Characteristics and Attribution Analysis of Non-stationary Extreme Tide Level in Huangpu River under Changing Environment

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ABSTRACT

Based on the maximum tide level series of four hydrological stations, Wusong, Huangpu Park, Wujing and Mishidu, along Huangpu River of China from 1964 to 2021, this paper assessed the non-stationary characteristics and its influencing factors. Our results showed that the maximum tide level showed an increasing trend, and gradually significant from the downstream to the upstream. But the two downstream stations showed a downward trend after the mutation years, thereby indicating that the upstream tide level had a pronounced dependence on the tidal upwelling and upstream inflow, while the downstream is affected by the typhoons and hydraulic engineering.

KEY WORDS: Huangpu River; non-stationary change; extreme tide level; attributional analysis.

INTRODUCTION

In the prevention and mitigation of coastal zones, the design of flood control tide level is a very critical task. As a key parameter for design tide level calculation, maximum tide level is also an important basis for coastal engineering planning and design (Huang, 2018; Zervas, 2005). Due to the magnitude and ubiquity of global climate change (Bograd, 2023; Feng, 2015; Talke, 2020) and the human activities (Orton, 2020), the stationary of tide level has changed in recent years. Milly (Milly, 2008) asserted that stationarity should no longer serve as a default assumption in water-resource risk assessment and planning, and a suitable successor should be found for human adaptation to change climate. The maximum tide level has changed non-stationary in recent years, which makes occurrence rules of hydrological extreme events more complicated (Ma, 2010; Nema, 2012; Wang, 2012). Therefore, it is of great necessary to grasp the non-stationary change law of tide level series under changing environment and clarify the reasons for the non-stationary change (Liu, 2018; Pei, 2020; Zhang, 2015).

Shanghai is a city with a large population and the most developed economy in China, a Riverside coastal megacity. Huangpu River which traverses the city, is easily affected by rainstorms, floods, typhoons and astronomical tides, causing abnormal rise of tide level and threatening the flood control safety of Shanghai (Liu, 2014; Quan, 2014; Yin, 2016). With the development of urbanization and the increasing influence of human activities, the frequency of flood is increasing year by year. In the past 30 years alone, there have been four major floods in the river basin in 1991, 1999, 2016 and 2020 (Qi, 2022), as well as a number of typhoon storm floods, such as “Maisha” in 2005, “Morakot” in 2009, “Haikui” in 2012, “Fitow” in 2013 and “In-Fa” in 2021, causing a large number of people missing, casualties and economic losses (Bao, 2015; Chen, 2021; Guo, 2020; Jing, 2014; Meng, 2007; Niu, 2011). In particular, the typhoon in 1997 impacted the tide level of Huangpu Park rose to 4.97m, and the tide level of Mishidu station in the upper reaches of Huangpu River also increased sharply due to the Typhoon “In-Fa”. Disaster prevention and reduction has become one of the important tasks in Shanghai, and it is of great significance for the tasks to master the non-stationary change law of tidal level sequence in the main stream of Huangpu River under changing environment and to clarify the causes of non-stationary change.

A large number of scholars have also carried out scientific research on the extreme tide level at Huangpu River, and the results show that there was a non-stationary change of extreme tide level over the year (Qu, 2018). The tide level of the main stream of Huangpu River is mainly affected by precipitation (Wang, 2018; Xu, 2007), sea level rise (Yin, 2013) and typhoon frequency (Yin, 2021), especially the astronomical tide (Lin, 2000) and construction of hydraulic projects (Li, 2011), which might cause the trend rise of the upstream tide level, upstream inflow, tidal upwelling and regional precipitation. In the future, the impact of upstream water level should also be considered in the construction of hydraulic engineering. And by using Pearson type III (P- III), Extreme Value Type One Distribution (EV- I) (Zhang, 2014) and Generalized Extreme Value (GEV) and other methods to analyze the frequency of the annual maximum tide level in the main stream of Huangpu River, some scholars found that the once-in-a-thousand years design tide level is higher than the flood control standard adopted in 1985 by the Ministry of Water Resources in Shanghai City (Ke, 2020; Ke, 2018). At present, the research on the change of extreme tide level in the main stream of Huangpu River is far from enough.

This paper selected four representative level stations of Wujing Station, Huangpu Park Station, Wujing Station and Wusong Station...