Forcing of sea level variability around Europe

Michael Tsimplis, National Oceanography Centre, Southampton, Empress Docks, Southampton, SO14 3ZH, UK

1. Mediterranean Sea Level

Mediterranean Sea level trends between 1960 and the mid 1990s were very close to zero or negative (Figure 1, Tsimplis and Baker, 2000). This was a significant change from sea level trends in the first part of the 20th century which was not reflected, at least to the same extent, at the tide-gauges of Lagos and Newlyn, nor at the Black Sea tide gauge of Port Tsuape. The output of a barotropic version of the HAMburg Shelf Circulation Model (HAMSOM) with resolution of 1/4° x 1/8° (Alvarez Fanjul et al, 1997) was used. The sea level trends of the model were compared to those derived from tide gauge data in Figure 2. The model has been arbitrarily scaled in (c).

The model sea level data permit us to estimate mean sea level variability for the Mediterranean between 1988-2001. The comparison of the tide-gauges with the model time series gave over the basin mean correlation coefficients of 0.71, even with 80 years of data the spread of the values is about ±3 cm. The model data from the Black Sea hydrometeorological dataset, NCEP (blue), and the steric height from the model (red) is shown in Figure 3.

The model leads the model output are shown in Figure 2. Atmospheric forcing has imposed negative sea level trends over the Mediterranean between 1988-2001. The comparison of the tide-gauges with the model time series gave over the basin mean correlation coefficients of 0.71, even with 80 years of data the spread of the values is about ±3 cm. The model data from the Black Sea hydrometeorological dataset, NCEP (blue), and the steric height from the model (red) is shown in Figure 3.

2. Reconstruction of Mediterranean Sea level

The model sea level data permit us to estimate mean sea level variability for the whole basin. This is well correlated with the NAO index. Thus we use NAO reconstructions to extend the time series backwards to 1800AD (Blasco and Blangero, 2005). Although the usefulness of such time series is questionable as the influence of the NAO over Europe is variable in time they provide an opportunity to assess error bars related to the NAO variability and NAO induced trends.

At the bottom of Figure 5 a change in the sea level slope between 1900 and the 1980s and the period before is clear. Such variation is consistent with what the tide-gauges show. Moreover, the trends estimated from samples of the reconstructed sea level record indicates that even with 80 years of data the spread of the values is about ±0.5 mm/yr and this spread is solely to the variation of the direct atmospheric forcing related to the NAO.

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3. Sea level rise in the Black Sea

Sea level in the Black Sea has been increasing even when the Mediterranean Sea level was going down (Figure 1). Stratospheric and atmospheric pressure variations do not produce significant changes even if the winter sea level rise is clearly dominated by the NAO variability. This influence is observed in the winter reconstructions are shown with the orange line. The sea level rise of 0.3 mm/yr is significant compared to the variations observed in the 1950-1970 period.

4. The North Sea

Sea level around the North Sea is dominated by direct atmospheric forcing effects and is well described by 2d models (Winkel et al., 2003). An attempt to assess the contribution of local steric variability has been made at Den Helder (Netherlands) where daily observations of sea level water availability are available (Van Aken, 2003).

Using water data (when the water column is homogenised) and assuming a depth of 18 m in the agreement between modelled-steric and observed sea level improved. The sea level is highly correlated to the NAO (0.679 depNADJ unit) with a very small trend of 0.010 degC/yr corresponding to 0.18 mm/yr. The tide-gauge trend was 1.9 mm/yr and the modelled-steric trend was 1.5 mm/yr. Thus the discrepancy was about 0.3 mm/yr well within the confidence intervals.

5. Conclusions

Several factors influence regional sea level. These range from direct atmospheric forcing which dominates interdecadal and centennial variability to local steric effects, local eustatic changes and deep water formation events. Most of the variability observed is explained with some confidence leaving small residuals in trends to be attributed to non-regional or global forcing.


Figure 1: Mean sea level trend in the Mediterranean Sea before 1988 and between 1988 and 1997 (Tsimplis and Baker, 2000). Stippled at the Southwest of England, Port Tsuape at the Black Sea tide and Lagos (Porthac) are shown for comparison. The location of most stations is shown in Figure 2.

Figure 2: Sea level trend over the Mediterranean Sea estimated from a 2-d model for the period 1950-2000. There are naturally the wind and atmospheric pressure changes and do not include any other forcing factor. The atmospheric pressure and wind fields were produced through model coupling from the NCEP (global model) and to the atmospheric forcing as the source of the rapid sea level rise there. Although Cazenave et al (2001) for correspondence with SST the comparison with the T and S changes indicate that the steric effects have a small contribution to the observed rapid sea level rise, thus the comparison that causes significant changes is linked with the Eastern Mediterranean Transient (a change in the deep water formation region in the Eastern Mediterranean from the Adriatic Sea to the South Aegean) is was the cause of the observed changes.

Figure 3: Sea level trend (mm/yr) from (a) tide-gauge data, (b) the model output (red) and (c) the model output is shown in Figure 3. The model leads the model output are shown in Figure 2. Atmospheric forcing has imposed negative sea level trends over the Mediterranean between 1988-2001. The comparison of the tide-gauges with the model time series gave over the basin mean correlation coefficients of 0.71, even with 80 years of data the spread of the values is about ±3 cm. The model data from the Black Sea hydrometeorological dataset, NCEP (blue), and the steric height from the model (red) is shown in Figure 3.

Figure 4: Sea level trend for the period 1950-2001 for the tide-gauge data, (a) model data from the regional model and (b) the model output (red) and (c) the model output is shown in Figure 3. The model leads the model output are shown in Figure 2. Atmospheric forcing has imposed negative sea level trends over the Mediterranean between 1988-2001. The comparison of the tide-gauges with the model time series gave over the basin mean correlation coefficients of 0.71, even with 80 years of data the spread of the values is about ±3 cm. The model data from the Black Sea hydrometeorological dataset, NCEP (blue), and the steric height from the model (red) is shown in Figure 3.