AN IMPROVEMENT OF THE SEMI-EMPIRICAL METHOD OF ANALYSIS AND PROJECTION OF SEA LEVEL

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Abstract

A new variant of the semi-empirical method used to analyze and project sea level is developed. The variant allows for two response times, one of them being arbitrary and the other extending to infinity. Three parameters underlying the variant are determined from global temperature and sea level data extending over the 1880-2009 interval. The results show that the data provide useful information on fast processes but do not adequately document slow processes. Projections based on the semi-empirical method that allows for fast processes reveal the future behavior not only of sea levels but also of related trends.

Keywords: Sea level, Temperature, Mediterranean Sea

Global warming brings about expansion of the sea and melting of the land-based ice and therefore results in a rise of sea level [1]. With about 10% of the global population living in the coastal area at an altitude not surpassing 10 m, the rise is already very worrisome and is expected to be even more so in the future. In the analysis and projection of sea level, two dynamic methods are commonly used: the process-based one and the semi-empirical one. It is increasingly recognized that a combination of the two methods represents the best approach to the study of sea level [2], because it strengthens confidence in the results obtained with both methods.

In a previous study [3] we have compared three variants of the semi-empirical method, all of them characterized by a single response time but assuming that the response of sea level to temperature forcing is purely equilibrium, purely inertial, or some combination of the two. It turned out that a realistic response time is obtained only if both the equilibrium and inertial dynamics are taken into account. In the same paper another variant of the semi-empirical method, allowing for two response times and assuming that one of them equals zero whereas the other extends to infinity, has also been commented upon. It was found that application of this variant results in at least one parameter having numerical value that is not physically acceptable.

Here we introduce a new variant of the semi-empirical method, allowing for two response times with the fast-process one being arbitrary and the slow-process one extending to infinity. The variant is calibrated using global temperature data [4, with updates] and global sea level data [5] that extend over the 1880-2009 interval. The three parameters underlying the variant are obtained by a two-step procedure. First, the equilibrium and inertia coefficients controlling the fast response are determined by performing a two-to-one orthogonal regression analysis of the data. Second, the inertia coefficient constraining the slow response is calculated by assuming that the two coefficients characterizing the fast response are known and therefore applying a one-to-one orthogonal regression analysis on the data.

It turns out that the two coefficients related to fast processes are realistic: the equilibrium coefficient equals 3.3 °C/m whereas the inertia coefficient amounts to 143 °Cyr/m, which implies the response time of 43 yr. On the other hand, the inertia coefficient related to slow processes is found to equal –605 °Cyr/m, thus suggesting that these processes are not well documented by the available data sets. It is not clear whether the problem stems from the method used to extend coastal measurements to the open ocean, from the way the glacial isostatic adjustment is taken into account, or from the influence of terrestrial water storage on sea level. Whatever the reason, it is concluded that the semi-empirical method and the available data allow fast processes to be projected into the future, but leave us silent on slow processes.

Finally, we present in Fig. 1 observations and projections of temperatures and related trends as well as of sea levels and related trends. Temperature projections under the RCP4.5 scenario are taken from literature [1], whereas sea level projections are obtained by the semi-empirical method allowing for fast processes only. The results are interesting. In particular, they show that the global warming hiatus has manifested itself in the recent slowdown of temperature increase, and that it will result in a steady, non-accelerating sea level rise over the next decade or two if the RCP4.5 scenario is realized.

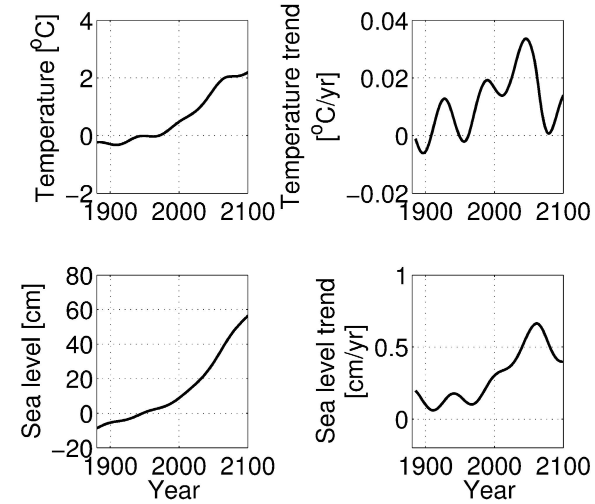

Fig. 1. Temperatures (up, left) and related trends (up, right), sea levels (down, left) and related trends (down, right). Time series represent observations prior to the year 2009 and projections under the RCP4.5 scenario after that year. Methodology used to construct the time series is explained in the text.

References

1 - Stocker T. F. and coauthors (Eds.), 2014. *Climate Change 2013 – The Physical Science Basis.* Cambridge University Press, Cambridge, 1535 pp.
2 - Orlic M. and Pasaric Z., 2013. Semi-empirical versus process-based sea-level projections for the twenty-first century. *Nature Clim. Change* 3: 735-738.
3 - Orlic M. and Pasaric Z., 2015. Some pitfalls of the semiempirical method used to project sea level. *J. Climate* 28: 3779-3785.
4 - Hansen J. and coauthors, 2001. A closer look at United States and global surface temperature change. *J. Geophys. Res.* 106: 23947-23963.
5 - Church J. A. and White N. J., 2011. Sea-level rise from the late 19th to the early 21st century. *Surv. Geophys.* 32: 585-602.