# Long-term sea level change in the Mediterranean Sea from multi-satellite altimetry and tide gauge stations (Biarritz 2002 - Jason-1 SWT Poster N. 231)

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**Abstract**

The long-term sea level change during 1992-2000 is investigated in the Mediterranean Sea from satellite altimetry data of the Topex-Poseidon (T/P), ERS-1 and ERS-2 missions and from tide-gauge (TG) data. An higher agreement is observed between TG and T/P that between TG and ERS-2. The relative drift between T/P and ERS-2 is corrected by a table computed from monthly averages of dual crossover (DXO) height differences.

## 1. Introduction

Long-term sea level changes from satellite altimetry have been mainly investigated using T/P data (Nerem et al., 1999; Cabanes et al., 2001), but also using ERS data (Anzenhofer and Gruber, 1998; Fenoglio-Marc, 2001). The multi-mission altimetry extends the data span. The stability of the altimeter instrument is very important for long-term studies, as a drift in the satellite instrument can be interpreted as change in sea level.

## 2. Regional unified multi-mission altimetry data set

The altimetry data used are T/P (MGDR-C) from September 1992 to August 2001 (cycles 1-333), ERS-1 from April 1992 to December 1993 (phase c, OPR V6) and from April 1995 to Mai 1996 (phase g) and ERS-2 from May 1995 to April 2001 (cycles 1-66). The DGM-E04 orbits are applied to ERS, the inverted barometer (IB) correction is not applied in the comparison with TG. For each mission the average over each cycle over the entire MED of corrected sea surface heights (SSH) above the mean sea surface MSSH95 (Yi, 1995) is computed (Fig.1). Mean monthly grids of 0.5 x 0.5 degrees are computed for each mission. The linear change in regional mean sea level (RMSL) estimated from monthly time-series at TG and at the nearest altimeter node (ATG) agree better to T/P than to ERS-2 (Table 1). ERS-2 data are therefore corrected for relative bias and linear drift using monthly corrections computed from DXO differences of SSH with less than 10-day DXO time difference (Fig.2).

## 3. Comparison of RMSL from altimetry and tide gauges

We select TG stations (PSMSL) for long records and short data gaps. The linear change of RMSL is compared during the overlapping time-span with T/P altimetry (Table 2). The agreement between TG and T/P is good at several stations.

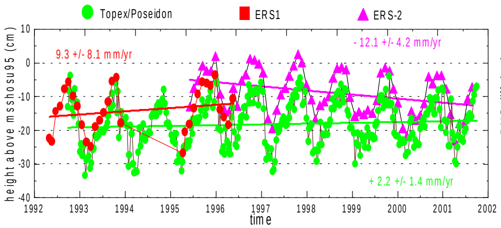



Figure 1. Average of SSH above MSS MSSH95.

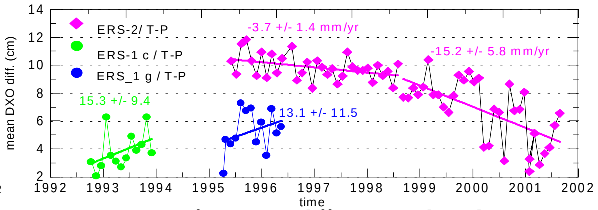



Figure 2. Average of SSH DXO differences with 10-day constraint.

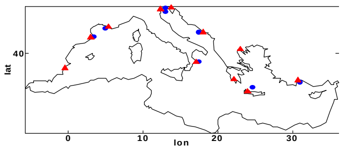



Figure 3. TG (triangles) and ATG (circles).

Table 1. Linear sea-level change (mm/yr) at TG and ATG in 1995.4-2000.4

| Station | TG monthly | T/P monthly (no ibc) | ERS-2 monthly (no ibc) | ERS-2 monthly corrected (no ibc) |
|---|---|---|---|---|
| Estartit | -8.4 +/- 3.7 | -10.5 +/- 3.9 | -9.2 +/- 4.2 | -2.3 +/- 4.2 |
| Trieste | 1.5 +/- 3.9 | - 5.6 +/- 5.9 | -12.5 +/- 5.6 | -5.3 +/- 5.5 |
| Dubrovnik | 9.4 +/- 4.2 | 0.3 +/- 3.4 | -12.4 +/- 4.5 | -6.3 +/- 4.3 |
| Soudhas | 12.4 +/- 3.6 | 14.7 +/- 3.3 | 7.9 +/- 3.5 | 14.7 +/- 3.5 |
| Crotone | -30.1 +/- 4.2 | -26.7 +/- 3.9 | -28.1 +/- 4.4 | -21.3 +/- 3.8 |

Table 4. Linear change of RMSL at TG and ATG (T/P), Correlation

| Station | 1970-1999 TG monthly | 1993-1999 TG monthly | 1993-1999 TG smoothed | 1993-1999 T/P (ibc) | r1 | 1993-1999 T/P (no ibc) | r2 |
|---|---|---|---|---|---|---|---|
| Estartit | | 4.2 +/- 2.9 | 5.3 +/- 1.1 | 5.3 +/- 1.6 | 0.79 | 6.1 +/- 2.7 | 0.90 |
| Marseille | 0.8 +/- 0.4 | 5.6 +/- 2.9 | 4.2 +/- 1.6 | 5.02 +/- 0.41 | 0.55 | 5.5 +/- 2.6 | 0.58 |
| Venezia | -0.2 +/- 0.4 | 10.9 +/- 2.9 | 9.6 +/- 0.7 | 10.7 +/- 2.5 | 0.79 | 11.6 +/- 3.6 | 0.81 |
| Trieste | -0.1 +/- 0.5 | 10.8 +/- 2.9 | 7.8 +/- 0.7 | 10.6 +/- 3.3 | 0.69 | 11.9 +/- 4.2 | 0.73 |
| Crotone | | -11.4 +/- 3.8 | | -11.5 +/- 2.2 | 0.55 | -12.8 +/- 2.6 | 0.54 |
| Dubrovnik | 0.1 +/- 0.4 | 12.9 +/- 2.5 | 10.5 +/- 0.5 | 8.1 +/- 1.7 | 0.81 | 8.7 +/- 2.3 | 0.84 |
| Soudhas | 1.6 +/- 0.46 | 9.7 +/- 2.4 | 8.5 +/- 0.6 | 16.0 +/- 1.9 | 0.79 | 16.2 +/- 2.5 | 0.86 |
| Anthalia | | 17.9 +/- 5.0 | 28.9 +/- 0.9 | 10.1 +/- 2.1 | 0.57 | 10.2 +/- 2.5 | 0.59 |

## Conclusions

The linear change in regional mean sea level is spatially not uniform. TG data agree with T/P and ERS-2 corrected altimetry in 1992-2001. TGs show an increase in sea level rise in 1990-2000 with respect to the previous decade. Sea level rise of almost similar strength was observed in the past from the longer tide gauge records indicating that the rise observed today by altimetry may have interannual or decadal frequencies.

## 4. Low-frequency variability of RMSL

During 1992-2001 the linear change of RMSL observed by T/P over the entire MED Sea is 2.2 mm/yr, in agreement with the global mean sea level (GMSL) change. In the western basin the change is small (0.4 mm/yr), it is higher in the eastern basin and in the Ionian Sea, 9.3 mm/yr and –11.9 mm/yr respectively (Fig.4.a). Due to the short altimetric time-series available, the linear sea level change depends on the time-interval selected when we choose subsets of the altimeter data (Figs.4.a,4.b). The corrected ERS-2 data gives results similar to T/P (Fig.4.d).

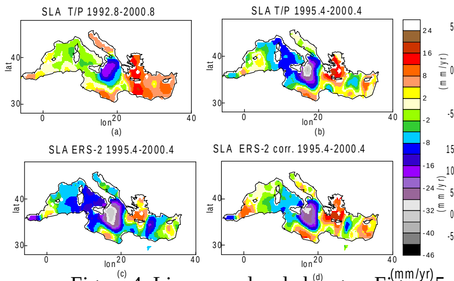



Figure 4. Linear sea-level change

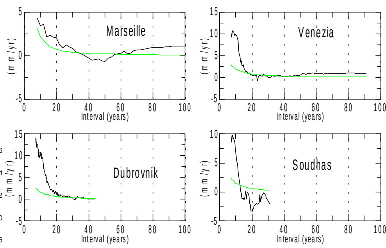
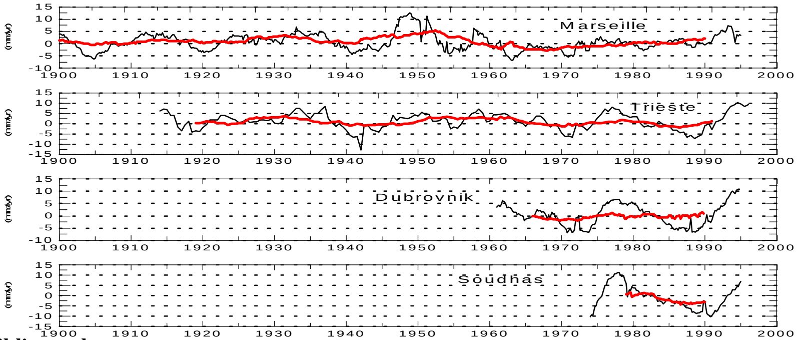



Figure 5. Linear sea-level change (X=before 2000)

The linear change of RMSL from TG in 1970-1999 is lower than in 1993-1999 (Table 2). The dependency of the linear change on the length of the time-series is shown in Fig.5. Relevant differences in the linear change are observed with intervals shorter than 20 years. To investigate if an acceleration in the linear change occurred recently, intervals of constant lengths are analysed. The longer data records (Marseille, Trieste) show a positive sea level rate of change since 1990. High values have been reached also in the past, in Trieste at the end of 1970s and are observed also at other stations (Fig.6).




**Bibliography**

Anzehofer M. and Gruber T. (1998), Fully reprocessed ERS-1 altimeter data from 1992 to 1995 feasibility of the detection of long-term sea level change, JGR103, 8089-8112

Cabanes C., Cazenave A. and Le Provost C. (2001), Sea level rise during past 40 years determined from satellite and in situ observations, Science, 294, 840-842

Fenoglio-Marc L. (2001), Analysis and representation of regional sea-level variability from altimetry and atmospheric oceanic data, Geophys. J. Int., 145, 1-18

Nerem R.S., Chambers D.P., Leuliette E., Mitchum G. and Giese B.S. (1999): Variations in global mean sea level during the 1997-1998 ENSO event, Geophys. Res. Lett., 26, 3005-3008