Climate change in the Mediterranean region: results from a global AOGCM coupled with a high-resolution model of the Mediterranean Sea

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State of the art (CMIP3-AR4) coupled models are inadequate to resolve the dynamical features of the Euro-Mediterranean region. 

Orography, Land-Sea mask and Mediterranean Sea bathymetry as represented in a “standard” CMIP3 (IPCC-AR4) model with horizontal resolution of \( \sim 300 \text{ Km} \)
The CMCC-MED MODEL: a global climate model with a fully resolved Mediterranean Sea developed in the framework of CIRCE (EU-FP7)

GLOBAL ATMOSPHERE MODEL
(dynamics, physics, prescribed gases and aerosols)
ECHAM5 T159 ~ 80 Km and 31 vert. levels
Roeckner et al. 2003

GLOBAL OCEAN & SEA-ICE MODEL
OPA/ORCA2 2° ~200 Km
31 vert. levels
Madec et al. (1998)
LOUVAIN-LA-NEUVE SEA-ICE MODEL
Timmermann et al. (1999)

COUPLER
OASIS 3 Valcke (2006)

MEDITERRANEAN SEA MODEL
NEMO/MFS 1/16° ~ 7 Km
71 vert. levels
Oddo et al. (2009)

T, S, u, v, η

Coupling between atmosphere and oceans every 2 hours
Coupling between global ocean and Mediterranean Sea every 8 hours
Orography, Land-Sea mask and Mediterranean Sea bathymetry in the new CMCC model
Simulation of the observed climate

Sea-Surface Temperature (SST) 1951-2000 mean
Simulation of the observed climate

Evolution of the global mean SST from 1951 to 2000: observation vs. model

The model reproduces well the global SST trend observed during the second half of the 20th Century.
Simulation of the observed climate

SST 1980-2000 mean

OBSERVATIONS

CMCC MODEL

MODEL - OBSERVATIONS

DJF

OSERVATIONS

CMCC MODEL

MODEL - OBSERVATIONS

JJA

-3 -2 -1 0 °C
Simulation of the observed climate

Precipitation 1951-2000 mean
The CMCC climate simulations: climate projection A1B scenario

Evolution of the simulated Mediterranean basin mean SST from 1951 to 2070 (A1B)

During the 2000-2070 period (A1B scenario) the model produces a warming trend of about 0.36 °C/decade
Climate change projection from an A1B scenario simulation

**SST change**

**PREcipitation change**

**DJF**

**Diff Mean (2041-2070) - (1971-2000)**

**JJA**

**Diff Mean (2041-2070) - (1971-2000)**

**mm/day**
Climate change projection from an A1B scenario simulation

The hydrologic cycle in the Mediterranean basin:

Water budget seasonal cycle (1971-2000)

- **Model = 591 mm/year**
- **OBS = 608 mm/year**

(OBS = CMAP + COADS + Med-HYCOS+GRDC)

Change in the water budget seasonal cycle

- **1971-2000**
- **2021-2050**
- **2071-2100**

Evolution of the water budget

Net mass transport at Gibraltar
Climate change projection from an A1B scenario simulation

The heat budget in the Mediterranean basin:

- Net mass transport at Gibraltar
- Heat transport at Gibraltar
- Net (downward) heat flux over the Med. Sea
- Heat budget in the Med. Sea
The CMCC-MED climate simulations: climate projection A1B scenario

Evolution of the **STERIC contribution to SLR** in the Mediterranean basin from 1951 to 2100 (A1B)
SUMMARY:

- a **new high-resolution model** suitable to investigate the **regional scales** and the **role of the Mediterranean Sea** in the global climate.

- the model reproduces the main features of the Euro-Mediterranean climate. It exhibits some **substantial improvement wrt CMIP3 models**.

FROM AN A1B SCENARIO SIMULATION:

- Mediterranean **SST increases of about 2°C** in the next decades (2041-2070); **precipitation increases** in North Europe and **decreases** in the Mediterranean area. Large response in the **Alpine region** (15-20%).

- **hydrologic cycle** in the Mediterranean basin substantially affected by global warming: **increased evaporation** and **reduced precipitation**. Implications for **water mass transport** at the Gibraltar Strait.

- change in salinity and temperature induce a **steric SLR of about 22 cm** wrt 1971-2000 mean
Thank you!
The CMCC-MED climate simulations: **climate projection A1B scenario**

Evolution of the simulated Mediterranean basin mean heat budget (Gibraltar+Surface) from 1951 to 2100 (A1B)
Simulation of the observed climate

10-m wind zonal component  1951-2000 mean

OBS (ECMWF reanalyses)  CMCC MODEL (80 Km)

DJF  DJF

JJA  JJA
The CMCC-MED climate simulations: reproduction of the observed climate

2-m Temperature
Simulation of the observed climate

SSS 1980-2000 mean

OBSERVATIONS

CMCC MODEL

MODEL - OBSERVATIONS

DJF

OSERVATIONS

CMCC MODEL

MODEL - OBSERVATIONS

JJA
The CMCC-MED climate simulations: **climate projection A1B scenario**

**PRECIPITATION standard deviation:**
year-to-year variability in a recent past and in a possible near future (A1B)
The CMCC-MED climate simulations: **climate projection A1B scenario**

2-meter TEMPERATURE standard deviation: year-to-year variability in a recent past and in a possible near future (A1B)
The CMCC climate simulations: **climate projection A1B scenario**

2-meter **TEMPERATURE change** in the Euro-Mediterranean region

**MODEL MEAN 1971-2000**

**MODEL MEAN 2041-2070**

**DIFF (2041-2070) - (1971-2000)**
The CMCC climate simulations: **climate projection A1B scenario**

**SST change in the Mediterranean Sea**

- **DIFF MEAN (2041-2070) - (1971-2000)**

**DJF**

- **DIFF MEAN (2041-2070) - (1971-2000)**

**JJA**

- **DIFF MEAN (2041-2070) - (1971-2000)**
The CMCC climate simulations: **climate projection A1B scenario**

**PRECIPITATION** change in the Euro-Mediterranean region

The CMCC climate simulations: climate projection A1B scenario

**PRECIPITATION** change in the Euro-Mediterranean region

The CMCC climate simulations: climate projection A1B scenario
The CMCC climate simulations: **reproduction of the observed climate**

**SST  standard deviation**

[Map showing SST standard deviation for Observations (INGV reanalyses) and MODEL]
The CMCC climate simulations: reproduction of the observed climate

SSS  standard deviation
The CMCC climate simulations: reproduction of the observed climate

Sea surface height 1980-2000 mean

Observations (INGV reanalyses) vs MODEL

DJF

JJA
The CMCC climate simulations: **reproduction of the observed climate**

**Sea surface height**

**standard deviation**

Observations (INGV reanalyses)  MODEL

![Map of Sea surface height and standard deviation](image)
The CMCC-MED climate simulations: **climate projection A1B scenario**
The CMCC-MED climate simulations: **climate projection A1B scenario**

**Mediterranean Sea Volume averaged temperature**
The CMCC-MED climate simulations: climate projection A1B scenario
The CMCC-MED climate simulations: **climate projection A1B scenario**
The CMCC-MED climate simulations: climate projection A1B scenario
The CMCC-MED climate simulations:

SEA-LEVEL CHANGE: **STERIC EFFECT**

**MONTHLY MEAN FIELDS** of Temperature and Salinity data from 1950 to 2070

**REFERENCE PERIOD 1970-2000:**

- Means of \(<T(x,y,z)>\), \(<S(x,y,z)>\) have been obtained for the reference period, then from \(<T>\) and \(<S>\), the mean density \(<D(x,y,x)>\) has been computed

Monthly values of density \(D(t,x,y,z)\) have been computed from the monthly means of \(T(t,x,y,z)\) and \(S(t,x,y,z)\)

\(D_0(z)\) is the reference (\(T=0^\circ\text{C}, S=35 \text{ psu}\)) in situ density

**STERIC EFFECT:**