« Med-CORDEX is an **open** club of **Mediterranean** **climate** **model** developers and users, **science-driven**, **self-organised** and based on **voluntary** efforts. »

Modelling the Sea in Med-CORDEX : a review

Samuel SOMOT

on behalf of the Med-CORDEX steering committee

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Med-CORDEX : an ocean-oriented initiative

- Definition of the overarching goals *(Ruti et al. 2016, Somot et al. 2018b, www.medcordex.eu) :*
  - ORCM and RCSM as central modelling tools
  - Study ocean or coupled climate phenomena
  - Serve ocean impact community

- Regional ocean modelling community is part of Med-CORDEX since 2009

- Half of the steering committee members have a strong ocean focus

Define ocean-dedicated modelling activities

the 5 modelling pillars of Med-CORDEX, phase 2 (2016-2022)

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

Design ocean-inclusive simulation protocols

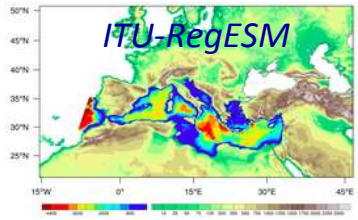
Illustrations with sections of the Phase 3 Baseline run protocol

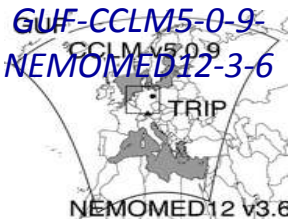
- Keep the **same Med-CORDEX minimal domain**: Mediterranean Sea, Black Sea and related catchment basins (except for the Nile)
- Use **fully-coupled RCSM** including, at least, **atmosphere**, **land**, **river** and **ocean** components
- Use **improved model versions** : coupled rivers, higher resolution (min. **12 km** mandatory for atm, min. **10 km** for ocean), new components accepted, improved present climate behaviour, sea level representation
- Share **common ocean initial conditions and common forcings**: MedHYMAP, ERA5/ORAS5, CMIP6 GCMs, constant 12-values for the Nile, Chl-a dataset, evolving GHG, evolving aerosols
- Share **common spin-up criteria**

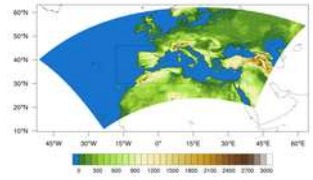
Create large coordinated simulation ensembles

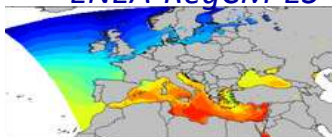
Phase 1+2 Baseline runs

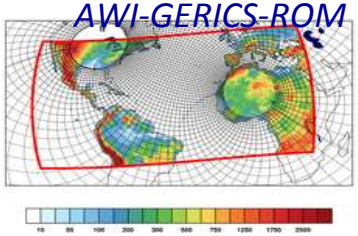
- RCSMs : Atmosphere, Land, Sea (+Rivers)
- Resolution: 5-25km for the sea
- 11 participating modelling groups : CNRM, ENEA, GUF, LMD, IPSL, CMCC, UBEL, ITU, AWI-GERICS, ICTP, INSTM
- 7 different ocean models, 21 different RCSM configurations
- 18 evaluation runs, 19 scenario runs, 6 driving GCMs, 3 RCPs

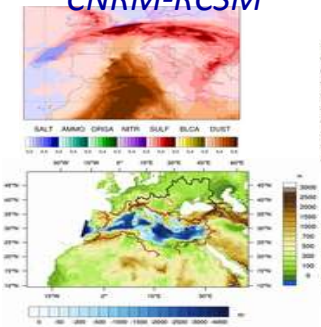


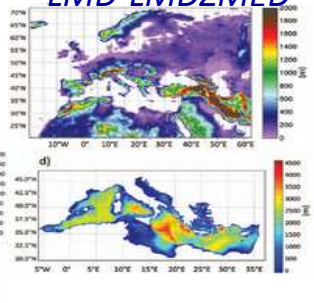


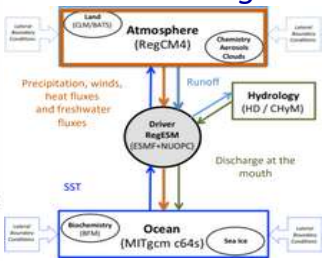












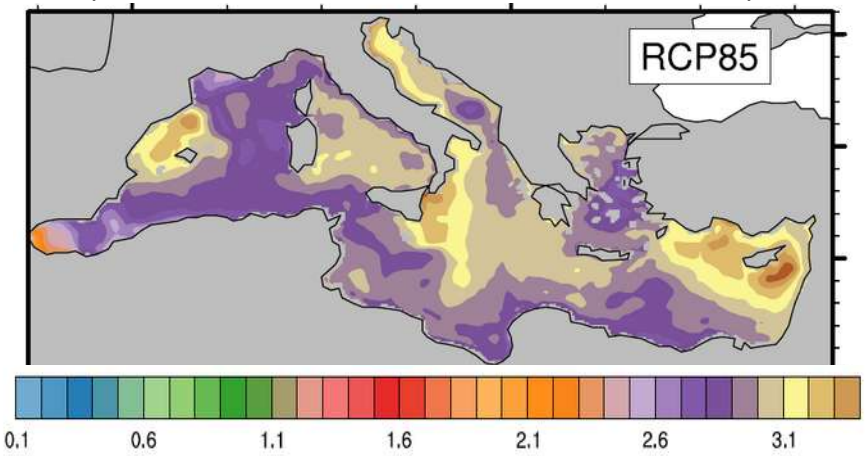
List of runs

Model Naming	Institute	Contact	Climate components	Model short description
CNRM-RCSM4	CNRM	S. Somot, F. Sevault	Atmosphere Land River Ocean	Atmosphere ALADIN@50km River CTRIP@50km, Ocean coupler OASIS@1day. Ref: Sevault et al. 2014
CNRM-RCSM4	CNRM	S. Somot, F. Sevault, P. Nabat	Atmosphere Aerosols Land (incl. Lake) River Ocean	Atmosphere ALADIN@12km Land-Surface SURFEX@12 Surf+hydrology CTRIP@50 Ocean NEMOv3.6-MED12-75 coupler OASIS-MCT@1hour. Ref: Darmaraki et al. 2019b,
ENEA-PROTHEUS v2	ENEA	A. Dell'Aquila	Atmosphere Land River Ocean	30km
ENEA-RegCM-ES	ENEA	G. Sannino	Atmosphere Land River	including RegCM4.5 (20km), coupler 3hourly or 1hourly Ref:
			Ocean	
ENEA-REG	ENEA	G. Sannino	Atmosphere Land River Ocean	including WRF (12km), MedM as coupler 1hourly/1day Ref: Anav et al. 2021
CLMcom-GUF-CCLM-NEMO	GUF	B. Ahrens	Atmosphere Land Ocean	including COSMO-CLM v5.00 NEMOv3.6-MED12,
CLMcom-GUF-CCLM5-0-9-NEMOMED12-3-6	GUF	B. Ahrens P. Kumar	Atmosphere Land River Ocean	including COSMO-CLM v5.00 NEMOv3.6-MED12, CTRIP, O Ref: Primo et al. 2019
LMD-LMDZMED_v1	LMD	L. Li	Atmosphere Land Ocean	including LMDZ4@30km, ORC no river coupling Ref: L'Hévéder et al. 2013
LMD-LMDZMED_v2	LMD	L. Li	Atmosphere Land River Ocean	including LMDZ4@30km, ORC simple river coupling scheme Ref:
IPSL-MORCEMED	IPSL	S. Bastin	Atmosphere Land Ocean	WRF311@20km , NEMOMED
IPSL-RegIPSL	IPSL	Y. Polcher R. Pennel	Atmosphere Land River Ocean	including WRF 3.7.1@20km-4 NEMOMED12-75L OASIS-MCT@1h Ref:
IPSL-RegIPSLv2	IPSL	Y. Polcher R. Pennel	Atmosphere Land River Ocean	including WRF4.3.1@20km, C NEMO4-MED36, OASIS-MCT Ref:
CMCC-CCLM4-21-NEMOMFS (50km)	CMCC	L. Cavicchia P. Lionello	Atmosphere Land Ocean	COSMO-CLM v4.21 at 50km 7km, 71L, OASIS3-MCT (no r
CMCC-CCLM4-21-NEMOMFS (12km)	CMCC	D. Conte P. Lionello	Atmosphere Land Ocean	including COSMO-CLM v4.21 v4.3 at 7km, 71L, OASIS3-MC Ref:
UBEL-EBUPOM2c	UBEL/GRADE	V. Djurdjevic	Atmosphere Land Ocean	including ETa (EBU+Eta Belgr phase 1 model) Ref:
ITU-RegESM1	ITU	B. Onol F. Batibeniz	Atmosphere Land Ocean	including RegCM4-0-0@50km
ITU-RegESM1.2	ITU	B. Onol F. Batibeniz	Atmosphere Land Ocean	including RegCM4-0-0@12km WAM-4@14km (no river coupl can be activated using RTM m frequency Ref: Turuncoglu and Sannino
AWI-GERICS-ROM44	AWI-GERICS	D. Sein W. Cabos	Atmosphere Land River Ocean Biogeochemistry	including REMO@25km, MPI HD, Biogeochemistry module, Ref:
AWI-GERICS-ROM22	AWI-GERICS	D. Sein W. Cabos	Atmosphere Land River Ocean Biogeochemistry	including REMO@25km, MPI HD, Biogeochemistry module, Ref:
AWI-GERICS-ROM11	AWI-GERICS	D. Sein W. Cabos	Atmosphere Land River	including REMO@12km, MPI HD, Biogeochemistry module, Ref:
			Ocean Biogeochemistry	
ICTP-RegCM-ES	ICTP	E. Coppola R. Farneti F. Di Sante	Atmosphere Land River Ocean	including RegCM-4.9.3@12km (close to ENEA model but diffe Ref: Sitz et al. 2017, Di Sante
INSTM-LMDZ/ROMS-MED	INSTM	A. Harzallah	Atmosphere Land Ocean	LMDZ4 and ROMS-MED

Develop multi-model scientific studies

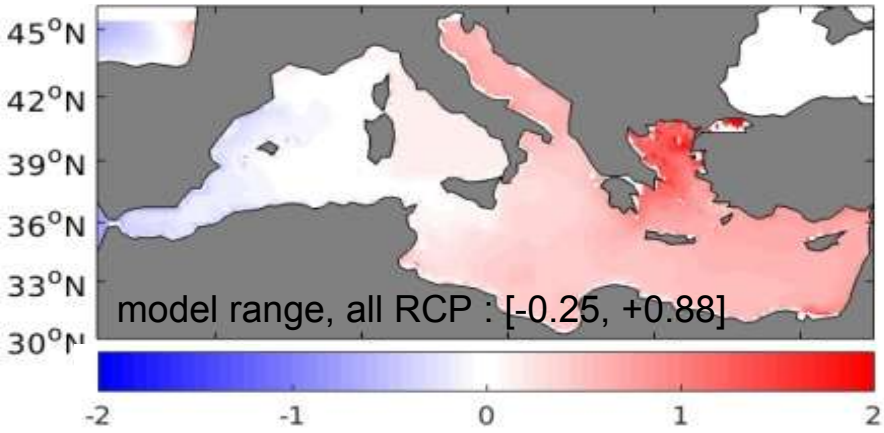
Yearly-mean SST change

(°C, 2071–2100 vs 1976–2005, RCP8.5)



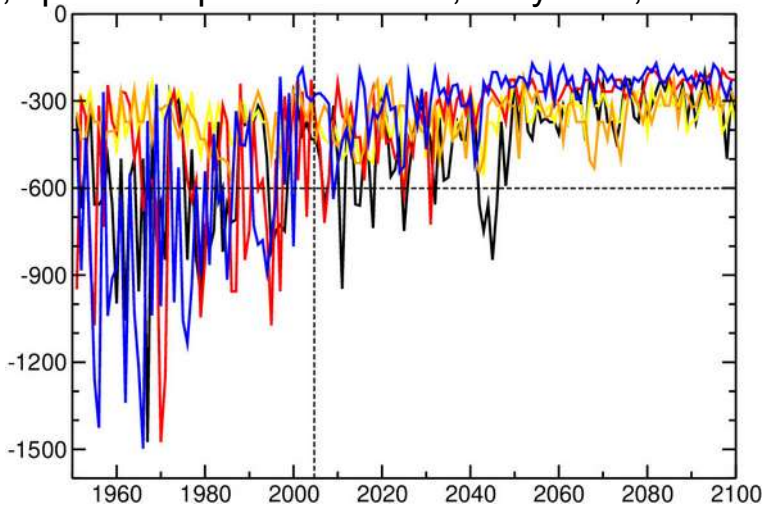
Yearly-mean SSS change

(-, 2075–2100 vs 1980–2005, RCP8.5)



Gulf of Lions Open-Sea Deep Convection

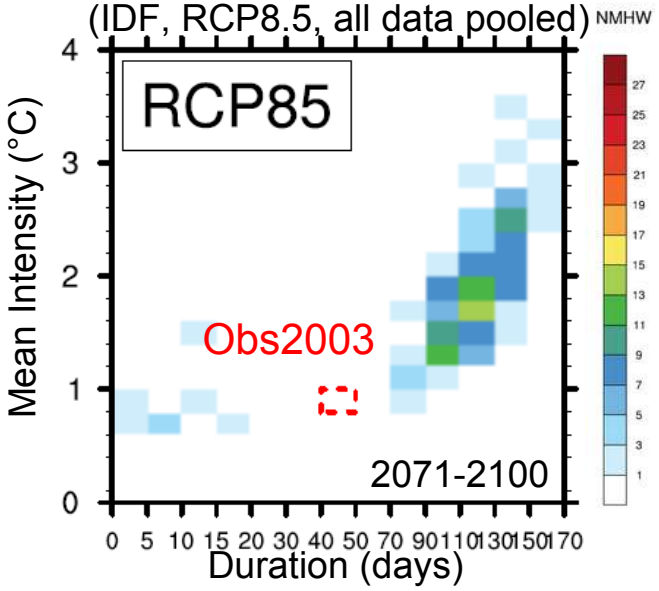
(m, spatio-temporal max MLD, daily data, RCP8.5)



Darmaraki et al. 2019a, Soto-Navarro et al. 2020, S.Somot (pers. comm.)

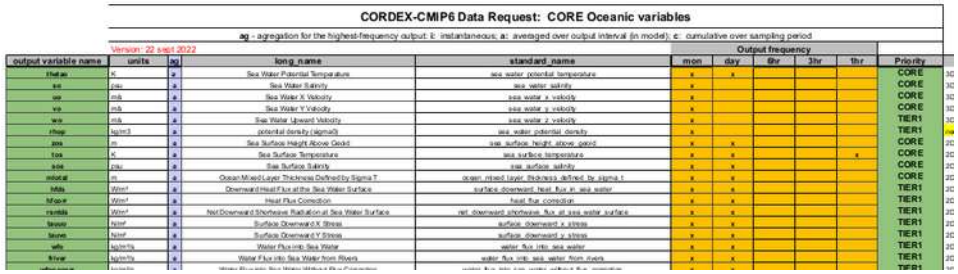
Marine heatwaves charact.

(IDF, RCP8.5, all data pooled)



Communication, standardization, data sharing

File naming & Variable lists for the ocean



CORDEX-CMIP6 Data Request: CORE Oceanic variables

ag - agregation for the highest-frequency output: i: instantaneous; a: averaged over output interval (in model); c: cumulative over sampling period

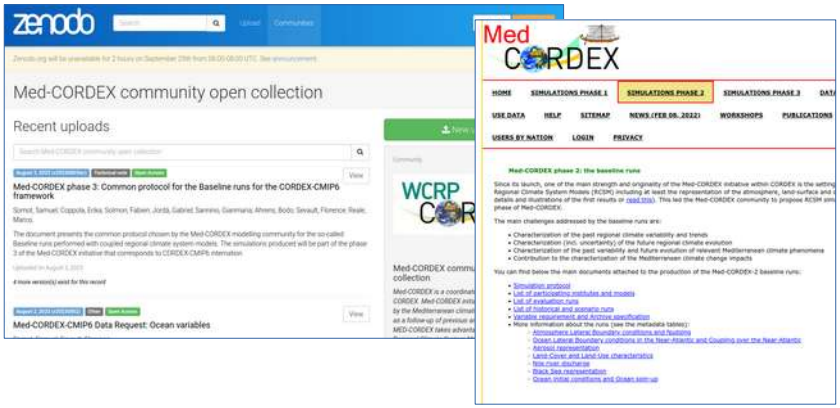
Version: 22 sept 2022

output variable name	units	ag	long_name	standard_name	Output frequency: mon	day	6hr	3hr	1hr	Priority
thetao	K	a	Sea Water Potential Temperature	sea_water_potential_temperature	x	x				CORE
so	psu	a	Sea Water Salinity	sea_water_salinity	x					CORE
uo	m/s	a	Sea Water X Velocity	sea_water_x_velocity	x					CORE
vo	m/s	a	Sea Water Y Velocity	sea_water_y_velocity	x					CORE
wo	m/s	a	Sea Water Upward Velocity	sea_water_z_velocity	x					TIER1
rhopo	kg/m3	a	potential density (sigma0)	sea_water_potential_density	x					TIER1
zos	m	a	Sea Surface Height Above Geoid	sea_surface_height_above_geoid	x	x				CORE
tos	K	a	Sea Surface Temperature	sea_surface_temperature	x	x			x	CORE
sos	psu	a	Sea Surface Salinity	sea_surface_salinity	x	x				CORE
mlotst	m	a	Ocean Mixed Layer Thickness Defined by Sigma T	ocean_mixed_layer_thickness_defined_by_sigma_t	x	x				CORE
hfds	W/m²	a	Downward Heat Flux at the Sea Water Surface	surface_downward_heat_flux_in_sea_water	x	x				TIER1
hfcorr	W/m²	a	Heat Flux Correction	heat_flux_correction	x	x				TIER1
rsntds	W/m²	a	Net Downward Shortwave Radiation at Sea Water Surface	net_downward_shortwave_flux_at_sea_water_surface	x	x				TIER1
tauuo	N/m²	a	Surface Downward X Stress	surface_downward_x_stress	x	x				TIER1
tauvo	N/m²	a	Surface Downward Y Stress	surface_downward_y_stress	x	x				TIER1
wfo	kg/m²/s	a	Water Flux into Sea Water	water_flux_into_sea_water	x	x				TIER1
friver	kg/m²/s	a	Water Flux into Sea Water from Rivers	water_flux_into_sea_water_from_rivers	x	x				TIER1

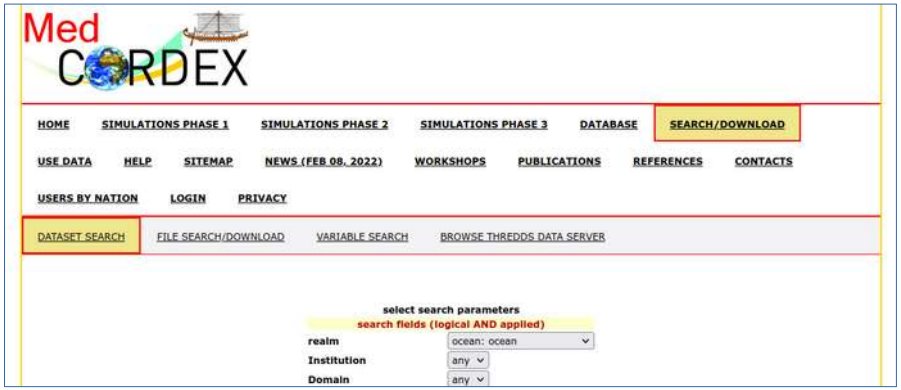
CORDEX/output/MED-11/CNRM/ECMWF-ERAINT/evaluation/r1i1p1/CNRM-RCSM6/v1/day/tos/

tos_MED-11_ECMWF-ERAINT_evaluation_r1i1p1_CNRM-RCSM6_v1_mon_200601-201012.nc

Open science strategy (web page, Med-CORDEX community zenodo page)



Database : Ocean realm & Ocean datasets

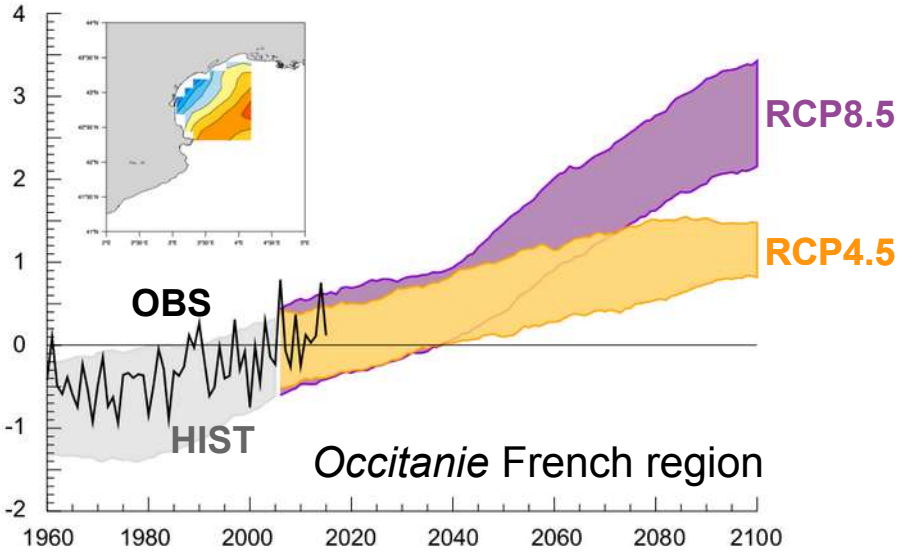


Med-CORDEX impacts outside the community

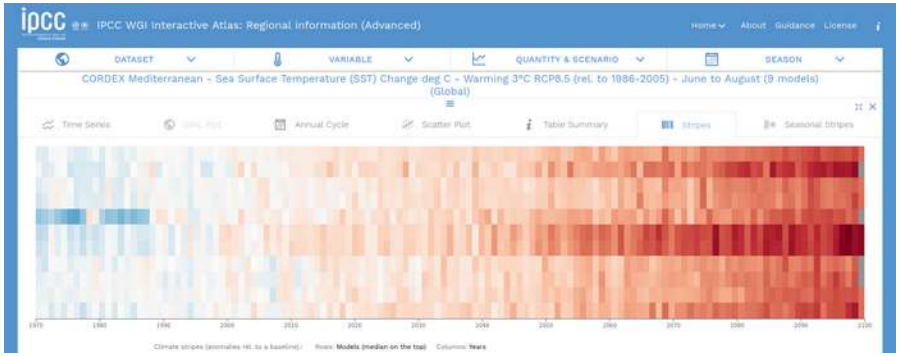
« the frequency and severity of marine heat waves of the Mediterranean Sea are projected to increase (Darmaraki et al. 2019) »
(IPCC-AR6-WGI, Chap. 10)

« a surface salinity increase in the eastern Mediterranean Basin is more likely than not [...] (Adloff et al. 2015; Soto-Navarro et al. 2020) »
(MedECC-MAR1, Chap. Drivers)

RECO-CROCC report : SST anomaly
(°C, wrt 2001-2020, 5 RCSMs, 20-yr filtered)



Med-CORDEX SST data in the IPCC Interactive Atlas



Med-CORDEX ocean datasets serve ocean climate change impact studies (fish habitat, biogeochemistry, MPA connectivity, fish biodiversity, sea level)

First contacts with ocean climate services

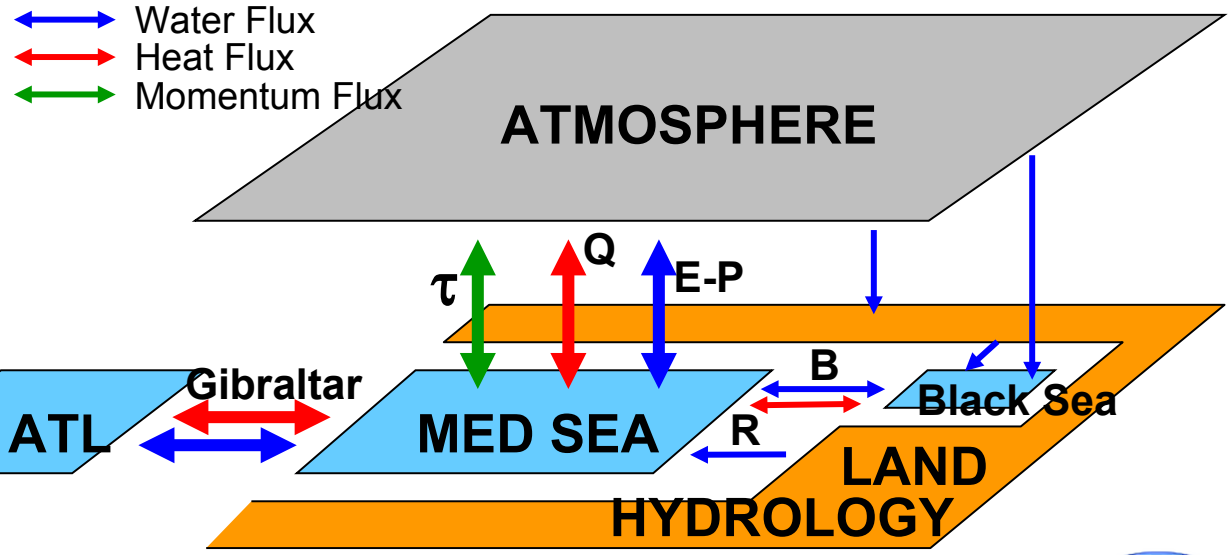
IPCC-AR6 (chap 10, 11, 12, Atlas), MedECC-Mediterranean Assessment Report #1, RECO-CROCC-2021

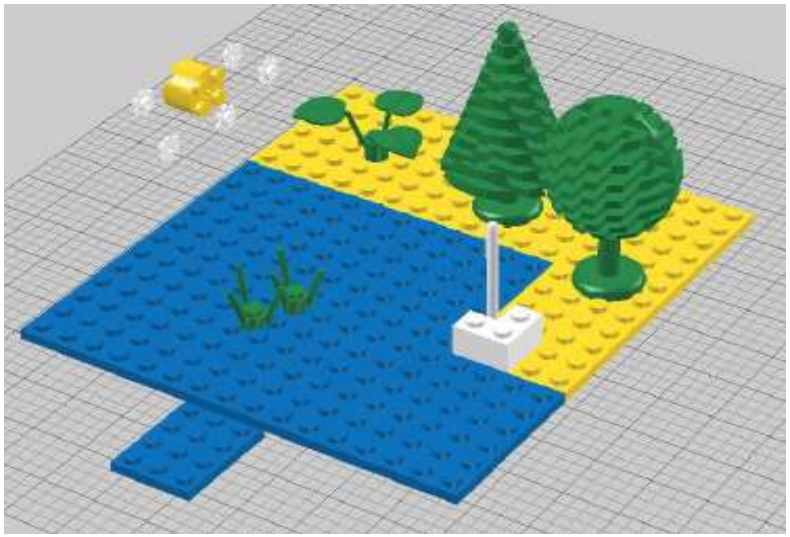
Advice for launching a CORDEX-Ocean initiative

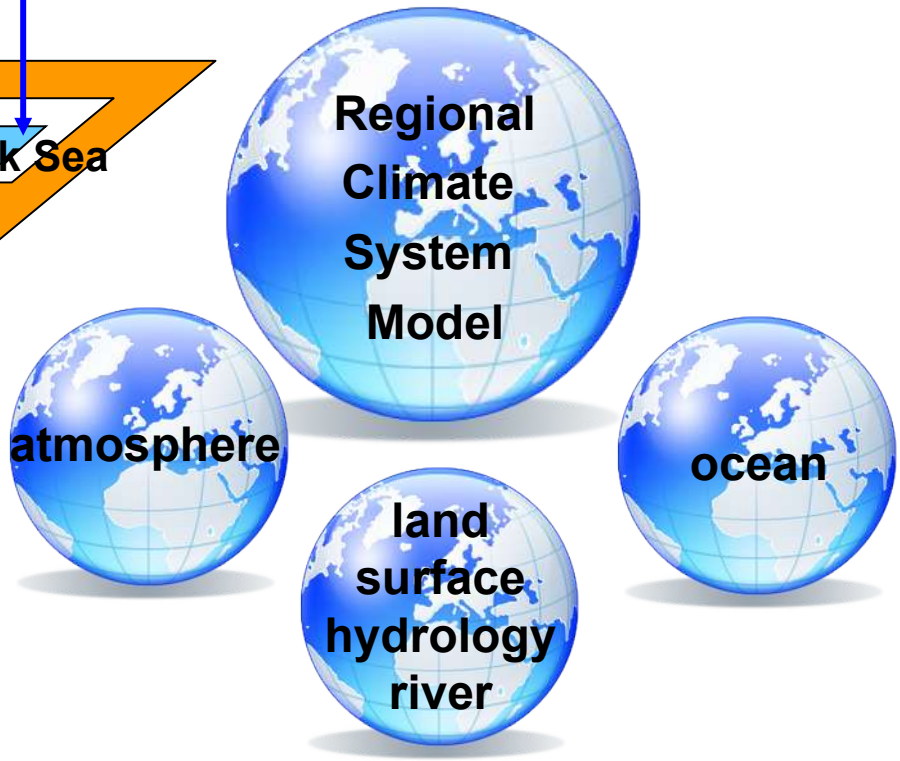
- Any new international initiative require time and efforts. Does it worse it ?
- Define cleary what we want to achieve as a community
- Define the targeted outcomes (users, IPCC-AR7) of the initiative and the timeline
- How to place the CORDEX-Ocean initiative wrt other WCRP modelling activities
- Secure a small number of steering persons to drive the initiative
- Set open and efficient communication tools
- Encourage scientific informal exchanges and networking within the club
- Built the trust among the initiative members
- Take into account the diversity of the participants: different values, different scientific perspectives, different objectives and different levels of resource
- Interact regularly with SAT to place the initiative in the long-term CORDEX vision
- Find financial support for the involved modelling groups

Representation of the regional climate system

The regional climate system is fully coupled



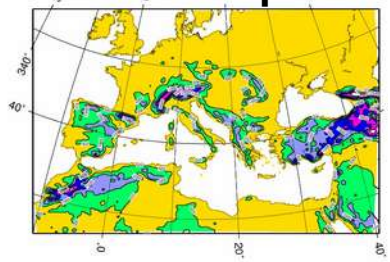




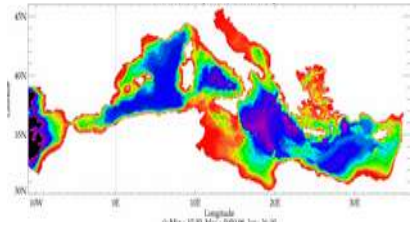
Three visions for the Med-CORDEX RCSMs :
Paolo Ruti, Annarita Mariotti, Samuel Somot

Ocean-dedicated simulation protocols : Med-CORDEX, phase 1 (2009-2015)

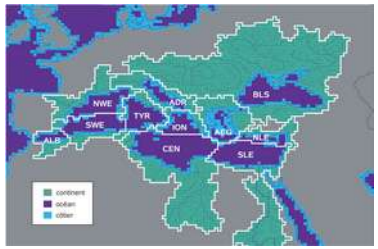
12km - atmosphere



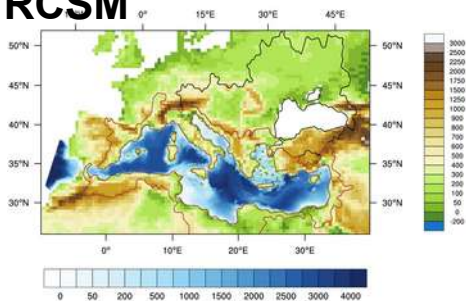
10km - ocean



50km – river



RCSM



explicit convection (~2.5 km)

~10 km

50 km

150-year control for RCSM

1950-2100

Time slices: 1976-2005, 2011-2040, 2041-2070

ARCM SST-driven

CORE

RCP4.5 and RCP8.5

RCP2.6

Other RCP scenarios

GCM-driven run

ERA-Interim driving 1989-2008

ERA-Interim driving 1979-2013

ERA40 driving

Big-Brother

HyMeX LOP

NCEP driving

Other GCMs

Ensemble runs

TIER1

TIER2

RESM

RCSM

Med sea

Land-Hydro

CORDEX mandatory

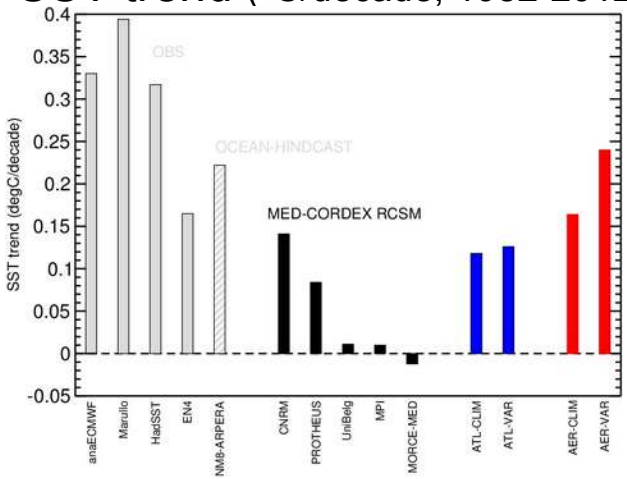
Ocean-oriented Med-CORDEX additional framework

Develop new knowledges

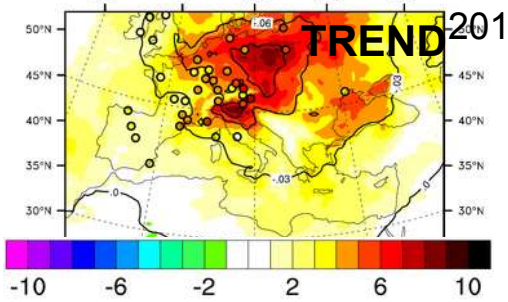
Explaining the Mediterranean SST past trend

- Sensitivity tests with and without aerosol trend in a coupled RCM over the last decades
- Aerosol brightening effect explains part of the SST past trend in the Mediterranean Sea
- Ocean coupling allows to study this impact

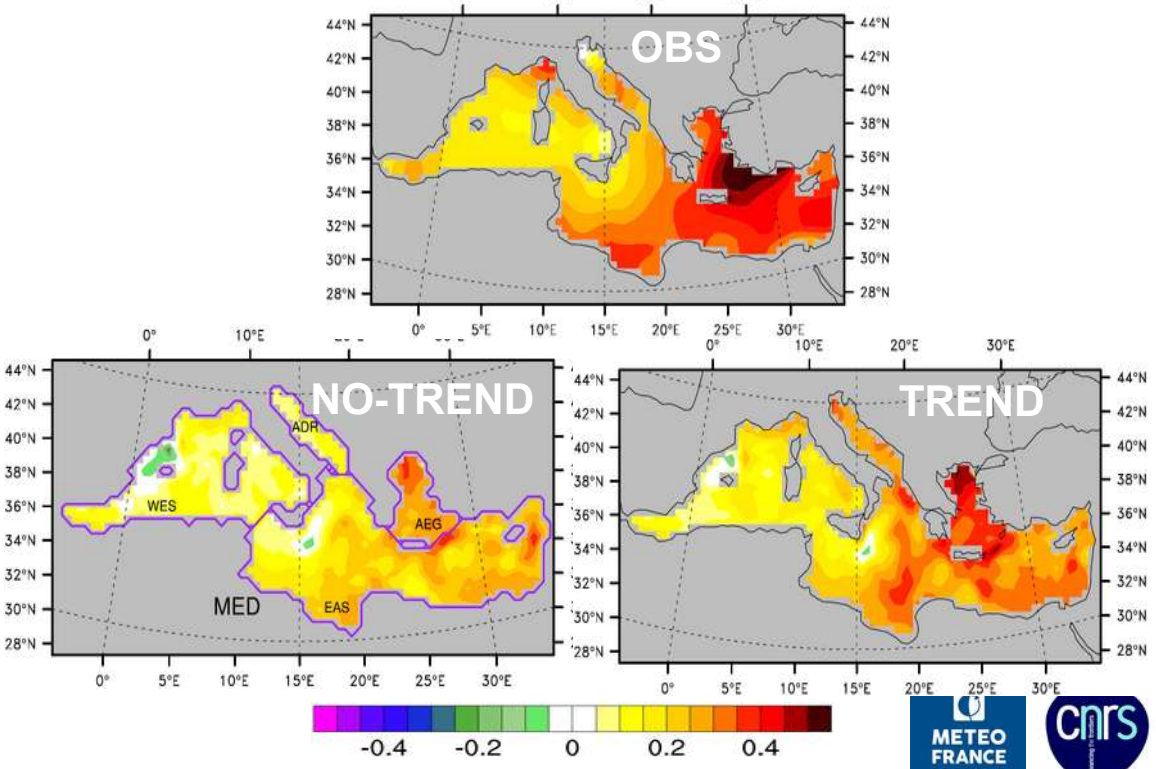
SST trend (°C/decade, 1982-2012, Med Sea)



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



SST trend
(°C/decade, 1982-2012)



Nabat et al. 2014