

Long-term morphology evolution of a macrotidal convergent turbid estuary

Aldo Sottolichio¹, Vincent Hanquiez², Joselyn Arriagada³, Isabel Jalon Rojas⁴

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Abstract

Recent studies have emphasized on the drastic morphodynamic evolution of many European urbanized estuaries, which have become more turbid during the XXth century because of human-induced deepening and narrowing (Winterwerp et al., 2013; De-Jonge et al., 2014). For some systems, the availability of data has allowed detailed analysis of evolution (Vandenbruwaene et al., 2013), while for some other estuaries, knowledge remains limited. For the latter, it is difficult to elucidate any effect due to climate change, extreme events or human activities.

Among them, the Gironde estuary is a macrotidal funnel-shape system, the largest estuary of Western Europe, and characterized by high levels of turbidity (Figure 1a). Despite numerous investigations on sedimentary processes carried out in this estuary in the past, there is poor knowledge on the evolution of its morphology and tides over the XXth century. Recently, an exhaustive investigation on tidal patterns has started in the Garonne tidal river, where it is known that gravel extraction during the sixties has deeply modified the mean depth of the channel (Jalon-Rojas et al., this issue). In the meantime, there is evidence of a long-term shift of the turbidity maximum in this area, mainly due to a reduction of river flow in the last 40 years (Jalon-Rojas et al., 2015). However, for the main estuarine portion, which represents 80% of the total surface (Figure 1b), morphology evolution and associated physical processes remain under-investigated.

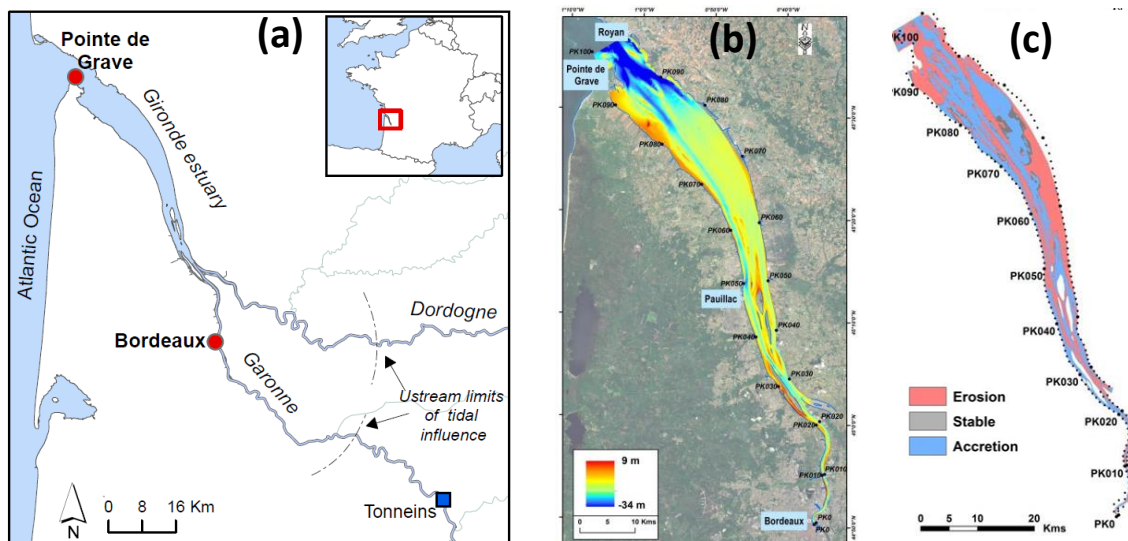


Figure 1:(a) General situation of the Gironde estuary, including the tidal rivers up to the tidal propagation limit. Tonneins is where the Garonne river flow is measured; (b) Bathymetry of the Gironde estuary in year 2000; (c) Changes on bathymetry between 1953 and 1994,

In this study the morphological evolution of the Gironde estuary has been documented and investigated for the first time, based on some bathymetric and tidal data collected from the archives of the port of Bordeaux. Six bathymetric maps covering a period of 50 years, from the 1953 to year 2000 were compared, highlighting areas of accretion and erosion (Figure 1c). Results show that the zone of maximum volume of deposited sediment has migrated continuously towards the upstream portion of the estuary, which is coherent with the intensification of the low river flow periods and the upstream shift of the turbidity maximum zone to the riverine sections, as concluded by Jalon-Rojas et al. (2015). In the meantime, despite relative weak visible transformation of the general morphology of the estuary, cross section areas have experimented high variation rate (up to 40% in some locations) with contrasted patterns between the upstream and the downstream portion of the estuary (Figure 2). While in the period 1962-1970 the downstream estuary experiences accretion and the upstream experiences erosion, the period 1980-1994 shows opposite trend, with a shift around an area at approximately km 45 downstream from Bordeaux, which acts as a nodal zone, where no net trend is observed.

¹ University of Bordeaux, EPOC Laboratory, aldo.sottolichio@u-bordeaux.fr

² University of Bordeaux, EPOC Laboratory, vincent.hanquiez@u-bordeaux.fr

³ University of Bordeaux, EPOC Laboratory, joselyn.arriagada@u-bordeaux.fr

⁴ University of Bordeaux, EPOC Laboratory, isabel.jalon-rojas@u-bordeaux.fr

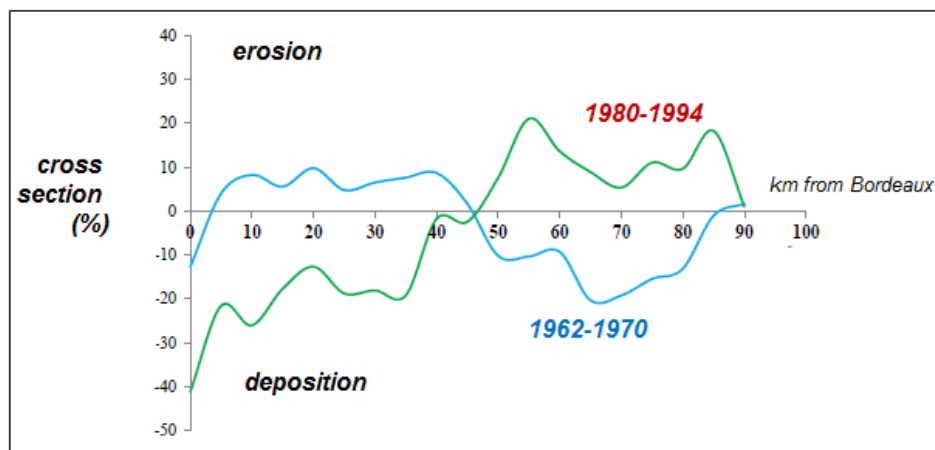


Figure 2: Relative changes on cross section in the Gironde estuary, from 1962 to 1970 and from 1989 to 1994. Positive values correspond to erosion, while negative values denote net sediment deposition

Tidal records for years 1953, 1962, 1970, and, 1994 were digitized and analysed jointly with modern records. Tidal patterns and interactions with estuarine geometry are analysed over the same period, particularly through the evaluation of the gamma coefficient, which accounts for averaged depth of the channel H_{HW} and H_{LW} , tidal amplitude and horizontal surface at high and low water S_{HW} and S_{LW} (Dronkers, 1986; Dronkers 1998).

Values of gamma change on time, suggesting significant evolution trends of the estuary. However, they also show on average that the estuary is in a general morphodynamic equilibrium state (Figure 3). On the basis of available data, little effect of human activity (mainly channel dredging and gravel extraction) and extreme events are observed, and averaged position of the turbidity maximum seems to be the main driver of changes in sections.

Changes on tidal range as a response of change on morphology are relatively weak, with little tidal amplification through 50 years between the mouth and Bordeaux. However differences on tidal asymmetry (rate of flood duration / ebbe duration) could explain the contrasted areas and the shift around km 45.

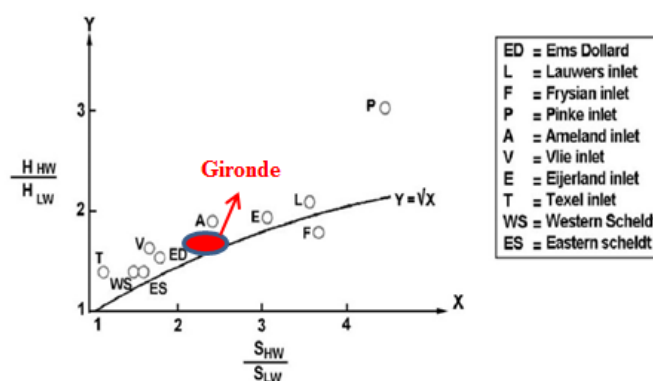


Figure 3: Estimation of morphodynamic equilibrium for several estuaries (after Dronkers, 1998). The Gironde is indicated in red.

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