Variance reduction for trend analysis of hydrochemical data in brackish waters

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Introduction

The concentrations of nutrients and other substances in a water body can be strongly influenced by random fluctuations in the mixing of waters of different origin. Hence, the water quality at given site can exhibit a large temporal variation that makes it difficult to extract anthropogenic signals from collected data. This is particularly true for estuaries, coastal waters and semi-enclosed seas, where the mixing of freshwater and sea water can be highly stochastic. In this paper, we examine how the human impact on nutrient concentrations in such water bodies can be clarified by replacing conventional time series or geostatistical approaches by trend detection techniques in which we analyse the variation in nutrient concentrations with salinity and time. In particular, we examine how data collected at different depths at a single station or a network of stations can be simultaneously analysed for temporal trends in the concentrations of different forms of nitrogen and phosphorus. The general principles for the trend detection are illustrated with data from the Baltic Sea.

Data set

The data consists of monthly measurements of different nutrients as well as other hydrological parameters at a number of sampling sites in the Baltic Sea during the period 1989-1998. In each sampling site observations are taken at different depth levels with a resolution of 5-10 metres.

Results

Figure 1 illustrates how the concentration of total phosphorus varies with sampling depth at one of the investigated sampling sites (BY31) in the Baltic proper. A halocline prevents mixing of surficial and deep water, and the highest concentrations occur below the halocline. However, this figure also shows that there is a substantial temporal variation in the concentrations measured at a fixed depth. Closer examination of the data revealed that this temporal variation is linked to natural fluctuations in salinity. Consequently, a considerable variance reduction can be achieved by plotting the concentration values against salinity (see figure 2) or salinity and time.

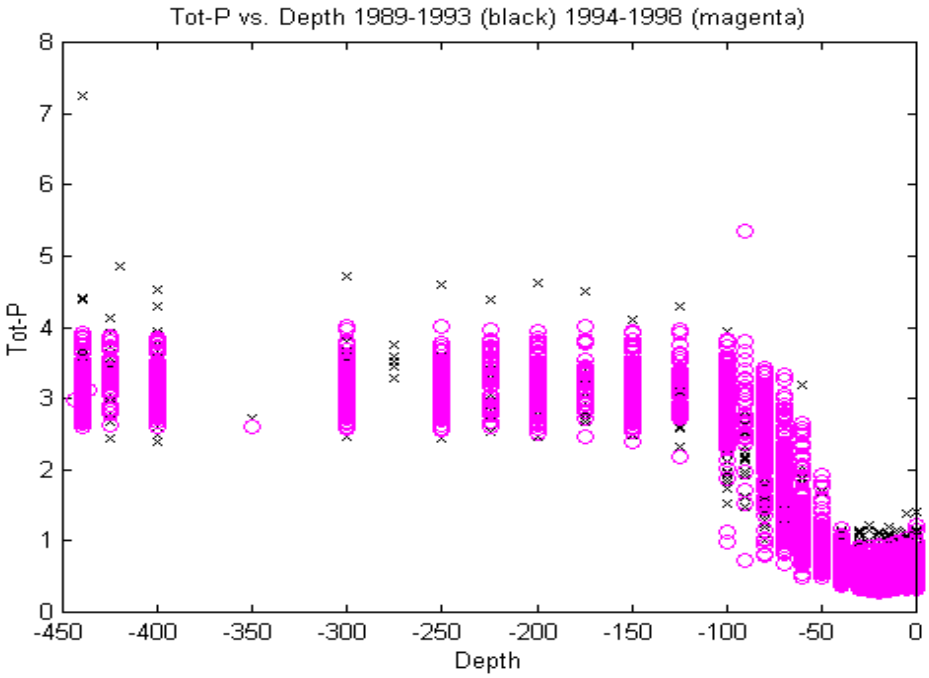

Figure 1. Concentrations of Total Phosphorus plotted against depth levels at location BY31 in the Baltic Proper ('x'=observations from 1989-1993, 'o'=observations from 1994-1998)

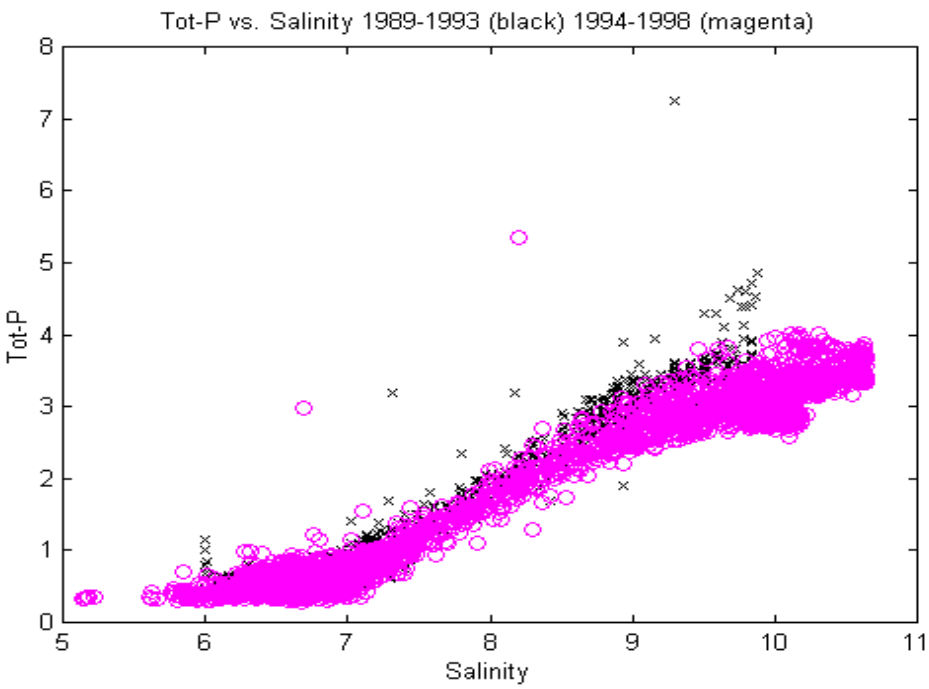

Figure 5. : Concentrations of Total Phosphorus at location BY31 plotted against salinity levels

The statistical significance of temporal changes in nutrient concentrations can be assessed by using parametric and nonparametric trend tests.

In the recent past a nonparametric trend test with correction for covariates was proposed (Libiseller and Grimvall, 2002). This test, however, can best be applied if trends are monotone in time, which is not necessarily fulfilled for the original data, since inflow from surrounding seas induces cyclical fluctuations in salinity and by that in Total Phosphorus concentrations. We therefore suggest that an overall trend test is computed as the weighted sum of trend test statistics computed for different salinity levels. By this means we receive a rather homogeneous time series in each subset, which considerably improves the power of the trend test.

In the parametric approach we suggest a regression model, with Total Phosphorus concentration as the dependent variable and time (months) as the explaining variable. The residuals from this model output are most likely non-independent and non-normally distributed, and we will therefore apply bootstrap assessment of the estimated parameters.

With these two approaches it is possible to perform significance tests for trends at locations where an obvious halocline is present in the water mass, while for other locations the suggested methods are not successful.

References

Libiseller C and Grimvall A (2002) Performance of Partial Mann-Kendall Tests for Trend Detection in the Presence of Covariates, *Environmetrics* 13, 71-84