Journal of South American Earth Sciences 80 (2017) 340–352

Contents lists available at ScienceDirect

Journal of South American Earth Sciences

journal homepage: www.elsevier.com/locate/jsames

Suspended sediment load in northwestern South America (Colombia): A new view on variability and fluxes into the Caribbean Sea

Juan Camilo Restrepo López [a, *], Andrés F. Orejarena R [a], Ana Carolina Torregroza [a, b]

[a] Grupo de Investigación en Geociencias GEO4, Departamento de Física y Geociencias, Universidad del Norte, km 5 vía Puerto Colombia, Barranquilla, Colombia
[b] Grupo de Investigación en Desarrollo Agro-Industrial Sostenible, Facultad de Ingenierías, Corporación Universidad de la Costa – CUC, Barranquilla, Colombia

ARTICLE INFO

Article history:
Received 6 July 2017
Received in revised form
5 October 2017
Accepted 5 October 2017
Available online 6 October 2017

Keywords:
Suspended sediment load
Caribbean sea
Hydrologic variability
Wavelet spectral analyses

ABSTRACT

Monthly averaged suspended sediment load data from seven rivers in northern Colombia (Caribbean alluvial plain) draining into the Caribbean Sea were analyzed to quantify magnitudes, estimate long-term trends, and evaluate variability patterns of suspended sediment load. Collectively these rivers deliver an average of around 146.3×10^6 t yr^{-1} of suspended sediments to the Colombian Caribbean coast. The largest sediment supply is provided by the Magdalena River, with a mean suspended sediment load of 142.6×10^6 t yr^{-1}, or 38% of the total fluvial discharge estimated for the whole Caribbean littoral zone. Between 2000 and 2010, the annual suspended sediment load of these rivers increased by as much as 36%. Wavelet spectral analyses identified periods of intense variability between 1987-1990 and 1994–2002, where major oscillation processes appeared simultaneously. The semi-annual, annual and quasi-decadal bands are the main factors controlling suspended sediment load variability in fluvial systems, whereas the quasi-biennial and interannual bands constitute second-order sources of variability. The climatic and oceanographic drivers of the oscillations identified through wavelet spectral analyses define a signal of medium-long-term variability for the suspended sediment load, while the physiographic and environmental characteristics of the basins determine their ability to magnify, attenuate or modify this signal.

1. Introduction

Fluvial sediments are an essential component of aquatic environments. It possess great importance to nutrient transfer, stability of water bodies and living organisms in general. Changes in suspended sediment load (SSL) may have significant impact on fluvial systems, as well as on deltaic and estuarine environments. Moreover, they were also shown to have large-scale effects such as changes in coastal ecosystems and reduction in fish populations (Wang et al., 2007, 2010; Gao et al., 2011). Although data on sediment loads are relatively scarce and often unreliable, rivers contribute an estimated 95% of all sediments delivered to oceans (Syvitski et al., 2003). Therefore, knowledge of average sediment loads is of utmost importance to evaluate ongoing impacts on marine and coastal environments, as well as to determine the ability of such environments to respond to changes induced by climatic change and anthropic activity (e.g. Gao et al., 2011; Syvitski and Kettner, 2011).

In Colombia, the study of sediment loads and their underlying processes, such as sediment yield, sediment delivery ratio, among others, is still incipient. Exceptions include the quantification of sediment loads in the country's major fluvial systems (Magdalena, Atrato, Sinú, San Juan, Patía and Mira rivers) (Restrepo and Kjerfve, 2000, 2004), the analysis of natural and anthropic factors controlling sediment yield/load in the Magdalena River basin (Restrepo et al., 2006; Restrepo and Syvitski, 2006; Higgins et al., 2016), and the formulation of statistical models to estimate suspended sediment load in Andean basins (Restrepo et al., 2009; Kettner et al., 2010). Those studies have highlighted the importance of sediment loads of Colombian rivers in global budgets of sediment supply to oceans, and the importance of fluvial fluxes in the progradation and architecture of Colombian deltas, despite significant destructive processes such as subsidence and tectonism (e.g.

* Corresponding author. Universidad del Norte, km. 5 vía Puerto Colombia, Departamento de Física, Bloque L – Oficina 2-24, Barranquilla, Colombia.
E-mail address: restrepocj@uninorte.edu.co (J.C. Restrepo López).

https://doi.org/10.1016/j.jsames.2017.10.005
0895-9811/

Serrano, 2004; Restrepo and López, 2008; Molinares et al., 2012). Nonetheless, most previous analyses were based on short-term time series (<20 years) collected until the mid-1990s. Such early estimates are therefore unlikely to reflect recent changes, in particular those induced by anthropic intervention. For example, by the late 1990s approximately 30% of the forest in the Colombian Caribbean region had been lost due to extensive agriculture and stock farming, which turned the region into a deforestation hot spot (Etter et al., 2006). In addition, there is evidence of recent changes in hydrological patterns of Colombian Caribbean rivers (Restrepo et al., 2014; Pierini et al., 2017), comprising the intensification of the quasi-decadal oscillatory signal, a pronounced increase in streamflows since 2000 (when yearly averages were up to 17% above long-term averages) and a significant increase in the occurrence of extreme events, such as floods and droughts. Neither the impact of these hydrologic changes on suspended sediment load in Colombian Caribbean rivers, nor analyses of recent changes, trends and patterns, have been properly investigated.

The detection of trends and patterns of variability in time series of sediment loads is a fundamental technique for a proper understanding of the relative contributions of climatic change, anthropic activity, and their interactions (e.g. Inman and Jenkins, 1999; Walling and Fang, 2003; Gao et al., 2011). Long-term time series are essential for an understanding of the dynamics of suspended sediment loads at basin scale, and for the subsequent estimation of nutrient and biogeochemical substance flows (e.g. Liquete et al., 2009; Slattery and Phillips, 2009). Here we present new analyses of time series of suspended sediment loads in seven of the main Colombian Caribbean rivers, with the aims of (*i*) updating the estimates of suspended sediment loads transported into the Colombian Caribbean coast, (*ii*) detecting significant changes in suspended sediment loads over the last 25 years, and (*iii*) identifying patterns of variability in suspended sediment transport at different timescales.

2. Colombian Caribbean rivers: general physical context

The Colombian Caribbean plain is localized in the northernmost region of South America (Fig. 1). The rivers draining the plain originate in the Andes Mountains (Mulatos, Sinú, Magdalena rivers) and the Sierra Nevada of Santa Marta, one of the highest coastal ranges in the world (Aracataca, Fundación, Palomino, Ranchería rivers). The Mulatos and Sinú rivers originate in the Nudo de Paramillo in the Cordillera Occidental. The Mulatos River drains a plateau for around 115 km along the south-north direction. The Sinú River has a drainage area of 14.7×10^3 km^2 housing a complex network of swamps, originating at an altitude of 3960 m and extending for 415 km. Both rivers flow into the Caribbean Sea. The Magdalena River represents the main river system in the Colombian Caribbean plain, with an extension of 1540 km and a drainage

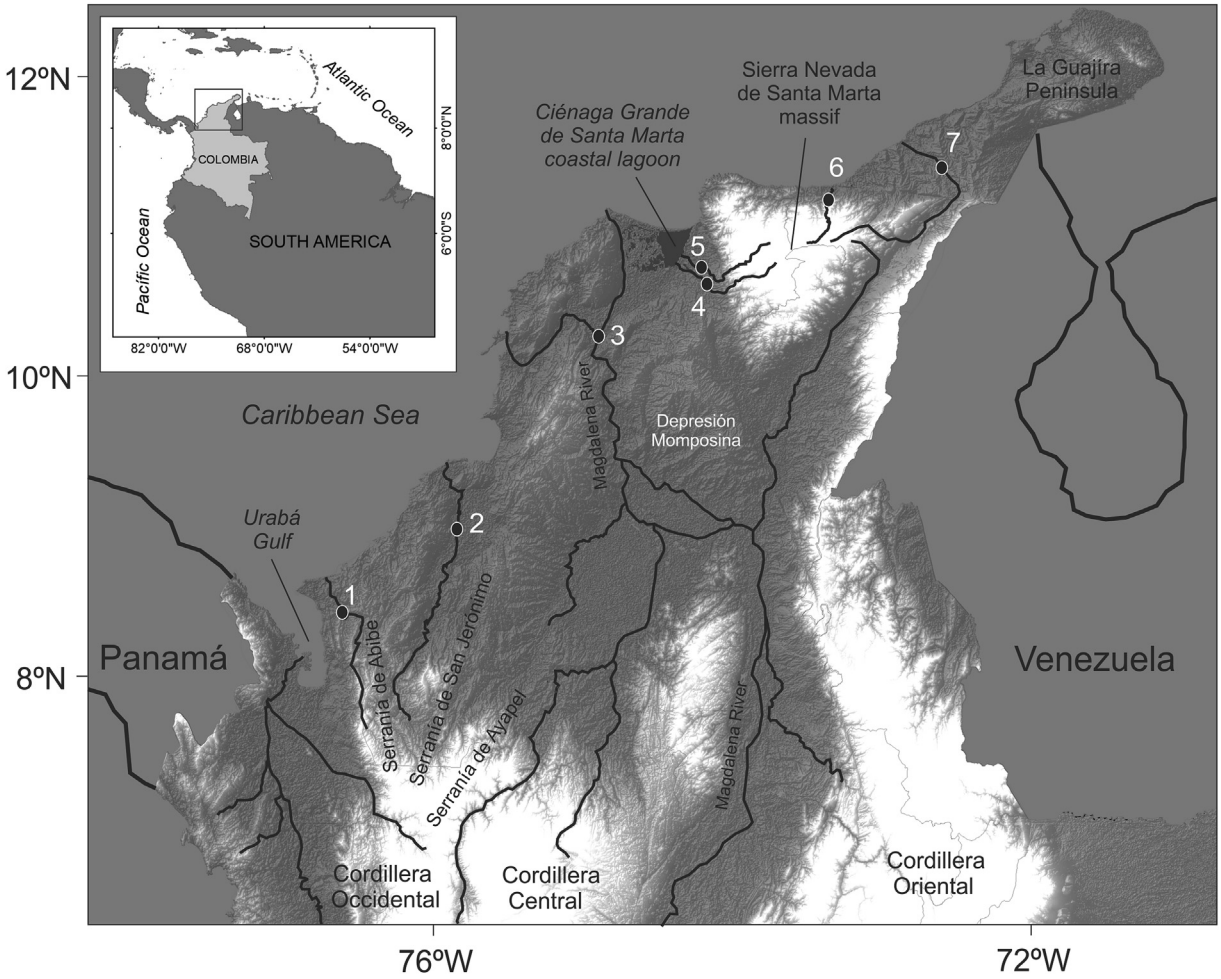

Fig. 1. Colombian Caribbean plain including the main geographical features, rivers and gauging stations. 1. Mulatos, 2. Sinú, 3. Magdalena, 4. Fundación, 5. Aracataca, 6. Palomino, y 7. Ranchería. The rectangle in the regional map highlights the Colombian Caribbean plain in northern South America. The Cordillera Occidental, Cordillera Central and Cordillera Oriental belong to the northern Andes range.