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2019

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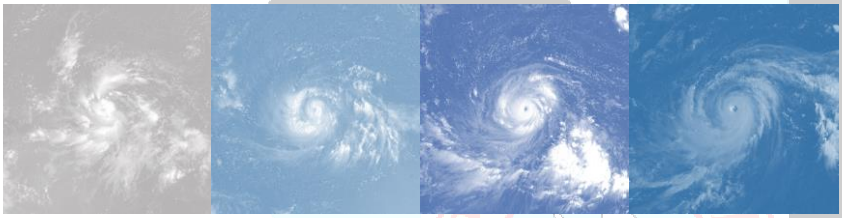


The **Annual Report on Philippine Tropical Cyclones (ARTC)** is an annual technical report published by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). This Report aims to provide a compendium of official information about the tropical cyclone (TC) season of 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 ARTC serves as the official source of information for Philippine TCs during the 2019 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

The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) named **21 tropical cyclones (TCs)** that occurred within the Philippine Area of Responsibility (PAR) during the 2019 Philippine TC season. This was near normal when compared against the 1981-2010 normal. However, the number of annual TC cases has been slightly decreasing since 1981. The months of August, September, and November were the most active months of the TC season. Although August and September had more TCs than July - usually the most active month during the third quarter of the year, the TC activity during the period was still within the climatological normal. On the other hand, November had a higher-than-normal TC activity this year compared to the climatological normal, which is characterized by a warning number of TC occurrences during the fourth quarter.

Most of the 2019 Philippine TCs developed from tropical disturbances (i.e., low pressure areas) outside the PAR region, with a majority developing over the Philippine Sea area east of 127°E. Southeast-northwest-oriented tracks over the Philippine Sea constitute roughly 62% of the TC cases within the PAR this season, with the Philippine Sea area north of 15°N and east of 122°E being the most frequented region by the 2019 TCs within the PAR. The TCs that entered that PAR had an average lifespan of 6 days and 11.7 hours while the average duration of these TCs inside the PAR was 3 days and 17.9 hours. In total, the Philippine TC season of 2019 lasted for 78 days and 15 hours. Observed trends since 1981 revealed a decreasing number of TCs occurring within the PAR region.

The season is also characterized by above normal number of TCs peaking tropical depression (TD) categories within PAR and near normal number (but lower than mean values) of TCs reaching tropical storm/severe tropical storm and typhoon/super typhoon categories. No TC that occurred within the PAR region reached the PAGASA super typhoon threshold at any point during its lifespan within the Western North Pacific (WNP) basin. Combined provisional track and best track data from PAGASA since 1981 suggests that on average, the TCs entering the PAR were less intense and lower peak intensities were reached within the region.

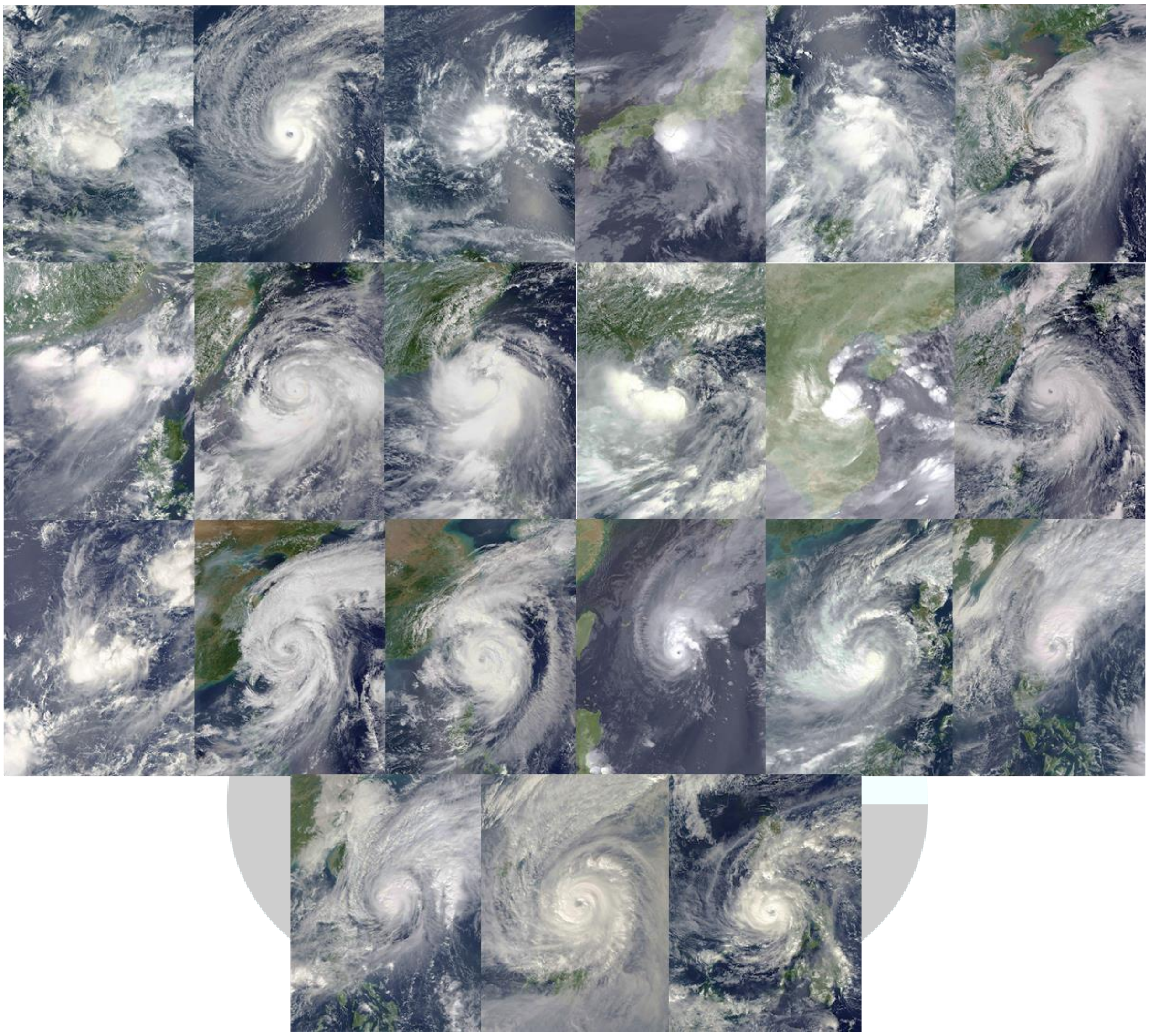
This season registered six landfalling TCs, lower than the previous season and the 30-year mean but near the 30-year normal. Most of the landfalling TCs during the season occurred during the last quarter of the year. Consolidated track data continues to show a slightly decreasing frequency of TCs making landfall or crossing the Philippine archipelago since 1981. Nearly all of the landfalling TCs for this season had a generally westward heading that did not exhibit recurvature along its path. The centers of these TCs crossed several localities in Northern Luzon, Central Luzon, Eastern Visayas, Western Visayas, and Southern Mindanao. Half of the landfalling TCs during the season were at typhoon 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 2019 for most areas of Luzon (with some areas in MIMAROPA reaching 70%), 20% to 40% for most areas of Visayas (but as much as 70% for portions of extreme northwestern Panay), and 10% to 30% for most areas of Mindanao. In terms of rainfall contribution during various monsoon regimes, the TC days during the mid to late phases of the Northeast Monsoon 2018-2019 accounted for up to 50% of the total rainfall over Mindanao during the period, up to 40% over Visayas, and up to 30% over Luzon. For the Southwest Monsoon, the rainfall during TC days constituted 60% to 80% of the total rainfall observed during the monsoon regime over southern Mindoro-northern Palawan area, 60% to 70% over Extreme Northern Luzon and northwestern mainland Luzon, 40% to 70% over the rest of Luzon, 20% to 50% over Visayas, and 10% to 40% over Mindanao. For the early phase of the Northeast Monsoon 2019-2020, the rainfall during TC days constituted 40% to 80% of the observed rainfall during the period for the eastern portion of Northern Luzon, Central Luzon, Metro Manila, CALABARZON, and Bicol Region, 20% to 50% for the rest of Luzon (except central and southern Palawan) and the northern half of Visayas, and 10% to 60% for Mindanao.

As the operational arm responsible for the national TC forecasting and warning program, the Weather Division issued 522 public and 287 marine TC products 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 14 TCs necessitated the hoisting of Tropical Cyclone Wind Signals in 85% of the provinces or localities of the country. Cagayan Valley was the region most frequently placed under a wind signal during the year. In particular, Batanes was placed under a wind signal during nine separate TC events. TCWS No. 3 was the highest level of wind signal put into effect during the 2019 season.

Despite disaster risk reduction and management activities, the National Disaster Risk Reduction and Management Council reported that the TC events of 2019 directly and indirectly claimed the lives of 67 individuals, the lowest in terms of proportion to total casualties since 2000. Furthermore, a total of 691 injured and 19 missing persons were reported. Aggregate cost of damage across the country amounted to Php 11.270 billion, lower than the 2019 figures. This makes 2019 the fifth deadliest and fifth costliest post-Yolanda TC season in the country, as well as the 18th deadliest and 15th costliest season since 2000. Damage to agriculture (e.g., crops, livestock) constituted more than half of the total reported cost. Data since 2000 showed no notable trend in the number of casualties and deaths and a slightly increasing trend in the combined cost of damage nationwide.

The publication of the 2019 Annual Report on Philippine Tropical Cyclones was pushed to September 2021 due to the Coronavirus Disease 2019 (COVID-19) pandemic in the Philippines.



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NATIONAL TROPICAL CYCLONE FORECASTING AND WARNING PROGRAM

National Tropical Cyclone
Forecasting and Warning Program

Created by law[1] 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[2]** 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 such as tropical cyclone (TC) passages to ensure the safety, well-being, and economic security of the people, safeguard the environment, and promote national progress and sustainable development. Under prevailing laws, PAGASA shall be responsible for the national TC forecasting and warning program as the national meteorological and hydrological service (NMHS) of the Republic of the Philippines.

To ensure its effective and efficient implementation, the Weather Division, through the Marine Meteorological Services Section, shall be primarily responsible for the operational activities related to the national TC forecasting and warning program. The Marine Meteorological Services Section, through the Tropical Cyclone Group, implements the day-to-day activities related to TC operations in accordance with the quality standards of the Weather Division.

Forecast Areas

Following its mandate of affording greater protection to the people through the provision of meteorological service, PAGASA has multiple forecast areas within the Western North Pacific for the analysis and forecasting of TCs and for issuance relevant warnings whenever a TC will threaten land and sea forecast areas under PAGASA's forecast responsibility.

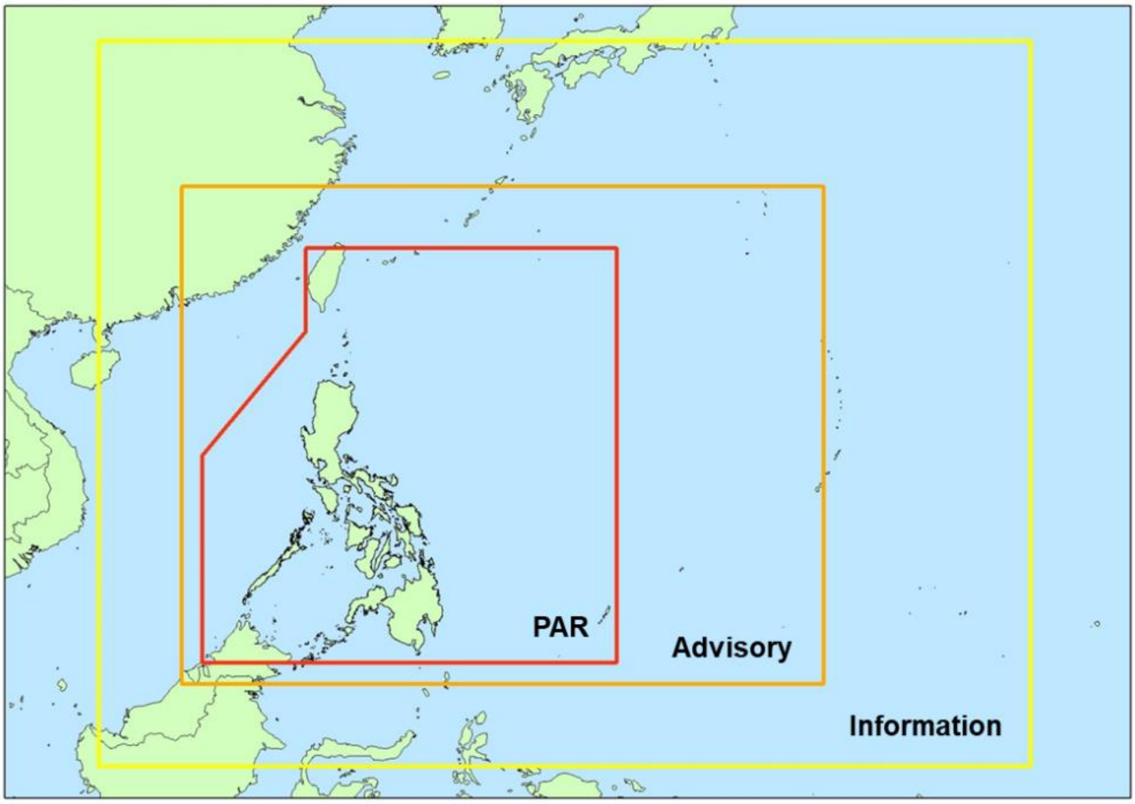

Fig. 1.1. PAGASA tropical cyclone forecast areas within the Western North Pacific basin.

[1] By virtue of Presidential Decree No. 78 s. 1972, as amended.
[2] In accordance with Republic Act No. 10692 or the PAGASA Modernization Act of 2015

Philippine Area of Responsibility

The Philippine Area of Responsibility (PAR) is the official forecast and warning area of responsibility of the Philippine state weather bureau as agreed upon with other member states of the Regional Association V of the World Meteorological Organization (WMO)[3]. As such, the PAR serves as the domain in which PAGASA has the responsibility for issuing tropical cyclone analyses, forecasts, and warnings for the public and maritime sectors. 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 the land territory of the Philippines except for the southernmost portions of Tawi-Tawi and some of the country's claims in the Kalayaan 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[4], West Philippine Sea[5], Luzon Strait, Mindanao Sea[6], Sulu Sea, and most of the Philippine Sea.

Extended Forecast Areas

In 2015, the Weather Division established the "Extended Forecast Areas" within the WNP basin that are larger in spatial extent than the existing PAR. The creation of additional forecast areas aimed to address the increasing demand from the public, disaster managers, news outlets, and other stakeholders for official information on tropical cyclones outside the PAR region. These forecast areas are referred to as the Tropical Cyclone Advisory Domain (TCAD) and the Tropical Cyclone Information Domain (TCID).

- The TCAD is defined as the region in the Western North Pacific bounded by rhumb lines connecting the coordinates 4°N 114°E, 28°N 114°E, 28°N 145°E and 4°N 145°E, excluding the region identified as the PAR.
- The TCID is defined as the region in the Western North Pacific bounded by rhumb lines connecting the coordinates 0° 110°E, 35°N 110°E, 35°N 155°E and 0°N 155°E, excluding the region identified as the PAR and TCAD.

Tropical Cyclone Identification

PAGASA identifies TCs within the PAR and the Extended Forecast Areas using an intensity-based classification scheme and a domestic naming scheme, both of which are distinct and separate from those being implemented by the Regional Specialized Meteorological Center – Tokyo Typhoon Center. This subsection discusses the identification protocols that were in effect during the 2019 Philippine TC season.

Classification of Tropical Cyclones

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 1.1 presents the classification of TCs under the current scheme and their corresponding maximum sustained winds near the center in Beaufort Force number/s, knots (nautical miles per hour), kilometers per hour, and meters per second. 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

[3] The extent of the PAR is based on Resolution 17 of the Fourth Session of WMO RA II (WMO-No. 181, 1966) and Resolution 10 of the Fourth Session of WMO RA V (WMO-No. 187, 1966).
[4] These archipelagic seas are the Sibuyan Sea, Visayan Sea, Camotes Sea, Samar Sea, and Bohol Sea.
[5] By virtue of Administrative Order No. 29 s. 2012, the West Philippine Sea is defined as the portion of the South China Sea within the exclusive economic zone (EEZ) of the Philippines. However, for ease of explanation, the entirety of the South China Sea will be referred to as the West Philippine Sea.
[6] 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.

of TC categories from three to five. The change was part of operational changes made by PAGASA following the passage of Super Typhoon Yolanda (Haiyan) in 2013.

Table 1.1 Classification of TCs used by PAGASA since May 2015

Category of TC	Maximum sustained winds near the center			
	Beaufort No.	kt	km/h	m/s
Tropical Depression (TD)	6 to 7	< 34	< 62	< 17.2
Tropical Storm (TS)	8 to 9	34 to 47	62 to 88	17.2 to 24.4
Severe Tropical Storm (STS)	10 to 11	48 to 63	89 to 117	24.5 to 32.6
Typhoon (TY)	12	64 to 120	118 to 222	32.7 to 61.7
Super Typhoon (STY)	12	> 120	> 222	> 61.7

Naming of Tropical Cyclones

Since 1963, PAGASA and its predecessor, the Philippine Weather Bureau, has been assigning domestic names to TCs of at least TD category within the PAR region, whether or not an "international" name has been assigned to the system by the Joint Typhoon Warning Center (1945-1999) or the Regional Specialized Meteorological Center (RSMC) Tokyo (since 2000). Nevertheless, the "international" name is also being used by PAGASA in all its TC products.

Guidelines for assigning domestic names

PAGASA assigns a domestic name to a TC of at least TD category that enters or develops within the PAR region. Under the naming guidelines[7] 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 local language or dialects in the Philippines.

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.

In addition, 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. As such, each set of auxiliary names is paired with a set of regular names. Auxiliary names are used in case the total number of TCs for the year exceeds 25. In such an event, 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. To date, all auxiliary names remained unused.

Decommissioning and delisting

Under the present naming guidelines, the domestic name of a TC, whether regular or auxiliary, can be removed from the operational set through the process of either decommissioning or delisting.

A TC name is decommissioned by the state weather bureau if the said TC directly caused either or both 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 or, in its absence, the last situational report issued by the National Disaster Risk Reduction and Management Council (NDRRMC). The list of approved decommissioned names and their corresponding replacements is presented to the public within the first quarter of the year following the end of the TC season.

[7] A new naming protocol was introduced in 2001 following the decision of the agency to end the old domestic naming scheme which has been in effect since 1963. The old naming scheme also has four (4) sets of regular and auxiliary names, but uses female Filipino names beginning with the letters of the Tagalog alphabet and ending with the suffix -ing.

On the other hand, a domestic name is deemed delisted when there is a necessity for the name to be replaced without meeting the criteria for decommissioning. Delisting can happen at the start or the middle of the TC season (i.e., before the name is assigned to a TC) for various reasons. In such an event, a delisted name is immediately replaced. An example of delisted name is the case of Set II's Kanor, which was delisted prior to its supposed usage in September 2014 and was immediately replaced by Karding due to negative feedback from the public because a person involved in an infamous series of sex videos with a minor at that time shares the same name ("Mang Kanor"). Another example of delisted name was the case of Set III's Nonoy in 2015, which was replaced by Nona despite the fact that the original name has already been used in three Severe Weather Bulletins. Nonoy was delisted from Set III because of its perceived similarity with the nickname of then-President Benigno Aquino III ("Noynoy").

Since the new naming scheme was introduced in 2001, PAGASA has decommissioned 44 names and delisted 38 names from its operational list.

Domestic names for the 2019 season

Table 1.2 presents the regular and auxiliary sets of names under Set III, which was the set of names used during the 2019 season. The names Liwayway, Nimfa, Perla, and Sarah were used for the first time in 2019 after the decommissioning of Lando and Nimfa in 2015 and Pedring and Sendong in 2011[8]. Tisoy and Ursula were eventually decommissioned by PAGASA after meeting the damage cost criteria.

Table 1.2. Regular and auxiliary domestic names under Set III. Names in gray and italics were unused during the season while those in bold were eventually decommissioned at the end of the season.

Regular names				
Amang	Betty	Chedeng	Dodong	Egay
Falcon	Goring	Hanna	Ineng	Jenny
Kabayan	Liwayway	Marilyn	Nimfa	Onyok
Perla	Quiel	Ramon	Sarah	**Tisoy**
Ursula	*Viring*	*Weng*	*Yoyoy*	*Zigzag*
Auxiliary names				
Abe	*Berto*	*Charo*	*Dado*	*Estoy*
Felion	*Gening*	*Herman*	*Irma*	*Jaime*

Analysis and Forecast Process

Tropical Cyclone Analysis

The routine analysis of TCs begins with the determination of the center position. The estimation of the low-level circulation center is accomplished using a combination of satellite data (geostationary, microwave, scatterometer (SCAT) wind fields), Doppler weather radar scans, and surface meteorological observations[9]. In addition, satellite fix reports from other meteorological centers and objective tools from the Cooperative Institute for Meteorological Satellite Studies (CIMSS) (Wimmers and Velden 2010, 2016) are also routinely used as reference when finalizing the center position analysis. Information on the direction and speed of movement of TCs are derived from the six-hourly displacement vectors of the center position.

The intensity of a TC in terms of maximum sustained winds and central pressure is primarily estimated from the conversion of Dvorak Final T (FT) and Current Intensity (CI) numbers, unitless parameters derived from the subjective analysis of satellite images using the Dvorak (1984) method. These values are provided operationally by the PAGASA Meteorological Satellite Facility, as well as from satellite fix reports from other meteorological centers. The conversion from CI number to maximum sustained winds

[8] Although Perla and Sarah were already listed under Set III during the 2015 season, both names were unused as the season only had 15 TCs.

[9] These observation data include reports of surface observation from fixed land stations (SYNOP or METAR), sea stations or marine vessels (SHIP), and meteorological buoys (moored or drifting; BUOY).

and central pressure is facilitated by a lookup table based on the relationship (Koba et al. 1991) between the reanalyzed (i.e., post-operational analysis) CI number and the corresponding best track intensities of WNP TCs during a six-year period in the 1980s when aircraft reconnaissance missions were still being flown by the United States in the basin. The estimates are then refined using SCAT wind fields, radial velocity analysis from Doppler weather radars, weather map analysis using available surface observations, and other objective tools from CIMSS (Olander and Velden 2007, Herndon and Velden 2018). Cyclone phase analyses (Hart 2003) are also consulted to diagnose extratropical transitions. The progression of eyewall replacement cycles (ERC) in mature typhoons and its impact on the intensity analysis is analyzed both subjectively using 85-82 GHz microwave images and objectively using ERC-relevant statistics derived from the same microwave images (Wimmers 2018)

The maximum gust is derived from the maximum sustained wind estimate using a multiplier (gust factor) that varies depending both on the exposure conditions near the center of a TC (Harper et al. 2010) and the wind averaging period of the maximum sustained winds and maximum gust. For the case of PAGASA, maximum sustained winds and maximum gust are estimated using 10-minute and 3-second averaging.

The wind field of a TC is determined by estimating the spatial extent of at least strong winds[10], gale-force winds[11], storm-force winds[12], and typhoon-force winds[13] in strength associated with the TC circulation. The extent of these TC winds is primarily estimated using the subjective analysis of SCAT wind fields, sea surface wind fields estimated from Himawari-8 low-level atmospheric motion vectors (AMV) (Nonaka et al. 2019), and weather map analysis using available surface observations. Objective wind field estimation tools (Knaff and DeMaria 2010; Knaff et al. 2016) are also being used as reference when refining the wind field analysis.

TC analysis is undertaken four (4) times daily at 00, 06, 12, and 18 UTC for all TCs situated within the PAR and the extended forecast areas. However, when a TC is forecast to make landfall or pass within 60 nmi of the Philippine coastline within 24 hours, additional analyses[14] are performed at 03, 09, 15, and 21 UTC. Moreover, as a requirement for public TC products, the center positions are also determined for the hour preceding the issuance time of the products.

Tropical Cyclone Forecast

PAGASA issues track and intensity (as category) forecasts up to 120-hours ahead, as well as the radii of probability circles at each forecast time of the track forecast. Normally[15], these forecasts are issued up to four (4) times daily with initial times of 00, 06, 12, and 18 UTC, with additional forecasts[16] provided at initial times of 03, 09, 15, and 21 UTC when a TC is forecast to make landfall or pass within 60 nmi of the Philippine coastline within 24 hours.

The primary basis for the track forecasts is the track forecast guidance from global and regional deterministic models. Both simple and selective consensus methods are used to process these model guidance products to create the track forecast. Global ensemble prediction systems from major numerical weather prediction (NWP) centers are also employed as reference to refine the track forecast. The environmental steering of the TC is also analyzed either by using hand-analyzed upper-air charts (single layer approach) or satellite AMV-derived variable deep-layer mean streamlines (Velden and Leslie 1991; Velden 1993) to serve as another reference for diagnosing the forecast near-term motion of a TC.

Intensity forecasts are primarily based on the several statistical and statistical-dynamical TC intensity guidance products. Dynamical intensity guidance from global and regional deterministic models are also used as reference when refining the intensity forecast, while cyclone phase forecast based on global deterministic models (Hart 2003) serve as primary reference for forecasting extratropical transitions. In addition, analysis of environmental parameters such as sea surface temperature, ocean

[10] "Strong winds" is defined as near-surface winds of 22 to 33 kt or Beaufort Force 6 or 7.
[11] "Gale-force winds" is defined as near-surface winds of 34 to 47 kt or Beaufort Force 8 or 9.
[12] "Storm-force winds" is defined as near-surface winds of 48 to 63 kt or Beaufort Force 10 or 11.
[13] "Typhoon-force winds" is defined as near surface winds of at least 64 kt or Beaufort Force 12.
[14] Additional analyses are terminated once the TC has left the 60-nmi coastal buffer.
[15] The frequency of the forecasts depends on the public or marine TC product being issued.
[16] Additional forecasts are terminated once the TC has left the 60-nmi coastal buffer.

heat content, vertical wind shear, and outflow characteristics along the forecast track are also considered. For near term intensity change of mature typhoons related to ERCs, a predictive model of ERC initiation based on the objectively-derived ERC-relevant eyewall statistics is also used (Wimmers 2018).

The track forecast issued by PAGASA incorporates the probability circles at each forecast time. The probability circle shows the range into which the TC center is forecast to move with 70% probability at each forecast time. The radii of these circles are statistically determined based on the result of the most recent five (5)-year track forecast verification.

Tropical Cyclone Product Description

Depending on the location of the TC within the monitoring domains and the threat posed by the TC to localities, the Weather Division issues different TC products to the public, disaster managers, national government agencies, local government units, and other specialized end users. This section presents the description of public and marine TC products issued by the Weather Division as of the 2019 season.

While PAGASA also provides aviation TC products in the form of WC SIGMET[17] when a TC of at least TS category enters the Manila Flight Information Region[18], these are not covered by this section or any section of this ARTC.

Tropical Cyclone Update

Although not a standalone product, the Tropical Cyclone Update (TCU) is a plain text message in the 24-Hour Public Weather Forecast that provides key updates on the location, intensity, and movement of all tropical cyclones of at least TD category within any of the TC forecast areas. The TCU includes the following elements in analysis:

Analysis	Center position Direction and speed of movement Maximum sustained winds Maximum gust

The 24-Hour Public Weather Forecast, where TCUs are incorporated, is issued twice daily at 4:00 AM PHT and 4:00 PM PHT.

Tropical Cyclone Advisory

The Tropical Cyclone Advisory (TCA) is a plain text product that provides information on the analysis, forecast, and warning for a TC of at least TD category is inside the TCAD that is projected to enter the PAR within 120 hours. The TCA incorporates the following elements in the analysis and forecast:

Analysis	Center position Direction and speed of movement Maximum sustained winds Maximum gust
24-, 48-, 72-, 96- and 120-h forecasts	Center position Intensity (as category)

[17] A SIGMET provides concise information issued by the Meteorological Watch Office of a particular FIR (i.e., PAGASA for Manila FIR) concerning the occurrence or expected occurrence of specific en-route weather and other atmospheric phenomena that may affect the safety of aircraft operations. The WC SIGMET is the specific SIGMET for TC of at least TS category.

[18] An FIR is a specified region of airspace in which a flight information service and an alerting service are provided. These services provide information pertinent to the safe and efficient conduct of flights and alerting the different relevant authorities should an aircraft be in distress.

In addition, TCA may include any warning and non-warning information relevant to the subject TC such as the list of areas where tropical cyclone wind signals will be first hoisted, general statement of hazards which may affect land areas and coastal waters, and date and time of forecast entry to the PAR region.

TCAs are normally[19] issued once daily at 11:00 AM PHT.

Severe Weather Bulletins

The Severe Weather Bulletin (SWB) is a plain text product that provides information on the analysis, forecast, and warning for a TC that is either within the PAR (irrespective of threat to land areas) or still outside the PAR but the forecast scenario already necessitates the hoisting of tropical cyclone wind signals over land areas. The SWB contains the following elements in the analysis and forecast:

Analysis	Center position Direction and speed of movement Maximum sustained winds Maximum gust
24-, 48-, 72-, 96- and 120-h forecasts	Center position Intensity (as category)

SWBs may include warning information such as the list of areas where wind signals are or will be in effect, forecast hazards that will affect land areas and coastal waters (i.e., heavy rainfall, severe winds, storm surge, high waves), landfall information, as well as non-warning information relevant to the TC such as expected date and time the TC will exit the PAR. In cases when a TC is at TY or STY category, the SWB may also include a warning statement related to areas presented affected and that will be affected in the next 3 hours by the violent conditions within the eyewall.

If no wind signals are in effect, SWBs are normally[20] 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 signals are in effect and the TC is forecast to make landfall or pass within 60 nmi of the Philippine coastline within 24 hours, additional issuances are also made at 2:00 AM PHT, 8:00 AM PHT, 2:00 PM PHT, and 8:00 PM PHT. The additional issuances shall cease to apply once the TC has left the 60-nmi coastal buffer.

Tropical Cyclone Warning for Shipping

A Tropical Cyclone Warning for Shipping or International Warning for Shipping (IWS) is a plain text product for marine vessels at sea that provides information on the analysis and forecast for a TC within the PAR that may pose threat to safety of maritime traffic. The provision of IWS shall be in accordance with the Worldwide Met-Ocean Information and Warning Service[21] mandatory requirement for the provision of warnings for weather systems that produce average wind speeds of 34 kt and greater. The IWS incorporates the following elements in the analysis and forecast:

Analysis	Center position Direction and speed of movement Maximum sustained winds Maximum gust Central pressure Extent of strong, storm-force, and typhoon-force winds
24-, 48-, 72-, 96- and 120-h forecasts	Center position Category

[19] The initial or final TCA may be issued at 5:00 AM, 11:00 AM, 5:00 PM, or 11:00 PM PHT.
[20] The initial or final SWB may be issued 5:00 AM, 11:00 AM, 5:00 PM, or 11:00 PM PHT.
[21] The WWMIWS is an internationally coordinated service established by the International Maritime Organization and the World Meteorological Organization for the promulgation of meteorological warnings and forecasts for the high seas, coastal waters, offshore waters, and local waters.

In addition, IWS also contains a request to all marine vessels within the vicinity of the TC circulation to transmit shipborne meteorological observations every three (3) hours.

IWSs are normally[22] issued four (4) times daily at 5:00 AM PHT, 11:00 AM PHT, 5:00 PM PHT, and 11:00 PM PHT.

Tropical Cyclone Wind Signal System

The Tropical Cyclone Wind Signal (TCWS) System is a five (5)-tier wind warning scheme used 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 analysis, and track forecast of the TC. Table 1.2 presents the wind signals of the TCWS system, the surface wind conditions associated with each wind signal, the general classification of potential damage, and the associated color code of each wind signal when presented on maps.

Table 1.2. Tropical Cyclone Wind Signal System

TCWS		Surface wind conditions and general description of potential damage
	Signal No. 1	Strong winds which may cause up to very light damage is prevailing or expected to prevail within 36 hours from the time the signal was raised
	Signal No. 2	Damaging gale- to storm-force winds[23] which may cause light to moderate damage is prevailing or expected to prevail within 24 hours from the time the signal was raised
	Signal No. 3	Destructive [24] typhoon force winds which may cause moderate to heavy damage is prevailing or expected to prevail within 18 hours from the time the signal was raised.
	Signal No. 4	Very destructive[25] typhoon force winds which may cause heavy to very heavy damage is prevailing or expected to prevail within 12 hours from the time the signal was raised.
	Signal No. 5	Devastating[26] typhoon force winds which may cause very heavy to widespread damage is prevailing or expected to prevail within 12 hours from the time the signal was raised.

The definition presented in Table 1.3 includes description of potential damage that can be sustained based on the prevailing wind conditions at each wind signal. To ensure consistent interpretation, the general classification of damage presented in Table 1.3 are defined below:

- Very light damage: Less than 5% of high-risk (HR) structures (and no damage to medium-risk (MR) and low-risk (LR) structures
- Light damage: 10% HR, 5% MR, and 0% LR
- Moderate damage: 25% HR, 10% MR, and 5% LR
- Heavy damage: 50% HR, 25% MR, and 10% LR
- Very Heavy damage: 80% HR, 50% MR, and 25% LR
- Widespread damage: Nearly 100% HR; more than 80% MR; more than 50% LR.

Moreover, the following definitions are used for the terms high-risk, medium-risk, and low-risk structures:

- High-risk structures: consist of old and densely built-up residential areas having light material structures and organic roof materials, squatter/slum areas, zone of mixed development, poor quality housing, warehouses, and old, dilapidated structures.

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[22] The initial (final) IWS is done in conjunction with the issuance of the initial (final) SWB.
[23] If the TC is still at TS category, the statement for TCWS #2 changes from "Damaging gale- to storm-force winds…" to "Damaging gale-force winds…"
[24] Typhoon-force winds of up to 170 km/h.
[25] Typhoon-force winds of more than 170 km/h but not exceeding 220 km/h.
[26] Typhoon-force winds in excess of 220 km/h.

- Medium-risk structures: consist of older parts of city/town centers, timber structures/galvanized iron roofs and generally belong to the middle-income group.
- Low-risk structures: consist of concrete/framed structures, low-density population/housing, and usually the modern part of the city/town.

Although a general description of damage per wind signal is presented in Table 1.2, a more detailed description of potential damage to structures and vegetations resulting from the surface wind conditions associated with each wind signal are presented in Table 1.3.

Table 1.3. Potential damage to structures and vegetation associated with the surface wind conditions at each wind signal level.

Wind Signal	Damage to structures	Damage to vegetation
TCWS #1	• Very light or no damage to low-risk structures. • Light damage to medium- to high-risk structures • Slight damage to some houses of very light materials or makeshift structures in exposed communities.	• Some banana plants are tilted, a few downed and leaves are generally damaged. • Twigs of small trees may be broken. • Rice crops, however, may suffer significant damage when it is in its flowering stage.
TCWS #2	• Light to moderate damage to high-risk structures. • Very light to light damage to medium-risk structures. • No damage to very light damage to low-risk structures. • Unshielded, old, dilapidated schoolhouses, makeshift shanties, and other structures of light materials are partially damaged or unroofed. • A number of nipa and cogon houses may be partially or totally unroofed. • Some old, galvanized iron (G.I.) roofs may be peeled or blown off. • Some wooden, old electric posts are tilted or downed. • Some damage to poorly constructed signs/billboards. • In general, the winds may bring light to moderate damage to the exposed communities.	• Most banana plants, a few mango trees, ipil-ipil, and similar types of trees are downed or broken. • Some coconut trees may be tilted with few others broken. • Rice and corn may be adversely affected. • Considerable damage to shrubbery and trees with some heavy-foliaged trees blown down.

TCWS #3	• Heavy damage to high–risk structures. • Moderate damage to medium-risk structures. • Light damage to low-risk structures. • Increasing damage (up to more than 50%) to old, dilapidated residential structures and houses of light materials. Majority of all nipa and cogon houses may be unroofed or destroyed. • Houses of medium strength materials (old, timber, or mixed timber-CHB structures, usually with G.I. roofing's) and some warehouses or bodega-type structures are unroofed. • There may be widespread disruption of electrical power and communication services.	• 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. • Rice and corn crops may suffer heavy losses. • Damage to shrubbery and trees with foliage blown off; some large trees blown down.
TCWS #4	• Very heavy damage to high–risk structures. • Heavy damage to medium-risk structures. • Moderate damage to low-risk structures. • Considerable damage to structures of light materials (up to 75% are totally and partially destroyed) with complete failure of roof structures. • Many houses of medium-built materials are unroofed with extensive damage to doors and windows; some with collapsed walls. • A few houses of first-class materials are partially damaged. • All signs/billboards are blown down.	• There is almost total damage to banana plantation. • Most mango trees, ipil-ipil, and similar types of large trees are downed or broken. • Coconut plantation may suffer extensive damage. • Rice and corn plantation may suffer severe losses.
TCWS #5	• Widespread damage to high-risk structures. • Heavy damage to medium risk structures. • Very heavy damage to low-risk structures. • Electrical power distribution and communication services severely disrupted. • All signs/billboards blown down.	• Total damage to banana plantation. • Most tall trees are broken, uprooted, or defoliated. • Coconut trees are stooped, broken or uprooted. • Few plants and trees survived.

Owing to the presence of natural and artificial obstructions such as local topography or nearby buildings, winds in a particular area (local winds) may be substantially stronger from the general wind strength (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 (e.g., 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.

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. Now, 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, wind signals may be raised on a sub-provincial level. In such instances, the municipalities or cities are identified accordingly.

Product Dissemination

For Public Tropical Cyclone Products

During TC occurrences, especially those that will trigger high impact weather in the country, ensuring the effective and efficient dissemination of public TC products to end users is the shared responsibility of the Weather Division and the Regional Services Divisions. As such, public TC products are disseminated using both digital and paper-based platforms which include facsimile, electronic mail (email), short messaging service (SMS), official website, and social network services in accordance with domestic requirements and quality standards. Moreover, the Weather Division continuously communicates with the NDRRMC to ensure timely dissemination of abbreviated versions of public TC products to the public through the Emergency Cell Broadcast System (ECBS)[27].

For Marine Tropical Cyclone Products

The rapid, efficient, and effective dissemination of meteorological maritime safety information (MSI) to mariners of vessels in the offshore waters under PAGASA's forecast responsibility to ensure the safety of lives at sea is the shared responsibility of PAGASA and the designated authorities or centers for the broadcast of MSIs. As such, constant coordination with these authorities or centers is in place to ensure that marine TC products are broadcasted through the applicable communication platforms of the Global Maritime Distress Safety System (GMDSS) (e.g., SafetyNET EGC satellite communications, DSC, HF NBDP, and NAVTEX) including schedules broadcast of coastal radio stations situated in the Philippines. The dissemination of meteorological MSIs is in accordance with all prevailing maritime legal instruments, convections, and/or protocols to which the Philippines is a State Party.

Apart from GMDSS communications platforms, marine TC products are also available for distribution through the digital and paper-based platforms in use for the dissemination of public TC products, as well as through the WMO Global Telecommunications System as part of regional exchange of TC forecast and warning information. GTS-based dissemination of the IWS uses the abbreviated headings WTPH20 RPMM, WTPH21 RPMM, and WTPH22 RPMM.

Expert Advice and Briefings

Apart from the distribution of public and marine TC products through multiple digital and paper-based dissemination platforms, PAGASA performs expert advice and briefing activities to various end users and stakeholders using traditional and emerging media platforms to ensure that their preparation, mitigation, and adaptation measures undertaken by the public, disaster managers, government agencies and institutions, and specialized sectors during TC events are data-driven and evidence based.

PAGASA meteorologists at the national and local levels undertake regular public briefings and press conferences at regular intervals[28]. These are broadcasted via television, radio, and the internet via the

[27] The ECBS is an alert broadcast system in the Philippines designed to disseminate emergency alerts and warning to mobile devices via cell broadcast system. This system is being implemented by the NDRMMC and all telecommunications companies in the country in accordance with Republic Act No. 10639 (Free Mobile Disaster Alerts Act).

[28] Regular public briefings during TC days are typically within 30 minutes of the issuance of SWBs (except during additional issuances of SWBs). However, special public briefings may be held during issuances of TCAs or when a significant change in the forecast scenario is present.

official website, social network services, and video streaming/sharing platforms. In addition, duty forecasters answer to interview requests[29] from news outlets and phone queries from the public.

To support risk-informed, evidence-based decision making of the national government and local government units ahead of an impending TC passage, 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. For the private sector, 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 cause significant disruption to their business activities.

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[29] These interviews may be on camera, through phone patch, or using a video conferencing platform.

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POST-SEASON ANALYSIS OF PHILIPPINE TROPICAL CYCLONES

Best Track Analysis of Philippine Tropical Cyclones

Best Track Analysis: A Forensic-like Investigation

The determination of analysis parameters such as center position, intensity, and motion of a tropical cyclone (TC) valid at a given synoptic time uses meteorological observation data from a wide array of platforms and formats and with varying degrees of observation latency[30]. However, in an operational environment, the rigid time schedule of each forecast cycle[31] adds not only the element of time pressure to the conduct of TC analysis but also limits the amount and type of observation data that can be considered to those with relatively low latency. As such, the duty forecaster's exercise of professional judgment within time constraints based on the observation data that was available at that time heavily influences the determination of the analysis parameters in an operational setting. The best estimates of these parameters are referred to as an "operational track" and may incorporate (although minimized) short-term motions, especially when analysis parameters are estimated at three (3)-hour intervals, which may be unrepresentative of the overall motion of the TC.

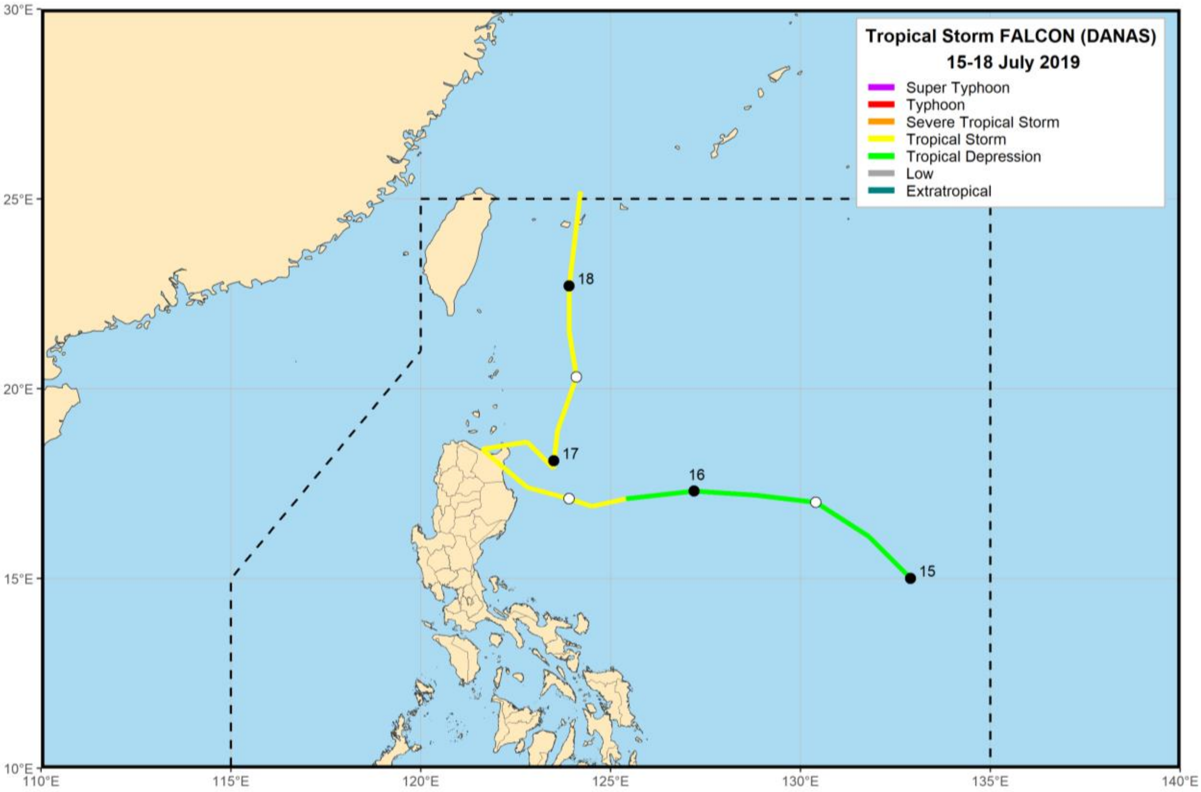
After the passage of the TC and the termination of operational activities, the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) collects all conventional and unconventional observation data not only from the Agency's domestic observation network but also those from other meteorological centers in the Western North Pacific (WNP) basin, including those that were not available to forecasters in both real and near real-time. Afterwards, the operational track is reviewed by performing a forensic-like analysis, which involves the re-construction of the motion and intensity change of TC throughout its lifespan using all the collected meteorological data and without the tight time constraints of the operational environment. This procedure is called a "best track analysis" and the final product of this investigation satisfies the basic components of the accepted definition[32] of "best track":

> *"A subjectively-smoothed representation of the motion and intensity change of a TC over its lifetime. The best track of a TC contains the latitude and longitude of the center position and the intensity in terms of maximum sustained winds[33] and central pressure at intervals of three (3) or six (6) hours. Best track positions and intensities, which are based on a post-event assessment of all collected meteorological data, may differ from values contained in operational advisories or bulletin and will also generally will not reflect any short-term erratic motion."*

A fundamental component of this definition that differentiates operational track from a best track is that the latter provides three (3)- or six (6)-hourly representative estimates of the TC center position. Plotted center fixes derived from observation data often reveal a series of irregular movements, such include trochoidal motion or other wobbles, which do not generally persist for more than a few hours. These are unrepresentative of the overall TC motion and a subjectively-smoothed "best track" that does not focus on these short-period transient motions is ideal.

The subjective smoothing procedure means that center positions in the operational track may be re-positioned" in the best track and from a sampling perspective, this re-positioning is part of a filtering procedure that is administered to avoid aliasing small-scale noise. For a given time series with data points ΔT apart, the smallest wavelength which can be depicted accurately the series is about 4 x ΔT. Since the TC analysis times of PAGASA are at least three (3) hours apart, the smallest periods which can be adequately represented are on the order of 12 hours. Thus, the typhoon forecaster in charge of best track analysis might try to avoid analyzing oscillations with a period less than 12 hours.

[30] Latency is the amount of time between the time of an observation and the time that the observation becomes available to forecasters in a form that they can assess and analyze.
[31] The forecast cycle is the 3-hour period beginning with a synoptic time (usually 00, 06, 12, and 18 UTC) where the (1) gathering, processing, and displaying of meteorological observation and forecast guidance, (2) determination of analysis information, (3) the formulation of forecast policy, and (4) preparation and issuance of relevant TC products and briefing materials are accomplished.
[32] PAGASA adopted the definition of "best track" from the National Hurricane Center.
[33] Both operational and best track intensities are estimated at 10-minute averaging periods.



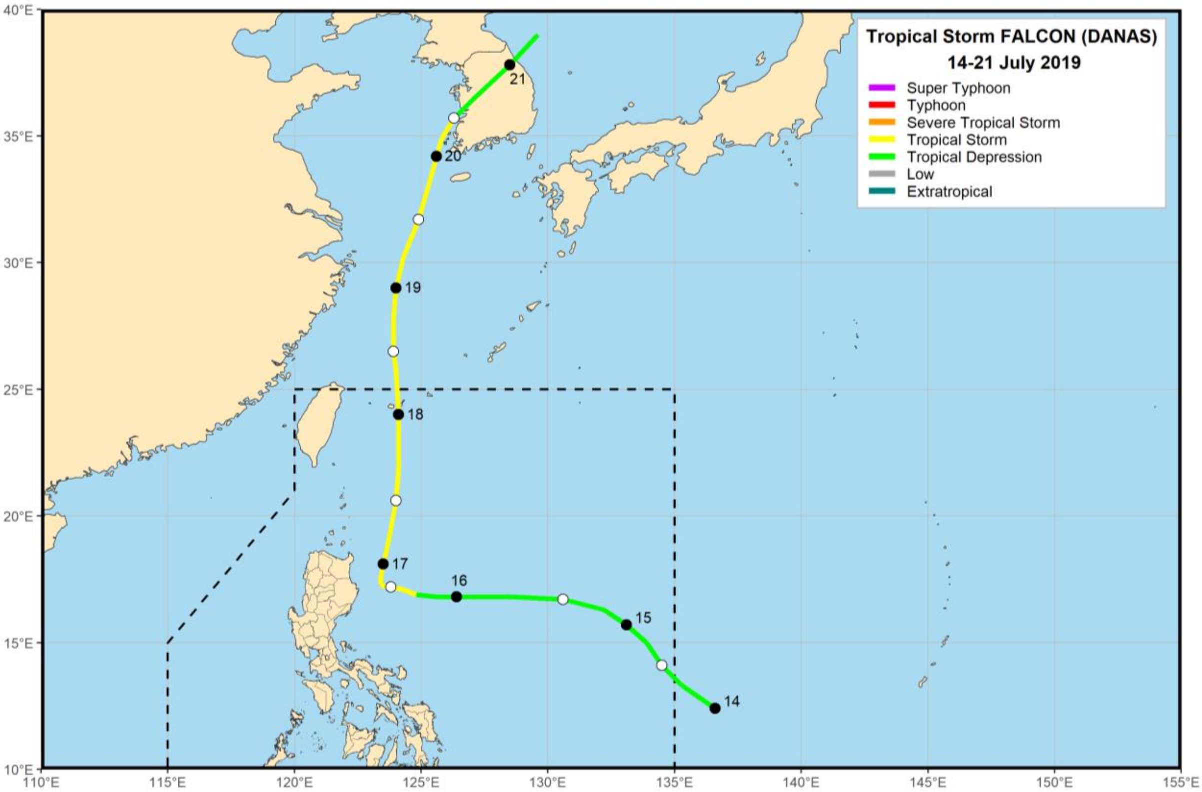


Fig 2.1. Operational (top) and best (bottom) track positions and intensities (as categories) of Tropical Storm Falcon (Danas). Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Best track analysis also allows the typhoon forecaster to adjust analysis parameters post real-time when, even in the absence of short-period transient motions, the re-constructed motion and intensity change of the TC based on all collected observation data do not agree with the values in the operational track. To better explain this, Fig. 2.1 shows both the operational and best track position and intensities of Tropical Storm Falcon (Danas) – one of the TCs of the 2019 season whose best track was strikingly different from its operational track. Although the operational and best tracks show similar motion in the initial and later phases of its existence within the PAR region, Fig. 2.1, clearly shows two clear differences that significantly changes the narrative of the storm:

- Tropical Storm Falcon developed into a tropical depression outside the PAR instead of inside it and much earlier than what the operational track shows. Moreover, the timing of intensification into a tropical storm was slightly later in the best track compared to its operational track counterpart.
- Best track analysis revealed that the storm did not make landfall over Cagayan Province during the late evening hours (local time) of 16 July 2019 compared to what was reported in the operational analysis. The analysis revealed the development of a remote low to the west of northern Luzon as Falcon's circulation neared Cagayan-Isabela area and interacted with the rugged northern Luzon landmass. Such finding was revealed by the use several meteorological data that were not available in a timely manner during the operational analysis.

Through best track analysis, important statistics of the season (e.g., number of landfalling TCs for the year or month and the number TCs that developed within or outside the PAR) or individual TCs (e.g., actual storm duration, peak intensity, landfall point and time), can be updated accordingly.

While best track serves as the best available representation of the synoptic-scale development and movement of TCs, these are by no means perfect. In fact, best tracks could be revised or refined in the future to incorporate meteorological data that were not available during the initial post-season best track analysis, as well as other latest information and research results.

Annual Report on Philippine Tropical Cyclones

The typhoon forecasters of the Marine Meteorological Services Section, 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 that were domestically named by PAGASA during the season based on the information provided by the post-season best track analysis. Also included are the operational activities of PAGASA during the TC season and the summary of post-season verification of official forecasts against the best track data.

The first issue of an annual report of this kind was "Tropical Cyclones of 1948", published by the Climatological Division under the direction of Dr. Casimiro del Rosario, then-Director of the post-war Weather Bureau. The publication of this yearly compendium of best track information of each Philippine TC continued for decades and was eventually taken over by PAGASA (then under the Ministry of National Defense) when it was formed in 1972 after the Weather Bureau was abolished. In the 1980s, the report series was renamed as the "Annual Tropical Cyclone Report" (ATCR), with its first issue covering the TC season of 1977. The publication of the ATCR was transferred from the Climatological Division to the Tropical Cyclone Division (TCD) of the National Weather Office (NWO).

The new series continued even after PAGASA was transferred to the National Science and Technology Authority (now the Department of Science and Technology) in 1984. However, with the dissolution of the Tropical Cyclone Division and the downsizing of the Weather Branch (WB; the successor to the NOW) in the succeeding years, the new publishing unit of the ARTC lacked the dedicated manpower to continue the best track analysis and the generation of these reports. In the early 1990s, the WB terminated both the best track analysis and the publication of the ARTC. The final issue of the ARTC covered the 1991 TC season.

In March 2019, following creation of an ad-hoc unit of typhoon forecasters within the Weather Division (successor to the WB), the publication of a TC report resumed with the release of the first issue of the "Annual Report on Philippine Tropical Cyclones" (ARTC) as an attempt to revitalize the TC-related services of PAGASA. Covering the TC season of 2017, the first ARTC based its contents on the operational track as the Weather Division was still in the process of finalizing its updated procedures for the best track analysis. The first best track dataset in more than 25 years was released by the Weather Division in June 2020 as part of the 2018 ARTC.

The present format of the ARTC has the following information which may be of interest to the public and various specialized end users such as operational forecasters from PAGASA and other meteorological centers, researchers, and disaster managers:

- Chapter 1 provides a discussion on the operational aspect of the National Tropical Cyclone Forecasting and Warning Program of PAGASA.
- Chapter 2 focuses on the rationale of best track analysis and the overview of the ARTC and its predecessor publications
- Chapter 3 provides the overview and statistical analysis for the entire TC season.
- Chapter 4 contains the narrative review of individual TC occurrences during the season.
- Chapter 5 features case study or studies related to the season, which may focus on specific TC event/s or TC-associated high-impact weather event in the country.
- Chapter 6 presents the tabular version of the best track positions and intensities for all TCs presented in Chapter 4.

The ARTC is available in both print (ISSN 2672-3190) and digital (ISSN 2799-0575) versions.

OVERVIEW AND STATISTICS OF THE 2019 PHILIPPINE TROPICAL CYCLONE SEASON

Overview and Statistics of the 2019 Philippine Tropical Cyclone Season

General Statistics

A total of 21 tropical cyclones (TCs) were observed within the Philippine Area of Responsibility (PAR) during the 2019 season (Fig. 3.1). This is near normal[34] when compared to the 1981-2010 normal of 18.8 ± 4.6 (Fig 3.2). Twelve of the 21 TCs in 2019 developed from areas of low pressure situated within the PAR, most of which were over the Philippine Sea area east of 127E. Meanwhile, of the nine that developed outside the PAR, four originated from the Philippine Sea, four from the Western North Pacific (WNP) near or in the vicinity of the Caroline Islands[35], and one over the West Philippine Sea. Of these 21 TCs, 13 eventually degenerated into remnant lows, while the rest transitioned into extratropical cyclones at the end of their tropical lifespan.

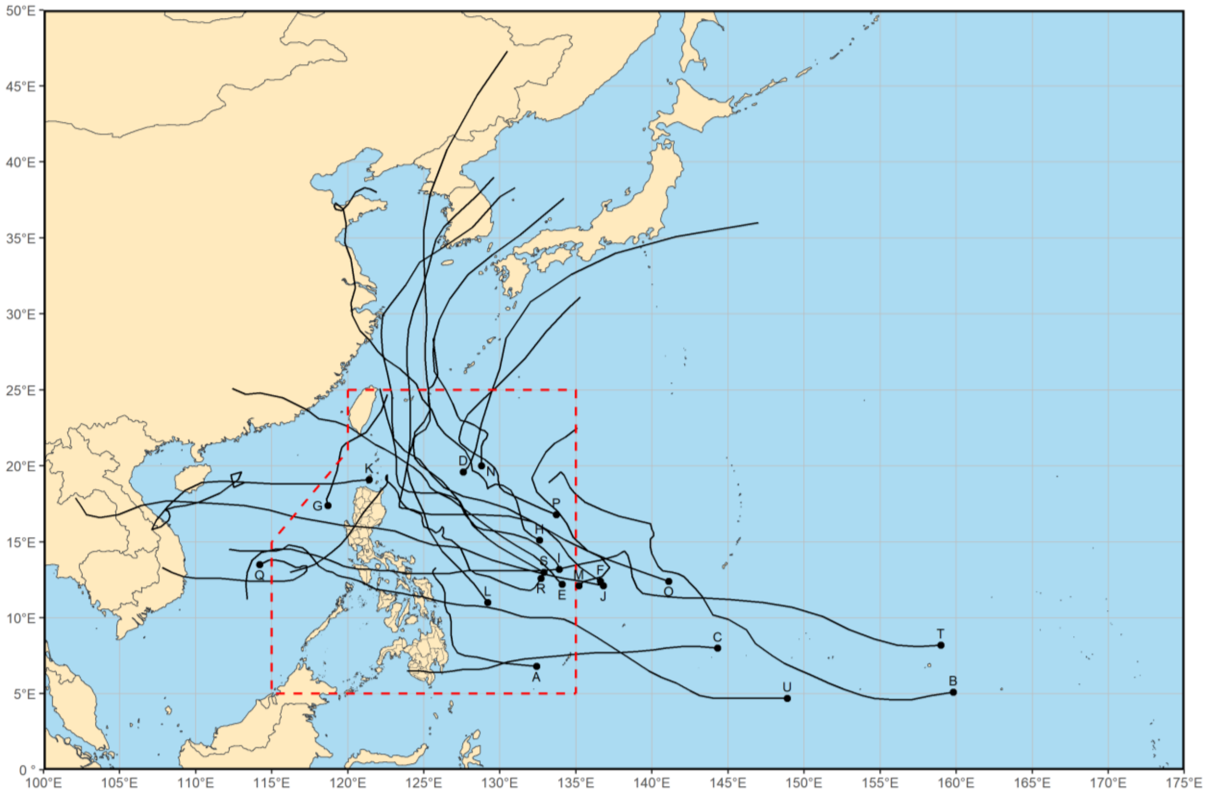


Fig. 3.1. PAGASA best track of TCs that entered or developed within the PAR in 2019. The filled circles in the tracks are the genesis points or locations where the TC was first noted as a tropical depression. The tracks are identified using the first letter of the domestic names of the TCs. The red dash line marks the limits of the PAR.

Fig 3.1 shows that roughly 62% of the TCs that entered the PAR in 2019 had tracks that were generally southeast-northwest oriented over the Philippine Sea. Except for 1, these TC events either made landfall in East Asia (e.g., China, Taiwan, Japan, Korea) or followed generally recurving paths that are far from any landmass. For the 2019 season, the Philippine Sea area north of 15°N and east of 122°E was the most frequented region by TCs within the PAR. The country also witnessed six landfalling TCs, most of which occurred during the last quarter of the season. While lower than the annual average, the number of landfalling TCs during the 2019 season was near normal when compared to the 1981-2010 baseline (Fig. 3.2). Five of the six landfalling TCs had a generally westward-moving path.

[34] 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.
[35] The Federated States of Micronesia and Palau comprise the Caroline Islands.

Table 3.1 lists down the duration of each 2019 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 2019 had an average lifespan[36] of 6 days and 11.7hours. TC Tisoy was the longest-lasting TC of the season with a basin-wide duration of 11 days and 12 hours. Lasting only 2 days and 18 hours, TC Amang had the shortest lifespan of the 2019 TCs. In terms of the duration within the PAR, the 2019 Philippine TC season logged a total of 78 days and 15 hours with an average TC duration of 3 days and 17.9 hours. Ramon and Kabayan were the longest-lasting and shortest-lasting TCs within the PAR during the 2019 season, respectively. Ramon took 9 days and 18 hours due to two periods of erratic, slow movement over the Philippine Sea east of Luzon Sea while Kabayan only took 13 hours because the area where it developed (Babuyan Islands) was near the northwestern limit of the PAR region

During their lifespans, ten of the 21 TCs peaked at typhoon (TY) category while six reached tropical storm (TS) or severe tropical storm (STS) category. For this season, no TC that entered or developed within the PAR reached the STY category at any point during its lifespan within the Western North Pacific (WNP) basin. Table 3.1 shows that TCs Betty and Hanna were the strongest TCs to occur within the PAR region during the 2019 season, reaching a peak intensity of 105 kt and 925 hPa. On the other hand, TC Egay was the weakest of the 21 TCs with a peak intensity of only 25 kt and 1002 hPa. A third of the TCs during the season reached their peak intensities while outside the PAR. Table 3.2 shows that in terms of peak intensity within the PAR, eight of the 21 TCs reached TY category, while 8 remained at TD category. Fig 3.2 shows that the number of TCs that remained a TD while inside the PAR was above normal. While lower than the 30-year average, the number of TCs that peaked at TS/STS and TY category while inside the PAR was within the normal range of values.

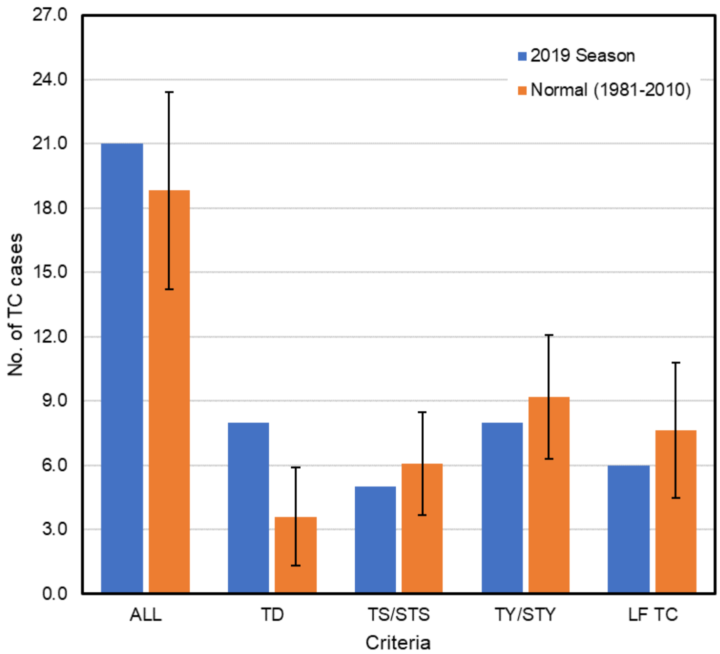


Fig. 3.2. The total number of TCs the occurred within the PAR (ALL), those that peaked at TD, TS/STS, and TY/STY categories within the PAR, and those that made landfall over the Philippine landmass (LF TC) during the 2019 season (blue bar) compared within the 1981-2010 normal (orange bar). The error bars indicate ±1 standard deviation from the normal value.

[36] Lifespan is defined as the duration beginning with the synoptic time where the TC was first noted as TD and ending with the synoptic time when the TC either degenerated into a remnant low or transitioned into extratropical cyclone (without re-developing or re-transitioning into a TC at a later point).

Table 3.1. Key meteorological information of the TCs that occurred within the PAR in 2019.

Domestic Name	International Name	Basin-wide tropical lifespan* (UTC)	Basin-wide peak intensity		
			Central Pressure (hPa)	Maximum Winds (kt)	Date and time of occurrence* (UTC)
Amang	*Unnamed*	01/19 06 to 01/22 00	1004	30	01/21 03
Betty	Wutip (1902)	02/19 00 to 03/02 06	925	105	02/23 12
Chedeng	*Unnamed*	03/15 00 to 03/19 06	1004	30	03/15 18
Dodong	Sepat (1903)	06/25 06 to 06/28 06	994	40	06/28 00
Egay	*Unnamed*	06/28 00 to 07/02 00	1002	25	06/30 18
Falcon	Danas (1905)	07/14 00 to 07/21 06	985	45	07/18 12
Goring	*Unnamed*	07/17 06 to 07/19 12	994	30	07/18 00
Hanna	Lekima (1909)	08/03 06 to 08/14 00	925	105	08/08 12
Ineng	Bailu (1911)	08/19 18 to 08/26 00	980	55	08/23 12
Jenny	Podul (1912)	08/25 06 to 08/31 00	992	40	08/28 18
Kabayan	Kajiki (1914)	08/31 06 to 09/06 12	996	35	09/02 12
Liwayway	Lingling (1913)	09/01 00 to 09/08 00	940	95	09/05 06
Marilyn	*Unnamed*	09/10 06 to 09/14 12	994	25	09/14 06
Nimfa	Tapah (1917)	09/17 00 to 09/23 00	970	65	09/21 00
Onyok	Mitag (1918)	09/26 18 to 10/03 06	965	75	09/30 06
Perla	Neoguri (1920)	10/15 18 to 10/21 12	970	75	10/19 18
Quiel	Nakri (1924)	11/04 12 to 11/11 06	975	65	11/08 06
Ramon	Kalmaegi (1926)	11/11 18 to 11/21 12	975	70	11/18 15
Sarah	Fung-wong (1927)	11/19 00 to 11/23 18	990	55	11/21 00
Tisoy	Kammuri (1928)	11/24 12 to 12/06 00	945	95	12/02 12
Ursula	Phanfone (1929)	12/20 00 to 12/28 18	970	80	12/24 09

* Provided as MM/DD HH.

Table 3.2. Periods of occurrence within the PAR and the number of public and marine TC products issued during each of the 21 TCs of 2019 season.

Domestic Name	International Name	Period within the PAR		Peak category within the PAR	Landfall
		Inclusive dates and times MM/DD HH (UTC)	Duration		
Amang	*Unnamed*	01/19 06 to 01/22 00	2d 18h	TD	No
Betty	Wutip (1902)	02/28 12 to 03/02 06	1d 18h	TD	No
Chedeng	*Unnamed*	03/17 00 to 03/19 06	2d 6h	TD	Yes
Dodong	Sepat (1903)	06/25 06 to 06/26 14	1d 16h	TD	No
Egay	*Unnamed*	06/28 00 to 07/02 00	4d 0h	TD	No
Falcon	Danas (1905)	07/14 08 to 07/18 04	3d 20h	TS	No
Goring	*Unnamed*	07/17 06 to 07/19 12	3d 6h	TD	No
Hanna	Lekima (1909)	08/03 06 to 08/08 16	5d 10h	TY	No
Ineng	Bailu (1911)	08/19 18 to 08/24 10	4d 16h	STS	No
Jenny	Podul (1912)	08/25 14 to 08/28 06	2d 16h	TS	Yes
Kabayan	Kajiki (1914)	08/31 06 to 08/31 19	0d 13h	TD	Yes
Liwayway	Lingling (1913)	09/01 00 to 09/05 08	4d 8h	TY	No
Marilyn	*Unnamed*	09/11 17 to 09/14 12	2d 19h	TD	No
Nimfa	Tapah (1917)	09/17 00 to 09/20 18	3d 18h	STS	No
Onyok	Mitag (1918)	09/27 16 to 09/30 14	2d 22h	TY	No
Perla	Neoguri (1920)	10/15 18 to 10/20 10	4d 16h	TY	No
Quiel	Nakri (1924)	11/05 03 to 11/09 02	3d 23h	TY	No
Ramon	Kalmaegi (1926)	11/11 18 to 11/21 12	9d 18h	TY	Yes
Sarah	Fung-wong (1927)	11/19 00 to 11/22 18	3d 18h	STS	No
Tisoy	Kammuri (1928)	11/30 05 to 12/04 20	4d 15h	TY	Yes
Ursula	Phanfone (1929)	12/22 18 to 12/28 01	5d 7h	TY	Yes

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 as TD, TS/ STS, and TY/STY within the PAR, and the number of TC cases making and not making landfall in the Philippines since 1981. It was observed that the number of TC occurrences within the PAR has been slightly decreasing. While changes in the number of TCs peaking at TD category has been very minimal, those 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 notably decreasing. This means that for the past 38 years, the highest intensities reached by the TCs while inside the PAR have been decreasing. 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. These trends remain consistent with those of Cinco et al. (2016).

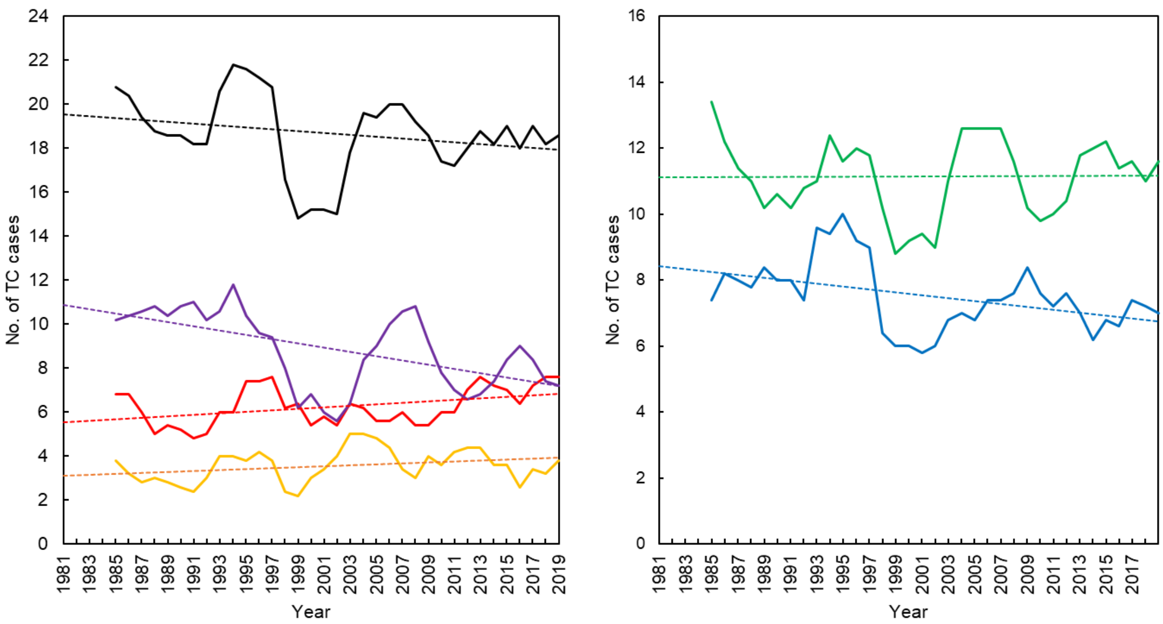


Fig. 3.3. Five-year running mean (solid lines) and corresponding linear trend (dash line) since 1981: Total TC cases within the PAR (gray), TCs peaking at TD (yellow), TS/STS (red), and TY/STY (violet) within the PAR, landfalling TCs (blue), and non-landfalling TCs (green).

Quarterly and Monthly Tropical Cyclone Activity

To make better sense of the TC activity that was witnessed by the PAR region during the 2019 season, Fig 3.4 presents the best tracks of 2019 TCs aggregated according to quarters based on their first day of occurrence within the PAR. The number of TC events per month[37] within the PAR during the season compared with the 1981-2010 normal is presented in Fig. 3.5.

PAGASA witnessed the occurrence of three TCs within its area of responsibility during the first quarter (January to March) of the 2019 season (Fig. 3.4a). With one TC occurring every month, this nature of TC activity during the usually “quiet” months of the year has been observed in the PAR region since 2017. Two of them, Amang and Chedeng, remained as TDs throughout their lifespan. Amang tracked initially westward, then turned generally northward as it neared the east coast of Mindanao Chedeng followed a generally westward and made landfall in the southern portion of Mindanao. Although TC Betty entered the PAR as a TD during its rapid weakening phase and remained very far from the country, this TC was noted for being the strongest February TC to date in the WNP after reaching its peak intensity of 105 kt while situated halfway between the easternmost boundary of the PAR and the Northern Mariana Islands.

[37] A TC is grouped by the month when it was first identified inside the PAR region.

The second quarter (April to June) of 2019 (Fig. 3.4b) only saw the occurrence of two non-landfalling TCs within the PAR, all of which only peaked at TD category and occurred during the month of June. The lack of TC activity during the months of April and May was within the normal range of values and was attributed (JMA 2020) to the post-El Niño warming of sea surface temperature in the Indian Ocean and the delay in the onset and progression of the Southwest Monsoon, resulting in suppressed convective activity of the WNP basin. TCs Dodong and Egay remained TD while inside PAR, with the former intensifying into a TS as it moved towards the sea south of Japan. Dodong followed a generally north northeastward track while Egay initially moved generally northwestward towards Extreme Northern Luzon but eventually turned northward towards the sea east of Taiwan.

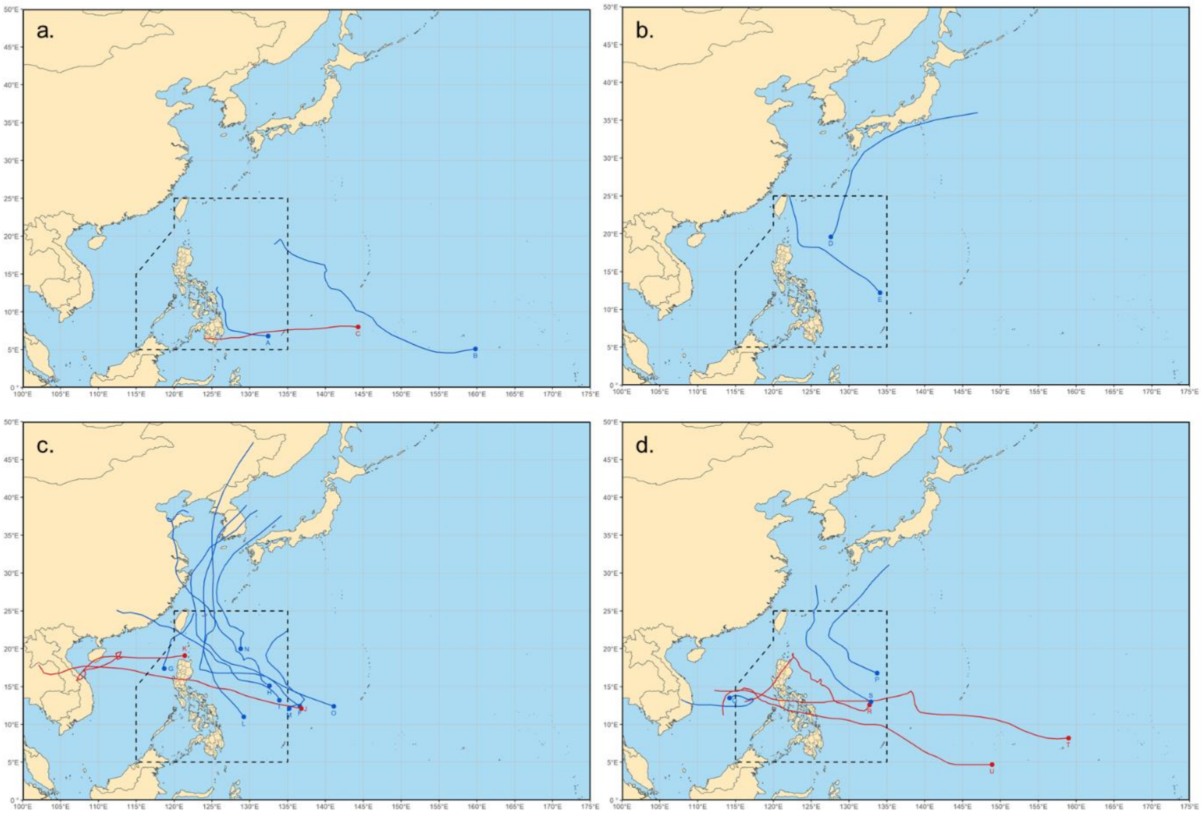


Fig 3.4. Best tracks of TCs that occurred within the PAR during January to March (a), April to June (b), July to September (c), and October to December (d) 2019. Red tracks are TCs that made landfall over the Philippine archipelago. The region enclosed by the black dash line is the PAR.

Being the most active months in terms of TC activity based on climatological data, the third quarter (July to September) (Fig. 3.4c) saw the highest number of TC occurrences within the PAR for this season. With four TC events each, the months of August and September had higher TC activity compared to July - usually the most active month based on the climatological normal. This was associated with the enhanced Southwest Monsoon activity during the months of August and September as suggested by the low-level cyclonic anomalies over the area from the northern portion of the West Philippine Sea to the Philippine Sea and over the low latitudes from 150°E to 180°E, and the stronger-than-normal monsoon trough over Southeast Asia (JMA 2020). Nevertheless, the number of TC cases every month during this quarter falls within the normal range of values.

During the period, the PAR region witnessed the passage of seven generally northwestward-moving, one north northeastward-moving, and two generally westward-moving TCs. All the non-westward-moving TCs during this quarter did not make landfall over the Philippine archipelago. Most of these non-landfalling TCs remained over the Philippine Sea during their passage within the PAR. This is consistent with the TC track climatology within the PAR region and the findings of Cinco et al. (2016). Of the landfalling cyclones, TC Jenny followed a west-northwestward to westward path and briefly crossed the landmass of Central Luzon, while TC Kabayan crossed Dalupuri Island in the Babuyan Archipelago shortly after developing, then tracked westward across the West Philippine Sea towards Hainan Island and Vietnam. It was also during this quarter that the PAR region saw the passage of one of the strongest

TCs for the 2019 season – TC Hanna, with a peak intensity of 105 kt that was reached while the system was inside the PAR. Despite the non-landfalling nature of the tracks for most of these TCs, the general orientation of their tracks within the PAR region and the synoptic environments during their passages resulted in the enhancement of the Southwest Monsoon following the mechanism identified by Cayanan et al. (2011) and Bagtasa (2019).

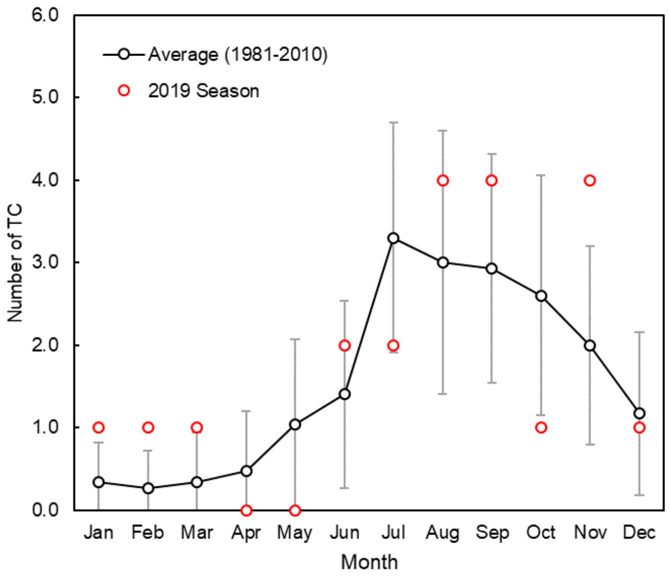


Fig. 3.5. Monthly number of TC occurrences within the PAR for 2019 compared to the climatological normal (1981-2010). The error bars extending from the 30-year normal values indicate ±1 standard deviation from the normal values.

A total of six TC events occurred within the PAR region during the last quarter of the year (October to December) (Fig. 3.4d). Although slightly less than the previous quarter, this period has a notably higher proportion of landfalling TCs. In addition, the fourth quarter of 2019 was notable because of the sudden decrease in TC activity in October (with only one TC event) and the higher-than-normal TC activity in November (with four TC events, similar to the more active months of August and September). The activity for both months falls outside the normal range of values. In juxtaposition, the climatological normal shows waning activity within the PAR towards and during the fourth quarter of the year. Over the entirety of the WNP basin, the TC activity for the month of October was near normal while those for November was also notably higher. The basin-wide activity during November 2019 was supported by high sea surface temperatures in the tropical WNP east of 160°E and enhanced low-level cyclonic vorticity between the westerly winds along the equator related to an active MJO phase and the equatorial waves and easterly flow in the tropical WNP south of 20°N (JMA 2020).

The last quarter of 2019 saw the passage of TC Tisoy, the longest-lived TC that entered the PAR this year and the strongest TC to make landfall in the Philippines in 2019, with a landfall intensity of 95 kt. Two of the TC events during this period, TCs Ramon and Quiel, exhibited peculiar tracks. The former initially tracked generally northwestward, with periods of erratic motion as it approached Northern Luzon. After stalling near Babuyan Islands, Ramon “dived” southwestward and crossed Northern and Central Luzon. On the other hand, Quiel initially tracked eastward over the West Philippine Sea west of Mindoro for two days. After moving erratically while turning 180° for a day, it eventually moved westward and made landfall over Vietnam.

Rainfall during Tropical Cyclone Days

Aside from the eyewall, 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 these distant precipitation events, instead of using a predetermined radius[38] 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[39] as delineating metric.

Fig. 3.6a presents the total rainfall over the country during TC days 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 during TC days were notably higher (at least 750 mm) for most of Luzon (except mainland Palawan) than in other parts of the country. In the Visayas, the total rainfall during TC days over Visayas (Mindanao) was slightly higher in the Samar and Panay Islands. The rainfall distribution presented three distinct maximum regions – over the Batanes-Babuyan archipelago and the northern portion of mainland Northern Luzon, the western portion of Central Luzon (i.e., Zambales-Bataan area), and the northern Palawan-southern Mindoro-far northwestern Panay area (including Calamian, Cuyo, and Caluya Islands). These areas received as much as 1500 to 2000 mm of total rainfall during TC days, with isolated areas having in excess of 2000 mm. When compared against the total rainfall for 2019 (Fig. 3.6b), the rainfall in most areas in Luzon during TC days accounted for 30% to 60% of the total rainfall for the year, with some areas in MIMAROPA reaching 70%. As for Visayas, the total rainfall during TC days in 2019 constitute 20% to 40% of the year-long rainfall in most areas, and as much as 70% for portions of far northwestern Panay. For Mindanao, TC-related rainfall constituted between 10% to 30% of the 2019 rainfall in most areas.

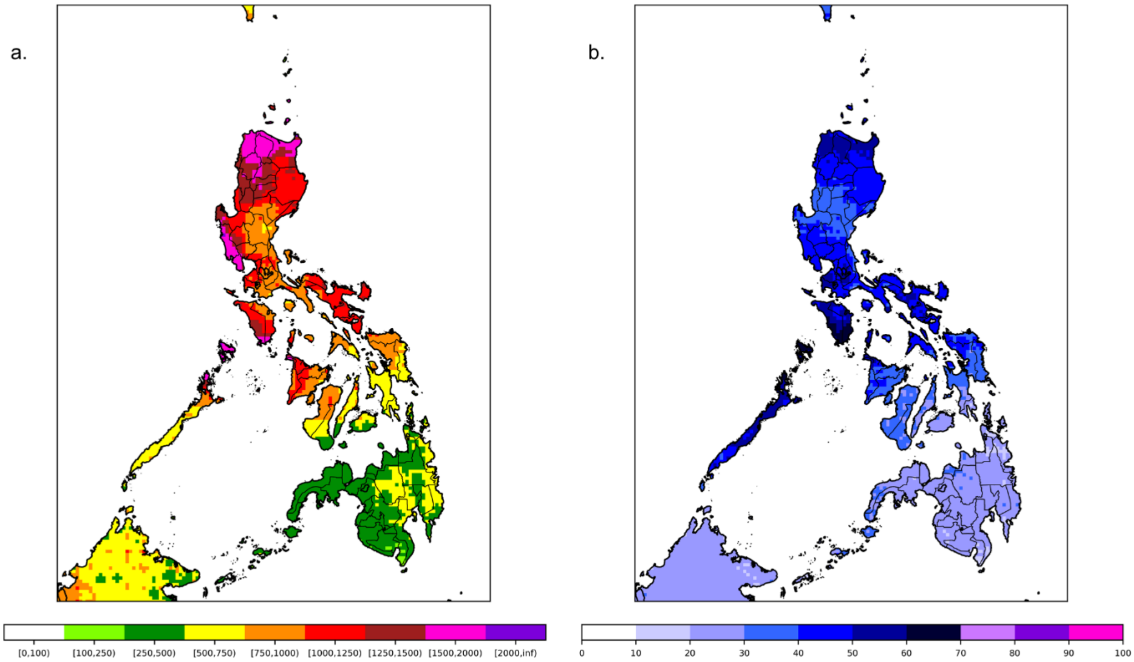


Fig 3.6. GSMaP-Gauge nationwide estimates of (a) total rainfall (mm) during TC days and (b) its percentage contribution to the total rainfall in 2019.

To determine the extent of rainfall during TC days that fall under the different monsoon regimes, the total rainfall during TC days were aggregated in terms of the approximate periods of each regime based on the discussion of Williams et al. (1993). For this report, the 2019 season was divided into four monsoon regimes. January to March cover the mid and late phases of the Northeast Monsoon of 2018-2019 (NEM1), while April and May fall under the inter-monsoon period or the trade winds regime (although this regime was excluded in the report because no TC occurred during this period). The

[38] 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.
[39] TC days are meteorological days with at least one tropical cyclone within the PAR region irrespectively of its proximity to the Philippine archipelago

months of June to October, the longest of the regimes, cover the onset, prevalence, and withdrawal of the Southwest Monsoon (SWM). Lastly, the period of November to December coincides with the early phase of the Northeast Monsoon of 2019-2020 (NEM2).

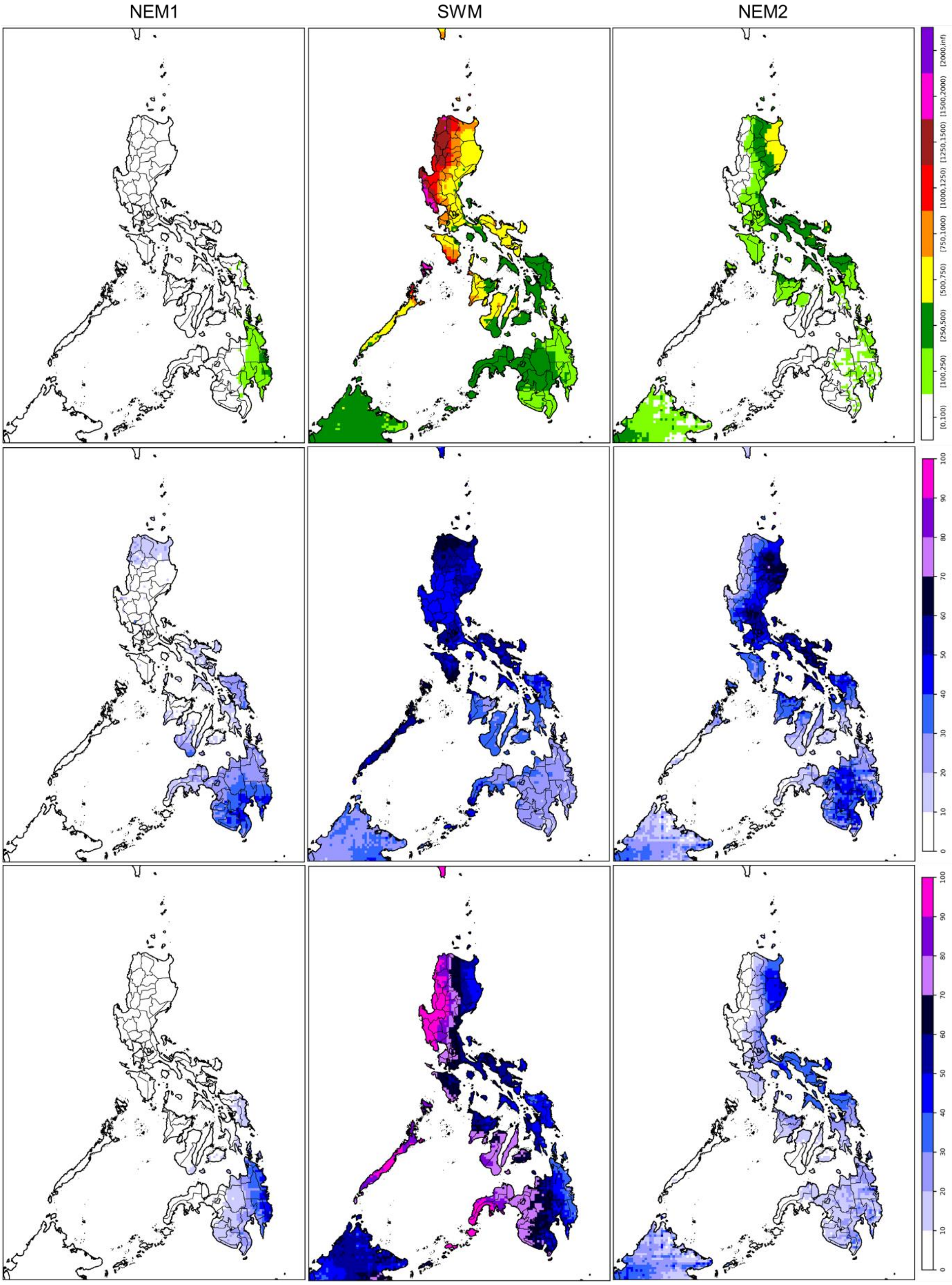


Fig 3.7. GSMaP-Gauge nationwide estimates of the total rainfall (mm) during TC days of NEM1, SWM, and NEM2 regimes in 2019 (first row) and their corresponding percentage contribution to the total rainfall (both TC and non-TC days) observed during each of the regime (second row) and to the total rainfall of all TC days in 2019 (third row).

The NEM1 period witnessed the occurrence of three TCs, two of which occurred near enough to the archipelago to bring rainfall. Fig. 3.7 shows that total rainfall during TC days of the NEM1 regime reached 250-500 mm over some areas in the eastern portion of Caraga and Davao Region (mainly southern Surigao del Sur, northern Davao Oriental), while the majority of Caraga and Davao Regions and some portions of in Samar Island received 100-250 mm of rain. The rest of the country only had up to 100 mm, mainly over the eastern portion of the country not included in the abovementioned areas and the southern portion of Mindanao. Such distribution of higher rainfall totals was because TC Amang passed over the sea off the eastern coasts of Eastern Visayas, Caraga, and Davao Regions while TC Chedeng made landfall in the vicinity of Davao Region.

Rainfall during TC days of NEM1 accounted for up to 50% of the total NEM1 rainfall of Mindanao, up to 40% over Visayas (especially over Eastern Visayas), and up to 30% over Luzon (mainly over northern Luzon). Furthermore, the total rainfall during TC days of NEM1 constitute roughly 20% to 50% of the total rainfall during TC days of 2019 for most of Caraga and Davao Region. For Visayas and the rest of Mindanao, this percentage contribution is up to 30% while for Luzon, this value is up to 10% only.

Twelve of the 21 TCs in 2019 occurred during the SWM regime. However, this period only witnessed one TC that archipelago (Jenny) while another one passed very close to the Babuyan Islands in Extreme Northern Luzon (Kabayan). Fig. 3.7 shows that TC days during the SWM had very high rainfall totals (at least 500 mm) over most of Luzon and Western Visayas. Three rainfall maxima regions were evident on the rainfall distribution map – over the western section of Central Luzon (i.e., Zambales-Bataan area), the northwestern portion of mainland Northern Luzon, and the Calamian Islands area. These areas received as much as 1500-2000 mm of total rainfall during all the TC days during the SWM period. The observed distribution of rainfall during TC days of the SWM regime was due to the prevalence of the enhanced monsoon flow in the presence of TCs passing through the north, northeast and northwest of Luzon but not making landfall, especially those the cross the imaginary line connecting northern Luzon and Okinawa, Japan (Cayanan et al. 2011; Bagtasa 2019). The presence of mountain ranges, especially those situated over western Luzon and Mindoro, plays a significant role (i.e., through orographic enhancement in the windward slopes and rain shadowing in the leeward slopes) in the magnitude and distribution of the observed rainfall during the SWM regime.

The TC days of the SWM had rainfall that constituted 60% to 80% of the total rainfall observed during the entirety of the SWM over southern Mindoro-northern Palawan area, 60% to 70% over Extreme Northern Luzon and northwestern mainland Luzon, 40% to 70% over the rest of Luzon, 20% to 50% over Visayas, and 10% to 40% over Mindanao. Furthermore, the rainfall during TC days of the SWM accounted for 60% to 100% of the total rainfall during TC days of 2019 for the western half of Luzon and Mindanao and most of the Western-Central Visayas area. For the remainder of the country, this percentage contribution ranges between 30% and 70%.

The NEM2 regime covering the months of November and December witnessed the passage of five TCs, three of which made landfall and crossed the archipelago. Fig. 3.7 shows that the eastern portions of Northern and Central Luzon, most of Southern Luzon (except for mainland Palawan), and the northern half of Visayas received anywhere between 100 mm and 750 mm of rainfall during the TC days of NEM2, with isolated portions of Extreme Northern Luzon receiving between 750 mm and 1250 mm. The rest of the country had up to 100 mm during the same period, with scattered areas of 100-250 mm in the eastern and central portions of Mindanao. Although isolated areas of 500-750 mm were observed over Bicol Region, the rainfall maximum region (reaching 500-750 mm) was observed over the eastern portion of Northern Luzon, including portions of Extreme Northern Luzon. The location of the rainfall maximum region was mainly the result of multiple heavy and sustained rainfall events associated not only with the landfall of TC Ramon, but also with the Northeast Monsoon cold surges (and the enhanced convergence along shear lines during surges) that were enhanced by TCs Quiel, Sarah, and Tisoy.

The total rainfall during the TC days of NEM2 accounted for 40% to 80% of the observed rainfall for the entire NEM2 period over the eastern portion of Northern Luzon, Central Luzon, Metro Manila, CALABARZON, and Bicol Region, between 20% to 50% for the rest of Luzon (except central and southern Palawan) and the northern half of Visayas. For Mindanao, the rainfall during the TC days of NEM2 was mainly 10% to 60% of the total rainfall for NEM2 of Mindanao (except Sulu Archipelago and western Zamboanga Peninsula), with higher percentages in the central portion of the island. For the rest of the country, this percentage contribution is anywhere between 0% and 40%. In terms of percentage contribution against the total rainfall during TC days of 2019, the rainfall during TC days of NEM2 accounted for 20% to 60% over the eastern section of Luzon and the northern portion of Visayas. For the rest of the country, this percentage contribution ranges from 0% to 30%, with isolated areas of 30-40% over eastern Mindanao.

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 land-based rainfall observations in the Philippines during TC days in 2019.

Record	Location	Value (mm)	Date or Period and Active TC
Highest 24-hour accumulated rainfall (landfalling TC)	Catarman, Northern Samar	605.5	12/02/2019 (TY Tisoy)
Highest 24-hour accumulated rainfall (non-landfalling TC)	Laoag City, Ilocos Norte	471.8	08/23/2019 (STS Ineng)
Highest storm duration rainfall (Landfalling TC)	Catarman, Northern Samar	641.5	11/30 to 12/04 (TY Tisoy)
Highest storm duration rainfall (Non-landfalling TC)	Laoag City, Ilocos Norte	572.2	08/19 to 08/24 (STS Ineng)

Table 3.4. Extremes of land-based wind and sea level pressure observations in the Philippines during TC days for landfalling or close-approaching TCs in 2019.

Record	Location	Value	Date / Time (UTC) and Active TC
Lowest sea level pressure	Juban, Sorsogon	963.4 hPa	12/02/2019 1600 (TY Tisoy)
Highest peak gust	Guiuan, Eastern Samar	WSW (240°), 97.2 kt (50 m/s)	12/24/2019 0914 (TY Ursula)

Casualty and Damage Statistics

Based on official report provided to PAGASA by the National Disaster Risk Reduction and Management Council (NDRRMC), the 21 TCs of the 2019 season directly and indirectly (e.g., distant precipitation through monsoon) resulted in 777 casualties – 67 dead, 691 injured, and 19 missing individuals. This makes the 2019 season both the 18th deadliest TC season since 2000 and the 5th deadliest post-Yolanda season on record. Moreover, the season was also that 11th worst since 2000 and 2nd worst post-2013 in terms of the total casualty count. At 8.6%, the 2019 season had the lowest proportion of deaths to casualties since 2000. No notable trend was observed in terms of casualty count or death toll since 2000, although the number of casualties was found to be slightly increasing since 2016.

Combined cost of damage to agriculture and infrastructure amounted to PHP 11.270 billion nationwide with agricultural damages accounting for 69.53% of the total damage cost (i.e., PHP 7.837 billion). This makes 2019 the 15th costliest TC season since 2000 and the 5th costliest post-STY Yolanda season. When adjusted for inflation using the published consumer price index (CPI) of the Philippine Statistics Authority, it can be observed that while no year-on-year trend is seen, the aggregated cost of damage due to tropical cyclone events has been steadily increasing since 2000 (Fig. 3.10).

Records from the NDRRMC show that TC Ursula, the Christmas typhoon of 2019 that crossed the central portion of the archipelago, was the deadliest TC of the season. This typhoon claimed the lives of 57 people in addition to 619 injured and 19 missing individuals across MIMAROPA, Bicol Region, Visayas, and Caraga Region. Although Ursula had more than PHP 4 billion in terms of combined cost of damage, TC Tisoy was the deadliest TC of 2019. Traversing the populated areas of Southern Luzon and affecting almost all of Luzon and portions of Western Visayas, Eastern Visayas, and Caraga Region, this typhoon caused damage to agriculture and infrastructure amounting to PHP 6.646 billion, more than half of which were agricultural damage. A tally of casualty and damage statistics per individual TC event is presented Table 3.5.

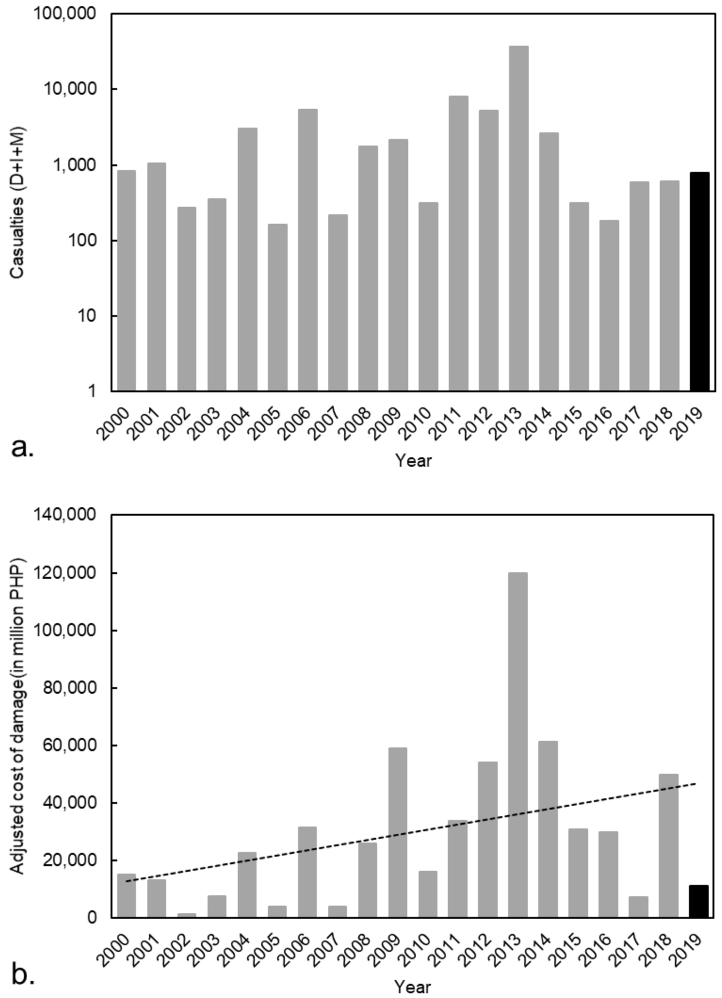


Fig 3.8. Yearly (a) number of casualties and (b) cost of damage (in million PHP) directly and indirectly caused by the 2019 TCs. Values for the 2019 season are in black bars. The y-axis in Fig. 3.8a uses logarithmic (base 10) scale. In Fig. 3.8b, the cost of damage is adjusted to 2019-equivalent values using the annual average CPIs published by the Philippine Statistics Authority, while the black dash line presents the linear trend (2000-2019) of this adjusted cost of damage.

Table 3.5 shows that while no TC caused the deaths of at least 300 individuals, the passage of TCs Tisoy and Ursula during the fourth quarter of the year both resulted in damage to agriculture and infrastructure amounting to more than the PHP 1 billion threshold required for the decommissioning of domestic names. As such, Tisoy and Ursula were decommissioned by PAGASA from Set III on 21 January 2020 and were replaced by Tamaraw and Ugong. These replacements will be introduced during the 2023 season. Furthermore, in its 52nd Session[40] on 10 June 2020, the Typhoon Committee approved the request of PAGASA to decommission the equivalent international names of Tisoy (Kammuri) and Ursula (Phanfone). During the 53rd Session of the Typhoon Committee on 23-25 February 2021, Koto and Nokaen were approved by the Committee as replacement names for Kammuri and Phanfone, respectively.

[40] Both the 52nd and 53rd Sessions of the Typhoon Committee were held virtually through videoconferencing due to the COVID-19 pandemic.

Table 3.5. Official report of casualties and cost of damage directly and indirectly associated with the TC events of 2019. Data provided by the Disaster Statistics Unit, Operations Service of the Office of Civil Defense[41].

Name of TC	Casualties			Cost of damage (in PHP thousands)		
	Dead	Injured	Missing	Agriculture	Infrastructure	Total
Amang	0	0	0	-	-	-
Chedeng	0	0	0	-	1,200.000	1,200.000
Egay	0	0	0	-	-	-
Falcon	0	0	0	745.320	-	745.320
Ineng and Jenny	0	0	0	209,064.797	31,400.000	240,464.797
Marilyn	0	0	0	-	-	-
Nimfa	0	0	0	-	-	-
Quiel	6	4	13	-	-	-
Ramon	0	0	0	-	-	-
Tisoy	4	318	0	3,701,081.562	2,944,998.526	6,646,080.088
Ursula	57	369	6	3,925,679.587	456,105.456	4,381,785.043

Note: The NDRRMC did not report any casualty or damage statistics for Betty, Dodong, Goring, Hanna, Kabayan, Liwayway, Onyok, Perla, and Sarah as they were assessed to have no effects over the country.

Provision of Tropical Cyclone Products and Wind Signals

PAGASA issued 522 public TC products throughout the entire 2019 season. These include 207 Tropical Cyclone Updates (TCU), 21 Tropical Cyclone Advisories (TCA), and 294 Severe Weather Bulletins (SWB). On the other hand, a total of 287 marine TC products in the form of Tropical Cyclone Warnings for Shipping (IWS) were provided by the Agency. Due to its length of occurrence within the PAR, TC Ramon warranted the issuance of 61 public TC products and 34 marine TC products – the highest of any TC in 2019. Table 3.6 presents the summary of issued TC products during the 2019 season.

Fourteen of the 21 TCs in 2019 necessitated the hoisting of Tropical Cyclone Wind Signals (TCWS) in the country due to the threat of strong to typhoon-force winds. In 2019, roughly 85% of the provinces[42] in the Philippines (including Metro Manila) were placed under a wind signal at least once during the 2019 season. The passage of TC Tisoy resulted in the hoisting of wind signals in over 51 provinces and sub-provincial localities, which was the highest of any TC during the year. On the other hand, the TCs with the least number of areas placed under TCWS were TCs Goring and Liwayway, with only 1 province (Batanes) placed under TCWS #1.

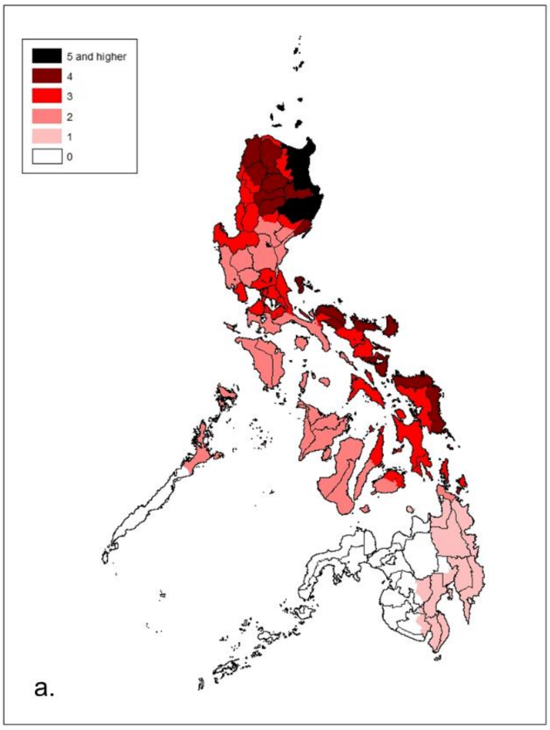
Fig. 3.9a presents the map showing the frequency of hoisting a TCWS at a provincial or sub-provincial locality during the 2019 season. Due to the nature of the observed TC events during the season, Cagayan Valley was the region that was most frequently subjected to wind signals, with most of the region being placed under TCWS at least 5 times within the year. The province most frequently placed under TCWS in 2019 was Batanes. Except for the central and southern portions of Palawan, the entirety of Bangsamoro and Zamboanga Peninsula, nearly all of Northern Mindanao, and the western portions of SOCCSKSARGEN and Davao del Norte, a TCWS was hoisted at least once in every province in the Philippines during the 2019 season.

Fig. 3.9b shows the season-wide highest level of wind signal that was put into effect in each province or sub-provincial locality. For 2019, the highest TCWS that was hoisted in the country was TCWS #3 due to the absence of any land-crossing TC in 2019 that reached super typhoon category or typhoon category with maximum winds of at least 92 kt. The map in Fig. 3.9b clearly shows two distinct wind signal maxima – a belt of TCWS #3 situated over the southern portion of Luzon and the northern half of Visayas and a region of TCWS #3 over the northeastern portion of Luzon. The former was related to the passage of TCs Tisoy and Ursula during the last quarter of the season, while the latter was due to the occurrence of TC Ramon which made landfall over northeastern mainland Luzon after moving erratically near Extreme Northern Luzon. Except for Dinagat Islands, the highest wind signal hoisted over any locality in Mindanao was TCWS #1.

[41] The Office of Civil Defense (OCD) serves as the secretariat of the NDRRMC.
[42] Including Metro Manila, the Philippines currently has 82 provinces.

Table 3.6. Summary of TC products and TCWS hoisted for each TC event of the 2019 season.

Name of TC	No. of public TC products issued				No. of IWS issued	No. of localities under TCWS	Highest TCWS hoisted
	TCU	TCA	SWB	Total			
Amang	4	0	16	20	9	15	TCWS #1
Betty	18	7	3	28	3	0	N/A
Chedeng	7	3	11	21	8	11	TCWS #1
Dodong	6	0	4	10	6	0	N/A
Egay	4	0	9	13	8	2	TCWS #1
Falcon	9	0	17	26	15	12	TCWS #2
Goring	1	0	3	4	3	1	TCWS #1
Hanna	14	0	16	30	22	2	TCWS #1
Ineng	11	0	18	29	17	7	TCWS #2
Jenny	6	0	14	20	9	29	TCWS #2
Kabayan	3	0	2	5	2	0	N/A
Liwayway	12	0	14	26	18	1	TCWS #1
Marilyn	8	2	6	16	11	0	N/A
Nimfa	11	0	11	22	15	0	N/A
Onyok	9	1	13	23	13	2	TCWS #1
Perla	11	0	11	22	19	0	N/A
Quiel	12	1	10	23	17	0	N/A
Ramon	16	0	45	61	34	22	TCWS #3
Sarah	8	0	15	23	16	3	TCWS #1
Tisoy	19	5	26	50	20	51	TCWS #3
Ursula	18	2	30	50	22	37	TCWS #3
Total	**207**	**21**	**294**	**522**	**287**		



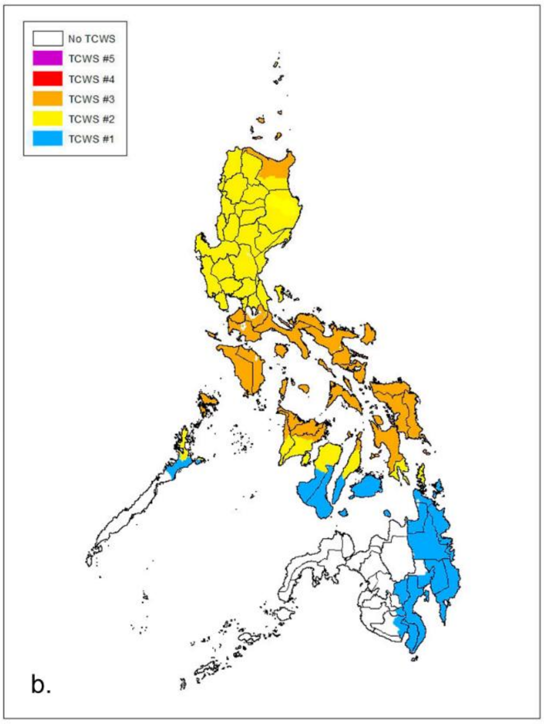


Fig. 3.9. (a) Frequency of hoisting TCWS per province or sub-provincial locality during the 2019 season and (b) the highest level of TCWS hoisted per locality.

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REVIEW OF THE PHILIPPINE TROPICAL CYCLONES OF 2019

Review of the Philippine Tropical Cyclones of 2019

This section of the report contains the individual reviews of each tropical cyclone (TC) in the Western North Pacific (WNP) basin that occurred within the Philippine Area of Responsibility (PAR) in 2019 based on the result of a post-season best track analysis of each TC by the typhoon forecasters of the Marine Meteorological Services Section, weather Division. Each individual TC review contains the following information:

- 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 of surface meteorological observation over land recorded by the PAGASA synoptic station network during the passage of the TC. These includes the top three highest 24-hour accumulated rainfall during any of the TC days, the top three highest storm duration[43] rainfall, the top three highest peak gust during any of the TC days, and the top three lowest sea level pressure during any of the TC days. The last two are only provided for landfalling or close-approaching[44] TC events. These data are obtained from TC passage reports, enhanced surface observations, or (in the absence of the two), regular synoptic observation reports.
- A summary of TC products and services provided by the Weather Division during the occurrence of the TC within the PAR region. This includes the number of public and marine TC products issued, the number of localities where TC Wind Signals (TCWS) were put into effect, and the highest wind signal hoisted throughout the occurrence of the TC.
- A summary of casualties and damages associated with the TC event based on aggregated reports and official communications from the National Disaster Risk Reduction and Management Council (NDRRMC) through the Disaster Statistics Unit, Operations Service of the Office of Civil Defense; and,
- A map showing the storm duration rainfall (in mm) over land within the PAR region based on the gauge-adjusted satellite-based estimates dataset (Mega et al. 2019) of the Global Satellite Mapping of Precipitation (Kubota et al. 2020).
- A map showing the distribution of highest wind signal hoisted during the occurrence of the TC, if applicable.

[43] Storm duration refers to the meteorological days the TC was inside the PAR.
[44] Close-approaching TCs are those that moved less than 60 nmi from the Philippine coastline.

TROPICAL DEPRESSION AMANG

19 to 22 January 2019

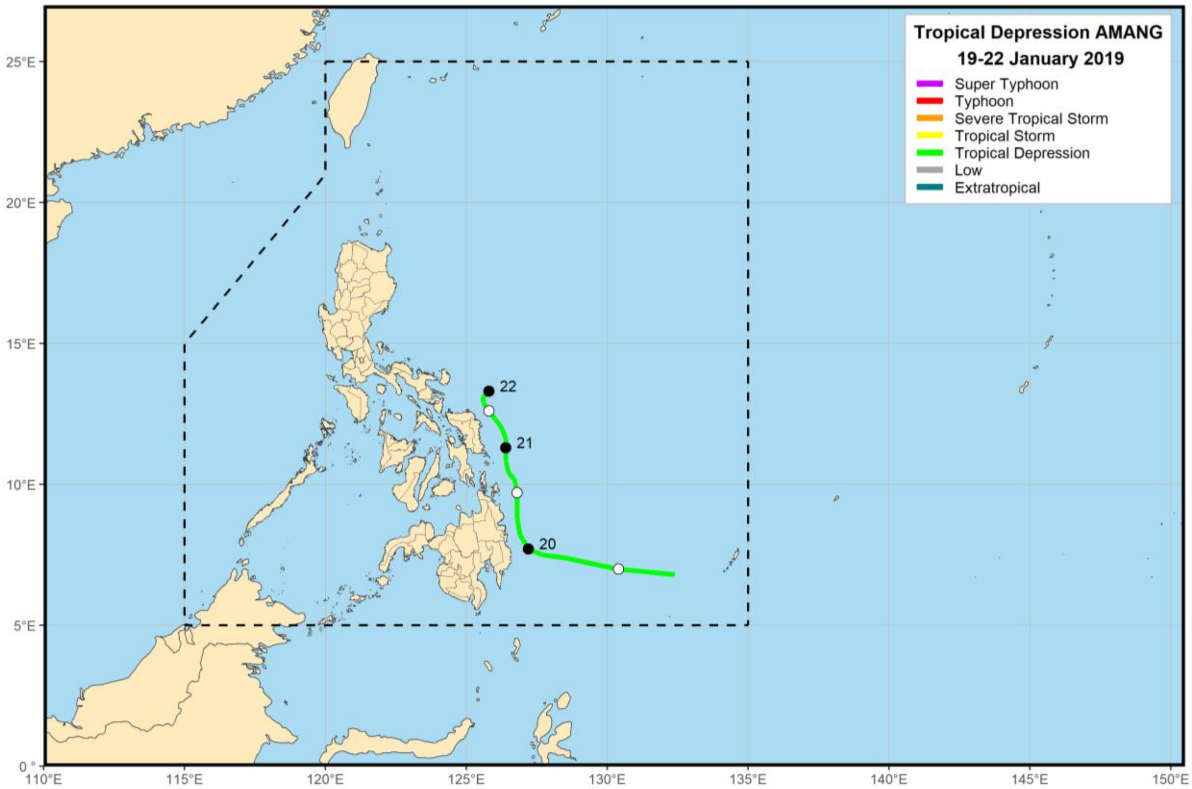

Fig 4.1.1. PAGASA best track positions and intensities of Tropical Depression Amang. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

The first TC of the 2019 season and the shortest-lasting TC within the WNP for the year, Amang, was first noted as a tropical depression by PAGASA at 06 UTC on 19 January while over the southern portion of the Philippine Sea west of Palau. Amang tracked generally west northwestward throughout that day, before turning generally northward on 20 January as it neared Davao Oriental. Throughout the remainder of its lifespan, Amang followed a northward to north northwestward track and remained offshore within 100-200 km from the east coasts of Davao Oriental, Surigao del Sur, Siargao-Bucas Grande Islands, Dinagat Islands, Eastern Samar, and Northern Samar. Unfavorable environmental conditions during its period of occurrence prevented the TC from reaching tropical storm category. Amang eventually weakened into a remnant low and was last tracked at 00 UTC on 22 January over the Philippine Sea northeast of Northern Samar or east of Albay.

Nationwide rainfall estimates reveal that despite not making landfall, the proximity of Amang's observed track to land result in heavy rainfall over portions of Bicol Region and the eastern portions of Visayas and Mindanao. Much of Caraga, Davao Oriental, Davao de Oro, Northern Samar, Eastern Samar, and Samar received between 50 and 200 mm, with the rainfall maximum region (100-200 mm) observed over Surigao del Sur and southeastern Agusan del Sur. The magnitude and distribution of rainfall during the occurrence of Amang was also influenced by the enhanced moisture convergence along the shear line that was present due to a prevailing cold surge at the time of passage of Amang. Normally, shear lines at the leading edge of cold surges 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 shear line. This results in the expansion of the areas affected by heavy rains to beyond those in the proximity of the TC circulation.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Hinatuan, Surigao del Sur: 113.9 mm, 19 January 2019
- Borongan City, Eastern Samar: 86.8 mm, 20 January 2019
- Calayan, Cagayan: 76.6 mm, 21 January 2019

Highest storm duration (19 to 21 January 2019) rainfall over land:

- Hinatuan, Surigao del Sur: 164.6 mm
- Borongan City, Eastern Samar: 103.6 mm
- Catarman, Northern Samar: 100.8 mm

Highest peak gust over land:

- Guiuan, Eastern Samar: NNE (30°) at 38.9 kt (20 m/s), 1430 UTC, 20 January 2019
- Borongan City, Eastern Samar: ENE (70°) at 29.2 kt (15 m/s), 1550 UTC, 20 January 2019
- Catarman, Northern Samar: N (360°) at 27.2 kt (14 m/s), 1800 UTC, 20 January 2019

Lowest sea level pressure over land:

- Tacloban City, Leyte: 1004.4 hPa, 0640 UTC, 21 January 2019
- Borongan City, Eastern Samar: 1004.5 hPa, 0700 UTC, 21 January 2019
- Hinatuan, Surigao del Sur: 1005.2 hPa, 0800 UTC, 20 January 2019
- Juban, Sorsogon, 1005.2 hPa, 0800 UTC, 21 January 2019

Summary of Warning Information

Number of public TC products issued: **20**

- Severe Weather Bulletins: **16**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **4**

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

Number of localities under TC Wind Signal (TCWS): **15**

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

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **Not provided**

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

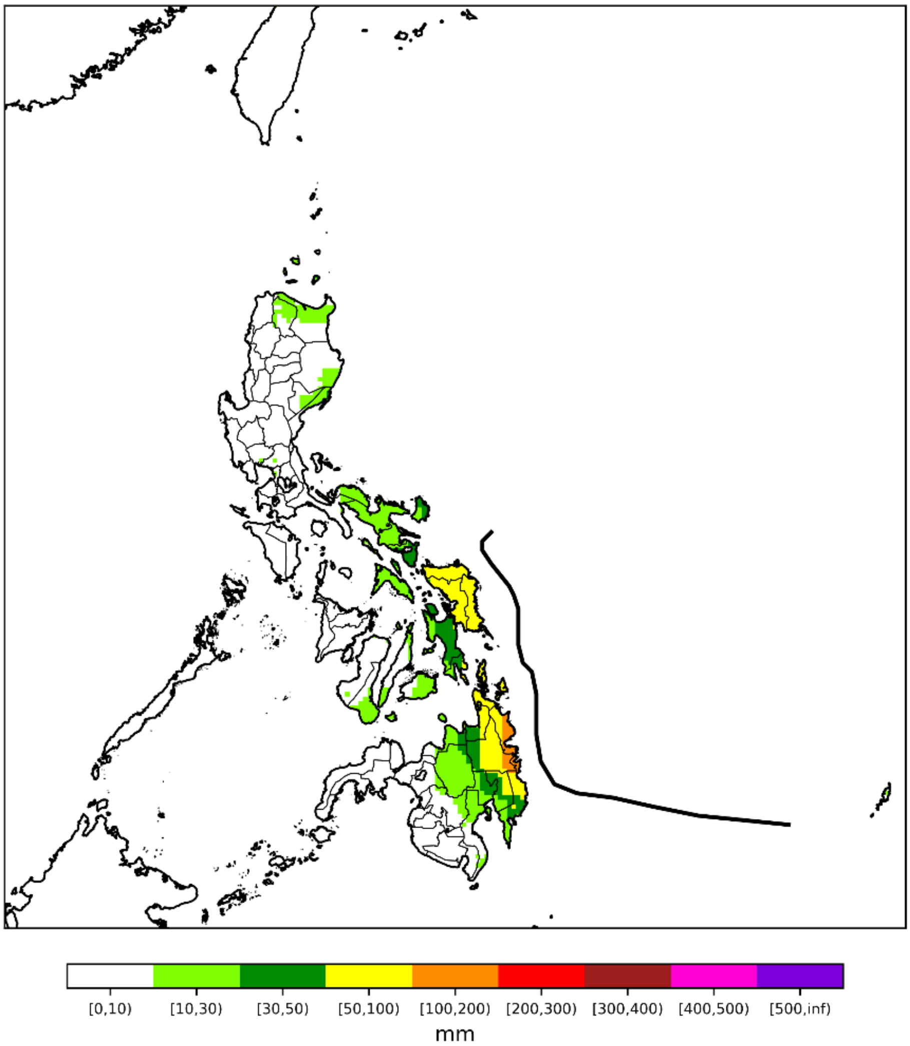

Fig 4.1.2. PAGASA best track of Tropical Depression Amang (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 19 to 21 January 2019.

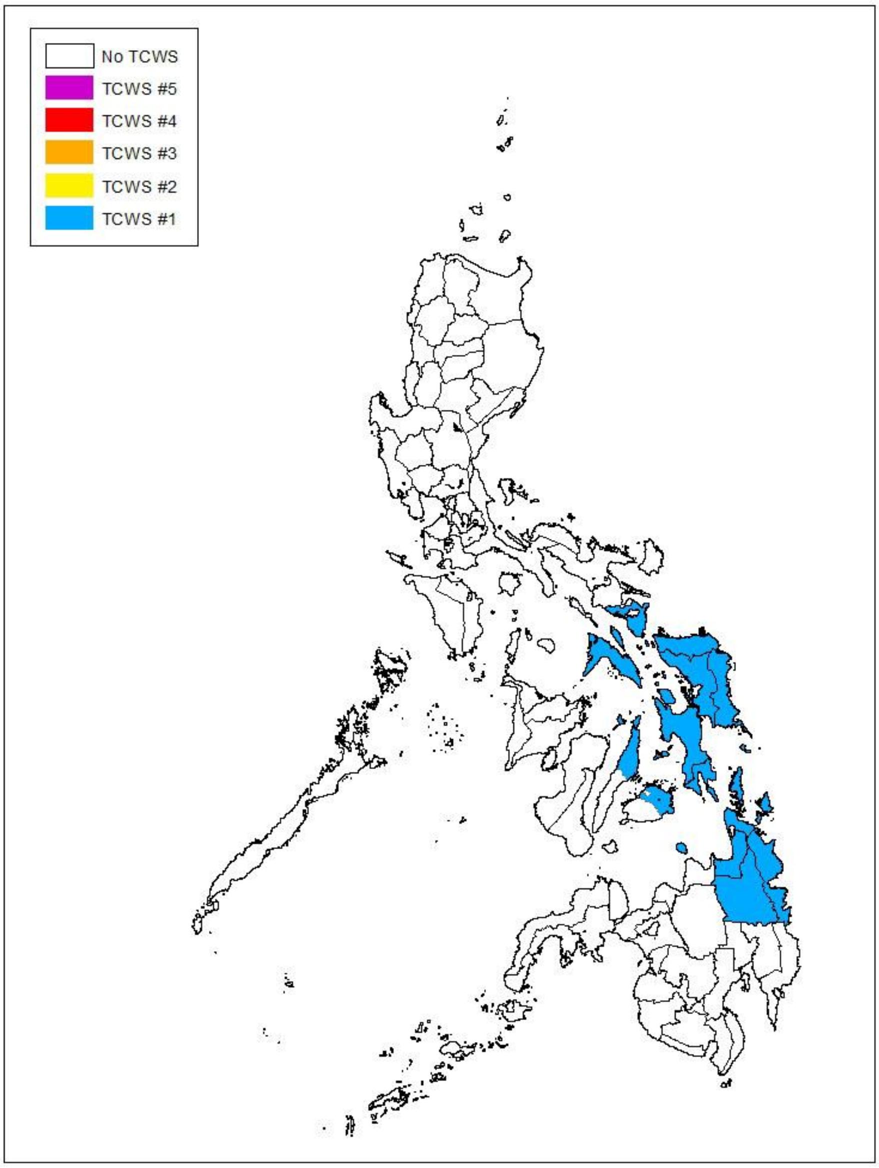

Fig 4.1.3. Highest wind signal hoisted by PAGASA during the occurrence of Tropical Depression Amang.

TYPHOON BETTY (WUTIP)

19 February to 02 March 2019

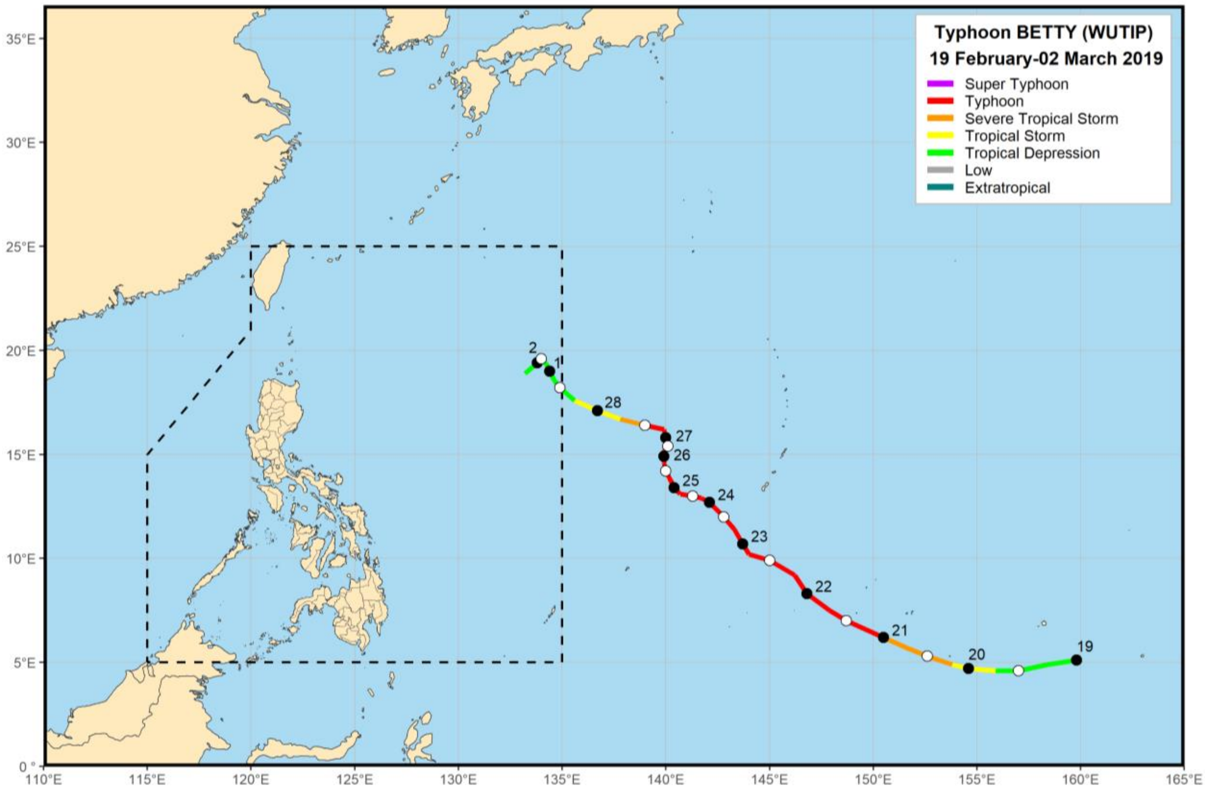

Fig 4.2.1. PAGASA best track positions and intensities of Typhoon Betty. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

The second longest-lived TC within the Western North Pacific (WNP) that entered the PAR region was first tracked as a tropical depression over the waters of Pohnpei in the Federated States of Micronesia at 00 UTC on 19 February. Moving generally westward towards Chuuk, Betty reached tropical storm category at 18 UTC on the same day. The storm turned west northwestward the next day as it started to rapidly intensify. Betty intensified into a severe tropical storm within 12 hours of reaching tropical storm category and into a typhoon 18 hours later. Over the waters of Yap, the typhoon shifted to a more northwestward heading. At this point, its rate of intensification had slowed. On 23 February, Betty started to decelerate as it moved over the sea southwest of Guam. At 12 UTC on that day, the typhoon reached its peak intensity of 105 kt and 925 hPa, making it the strongest February TC over the WNP basin on record. However, this peak intensity was not sustained for long as the typhoon began undergoing an eyewall replacement cycle (ERC) six hours after.

On 24 February, Betty turned west northwestward as it continued to decelerate and weaken. At around 18 UTC on the same day, the typhoon finished its (ERC) and started to re-intensify. As the typhoon turned north northwestward on the 25th, it reached its secondary peak intensity of 100 kt and 935 hPa. Early on 26 February, Betty encounter increasing vertical wind shear as it slowed down even further, thereby starting a period of rapid weakening. At around 12 UTC on the next day, the typhoon made a turn to the west northwest and accelerated while under increasingly hostile environmental conditions. At 06 UTC on 28 February, Betty weakened into a tropical depression. Roughly six hours after, the TC entered the PAR region. After slowing down once again, Betty degenerated into an area of low pressure and was last tracked at 18 UTC on 02 March.

Due to its sheer distance from the Philippine landmass, no significant rainfall directly or indirectly caused by Betty was noted over land either by the network of manned synoptic stations or by satellite-derived products.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Surigao City, Surigao del Norte: 45.6 mm, 28 February 2019
- Borongan City, Eastern Samar: 15.2 mm, 28 February 2019
- Borongan City, Eastern Samar: 5.6 mm, 01 March 2019

Highest storm duration (28 February to 02 March 2019) rainfall over land:

- Surigao City, Surigao del Norte: 49.8 mm
- Borongan City, Eastern Samar: 20.8 mm
- Hinatuan, Surigao del Sur: 5.5 mm

Summary of Warning Information

Number of public TC products issued: **28**

- Severe Weather Bulletins: **3**
- Tropical Cyclone Advisories: **7**
- Tropical Cyclone Updates: **18**

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: **Not provided**

Combined cost of damage: **Not provided**

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

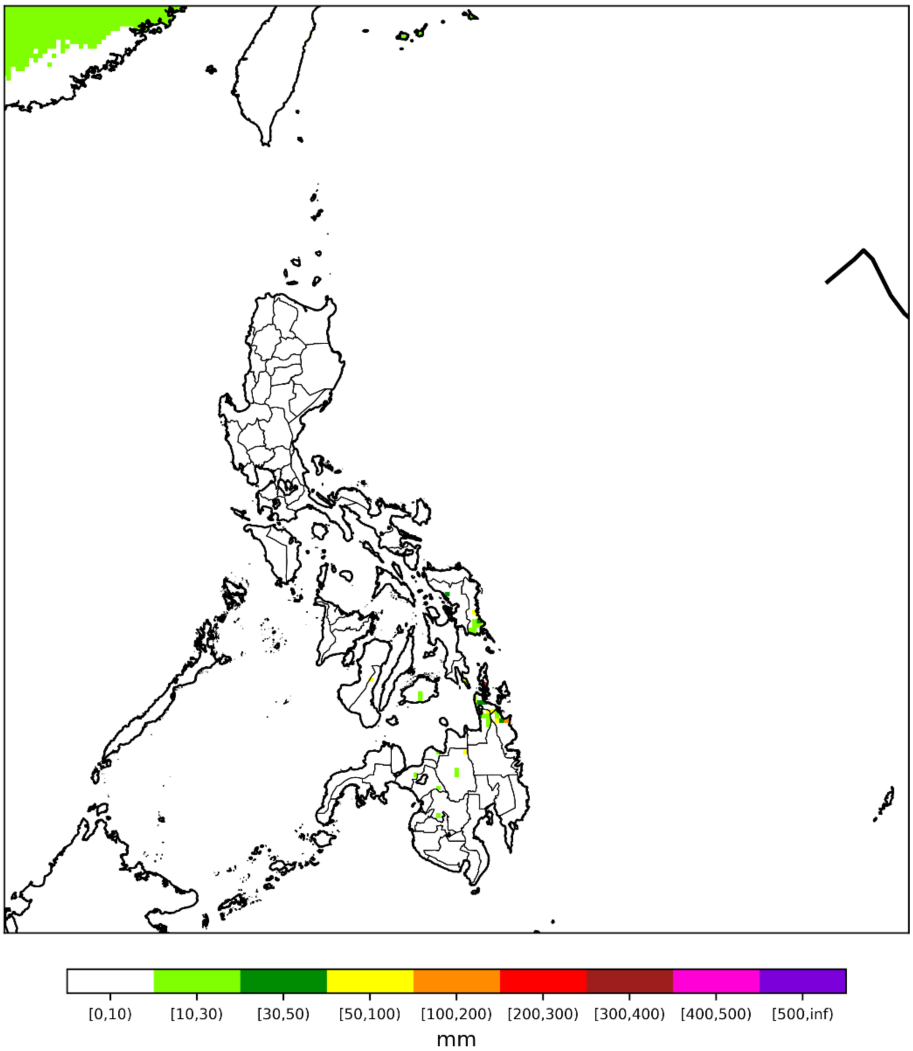

Fig 4.2.2. PAGASA best track of Typhoon Betty (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 28 February to 02 March 2019.

TROPICAL DEPRESSION CHEDENG

15 to 19 March 2019

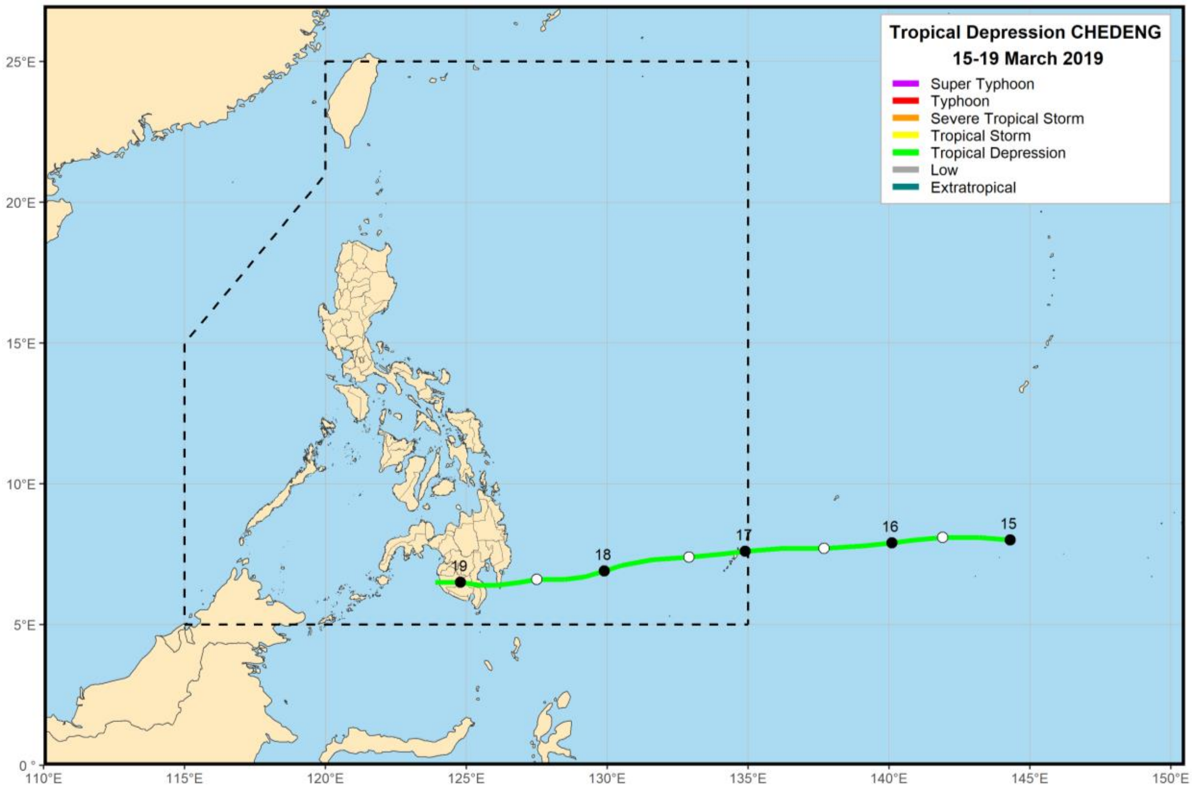

Fig 4.3.1. PAGASA best track positions and intensities of Tropical Depression Chedeng. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

The third TC of the 2019 season developed outside the PAR region and was first tracked as a tropical depression over the waters of Yap in the Federated States of Micronesia. Over the next couple of days, Chedeng, as it was domestically named, tracked generally westward and remained at tropical depression category throughout its existence. Chedeng entered the PAR at 00 UTC on 17 March and made landfall in the vicinity of Palau shortly thereafter. After traversing the southern Philippine Sea for more than 36 hours, the tropical depression made its first landfall in the vicinity of Mati City, Davao Oriental at around 18 UTC on 18 March. Roughly three hours after, Chedeng made its final landfall in the vicinity of Malita, Davao Occidental on the other side of the Davao Gulf. The mountainous terrain of southern Mindanao contributed to Chedeng's eventual demise and as it emerged over the coastal waters of Sultan Kudarat, the tropical depression degenerated into a remnant low at 06 UTC on 19 March. Whatever was left of Chedeng continued moving westward towards the southern Sulu Sea, where it finally dissipated the next day.

Much of the heavy rainfall brought by Chedeng was observed over Mindanao, especially over its eastern half. As much as 50-200 mm were noted over Caraga and Davao Regions (with isolated areas of up to 300 mm over Davao Oriental), while up to 50 mm of rainfall were observed over the rest of mainland Mindanao. Isolated areas of heavy rain were also observed over the southern portion of Visayas. The onshore flow of winds from the tropical depression and its interaction with the mountain terrain of eastern Mindanao heavily contributed to the high rainfall totals observed over the area (i.e., orographic enhancement).

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Hinatuan, Surigao del Sur: 121.1 mm, 18 March 2019
- Davao City: 90.2 mm, 18 March 2019
- Dauis, Bohol: 31.4 mm, 17 March 2019

Highest storm duration (17 to 19 March 2019) rainfall over land:

- Hinatuan, Surigao del Sur: 174.2 mm
- Davao City: 110.9 mm
- Surigao City, Surigao del Norte: 57.5 mm

Highest peak gust over land:

- Surigao City, Surigao del Norte: E (90°) at 29.2 kt (15 m/s), 0852 UTC, 19 March 2019
- Hinatuan, Surigao del Sur: NE (40°) at 27.2 kt (14 m/s), 0048 UTC, 18 March 2019

Lowest sea level pressure over land:

- Cotabato City: 1006.8 hPa, 2100 UTC, 18 March 2019
- Hinatuan, Surigao del Sur: 1008.2 hPa, 2100 UTC, 18 March 2019
- Davao City: 1008.9 hPa, 1900 UTC, 18 March 2019
- General Santos City: 1008.9 hPa, 1900 UTC and 2000 UTC, 18 March 2019

Summary of Warning Information

Number of public TC products issued: **21**

- Severe Weather Bulletins: **11**
- Tropical Cyclone Advisories: **3**
- Tropical Cyclone Updates: **7**

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

Number of localities under TC Wind Signal (TCWS): **11**

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

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **PHP 1,200,000.00**

- Damage to agriculture: **Not provided**
- Damage to infrastructure: **PHP 1,200,000.00**

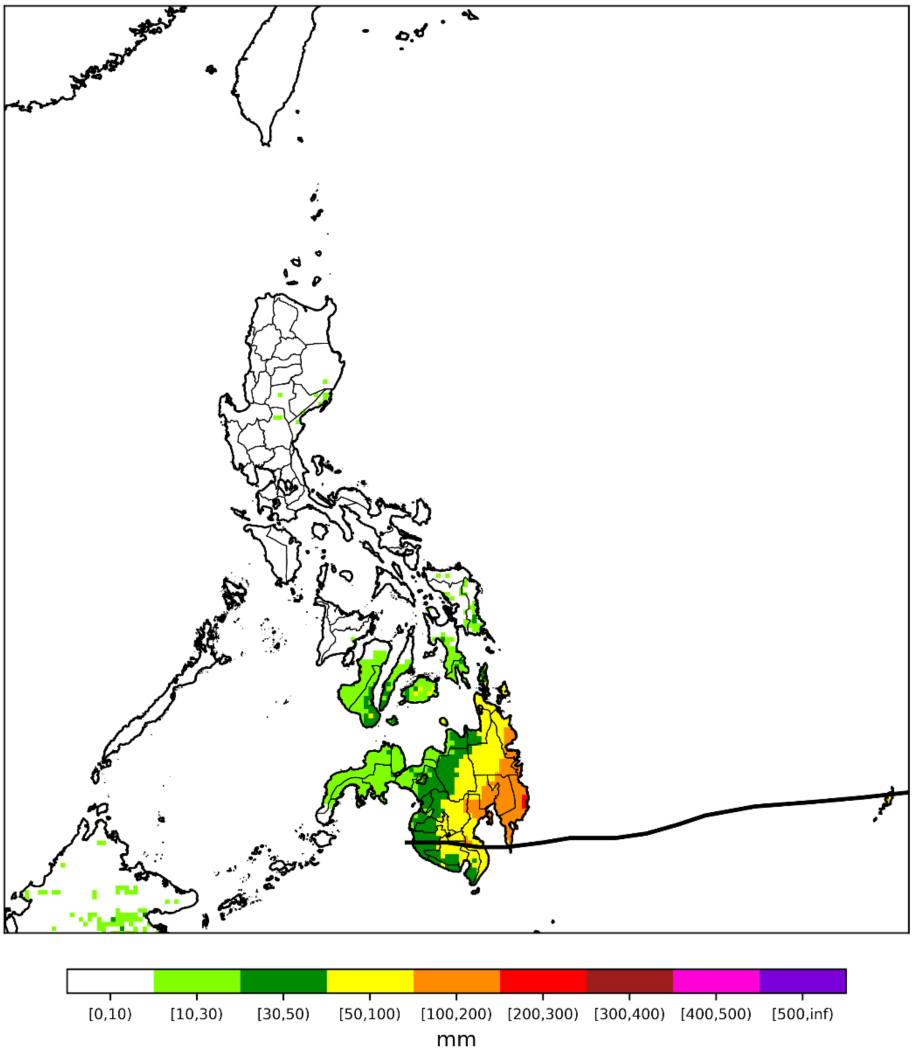

Fig 4.3.2. PAGASA best track of Tropical Depression Chedeng (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 17 to 19 March 2019.

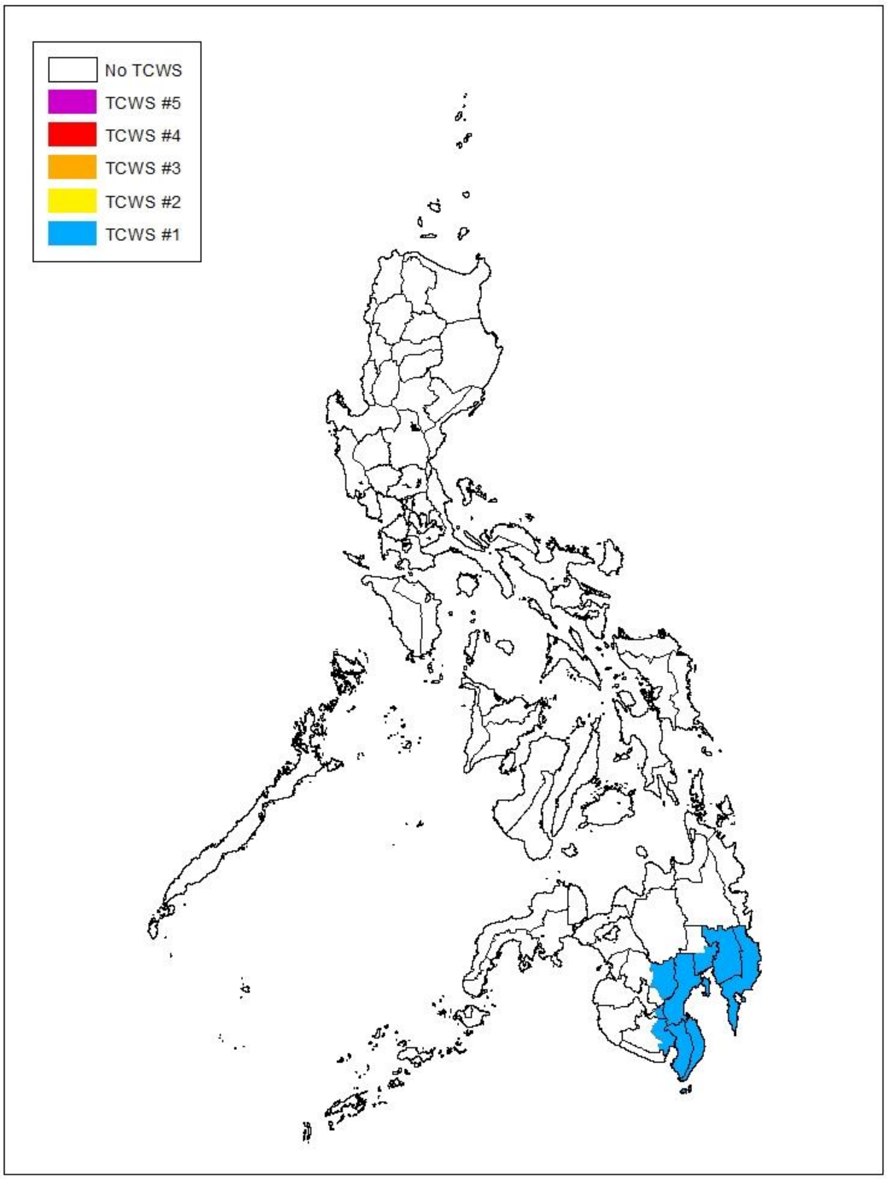

Fig 4.3.3. Highest wind signal hoisted by PAGASA during the occurrence of Tropical Depression Chedeng.

TROPICAL STORM DODONG (SEPAT)

25 to 28 June 2019

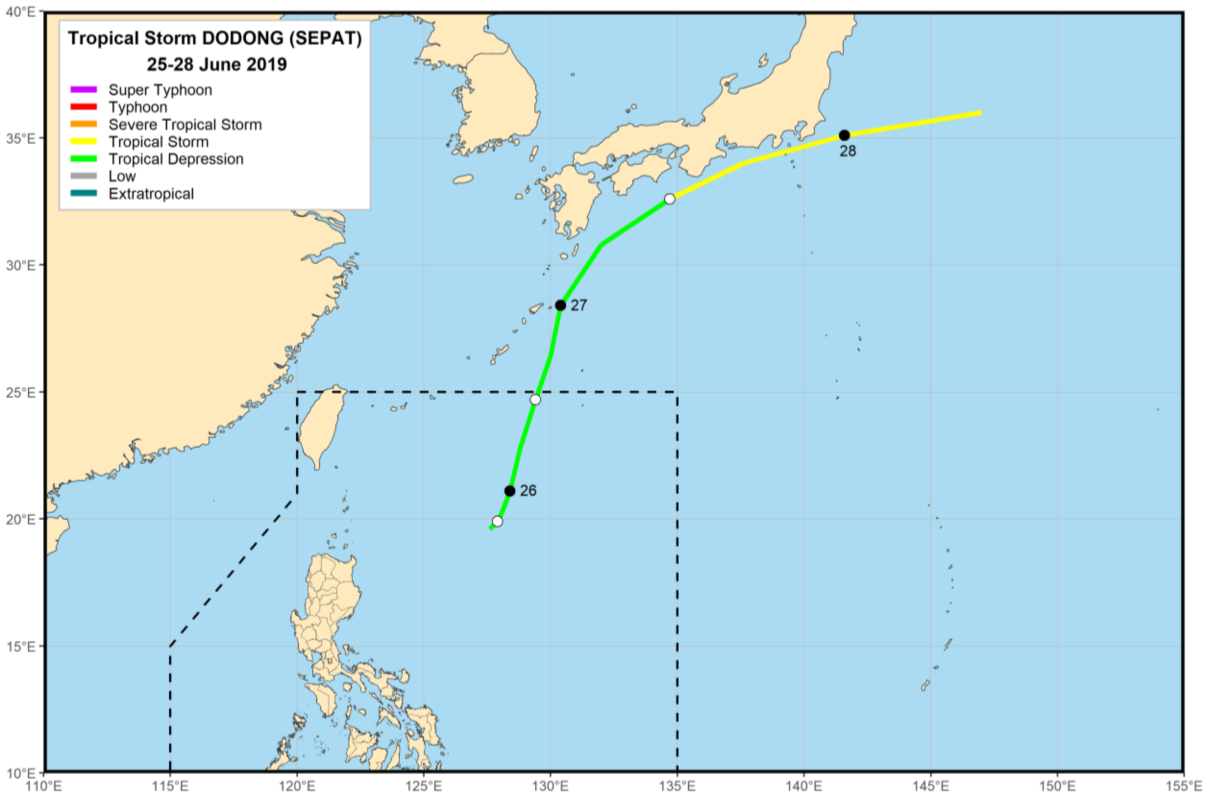

Fig 4.4.1. PAGASA best track positions and intensities of Tropical Storm Dodong. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

After roughly two months of quiescence, TC activity within the PAR resumed when an area of low pressure embedded along a formative monsoon trough developed into a tropical depression at 06 UTC on 25 June. Tracking north northeastward over the northern Philippine Sea, Dodong remained a weak depression while inside the PAR region. A slight intensification to 30 kt was observed at 12 UTC on 26 June, roughly two hours before it left the PAR region.

Outside the PAR, Dodong maintained its north northeastward heading until it was over the east of the northern Ryukyu Archipelago (Amami-Tokara-Ōsumi Islands), when it started turning northeastward and moved parallel to the southern coast of the main Japanese islands. At 12 UTC, as it began turning east northeastward over the sea south of Honshu, Dodong intensified into a tropical storm. At around 21 UTC, the storm crossed the Nii-jima Islands in the northern Izu Archipelago. The storm eventually transitioned into an extratropical low and was last tracked by PAGASA at 06 UTC on 28 June.

Far from the Philippine landmass throughout its period of existence, Dodong did not directly bring heavy rainfall in the country. However, the Southwest Monsoon and the monsoon trough where it was originally embedded resulted in storm-duration rainfall of 30 to 100 mm over the western portion of Central Luzon, portions of CALABARZON and Metro Manila, Palawan, and the western portion of Mindoro. However, the enhancement of monsoon activity by Dodong was minimal.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Tanay, Rizal: 111.4 mm, 25 June 2019
- Coron, Palawan: 81.0 mm, 25 June 2019
- Catbalogan City, Samar: 53.8 mm, 26 June 2019

Highest storm duration (25 to 26 June 2019) rainfall over land:

- Tanay, Rizal: 126.6 mm
- Coron, Palawan: 86.6 mm
- Iba, Zambales: 64.5 mm

Summary of Warning Information

Number of public TC products issued: **10**

- Severe Weather Bulletins: **4**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **6**

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

Number of casualties: **Not provided**

Combined cost of damage: **Not provided**

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

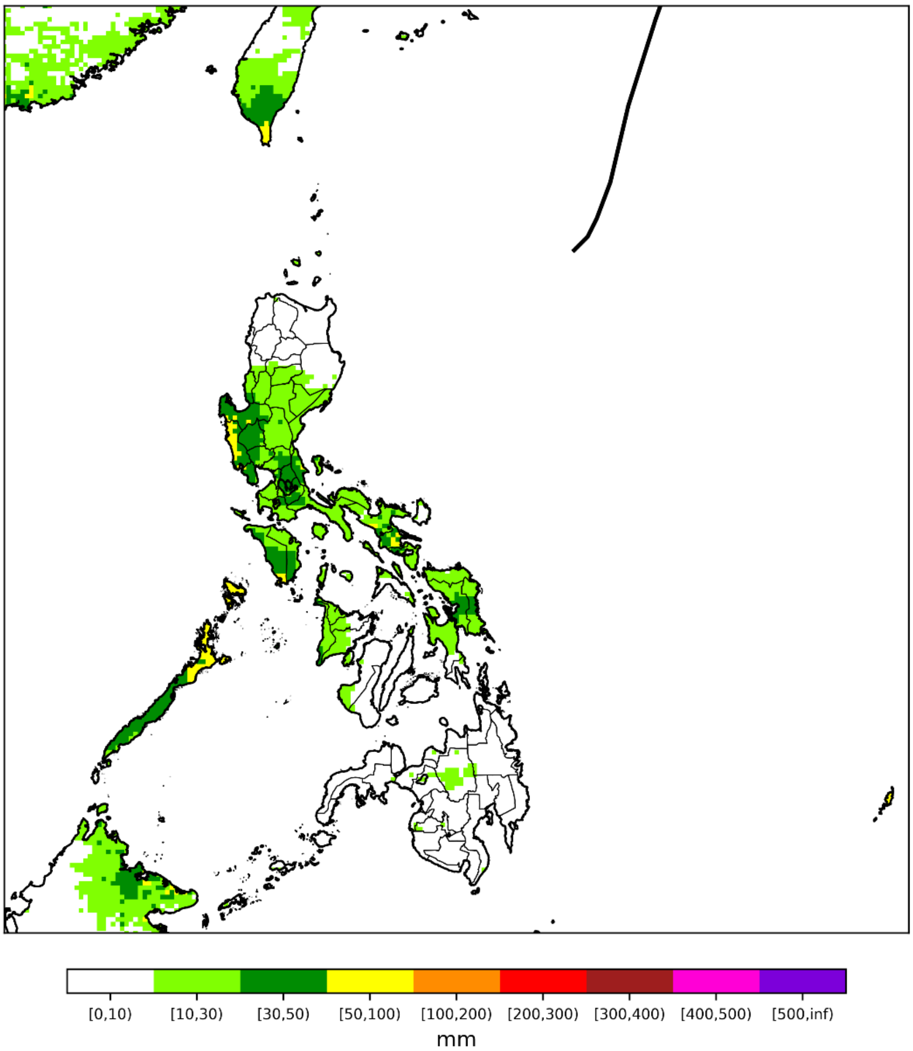

Fig 4.4.2. PAGASA best track of Tropical Storm Dodong (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 25 to 26 June 2019.

TROPICAL DEPRESSION EGAY

28 June to 02 July 2019

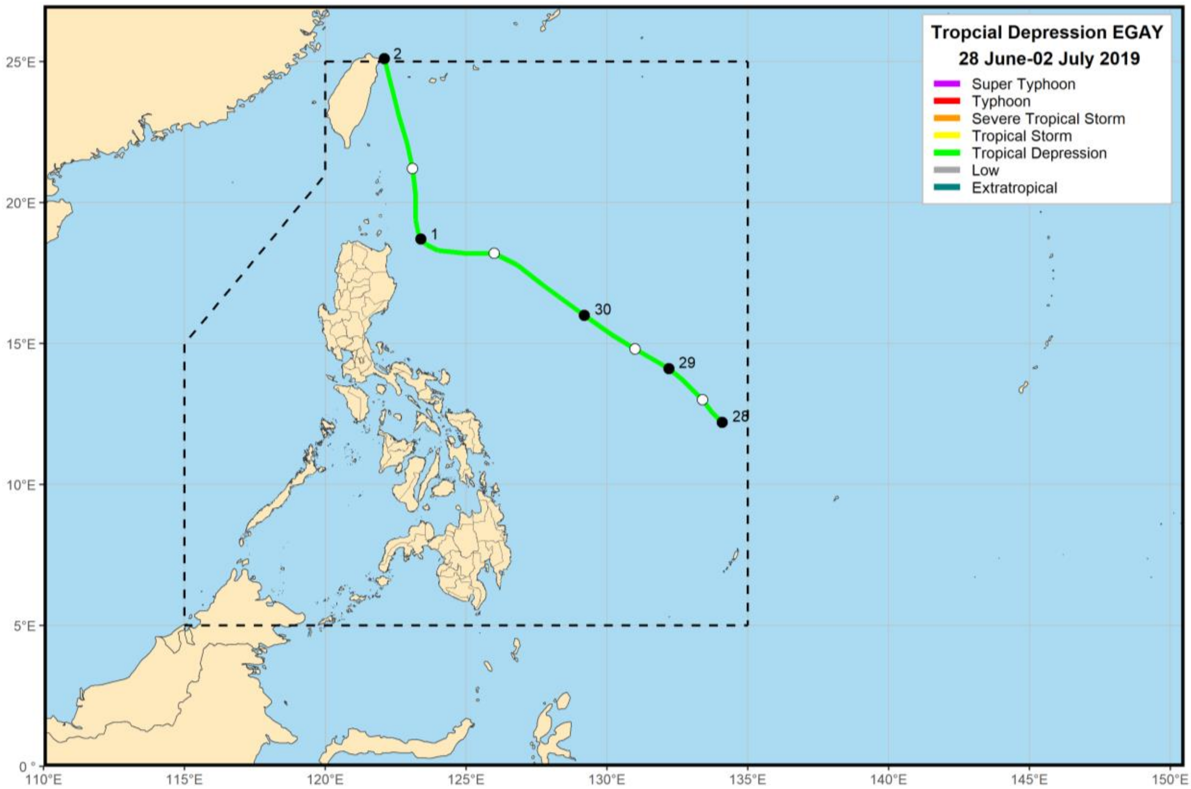

Fig 4.5.1. PAGASA best track positions and intensities of Tropical Depression Egay. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

Following the occurrence of Tropical Storm Dodong, another low pressure area embedded within the active monsoon trough was first noted as a tropical depression at 00 UTC on 28 June. Egay, as it was domestically named, remained a weak depression throughout its existence. Egay tracked generally northwestward until 12 UTC on 30 June, when it started turning westward and neared Extreme Northern Luzon. However, the depression turned northward on early on 01 July and moved over the sea east of Batanes and Babuyan Islands. Egay weakened into an area of low pressure at 00 UTC on 02 July as it left the PAR and passed very close to the northeastern corner of Taiwan.

The monsoon trough was active during the occurrence of Egay and during its period of occurrence within the PAR region, accumulated rainfall of at least 50 mm were observed over the western portions of Luzon and Visayas, as well as in some areas in the Bicol Region. Rainfall estimates revealed that the Zambales-Bataan area received the brunt of the monsoon rains, with rainfall totals reaching 200-300 mm in most areas. Furthermore, there were isolated areas (i.e., in the areas near Subic Bay) over these provinces that received between 300 and 400 mm of rainfall based on corroborating data from satellite and ground measurements.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Subic Bay International Airport, Morong, Bataan: 135.5 mm, 01 July 2019
- Clark International Airport, Mabalacat, Pampanga: 114.8 mm, 01 July 2019
- Subic Bay International Airport, Morong, Bataan: 100.0 mm, 28 June 2019
- Cuyo, Palawan: 100.0 mm, 30 June 2019

Highest storm duration (28 June to 01 July 2019) rainfall over land:

- Subic Bay International Airport, Morong, Bataan: 370.5 mm
- Iba, Zambales: 257.5 mm
- Clark International Airport, Mabalacat, Pampanga: 180.7 mm

Highest peak gust over land:
Basco, Batanes: W (280°) at 31.1 kt (16 m/s), 0740 UTC, 01 July 2019

Lowest sea level pressure over land:

- Baguio City: 1000.5 hPa, 0600 UTC, 30 June 2019
- Tuguegarao City, Cagayan: 1000.7 hPa, 0900 UTC, 30 June 2019
- Basco, Batanes: 1001.0 hPa, 0900 UTC, 01 July 2019

Summary of Warning Information

Number of public TC products issued: **13**

- Severe Weather Bulletins: **9**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **4**

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

Number of localities under TC Wind Signal (TCWS): **2**

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

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **Not provided**

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

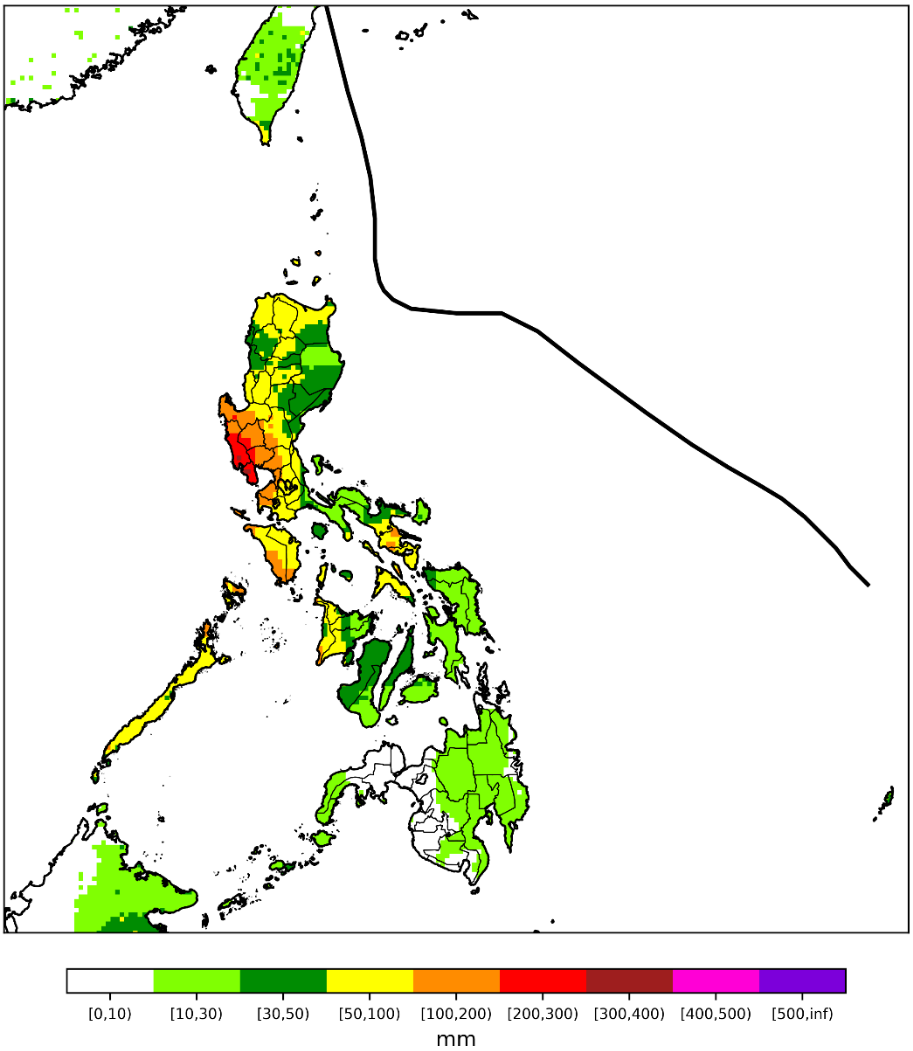

Fig 4.5.2. PAGASA best track of Tropical Depression Egay (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 28 June to 01 July 2019.

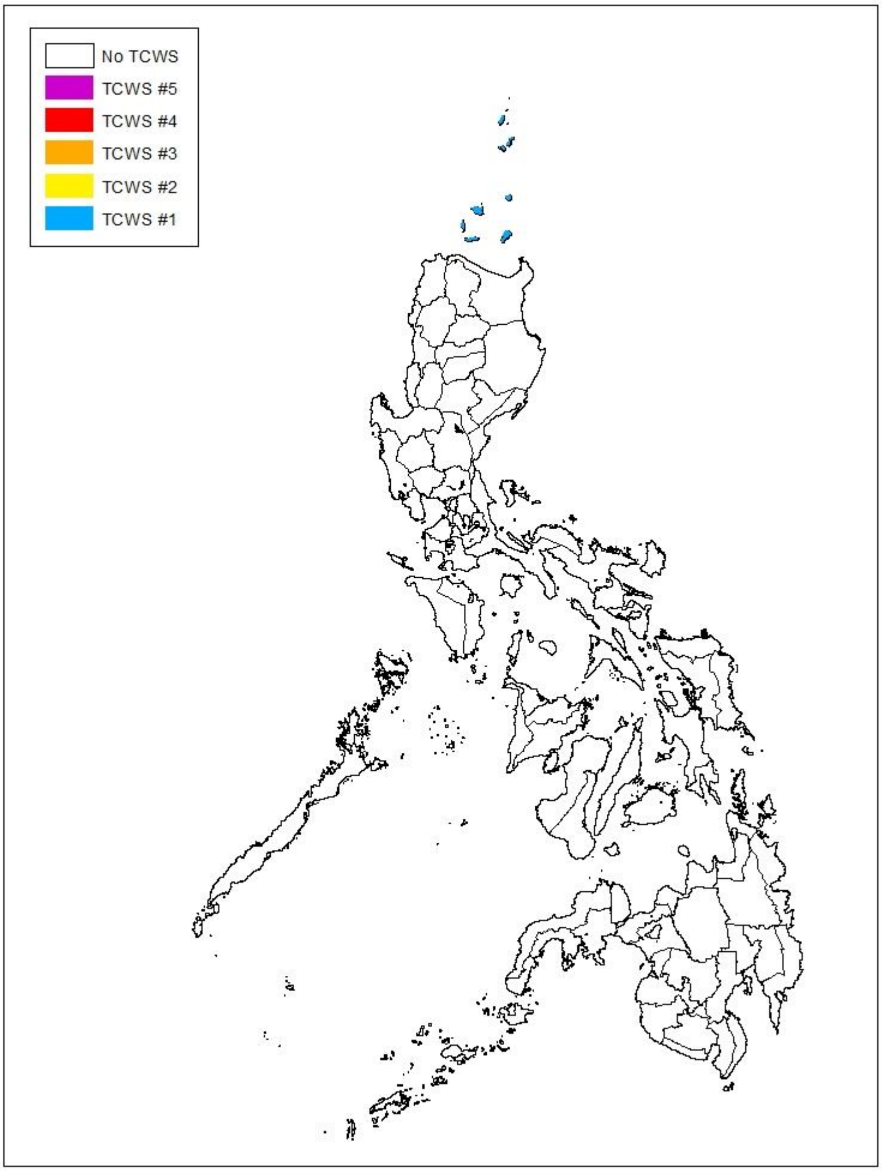

Fig 4.5.3. Highest wind signal hoisted by PAGASA during the occurrence of Tropical Depression Egay.

TROPICAL STORM FALCON (DANAS)

14 to 21 July 2019

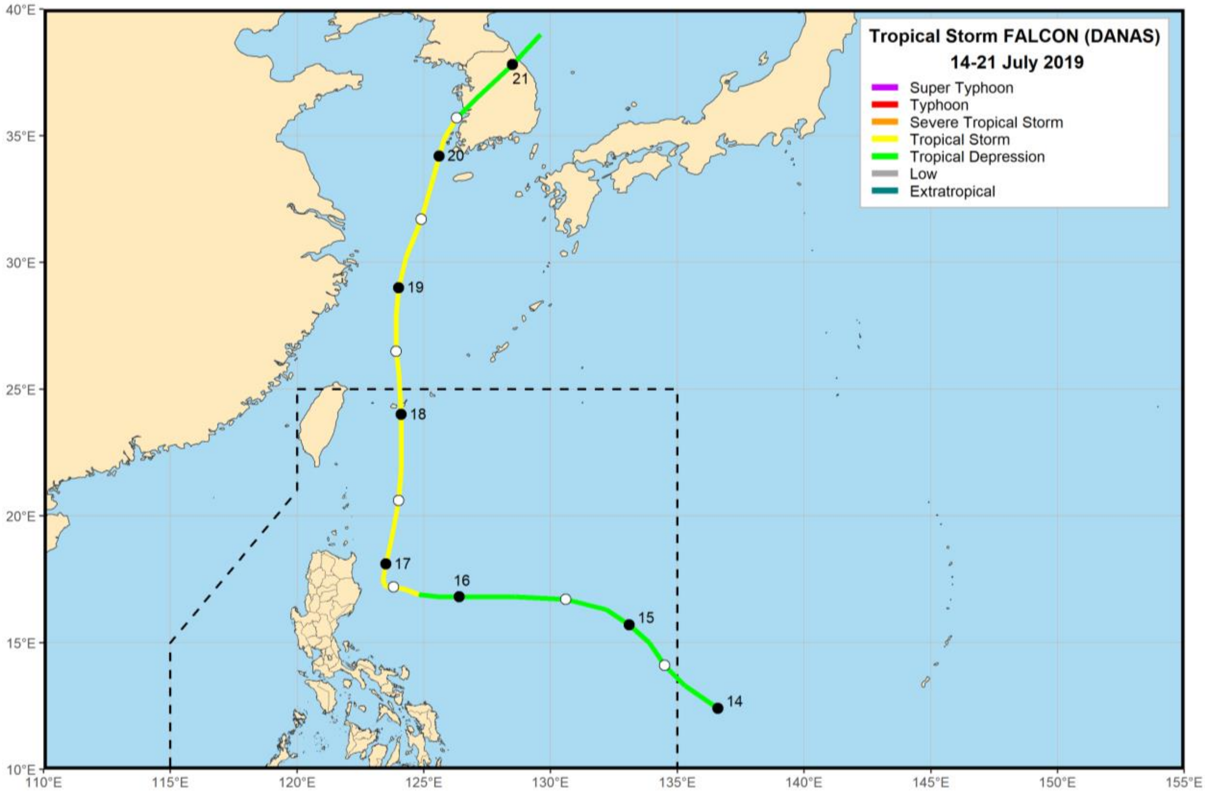

Fig 4.6.1. PAGASA best track positions and intensities of Tropical Storm Falcon. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

With the monsoon trough extending over the Philippine Sea, an embedded tropical disturbance outside the PAR region was first noted as a tropical depression at 00 UTC on 14 July while situated more than 700 km west of Guam. Moving northwestward, Falcon entered the PAR region at 08 UTC of the same day. At around 06 UTC of the following day, the depression started turning more westward towards the direction of Northern Luzon. On 16 July, Falcon started to decelerate as it moved closer to the waters off the east coast of Cagayan Valley and at around 15 UTC of that day, the storm became almost stationary as it started to pivot to a more northward heading. Vertical wind shear and interaction with the rugged landmass of Luzon displaced much of the convection of Falcon to the west and resulted in the formation of a remote low over the waters west of Ilocos Region. This low eventually developed into Tropical Depression Goring. While operational analysis suggested that Falcon made landfall over Northern Luzon, a best track analysis indicated that Falcon remained offshore.

During the early hours of the following day, Falcon started to accelerate north northeastward, then northward over the northern region of the Philippine Sea towards the southern portion of the Ryukyu Islands. Shortly past 00 UTC on 18 July, the storm crossed the islands of Taketomi and Ishigaki and at 04 UTC of the same day, Falcon exited the PAR.

Outside the PAR, Falcon continued moving northward over the East China Sea throughout 18 July. At 12 UTC of the same day, the storm reached a peak intensity of 45 kt and 985 hPa. A turn to the north northeast was observed the following day as it moved closer towards the Korean Peninsula. At around 13 UTC on 20 July, Falcon made landfall as a tropical depression in the vicinity of North Jeolla Province near Gunsan City in South Korea. The depression traversed the peninsula throughout the remainder of

20 July and during the early hours of 21 July. After emerging over the Sea of Japan, Falcon transitioned into an extratropical low at 06 UTC on 21 July.

The passage of Tropical Storm Falcon resulted in the enhancement of the monsoon southwesterly flow over the country. This, along with the displaced convection of Falcon which resulted in the formation of the remote low which eventually became Tropical Depression Goring, resulted in large areas of western Luzon and Visayas receiving five-day rainfall in excess of 100 mm and scattered areas over the rest of Luzon and Visayas experiencing total rainfall of at least 50 mm over a five-day period. Rainfall estimates show that the northwestern portion of Luzon (Ilocos Region, and the western portion of Cordillera Administrative Region) and the extreme northern portion of Palawan including Calamian and Kalayaan Islands received the brunt of rainfall during the occurrence of Falcon, with rainfall totals reaching 200-300 mm in most areas.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Laoag City, Ilocos Norte: 181.8 mm, 16 July 2019
- Juban, Sorsogon: 145.2 mm, 15 July 2019
- Coron, Palawan: 133.4 mm, 16 July 2019

Highest storm duration (14 to 18 July 2019) rainfall over land:

- Coron, Palawan: 270.2 mm
- Laoag City, Ilocos Norte: 253.2 mm
- Baguio City: 190.8 mm

Highest peak gust over land:

- Basco, Batanes: NE (50°) at 48.6 kt (25 m/s), 2240 UTC, 16 July 2019
- Aparri, Cagayan: NNE (30°) at 38.9 kt (20 m/s), 1017 UTC, 16 July 2019
- Baler, Aurora: W (260°) at 35.0 kt (18 m/s), 1758 UTC, 16 July 2019

Lowest sea level pressure over land:

- Casiguran, Aurora: 994.0 hPa, 2001 UTC, 16 July 2019
- Laoag City, Ilocos Norte: 995.0 hPa, 0810 UTC, 17 July 2019
- Basco, Batanes: 995.1 hPa, 1000 UTC, 17 July 2019

Summary of Warning Information

Number of public TC products issued: **26**

- Severe Weather Bulletins: **17**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **9**

Number of TC Warning for Shipping issued: **15**

Number of localities under TC Wind Signal (TCWS): **12**

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

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **PHP 745,320.00**

- Damage to agriculture: **PHP 745,320.00**
- Damage to infrastructure: **Not provided**

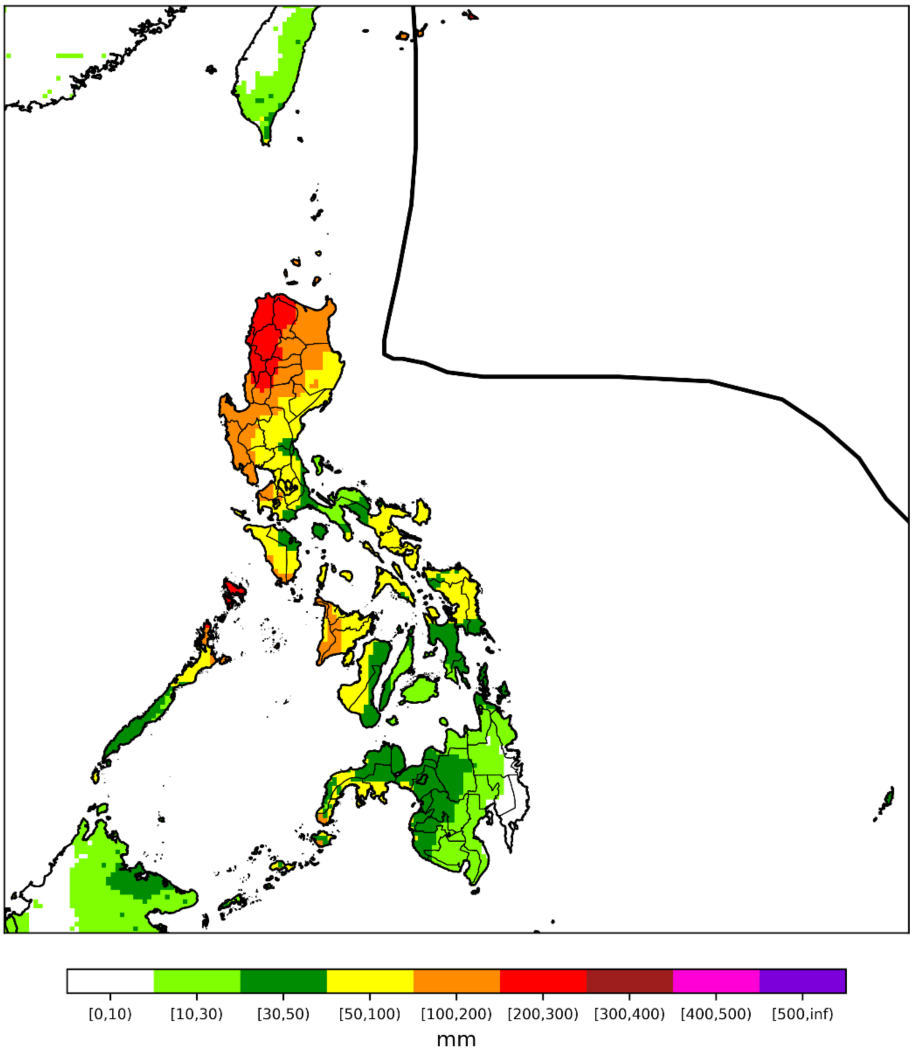

Fig 4.6.2. PAGASA best track of Tropical Storm Falcon (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 14 to 18 July 2019.

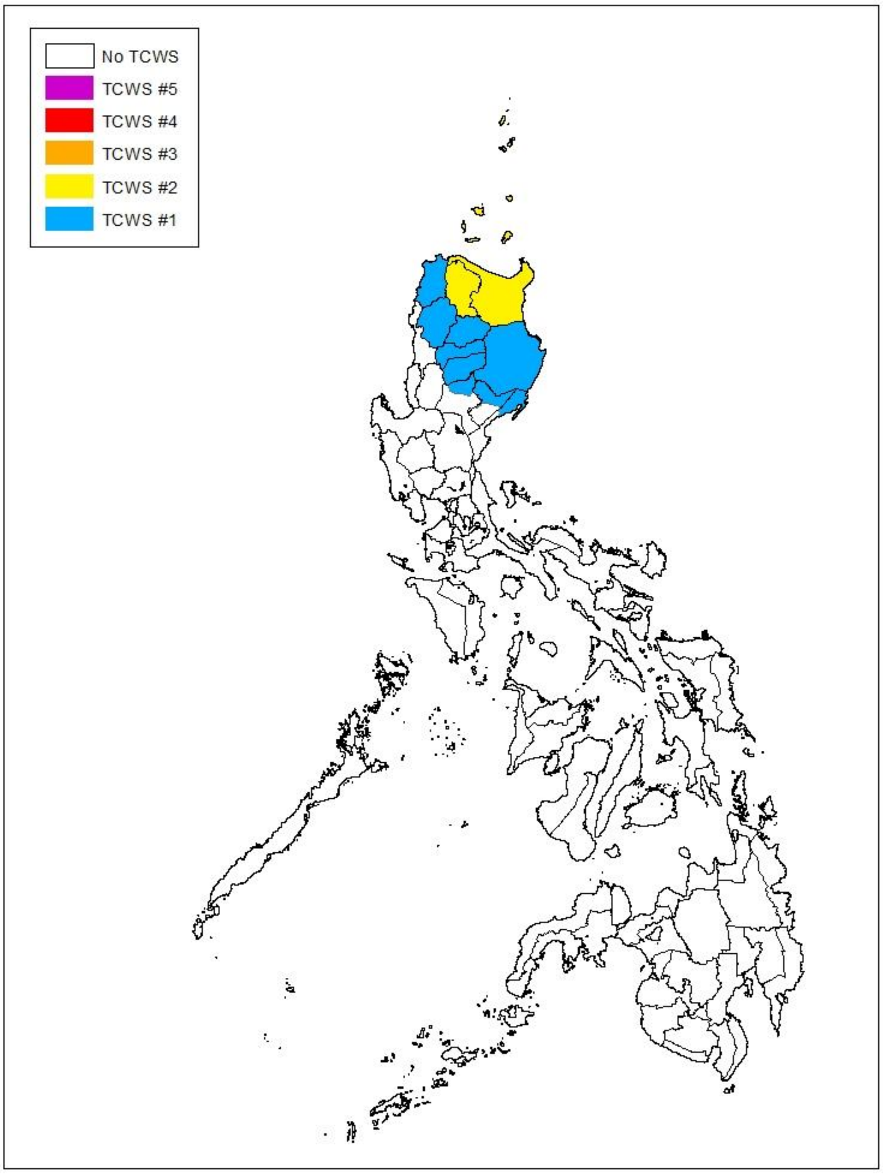

Fig 4.6.3. Highest wind signal hoisted by PAGASA during the occurrence of Tropical Storm Falcon.

TROPICAL DEPRESSION GORING

17 to 19 July 2019

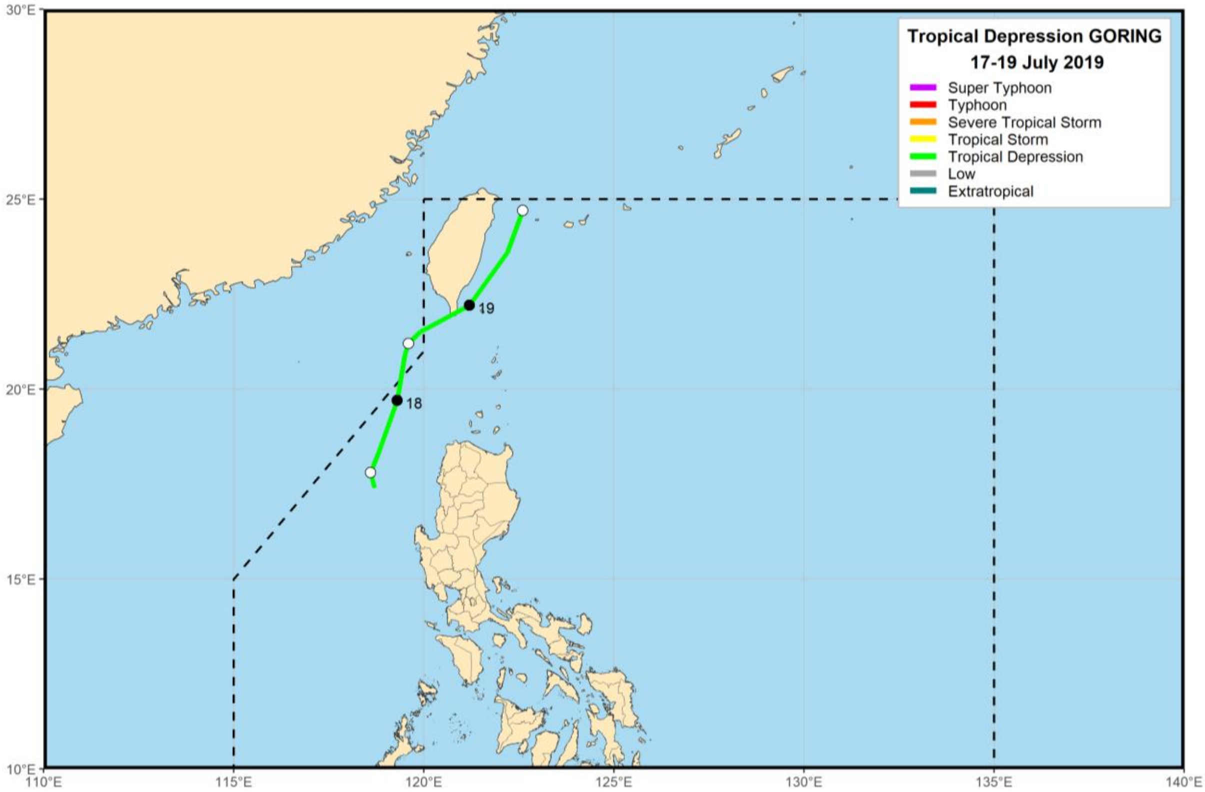

Fig 4.7.1. PAGASA best track positions and intensities of Tropical Depression Goring. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

Tropical Depression Goring originated from the remote area of low pressure that was induced by the interaction of Tropical Storm Falcon with the rugged landmass of Luzon and the displaced convection of the said storm due to prevailing vertical wind shear. Goring was first noted as a tropical depression at 06 UTC on 17 July while over the West Philippine Sea west of Ilocos Region. It initially tracked north northeastward for roughly 24 hours, bringing its center outside the PAR region for a brief period.

At 12 UTC on 18 July, Goring turned northeastward and shortly past 18 UTC, it reentered the PAR region. At around 22 UTC on 18 July, the depression made landfall in the southern portion of Pingtung Country in Taiwan. After crossing the southern tip of Taiwan, the Goring turned north northeastward on 19 July and moved parallel to the east coast of Taiwan. At 12 UTC on the same day, the depression degenerated into an area of low pressure. Its remnants were absorbed by circulation of Tropical Storm Falcon.

The occurrence of Goring within the PAR region coincided with the passage of Tropical Storm Falcon. Although the depression remained offshore throughout its occurrence and Falcon was already moving generally northward away from northern Luzon, both systems continued to enhance the prevailing Southwest Monsoon. This resulted in monsoon rains in excess of 50 mm for a period of three days over Ilocos Region, Zambales, Bataan, Tarlac, and the western provinces of the Cordillera Administrative Region. Rainfall estimates revealed that Zambales, Pangasinan, Benguet, and southern Ilocos Sur received the highest accumulated rainfall during the occurrence of Goring, with rainfall totals reaching 100-200 mm.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Baguio City: 74.6 mm, 17 July 2019
- Subic Bay International Airport, Morong, Bataan: 70.4 mm, 17 July 2019
- Laoag City, Ilocos Norte: 64.8 mm, 18 July 2019

Highest storm duration (17 to 19 July 2019) rainfall over land:

- Baguio City: 144.0 mm
- Subic Bay International Airport, Morong, Bataan: 134.3 mm
- Iba, Zambales: 116.1 mm

Summary of Warning Information

Number of public TC products issued: **4**

- Severe Weather Bulletins: **3**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **1**

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

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: **Not provided**

Combined cost of damage: **Not provided**

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

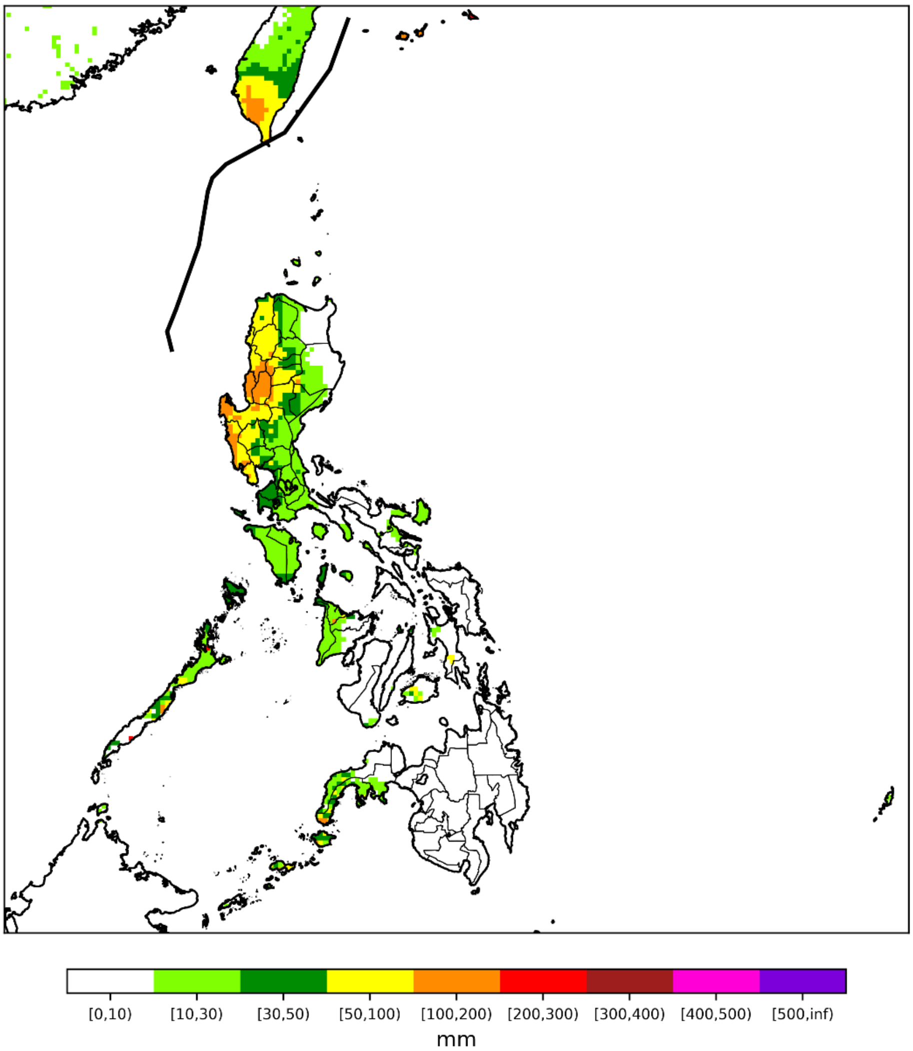

Fig 4.7.2. PAGASA best track of Tropical Depression Goring (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 17 to 19 July 2019.

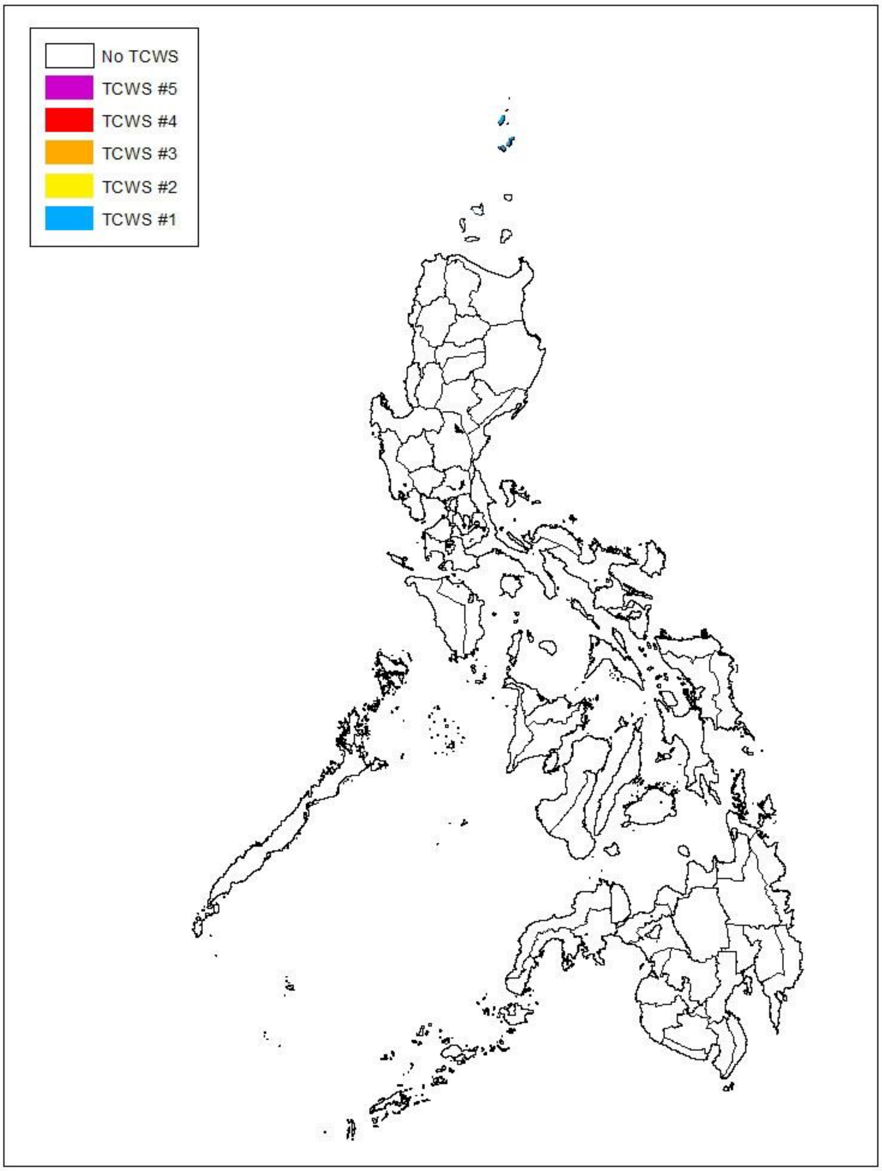

Fig 4.7.3. Highest wind signal hoisted by PAGASA during the occurrence of Tropical Depression Goring.

TYPHOON HANNA (LEKIMA)

03 to 14 August 2019

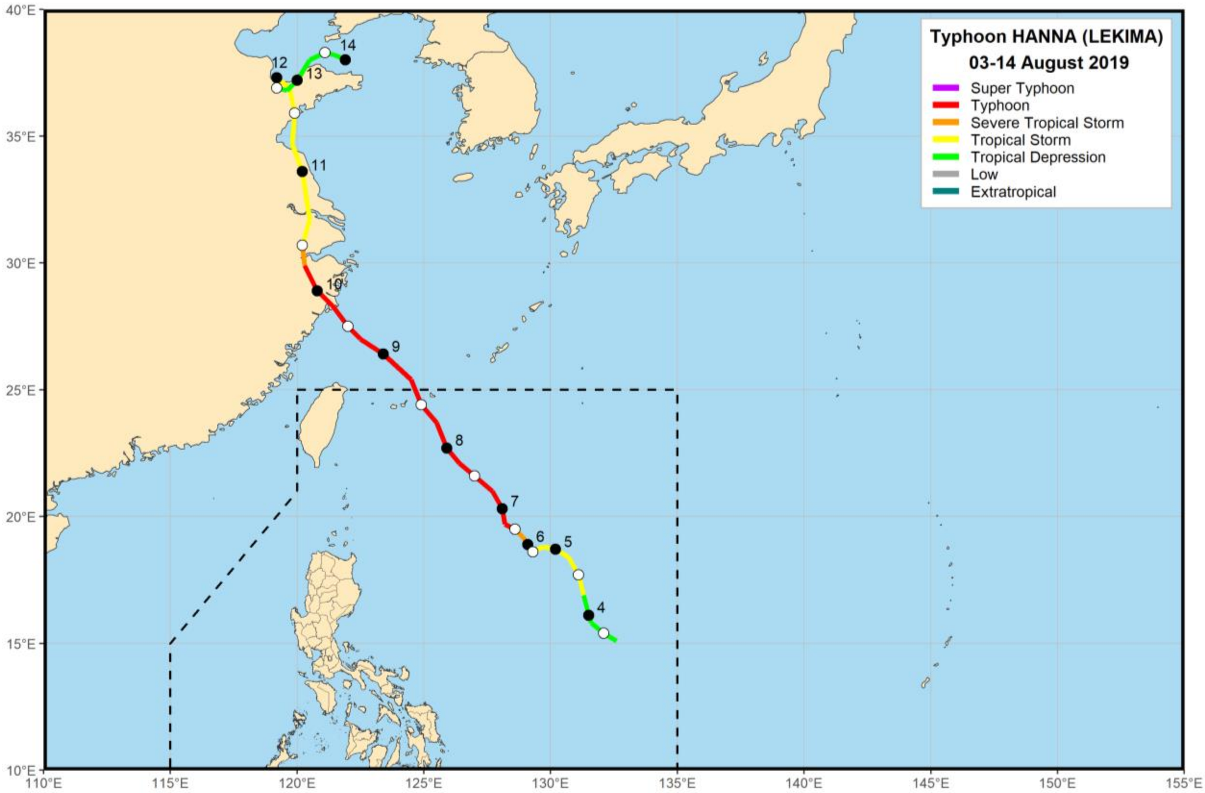

Fig 4.8.1. PAGASA best track positions and intensities of Typhoon Hanna. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

Hanna, the first tropical cyclone to reach typhoon category within the PAR region, was first tracked as a tropical depression at 06 UTC on 03 August while over the central portion of the Philippine Sea nearly 1000 km from the coast of Central Luzon. Moving north northwestward, Hanna was upgraded to tropical storm roughly 24 hours after formation. Intensification slowed down on 05 August as storm turned westward and became almost stationary in the absence of a steering current. At 18 UTC of the same day, Hanna reached severe tropical storm category.

In the presence of a growing subtropical ridge, Hanna turned northwestward and began accelerating the following day. At 12 UTC on 06 August, Hanna intensified into a typhoon. Environmental conditions allowed the typhoon to undergo rapid intensification and by 12 UTC on 08 August, the typhoon reached its peak intensity of 105 kt and 925 hPa as it passed between the islands of Tarama and Miyako in the Ryukyu Archipelago. The eye of the typhoon left the PAR at 16 UTC of the same day as it entered the East China Sea.

Shortly after reaching its peak intensity, Hanna started to weaken as it underwent an eyewall replacement cycle. Environmental conditions over the East China Sea further contributed to the weakening trend. At 1745 UTC on 09 August, the typhoon made landfall in the vicinity of Wenling City in China's Zhenjiang Province. Hanna was downgraded to severe tropical storm category at 06 UTC of the following day and to tropical storm category six hours after as it moved inland in a more northward path. The storm emerged over the Yellow Sea at around 06 UTC on 11 August and made its second landfall in the Qingdao City, Shandong Province at around 12 UTC of the same day. Hanna meandered in the vicinity of Shandong Peninsula and Bohai Sea over the next two days. The cyclone was last tracked at 00 UTC on 14 August when it transitioned into an extratropical low.

Despite remaining far from the Philippine archipelago, the passage of Typhoon Hanna over the northeastern region of the PAR resulted in the enhancement of the westerlies associated with the prevailing Southwest Monsoon. Over a period of six days, more than 50 mm of rainfall were experienced over Ilocos Region, Cordillera Administrative Region, Metro Manila, the northern portion of MIMAROPA, and most of Central Luzon, CALARBARZON, and Western Visayas. Higher rainfall totals were observed over the western portions of these areas, with rainfall estimates showing a rainfall maximum region over the extreme northern portion of mainland Palawan, Calamian Islands, and coastal areas of southwestern Mindoro wherein total rainfall is more than 300 mm. In particular, the monsoon rainfall for Calamian Islands exceeded 500 mm based on both satellite-based estimates and ground observations. Another rainfall maximum region was also observed over the Zambales-Bataan-western Pangasinan area, with total rainfall generally reaching 200-300 mm (and isolated areas along the coast of Zambales reaching 300-400 mm of rain).

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Coron, Palawan: 221.2 mm, 05 August 2019
- Subic Bay International Airport, Morong, Bataan: 153.5 mm, 03 August 2019
- Iba, Zambales: 139.0 mm, 03 August 2019

Highest storm duration (03 to 08 August 2019) rainfall over land:

- Coron, Palawan: 533.8 mm
- Subic Bay International Airport, Morong, Bataan: 333.8 mm
- San Jose, Occidental Mindoro: 333.5 mm

Summary of Warning Information

Number of public TC products issued: **30**

- Severe Weather Bulletins: **16**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **14**

Number of TC Warning for Shipping issued: **22**

Number of localities under TC Wind Signal (TCWS): **2**

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

Summary of Casualties and Damage to Property

Number of casualties: **Not provided**

Combined cost of damage: **Not provided**

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

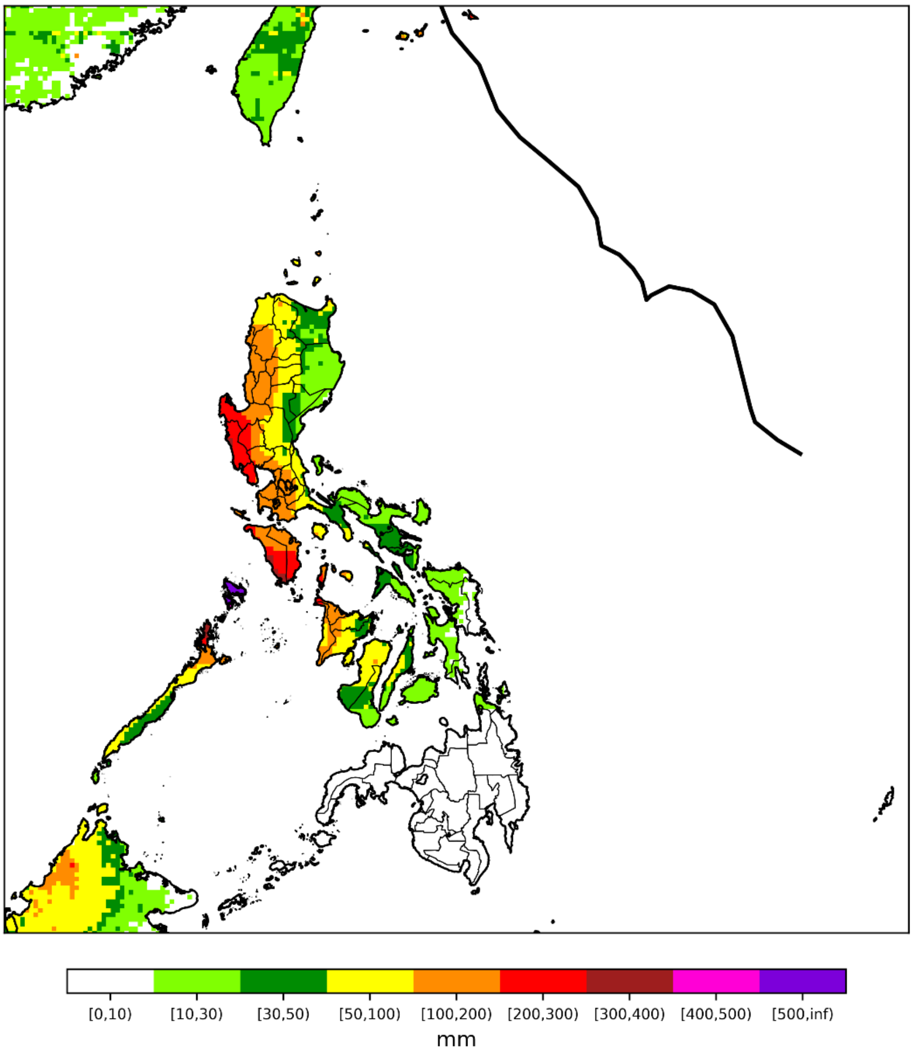

Fig 4.8.2. PAGASA best track of Typhoon Hanna (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 03 to 08 August 2019.

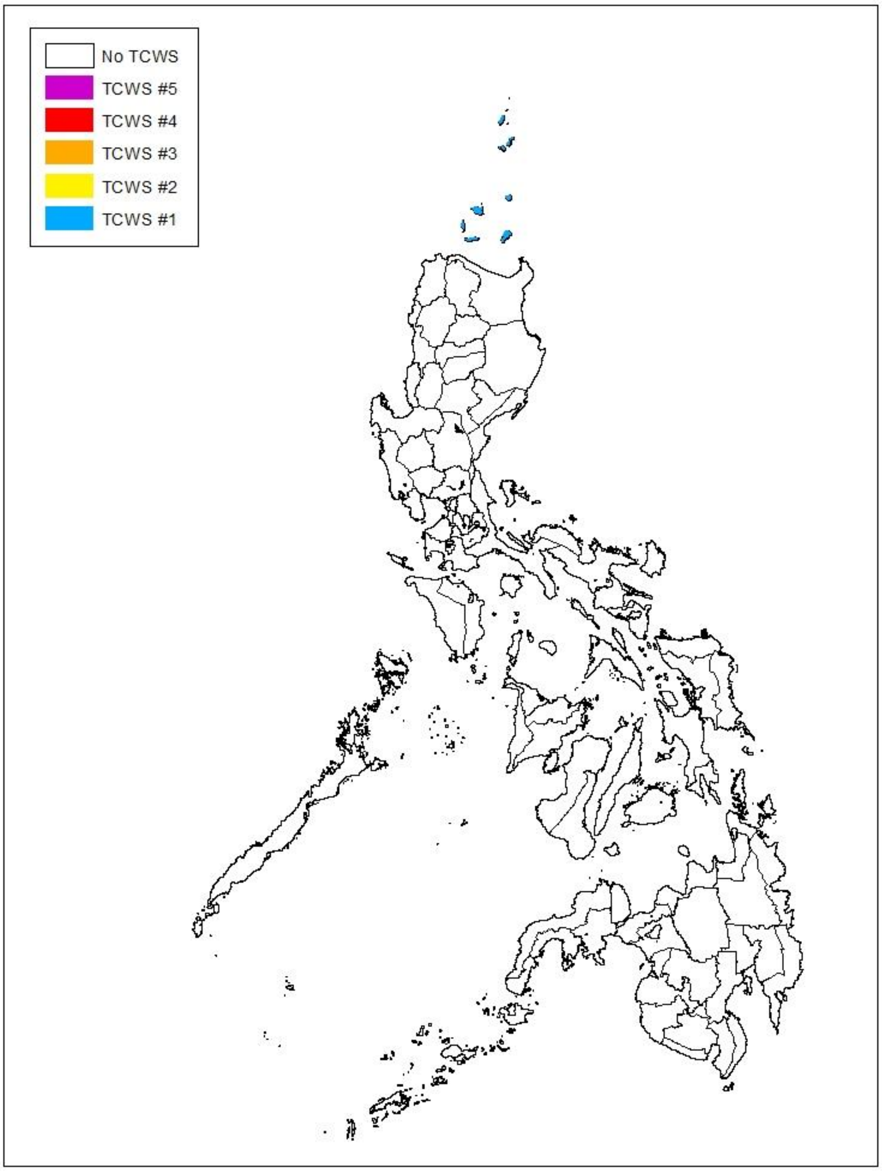

Fig 4.8.3. Highest wind signal hoisted by PAGASA during the occurrence of Typhoon Hanna.

SEVERE TROPICAL STORM INENG (BAILU)

19 to 26 August 2019

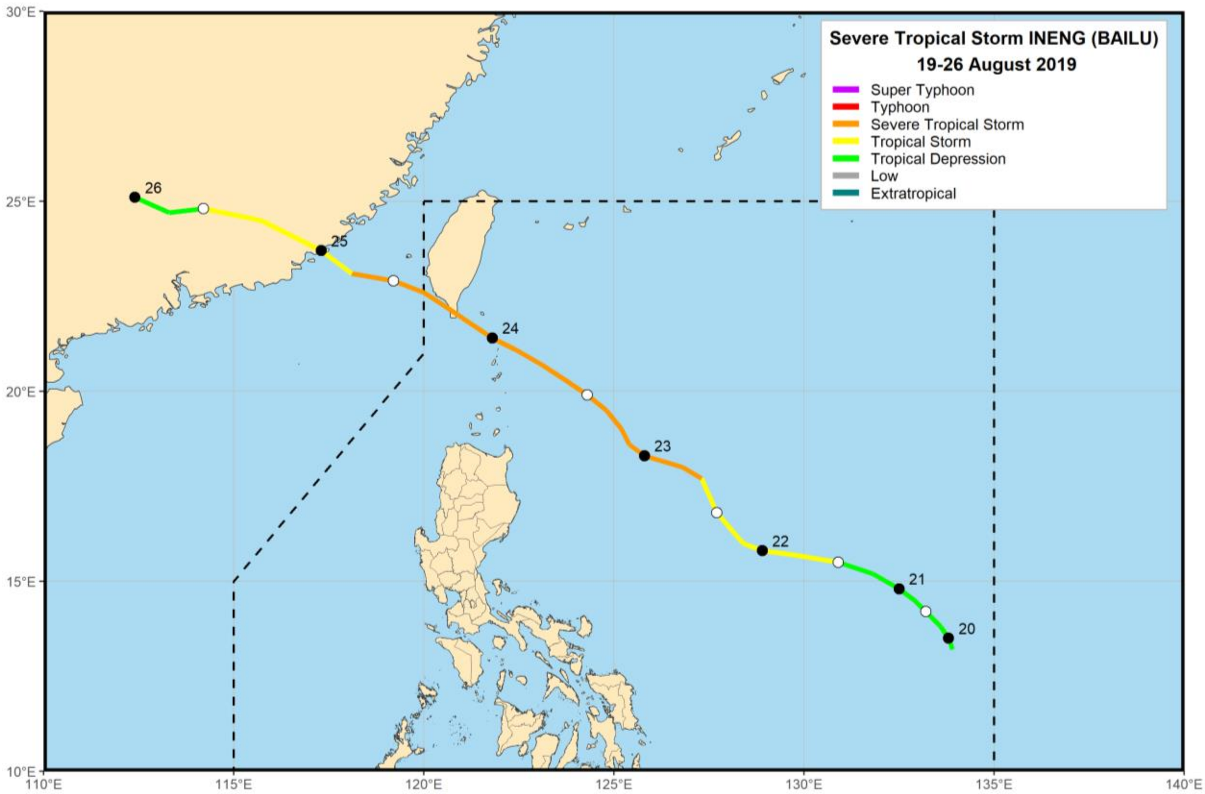

Fig 4.9.1. PAGASA best track positions and intensities of Severe Tropical Storm Ineng. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

The progenitor disturbance of would-be Severe Tropical Storm Ineng was first tracked as a tropical depression at 18 UTC on 19 August over the Philippine Sea nearly 1000 km from the east coast of Bicol Region. Tracking generally northwestward, Ineng gradually intensified over the Philippine Sea and at 12 UTC on 21 August, it was upgraded into a tropical storm. At 18 UTC on 22 August, while over the Philippine Sea more than 500 km from the east coast of Cagayan Valley, Ineng intensified into a Severe Tropical Storm. It made its closest point of approach to the Philippine archipelago between 21 UTC on 23 August and 00 UTC of the following day when it traversed the Bashi Channel close to Mavulis Island, the northernmost point of the country. At 15 UTC on 24 August, the center of Ineng made landfall in the vicinity of Manzhou Township, Pingtung County in the southern tip of Taiwan. The storm left the PAR region at 10 UTC on the same day as it entered the Strait of Taiwan towards southeastern China.

Outside the PAR, Ineng was downgraded into a tropical storm at 18 UTC on 24 August before making its final landfall in the vicinity of Dongshan County, Fujian Province at around 0535 UTC of the following day. The storm rapidly weakened as it moved inland over Fujian and Guangdong Provinces. Ineng weakened into a tropical depression at 12 UTC on 25 August and degenerated into a remnant low at 00 UTC of the next day. Its remnants eventually dissipated in less than 24 hours.

Much of Luzon, especially the northern provinces, were battered not only by Severe Tropical Storm Ineng but by the Southwest Monsoon that it enhanced during its passage over the Philippine Sea and Luzon Strait. At least 50 mm of accumulated rainfall was observed over the entire Northern and Central Luzon, Metro Manila, Bicol Region, Western Visayas, the extreme northern portion of Palawan including Calamian and Cuyo Islands, most of CALABARZON, Mindoro Provinces, and Central Visayas, and large areas of Northern Mindanao and Davao Region. Despite the proximity of the islands in Extreme Northern Luzon to the core of the storm, the highest rainfall totals were recorded over Ilocos Region, the western portion of Cordillera Administrative Region, Zambales, Bataan, and Calamian Islands. The six-day rainfall over these areas reached 300 mm for most areas, with higher rainfall totals between 300 and 500 mm were estimated or observed over Ilocos Norte, most of Abra, and the northern portion of Ilocos Sur.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Laoag City, Ilocos Norte: 471.8 mm (23 August 2019)
- Sinait, Ilocos Sur: 188.4 mm (23 August 2019)
- Aparri, Cagayan: 146.4 mm (23 August 2019)

Highest storm duration (19 to 24 August 2019) rainfall over land:

- Laoag City, Ilocos Norte: 572.2 mm
- Baguio City: 354.6 mm
- Iba, Zambales: 317.8 mm

Highest peak gust over land:

- Basco, Batanes: NNW (340°) at 58.3 kt (30 m/s), 1843 UTC, 23 August 2019
- Baler, Aurora: WNW (290°) at 42.8 kt (22 m/s), 0437 UTC, 23 August 2019
- Aparri, Cagayan: WNW (300°) at 25.3 kt (13 m/s), 0106 UTC, 23 August 2019

Lowest sea level pressure over land:

- Basco, Batanes: 987.7 hPa, 1900 UTC and 200 UTC, 23 August 2019
- Calayan, Cagayan: 996.8 hPa, 1800 UTC, 23 August 2019
- Aparri, Cagayan: 1000.3 hPa, 0800 UTC and 2200 UTC, 23 August 2019

Summary of Warning Information

Number of public TC products issued: **29**

- Severe Weather Bulletins: **18**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **11**

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

Number of localities under TC Wind Signal (TCWS): **7**

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

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **PHP 240,464,797.00**

- Damage to agriculture: **PHP 209,064,797.00**
- Damage to infrastructure: **PHP 31,400,000.00**

Note: Statistics for Ineng and Jenny were aggregated by the NDRRMC.

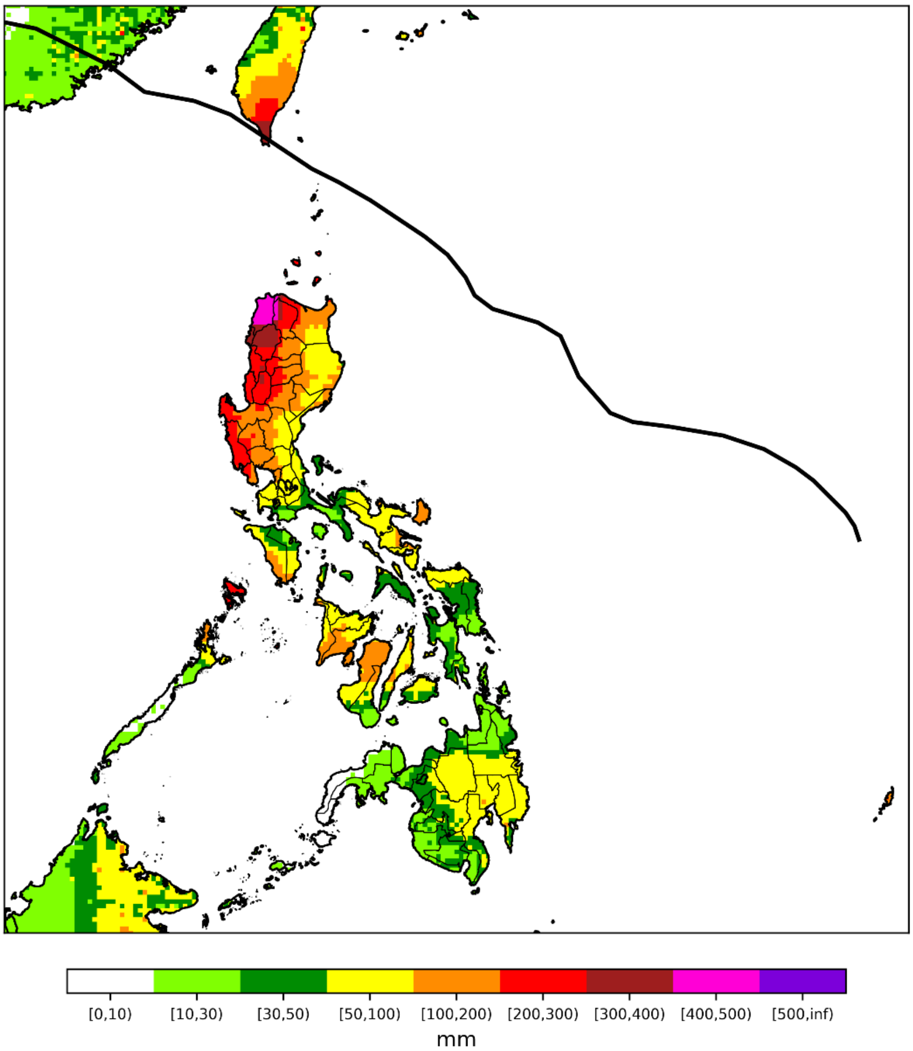

Fig 4.9.2. PAGASA best track of Severe Tropical Storm Ineng (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 19 to 24 August 2019.

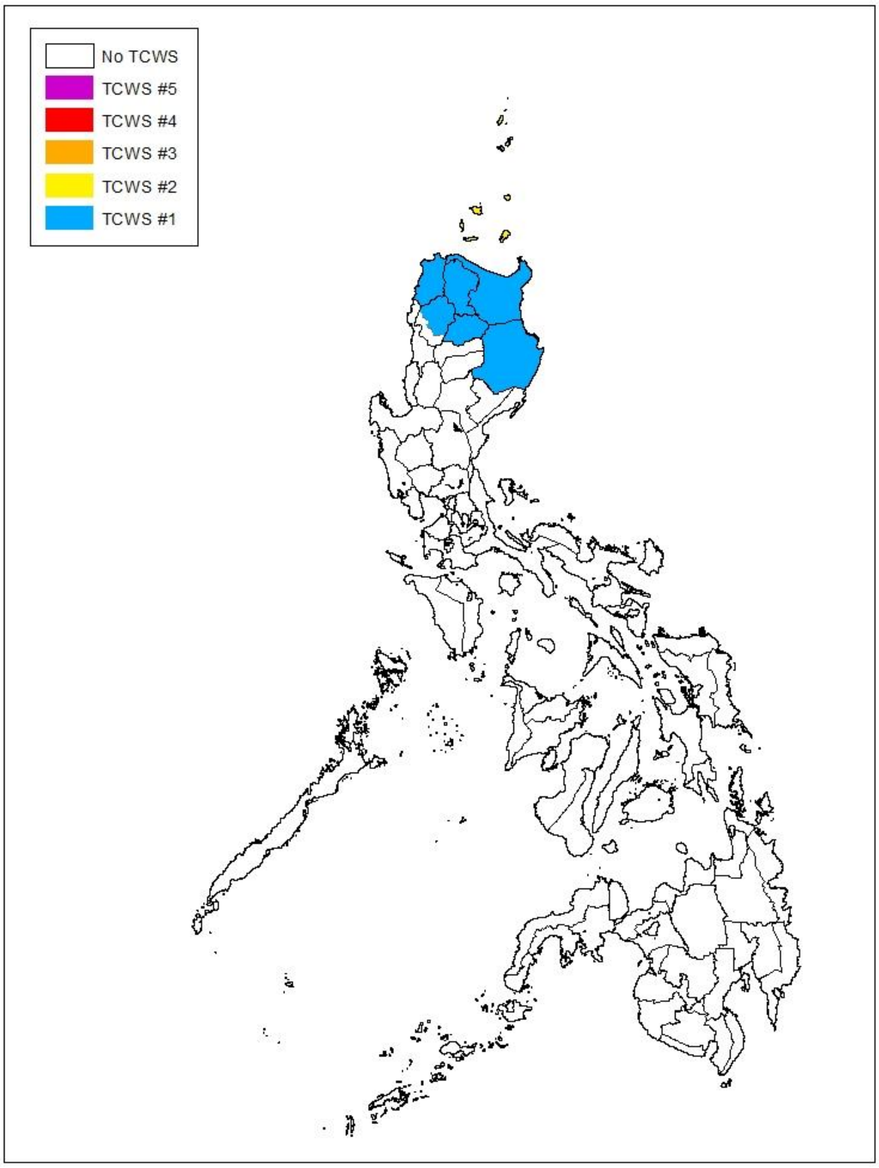

Fig 4.9.3. Highest wind signal hoisted by PAGASA during the occurrence of Severe Tropical Storm Ineng.

TROPICAL STORM JENNY (PODUL)

25 to 31 August 2019

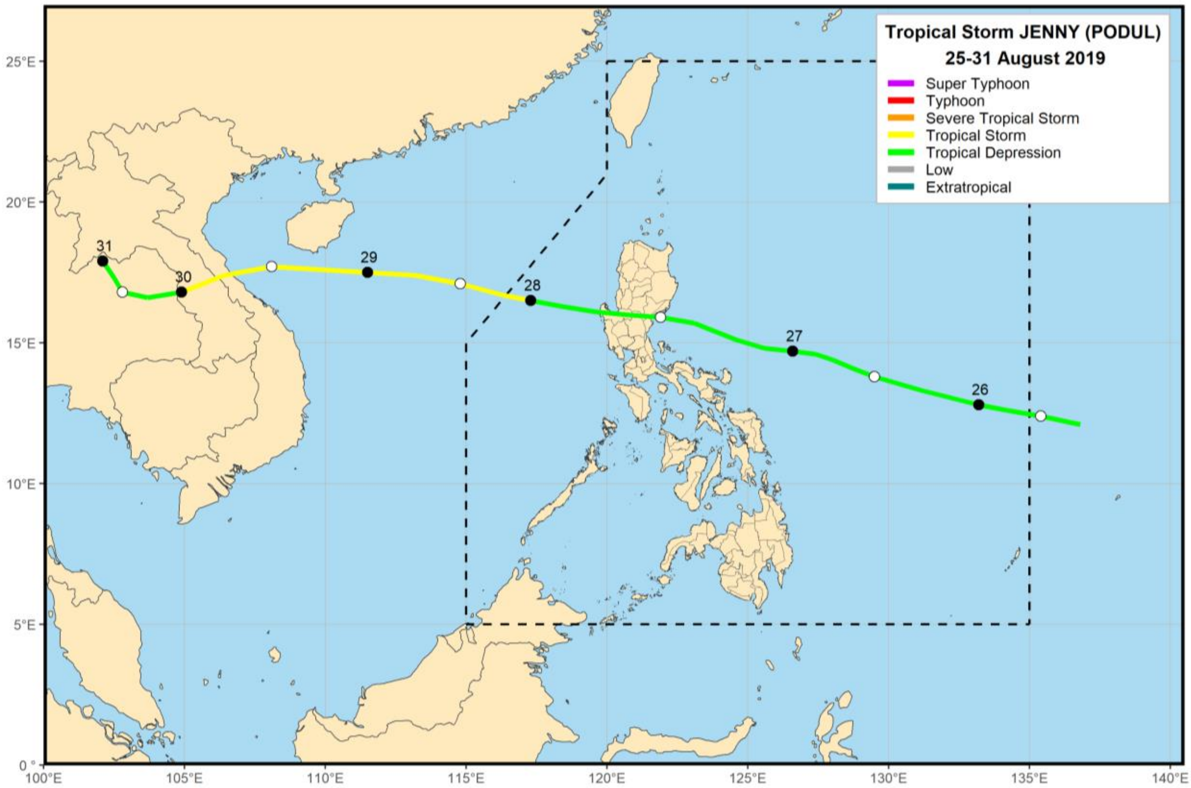

Fig 4.10.1. PAGASA best track positions and intensities of Tropical Storm Jenny. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

A broad area of low pressure from the Federated States of Micronesia was first tracked as a tropical depression at 06 UTC on 25 August. Moving generally west northwestward, Jenny entered the PAR region at 14 UTC on the same day. Over the next two days, the depression minimally intensified as it struggled to fully consolidate while moving towards Luzon. At around 1300 UTC, the center of Tropical Depression Jenny made landfall in the vicinity of Dipaculao, Aurora. Due to the weak nature of the low-level circulation of the depression at the time of landfall, it was able to traverse the width of Luzon landmass within roughly six hours, although it did not weaken or degenerate into a low pressure area during the process. Operational analysis showed that Jenny crossed Luzon as a tropical storm (which explains the hoisting of Tropical Cyclone Wind Signal #2) but be

Over the West Philippine Sea, Jenny continued moving west northwestward. It intensified into a tropical storm at 00 UTC on 28 August and left the PAR six hours later. Outside the PAR, Jenny turned more westward as it headed towards the central portion of Vietnam. Between 17 UTC and 18 UTC on 29 August, the storm made landfall in the vicinity of Hà Tĩnh Province in central Vietnam after turning west southwestward hours earlier. Weakening soon followed as the storm progressed further inland. At 00 UTC of the following day, the storm was downgraded to tropical depression category near the Laos-Thailand border. Jenny was last tracked at 00 UTC on 31 August as it degenerated into a remnant low in the vicinity of Udon Thani Province.

Rainfall estimates revealed that much of the heavy rainfall during the passage of Jenny was not observed in localities near the observed track of the cyclone. This was attributed to the disorganized nature of Jenny's convection, its fast forward speed, and the Southwest Monsoon that was slightly enhanced at the time of its passage. Accumulated rainfall throughout the period Jenny was inside the PAR reached in excess of 50 mm over Cagayan Valley, Cordillera Administrative Region, Ilocos Provinces, Zambales, Bataan, Cavite, southern Mindoro Provinces, extreme northern Palawan including Calamian and Cuyo Islands, Negros Provinces, Siquijor, and most of Bicol Region, Eastern Visayas, and Zamboanga Peninsula. Three rainfall maximum regions were noted in the isohyetal maps – over the northern provinces of northern Luzon regions, over the northern half of Samar Island, and over the western portion of Calamian Islands. These areas generally experienced as much as 100-200 mm of rainfall (with isolated area of 200-300 mm over extreme northwestern Cagayan.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
- Aparri, Cagayan: 125.6 mm, 27 August 2019
- Catarman, Northern Samar: 120.1 mm, 26 August 2019
- Catbalogan City, Samar: 113.4 mm, 26 August 2019

Highest storm duration (25 to 28 August 2019) rainfall over land:
- Aparri, Cagayan: 146.0 mm
- Catarman, Northern Samar: 130.1 mm
- Catbalogan City, Samar: 117.6 mm

Highest peak gust over land:
- Baguio City: E (100°) at 38.9 kt (20 m/s), 2235 UTC, 27 August 2019
- Basco, Batanes: ENE (60°) at 38.9 kt (20 m/s), 2022 UTC, 27 August 2019
- Baler, Aurora: W (270°) at 29.2 kt (15 m/s), 1400 UTC, 27 August 2019
- Virac, Catanduanes: W (270°) at 19.4 kt (10 m/s), 0151 UTC, 27 August 2019

Lowest sea level pressure over land:
- Baguio City: 998.9 hPa, 1900 UTC, 27 August 2019
- Sinait, Ilocos Sur: 1000.0 hPa, 1900 UTC, 27 August 2019
- Dagupan City, Pangasinan: 1000.4 hPa, 1900 UTC, 27 August 2019
- Baler, Aurora: 1000.4 hPa, 0800 UTC, 27 August 2019

Summary of Warning Information

Number of public TC products issued: **20**
- Severe Weather Bulletins: **14**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **6**

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

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

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

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **PHP 240,464,797.00**
- Damage to agriculture: **PHP 209,064,797.00**
- Damage to infrastructure: **PHP 31,400,000.00**

Note: Statistics for Ineng and Jenny were aggregated by the NDRRMC.

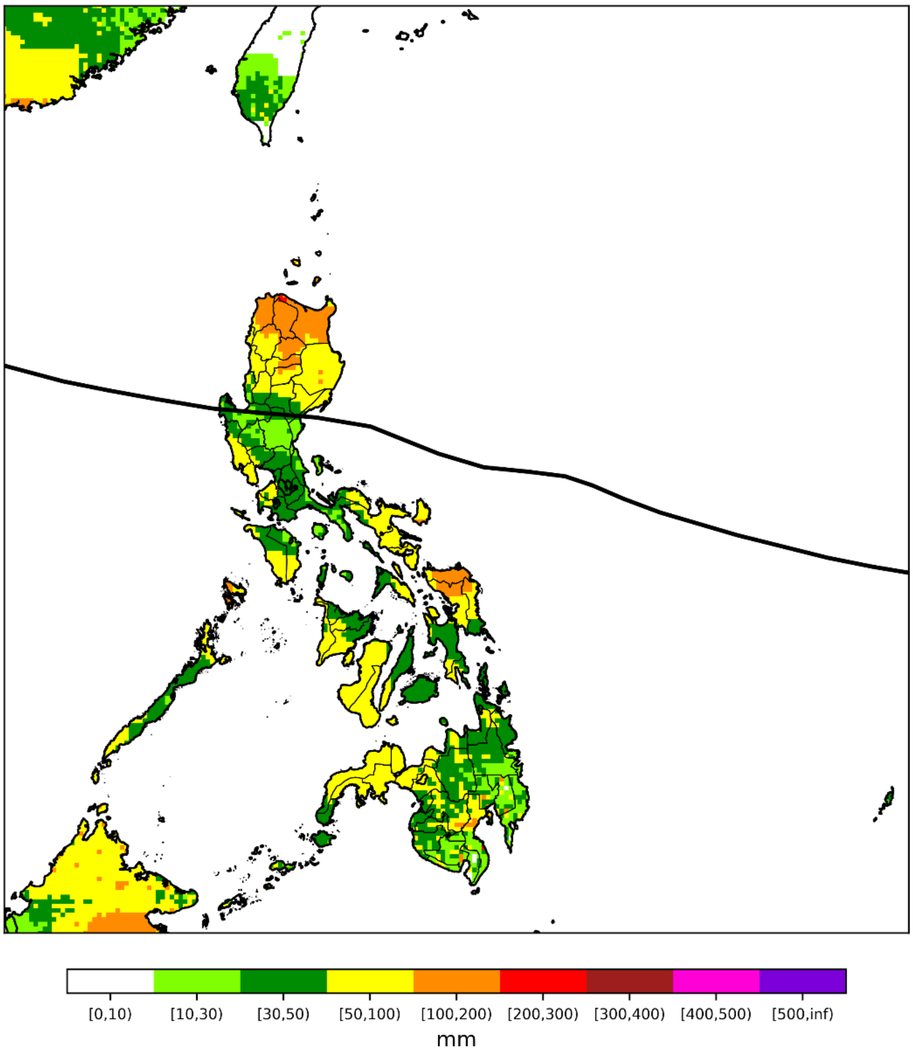

Fig 4.10.2. PAGASA best track of Tropical Storm Jenny (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 25 to 28 August 2019.

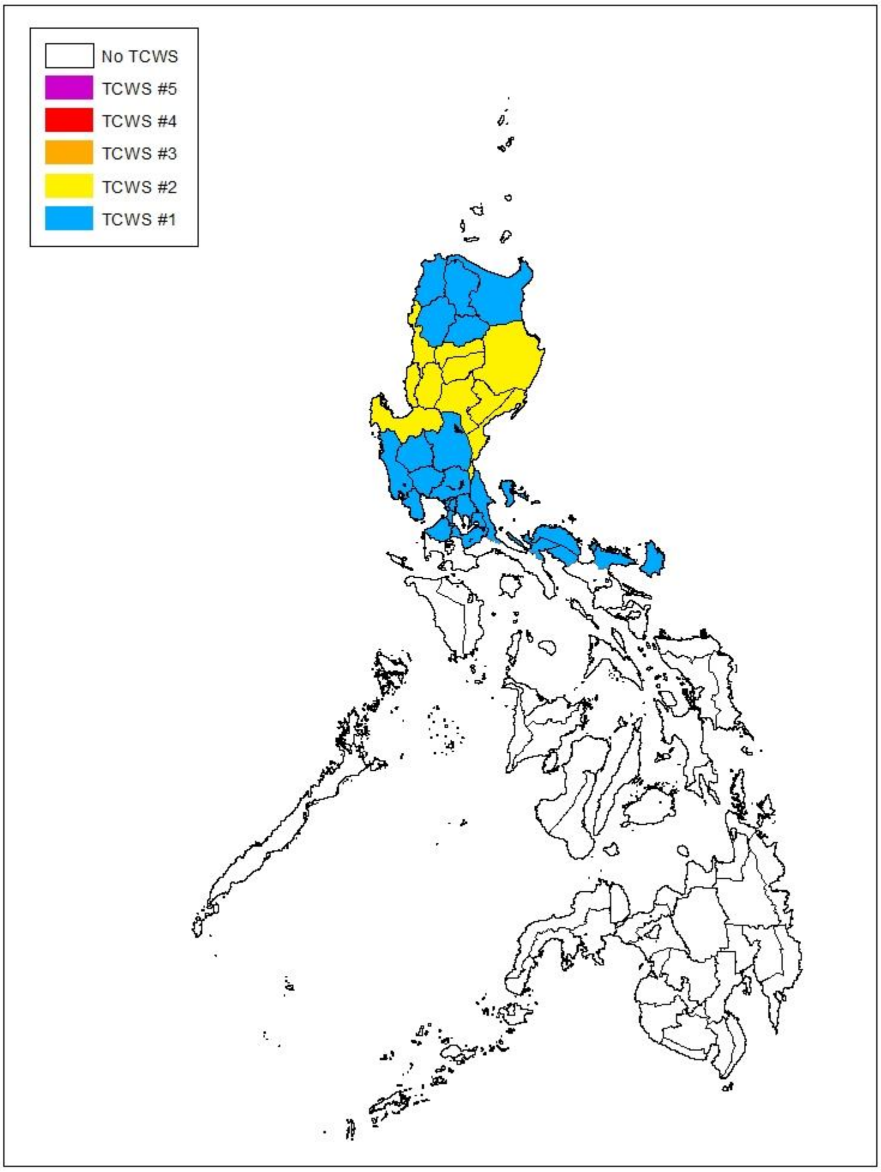

Fig 4.10.3. Highest wind signal hoisted by PAGASA during the occurrence of Tropical Storm Jenny.

TROPICAL STORM KABAYAN (KAJIKI)

31 August to 06 September 2019

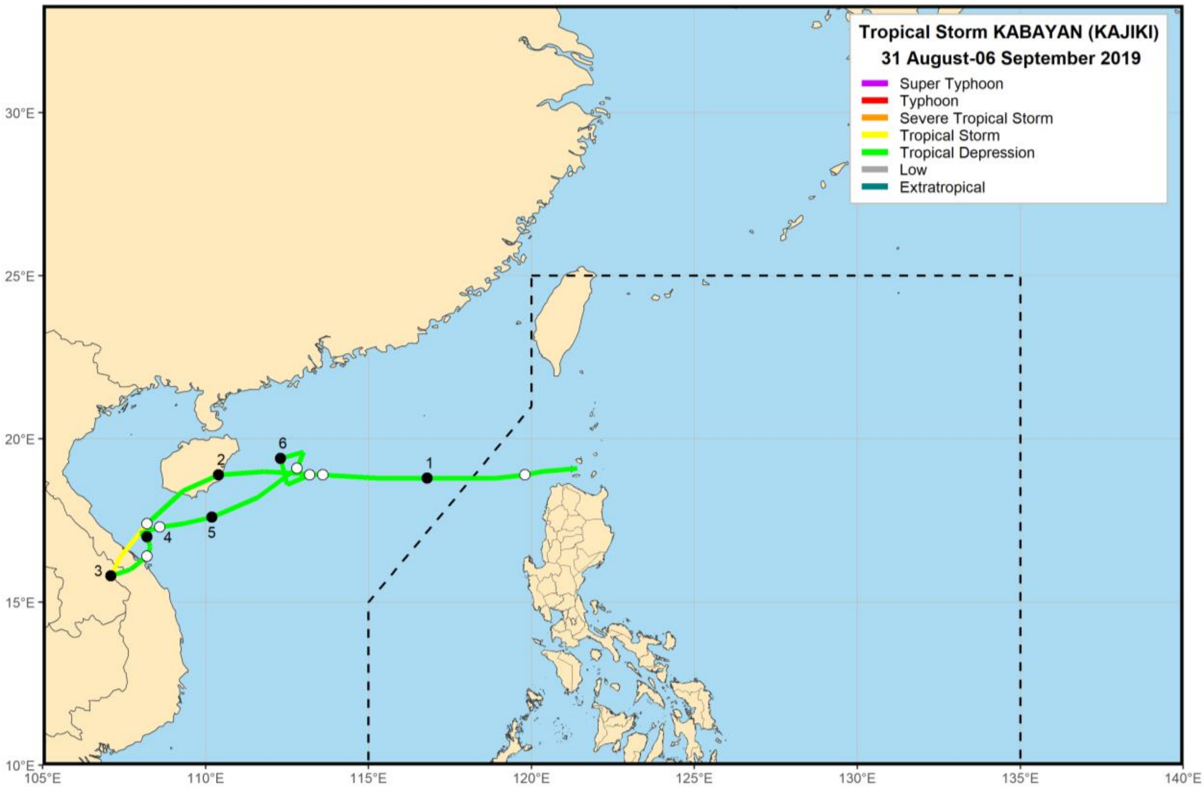

Fig 4.11.1. PAGASA best track positions and intensities of Tropical Storm Kabayan. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

A westward propagating tropical disturbance that crossed the vicinity of Babuyan Archipelago developed into a tropical depression at 06 UTC on 31 August 2019 while over the coastal waters of Dalupiri Island. After crossing Dalupiri Island, Kabayan continued moving westward over the West Philippine Sea. The tropical depression left the PAR region at 19 UTC on 31 August. No Tropical Cyclone Wind Signal was hoisted despite the depression forming in the vicinity of the Babuyan Islands because operational analysis did not identify Kabayan as a depression until it was about to leave the PAR region.

Outside the PAR, Kabayan maintained its heading as it moved towards China's Hainan Island. After slightly intensifying at 12 UTC on 01 September, the depression made landfall at around 00 UTC on 02 September in the vicinity of Wanning City, Hainan Province. While crossing the island, Kabayan turned southwestward and headed towards central Vietnam. After emerging over the Gulf of Tonkin, Kabayan intensified into a weak tropical storm at 12 UTC on 02 September and made landfall in the vicinity of Thừa Thiên Huế Province, Vietnam near the city of Huế at around 17 UTC of the same day. After being downgraded to tropical depression category, Kabayan re-emerged over the South China Sea at around 12 UTC on 03 September as it interacted with another weak tropical depression in Hainan Island. Over the next three days, the depression meandered slowly to the northeast over the South China Sea until it eventually degenerated into a remnant low at 12 UTC on 06 September.

Nationwide rainfall estimates for 31 August revealed that widespread heavy rainfall was not observed during the passage of Kabayan. Nevertheless, accumulated rainfall reached in excess of 50 mm over Ilocos Provinces, Camarines Provinces, La Union, Abra, Bataan, the northern portion of La Union, and the western portions of Kalinga and Mountain Province. Maximum rainfall during the period was estimated at 50-100 mm over Abra, Ilocos Sur, and Camarines Provinces. However, ground observations show both higher totals in the rainfall maximum regions and isolated 50-100 mm totals outside of areas identified by gauge-adjusted satellite estimates. While the rainfall observed in the northwestern provinces could be attributed to the convection of Kabayan, rainfall observed elsewhere were likely brought about by the prevailing monsoon trough where the cyclone was embedded into.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Sinait, Ilocos Sur: 156.8 mm, 31 August 2019
- Ambulong, Tanauan City, Batangas: 96.4 mm, 31 August 2019
- Port Area, Manila: 89.0 mm, 31 August 2019

Highest storm duration (31 August 2019) rainfall over land:
Same as those listed above.

Highest peak gust over land:

- Basco, Batanes: E (80°) at 31.1 kt (16 m/s), 0246 UTC, 31 August 2019
- Port Area, Manila: SSW (200°) at 27.2 kt (14 m/s), 0844 UTC, 31 August 2019
- Itbayat, Batanes: ESE (120°) at 23.3 kt (12 m/s), 0831 UTC, 31 August 2019
- Aparri, Cagayan: SSE (160°) at 23.3 kt (12 m/s), 1153 UTC, 31 August 2019

Lowest sea level pressure over land:

- Calayan, Cagayan: 1004.0 hPa, 0600 UTC, 31 August 2019
- Laoag City, Ilocos Norte: 1004.0 hPa, 0900 UTC, 31 August 2019
- Baguio City: 1004.0 hPa, 0900 UTC, 31 August 2019
- Basco, Batanes: 1004.2 hPa, 0600 UTC and 0900 UTC, 31 August 2019
- Aparri, Cagayan: 1004.4 hPa, 0900 UTC, 31 August 2019

Summary of Warning Information

Number of public TC products issued: **5**

- Severe Weather Bulletins: **2**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **3**

Number of TC Warning for Shipping issued: **2**

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: **Not provided**

Combined cost of damage: **Not provided**

- Damage to agriculture: **Not provided**
- Damage to infrastructure: **Not provided**.

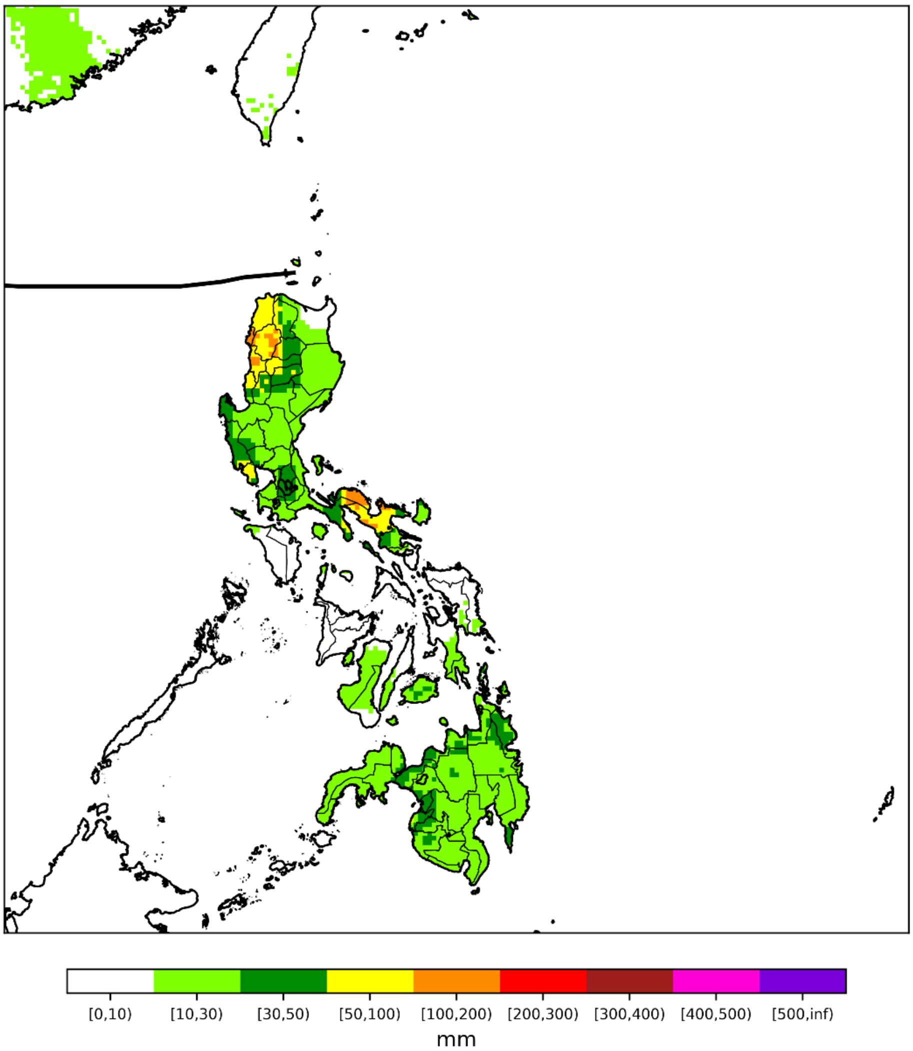

Fig 4.11.2. PAGASA best track of Tropical Storm Kabayan (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 31 August 2019

TYPHOON LIWAYWAY (LINGLING)

01 to 08 September 2019

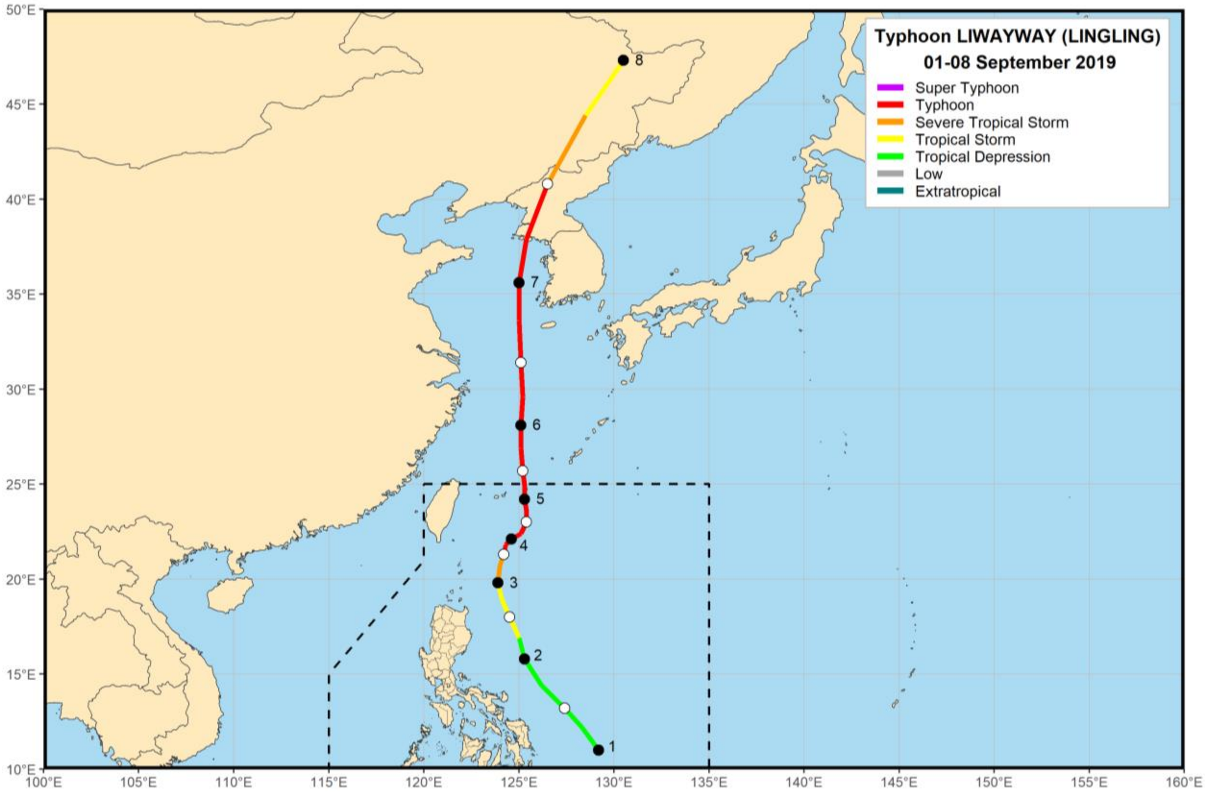

Fig 4.12.1. PAGASA best track positions and intensities of Typhoon Liwayway. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

Over the Philippine Sea less than 500 km from the east coast of Eastern Visayas, an area of low pressure within the monsoon trough was first tracked as tropical depression named Liwayway at 00 UTC on 01 September. Over the next two days, the depression tracked northwestward and north northwestward while gradually intensifying. At 06 UTC of the following day, Liwayway intensified into a tropical storm while over the sea east of Cagayan Valley. Afterwards, the storm underwent a period of rapid intensification. At 00 UTC on 03 September, the storm was upgraded to severe tropical storm category as it started to slow down and turn more northeastward over the sea east of Batanes-Babuyan Archipelago. Eighteen hours after, Liwayway reached typhoon category while decelerating even further. At 12 UTC on 04 September, the typhoon turned northward and headed towards the Miyako Island in the Ryukyu Archipelago, where it eventually made landfall at 1405 UTC of the following day. An hour after, Liwayway reached its peak intensity of 95 kt and 940 hPa. The eye of the typhoon exited the PAR at 08 UTC on 05 September.

Outside the PAR region, Liwayway maintained a northward heading over the East China Sea while gradually accelerating. At 06 UTC on 06 September, the typhoon started to gradually weaken but remained within the typhoon category until its eventual landfall over the Korean Peninsula. While over the Yellow Sea west of South Korea, the typhoon started turning north northwestward and at 0530 UTC on 07 September, its eye made landfall in the vicinity of Kangryŏng County in North Korea's South Hwanghae Province. Weakening followed suit as the typhoon rapidly moved inland towards the northeastern portion of China. After being downgraded into a tropical storm within 12 hours of landfall, Liwayway transitioned into an extratropical cyclone over Heilongjiang Province, China at 00 UTC on 08 September, where it was last tracked.

The passage of Typhoon Liwayway over the waters east of the country took place during a period when the monsoon trough was already active following the occurrence of Tropical Storm Kabayan less than a week earlier. The combined effects of the outer rainbands of Liwayway and the active Southwest Monsoon resulted in 50-200 mm of total rainfall over Ilocos Region, Cordillera Administrative Region, Babuyan Islands, Zambales, Bataan, Tarlac, Pampanga, most of Bataan, Nueva Ecija, and Nueva Vizcaya, and portions of Bulacan. Isolated areas of 200-300 mm were estimated over some islands in the Babuyan Group. In other areas of the country, monsoon rains and the formative rainbands of then-Tropical Depression Liwayway brought up to 50 mm were also noted over Western Visayas, Central Visayas, Bukidnon, Davao del Norte, Agusan del Sur, and Davao City.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Laoag City, Ilocos Norte: 88.4 mm, 04 September 2019
- Itbayat, Batanes: 80.3 mm, 03 September 2019
- Basco, Batanes: 71.0 mm, 04 September 2019

Highest storm duration (01 to 05 September 2019) rainfall over land:

- Iba, Zambales: 172.3 mm
- Basco, Batanes: 149.0 mm
- Sinait, Ilocos Sur: 148.7 mm

Summary of Warning Information

Number of public TC products issued: **26**

- Severe Weather Bulletins: **14**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **12**

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

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: **Not provided**

Combined cost of damage: **Not provided**

- Damage to agriculture: **Not provided**
- Damage to infrastructure: **Not provided**.

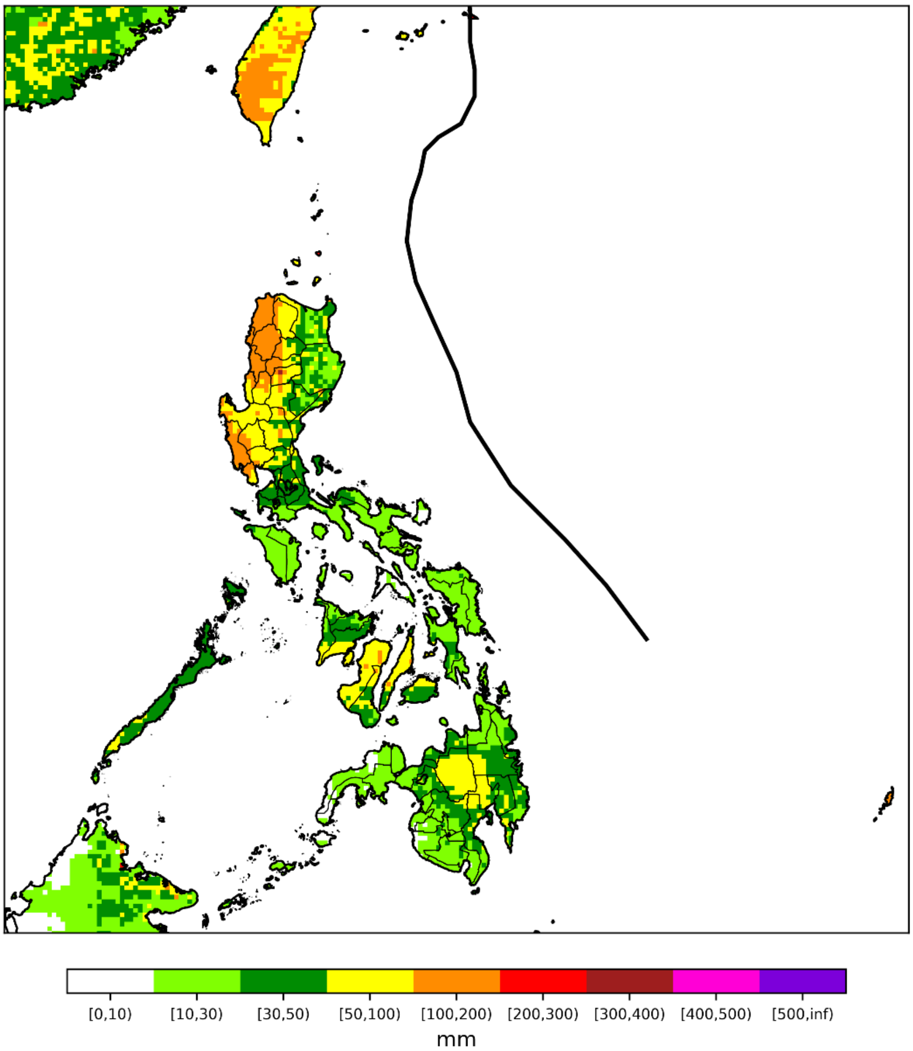

Fig 4.12.2. PAGASA best track of Typhoon Liwayway (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 01 to 05 September 2019.

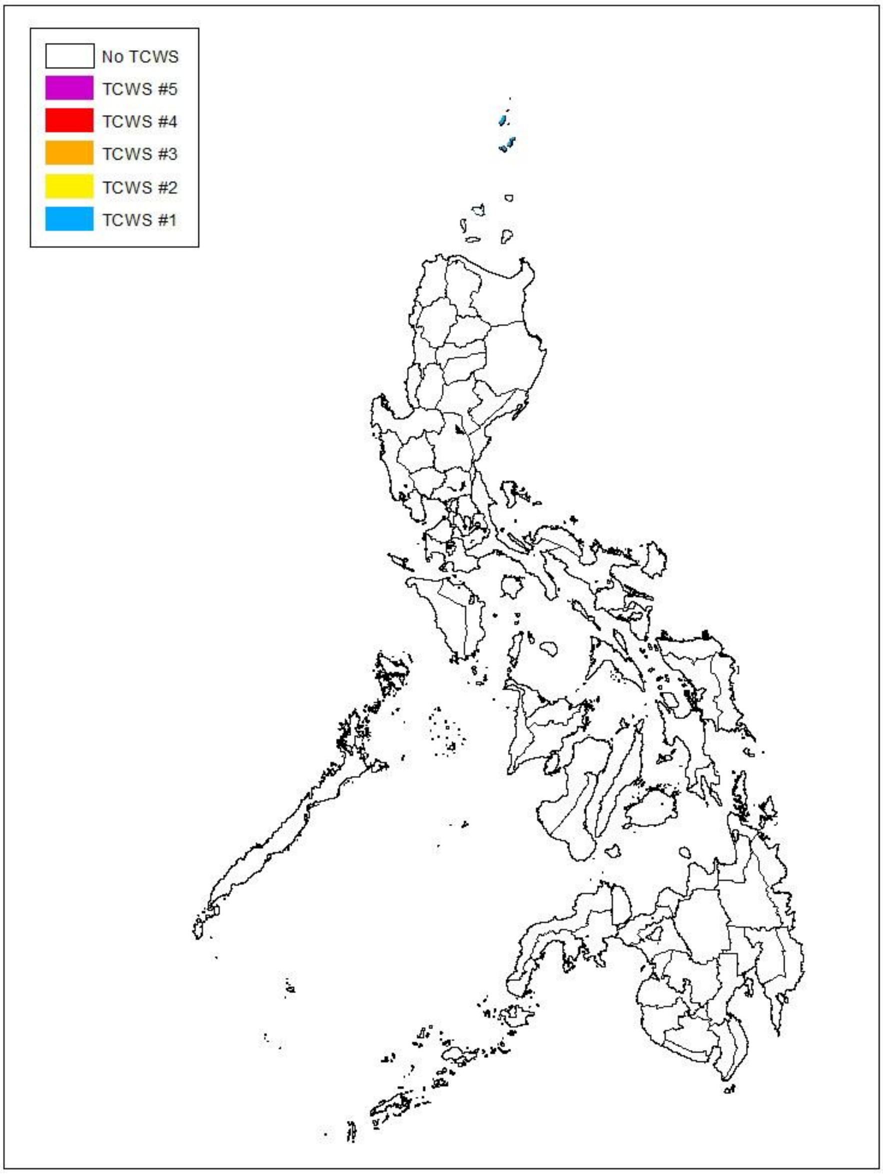

Fig 4.12.3. Highest wind signal hoisted by PAGASA during the occurrence of Typhoon Liwayway.

TROPICAL DEPRESSION MARILYN

10 to 14 September 2019

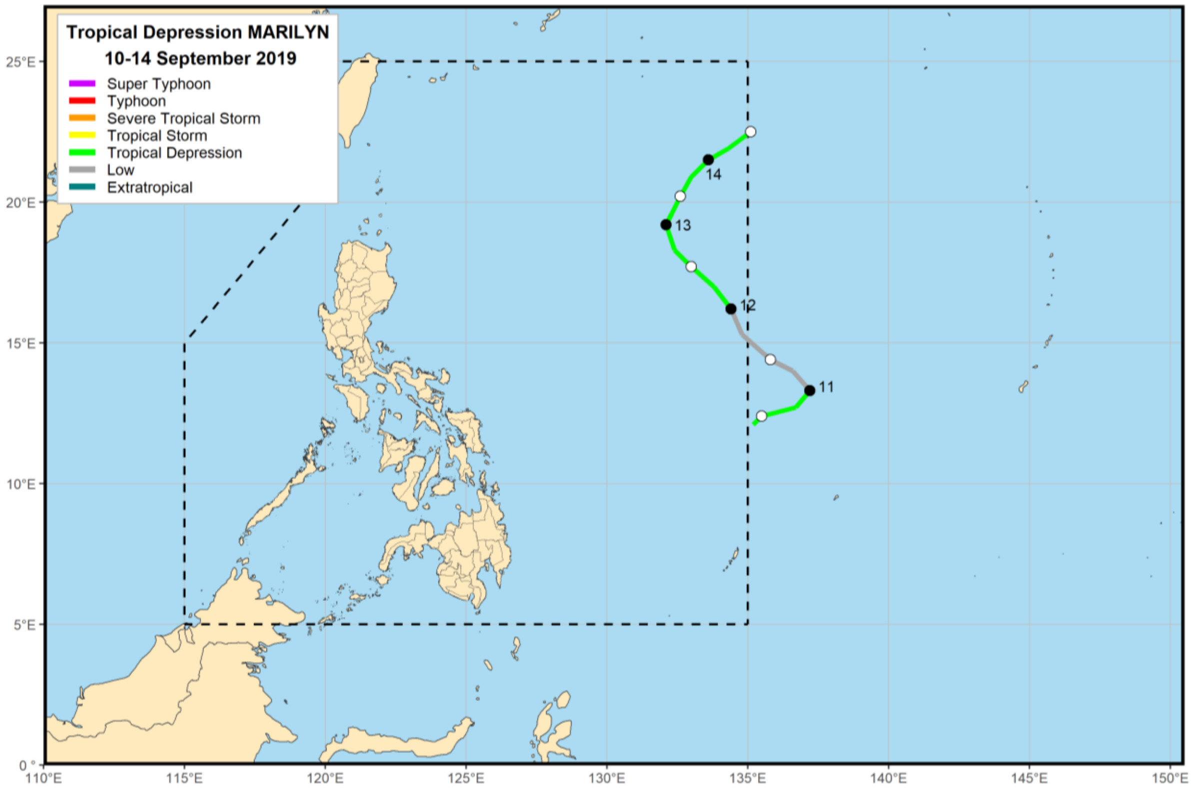

Fig 4.13.1. PAGASA best track positions and intensities of Tropical Depression Marilyn. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

At 06 UTC on 10 September, a broad area of low pressure over the Philippine Sea just to the east of the eastern limit of the PAR region developed into a weak tropical depression with the characteristics consistent of a monsoon depression (i.e., presence of loosely organized convective cloud clusters, mostly situated in the periphery; has a light wind core surrounded by a band of stronger winds at large radii; presence of multiple mesovortices in the central region). The depression briefly meandered northeastward until 00 UTC of the following day, when the system turned northwestward. However, the tropical depression was downgraded to a low pressure area after the area of strong winds moved further away from the core of the monsoon depression and struggling to maintain a persistent low-level circulation center. Throughout 11 September, the monsoon depression propagated generally northwestward and at 06 UTC of that day, it entered the PAR region.

The monsoon depression was upgraded once again to a tropical depression, now named Marilyn, at 00 UTC on 12 September as the system tried to consolidate. Despite slight improvements in its overall structure, Marilyn struggled to intensify and remained a weak tropical depression throughout its lifetime. The depression continued moving northwestward until 13 September when it started to turn northeastward. At 12 UTC of the following day, as it left the PAR region, Marilyn was again downgraded to an area of low pressure. The remnants of the depression, now possessing the characteristics of a monsoon gyre, meandered further to the northeast, then turned southwestward to re-enter the PAR region on 16 September. The day after, its remnants eventually consolidated and developed into then-Tropical Depression Nimfa.

Marilyn did not directly bring heavy rainfall over the country due to its sheer distance from the archipelago. However, the Southwest Monsoon remained active over the country throughout the occurrence of the depression within the PAR region. Up to 50-100 mm of rainfall over four days was generally observed over Bicol Region, Zamboanga Peninsula, southern Isabela, Nueva Vizcaya, Ifugao, Benguet, Nueva Ecija, Bulacan, Aurora, Bataan, Rizal, Laguna, Quezon, Marinduque, Basilan, Sulu, nearly all of MIMAROPA, and most of Western Visayas, Eastern Visayas, Negros Oriental, Lanao del Norte, and Misamis Occidental. The highest accumulated rainfall over the country was observed over mainland Palawan, with rainfall totals reaching 200-300 mm over the central portion of the island province.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Zamboanga City: 124.2 mm, 12 September 2019
- Daet, Camarines Norte: 110.4 mm, 11 September 2019
- Casiguran, Aurora: 109.2 mm, 12 September 2019

Highest storm duration (11 to 14 September 2019) rainfall over land:

- Puerto Princesa City, Palawan: 205.9 mm
- San Jose, Occidental Mindoro: 156.6 mm
- Zamboanga City: 148.8 mm

Summary of Warning Information

Number of public TC products issued: **16**

- Severe Weather Bulletins: **6**
- Tropical Cyclone Advisories: **2**
- Tropical Cyclone Updates: **8**

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: **Not provided**

- Damage to agriculture: **Not provided**
- Damage to infrastructure: **Not provided**.

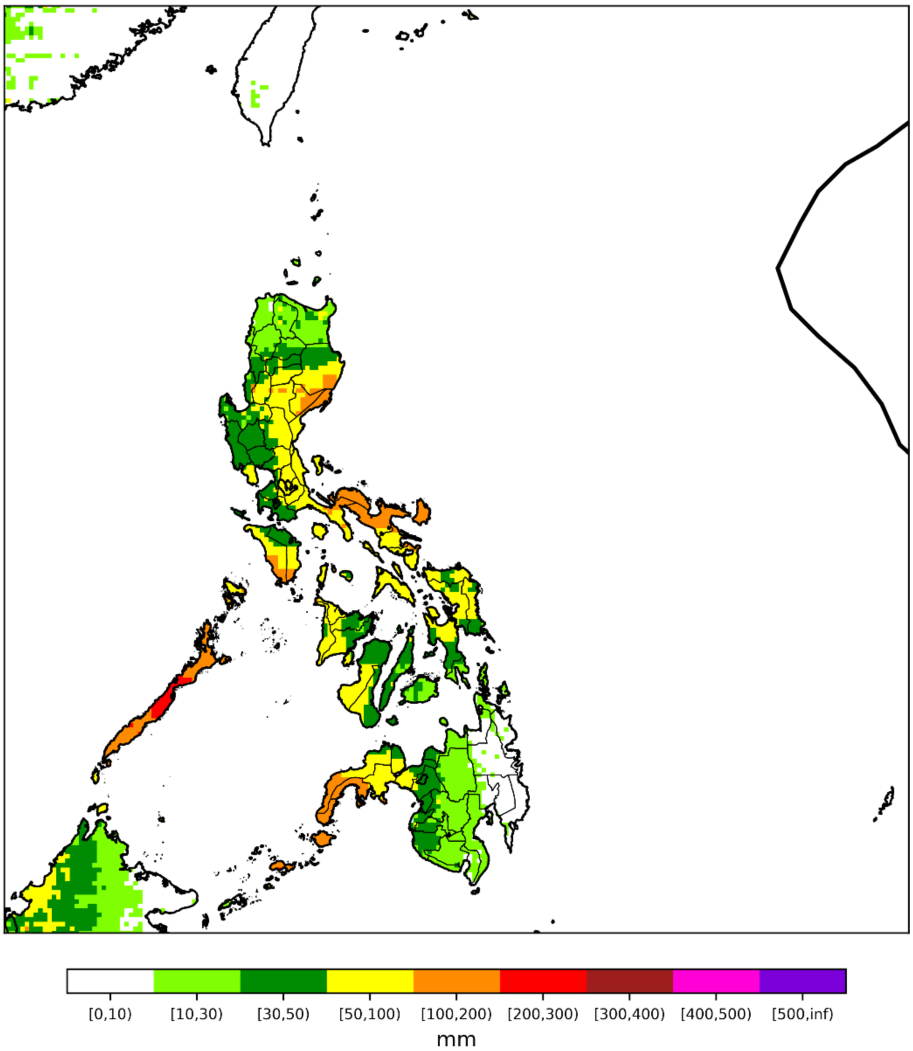

Fig 4.13.2. PAGASA best track of Tropical Depression Marilyn (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 01 to 05 September 2019.

TYPHOON NIMFA (TAPAH)

17 to 23 September 2019

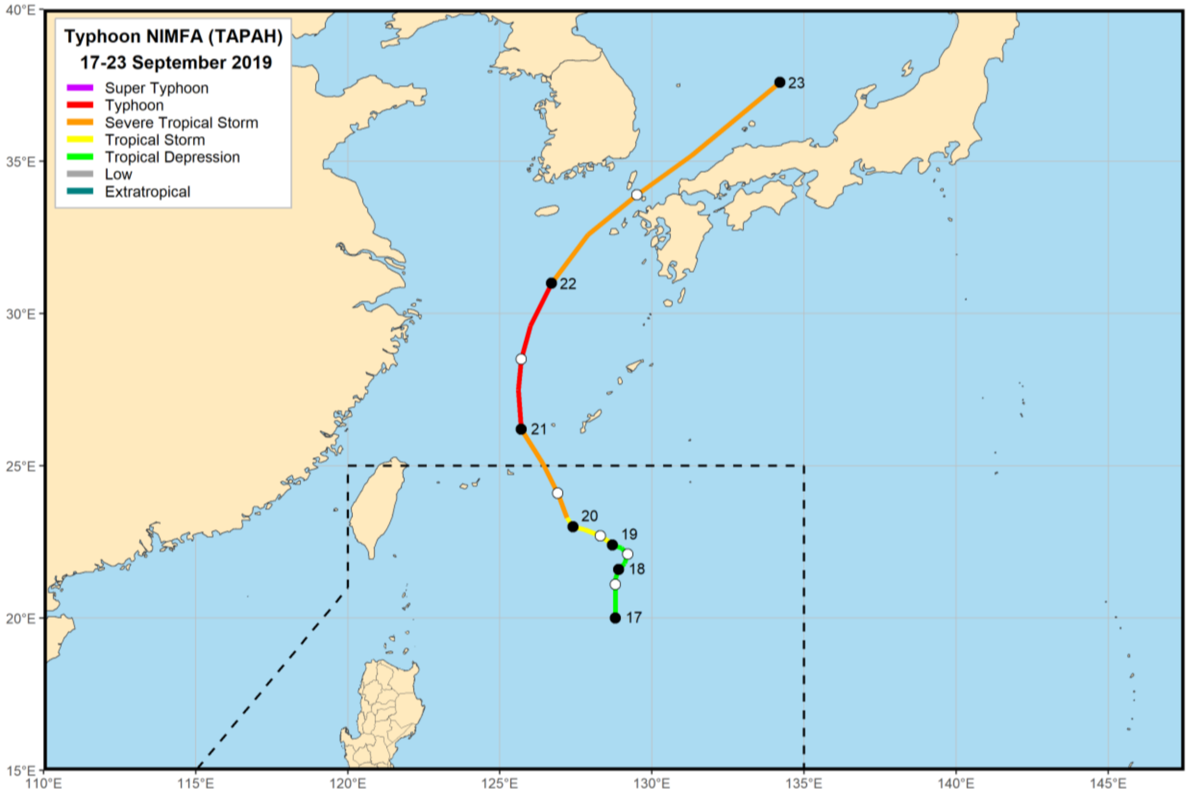

Fig 4.14.1. PAGASA best track positions and intensities of Typhoon Nimfa. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

From the remnants of Tropical Depression Marilyn which is embedded within a monsoon gyre circulation, a tropical depression developed and was first tracked at 00 UTC on 17 September over the Philippine Sea. Nimfa, as it was locally called, tracked slowly northward and north northeastward until around 12 UTC of the following day, when it started turning generally west northwestward. At 06 UTC on 19 September, Nimfa was upgraded to tropical storm category. On 20 September, the storm turned northwestward and headed towards the Kerama Gap between the Miyako and Okinawa Islands. At 06 UTC of that day, Nimfa intensified further into a severe tropical storm. Twelve hours after, the storm left the PAR region as it passed over the Kerama Gap towards the East China Sea.

Outside the PAR, Nimfa followed a recurving track over the East China Sea. At 00 UTC on 21 September, it intensified into a minimal typhoon with a peak intensity of 120 km/h and 970 hPa. Tracking northeastward towards the Tsushima Strait, the cyclone was downgraded to severe tropical storm category at 00 UTC on 22 September. Between 06 and 18 UTC, the storm moved over the Tsuhima Strait and passed to the west and north of Gotō, Iki, and Hirado Islands and to the south and east of Tsushima Island. At 00 UTC on 23 September, Nimfa was last tracked by PAGASA as it transitioned into an extratropical low over the Sea of Japan.

Despite its sheer distance from the Philippine archipelago, the occurrence of Nimfa resulted in continuous monsoon activity over most of Luzon. During the four-day period beginning on 17 September, accumulated rainfall over Northern Luzon, Central Luzon, Metro Manila, most of CALABARZON, Mindoro Provinces, and Calamian Islands reached in excess of 50 mm. The highest rainfall totals were estimated and observed over Zambales and Bataan, with values reaching 200-300 mm.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
- Subic Bay International Airport, Morong, Bataan: 231.5 mm, 20 September 2019
- Tanay, Rizal: 111.4 mm, 19 September 2019
- Iba, Zambales: 107.7 mm, 17 September 2019

Highest storm duration (17 to 20 September 2019) rainfall over land:
- Subic Bay International Airport, Morong, Bataan: 371.9 mm
- Iba, Zambales: 330.0 mm
- Tanay, Rizal: 197.6 mm

Summary of Warning Information

Number of public TC products issued: **22**
- Severe Weather Bulletins: **11**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **11**

Number of TC Warning for Shipping issued: **15**

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: **Not provided**
- Damage to agriculture: **Not provided**
- Damage to infrastructure: **Not provided**.

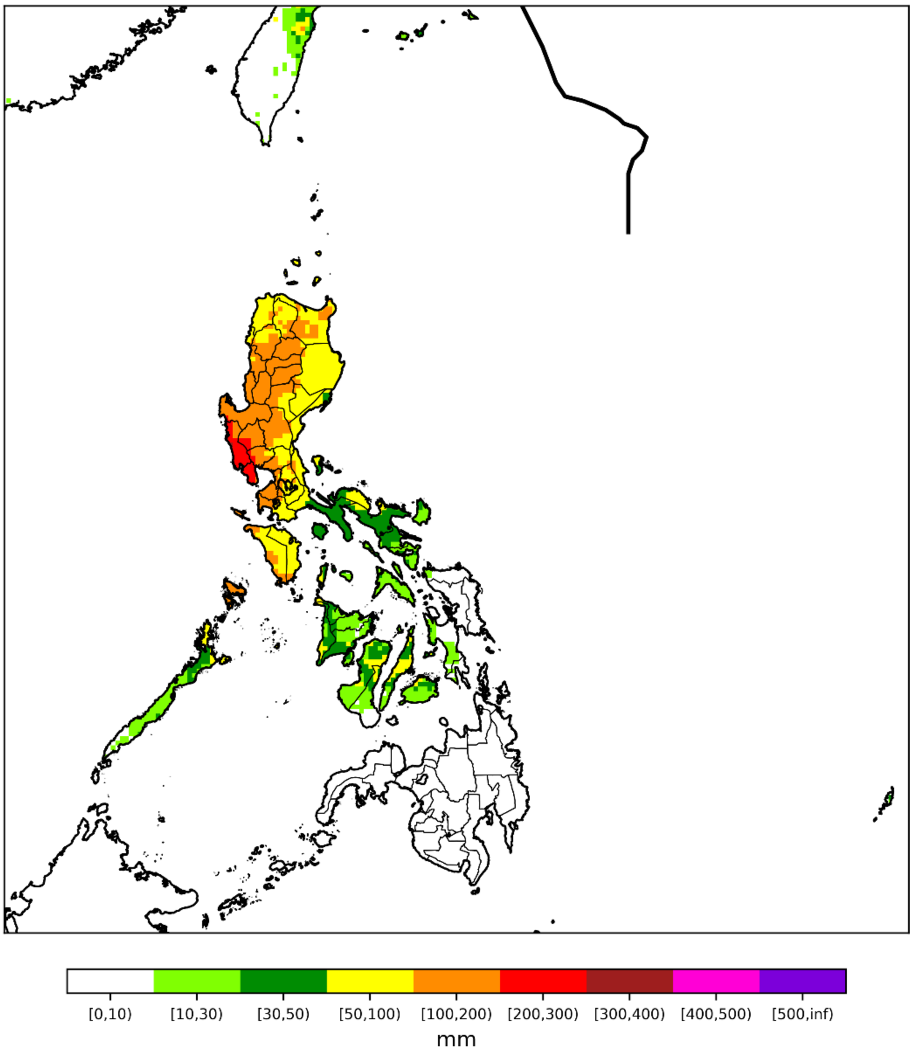

Fig 4.14.2. PAGASA best track of Typhoon Nimfa (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 17 to 20 September 2019.

TYPHOON ONYOK (MITAG)

26 September to 03 October 2019

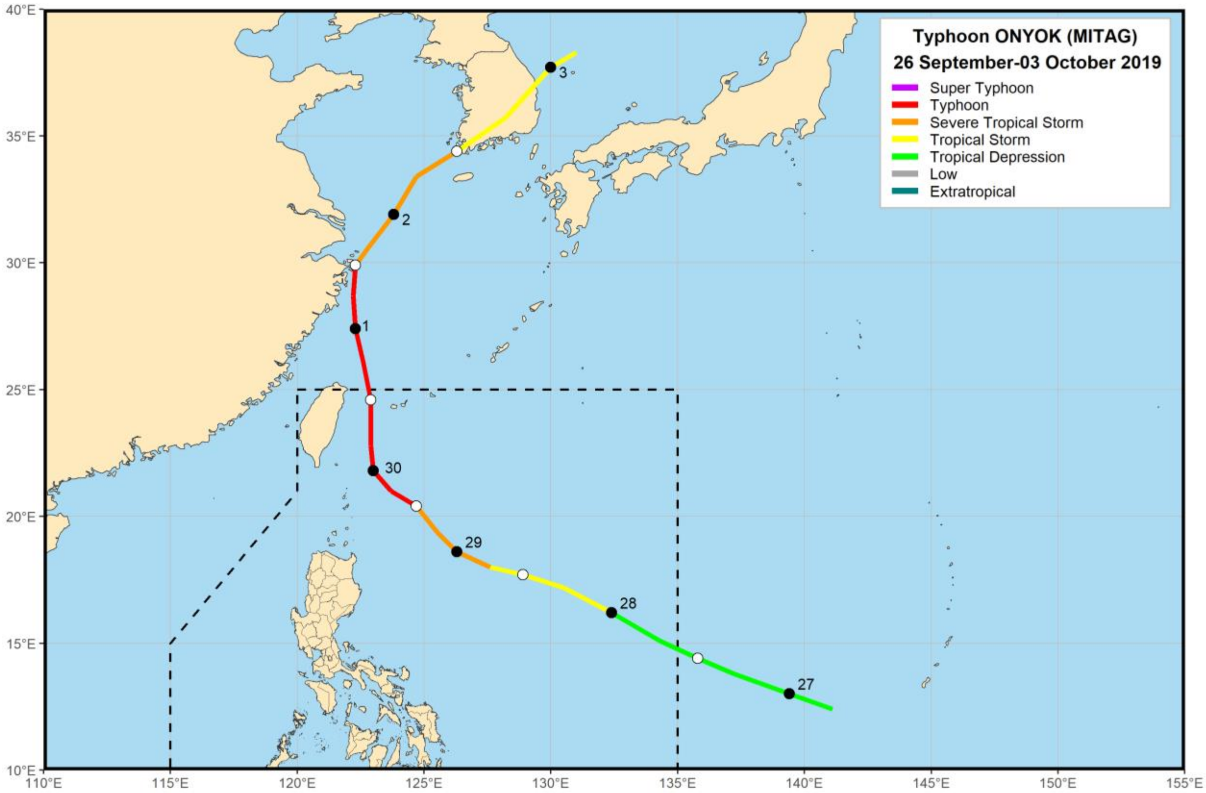

Fig 4.15.1. PAGASA best track positions and intensities of Typhoon Onyok. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

An area of low pressure near the Federated States of Micronesia tracked generally northwestward and was first noted on weather charts as a tropical depression at 18 UTC on 26 September over the Philippine Sea west of Guam. The depression entered the PAR region at 16 UTC of the following day and was named Onyok. Turning more west northwestward, the depression intensified into a tropical storm on 00 UTC on 28 September and into a severe tropical storm 18 hours later. On 29 September, the storm turned northwestward while continuously intensifying and at 12 UTC of that day, Onyok was upgraded into typhoon-category cyclone. On 30 September, the typhoon turned northward over the sea northeast of Batanes and moved roughly parallel to the east coast of Taiwan. At 06 UTC of the same day, Onyok reached its peak intensity of 75 kt and 965 hPa. Roughly seven hours later, the typhoon left the PAR region as it entered the East China Sea.

Weakening trend commenced on 01 October as the typhoon tracked slightly north northwestward and moved closer towards the coast of eastern China over a region of increasing vertical wind shear and cooler waters. Onyok was downgraded into a severe tropical storm at 12 UTC of the same day and made its first landfall in the vicinity of Zhousan City in China’s Zhejiang Province. Afterwards, the storm turned northeastward and moved towards the southwestern portion of the Korean Peninsula. Over the sea west of South Korea, the storm started its extratropical transition. Onyok was downgraded into a tropical storm at 12 UTC on 02 October as it made its second landfall in the vicinity of Jindo County, South Jeolla Province, South Korea. After briefly crossing the Korean Peninsula, the storm emerged over the Sea of Japan where it eventually transitioned into an extratropical low at 06 UTC on 03 October.

The passage of Typhoon Onyok did not enhance the Southwest Monsoon over the country. Nevertheless, the outer rainbands and inflow winds of the cyclone brought about rains over the northern provinces of Luzon. Satellite-derived estimates show that storm duration rainfall of 50 to 100 mm was noted over Batanes, Cagayan including Babuyan Islands, Ilocos Norte, Apayao, Kalinga, Abra, Mountain Province, and the northern portions of Isabela and Ilocos Sur, although ground observations from synoptic stations in these provinces yielded generally lower rainfall values. In particular, there were some stations with higher 24-hour and storm duration rainfall observations during the period of occurrence of Onyok compared to those situated in Northern Luzon. These were found to be caused by thunderstorm activity.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Muñoz City, Nueva Ecija: 123.0 mm, 30 September 2019
- Laoag City, Ilocos Norte: 63.4 mm, 29 September 2019
- Malaybalay, Bukidnon: 57.4 mm, 28 September 2019

Highest storm duration (27 to 30 September 2019) rainfall over land:

- Muñoz City, Nueva Ecija: 123.0 mm
- Laoag City, Ilocos Norte: 69.4 mm
- Malaybalay, Bukidnon: 67.3 mm

Summary of Warning Information

Number of public TC products issued: **23**

- Severe Weather Bulletins: **13**
- Tropical Cyclone Advisories: **1**
- Tropical Cyclone Updates: **9**

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

Number of localities under TC Wind Signal (TCWS): **2**

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

Summary of Casualties and Damage to Property

Number of casualties: **Not provided**

Combined cost of damage: **Not provided**

- Damage to agriculture: **Not provided**
- Damage to infrastructure: **Not provided**.

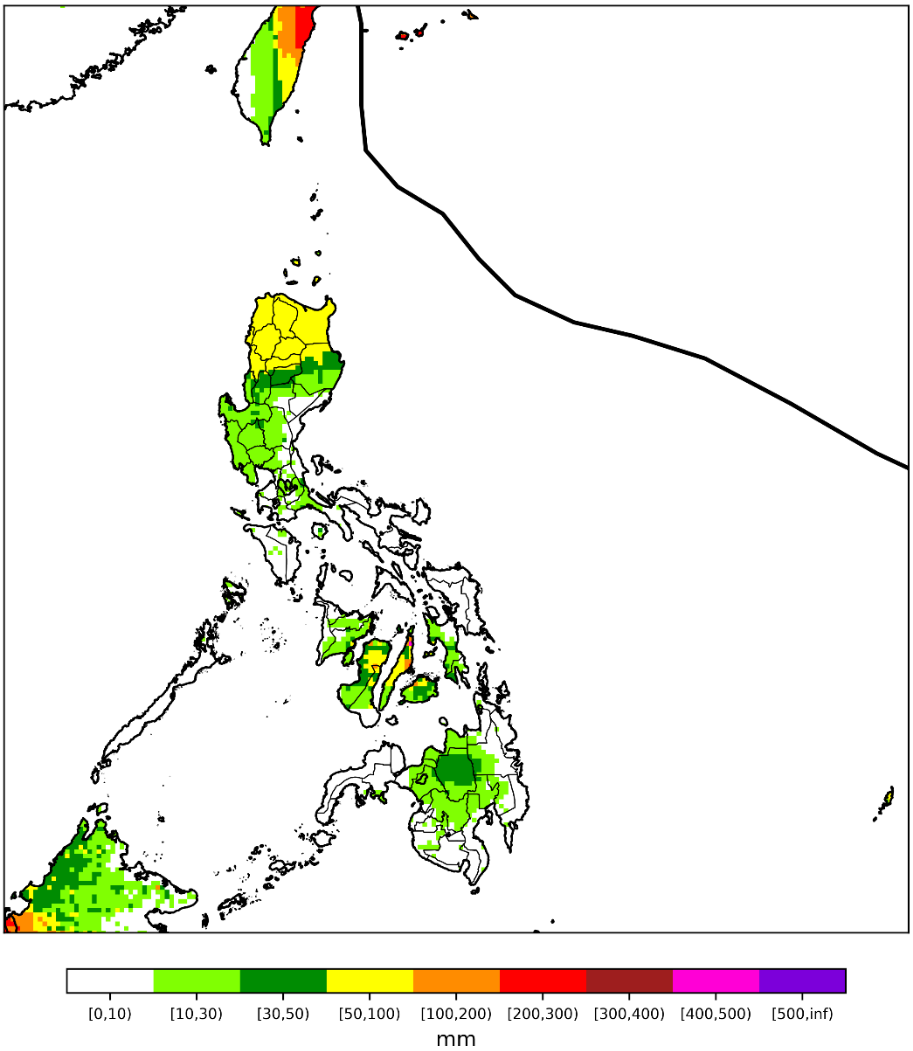

Fig 4.15.2. PAGASA best track of Typhoon Onyok (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 27 to 30 September 2019.

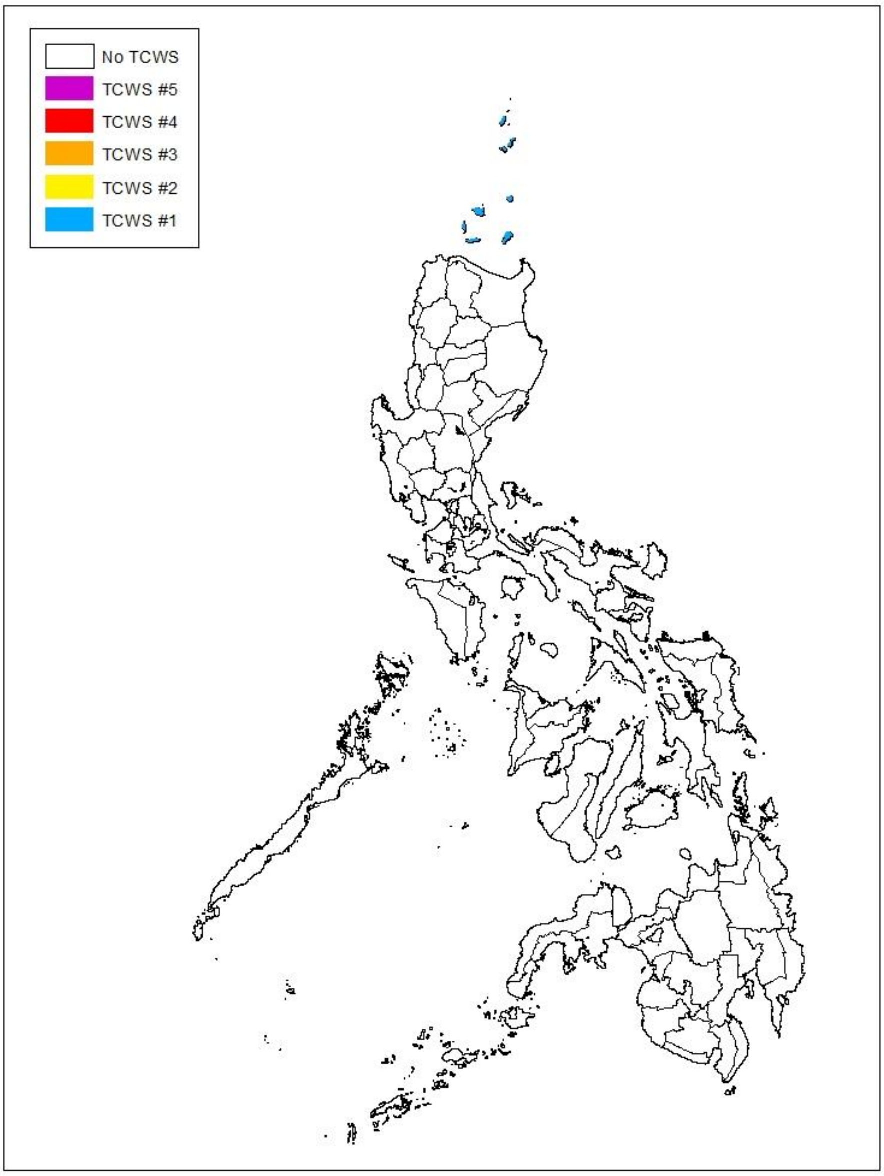

Fig 4.15.3. Highest wind signal hoisted by PAGASA during the occurrence of Typhoon Onyok.

TYPHOON PERLA (NEOGURI)

15 to 21 October 2019

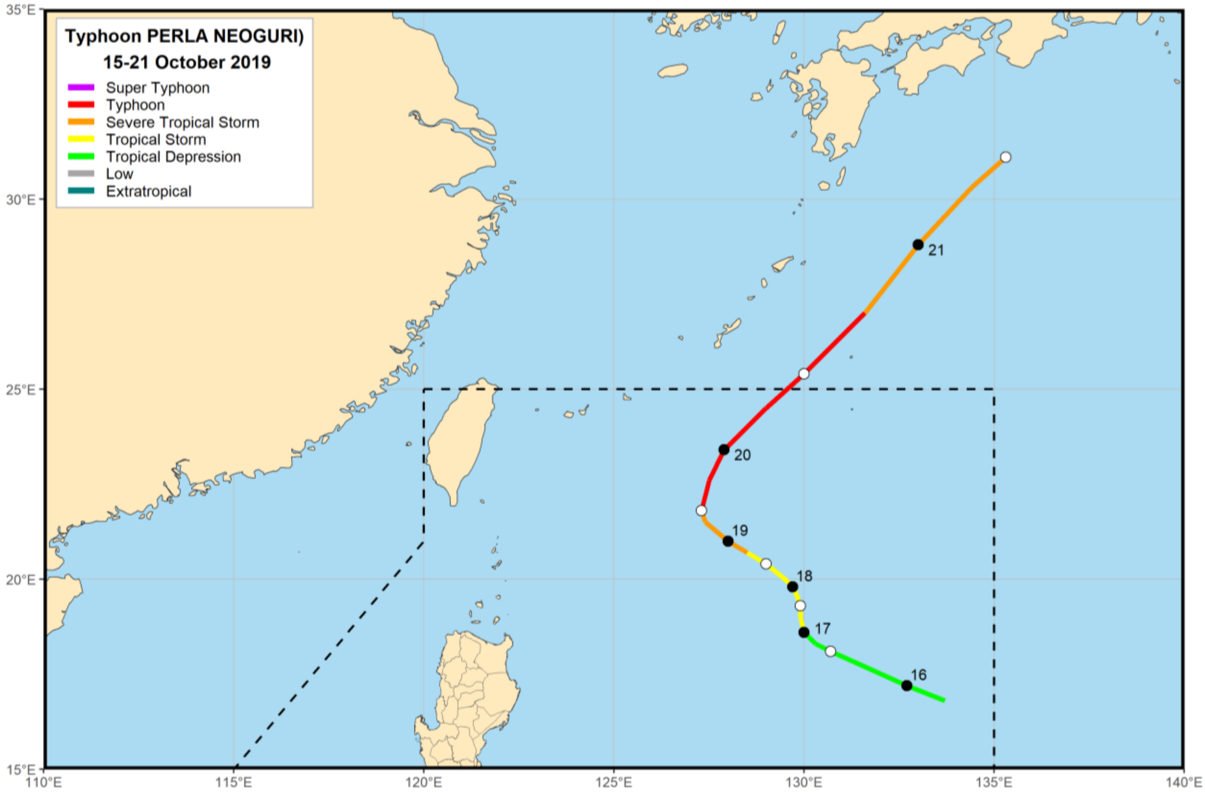

Fig 4.16.1. PAGASA best track positions and intensities of Typhoon Perla. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

Typhoon Perla was first noted by PAGASA as a tropical depression at 18 UTC on 15 October. It initially tracked generally northwestward over the Philippine Sea until 00 UTC on 17 October, when it intensified into a tropical storm while decelerating and turning northward. An increasing in its forward speed was observed the next day as it returned to a more northwestward heading while gradually intensifying. At 18 UTC on 18 October, Perla was upgraded to severe tropical storm category.

Perla started to recurve northeastward on 19 October while gradually accelerating. At 12 UTC of the same day, it intensified into a typhoon. Perla reached a peak intensity of 75 kt and 970 hPa roughly 12 hours later as it tracked towards the northern limit of the PAR region. The eye of the typhoon left the PAR at 10 UTC on 20 October. Outside the PAR, the typhoon continued moving northeastward as it entered its weakening phase associated with its extratropical transition. Over the sea south of Japan, Perla, now a severe tropical storm, transitioned into an extratropical low at 12 UTC on 21 October.

The passage of Typhoon Perla within the PAR region did not directly cause a widespread rainfall event over the country as it did not enhance any prevailing monsoonal flow over the archipelago. However, the trough of the typhoon resulted in six-day rainfall totals between 50 and 200 mm over the northwestern Bicol Region, particularly in the vicinity of Camarines Norte and Camarines Sur, and southeastern portion of Quezon Province. These estimates were corroborated by observations from manned synoptic stations. These data show that much of the rainfall was observed on 19-20 October.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Daet, Camarines Norte: 87.4 mm, 19 October 2019
- Daet, Camarines Norte: 48.6 mm, 20 October 2019
- Tayabas, Quezon: 44.0 mm, 19 October 2019

Highest storm duration (15 to 20 October 2019) rainfall over land:

- Daet, Camarines Norte: 193.5 mm
- Alabat, Quezon: 131.0 mm
- Tayabas, Quezon: 80.7 mm

Summary of Warning Information

Number of public TC products issued: **22**

- Severe Weather Bulletins: **11**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **11**

Number of TC Warning for Shipping issued: **19**

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: **Not provided**

Combined cost of damage: **Not provided**

- Damage to agriculture: **Not provided**
- Damage to infrastructure: **Not provided**.

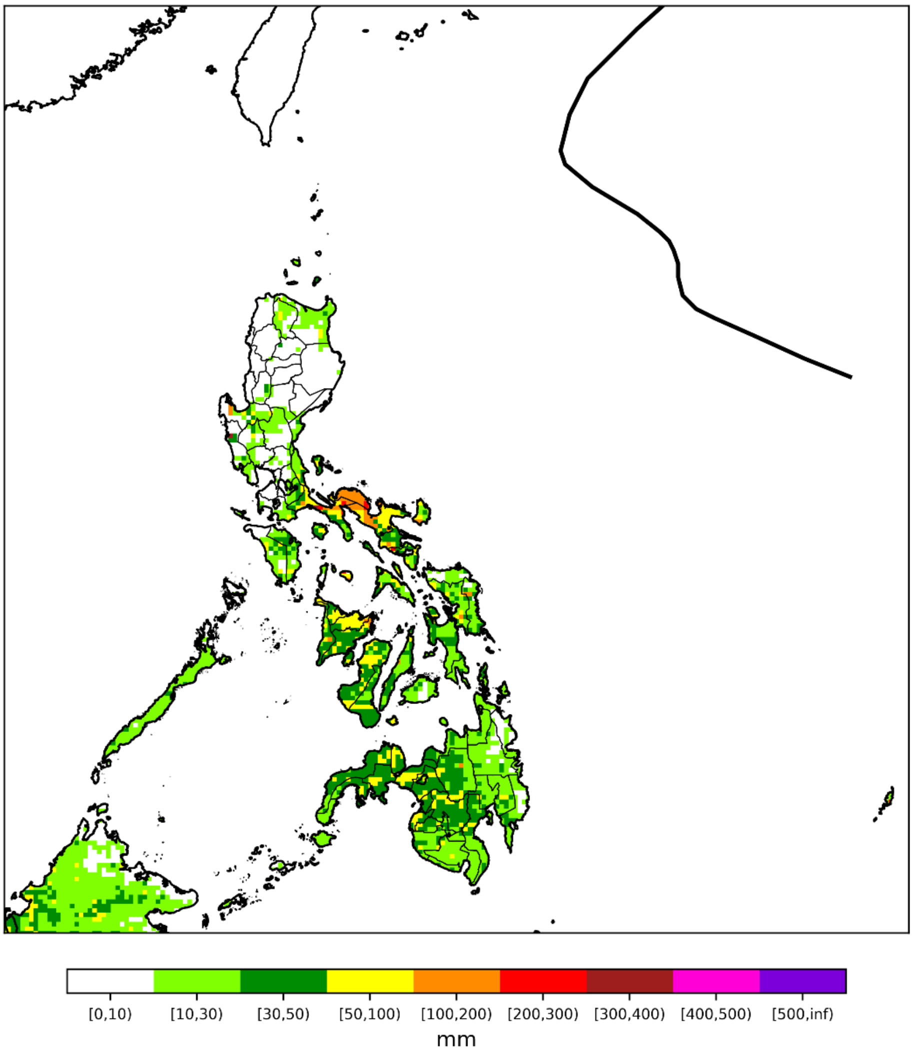

Fig 4.16.2. PAGASA best track of Typhoon Perla (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 15 to 20 October 2019

TYPHOON QUIEL (NAKRI)

04 to 11 November 2019

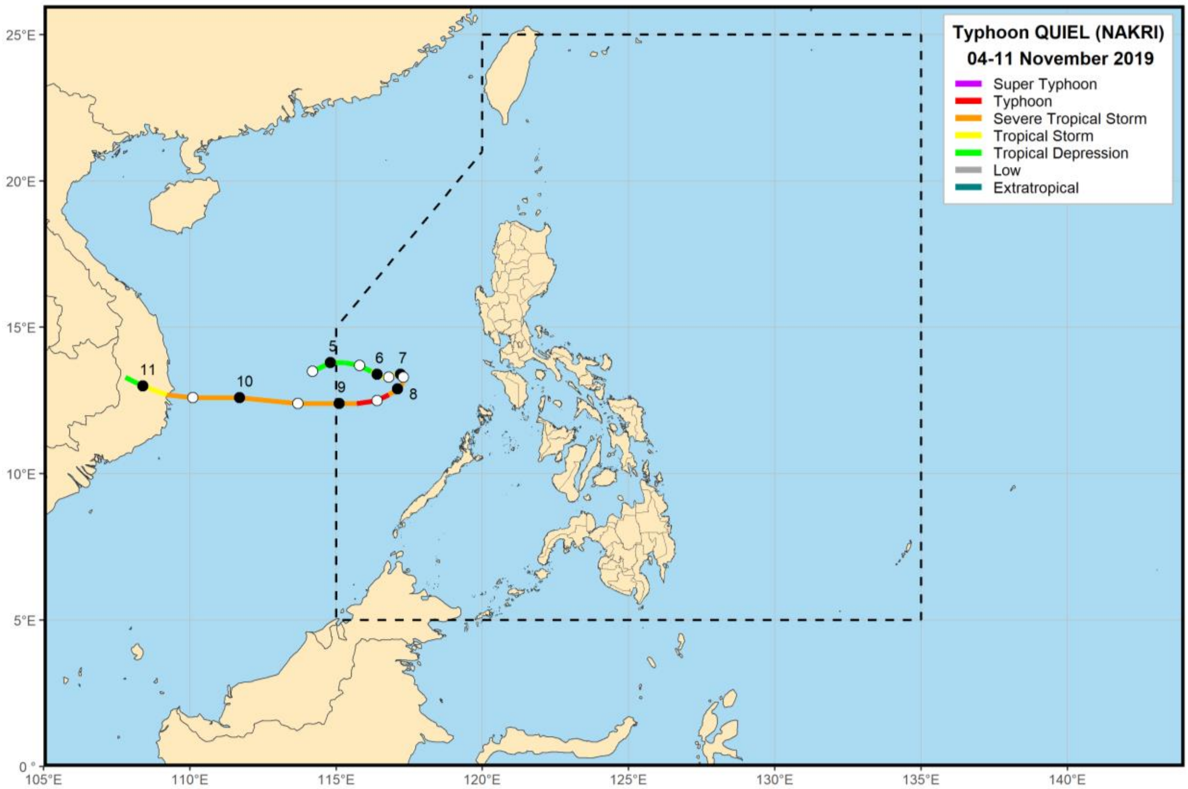

Fig 4.17.1. PAGASA best track positions and intensities of Typhoon Quiel. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

A westward-propagating tropical disturbance that crossed the archipelago during the first three days of November was first noted as a tropical depression on weather charts at 12 UTC on 04 November. At that time, the depression was in a quasi-stationary state over the West Philippine Sea while interacting with a shear line extending from a cold front over the sea southeast of Japan. After entering the PAR at 03 UTC on 05 November, Quiel, as it was locally called, slowly drifted eastward over the West Philippine Sea over the next three days while interacting with the cold surge-induced shear line. The cyclone was upgraded into a tropical storm at 18 UTC on 05 November and into a severe tropical storm at 00 UTC on 07 November.

On 08 November, Quiel started to gain forward speed and turned west southwestward and westward. For a period of less than 12 hours beginning at 06 UTC on that day, it was categorized as a typhoon with sustained winds reaching 65 kt and central pressure of 975 hPa. At 02 UTC on 09 November, Quiel left the PAR region. Over the next two days, it continued tracking westward as a severe tropical storm over the West Philippine Sea towards southern Vietnam. At around 18 UTC on 10 November, Quiel was downgraded into a tropical storm as it made landfall in the vicinity of Vạn Ninh District, Khánh Hòa Province situated in the south-central coast region of Vietnam. Rapid weakening ensued and the storm degenerated into an area of low pressure roughly 12 hours later near the Vietnam-Cambodia border.

During the period of its erratic, looping movement within the PAR region, satellite data estimated 50 to 100 mm of rainfall from 05 to 08 November (with isolated areas receiving amounts not exceeding 200 mm) over the western portions of Central Luzon and CALABARZON, Occidental Mindoro, Oriental Mindoro, extreme northern Palawan including Calamian, Cuyo, and Kalayaan Islands, and portions of

Panay Island. However, much of the heavy rainfall observed in the country during the period of occurrence of Quiel was over Northern Luzon. This was caused by the enhanced convergence zone along the shear line that was interacting with the typhoon. The shear line was brought about by the presence of a Northeast Monsoon cold surge during the period of occurrence of Quiel. Rainfall estimates reveal four-day rainfall of at least 50 mm over nearly all over Cagayan Valley, Cordillera Administrative Region, and Ilocos Region, with provinces north of 17.5°N receiving at least 100 mm of rainfall. The highest rainfall totals reached 300-400 mm, which were both estimated and observed over northern mainland Cagayan and Apayao.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Aparri, Cagayan: 366.6 mm, 07 November 2019
- Sinait, Ilocos Sur: 83.9 mm, 07 November 2019
- Subic Bay International Airport, Morong, Bataan: 83.5 mm, 05 November 2019

Highest storm duration (05 to 08 November 2019) rainfall over land:

- Aparri, Cagayan: 483.3 mm
- Calayan, Cagayan: 147.0 mm
- San Jose, Occidental Mindoro: 119.2 mm

Summary of Warning Information

Number of public TC products issued: **23**

- Severe Weather Bulletins: **10**
- Tropical Cyclone Advisories: **1**
- Tropical Cyclone Updates: **12**

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

Number of casualties: **6 dead, 4 injured, and 13 missing persons**

Combined cost of damage: **Not provided**

- Damage to agriculture: **Not provided**
- Damage to infrastructure: **Not provided**.

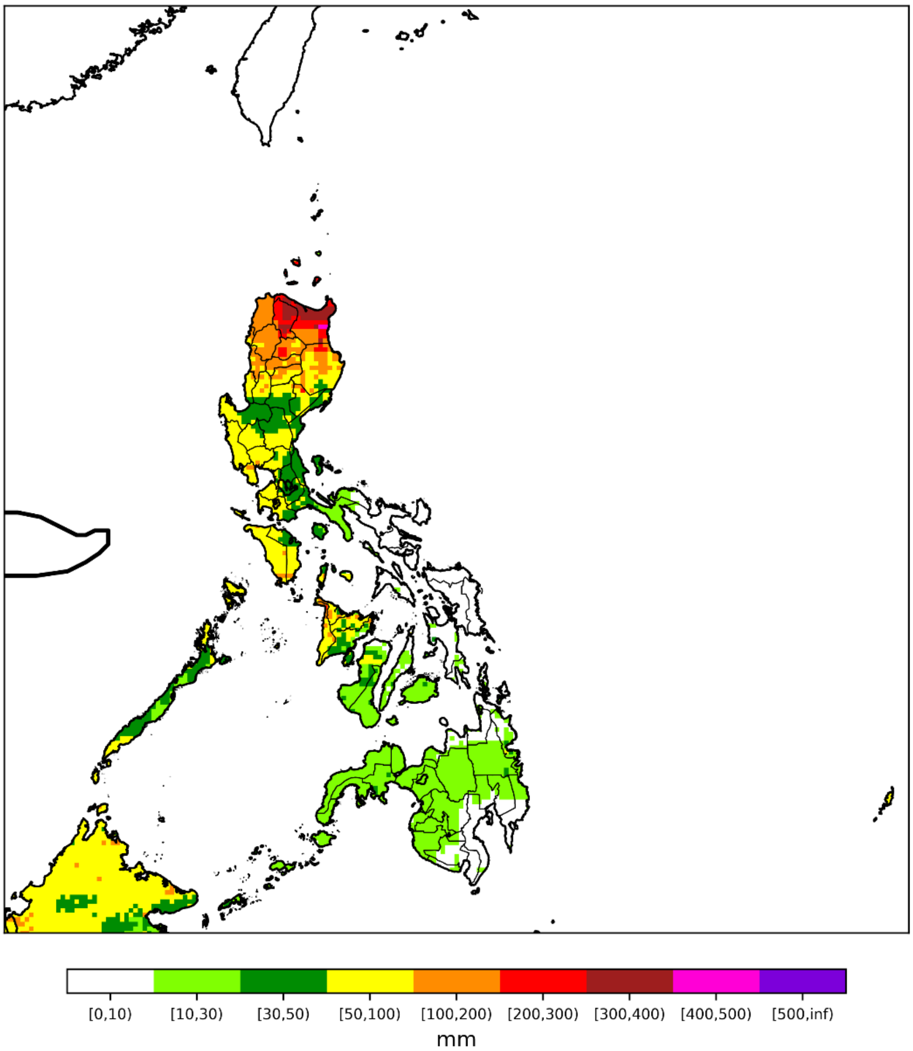

Fig 4.17.2. PAGASA best track of Typhoon Quiel (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 05 to 08 November 2019.

TYPHOON RAMON (KALMAEGI)

11 to 21 November 2019

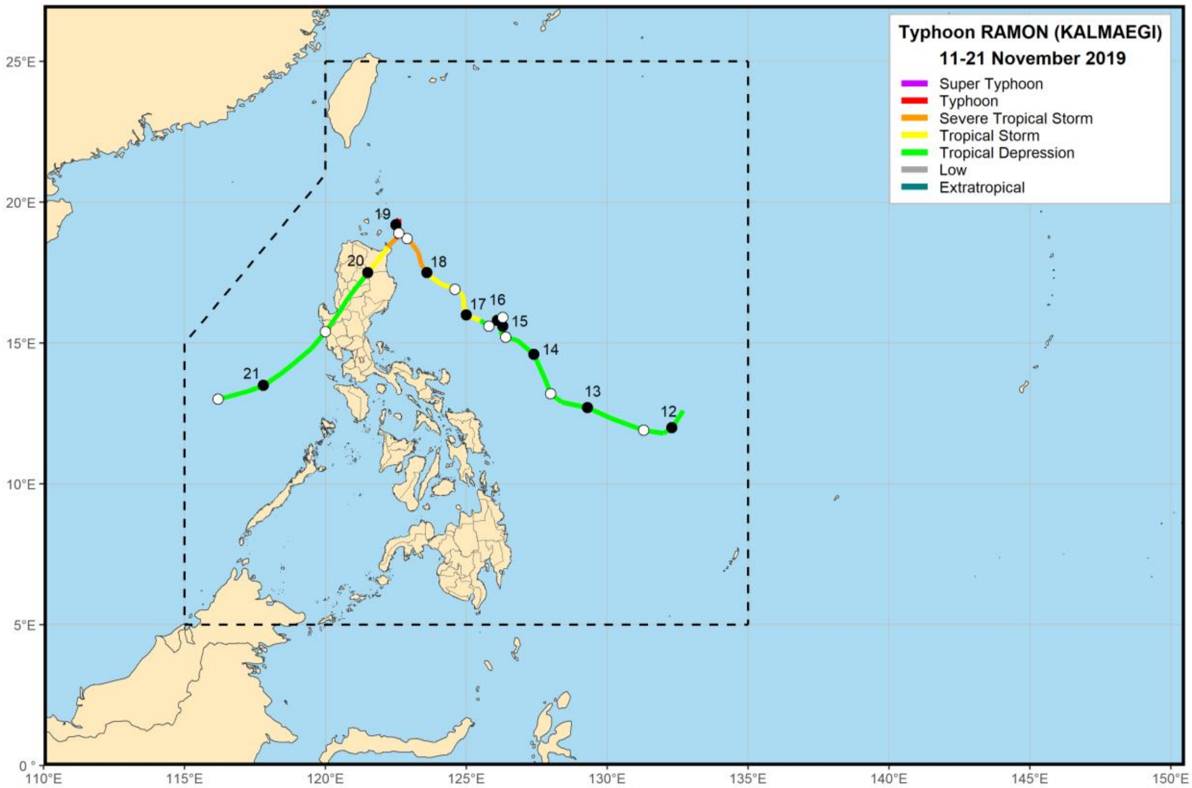

Fig 4.18.1. PAGASA best track positions and intensities of Typhoon Ramon. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

The second TC for the month of November 2019 and the longest-lasting TC within the PAR region for the year originated from a tropical disturbance over the Philippine Sea less than 800 km from the east coast of Samar Island which was first tracked as a tropical depression at 18 UTC on 11 November. Moving generally west northwestward and northwestward over the Philippine Sea, Ramon, as it was locally called, remained disorganized with partly to fully exposed low-level center up until 16 November due to intrusion of dry air and high vertical wind shear. This resulted in the TC struggling to intensify. Furthermore, the weak nature of its circulation made it sensitive to changes in its low-level steering environment, with the depression moving erratically or becoming quasi stationary by 15 and 16 November.

Improvement in environmental conditions beginning late on 16 November allowed Ramon to begin intensifying. At 18 UTC of the same day, the cyclone was upgraded to tropical storm category while tracking northwestward. At 00 UTC on 18 November, it was further upgraded to severe tropical storm category over the sea east of Isabela. Ramon reached typhoon category 12 hours later over the waters east of Babuyan Islands. Peak intensity was achieved at 15 UTC on 18 November when the typhoon reached sustained winds of 70 kt and central pressure of 975 hPa.

Ramon started to decelerate over the water east of Babuyan Islands at around 12 UTC on 18 November, with the typhoon becoming quasi-stationary for most of 19 November. This was attributed to the shifting of the dominant steering system from the subtropical ridge to the east of the typhoon to the subtropical ridge centered over the West Philippine Sea. At 12 UTC on 19 November, Ramon started to turn southwestward towards northeastern mainland Cagayan. At the same time, increasing vertical wind shear and land interaction triggered a period of rapid weakening. Prior to landfall, Ramon was downgraded to severe tropical storm category at 15 UTC on 19 November following a 3-hour intensity drop of 15 kt. At 1620 UTC, the center of the eye of Ramon made landfall in the vicinity of Santa Ana, Cagayan as confirmed by PAGASA Aparri Radar.

Rapid weakening continued as the storm moved southwestward inland over Northern Luzon and the western section of Central Luzon. At 18 UTC on 19 November, Ramon was downgraded into a tropical storm while over Santa Ana, Cagayan and at 00 UTC of the following day, it was further downgraded into a tropical depression near the Kalinga-Cagayan border. The TC eventually emerged over waters west of Zambales past 12 UTC on 20 November as a minimal tropical depression. Ramon continued moving southwestward and west southwestward for the next 24 hours over the West Philippine Sea and was last tracked at 12 UTC on 21 November when it degenerated into a remnant low.

Storm duration rainfall estimates reveal that the passage and landfall of Typhoon Ramon resulted in 11-day rainfall between 50 and 200 mm (with isolated areas of up to 400 mm in upland areas of northeastern Cagayan and some islands in the Babuyan Archipelago) over Cagayan including Babuyan Islands, Batanes, Isabela, Quirino, northern Aurora, Apayao, Kalinga, Mountain Province, and Ifugao. In addition, the sheared convection of Ramon during the early stages of its lifespan and the associated inflow rainbands of the TC resulted in accumulated rainfall between 50 to 200 mm over Quezon, Marinduque, Romblon, Bicol Region, the northern portion of Eastern Visayas, most of Panay Island, Guimaras, and northern Negros Occidental (with isolated totals reaching 300 mm over portions of Catanduanes). The rapid weakening of Ramon post landfall and the presence of mountain ranges in Northern and Central Luzon prevented the occurrence of heavy rainfall in other areas of mainland Luzon.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Basco, Batanes: 117.4 mm, 18 November 2019
- Tuguegarao City, Cagayan: 116.2 mm, 20 November 2019
- Virac, Catanduanes: 98.5 mm, 13 November 2019

Highest storm duration (11 to 21 November 2019) rainfall over land:

- Tuguegarao City, Cagayan: 209.2 mm
- Basco, Batanes: 200.3 mm
- Aparri, Cagayan: 166.0 mm

Highest peak gust over land:

- Basco, Batanes: NE (40°) at 77.7 kt (40 m/s), 0240 UTC, 19 November 2019
- Aparri, Cagayan: NNE (20°) at 54.4 kt (28 m/s), 2104 UTC, 19 November 2019
- Calayan, Cagayan: 38.9 kt (20 m/s), between 20 and 21 UTC, 18 November 2019*

Lowest sea level pressure over land:

- Calayan, Cagayan: 1002.6 hPa, 2100 UTC, 18 November 2019*
- Tuguegarao City, Cagayan: 1003.3 hPa, 2220 UTC, 19 November 2019
- Aparri, Cagayan: 1004.0 hPa, 2000 UTC, 19 November 2019

** From the last enhanced (hourly) observation report of the station for the entire passage.*

Summary of Warning Information

Number of public TC products issued: **61**

- Severe Weather Bulletins: **45**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **16**

Number of TC Warning for Shipping issued: **34**

Number of localities under TC Wind Signal (TCWS): **22**

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

Summary of Casualties and Damage to Property

Number of casualties: **None**

Combined cost of damage: **Not provided**

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

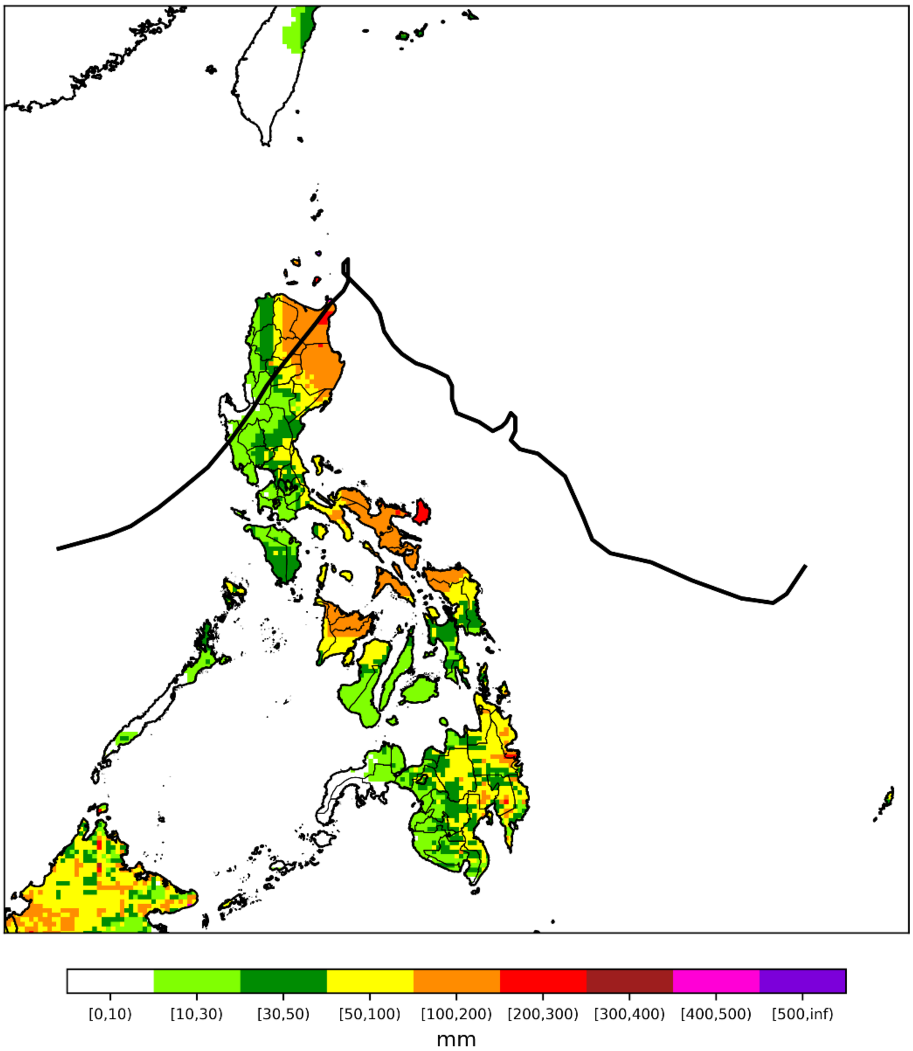

Fig 4.18.2. PAGASA best track of Typhoon Ramon (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 11 to 21 November 2019.

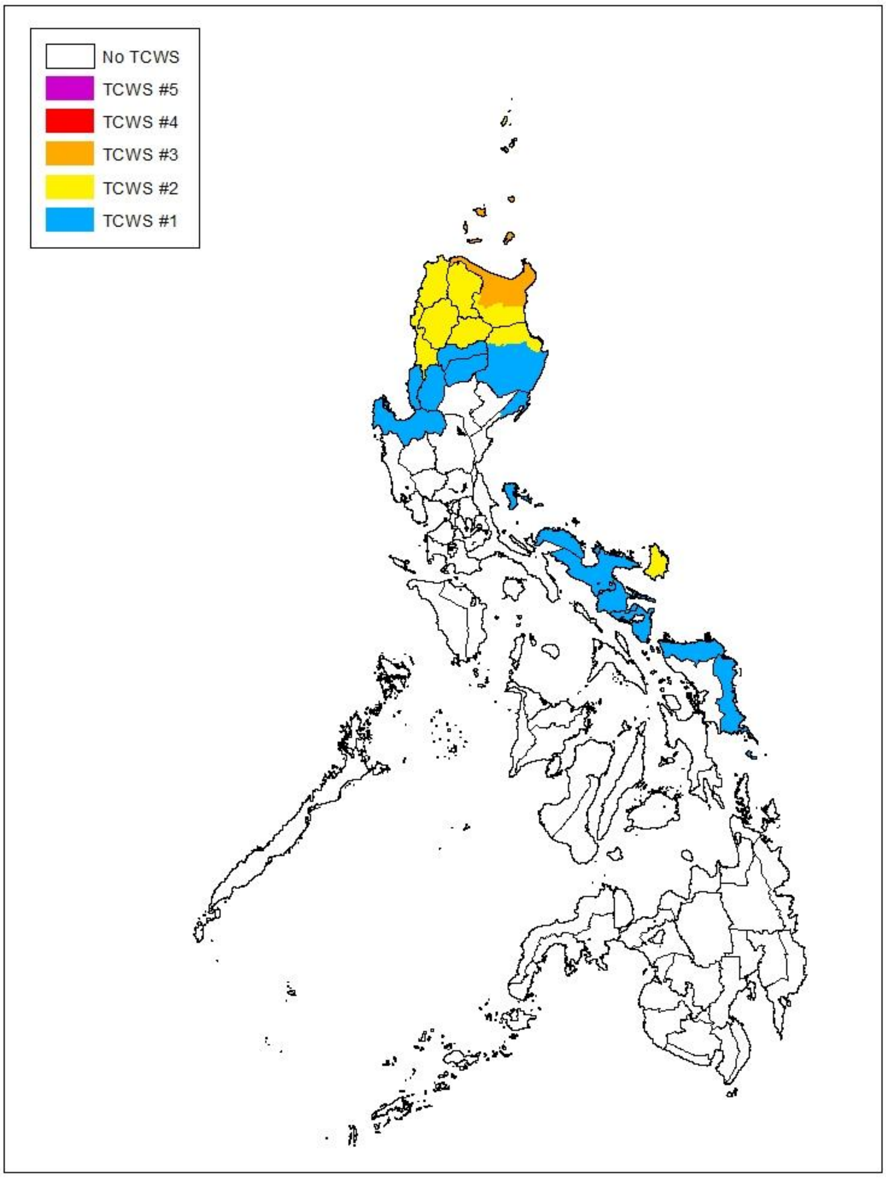

Fig 4.18.3. Highest wind signal hoisted by PAGASA during the occurrence of Typhoon Ramon.

SEVERE TROPICAL STORM SARAH (FUNG-WONG)

19 to 23 November 2019

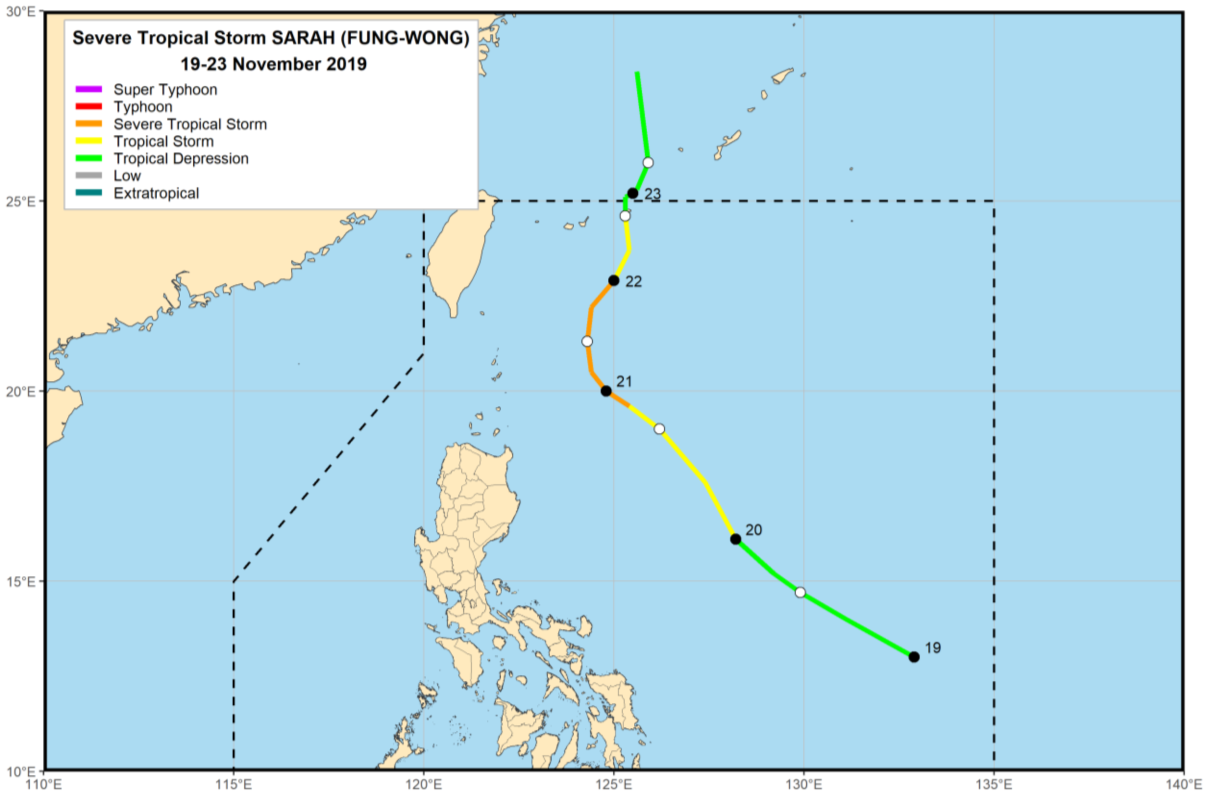

Fig 4.19.1. PAGASA best track positions and intensities of Severe Tropical Storm Sarah. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

A westward-propagating tropical disturbance originating from the Pacific waters off the Federated Sates of Micronesia developed into a tropical depression within the PAR at 00 UTC on 19 November. For the next two days, Sarah, as it was locally called, tracked generally northwestward over the Philippine Sea while gradually intensifying. Roughly 24 hours after forming, the TC intensified into a tropical storm. It was further upgraded into a severe tropical storm at 18 UTC on 20 November.

Sarah started turning northward and north northeastward on 21 November while over the waters less than 400 km to the east of Batanes. At 00 UTC of the same day, the storm reached its peak intensity of 55 kt and 990 hPa. Moving towards the southern portion of the Ryukyu Archipelago, Sarah started to considerably weaken in the presence of increasing northeasterly wind shear. It was downgraded to tropical storm category at 00 UTC on 22 November and to tropical depression category 12 hours later. At 1310 UTC of the same day, Sarah made landfall in the vicinity of Miyako Island, Okinawa Prefecture near the northern limit of the PAR. After leaving the PAR region at 18 UTC of the same day, Sarah continued tracking northward over the East China Sea. PAGASA last tracked the TC at 18 UTC on 23 November as it degenerated into an area of low pressure.

Severe Tropical Storm Sarah tracked over the waters east of Northern Luzon during a period of cold surge of the Northeast Monsoon. As such, the storm enhanced the convergence along the shear line that extended from a stationary front at the leading edge of the said cold surge. The resulting storm-shear line interaction resulted in heavy rains of around 50-200 mm over Apayao, Kalinga, Isabela, Cagayan including Babuyan Islands, and portions of Batanes, Mountain Province, and Ifugao (with isolated areas of up to 300 mm over extreme northeastern mainland Luzon and portions of Babuyan Islands that were far from manned synoptic stations).

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- Tuguegarao City, Cagayan: 116.2 mm, 20 November 2019
- Aparri, Cagayan: 73.8 mm, 19 November 2019
- Basco, Batanes: 72.6 mm, 19 November 2019

Highest storm duration (19 to 22 November 2019) rainfall over land:

- Tuguegarao City, Cagayan: 165.0 mm
- Aparri, Cagayan: 102.4 mm
- Basco, Batanes: 77.2 mm

Summary of Warning Information

Number of public TC products issued: **23**

- Severe Weather Bulletins: **15**
- Tropical Cyclone Advisories: **None**
- Tropical Cyclone Updates: **8**

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

Number of localities under TC Wind Signal (TCWS): **3**

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

Summary of Casualties and Damage to Property

Number of casualties: **Not provided**

Combined cost of damage: **Not provided**

- Damage to agriculture: **Not provided**
- Damage to infrastructure: **Not provided**.

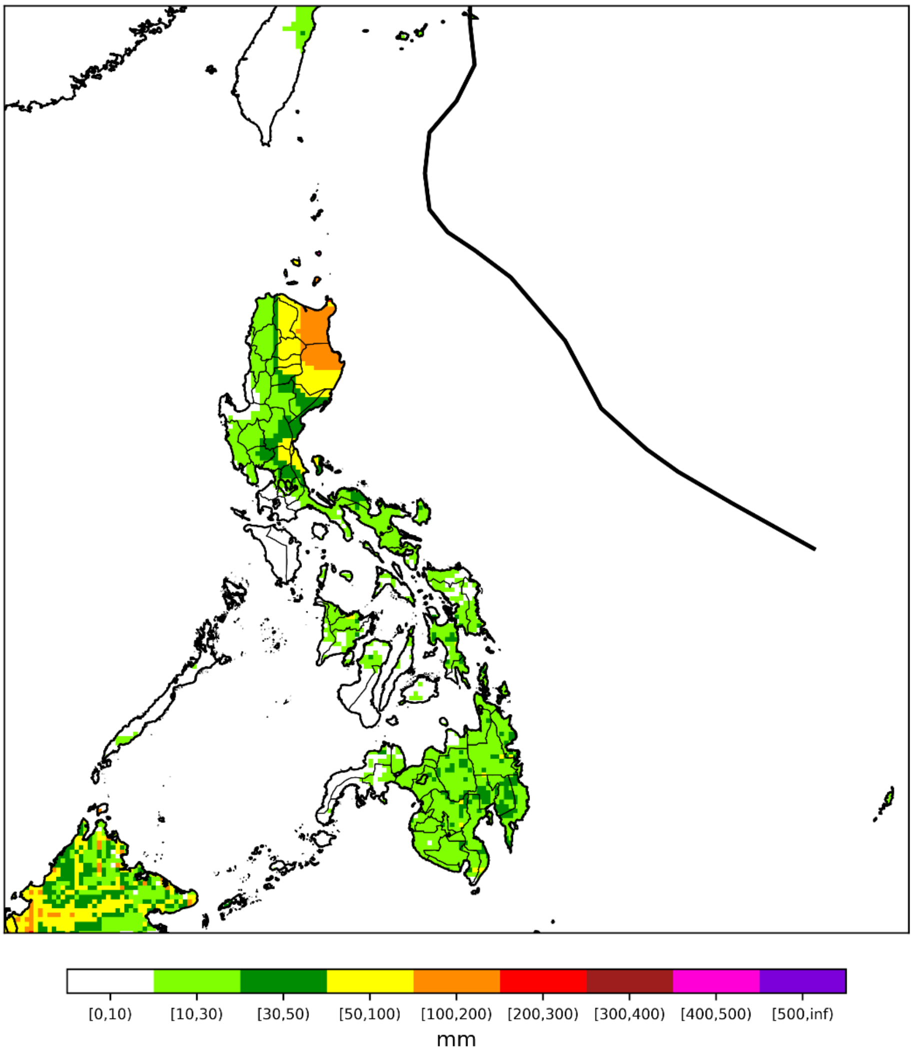

Fig 4.19.2. PAGASA best track of Severe Tropical Storm Sarah (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 19 to 22 November 2019.

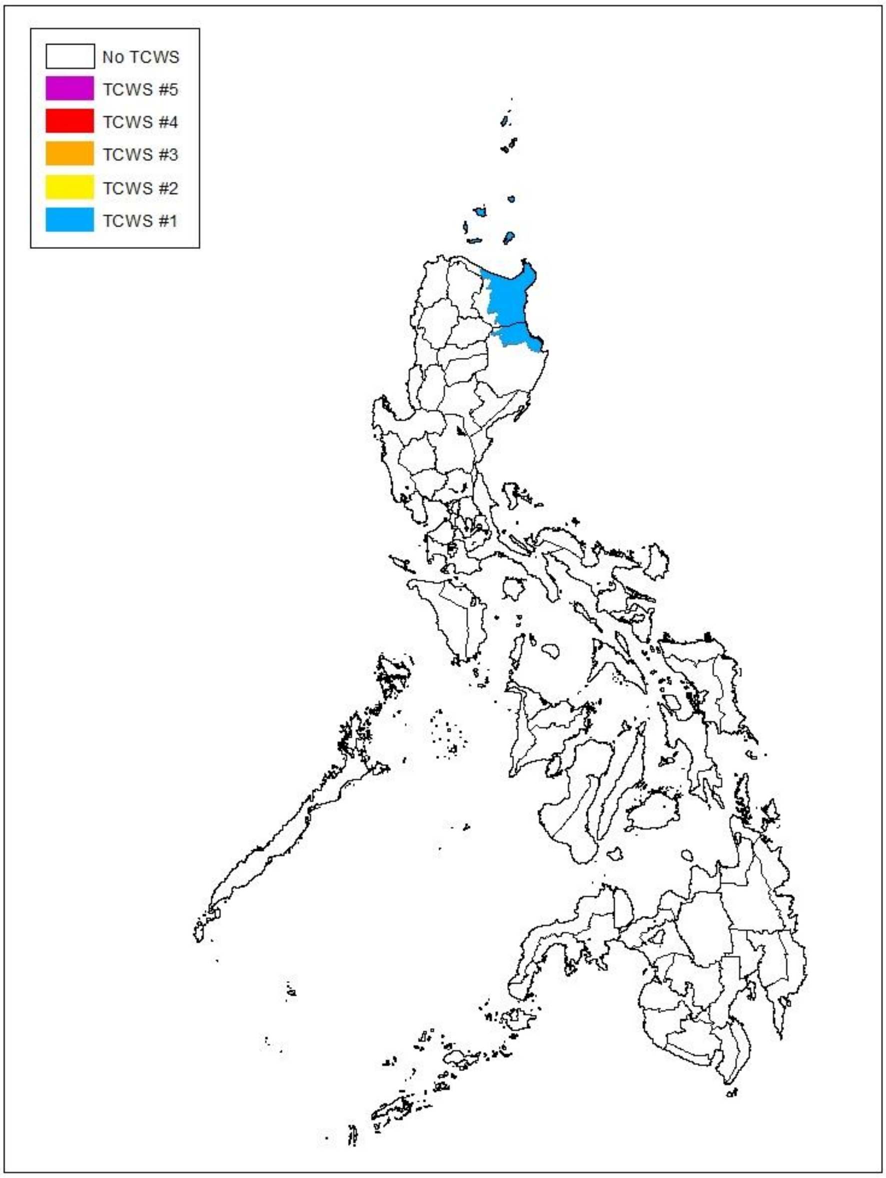

Fig 4.19.3. Highest wind signal hoisted by PAGASA during the occurrence of Severe Tropical Storm Sarah.

TYPHOON TISOY (KAMMURI)

24 November to 06 December 2019

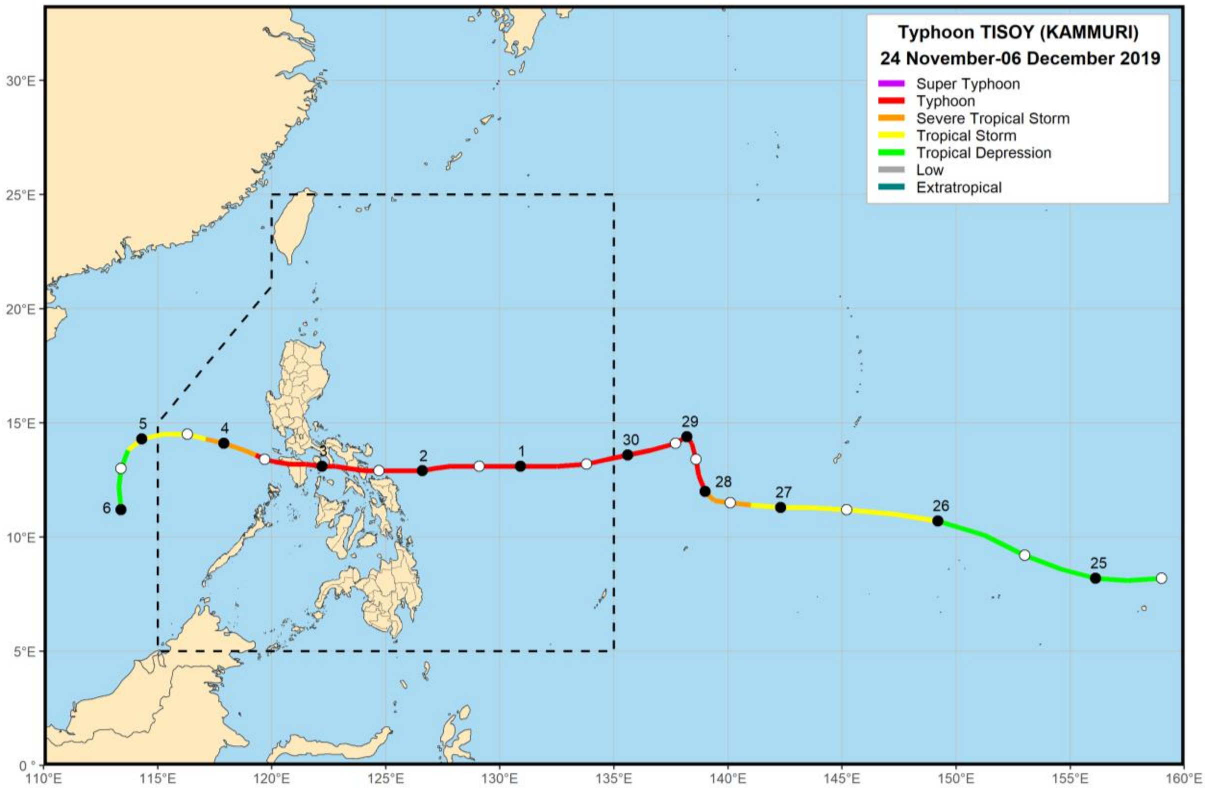

Fig 4.20.1. PAGASA best track positions and intensities of Typhoon Tisoy. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

The strongest TC to make landfall in the Philippines and the longest-lasting TC within the WNP basin for the season was first tracked as a tropical depression at 12 UTC on 24 November over the Pacific waters of Pohnpei, Federated States of Micronesia roughly 2,400 km from the eastern limit of the PAR region. Tracking west northwestward, the TC gradually intensified and was upgraded to tropical storm category at 00 UTC on 26 November. For the next two days. the storm, internationally named Kammuri, turned more westward and gradually decelerated as it passed over the sea south of the Northern Mariana Islands. Intensification continued during the said period and at 06 UTC on 27 November, Kammuri reached severe tropical storm category.

At 00 UTC on 28 November, the TC reached typhoon category in the presence of marginally supportive environment for intensification. At the same time, the typhoon started turning more north northwestward and continued decelerating towards a col area in the subtropical ridge to the north. Early on 29 November, the typhoon became quasi-stationary. Following its intensification into a typhoon, Kammuri entered a period of arrested development due to combined effects of lowered ocean heat content (related to ocean upwelling resulting from its slow movement) and moderate vertical wind shear. As a result, the typhoon remained at 65 kt for roughly two and a half days.

Late into 29 November, Kammuri started to accelerate west southwestward as a subtropical ridge to its west became the primary steering influence. The typhoon eventually entered the PAR region at 05 UTC on 30 November and was domestically named Tisoy. Past 12 UTC of the same day, the typhoon started moving more westward towards Bicol Region. Less than 400 km from the east coast of Bicol Region, lowering of vertical wind shear and increasing ocean heat content allowed Typhoon Tisoy to resume intensifying from a prolonged period of arrested development. At 12 UTC on 02 December, the typhoon reached a peak intensity of 95 kt and 945 hPa as it entered the coastal waters of Northern Samar and Sorsogon. PAGASA weather radars in Bicol Region reported that the center of the eye of Typhoon Tisoy made landfall at peak intensity in the vicinity of Gubat, Sorsogon at 1500 UTC on 02 December. This made Tisoy the strongest landfalling TC in the Philippines for the 2021 season in terms of landfall intensity.

For the remainder of 02 December and into 03 December, Tisoy crossed the Bicol Region, Marinduque, and Mindoro Provinces and traversed the inland seas of Southern Luzon (i.e., Burias Pass, Sibuyan Sea, and Tablas Strait). The network of PAGASA weather radars reported three additional landfalls during the period in the vicinity of the following localities:

- San Pascual (Burias Island), Masbate: 2000 UTC, 02 December
- Torrijos, Marinduque: 0030 UTC, 03 December
- Naujan, Oriental Mindoro: 0430 UTC, 03 December

Due to land interaction, Typhoon Tisoy weakened during its traverse of Southern Luzon. By the time the typhoon emerged over the Mindoro Strait at around 08 UTC on 03 December, it had weakened by 15 kt, but still within typhoon category.

Despite moving over the waters west of Mindoro Island, Tisoy continued to weaken as it moved west northwestward towards a high-shear environment associated with a prevailing cold surge. The TC was downgraded into a severe tropical storm at 15 UTC on 03 December and into a tropical storm at 06 UTC of the following day. As the system continued to deteriorate under hostile environmental conditions, its low-level circulation center became exposed and embedded in the northeasterly flow of the cold surge. After leaving the PAR region at 20 UTC on 04 December, Tisoy turned southward over the West Philippine Sea. Further weakening ensued and the TC was further downgraded to tropical depression category at 06 UTC on 05 December. PAGASA last tracked Tisoy at 00 UTC of the following day as it degenerated into a remnant low.

The passage of Typhoon Tisoy during a cold surge event resulted in enhanced convergence along the shear line extending from a weather front over the Pacific waters southeast of Japan. In addition, the passage of the typhoon during the cold surge resulted in a steeper pressure gradient between the typhoon and the high pressure area over mainland Asia. Both of these resulted in heavy rains not only in the vicinity of the observed track of the typhoon (i.e., Southern Luzon, most of Eastern Visayas, and portions of Western Visayas) but also over the eastern section of Northern and Central Luzon. Much of the higher precipitation amounts (i.e., at least 200 mm) were estimated and observed over the windward areas of the upland and mountainous localities along the eastern section of Luzon and the northern portion of Samar Provinces.

Along the vicinity of the observed track, there were isolated localities, especially in the Bicol Region-Samar Island areas that were directly hit by the eyewall, that received rainfall amounts in excess of 300 mm based on satellite estimates (some of which was corroborated by ground observations). In addition, there were areas along the eastern portion of Cagayan Valley and the northern portion of Aurora that also received in excess of 300 mm of storm-duration rainfall.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:
- Catarman, Northern Samar: 605.5 mm, 02 December 2019
- Juban, Sorsogon: 298.8 mm, 02 December 2019
- Virac, Catanduanes: 247.4 mm, 02 December 2019

Highest storm duration (30 November to 04 December 2019) rainfall over land:
- Catarman, Northern Samar: 641.5 mm
- Casiguran, Aurora: 373.2 mm
- Juban, Sorsogon: 316.8 mm

Highest peak gust over land:

- Legazpi City, Albay: NNE (20°) at 77.7 kt (40 m/s), 1822 UTC, 02 December 2019
- Romblon, Romblon: N (360°) at 77.7 kt (40 m/s), 0139 UTC, 03 December 2019
- Catarman, Northern Samar: SW (220°) at 73.9 kt (38 m/s), 2035 UTC, 02 December 2019

Lowest sea level pressure over land:

- Juban, Sorsogon: 963.4 hPa, 1600 UTC, 02 December 2019
- Legazpi City, Albay: 963.8 hPa, 1637 UTC, 02 December 2019
- Catarman, Northern Samar: 971.0 hPa, 1200 UTC, 02 December 2019

Summary of Warning Information

Number of public TC products issued: **50**

- Severe Weather Bulletins: **26**
- Tropical Cyclone Advisories: **5**
- Tropical Cyclone Updates: **19**

Number of TC Warning for Shipping issued: **20**

Number of localities under TC Wind Signal (TCWS): **51**

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

Summary of Casualties and Damage to Property

Number of casualties: **4 dead and 318 injured persons**

Combined cost of damage: **PHP 6,646,080,088.00**

- Damage to agriculture: **PHP 3,701,081,561.58**
- Damage to infrastructure: **PHP 2,944,998,526.42**

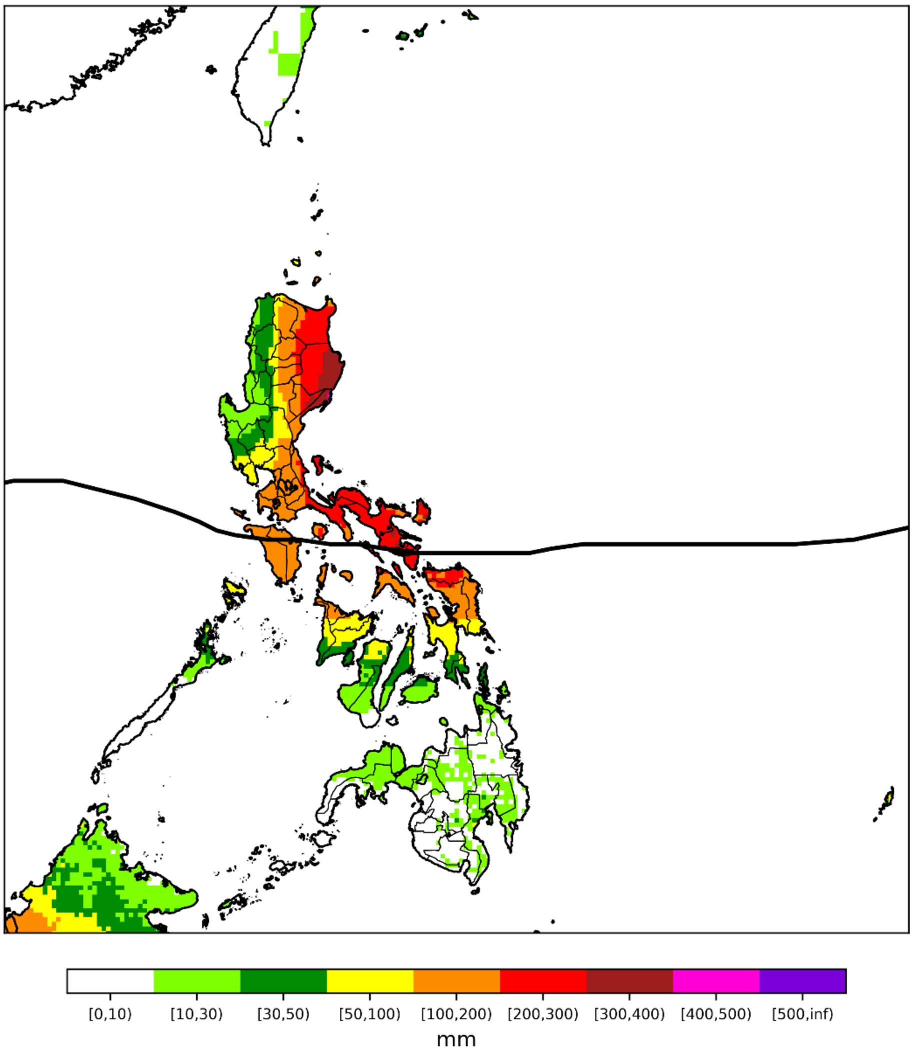

Fig 4.20.2. PAGASA best track of Typhoon Tisoy (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 30 November to 04 December 2019.

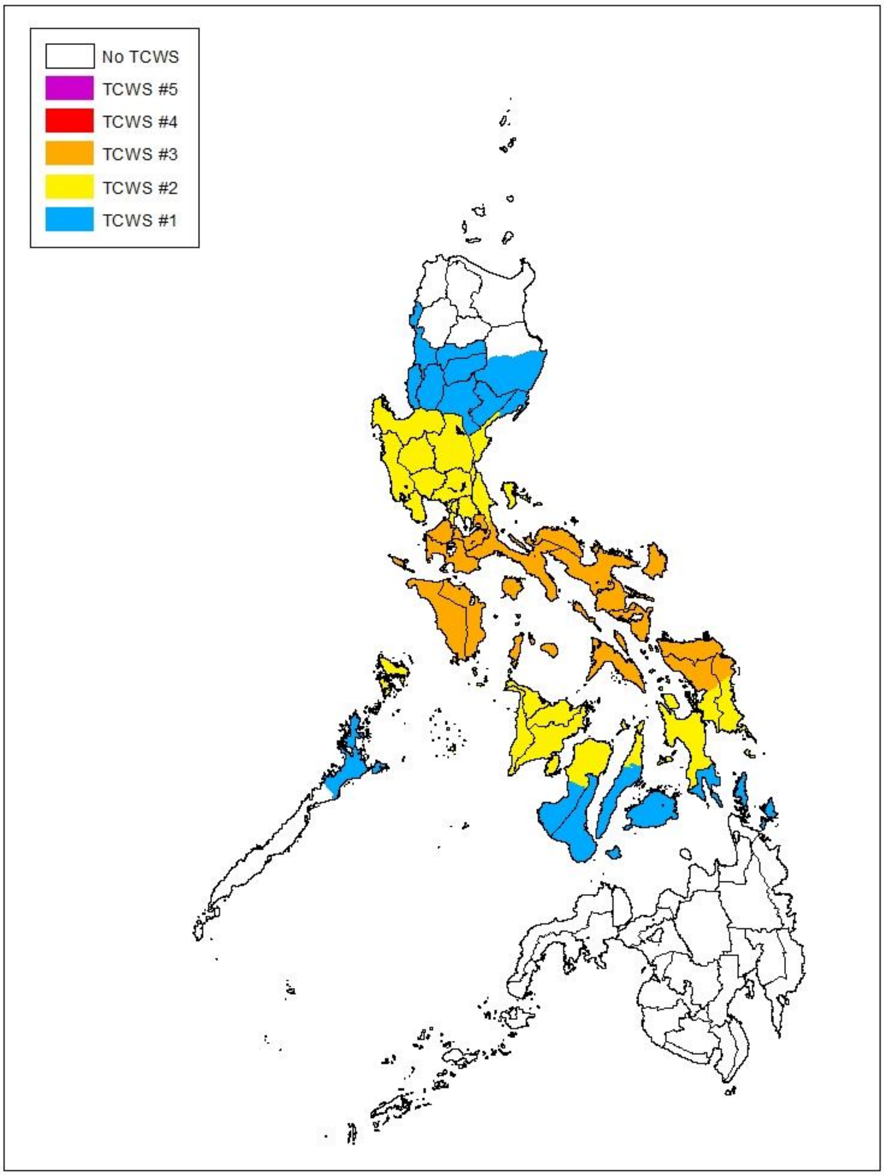

Fig 4.20.3. Highest wind signal hoisted by PAGASA during the occurrence of Typhoon Tisoy.

TYPHOON URSULA (PHANFONE)

20 to 28 December 2019

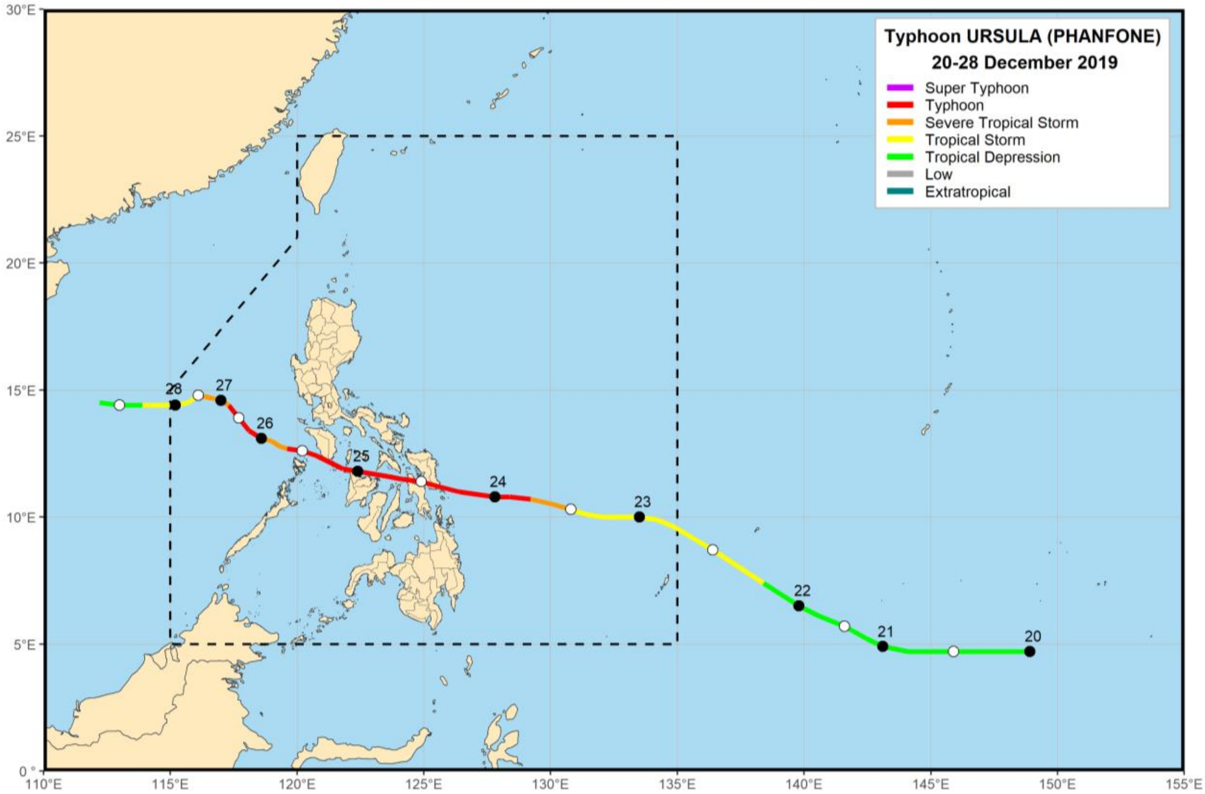

Fig 4.21.1. PAGASA best track positions and intensities of Typhoon Ursula. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Meteorological History

The last TC of the 2021 season and the second TC to make landfall as a typhoon-category cyclone originated from an area of low pressure over the waters off Federated States of Micronesia and was first tracked as a tropical depression near Chuuk at 00 UTC on 20 December. Initially tracking westward, the depression turned more northwestward on 21 December while slowly intensifying. At 06 UTC on 22 December, it intensified into a tropical storm with the international name Phanfone. Passing well north of Palau, the storm entered the PAR at 01 UTC of the same day as it began turning west northwestward over the Philippine Sea.

Further intensification ensued on 23 December owing to favorable environmental conditions. Ursula, as it was locally named, intensified into a severe tropical storm at 12 UTC of the same day and into a typhoon-category cyclone six hours later. Ursula continued strengthening until it made its first landfall in the vicinity of Salcedo, Eastern Samar at 0845 UTC on 24 December. The typhoon reached its peak intensity of 85 kt and 970 hPa at 09 UTC of the same day, making it the second strongest TC to hit the country in 2021 in terms of landfall intensity.

Throughout Christmas Eve and Christmas Day, Typhoon Ursula tracked generally west northwestward over several inland seas between Southern Luzon and Visayas (i.e., Visayan Sea, Sibuyan Sea, Tablas Strait, and Mindoro Strait), and crossed several localities in Eastern Visayas, the northern portion of Western Visayas, and the southern portion of Mindoro Island. The network of PAGASA weather radars in Visayas and Southern Luzon reported four additional landfalls during the passage of the typhoon in the vicinity of the following localities:

- Carles (Gigantes Islands), Iloilo: 1830 UTC, 24 December
- Ibajay, Aklan: 0040 UTC, 25 December
- Caluya (Semirara Island), Antique: 0500 UTC, 25 December
- Bulalacao, Oriental Mindoro: 0700 UTC, 25 December.

Owing to warm inland seas and other favorable environmental factors that offset the impact of land interaction, Ursula was able to maintain its peak intensity until before it made landfall in the province of Aklan. A weakening trend began on Christmas Day as it further interacted with the more rugged terrain of Panay and Mindoro Islands. Over the West Philippine Sea, Ursula was downgraded into a severe tropical storm at 15 UTC of the same day, roughly 12 hours after it emerged over the Mindoro Strait. However, the TC was able to regain its strength as it moved over the West Philippine Sea and at 00 UTC of the following day, it was upgraded once again to typhoon category.

Ursula continued tracking generally west northwestward over the West Philippine Sea on 26 December but decelerated as it encountered a cold surge. After slightly intensifying to a secondary peak intensity of 75 kt and 975 hPa, the typhoon began losing strength due to increasingly unfavorable atmospheric and oceanic environment brought about by the cold surge. The typhoon was downgraded to severe tropical storm category at 18 UTC of the same day and to tropical storm category 18 hours later.

As the system continued to deteriorate under hostile environmental conditions, its low-level circulation center became exposed and embedded in surface wind flow of the cold surge. Ursula turned west southwestward and westward beginning at 12 UTC on 27 December and was further downgraded into a tropical depression at 06 UTC of the following day. Ursula was last noted at 18 UTC on 28 December when it finally degenerated into an area of low pressure.

The passage of Typhoon Ursula brought about heavy rainfall in localities that were affected by the eyewall and rainbands of the typhoons, with higher total rainfall in areas nearer to the observed track, unlike in the case of Tisoy wherein higher rainfall accumulations were also observed well to the north of the observed track. Synoptic analysis revealed that the shear line that was present during the passage of Ursula over the central portion of the archipelago was already “diffused” because the monsoon cold surge had already transitioned to a more easterly state. Nevertheless, the passage of the typhoon enhanced the easterly flow over the northern semicircle of the typhoon’s outer circulation that interacted with the mountainous terrain over the east coast of Luzon, resulting in heavy rains that also reached well to the north of the track of the typhoon.

Satellite-derived estimates show around 50 to 200 mm of storm-duration rainfall over Eastern Visayas, Western Visayas, CALABARZON, Metro Manila, Bulacan, Aurora, Mindoro Provinces, Marinduque, Romblon, extreme northern Palawan (including Calamian and Cuyo Islands), Dinagat Islands, Surigao del Norte, and most of Bicol Region and Central Visayas. The rainfall maximum region was estimated in the vicinity of Aklan, with more than half of the province receiving 200-300 mm of rainfall. Isolated areas of 200-300 mm were also noted over southern Occidental Mindoro, Capiz, Iloilo, and Northern Samar.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Highest 24-hour rainfall over land:

- San Jose, Occidental Mindoro: 217.2 mm, 25 December 2019
- Roxas City, Capiz: 155.0 mm, 24 December 2019
- Tacloban City, Leyte: 143.2 mm, 24 December 2019

Highest storm duration (22 to 27 December 2019) rainfall over land:

- San Jose, Occidental Mindoro: 218.9 mm
- Guiuan, Eastern Samar: 190.1 mm
- Tacloban City, Leyte: 185.3 mm

Highest peak gust over land:

- Guiuan, Eastern Samar: WSW (240°) at 97.2 kt (50 m/s), 0914 UTC, 24 December 2019

- Roxas City, Capiz: WNW (290°) at 83.6 kt (43 m/s), 2120 UTC, 24 December 2019
- Tacloban City, Leyte: S (180°) at 83.6 kt (43 m/s), 1220 UTC, 24 December 2019
- San Jose, Occidental Mindoro: S (180°) at 81.6 kt (42 m/s), 0838 UTC, 25 December 2019

Lowest sea level pressure over land:

- Guiuan, Eastern Samar: 967.0 hPa, 0900 UTC, 24 December 2019
- Roxas City, Capiz: 979.5 hPa, 2200 UTC, 24 December 2019
- Tacloban City, Leyte: 980.0 hPa, 1100 UTC, 24 December 2019

Summary of Warning Information

Number of public TC products issued: **50**

- Severe Weather Bulletins: **30**
- Tropical Cyclone Advisories: **2**
- Tropical Cyclone Updates: **18**

Number of TC Warning for Shipping issued: **22**

Number of localities under TC Wind Signal (TCWS): **37**

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

Summary of Casualties and Damage to Property

Number of casualties: **57 dead, 369 injured, and 6 missing persons**

Combined cost of damage: **PHP 4,381,785,043.00**

- Damage to agriculture: **PHP 3,925,679,587.00**
- Damage to infrastructure: **PHP 456,105,456.00**

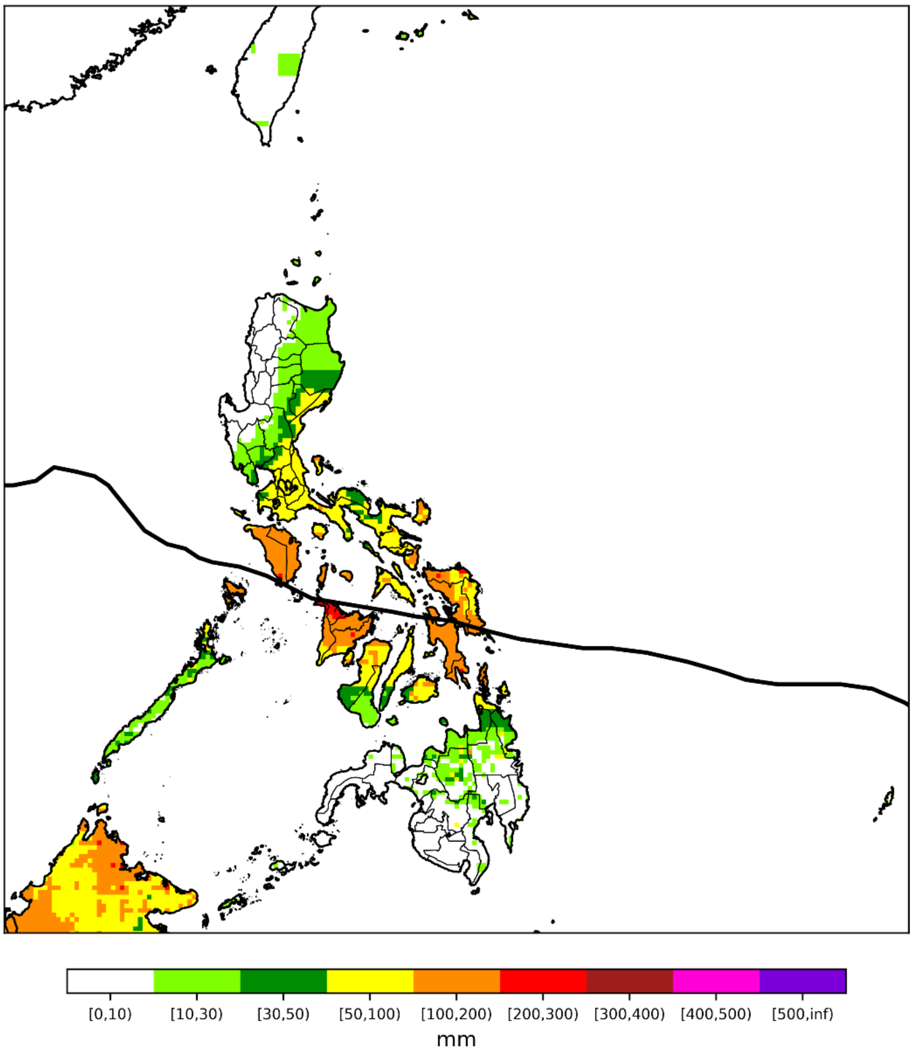

Fig 4.21.2. PAGASA best track of Typhoon Ursula (thick black line) and the gauge-adjusted satellite rainfall estimates (mm) over land within the PAR region for the period of 22 to 27 December 2019.

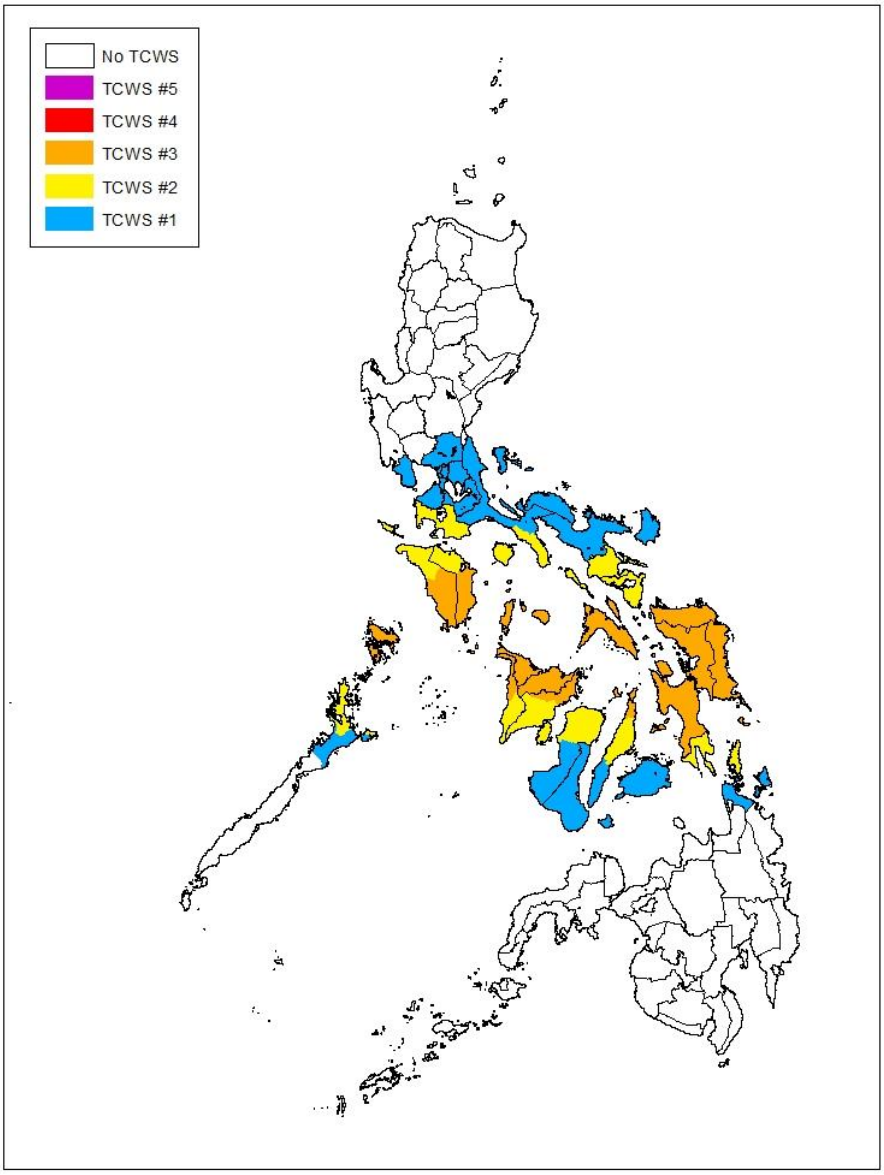

Fig 4.21.3. Highest wind signal hoisted by PAGASA during the occurrence of Typhoon Ursula.

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SPECIAL STUDIES OR REPORTS ON THE 2019 PHILIPPINE TROPICAL CYCLONES

Special Studies or Reports on the 2019 Philippine Tropical Cyclones

This section of the report features several special studies or reports related to the tropical cyclone (TC) season covered by the Annual Report on Philippine Tropical Cyclones (ARTC) or any individual TC case during the TC season of interest. The scope of such studies or reports generally focuses on the monitoring, forecasting, and warning of TCs and their associated hazards, and specifically includes the following areas of interest:

- Detailed reviews of TCs that exhibited unusual characteristics or behavior or those that resulted in disastrous impacts in the Philippines
- Advances in basic or applied TC research or technologies to improve the national TC forecasting and warning program.
- Basic theoretical studies using TC cases during the season of interest of the ARTC.
- Impacts, risk assessments, and risk management techniques related to TC events of the season being discussed.

These contributions could be those that were specifically written for publication as part of the ARTC or commissioned in conjunction with the research and development projects/programs wherein operational meteorologists of the Weather Division are currently or previously involved in.

For the 2019 ARTC, two special studies are featured under this section, all of which were commissioned as case study reports under the Weather and Climate Science for Service Partnership (WCSSP) – Southeast Asia Philippines Project.

Verification of Model Predictions of Southwest Monsoon Rains in the Philippines during Tropical Cyclone Ineng (Bailu)

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Introduction

In the Philippines, roughly 43% of the country's total rainfall happens during the tropical Western North Pacific (WNP) summer monsoon. The Southwest Monsoon (SWM) or *Habagat*, as it is locally termed, usually starts by late May or early June and ends in late September or early October and coincides with the rainy season of the country. During this season, the prevailing westerlies bring in warm moist air towards the western sections of the country, resulting in monsoon rains. On average, the distribution of SWM rainfall in the country shows that heavy rains in the range of 1,500 mm to 2,000 mm are observed annually over the western sections of Luzon, with accumulations in excess of 2,000 mm concentrated over mountainous areas (Asuncion et al. 1980). The SWM season also sees the greatest number of tropical cyclones (TC) entering the forecast area of responsibility (PAR) of the state weather bureau Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), with 11.1 of the 19.4 TCs occurring within the PAR during the SWM season (Cinco et al. 2016).

The western Luzon region receives the highest TC-induced rainfall (as much as 1,400 mm) and TC rain contribution (around 54%) every year in the Philippines (Bagtasa 2017). In a separate investigation of high precipitation event[45] (HPE) days over western Luzon during the SWM season from 1958-2017, Bagtasa (2019) revealed that while more than 90% of the HPE days in the region coincided with TC occurrence within the WNP basin, only 12.8% to 15.1% of HPE days were coincident with TCs crossing the archipelago. In the presence of non-landfalling TCs, the HPE days over western Luzon were brought about by the enhancement of the prevailing monsoonal flow when these TCs passed north, northeast, or northwest of Luzon (Cayanan et al. 2011), especially when they cross the vicinity of an imaginary line segment containing northern Luzon and Okinawa, Japan (Bagtasa 2019). The mountain ranges in western Luzon (Fig. 1) induces orographic lift on the enhanced monsoonal flow, which contributes to the occurrence of heavy rains in the region (Cagayan et al. 2011)

In the last 10 years, SWM heavy rainfall events have resulted in significant number of casualties and damages to infrastructure and agriculture. One notable event was the *Habagat 2012*, which was the heavy rainfall event from 6 to 9 August over western Luzon, including the capital region Metropolitan Manila. Over this 3-day period, the western sections of Central and Southern Luzon received in excess of 200 mm of rain. A reconstruction of the event using gauge-adjusted radar data (Heistermann et al. 2013) suggests that the northern Metropolitan Manila area received anywhere between 500 to 1100 mm of rainfall. Affected population reached 4.45 million, with 112 dead, 14 injured, and 4 missing individuals. In addition, damages to infrastructure and agriculture amounted to PHP 3.182 billion (US$ 76.2 million[46]) (NDRRMC 2012).

Given that 44.9% of the Philippine population (roughly 45.3 million people) live in the region of western Luzon (PSA 2016), understanding the performance of numerical weather prediction (NWP) models in providing rainfall forecast during these events is important in improving their predictability, thereby reducing their impacts of these phenomena. This paper aims to describe the performance in predicting day-1 to day-3 24 h accumulated rainfall of the three NWP models being used by PAGASA in operational forecasting during the SWM HPE associated with the passage of Tropical Cyclone Ineng (Bailu) in August 2019 (herein referred to as the AUG19 event). The next section discusses the data and methodologies used to perform the model forecast verification. In section 3, the discussion of the synoptic condition, the distribution of accumulated rainfall and forecast performance of each NWP model for each TC case are presented. Section 4 summarizes the results of this study.

[45] HPE days were determined by Bagtasa (2019) using daily rainfall values in the upper 85th, 95th and 99th percentile averaged over 8 PAGASA synoptic stations in western Luzon.
[46] US$ 1 = PHP 41.7800 as of 11 August 2012

Data and Method

Rainfall data

Due to sparse density of quality-controlled rainfall data from the observation network in the Philippines and the lack of gridded rainfall observation that can be used to be verify rainfall forecasts from NWP models, the study utilized satellite-derived rainfall estimates generated by the Global Satellite Mapping of Precipitation (GSMaP) project (Kubota et al. 2020). In particular, the gauge-calibrated rainfall product (GSMAP-Gauge; Mega et al. 2019) with a horizontal resolution of 0.1° x 0.1° degrees was used. The product is based from the GSMAP moving vector with Kalman filter method (GSMaP-MVK; Ushio et al. 2009) corrected using daily gauge-based rainfall analysis from the Climate Prediction Center (Xie et al. 2010) to improve the underestimation of precipitation over land. The hourly rain rate products of GSMaP-Gauge constituting one meteorological day were merged to form daily estimates of rainfall accumulations over the Philippines. For the case of AUG10 event, the period considered for verification was 20 to 24 August 2019.

Table 1. Key configurations of operational NWP models used for PAGASA rainfall forecasts.

Parameters	Unified Model (UM)	Global Spectral Model (GSM)	Weather Research and Forecasting (WRF)
Version	GA7.0	GSM1705	WRF-ARW 4.0.2
Domain	Global	Global	3°N-25°N 115°E-135°E
Horizontal resolution	~10 km (2560 x 1920 grid points) in mid-latitude areas	Spectral triangular 959 (TL959), reduced Gaussian grid system, roughly 0.1875° (20 km)[47]	12 km (182 x 214 grid points)
Number of vertical levels	70	100	50
Model top	~80 km	0.01 hPa	50 hPa (~20 km)
Initial / lateral boundary conditions[48]	Hybrid Incremental 4D-Var with flow-dependent background errors from 44-member global ensemble.	Incremental 4D-Var	NCEP GFS 0.25°
Initial times (UTC)	00, 06, 12, 18[49]	00, 06, 12, 18	00, 03, 06, 09, 12, 15, 18, 21
Forecast length	144 hours (00, 12 UTC)	132 hours (00, 06, 18 UTC) 264 hours (12 UTC)	144 hours
Output format	grib2	grib2	grib2
Run by	Met Office	JMA	PAGASA

NWP model data

PAGASA meteorologists have access to raw and post-processed model forecasts from two global-scale and two convective-scale models. These are the Global Spectral Model (GSM; Japan Meteorological Agency 2019) of the Japan Meteorological Agency (JMA) and the Unified Model (UM; Walters et al. 2019) of the UK Met Office. These models are primarily utilized by forecasters to diagnose the evolution of synoptic-scale patterns and the general distribution of precipitation over the Philippines. However, due to the coarse horizontal resolution of such models, the GSM and UM models may not fully capture mesoscale events and other meteorological features that are smaller than the horizontal resolution of

[47] Available resolution of model outputs via the JMA High Resolution Data Service is 0.25° (~28 km) and 0.50° (~56 km) for surface and upper air layers respectively.
[48] Global models have no lateral boundary conditions.
[49] Only outputs from 00 and 12 UTC are received through the FTP service of the UK Met Office

these model. To address this, PAGASA operates the Weather Research and Forecasting (WRF; Skamarock et al. 2019) model at 3 km and 12 km horizontal resolution with the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) providing the initial and lateral boundary conditions. In this report, only 12-km WRF was subjected to forecast verification because the forecast length of WRF3 was less than 72 hours. The summary of key configurations of the NWP models discussed in this report are presented in Table 1. The gridded outputs of the GSM and UM were made available[50] to PAGASA in real-time through the website of the JMA High Resolution GSM Data Service (https://www.wis-jma.go.jp/cms/gsm/) and the File Transfer Protocol (FTP) service of the UK Met Office (http://ftpids.metoffice.gov.uk/) respectively. On the other hand, the gridded data from the WRF model is automatically pushed by the Numerical Modelling Section of PAGASA to an FTP server accessible to the Weather Division.

Standard categorical and continuous scores (Japan Meteorological Agency 2019) were used in order to compare the day-1, day-2, and day-3 forecasts of 24-hour rainfall of the over land of GSM, UM, WRF3, and WRF12 against GSMAP-Gauge estimates for 20 to 24 August 2020. Only the 00 UTC runs of the models were verified. Given this, model initializations at 00 UTC from 18 to 24 August were used. In addition, only model grids on land were considered for verification as the study is concerned on the rainfall forecast over land.

Table 1 shows that the NWP models in this report have varying horizontal resolutions, none of which matches the 0.1° x 0.1°grid resolution of GSMaP-Gauge. Given this circumstance, the gridded model outputs were re-scaled using inverse distance weighing (IDW) to match the native resolution of the GSMaP-Gauge.

Forecast Verification

Tropical Cyclone Ineng developed from an area of low pressure over the Philippine Sea east of Visayas at around 12 UTC on 19 August to become the ninth TC within the PAR in 2019. The TC did not make landfall over the country during its period of occurrence. Instead, it followed a generally northwestward track within the PAR, crossed the imaginary line between northern Luzon and Okinawa, Japan, and made landfall over the southern tip of Taiwan on 24 August before heading out towards southern China (Fig. 5.1.1a). Despite having a non-landfalling track, the resulting synoptic setup brought in an enhanced monsoon southwesterlies (Fig. 5.1.2) and widespread heavy monsoon rains (100+ mm) over Ilocos Region, Cordillera, Zambales, Bataan, Tarlac, Pampanga, Bulacan, Metro Manila, Cavite, Mindoro Provinces, and the northern portion of Palawan. Over the northwestern portion of Luzon (i.e. Ilocos Norte and Abra), five-day total rainfall was estimated between 300-500 mm (Fig. 5.1.1b) with higher accumulations[51] from rain gauge observations in the area. Much of the heavy rains during the passage of Ineng were observed on 23 and 24 August. In terms of the magnitude and extent of monsoon rains, the HPE associated with the passage of Ineng is considered to be one of the wettest during the SWM season of 2019.

Fig. 5.1.3 shows the bias (or mean error) and root mean square error (RMSE) of day-1 to day-3 forecasts of 24-hour accumulated rainfall during the AUG19 event from UM, GSM, and WRF 00 UTC runs averaged over all inland forecast grids. Overall, all the NWP models were found to have a negative bias at all forecast intervals for land grids. UM had the least negative bias of the three models, while the WRF had the most negative bias. While this may suggest that UM had generally better forecast performance than GSM and WRF, the average RMSEs of day-1 to day-3 forecasts show that UM had the highest RMSE of the three models at all forecast intervals. Except for day-1 forecast (wherein WRF has slightly lower RMSE), the GSM forecasts were slightly better than WRF. This suggests that the smaller negative bias of UM compared to GSM and WRF at all forecast intervals may also attribute to the model having forecast grids with substantially high positive bias that could have offset the negative bias observed in most of the model's forecast grids.

[50] Access remains restricted to those with user login credentials for security purposes.
[51] The accumulated rainfall from 20 to 24 August reported by the synoptic station in Laoag City, Ilocos Norte (98223) reached 569.8 mm.

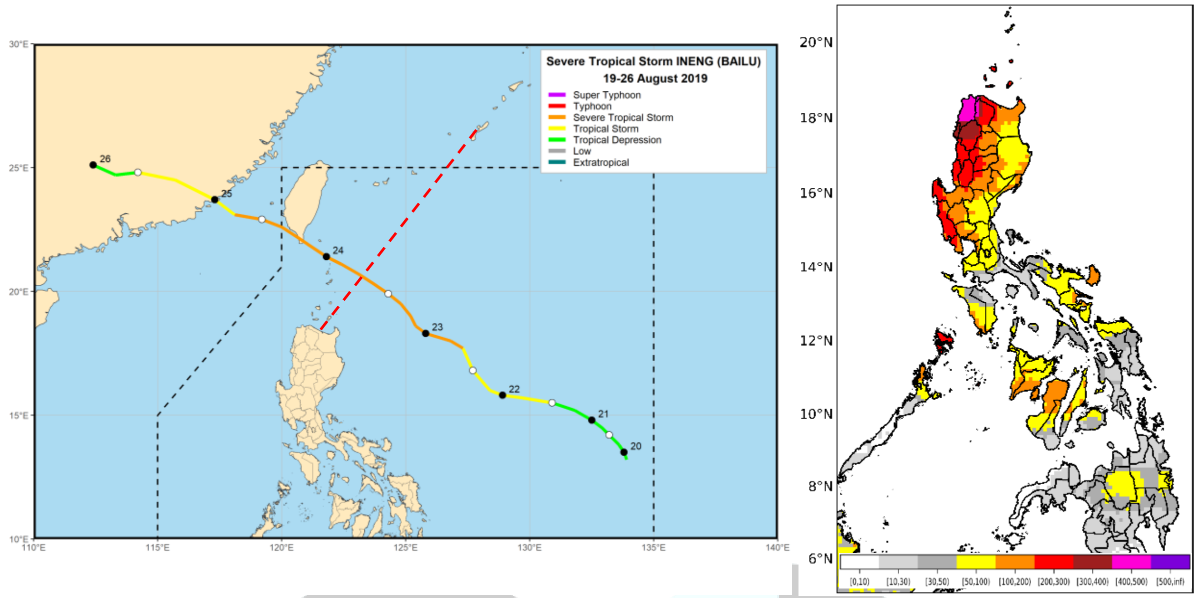

Fig. 5.1.1. (a) RSMC Tokyo best track (six-hourly) positions of Tropical Cyclone Ineng. Open (filled) circles along the track mark the position at 00 (12) UTC. The red dash line is the imaginary line connecting the northern portion of Luzon and Okinawa, Japan as described in Bagtasa (2019). (b) GSMaP-Gauge estimate of accumulated rainfall over land in the Philippines from 20 to 24 August 2019.

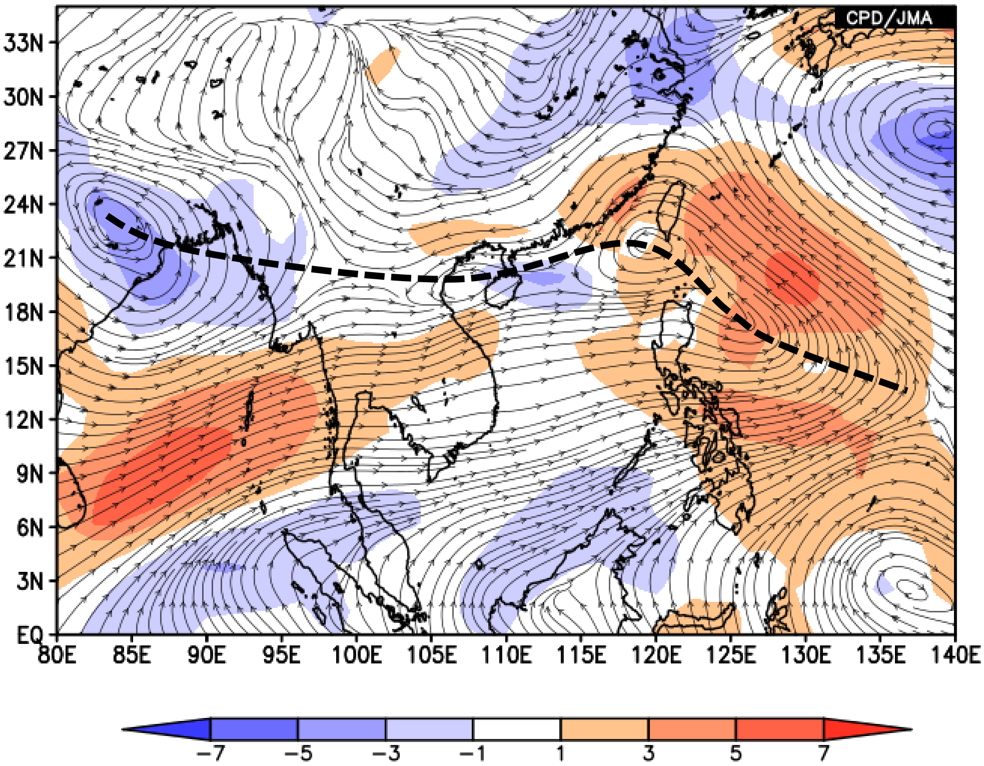

Fig. 5.1.2. JRA-55 reanalysis (Kobayashi et al. 2015) of horizontal wind streamline and horizontal wind speed anomaly (shading, in m/s) at 850 hPa averaged over from 20 to 24 August. Redder (bluer) shade means stronger-than-normal vector wind speed. Dash line indicates the axis of the monsoon trough.

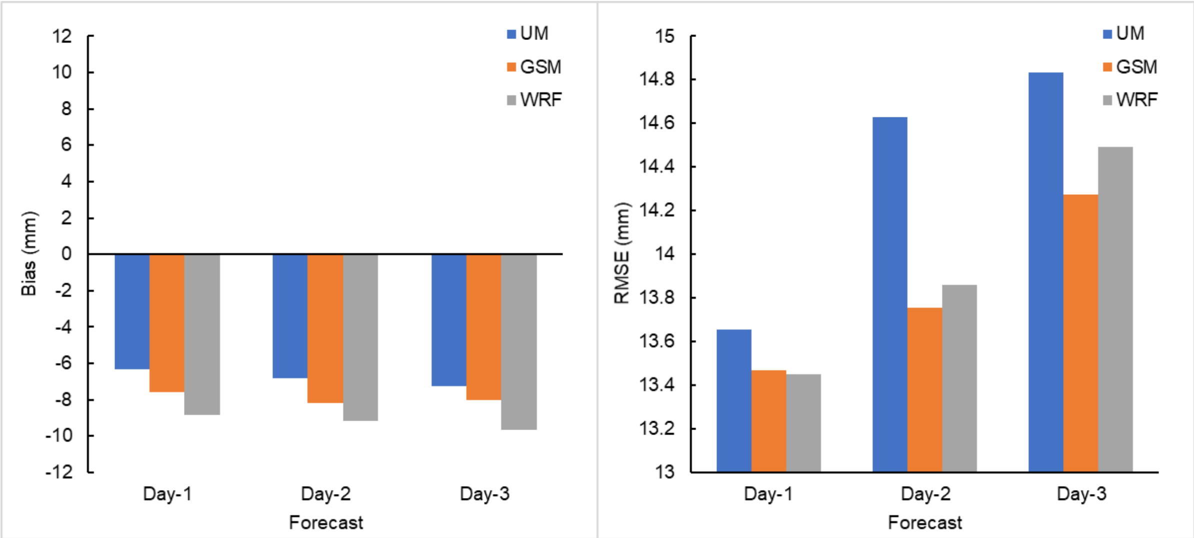

Fig. 5.1.3. (a) Bias and (b) RMSE of day-1 to day-3 forecasts of 24-hour accumulated rainfall (over land) for the period of 20 to 24 August 2020 by UM, GSM, and WRF 00 UTC runs from 18 to 24 August 2020.

Fig. 5.1.4 shows that the three NWP models underpredicted to magnitude and extent of monsoon rains over Cagayan, Ilocos Region, Zambales, Bataan, Tarlac, Pampanga, northern Palawan, and northern Negros Occidental. Of the three models being investigated, the UM appeared to have better performance over GSM and WRF for the monsoon rains over western Luzon mainland during the AUG19 event. The underprediction of monsoon rains over Ilocos Norte was least severe on UM. While the other models showed dry bias in excess of 80 mm for day-1 to day-3 forecasts, the UM only had this magnitude of dry bias for day-3. In addition, the magnitude of dry bias over Zambales and Bataan (the provinces that are commonly exposed to monsoon rains) was the least compared to GSM and WRF, with some isolated areas along the coast having wet bias of at most 40 mm. However, the UM also exhibited higher wet bias in other areas of Luzon and in some areas over the western portion of Visayas. For instance, for day-1 to day-3 forecasts, the UM had regions of wet bias of up to 40 mm over Nueva Ecija, Bulacan, CALABARZON, Bicol Peninsula, Occidental Mindoro, Antique, and in isolated areas over the western portion of Negros Island. Such degree of wet bias over these provinces were not observed in both GSM and WRF day-1 to day-3 forecasts. Moreover, the provinces where the overforecast was observed were all situated on the windward side of mountain ranges. This was most notable over Occidental Mindoro, with a dry bias exceeding 80 mm in some areas on the northwestern portion of Mindoro Island. In terms of RMSE, Fig. 5.1.5 confirms that UM had relatively better performance in predicting the monsoon rains over western Luzon at day-1 to day-3 forecast intervals, with day-1 predictions having RMSE not exceeding 80 mm. Moreover, day-1 and day-2 predictions of UM over northwestern Luzon had smaller areas with RMSE of 60 to 80 mm. However, high RMSE was also noted over Occidental Mindoro and Antique which corresponded to the overforecast over these provinces as noted in Fig. 5.1.4.

The bias scores and equitable threat scores at different rainfall thresholds of the 24-hour accumulated rainfall forecast from 00 UTC runs of UM, GSM, and WRF are presented in Fig. 5.1.6. At all forecast intervals, the WRF underpredicted rainfall accumulations in excess of 5.0 mm more than GSM and UM. While GSM and UM had similar degrees of underprediction (overprediction) of rainfall in excess of 5.0 mm (of at most 5.0 mm), the performance of UM diverges with GSM for accumulated rainfall in excess of 30 mm, with UM having better predictions and GSM having similar degree of underprediction as WRF. The ETS scores in Fig. 5.1.6 shows that for day-2 and day-3 forecasts, the UM slightly performed better in forecasting rainfall of more than 10 mm during the AUG19 event, although the disparity between the performance of UM, GSM, and WRF was minimal. For the day-1 forecast, UM also made better predictions of rainfall in excess of 10 mm than the other NWP models. However, its performance was better at higher rainfall thresholds (i.e., > 30 mm).

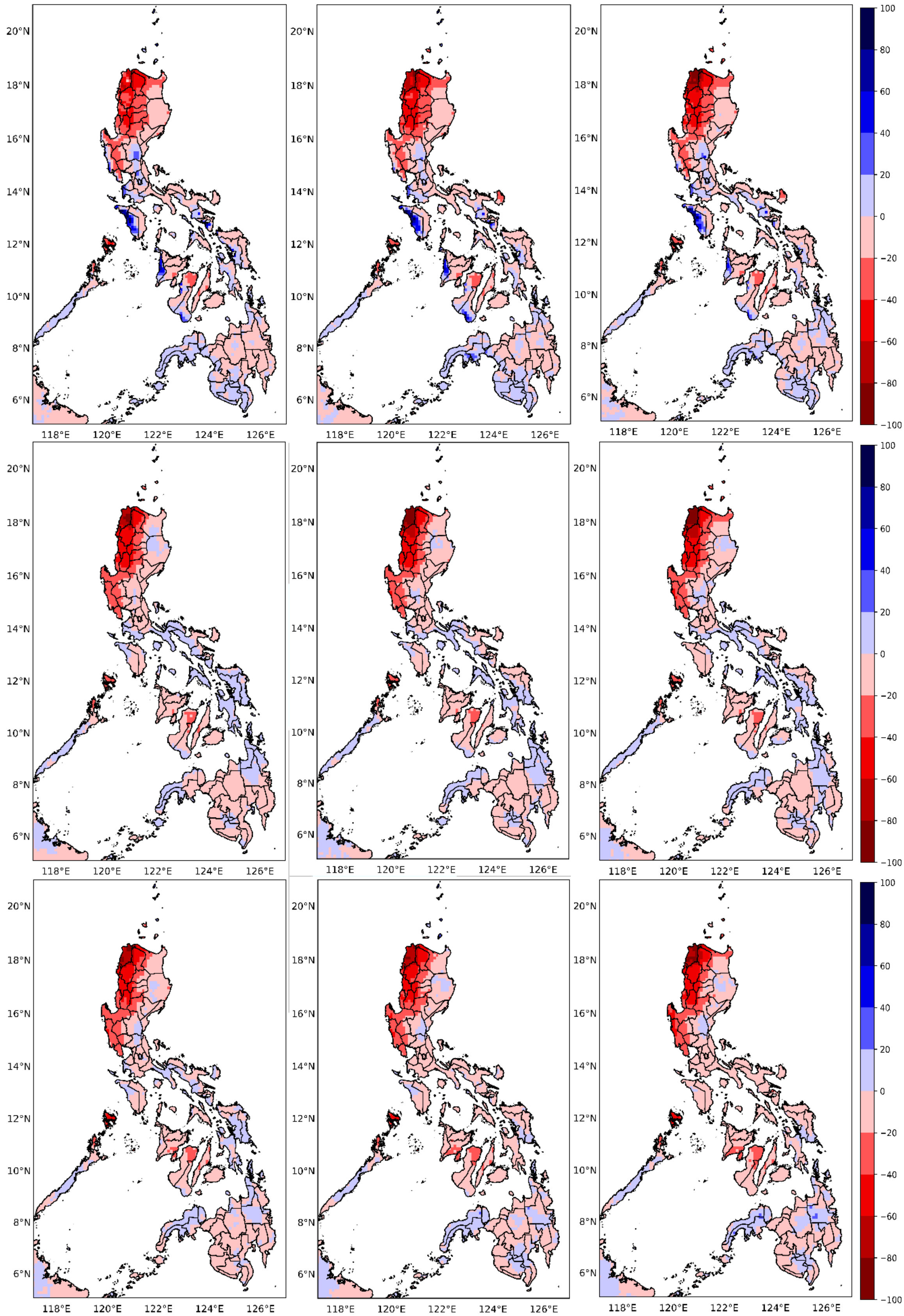

Fig. 5.1.4. Mean error (in mm) of day-1 (left column), day-2 (middle column), and day-3 (right column) forecasts of 24-hour accumulated rainfall from 00 UTC initializations of UM (top row), GSM (middle row), and WRF (bottom row).

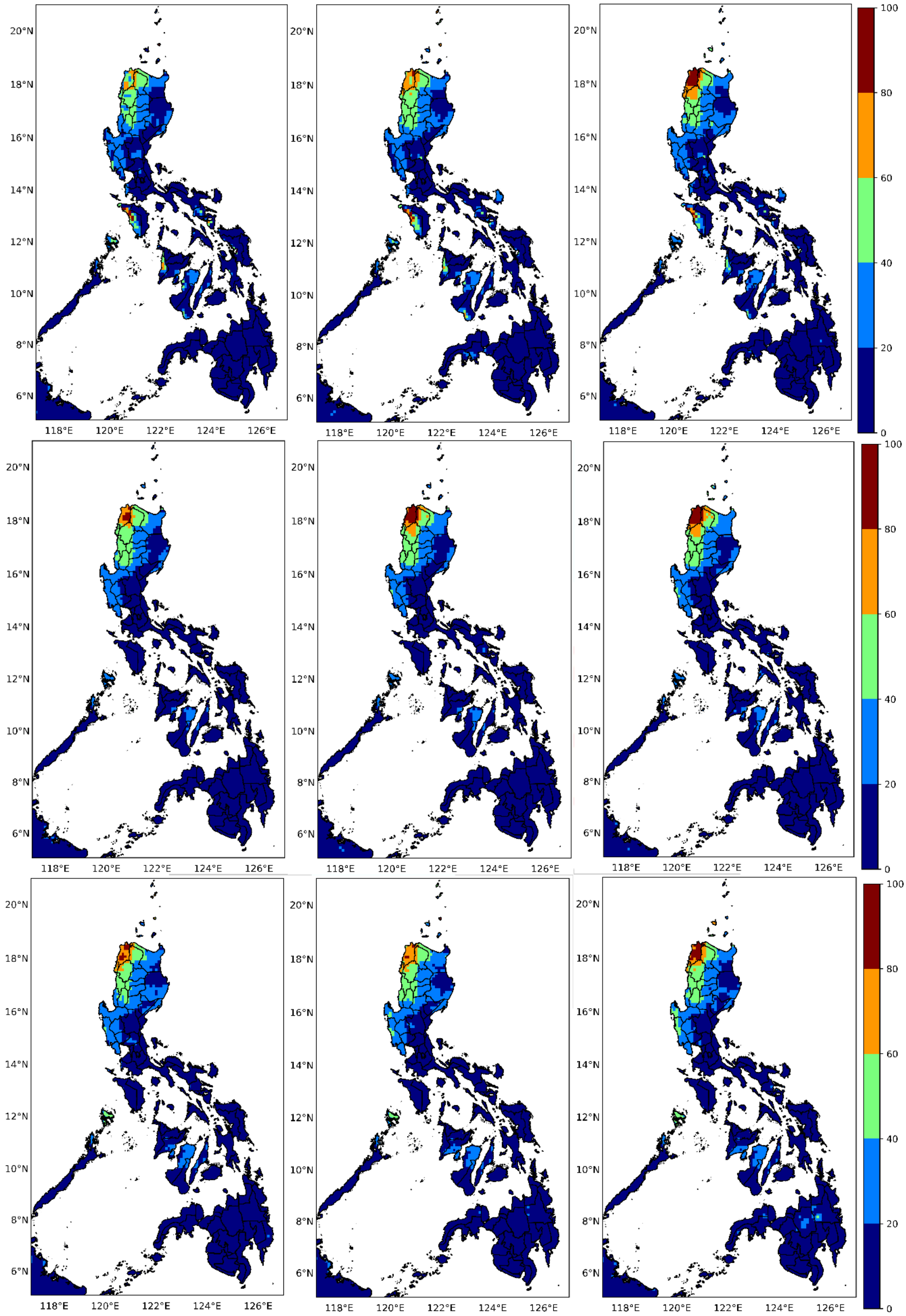

Fig. 5.1.5. Same as in Fig. 5.1.4 but for RMSE (in mm).

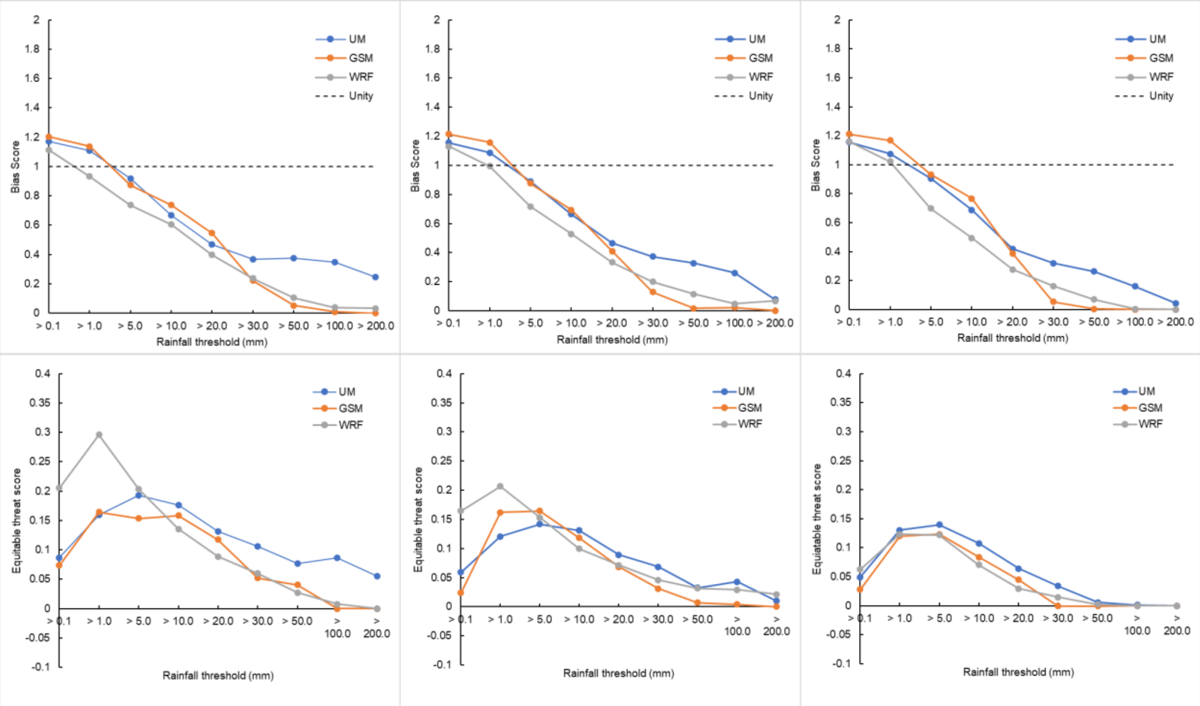

Fig. 5.1.6. Bias score (top row) and equitable threat score (bottom row) at different rainfall thresholds of day-1 (left column), day-2 (middle column), and day-3 (right column) forecasts of 24-hour accumulated rainfall from 00 UTC initializations of UM, GSM, and WRF.

Summary and Concluding Remarks

Improving the predictability and reducing the impacts of monsoon rains associated with an enhanced SWM during tropical cyclone events in the Philippines remains one of the priority areas of research and development given that a significant portion of the Philippine population resides in localities that are at risk to these hazards. It is therefore imperative to understand and assess the performance of NWP models that are providing rainfall forecast guidance to PAGASA meteorologists. In this report, the day-1 to day-3 forecasts of 24-hour accumulated rainfall from UM, GSM, and WRF models during the AUG19 event was evaluated over the country using gridded gauge-adjusted satellite-based rainfall estimates as observation proxy.

Categorical and continuous scores revealed that all the NWP models were not able to fully capture the magnitude and extent of monsoon rains over Northern Luzon. Of the three models being evaluated, UM performed relatively better than GSM and WRF in most areas. However, the UM predicted higher magnitudes of orographic rainfall associated with the monsoon. The high horizontal resolution of UM compared to WRF and GSM allowed the model to resolve heavy rainfall associated with orographic effect. However, the failure to the capture the general distribution of monsoon rainfall in Luzon resulted in UM having poorer performance in some areas of southwestern Luzon and western Visayas that were not observed in GSM and WRF such as over Occidental Mindoro and Antique. By assessing the performance at various rainfall thresholds, the UM was found to have provided better guidance to forecasters on higher rainfall accumulations during the AUG19 event than GSM and WRF, especially in the day-1 forecast of the model. Its performance was more notable for rainfall accumulations of more than 30 mm.

This report serves as an important input to the continuous research and development activities to improve the capability of numerical model guidance tools to predict HPEs associated with strong SWM events in the Philippines. While the sensitivity testing and fine-tuning of these NWP models remain an on-going effort by numerical modelers, the improvements in numerical predictions may not manifest in the near-term. Despite this limitation, operational meteorologists can utilize the findings discussed in this report as a form of guidance when interpreting model predictions of heavy rainfall from the current configuration of UM, GSM, and WRF during tropical cyclone enhanced SWM events in the Philippines. It is also imperative that forecasters identify more test cases of high impact weather that highlighted the strengths and weaknesses of these models. Such cases may be examples of forecast success and forecast busts. The identification of more case studies is important in further understanding the behavior of these models at different lead times during different meteorological setups.

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Panay Island Heavy Rainfall Event of December 2019: Ground Observations and Model Forecast Performance

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Introduction

As one of the most at-risk countries to natural disasters (Heintze et al. 2018), the Philippines is no stranger to high-impact hydrometeorological events such as tropical cyclones (TCs) and monsoon rains including their epiphenomena (i.e., flooding and landslides) that result in multiple disaster events which bring about significant loss of lives and damages to personal and public property, besetting different regions in the country (Yumul et al. 2011). Over the last four decades, these high impact weather phenomena accounted for more than US$ 2 billion in damages to agriculture and infrastructure and thousands of deaths in the Philippines (Cinco et al. 2016). Historical accounts of TCs crossing the country since the 1700s emphasize the destructive potential of these severe weather systems (Ribera et al. 2008). As such, understanding the performance of numerical weather prediction (NWP) models in providing rainfall forecast guidance during TC events that cross the Philippine archipelago is important in improving the predictability of these events in an operational setting, thereby reducing their impacts of these phenomena through increased reliability of forecasts and warnings.

The 2019 TC season in the Philippines was marked by the passage of two deadly and costly typhoons in the central portion of the archipelago during the last quarter of the year. On Christmas Eve and Christmas Day, Typhoon Ursula (Phanfone) traversed the southern portion of Southern Luzon and the northern and eastern portions of Visayas, bringing torrential rainfall over the central portion of the Philippines during the most festive season in the country. Cumulative rainfall estimates from 24 to 26 December 2019 revealed that the typhoon brought between 50 and 200 mm in most areas directly affected by the typhoon's circulation with isolated areas of 200-300 mm near the observed track of the typhoon, resulting in widespread flooding and landslide incidents. The National Disaster Risk Reduction and Management Council (2019) reported a total of 57 dead, 369 injured, and 6 missing individuals due to the typhoon, making it the deadliest TC to hit the country in 2019. Ursula was also noted as the second costliest TC during the 2019 season with combined cost of damage to infrastructure and agriculture amounting to Php 4.348 billion.

Investigating the rainfall forecast guidance provided by numerical weather prediction (NWP) models available to operational forecasters of the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) during the passage of strong typhoons such as 2019's Ursula is important to understand how these models perform and behave during similar scenarios (i.e., mature landfalling typhoons) so that forecasters can effectively interpret raw model forecasts and translate them into advice that can help mitigate against high impact weather (HIW). To achieve this, PAGASA has been in a joint research and development project with the Met Office and various universities in the United Kingdom. One of the approaches adopted by the project to improve forecasts and warnings during HIW is the near-real time assessment of 24-h rainfall forecasts out to 72 h into the future by operational forecasters. This report aims to present the evaluation of the rainfall forecast by 2 global and 2 limited-area NWP models used by PAGASA forecasters during the passage of Typhoon Ursula. Fig. 5.2.1 shows the best track of the typhoon. A focus is given on the prediction of the typhoon-induced heavy rainfall event (HRE) over the island of Panay in the Western Visayas Region that resulted in widespread flooding over two major river basins.

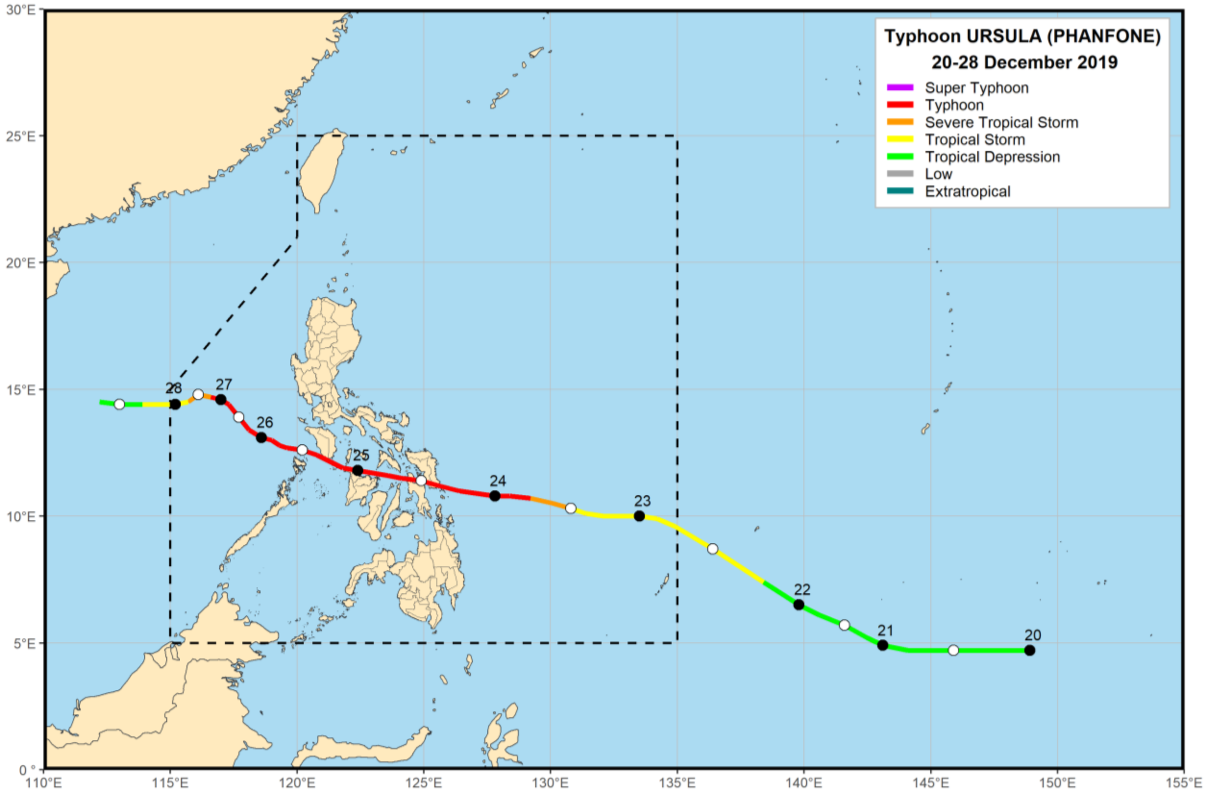

Fig. 5.2.1. PAGASA best track positions and intensities of Typhoon Ursula. Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

Study Area: Panay Island

Panay is a triangular island located on the western portion of the Visayas archipelago. With a total land area of of 12,011 km^2 and population of 4,477,247, it is the sixth largest and fourth most populous in the Philippines. It is administratively grouped under Western Visayas Region and is divided into four provinces: Aklan to the northwest, Capiz to the north and northwest, Antique to the west, and Iloilo to the south and east. Off the mid-southeastern coast of the island lies the island province of Guimaras. Panay is located southeast of Mindoro Island and northwest of Negros Island across the Guimaras Strait. To the north and northeast is the Sibuyan Sea, Jintotolo Channel and the island provinces of Romblon and Masbate, to the west and southwest is the Sulu Sea and the Palawan archipelago, and to its south lies the Panay Gulf.

Fig. 5.2.2a shows the topographic map of Panay Island and nearby islands, as well as the bodies of water surrounding it. The island is bisected by the 170-km long Central Panay Mountain Range, its longest and largest mountain range. The mountain range separates the province of Antique from the rest of Panay. The highest point on the island is Mount Madia-as with an elevation of 2,117m above sea level. The island is also home to two of 18 major river basins in the country (or river basins having an area greater than 1,400 km^2), Jalaur and Panay River Basins, the extent within Panay Island of which is presented in Fig. 5.2.2b. Panay River Basin, the larger of the two, covers an area of 2,717.92 km^2 and lies within the provinces of Iloilo, Capiz, and Aklan. On the other hand, with an area of 1,503 km^2, Jalaur River Basin situated entirely within the province of Iloilo.

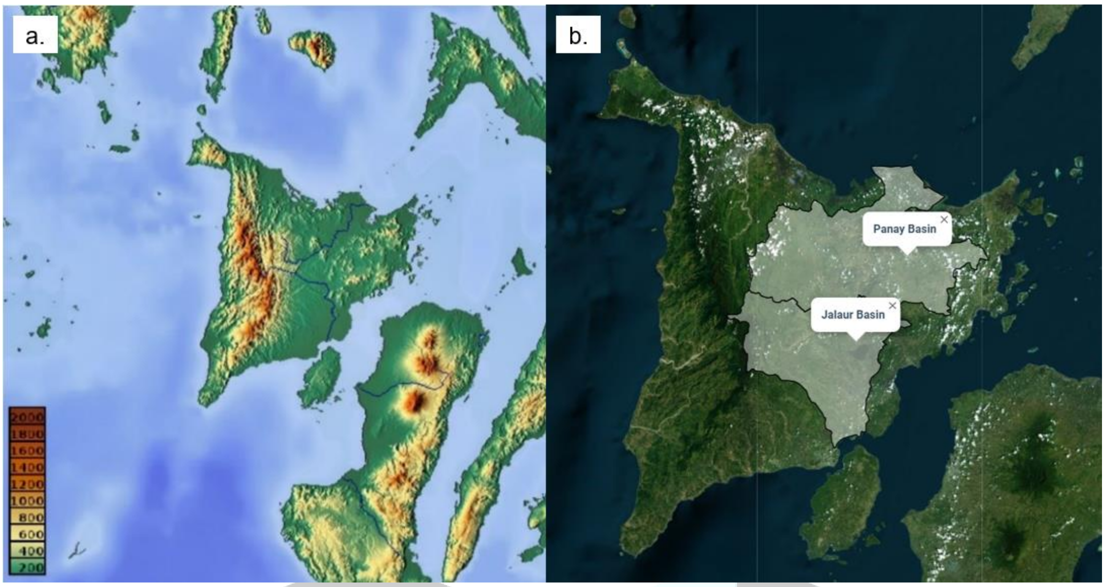

Fig. 5.2.2. (a) Topographic relief map of Panay Island and nearby island provinces. Color indicates elevation in meters above mean sea level. The dark blue line originating from the Central Panay Mountain Range and heading towards the northern (southern) coast marks the main channel of the Panay (Jalaur) River. (b) The boundaries of Panay and Jalaur River Basins within Panay Island.

High-resolution hazard maps (Fig. 5.2.3) from the Mines and Geosciences Bureau revealed that the western section of Panay Island is predominantly moderate to very highly susceptible to rain-induced landslides due to the presence of the Central Panay Mountain Range. Other areas with significant landslide susceptibility are situated on patches of highlands over the east and northeast portions of Panay (within Capiz and Iloilo). Around 912,976 individuals live in areas identified to be significantly susceptible to these hazards. In addition, around 147 people live in sites that are potential debris flow/accumulation zones. Table 5.2.1 lists down the meaning of each susceptibility level for rain-induced landslides

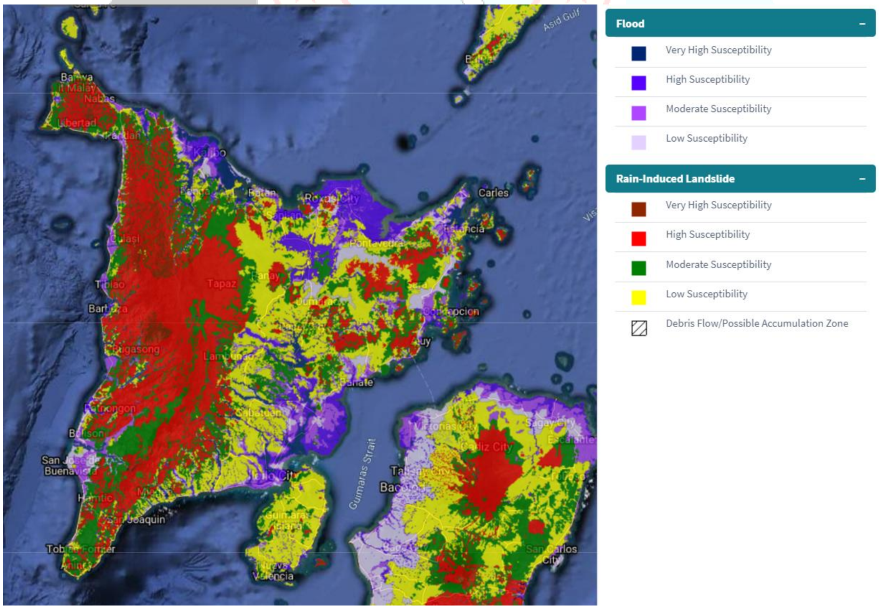

Fig. 5.2.3. High-resolution flood and rain-induced landslide hazard map of Panay Island from the Mines and Geosciences Bureau via the HazardHunterPH website (https://hazardhunter.georisk.gov.ph/).

In terms of flood hazard, the areas that are moderate to very highly susceptible to flooding in the island are mostly situated over the flood plains and lowlands within the two major river basins (Panay and Jalaur), as well as the lowland regions of the Iloilo-Batiano (107 km^2) and Aklan (1,082 km^2) River Basins. Some of the highly populated areas in Panay Island, such as Roxas City, Kalibo, and Metro Iloilo-Guimaras are situated in these flood-prone areas. In total, 1,139,476 people in the provinces of

Aklan, Antique, Capiz, and Iloilo are living in areas that are moderate, highly, and very highly susceptible to flooding.

Panay Island Heavy Rainfall Event of December 2019

The Panay Island has a single operational manned surface observation station (WMO ID: 98538) located in the capital city of Roxas in the province of Capiz. The synoptic station (SYNOP) observes accumulated rainfall using a combination of standard 8" rain gauge and tipping bucket rain gauge equipped with a rain recorded. Rainfall data are reported and transmitted every 3 h from the station to the agency's telecommunication network at standard (00, 06, 12, and 18 UTC) and intermediate (03, 09, 15, 21 UTC) synoptic times along with other synoptic observation variables. Historical data from PAGASA synoptic stations are available through an internal Meteorological Information System (PUMIS) that is accessible within the agency's intranet.

To supplement the lack of manned surface station in the other provinces within Panay Island, both PAGASA and the Advanced Science and Technology Institute (ASTI) deployed several unmanned meteorological and hydrological observation platforms such as automatic weather stations (AWS), automatic rain gauges (ARG), and tandem ARG-water level monitoring sensor (ARG-WL) in the area. Historical data from PAGASA-borne sensors are available through PUMIS while those from ASTI-borne sensors are publicly available through the PhilSensors Portal (http://philsensors.asti.dost.gov.ph/). In Panay Island, PAGASA has 2 AWS and 1 ARG sites while ASTI has 18 AWS, 43 ARG, and 21 ARG-WL sites. However, an inspection of data integrity and quality revealed that only 1 PAGASA AWS, 1 ASTI AWS, 9 ASTI ARG, and 7 ASTI ARG-WL sites have complete data for the period of 24 and 25 December 2019 or during the passage of Typhoon Ursula. The data from these stations are provided at 10-min or 10-min intervals. To match the temporal resolution of the synoptic station data, the rainfall observations from unmanned stations are processed to produce 3-h rainfall data at standard and intermediate synoptic times. Table 5.2.1 lists down the metadata of the synoptic station and unmanned stations whose data are used in this report while Fig. 5.2.4 presents these metadata in a map form.

Table 5.2.1. Metadata of manned (SYNOP) and unmanned (AWS, ARG, ARG-WL) rainfall stations in Panay Island whose rainfall data are utilized in this report. The four-character code in bold preceding the location of each sensor is the station code created for this report for referencing purposes.

Operator	Type	Location	Latitude (°N)	Longitude (°E)
PAGASA	SYNOP	**CPZ1:** Roxas Airport, Brgy. Gabuan, Roxas City, Capiz	11.600249	122.749696
PAGASA	AWS	**ILO1:** Iloilo Radar Station AWS, Jaro, Iloilo City	10.858086	122.718897
ASTI	AWS	**ILO2:** ISATU Miag-ao Campus, Miag-ao, Iloilo	10.649308	122.241123
ASTI	ARG	**ILO3:** Brgy. Caboloan Sur, Oton, Iloilo	10.741883	122.480579
ASTI	ARG	**ILO4:** Ungka II Elementary School, Pavia, Iloilo	10.751466	122.538881
ASTI	ARG	**ILO5:** Santa Barbara, Iloilo	10.824111	122.533611
ASTI	ARG	**ILO6:** Pototan Municipal Hall, Pototan, Iloilo	10.949922	122.634483
ASTI	ARG	**ILO7:** San Rafael Plaza, San Rafael, Iloilo	11.175817	122.828367
ASTI	ARG	**AKL1:** MDRRMO Evacuation Center, New Washington, Aklan	11.648111	122.434704
ASTI	ARG	**AKL2:** Altavas, Aklan	11.501800	122.475733
ASTI	ARG	**ATQ1:** Brgy. Villafont, Sibalom, Antique	10.787519	122.768431
ASTI	ARG	**CPZ2:** Brgy. Tapulan, Ma-ayon, Capiz	11.352636	122.768431
ASTI	ARG-WL	**CPZ3:** Tapaz Bridge, Tapaz, Capiz	11.264800	122.546683
ASTI	ARG-WL	**CPZ4:** Jamindan Bridge, Jamindan, Capiz	11.407300	122.512017
ASTI	ARG-WL	**ILO8:** Jalaur Bridge, Zarraga, Iloilo	10.847614	122.650389
ASTI	ARG-WL	**ILO9:** Suage Bridge, Janiuay, Iloilo	10.953456	122.504908
ASTI	ARG-WL	**ILO10:** Brgy. Cansalanan, Badiangan, Iloilo	10.978795	122.499586
ASTI	ARG-WL	**ILO11:** Lambuyao-Abilay Bridge, Oton, Iloilo	10.874490	122.124834
ASTI	ARG-WL	**ATQ2:** Bugo Bridge, San Remigio, Antique	10.714110	122.493796

Examination of rainfall observations from the 19 rainfall stations with reliable data during the passage of Typhoon Ursula over the central portion of the Philippines on Christmas Eve and Christmas Day 2019 revealed that roughly 89% to 100% of the rainfall accumulations over this two-day period was observed within a 24-h period between 12 UTC on 24 December 2019 and 12 UTC on 25 December 2019. This 24-h period coincides with the time when Typhoon Ursula was closest to Panay Island. Fig. 1 shows that the center of the typhoon passed less than 50 km from the coast of Capiz and Iloilo and crossed the northwestern portion of Aklan. Due to the proximity of the typhoon's center to Panay Island during the passage, the inner rainbands and eyewall of the typhoon, where much of the heavy rainfall is usually observed, directly affected the northern half of the island while the outer rainbands affected the rest of the island (Fig. 5.2.5).

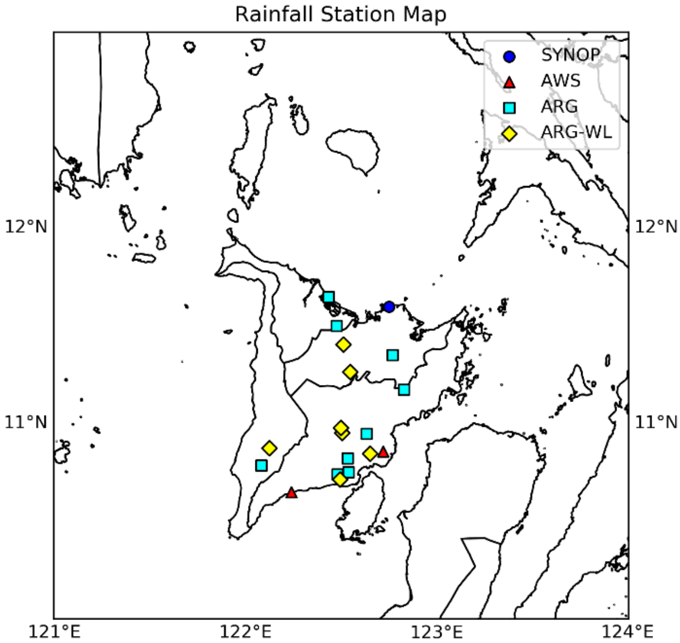

Fig. 5.2.4. Spatial distribution of the rainfall observation stations within Panay Island that are identified in Table 5.2.1.

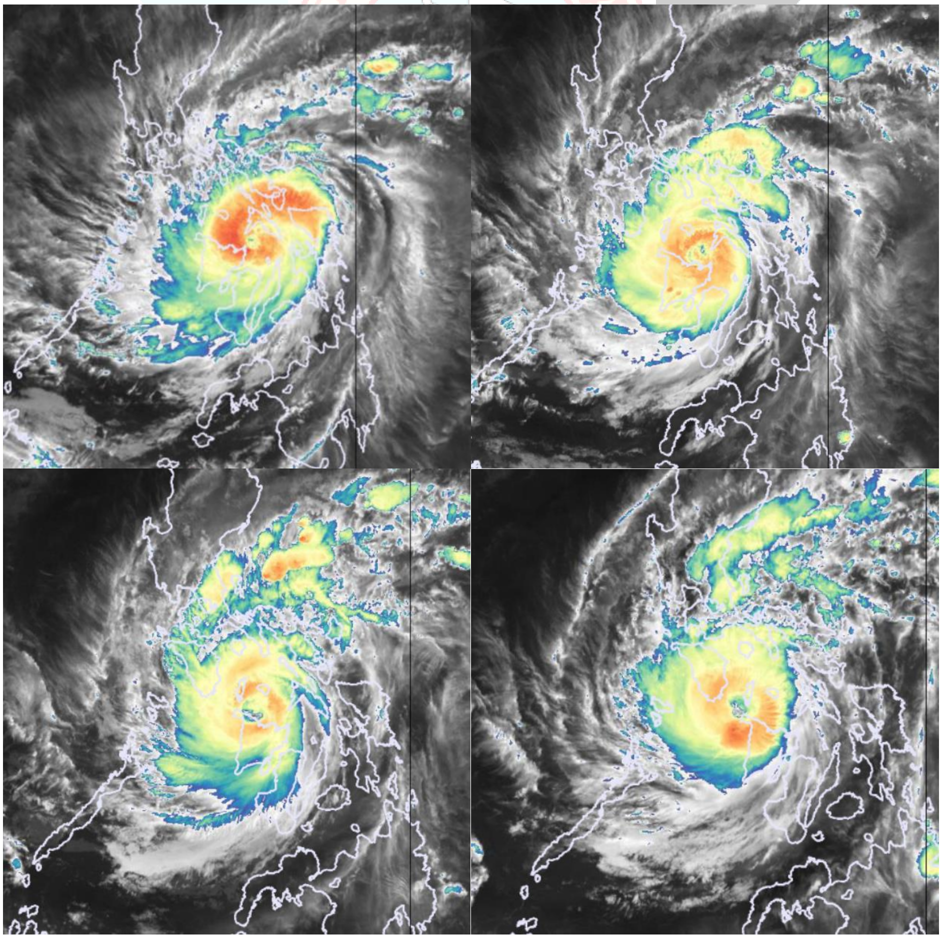

Fig. 5.2.5. Enhanced infrared image of Typhoon Ulysses taken at (left to right, top row) 18 and 21 UTC on 24 December 2019 and (left to right, bottom row) at 00 and 03 UTC on 25 December 2019

Fig. 5.2.6 presents the observed 24-h accumulated rainfall ending at 12 UTC 25 December by the rainfall stations identified in Fig. 4. Nearly all the rainfall stations situated in Iloilo, in the southern portion of Antique, and along the Iloilo-Capiz border reported rainfall between 50 mm and 100 mm during the 24-h HRE. Higher rainfall accumulations were more concentrated over the northern portion of Panay Island, with 5 stations situated in Capiz and Aklan reporting rainfall exceeding 100 mm. Fig. 6 shows that these stations were observed in areas that were within 75 to 100 km of the center of the typhoon eye - roughly the region affected by the eyewall and inner rainbands of the typhoon. Of the 19 stations used in this report, the ARG at the MDRRMO Evacuation Center in New Washington, Aklan reported 257.0 mm – the highest accumulated rainfall for the period being investigated. The same station also reported the highest 3-h rainfall, reaching 119.0 mm from 21 UTC 24 December 2019 to 00 UTC 25 December 2019 – during the period when the station was within the eyewall. On the other hand, the lowest 24-h accumulated rainfall observed in Panay Island was 38.8 mm over Jalaur Bridge in Zarraga, Iloilo.

The lack of reliable observation data over northeastern Iloilo, northwestern Aklan, and northern and central Antique prevented any meaningful analysis over the western and northwestern portion of Panay Island. While it can be also be inferred that the northwestern portion of Aklan, the northeastern portion of Iloilo, and the extreme northern portion of Antique may have experienced rainfall of around 100 to 200 mm (with isolated areas of 200-300 mm) based on Fig. 7, the nature of the track of the typhoon suggested that high rainfall accumulations could have been observed over northern and central Antique due to orographic enhancement brought about by the presence of the Central Panay Mountain Range. Furthermore, the rainfall data presented in Fig. 7 cannot conclusively determine whether rainfall exceeding 200 mm were only isolated in nature or more widespread due to the sparse distribution of stations with reliable data over the northern half of Panay Island (i.e., only 7 stations are found on the northern half of the island).

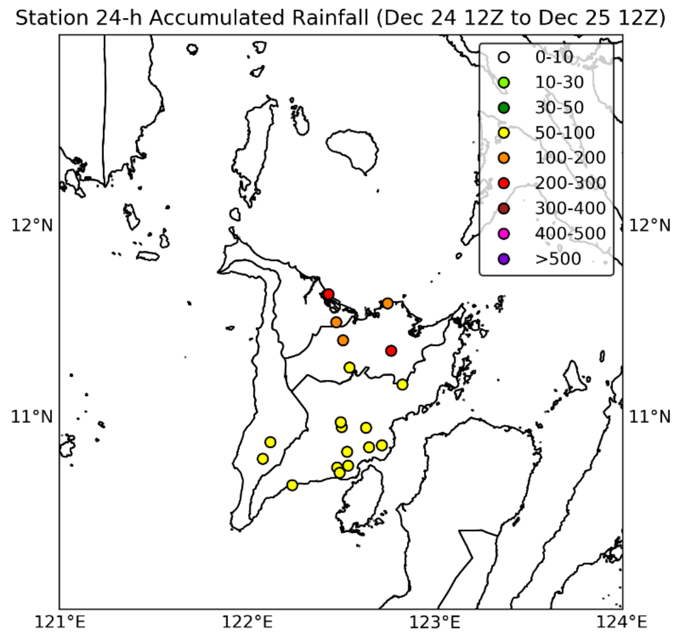

Fig. 5.2.6. Observed 24-h accumulated rainfall ending at 12 UTC on 25 December 2019 from rainfall stations in Panay Island

Subsequent Widespread Flooding

The HRE during the 24-h period ending at 12 UTC on 25 December 2019 resulted in rapid rise and prolonged fall (especially over the midstream and downstream portions) of water level within the principal river basins situated in Panay Island (Panay, Jalaur, Aklan, and Iloilo-Batiano). Observation data from several water level monitoring sensors strategically situated along the main river and tributaries of these river basins suggest a peak increase of 5 to 8 m in water level at the midstream and downstream portions of river channels and as much as 4 m in the upstream segments. Although water level in the upstream areas receded to below +1 m of pre-Ursula level within 48 h of the start of the

HRE, the water level at the midstream and downstream channels did not recede significantly until 3 to 4 days after the HRE started with some downstream areas not seeing water level below +1 m of pre-Ursula level until the yearend.

The combination of the hydrologic response of the principal river basins in Panay Island to the HRE and the surface runoff especially coming from the upland areas within the Central Panay Mountain Range resulted in widespread flash flood and river flooding. Much of the moderate to very high-risk areas identified in hazards maps (i.e., Fig. 5.2.3), especially those near the main river and tributary channels, experienced flooding with severity like those captured in amateur footages from President Roxas, Cuartero, and Pontevedra towns in Capiz (Figs. 5.2.7 and 5.2.8).

Forecast Assessment

PAGASA meteorologists have access to raw and post-processed model forecasts from two global-scale and two convective-scale models. These are the Global Spectral Model (GSM; Japan Meteorological Agency 2019) of the Japan Meteorological Agency (JMA) and the Unified Model (UM; Walters et al. 2019) of the UK Met Office. These models are primarily utilized by forecasters to diagnose the evolution of synoptic-scale patterns and the general distribution of precipitation over the Philippines. However, due to the coarse horizontal resolution of such models, the GSM and UM models may not fully capture mesoscale events and other meteorological features that are smaller than the horizontal resolution of these model. This is especially true in terms of capturing rainfall enhancement due to orographic left. To address this, PAGASA also operates the Weather Research and Forecasting (WRF; Skamarock et al. 2019) model at 12-km (D01) and 3-km (D02) horizontal resolution with the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) providing the initial and lateral boundary conditions. The summary of key configurations of the NWP models discussed in this report are presented in Table 5.1.2. The gridded outputs of the GSM and UM were made available to PAGASA in real-time through the website of the JMA High Resolution GSM Data Service (https://www.wis-jma.go.jp/cms/gsm/) and the File Transfer Protocol (FTP) service of the UK Met Office (http://ftpids.metoffice.gov.uk/) respectively. On the other hand, the gridded data from the WRF model is automatically pushed by the Numerical Modelling Section of PAGASA to an FTP server accessible to the Weather Division.

Standard verification scores (Japan Meteorological Agency 2019) for continuous (i.e., not yes/no) forecasts were used to evaluate the 24-h accumulated rainfall forecast from GSM, UM, WRFD01, and WRFD02 models for the period of 12 UTC 24 December 2019 to 12 UTC 25 December 2019. For this report, only the 12 UTC runs of the 4 NWP models from 22 to 24 December 2019 were included. The verification scores were calculated from the objective comparison between the 24-h rainfall recorded by manned and unmanned rain gauges identified in Table 1 and the forecasts of GSM, UM, WRFD01, and WRFD02 over the model grid points nearest to the grid coordinates of the rain gauges. No interpolation was performed to determine the model forecasts over the exact grid coordinates of the rain gauges to prevent the introduction of additional error inherent from the use of interpolation.

Fig. 5.2.7. Amateur photos of areas in (a, c, e) President Roxas and (b, d) Cuartero municipalities in Capiz that were submerged in flooding following the passage of Typhoon Ursula. Photos are from Rappler (2019) contributors.

Fig 5.2.8. Aerial survey image of downtown Pontevedra in Capiz showing the extent of river flooding in the areas near the Panay River. Photo courtesy of Panay News (2019) contributor.

Table 2. Key configurations of operational NWP models used for PAGASA rainfall forecasts.

Parameters	UM	GSM	WRF (D01)	WRF (D02)
Version	GA7.0	GSM1705	WRF-ARW 4.0.2	WRF-ARW 4.0.2
Domain	Global	Global	2.35°N to 25.09°N, 114.99°E to 135.01°E	5.08°N to 21.03°N, 117.06°E to 127.04°E
Horizontal resolution	~10 km	~0.1875° (20 km)[52]	~12 km	~3 km
Vertical levels (top height)	70 (~80 km)	100 (0.01 hPa)	50 (50 hPa)	50 (50 hPa)
Initial / boundary conditions	Hybrid Incremental 4D-Var	Incremental 4D-Var	GFS 0.25°	Initial: GFS 0.25° Boundary: WRF D01
Initial times (UTC)	00, 06, 12, 18	00, 06, 12, 18	00, 03, 06, 09, 12, 15, 18, 21	
Forecast length	144 h (00, 12 UTC)	132 h (00, 06, 18 UTC) 264 h (12 UTC)	144 h	48 h
Output format	grib2	grib2	grib2	grib2
Run by	Met Office	JMA	PAGASA	PAGASA

The root mean square error (RMSE), bias, and correlation coefficient (CC) of the model rainfall predictions for the Panay Island HRE from 12 UTC runs of 4 operational NWP guidance models between 22 and 24 December 2020 are presented in Fig. 5.2.9. Because WRFD02 has a maximum forecast length of 48 h, the 12 UTC run on 22 December 2019 has no 24-h rainfall forecast for the HRE, thus the absence of verification scores for WRFD02 at that initial time. In this discussion, 12 UTC model runs on 24 December 2020 are referred to as D24 run, while those from the 23 and 22 December 2020 runs are referred to as D23 and D22 runs, respectively.

The forecasts from the global models GSM and UM had strong correlation with the observed rainfall over the 19 rain gauges in Panay Island for D24 runs. The CC values for GSM slightly decreases for the D23 run but increases a much higher value (relative to D24 CC) for the D22 run. The RMSE of both models had similar trends with increasing lead time with UM exhibiting slightly higher RMSE than GSM. In terms of bias, GSM had a consistent dry bias whose magnitude follows a trend similar to its RMSE. On the other hand, the UM had minimal wet bias for D24 run and large magnitude of dry bias for the other runs. In fact, all models coming from the D23 and D22 runs underestimated the forecast rainfall for the HRE.

In terms of the limited-area models, the forecast performance of WRFD01 and WRFD02 for the HRE was starkly different from one another across the three model runs. While both exhibited increasing correlation with ground observation with increasing lead time, the CC of the forecast from the D24 run of WRFD01 was considerably lower than WRFD02, whose CC is comparable to the global models. For the D23 runs, the CC of WRFD02 was notably higher than the other 3 models while WRFD01 forecasts had similar correlation to ground observation as UM. The RMSE of WRFD01 had an increasing trend with increasing lead time while the inverse is true for WRFD02. Although not much different, the RMSE of WRFD01 was the lowest of the models for the D24 runs while those of WRFD02 was the highest. For the D23 runs, both WRF configurations performed better than the global models with WRFD02 reporting the lowest RMSE. For the D22 run, WRFD01 had similar magnitude of error as the global models. Bias values revealed that WRFD01 had dry bias for all forecast runs although the extent was significantly higher in the earlier runs. While WRFD02 had a considerable degree of wet bias in its D24 run, its magnitude was the lowest of the four models.

[52] Available resolution of model outputs via the JMA High Resolution Data Service is 0.25° (~28 km) and 0.50° (~56 km) for surface and upper air layers, respectively.

These scores suggest that roughly 24 h before the beginning of the HRE (D23 run), despite the underestimation of the magnitude of heavy rainfall, both WRF configurations, especially WRFD02, performed way better than the global models in its heavy rainfall forecast over Panay Island. On the other hand, both the global and limited-area models performed similarly in predicting the HRE roughly 48 h before the onset of the event with GSM slightly outperforming the other two. However, the performance of the forecasts from the model initialization on the onset of the event (D24 run) needs to be investigated further given that the scores did not easily present a better model guidance compared to the D23 and D22 runs.

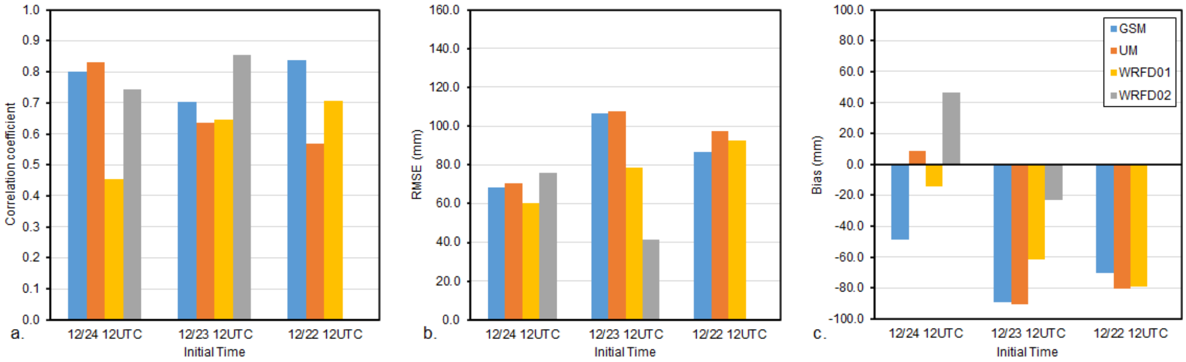

Fig. 5.2.9. (a) Root mean square error (RMSE), (b) bias, and (c) correlation coefficient of 24-h accumulated rainfall forecast for the period ending at 12 UTC 25 December from GSM, UM, WRFD01, and WRFD02 12 UTC runs on 22, 23, and 24 December 2019.

While not particular useful in the operational setting as the other two runs, the verification scores for the D24 run showed that UM performed better than the three other model due to the strong correlation of its forecast with gauge observations and despite having similar RMSE as GSM and slightly higher RMSE than WRFD01, the UM forecast had neither the notable bias of GSM nor the low CC of WRFD01. By plotting the observed rainfall during the HRE against the corresponding rainfall forecasts from the D24 runs of the four models (Fig. 5.2.10), it can be observed that while the performance of UM was generally better, the forecasts from WRFD01 clustered fairly near the reference line (i.e., red line in Fig. 5.2.10) for rainfall values of up to 100 mm while the UM predictions had the worst underestimation of the 4 models. While the spread of the scatterplot for WRFD01 and GSM was slightly similar for rainfall values above 100 mm, the latter consistently underestimated rainfall in its forecast which resulted in its CC value becoming higher than the former.

It is important to investigate how both the global and limited-area models simulated in its initializations 24 h and 48 h before the onset of the HRE the circulation and movement of the typhoon during its passage over Visayas because rainfall forecasts during typhoon events are strongly dependent on these. Initial model predictions during Typhoon Ambo (Vongfong) did not forecast the typhoon's close approach over Metro Manila, resulting in the models not capturing the occurrence of heavy rains much earlier during the warning stage of the typhoon (Gile et al. 2020). Moreover, the verification scores presented in this report are based on the corresponding model grid forecast over the 19 sampling points corresponding to the available rain gauges in Panay Island. It was earlier pointed that the absence of rain gauges in the western and northwestern portions of the island prevented meteorologists from (1) capturing torrential rains associated with either direct eye passage or orographic enhancement through the Central Panay Mountain Range as well as (2) verifying model predictions over these critical ungauged areas.

Fig. 5.2.11 presents the gridded rainfall forecast for the HRE period by GSM, UM, WRFD01, and WRFD02 from the runs investigated in this report. Global models, in its D22 and D23 runs, predicted that the typhoon would follow a generally west-northwestward track whose orientation will bring its center in the vicinity of Masbate and Romblon instead of passing off the coastal waters of Capiz and northeastern Iloilo before crossing the northwestern portion of Aklan. Much of the higher rainfall accumulation remained offshore with northwestern Panay being the only area with significant rainfall forecast for both the D23 and D22 runs. This meant that even 24 h before the onset of the HRE, both GSM and UM were not predicting any significant rainfall event over Panay Island.

For all runs, GSM only predicted at most 100-200 mm over Panay Island for the 24-h HRE period, with the higher accumulations confined near the center track of the typhoon. Furthermore, later runs of GSM predicted smaller swaths of 100-200 mm and larger swaths of 50-10 mm compared to its earlier runs. On the other, the later runs of UM started predicting isolated areas of 400-500 mm especially along the track of the typhoon. Furthermore, no notable reduction in the swath of rains of at least 100 mm was observed in UM with later runs.

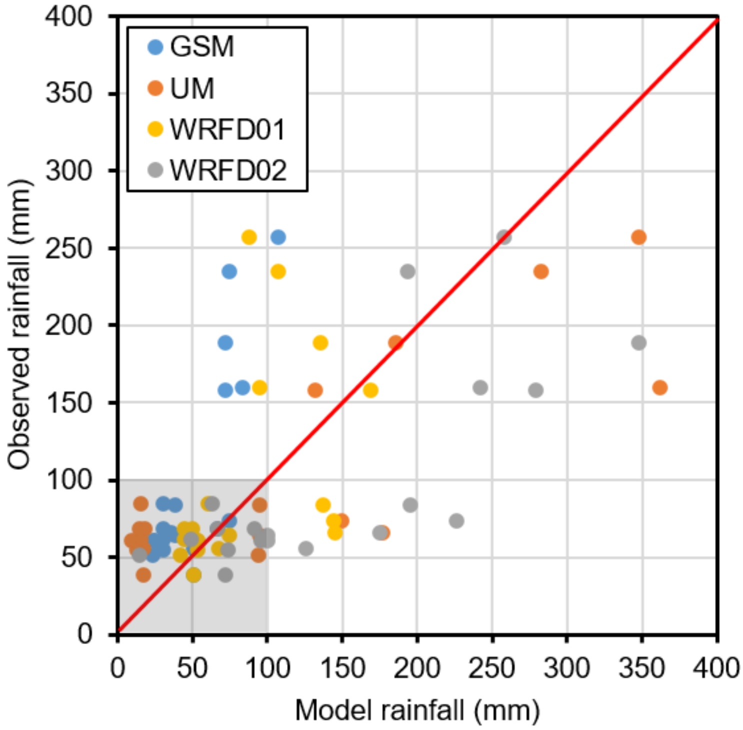

Fig. 5.2.10. Scatterplot of observed rainfall by the 19 rain gauge sites in Panay Island during the HRE against the corresponding forecast rainfall from GSM, UM, WRFD01, and WRFD02 models that were initialized at 12 UTC on 24 December 2020. The shaded gray area marks the plot subsection wherein observed or forecast 24-h rainfall value is 100 mm or less. The red diagonal line is the reference line indicating a perfect forecast (i.e., forecast perfectly correlates with observation)

Unlike the global models, the D22 and D23 runs of WRFD01 and WRFD02 predicted a typhoon track resembling the best track in Fig. 5.2.1, while the D24 run of both models had a similar forecast path of the typhoon as the D24 run of UM. WRFD01 forecasts showed increasing size of rain swath of at least 100 mm with later runs while WRFD02 had a consistently large rain swath of at least 100 mm for all its runs. Despite capturing the path of the typhoon better than the global models 24 h and 48 h before the onset of the HRE, the relatively smaller rain swath of WRFD01 forecasts in the earlier runs compared to WRFD02 meant that former was not able to capture the HRE in the D23 and D22 runs while WRFD01 was able to forecast heavy rains over Panay Island. Both WRFD01 and WRFD02 predicted rainfall of up to 300 mm within the swath, while WRFD02 had isolated areas of 300-500 mm associated with orographic enhancement of rainfall that was captured by the model’s high spatial resolution.

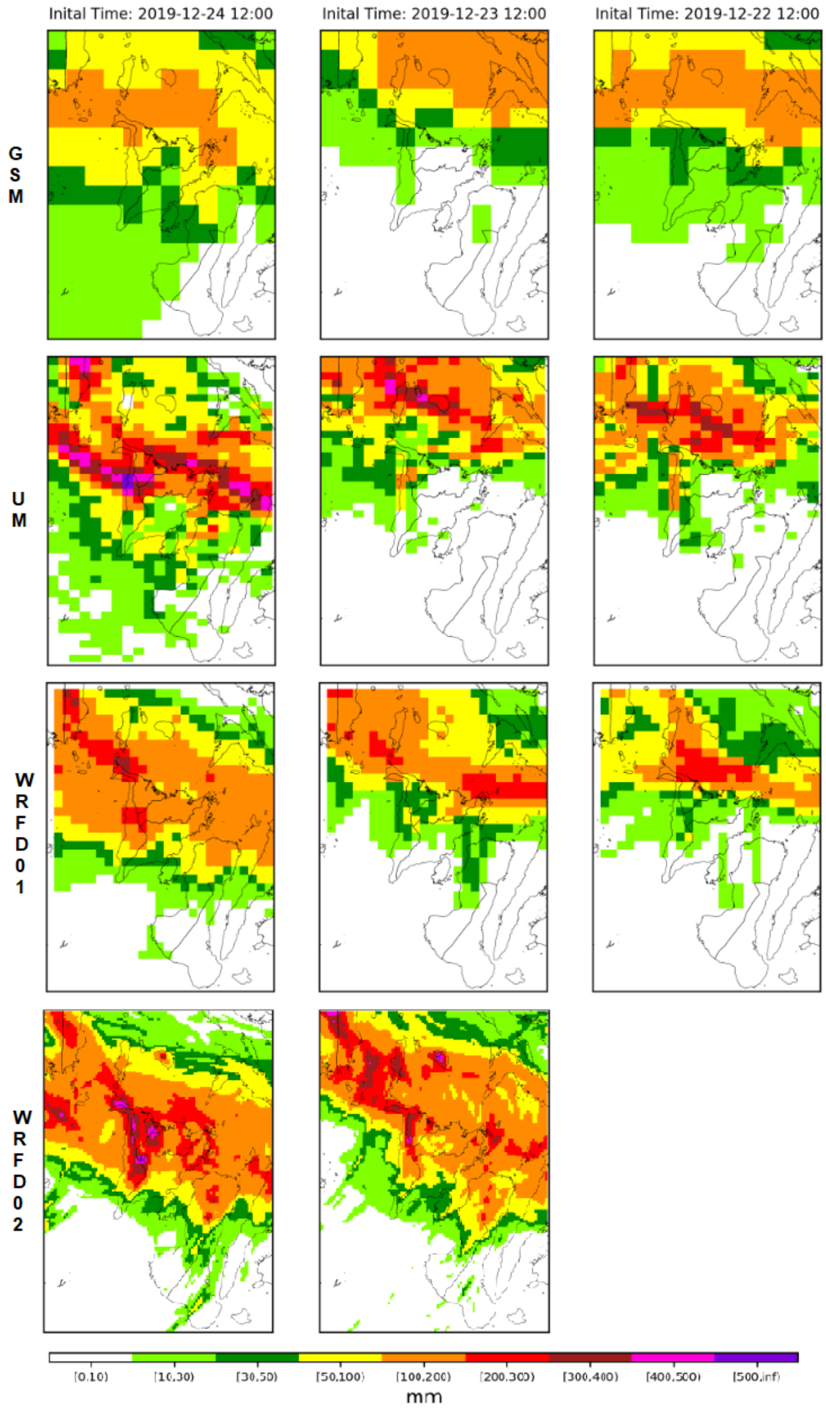

Fig. 5.2.11. Spatial distribution of gridded rainfall forecast from GSM, UM, WRFD01, and WRFD02 for the Panay HRE. Forecast initializations used were 12 UTC runs from 22 to 24 December 2020.

Summary and Concluding Remarks

The passage of Typhoon Ursula during the period of Christmas Eve and Christmas Day 2019 over the central portion of the Philippine archipelago brought about torrential rainfall that resulted in widespread flooding over several areas in Southern Luzon and Visayas provinces. One notable HRE was the 24-h rainfall period between 12 UTC 24 December 2019 and 12 UTC 25 December 2019 over Panay Island that was directly caused by the passage of the typhoon’s inner rainbands and eyewall region over the area. A total of 19 rainfall stations in the island reported at least 50 mm of 24-h rainfall, with 257.0 mm being the highest observed. However, the absence and/or sparse distribution of rain gauges in Panay Island, most notably in the localities situated along the Central Panay Mountain Range in the western and northwestern portions of the island, prevented meteorologists from capturing higher rainfall accumulations over Aklan (where the typhoon made landfall) and over the upland regions (where orographic effect likely caused rainfall enhancement). Water level monitoring stations over the four principal river basins in Panay revealed that the HRE triggered a hydrologic response that, combined with the flash flooding from the surface runoff, resulted in severe flooding events over the midstream and downstream portions of these basins.

The model guidance predictions of the Panay HRE resulting from the passage of Typhoon Ursula was evaluated to determine if the global and limited-area NWP models that were available to PAGASA forecasters during that time was able to capture the said event and to better understand the models' capability in providing reliable heavy rainfall guidance to forecasters, thereby improving the way forecasters translate model predictions into reliable warnings and advisories during similar events in the future. To accomplish this, rainfall forecasts for the HRE from the 12 UTC initializations of GSM, UM, WRFD01, and WRFD02 models from 22 to 24 December 2019 were compared against ground observations made by the 19 rainfall stations over the study area. A point-to-grid comparison was adopted wherein the model grid point nearest to the grid coordinates of a rain gauge was treated as the model forecast over that gauge to ensure non-introduction of additional error resulting from interpolation schemes.

The continuous verification scores revealed that global and limited-area models had the same forecast performance for the HRE roughly 48 h before the onset of the event and while the predictions at that lead time allows forecasters to have a general idea on where heavy rainfall is likely to fall, the strong dry bias and the magnitude of forecast error observed from these initializations suggest that raw model forecasts may not be relied upon for quantitative precipitation forecast 48 h before the onset of an HRE induced by a landfalling, intensifying typhoon of the same nature as Typhoon Ursula without corrective intervention of subjective (i.e., forecasters' decision making) or objective (i.e., model output statistics). However, 24 h before the onset of the HRE, scores revealed that the D01 and D02 configurations of the PAGASA WRF model outperformed the global models in the provision of quantitative precipitation forecast for the HRE. In particular, the predictions from the 3-km WRF model had the lowest dry bias, smallest RMSE, and highest correlation with ground-based observations. However, given that the high spatial resolution of WRFD02 produced higher rainfall amounts in the areas within Panay Island that have no operational gauges, it is likely that the scores reported herein will be different if such rainfall amounts were verified on the ground.

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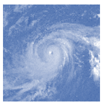

TROPICAL CYCLONE BEST TRACK DATASET

Tropical Cyclone 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 2019 season. Provided in a tabular format, each entry consists of the following information

- Date and time of analysis (DTG; 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 (PRES) 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 an area of low pressure or extratropical cyclone at a particular synoptic time, the indicator L or XT is written on the MXWD field respectively.

The best track position and intensity information is always provided at standard synoptic times (00, 06, 12, and 18 UTC). In the case of a landfalling TC or a TC which passed within 60 nmi of the Philippine coastline, best track entries are provided at intermediate synoptic times as well (03, 09, 15, and 21 UTC) beginning at the point when the TC is 24 hours from landfall or closest approach[53]. The best track data reverts to using standard synoptic times once the TC is more than 60 nmi 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 in this report supersedes both those the operational or warning track[54] and the provisional best track[55] that were issued by the Weather Division, PAGASA.

[53] This reference event is used for non-landfalling TCs that passed within 60 nmi of the Philippine coast line.
[54] Dataset containing the positions and intensities of a TC at standard (and if possible, intermediate) synoptic times that were issued in real time during the warning period.
[55] An initial version of the best track of a TC based on the revision of the operational track following a near-real time reanalysis of positions and intensities.

Table 6.1. Best track positions and intensities of Tropical Depression Amang.

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
01/19 06	6.8	132.4	25	1006
01/19 12	7.0	130.4	25	1006
01/19 15	7.2	129.4	25	1006
01/19 18	7.4	128.5	25	1006
01/19 21	7.5	127.7	25	1006
01/20 00	7.7	127.2	25	1006
01/20 03	8.2	126.9	25	1006
01/20 06	8.8	126.8	25	1006
01/20 09	9.2	126.8	25	1006
01/20 12	9.7	126.8	25	1006
01/20 15	10.2	126.7	25	1006
01/20 18	10.4	126.5	25	1006
01/20 21	10.8	126.4	25	1006
01/21 00	11.3	126.4	25	1006
01/21 03	11.6	126.4	30	1004
01/21 06	11.9	126.3	30	1004
01/21 09	12.1	126.2	30	1004
01/21 12	12.6	125.8	30	1004
01/21 15	12.9	125.6	30	1004
01/21 18	13.1	125.6	25	1006
01/21 21	13.2	125.7	25	1006
01/22 00	13.3	125.8	L	1006

Table 6.2. Best track positions and intensities of Typhoon Betty (Wutip).

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
02/19 00	5.1	159.8	25	1004
02/19 06	4.9	158.4	25	1004
02/19 12	4.6	157.0	30	1002
02/19 18	4.6	155.9	35	1000
02/20 00	4.7	154.6	45	0994
02/20 06	4.9	153.8	50	0990
02/20 12	5.3	152.6	55	0985
02/20 18	5.7	151.6	60	0980
02/21 00	6.2	150.5	65	0975
02/21 06	6.6	149.6	70	0970
02/21 12	7.0	148.7	70	0970
02/21 18	7.5	147.9	70	0970
02/22 00	8.3	146.8	75	0965
02/22 06	9.2	146.2	80	0960
02/22 12	9.9	145.0	80	0960
02/22 18	10.2	144.0	85	0955
02/23 00	10.7	143.7	85	0955
02/23 06	11.4	143.3	95	0945
02/23 12	12.0	142.8	105	0925
02/23 18	12.4	142.4	100	0930
02/24 00	12.7	142.1	95	0940
02/24 06	12.9	141.7	90	0950
02/24 12	13.0	141.3	85	0955
02/24 18	13.1	140.7	90	0945
02/25 00	13.4	140.4	95	0940
02/25 06	13.8	140.2	100	0935
02/25 12	14.2	140.0	100	0935
02/25 18	14.6	139.9	100	0935
02/26 00	14.9	139.9	95	0940
02/27 06	15.2	139.9	90	0945
02/27 12	15.4	140.1	85	0955
02/27 18	15.6	140.1	80	0965
02/28 00	15.8	140.0	75	0970
02/28 06	16.2	139.9	65	0980
02/28 12	16.4	139.0	55	0996
02/28 18	16.7	137.8	45	1002
03/01 00	17.1	136.7	35	1006
03/01 06	17.6	135.6	30	1008
03/01 12	18.2	134.9	25	1010
03/01 18	18.6	134.6	25	1010
03/02 00	19.0	134.4	25	1012
03/02 06	19.4	134.2	25	1010
03/02 12	19.6	134.0	25	1012
03/02 18	19.5	133.9	25	1010
03/03 00	19.4	133.8	25	1010
03/23 06	18.9	133.2	L	1008

Table 6.3. Best track positions and intensities of Tropical Depression Chedeng.

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
03/15 00	8.0	144.3	25	1006
03/15 06	8.1	143.2	25	1006
03/15 12	8.1	141.9	25	1006
03/15 18	8.0	140.9	30	1004
03/16 00	7.9	140.1	30	1004
03/16 06	7.8	139.1	30	1004
03/16 12	7.7	137.7	30	1004
03/16 18	7.7	136.2	30	1004
03/17 00	7.6	134.9	30	1004
03/17 06	7.5	134.0	30	1004
03/17 12	7.4	132.9	25	1006
03/17 18	7.3	131.6	25	1006
03/17 21	7.1	130.5	25	1006
03/18 00	6.9	129.9	25	1006
03/18 03	6.7	129.2	25	1006
03/18 06	6.6	128.5	25	1006
03/18 09	6.6	127.9	25	1006
03/18 12	6.6	127.5	25	1006
03/18 15	6.5	126.9	25	1006
03/18 18	6.4	126.1	25	1006
03/18 21	6.4	125.5	25	1006
03/19 00	6.5	124.8	25	1008
03/19 03	6.5	124.3	25	1008
03/19 06	6.5	123.9	L	1010

Table 6.4. Best track positions and intensities of Tropical Storm Dodong (Sepat).

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
06/25 06	19.6	127.6	25	1006
06/25 12	19.9	127.9	25	1006
06/25 18	20.3	128.1	25	1006
06/26 00	21.1	128.4	25	1004
06/26 06	22.8	128.8	25	1004
06/26 12	24.7	129.4	30	1002
06/26 18	26.4	130.0	30	1002
06/27 00	28.4	130.4	30	1002
06/27 06	30.8	132.0	30	1000
06/27 12	32.6	134.7	35	998
06/27 18	34.0	137.6	40	996
06/28 00	35.1	141.6	40	994
06/28 06	36.0	147.0	XT	992

Table 6.5. Best track positions and intensities of Tropical Depression Egay.

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
06/28 00	12.2	134.1	25	1006
06/28 06	12.6	133.7	25	1006
06/28 12	13.0	133.4	25	1006
06/28 18	13.7	132.7	25	1006
06/29 00	14.1	132.2	25	1006
06/29 06	14.4	131.7	25	1006
06/29 12	14.8	131.0	25	1006
06/29 18	15.3	130.2	25	1006
06/30 00	16.0	129.2	25	1006
06/30 06	17.1	127.7	25	1004
06/30 09	17.8	126.8	25	1004
06/30 12	18.2	126.0	25	1004
06/30 15	18.2	125.0	25	1004
06/30 18	18.3	124.0	25	1002
06/30 21	18.5	123.6	25	1002
07/01 00	18.7	123.4	25	1002
07/01 03	18.9	123.3	25	1002
07/01 06	19.4	123.2	25	1002
07/01 09	20.3	123.2	25	1002
07/01 12	21.2	123.1	25	1002
07/01 15	22.1	122.9	25	1002
07/01 18	23.1	122.6	25	1002
07/02 00	25.1	122.1	L	1004

Table 6.6. Best track positions and intensities of Tropical Storm Falcon (Danas).

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
07/14 00	12.4	136.6	25	1004
07/14 06	13.3	135.3	25	1004
07/14 12	14.1	134.5	25	1004
07/14 18	15.0	133.9	25	1002
07/15 00	15.7	133.1	25	1002
07/15 06	16.3	132.2	25	1000
07/15 12	16.7	130.6	25	1000
07/15 18	16.8	128.6	30	998
07/15 21	16.8	127.4	30	998
07/16 00	16.8	126.4	30	998
07/16 03	16.8	125.6	30	998
07/16 06	16.9	124.8	35	994
07/16 09	17.1	124.3	35	994
07/16 12	17.2	123.8	35	994
07/16 15	17.2	123.6	35	994
07/16 18	17.3	123.4	35	994
07/16 21	17.6	123.4	35	994
07/17 00	18.1	123.5	35	994
07/17 06	19.0	123.7	35	994
07/17 12	20.6	124.0	35	992
07/17 18	21.9	124.1	35	992
07/18 00	24.0	124.1	40	990
07/18 06	25.7	124.0	40	990
07/18 12	26.5	123.9	45	985
07/18 18	27.9	123.9	45	985
07/19 00	29.0	124.0	40	990
07/19 06	30.2	124.3	40	990
07/19 12	31.7	124.9	40	990
07/19 18	33.1	125.3	40	990
07/20 00	34.2	125.6	35	992
07/20 06	34.9	125.8	35	992
07/20 12	35.7	126.3	30	994
07/20 18	36.6	127.2	30	996
07/21 00	37.8	128.5	25	998
07/21 06	39.0	129.6	XT	996

Table 6.7. Best track positions and intensities of Tropical Depression Goring.

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
07/17 06	17.4	118.7	25	0996
07/17 12	17.8	118.6	25	0996
07/17 18	18.3	118.8	25	0996
07/18 00	19.7	119.3	30	0994
07/18 06	20.9	119.5	30	0994
07/18 12	21.2	119.6	30	0994
07/18 18	21.5	119.9	25	0996
07/19 00	22.2	121.2	25	0996
07/19 06	23.6	122.2	25	0996
07/19 12	24.7	122.6	L	0998

Table 6.8. Best track positions and intensities of Typhoon Hanna (Lekima).

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
08/03 06	15.1	132.6	25	1000
08/03 12	15.4	132.1	25	1000
08/03 18	15.8	131.6	30	998
08/04 00	16.1	131.5	30	998
08/04 06	16.9	131.3	35	996
08/04 12	17.7	131.1	40	994
08/04 18	18.4	130.7	40	994
08/05 00	18.7	130.2	45	990
08/05 06	18.8	129.7	45	990
08/05 12	18.6	129.3	45	990
08/05 18	18.5	129.2	50	985
08/06 00	18.9	129.1	50	985
08/06 06	19.2	128.9	55	980
08/06 12	19.5	128.6	65	975
08/06 18	19.7	128.2	70	970
08/07 00	20.3	128.1	75	960
08/07 06	21.0	127.7	80	950
08/07 12	21.6	127.0	90	940
08/07 18	22.1	126.4	95	935
08/08 00	22.7	125.9	100	930
08/08 06	23.7	125.5	100	930
08/08 12	24.4	124.9	105	925
08/08 18	25.4	124.5	100	930
08/09 00	26.4	123.4	95	935
08/09 06	27.0	122.5	90	940
08/09 12	27.5	122.0	90	940
08/09 18	28.3	121.4	85	950
08/10 00	28.9	120.8	65	970
08/10 06	29.9	120.3	55	975
08/10 12	30.7	120.2	45	980
08/10 18	31.7	120.5	45	980
08/11 00	33.6	120.2	45	980
08/11 06	34.7	119.8	45	980
08/11 12	35.9	119.9	45	980
08/11 18	36.9	119.7	45	980
08/12 00	37.3	119.2	40	985
08/12 06	37.1	119.1	35	990
08/12 12	36.9	119.2	30	992
08/12 18	36.8	119.6	30	992
08/13 00	37.2	120.0	30	994
08/13 06	38.0	120.5	30	996
08/13 12	38.3	121.1	25	998
08/13 18	38.2	121.5	25	998
08/14 00	38.0	121.9	XT	1000

Table 6.9. Best track positions and intensities of Severe Tropical Storm Ineng (Bailu)

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
08/19 18	13.2	133.9	25	1004
08/20 00	13.5	133.8	25	1004
08/20 06	13.8	133.6	25	1002
08/20 12	14.2	133.2	25	1002
08/20 18	14.5	132.9	30	1000
08/21 00	14.8	132.5	30	1000
08/21 06	15.2	131.8	30	1000
08/21 12	15.5	130.9	35	998
08/21 18	15.7	129.7	35	996
08/22 00	15.8	128.9	40	994
08/22 06	16.0	128.4	40	994
08/22 12	16.8	127.7	45	990
08/22 18	17.7	127.3	50	985
08/22 21	18.0	126.8	50	985
08/23 00	18.3	125.8	50	985
08/23 03	18.6	125.4	50	985
08/23 06	19.0	125.2	50	985
08/23 09	19.5	124.8	50	985
08/23 12	19.9	124.3	55	980
08/23 15	20.3	123.7	55	980
08/23 18	20.7	123.1	55	980
08/23 21	21.1	122.4	55	980
08/24 00	21.4	121.8	55	980
08/24 03	21.8	121.2	55	980
08/24 06	22.2	120.6	55	980
08/24 09	22.6	120.0	55	980
08/24 12	22.9	119.2	50	985
08/24 18	23.1	118.1	45	990
08/25 00	23.7	117.3	40	994
08/25 06	24.5	115.7	35	996
08/25 12	24.8	114.2	30	998
08/25 18	24.7	113.3	25	1000
08/26 00	25.1	112.4	L	1002

Table 6.10. Best track positions and intensities of Tropical Storm Jenny (Podul)

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
08/25 06	12.1	136.8	25	1004
08/25 12	12.4	135.4	25	1004
08/25 18	12.6	134.2	25	1002
08/26 00	12.8	133.2	25	1002
08/26 06	13.3	131.2	25	1002
08/26 12	13.8	129.5	25	1002
08/26 15	14.1	128.7	25	1002
08/26 18	14.4	128.0	25	1002
08/26 21	14.6	127.4	25	1002
08/27 00	14.7	126.6	30	1000
08/27 03	14.8	125.6	30	1000
08/27 06	15.1	124.6	30	1000
08/27 09	15.7	123.1	30	1000
08/27 12	15.9	121.9	30	1002
08/27 15	16.0	120.7	30	1002
08/27 18	16.1	119.6	30	1000
08/27 21	16.3	118.4	30	1000
08/28 00	16.5	117.3	35	998
08/28 06	16.7	116.3	35	996
08/28 12	17.1	114.8	35	994
08/28 18	17.4	113.2	40	992
08/29 00	17.5	111.5	40	992
08/29 06	17.6	109.8	40	992
08/29 12	17.7	108.1	40	992
08/29 18	17.4	106.4	35	994
08/30 00	16.8	104.9	25	996
08/30 06	16.6	103.7	25	996
08/30 12	16.8	102.8	25	996
08/30 18	17.3	102.5	25	998
08/31 00	17.9	102.1	L	1000

Table 6.11. Best track positions and intensities of Tropical Storm Kabayan (Kajiki)

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
08/31 06	19.1	121.4	25	1004
08/31 09	19.0	120.3	25	1004
08/31 12	18.9	119.8	25	1004
08/31 15	18.8	118.9	25	1004
08/31 18	18.8	118.2	25	1002
09/01 00	18.8	116.8	25	1002
09/01 06	18.8	115.3	25	1002
09/01 12	18.9	113.6	30	1000
09/01 18	19.0	111.8	30	1000
09/02 00	18.9	110.4	30	998
09/02 06	18.4	109.3	30	998
09/02 12	17.4	108.2	35	996
09/02 18	16.4	107.4	35	996
09/03 00	15.8	107.1	30	998
09/03 06	16.0	107.7	30	998
09/03 12	16.4	108.2	30	998
09/03 18	16.7	108.3	30	998
09/04 00	17.0	108.2	30	998
09/04 06	17.1	108.0	30	998
09/04 12	17.3	108.6	30	998
09/04 18	17.4	109.3	25	1000
09/05 00	17.6	110.2	25	1000
09/05 06	18.2	111.6	25	1000
09/05 12	19.1	112.8	25	1000
09/05 18	19.6	113.0	25	1000
09/06 00	19.4	112.3	25	1000
09/06 06	18.6	112.5	25	1000
09/06 12	18.9	113.2	L	1002

Table 6.12. Best track positions and intensities of Typhoon Liwayway (Lingling)

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
09/01 00	11.0	129.2	25	1004
09/01 06	12.2	128.3	25	1004
09/01 12	13.2	127.4	25	1004
09/01 18	14.4	126.2	25	1004
09/02 00	15.8	125.3	30	1002
09/02 06	16.9	125.0	35	1000
09/02 12	18.0	124.5	40	998
09/02 18	18.9	124.1	45	994
09/03 00	19.8	123.9	50	992
09/03 06	20.7	124.0	60	985
09/03 12	21.3	124.2	65	980
09/03 18	21.8	124.3	70	975
09/04 00	22.1	124.6	70	975
09/04 06	22.4	125.1	75	970
09/04 12	23.0	125.4	80	965
09/04 18	23.6	125.4	85	955
09/05 00	24.2	125.3	90	945
09/05 06	24.9	125.3	95	940
09/05 12	25.7	125.2	95	940
09/05 18	26.9	125.1	95	940
09/06 00	28.1	125.1	95	940
09/06 06	29.6	125.2	90	945
09/06 12	31.4	125.1	85	950
09/06 18	33.6	125.0	80	955
09/07 00	35.6	125.0	70	965
09/07 06	37.9	125.4	65	970
09/07 12	40.8	126.5	50	985
09/07 18	44.4	128.5	45	990
09/08 00	47.3	130.5	XT	985

Table 6.13. Best track positions and intensities of Tropical Depression Marilyn.

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
09/10 06	12.1	135.2	25	998
09/10 12	12.4	135.5	25	998
09/10 18	12.7	136.7	25	998
09/11 00	13.3	137.2	999	1000
09/11 06	14.0	136.6	999	1000
09/11 12	14.4	135.8	999	1000
09/11 18	15.3	134.8	999	1000
09/12 00	16.2	134.4	25	998
09/12 06	17.0	133.8	25	998
09/12 12	17.7	133.0	25	998
09/12 18	18.3	132.4	25	998
09/13 00	19.2	132.1	25	996
09/13 06	19.6	132.3	25	996
09/13 12	20.2	132.6	25	998
09/13 18	20.9	133.0	25	998
09/14 00	21.5	133.6	25	996
09/14 06	21.9	134.3	25	994
09/14 12	22.5	135.1	L	996

Table 6.14. Best track positions and intensities of Typhoon Nimfa (Tapah).

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
09/17 00	20.0	128.8	25	1000
09/17 06	20.8	128.8	30	998
09/17 12	21.1	128.8	30	998
09/17 18	21.3	128.8	30	998
09/18 00	21.6	128.9	30	998
09/18 06	21.8	129.1	30	998
09/18 12	22.1	129.2	30	998
09/18 18	22.3	129.0	30	998
09/19 00	22.4	128.7	30	998
09/19 06	22.5	128.6	35	996
09/19 12	22.7	128.3	40	994
09/19 18	22.9	127.8	40	992
09/20 00	23.0	127.4	45	990
09/20 06	23.3	127.2	50	985
09/20 12	24.1	126.9	55	980
09/20 18	25.1	126.4	60	975
09/21 00	26.2	125.7	65	970
09/21 06	27.5	125.6	65	970
09/21 12	28.5	125.7	65	970
09/21 18	29.6	126.0	65	970
09/22 00	31.0	126.7	60	975
09/22 06	32.6	127.9	60	975
09/22 12	33.9	129.5	55	980
09/22 18	35.2	131.3	50	985
09/23 00	37.6	134.2	XT	992

Table 6.15. Best track positions and intensities of Typhoon Onyok (Mitag)

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
09/26 18	12.4	141.1	25	1006
09/27 00	13.0	139.4	25	1006
09/27 06	13.8	137.2	25	1006
09/27 12	14.4	135.8	30	1004
09/27 18	15.1	134.3	30	1004
09/28 00	16.2	132.4	35	1000
09/28 06	17.2	130.5	40	998
09/28 12	17.7	128.9	45	996
09/28 18	18.0	127.6	50	990
09/29 00	18.6	126.3	55	985
09/29 06	19.4	125.5	60	980
09/29 12	20.4	124.7	65	975
09/29 18	21.0	123.7	65	975
09/30 00	21.8	123.0	70	970
09/30 06	22.8	122.9	75	965
09/30 12	24.6	122.9	75	965
09/30 18	26.1	122.6	75	965
10/01 00	27.4	122.3	70	970
10/01 06	28.7	122.2	65	975
10/01 12	29.9	122.3	60	980
10/01 18	30.6	122.8	55	985
10/02 00	31.9	123.8	50	990
10/02 06	33.4	124.7	50	990
10/02 12	34.4	126.3	45	992
10/02 18	35.7	128.2	40	994
10/03 00	37.7	130.0	40	992
10/03 06	38.3	131.0	XT	990

Table 6.16. Best track positions and intensities of Typhoon Perla (Neoguri).

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
10/15 18	16.8	133.7	25	1006
10/16 00	17.2	132.7	25	1006
10/16 06	17.7	131.6	25	1006
10/16 12	18.1	130.7	25	1006
10/16 18	18.3	130.3	30	1004
10/17 00	18.6	130.0	35	1002
10/17 06	19.0	129.9	35	1002
10/17 12	19.3	129.9	35	1002
10/17 18	19.6	129.8	40	1000
10/18 00	19.8	129.7	45	998
10/18 06	20.0	129.5	45	998
10/18 12	20.4	129.0	45	998
10/18 18	20.7	128.5	50	992
10/19 00	21.0	128.0	55	990
10/19 06	21.5	127.4	60	985
10/19 12	21.8	127.3	70	975
10/19 18	22.6	127.5	75	970
10/20 00	23.4	127.9	75	970
10/20 06	24.5	129.0	70	975
10/20 12	25.4	130.0	65	980
10/20 18	27.0	131.6	60	985
10/21 00	28.8	133.0	60	985
10/21 06	30.3	134.4	55	990
10/21 12	31.1	135.3	XT	998

Table 6.17. Best track positions and intensities of Typhoon Quiel (Nakri).

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
11/04 12	13.5	114.2	25	1004
11/04 18	13.6	114.4	25	1004
11/05 00	13.8	114.8	25	1004
11/05 06	13.8	115.3	30	1002
11/05 12	13.7	115.8	30	1000
11/05 18	13.5	116.2	35	998
11/06 00	13.4	116.4	35	996
11/06 06	13.3	116.6	40	994
11/06 12	13.3	116.8	40	994
11/06 18	13.4	117.0	45	992
11/07 00	13.4	117.2	50	990
11/07 06	13.4	117.3	55	985
11/07 12	13.3	117.3	60	980
11/07 18	13.1	117.3	60	980
11/08 00	12.9	117.1	60	980
11/08 06	12.7	116.8	65	975
11/08 12	12.5	116.4	65	975
11/08 18	12.4	115.7	60	980
11/09 00	12.4	115.1	60	980
11/09 06	12.4	114.4	60	980
11/09 12	12.4	113.7	55	985
11/09 18	12.5	112.7	55	985
11/10 00	12.6	111.7	55	985
11/10 06	12.6	110.8	55	985
11/10 12	12.6	110.1	50	990
11/10 18	12.7	109.2	40	996
11/11 00	13.0	108.4	30	1002
11/11 06	13.3	107.8	L	1006

Table 6.18. Best track positions and intensities of Typhoon Ramon (Kalmaegi)

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
11/11 18	12.6	132.7	25	1004
11/12 00	12.0	132.3	25	1004
11/12 06	11.8	132.0	25	1004
11/12 12	11.9	131.3	25	1004
11/12 18	12.3	130.2	25	1002
11/13 00	12.7	129.3	25	1002
11/13 06	12.9	128.4	25	1002
11/13 12	13.2	128.0	25	1002
11/13 18	13.7	127.8	25	1002
11/14 00	14.6	127.4	25	1002
11/14 06	15.1	126.8	25	1002
11/14 12	15.2	126.4	25	1002
11/14 18	15.4	126.2	25	1002
11/15 00	15.6	126.3	25	1002
11/15 06	15.8	126.3	25	1002
11/15 12	15.9	126.3	25	1002
11/15 18	16.0	126.2	30	1000
11/16 00	15.8	126.1	30	1000
11/16 06	15.7	126.0	30	1000
11/16 12	15.6	125.8	30	1000
11/16 18	15.8	125.5	35	998
11/17 00	16.0	125.0	35	998
11/17 03	16.3	124.9	35	998
11/17 06	16.6	124.9	40	996
11/17 09	16.8	124.8	40	996
11/17 12	16.9	124.6	45	994
11/17 15	17.0	124.4	45	994
11/17 18	17.1	124.1	45	994
11/17 21	17.3	123.8	45	994
11/18 00	17.5	123.6	50	992
11/18 03	17.8	123.4	55	990
11/18 06	18.2	123.3	60	985
11/18 09	18.5	123.1	60	985
11/18 12	18.7	122.9	65	980
11/18 15	18.9	122.7	70	975
11/18 18	19.0	122.6	70	975
11/18 21	19.1	122.5	70	975
11/19 00	19.2	122.5	70	975
11/19 03	19.3	122.5	70	975
11/19 06	19.4	122.6	70	975
11/19 09	19.3	122.6	70	975
11/19 12	18.9	122.6	70	975
11/19 15	18.7	122.5	55	985
11/19 18	18.4	122.2	45	1000
11/19 21	18.0	121.9	35	1002
11/20 00	17.5	121.5	30	1006
11/20 03	17.0	121.1	30	1006
11/20 06	16.6	120.8	30	1006
11/20 09	16.1	120.5	30	1006
11/20 12	15.4	120.0	30	1006
11/20 15	14.8	119.5	25	1008
11/20 18	14.3	118.9	25	1008
11/20 21	13.9	118.4	25	1008
11/21 00	13.5	117.8	25	1008
11/21 06	13.3	117.3	25	1008
11/21 12	13.0	116.2	L	1010

Table 6.19. Best track positions and intensities of Severe Tropical Storm Sarah (Fung-wong).

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
11/19 00	13.0	132.9	25	1004
11/19 06	14.0	131.1	30	1002
11/19 12	14.7	129.9	30	1002
11/19 18	15.2	129.2	30	1002
11/20 00	16.1	128.2	35	1000
11/20 06	17.6	127.4	40	998
11/20 12	19.0	126.2	45	994
11/20 18	19.6	125.4	50	992
11/21 00	20.0	124.8	55	990
11/21 06	20.5	124.4	55	990
11/21 12	21.3	124.3	50	994
11/21 18	22.2	124.4	50	994
11/22 00	22.9	125.0	45	996
11/22 06	23.7	125.4	35	1002
11/22 12	24.6	125.3	30	1010
11/22 18	25.1	125.3	30	1010
11/23 00	25.2	125.5	25	1012
11/23 06	25.3	125.6	25	1012
11/23 12	26.0	125.9	25	1012
11/23 18	28.4	125.6	XT	1014

Table 6.20. Best track positions and intensities of Typhoon Tisoy (Kammuri).

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
11/24 12	8.2	159.0	25	1004
11/24 18	8.1	157.5	25	1004
11/25 00	8.2	156.1	25	1004
11/25 06	8.6	154.6	25	1004
11/25 12	9.2	153.0	30	1002
11/25 18	10.1	151.2	30	1002
11/26 00	10.7	149.2	35	1000
11/26 06	11.0	147.3	40	998
11/26 12	11.2	145.2	40	998
11/26 18	11.3	143.6	45	994
11/27 00	11.3	142.3	45	994
11/27 06	11.4	141.0	50	992
11/27 12	11.5	140.1	55	990
11/27 18	11.6	139.4	60	985
11/28 00	12.0	139.0	65	980
11/28 06	12.7	138.7	70	975
11/28 12	13.4	138.6	70	975
11/28 18	14.1	138.4	70	975
11/29 00	14.4	138.2	65	980
11/29 06	14.3	138.0	65	980
11/29 12	14.1	137.7	65	980
11/29 18	13.8	136.6	65	980
11/30 00	13.6	135.6	65	980
11/30 06	13.4	134.7	65	980
11/30 12	13.2	133.8	65	980
11/30 18	13.1	132.5	65	980
12/01 00	13.1	130.9	65	980
12/01 06	13.1	130.0	65	980
12/01 12	13.1	129.1	65	980
12/01 15	13.1	128.4	70	975
12/01 18	13.1	127.8	75	970
12/01 21	13.0	127.1	75	970
12/02 00	12.9	126.6	80	960
12/02 03	12.9	126.1	80	960
12/02 06	12.9	125.7	85	955
12/02 09	12.9	125.2	85	955
12/02 12	12.9	124.7	90	950
12/02 15	12.9	124.1	90	950
12/02 18	13.0	123.4	90	950
12/02 21	13.1	122.8	85	955
12/03 00	13.1	122.2	80	960
12/03 03	13.2	121.5	75	965
12/03 06	13.2	120.8	70	970
12/03 09	13.3	120.1	70	970
12/03 12	13.4	119.7	65	975
12/03 15	13.6	119.3	60	980
12/03 18	13.8	118.8	55	985
12/04 00	14.1	117.9	50	992
12/04 06	14.3	117.1	45	994
12/04 12	14.5	116.3	40	998
12/04 18	14.5	115.2	35	1000
12/05 00	14.3	114.3	35	1002
12/05 06	13.8	113.7	30	1004
12/05 12	13.0	113.4	30	1004
12/05 18	12.2	113.3	25	1008
12/06 00	11.2	113.4	L	1010

Table 6.21. Best track positions and intensities of Typhoon Ursula (Phanfone).

DTG (UTC)	CLAT (°N)	CLON (°E)	MXWD (kt)	PRES (hPa)
12/20 00	4.7	148.9	25	1006
12/20 06	4.7	147.5	25	1006
12/20 12	4.7	145.9	25	1006
12/20 18	4.7	144.1	25	1006
12/21 00	4.9	143.1	30	1004
12/21 06	5.2	142.5	30	1004
12/21 12	5.7	141.6	30	1004
12/21 18	6.1	140.6	30	1004
12/22 00	6.5	139.8	30	1004
12/22 06	7.4	138.4	35	1002
12/22 12	8.7	136.4	35	1002
12/22 18	9.6	134.9	35	1002
12/22 21	9.9	134.2	35	1002
12/23 00	10.0	133.5	40	1000
12/23 03	10.0	132.8	40	1000
12/23 06	10.0	132.1	45	998
12/23 09	10.1	131.4	45	998
12/23 12	10.3	130.8	50	994
12/23 15	10.5	130.1	55	990
12/23 18	10.7	129.2	65	985
12/23 21	10.8	128.4	65	985
12/24 00	10.8	127.8	70	980
12/24 03	10.9	127.1	70	980
12/24 06	11.0	126.4	75	975
12/24 09	11.2	125.6	80	970
12/24 12	11.4	124.9	80	970
12/24 15	11.5	124.1	80	970
12/24 18	11.6	123.6	80	970
12/24 21	11.7	123.0	80	970
12/25 00	11.8	122.4	75	975
12/25 03	11.9	121.8	75	975
12/25 06	12.1	121.4	70	980
12/25 09	12.4	120.8	70	980
12/25 12	12.6	120.2	65	985
12/25 15	12.7	119.6	60	990
12/25 18	12.8	119.3	55	992
12/25 21	13.0	119.0	60	990
12/26 00	13.1	118.6	65	985
12/26 06	13.4	118.1	75	975
12/26 12	13.9	117.7	65	985
12/26 18	14.4	117.3	60	990
12/27 00	14.6	117.0	55	992
12/27 06	14.7	116.6	50	996
12/27 12	14.8	116.1	45	998
12/27 18	14.5	115.7	40	1000
12/28 00	14.4	115.2	35	1004
12/28 06	14.4	113.9	30	1006
12/28 12	14.4	113.0	25	1008
12/28 18	14.5	112.2	L	1010

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