# Model-based approach for uncertainty evaluation of time-dependent measurements

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The measurements quality is a crucial factor of the confidence in data and, consequently, in the analyses and results obtained from those data. When the measurements are taken, some errors can occur associated with the instrument, the responsible person of the measurement or the environmental conditions. These errors are accounted for in the concept of uncertainty. When the measurand is static, the sample standard deviation of the mean is used to measure this dispersion. Some measurements result from operations between multiple variables, each one with associated uncertainty; in this situation (propagation of uncertainty), the Delta method, Monte Carlo simulations or static models can be used to estimate the uncertainty in the resulting quantity.

The methods referred to above are only correct if the observations of the same measurand are independent. When a dynamic system generates time-dependent measurements, it is necessary to account for that dependence on the uncertainty calculation. Although some techniques to estimate the uncertainty of time-series measurements have been developed, the uncertainty calculation of dependent measurements is still a challenging task.

This work aims to propose a model-based approach to estimate the uncertainty when measurements are time-dependent and not collected in situ. National Physical Laboratory guides present guidelines to be followed when a model is used. However, all the models presented are static and not applicable to time-dependent measurements. The extension can be made using statistical models for the situation where measurements may have internal correlations. Fitting an appropriate model to the measurements, then resampling and refitting it, the uncertainty of each measure is possible to estimate. This approach was validated using measurements obtained from typical time-series models and compared with theoretical values. To illustrate the capacity of the method to estimate the uncertainty of single time measurements, a real example from a water system is also presented.

**Keywords:** Metrology, Resampling, Time-dependent measurements, Uncertainty