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0.1 Trend analysis of δ^{18}O composition of precipitation in Germany: Combining Mann-Kendall trend test and ARIMA models to correct for higher order serial correlation

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Spatio-temporal dynamics of stable oxygen (^{18}O) and hydrogen (^{2}H) isotopes in precipitation can be used as proxies for changing hydro-meteorological and regional and global climate patterns. While spatial patterns and distributions gained much attention in recent years the temporal trends in stable isotope time series are rarely investigated and our understanding of them is still limited. These might be a result of a lack of proper trend detection tools and effort for exploring trend processes. Here we make use of an extensive data set of stable isotope in German precipitation. In this study we investigate temporal trends of δ^{18}O in precipitation at 17 observation station in Germany between 1978 and 2009. For that we test different approaches for proper trend detection, accounting for first and higher order serial correlation. We test if significant trends in the isotope time series based on different models can be observed. We apply the Mann-Kendall trend tests on the isotope series, using general multiplicative seasonal autoregressive integrate moving average (ARIMA) models which account for first and higher order serial correlations. With the approach we can also account for the effects of temperature, precipitation amount on the trend. Further we investigate the role of geographic parameters on isotope trends. To benchmark our proposed approach, the ARIMA results are compared to a trend-free prewhiting (TFPW) procedure, the state of the art method for removing the first order autocorrelation in environmental trend studies. Moreover, we explore whether higher order serial correlations in isotope series affects our trend results. The results show that three out of the 17 stations have significant changes when higher order autocorrelation are adjusted, and four stations show a significant trend when temperature and precipitation effects are considered. Significant trends in the isotope time series are generally observed at low elevation stations ($\leq$315 m a.s.l.). Higher order autoregressive processes are important in the isotope time series analysis. Our results show that the widely used trend analysis with only the first order autocorrelation adjustment may not adequately take account of the high order autocorrelated processes in the stable isotope series. The investigated time series analysis method including higher autocorrelation and external climate variable adjustments is shown to be a better alternative.