

Distribution features of the typhoons in the South China Sea

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Abstract. On the basis of statistical analysis, studies of the features of the distribution of typhoons in the South China Sea for the period 1951–2019 were carried out using satellite information. As a result, it was revealed that 851 typhoons were observed over the water area of the South China Sea (SCS) during this period. Of these, 464 had a maximum speed of over 33 m/s. Typhoons were observed more often in the northern part of the sea and were more intense than in the southern one. Most typhoons originate in the northwestern Pacific Ocean near the Philippine Islands, while the rest originate directly in the South China Sea. The South China Sea has an average of more than 12 storms per year, which is about half of all storms in the NW Pacific. As a general rule, the highest frequency of storms in the SCS during the mid-summer to mid-autumn period (July–September) is the period with a strong

tropical convergence zone in the northern hemisphere. Occurrences of hurricanes (the most powerful typhoon with a maximum wind speed of over 33 m/s) were mostly in September: 146 storms were observed over the entire study period. More than 18 typhoons were observed for 5 years (1964, 1971, 1974, 1995, 1996) for the period. In 1964 and 1996, both years have 21 hurricanes crossed the South China Sea. The areas with very strong storms in Vietnam are Quang Ninh and South Ha Tinh – Deo Ngang and the less active storm areas are Vung Tau – Ho Chi Minh City.

Introduction

The South China Sea (SCS) covers an area of 3,447,000 km², including the Gulf of Tonkin and the Gulf of Thailand, with an average depth of 1140 m, the maximum measured depth – 5567 m, volume of water mass about 3,928,000 km³, a length of 3500 km (Figure 1). The SCS is relatively enclosed, surrounded by islands and mainland. The SCS is connected with neighboring seas and oceans through straits. The southwestern part of the SCS opens to the Indian Ocean by the Strait of

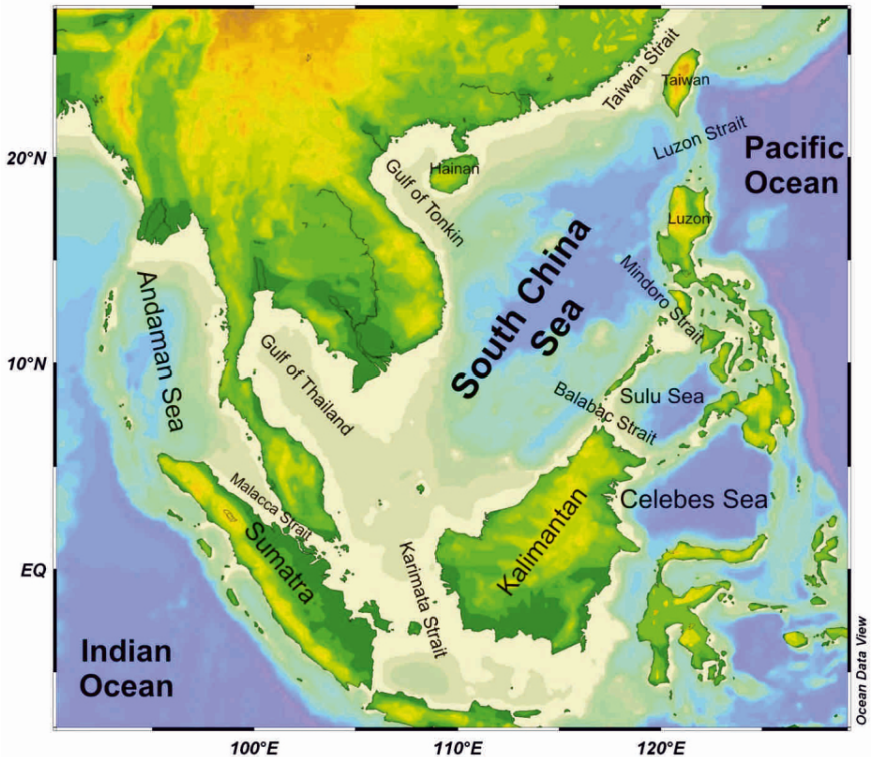


Figure 1. Map of the South China Sea.

Malacca between Peninsula Malaysia and Sumatra Island (Indonesia). The southern part of the sea is connected with the Indian Ocean through the Karimata Strait, and the Java Sea (Indonesia) through two Sunda gates (between Jakarta and Lombok (near Bali)). The northern part of the sea is connected to the East China

Sea by the Taiwan Strait. The eastern part of the sea is connected to the Philippine Sea (western Pacific) by the large Luzon Strait and other deep-water straits of the Philippine Islands.

The SCS is surrounded by 9 countries: China, the Philippines, Malaysia, Indonesia, Brunei, Singapore, Thailand, Cambodia, and Vietnam. There are also dependent territories with developed economies, such as Taiwan, Hong Kong, Macau, located on the northeastern coast of the SCS. China is the largest country bordering by the SCS. Indonesia and the Philippines have thousands of large and small islands in the southern and eastern parts of the SCS. Vietnam is the western coastal country of the SCS, along with Cambodia and Thailand, and Vietnam has 3260 km of coastline.

Hurricanes and tropical depressions are natural disasters. The influence of a tropical storm on socio-economic activities in Vietnam's coastal regions is very serious. Hurricanes cause not only strong winds and high waves, which directly affect economic activity at sea but also torrential rains, floods, landslides, etc., directly affecting all sectors of the international economy and people's lives.

At present, many different studies of fluctuations in the characteristics of storms and tropical depressions in

the SCS and the coastline of Vietnam have been carried out based on various sources and research methods. The tropical cyclone and cyclones databases used in the studies also have differences. For example, CMA (China Meteorological Administration, China), takes an average wind speed for 2-minutes, JTWC (Joint Typhoon Warning Center, USA) – 1-minute, other objects such as JMA (Japan Meteorological Agency, Japan), HKO (Hong Kong Observatory, Hong Kong), IBTrACS (International Archive of the Best Climate Management Tracks) – 10-minutes. It is noted in the report of the WMO (World Meteorological Organization) on the impact of climate change on tropical cyclones in 2012 [WMO, 2012]. The report also shows that most tropical cyclones and cyclones that occur in the Philippines and the SCS are concentrated in the latitudes between 10° and 25° N. According to the results of the study by Dinh Van Uu, [2011], the north-central region of the coast of Vietnam (17° – 20° N) is subject to the most severe storms and typhoons. Vu Thanh Hang et al., [2010] using data from the US Department of Meteorology for 1945–2007 showed that the number of storms increased linearly over the specified period. However, since the authors did not indicate the method for selecting eddies for statistics, it is really dif-

difficult to compare with our results. According to these authors, in the period from 1945 to 2007, the largest number of storms (13) was in 1996. Using the data of the Japan Meteorological Office for the period 1951–2019, we found that the largest number of typhoons and tropical depressions was in 1964 and 1996 (21).

In this paper, information from various databases was used to statistically analyze the characteristics of typhoons in SCS (type, category, pressure, maximum sustained wind speed) to create a collection of these parameters for the period 1951–2019.

Data and Methods

The collection of data on tropical cyclones that struck the coast of the SCS in the period from 1951 to 2019 was carried out from the websites: <https://coast.noaa.gov/hurricanes/> (USA) and http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/RSMC_HP.htm (Japan). Indicated data include wind speed, the pressure at the center of the cyclone, its position, the radius of maximum wind speed, and the trajectory of tropical cyclones. The hurricane scale was determined by the Saffir-Simpson scale used by the United States National Meteorological Service (Table 1).

Table 1. Saffir-Simpson Hurricane Intensity Scale

Type	Category	Pressure (mb)	Maximum sustained wind speed (knots)	Maximum sustained wind speed (m/s)
Tropical Depression	TD	–	< 34	< 17
Tropical Storm	TS	–	35–63	18–32
Hurricane	1	> 980	64–82	33–42
Hurricane	2	965–980	83–95	43–49
Hurricane	3	945–965	96–112	50–58
Hurricane	4	920–945	113–134	59–69
Hurricane	5	< 920	> 134	70+

From this Saffir-Simpson Scale, hurricanes were selected as the highest category of cyclones for the period 1951–2019. Based on the statistical analysis, all identified hurricanes in the South China Sea in the range of 0° – 24° N and 99° – 122° E have been analyzed.

Results and Discussion

Interannual Fluctuations

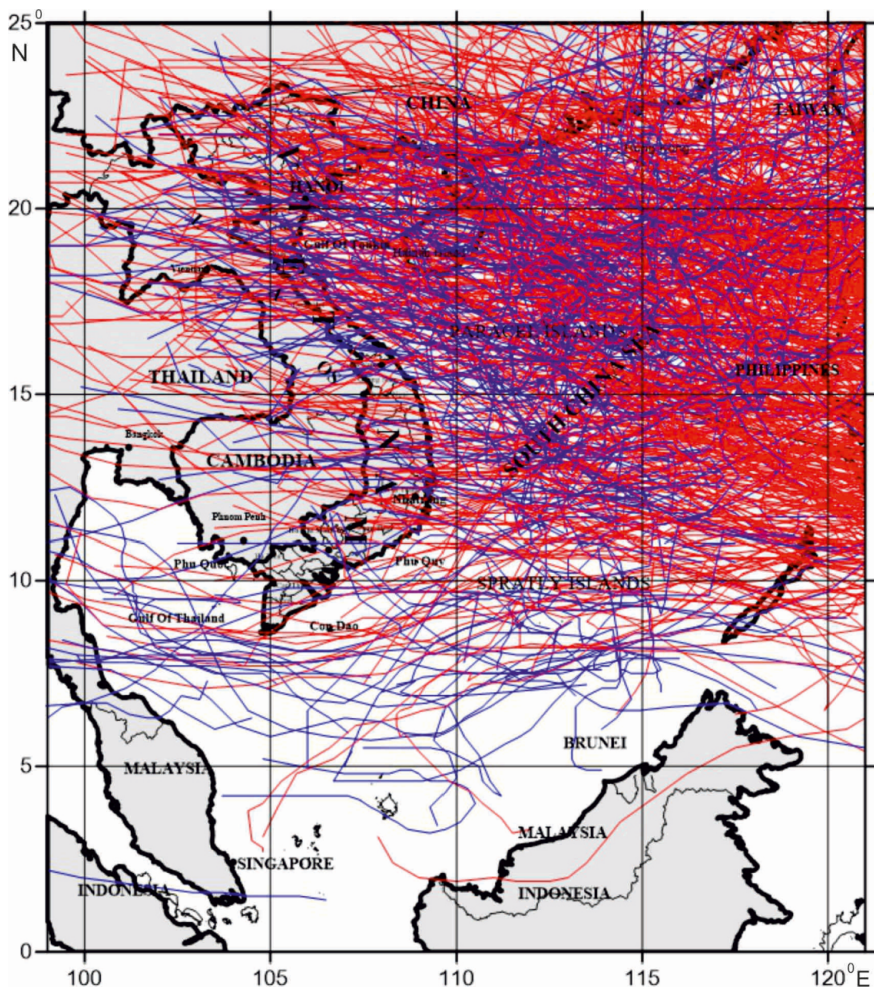
In total, 851 hurricanes occurred in the water area of the SCS, including 464 typhoons with a maximum wind speed ($V_{\max}$) > 33 m/s, 298 tropical storms with $17 \text{ m/s} < V_{\max} < 33 \text{ m/s}$ and 89 subtropical storms with $V_{\max} < 17 \text{ m/s}$ (Table 2).

The Philippine Sea in the east is the place where most of the typhoons occur, the rest of the typhoons originate directly in the SCS. The SCS has an average of more than 12 storms per year, which is about half of all storms in the NW Pacific (Figure 2). As a general rule, the highest frequency of storms in the SCS during the mid-summer to mid-autumn period (July–September) is the period with a strong tropical convergence zone in the northern hemisphere.

According to *Le Duc To*, [1999], the north of the SCS

Table 2. Statistics of Tropical Cyclones Based on Saffir-Simpson Scale for Period 1951–2019

Tropical cyclones	Tropical depression	Tropical storm	Hurricane	Total
Numbers of occurrence	89	298	464	851
Percentage (%)	10.46	35.02	54.52	100



-  : The tropical cyclones track originating in the Pacific Ocean
 : The tropical cyclones track originating in the South China Sea

Figure 2. The tropical cyclones track originating in the South China Sea and the Northwest Pacific Ocean for the period 1951–2019.

region is where storms from the Pacific Ocean or from the eastern part of the SCS usually occur from mid-summer onwards, with very strong intensity on the way to the west. Wind speeds in the strongest storm can reach and exceed 50 m/s, causing enormous destruction. Storms in the north of the SCS appear more often in summer. The southern part of the SCS observed much fewer storms than the northern part. Storms in the southern part were observed later than in the northern. Also, typhoons operating in the southern parts of the SCS are usually less intense than storms operating in the north. The number of storms hitting Vietnam varies greatly at different years and different latitudes.

From Figure 3 can be seen that the interannual distribution of hurricanes in the study area was not regular. The number of hurricanes (over 18) was observed in 1964, 1971, 1974, 1995, 1996. Of these, 21 hurricanes were observed in 1964 and 1996 (Figure 4).

Seasonal Fluctuations

Occurrences of hurricanes were mostly in September (17.16%), July (14.92%), August (14.69%), October (14.22%), and November (13.98%) (see Table 3 and Figure 5).

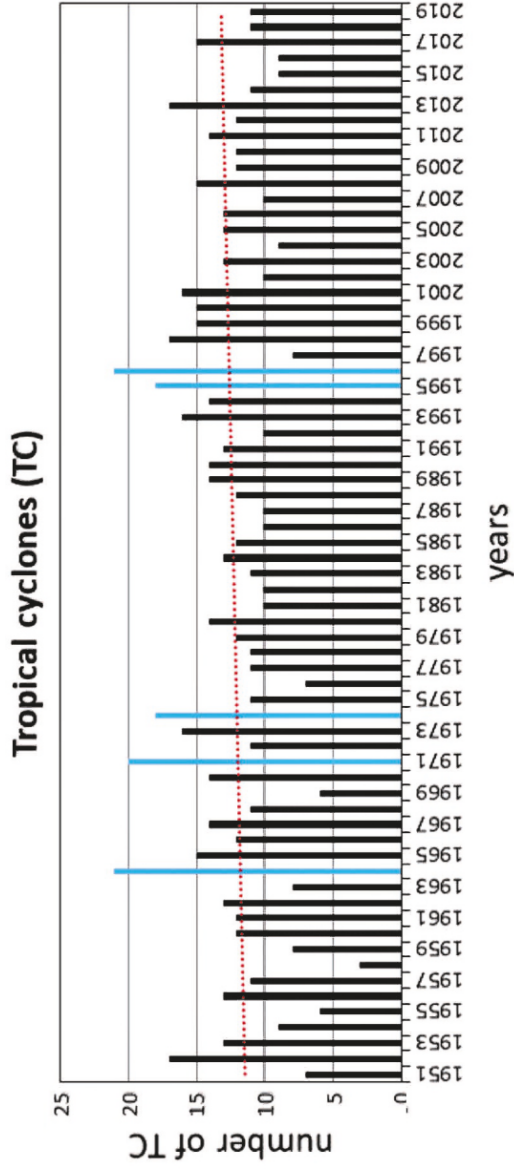
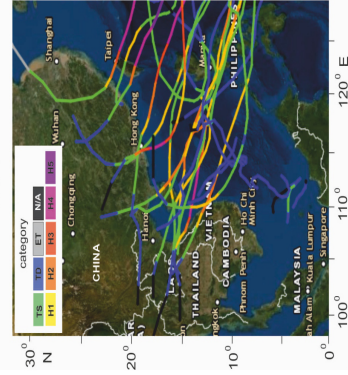
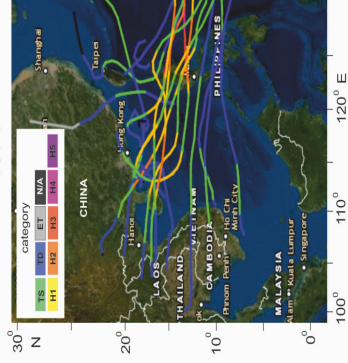


Figure 3. Interannual variability of tropical cyclones in the South China Sea for the period 1951–2019.

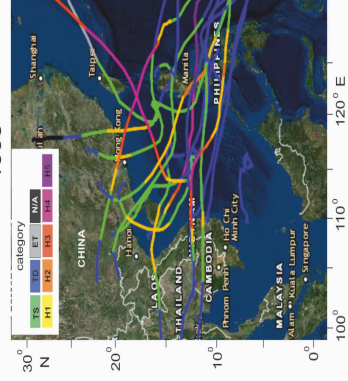
1971



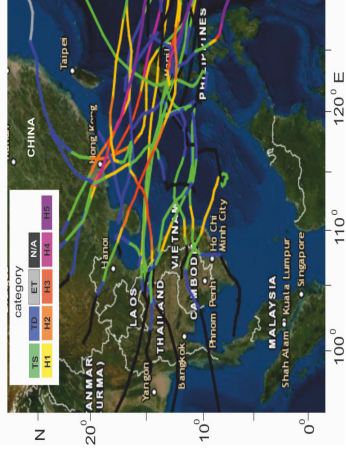
1974



1995



1964



1996

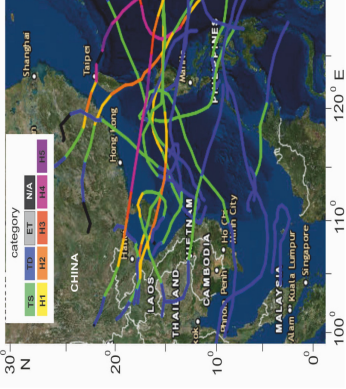


Figure 4. The track of hurricanes that crossed and affected directly to the SCS (<https://coast.noaa.gov/hurricanes>). TS – tropical storm, TD – tropical depression, ET – data is expected, N/A – no data available, H1-H5 – hurricanes intensity from 1 to 5.

Table 3. Monthly Distribution of Hurricanes Over the SCS During 1951–2019

Month	October	November	December	January	February	March
Numbers	121	119	62	16	7	10
Percentage (%)	14.22	13.98	7.29	1.88	0.82	1.18

Month	April	May	June	July	August	September
Numbers	18	33	67	127	125	146
Percentage (%)	2.12	3.88	7.87	14.92	14.69	17.16

Tropical cyclones (TC)

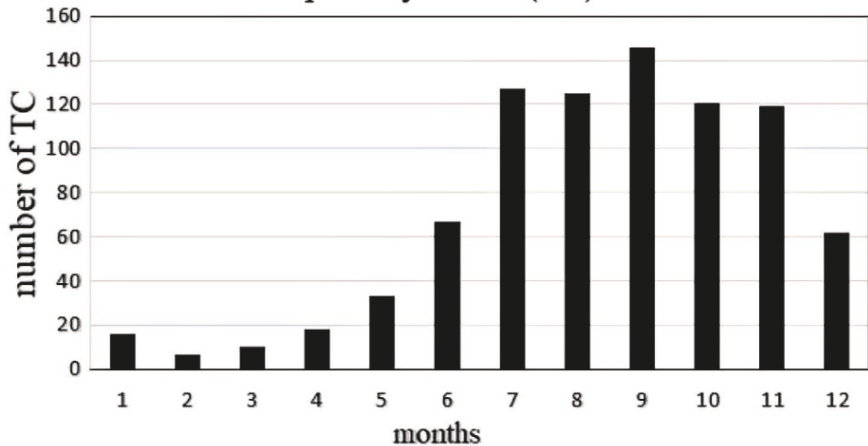


Figure 5. Monthly distribution of tropical cyclones in the SCS for the period 1951–2019.

According to *Le Duc To*, [1999], storms occur rarely in May and June, the direction of movement is usually north and northwest or northeast, following a parabolic orbit towards the southern coast of China. In the following months, including July, August, and September, the storm usually moves in a northwest direction, then, reaching the coast of southern China, turns west and heads towards northern Vietnam. In October, the trajectory of typhoons is on average oriented westward towards the central coast of Vietnam. In November and December, it shifts south (13° – 12° N) to the coast of southern Vietnam.

Thus, for the whole Vietnamese coast, the typhoon season is from June to December. In Vietnam, the areas with very strong storms are from Quang Ninh to Ha Tinh (21.5° – 18° N) and the less active storm areas are from Vung Tau to Ca Mau (10.5° – 8° N).

Conclusion

- From 1951 to 2019, 851 hurricanes occurred in the Vietnamese coastal area, an average of 12.33 hurricanes per year, with 464 typhoons having a maximum wind speed $V_{\max} > 33$ m/s. The Philippine Sea is the place where most of the typhoons occur, the rest of the typhoons originate directly in the SCS;
- More than 18 typhoons were observed for 5 years (1964, 1971, 1974, 1995, 1996) for the entire period 1951–2019. In 1964 and 1996, both years have 21 hurricanes crossed the SCS;
- Storms in the north of the SCS are observed much more often than in the southern part in summer. Storms in the south of the SCS are observed later than in the northern part. Also, typhoons operating in the southern parts of the SCS are usually less intense than those operating in the north;

- Months with a maximum frequency of storms in the SCS are July, August, September (mid-summer to mid-autumn). A strong tropical convergence band is observed in the northern hemisphere during this period, especially in September, when the most hurricanes are observed (146);
- The number of storms hitting Vietnam varies greatly from year to year and at different latitudes. The typhoon season is from June to December. In May and June, storms orbit towards the southern coast of China. In the following months July, August, and September storms usually follow from the south of China to the north of Vietnam. In October, they often move to the central coast of Vietnam. In November and December, the typhoon moves completely southward, at about 13° – 12° N, heading towards the coast of southern Vietnam.

Acknowledgments. The authors gratefully acknowledge the support of the joint grant-project between the Vietnam Academy of Science and Technology (VAST) and Il'ichev Pacific Oceanological Institute, Far Eastern Branch, Russian Academy of Sciences (POI FEB RAS) on the topic "Structure and dynamics of the Vietnam waters and their variability due to modern climatic tendencies" (Project numbers: QTRU02.04/19-20 and VAST19-020), and Vietnam National project on the topic "Study some interac-

tion processes between Sea-Atmosphere-Land and environmental variation corresponding to the context of global climate change within the framework of the IOC/WESTPAC program" (Project number: DTDL.CN-28/17). The main author, the Senior Researcher Dr. Mau Dinh Le, is also thankful to the Vietnam Academy of Science and Technology (VAST) for supporting his scientific activities for the year 2021 (Code number: NCVCC.17.04/21-21). The authors are also thankful to all colleagues for their kind help and encouragement throughout the preparation of this paper.

References

- Dinh, Van Uu (2011) , The characteristics of storm fluctuations and tropical depressions directly affect the mainland of Vietnam, *Journal of the Nature Science and Technology*, 27, p. 266–272 (in Vietnamese).
- Le, Duc To (1999) , *Oceanography in the South China Sea*, 127 pp., The Vietnam National University, Hanoi (in Vietnamese).
- Vu, Thanh Hang, et al. (2010) , Some characteristics of typhoon activity in Vietnam coastal regions during 1945–2007, *Journal of Science, Natural Sciences and Technology*, 26, no. 3S, p. 344–353 (in Vietnamese).
- WMO, (2012) , WMO statement on the status of the global climate in 2012, WMO-No. 1108, Communications and Public Affairs Office, Geneva (<http://www.wmo.int>).
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