The VANIMEDAT Project:
decadal and interdecadal sea-level variability in the Mediterranean Sea and the Northeastern sector of the Atlantic Ocean

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Overall goals of the Project

- To describe the long-term (from the seasonal cycle to interdecadal) sea-level variability in the Mediterranean Sea and the NE Atlantic ocean. In particular:

1.1- To characterize the spatial pattern from altimetry data

1.2- To characterize the time variability from long-term tide gauge series

1.3- To attempt the extrapolation of altimetric fields backwards in time

- To quantify the contribution of the different forcings acting on the sea-level variability. Namely:

2.1- The mechanical atmospheric forcing (atmospheric pressure and wind)

2.2- The steric contribution (volume increase due to T, S changes)

2.3- The mass variations (due to changes in continental ice and in the evaporation, precipitation and river run-off balance).

The project is currently in its 3rd and last year. Here we present results for the 2nd year, corresponding to objectives 1.1., 1.2, 1.3, 2.1 and 2.2

Characterization of the spatial pattern from altimetry fields

The data set: inter-calibrated altimetry data covering from January 1993 to present.

Along-track processing: usual geophysical corrections; spline interpolation every 7 km

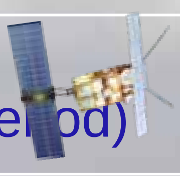
Test of 3 atmospheric corrections: inverse barometer and MOG2D and HAMSOM models

Objective analysis: optimal interpolation + multi-satellite combination; long wavelength error corrected (tests BGLO). Weekly maps with 1/4º spatial resolution.

TP
(10-day repeat period)

JASON
(10-day repeat period)

ERS
(35-day repeat period)



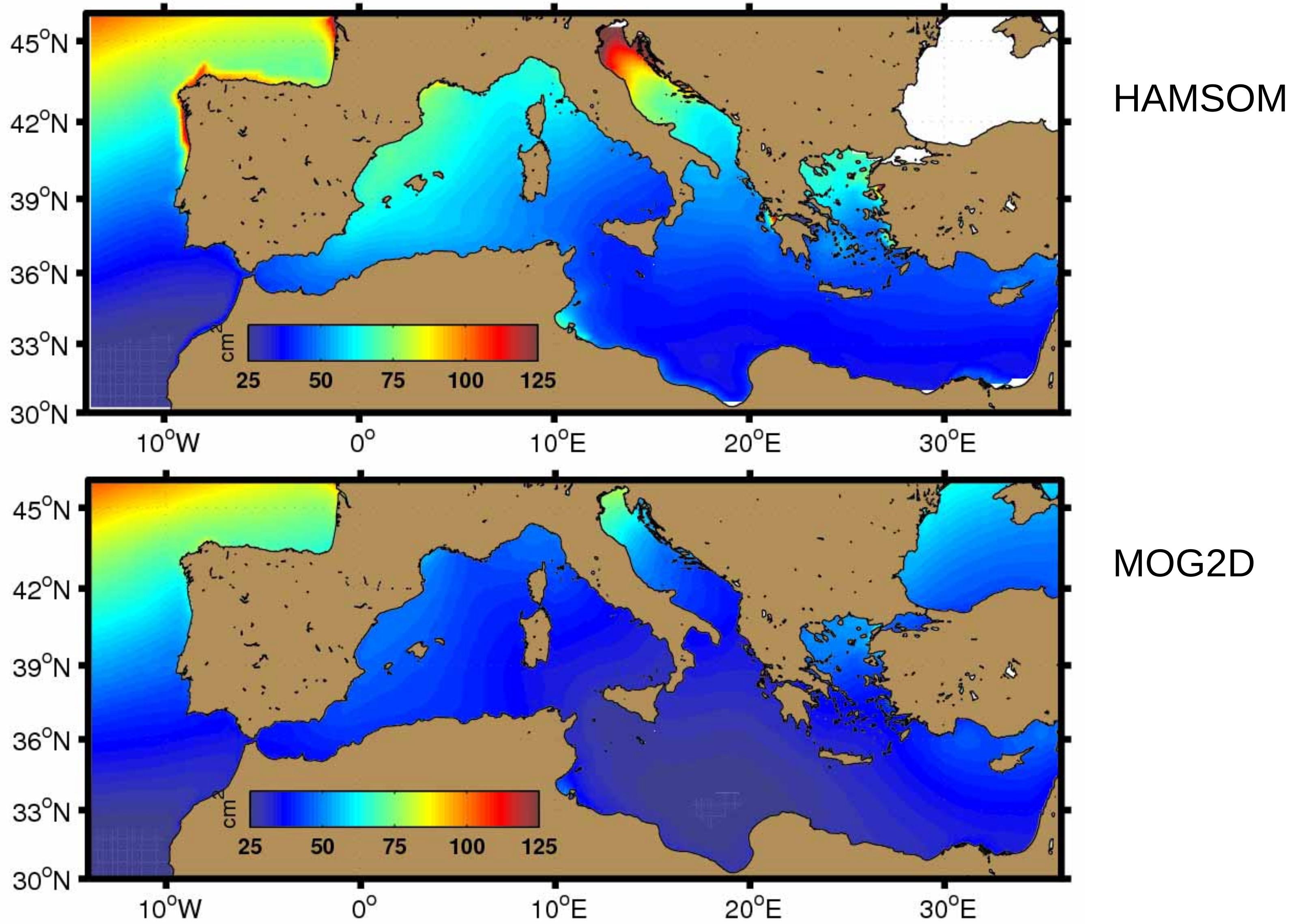
ENVISAT
(35-day repeat period)

	HAMSOM	MOG2D
Spatial resolution	1/6º lat 1/4º lon	20-200 km
Temporal resolution	1 h	6 h
Period	1958-2001	1993-present
Region	Med/NEAtl	Global
Atmospheric Forcing	REMO 6h (NCEP/NCAR)	ECMWF 6h

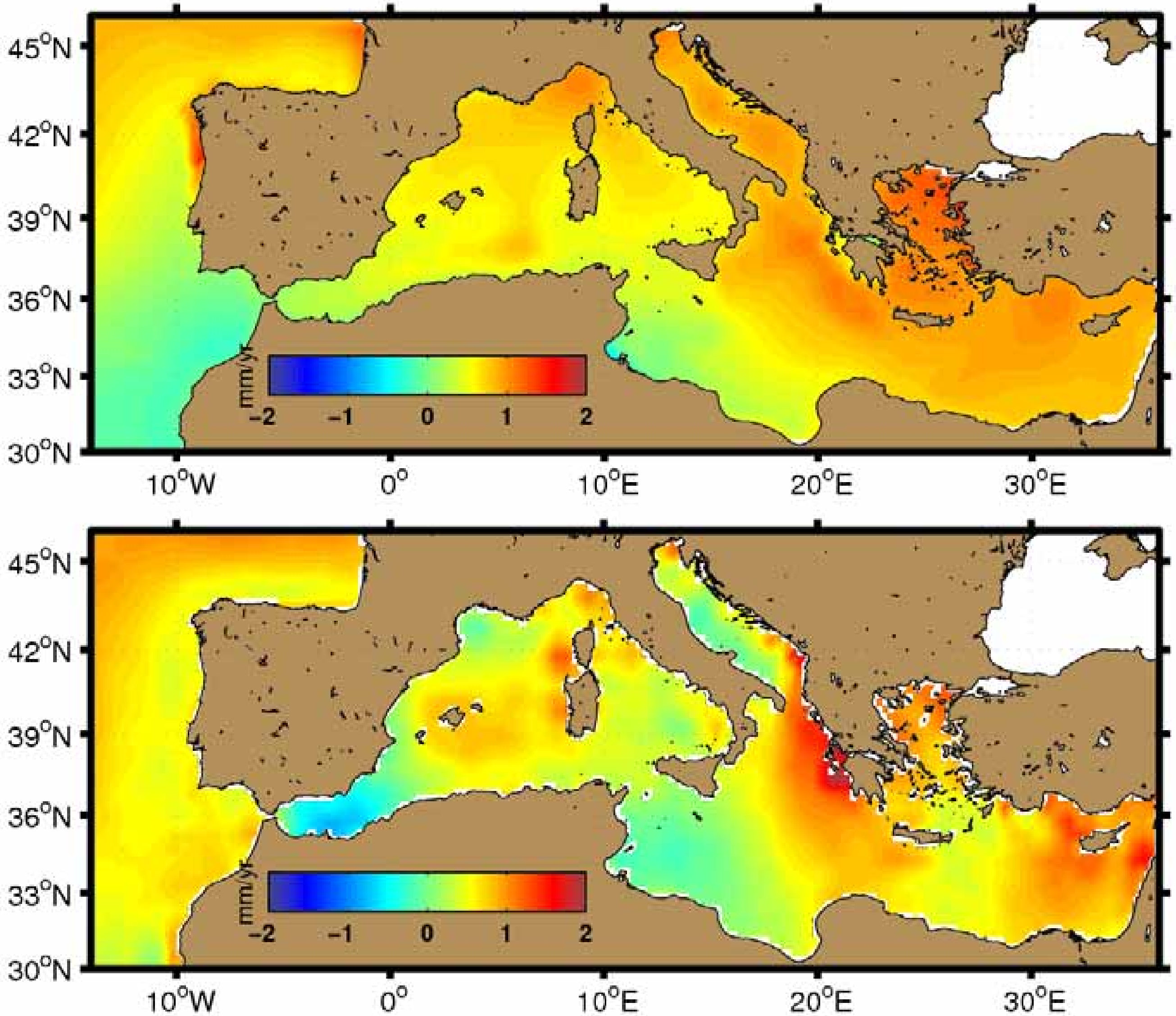
1. Both MOG2D and HAMSOM models improve the Inverse Barometer correction.

2. On average, HAMSOM reduces more variance than MOG2D, particularly in the Atlantic. In the Adriatic MOG2D behaves better than HAMSOM

3. For Low Frequencies HAMSOM is largely better than MOG2D everywhere. For High Frequencies MOG2D behaves slightly better than HAMSOM (much better in the Adriatic) except in the Atlantic



Variance (cm²) of the sea level response to atmospheric pressure and wind forcing



HAMSOM

Mea value:
0.61 mm/yr

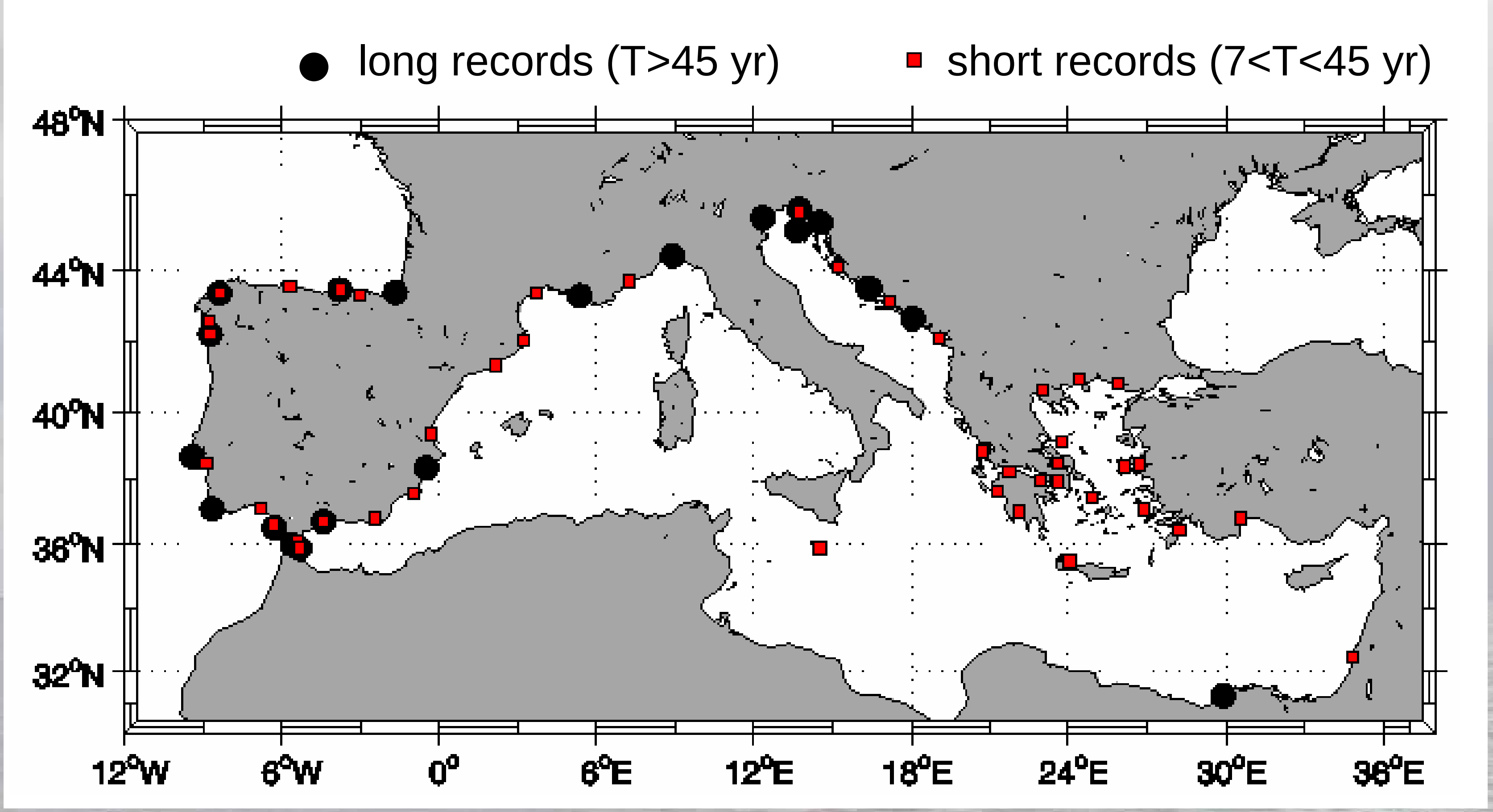
MOG2D (=IB)

Mea value:
0.58 mm/yr

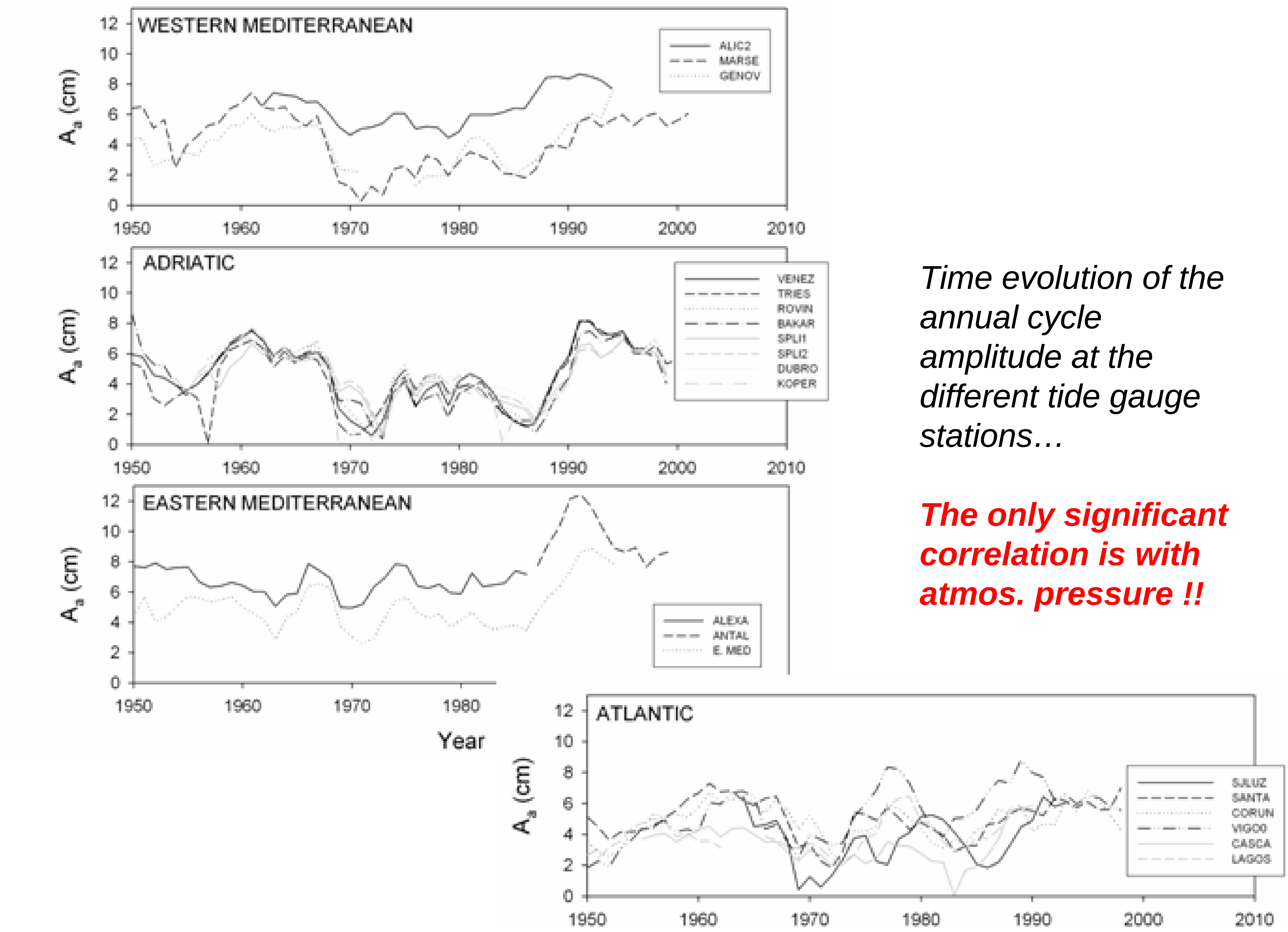
Trends (mm/yr) of the sea level response to atmospheric pressure and wind forcing for the period (1993-2001)

Characterization of the time variability from long tide gauge records

The data set:

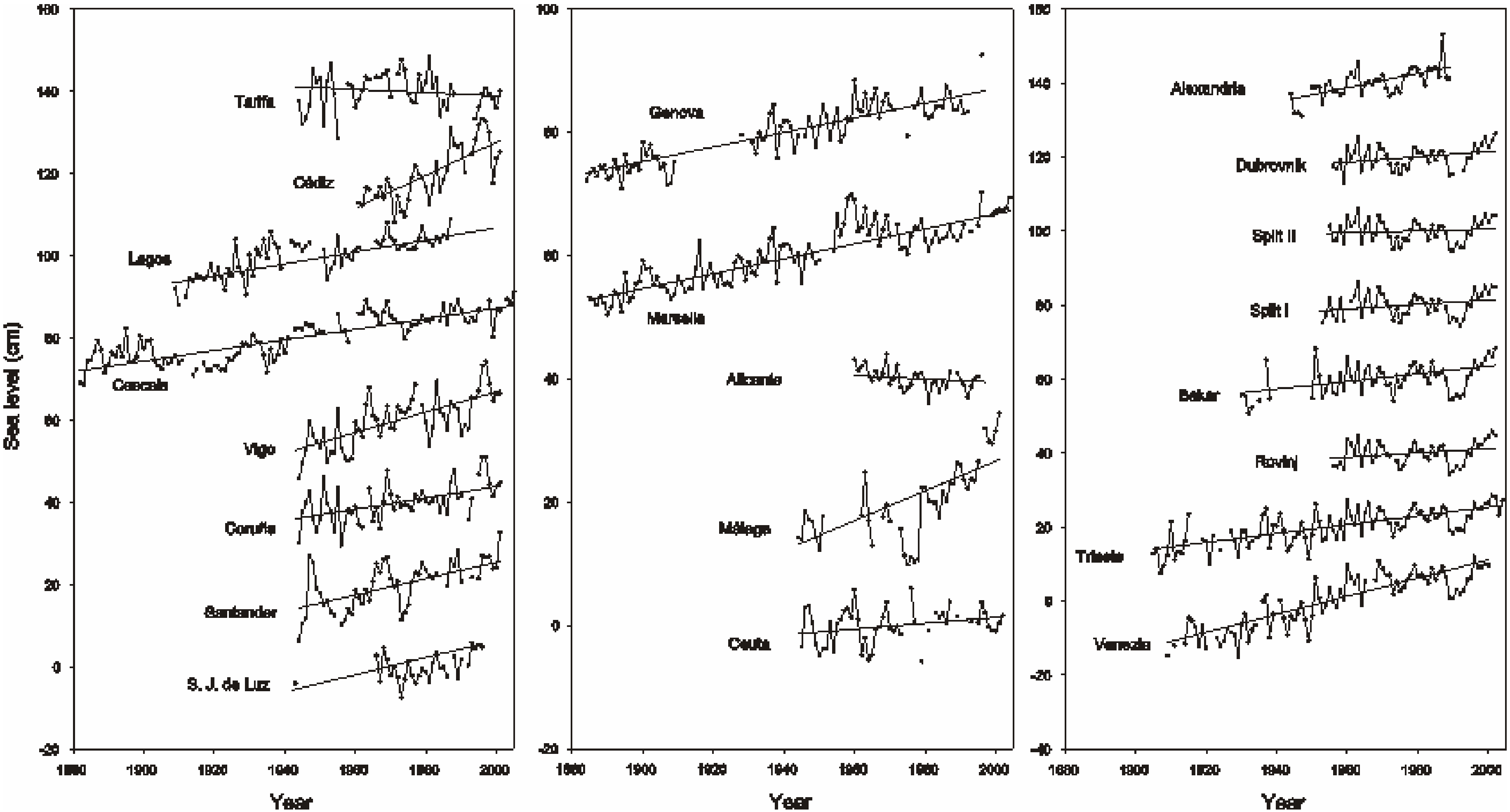


Tide gauge stations in the Mediterranean Sea and the Atlantic Iberian shores

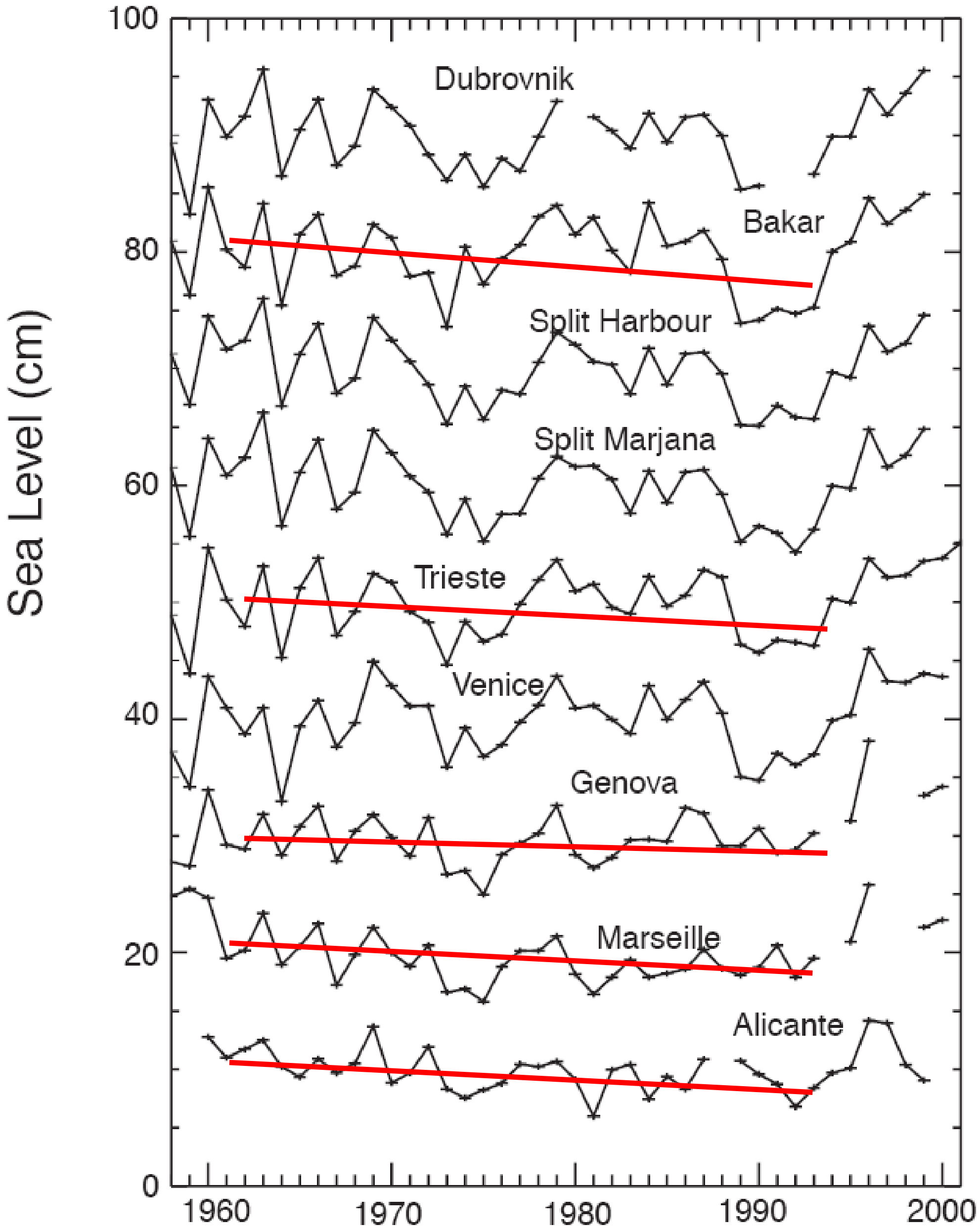


Time evolution of the annual cycle amplitude at the different tide gauge stations…

The only significant correlation is with atmos. pressure !!



Yearly observations and linear sea level trends for the longest (> 45 years) records in Southern Europe. Left: Atlantic area and Gibraltar;
Middle: remaining stations in Gibraltar and Western Med;
Right: Adriatic and Eastern Mediterranean



Sea Level (cm)
100
80
60
40
20
0
1960
1970
1980
1990
2000
Dubrovnik
Bakar
Split Harbour
Split Marjana
Trieste
Venice
Genova
Marseille
Alicante

Reconstructing sea-level fields backwards in time

Objective: to take advantage from:

- log-term variability of (local) tide gauge records
- spatial coverage of (short-term) altimetry data

To obtain:

- long-term spatially-complete fields

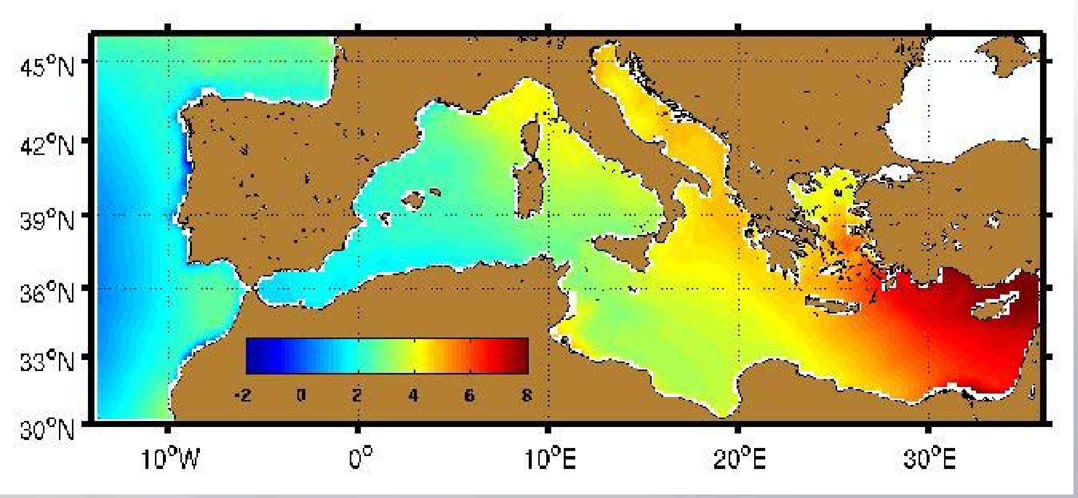
Two methodologies have been used:

- a multiple linear regression of altimetry data on tide gauge data
- substitution of the leading EOF amplitudes of altimetry by the EOF amplitudes of tide gauge records.

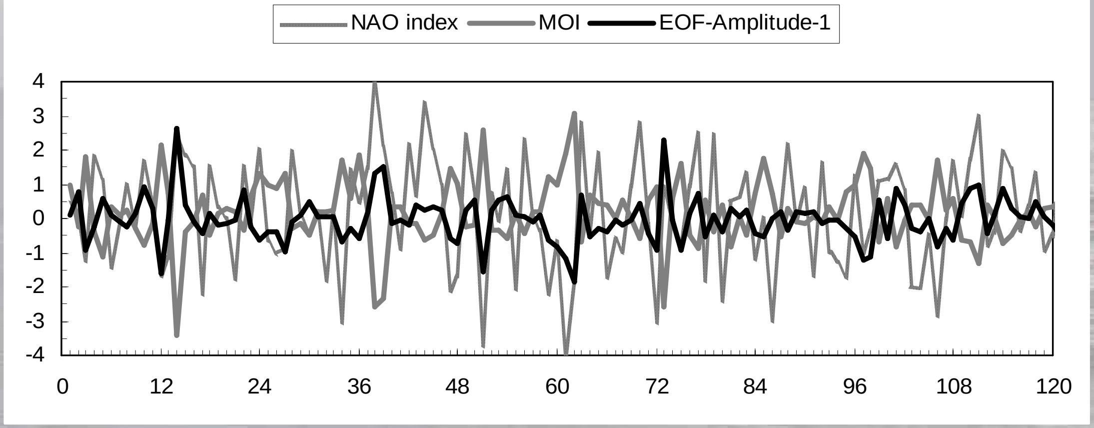
… presentation by F Mir-Calafat et al.

The mechanical atmospheric forcing of sea level

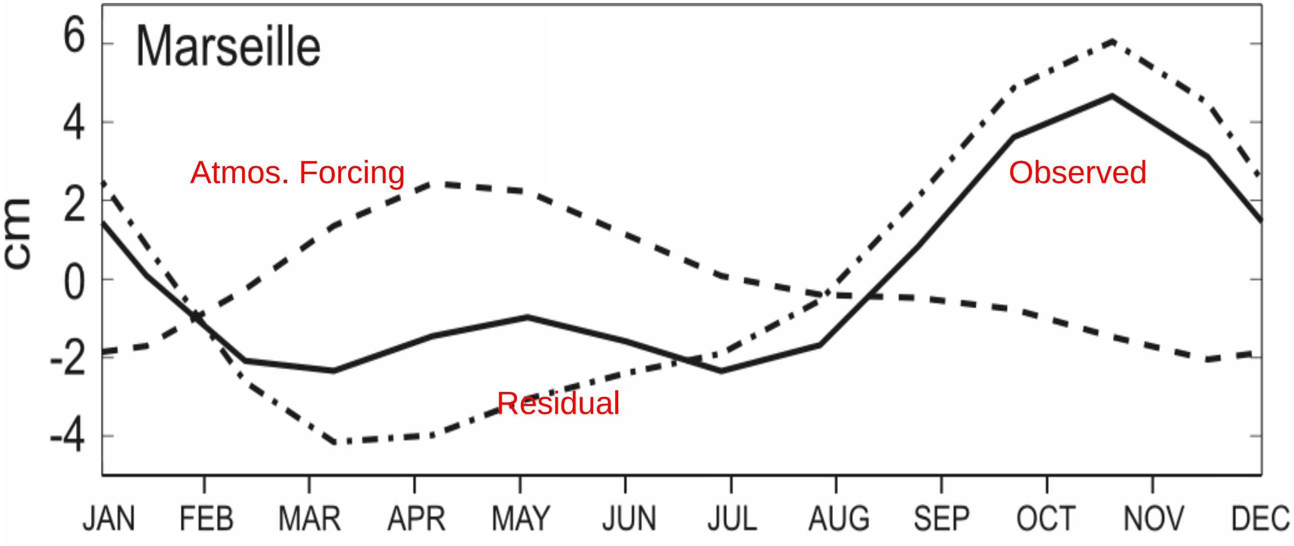
The data set: 44 years (1958-1991) of hourly data generated by the barotropic model HAMSOM. The model was forced with a downscaling of atmospheric pressure and wind fields generated by the model REMO (NCEP re-analysis).



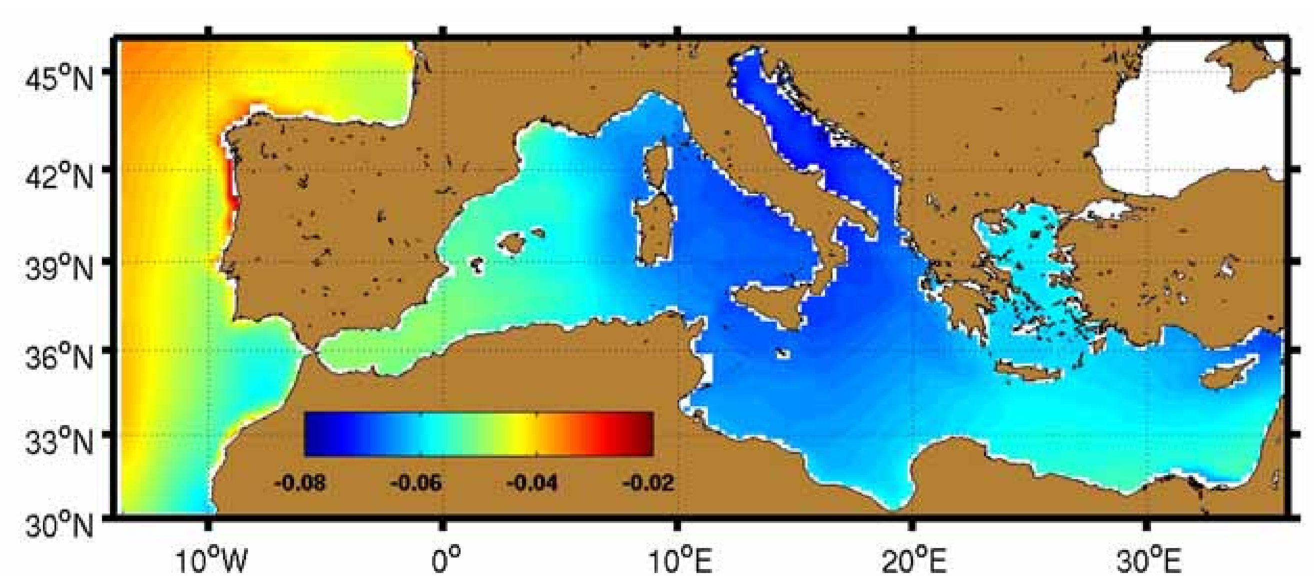
Mean sea level (1958-2001)



Correlation with climatic indices:
r = 0.628 for the NAO
r = 0.935 for the MOI



The <u>atmospherically forced seasonal cycle</u> is not the major contributor to the total sea level cycle, but ***it explains the secondary maximum observed in spring***



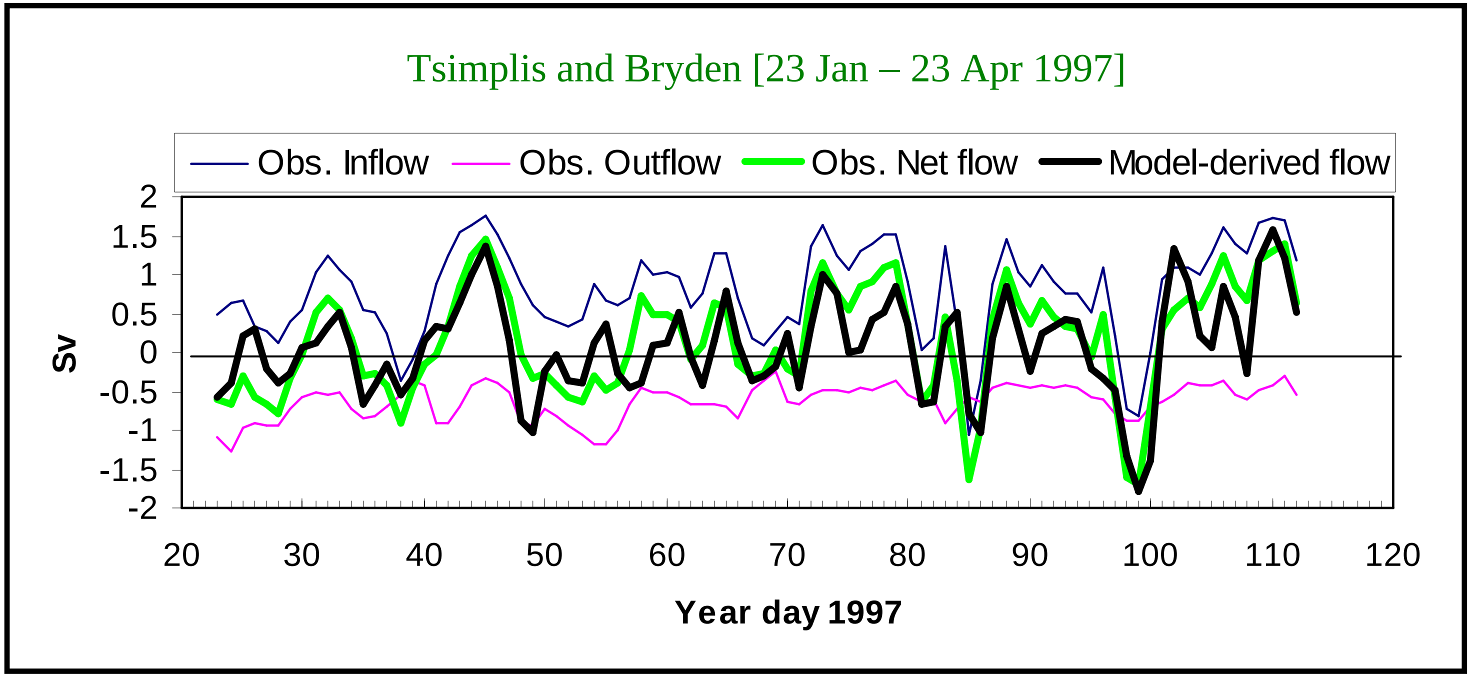
Trends of the sea level response to atmospheric pressure and wind for the period (1958-2001).

Mean value:

-0.6 mm/yr

Comparison of

- the barotropic flow through Gibraltar estimated from basin-mean sea level changes as given by the HAMSOM model (e.g., atmospheric forcing only)
- flow estimates inferred from currentmeter observations.



Corr.: **0.81**
Bias: **0.085 Sv**

→ At intra-seasonal time scales the atmospheric forcing completely dominates the barotropic exchange at Gibraltar.

→ At seasonal and interannual time scales the E-P budget dominates over the atmospheric forcing.

The steric contribution to sea level

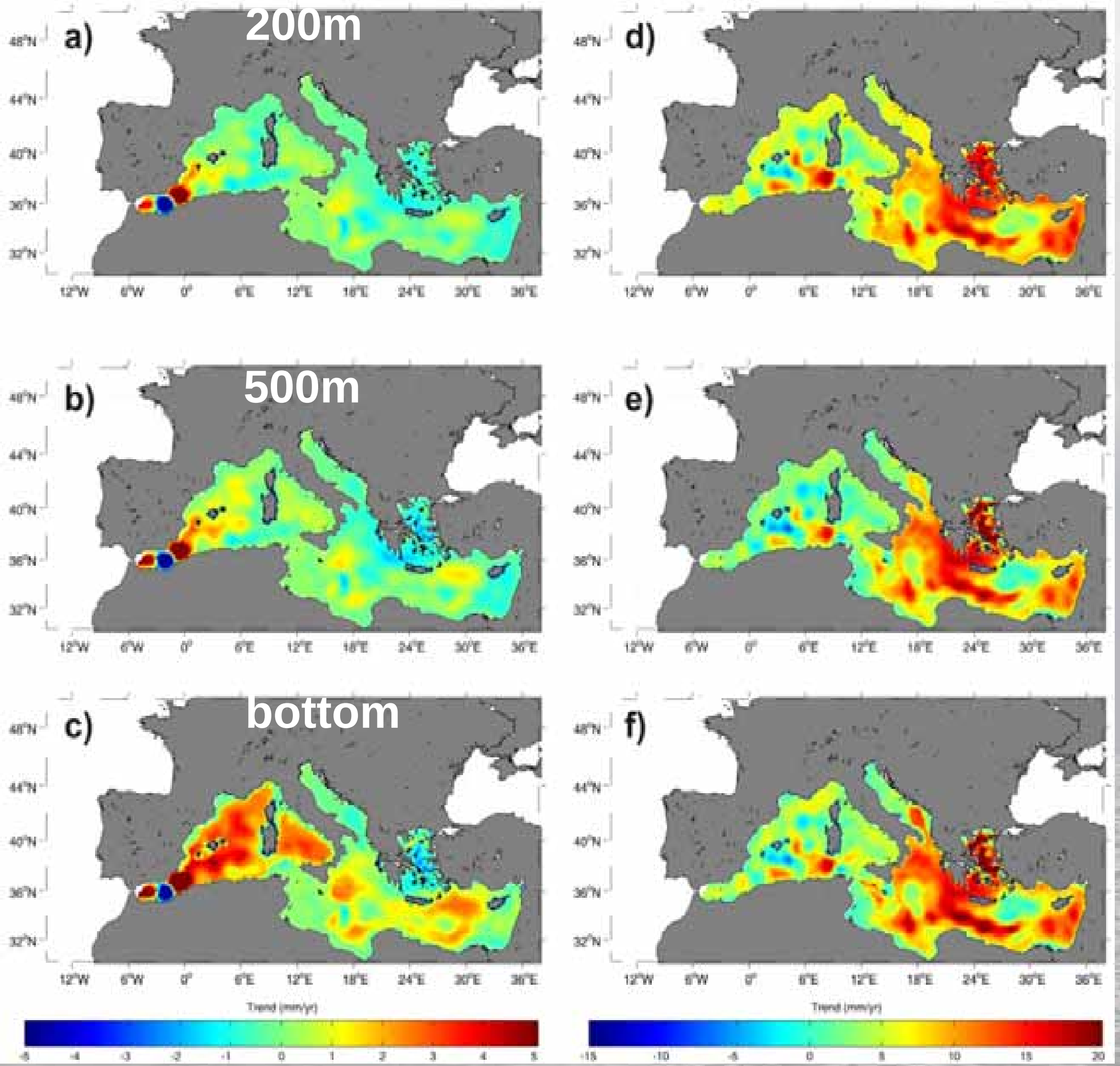
Steric sea level trends computed from a 40-yr 3D hindcast

Hindcast: A high resolution (1/8° x 1/8°cos(lat), 43 non-uniform vertical Z-levels) model of the Mediterranean Sea (OPAMED8, Somot et al. 2006) based on a limited-area version of the OPA model.

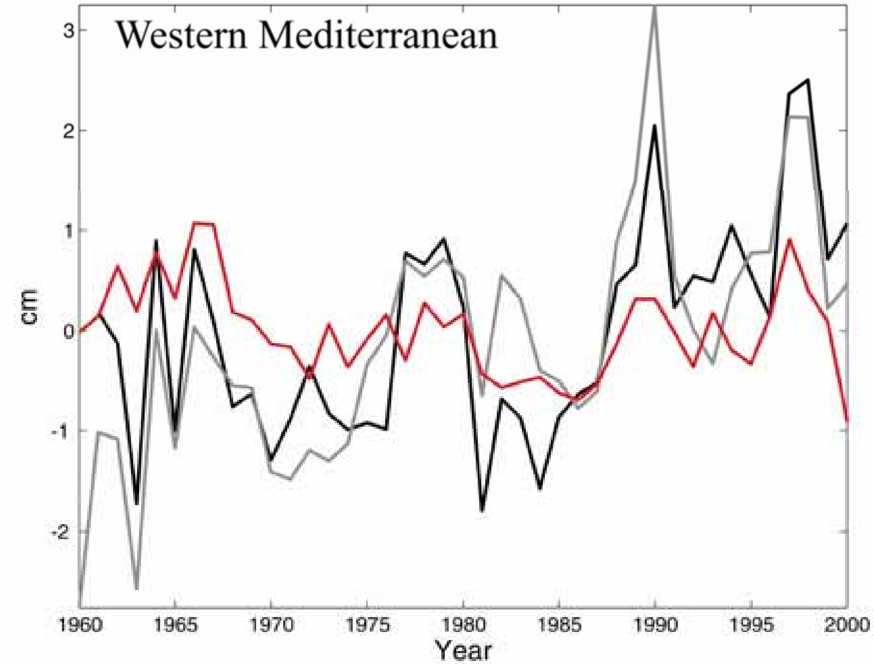
Atmospheric forcing: ERA-40 dynamical downscaling.

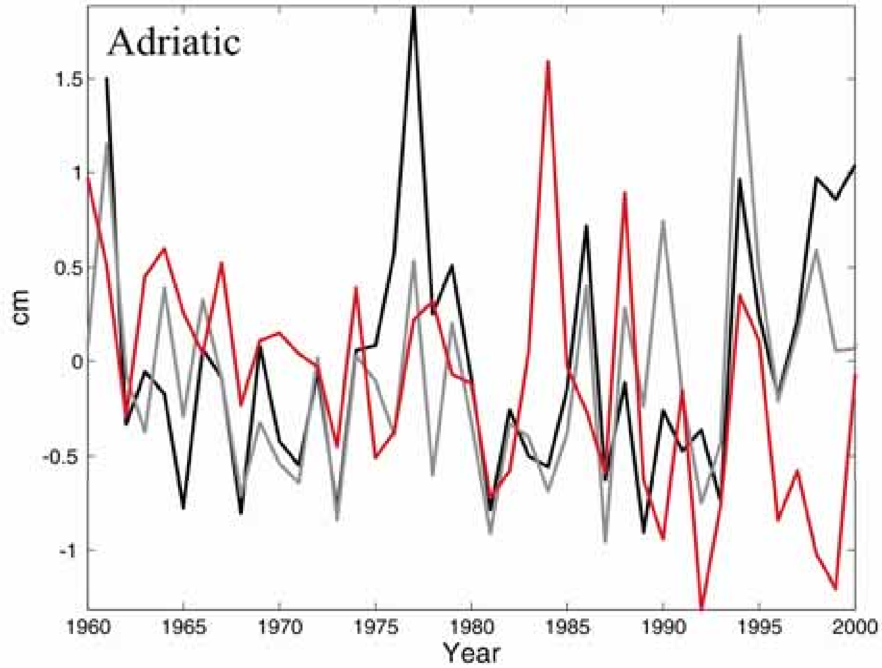
Steric sea level is computed from the vertical integration of the specific volume anomalies, therefore accounting for the changes in temperature and salinity

1961-1993 1993-2000



Comparison of 3D models with *in situ* data: basin averages





Yearly time series of steric sea level integrated down to 300 m and averaged over the western Mediterranean (upper panel) and the Adriatic Sea (lower panel).

Grey line *corresponds to a global model*

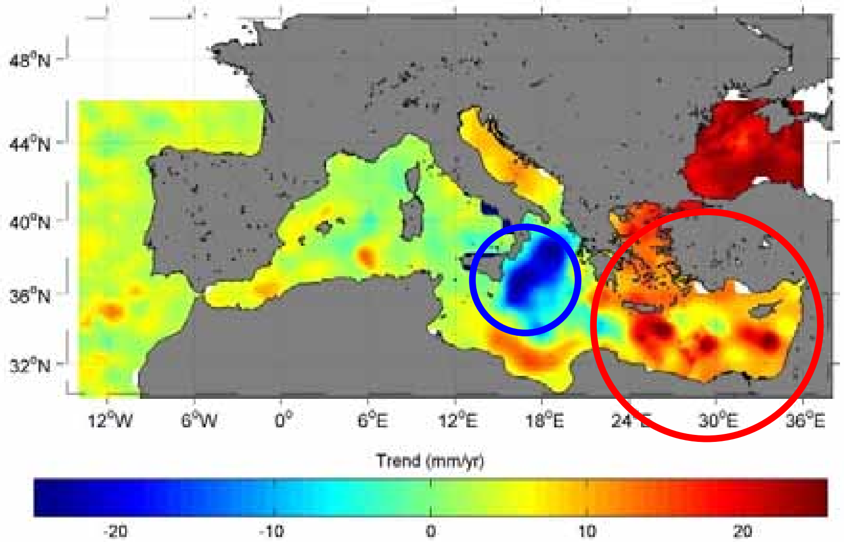
Black line *to the regional model*

Red line *are data from MEDAR.*

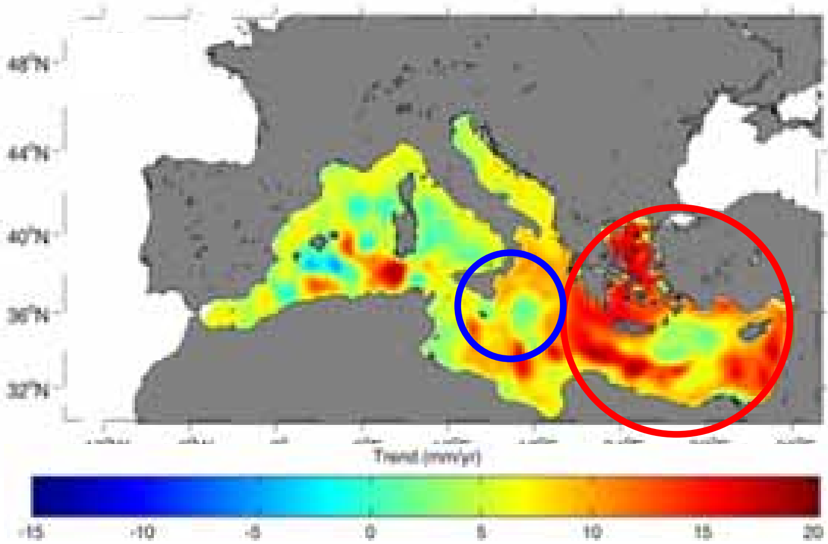
→ **The correct representation of the Strait of Gibraltar is crucial…**

Comparison of 3D model outputs with altimetry data:

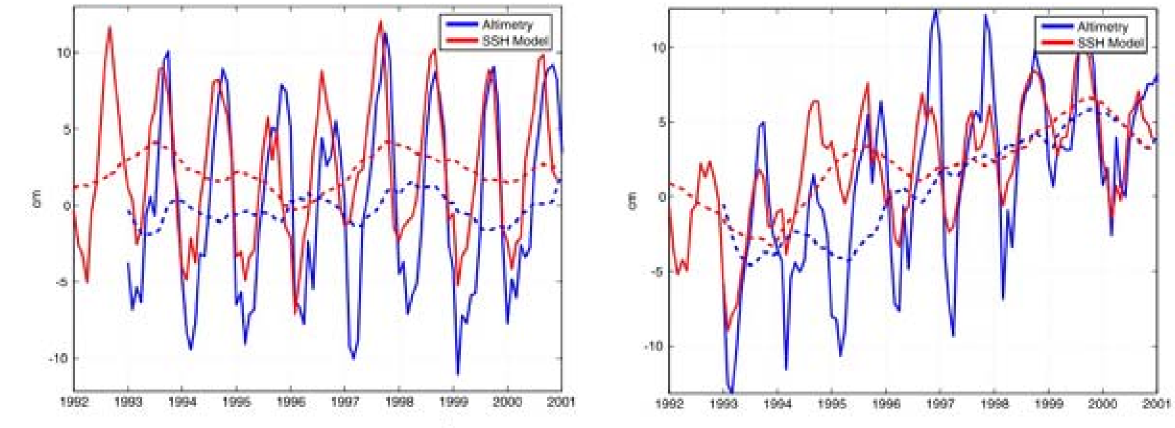
Sea level trends (mm/yr) from the multisensor altimetry product for the period 1993-2000.

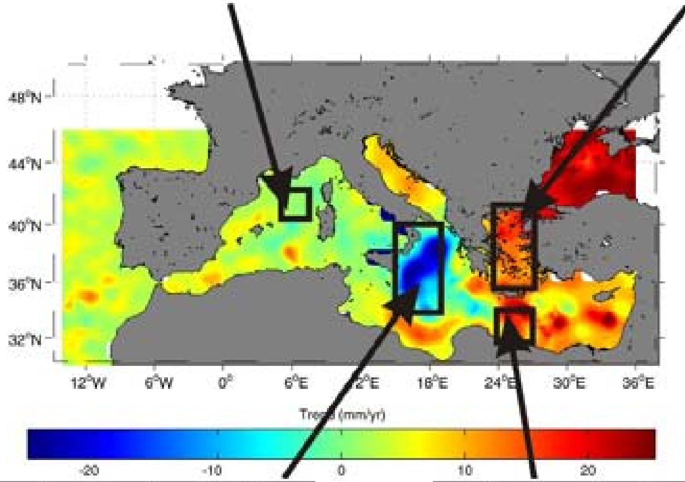


Sea level trends (mm/yr) computed from model dynamic height for the period 1993-2000.

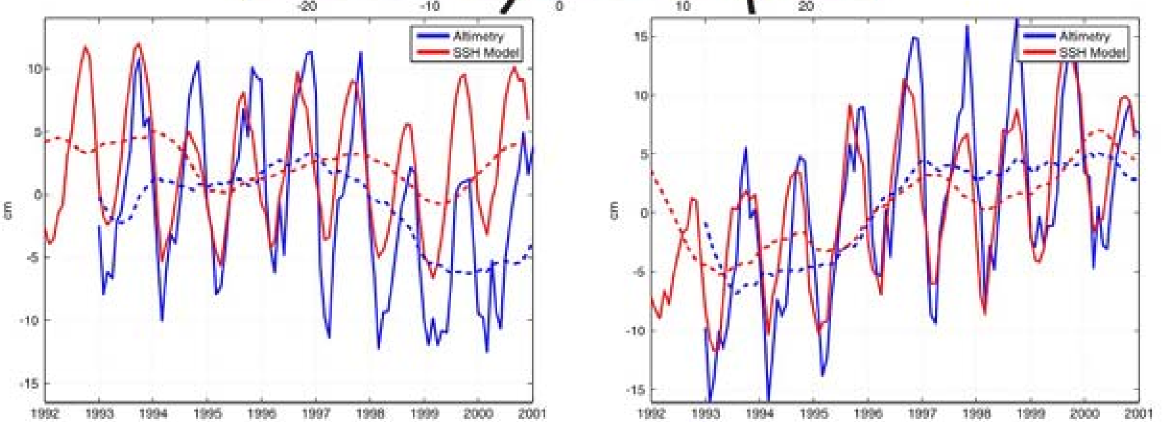


→ Differences between SLA trends and steric trends computed from the model are due to changes in the circulation (the 'dynamical' contribution) and mass changes (atmospheric pressure is removed from both, SLA and the model)



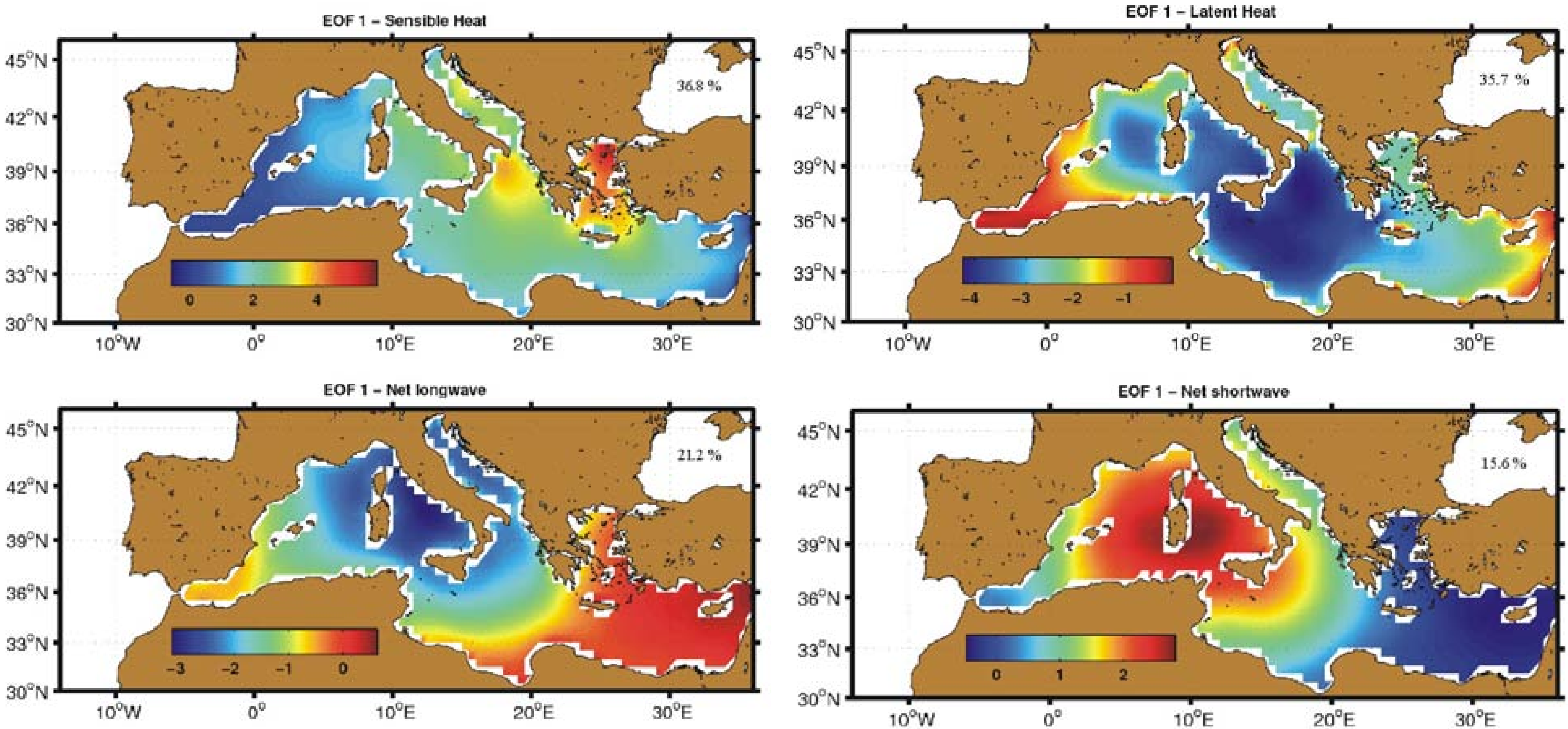


Altimetric trends (1993-2000) and comparison of altimetric (blue) and modelled (red) averaged sea level for selected areas. Dashed lines are 12 month running averages.



Adding the dynamical contribution to sea-level changes (e.g., using the model SSH instead of dynamic height), results are more realistic

New hindast to be carried out with HIPOCAS heat fluxes…



Summary

- ✓ 1.1- To characterize the spatial pattern from altimetry data
- ✓ 1.2- To characterize the time variability from long-term tide gauge series
- ✓ 1.3- To attempt the extrapolation of altimetric fields backwards in time
- ✓ 2.1- The mechanical atmospheric forcing (atmospheric pressure and wind)
- 2.2- The steric contribution (volume increase due to T, S changes)
  - Recomputation with HIPOCAS heat fluxes
- 2.3- The mass variations (due to changes in continental ice and in the evaporation, precipitation and river run-off balance).

.- Repeat the computations for the XXI century

→ barotropic model HAMSOM to quantify the atmospheric contribution

→ a 3D baroclinic model forced with regional climate model outputs

Publications from the VANIMEDAT project:

Gomis. D., S. Ruiz, M.G. Sotillo, E. Alvarez-Fanjul, J. Terradas. Low frequency Mediterranean sea level variability: the contribution of atmospheric pressure and wind. Global and Planetary Change (in press)

Marcos, M., and M. N. Tsimplis (2007), Variations of the seasonal sea level cycle in southern Europe, J. Geophys. Res.,112, C12011, doi:10.1029/2006JC004049.

Marcos, M., and M. N. Tsimplis (2007), Forcing of coastal sea level rise patterns in the North Atlantic and the Mediterranean Sea, Geophys. Res. Lett., 34, L18604, doi:10.1029/2007GL030641.

Pascual, A., M. Marcos, D. Gomis. Comparing the sea level response to pressure and wind forcing of two barotropic models: validation with tide gauge and altimetry data. J. Geophys. Res. (accepted)

Ruiz, S., D. Gomis, M.G. Sotillo, S. Josey. Characterization of surface heat fluxes in the Mediterranean Sea from 44-year highresolution atmospheric data set. Global and Planetary Change (in press)

Tsimplis, M.N., M. Marcos, S. Somot. 21st century Mediterranean sea level rise: Steric and atmospheric pressure contributions from a regional model. Global and Planetary Change (in press)

Tsimplis, M., A. Shaw, A. Pascual, M. Marcos, M. Pasaric, L. Fenoglio-Marc. Can we reconstruct the 20th century sea level variability in the Mediterranean Sea on the basis of recent altimetric measurements? Chapter in Remote Sensing of the European Seas (in press)