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MOTION AND INTENSITY AND IMPACT CHARACTERISTICS OF TROPICAL CYCLONE AFFECTING THE LIAODONG PENINSULA

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ABSTRACT: Conventional data and the *Yearbook on Tropical Cyclones* (TC) data from 1971 to 2000 are used to study the climate and disaster features of TC affecting the Liaodong Peninsula. Results indicate that interannual change of TC activities is obvious. Different sources of TC have different impacts on the area of interest. Intensity and moving speed of TC vary substantially in the progress of northward movement. Besides, tracks and damage distributions of TC are quite different.

Key words: tropical cyclones; impacts on the Liaodong Peninsula; climate features; statistics

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1 INTRODUCTION

Flanked by the Bohai Sea, Bohai Strait and northern Yellow Sea on three sides, the Liaodong Peninsula has long and zigzagging coastline that is potential landfall site for tropical cyclones (to be shortened as TCs hereafter). The Bohai Sea is an interior sea in northern China while the Yellow Sea is semi-enclosed shallow sea. Their complicated topographic features interact with TCs and mid-latitude systems to cause frequent, intense storm surges and mesoscale convective heavy rain. TCs-related disasters are thus worsened, resulting in severe and widespread immediate and derived damages. Inflicting enormous economic losses and even threatening human life, north-going TCs usually affect coastal provinces and municipalities such as Shandong, Hebei, Tianjin and Liaoning and even have their influence felt in inland provinces of Shanxi, Inner Mongolia, Jilin and Heilongjiang. For instance, in the summer of 1972, TC Rita, coded No.7203, made three loops over ocean surface in its northward journey, covered long distance over land and finally migrated to the Bohai Sea via the Bohai Strait. The TC brought heavy rain in the west and south of Liaodong Peninsula and sustained onshore gales of Force 9 – 10 (on the Beaufort scale, the same below) and gusts of Force 12 for more than six hours, and triggered strong winds and storm surges in the Bohai Sea. 19 people were killed and 51 injured. The economy was hard hit in the area of Liaodong Peninsula. Some TCs are more beneficial than harmful. The area of interest has limited water resources. TCs relieve the local area from drought and fill up the reservoirs with more water. The cases of TC Mamie (8509) and TC Winnie (9711) are good examples in this aspect. Annually speaking, there are not many TCs that affect the Liaodong Peninsula and waters of the Yellow Sea and Bohai Sea, but they sometimes transform and strengthen during the course of landfall and northward travel to increase the difficulty of forecasting the track and intensity. A lot of works have documented large amount of analyses of intensity change, track features and precipitation distribution after the landfall of TCs affecting

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the South China Sea and East China Sea, but few have attempted extensive study on the climatic background with which TCs affect the marine areas in northern China. The present work focuses on TCs active over the Liaodong Peninsula, Yellow Sea and Bohai Sea to determine the characteristics of their movement, intensity and impacts, in the hope that the result could provide basis for the research on northward-going TCs, serve well for their accurate forecasting and help to prevent and mitigate the destruction associated with them.

2 STATISTICAL METHODS AND DATA

2.1 *Definition of area of interest*

As the weather observatory of a city on the southernmost tip of the Peninsula, the Dalian Observatory is a forecaster for the marine weather over waters in the central and northern Yellow Sea. The region north of 35°N and west 125°E (as shown in Fig.1) is what will be studied in this work. In routine practice, its eastern boundary should be parallel with the national border in northeastern China. In view of actual operational needs and also for the sake of convenience, the line connecting diagonally through a northeast-southwest 5° lat.×5° long. mesh is used as the eastern boundary[7].

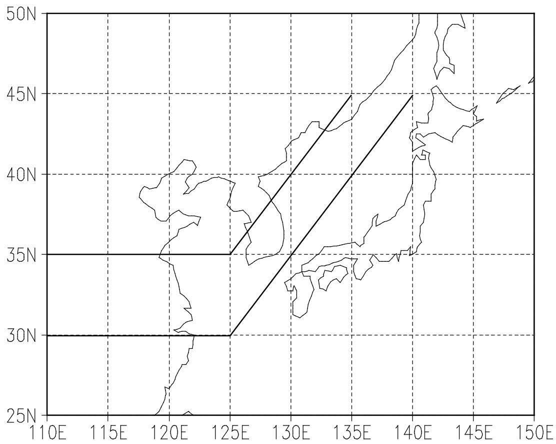

Fig.1 The area of interest on which TCs make impacts.

(1) The line connecting the three points (45°N, 135°E), (40°N, 130°E) and (35°N, 125°E) is used as the eastern boundary and the latitude of 35°N as the southern boundary. North China, Northeast China, Korean Peninsula and the Yellow Sea and Bohai Sea, as bounded by the boundaries, are the area of interest for the present study on TCs that are active over the Liaodong Peninsula, Yellow Sea and Bohai Sea.

(2) The line connecting the four points (45°N, 140°E), (40°N, 135°E), (35°N, 130°E) and (30°N, 125°E) is used as the eastern boundary and the latitude of 35°N as the southern boundary. North China, Northeast China, the Yellow Sea, Bohai Sea and Sea of Japan as bounded by the boundaries, are the area of interest for the present study on TCs that are active over the Liaodong Peninsula, Yellow Sea and Bohai Sea.

2.2 *Data and methods of track extension*

The data used in the present work include upper-level and surface weather maps, surface observations and extracts from the *Yearbook on Tropical Cyclones* for 1971 – 2000. Some TCs disappear in late stages of their life cycle, as shown in routine forecasting, but the huge amount of warm and humid air that they carry along plays an important role in the formation of heavy precipitation. Following the method introduced below, the tracks of TCs illustrated in the *Yearbook on Tropical Cyclones* are extended based on the upper-level and surface weather maps[7]. Within the area bounded by 30°N – 35°N and 115°E – 128°E, (1) the center of a clear cyclonic circulation in the surface map will be the starting point of track extension, even there are no enclosed isolines of pressure; if there are more than one center of circulation, the track will be extended where the center of dewpoint coincide with that of a negative 24-h pressure change ; (2)

if cyclonic circulation is not clear on the surface weather map, the 700-hPa cyclonic center of circulation will be the starting point of track extension; (3) if neither cyclonic circulation is clear on the surface or 700-hPa levels, no track extension will be done; (4) when the TC transforms to an extratropical cyclone or merges into a depression, the track of the cyclone or depression can be seen as the extended track of the TC.

3 ANALYSIS OF CHARACTERISTICS OF TCS AFFECTING LIAODONG PENINSULA AND YELLOW SEA AND BOHAI SEA

3.1 *TC source location*

The source location of TCs that migrate into the area of interest is mainly within 8°N – 30°N, 110°E – 160°E (Fig.2). In other words, in the area to the east of the Philippines, to the west of Mariana Islands, north of Caroline Islands and south of Ogasawara Islands, the number of TCs takes up about 70% of the total studied, TCs moving from the South China Sea and East China Sea into the areas north of 35°N and west of 125°E account for 9% each. Most of the TCs that pose serious impacts on the Liaodong Peninsula and the Yellow Sea and Bohai Sea originate from areas to the east of the Philippines, around the Ryukyu Islands and over northern Mariana Islands. Over the 30-year period, there are only two TCs that form right in the East China Sea.

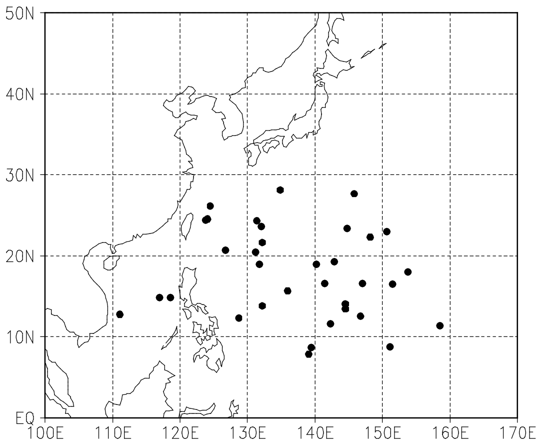

Fig.2 The distribution of source location for TCs making impacts on the area of interest.

Only three of the TCs moving into the area of interest during 1971 – 2000 form over the South China Sea, namely, No.7304 (Dot), No.7412 (Jean) and No.0004 (Kai-tak), respectively, with the intensity of typhoon, tropical storm and typhoon respectively at the stage of generation. None of them caused major and immediate damages to the peninsula and the two seas.

TCs affecting the area of interest generally originate from the location as those from the northwestern Pacific[10], implying that the latter could also affect the area of interest. As TCs have to follow long and zigzagging paths before reaching the area of interest, their number could only be small.

3.2 *TC interannual variation*

Over the 34-year period from 1971 to 2000, 34 TCs moved into the area of interest, taking up only 3.1% of the northwestern Pacific total. As shown in Fig.3a, the TCs of interest have obvious interannual variation. There are 1.1 TCs per year on average and 4 TCs per year for the most. There are 11 years in which no TCs migrate into the area of concern, namely, 1976, 1977, 1979, 1982, 1983, 1986, 1988, 1989, 1993, 1996 and 1998, taking up about 36.7% of the total number of years studied. The decaying stage of the TC is closely linked with the El Niño episodes taking place over the same period of years. 1972, 1976 – 1977, 1982 – 1983, 1986 – 1987, 1991 – 1992, 1993 – 1994, 1995, 1997 – 1998 are defined to be the years with weak El Niño episodes. During these years, TCs generating over the west Pacific and South China Sea are much more than usual. It is worth noticing that there were 32 TC geneses from June to October in 1994, 11 more than the multi-year mean, while there were only 20 geneses in 1995, 12 less than the previous year. It is a record high for two contiguous years to differ so much in the frequency of TCs during mature stages. During the El Niño years in which the of TC genesis is high, though, there are not many TCs that pose direct impacts on the peninsula as the west Pacific subtropical high is more southward and the westernmost tip of the ridge is more westward than usual.

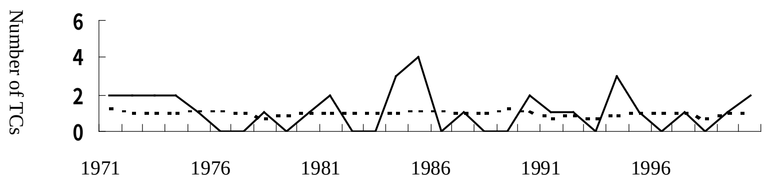

Fig.3a Curves of year-to-year variation of the frequency of TCs making impacts on the Liaodong Peninsula, Yellow Sea and Bohai Sea. The broken line is the 5-year running mean and the solid one the number of tropical cyclones.

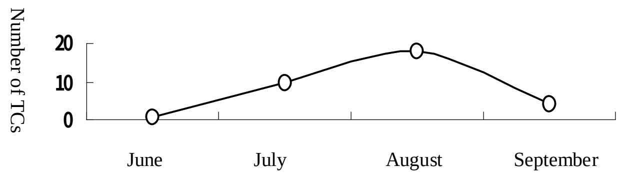

Fig.3b Monthly frequency of TCs making impacts on the area of interest.

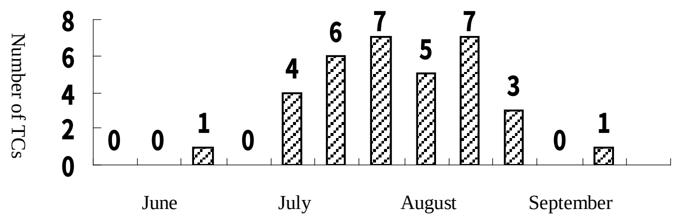

Fig.3c Ten-day frequency of TCs making impacts on the area of interest.

It is found from the analysis of the monthly and ten-day distribution of TCs (Fig.3b & 3c) that August is the month that sees the most TCs moving into the area of interest, followed in turn by July and September, with June being the month with the least number (only one TC). The most concentrated advancement of TCs happen from mid-July to early September, especially over the period from mid-July to late August, taking up about 85% of the total, while isolated cases appear in the time prior to mid-June and after mid-September. Such climatological characteristics are closely connected with the pattern of monthly variation of the activity of both the subtropical high and westerly system. Two northward jumps of the subtropical high in July and August occur in a time when its location is the northernmost in the year and the westerly jet is also shifted well to the north. Meanwhile, blocking patterns also frequently establish in East Asia during the two months, which turn the Yellow Sea into an area of pentad-mean troughs and align the subtropical high ridge in the north-south direction. The situation helps push the TC to higher latitudes to affect the Liaodong Peninsula and the Yellow and Bohai Seas.

3.3 *TC track and destructive weather*

After formation in the tropics, the TC moves to the west and east subjected to various internal and external forces before weakening over tropical land or turning to progress into middle latitudes over land or fills up at sea. It makes it possible for the TC to follow vastly different tracks depending on marine and land areas. In the meantime, seasonal changes are also very large. The site of TC landfall in China varies with the season. Typically from July to September, it is possible for the TC to affect the area of interest and their track can be roughly divided to groups of travelling westward, northwestward, northward or northeastward. During the late stage of the TC, it can disappear after landfall or while still at sea, or turn to the east or northeast, or make recurvature after landfall or over the sea.

The track of TCs can be quite complicated in July (Fig.4a), which either disappears over land and sea or turns west or northeast. There are two main tracks of movement. One is moving northwest over waters east of the Philippines and west of Guam; one branch of it passes near Taiwan before making landfall in the coast of southeast China, heading north and disappearing, and the other branch keeps going north over the southern Yellow Sea after landfall before entering the Yellow Sea and Bohai Sea and even traveling to the northeast by way of the Liaoning, Jilin and Heilongjiang provinces. The other main route starts from the northern Mariana Islands and goes through the Ryukyu Islands on a northwest route; one branch of it moves across the Shandong Peninsula and enters the Bohai Sea and even heads further north; the other branch moves from the central to the northern part of the Yellow Sea and waters off the Democratic People's Republic of Korea (DPRK) and some TCs go across the latter or the eastern part of Northeast China and move into the Sea of Japan (it is not until around 20°N that relevant TC tracks begin to be designated).

The track of TCs is generally in the shape of parabola in August (Fig.4b), which moves out of Northeast China after turning in movement direction. Mainly converging west off the Korean Peninsula, TCs start their journey to the northwest near Guam and turn northeast over waters east off the estuary of the Yangtze River before heading northeast via northern Yellow Sea and central and northern Korean Peninsula towards Northeast China or further eastwards into the Sea of Japan. There are two main branches for the main track. One track starts from northern Taiwan and advances in the Chinese mainland, after which some TCs turn towards the Yellow Sea and Bohai Sea in a northeast track while others disappear after landfall. The other track starts from central Yellow Sea and heads northwest into the Bohai Sea via the Shandong Peninsula, or turns northeast and moves over waters from northern Yellow Sea and west off the Korean Peninsula.

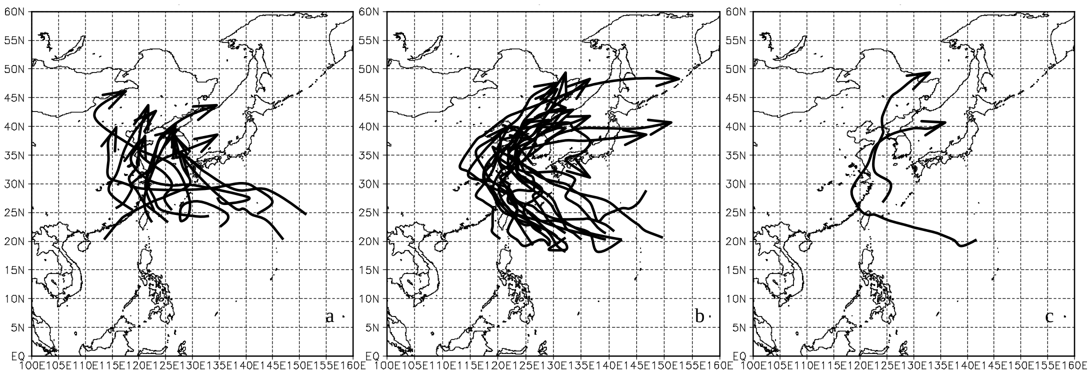

Fig.4 The tracks of TCs affecting the area of interest in July (a), August (b) and September (c) from 1971 to 2000.

The concentrated area of TC tracks shifts slightly to the east in August.

In September (Fig.4c), relatively few TCs affect the area of interest and their tracks concentrate in the northern Yellow Sea and waters west of Korean Peninsula.

In August and September, the tracks of the TCs affecting the area of interest are mainly in waters east of the Strait of Bohai Sea and west of the Korean Peninsula. It is determined by the characteristic that TC tends to move towards warmer regions. Air temperature differs mildly over individual waters of the Liaodong Peninsula, but shifts dramatically on the seasonal scale. The annual mean temperature is between 8°C and 13°C and mean temperature for July is between 21°C and 27°C. It is warmer in the Bohai Sea than the Yellow Sea and the maximum air temperature mostly occurs in August for the Yellow Sea.

Based on the distribution of destructive weather caused by TCs in the area of interest, the track can be roughly divided into three groups of disappearing, left-turning and right-turning and further subdivided into eight smaller groups (Fig.5). For the disappearing group, the TC disappears over land and off the west coast of DPRK. For the left-turning group, the TC makes landfall west of Dalian, turns the direction of movement after landfall or travels northeast along the west coast of the Bohai Sea. For the right-turning group, the TC makes landfall in Dalian and Dandong, turns to reenter into the Yellow Sea after landfall, and makes landfall in the southern and northern parts of the DPRK. Next is a detailed introduction to the characteristics of different groups of TCs.

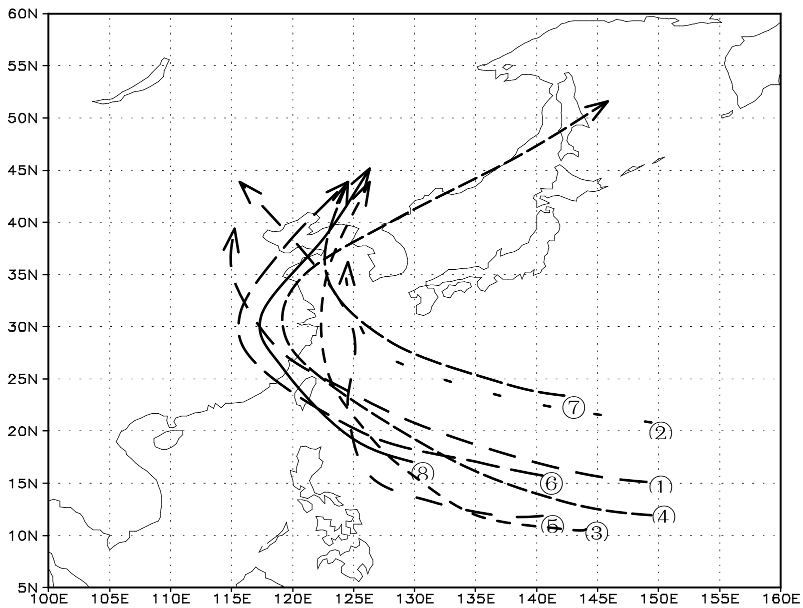

Fig.5 Classification of the tracks of TCs affecting the area of interest.

The right-turning track takes up the most (47.1%), with most of the TCs making landfall in the southern DPRK, indicating that only a small amount of TCs have direct impacts on the area of interest. The disappearing group follows by 29.4% and the left-turning group takes up the least by 23.4%. Though with the smallest percentage, the left-turning TC tends to have irregular track, often accompanied with such destructive weather as gales, heavy rain and storm surge. It becomes a difficult part in the forecasting of TC track. For the right-turning group, TCs making landfall in Dalian and Dandong or turning to move into the Yellow Sea after landfall are also limited in number and eastward in location. However, the orographic effect of residual Qianshan Mountain range lying northeast – southwest across the region of Dalian exposes the Liaodong

Peninsula to concurrent gales, heavy rain and even unusually heavy rain. Whey they take place with major astronomical tides, secondary destruction can happen from time to time to worsen the TC-inflicted damages (Tab.1).

3.3.1 THE DISAPPEARING GROUP

For the disappearing group, the TCs travel northwest from its source location, some making landfall in areas south of the estuary of the Yangtze River and north of Taiwan and disappearing inland (Fig.6a) while the others are moving northwest till the central Yellow Sea or western coast of Korean Peninsula before disappearing (Fig.6b). This group of TCs comes with local instead of regional heavy rain. Southerly gales at Force 7 – 8, with the maximum at Force 9 – 10, are quite common in the northern and central parts of the Yellow Sea.

Tab.1 Categorized statistics of TC tracks affecting the area of interest

groups	Disappearing over		Left-turning		Right-turning			
	land	W. coast of DPRK	Land west of Dalian	Turn to Bohai Sea or move NE on its coast	Land in S. DPRK	Land in N. DPRK	Land in Dalian, Dandong	Land & turn to Yellow Sea
%	5	5	2	6	7	2	3	4
Group %	10		8		16			
%	14.7	14.7	5.9	17.6	20.6	5.9	8.8	11.8
Group %	29.4		23.5		47.1			

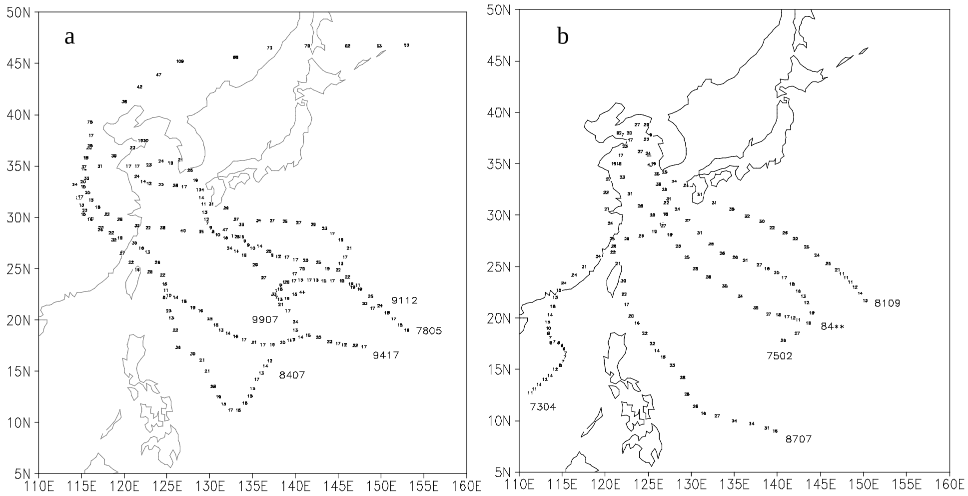

Fig.6 The codes and tracks of disappearing TCs affecting the area of interest. The numerals indicate the moving speed of the TC, same below.

3.3.2 THE LEFT-TURNING GROUP

For the left-turning group, TCs that make landfall before turning to the Bohai Sea or move on its western coast are having the most serious impacts (Fig.7a). Most of them go north from around the Ryukyu Islands or make landfall on the coast of southeastern China or in areas north of the Yangtze River and then move across the Shandong Peninsula and into the Bohai Sea. This group of TCs often causes heavy rain over extended areas and even unusually heavy rain when they are active in twins or meet with major astronomical tides, with the hyetal mainly occurring to the right of the track.

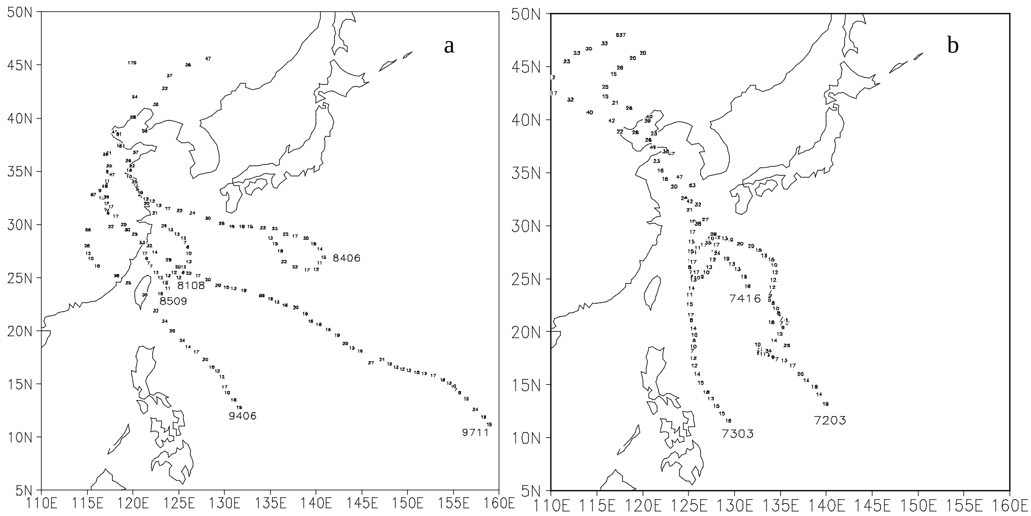

Fig.7 The codes and tracks of left-turning TCs affecting the area of interest.

For TCs that make landfall west of Dalian (Fig.7b), they move northwest from around the Caroline Islands, with some of them making loops or stagnating on the way, but mainly keep going in the NW direction once north of 30°N and move into the Bohai Sea after crossing the Shandong Peninsula. This group of TCs often cause local heavy rain in the Liaodong Peninsula with the hyetal concentrating to the east of the track.

Left-turning TCs all result in gales over the sea and land, mainly southeasterly or northeasterly with those making landfall west of Dalian and mainly southerly with those making landfall before turning to the Bohai Sea or moving northeast along its western coast, with the maximum wind between Force 8 and 10.

3.3.3 THE RIGHT-TURNING GROUP

For the right-turning group, TCs that make landfall in Dalian and Dandong (Fig.8a) and make landfall before turning to the Yellow Sea (Fig.8b) are the focus of the study. For the former,

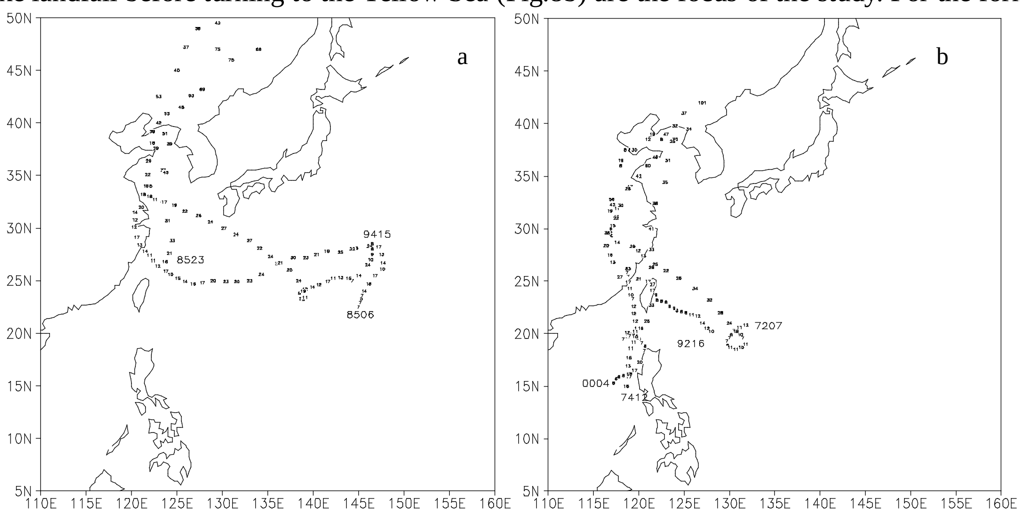

Fig.8 The codes and tracks of right-turning TCs affecting the area of interest.

most of the TCs cause heavy rain and northerly gale, unusually heavy rain in some parts of the area, with severe precipitation appearing on both sides of the track (Fig.9b). Due to topographically dynamic lifting, the eastern part of Liaodong Peninsula has greater probability of intense precipitation. Gales of Force 8 occur over the Bohai Sea and land, Force 9 – 10 over the northern Yellow Sea and Force 10 – 11 over the central Yellow Sea, with the wind mainly from the north to northeast.

For the subgroup in which the TC makes landfall before turning to the Yellow Sea, the affected area is very large. This type of TCs usually brings about intense precipitation. Due to its advancement into the Yellow Sea, rainfall is large (at the level of heavy rain or even unusually heavy rain) in the southeastern Liaodong Peninsula, with the hyetal mainly to the left of the track (Fig.9c). Rainfall can be extremely heavy if the TC meets with major astronomical tides. Gales appear more eastward, with the Bohai Sea Strait, northern and central Yellow Sea experiencing northerly or southerly gales at Force 8 – 9.

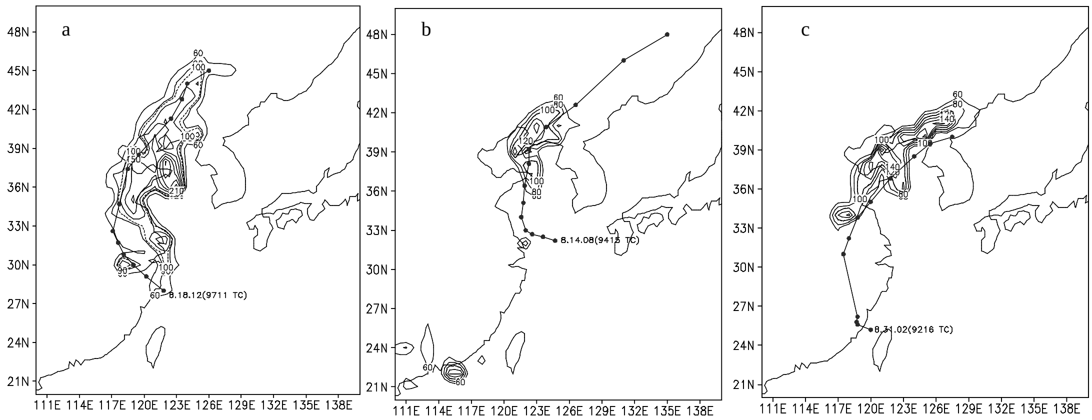

Fig.9 Distribution of track and precipitation (unit: mm) for TCs 9711 (a,), 9415 (b,) and 9216 (c,), which brought heavy rain to the Liaodong Peninsula.

For the group making landfall in southern DPRK (Fig.10a), the TC moves northwest from the Mariana Islands, turns direction south of 35°N into the central Yellow Sea, makes landfall in central Korean Peninsula (35°N – 38°N) and across it to migrate into the Sea of Japan. Locating southward, these TCs have mild impacts on the area of interest. When they turn at more northward locations, however, heavy rain can take place in some parts of southeastern Liaodong Peninsula, which is mainly to the northwest of the track. Gales are mostly northerly to northeasterly and the strength is no larger than Force 8 over sea.

For the group making landfall in northern DPRK (Fig.10b), the TC moves northwest after formation at sea till it reaches the waters east of the estuary of the Yangtze River, then goes north to the central Yellow Sea where it turns and makes landfall in northern Korean Peninsula (north of 38°N). Afterwards, it enters the Northeast China following a northeast route or moves east into the Sea of Japan. Locating eastward, these TCs cause heavy rain in some parts of the eastern Liaodong Peninsula with the hyetal mainly to the west of the track. There are usually gales at Force 8 – 9 over all individual areas of waters.

3.4 *Direction and speed of TC movement*

TCs affecting the area of interest are already in the late stage of life cycle. In the area of interest, TCs are usually free of making loops or irregular changes in track; most of them do not change dramatically in speed — they just slow down before turning and speed up again after it, except a few that experience significant speed change.

To reflect the pattern of TC speed change from south to north, the *Tropical Cyclone YearBook* is used to calculate the moving speed of TC (*v*).

The latitude and longitude at which the TC turns is changing with season (Fig.11). In the typhoon season, the mean point of direction change is at 32.2°N, 119.6°E, being most westward in July, most northward in August and both southward and eastward in September. It is consistent with two northward shifts of the subtropical high in July and August and the southward retreat in September and seasonal change in the distribution of solar radiation energy[11].

$$n = \frac{\sqrt{(\text{lat}2 - \text{lat}1)^2 + (\text{lon}2 - \text{lon}1)^2} \times 100}{6} \quad \text{(unit: km/h)}$$

in which lat2, lon2 and lat1, lon1 are respectively the latitudes and longitudes of TCs at the moment after and prior to the current one, with the interval between two contiguous points of time at 6 h.

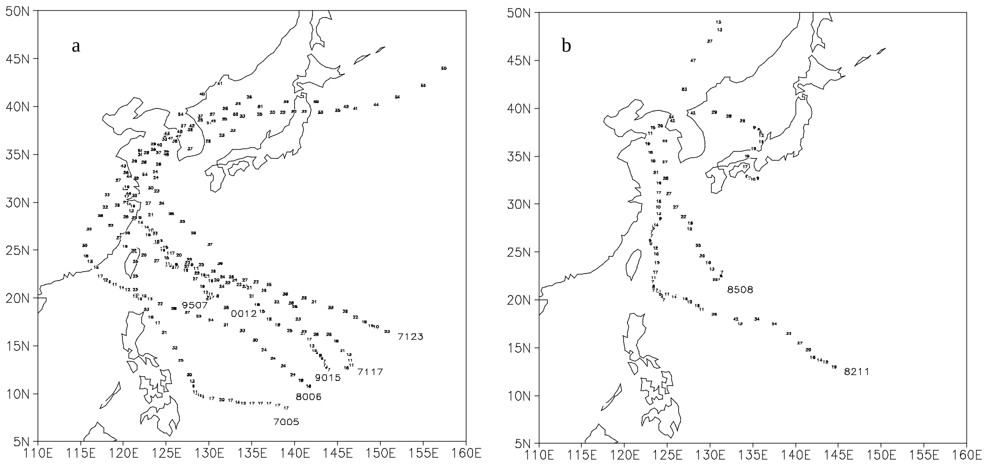

Fig.10 The codes and tracks of right-turning TCs affecting the area of interest.

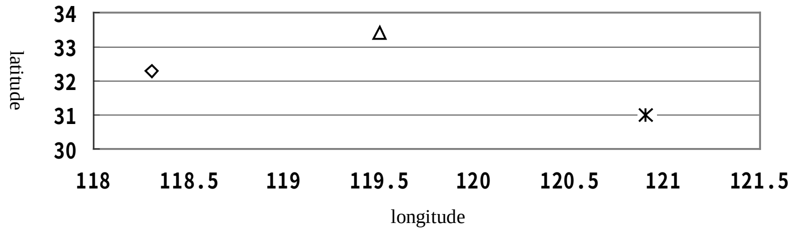

Fig.11 The points of turning for TCs affecting the area of interest.
◇ indicates July, △ August, ∗ September.

The TC moves at an average speed of 20 – 30 km/h. Before turning in direction, especially just before or during the turning, it goes from one basic flow (like the easterly) to another (like the westerly) and slows down as it crosses from one prevailing wind direction to another. The TC moves at the lowest speed when it stagnates or makes loops. On the contrary, after turning, it comes into the westerly zone that is relatively fast and moves much faster, sometimes over 80 km/h.

The TC moves faster in the low-latitude areas (10°N – 20°N) than in the mid-and lower-latitude areas (20°N – 30°N), though it is the fastest in areas north of 35°N. The center of maximum speed is in the eastern Northeast China where the speed is more than three as large as that in the mid- and lower- latitude areas (Fig.12). The figure also shows that the central part of the Yellow Sea is the area that sees the most frequent migration of TCs and is the part of the route through which they follow before turning east. It agrees well with the previous analysis of track.

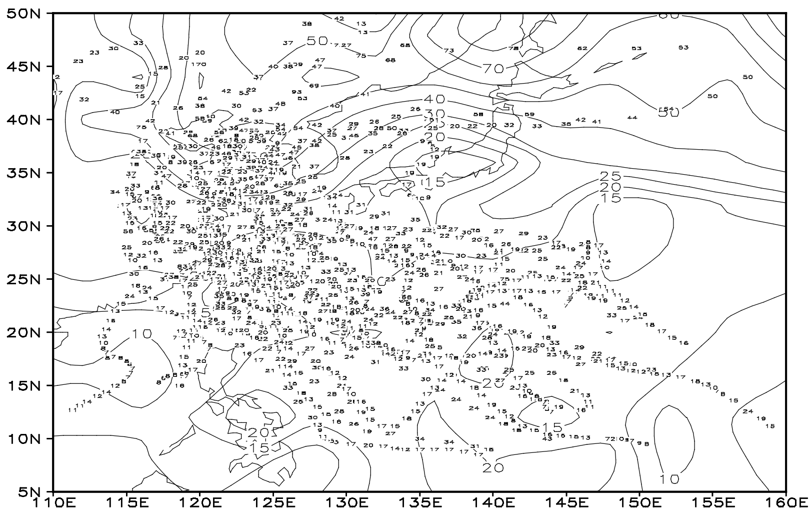

Fig.12 The speed of TCs affecting the area of interest. The numerals depict the speed of TCs.

3.5 *Intensity of TC*

Traveling from low-latitude sources to the high-latitude area of interest, the TC has significantly weakened. Tab.2 gives the statistics of intensity comparing the time when TC forms and that when it is in the area of interest.

Tab.2 shows that when they enter the area of interest, 44% of the TCs are at the intensity of tropical depression (TD), 24% tropical storm (TS) and 29% severe tropical storm (STS) and only 2% typhoon (TY). Those with intensity at STS and TY at the time of genesis take up the total of 88% and the number reduces by 56% by the time they are in the area of interest, with most of them weakening to TD and TS.

Tab.3 shows that 79% of the TCs inside the area of interest have minimum pressure between 981 hPa and 1000 hPa, 9% between 966 hPa and 980 hPa and none beneath 965 hPa. In other words, most of the TCs migrating into the area of interest are of moderate to weak intensity.

Studying the number of TY and STS that move into the area of interest shows that they appear the most in August, about 24%, followed by July, about 9%, and there are not any TY or STS in June and September.

All of the TCs affecting the area of interest from 1971 to 2000 are of TY and STS and the rate of landfall is 45%, i.e. about one in two land. In contrast, none of the weaker ST and TD affects the area of interest.

Tab.2 Comparison of intensity for the TCs affecting the area of interest

Intensity in source location	TD	TS		STS			TY			
Times of impact	2	2		11			19			
Intensity in area of interest	TD	TS	TD	STS	TS	TD	TY	STS	TS	TD
Times of impact	2		2	3	2	6	1	7	6	5

Tab.3 Comparison of center pressure for the TCs affecting the area of interest

Min pressure / hPa	961 – 965	966 – 970	971 - 975	976 – 980	981 – 985
Times of impact		2		1	6
Min pressure / hPa	986 – 990	991 – 995	996 – 1000	1001 - 1005	1006 – 1010
Times of impact	2	10	8	2	

4 CONCLUDING REMARKS

TCs moving into the area north of 35°N and west of 125°E over the period from 1971 to 2000 are studied in terms of temporal and spatial variation patterns, track and speed of movement and intensity change, and characteristics have been obtained as regard to the movement, intensity and impacts of TCs in the area of interest.

a. There are a total of 34 TCs in the area north of 35°N and west of 125°E over the period from 1971 to 2000, and the number varies greatly from year to year. The annual mean is 1.1 and the year with the most occurrence can be as high as 4.0. The active and inactive seasons of TCs appear by turns.

b. Most of the TCs having immediate, major impacts on the area of interest come from waters east of the Philippines, around the Ryukyu Islands and over the northern Mariana Islands. Over the 30-year period, only two of the TCs formed in the East China Sea but none in the South China Sea.

c. August is the month that witnesses the most TCs in the area of interest, followed by July and then September, and June is the month with the least number, only one TC. TCs concentrate in the period from mid-July to early September, especially from mid-July to late August, which accounts for about 85% of the total. Few TCs appear before mid-June or after mid-September.

d. During the movement of TCs, sharp differences in track exist with the change of marine and land areas. In the meantime, seasonal variation is also obvious.

e. The TC moves faster in the low-latitude areas (10°N – 20°N) than in the mid-and lower-latitude areas (20°N – 30°N), though it is the fastest in areas north of 35°N. The center of maximum speed is in the eastern Northeast China where the speed is more than three times as large as that in the mid- and lower- latitude areas.

f. The turning point of the TC changes with season.

g. The small number of TCs that hit the area of interest can be very serious. The most destructive of them are those that make landfall and then turn to the Bohai Sea or move northeast along its western coast or those that make landfall in Dalian and Dandong and then turn into the Yellow Sea.

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