A REAPPRAISAL OF THE EXTREME SEA LEVELS ALONG THE CROATIAN ADRIATIC COAST

N. Domijan *, S.A. Čupić , H. Mihanović , N. Leder , G. Strinić , Z. Gržetić
Hydrographic Institute of the Republic of Croatia, Zrinsko-Frankopanska 161, 21000 Split, Croatia - nenad.domijan@hhi.hr

Abstract
Sea-level time series from 1955 to 2004 relevant to the northern (Rovinj), middle (Split-harbour) and southern (Dubrovnik) part of the Croatian Adriatic coast have been analysed to make estimates of return sea levels for 100-years return period. This was done by fitting observed annual sea level maxima and minima to an assumed parametric "Generalised Extreme Value" (GEV) distribution function with three parameters. A little discrepancy in the predicted return sea levels estimates for 100-years return period exists in comparison with previous studies, due to different methodologies used in the analysis and diverse length of the time series data.
Keywords : Adriatic Sea, Tides, Sea Level.

One of the most valuable applications of long-term sea level records is the estimation of risks of coastal flooding. Typical questions associated to the problem are: What is the probability that a sea wall of a certain height is overtopped during one year? What is the height of a sea wall that should be built so that it is overtopped with a probability 1/N in a particular year (N - year return levels)? Therefore, estimates of the sea level heights with an expected return period of 50, 100 or more years are of a great importance.
Along the Croatian Adriatic coast long series (50-years) of sea level measurements exist at three sites under the authority of the Hydrographic Institute of Republic of Croatia (HIRC). These stations are Rovinj, Split-harbour and Dubrovnik, enabling us to make a reappraisal of the height of extreme sea levels measured from 1955 to 2004. Although previous studies exist [1, 2], it is known that the return sea level estimates obtained for 100-years return period may vary due to a number of mechanisms that affect the components of sea level and because of different methodologies used in the analysis. These can contribute to changes in extremes [3]. Therefore, if possible, the longest sea level series should be used in determining the extreme sea levels expected within any given period. This requires that a chosen distribution is fitted to available sea level data and then extrapolated to the desired exceedance probability. However, there are a large number of different approaches discussed widely in the literature [4, 5, 6].

In this presentation, sea level data from HIRC tide gauge stations that are working continuously since 1955 are used in the analysis. The coordinates of these stations are: Rovinj (Φ = 45° 05.0' N, λ = 13° 37.7' E), Split-harbour (Φ = 43° 30.4' N, λ = 16° 26.5' E) and Dubrovnik (Φ = 42° 39.5' N, λ = 18° 03.8' E), representing northern, middle and southern part of the east coast of the Adriatic respectively. Extreme sea levels, annual maxima and minima are derived from sea level records [7]. In the analysis we applied the best known, simplest, and most widely used method of analysis of extreme sea levels. It is the annual maxima method considering the case where there is no trend and where the series of annual maxima and minima are stationary [4]. In brief, the analysis estimates the asymptotic distribution of sea level maxima through fitting to a "Generalised Extreme Value" (GEV) distribution to the ranked annual extremes, and uses this frequency distribution to estimate, by extrapolation, the return levels and the associated return periods. We processed the data by applying the Extremes Toolkit (extRemes) designed to facilitate the use of extreme value theory in applications oriented toward weather and climate problems [8].

One hundred years return values based on sea level data from three tide gauge stations were analysed as shown in Fig 1. Return periods and return levels of annual extreme sea levels show a consistent spatial distribution with the maximum values found in the north Adriatic Sea (Rovinj). Model GEV maxima return levels of 100-years return period above local "Mean Sea Level" (MSL) are as follows: 1.28±0.18 m in Rovinj (1.28 m observed), 0.93±0.20 m in Split (0.88 m observed) and 0.69±0.04 m in Dubrovnik (0.68 m observed). Model GEV minima return levels of 100-years return period below local "Mean Sea Level" (MSL) are as follows: 0.94±0.09 m in Rovinj (0.91 m observed), 0.63±0.20 m in Split (0.60 m observed) and 0.58±0.09 m in Dubrovnik (0.52 m observed). Comparison with previous works ([1], [2]) shows a small discrepancy of a few centimetres in the predicted return levels for 100-years return period, because of different methodologies used and due to diverse length of annual maxima and minima time series.

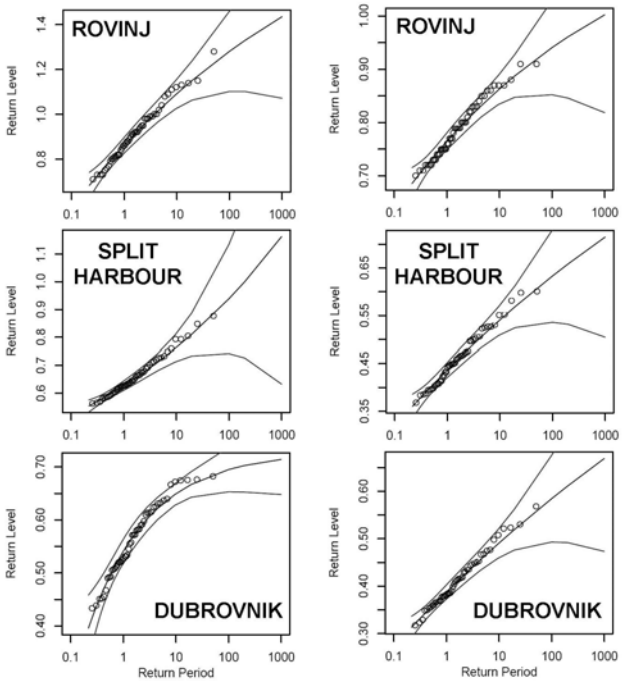

Fig. 1. Return sea level plots for Rovinj, Split-harbour and Dubrovnik calculated from associated GEV distribution (solid line) with 95% confidence interval approximately. Left panel shows maxima sea level data above local MSL while right panel shows minima sea level data below local MSL. Return period are in years and return level are in meters.

References

1 - Pršić M., 1989. Metode prognoza ekstremnih povratnih vrijednosti parametara denivelecija površine mora i njihova usporedba (in Croatian), Hidrografski godišnjak, pp.63-71.
2 - Vilibić I., Smirčić A. and Leder N., 1996. Analysis of extreme sea levels along Croatian coast in the period 1955-1995. *Izvanr. meteorol. hidrol. prilike Hrvat.*, 19: 125-130.
3 - Flather R.A., 2001. Statistics of extreme sea levels and their change with time. Final Workshop of COST Action 40, pp. 66-67.
4 - Dixon M.J. and Tawn J.A., 1994. Extreme sea-levels at the UK A-class sites: Site-By-Site analyses, Proudman Oceanographic Laboratory, UK, Internal Document No. 65.
5 - Pugh D.T., 2005. Changing sea levels: effects of tides, weather and climate. Cambridge University press, 265 pp.
6 - Tsimplis M. N. and Blackman D., 1997. Extreme sea level distribution and return periods in the Aegean and Ionian seas. *Estuar. Coast. Shelf S.*, 44 (1): 79-89.
7 - HIRC, 1955-2004. Report on sea level measurements along the east Adriatic coast, Split.
8 - Gilleland E. and Katz R.W., 2005. Extremes Toolkit: Weather and Climate Applications of Extreme Value Statistics. (http://www.isse.ucar.edu/extremevalues/evtkt.html).