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SENSITIVITY OF THE CALCULATION OF LOCAL MEAN SEA LEVELS TO THE USE OF DIFFERENT PERIODS AND METHODS OF TIME SERIES ANALYSIS IN INUNDATION STUDIES IN VALDELAGRANA (CÁDIZ)

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I. INTRODUCTION

In the last decade, the concern about the effects of the sea level rise as a result of climate change has been accepted not only by the scientific community, but also by governments and international institutions, multiplying the works that have attempted to assess the consequences of such increase in all types of coasts in the world (e.g. IPCC 2007; EEA 2010). Some of these institutions (e.g. International Panel on Climate Change, IPCC 2007; European Environmental Agency, EEA 2010) have encouraged the development of analysis at regional and local scales in order to evaluate and assess the effects of the sea level rise on different coastal areas of the planet.

Even there have been many approaches, most of the works (Titus y Richmann, 2000, Marfai y King, 2005, Zhang, 2011, Fraile et al. 2012a) coincide in considering as inundated those areas of a DEM which height are under a marine inundation local level. This level is usually calculated as the integration of a few variables as the future sea level rise (from climate change numeric models), the tide and the topographic datum. In summarize, most of the techniques agree in the necessity of modeling two surfaces: i) a topographic surface (generally known by means of a DEM), which often is referred to an official altimetry datum

(NMMA in Spain); and ii) a sea surface, the local mean sea level (NMML), which is defined as the vertical difference between a local sea level (generally an averaged value) and NMMA level. Tide gauges are often used to calculate NMML.

NMMA is the altimetry reference (0 m level) in the topographic maps and DEMs in Spain. Nevertheless, this value does not necessary match with NMML. This discrepancy makes differences in the calculation of marine inundation local levels. It might involve significant difference in the calculation of inundated areas.

Although different approaches to calculate NMML have been used (Wyrtki y Mitchum, 1990; Woodworth et. al, 1999; Woodworth et. al, 2009), none of them studied the importance of the period and the method to calculate it.

II. OBJETIVES AND STUDY AREA

The aim, of this work is to evaluate the sensitivity of the studies of inundated areas to the use of different methods and periods in the calculation of the local mean sea level.

The study area is located in the beach and marshes of Valdelagrana, between the beach and the right shore of San Pedro river. It was chosen three factors: i) there is a tide gauge (Cádiz) closer than 5 km, what means that its registers (trends, time variability) can be assumed for this area without spatial interpolation processes; ii) the tide gauge has a high sea level trend, a necessary condition for this study to maximize the differences between time periods; iii) due to its spatial variability, it is a very representative area of the atlantic coast (marshes, mesotidal coast…); and iv) there is a high spatial resolution DEM, what was essential to guarantee a right analysis of the

III. MATERIALS AND METHODS

3.1. Materials

Two types of data have been used to elaborate this work:

- Sea level surface altimetry data: Monthly mean values of the tide gauge of Cadiz, from the Permanent Service for Mean Sea Level (PSMSL).
- Emerged surface altimetry data: a Lidar DEM, whicha data were obtained during a survey in 2009. It has a spatial resolution of 1m and a vertical precision of 0,15 m.

3.2. Methods

3.2.1. The influence of the time period

Three mean value were averaged (M1, M2, and M3) in order to evaluate the importance of the length and position of the time period in the NMML calculation.

M1 matches with the total length of the time serie, 1961-2009. M2 takes from 1990 to 1990 (matching with the period used by IPCC (2007) as a mean sea level reference. M3 covers from 1992 to 2009, corresponding to the beginning of the satellite sea level measurements.

3.2.2. The influence of the method

Two NMML were calculated by means of a linear regression analysis, in which the value of the NMML was the corresponding one to the final position of the trend line. In order to compare them with the same periods but a different method of calculation, R1 and R3 were calculated using the same period as M1 and M3 respectively.

3.2.3. Spatial analysis method.

In order to evaluate the sensivity of the inundation analysis to the period and the methods, each of the calculated NMML were projected over the DEM. Before this analysis, it was necessary to correct the altimetry datum, which are referred to the «tide gauge zero» to the NMMLA datum. The tide gauge zero is 1,885 below NMMA in Cádiz.

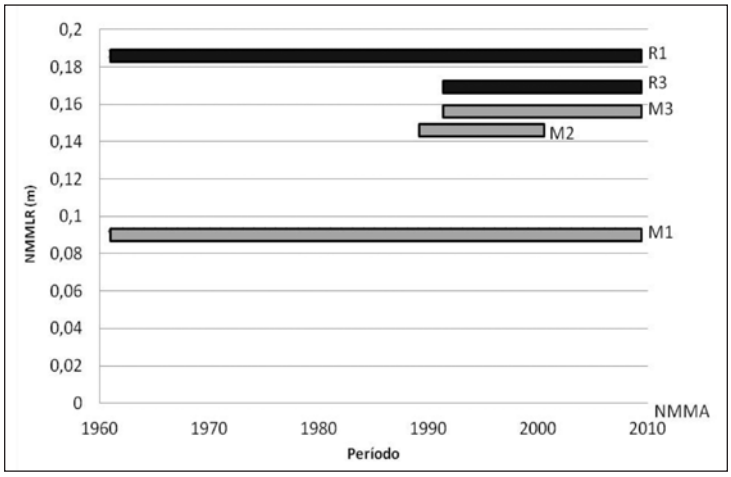
In order to identify the inundate areas, the height of the DEM and of the marine inundation surfaces were compared, identifying the cells of the DEM with a height under the height of the marine inundation surface as potentially inundated areas.

A high tide of 1.7 over NMMA was necessary added to the NMML to exceed the minimum height of 0.47 m of the DEM used. A level named H0 was used as a reference to check the importance of considering any NMML.

IV. RESULTS

The importance of the method is obvious when comparing the obtained results for all the length of the time serie (1961-2009) (fig. 1). There is a difference of 9.5 cm when the same period but different method is used. Lineal regression analysis obtains the highest value of NMML (18.7 cm).

Figure 1
DIAGRAM OF THE NMML LEVELS, ACCORDING TO THEIR LENGTH AND METHOD

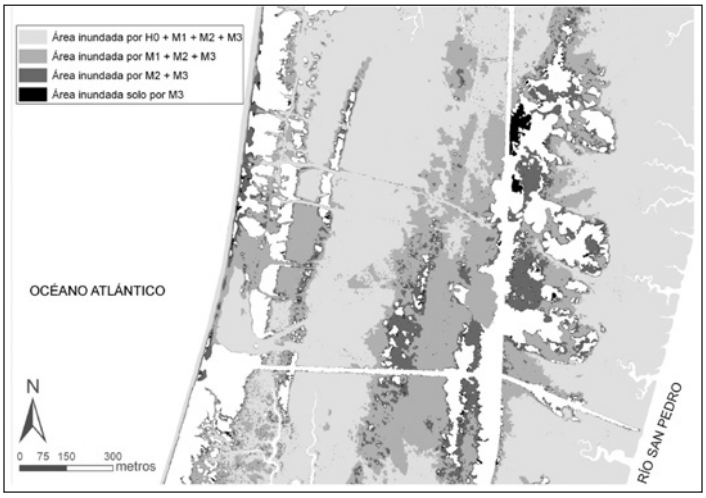


The difference between both methods is not constant. M3 and R3 levels (1992-2009 period), differences are much smaller, even R3 is still higher than M3 (17 cm vs. 15.5 cm). The shorter the period is, the smaller the difference between two methods will be.

Regarding the importance of the periods, the averaging methods make that the NMML level increase as closer they are to the end of the time serie (if the time serie has a positive trend). This effect can be observed even when the there is a longer period (M3 vs M2).

All the inundated areas showed relevant differences between them and the reference period H0 (fig 2.) Even there are differences between all the calculated NMML were smaller than 10 cm, significant differences were found when they were projected over a DEM of a very flat area.

Figure 2
INUNDATIONS OF H0, M1, M2 AND M3 LEVELS



V. CONCLUSIONS

The high spatial variability obtained in the results show the sensitivity of the NMML to the period and method used in its calculation. It means a new issue in the analysis of future scenarios of sea level rise, and the natural hazards studies focused on this topic.

The studied parameters –period and method have been defined and used by international institutions and scientific works (Titus and Narayan, 1998; IPCC, 2001; IPCC, 2007), but they have not been enough discussed by the scientific community. They are often not mentioned in many studies, even if the DEM used for the analysis are referred to a topographic datum.

This work remarks the necessity of referring future sea level rise studies, considering carefully the characteristics of the time series and the method used to calculate the NMML. It might involve to minimize the potential errors derived from the issue of this paper.