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Controling the Location of Deposits in Meandering Channelized Reservoir Models

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SUMMARY

Process-based stochastic models are useful to simulate realistically sedimentary bodies and arrangements resulting from complex systems like fluvial meandering channelized systems. However, the processes should not be limited to the geographical domain to be simulated, since the deposits within the domain may be also influenced by the processes outside the domain. While necessarily simplified, these should be fine enough to avoid artificial border effects. An extrapolation procedure was developed, that ensures a better control of the distribution of sand throughout the deposit (e.g. an even distribution if desired). Another issue is to distribute sand preferentially in some areas (e.g. determined by seismic data). A combined use of the topography and erodibility maps was developed for this.

Introduction

Process-based stochastic models have been shown to be an appropriate way to simulate realistically 3D blocks resulting from a fluvial meandering system (Lopez 2003, Lopez et al. 2004, in press; Cojan et al. 2006). Basically the evolution of the channel centerline while migrating in time is ruled by hydraulic equations first developed by Ikeda et al (1981). Migration is accompanied with deposition of sand point-bars (having good reservoir properties, but complex geometries). Aggradation of the system is caused by overbank floods, resulting in the deposition of sandy channel lag within the channel, levee on its borders, and a decreasing thickness of fine-grained overbank sediment further away in the floodplain. Levee breaches can occur, possibly leading to a new path for the channel: these are local avulsions (breach within the domain) or regional avulsions (breach upstream of the domain). The control of the deposition of sand deposits throughout the domain is, however, faced to (at least) the two issues developed in this paper.

The process outside the domain

A fine processing within the domain is not sufficient to model the domain. The channel may exit from the domain and re-enter further down slope. It may also be responsible for deposition over the domain while being completely off the domain. In short, some processing outside the domain is necessary. To keep the efficiency of the simulation, the process outside the domain is necessarily much simpler than within the domain: in particular there are no deposits stored, and no topography recorded. However the process must be fine enough to avoid any artifact due to borders. It is specially so if one wants an even (stationary) distribution of sand within the simulated domain.
A solution has been developed, based on an extrapolation of the topography outside the domain, that avoids both discontinuity at the borders (by preserving continuity and orthogonal gradient across the borders) and lateral trends (that would shift off channel path or regional avulsions) (Fig. 1). The method allows us to calculate rapidly an extrapolated value for any grid point of the space, with the same resolution as that of the simulated domain. A similar extrapolation has been introduced for the erodibility. These extrapolated fields allow the basic processes, such as migration and avulsions, to be used with no change when getting outside the domain, and so to reduce substantially border effects (Fig. 2 and 3).

Preferential areas within the domain

In practice we could want to deposit more sand in some areas of the domain, based on seismic information. An original idea was previously developed, based on the fact that the channel migration at a given location is proportional to the erodibility at this location. It was to favor the migration and the consequent deposition of sand in some areas by using an erodibility map, or “Emap”, e.g. built from seismic attributes giving the sand proportion distribution over the simulated domain (Lopez 2003; Cojan et al. 2005, Fig. 4). However, by favoring migration within highly erodable areas, the aggradation is faster in these areas, as the thickness of overbank deposits decreases away from the channel centerline. As a consequence non-erodable areas, where sand is not desired, will have a relatively lower elevation. They will then attract the channel during avulsions, which will deposit some undesired sand in these areas.
To avoid this undesired effect, and to drive new avulsion paths preferentially in erodable areas, a solution has been developed. This consists in generating new paths not directly on the current topography, but on a topography modified by the erodibility map, as illustrated in Fig. 5, 6, 7.

Conclusions

Although process-based modeling is able to produce realistic images of deposits, the control of the location of deposits is dependent on a fast but efficient processing outside the simulated domain. In addition, the constraints on the output from the model given by the real data are to be expressed in terms of input parameters in the processes. This leads to interpret with some flexibility the role of variables such as the erodibility and topography in processes like migration or avulsion.

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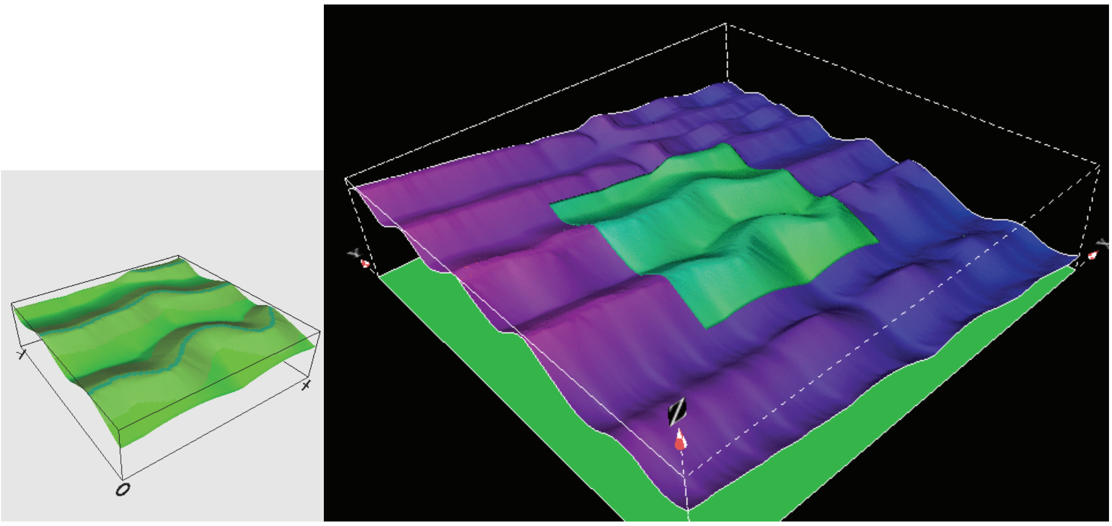

Fig. 1: Extrapolation of the topography from the modeled domain (inner green square) to its borders (purple/blue). The smaller figure on the left shows two systems of abandoned levees (dark green) dominating the floodplain (light green).

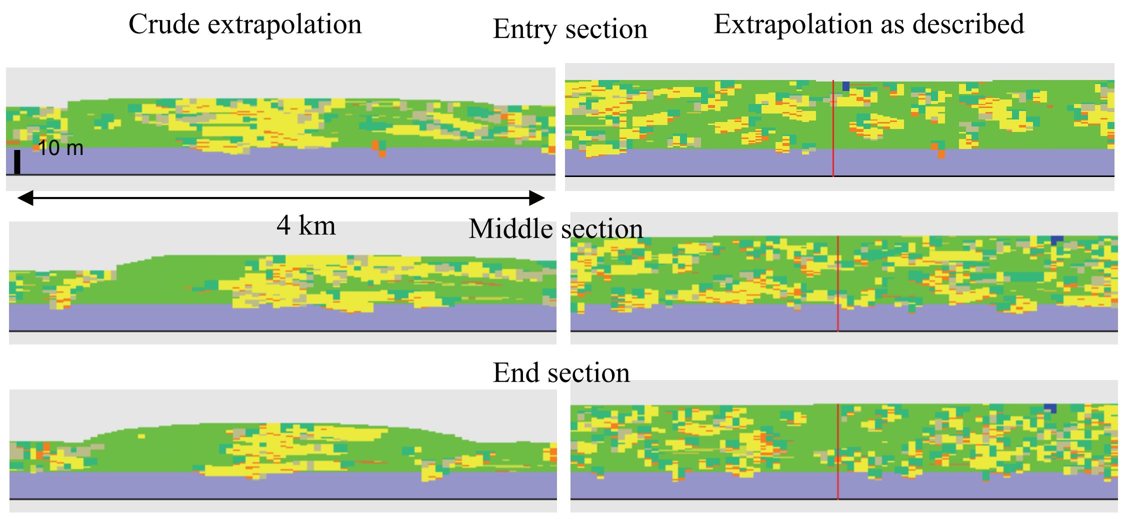

Fig. 2: Cross-sections in a simulation. No preferential location of deposits was desired. The difference between left and right is entirely due to the processes outside of the modeled domain. Note the artifacts on the left column, and the much more even distribution obtained on the right. Yellow and brown: sand; dark green: levees; light green: overbank sediments.

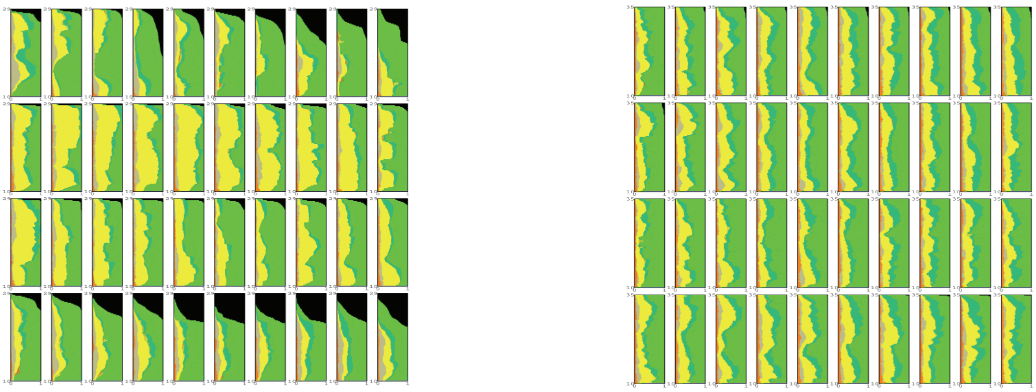

Fig. 3: Vertical Proportion Curves within the modeled domain, corresponding to Fig. 2, with same comments. For each of the two figures, entry on the left, end on the right (modeled domain 10x4 km, each VPC is calculated over a 1x1 km area).

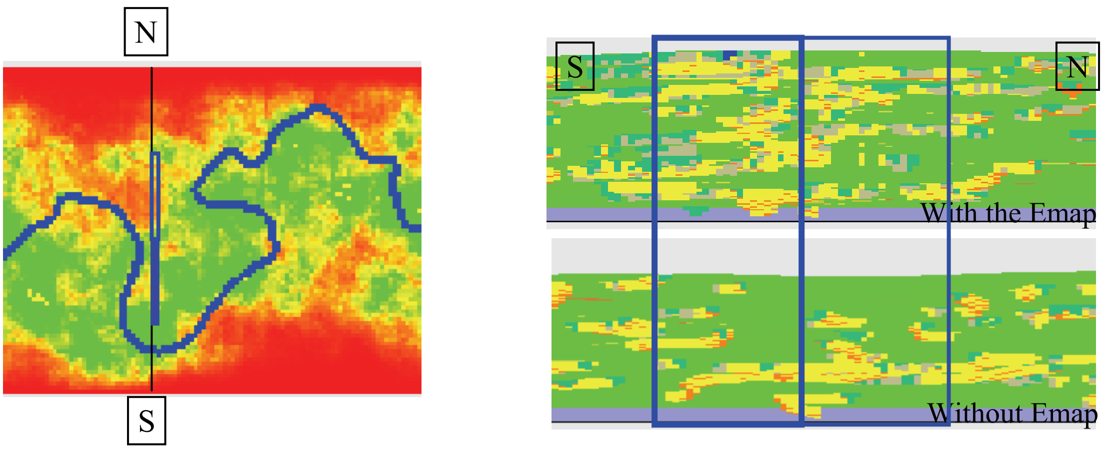

Fig. 4: The Emap (left, 7x4 km) enables to locate preferentially the deposits (heavy line on section corresponds to high erodibility values; these increase from red - zero value - to green).

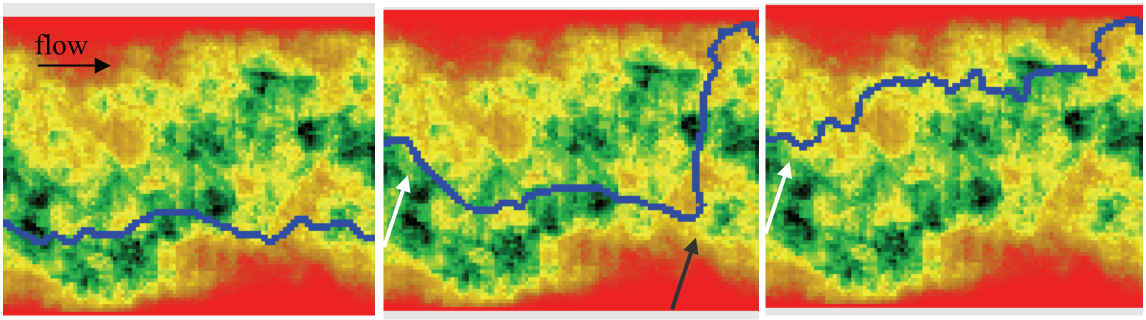

Fig. 5: The Emap controls the location of the channel, during both migration and avulsions. Left: initial state. Middle: after a local avulsion (black arrow) and just before a new avulsion (white arrow) leading to figure on right.

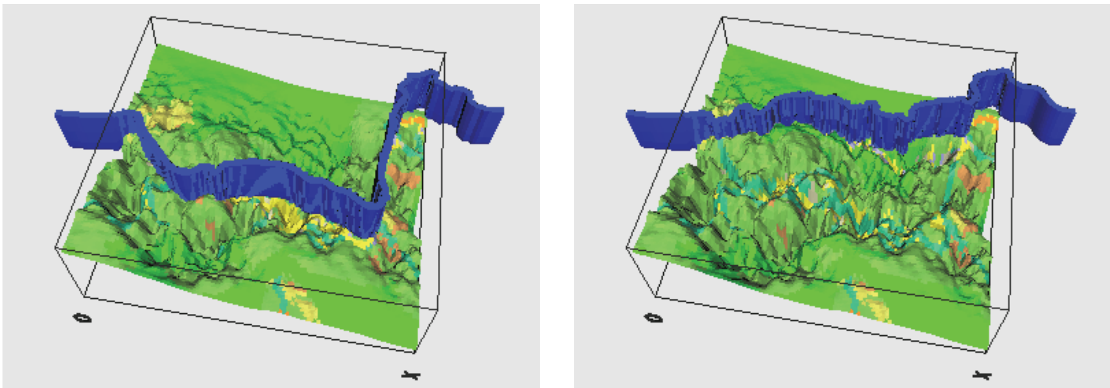

Fig. 6: The topography modified by the erodibility is used to drive the new path of the channel during avulsions (here corresponding to the middle and right figures of Fig. 5).

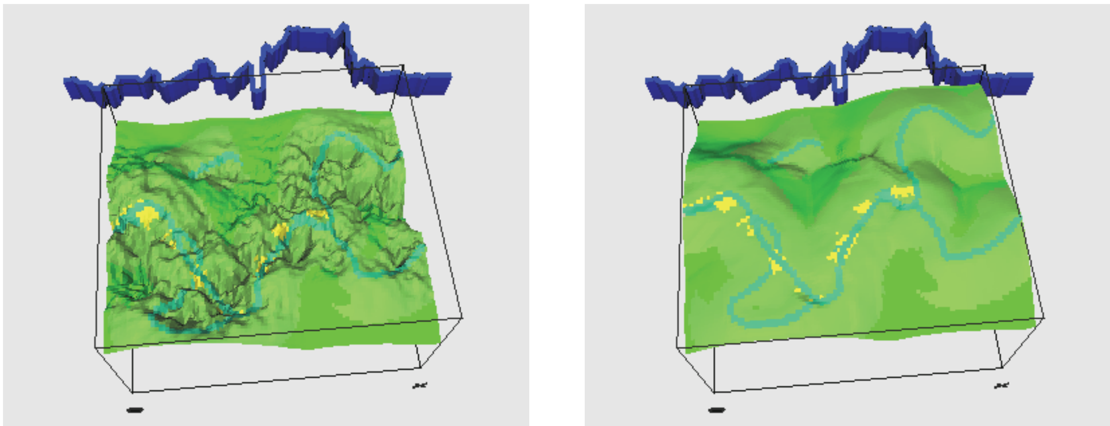

Fig. 7: Left: the topography modified by the erodibility can also be extrapolated to toss a new path outside the domain. Right: the actual topography.