# Effectiveness of Emergency Response to Typhoons: Lessons Learned from Historical Typhoon Disasters in Zhuhai, China

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**ABSTRACT**

Typhoons significantly impact socio-economics, varying in impact due to unique characteristics. However, limited studies explore why similar intensity typhoons affect regions differently. This study compares the emergency response measures of Zhuhai, Guangdong Province, China, in response to typhoon Hato (2017), Mangkhut (2018), and Higos (2020). These three similar typhoons offer an empirical opportunity to assess the effectiveness of emergency management. This research builds a timeline of Zhuhai's emergency response measures to the typhoons, collects Weibo data 72 hours before and after the typhoon landfall, performs keyword frequency analysis on contents and analyzes in detail the content of weibo postings, and changes in sentiment. Results show that timely and systematic emergency response measures may reduce disaster losses, which means emergency management is crucial in mitigating typhoon impacts, offering valuable lessons for other coastal cities.

**Keywords**

Typhoon disaster, emergency management, comparative analysis, data mining.

## INTRODUCTION

Typhoon is an extremely destructive natural disaster whose impact spans the corners of globe (Gettelman et al., 2018). Worldwide, about 150 million people are affected by typhoons each year (Geiger et al., 2021). The Typhoon can trigger strong winds, heavy rainfall, storm surges and other disasters, posing a significant threat to human life safety and social property, and causing severe impact on industries such as agriculture, fisheries, and transportation. For example, Hurricane Katrina in 2005 caused severe flooding in areas such as New Orleans, which dislocated a large number of residents and resulted in more than 1,800 deaths and an estimated $125 billion in economic damages, also exposing the humanitarian crises (Guidotti, 2006). Similarly, Hurricane Haiyan in the Philippines in 2013 affected about 12.2 million people, causing almost 490,000 homes completely destroyed and

more than 590,000 homes partially destroyed, resulting in economic losses estimated at PhP 424 billion, representing 3.7 percent of GDP that year in Philippines (Santos et al., 2016). In addition, Typhoon Haima in 2016 (Zhang et al., 2019) and Super Typhoon Mangosteen in 2018 (Choy et al., 2020) wreaked havoc in the Philippines and Southeast Asia, causing thousands of loss lives and devastating the local economy and social stability. These cases highlight the threat and danger of typhoons as an extreme weather phenomenon. Studies have shown that under global warming and climate change, the intensity and uncertainty of typhoons are continuing to increase, and the number and proportion of typhoons with high intensity will rise (Xu et al., 2020). Hence, there is an urgent need to attach greater importance to typhoon disasters and the corresponding emergency management measures.

Typhoon disaster emergency management encompasses organized, planned, and coordinated activities to mitigate the impact of typhoons on lives, property, and the socio-economy. Worldwide research focuses on risk assessment, early warning, emergency response, and post-disaster recovery. Risk assessment is crucial for comprehensive disaster mitigation and emergency management, helping prevent and reduce losses (Shiyuan et al., 2006). Early warning systems are essential, and researchers aim to improve prediction accuracy using modern meteorological and information technology (Huo et al., 2019; Jiang et al., 2018). Innovations like drone technology enhance monitoring, visualization, and analysis, strengthening meteorological and disaster forecasting collaboration (Chen et al., 2020). Multi-departmental and multi-level warning systems are established and improved, with various release channels to ensure timely warnings to the public. Post-typhoon reconstruction aims to restore normalcy, emphasizing environmental protection and sustainable resource use. It also promotes social psychological recovery and economic revitalization. Comprehensive measures, including enhanced early warning systems and improved policies, aim to address the profound impact of typhoons, ensuring a sustainable and steady future for society (Sylwanowicz et al., 2018).

Typhoon disaster emergency management hinges on swift and effective emergency response. Scientific typhoon emergency plans delineate departmental responsibilities, coordinate resources, and ensure rapid, effective responses. A study retrieve the most similar historical cases, providing a reference for generating emergency plans for target typhoon trajectories (Li, 2022). Scientific evacuation plans (Sun et al., 2020) and the selection of emergency shelter locations (Anping, 2010) are directly related to personnel safety. A model based on typhoon track changes aids in emergency shelter allocation (Qin et al., 2019). Meanwhile, the reserve and demand forecasting of relief supplies are crucial aspects of emergency response (Pan et al., 2017; Uichanco, 2022). By predicting the real-time and future needs of affected areas, various types of relief supplies can be reasonably stocked to ensure timely and effective rescue operations after disasters occur. Additionally, the adequacy of household emergency preparedness has garnered attention. Through investigative research, scholars have found that enhancing household awareness and preparatory measures for typhoon events can effectively reduce disaster-related losses (Chan et al., 2019). The timeliness and effectiveness of post-disaster rescue are crucial for mitigating disaster losses and safeguarding people's lives (Santiago et al., 2016). The restoration of water networks (Wei et al., 2018), power grids (Liu et al., 2023), communications (G.C et al., 2019), and transportation (Wang et al., 2018) is essential for resuming normal social functions in affected areas. Researchers are dedicated to enhancing the disaster resistance of these infrastructures and studying efficient restoration solutions to expedite the return to normal social operations after disasters. The recovery of the healthcare system is a critical aspect of typhoon disaster emergency response. Scholars focus on ensuring adequate medical resources, timely emergency services, and optimizing the organizational structure of the healthcare system to meet medical needs during disasters (Lai et al., 2003; Su, 2013). In recent years, social media has demonstrated a significant role in crisis response (Liu et al., 2020), particularly in typhoon disaster emergency management (Athanasia & Stavros, 2015; Pollack et al., 2015). Its immediacy and interactivity make it a pivotal channel for information dissemination, aiding the public in quickly accessing warnings and emergency measures. Social media content analysis offers new insights and means for risk assessment and early warning. Furthermore, social media facilitates the coordination and integration of rescue efforts, enhancing rescue efficiency. For instance, studies have employed sentiment analysis through artificial neural networks to assess the urgency of relevant social media information, thereby enhancing the efficiency and effectiveness of emergency management (Ermino et al., 2022).

China, with its extensive coastlines and unique geography, is highly susceptible to typhoons (Wang et al., 2021), particularly in the major deltas of Tianjin, Shanghai, and Guangzhou (Yin et al., 2013). The southeast coast experiences frequent typhoons and significant damage, while rapid economic development and population density have increased economic losses from typhoon disasters (Li et al., 2016). As a coastal city in Guangdong Province, Zhuhai is located on the west bank of the Pearl River and is directly affected by the typhoon season. Historical records show that Zhuhai has endured numerous severe typhoons, posing constant challenges to urban management and disaster prevention and mitigation efforts. Differences in actual damage caused by similar-intensity typhoons are observed. This study compares three recent typhoons—Pigeon (2017), Mangkhut (2018), and Higos (2020)—with similar paths and intensity, all significantly impacting production and living in Zhuhai.

Using a comprehensive big data approach, this study analyzes news and social media data on Zhuhai's typhoon disaster emergency management. Through word frequency and categorical analysis, we aim to understand the evolution of Zhuhai's emergency response to similar-intensity typhoons. Results show Zhuhai's consistent optimization of emergency measures, which improves the city system's resilience to natural disasters. This study provides theoretical insights for disaster prevention, mitigation, and sustainable urban resilience.

## OVERALL STRUCTRUE

This study (Figure 1) focuses on three recent typhoons hitting Zhuhai — Hato (2017), Mangkhut (2018) and Higos (2020) — with similar tracks and intensities. Data mining is used to collect relevant news articles and Weibo data tagged with 'Zhuhai' and 'typhoon', while web crawling retrieves Weibo during a 144-hour window, encompassing 72 hours before and 72 hours after each typhoon's landfall, forming a comprehensive disaster event dataset. Analyzing Weibo content via lexical frequency, word clouds and categorization, the study uncovers prominent public concerns and tracks changes in emotional sentiment throughout the warning-to-recovery cycle. It offers a new perspective on disaster management by vividly illustrating these fluctuations in a time series graph.

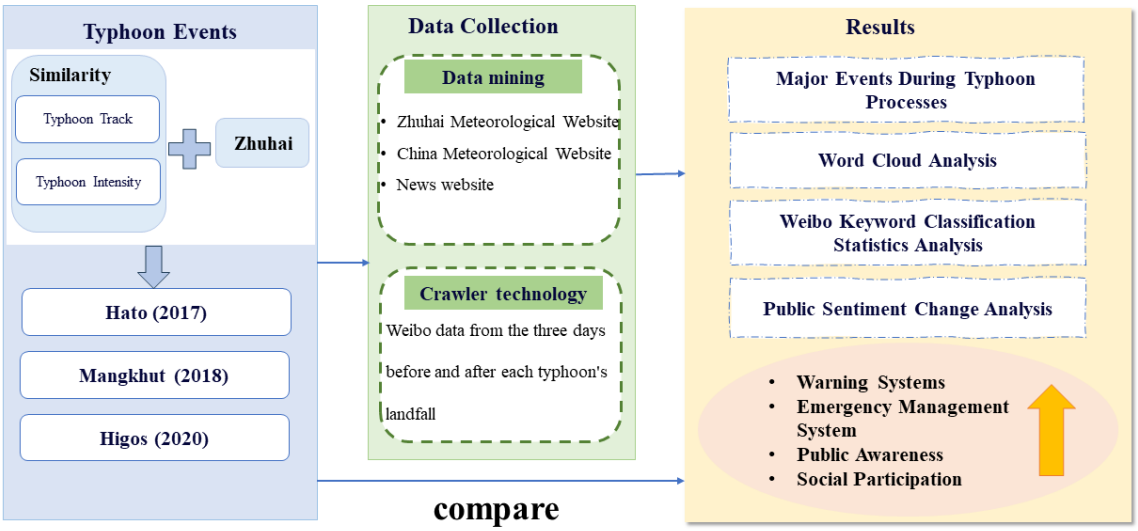



**Figure 1. The overall structure of this paper**

## STUDY AREA AND TYPHOON EVENTS

### Study Area

Zhuhai, situated in Guangdong Province's southwestern Pearl River Delta, is a central Pearl River Delta city and boasts the region's largest ocean area, most islands, and longest coastline. It uniquely connects to both Hong Kong and Macao via road. Covering 1,725 km² of land and 9,348 km² of sea within its territorial baseline, Zhuhai had 2.477 million residents by late 2022, with a 90.76% urbanization rate. Administered through Xiangzhou, Doumen, and Jinwan districts, it includes 15 counties, 10 streets, and 329 villages/communities (Figure 2). Zhuhai experiences a subtropical monsoon climate, prone to various catastrophic weather influences and emergencies, particularly typhoons in summer and autumn. Typhoons bring substantial unpredictability and complexity, inflicting wind, rain-induced flooding, and coastal storm surge disasters on Zhuhai. The city averages around 4 typhoons annually, with 1 severe impact and 5 instances of heavy rainfall, according to the Zhuhai Meteorological Bureau's "White Paper on Meteorological Public Services". (Su et al., 2022)"

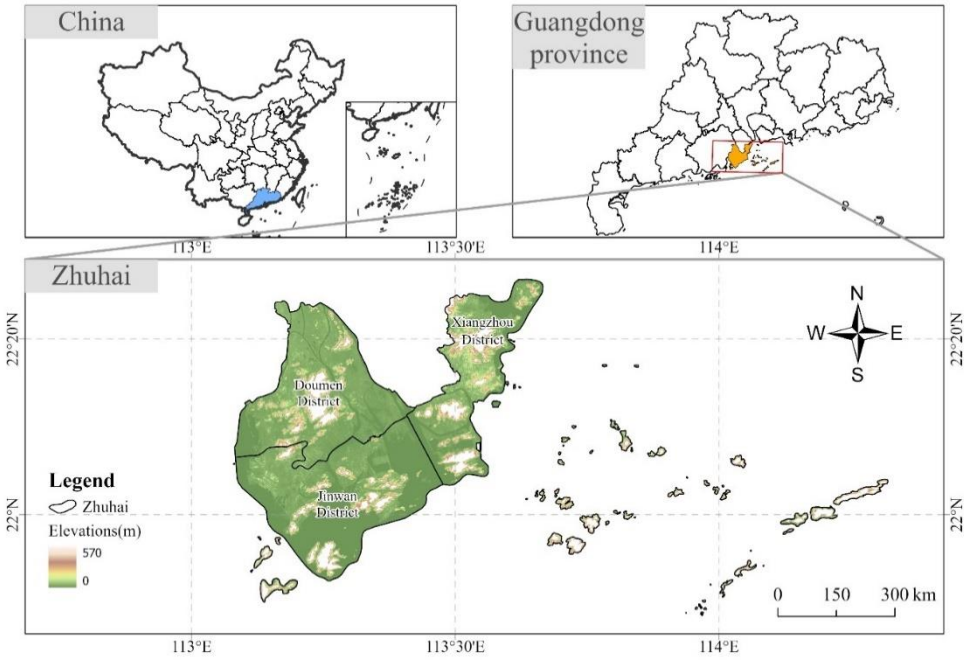



**Figure 2. Geographic location of zhuhai**

### Typhoon Events

Using the 1949-2022 tropical cyclone dataset from the China Meteorological Administration (Lu et al., 2021; Ying et al., 2014), a 300 km radius around Zhuhai was analyzed for typhoon impact. Excluding the unnumbered typhoons, a total of 1540 typhoons are collected in the dataset, and finally 228 typhoons affecting Zhuhai are extracted, averaging 3.08 typhoons per year. Typhoons Hato (2017), Mangkhut (2018), and Higos (2020) are selected as the study objects (Table 1) based on their intensity, wind speeds, trajectories (Figure 3), and impact on Zhuhai.

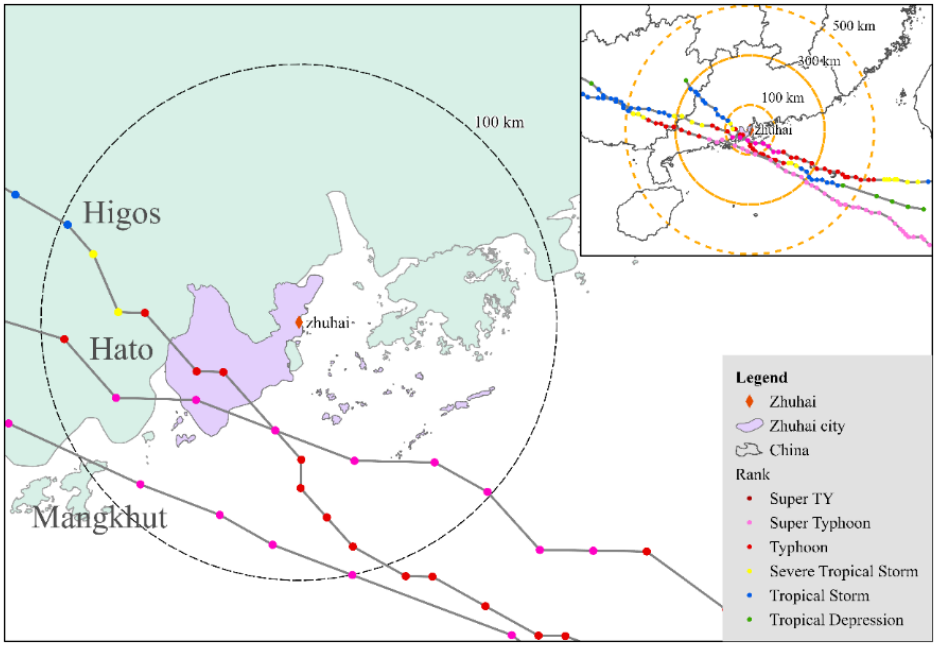



**Figure 3. Trajectories of typhoon Hato, Mangkhut, Higos**

**Table 1. Disaster Information of Typhoons and its Impact on Guangdong Province**

| Typhoon | Hato | Mangkhut | Higos |
|---|---|---|---|
| Year | 2017 | 2018 | 2020 |
| Generation time(month/day) | 8/20 | 9/7 | 8/16 |
| Landing time(month/day) | 8/23 | 9/16 | 8/19 |
| Landing site | Zhuhai, Guangdong | Taishan, Guangdong | Zhuhai, Guangdong |
| Landing intensity | Super Typhoon | Super Typhoon | Typhoon |
| Maximum wind power (level) (wind speed, m/s) | 14(48) | 14(42) | 12(33) |
| Affected areas (mainland China) | Guangdong, Guangxi, Yunnan, Hunan, Guizhou, Fujian | Guangdong, Guangxi, Hainan, Hunan, Yunnan, Guizhou | Guangdong, Guangxi |
| **Impact on Guangdong Province** | | | |
| Affected population(10,000 people) | 142.4 | 306.6 | 6.3 |
| Deaths (people) | 13 | 5 | 0 |
| Missing (people) | 0 | 0 | 0 |
| Transfers (10,000 people) | 21.3 | 126.4 | 4.7 |
| Collapsed houses (10,000) | 0.1 | 0.2 | 0 |
| Affected area (10,000 hectares) | 6.4 | 23.2 | 1.23 |
| Direct Economic Losses (Billions of CNY) | 27.36 | 13.29 | 0.42 |

The typhoons Hato, Mangkhut, and Higos share similarities: they occurred consecutively, hit Guangdong Province with typhoon-level intensity, and exhibited distinct seasonal patterns. Their similar tracks suggest Guangdong, particularly Zhuhai, is a key impact zone. Despite these similarities, they differed in their impact on Guangdong. Based on statistical data regarding the affected population and areas, typhoon Hato demonstrates an exceptionally high level of destructiveness and ferocity. Nevertheless, it is noteworthy that the direct economic losses attributed to Hato are merely half of those incurred by Mangkhut, along with a relatively lower count of fatalities. Similarly, despite its slightly reduced intensity, Higos has incurred lesser losses, leading us to inquire about the presence of other influencing factors. These unusual phenomena have piqued our curiosity, necessitating a further exploration of the underlying reasons for such outcomes.

## METHODOLOGY

The data collection process involves systematically scraping web content using the Octopus Crawler. Octopus Crawler analyzes web pages and, leveraging regular expressions and XPath techniques, accurately locates and extracts HTML elements containing target data from the web pages. Data pre-processing includes manual deduplication and filtering of invalid content. In the deduplication process, user IDs, posting times, and text contents are compared to effectively remove duplicate Weibo entries. Invalid content filtering removes irrelevant items such as advertisements, entertainment news, and posts containing only emoticons, symbols, and web links with minimal text information, thereby improving the purity and accuracy of the data. Next, the preprocessed dataset is utilized for keyword extraction using the "jieba" package and TF-IDF (Term Frequency-Inverse Document Frequency) algorithm in Python 3.11. The "jieba" package performs Chinese word segmentation, laying the foundation for TF-IDF calculation. TF-IDF takes into account both term frequency (TF) and inverse document frequency (IDF), where TF reflects the importance of a word in the current document (Equation (1)), while IDF reflects its generality in the corpus (Equation (2)). The TF-IDF value is obtained by multiplying TF and IDF (Equation (3)), with a higher value indicating greater importance of the word. Where $n$ represents the frequency of word $t$ in document $d$, $N$ stands for the total number of words in document $d$, $p$ denotes the total count of documents in corpus $D$, and $q$ indicates the number of documents that contain word $t$.

$$\mathrm{TF}(t,d) = \frac{\mathrm{n}}{\mathrm{N}} \tag{1}$$

$$\mathrm{IDF}(t,D) = log\,\frac{p}{\mathrm{q}+1} \tag{2}$$

$$\mathrm{TF-IDF(t,d,D)} = \mathrm{TF}(t,d) \times \mathrm{IDF(t,D)} \tag{3}$$

SnowNLP is a package in Python 3.11 for Chinese text sentiment analysis. It assigns a sentiment score between 0 and 1, with values closer to 1 indicating a more positive sentiment, closer to 0 denoting a more negative sentiment, and around 0.5 suggesting neutrality or ambiguity. The score is often discretized into positive, neutral, and negative categories for easier interpretation in practical applications.

## RESULTS

### Major Events During Typhoon Processes

Utilizing big data technology, a systematic collection and chronological arrangement of key event news is conducted for the 72 hours surrounding typhoon landings, encompassing sources such as Zhuhai meteorological websites. This encompasses timely warnings, government emergency responses, societal participation, mutual assistance, and post-disaster recovery. Through in-depth analysis, a comprehensive understanding of typhoon emergency management is achieved. Specifically, by comparing response effectiveness, practical strategies are identified, and areas for improvement are pinpointed. In responding to the typhoon, Zhuhai has adopted a series of effective and strategic emergency response initiatives (Table 2). Typhoons Hato, Mangkhut and Higos have some similarities in Zhuhai's emergency management initiatives, including the following:

1. Early warning system activation: Before typhoon strikes, Zhuhai city has activated the early warning system, releasing early warning information to the public through radio, television, cell phone text messages and other means to remind the public to take precautionary measures.
2. Emergency plan initiation: Before the typhoon struck, Zhuhai all activated their emergency plans, taking measures such as stopping work, production, market and classes, opening a number of shelters, relocating people from areas likely to be affected, carrying out hidden dangers, and taking precautionary and coping measures to minimize the impact of the typhoon on production and life.
3. Organization of rescue forces: In the wake of typhoons, Zhuhai has promptly organized rescue forces, including firefighting, medical and public security departments, to be ready to respond to emergencies and to actively carry out rescue work to ensure that the affected citizens receive timely relief.
4. Post-disaster recovery work: In the aftermath of typhoon, Zhuhai acted swiftly and actively carried out post-disaster recovery work. Government staff, the public, party members and volunteers from all sectors of society made concerted efforts to work together on infrastructure repair, road clearing, food safety inspections, etc., to ensure that citizens' living and working order returned to normal as soon as possible.

Comparative analysis of typhoons Mangkhut and Higos shows earlier warnings, leading to better Zhuhai preparation. Government, organizations, and public responded swiftly and effectively during critical 24 hours, with district governments actively identifying risks. This improved typhoon response in Zhuhai is not coincidental, but a result of past reflections and improvements. Before super typhoon Hato, Zhuhai lacked similar-sized typhoon references, potentially leading to underestimation of the typhoon's hazards by the public. Challenges prompt Zhuhai to improve its response, significantly enhancing warning accuracy and timeliness. The emergency response becomes more efficient, with departments quickly coordinating resources and protecting infrastructure. For instance, during Higos, a comprehensive emergency command center ensures timely and accurate warning dissemination.

**Table 2. Timeline of emergency management measures for typhoon Hato, Mangkhut, Higos**

| | Hato | Mangkhut | Higos |
|---|---|---|---|
| Pre-72-48h | / | ● Disaster warning<br>① Typhoon White Warning issued | ● Disaster warning<br>① Tropical Depression forcast issued |
| Pre-48-24h | ● Disaster warning<br>① Typhoon White Warning issued<br>② Typhoon Orange Warning issued<br>③ Typhoon Blue Warning issued<br>● Governmental Emergency response<br>① Level IV Emergency response activated | ● Disaster warning<br>① Typhoon Blue Warning issued<br>② Typhoon Yellow Warning issued<br>● Governmental Emergency response<br>① Level II Emergency response activated | ● Disaster warning<br>① Typhoon White Warning issued |

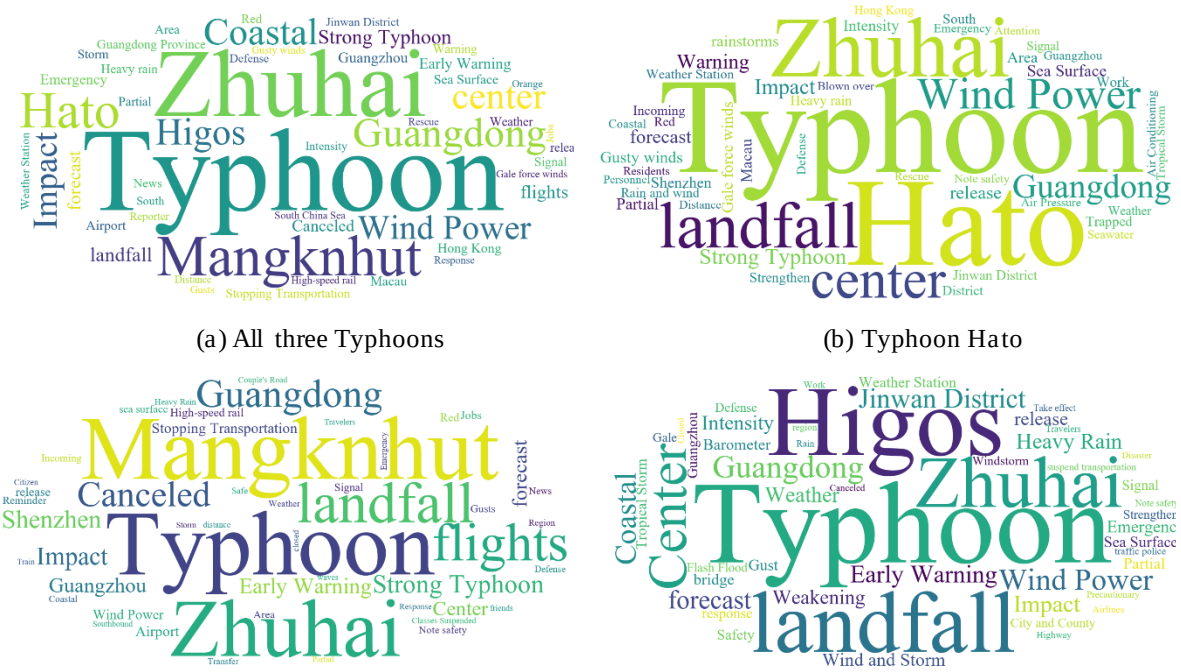
| | Hato | Mangkhut | Higos |
|---|---|---|---|
| Pre-24h | ● Disaster warning<br>① Typhoon Yellow Warning issued<br>② Typhoon Red Warning issued<br>③ Rainstorm Orange Warning issued<br>④ Rainstorm Yellow Warning issued<br>⑤ Wave I Alert (Red) and Storm Surge II Alert (Orange) issued<br>● Governmental Emergency response<br>① Level III Emergency response for typhoon prevention activated<br>② Level I Emergency response for typhoon prevention activated<br>● Social Emergency response<br>① Stopping work, business, market and school<br>② Controlling traffic control successively<br>③ Transferring people in close proximity to danger and opening shelters<br>④ Pre-positioning of rescue and relief materials and staff | ● Disaster warning<br>① Typhoon Red Warning issued<br>② Rainstorm Red Warning issued<br>● Governmental Emergency response<br>① Level I Emergency response for typhoon prevention activated<br>② Level I Emergency response for flood activated<br>③ "Emergency Mobilization Order to All Citizens on typhoon" issued<br>④ Level II Emergency response for disaster issued<br>● Social Emergency response<br>① Stopping work, business, market and school<br>② Controlling traffic control timely<br>③ Transferring people in close proximity to danger and opening shelters<br>④ Pre-positioning of rescue and relief materials and staff<br>⑤ Detecting potential danger | ● Disaster warning<br>① Typhoon Blue Warning issued<br>② Typhoon Yellow Warning issued<br>③ Typhoon Orange Warning issued<br>④ Typhoon Red Warning issued<br>⑤ Rainstorm Yellow Warning and Thunderstorm Warning issued<br>⑥ Rainstorm Red Warning issued<br>● Governmental Emergency response<br>① Level IV Emergency response for typhoon and flood prevention activated<br>② Level III Emergency response for typhoon prevention activated<br>③ Level I Emergency response for typhoon prevention activated<br>● Social Emergency response<br>① Stopping work, business, market and school<br>② Controlling traffic control timely<br>③ Transferring people in close proximity to danger and opening shelters<br>④ Pre-positioning of rescue and relief materials and staff<br>⑤ Detecting potential danger<br>⑥ Government departmental coordination and emergency management system |

| | Hato | Mangkhut | Higos |
|---|---|---|---|
| 24h | ● Disaster warning<br>① Typhoon Blue Warning issued<br>② Rainstorm Warning cancelled<br>③ Typhoon Warning cancelled<br>● Social Emergency response<br>① Traffic unblocked gradually<br>② Emergency rescue and repair<br>③ Road clearing | ● Disaster warning<br>① Typhoon Orange Warning issued<br>② Typhoon Red Warning issued<br>● Social Emergency response<br>① Traffic unblocked gradually<br>② Emergency rescue and repair<br>③ Road clearing | ● Disaster warning<br>① Typhoon Orange Warning issued<br>② Typhoon Blue Warning issued<br>● Social Emergency response<br>① Traffic unblocked gradually<br>② Emergency rescue and repair<br>③ Road clearing |
| 24-48h | / | ● Disaster warning<br>① Typhoon Warning cancelled | / |
| 48-72h | / | / | / |

**Word Cloud Analysis**

Public attention and participation in typhoon disasters play a vital role in emergency management. Employing data scraping techniques on the Weibo platform, we captured and analyzed public Weibo postings spanning the entire three days before and after each typhoon landfall, inclusive of details such as post timestamps, authors, and content. This yielded a rich trove of raw data for subsequent analysis, enabling an in-depth exploration of public focus points, emotional attitudes, and shifts in social discourse during typhoon events. After meticulous screening and organization, 11,221 Weibo posts were retained from an initial pool of 12,924. Of these, 4,693 pertained to typhoon Hato (2017), 4,862 to typhoon Mangkhut (2018), and 1,666 to typhoon Higos (2020).

Employing the "jieba" package and TF-IDF calculations for keyword extraction, we observed that keywords with higher term frequencies typically exhibit correspondingly elevated TF-IDF values, substantiating the efficacy of our keyword extraction approach. A threshold of 0.1 is chosen, selecting keywords as those with TF-IDF values exceeding this threshold. The Chinese keywords are then manually translated into English and used to generate a word cloud via Python programming. This allowed us to gain a visual, intuitive understanding of the focal points of public attention and emotional responses during the typhoon period. Statistical analysis of Weibo posts on the three typhoons identified high-frequency words (Figure 4a) like "typhoon," "Zhuhai," "landfall," "news," and "warning," reflecting the substantial societal impact and concern for the affected region. Meanwhile, each typhoon showed distinct focal points: typhoon Hato in 2017 (Figure 4b) emphasized intensity, urgency, and severe damages; Mangkhut in 2018 (Figure 4c) highlighted the importance of preparedness, safety measures, and post-disaster rescue; Higos in 2020 (Figure 4d) underscored the role of early warning systems in risk mitigation and loss reduction. These findings demonstrate continuous improvements in typhoon emergency management in terms of technology, response maturity, risk management strategies, social engagement, and public awareness.




(a) All three Typhoons (b) Typhoon Hato

(c) Typhoon Mangkhut (d) Typhoon Higos

**Figure 4. Weibo content keywords about typhoons**

### Weibo Keyword Classification Statistics Analysis

Weibo user content is categorized as Warning (disaster alerts and prevention), Damage (post-landfall situations), and Response (immediate rescue and aid). Figure 5 highlights the stage characteristics in the 144 hours surrounding typhoon landfall. As typhoons approach, content shifts from warnings to damage reports and response efforts. The number of posts peaks post-landfall, reflecting societal concern and urgent response. Before landfall, Weibo disseminates warnings to prepare the public. Afterwards, damage reports and rescue actions dominate, with posts peaking, reflecting societal urgency. As recovery begins, content transitions to reflecting progress, unity, and hope for the future. The process of discussions, ranging from early warnings to disasters and then to rescue efforts, reflects the evolution of typhoon characteristics and the shift of public attention. Furthermore, comparing the three typhoons, Typhoon Mangkhut had the highest information volume, with a significant focus on warnings around landfall. In contrast, Typhoon Hato mainly comprised damage messages, possibly due to lessons learned from the previous year, leading to increased emphasis on pre-disaster warnings and mitigation, which may have contributed to reduced losses during Typhoon Mangkhut. The lower volume and attention for Typhoon Higos may be attributed to its milder impact, swift movement, and the accumulation of typhoon experience, enabling improved early warning and response. Social media is vital in typhoon management, providing real-time information and mobilizing the public.

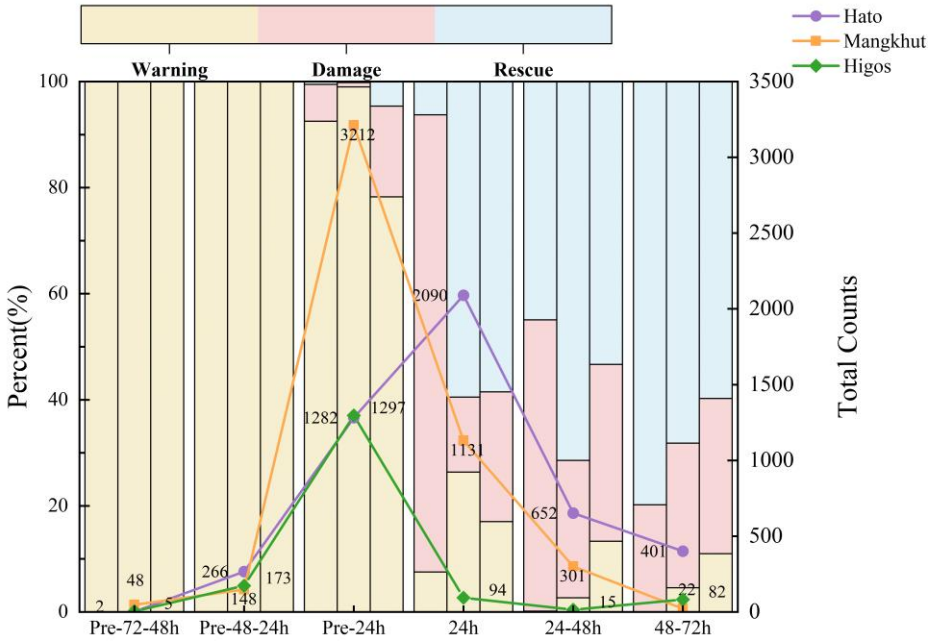



**Figure 5. Weibo messages classification and counts**

**(Left to right: typhoon Hato, Mangkhut, Higos. Bar show percentages, Line are number of Weibo posts)**

### Public Sentiment Change Analysis

SnowNLP package is used for sentiment analysis, classifying Weibo content as positive, negative, or neutral based on sentiment scores (scores > 0.6 = positive, < 0.4 = negative, 0.4-0.6 = neutral). Figure 6 reveals how Weibo reflect public emotional responses to approaching typhoons. Prior to a typhoon, positive emotions tend to gradually decrease or remain stagnant, while negative emotions escalate, indicative of rising anxiety and concern. During the typhoon, negative sentiments peak due to fear and distress caused by the storm's impact and hazards. Post-typhoon, positive emotions rebound and negative ones subside as individuals recover and appreciate relief efforts. By comparative analysis, typhoon Higos exhibits a comparatively high level of positive sentiment, paralleling its relatively low disaster intensity and damage, along with more structured and efficient emergency management strategies. Furthermore, there has been a decline in the proportion of negative sentiment and a concurrent increase in positive sentiment from 2017 to 2020, suggesting that the public has become more proficient in typhoon emergency response. This accumulated experience not only assists individuals in overcoming their fears but also testifies the continuous improvement in emergency management practices.

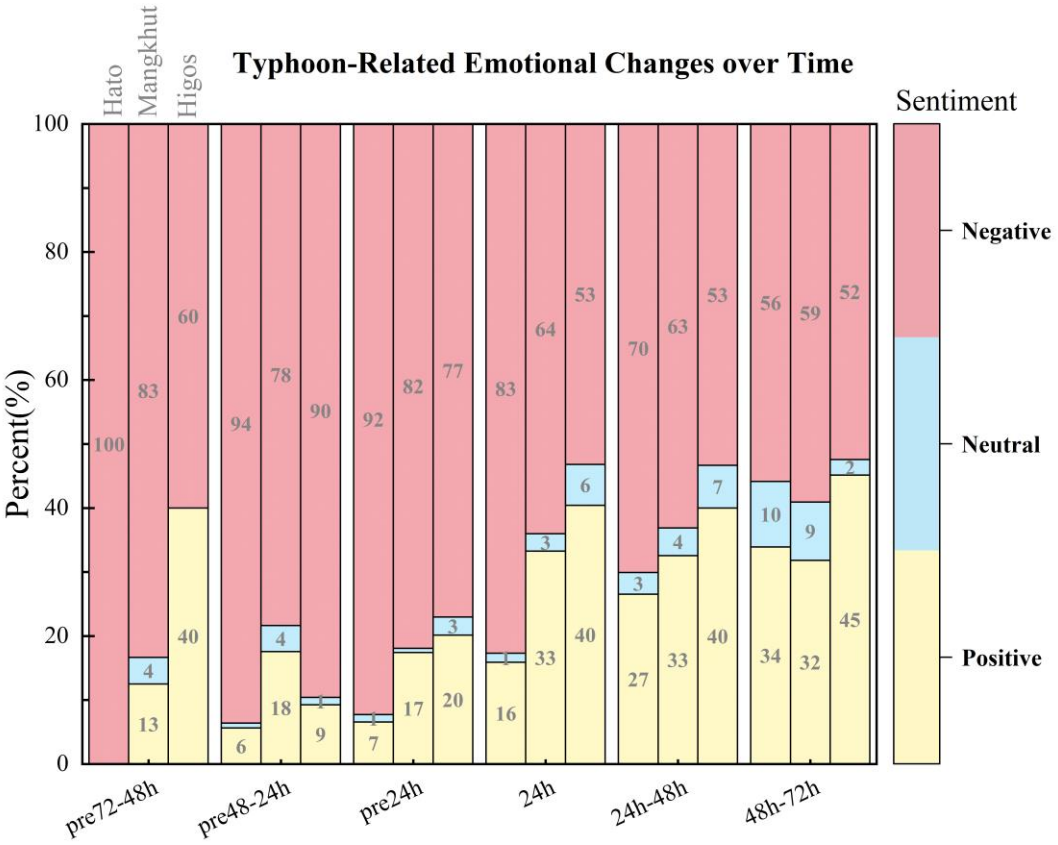



**Figure 6. Sentiment evolution in public Weibo activity during typhoons**

**(Left to right: typhoon Hato, Mangkhut, Higos)**

## DISCUSSION

This study presents a comprehensive examination of the impacts of typhoons Hato (2017), Mangkhut (2018), and Higos (2020) on Zhuhai, incorporating an analysis of typhoon characteristics, response strategies, and public sentiment. Initially, comparative analysis of typhoon paths and collation of key disaster data facilitated a holistic understanding of the typhoons and their effects on Zhuhai. Subsequent scrutiny of implemented response measures post-landfall revealed a decreasing trend in economic losses and casualties, indicating enhanced emergency management capabilities and accumulated experience. Weibo data analysis was employed to gauge public sentiment and concerns. The keyword clouds generated from this analysis reveal distinct foci of public attention, ranging from the intensity of Hato, to the rescue efforts during Mangkhut, and the warning systems associated with Higos. Statistical analysis of content categories elucidated the shifting public attention, encompassing warnings, disaster impacts, and rescue operations. Sentiment analysis of Weibo showed negative emotions prevailing during typhoons, gradually giving way to positive sentiments as focus shifted towards recovery. A declining trend in negative emotions from 2017 to 2020 suggests improving emergency management practices.

All typhoons have provided valuable experiences and lessons to Zhuhai, leading to enhancements in typhoon prevention mechanism. The Hato specifically highlighted the seriousness and complexity of typhoon disasters, resulting in significant improvements. Zhuhai has upgraded its early warning system, forecast accuracy, and emergency response, reflected in the "Zhuhai Typhoon Prevention Regulations" since February 2020. Technological advancements have strengthened Zhuhai's emergency management. Media and education have raised public awareness, fostering community-wide disaster prevention and government cooperation. Despite challenges from climate change and urbanization, Zhuhai's progress highlights the need for enhanced early warning systems, cross-sectoral coordination, infrastructure, and social participation in disaster response. Zhuhai's achievements in typhoon prevention underscore the significance of experience summarization, mechanism building, and public awareness in tackling natural disasters. Sharing effective emergency management practices globally is crucial to reducing typhoon threats.

## LIMITATIONS

When conducting a thorough examination of the study, several limitations must be acknowledged, which may potentially impact the accuracy and comprehensiveness of our findings. Firstly, technological and platform constraints limit data collection to hourly intervals and a maximum of 50 pages, possibly omitting crucial content and affecting the comprehensiveness and depth of the data. Secondly, the classification of Weibo content involves subjective judgments, such as simplifying complex content related to disasters and rescue into a single category, which may affect the accuracy of the results. Moreover, In employing SnowNLP for sentiment analysis, its limitations primarily stem from inadequate handling of emotional complexity. Social media texts often exhibit user sentiments that are not simply dichotomized as positive, neutral, or negative, but rather may encompass various compounded emotions interwoven within a single post. General-purpose sentiment models like SnowNLP may struggle to discern subtle emotional variations in public responses to typhoon events. Categorical sentiment classification (positive, neutral, negative) as opposed to fine-grained scoring, sacrifices analytical precision. Despite these limitations, this study still provides meaningful analysis and conclusions based on the available data.

## CONCLUSIONS

Typhoons, characterized by immense destructiveness and unpredictability, pose substantial threats to human life, infrastructure, and societal stability. While the extent of damage varies for typhoons of comparable intensity and trajectory, efficacious emergency management is vital. Essential components include early warnings, evacuations, preparedness training, and swift post-event recovery, which collectively mitigate impacts, minimize casualties, and enhance community resilience.

This study examines the coastal city of Zhuhai, China, frequently battered by typhoons, comparing its emergency management during Hato (2017), Mangkhut (2018), and Higos (2020). Employing a big data approach, it collates news, Weibo posts, and ancillary data preceding and following each typhoon's landfall. Key event sequences for 72 hours around landfall and word frequency analysis, categorical statistics, and sentiment analysis on Weibo contents are conducted to trace the emergency management process, analyze Zhuhai's measures, characteristics, and effectiveness. Zhuhai demonstrates continuous adaptation and optimization of its response to similarly intense typhoons. The study draws the following main conclusions: Enhanced warning systems significantly boost public responsiveness, curbing disaster losses. Systematic coordination in emergency management is pivotal for seamless rescue and recovery. Heightened public awareness and social engagement are instrumental in loss mitigation.

The study illuminates Zhuhai's strategic adaptations in typhoon response, offering a critical lens on its coping mechanisms. These experiences and strategies provide instructive references for Zhuhai and other coastal cities to better prepare for and mitigate typhoon impacts. The derived lessons hold global significance in strengthening coastal cities' disaster response capabilities, reducing typhoon-related losses, protecting lives and assets, and fostering sustainable urban development.

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