https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

Indonesia Tornado Database: Tornado Climatology of Indonesia

Irfans Maulana Firdaus[1], Takeshi Yamazaki[1], Muhammad Rais Abdillah[2], and Edi Riawan[2]

[1]Graduate School of Science, Tohoku University, Sendai, Japan

[2]Atmospheric Sciences Research Group, Faculty of Earth Sciences and Technology, Institut Teknologi Bandung, Bandung, Indonesia

Correspondence: Irfans Maulana Firdaus (firdaus.irfans.maulana.q6@dc.tohoku.ac.jp)

Abstract. The climatology of tornadoes, waterspouts, and funnel clouds for Indonesia is constructed into a new tornado database based on newspaper archives, news on the Internet, and social media (X, YouTube) covering the period of 1834–2024. We present the analysis over two periods: (i) historical and (ii) recent periods. The climatology includes the annual, monthly, diurnal, and geographical for tornado cases. Based on a review of 47,669 reports mentioning tornadoes, we identified 436 tornado cases with sufficient evidence to be classified as tornado events. In the recent period (2010–2024), the annual frequency of tornadoes was 16.20 cases/year, while in the historical period (1834–2009), the annual frequency was 1.10 cases/year. Tornadoes were mostly documented in Java Island, followed by Sumatra and Sulawesi. The monthly variability of tornadoes shows a maximum during November, followed by December and January. The peak of the diurnal cycle of tornado cases is between 1300 to 1700 Local Solar Time.

1 Introduction

Tornadoes are among the most destructive meteorological phenomena, causing significant damage to buildings, infrastructure, and landscapes. The climatology of tornadoes is important for understanding the dynamics and characteristics of tornado occurrences, and also for improving risk assessment and mitigation strategies. Knowledge of tornado characteristics can enhance community response to the tornado threats and help identify vulnerable population (Johnson et al., 2021). Several open databases have been published online by countries, including the European countries (European Severe Weather Database or ESWD, Dotzek et al. (2009); https://eswd.eu/), the United States (National Centers for Environmental Information, NCEI; www.ncdc.noaa.gov/), Canada (Northern Tornadoes Project, NTP; https://uwo.ca/ntp/), and Japan (Japan Meteorological Agency, JMA; https://www.data.jma.go.jp/stats/data/bosai/tornado/list.html).

On the other hand, tornado climatologies have been published for several countries across Europe (Antonescu et al., 2016), South America (Veloso-Aguila et al., 2024), Australia (Kounkou et al., 2009), and the Asia countries such as Japan (Niino et al., 1997; Kawazoe et al., 2023), China (Chen et al., 2018; Zhang et al., 2023), India-Pakistan (Bhan et al., 2016), and Philippines (Capuli, 2024). Antonescu et al. (2016) summarize the tornado observation for 30 countries across Europe (see their Appendix A). In addition to local meteorological agency sources for tornado reports, other primary sources include old newspaper archives, news on internet, and social media (Newark, 1984; Paul, 2001; Rauhala et al., 2012; Kahraman and Markowski, 2014; Matsangouras et al., 2014; Antonescu and Bell, 2015; Veloso-Aguila et al., 2024). The term of tornado

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

Figure 1. (a) Tornado in Rancaekek, West Java, on 21 February 2024 (Jawa Pos, 2024), (b,c) damage caused by a tornado in Rancaekek (Tempo, 2024; RRI, 2024), (d) Tornado in Bogor City, West Java on 6 December 2018 (Hidayatullah, 2018), (e,f) damage caused by a tornado in Bogor City (Tempo, 2018; Kompas, 2018). The figures are downloaded from news article online.

may vary for each country. For example, words such as *kasırga*, *fırtına*, and *siklon* are described as a tornado events in Turkey (Kahraman and Markowski, 2014). Moreover, in Romania, they use words like *uragan/orcan*, *trombă*, *tornadă*, and *vârtej* to describe a tornado events.

The occurrence of tornado in Indonesia is rare (Maas et al., 2024) compared to mid-latitudes region such as the United States. Nevertheless, their impact can still be devastating. Figure 1 shows the tornado cases occurred in Indonesia. A tornado hit Rancaekek, Sumedang, West Java on 21 February 2024, damaged over 1,000 buildings and caused at least 47 injuries (Figure 1a-c). On 6 December 2018, a tornado occurred in Bogor, West Java, and resulting in damage to 854 buildings (Figure 1d-f). However, tornado reports in Indonesia have not been systematically recorded, unlike in countries such as the United States and those in Europe.

The aims of this paper are to identify tornado cases in Indonesia from numerous scattered reports and to investigate basic climatology characteristics of the tornadoes in Indonesia. The identified tornadoes are published in an open repository that can catalyst future tornado studies in the tropics. This paper is organized as follows: in section 2 the data and methodology related to the collection of tornado reports and categorization of tornado reports for the database are presented. Section 3 presents the result of the tornado climatology for Indonesia, and the last section provides a discussion and conclusion.

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

Table 1. Category tornado reports.

Category	Criteria
Confirmed	1. A photograph or video of a tornado 2. Damage survey of tornado
Probable	1. Credible eyewitness observation of tornado 2. Credible eyewitness report of typical tornado damage 3. Credible eyewitness who reported seeing rotation wind and/or column air 4. A photograph of a typical tornado damage
Possible	1. Credible eyewitness who reported hearing thunderous sound 2. There was hail 3. Cause of the damage is not confirmed by the observations of an eyewitness

2 Data and Methods

This section describes the development of the tornado database for Indonesia. The term 'tornado' is not commonly used in Indonesia, as it has a local name called *angin puting beliung*, which means 'rotating wind'. In this article, we use the term 'tornado' instead of *angin puting beliung* and address the criteria and definition of a tornado. With a clear definition of tornadoes, we created a new tornado database by collecting historical reports from archives, such as newspapers and social media. Finally, we analyze the climatology of tornadoes in Indonesia.

The Meteorological, Climatological, and Geophysical Agency of Indonesia (BMKG RI) defines a tornado as "a rotating, strong wind originating from a cumulonimbus cloud, occuring for a short period of time". Meanwhile, the National Disaster Management Authority of Indonesia (BNPB RI) defines a tornado as "a sudden, rotating, strong wind with a center and spiral-like appearance, extending to the ground and dissipating within a short time (3-5 minutes)". Given these differing definitions, we deal with the definition of tornado. In this article, the tornado definition is adopted from American Meteorological Society (2024). Tornado is defined as "a rapidly rotating column of air that extends from the surface to the base of a cumuliform cloud and is often visible as a funnel cloud". Additionally, this definition is extended to include all waterspouts, whether or not they make landfall, in line with the tornado definition by Rauhala et al. (2012).

The criteria for evaluating tornado cases were adopted and modified from Rauhala et al. (2012) (Table 1). We made additions and modifications to the 'probable' and 'possible' categories. A credible eyewitness who reported observing rotating winds and/or a column of air was included in the 'probable' category, while a credible eyewitness who reported hearing a thunderous sound and observing hail was placed in the 'possible' category. A report is categorized as a tornado case if any of the criteria are satisfied. All criteria were accepted in the new database, but only confirmed and probable tornado cases were analyzed for tornado climatology in Indonesia (Rauhala et al., 2012; Kahraman and Markowski, 2014).

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

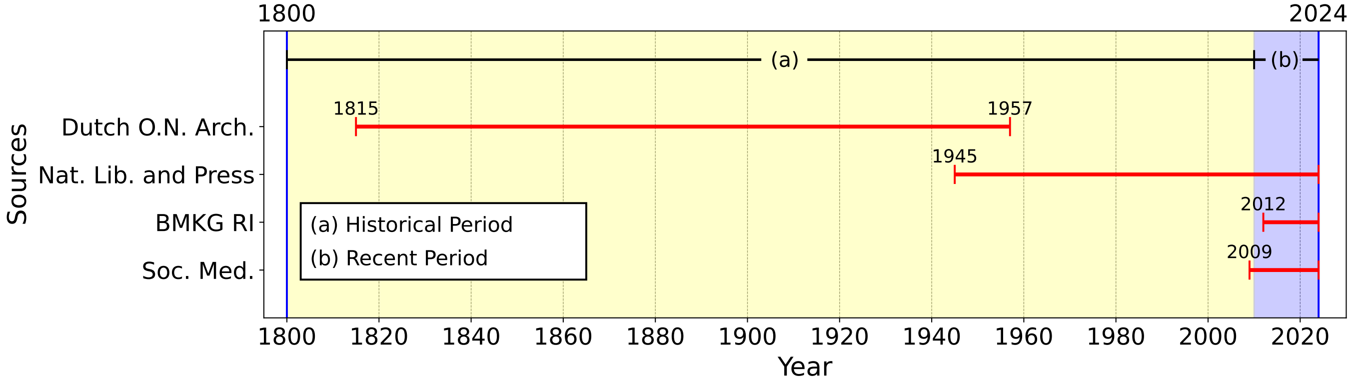

Figure 2. Period of tornado reports sources. There are four main sources: (i) the Dutch old newspaper archives, (ii) National Library and Press Museum, (iii) BMKG RI extreme weather database, and (iv) Social media.

The tornado climatology in Indonesia was divided into two different period. The first period is the historical period, starting in 1800 and ending in 2009. The second period is the recent period, starting in 2010 and ending in 2024, following the release of the BMKG regulation on the "Standard Operating Procedure for Early Warning Implementation, Reporting, and Dissemination of Extreme Weather Information", as well as the period when the Internet became widely used. The periods of tornado report sources are illustrated in Figure 2.

2.1 Historical period

Tornado reports for the historical period were collected from old newspaper archives. There are two sources were used: (1) Dutch old newspaper archives (1800-1957), which were accessed via the online website (https://www.delpher.nl/) and (2) the National Library and Press Museum newspaper archives (1945-2009), which were accessed via the online website (https://mpn.kominfo.go.id/arsip/; http://khastara.perpusnas.go.id). The Dutch newspaper archives were searched using three keywords: (a) tornado, (b) windhoos, and (c) wervelwind. We filtered the archive newspapers by region, specifically *Nederlands-Indie/Indonesie*. The archived newspapers included *Java Govt. Gazette, De Locomotief, Javasche Courant, Deli Courant, Soerabaiasch-Handelsblad, Batavia Nieuwsblad, De Preangerbode, De Indische Courant, Het Nieuws Van Den Dag, De Sumatra Post, Java Bode, Sumatra-Courant, etc*. The newspaper archives from the National Library and Press Museum were searched using two keywords: (a) *angin puyuh* and (b) *angin puting beliung*.

In total, 9,930 reports were collected from the Dutch old newspaper archives and 18,958 reports from National Library and Press Museum newspaper archives (Table 2). A total of 193 tornado reports were accepted into the database. The first recorded tornado case in Indonesia was reported by the *Java Govt. Gazette*. The tornado occurred in Surabaya, East Java, on 7 December 1815. The tornado passed through the town, resulting in one house being destroyed, with one fatality and four people injuries. However, this case was categorized as a possible tornado. The first probable tornado case occurred in Temanggung, Central

Table 2. Total tornado reports and total tornado cases were identified.

No.	Source	Total reports	Total tornado cases
1	Dutch old newspaper archives	9,330	173
2	National Library and Press Museum	18,958	36
3	BMKG RI	1,832	70
4	Social Media	17,549	157
	Total	47,669	436

Java, on 30 December 1834. The tornado struck a large tree, destroyed 70 houses, and damaged rice fields. Fortunately, there ware no fatalities in this disaster.

2.2 Recent period

The main sources for the recent period were the newspaper archives of the National Library and Press Museum (2010-2024), the BMKG RI extreme weather database (2012-2024), and social media (2010-2024, including X, YouTube, and News). The BMKG RI extreme weather database collects internet news and compiles into an extreme weather database, which can be accessed online at https://pikacu.bmkg.go.id/. Tornado reports from social media platforms, such as X, were used to improve the quality of the reports (Baranowski et al., 2020). The tornado cases were extracted through data mining using python and Generative AI (Gemini API) to eliminate noisy data, such as metaphorical terms. The keywords used for mining the tornado cases were similar to those used in the old newspaper archives. The tornado cases were the categorized based on the criteria in Table 1. In total, there were 1,832 reports from the BMKG RI extreme weather database and 17,549 reports from social media (Table 2). For the recent period, 243 tornado cases were accepted into the database.

2.3 Indonesia Tornado Database

Indonesia has no tornado database by now. While the BMKG RI provides an extreme weather database via the online website at https://pikacu.bmkg.go.id/ and the BNPB RI maintains the disaster database which can be accessed online at https://gis.bnpb.go.id/, neither offers detailed information on tornado cases. The BMKG RI's extreme weather database collects news from the internet and compiles it with other disaster data, such as floods, landslides, hail, strong winds, and heavy rainfall. On the other hand, the BNPB RI disaster database does not specifically mention tornadoes, as tornadoes are categorized under extreme weather events, alongside strong winds, hail, tropical cyclones, and extreme temperature changes. Therefore, we developed the Indonesia Tornado Database to document the tornado cases that have occurred in Indonesia (Firdaus and Iswahyudi, 2025). Table 3 shows the attributes of the Indonesia Tornado Database.

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

Table 3. Structure of Indonesia Tornado Database

Field name	Description	Field Type
ID	Identifier of a tornado	Number
Type	Type of a tornado	List: F for Funnel Cloud, T for Tornado, WS for Waterspout
Category	Categorization of a tornado	List: Confirmed, Probable, Possible
Date	Date of a tornado	Date
Time (LST)	Time of a tornado	Time in Local Solar Time (LST)
Time (UTC+7)	Time of a tornado	Time (UTC+7)
Province	Province of a tornado occurred	String
Regency	Regency of a tornado occurred	String
District	District of a tornado occurred	String
Village	Village of a tornado occurred	String
Lon	Longitude	Number
Lat	Latitude	Number
Building Damage	Dividing into three categories: Severe, Moderate, Slight. The total number of building damage caused by a tornado	Number
Injuries	Dividing into two categories: Death and Injuries. The total number of injuries caused by a tornado	Number
Economic Loss (Approximation)	The approximation of economic loss caused by a tornado	Number (in Indonesia currency: Rupiah)
Source	The source of tornado reports	List: Website, National Library & Press Museum, BMKG RI, and Social Media
Website	The source website	String

3 Results

3.1 Decadal and Annual Frequency

The total number of tornado cases in Indonesia, including confirmed and probable cases, from 1834 to 2024 is about 436 cases. More than a half of these cases (243 cases) occurred in the last 15 years (Fig. 3). The increasing trend in tornado cases is likely attributed to advances in technology, such as the widespread use of the internet and social media. Therefore, it is not possible to determine whether tornadoes, as a natural hazard, are increasing.

In the historical period, the total number of tornado cases is 193, which occurred between 1834 and 2009 (175 years). This means the average number of tornado cases is 1.10 tornadoes per year. There was a significant increase in tornado reports

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

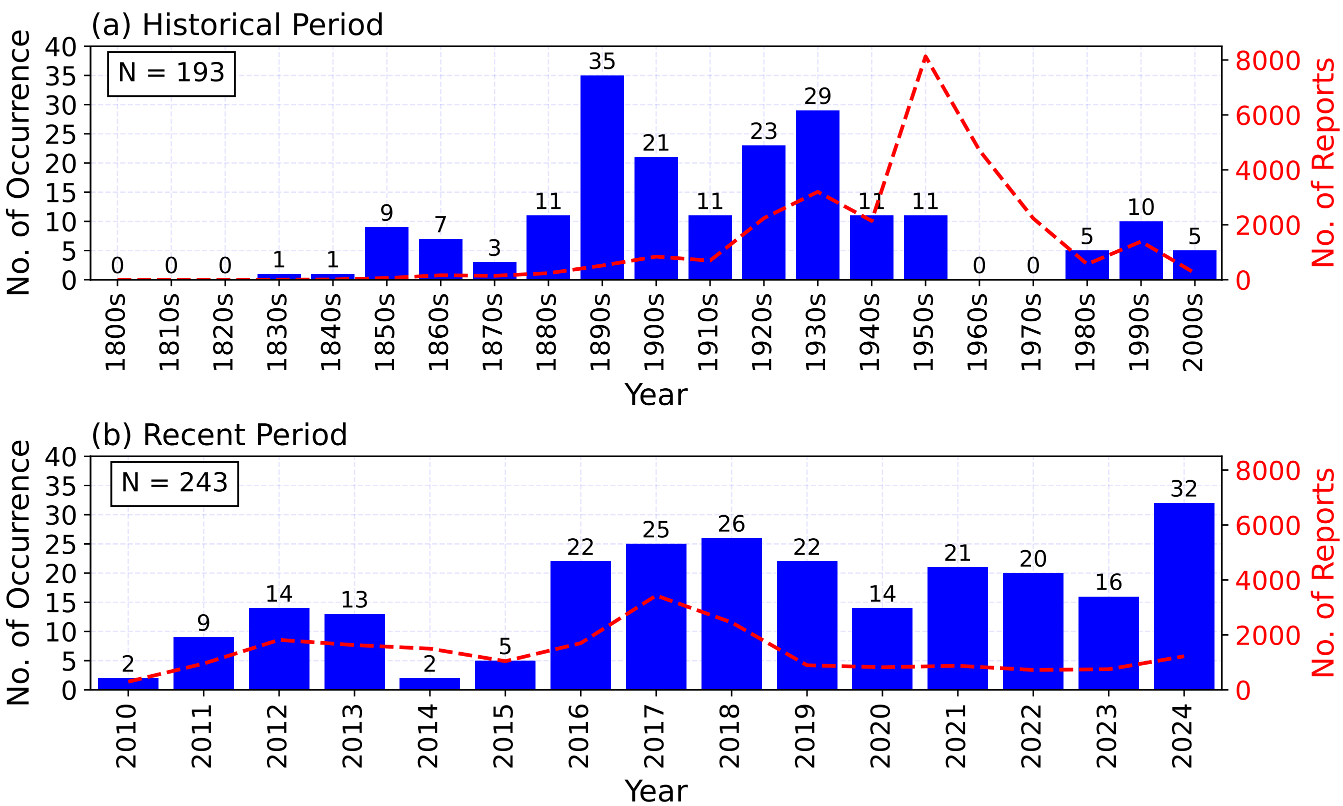

Figure 3. Annual frequency of tornado cases and number of tornado reports: (a) Historical period from 1830s until 2000s (per decades) and (b) Recent period from 2010 until 2024.

from the 1830s to the 1870s, followed by another rise from the 1880s to the 1950s. This increase is presumed to be due to the growing number of newspaper publishers during that period (from 15 publishers to 20 publishers). A break of tornado cases is found from the 1960s to the 1970s. We speculate that this gap resulted from a shift from Dutch newspapers to Indonesia newspapers, which led to changes in newspaper content management. After the 1980s, tornado reports remained relatively constant until the 2000s.

On the other hand, the total number of tornado cases is about 243 tornadoes between 2010 and 2024 (15 years), showing a increase during this period. The average number of tornado cases is about 16.20 tornadoes per year. A notable difference is observed before and after 2016. We speculate that the increase in tornado cases is due to the widespread use of the internet and social media. In addition to that, public awareness of extreme weather events has grown, which has likely influenced the tornado database in recent years (Antonescu et al., 2016).

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

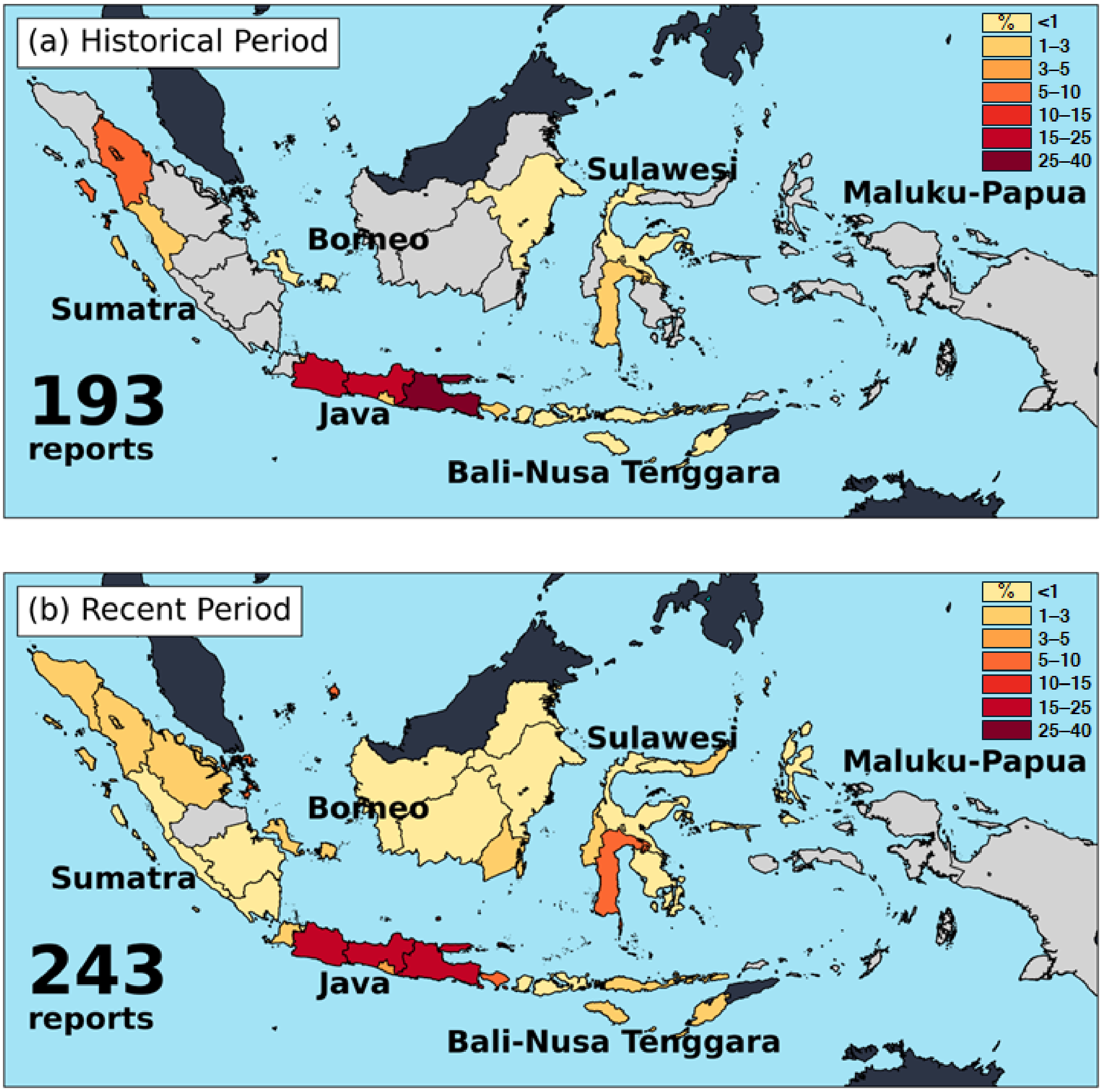

Figure 4. Percentage spatial distribution of tornado cases in Indonesia: (a) Historical period from 1830s until 2000s (per decades) and (b) Recent period from 2010 until 2024.

3.2 Spatial Distribution

The spatial distribution of tornado cases is shown in Figure 4 for six regions: (i) Sumatra, (ii) Java, (iii) Borneo, (iv) Sulawesi, (v) Bali-Nusa Tenggara, and (vi) Maluku-Papua. In our database, tornado cases are most frequent in Java for both periods. The lowest occurrence of tornadoes was reported in Maluku-Papua. In the historical reports, over 75% of tornado reports came from Java, with fewer reports from northern Sumatra, eastern Borneo, central Sulawesi, and Bali-Nusa Tenggara. No tornado reports

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

were recorded from Maluku-Papua. We speculate that the higher frequency of tornado reports in Java and the lower frequency in certain regions are due to: (i) the newspaper publishers and (ii) density population. The old newspaper archives were primarily found in large cities, such as *Java Govt. Gazette* from Batavia (now Jakarta)in Java, *De Locomotief* from Surabaya in Java, *Deli Courant* from Surabaya in Java, *De Preangerbode* from Bandung in Java, *De Sumatra Post* from Medan in Sumatra and *Sumatra-Courant* from Padang in Sumatra. Additionally, Indonesia's population is not evenly distributed (Figure S1). Over 63.8% Indonesia's population lived in Java and 17.4% lived in Sumatra.

In the recent period, tornado reports have been more evenly distributed compared to the historical period, although tornado reports remain most frequent in Java. There has been an increase in tornado reports across Sumatra, Borneo, Sulawesi, Bali-Nusa Tenggara. The usage of the internet and population growth are the main reasons for the increase in tornado reports during this period (Anderson et al., 2007). The population growth in Sumatra, Borneo, Sulawesi, Maluku-Papua has increased by 2-5 times in 2024 compared to 1971 (Figure S2). Over the past 15 years, the internet and social media have been widely used globally, including in Indonesia. For example, the number of X users in Indonesia was about 29.4 million in 2012 (Carley et al., 2015), and this number is expected to have increased since then. This widespread use of the internet means that information, including disaster reports, can be disseminated easily (Baranowski et al., 2020).

3.3 Monthly and Diurnal Distribution

Figure 5 shows the monthly and diurnal distribution of tornado cases in Indonesia from 1834 to 2024. Approximately 64% of tornado cases occurred between November and March (Figure 5a). This pattern is coinciding with the Asia-Australia monsoon system, which is active during the boreal winter (Wheeler and McBride, 2005). Tornadoes occurred most frequently in November and least frequently in June.

The percentage of monthly distribution for each region is shown in Figure 5b. The monthly peak of tornado cases varies by region. The peak differences among regions are coinciding with the precipitation pattern in Indonesia (Aldrian and Susanto, 2003). Java and Bali-Nusa Tenggara have a peak of tornado cases during the Nov-Dec-Jan-Feb season, while Maluku-Papua has a peak between May-Jul and Borneo peak between Jul-Aug. Sulawesi has peak tornado cases in the March, September, and December. Sumatra has peak tornado cases in the April, August, and November. These patterns are a result of the distinct precipitation patterns characteristic of these islands.

The diurnal distribution of tornado cases in Indonesia was placed into 1-hour bins in Local Solar Time (LST): 0000-0059, 0100-0159, etc (Figure 5c). The old newspaper archives sometimes do not provide detailed information regarding the timing of tornado occurrences. Therefore, we categorized that data into five terms: Mor (morning), Aft (afternoon), Eve (evening), Nig (night), and NaN (no information available). Tornadoes were most frequently reported during the daytime between 1300-1700 LT and in the evening, with approximately 56% of tornado cases occurring during this time. A smaller portion of tornado cases occurred in the early-morning and at night. This pattern coincides with the diurnal cycle of precipitation in Indonesia. Peatman et al. (2021) stated that diurnal cycle of precipitation in Indonesia is driven by temperature contrasts between land and sea, which create deep convection in the afternoon. In addition to that, the complex topography in Indonesia can influence and enhance this convection through orography (Peatman et al., 2021; Firdaus et al., 2024).

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

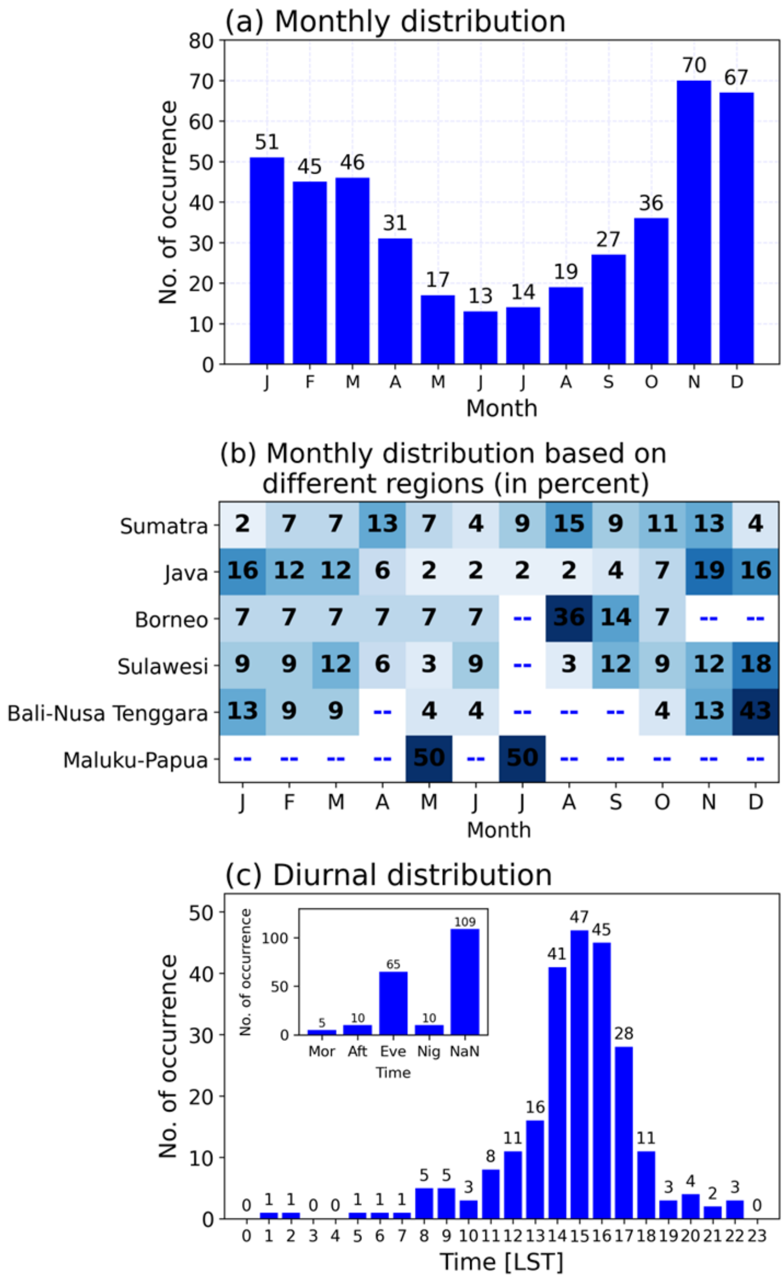

Figure 5. (a) Monthly distribution, (b) percentage of monthly distribution based on different regions, and (c) diurnal distribution of tornado cases in Indonesia for the historical and recent period. The percentage is calculated by dividing the number of tornado cases for a specific month and region by the total number of tornado cases in that region. In the inset of panel (c), 'Mor', 'Aft', 'Eve', 'Nig', 'NaN' represent morning, afternoon, evening, night, and missing data, respectively.

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

4 Discussion and Conclusion

This paper presents what is believed to be the first climatological analysis of tornado cases in Indonesia to date. A total of 436 tornado cases occurring over 190 years, from 1834 to 2024, were analyzed. The reports were collected from four main sources: (i) old newspaper archives from the website https://delpher.nl/, (ii) the National Library and Press Museum, (iii) the BMKG RI extreme weather database, and (iv) Social media.

On average, one tornado occurred during the historical period (1834-2009), while 16-17 tornadoes occurred during the recent period (2010-2024). The most frequent tornado reports were reported in Java for both periods, followed by Sumatra, Sulawesi, Bali-Nusa Tenggara, Kalimantan, and Maluku-Papua. Tornado cases mostly occurred during Nov-Dec-Jan-Feb-Mar, coinciding with the active phase of the Asia-Australia monsoon system and other convective activity precursors. However, further investigation is needed to assess the influence of convective precursors, such as the Asia-Australia monsoon system, Madden-Julian Oscillation (MJO) (Da Silva and Matthews, 2021), El Niño–Southern Oscillation (ENSO) (Kurniadi et al., 2021), and Cross-Equatorial Northerly Surge (CENS) (Hattori et al., 2011) on tornado activity in Indonesia. The majority of tornado cases occurred between 1300-1700 LT and in the evening.

The rating of tornadoes is critically important for understanding and mitigating the impacts of these severe weather events. Tornado ratings typically use the Fujita scale (Fujita, 1973) or the T-Scale (Meaden, 1976; Feuerstein et al., 2011), both of which are based on the severity of damage caused by strong winds. The Fujita Scale was later updated to The Enhanced Fujita Scale (EF-Scale) in 2007 (McDonald and Mehta, 2006). The EF-Scale uses damage indicators (DIs), with each DI having several degrees of damage (DODs). Various adaptations of the EF-Scale have been developed in different countries, such as in Canada (David et al., 2014; Environment Canada's Weather Service, 2018) which is named EF-Scale Canada and Japan (Japan Meteorological Agency, 2015) which is named Japanese EF-Scale (JEF-Scale). These adaptations modify the DI and DOD based on regional factors such as building structures, vegetation, and construction materials, which vary by country.

In Indonesia, there is currently no standardized procedure to assess tornado damage, and as a result, tornadoes in the country are not rated. Two recent tornado events, the Tornado Bogor (2018) and Tornado Rancaekek (2024) (Figure 1), did not have a rating. Figure 1 shows the appearance of the Tornado Rancaekek and Tornado Bogor with the damaged buildings and trees caused by these events. The Tornado Rancaekek damaged 1,177 houses and buildings, while the Tornado Bogor damaged 1,697 houses and buildings.

Table 4 presents the tornado assessment for Tornado Rancaekek and Tornado Bogor based on both the EF-Scale and the JEF-Scale. Both scales use the DI and DOD to assess the expected wind speed of a tornado, assigning ratings based on the highest wind speed. According to the EF-Scale, Tornado Rancaekek can be categorized as EF2, as it caused significant damage to a factory building, while Tornado Bogor is categorized as EF1, due to the loss of roof covering materials on buildings. On the other hand, according to the JEF-Scale, Tornado Rancaekek is classified as JEF3, while Tornado Bogor is categorized as JEF1.

It is clear from the evidence above that there is a different rating between the EF-Scale and the JEF-Scale caused by their DI and DOD classification. Indonesia has distinct building and structural characteristics compared to countries such as the United

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

Table 4. Tornado Rancaekek and Bogor assessment (Figure 1).

No.	Tornado	Assessment	
		EF-Scale	JEF-Scale
1.	Rancaekek	(Figure 1b) DI 23: Warehouse Building DOD 5: Collapse of other non-bearing exterior walls Expected wind speed: 114 miles/hour	DI 2: Industrialized steel-framed houses (prefabricated) DOD 5: Deformation/loss of wall cladding Expected wind speed: 75 m/s
		(Figure 1c) DI 28: Trees-Softwood DOD 4: Trunk snapped Expected wind speed: 104 miles/hour	DI 25: Broad-leaved trees DOD 3: Trunk snapping (without decay) Expected wind speed: 60 m/s
		EF-Scale: EF-2	JEF-Scale: JEF-3
2.	Bogor	(Figure 1e) DI 1: Small Barns and Farm Outbuildings DOD 4: Major loss of roof panels Expected wind speed: 90 miles/hour	DI 1: Wooden houses and stores DOD 4: Destruction/detachment of eaves or sheathing roof boards Expected wind speed: 50 m/s
		(Figure 1f) DI 28: Trees-Softwood DOD 3: Trees uprooted Expected wind speed: 87 miles/hour	DI 25: Broad-leaved trees DOD 2: Uprooting without root decay Expected wind speed: 45 m/s
		EF-Scale: EF-1	JEF-Scale: JEF-1

States and Japan. For instance, many houses in Indonesia are constructed with wood and brick, and roofs are often made of tiles. These factors influence the DOD classification, which can lead to overestimation of the tornado's rating when applying the EF-Scale or JEF-Scale. Therefore, it is recommended that Indonesia develop its own tornado scale, tailored to its unique construction practices, to more accurately assess and rate tornado events in Indonesia.

Data availability. The Indonesia Tornado Database is available at ttps://doi.org/10.5281/zenodo.15099438 (Firdaus and Iswahyudi, 2025). The old newspaper archives were collected and saved by the author. These are available upon request from the corresponding author on reasonable request.

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

Author contributions. IMF: conceptualization, data curation, methodology, writing (original draft). TY: supervision, writing (review and editing). MRA: supervision, writing (review and editing). ER: supervision, writing (review and editing).

Competing interests. The contact author has declared that none of the authors has any competing interests.

Acknowledgements. The first author was funded by a scholarship from Japan International Cooperation Agency (JICA) under Human Resources Development in Science, Technology and Innovation Program. The first author would like to thank National Press Museum and National Library who provide the old newspaper archives. Thank to Ridha Fatony Iswahyudi for helping the first author to collect the tornado reports. This study is partly funded by "Program Riset ITB tahun 2025" and "Program PPMI FITB 2025".

References

Aldrian, E. and Susanto, R. D.: Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature, International Journal of Climatology, 23, 1435–1452, https://doi.org/https://doi.org/10.1002/joc.950, 2003.

American Meteorological Society: Tornado, accessed 20 August 2024, https://glossary.ametsoc.org/wiki/Tornado, 2024.

Anderson, C. J., Wikle, C. K., Zhou, Q., and Royle, J. A.: Population Influences on Tornado Reports in the United States, Weather and Forecasting, 22, 571 – 579, https://doi.org/10.1175/WAF997.1, 2007.

Antonescu, B. and Bell, A.: Tornadoes in Romania, Monthly Weather Review, 143, 689 – 701, https://doi.org/10.1175/MWR-D-14-00181.1, 2015.

Antonescu, B., Schultz, D. M., Lomas, F., and Kühne, T.: Tornadoes in Europe: Synthesis of the Observational Datasets, Monthly Weather Review, 144, 2445 – 2480, https://doi.org/10.1175/MWR-D-15-0298.1, 2016.

Baranowski, D. B., Flatau, M. K., Flatau, P. J., Karnawati, D., Barabasz, K., Labuz, M., Latos, B., Schmidt, J. M., Paski, J. A. I., and Marzuki: Social-media and newspaper reports reveal large-scale meteorological drivers of floods on Sumatra, Nature Communications, 11, https://doi.org/10.1038/s41467-020-16171-2, 2020.

Bhan, S., Paul, S., Chakravarthy, K., Saxena, R., Ray, K., and Gopal, N.: Climatology of Tornadoes over northwest India and Pakistan; and Meteorological Analysis of recent Tornadoes over the Region, Journal of Indian Geophysical Union, 20, 75, 2016.

Capuli, G.: Project Severe Weather Archive of the Philippines (SWAP) Part 1: Establishing a Baseline Climatology for Severe Weather across the Philippine Archipelago, Annals of Geophysics, 67, GC553, https://doi.org/10.4401/ag-9151, 2024.

Carley, K., Malik, M., Kowalchuck, M., Pfeffer, J., and Landwehr, P.: Twitter usage in Indonesia, Nature Communications, available at SSRN: https://ssrn.com/abstract=2720332, 2015.

Chen, J., Cai, X., Wang, H., Kang, L., Zhang, H., Song, Y., Zhu, H., Zheng, W., and Li, F.: Tornado climatology of China, International Journal of Climatology, 38, 2478–2489, https://doi.org/https://doi.org/10.1002/joc.5369, 2018.

Da Silva, N. A. and Matthews, A. J.: Impact of the Madden–Julian Oscillation on extreme precipitation over the western Maritime Continent and Southeast Asia, Quarterly Journal of the Royal Meteorological Society, 147, 3434–3453, https://doi.org/https://doi.org/10.1002/qj.4136, 2021.

David, M. S., McCarthy, P. J., and Kopp, G. A.: Implementation and Application of the EF-Scale in Canada, 24th Conference on Severe Local Storms, American Meteorological Society, 2014.

Dotzek, N., Groenemeijer, P., Feuerstein, B., and Holzer, A. M.: Overview of ESSL's severe convective storms research using the European Severe Weather Database ESWD, Atmospheric Research, 93, 575–586, https://doi.org/https://doi.org/10.1016/j.atmosres.2008.10.020, 4th European Conference on Severe Storms, 2009.

Environment Canada's Weather Service: Enhanced Fujita scale for wind damage, website: https://www.canada.ca/en/environment-climate-change/services/seasonal-weather-hazards/enhanced-fujita-scale-wind-damage.html, 2018.

Feuerstein, B., Groenemeijer, P., Dirksen, E., Hubrig, M., Holzer, A. M., and Dotzek, N.: Towards an improved wind speed scale and damage description adapted for Central Europe, Atmospheric Research, 100, 547–564, https://doi.org/https://doi.org/10.1016/j.atmosres.2010.12.026, 5th European Conference on Severe Storms, 2011.

Firdaus, I. M. and Iswahyudi, R. F.: Indonesia Tornado Database, https://doi.org/10.5281/zenodo.15233333, 2025.

Firdaus, I. M., Trilaksono, N. J., and Yamazaki, T.: Mechanism of Initiation and Regeneration of Convective Cell in Bandung Basin, Indonesia, Geoscience Letters, 11, https://doi.org/10.1186/s40562-024-00359-1, 2024.

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

Fujita, T. T.: Tornadoes Around the World, Weatherwise, 26, 56–62, 78–83, 1973.

Hattori, M., Mori, S., and Matsumoto, J.: The Cross-Equatorial Northerly Surge over the Maritime Continent and Its Relationship to Precipitation Patterns, Journal of the Meteorological Society of Japan. Ser. II, 89A, 27–47, https://doi.org/10.2151/jmsj.2011-A02, 2011.

Hidayatullah: Angin Kencang Bogor, 1 Korban Jiwa, Pohon Tumbang, Rumah Rusak, accessed 27 August 2024, https://hidayatullah.com/berita/nasional/2018/12/06/156075/angin-kencang-bogor-1-korban-jiwa-pohon-tumbang-rumah-rusak.html, 2018.

Japan Meteorological Agency: Guidelines for the Japanese Enhanced Fujita Scale, Tech. rep., Japan Meteorological Agency, 2015.

Jawa Pos: Peneliti BRIN Ungkap Penyebab Angin Puting Beliung di Rancaekek Bandung Mirip Tornado, accessed 27 August 2024, https://www.jawapos.com/nasional/014330527/peneliti-brin-ungkap-penyebab-angin-puting-beliung-di-rancaekek-bandung-mirip-tornado, 2024.

Johnson, V. A., Klockow-McClain, K. E., Peppler, R. A., and Person, A. M.: Tornado Climatology and Risk Perception in Central Oklahoma, Weather, Climate, and Society, 13, 743 – 751, https://doi.org/10.1175/WCAS-D-20-0137.1, 2021.

Kahraman, A. and Markowski, P. M.: Tornado Climatology of Turkey, Monthly Weather Review, 142, 2345 – 2352, https://doi.org/10.1175/MWR-D-13-00364.1, 2014.

Kawazoe, S., Inatsu, M., Fujita, M., Sugimoto, S., Okada, Y., and Watanabe, S.: Evaluation of tornadic environments and their trends and projected changes in Japan, npj Climate and Atmospheric Science, 6, https://doi.org/10.1038/s41612-023-00524-x, 2023.

Kompas: Dampak Puting Beliung di Bogor, Satu Orang Tewas hingga 770 Rumah Rusak, accessed 26 August 2024, https://regional.kompas.com/read/2018/12/08/08235741/dampak-puting-beliung-di-bogor-satu-orang-tewas-hingga-770-rumah-rusak, 2018.

Kounkou, R., Mills, G., and Timbal, B.: A reanalysis climatology of cool-season tornado environments over southern Australia, International Journal of Climatology, 29, 2079–2090, https://doi.org/https://doi.org/10.1002/joc.1856, 2009.

Kurniadi, A., Weller, E., Min, S.-K., and Seong, M.-G.: Independent ENSO and IOD impacts on rainfall extremes over Indonesia, International Journal of Climatology, 41, 3640–3656, https://doi.org/https://doi.org/10.1002/joc.7040, 2021.

Maas, M., Supinie, T., Berrington, A., Emmerson, S., Aidala, A., and Gavan, M.: The Tornado Archive: Compiling and Visualizing a Worldwide, Digitized Tornado Database, Bulletin of the American Meteorological Society, 105, E1137 – E1152, https://doi.org/10.1175/BAMS-D-23-0123.1, 2024.

Matsangouras, I. T., Nastos, P. T., Bluestein, H. B., and Sioutas, M. V.: A climatology of tornadic activity over Greece based on historical records, International Journal of Climatology, 34, 2538–2555, https://doi.org/https://doi.org/10.1002/joc.3857, 2014.

McDonald, J. R. and Mehta, K. C.: A Recommendation for an Enhanced Fujita Scale (EF-Scale), Revision 2, Wind Science and Engineering Research Center, Texas Tech University, Lubbock, TX, 111, 2006.

Meaden, G.: Tornadoes in Britain: their intensities and distribution in space and time, The Journal of Meteorology, 1976.

Newark, M. J.: Canadian tornadoes, 1950–1979, Atmosphere-Ocean, 22, 343–353, https://doi.org/10.1080/07055900.1984.9649203, 1984.

Niino, H., Fujitani, T., and Watanabe, N.: A Statistical Study of Tornadoes and Waterspouts in Japan from 1961 to 1993, Journal of Climate, 10, 1730 – 1752, https://doi.org/10.1175/1520-0442(1997)010<1730:ASSOTA>2.0.CO;2, 1997.

Paul, F.: A developing inventory of tornadoes in France, Atmospheric Research, 56, 269–280, https://doi.org/https://doi.org/10.1016/S0169-8095(00)00077-6, conference on European Tornadoes and Severe Storms, 2001.

Peatman, S. C., Schwendike, J., Birch, C. E., Marsham, J. H., Matthews, A. J., and Yang, G.-Y.: A Local-to-Large Scale View of Maritime Continent Rainfall: Control by ENSO, MJO, and Equatorial Waves, Journal of Climate, 34, 8933 – 8953, https://doi.org/10.1175/JCLI-D-21-0263.1, 2021.

https://doi.org/10.5194/egusphere-2025-1857
Preprint. Discussion started: 14 May 2025

Rauhala, J., Brooks, H. E., and Schultz, D. M.: Tornado Climatology of Finland, Monthly Weather Review, 140, 1446 – 1456, https://doi.org/10.1175/MWR-D-11-00196.1, 2012.

RRI: BMKG Sebut Bencana di Rancaekek Puting Beliung, accessed 26 August 2024, https://www.rri.co.id/daerah/566180/bmkg-sebut-bencana-di-rancaekek-puting-beliung, 2024.

Tempo: Awan Bunga Kol dan Ancaman Puting Beliung di Masa Pancaroba, accessed 26 August 2024, https://fokus.tempo.co/read/1153197/awan-bunga-kol-dan-ancaman-puting-beliung-di-masa-pancaroba, 2018.

Tempo: Beda Pendapat Soal Amukan Angin di Rancaekek, Begini Cara Membedakan Puting Beliung dan Tornado, accessed 26 August 2024, https://tekno.tempo.co/read/1836798/beda-pendapat-soal-amukan-angin-di-rancaekek-begini-cara-membedakan-puting-beliung-dan-tornado, 2024.

Veloso-Aguila, D., Rasmussen, K. L., and Maloney, E. D.: Tornadoes in Southeast South America: Mesoscale to Planetary-Scale Environments, Monthly Weather Review, 152, 295 – 318, https://doi.org/10.1175/MWR-D-22-0248.1, 2024.

Wheeler, M. C. and McBride, J. L.: Australian-Indonesian monsoon, pp. 125–173, Springer Berlin Heidelberg, Berlin, Heidelberg, ISBN 978-3-540-27250-2, https://doi.org/10.1007/3-540-27250-X_5, 2005.

Zhang, C., Xue, M., Zhu, K., and Yu, X.: Climatology of Significant Tornadoes within China and Comparison of Tornado Environments between the United States and China, Monthly Weather Review, 151, 465 – 484, https://doi.org/10.1175/MWR-D-22-0070.1, 2023.