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Calculating the sediment flux of the small coastal watersheds: a modification of global equations

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Abstract

Two kinds of regression equations are used to reproduce the sediment flux of the 26 small coastal watersheds in southeastern China. The first kind is the global equations suggested by Milliman and Syvitski (1992), Mulder and Syvitski (1996), Syvitski et al. (2003), and Syvitski and Milliman (2007). The second kind is the modified equations revised by the characteristics of the coastal watersheds, including the drainage area, mean water discharge, and mean sediment discharge. Compared with the observations of the hydrometric stations, the global equations overestimate the sediment flux by 1–2 orders of magnitude. By using the modified equations, the accuracy of the estimated sediment flux is significantly improved, with the relative error in the range of 7%–24%. The reason for the overestimation mainly caused by different parameters' domain and regression coefficients between global rivers and study coastal watersheds. This study demonstrates that modification needs to be considered when using global regression equations to reproduce the sediment flux of the small coastal watersheds in southeastern China.

Key words: sediment flux, global equation, modified equation, small coastal watersheds, southeast China

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1 Introduction

Continental shelf sedimentary systems grow or retreat in response to fluvial sediment discharge. They are the tape records of the past climate, environment, and ecosystem changes (Bianchi and Allison, 2009; Gao and Collins, 2014). Crucial to this understanding is knowledge of the ambient fluvial sediment flux (Milliman and Meade, 1983; Syvitski et al., 2003; Jia et al., 2018). Traditionally, the most direct way to estimate the fluvial sediment flux is to analyze the data of hydrometric stations near an estuary (Holeman, 1968; Milliman and Farnsworth, 2013). Meanwhile, not all rivers have hydrometric stations near the estuaries. Consequently, empirical regression models, namely the global equations in this study, are built for estimating the long-term flux of sediment to the sea/ocean (e.g., Milliman and Syvitski, 1992; Mulder and Syvitski, 1996; Syvitski et al., 2003; Syvitski and Milliman, 2007). These models not only can be used to assess the impact of perturbations in sediment discharge but also can be provided in areas where there are no observational data.

The global regression equations are built on an extensive database of hundreds of global rivers. Milliman and Syvitski (1992) suggested that a strong correlation exists between the fluvial sediment flux and the watershed area, considering relief classes. Mulder and Syvitski (1996) introduced the maximum relief of watershed into the global equation, instead of the relief classes. Syvitski et al. (2003) pointed out that the watershed temperature also affects a river's sediment flux. Syvitski and Milliman (2007) established the famous sediment flux predictor, i.e., the BQART model, taking the impact of human activities into consideration. Based on these global regression equations, only a few watershed characteristics, such as the area, maximum relief, and mean temperature, are enough for calculating the sediment flux of a coastal watershed (e.g., Nienhuis et al., 2015; Li et al., 2018; Tessler et al., 2018; Molliex et al., 2019).

Despite considerable advantages, the sediment loads of small rivers calculating by using these global regression equations are of uncertainty. For major sediment-discharging rivers (greater than 10 Mt/a), the sediment yield decreases about 7-fold with every order of magnitude increase in watershed area (Milliman and Meade, 1983). The authors suggested that in a smaller watershed, what is eroded is more wholly removed to the sea/ocean, resulting in larger yields than larger watersheds. For example, small rivers drainage the East Indies and Taiwan Island discharge a disproportionately large amount of sediment to the ocean. Because of the high topographic relief, relatively young and erodible rocks, and heavy rainfall (Milliman et al., 1999; Dadson et al., 2003). On the contrary, Li et al. (2019) pointed out that the BQART model overestimates one order of magnitude of the sediment flux for the small rivers in coastal Hainan, southern China. However, it is necessary to carry out a systematic investigation into the applicability of global equations in local small

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rivers.

This paper attempted to reproduce the sediment flux of small coastal watersheds in southeast China (Fig. 1). First, a database of watershed characteristics is established based on published studies. Second, the four global equations are used to calculate the sediment flux of the coastal watersheds. Third, regression coefficients of global equations are modified using the characteristics of the coastal watersheds. So, then the modified equations are used to calculate the sediment flux of the coastal watersheds. On such a basis, why and how much the rivers in southeast China deviate from the global trend and how to use the global equations to reproduce the sediment flux of small coastal rivers are analyzed.

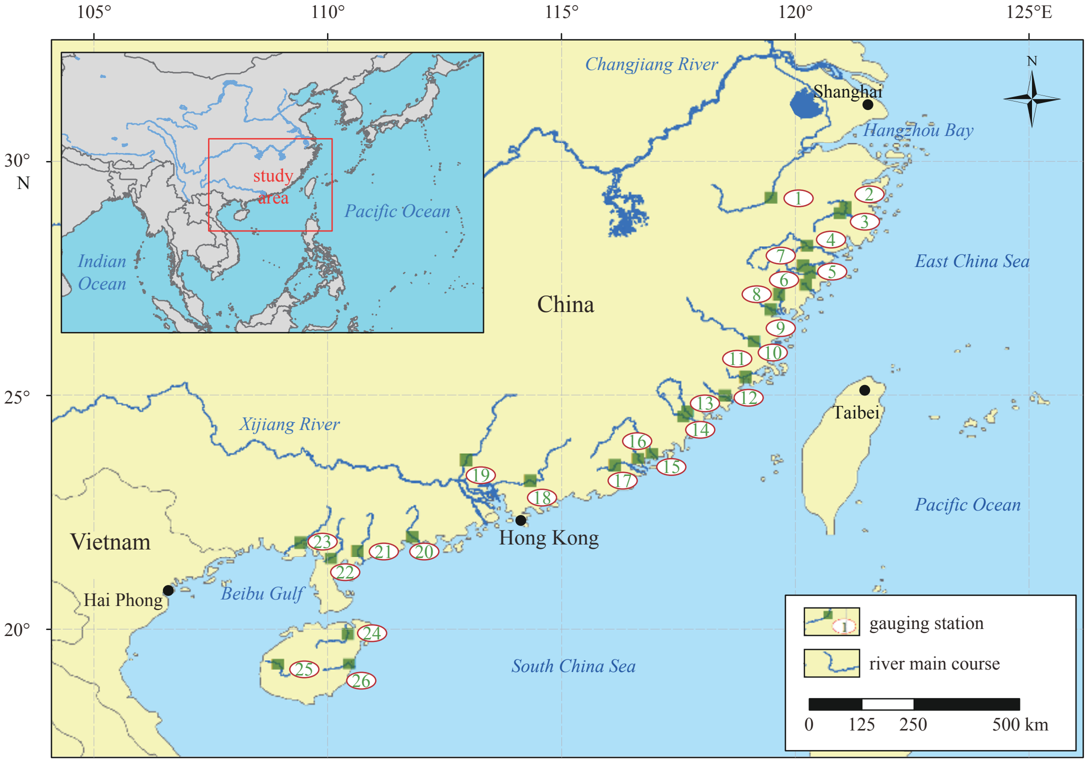

Fig. 1. Locations of the river main courses and their gauging stations of the 26 coastal watersheds in southeast China: (1) Qiantangjiang River; (2) Jiao-Yonganxi; (3) Jiao-Shifengxi; (4) Ou River; (5) Feiyunxi ; (6) Aojiang River; (7) Shuibeixi; (8) Saijiang River; (9) Huotongxi; (10) Minjiang River; (11) Mulanxi; (12) Jinjiang River; (13) Jiulongjiang-Beixi; (14) Jiulongjiang-Xixi; (15) Huanggang; (16) Hanjiang River; (17) Rongjiang River; (18) Dongjiang River; (19) Beijiang River; (20) Moyang; (21) Jianjiang River; (22) Jiuzhoujiang River; (23) Nanliujiang River; (24) Nandujiang River; (25) Changhuajiang River; (26) Wanquan.

2 Materials and methods

2.1 *Study area*

The study area includes 26 coastal watersheds in southeast China (Fig. 1). They are located on the east Qinzhou-South China orogenic belt. Their outcrop rocks composed of almost consistent Cenozoic-Holocene igneous and sedimentary rocks (Gao, 1988; Gao et al., 2016). Tropical monsoons dominate the climate. Northerly wind dominates in winter (from November to March), whereas southeasterly wind dominates in summer (from May to September). During summer months, these watersheds are significantly influenced by typhoons (Shanghai Typhoon Institute of China Meteorological Administration, 2006; Gao et al., 2016). Their maximum relief and mean temperature are within the range of 596–2 158 m and 15.5–24.0°C, respectively. The drainage areas of hydrometric stations are in the range of 341–54 500 km^2.

2.2 *Data collection*

Two data sets are used in this study. The first data set is the parameters of background setting, including the maximum relief and mean temperature (Figs 2a and b). The characteristic values of hydrometric gauging stations, including the drainage area, mean water discharge, and mean sediment discharge, is the second data set (Figs 2c, d and e). The data sources of these data sets are collected from published papers, books, and websites, such as Zhang et al. (2015), WRD (2016), Editorial Board of *Encyclopedia of Rivers and Lakes in China* (2013, 2014), and Baidu Wikipedia (http://baike.baidu.com).

The effects of both intensive human activities and climate changes of the recent 40 years on water discharge and sediment discharge are determined by two situations. The first situation is defined as the value before large-scale human activities (pristine discharge), which takes the averaged measured value of hydrometric gauging stations prior to 1980 as a characteristic value. The second situation is the value influenced intensively by human activities and climate changes (disturbed discharge), which takes the averaged measured value since 1980 as a characteristic value. The pristine and disturbed sediment discharge are in the range of 0.06–7.48 Mt/a and 0.03–6.61 Mt/a, respectively.

Among all coastal watersheds, the pristine sediment and water discharge of the Mulanxi, Jiulongjiang-Xixi, Huanggang, Rongjiang River, Moyang, and Jiuzhoujiang River are not available, and the disturbed water discharge of Jiulongjiang-Beixi is not available. According to the statistic results of available data, on average, the pristine water discharge is slightly lower (0.48%) than the disturbed water discharge. However, the pristine sediment discharge is relatively higher (21.48%) than the disturbed

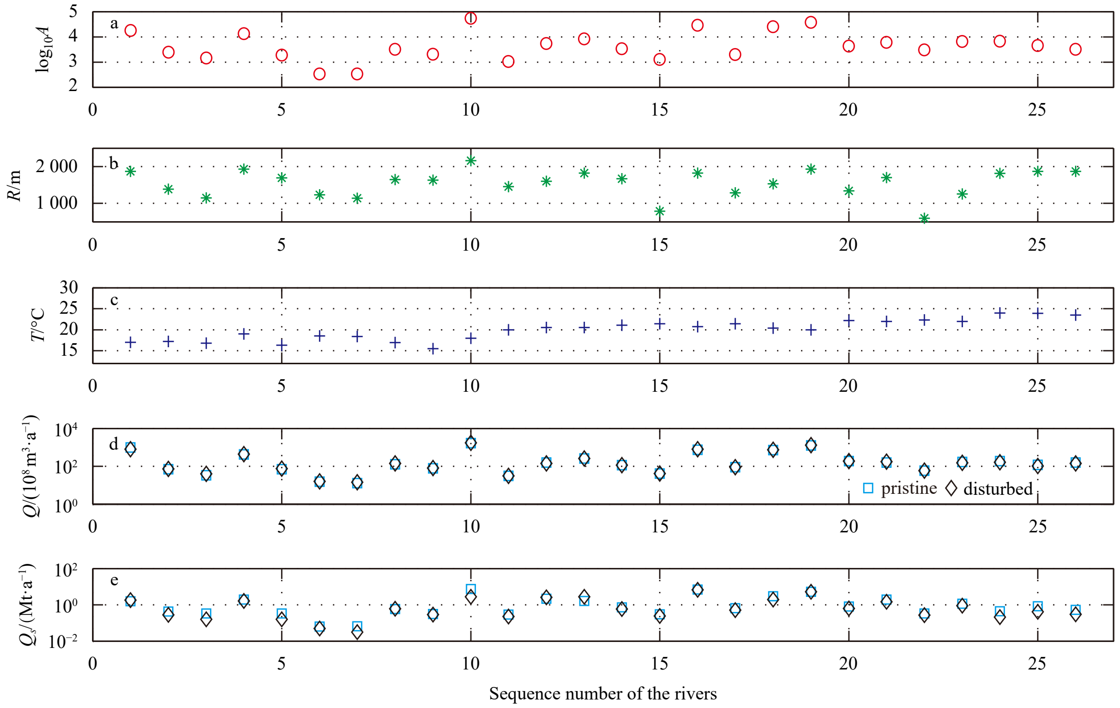

Fig. 2. Characteristic values of the parameters of the 26 coastal watersheds in southeast China: Drainage area (a); maximum relief (b); mean temperature (c); water discharge (d); sediment discharge (e) (see Table 1 for the references).

sediment discharge. In this study, those unavailable data values are calculated by their pristine values multiplied by the above-changed coefficients.

2.3 *Analysis methods*

In this study, four global equations were used to calculate the sediment flux of the study area. The first equation is the Milliman and Syvitski (1992) model (Model$_1$), which relates the sediment flux (Q_s) to the catchment area:

$$Q_s = aA_1^b, \tag{1}$$

where A_1 is the catchment area (10^6 km^2), a and b are the regression coefficients.

The second one is the Mulder and Syvitski (1996) model (Model$_2$), which includes the basin area and maximum elevation:

$$Q_s = \alpha 10^{(c\log_{10}(A_2)+d\log_{10}(R_2)+f)}, \tag{2}$$

where α is a constant (0.031 5, for the unit conversion from kg/s to Mt/a); A_2 is the catchment area (km^2); and R_2 is the maximum elevation of the catchment (m); c, d and f are the regression coefficients.

The third one is the Syvitski et al. (2003) model (Model$_3$), which is associated with the average discharge, maximum relief, and mean temperature:

$$Q_s = 2\alpha A_3^g R_3^h \mathrm{e}^{iT}, \tag{3}$$

where A_3 is the catchment area (km^2); R_3 is the maximum relief (m); T is the average temperature of the catchment in consideration (°C); g, h and i are the regression coefficients.

The fourth one is the Syvitski and Milliman (2007) model (Model$_4$). The Q_s is estimated based upon geomorphic and tectonic influences (basin area and relief), geography (temperature, runoff), geology (lithology, ice cover), and human activities (reservoir trapping, soil erosion):

$$Q = jA_4^k, \tag{4}$$

$$Q_s = \omega B Q^l A_4^m R_4 T, \tag{5}$$

where Q is fluvial discharge (m^3/s); A_4 is drainage area (km^2); ω=0.000 6 is a constant of proportionality; and k, l and m are the regression coefficients. B=IL(1-T_E)E_h accounts for geological and land-use factors. I is glacier erosion factor (1 in this case). L is an average basin-wide lithology factor. T_E and E_h account respectively for the trapping efficiency of lakes and human-made reservoirs and human-influenced soil erosion factor, which we assumed to cancel out (Syvitski and Milliman 2007; Nienhuis et al., 2015). For the outcrop rocks of the study areas mainly composed of igneous and sedimentary rocks (Gao, 1988), this study assigned L=1 (Syvitski and Milliman, 2007). R_4 is relief (km), and T is the basin average temperature (°C).

In Eqs (1), (2), (3), (4) and (5), the values of regression coefficients a, b, c, d, f, g, h, i, j, k, l, and m were defined by two cases. In the first case, the coefficients of four global empirical equations (Milliman and Syvitski, 1992; Mulder and Syvitski, 1996; Syvitski et al., 2003; Syvitski and Milliman, 2007) were used to calculate the sediment flux of the study areas. In the second case, the global empirical equations were modified by the two data sets, i.e., pristine and disturbed sediment discharge, of the coastal watersheds, southeast China. Their regression coefficients were determined by the method of least squares. The regression coefficients' values of global equations and modified equations are shown in Table 2.

Table 1. Hydrological and sediment data for the 26 coastal watersheds in southeast China

No.	River	Relief /m	Temperature/°C	Gauging station	Drainage area/km^2	Pristine discharge				Disturbed discharge			
						Q_s/ (10^4 t·a^{-1})	Q/10^8 m^3	Period	Reference	Period	Q_s/ (10^4 t·a^{-1})	Q/10^8 m^3	Reference
1	Qiantangjiang River	1 865	17.0	Lanxi	18 233	155.95	314.4	1960–1979	Zhang (2015)	1980–2012	179.85	252.67	Zhang et al. (2015)
2	Jiao-Yonganxi	1 382	17.2	Bozhiao	2 475	42.32	22.10	1960–1979	Zhang (2015)	1980–2012	28.15	23.03	Zhang et al. (2015)
3	Jiao-Shifengxi	1 144	16.8	Shaduan	1 482	33.31	10.40	1960–1979	Zhang (2015)	1980–2012	15.85	12.64	Zhang et al. (2015)
4	Ou River	1 929	19.0	Hecheng	13 400	195.15	133.75	1960–1979	Zhang (2015)	1980–1999	163.41	138.35	Zhang et al. (2015)
5	Feiyunxi	1 690	16.3	Xuekou	1 930	33.43	22.20	1960–1979	Zhang (2015)	1980–2012	15.69	23.63	Zhang et al. (2015)
6	Aojiang River	1 232	18.5	Daitou	343	6.38	4.91	1960–1979	Zhang (2015)	1980–2012	5.01	4.98	Zhang et al. (2015)
7	Shuibeixi	1 141	18.4	Gaotan	341	6.51	4.12	1970–1979	Chen (2007)	1990–1992	3.15	4.52	Chen (2007)
8	Saijiang River	1 649	16.9	Baita	3 270	58.35	40.55	1960–1979	Chen (2007)	1980–2006	61.23	44.81	Chen (2007)
9	Huotongxi	1 627	15.5	Yangzhongban	2 082	31.49	24.78	1960–1979	Chen (2007)	1980–2006	28.60	25.13	Chen (2007)
10	Minjiang River	2 158	18.0	Zhuqi	54 500	748.00	539.00	1950–1978	Zhang (2000)	2006–2015	279.40	540.70	Sun et al. (1983); WRD (2016)
11	Mulanxi	1 451	20.0	Laixi	1 070	29.30	9.85	1959–1979	Chen (1988)	–	23.01 1)	9.90 1)	–
12	Jinjiang River	1 600	20.5	Shilong	5 460	217.28	50.04	1950–1979	Shao (1991)	1980–1989	263.64	44.78	Shao (1991)
13	Jiulongjiang-Beixi	1 823	20.5	Punan	8 490	166.72	82.41	1952–1979	Shao (1991)	1996–2014	275.00	82.81 1)	Chen et al. (2018)
14	Jiulongjiang-Xixi	1 666	21.1	Zhengdian	3 419	73.90	36.37	1952–1979	Shao (1991)	–	58.03 1)	36.54 1)	-
15	Huanggang	784	21.4	Hongxia	1 270	30.60	13.00	1956–1961	Wang et al. (1991)	–	24.03 1)	13.06 1)	Zhang et al. (2013)
16	Hanjiang River	1 823	20.8	Chaoan	29 077	703.44	237.10	1955–1979	Yang et al. (2017)	1980–2012	661.47	251.80	Yang et al. (2017)
17	Rongjiang River	1 285	21.4	Dongqiaoyuan	2 016	65.40	28.10	1949–1979	Wang et al. (1991)	–	51.35 1)	28.23 1)	Chen (2010)
18	Dongjiang River	1 529	20.4	Boluo	25 325	296.00	224.67	1954–1979	Zhang et al. (2011)	1980–2006	194.67	233.20	Zhang et al. (2011)
19	Beijiang River	1 929	20.0	Shijiao	38 363	532.67	406.57	1954–1979	Zhang et al. (2011)	1980–2006	523.67	419.87	Zhang et al. (2011)
20	Moyang	1 337	22.2	Shuangjie	4 345	80.00	59.10	1954–1979	Wang et al. (1991)	–	62.82 1)	59.38 1)	Chen and Chen (2006)
21	Jianjiang River	1 703	22.0	Huazhou	6 157	197.00	49.60	1953–1979	Huang (2010)	1990–2008	146.12	55.06	Wang et al. (1991); Huang (2010)
22	Jiuzhoujiang River	596	22.3	Gangwayao	3 086	34.00	18.40	1953–1979	Xie (2013)	–	26.70 1)	18.49 1)	Wang et al. (1991)
23	Nanliujiang River	1 257	22.0	Changle	6 592	115.00	52.79	1956–1979	Xu and Ou (2007)	1980–2000	91.20	49.01	Xu and Ou (2007)
24	Nandujiang River	1 811	24.0	Longtang	6 841	44.99	59.98	1957–1979	Yang et al. (2013)	1980–1987, 2006–2008	21.24	51.90	Yang et al. (2013)
25	Changhuajiang River	1 867	23.9	Baoqiao	4 634	83.88	37.99	1957–1979	Yang et al. (2013)	1980–1987, 2006–2008	40.70	32.72	Yang et al. (2013)
26	Wanquan	1 867	23.5	Jiaji	3 236	52.97	49.89	1957–1979	Yang et al. (2013)	1980–1987, 2006–2008	30.04	45.16	Yang et al. (2013)

Notes: 1) Values of these unavailable data are calculated by their pristine values multiplied by the above-changed coefficients derived from other available data. – means no data available.

3 Results

Figure 3 shows the sediment flux of the 26 coastal watersheds calculated by using different regression equations. When using the Model$_1$, Model$_2$, and Model$_4$, the magnitude of sediment discharge is one order higher than the observations, ranging between 0.45 Mt/a and 37.18 Mt/a. As using the Model$_3$, the magnitude of sediment discharge is two orders higher than the observations, ranging between 9.18 Mt/a and 134.14 Mt/a. When using the modified equations, the sediment discharge is in the range of 0.05–7.58 Mt/a. This magnitude of calculated sediment flux is in the same as the magnitude of the observations (Figs 3b and c).

Figure 4 shows the relative errors between different regression equations and gauging station observations. The results show that when using the global equations, the calculated results deviate significantly from the observations. The mean relative error is in the range of 253%–7 097% (Figs 4a and b). Model$_3$ calculates significantly higher values of relative error than other regression equations. The relative errors of Model$_3$ are in the range of 919%–14 836% and 984%–29 073% for pristine and disturbed sediment discharge, respectively. Model$_2$ calculates the smallest values of relative error, ranging between –10% to 779% and –4% to 1 162% for pristine and disturbed sediment discharge, respectively.

Table 2. The values of regression coefficients of global equations and modified equations

Coefficient	Global	Pristine	Disturbed
a	65.00	102.48	95.67
b	0.56	0.90	0.94
c	0.41	0.88	0.94
d	1.28	0.14	0.04
f	–3.68	–2.28	–2.26
g	0.45	0.95	1.01
h	0.57	–0.68	–0.76
i	–0.09	0.02	-0.03
j	0.08	0.04	0.05
k	0.80	0.97	0.95
l	0.31	0.82	1.08
m	0.50	–0.03	–0.22

When using the modified equations, the calculated results of the coastal watersheds are in good agreement with the observations. The mean relative errors are in the range of 7%–10% and 18%–24% for pristine and disturbed sediment discharge, respectively. The smaller relative error indicates that the fitting effect of modified equations is better than the global equations. Model$_1$ and Model$_2$ calculate relative lower relative error than Model$_3$ and Model$_4$. The relative errors of the former two have the range between –45% and 165%, whereas that of the latter two have the range between –53% and 185%. As such, the best regression equations of sediment flux for the coastal watersheds, southeast China, are the Model$_1$ and Model$_2$.

4 Discussion

Traditionary, many global equations are directly used to calculate the sediment flux of small coastal watersheds, resulting in the underestimation of the fluvial sediment flux (Milliman and Meade, 1983; Milliman et al., 1999). In this study, we assess the relative error of sediment flux calculated by four global equations, taking the 26 small coastal watersheds in southeast China as examples. Results show that when using the global equations, the magnitude of sediment discharge is 1–2 orders of magnitude higher than the observations, with the mean relative error in the range of 253%–7 097%. A similar overestimation of sediment flux has been reported in the coastal Hainan rivers (Li et al., 2019). That is, the use of global equations in small rivers will also cause overestimation of sediment flux. The reason for this overestimation mainly caused by the different domain of watershed parameters and regression coefficients between global equations and study coastal watersheds.

For the global equations, the drainage area, maximum relief, mean temperature, sediment flux, and sediment yield are in the range of 10^2–10^6 km^2, 10^1–10^3 m, 0–27.9°C, 0.1–1 193.4 Mt/a, and

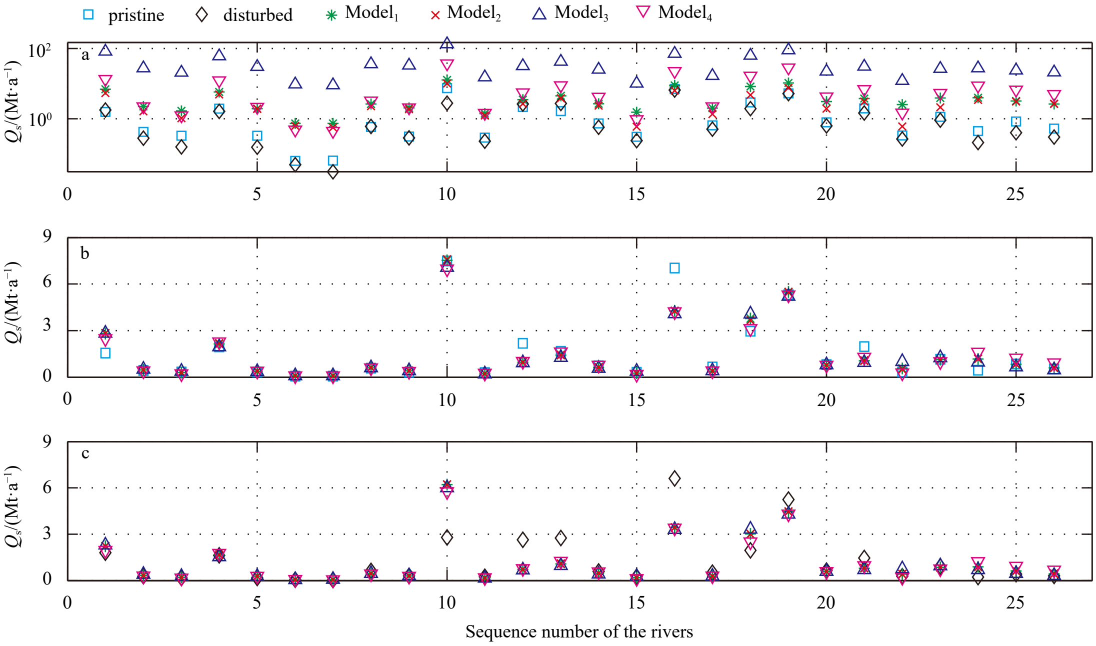

Fig. 3. Sediment flux of the 26 coastal watershed in southeast China calculated by: the global equations (a); the modified equations for pristine sediment discharge (b); the modified equations for disturbed sediment discharge (c).

1–16 454 t/(km²·a), respectively (Milliman and Syvitski, 1992; Mulder and Syvitski, 1996; Syvitski et al., 2003; Syvitski and Milliman, 2007). For the 26 coastal watersheds, southeast China, the responding values are in the range of 10^2–10^4 km², 10^2–10^3 m, 16.3–24.0°C, 0.03–7.48 Mt/a, and 51.27–397.95 t/(km²·a), respectively. Figure 5 shows that the data points of the coastal watersheds' characteristics mainly located at the bottom and middle part of the data points of the global rivers. When using the global equations in the same kind of river systems as the coastal watersheds, southeast China, the calculation sediment flux will be overestimated. Meanwhile, there are many data points located in the upper part. If the input data belongs to this kind of river sys-

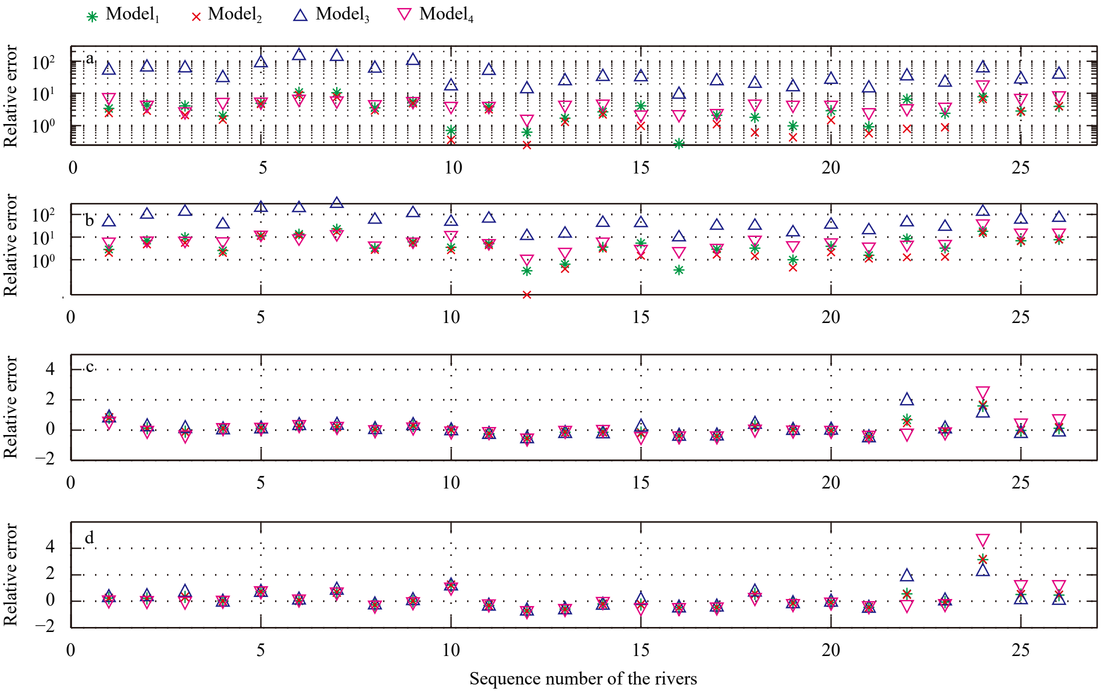

Fig. 4. Relative errors between different sediment flux regression models and gauging station observations. a. Global model vs pristine sediment discharge; b. global model vs disturbed sediment discharge; c. modified model vs pristine sediment discharge; d. modified model vs disturbed sediment discharge.

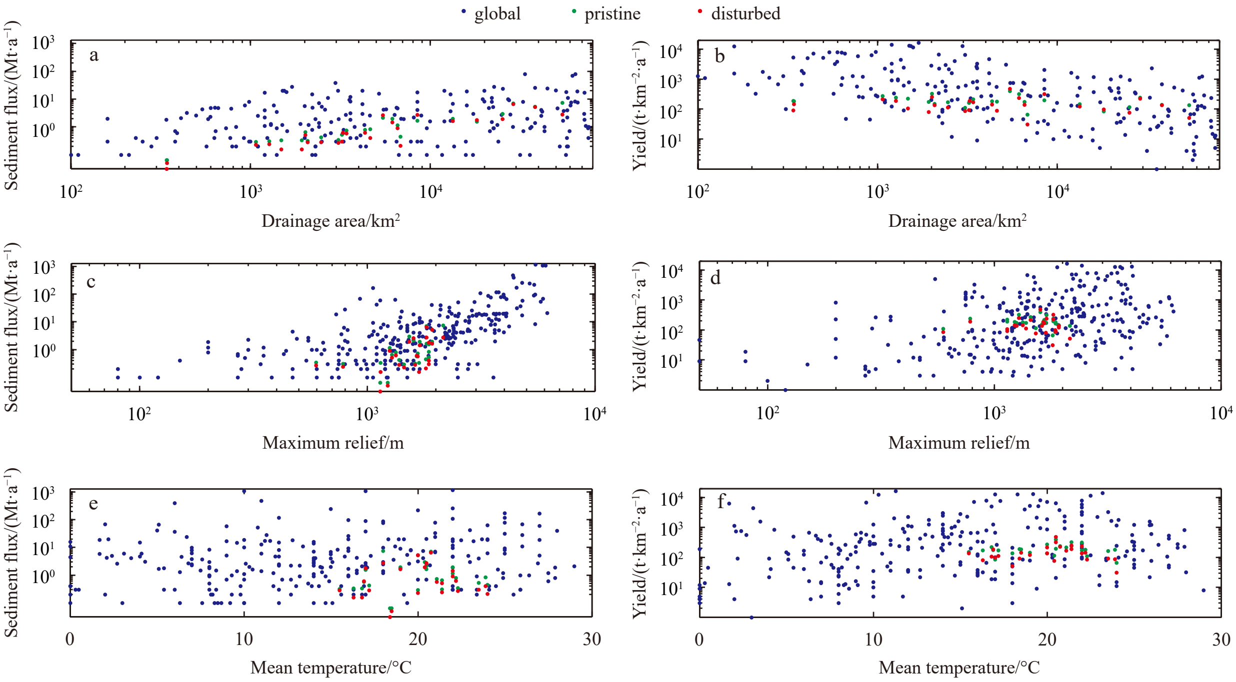

Fig. 5. Relationship between annual sediment flux (a, c, e) and sediment yield (b, d, f) and watersheds characteristics (drainage area, maximum relief, and mean temperature) for the database of the Global equation (Syvitski and Milliman, 2007) and of the coastal watersheds in southeast China.

tems, the calculation sediment flux will be underestimated.

The deviations derived from the global equations need to be evaluated. First, we assume that pristine sediment flux calculated by modified equations represents the true values as the same as the observations. Then, we introduce the index P for assessing the difference, which is defined as:

$$P=\frac{\text{global equation}}{\text{modified equation}}. \tag{6}$$

As Model$_1$ is mentioned, we can get $P = 0.63A^{-0.34}$. Here, P is a monotone decreasing exponential function. Higher A leads to lower P. Plugging the true values of A into P, we have $1.69 \leqslant P \leqslant 9.51$. For Model$_2$, $P=10^{(-0.47\log_{10}A+1.14\log_{10}R-1.4)}$. Higher A is associated with lower P, and higher R will result in higher P. By substituting the extremum of A and R into P, we can get $0.34 \leqslant P \leqslant 16.23$. For the Model$_3$, $P=A^{-0.5}R^{1.25}\,\mathrm{e}^{-0.07T}$. Higher A is associated with lower P, and higher R results in higher P, and higher T leads to lower P. Plugging the extremum of A, R and T into P, we have $2.35 \leqslant P \leqslant 269.14$. For the Model$_4$, $P=6.4A^{0.17}$. Higher the value of A, the higher the value of P. By substituting the extremum of A into P, we have $17.25 \leqslant P \leqslant 40.87$. Therefore, when using global equations in the study area, sediment flux will be overestimated by 10^0–10^2 orders of magnitude, which is a function of A, R and T.

As the relative error of the calculation sediment flux is too big, a revision of the regression equation is needed to be considered. When using the global equations in the study area, the magnitude of sediment discharge is 1–2 orders of magnitude overestimated than the observations. Then, the global equations were modified using the regional characteristics. Compare with the global equations, the relative error of the sediment flux calculated by the modified equations is significantly decreased. Similarly, Milliman et al. (1999) modified the Model$_1$ to calculate the sediment flux of rivers draining the Indonesian Islands. The database only includes those rivers from Southeast Asia and the East Indies, rather than the global rivers. They have more than 500 mm/a run-off and whose headwaters drain terrain at least 1 000 m in elevation. Results indicated that these high-standing islands transport about 4.2×10^9 t/a, a disproportionately large amount of sediment, to the ocean.

Nowadays, the water and sediment discharges entering the sea significantly changed induced by the effects of changing the climate and frequent human activities. These changes have a significant impact on river delta sedimentary systems (Gao et al., 2019; Guo et al., 2019). The sediment flux reaching the world's coasts have reduced by $(1.4\pm0.3)\times10^9$ t/s owing to the retention of the sediment and freshwater supply within reservoirs (Syvitski et al., 2005, 2009; Giosan et al., 2014; Day et al., 2016). For the southeast China coastal watersheds, the pristine water discharge is slightly lower (0.48%) than the disturbed water discharge. However, the pristine sediment discharge is relatively higher (21.48%) than the disturbed sediment discharge. Therefore, two kinds of regression equations, i.e., for both the pristine and disturbed sediment discharge, need to be considered.

Future works should focus on the following questions amid the pressures both of human development and climate change. First, the error arising from the location of gaging stations needs to be revised. They are commonly at distances far enough upstream. So that some of the sediment load may deposit or additional sediment derived from downstream tributaries may add to the load between the station and the estuary (Milliman and Meade, 1983). Second, the sediment flux of the continental shelf islands needs to be quantified. In the inner continental shelves of southeast China, there are thousands of islands (Xia, 2012). However, the major obstacle to evaluating their sediment flux is the lack of gauging station records on these continental islands. One of the possible ways to quantify the sediment flux of the continental island is to relate river-derived sediment yield to island-wide sediment yield and thus delivery to the coastal ocean (Li et al., 2018).

5 Conclusions

(1) On average, the pristine water discharge of the coastal watersheds in southeast China is slightly lower (0.48%) than the disturbed water discharge. However, the pristine sediment discharge is relatively higher (21.48%) than the disturbed sediment discharge.

(2) By using the global equations, the calculated sediment flux of the coastal watersheds is 1–2 orders of magnitude higher than the observations of the hydrometric gauging stations. The mean relative errors of the coastal watersheds are in the range of 253%–7 097%.

(3) By using the modified equations, the magnitude of calculated sediment flux is the same as that of the observations. The mean relative errors are in the range of 7%–24%.

(4) The reason for sediment flux overestimation mainly caused by different parameters' domain and regression coefficients between global rivers and the study coastal watersheds.

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