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A New Understanding of the Poyang Lake-Yangtze River Interaction: A Backwater Effect on the Yangtze River Perspective

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Key Points:

- The water surface slope of the Yangtze near the confluence can be halved due to backwater effects
- The backwater effects can extend to around 74 km upstream of the confluence
- The highest elevated water level at Jiujiang (24 km upstream of the confluence) is estimated to be up to 14.1 m

Supporting Information:

Supporting Information may be found in the online version of this article.

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Abstract Interconnected river-lake systems are much more complex than either one due to their interactions. The Poyang Lake-Yangtze River system has received much attention due to the reverse flow from the Yangtze River, which blocks the flow of Poyang Lake and causes extensive inundation. However, a less explored perspective is the backwater effects of lake outflow on the Yangtze River. This study seeks to fill this gap by investigating the water surface slope (WSS) along the 294 km reach upstream of the confluence. Results show that huge variations of WSS (the maximum doubles the minimum) occur due to the dynamics of lake outflow and river discharge. The backwater can extend upstream to around 74 km. Elevated water level at Jiujiang can be up to 14.1 m in the worst case. The findings can advance our understanding of complex hydrodynamic processes in river-lake systems and provide important policy implications for flood management.

Plain Language Summary River networks are very complex. When two rivers meet, they can lead to complicated hydraulic characteristics at the confluence. For instance, their interaction can cause variations in flow velocity by giving an additional gradient in water level, which is known as a backwater effect. Such an effect can cause severe flood events due to the elevated water levels. In this study, we investigated the effects of Poyang Lake outflow on the Yangtze River from a novel perspective of river surface slope. With the advancements in wide-swath altimetry, the hydraulic characteristics of river-lake confluence can be better quantified. The findings shown in this study are essential for flood control, flood risk evaluation, and engineering issues.

1. Introduction

Rivers and lakes are fundamental landscape units, and supply water that supports many forms of life (Poff, 2019). Connected rivers and lakes, often referred to as river-lake systems, are more complex than either due to the river-lake interactions (Lesack & Marsh, 2010). The Yangtze River-Poyang Lake system in China is such a complex system (Hu et al., 2007). However, instead of river-lake connection in series, Poyang Lake is a major tributary recharging the Yangtze River. There are five major rivers draining a total area of about 136,000 km^2 into the Poyang Lake, and then the lake naturally discharges an average of about 140 km^3 per year to the Yangtze River. Poyang Lake is a critical habitat for fish species and many migratory birds. However, the hydrological regime has undergone pronounced changes during the past two decades, and the ecosystem is under threat from both human activities and climate change (Q. Zhang et al., 2023). The dynamic lake-river interactions have received much attention in the context of recent extreme events. Most studies focus on the exchange of water, sediment, and pollutants between lakes and rivers, as well as hydrodynamic modeling in the context of climate change and human activities (M. Chen et al., 2022; Guo et al., 2012; Hu et al., 2007; Yang et al., 2016). In the recent decade, more effort has been put into understanding the severe and extended dry periods of Poyang Lake (Feng et al., 2013; Guo et al., 2012; Hu et al., 2007; Wang et al., 2017; Yang et al., 2016). For instance, Li et al. (2023)

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found that hydrological droughts became increasingly severe from 1964 to 2016, and such changes may relate to large-scale climate systems.

However, previous studies mostly focus on the impacts of Yangtze River on the Poyang Lake. A less explored perspective is the backwater effects of Poyang Lake on the Yangtze River. Broadly, the backwater effects may occur when one or more downstream elements, such as lakes, tributaries, ponds, dams, levees, and tides, exist. Consequently, the river flow will be blocked, and water will be backed up in its course by the downstream elements such that the water level is higher than the smallest level required for conveying the same discharge (Chow, 1959; Petersen-Øverleir & Reitan, 2009). Therefore, the WSS gets smaller due to the loss of water energy for a similar discharge over the affected river reach (Castelltort et al., 2020; Hidayat et al., 2011). One of the most representative examples of such backwater effects is the Amazon river system (Meade et al., 1991; Trigg et al., 2009), where the lengths of reach affected by backwater were estimated to be at least 300 km, 810 km, and 890 km in the Negro River, the Madeira River, and the Purus River, respectively. Moreover, the elevated river level can be 2–3 m at a station even 260 km upstream of the Madeira River, which leads to a halved river surface slope (Meade et al., 1991). The backwater effects at confluences of many other rivers have also been studied, such as the Mississippi River (Edwards et al., 2016; Lamb et al., 2012), the Missouri River (Liu et al., 2023), and so on. Practically, this elevated water level can increase the flood risk vulnerability in flood-prone areas (Jiang et al., 2020; Luo et al., 2017; X. Zhang et al., 2023).

The backwater effects of lake outflow are widely reported. For instance, the backwater flow from lakes (e.g., Lake Tana, Lake Kyoga, Lake Victoria, etc.) in the Nile River basin has been widely studied (Sutcliffe & Brown, 2018; TATE et al., 2001). Abate et al. (2015) attributed the sediment deposition in the Gumara River of the upper Blue Nile basin to the backwater effect of Lake Tana. Petersen-Øverleir and Reitan (2009) found that Lake Vansjø backed up the flow in the Guthusbekken stream for almost a month during a major flood event. Moreover, Hidayat et al. (2011) concluded that the backwater effects from lakes and tributaries have a considerable impact on river discharge estimates. Lake outflow changes the flow regime not only upstream (backwater) but also downstream (drawdown).

Poyang Lake and Yangtze River are more complex than other run-of-river lake-river systems. However, it has not been well studied in the literature that how Poyang Lake affects Yangtze River. Several questions remain to be answered. Is the backwater effect of the Poyang Lake negligible or pronounced? To what extent does the backwater affect the Yangtze River? How does the interplay of the Poyang Lake outflow and the Yangtze River discharge affect the backwater events? Therefore, the overarching goal of this study is to investigate and analyze the response of Yangtze River flow to the outflow of Poyang Lake from the perspective of water level change and associated river WSS.

2. Data and Methods

2.1. Study Area

The Yangtze-Poyang Lake system is one of the largest river-lake systems worldwide. In this study, we focus on the reach between Hankou station (GS_1) and Pengze station (GS_6), which is about 335 km. As shown in Figure 1, the studied reach is separated into small reaches by the six gauging stations, which are numbered in downstream order. The Poyang Lake joins the Yangtze River around the Hukou station (GS_5), where the elevation difference between GS_5 and the confluence is negligible (see Text S1 and Table S1 in Supporting Information S1). The Jiujiang-Hukou reach (RR_4-5) and the Hukou-Pengze reach (RR_5-6) are the adjacent upstream and downstream reaches referencing the Hukou station. In general, the slope of the whole reach is gentle as shown in Figure 1. Clearly, DEM-derived water slopes of RR_2-3 and RR_3-4 are negative most likely due to lower accuracy of SRTM DEM. Therefore, we estimate the slopes based on dry season water levels.

2.2. Data

The main gauge data used are water level and discharge from the Hubei Hydroinfo website. Daily water levels between 2007 and 2022 were collected at all six gauging stations, while discharge was only available at GS_1, GS_4, and GS_5 for the same period. Below, we used the symbols Q1, Q4, and Q5 to indicate the discharge at GS_1, GS_4, and GS_5, respectively. Q5 represents the Poyang Lake outflow. In principle, Water Surface Slope (WSS) can be calculated for reaches between any two stations, which is indicated by the acronym WSS followed

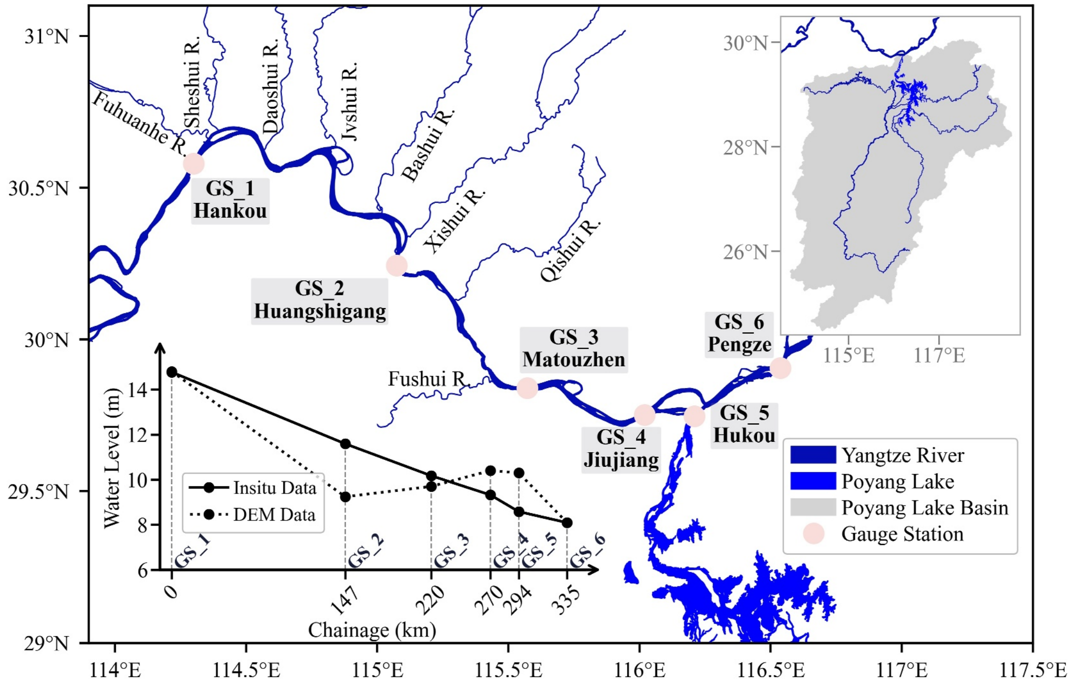

Figure 1. A detailed river network of the Yangtze River between Hankou station and Pengze station, along with the six gauging stations. Major tributaries of the Yangtze River are shown with labeled names. Rivers and lake were obtained from National Geomatics Center of China (https://www.ngcc.cn/). The left inset plot shows the river longitudinal profile, with the chainage referencing to Hankou station. Note that the insitu data in the profile is the median of observed water level during the dry season (Dec, Jan, and Feb) over the period from 2007 to 2020 while DEM from MERIT DEM.

by the station numbers (e.g., WSS_1–4 for the slope of the reach between stations GS_1 and GS_4). In addition, river cross-sectional profiles at station GS_4 were also collected from the China Hydrological Yearbook to calculate the water depth.

2.3. Methods

Based on the twin-gauge approach, the WSS of each river reach can be calculated using the equation below:

$$\mathrm{WSS} = \frac{\Delta Z}{x} \tag{1}$$

where x is the reach length (m), ΔZ is the water level difference at the twin gauges of the reach of interest (m). The WSS values are expressed in units of cm/km.

To understand the raised water level by backwater, the difference between the normal depth and actual water depth is used and calculated as follows:

$$y_{\mathrm{diff}} = y_a - y_n \tag{2}$$

where y_n is the normal water depth, which refers to the water depth under steady uniform flow, and y_a is the actual water depth. y_a can be directly calculated by subtracting the channel datum from the water level.

Below, we describe the way to calculate y_n. Since we only have the cross-section profiles at station GS_4, the y_a is thus only calculated for this section. Here, we assume the riverbed gradient is constant between GS_4 and GS_5.

Based on surveyed cross-section data, the river width (w), wetted perimeter (P), and flow area (A) corresponding to the daily water level can be calculated. Thus, we can obtain the hydraulic radius R, that is, A/P. Therefore, we can express the discharge using Manning's equation as:

$$Q = \frac{1}{n} AR^{2/3} S_f^{1/2} \tag{3}$$

where Q donates the discharge, S_f is the friction slope, which can be approximated by the riverbed slope (S_0) under steady flow. Here, S_f is calculated based on the water levels in November 2022 (Text S2 and Figure S1 in Supporting Information S1) when we assume the flow is in a steady state. Note that the choice of dry season months has marginal impact on the calculation of S_f, which consequently has little influence on y_{diff} (refer to Table S2 in Supporting Information S1). In this way, we can resolve the Manning's n as below:

$$n = \frac{1}{Q} AR^{2/3} S_0^{1/2} \tag{4}$$

Based on the data during the dry season (Nov to Feb, see Text S3, Figure S2b in Supporting Information S1), the calculated range of n is between 0.026 and 0.053. The accurate Manning's n for a certain water level is difficult to determine. It is well known that Manning's n decreases with the increase of discharge or depth for large rivers (Alves et al., 2020; Tahmid et al., 2021). Here, we assume that n is inversely proportional to the water level, as expressed below:

$$n = n_{\max} - (n_{\max} - n_{\min}) \times \left(y_a / y_a^{\max}\right) \tag{5}$$

Linear instead of exponential relationships used is because of the lack of data to fit such a function. Since Manning's n can be slightly different in the wet seasons, different values of the maximum ($n_{\max}$) and minimum ($n_{\min}$) were used to consider the uncertainty. Based on the values calculated using dry season flows, the maximum ($n_{\max}$) and minimum ($n_{\min}$) are in the range of [0.05, 0.06] and [0.005, 0.03], respectively, and with an interval of 0.005. Therefore, a total of 18 combinations of $n_{\min}$ and $n_{\max}$ were obtained. Consequently, the calculated normal depth y_n and raised water level y_{diff} also have 18 values.

Given that y_n is a function of cross-sectional geometry (i.e., $AR^{2/3}$, see Figure S3 in Supporting Information S1), we just solve Equation 3 for $AR^{2/3}$ under the steady uniform flow condition to determine y_n. Substituting the values of above variables under steady uniform state, we can get the normal water depth y_n:

$$y_n = \left(\frac{Q \cdot n}{\alpha \cdot S_f^{\frac{1}{2}}} \right)^{\frac{1}{\theta}} \tag{6}$$

where α and θ are the fitting parameters derived from the relationship $AR^{2/3} \sim y_n$. Considering the varying nature of the cross-sectional profile, we fit a power-law function between y_n and $AR^{2/3}$ for each year from 2011 to 2020 (Table S3 in Supporting Information S1).

3. Results

3.1. Backwater Effects at the Confluence

Figure 2a shows the daily WSS variations of 11 reaches over a long term. It is obvious that the WSS for most reaches less variable throughout the year, while WSS_4-5 is remarkably higher during the dry seasons than wet seasons. Nevertheless, the Froude number (Fr) at GS_4 throughout the year is always far less than 1, indicating that the flow is always in subcritical state, excluding the flow state change (Fr < 0.2, see Text S4 and Figure S4 in Supporting Information S1). Clearly, close to the river-lake confluence, WSS_4-5 and WSS_5-6 have very distinct temporal patterns. Specifically, WSS_4-5 quickly declines at mid-February. WSS_4-5 reaches three local minimums at the end of March, June, and September, respectively, and reaches the maximum at the end of December. Correspondingly, WSS_5-6 generally follows the opposite direction, quickly rising at the end of March, reaching a maximum in June and July, and resuming the lower value at the end of December. Moreover, WSS_5-6 even exceeds WSS_4-5 from June to July. Such a phenomenon is mainly due to the backwater effects because, in a normal state, the WSS of a river reach does not change dramatically, not to mention over such a long period as 12 months in a multi-year average condition.

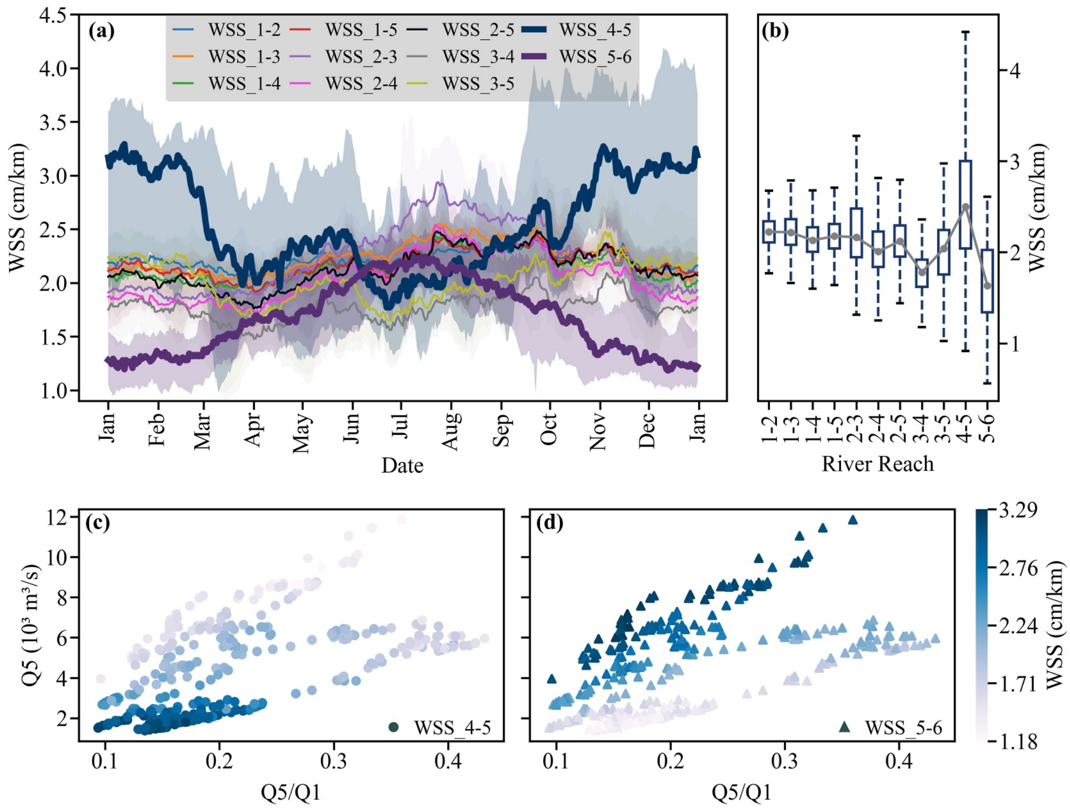

Figure 2. Intra-annual variation of water surface slope (WSS) at the multi-year (2007–2020) level for the total of 11 river reaches from Hankou to Pengze. (a) The line indicates the median daily WSS value for each river reach, and the shaded area represents the 5%–95% confidence interval. (b) The boxplot of all daily WSS values for the 11 river reaches over the entire period, with the gray line connecting the median values of each group. (c) Scatter plots of the relationships between WSS_4–5 and the corresponding Q5 and Q5/Q1. (d) Similar to (c), but for WSS_5–6.

This pattern is very well aligned with the ratio of lake outflow and river flow (Q5/Q1, see Figure S5 in Supporting Information S1). As the ratio increases, the backwater effects are more pronounced, leading to a raised water level at the confluence. Consequently, WSS_4-5 declines and WSS_5-6 increases, respectively. However, it has to be noted that the backwater effects not only rely on the flow ratio but also the absolute value of the lake outflow (Q5), as illustrated in Figures 2c and 2d. For instance, when the ratio is about 0.3, the backwater would be stronger when Q5 is larger, that is, larger WSS_5-6 (darker triangles) and smaller WSS_4-5 (lighter circles).

The intra-annual variability of WSS is pronounced, especially for the reaches close to the confluence, as indicated by the thick lines and boxplots in Figures 2a and 2b, respectively. The WSS is nearly halved or doubled for WSS_4-5 and WSS_5-6 in June and July when the flows are larger (Figure S5b in Supporting Information S1), and the backwater effects are also stronger. Throughout the year, the long-term daily median value of WSS_4-5 varies between 1.77 and 3.29 cm/km, while the median value of WSS_5-6 varies between 1.18 and 2.24 cm/km. Moreover, the WSS values of different river reaches are markedly different across seasons (Figure S6 in Supporting Information S1) due to the interplay of the two flows. The smallest variations are in winter, which is reasonable considering the low flow of both the Yangtze River and Poyang Lake (Figure S6 in Supporting Information S1).

The above results clearly indicate the backwater effects of the Poyang Lake exerted on the Yangtze River, mainly leading to elevated water levels and associated declined WSS upstream. We can also see that the variation of WSS_3–5 is also large, indicating a larger spatial extent of the backwater effects. Below, we will further explore how far upstream the backwater affects.

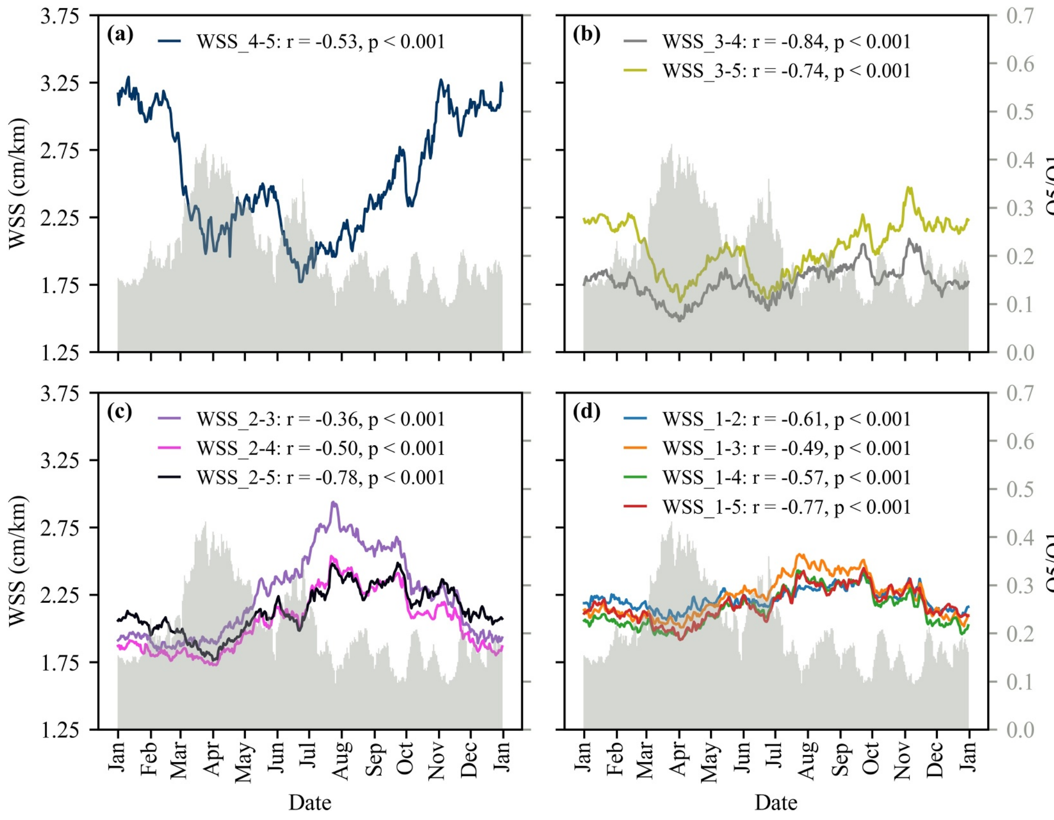

Figure 3. Temporal variations of water surface slope (WSS) and the ratio of discharge for 10 reaches under multi-year average conditions (2007–2020). Lines representing WSS refer to the left *y*-axis, and gray shading areas representing Q5/Q1 refer to the right *y*-axis. (a) to (d) shows reaches with upstream gauge station GS_4, GS_3, GS_2, and GS_1, respectively. Pearson's correlation coefficient and *p*-value between WSS and the Q5/Q1 for each river reach have been labeled in the corresponding legends. The color scheme is consistent with Figure 2a.

3.2. Spatial Extent of Backwater Affected Reaches

As shown in Figure 3, the reaches upstream of the confluence are grouped into four based on the upstream gauge station of each reach. Overall, the WSS of all reaches is well negatively correlated with the flow ratio, indicating a potential backwater effect. As shown in Figure 3a, we know that this reach is clearly affected by backwater, but the correlation between WSS and Q5/Q1 is not perfect ($r = -0.53$). This can be explained by the unequal impacts of backwater exerted on GS_4 and GS_5, which leads to different rises in water levels at the gauges. This means that the backwater extends further upstream gauge 4, which can be proved by Figure 3b. Both WSS_3–5 and WSS_3-4 decline as the flow ratio increases. One may argue that this might be due to upstream flood events. However, this is not possible in multi-year conditions. Moreover, the difference (ΔWSS_35–34) between WSS_3–5 and WSS_3–4 also declines instead of constant. In the latter case, it will be likely due to floods. The reason for this varying ΔWSS_35–34 is that the water level rising rate is also changing and larger at GS_5 than at GS_4. As shown in Figure 3b, in January and February, RR_3–5 is steeper than RR_3–4. As the flow ratio increases, RR_3–5 is getting less steep, and in June, it is almost the same as RR_3–4, indicating that the backwater is stronger at GS_5 than GS_4. Nevertheless, this analysis suggests that the backwater can extend up to GS_4, although not that strong compared to GS_5. This is consistent with Wang et al. (2013), that the Poyang Lake outflow caused strong backwater effects on the upstream vicinity of Jiujiang (i.e., GS_4).

Taking longer reach into consideration, the WSS variations are very different, as shown in Figure 3c. The temporal patterns of WSS_2–3, WSS_2–4, and especially WSS_2–5 are very similar to that of WSS_3–4 and WSS_3–5 before mid-May but differ after. The reason is that Q1 increases sharply in May and peaks in late July, while Q5 increases in March and peaks in late June (Figure S5b in Supporting Information S1). Besides, several tributaries recharge the Yangtze River upstream GS_2. Such configuration leads to complex interplay at reaches

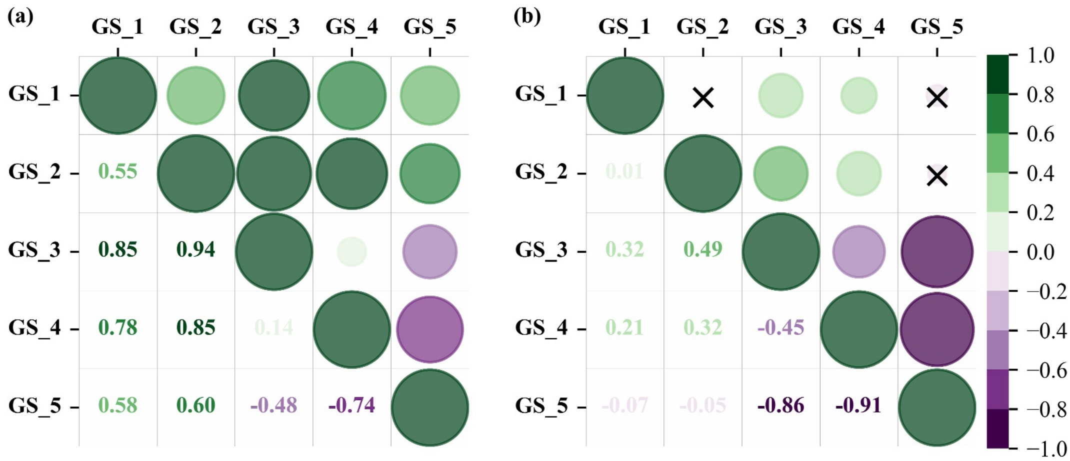

Figure 4. The correlation matrix of median water surface slope (WSS) with median Q values under the multi-year (2007–2020) condition. The labels on the top and left indicate the gauge station thus, the element (GS_2, GS_1), for example, is the correlation for reach RR_1–2. The symbol "×" indicates the correlation is not significant at 0.05 level. The size of the circles indicates the magnitude of the correlation coefficients, as numbered in the elements below the main diagonal. (a) The correlation between Q1 and the WSS, and (b) The correlation between Q5 and the WSS.

RR_2–5 between upstream floods and downstream backwater. For instance, the rise of WSS_2–3 after May is much larger than WSS_2–4 and WSS_2–5 due to the increased upstream flow, while due to the backwater effects, the latter two are not that much (Figure 3c). Therefore, GS_2 is likely more affected by upstream flow, while GS_3 is more affected by backwater, at least in the summer period. Figure 3d shows that backwater at GS_1 is very likely marginal if not free.

We further explored the potential effects of upstream flow and downstream backwater by analyzing the correlation between flows from the upstream Yangtze River and Poyang Lake and WSS, as shown in Figure 4. In general, the closer to GS_1 (Q1), the stronger the correlation between Q1 and WSS, indicating larger flow increases the WSS. One exception is WSS_1–2, which shows a weaker correlation with Q1. This can be attributed to the influences of six major tributaries between GS_1 and GS_2 (Figure 1). However, no large lateral inflows downstream GS_2 recharge into the Yangtze River (see Text S5 and Figure S7 in Supporting Information S1). All reaches starting from GS_2 are strongly correlated with Q1, showing the dominant control of upstream flow at GS_2. Moreover, we can see that WSS_3–5 and WSS_4–5 are negatively correlated with Q1, indicating that backwater is the dominant factor influencing WSS at these two reaches. This is in line with the above findings.

Figure 4b shows the effect of Poyang Lake flow (Q5) on WSS. There are no statistical correlations between WSS_1–2 and Q5, and the correlations between WSS_1–3, WSS1-4, and Q5 are weak, indicating no backwater effect at GS_1. This is also in line with Figure 3d. The correlations between WSS_2–3, WSS2-4, and Q5 are positive but weaker than with Q1, suggesting a dominant control of upstream flow at GS_2. In contrast, both WSS_3–5 and WSS_4–5 have strong negative correlations with Q5, suggesting the backwater effect. While WSS_3–4 negatively correlates with Q5, it very weakly correlates with Q1, indicating that RR_3–4 is still dominated by downstream backwater.

In short, the backwater can extend up to around GS_3, which is 74 km away from the confluence. However, the reach RR_23 may still be affected by the backwater, especially before March (Figure 3c). Because GS_2 is greatly affected by its upstream inflows (mainstem and tributaries). Therefore, the backwater effect cannot be distinguished.

3.3. Elevated Water Levels Due to Backwater Effects

Due to the lack of river bathymetry, we only focused on the section at GS_4. As mentioned in the method section, the uncertainty was considered by adopting different Manning's n values. Figure 5 shows the elevated water levels, that is, y_{diff}, using different values of Manning's n. Clearly, Manning's n has a large impact on the elevated water levels. Nevertheless, the elevated water level increase with the decrease of WSS in all scenarios (Figure 5).

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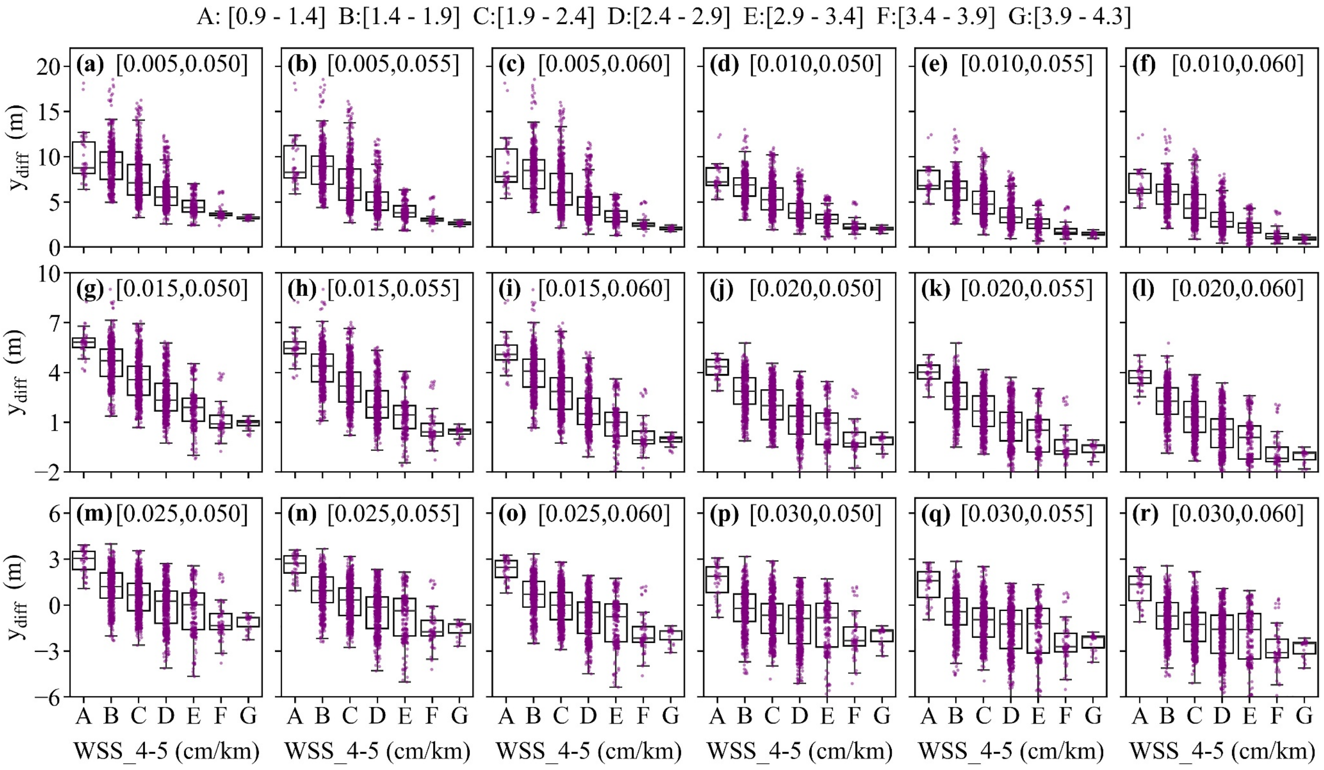

Figure 5. Estimates of raised water level, that is, y_{diff}, grouped into different water surface slope intervals under 18 sets of minimum and maximum Manning's n values. Symbols A to G represent the seven different WSS_4–5 intervals. The purple dots indicate the data points of the water depth difference y_{diff}. Note that here $S_0 = 4.3$ cm/km and Q4 from March to October of each year from 2011 to 2020 were used.

And the strong backwater (higher y_{diff}) generally leads to a very flat slope, that is, 0.9–1.4 cm/km. The range of the max values of y_{diff} for different combinations is 2.6–14.1 m (Figure 5). This means that in the worst case, y_{diff} can be up to 14.1 m (Figure 5a), while in the best case the max y_{diff} is still up to 2.6 m (Figure 5r). In the most reasonable case, that is, Manning's n taking the value between 0.015 and 0.055, the highest elevated water level is about 7.1 m (Figure 5h). One might notice that negative y_{diff} are shown in some cases. This can be explained by either unreasonable n values used or the poor power-law fitting equation for low flow seasons. This can be clearly seen in years 2013 and 2017 (Figures S3 and S8 in Supporting Information S1, refer to Text S6 in Supporting Information S1 for more details).

WSS_4–5 and the flow ratio show a strong negative correlation in all years except 2020 (Figure S9 in Supporting Information S1), indicating that given similar Yangtze River flow (Q4), a larger flow (Q5) from Poyang Lake will result in stronger backwater effects, leading to a smaller WSS. In other words, if the WSS_4–5 is continuously monitored, the backwater and elevated water levels can be estimated. Regarding the 2020 case, the Pearson correlation coefficient between WSS_4–5 and the flow ratio is strong before 17 June 2020. However, due to the quick increase of Yangtze River flow since 17 June 2020, the Poyang Lake flow was reversed, resulting in a negative flow ratio (Figure S10 in Supporting Information S1). The complex interactions of the two flows over the period thereafter leads to a poor overall correlation between WSS_4–5 and discharge in 2020.

4. Discussion and Conclusions

In this study, we revisited the Poyang Lake-Yangtze River interaction from a new perspective. Previous studies have mainly focused on the impact of the Yangtze River on Poyang Lake, while the reverse has been studied less. Using water levels and associated water surface slopes, we first identified the pronounced backwater effects of Poyang Lake outflows on the Yangtze River. Then, we quantified the spatial extent of such effects. We also estimated the water levels raised at the confluence due to such phenomena.

We found that the backwater is pronounced at the confluence of the Poyang Lake-Yangtze River, leading to halved and doubled water surface slopes upstream and downstream the confluence during summer seasons. Further analyses indicate that the backwater can extend much further upstream to around 74 km at the Matouzhen station (GS_3) and may be even further to Huangshigang (147 km, GS_2) in March. Nevertheless, we also found that backwater can result in the highest elevated water level up to 7.1 m in the most reasonable case while 14.1 m in the worst case at the Jiujiang station (GS_4), which is 24 km away from the confluence.

The results indicate that by observing the WSS, say from SWOT (Surface Water and Ocean Topography) mission (Biancamaria et al., 2016) for example, we are able to detect whether backwater event occurs. This might be useful to monitor the interactions between the Yangtze River and Poyang Lake and inform the flood conditions. Moreover, the findings also indicate that pronounced backwater events can occur when the Poyang Lake outflow is large and the ratio between the Yangtze River flow and Poyang Lake outflow is high. Such events often lead to elevated water levels upstream the confluence and consequently, increase the flood risks. To reduce the risk brought by backwater events, we need to reduce either the lake outflow or the ratio of two flows. In this context, lake flow or river flow has to be regulated. For instance, building a dam on the Poyang Lake might solve this issue.

However, due to limited gauges and cross-section data, we are still not able to determine the precise location where the backwater effects extend to. Moreover, the extent may also vary in time due to the combination of the flows of Yangtze River and Poyang Lake. In the future, with detailed river bathymetry and finer-scale longitudinal profiles such as that from SWOT, we can better quantify the extent of backwater effects and the resulting elevated water levels along the river. Similarly, the raised water level of Poyang Lake may also be investigated using SWOT data. Although our study provides an estimation of the backwater effects from a spatial perspective, we are unable to fully capture the temporal dynamics of the backwater effect. In reality, the backwater effect takes time to propagate upstream. This may be addressed by using higher spatiotemporal resolution data in the future.

In a warming climate, extreme flood events will likely become more frequent (J. Chen et al., 2023; Huang et al., 2024), which will likely induce stronger backwater at the confluence of the Poyang Lake and Yangtze River. Therefore, the backwater affected reach will likely be more upstream, and the associated water levels will also be much higher. Such situations will increase flood risks and challenge the current flood-prevention infrastructure of the Yangtze River. Therefore, a better understanding of the river-lake interaction is of great importance. Moreover, in the future, continuous monitoring of river long profile dynamics from space, for example, SWOT would be very helpful.

Data Availability Statement

Data used in this study were mainly downloaded from the Hubei Hydroinfo website (https://hbwater.wetruetech.com/water/portal/water_details2).

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