM improves SST and SSS spatial variability with respect to GCM

RCSM can improve the fine-scale and high-frequency variability of the SST, leading to potential changes in air-sea fluxes, in moisture and heat transports and finally influencing the surrounding land areas

SST spatial pattern (°C)



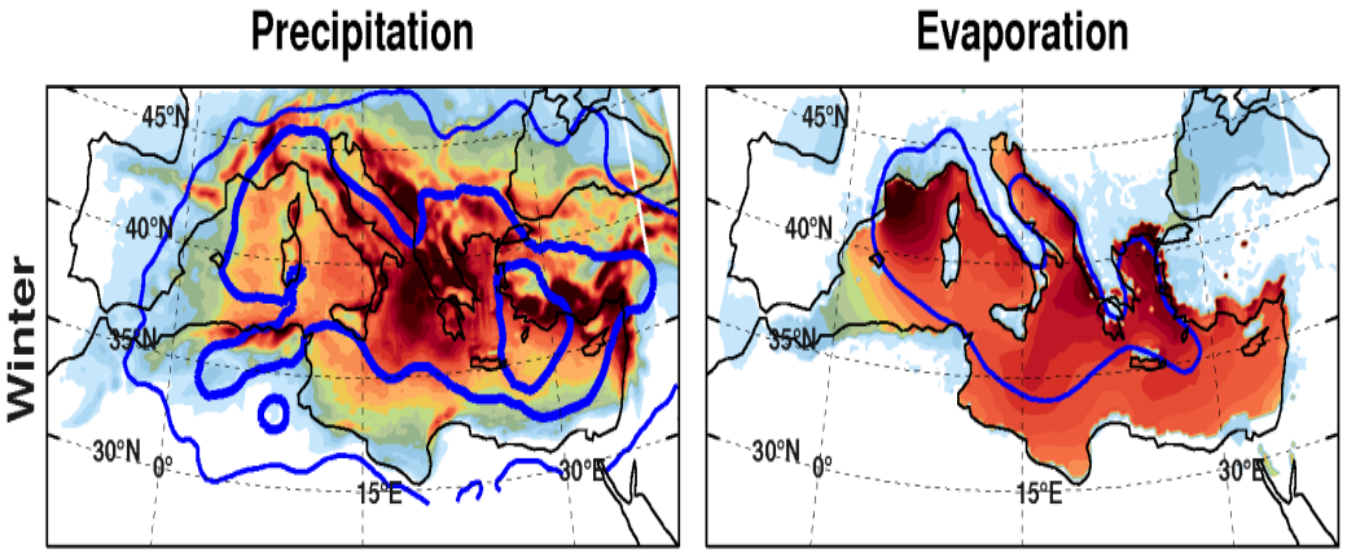
SSS spatial pattern (psu)



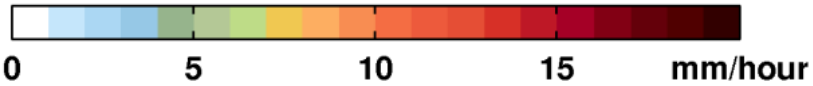
S. Calmanti, pers. comm., CIRCE project, Li et al. 2012

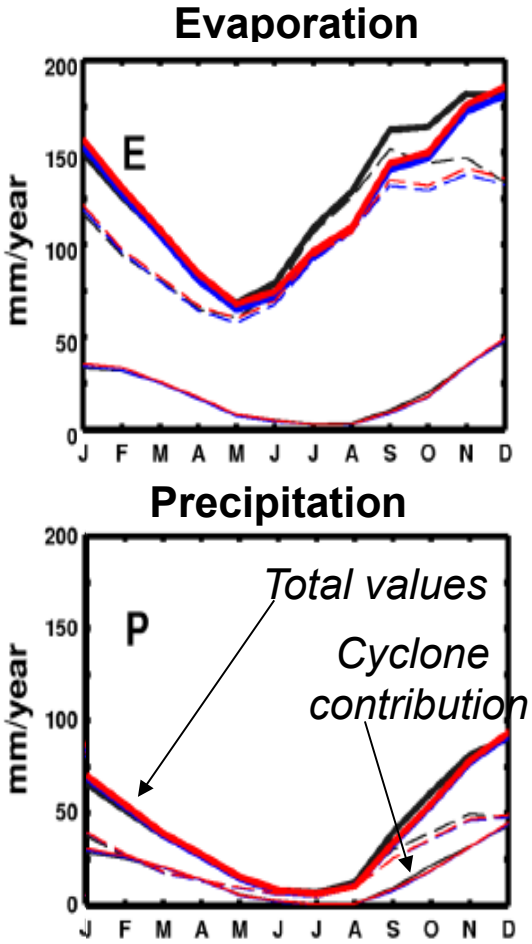
RCSM as a tool to answer scientific questions

Contribution of Mediterranean cyclones to Med Sea Water Budget



% of cyclone contribution
(>25% thin blue, >50% thick blue)



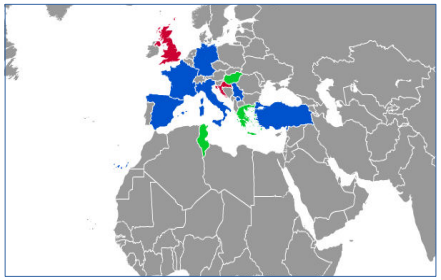


Mediterranean cyclones strongly impact the Evaporation over the sea and the Precipitation over the sea and surrounding land area

Rare and intense events (5% of the days) represent 15-17 % of the annual Evaporation budget and 22-30% of the annual Precipitation budget over the sea

Flaounas et al. 2015, Lebeaupin-brossier et al. 2015

Med-CORDEX, phase 2 : the modelling exercise



Baseline runs
Other modelling groups
Other contributions

BASELINE runs

Charact. past climate variability and future change, climate phenomena and impacts

RCSM Atm-Land-River-Ocean — 10-50 km

Evaluation 1979-2015

Scenario, 1971-2100 RCP8.5, RCP2.6

FMZ: free modelling zone
Push the limits of current protocols
Test new ideas

FPS convection

Convection phenomena at high-resolution over Europe and the Mediterranean

Convection-Permitting RCM — 1-3 km
1°-17°E ; 40°-50°N

Case study

Evaluation 2000-2014

Scenario RCP8.5
1996-2005
2041-2050
2090-2099

FPS air-sea

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

Sensitivity tests to RCSM baseline runs

wave

ORCM

Ocean zoom

Evaluation 1979-2015

Scenario, 1971-2100 RCP8.5, RCP2.6

FPS aerosol

Role of the natural and anthropogenic aerosols in the Mediterranean region

improved aerosol climatology

interactive aerosol

Evaluation 1979-2015

Scenario, 1971-2100 RCP8.5, RCP2.6

Baseline runs : 11 (12) participating modelling groups so far: CNRM, ENEA, GUF, LMD, IPSL, CMCC-UnivSalento, Univ of Belgrade, ITU, AWI-GERICS, UCLM, ICTP, *BSC ?*

History of CNRM-RCSM development for the Mediterranean

(*) RCSM : Regional Climate System Model

The first AORCMs :

Baltique (Döscher et al. 2002), Arctique (Rinke et al. 2003, Mikolajewicz et al. 2005), Indonésie (Aldrian et al. 2005)

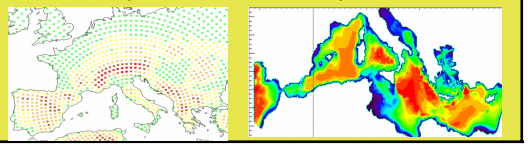
2001 — 2000s — 2009 — 2011 — 2012 — 2014 — 2017

1er AORCM au CNRM

CNRM-RCSM1

ARPEGE-stretched/OPAMED8

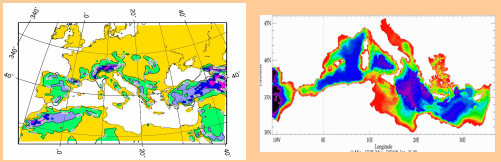
(Somot et al. 2008)



CNRM-RCSM3:

ALADIN/NEMOMED8

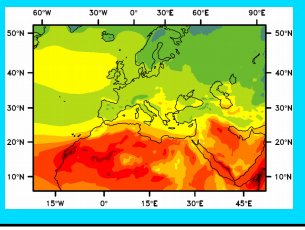
(Herrmann et al. 2011)



CNRM-RCSM5: Atm-Aero-Land-Sea,

ALADIN/TACTIC/ISBA/NEMOMED8

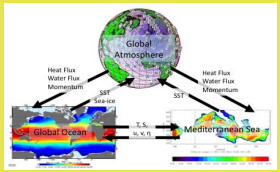
(Nabat et al., 2015b)



CNRM-RCSM2 - tri-couplé

ARPEGE étiré/OPA/NEMOMED8

(Somot et al. 2009, Dubois et al. 2012)

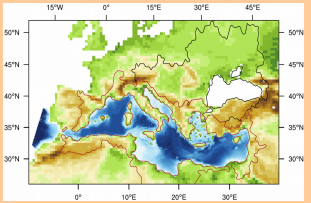


CNRM-RCSM4 :

Atm-Land-River-Sea

ALADIN/ISBA/TRIP/NEMOMED8

(Sevault et al. 2014, Nabat et al. 2015a)



CNRM-RCSM6: Atm-Aero-Land-City-Lake-River-Sea,

ALADIN/TACTIC/SURFEX-ISBA-TEB-FLAKE/CTRIP/NEMOMED12-AGRIF

(Voldoire et al., 2017)