The devastating 26 July 2017 floods in Yulin City, Northern Shaanxi, China

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ARTICLE HISTORY
Received 31 August 2017
Accepted 16 November 2017

ABSTRACT
This Express Letter gives a brief report of the devastating floods in Yulin City, Northern Shaanxi, NW China, which occurred after colossal rainstorms on 26 July 2017. Here, we discuss the disaster and rescue measures, compare them to a set of 149 major rainstorms in Yulin City from 1971 to 2016, and then analyze the correlation coefficients between the rainstorms and the Circulation Characteristics Index. The results show annual increases in the economic losses caused by flood disasters. In addition, the Western Pacific Subtropical High and the Northeast Cold Air are related to precipitation and floods in Yulin City from July to August, so they are important keys to predict future flood disasters in the region.

KEYWORDS
Devastating floods; Yulin city; colossal rainstorms; rescue measures; circulation characteristics index

1. Introduction
In recent years, the precipitation in the South is less than in the North in Shaanxi. Especially, the precipitation in Yulin City is too much, while Ankang City is arid. The Yulin City is located in the northernmost of Shaanxi. The average annual precipitation is 365.7 mm; however, affected by the geographical position, topography and other natural conditions, the precipitation accounts for 40% to 50% from July to August. It has the characteristics of high intensity, short time, high frequency, and often causes floods and huge losses to people’s lives and property (Wang et al. 2014).

Big rainstorms appeared in Fugu county, Yulin City, and the rainfall reached 70 mm from 5:00 a.m. to 6:30 p.m on 30 July 2003 (Qiu et al. 2017, 2018b). Heavy rains caused river flooding swiftly and steeply in the county – 17,438 acres of farmland were destroyed and 950 acres of nursery were destroyed; 19 reservoirs burst; 1071 kilometers of county, township, and village roads were seriously damaged; 1458 houses were damaged and 43 collapsed. The total direct economic loss was 38 million 640 thousand yuan (Chen et al. 2007). There were three rainstorms of short duration, high intensity, and great magnitude. Rainfall in 56 townships exceeded 50 mm, in 21 townships exceeded 100 mm in northern Yulin at 9 o’clock in the evening of 27 July 2012. Four hundred and thirteen thousand people were affected, there were 18 deaths, and 12 missing; 54,372 hectares of crops were affected; 1507 houses collapsed. The direct economic loss was 633 million yuan (Li et al. 2013). Rainstorms generally emerged in Yulin, and the maximum rainfall was 223.6 mm and appeared in Jiaxian county between 7 July 2016 and 9 July 2016. More than 21,000 people were affected, and more than 1200 people were evacuated. More than 850 houses were damaged, more than 1100 kilometers of roads were damaged, and 30 bridges and culverts were damaged; 11 landslides and other geological disasters were produced. The direct economic loss was about 150 million yuan. The Express Letter briefly reports the flood disasters and subsequent...
disasters which were caused by heavy rains in Yulin on 26 July 2017, and analyzes the causes of the flood disasters.

2. Area and background

Yulin City is located at the junction of the Mu Us Desert and the Loess Plateau in Northern Shaanxi, and is the transitional region between the Loess Plateau and Inner Mongolia Plateau (Figure 1). It has semi-arid temperate continental monsoon climate, but in such a city near the desert, heavy rainstorms are very frequent in recent years.

3. Data collection

The frequency of 149 rainstorms in 12 counties of Yulin City, from 1971 to 2016 (Figure 2), was statistically analyzed.

On average, there were 3.3 times every year, 33 times in 1970s, 32 times in 1980s, 35 times in 1990s, 41 times from 2001 to 2010, and 8 times from 2011 to 2016 with the annual distribution (Qiu et al. 2018a; Lai et al. 2018b). More than five rainstorms occurred in 1978, 1988, 1994, 1995, 2000, 2012, and 2016, respectively. Rainstorms appeared every year, and the economic loss increased year by year (Lai et al. 2015, 2016a, 2016c, 2016d, 2017). The daily extreme maximum precipitation of 12 stations in Yulin City is shown in the Table 1. Three stations appeared in the 1970s, three stations appeared in the 1990s, and six stations have appeared since 2000, and it was indicated that the frequency and intensity of rainstorms increased in recent years (source: http://old.yltravel.gov.cn/yinxiang/show-4.html). The correlation coefficients between the rainstorms and the Circulation...
Characteristics Index in Yulin from 1971 to 2016 are shown in Table 2 (source: http://www.sxmb.gov.cn/s.php/yulin/).

4. Disaster overview and rescue operation

4.1. Flood disaster

There was a regional heavy rainstorm, and the precipitation of spatial and temporal distribution was uneven in Yulin City, Shaanxi, from 6 o’clock of 25 July 2017 to 6 o’clock of 26 July 2017. Precipitation in Yuyang county was 46.8 mm, Shenmu county was 34.8 mm, Fugu county was 17.5 mm, Dingbian was 4.9 mm, Jingbian was 89.0 mm, Hengshan was 111.1 mm, Jiaxian was 62.9 mm, Mizhi county was 133.9 mm, Zizhou was 203.0 mm, Suide county was 103.4 mm, Wuban county was 95.4 mm, and Qingjian county was 4.1 mm. The maximum rainfall in Zizhou county was 203 mm – the Dali River, the tributary of Wuding River in Zizhou county reached the highest water level.

Heavy rainfall created dangerous situations in many counties within Yulin City, and Suide and Zizhou counties suffered the most serious flood disasters (Figure 3). So far, 432,500 people have been affected by the disaster. There have been 12 confirmed deaths (1 person is still missing). Eighty

Table 1. Statistics of maximum daily precipitation in Yulin from 1971 to 2016 (sources: http://www.sxmb.gov.cn/s.php/yulin/ and recounted by authors).

| County name | Fugu | Shenmu | Dingbian | Jingbian | Hengshan | Yuyang | Jiaxian | Mizhi | Suide | Zizhou | Wuban | Qingjian |
|-------------|------|--------|----------|----------|----------|--------|--------|-------|-------|--------|-------|----------|
| Precipitation /mm | 181.8 | 141.1 | 107.4 | 113.2 | 92.3 | 102.9 | 216.4 | 103.0 | 116.3 | 150 | 112.5 | 93.4 |
| Time | 1995 | 1991 | 2001 | 1994 | 2001 | 2001 | 2012 | 2001 | 1978 | 1977 | 2011 | 1973 |
Table 2. Simultaneous correlation coefficients between the number of disaster rainstorms and the Circulation Characteristics Index in Yulin from 1971 to 2016 (sources: http://www.sxmb.gov.cn/s.php/yulin/ and recounted by authors).

| Circulation Characteristics Index | Western Pacific Subtropical High Area Index | Western Pacific Subtropical High Intensity Index | Western Pacific Subtropical High Ridge Line | Northern Boundary of Western Pacific Subtropical High | East Asian Trough Position | East Asian Trough Strength | East Asian Summer Monsoon Index |
|----------------------------------|------------------------------------------|-----------------------------------------------|------------------------------------------|-----------------------------------------------|----------------------------|-----------------------------|----------------------------------|
| Frequency of rainstorms           | 42                                       | 38                                            | 68                                       | 67                                            | 73                         | 75                          | 53                               |
| Correlation coefficients          | 0.279                                    | 0.255                                         | 0.458                                    | 0.449                                         | 0.492                      | 0.501                        | 0.357                            |

Figure 3. The disaster site of the Yulin City: (a) the Dali River; (b) the dam burst (source: http://xian.qq.com/a/20170727/002191.htm); (c) the Suide county in floods (source: http://news.cnwest.com/content/2012-07/27/content_6924033.htm); (d) the collapsed road (source: http://www.tianqi.com/news/194088.html); (e) the collapsed houses; (f) the muddy shops (sources: http://news.sina.com.cn/o/2017-07-26/doc-ifyihrwk2472627.shtml and http://baijiahao.baidu.com/s?id=1574438269250473&wfr=spider&for=pc).
four thousand five hundred people were evacuated urgently, and 113,400 people needed emergency assistance. Sixty eight thousand one hundred and twenty hectares of crops were also affected, of which 21,170 hectares were destroyed, and 126 hectares of farmland were destroyed, causing the death of 562 livestock. One thousand one hundred and ninety-six houses collapsed, 8318 houses were seriously damaged, and 12,392 houses sustained some storm damage (sources: http://xian.qq.com/a/20170727/020191.htm, http://news.cnwest.com/content/2012-07/27/content_6924033.htm, http://www.tianqi.com/news/194088.html, http://news.sina.com.cn/o/2017-07-26/doc-ifyihrwk2472627.shtml, and http://baijiahao.baidu.com/s?id=1574438269250473&wfr=spider&for=pc).

In terms of infrastructure, Yulin–Suide of Yulin–Shangluo Expressway, the Mizhi–Suide of the National Highway 210, and the Suide–Jingbian of the National Highway 307 were seriously damaged, while 32 county roads were interrupted. One small reservoir burst, 167 warping land dams were damaged, as was a 2.83-km embankment, 320 wells, and more than 7000 meters of water pipelines were damaged. One hundred and twenty kilometers of communications and power facilities were damaged. The direct economic loss was 6.933 billion yuan – agricultural loss was 618 million yuan, industrial and mining enterprises losses were 1.248 billion yuan, infrastructure loss was 2.713 billion yuan, public welfare facilities loss was 640 million yuan, and household property loss was 1.714 billion yuan.

4.2. Rescue measures

After the flood disasters, the Shaanxi Provincial Party Committee and the Shaanxi Provincial Government attached great importance to recovery efforts. The Shaanxi Commission for Disaster Reduction and the Department of Civil Affairs of Shaanxi started the provincial natural disaster contingency plans for level-four emergency response, and sent six working groups to the disaster area. The Shaanxi Provincial Finance Department immediately dispatched 10 million yuan of relief funds, 15,000 towels, 5000 quilts, and 200 toilets and tents to the disaster struck areas urgently, and appealed to the Ministry of Civil Affairs, and strived for central funding and material support. On 28 July 2017, the Shaanxi Provincial Development and Reform Commission issued provincial budget funds of 15 million yuan for repairing the water supply, roads, and general city infrastructure.

The China National Commission for Disaster Reduction and the Ministry of Civil Affairs of the People's Republic of China started national disaster relief plans for level-four emergency response on 29 July 2017. They sent a working group to the disaster area to assess the situation, and helped organize local relief work at 13 o’clock. The Shaanxi Provincial Finance Department and the Department of Civil Affairs of Shaanxi allocated 100 million yuan for the emergency transfer, earmarked for transitional life aid, rebuilding the damaged houses, and disaster relief work, on 3 August 2017. The Shaanxi Province Secret Service Squadron had already sent out a rescue vehicle, a fire-extinguishing water tanker, a high-explosive fire engine, and 19 officers on 26 July 2017, along with rescue assault boats, canoes, life jackets, and rescue ropes. They split up into two teams; one team, which carried the assault boat to Zizhou county, and the other team stayed in Suide county to carry out search and rescue work at 6 o’clock.

The flood control and disaster relief headquarters of Suide county also organized forces to repair the damaged infrastructure, and the communications and broadcasting networks gradually returned to normal. Sixteen thousand broadcast networks broke down in the city; as of 28 July 2017, 4000 had been repaired, in addition to those in the Suide Middle School and Suide Normal School. All the other districts resumed communications shortly thereafter, and the restoration rate of the communications network in the county reached 75% (Figure 4) (source: http://www.xyl.gov.cn/html/news/2017-07/251057.html, http://www.xyl.gov.cn/html/news/2017-07/251060.html, and http://www.xyl.gov.cn/html/news/2017-07/251091.html). Caring people also sent disaster relief supplies to the affected areas and some volunteers helped with transportation (Figure 5) (source: http://www.
The Health and Family Planning Commission of Shaanxi Municipality organized experts to participate in disaster emergency, issued 10,000 copies of flood prevention knowledge leaflets, and released 50 manual sprayers, 50 electric powder-spraying machines, and 50 bags of bleaching powder (Figure 6) (source: http://www.xyl.gov.cn/html/news/2017-08/251384.html and http://www.xian.qq.com/a/20170730/013806.htm).
5. Results and discussion

In general, southern rainstorms were more severe than those in the North, and eastern rainstorms were more severe than those in the West of the Yulin City. Due to concentrated industrial areas and dense populations, two districts were especially prone to disastrous rainstorms: the Shenmu and Fugu counties in the North and the Zizhou and Wubao counties in the South. Wubao and Zizhou counties have mountainous terrain, and the rainstorms had maximum impact on agriculture. The floods in Hengshan, Jingbian, and Dingbian counties were the lightest because of the least rainstorms and small population. The floods destroyed a large number of transportation facilities and caused great losses (Huang et al. 2015; Agbelie et al. 2016; Lai et al. 2018a).

Figure 6. Disinfection and epidemic prevention work: (a) post disaster disinfection (source: http://www.xyl.gov.cn/html/news/2017-08/251384.html); (b) epidemic prevention work (source: http://xian.qq.com/a/20170730/013806.htm).

Figure 7. Meteorological causes of rainstorms in Yulin City (source: drawn by authors).
The atmospheric circulation system has different effects on the climate of different regions, but it has some relationship with rainfall (Lai et al. 2016b). The frequency of rainstorms in Yulin is positively related to the Western Pacific Subtropical High Area Index, Intensity Index, Subtropical High Ridge Line, Northern Boundary of Western Pacific Subtropical High, East Asian Trough Position, East Asian Trough Strength, and East Asian Summer Monsoon Index.

When the warm pressure of the Western Pacific Subtropical High meets the cold pressure from Northeast China, it causes a lot of precipitation and even floods in Yulin City, from July to August (Ding et al. 2008; Liu et al. 2009; Ren et al. 2012; Li et al. 2017) (Figure 7). The results showed that the Western Pacific Subtropical High was stronger than the North, the East Asian Trough Position was weaker than the East, the East Asian Summer Monsoon Index was northerly, and the polar vortex of the Asian region was stronger, indeed, which was beneficial to rainstorms in Yulin City (Li et al. 2015).

6. Conclusion

In review of the history of Yulin City, heavy rainstorms appeared every July and August in the summer, have even caused big floods several times, brought great losses to people’s lives and property, and the floods in Yulin City were the epitome of floods in Northern Shaanxi in recent years (Liu et al. 2017; Yang et al. 2017). There were many floods which were caused by similar reasons in Northern Shaanxi Province. The frequency of rainstorms causing floods has increased every year in Yulin City. Since the generation time of the annual Western Pacific Subtropical High and the Northeast Cold Air is important to predict the rainstorms in Yulin, meteorological should focus on this point.

Likewise, Northern Shaanxi has had major water shortage in recent years. The main watershed carrying capacity is poor, but the possibility of heavy rainfall occurrence is high. The future work should combine the prevention and control measures to promote the scientific and rational use of rainwater resources.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

Special Fund for Basic Scientific Research of Central Colleges of Chang’an University [grant number 310821153312]; National Key R&D problem of China [grant number 2017YFC0805306].

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References

Agbelie BRDK. 2016. Random-parameters analysis of highway characteristics on crash frequency and injury severity. J Traffic Transp Eng (English Edition). 3(3):236–242.
Chen GH, Chu JH, Cao SL, Li Y, Ma WJ. 2007. [Analysis of the rainstorm and flood in Fugu at “July30. 2003“ of the middle reaches of Yellow river]. J Water Resour Water Eng. 18(4):72–75. Chinese.
Ding YH, Wang ZY, Sun Y. 2008. Inter-decadal variation of the summer precipitation in east China and its association with decreasing Asian summer monsoon. Part I: observed evidences. Int J Climatol. 28(9):1139–1161. doi: 10.1002/joc.1615.
Huang C, Shen J, Zhou M, Lee GC. 2015. Force-based and displacement-based reliability assessment approaches for highway bridges under multiple hazard actions. J Traffic Transp Eng (English Edition). 2(4):223–232.
Lai JX, Fan HB, Chen JX, Qiu JL, Wang K. 2015. Blasting vibration monitoring of undercrossing railway tunnel using wireless sensor network. Int J Distrib Sens Netw. 11(6):7. Article ID 703980.

Lai JX, Feng ZH, Qiu JL, Chen JX, Fan HB. 2016a. In situ test of grouting reinforcement for water-enriched sandy gravel ground in river floodplain. Adv Mater Sci Eng. 2016(12):12. Article ID 2129659.

Lai JX, He SY, Qiu JL, Chen JX, Wang LX, Wang K, Wang JB. 2017. Characteristics of earthquake disasters and aseismic measures of tunnels in Wenchuan earthquake. Environ Earth Sci. 76(2):94. doi: 10.1007/s12665-017-6405-3.

Lai JX, Mao S, Qiu JL, Fan HB, Zhang Q, HuZN, Chen JX. 2016b. Investigation progresses and applications of fractional derivative model in geotechnical engineering. Math Probl Eng. 2016(3):15. Article ID 9183296.

Lai JX, Qiu JL, Fan HB, Zhang Q, HuZN, Wang JB, Chen JX. 2016c. Fiber bragg grating sensors-based in-situ monitoring and safety assessment of Loess tunnel. J Sens. 2016(6):10. Article ID 8658290.

Lai JX, Wang KY, Qiu JL, Niu FY, Wang JB, Chen JX. 2016d. Vibration response characteristics of the cross tunnel structure. Shock Vib. 2016(5):16. Article ID 9524206.

Lai JX, Wang XL, Qiu JL, Zhang GZ, Chen JX, Xie YL, Luo YB. 2018a. A state-of-the-art review of sustainable energy based freeze proof technology for cold-region tunnels in China. Renew Sust Energ Rev. doi: 10.1016/j.rser.2017.10.104.

Lai JX, Zhou H, Wang K, Qiu JL, Wang LX, Wang JB, Feng ZH. 2018b. Shield-driven induced ground surface and Ming Dynasty city wall settlement of Xi’an metro. Tunnel Underground Space Technol. In press.

Li PY, Qian H, Howard Ken WF, Wu JH. 2015. Building a new and sustainable “Silk Road economic belt.” Environ Earth Sci. 74(10):7267–7270. doi: 10.1007/s12665-015-4739-2.

Li Q. (2013.). 3 consecutive contrast analysis of heavy rainstorm process in Northern Shaanxi, July 2012. J Shaanxi Meteorol. 2:1–7. Chinese.

Li Y, Ding YH, Li WJ. 2017. Interdecadal variability of the Afro-Asian summer monsoon system. Adv Atmos Sci. 34(7):833–846. doi: 10.1007/s00376-017-6247-7.

Liu YJ, Ding YH, Song YF, Zhang J. 2009. Climatological characteristics of the moisture budget and their anomalies over the joining area of ASIA and the Indian-Pacific Ocean. Adv Atmos Sci. 26(4):642–655. doi: 10.1007/s00376-009-9010-x.

Liu TZ, Zhang HB, Li XW, Li HY. 2017. Effects of organization factors on flood-related Natechs in urban areas of China. Nat Hazards. 88(1):355–365. doi: 10.1007/s11069-017-2868-5.

Qiu JL, Wang XL, He SY, Liu HQ, Lai JX, Wang LX. 2017. The Catastrophic landslide in Maoxian County, Sichuan, SW China on June 24, 2017. Nat Hazards. 89(3), 1485–1493. doi: 10.1007/s11069-017-3026-9.

Qiu JL, Liu HQ, Lai JX, Lai HP, Chen JX, Wang K. 2018a. Investigating the long term settlement of a tunnel built over improved loessial foundation soil using jet grouting technique. J Perform Construct Fac. doi: 10.1061/(ASCE)CF.1943-5509.0001155.

Qiu JL, Xie YL, Fan HB, Wang ZC, ZhangYW. 2018b. Centrifuge modelling of twin-tunnelling induced ground movements in loess strata. Arabian J Geosciences. doi: 10.1007/s12517-017-3297-1.

Ren GY, Ding YH, Zhao ZC, Zheng JY, Wu TW, Tang GL, Xu Y. 2012. Recent progress in studies of climate change in China. Adv Atmos Sci. 29(5):958–977. doi: 10.1007/s00376-012-1200-2.

Wang H, He JR, Ma F. 2014. Temporal and spatial distribution characteristics of rainstorm disasters caused by disaster in Yulin. J Shaanxi Meteorol. 1:21–24. Chinese.

Yang YM, Du J, Chen LL, Xu W. 2017. Applicability of TRMM satellite precipitation in driving hydrological model for identifying flood events: a case study in the Xiangjiang River basin. Nat Hazards. 87(3):1489–1505. doi: 10.1007/s11069-017-2836-0.