DOST-PAGASA ANNUAL REPORT ON PHILIPPINE TROPICAL CYCLONES

2018

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Philippine Atmospheric, Geophysical and
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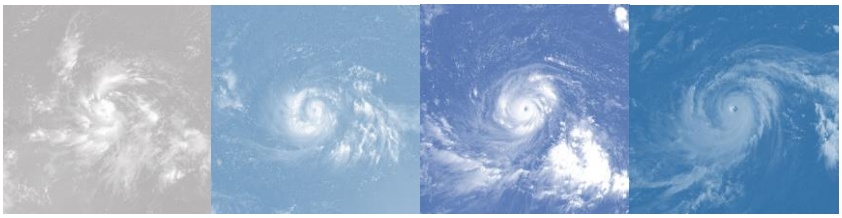


The **Annual Report on Philippine Tropical Cyclones** is an annual technical report published by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). This Report aims to provide a compendium of official information about the tropical cyclone (TC) season of interest, the TCs within the Philippine Area of Responsibility (PAR) for the season, and the warning services provided by the agency in relation to each TC event. As such, this iteration of the Annual Report serves as the official source of information for Philippine TCs during the 2018 season, unless a superseding reanalysis report is released by the agency.

The first issue of an annual report of this kind, entitled “Tropical Cyclones of 1948”, was published by the Climatological Division under the direction of Dr. Casimiro del Rosario, Director of the post-war Weather Bureau. After more than a decade of hiatus, the tropical cyclone meteorologists of the Weather Division resumed the printing of the annual tropical cyclone publication in March 2019 under the series “Annual Report on Philippine Tropical Cyclones”.

EXECUTIVE SUMMARY

A total of **21 tropical cyclones (TCs)** developed within or entered the Philippine Area of Responsibility (PAR) in 2018, all of which were subject to the analysis, forecast, and warning by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). This season had a near normal number of TC occurrences within the PAR and since 1981, the number of annual TC cases has been slightly decreasing. July and September were the most active months of the year, while no TC events were observed in April and May.

Most of the 2018 Philippine TCs developed from active low pressure areas (LPAs) outside the PAR region. Northwestward tracking TCs (both recurving and non-recurving) constitute roughly 48% of the TCs that entered the PAR, while around 38% followed a generally westward, non-recurving path. The TCs that entered that PAR had an average lifespan of 7 days and 10 hours while the average duration of these TCs inside the PAR was 3 days and 1/2 hour. In total, the Philippine TC season of 2018 lasted for 63 days and 9 hours. The season is also characterized by above normal number of TCs peaking at tropical storm (TS) and severe tropical storm (STS) categories within PAR and slightly below normal number of TCs reaching typhoon (TY) or super typhoon (STY) category. Best and warning track data since 1981 suggests that on average, the TCs entering the PAR were less intense and lower peak intensities were reached within the region.

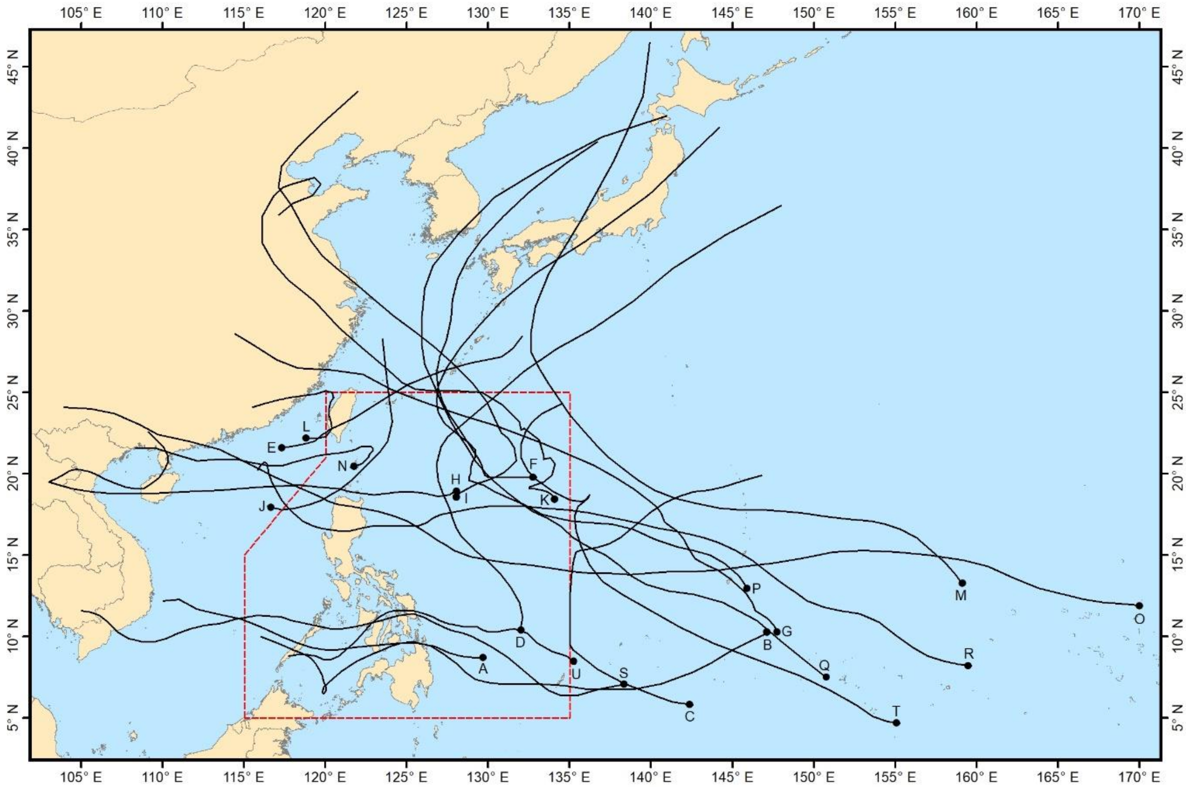
This season registered seven landfalling TCs, lower than 2017 and near the long-term average. Long term trend shows a slightly decreasing frequency of TCs crossing the Philippine archipelago since 1981. Landfalling TCs for this season had a generally westward heading and did not exhibit recurvature along its path. The centers of these TCs crossed the areas of Northern Luzon, Palawan, Visayas, and extreme northeastern Mindanao. Most of these were at tropical depression category at the time of initial landfall.

The total rainfall during TC days in the Philippines accounted for 30% to 60% of the total rainfall in 2018 for most areas of Luzon (especially its western section) and 10% to 40% for other areas of the country. The TC days during the Southwest Monsoon accounted for 30% to 60% of the 2018 rainfall for western Luzon and 10% to 30% for other areas. In comparison, the TC days during the Northeast Monsoon only accounted up to 20% of the total rainfall for the year.

PAGASA, through the Weather Division, issued 518 domestic and 248 international bulletins, warnings, and updates during the season to its end users, in addition to the provision of expert advice and briefings to public and private sector partners. A total of 9 TCs necessitated the raising of Tropical Cyclone Wind Signals in 74 provinces or localities of the country. TCWS No. 4 was the highest level of wind signal raised in 2018.

Despite disaster risk reduction and management activities, the TC events of 2018 directly and indirectly claimed the lives of 298 individuals. Furthermore, a total of 274 injured and 33 missing persons were reported. Aggregate cost of damage across the country amounted to Php 48.679 billion which was higher than the 2017 figures. This makes 2018 the second deadliest and second costliest (both after 2014) post-Yolanda TC season in the country. Damage to agriculture (e.g., crops, livestock) constituted more than two-thirds of the total reported cost.

The publication of the 2018 Annual Report on Philippine Tropical Cyclones was pushed to June 2020 due to the 2019-2020 pandemic of the Coronavirus Disease 2019 (COVID-19) in the Philippines.



PHILIPPINE ATMOSPHERIC GEOPHYSICAL AND ASTRONOMICAL SERVICES ADMINISTRATION (PAGASA)
2018 PHILIPPINE TROPICAL CYCLONE BEST TRACK

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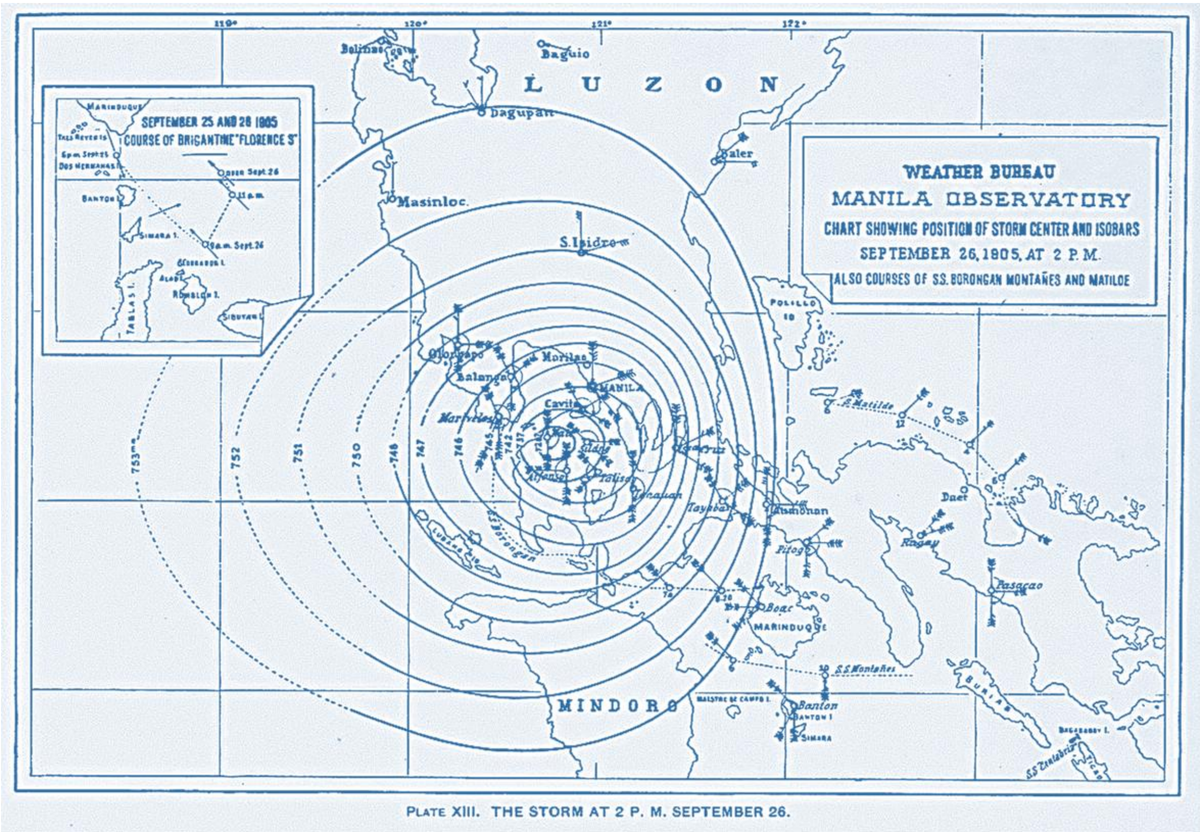
HISTORY OF TROPICAL CYCLONE SERVICES IN THE PHILIPPINE ISLANDS



Plots of surface and ship observation over Central and Southern Luzon at 06 on 26 September 1905 and isobaric analysis showing a tropical cyclone with center over Cavite. Photo courtesy of the Manila Observatory Archives

History of Tropical Cyclone Services in the Philippine Islands

Inception of Typhoon Observation and Warning (1865-1920s)

With entries from Montalvan (2013) and Manila Observatory (2014, 2015)

Although the current national meteorological and hydrological service of the Philippines, the PAGASA, was only instituted on 8 December 1972, the provision of meteorological service in the Philippines, including the issuance of typhoon warnings, dates back to the 19th century with the *Observatorio del Ateneo Municipal* (Observatory of Ateneo Municipal) – a Jesuit institution established in 1865. The Observatory was founded following an article published by Fr. Jaime Nonell describing the observations of a typhoon in September 1865 by Fr. Francisco Colina. Despite initial hesitations to continue systemic observations due to primitive equipment, the Jesuits proceeded to establish the Observatory after being promised of a Secchi universal meteorograph from the Holy See. This meteorograph arrived in the Observatory in 1869, which at that time, was one of three in existence in the world.

Based on the understanding about tropical cyclones (TCs) in other ocean basins (i.e. hurricanes in the Atlantic and cyclones in the Indian Ocean) at that time, Fr. Federico Faura, the founding director of the Observatory, hypothesized that the typhoons in the Far East come from the Pacific and were not essentially dissimilar from other TCs as far as their nature and precursory phenomena were concerned because the popular myth at that time was that typhoons in the Far East come from the mountains. His hypothesis was put into test when barometric readings fell and changes in wind direction were observed on 7 July 1879. From this observation, Fr. Faura announced that a typhoon has passed over Northern Luzon which was later confirmed. This was the first TC warning issued in the Philippines.

Following this feat, in November of the same year, the Observatory announced that a typhoon will be crossing Manila which was the first TC forecast in the country. Although the lack of telegraph communications prevented the information from being disseminated outside Manila (resulting in casualties and damages in these areas), the early warning helped mariners to secure their vessels ahead of the typhoon as well as prevented further sea travel in the Manila area.

In 1884, King Alfonso XII promulgated of a royal decree instituting a *Servicio Meteorológico* (Meteorological Service) under the direction of the Observatory as the official state organ for the observation and prediction of weather. The Observatory, now called the *Observatorio Meteorológico de Manila* (Meteorological Observatory of Manila), made further strides in improving TC forecasting and warning in the Far East. In 1886, a typhoon barometer was developed by Fr. Faura for use by mariners in the Philippine seas and the South China Sea. In 1897, Fr. José Maria Algué, the successor of Faura as director of the Observatory, invented the barocyclonometer. This improvement of Faura's aneroid barometer allowed the prediction of TCs throughout the entire Far East. The Algue barocyclonometer technology was so advanced that in 1911, the instrument was applied to the Atlantic basin and adopted for use in all Atlantic naval stations of the United States Navy. Lastly, Fr. Algué was also credited for publishing the *Baguios ó ciclones Filipinos: Estudio teórico-practico* (Typhoons or Filipino cyclones: A study in theory and practice) in 1894 which served as an important guide for mariners in understanding and dealing with TCs in the Far East.

During the period of provisional military authority by the Americans, the Philippine Commission promulgated Act No. 131 in 1901 which reorganized the Observatory as the *Oficina Meteorológico* (Weather Bureau). Now under a civilian government, the Weather Bureau was placed under the Department of Interior with Fr. Algué as its first director. In the same year, 72 meteorological stations were established by the Bureau, allowing the systematic observation of rainfall and temperature across the country. In the following years, aside from the production of weather maps from electronically transmitted data (Fig 1.1), the mystification of Far East TCs was finally ended when Fr. Algué finally categorized TCs from the Pacific Ocean into 11 types. By the end of 1923, a total of 159 stations comprised the Bureau's observation network with 90 additional stations established by local volunteers the year after. By 1926, the Bureau was regularly exchanging TC warnings with other observatories in the Far East.

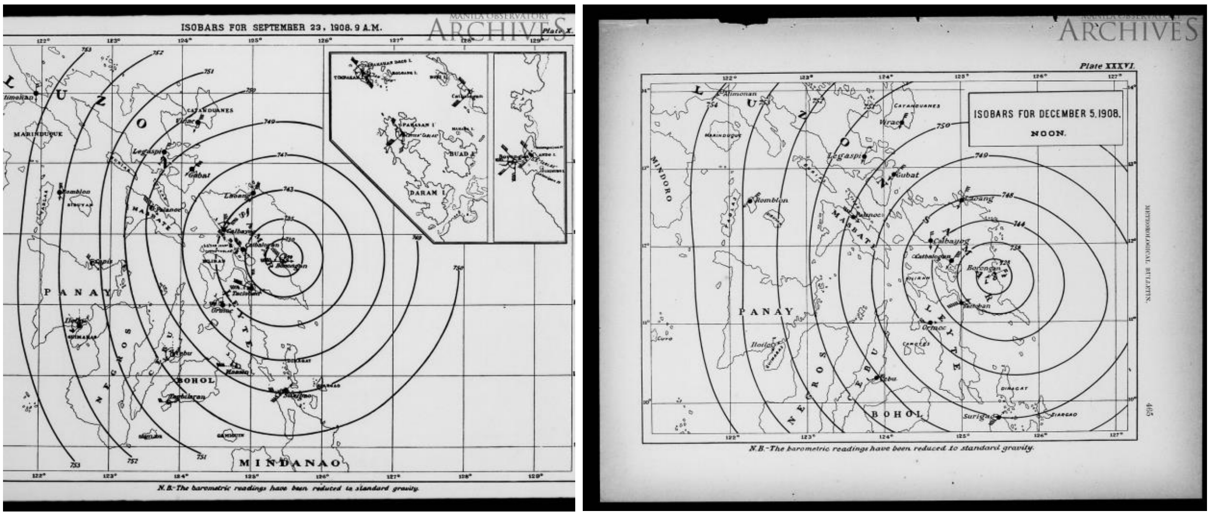


Fig. 1.1. Surface weather charts at (a) 9:00 AM on 23 September 1908 and (b) 12:00 PM on 5 December 1908 showing the isobar analysis of a TC making landfall in Eastern Samar. Images obtained from the website of the Manila Observatory Archives (http://archives.observatory.ph).

Origin of Tropical Cyclone Wind Signals

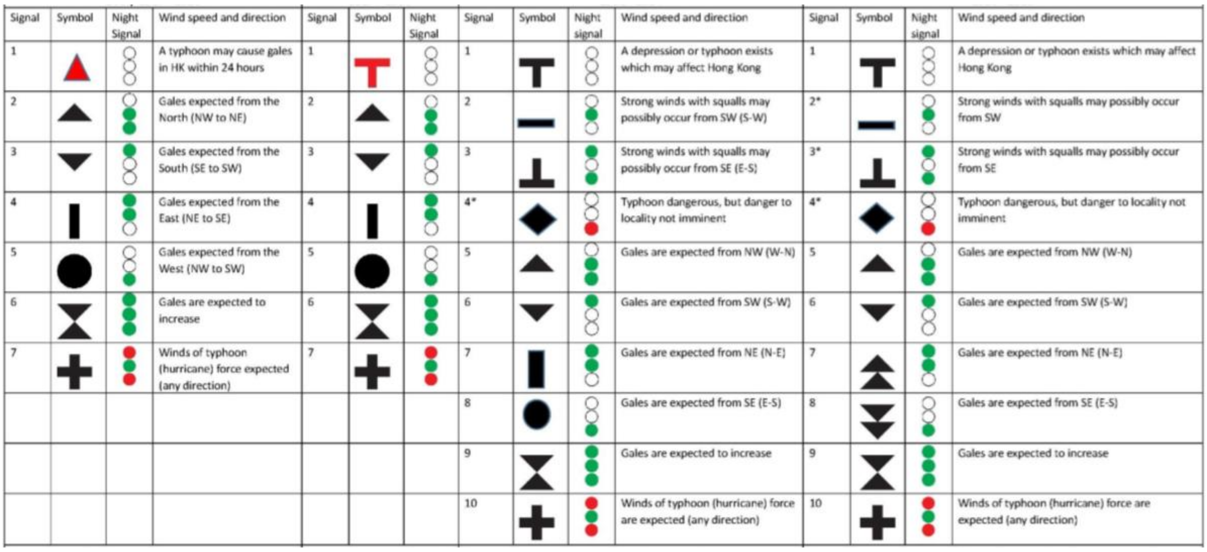
With entries from Lui et al. (2018)

The origin of the Tropical Cyclone Wind Signal (TCWS) system of the Philippines can be traced back to the 1917 system of numbered storm signal codes developed by the Royal Observatory Hong Kong (now Hong Kong Observatory or HKO). This system provided a standby signal, gale signals in four directions (N, S, E, W), an increasing gale signal, and a hurricane signal and was designed to warn the public of the impending threat of winds associated with an approaching TC in Hong Kong. Fig. 1.2 presents the evolution of the numbered storm signal system and the symbols associated with each signal that were hoisted in signal station masts.

Following a minor revision in 1927, the system was modified in 1930 based on the recommendations made during the Conference of Directors of Far Eastern Weather Services. The conference which was attended by Fr. Miguel P. Selga on behalf of the Weather Bureau aimed to introduce uniformity in local and non-local TC signals used by meteorological services in the Far East. Based on the recommendations, the seven-tier system was extended to 10 by introducing two signals for strong winds with squalls and a signal indicating the “presence of a dangerous typhoon, but danger to locality was not imminent”. The new system was adopted by the Bureau in 1931.

Amendments to the 1930 numbered storm signal system were made in 1935 following an agreement between the Bureau and the HKO. In the new system, Signals 2 to 4 were not used in Hong Kong, while Signal 9 was not implemented by the Bureau in the country. This is addition to changes in the symbols used for Signal Nos. 7 and 8. The 1935 version of the 10-tier system remained in effect until the demise of the pre-war Weather Bureau following its destruction during the Battle of Manila in February 1945.

The current design of the TCWS system originated from the public storm warning signal (PSWS) system used by the post-war Weather Bureau, now a purely civilian agency of the government. Much simpler than the pre-war 10-tier numbered signal system where it was loosely based, the PSWS system consists of three storm signal levels wherein a higher signal number indicates stronger winds expected over a locality where it is raised. Unlike the current warning signal system, the original PSWS had a fixed lead time of 18 hours.



(a) (b) (c) (d)

Fig. 1.2. Evolution of the numbered storm signal system in the Far East: (a) 1917 HKO, (b) 1927 HKO, (c) 1931 Far East, and (d) 1935 Far East.

The post-war PSWS remained in use by the Bureau and its successor agency, PAGASA, until 1990, when it was deemed that the existing system failed to emphasize the threat posed by winds in excess of 185 km/h. In response, the PSWS was modified in 1991 to increase the lead time of lower storm signal levels to at most 36 hours and to include a Signal No. 4 to be raised in areas where TC winds of more than 185 km/h are expected. The new system, called the modified PSWS, was first tested when the first Signal No. 4 was raised during the passage of Typhoon TRINING in Luzon on 27 October 1991 and remained in use by PAGASA until 2015, when the system was amended in response to the public clamor for changes in the modified PSWS following the disaster of Super Typhoon YOLANDA in November 2013. In order to address these demands, PAGASA introduced the TCWS in May 2015 to supersede the modified PSWS system. Aside from revising the range of wind speeds in Signal Nos. 2 to 4, the new TCWS introduced a Signal No. 5 in order to emphasize the threat posed by typhoon winds in excess of 220 km/h. Table 1.1 summarizes the changes from the original PSWS to the current TCWS.

Table 1.1. Evolution of post-war warning/wind signals from the PSWS system to the TCWS system.

Signal No.	Expected or prevailing wind speeds and longest available lead time from first issuance		
	PSWS (until 1990)	Modified PSWS (1991-2014)	TCWS (2015-Present)
1	30 to 60 km/h 18 hours	30 to 60 km/h 36 hours	30 to 60 km/h 36 hours
2	61 to 100 km/h 18 hours	61 to 100 km/h 24 hours	61 to 120 km/h 24 hours
3	In excess of 100 km/h 18 hours	101 to 185 km/h 18 hours	121 to 170 km/h 18 hours
4	-	In excess of 185 km/h 12 hours	171 to 220 km/h 12 hours
5	-	-	In excess of 220 km/h 12 hours

History of Tropical Cyclone Naming in the Western North Pacific

Systematic naming of TCs within the Western North Pacific (WNP)[1] basin including the Philippine region began when in 1945, the United States Fleet Weather Central/Typhoon Tracking Center in Guam, now called the Joint Typhoon Warning Center (JTWC) started assigning female English names to TCs of at least tropical depression category in alphabetical order. This naming practice was updated in 1979

[1] Unless explicitly identified, the Western North Pacific basin described in this report includes the West Philippine Sea / South China Sea region.

when JTWC introduced male names to be used alternately with female names. However, in 1963, the post-war Weather Bureau started naming TCs entering or developing within the Philippine Area of Responsibility (PAR) using female Filipino names ending in *-ng* in native alphabetical order, resulting in Western North Pacific TCs having two names when the system occurs within the PAR. In the Philippines, the names assigned by the JTWC (and later on, JMA) are referred to as *international names*, while the names assigned by the Bureau (and later on, PAGASA) are called *domestic names*.

Beginning in 2000, the World Meteorological Organization (WMO) transferred the TC monitoring duties in the WNP, including the assignment of international names, from the JTWC to the Japan Meteorological Agency after the latter's Tokyo Typhoon Center's assignment as the Regional Specialized Meteorological Center. In addition, a new scheme of international names was adopted to replace the alphabetical naming scheme used by the JTWC since 1945. In the new system, the 14 member-countries of the Typhoon Committee under the WMO and United Nations Economic and Social Commission for Asia and the Pacific contributed a set of 10 names using their respective languages. Unlike the JTWC system, the rotation of names under the new scheme is based on the alphabetical order of the contributing nations.

Meanwhile, changes in the domestic naming scheme were also introduced by PAGASA (which assumed tropical cyclone services from the Bureau in 1972) in 2001 when the agency began using new sequential sets of TC names based on the English alphabet that do not just end in *-ing* and departed from the old practice of using only feminine names. The new PAGASA naming scheme remains in use today and is further discussed alongside the current scheme of international names in the subsequent sections of this report.

Evolution of Post-War Tropical Cyclone Annual Publication

The first issue of an annual report from the post-war Weather Bureau that provides individual accounts of TCs in the WNP that develops within or enters the PAR was published in 1950 by the Climatological Division as the "Tropical Cyclones of YYYY" (with YYYY being the year being discussed in the report) with "Tropical Cyclones of 1948" as the first issue of the series. The report provides a narrative account of each TC that occurred within the PAR and includes its best track positions and intensities (from incipience to its dissipation and/or exit from the PAR), peak 24-hour rainfall attributed to each TC as recorded by field stations, maximum sustained winds over land as reported by field stations and over water based on aircraft reconnaissance or ship observations, casualties and cost of damage to agriculture and infrastructure, and tally of TC bulletins issued by PAGASA during the passage of TCs within the PAR.

In December 1981, the Tropical Cyclone Division of the PAGASA National Weather Office took over the responsibility of publishing the annual report under a new series, the "Annual Tropical Cyclone Report" (ATCR), the first issue of which was entitled "1977 Annual Tropical Cyclone Report". A new format was introduced in this series with the intention of addressing the growing need for additional TC-related data in readily usable forms. Aside from the individual narratives or reports of the TC events for the year, the new series also included the statistical analysis of the entire TC season, rainfall data of all PAGASA weather stations throughout the duration of the TC within the PAR, rainfall pattern charts, and TC forecast verification data. Following the re-organization of PAGASA, the newly-formed Weather Branch took over the responsibility of printing the ATCR. However, the re-organization and rationalization program implemented during the mid-1990s made it hard for the Weather Branch to fully commit to the annual publication of the report. The last regular issue under this series was published in 1995.

In 2019, the Weather Division through the Tropical Cyclone Group resumed the regular publication of PAGASA's TC annual report under "Annual Report on Philippine Tropical Cyclones" (ARTC) series with its first issue covering the 2017 TC season. The re-introduction of the annual TC publication addresses the ever-growing demand for official post-analyzed accounts and the surge of information and disinformation from unverified sources (usually weather enthusiasts and meteorologists acting on their personal capacity). The 2020 iteration of the ARTC (covering the 2018 season) marks the resumption in the provision of TC best track information by PAGASA since it was suspended in 1995.

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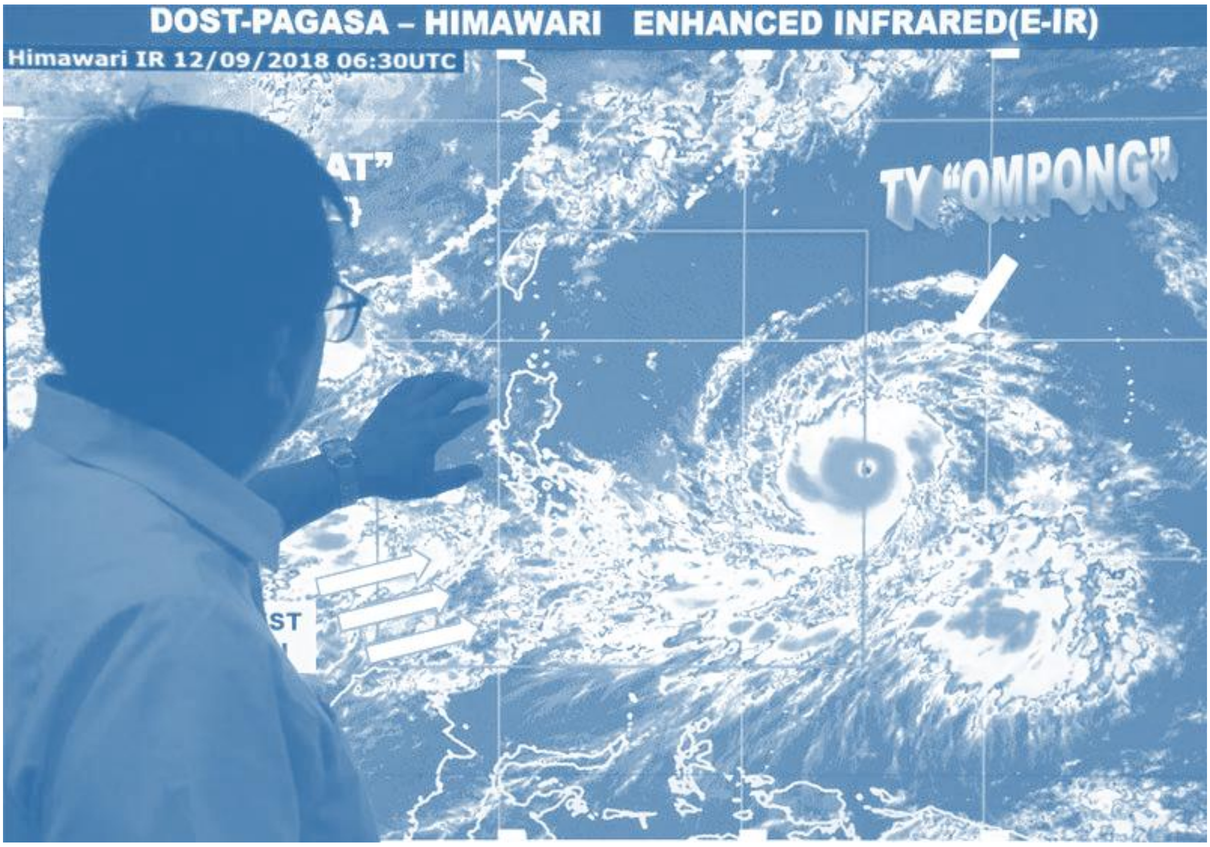
DOST-PAGASA TROPICAL CYCLONE SERVICES



PAGASA meteorologist Marino Mendoza presenting to the media he satellite animation of Tropical Cyclone Ompong (Mangkhut) when it entered the Philippine Area of Responsibility

DOST-PAGASA Tropical Cyclone Services

Created by law[2] in 8 December 1972 as the successor to the post-war Philippine Weather Bureau, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) is the **only mandated[3]** national government agency tasked with the provision of adequate, up-to-date, and timely information on atmospheric phenomena (i.e. provision of meteorological service) especially during high impact weather events to ensure the safety, well-being, and economic security of the people, safeguard the environment, and promote national progress and sustainable development. PAGASA has been a scientific and technological services institute of the Department of Science and Technology (DOST) since 1984 and represents the Philippines in the World Meteorological Organization (WMO), an intergovernmental organization of the United Nations.

Forecast Areas

Following its mandate of affording greater protection to the people through the provision of meteorological service, the Weather Division of PAGASA provides analysis, forecast and warning services to various end users when tropical cyclones (TCs) develop or enter within any of the three operational TC forecast areas of the agency as presented in Fig. 2.1.

Philippine Area of Responsibility

The Philippine Area of Responsibility (PAR) is the official forecast and warning area of responsibility of PAGASA as designated by the World Meteorological Organization (WMO)[4]. As such, the PAR serves as the domain in which PAGASA has the responsibility for issuing domestic tropical cyclone warnings as well as warnings for exchange with other meteorological centers in the region. In addition, the domain also serves as the limit of high seas forecast areas of the agency. The PAR is the region in the Western North Pacific (WNP) basin bounded by rhumb lines connecting the coordinates 5°N 115°E, 15°N 115°E, 21°N 120°E, 25°N 120°E, 25°N 135°E, and 5°N 135°E and encompasses nearly all of the land territory of the Philippines except for the southernmost portions of Tawi-Tawi and some of the country's claims in the Kalayaan Group of Islands. The area also includes the entire Palau archipelago, nearly all of Taiwan, as well as portions of the Malaysian state of Sabah and the Japanese prefecture of Okinawa. The bodies of water within the PAR include all archipelagic seas of the Philippines[5], West Philippine Sea[6], Luzon Strait, Mindanao Sea[7], Sulu Sea, and most of the Philippine Sea.

All WNP TCs entering the PAR are assigned a domestic name, whether or not they possess an international name from the RSMC-Tokyo. During TC occurrences within the PAR, PAGASA routinely analyzes the center position, intensity, wind field, and motion of all TCs every 3 hours and issues Severe Weather Bulletins between twice and eight times daily and Tropical Cyclone Warnings for Shipping four times daily.

Tropical Cyclone Advisory Domain

The region in the WNP basin bounded by rhumb lines connecting the coordinates 4°N 114°E, 28°N 114°E, 28°N 145°E, and 4°N 145°E except the region within the PAR, is referred as the Tropical Cyclone Advisory Domain (TCAD). PAGASA routinely analyzes the center position, intensity, and motion of all TCs within the TCAD every 6 hours and issues Tropical Cyclone Advisories once daily for TCs that are forecast to enter the PAR within 5 days.

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[2] By virtue of Presidential Decree No. 78 s. 1972 as amended.
[3] The current mandate of PAGASA is stipulated under Republic Act No. 10692.
[4] The extent of the PAR is based on the agreement between the WMO Regional Associations II and V (Res. 17 (IV-RA II; WMO-181, 1966) and Res.10 (IV-RA V; WMO-187, 1966)).
[5] These archipelagic seas are the Sibuyan Sea, Visayan Sea, Camotes Sea, Samar Sea, and Bohol Sea.
[6] By virtue of Administrative Order No. 29 s. 2012, the portion of the South China Sea within the exclusive economic zone (EEZ) of the Philippines is referred to as the West Philippine Sea.
[7] The portion of the Celebes Sea that lies north of the boundary line delimiting the overlapping EEZs of the Philippines and Indonesia is referred to as the Mindanao Sea. This boundary line was agreed upon by both countries in 2014 was ratified by the Philippine Senate under Senate Resolution No. 1048 in 2019.

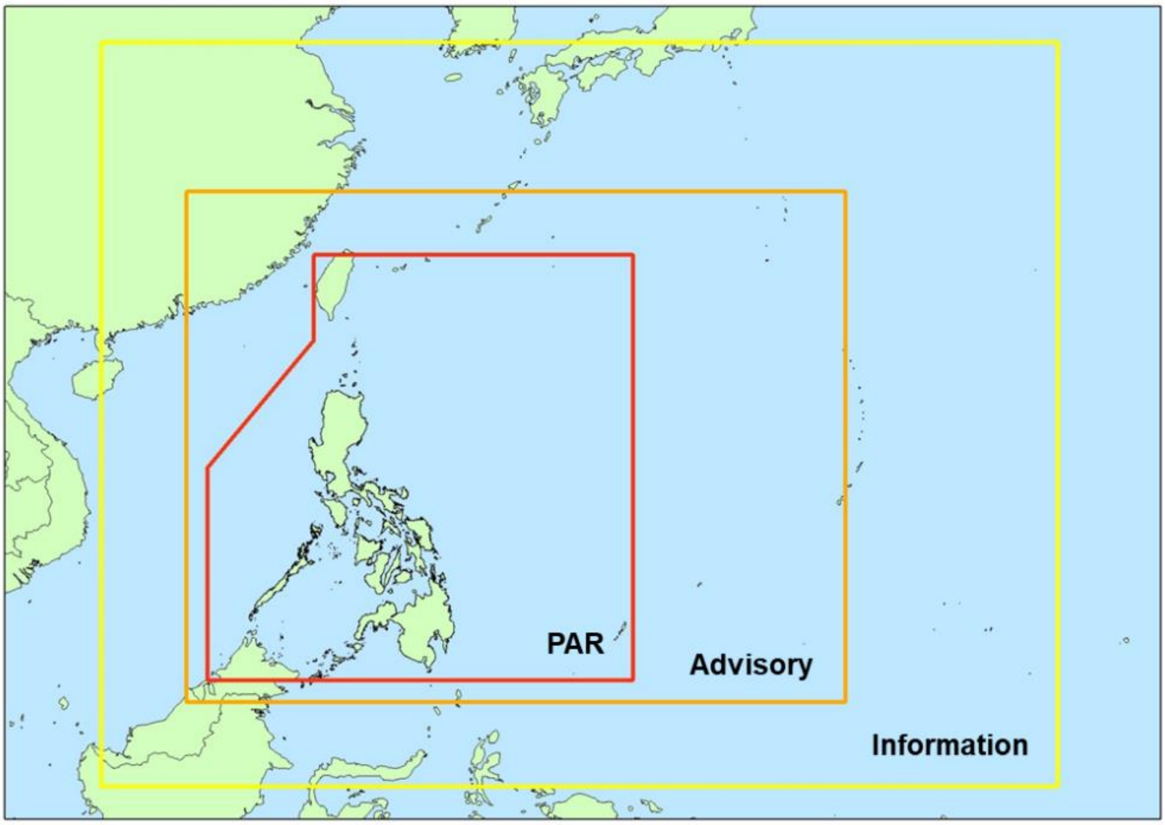


Fig. 2.1. PAGASA forecast areas for TC analysis, forecast, and warning responsibilities.

Tropical Cyclone Information Domain

The region in the WNP basin bounded by rhumb lines connecting the coordinates 0° 110°E, 35°N 110°E, 35°N 155°E, and 0° 155°E except the region within the PAR and the TCAD is referred as the Tropical Cyclone Information Domain (TCID). Routine analysis of center position, intensity, and motion is undertaken every 6 hours for all TCs within the TCID.

Tropical Cyclone Classification

WNP TCs are classified by PAGASA according to their maximum sustained winds near their centers using a 10-minute averaging period. The current scheme, in place since 2015, is a 5-tier scale with Tropical Depression as the weakest of the categories and Super Typhoon as the strongest. Table 2.1 presents the classification of TCs under the current scheme and their corresponding maximum sustained winds near the center in kilometers per hour, meters per second, and nautical miles per hour or knots. The difference between the pre-2015 categories and the current scheme is the adoption of Severe Tropical Storm and Super Typhoon, thereby increasing the number of TC categories from three to five. The change was part of operational improvements made by PAGASA following the disaster of Super Typhoon Yolanda (Haiyan) in 2013.

Table 2.1 Classification of TCs used by PAGASA since May 2015

Category of TC	Maximum sustained winds near the center		
	kt	km/h	m/s
Tropical Depression (TD)	< 34	< 62	< 17.2
Tropical Storm (TS)	34 to 47	62 to 88	17.2 to 24.4
Severe Tropical Storm (STS)	48 to 63	89 to 117	24.5 to 32.6
Typhoon (TY)	64 to 120	118 to 222	32.7 to 61.7
Super Typhoon (STY)	> 120	> 222	> 61.7

Domestic Tropical Cyclone Names

PAGASA assigns a domestic name to a TC that enters or develops within the PAR, whether or not an international name from has been assigned to the TC by the RSMC Tokyo. Four sets of regular names from A to Z of the English alphabet, excluding X, are being rotated every year. The first TC of the year that enters of develops within the PAR will be given the name beginning with letter A, the second B, the third C, and so on until the 25th name is assigned. If the list is not exhausted within the year, the first TC of the succeeding year will be given the name from the set assigned for the succeeding year beginning with the letter A. Table 2.2 lists down the four regular sets of domestic names as of 2018.

Four sets of auxiliary names from A to J of the English alphabet are also rotated every year in the same manner as the regular names. In case the total number of TCs for the year exceeds 25, the 26th TC will be given the name from the auxiliary set beginning with letter A, the 27th B, the 28th C, and so until auxiliary set is exhausted by the 35th TC of the year. Table 2.3 lists down the four auxiliary sets of domestic names as of 2018.

The names in regular set I were used for the 2018 season with Gardo, Josie, Maymay, Rosita, Samuel and Usman being used for the first time. The first TC was given the name Agaton, the second Basyang, the third Caloy, and so on until the 21st and last TC of the year Usman. The names in auxiliary set I was not used in 2018 because the number of TCs did not exceed 25. However, if the number of TCs did exceed 25, the 26th TC would have been named Agila.

Under the new guidelines which has been in effect since 2001, all domestic names should not exceed nine letters and three syllables and not bear any negative or offensive meanings. The names must be that of Filipino persons (male or female), places, animals, flowers, plants/trees, or traits reflecting Filipino culture or tradition and can come from any language or dialects in the Philippines.

The domestic name of a TC is decommissioned if the TC directly caused either the deaths of at least 300 individuals or damage to infrastructure and agriculture amounting to at least PHP 1,000,000,000.00 based on the final report of the National Disaster Risk Reduction and Management Council (NDRRMC). A decommissioned name is removed from the rotating list and is replaced by PAGASA with a new name having the same first letter from a pre-determined reserved set of names. The list of decommissioned names is released by the Agency within a month after the end of the TC season.

International Tropical Cyclone Names

The Regional Specialized Meteorological Center – Tokyo Typhoon Center (RSMC Tokyo) is responsible for assigning international names to any TC with maximum sustained winds of at least 34 kt (i.e., at least TS category) within its area of responsibility (region in the WNP basin bounded by rhumb lines connecting the coordinates 0° 100°E, 60°N 100°E, 60°N 180°E and 0° 180°E). Table 2.4 presents the list of international names for use during the 2018 season as contributed by member countries and territories of the Typhoon Committee.

The names are used sequentially and all names in a column must be exhausted first before the names of the next column is used. Because Tembin was the last TC of at least TS category for the 2017, the first TC to reach TS category in 2018 was named Bolaven, followed by Sanba, Jelawat, Ewiniar, and so on with Usagi being the last for the year. A four-digit identification number is usually appended to the international name with the first two digits indicating the last two digits of the year and the last two digits representing the sequence number of the TC based on the order of conferment of international name. For instance, 1804 represents the fourth TC during the 2018 season that was given an international name.

Similar to the domestic naming scheme, the international names used by the RSMC Tokyo can be requested for decommissioning by the member countries and territories of the Typhoon Committee especially if the TC resulted in significant number of casualties or damage to properties (although decommissioning may be requested for other reasons). The decommissioning of names for a particular year is decided upon by the Typhoon Committee during its Annual Session scheduled in the immediately succeeding year. Once the decommissioning is approved, the country that contributed the name will submit a set of 3 potential replacement names. The final replacement name will be decided during the session of the Integrated Workshop of the same year.

Table 2.2. Regular domestic names by the start of the 2018 season

I (2021, 2025, 2029, 2033)	**II** (2018, 2022, 2026, 2030)	**III** (2019, 2023, 2027, 2031)	**IV** (2020, 2024, 2028, 2032)
Auring	Agaton	Amang	Ambo
Bising	Basyang	Betty	Butchoy
Crising	Caloy	Chedeng	Carina
Dante	Domeng	Dodong	Dindo
Emong	Ester	Egay	Enteng
Fabian	Florita	Falcon	Ferdie
Gorio	Gardo	Goring	Gener
Huaning	Henry	Hanna	Helen
Isang	Inday	Ineng	Igme
Jolina	Josie	Jenny	Julian
Kiko	Karding	Kabayan	Kristine
Lannie	Luis	Liwayway	Leon
Maring	Maymay	Marilyn	Marce
Nando	Neneng	Nimfa	Nika
Odette	Ompong	Onyok	Ofel
Paolo	Paeng	Perla	Pepito
Quedan	Queenie	Quiel	Quinta
Ramil	Rosita	Ramon	Rolly
Salome	Samuel	Sarah	Siony
Tino	Tomas	Tisoy	Tonyo
Uwan*	Usman	Ursula	Ulysses
Verbena*	Venus	Viring	Vicky
Wilma	Waldo	Weng	Warren
Yasmin	Yayang	Yoyoy	Yoyong
Zoraida	Zeny	Zigzag	Zosimo

* New names following the decommissioning of Urduja (for Uwan) and Vinta (for Verbena).

Table 2.3. Auxiliary domestic names by the start of the 2018 season

I (2021, 2025, 2029, 2033)	**II** (2018, 2022, 2026, 2030)	**III** (2019, 2023, 2027, 2031)	**IV** (2020, 2024, 2028, 2032)
Alamid	Agila	Abe	Alakdan
Bruno	Bagwis	Berto	Baldo
Conching	Chito	Charo	Clara
Dolor	Diego	Dado	Dencio
Ernie	Elena	Estoy	Estong
Florante	Felino	Felion	Felipe
Gerardo	Gunding	Gening	Gomer
Hernan	Harriet	Herman	Heling
Isko	Indang	Irma	Ismael
Jerome	Jessa	Jaime	Julio

Table 2.4 International names of TCs from RSMC Tokyo (http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/tyname.html).

Contributed by	I	II	III	IV	V
Cambodia	Damrey	Kong-rey	Nakri	Krovanh	Trases
China	Haikui	Yutu	Fengshen	Dujuan	Mulan
DPR Korea	Kirogi	Toraji	Kalmaegi	Surigae	Meari
Hong Kong, China	Yun-yeung*	Man-yi	Fung-wong	Choi-wan	Ma-on
Japan	Koinu*	Usagi	Kammuri	Koguma	Tokage
Lao PDR	Bolaven	Pabuk	Phanfone	Champi	Hinnamnor
Macao, China	Sanba	Wutip	Vongfong	In-fa	Muifa
Malaysia	Jelawat	Sepat	Nuri	Cempaka	Merbok
Micronesia	Ewiniar	Mun	Sinlaku	Nepartak	Nanmadol
Philippines	Maliksi	Danas	Hagupit	Lupit	Talas
RO Korea	Gaemi	Nari	Jangmi	Mirinae	Noru
Thailand	Prapiroon	Wipha	Mekkhala	Nida	Kulap
U.S.A.	Maria	Francisco	Higos	Omais	Roke
Vietnam	Son-Tinh	Lekima	Bavi	Conson	Sonca
Cambodia	Ampil	Krosa	Maysak	Chanthu	Nesat
China	Wukong	Bailu	Haishen	Dianmu	Haitang
DPR Korea	Jongdari	Podul	Noul	Mindulle	Nalgae
Hong Kong, China	Shanshan	Lingling	Dolphin	Lionrock	Banyan
Japan	Yagi	Kajiki	Kujira	Kompasu	Yamaneko*
Lao PDR	Leepi	Faxai	Chan-hom	Namtheun	Pakhar
Macao, China	Bebinca	Peipah	Linfa	Malou	Sanvu
Malaysia	Rumbia	Tapah	Nangka	Nyatoh	Mawar
Micronesia	Soulik	Mitag	Saudel	Rai	Guchol
Philippines	Cimaron	Hagibis	Molave	Malakas	Talim
RO Korea	Jebi	Neoguri	Goni	Megi	Doksuri
Thailand	Mangkhut	Bualoi	Atsani	Chaba	Khanun
U.S.A.	Barijat	Matmo	Etau	Aere	Lan
Vietnam	Trami	Halong	Vamco	Songda	Saola

* Replacement names for Hato (now Yamaneko), Kai-tak (now Yun-yeung), and Tembin (now Koinu). These names were decommissioned following the end of the 2017 Pacific typhoon season.

Tropical Cyclone Product Description

Depending on the location of the TC within the monitoring domains, PAGASA issues different forecast and warning products to the public, disaster managers, national and local government institutions end other end users. This subsection discusses each warning product issued by the agency during tropical cyclone events.

Tropical Cyclone Update

The Tropical Cyclone Update (TCU) is a brief entry in the Public Weather Forecast containing the current latitude and longitude coordinates and its corresponding distance from a reference PAGASA weather station, maximum sustained winds in kilometers per hour, and the current motion of all tropical cyclones being monitored in all TC forecast areas.

TCUs are normally[8] issued every 12 hours at 4:00 AM PHT and 4:00 PM PHT.

Tropical Cyclone Advisory

The Tropical Cyclone Advisory (TCA) is a domestic product that provides the current latitude and longitude coordinates and its corresponding distance from a reference PAGASA weather station, maximum sustained winds and maximum gust in kilometers per hours, and the current motion for a TC

[8] Initial and final issuance are done 3 hours after synoptic time (defined as 00, 03, 06, 09, 12, 15, 18, and 21 UTC). Note that the Philippine Standard Time or PHT is eight hours ahead of Coordinated Universal Time or UTC.

within the TCAD that is forecast to enter the PAR within 5 days. The TCA also contains forecasts of the TC positions and intensities out to 5 days at 24-hour intervals.

TCAs may include additional warning information such as potential high impact weather and list of areas where wind warnings may be first raised, as well as non-warning information relevant to the TC such as expected date and time the TC will enter the PAR.

TCAs are normally[9] issued once daily at 11:00 AM PHT.

Severe Weather Bulletins

Severe Weather Bulletin (SWB) is a domestic product that contains the current latitude and longitude coordinates and its corresponding distance from a reference PAGASA weather station, maximum sustained winds and maximum gust in kilometers per hours, and the current motion for a TC that is either within the PAR or outside the PAR but the wind field of at least near-gale force is predicted to reach the coastal or inland areas of the country within 36 hours. The SWB also include forecasts of the TC positions and intensities out to 5 days at 24-hour intervals.

SWBs may include warning information such as the list of areas where wind or storm surge warnings are or will be in effect, forecast high impact weather, and landfall information, as well as non-warning information relevant to the TC such as expected date and time the TC will exit the PAR.

If no wind warnings are in effect, SWBs are normally[10] every 12 hours at 11:00 AM PHT and 11:00 PM PHT. If wind warnings are in effect, SWBs are also issued at 5:00 AM PHT and 5:00 PM. If wind warnings are in effect and the TC is forecast to make landfall or pass within 100 km of the Philippine coastline, SWBs are also issued at 2:00 AM PHT, 8:00 AM PHT, 2:00 PM PHT, and 8:00 PM PHT. These additional issuances remain in place until the center of the TC leaves the aforementioned 100-km buffer region.

Tropical Cyclone Warning for Shipping

The Tropical Cyclone Warning for Shipping, also known as International Warning for Shipping (IWS) contains information on the current latitude and longitude coordinates, maximum sustained winds in knots, estimated or measured minimum central pressure in hectopascal, current motion, and maximum extent of wind areas of at least near gale-force, storm-force, and typhoon-force for a TC that is the subject of domestic issuance of SWBs. The IWS also includes forecasts of the TC positions and intensities out to 5 days at 24-hour intervals, as well as a request for three-hourly meteorological data from marine vessels within the wind area of the TC.

IWSs are issued every 6 hours at 5:00 AM PHT, 11:00 AM PHT, 5:00 PM PHT, and 11:00 PM PHT.

The IWS is the only tropical cyclone product of PAGASA that is broadcasted to other meteorological centers using the WMO Global Telecommunications System (GTS). This product uses the header WTPH20 RPMM.

Tropical Cyclone Wind Signal System

The Tropical Cyclone Wind Signal (TCWS) System is a 5-tier wind warning scheme being used by PAGASA to warn the localities at most 36 hours ahead of potential damaging, destructive or devastating winds associated with an approaching TC. The wind signals raised over the localities are primarily dependent on the maximum sustained winds, wind field, and forecast track of the TC. Table 2.5 presents the wind signals of the TCWS system, corresponding range of wind speeds, and the lead time before the onset of such winds.

[9] Initial and final issuance are done 3 hours after synoptic time (defined as 00, 03, 06, 09, 12, 15, 18, and 21 UTC). Note that the Philippine Standard Time or PHT is eight hours ahead of Coordinated Universal Time or UTC.
[10] Initial and final issuance are done 3 hours after synoptic time (defined as 00, 03, 06, 09, 12, 15, 18, and 21 UTC). Note that the Philippine Standard Time or PHT is eight hours ahead of Coordinated Universal Time or UTC.

Table 2.5. Tropical Cyclone Wind Signal System

TCWS	Surface Wind Condition
Signal No. 1	Winds of 30 to 60 km/h is prevailing or is expected to prevail within the next 36 hours from the time the signal was raised.
Signal No. 2	Winds of 61 to 120 km/h is prevailing or is expected to prevail within the next 24 hours from the time the signal was raised.
Signal No. 3	Winds of 121 to 170 km/h is prevailing or is expected to prevail within the next 18 hours from the time the signal was raised.
Signal No. 4	Winds of 171 to 220 km/h is prevailing or is expected to prevail within the next 12 hours from the time the signal was raised.
Signal No. 5	Winds in excess of 220 km/h is prevailing or is expected to prevail within the next 12 hours from the time the signal was raised.

In plain language entries in PAGASA TC products, winds associated with TCWS #1 are also referred to as “strong winds”, TCWS #2 as “damaging winds”, TCWS #3 as “destructive winds”, and TCWS #4 and #5 as “violent or catastrophic winds”. The damage to infrastructure and agriculture associated with each of the TCWS are presented in Table 2.6.

Owing to the presence of natural and artificial obstructions such as local topography or nearby buildings, winds in a particular area (i.e., local winds) may be substantially stronger from the general wind strength (i.e., regional winds) over the provincial or sub-provincial locality implied by the wind signal. Compared to the prevailing regional winds, the local winds are generally stronger over offshore water, on high ground (i.e., on mountainous areas), and in areas where channeling effect between obstructions occur. On the other hand, local winds are weaker in areas that are sheltered from the prevailing wind direction. In addition, the wind speed described in the TCWS system is in terms of mean winds defined as the speed of the wind averaged over a 10-minute period at 10 meters above the ground. As such, a locality may experience gusts (instantaneous peak values of surface wind speed) that are higher than the range of wind speed expressed by the highest TCWS raised during the passage of a TC.

Table 2.6. General description of damage to infrastructure and agriculture based on the highest TCWS that can be raised on a locality.

TCWS	Damage to structures			Damage to crops and vegetation
	High risk	Medium risk	Low risk	
Signal No. 1	Up to L	Up to VL	Up to VL	• Some banana plants are tilted, a few downed and leaves are generally damaged • Twigs of small trees may be broken. • Rice crops, may suffer significant damage when it is in its flowering stage.
Signal No. 2	L to M	VL to L	Up to VL	• Most banana plants along with a few mango, ipil-ipil, and similar trees are downed or broken. • Some coconut trees tilted with few others broken. • Rice and corn may be adversely affected.
Signal No. 3	H	M	L	• Almost all banana plants are downed, some big trees (acacia, mango, etc.) are broken or uprooted, • Dwarf-type or hybrid coconut trees are tilted or downed • Considerable damage to shrubbery and trees with heavy foliage blown off; some large trees blown down.
Signal No. 4	VH	H	M	• There is almost total damage to banana plantation, • Coconut plantation may suffer extensive damage. • Rice and corn plantation may suffer severe losses.
Signal No. 5	D	VH	H	• Total damage to banana plantation • Most tall trees are broken, uprooted or defoliated; • Coconut trees are stooped, broken or uprooted. • Few plants and trees survive

Note: VL – very light; L – light; M – moderate; H – heavy; VH – very heavy; D - devastating

The wind signals are meant to warn the public of the threat of winds associated with a tropical cyclone. As such, the weather condition in the different parts of the Philippines cannot be simply inferred from the signal issued. Simply knowing what signal is in effect is not enough. At the moment, the warning signals are raised on a provincial level, although depending on the wind structure of the TC, the size of the province, and the orientation of the province with respect to the forecast track, warning signals may be raised on a sub-provincial level.

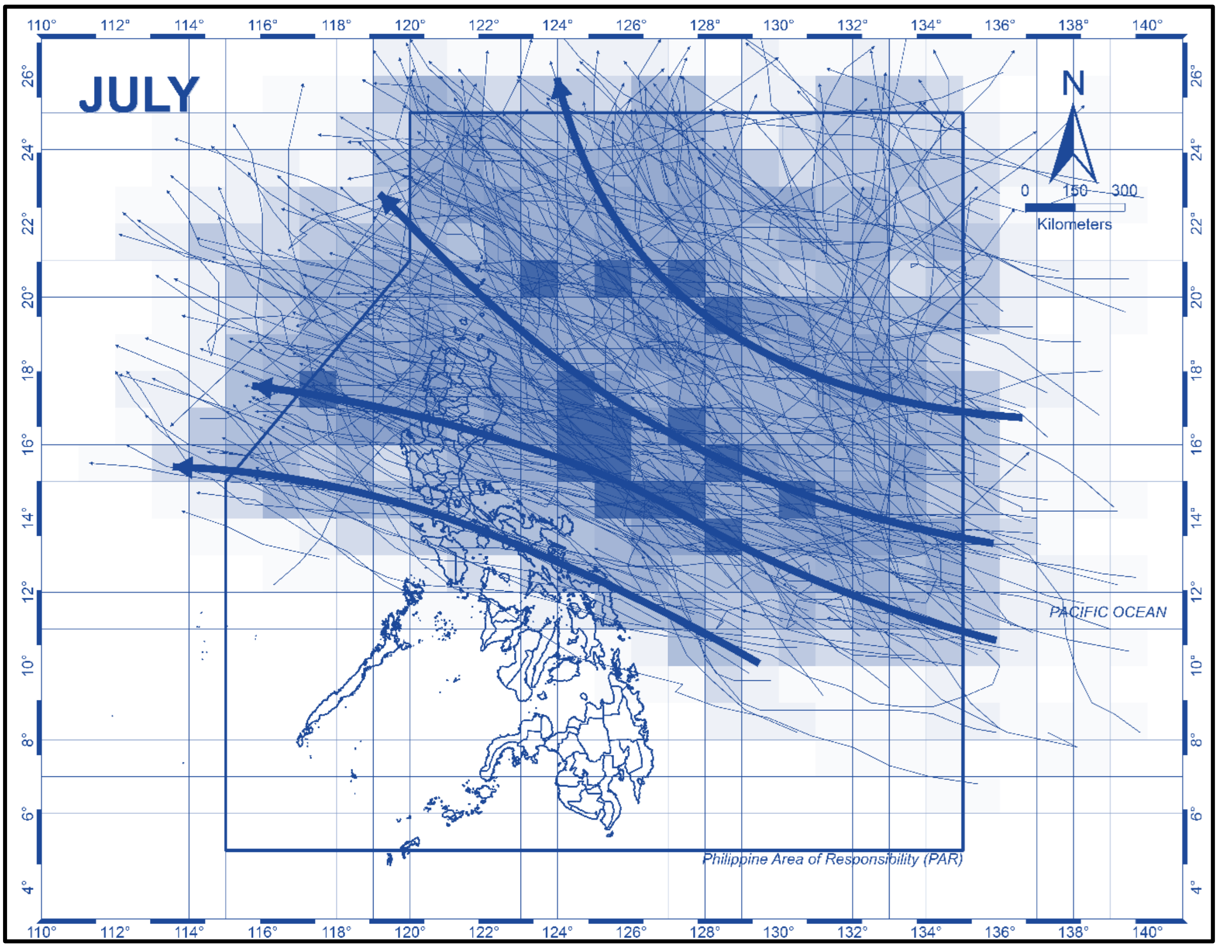
Tropical Cyclone Expert Advice and Briefings

Apart from the provision of tropical cyclone products and disseminating them through contemporary media (i.e., print, television, radio) and the internet (i.e., social networking services, livestreaming), PAGASA meteorologists provide expert advice through detailed briefings and decision support to disaster managers at the national and local governments. These include pre-disaster risk assessment meetings of the NDRRMC Operations Center and local disaster risk reduction and management offices and phone briefings to heads of local governments. In addition, forecasters also give expert advice to business continuity planners and managers in the private sector especially in case wherein high impact weather will affect the economic centers of the country and likely bring significant disruption in their business activities. For the public and members of the media, regular press briefings and press conferences are held and broadcasted via television, radio, and the internet. All these measures are undertaken to ensure that their preparation, mitigation and adaptation measures to TC events and their associated high impact weather phenomena are data-driven and evidence based.

Annual Report on Philippine Tropical Cyclones

The TC meteorologists of the Weather Division are responsible for the publication of the Annual Report on Philippine Tropical Cyclones (ARTC) every year. Published every March two years after a particular TC season, the ARTC provides a compendium of official information about the TC season of interest and each TC occurrence within the PAR during the season. The information provided in the ARTC is based on the post analysis performed by the Tropical Cyclone Group after each TC season. In particular, the ARTC has the following information which may be of interest to various end users such as the history and present TC services of PAGASA (Chapters 1 and 2), overview and statistical analysis of the TC season (Chapter 3), review of individual TC occurrences during the season (Chapter 4), feature case study on selected TC/s and/or associated high impact weather (HIW) event/s during the season (Chapter 5), and tabular version of best track positions and intensities (Chapter 67).

To ensure consistency with other domestic and foreign meteorological data and information, the ARTC uses the Coordinated Universal Time (UTC). The Philippine Standard Time (PhST) is 8 hours ahead of the UTC. For instance, 00 UTC of 01 January 2020 is the same as 8:00 AM PhST of 01 January 2020, while 18 UTC of 01 January 2020 is 2:00 AM PhST of 02 January 2020. In relation to this, a meteorological day begins and ends not at 12:00 AM PhST but at 8:00 AM PhST (00 UTC).



Observed tracks (1948-2017) and corresponding density plot in 1°x1° grids and average track of tropical cyclones within the Philippine Area of Responsibility for the month July.

Tropical Cyclone Season Overview and Statistics

A total of 21 tropical cyclones (TCs) were observed within the Philippine Area of Responsibility (PAR) during the 2018 season (Fig. 3.1). This is considered to be near normal[11] when compared to the 1981-2010 annual average of 18.8 ± 4.6 (Fig 3.2). Seven of the 21 TCs in 2018 originated from low pressure areas (LPAs) within the PAR, particularly over the Philippine Sea and the Luzon Strait. Meanwhile, of the 14 that developed outside the PAR, three originated from the West Philippine Sea while the rest formed over the Philippine Sea or the Western North Pacific (WNP) near the Mariana and Caroline Islands[12]. Of these 21 TCs, 11 eventually weakened into a remnant lows, while the rest transitioned into extratropical cyclones towards the end of their tropical lifespan. Fig 3.1 shows that most of the TCs that entered the PAR in 2018 had tracks that are either generally east-west-oriented (8) or southeast-northwest oriented with or without recurvature (10). The remaining 3 had a southwest-northeast oriented track, which is a common feature of TC events developing from the West Philippine Sea region.

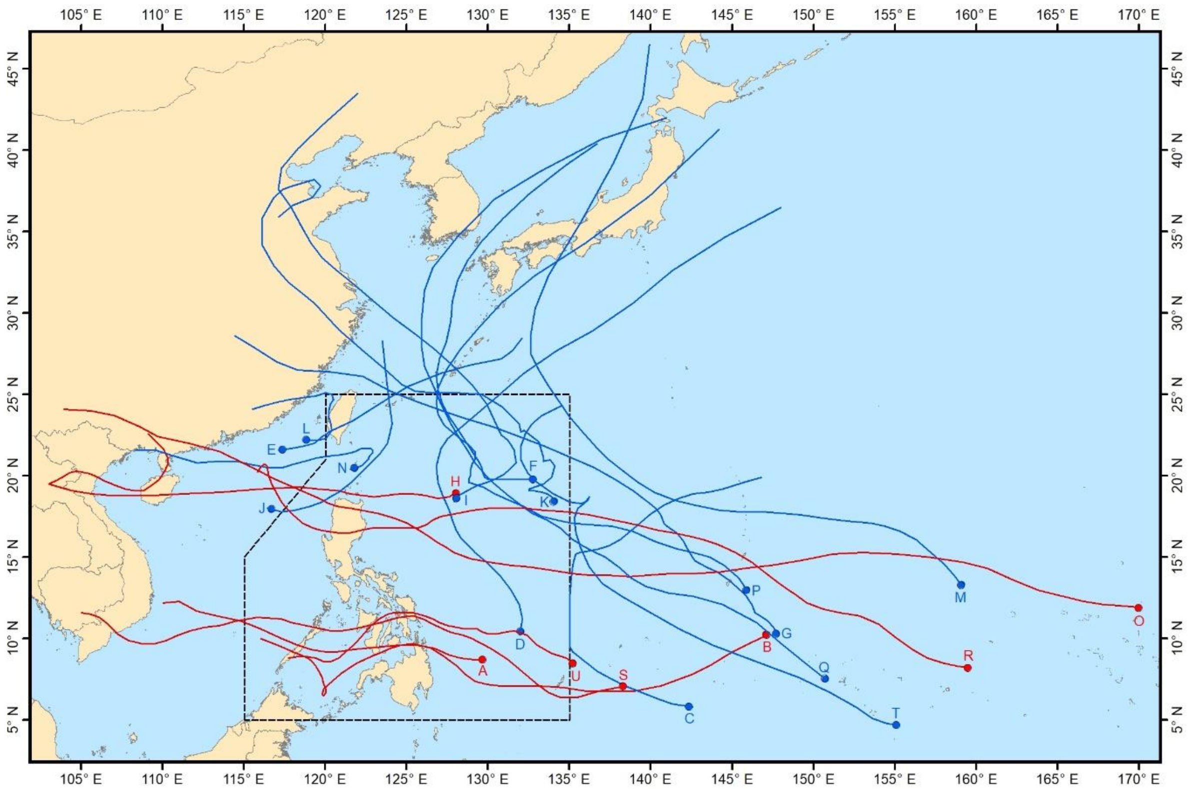


Fig. 3.1. PAGASA best track of TCs that entered or developed within the PAR in 2017. Red (blue) tracks are for landfalling (non-landfalling) TC cases. The filled circles in the tracks are the genesis points or locations where the TC was first noted as a tropical depression. The tracks are identified using the first letter of the domestic names of the TCs. The black dash line marks the limits of the PAR.

Table 3.1 lists down the duration of each 2018 TC event from its genesis or formation to its weakening to a remnant low or transitioning into an extratropical cyclone, while Table 3.2 presents the duration of these TCs within the PAR. The TCs that entered the PAR in 2018 had an average lifespan[13] of 7 days

[11] In this report, a value is deemed near normal if it lies within ± 1 standard deviation of the normal value. Reference period for the 30-year normal is 1981-2010.

[12] The Northern Mariana Islands and Guam constitute the Mariana Islands. The Federated States of Micronesia and Palau comprise the Caroline Islands. Both regions form part of the larger Micronesia Region (which also includes the Gilbert and Marshall Islands

[13] Lifespan is defined as the duration between the synoptic time where the TC was first noted as TD and the synoptic time when the TC either weakened into a remnant low or transitioned into extratropical cyclone.

and 10 hours. TC Rosita was the longest-lasting TC of the season with a basin-wide duration of 12 days and 18 hours. Lasting only 2 days and 18 hours, TC Josie had the shortest lifespan of the 2018 TCs. In terms of the duration within the PAR, the 2018 Philippine TC season logged a total of 63 days and 9 hours with an average TC duration of 3 days and 1/2 hour. TCs Paeng and Maymay had the longest and shortest warning duration within the PAR among all the 2018 TCs respectively. Paeng took 5 days and 21 hours due to a period of slowdown over the northern Philippine Sea while Maymay only took 10 hours because it only skirted the extreme northeastern section of the PAR.

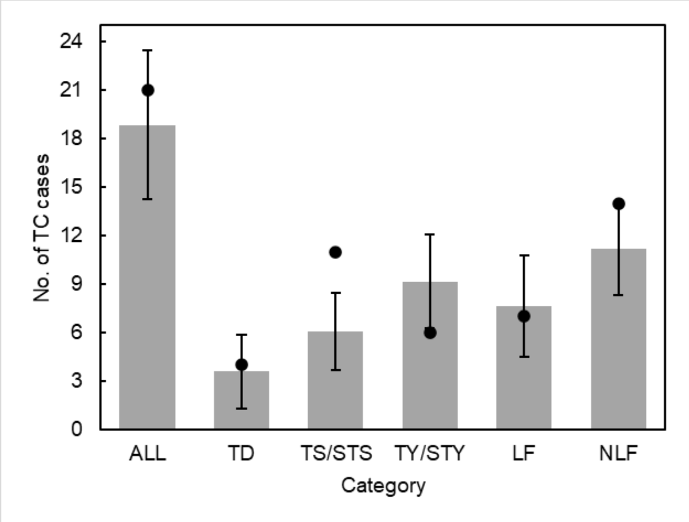


Fig. 3.2. Number of 2018 Philippine TC cases (dots) against their 1981-2010 normal values (bar graph and whiskers for mean ±1 standard deviation): ALL – total TC cases within PAR; TD – TC cases peaking within PAR as tropical depression; TS/STS – TC cases peaking within PAR as tropical storm or severe tropical storm; TY/STY – TC cases peaking within PAR as typhoon or super typhoon; LF – TC cases making landfall; NLF – TC cases not making landfall.

During their lifespans, nine of the 21 TCs peaked at tropical storm (TS) or severe tropical storm (STS) category while 9 reached typhoon (TY) category. For this season, no TC that entered or developed within the PAR reached the STY category anywhere within the Western North Pacific (WNP) basin. TCs Queenie and Rosita were the strongest TCs to enter the PAR in 2018 with a peak intensity of 115 kt and 900 hPa. TC Usman was the weakest of the 21 TCs with a peak intensity of only 30 kt and 998 hPa. More than half of the TCs that entered the PAR (12 of 21) reached peak intensity while outside the PAR. Within the PAR region, 11 of the 21 TCs peaked at TS or STS category, 6 at TY category, and 4 at tropical depression (TD) category. Fig 3.2 shows that the number of TCs that peaked at TS and STS was above normal (6.1 ± 2.4) while those that reached TY was slightly below normal (9.2 ± 2.9). Those that remained at TD category within PAR was near the 30-year average (3.6 ± 2.3). Table 2.1 presents a list of these 21 TCs and key meteorological information about these TCs such as lifespan or duration, basin-wide peak intensity and peak category within the PAR. Details on the basin-wide peak intensity (in terms of peak maximum sustained winds, minimum central pressure, and time of occurrence) and the peak intensity reached within the PAR for each TC are presented in Table 3.1.

Table 3.1. Key meteorological information of the TCs that developed within or entered the PAR in 2018.

Domestic Name	RSMC Name	Basin-wide TC duration MM/DD HH (UTC)	Basin-wide peak intensity: Date and Time MM/DD HH (UTC)	CP (hPa)	MX WD (kt)	Peak category within PAR
Agaton	Bolaven	01/01 00 to 01/04 06	01/03 00	1002	35	TS
Basyang	Sanba	02/09 00 to 02/16 00	02/11 06 !	1000	35	TS
Caloy	Jelawat	03/24 18 to 04/01 12	03/30 06 !	920	105	TS
Domeng	Maliksi	06/05 00 to 06/11 18	06/10 00	970	60	STS
Ester	Gaemi	06/13 12 to 06/17 00	06/16 06 !	990	40	TS
Florita	Prapiroon	06/28 00 to 07/04 12	07/02 00 !	965	65	STS
Gardo	Maria	07/03 00 to 07/12 00	07/08 12	915	105	TY
Henry	Son-tihn	07/15 12 to 07/24 06	07/17 12 !	990	40	TS
Inday	Ampil	07/17 12 to 07/24 18	07/20 00	985	50	STS
Josie	-	07/20 12 to 07/23 06	07/21 06	994	30	TD
Karding	Yagi	08/06 00 to 08/16 00	08/11 12 !	990	40	TS
Luis	-	08/22 00 to 08/26 00	08/23 00	994	30	TD
Maymay	Jebi	08/27 06 to 09/05 00	08/31 06 !	910	110	TY
Neneng	Barijat	09/08 06 to 09/13 12	09/11 06 !	998	40	TD
Ompong	Mangkhut	09/06 12 to 09/17 18	09/11 12 !	905	110	TY
Paeng	Trami	09/20 12 to 10/01 00	09/24 18	915	105	TY
Queenie	Kong-rey	09/28 00 to 10/07 00	10/01 18	900	115	TY
Rosita	Yutu	10/21 00 to 11/02 18	10/24 12 !	900	115	TY
Samuel	Usagi	11/17 12 to 11/26 12	11/24 00 !	985	60	TS
Tomas	Man-yi	11/20 00 to 11/27 18	11/24 12 !	960	80	STS
Usman	-	12/25 06 to 12/30 12	12/28 00	998	30	TD

! The peak intensity (or its first occurrence) was observed outside the PAR.
Note: MXWD: Maximum sustained winds; CP: Central pressure

Table 3.2. Periods of warning within the PAR and the number of TC products issued during each of the 21 TCs of 2018.

Domestic Name	RSMC Name	Duration within the PAR: Inclusive dates and times (PHT)	No. of days (d) and hours (h)	No. of issued TC products: TCU	TCA	SWB	IWS
Agaton	Bolaven	01/01 00 to 01/03 06	2d 06h	6	0	14	9
Basyang	Sanba	02/11 11 to 02/16 00	4d 13h	7	2	23	13
Caloy	Jelawat	03/27 00 to 03/28 01	1d 01h	14	7	2	3
Domeng	Maliksi	06/05 00 to 06/10 01	5d 01h	13	0	11	21
Ester	Gaemi	06/14 16 to 06/15 15	0d 23h	6	0	5	6
Florita	Prapiroon	06/28 00 to 07/01 11	3d 11h	10	0	7	11
Gardo	Maria	07/08 19 to 07/10 11	1d 16h	18	6	5	8
Henry	Son-tihn	07/15 12 to 07/17 00	1d 12h	5	0	13	7
Inday	Ampil	07/17 12 to 07/20 16	3d 04h	11	2	7	12
Josie	-	07/20 19 to 07/22 20	2d 01h	5	0	14	9
Karding	Yagi	08/06 00 to 08/11 01	5d 01h	12	2	9	17
Luis	-	08/22 18 to 08/24 13	1d 19h	4	2	4	7
Maymay	Jebi	09/02 06 to 09/02 16	0d 10 h	13	5	3	3
Neneng	Barijat	09/08 06 to 09/10 14	2d 08h	6	2	4	4
Ompong	Mangkhut	09/12 07 to 09/15 12	3d 05h	15	4	23	14
Paeng	Trami	09/23 01 to 09/28 22	5d 21h	10	4	13	24
Queenie	Kong-rey	10/01 08 to 10/04 10	3d 02h	16	3	8	14
Rosita	Yutu	10/27 00 to 10/31 08	4d 08h	23	4	22	18
Samuel	Usagi	11/18 03 to 11/22 10	4d 07h	16	2	26	18
Tomas	Man-yi	11/25 12 to 11/27 18	2d 06h	12	2	8	14
Usman	-	12/25 10 to 12/30 12	5d 02h	8	0	20	16
		Total:	63d 9h	230	47	241	248

Landfalling Tropical Cyclones

The red tracks in Fig. 3.1 marks the tracks of TCs that made landfall[14] during the season. A total of 7 TCs, roughly 33% of the total TC occurrence within the PAR in 2018 and is near the 1981-2010 normal (7.6 ± 3.2; Fig. 3.2). While most of these TCs crossed the archipelago as a tropical depression, two of the 7 TCs, Ompong and Rosita, made landfall as typhoons. Both TCs crossed the northern portion of Luzon island in later half of the year. TC Ompong is the strongest to make landfall in the country in 2018 with maximum winds and central pressure at landfall of 110 kt and 905 hPa (its peak intensity) respectively. For this season, all landfalling TCs exhibited a generally westward or west-northwestward track without recurvature along its path. None of the landfalling TCs crossed Central Luzon, Southern Luzon (except Palawan) and Mindanao (except for its extreme northeastern section).

On the other hand, non-landfalling TCs accounted for roughly 67% (14 of 21) of the 2018 TCs and is at the upper limit of the range of 1981-2010 normal (11.2 ± 2.9; Fig 3.2).

Observed Trends within the PAR

Fig. 3.3 presents the 5-year running mean and the corresponding linear trend of the total number of TC cases within the PAR, the number of TCs peaking at TD, TS or STS, and TY or STY within the PAR, and the number of landfalling and non-landfalling TC cases. It was observed that since 1981, the number of TC occurrences within the PAR was slightly decreasing. While changes in the number of TCs peaking at TD category for almost 40 years, the number of TCs peaking at TS or STS categories has been slightly increasing, while the frequency of TCs reaching TY or STY while inside the PAR has been decreasing. This means that on average, TCs entering the PAR were less intense and reached lower peak intensities. A slightly decreasing trend has also been observed in the frequency of TCs crossing the archipelago while the number of non-landfalling TCs has been stable since 1981. Such findings have been consistent with those of Cinco et al. (2016) but using PAGASA best track and warning track data from 1971 to 2013.

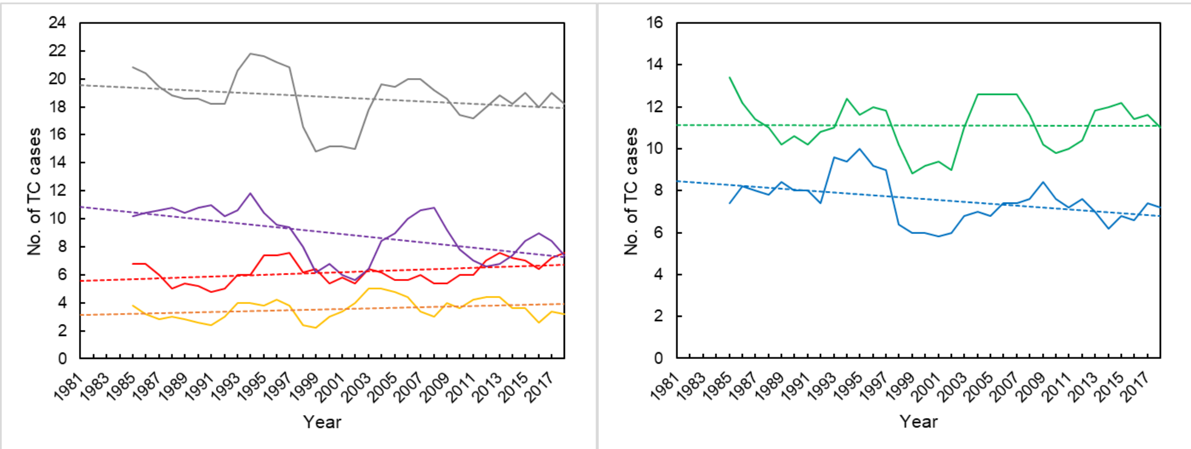


Fig. 3.3. Five-year running mean (solid lines) and corresponding linear trend (dash line) since 1981: Total TC cases within the PAR (gray), TCs peaking at TD (gray), TS/STS (red), and TY/STY (violet) within the PAR, landfalling TCs (blue), and non-landfalling TCs (green).

[14] Landfall is operationally defined by PAGASA as the onshore passage of a TC center across the coast line from a substantially-sized body of water. This center is the pressure or wind center of a TC or, for mature TCs, the geometric center of the eye feature.

Notable Months of the Tropical Cyclone Season

Fig 3.4a presents the monthly distribution[15] of TCs for 2018 and the corresponding normal values for each month based on combined PAGASA best track and warning track dataset. July and September were the most active months of the 2018 season with 4 cases each. The number of TCs within the PAR in August, while near normal, was notably lower compared to July and September. However, the RSMC Tokyo (2019) reported that August 2018 represented the third most active August for the WNP basin on record[16] since 1951 with 9 TCs of TS category or higher. An investigation of mean streamlines at 850 hPa and outgoing longwave radiation for August 2018 shows that most of the TCs in the basin that developed in August originated situated east of 140°E, in a portion of the band of active convection between 10°N and 20°N (Fig. 3.5a,c). This region had an above-normal low-level cyclonic vorticity (redder shade) associated with a stronger-than-normal monsoon trough (MT) and above-normal upper-level divergence (redder shade) caused by the tropical upper tropospheric trough (TUTT) extending to the northeast of the aforementioned region (Fig. 3.5b,d). From their genesis points, these TCs followed a recurving track, preventing most of them from entering the PAR. Apart from Karding (which originated inside the PAR), the only other RSMC-named TC for August that entered the PAR was Maymay, which became the first TC to enter the PAR in September.

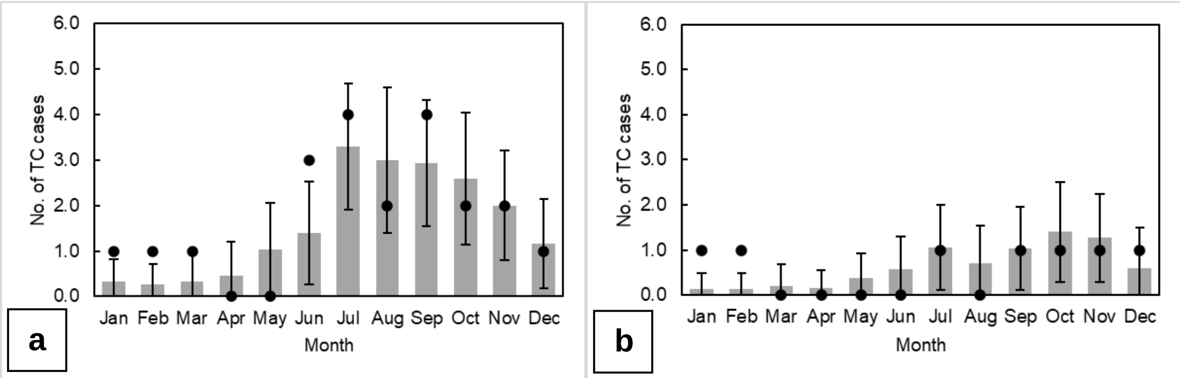


Fig 3.4. Monthly distribution of (a) TC cases within the PAR and (b) landfalling TC cases in 2018 (dots) and the corresponding 1981-2010 normal values (bar graph and whiskers for mean ±1 standard deviation).

Fig. 3.4a also shows that three TCs were observed within the PAR from January to March, slightly higher than the 1981-2010 normal. The number of landfalling TCs for this period was notable for the period (Fig. 3.4b). Two of the three TCs for January-March crossed the Philippines south of 10°N in a generally westward track. The TC activity within the PAR during this period was attributed to above-normal sea surface temperature (SST) over the southern Philippine Sea region where these TCs originated and tracked (Fig. 3.6a). The warmer SST was associated with a prevailing La Niña[17]. Corporal-Lodangco et al. (2016) identified that the displacement of the warm pool during La Niña conditions results in the westward displacement of the mean cyclogenesis location (making it more proximal to the Philippines) and the dominance of low-latitude straight moving TC tracks such as those observed in 2 of the 3 TC cases for January-March 2018. A similar above-normal SST condition over the southern Philippine Sea was observed in January-March 2013 (Fig 3.6b) when there were also 3 TCs cases within the PAR.

To put this into contrast, during the same months in 2016, no TC was observed within the PAR. The SST over the southern Philippine Sea was found to be near average (Fig. 3.6c). La Niña conditions were not present over the equatorial Pacific during this period.

[15] A tropical cyclone is counted for a particular month based on the date it was first noted as a TC within the PAR.
[16] August 1960 and 1966 reported 10 TCs of at least TS category per RSMC Tokyo records.
[17] Based on the value of the Oceanic Niño Index or the 3 month running mean of ERSST v5 SST anomalies in the Niño 3.4 region (5°N-5°S, 120°E-170°W). Values for JFM 2013, 2017, and 2018 were -0.3°C, -0.1°C, and -0.8°C respectively

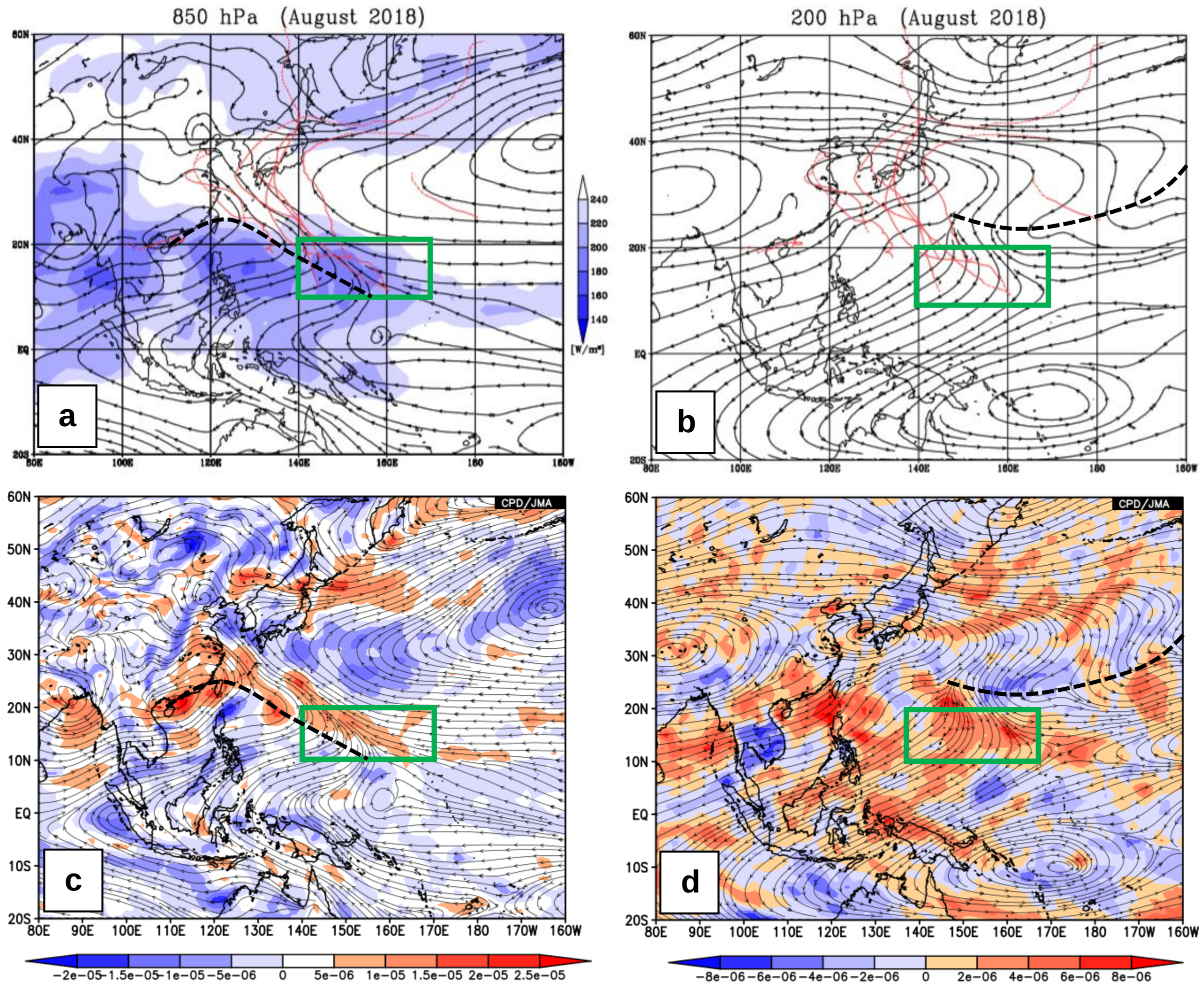


Fig. 3.5. August 2018 mean streamlines at (a, c) 850 hPa and (b, d) 200 hPa. The shadings in a, c, and d indicate mean outgoing longwave radiation (K), mean 850 hPa relative vorticity anomaly (1/s), and mean 200 hPa relative divergence (1/s) respectively. The 9 TCs of at least TS category in the WNP basin that developed in August are superimposed in red while the MT (TUTT) axes are marked as black dashes in a and c (b and d). The region of active convection discussed in this subsection is enclosed in green. Figs. 3.5a and b were adapted from RSMC Tokyo (2019), while c and d used the data from the JRA-55 reanalysis dataset (Kobayashi et al. 2015) via the Interactive Tool for Analysis of the Climate System (iTacs; https://extreme.kishou.go.jp/itacs5)

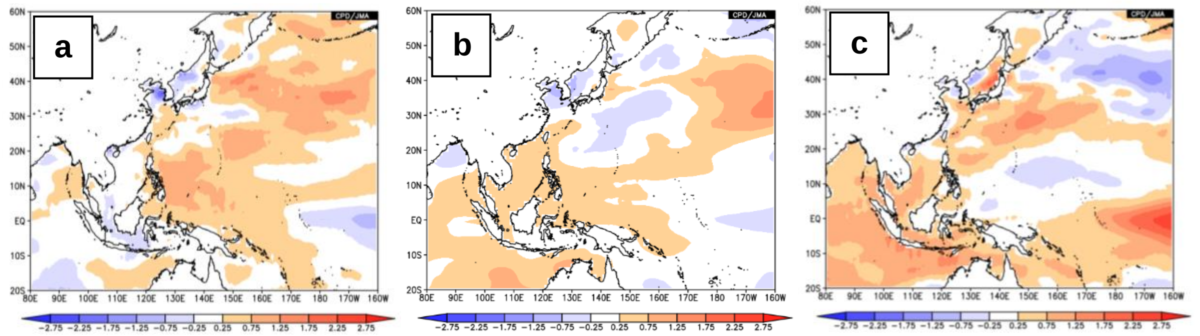


Fig. 3.6. Mean SST anomaly (°C) from January to March for (a) 2013, (b) 2016, and (c) 2018. Data are from the JRA-55 reanalysis and COBE-SST (Ishii et al. 2005) datasets via the iTacs.

Slightly above-normal number of TCs was observed in June 2018 (3 TCs) and was the most active June since 2013 (4 TCs). During this month, a region of enhanced cyclonic vorticity at 850 hPa in the monsoon trough was observed over the northern portions of the Philippine Sea and West Philippine Sea (Fig 3.7a). This is associated with the convergence of both stronger than normal southwesterly winds and easterly winds on the southwestern side of the North Pacific Subtropical High (Fig. 3.7d). Similarly, an enhanced low-level cyclonic vorticity region in the monsoon trough was also present over the Philippine Sea between 0° and 15°N (Fig. 3.7b) in June 2013. In this case, although the monsoon southwesterly winds over the Philippine Sea and West Philippine Sea were near or slightly weaker than normal, stronger than normal easterly winds were observed to be reaching the monsoon trough region (Fig. 3.7e), The genesis points of the TCs that were observed within the PAR in June 2013 and 2018 were situated in these enhanced vorticity regions.

Putting this into contrast, only one TC case was reported within the PAR in June 2016. Fig 3.7c shows that the region of enhanced cyclonic vorticity in the monsoon trough during this period was only limited to the Sulu Sea and the southern portion of the Philippine Sea between 5°N and 10°N. Furthermore, both the easterly winds reaching the monsoon trough and the monsoon southwesterly flow were weaker than normal (Fig. 3.7f), suggesting suppressed monsoon activity.

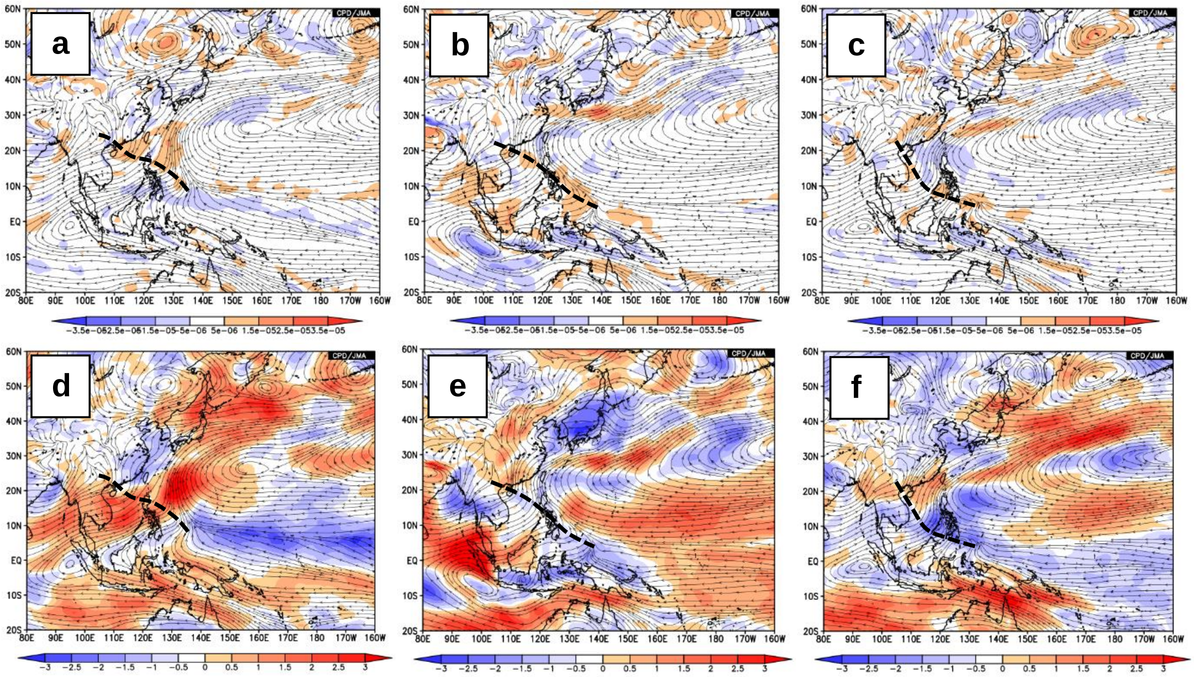


Fig. 3.7. Mean 850 hPa streamlines for (a, d) June 2018, (b, e) 2013, and (c, f) 2017. The shadings indicate mean 850 hPa relative vorticity anomaly (1/s; a-c) and mean horizontal wind speed anomaly (m/s; d-f). Data are from the JRA-55 reanalysis dataset via the iTacs. The axis of the monsoon trough is superimposed in black.

Rainfall During Tropical Cyclone Days

Aside from the immediate rain bands or surface troughs of the TC, the country can also experience rainfall in the presence of the TC within the PAR through its interaction with the prevailing monsoon system. For instance, distant heavy rainfall events related to a TC occurrence within the PAR may be observed because of the TC enhancement of the Southwest Monsoon (Cayanan et al. 2011; Bagtasa 2019) or the enhanced moisture convergence in shear lines during strong Northeast Monsoon surges in the presence of a TC or other cyclonic disturbance (Yokoi and Matsumoto 2008; Ogino et al. 2018; Olaguera et al. 2020). To capture this distant precipitation events, instead of using a predetermined radius[18] from the TC center to delineate TC rainfall as suggested in existing literature (Jiang et al. 2008; Kubota and Wang 2009; Bagtasa 2017), this section presents the observed and estimated TC-related rainfall in the country using TC days[19] as delineating metric.

[18] Existing studies suggest using 10° radius (approximately 1100 km) from the TC center to delineate TC rainfall because rainfall amount decreases with a larger TC influence radius and becomes almost constant from around a 10° radius onward.

[19] TC days are meteorological days with at least one tropical cyclone within the PAR irrespectively of its proximity to the Philippines.

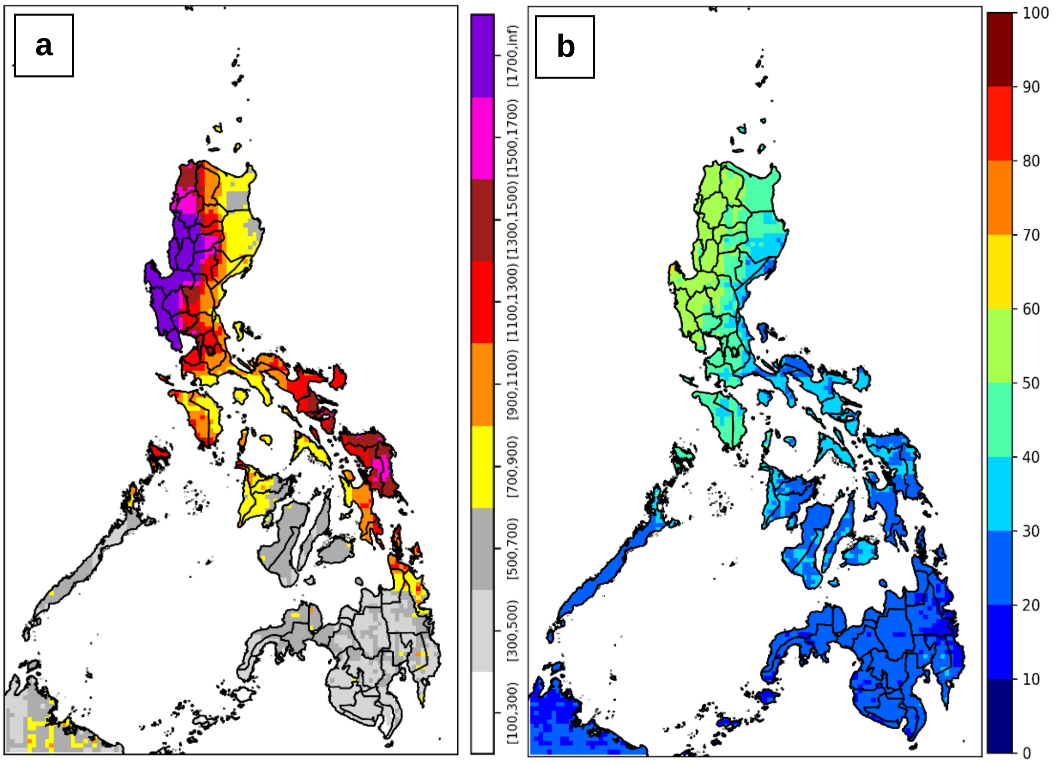


Fig 3.8. GSMaP-Gauge nationwide estimates of (a) total rainfall (mm) during TC days and (b) its percentage contribution to the total rainfall in 2018.

Fig. 3.8 presents the total rainfall over the country during TC days and its percentage contribution to the total rainfall in the country based on gauge-adjusted satellite-based rainfall estimates (Mega et al. 2019) of the Global Satellite Mapping of Precipitation (Kubota et al. 2020). The total rainfall during TC days in the Philippines shows that the observed rainfall over Luzon during TC days were notably higher than in other parts of the country (with the exception of mainland Palawan). In the Visayas, the total rainfall during TC days over Visayas (Mindanao) was disproportionately higher in the Samar Island (extreme northeastern portion). The rainfall distribution presented two rainfall maxima regions - over the western portion of Northern and Central Luzon and over the southern Bicol Peninsula and Samar Island. The former was found to have higher rainfall totals (at least 1,700 mm) compared to the former (1300-1700 mm). When compared against the total rainfall for 2018, the rainfall in most areas in Luzon (the exception being portions of Quezon, Aurora, mainland Palawan, and Bicol Peninsula) during TC days accounted for 30% to 60% of the total rainfall for the year. In other areas, TC-related rainfall constituted between 10% to 40% of the 2018 rainfall.

To determine the extent of rainfall during TC days that fall under the different monsoon regimes, the periods of the Southwest and Northeast Monsoon regimes shall be June-October and November-March, respectively. The period of April to May is referred to as the trade winds regime. (Williams et al. 1993). However, no TC was observed within the PAR during the trade winds regime.

Thirteen of the 21 TCs in 2018 occurred during the Southwest Monsoon regime, with two making landfall and two passing within 100 km of the Philippine coast line. Fig. 3.9a shows that TC days during the Southwest Monsoon had very high rainfall totals over most of Luzon with its rainfall maximum situated over the western sections of Northern and Central Luzon (1,700 mm and above). The TC days during Southwest Monsoon brought about 30 to 60% of the total rainfall for 2018 in Ilocos Region, Cordillera Administrative Region, western portion of Cagayan Valley, Metro Manila, and most of Central Luzon (except Aurora), CALABARZON (except Quezon and eastern portion of Batangas), Mindoro Provinces, and Northern Palawan (mainly Calamian Islands).

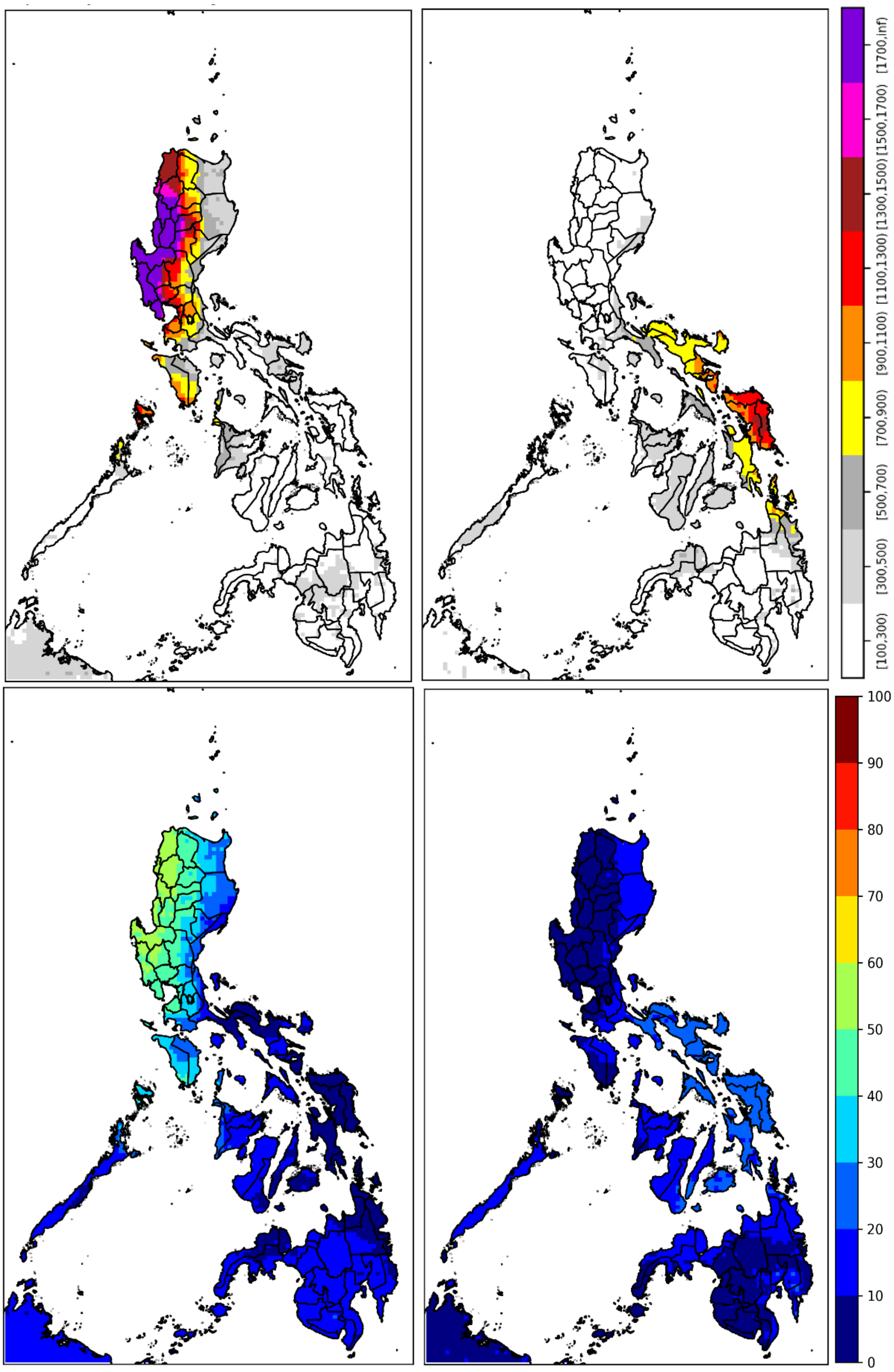


Fig. 3.9. Total rainfall (mm) during TC days of the (a) Southwest and (b) Northeast Monsoon and (c and d respectively) their corresponding percentage contributions to the total rainfall in 2018.

During the Northeast Monsoon regime, eight TCs were observed inside the PAR with five crossing land. Despite the large number of landfalling TCs during this period, the estimated rainfall during TC days were notably less than in Southwest Monsoon regime. Bicol Region, Eastern Visayas, and extreme northeastern Mindanao (Dinagat Islands, Surigao del Norte and northern portions of Surigao del Sur and Agusan del Norte) had total rainfall of 700 to 1,500 mm. Samar Island received the highest total rainfall during TC days of the Northeast Monsoon (900-1,500 mm) (Fig.3.8b). Despite these values, the TC days during the Northeast Monsoon only accounted up to 20% of the total rainfall observed in 2018. (Fig. 3.9d).

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Tables 3.3 and 3.4 present the extremes of rainfall, wind, and sea level pressure observations recorded by the network of manned synoptic stations of PAGASA during the passage of landfalling and non-landfalling tropical cyclones. Compared to real-time reports, these data have undergone post-real time quality control from the Climatology and Agrometeorology Data Section of the Climatology and Agrometeorology Division.

Table 3.3. Extremes of rainfall observations during TC days in 2018.

Record	Location	Value (mm)	Date or Period and Active TC
Highest 24-hour accumulated rainfall (landfalling TC)	Baguio City (98328)	536.0	09/15/2018 (TC Ompong)
Highest 24-hour accumulated rainfall (non-landfalling TC)	Subic Bay International Airport, Morong, Bataan (98426)	436.4	07/22/2018 (TC Josie)
Highest storm duration rainfall (Landfalling TC)	Baguio City (98328)	795.0	09/12-09/15 (TC Ompong)
Highest storm duration rainfall (Non-Landfalling TC)	Dagupan City, Pangasinan (98325)	648.9	07/17-07/20 (TC Inday)

Table 3.4. Extremes of wind and sea level pressure observations during TC days for landfalling and close-approaching[20] TCs in 2018.

Record	Location	Value	Date / Time and Active TC
Lowest sea level pressure	Tuguegarao City, Cagayan (98233)	949.0 hPa	09/14/2018 1900 (TC Ompong)
Highest peak gust	Aparri, Cagayan (98223)	NNE (20°) 49 m/s	09/14/2018 1838 (TC Ompong)

Casualty and Damage Statistics

Based on the latest information[21] provided by the National Disaster Risk Reduction and Management Council (NDRRMC), the 21 TCs of the 2018 season directly and indirectly (e.g., distant precipitation through monsoon) resulted in 605 casualties - 298 dead, 274 injured, and 33 missing individuals. Combined cost of damage to agriculture and infrastructure amounted to PHP 48.679 billion nationwide with agricultural damages accounting to roughly 73% of the total damages. This makes the 2018 both the 10th deadliest and 5th costliest TC season since 2000, as well as the 2nd deadliest and 2nd costliest following the disastrous year of STY Yolanda. While there has been no notable trend in the number of casualties since 2000, the inflation-adjusted total cost of damage has been steadily increasing (Fig. 3.10).

Despite being a TD during landfall, Usman was the deadliest TC of 2018, claiming the lives of 158 people in addition to 105 injured and 26 missing individuals across MIMAROPA, Bicol and Eastern Visayas Regions. Meanwhile, Ompong was the costliest TC event of 2018 with damage to agriculture and infrastructure amounting to PHP 26.770 billion and PHP 7.161 billion respectively. Table 3.3 lists

[20] Close-approaching are non-landfalling TCs that passed within 100 km of the Philippine coast.
[21] The information is the consolidation of data from the report prepared by the NDRRMC Operations Center dated 13 December 2018 and the last Situational Report (No. 26) on Preparedness Measures and Effects of Tropical Depression (TD) “USMAN” dated 20 January 2019

down the casualties and cost of damage resulting from high impact weather directly or indirectly associated with the TCs of 2018

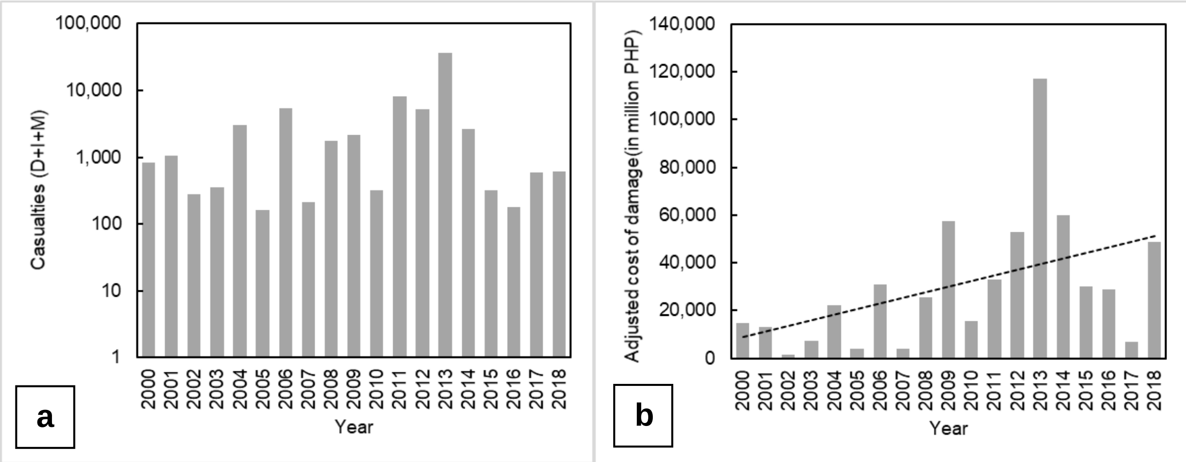


Fig 3.10. Yearly (a) number of casualties and (b) cost of damage (in million PHP) directly and indirectly caused by the 2018 TCs. The y-axis in Fig. 3.10a uses logarithmic (base 10) scale. In Fig. 3.10b, the cost of damage is adjusted to 2018-equivalent values using the consumer price indices from the Philippine Statistics Authority while the black dash line presents the linear trend (2000-2018) of this adjusted cost of damage.

Table 3.5 shows that TCs Ompong, Rosita, and Usman directly resulted in damages each amounting to more than PHP 1 billion. As such, PAGASA formally decommissioned Ompong, Rosita, and Usman in 8 February 2019 and were replaced by Obet, Rosal, and Umberto respectively. The replacement names will be implemented in the 2022 season. Furthermore, the Typhoon Committee in its 51st Annual Session from 26 February to 1 March 2019 approved the decommissioning of Mangkhut, the corresponding international name of Ompong, following the request of PAGASA. A replacement name remains pending due to the postponement of the 52nd Annual Session due to the Coronavirus Disease 2019 pandemic.

Table 3.5. Tally of casualties and cost of damage directly and indirectly associated with the TC events of 2018 based on the data from the NDRRMC Operations Center. TCs that were deemed by the NDRRMC to have “no effect” in terms of casualties and cost of damage are omitted.

Name of TC	Casualties			Cost of damage (in PHP millions)		
	Dead	Injured	Missing	Agriculture	Infrastructure	Total
Agaton	4	9	0	527.245	27.480	554.725
Basyang	15	16	1	167.995	-	167.955
Domeng and Ester*	3	3	0	-	-	-
Gardo*	0	0	0	-	-	-
Henry, Inday and Josie*	16	1	1	3,279.640	1,380.971	4,660.611
Karding*	2	0	3	43.711	952.290	996.001
Luis*	0	0	0	-	-	-
Ompong	82	138	2	26,769.718	7,161.016	33,930.734
Rosita	20	2	0	2,904.840	-	2,904.840
Samuel	-	-	-	52.228	-	52.228
Usman	156	105	26	1,948.429	3,463.364	5,411.793
Total	298	274	33	35,693.766	12,985.121	48,678.887

* Reported casualties and cost of damage are directly and/or indirectly caused by the TC.
Note 1: “-“ indicate that data was not reported and verified by the NDRRMC.
Note 2: The statistics for Domeng, Ester, and the resulting Southwest Monsoon (SWM) surges were consolidated by the NDRRMC in its final report and real-time situational reports.
Note 3: The statistics for Henry, Inday, Josie, and the resulting SWM surges were also consolidated in the NDRRMC reports.
Note 4: The NDRRMC noted “no effects” for TCs Caloy, Florita, Maymay, Neneng, Paeng, Queenie, and Tomas.

Provision of Tropical Cyclone Products and Wind Signals

PAGASA issued 518 domestic products to the general public, disaster managers and other domestic end users. This is composed of 230 Tropical Cyclone Updates (TCU), 47 Tropical Cyclone Advisories (TCA), and 241 Severe Weather Bulletins (SWB). For the purpose of marine warnings and regional exchange of TC bulletins among TC warning centers within the WNP basin, a total of 248 Tropical Cyclone Warning for Shipping (IWS; WTPH20 RPMM) were provided to mariners within the high seas under PAGASA's forecast responsibility and to the WMO Global Telecommunications System. TC Rosita warranted the issuance of the greatest number of domestic products with 23 TCUs, 4 TCAs, and 22 SWBs during its warning period. On the other hand, the greatest number of international TC products issued for a single TC occurrence happened during TC Paeng when PAGASA issued a total of 24 IWS.

Nine of the 21 TCs in 2018 necessitated the raising of Tropical Cyclone Wind Signals (TCWS) in the country due to the threat of potentially damaging or destructive TC winds. In 2018, roughly 90% of the provinces in the Philippines (including Metro Manila) were placed under a TCWS or an average of 21 to 22 provinces per TC event. TC Ompong resulted in the raising of TCWS in over 38 provinces, which was the highest of any TC during the year. On the other hand, the TC with the least number of areas placed under TCWS was TC Neneng with only 1 province (Batanes).

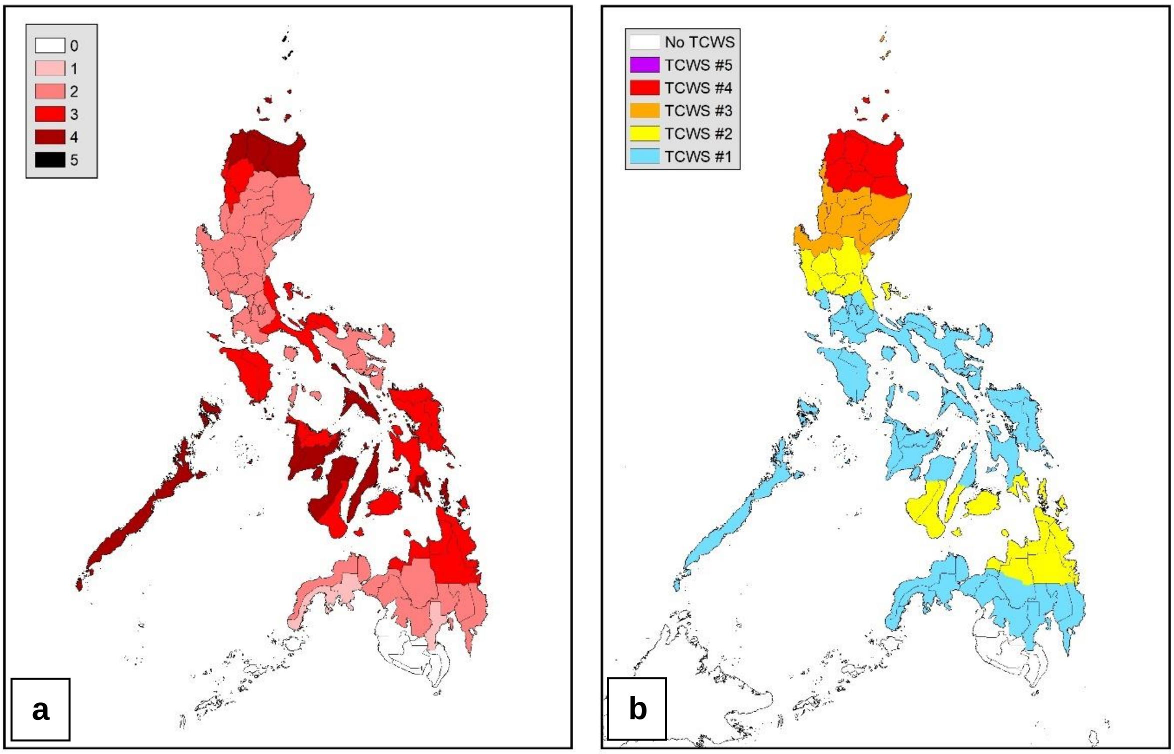


Fig. 3.11. (a) Frequency of raising of TCWS per province and (b) the highest TCWS raised per province or sub-provincial locality. In Fig 3.11a, if a portion of the province is put under TCWS more frequently than the other areas of the province (e.g. thrice for the central and southern portions of Quezon and twice for thr northern portion of Quezon), the higher count will be considered as the frequency for that province. In Fig. 3.11b, if a maximum TCWS for a portion of the province (e.g. the northern portion of Quezon maxed at TCWS #2) is higher compared to the rest of the province (the central and southern portions of Quezon only peaked at #1), both maxima will be reflected accordingly.

Fig. 3.11a presents the frequency of raising of TCWS in each province across the country. On average, wind signals were raised over a province roughly two to three times in 2018. The province most frequently placed under TCWS in 2018 was Batanes. On the other hand, TCWS was never raised over most of Bangsamoro (only Lanao del Sur was placed under TCWS #1), Davao Occidental, Sarangani and South Cotabato. Wind signals were more frequently raised (thrice or higher) over the northern portion of Northern Luzon, northeastern portion of Mindanao, Visayas, Palawan, Masbate, Quezon, and Mindoro Provinces than in the other parts of the country in 2018.

Fig. 3.11b shows that highest wind signal that was put into effect in each province or sub-provincial locality in 2018. Due to the absence of a TC of at least TY category that threatened and/or crossed Visayas and Mindanao during the year, the wind signals outside Luzon did not exceed TCWS #2. There has never been a single TC after Lawin (Haima) in 2016 that necessitated the raising of TCWS #5 in the Philippines. TCWS #4 was the highest wind signal raised in any locality during the 2018 season and was put into effect in six provinces of Northern Luzon during the passage of TC Ompong.

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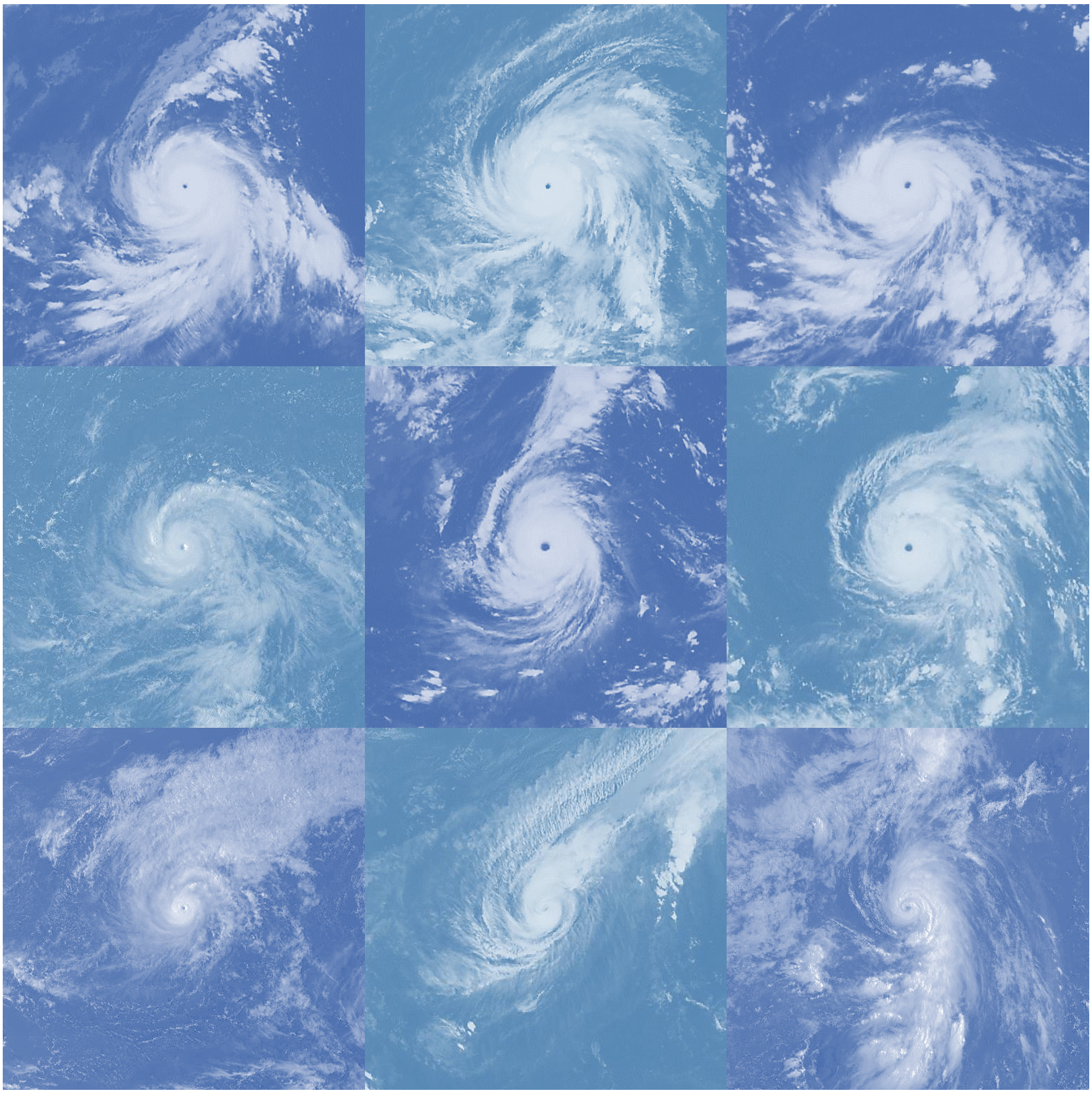
REVIEW OF PHILIPPINE TROPICAL CYCLONES OF 2018



Satellite images at peak intensity of the nine most intense tropical cyclones of 2018 that entered the Philippine Area of Responsibility

Review of Philippine Tropical Cyclones 2018

This section of the report contains the individual reviews of each tropical cyclone (TC) in the Western North Pacific basin that occurred within the Philippine Area of Responsibility (PAR) in 2018 based on the result of a post-season reanalysis of each event by the meteorologists of the Weather Division. Each individual TC review contains the following information which may be of interest to various end-users:

- A map showing the best track positions and intensities (as categories) of the TC;
- A narrative of the meteorological history of the TC from its genesis to its transition to a remnant low or a non-tropical system including a short entry on the estimated and observed rainfall across the country directly or indirectly associated with the TC being discussed;
- The extremes[22] of surface meteorological observation over land recorded by the PAGASA synoptic station network: the highest 24-hour accumulated rainfall during any of the TC days, highest storm duration[23] rainfall, peak gust during any of the TC days, and lowest sea level pressure during any of the TC days. The last two are only provided for landfalling and close-approaching TCs.
- A summary of warning information from PAGASA during the TC occurrence. This includes the number of domestic and international TC products issued, the number of localities where TC Wind Signals (TCWS) were put into effect, and the highest wind signal raised throughout the passage;
- A summary of casualties and damages directly and indirectly associated with the TC event based on aggregated reports and official communications from the Operations Center of the National Disaster Risk Reduction and Management Council (NDRRMC); and,
- A map showing the storm duration rainfall (in mm) across the country based on the gauge-adjusted satellite-based estimates dataset (Mega et al. 2019) of the Global Satellite Mapping of Precipitation (Kubota et al. 2020)

Depending on the TC being discussed, the following information are also incorporated in the review:

- For TCs the necessitated the raising of TCWS, a map showing the highest wind signal raised for each province or sub-provincial locality;
- For TCs that triggered or enhanced the Southwest Monsoon and brought heavy monsoon rains, a chart showing 850 hPa stream line and 850 hPa horizontal wind speed anomaly (in m/s) averaged throughout the storm duration within the region of 0°-40°N and 100-150°E using the JRA-55 reanalysis dataset (Kobayashi et al. 2015). The charts are plotted using the Interactive Tool for Analysis of the Climate System (iTacs; https://extreme.kishou.go.jp/itacs5);
- For TCs that needed a visual presentation of the synoptic environment (i.e. to show the presence of surface troughs or shear lines) that influenced the observed inclement weather in the country, Western North Pacific surface weather analysis of the Japan Meteorological Agency. The charts are made available by Dr. Asanobu Kitamoto of the National Institute of Informatics through the Digital Typhoon Portal (http://agora.ex.nii.ac.jp/digital-typhoon/weather-chart/).

[22] Peak gust and 24-hour rainfall values that broke climatological records are also noted.
[23] Storm duration refer to the meteorological days the TC was inside the PAR.

Tropical Cyclone Agaton (1801 Bolaven)

01 to 04 January 2018

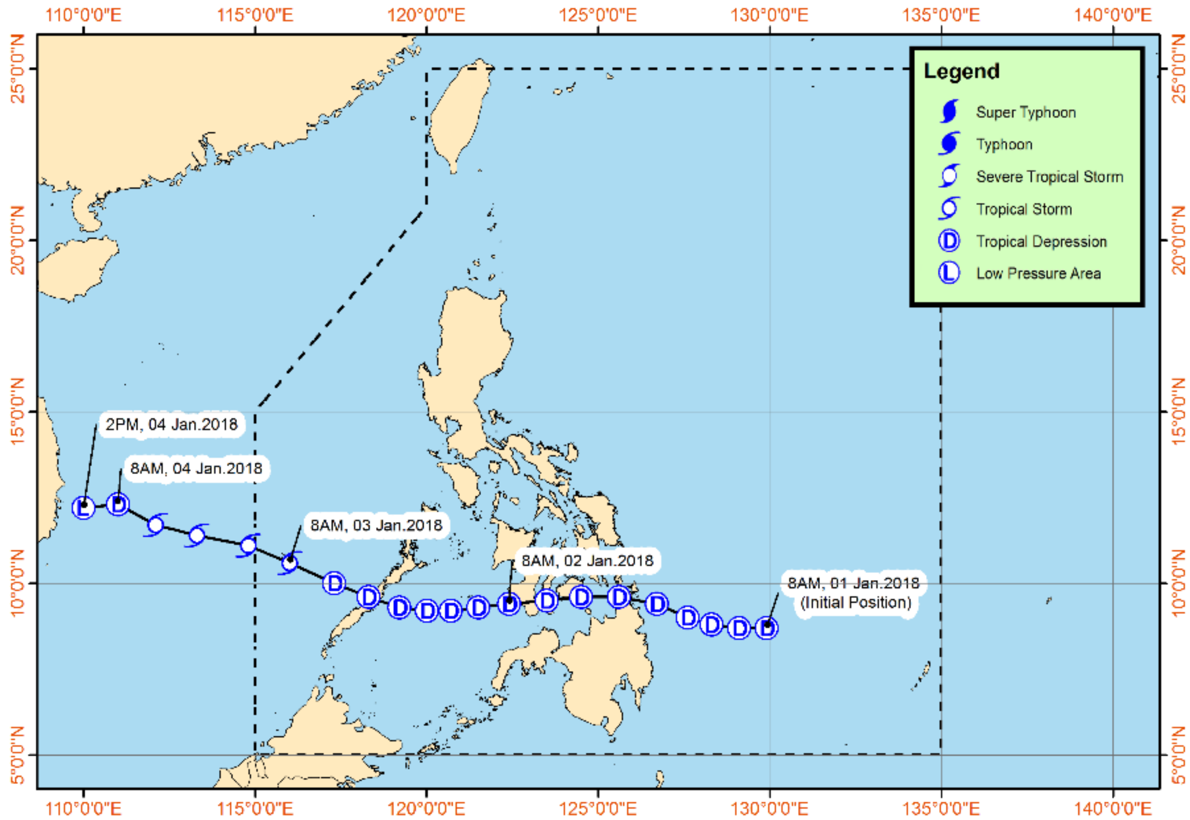


Fig 4.1. PAGASA best track positions and intensities of Tropical Cyclone Agaton

Meteorological History

The first tropical cyclone (TC) of the 2018 season, Agaton, was first noted as a tropical depression at 00 UTC on 01 January while over the southern portion of the Philippine Sea east of Mindanao. Moving generally westward, its center passed off the southern coast of Bucas Grande Island and made landfall over Claver, Surigao del Norte before 15 UTC of the same day. A slight intensification was observed as it emerged over the Bohol Sea. After passing off the southern coast of Bohol and Panglao Islands, Agaton traversed the southern portion of Cebu and Negros Islands between 21 UTC on 01 January and 00 UTC on 02 January. It then tracked westward to west-northwestward over the Sulu Sea. At around 14 UTC on 02 January, Agaton made its final landfall in the Philippines over Aborlan, Palawan.

Roughly 9 hours after emerging over the West Philippine Sea, Agaton intensified into a tropical storm (TS). It left the Philippine Area of Responsibility (PAR) at around 06 UTC on 03 January and remained a weak TS as it moved towards southern Vietnam. Increasingly unfavorable conditions related to a prevailing northeast monsoon surge resulted in a rapid weakening to a low pressure area. Agaton weakened into a remnant low and was last tracked at 06 UTC on 04 January.

Rainfall estimates across the country during the passage of Agaton show accumulated rainfall in excess of 50 mm over Visayas, southern Quezon-Bicol region area, Palawan, and northeastern portion of Mindanao with higher accumulations (200-300 mm) over Samar Island, Albay, and Sorsogon. The synoptic station in Juban, Sorsogon reported both the highest storm duration (354.9 mm) and the highest 24-hour accumulated (228.3 mm) rainfall during the passage. Although higher accumulations were also noted in the areas near or along the path of Agaton, the rainfall maximum region was observed in areas north of the observed track (i.e. Samar Island and the southern portion of Bicol Region)

The magnitude and spatial distribution of rainfall in both storm duration estimates and gauge observations can be explained by the enhanced moisture convergence along the shear line during strong Northeast Monsoon surges in the presence of the cyclonic circulation of Agaton. Normally, shear lines are associated with predominantly light stratiform rainfall with isolated heavy showers. However, increased convergence in the shear line during TC events result in scattered to widespread heavy rains in the areas affected by the shearline. In particular, the rainfall totals are usually higher in the areas affected by the shear line than in the areas near or along the observed track of the TC.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest peak gust over land:
Guiuan, Eastern Samar (98558) / NNE (30°) 22 m/s / 01 January 2018, 1300 UTC

Lowest sea level pressure over land:
Maasin City, Southern Leyte (98648) / 996.0 hPa / 01 January 2018, 1700 UTC

Highest 24-hour rainfall over land:
Juban, Sorsogon (98545) / 228.3 mm / 02 January 2018

Highest storm duration rainfall over land:
Juban, Sorsogon (98545) / 354.9 mm / 01-03 January 2018

Summary of Warning Information

Number of domestic products issued: **20**

- Severe Weather Bulletins: **14**
- Tropical Cyclone Updates: **6**
- Tropical Cyclone Advisories: **0**

Number of TC Warning for Shipping issued: **9**

Number of localities under TC Wind Signal (TCWS): **27**

Highest wind signal put into effect: **TCWS #1**

Summary of Casualties and Damage to Property

Number of casualties: **4 dead and 9 injured**

Combined cost of damage: **PHP 554.725 million**

- Damage to agriculture: **PHP 527.245 million**
- Damage to infrastructure: **PHP 27.480 million**

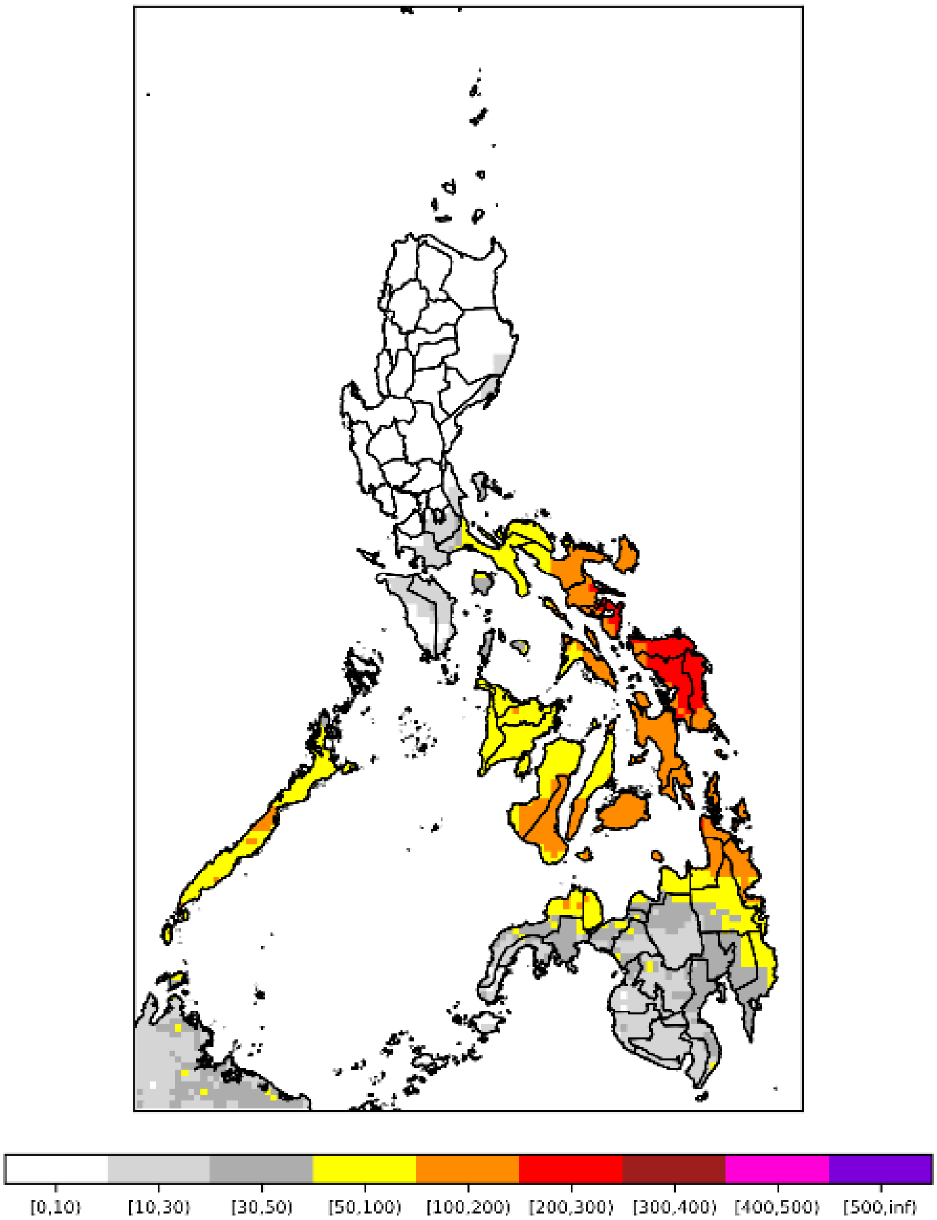


Fig 4.2. Nationwide estimate of storm duration rainfall (mm) for the period of 01-03 January 2018.

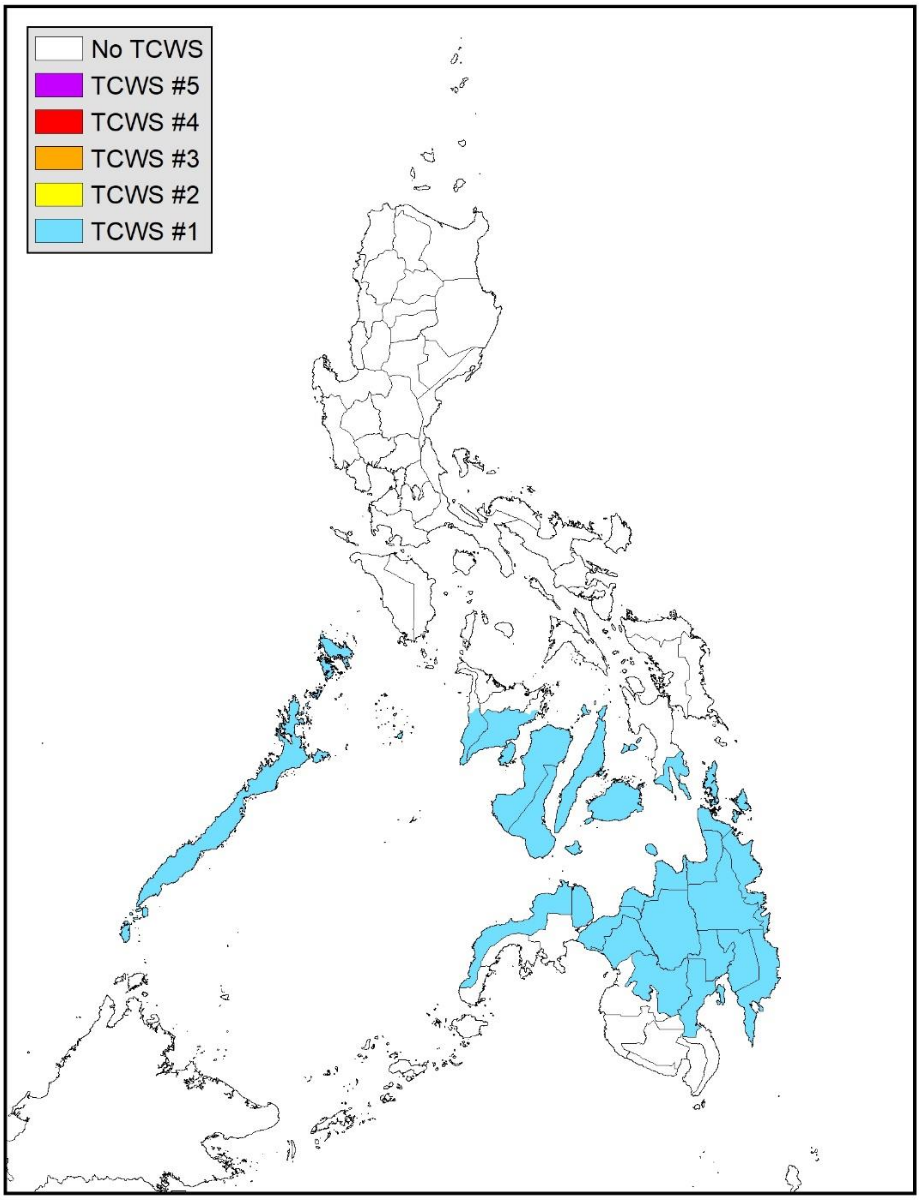


Fig 4.3. Highest wind signal raised by PAGASA during the passage of TC Agaton in each province or subprovincial locality.

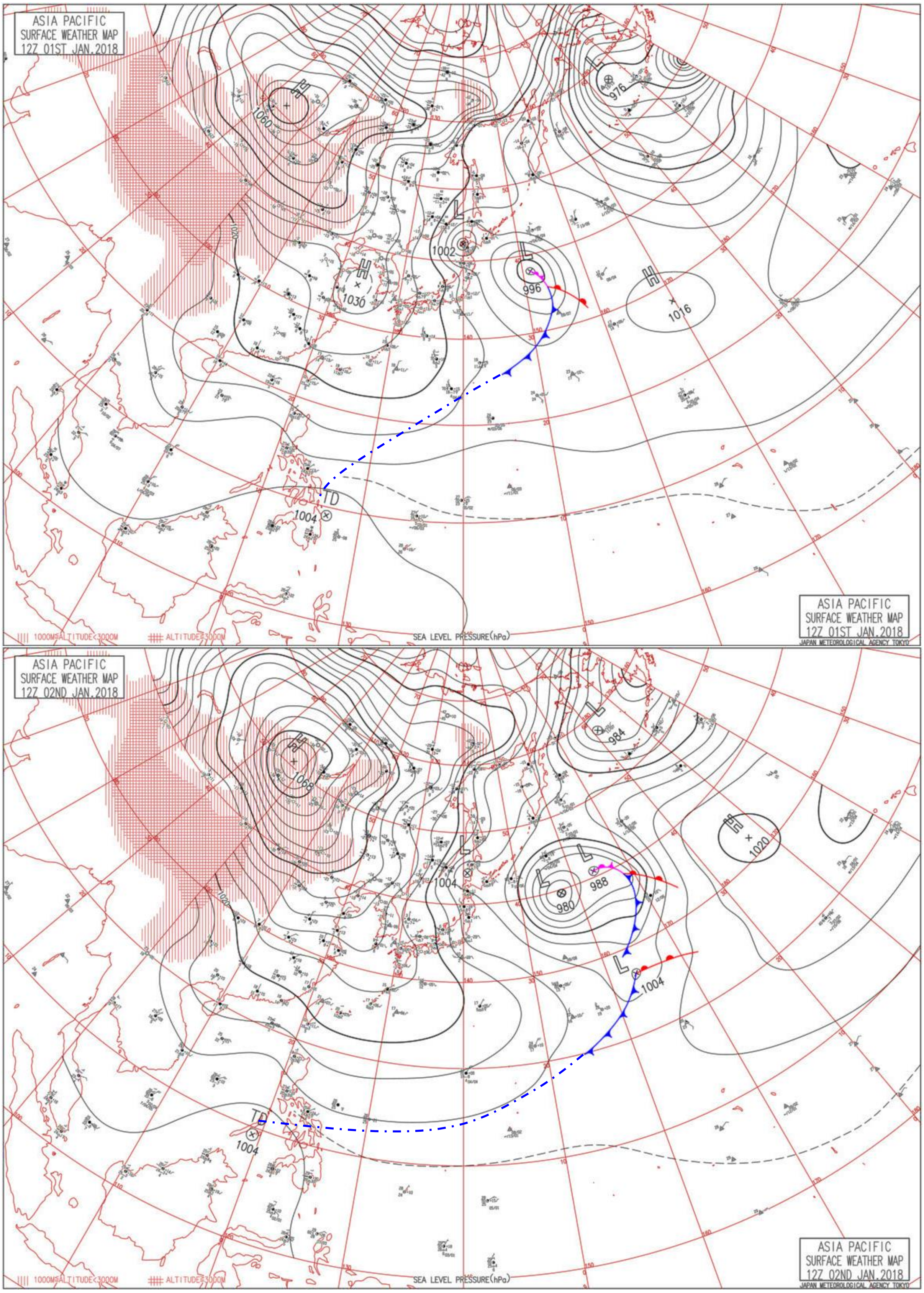


Fig. 4.4. Regional surface chart at 12 UTC on 01 (top) and 02 January (bottom) showing the steep pressure gradient north of 10°N associated with a strong Northeast Monsoon surge and the shear line (blue dash-dot line) extending from the cold front of an extratropical cyclone to the circulation of TC Agaton. Isobars are at 4 hPa intervals.

Tropical Cyclone Basyang (1802 Sanba)

09 to 16 February 2018

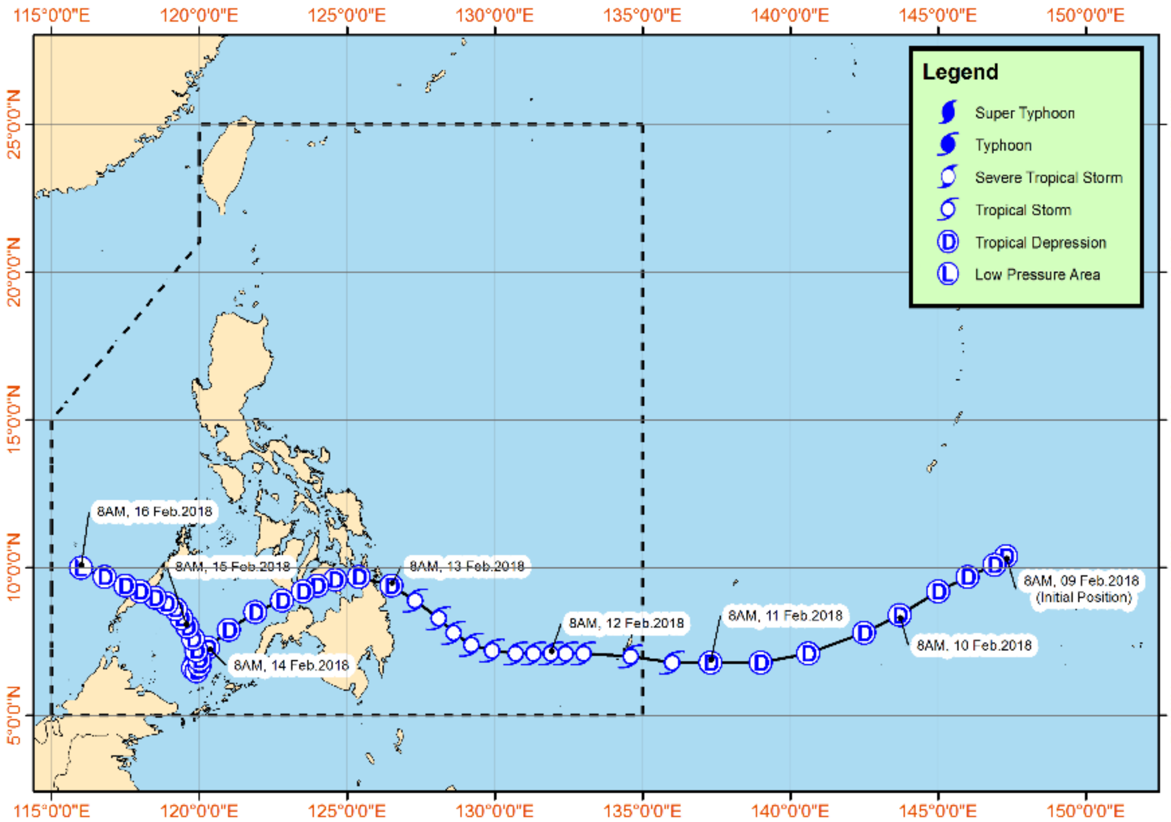


Fig 4.5. PAGASA best track positions and intensities of Tropical Cyclone Basyang

Meteorological History

Tropical Cyclone (TC) Basyang originated from a low pressure area in the vicinity of the Federated States of Micronesia and was first noted as a tropical depression (TD) at 00 UTC on 09 February. Tracking southwestward towards the direction of Palau, Basyang struggled to strengthen. As it shifted to a more westward heading, the system eventually intensity to a tropical storm (TS) at 06 UTC on 11 February. At around 11 UTC of the same day, the TS entered the PAR and crossed the island of Peleliu in the southern portion of Palau.

Within the PAR and prior to landfall, Basyang remained a weak TS. At around 12 UTC on 12 February, the TS started tracking northwestward towards the northeastern portion of Mindanao. It weakened into a TD at 00 UTC of the following day as it approached the Siargao-Bucas Grande group of islands. The center of Basyang crossed the southern portion of Bucas Grande Island and made landfall over Placer, Surigao del Norte between 00 UTC and 03 UTC of the same day. After emerging over the Bohol Sea, Basyang turned southwestward and between 11 UTC and 14 UTC on 13 February, the TD crossed Siquijor and grazed the coasts of Zamboanguita and Siaton in Negros Oriental. Throughout the remainder of the day, the TD moved southwestward over the Sulu Sea where it subsequently looped between 03 UTC and 15 UTC on 14 February. Basyang eventually made its last landfall at around 14 UTC on 15 February over the southern part of Palawan near the boundary of Narra and Sofronio Española. It finally deteriorated into a remnant low at 00 UTC on 16 February over the West Philippine Sea.

Storm duration rainfall estimates revealed that the eastern section of the central Philippines such as Eastern Visayas had disproportionately higher rainfall accumulations compared to areas near or along the observed path of the TC. Accumulated rainfall in excess of 50 mm were estimated over Visayas, northeastern portion of Mindanao, Bicol Region, Zamboanga Peninsula, Marinduque, Romblon, and southern portion of Palawan. Higher accumulations (i.e. 200+ mm) were even observed over Eastern Visayas and the northern portion of Caraga Region. The rainfall maximum region was found to be over Samar Island with estimates in excess of 500 mm. The synoptic station in Borongan, Eastern Samar reported both the highest storm duration (670.2 mm) and the highest 24-hour accumulated (433.0 mm) rainfall during the passage. In general,

The magnitude and spatial distribution of rainfall in both storm duration estimates and gauge observations can be explained by the enhanced moisture convergence along the shear line during strong Northeast Monsoon surges in the presence of the cyclonic circulation of Basyang. Normally, shear lines are associated with predominantly light stratiform rainfall with isolated heavy showers. However, increased convergence in the shear line during TC events result in scattered to widespread heavy rains in the areas affected by the shearline. In particular, the rainfall totals are usually higher in the areas affected by the shear line than in the areas near or along the observed track of the TC.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest peak gust over land:
Guiuan, Eastern Samar (98558) / NNE (30°) 22 m/s / 12 February 2018, 2346 UTC

Lowest sea level pressure over land:
Dauis, Bohol (98644) / 1004.6 hPa / 13 February 2018, 0830 UTC

Highest 24-hour rainfall over land:
Borongan City, Eastern Samar (98553) / 433.0 mm / 13 February 2018
Highest 24-hour rainfall observed by the station since records began in 1951

Highest storm duration rainfall over land:
Borongan City, Eastern Samar (98553) / 670.2 mm / 11-15 February 2018

Summary of Warning Information

Number of domestic products issued: **32**

- Severe Weather Bulletins: **23**
- Tropical Cyclone Updates: **7**
- Tropical Cyclone Advisories: **2**

Number of TC Warning for Shipping issued: **13**

Number of localities under TC Wind Signal (TCWS): **35**

Highest wind signal put into effect: **TCWS #2**

Summary of Casualties and Damage to Property

Number of casualties: **15 dead, 16 injured, and 1 missing**

Combined cost of damage: **PHP 167.955 million**

- Damage to agriculture: **PHP 167.955 million**
- Damage to infrastructure: **Not available**

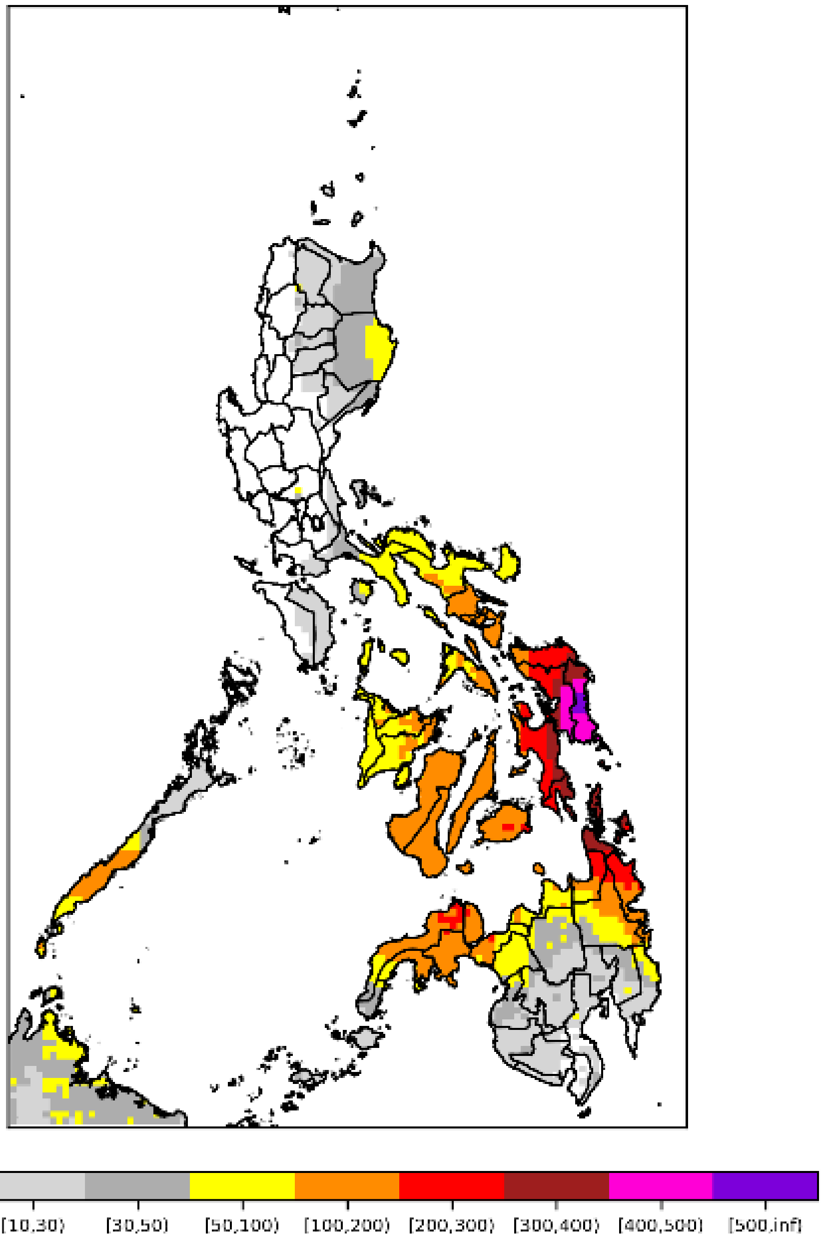


Fig 4.6. Nationwide estimate of storm duration rainfall (mm) for the period of 11-15 February 2018.

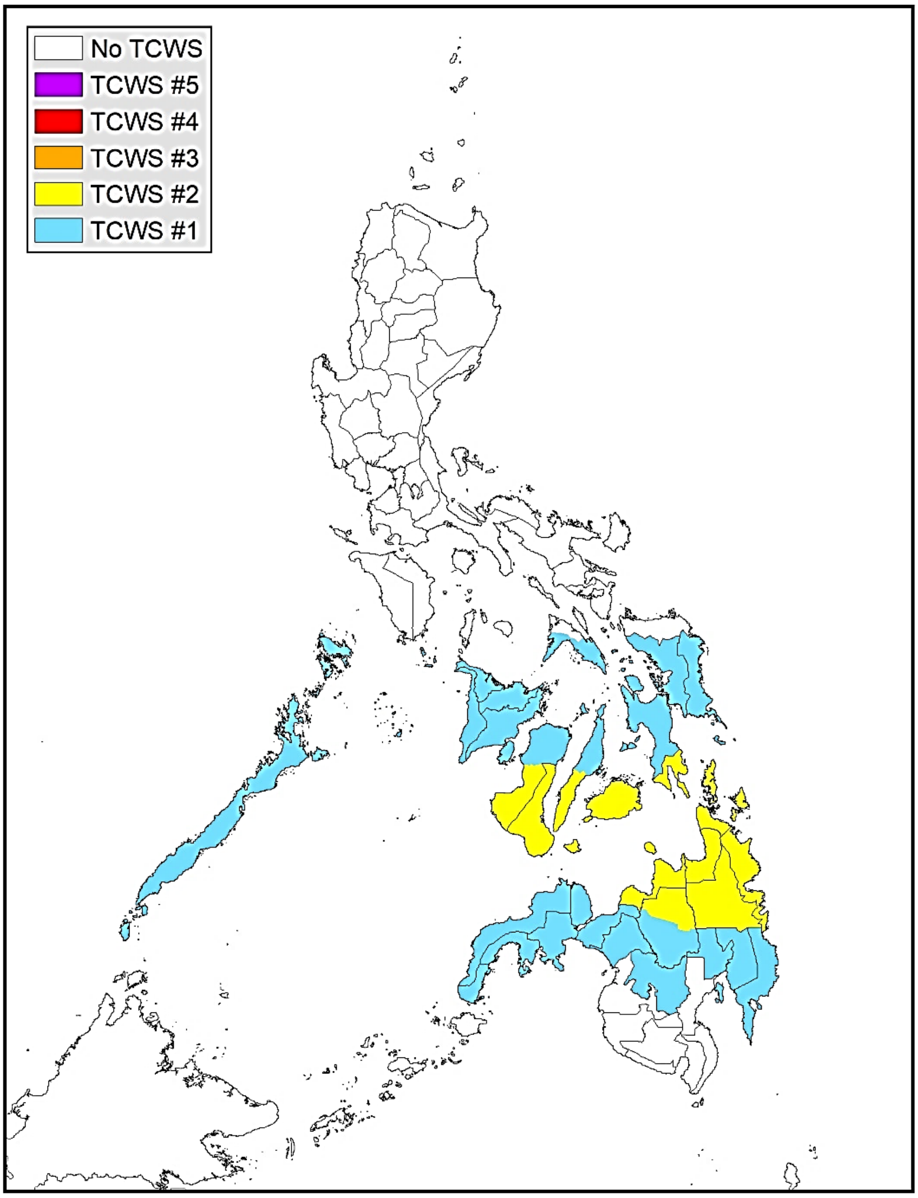


Fig 4.7. Highest wind signal raised by PAGASA during the passage of TC Basyang in each province or subprovincial locality.

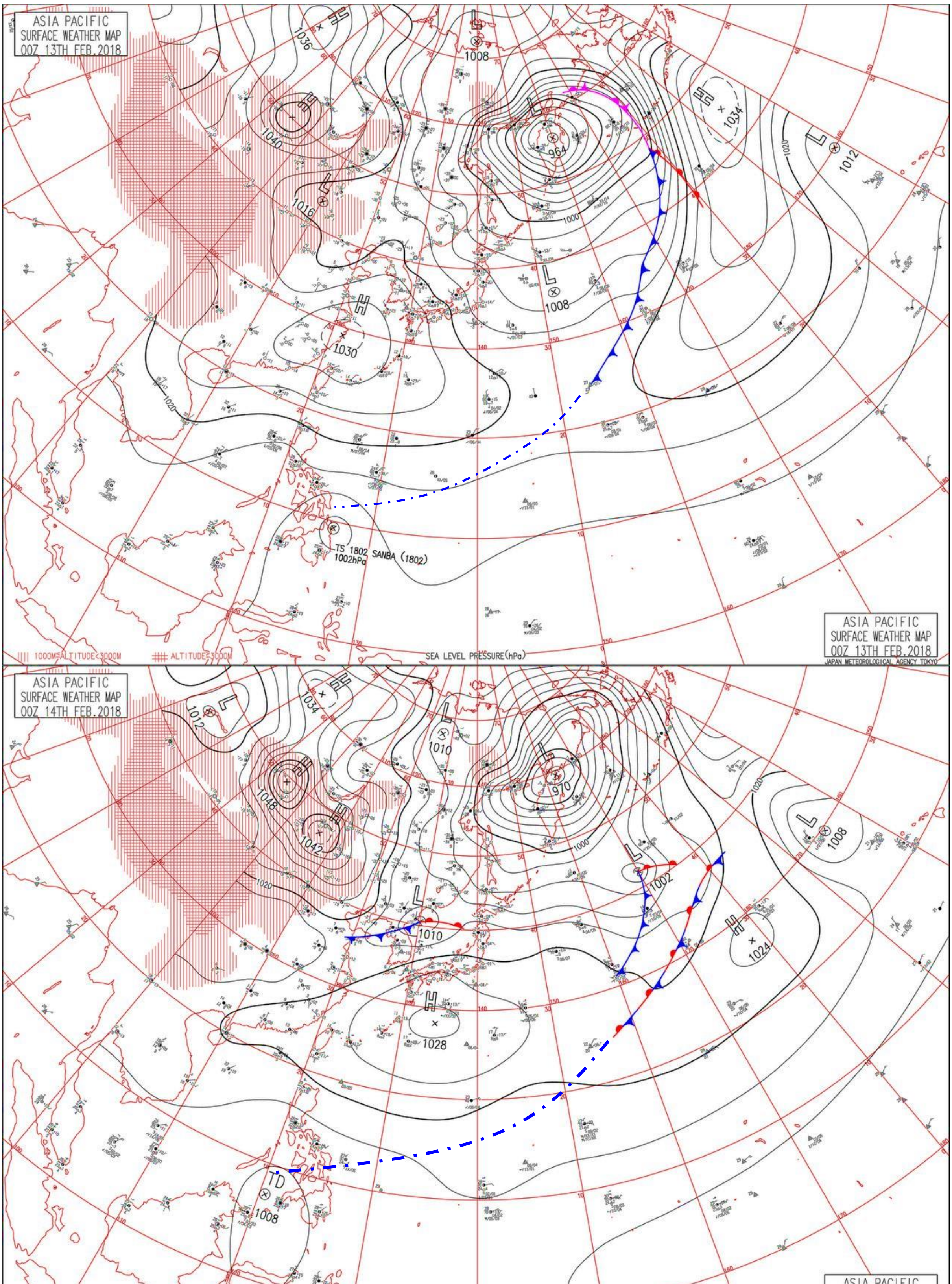


Fig. 4.8. Regional surface chart at 00 UTC on 13 (top) and 14 February (bottom) showing the steep pressure gradient north of 10°N associated with a strong Northeast Monsoon surge and the shear line (blue dash-dot line) extending from the frontal systems in the Northern Pacific to the circulation of TC Basyang. Isobars are at 4 hPa intervals.

Tropical Cyclone Caloy (1803 Jelawat)

24 March to 01 April 2018

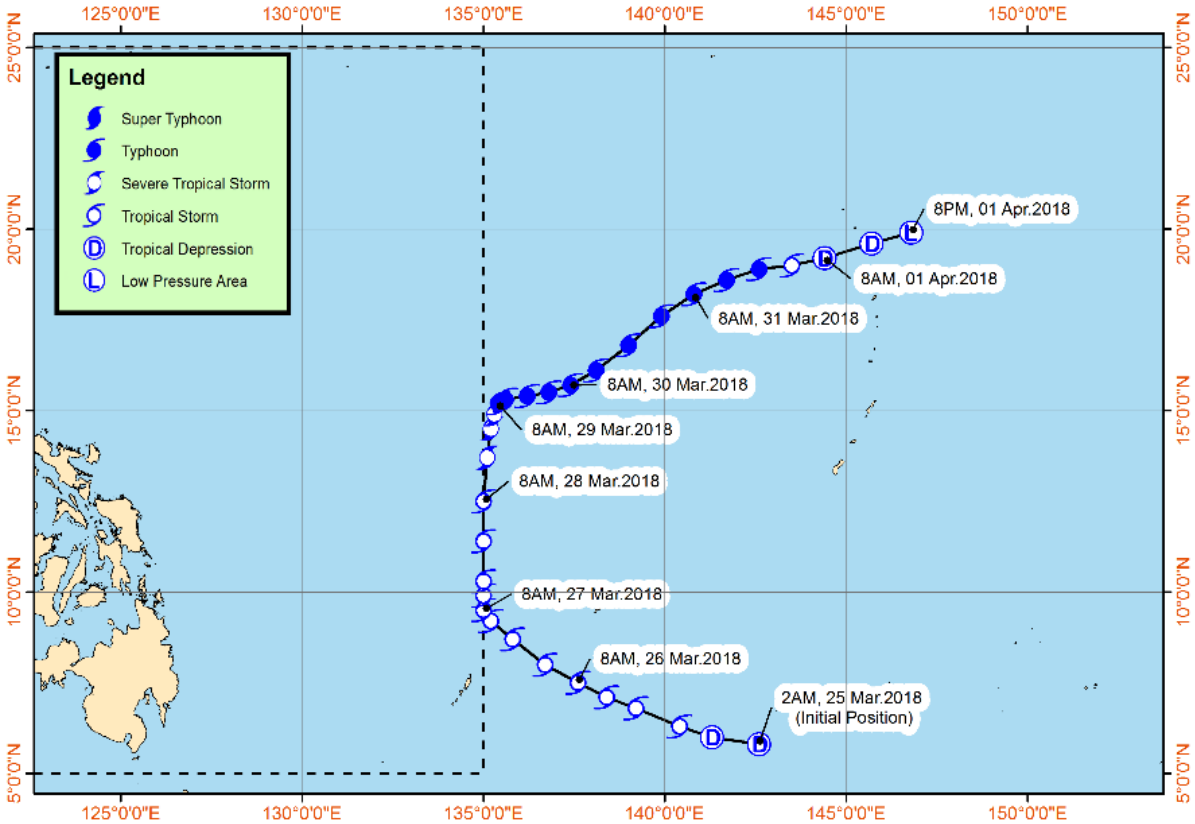


Fig 4.9. PAGASA best track positions and intensities of Tropical Cyclone Caloy.

Meteorological History

Tropical Cyclone (TC) Caloy developed into a tropical depression (TD) at 18 UTC on 24 March while situated south of Yap in the Federated States of Micronesia. Within 12 hours of formation, the TD was upgraded to a tropical storm (TS). At 12 UTC of 26 March, the TS gradually slowed down as it approached the eastern boundary of the Philippine Area of Responsibility (PAR). By the time Caloy entered the PAR at 00 UTC of the following day, it had significantly slowed down and shifted to a more northward heading. Throughout 27 March, Caloy moved northward along the 135°E while maintaining strength. Slight improvement in environmental conditions the following day allowed the TS to slowly intensify. At around 01 UTC on 28 March, Caloy left the PAR and intensified into a severe tropical storm.

Rapid intensification ensued on the evening of the same day, allowing Caloy to reach typhoon (TY) category the following day. Now tracking northeastward over the Philippine Sea west of Northern Mariana Islands, it reached its peak intensity of 105 kt and 920 hPa at 06 UTC on 30 March. This was followed by a period of rapid weakening due to deteriorating conditions. Caloy weakened from a TY to a TD within a period of 12 hours and eventually gained extratropical characteristics at 12 UTC on 01 April. Caloy did not make landfall in any landmass during its occurrence.

Owing to the sheer distance of Caloy from the Philippine landmass, no significant heavy rainfall was observed that is directly or indirectly brought by this TC. The highest storm duration and 24-accumulated rainfall in the country was recorded by the synoptic station in Daet, Camarines Norte (16.7 mm)

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
Daet, Camarines Norte (98440) / 16.7 mm / 27 March 2018

Highest storm duration rainfall over land:
Daet, Camarines Norte (98440) / 16.7 mm / 27-28 March 2018

Summary of Warning Information

Number of domestic products issued: **23**

- Severe Weather Bulletins: **2**
- Tropical Cyclone Updates: **14**
- Tropical Cyclone Advisories: **7**

Number of TC Warning for Shipping issued: **3**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **None**

- Damage to agriculture: **None**
- Damage to infrastructure: **None**

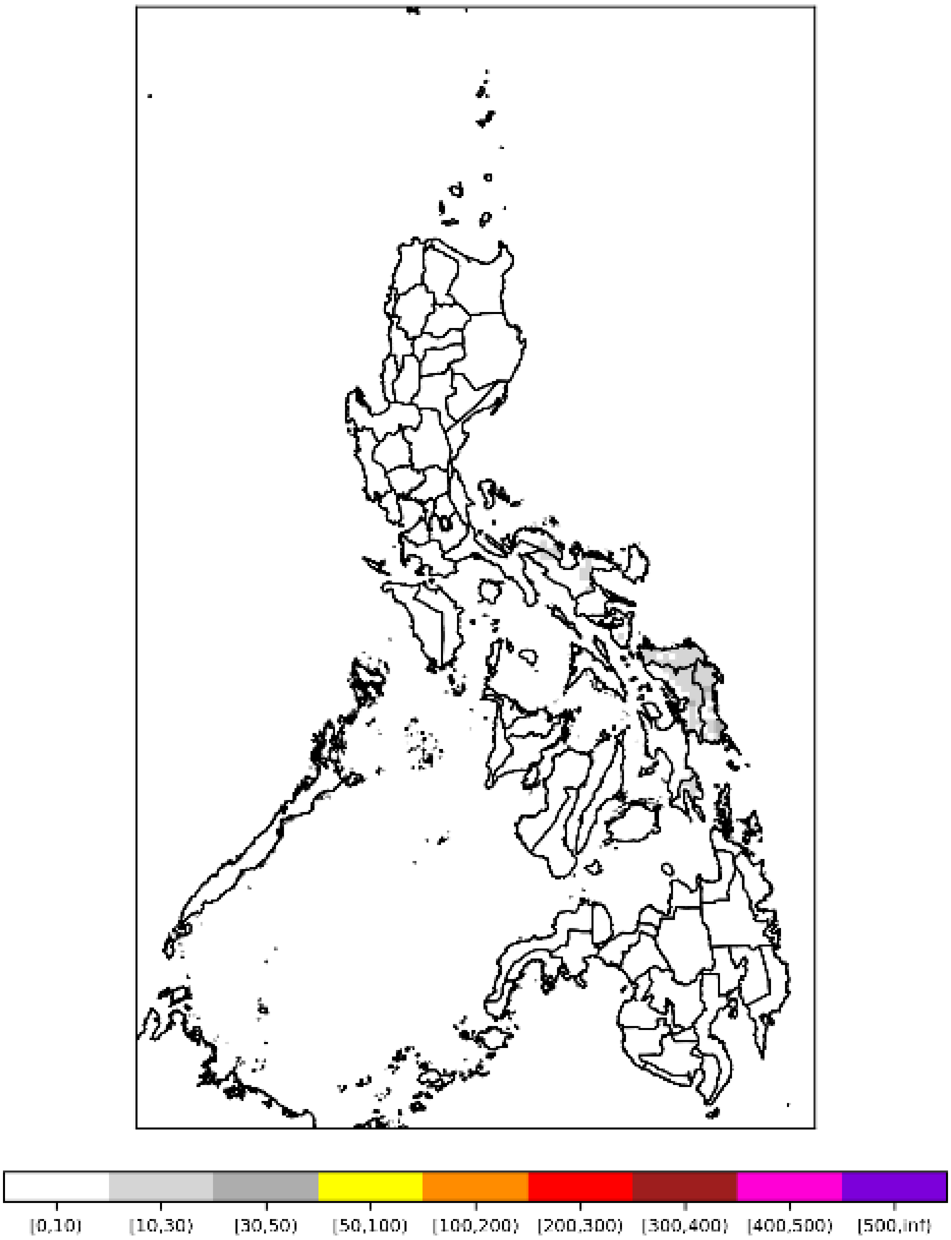


Fig 4.10. Nationwide estimate of storm duration rainfall (mm) for the period of 27-28 March 2018.

Tropical Cyclone Domeng (1805 Maliksi)

05 to 11 June 2018

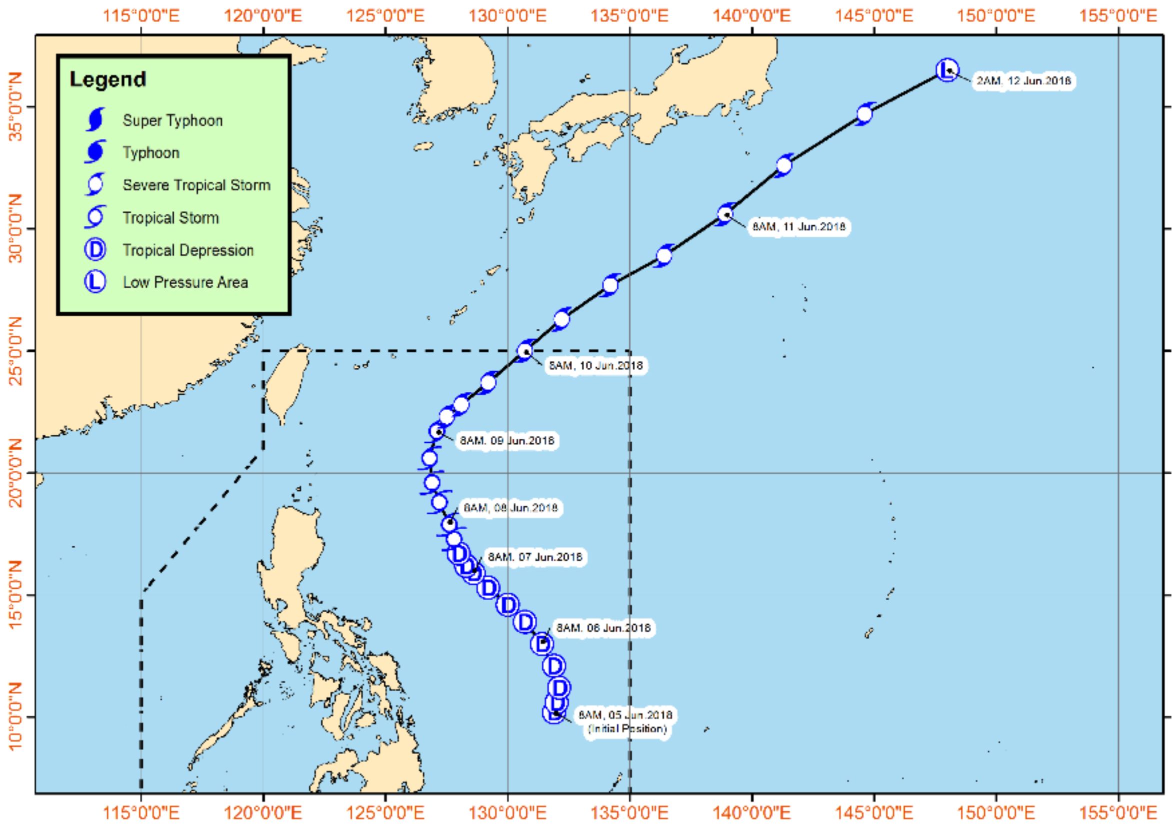


Fig 4.11. PAGASA best track positions and intensities of Tropical Cyclone Domeng

Meteorological History

A low pressure area situated northwest of Palau developed into a tropical depression named Domeng at 00 UTC on 05 June. It developed slowly while tracking generally northwestward over the Philippine Sea, becoming a tropical storm at 18 UTC on 07 June. As Domeng started to recurve to the northeast, it further intensified into a severe tropical storm (STS) at 06 UTC of next day. It reached its peak intensity of 60 kt and 970 hPa as it crossed the northern boundary of the Philippine Area of Responsibility at 01 UTC on 10 June. After attaining peak intensity, Domeng eventually weakened over the course of 2 days as it underwent extratropical transition. The STS evolved into an extratropical cyclone at 18 UTC on 11 June while situated over the sea east of Honshu Island of Japan. Domeng did not make landfall in any country during its occurrence.

The occurrence of Domeng triggered the onset of the Southwest Monsoon in the Philippines. The monsoon southwesterlies enhanced by Domeng dumped monsoon rains in excess of 50 mm over a 5-day period over most parts of Luzon and portions of Western Visayas, and Samar island with higher accumulations (200-300 mm) over the Zambales, Bataan, Metro Manila, Rizal, Cavite, Calamian Islands, and portions of Tarlac, Pampanga, Bulacan, Batangas, Occidental Mindoro. Most of these provinces were situated on the windward side of mountain ranges in mainland Luzon and Mindoro Island. The synoptic station at PAGASA Science Garden in Quezon City reported 370.7 mm accumulated rainfall from 05 to 10 June. This was the highest storm duration rainfall observed by any synoptic station nationwide. The same station recorded the highest 24-hour rainfall during the same period (193.5 mm).

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
Science Garden, Quezon City (98430) / 193.5 mm / 09 June 2018

Highest storm duration rainfall over land:
Science Garden, Quezon City (98430) / 370.7 mm / 05-10 June 2018

Summary of Warning Information

Number of domestic products issued: **24**

- Severe Weather Bulletins: **11**
- Tropical Cyclone Updates: **13**
- Tropical Cyclone Advisories: **0**

Number of TC Warning for Shipping issued: **21**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property

(Effects of monsoon rains continuously enhanced by TC Domeng and Ester)

Number of casualties: **3 dead and 3 injured**

Combined cost of damage: **Not available**

- Damage to agriculture: **Not available**
- Damage to infrastructure: **Not available**

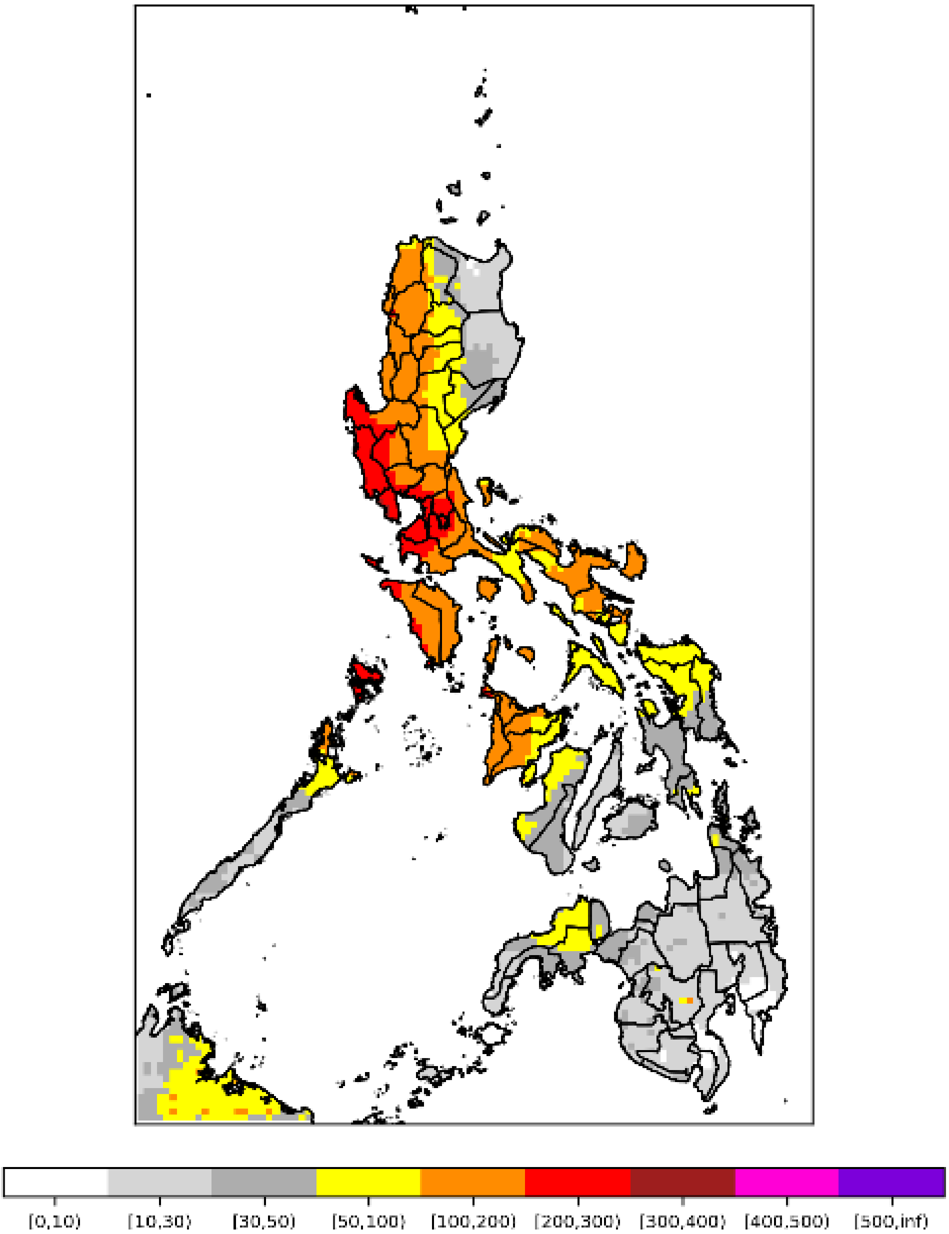


Fig 4.12. Nationwide estimate of storm duration rainfall (mm) for the period of 05-10 June 2018.

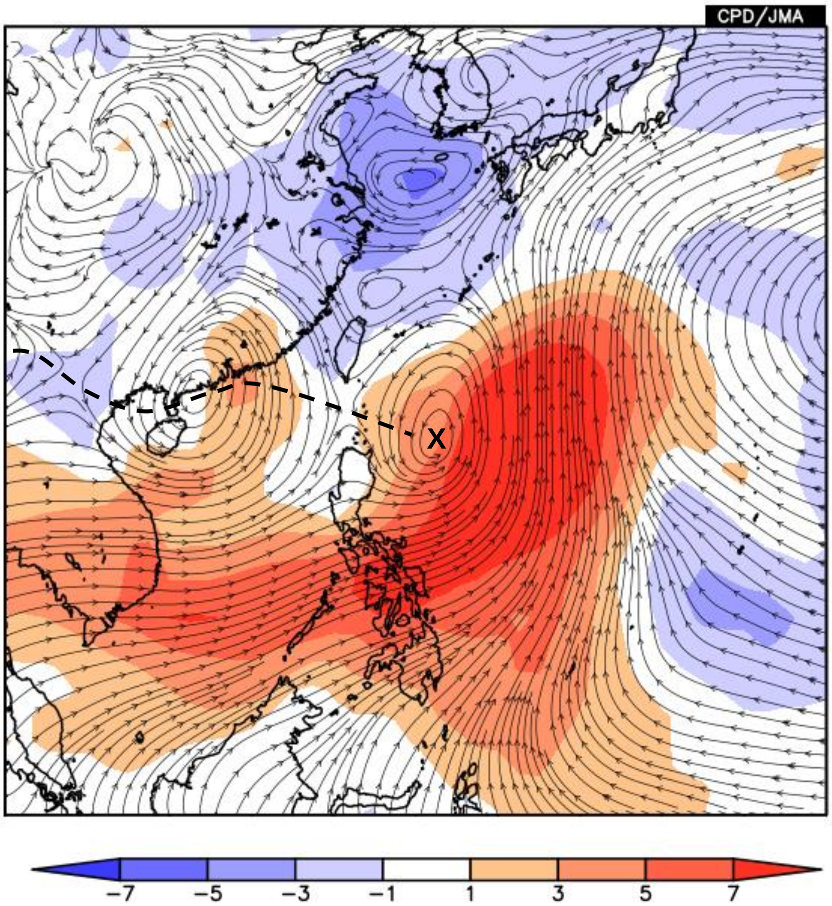


Fig. 4.13. The enhancement of the Southwest Monsoon as seen on the JRA-55 mean 850 hPa streamlines throughout the duration of TC Domeng within the PAR. The shadings indicate mean 850 hPa horizontal wind speed anomaly (m/s). Redder (bluer) shade indicates stronger (weaker) winds than the 1981-2010 normal. The signals of the circulation center of TC Domeng and the active monsoon trough in the mean streamline field are marked by “X” and black dash line respectively.

Tropical Cyclone Ester (1806 Gaemi)

13 to 17 June 2018

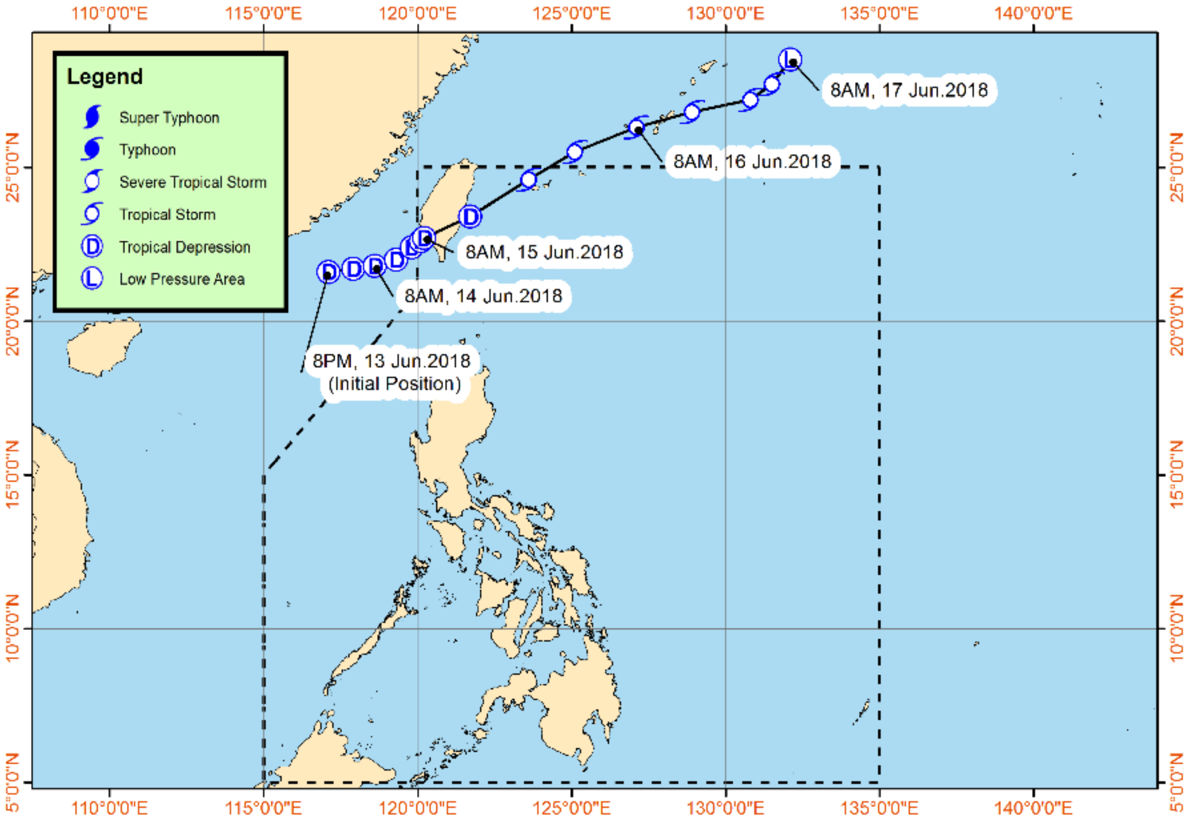


Fig 4.14. PAGASA best track positions and intensities of Tropical Cyclone Ester.

Meteorological History

Tropical Cyclone (TC) Ester originated from a disturbance within the mei-yu front which was first identified by PAGASA as tropical depression at 12 UTC on 13 June. Tracking east-northeastward, it entered the Philippine Area of Responsibility (PAR0 at around 16 UTC on 14 June and made landfall at 00 UTC of the following day over Kaohsiung City in Taiwan. It crossed the Taiwan island after roughly 6 hours and continued tracking east-northeastward towards the southern Ryukyus. After intensifying into a tropical storm near the Yaeyama Islands, Ester left the PAR at around 15 UTC on 15 June. It eventually reached a peak intensity of 40 kt and 990 hPa at 06 UTC on 16 June after crossing Okinawa Island. Ester fully acquired extratropical characteristics and was last tracked by PAGASA at 00 UTC of the following day.

While the rains directly associated with Ester did not affect the country, the storm sustained the strong Southwest Monsoon that was previously enhanced by TC Domeng days prior. Total rainfall from 14 to 15 June over the provinces in Ilocos Region and the western section of Cordillera Administrative Region and Central Luzon reached between 50 and 200 mm. Higher rainfall totals were observed specifically in localities on the windward side of Cordillera Central and Zambales Mountain Range with some areas near the coast (i.e in Zambales, Bataan and Pangasinan) receiving between 200-300 mm. The synoptic station at Subic Bay International Airport in Morong, Bataan received the highest single-day (141.2 mm) and storm duration (270.0 mm) rainfall during the monsoon rains enhanced by Ester.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
Subic Bay International Airport, Morong, Bataan (98426) / 141.2 mm / 14 June 2018

Highest storm duration rainfall over land:
Subic Bay International Airport, Morong, Bataan (98426) / 270.0 mm / 14-15 June 2018

Summary of Warning Information

Number of domestic products issued: **11**

- Severe Weather Bulletins: **5**
- Tropical Cyclone Updates: **6**
- Tropical Cyclone Advisories: **0**

Number of TC Warning for Shipping issued: **6**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property

(Effects of monsoon rains continuously enhanced by TC Domeng and Ester)

Number of casualties: **3 dead and 3 injured**

Combined cost of damage: **Not available**

- Damage to agriculture: **Not available**
- Damage to infrastructure: **Not available**

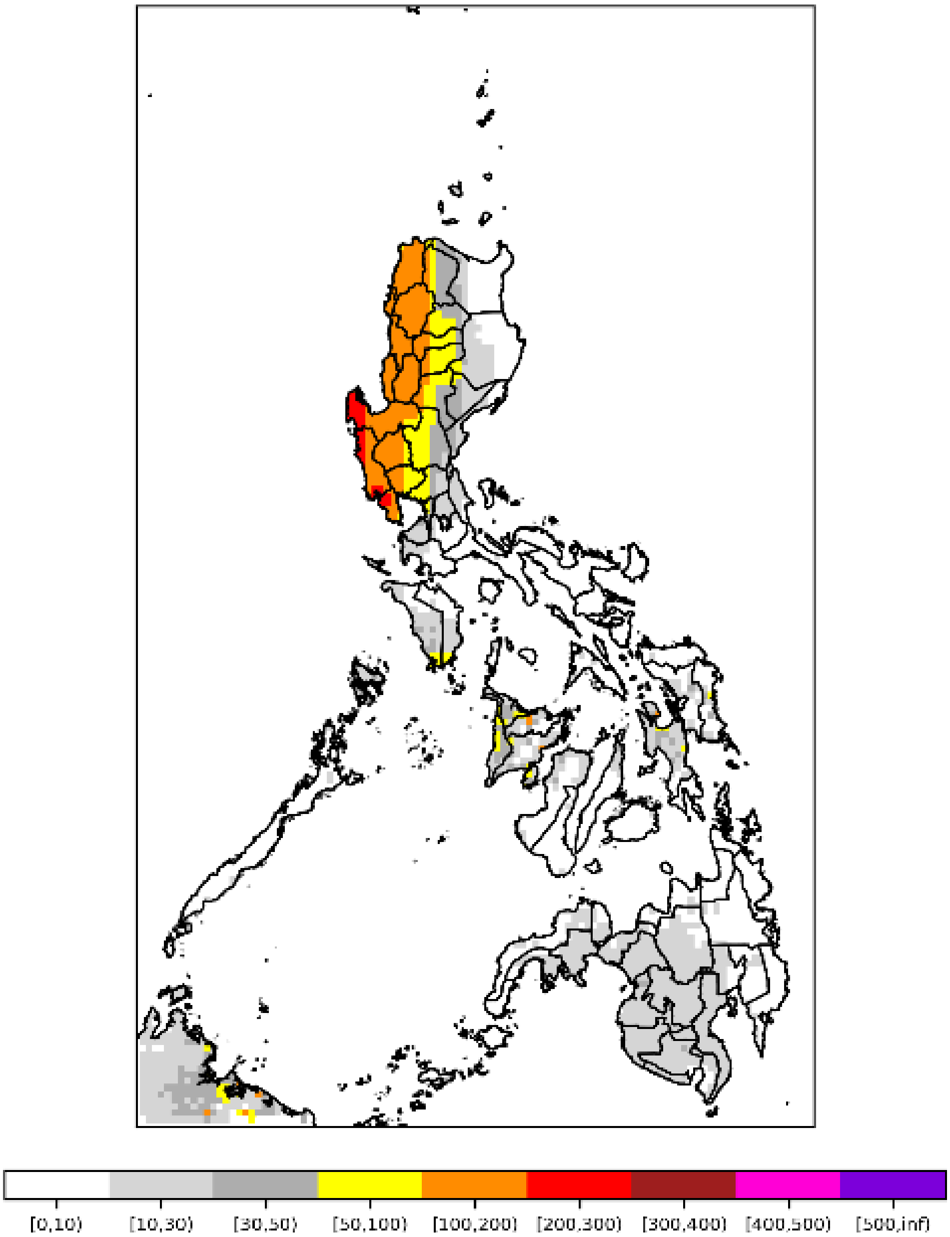


Fig 4.15. Nationwide estimate of storm duration rainfall (mm) for the period of 14-15 June 2018.

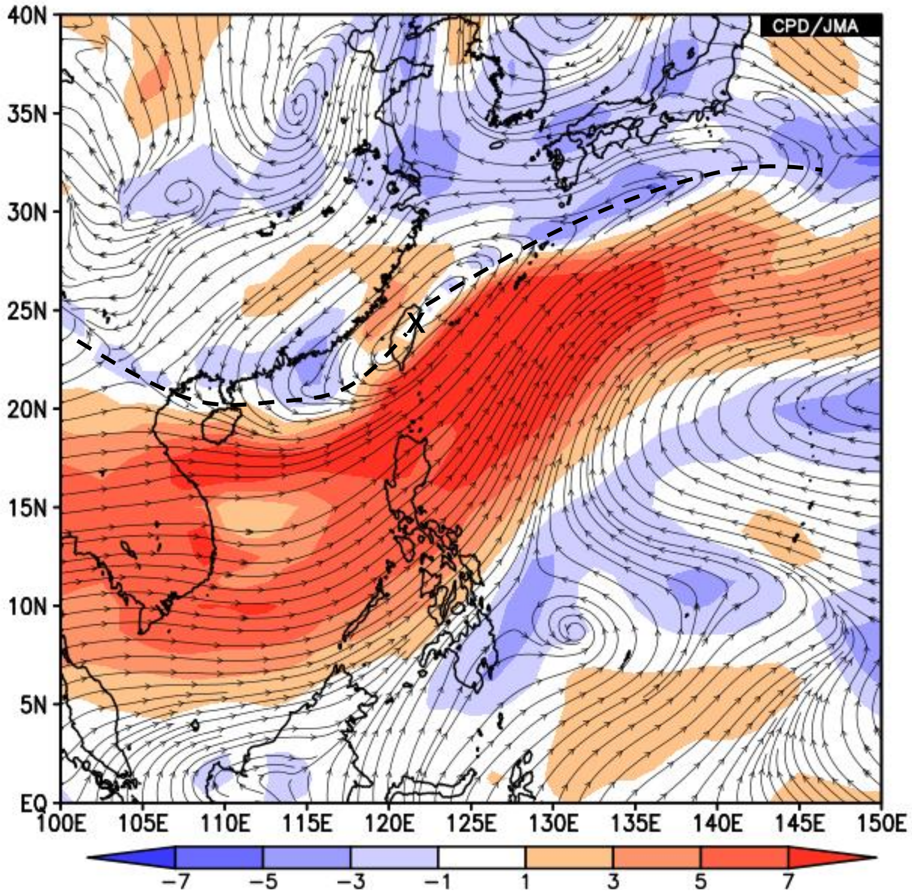


Fig. 4.16. The enhancement of the Southwest Monsoon as seen on the JRA-55 mean 850 hPa streamlines throughout the duration of TC Ester within the PAR. The shadings indicate mean 850 hPa horizontal wind speed anomaly (m/s). Redder (bluer) shade indicates stronger (weaker) winds than the 1981-2010 normal. The signals of the circulation center of TC Ester and the active monsoon trough in the mean streamline field are marked by "X".

Tropical Cyclone Florita (1807 Prapiroon)

28 June to 04 July 2018

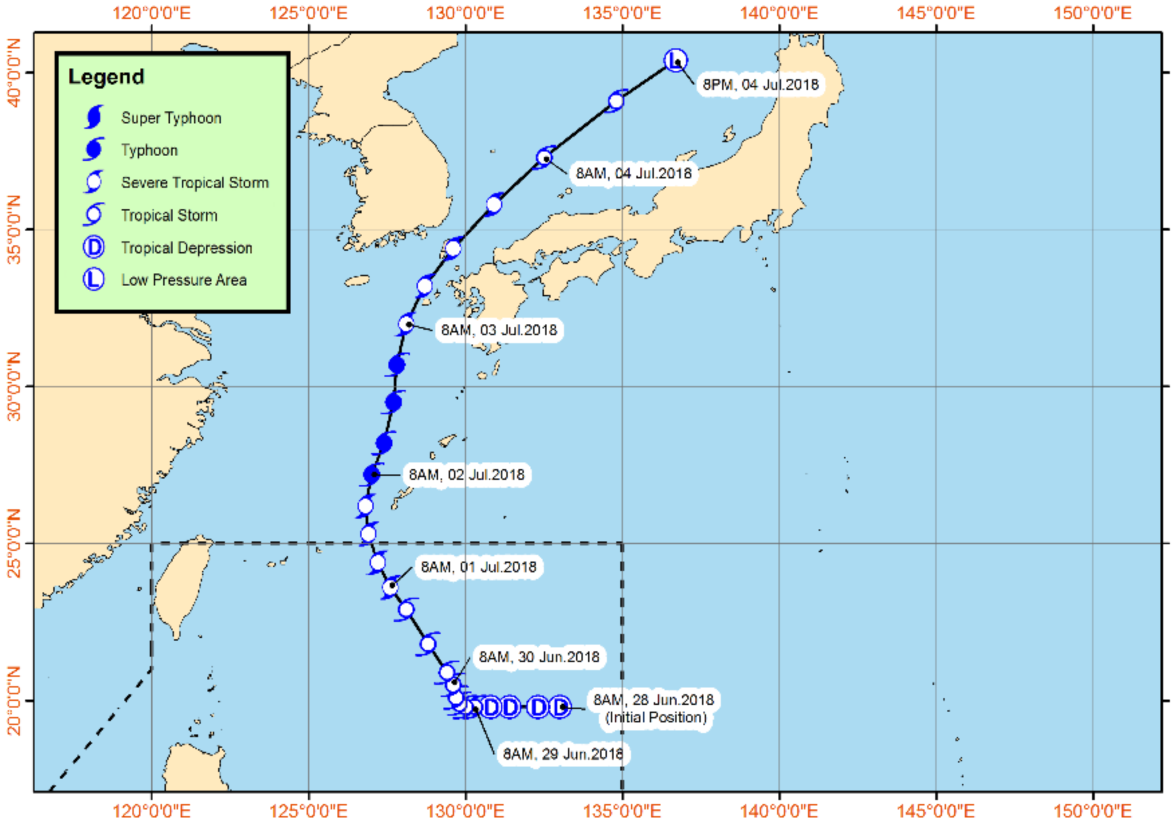


Fig 4.17. PAGASA best track positions and intensities of Tropical Cyclone Florita.

Meteorological History

The sixth tropical cyclone (TC) of the year, Florita, developed from an area of low pressure situated more than 1000 km east of Extreme Northern Luzon at 00 UTC on 28 June. Tracking westward, it was upgraded to a tropical storm (TS) the following day. At around 12 UTC on 29 June, the TS shifted to a more northwestward heading towards the Ryukyu Islands. Florita further intensified into a severe tropical storm (STS) at 00 UTC on 01 July and left the Philippine Area of Responsibility at 11 UTC of the same day.

As the STS started to recurve towards the East China Sea at around 18 UTC on 01 July, its center crossed the island of Kume (part of the Ryukyu Islands). After 6 hours, Florita intensified into a typhoon and reached its peak intensity of 65 kt and 965 hPa. It began moving more northeastward at around 18 UTC on 02 July as it approached the Tsushima Strait. While tracking the Tsushima Strait, Florita center passed closely to the Goto Islands and Tsushima Island between 03 UTC and 12 UTC on 03 July. Throughout 03 and 04 July, a weakening trend was observed as the TC underwent an extratropical transition. Florita evolved into an extratropical cyclone at 12 UTC on 04 July.

Florita did not enhance the Southwest Monsoon, resulting in the absence of widespread monsoon rains over the western section of Luzon and Visayas that characterized the two TCs that preceded it. The highest 24-hour and storm duration rainfall in the country were recorded in Tacloban City (62.4 mm) and Iba, Zambales (69.6 mm) respectively.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
Tacloban City, Leyte (98550) / 62.4 mm / 29 June 2018

Highest storm duration rainfall over land:
Iba, Zambales (98324) / 69.6 mm / 28 June-01 July 2018

Summary of Warning Information

Number of domestic products issued: **17**

- Severe Weather Bulletins: **7**
- Tropical Cyclone Updates: **10**
- Tropical Cyclone Advisories: **0**

Number of TC Warning for Shipping issued: **11**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **None**

- Damage to agriculture: **None**
- Damage to infrastructure: **None**

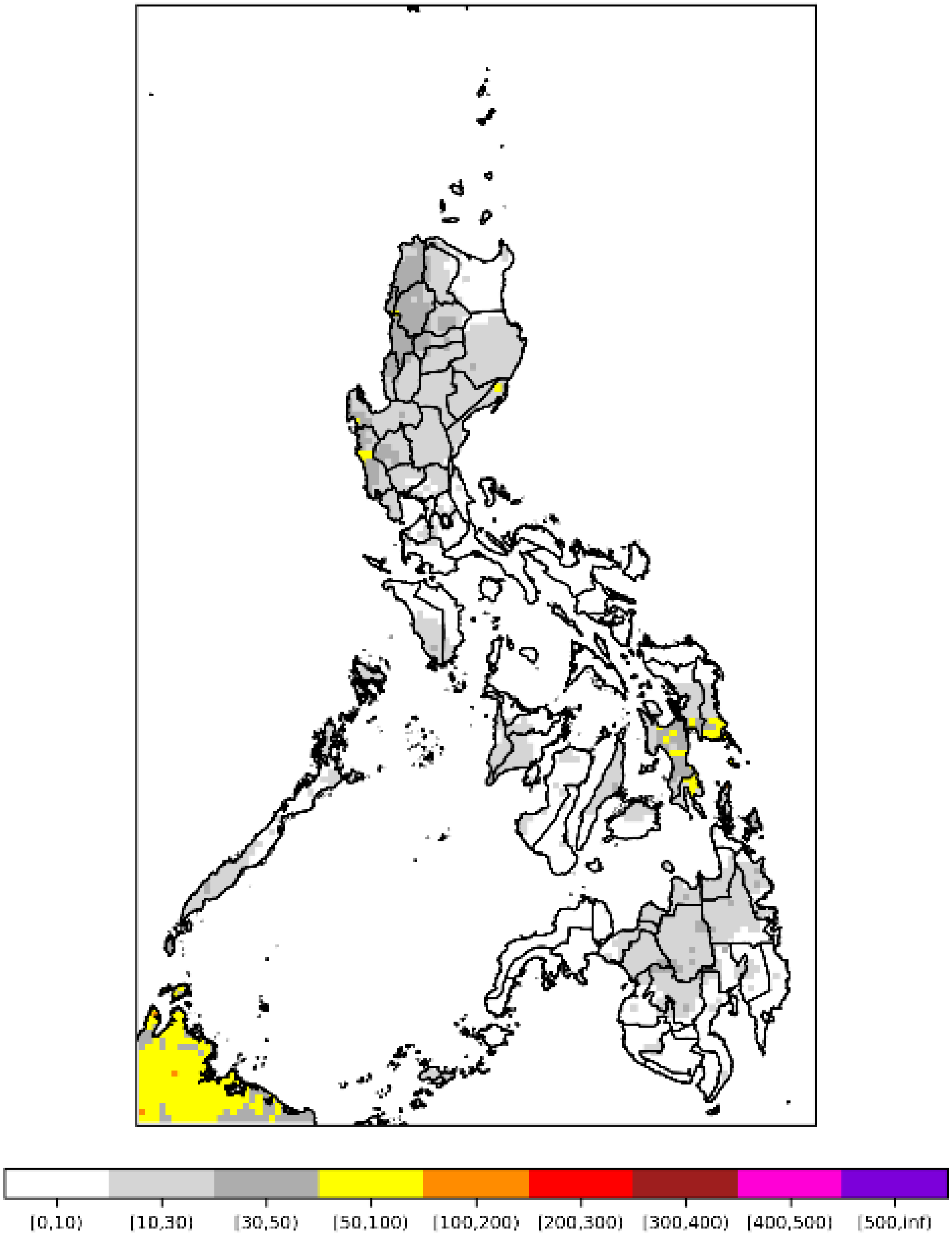


Fig 4.18. Nationwide estimate of storm duration rainfall (mm) for the period of 28 June-01 July 2018.

Tropical Cyclone Gardo (1808 Maria)

03 to 12 July 2018

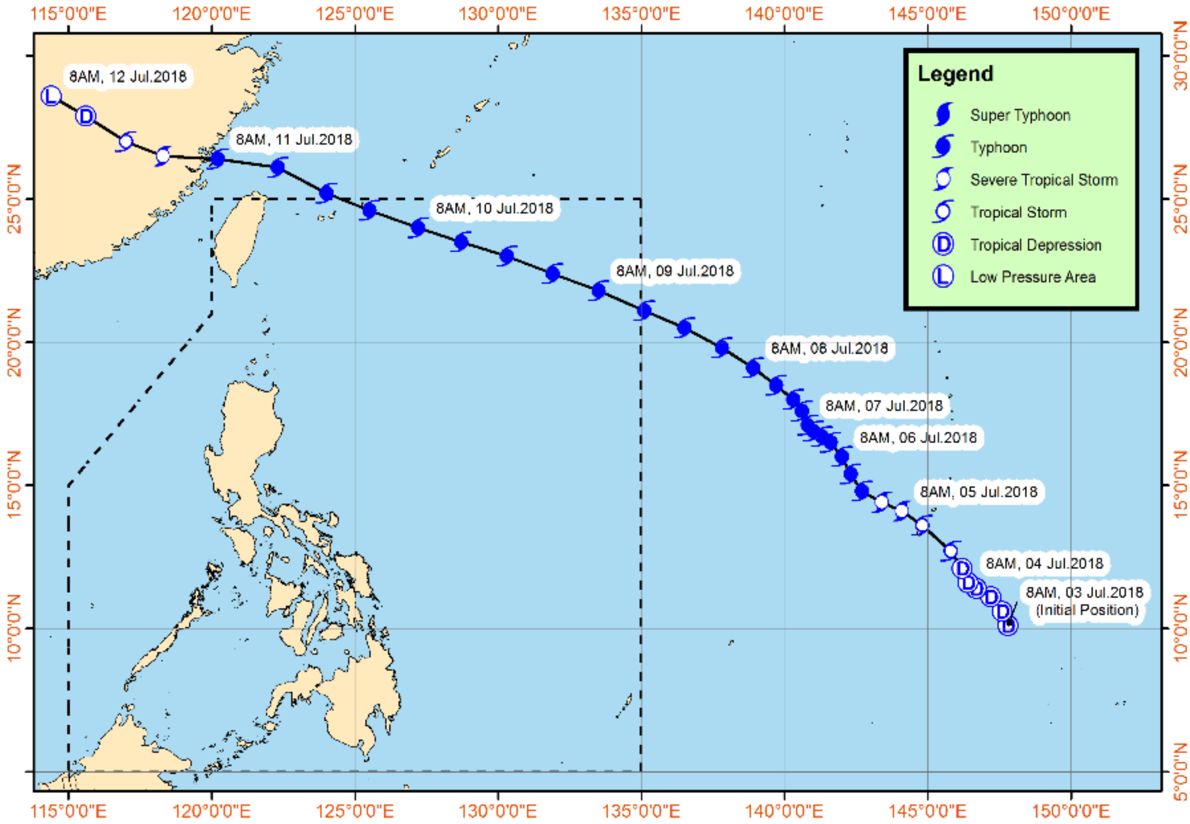


Fig 4.19. PAGASA best track positions and intensities (a) and storm duration rainfall estimates (b) of Tropical Cyclone Gardo.

Meteorological History

The first tropical cyclone (TC) in 2018 to reach typhoon category within the PAR, Gardo, was first tracked by PAGASA as a tropical depression situated southeast of Guam at 00 UTC of 03 July Moving northwestward towards Guam, it intensified into a tropical storm at 12 UTC on 04 July and started a period of rapid intensification. The circulation center of this TC crossed the northern portion of Guam shortly before 18 UTC on 04 July. By 00 UTC of the following day, Gardo, now a severe tropical storm (STS), had already intensified by 20 kt over the last 24 hours.

As the STS tracked northwestward and started slowing down, its rate of intensification continued to increase. At 12 UTC on 05 July, Gardo was upgraded to typhoon (TY) and at 00 UTC of the following day, its intensity reached 100 kt, equivalent to a 50-kt increase in maximum sustained winds in a span of 24 hours. The TY slightly weakened to 95 kt at 18 UTC of the same day due to an eyewall replacement cycle ERC. However, as soon as the cycle completed, the TY re-intensified, eventually reaching its peak intensity of 105 kt and 915 hPa at 12 UTC on 08 July. During this period, Gardo slightly accelerated and shifted to a more west-northwestward heading. It entered the Philippine Area of Responsibility (PAR) at peak intensity at around 19 UTC of the same day.

Within the PAR, Gardo maintained a consistent speed and heading, moving west-northwestward towards the Miyako Islands in the southern Ryukyus. However, owing to cooler sea surface temperatures, a slight weakening was observed. The TY grazed the islands of the Miyako group between 06 and 09 UTC on 10 July and left the PAR at around 11 UTC. By the time it left the PAR, Gardo had weakened to 85 kt. Throughout the remainder of 10 July, the TY continued tracking west-northwestward over the sea just north of Taiwan. Gardo made landfall over Huangqi Peninsula in

Fuzhou City, Fujian, China at around 09 UTC on 11 July. Following a rapid weakening due to land interaction, Gardo became a remnant low at 00 UTC on 12 July.

Over the Philippines, the presence of an active monsoon trough extending from the mainland Southeast Asia brought rains over the western portions of the Luzon. However, the passage of Gardo over the northern portion of the Philippine Sea did not result in a significant enhancement in the monsoon activity. Rainfall totals in excess of 50 mm were estimated from 09 to 10 July over the areas Zambales, Bataan, western portion of Pangasinan, southern portion of Mindoro Provinces, Calamian Islands, and Tablas Island of Romblon with isolated areas in southern Zambales receiving between 100 and 200 mm. The highest 24-hour accumulated rainfall during the passage period was observed in San Jose, Occidental Mindoro (84.5 mm) while the highest storm duration rainfall was recorded in Iba, Zambales (128.7 mm).

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
San Jose, Occidental Mindoro (98531) / 84.5 mm / 10 July 2018

Highest storm duration rainfall over land:
Iba, Zambales (98324) / 128.7 mm / 09-10 July 2018

Summary of Warning Information

Number of domestic products issued: **29**

- Severe Weather Bulletins: **5**
- Tropical Cyclone Updates: **18**
- Tropical Cyclone Advisories: **6**

Number of TC Warning for Shipping issued: **8**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property

(Effects of monsoon rains slightly enhanced by TC Gardo)

Number of casualties: **None**

Combined cost of damage: **None**

- Damage to agriculture: **Not available**
- Damage to infrastructure: **Not available**

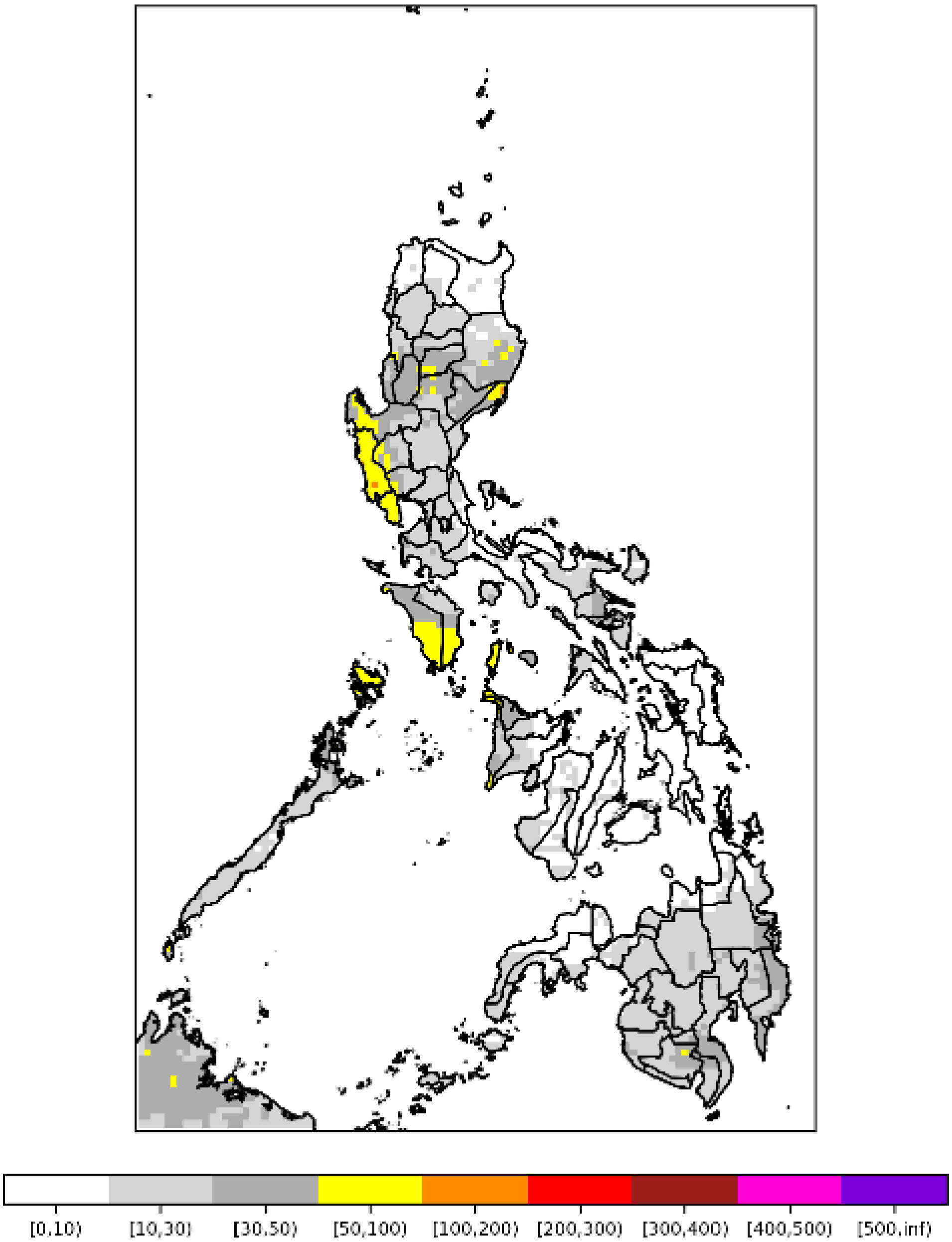


Fig 4.20. Nationwide estimate of storm duration rainfall (mm) for the period of 09-10 July 2018.

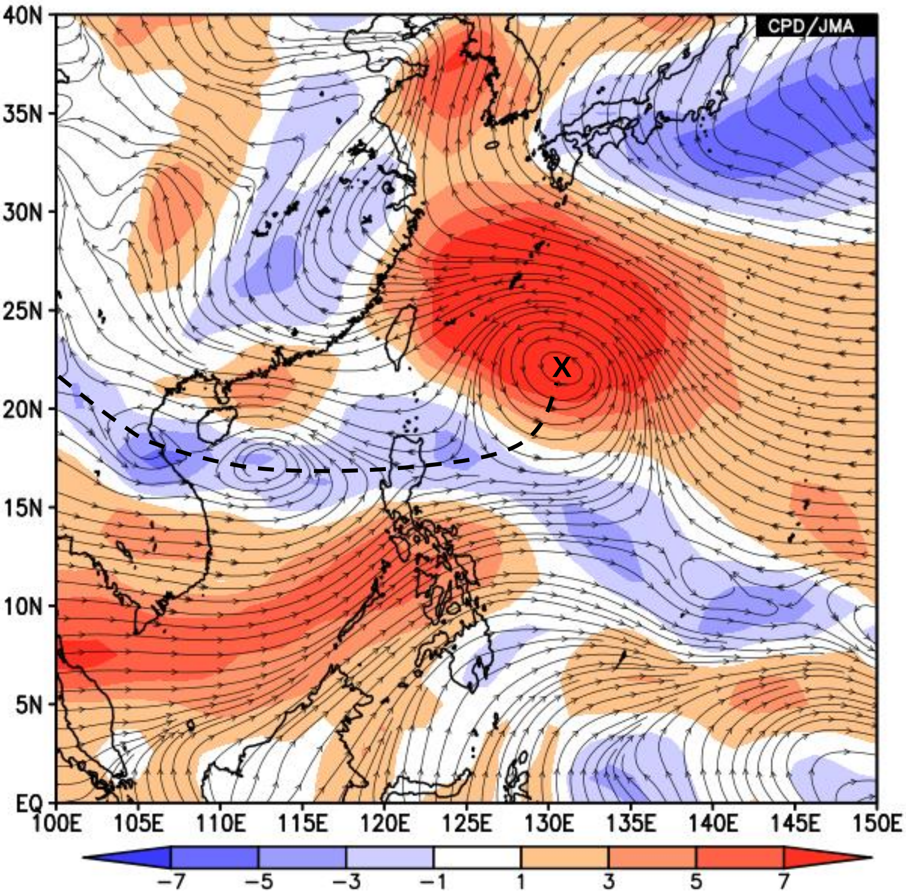


Fig. 4.21. The enhancement of the Southwest Monsoon as seen on the JRA-55 mean 850 hPa streamlines throughout the duration of TC Gardo within the PAR. The shadings indicate mean 850 hPa horizontal wind speed anomaly (m/s). Redder (bluer) shade indicates stronger (weaker) winds than the 1981-2010 normal. The signals of the circulation center of TC Gardo and the monsoon trough in the mean streamline field are marked by “X” and black dash line respectively.

Tropical Cyclone Henry (1809 Son-Tihn)

15 to 24 July 2018

Fig 4.22. PAGASA best track positions and intensities of Tropical Cyclone Henry.

Meteorological History

An area of low pressure situated east of Extreme Northern Luzon developed into a tropical depression (TD) named Henry at 12 UTC on 15 July. Slowly intensifying while moving westwards towards the Babuyan Channel, it crossed or grazed several islands in the Babuyan group (Camiguin, Pamuktan, Fuga, Irao, and Dalupiri) between 13 UTC and 17 UTC on 16 July. The TD eventually intensified into a tropical storm (TS) and left the Philippine Area of Responsibility at 00 UTC on 17 July. Throughout the day, Henry continued tracking westward fast over the northern portion of West Philippine Sea. After peaking at 40 kt and 992 hPa at 12 UTC on 17 July, the TS made landfall over Hainan Island on southern portion of China at around 21 UTC of the same day. This resulted in a slight weakening but the intensity remained within the TS category. Later that day, Henry emerged over the Gulf of Tonkin where it managed to re-intensify. The TS eventually made landfall over Nghệ An Province in the northern portion of Vietnam just before 18 UTC on 18 July. Henry weakened into a TD after 6 hours.

Through 19 and 20 July, the TD curved northwards and eastwards over the northern portions of Vietnam and Laos before turning southeastwards towards the Gulf of Tonkin on 21 July. On the following da°y, the Henry turned northeastward and crossed Hainan Island and through 23 and 24 July, curved northward over the Leizhou Peninsula in Guangdong Province, China. At 06 UTC on 24 July, the TD weakened into a remnant low and was last tracked by PAGASA over the Guangxi Zhuang Autonomous Region in southern portion of China.

The passage of Henry in Extreme Northern Luzon resulted in rainfall totals of 50-100 mm over Ilocos Region, western portion of the Cordillera Administrative Region, Batanes, and the northern portion of Cagayan. However, the higher rainfall totals were estimated in areas that were drenched by the monsoon rains associated with the enhancement of the Southwest Monsoon. In particular, between 50 and 200 mm were estimated over Metro Manila, Mindoro Provinces, northern portion of Palawan, and western portion of Central Luzon and CALABARZON. The stations with the highest storm duration (189.5 mm at Subic Bay International Airport) and 24-hour (125.0 mm at Iba, Zambales) rainfall were both situated in the aforementioned areas affected by the monsoon rains. In comparison, the storm duration rainfall reported by the stations near the observed track of Henry ranged from 47.4 mm (Aparri, Cagayan) to 59.9 mm (Sinait, Ilocos Sur).

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest peak gust over land:
Calayan, Cagayan (98133) / NE (040°) 24 m/s / 16 July 2018, 1600 UTC
Basco, Batanes (98134) / E (100°) 24 m/s / 15 July 2018, 1550 UTC

Lowest sea level pressure over land:
Calayan, Cagayan (98133) / 994.7 hPa / 16 July 2018, 1600 UTC

Highest 24-hour rainfall over land:
Iba, Zambales (98324) / 125.0 mm / 16 July 2018

Highest storm duration rainfall over land:
Subic Bay International Airport, Morong, Bataan (98426) / 189.5 mm / 15-16 July 2018

Summary of Warning Information

Number of domestic products issued: **18**

- Severe Weather Bulletins: **13**
- Tropical Cyclone Updates: **5**
- Tropical Cyclone Advisories: **0**

Number of TC Warning for Shipping issued: **7**

Number of localities under TC Wind Signal (TCWS): **4**

Highest wind signal put into effect: **TCWS #1**

Summary of Casualties and Damage to Property

(Direct effects of TC Henry and Josie and effects of monsoon rains continuously enhanced by TC Henry, Inday, and Josie)

Number of casualties: **16 dead, 1 injured, and 1 missing**

Combined cost of damage: **PHP 4,660.611 million**

- Damage to agriculture: **PHP 3,279.640 million**
- Damage to infrastructure: **PHP 1,380.971 million**

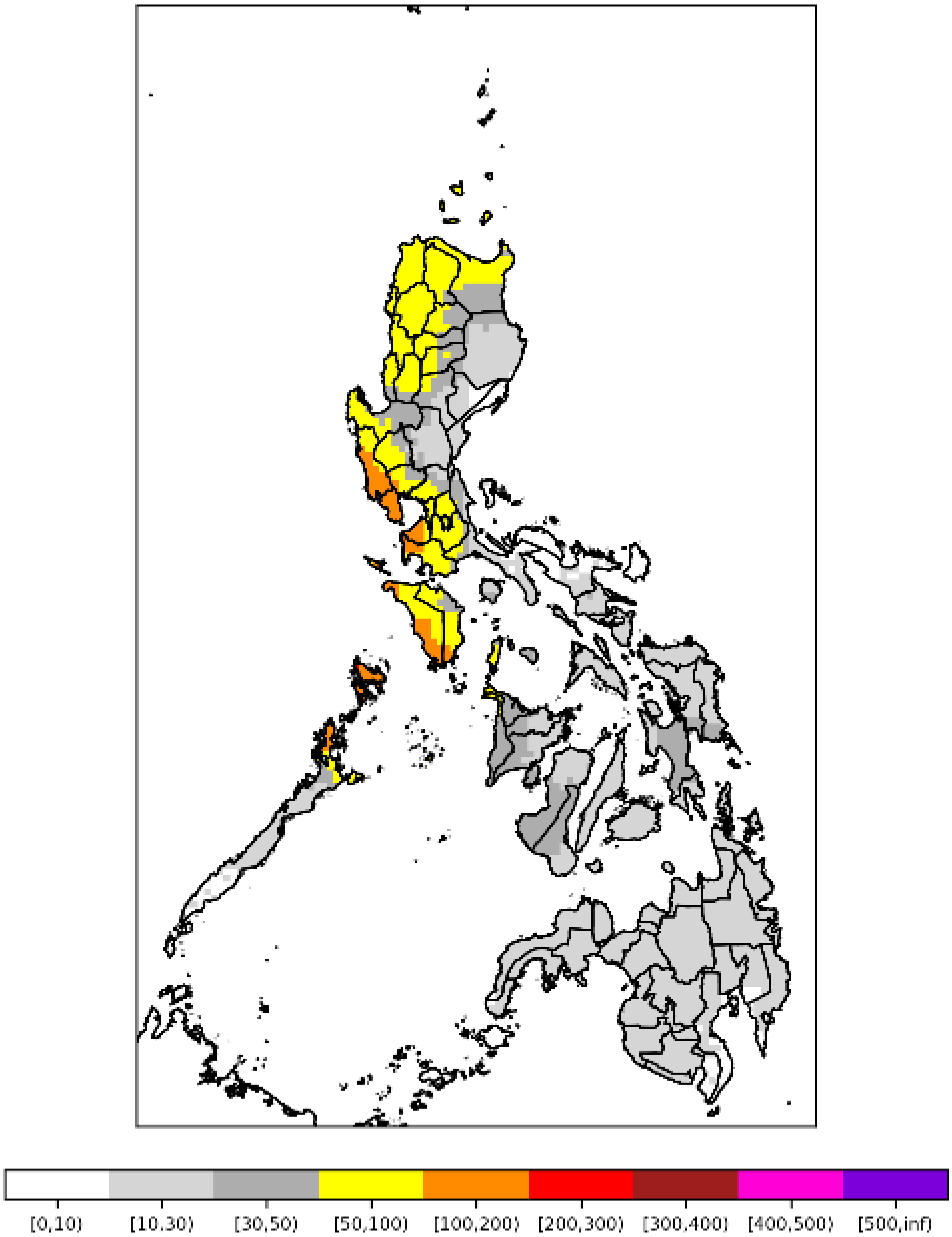


Fig 4.23. Nationwide estimate of storm duration rainfall (mm) for the period of 15-16 July 2018.

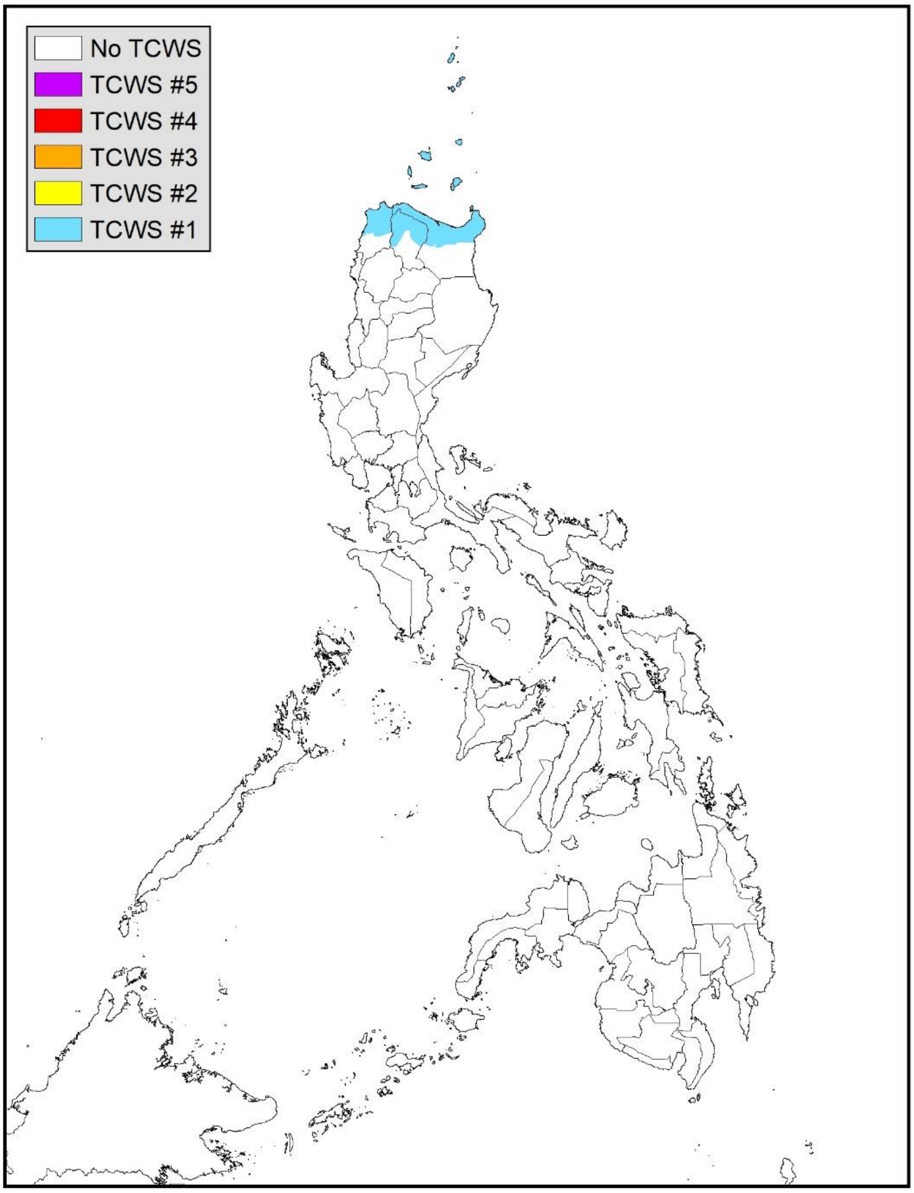


Fig 4.24. Highest wind signal raised by PAGASA during the passage of TC Henry in each province or subprovincial locality.

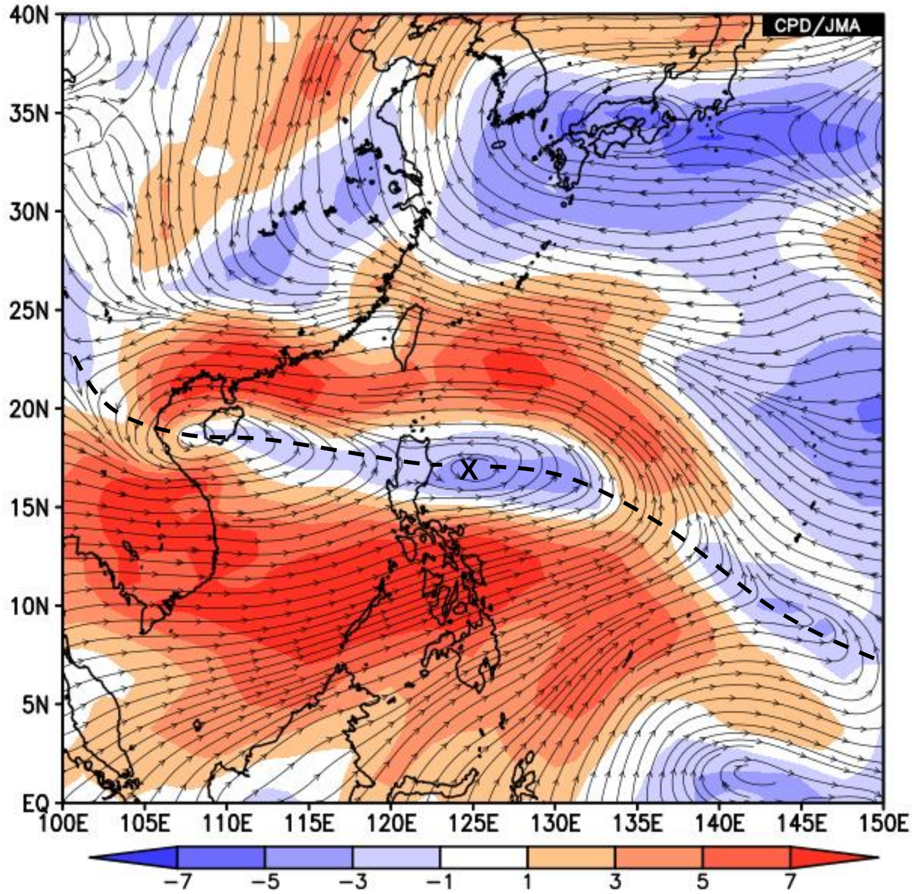


Fig. 4.25. The enhancement of the Southwest Monsoon as seen on the JRA-55 mean 850 hPa streamlines throughout the duration of TC Henry within the PAR. The shadings indicate mean 850 hPa horizontal wind speed anomaly (m/s). Redder (bluer) shade indicates stronger (weaker) winds than the 1981-2010 normal. The signals of the circulation center of TC Henry and the active monsoon trough in the mean streamline field are marked by "X" and black dash line respectively.

Tropical Cyclone Inday (1810 Ampil)

17 to 24 July 2018

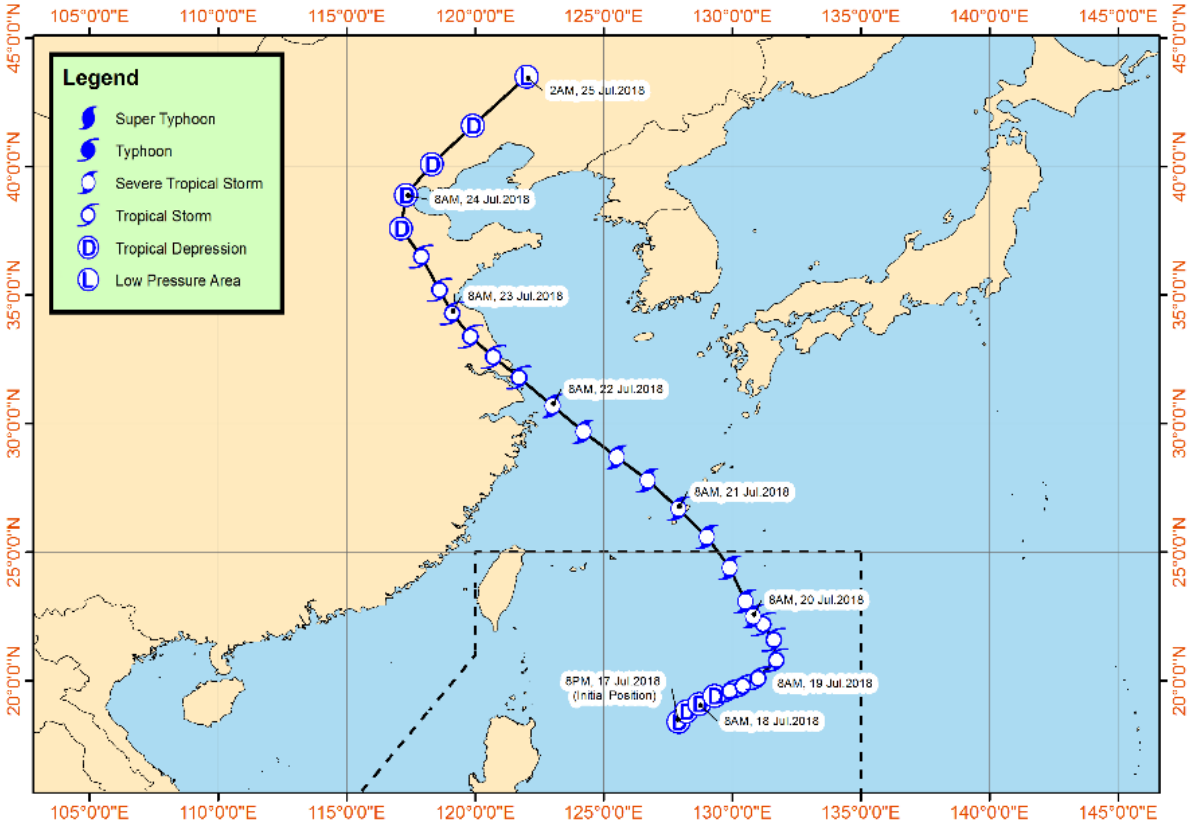


Fig 4.26. PAGASA best track positions and intensities of Tropical Cyclone Inday.

Meteorological History

Tropical Cyclone (TC) Inday was first noted by PAGASA as a tropical depression (TD) at 12 UTC on 17 July while situated east of Extreme Northern Luzon. It initially tracked generally northeastward and moving away from any landmass. It was upgraded into a tropical storm (TS) within 24 hours of its formation. On 19 July, Inday slowly turned northward and northwestward towards. It further intensified into a severe tropical storm (STS) and reached its peak intensity of 50 kt and 985 hPa at 00 UTC of the following day and started to accelerate northwestward towards the Ryukyu Islands at around 06 UTC.

At around 16 UTC on 20 July, Inday left the Philippine Area of Responsibility and at around 23 UTC of the same day, the STS crossed the Okinawa Island in the Ryukyu archipelago. The STS then continued moving northwestward at a consistent speed over the the East China Sea. Shortly past 04 UTC on 22 July, Inday made landfall over Shanghai Municipality on the eastern coast of China and was downgraded to a TS. Despite moving inland, the TS did not rapidly weaken and was only downgraded to a TD at 18 UTC on 23 July. It fully acquired extratropical characteristics after 24 hours.

Although Inday did not directly caused rainfall over the country due to its sheer distance, the strong Southwest Monsoon initially triggered by TC Henry was subsequently enhanced by Inday. Strong moisture transport resulted in heavy monsoon rains over the western section of Luzon. Rainfall totals from 17 to 20 July were in excess of 50 mm over most of mainland Luzon and in some isolated areas within Romblon, Antiquw, Aklan, and Occidental Mindoro. The highest rainfall accumulations (500 mm and higher) were observed over most of Pangasinan, northern portions of Zambales and Tarlac, and the southern portion of La Union. The synoptic station in Dagupan City, Pangasinan measured the highest storm duration (648.9 mm) and 24-hour accumulated (221.3 mm) rainfall during the occurrence of TC Inday.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
Dagupan City, Pangasinan (98325) / 221.3 mm / 18 July 2018

Highest storm duration rainfall over land:
Dagupan City, Pangasinan (98325) / 648.9 mm / 17-20 July 2018

Summary of Warning Information

Number of domestic products issued: **20**

- Severe Weather Bulletins: **7**
- Tropical Cyclone Updates: **11**
- Tropical Cyclone Advisories: **2**

Number of TC Warning for Shipping issued: **12**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property

(Direct effects of TC Henry and Josie and effects of monsoon rains continuously enhanced by TC Henry, Inday, and Josie)

Number of casualties: **16 dead, 1 injured, and 1 missing**

Combined cost of damage: **PHP 4,660.611 million**

- Damage to agriculture: **PHP 3,279.640 million**
- Damage to infrastructure: **PHP 1,380.971 million**

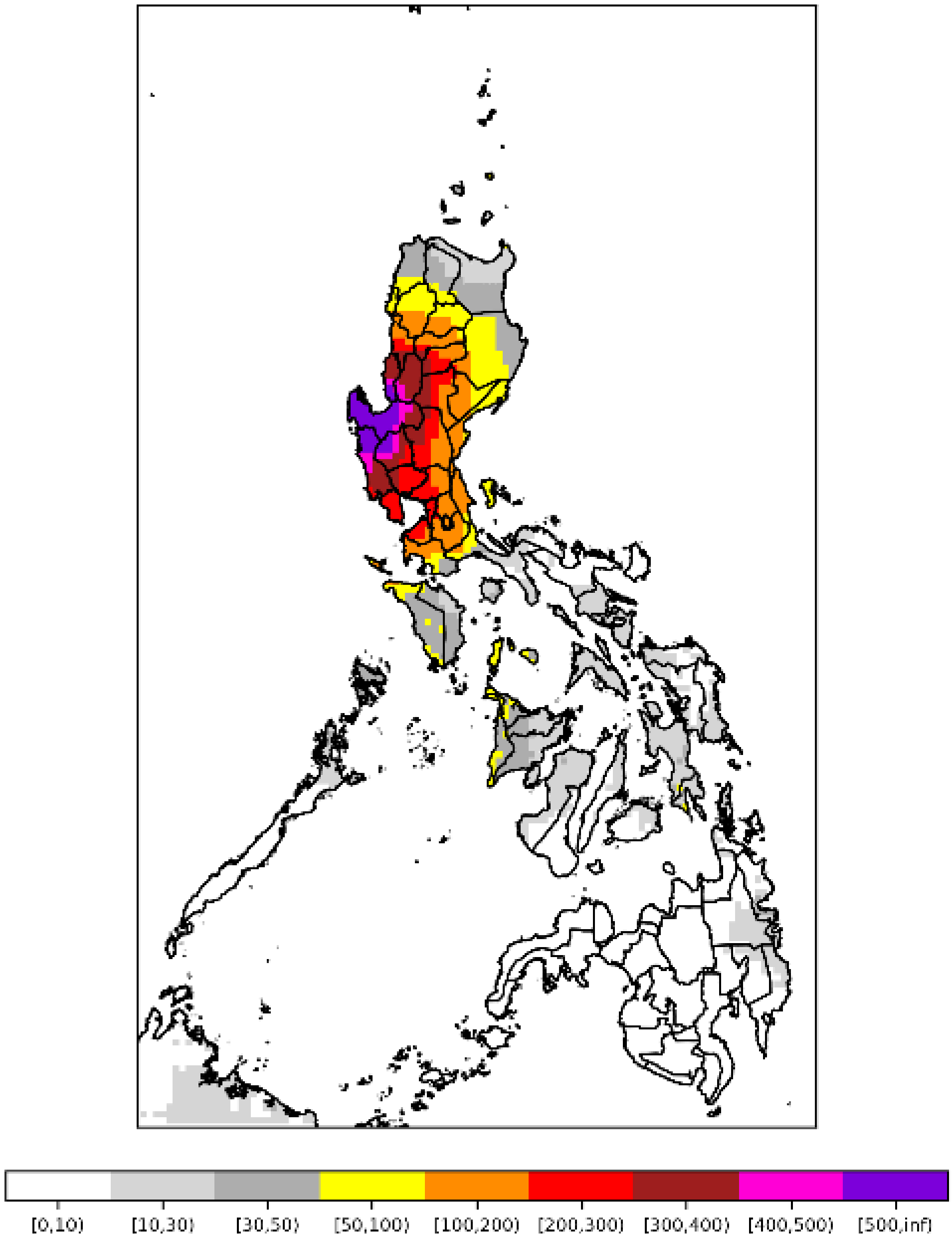


Fig 4.27. Nationwide estimate of storm duration rainfall (mm) for the period of 17-20 July 2018.

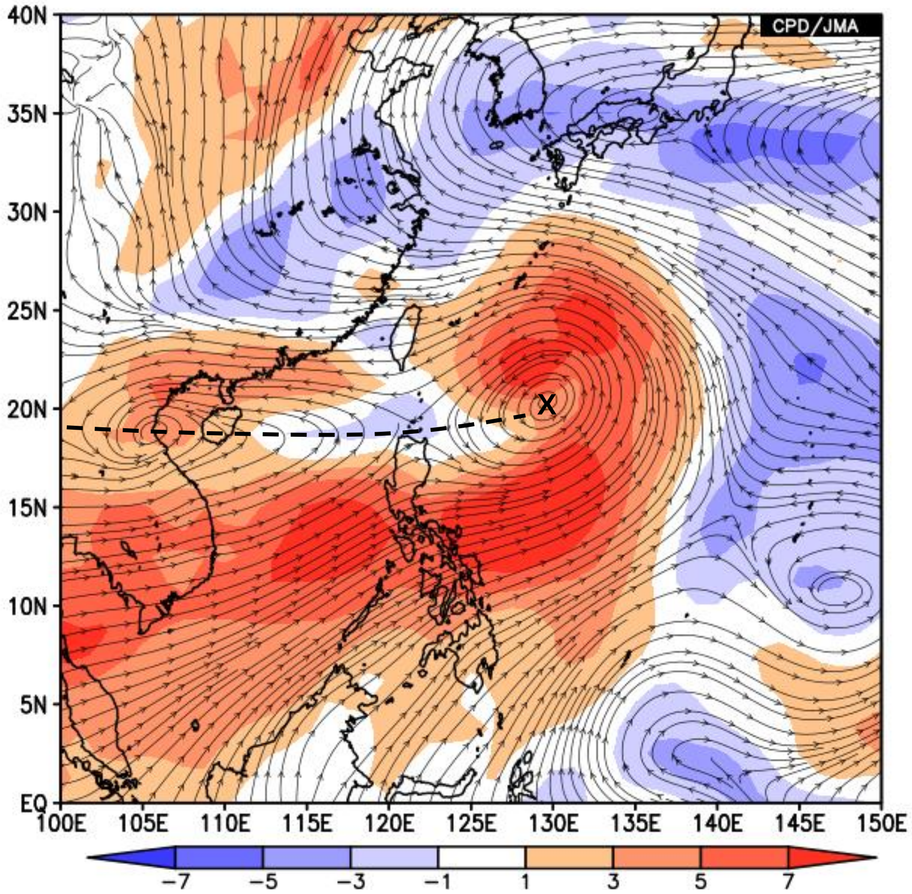


Fig. 4.28. The enhancement of the Southwest Monsoon as seen on the JRA-55 mean 850 hPa streamlines throughout the duration of TC Inday within the PAR. The shadings indicate mean 850 hPa horizontal wind speed anomaly (m/s). Redder (bluer) shade indicates stronger (weaker) winds than the 1981-2010 normal. The signals of the circulation center of TC Inday and the active monsoon trough in the mean streamline field are marked by “X” and black dash line respectively.

Tropical Cyclone Josie

20 to 23 July 2018

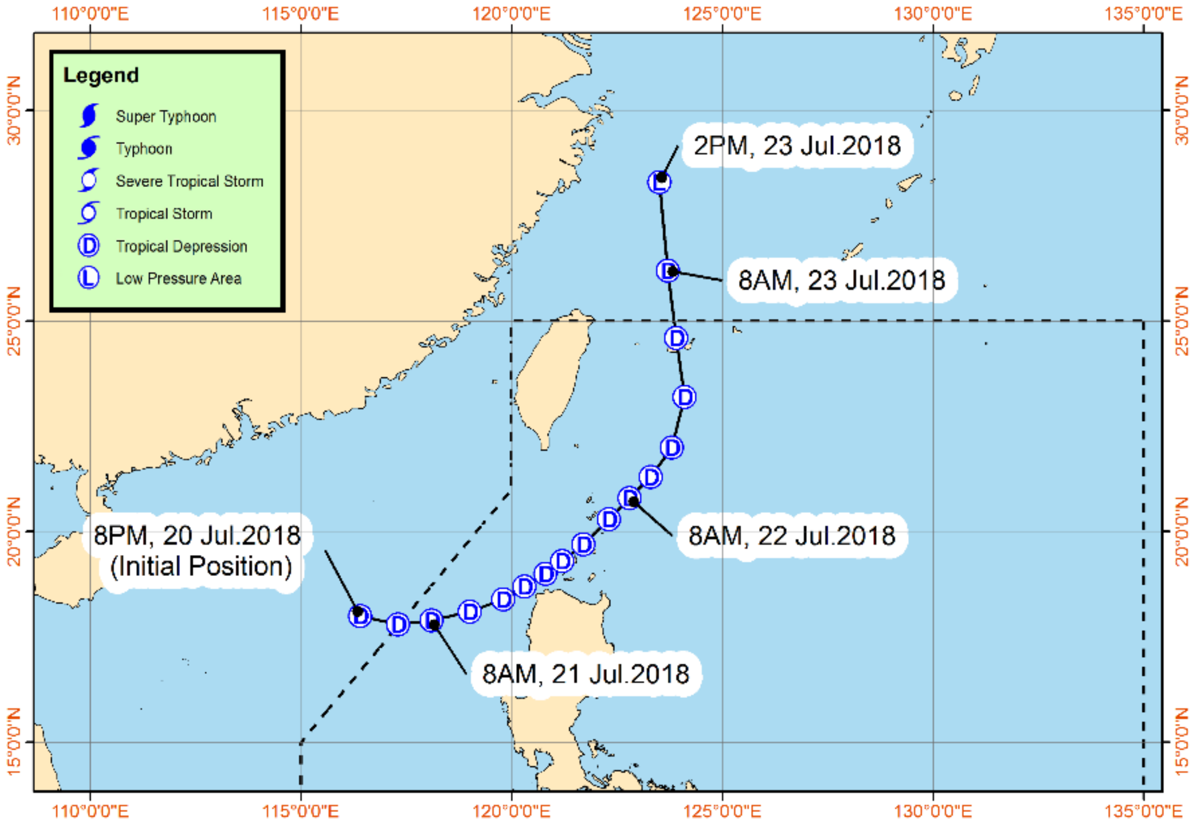


Fig 4.29. PAGASA best track positions and intensities of Tropical Cyclone Josie.

Meteorological History

Josie, the first tropical cyclone (TC) of 2018 to not possess an international name from RSMC Tokyo, developed from a disturbance embedded along an active monsoon trough and was first noted by PAGASA as a tropical depression (TD) at 12 UTC on 20 July, just as it is about to enter the northwestern limits of the Philippine Area of Responsibility (PAR). After entering the PAR, Josie slightly intensified and tracked northeastward towards the northwestern corner of mainland Luzon and the archipelago situated over the Luzon Strait. Between 09 UTC and 12 UTC on 21 July, the TD made its closest approach to Luzon at Negra Pt. and Mayraira Pt. in Ilocos Norte. Throughout the remainder of 21 July, Josie tracked northwestward over the Balintang Channel, passing near the islands of both the Babuyan group and the Batanes Province. By 12 UTC of 22 July, Josie had shifted to a more northward heading towards the Yaeyama Islands. After crossing the island group between Iriomote and Ishigaki islands, Josie left the PAR at around 20 UTC on 22 July. The TD eventually weakened into a remnant low 12 hours later over the East China Sea.

A strong Southwest Monsoon surge triggered and enhanced by the passage of TC Henry and Inday had been prevailing over the country with western Luzon receiving torrential amounts of rainfall for 5 days prior to Josie's formation. The passage of Josie resulted in a sustainment of the strong monsoon activity. Throughout the period the TD was inside the PAR (20-22 July), Josie and the enhanced Southwest Monsoon brought rainfall totals in excess of 50 mm over most of mainland Luzon, the entire Mindoro Provinces, northern portion of Palawan, and isolated portions of Antique, Aklan, Romblon, and Marinduque. Two rainfall maxima regions were observed in the rainfall estimates: a region of 400-500 mm over Bataan-Southern Zambales area and a region of 500 mm and higher situated over the western portion of Pangasinan. The latter was in the same rainfall maximum region for TC Inday. However, gauge observations suggest a slightly higher accumulation for the Bataan-Southern Zambales area.

The synoptic station at Subic Bay International Airport in Morong, Bataan reported both the highest storm duration (572.0 mm) and 24-hour (436.4 mm) rainfall for Josie.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest peak gust over land:
Subic Bay International Airport, Morong, Bataan (98426) / SW (220°) 23 m/s / 21 July 2018, 0305 UTC

Lowest sea level pressure over land:
Laoag City, Ilocos Norte (98223) / 994.9 hPa / 21 July 2018, 0700 UTC

Highest 24-hour rainfall over land:
Subic Bay International Airport, Morong, Bataan (98426) / 436.4 mm / 22 July 2018
Highest 24-hour rainfall observed by the station since records began in 1994

Highest storm duration rainfall over land:
Subic Bay International Airport, Morong, Bataan (98426) / 572.0 mm / 20-22 July 2018

Summary of Warning Information

Number of domestic products issued: **19**

- Severe Weather Bulletins: **14**
- Tropical Cyclone Updates: **5**
- Tropical Cyclone Advisories: **0**

Number of TC Warning for Shipping issued: **9**

Number of localities under TC Wind Signal (TCWS): **6**

Highest wind signal put into effect: **TCWS #1**

Summary of Casualties and Damage to Property

(Direct effects of TC Henry and Josie and effects of monsoon rains continuously enhanced by TC Henry, Inday, and Josie)

Number of casualties: **16 dead, 1 injured, and 1 missing**

Combined cost of damage: **PHP 4,660.611 million**

- Damage to agriculture: **PHP 3,279.640 million**
- Damage to infrastructure: **PHP 1,380.971 million**

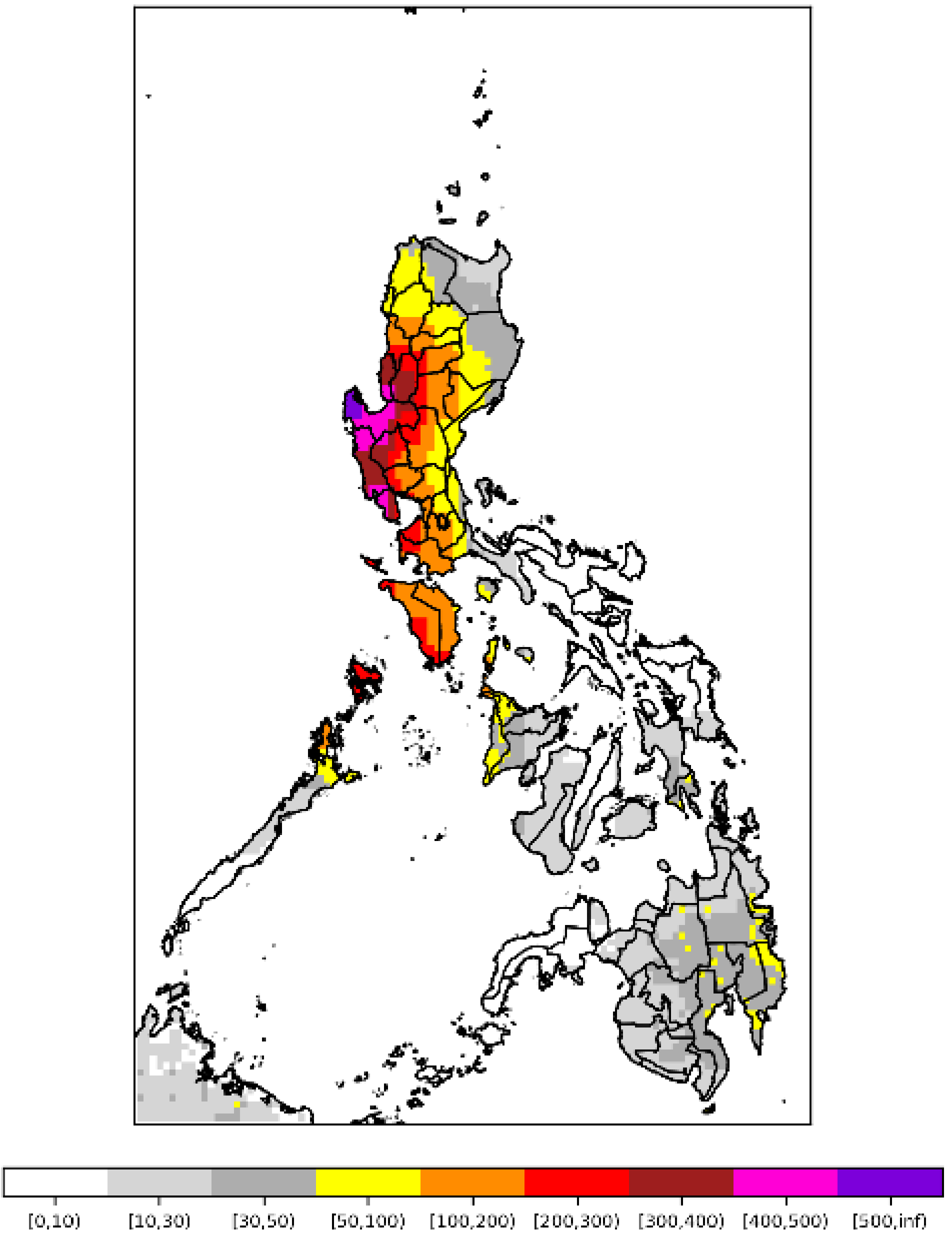


Fig 4.30. Nationwide estimate of storm duration rainfall (mm) for the period of 20-22 July 2018.

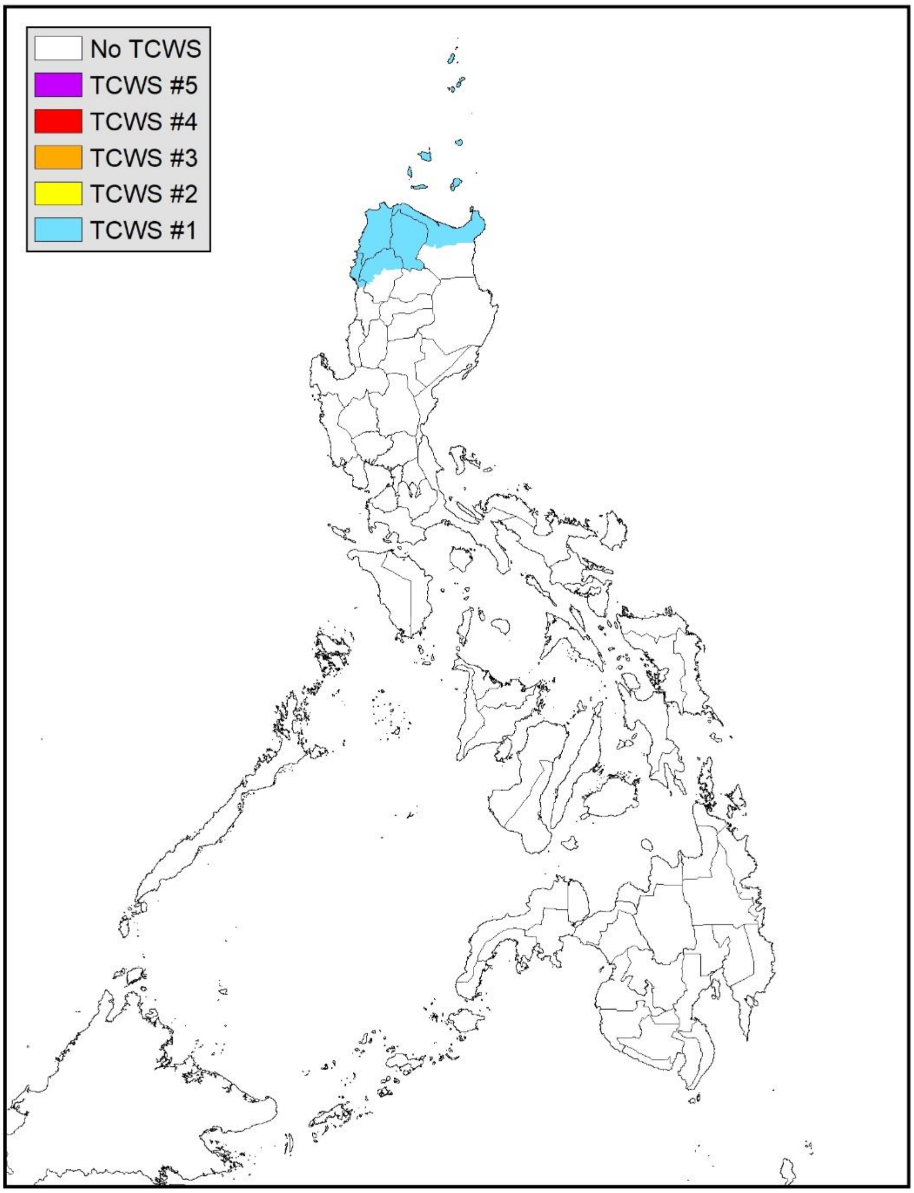


Fig 4.31. Highest wind signal raised by PAGASA during the passage of TC Josie in each province or subprovincial locality.

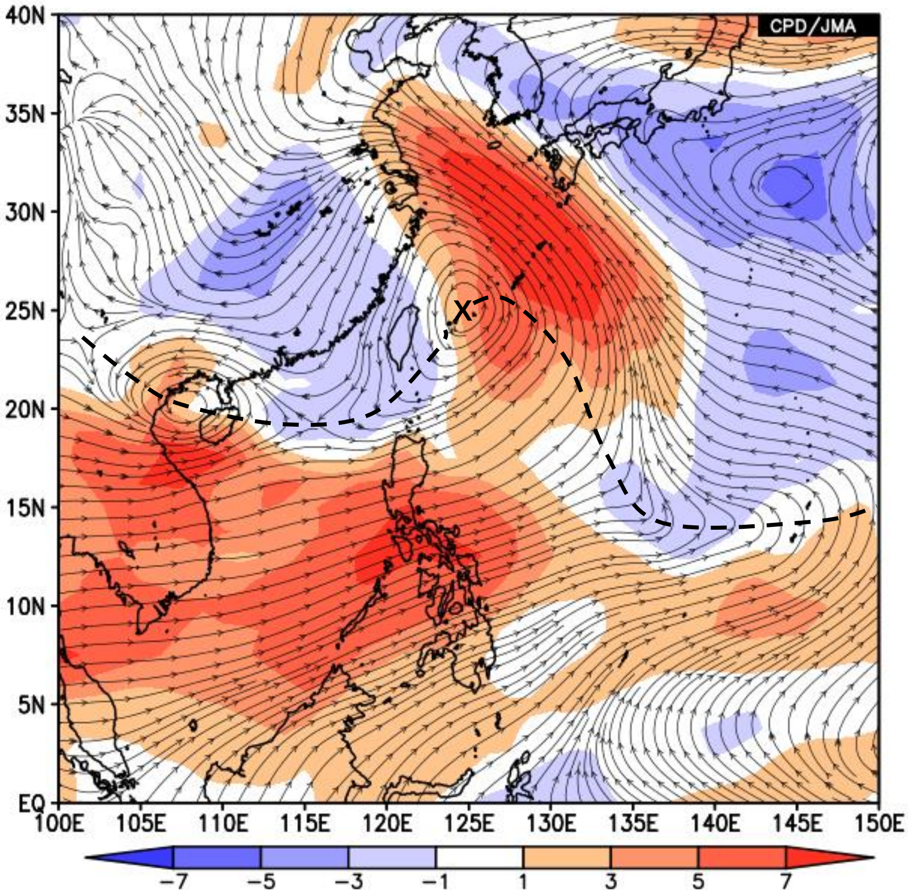


Fig. 4.32. The enhancement of the Southwest Monsoon as seen on the JRA-55 mean 850 hPa streamlines throughout the duration of TC Josie within the PAR. The shadings indicate mean 850 hPa horizontal wind speed anomaly (m/s). Redder (bluer) shade indicates stronger (weaker) winds than the 1981-2010 normal. The signals of the circulation center of TC Josie and the active monsoon trough in the mean streamline field are marked by “X” and black dash line respectively.

Tropical Cyclone Karding (1814 Yagi)

06 to 16 August 2018

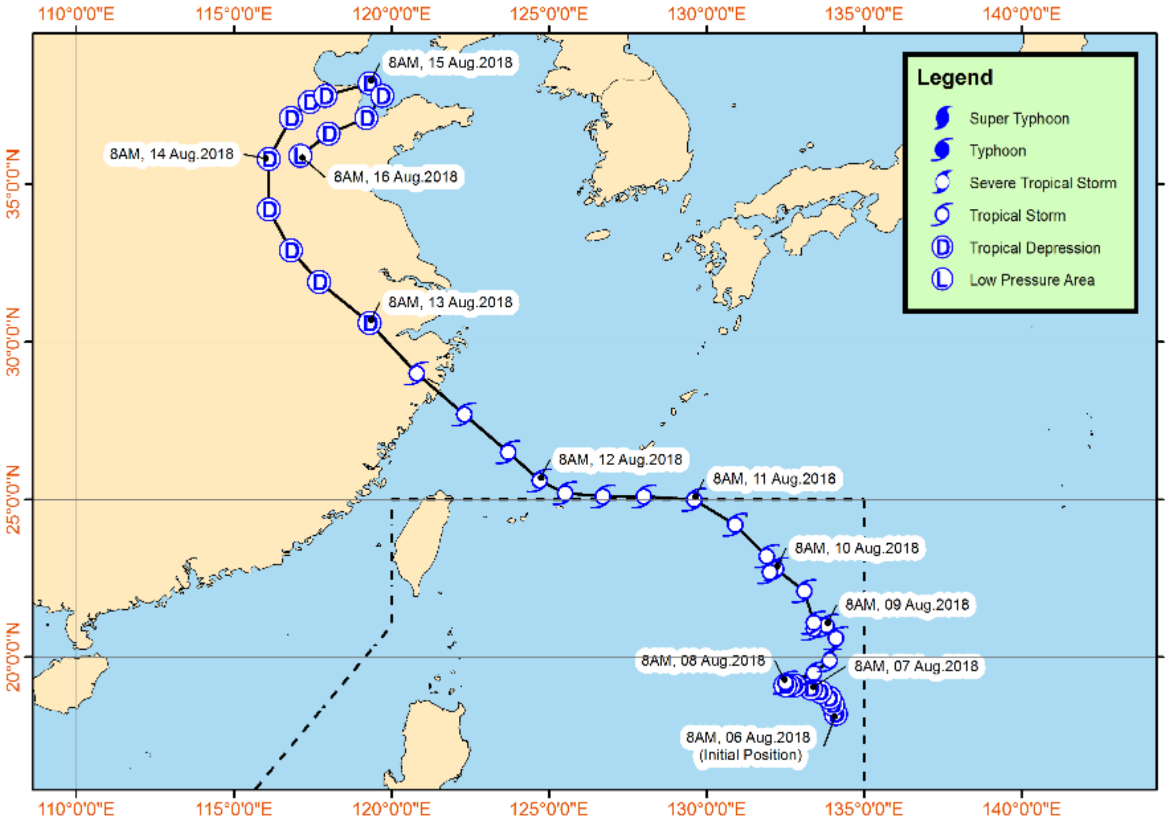


Fig 4.33. PAGASA best track positions and intensities of Tropical Cyclone Karding.

Meteorological History

A low pressure area situated more than 1000 km east of Extreme Northern Luzon developed into a tropical depression (TD) named Karding at 00 UTC on 06 August. Over the next 2 days, the TD tracked northwestward slowly over the Philippine Sea. After intensifying into a tropical storm (TS) at 00 UTC on 08 August, Karding sharply turned northeastward. However, by 18 UTC of the same day, the TS shifted to a northwestward heading. Throughout 09 and 10 August, the TS tracked generally northwestward although it moved erratically between 00 UTC and 12 UTC.

At 00 UTC on 11 August, the TS reached the northern limits of the Philippine Area of Responsibility (PAR) and turned westward. Karding left the PAR at around 01 UTC and reached its peak intensity of 40 kt and 990 hPa at 12 UTC. 6 hours later, the TS made its closest approach to Miyako Island in the southern portion of the Ryukyu archipelago. Turning northwestward, the TS slightly accelerated as it crossed the East China Sea . Karding made landfall over Taizhou City in Zhejiang Province, China at around 15 UTC on 12 August and was downgraded to a TD at 00 UTC of the following day. Throughout 13 and 14 August, the TD turned northward and northeastward as it moved further inland over Eastern China. It eventually transitioned to an extratropical cyclone at 00 UTC on 16 August after looping over the Shandong Province on 15 August.

The occurrence of TC Karding resulted in the enhancement of the Southwest Monsoon. A strong monsoon surge resulted in storm duration totals of at least 50 mm over most of Luzon and Mindoro, Romblon, Antique, Aklan, Capiz, and Iloilo based on gauge-adjusted satellite estimates. The rainfall maximum region was estimated to be over Ilocos Sur with total rainfall of around 300-500 mm. Reports from the synoptic stations suggest slightly higher rainfall totals over portions of the Cordillera Administrative Region compared to the gauge-adjusted satellite estimates. The synoptic station in Baguio City registered the highest storm duration rainfall (453.0 mm) for the period of 06 to 11 August.

This was higher than the reported accumulated rainfall of the station situated within the estimated rainfall maximum region (Sinait, Ilocos Sur: 407.8 mm)

In terms of the record daily rainfall, the station at Science Garden in Quezon City reported 270.1 mm which was the highest across the country for this TC event. To put this into context, aside from being higher than in any stations situated in the western section of Northern Luzon, this 24-hour observation was higher than the estimated storm duration rainfall for Metro Manila (100-200 mm) in Fig. 4.11b. Although the other synoptic stations in the Metro Manila area and the neighboring Rizal and Cavite Provinces recorded rainfall that were within the range suggested in the satellite estimates, the rainfall observation at Science Garden showed the possibility of higher rainfall totals in some isolated areas within the upland Metro Manila area.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
Science Garden, Quezon City (98430) / 270.1 mm / 11 August 2018

Highest storm duration rainfall over land:
Baguio City (98328) / 453.0 mm / 06-11 August 2018

Summary of Warning Information

Number of domestic products issued: **23**

- Severe Weather Bulletins: **9**
- Tropical Cyclone Updates: **12**
- Tropical Cyclone Advisories: **2**

Number of TC Warning for Shipping issued: **17**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property
(Effects of monsoon rains enhanced by TC Karding)

Number of casualties: **2 dead and 3 missing**

Combined cost of damage: **PHP 996.001 million**

- Damage to agriculture: **PHP 43.711 million**
- Damage to infrastructure: **PHP 952.290 million**

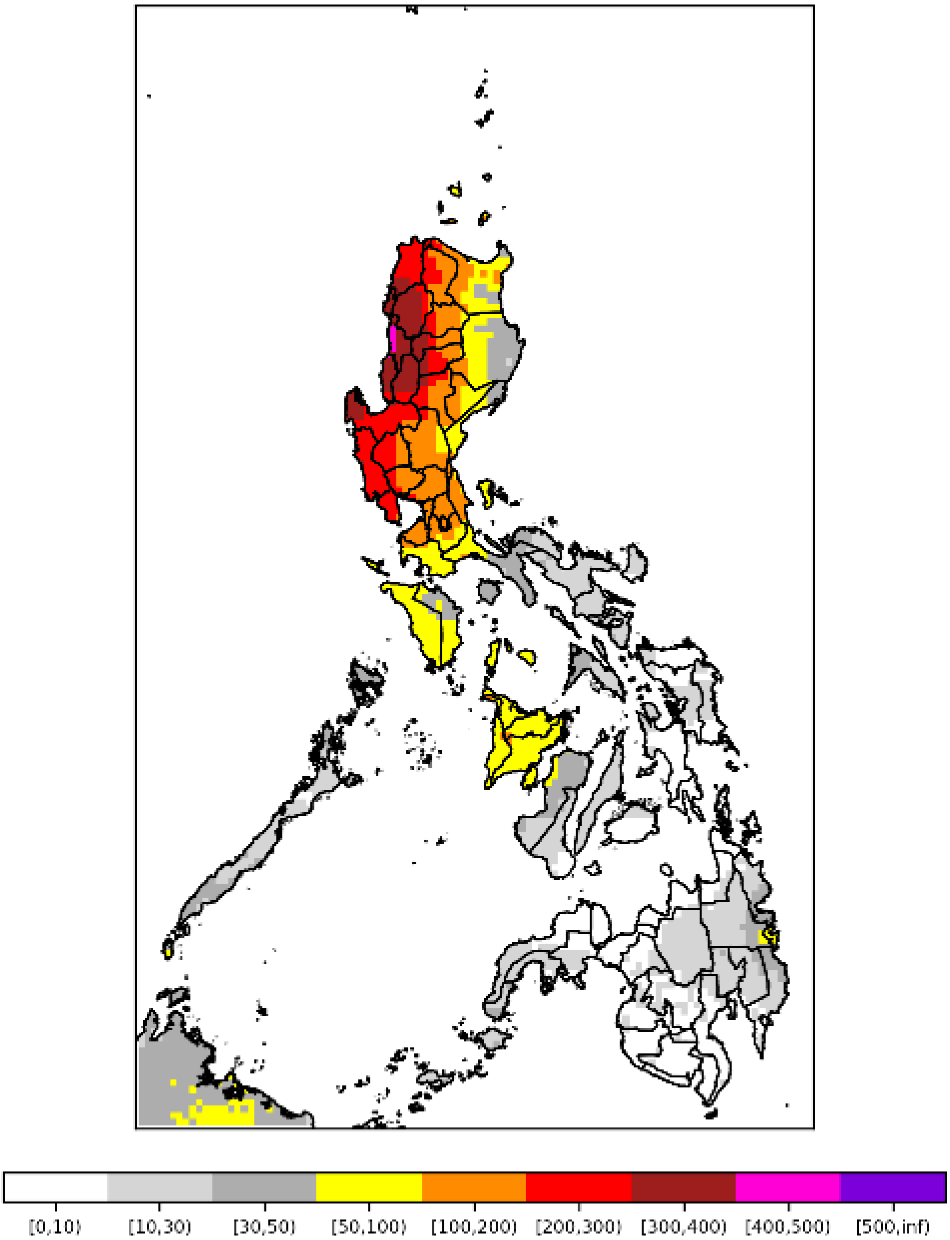


Fig 4.34. Nationwide estimate of storm duration rainfall (mm) for the period of 06-11 August 2018.

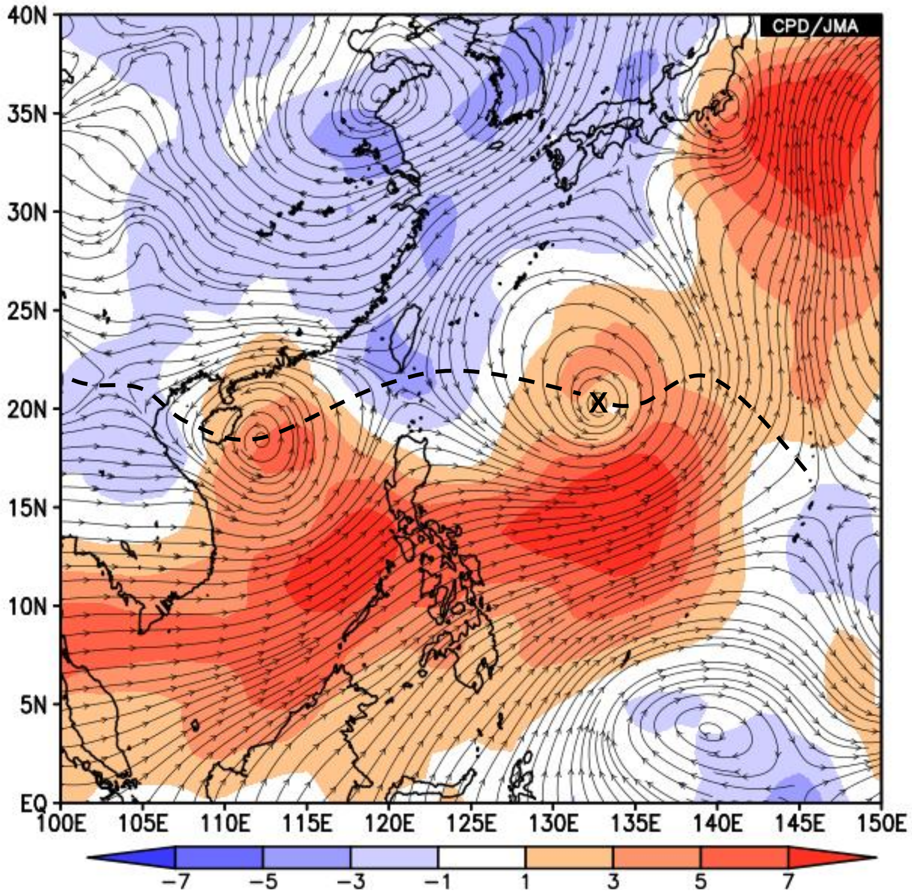


Fig. 4.35. The enhancement of the Southwest Monsoon as seen on the JRA-55 mean 850 hPa streamlines throughout the duration of TC Karding within the PAR. The shadings indicate mean 850 hPa horizontal wind speed anomaly (m/s). Redder (bluer) shade indicates stronger (weaker) winds than the 1981-2010 normal. The signals of the circulation center of TC Karding and the active monsoon trough in the mean streamline field are marked by “X” and black dash line respectively.

Tropical Cyclone Luis

22 to 26 August 2018

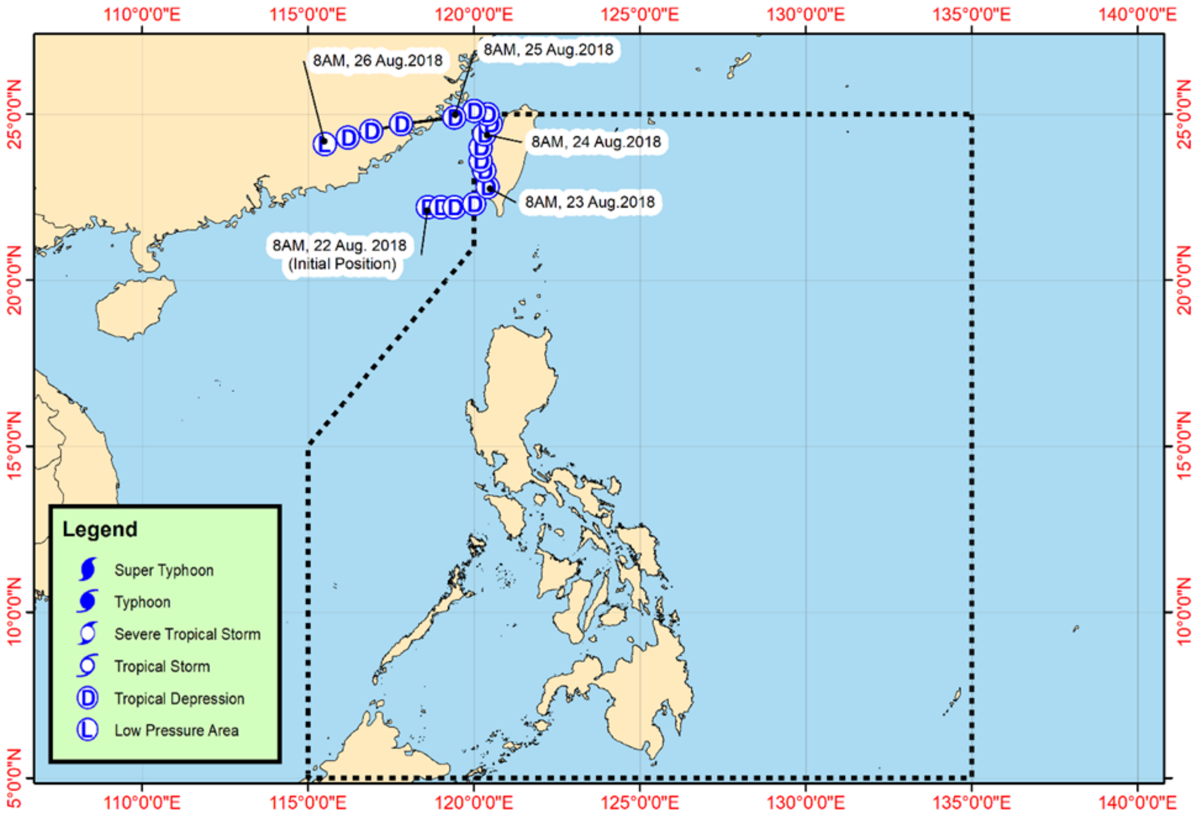


Fig 4.36. PAGASA best track positions and intensities of Tropical Cyclone Luis

Meteorological History

Tropical Cyclone (TC) Luis developed from a disturbance situated over the northern portion of the West Philippine Sea and embedded within an active monsoon trough. It was first noted by PAGASA as an eastward-moving tropical depression (TD) at 00 UTC on 22 August. After entering the Philippine Area of Responsibility (PAR) at 18 UTC of the same day, the TD turned to the northeast and made landfall in the vicinity of Kaohsiung City in Taiwan around 22 UTC. It then turned northward and traversed the counties in the southwestern portion of Taiwan. At around 15 UTC on 23 August, Luis emerged over the Taiwan Strait and started to curve northeastward. On the following day, the TD curved northward then westward, eventually leaving the PAR at around 13 UTC. It made its final landfall over the coast of Fujian Province in southeastern China at around 03 UTC on 25 August and degenerated into a remnant low over Guangdong Province at 00 UTC on 26 August.

Despite being a weak TC, the occurrence of Luis triggered an enhanced Southwest Monsoon activity. Along with the other TCs in the basin, Luis formed part of a reversed-oriented monsoon trough. The strong monsoon flow resulted in storm duration rainfall totals in excess of 50 mm over the western portion of Northern and Central Luzon. The rainfall maximum region over Ilocos Provinces, Abra, and portions of Mountain Province, Benguet and La Union had rainfall totals ranging from 300 to 400 mm. The highest storm duration and 24-hour accumulated rainfall during the occurrence of Luis based on synoptic station reports were recorded in Laoag City, Ilocos Norte (406.0 mm) and Baguio City (216.0 mm) respectively.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
Baguio City (98328) / 216.0 mm / 24 August 2018

Highest storm duration rainfall over land:
Laoag City, Ilocos Norte (98223) / 406.0 mm / 22-24 August 2018

Summary of Warning Information

Number of domestic products issued: **10**

- Severe Weather Bulletins: **4**
- Tropical Cyclone Updates: **4**
- Tropical Cyclone Advisories: **2**

Number of TC Warning for Shipping issued: **7**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property

(Effects of monsoon rains enhanced by TC Luis)

Number of casualties: **None**

Combined cost of damage: **Not available**

- Damage to agriculture: **Not available**
- Damage to infrastructure: **Not available**

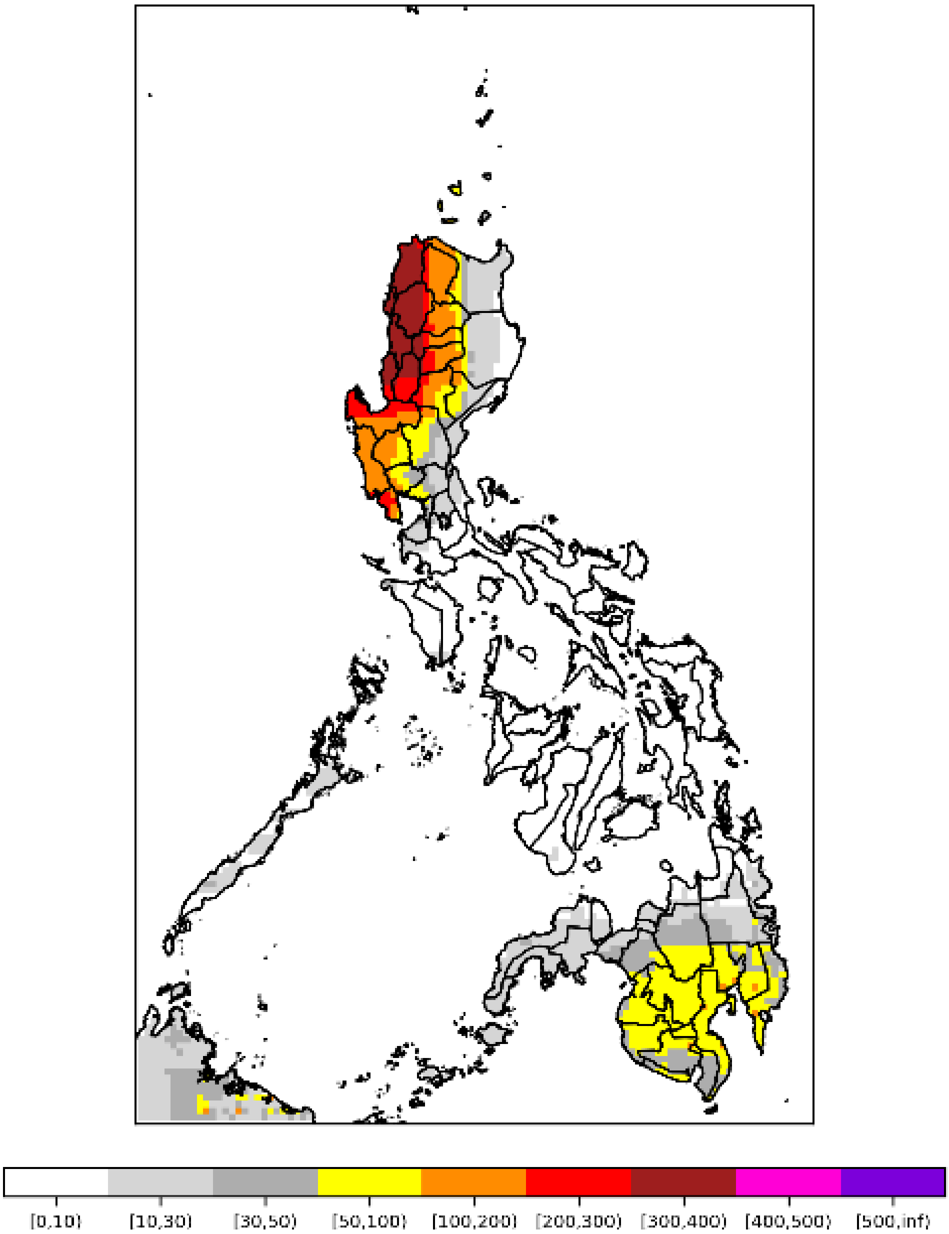


Fig 4.37. Nationwide estimate of storm duration rainfall (mm) for the period of 22-24 August 2018.

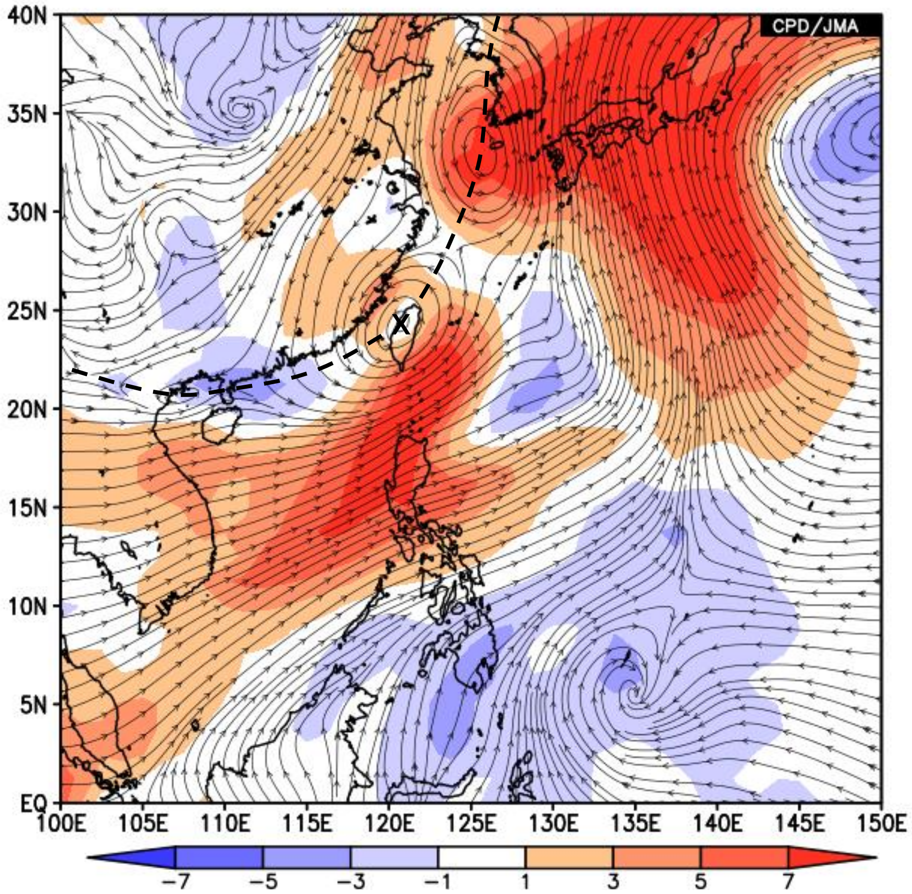


Fig. 4.38. The enhancement of the Southwest Monsoon as seen on the JRA-55 mean 850 hPa streamlines throughout the duration of TC Luis within the PAR. The shadings indicate mean 850 hPa horizontal wind speed anomaly (m/s). Redder (bluer) shade indicates stronger (weaker) winds than the 1981-2010 normal. The signals of the circulation center of TC Luis and the active monsoon trough in the mean streamline field are marked by “X” and black dash line respectively.

Tropical Cyclone Maymay (1821 Jebi)

27 August to 05 September 2018

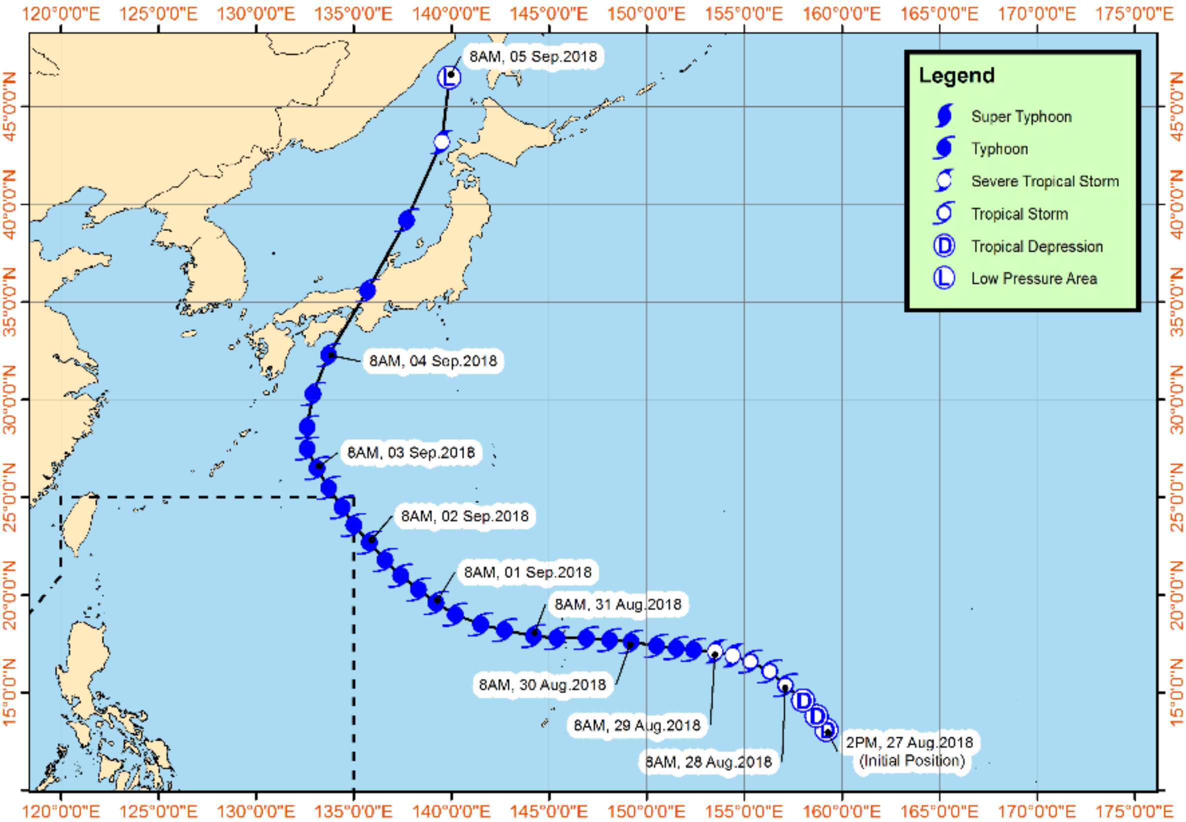


Fig 4.39. PAGASA best track positions and intensities of Tropical Cyclone Maymay

Meteorological History

Tropical Cyclone (TC) Maymay developed into a tropical depression at 06 UTC on 27 August over the sea north of Pohnpei in the Federated States of Micronesia. Moving northwestward, it continuously intensified and was upgraded to a tropical storm at 00 UTC on 28 August and into a severe tropical storm (STS) 18 hours after. As Maymay shifted to a more westward heading on 29 August, a period of rapid intensification took place. It intensified into a typhoon (TY) at 06 UTC 29 August and at 18 UTC, the TY has intensified by 30 kt over the last 24 hours. Between 15 UTC and 18 UTC on 30 August, the eye of Maymay crossed the Northern Mariana archipelago and passed between Pagan and Alamagan Islands, then gradually turned northwestward. At around 06 UTC on 31 August, the TY reached its peak intensity of 110 kt and 910 hPa.

On 01 September, Maymay started to slowly weaken as it moved over the colder waters in the northern portion of the Philippine Sea. On the following day, the TY briefly passed the far northeastern region of the Philippine Area of Responsibility, entering its the eastern limits at 06 UTC and exiting its northern limits at 16 UTC. The TY turned northeastward on 03 September as it headed for Shikoku Island in mainland Japan. On 04 September, as Maymay underwent an extratropical transition, it traversed the mainland Japan, resulting in an increased rate of weakening. It made its first landfall over the southern part of Tokushima Prefecture at around 03 UTC. Afterwards, it crossed the Awaji Island in Hyōgo Prefecture an hour later and made another landfall over Kobe City at around 05 UTC. By the time it emerged over the Sea of Japan at around 06 UTC, its intensity had dropped to 75 kt. After being downgraded to an STS at 18 UTC on 04 September, Maymay fully acquired extratropical characteristics at 00 UTC on 05 September while situated over the Sea of Japan to the southeast of Primorsky Krai in the Russian Far East.

Due to the sheer distance of Maymay from the Philippine landmass, the country did not experience the typical monsoon rains associated within a strong monsoon activity. Nevertheless, rains between 50 and 100 mm associated with the Southwest Monsoon were estimated on 02 September over Benguet, Pangasinan, Zambales, Pampanga and Tarlac with slightly higher gauge observations in some areas. For instance, the 24-hour accumulated rainfall (which is equivalent to the storm duration rainfall for Maymay) recorded at Clark International Airport in Mabalacat, Pampanga reached 118.8 mm which was, aside from being the highest across the country, higher than the 50-100 mm estimate for the Pampanga area. The same was also observed for Science Garden in Quezon City with 24-hour rainfall reaching 115.7 mm (the second highest nationwide) compared to the 30-50 mm estimate for Metro Manila. However, the observed rainfall in the other stations within the Metro Manila area was well within the 30-50 mm estimate (i.e. Port Area, Manila and Ninoy Aquino International Airport, Pasay City reached 11.5 mm and 2.0 mm respectively).

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
Clark International Airport, Mabalacat, Pampanga (98327) / 118.8 mm / 02 September 2018

Highest storm duration rainfall over land:
Clark International Airport, Mabalacat, Pampanga (98327) / 118.8 mm / 02 September 2018

Summary of Warning Information

Number of domestic products issued: **21**

- Severe Weather Bulletins: **3**
- Tropical Cyclone Updates: **13**
- Tropical Cyclone Advisories: **5**

Number of TC Warning for Shipping issued: **3**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **None**

- Damage to agriculture: **None**
- Damage to infrastructure: **None**

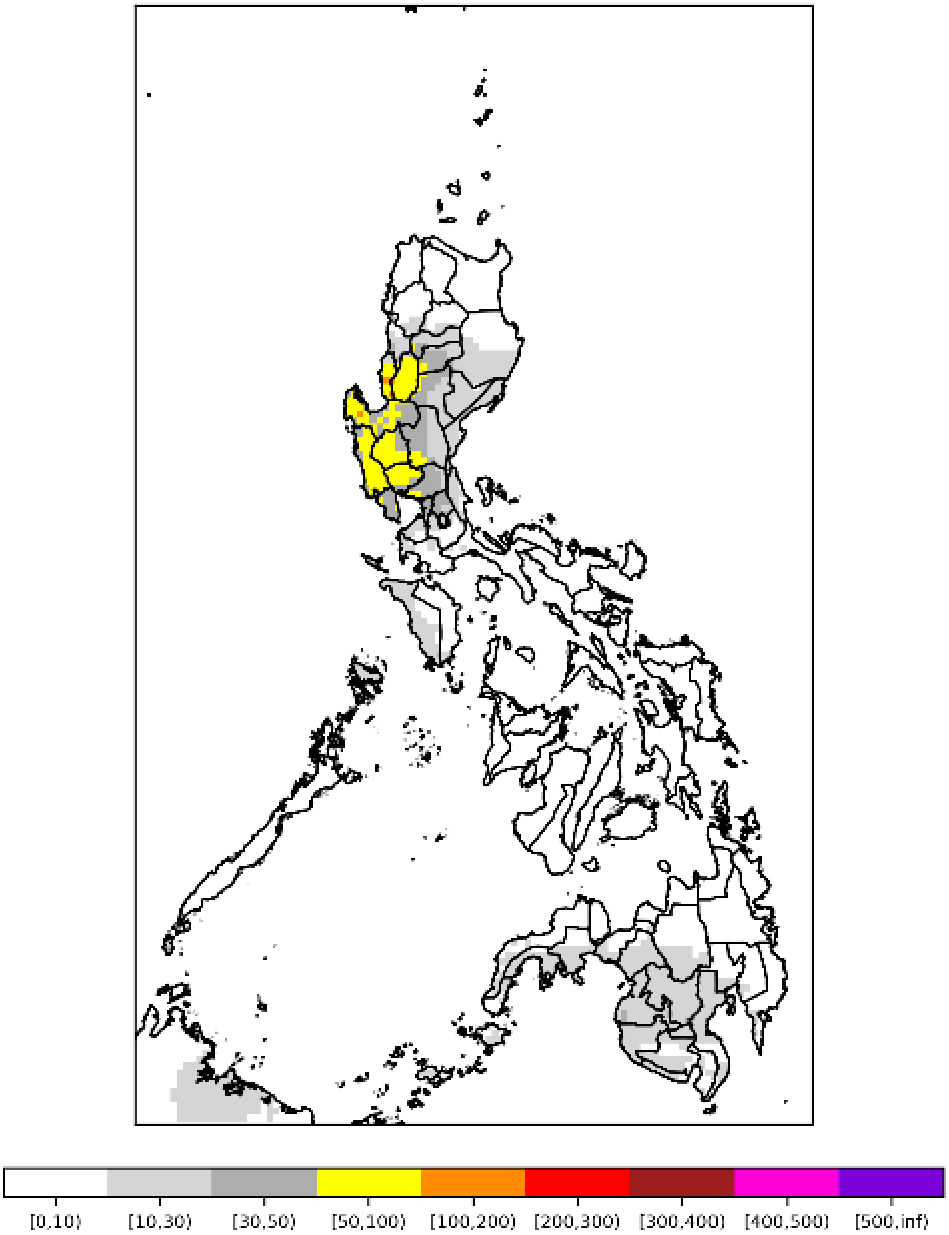


Fig 4.40. Nationwide estimate of storm duration rainfall (mm) for the period of 02 September 2018.

Tropical Cyclone Neneng (1823 Barijat)

08 to 13 September 2018

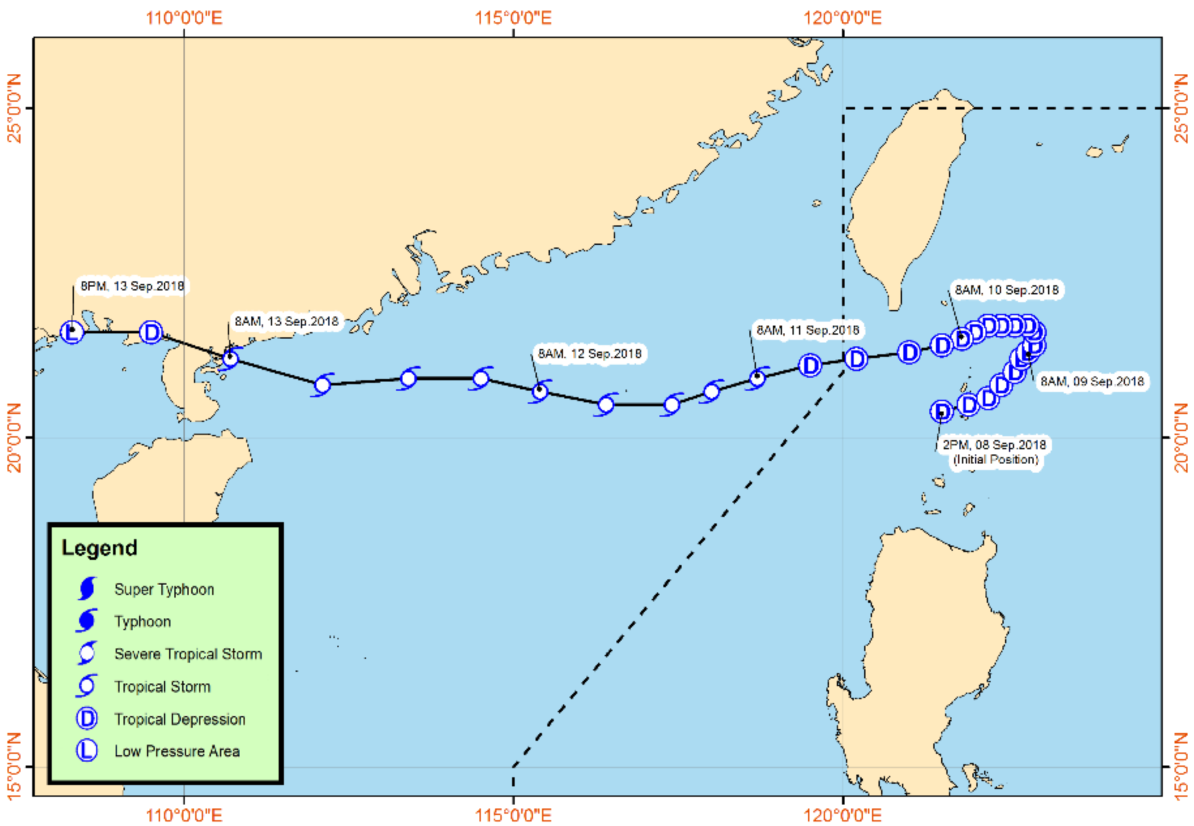


Fig 4.41. PAGASA best track positions and intensities of Tropical Cyclone Neneng.

Meteorological History

A tropical disturbance over the Luzon Strait was first noted by PAGASA as a tropical depression (TD) named Neneng at 06 UTC on 08 September while situated within the coastal waters of Batanes. Throughout the day, the TD tracked northeastward over the waters separating Itbayat and Batan Islands, passing very close to the latter at around 10 UTC.

On 09 September, Neneng turned westward sharply over the Bashi Channel. After slightly accelerating, the TD left the Philippine Area of Responsibility at around 14 UTC on 10 September. Moving generally westward, it was upgraded to a tropical storm at 00 UTC on the following day and reached at peak intensity of 40 kt and 998 hPa 6 hours later. Neneng eventually made landfall over the Leizhou Peninsula within the Guangdong Province in southern China past 00 UTC on 13 September. The TS rapidly weakened and degenerated to a remnant low at 12 UTC of the same day.

Heavy rains were experienced in the Batanes and Babuyan Islands due to the passage of Neneng. However, the Southwest Monsoon activity was not enhanced by it, resulting in the absence of monsoon rain signature in the storm duration rainfall distribution. The Babuyan Islands had storm duration rainfall between 50 mm and 200 mm while the Batanes Provinces received anywhere between 200 mm and 400 mm. The synoptic stations at Basco and Itbayat in Batanes recorded the highest storm duration (345.0 mm) and 24-hour accumulated (161.8 mm) rainfall during the passage of Neneng.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest peak gust over land:
Basco, Batanes (98134) / SW (220°) 14 m/s / 08 September 2018, 1726 UTC
Basco, Batanes (98134) / W (280°) 14 m/s / 09 September 2018, 2330 UTC

Lowest sea level pressure over land:
Basco, Batanes (98134) / 1006.4 hPa / 08 September 2018, 0600 UTC

Highest 24-hour rainfall over land:
Itbayat, Batanes (98132) / 161.8 mm / 09 September 2018

Highest storm duration rainfall over land:
Basco, Batanes (98134) / 345.0 mm / 08-10 September 2018

Summary of Warning Information

Number of domestic products issued: **12**

- Severe Weather Bulletins: **4**
- Tropical Cyclone Updates: **6**
- Tropical Cyclone Advisories: **2**

Number of TC Warning for Shipping issued: **4**

Number of localities under TC Wind Signal (TCWS): **1**

Highest wind signal put into effect: **TCWS #1**

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **None**

- Damage to agriculture: **None**
- Damage to infrastructure: **None**

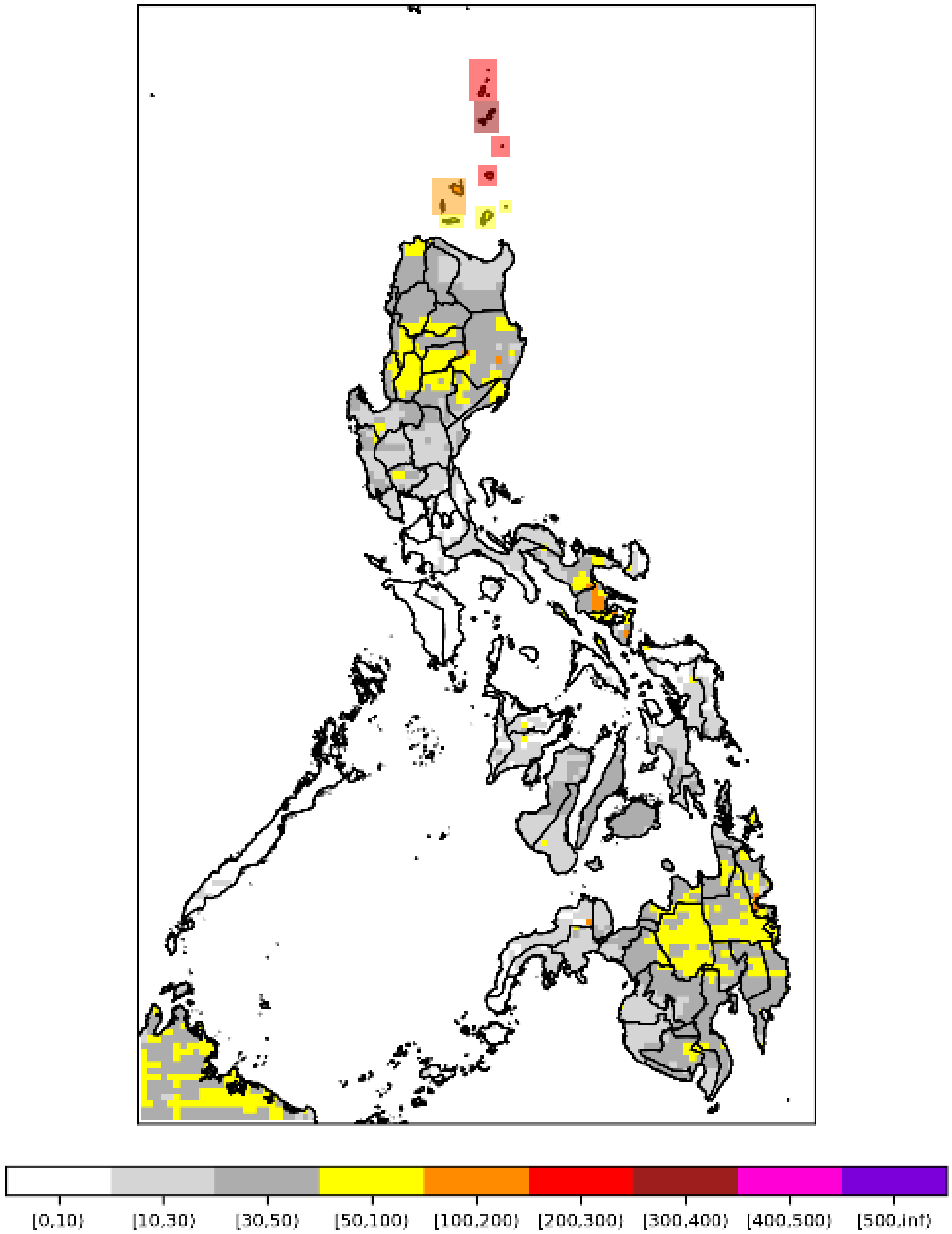


Fig 4.42. Nationwide estimate of storm duration rainfall (mm) for the period of 08-10 September 2018. The colors for the Batanes-Babuyan Islands are emphasized.

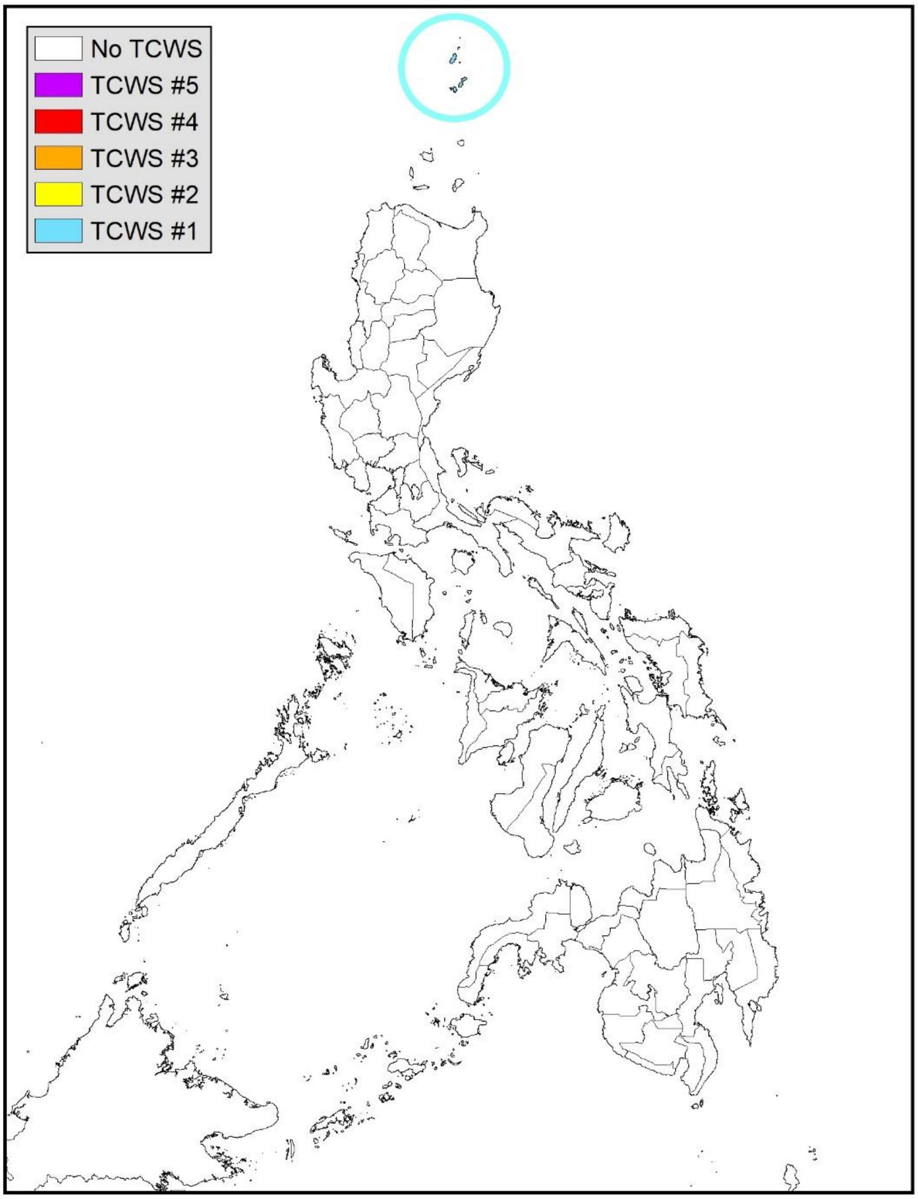


Fig 4.43. Highest wind signal raised by PAGASA during the passage of TC Neneng in each province or subprovincial locality.

Tropical Cyclone Ompong (1822 Mangkhut)

06 to 17 September 2018

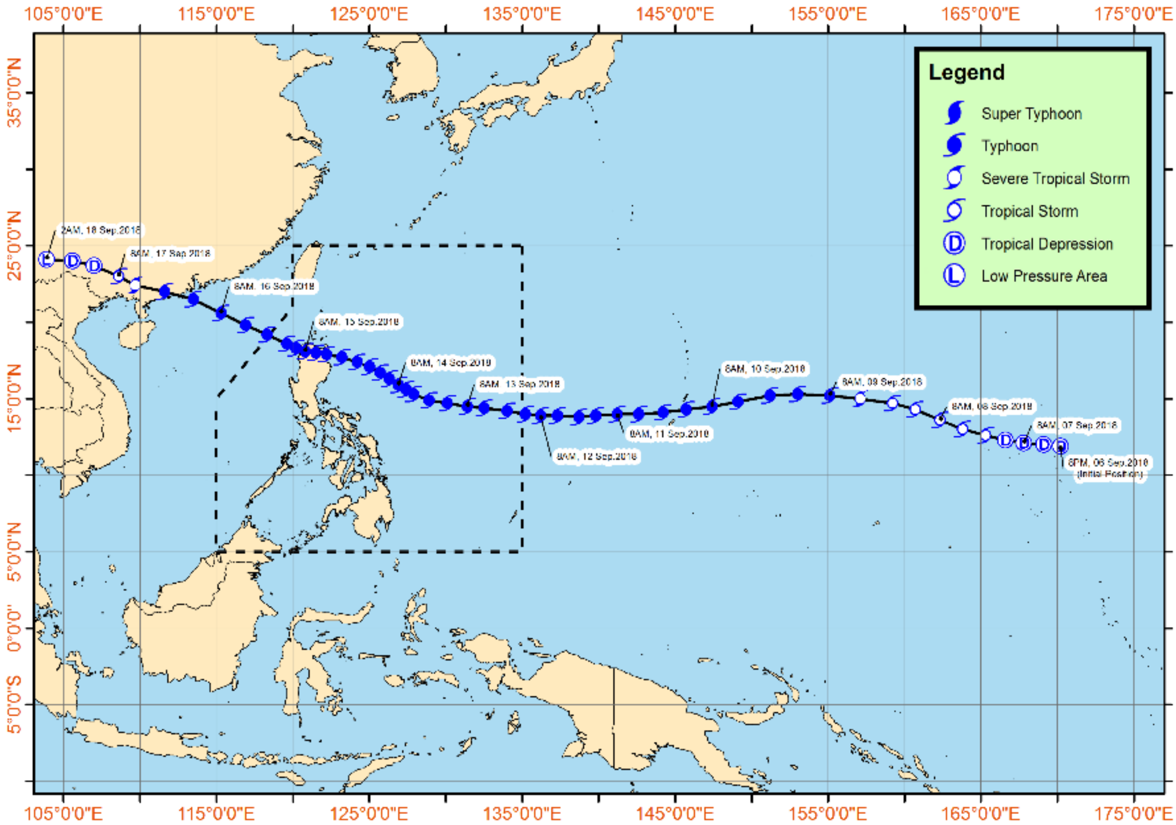


Fig 4.44. PAGASA best track positions and intensities of Tropical Cyclone Ompong.

Meteorological History

The strongest tropical cyclone (TC) to make landfall in the Philippines developed as a tropical depression (TD) named Ompong in the vicinity of the Marshall Islands at 12 UTC on 06 September. Moving west-northwestward, the TD continuously intensified and was upgraded to a tropical storm at 12 UTC on 07 September. At 00 UTC on 09 September, Ompong entered the forecast area of PAGASA, slightly shifted to a more westward heading, and was upgraded to a typhoon (TY). Ompong continued intensifying as it moved westward, eventually grazing the island of Rota in the Northern Mariana archipelago at around 08 UTC on 10 September. At 12 UTC of the following day, the TY reached its peak intensity of 110 kt and 905 hPa. The TY entered the Philippine Area of Responsibility (PAR) at peak intensity at around 07 UTC on 12 September.

Ompong maintained its intensity as it traversed the Philippine Sea region within the PAR. At around 12 UTC on 13 September, the TY started tracking more northwestward as it headed towards the northern portion of Luzon. However, roughly 12 hours before making landfall, the TY shifted to a more westward heading. Despite the onset of an eyewall replacement cycle early on 14 September, the TY did not weaken. At around 18 UTC of the same day, the eye of Ompong made landfall on the town of Baggao in Cagayan with an intensity of 105 kt, making it the strongest TC to cross the country in terms of intensity at the time of initial landfall. Ompong weakened as it crossed the rugged terrain of Northern Luzon and by the time it emerged over the coastal waters of Ilocos Norte between 01 UTC and 02 UTC on 15 September, the TY had weakened to 90 kt.

Over the West Philippine Sea, Ompong shifted to a more northwestward heading. However, the TY continued to weaken as it approached the southern coast of China. The TY left the PAR at around 12

UTC on 15 September and made its final landfall over Jiangmen City in Guangdong Province, China at around 09 UTC on 16 September. Rapid weakening ensured as the TY moved inland. It finally degenerated into a remnant low at 18 UTC on 17 September and was last spotted in the vicinity of Yunnan Province in the southern portion of China.

Heavy rains directly caused by the passage of Ompong and the enhanced Southwest Monsoon resulted in storm duration rainfall in excess of 50 mm over the whole of Luzon and portions of Eastern Visayas, Western Visayas, Zamboanga Peninsula, and Bangsomoro. The northern and western sections of Northern and Central Luzon received higher rainfall totals than in the other portions of Luzon. In particular, a rainfall maximum region with storm duration totals of at least 400 mm was estimated over Benguet, La Union, and portions of Ilocos Sur, Mountain Province, Ifugao, Nueva Vizcaya, and Pangasinan. The synoptic station in Baguio City recorded both the highest storm duration (795.0 mm) and 24-hour accumulated (536.0 mm) rainfall during the passage of Ompong. The rainfall pattern observed during the passage of Ompong presents a classic example of the impact of orographic effect on the enhancement of rainfall in mountainous regions.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest peak gust over land:
Aparri, Cagayan (98232) / NNE (20°) 49 m/s / 14 September 2018, 1838 UTC
Highest peak gust observed by the station since records began in 1997

Lowest sea level pressure over land:
Tuguegarao City, Cagayan (98233) / 949.0 hPa / 14 September 2018, 1900 UTC

Highest 24-hour rainfall over land:
Baguio City (98328) / 536.0 mm / 15 September 2018

Highest storm duration rainfall over land:
Baguio City (98328) / 795.0 mm / 12-15 September 2018

Summary of Warning Information

Number of domestic products issued: **42**

- Severe Weather Bulletins: **23**
- Tropical Cyclone Updates: **15**
- Tropical Cyclone Advisories: **4**

Number of TC Warning for Shipping issued: **14**

Number of localities under TC Wind Signal (TCWS): **38**

Highest wind signal put into effect: **TCWS #4**

Summary of Casualties and Damage to Property

Number of casualties: **82 dead, 138 injured, and 2 missing**

Combined cost of damage: **PHP 33,930.734 million**

- Damage to agriculture: **PHP 26,769.718 million**
- Damage to infrastructure: **PHP 7,161.016 million**

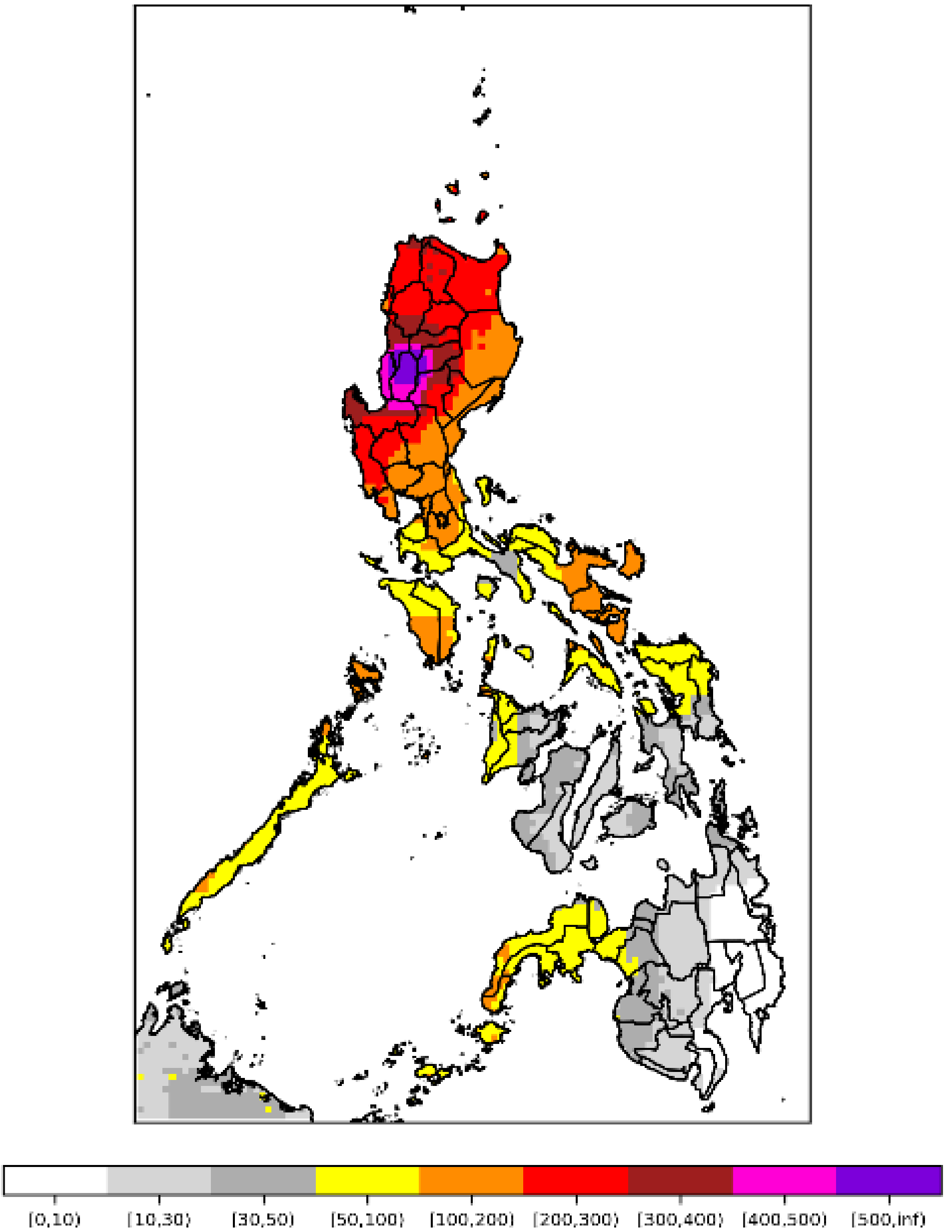


Fig 4.45. Nationwide estimate of storm duration rainfall (mm) for the period of 12-15 September 2018.

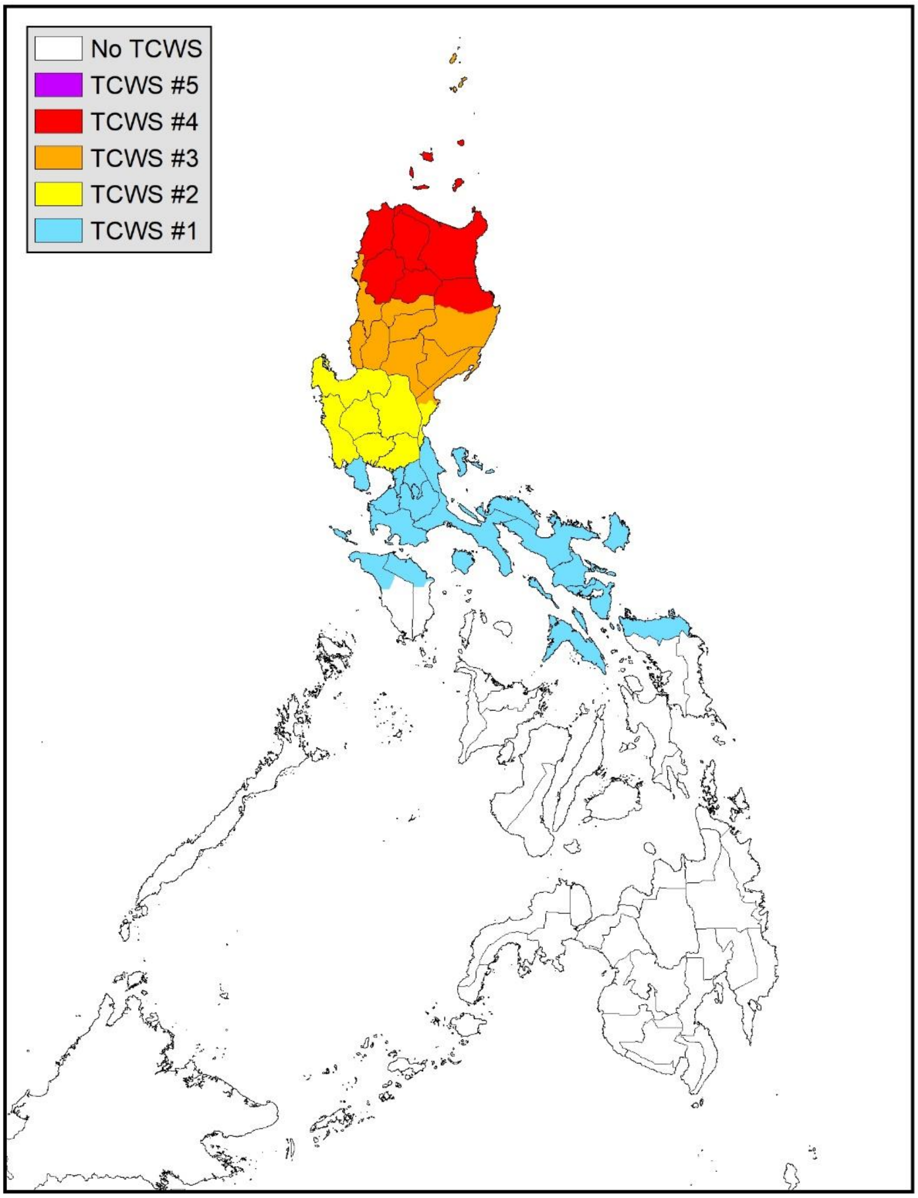


Fig 4.46. Highest wind signal raised by PAGASA during the passage of TC Ompong in each province or subprovincial locality.

Tropical Cyclone Paeng (1824 Trami)

20 September to 01 October 2018

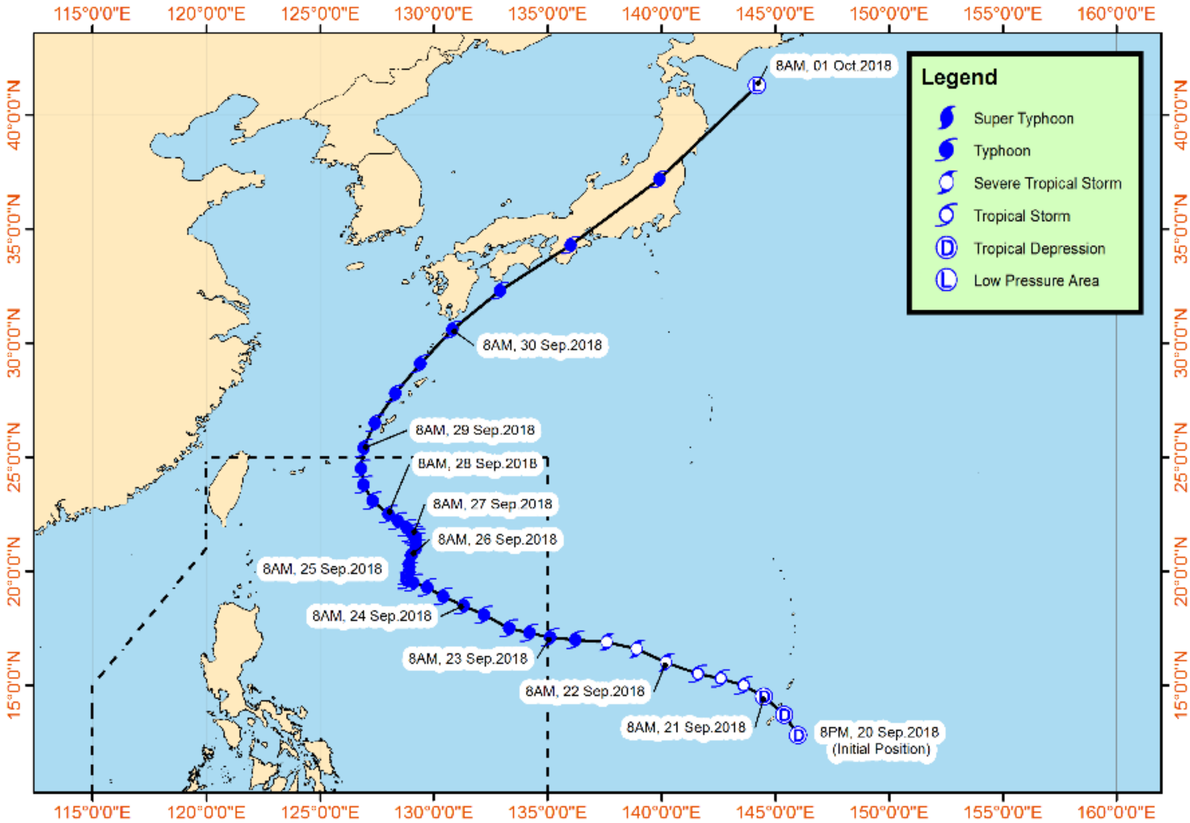


Fig 4.47. PAGASA best track positions and intensities of Tropical Cyclone Paeng.

Meteorological History

Tropical Cyclone (TC) Paeng developed from an area of low pressure situated to the east-southeast of Guam at 12 UTC on 20 September. Tracking northwestward, it passed the Mariana island chain between Rota and Guam at around 08 UTC on 21 September. Paeng intensified into a tropical storm (TS) at 06 UTC on 21 September as the storm started to move west-northwestward. Over the next 4 days, the TS continued to intensifying over the warm waters of the Philippine Sea. It was upgraded into a severe tropical storm at 00 UTC on 22 September and into a typhoon 18 hours later. At around 01 UTC on 23 September, the eye of Paeng entered the Philippine Area of Responsibility (PAR).

Throughout 23 and 24 September, the TY slightly turned more northwestward as it continued to intensify. By 12 UTC on 23 September, the TY had intensified by 30 kt over the last 24 hours – a period of rapid intensification. Paeng eventually reached a peak intensity of 105 kt and 915 hPa at 18 UTC on 24 September. The lack of a dominant steering current resulted in the TY slowing down and turning northward. This slow movement resulted in upwelling of cooler waters in the vicinity of the TY. Paeng weakened to 85 kt, a 20-kt drop in 24 hours, at 06 UTC on 26 September due to the cooler waters and dry air intrusion. Throughout 27 and 28 September, the TY moved northwest and northward at the slow pace. At around 22 UTC on 28 September, Paeng left the PAR as it started to turn northeastward towards the Okinawa group of islands in the Ryukyu archipelago. It crossed the vicinity of Okinawa group of islands between 03 UTC and 09 UTC on 29 September, particularly passing directly over the Kerama Islands.

Throughout 29 September, Paeng accelerated northeastward while tracking near the Ryukyu archipelago. It passed over the Tokara Islands between 09 UTC and 15 UTC on 29 September and crossed the islands of Tanegashima, Mageshima, and Yakushima between 22 UTC of the same day and 01 UTC of the following day. The TY made landfall over mainland Japan in the vicinity of Tanabe

City within Wakayama Prefecture at around 11 UTC on 30 September. After crossing Honshu Island and emerging over the sea east of Iwate Prefecture, Paeng transitioned into an extratropical cyclone at 00 UTC on 01 October.

The trough of Paeng extended over the country during its passage, resulting in distant precipitation related to scattered thunderstorm activity. The extreme northern portion of mainland Palawan and the Calamian Islands received a storm duration rainfall of 100-200 mm. These estimates were corroborated by ground observations. The synoptic station in Coron, Palawan recorded both the highest storm duration (158.7 mm) and 24-hour accumulated rainfall (115.6 mm) during the passage of Paeng.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
Coron, Palawan (98526) / 115.6 mm / 26 September 2018

Highest storm duration rainfall over land:
Coron, Palawan (98526) / 158.7 mm / 23-28 September 2018

Summary of Warning Information

Number of domestic products issued: **27**

- Severe Weather Bulletins: **13**
- Tropical Cyclone Updates: **10**
- Tropical Cyclone Advisories: **4**

Number of TC Warning for Shipping issued: **24**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **None**

- Damage to agriculture: **None**
- Damage to infrastructure: **None**

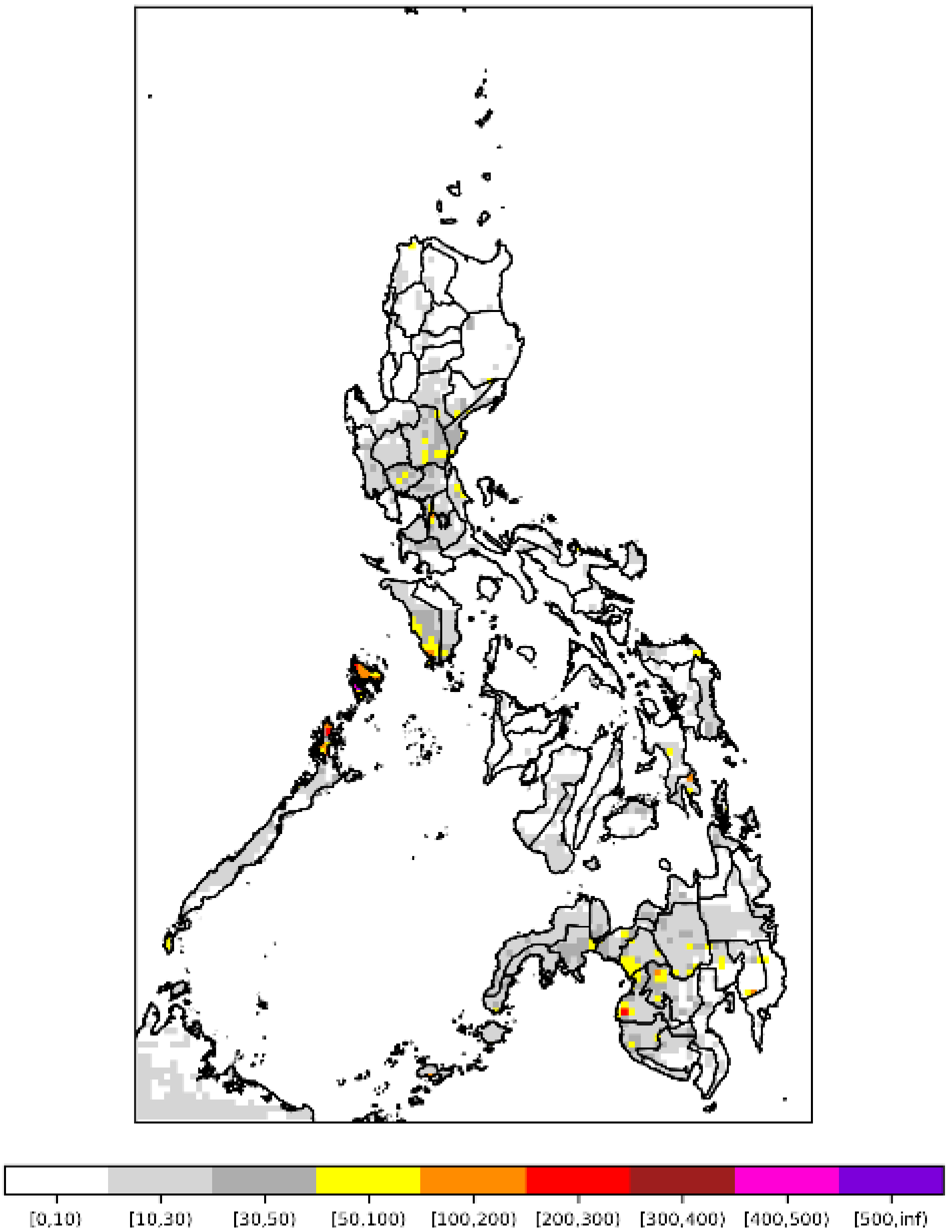


Fig 4.48. Nationwide estimate of storm duration rainfall (mm) for the period of 23-28 September 2018.

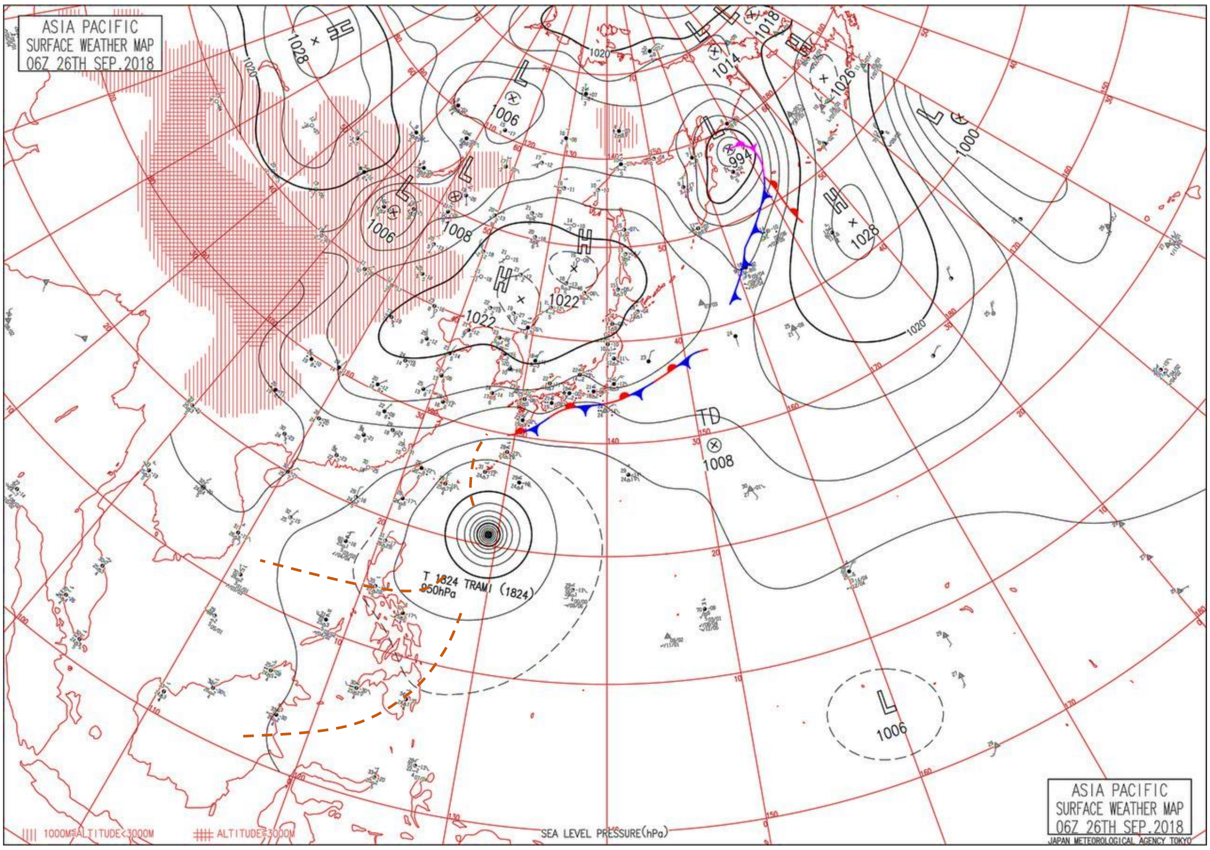


Fig. 4.49. Regional surface chart at 06 UTC on 26 September showing the trough axes (orange dash line) of TC Paeng extending towards the Philippines. Isobars are at 4 hPa intervals.

Tropical Cyclone Queenie (1825 Kong-rey)

28 September to 07 October 2018

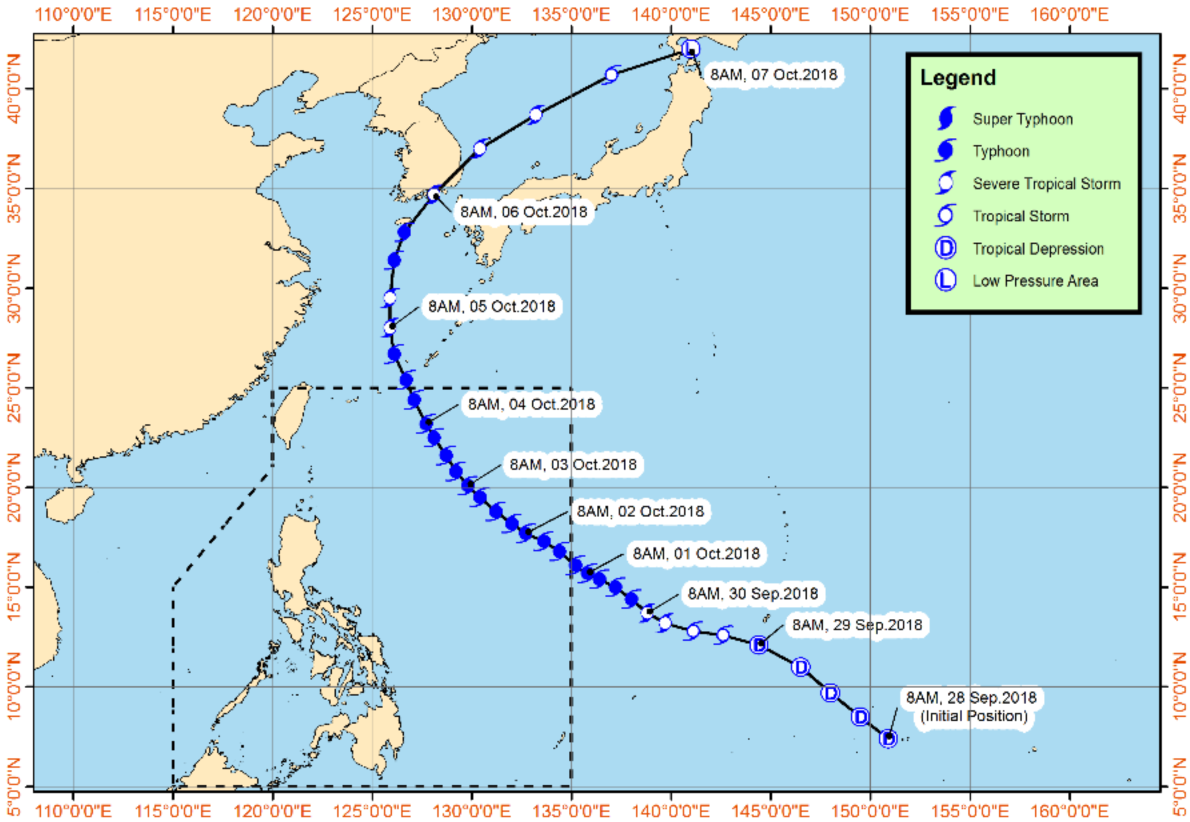


Fig 4.50. PAGASA best track positions and intensities of Tropical Cyclone Queenie.

Meteorological History

0One of the two most powerful tropical cyclones (TC) in 2018, Queenie, originated from an area of low pressure that developed into a tropical depression (TD) in the vicinity of Chuuk, Federated States of Micronesia at 00 UTC on 28 September. While tracking generally northwestward over the Philippine Sea, it was upgraded to a tropical storm (TS) at 06 UTC on 29 September while situated over the sea west-southwest of Guam. Throughout the period of 29 September to 01 October, Queenie rapidly intensified due to favorable conditions. The TS was upgraded into a severe tropical storm (STS) at 18 UTC on 29 September and into a typhoon (TY) 12 hours after. Queenie entered the eastern limits of the Philippine Area of Responsibility (PAR) at around 08 UTC on 01 October.

Within the PAR, the TY continued to rapidly intensify over the warm waters of the Philippine Sea. At 18 UTC on 01 October, the period of rapid intensification culminated when Queenie reached its peak intensity of 115 kt and 900 hPa, making it one of the most intense Western North Pacific TC to enter the PAR in 2018 (record tied with TC Rosita). As the TY continued moving northwestward, increasingly unfavorable atmospheric and oceanic conditions and the onset of an eyewall replacement cycle resulted in a period of weakening roughly 12 hours after it reached its peak intensity. By the time Queenie left the PAR at around 10 UTC on 04 October, it had already weakened to a minimal TY (65 kt).

At 00 UTC on 05 October, Queenie was downgraded to STS category while moving northward over the East China Sea towards the Korean Peninsula. However, at 12 UTC of the same day, it slightly re-intensified into a minimal TY. Queenie subsequently turned northeastward and grazed the southeastern corner of Jeju Island between 19 and 20 UTC on 05 October. At 00 UTC of the following day, the TY was downgraded to STS while off the southern coast of the Korean Peninsula. It came onshore less than hour later in the vicinity of Tongyeong City in South Korea's South Gyeongsang Province. Over the Sea of Japan, Queenie continued to weaken as it underwent extratropical transition. Shortly after making landfall as a TS over the Oshima Peninsula in Hokkaido Prefecture, Japan, the TC fully acquired extratropical characteristics at 00 UTC on 07 October.

The trough of Queenie extended over the country during its passage within the PAR, resulting in distant precipitation related to scattered thunderstorm activity. The areas that received 50-100 mm of four-day rainfall were scattered in nature but are mainly situated over the eastern section of the country. The synoptic station in Catbalogan City, Samar registered the highest storm duration (94.8 mm) rainfall in the country. This accumulated rainfall was caused by a single thunderstorm event on 01 October over the station. The 24-hour rainfall reported by the Catbalogan City station on 01 October was the highest during the period of occurrence of Queenie within the PAR.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
Catbalogan City, Samar (98548) / 94.8 mm / 01 October 2018

Highest storm duration rainfall over land:
Catbalogan City, Samar (98548) / 94.8 mm / 01-04 October 2018

Summary of Warning Information

Number of domestic products issued: **27**
- Severe Weather Bulletins: **13**
- Tropical Cyclone Updates: **10**
- Tropical Cyclone Advisories: **4**

Number of TC Warning for Shipping issued: **24**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **None**
- Damage to agriculture: **None**
- Damage to infrastructure: **None**

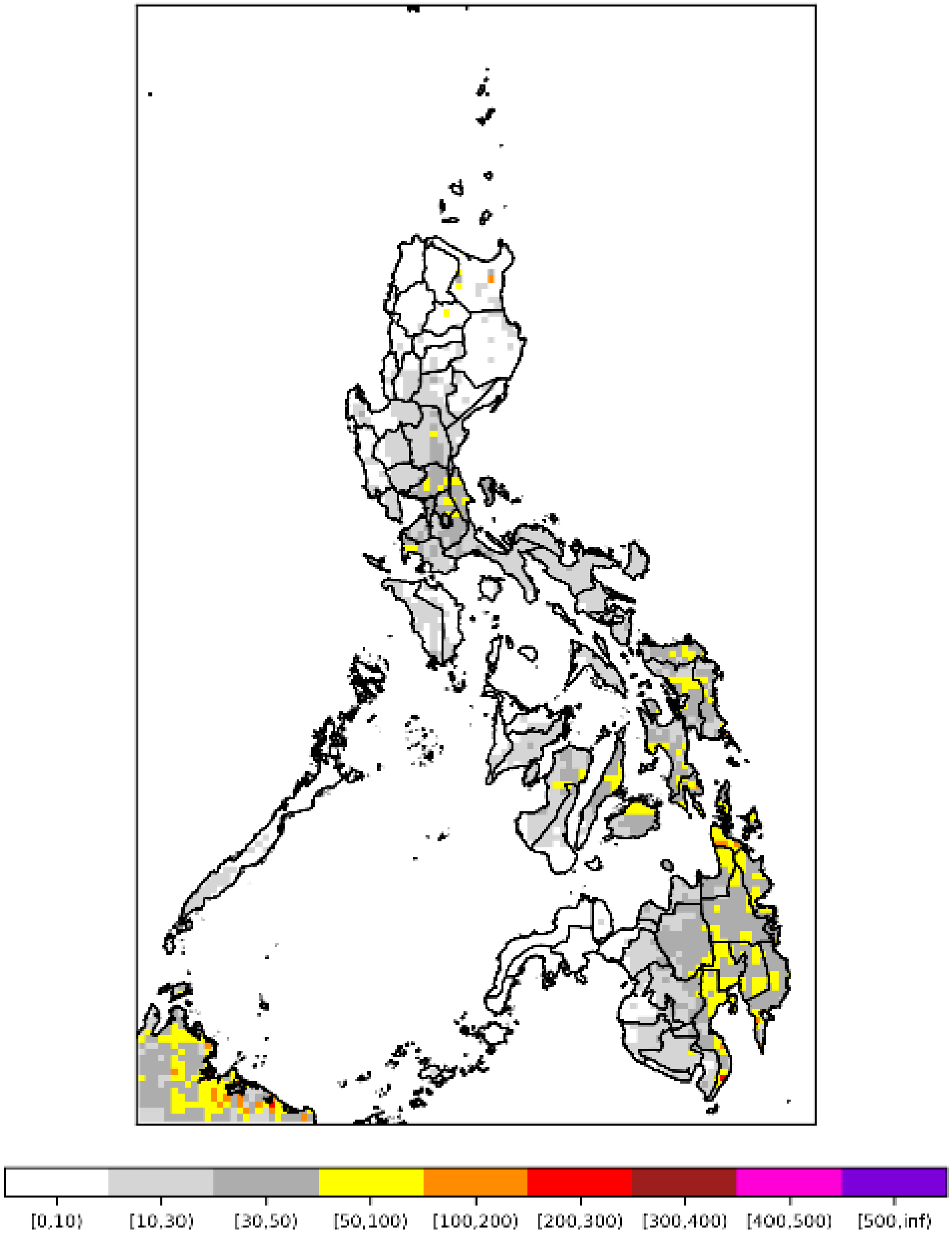


Fig 4.51. Nationwide estimate of storm duration rainfall (mm) for the period of 01-04 October 2018.

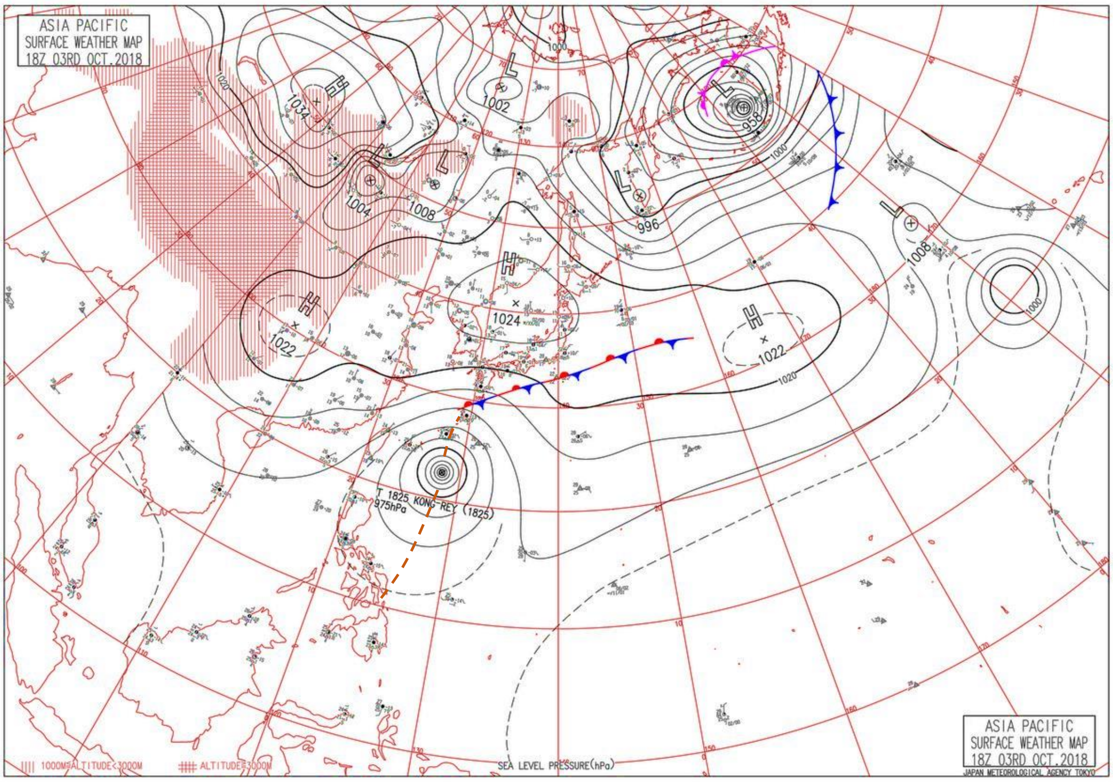


Fig. 4.52. Regional surface chart at 18 UTC on 03 October showing the trough axis (orange dash line) of TC Queenie extending towards the Philippines. Isobars are at 4 hPa intervals.

Tropical Cyclone Rosita (1826 Yutu)

21 October to 02 November 2018

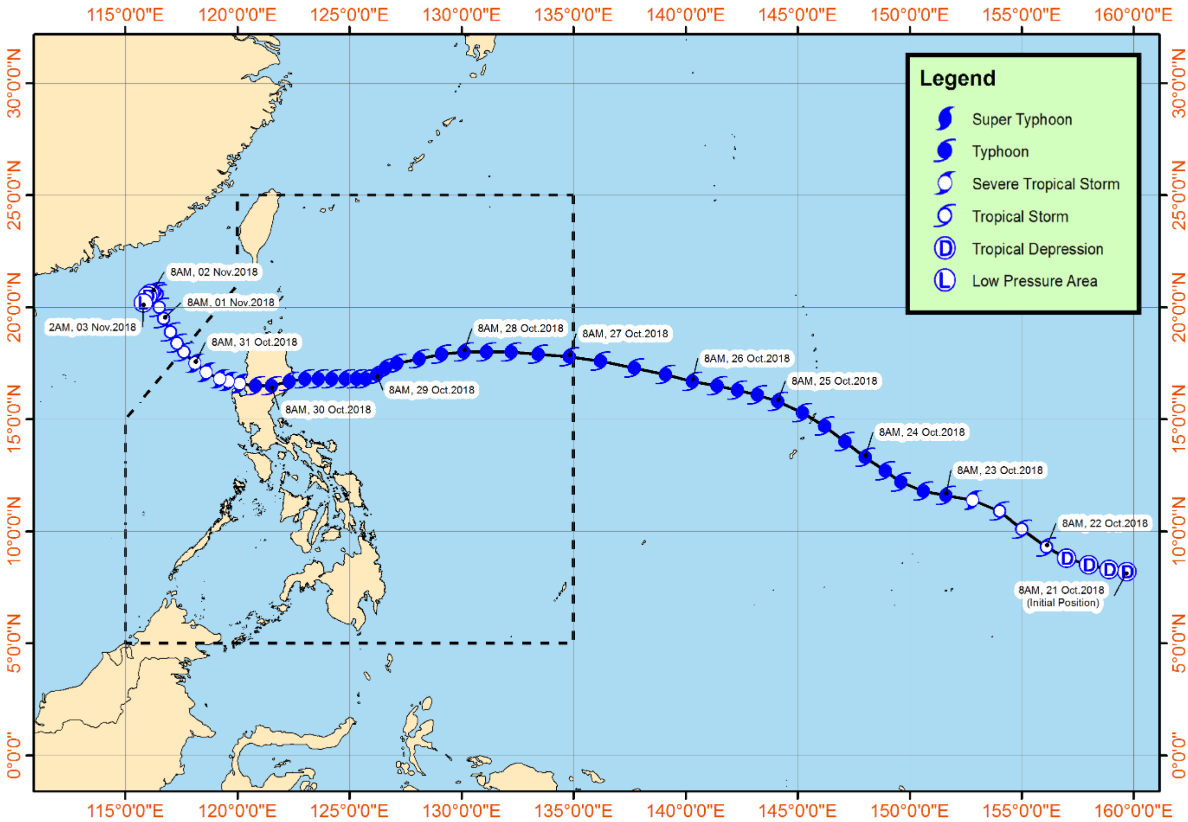


Fig 4.53. PAGASA best track positions and intensities of Tropical Cyclone Rosita.

Meteorological History

At 00 UTC on 21 October, a low pressure area situated in the vicinity of Pohnpei, Federated States of Micronesia developed into a tropical depression named Rosita. Tracking west-northwestward, it intensified into a tropical storm at 00 UTC of the following day. Over the next 3 days, favorable conditions allowed Rosita to rapidly intensify. It was upgraded to a severe tropical storm (STS) at 18 UTC on 22 October and to a typhoon (TY) 6 hours later. At 12 UTC on 24 October, Rosita reached its peak intensity of 115 kt and 900 hPa, making it one of the most intense Western North Pacific tropical cyclone (TC) of 2018 (record tied with TC Queenie). Roughly 3 hours after, the eye of the TY crossed Tinian Island and the southern part of Saipan Island on Northern Mariana archipelago. On 25 October, Rosita underwent an eyewall replacement cycle, causing it to weaken to 95 kt. On the next day, the cycle completed, allowing the TY to reintensify.

Now moving generally westward, Rosita entered the Philippine Area of Responsibility (PAR) at around 00 UTC on 27 October. The TY reached its secondary peak intensity of 105 kt at 18 UTC of the same day. However, the TY was only able to maintain its peak intensity for 24 hours as cooler waters to the east of Luzon and increasingly unfavorable atmospheric environment caused it to weaken. By 18 UTC on 28 October, the TY had weakened to 80 kt. Throughout 29 October, the TY moved steadily westward while maintaining its strength. Rosita made landfall over the coastal town of Dinapigue in Isabela between 20 UTC and 21 UTC on 29 October. The TY weakened substantially as it crossed the mountainous terrain of Northern Luzon. Shortly before 03 UTC on 30 September, Rosita emerged over the Lingayan Gulf and was downgraded to an STS.

Tracking generally northwestward over the West Philippine Sea, Rosita continued to weaken as the cold and dry air of the Northeast Monsoon intruded its circulation. The TC was further downgraded to TS category at 06 UTC on 31 October and left the PAR 2 hours later. At around 12 UTC on 01

November, the TS rapidly decelerated as it encountered a cold surge of the Northeast Monsoon. On the following day, Rosita became embedded in the cold surge, forcing the TS to rapidly weaken and turn southwestward. It degenerated into a remnant low at 18 UTC on 02 November over the West Philippine Sea and dissipated after less than 12 hours

Storm duration estimates revealed that rainfall totals between 50 and 200 mm were experienced over the provinces in Northern Luzon (apart from Ilocos Norte, northern portion of Ilocos Sur, and northwestern portion of Abra) and Central Luzon, Metro Manila, Rizal, and the northern portion of Quezon with an isolated area in the extreme northern portion of Aurora receiving between 200 and 300 mm. The rapid deterioration in the structure of Rosita as it crossed Luzon resulted in generally higher rainfall amounts over the eastern sections of Northern and Central Luzon compared to the western side, although ground observations from PAGASA stations suggested the influence of orographic effect in amplifying TC rainfall. Both the highest storm duration (177.8 mm) and 24-hour accumulated rainfall (170.0 mm) were recorded at Baguio City synoptic station.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest peak gust over land:
Casiguran, Aurora (98336) / N (360°) 36 m/s / 29 October 2018, 2125 UTC

Lowest sea level pressure over land:
Casiguran, Aurora (98336) / 971.8 hPa / 29 October 2018, 2100 UTC

Highest 24-hour rainfall over land:
Baguio City (98328) / 170.0 mm / 30 October 2018

Highest storm duration rainfall over land:
Baguio City (98328) / 177.8 mm / 27-31 October 2018

Summary of Warning Information

Number of domestic products issued: **49**

- Severe Weather Bulletins: **22**
- Tropical Cyclone Updates: **23**
- Tropical Cyclone Advisories: **4**

Number of TC Warning for Shipping issued: **18**

Number of localities under TC Wind Signal (TCWS): **29**

Highest wind signal put into effect: **TCWS #3**

Summary of Casualties and Damage to Property

Number of casualties: **20 dead and 2 injured**

Combined cost of damage: **PHP 2,904.840 million**

- Damage to agriculture: **PHP 2,904.840 million**
- Damage to infrastructure: **Not available**

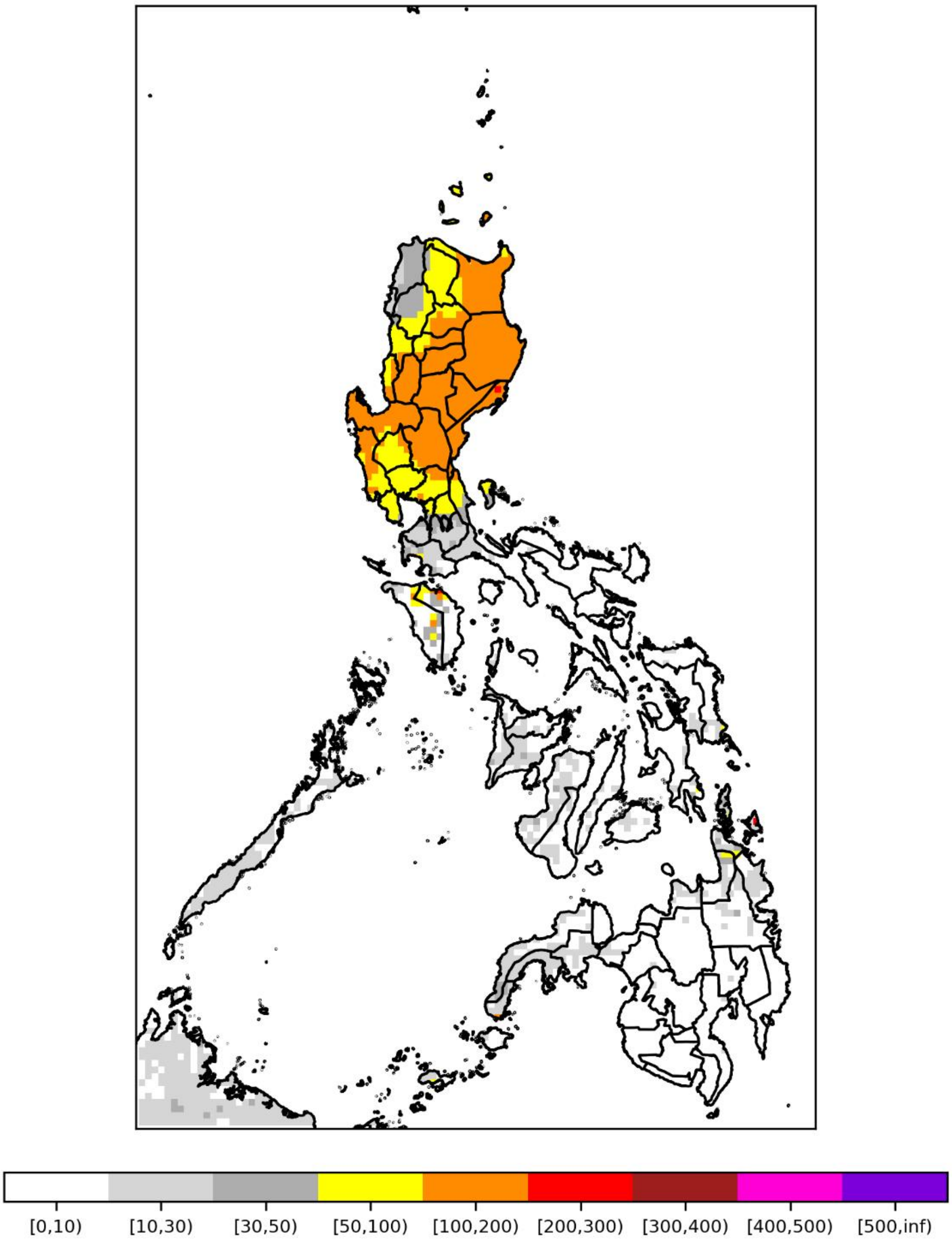


Fig 4.54. Nationwide estimate of storm duration rainfall (mm) for the period of 27-31 October 2018.

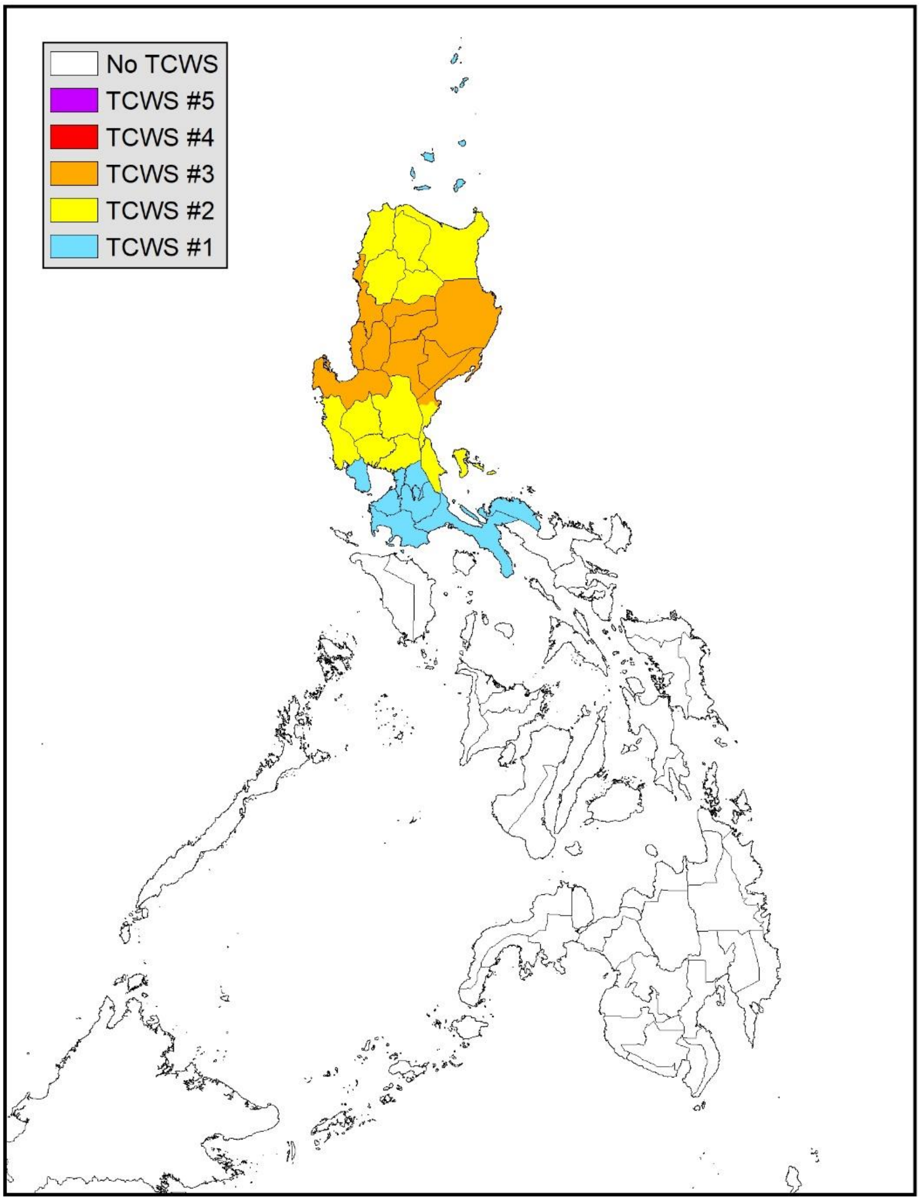


Fig 4.55. Highest wind signal raised by PAGASA during the passage of TC Rosita in each province or subprovincial locality.

Tropical Cyclone Samuel (1829 Usagi)

21 October to 02 November 2018

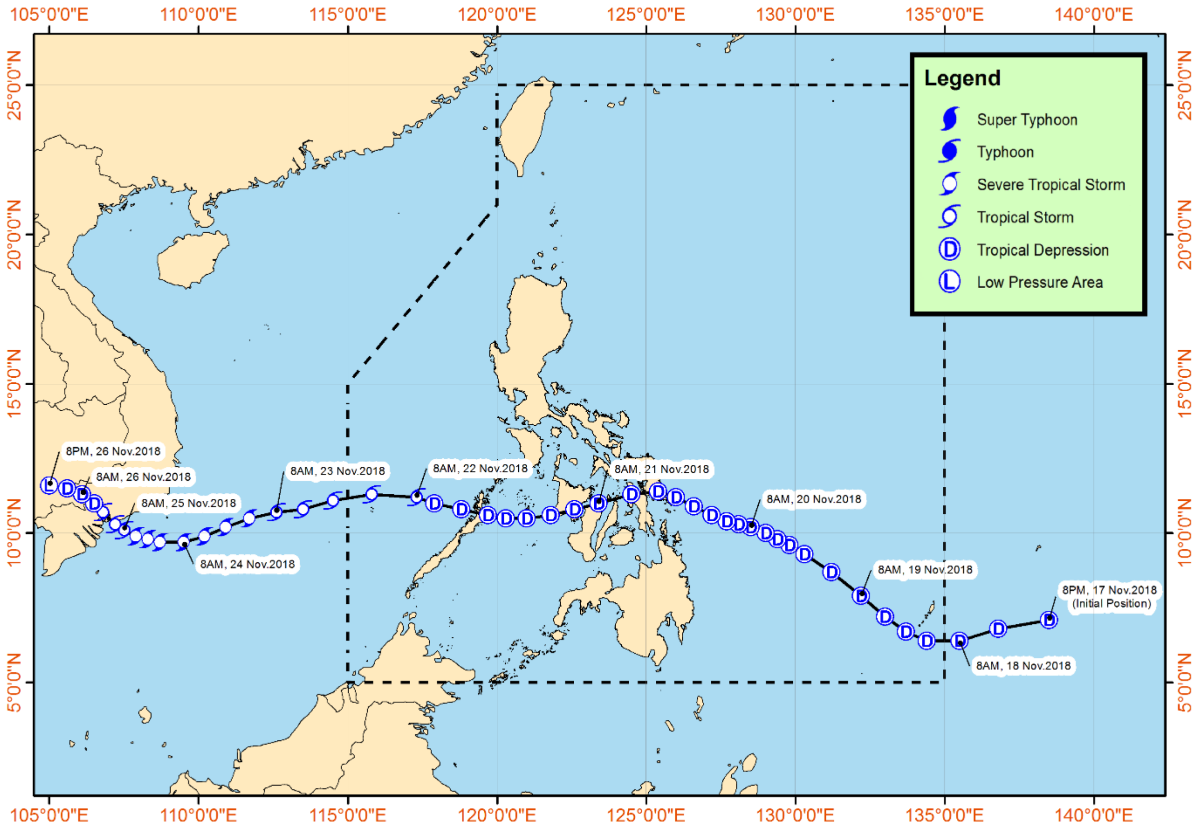


Fig 4.56. PAGASA best track positions and intensities of Tropical Cyclone Samuel.

Meteorological History

An area of low pressure situated south of Yap Island in the Federated States of Micronesia was first noted as a tropical depression (TD) by PAGASA at 12 UTC on 17 November. Tracking generally west-southwestward, the TD entered the Philippine Area of Responsibility (PAR) at around 03 UTC on 18 November. As the TD approached Palau between 06 UTC and 12 UTC of the same day, it turned northwestward. Throughout 19 and 20 November, Samuel tracked generally northwestward over the Philippine Sea towards Eastern Visayas where it eventually made its first landfall.

At around 17 UTC on 20 November, the center of the TD came onshore over Hernani in Eastern Samar. Now moving generally west-southwestward, Samuel traversed the islands of Samar and Leyte and emerged over the northern portion of Camotes Sea past 21 UTC on the same day. Over the next 5 hours, the center of the TD made successive landfalls over Daanbantayan (22 UTC) and Bantayan (23 UTC) in Cebu, Cadiz City in Negros Occidental (00 UTC on 21 November), and Dumangas in Iloilo (02 UTC) before emerging over the Sulu Sea at 06 UTC on 21 November. The TD then gradually turned to the west-northwest as it passed south the Cuyo archipelago. It made its final landfall in the vicinity of Araceli, Palawan at around 13 UTC. Over West Philippine Sea, Samuel gradually intensified despite the prevailing Northeast Monsoon surge due to offsetting favorable conditions. It was upgraded to tropical storm (TS) category at around 00 UTC on 22 November. The TS then left the PAR at around 10 UTC of the same day.

Outside the PAR, the TS continued to strengthen throughout the remainder of 22 November and onto the following day while tracking west-southwestward. Samuel intensified into a severe tropical storm (STS) at 06 UTC on 23 November and its intensity peaked 18 hours later at 60 kt and 985 hPa. However, 12 hours after reaching peak intensity, the STS started to weaken due to increasingly deteriorating environmental conditions and its proximity to land. Now tracking northwestward, Samuel was downgraded to TS category at 00 UTC on 25 November. At around 07 UTC of the same day, the TS made landfall over the city of Vũng Tàu in Vietnam's Bà Rịa–Vũng Tàu Province. Moving inland, it degenerated into a remnant low at 12 UTC on 26 November in the vicinity of Kandal Province in Cambodia.

Estimates of storm duration rainfall in the Philippines revealed that Bicol Region, Dinagat Islands, Surigao del Norte, Romblon, most of Visayas, and portions of Quezon, Palawan, Mindoro Provinces, Agusan Provinces, and Surigao del Sur received between 50 and 200 mm with isolated areas of 200-300 mm in Samar Provinces and Cuyo archipelago. The rainfall distribution based on both satellite estimates and ground observation suggests that the rainfall maximum region was situated over the Cuyo Archipelago, Samar Provinces, Biliran, Albay, and Sorsogon. The synoptic station in Cuyo, Palawan reported the highest storm duration (314.0 mm) and 24-hour accumulated rainfall (291.4 mm) during the passage of Samuel

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest peak gust over land:
Basco, Batanes (98134) / NNE (30°) 18 m/s / 22 November 2018, 1105 UTC

Lowest sea level pressure over land:
Cuyo, Palawan (98630) / 1003.1 hPa / 21 November 2018, 0800 UTC

Highest 24-hour rainfall over land:
Cuyo, Pawalan (98630) / 291.4 mm / 21 November 2018

Highest storm duration rainfall over land:
Cuyo, Pawalan (98630) / 314.0 mm / 18-22 November 2018

Summary of Warning Information

Number of domestic products issued: **44**

- Severe Weather Bulletins: **26**
- Tropical Cyclone Updates: **16**
- Tropical Cyclone Advisories: **2**

Number of TC Warning for Shipping issued: **18**

Number of localities under TC Wind Signal (TCWS): **28**

Highest wind signal put into effect: **TCWS #1**

Summary of Casualties and Damage to Property

Number of casualties: **Not available**

Combined cost of damage: **PHP 52.228 million**

- Damage to agriculture: **PHP 52.228 million**
- Damage to infrastructure: **Not available**

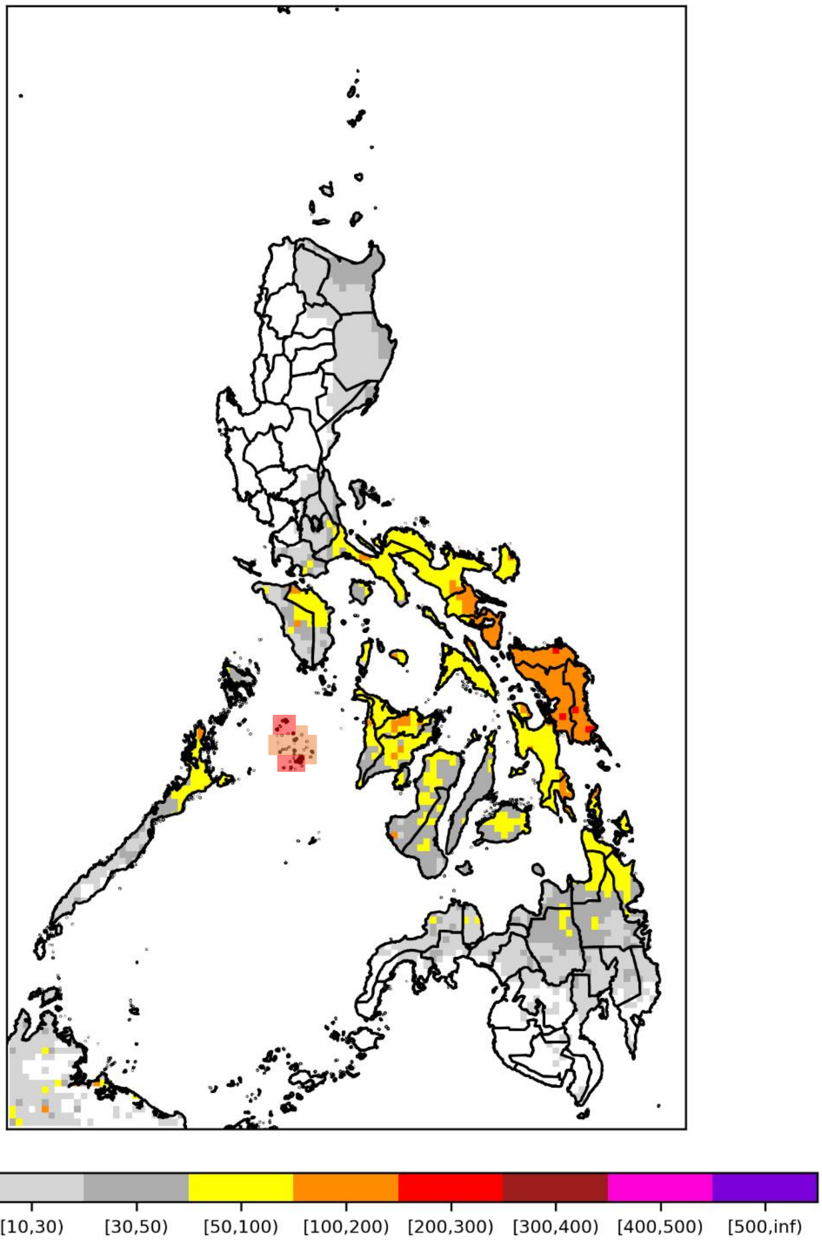


Fig 4.57. Nationwide estimate of storm duration rainfall (mm) for the period of 18-22 November 2018. The colors for the Cuyo archipelago are emphasized.

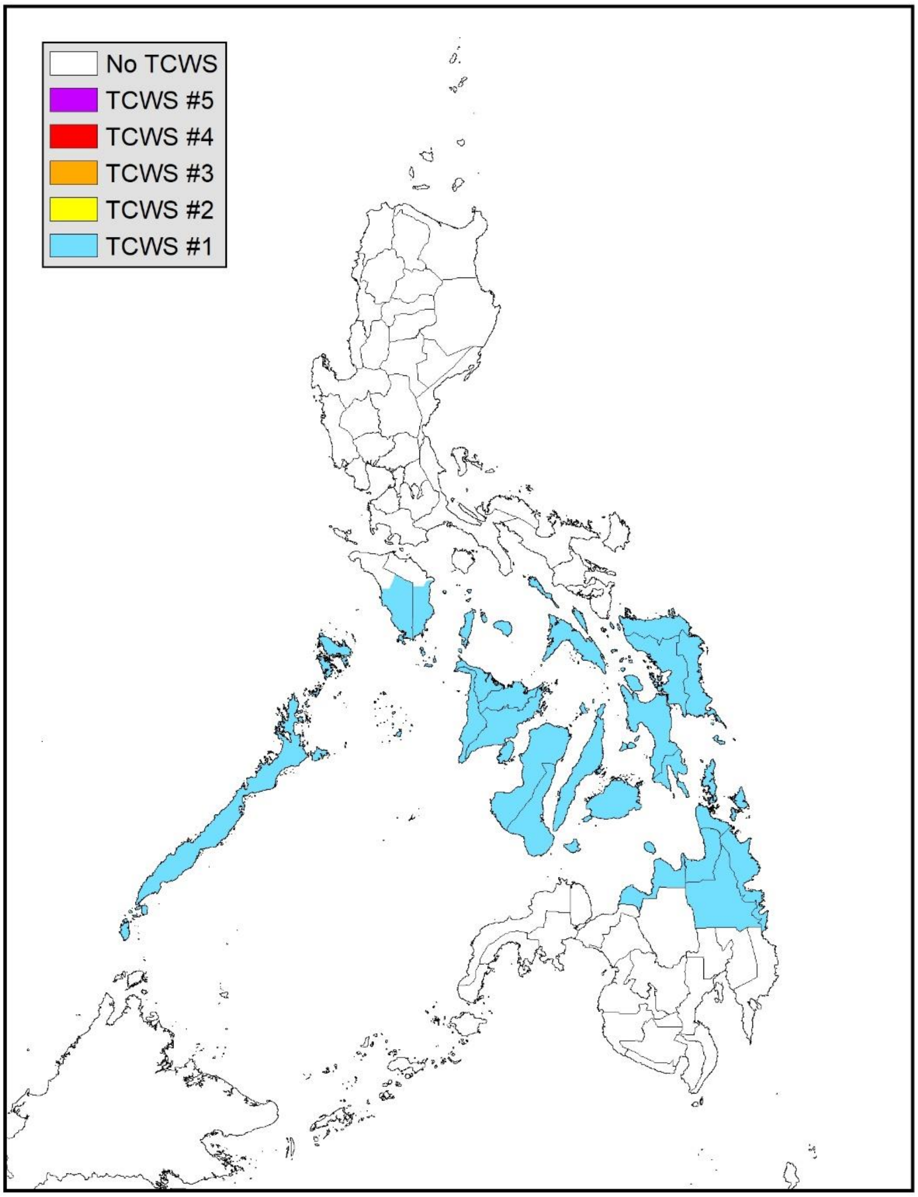


Fig 4.58. Highest wind signal raised by PAGASA during the passage of TC Samuel in each province or subprovincial locality.

Tropical Cyclone Tomas (1828 Man-yi)

21 October to 02 November 2018

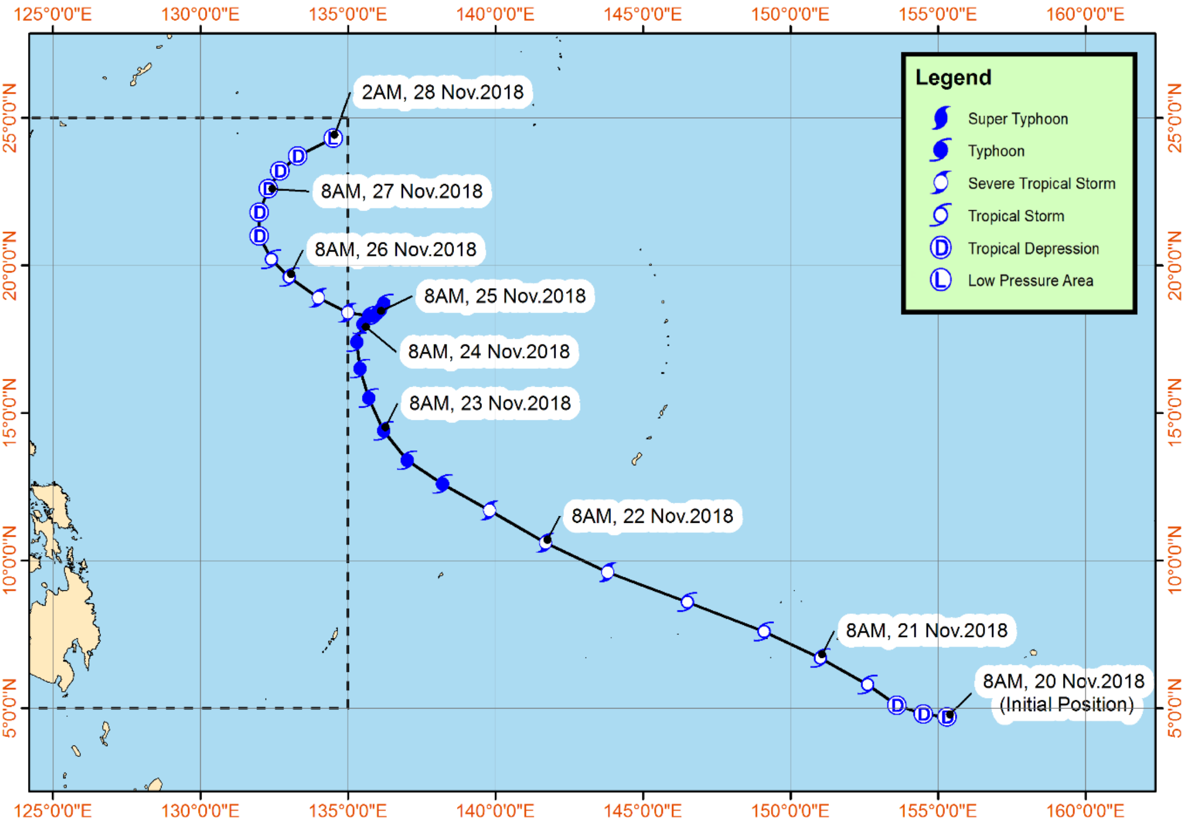


Fig 4.59. PAGASA best track positions and intensities of Tropical Cyclone Tomas.

Meteorological History

Tropical cyclone (TC) Tomas was first tracked by PAGASA as a tropical depression (TD) at 00 UTC on 20 November over the sea southwest of Pohnpei Island in the Federated States of Micronesia. After being upgraded into a tropical storm (TS) at 18 UTC of the same day, Tomas accelerated northwestward towards the Philippine Sea. The TS continued to intensify and was upgraded to a severe tropical storm at 18 UTC on 21 November and a typhoon (TY) 18 hours later. On 23 November, in the presence of other synoptic weather systems, Tomas decelerated and turned north-northwestward then northward roughly 300 km from the eastern limits of the Philippine Area of Responsibility (PAR). Throughout 24 November, the TY tracked slowly and looped anticyclonically and at 12 UTC of the same day, it reached its peak intensity of 80 kt and 960 hPa.

On 25 November, Tomas started moving westward then northwestward towards the PAR. The TY also began succumbing to increasing hostile environmental conditions due to a prevailing Northeast Monsoon surge and cooler waters over the northern portion of the Philippine Sea. By the time Tomas entered the PAR at 12 UTC of the same day, its intensity had dropped below TY category. Throughout 26 and 27 November, Tomas curved to the northeast and continued to weaken. It degenerated into a TD at 12 UTC on 26 November and fully acquired extratropical characteristic at 18 UTC of the following day near the northeastern corner of the PAR.

The occurrence of Tomas did not adversely affect the Philippines throughout its lifespan. While the presence of Tomas and Samuel (by this time situated over the sea east of Southern Vietnam) enhanced the prevailing surge of the Northeast Monsoon, the country generally experienced light rains and isolated rain showers. The highest storm duration (38.9 mm) and 24-hour accumulated rainfall (30.8 mm) were both observed at Surigao City, Surigao del Norte.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
Surigao City, Surigao del Norte (98653) / 30.8 mm / 25 November 2018

Highest storm duration rainfall over land:
Surigao City, Surigao del Norte (98653) / 38.9 mm / 25-27 November 2018

Summary of Warning Information

Number of domestic products issued: **22**

- Severe Weather Bulletins: **8**
- Tropical Cyclone Updates: **12**
- Tropical Cyclone Advisories: **2**

Number of TC Warning for Shipping issued: **14**

Number of localities under TC Wind Signal (TCWS): **None**

Highest wind signal put into effect: **None**

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **None**

- Damage to agriculture: **None**
- Damage to infrastructure: **None**

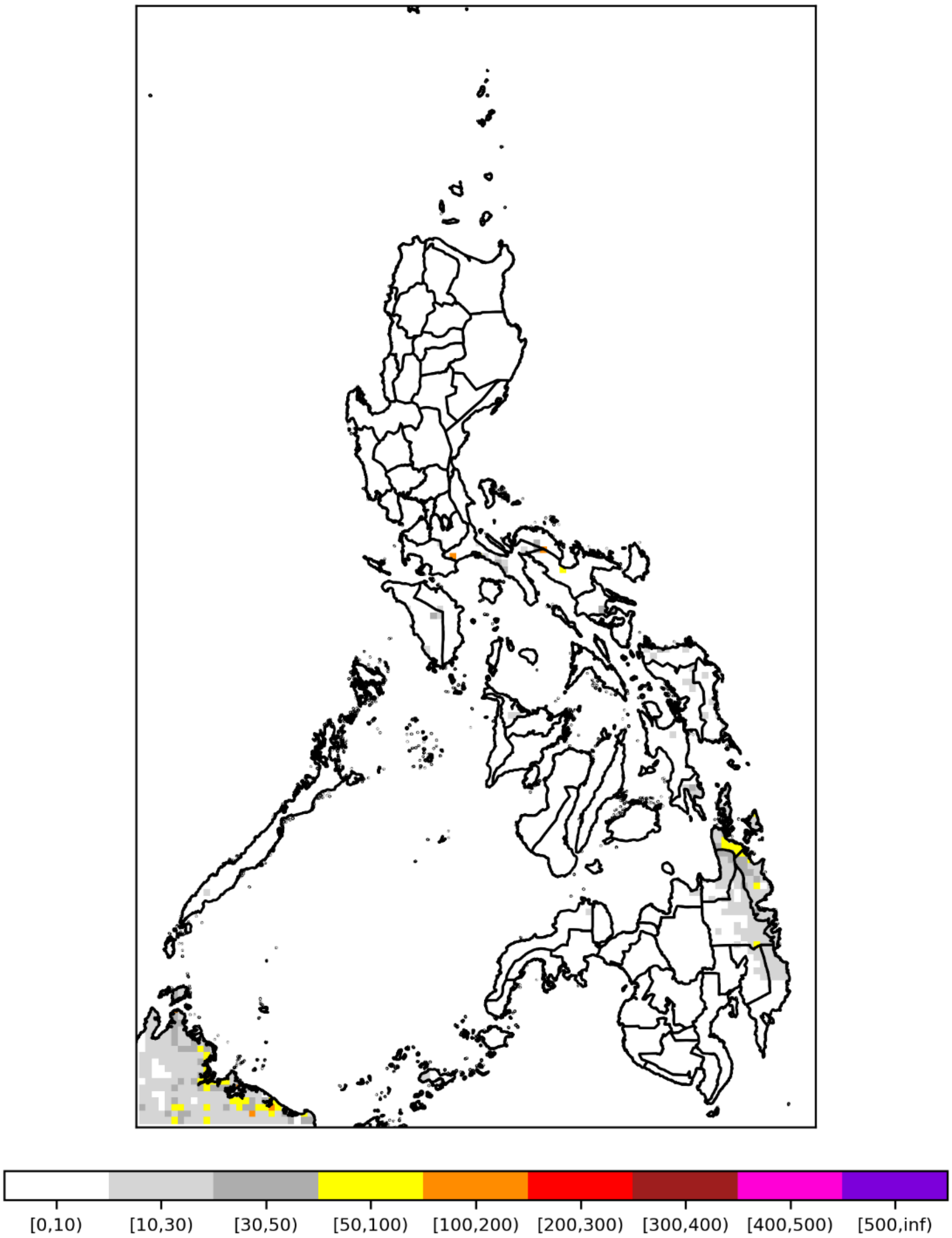


Fig 4.60. Nationwide estimate of storm duration rainfall (mm) for the period of 25-27 November 2018.

Tropical Cyclone Usman

25 to 30 December 2018

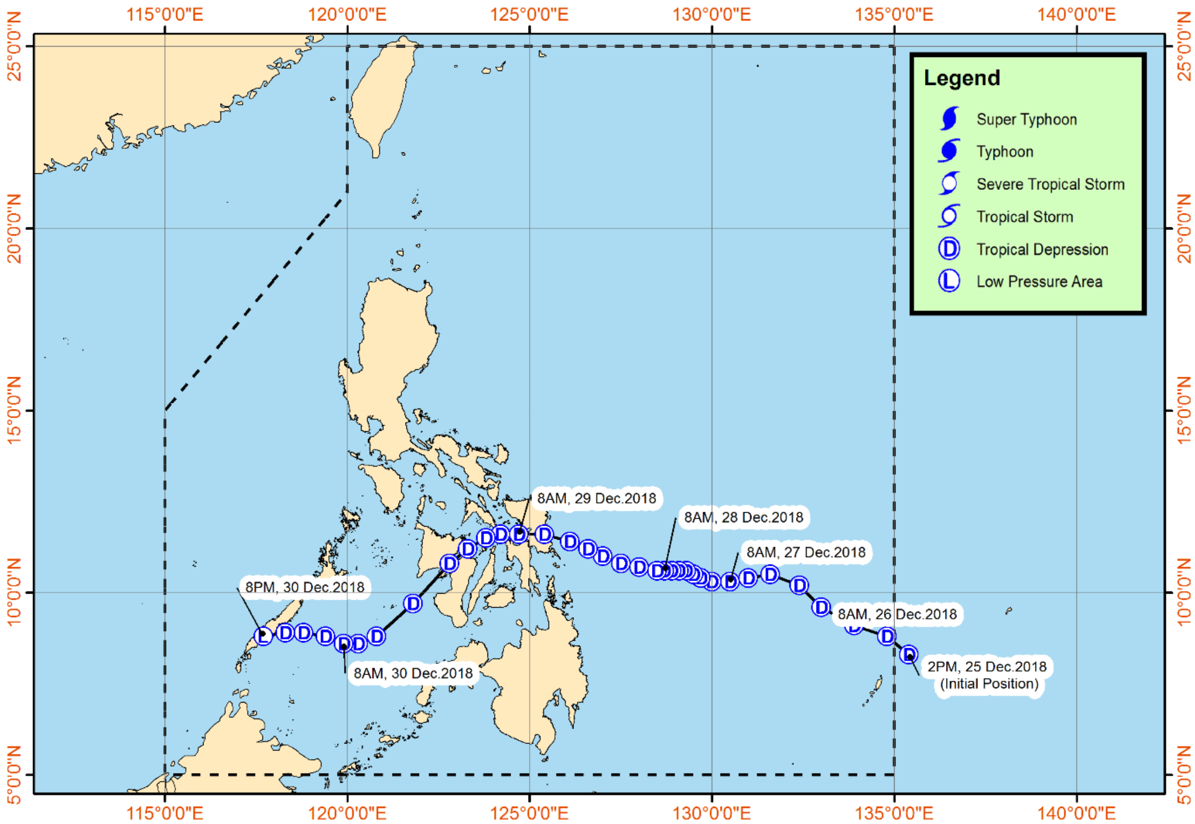


Fig 4.61. PAGASA best track positions and intensities of Tropical Cyclone Usman.

Meteorological History

The last tropical cyclone (TC) to enter the Philippine Area of Responsibility (PAR) in 2018 was first tracked by PAGASA as a tropical depression (TD) at 06 UTC on 25 December while situated over the sea northeast of Palau. Tracking northwestward, the TD entered the PAR at around 10 UTC of the same day. On 27 December, Usman decelerated and shifted to a more westward heading. At 12 UTC of the same day, the TD slightly intensifies to 30 kt. This intensity was maintained by the TD until its first landfall over Eastern Visayas. On 28 December, Usman turned west-northwestward and slightly accelerated, eventually making landfall over Borongan City in Eastern Samar at around 21 UTC.

After crossing Samar Island, the TD made landfall over the Caibiran-Culaba area in Biliran at 01 UTC on 29 December and emerged over the Visayan Sea 2 hours later. At this point, the circulation of Usman significantly deteriorated due to land interaction and increasingly unfavorable atmospheric environment and its center became ill-defined. At around 06 UTC on 29 December, Usman turned southwestward towards the Guimaras Strait under the influence of the prevailing monsoon surge. It crossed the island province of Guimaras at around 12 UTC and reached the Sulu Sea roughly 3 hours later.

After traversing the Visayan archipelago, the ill-defined circulation of Usman improved and became more evident over the Sulu Sea. At around 21 UTC on 29 December, the TD started tracking generally westward towards the southern portion of Palawan. The TD made landfall over the town of Brooke's Point in Palawan at around 12 UTC of the same day where it finally degenerated into a remnant low.

Storm duration rainfall estimates during the passage of Usman revealed that significant portion of the country received in excess of 50 mm of total rainfall. Localities situated on the eastern section of the country that are north of the observed track such as the southeastern portion of Luzon and northern portion of Eastern Visayas disproportionately received very high rainfall accumulations compared to other areas, especially those situated near or along the observed track. In particular, Camarines Provinces, Albay, Sorsogon, Catanduanes, Ticao Island, Northern Samar, northern portion of Samar and Eastern Samar, and extreme southeastern portion of Quezon had at least 400 mm of total rainfall. The highest storm duration rainfall was recorded by the synoptic station at Daet, Camarines Norte (633.5 mm), while the highest single-day rainfall was observed at Catarman, Northern Samar (438.0 mm).

The magnitude and spatial distribution of rainfall in both storm duration estimates and gauge observations can be explained by the enhanced moisture convergence along the shear line during strong Northeast Monsoon surges in the presence of the cyclonic circulation of Usman. Normally, shear lines are associated with predominantly light stratiform rainfall with isolated heavy showers. However, increased convergence in the shear line during TC events result in scattered to widespread heavy rains in the areas affected by the shearline. In particular, the rainfall totals are usually higher in the areas affected by the shear line than in the areas near or along the observed track of the TC.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest peak gust over land:
Legazpi City, Albay (98444) / NE (50°) 33 m/s / 29 December 2018, 0445 UTC

Lowest sea level pressure over land:
Tacloban City, Leyte (98550) / 1000.1 hPa / 28 December 2018, 0800 UTC
Borongan City, Eastern Samar (98553) / 1000.1 hPa / 28 December 2018, 0700 UTC

Highest 24-hour rainfall over land:
Catarman, Northern Samar (98546) / 438.0 mm / 28 December 2018

Highest storm duration rainfall over land:
Daet, Camarines Norte (98440) / 633.5 mm / 25-30 December 2018

Summary of Warning Information

Number of domestic products issued: **28**

- Severe Weather Bulletins: **20**
- Tropical Cyclone Updates: **8**
- Tropical Cyclone Advisories: **0**

Number of TC Warning for Shipping issued: **16**

Number of localities under TC Wind Signal (TCWS): **26**

Highest wind signal put into effect: **TCWS #1**

Summary of Casualties and Damage to Property

Number of casualties: **156 dead, 105 injured, and 26 missing**

Combined cost of damage: **PHP 5,411.793 million**

- Damage to agriculture: **PHP 1,948.429 million**
- Damage to infrastructure: **PHP 12,985.121 million**

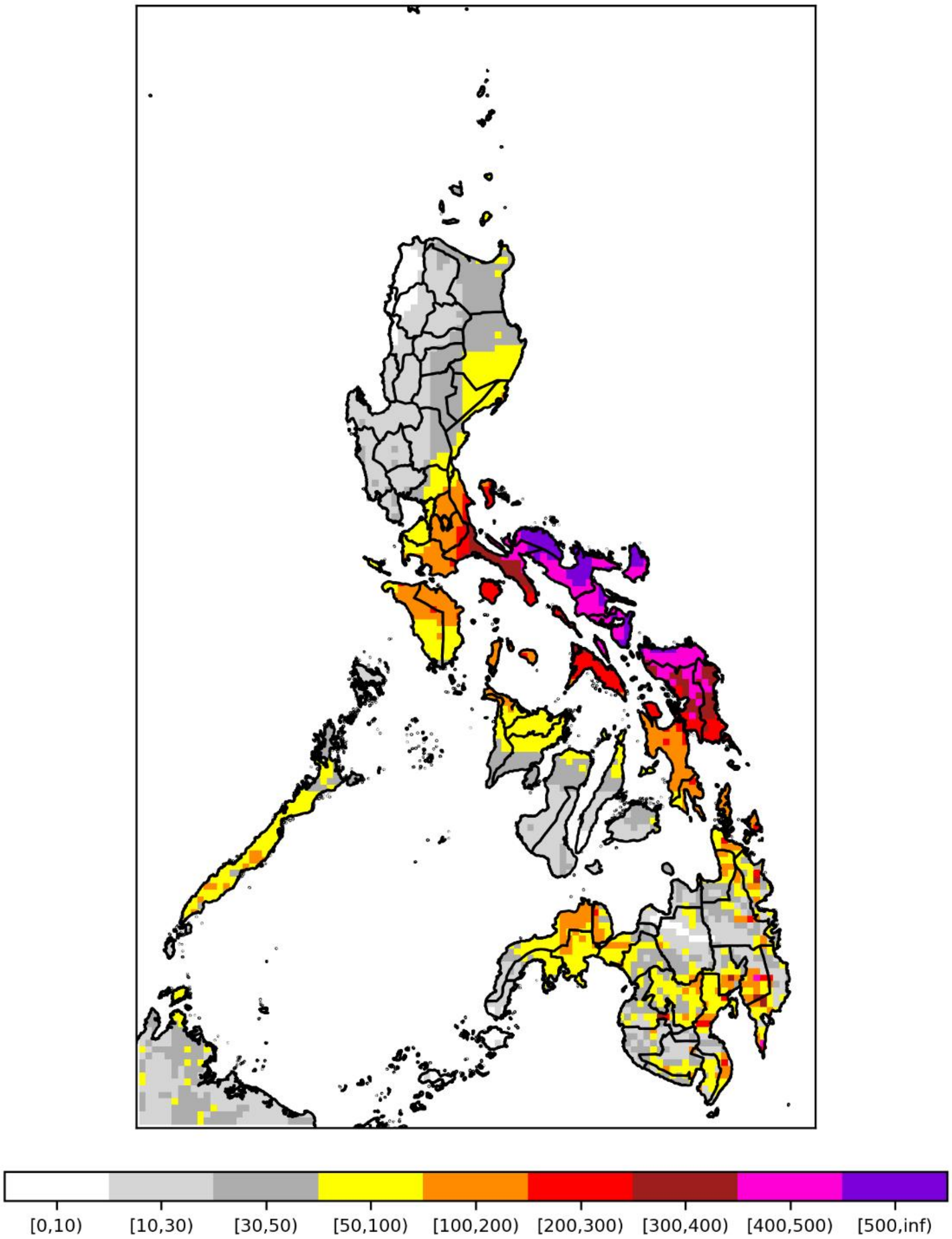


Fig 4.62. Nationwide estimate of storm duration rainfall (mm) for the period of 25-30 December 2018.

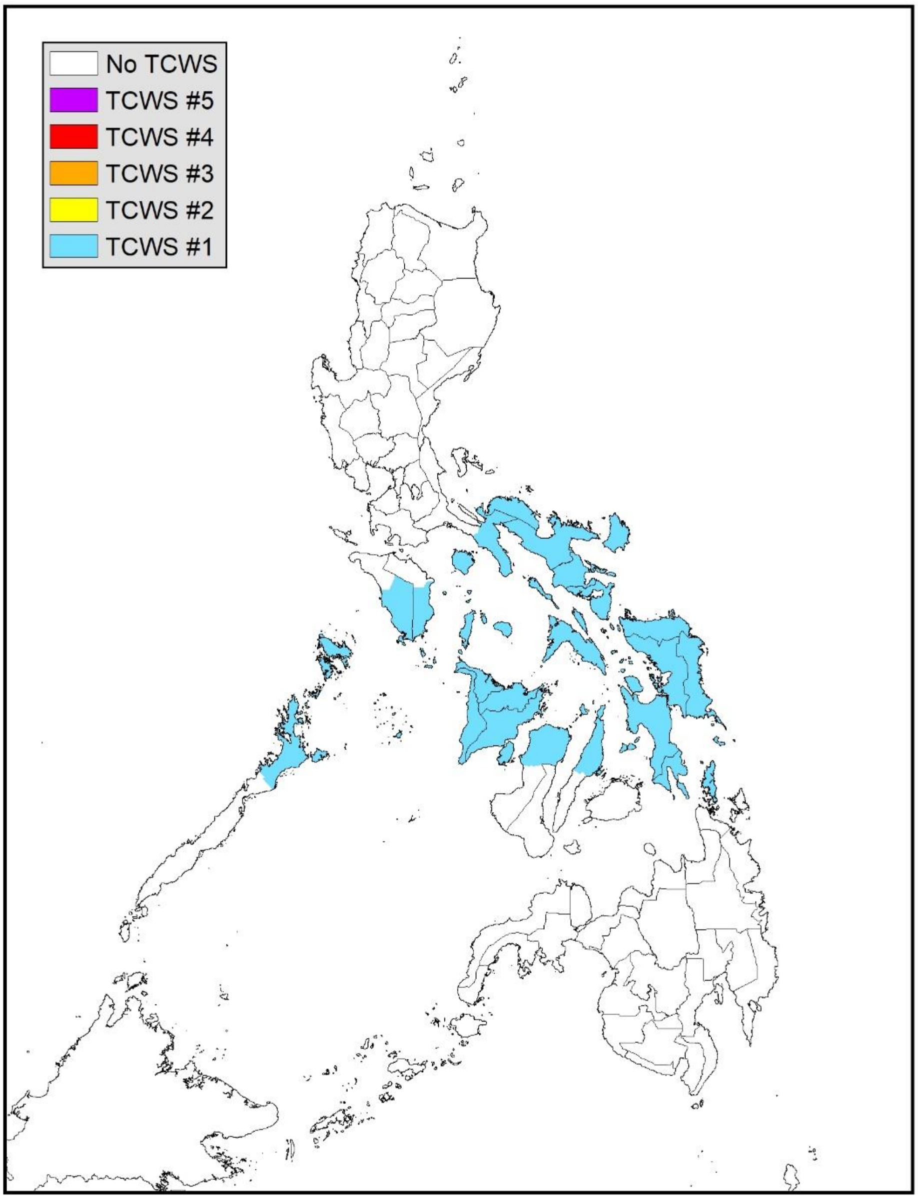


Fig 4.63. Highest wind signal raised by PAGASA during the passage of TC Usman in each province or subprovincial locality.

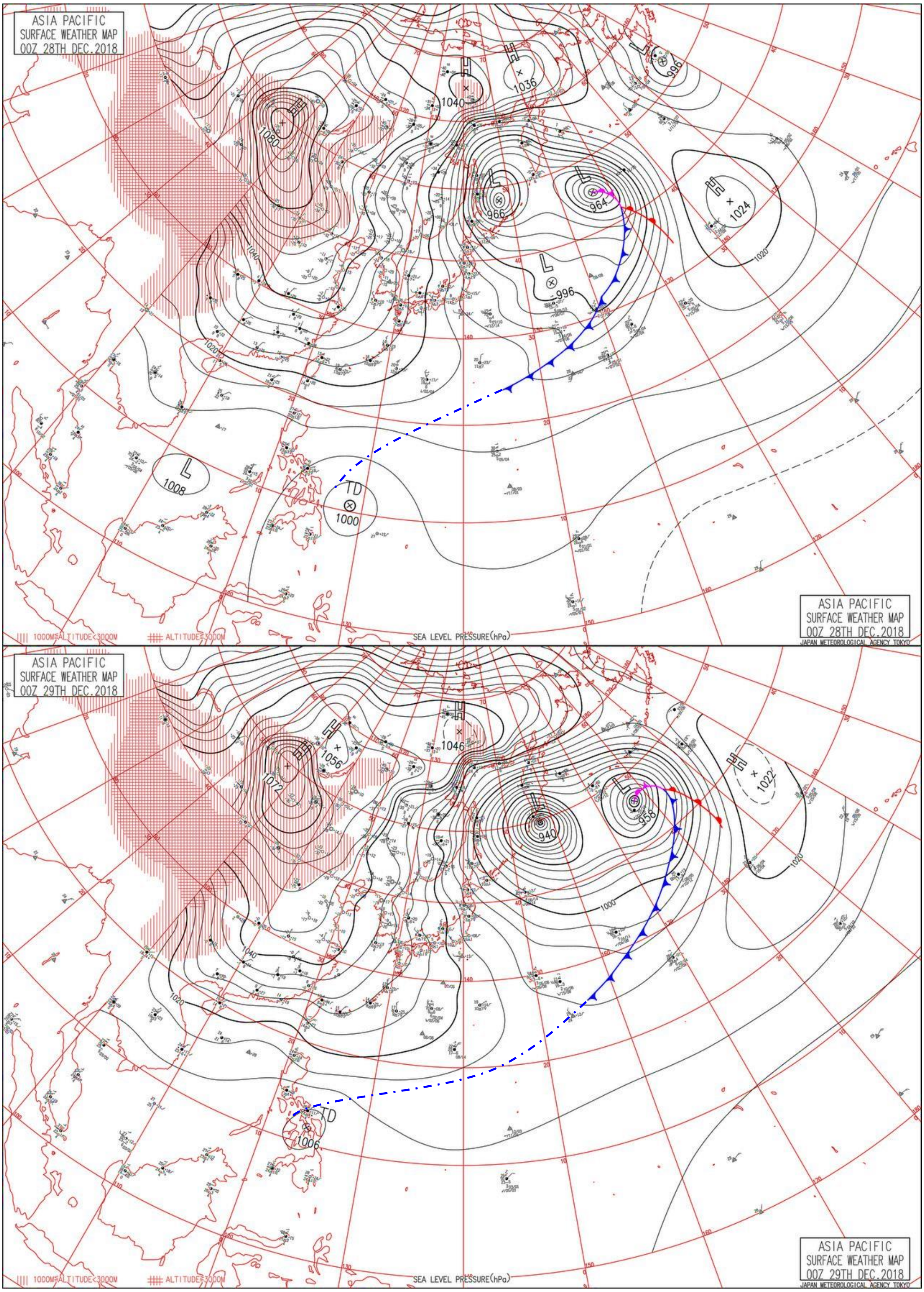


Fig. 4.64. Regional surface chart at 00 UTC on 28 (top) and 29 December (bottom) showing the steep pressure gradient north of 15°N associated with a strong Northeast Monsoon surge and the shear line (blue dash-dot line) extending from the cold front of an extratropical cyclone in the Northern Pacifc to the circulation of TC Usman. Isobars are at 4 hPa intervals.

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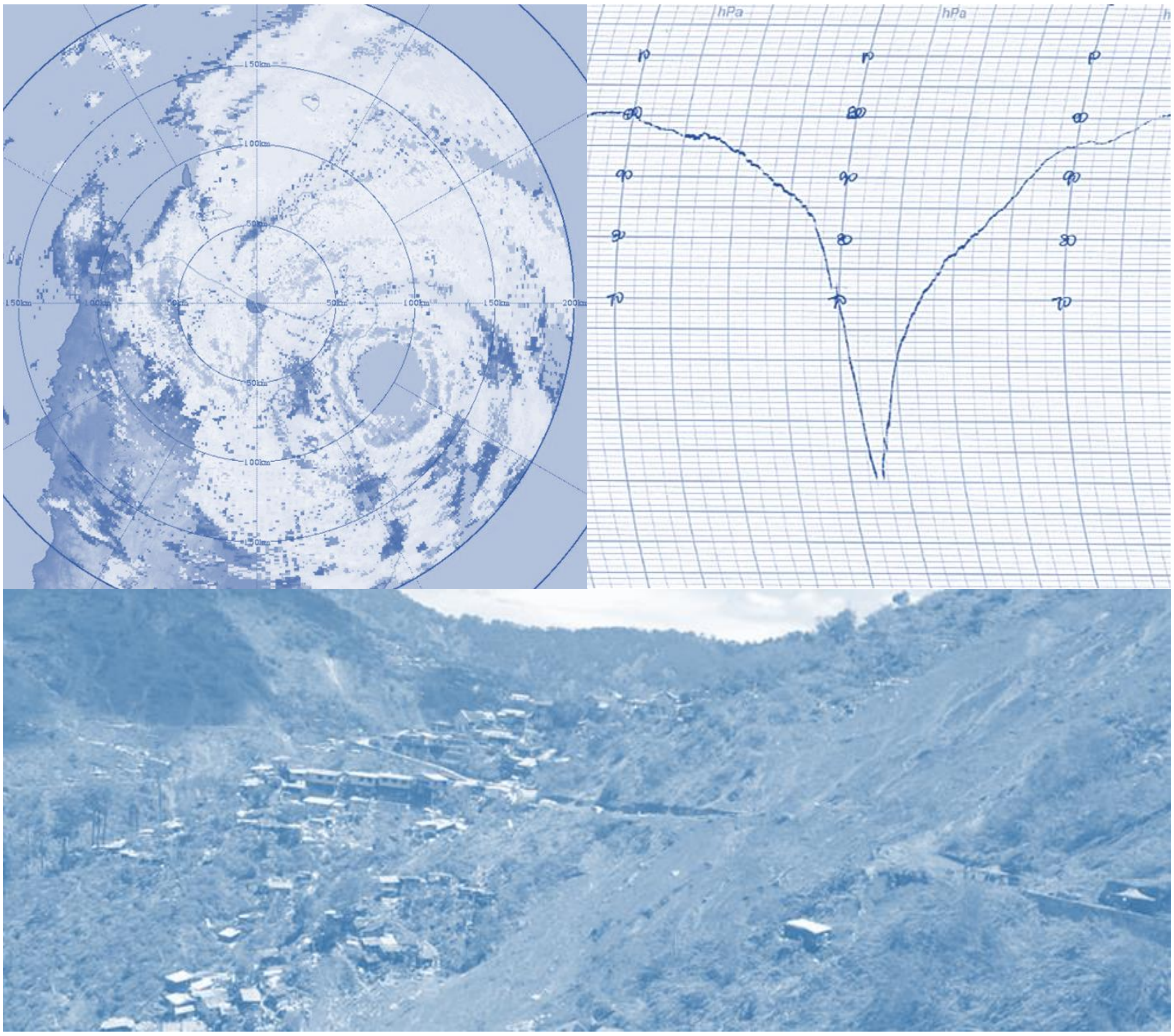
THE ITOGON HEAVY RAINFALL DISASTER OF SEPTEMBER 2018



Tropical Cyclone Ompong, the strongest to make landfall in the Philippines in 2018 and the resulting landslide event that made it the second deadliest tropical cyclone of the year.

The Itogon Heavy Rainfall Disaster of September 2018

Between 14 and 15 September, Tropical Cyclone (TC) Ompong crossed the northern portion of Luzon island as a typhoon (TY) at peak intensity, making it the strongest TC to cross the Philippine archipelago in 2018. Its passage and the enhancement of monsoon rains resulted in widespread heavy rains over much of Luzon. However, the rainfall distribution over Luzon showed that the areas in the southern segment of the Cordillera Central mountain range (roughly 150-200 km S of the observed track) had rainfall accumulations that were notably higher than in areas directly affected inner core convection of the TY. For instance, gauge-adjusted satellite estimates of rainfall over the provinces of Benguet and La Union from 12 to 15 September[24] were at least 400 mm.

The heavy rains in the mountainous regions of Northern Luzon resulted in at least 15 landslide incidents in the Cordillera Administrative Region based on the reports of the National Disaster Risk Reduction and Management Council. Of these 15, the incident that took place in the town of Itogon, Benguet stood out. Between 05 and 06 UTC on 15 September, a massive debris flow[25] event devastated a small-scale mining community in Sitio First Gate, Barangay Ucab. The landslide buried bunkhouses and shanties that were built along the mountain slopes, resulting in the death of 51 people or roughly 62% of the total number of deaths associated with Ompong. This case study presents a meteorological narrative of the heavy rainfall disaster that lead to the deadly landslide in Itogon, Benguet.

Landslide Susceptibility of the Cordilleras

The northern portion of Luzon has a predominantly rugged terrain with upland areas (> 100 m above sea level) covering more than 75% of the region (Fig. 5.1a). This topography is associated with the presence of three mountain ranges: Cordillera Central on the western and central portion, Northern Sierra Madre along the eastern coast, and the Caraballo which connects the two aforementioned ranges and separates the Central Luzon flatlands from the Cagayan Valley basin. The Cordillera Central is the highest and largest massive mountain range in the Philippines. It has a total area of 18,300 km^2 and has numerous peaks above 1,500 m, the highest of which is Mount Pulag (2,922 m). The Cordillera Administrative Region (CAR), an administrative region composed of six provinces (Abra, Apayao, Kalinga, Mountain Province, Ifugao, and Benguet) and one highly urbanized city (Baguio City), covers most of the Cordillera Central.

The presence of these mountain ranges makes the region prone to landslides due to prolonged period of rainfall or short-duration torrential rains. The Mines and Geosciences Bureau (MGB) has identified (Fig. 5.1b) most areas in the CAR as "highly susceptible" to rain-induced landslides (RILs) in its 1;10,000 scale hazard maps, with some portions marked as "very highly susceptible". Of the ten provinces with highest percentage of areas at risk of landslides, six are situated in the CAR with Benguet being on top of the list. The hazard assessment for RILs of the MGB follows four-tier susceptibility scale whose definitions are as follows:

- **Areas with low susceptibility** to RILs, marked as yellow, are gently sloping areas with no identified landslides.
- **Areas with moderate susceptibility** to RILs, marked as green, are those with moderately steep slopes where soil creep and other indications of possible landslide occurrence are present.
- **Areas with high susceptibility** to RILs, marked as red, usually have steep to very steep slopes that are underlain by weak materials, with the presence of numerous old/inactive landslides. These sites may be considered not suitable for permanent habitation but may be developed for alternative uses subject to the implementation of appropriate mitigation measures after performing site-specific geotechnical studies
- **Areas with very high susceptibility** to RILs, mark as brown, usually have steep to very steep slopes that are underlain by weak materials, and have recent landslides, escarpments, and

[24] Period of occurrence within the Philippine Area of Responsibility (PAR)
[25] Debris flows occur when water-laden masses of poorly sorted sediments (e.g. soil, fragmented rocks) surge down slopes in response to gravity (Iverson 1997). These funnel into stream channels, entrain objects in their paths, and form thick, muddy deposits on valley floors.

tension cracks present. These could be aggravated by human-initiated effects. These are considered as critical geohazard areas and are not suitable for development. Thus, it is recommended that these be declared as “No Habitation/No Build Zones” by the LGU, and that affected households/communities be relocated.

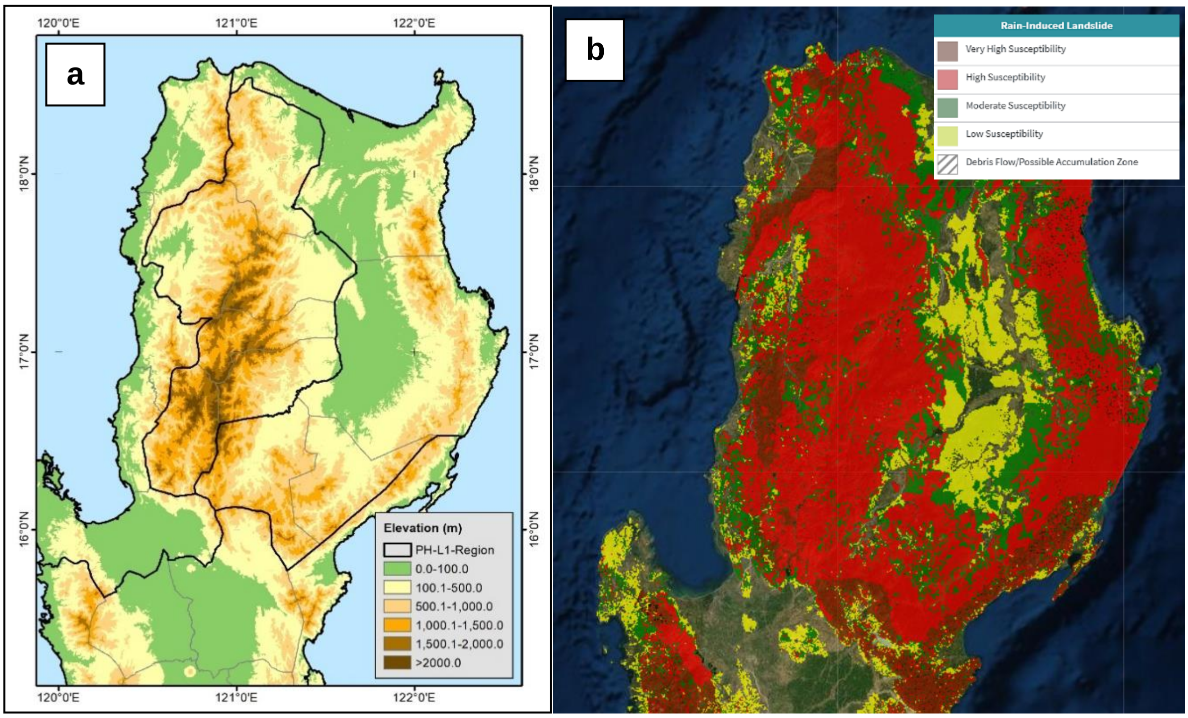


Fig. 5.1. (a) Topographical map (using SRTM 3-arcsecond digital elevation[26]) and (b) rain-induced landslide hazard map[27] of Northern Luzon. Regional and provincial boundaries in Fig. 5.1a are superimposed in thick black and thin gray lines respectively.

Disaster Site: Itogon, Benguet

Itogon is a first class municipality of Benguet and is situated at the southeast end of the province. The town is politically subdivided into nine barangays and has a population[28] of 59,820 with barangay-level density ranging from 3.6% (Gumatdang) to 18.6% (Ampucao). With a land area of 449.73 km^2, Itogon is the largest municipality in Benguet by land area. It is considered as a mining town with seven of its nine barangays currently hosting both large- and small-scale mines (Municipality of Itogon 2020a).

The town has a generally mountainous terrain with deep valleys and steep slopes. Situated at the southern slopes of the Cordillera Central, its elevation rises from 100 m in areas bordering Pangasinan to the thousands of meters above sea level at the northern and eastern portions of the town. The highest point of the municipality reaches 2,150 m above sea level at the summit of Mt. Ugo along the Benguet-Nueva Vizcaya border. In terms of slope class, roughly 75% of Itogon has more than 50% grade slope[29] (Municipality of Itogon 2020b).

[26] SRTM: Shuttle Radar Topography Mission. Digital elevation data used in this report are courtesy of the US Geological Survey (https://www.usgs.gov/centers/eros/science/usgs-eros-archive-digital-elevation-shuttle-radar-topography-mission-srtm)

[27] Hazard maps are produced by the Mines and Geosciences Bureau and visualized using the HazardHunterPH website (https://hazardhunter.georisk.gov.ph/) of the GeoRisk Philippines (wherein PAGASA is a collaborating agency).

[28] Based on the 2015 census of the Philippine Statistics Authority.

[29] Slope is expressed in terms of percentage “grade”, the formula for which is 100 x rise/run. Steeper slopes have higher grades.

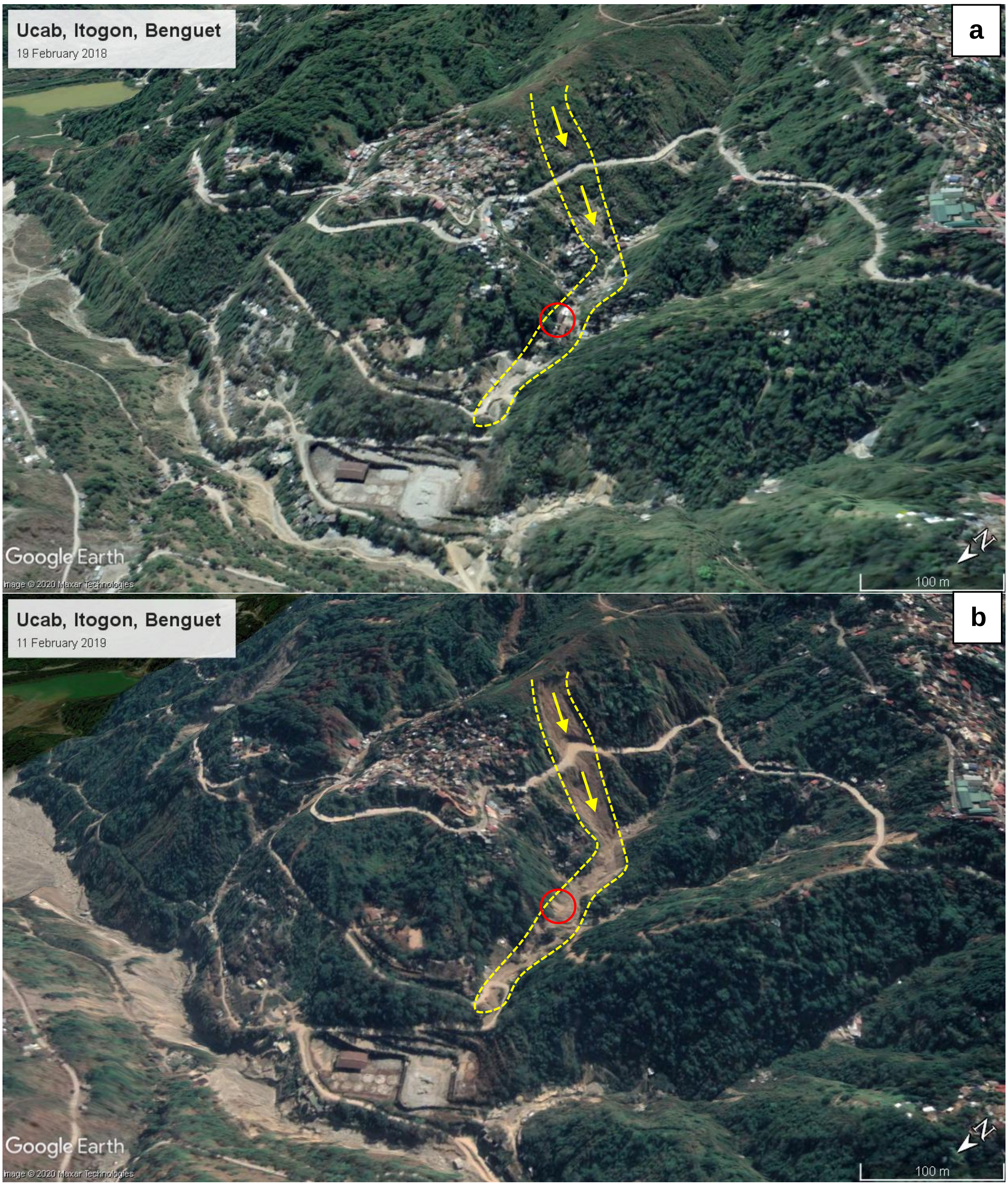


Fig. 5.2. Google Earth images of Sitio First Gate, Barangay Ucab, Itogon, Benguet on (a) 19 February 2018 and (b) 11 February 2019. The debris flow is outlined in yellow while the arrows show the direction of the landslide. The approximate location of the concrete bunkhouse that was used as evacuation shelter by the miners and their families is encircled in red. In Fig. 5.2b, the Baguio-Bua-Itogon road had already been cleared of obstruction because the image was taken nearly 5 months after the incident.

A comparison of satellite images of the disaster site before and after the debris flow event is shown in Fig. 5.2. Located in Sitio First Gate of Barangay Ucab, the ground failure occurred at the western slope of a north-south oriented spur. Composed of highly weathered, altered, and fractured diorite, andesite and pyroclastic rocks, the landslide flowed west-northwestward down the slope towards a gully where the debris materials were funneled. The debris flow covered roughly 2 hectares of land downslope and destroyed several shanties and other permanent structures built along the unstable slope and the gully downhill. The Baguio-Bua-Itogon Road was also buried during the landslide but was immediately cleared of obstruction as seen if Fig. 5.2b. The debris flow reached as far as a concrete bunkhouse-turned-chapel roughly 300 to 400 meters downhill near the portal of an old mining tunnel. According to the local police chief (Rappler 2018), the bunkhouse was abandoned by the Benguet Corporation when they ceased mining operations in the area in 1997. Without consulting the local government or the disaster managers, this old concrete structure had served as evacuation shelter for small-scale miners and their families for years during high impact weather events. Relying on experience and instinct, the victims did not heed pre-emptive evacuation orders during the passage of Ompong and sought refuge in this bunkhouse where they were eventually buried alive and killed in the resulting landslide.

Hazard mapping revealed that the entire area is very highly susceptible to RILs and is considered as a "no habitation/no build" zone. Rapid hazard assessment[30] revealed that of the 9,409 residents of Barangay Ucab[31], 34.7% (3,267) live in areas that are very highly susceptible to RILs while 64.4% (6,063) are in highly susceptible areas. Despite being a critical geohazard area, several permanent structures such as bunkhouses, shanties, and other habitation structures were still built along the mountain slopes and gullies in Barangay Ucab, all of which are visible in Fig. 5.2.

The Landslide-Triggering Rainfall Event

A post-event investigation of rainfall observation data in the Cordillera Central revealed that despite the dense network of automatic rain gauges operated by both PAGASA and Advanced Science and Technology Institute in the area, inclement weather during the passage of Ompong resulted in a gauge-denial scenario over Itogon and nearby municipalities. As such the most reliable observation during the passage was the 3-hourly rainfall reports from the synoptic station at Baguio City located 7 km to the west-northwest of the disaster site. Fig 5.3 presents the time series of the rainfall observation and observed weather condition from the said station from 14 to 15 September.

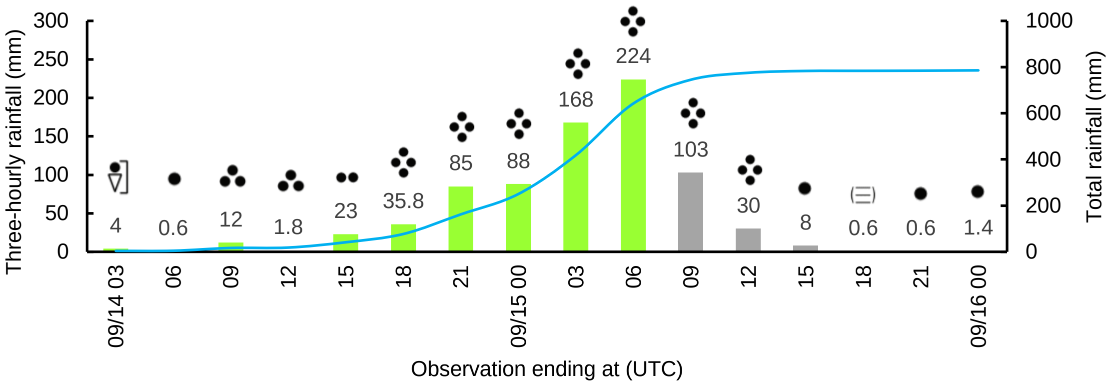


Fig. 5.3. Three-hourly (bar graph) and accumulated rainfall (line graph) starting 13 September 00 UTC of Baguio City Synoptic Station (98328). The observation window presented in the figure is from 13 September 00 UTC to 16 September 00 UTC. The symbol and value (in mm) on top of each bar denotes weather condition at observation time and the rainfall over the past 3 hours. Bar graphs in green (gray) are observation covering the period before and during (after) the debris flow event.

Meteorological data showed that while rains were continuous from roughly 27 hours (09 UTC of 14 September to 12 UTC of 15 September) over the Baguio City station, the rainfall was predominantly stratiform type with light to moderate intensity before 18 UTC on 14 September. Between 00 and 18 UTC, the 3-hourly rainfall gradually increased from 0.6 mm to 35.8 mm with total rainfall reaching 77.2 mm by 18 UTC. Fig 5.4a shows that the rainfall was brought by the outer rainband region (ORB) of the TY. During this time, strong orographic uplift in the Cordillera Central was not yet evident on pressure vertical velocity fields (Fig. 5.5a)

[30] The hazard assessment was made using the GeoAnalyticsPH (https://geoanalytics.georisk.gov.ph/) application of the GeoRisk Philippines (wherein PAGASA is a collaborating agency).
[31] Based on the 2015 census of the Philippine Statistics Authority.

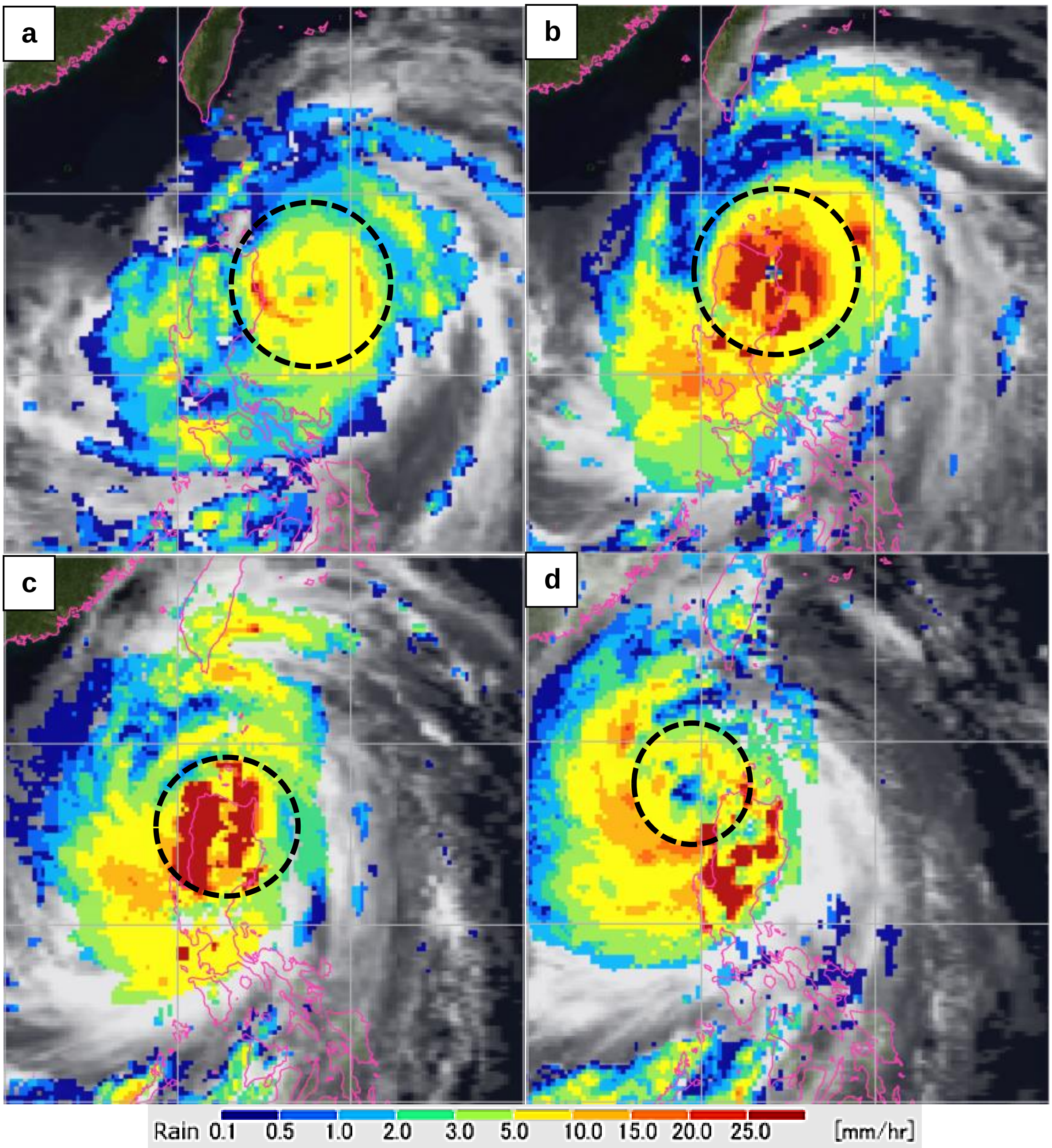


Fig. 5.4. GSMaP-MVK[32] (Ushio et al. 2009; Kubota et al. 2020) estimated rain rates (mm/h) and infrared satellite imagery at (a) 12 UTC and (b) 18 UTC on 14 September and (c) 00 UTC and (d) 06 UTC on 15 September within the region of 10-25°N, 115-130°E. The dashed circle encloses the approximate region of the inner rainband, eyewall, and eye. The rainbands situated outside this circle form part of the outer rainband region

[32] Images captured from the JAXA Global Rainfall Watch website (https://sharaku.eorc.jaxa.jp/GSMaP/index.htm)

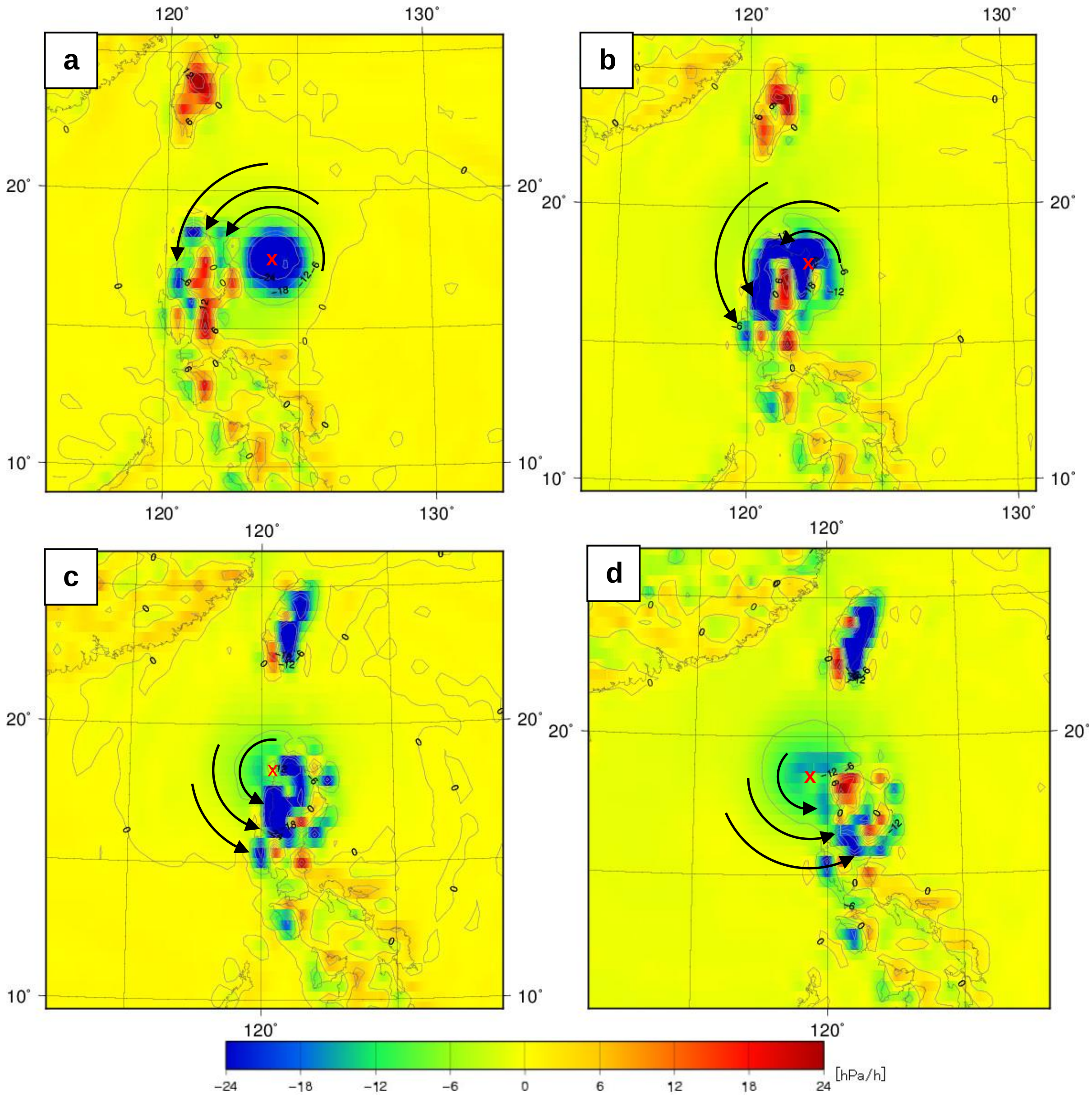


Fig. 5.5. Global Spectral Model (GSM; Muroi et al. 2019) storm-centered analyses of pressure vertical velocity (hPa/s) at 1000 hPa level at (a) 12 UTC and (b) 18 UTC on 14 September and (c) 00 UTC and (d) 06 UTC on 15 September. The red “x” marks the approximate location of the TC center. The prevailing direction of the TC wind flow is marked by the black arrows. Figures generated using the Vertical Earth tool of Japan Research Organization of Information and Systems’ Vertical Earth Project (http://earth.nii.ac.jp/atmosphere/vertical-typhoon/h/)

Continuous heavy rains[33] started to affect the Benguet area at around 18 UTC on 14 September with gauge observation in Baguio City showing increasing 3-hourly accumulated rainfall. A strong orographic uplift was observed over the windward[34] areas of the Cordillera Central (Fig. 5.5b; i.e. its western and southern portions) as the inner rainband region (IRB) of Ompong started affecting the area (Fig. 5.4b). Over the next 7 to 8 hours, the IRB deteriorated due to the land interaction (Fig 5.4c). However, strong uplift remained over the western and southern portions of the Cordillera Central throughout the TY's traverse of Northern Luzon (Fig. 5.5c). With the strong moisture inflow from the Southwest Monsoon feeding the TY from the south, the orographic lift amplified the observed rainfall over Baguio City. By 00 UTC of the following day, the total rainfall had reached 250.2 mm.

As Ompong started to move away from Northern Luzon past 00 UTC on 15 September, the impact of land interaction became evident with the formation of a large, ragged eye-like feature. Much of the convection of the IRB has significantly deteriorated (Fig. 5.4d). The uplift associated with orographic effect and the estimated rain rates over much of Cordillera Central started to weaken was the TY moved away from Northern Luzon. However, the moist TC inflow in the ORB continued to be uplifted over the southern portion of the Cordillera Central as this segment of the mountain range remained on the windward side with respect to the circulation of the TY. Heavy rains over the southern portion of the Cordillera Central (Fig. 5.5d) were further amplified by the persistent lift. The 3-hourly rainfall over Baguio City rapidly increased between 00 UTC and 06 UTC with the value peaking at the 03-06 UTC period (224.0 mm). Past 06 UTC, the reported 3-hourly rainfall over Baguio City rapidly decreased as the TY continued to move further away from the country and the low-level moisture inflow of the ORB no longer interacted significantly with the southern portion of the Cordillera Central. After 18 hours of continuous heavy rains, the station only observed intermittent light rains during this period. By 00 UTC on 16 September, the total rainfall over Baguio City had reached 785.8 mm.

Was the heavy rainfall event enough to trigger the entire landslide event?

In a preliminary inventory of RILs and corresponding rainfall at the Baguio City synoptic station from 2000 to 2013 (Nolasco-Javier et al. 2015), it was determined that most of these landslide events that are associated with TCs and/or enhanced monsoons have 24-hour rainfall ranging from 73 mm to 1,086 mm. As such, an "indicative"[35] 24-hour rainfall threshold of 70 mm for RILs was identified for the Baguio City and neighboring municipalities. Fig. 5.3 shows that throughout the 24-hour period preceding the debris flow event in Itogon (06 UTC on 14 September to 06 UTC on 15 September), the accumulated rainfall over Baguio City reached 637.6 mm or more than nine times the indicative threshold. Fig. 5.6 revealed that prior to the onset of the heavy rainfall event associated with Ompong, the synoptic station at Baguio City did not report a 24-hour rainfall in excess of 100 mm since 25 August[36]. However, there have been nine days with at least 10 mm of daily rainfall during the same period, two of which reached between 50 mm and 100 mm. Although a TC occurred within the PAR roughly 4 days before the event (TC Neneng), its passage did not (directly or indirectly) bring heavy rains over Benguet. Nolasco-Javier and Kumar (2017) noted that there have been RILs[37] in Baguio City and nearby municipalities that took place even with minimal antecedent rainfall because the 24-hour rainfall is sufficiently high to saturate the soil and trigger ground failure.

[33] In Fig. 5.3, "continuous heavy rains (non-showers) at the time of observation" is indicated as ⁘ following its corresponding standard symbol used for plotting present weather in station plots of surface weather charts.
[34] Windward areas are the portions of mountainous regions facing the direction where the prevailing wind is blowing.
[35] Given the limited number of landslides and analysis of landslide occurrence in relation to other controlling/predisposing factors undertaken, the threshold identified can only be regarded as indicative (Nolasco-Javier et al. 2015)
[36] The observed rainfall on 25 August is caused by a continuing monsoon activity that was enhanced by TC Luis.
[37] Incidents covered in the study occurred during the months of May and October from 2000 to 2013.

Using both antecedent rainfall and the 24-hour rainfall, Nolasco-Javier et al. (2017) developed a decision flowchart for a potential landslide early warning in Baguio City and nearby municipalities and identified that RILs are likely in the area when, in addition to the "indicative" 24-hour rainfall threshold of 70 mm (Nolasco-Javier et al. 2015), one or a combination of the following conditions are met:

- The 24-hour rainfall is 0.02% to 28% of the mean annual precipitation (MAP) of Baguio City (3,892 mm).
- The total rainfall over Baguio City since the onset of the rainy season has exceeded 500 mm.
- The rainfall over Baguio City approaches or has breached that intensity-duration (ID) threshold $I = 6.46D^{-0.28}$ for the durations between 24 and 264 h.

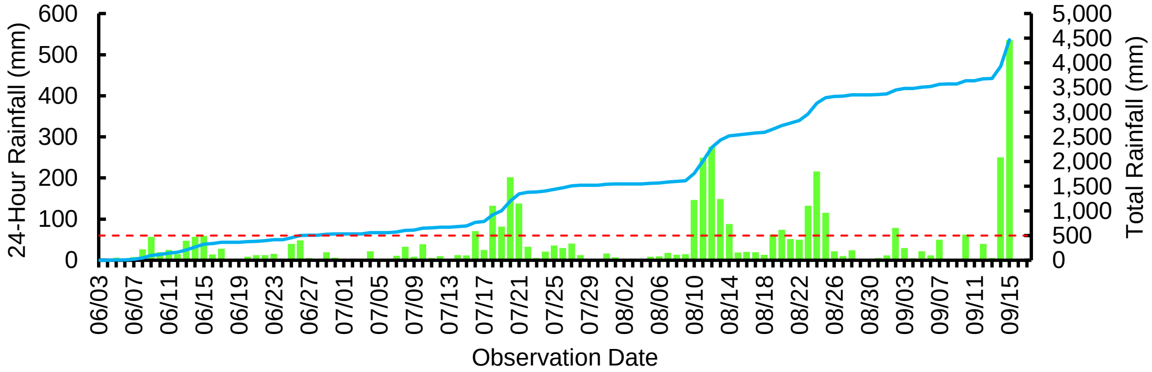


Fig. 5.6. Observed 24-hour (bar graph) and accumulated (line graph) rainfall of the Baguio City Synoptic Station (98328) starting from the onset of the rainy season until the day of the landslide incident. The dashed line marks the 500 mm cumulative rainfall requirement detailed in Nolasco-Javier and Kumar (2017)

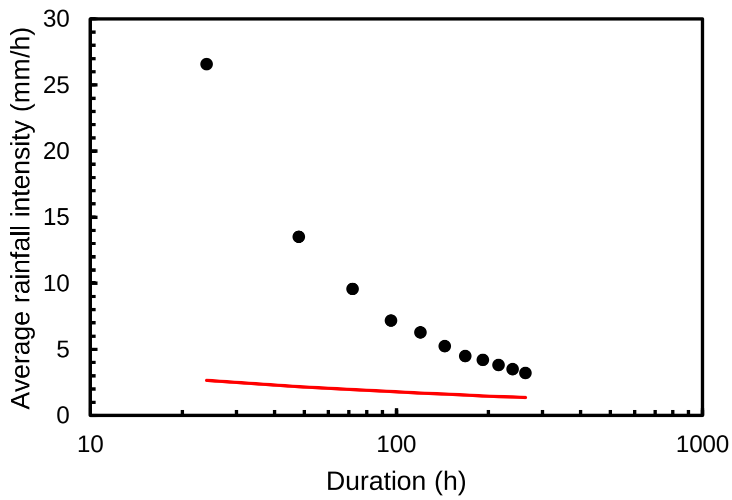


Fig. 5.7. Minimum ID threshold curve for RILs in Baguio City and nearby municipalities according to Nolasco-Javier and Kumar (2017) (red line) and the average rainfall intensities (mm/h) throughout varying durations preceding the landslide event using the accumulated rainfall data in Fig. 5.6 (dots). For instance, the value "9.5 mm/h" for 72-h duration is the average rainfall intensity throughout the 72-h period preceding the landslide event (that is, from 06 UTC on 12 September to 06 UTC on 15 September).

Applying these criteria to the rainfall data from Baguio City, it can be said that the observed rainfall (637.6 mm) over Baguio City during the 24-hour period preceding the RIL in Itogon was 16.38% of the station's MAP, within the 0.02-28% range identified in the study. Moreover, by 13 September, the total rainfall over Baguio City since the onset of the rainy season on 03 June had reached 3,681.7 mm or more than seven times the threshold identified in the second criterion (Fig. 5.6). The total rainfall over the station since the start of the rainy season exceeded 500 mm on 26 June. Lastly, Fig. 5.7 clearly shows that at all durations, the average rainfall rate over Baguio preceding the debris flow event was found to be well above the established threshold especially at shorter durations.

It can be inferred from these data that the observed 24-hour rainfall prior to the RIL in Itogon was more the sufficient to initiate ground failure and that the antecedent rainfall was not a major trigger. While there had been a notable amount of rainfall over Benguet since the start of the rainy season that possibly retained in the subsurface and contributed to the soil instability, the amount of near-term antecedent rainfall (e.g. ~19 days) was minimal compared to the sudden onset and escalation of heavy rains in the area, especially during the 6-hour period preceding the debris flow.

Concluding Remarks

The massive RIL that took place in Itogon, Benguet was a disaster in the making. While the amount of antecedent rainfall was not a major trigger for the ground failure to take place, the sudden onset and rapid escalation of heavy rains associated with the passage of Ompong was enough to mobilize the unstable soil and trigger a landslide event. The amount of rainfall that fell over the entire Cordillera region within the 24-hour period preceding the debris flow event (637.6 mm) was more than enough to trigger any major landslide not just in Itogon, Benguet, but also in other areas in the mountain range that have the same soil characteristics and geomorphology as the disaster site. The location of Itogon, Benguet with respect to the observed track of the typhoon meant that the area became the windward side of the Cordillera Central as the typhoon as it crossed the mountain range and emerged over the West Philippine Sea, thereby amplifying the observed rainfall through orographic enhancement.

It is unfortunate that the disaster resulting from the Itogon debris flow event was entirely preventable not only because hazard maps already identified the high susceptibility of Itogon, Benguet to RILs but also because PAGASA forecast records revealed that the heavy rains over the Cordillera region, especially in the provinces situated south of the observed track of Ompong was well predicted days in advance. The high-resolution numerical weather prediction models of PAGASA captured the orographic enhancement of rainfall over the Cordillera region and forecasters repeated in numerous instances that the Cordillera region will see the brunt of the heavy rainfall throughout the passage of the typhoon. Another significant factor that contributed greatly to the occurrence of this disaster was the refusal of the residents of Sitio First Gate, Barangay Ucab to evacuate because they relied more on their "indigenous" knowledge of the area than the predictions made by state meteorologists and the warnings given off by disaster managers.

Effective disaster preparedness measures rely heavily not just on the reliability of weather forecasts especially during the occurrence of high impact weather events but also the usage of hazard maps by local government units in identifying safe zones not just for habitation but also for construction of evacuation centers, clinics, and other critical facilities. It is therefore important to (1) continuously improve the quality of weather predictions, especially those produced by numerical weather prediction models, (2) regularly update the hazard maps and employ higher-resolution mapping technologies using LIDAR or light detection and ranging, and (3) continuously educate the public about the hazards in their localities, areas that are safe for evacuation, and the consequences of not heeding evacuation orders.

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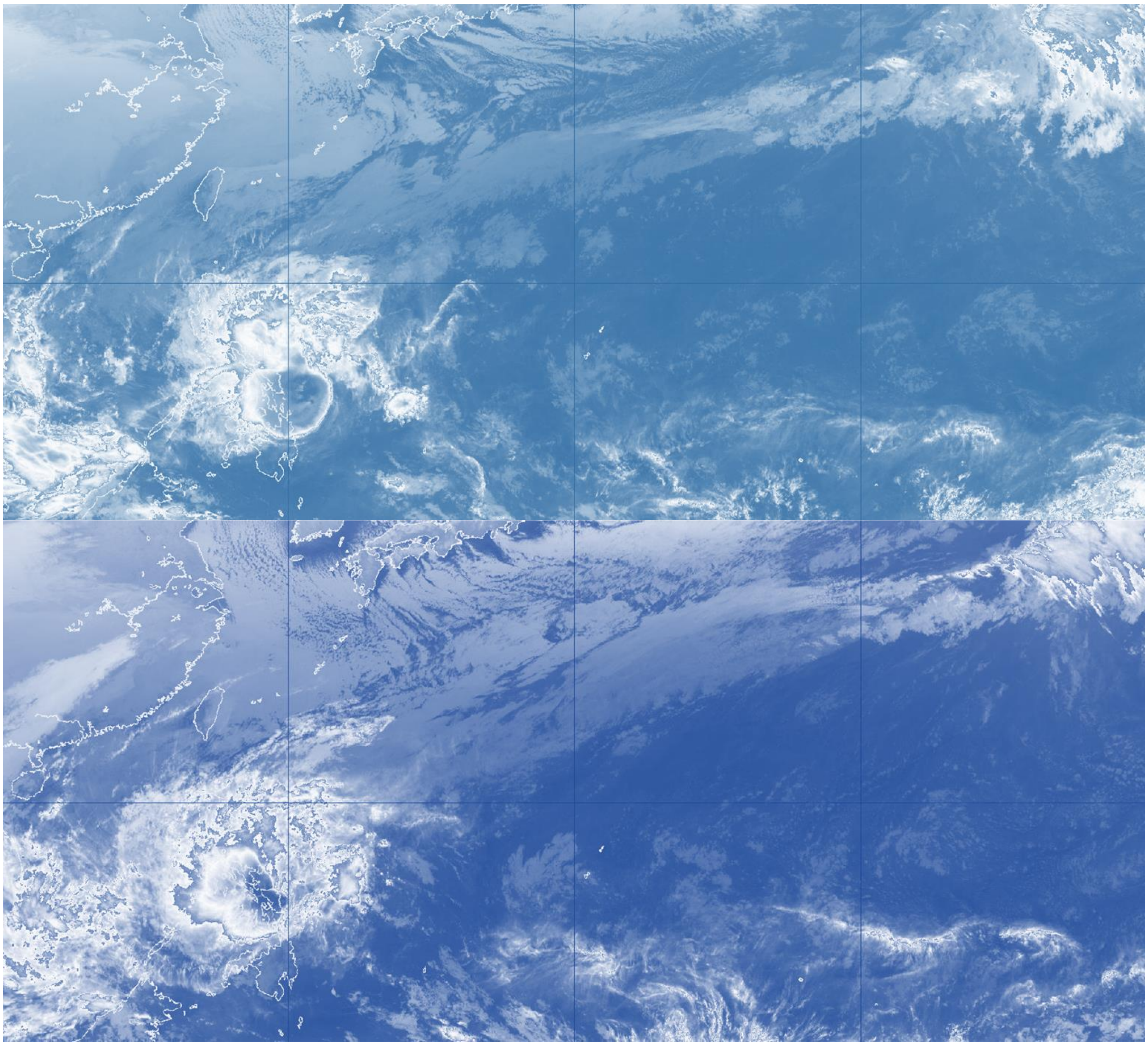
TROPICAL DEPRESSION-COLD SURGE INTERACTION: THE DECEMBER 2018 HEAVY RAINFALL EVENT



Usman, a weak disturbance compared to the other landfalling tropical cyclones that preceded it, became the deadliest tropical cyclone of 2018 when it enhanced a Northeast Monsoon shear line over the southeastern portion of Luzon.

Tropical Depression-Cold Surge Interaction: A Case of 28-29 December 2018 Heavy Rainfall Event

The occurrence of Tropical Cyclone (TC) Usman from 25 to 30 December and its passage over the Visayas archipelago during a strong Northeast Monsoon (NEM) cold surge (CS) event resulted in a heavy rainfall event over the southeastern portion of Luzon and the eastern portion of Visayas. In particular, Bicol Region and portions of Samar Provinces received the brunt of the heavy rainfall with total rainfall from 25 to 30 December of at least 400 mm estimated by satellite-borne observations with higher ground-based reports. The bulk of the observed rainfall during the passage of Usman was recorded during the period of 28-29 December. The resulting flooding and landslides claimed the lives of 156 individuals and injured 105 others in three regions (MIMAROPA, Bicol Region, and Eastern Visayas), making it the deadliest TC to hit the country in 2018.

Yokoi and Matsumoto (2008) revealed that the presence of a tropical depression-type disturbance (TDD) over Central South China Sea during a CS event prevented the stronger-than-usual northeasterlies of the CS from propagating southward and created a strong low-level convergence zone in the Northern South China Sea, resulting in heavy orographic rainfall in Central Vietnam. In the Philippine setting, Olaguera et al. (2020) showed that the interaction of a westward-propagating non-TC cyclonic circulation over Mindanao and a shear line associated with a CS resulted in enhanced moisture convergence and heavy rainfall over Mindanao. This report investigates whether the aforementioned synoptic scale features were present during the 28-29 December heavy rainfall event (herein referred to as DEC18 event).

Heavy Rainfall Observations

The passage of TC Usman during a strong CS event resulted in widespread heavy rains over Bicol Region, Eastern Visayas and portions of MIMAROPA and CALABARZON. From 28 to 29 December 2018, prolonged and excessive rainfall over these areas resulted in multiple landslides and flooding incidents that claimed the lives of more than 150 people and caused extensive damages to agriculture and infrastructure, making it the deadliest TC event of the year.

Based on manned and unmanned rain gauge observations during the event, Bicol Region, Samar Island (particularly over Northern and Eastern Samar), Quezon, Oriental Mindoro, Romblon, Marinduque, and portions of northern Panay island received 2-day rainfall of at least 100 mm over the two-day period of the event. Bicol Region, Northern Samar and the southern portion of Quezon receiving the brunt of heavy rains, with 2-day rainfall accumulations of 250 mm or greater. In particular, all of the 11 operational rain gauges in Bicol Region reported 2-day rainfall of at least 250 mm. These observations corroborated with the satellite-derived rainfall estimates presented in Fig. 6.1. The areas that received the brunt of the widespread heavy rains were situated to the north of the observed track of Usman.

Of the 139 stations with reliable observation data during the DEC18 event, the highest two-day rainfall was observed in Daet, Camarines Sur (573.2 mm). With 438.0 mm on 28 December, the synoptic station at Catarman, Northern Samar reported the highest 24-hour rainfall during the DEC18 event. The ten highest two-day rainfall observations from the 139 operational stations is presented in Table 6.1. The rainfall records from synoptic stations were also compared against the average monthly rainfall for December (period: 1981-2010).

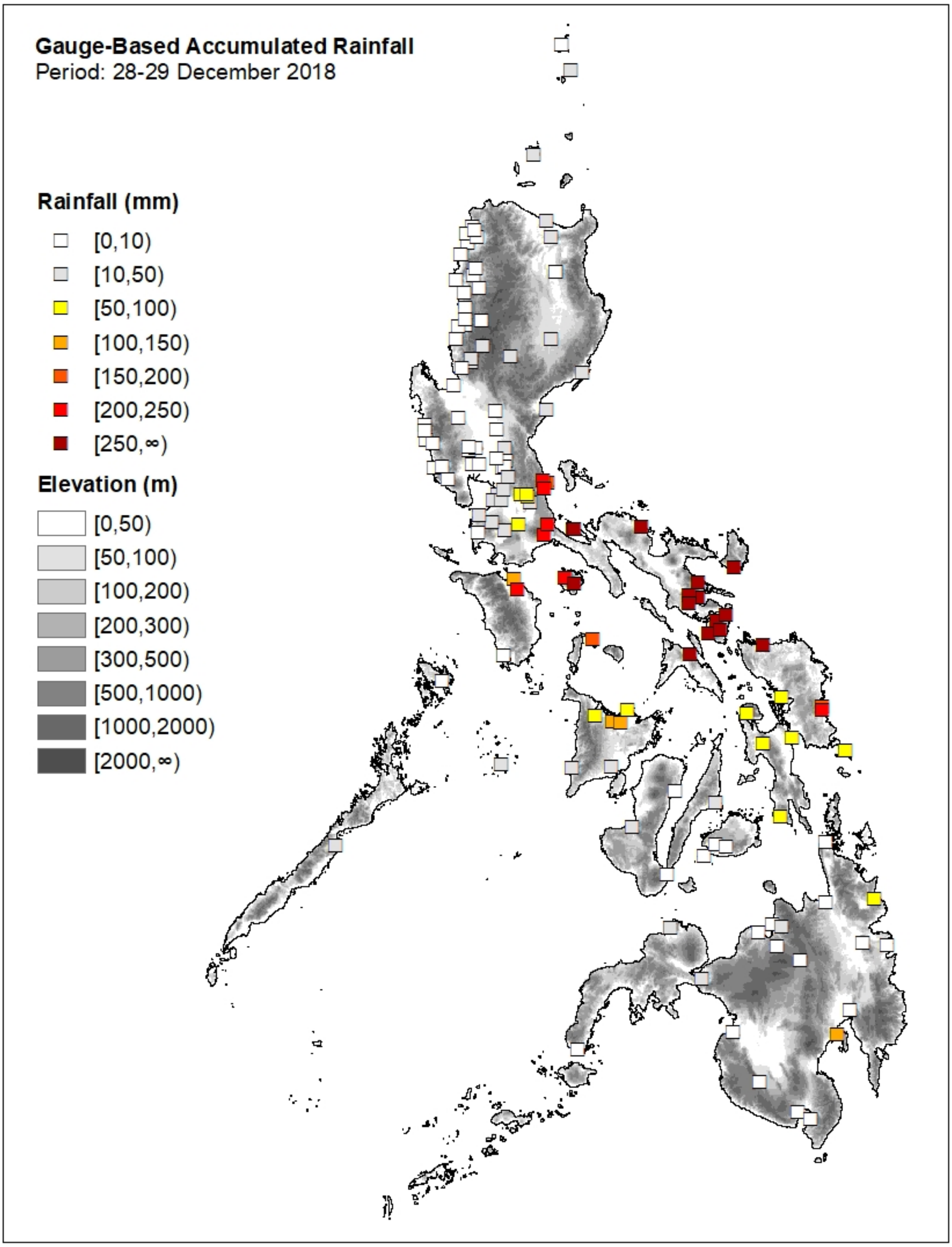


Fig. 6.1. Nationwide observation of accumulated rainfall during DEC18 event from reports of PAGASA synoptic stations and automatic rain gauges.

Table 6.1. Ten highest rainfall observations (mm) from manned and unmanned stations during the DEC18 event. For synoptic stations (except Juban, see note below), the DEC18 event rainfall is also compared against the average monthly rainfall for December over these stations.

Station Category	Location	DEC18 event	Average monthly rainfall (AMR)	DEC18 event as % of AMR
Synoptic Station	Daet, Camarines Norte	573.2	588.4	97.4
Synoptic Station	Legazpi City, Albay	460.1	520.2	88.4
Synoptic Station	Catarman, Northern Samar	446.8	-	-
Synoptic Station	Alabat, Quezon	430.7	636.6	67.7
Automatic Rain Gauge	Tabaco City, Albay	429.0	-	-
Automatic Rain Gauge	Bulan, Sorsogon	395.0	-	-
Synoptic Station	Virac, Catanduanes	384.1	451.8	85.0
Synoptic Station	Juban, Sorsogon	368.2	-	-
Automatic Rain Gauge	Guinobatan, Albay	337.0	-	-
Automatic Rain Gauge	Irosin, Sorsogon	333.0	-	-

Note: Juban Synoptic Station has no normal rainfall because the station record is less than 30 years.

Synoptic Situation of the DEC18 Event

In this section, the synoptic scale features in the lower part of the troposphere during the DEC18 events is presented. The horizontal wind field at 925 hPa over the Western North Pacific (WNP) at 00 UTC on 28 December (Fig. 6.2a) was characterized by a strong northerly wind flow originating from the Yellow Sea and blowing into the Philippine archipelago along the eastern and southern coast of mainland China. The NEM winds over Philippine Sea (PHS) and West Philippine Sea (WPS) north of 12°N during the DEC18 event was in excess of 20 m/s, which was roughly twice the climatological average of 10-14 m/s. On the other hand, the wind direction on 28 December was similar to the climatological monsoon northeasterlies during late December (Fig. 6.2b). The zonal wind anomaly at 925 hPa (Fig. 6.2c) featured enhanced westerlies south of 12°N (i.e. Visayas, Mindanao, insular southern Luzon, and their surrounding seas) and enhanced easterlies north of 12°N (i.e. the rest of Luzon and its surrounding seas). On the other hand, meridional wind anomaly field (Fig. 6.2d) shows enhanced northearlies penetrating through most of the archipelago except for the easternmost portions of Visayas and Mindanao, where enhanced southerlies is observed. The strong northerly wind flow observed over the Philippine region was associated with a NEM CS originating from continental Asia. The strong northerly winds of the CS over the Philippine region and the surrounding region is due to the strong pressure gradient induced by the cyclonic circulations of Usman and another low pressure area southeast of Vietnam and the Siberia-Mongolia High over the Asian continent as seen on the surface weather chart of the Japan Meteorological Agency for 00 UTC on 28 December (Fig. 6.2e). Equivalent potential temperature (θ_e) field (Fig. 6.2e) on that day shows the presence of warm and humid tropical air mass over the PHS and WPS south of 15°N and a front-like zone with a strong horizontal gradient oriented west-southwest to east-northeast. The segment of this zone situated east of 145°E was analyzed in the surface weather chart (Fig. 6.3a) as a cold front. The arrival of a northerly CS is usually preceded by the passage of a cold front (Wu and Chan 1995).

Similar to the CS case presented in Yokoi and Matsumoto (2008), because the wind speed maximum of the CS is situated close to the 335 K θ_e isotherm, the stronger-than-normal northeasterlies of the CS brought relatively thermally unstable air into the Philippine region. The enhanced westerlies over Palawan, Visayas and Mindanao and enhanced southerlies over the Philippine Sea east of Visayas and Mindanao brought in moisture from the Maritime Continent into the Philippine region. Horizontal divergence anomaly field at 850 hPa (Fig. 6.3b) revealed a line of enhanced convergence extending equatorward from the tail-end of the aforementioned cold front towards the circulation of the TDD. This lline of convergence is called a shear line and extends equatorward from the tail-end of a cold or stationary front along the leading edge of a CS. During the DEC18 event, this axis of this shear line was analyzed to be over Bicol Region. The thermally unstable air brought by the northeasterly suge and the moisture flow from the Maritime Continent region created suitable conditions for enhanced convective activity and heavy rainfall along the convergence boundary of the shear line.

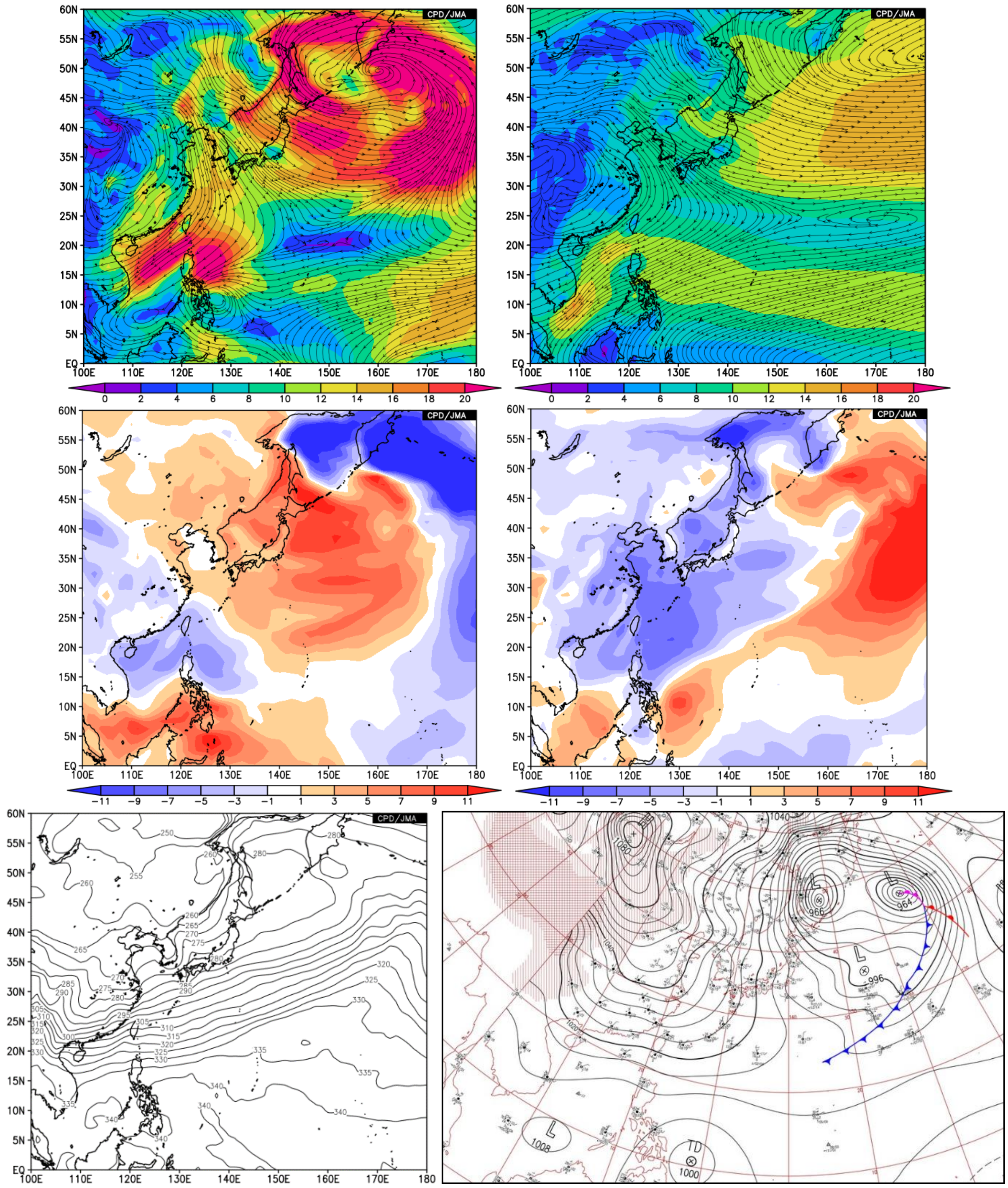


Fig 6.2. Synoptic situation at 00 UTC on 28 December: (a) Horizontal wind streamlines and speed (shading, in m/s) at 925 hPa. (b) Same as in (a) but for the climatological wind field on 28 December. (c) zonal wind anomaly (shading, in m/s) at 925 hPa. (d) Same as in (c) but for the meridional wind anomaly. (e) Equivalent potential temperature (in K) field at 925 hPa. Contour interval is 5 K. (e) Surface synoptic chart of JMA showing the frontal system associated with extratropical low cented southeast of Kamchatka Peninsula and the shear line extending equatorward from the tail-end of the cold front.

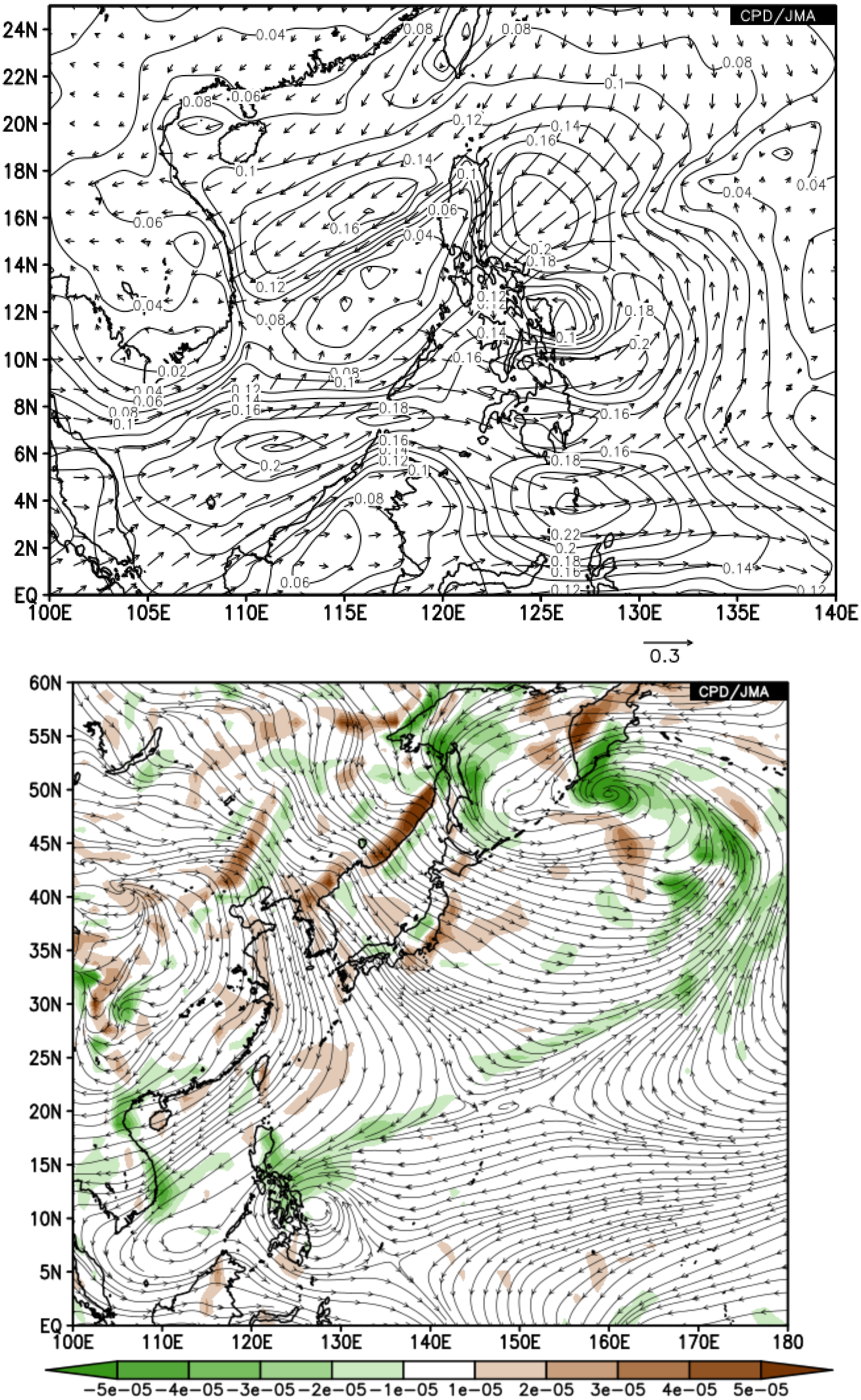


Fig. 6.3. (a) Horizontal moisture flux anomaly at 925 hPa on 28 December. Contour interval is 0.02 kg/m/s. Unit vector corresponds to value of 0.3 kg/m/s. (b) Horizontal wind streamline and horizontal divergence anomaly (shading, in 1/s) at 925 hPa. Browner (greener) shade means enhanced low-level divergence (convergence).

To confirm the presence of unstable conditions over Bicol Region, Table 6.1. presents the Showalter Index (SI), Lifted Index (LI), Severe Weather Threat Index (SWEAT), K Index (KI), and Totals Totals Index (TT) derived from the 00 UTC radiosonde observations from 27 to 31 December at Legazpi City, Albay. During 28-29 December, all five indices presented in Table 6.1 suggested unstable environment, with SWEAT, KI and TT (SI and LI) indices increasing (decreasing) dramatically. Furthermore, unstable conditions persisted over Bicol Region even after the DEC18 event (i.e. through 31 December), suggesting that the cold, dry air in the lower troposphere associated with the CS did not arrive over Bicol Region and is indicative of a potential stalling of the CS north of the sounding station.

Table 6.2. Showalter Index (SI), Lifted Index (LI), Severe Weather Threat Index (SWEAT), K Index (KI), and Totals Totals Index (TT) from the 00 UTC radiosonde observations at PAGASA Upper Air Station in Legazpi City, Albay (98444) covering the period of 27-31 December.

Sounding	SI	LI	SWEAT	KI	TT
12/27 00	7.00	2.29	143.60	-18.70	36.00
12/28 00	-0.30	0.05	291.81	38.40	42.70
12/29 00	-0.17	-0.71	308.38	35.60	42.20
12/30 00	0.91	-2.67	249.22	36.20	41.60
12/31 00	-0.99	-2.56	241.22	37.30	45.40

A time-latitude cross section of meridional winds at 925 hPa averaged over 120°E-130°E (Fig. 6.4a) reveals that the northerly winds stronger than 7 m/s associated with the CS during the DEC18 event originated near 40°N on 25 December. The northerly winds of the CS rapidly propagated southwards, reaching the northern limits of the Philippine Area of Responsibility (PAR) within 24 hours of the outbreak. On 27 December, the northerly signal had reached 15°N. In terms of the propagation of drier air from the midlatitude during this CS event, winds with dewpoint depression at 2 m (DD) of at least 3°C originated at around 30°N and rapidly propagated southward. However, from 27 December until the end of the month, the CS signal in both meridional winds and DD appeared to have stalled at around 15°N (17°N -18°N for the DD signal), preventing stable cold, dry air of the CS over the lower troposphere from propagating further southwards to the vicinity of the upper-air station (13.1509°N, 123.7386°E). During a normal CS, the shearline that marks the leading edge of the surge event propagates southward as the CS progresses before eventually degenerating as the surge shifts from northerly to easterly as the source anticyclone moves southeastward from mainland Asia to the Yellow Sea-East China Sea region. The stalling of the northeasterly surge in this case resulted in the prolonged lingering of the shearline and its associated heavy rainfall over the Bicol Region, manifesting as the DEC18 event.

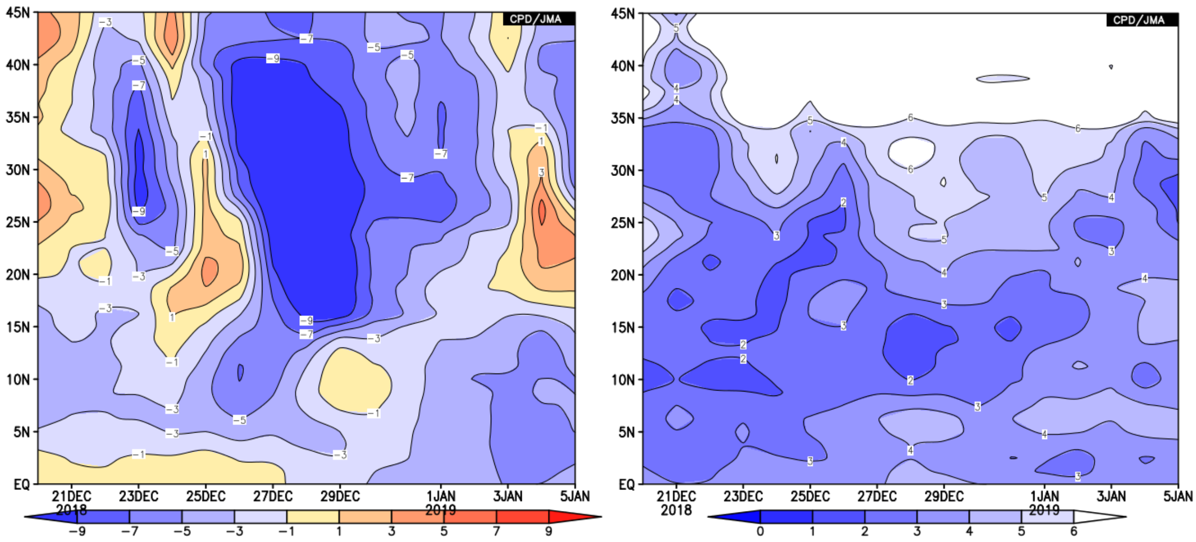


Fig. 6.4. (a) Time-latitude cross section of meridional winds at 925 hPa averaged in 120°E -130°E for the period of 20 December 2018 to 5 January 2019. Contour interval is 2 m/s. Bluer (redder) shading indicates stronger northerly (southerly) winds. (b) Same as (a) but for 2-m dewpoint depression. Contour interval is 1°C. Darker shading indicates smaller dewpoint depression and moister conditions near the surface.

In Yokoi and Matsumoto (2008), the CS associated with heavy rainfall event on 2-3 November 1999 in central Vietnam stalled in the presence of a TDD in southern Vietnam. It was noted that the southerly wind anomaly induced by the TDD seemed to prevent the CS from propagating farther southward through a “change in the dynamic balance on the meridional propagation of the CS”. This meant that southerly wind anomaly had been stronger than the speed of propogation of the CS[38]. In the case of the DEC18 event, the CS propagated meridionally in the 15°N-20°N at around 6 m/s based on the time-latitude cross section diagram in Fig. 6.4a, while the southerly anomaly induced by the TDD over the Philippine Sea was around 9-11 m/s. This meant that the southerly anomaly during the DEC18 event was substantial enough to prevent the CS from propagating southward beyond 15°N.

Impact of Vertical Wind Shear on the DEC18 event

Fig. 6.1 showed that the observed rainfall over most of Eastern Visayas (the exceptions being Northern Samar and the northern and central portions of Eastern Samar)[39] was disproportionately lower than in Bicol Region and Quezon where the highest accumulations were observed. It has been established in this report as supported by other literature (e.g. Yokoi and Matsumoto 2008; Olaguera et al. 2020) that the distribution and magnitude of heavy rainfall observed during the DEC18 event was primarily governed by the enhanced wind and moisture convergence along the CS shear line that stalled along over the Bicol Region area due to the passage of TC Usman.

The CS that coincided with the passage of TC Usman brought unfavorable levels of vertical wind shear (VWS) over the Philippine region. Fig 6.5a shows that on 28 December, the TC was situated in a moderate to high easterly to southerly VWS. Due to the prevailing shear, the convective clouds of the TDD were displaced to the northern semicircle of the circulation. The degree of shearing is well-evident in the 89 GHz color composite image of Usman in Fig. 6.5b wherein convective clouds were displaced by at least 1° from the fully exposed low level circulation center (LLCC).

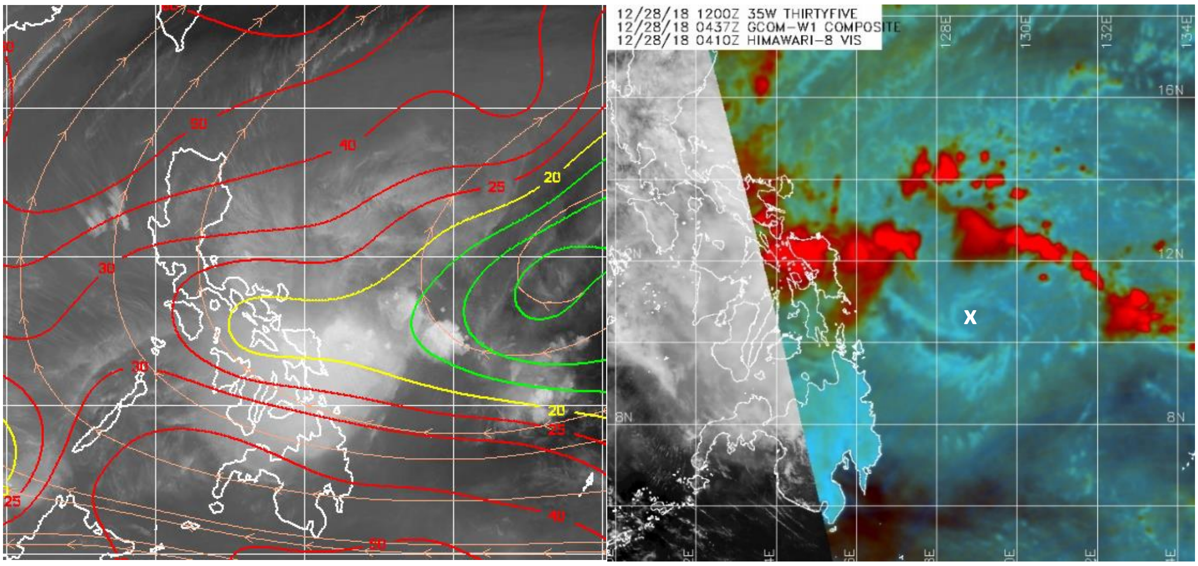


Fig. 6.5. (a) Deep-layer (200-850 hPa) vertical wind shear (VWS) magnitude (contours) and direction (streamlines) derived from Himawari-8 atmospheric motion vectors at 03 UTC on 28 December and the corresponding water vapor image. Contour interval is 5 kt. Green, yellow, and red contour lines indicate low, moderate, high VWS. (b) Color composite of 89 GHz AMSR2 microwave image at 0437 UTC on 28 December from GCOM-W1 satellite. Deep convection appears red in the image. Low-level cloud line is marked with white curved lines while the low-level circulation center is marked with “x”.

The presence of a moderate to high VWS environment prevented the consolidation of deep convection near the LLCC of Usman. Because of this, much of the widespread heavy rains were experienced far from the center of the TDD. The direction of the shear brought much of these heavy rainfall to the

[38] In the CS event discussed in Yokoi and Matsumoto (2008), the CS had a meridional propagation speed of around 5 m/s while the southerly anomaly induced by the TDD was estimated to be around 6 m/s.
[39] Catarman and Borongan City Synoptic Stations reported 446.8 mm and 195.2 mm respectively.

northern semicircle of Usman – the same region wherein the axis of the shear line was situated. Moreover, because of the sheared nature of the deep convection of Usman, Eastern Visayas received the brunt of heavy rains (i.e. 50.0+ mm) prior to the landfall of Usman (i.e. between 18 UTC of 27 December and 18 UTC of 28 December. Past 18 UTC, the network of synoptic stations in the region only recorded six-hourly rainfall not exceeding 15.0 mm while heavy rains still continued over Bicol Region and Southern Quezon. Fig. 6.6 shows the six-hourly rainfall reports of synoptic stations over these three areas.

Station name and number		12/27 06	12/27 12	12/27 18	12/28 00	12/28 06	12/28 12	12/28 18	12/29 00	12/29 06	12/29 12	12/29 18	12/30 00	12/30 06	12/30 12	12/30 18	12/31 00
98435	Alabat, Quezon	0.0	0.0	0.0	6.2	7.6	73.2	36.8	65.4	79.0	49.4	24.4	94.4	57.0	9.0	0.4	3.0
98440	Daet, Camarines Norte	0.0	0.0	1.8	5.4	24.2	22.8	45.8	81.2	34.0	91.4	257.8	16.0	22.0	1.4	11.8	17.2
98446	Virac, Catanduanes	0.0	0.0	7.2	1.4	24.4	8.8	68.6	119.6	53.2	75.2	17.3	17.0	0.0	2.2	1.2	20.4
98444	Legazpi City, Albay	0.0	1.0	0.8	1.8	16.8	108.2	100.0	16.4	94.4	17.3	85.6	18.0	2.2	1.8	14.4	11.6
98545	Juban, Sorsogon	0.0	1.8	0.4	11.0	80.0	83.4	89.2	16.0	60.6	0.6	25.4	13.0	20.0	0.0	4.0	16.0
98553	Borongan City, Eastern Samar	0.4	0.2	8.0	24.6	63.0	7.4	117.0	0.4	0.0	0.0	0.0	7.4	0.0	7.8	31.8	7.0
98546	Catarman, Northern Samar	5.0	2.0	7.0	18.0	94.5	269.9	61.6	12.0	6.4	0.0	1.4	1.0	0.2	0.0	9.8	8.4
98543	Masbate City, Masbate	0.0	0.6	0.2	3.8	5.6	50.2	19.2	58.8	143.2	0.0	0.0	0.0	0.0	0.0	1.4	0.0
98548	Catbalogan, Western Samar	0.0	0.4	3.8	87.3	57.9	19.4	12.4	1.2	0.2	0.2	0.0	6.2	0.4	0.0	1.8	32.5
98558	Guiuan, Eastern Samar	10.0	1.0	10.5	39.0	27.0	25.0	0.2	1.4	0.0	0.2	0.1	0.2	0.0	0.1	5.4	1.8
98550	Tacloban City, Leyte	0.0	5.0	1.4	8.8	13.6	65.8	19.2	0.6	0.0	0.0	0.0	0.4	0.0	2.0	4.8	42.0
98648	Maasin City, Southern Leyte	0.0	2.4	3.2	13.8	3.8	46.8	43.6	0.0	0.0	0.0	0.0	4.2	5.6	0.0	0.8	0.0

Legend: 30.0-49.9 mm | 50.0-99.9 mm | 100.0-199.9 mm | 200.0+ mm

Fig. 6.6. Six-hourly rainfall observation from selected synoptic stations in Southern Quezon, Bicol Region, and Eastern Visayas between 00 UTC of 27 December and 00 UTC of 31 December. Date and time indicated in the header is the end time of the six-hour observation window.

Aggravating Factor: Antecedent Rainfall

In the week preceding the DEC18 event, heavy rains were already reported by several weather stations over the eastern sections of Luzon and Visayas. In particular, rainfall accumulations in excess of 100 mm were observed over Bicol Region mainland, Samar island, Aurora, Quezon and Rizal (Fig. 6.7). These were roughly the same areas that experienced widespread heavy rains during the DEC18 event. Of the 139 operational stations used in this report, the highest 1-week rainfall observed was 336.5 mm over General Nakar, Quezon. The rest of the 10 stations with the highest antecedent rainfall is presented in Table 6.3.

Table 6.3. Stations with the highest rainfall observation during the week before the Heavy Rainfall Event and the corresponding daily rainfall over these stations for 22 and 23 December.

Station Category	Location	Accumulated Rainfall (mm)		
		21-27 December	22 December	23 December
Automatic Rain Gauge	General Nakar, Quezon	336.5	54.0	194.5
Synoptic Station	Daet, Camarines Norte	287.3	52.0	212.5
Synoptic Station	Juban, Sorsogon	277.0	160.4	100.6
Automatic Rain Gauge	Sampaloc, Quezon	253.0	79.5	77.0
Automatic Rain Gauge	Real, Quezon	222.5	34.0	124.5
Synoptic Station	Infanta, Quezon	220.8	30.4	133.1
Automatic Rain Gauge	Tabaco City, Albay	214.5	24.0	154.0
Synoptic Station	Casiguran, Aurora	214.1	39.0	109.5
Synoptic Station	Aparri, Cagayan	193.4	0.0	5.0
Automatic Rain Gauge	Gubat, Sorsogon	191.5	129.5	53.0

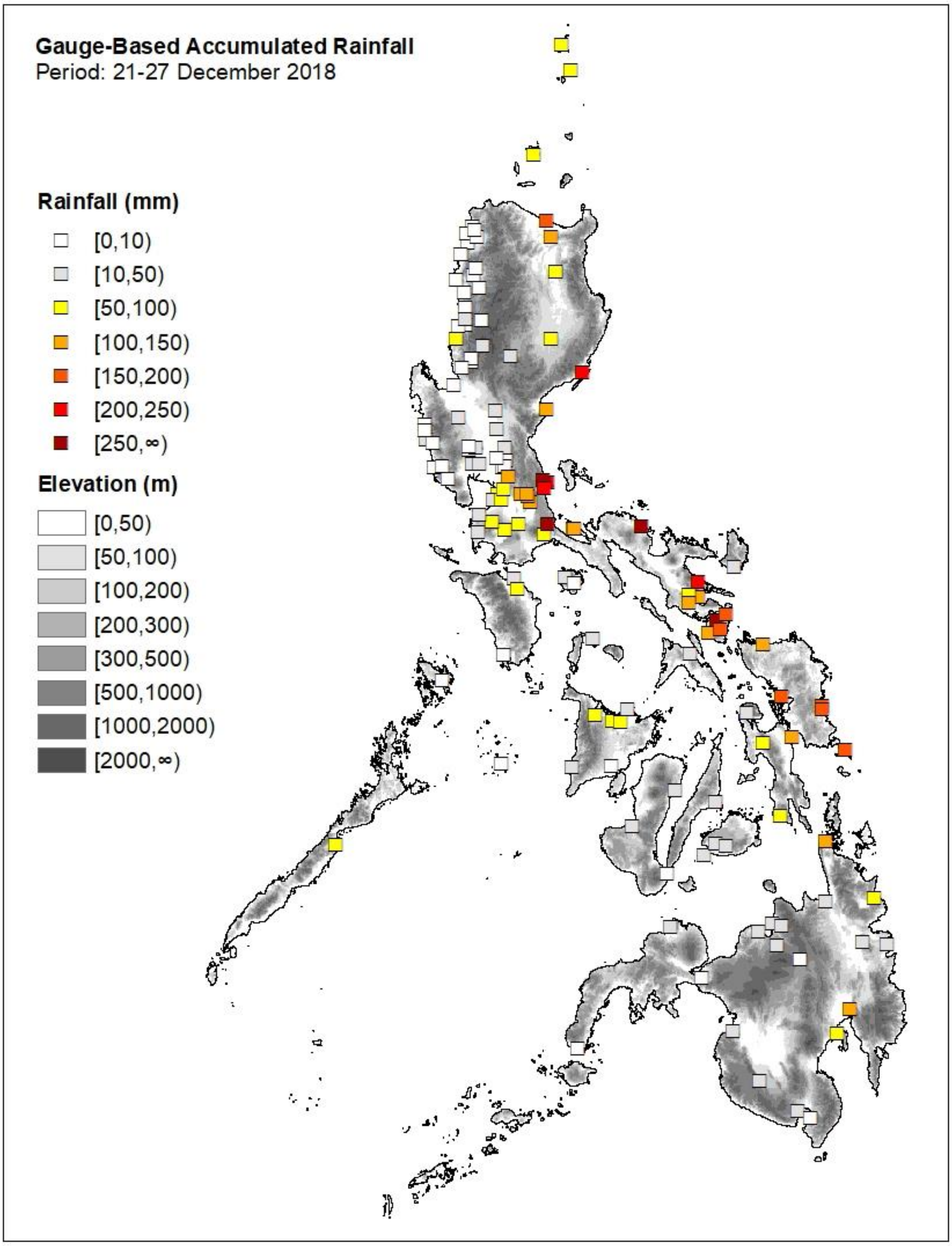


Fig. 6.7. Nationwide observation of accumulated rainfall during the period of 21-27 December (seven-day period preceding the DEC18 event) from reports of PAGASA synoptic stations and automatic rain gauges.

In the areas that received accumulated rainfall of at least 100 mm during the week preceding the DEC18 event, much of the heavy rains were recorded from 22 to 23 December. For the 10 stations listed in Table 2, except for Aparri, Cagayan, between 61.9 and 95.3% of the 1-week antecedent rainfall was observed within the said 2-day period. The heavy rainfall period during this two-day period was associated with passage of a westward-moving shallow low pressure area in the central portion of the archipelago (Fig. 6.8) and its subsequent interaction with a northeasterly CS event following the same mechanism earlier described in this report and in Yokoi and Matsumoto (2008) and Olaguera et al. (2020). The presence of significant antecedent rainfall may have contributed to the eventual ground failure triggered by the widespread heavy rains of the DEC18 event over several areas in the Bicol Region.

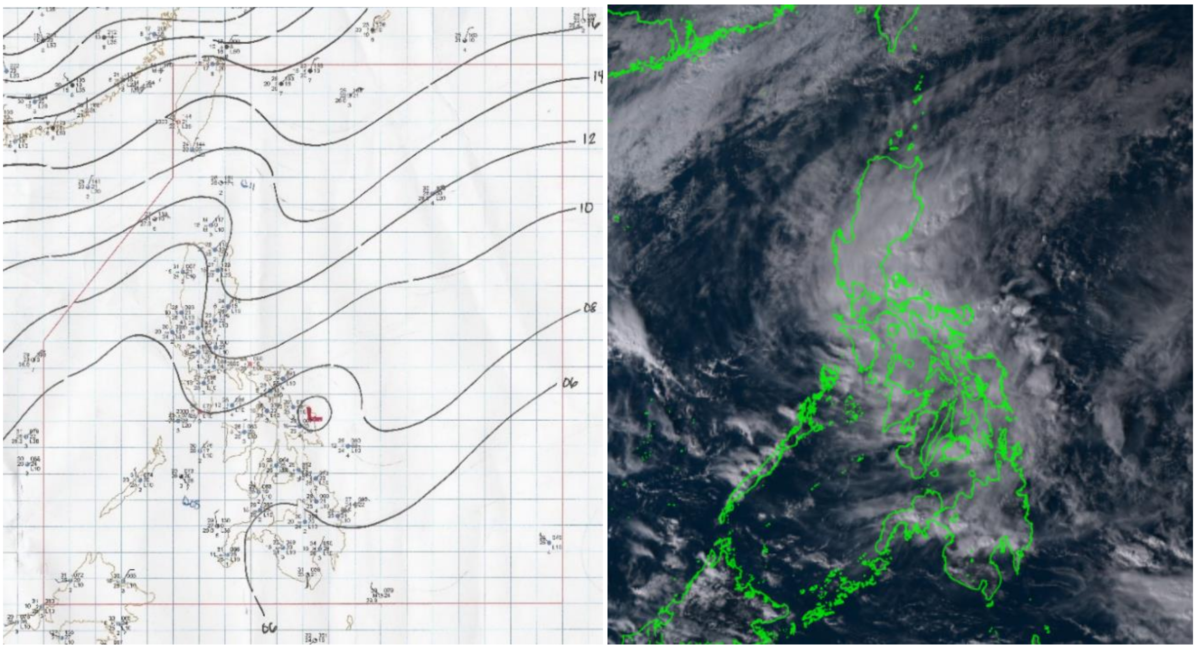


Fig. 6.8. (a) Surface synoptic chart of PAGASA over the PAR region at 06 UTC on 23 December. Contour interval is 2 hPa. The shallow low pressure area being discussed in this subsection is marked with “L”. The limits of the PAR is marked by the red polygon. (b)

Concluding Remarks

Improving our understanding of the synoptic situation and mechanism that causes heavy rainfall events such as those observed in the DEC18 event and other similar events is essential in increasing the predictability of these severe weather events. The DEC18 event that claimed the lives of 156 individuals and injured 105 others was the result of the complex interaction between a westward-moving TDD (TC Usman) towards Visayas and a strong CS event of the NEM. The analysis of synoptic scale features during the period of the heavy rainfall disaster revealed that the synoptic condition and mechanism leading to the DEC18 event were found to be similar to those observed during heavy rainfall occurences related to cyclonic disturbances during CS events as discussed in Yokoi and Matsumoto (2008) and Olaguera et al. (2020). In particular, the presence of a tropical disturbance during a strong CS event aggravates the observed convergent flow along the shear-line at the leading edge of the CS, resulting in enhanced convection and heavy rainfall. The presence of the disturbance also prevents the CS from propagating southward, resulting in prolonged precipitation over the affected areas due to the stalling of the shear line.

The DEC18 event demonstrated the importance of accounting for antecedent rainfall in providing warnings related to flooding and/or rain-induced landslides during high impact weather scenarios. In this report, the resulting ground failure in various localities during the DEC18 event were aggravated by the presence of significant antecedent rainfall during the seven-day period preceding the DEC18 event, much of which were observed over a two-day period when a low pressure area crossed the central portion of the archipelago.

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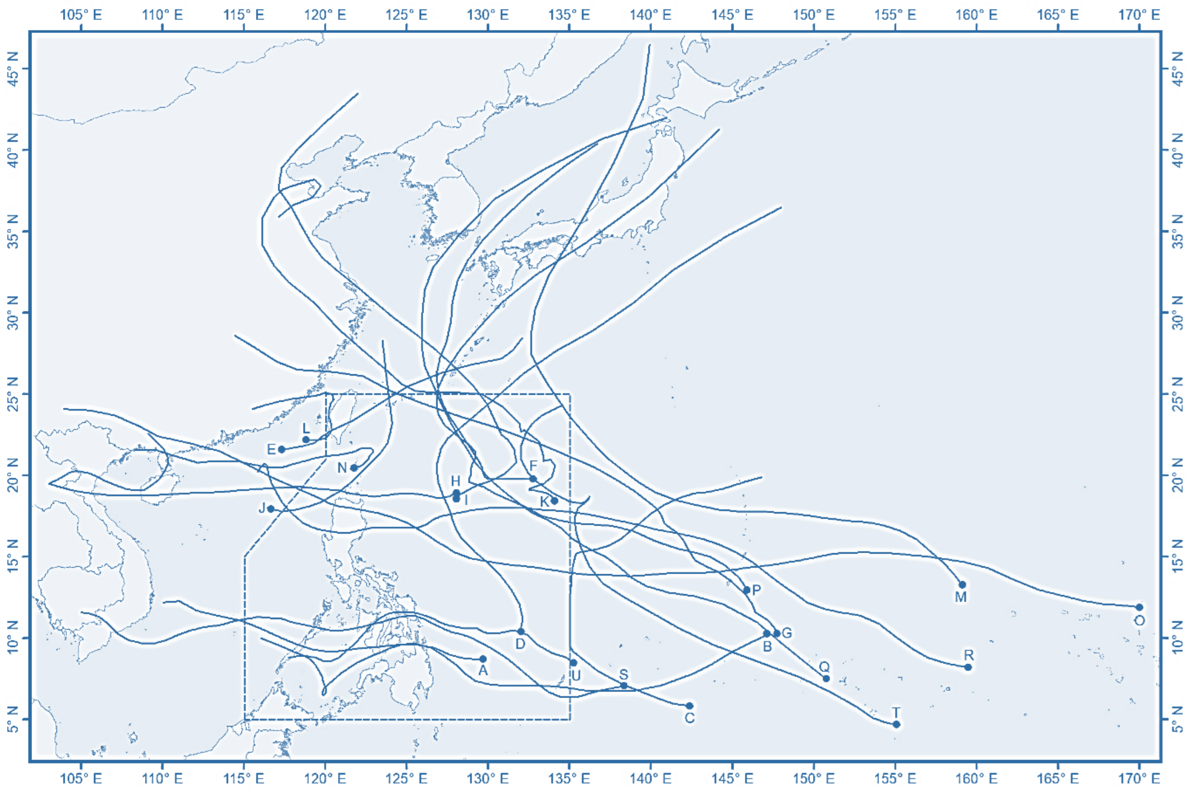
BEST TRACK DATASET



PHILIPPINE ATMOSPHERIC GEOPHYSICAL AND ASTRONOMICAL SERVICES ADMINISTRATION (PAGASA)
2018 PHILIPPINE TROPICAL CYCLONE BEST TRACK

A map of the Western North Pacific basin showing the best track of 2018 tropical cyclones that developed within or entered the Philippine Area of Responsibility

Best Track Dataset

The following information are the details of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) best track of each tropical cyclone (TC) during the 2018 season in tabular format. Each entry consists of the following information

- Date and time of analysis (DT; Format: MM/DD HH) in Coordinated Universal Time (UTC);
- Latitude (CLAT) and longitude (CLON) coordinates of the center position rounded off to the nearest 0.1°N and 0.1°E respectively;
- Maximum sustained winds (MXWD) at 10-minute averaging in knots (kt) and rounded off to the nearest 5 kt; and,
- Sea level pressure at the estimated center position (CP) in hectopascal (hPa) and rounded off to the nearest even integer for estimates of 990 hPa and higher or to the nearest 5 hPa for estimates below 990 hPa.

If the disturbance is classified as a remnant low or extratropical cyclone, the indicator L or ET is written on the MXWD field respectively.

The best track position and intensity information is available at standard synoptic times (00, 06, 12, and 18 UTC) except for landfalling or close-approaching TC events. In these cases, the entries are provided at standard and intermediate synoptic times (00, 03, 06, 09, 12, 15, 18, and 21 UTC) beginning at the point when the TC is 24 hours from landfall or closest approach. The best track data reverts to using standard synoptic times once the TC is more than 100 km away from the Philippine coast line. The best track information covers from the time the TC was first classified as a tropical depression to its weakening into a remnant low or transitioning into an extratropical cyclone.

The best track positions and intensities supersedes the positions and intensities issued by PAGASA in real time during the warning stage of a TC.

Table 7.1. PAGASA best track position and intensities of TC Agaton

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
01/01 00	8.7	129.9	25	1004	01/02 09	9.2	120	30	1004
01/01 03	8.7	129.1	25	1004	01/02 12	9.3	119.2	30	1004
01/01 06	8.8	128.3	25	1004	01/02 15	9.6	118.3	30	1004
01/01 09	9.0	127.6	25	1004	01/02 18	10.0	117.3	30	1004
01/01 12	9.4	126.7	25	1004	01/03 00	10.6	116.0	35	1002
01/01 15	9.6	125.6	25	1004	01/03 06	11.1	114.8	35	1002
01/01 18	9.6	124.5	30	1004	01/03 12	11.4	113.3	35	1002
01/01 21	9.5	123.5	30	1004	01/03 18	11.7	112.1	35	1002
01/02 00	9.4	122.4	30	1004	01/04 00	12.3	111.0	30	1006
01/02 03	9.3	121.5	30	1004	01/04 06	12.2	110.0	L	1008
01/02 06	9.2	120.7	30	1004					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.2. PAGASA best track position and intensities of TC Basyang

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
02/09 00	10.4	147.3	25	1006	02/13 06	9.6	124.6	30	1004
02/09 06	10.1	146.9	25	1004	02/13 09	9.4	124.0	30	1004
02/09 12	9.7	146.0	25	1006	02/13 12	9.2	123.5	25	1008
02/09 18	9.2	145.0	25	1004	02/13 15	8.9	122.8	25	1008
02/10 00	8.4	143.7	25	1006	02/13 18	8.5	121.9	25	1008
02/10 06	7.8	142.5	25	1004	02/13 21	7.9	121.0	25	1008
02/10 12	7.1	140.6	25	1004	02/14 00	7.3	120.3	25	1008
02/10 18	6.8	139.0	30	1002	02/14 03	6.9	119.9	25	1008
02/11 00	6.8	137.3	30	1002	02/14 06	6.6	119.8	25	1008
02/11 06	6.8	136.0	35	1000	02/14 09	6.5	119.9	25	1008
02/11 12	7.0	134.6	35	1000	02/14 12	6.7	120.0	25	1010
02/11 18	7.1	133.0	35	1000	02/14 15	6.9	120.0	25	1010
02/11 21	7.1	132.4	35	1000	02/14 18	7.2	119.9	25	1008
02/12 00	7.1	131.9	35	1000	02/14 21	7.6	119.8	25	1008
02/12 03	7.1	131.3	35	1000	02/15 00	8.0	119.6	25	1010
02/12 06	7.1	130.7	35	1000	02/15 03	8.3	119.4	25	1010
02/12 09	7.2	129.9	35	1000	02/15 06	8.6	119.2	25	1008
02/12 12	7.4	129.2	35	1000	02/15 09	8.8	118.9	25	1008
02/12 15	7.8	128.6	35	1000	02/15 12	9.0	118.5	25	1010
02/12 18	8.3	128.1	35	1000	02/15 15	9.2	118.0	25	1010
02/12 21	8.9	127.3	35	1000	02/15 18	9.4	117.5	25	1010
02/13 00	9.4	126.5	30	1004	02/15 21	9.7	116.8	25	1010
02/13 03	9.7	125.4	30	1004	02/16 00	10.0	116.0	L	1012

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.3. PAGASA best track position and intensities of TC Caloy.

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
03/24 18	5.8	142.6	25	1004	03/28 18	14.9	135.3	55	985
03/25 00	6.0	141.3	30	1002	03/29 00	15.2	135.4	65	975
03/25 06	6.3	140.4	35	1000	03/29 06	15.3	135.6	70	965
03/25 12	6.8	139.2	35	1000	03/29 12	15.4	136.2	80	955
03/25 18	7.1	138.4	35	1000	03/29 18	15.5	136.8	85	945
03/26 00	7.5	137.6	35	1000	03/30 00	15.7	137.4	95	935
03/26 06	8.0	136.7	35	1000	03/30 06	16.1	138.1	105	920
03/26 12	8.7	135.8	35	1000	03/30 12	16.8	139.0	105	920
03/26 18	9.2	135.2	35	1000	03/30 18	17.6	139.9	100	925
03/27 00	9.5	135.0	35	1000	03/31 00	18.2	140.8	80	955
03/27 06	9.9	135.0	35	1000	03/31 06	18.6	141.7	70	965
03/27 12	10.3	135.0	35	998	03/31 12	18.9	142.6	65	975
03/27 18	11.4	135.0	40	996	03/31 18	19.0	143.5	35	992
03/28 00	12.5	135.0	45	994	04/01 00	19.2	144.4	30	996
03/28 06	13.7	135.1	50	990	04/01 06	19.6	145.7	30	996
03/28 12	14.5	135.2	50	990	04/01 12	19.9	146.8	ET	998

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.4. PAGASA best track position and intensities of TC Domeng.

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
06/05 00	10.2	131.9	25	1004	06/08 12	19.6	126.9	35	996
06/05 06	10.6	132.0	25	1004	06/08 18	20.6	126.8	40	992
06/05 12	11.2	132.1	25	1004	06/09 00	21.7	127.1	45	990
06/05 18	12.1	131.9	25	1002	06/09 06	22.3	127.5	50	985
06/06 00	13.0	131.4	25	1004	06/09 12	22.8	128.1	50	985
06/06 06	13.9	130.7	25	1002	06/09 18	23.7	129.2	55	975
06/06 12	14.6	130.0	25	1004	06/10 00	25.0	130.7	60	970
06/06 18	15.3	129.2	25	1004	06/10 06	26.3	132.2	60	970
06/07 00	15.9	128.6	30	1002	06/10 12	27.7	134.2	55	975
06/07 06	16.2	128.3	30	1000	06/10 18	28.9	136.4	55	980
06/07 12	16.7	128.0	30	1000	06/11 00	30.6	138.9	50	980
06/07 18	17.3	127.8	35	996	06/11 06	32.6	141.3	50	980
06/08 00	17.9	127.6	35	996	06/11 12	34.7	144.6	50	980
06/08 06	18.8	127.2	35	996	06/11 18	36.5	148.0	ET	985

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.5 PAGASA best track position and intensities of TC Ester.

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
06/13 12	21.6	117.1	25	996	06/15 12	24.6	123.6	35	992
06/13 18	21.7	117.9	25	996	06/15 18	25.5	125.1	35	992
06/14 00	21.8	118.6	25	996	06/16 00	26.3	127.1	35	992
06/14 06	22.0	119.3	30	994	06/16 06	26.8	128.9	40	990
06/14 12	22.4	119.8	30	994	06/16 12	27.2	130.8	40	990
06/14 18	22.6	120.1	30	994	06/16 18	27.7	131.5	35	992
06/15 00	22.7	120.2	30	994	06/17 00	28.5	132.1	ET	996
06/15 06	23.4	121.7	30	994					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.6 PAGASA best track position and intensities of TC Florita.

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
06/28 00	19.8	133.0	25	1004	07/01 12	25.3	126.9	55	980
06/28 06	19.8	132.3	25	1004	07/01 18	26.2	126.8	60	970
06/28 12	19.8	131.4	25	1004	07/02 00	27.2	127.0	65	965
06/28 18	19.8	130.8	30	1002	07/02 06	28.2	127.4	65	965
06/29 00	19.8	130.3	35	998	07/02 12	29.5	127.7	65	965
06/29 06	19.8	130.0	35	998	07/02 18	30.7	127.8	65	960
06/29 12	19.9	129.8	40	996	07/03 00	32.0	128.1	60	965
06/29 18	20.1	129.7	40	996	07/03 06	33.2	128.7	60	965
06/30 00	20.5	129.6	45	994	07/03 12	34.4	129.6	55	975
06/30 06	20.9	129.4	45	992	07/03 18	35.8	130.9	50	980
06/30 12	21.8	128.8	45	992	07/04 00	37.3	132.5	45	985
06/30 18	22.9	128.1	45	992	07/04 06	39.1	134.8	45	985
07/01 00	23.6	127.6	50	985	07/04 12	40.4	136.7	ET	985
07/01 06	24.4	127.2	55	980					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.7. PAGASA best track position and intensities of TC Gardo.

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
07/03 00	10.1	147.8	25	1004	07/07 18	18.5	139.7	95	935
07/03 06	10.6	147.6	25	1004	07/08 00	19.1	138.9	95	935
07/03 12	11.1	147.2	25	1004	07/08 06	19.8	137.8	100	925
07/03 18	11.4	146.7	30	1002	07/08 12	20.5	136.5	105	915
07/04 00	11.6	146.4	30	1002	07/08 18	21.1	135.1	105	915
07/04 06	12.1	146.2	30	1000	07/09 00	21.8	133.5	105	915
07/04 12	12.7	145.8	35	998	07/09 06	22.4	131.9	100	925
07/04 18	13.6	144.8	45	992	07/09 12	23.0	130.3	95	935
07/05 00	14.1	144.1	50	990	07/09 18	23.5	128.7	95	935
07/05 06	14.4	143.4	55	985	07/10 00	24.0	127.2	90	940
07/05 12	14.8	142.7	70	965	07/10 06	24.6	125.5	90	940
07/05 18	15.4	142.3	85	950	07/10 12	25.2	124.0	85	950
07/06 00	16.0	142.0	100	925	07/10 18	26.1	122.3	85	950
07/06 06	16.5	141.6	100	925	07/11 00	26.4	120.2	80	955
07/06 12	16.7	141.3	100	925	07/11 06	26.5	118.3	55	980
07/06 18	16.9	141.0	95	935	07/11 12	27.0	117.0	45	992
07/07 00	17.1	140.8	95	935	07/11 18	27.9	115.6	30	998
07/07 06	17.6	140.6	95	935	07/12 00	28.6	114.4	L	1000
07/07 12	18.0	140.3	95	935					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.8. PAGASA best track position and intensities of TC Henry.

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
07/15 12	19.1	128.2	25	1002	07/19 06	19.4	103.3	25	1000
07/15 15	18.7	127.6	25	1002	07/19 12	19.5	103.0	25	1000
07/15 18	18.6	126.9	25	1002	07/19 18	19.7	103.4	25	1000
07/15 21	18.8	126.1	25	1002	07/20 00	19.9	103.8	25	1000
07/16 00	18.9	125.3	25	1000	07/20 06	20.2	104.3	25	1000
07/16 03	18.9	124.6	25	1000	07/20 12	20.3	104.7	25	1000
07/16 06	18.8	123.8	30	996	07/20 18	20.2	105.2	25	1000
07/16 09	18.7	123.0	30	996	07/21 00	20.1	105.6	25	1000
07/16 12	18.8	122.2	30	994	07/21 06	19.9	106.0	25	998
07/16 15	18.9	121.5	30	994	07/21 12	19.7	106.4	25	996
07/16 18	19.1	120.8	30	994	07/21 18	19.4	107.1	25	996
07/16 21	19.2	119.6	30	994	07/22 00	19.2	107.7	25	996
07/17 00	19.3	118.4	35	992	07/22 06	19.1	108.3	25	996
07/17 06	19.2	115.9	35	992	07/22 12	19.1	108.8	30	994
07/17 12	19.0	113.6	40	990	07/22 18	19.4	109.3	30	994
07/17 18	18.9	111.3	40	990	07/23 00	19.8	109.8	30	994
07/18 00	18.8	109.5	35	992	07/23 06	20.3	110.1	30	994
07/18 06	18.8	108.0	40	990	07/23 12	20.7	110.3	30	994
07/18 12	18.8	106.7	40	990	07/23 18	21.1	110.3	25	996
07/18 18	18.9	105.6	35	994	07/24 00	21.7	110.0	25	996
07/19 00	19.1	104.4	30	998	07/24 06	22.6	109.1	L	998

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.9. PAGASA best track position and intensities of TC Inday.

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
07/17 12	18.4	127.9	25	1000	07/21 06	27.8	126.7	50	985
07/17 18	18.8	128.2	25	1000	07/21 12	28.7	125.5	50	985
07/18 00	19.1	128.7	30	998	07/21 18	29.7	124.2	50	985
07/18 06	19.4	129.3	30	998	07/22 00	30.7	123.0	50	985
07/18 12	19.6	129.9	35	996	07/22 06	31.8	121.7	45	985
07/18 18	19.8	130.4	35	996	07/22 12	32.6	120.7	45	985
07/19 00	20.1	131.0	40	994	07/22 18	33.4	119.8	40	990
07/19 06	20.8	131.7	40	994	07/23 00	34.3	119.1	35	992
07/19 12	21.6	131.6	45	990	07/23 06	35.2	118.6	35	992
07/19 18	22.2	131.2	45	990	07/23 12	36.5	117.9	35	992
07/20 00	22.5	130.8	50	985	07/23 18	37.6	117.1	30	994
07/20 06	23.1	130.5	50	985	07/24 00	38.9	117.3	30	994
07/20 12	24.4	129.9	50	985	07/24 06	40.1	118.3	25	996
07/20 18	25.6	129.0	50	985	07/24 12	41.6	119.9	25	996
07/21 00	26.7	127.9	50	985	07/24 18	43.5	122.0	ET	996

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.10. PAGASA best track position and intensities of TC Josie.

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
07/20 12	18.0	116.4	25	1002	07/21 21	20.3	122.3	30	996
07/20 18	17.8	117.3	25	1000	07/22 00	20.8	122.8	30	996
07/21 00	17.9	118.1	30	998	07/22 03	21.3	123.3	30	996
07/21 03	18.1	119.0	30	996	07/22 06	22.0	123.8	30	996
07/21 06	18.4	119.8	30	994	07/22 12	23.2	124.1	30	996
07/21 09	18.7	120.3	30	994	07/22 18	24.6	123.9	30	996
07/21 12	19.0	120.8	30	996	07/23 00	26.2	123.7	25	998
07/21 15	19.3	121.2	30	996	07/23 06	28.3	123.5	L	1000
07/21 18	19.7	121.7	30	996					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.11. PAGASA best track position and intensities of TC Karding

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
08/06 00	18.2	134.1	25	1000	08/11 06	25.1	128.0	35	992
08/06 06	18.5	134.0	25	1000	08/11 12	25.1	126.7	40	990
08/06 12	18.7	133.9	25	998	08/11 18	25.2	125.5	40	990
08/06 18	18.9	133.6	25	998	08/12 00	25.6	124.7	40	990
08/07 00	19.0	133.3	25	998	08/12 06	26.5	123.7	40	990
08/07 06	19.1	132.8	30	996	08/12 12	27.7	122.3	40	990
08/07 12	19.1	132.6	30	996	08/12 18	29.0	120.8	35	992
08/07 18	19.1	132.5	30	996	08/13 00	30.6	119.3	30	994
08/08 00	19.2	132.5	35	994	08/13 06	31.9	117.7	30	994
08/08 06	19.5	133.4	35	994	08/13 12	32.9	116.8	30	996
08/08 12	19.9	133.9	35	994	08/13 18	34.2	116.1	25	998
08/08 18	20.6	134.1	35	994	08/14 00	35.8	116.1	25	1000
08/09 00	21.0	133.8	35	994	08/14 06	37.1	116.8	25	1000
08/09 06	20.9	133.4	35	994	08/14 12	37.6	117.4	25	1000
08/09 12	21.1	133.4	35	994	08/14 18	37.8	117.9	25	1002
08/09 18	22.1	133.1	35	994	08/15 00	38.2	119.3	25	1002
08/10 00	22.8	132.2	35	994	08/15 06	37.8	119.7	30	1000
08/10 06	22.7	132.0	35	994	08/15 12	37.1	119.2	30	1000
08/10 12	23.2	131.9	35	994	08/15 18	36.6	118.0	25	1004
08/10 18	24.2	130.9	35	994	08/16 00	35.9	117.1	ET	1006
08/11 00	25.0	129.6	35	994					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.12. PAGASA best track position and intensities of TC Luis

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
08/22 00	22.2	118.6	25	998	08/24 06	24.7	120.5	30	996
08/22 06	22.2	119.0	25	998	08/24 12	25.0	120.4	30	996
08/22 12	22.2	119.5	25	998	08/24 18	25.1	120.0	30	996
08/22 18	22.3	120.0	25	996	08/25 00	24.9	119.4	25	998
08/23 00	22.8	120.4	30	994	08/25 06	24.7	117.8	25	998
08/23 06	23.3	120.3	30	994	08/25 12	24.5	116.9	25	998
08/23 12	23.6	120.2	30	996	08/25 18	24.3	116.2	25	998
08/23 18	24.0	120.2	30	996	08/26 00	24.1	115.5	L	1000
08/24 00	24.4	120.3	30	996					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.13. PAGASA best track position and intensities of TC Maymay

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
08/27 06	13.1	159.2	25	1006	08/31 18	19.0	140.2	110	910
08/27 12	13.8	158.7	30	1004	09/01 00	19.6	139.2	105	915
08/27 18	14.6	158.0	30	1002	09/01 06	20.3	138.3	105	915
08/28 00	15.4	157.1	35	1000	09/01 12	21.0	137.4	100	925
08/28 06	16.1	156.3	40	996	09/01 18	21.8	136.6	95	935
08/28 12	16.6	155.3	45	994	09/02 00	22.7	135.8	95	935
08/28 18	16.9	154.4	50	990	09/02 06	23.6	135.0	95	935
08/29 00	17.1	153.5	60	985	09/02 12	24.5	134.4	95	935
08/29 06	17.2	152.4	65	980	09/02 18	25.5	133.7	95	935
08/29 12	17.3	151.5	70	975	09/03 00	26.5	133.1	90	940
08/29 18	17.4	150.5	80	965	09/03 06	27.5	132.6	90	940
08/30 00	17.6	149.2	85	955	09/03 12	28.6	132.6	90	940
08/30 06	17.7	148.1	90	945	09/03 18	30.3	132.9	85	945
08/30 12	17.8	146.9	95	935	09/04 00	32.3	133.7	80	950
08/30 18	17.8	145.4	100	925	09/04 06	35.6	135.7	75	965
08/31 00	17.9	144.2	105	915	09/04 12	39.2	137.7	65	970
08/31 06	18.2	142.7	110	910	09/04 18	43.2	139.5	50	975
08/31 12	18.5	141.5	110	910	09/05 00	46.5	139.9	ET	975

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.14. PAGASA best track position and intensities of TC Neneng

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
09/08 06	20.4	121.5	25	1006	09/10 03	21.4	121.5	25	1006
09/08 09	20.5	121.9	25	1006	09/10 06	21.3	121.0	25	1006
09/08 12	20.6	122.2	25	1008	09/10 12	21.2	120.2	25	1006
09/08 15	20.8	122.4	25	1008	09/10 18	21.1	119.5	30	1004
09/08 18	21.0	122.6	25	1006	09/11 00	20.9	118.7	35	1000
09/08 21	21.2	122.7	25	1006	09/11 06	20.7	118.0	40	998
09/09 00	21.3	122.8	25	1006	09/11 12	20.5	117.4	40	998
09/09 03	21.4	122.9	25	1006	09/11 18	20.5	116.4	40	998
09/09 06	21.6	122.9	25	1006	09/12 00	20.7	115.4	40	998
09/09 09	21.7	122.8	25	1006	09/12 06	20.9	114.5	40	998
09/09 12	21.7	122.6	25	1008	09/12 12	20.9	113.4	40	998
09/09 15	21.7	122.4	25	1008	09/12 18	20.8	112.1	40	998
09/09 18	21.7	122.2	25	1006	09/13 00	21.2	110.7	35	1002
09/09 21	21.6	122.0	25	1006	09/13 06	21.6	109.5	25	1006
09/10 00	21.5	121.8	25	1006	09/13 12	21.6	108.3	L	1008

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.15. PAGASA best track position and intensities of TC Ompong

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
09/06 12	11.9	170.2	25	1008	09/13 00	14.5	131.4	110	905
09/06 18	12.0	169.1	25	1008	09/13 06	14.7	130.1	110	905
09/07 00	12.1	167.8	25	1008	09/13 12	14.9	128.9	110	905
09/07 06	12.3	166.6	30	1006	09/13 18	15.3	127.9	110	905
09/07 12	12.6	165.3	35	1000	09/13 21	15.6	127.4	110	905
09/07 18	13.0	163.8	35	1000	09/14 00	15.9	126.9	110	905
09/08 00	13.6	162.3	40	998	09/14 03	16.3	126.3	110	905
09/08 06	14.3	160.7	40	996	09/14 06	16.7	125.7	110	905
09/08 12	14.7	159.2	45	992	09/14 09	17.1	125.0	110	905
09/08 18	15.0	157.1	50	985	09/14 12	17.4	124.2	110	905
09/09 00	15.2	155.1	65	975	09/14 15	17.7	123.2	110	905
09/09 06	15.3	153.0	65	975	09/14 18	17.9	122.2	105	915
09/09 12	15.2	151.2	70	970	09/14 21	18.0	121.5	100	925
09/09 18	14.8	149.1	75	960	09/15 00	18.1	120.8	95	935
09/10 00	14.5	147.4	80	955	09/15 03	18.3	120.2	90	940
09/10 06	14.3	145.7	80	955	09/15 06	18.6	119.6	90	940
09/10 12	14.1	144.2	85	950	09/15 12	19.2	118.3	85	950
09/10 18	14.0	142.6	90	940	09/15 18	19.8	116.9	80	955
09/11 00	14.0	141.2	95	930	09/16 00	20.6	115.3	75	960
09/11 06	13.9	139.8	105	915	09/16 06	21.5	113.5	75	960
09/11 12	13.8	138.7	110	905	09/16 12	22.0	111.6	65	970
09/11 18	13.9	137.3	110	905	09/16 18	22.4	109.7	60	975
09/12 00	13.9	136.2	110	905	09/17 00	23.0	108.6	45	992
09/12 06	14.0	135.2	110	905	09/17 06	23.7	107.0	30	998
09/12 12	14.2	134.0	110	905	09/17 12	24.0	105.6	25	1002
09/12 18	14.4	132.5	110	905	09/17 18	24.1	103.9	L	1004

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.16. PAGASA best track position and intensities of TC Paeng

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
09/20 12	12.8	146.0	25	1004	09/26 00	20.7	129.0	85	950
09/20 18	13.7	145.4	30	1002	09/26 06	21.0	129.2	85	950
09/21 00	14.5	144.5	30	1002	09/26 12	21.3	129.2	85	950
09/21 06	15.0	143.6	35	1000	09/26 18	21.5	129.2	85	950
09/21 12	15.3	142.6	40	996	09/27 00	21.6	129.1	85	950
09/21 18	15.5	141.6	45	994	09/27 06	21.7	129.0	85	950
09/22 00	16.0	140.2	50	990	09/27 12	21.9	128.8	85	950
09/22 06	16.6	138.9	55	985	09/27 18	22.2	128.4	85	950
09/22 12	16.9	137.6	55	985	09/28 00	22.5	128.0	85	950
09/22 18	17.0	136.2	65	975	09/28 06	23.1	127.3	85	950
09/23 00	17.1	135.1	70	965	09/28 12	23.8	126.9	85	950
09/23 06	17.3	134.2	80	955	09/28 18	24.5	126.8	85	950
09/23 12	17.5	133.3	85	945	09/29 00	25.4	126.9	85	950
09/23 18	18.1	132.2	90	940	09/29 06	26.5	127.4	85	950
09/24 00	18.5	131.3	95	935	09/29 12	27.8	128.3	85	950
09/24 06	18.9	130.4	100	925	09/29 18	29.1	129.4	85	950
09/24 12	19.3	129.7	100	925	09/30 00	30.6	130.8	85	950
09/24 18	19.5	129.1	105	915	09/30 06	32.3	132.9	80	955
09/25 00	19.6	128.8	105	915	09/30 12	34.3	136.0	80	960
09/25 06	19.8	128.8	105	915	09/30 18	37.2	139.9	70	970
09/25 12	20.0	128.9	100	925	10/01 00	41.3	144.2	ET	970
09/25 18	20.3	128.9	95	935					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.17. PAGASA best track position and intensities of TC Queenie

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
09/28 00	7.4	150.9	25	1004	10/02 18	19.5	130.4	95	930
09/28 06	8.5	149.5	25	1002	10/03 00	20.1	129.8	90	940
09/28 12	9.7	148.0	30	1000	10/03 06	20.8	129.2	85	945
09/28 18	11.0	146.5	30	1000	10/03 12	21.6	128.7	80	955
09/29 00	12.1	144.4	30	1000	10/03 18	22.5	128.1	75	960
09/29 06	12.6	142.6	35	998	10/04 00	23.2	127.7	70	970
09/29 12	12.8	141.1	40	996	10/04 06	24.4	127.1	65	975
09/29 18	13.2	139.7	50	985	10/04 12	25.4	126.7	65	975
09/30 00	13.7	138.8	60	980	10/04 18	26.7	126.1	65	975
09/30 06	14.4	138.0	65	975	10/05 00	28.0	125.9	60	980
09/30 12	15.0	137.2	75	965	10/05 06	29.5	125.9	60	980
09/30 18	15.4	136.4	80	955	10/05 12	31.4	126.1	65	975
10/01 00	15.7	135.8	90	940	10/05 18	32.8	126.6	65	975
10/01 06	16.1	135.2	100	925	10/06 00	34.7	128.1	60	975
10/01 12	16.8	134.4	110	910	10/06 06	37.0	130.4	55	980
10/01 18	17.3	133.6	115	900	10/06 12	38.7	133.2	50	985
10/02 00	17.7	132.7	115	900	10/06 18	40.7	137.0	45	990
10/02 06	18.2	132.0	115	900	10/07 00	42.0	141.0	ET	994
10/02 12	18.8	131.2	105	915					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.18. PAGASA best track position and intensities of TC Rosita

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
10/21 00	8.2	159.7	25	1008	10/28 12	17.7	128.1	85	945
10/21 06	8.3	158.9	25	1004	10/28 18	17.5	127.1	80	950
10/21 12	8.5	158.0	25	1006	10/28 21	17.3	126.6	80	950
10/21 18	8.8	157.0	30	1004	10/29 00	17.0	126.2	80	955
10/22 00	9.3	156.1	35	1002	10/29 03	16.8	125.7	80	955
10/22 06	10.1	155.0	40	996	10/29 06	16.8	125.3	80	955
10/22 12	10.9	154.0	45	990	10/29 09	16.8	124.8	80	955
10/22 18	11.4	152.8	55	985	10/29 12	16.8	124.2	80	955
10/23 00	11.6	151.6	65	975	10/29 15	16.8	123.6	80	955
10/23 06	11.8	150.6	70	965	10/29 18	16.8	123.0	80	955
10/23 12	12.2	149.6	80	955	10/29 21	16.7	122.3	75	965
10/23 18	12.7	148.9	85	945	10/30 00	16.5	121.5	70	970
10/24 00	13.3	148.0	100	925	10/30 03	16.5	120.8	65	975
10/24 06	14.0	147.1	110	910	10/30 06	16.6	120.1	60	980
10/24 12	14.7	146.2	115	900	10/30 09	16.7	119.6	55	985
10/24 18	15.3	145.2	115	900	10/30 12	16.8	119.2	55	985
10/25 00	15.8	144.1	115	900	10/30 18	17.1	118.6	50	990
10/25 06	16.1	143.2	105	915	10/31 00	17.5	118.1	50	990
10/25 12	16.3	142.3	100	925	10/31 06	18.0	117.6	45	992
10/25 18	16.5	141.4	95	935	10/31 12	18.4	117.3	45	992
10/26 00	16.7	140.3	95	935	10/31 18	18.9	117.0	45	992
10/26 06	17.0	139.1	100	925	11/01 00	19.5	116.7	45	994
10/26 12	17.3	137.7	100	925	11/01 06	20.0	116.5	45	994
10/26 18	17.6	136.2	105	915	11/01 12	20.6	116.4	45	994
10/27 00	17.8	134.8	105	915	11/01 18	20.7	116.3	40	996
10/27 06	17.9	133.4	105	915	11/02 00	20.7	116.2	35	1002
10/27 12	18.0	132.2	105	915	11/02 06	20.6	116.1	30	1004
10/27 18	18.0	131.1	105	915	11/02 12	20.5	116.0	25	1008
10/28 00	18.0	130.1	100	925	11/02 18	20.2	115.8	L	1008
10/28 06	17.9	129.1	95	935					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.19. PAGASA best track position and intensities of TC Samuel

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
11/17 12	7.1	138.5	25	1004	11/21 12	10.5	120.3	25	1004
11/17 18	6.8	136.8	25	1004	11/21 15	10.6	119.7	25	1004
11/18 00	6.4	135.5	25	1004	11/21 18	10.8	118.8	30	1002
11/18 06	6.4	134.4	30	1002	11/21 21	11.0	117.9	30	1002
11/18 12	6.7	133.7	30	1004	11/22 00	11.2	117.3	35	1000
11/18 18	7.2	133.0	30	1002	11/22 06	11.3	115.8	35	1000
11/19 00	7.9	132.2	30	1004	11/22 12	11.1	114.5	35	1000
11/19 06	8.7	131.2	30	1002	11/22 18	10.8	113.5	35	1000
11/19 12	9.3	130.3	30	1004	11/23 00	10.7	112.6	45	996
11/19 15	9.6	129.8	30	1004	11/23 06	10.5	111.7	50	992
11/19 18	9.8	129.4	30	1002	11/23 12	10.2	110.9	50	992
11/19 21	10.0	129.0	30	1002	11/23 18	9.9	110.2	55	990
11/20 00	10.2	128.5	30	1004	11/24 00	9.7	109.5	60	985
11/20 03	10.3	128.1	30	1004	11/24 06	9.7	108.7	60	985
11/20 06	10.4	127.7	30	1002	11/24 12	9.8	108.3	55	990
11/20 09	10.6	127.2	30	1002	11/24 18	9.9	107.9	55	990
11/20 12	10.9	126.6	25	1004	11/25 00	10.1	107.5	45	996
11/20 15	11.2	126.0	25	1004	11/25 06	10.3	107.2	40	998
11/20 18	11.4	125.4	25	1004	11/25 12	10.7	106.8	35	1000
11/20 21	11.3	124.5	25	1004	11/25 18	11.0	106.5	30	1004
11/21 00	11.0	123.4	25	1004	11/26 00	11.3	106.1	25	1008
11/21 03	10.8	122.6	25	1004	11/26 06	11.5	105.6	25	1008
11/21 06	10.6	121.8	25	1004	11/26 12	11.6	105.0	L	1010
11/21 09	10.5	121.0	25	1004					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.20. PAGASA best track position and intensities of TC Tomas

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
11/20 00	4.7	155.3	25	1004	11/24 00	18.0	135.5	75	965
11/20 06	4.8	154.5	25	1004	11/24 06	18.3	135.9	75	965
11/20 12	5.1	153.6	30	1004	11/24 12	18.7	136.2	80	960
11/20 18	5.8	152.6	35	1000	11/24 18	18.5	136.1	80	960
11/21 00	6.7	151.0	35	1000	11/25 00	18.4	136.0	80	960
11/21 06	7.6	149.1	40	996	11/25 06	18.3	135.7	70	970
11/21 12	8.6	146.5	45	994	11/25 12	18.4	135.0	60	980
11/21 18	9.6	143.8	50	990	11/25 18	18.9	134.0	50	992
11/22 00	10.6	141.7	55	985	11/26 00	19.6	133.0	40	998
11/22 06	11.7	139.8	60	980	11/26 06	20.2	132.4	35	1000
11/22 12	12.6	138.2	65	975	11/26 12	21.0	132.0	30	1006
11/22 18	13.4	137.0	70	970	11/26 18	21.8	132.0	30	1006
11/23 00	14.4	136.2	75	965	11/27 00	22.6	132.3	25	1008
11/23 06	15.5	135.7	75	965	11/27 06	23.2	132.7	25	1008
11/23 12	16.5	135.4	75	965	11/27 12	23.7	133.3	25	1008
11/23 18	17.4	135.3	75	965	11/27 18	24.3	134.5	ET	1010

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.

Table 7.21. PAGASA best track position and intensities of TC Usman

DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)	DT (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	CP (hPa)
12/25 06	8.3	135.4	25	1004	12/28 12	11.0	127.0	30	1000
12/25 12	8.8	134.8	25	1004	12/28 15	11.2	126.6	30	1000
12/25 18	9.1	133.9	25	1004	12/28 18	11.4	126.1	30	1000
12/26 00	9.6	133.0	25	1004	12/28 21	11.6	125.4	30	1002
12/26 06	10.2	132.4	25	1002	12/29 00	11.6	124.7	25	1004
12/26 12	10.5	131.6	25	1002	12/29 03	11.6	124.2	25	1004
12/26 18	10.4	131.0	25	1002	12/29 06	11.5	123.8	25	1004
12/27 00	10.3	130.5	25	1002	12/29 09	11.2	123.3	25	1006
12/27 06	10.3	130.0	25	1002	12/29 12	10.8	122.8	25	1008
12/27 09	10.4	129.7	25	1002	12/29 15	9.7	121.8	25	1008
12/27 12	10.5	129.5	30	1000	12/29 18	8.8	120.8	25	1006
12/27 15	10.6	129.3	30	1000	12/29 21	8.6	120.3	25	1006
12/27 18	10.6	129.1	30	1000	12/30 00	8.6	119.9	25	1008
12/27 21	10.6	128.9	30	1000	12/30 03	8.8	119.4	25	1008
12/28 00	10.6	128.7	30	998	12/30 06	8.9	118.8	25	1006
12/28 03	10.6	128.5	30	998	12/30 09	8.9	118.3	25	1006
12/28 06	10.7	128.0	30	998	12/30 12	8.8	117.7	L	1008
12/28 09	10.8	127.5	30	998					

Note: DT – date and time; CLAT – latitude coordinate; CLON – longitude coordinate; MXWD – maximum sustained winds; CP – central sea level pressure; L – remnant low; ET – extratropical.