Study on long-range correlation about CODMn in Poyang Lake Inlet and Outlet on the basis of DCCA method

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Abstract. Detrended Cross-Correlation Analysis (DCCA) is applied to the the long-range correlation analysis of CODMn series in Poyang Lake Inlet and Outlet in China. The results show that the two CODMn series are characterized long-range correlation at a certain time scale. Moreover, the correlations between the fluctuations in lake water CODMn do not obey the classical Markov-type stochastic behavior, but display more slowly decaying correlations. This work can be helpful to improvement of modeling of lake water quality.

1. Introduction

The definitions of CODMn are the quantity of oxidizing agent $KMnO_4$ consumed when the reducible matter is oxidized per unit of water body under specified conditions, which is generally used to measure the organic matter content [1]. The CODMn is also the important index for routine monitoring measuring and water pollution control and is an integrative index for evaluating the degrees of water quality. Along with the increasingly highlighted pollution problems in river, lake and other water bodies, the CODMn indicator had already been launched successively to the main rivers and lakes inland [2]. Poyang Lake, situated in the north of Jiangxi Province, is the largest freshwater lake in China, and also the important swamp protection and migratory bird habitat. In recent years, With the rapid development of economic construction and the rise of the people's living standards, the pollution of eutrophication and heavy metal in the Poyang Lake becomes more and more serious. At present, many scholars usually focus on the heavy metal pollution [3-5], eutrophication [6-7] and so on, but did not emphasize the analysis of CODMn, a very important monitoring parameter [8]. Though right now the experimental data showed the annual dirt holding capacity of CODMn is smaller than that of water quality standard III grade in the Poyang Lake, the study on dynamic variation rule of CODMn can help reveal the main causes of water pollution. Moreover, there are many researches relevant to the correlation between CODMn and other pollution, such as BOD_5, NH_3-N, DO and so on, but much less attention has been paid to the long-range correlation of CODMn [9].

   In this study, the nonlinear dynamic characteristics of CODMn series of Poyang Lake Inlet and Outlet was explored using the space trajectory. Next, we explore the long-range correlation of

CODMn series in Poyang Lake Inlet and Outlet in China. This work can be helpful to improvement of modelling of lake water quality.

2. Study area and data

In this paper, Poyang Lake Inlet and Outlet water CODMn series are chosen as research objects. Poyang Lake (115º47′~116º45′E, 28º22′~29º45′N) is the largest freshwater lake in China [10]. Poyang Lake Inlet and Outlet water quality data are provided freely on the Internet by Ministry of Environmental Protection the People's Republic of China web site: http://www.mep.gov.cn/. We have used weekly average CODMn monitoring data of Poyang Lake Inlet and Outlet during 2016. The study area and monitoring sections are shown in figure 1. In this study, we investigate the long-range correlation of CODMn between Poyang Lake Inlet and Outlet in China by the detrended cross-correlation analysis (DCCA). The study area and monitoring sections are shown in figure 2.
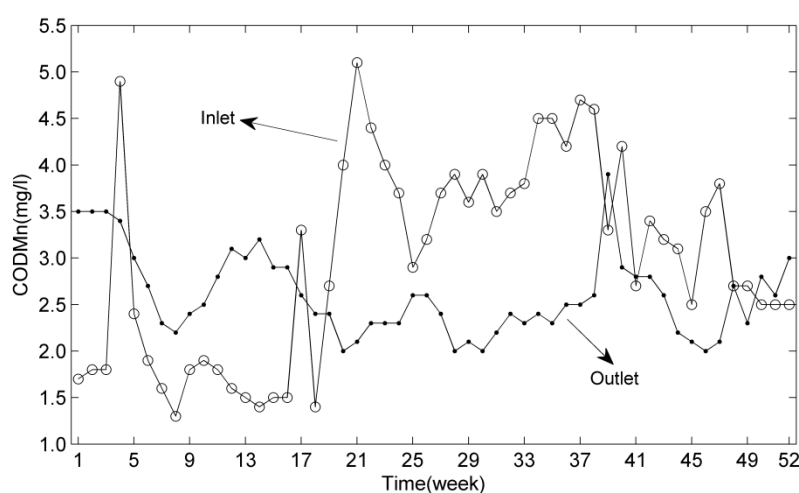
Figure 1. The weekly average CODMn monitoring data of Poyang Lake Inlet and Outlet in 2016. The data lengths all are 52 (weeks).
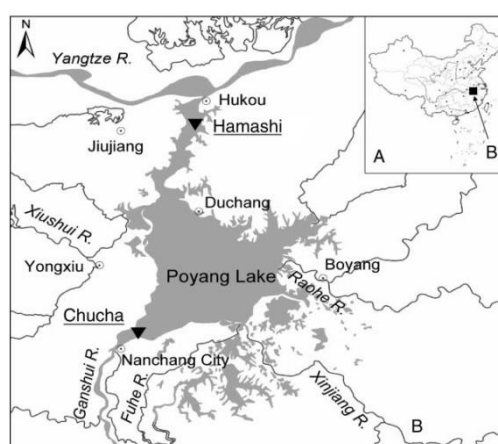
Figure 2. Location of the study area and monitoring sections.
(A) China. (B) Poyang Lake and its vicinity.

3. Method

DCCA was proposed by Podobnik and Stanley (2008) [11], which is an advanced method for avoiding the spurious correlation circumstance between two sequences resulted by their unstability, so it has become the most scientific and effective method to conduct quantitative analysis towards two groups of non-stationary time sequences and their interactive time scale characteristic. At present, the proposed method has been successfully applied in correlation analysis of natural science, such as financial market [12], biology [13], climatic change [14-15], Hydrological analysis [16], etc.

The detrended fluctuation covariance function $F(s)$ and scale s obey power-law cross-correlations in double logarithmic coordinates as shown $F^2(s) \sim s^\lambda$ [17], where λ is the long-range cross-correlation scale index, there is long-range interrelation between two sequences. $\lambda > 0.5$ indicates a positive long-range cross-correlation between two sequences; $\lambda < 0.5$, a negative long-range cross-correlation is present. As for $\lambda = 0.5$, there is non-long-range cross-correlation between two sequences.

4. Results and discussion

4.1. The nonlinear dynamic characteristics of CODMn sequence

We had drawn these type from field data of weekly average CODMn series of Poyang Lake Inlet and Outlet in 2D phase space as shown figure 3. As far as CODMn series is concerned, the delay time is 1w and 2w respectively. It could be seen from figure 3 that the shape of these tracks present the irregular mode of motion roughly, namely the centers are relatively dense and the margins are relatively sparse, which accounts for the mechanism that dominates Poyang Lake's CODMn is nonlinear, and the complexity of chaotic dynamics with certainty may be featured. This is unanimous to the research on CODMn series by foreign scholars. We could believe that CODMn sequence does not show a kind of purely random event at all, so the Hurst effect may exist[18].
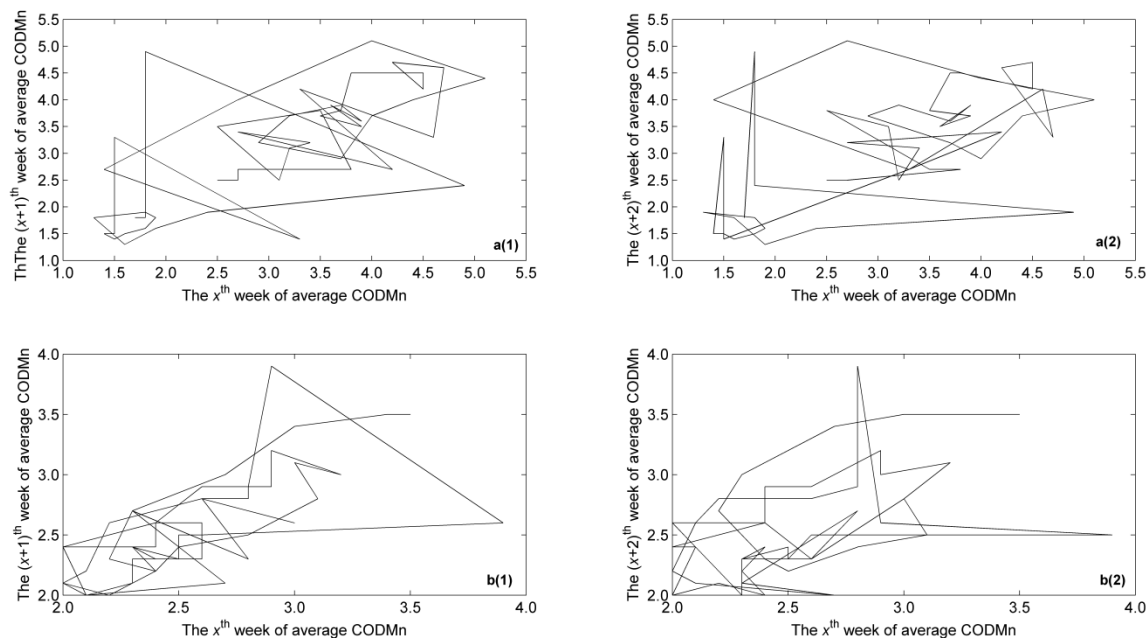

Figure 3. These type from field data of weekly average CODMn series of Poyang Lake Inlet (**a(1)** and **a(1)**) and Outlet (**b(1)** and b(**1**)) in 2D phase space

4.2. DCCA analysis

Figure 4 shows DCCA analysis results of CODMn of Poyang Lake Inlet and Outlet. There only scaling regions in the double logarithm curve $\log F^2(s) \sim \log s$. Namely, their long-range correlation show one scaling regimes with one different scale index λ. Linear fitting was respectively conducted

on the scaling regimes and the scale index λ is obtained, which reflecting the multi-scale response of the CODMn of Poyang Lake Inlet to that of Outlet in temporal scaling. $\lambda = 1.1062$ indicates high long-range correlation. The long-range correlation signifies that the water CODMn fluctuations in Lake Inlet and Outlet, from small time intervals to larger ones (up to 1 years at least), are positively correlated in a power-law fashion. For example, there is a tendency for increase in water CODMn to be followed by another increase in water CODMn at a different time in a power-law fashion. This suggests that the correlations between the fluctuations in lake water CODMn do not obey the classical Markov-type stochastic behavior (exponential decrease with time), but display more slowly decaying correlations[19]. This implies that the long-range correlation should be considered in the trend prediction of water CODMn as an important factor. However, the data set is only 1 years long. It needs longer series to confirm the critical correlated time scale where power-law scaling is varied.
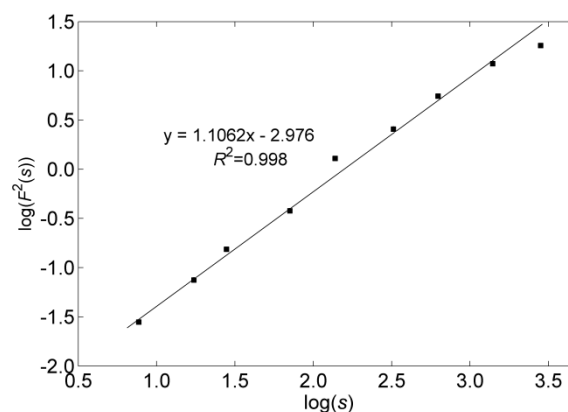
Figure 4. DCCA of of weekly average CODMn series of
Poyang Lake Inlet and Outlet

5. Conclusions

The temporal evolution of lake pollution is a complex phenomenon, which is formed with a complex interaction of various factors, such as the movements and transformation of pollutants, pollutants emission and climate condition. It is this complexity, which result in the mechanisms that drive lake pollutant temporal evolution. In this paper, the nonlinear dynamic characteristics of CODMn series of Poyang Lake Inlet and Outlet was explored using the space trajectory, which is the foundation of complexity research and of great significance. On this basis, long-range correlation between CODMn series of Poyang Lake Inlet and Outlet is investigated at the time scale of 52 weeks. The correlation showed the fluctuations in lake water CODMn do not obey the classical Markov-type stochastic behavior, but display more slowly decaying correlations.

Because of the evolution of CODMn concentration in Poyang Lake Inlet and Outlet exits non-linearity, non-stationery, complexity and so forth, the correlation and time scale characteristic of the stationary time sequence could not be analyzed accurately by means of traditional and statistical method easily. To adopt DCCA method will be beneficial for discussing the long-term interactive mechanism of CODMn between Poyang Lake Inlet and Outlet

The study can help to develop effective warning strategies to reduce impacts on lake pollution. It seems evident that the understanding of the complex dynamic characteristics of CODMn can contribute to developing advanced techniques for lake pollution forecasting.

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