The Epidemiology of Lightning in Mainland China – A Review of Two Datasets from the 1950s to 2018

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***Abstract*—Lightning is among the top storm-related fatality and injury hazards in mainland China. This study shows the lightning fatalities and injuries in mainland China from the 1950s to 2018 based on two publicly available datasets. Although there is inconsistency in both datasets, they still provide a valuable set of information to help us understand the history of lightning fatality and injuries in mainland China that can used to provide guidance for future lightning safety education.**

Keywords—Lightning, Lightning fatalities, Lightning injuries, Hazards, China

I. Introduction

Lightning causes an estimate of a few thousand [1] to 24,000 fatalities [2] annually world-wide. A detailed summary of 24 prior national multi-year lightning fatality studies is in [3]. Developing countries are more vulnerable to lightning hazards, as the estimated annual fatality rate per million in Africa is from 1 or 2 in Uganda and Burundi to 10 to 20 in Swaziland and Zimbabwe and may be as large as 84 in Malawi [4]. Developed countries have much lower rates of an estimated 0.1-1.5 annual fatality rate per million [3, 4]. Lightning is estimated to be responsible for hundreds of deaths and injuries as well as hundreds of million RMB (approximately 30 million U.S. dollars) economic losses annually in China [5, 6].

Two prior studies of this topic for different periods also have been made for China. One used the National Lightning Hazards Database from 1997 to 2009 and found 5,033 deaths and 4,670 injuries [5] for an average of 387 deaths and 359 injuries per year for this period; the average fatality rate is 0.29 per million per year. The second used the National Lightning Disaster Compilations from 2009 to 2018 to find 1,789 deaths and 1,552 injuries [6] for an average of 179 deaths and 155 injuries per year in this time frame; the average fatality rate is 0.13 per million per year. The present study extends these studies back further and uses two somewhat different databases. Here, we examine two publicly available data resources and study the reports of the annual lightning fatality and injuries in mainland China.

II. Data Resources

Two publicly available data resources were used in this study of lightning fatalities and injuries in mainland China that have not been previously examined for lightning impacts. The first is the Chinese Meteorological Hazards Collection from the 1950s to 2000. The second is the Chinese Meteorological Hazards Yearbooks from 2003 to 2018. Unfortunately, we were not able to find publicly available data from these publications for 2001 and 2002, as well as the most recent years.

A. The Chinese Meteorological Hazards Collection

The Chinese Meteorological Hazards Collection is published by the Meteorological Press (中国气象灾害大典综合卷，气象出版社，2008 年 9 月第一版, Figs. 1, 2). The Collection consists of a variety of types of meteorological hazard records in mainland China from the 1900s to 2000 including lightning, fog, hail, tornado, drought, extreme temperature, etc. Note that only the "major/severe" events are reported in the Collection. However, there is no definition of "major" or "severe" in the Collection itself. According to the definition in the Chinese Meteorological Hazards Yearbook 2008 (section II B), published by the Meteorological Press in December, 2008 (中国气象灾害年鉴 2008，气象出版社，2008 年 12 月第一版), a "major/severe" lightning hazard event is defined as one of the following: 1) two or more deaths; 2) one death and two and more injuries; 3) zero deaths and three and more injuries; 4) economic loss over 1,000,000 Yuan (about US$150,000). Also note that the definitions appear to change according to the instructions in the Yearbooks from different years.

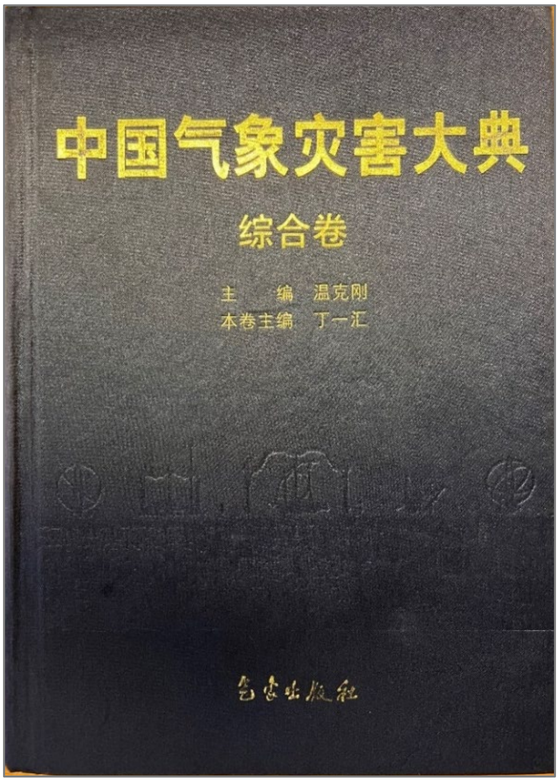
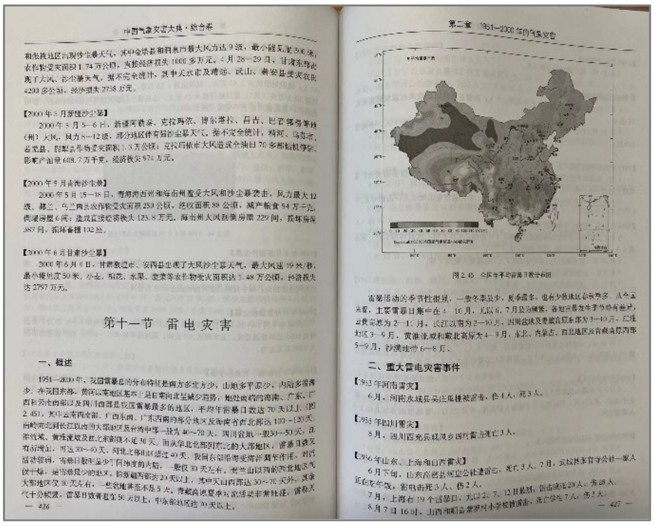


Fig. 1. Cover of the Chinese Meteorological Hazards Collection published by the Meteorological Press; sample pages in Fig. 2.

Most of the lightning hazard records include information about the year, date, province, county/region, fatalities, injuries, other damages, and a brief description of the hazard event with some having more details but some less. For instance, some records only have an exact number of deaths but a rough number of injuries or only an exact number of total deaths and injuries (Fig. 2). There are also cases where only numbers are recorded without any event description. Those events are included in this study because 1) there are many of them; 2) the numbers look reasonable; 3) some of the locations had previously reported lightning fatalities and injuries; 4) the time looks reasonable (either happened on a day in the summertime or during a few-day period with no exact date).

Due to the fact that the records were mostly collected on a county basis, some of the records seemed to be from the same thunderstorm event passing over different counties, which caused fatalities or injuries in these counties. On the other hand, there are some events when the fatalities and injuries were not directly caused by lightning. For instance, there was a record of an airplane crash that was responsible for 49 deaths. The description stated that the crash was likely to be caused by lightning. However, a microburst is more likely to account for that event. These irrelevant events were not included in this study.

There might be year-to-year variations in the records due to various reasons. Although the Collection includes data since the 1900s, the collecting standards and the county-wise political geography boundaries might be different before the 1950s. In order to avoid any possible inconsistency and confusion, only records after 1953 are included in this study. Therefore, due to the varying definitions and the possible missing records, the lightning fatality and injury records in the Collection may not be complete. On the other hand, there could be cases (without event description) where the fatalities and injuries were not directly caused by lightning but still counted in the analysis. Regardless, the Collection is still a useful resource for us to understand the lightning fatalities, injuries, and other damages in the mainland China from the 1950s to 2000.


第十一节 雷电灾害

一、概述

二、重大雷电灾害事件

Fig. 2. Lightning hazard report examples in the Chinese Meteorological Hazards Collection; cover is shown in Fig. 1.

B. *Yearbooks of Meteorological Hazards In China*

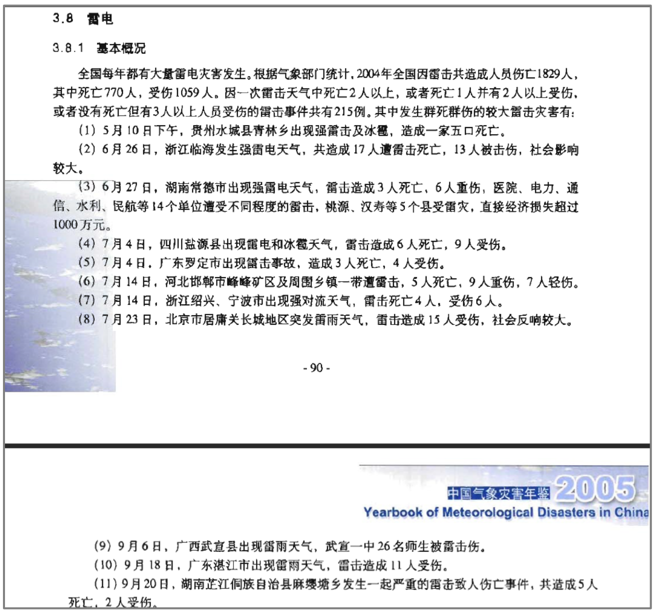
Starting in 2005, the Yearbooks of Chinese Meteorological Hazards are published annually by the Meteorological Press (中国气象灾害年鉴，气象出版社, Fig. 3). Each Yearbook collects the “major/severe” meteorological disaster/hazard events from the previous year, in which the definitions could vary year by year. Fortunately, the Yearbooks since 2006 includes information about the annual lightning fatalities and injuries in 2003 and 2004, although individual reports in the two years are not available. Therefore, some statistics can be traced back to 2003 for this study.

Since 2008 (in the 2009 Yearbook), the definitions of “major/severe” lightning hazards that were used to select cases to be included in the Yearbook changed dramatically. Before 2008, the Yearbook included fatal events when there were either at least two or more deaths, or one death and two and more injuries, which is consistent with the Collection described in section II A. However, the Yearbooks since 2008 only includes fatal events when at least three or more deaths or the total number of deaths and injuries exceeded four. Hence, we do not have much information for individual events since 2008, but only a total number of fatalities and injuries. As a result, the data since 2008 can only be considered as rough statistics with no explicit examination.

Regardless, all available individual hazard reports were examined to verify that they were lightning-related fatalities and injuries. In addition, many more lightning hazard cases with great economic losses (both direct and indirect) with no fatalities or injuries were also included in the Yearbooks.

III. Results

Due to the limitations in the dataset that are mentioned above, we separated the data as before and including 2000, and after 2000 (with 2001 and 2002 missing data). All data from 2000 and earlier were from the Chinese Meteorological Hazards Collection (Figs. 1 and 2) and all data after 2000 were from the Yearbooks of Meteorological Hazards in China (Fig. 3).


3.8 雷电

3.8.1 基本概况

全国每年都有大量雷电灾害发生。根据气象部门统计，2004年全国因雷击共造成人员伤亡1829人，其中死亡770人，受伤1059人。因一次雷击天气中死亡2人以上，或者死亡1人并有2人以上受伤，或者没有死亡但有3人以上人员受伤的雷击事件共有215例。其中发生群死群伤的较大雷击灾害有：

(1) 5月10日下午，贵州水城县青林乡出现强雷击及冰雹，造成一家五口死亡。

(2) 6月26日，浙江临海发生强雷电天气，共造成17人遭雷击死亡，13人被击伤，社会影响较大。

(3) 6月27日，湖南常德市出现强雷电天气，雷击造成3人死亡、6人重伤，医院、电力、通信、水利、民航等14个单位遭受不同程度的雷击，桃源、汉寿等5个县受雷灾，直接经济损失超过1000万元。

(4) 7月4日，四川盐源县出现雷电和冰雹天气，雷击造成6人死亡，9人受伤。

(5) 7月4日，广东罗定市出现雷击事故，造成3人死亡，4人受伤。

(6) 7月14日，河北邯郸市峰峰矿区及周围乡镇一带遭雷击，5人死亡，9人重伤，7人轻伤。

(7) 7月14日，浙江绍兴、宁波市出现强对流天气，雷击死亡4人，受伤6人。

(8) 7月23日，北京市居庸关长城地区突发雷雨天气，雷击造成15人受伤，社会反响较大。

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中国气象灾害年鉴 2005
Yearbook of Meteorological Disasters in China

(9) 9月6日，广西武宣县出现雷雨天气，武宣一中26名师生被雷击伤。

(10) 9月18日，广东湛江市出现雷雨天气，雷击造成11人受伤。

(11) 9月20日，湖南芷江侗族自治县麻缨塘乡发生一起严重的雷击致人伤亡事件，共造成5人死亡，2人受伤。

Fig. 3. Lightning hazard report examples in the Yearbook of Meteorological Disasters in China for 2005.

A. Annual Lightning Fatalities and Injuries Before 2000

Fig. 4 shows the annual lightning fatalities (black) and injuries (blue) from 1953 to 2000 reported in the Chinese Meteorological Hazards Collection. On average, less than 100 deaths were reported each year during the period of 1953 to 2000. The highest number of annual fatalities was reported in 1987 with 107 deaths. Note that because of a variety of reasons, the reports are not exhaustive, so the real numbers should be higher than what is shown here. The annual injuries followed the annual fatality pattern due to the fact that lightning hazards with no fatalities were not included in the Collection. The real numbers for the injuries, therefore, should be higher than what is shown here. The year with highest number of lightning injuries was 1997 with 143 reported injuries and three deaths. Lightning struck a school in Sichuan Province while students were having classes. There was also a case reporting 35 fatalities within a single county, Yanjin, in Yunnan Province on a day. Unfortunately, no additional information was included in the case report, so it is unclear whether these fatalities were all due to lightning.

Overall, cities hardly had any "major" cases despite their dense population. Most of the fatalities and injuries reported during this period were in rural areas, where many people may have been involved in labor-intensive agriculture, there was a lack of lightning-safe structures, and minimal lightning safety education. The most frequent fatality activities involve farming, hiding from rain under a tree or in a warehouse or doing construction works. Due to the seasonal thunderstorm climatology in China (i.e. mostly in the summer), "major" cases mostly occurred in the spring and summer similar to results in [5, 6]. In addition, there is more thunderstorm activity in the south and/or along the coastal areas. The majority of the cases were in the southern provinces or coastal regions. For the 26 provinces that had lightning hazard reports, Sichuan (southwestern China) had the most lightning fatality of 70, followed by Hunan (55, south China) and Shandong (54, east coastal China), similar to maps in [5, 6]. Although only 16% of the reports included the times in the day when the cases occurred, most of the reported times were in the afternoon or late evening, which also follows the diurnal thunderstorm activity patterns in China.

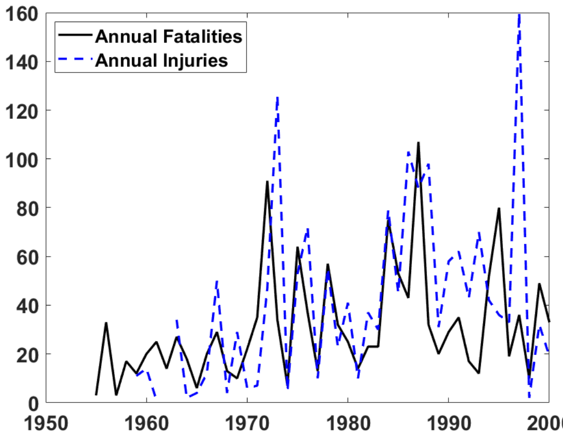

Fig. 4. Annual lightning fatalities and injuries from 1953 to 2000 reported in the Chinese Meteorological Hazards Collection. Black and blue curves represent the annual fatalities and injuries, respectively.

B. Annual Lightning Fatalities and Injuries After 2000

Fig. 5 shows the annual lightning fatalities (black) and injuries (blue) from 2003 to 2018 reported in the Yearbooks of Meteorological Hazards in China, and damages in Fig. 6. The data after 2000 show several times more fatalities and injuries each year than before 2000. From 2003 to 2008, the average is about 600 deaths and about the same number of injuries. However, from 2010 through 2018, there is an average of around 100 deaths and 100 injuries each per year.

The highest fatality total was reported in 2007 with 827 deaths, followed by 770 deaths in 2004. The most severe hazard in 2007 occurred at an elementary school in Chongqing City, where lightning struck the school building when students were in class, leading to seven deaths and 44 injuries. In 2004, another event related to the lightning hazard in Zhejiang Province caused 17 deaths and 13 injuries. As with the general lightning fatalities and injuries patterns before 2000, most of these major events occurred in the summer months, in the afternoon, and in the southern and coastal regions.

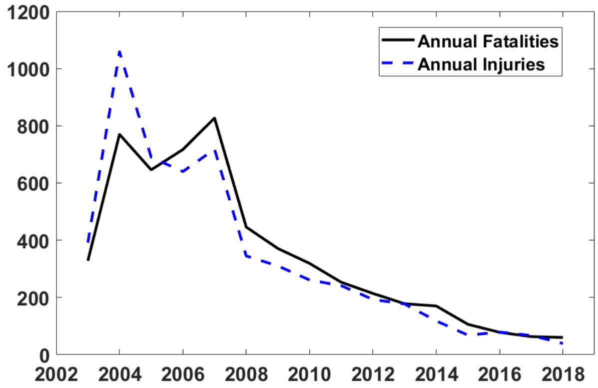

Fig. 5. Annual lightning fatalities and injuries from 2003 to 2018 reported in the Yearbooks of Meteorological Hazards in China. Black and blue curves represent the annual fatalities and injuries, respectively.

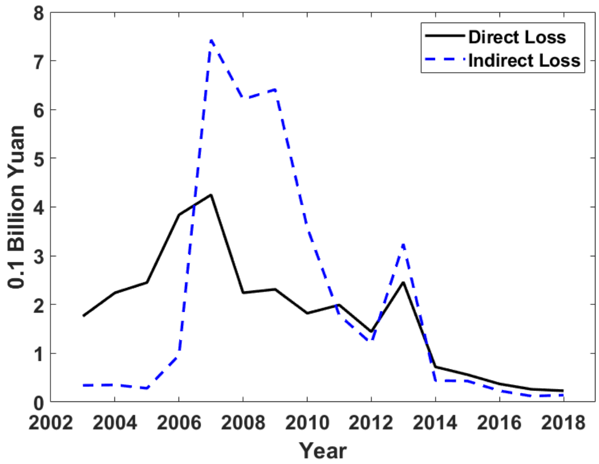

Fig. 6. Annual lightning direct (black solid) and indirect (blue dashed) losses from 2003 to 2018 from the Yearbooks of Meteorological Hazards in China.

Moreover, one of the most severe lightning hazards with a great economic loss occurred at 10:00 a.m. on May 22nd, 2007 in Da Hinggan Ling (now known as Daxing'anling) Prefecture in Heilongjiang Province. Lightning caused wildfires and a total of 14,797 people including 1,363 firefighters, 3,642 professional experts, and 9,792 civilians were involved in the 12-day wildfire extinguishment, which cost an indirect economic loss of almost US$10 million.

C. Comparisons with Previous Studies

Since the datasets used in the previous studies can be from different sources, it is useful to compare ours to theirs. Zhang et al. [5] did not provide the exact numbers of lightning fatalities and injuries from most individual years, but they did mention a few numbers that give us a hint. According to [5], "The number of lightning fatalities and injuries increased from 144 and 169 in 1997 to the maxima of 827 and 718 in 2007 and then decreased to 371 deaths and 310 injuries in 2009." The 2007 and 2009 statistics match well with ours when our data resource was the Yearbooks since 2003. It gives us some confidence to say that our numbers between 2003-2009 might be the same as theirs. However, their numbers in 1997 are larger than ours with 36 deaths and 160 injuries when our resource was the Collection. We are not sure why there is such a big gap in the number of fatalities while there is not much difference in the injuries. The Collection is certainly not a complete dataset, and we do not know how much it is missing. Interestingly, the numbers given in [6] are slightly smaller than what we collected in the Yearbooks. Reference [6] claimed 1,789 deaths and 1,552 injuries between 2009 and 2018, whereas the Yearbooks reported 1,812 deaths and 1,553 injuries. Since they did not have statistics for individual years, we could not find where the differences originated, and which dataset might be more accurate.

D. Population-weighted Fatality Rates

In order to take into account the large change in population in China during this period, Fig. 7 plots the relationship between population-weighted fatality rates and rural population percentages for the U.S. and China in two periods. Fig. 7(a) shows the well-documented decrease in U.S. weighted lightning fatality rates that decreases from as high as 6 deaths per million per year in the early 1900s to very low rates in recent years [3, 8]. Also shown in Fig. 7(a) is a decrease in the percentage of the U.S. population living in rural areas from 60% in 1900 to under 20% in 2020 [3, 8, 9].

Fig. 7(b) shows the same parameters in China from 1960 to 2000. The fatality data are from Fig. 4. The weighted fatality rate shows a wide interannual variability but no trend at all when population weighting is taken into account. The rural percentage in China reduces from 84% in 1960 to 64% in 2000 [9]. A reduction in rural population can be identified as being associated with a reduction in lightning deaths and injuries. In general, the main impacts from a rural percentage reduction may be that fewer people are involved in labor-intensive manual agriculture on small farms [10], along with fewer people living in lightning-unsafe rural dwellings [11]. Fig. 6 in [5] indicates that 66 to 92% of lightning casualties in mainland China were in rural areas from 2009 to 2018.

For the later period from 2003 to 2018 for China using fatality data from Fig. 5, the same type of population weighting and rural percent are plotted in Fig. 8. Here we find that the lightning deaths per million per year have reduced from over 0.6 in the early years to under 0.1 in later years. The percentage of rural population has reduced by about one third during this period, but the reduction is nowhere near the tenfold decrease in fatality rate. It can be concluded that the population has not suddenly changed from being vulnerable to lightning to not vulnerable in such a short period. We are left to conclude that the reporting change starting in 2008 may be responsible for this large decrease in the population-weighted fatality rate. Unfortunately, we are not able to verify this with the available data.

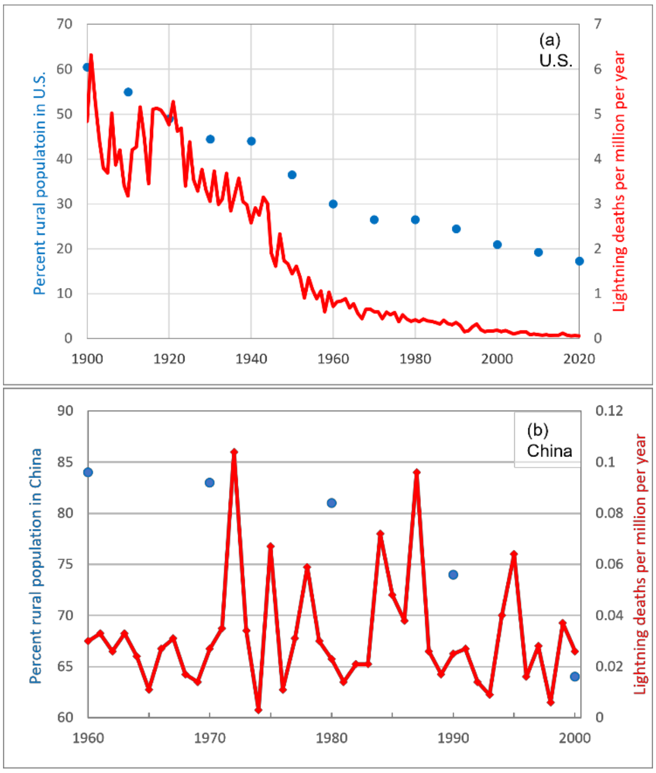

Fig. 7. Time series of population-weighted fatality rates (red lines) and percent rural population (blue circles) for (a) U.S. from 1900 to 2020, and (b) China from 1960 to 2000.

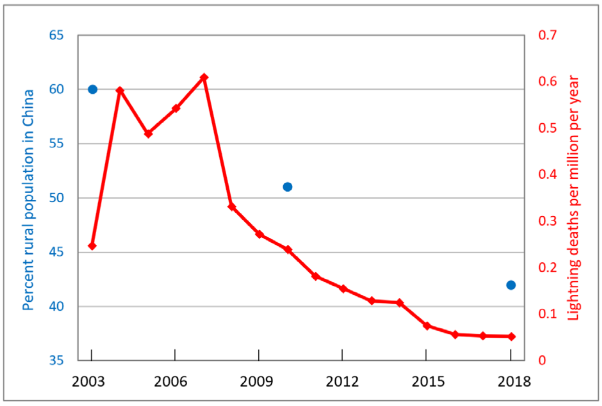

Fig. 8. Time series of population-weighted fatality rates (red lines) and percent rural population (blue circles) for China from 2003 to 2018.

E. Major/Severe Hazards

A percentage of fatalities and injuries from these hazards can be calculated, given a limited number of years (2004-2007) with both detailed individual reports for "major/severe" lightning hazards (see section II for the detailed definitions) and the numbers of total fatalities and injuries in the 2005-2008 Yearbooks. Tables I and II show that the fatality percentage in the major/severe hazards ranges from 22% to nearly 50% of total fatalities. In other words, nearly 50% to 78% of the fatalities came from events that were not considered major/severe, which means the lightning hazard only caused one death with less than two injuries. For injuries, the percentage ranges from nearly 30% to nearly 60%, which means that 40-70% of the injuries came from lightning that caused no deaths but less than two injuries. This can somewhat explain the large difference in the fatalities in 1997 and possibly other years reported by the Collection.

TABLE I. LIGHTNING FATALITES IN MAJOR/SEVERE HAZARD REPORTS AND THEIR PERCENTAGE OF THE TOTAL FATALITIES

	2004	2005	2006	2007
Fatalities in Major/Severe	373	211	159	211
Total Fatalities	770	646	717	827
Major/ Severe Fatality Percentage	48.4%	32.7%	22.2%	25.5%

TABLE II. LIGHTNING INJURIES IN MAJOR/SEVERE HAZARD REPORTS AND THEIR PERCENTAGE OF THE TOTAL INJURIES

	2004	2005	2006	2007
Injuries in Major/Severe	602	328	199	385
Total Injuries	1059	690	640	718
Major/Severe Injury Percentage	56.8%	47.5%	27.8%	53.6%

Unfortunately, there were no such detailed reports in other years' Yearbooks and the definitions of "major/severe" hazards changed in the 2009 Yearbook and thereafter. Hence, we do not have the percentage information for the other years. In addition, the Collection (data before and including 2000) did not provide the annual total number of lightning fatalities and injuries but only individual reports. As mentioned in section III A, the numbers included in the Collection are not complete, so we cannot calculate such percentages in those years.

F. Uncommon Reports

Ball lightning relevant cases were reported in the Chinese Meteorological Hazards Collection, although the existence of the phenomenon and its underlying physical processes have not been verified. On August 2nd, 1987 at 5:00 p.m., an unfinished house in Yu County in Hebei Province was struck by the term "ball lightning." All 14 people who were hiding the rain in the house passed out and four died immediately along with four who were injured.

On August 13th, 1994, what was described as a fireball broke in a window and went in a room in Linzhou City in Henan Province. A fireball circled around the room and went out, knocking five people down; three people died immediately and two were severely injured. There is no other information (e.g. an incident investigation report) or data that can be used to verify the involvement of ball lightning in either case, but the description of both cases indicated some atmospheric electricity phenomena were responsible for the fatalities and injuries.

IV. DISCUSSION

Table III presents a summary of the two current and two previously published datasets. Close examination of these two publicly available databases show consistency in many situations when direct comparisons are possible. However, the large number of deaths and injuries from 2003 to 2008 in Fig. 4 is problematic.

TABLE III. LIGHTNING DEATHS PER YEAR IN FIVE TIME PERIODS FROM FOUR SOURCES

Period / Source	Deaths per year	Fatality rate
1953-2000 Chinese Meteorological Hazards Collection	<100	**0.03 per million per year**
1997-2009 Zhang et al., 2011 [5]	387	**0.29 per million per year**
2003-2008 Yearbooks of Meteorological Hazards in China	622	**0.47 per million per year**
2009-2018 Yin et al., 2021 [6]	179	**0.13 per million per year**
2009-2018 Yearbooks of Meteorological Hazards in China	181	**0.13 per million per year**

Notable results in Table III are the following:

- The earlier years from 1960 to 2000 in the Collection have a very low rate of 0.03 per million per year. When population is taken into account, there is no trend. It is possible that data collection was quite sparse during these earlier years and resulted in an undercount by an unknown amount.
- From 1997 to 2009, [5] reports a rate of 0.29.
- From 2003-2008, the Yearbooks report a rate of 0.47.
- From 2009-2018, [6] reports a rate of 0.13.
- From 2010 to 2018, the Yearbooks have a major reduction to 0.13.

We can consider the possibility that the low rates in the early data in the Collection may be due to undercounting in that period. Less obvious is what occurs within the two Yearbook data periods. The most striking behavior is a sudden decrease in both the annual fatalities and injuries starting from 2008. Whether this pattern is partly because of the definition changes since the 2009 Yearbook is not clear. There is a possibility that the real numbers decreased due to the installation of more lightning-safe structures, fewer people involved in labor-intensive agriculture, and improved lightning education over the years, especially in the rural areas that suffered the most lightning fatalities and injuries. However, it does not appear reasonable that such changes occurred rather suddenly and resulted in such a large reduction in the fatality rate in Fig. 8.

Although there is no information for all individual fatality or injury reports after 2008, a closer look at the province rank of the fatalities and injuries weighted by populations gives us some hints: provinces with the highest ranks were either having larger rural areas where labor-intensive agriculture still occurs (e.g. Tibet or known as Xizang, Qinghai, Yunan, and Guangxi), or in the southeast and/or south China where lightning density is much higher (e.g. Guangdong, Fujian, and Jiangxi). The ranks in individual years have slight differences, but the overall trend is similar. In addition, more lightning hazards weighted by populations were reported in the western provinces (e.g., Tibet and Qinghai) than in the east.

Given the fast pace of urbanization in China, especially since 2000 (Fig. 8), the agricultural population indeed decreased, and the city population increased. The urbanization in the east is much higher than in the west. This could be one of the contributing factors to the overall decreasing trend of lightning fatalities and injuries but increasing rates in the western provinces. In addition, the annual lightning hazards direct and indirect losses in Fig. 6 show a similar decreasing trend since 2008 as the fatalities and injuries, although there was a 30% increase in 2013. The major lightning hazard events reported in 2013 were mostly related to large and important facilities and equipment hit by lightning. Note that there were 300-500% more indirect losses in 2007-2009 than the other years. These large economic losses could be a trigger for improved lightning safety measures and possibly resulted in the continuous decreasing trend of the lightning fatalities and injuries since 2008.

V. SUMMARY

Two new resources have been examined for the number of lightning-caused deaths and injuries in mainland China. While the numbers before 2008 are often in general agreement with previous analyses, the data collection criteria vary sporadically from year to year and show the difficulty of obtaining a consistent and comprehensive estimate of the lightning impacts on people in mainland China.

The lesson here is important for those attempting to collect data on lightning impacts anywhere. A seemingly unimportant change in reporting methods can potentially have a large consequence, as we see in the sudden drop after 2008 when the rules apparently were changed. To some extent, every lightning casualty dataset is susceptible to this issue, and here we have seen it arise quite clearly. In the U.S., it was shown in [12] that 91% of lightning deaths were due to single-person events. Assuming that a somewhat similar distribution is occurring in China, these datasets are to be considered carefully, as is true of such information from other areas of the world!

Even though it is not clear whether the sudden decrease since 2008 was valid or due to the incompleteness of the collection, it is still believed that the numbers are going down owing to improved on-site lightning safety facilities, warning systems, public awareness, and education [7].

ACKNOWLEDGMENT

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REFERENCES

[1] R. Gomes and ab Kadir, "A theoretical approach to estimate the annual lightning hazards on human beings," Atmos. Res., vol. 101, 2011, pp. 719-725.

[2] R. L. Holle and R. E. López, "A comparison of current lightning death rates in the U.S. with other locations and times," 33rd Intl. Conf. on Lightning Protection, Estoril, Portugal, September 25-30, 2016.

[3] R. L. Holle, "A summary of recent national-scale lightning fatality studies," Weather, Climate, and Society, vol. 8, 2016, pp. 35-42.

[4] Cooper, M. A., and R. L. Holle, "Reducing lightning injuries worldwide," Springer Natural Hazards, New York, 2018, 233 pp.

[5] W. Zhang, Q. Meng, M. Ma, and Y. Zhang, "Lightning casualties and damages in China from 1997 to 2009," Nat. Hazards, vol. 57, no. 2, 2011, pp. 465–476.

[6] Q. Yin, et al., "Lightning fatalities in China, 2009-2018," J. Agricultural Meteorology, vol. 77, no. 2, 2021, pp.150-159.

[7] D. Zhang, "The legacy of the Chinese lightning and thunder gods," Weatherwise, vol. 75, no. 2, 2022, pp.24-28.

[8] R. E. López and R. L. Holle, 1998: "Changes in the number of lightning deaths in the United States during the twentieth century," J. Climate, vol. 11, 1998, pp. 2070-2077.

[9] https://www.macrotrends.net/countries/CHN/china/rural-population. China Rural Population 1960-2022. www.macrotrends.net. Retrieved 2022-07-06.

[10] R. L. Holle, "Lightning-caused deaths and injuries related to agriculture," paper presented at 6th Intl. Lightning Meteorology Conf., Vaisala, San Diego, California, April 18-21, 2016, 5 pp.

[11] R. L. Holle, "Lightning-caused deaths and injuries in and near dwellings and other buildings," paper presented at 4th Conf. on Meteorological Applications of Lightning Data, Amer. Meteor. Soc., Phoenix, Arizona, January 11-15, 2009, 20 pp.

[12] E. B. Curran, R. L. Holle, and R. E. López, "Lightning casualties and damages in the United States from 1959 to 1994," J. Climate, vol. 13, 2000, pp. 3448-3453.