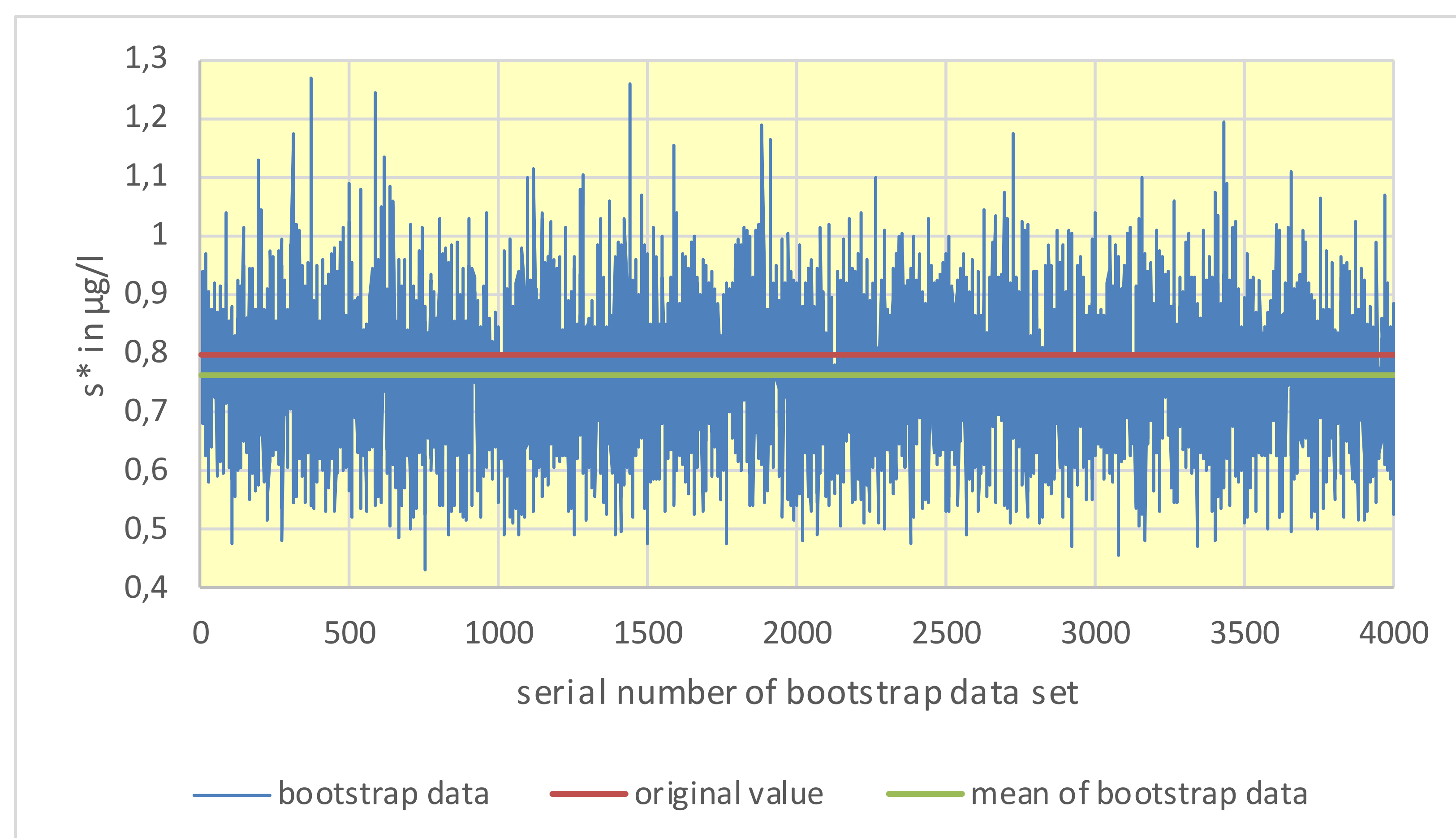


Introduction

- ISO 13528:2015 describes the Q method as a robust estimate for the standard deviation and the Hampel estimator for the mean
- ISO 13528:2015 also describes and recommends resampling techniques („bootstrapping“) for the estimation of the standard error
- When applying this technique to results from the combined Q/Hampel method the mean of bootstrap samples for the standard deviation estimate using the Q method is biased to low results

Example data

Data set from a proficiency test on tetrachloroethene with 52 results



The mean of the standard deviations of bootstrap data sets (green line) is significantly lower than the robust standard deviation of the original data set (red line)

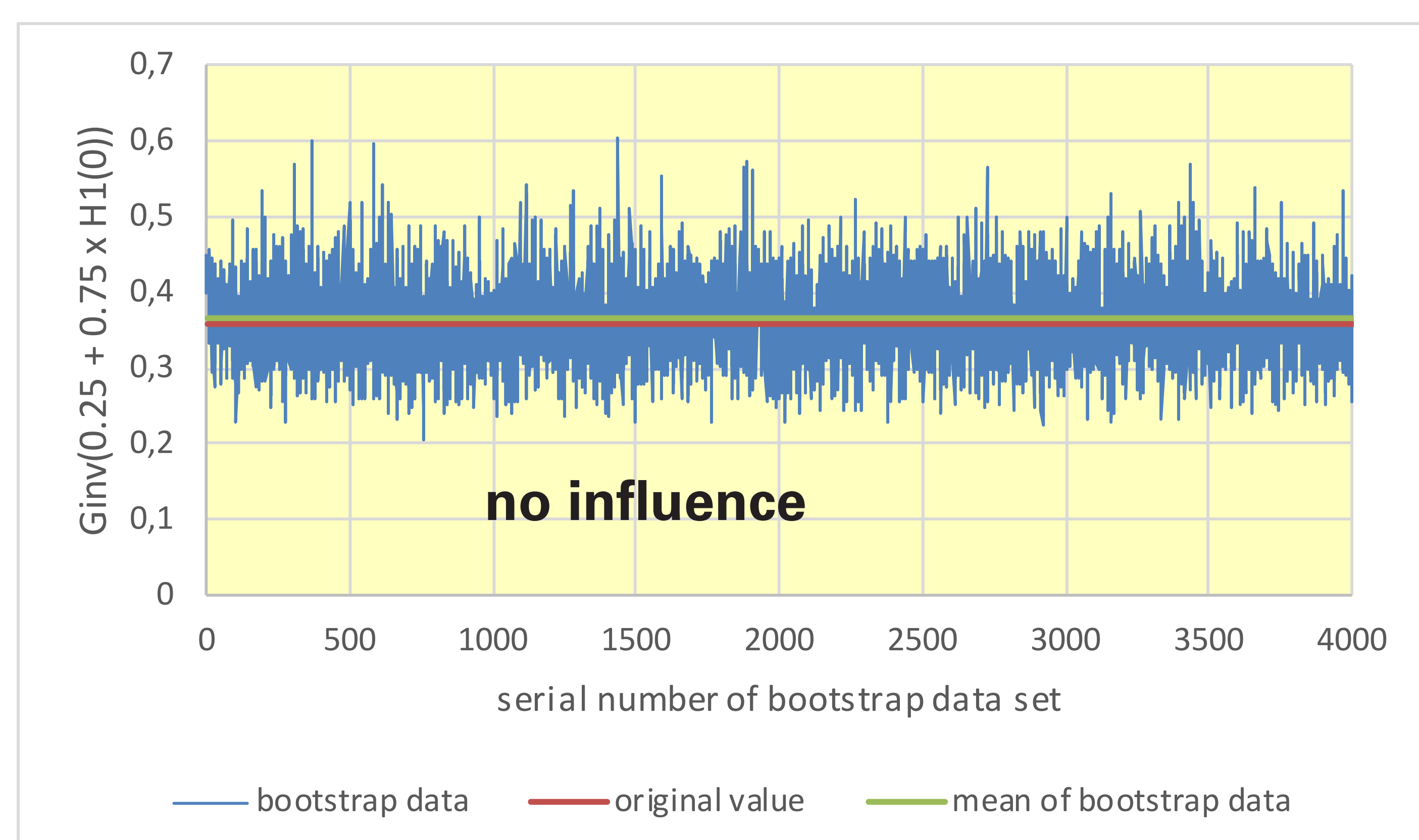
The bootstrapping process

- Data sets are created by random sampling from the original data set with replacement
- Replacement leads to a significantly higher number of differences that are zero $H_1(0)$ and therefore influence the standard deviation estimate

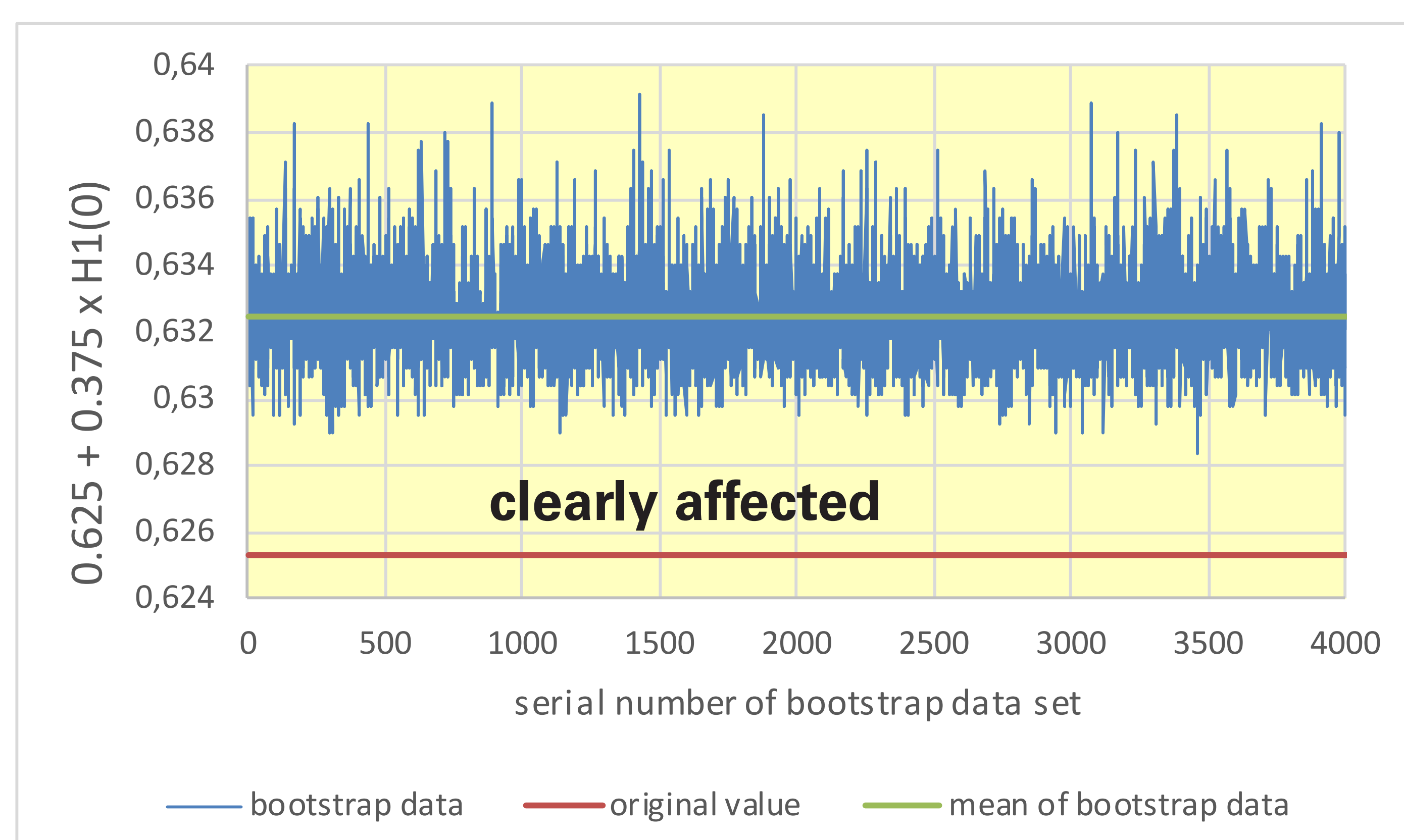
Calculation formula for Q method

$$s^* = \frac{G_1^{-1}(0.25 + 0.75 \times H_1(0))}{\sqrt{2} \times \Phi^{-1}(0.625 + 0.375 \times H_1(0))}$$

Influence of the bootstrapping on the numerator



denominator



Further conclusions

Since the Hampel estimator in the Q/Hampel method depends on a previous estimation of a standard deviation, the application of the bootstrapping method will also yield biased results for the estimation of the uncertainty of the Hampel estimator