MedCLIVAR Workshop on: "Scenarios of Mediterranean Climate Change under Increased Radiative Active Gas Concentration and the Role of Aerosols

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XXI Century Marine Climate Scenarios for the Mediterranean Sea

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XXI century marine climate scenarios for the Mediterranean Sea

The VANIMEDAT-2 and ESCENARIOS projects

G. Jordà, F. M. Calafat, M. Marcos, D. Gomis
IMEDEA

E. Álvarez, R. Aznar, M. Gómez, M. G. Sotillo, B. Pérez
Puertos del Estado

S. Somot (Météo-France), M. Tsimplis (NOC)
**Main objective:** describe the marine climate of the Med Sea and a sector of the NE Atlantic Ocean under different GHG scenarios for the 21st century

Namely, we intend to answer why, where and how large will be the eventual changes in...

- the hydrodynamics (temperature, salinity and circulation)
- total sea level and its different components
- the wave field

→ We focus on both, mean regimes and extreme events

→ Determination of uncertainties as important as the projections themselves!
Framework: the ‘VANIMEDAT-2’ and ‘ESCENARIOS’ projects

- **VANIMEDAT-2** is funded by the Spanish Marine Science and Technology Program and focuses on the scientific issues of the projections such as the impact of model configurations or the physical processes underlying the projected changes.

- **ESCENARIOS** is funded by the Spanish Met Office (AEMET) and focuses on products: marine scenarios obtained under specific atmospheric projections and the associated uncertainties.

Outline

- Barotropic Sea Level
- Assessing uncertainties in Mediterranean baroclinic models
## Methodology

### PLANNED SIMULATIONS (~2012)

<table>
<thead>
<tr>
<th>Number of planned runs</th>
<th>Reanalysis</th>
<th>Control</th>
<th>B1</th>
<th>A1b</th>
<th>A2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave model</td>
<td>West Med</td>
<td>8 (1)</td>
<td>8 (1)</td>
<td>1 (1)</td>
<td>8 (1)</td>
</tr>
<tr>
<td></td>
<td>Atlantic</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Storm surge</td>
<td></td>
<td>8 (1)</td>
<td>8 (1)</td>
<td>1 (1)</td>
<td>8 (1)</td>
</tr>
<tr>
<td>3D model</td>
<td></td>
<td>2(1)</td>
<td>3(1)</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

(*) In parenthesis the runs already finished

Reanalysis ~ Hindcast

Different combinations of RCM’s at different resolutions forced by different AOGCM’s
**Atmospheric contribution to sea level**

- HAMSOM model implemented at 1/6° x 1/4° in the whole Mediterranean and a NE Atlantic sector (same than HIPOCAS)
- Forced by ARPEGE model (~50km over the Mediterranean) with 6h frequency
- Output > 1h sea level

Comparison of reanalysis with tide gauges lead to a rms of 3.2 cm and averaged correlation 0.8
Atmospheric contribution to sea level

Validation of Control Run (present climate)

Sea Level Annual Cycle

Seasonal patterns

Interdecadal variability

Jordà et al., 2010
Atmospheric contribution to sea level

Scenarios Results

Sea Level pdf Western Mediterranean

- Frequency increase of negative events (more high pressures)
- Frequency decrease of positive events (less low pressures)

Median doesn’t change
Winter decrease (up to 8 cm at the end of the century in the Adriatic) and summer slight increase.

Larger GHGs concentrations induce larger trends.
Atmospheric contribution to sea level

Scenarios Results

Seasonal Changes directly linked to SLP fields. The ARPEGE results are consistent with other RCM’s

SLP change (mb, 2071-2100 minus 1961-1990), MGME ensemble average, A1B scenario

Giorgi and Lionello (2008)
Atmospheric contribution to sea level

Scenarios Results

Extreme Events

Number of events per year

Reduction in the frequency of moderate and strong events (up to ~50% under A2 scenario)

Marcos et al., 2010
Atmospheric contribution to sea level

Scenarios Results

50 year Return Level difference respect to present

Reduction in the RL of positive surges 6-10%
Increase in the RL of negative surges of 15%

Uncertainties are as important as changes!
Atmospheric contribution to sea level

Conclusions

- The atmospheric contribution to sea level would induce a decrease up to 8 cm during winter and a slight increase during summer.
- This would be due to the increase of the positive phases of the NAO, which is a robust result among different RCM’s.
- The number of extreme events would decrease up to 50% for negative events and increase for positive events.
- The return levels would change consistently but with smaller relative changes. However, the uncertainties are large and no strong consensus among different models is reached (link to the number of cyclones).

Wave simulations lead to similar conclusions with general decrease in the Western Mediterranean of $H_s$ and extreme events.
Before discussing the projections from 3D models we should feel confident about them. The main questions are:

- Are the estimates of sea level from models adequate?
- Which are the sources of uncertainty?

We perform a comparison from 3 Mediterranean Climate models for the period 1960-2000.
Comparison of Mediterranean Climate models

**ORCA**
(Barnier et al., 2006)
- NEMO model
- Free Surface
- Global model (1/4°)
- Forced with ERA40
- Climatological river runoff
- Real variability in the Atlantic
- SSS relaxation

**OM8**
(Somot et al., 2006)
- OPA model
- Rigid lid
- Regional model (1/8°)
- Forced with ARPEGE (~50km)
- Climatological river runoff
- Climatology in the Atlantic box
- Zero net flow at Gibraltar
- No SSS relaxation

**PROTHEUS**
(Artale et al., 2009)
- MITgcm model
- Free surface
- Regional model (1/8°)+Local model at Gibraltar
- Coupled to RegCM (~30km)
- Interactive river scheme
- Climatology in the Atlantic box
- Natural SSS Bound. Cond.
**Temperature Trends**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Western Mediterranean</th>
<th>Eastern Mediterranean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-100</td>
<td>100-500</td>
</tr>
<tr>
<td><strong>MEDAR</strong></td>
<td>7.8±2.5</td>
<td>-0.3±1.2</td>
</tr>
<tr>
<td><strong>ORCA</strong></td>
<td>0.2±2.9</td>
<td>8.1±1.2</td>
</tr>
<tr>
<td><strong>OMS</strong></td>
<td>6.0±2.6</td>
<td>4.1±1.2</td>
</tr>
<tr>
<td><strong>MITgcm</strong></td>
<td>6.0±2.6</td>
<td>4.1±1.2</td>
</tr>
</tbody>
</table>

**Salinity Trends**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Western Mediterranean</th>
<th>Eastern Mediterranean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-100</td>
<td>100-500</td>
</tr>
<tr>
<td><strong>MEDAR</strong></td>
<td>0.7±0.8</td>
<td>1.9±0.6</td>
</tr>
<tr>
<td><strong>ORCA</strong></td>
<td>-1.8±0.3</td>
<td>-1.2±0.3</td>
</tr>
<tr>
<td><strong>OMS</strong></td>
<td>-0.8±0.5</td>
<td>0.4±0.2</td>
</tr>
<tr>
<td><strong>MITgcm</strong></td>
<td>-1.7±0.6</td>
<td>-1.1±0.6</td>
</tr>
</tbody>
</table>

No agreement with data at any depth

Warming deeper layers by all models, especially in the West Med.

Changes in the vertical stratification
Comparison of Mediterranean Climate models

T/S detrended time series at different layers in the W Med

Good correlation in Temperature up to 500 m but it worsens below.

> Good surface heat flux but wrong vertical transfer of heat. Impact of Gibraltar outflow seems of 2nd order

Salinity performs worse. Only MITgcm model reproduces some of the features.

> Probably due to wrong E-P-R balance
Comparison of Mediterranean Climate models

Dense water formation enhance vertical heat transfer and also impacts on sea level

Deep Water Formation

Intermediate Water Formation

• Large discrepancies among models

• ORCA rates are very small (due to low resolution in model and forcings)

• MITgcm production rates are larger than the others especially in the Aegean

Role of freshwater treatment. Also coupling??
Comparison of Mediterranean Climate models

Sea Level Trends (1993-2001)

Only MITgcm captures the EMT > Role of River Scheme
Weaker signals are, in general, not captured by any model
Comparison of Mediterranean Climate models

Long term Sea Level Trends (1960-2001)

(a) Aegean

(b) Ionian

Reconstruction
MITgcm
ORCA
OM8

MSL [cm]

Comparison of Mediterranean Climate models

Long term basin averaged Sea Level Trends (1960-2001)

Except for ORCA, the trends would seem acceptable but not the interannual variability

However …
Comparison of Mediterranean Climate models

Long term basin averaged Sea Level Trends (1960-2001)

Sea level variability = Steric component + Mass component

But Regional models doesn’t account for mass component estimated to be $1.2 \pm 0.2$ mm/year (Mir-Calafat et al. 2009)!!

Data includes the mass component and models the spurious warming in deep layers!!
Regional models can reproduce T variability for z<500m. High resolution seems a key element as well as good quality heat fluxes. S is more problematic due to uncertainties in the E-P-R budget.

Atypical events as the EMT can be approximated with proper schemes (PROTHEUS system, role of interannual variability of rivers runoff). Maybe coupling also plays a role.

All models lack in reproducing the deep layers evolution. This maybe due to a problem in the mechanisms transfering heat from the surface to deep layers. This has negative impact on the sea level evolution (trends in the western Med are doubled!)

Concerning sea level, models fail in reproducing large part of interannual variability and trends at regional and basin scale.
Thanks for your attention ...