A 400-year discharge record of Lower Rhine floods, based on the sedimentary characteristics of flood deposits

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Many abandoned channels and dike-breach scour holes characterize the floodplains at the apex of the Rhine Delta (Germany and the Netherlands). The sedimentary fill of these features has accumulated during successive floods, resulting in a layered fluvial archive that is useful for investigations into historical and palaeoflood magnitudes (Toonen et al., 2012). Information on the magnitude and recurrence times of palaeofloods is valuable input for assessing safety levels in flood-prone regions, such as the Lower Rhine in the Netherlands. Current flood protection designs are based on extrapolated rating curves from discharge data spanning only the last century. This is known to poorly resolve the characteristics of extreme events because of a too limited time frame. Nonetheless, this short record is used in the Netherlands to estimate the magnitude for a design flood with a recurrence interval of 1,250 years.

To lengthen discharge data series for rare-frequency high-magnitude discharge events, it is possible to derive discharge information from sedimentary archives. Cores were recovered and analysed from a sub-recently infilled abandoned channel and a dike breach scour hole, which form natural depression/sediment traps in the floodplain. Each site covers the flooding history of the last ~400 years (1595 – 2010 AD), which enables comparison with historical records, discharge measurements of the last century, and historical water levels (going back to ~1772 AD). Laser-diffraction grain size results were used to assess flood magnitudes for individual flood event layers. Continuous sampling of ~2 cm intervals provided a high-resolution record, resolving the sedimentary records at an annual scale. End-member modelling was applied to characterize the coarse particle admixtures to the grain size distribution, which is indicative of higher flow velocities experienced only during floods exceeding critical magnitudes. End-member scores of flood deposits of the last century show a relation with historical events of known discharge. Using regression analysis, discharges are predicted based on grain size, which is useful to estimate magnitudes of floods that occurred prior to modern measurements began (Fig. 1).

Historical geographical information, palynological results (introduction of agricultural species), and palaeomagnetic secular variation measurements allowed the construction of initial age-depth models. Traditional radiocarbon dating was not possible as no suitable identifiable organic material was available in the cores. Major floods in the sedimentary record are used to fine-tune the age models by lining them up with most catastrophic events described in historical records and by cross-relating age information from different research sites. This method allows reproduction of flood dates within several years; the dated flooding events are used as age tie-points for further improvement of the initial age-depth model. The refined model is used to date sedimentary layers deposited by floods of a medium magnitude, which are more numerous and thus more difficult to individually relate to a specific historical peak discharge.

This study demonstrates the suitability of sedimentary records for (palaeo)flood characterization. Based on a network of sites, it is possible to provide an accurate (internally cross-validated) flood chronology for the Lower Rhine and delta, and to reconstruct regional differences in the impact of floods (e.g., by ice jams or local dike breaches). Moreover, given the preservation of filled oxbows from all periods along the Lower Rhine, it is possible to extend flood chronologies and magnitude estimations back to the Early Holocene using sedimentary data.

References

Toonen, W.H.J., Kleinhans, M.G., and **Cohen, K.M.** (2012). Sedimentary architecture of abandoned channels. *Earth Surface Processes and Landforms,* 37, 459-472.