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The Number of Documented Global Lightning Fatalities

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***Abstract*—A recent publication [Holle, 2016a] summarized the lightning fatality rates per million people for 23 published national-scale studies ending in 1979 or later. An additional dataset was recently published for Mongolia. A major difference was found between the low fatality rates in more developed countries and higher fatality rates in lesser-developed countries. There have been several recent estimates of the total number of global annual lightning fatalities that range from 6,000 to 24,000 per year. This study takes the results from Holle [2016] and converts them into the number of deaths. The global total from these 24 studies only is determined to be 4,101 lightning fatalities per year, but data from many countries are missing and additional multi-year national-scale studies are needed.**

Keywords—Lightning fatalities; national lightning fatality rates; global lightning fatalities.

I. Introduction

A recent paper summarized the lightning fatality rates per million people for 23 published national-scale studies during periods ending in 1979 and later [Holle, 2016a]. A major difference was found between low to very low fatality rates in more developed countries and higher fatality rates in lesser-developed countries. The paper collected all published national studies and standardized the results to fatality rates per million people by country using the number of fatalities indicated in each paper, combined with the population of the countries for the period when the fatality data were collected. The color-coded map of fatality rates by country is shown in Fig. 1. Mongolia has been added since that publication so that Fig. 1 now shows fatality rates for 24 countries with national multi-year fatility rates since 1979.

There have been several recent estimates of the total number of global annual lightning fatalities. One estimate is several thousand [Gomes and Ab Kadir, 2011]; another is 6,000 fatalities per year [Cardoso et al., 2011]; and the third is 24,000 fatalities per year [Holle and López, 2003]. At present there is no collection of fatality totals into one publication so that the existing estimates can be evaluated;. The current paper is intended to provide such a summary.

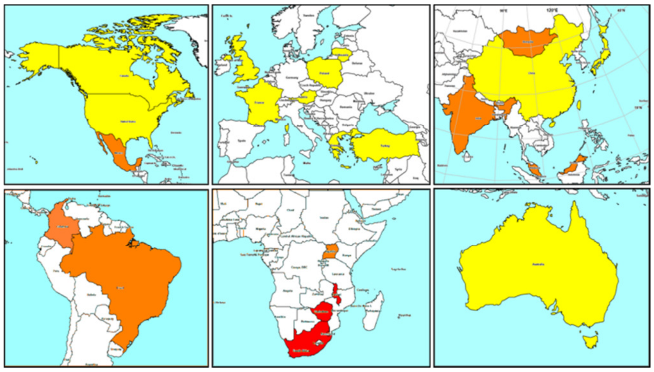

Fig. 1. National lightning fatality rates per million people per year by continent. Red shading indicates rates > 5.0 fatalities per million per year, orange is 0.6 to 5.0, and yellow is 0.5 or less. White indicates no national summaries have been published for periods ending in 1979 or later.

II. List of National Annual Fatalities

Table 1 lists the fatalities per year for the 23 countries in [Holle, 2016] plus Mongolia. A total of 4,101 fatalities per year are found in these publications and resources.

For India, one publication [Illiyas et al., 2014] found an average of 1,755 fatalities per year. Another recent publication [Singh and Singh, 2015] found only 159 fatalities from another database, which appears to be low. The total from Illiyas et al. [2014] is in Table 1. The difference shows the difficulty in collecting national-scale fatality totals.

For Japan, the author received a personal note from Dr. Nobu Kitigawa, who performed many demographic studies of lightning. His estimate, though unpublished, is in Table 1.

For Turkey, a major increase in fatalities was determined for the last several years [Tilev-Tanriover et al., 2015]. Rather than a much lower long-term rate that no longer applies, the most recent three years of data are used.

For Zimbabwe, two estimates at a 1990 Zimbabwe conference were 100 deaths [Van Olst, 1990] and 150 fatalities [Chitauro, 1990] per year for unknown periods of record. The lower total is used in Table 1.

TABLE 1. PUBLISHED ANNUAL LIGHTNING FATALITY RATES PER MILLION PEOPLE AND NUMBER OF FATALITIES BY COUNTRY ENDING IN 1979 OR LATER.

Continent Country	**References**	**Period**	**Annual fatality rate per million**	**Fatalities per year**
Africa				
Malawi	Mulder et al. [2012]	2007-2010	84.0	1008
South Africa	Blumenthal [2005]	1997-2000	6.3	264
Swaziland	Dlamini [2008]	2000-2007	15.5	15
Uganda	Ahurra and Gomes [2012]	2007-2011	0.9	30
Zimbabwe	Chitauro[1990]; Van Olst [1990]	Unknown	14 to 21	100-150
Asia				
China	Zhang et al. [2010]	1997-2009	0.3	360
India	Illiyas et al. [2014]	1967-2012	2.0	1755
Japan	Kitagawa, personal communication	1990-1997	>0	2
Malaysia	Ab Kadir et al. [2012]	2008-2011	0.8	22
Mongolia	Doljinsuren and Gomes [2015]			5
Singapore	Pakiam et al. [1981]	1970-1979	1.5	3
Australia				
Australia	Coates et al. [1993]	1980-1989	0.1	2
Europe				
Austria	Kompacher et al. [2012]	2001-2010	>0	1
France	Gourbière [1999]	1990-1995	0.2	11
Greece	Peppas et al. [2012]	2000-2010	0.1	5
Lithuania	Galvonaite [2004]	1994-2003	0.1	2
Poland	Loboda [2008]	2001-2006	0.3	8
Turkey	Tilev-Tanriover et al. [2015]	2012-2014	0.4	28
U.K.	Elsom and Webb [2014]	1988-2012	>0	2
North America				
Canada	Mills et al. [2010]	1990-2004	0.2	9
Mexico	Raga et al. [2014]	1979-2011	2.7	230
United States	www.lightningsafety.noaa.gov	2006-2015	0.1	31
South America				
Brazil	Cardoso et al. [2014]	2000-2009	0.8	132
Colombia	Navarrete-Aldana et al. [2014]	2000-2009	1.8	76

III. DISCUSSION

The fatality total from the 24 countries is 4,101. There are many countries missing from this list, and some of them can be expected to have large fatality totals. One national study deserving special emphasis in this regard is that from Malawi [Mulder et al., 2012]. A fatality rate of 84 deaths per million people per year was found, far exceeding the rate in any other country [Holle, 2016a]. Their result is 1,008 fatalities per year for this small but populous country. It is unknown if the data collection method was so complete that such a rate is actually what other countries in the region should report, or if there are special circumstances in the data collection such as including secondary and indirect causes.

Such a high fatality rate in Malawi, when extended to other adjacent countries, indicates that very large numbers of lightning fatalities may be occurring but they are not documented. If a rate approaching 84 per million per year is applied to the other lesser-developed countries in the equatorial region of Africa with no lightning fatality data, then thousands more fatalities are occurring then the present summary indicates.

In addition, there are several countries in Southeast Asia that are not included. It is known that agricultural lightning fatalities frequently occur in these countries [Holle, 2016b]. Anecdotal web reports for short periods and portions of these nations lead to the likely conclusion that there are many missing reports around the world.

With regard to injuries, a ratio of ten injuries per fatality was found for the state of Colorado in the United States over a long period [Cherington et al., 1999]. Every available dataset from emergency rooms, medical clinics, and similar organizations was searched to find this result. Such a 10:1 ratio of injuries to deaths appears to apply in the more developed countries of the world. It is unknown if such a ratio applies in less developed countries where no lightning-safe location is often readily available at work during the day or at home at night. It appears that more people are killed in multiple-casualty events such as agriculture [Holle, 2016b] than occur in the United States, for example, where 90% of all fatalities and injuries are to one person per event [Curran et al., 2000].

Taking all of these factors into account, we can be quite certain that the estimate of several thousand fatalities per year [Gomes and Ab Kadir, 2011] is being surpassed based on the available data from 24 countries with multi-year national publications. The next threshold is 6,000 fatalities per year [Cardoso et al., 2011] that appears to be possible based on present data. Finally, it remains unknown if the estimate of 24,000 fatalities per year [Holle and López, 2003] could be true. Such a total is conceivable, depending on the reliability and extendibility of the Malawi report of an extraordinarily high fatality rate.

Since lightning fatality data continue to be missing for so many countries where large numbers of deaths are expected, another approach could be considered. A recent study indicated how the product of lightning flash density and population could make an estimate of fatalities [Roeder et al., 2015]. A similar study is planned for Colombia, using the data from Navarrete-Aldana et al. [2014]. It is possible that after the Colombia test, the method could be applied to estimate global lightning fatalities. This may be a way to circumvent the likely long delay until quality national-scale fatality data collection can be made in lesser-developed countries.

IV. CONCLUSIONS

A summary of published national multi-year lightning fatalities studies finds that 4,101 deeaths per year occur in these 24 countries. There are many other populous developing nations where lightning fatality data have not been collected. An especially high lightning fatality rate in Malawi may indicate that rates in less-developed countries are much higher than is reported. Ten injuries occur per fatality in developing countries such as the United States where most lightning deaths and injuries occur to one person at a time [Curran et al., 2000]. In developing countries, there tend to be frequent multi-casualty events in agriculture [Holle, 2016b] so the ratio of injuries per fatality may be different. More information needs to be collected over multiple years on national scales in order to make a better estimate. Nevertheless it appears that the known fatality total is more than one recent estimate of several thousand, is approaching the 6,000 determined from another study, and may be closer to another estimate of 24,000 global fatalities per year.

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