

SEA LEVEL VARIATIONS IN THE MEDITERRANEAN SEA

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1. ABSTRACT

Mediterranean Sea level variations have been studied from altimetry data in both temporal and spatial scales. We use a specific solution for the Mediterranean Sea of Sea Level Anomaly (SLA) data, which has been derived from several altimetric satellites. An analysis of Empirical Orthogonal Functions (EOF) has been applied to the data:

1st Mode: Annual signal. Annual amplitude around 9 cm, which is reached in late September in the Eastern basin, in early October in the central and Western basins, and in early November in the north Adriatic

2nd Mode: Interannual variations. It is shown that the trend variations in the Mediterranean are time-dependent: We find the mean sea level rise 1.71 cm in the whole period with a rate of 1.1 mm/year, but with an abrupt changes. Until the beginning of 1999 the trend is positive with a rate of -6.4 mm/year and there the trend change to -0 mm/year for about 5 years. Then, since 2004, this trend has been reversed and the mean sea level is dropping with a rate of -5.5 mm/year.

2. DATA DESCRIPTION

Altimetry Dataset:

- Format: Weekly SLA measurement from AVISO Altimetry regional products from combination of several satellites (Topex/Poseidon, Jason-1, ERS-1/2, ENVISAT).
- Resolution: $1/8^\circ \times 1/8^\circ$
- Span of time: 14/10/1992 – 23/01/2008
- Geographic coverage: Mediterranean Sea (30°N - 46°N , 5°W - 36°E)
- Corrections: orbit error reduction of ERS and ENVISAT via the precise orbit of T/P and Jason-1, geophysical (dry and wet troposphere, ionosphere and inverse barometer effect), and tides (ocean and load tides, solid earth tide and pole tide).

3. EOF ANALYSIS

In order to study the spatial and temporal variations the SLA an EOF analysis has been applied.

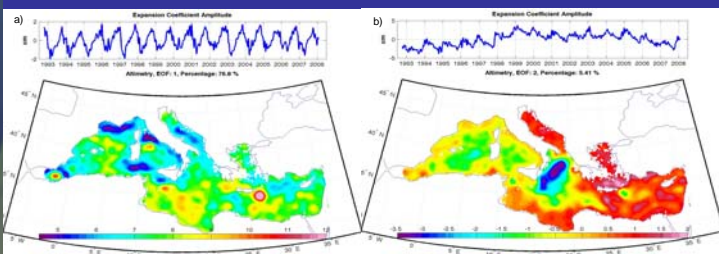


Figure 1. First two EOF and their associated time series for the whole period

3.1 First EOF

The first EOF explains 76.8% of the variance of the data. The EOF pattern has a positive sign everywhere, which implies a motion in phase of the whole basin accordingly to the associated time series. The latter shows a clear annual signal.

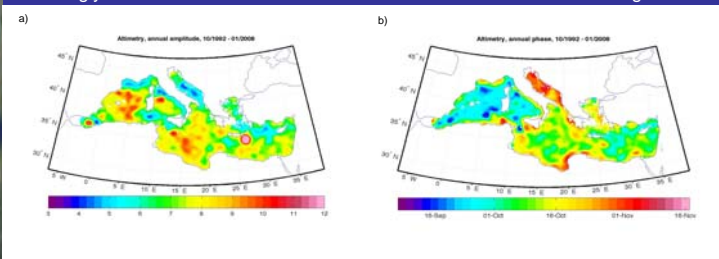


Figure 2. a) annual amplitude and b) annual phase for the whole period

The annual amplitude of the data showed is around 9 cm in the whole basin, with smaller values in the Adriatic and the Aegean Sea. The annual phase reveals that the maximum is reached in late September in the Eastern basin, in early October in the central and Western basins, and in early November in the north Adriatic.

3.2. Second EOF

The second EOF explains for 5.4% of the variance of the data. This mode represents much less variance than the first one, but it accounts for all the long term variations of the data. The EOF pattern shows positive and negatives regions, which indicates that the long term variations are not uniform in sign. Besides, variations of the associated time series show that the variations are not constant in time.

The linear rates at different periods show:

1st Period: 14/10/1992 – 30/12/1998 associated PC is rising

2nd Period: 06/01/1999 – 31/12/2003 associated PC is neither rising nor dropping

3rd Period: 07/01/2004 – 23/01/2008 associated PC is dropping

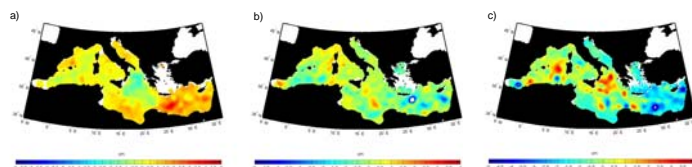


Figure 3. Sea Level Trends for the three sub-temporal period: a) Period I: 14/10/1992 – 30/12/1998 b) Period II: 06/01/1999 – 31/12/2003 c) Period III: 07/01/2004 – 23/01/2008

Trends in both East and West basins are positive up to 1999, near zero between 1999 and 2004 and negatives after 2004. Trend in the Ionian Sea is the opposite, it is negative up to 1999 and positive after 2004.

4. RESULTS

Mediterranean Sea Level variations display an annual cycle which represent the 76.8% of the variance of the data, like show 1st EOF. It maximum is reached between late September and early November, showing a lack of phase in the different basins.

The inter-annual variations explain the 5.41% of the variance of the data and show different behaviours. As commented above, Mediterranean variations are not constant in both time (associated time series) and space (positive and negative regions)

The 2nd EOF also verify the two most-extreme point in the whole-period trends map (figure 4b), the Ionian Sea and the surface between Cretan Island and Peloponnesus. They are the two zones with the most-extreme variation in an inter-annual cycle.

The mean time series of the Mediterranean (figure 4a) shows:

| Time Period | 10/1992–12/1998 | 01/1999–12/2003 | 01/2004–01/2008 | whole |
|-----------------|-----------------|-----------------|-----------------|-------|
| Slope (mm/year) | 6.4 | 0.1 | -5.5 | 1.1 |
| Rise (cm) | 4 | 0.05 | -2.25 | 1.7 |

and we can compare with the time series in the 2nd EOF to corroborate these tendencies.

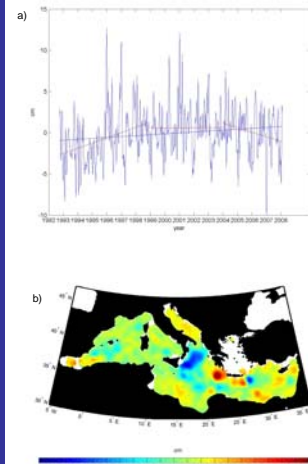


Figure 4. Time series of the Mediterranean SLA (a) and Sea Level Trends (b) for the whole period

5. CONCLUSIONS

- Annual cycle is dominant. Further studies from Time-Variable Gravity and hydrographic data are need to explain the percentage of the variations produced by mass and density variations.
- An inter-decadal cycle may exist in the Mediterranean SLA variations
- Although in the firsts years of altimetry data the sea level was rising, at present it is dropping.

FUTURE WORK

1. Because an annual cycle is clear, it would be interested looking at the principal and secondary influential behaviour-factors of the Sea Level Variation like heating and cooling, radiation, humidity, latent heat, precipitation-evaporation rates, in-out flow through Gibraltar Strait...Because an inter-decadal cycles could be clear, we only can wait until new altimetry data will be available.
2. Determination of the geoid from GOCE satellite data to make an estimation of the Mediterranean geostrophic currents.

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