Comparison of Tropical Cyclones Haiyan and Talas with Tropical Cyclones Having Similar Tracks in the Past 120 Years

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Abstract

Tropical cyclone (TC) Talas caused heavy rainfall and landslides in the Kii Peninsula of Japan in 2011, and TC Haiyan caused storm surges in Samar and Leyte islands of the Philippines in 2013. There are records of TC tracks similar to TC Haiyan and TC Talas in the past which show similar damages. In this study, we focus on these two TCs and compare their tracks with TCs having similar tracks observed during the past 117 and 122 years in the Philippines and Japan, respectively. Two TCs in 1897 and 1912 made landfall in the same area as TC Haiyan, which caused storm surges. TC Haiyan made landfall in the Visayas area of the Philippines. About 15 TCs land in the Visayas area every 10 years. However, these three TCs (including Haiyan) were among the strongest TCs landing in the Visayas area during the past 117 years. Intense TCs landed in the Visayas area posed a risk of storm surges to Samar and Leyte Islands. A TC in 1889 brought heavy rainfall and landslides to the same area as TC Talas did. About 3.7 TCs make landfall in the Kochi prefecture in Japan every 10 years. TC Talas and the TC in 1889 were among the slowest TCs that made landfall in the Kochi prefecture. Although more intensified TCs landed in the same area, they tended to propagate faster and produced less rainfall in the Kii Peninsula. Slow movements of TCs make landfall in the Kochi prefecture pose a risk of heavy rainfall and landslides in the Kii Peninsula. Imaging and digitization of historical paper-based instrumental meteorological records including TC tracks are referred to as “data rescue”. Longer TC records allow us to study TC cases with similar damage even when the frequencies of TC disaster are low.

Key words: tropical cyclone, Haiyan, Talas, data rescue

I. Introduction

Tropical cyclone (TC) provides precious fresh water to the land, but its landfall may cause disaster due to strong winds, heavy rain and storm surge. Meteorologists tried to predict TC and issue a warning before its landfall to prevent disasters. One of the first weather stations in East and Southeast Asia started in Manila, Philippines in 1865 (Udias, 1996). The first remarkable TC passage was observed at the Manila station around September 27, 1865 (Deppermann, 1939). Five different agencies of Manila Observatory (Algué, 1904), Hong Kong Observatory (Chin, 1958), Zikawei (Shanghai) Observatory (Froc, 1920), Tokyo Meteorological Observatory (Central Meteorological Observatory of Tokyo Japan (CMOJ), 1944), and

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Deutzchen Seewarte Hamburg (Deutzchen Seewarte, 1897) in the western North Pacific reported the TC track data from the late 19th century (Visher, 1925). We can trace back the signal of TCs in the western North Pacific for 120 years by using these data. However, the definition of TC was not clearly defined before 1945, and there was a gap before and after the 1940s in each agency. Kubota and Chan (2009) defined TC using station pressure data and re-analyzed the TC landfall numbers in the Philippines from 1902 to 2005. Kumazawa et al. (2016) defined TC using station pressure and wind data for TC landfall in Japan from 1900 to 2014. TC landfall datasets in the Philippines and Japan were reconstructed from the beginning of the 20th century under the cooperative activities of data rescue (Allan et al., 2011).

Many TC-induced disasters occurred during the past 120 years with more than 1000 casualties (Miyazawa, 2008). Some records indicate TCs causing similar damage multiple times in the same area. TC Haiyan made landfall in Samar and Leyte islands in the Visayas of the Philippines on Nov. 8, 2013. Its central pressure was measured at 895 hPa before the landfall by the Joint Typhoon Warning Center (JTWC) and the Japan Meteorological Agency (JMA) best track data; and the maximum wind speed was estimated to be about 101 m/s using the Doppler radar (Shimada et al., 2017). Storm surges occurred along the coast of Samar and Leyte islands up to 7 m height, with casualties of more than 6000 (Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), 2014). Similar TC tracks as Haiyan were found in 1912 and 1897, with reports of storm surges (Algué, 1898, 1912; Kubota, 2017).

Another area with repeated TC-induced damage is in Japan. TC Talas (TC1112) made landfall in the Kochi prefecture of Japan on Sep. 3, 2011. Heavy rainfall of more than 1800 mm was observed in the Kii Peninsula on the eastern side of the TC. Associated landslides were responsible for 100 casualties (Makihara, 2012). A TC track similar to the track of TC Talas was found in 1889, with reports of heavy rainfall and landslides in a similar area (Makihara, 2012; Ninomiya, 2013; Kubota, 2017). Casualties reached about 1500 and about 2500 residents migrated after the disaster and created another village in Hokkaido of northern Japan (Kamata and Kobayashi, 2006; Miyazawa, 2008). However, TC Haiyan and TC Talas followed one of the major TC tracks, which frequently lead to landfall. Previous studies have not mentioned many TCs having similar tracks that led to landfall in Samar and Leyte islands in the Philippines and Kochi prefecture in Japan in the past; and have not discussed why only two or three TCs caused huge damage in similar areas while others did not. In this study, TC Haiyan and TC Talas are chosen, respectively, because they caused similar damages in the same areas as recorded in the past. The similarities and differences of other TCs with similar tracks are compared during the past 117 and 122 years, respectively. The long records of historical data allow us to capture similar repeated damage in the past.

In section II, we describe the data used in this study. TC Haiyan is the focus in section III and is compared with the TCs in the past 117 years. TC Talas is the focus in section IV and compared with the TCs in the past 122 years. In section V, we give a summary with discussion.

II. Data

TC landfall data in the Philippines contain landfall date, nearest weather station and its minimum pressure, which were used in Kubota and Chan (2009). Their data are based on the Monthly Bulletins of the Philippine Weather Bureau (MBP) from 1901 to 1940 and the JTWC best track data from 1945 to 2013. TC data in 1897 are based on Chin (1958). In this study, the TC track data in the Philippines in 1897, 1903–1939 and 1947–2013 are used. TC landfall data in Japan contain landfall date, nearest weather station, minimum pressure, and maximum wind speed and wind direction, which were used in Kumazawa et al. (2016).
These data are based on the Geophysical Review from 1902 to 1950, Trajectories of TCs from 1940 to 1950 (CMOJ, 1951), Eighty-years typhoon tracks 1892–1977 (CWB, 1973), and JMA best track data from 1951 to 2011. TC data in 1889 are based on Gao and Zeng (1957).

In this study, the TC track data in Japan in 1889 and 1911–2011 are used. Station data in Kochi, Wakayama and Shionomisaki in Japan include Monthly Weather reports of CMOJ from 1889 to 1956 and JMA Monthly Weather reports from 1956 to 2011 (Fig. 1a). Rainfall data from three local station in the Wakayama prefecture are used from Wakayama weather comparison reports (Wakayama Station, 1889), Wakayama weather station monthly reports (Wakayama Station, 1917–1918), Wakayama monthly weather reports (Wakayama Station, 1929–1938, 1942–1975), Wakayama local weather station monthly weather reports (Wakayama Station, 1941), Wakayama Geophysical Review (Wakayama Station, 1950), and automatic weather station data in Wakayama (1987–2011) (Fig. 1a). The standard times for daily rainfall data were available at 22 Japan standard time (JST) during 1889–1949 and at 00 JST after 1950 at Wakayama and Shionomisaki stations. Three local stations used 14 JST in 1889, 22 JST from 1917 to 1920, 10 JST from 1928 to 1950, 09 JST from 1960 to 1975 and 00 JST after 1987 (Fig. 1b).

TC intensity is estimated from the nearest station minimum pressure data based on the relationship between maximum wind speed and minimum pressure (Atkinson and Holiday, 1977). A TC is defined as a low pressure system with a minimum station pressure less than 1000 hPa following Kubota and Chan (2009). Station minimum pressure data during TC landfall in the Philippines are from Algué (1898) for the case in 1897, MBP from 1901 to 1940, Bonjoc (1978) from 1951 to 1978, and PAGASA data from 1979 to 2013.

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Fig. 1  Station rainfall and pressure data during 1889–2011 (boxes) and 1889–1979 (triangles) (a). Ryujin and Kurisu-gawa stations were upgraded to automatic weather stations in 1978 and 1979, respectively. Transition of the standard time for daily rainfall in local weather station in Wakayama (Tanabe, Ryujin and Kurisugawa) (b). Numbers indicate local time.
III. TC Haiyan and the TCs in the Philippines in the past 117 years

1) TC Haiyan

TC Haiyan made landfall in the Visayas of the central Philippines on Nov. 8, 2013. Figure 2 shows the 200-km radius reflectivity observed by Guiuan radar of TC Haiyan from 00:05 to 04:20 Philippine local time (PLT) on Nov. 8, 2013. After 04:20, Guiuan radar was broken due to strong wind when TC Haiyan center was located about 40 km southeast of the Guiuan station. Guiuan station measured minimum pressure of 910 hPa (916.8 hPa of sea level pressure) at 05:15 PLT. However, the observation was interrupted after that because the weather station was damaged by TC wind. Storm surge occurred along the coasts of Samar and Leyte islands, and reached 7.14 m height in Guiuan (PAGASA, 2014).

2) Strong TC landfalls in the Philippines after 1951

Strong TCs made landfall in the Philippines. There were four TCs with center pressure less than 900 hPa before their landfall after 1951 (Fig. 3). TC Haiyan had the southernmost track. Direct TC intensity measurements were made by aircraft reconnaissance from 1945 to 1987 over the western North Pacific. This can measure more accurate TC intensity than the present Dvorak technique (Velden et al., 2006). The intensities of TC Rita and Betty were measured during the aircraft observation period. TC Megi was also measured by aircraft reconnaissance during the Interaction of Typhoon and Ocean Project (ITOP) (Moore, 2013). The JTWC started to provide center pressure data after 2001. On the other hand, the intensity of TC Haiyan was also estimated by the Guiuan radar, which reaching a minimum pressure of 908 hPa with wind speeds of 101 m/s at 4 km height at 04:20 PLT on Nov. 8 (Shimada et al., 2017).

3) TC landfall in the Visayas area

TC Haiyan made landfall in the Visayas area, which is not a rare event. What are the differences between TC Haiyan and the past TCs making landfall in the Visayas area? We counted the TCs that made landfall in the Visayas area from 10° to 13°N during 1903–2013 (Fig. 4a) and find about 15 TCs landed in the Visayas area every 10 years except for 1903–1910 and 2011–2013. The maximum TC landfall numbers appeared around the 1980s, and the numbers decreased there after that. Strong TC landfalls of less than 935 hPa were often seen during the 1950s to the 1960s and in the 1980s. TC central pressure and minimum pressure observed in the Visayas area during landfall are plotted in Fig. 4b. TC Haiyan had the lowest land station pressure observation since 1903. The reason why TC Haiyan caused a huge disaster in the Philippines is that it was one of the strongest TC observed in the Philippines. Landfall location is another factor for causing huge damage by storm surge (Mori et al., 2014).

4) Similar TC tracks as TC Haiyan

Figure 5 shows similar TC tracks as TC Haiyan, which was observed at less than 935 hPa. Each TC produced huge damage in the Philippines, and the fatalities reached more than 1000 in TC Agnes. Storm surge damage was reported by the TCs in 1897 and 1912 (Algué, 1898, 1912). The TC in 1912 was measured at 924.0 hPa at Tacloban, which was the lowest station pressure during the early 20th century (Fig. 4b). The TC in 1897 was measured at least than 938.6 hPa (unconfirmed pressure of 925.2 hPa was also reported) at Tanauan and its track was the closest to that of TC Haiyan during landfall among the four TCs (Algué, 1898; Depperman, 1939). Storm surge height reached 7.3 m at Hernani and 7 m at Santa Rita in 1897 and 1912, respectively (Algué, 1898; Depperman, 1939). The evidence of TC Haiyan and the TCs in 1897 and 1912 demonstrates that similar damages of storm surges in Samar and Leyte islands were due to similar tracks and the strongest TC landfall during the past 117 years. The long records of historical data allow us to find the evidence that 155 TCs landed in the Visayas area during 1903–2013, and people experienced three destructive TC landfalls. The percentage of destructive TC landfall is
Fig. 2 Map of 200 km radius reflectivity of TC Haiyan at 1 degree elevation angle observed by Guiuan radar from 00:05 PLT (a) to 04:20 PLT (f) on Nov. 8, 2013. Guiuan radar station is located in center of the figure. Inner and outer circles indicate 100- and 200-km radii from the radar, respectively. (f) is adapted after Kubota (2017).
about 2%, and the frequency of destructive TC landfalls has a large variability from 15 to 101 years.

IV. TC Talas and the TCs in the past 122 years

1) TC Talas
TC Talas (TC1112) made landfall in the Kochi prefecture of Japan on Sep. 3, 2011. Heavy rainfall was observed in the Kii Peninsula, and rainfall accumulated up to 1808.5 mm at Kamikitayama of the Kii Peninsula during Aug. 30 to Sep. 6, 2011, which was located about 300 km east of the TC landfall. Maximum 24-h rainfall was observed at Miyakawa of 872.5 mm on Sep. 4, 2011. About 100 casualties were reported due to the landslides (Makihara, 2012). During TC Talas’ landfall, its central pressure was observed at 984 hPa.
(JMA best track data) and minimum station pressure was observed at 976.1 hPa at Murotomisaki station at 19:00 JST Sep. 2, 2011. The TC intensity was not strong compared to past landfall TCs in Japan (Kumazawa et al., 2016).

2) Similar TC in 1889

A similar TC track as TC Talas was found on Aug. 19, 1889, which made landfall in the same Kochi prefecture with heavy rainfall and landslides in a similar area of the Kii Peninsula (Makihara, 2012; Ninomiya, 2013; Fig. 6a). Heavy rainfall accumulated up to 1295.4 mm at Tanabe weather station during Aug. 18 to 20, 1889 (Fig. 1a). Daily rainfall was recorded at every 14:00 JST, and reached 901.7 mm on Aug. 20 at the same weather station. The location of Tanabe was not the same as that of observed maximum rainfall during the passage of TC Talas. However, it had stronger daily rainfall than that during the passage of TC Talas.

3) TC landfall in the Kochi prefecture

The strongest TC landing in the Kochi prefecture was TC Muroto on Sep. 21, 1934, which had minimum pressure of 911.9 hPa at Muroto station (formerly Muroto-misaki station). Fortunately, severe landslides in the Kii Peninsula were not observed during its passage. What caused a huge amount of rainfall and landslides in the Kii Peninsula by TC Talas and by the TC in 1889 compared to other TCs making landfall in Kochi prefecture? We counted the number of TCs that landed in Kochi prefecture from 1911 to 2010 (Fig. 6). About 3.7 TCs landed in Kochi prefecture every 10 years (Fig. 6b). More TCs were landed during the early 20th century. After the 1970s, TC landfalls were less than 2 TCs every 10 years.

4) TC intensity, propagation speed and rainfall

We choose 39 TC cases which landed in Kochi prefecture from 1911 to 2010 and TC Talas and the TC in 1889. Figure 7 shows the 39 TC cases in terms of the rainfall amount at Wakayama station, the minimum pressure measured at Kochi station as a reference for TC intensity, and the TC propagation speed after landfall in Kochi prefecture. TC propagation speed is calculated by the distance and time difference of two locations observed before and after TC landfall. TC numbers are listed from the oldest TC in 1889 to the latest TC Talas. Rainfall amounts are totals accumulated amount during the TC. Rainfall amount are weakly correlated to Kochi pressure of TC intensity, with correlation coefficient $-0.29$ at the 90% significant level based on t-test. On the other hand, TC propagation speed after landfall was correlated to Kochi pressure of TC intensity, with $-0.44$ correlation coefficient at the 99% significant level. The relationship between TC propagation speed and station rainfall amount during the TC passage is plotted for the five stations in
the Kii Peninsula (Fig. 8a). Table 1 shows the correlation between TC propagation speed after landfall and rainfall at each station. When the TC propagation speed was slower, the rainfall amount tended to increase significantly except for Wakayama and Tanabe. The relationship
between TC intensity by using the minimum pressure data at Kochi station and station rainfall amount during the TC passage is plotted in Fig. 8b. More rainfall was observed in the Kii Peninsula by TC intensity around 980 hPa. TC intensity around 970–990 hPa had significantly more averaged rainfall compared to that of less than 970 hPa and more than 990 hPa at the 95% confidence level. This indicates that even the TC was intensified to below 970 hPa, the rainfall amount was less than that of TC with intensity around 970–990 hPa. Figure 8c shows the seasonality of the relationship between TC intensity and its propagation speed. TC Talas and the TC in 1889 are among the slowest TCs with moderate intensity around 980 hPa. TC intensity around 970–990 hPa had significantly more averaged rainfall compared to that of less than 970 hPa and more than 990 hPa at the 95% confidence level. This indicates that even the TC was intensified to below 970 hPa, the rainfall amount was less than that of TC with intensity around 970–990 hPa. Figure 8c shows the seasonality of the relationship between TC intensity and its propagation speed. TC Talas and the TC in 1889 are among the slowest TCs with moderate intensity around 980 hPa at Kochi station. On the other hand, the TCs in September tended to be significantly stronger but propagating speed was faster at the 99% confidence level compared to those in August. The cases of TC Talas and the TC in 1889 demonstrate that heavy rainfall in the Kii Peninsula were produced by slow movement of the TC, which made landfall in the Kochi prefecture. Another case of TC Moracot, which made landfall in Taiwan in 2009, produced heavy rainfall accumulated to 2700mm in high terrain area (Ge et al., 2010). The Kii Peninsula is also surrounded by high terrain. These results suggest that slow moving TCs pose a risk of heavy rainfall to a high terrain area.

V. Summary

There are records of TCs with tracks similar to TC Haiyan and TC Talas in the past, and the records show similar damage in the past in the same areas. In this study, we focus on these two modern-day TCs and compared their tracks with TCs having similar tracks observed during the past 117 and 122 years in the Philippines and Japan, respectively. The TCs in 1897 and 1912 made landfall in the same area as TC Haiyan, which also caused storm surges. In 1889, heavy rainfall and landslides were reported in the same Kii Peninsula in Japan, as by TC Talas. Historical records of TC landfall data with similar tracks to TC Haiyan and TC Talas during the past 120 years are used to investigate the similarity and difference from these two TCs.

TC Haiyan was the southernmost TC making landfall in the Philippines whose central pressure was measured at less than 900 hPa since 1951. TC Haiyan made landfall in the Visayas area. TC landfall in the Visayas is not a rare event. About 15 TCs make landfall in the Visayas area every 10 years. Among them, three TCs including Haiyan, and the TCs in 1912 and in 1897 were among the strongest TCs that made landfall in the Visayas area, which causing storm surges in Samar and Leyte islands.

TC Talas made landfall in the Kochi prefecture in Japan. However, heavy rainfall and landslides occurred in the Kii Peninsula about 300 km east of TC landfall. About 3.7 TCs land in the Kochi prefecture every 10 years. When the TC propagation speed becomes slower, the rainfall amount accumulated becomes higher in the Kii Peninsula. TC Talas and the TC in 1889 demonstrate that heavy rainfall in the Kii Peninsula were produced by slow movement of the TC, which made landfall in the Kochi prefecture. Another case of TC Moracot, which made landfall in Taiwan in 2009, produced heavy rainfall accumulated to 2700mm in high terrain area (Ge et al., 2010). The Kii Peninsula is also surrounded by high terrain. These results suggest that slow moving TCs pose a risk of heavy rainfall to a high terrain area.

| station   | correlation coefficients |
|-----------|--------------------------|
| Wakayama  | 0.22                     |
| Shionomisaki | -0.31*                   |
| Ryujin    | -0.32*                   |
| Kurisugawa | -0.33*                   |
| Tanabe    | -0.16                    |

* is the station, which correlation coefficient is at the 95% confidence level.
cases that did not cause severe damage.

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2013年台風30号（ハイエン）と2011年台風12号（タラス）の過去120年間の類似台風との比較

久保田尚之

2011年台風12号（タラス）は、紀伊半島に大雨と土砂崩れを引き起こし、2013年台風30号（ハイエン）は、フィリピンのサマールとレイト島に高潮を引き起こした。台風ハイエンと台風タラスは、過去に類似の台風経路で類似の被害をもたらした記録が残されている。本論文では、これらフィリピンと日本の2つの台風に着目し、過去117年と過去122年間に観測された類似台風との比較を行った。台風ハイエンと同じ地域に上陸した1897年と1912年の2つの台風は、高潮をもたらしていた。台風ハイエンはフィリピンのビサイヤ地域に上陸した。ビサイヤ地域には、10年間で約15個の台風が上陸している。しかししながら、台風ハイエンを含むこれら3つの台風は、過去117年間でビサイヤ地域に上陸したもっとも強い多風だった。ビサイヤ地域に上陸する強い台風は、サマールとレイト島に高潮のリスクがあることがわかった。1889年の台風は、台風タラスと同じ地域に大雨と土砂崩れをもたらした。高知県には、10年間で約3.7個の台風が上陸している。台風タラスと1889年の台風は、高知県に上陸した台風のなかでもっとも遅い速度の台風だった。同じ地域には、より強い台風が上陸したにもかかわらず、移動速度が速いために紀伊半島にもたらす雨量は少なかった。高知県に上陸する速度の遅い台風は、紀伊半島に大雨と土砂崩れをもたらすリスクがあることがわかった。台風経路を含む歴史的資料の気象測器の観測記録の画像化やデジタル化は、「データレスキュー」と呼ばれる。長期の台風記録は、台風災害の頻度が小さい場合でも類似の台風被害を調べることを可能にしている。

キーワード：台風、2013年台風30号（ハイエン）、2011年台風12号（タラス）、データレスキュー

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