An overview of the tropical cyclone database at the Central Weather Bureau of Taiwan

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Abstract

Taiwan’s Central Weather Bureau (CWB) has established a new version of tropical cyclone (TC) database to provide users with comprehensive TC data services. As of June 2022, the database includes 1673 TCs originating in the western North Pacific and South China Sea regions since the CWB began TC forecasting operations in 1958. It collects not only the track dataset, satellite imagery, and synoptic weather charts, but also more detailed data and products of TCs that have impacted Taiwan, such as radar reflectivity imagery, high-density surface observations, dropwindsonde data from aircraft observations, and mesoscale analysis maps of rainfall, wind, pressure, and temperature. Such detailed data realistically preserves the TC’s journey across Taiwan and is a feature of the CWB TC database. In addition, the TC database website (https://rdc28.cwb.gov.tw/TDB/) provides tools that allow users to search for TCs of interest based on track, rainfall, and wind. Digital best track data since 1958 is available (https://rdc28.cwb.gov.tw/TDB/manager/obs_data_download/) for users to download and conduct TC research. Also included are technical reports summarizing extensive historical observational research focusing on the mesoscale variations during a TC’s passage over Taiwan. The TC database has been widely used in academic research, disaster prevention, crop revenue insurance, offshore wind power, and other fields. It will continue to develop useful products and integrate more diverse observations to meet the needs of different users.

Keywords: Tropical cyclone, Database, Mesoscale analysis

Key points

1. The detailed data contained in the CWB TC database realistically preserves the TC’s journey across Taiwan
2. The mesoscale observations and analyses collected in the TC database also provide validation for model forecasts or simulations so that models can be improved to further enhance typhoon research and prediction
3. Several tools are provided in the TC database website (https://urldefense.com/v3/__https://rdc28.cwb.gov.tw/TDB/__https://rdc28.cwb.gov.tw/TDB/manager/obs_data_download/) to facilitate users to search for TCs of interest based on track, rainfall and wind

1 Introduction

The western North Pacific (WNP) is the most active tropical cyclone (TC) basin on Earth, with an average of 26 TCs per year. Taiwan is located on its western edge and is hit by an annual average of three to four TCs. The Central Weather Bureau (CWB) of Taiwan is responsible for monitoring and forecasting all TC activity in the WNP and South China Sea (SCS) and issuing the sea and land warnings for the TCs that have impacted Taiwan since 1958. Furthermore, the CWB has collected all of the data and relevant analysis results for each storm via
the database, especially the comprehensive archives of raw observational data for TCs affecting Taiwan. The evolution of the TC database at the CWB can be roughly divided into two periods. Before 2014, the general TC data, such as the best-track dataset, satellite images, synoptic weather charts, and land-based observations were collected in the "TC basic data bank" (Cheng 2001). The post-storm analysis products, such as the hourly track, secondary centers, and local distributions of strong winds, sea-level pressure, rainfall, and foehn associated with a TC that passed over Taiwan, were recorded in the "Taiwan post-storm analysis data bank" (Wang 1980; Shieh et al. 1996). The impact of the steep terrain of Taiwan on TCs is an interesting scientific and forecasting topic, in part because of the complex interactions between the storm and the topographic barriers. Therefore, the CWB has generated post-storm analysis products for the TCs that have impacted Taiwan for decades (Shieh et al. 1998; Wang 2007).

In the second period, the construction of the new version of the TC database was not only based on the above two data banks, but also added other advanced data, such as the aircraft dropwindsonde data and the high-density automated surface observations in Taiwan. The most detailed data of the TCs that have impacted Taiwan are characteristic of the new TC database, which has also been widely used in related TC studies (e.g., Wu and Kuo 1999; Wu et al. 2002; Jian et al. 2006; Jian and Wu 2008; Liou et al. 2016; Lin and Wu 2021). Furthermore, the new TC database is expected to provide a comprehensive service, and its website (https://rdc28.cwb.gov.tw/TDB/) has continued to develop several tools for searching the TCs of interest.

This study describes the contents, characteristics, access, and potential applications of the TC database maintained and developed by the CWB, with the aim of providing users with a useful guide to facilitate its application in scientific research and related fields. This paper is organized as follows. Section 2 gives the contents of the CWB TC database. The flexible search feature that allows users to obtain the desired information from the website of the TC database is presented in Sect. 3. Finally, discussion and conclusions are provided in Sect. 4.

## 2 Contents of the CWB TC database

The CWB has conducted routine TC operations since 1958. The TC database includes a total of 1673 TCs that formed over the WNP and SCS regions from 1958 to the present (June 2022), of which 422 TCs near Taiwan caused TC warnings to be issued by the CWB. During the same period, Taiwan was impacted by and suffered disasters from 203 TCs, with 113 of them making landfall (where the TC center crossed the land) on the island. The contents of the collected materials in the TC database are described as follows. If a sample case is required to enhance understanding, it will be illustrated with the example of Typhoon Soulik (2013).

### 2.1 TC track

Before 1980, the track data were primarily determined by synoptic analysis of surface observations, ship reports, and upper-air analysis. The data from more advanced instruments, such as geostationary satellite images, high-density surface stations, and Doppler radars, as well as dropwindsonde data from aircraft observations, were gradually incorporated into the CWB’s track analysis, starting from 1981, 1990, 1996, and 2003, respectively. It is worth mentioning that the CWB initiated a TC reanalysis project (1993–1998) funded by Taiwan’s Ministry of Science and Technology to include more raw data to further improve the data quality and reliability for the older storm tracks that dated from before 1996 (Shieh et al. 1998). Through this project, the reanalysis procedures were established, including the mesoscale analysis, as described in Sect. 2.5, which have been applied to TCs since 1996. Along each TC track, the longitudinal and latitudinal positions, the maximum surface wind, the radii of 15 m s\(^{-1}\) and 25 m s\(^{-1}\) wind speeds, and the sea level pressure at the center are estimated at 6-hourly intervals over the ocean and 3-hourly (hourly) intervals during the sea (land) warnings to the Taiwan area. Data are presented in yearly compressed dataset (.zip) files and individual TC (.txt) files. The digital best track data since 1958 is available and can be downloaded from https://rdc28.cwb.gov.tw/TDB/manager/obs_data_download/, which is part of the CWB TC website as described in Sect. 3. An example of a tracking chart for Typhoon Soulik is shown in Fig. 1. The CWB uses a purple circle to depict a tropical depression, an unfilled blue symbol to depict a tropical storm, and a filled green or red symbol to depict a typhoon with moderate or strong intensity.

### 2.2 Satellite image

The CWB has operated 24 h a day to receive, process, and analyze geostationary satellite data from Japan since 1981. The TC database includes the visible and infrared images for each storm over the WNP region from 1981 to the present. The images collected in the TC database are at 1-hourly intervals for the GMS (Geostationary Meteorological Satellite), 30-min intervals for the MTSAT (Multi-functional Transport Satellite) series, and 10-min intervals for the Himawari-8 (see Table 1), based on the upgraded meteorological satellites of Japan. Users can view, animate, and download the collected TC satellite imagery from the website.
2.3 Synoptic chart

The CWB routinely produces synoptic charts at the surface and the six pressure levels that meteorologists monitor most frequently: 925 hPa, 850 hPa, 700 hPa, 500 hPa, 300 hPa, and 200 hPa. The synoptic charts have been included in the TC database for each storm since 1958. In addition to the general information about high and low pressure areas, fronts, and isobars, detailed TC information has been included in the surface chart at 6-hourly intervals (00, 06, 12 and 18 UTC). The upper air charts are made twice daily (00 and 12 UTC), which are used to examine the atmospheric conditions surrounding a TC.

2.4 Composite radar reflectivity image

The current operational CWB radar network consists of one S-band dual-polarization, three S-band single-polarizations and three C-pol radars. Chang et al. (2021) gave an excellent review of the radar technical specifics and the applications for meteorological and hydrological predictions. The CWB regularly conducts preventive maintenance and calibrations on each radar to ensure the accuracy of the observations. The composite reflectivity images are recorded in the TC database for the TCs for which there have been warnings issued from 2000 to the present. The radar imagery is available at 30-min intervals until 2012 and has been upgraded to 6-min intervals since 2013. Users can also view, animate, and download images of interest from the website.

2.5 Surface observations

In addition to the original manned weather stations, the CWB established an automatic weather monitoring network in 1985. The number of automatic monitoring stations has significantly increased since 1990. Now, there are 25 manned weather stations, 437 automatic weather stations, and 139 automatic rain gauge stations over Taiwan. As can be seen in Fig. 2, the stations are
quite uniformly distributed over the plain, and the percentage of stations located above the altitude of 500 m is higher than 28%. The network of more than 600 stations implies that Taiwan has one station every 8 km. Such high-density observational data, including pressure, temperature, wind, precipitation, and humidity, is available for the TCs for which warnings have been issued and can be downloaded from the website of the CWB TC database. Furthermore, the database also provides some useful charts, such as rainfall distribution and mesoscale...
analysis during the passage of a TC over Taiwan, which are produced based on high-density data. The details are described below.

2.5.1 Rainfall distribution

It has been suggested that the topographic effect of the Central Mountain Range (CMR) in Taiwan is an important factor influencing the TC-related rainfall (e.g., Chang et al. 1993; Kuo et al. 2017). In order to provide a more accurate representation of the TC-induced precipitation, the CWB has made a great effort to expand the high-altitude stations in recent years, even though it is quite difficult and dangerous to build as well as do the follow-up maintenance. There are 172 automatic weather stations located above the altitude of 500 m so far, including 90 stations above 1000 m.

In addition to collecting rainfall data in text format, the TC database includes the maps of daily and storm-total rainfall induced by the TCs that have impacted Taiwan since 1958. Hourly rainfall maps have also been included since 1991, when the number of automatic weather stations significantly increased. Moreover, a 24-h maximum precipitation chart for all manned weather stations is also provided, which can be used to characterize the TC’s sustained rainfall intensity and hazard potential. For instance, Typhoon Herb (1996) and Morakot (2009) both resulted in catastrophic floods and landslides. In terms of the total accumulation, Morakot produced torrential rainfall with a peak of 2859 mm, far exceeding the 1987 mm previously recorded by Herb at the same weather station in Mount A-Li, central Taiwan. In terms of the 24-h maximum rainfall, however, Herb brought extreme rainfall of 1749 mm that was even more severe than Morakot’s 1624 mm recorded at Mount A-Li station. This reveals that the torrential rainfall induced by Herb was almost concentrated in a 24-h period, and therefore it caused no less damage than Morakot.

2.5.2 Mesoscale analysis

The interaction of the TC circulation with the CMR frequently produces significant mesoscale variations in pressure, wind, temperature, and rainfall distribution over Taiwan. Focusing on the TC-associated phenomena that may be of interest for research purposes, the TC database provides subjective analysis maps of the mesoscale structure on pressure, wind, and temperature for the TCs that have impacted Taiwan since 1958. Figure 3 shows the example of Typhoon Soulik, which moved northward and followed a straight track as it approached the northeastern shoreline of Taiwan (see Fig. 1). During the passage of Soulik over Taiwan, the high-density observations gave high confidence in the results of isobar analysis. The mesoscale analysis map provided by the TC database shows that Soulik made landfall about 20 km northeast of the Ilan station at around 1900 UTC on 12 July (Fig. 3a) and then turned for the next 1 h to the west of Ilan (Fig. 3b). Afterwards, Soulik was downgraded to a tropical storm while moving toward the Hsinchu station, and entered the Taiwan Strait around 0000 UTC on 13 July (Figs. 3c and d). The surface observations also reveal that a terrain-induced pressure trough was located on the lee side in southeastern Taiwan and a ridge was analyzed on the windward side over the central and southern regions of western Taiwan, as shown in Fig. 3.

One of the scientific goals of incorporating mesoscale analysis products into the CWB TC database is to present and preserve a TC’s journey through Taiwan as realistically as possible. In addition to the pressure distribution, the TC database includes the mesoscale analysis maps of wind and temperature, as shown in the example of Typhoon Soulik in Fig. 4. Based on intensive wind observations in northern Taiwan, the surface circulation center of Soulik can be determined reasonably well (see black dashed lines in Fig. 4). The strongest winds on Taiwan’s northeastern coast were mainly observed by Doppler radar, in part because fewer observations were made on the neighboring small islands. Figure 4 also shows that there was a local high temperature area in the plain region of southeastern Taiwan (red dashed lines), which was located on the lee side as Soulik passed through northern Taiwan.

To provide users with a quick review, the TC database has produced time series charts of hourly observed data from all manned weather stations for the TCs that have impacted Taiwan since 1958. This product is quite useful for monitoring and documenting the passage of TCs, especially for those that have made landfall in Taiwan. Take the product of Typhoon Soulik (2013) in the TC database as an example. As shown in Fig. 5a, the pressure at the Ilan station dropped rapidly as Soulik approached, and reached a minimum when the typhoon made landfall at 0300 local time on 13 July (1900 UTC 12 July). The wind direction changed counterclockwise from north to the southeast, as shown in Fig. 5a, indicating that Soulik’s center passed by the north side near the Ilan station. The pressure at the Taipei and Hsinchu stations then dropped significantly, and Soulik took only about 2 h to travel from Ilan to the north side of the Hsinchu station (Figs. 5b and c). In addition, the hourly rainfall, temperature, and dewpoint are displayed in the time series chart to further study the foehn associated with the storms affecting Taiwan. For example, a local high temperature area occurred in the plain region of southeastern Taiwan during the night of 12–13 July, as shown in Fig. 4. The time series chart of Taitung station (see Fig. 3 for location) can be obtained from the TC database to examine
Fig. 3 The sea-level pressure with a 4-hPa contour interval of Typhoon Soulik (2013) at a 1900 UTC 12 July, b 2000 UTC 12 July, c 2200 UTC 12 July, and d 0000 UTC 13 July. The red asterisks indicate the locations of Ilan, Taipei, Hsinchu, and Taitung stations.
Fig. 4 The surface isotachs (solid lines) with a 10-kts contour interval and corresponding surface streamlines (dashed lines) of Typhoon Soulik (2013) at a 1900 UTC 12 July, b 2000 UTC 12 July, c 2200 UTC 12 July, and d 0000 UTC 13 July. The red lines indicate the high temperature associated with foehn winds over southeastern Taiwan.
the hourly evolution of the observed data (Fig. 5d). It can be seen that the temperature at Taitung started to rise, along with a drop in dewpoint about 3 h before Soulik made landfall, as the northwesterly wind in western Taiwan crossed the CMR and caused the foehn event in southeastern Taiwan. The temperature rose by about 7 °C to 36.8 °C within 2 h. At the same time, the dewpoint dropped by about 6 °C to 19.2 °C, and the relative humidity was only 36%.

In summary, the mesoscale observations and analyses collected in the TC database not only record the physical phenomena of TCs in Taiwan, but also provide validation for model forecasts or simulations so that models can be improved to further enhance typhoon research and prediction.

2.6 Dropwindsonde data
Over the open ocean, the observations are insufficient to correctly represent the TC structure. This deficiency constrains TC forecast accuracy. Starting from 2003, the program of Dropwindsonde Observations for Typhoon Surveillance near the Taiwan Region (DOTSTAR) was launched with collaboration between researchers from the National Taiwan University and the CWB (Wu et al. 2005). An Astra jet was used for surveillance at up to about 14 km in height, with a flight time of around 4–5 h. Dropwindsondes were released about every 150–200 km. DOTSTAR has successfully conducted 86 surveillance flight missions for 70 TCs and deployed 1,319 dropwindsondes from 2003 to 2021. The observation time and the number of dropwindsondes released of each observed TC are summarized in Table 2. The CWB TC database collects complete information of all observed cases, including the raw data of dropwindsondes, the map of the flight route, the skew-T/log-P diagram at each observation position, and the map of wind vectors at pressure levels of 1000 hPa, 950 hPa, 925 hPa, 900 hPa, 850 hPa, 800 hPa, 700 hPa, 600 hPa, 500 hPa, 400 hPa, 300 hPa, and 250 hPa [see Fig. 6 for some maps of the mission for Typhoon Soulik (2013)]. The dropwindsonde data has been operationally used to better diagnose the radius of gale-force wind and assimilated into the CWB’s forecast.
model in real time. Assimilation of dropwindsonde data into the CWB’s model reduces the mean track error of the 72-h forecast by 6.2% (Lin 2021).

2.7 Use of the product
In order to facilitate users to understand the functions of the products in the database more specifically, this section uses the TC case of Typhoon Soulik (2013) to illustrate how to identify the track map, synoptic map,
related satellite images, surface and radar observations. The track map (Fig. 1) shows the TC locations and intensity levels throughout the life cycle. The CWB divided the TC intensity into four categories, with a maximum sustained wind (10-min-averaged) below 17.2 m s\(^{-1}\) assigned for the tropical depression. A tropical storm has wind speeds between 17.2 and 32.6 m s\(^{-1}\). A moderate typhoon has winds of 32.7–50.9 m s\(^{-1}\), while a strong typhoon has wind speeds of 51.0 m s\(^{-1}\) or greater. The surface synoptic map (Fig. 7c) shows that Soulik developed from a tropical disturbance at the subtropical latitude (19.1° N) and was upgraded to a tropical storm at 0000 UTC 8 July. The surrounding environmental flow can be examined using the upper-air synoptic maps as mentioned in Sect. 2.3. As shown on the synoptic maps at 500 hPa (Fig. 7a and b), a subtropical high centered south of Japan led to a primary steering current that guided Soulik to the northwest on a roughly straight track across the western North Pacific and approached Taiwan on 12 July (Fig. 7d). The tropical upper-tropospheric trough (TUTT) can be examined using synoptic maps at 200 hPa and 300 hPa to further study the impact on the TC cases of interest, though there was no TUTT associated with Soulik.

The products of DOTSTAR observations collected in the database are useful for users to better diagnose the TC’s radius of galeforce winds and cyclonic circulation. To take Soulik as an example. The flight mission released 16 dropwindsondes around Soulik at 1200 UTC 11 July. The data shown in Fig. 6 indicates that the DOSTART observations captured the asymmetric features of Soulik with higher winds in the eastern quadrant of the TC. Such asymmetric wind fields were important information for forecasting operations and numerical studies. Satellite images can not only show the location of the TC but also estimate its intensity based on the Dvorak technique (Dvorak 1975). The infrared satellite images (Fig. 8a and b) reveal that the higher cloud top was located on the eyewall and the spiral bands along the southern and eastern quadrants of Soulik. Although the visible satellite imagery can only be viewed during the day, it has a higher resolution and displays cloud textures better. The brighter white areas on the visible images (Fig. 8c and d) almost overlapped with the areas of higher cloud tops on the infrared images, implying that deep convections have developed up to the tropopause.

Doppler radar observations are very important for determining the TC center and tracking the evolution of eyewall and rainbands as a TC approaches Taiwan.
TC eye tracking algorithm has been operated at the CWB to automatically track the TC center when the eyewall is well organized (Chang 2009). The composite radar reflectivity provided by the TC database indicate that Soulik had a concentric eyewall before making landfall on the coastline near Ilan county (Fig. 9a–e). At landfall, strong echoes were observed over most of the island (Fig. 9f), except for the southeastern Taiwan, which was located on the lee side. The database also provides the mesoscale analysis products, which were produced from Taiwan's high-density surface observations, for users to further study the related physical process during the passage of a TC. In this study, the TC case of Soulik has been used to illustrate the product functions of mesoscale analysis in the database and can be found in Sect. 2.5.

3 Tools for searching

The website of the CWB TC database (https://rdc28.cwb.gov.tw/TDB/) is aimed to serve as a platform for users to obtain data and graphical products of TCs over the WNP and SCS region, especially for storms that have impacted Taiwan. For ease of use, the website provides users with two basic tools to search for the TC data of interest, as described below.

3.1 Search by TC track

The CWB classifies the track of TCs that have impacted Taiwan into 10 different categories, as shown in Fig. 10. Categories 1–5 are the westward-moving (or northwest-moving) TCs, which pass through the northern sea (12.76% of the total cases that have impacted Taiwan), northern Taiwan (13.28%), central Taiwan (12.76%), southern Taiwan (9.64%), and the southern sea (18.23%), respectively. Categories 6 and 7 are the northward-moving TCs, which move along the eastern sea (12.50%) and the Taiwan Strait (6.77%). Categories 8 and 9 are the northeastward-moving TCs. The track of Category 8 is through the southern sea (3.39%), while the TCs of Category 9 enter the Taiwan Strait or even make landfall on the west coast of Taiwan (6.77%). The final type (Category
10) is for all other TCs (3.91%). In addition to track category, the intensity is often an important feature. For example, the user might want to look for the Category 2 typhoons with strong intensity during a certain period. After setting the category and time period, this tool also provides the user with another optional condition—"TC intensity"—to further focus on the desired TCs data as needed.

Another way is to search for TCs by a specified area. This tool allows the user to select a specific area of interest by setting the latitude and longitude at the southwest and northeast corners. The search result is a list of TCs that have entered the specified range. Users can also click on a TC in the list to link to the storm details, as described in Sect. 2.

3.2 Search by observed rainfall and wind
As mentioned earlier, the CWB’s automatic monitoring network has more than 600 stations for real-time observing and recording of TC-induced weather elements, such as rainfall, wind, pressure, and humidity. The TC database fully includes observational data from these stations and its website provides a tool to search for TCs of interest by observed rainfall and wind. In particular, historical events of TC-induced extreme rainfall are very important for disaster prevention, since serious flooding or landslide events are generally associated with torrential rainfall. In terms of searching by rainfall, users can query the required TC data by setting the three conditions of "rainfall threshold", "select by time period", and "select by station", according to their needs. Among them, the
Fig. 9  Radar reflectivity from the Doppler radars of CWB at a 1400 UTC, b 1500 UTC, c 1600 UTC, d 1700 UTC, e 1800 UTC, and d 1900 UTC 12 July 2013
"rainfall threshold" is determined by a rainfall accumulation period and a rainfall value. There are six rainfall accumulation periods (1, 3, 6, 12, 24 h, storm-total) and 12 rainfall values (more than 0.1, 1, 40, 50, 80, 100, 130, 200, 250, 350, 500, 1000 mm) for the users to select a set of conditions. For example, to query the location and rainfall data of stations with accumulated rainfall exceeding 500 mm during the passage of Typhoon Soulik, the three conditions can be set as "more than 500 mm during storm-total period", "2013 Soulik", and "all stations", respectively. If the users want to know which TCs caused the 24-h accumulated rainfall to exceed 1000 mm at Mount A-Li, the query conditions can set as "more than 1000 mm in 24-h", "from 1958 to 2022", and "Mount A-Li station". The query results for this extreme rainfall example occurred only for Typhoon Herb (1996) and Typhoon Morakot (2009), with rainfall of 1749 mm and 1624 mm. In addition, taking Taipei station as an example, the query results show that there were three and 25 TCs with a storm-total rainfall exceeding 500 mm and 250 mm during the period of influence, but no typhoon caused an accumulated rainfall exceeding 1000 mm. The TCs searched can be listed in order of rainfall or occurrence time. The storm details described in Sect. 2 are also available by clicking on the TC link in the list.

The method of searching for the TCs of interest based on wind is similar to searching based on rainfall, but changes the rainfall threshold to the wind speed threshold. The website allows users to set thresholds for sustained winds (10-min-averaged wind) and gusts in m s$^{-1}$ or the Beaufort scale. Basically, this tool has taken into account the possible needs of users, such as finding the locations and times of strong winds caused by a certain TC, searching the historical strong winds and occurrence times for a certain station for a certain time period, or looking for the locations and associated TCs above a specified wind speed for a specific time period. Using this tool to search for historical extremes from 1958 to the present, the strongest sustained wind of 50.4 m s$^{-1}$ was observed at 2200 UTC on 25 August 2004 when the eyewall of Typhoon Aere (2004) struck Pengchiayu station offshore of northern Taiwan. Furthermore, the strongest wind gust of up to 78.4 m s$^{-1}$ was observed at 1500 UTC on 21 August 2000 at Chengkung station while Typhoon Bilis (2000) was making landfall in eastern Taiwan.

In addition to searching with the above tools, the TC database produced some tables of the top 10 rainfall and wind speeds at all manned weather stations in Taiwan. This helps users quickly review the historical extreme events. Since the heavy rainfall data caused by TC is important upstream information for disaster prevention, the CWB TC database provides the top 10 rainfall tables for various accumulated time periods, including hourly, and 3, 6, 12, 18, and 24-hourly, and storm-total.

4 Discussion and conclusions

This article describes the contents of the TC database at Taiwan’s CWB and the useful tools for finding the TC data of interest. The database includes 1,673 TCs in the WNP and SCS regions since the CWB began TC forecasting operations in 1958. Among them, the CWB has issued warnings to Taiwan for 422 TCs, of which 203 have impacted Taiwan and 113 have made landfall. There are three kinds of data in the TC database that can be downloaded as text files, including the digital best-track dataset, the dropwindsonde observations of the TCs as shown in Table 2, and the hourly data from high-density surface observations over the Taiwan area. In addition, the TC tracking charts, satellite images, and synoptic weather maps for each storm are included. Regarding the TCs for which the CWB had issued warnings to Taiwan, the TC database provides more detailed information, such as composite radar reflectivity images, rainfall distribution maps, mesoscale analysis maps of pressure, wind, and temperature, and charts with aircraft drop-windsonde observations.

According to the World Meteorological Organization (WMO) resolution made by the 31st session of Typhoon Committee meeting, a new TC naming system has been put into service for international aviation and navigation since January 2000. The WMO Regional Specialized
Meteorological Center (RSMC) based in Tokyo, Japan, is responsible for naming the TCs that occur in the WNP and SCS regions according to the arranged set of names. The new naming system also retains the numbering method (e.g., 2201 for the first one that occurred in 2022), which is important as the timing of TC formation may be slightly different for the CWB and RSMC Tokyo analyses, such as Tropical Storms (TSs) Mekkhala (2020), Aere (2016), and Yutu (2001). What these three TSs had in common is that they were all generated near Taiwan. Based on the observations nearby Taiwan, the CWB determined that the TSs formed before the RSMC Tokyo named them. Although the timing of formation may be different, to date, the annual number of TCs at the CWB and RSMC Tokyo was the same.

It has been suggested that the best-track intensities from the RSMCs had temporal and spatial heterogeneities since the operational procedures differ at each agency (Knapp and Kruk 2010; Lander 2008). The differences in the analyzed TC intensity between the CWB and the Joint Typhoon Warning Center (JTWC) were mainly derived from the measurement of maximum sustained surface winds. As required by the U.S. National Hurricane Operations Plan, JTWC reported the maximum sustained surface winds in the TCs as a 1-min mean wind speed. The CWB and RSMC Tokyo, however, reported maximum sustained surface winds averaged over a 10-min time interval. The difference mean that the best-track intensity at JTWC was generally higher than that at CWB and RSMC Tokyo for the same cyclone.

In order to obtain the desired TC data more easily, the TC database website provides a variety of tools to search for TCs of interest based on track, rainfall, and wind. It also includes a series of tables for the top 10 heavy rainfalls and strong winds caused by TCs at all manned weather stations in Taiwan. It is worth mentioning that there are some technical reports about the empirical forecast guides for TC track changes, strong winds, rainfalls, foehns, and the development of secondary centers under the influence of the CMR in the original "Taiwan Post-Storm Analysis Database", as mentioned in Sect. 1. These reports summarize extensive historical observational studies focusing on TCs affecting Taiwan and are integrated into the technical reporting area of the current TC database for reference in storm research and prediction.

Since TCs are one of the most common natural disasters in Taiwan, there are application demands for TC data in many fields. The CWB TC database has been widely used in academic research, disaster prevention, crop revenue insurance, offshore wind power, and other fields. For example, the design of crop natural disaster insurance requires the use of a large number of TC observations. In addition, Taiwan is increasing the proportion of power generation from renewable energy through the "Thousand Wind Turbines Project". The strong wind data in the CWB TC database are important information for the operational safety of wind turbines and supporting structures. The TC database will continue to develop useful products, integrate more diverse observations from the CWB, and do its best to meet application needs in various fields.

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JGJ drafted the manuscript, handled the revision, and performed the finalized version of the manuscript. All authors give their effort for this manuscript submission. All authors read and approved the final manuscript.

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Consent for publication
This study does not contain data from any individual person.

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