Necessary conditions for dynamic meandering

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Abstract
Long-term dynamic meanders were produced in both flume experiments and numerical modeling. Lateral movement of the upstream inflow resulted in continuously active meander migration, with several cycles of bend growth and cut-offs. This demonstrated that upstream lateral channel migration is necessary for downstream dynamic meandering. Also, floodplain formation is necessary to retain a single-threaded channel.

Introduction
Explanation and prediction of dynamic river meandering has been a topic of scientific research for multiple decennia and still forms a major challenge for river management. River meanders grow and migrate by bank erosion, whilst constant channel width is maintained by floodplain formation. Meander amplitude is restricted by cut-offs, restoring low amplitude meanders. Meandering is thought to originate from bend instability, starting with small perturbations in channel curvature that lead to erosion in outer bends. However, in experiments and 2D/3D computer models to date, dynamic meandering never sustained beyond initial bend formation, the single-thread channel evolved into a braiding system. As showed by Lanzoni and Seminara (2006), initial perturbation is insufficient to maintain a meandering channel, due to downstream migration of the meander bends.
Our objective was to understand the necessary conditions for continuing meander migration, using long-term flume experiments and morphodynamic modeling. Two novel methods have been applied, related to upstream channel migration and floodplain formation.

Method
We performed flume experiment and numerical modeling, using simple conditions with constant discharge, constant base level, straight initial channel and uniform bed slope. The upstream inflow is harmonically moved in lateral direction, mimicking the presence of actively meandering bends upstream of the investigated channel reach. The flume experiments were executed in the 11 x 8 m Eurotank of the Utrecht University (Van Dijk et al., 2012). Poorly sorted sand (D_{50} = 0.51 mm), a valley-slope of 5.5-10 mm/m, discharge of 0.3-1.0 l/s and an initial channel of 15-30 cm wide and 1.0-1.5 cm deep were applied. Floodplain formation was achieved by adding fine, cohesive sediment (silica) to the upstream inflow. Also, runs with variable discharge were executed.
For the numerical modeling, the 2D-depth averaged morphodynamic model Nays2D (Dulal et al., 2010) was used. Its curvilinear grid is boundary fitted and adjusts to bank line migration. Bank migration is computed using local incision and transverse sediment transport rate, corrected for armoring of the bank by previously eroded slump blocks. Floodplain formation is achieved by assuming a threshold water depth for the conversion from channel to floodplain. A discharge of 2500 m^3/s, initial channel of 200 m wide and 10 km long, bed-slope of 0.2 mm/m and D_{50} of 2 mm were applied.

Results
Initially, small free bars formed along the entire channel (Figure 1a). Migration of the upstream channel to the left triggered the formation of a meander at the right (Figure

1b). When the upstream channel migrated back to the center, meander migration accelerated and multiple consecutive high sinuosity meander bends arose (Figure 1c). This was also observed in the flume experiments. Without a lateral migrating upstream boundary, no meander bends were formed, retaining a straight channel. The bends created by the model showed the typical meander morphology: a deep channel in the outer bend and a shallow pointbar in the inner bend. And similar to nature, continuous growth of meanders leaded to meander neck cut-offs.
In the flume experiments, a comparable channel behavior was observed (Figure 2). Lateral upstream boundary movement was necessary to initiate and continue meander migration and to induce high sinuosity meanders. In more detail, the pointbars were built up from scroll-bars, similar to natural pointbars. As meander bends continued to grow and pointbars were relatively low, chute cutoffs occurred in experiments with limited floodplain formation. After such chute cut-off, the transverse moving boundary re-initiated the formation of new bends. The cohesive sediment limited bank erosion and filled abandoned channels. Variable discharge gave comparable results as constant discharge.

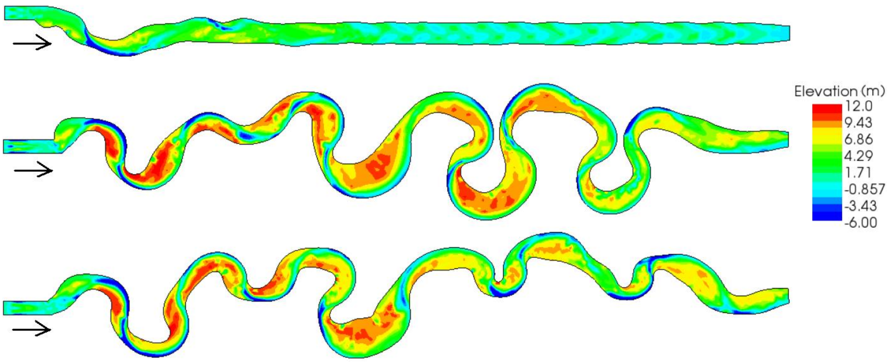

Figure 1. Meander initiation and continuous meander migration in Nays2D. Note the lateral movement of the upstream boundary and the neck cut-off in the two downstream bends. The length of the initial channel is 10 km. Flow is from left to right.

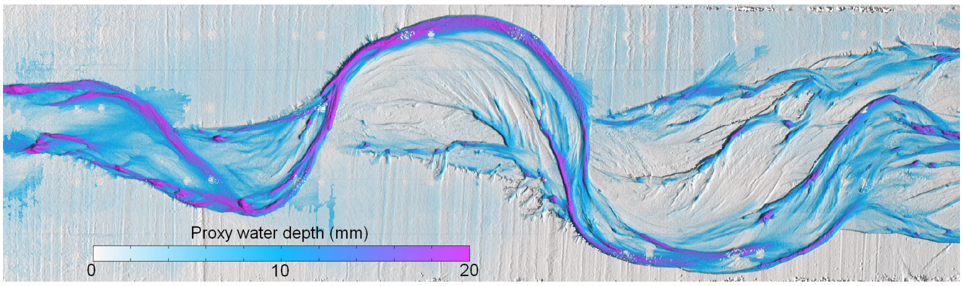

Figure 2. Flume experiments: floodplain with a meandering channel and scroll-bars in the inner-bends. Flow is from left to right.

Conclusion

We conclude that continuously meander migration can be achieved by continuous upstream bend instability. Also, floodplain formation is a key process for retaining a single-threaded channel.

References

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