LONG-TERM STERIC EFFECT ON SEA LEVEL AT TRIESTE, NORTH ADRIATIC

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Abstract
The long-term annual and seasonal steric effect on sea level is estimated for the Bay of Trieste, in the North Adriatic Sea, using temperature and salinity observations performed during several decades. Data availability allows evaluating the thermo-steric effect since the early 20^{th} century and the halo-steric effect for the second half of the century. Data gaps are partly filled by means of objective analysis. As a result, during the period 1965-2004 the steric effect on Trieste sea level amounts to 1.0 mm/100 yr, where the thermo-steric and halo-steric components are 8.3 and -5.9 mm/100 yr, respectively. The 1915-2004 correction due to the thermo-steric effect alone is about 2.3 mm/100 yr.
Keywords : Adriatic Sea, Sea Level, Time Series.

An important component of sea level variability is connected with changes in sea water density, determined by temperature and salinity variability induced by climate variability. The effects of such changes on sea level can be quantified in terms of steric anomalies. In the Mediterranean Sea the data availability is limited, particularly for salinity, and such estimates can generally be made using temperature and salinity values averaged over relatively large areas and long time periods. Moreover, the comparison of steric changes with observed sea level is difficult because the former are mostly estimated for open ocean areas and the latter is measured at coastal sites [1, 2].

In this work annual and seasonal steric anomalies are estimated for the Bay of Trieste, an area of approximately 500 km^2 and 20-25 m depth in front of the Trieste sea-level station (North Adriatic). For this area multi-decadal time series of marine data exist, as well as a centennial sea-level time series, and its small size makes the steric sea-level change estimates suitable to be compared with the observed sea level.

The steric effect is estimated for the second half of the 20^{th} century, when a reasonable amount of both temperature and salinity profiles is available. Such observations come from MEDATLAS 2000 (www.ifremer.fr), ADRICOSM (www.santateresa.enea.it), PRISMA and NADS (poseidon.ogs.trieste.it) data sets. Time gaps are filled by means of objective analysis of anomalies relative to climatology. The scarcity of salinity data before 1960 does not allow a reliable estimate of the full steric anomalies except for a few isolated years, and, therefore, prevents the assessment of secular trends.

Taking into account only thermo-steric anomalies, the study can be extended backward in time to the early 20^{th} century. Monthly mean sea temperatures at 2 m depth are available for Trieste harbour during the periods 1899-1920 (with major gaps) and 1934-present (with few gaps). The period 1921-1933 is reconstructed via linear regression between temperatures measured at Trieste and Rovinj (Croatia) [3]. The few remaining gaps are filled with objective analysis. As a result a 2-m temperature time series for 1915-2004 is obtained. Temperatures at 0, 5, 10, 20 m depths are estimated on a statistical basis using the climatological MEDATLAS profiles.

From the analysis of 1965-2004 data, the annual steric effect has caused an increment of sea-level with a trend of 1.0 mm/100 yr. This represents the combined effect of increased temperature, which amounts to 8.3 mm/100 yr, and that of increased salinity, namely -5.9 mm/100 yr. In other words the "true" sea-level trend (except for vertical crustal movements) is 1.0 mm/100 yr less than the observed one.

The average annual cycle of the steric effect, deduced from the period 1965-2004, exhibits a mean value of 2.0 cm, a minimum of -2.7 cm in February and a maximum of 8.0 cm in August.

The long-term thermo-steric effect alone can be estimated for the period 1915-2004, giving a sea-level trend increment of 2.3 mm/100 yr.

On a seasonal basis, it is possible to estimate thermo-steric effects only, since salinity data are insufficient, particularly in winter. Concerning long-term (1915-2004) trends, winter and autumn have become warmer, determining 3.5 and 4.8 mm/100 yr sea-level increments, respectively. By contrast, changes in spring and summer are much smaller, namely 0.0 and 0.5 mm/100 yr, respectively. During 1965-2004 the thermo-steric effect is positive in all seasons, with minimum trend in winter, with 3.1 mm/100 yr, larger in spring and summer (5.9 and 7.0 mm/100 yr, respectively), and particularly large in summer, with 16.9 mm/100 yr.

The results outlined above concern a specific area, characterized by very shallow water and largely affected by continental air masses, and, therefore, cannot be generalized to the open sea. However, it is evident that the sole thermo-steric effect cannot be representative for the observed density-induced variability of sea level. In absolute terms, the shallowness of the Bay of Trieste makes the steric trends almost negligible compared to the observed sea-level trends, namely 1.1 mm/yr for 1915-2004 and 0.8 mm/yr for 1965-2004.

References

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