A process-based method to predict 3D sedimentary architecture conditioned to real-world data: alluvial architecture in the Rhine-Meuse delta

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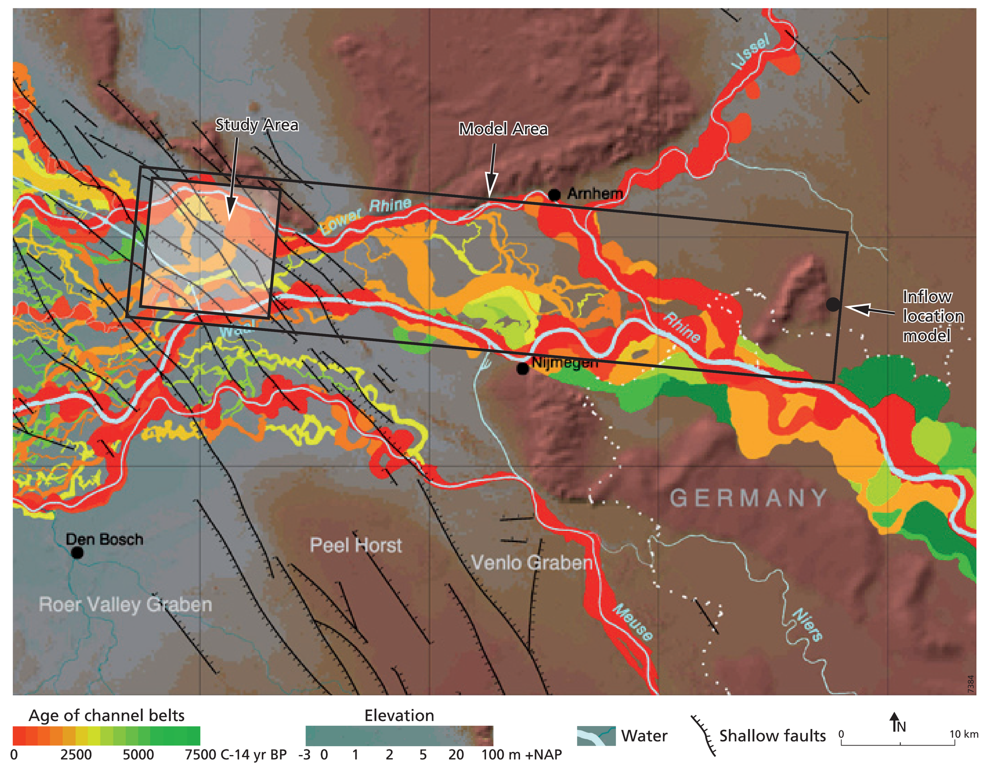
Current methods for interpretation and interpolation of sedimentological records often rely on qualitative knowledge. This has the disadvantage that results are subjective. An alternative approach is to use process-based models simulating processes that were active to produce the observed deposit. Because process-based models formalize process knowledge in mathematical equations, this approach has the advantage of being more objective. So far, the use of process-based models to create 3-D models of sedimentological architecture is limited to artificial data sets (e.g. Karssenberg et al, 2001), because it is considered difficult to condition the models to observations. Here we present results that show that conditioning of process-based models to real-world data is possible, using the fluvial system as an example.

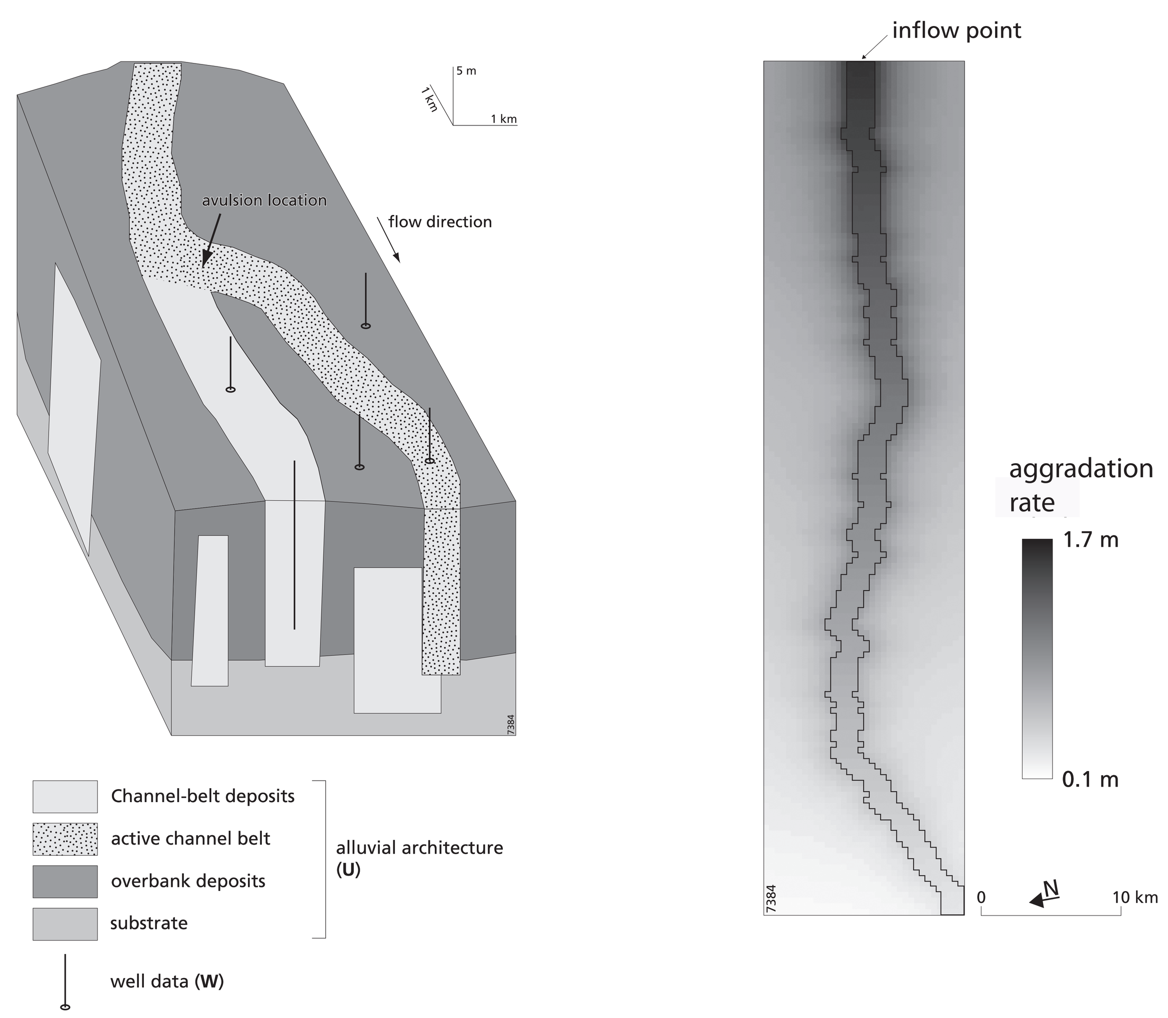
Data set



We use a 100 km^2 study area (above, rectangle) located in the Rhine-Meuse delta, the Netherlands. The area contains an appr. 10 m thick Holocene, fluvial, deposit. Position of channel belts was mapped in 3D using a large number of boreholes. We use a larger area (above, rectangle) to run the process-based model, aiming at 3D mapping in the study area.

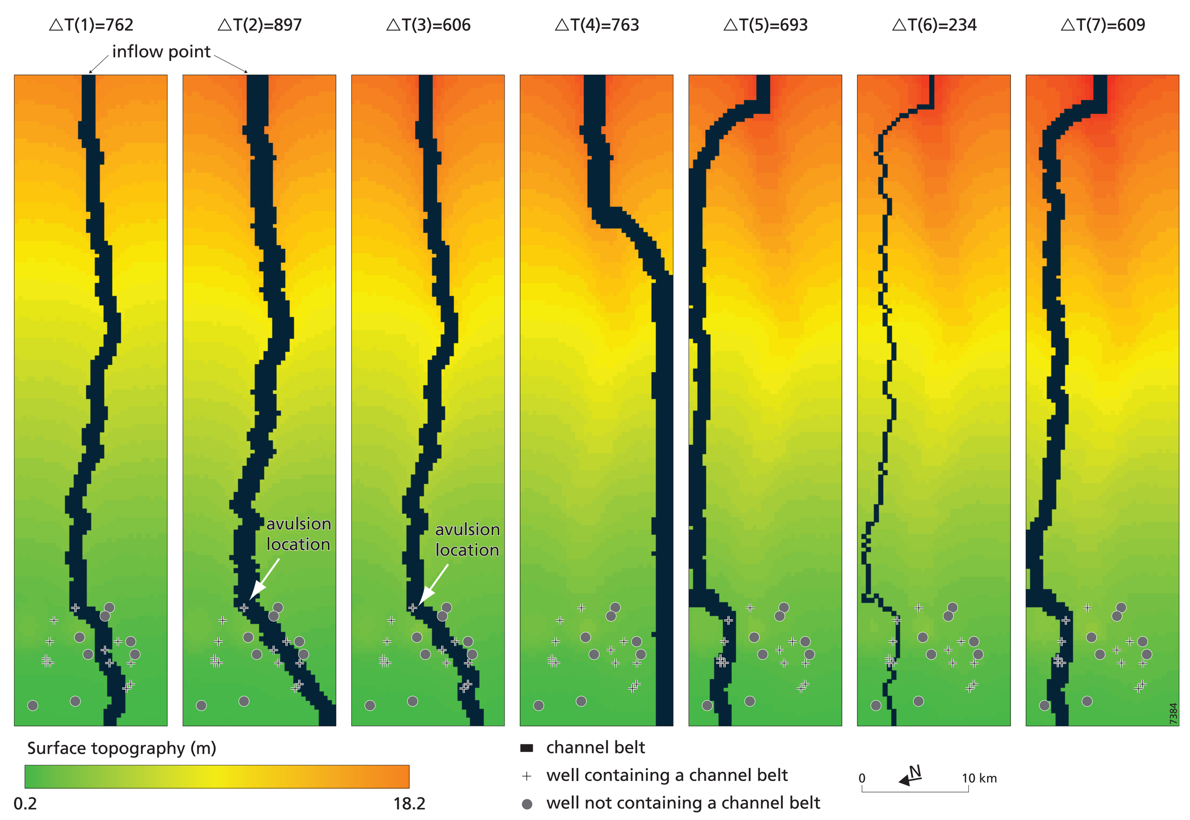
The model

In order to reduce run times required for conditioning, we use a simplified version of the Karssenberg & Bridge (2008) model. The model simulates an aggrading floodplain with avulsing channel belts of variable width and thickness (next column, left). Overbank

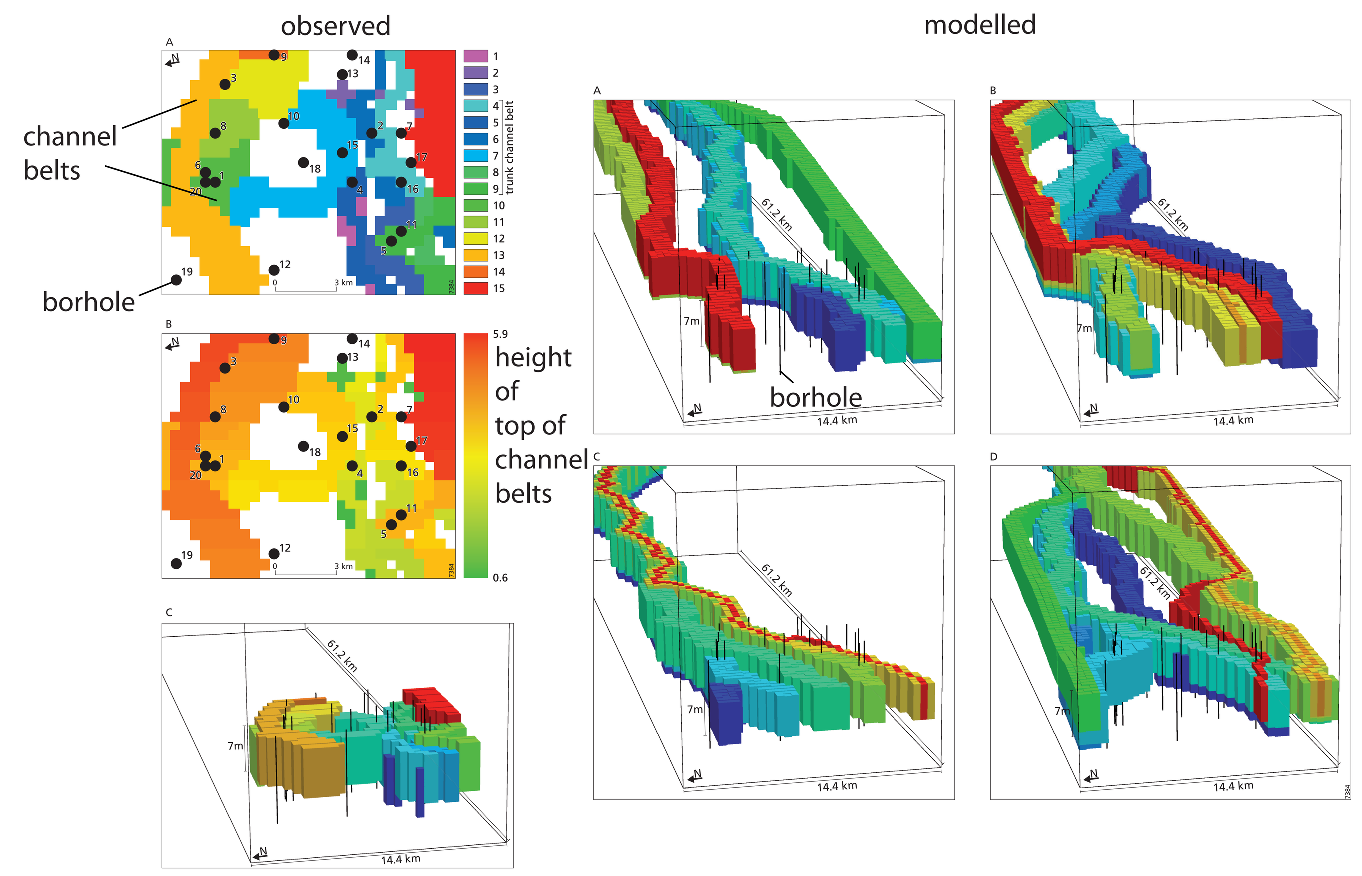


aggradation decreases away from channel belt (above, right). The model parameters are defined as stochastic variables with a uniform prior. Fitting the model to borehole data (above, left) is done by automatically adjusting parameters and inputs until model outputs are found that condition to the observed stratigraphy in vertical and horizontal direction at boreholes. This is done using a genetic algorithm.

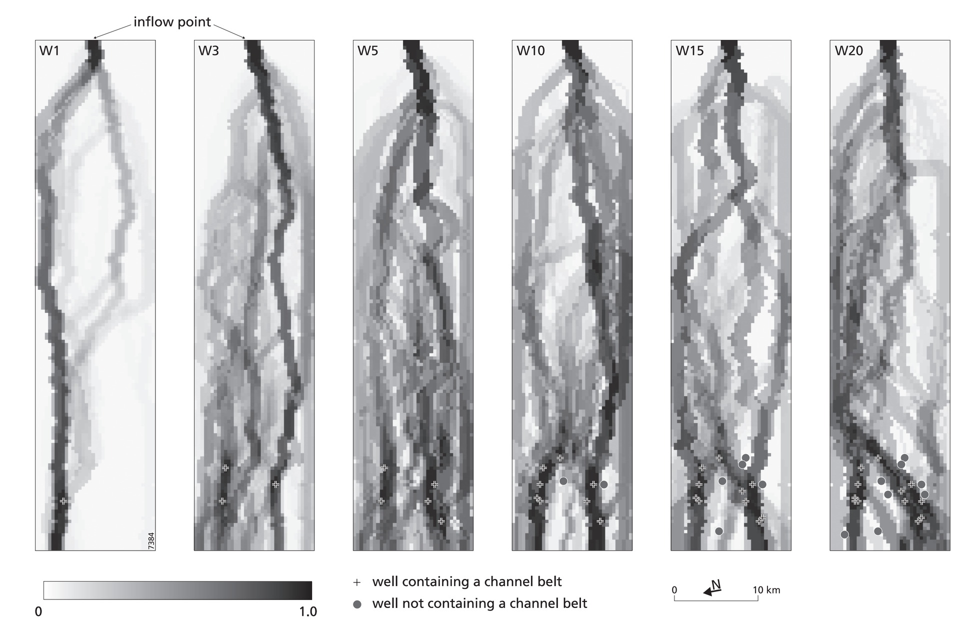
Results



The model simulates a time series of channel belts that fit the observed deposits at 20 borehole locations (above). Channel belts follow the surface topography, and have variable thickness.



The approach can be used to create multiple modelled stratigraphies (above, right panels) that all fit the observational data (left). This gives important information about the reliability of the predicted deposit.



The maps above show the probability of channel belt deposits, for different scenarios of borehole data, ranging from 1 (left) to 20 (right) boreholes. Results improve when larger numbers of borehole data are used.

Main findings

It is possible to condition process-based alluvial architecture models to real-world observations. The approach described provides information about the reliability of the results.

References

Karssenberg, D. Törnqvist, T.E., Bridge, J.S., 2001, Conditioning a process-based model of sedimentary architecture to well data: Journal of Sedimentary Research, v. 71, p. 868-879.

Karssenberg, D. & Bridge, J.S., 2008, A three-dimensional numerical model of sediment transport, erosion and deposition within a network of channel belts, floodplain and hill slope: extrinsic and intrinsic controls on floodplain dynamics and alluvial architecture.: Sedimentology, 55, 1717-1745.