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How to estimate timing errors in flood forecasting systems?

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The systematic verification of hydrological forecasts is a growing area of research and constitutes a core component of modern flood forecasting systems. Classical methods for assessing the quality of such forecasts compare the vertical offset between the observed and predicted hydrograph (amplitude errors). The horizontal time offset (timing errors) has reveived less attention although frequently mentioned by the users as a key factor to assess the quality of the forecasts.
To investigate this issue, four different types of timing errors estimation were compared:
(1) the optimal lag between the observations and the forecasts,
(2) the difference between values of a characteristic time calculated for the observed and predicted hydrographs, such as the peak time and the centroid time,
(3) the calculation and comparison of the cumulative volume of the two hydrographs and
(4) the phase difference of the cross wavelet comparison between the observed and predicted hydrograph.
The four methods have been applied on synthetic data with known perturbations and assessed according to the following criteria: applicability to complex floods with multiple peaks, robustness against noisy data and suitability for online calculation. The last criterion is driven by the need to asses the quality of forecasts, not only for long historical records, but also during a flood event.