NUMERICAL MODELLING OF FLUVIAL SYSTEMS OVER GEOLOGICAL TIMESCALES: FLUVER

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INTRODUCTION

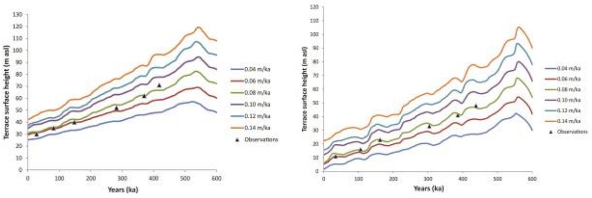
FLUVER2 is a numerical model that quantifies the influence of external factors such as tectonics, climate and sea level change, and internal factors such as sediment distribution on the evolution of fluvial systems. It does so by simulating sedimentation and erosion events along a 2-D longitudinal profile of a river over a range of user-defined spatial and temporal scales (Veldkamp and Van Dijke, 1998; 2000). The model has successfully been applied over the past 16 years to various fluvial systems worldwide. Examples include elucidating the influence of tectonics as well as climate change over the past 250 ka on the 1000-km-long European Meuse River (Tebbens et al., 2000; Veldkamp and Tebbens, 2001); fluvial terrace stratigraphy and geomorphological development of the French Allier/Loire and Dutch Meuse Rivers (Veldkamp and Van Dijke, 1998; 2000); the evolution of fluvial sediment mineralogy (Tebbens and Veldkamp, 2000); and the importance of horst and graben tectonics on fluvial landscape stability in northern Germany (Veldkamp et al., 2002). More recently, an effort was made to use FLUVER2 for the development of a 400-ka long palaeodischarge record which was calibrated against the fluvial terrace staircase properties of the British Upper Thames River (Stemerdink et al., 2010).

In this abstract, we will outline some of the more recent advances that have been made with the FLUVER2 model. We will discuss two study cases: i) the quantification of regional tectonics and global sea level changes by simulating the fluvial terrace staircase development of the northwest Spanish/Portuguese Miño River; and ii) the importance of climate change fluctuations and the availability of hillslope sediment supply on the evolution of the south Spanish Tabernas basin.

REGIONAL TECTONICS AND GLOBAL SEA LEVEL CHANGES: THE LOWER MIÑO RIVER

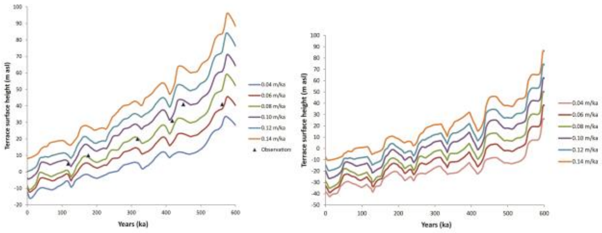
In the northwest Spanish/Portuguese lower Miño region, a well-developed fluvial terrace staircase of 10 terraces is present (Viveen et al., 2013a). These terraces, in combination with the presence of a dense network of active faults and deeply incised river valleys (Viveen et al., 2013a), suggest the presence of active tectonic uplift. An initial estimation of tectonic uplift, based on ^{10}Be- and OSL-dated fluvial terraces, suggested an uplift rate of 70-90 m Ma^{-1} (Viveen et al., 2012). For this reason, five tectonic scenarios were investigated, with uplift rates ranging from 40 m to 140 m Ma^{-1} (Viveen et al., 2013b). The modelled fluvial terrace surface altitudes were compared against mapped terrace surfaces in the field at four positions along the course of the lower Miño River. The number of fluvial terraces and their altitudes agree best with field evidence when a regional tectonic uplift rate of 80 m Ma^{-1} is applied (Fig. 1). This agrees with the earlier predicted uplift rate of 70-90 m Ma^{-1} (Viveen et al., 2012b).

The modelling results also show that sea level changes are the other main driver for terrace formation (Fig. 2). During interglacial sea level highstands, a delta developed at the Miño coastal plain. When sea level dropped during the onset of glacial periods, the Miño River started to incise in its own sediments. However, backfilling of fluvial sediments still occurred more upstream even though incision occurred downstream. Eventually, incision migrated upstream as well, forming the fluvial terraces. These model results demonstrate the complex time-transgressive nature of feedbacks within the fluvial system, and show that fluvial terrace formation downstream and upstream may have different ages, even though they were formed during the same forcing factor.



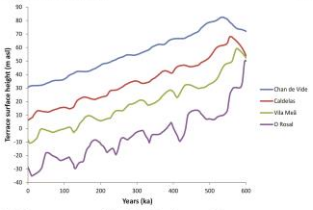
(A) Chan de Vide terraces

(B) Caldelas terraces



(C) Vila Meã terraces

(D) O Rosal terraces



(E) Four transects combined (0.08 m/ka scenario)

Fig. 1. *Terrace altitudes of four different transects. From Viveen et al., 2013b.*

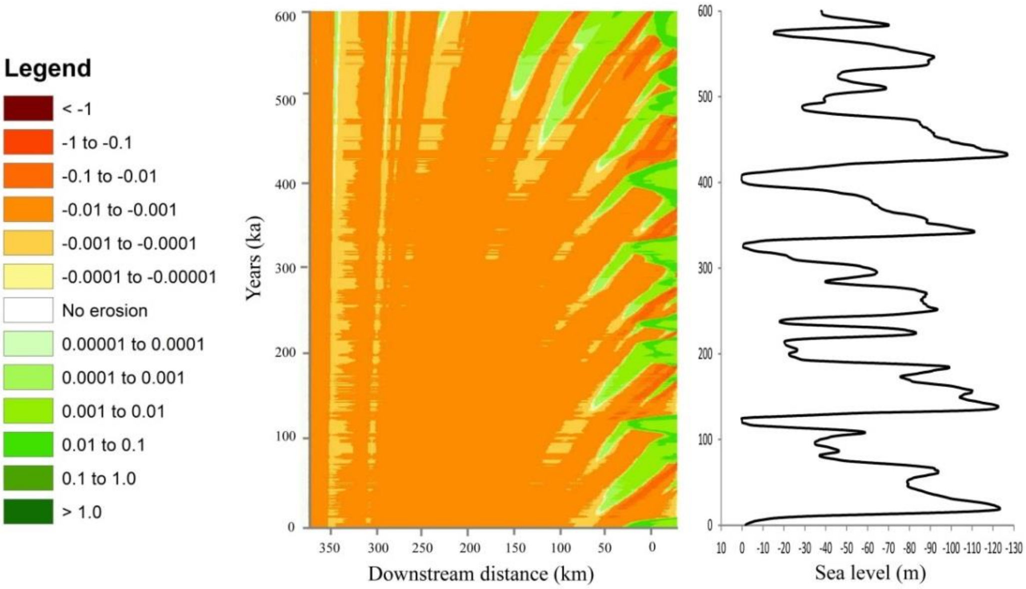


Fig. 2 *Fluvial dynamics through time. Orange-red colors: erosion; Green colors: sedimentation. Sea level on right side of figure. From Viveen et al., 2013b.*

CLIMATE CHANGE AND HILLSLOPE DYNAMICS: THE TABERNAS BASIN

In the Tabernas basin in south Spain, a series of four fluvial terraces is found in the midstream part of the basin. The area experiences a significant amount of tectonic activity due to the ongoing plate convergence of the Iberian and African plates. But tectonic deformation alone cannot explain the presence of the thick stacks of fluvial sediments (Harvey et al., 2003), and available age control of the terraces suggests a link with climate changes over the past 250 ka (Geach et al., 2014). To investigate this hypothesis, a palaeodischarge record was constructed on the basis of Mediterranean sea surface temperature (SST) and regional pollen assemblages (Geach et al., submitted). The discharge record was fed into the FLUVER2 model along with reconstructed tectonic uplift rates and a record of sea level change.

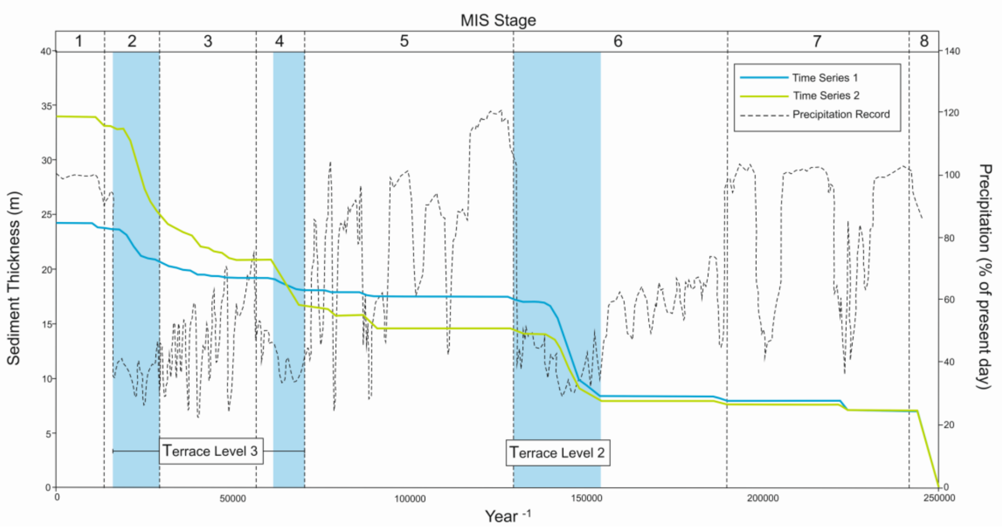


Fig. 3. *Sediment deposition (blue boxes) for time series 1 and 2 against the reconstructed precipitation record. Figure from Geach et al., submitted.*

The modelling results for two time series along the river course indicated that fluvial deposition occurred during the transition from Marine Isotope Stage (MIS) 6 to 5, from the transition of MIS 5 to 4, and during the Last Glacial Maximum (LGM; see Fig. 3). These periods coincide with phases of reduced discharge in the catchment, and may thus be related to a relative increase of transported sediment load. Experiments with increasing and decreasing the amount of available sediment through hillslope erosion (not shown) indicated that the hillslopes were the dominant source for sediment to the fluvial system. This explained the occurrence of thick successions of alluvial fan sediments in the terrace record which were subsequently incised by the main axial drainage (Geach et al., submitted).

CONCLUSIONS

The FLUVER2 model is a suitable model to simulate the influence of external factors such as tectonics, sea level and climate change as well as internal feedbacks on the behavior of fluvial systems over geological timescales. Comparing model output with field observations leads to more reliable results and should always be part of the modelling procedure. New study areas in for instance the Peruvian Andes will lead to future improvements in the model structure and modelling procedures.

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