The Abdus Salam
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International Atomic Energy Agency

2210-19

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

23 - 25 September 2010

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

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IMEDEA

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Puertos del Estado

S. Somot (Météo-France), **M.Tsimplis** (NOC),

IMEDEA (CSIC-UIB)

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, <u>mean regimes</u> and <u>extreme events</u>

→ Determination of uncertainties as important as the projections themselves !

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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.

- Temporal framework: 1.1.2010 – 31.12.2012

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MINISTERIO DE EDUCACIÓN Y CIENCIA

Plan E
Plan Español para el Estímulo de la Economía y el Empleo
FONDO DE INVERSIÓN LOCAL PARA EL EMPLEO

AEMet
Agencia Estatal de Meteorología

Outline

- Barotropic Sea Level

- Assessing uncertainties in Mediterranean baroclinic models

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Methodology

PLANNED SIMULATIONS (~2012)

Number of planned runs		Reanalysis	Control	B1	A1b	A2
Wave model	*West Med*	8 *(1)*	8 *(1)*	1 *(1)*	8 *(1)*	2 *(1)*
	Atlantic	2	2	-	2	-
Storm surge		8 *(1)*	8 *(1)*	1 *(1)*	8 *(1)*	2 *(1)*
3D model		2*(1)*	3*(1)*	1	3	1*(1)*

(*) In parenthesis the runs already finished

Reanalysis ~ Hindcast

Different combinations of RCM's at different resolutions forced by different AOGCM's

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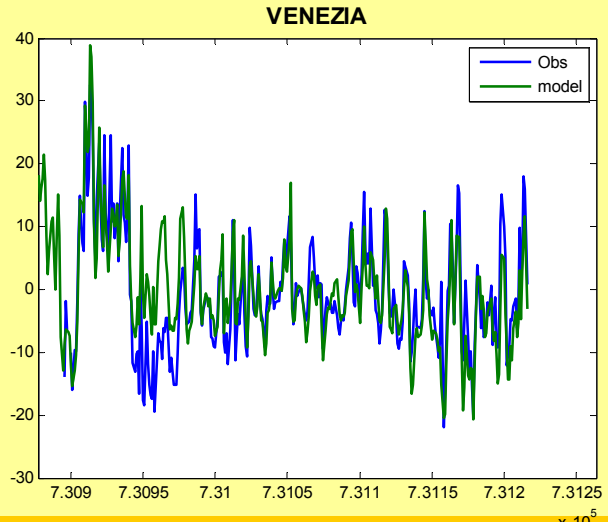
Atmospheric contribution to sea level

- **HAMSOM model implemented at 1/6º x 1/4º in the whole Mediterranean and a NE Atlantic sector (*same than HIPOCAS*)**
- **Forced by ARPEGE model (~50km over the Mediterranean) with 6h frequency**
- **Runs: Reanalysis (1958-2001), Control (1950-2000) and scenarios B1, A1b and A2 (2001-2100)**
- **Output > 1h sea level**

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



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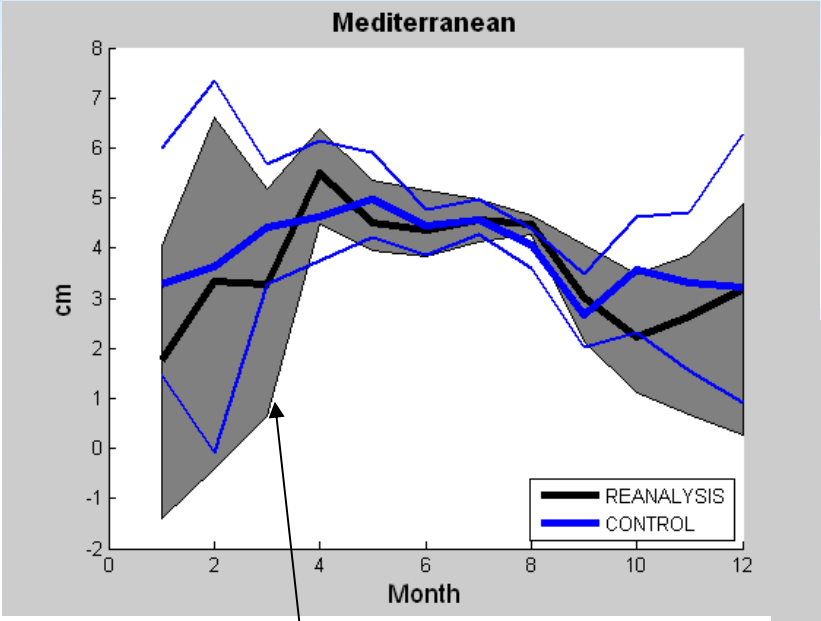
Atmospheric contribution to sea level

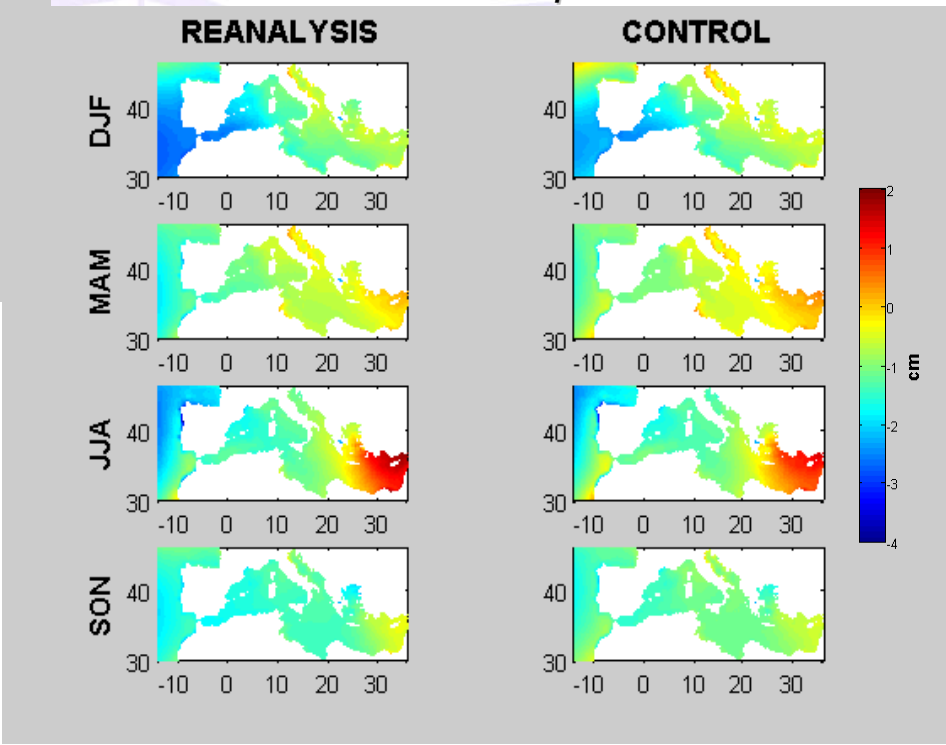
Validation of Control Run (present climate)

Sea Level Annual Cycle



Interdecadal variability

Seasonal patterns



Jordà et al., 2010

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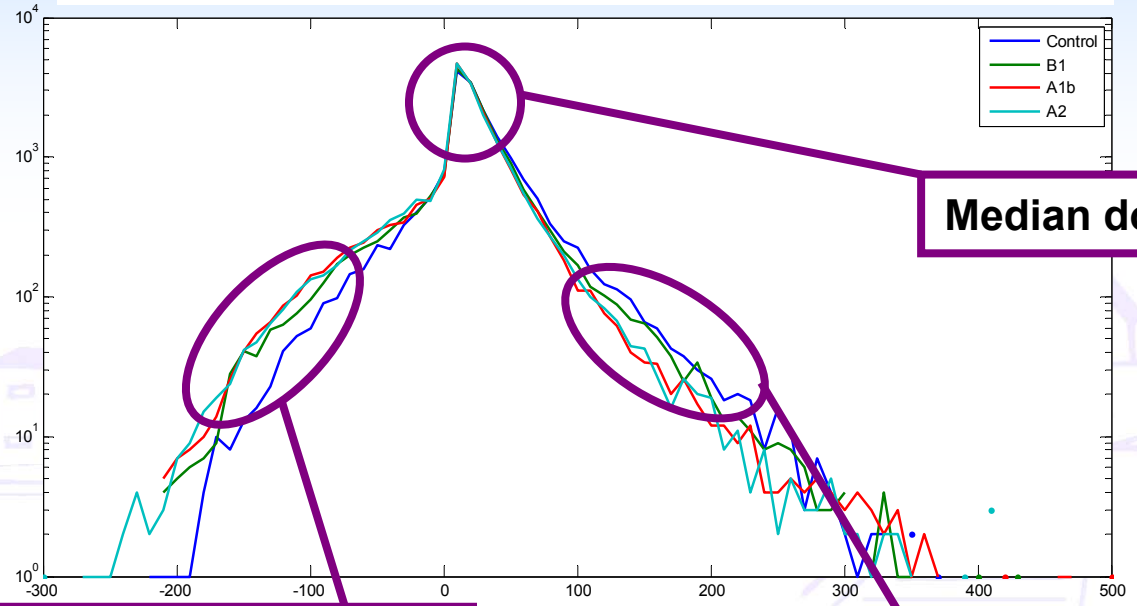
Atmospheric contribution to sea level

Scenarios Results

Sea Level pdf Western Mediterranean



Median doesn't change

Frequency Increase of negative events

(more high pressures)

Frequency decrease of positive events

(less low pressures)

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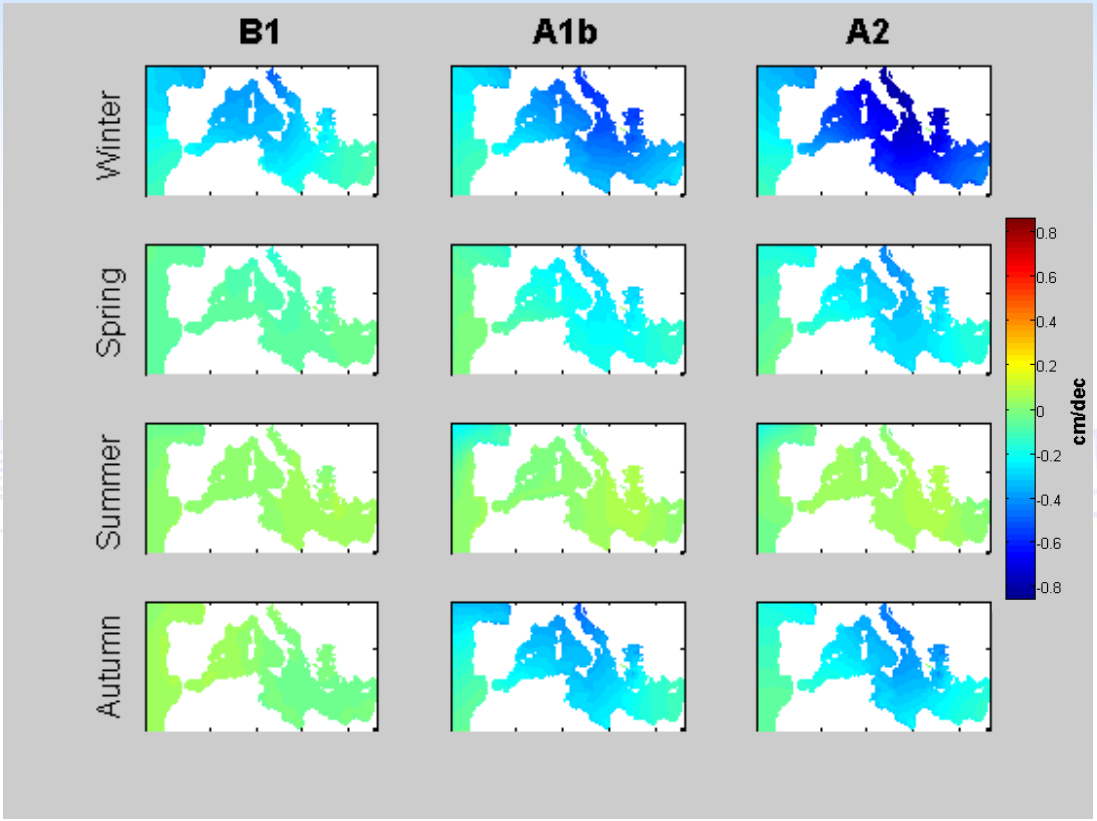
Atmospheric contribution to sea level

Scenarios Results

Seasonal Trends



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

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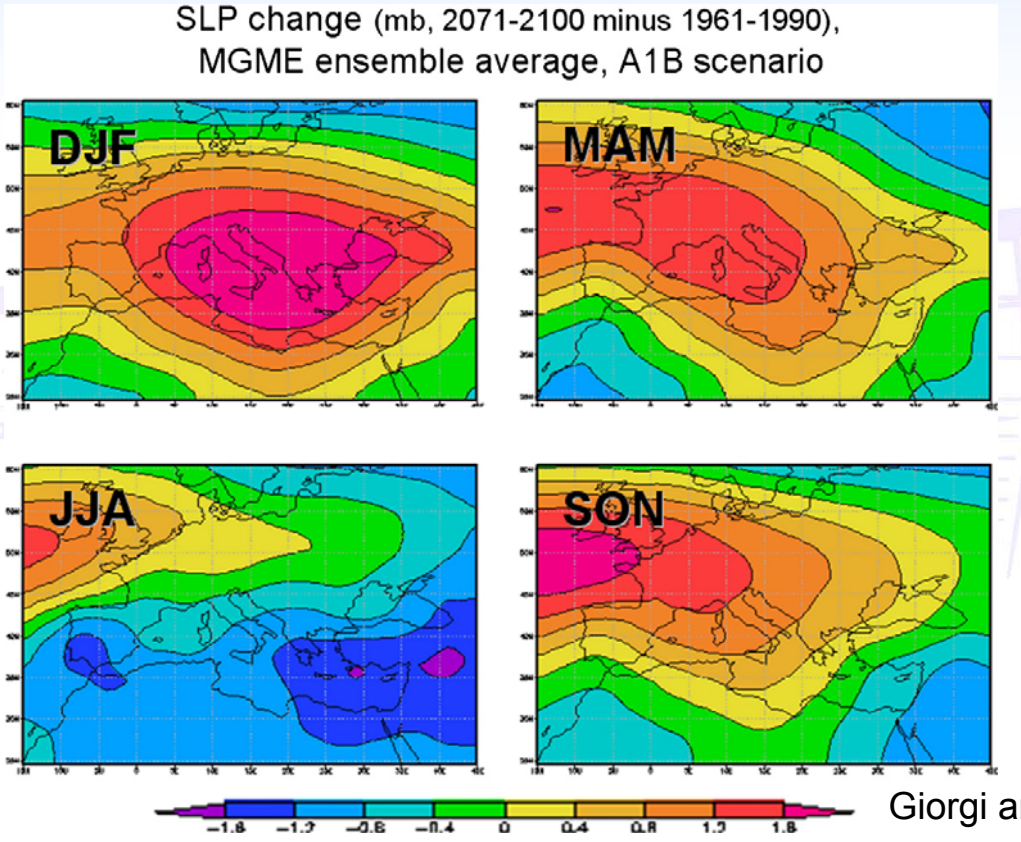
Atmospheric contribution to sea level

Scenarios Results

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



Giorgi and Lionello (2008)

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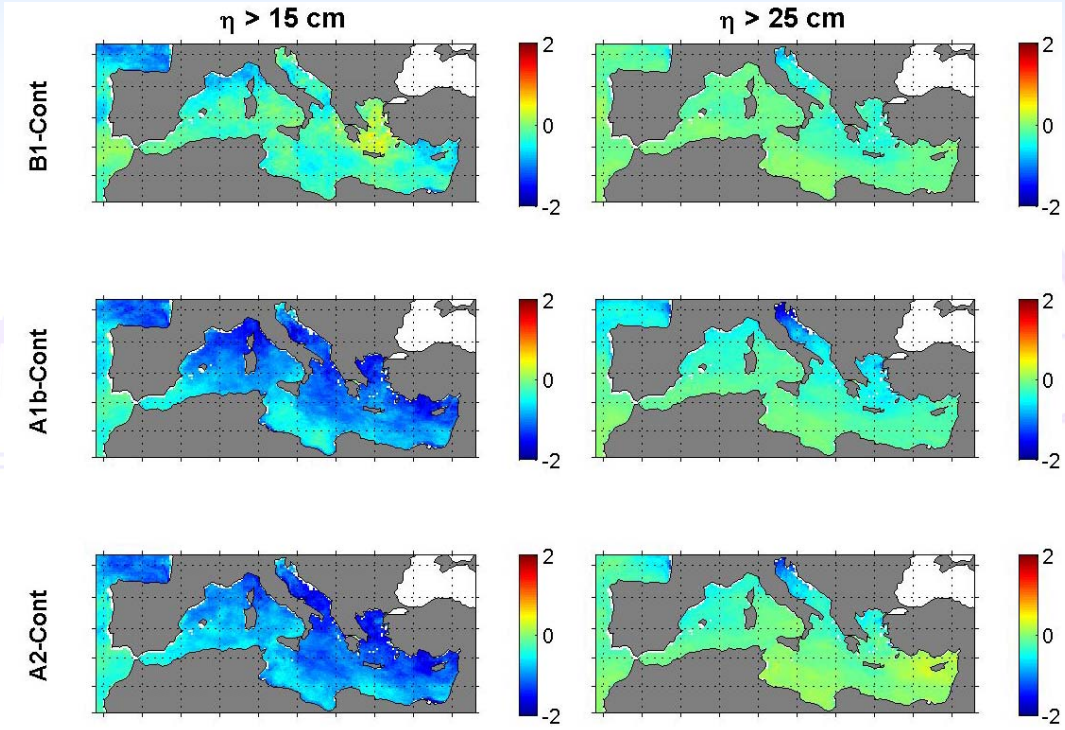
Atmospheric contribution to sea level

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

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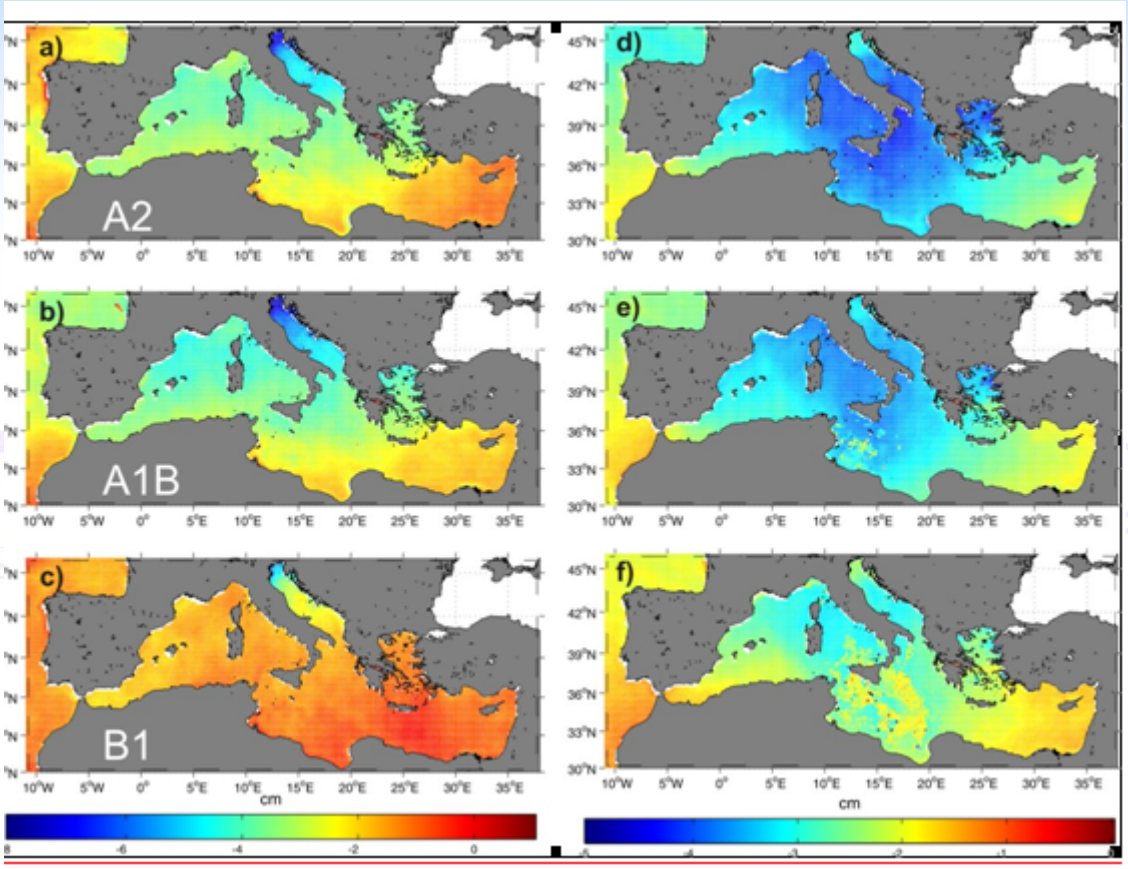
Atmospheric contribution to sea level

Scenarios Results

50 year Return Level difference respect to present

Positive events



Negative events

Reduction in the RL of positive surges 6-10%

Increase in the RL of negative surges of 15%

Uncertainties are as important as changes !

IMEDEA (CSIC-UIB)

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 consistenly 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 Hs and extreme events

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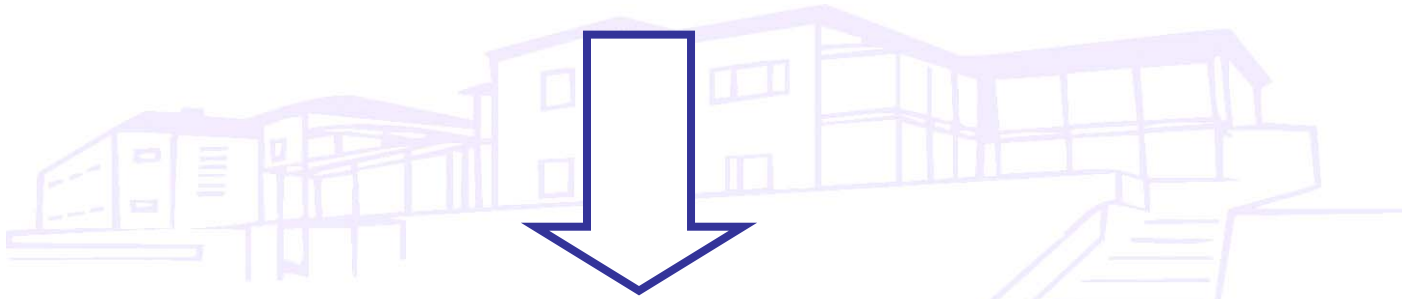
Comparison of Mediterranean Climate models

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

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Comparison of Mediterranean Climate models

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

OM8
(Somot et al., 2006)
OPA model
Rigid lid
Regional model (1/8º)
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 (1/8º)+Local model at Gibraltar
Coupled to RegCM (~30km)
Interactive river scheme
Climatology in the Atlantic box
Natural SSS Bound. Cond.

IMEDEA (CSIC-UIB)

IMEDEA (CSIC-UIB)

Temperature Trends

Mir-Calafat et al., 2010

TEMPERATURE

WESTERN MEDITERRANEAN [1e-3 °C/year]

Layer	0-100	100-500	500-1000	1000-2000
MEDAR	7.8± 2.5	-0.3± 1.2	2.2± 0.5	2.7± 0.2
ORCA	0.2± 2.9	8.1± 1.2	13.2± 0.6	0.6± 0.1
OM8	8.3± 2.2	5.8± 1.1	12.9± 0.8	6.2± 0.1
MITcgm	6.0± 2.6	4.1± 1.2	8.0± 0.6	9.7± 0.4

EASTERN MEDITERRANEAN [1e-3 °C/year]

Layer	0-100	100-500	500-1000	1000-2000
MEDAR	-0.5± 2.8	-6.7± 1.3	-0.3± 0.4	0.5± 0.3
ORCA	0.0± 2.3	3.3± 0.8	3.5± 0.1	0.2± 0.4
OM8	0.3± 3.0	-3.8± 1.1	6.0± 0.3	4.4± 0.1
MITcgm	1.4± 2.8	-2.4± 1.5	3.7± 0.5	6.7± 0.2

Salinity Trends

SALINITY

WESTERN MEDITERRANEAN [1e-3 psu/year]

Layer	0-100	100-500	500-1000	1000-2000
MEDAR	0.3± 0.8	1.9± 0.6	1.1± 0.2	1.1± 0.1
ORCA	-1.8± 0.3	-1.2± 0.3	1.2± 0.1	0.1± 0.1
OM8	-0.8± 0.5	0.4± 0.2	0.9± 0.1	0.4± 0.1
MITcgm	-1.7± 0.6	-1.1± 0.6	0.6± 0.2	1.4± 0.1

EASTERN MEDITERRANEAN [1e-3 psu/year]

Layer	0-100	100-500	500-1000	1000-2000
MEDAR	-2.7± 0.5	-0.5± 0.3	0.2± 0.3	0.4± 0.4
ORCA	-0.2± 0.3	-0.9± 0.1	-0.1± 0.1	0.0± 0.1
OM8	-2.8± 0.4	1.7± 0.2	0.5± 0.1	0.7± 0.1
MITcgm	-2.2± 0.6	-4.3± 0.2	0.3± 0.2	0.6± 0.1

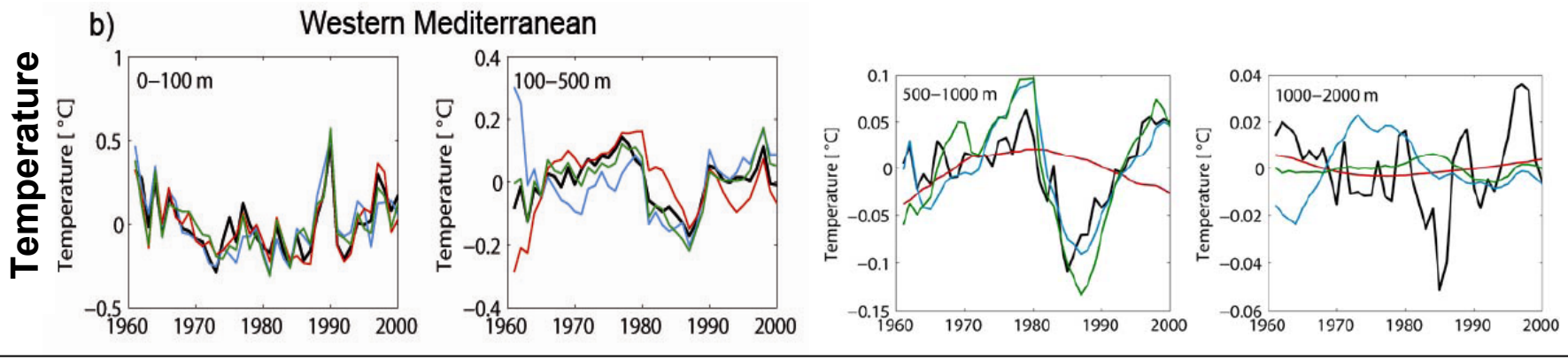
No agreement with data at any depth

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

Changes in the vertical estratification

Comparison of Mediterranean Climate models

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



Ishii observations (black line) ,MITgcm (blue line), ORCA (red line) and OM8 (green line).

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

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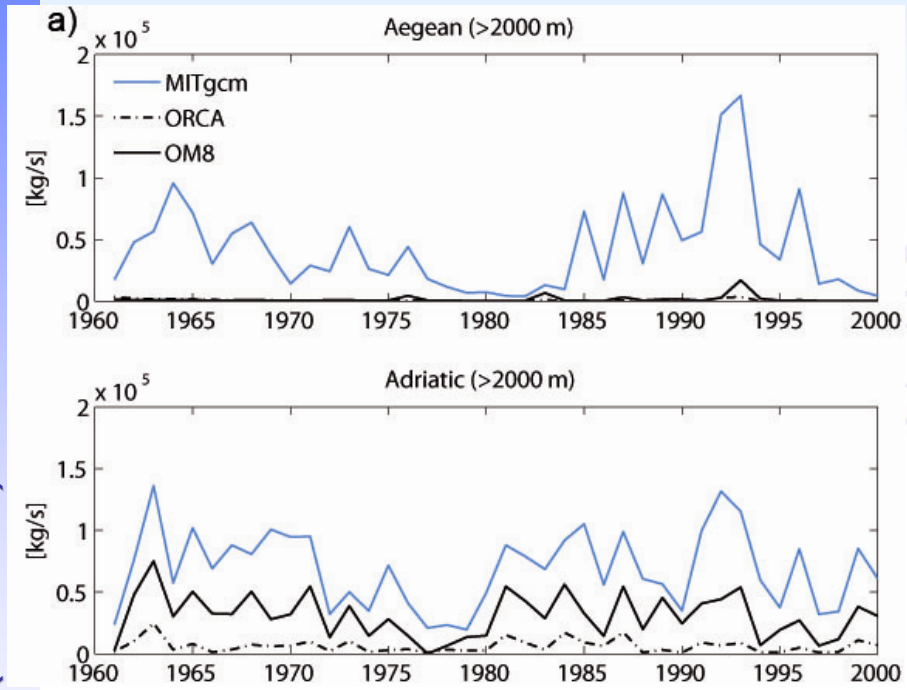
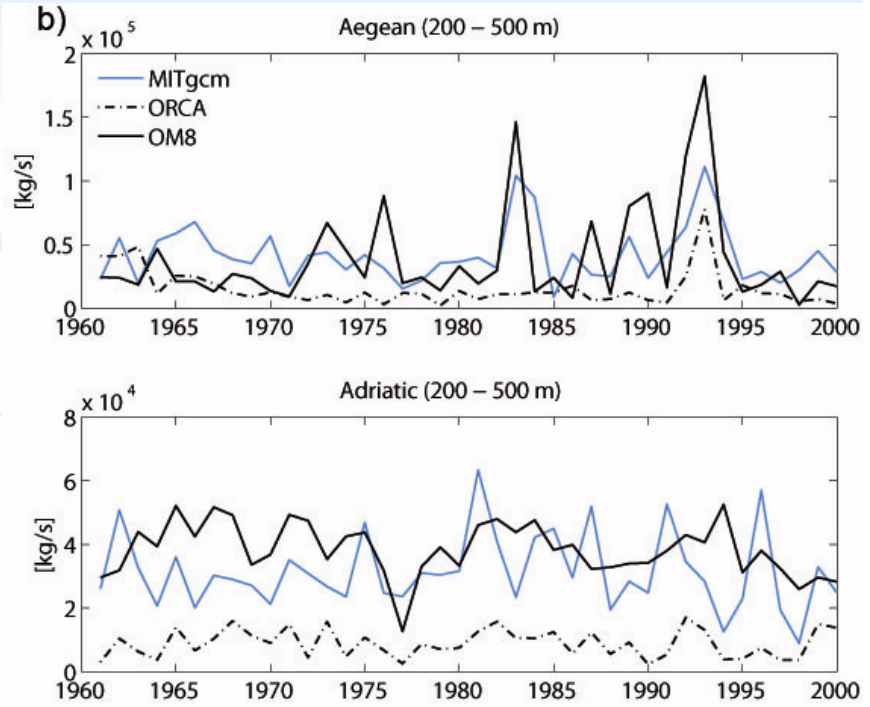
Comparison of Mediterranean Climate models

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??***

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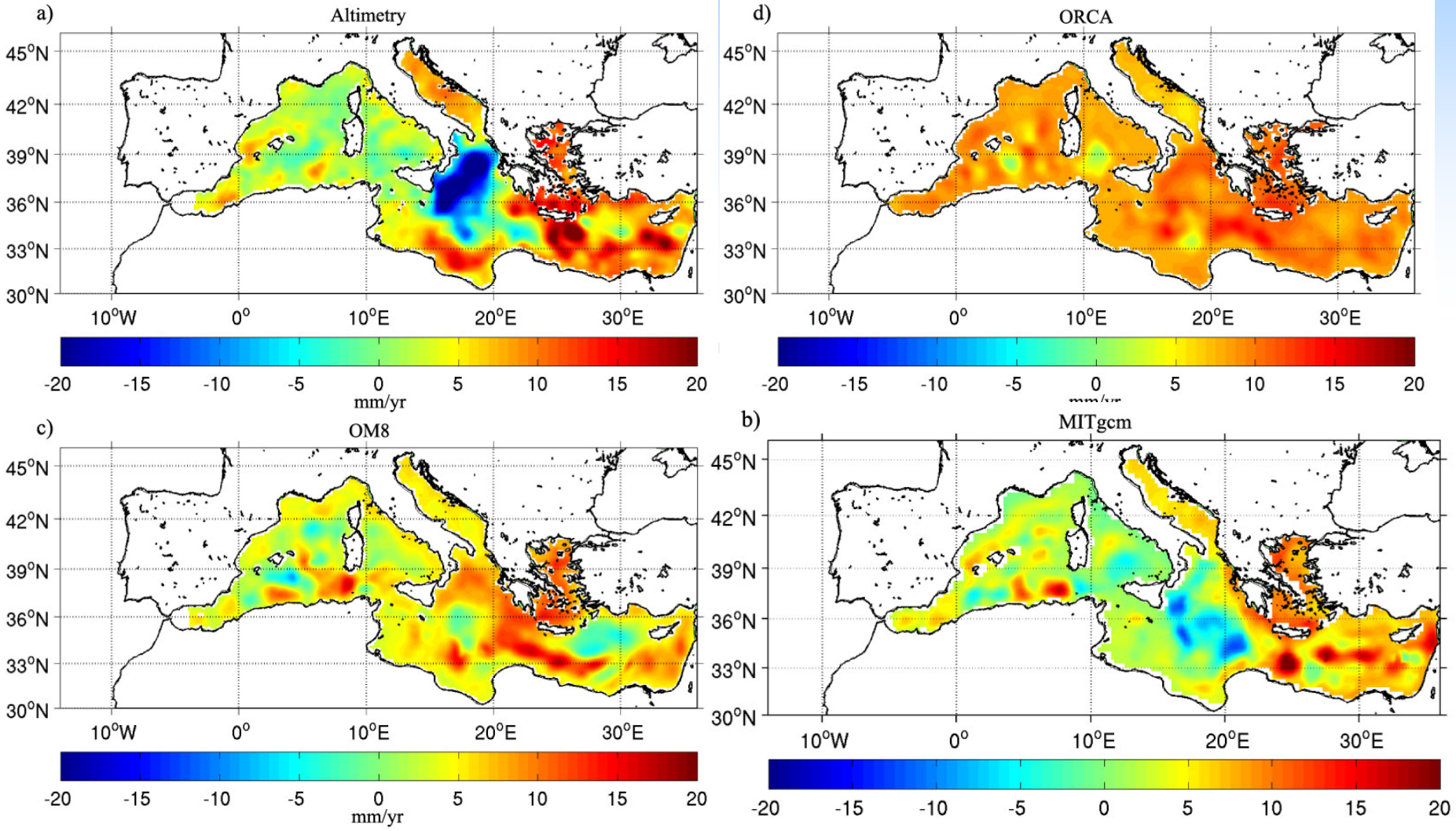
Comparison of Mediterranean Climate models

Sea Level Trends (1993-2001)

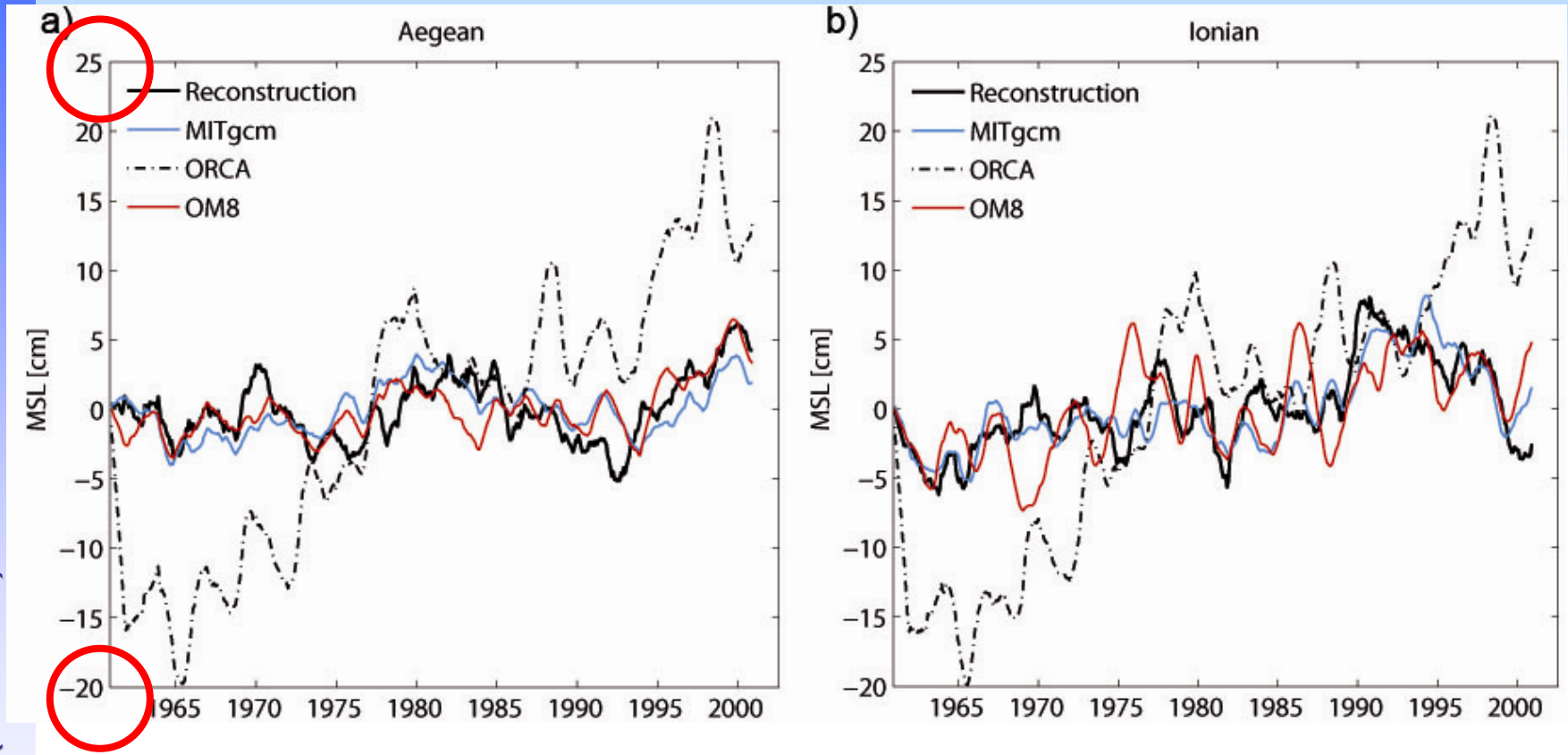


Only MITgcm captures the EMT > *Role of River Scheme*

Weaker signals are, in general, not captured by any model

Comparison of Mediterranean Climate models

Long term Sea Level Trends (1960-2001)



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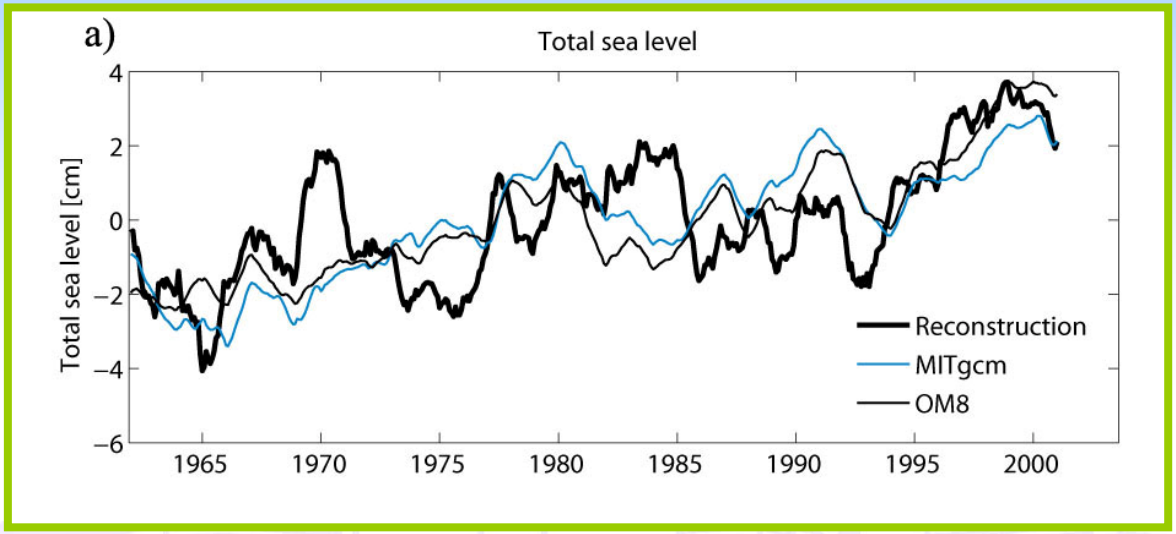
Comparison of Mediterranean Climate models

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



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

However …

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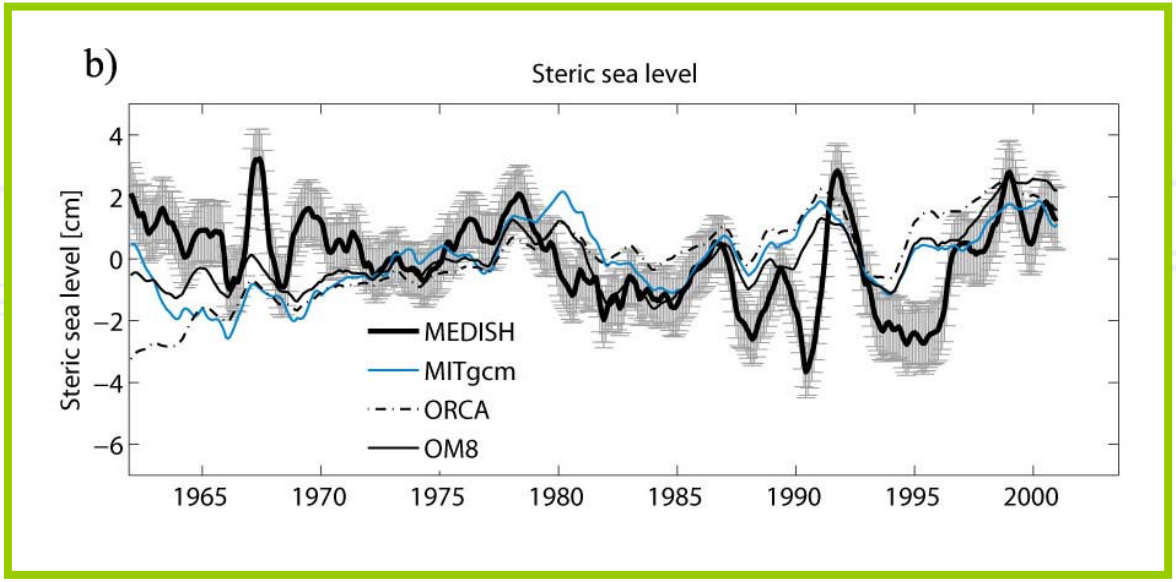
Comparison of Mediterranean Climate models

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±0.2 mm/year (Mir-Calafat et al. 2009) !!



Data includes the mass component and models the spurious warming in deep layers!!

IMEDEA (CSIC-UIB)

Comparison of Mediterranean Climate models

Conclusions

- **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.**

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Thanks for your attention …

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