

Introduction to the Central Weather Administration(CWA) Typhoon Probability Product

Updated: 4 Mar. 2025

Typhoon tracks are often unpredictable and notoriously variable. Although modern technology has made progress in forecasting capabilities, it remains incapable of completely mastering the task, resulting in a certain degree of error. An analysis of typhoon track forecast errors from the CWA in the western North Pacific Ocean and South China Sea over the past five years (2019 to 2023) shows that the average track errors for 12, 24, 48, 72, 96, and 120-hour forecasts are 56, 83, 143, 215, 275, and 357 kilometers, respectively. These error values are comparable to those forecasted by the meteorological authorities in various countries, reflecting the current difficulty of typhoon forecasting; the longer the forecast period, the greater the error. To fully illustrate the uncertainty of the forecasts, the CWA provides the following typhoon-related probability forecast auxiliary products on the official typhoon information website. These products are available to the public and for decision-makers involved in typhoon disaster prevention and rescue, supporting appropriate preparedness and response decisions:

1. Typhoon potential track forecast chart (Figure 1)
2. 120-hour Typhoon Wind Speed Probability (WSP) overlaid with Most Likely Arrival Time and Earliest Reasonable Arrival Time of storm-force (30 kt) winds (Figure 2)
3. 120-hour Typhoon WSP for major cities and islands (Figure 3)
4. Trend Changes in 120-hour Typhoon WSP (Figure 4)
5. Typhoon WSP for every 6 hours in the future (Figure 5)

In Figure 1, the light yellow area indicates the region where the typhoon center is likely (with a 70% probability) to pass within 120 hours. White dots and time labels represent the forecast positions of the typhoon in the future. The pink shaded area and circles represent the asymmetric storm area of the 30 kt [scale number seven (7/near-gale) of the Beaufort Scale] and its average radius range, respectively. Figures 2 to 5 show the probability of 30 kt winds occurring, calculated based on statistical results derived from the CWA's forecast track error over the past five years. A 60% probability indicates that in similar forecast situations over the past 100 instances within the forecast time range, there were 60 cases where the location was hit by a storm. This information serves as a reference for users in risk assessment. However, since the vulnerability to typhoon impacts varies across different sectors, and the time required for typhoon preparedness also differs, different precautionary strategies may be adopted based on specific needs.

To enhance early warning information for typhoons, the CWA added new features to its "120-hour Typhoon WSP" product for the 2024 typhoon season. These new features include Most Likely Arrival Time and Earliest Reasonable Arrival Time of storm-force (30 kt) winds (depicted as timelines in Figure 2). These additions are designed to assist groups with lower risk tolerance and longer preparation times.

The new product is based on the statistical forecast errors from the CWA. Assuming we have 1,000 possible typhoon positions, after a forecast period, we select typhoon positions with median speed (50th percentile) and faster speed (90th percentile) based on the distance of each typhoon member from the origin. These are designated as "Most Likely Arrival Time" and "Earliest Reasonable Arrival Time," respectively. In simple terms, the "Most Likely Arrival Time" is usually 0-12 hours earlier than the official forecast, while the "Earliest Reasonable Arrival Time" is about 12-24 hours earlier. As the typhoon approaches, these time differences with the official forecast will gradually narrow. These estimates are based on the forecast error characteristics of the past five years and are updated annually to ensure greater accuracy.

It is important to note that the estimated storm arrival times are not the same as the warning issuance times. For the warning issuance standards, please refer to the "Weather FAQ" section on the CWA's official website (<https://gov.tw/usS>). Additionally, for typhoons that are moving slowly, stationary, or circling, the uncertainty is higher, making the "Most Likely Arrival Time" and "Earliest Reasonable Arrival Time" products less applicable for assessment in such scenarios.

Figures 1 to 5 are updated every 6 hours. For typhoon forecast information within 24 hours during the warning period, please refer to the CWA's typhoon warning bulletins, wind and rain forecasts, and weather warnings, which are updated more frequently.

Example

At 8:00 PM on October 1st, 2023, Typhoon Koinu was located east of the Philippines (Figure 1). The 72-hour forecast (by 8:00 PM on October 4th) predicted the typhoon's center to be near the

southeastern coast of Taiwan, passing westward across the Hengchun Peninsula, and reaching the southern Taiwan Strait by 96 hours (by 8:00 PM on October 5th). Over the next 120 hours, the WSP (Figure 2) shows probabilities ranging from 60-80% for eastern and southern Taiwan, and 40-60% for central and northern Taiwan. Figure 3 provides a detailed probability distribution for major cities and islands in Taiwan. For instance, in Taitung City (Figure 3), the WSP within the next 120 hours is 72%, meaning that in similar forecast scenarios over 100 instances, storms have struck Taitung City 72 times.

Based on the latest track forecast, the storm area may arrive in Taitung City between 8:00 AM and 2:00 PM on October 4th (Figure 2A). If the storm accelerates, historical data suggests the storm area could arrive as early as 8:00 PM to midnight on October 3rd (Figure 2B). Considering the uncertainty in typhoon forecast errors, it is crucial to complete typhoon preparedness measures before this time.

To understand the changes in the probability of the storm hitting Taitung City over time, please refer to Figure 4. It shows that the probability increased gradually from 11% at 2:00 PM on September 29th to 72% at 8:00 PM on October 1st, indicating a growing likelihood of the storm hitting as time progressed and highlighting the need for appropriate typhoon preparedness.

Additionally, for a detailed view of how WSP changes every 6 hours for Taitung City, refer to Figure 5, where the highest probability peaks at 50% from 8:00 AM to 2:00 PM on October 4th (matching the previously estimated most likely arrival time). After this period, the probability gradually decreases, indicating that the storm area may move farther away or uncertainty may increase with time. The probability of the storm arriving earliest in Taitung (around 8:00 PM to midnight on October 3rd) drops to 31% in each 6-hour period. Note that due to the different time sampling lengths, the probability values for each 6-hour period are almost always lower than the probability values for the next 120 hours.

Important Notes: To avoid misinterpretation and public dissemination leading to misperception, we hereby declare the following:

The CWA issues this product solely to assist in interpreting the uncertainty of typhoon forecasts through probability values. During a typhoon warning period, the primary source of information remains the typhoon warning Bulletin itself. When reporting on typhoon warnings, the media should take note of relevant coordination matters.

This product does not directly or indirectly indicate the following:

1. Probability of the typhoon center making landfall.
2. Types of disasters that the typhoon may cause and their probabilities.
3. Timing and probability of typhoon warning issuance by the CWA.
4. Timing of various counties and cities entering typhoon sea or land warning areas.

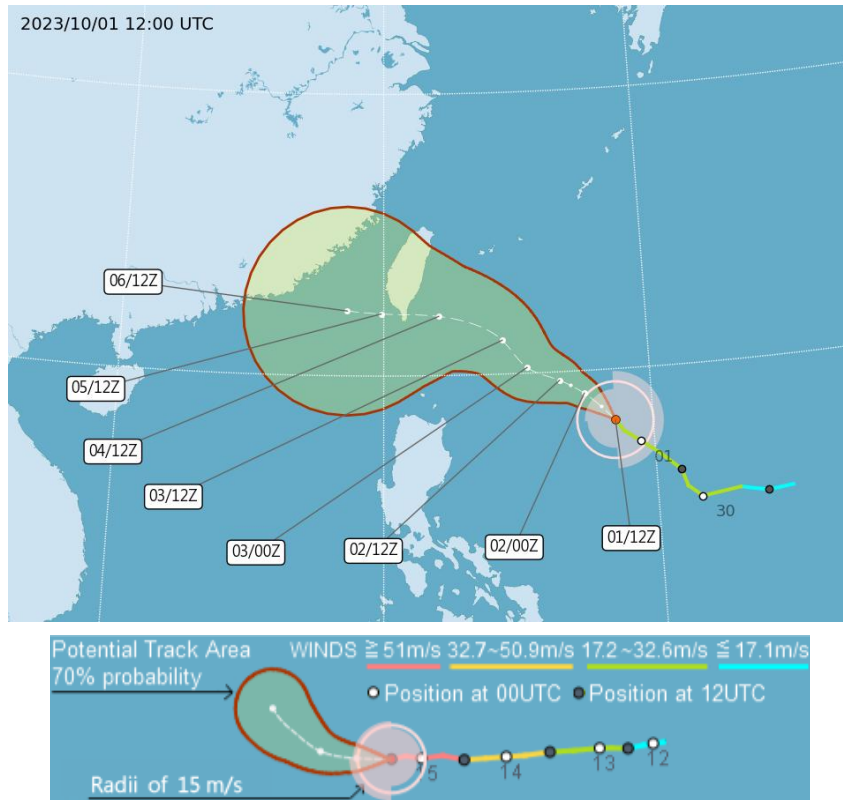


Figure 1 Typhoon potential track forecast

The light yellow area indicates the region where the typhoon center is likely (with a 70% probability) to pass within 120 hours. White dots and time labels represent the forecast positions of the typhoon in the future. The pink shaded area and circles represent the asymmetric radii area of the 30 kt winds and its average storm radius. Example from Typhoon Koinu at 8:00 PM on October 1, 2023.

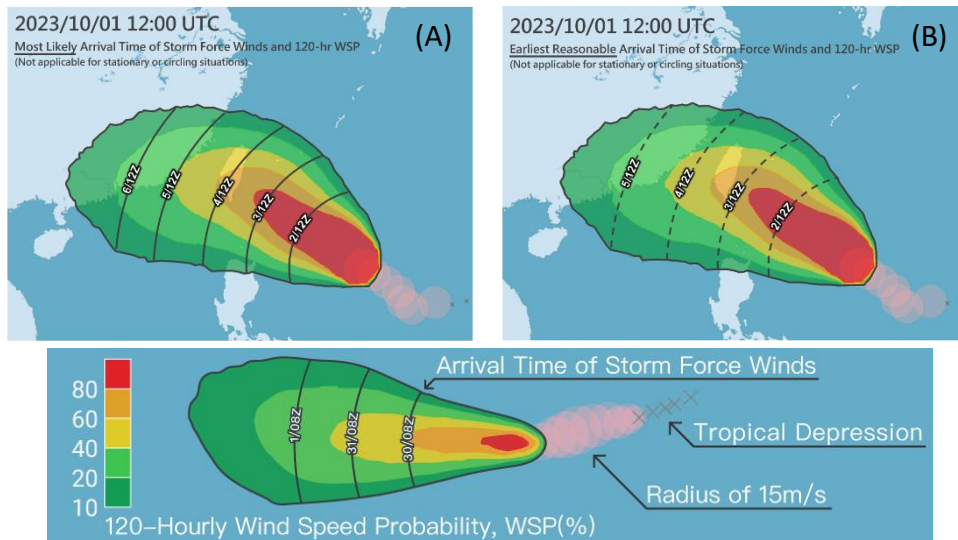


Figure 2 120-Hourly WSP Overlaid with Most Likely Arrival Time and Earliest Reasonable Arrival Time of storm-force (30 kt) winds (Figure 2)

This product is based on the official typhoon forecast positions (see Figure 1), taking into account past forecast error statistics to calculate the probability distribution of WSP over the next 120 hours. The pink circle represents the average storm area observed every 6 hours in the past, the gray "x" symbol indicates the positions of tropical depression centers observed every 6 hours, and the dark gray lines represent the (A) Most Likely Arrival Time and (B) Earliest Reasonable Arrival Time of storm-force winds. Example from Typhoon Koinu at 8:00 PM on October 1, 2023.

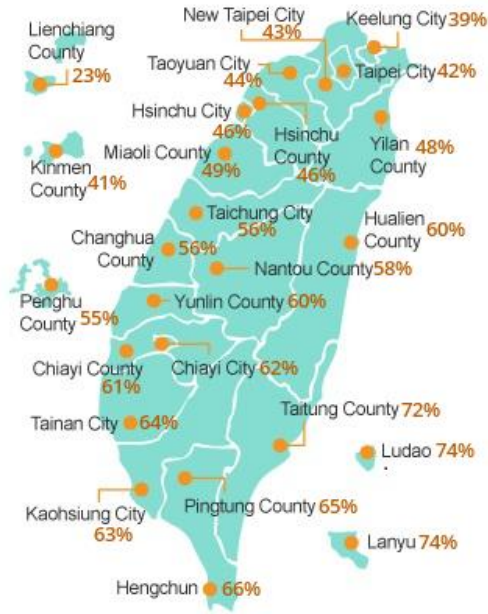


Figure 3 120-hour Typhoon WSP for major cities and islands
 Refer in Figure 2, here is the WSP of major cities and islands in Taiwan being affected by the typhoon within the next 120 hours. Example from Typhoon Koinu at 8:00 PM on October 1, 2023.

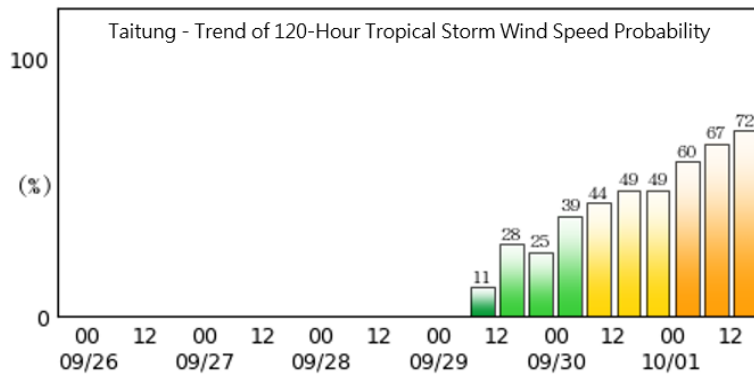


Figure 4 Trend Changes in 120-hour Typhoon WSP
 Refer in Figure 3, the sequence of "WSP in Taitung within 120 Hours" with Time of forecast release. Example from the impact of Typhoon Koinu on Taitung City at 8:00 PM on October 1, 2023

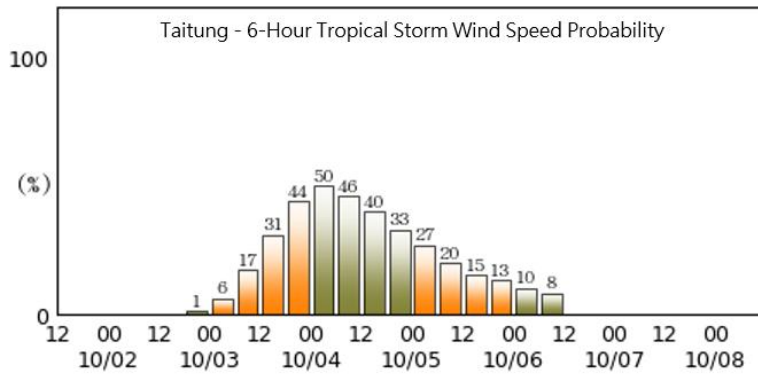


Figure 5 Typhoon WSP for Every 6 Hours in the Future
 WSP every 6 Hours within the Next 120 Hours. Example from the impact of Typhoon Koinu on Taitung City at 8:00 PM on October 1, 2023.

Q1. Why is a typhoon wind speed probabilities (hereafter WSP) product necessary?

A1. Since typhoon forecasts cannot achieve 100% accuracy, it is essential to provide WSP as reference for decision-making. Different industries require varying response times and levels of preparedness when facing a typhoon. Based on different risk management considerations, decision-makers can activate phased preventive measures according to changes in probability. This approach aligns with practices in advanced countries worldwide. It is important to note, however, that WSP does not directly or indirectly indicate the following: the probability of the typhoon's center making landfall, the magnitude of potential typhoon-related disasters, the probability of such disasters occurring, or the timing of the issuance of typhoon warnings by the CWA.

Q2. When and how often are typhoon analysis and forecast products released? Also, why aren't the 8:00 AM typhoon analysis and forecast issued exactly at 8:00 AM?

A2. Whenever a typhoon or tropical depression develops in the Western North Pacific Ocean or the South China Sea, our typhoon analysis and forecast products are made available on the CWA's official webpage, with updates every six hours. Once such weather systems dissipate, these products are no longer provided. Typhoon analysis and forecast follow international meteorological observation times (02:00, 08:00, 14:00, and 20:00 UTC daily). After we collect the observation data, our forecasters analyze, interpret, and edit the products. This process typically takes about 1.5 to 2 hours, which is why the 8:00 AM analysis and forecast products are not published exactly at 8:00 AM.

Q3. What does typhoon potential track area (hereafter PTA) mean?

A3. PTA represents a domain that a typhoon/tropical storm center will likely move in at a specific time, which implies track forecast uncertainties, based on the CWA official track error statistics in the past five years. These yellow shaded areas do not refer to the typhoon/tropical storm radius, rather, a circle of 70% probability that the storm center is entering within.

Q4. What are the major factors affecting the size of the PTA?

A4. Size of the PTA circle is primarily related to the forecast period. However, it is also affected by the storm's moving speed and direction. The PTA circle is typically larger if a typhoon/tropical storm is expected to move faster or undergo recurvature.

Q5. What does the WSP indicate?

A5. The WSP is a measure of how likely it is that a certain event will occur. For example, WSP 80% indicates that 80 times out of 100 forecasts that the storm radius of 30 kt winds passes through a given location, based on 100 similar track forecasts issued by the CWA in the past five years.

Q6. Does a higher WSP value mean stronger winds and heavier rain?

A6. As a typhoon approaches, the probability value generally increases, indicating a higher likelihood of stronger winds and heavier rain. However, due to the asymmetric structure of typhoons and the influence of terrain, the intensity of winds and rain can vary across different locations. Therefore, the probability value alone cannot fully determine the extent of wind and rain. For accurate forecasts on wind and rain intensity, it is strongly recommended to refer to typhoon warning bulletin and weather warnings issued by the CWA.

Q7. What is the difference between the 6h-WSP-6h and the 120h-WSP?

A7. According to the characteristics calculated from probability values, the individual 6-hour probabilities will not exceed the 120-hour probabilities, and the cumulative 6-hour probabilities for 120 hours will not be equal to the single 120-hour probabilities; just like that, for example, if the probability of precipitation (POP) for the daytime is 60% and the nighttime 60%, the POP for the whole day can not be 120% (greater than 100%).

Q8. How are “Most Likely Arrival Time” and “Earliest Reasonable Arrival Time of storm-force winds” determined?

A8. This product utilizes the CWA's official forecast error statistics, arranging the actual potential arrival times from slowest to fastest. It then selects the 50th percentile (with 50% of the time points on either side, indicating a median speed) and the 90th percentile (with 90% of the time points slower than this value, indicating a faster speed). These are designated as the "Most Likely Arrival Time" and "Earliest Reasonable Arrival Time," respectively. It is recommended that vulnerable groups complete disaster preparedness work before the earliest reasonable arrival time.

Q9. Why should the “120-hour WSP” and the “Most Likely/Earliest Reasonable Arrival Time of storm-force winds” be presented on the same map ?

A9. The information on Most Likely/Earliest Reasonable Arrival Time of storm-force winds is recommended to be interpreted together with the storm impact probability (shaded). If the arrival time information is considered alone without taking into account the WSP, it may mistakenly suggest that the storm will definitely arrive at that time, leading to an "overestimation" of the risk of storm impact.

Q10. How should the "Most Likely Arrival Time” and the “Earliest Reasonable Arrival Time of storm-force winds” be applied, and what precautions should be taken?

A10. This product can be used as an early warning reference 3 to 5 days before the typhoon approaches, aimed at groups with higher risk management needs and moderate to low risk tolerance. It is recommended to complete disaster preparedness measures before the **Most Likely/Earliest Reasonable Arrival Time of storm-force winds** conditions. It is important to note that this product is not suitable for scenarios where the typhoon track forecast is highly uncertain, such as in slow-moving, stationary, or circling situations. Additionally, for accurate forecasts on wind and rain intensity within 24 hours, it is strongly recommended to refer to the typhoon warning bulletin and weather warnings issued by the CWA.