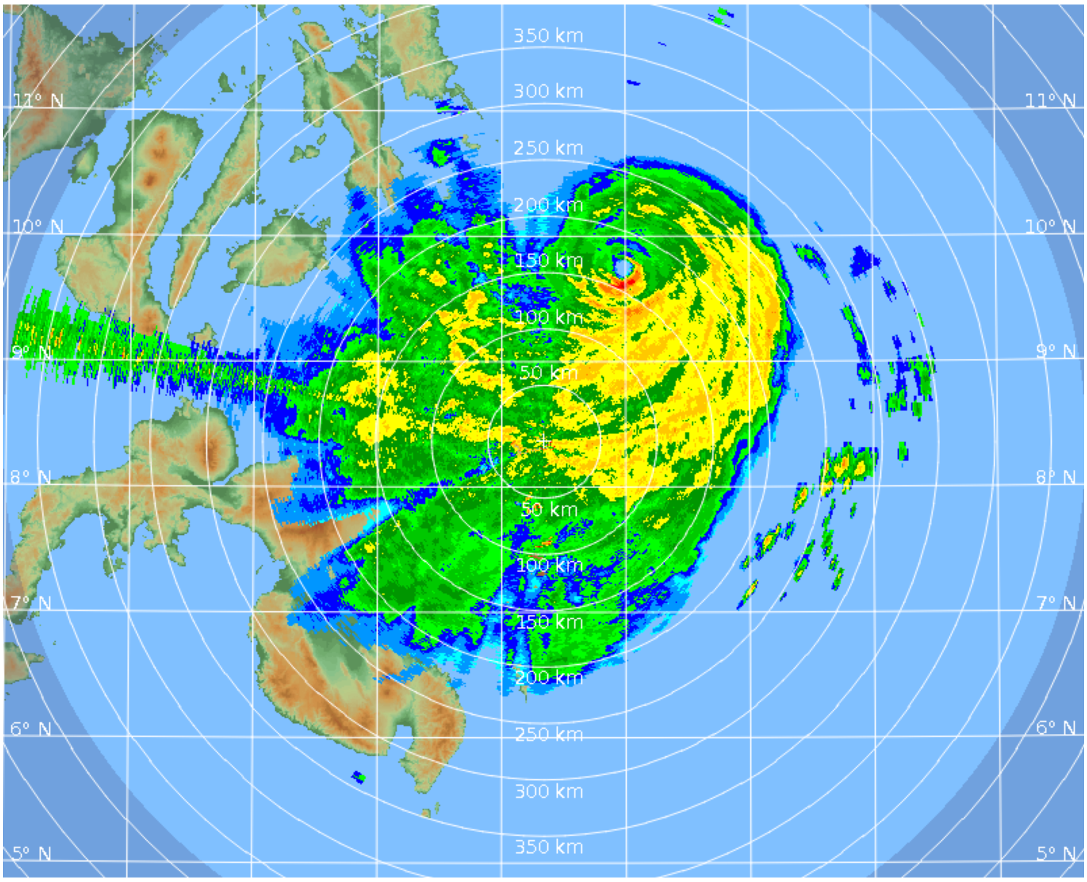
ANNUAL REPORT ON PHILIPPINE TROPICAL CYCLONES 2021



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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) which serves as the yearly compendium of technical reviews of tropical cyclones that occurred within the Philippine Area of Responsibility based on the outputs of the post-season best track analysis conducted by the tropical cyclone meteorologists of the agency. The report also includes a summary of forecast and warning services provided by the agency for the entire season and each tropical cyclone.

Cover image: Radar image of Super Typhoon ODETTE during its peak intensity over the waters east of Surigao del Norte as seen from the PAGASA Doppler Weather Surveillance Radar in Hinatuan, Surigao del Sur.

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EXECUTIVE SUMMARY

The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) named 15 tropical cyclones (TCs) that occurred within the Philippine Area of Responsibility (PAR) during the 2021 Philippine TC season. This year was deemed to be below normal relative to the 1991-2020 average, although no long-term increase or decrease in the annual number of TCs within the PAR region was noted since 1991. The quarterly TC activity within the PAR region was modulated by a weakening La Niña turning ENSO-neutral conditions during the first half and mid-third quarter of the year and a re-developing La Niña on the fourth quarter, as well as the negative Indian Ocean Dipole phase and the intra-seasonal variation of the North Pacific Subtropical High.

In general, majority of the TCs that occurred within the PAR region in 202 developed over the Philippine Sea and Western North Pacific (WNP) south of 15°N and east of 125°E, with seven of the 15 TCs forming within the PAR region. Two-thirds of the TCs that occurred within the PAR region in 2021 had tracks that were generally oriented northwest-southeast, west northwest-east southeast, or east-west as they passed within the PAR, while the second largest cluster of TC tracks during the season, constituting 20% of the total TC events, were mainly recurving in nature within the PAR region and had tracks ending over the East China Sea or the Sea of Japan. The TCs that entered that PAR had an average lifespan of 7 days and 12 hours while the average duration of these TCs inside the PAR was 3 days and 20.7 hours.

While the number of TCs that peaked at TD, TS/STS, and TY/STY within the PAR region was lower than the climatological average (due to the below-normal TC activity), in terms of its proportion to the total number of TCs in 2021, the number of TCs that peaked at TD were close to the climatological average, while those that reached TS/STS and TY/STY were higher and lower than average, respectively. Nevertheless, the proportions observed in 2021 for each intensity categories were all within the range of near-normal values. Three of 15 TC events within the PAR region this season reached super typhoon category while inside the PAR region. Combined warning track and best track data from PAGASA since 1991 shows that the annual number of TCs peaking at TS/STS and TY/STY categories entering the PAR region was stable since 1991, with the slightly decreasing trend deemed to be not significant. On the other hand, the number of TCs that remained as a TD within the PAR has been on a slightly increasing trend since 1991. However, this was associated with the increased reliability of on-site and remote sensing observation platforms being utilized by PAGASA forecasters for judging the formation of TDs.

The season also registered nine landfalling TCs, which was roughly 60% of the total TC events in 2021. This was slightly lower than the preceding season, and slightly higher (albeit near normal) the climatological average. In terms of its proportion to the total number of TCs, the number of landfalling TCs was above average but near normal, while the number of non-landfalling TCs relative to the total was below normal. The number of landfalling TCs were equally divided between the first and second half of the year. Consolidated track data continues to show a notably decreasing trend in the number of TCs that cross the archipelago for the past three decades. Most all of these landfalling TCs tracked over the central portion of the archipelago between Southern Luzon and Northeastern Mindanao. Nearly half of the landfalling TCs during the season were depressions at the time of initial landfall.

The total rainfall during TC days in the Philippines accounted for 40% to 70% of the total rainfall in 2020 over the western half of Luzon, 20 to 50% in other areas of Luzon, 20% to 50% over Visayas (with higher proportions over Western Visayas), and 20% to 40% for most areas in Mindanao. It was also observed that Palawan had similar observed proportions with those found in Panay Island, which could be attributed to its geographic location. The observed rainfall during TC days were notably higher (at least 1,000 mm) for most of Luzon (except mainland Palawan, most of Quezon, Camarines Provinces, and Masbate), Eastern Visayas, Panay Island, and Caraga Region than in any other areas. Highest rainfall accumulations during TC days were noted over some areas in Benguet and La Union (with values reaching in excess of 2,000 mm).

As the operational arm responsible for the national TC forecasting and warning program, the Weather Division issued 317 public TC products, 242 TC Warnings for Shipping, and 97 Significant Meteorological Information for TC its end users during the 2021 season, in addition to the provision of expert advice and briefings to public and private sector partners. A total of 11 TCs necessitated the hoisting of Tropical Cyclone Wind Signals in all provinces or portions thereof except for most of Bangsamoro and SOCCSKARGEN regions, and the southern half of Davao Region and Zamboanga Peninsula. Wind signals were most frequently hoisted over Caraga Region, Eastern Visayas, Extreme Northern Luzon, and most of Central and Western Visayas. These areas had wind signal levels of at least 1 hoisted at least four times during the 2021 season.

Despite disaster risk reduction and management activities, the National Disaster Risk Reduction and Management Council reported that the TC events of 2021 claimed the lives of 484 individuals, making 2021 the 18th deadliest TC season since 1970 and the deadliest post-Yolanda season. Data since 1970 shows no notable trend in the casualty count and death toll. However, data from 2015 suggests a generally increasing trend in number of deaths and injuries have been noted since 2015, with the trend more pronounced in the latter. On the other hand, the number of missing individuals has been on a slightly downward trend since 2015.

Furthermore, a total of 1,462 injured and 78 missing persons were reported. Aggregate cost of damage across the country amounted to PHP 61.323 billion (adjusted for inflation), making it the 6th costliest TC season since 1970 and the 2nd costliest post-Yolanda season. Damage to public infrastructure accounted for most of the total damage cost. While year-on-year fluctuations exist in the reported damage cost, the aggregated annual cost of damage due to TC events has been steadily increasing since 1970.

Verification statistics shows that over the past decade, PAGASA has been steadily improving in its operational TC track forecast, although year-on-year fluctuations are also observed. In particular, it can be seen that DPEs for this season were higher at all forecast times than in 2020. Nevertheless, the mean DPE for the first 72 hours of PAGASA track forecasts during the 2021 season were the 2nd or 3rd lowest since 2014 (and potentially in the history of PAGASA), while forecast positions beyond 72 hours were the 3rd lowest since 2018. Most of the typhoon and super typhoon cases during the season showed relatively small position errors across various forecast times. Most of the TCs that reported relatively large position errors for the season were associated with considerable slow and righthand/poleward bias in track forecasts. The mean directional bias across all forecast times and mean speed bias at 24-, 48-, and 72-hour were found to be small, although a generally slow bias in the track forecasts was observed. On average, the hit rate of forecast confidence circles during the 2021 season was 75.9% for the 24-hour forecast. The corresponding hit rates for the 48-, 72-, 96-, and 120-hour forecasts were 71.3%, 74.0%, 66.7%, and 71.8%.

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The Annual Report on Philippine Tropical Cyclone (ARTC) 2021 was made possible through the efforts of the following forecasters and meteorologists of the Weather Division

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NATIONAL TROPICAL CYCLONE FORECASTING AND WARNING PROGRAM

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National Tropical Cyclone Forecasting and Warning Program

Since 1879[1], the government meteorological service[2] of the Philippines has been providing tropical cyclone (TC) forecasts and warnings to ensure the safety, well-being, and economic security of the people, safeguard the environment, and promote national progress and sustainable development. Created by law[3] in 8 December 1972 as the successor to the Weather Bureau, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) is a scientific and technological services institute of the Department of Science and Technology (DOST) mandated[4] to provide adequate, up-to-date, and timely information on atmospheric phenomena especially during high impact weather events such as TC occurrences. As the national meteorological and hydrological service (NMHS) of the Republic of the Philippines, PAGASA is responsible for the national TC forecasting and warning program of the country.

To ensure its effective and efficient implementation, the Weather Division, through the Marine Meteorological Services Section (MMSS), is primarily responsible for the operational activities related to the national TC forecasting and warning program. The typhoon forecasters of the MMSS implements the day-to-day activities related to TC operations of the agency in coordination with operational forecasters from the Weather Forecasting Section (WFS) and Aeronautical Meteorological Services Section (AMSS) of the Weather Division, as well as the forecasters from the five (5) PAGASA Regional Services Divisions (PRSDs).

Forecast Areas

On average, the Western North Pacific (WNP) basin accounts for one-third of the TC activity on the planet and sees activity all year round. With the Philippines receiving approximately 8 to 9 TC landfalls every year and with indirect wind and water impacts also likely in the presence of other weather systems (such as monsoons), the effective implementation of a TC forecasting and warning program is essential to protect lives and properties and mitigating the worsening impacts of these weather systems under a warming climate. To achieve this, PAGASA monitors TC activity across multiple forecast areas within the WNP basin. Appropriate forecasts, warnings, and expert advice are provided by the agency to the public and other stakeholders whenever a TC within these forecast areas may bring impacts to land, sea areas, and airspace under PAGASA's forecast responsibility.

This section describes each of the areas of responsibility of PAGASA relevant to the implementation of the national tropical cyclone forecasting and warning program for the 2021 season[5].

Philippine Area of Responsibility

Originating as a storm warning area for shipping forecasts from the Philippines as agreed upon with other member states of the Regional Association V of the World Meteorological Organization (WMO)[6], the Philippine Area of Responsibility (PAR) presently serves as the region in the WNP wherein PAGASA has the responsibility for issuing tropical cyclone analyses, forecasts, and warnings for both the public and maritime sectors. Domestic names are also provided for TCs that occur within the PAR region.

The PAR region is geographically defined as the land and sea areas within the WNP basin encompassed by rhumb lines that connect the coordinates 5°N 115°E, 15°N 115°E, 21°N 120°E,

[1] The first typhoon warning of its kind in the Philippines was issued in 1879 indicating that a tropical cyclone was crossing northern Luzon.
[2] Observatorio Meteorológico de Manila (1865-1901), Weather Bureau (1901-1972), PAGASA (1972-present)
[3] Presidential Decree No. 78 s. 1972, as amended.
[4] Republic Act No. 10692 (PAGASA Modernization Act of 2015)
[5] PAGASA TC forecast areas have been updated on 23 March 2022.
[6] 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).

25°N 120°E, 25°N 135°E, and 5°N 135°E. This 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[7], West Philippine Sea[8], Luzon Strait, Mindanao Sea[9], Sulu Sea, and most of the Philippine Sea.

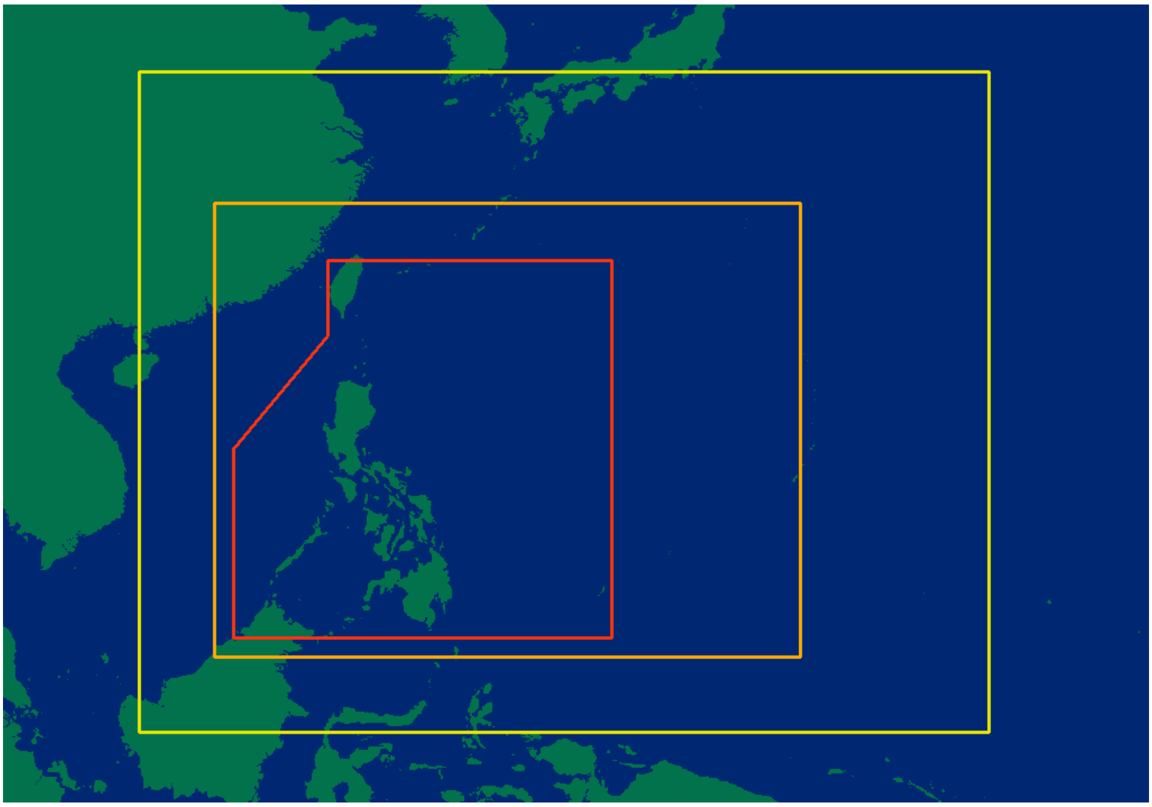

Fig. 1.1. TC forecast areas of PAGASA within the WNP basin (2015-2022).

Extended Forecast Areas

In 2015, the Weather Division established the Extended Forecast Areas within the WNP basin to address the increasing demand from the public, disaster managers, news outlets, and other stakeholders for official information on TCs outside the PAR region. Larger than the PAR region, these forecast areas were created to define the region where PAGASA will provide additional public TC information.

The Tropical Cyclone Advisory Domain (TCAD) and the Tropical Cyclone Information Domain (TCID) constitute the Extended Forecast Areas of PAGASA. These regions are geographically defined as follows:

- The TCAD is the region in the WNP 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 the region in the WNP 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.

[7] These archipelagic seas are the Sibuyan Sea, Visayan Sea, Camotes Sea, Samar Sea, and Bohol Sea.
[8] 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.
[9] 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.

High Seas and Offshore Waters Forecast Zones

Under the framework of the International Maritime Organization (IMO)/WMO World-Wide Met-Ocean Information and Warning Service (WWMIWS) in accordance with Resolution A.1051(27), as amended, and pursuant to the provisions of WMO-No. 49 Vol. I (Technical Regulations: General Meteorological Standards and Recommended Practices), PAGASA, through the MMSS, is the designated promulgation service for the provision of meteorological maritime safety information (MSI) and other meteorological products and services relevant to shipping in waters within PAGASA's identified area of forecast responsibility, taking into account applicable standards and guidelines set forth by the WMO and IMO.

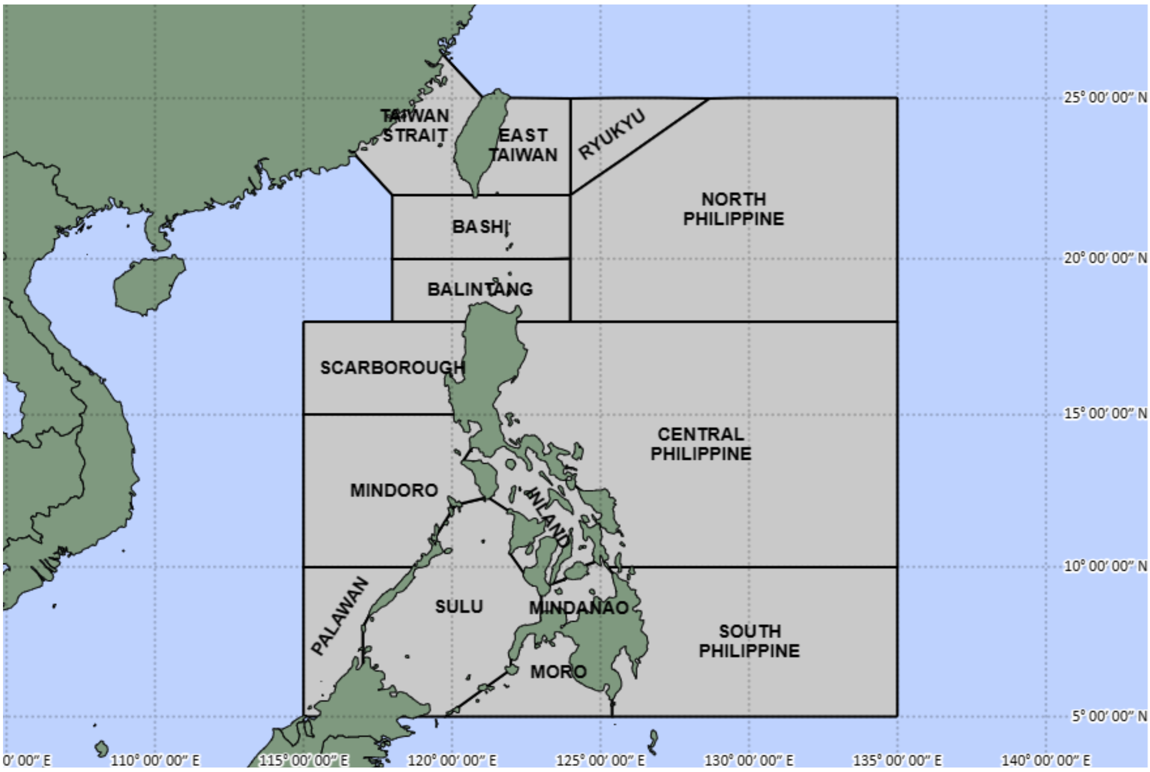

Fig. 1.2. Marine forecast zones for the high seas and offshore waters.

The waters to which PAGASA has forecast responsibility include, but not limited to, the Sea Area A1[10], Sea Area A2[11], and NAVTEX[12] service area designated by the maritime administration in coordination with the METAREA XI Coordinator and with full consideration to the full extent of the maritime jurisdiction of the Philippines. Considering the vastness of offshore waters and the high seas[13] within the PAR region, as well as the Taiwan Strait, are subdivided into 15 marine forecast zones to facilitate the efficient provision of meteorological MSI within the high seas and offshore waters of the Philippines.

[10] Sea Area A1, also referred to as coastal waters, is the region of sea or ocean within the coverage of at least one very high frequency (VHF) coast radio station where continuous digital selective calling (DSC) alerting is available.
[11] Sea Area A2 refers to the region of sea or ocean outside Sea Area A1 that falls within the range of at least one medium frequency (MF) coast radio station with continuous DSC alerting.
[12] Navigational telex or NAVTEX is a system for the broadcast and automatic reception of navigational and meteorological warnings, meteorological forecasts, and other urgent safety-related messages broadcast to ship using narrow-band direct-printing telegraphy.
[13] In this context, offshore waters refer to the body of water outside of designated Sea Area A1 but situated with the exclusive economic zone and extended continental shelf of the Philippines, while the high seas in this context refers to the waters outside the designated Sea Area A1 and offshore waters.

Manila Flight Information Region

A Flight Information Region (FIR) is a specified region of airspace covering the entirety of the Philippines and its surrounding waters (including the extreme eastern portion of Sabah, Malaysia and northern half of Talaud Islands, Indonesia) where flight information service and alerting service are provided by the country to which the International Civil Aviation Organization (ICAO) has delegated operational control of the said airspace. In the Philippines, this airspace is referred to as the Manila FIR. Shown in Fig. 1.3, the FIR is the region of airspace bounded by rhumb lines connecting the coordinates 21°N 117.5°E, 21°N 121.5°E, 21°N 130°E, 7°N 130°E, 3.5°N 133°E, 3.5°N 132°E, 4°N 132°E, 4°N 120°E, 7.5°N 117.5°E, 8.41667°N 116.5°E, 10.5°N 114°E, 14.5°N 114°E, and 16.667°N 114°E.

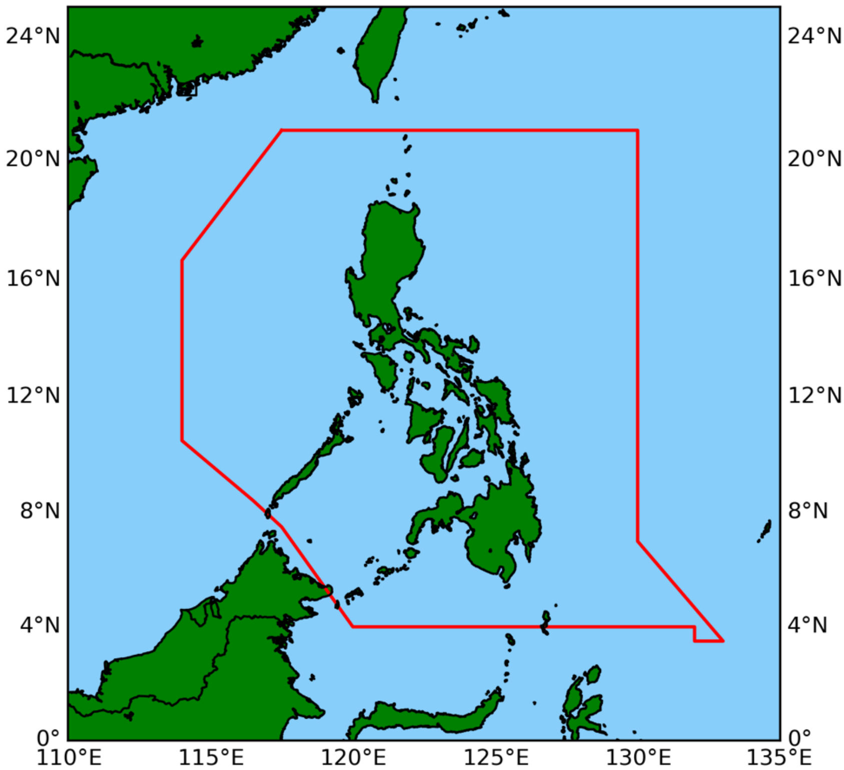

Fig. 1.3. Manila Flight Information Region.

In accordance with Annex 3 of the Convention on International Civil Aviation (ICAO Annex 3) and pursuant to Philippine Civil Aviation Regulations, Part 3 and Manual of Standards for Aeronautical Meteorology, PAGASA is the designated and approved meteorological service provider for international air navigation, with AMSS serving as the meteorological watch office (MWO) for Manila FIR. The designated MWO is primarily responsible for, among others, the preparation of SIGMET information for TCs within Manila FIR, supplying of SIGMET information to associated air traffic services units, disseminate SIGMET, and coordinate its issuance with other MWOs of adjacent FIRs.

Classification of Tropical Cyclones

All TCs occurring within the WNP basin are categorized by PAGASA according to their maximum 10-minute winds near the center. The current classification system, which has since been updated[14] in March 2022, follows a five-tier scale with tropical depressions as the weakest of the categories and super typhoons as the strongest. The five-level system was originally introduced in 2015 following the onslaught of Super Typhoon Yolanda (Haiyan) in the Central Philippines in

[14] The five tropical cyclone categories used by PAGASA was updated in March 2022 to harmonize the domestic definition of Super Typhoon with equivalent peak categories used by other meteorological centers in the WNP basin. The new definition has been retroactively applied to all TCs pre-March 2022.

order to give emphasis to violent cases of typhoons, as well as to distinguish TCs possessing gale-force winds to those bearing storm-force winds (i.e., pre-2015 system classifies TCs with both gale-force and storm-force maximum winds as tropical storms). Table 1.1 presents the TC categories in use under the current scheme and equivalent range of maximum winds near the center in Beaufort, knots (nautical miles per hour), kilometers per hour, and meters per second.

Table 1.1 Categories of TC used by PAGASA.

Category of TC	Maximum sustained winds near the center			
	Beaufort	kt	km/h	m/s
Tropical Depression (TD)	BF6 to BF7 (Strong winds)	22 to 33	39 to 61	10.8 to 17.1
Tropical Storm (TS)	BF8 to BF9 (Gale-force winds)	34 to 47	62 to 88	17.2 to 24.4
Severe Tropical Storm (STS)	BF10 to BF11 (Storm-force winds)	48 to 63	89 to 117	24.5 to 32.6
Typhoon (TY)	BF12 (Typhoon-force winds)	64 to 99	118 to 184	32.7 to 51.2
Super Typhoon (STY)	BF12 (Typhoon-force winds)	$\geq$ 100	$\geq$ 185	$\geq$ 51.3

Naming of Tropical Cyclones

Brief History

The practice of using names to identify TC events in the WNP goes back several centuries, with TCs being named after affected places, saints, or things they hit. Some of these TCs include the Kamikaze of 1274 and 1281, the 1881 Haiphong Typhoon, the 1906 Hong Kong Typhoon, the 1912 China Typhoon, the 1922 Swatow Typhoon, and the 1934 Muroto Typhoon. In 1944, while the world is in the midst of a global war, forecasters from the United States Army Air Forces based in the newly established weather center at Saipan (Northern Mariana Islands) informally named TCs after their wives and girlfriends. The practice reduced confusion when identifying these weather systems during map discussions.

With the growing popularity of this naming practice among military forecasters, the United States Armed Services began publicly assigning names for TCs within the WNP in 1945, thereby formalizing the practice. Eventually, in 1959, the Joint Typhoon Warning Center (JTWC) assumed the responsibility of assigning “international names” for TCs within the WNP. In 2000, Japan Meteorological Agency, acting as the WMO Regional Specialized Meteorological Center - Tokyo Typhoon Center (RSMC Tokyo), took over the naming responsibility from the JTWC.

Until 1962, the then-Weather Bureau has been relying on names assigned by the US military (JTWC). However, this changed in 1963 when the bureau decided to separately assign domestic names to TCs of at least TD category within the PAR region. One of the key reasons for the adoption of domestic naming is the absence of names for TCs that do not reach tropical storm category. These weather systems, despite their weaker winds, usually bring significant amount of heavy rainfall that causes widespread flooding and rain-induced landslides. PAGASA has since maintained this practice of assigning domestic names when it took over the functions of the Weather Bureau in 1972.

Domestic Naming Scheme

PAGASA assigns a domestic name to a TC of at least tropical depression category that enters or develops within the PAR region. Under the naming guidelines[15] which has been in effect since 2001, all domestic names do not exceed nine letters and three syllables and not bear any negative or offensive meaning. The names can 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 occurs 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 on, until auxiliary set is exhausted by the 35th TC of the year. To date, all auxiliary names remained unused.

Retiring Domestic Names

Under the present naming guidelines, the domestic name of a TC, whether regular or auxiliary, can be retired from the operational set through any of the two processes: decommissioning or delisting.

A domestic name is decommissioned by PAGASA if the 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.

On the other hand, a domestic name can be delisted when there is a necessity for the name to be replaced without meeting the criteria for decommissioning. Delisting can happen at any time during 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 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 inappropriate videos with a minor at that time shares the same name (i.e., "Mang Kanor" scandal). Another example of delisted name was the case of Set III's NONOY in 2015, which was replaced by NONA even though the original name has already been used in three public TC products. NONOY was delisted because of its perceived similarity with the nickname of then-President Benigno Aquino III ("Noynoy").

Since the adoption of domestic naming in 1963, PAGASA has decommissioned 71 names and delisted 50 names from the operational listing.

Domestic names for the 2021 season

Table 1.2 presents the regular and auxiliary sets of names under Set I, which was the set of names used during the 2021 season. Names under Set I were last used during the 2017 season and is scheduled to be used again during the 2025 season (except for those that will be replaced in case of decommissioning). A total of 15 names were used in 2021, with no new names that were used for the first time this season. No names from the auxiliary set in 2021 were used.

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[15] 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.

The names JOLINA, MARING, and ODETTE were decommissioned after the conclusion of the 2021 season due to the magnitude and extent of reported casualties and damage to houses, infrastructure, and agriculture. Their replacement names, JACINTO, MIRASOL, and OPONG, will be introduced during the 2025 season.

Table 1.2. Regular and auxiliary domestic names during the 2021 season. Names in gray were unused during the season while those in bold were decommissioned at the end of the season.

Regular Set I				
Auring	Fabian	Kiko	Paolo	Uwan
Bising	Gorio	Lannie	Quedan	Verbena
Crising	Huaning	**Maring**	Ramil	Wilma
Dante	Isang	Nando	Salome	Yasmin
Emong	**Jolina**	**Odette**	Tino	Zoraida
Auxiliary Set I				
Alamid	Conching	Emer	Gerardo	Isko
Bruno	Dolor	Florante	Hernan	Jerome

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)), Doppler weather radar scans, and surface meteorological observations[16]. 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. 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 and from satellite fix reports from other meteorological centers. Objective Dvorak estimates from computerized algorithms (e.g., Olander and Velden 2019, Olander et al. 2021) are also taken into consideration. The conversion from FT and CI numbers to maximum sustained winds 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.

Initial estimates from the Dvorak method are refined using surface wind estimates from SCAT, synthetic aperture radar (SAR), and microwave sensors, radial velocity analysis from Doppler weather radars, weather map analysis using available surface observations, and other objective tools from CIMSS (e.g., 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 on both the exposure conditions near the center of a TC (Harper et

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

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 strong winds[17], gale-force winds[18], storm-force winds[19], and typhoon-force winds[20] associated with the TC circulation across four quadrants (NE, SE, SW, and NW). The extent of these TC winds is primarily estimated using the subjective analysis of SCAT, SAR, and microwave-based wind fields, sea surface wind fields estimated from Himawari-8 low-level atmospheric motion vectors (AMV) (Nonaka et al. 2019), objective wind field estimation tools (Knaff and DeMaria 2010; Knaff et al. 2016), and weather map analysis using available surface observations.

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 30 nmi of the Philippine coastline within 24 hours, additional analyses[21] 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.

All analysis parameters are compared by typhoon forecasters against operational estimates of other TC warning centers for consistency purposes.

Tropical Cyclone Forecast

PAGASA issues track and intensity forecasts out to 120 hours, as well as the radii of probability circles at each forecast time of the track forecast. Forecasts are 12-hourly up to 72 hours and 24-hourly beyond 72 hours. Normally[22], these forecasts are issued up to four (4) times daily with initial times of 00, 06, 12, and 18 UTC, with additional forecasts[23] provided at initial times of 03, 09, 15, and 21 UTC when a TC is forecast to make landfall or pass within 30 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. These maps are also compared against satellite imagery analysis (e.g., water vapor channels) to determine synoptic environmental influences to steering (e.g., midlatitude troughs, tropical upper tropospheric troughs, jet stream or westerlies).

Intensity forecasts are primarily based on several statistical (Tsai and Elsberry 2015, Gile et al. 2021) and statistical-dynamical (DeMaria 2009, Yamaguchi et al. 2018, Ono et al. 2019) TC intensity guidance products. Dynamical intensity guidance from global and regional deterministic models are also referenced 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, environmental influences (e.g., sea surface temperature, ocean heat content, vertical wind shear, low-mid level moisture, and outflow) along and in the surrounding region of the track forecast based on weather maps, satellite imageries, and oceanic datasets 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).

[17] "Strong winds" is defined as near-surface winds of 22 to 33 kt or Beaufort Force 6 or 7.
[18] "Gale-force winds" is defined as near-surface winds of 34 to 47 kt or Beaufort Force 8 or 9.
[19] "Storm-force winds" is defined as near-surface winds of 48 to 63 kt or Beaufort Force 10 or 11.
[20] "Typhoon-force winds" is defined as near surface winds of at least 64 kt or Beaufort Force 12.
[21] Additional analyses are terminated once the TC has left the 30-nmi coastal buffer.
[22] The frequency of the forecasts depends on the TC product being issued.
[23] Additional forecasts are terminated once the TC has left the 30-nmi coastal buffer.

The track forecast issued by PAGASA incorporates the forecast confidence circles at each forecast time. The forecast confidence 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 against combined preliminary and final best track data. For the 2021 season, the radii of the forecast confidence circles were 97 km, 161 km, 245 km, 293 km, and 434 km for the 24-, 48-, 72-, 96-, and 120-hour forecast positions, respectively. Values for the 12-, 36-, and 60-hour forecast confidence circles were interpolated based on aforementioned values.

For consistency, track and intensity forecasts are also compared by typhoon forecasters against operational estimates of other TC warning centers for consistency purposes, taking into account the differences in wind averaging times used by these centers.

Tropical Cyclone Product Description

Depending on the location of the TC within the forecast areas and the threat posed by the TC to land and sea areas under PAGASA's responsibility, the Weather Division issues different TC products to the public, disaster managers, national government agencies, local government units, and specialized end users (i.e., maritime and civil aviation sectors). This section presents the description of various public, marine, and civil aviation TC products issued by the Weather Division during the 2021 season.

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 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
12- 24-, 36- 48-, 72-, 96- and 120-h forecasts	Center position Maximum sustained winds Forecast confidence circle (as part of forecast chart)

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 may be first hoisted, general outlook of hazards which may affect land areas and coastal waters, narrative of track and intensity outlook, and date and time of forecast entry to the PAR region.

TCAs are normally[24] issued twice daily at 11:00 AM and 11:00 PM.

Tropical Cyclone Bulletins

The Tropical Cyclone Bulletin (TCB)[25] 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 of the country. The TCB contains the following elements in the analysis and forecast:

Analysis	Center position Direction and speed of movement Maximum sustained winds

[24] The initial or final TCA may be issued at 5:00 AM, 11:00 AM, 5:00 PM, or 11:00 PM PHT.
[25] TCB was first issued during Tropical Storm DANTE (CHOI-WAN) to replace the legacy Severe Weather Bulletin (SWB).

	Maximum gust Extent of tropical cyclone winds
12- 24-, 36- 48-, 72-, 96- and 120-h forecasts	Center position Maximum sustained winds Forecast confidence circle (as part of forecast chart)

TCBs may include warning information such as the list of areas where wind signals are or will be hoisted, 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 a narrative of track and intensity outlook and the forecast date and time the TC will exit the PAR. In cases when a TC is at TY or STY category, the TCB may include emergency statements related to areas affected and that will be affected in the next 3 hours by the violent conditions within the eyewall.

TCBs are issued every six hours at 5:00 AM, 11:00 AM, 5:00 PM, and 11:00 PM. Additional issuances are also made at 2:00 AM, 8:00 AM, 2:00 PM, and 8:00 PM if the TC is forecast to make landfall or pass within 30 nmi of the Philippine coastline within the next 24 hours. The additional issuances cease once the TC exits the 30-nmi coastal buffer.

Tropical Cyclone Warning for Shipping

The Tropical Cyclone Warning for Shipping, more commonly known as the “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 region that may pose threat to safety of maritime traffic. As a meteorological MSI, the provision of IWS is in accordance with convention obligations under SOLAS 1974 and all applicable WMO and IMO technical regulations, standards, and guidelines.

The IWS incorporates the following elements in the analysis and forecast:

Analysis	Center position Direction and speed of movement Maximum sustained winds Central pressure Extent of gale-, storm-, and typhoon-force winds
12- 24-, 36- 48-, 72-, 96- and 120-h forecasts	Center position Maximum sustained winds

In addition, IWS also contains a request to all marine vessels within the 300 nautical miles from the center of the TC to transmit, using all available means, shipborne meteorological observations every three (3) hours. To ensure prioritization in broadcasted MSI by radiocommunication facilities, the phrase “SECURITE” is appended at the start of the IWS.

IWSs are normally[26] issued four (4) times daily at 5:00 AM PHT, 11:00 AM PHT, 5:00 PM PHT, and 11:00 PM PHT.

WC SIGMET for Civil Aviation

The WC SIGMET (Significant Meteorological Information for Tropical Cyclones) is a plain text warning issued by the designated MWO (AMSS) to provide concise information concerning the occurrence or expected occurrence of TCs of at least TS category within Manila FIR which may affect the safety of aircraft operations. As a critical meteorological information for civil aviation, the provision of SIGMET is accordance with the provisions of ICAO Annex 3 and all applicable technical regulations, standards, and guidelines from the WMO, ICAO, and CAAP.

The WC SIGMET incorporates the following elements in the analysis and forecast:

[26] The initial (final) IWS is done in conjunction with the issuance of the initial (final) SWB.

Analysis	Center position Direction and speed of movement

In addition, the WC SIGMET also contains the extent of cumulonimbus (CB) clouds associated with the TC, often delineated by a radius from the center position of the TC or by a polygon, as well as the height of the CB tops, expressed in terms of flight levels.

WC SIGMET is normally[27] 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 Updates in other Forecast Products

Aside from the TC products being issued, updates on the center position, intensity, and movement of all TCs being monitored within the PAR and extended forecast areas (although forecast parameters are not included to ensure conciseness) are also incorporated in the following forecast and warning products:

- 24-Hour Public Weather Forecast issued by the WFS at 4:00 AM and 4:00 PM daily.
- Area Synopsis and 24-Hour Shipping Forecast issued by the MMSS at 4:00 AM and 4:00 PM daily.
- Regional or Local Weather Forecasts issued by the PRSDs at 5:00 AM and 5:00 PM daily.

Tropical Cyclone Wind Signal System

The Tropical Cyclone Wind Signal (TCWS) System is a five-level land warning in plain text format used to warn land areas of TC winds of at least strong wind force on the Beaufort Scale for at most 36 hours before the onset of such meteorological conditions. This wind signal system is numbered 1 to 5, with higher signal number associated with higher general wind strength and short warning lead time (i.e., hours before onset of wind threat).

Originally introduced in the 1930s to standardize typhoon wind warnings in the Far East region, the TCWS system has been updated several times in the past to facilitate the warning of more violent wind conditions and their potential impacts. The most recent changes in the system was made in March 2022 to harmonize the wind warning system with the existing typhoon damage scales for the Philippines, damage survey information, warning best practices from other tropical cyclone warning centers in the WNP basin, and the results of severe wind risk analysis projects undertaken by PAGASA researchers. However, for the purpose of this ARTC, this subsection presents the TCWS system as it was implemented during the 2021 season. Table 1.3 presents the wind signals of the TCWS system, the general wind strength associated with each wind signal, description of potential damage to structures and vegetation, and the associated color of each wind signal when presented on maps.

To ensure consistent interpretation, the generalized description 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.

[27] The initial WC SIGMET is issued when a TC inside Manila FIR reaches TS category or when a TC of at least TS category is about to enter Manila FIR within 12 hours. Cancellation of WC SIGMET is undertaken when the TC inside Manila FIR weakens into a TD or when TC of at least TS category has moved out or is moving out of Manila FIR. All initial and final WC SIGMET issuances are undertaken with close coordination with MWOs of adjacent FIR under the “Collaborative SIGMET Issuance” (CSI) Scheme.

Moreover, the terms high-risk, medium-risk, and low-risk structures are defined as follows:

- 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.
- 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.

Table 1.3. PAGASA TCWS system during the 2021 season

TCWS	General wind strength and description of potential damage to structures and vegetation
Wind 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 hoisted
Wind Signal No. 2	Damaging gale- to storm-force winds[28] which may cause light to moderate damage is prevailing or expected to prevail within 24 hours from the time the signal was hoisted
Wind Signal No. 3	Destructive[29] 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 hoisted.
Wind Signal No. 4	Very destructive[30] 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 hoisted.
Wind Signal No. 5	Devastating [31] 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 hoisted.

Although a general description of damage per wind signal is presented in Table 1.3, 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 1.4.

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 general wind strength associated with each wind signal 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 speeds expressed by the highest TCWS raised during the passage of a TC.

[28] 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…”
[29] Typhoon-force winds of up to 170 km/h.
[30] Typhoon-force winds of more than 170 km/h but not exceeding 220 km/h.
[31] Typhoon-force winds more than 220 km/h.

Table 1.4. 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.

Table 1.4. (*Continuation*)

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.

Product Dissemination

For Public Tropical Cyclone Products

Ensuring the effective and efficient dissemination of public TC products to end users is the shared responsibility of the Weather Division and the PRSDs especially during periods of high impact weather events in the country. As such, public TC products are disseminated using both digital and paper-based platforms which include fax, electronic mail (email), short messaging service (SMS), official website, and social media 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)[32].

For Marine Tropical Cyclone Products

The timely and efficient dissemination of IWS and other similar meteorological MSI to mariners of vessels within the sea areas under PAGASA's forecast responsibility is the shared responsibility of PAGASA (as the national meteorological service and MSI promulgation service) and the., Philippine Coast Guard (PCG; as the maritime radiocommunications service) in accordance with convention obligations under SOLAS 1974. As such, constant coordination with these authorities or centers is in place to ensure that marine TC products are broadcasted through the shore-based radiocommunication facilities[33] of the PCG, taking into consideration the provisions under applicable WMO and IMO technical regulations.

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.

For Aeronautical Tropical Cyclone Products

Pursuant to applicable technical regulations, standards, and agreements between PAGASA and CAAP and in accordance with convention obligations of ICAO Annex 3, PAGASA is responsible for the timely and efficient dissemination of WC SIGMET to other Aeronautical Meteorological Offices (AMOs) designated by PAGASA, local air traffic services units, other MWOs (especially those involved in the CSI scheme), designated centers for VOLMET or D-VOLMET[34] broadcast, responsible ROBEX[35] centers and regional operational meteorological (OPMET) data banks, and other civil aviation users through the Aeronautical Fixed Telecommunications Network (AFTN) and other identified dissemination mechanisms.

Apart from the identified communication platforms, WC SIGMET is also distributed in 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. The abbreviated heading WCPH31 RPLL is used for the GTS-based dissemination of the WC SIGMET.

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 to various end users and stakeholders using traditional and emerging media platforms to ensure that preparation, mitigation, and adaptation measures undertaken by the public, disaster managers, government agencies and institutions, and specialized sectors during TC events are risk-informed, scenario-driven, and evidence-based.

[32] 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).

[33] Under the Global Maritime Distress and Safety System (GMDSS), these platforms include marine VHF/MF/HF coast radio stations, NAVTEX coast stations, and HF narrow band direct printing (NBDP).

[34] VOLMET and D-VOLMET (Digital VOLMET) refer to meteorological information for aircraft in flight, which is a worldwide network of radio stations broadcasting TAF, SIGMET, and METAR reports on shortwave and VHF frequencies.

[35] ROBEX or the Regional OPMET Bulletin Exchange is scheme established by ICAO to ensure the most efficient exchange of OPMET information within ASIA/PAC and MID Regions, as well as with other ICAO regions, as well as ensure the implementation of OPMET-related standards and recommended practices in ICAO Annexes 3 and 10 and relevant provisions of air navigational plans of the ASIA/PAC and MID Regions.

PAGASA meteorologists at the national and local levels undertake regular public briefings and press conferences at regular intervals[36]. These are broadcasted via television, radio, and the internet via the official website, social media, and video streaming/sharing platforms. In addition, duty forecasters answer to interview requests[37] from news outlets and phone queries from the public and other interested parties and end users.

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 by the Weather Division and local disaster risk reduction and management offices and phone briefings to heads of local governments by PRSDs. For the private sector, forecasters also give expert advice to business continuity planners and managers, especially when TCs (and other weather systems that are enhanced by them) will affect the economic centers of the country and likely cause significant disruption to their business activities.

These expert briefings and advices to the public and private sectors are supported by continuous information, education, and communication campaigns such as lectures, speaking engagements, and seminar-workshops to ensure that they effectively utilize the meteorological information that PAGASA provides them for their decision-making.

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[36] 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.
[37] These interviews may be on camera, through phone patch, or using a video conferencing platform.

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POST-SEASON BEST TRACK ANALYSIS
OF PHILIPPINE TROPICAL CYCLONES

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Post-Season Best Track Analysis of Philippine Tropical Cyclones

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 utilizes meteorological observation data from a wide array of platforms and formats, each having varying degrees of observation latency[1]. However, in an operational environment, the rigid time schedule of each forecast cycle[2] not only adds 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 termination of operational activities for a particular TC event, the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) collects all conventional and unconventional observation data not only from the domestic weather 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[3] 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[4] 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 not generally 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 motion. 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 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

[1] 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.
[2] 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.
[3] PAGASA adopted the definition of "best track" from the National Hurricane Center (Avila 2002)
[4] Both operational and best track intensities are estimated at 10-minute averaging periods.

in charge of best track analysis might try to avoid analyzing oscillations with a period less than 12 hours.

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 DANTE (CHOI-WAN) - one of the TCs of the 2021 season whose best track considerably changed from its operational track.

Although the operational and best tracks still featured the generally northwestward motion, the looping movement on 18 to 19 February and a landfall along the east coast of the country, Fig. 2.1 also shows considerable differences that significantly changes the narrative of DANTE. For instance, it had a wider looping path from 18 to 19 February in the best track compared to the operational track. In addition, the "wavy" like nature of the track after the looping motion as the storm made its way towards the country was minimized in the best track.

Operationally, DANTE was analyzed to have skirted the extreme northern portion of Eastern Samar and the extreme eastern portion of Northern Samar before making its final landfall over Bicol Region as a tropical depression. It weakened into a remnant low over Albay at 06 UTC on 22 February. In comparison, the best track showed DANTE making landfall in Eastern Samar as a tropical depression. It weakened into a remnant low near the boundary junction of Samar Island provinces at 00 UTC on 22 February (i.e., 6 hours earlier).

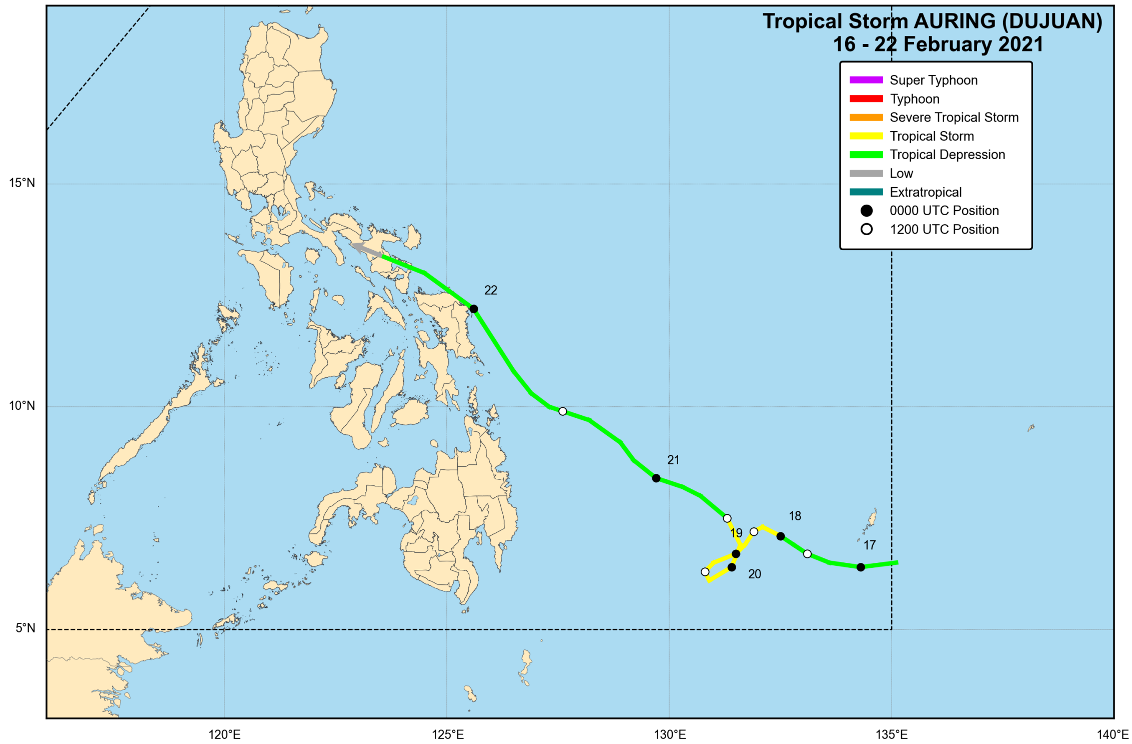
A best track analysis may also result in an upward or downward revision of intensity estimates at each synoptic time. A good example of this case for the 2021 season is Typhoon JOLINA. As a considerably small TC, the operational analysis of its intensity was challenging. During the warning period, it was only PAGASA who upgraded JOLINA into a typhoon prior to its initial landfall over Eastern Samar due to the timely arrival of the 13 UTC 06 September synoptic report[5] from Guiuan station and the presence of a radar eye signature. JOLINA was analyzed at that time to have maintained typhoon status for 6 hours as it crossed Samar Island. The best track still showed JOLINA reaching typhoon category prior to landfall but only maintained it for 3 hours.

The operational track of JOLINA showed the TC maintaining its severe tropical storm category for the remainder of its passage across the archipelago. However, a post-real time high resolution surface wind field from a synthetic aperture radar (SAR) overpass of the TC when it over the waters west of Marinduque revealed maximum winds reaching 65-70 kt, clearly indicating that it re-intensified into a typhoon prior or during its passage over Marinduque and maintained this strength before making landfall in Batangas. This re-intensification was represented in the best track data.

Through best track analysis, important statistics of the season (e.g., number of landfalling TCs for the year or month and the number of 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 track data can be further 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.

At the present, TC meteorologists from PAGASA perform both preliminary best track analysis in near-real time and post-season best track analysis after the season has ended to correct position and intensity estimates, with the latter benefitting from a larger set of real time, near-real time, and post-real time meteorological data and analyses.

[5] The report indicated average winds of 32 m/s and peak gust of 38 m/s.



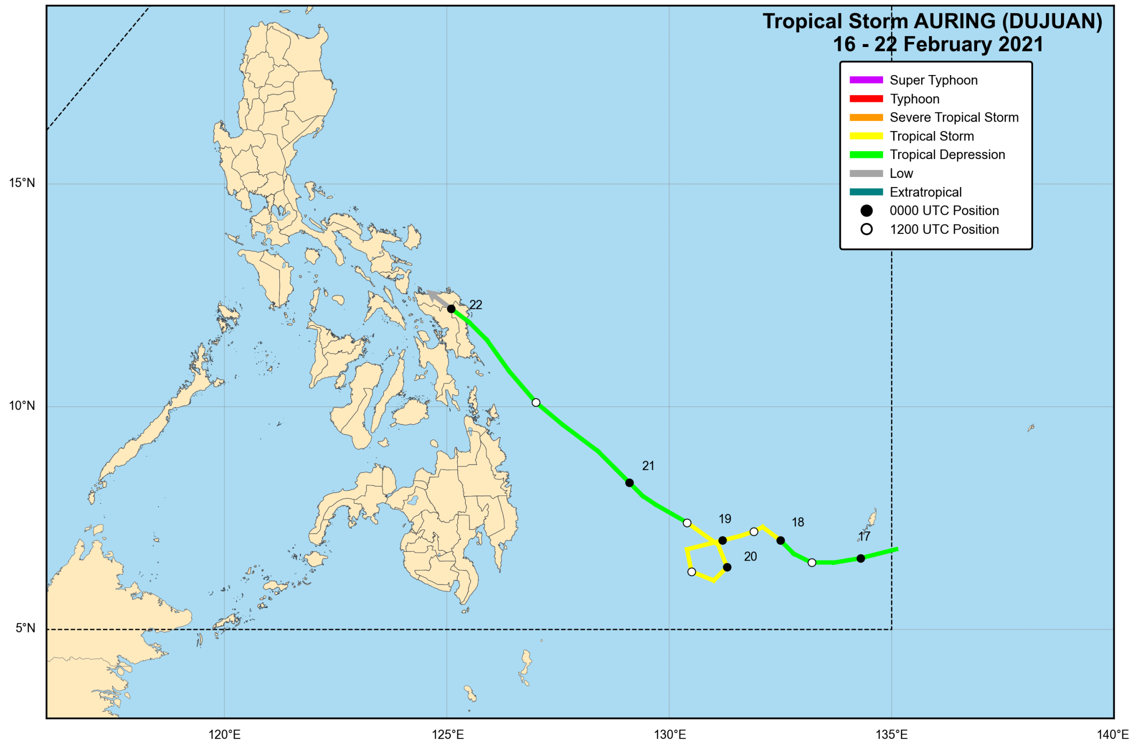


Fig 2.1. Operational (left) and best (right) track positions and intensities (as categories) of Tropical Storm AURING (DUJUAN). Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

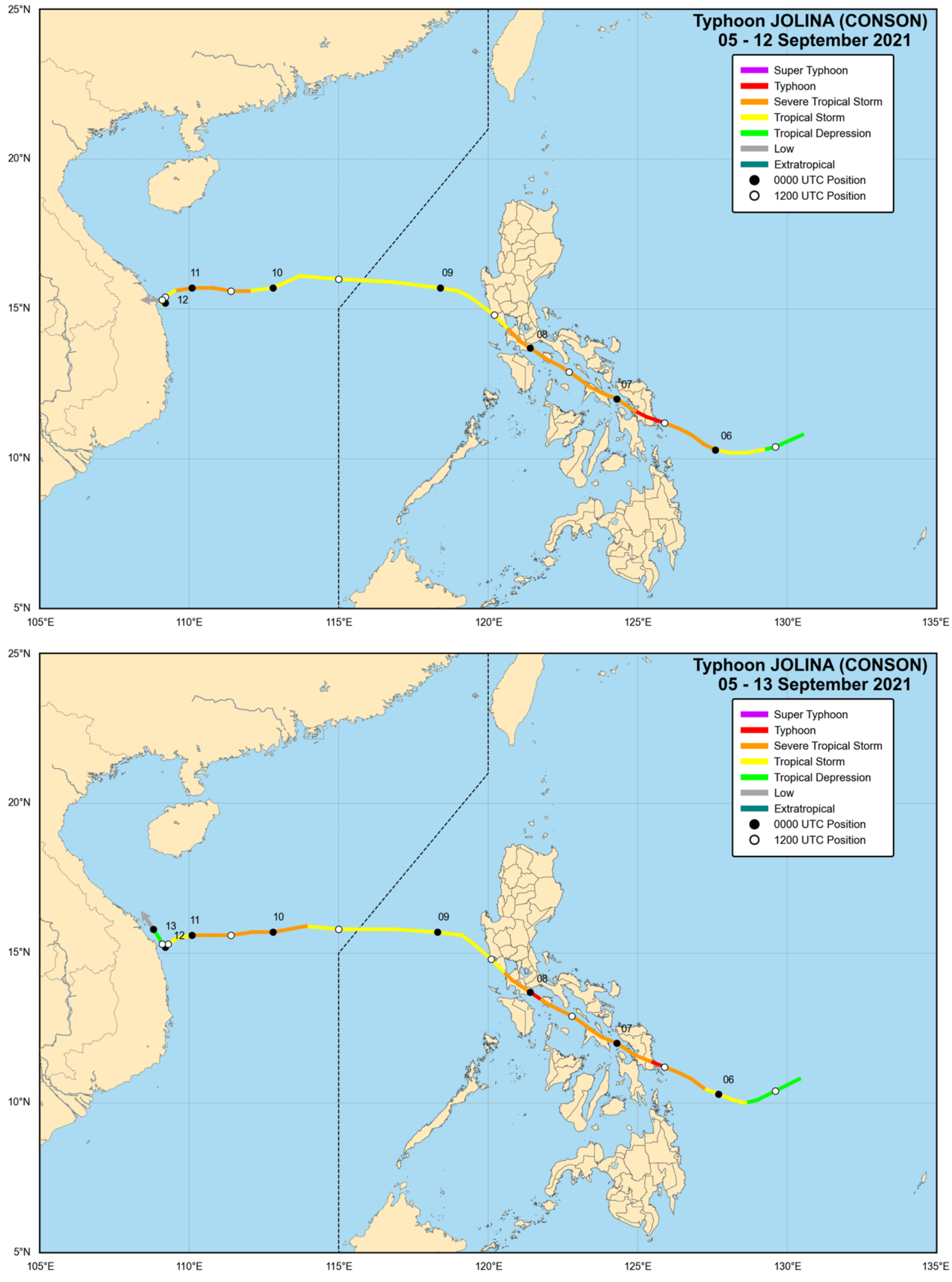


Fig 2.2. Operational (left) and best (right) track positions and intensities (as categories) of Typhoon JOLINA (CONSON). Line color indicates the category of TC. Shaded circles with date labels indicate 00 UTC positions while open circles indicate 12 UTC positions.

PAGASA Tropical Cyclone Publication Series

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 within two years after the termination of a particular TC season, the ARTC provides a yearly compendium of technical reviews of TCs that occurred within the Philippine Area of Responsibility (PAR) based on the outputs of 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, Director of the then-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 December 1981, a new report series, the “Annual Tropical Cyclone Report” (ATCR) was issued by the Tropical Cyclone Division (TCD) of the National Weather Office (NWO), with its first issue covering the TC season of 1977. The old series under the Climatological Division continued, although the ATCR became the definitive technical report series of PAGASA due to its more comprehensive content.

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 NWO) 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.

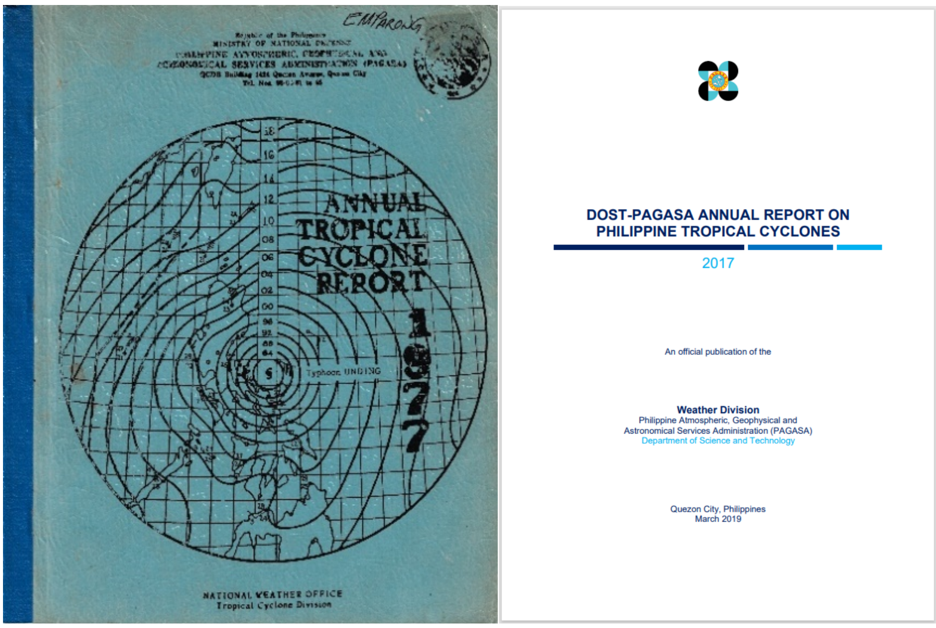


Fig. 2.2. Launch issues of the ATCR (1977 season, left) and ARTC (2017 season, right).

Several attempts were made to revive the publication of a TC technical report series. In March 2019, following creation of the Tropical Cyclone Group (TCG)[6] within the Weather Division (the successor to the WB), the publication of a TC report series resumed with the first issue of the “Annual Report on Philippine Tropical Cyclones” (ARTC). The launch issue covered the TC season of 2017 and was based on the operational track dataset of the season as the TCG was still in the

[6] The TCG is a unit of the Marine Meteorological Services Section responsible for the implementation of the tropical cyclone operational activities of the Weather Division.

process of finalizing the procedures for 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 ARTC is available in both print (ISSN 2672-3190) and digital (ISSN 2799-0575) versions, the latter of which is available in the official website of PAGASA.

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Avila, L. A., 2002: Best Track Determination at NHC. *25th Conf. on Hurr. and Trop. Meteor.,* San Diego, CA, Amer. Meteor. Soc., 11C.1, https://ams.confex.com/ams/pdfpapers/36320.pdf

PHILIPPINE TROPICAL CYCLONE SEASON OF 2021: AN OVERVIEW

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Philippine Tropical Cyclone Season of 2021: An Overview

General Statistics

The overview of the tracks of the tropical cyclones (TCs) that were observed within the Philippine Area of Responsibility (PAR) in 2021 is presented in Fig. 3.1. A total of 15 TCs were observed within the PAR region during the 2021 season. Compared to the 30-year average[1] of 20.2, the TC activity for the year within the PAR for this year is below normal[2] (Fig. 3.2). In general, most of the TCs that occurred within the PAR region developed over the waters of the Philippine Sea and Western North Pacific (WNP) south of 15°N and east of 125°E. Seven of the 15 TCs formed over the Philippine Sea inside the PAR region. Of those that formed outside the PAR, four developed over the waters near or surrounding the Federated States of Micronesia, two over the Philippine Sea west of the Northern Mariana Islands, and one over the offshore waters of southern China. A notable case for this year was that of Severe Tropical Storm (STS) ISANG, which was first tracked as a tropical depression (TD) less than 300 km west of the International Date Line. Most of the 2021 TCs degenerated into remnant lows over land, while the rest transitioned into a post-tropical[3] low or cyclone at the end of their tropical lifespan.

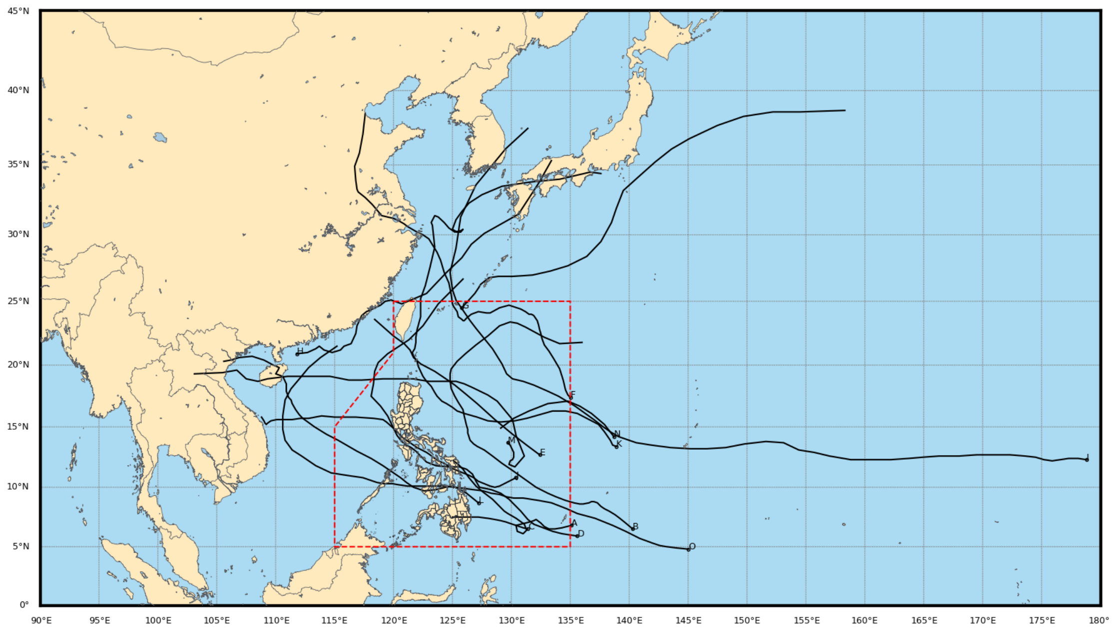

Fig. 3.1. PAGASA best track of TCs that occurred within the PAR in 2021. The filled circles in the tracks are the "genesis points" or locations where the TCs were first noted as a tropical depression on the best track data. The tracks are identified using the first letter of the domestic names of the TCs. The red dash line marks the limits of the PAR.

Fig. 3.1 shows that within the PAR region, two-thirds of the TCs that occurred within the PAR region in 2021 had tracks that were generally oriented northwest-southeast, west northwest-east southeast, or east-west as they passed within the PAR. These tracks mainly originated from the Philippine Sea and terminated over mainland China, the coastal waters of China or Vietnam, or the mainland Southeast Asia. The second largest cluster of TC tracks during the season, constituting 20% of the total TC events, were mainly recurving in nature within the PAR region and had tracks ending over the East China Sea or the Sea of Japan. Majority of the TCs within the PAR region during the 2021 season passed over the land or sea areas of the PAR south of 20°N.

[1] The reference period of the 30-year normal/average is 1991-2020.

[2] Beginning with the Annual Report on Philippine Tropical Cyclones 2021, a value is deemed near normal if it lies within 80.1-120% of the normal value. This follows the definition in use by PAGASA's Climatology and Agrometeorology Division (CAD),

[3] Post-tropical lows or cyclones can be either subtropical or extratropical in nature.

The country also witnessed a total of nine landfalling TCs in 2021, which is 60% of the total number of TCs that occurred within the PAR. The number of landfalling TCs were equally divided between the first and second half of the year, although the months of May, September, and October had equal number of landfalling TCs (i.e., two each). Relative to the climatological average (8.4 TCs), the number of landfalling TCs in 2021 was near normal (Fig. 3.2). In terms of its proportion to the total number of TCs for the 2021 season, the number of landfalling TCs was above average but near normal, while the number of non-landfalling TCs relative to the total number of TCs for the year was below normal (Fig. 3.3). Most of the landfalling TCs this season were at TD category at the time of their initial[4] TC landfalls. With maximum winds of 110 kt and central pressure of 920 hPa, Super Typhoon (STY) KIKO had the highest intensity of any TC during the 2021 season at the time of initial landfall.

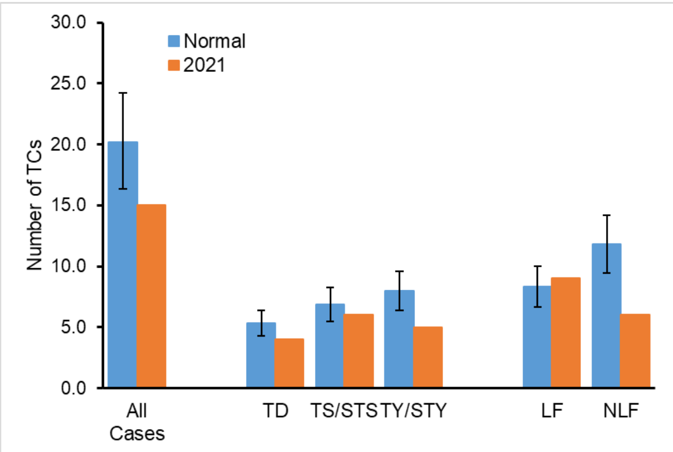

Fig. 3.2. The climatological normal of all TC occurrences within the PAR, depressions, storms (i.e., tropical storm and severe tropical storm categories), typhoons (i.e., typhoon and super typhoon categories), landfalling TCs, and non-landfalling TCs (blue bars) compared with those observed during the 2021 season (orange bars). Categorization of intensities is based on the peak intensity within the PAR region only. The errors bars indicate the range of near normal values.

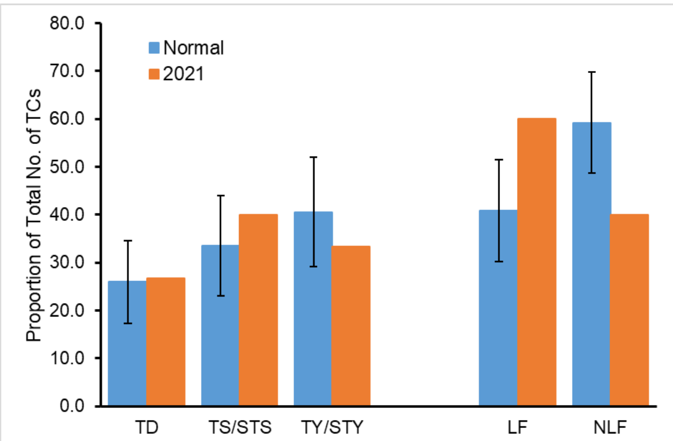

Fig. 3.3. Similar to Fig. 3.2, but the number of depressions, storms, typhoons, landfalling TCs, and non-landfalling TCs are expressed as proportion of the climatological average number of TCs (for normal values) and the total number of TCs that occurred within the PAR in 2021 (for the 2021 season). The errors bars indicate the range of near normal values.

Table 3.1 lists down the duration of occurrence of each 2021 TC event from its genesis or formation to its weakening to an area of low pressure or transitioning into post-tropical low or cyclone, while Table 3.2 presents the duration of these TCs within the PAR. The TCs that occurred within the

[4] Initial TC landfall refers to the first occurrence of a landfall of a TC of at least TD category in the Philippine archipelago.

PAR in 2020 had an average lifespan[5] of 7 days and 12 hours. Of those that occurred within the PAR this season, Typhoon FABIAN was the longest-lasting, with a basin-wide lifespan reaching 14 days. On the other hand, Tropical Storm (TS) CRISING and TD NANDO were the shortest-lasting of the 2021 TCs within the PAR region, with a basin-wide lifespan of only 2 days. Within the PAR region, TCs lasted an average of 3 days and 20.7 hours. Lasting 9 days, STY BISING remained within the PAR longer than any other TC in 2021. On the other hand, TS HUANING only logged 6 hours within the PAR, making it the TC with the shortest period of occurrence within the PAR for the year.

Table 3.1 also shows that during their lifespans in the WNP basin, eight of the 15 TCs in 2021 peaked at TS or STS category, while five reached typhoon (TY) or STY category. Three of the 2021 TCs, BISING, KIKO, and ODETTE, reached STY category with peak intensities happening inside the PAR region. Peaking at 120 kt and 895 hPa, STY BETTY was the most intense TC to occur both within the WNP basin and the PAR region in 2021, although it remained mainly over the Philippine Sea. The strongest TC to make landfall based on intensity at the time of initial landfall was STY KIKO (110 kt and 920 hPa). On the other hand of the scale, TD EMONG had the weakest basin-wide peak intensity of the 15 TCs in 2021 (i.e., 30 kt and 1002 hPa). While LANNIE had a lower peak intensity within the PAR region (i.e., 25 kt and 1002 hPa) than EMONG, the former was able to reach TS category outside the PAR. LANNIE was also the weakest TC to hit the Philippine landmass based on initial landfall intensity. Table 3.2 shows that in terms of peak intensity reached within the PAR, six peaked at TS or STS category, five reached TY or STY category within the PAR, while the rest remained as TD.

Table 3.1. Key basin-wide parameters of each TC that occurred within the PAR region in 2021.

Domestic Name	International Name	Basin-wide tropical lifespan* (UTC)	Basin-wide peak intensity: MWXD (kt)	Basin-wide peak intensity: PRES (hPa)	Basin-wide peak intensity: Date/s and time/s of occurrence* (UTC)
AURING	DUJUAN (2101)	02/16 18 to 02/22 00	45	994	02/19 00
BISING	SURIGAE (2102)	04/12 12 to 04/25 00	120	895	04/17 18
CRISING	Unnamed	05/12 00 to 05/14 00	35	1002	05/13 00
DANTE	CHOI-WAN (2103)	05/29 12 to 06/05 06	40	996	05/31 06, 06/03 00
EMONG	Unnamed	07/03 18 to 07/06 06	30	1002	07/04 06
FABIAN	IN-FA (2106)	07/15 18 to 07/29 18	80	955	07/21 00
GORIO	MIRINAE (2110)	08/03 18 to 08/10 00	50	980	08/07 18
HUANING	LUPIT (2109)	08/02 12 to 08/09 00	45	985	08/04 18, 08/08 18
ISANG	OMAIS (2112)	08/10 12 to 08/24 00	55	992	08/21 12
JOLINA	CONSON (2113)	09/05 06 to 09/13 00	65	985	09/06 12, 09/07 21
KIKO	CHANTHU (2114)	09/05 18 to 09/18 06	115	910	09/10 06
LANNIE	LIONROCK (2117)	10/03 12 to 10/10 18	35	992	10/08 00
MARING	KOMPASU (2118)	10/07 06 to 10/14 18	55	975	10/11 12
NANDO	Unnamed	10/07 12 to 10/09 12	30	996	10/09 06
ODETTE	RAI (2122)	12/12 00 to 12/21 06	105	915	12/16 00, 12/18 18

* Provided as MM/DD HH. MXWD: Maximum winds. PRES: Central pressure.
Note: OMAIS had a period when it was tracked as a tropical low from 08/15 12 UTC to 08/18 06 UTC.

Fig. 3.2 shows that the number of TCs that peaked at TD, TS/STS, and TY/STY within the PAR region was lower than the climatological average, although those reaching TS/STS remained within the range of near-normal values and those peaking at TD and TY/STY were below normal. However, in terms of its proportion to the total number of TCs of the year (Fig. 3.3), those that peaked at TD were close to the climatological average, while those that reached TS/STS and

[5] Lifespan is defined as the duration beginning with the synoptic time when the TC was first noted as TD and ending with the synoptic time when the TC either weakened into an area of low pressure or completed its post-tropical transition (without re-developing or re-transitioning into a TC at a later point).

TY/STY were higher and lower than average, respectively. Nevertheless, the proportions observed in 2021 for each intensity categories were all within the range of near-normal values.

Table 3.2. Period of occurrence and duration within the PAR, peak category within the PAR, and landfall occurrence of each TC that occurred within the PAR region in 2020.

Domestic Name	International Name	Period within the PAR		Peak category in PAR	Landfall
		Inclusive dates and times (UTC)	Duration		
AURING	DUJUAN (2101)	02/16 19 to 02/22 00	5d 5h	TS	Yes
BISING	SURIGAE (2102)	04/15 21 to 04/24 21	9d	STY	No
CRISING	Unnamed	05/12 00 to 05/14 00	2d	TS	Yes
DANTE	CHOI-WAN (2103)	05/29 15 to 06/05 01	6d 10h	TS	Yes
EMONG	Unnamed	07/03 18 to 07/06 01	2d 7h	TD	Yes
FABIAN	IN-FA (2106)	07/15 18 to 07/23 14	7d 20h	TY	No
GORIO	MIRINAE (2110)	08/03 18 to 08/04 06	12h	TD	No
HUANING	LUPIT (2109)	08/06 21 to 08/07 03	6h	TS	No
ISANG	OMAIS (2112)	08/19 01 to 08/22 06	3d 5h	STS	No
JOLINA	CONSON (2113)	09/05 06 to 09/09 13	4d 7h	TY	Yes
KIKO	CHANTHU (2114)	09/07 10 to 09/12 06	4d 20 h	STY	Yes
LANNIE	LIONROCK (2117)	10/03 12 to 10/05 21	2d 9h	TD	Yes
MARING	KOMPASU (2118)	10/07 06 to 10/12 04	4d 22h	STS	Yes
NANDO	Unnamed	10/08 11 to 10/09 12	1d 1h	TD	No
ODETTE	RAI (2122)	12/14 10 to 12/18 05	3d 19h	STY	Yes

Observed Trends within the PAR

Fig. 3.4 presents the yearly number of TCs occurring within the PAR and its corresponding 5-year running mean and linear trend, as well as the 5-year running mean and linear trend of the number of TCs peaking as TD, TS/ STS, and TY/STY within the PAR, and the number of landfalling and non-landfalling TCs in Philippines since 1991. The trend is based on the combined best track and warning track data from PAGASA.

Except for interannual variability in the number of TC cases within the PAR every year, there was no considerable increase or decrease in its long-term trend since 1991. In terms of landfalling TCs, a notably decreasing trend in the number of TCs that crossed the archipelago since 1991, although yearly values exhibited considerable interannual variability. The annual number of TCs peaking at TS/STS and TY/STY categories entering the PAR region was also found to be stable since 1991, with the slightly decreasing trend deemed to be not significant. On the other hand, the number of TCs that remained as a TD within the PAR has been on a slightly increasing trend since 1991. The increased reliability of on-site and remote sensing observation platforms being utilized by PAGASA forecasters had been a factor in identifying more TD cases in recent years, potentially resulting in the slightly increasing trend that was noted.

The observed trend in the annual number of TC occurrences within the PAR, the number of TCs peaking at TS/STS categories within the PAR, and the number of landfalling TCs in the Philippines remained consistent with those found by Cinco et al. (2016), although the same could not be said with the trends in terms of number of TCs peaking at TD and TY/STY categories. The investigation by Cinco et al. (2016), which used data from 1971 to 2013, noted a stable number of TD cases and considerably decreasing trend in TCs peaking at TY/STY within the PAR.

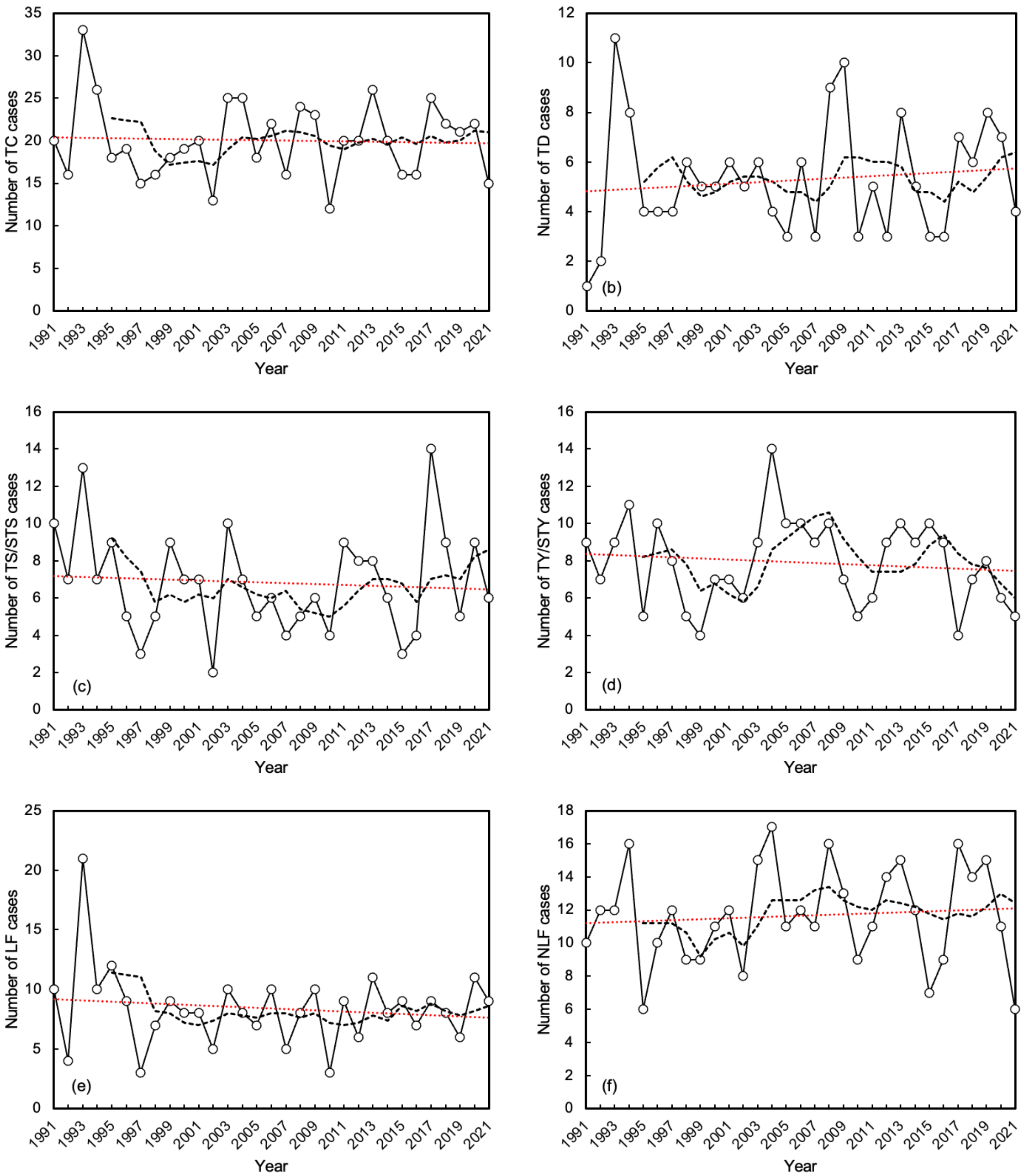

Fig. 3.4. Number of TCs that occurred in the PAR region per peak category within the PAR since 1991 – (a) all categories, (b) TD, (c) TS/STS, and (d) TY/STY; and TCs that (e) crossed (or made landfall; LF) and (f) did not cross the Philippines (including close approach cases; NLF) from 1991 to 2021. Dashed lines show five-year running mean and dotted red lines show linear trends.

Quarterly and Monthly Tropical Cyclone Activity

To make better sense of the progression of TC activity within the PAR region during the 2021 season, Figs. 3.5 presents the best track of TCs that occurred during January-March, April-June, July-September, and October-December 2021. In addition, the number of TC events per month within the PAR during the 2021 season and the corresponding monthly climatological averages are presented in Fig. 3.6. In both figures, the TCs were grouped in their corresponding quarter or month of occurrence based on the date and time (in UTC) it was first tracked within the PAR region. Furthermore, to make sense of the observed TC activity, quarterly mean global sea surface temperature (SST) and outgoing longwave radiation (OLR) maps are provided in Figs. 3.7 and 3.8, respectively based on gridded analyses from the Tokyo Climate Center, Climate Prediction Division of the Japan Meteorological Agency (JMA).

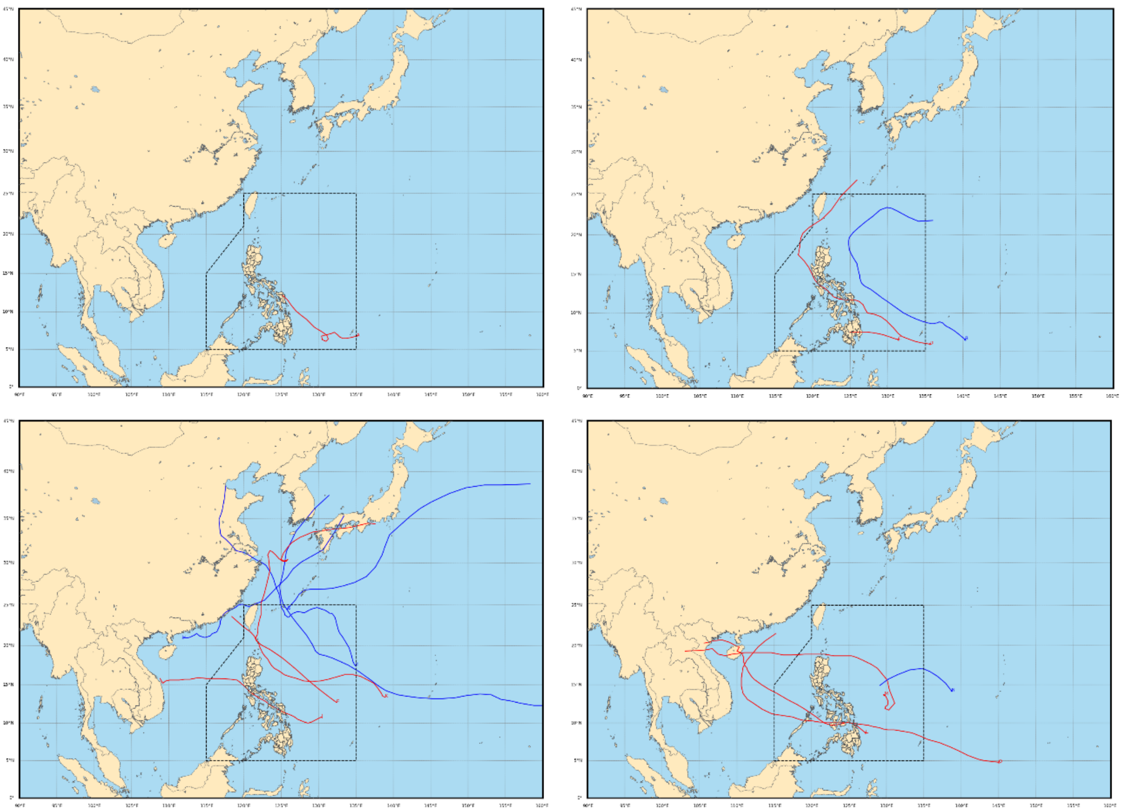

Fig 3.5. Best track of TCs that occurred within the PAR during (a) January to March, (b) April to June, (c) July to September, and (d) October to December 2021. Red tracks are TCs that made landfall over the Philippine archipelago. The region enclosed by the black dash line is the PAR region

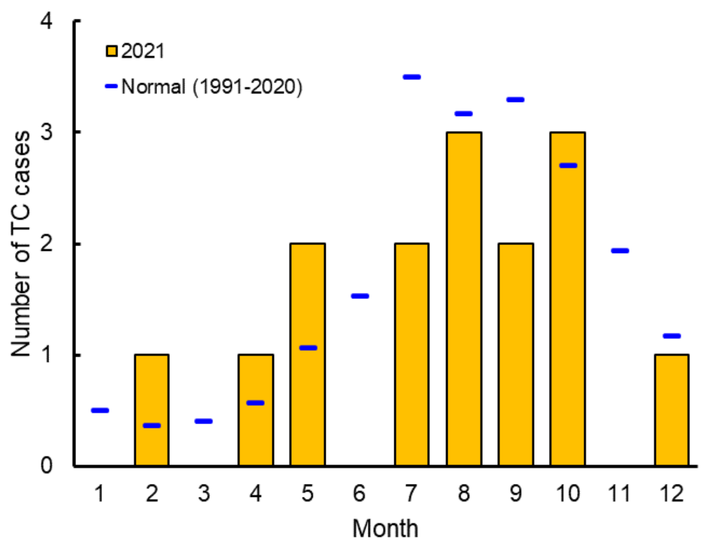

Fig. 3.6. Monthly number of TC occurrences within the PAR region for the 2021 season compared to the climatological normal (1991-2020).

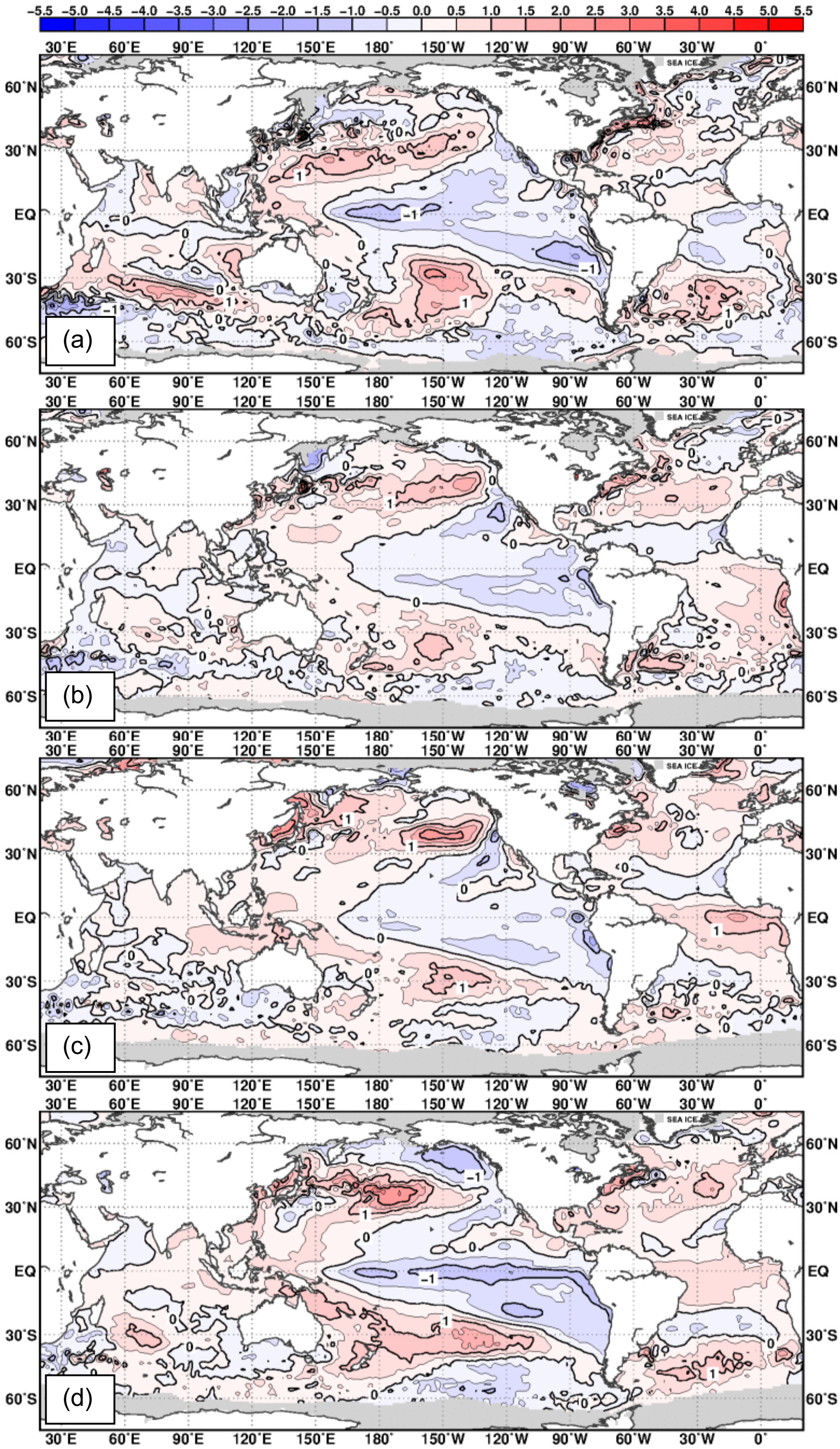

Fig. 3.7. Quarterly mean SST anomalies based on COBE-SST2 and MGDSST for the period of (a) January to March, (b) April to June, (c) July to September, and (d) October to December 2021. Contours and shading show SST anomalies at 0.5°C intervals. Gray shading indicates maximum sea ice coverage.

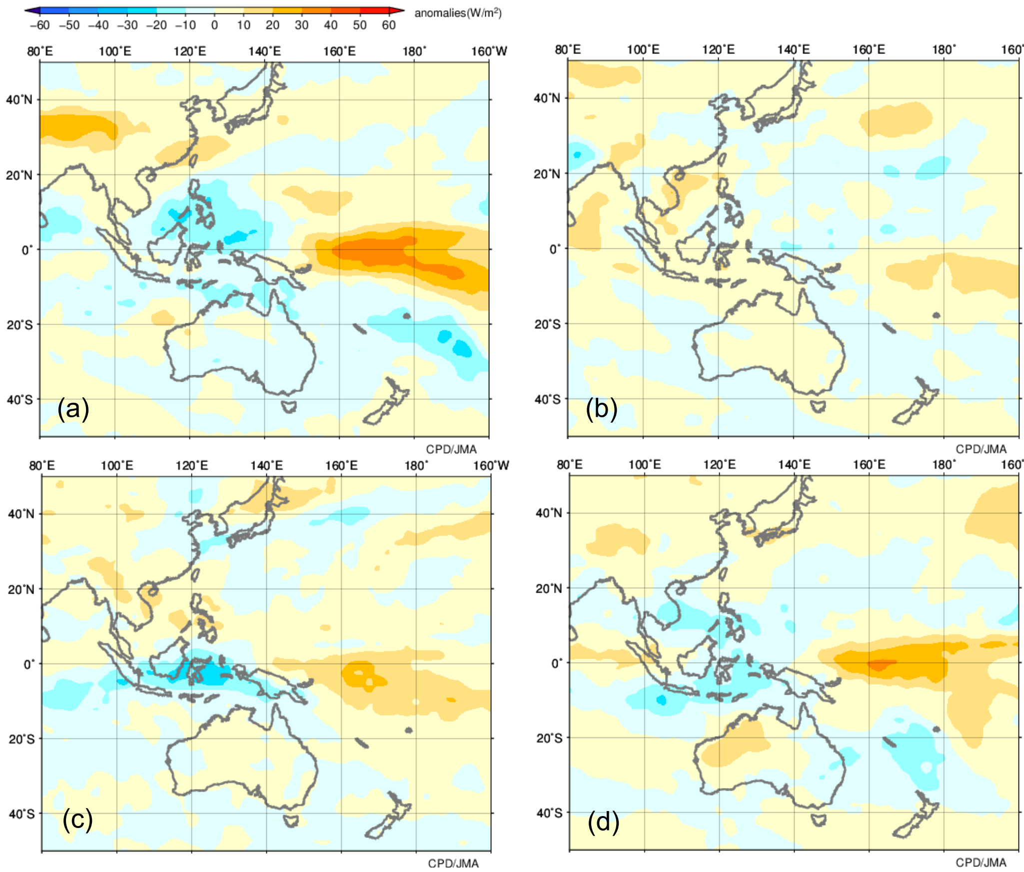

Fig. 3.8. Quarterly mean OLR anomalies based on COBE-SST2 and MGDSST for the period of (a) January to March, (b) April to June, (c) July to September, and (d) October to December 2021. Shading shows OLR anomalies at 10 W/m^2 intervals.

The first quarter (January to March) of the 2021 season saw a period of relative quiescence within the PAR region. The period was also characterized by the gradual weakening phase of a La Niña event which began in the boreal summer of 2020 (Fig. 3.7a) (JMA 2021). Tropical convection was enhanced over the Philippines and the Maritime Continent for the period (Fig. 3.7a). The first TC of the season and the only TC for the first quarter of the year, TS AURING, developed over the Philippine Sea and made landfall as a weak depression over Eastern Samar. While a TC activity for the month of February was an above average condition, the TC activity for the quarter was deemed near normal.

Under the influence of a weakening La Niña which eventually transitioned into ENSO-neutral conditions (albeit with below normal SST) (Fig. 3.7b) towards the beginning of the boreal summer (e.g., June), the second quarter (April to June) of 2021 was a near normal period for TC activity. During the period, the strongest TC to ever form before the active months of the WNP basin (e.g., May to December) occurred within the PAR region. STY BISING, which formed in April, remained over the Philippine Sea throughout its lifetime. Two other landfalling TCs, TS CRISING and TS DANTE, formed during the month of May, with the latter crossing the archipelago during the first few days of June.

The third quarter (July to September) is climatologically considered to be most active months of the year in terms of TC activity both within the PAR region and the WNP basin. In 2021, atmospheric and oceanographic conditions indicated ENSO-neutral conditions initially during this period (albeit with below normal sea surface temperatures (SST) in the Eastern Pacific) (Fig. 3.7c), which eventually developed into a La Niña towards the end of the quarter. The TC activity during the period was slightly below normal within the PAR region (i.e., seven TCs for 2021 against 8 to 12 on average) and was attributed to the negative phase of the Indian Ocean Dipole (IOD) (Fig. 3.7c) and a generally suppressed convective activity across the Asian summer monsoon region during the period (Fig. 3.8c) (JMA 2021). Of the seven TCs this quarter, more than half remained far from the Philippine landmass (TY FABIAN, STS GORIO, TS HUANING, STS ISANG). The landfalling events were TD EMONG (which passed over Batanes) in July and TY JOLINA (which crossed Eastern Visayas and Southern Luzon) and STY KIKO (which passed over Batanes) in September. During these quarter, two TCs (GORIO and HUANING), which occurred in a reverse-oriented monsoon trough configuration, followed atypical southwest-to-northeast tracks. Of the non-landfalling TCs during the period, TY FABIAN severely enhanced the Southwest Monsoon following the mechanism identified by Cayanan et al. (2011) and Bagtasa (2019).

The below-normal activity during the third quarter of 2021 was characterized by a below normal July and September activity and a nearly average August activity. It is possible that distribution of TC cases each month for the quarter was greatly influenced by the observed intra-seasonal variations in the North Pacific Subtropical High (NPSH) (Fig. 3.6). For instance, the westward expansion of NPSH was weaker the normal in July, and was stronger than normal in September. This synoptic pattern could also explain the generally landfalling nature of TC tracks observed in September 2021.

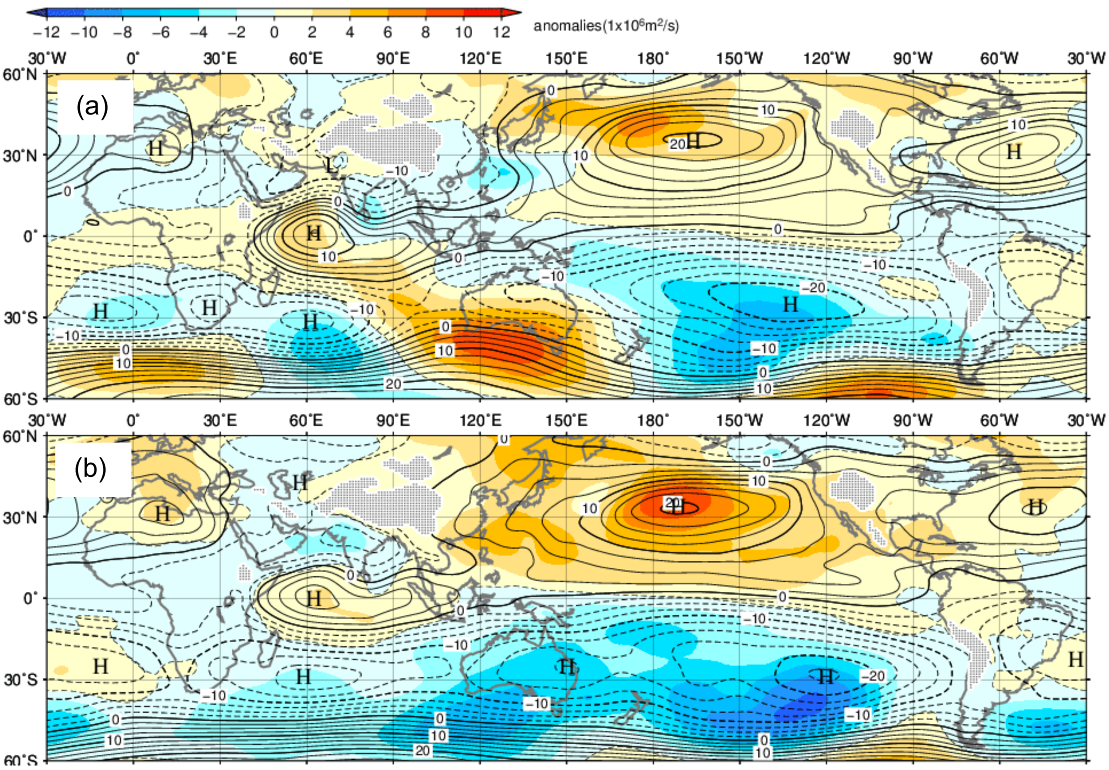

Fig. 3.9. Mean 850 hPa stream function and anomaly for (a) July and (b) September 2021. Contours show stream functions at 2.5 x 10^6 m^2/s intervals, while the shading shows stream function anomalies at 2 x 10^6 m^2/s intervals. Areas with hatch have altitudes exceeding 1,600 m. Figures courtesy of the Tokyo Climate Center, Climate Prediction Division of JMA.

The fourth quarter (October to December) of 2021 marked the full redevelopment of La Niña conditions in the tropical Eastern and Central Pacific (a condition which will persist until February 2023) (Fig. 3.7d). Despite the persistence of the negative IOD phase, enhanced tropical convection have been noted over the Philippine region due to La Niña (Fig 3.8d). During this quarter, four TCs occurred within the PAR region. Except for TD NANDO, which underwent a binary interaction with STS MARING and was eventually assimilated by it, all TCs during the fourth quarter of 2021 made landfall in the country. The strongest of them was STY ODETTE, which underwent rapid intensification prior to landfall and traversed the central portion of the Philippine archipelago. Consistent with climatology, the four TCs followed a generally west northwestward or westward path across the PAR region.

The TC activity during the quarter within the PAR was found to be below normal compared to the climatological average. Examination of monthly activity showed that while the TC activity during October and December was near normal, no TC occurred within the PAR for the month of November. Synoptic analysis at the lower atmosphere revealed the anomalous westward expansion of the NPSH during the said month towards the Philippine Sea (Fig. 3.10a), which suppressed tropical convection over the said region (Fig. 3.10b). Consistent with negative IOD, convection over much of the Maritime Continent remained enhanced.

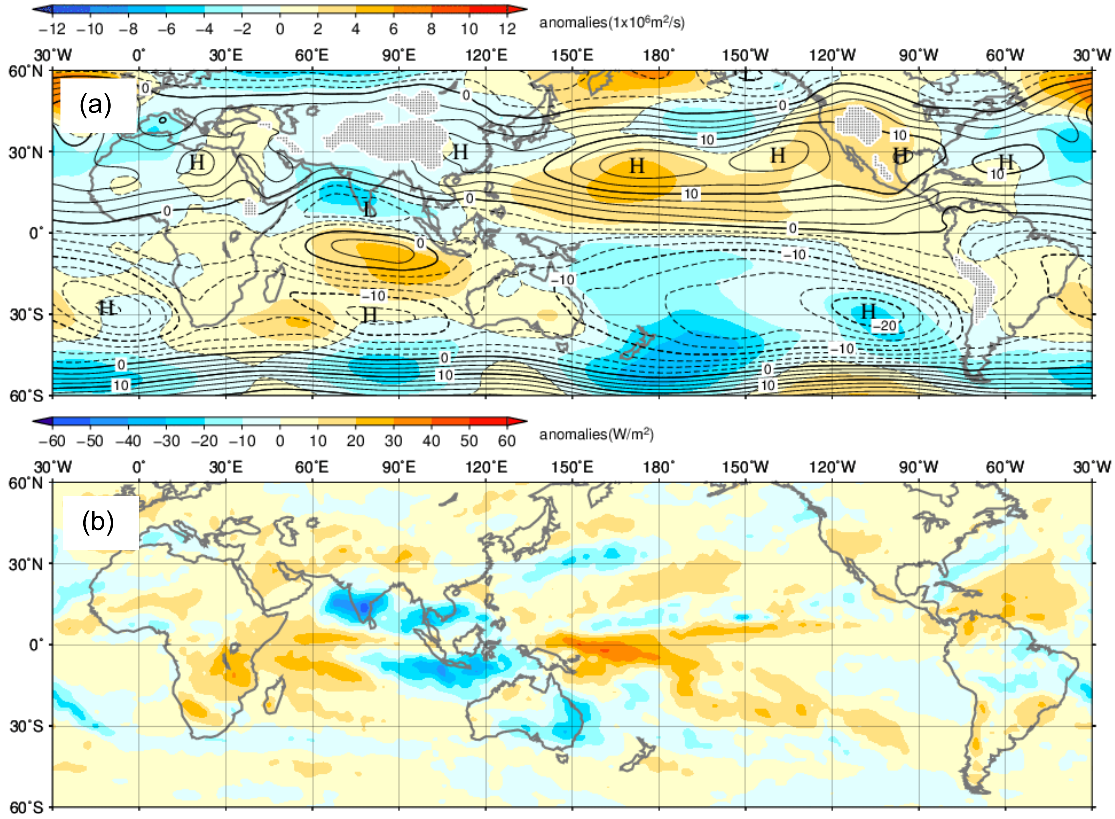

Fig. 3.10. (a) Mean 850 hPa stream function and anomaly and (b) mean OLR anomaly for November 2021. Contours show stream functions at 2.5 x 10^6 m^2/s intervals, while the shading shows stream function anomalies at 2 x 10^6 m^2/s intervals for (a) and at 10 W/m^2 intervals for (b). Areas in (a) with hatch have altitudes exceeding 1,600 m. Figures courtesy of the Tokyo Climate Center, Climate Prediction Division of JMA.

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[6] 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[7] as delineating metric.

Fig. 3.11a 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

[6] 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.
[7] TC days are meteorological days with at least one tropical cyclone within the PAR region irrespectively of its proximity to the Philippine archipelago

rainfall was notably higher (at least 1,000 mm) for most of Luzon (except mainland Palawan, most of Quezon, Camarines Provinces, and Masbate), Eastern Visayas, Panay Island, and Caraga Region. The remaining areas of Luzon and Visayas had rainfall amounts of at least 500-750 mm. For other areas of Mindanao, portions of Zamboanga Peninsula and Davao Region, and much of Bangsamoro and SOCCSKSARGEN received rainfall not exceeding 750 mm, while the other areas had values not exceeding 1,000 to 1,250 mm. The rainfall distribution presented a rainfall maximum region covering the western portions of Northern and Central Luzon, Catanduanes, portions of Mindoro, Surigao del Norte, and portions of Agusan del Norte and Surigao del Sur, with values generally exceeding 1,500 mm in most areas. Some areas in Benguet and La Union received total rainfall during TC days that reached in excess of 2,000 mm.

When compared against the total rainfall for 2021 (Fig. 3.11b), the total rainfall in Ilocos Region, Cordillera Administrative Region and most of Central Luzon, Metro Manila, CALABARZON, and MIMAROPA during TC days accounted for 40 to 70% of the total rainfall for the year. For the other areas of Luzon, total rainfall during TC days accounted for 20 to 50% of annual rainfall. For Visayas, the total rainfall during TC days in 2020 constituted 30% to 50% of the year-long rainfall in Western Visayas and 20 to 40% elsewhere. It was also observed that Palawan had similar observed proportions with those found in Panay Island, which could be attributed to its geographic location. In most areas of Mindanao, TC-related rainfall was 20% to 40% of the total rainfall for the year.

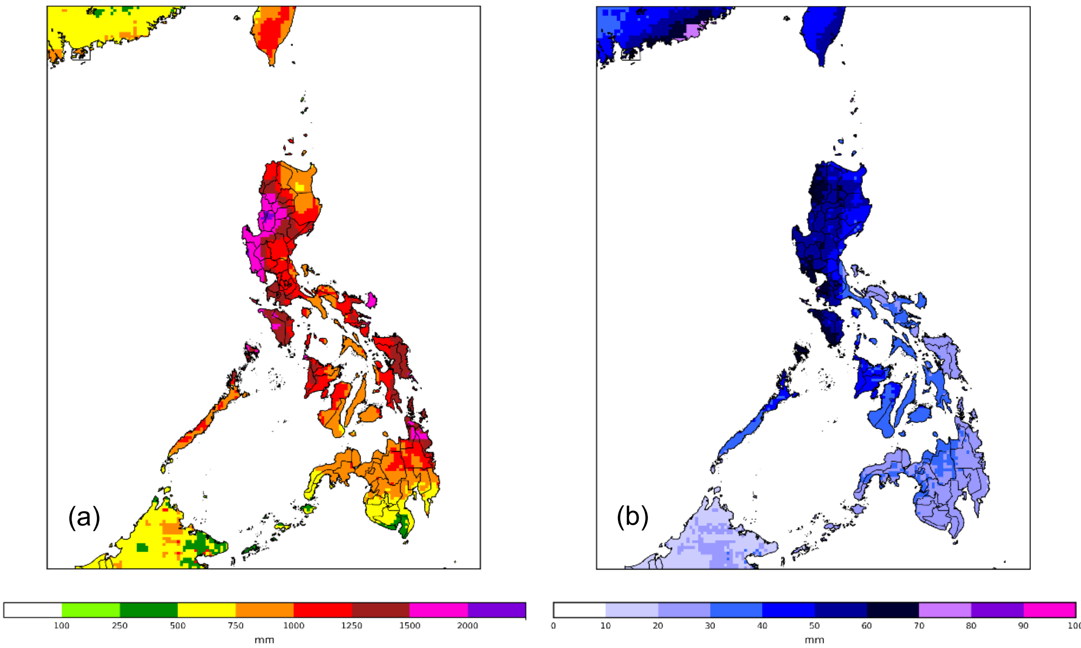

Fig. 3.6. GSMaP-Gauge nationwide estimates of (a) total rainfall (mm) during TC days and (b) its percentage contribution to the total rainfall in 2021.

To determine the extent of rainfall during TC days 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 2021 season was divided into four monsoon regimes. January to March were considered to be the mid and late phases of the Northeast Monsoon of 2020-2021 (NEM1) (although this regime was excluded in the report because no TC occurred during this period), while April and May were categorized as the inter-monsoon period or the trade winds regime (TWR). The 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 2021-2022 (NEM2).

The observed rainfall across the country during the TC days of NEM1 was associated with a single TC occurrence (TS AURING). Cumulative rains were at least 100 mm across most of Bicol, Eastern Visayas, and Caraga Region (reaching up to 300 mm in this region in particular), as well as some isolated areas in Negros Oriental. Other areas of the country received less than 100 mm during TC days of NEM1. TC-day rainfall during NEM1 accounted for up to 20% of the total NEM1 rainfall and the total TC-day rainfall for 2021.

Most of the higher rainfall accumulations during the TWR were situated over Bicol Region, Eastern Visayas, Caraga, and Davao Region, with values ranging from 100 to 500 mm. In the rest of mainland Mindanao, the total TC-day rainfall during TWR was up to 250 mm in most areas, with isolated areas in excess of 250 mm but not exceeding 500 mm. The rest of the country received up to 100 mm in most areas, with isolated areas not exceeding 250 mm. The rainfall during TC days of TWR accounted for the following proportions of the total TWR rainfall of the following areas:

- Between 30% and 100% of total TWR rainfall over most of Cagayan Valley.
- Between 30% and 80% for Eastern Visayas.
- Between 20% and 90% for most of Central Luzon and Bicol Region.
- Between 20% and 70% for CALABARZON, Western Visayas, and Central Visayas.
- Between 20% and 50% for Mindanao.
- Up to 50% for the rest of the country.

Due to the relatively shorter duration of the TWR compared with other monsoon regimes, despite the passage of three TC events during the period, TC-day rainfall during TWR accounted for 10 to 50% of total rainfall in 2020 in Mindanao (especially in the Davao Region), up to 30% over Bicol Region, and Eastern Visayas, up to 20% over mainland Palawan and the rest of Visayas, and up to 10% over the rest of the country.

The SWM period accounted for more than half of the 15 TCs of the 2021 season (i.e., 10 TCs). Estimates show that most of Luzon (particular the western half) and Western Visayas received total rainfall of at least 750 mm for the TC days of the SWM, while the rest of Visayas had between 250 and 1,000 mm. Mindanao, being the area not fully exposed to the SWM and to landfalling TCs during the said period, received between 100 and 750 mm of total TC-day rainfall during the SWM (except for Dinagat Islands and Surigao del Norte), whose total rainfall ranged from 500 to 1,000 mm). Rainfall distribution show three distinct maximum areas: the Ilocos Region-western Cordillera Administrative Region area, the western portion of Central Luzon (Tarlac, Pampanga, Zambales, Bataan), and the Occidental Mindoro-Calamian Islands area. The areas had total SWR TC-day rainfall of at least 1,000 mm, with maximum values in excess of 1,500 mm.

As a proportion of the total rainfall during the SWM regime, TC days during the SWM account for 50 to 80% of the SWM total rainfall over Northern Luzon, Central Luzon, and the western portion of Southern Luzon, and 40 to 70% over the Visayas, the rest of Luzon, and Dinagat Islands. The rest of country. For the rest of Mindanao, the rainfall during SWM TC days only constituted 20 to 50% of the total SWM rainfall in the area (the higher proportions of which were over the northern and western regions).

The rainfall during TC days of the SWM accounted for at least 30% of the total rainfall for the year. The share was 50 to 100% for Luzon, with the northern and western portions of the island group having higher proportions (at least 80%). The western half of Visayas also received TC-day rainfall during the SWM period that accounted for 50 to 100% (i.e., higher portions in Panay Island), while the eastern half had between 50 to 80%. For Mindanao, the TC-day rainfall accounted for 50% to 90% of total rainfall in 2021 over Zamboanga Peninsula, Bangsamoro, Northern Mindanao, and SOCCSKSARGEN regions, and between 30 and 60% over the remaining regions. These show that much of the total rainfall observed in 2021, especially over the western portion of the country, were generated, directly (during the landfall or close approach) or indirectly (through monsoon enhancement or interaction with other synoptic weather systems) during the TC days of the SWM. However, such large proportions could be attributed to the larger number of TC cases during the period of SWM, as well as the generally longer period of SWM (five months) compared to NEM1 (three months), TWR (two months), and NEM2 (two months).

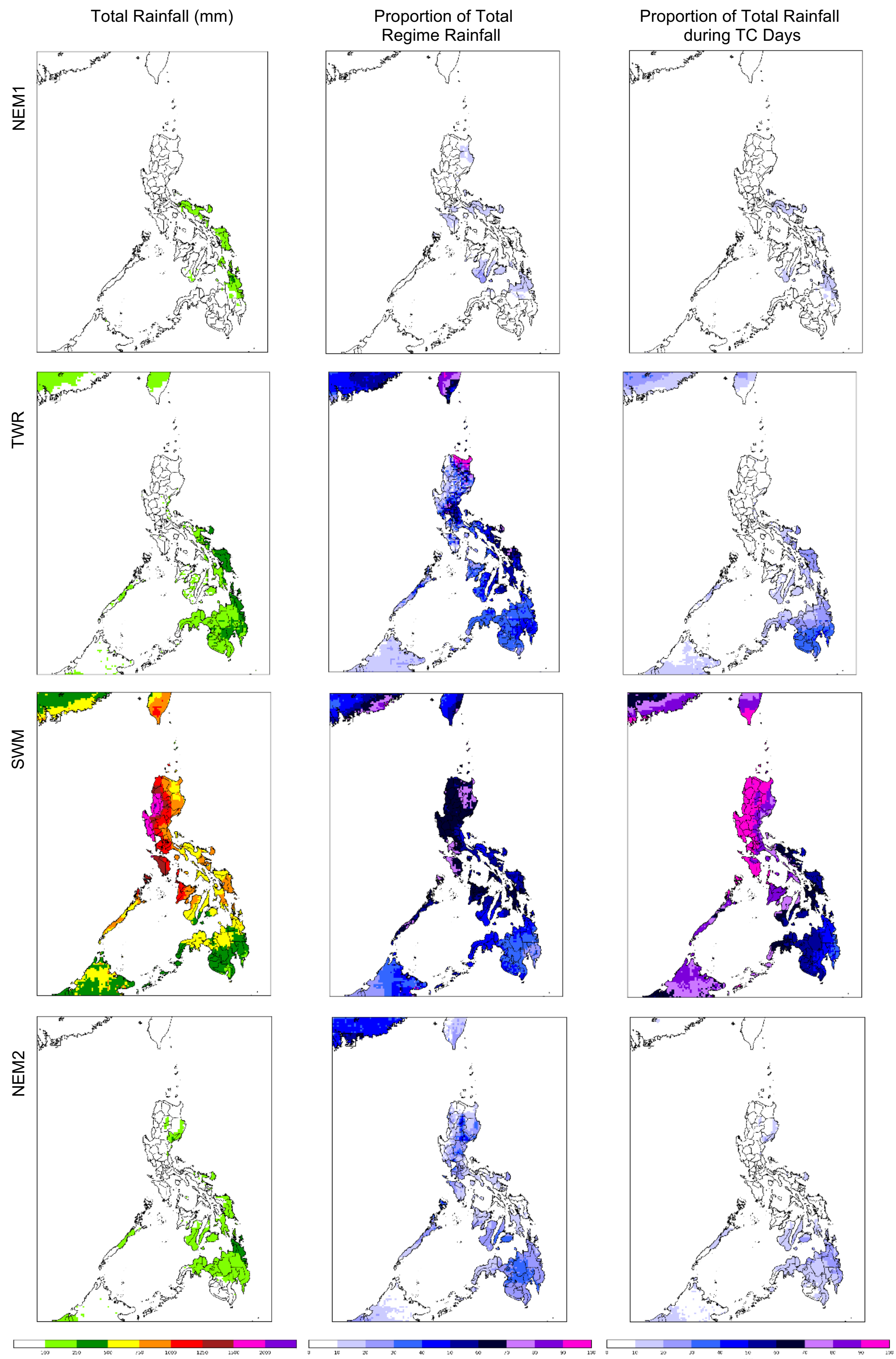

Fig 3.12. GSMaP-Gauge nationwide estimates of the total rainfall (mm) during TC days of NEM1, TWR, SWM, and NEM2 and its corresponding percentage contribution to the total rainfall observed during each monsoon regime and the total TC-day rainfall in 2021.

Only one TC, STY ODETTE, occurred within the PAR occurred during the NEM2 period. Comparing the rainfall distribution map against those from SWM shows a shift in the maximum rainfall region from the western section of Luzon to the eastern section of Mindanao – consistent with the change in the general synoptic patterns associated with the transition from SWM to NEM2. While similarity exists between the distribution of total TC-day rainfall of NEM2 and NEM1 (given their similar long-term synoptic characteristics), the location of the maximum rainfall region was heavily dictated by the TCs that occurred during these periods, especially since NEM2 and NEM1 only had one TC case each.

Owing to the nature of ODETTE's path and the prevailing monsoon regime, the NEM2 TC-day rainfall was at least 100 mm over the eastern and southern portions of Visayas, the northern and eastern portions of Mindanao, and portions of Palawan, as well as in isolated portions of Bicol Region, Aurora, and Quezon. The rainfall maximum was in Caraga region, with accumulated TC-day rainfall not exceeding 500 mm.

The rainfall during TC days for NEM2 constituted up to 60% of the total NEM2 rainfall over upland Northern Luzon (despite having generally lower accumulated rainfall), up to 40% over Mindanao, Central Visayas, and portions of Central Luzon and Palawan, and up to 30% in other areas of the country. In terms of its share of the total rainfall of 2021, the total TC-day rainfall during NEM2 rainfall accounted for 10 to 30% in Caraga, Davao, and Central Visayas regions and not exceeding 20% in other areas of the country.

Extremes of Surface Meteorological Observations during Tropical Cyclone Days

Tables 3.3 and 3.4 present the extremes of rainfall, gust wind, and mean sea level pressure observations recorded by the network of manned surface weather stations (i.e., both synoptic and agrometeorological research stations) of PAGASA during the passage of landfalling (including close-approaching) and non-landfalling tropical cyclones. Compared to real-time reports, these data have undergone post-real time quality control from the Meteorological Guides and Standards Section, Engineering and Technical Services Division and the Climatology and Agrometeorology Data Section, Climatology and Agrometeorology Division. The data was retrieved through the PAGASA Unified Meteorological Information System.

Table 3.3. Extremes of land-based rainfall observations in the Philippines during TC days in 2021.

Parameter	Location	Value (mm)	Active TC and date / time of occurrence
Highest storm duration rainfall (landfalling or close-approaching TCs)	Itbayat, Batanes	688.2	STY KIKO 07 to 12 September
Highest storm duration rainfall (other TCs)	Mt. Cabuyao, Tuba, Benguet	984.4	TY FABIAN 15 to 23 July
Highest 24-hour accumulated rainfall (landfalling or close-approaching TCs)	Baguio City	625.3	STS MARING 11 October
Highest 24-hour accumulated rainfall (other TCs)	Catarman, Northern Samar	265.5	STY BISING 18 April

Rainfall observations show that the four of the five highest storm duration rainfall observed nationwide were caused by TC interacting with another synoptic-scale weather system which directly affected the country at the time of the passage (e.g., enhanced Southwest Monsoon). However, in terms of the peak 24-hour accumulated rainfall, all of the five highest reported nationwide were brought by the direct influence of the TC itself. In terms of mean sea level pressure and gust wind extremes, the lowest and highest reported values, respectively, were from Basco, Batanes during the passage of STY KIKO (which directly hit the weather station).

Table 3.4. Extremes of land-based gust wind and mean sea level pressure observations in the Philippines during TC days for TCs whose passage resulted in the hoisting of wind signals.

Parameter	Location	Value	Active TC and date / time of occurrence
Lowest mean sea level pressure	Basco, Batanes	927.9 hPa	STY KIKO 0000 UTC, 11 September 2021
Highest 3-s peak gust	Basco, Batanes	86 m/s (309.6 km/h, 167.2 kt)	STY KIKO 2350 UTC 10 September 2021

Tropical Cyclone Impacts: Casualties and Damage

Year-on-year statistics of dead, injured, and missing persons due to TC occurrences within the PAR region are presented in Fig. 3.13. Based on official report provided to PAGASA by the National Disaster Risk Reduction and Management Council (NDRRMC), the 2021 TC season in the Philippines resulted in 2,024 casualties – 484 dead, 1,462 injured, and 78 missing individuals. This made the 2021 season both the 18th deadliest TC season since 1970 and the deadliest season following the onslaught of STY YOLANDA in 2013. Moreover, 2020 was also the 16th worst season since 1970 and 2nd worst since 2013 in terms of the total casualty count. At 23.9%, the proportion of deaths to casualties during the 2021 season was the 43rd highest since 1970 and 4th highest since 2013. Since 1970, TC events have claimed the lives of at least 34,919 people and caused injuries to at least 76,496 individuals. While there is an interannual variability to the casualty statistics, no notable trends were observed in terms of casualty count and death toll since 1970. However, a generally increasing trend in number of deaths and injuries have been noted since 2015, with the trend more pronounced in the latter. The number of missing individuals, on the other hand, has been on a slightly downward trend since 2015.

The combined nationwide cost of damage to agriculture and infrastructure due to TCs of 2021 (Fig. 3.14) amounted to PHP 61.323 billion. Damage to infrastructure accounted for the majority (54.9%) of the total cost. When adjusted for inflation using the published consumer price index (CPI) of the Philippine Statistics Authority, the 2021 season was the 6th costliest TC season since 1970 and the 2nd costliest season post-STY YOLANDA. While year-on-year fluctuations exist in the reported damage cost, the aggregated annual cost of damage due to TC events has been steadily increasing since 1970.

Data from the NDRRMC (Table 3.5) also shows that the casualties and aggregated cost of damage reported for the 2020 season were attributed to TS AURING, STY BISING, TS CRISING, TS DANTE, TY JOLINA, STY KIKO, TS LANNIE, STS MARING, AND STY ODETTE. With 405 deaths, STY ODETTE was the deadliest TC to occur in 2021. It also had the highest number of reported casualties (1,828 individuals). The reported dead, injured, and missing individuals due to ODETTE accounted for 83.7, 93.8, and 90.3% of the total number of dead, injured, and missing individuals for the entire 2021 season. Only this TC met the decommissioning criteria of PAGASA in terms of death toll[8].

In terms of damage cost, three TCs (JOLINA, MARING, and ODETTE) resulted in damage to agriculture and infrastructure with amounts exceeding the criteria[9] for the decommissioning of domestic names. Of these, TY Ulysses was the costliest TC of the 2020 season. Traversing the northeastern portion of Mindanao, much of Visayas (including Metro Cebu), and the central portion of Palawan, this STY resulted in damage to properties amounting to PHP 51.706 billion – roughly 84.3% of the total cost of damage caused by TC events in 2021.

[8] Deaths of at least 300 individuals as reported by the NDRRMC.
[9] Damage of at least PHP 1 billion as reported by the NDRRMC.

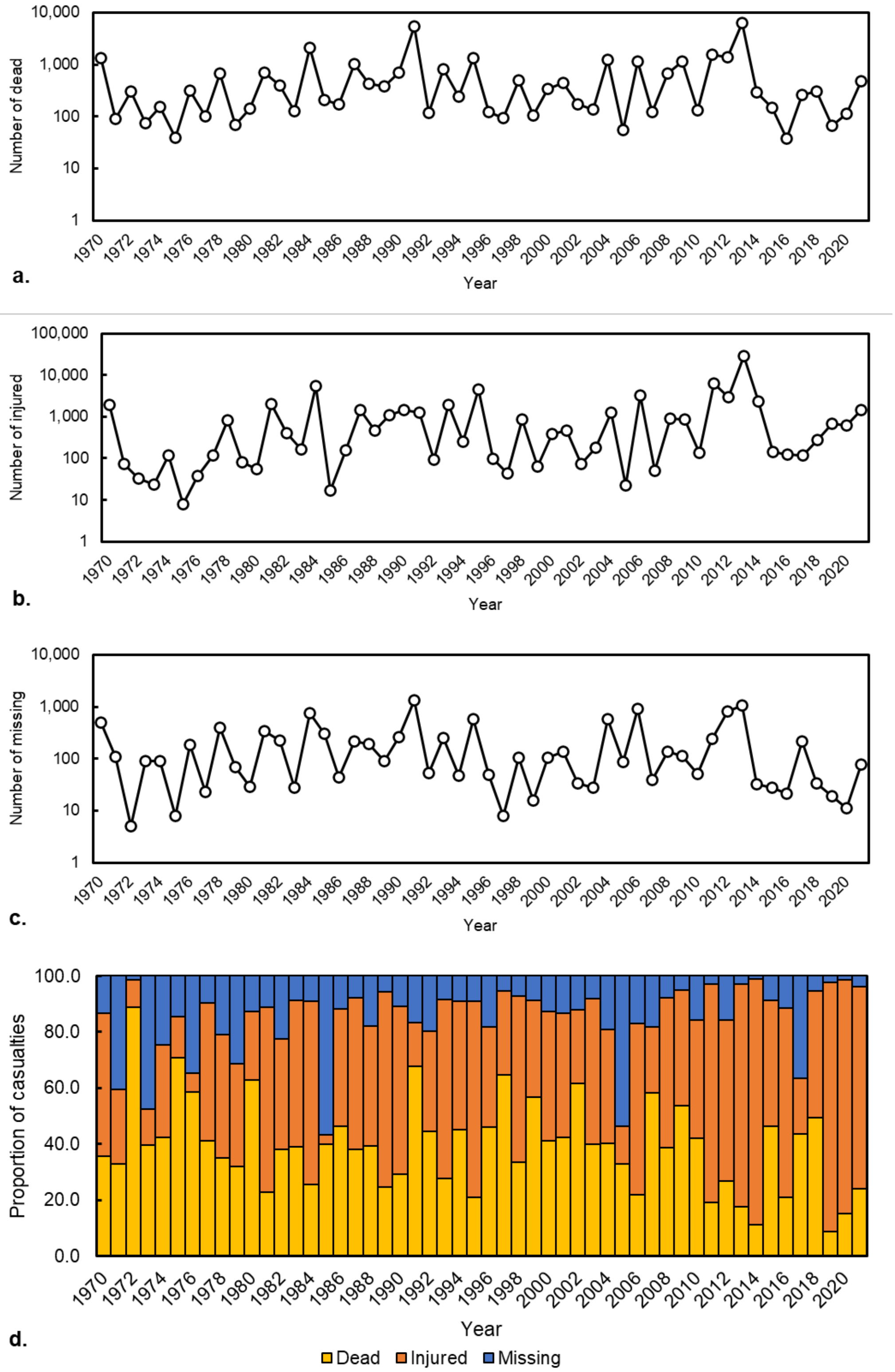

Fig. 3.13. Statistics of (a) dead, (b) injured, and (c) missing persons caused by tropical cyclones in the PAR region from 1970 to 2021. Actual number of persons are presented in (a) to (c), while (d) shows these numbers as a percentage of the total casualties. The y-axis in (a) to (c) uses a logarithmic (base 10) scale.

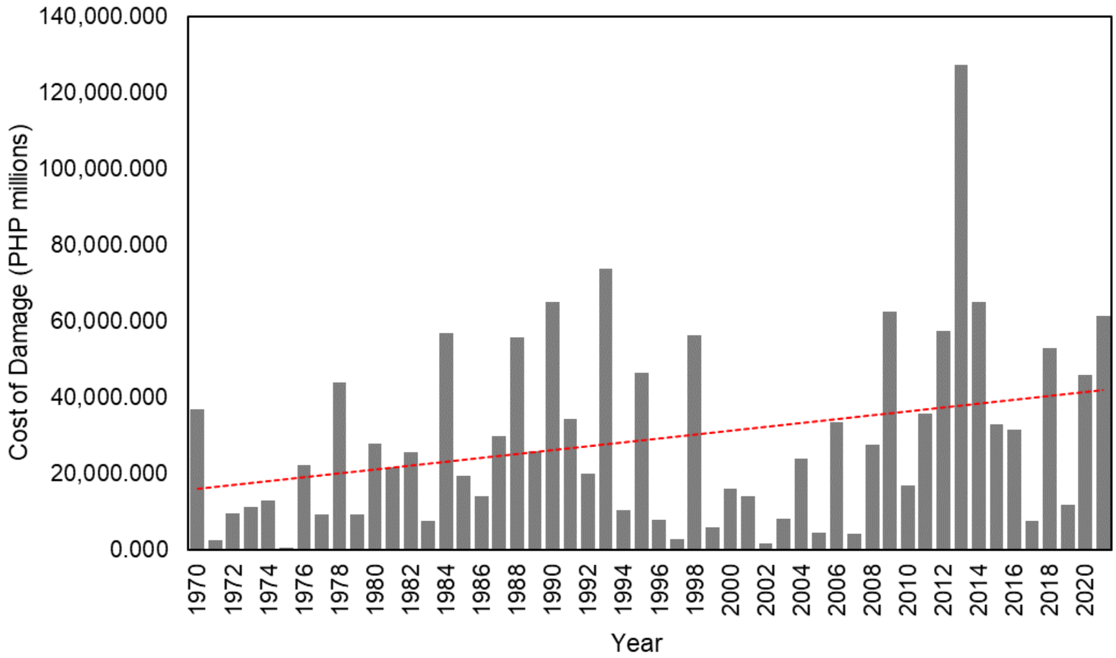

Fig. 3.14. Yearly total cost of damage (in PHP millions) caused by tropical cyclones in the PAR region from 1970 to 2021. The cost values are adjusted to 2021-equivalent values to account for inflation using the annual average CPIs (2018=100) published by the Philippine Statistics Authority. The red dash line presents the linear trend of the adjusted cost of damage.

Table 3.5. Casualty and cost of damage statistics caused by TCs that occurred within the PAR region in 2021. Note that other TCs were not included due to the absence of reported information from the NDRRMC.

Name of TC	Casualties				Cost of damage (PHP millions)		
	Dead	Injured	Missing	Total	Agriculture	Infrastructure	Total
AURING	1	2	4	7	106.778	53.052	159.830
BISING	9	20	0	29	261.911	10.870	272.781
CRISING	0	4	2	6	23.164	-	23.164
DANTE	3	0	0	3	152.110	157.638	309.748
JOLINA	20	33	4	57	1,349.221	63.676	1,412.897
KIKO	0	27	0	27	37.355	-	37.355
LANNIE	3	0	0	3	12.225	-	12.225
MARING	43	5	16	64	3,321.719	4,066.475	7,388.194
ODETTE	405	1,371	52	1,828	22,368.179	29,338.185	51,706.364
TOTAL	**484**	**1,462**	**78**	**2,024**	**27,632.661**	**33,689.897**	**61,322.558**

Following the termination of the 2021 season, on 27 January 2022, the names JOLINA, MARING, and ODETTE were decommissioned from Set I of the official list domestic names and were subsequently replaced by JACINTO, MIRASOL, AND OPONG, respectively. These replacements will be first introduced during the 2025 TC season. Furthermore, in its 55th Session on 07 to 09 March 2023, the Typhoon Committee noted the request of PAGASA to retire the equivalent international names of JOLINA (CONSON), MARING (KOMPASU), and ODETTE (RAI). These names were eventually replaced by LUC-BINH (for CONSON), TOKEI (for KOMPASU), and SARBUL (for RAI) during the 56th Session of the Typhoon Committee on 27 February to 01 March 2024

Provision of Tropical Cyclone Products and Wind Signals

As the national meteorological and hydrological service of the Philippines, PAGASA issued 317 public TC products throughout the 2021 TC season. These included 19 Tropical Cyclone Advisories (TCA), 68 Severe Weather Bulletins (SWB) and 230 Tropical Cyclone Bulletins (TCB). To ensure the safety of all vessels and aircraft enroute or at ports or aerodromes, a total of 242 Tropical Cyclone Warnings for Shipping (IWS) and 97 Significant Meteorological Information (SIGMET) were issued by PAGASA to the maritime and civil aviation sectors, respectively. Due to its length of occurrence within the PAR, STY BISING warranted the issuance of 38 public TC products, 37 IWS and 21 SIGMET – the highest of any TC in 2021. Table 3.5 presents the summary of issued TC products during the 2021 season.

Table 3.6 also shows that 11 of the 15 TCs in 2021 triggered the hoisting of Tropical Cyclone Wind Signals in the country due to the threat of strong to typhoon-force winds. During the season, wind signals were hoisted by PAGASA in all provinces or portions thereof except for most of Bangsamoro and SOCCSKARGEN regions, and the southern half of Davao Region and Zamboanga Peninsula. Due to the nature of its track, the passage of TS DANTE resulted in the hoisting of wind signals in 59 provinces (or portions thereof) – more than any TC during the season. Fig. 3.15a presents the map showing the frequency of hoisting wind signals during the 2021 season across the different localities of the country. Due to the nature of the observed TC events during the season, wind signals were most frequently hoisted over Caraga Region, Eastern Visayas, Extreme Northern Luzon, and most of Central and Western Visayas. These areas had wind signal levels of at least 1 hoisted at least four times during the 2021 season.

Fig. 3.15b shows the highest level of wind signal that was hoisted in each provincial or sub-provincial locality in the country during the 2021 season. Owing to the passage of STY KIKO and STY ODETTE, Wind Signal No. 4 was the highest level of wind warning hoisted over any portion of the country during the year. The figure shows an east-to-west oriented band of Wind Signal Nos. 3 to 4 over Visayas, Caraga Region, and Palawan due to STY ODETTE and over northeastern mainland Cagayan and Extreme Northern Luzon due to STY KIKO. Furthermore, the passage of TY JOLINA also resulted in a band of Wind Signal No. 3 across the central portion of Eastern Visayas, which extends northwestward towards Bicol Region and the Bondoc Peninsula of southeastern Quezon.

Table 3.6. Summary of TC products and hoisting of wind signals for each TC in 2021.

Name of TC	No. of TC products issued					No. of provinces under wind signal	Highest wind signal level hoisted
	TCA	TCB	Public products	IWS	SIGMET		
AURING	1	24	25	22	8	36	Wind Signal No. 2
BISING	5	33	38	37	21	27	Wind Signal No. 2
CRISING	0	11	11	6	2	20	Wind Signal No. 2
DANTE	1	35	36	26	16	59	Wind Signal No. 2
EMONG	0	13	13	9	0	2	Wind Signal No. 1
FABIAN	0	31	31	31	0	2	Wind Signal No. 1
GORIO	0	2	2	2	0	0	-
HUANING	0	2	2	2	0	0	-
ISANG	1	14	15	14	2	0	-
JOLINA	0	26	26	16	14	42	Wind Signal No. 3
KIKO	4	29	33	20	12	9	Wind Signal No. 4
LANNIE	0	15	15	10	0	25	Wind Signal No. 1
MARING	0	29	29	23	10	29	Wind Signal No. 2
NANDO	1	5	6	5	0	0	-
ODETTE	6	29	35	19	12	46	Wind Signal No. 4

* TCB superseded SWB beginning with TS DANTE.

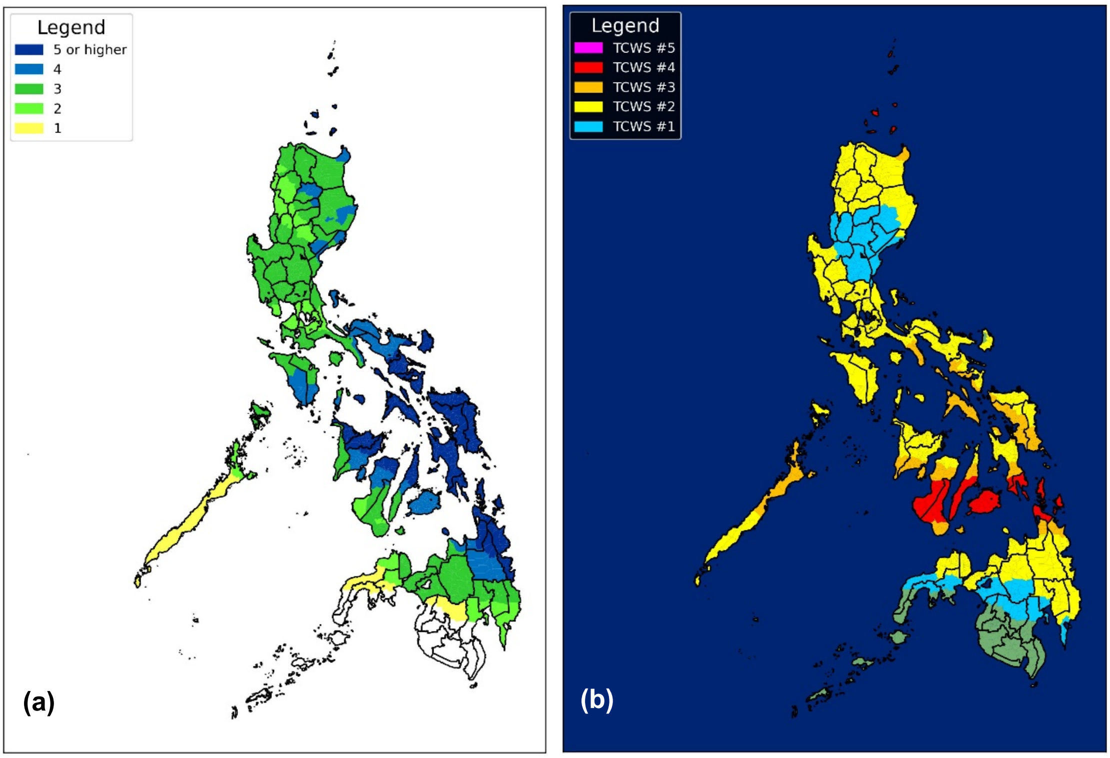

Fig. 3.15. (a) Frequency of hoisting TCWS per province or sub-provincial locality during the 2020 season and (b) the highest level of TCWS hoisted per locality.

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REVIEW OF THE PHILIPPINE TROPICAL CYCLONES OF 2021

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Review of the Philippine Tropical Cyclones of 2021

This section of the report contains the individual reviews of each Western North Pacific (WNP) tropical cyclone (TC) that occurred within the Philippine Area of Responsibility (PAR) during the 2021 season based on the result of post-season best track analysis of the Marine Meteorological Services Section, Weather Division. Each individual TC review includes the following information:

- A map showing the best track positions and intensities (as categories).
- A summary of the meteorological history of the TC presented in a tabular format.
- The top station-observed extremes of the following surface weather observation over land during the occurrence of the TC within the PAR, including the corresponding dates and times of observation:
  - Highest storm duration[1] rainfall (in mm)
  - Highest 24-hour rainfall (in mm)
  - Highest peak 3-second gust speed (in m/s)[2] and direction (as cardinal direction and bearing)
  - Lowest sea level pressure (in hPa)

  The last two parameters are only provided for TCs whose passage within the PAR region resulted in the hoisting of TC wind signals.
- A summary of TC products provided by the Weather Division during the occurrence of the TC within the PAR region and Manila FIR, the number of provinces[3] where TC wind signals were hoisted and the highest wind signal hoisted during the occurrence of the TC.
- A summary of casualties and damage statistics 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 distribution of storm-duration rainfall over the land areas within the PAR region based on gauge-corrected satellite retrievals of the Global Satellite Mapping of Precipitation Project (GSMAP; Kubota et al. 2020) and reports from the PAGASA surface weather observation network. It must be noted that satellite retrievals may or may not be coherent with ground observations.

Relevant weather radar images, if available, and other figures pertinent to the best track analysis of each TC event are also included

[1] Storm duration refers to the storm duration refers to the meteorological days the TC was inside the PAR region.
[2] Despite the use of kt as primary unit of wind speed in all TC-related information, m/s is used as standard unit for 10-m wind observations from PAGASA manned weather stations.
[3] For this purpose, a province is counted even if not all its municipalities or cities were placed under a wind signal. Furthermore, Metro Manila is counted as one (1) province, while other highly urbanized and independent component cities are counted under the province to which they are commonly geographically grouped.

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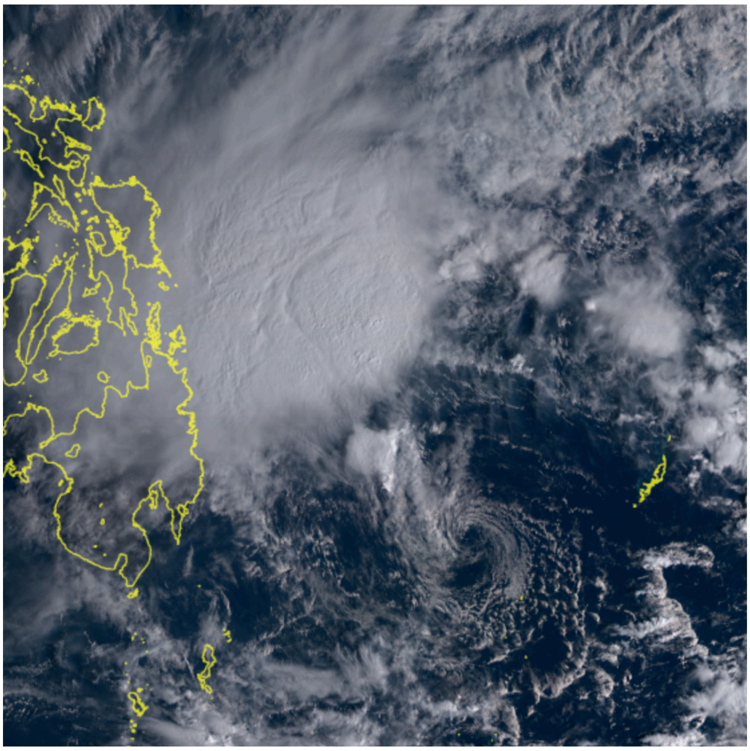
Tropical Storm AURING
DUJUAN (2101)

16 to 22 February 2021



Basin-wide peak intensity:
Tropical Storm
45 kt (85 km/h)
994 hPa

Developed:
18 UTC, 16 February 2021

Degenerated:
00 UTC, 22 February 2021

Duration within the PAR:
5 days and 5 hours

Peak category within the PAR:
Tropical Storm

Highest wind signal hoisted:
Wind Signal No. 2

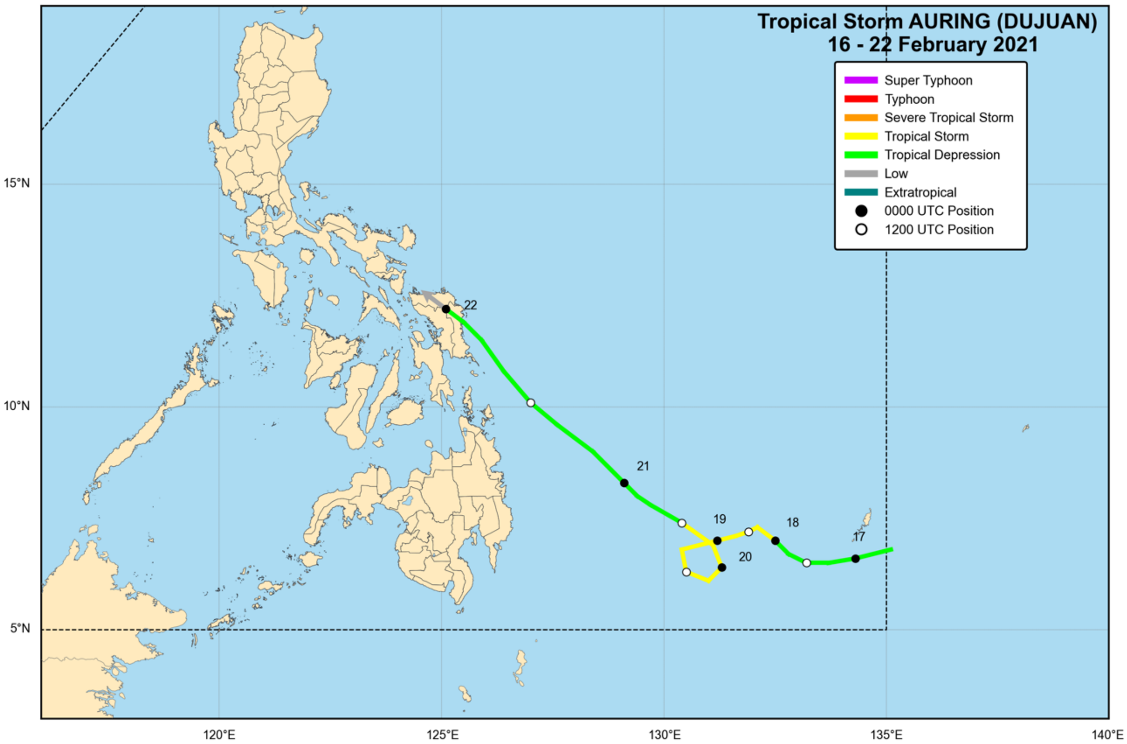


Fig. 4.1.1. Best track position and intensities of Tropical Storm AURING.

Summary of Meteorological History

Table 4.1.1. Key information about Tropical Storm AURING

Parameter	Details
First tracked as a tropical low pressure area	12 UTC, 13 February 2021 Over the sea southeast of Palau
Developed into a TC	18 UTC, 16 February 2021 Over the Philippine Sea near Palau
Weakened into a remnant low	00 UTC, 22 February 2021 In the vicinity of Matuguinao, Samar
Period of occurrence (lifetime)	5 days and 6 hours
Entered the PAR region	19 UTC, 16 February 2021
Exited the PAR region	Not applicable
Period of occurrence (within the PAR)	5 days and 5 hours
Peak intensity (lifetime)	Tropical Storm: 45 kt (85 km/h), 994 hPa 00 UTC, 19 February 2021
Peak intensity (within the PAR region)	Tropical Storm: 45 kt (85 km/h), 994 hPa 00 UTC, 19 February 2021
Observed landfalls	**Philippines:** 2130 UTC, 21 February 2021 (TD): Can-avid, Eastern Samar **Elsewhere:** None

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.1.2. Highest storm duration (17 to 21 February 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Pili, Camarines Sur	217.6
Borongan City, Eastern Samar	152.4
Hinatuan, Surigao del Sur	148.2
Surigao City, Surigao del Norte	133.8
Dumaguete City, Negros Oriental	131.9

Table 4.1.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Pili, Camarines Sur	102.6	20 February 2021
Juban, Sorsogon	91.0	21 February 2021
Dumaguete City, Negros Oriental	71.7	17 February 2021
Surigao City, Surigao del Norte	70.3	21 February 2021
Maasin City, Southern Leyte	66.2	21 February 2021

Table 4.1.4. Lowest mean sea level pressure over land.

Location of weather station	Minimum MSLP (hPa)	Date (MM/DD) and Time (UTC)
Juban, Sorsogon	1005.2	02/21 1800
Borongan City, Eastern Samar	1005.4	02/21 0600
Hinatuan, Surigao del Sur	1005.6	02/20 2100
Surigao City, Surigao del Norte	1006.2	02/20 2100
Tacloban City, Leyte	1006.7	02/21 0700

Table 4.1.5. Highest peak gust over land.

Location of weather station	Peak gust speed (m/s)	Peak gust direction	Date and Time (UTC)
Guiuan, Eastern Samar	20	NNE (030) NNE (020)	02/17 1450 02/19 0000
Surigao City, Surigao del Norte	16	NNE (030)	02/19 0312
Legazpi City, Albay	15	NE (040)	02/19 0106
Butuan City, Agusan del Norte	14	N (350)	02/19 1233
Borongan City, Eastern Samar	12	N (360)	02/19 0520
Maasin City, Southern Leyte	12	NE (040)	02/19 0523
Tacloban City, Leyte	12	NNE (020)	02/19 0412

Summary of Warning Information

Number of TC products issued

- Severe Weather Bulletins: **24**
- Tropical Cyclone Advisories: **1**
- Tropical Cyclone Warning for Shipping: **22**
- WC SIGMET: **8**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **Wind Signal No. 2**
- No. of provinces with hoisted wind signal: **36**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **1 dead, 2 injured, and 4 missing**
Total cost of damage: **PHP 159,830,171.02**

- Damage to agriculture: **PHP 106,777,735.00**
- Damage to infrastructure: **PHP 53,052,436.02**

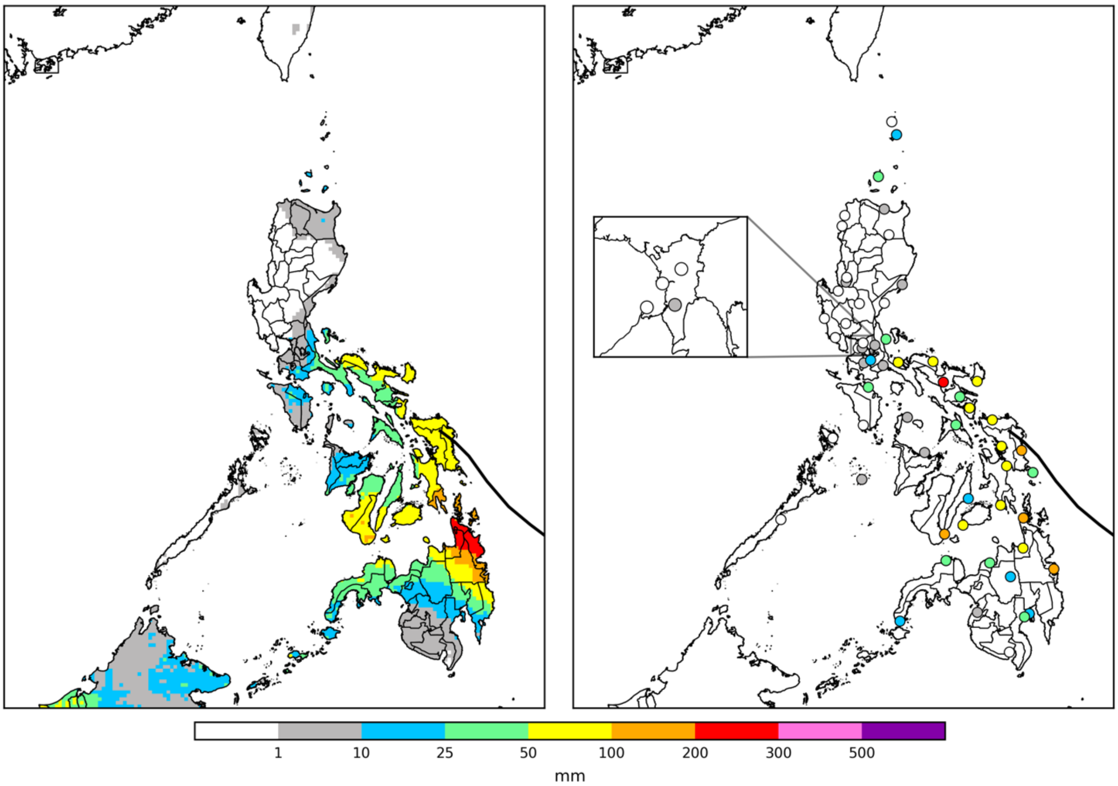


Fig. 4.1.2. Storm duration rainfall over land during the passage of Tropical Storm AURING within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line.

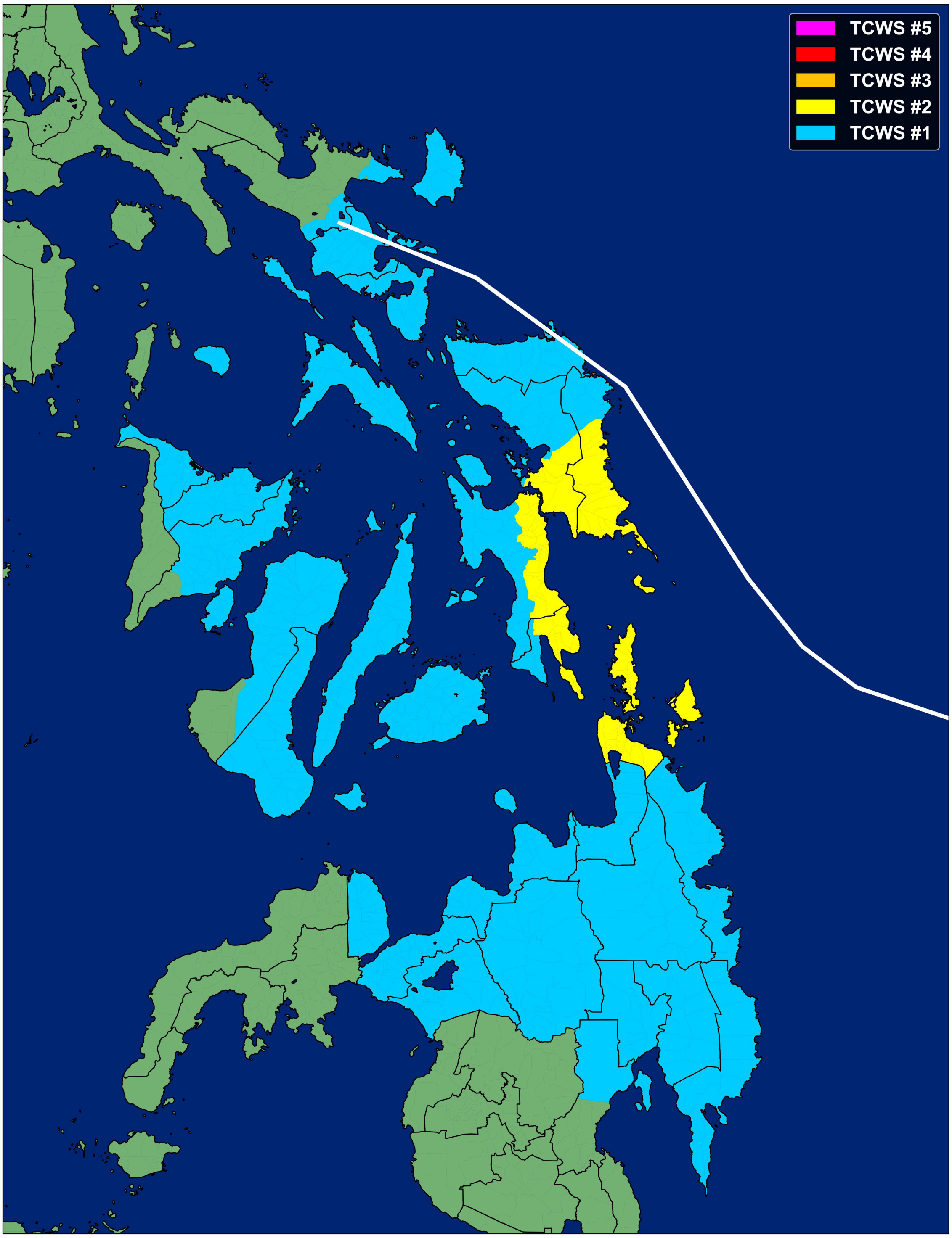
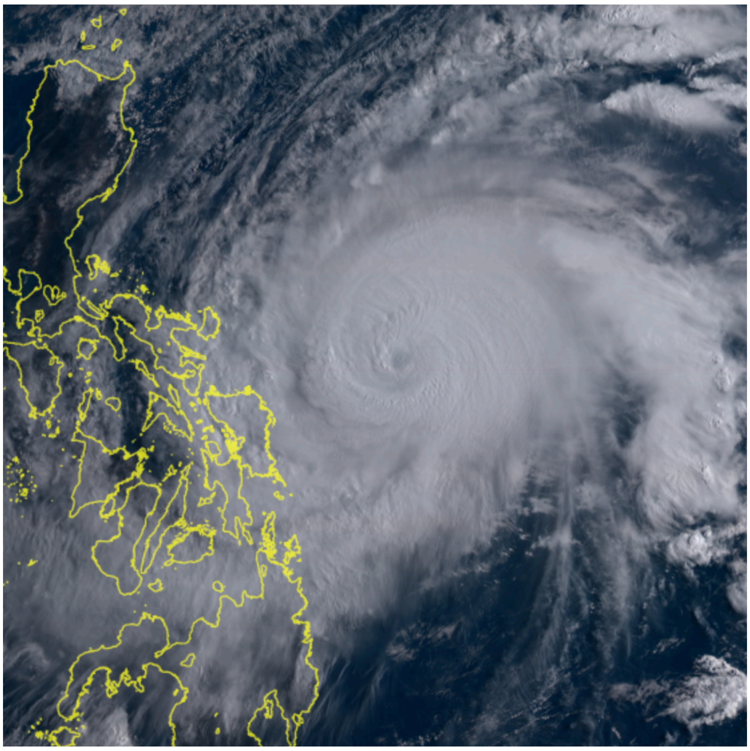


Fig. 4.1.3. Distribution of highest level of wind signal hoisted per province or sub-provincial locality during the passage of Tropical Storm AURING. The best track is also overlaid as a solid thick white line.

Super Typhoon BISING
SURIGAE (2102)

12 to 25 April 2021



Basin-wide peak intensity:
Super Typhoon
120 kt (220 km/h)
895 hPa

Developed:
12 UTC, 12 April 2021

Transitioned:
00 UTC, 25 April 2021

Duration within the PAR:
9 days

Peak category within the PAR:
Super Typhoon

Highest wind signal hoisted:
Wind Signal No. 2

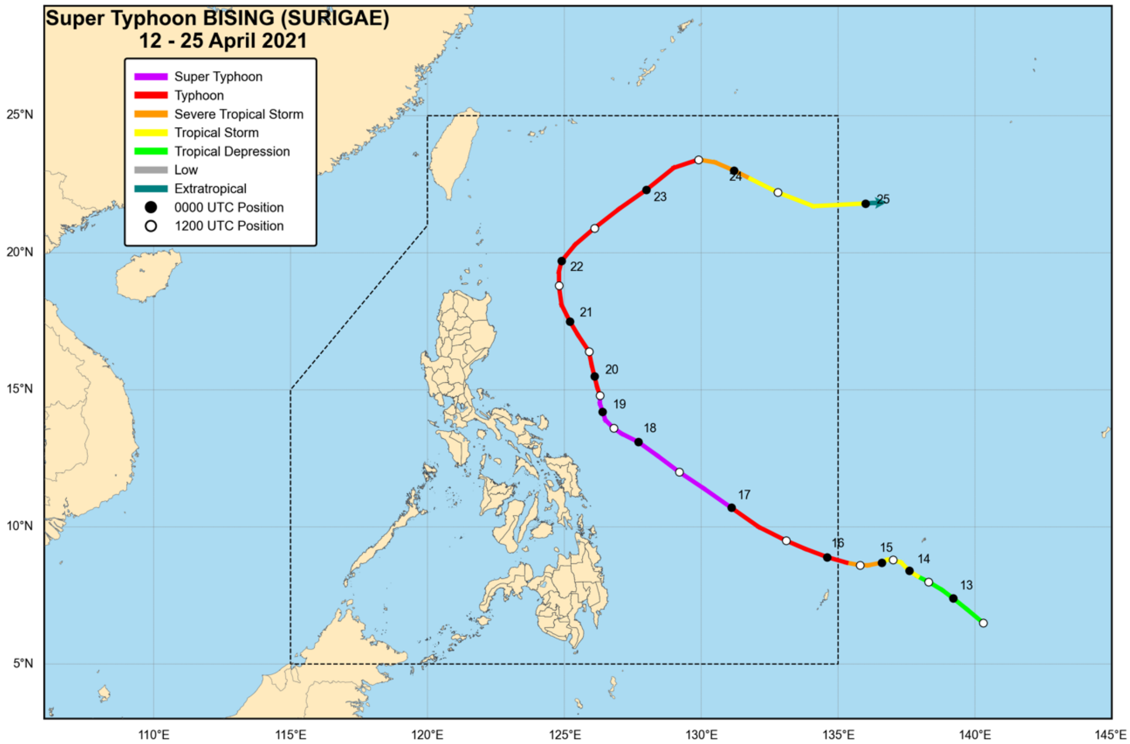


Fig. 4.2.1. Best track position and intensities of Super Typhoon BISING.

Summary of Meteorological History

Table 4.2.1. Key information about Super Typhoon BISING.

Parameter	Details
First tracked as a tropical low pressure area	18 UTC, 9 April 2021 Over the sea near Yap, Federated States of Micronesia
Developed into a TC	12 UTC, 12 April 2021 Over the sea near Yap, Federated States of Micronesia
Transitioned into a post-tropical low	00 UTC, 25 April 2021 Over the Philippine Sea southwest of Ogasawara Islands, Japan
Period of occurrence (lifetime)	12 days and 12 hours
Entered the PAR region	21 UTC, 15 April 2021
Exited the PAR region	21 UTC, 24 April 2021
Period of occurrence (within the PAR)	9 days
Peak intensity (lifetime)	Super Typhoon: 120 kt (220 km/h), 895 hPa 18 UTC, 17 April 2021
Peak intensity (within the PAR region)	Super Typhoon: 120 kt (220 km/h), 895 hPa 18 UTC, 17 April 2021
Observed landfalls	**Philippines:** None **Elsewhere:** None

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.2.1. Highest storm duration (16 to 24 April 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Virac, Catanduanes	520.8
Catarman, Northern Samar	348.1
Pili, Camarines Sur	307.0
Legazpi City, Albay	191.6
Borongan City, Eastern Samar	179.1

Table 4.2.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Catarman, Northern Samar	265.5	18 April 2021
Virac, Catanduanes	252.2	19 April 2021
Pili, Camarines Sur	141.6	17 April 2021
Catbalogan City, Samar	124.2	18 April 2021
Guiuan, Eastern Samar	102.9	17 April 2021

Table 4.2.4. Lowest mean sea level pressure over land.

Location of weather station	Minimum MSLP (hPa)	Date (MM/DD) and Time (UTC)
Borongan City, Eastern Samar	996.3	04/18 0600
Virac, Catanduanes	998.4	04/18 2000
Catarman, Northern Samar	998.8	04/18 0900
Guiuan, Eastern Samar	999.4	04/18 0800
Catbalogan City, Samar	1000.6	04/18 0700

Table 4.2.5. Highest peak gust over land.

Location of weather station	Peak gust speed (m/s)	Peak gust direction	Date and Time (UTC)
Virac, Catanduanes	30	WNW (290)	04/18 2230
Guiuan, Eastern Samar	26	W (280)	04/18 0747
Tacloban City, Leyte	22	WNW (290)	04/18 0830
Basco, Batanes	21	N (360) NNE (020)	04/21 1732 04/21 1948
Borongan City, Eastern Samar	20	SW (230)	04/18 0800-0900*

* No specific time reported, but happened within this range of synoptic hours.

Summary of Warning Information

Number of TC products issued

- Severe Weather Bulletins: **33**
- Tropical Cyclone Advisories: **5**
- Tropical Cyclone Warning for Shipping: **37**
- WC SIGMET: **21**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **Wind Signal No. 2**
- No. of provinces with hoisted wind signal: **27**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **9 dead, 20 injured, and 0 missing**
Total cost of damage: **PHP 272,780,999.56**

- Damage to agriculture: **PHP 261,910,999.56**
- Damage to infrastructure: **PHP 10,870,000.00**

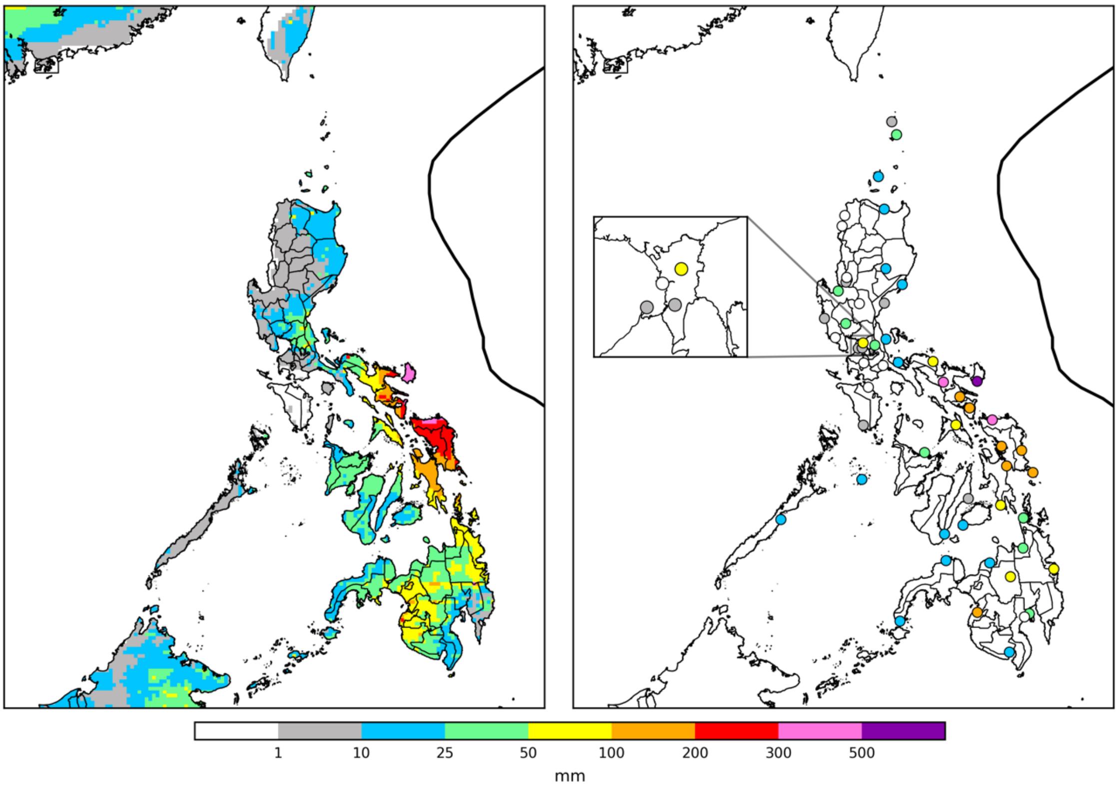


Fig. 4.2.2. Storm duration rainfall over land during the passage of Super Typhoon BISING within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line.

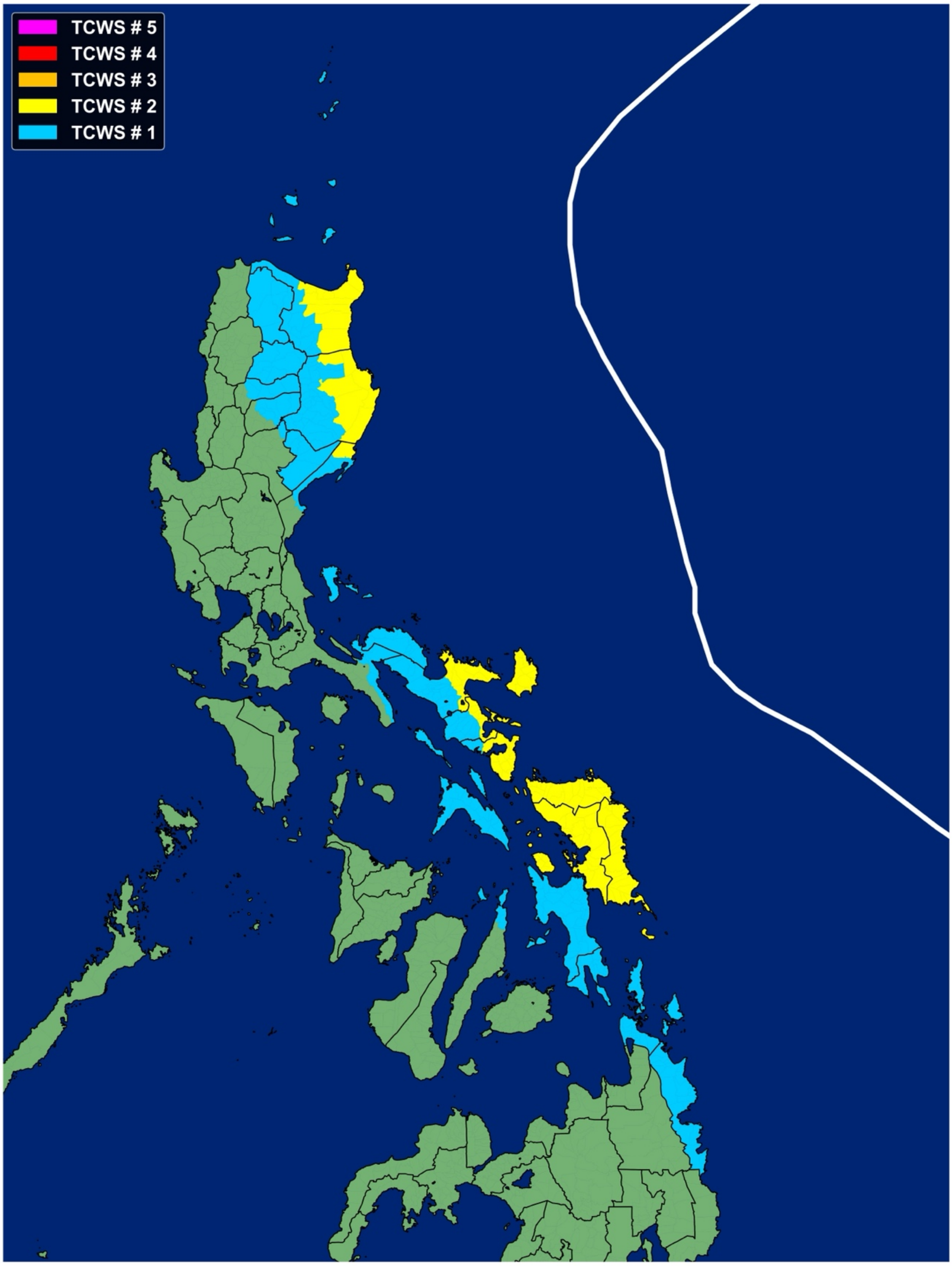


Fig. 4.2.3. Distribution of highest level wind signal hoisted per province or sub-provincial locality during the passage of Super Typhoon BISING. The best track is also overlaid as a solid thick white line.

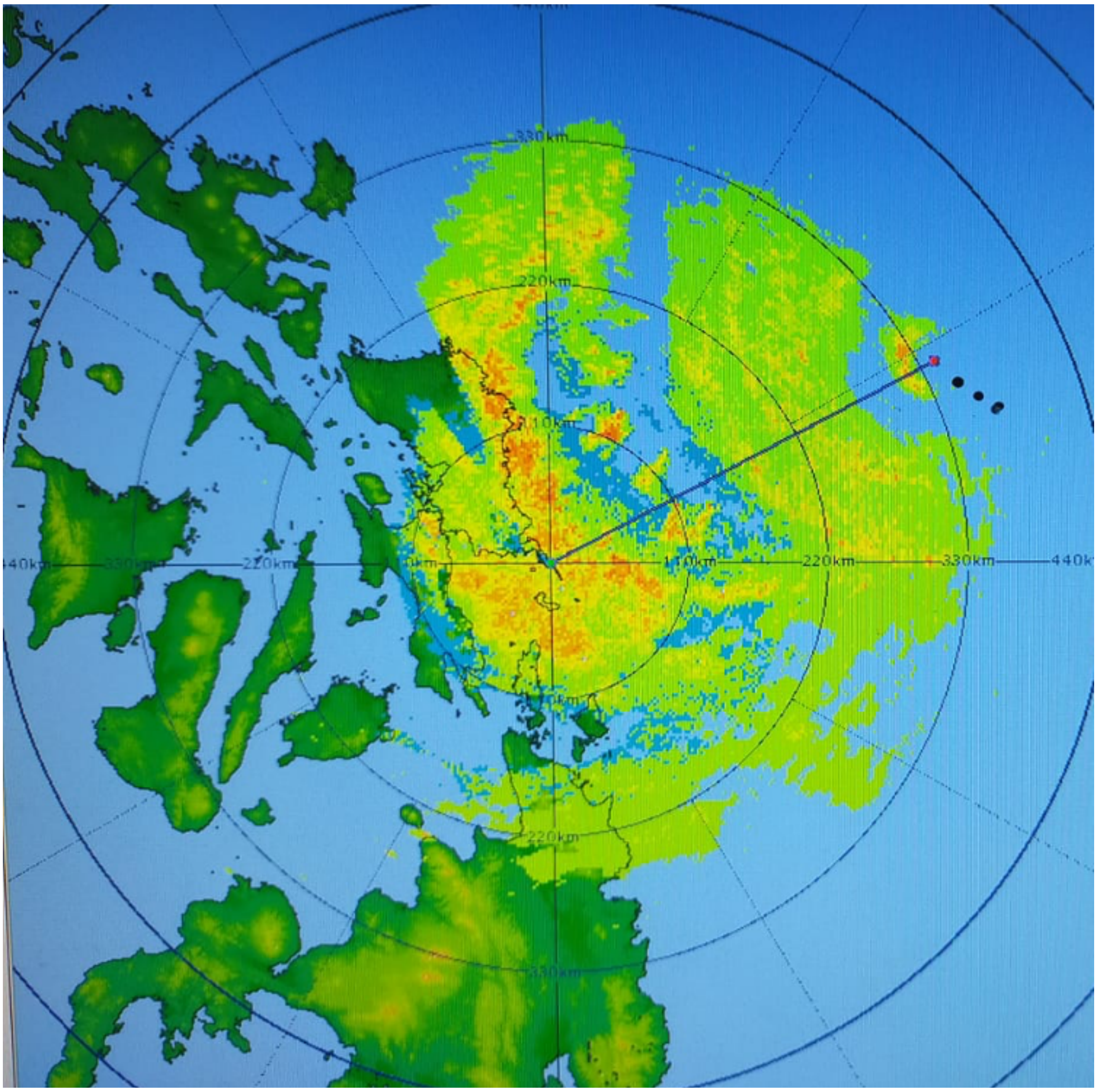
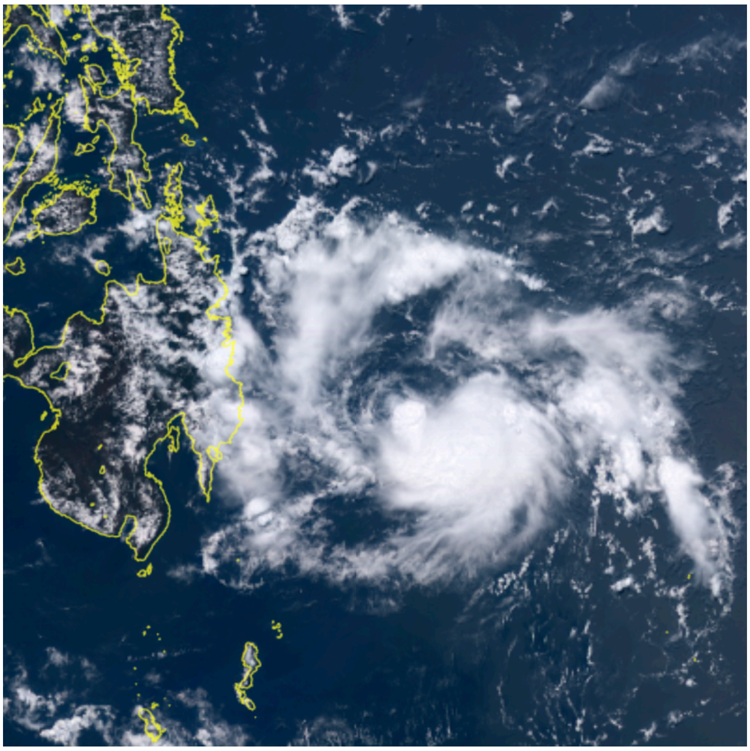


Fig. 4.3.4. Radar imagery (PPI 440-km range)of Super Typhoon BISING at 1701 UTC, 17 April 2024 near its peak intensity. Data from the PAGASA Guiuan Weather Surveillance Radar Station. A concentric eyewall signature is evident from the image. Black dots were radar eye fix marks from the station personnel.

Tropical Storm CRISING
UNNAMED

12 to 14 May 2021



Basin-wide peak intensity:
Tropical Storm
35 kt (65 km/h)
1002 hPa

Developed:
00 UTC, 12 May 2021

Degenerated:
00 UTC, 14 May 2021

Duration within the PAR:
2 days

Peak category within the PAR:
Tropical Storm

Highest wind signal hoisted:
Wind Signal No. 2

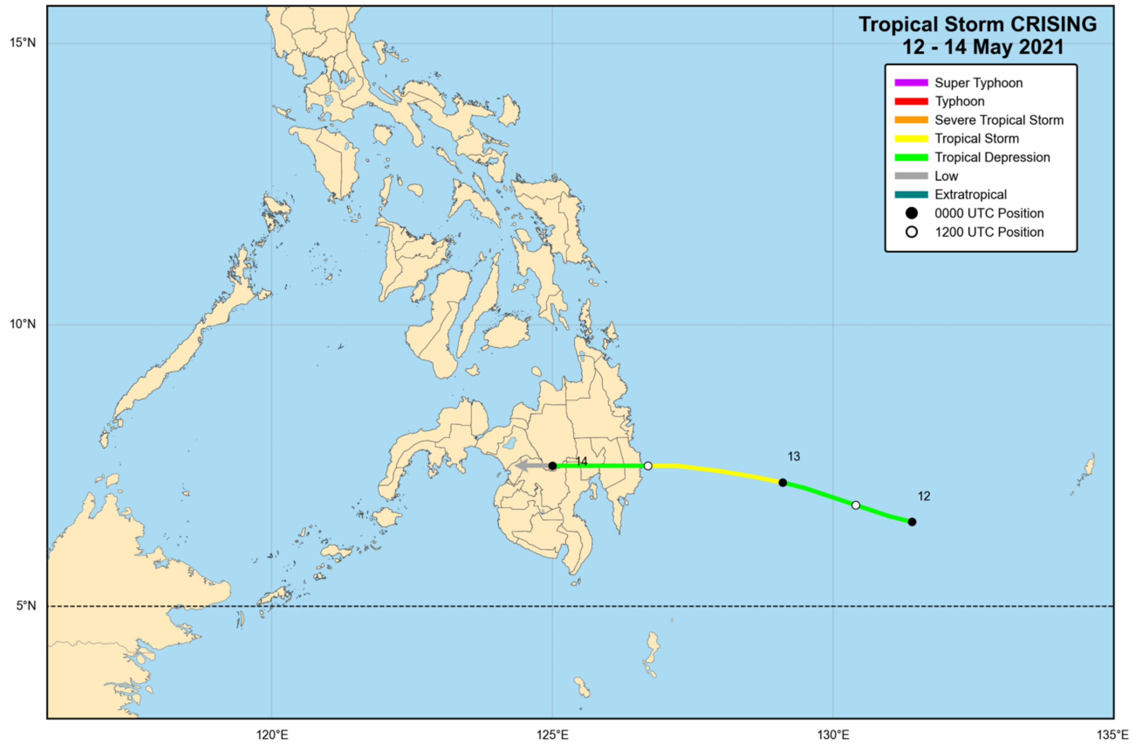


Fig. 4.3.1. Best track position and intensities of Tropical Storm CRISING.

Summary of Meteorological History

Table 4.3.1. Key information about Tropical Storm CRISING.

Parameter	Details
First tracked as a tropical low pressure area	00 UTC, 11 May 2021 Over the Philippine Sea near Palau
Developed into a TC	00 UTC, 12 May 2021 Over the Philippine Sea east of Davao Region
Weakened into a remnant low	00 UTC, 14 May 2021 In the vicinity of Damulog, Bukidnon
Period of occurrence (lifetime)	2 days
Entered the PAR region	Not applicable
Exited the PAR region	Not applicable
Period of occurrence (within the PAR)	2 days
Peak intensity (lifetime)	Tropical Storm: 35 kt (65 km/h), 1002 hPa 00 UTC, 13 May 2021
Peak intensity (within the PAR region)	Tropical Storm: 35 kt (65 km/h), 1002 hPa 00 UTC, 13 May 2021
Observed landfalls	**Philippines:** 1300 UTC, 13 May 2021 (TD): Baganga, Davao Oriental **Elsewhere:** None

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.3.2. Highest storm duration (12 to 13 May 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Hinatuan, Surigao Del Sur	100.4
Surigao City, Surigao Del Norte	87.8
PCA Bago-Oshiro, Davao City	75.9
Davao International Airport, Davao City	62.0
Borongan City, Eastern Samar	56.6

Table 4.3.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Hinatuan, Surigao del Sur	84.1	13 May 2021
PCA Bago-Oshiro, Davao City	74.8	12 May 2021
Surigao City, Surigao del Norte	72.8	13 May 2021
Borongan City, Eastern Samar	53.0	13 May 2021
Puerto Princesa City, Palawan	42.4	13 May 2021

Table 4.3.4. Lowest mean sea level pressure over land.

Location of weather station	Minimum MSLP (hPa)	Date (MM/DD) and Time (UTC)
Cotabato City	1003.8	05/13 0600
General Santos City	1004.2	05/13 0600
Davao International Airport, Davao City	1005.2	05/13 0600
El Salvador City, Misamis Oriental	1005.4	05/13 0900
Hinatuan, Surigao del Sur	1005.7	05/13 0700

Table 4.3.5. Highest peak gust over land.

Location of weather station	Peak gust speed (m/s)	Peak gust direction	Date and Time (UTC)
Hinatuan, Surigao del Sur	14	E (90)	05/13 0900-1000*

* No specific time reported, but happened within this range of synoptic hours.

Summary of Warning Information

Number of TC products issued

- Severe Weather Bulletins: **11**
- Tropical Cyclone Advisories: **0**
- Tropical Cyclone Warning for Shipping: **6**
- WC SIGMET: **2**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **Wind Signal No. 2**
- No. of provinces with hoisted wind signal: **20**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **0 dead, 4 injured, and 2 missing**
Total cost of damage: **PHP 23,163,587.69**

- Damage to agriculture: **PHP 23,163,587.69**
- Damage to infrastructure: **No report**

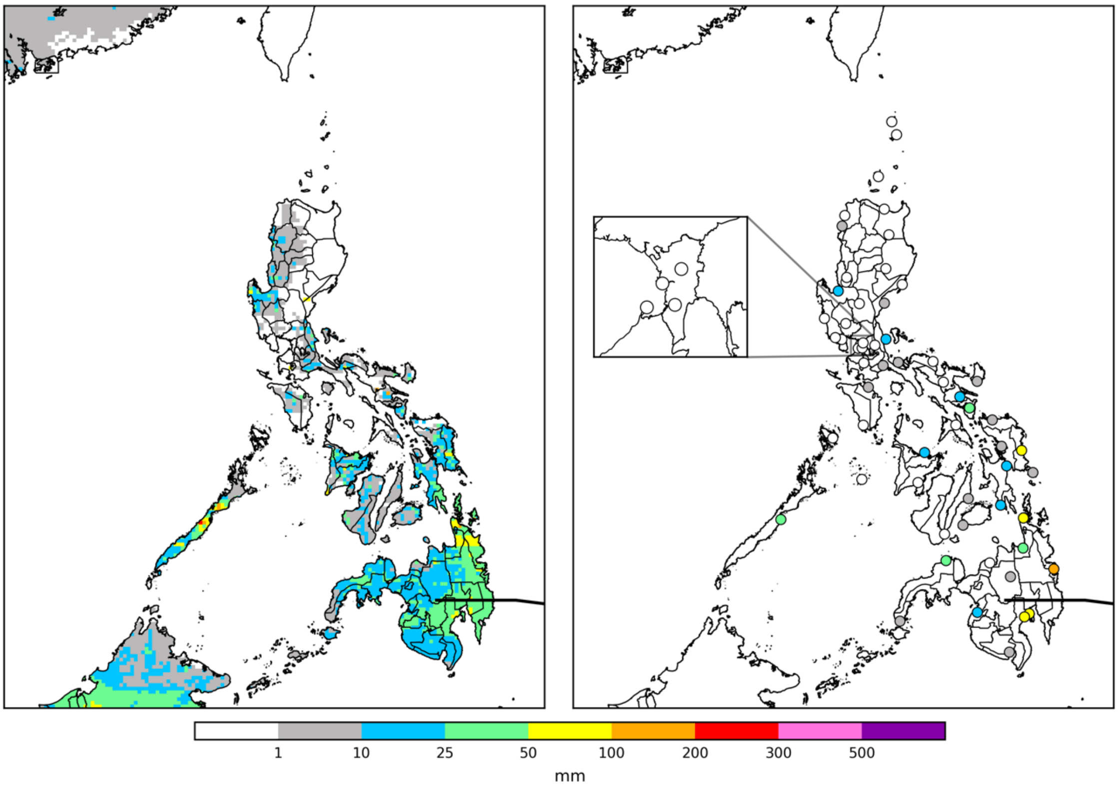


Fig. 4.3.2. Storm duration rainfall over land during the passage of Tropical Storm CRISING within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line.

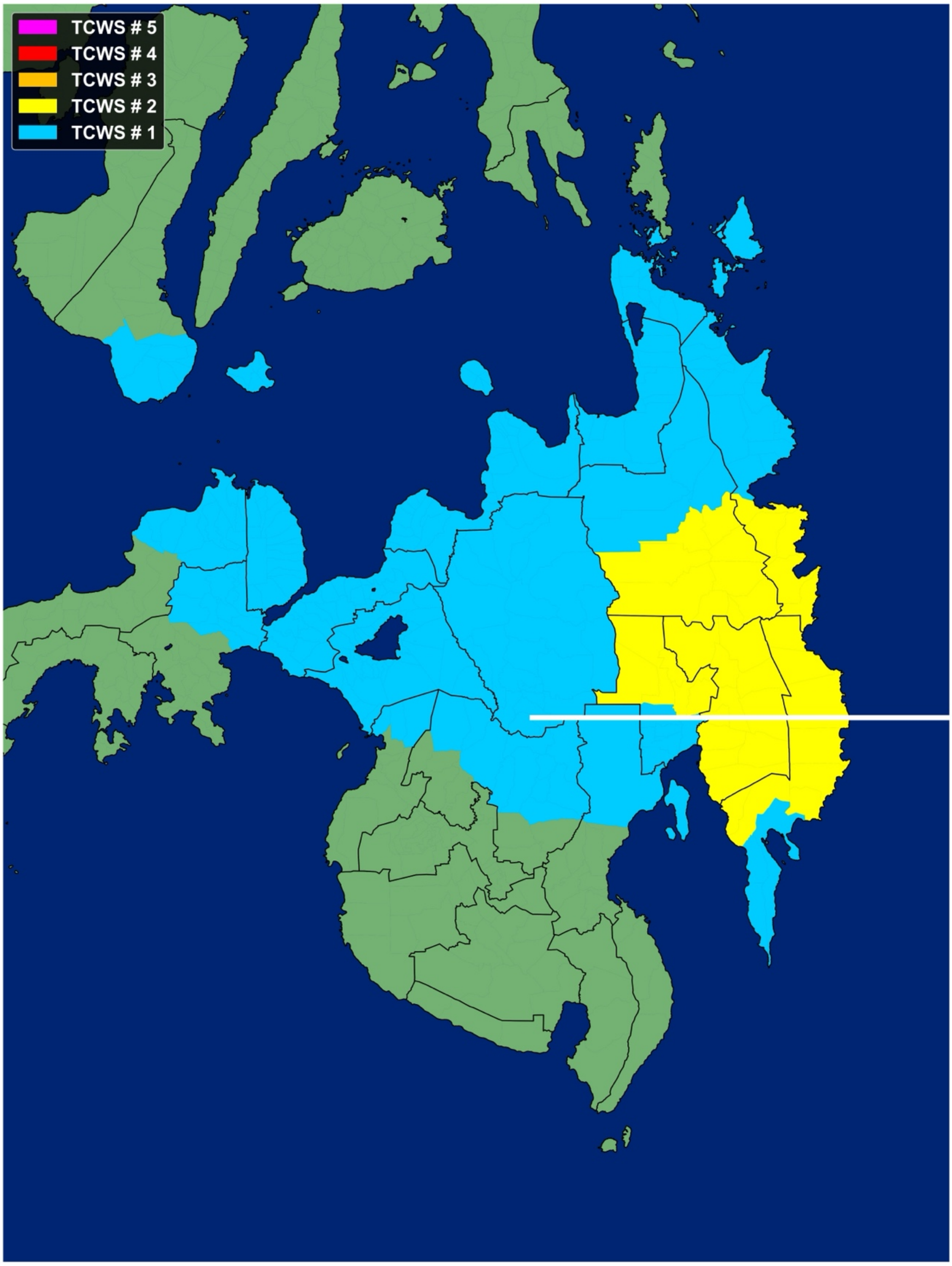
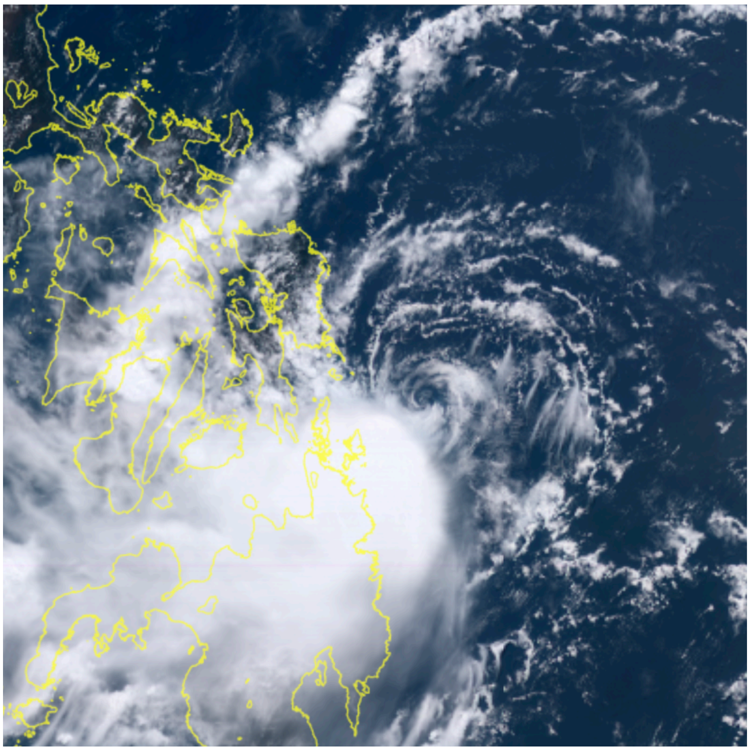


Fig. 4.3.3. Distribution of highest level wind signal hoisted per province or sub-provincial locality during the passage of Tropical Storm CRISING. The best track is also overlaid as a solid thick white line.

Tropical Storm DANTE
CHOI-WAN (2103)

29 May to 05 June 2021



Basin-wide peak intensity:
Tropical Storm
40 kt (75 km/h)
996 hPa

Developed:
12 UTC, 29 May 2021

Transitioned:
06 UTC, 05 June 2021

Duration within the PAR:
6 days and 10 hours

Peak category within the PAR:
Tropical Storm

Highest wind signal hoisted:
Wind Signal No. 2

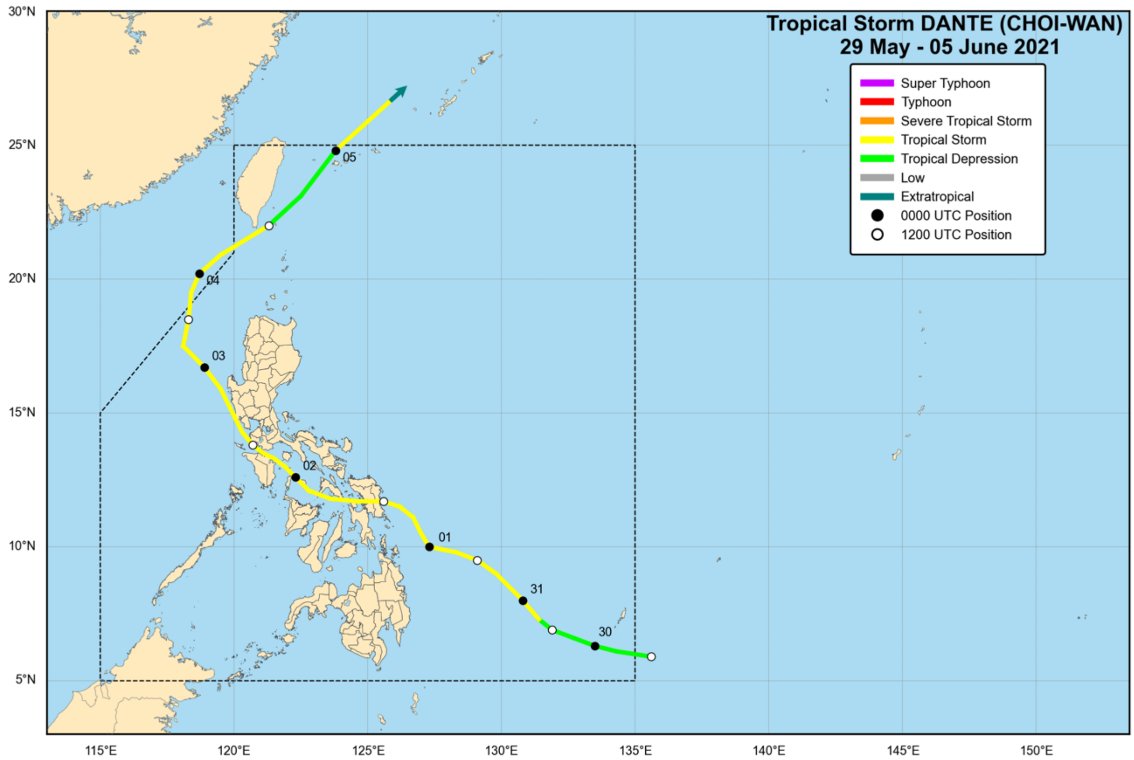


Fig. 4.4.1. Best track position and intensities of Tropical Storm DANTE.

Summary of Meteorological History

Table 4.4.1. Key information about Tropical Storm DANTE.

Parameter	Details
First tracked as a tropical low pressure area	06 UTC, 28 May 2021 Over the sea south of Yap, Federated States of Micronesia
Developed into a TC	12 UTC, 29 May 2021 Over the sea southeast of Palau
Transitioned into a post-tropical low	06 UTC, 05 June 2021 Over the East China Sea west of Okinawa Islands, Japan
Period of occurrence (lifetime)	6 days and 18 hours
Entered the PAR region	15 UTC, 29 May 2021
Exited the PAR region	01 UTC, 05 June 2021
Period of occurrence (within the PAR)	6 days and 10 hours
Peak intensity (lifetime)	Tropical Storm: 40 kt (75 km/h), 996 hPa 06 UTC, 31 May 2021 00 UTC, 03 June 2021
Peak intensity (within the PAR region)	Tropical Storm: 40 kt (75 km/h), 996 hPa 06 UTC, 31 May 2021 00 UTC, 03 June 2021
Observed landfalls	**Philippines:** 1230 UTC, 01 June 2021 (TS): Borongan City, Eastern Samar 1410 UTC, 01 June 2021 (TS): Zumarraga, Samar (Majaba Is.) 1420 UTC, 01 June 2021 (TS): Zumarraga, Samar (Bagatao Is.) 1430 UTC, 01 June 2021 (TS): Daram, Samar 1630 UTC, 01 June 2021 (TS): Pio V. Corpus, Masbate 1930 UTC, 01 June 2021 (TS): Balud, Masbate 2200 UTC, 01 June 2021 (TS): San Fernando, Romblon 0010 UTC, 02 June 2021 (TS): Romblon, Romblon 0140 UTC, 02 June 2021 (TS): Corcuera, Romblon 1030 UTC, 02 June 2021 (TS): Tingloy, Batangas 1220 UTC, 02 June 2021 (TS): Calatagan, Batangas **Elsewhere:** None

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.4.2. Highest storm duration (29 May to 04 June 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Maasin City, Southern Leyte	470.0
San Jose, Occidental Mindoro	197.0
Coron, Palawan	183.5
Guiuan, Eastern Samar	170.8
Abucay, Bataan	167.9

Table 4.4.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Maasin City, Southern Leyte	395.4	01 June 2021
San Jose, Occidental Mindoro	137.3	02 June 2021
El Salvador City, Misamis Oriental	121.8	30 May 2021
Hinatuan, Surigao Del Sur	104.0	31 May 2021
Abucay, Bataan	103.0	02 June 2021

Table 4.4.4. Lowest mean sea level pressure over land.

Location of weather station	Minimum MSLP (hPa)	Date (MM/DD) and Time (UTC)
Borongan City, Eastern Samar	997.4	06/01 1200
Romblon City, Romblon	998.6	06/02 0030
Calapan City, Oriental Mindoro	999.1	06/02 1600
Catbalogan City, Samar	1000.1	06/01 1300
Baguio City	1001.7	06/02 1800

Table 4.4.5. Highest peak gust over land.

Location of weather station	Peak gust speed (m/s)	Peak gust direction	Date and Time (UTC)
Romblon City, Romblon	22	N(360)	06/02 0200-0300*
Abucay, Bataan	20	SE(140)	06/02 1500-1600*
Guiuan, Eastern Samar	20	WSW(240)	06/01 1230
San Jose, Occidental Mindoro	19	WSW(240)	06/02 0300
Basco, Batanes	17	SSE(150) SSE(150)	06/03 0115 06/03 0400
Catarman, Northern Samar	17	NE(40)	06/01 1300-1400*
Calapan City, Oriental Mindoro	16	SW(220)	06/02 0754
Itbayat, Batanes	16	WSW(250)	06/04 0428
Mactan-Cebu International Airport, Lapu-Lapu City	16	N(10)	05/30 0608
Sangley Pt., Cavite City, Cavite	16	ENE(060)	06/02 1214

* No specific time reported, but happened within this range of synoptic hours.

Summary of Warning Information

Number of TC products issued

- Tropical Cyclone Bulletins: **35**
- Tropical Cyclone Advisories: **1**
- Tropical Cyclone Warning for Shipping issued: **26**
- WC SIGMET: **16**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **Wind Signal No. 2**
- No. of provinces with hoisted wind signal: **59**

Reported Casualties and Cost of Damage
Based on reports from the Office of Civil Defense

Number of reported casualties: **3 dead, 0 injured, and 0 missing**
Total cost of damage: **PHP 309,748,102.08**

- Damage to agriculture: **PHP 152,110,102.08**
- Damage to infrastructure: **PHP 157,638,000.00**

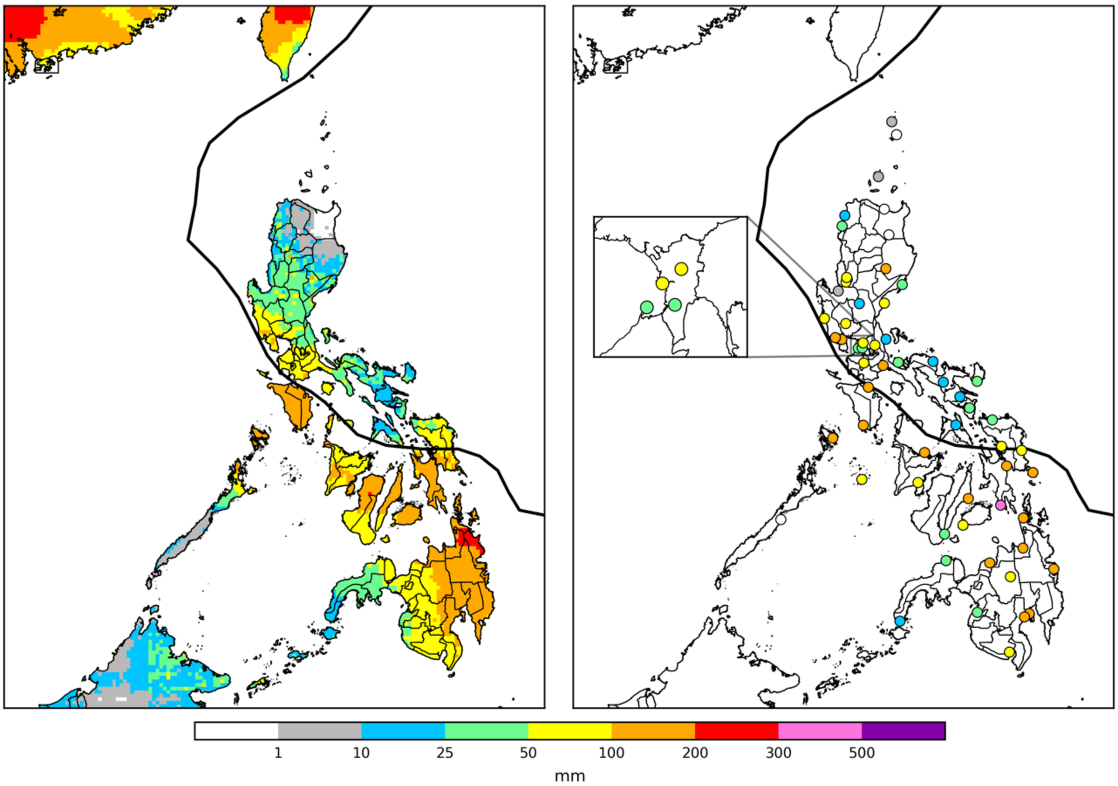


Fig. 4.4.2. Storm duration rainfall over land during the passage of Tropical Storm DANTE within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line.

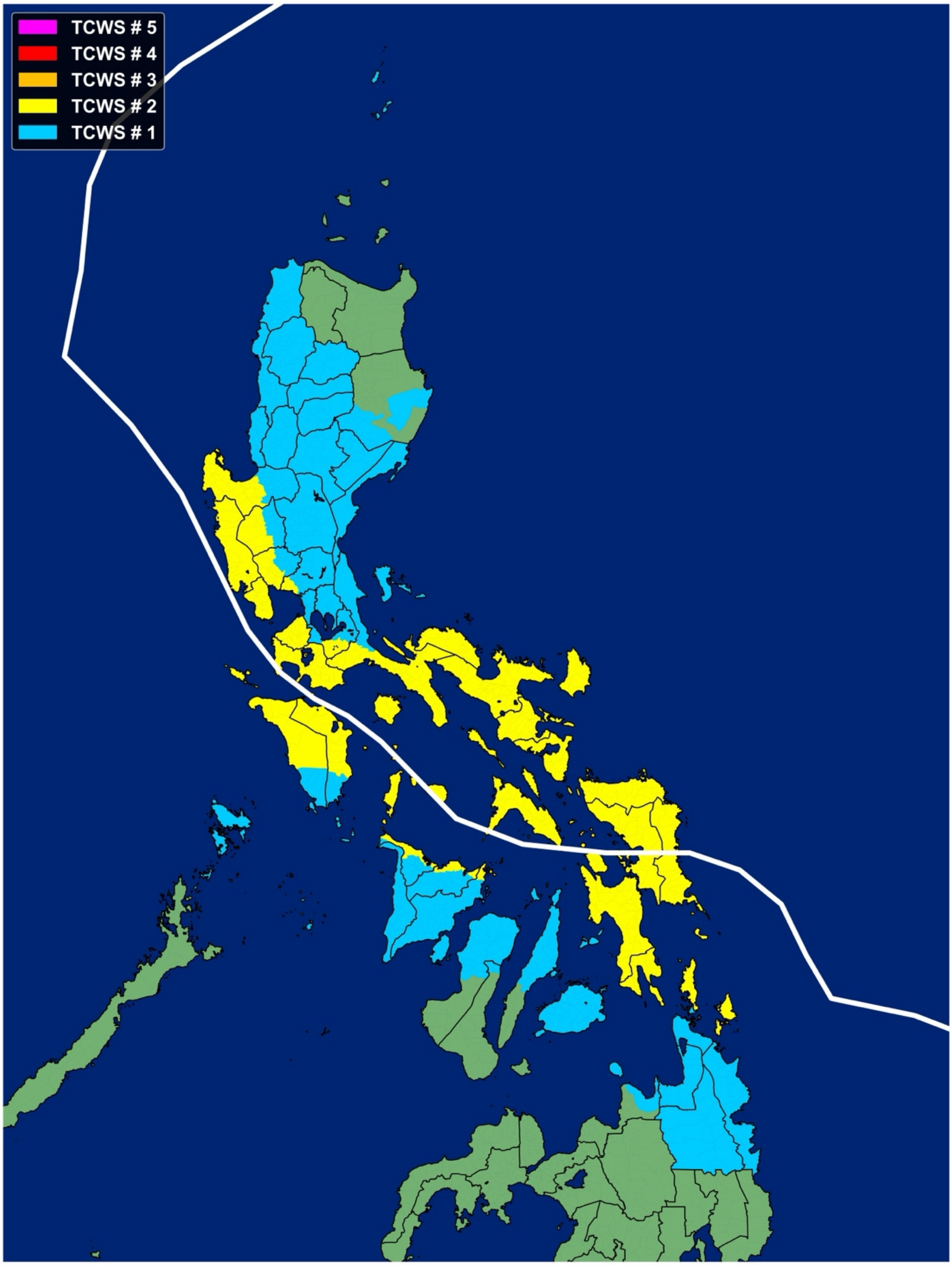
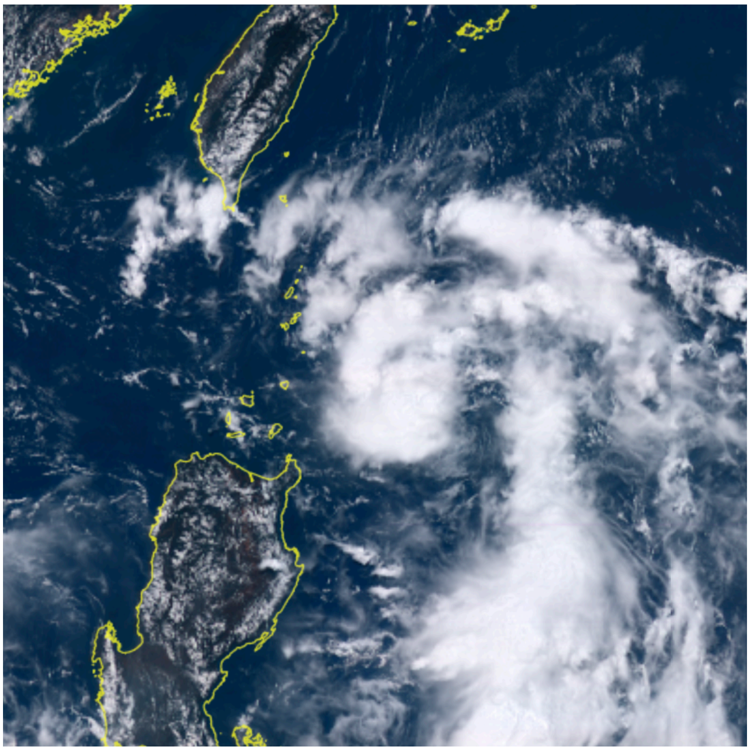


Fig. 4.4.3. Distribution of highest level wind signal hoisted per province or sub-provincial locality during the passage of Tropical Storm DANTE. The best track is also overlaid as a solid thick white line.

Tropical Depression EMONG
UNNAMED

3 to 6 July 2021



Basin-wide peak intensity:
Tropical Depression
30 kt (55 km/h)
1002 hPa

Developed:
18 UTC, 03 July 2021

Degenerated:
06 UTC, 06 June 2021

Duration within the PAR:
2 days and 7 hours

Peak category within the PAR:
Tropical Depression

Highest wind signal hoisted:
Wind Signal No. 1

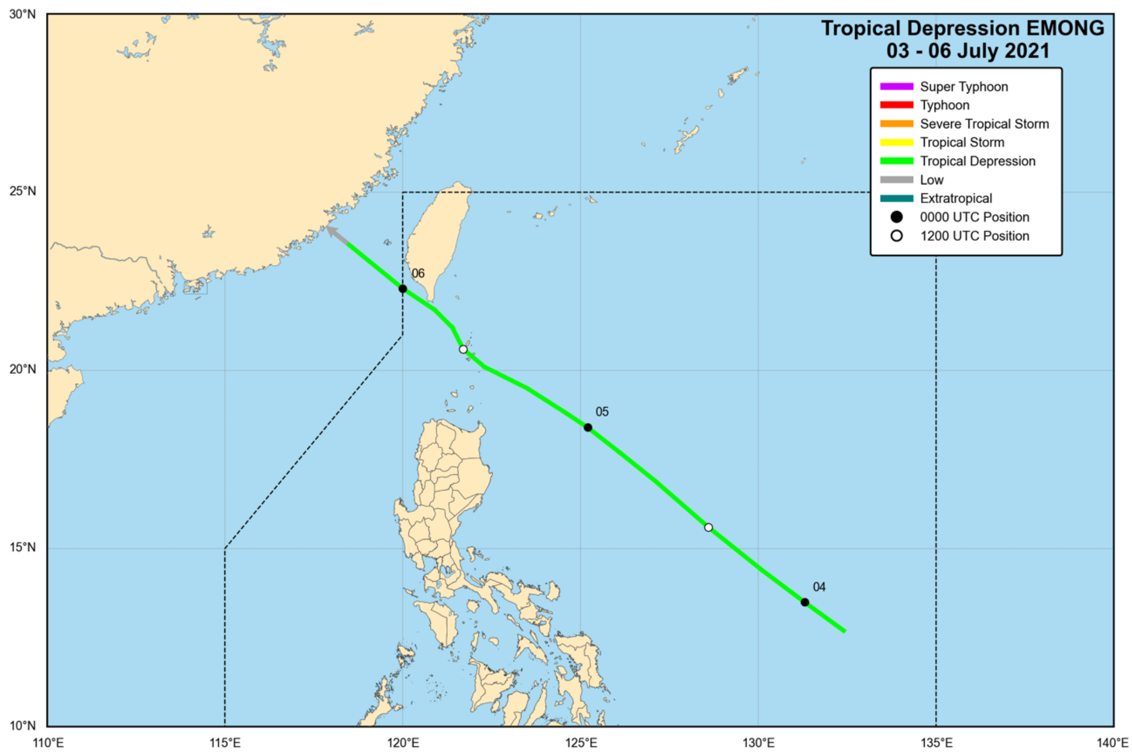


Fig. 4.5.1. Best track position and intensities of Tropical Depression EMONG.

Summary of Meteorological History

Table 4.5.1. Key information about Tropical Depression EMONG.

Parameter	Details
First tracked as a tropical low pressure area	00 UTC, 03 July 2021 Over the Philippine Sea northwest of Palau
Developed into a TC	18 UTC, 03 July 2021 Over the Philippine Sea east of Eastern Visayas
Weakened into a remnant low	06 UTC, 06 July 2021 Over the Taiwan Strait off the coast of Fujian, China
Period of occurrence (lifetime)	2 days and 12 hours
Entered the PAR region	Not applicable
Exited the PAR region	0100 UTC, 06 July 2021
Period of occurrence (within the PAR)	2 days and 7 hours
Peak intensity (lifetime)	Tropical Depression: 30 kt (55 km/h), 1002 hPa 06 UTC, 04 July 2021
Peak intensity (within the PAR region)	Tropical Depression: 30 kt (55 km/h), 1002 hPa 06 UTC, 04 July 2021
Observed landfalls	**Philippines:** 1030 UTC, 05 July 2021 (TD): Uyugan, Batanes **Elsewhere:** None

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.5.2. Highest storm duration (03 to 05 July 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Baler, Aurora	205.6
Iba, Zambales	168.8
Alabat, Quezon	159.0
Tayabas City, Quezon	140.8
Virac, Catanduanes	125.4

Table 4.5.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Iba, Zambales	166.8	03 July 2021
Alabat, Quezon	154.2	03 July 2021
Baler, Aurora	122.0	05 July 2021
Virac, Catanduanes	85.8	05 July 2021
Tanay, Rizal	81.3	03 July 2021

Table 4.5.4. Lowest mean sea level pressure over land.

Location of weather station	Minimum MSLP (hPa)	Date (MM/DD) and Time (UTC)
Baguio City	1001.5	07/05 0600
Tuguegarao City, Cagayan	1002.4	07/05 0700
Basco, Batanes	1003.3	07/05 1000 07/05 1100
Aparri, Cagayan	1003.6	07/05 0700
Laoag City, Ilocos Norte	1003.6	07/04 0600
Calayan, Cagayan	1004.0	07/05 0900
Sinait, Ilocos Sur	1004.0	07/04 0600

Note: Itbayat Synoptic Weather Station may have similar or lower minimum MSLP, but was not recorded since the barometer was inoperative at the time of passage.

Table 4.5.5. Highest peak gust over land.

Location of weather station	Peak gust speed (m/s)	Peak gust direction	Date and Time (UTC)
Basco, Batanes	20	E(090)	07/04 1538
Baguio City	10	ESE(110)	07/04 0256
Baler, Aurora	10	WNW(290)	07/05 1155
Calayan, Cagayan	10	E(090)	07/05 0200-0300*

* No specific time reported, but happened within this range of synoptic hours.

Summary of Warning Information

Number of TC products issued

- Severe Weather Bulletins: **13**
- Tropical Cyclone Advisories: **0**
- TC Warning for Shipping issued: **9**
- WC SIGMET: **0**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **Wind Signal No. 1**
- No. of provinces with hoisted wind signal: **2**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **No report**
Total cost of damage: **No report**

- Damage to agriculture: **No report**
- Damage to infrastructure: **No report**

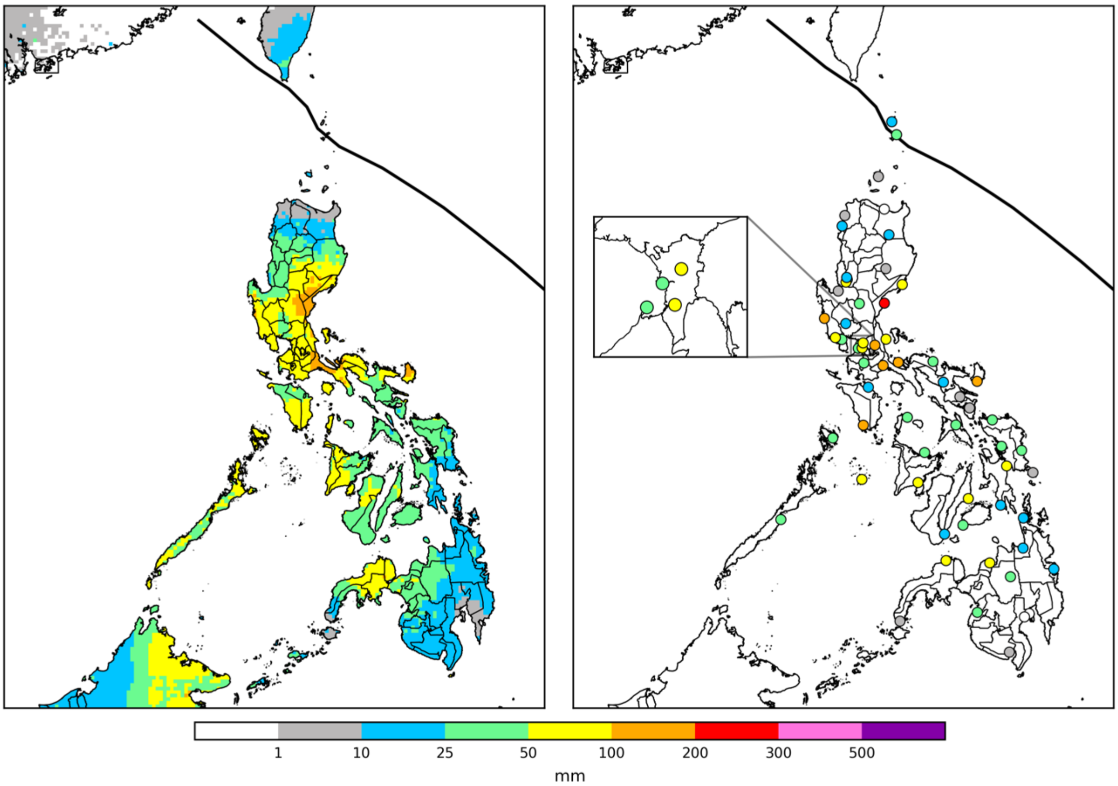
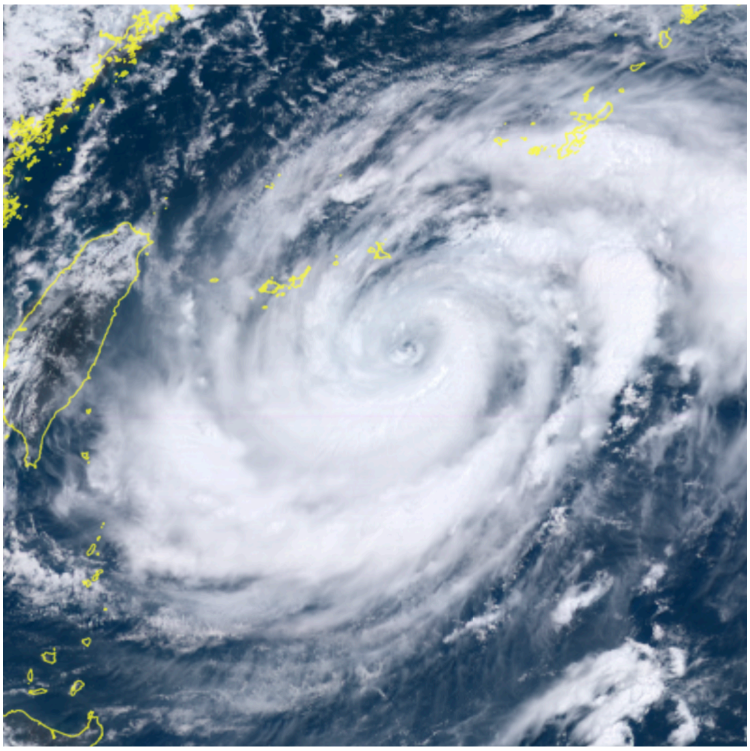


Fig. 4.5.2. Storm duration rainfall over land during the passage of Tropical Depression EMONG within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line.

Fig. 4.5.3. Distribution of highest level wind signal hoisted per province or sub-provincial locality during the passage of Tropical Depression EMONG. The best track is also overlaid as a solid thick white line.

Typhoon FABIAN
IN-FA (2106)

15 to 29 July 2021



Basin-wide peak intensity:
Typhoon
80 kt (150 km/h)
955 hPa

Developed:
18 UTC, 15 July 2021

Degenerated:
18 UTC, 29 July 2021

Duration within the PAR:
7 days and 20 hours

Peak category within the PAR:
Typhoon

Highest wind signal hoisted:
Wind Signal No. 1

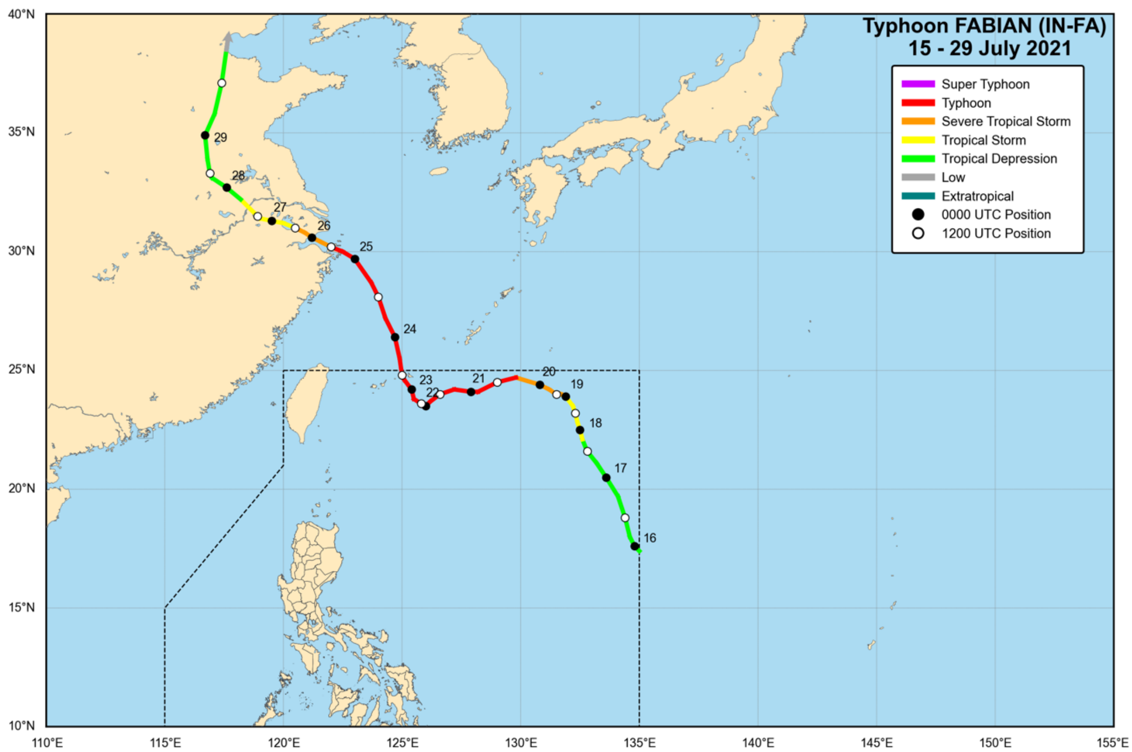


Fig. 4.6.1. Best track position and intensities of Typhoon FABIAN.

Summary of Meteorological History

Table 4.6.1. Key information about Typhoon FABIAN.

Parameter	Details
First tracked as a tropical low pressure area	06 UTC, 14 July 2021 Over the Philippine Sea west of Northern Mariana Islands (US)
Developed into a TC	18 UTC, 15 July 2021 Over the Philippine Sea far east of Northern Luzon
Weakened into a remnant low	18 UTC, 29 July 2021 In the vicinity of Cangzhou City, Heibei, China
Period of occurrence (lifetime)	14 days
Entered the PAR region	Not applicable
Exited the PAR region	14 UTC, 23 July 2021
Period of occurrence (within the PAR)	7 days and 20 hours
Peak intensity (lifetime)	Typhoon: 80 kt (150 km/h), 955 hPa 00 UTC, 21 July 2021
Peak intensity (within the PAR region)	Typhoon: 80 kt (150 km/h), 955 hPa 00 UTC, 21 July 2021
Observed landfalls	**Philippines:** None **Elsewhere:** 0700 UTC, 25 July 2021 (TY): Zhoushan City, Zhejiang, China (Mount Putuo Is.) 0830 UTC, 25 July 2021 (TY): Zhoushan City, Zhejiang, China (Lianghengshan Is.) 0900 UTC, 25 July 2021 (TY): Zhoushan City, Zhejiang, China (Zhoushan Is.) 0130 UTC, 25 July 2021 (STS): Jiaxing City, Zhejiang, China

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.6.2. Highest storm duration (15 to 23 July 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Mt. Cabuyao, Tuba, Benguet	984.4
Iba, Zambales	770.5
La Trinidad, Benguet	729.6
Abucay, Bataan	701.1
Cubi Point, Subic Bay International Airport	636.2

Table 4.6.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Mt. Cabuyao, Tuba, Benguet	246.8	20 July 2021
Abucay, Bataan	218.1	23 July 2021
Baguio City	214.6	22 July 2021
Iba, Zambales	213.6	22 July 2021
Port Area, Manila	206.9	23 July 2021

Table 4.6.4. Lowest mean sea level pressure over land.

Location of weather station	Minimum MSLP (hPa)	Date (MM/DD) and Time (UTC)
Basco, Batanes	992.5	07/22 2100
Aparri, Cagayan	996.1	07/23 2100
Calayan, Cagayan	996.4	07/22 1800
Tuguegarao City, Cagayan	996.4	07/23 0900
Casiguran, Aurora	996.7	07/23 0900
Baler, Aurora	997.0	07/22 1500

Note: Itbayat Synoptic Weather Station may have similar or lower minimum MSLP, but was not recorded since the barometer was inoperative at the time of passage.

Table 4.6.5. Highest peak gust over land.

Location of weather station	Peak gust speed (m/s)	Peak gust direction	Date and Time (UTC)
Baler, Aurora	26	WNW(290)	07/22 1445
Baguio City	20	SW(220)	07/23 0336
Basco, Batanes	20	WNW(290)	07/23 0135
		WNW(290)	07/23 0420
		W(280)	07/23 0735
		W(280)	07/23 1116
		W(280)	07/23 1322
Laoag City, Ilocos Norte	13	SW(220)	07/23 0354
Aparri, Cagayan	12	SW(220)	07/23 0841
Itbayat, Batanes	12	W(270)	07/22 2245
Casiguran, Aurora	10	SW(220)	07/22 0410
		SW(220)	07/23 1755
		SW(220)	07/23 2055

* No specific time reported, but happened within this range of synoptic hours.

Summary of Warning Information

Number of TC products issued

- Tropical Cyclone Bulletins: **31**
- Tropical Cyclone Advisories: **0**
- Tropical Cyclone Warning for Shipping issued: **31**
- WC SIGMET: **0**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **Wind Signal No. 1**
- No. of provinces with hoisted wind signal: **2**

Reported Casualties and Cost of Damage
Based on reports from the Office of Civil Defense

Number of reported casualties: **No report**
Total cost of damage: **No report**
- Damage to agriculture: **No report**
- Damage to infrastructure: **No report**

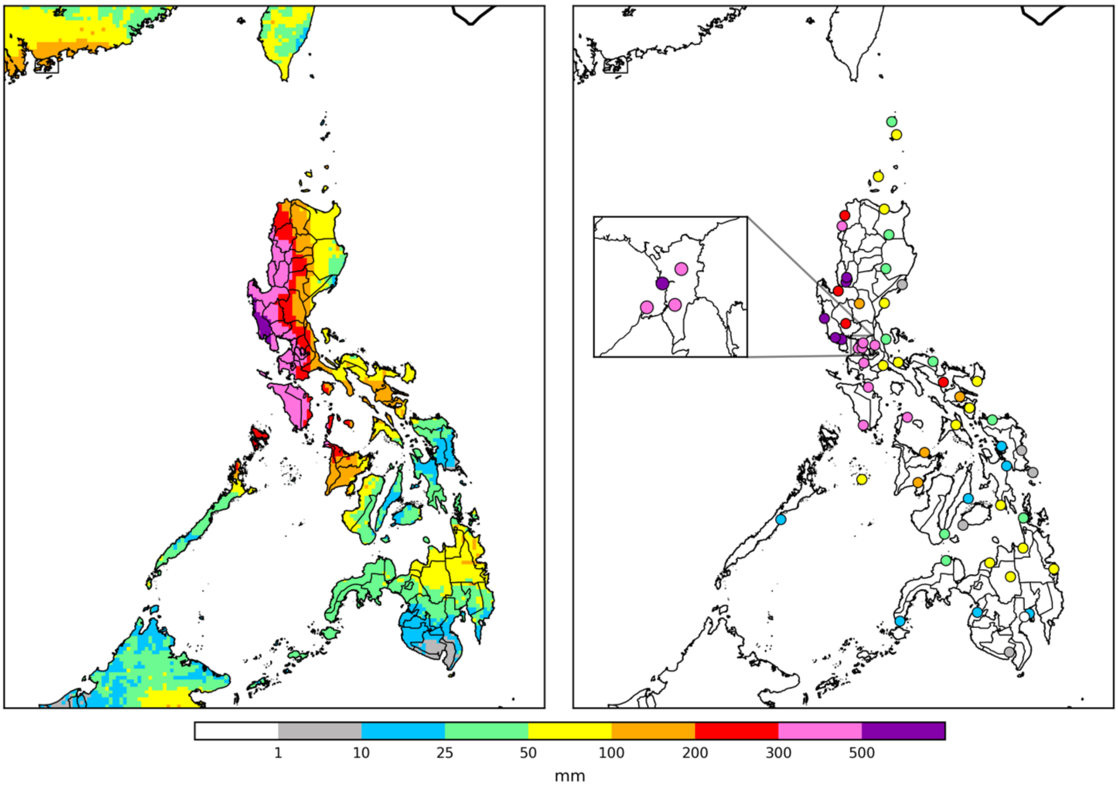


Fig. 4.6.2. Storm duration rainfall over land during the passage of Typhoon FABIAN within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line on the upper right corner of the figure.

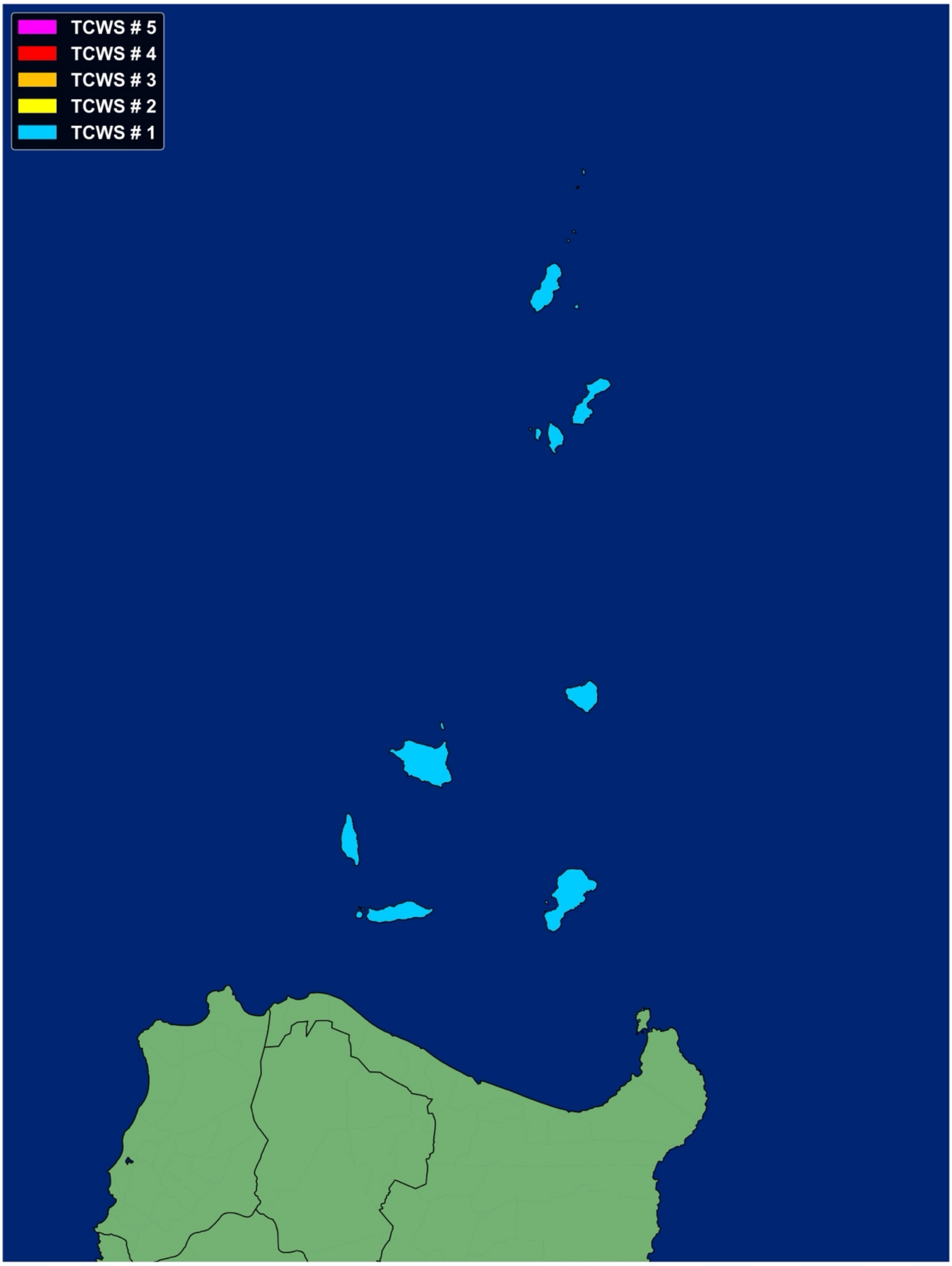


Fig. 4.6.3. Distribution of highest level wind signal hoisted per province or sub-provincial locality during the passage of Typhoon FABIAN. The best track is outside the domain of this image.

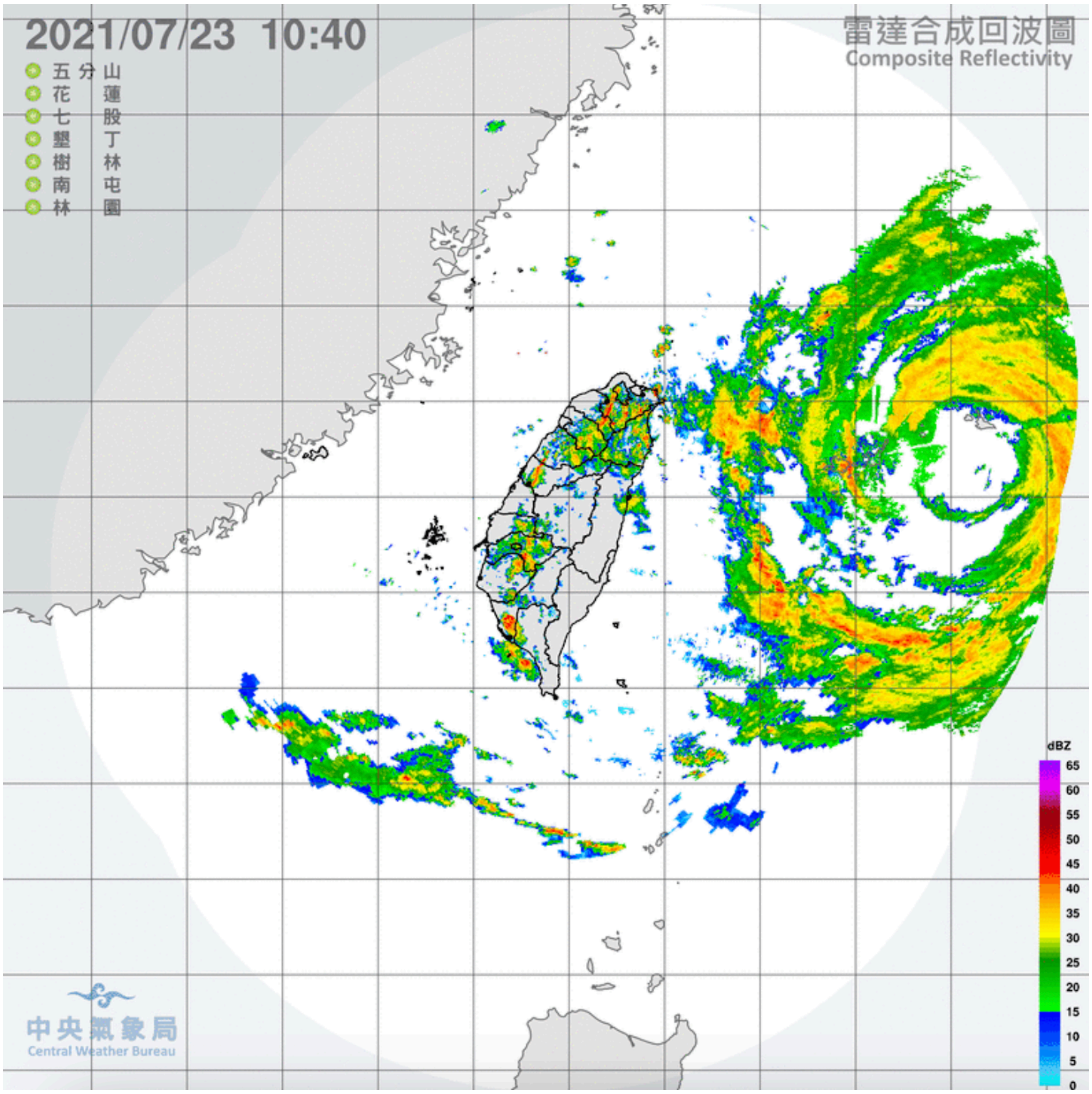
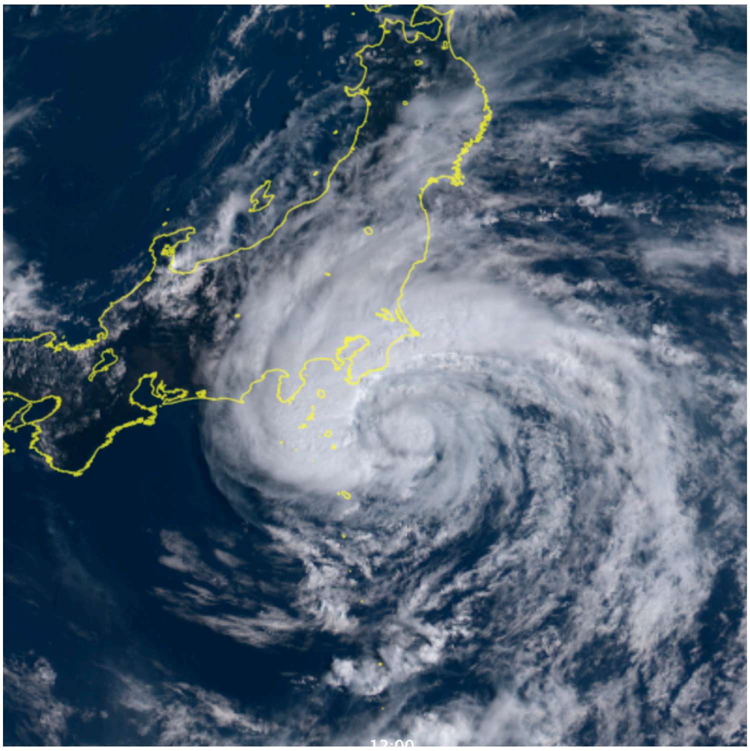


Fig. 4.6.4. Composite radar reflective image of Typhoon INFA at 0240 UTC, 23 July 2021, while nearing the Miyako Islands in the southern Ryukyu archipelago. Image courtesy of Central Weather Administration of Taiwan.

Severe Tropical Storm GORIO
MIRINAE (2110)

03 to 10 August 2021



Basin-wide peak intensity:
Severe Tropical Storm
50 kt (95 km/h)
980 hPa

Developed:
18 UTC, 03 August 2021

Transitioned:
00 UTC, 10 August 2021

Duration within the PAR:
12 hours

Peak category within the PAR:
Tropical Depression

Highest wind signal hoisted:
None

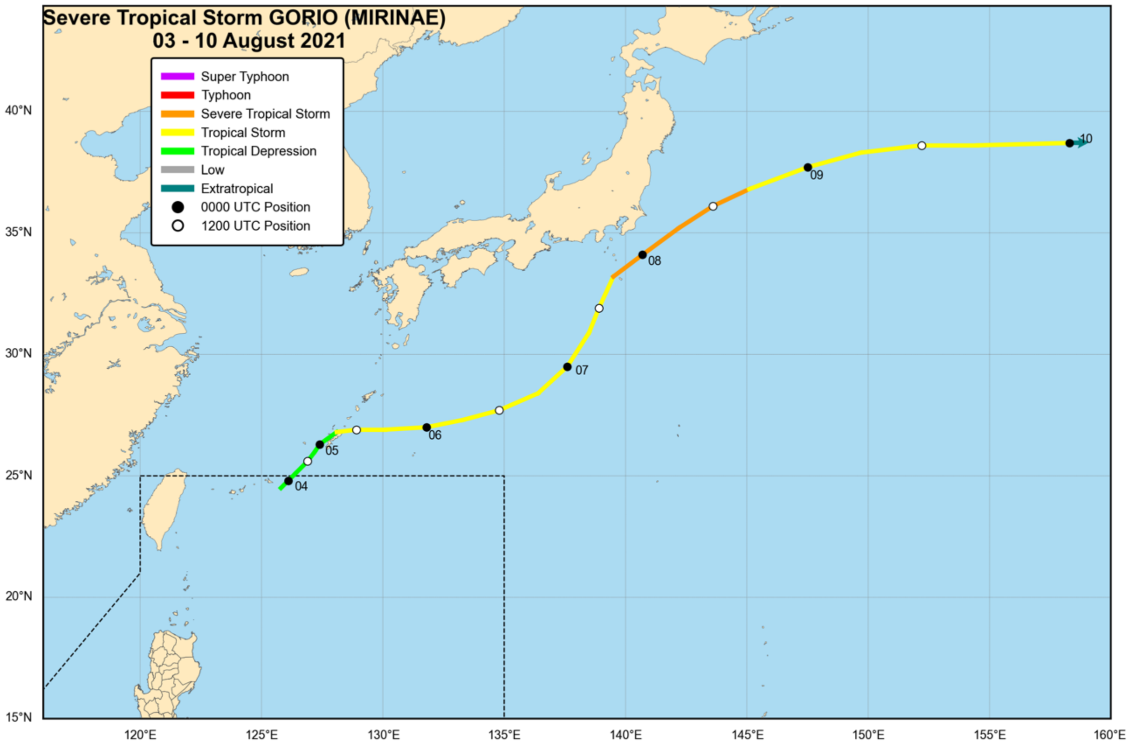


Fig. 4.7.1. Best track position and intensities of Severe Tropical Storm GORIO

Summary of Meteorological History

Table 4.7.1. Key information about Severe Tropical Storm GORIO.

Parameter	Details
First tracked as a tropical low pressure area	06 UTC, 01 August 2021 Over the East China Sea near Okinawa Islands, Japan
Developed into a TC	18 UTC, 03 August 2021 Over the Philippine Sea near Miyako Islands, Japan
Transitioned into a post-tropical low	00 UTC, 10 August 2021 Over the sea far east of mainland Japan
Period of occurrence (lifetime)	6 days and 6 hours
Entered the PAR region	Not applicable
Exited the PAR region	06 UTC, 04 August 2021
Period of occurrence (within the PAR)	12 hours
Peak intensity (lifetime)	Severe Tropical Storm: 50 kt (95 km/h), 980 hPa 18 UTC, 07 August 2021
Peak intensity (within the PAR region)	Tropical Depression: 25 kt (45 km/h), 998 hPa 18 UTC, 03 August 2021
Observed landfalls	**Philippines:** None **Elsewhere:** None

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.7.2. Highest storm duration (3 to 4 August 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Abucay, Bataan	240.1
Mt. Cabuyao, Tuba, Benguet	212.0
Baguio City	123.7
La Trinidad, Benguet	109.3
Itbayat, Batanes	77.8

Table 4.7.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Abucay, Bataan	147.0	04 August 2021
Mt. Cabuyao, Tuba, Benguet	130.8	03 August 2021
Baguio City	89.3	03 August 2021
La Trinidad, Benguet	77.3	04 August 2021
Itbayat, Batanes	56.0	03 August 2021

Summary of Warning Information

Number of TC products issued

- Tropical Cyclone Bulletins: **2**
- Tropical Cyclone Advisories: **0**
- Tropical Cyclone Warning for Shipping issued: **2**
- WC SIGMET: **0**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **None**
- No. of provinces with hoisted wind signal: **0**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **No report**
Total cost of damage: **No report**

- Damage to agriculture: **No report**
- Damage to infrastructure: **No report**

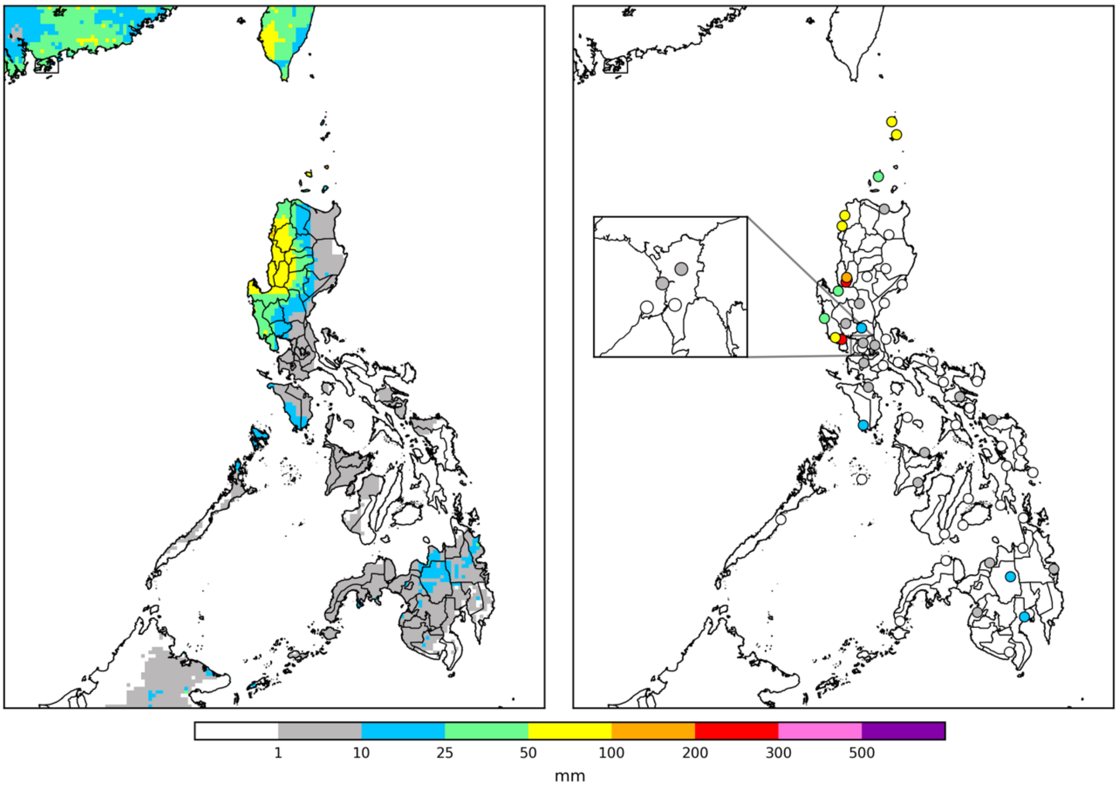
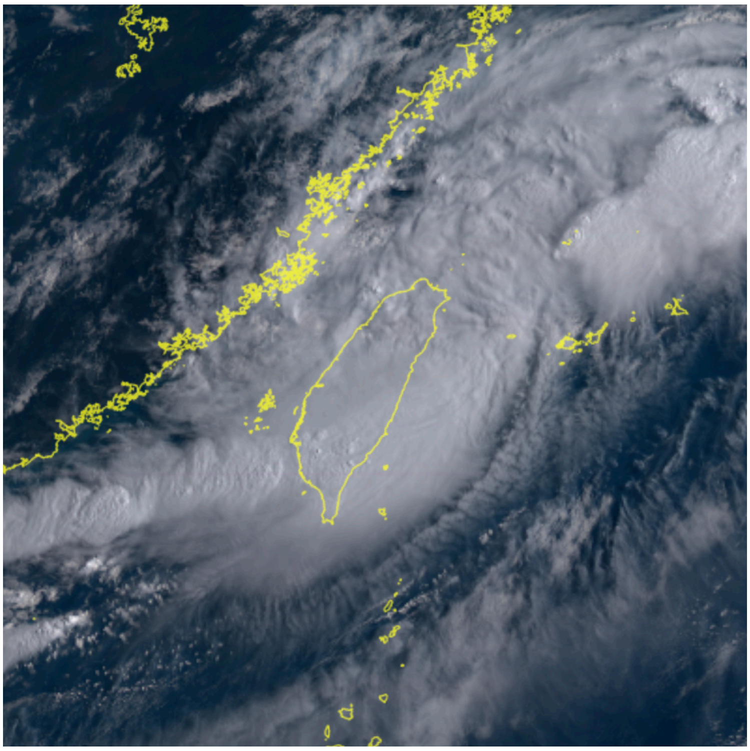


Fig. 4.7.2. Storm duration rainfall over land during the passage of Severe Tropical Storm GORIO within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is outside the domain of the figure.

Tropical Storm HUANING
LUPIT (2109)

02 to 09 August 2021



Basin-wide peak intensity:
Tropical Storm
45 kt (85 km/h)
985 hPa

Developed:
12 UTC, 02 August 2021

Transitioned:
00 UTC, 09 August 2021

Duration within the PAR:
6 hours

Peak category within the PAR:
Tropical Storm

Highest wind signal hoisted:
None

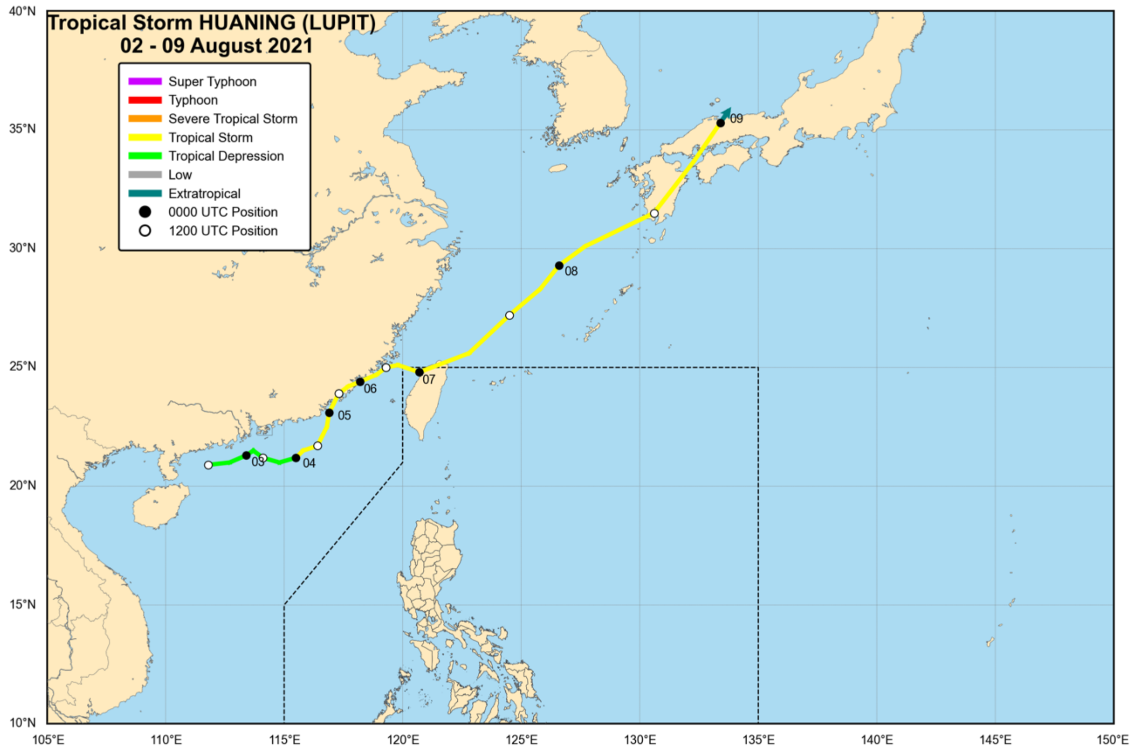


Fig. 4.8.1. Best track position and intensities of Tropical Storm HUANING

Summary of Meteorological History

Table 4.8.1. Key information about Tropical Storm HUANING.

Parameter	Details
First tracked as a tropical low pressure area	00 UTC, 02 August 2021 In the vicinity of Guangxi, China
Developed into a TC	12 UTC, 02 August 2021 Over the West Philippine Sea off the coast of Guangdong, China
Transitioned into a post-tropical low	00 UTC, 09 August 2021 In the vicinity of Saihaku District, Tottori, Japan
Period of occurrence (lifetime)	6 days and 12 hours
Entered the PAR region	21 UTC, 06 August 2021
Exited the PAR region	03 UTC, 07 August 2021
Period of occurrence (within the PAR)	6 hours
Peak intensity (lifetime)	Tropical Storm: 45 kt (85 km/h), 985 hPa 18 UTC, 04 August 2021 18 UTC, 08 August 2021
Peak intensity (within the PAR region)	Tropical Storm: 35 kt (65 km/h), 992 hPa 00 UTC, 07 August 2021
Observed landfalls	**Philippines:** None **Elsewhere:** 0320 UTC, 05 August 2021 (TS): Shantou City, Guangdong, China (Nan'ao Is.) 0850 UTC, 05 August 2021 (TS): Zhangzhou City, Fujian, China 0010 UTC, 06 August 2021 (TS): Kinmen, Taiwan (Lesser Kinmen Is.) 0100 UTC, 06 August 2021 (TS): Kinmen, Taiwan (Kinmen Is.) 0100 UTC, 07 August 2021 (TS): Hsinchu City, Taiwan 1100 UTC, 08 August 2021 (TS): Minamisatsuma City, Kagoshima, Japan 1900 UTC, 08 August 2021 (TS): Suō-Ōshima, Yamaguchi, Japan 1930 UTC, 08 August 2021 (TS): Kure City, Hiroshima, Japan (Kurahashi-jima Is.) 2000 UTC, 08 August 2021 (TS): Kure City, Hiroshima, Japan (mainland)

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.8.2. Highest storm duration (7 August 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Echague, Isabela	64.3
General Santos City	47.2
Baguio City	27.0
Pili, Camarines Sur	14.4
La Trinidad, Benguet	13.6

Table 4.8.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Echague, Isabela	64.3	07 August, 2021
General Santos City	47.2	07 August, 2021
Baguio City	27.0	07 August, 2021
Pili, Camarines Sur	14.4	07 August, 2021
La Trinidad, Benguet	13.6	07 August, 2021

Summary of Warning Information

Number of TC products issued
- Tropical Cyclone Bulletins: **2**
- Tropical Cyclone Advisories: **0**
- Tropical Cyclone Warning for Shipping issued: **2**
- WC SIGMET: **0**

Hoisting of TC Wind Signals
- Highest wind signal level hoisted: **None**
- No. of provinces with hoisted wind signal: **0**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **No report**
Total cost of damage: **No report**
- Damage to agriculture: **No report**
- Damage to infrastructure: **No report**

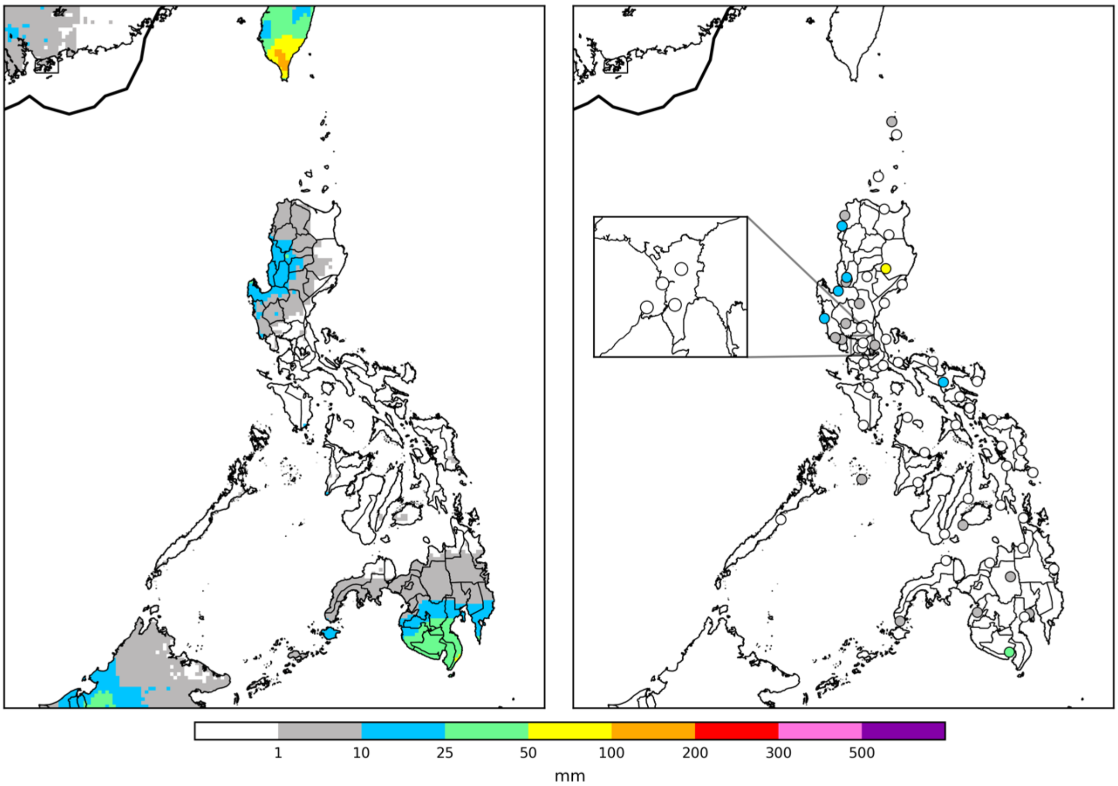
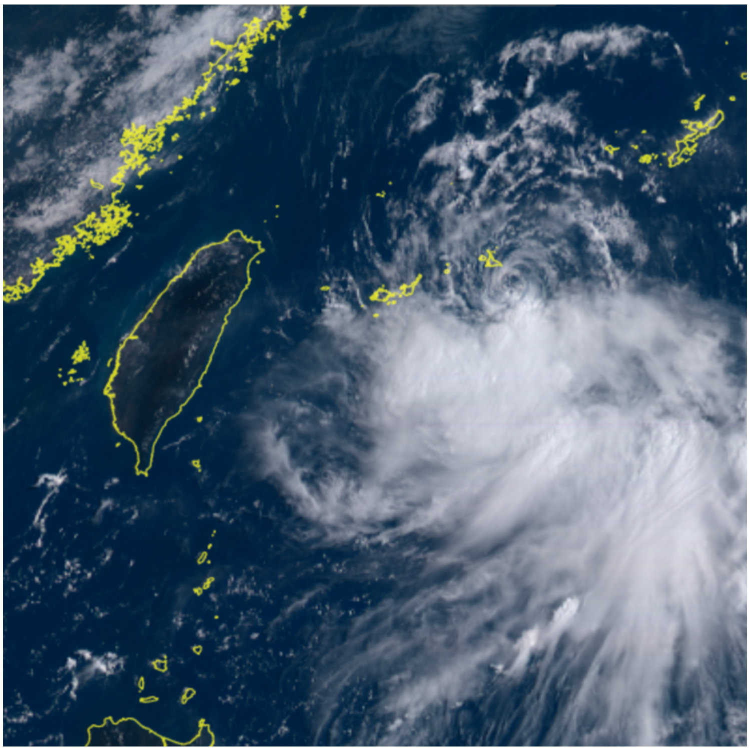


Fig. 4.8.2. Storm duration rainfall over land during the passage of Tropical Storm HUANING within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line on the upper left corner of the figure.

Severe Tropical Storm ISANG
OMAIS (2112)

10 to 24 August 2021



Basin-wide peak intensity:
Severe Tropical Storm
55 kt (100 km/h)
992 hPa

Developed:
12 UTC, 10 August 2021

Transitioned:
00 UTC, 24 August 2021

Duration within the PAR:
3 days and 5 hours

Peak category within the PAR:
Severe Tropical Storm

Highest wind signal hoisted:
None

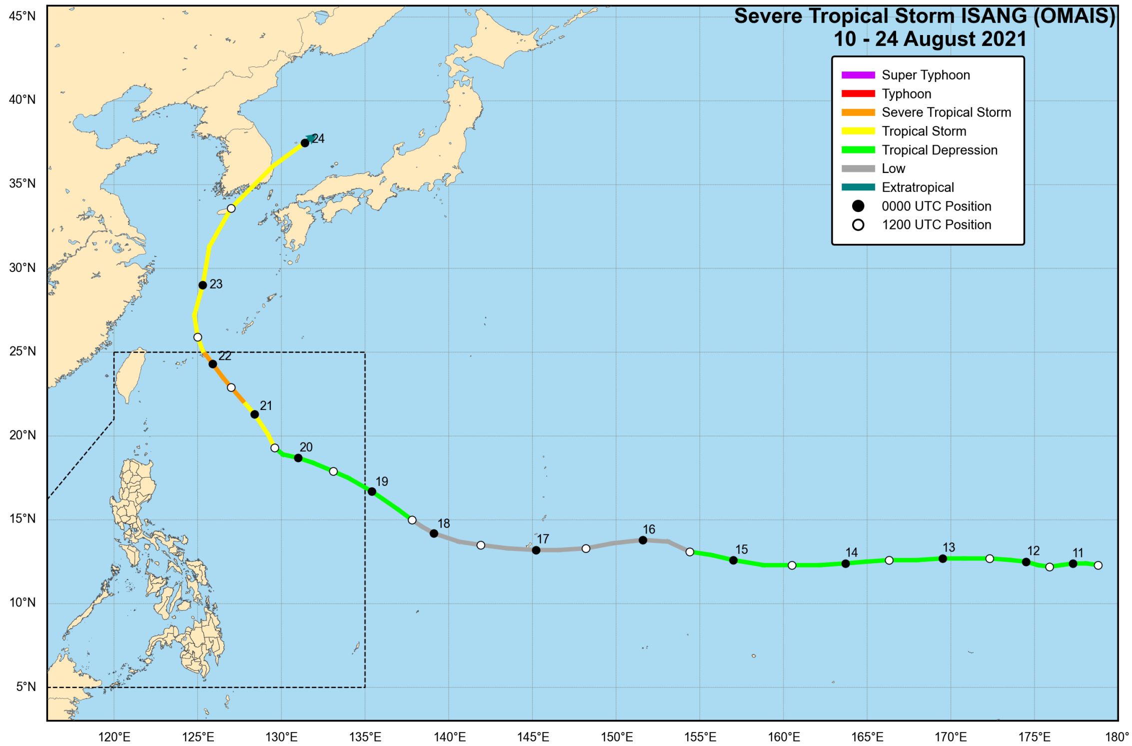


Fig. 4.9.1. Best track position and intensities of Severe Tropical Storm ISANG

Summary of Meteorological History

Table 4.9.1. Key information about Severe Tropical Storm ISANG.

Parameter	Details
First tracked as a tropical low pressure area	00 UTC, 06 August 2021 Over the sea northwest of Line Islands, Kiribati
Developed into a TC	12 UTC, 10 August 2021 Over the sea northeast of Marshall Islands
Transitioned into a post-tropical low	00 UTC, 24 August 2021 Over the Sea of Japan off the coast of North Gyeongsang, South Korea (Ulleung Is.)
Period of occurrence (lifetime)	10 days and 12 hours*
Entered the PAR region	01 UTC, 19 August 2021
Exited the PAR region	06 UTC, 22 August 2021
Period of occurrence (within the PAR)	3 days and 5 hours
Peak intensity (lifetime)	Severe Tropical Storm: 55 kt (100 km/h), 992 hPa 12 UTC, 21 August 2021
Peak intensity (within the PAR region)	Severe Tropical Storm: 55 kt (100 km/h), 992 hPa 12 UTC, 21 August 2021
Observed landfalls	**Philippines:** None **Elsewhere:** 1140 UTC, 23 August 2021 (TS): Seogwipo City, Jeju, South Korea 1350 UTC, 23 August 2021 (TS): Yeosu City, South Jeolla, South Korea (Yeondo Is.) 1430 UTC, 23 August 2021 (TS): Tongyeong City, South Gyeongsang, South Korea (Hado Is.) 1450 UTC , 23 August 2021 (TS): Goseong County, South Gyeongsang, South Korea

* During its period of occurrence, ISANG degenerated into a tropical low on 12 UTC, 15 August 2021. It re-developed into a tropical depression on 12 UTC, 18 August 2021.

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.9.2. Highest storm duration (19 to 22 August 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Echague, Isabela	120.2
Pili, Camarines Sur	109.0
Indang, Cavite	100.9
Muñoz City, Nueva Ecija	98.2
Bayombong, Nueva Vizcaya	87.7

Table 4.9.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Virac, Catanduanes	73.2	20 August, 2021
Bayombong, Nueva Vizcaya	72.8	20 August, 2021
Ambulong, Tanauan City, Batangas	64.6	19 August, 2021
Indang, Cavite	61.6	21 August, 2021
Echague, Isabela	60.1	20 August, 2021

Summary of Warning Information

Number of TC products issued

- Tropical Cyclone Bulletins: **14**
- Tropical Cyclone Advisories: **1**
- Tropical Cyclone Warning for Shipping issued: **14**
- WC SIGMET: **2**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **None**
- No. of provinces with hoisted wind signal: **0**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **No report**
Total cost of damage: **No report**

- Damage to agriculture: **No report**
- Damage to infrastructure: **No report**

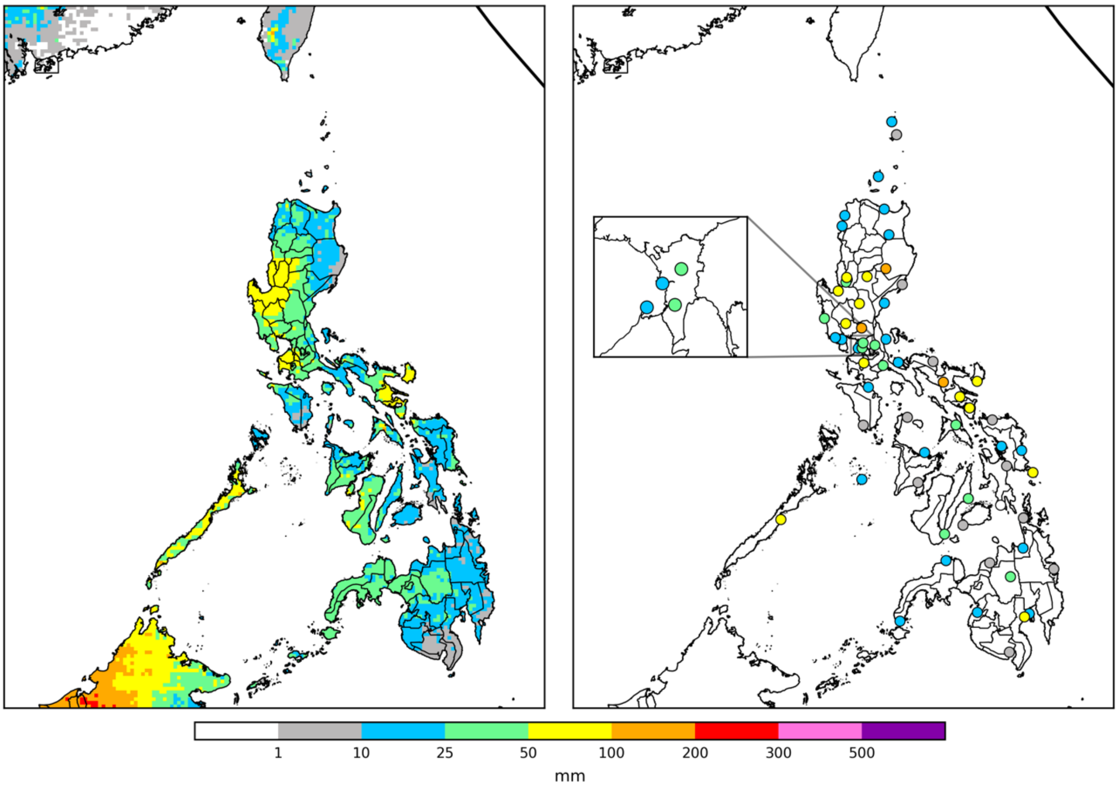
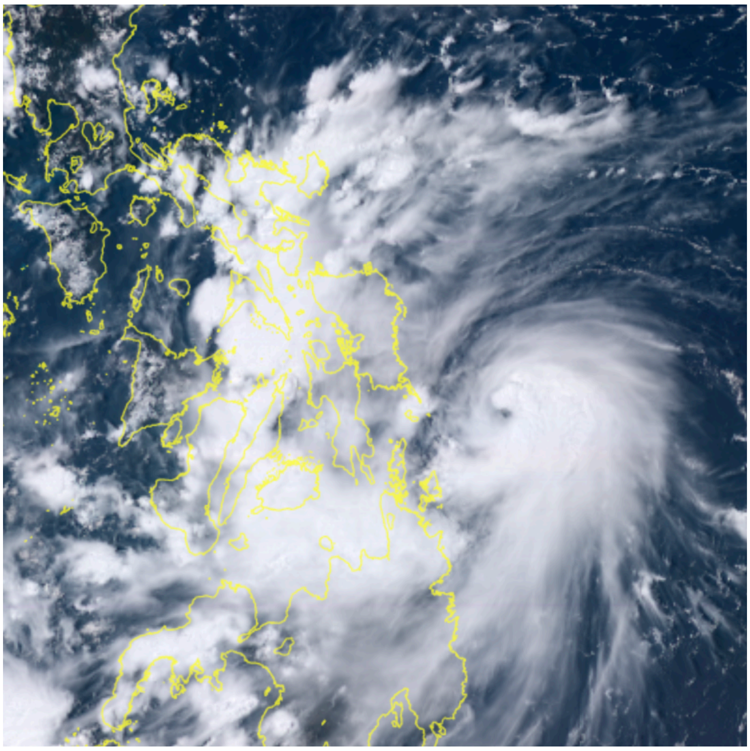


Fig. 4.9.2. Storm duration rainfall over land during the passage of Severe Tropical Storm ISANG within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line on the upper right corner of the figure.

Typhoon JOLINA
CONSON (2113)

05 to 13 September 2021



Basin-wide peak intensity:
Typhoon
65 kt (120 km/h)
985 hPa

Developed:
06 UTC, 05 September 2021

Degenerated:
00 UTC, 13 September 2021

Duration within the PAR:
4 days and 7 hours

Peak category within the PAR:
Typhoon

Highest wind signal hoisted:
Wind Signal No. 3

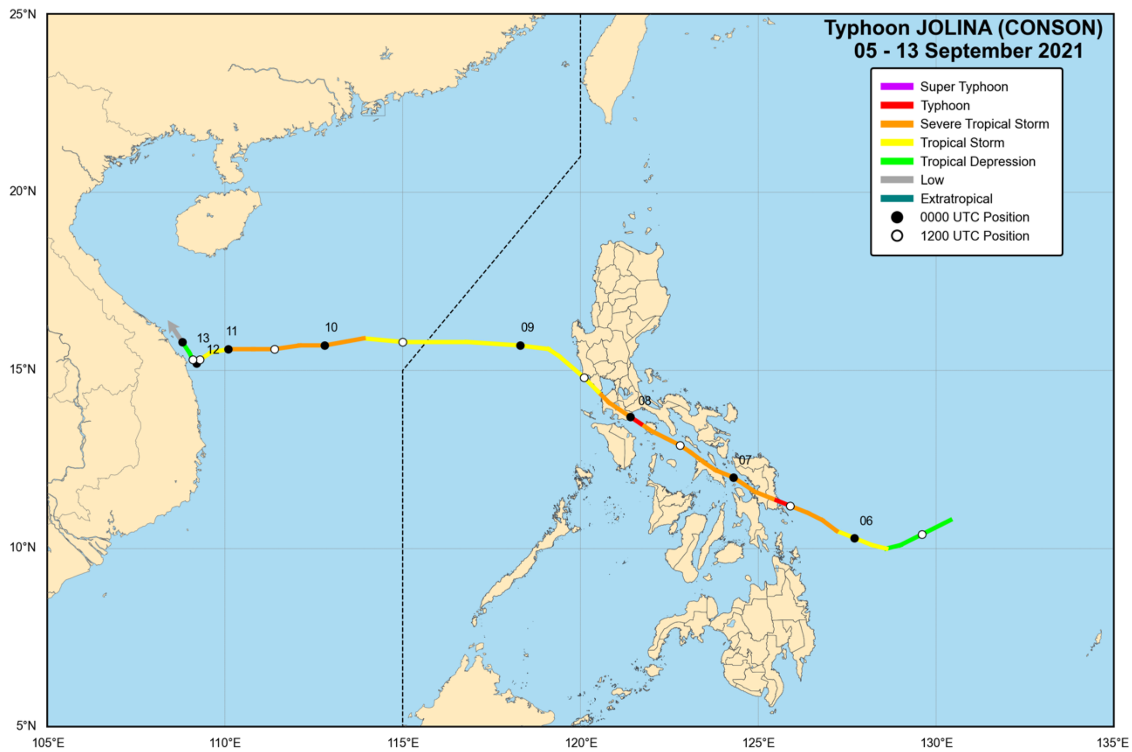


Fig. 4.10.1. Best track position and intensities of Typhoon JOLINA.

Summary of Meteorological History

Table 4.9.1. Key information about Typhoon JOLINA.

Parameter	Details
First tracked as a tropical low pressure area	18 UTC, 04 September 2021 Over the Philippine Sea far east of Eastern Visayas
Developed into a TC	06 UTC, 05 September 2021 Over the Philippine Sea east of Eastern Visayas
Weakened into a remnant low	00 UTC, 13 September 2021 Over the West Philippine Sea off the coast of Quảng Nam, Vietnam
Period of occurrence (lifetime)	7 days and 18 hours
Entered the PAR region	Not applicable
Exited the PAR region	13 UTC, 09 September 2021
Period of occurrence (within the PAR)	4 days and 7 hours
Peak intensity (lifetime)	Typhoon: 65 kt (120 km/h), 985 hPa 12 UTC, 06 September 2021 21 UTC, 07 September 2021*
Peak intensity (within the PAR region)	Typhoon: 65 kt (120 km/h), 985 hPa 12 UTC, 06 September 2021 21 UTC, 07 September 2021*
Observed landfalls	**Philippines:** 1400 UTC, 06 September 2021 (TY): Hernani, Eastern Samar 1750 UTC, 06 September 2021 (STS): Villareal, Samar (Lamingao Is.) 1800 UTC, 06 September 2021 (STS): Villareal, Samar (Guintarcan Is.) 1910 UTC, 06 September 2021 (STS): Daram, Samar 2230 UTC, 06 September 2021 (STS): Santo Niño, Samar (Santo Niño Is.) 2320 UTC, 06 September 2021 (STS): Almagro, Samar (Kerikite Is.) 0040 UTC, 07 September 2021 (STS): Tagapul-an, Samar 0200 UTC, 07 September 2021 (STS): Palanas, Masbate 1740 UTC, 07 September 2021 (STS): Torrijos, Marinduque 2340 UTC, 07 September 2021 (TY): San Juan, Batangas 0900 UTC, 08 September 2021 (TS): Mariveles, Bataan 1130 UTC, 08 September 2021 (TS): San Antonio, Zambales **Elsewhere:** None

* A second peak intensity was determined through best track analysis. Refer to Fig. 4.10.6 for context.

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.10.2. Highest storm duration (05 to 09 September 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Tayabas City, Quezon	313.4
Mt. Cabuyao, Tuba, Benguet	276.8
Indang, Cavite	240.5
La Trinidad, Benguet	232.1
Guiuan, Eastern Samar	199.4

Table 4.10.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Mt. Cabuyao, Tuba, Benguet	187.8	09 September 2021
Tayabas City, Quezon	166.8	08 September 2021
Catbalogan City, Samar	152.1	06 September 2021
Guiuan, Eastern Samar	150.1	06 September 2021
Tacloban City, Leyte	141.2	06 September 2021

Table 4.10.4. Lowest mean sea level pressure over land.

Location of weather station	Minimum MSLP (hPa)	Date (MM/DD) and Time (UTC)
Guiuan, Eastern Samar	991.6	09/06 1300
Catbalogan City, Samar	993.4	09/06 1800
Masbate City, Masbate	997.2	09/07 0400
Ambulong, Tanauan City, Batangas	998.2	09/08 0500
Calapan City, Oriental Mindoro	1001.1	09/08 0000

Table 4.10.5. Highest peak gust over land.

Location of weather station	Peak gust speed (m/s)	Peak gust direction	Date and Time (UTC)
Guiuan, Eastern Samar	38	W (260)	09/06 1230
Ambulong, Tanauan City, Batangas	24	N (360)	09/08 0336
Tanay, Rizal	23	SSE (160)	09/06 1840
Catbalogan City, Samar	22	N (360)	09/06 1822
Borongan City, Eastern Samar	20	NE (040)	09/06 1315
Masbate City, Masbate	20	ENE (070)	09/07 0319

Summary of Warning Information

Number of TC products issued

- Tropical Cyclone Bulletins: **26**
- Tropical Cyclone Advisories: **0**
- Tropical Cyclone Warning for Shipping issued: **16**
- WC SIGMET: **14**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **Wind Signal No. 3**
- No. of provinces with hoisted wind signal: **42**

Reported Casualties and Cost of Damage
Based on reports from the Office of Civil Defense

Number of reported casualties: **20 dead, 33 injured, and 4 missing**
Total cost of damage: **PHP 1,412,897,089.10**

- Damage to agriculture: **PHP 1,349,221,036.10**
- Damage to infrastructure: **PHP 63,676,053.00**

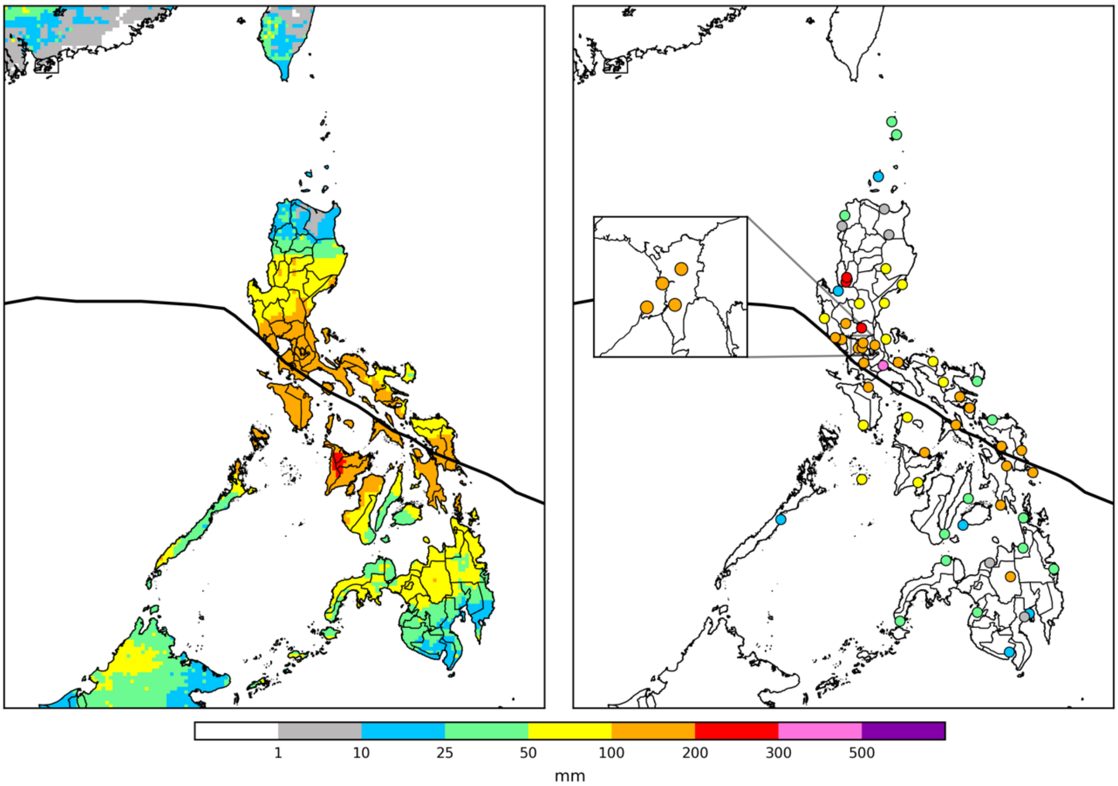


Fig. 4.10.2. Storm duration rainfall over land during the passage of Typhoon JOLINA within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line.

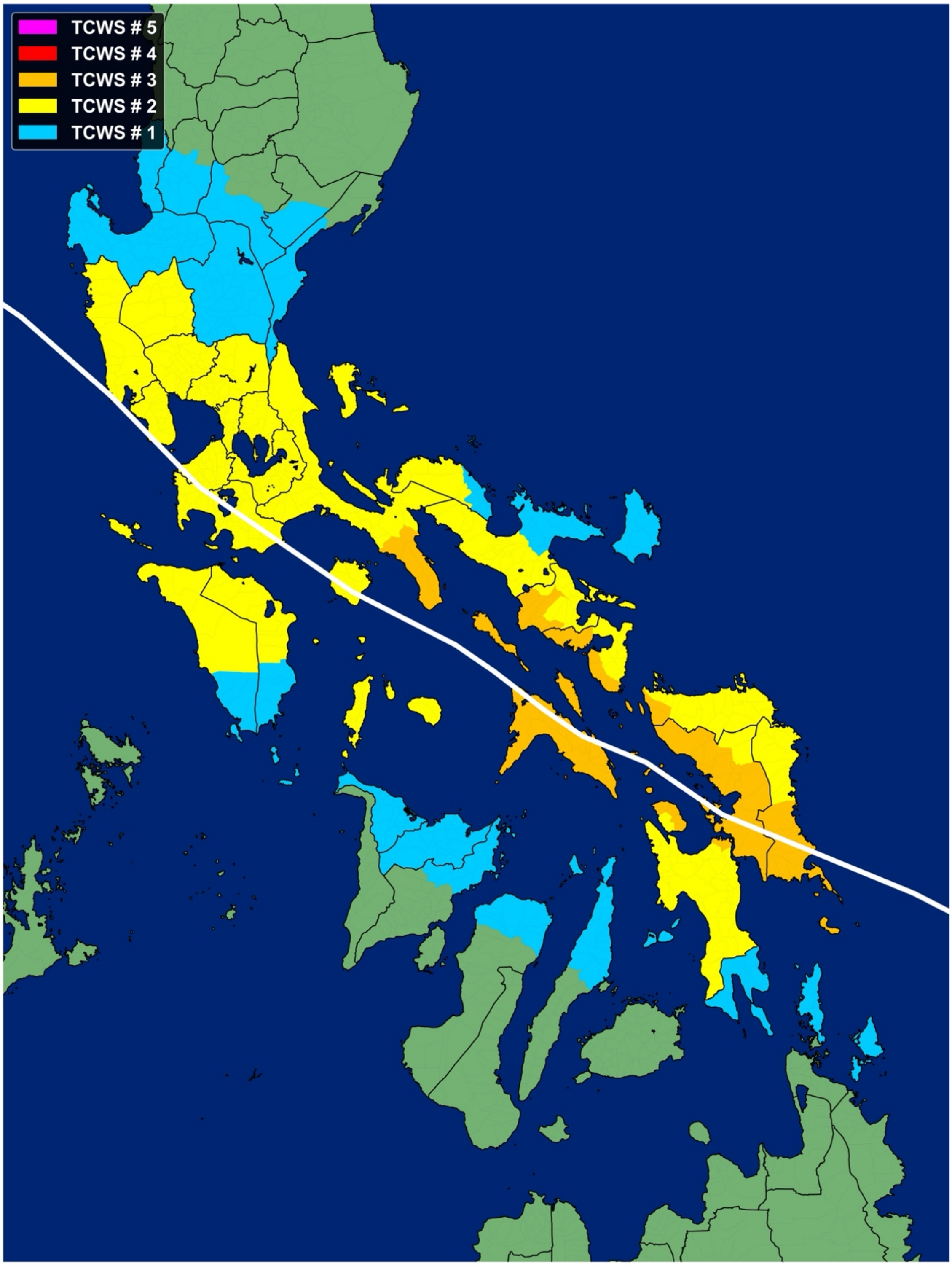


Fig. 4.10.3. Distribution of highest level wind signal hoisted per province or sub-provincial locality during the passage of Typhoon JOLINA. The best track is also overlaid as a solid thick white line.

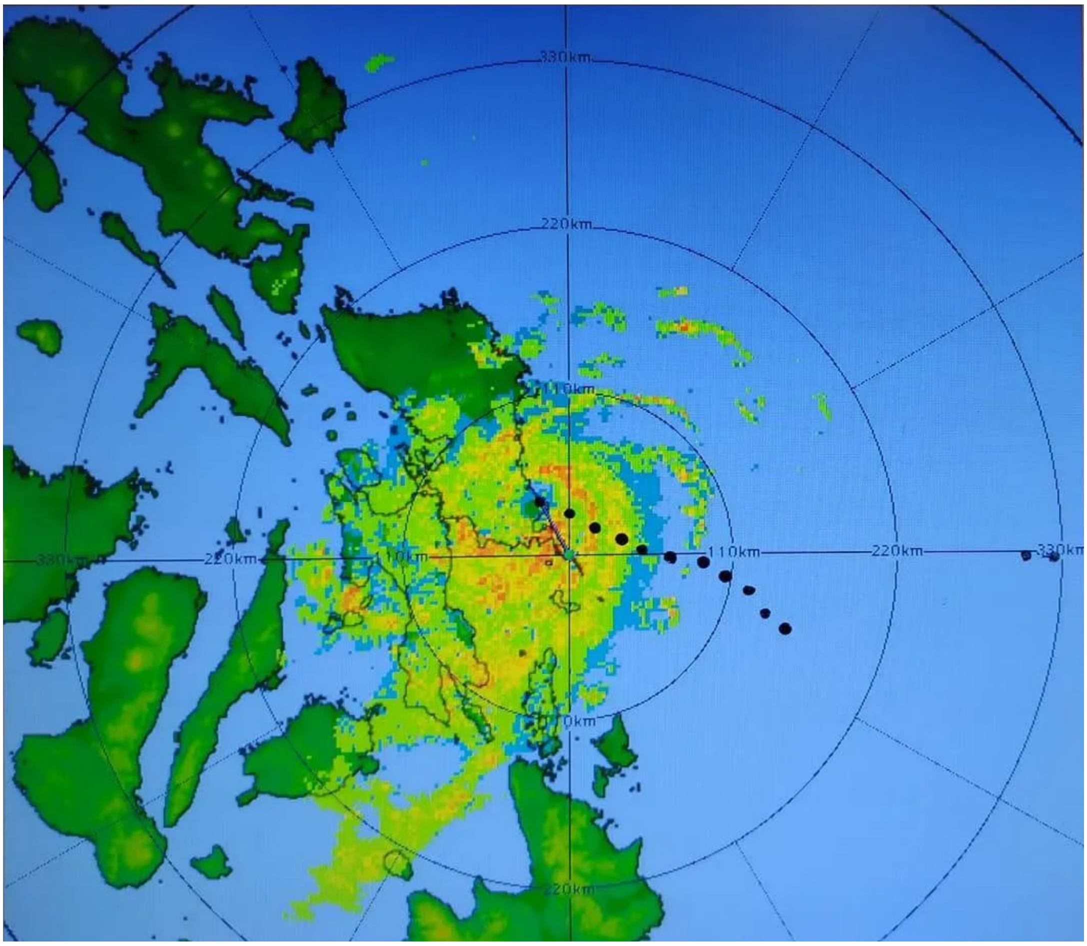


Fig. 4.10.4. Radar imagery PPI 440-km range) of Typhoon JOLINA at 1400 UTC, 06 September 2021 while making landfall over Hernani, Eastern Samar. Data from the PAGASA Guiuan Weather Surveillance Radar Station. Black dots were radar eye fix marks from the station personnel. Radar images, along with Fig. 4.10.5 and surface weather observation from Guiuan Synoptic Weather Station, triggered the upgrading of JOLINA into a typhoon as 1200 UTC of the same day – the only meteorological center to do so during the warning period.

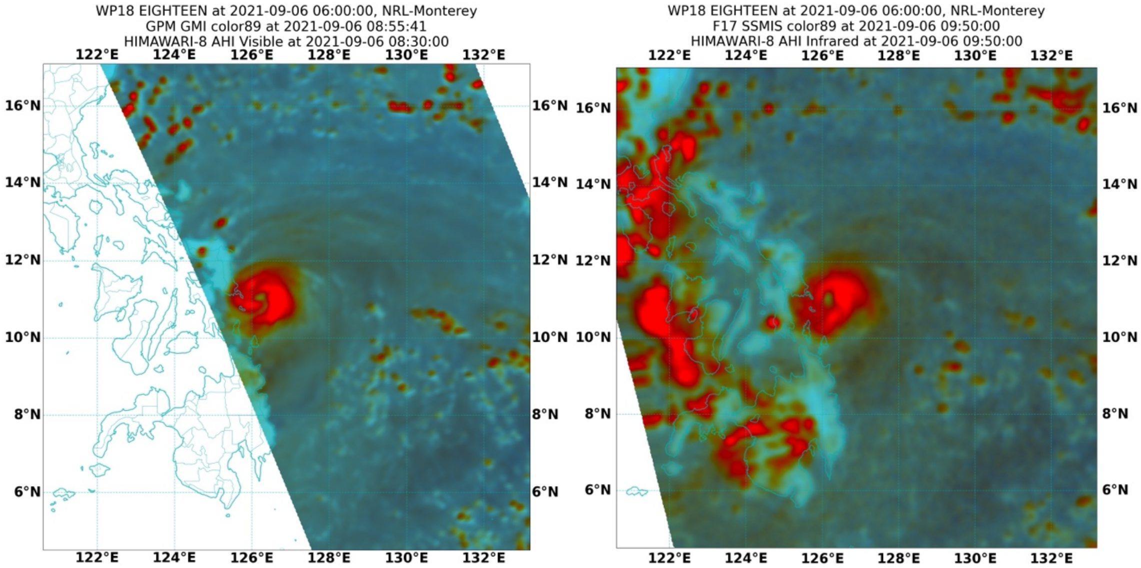


Fig. 4.10.5. Color-enhanced 89 GHz microwave overpass of then-Severe Tropical Storm JOLINA over the waters off Eastern Samar at 0855 UTC (left) and 0950 UTC (right) on 06 September 2021. These images, along with Fig. 4.10.4 and surface weather observation from Guiuan Synoptic Weather Station, triggered the upgrading of JOLINA into a typhoon as 1200 UTC of the same day – the only meteorological center to do so during the warning period. Image courtesy of US Naval Research Laboratory – Monterey.

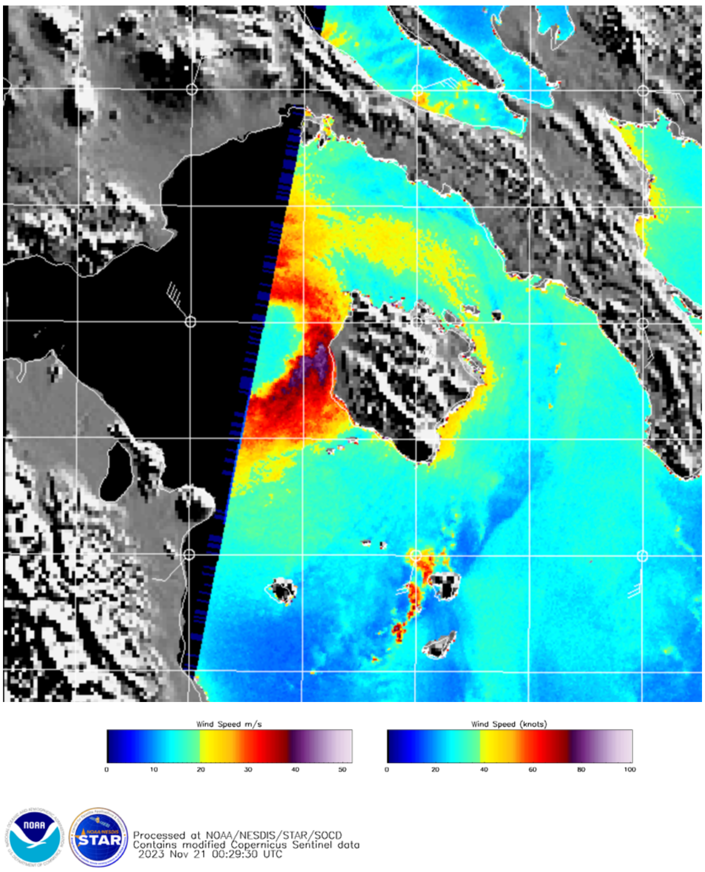
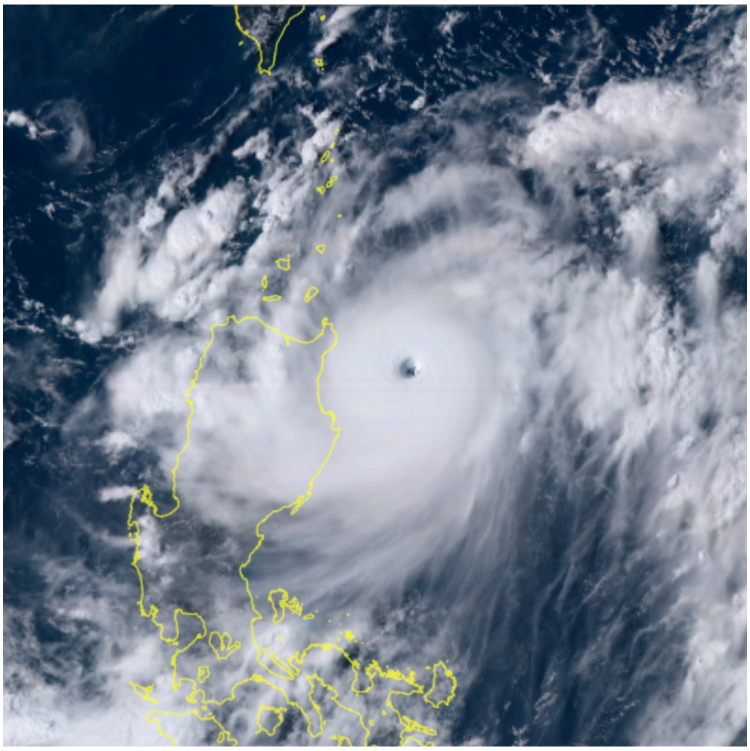


Fig. 4.10.6. 10-m wind speed estimates over the location of Typhoon JOLINA and its surrounding waters from a synthetic aperture radar overpass at 2139 UTC, 07 September 2021. This post-real time data resulted in JOLINA's second intensification into Typhoon category in the PAGASA best track data. Data from NOAA/NESDIS/STAR.

Super Typhoon KIKO
CHANTHU (2114)

05 to 18 September 2021



Basin-wide peak intensity:
Super Typhoon
115 kt (215 km/h)
910 hPa

Developed:
18 UTC, 05 September 2021

Transitioned:
06 UTC, 18 September 2021

Duration within the PAR:
4 days and 20 hours

Peak category within the PAR:
Super Typhoon

Highest wind signal hoisted:
Wind Signal No. 4

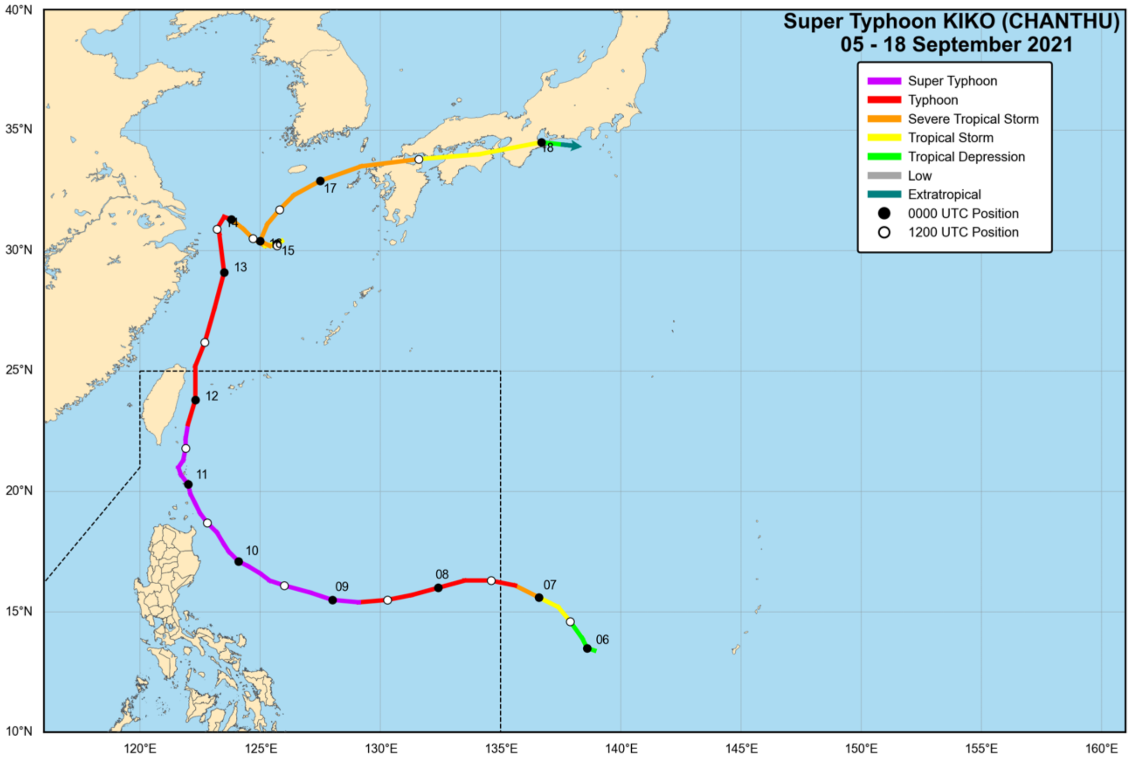


Fig. 4.11.1. Best track position and intensities of Super Typhoon KIKO.

Summary of Meteorological History

Table 4.9.1. Key information about Super Typhoon KIKO.

Parameter	Details
First tracked as a tropical low pressure area	06 UTC, 05 September 2021 Over the Philippine Sea southwest of Guam (US)
Developed into a TC	18 UTC, 05 September 2021 Over the Philippine Sea west of Guam (US)
Transitioned into a post-tropical low	06 UTC, 18 September 2021 Over the sea off the coast of Shizuoka, Japan
Period of occurrence (lifetime)	12 days and 12 hours
Entered the PAR region	10 UTC, 07 September 2021
Exited the PAR region	06 UTC, 12 September 2021
Period of occurrence (within the PAR)	4 days and 20 hours
Peak intensity (lifetime)	Super Typhoon: 115 kt (215 km/h), 910 hPa 06 UTC, 10 September 2021
Peak intensity (within the PAR region)	Super Typhoon: 115 kt (215 km/h), 910 hPa 06 UTC, 10 September 2021
Observed landfalls	**Philippines:** 0030 UTC, 11 September 2021 (STY): Ivana, Batanes **Elsewhere:** 0930 UTC, 17 September 2021 (STS): Fukutsu City, Fukuoka, Japan 1330 UTC, 17 September 2021 (TS): Kaminoseki City, Yamaguchi, Japan (Nagashima Is.) 1340 UTC, 17 September 2021 (TS): Kaminoseki City, Yamaguchi, Japan (mainland) 1400 UTC, 17 September 2021 (TS): Suō-Ōshima, Yamaguchi, Japan 1600 UTC, 17 September 2021 (TS): Matsuyama City, Ehime, Japan (Gogo Is.) 1620 UTC, 17 September 2021 (TS): Matsuyama City, Ehime, Japan (mainland/Shikoku Is.) 2110 UTC, 17 September 2021 (TS): Wakayama City, Wakayama, Japan

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.11.2. Highest storm duration (07 to 12 September 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Itbayat, Batanes	688.2
Basco, Batanes	604.9
Iba, Zambales	345.4
Abucay, Bataan	337.4
Cubi Point, Subic Bay International Airport	332.8

Table 4.11.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Itbayat, Batanes	510.0	11 September 2021
Basco, Batanes	420.7	11 September 2021
Mt. Cabuyao, Tuba, Benguet	187.8	09 September 2021
Tayabas City, Quezon	166.8	08 September 2021
Iba, Zambales	137.2	11 September 2021

Table 4.11.4. Lowest mean sea level pressure over land.

Location of weather station	Minimum MSLP (hPa)	Date (MM/DD) and Time (UTC)
Basco, Batanes	927.9	09/11 0000
Calayan, Cagayan	996.2	09/10 1900
Aparri, Cagayan	1000.9	09/10 1800
Tuguegarao City, Cagayan	1002.1	09/10 1700
Baguio City	1002.4	09/09 0600 09/10 0600

Note: Itbayat Synoptic Weather Station may have similar or lower minimum MSLP, but was not recorded since the barometer was inoperative at the time of passage.

Table 4.11.5. Highest peak gust over land.

Location of weather station	Peak gust speed (m/s)	Peak gust direction	Date and Time (UTC)
Basco, Batanes	86	ESE(120)	09/10 2350
Itbayat, Batanes	60	E(090)	09/11 0140
Calayan, Cagayan	30	W(270)	09/10 1900-2000*
Aparri, Cagayan	15	NNE(020)	09/10 0545
Baler, Aurora	13	W(270)	09/09 2040
Laoag City, Ilocos Norte	13	WSW(250) S(180)	09/11 0325 09/12 0244

* No specific time reported, but happened within this range of synoptic hours.
Note: The wind instrument at Basco Synoptic Weather Station was totally damaged after the 86 m/s peak gust was observed.

Summary of Warning Information

Number of TC products issued

- Tropical Cyclone Bulletins: **29**
- Tropical Cyclone Advisories: **4**
- Tropical Cyclone Warning for Shipping issued: **20**
- WC SIGMET: **12**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **Wind Signal No. 4**
- No. of provinces with hoisted wind signal: **9**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **0 dead, 27 injured, and 0 missing**
Total cost of damage: **PHP 37,354,667.52**

- Damage to agriculture: **PHP 37,354,667.52**
- Damage to infrastructure: **No report**

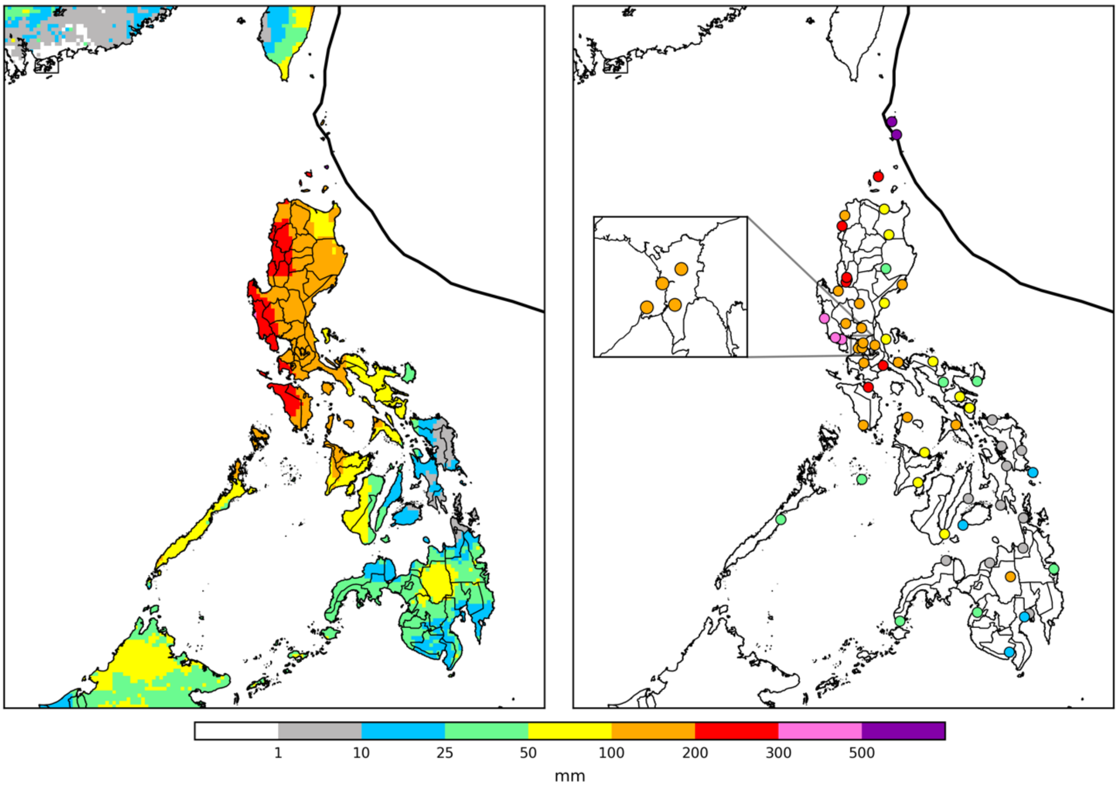


Fig. 4.11.2. Storm duration rainfall over land during the passage of Super Typhoon KIKO within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line.

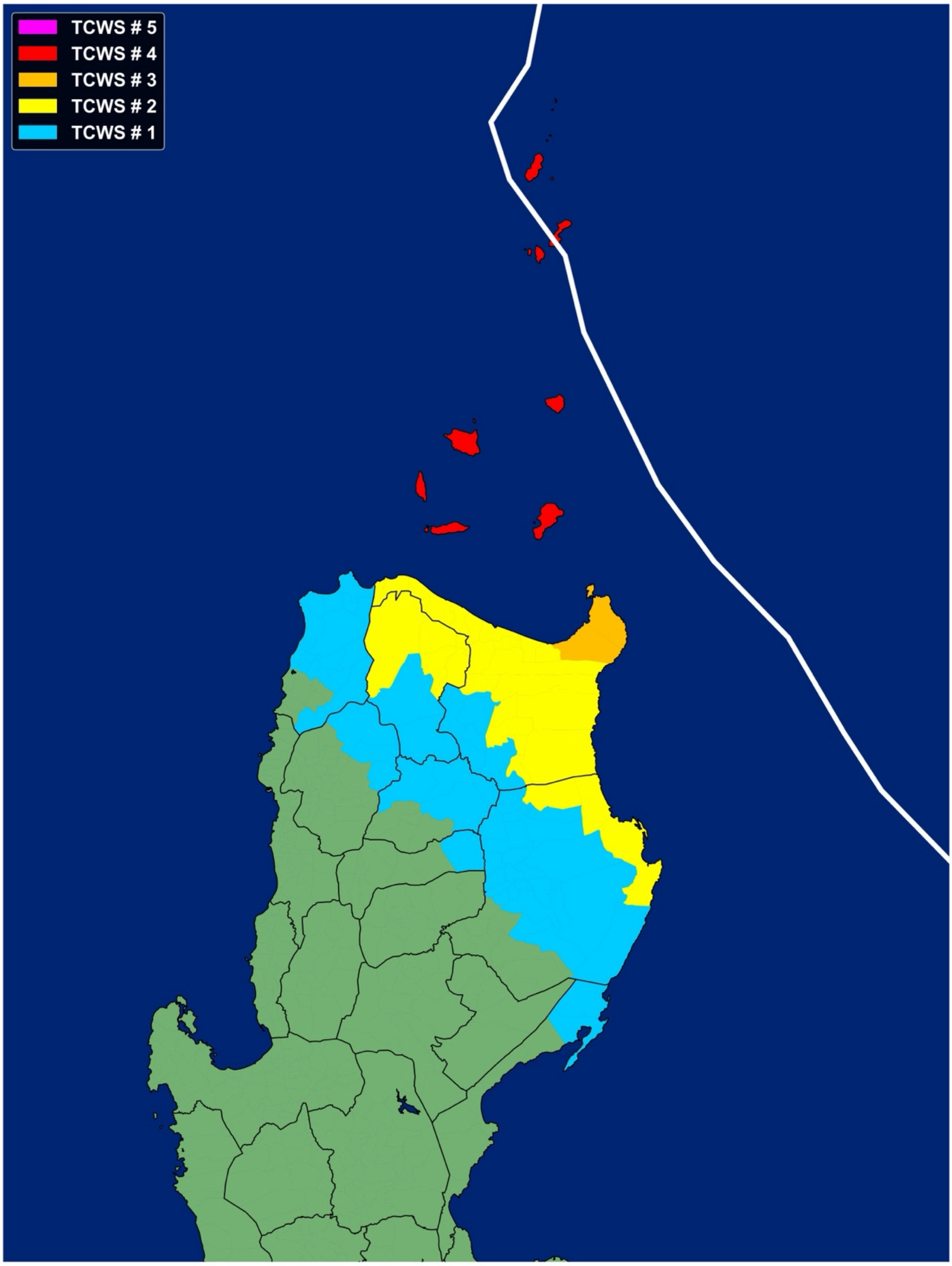


Fig. 4.11.3. Distribution of highest level wind signal hoisted per province or sub-provincial locality during the passage of Super Typhoon KIKO. The best track is also overlaid as a solid thick white line.

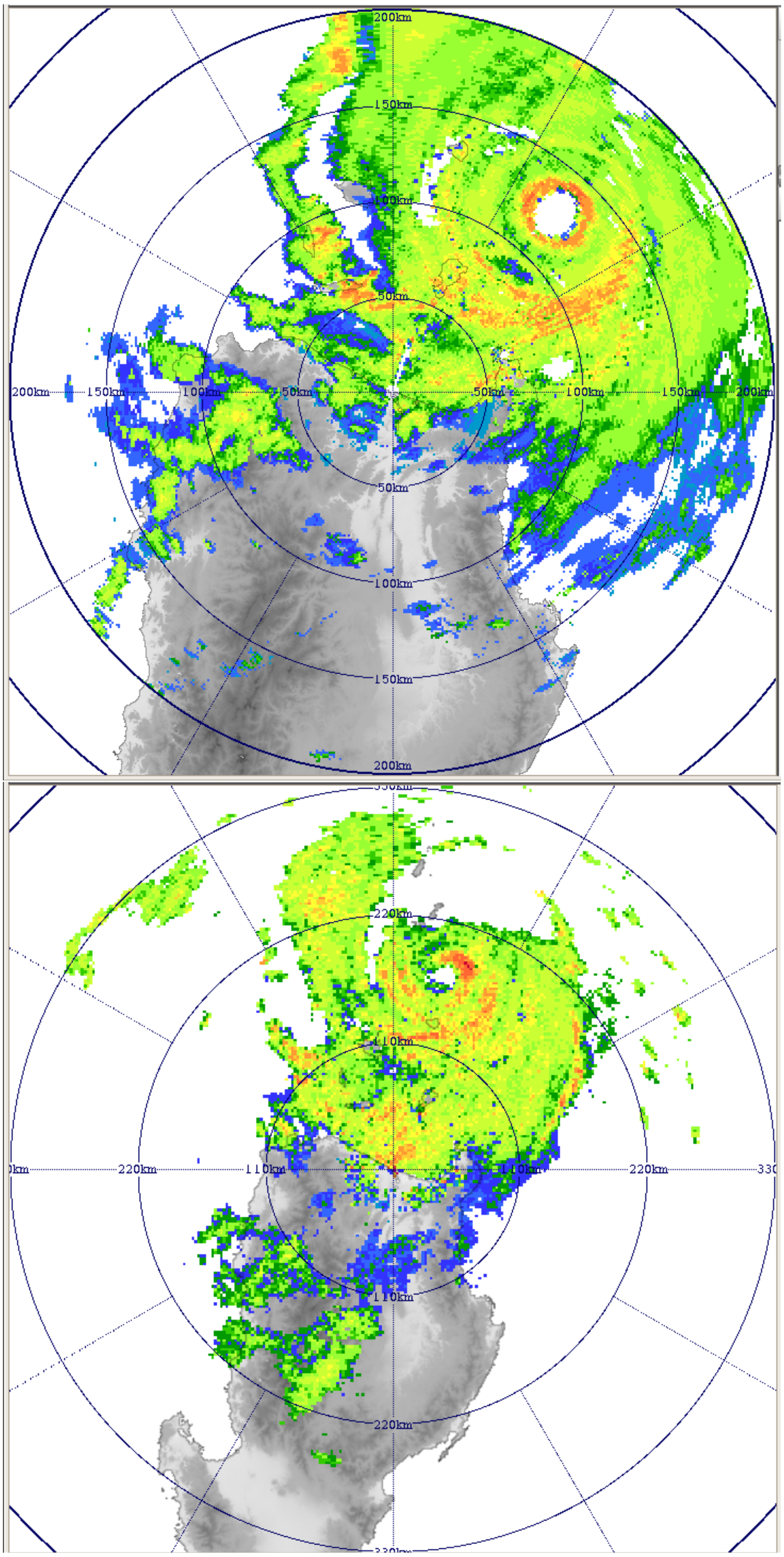


Fig. 4.11.4. Radar imagery of Super Typhoon KIKO at 1555 UTC (top; 1-km CAPPI 200-km range) and 2100 UTC (bottom; PPI 440-km range), 10 September 2021 while moving towards Batanes at peak intensity. Data from the PAGASA Aparri Weather Surveillance Radar Station. Concentric eyewall signature can be noted on both images.

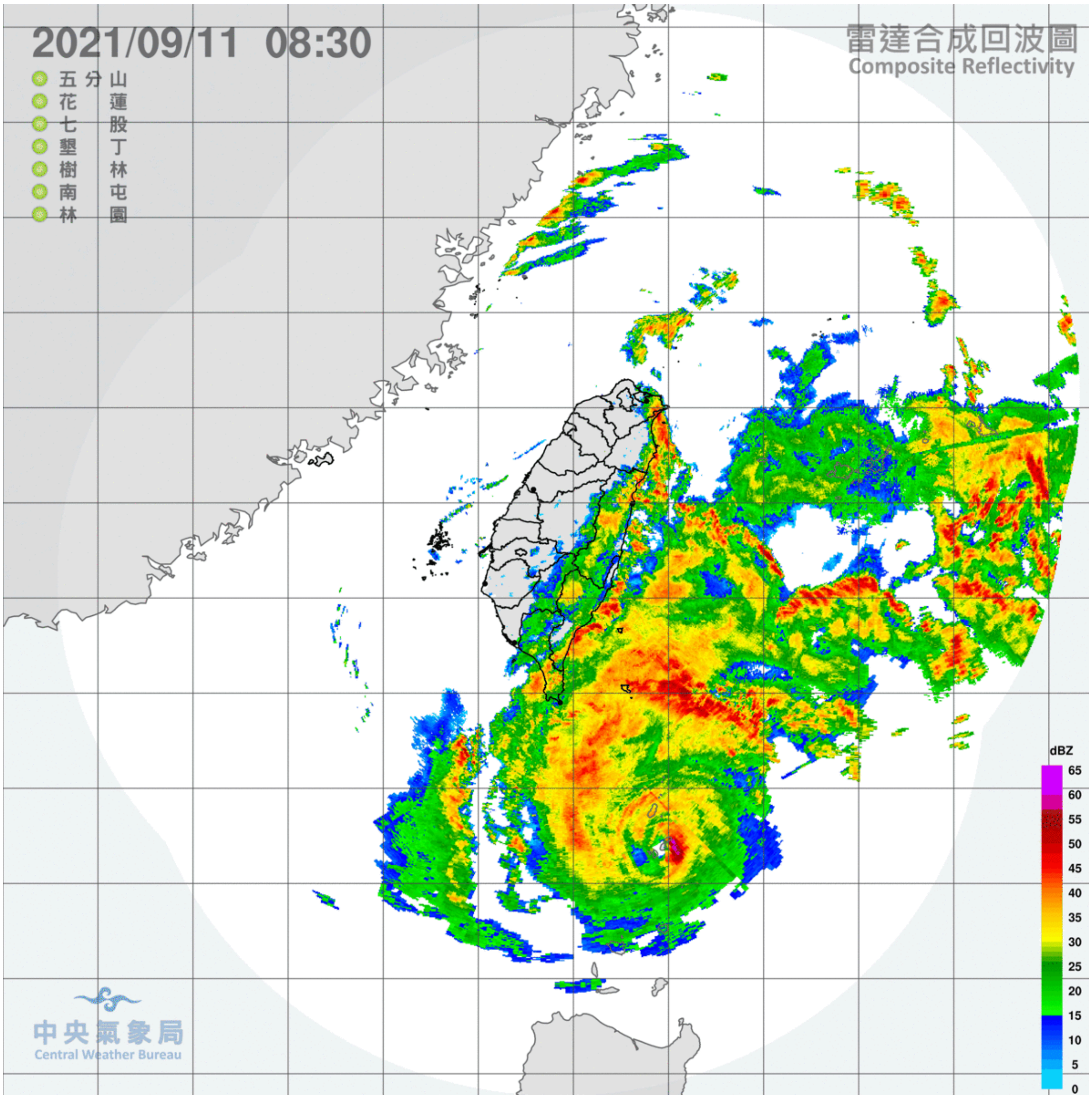
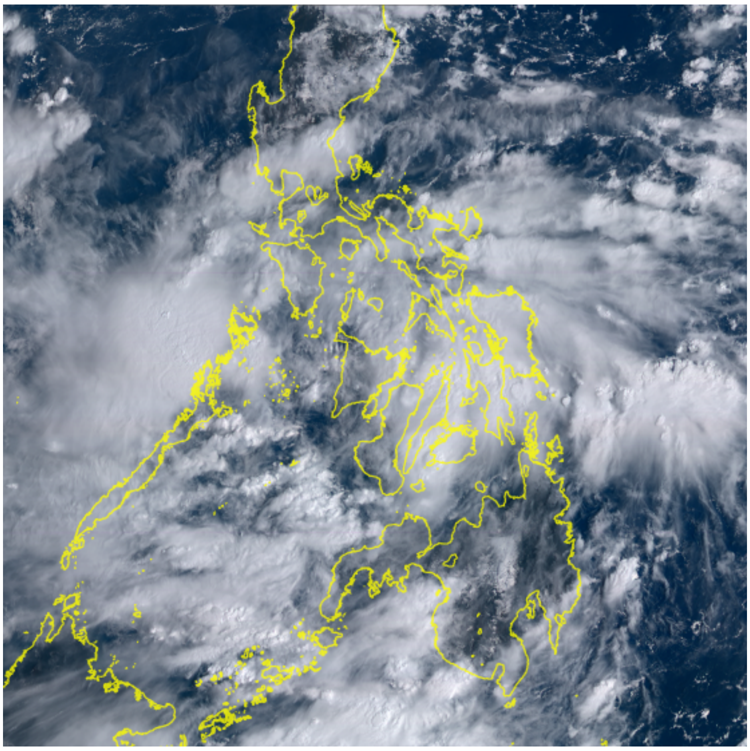


Fig. 4.11.5. Composite radar reflective image of Super Typhoon KIKO at 0030 UTC, 11 September 2021 at the time of landfall in Ivana, Batanes. Deterioration of eyewall region is evident in this stage of KIKO's passage. Image courtesy of Central Weather Administration of Taiwan.

Tropical Storm LANNIE
LIONROCK (2117)

03 to 10 October 2021



Basin-wide peak intensity:
Tropical Storm
35 kt (65 km/h)
992 hPa

Developed:
12 UTC, 03 October 2021

Degenerated:
18 UTC, 10 October 2021

Duration within the PAR:
2 days and 9 hours

Peak category within the PAR:
Tropical Storm

Highest wind signal hoisted:
Wind Signal No. 1

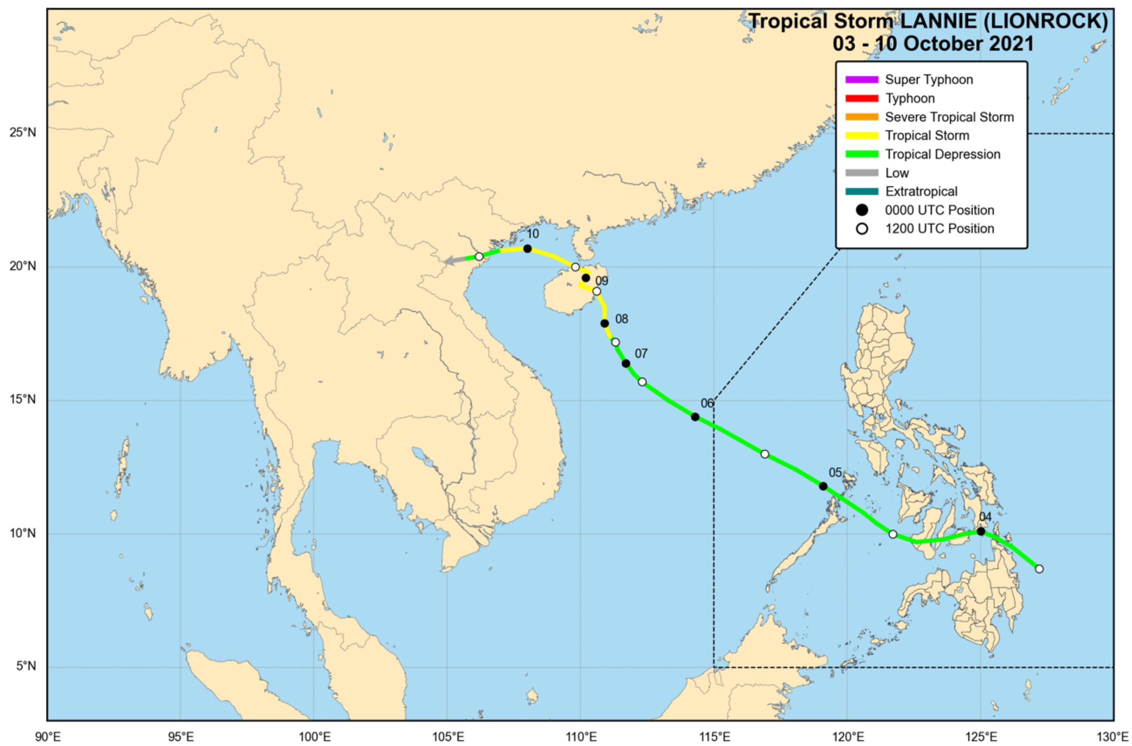


Fig. 4.12.1. Best track position and intensities of Tropical Storm LANNIE.

Summary of Meteorological History

Table 4.12.1. Key information about Tropical Storm LANNIE.

Parameter	Details
First tracked as a tropical low pressure area	18 UTC, 01 October 2021 Over the sea near Yap, Federated States of Micronesia
Developed into a TC	12 UTC, 03 October 2021 Over the Philippine Sea off the coast of Surigao del Sur
Weakened into a remnant low	18 UTC, 10 October 2021 In the vicinity of Thạch Thành District, Thanh Hoa, Vietnam
Period of occurrence (lifetime)	7 days and 6 hours
Entered the PAR region	Not applicable
Exited the PAR region	21 UTC, 05 October 2021
Period of occurrence (within the PAR)	2 days and 9 hours
Peak intensity (lifetime)	Tropical Storm: 35 kt (65 km/h), 992 hPa 00 UTC, 08 October 2021
Peak intensity (within the PAR region)	Tropical Depression: 25 kt (45 km/h), 1002 hPa 18 UTC, 04 October 2021
Observed landfalls	**Philippines:** 1900 UTC, 03 October 2021 (TD): Socorro, Surigao del Norte 2000 UTC, 03 October 2021 (TD): Surigao City, Surigao del Norte (Hinatuan Is.) 2030 UTC, 03 October 2021 (TD): Surigao City, Surigao del Norte (Nonoc Is.) 2050 UTC, 03 October 2021 (TD): Surigao City, Surigao del Norte (Hikdop Is.) 2230 UTC, 03 October 2021 (TD): San Ricardo, Southern Leyte 0000 UTC, 04 October 2021 (TD): Padre Burgos, Southern Leyte 0220 UTC, 04 October 2021 (TD): Ubay, Bohol 0610 UTC, 04 October 2021 (TD): Dalaguete, Cebu 0730 UTC, 04 October 2021 (TD): Bindoy, Negros Oriental 2200 UTC, 04 October 2021 (TD): Linapacan, Palawan (Calibang Is.) **Elsewhere:** 1210 UTC, 08 October 2021 (TS): Wanning City, Hainan, China 0900 UTC, 10 October 2021 (TD): Thái Thụy District, Thái Bình, Vietnam

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.12.2. Highest storm duration (03 to 05 October 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Surigao City, Surigao del Norte	193.3
Casiguran, Aurora	191.8
Iloilo City	183.2
Virac, Catanduanes	181.1
Tayabas City, Quezon	179.4

Table 4.12.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Casiguran, Aurora	129.4	05 October 2021
Borongan City, Eastern Samar	108.0	03 October 2021
Surigao City, Surigao del Norte	107.7	03 October 2021
Calayan, Cagayan	96.4	03 October 2021
Virac, Catanduanes	91.8	04 October 2021

Table 4.12.4. Lowest mean sea level pressure over land.

Location of weather station	Minimum MSLP (hPa)	Date (MM/DD) and Time (UTC)
Dauis, Bohol	1002.6	10/04 0600
Dumaguete City, Negros Oriental	1002.7	10/04 0800
Hinatuan, Surigao Del Sur	1002.7	10/04 0600
Mactan-Cebu International Airport, Lapu-Lapu City	1002.8	10/04 0800
Surigao City, Surigao del Norte	1002.8	10/04 0600 10/04 0700
Coron, Palawan	1003.0	10/04 1900
Borongan City, Eastern Samar	1003.1	10/04 0600 10/04 0700
Butuan City, Agusan del Norte	1003.1	10/04 0600

Table 4.12.5. Highest peak gust over land.

Location of weather station	Peak gust speed (m/s)	Peak gust direction	Date and Time (UTC)
Guiuan, Eastern Samar	22	NNE(030)	10/03 2116
Tacloban City, Leyte	18	ESE(110)	10/03 1116
Cuyo, Palawan	12	NNE(020)	10/04 1141
San Jose, Occidental Mindoro	12	SW(230)	10/05 1207
Mactan-Cebu International Airport, Lapu-Lapu City	11	N(360)	10/04 0000-0100*
Masbate City, Masbate	11	E(090)	10/03 1405
Borongan City, Eastern Samar	10	NE(040)	10/04 0200-0300*
Surigao City, Surigao del Norte	10	NE(040)	10/03 1822

* No specific time reported, but happened within this range of synoptic hours.

Summary of Warning Information

Number of TC products issued

- Tropical Cyclone Bulletins: **15**
- Tropical Cyclone Advisories: **0**
- Tropical Cyclone Warning for Shipping issued: **10**
- WC SIGMET: **0**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **Wind Signal No. 1**
- No. of provinces with hoisted wind signal: **25**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **3 dead, 0 injured, and 0 missing**
Total cost of damage: **PHP 12,225,109.47**

- Damage to agriculture: **PHP 12,225,109.47**
- Damage to infrastructure: **No report**

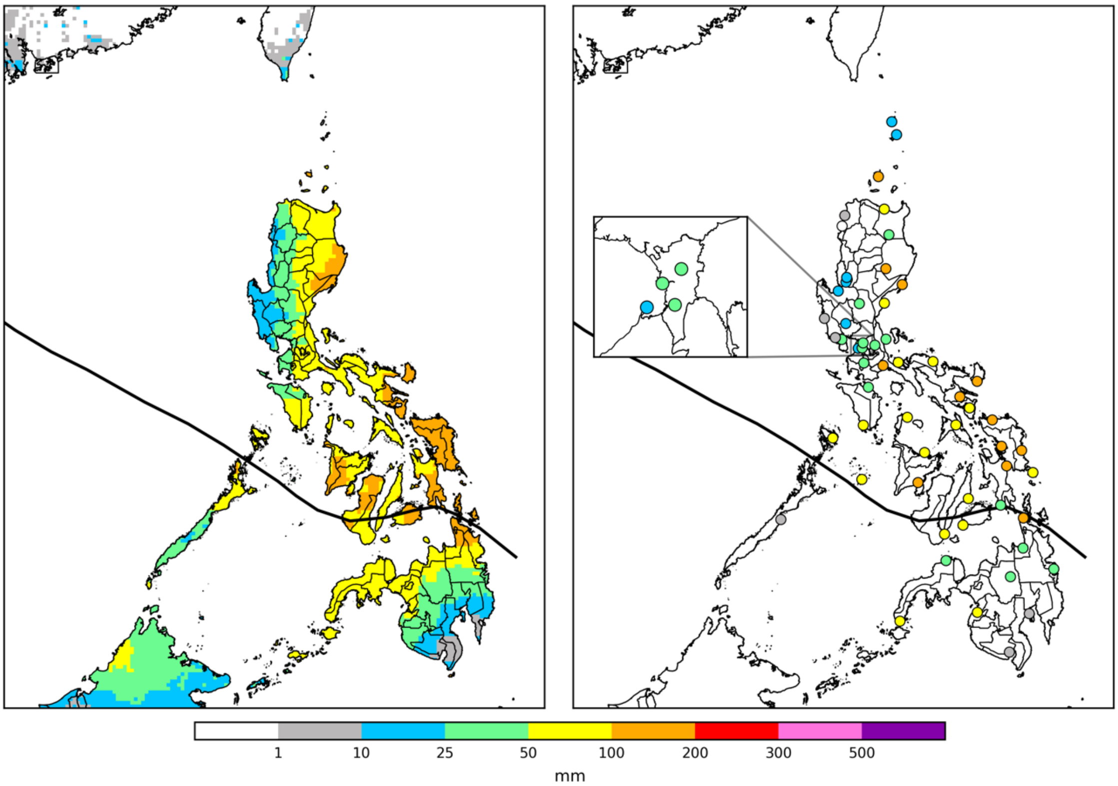
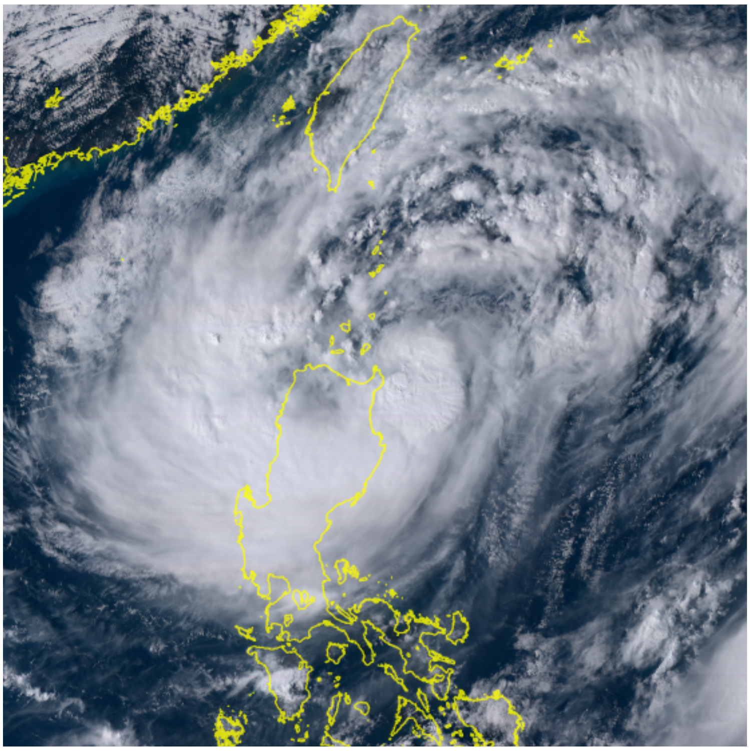


Fig. 4.12.2. Storm duration rainfall over land during the passage of Tropical Storm LANNIE within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line.

Fig. 4.12.3. Distribution of highest level wind signal hoisted per province or sub-provincial locality during the passage of Tropical Storm LANNIE. The best track is also overlaid as a solid thick white line.

Severe Tropical Storm MARING
KOMPASU (2118)

07 to 14 October 2021



Basin-wide peak intensity:
Severe Tropical Storm
55 kt (100 km/h)
975 hPa

Developed:
06 UTC, 07 October 2021

Degenerated:
18 UTC, 14 October 2021

Duration within the PAR:
4 days and 22 hours

Peak category within the PAR:
Severe Tropical Storm

Highest wind signal hoisted:
Wind Signal No. 2

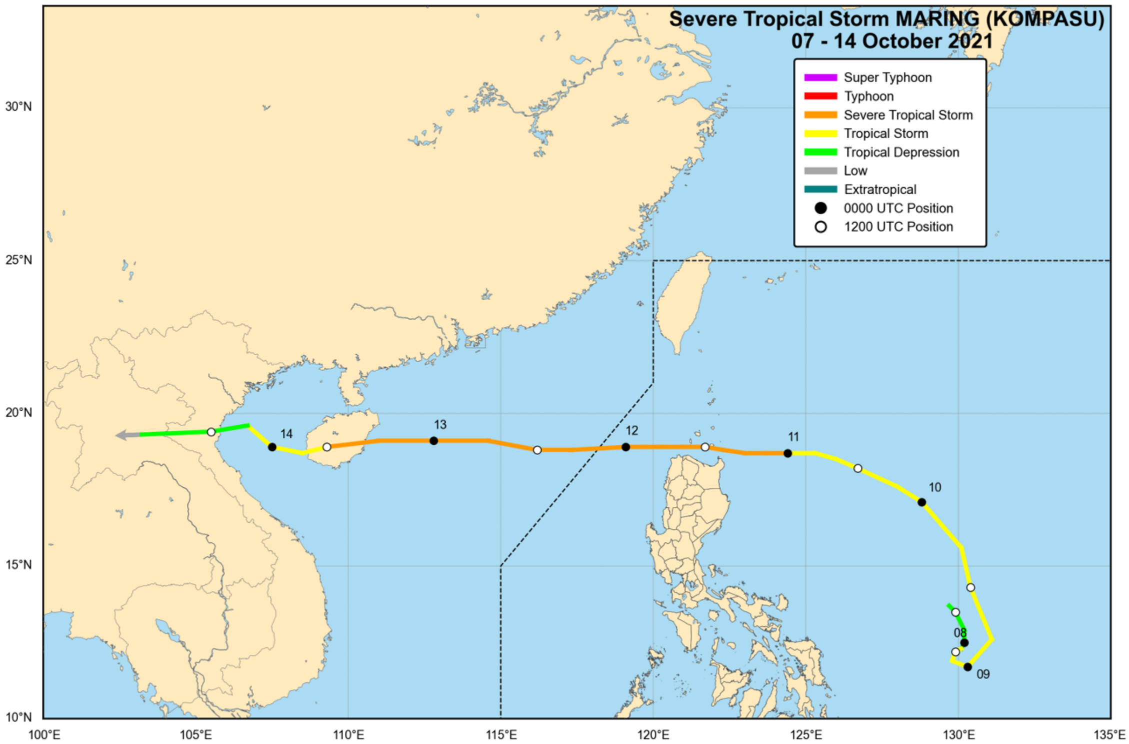


Fig. 4.13.1. Best track position and intensities of Severe Tropical Storm MARING.

Summary of Meteorological History

Table 4.13.1. Key information about Severe Tropical Storm MARING.

Parameter	Details
First tracked as a tropical low pressure area	00 UTC, 05 October 2021 Over the sea near Yap, Federated States of Micronesia
Developed into a TC	06 UTC, 07 October 2021 Over the Philippine Sea far east of Bicol Region
Weakened into a remnant low	18 UTC, 14 October 2021 In the vicinity of Phaxay District, Xiangkhouang, Laos
Period of occurrence (lifetime)	7 days and 12 hours
Entered the PAR region	Not applicable
Exited the PAR region	04 UTC, 12 October 2021
Period of occurrence (within the PAR)	4 days and 22 hours
Peak intensity (lifetime)	Severe Tropical Storm: 55 kt (100 km/h), 975 hPa 12 UTC, 11 October 2021
Peak intensity (within the PAR region)	Severe Tropical Storm: 55 kt (100 km/h), 975 hPa 12 UTC, 11 October 2021
Observed landfalls	**Philippines:** 1130 UTC, 11 October 2021 (STS): Calayan, Cagayan (Camiguin Is.) 1300 UTC, 11 October 2021 (STS): Aparri, Cagayan (Fuga Is.) **Elsewhere:** 0740 UTC, 13 October 2021 (STS): Wanning City, Hainan, China 1030 UTC, 14 October 2021 (TD): Tĩnh Gia District, Thanh Hóa, Vietnam

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.13.2. Highest storm duration (07 to 11 October 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Baguio City	674.4
Mt. Cabuyao, Tuba, Benguet	565.4
Dagupan City, Pangasinan	249.7
Aparri, Cagayan	227.2
Calayan, Cagayan	218.2

Table 4.13.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Baguio City	625.3	11 October 2021
Mt. Cabuyao, Tuba, Benguet	500.8	10 October 2021
Dagupan City, Pangasinan	241.3	11 October 2021
San Jose, Occidental Mindoro	140.8	09 October 2021
Aparri, Cagayan	138.4	11 October 2021

Table 4.13.4. Lowest mean sea level pressure over land.

Location of weather station	Minimum MSLP (hPa)	Date (MM/DD) and Time (UTC)
Laoag City, Ilocos Norte	979.6	10/11 1800
Calayan, Cagayan	980.7	10/11 1200
Aparri, Cagayan	981.4	10/11 1100
Sinait, Ilocos Sur	982.0	10/11 2000
Tuguegarao City, Cagayan	985.7	10/11 1300

Note: Itbayat Synoptic Weather Station may have similar or lower minimum MSLP, but was not recorded since the barometer was inoperative at the time of passage.

Table 4.13.5. Highest peak gust over land.

Location of weather station	Peak gust speed (m/s)	Peak gust direction	Date and Time (UTC)
Basco, Batanes	34	NE(040)	10/11 0606
Calayan, Cagayan	28	SE(140)	10/11 1400
Itbayat, Batanes	25	NNE(020)	10/11 0403
Aparri, Cagayan	24	NW(320)	10/11 0034
Baler, Aurora	24	WNW(290)	10/11 0800
Dagupan City, Pangasinan	22	WNW(290)	10/11 0300-0400*

* No specific time reported, but happened within this range of synoptic hours.

Summary of Warning Information

Number of TC products issued

- Tropical Cyclone Bulletins: **29**
- Tropical Cyclone Advisories: **0**
- Tropical Cyclone Warning for Shipping issued: **23**
- WC SIGMET: **10**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **Wind Signal No. 2**
- No. of provinces with hoisted wind signal: **29**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **43 dead, 5 injured, and 16 missing**
Total cost of damage: **PHP 7,388,193,660.82**

- Damage to agriculture: **PHP 3,321,718,527.47**
- Damage to infrastructure: **PHP 4,066,475,133.35**

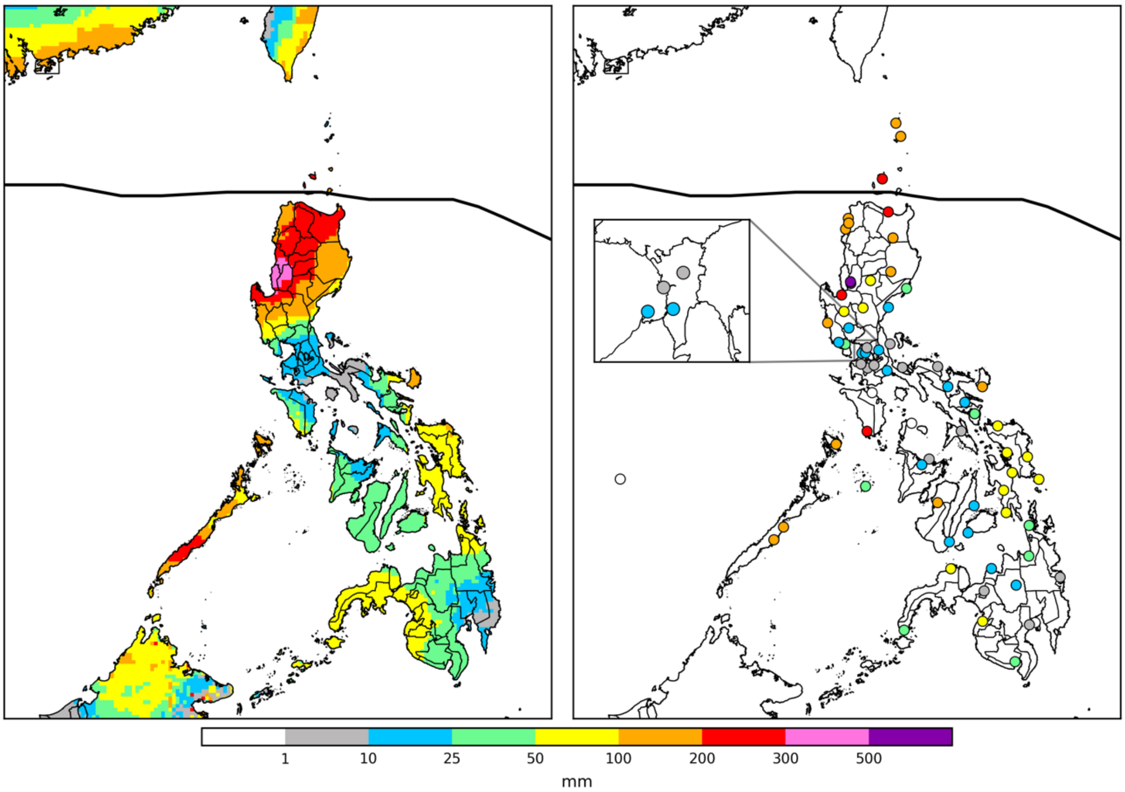


Fig. 4.13.2. Storm duration rainfall over land during the passage of Severe Tropical Storm MARING within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line.

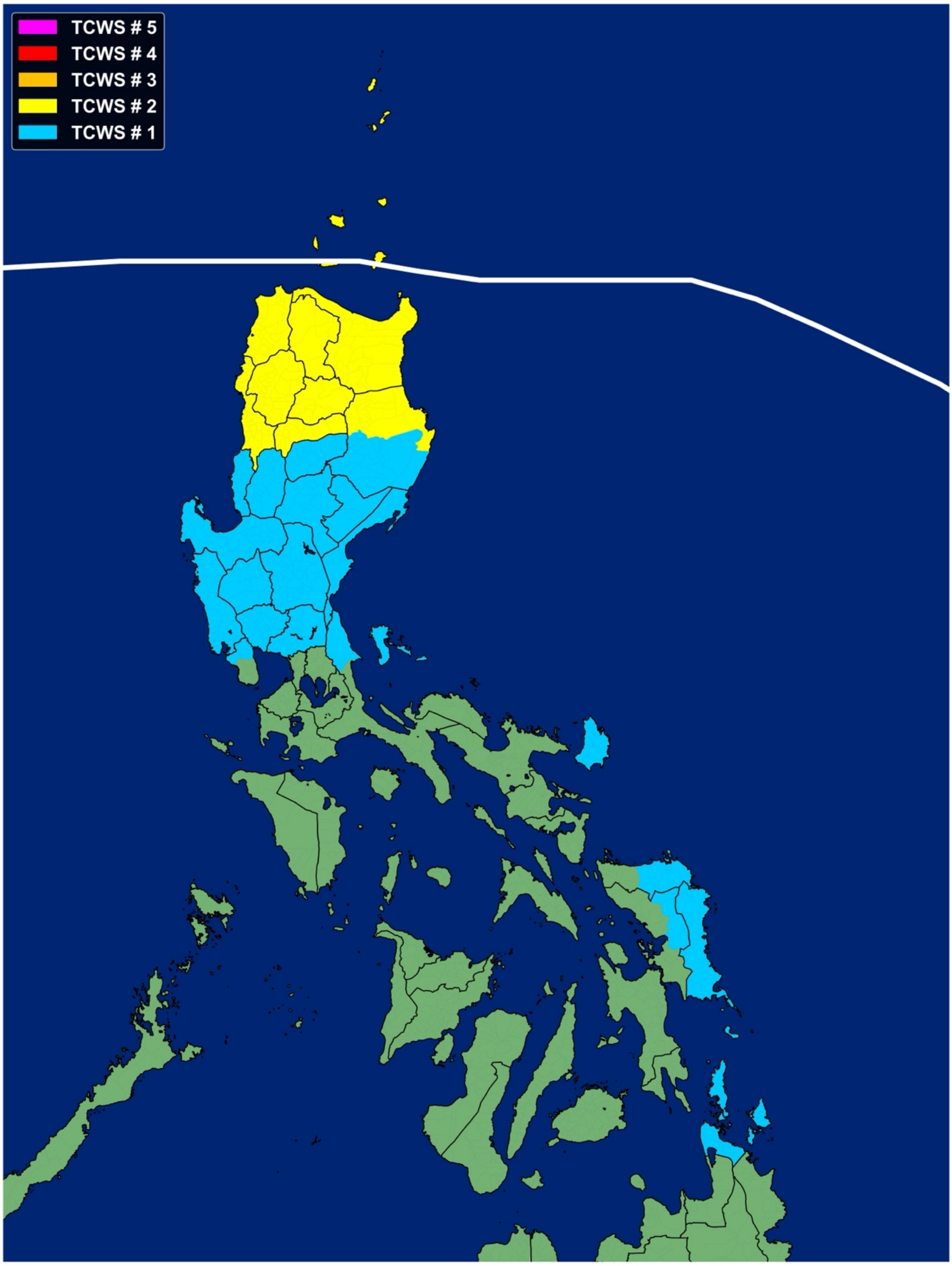


Fig. 4.13.3. Distribution of highest level wind signal hoisted per province or sub-provincial locality during the passage of Severe Tropical Storm MARING. The best track is also overlaid as a solid thick white line.

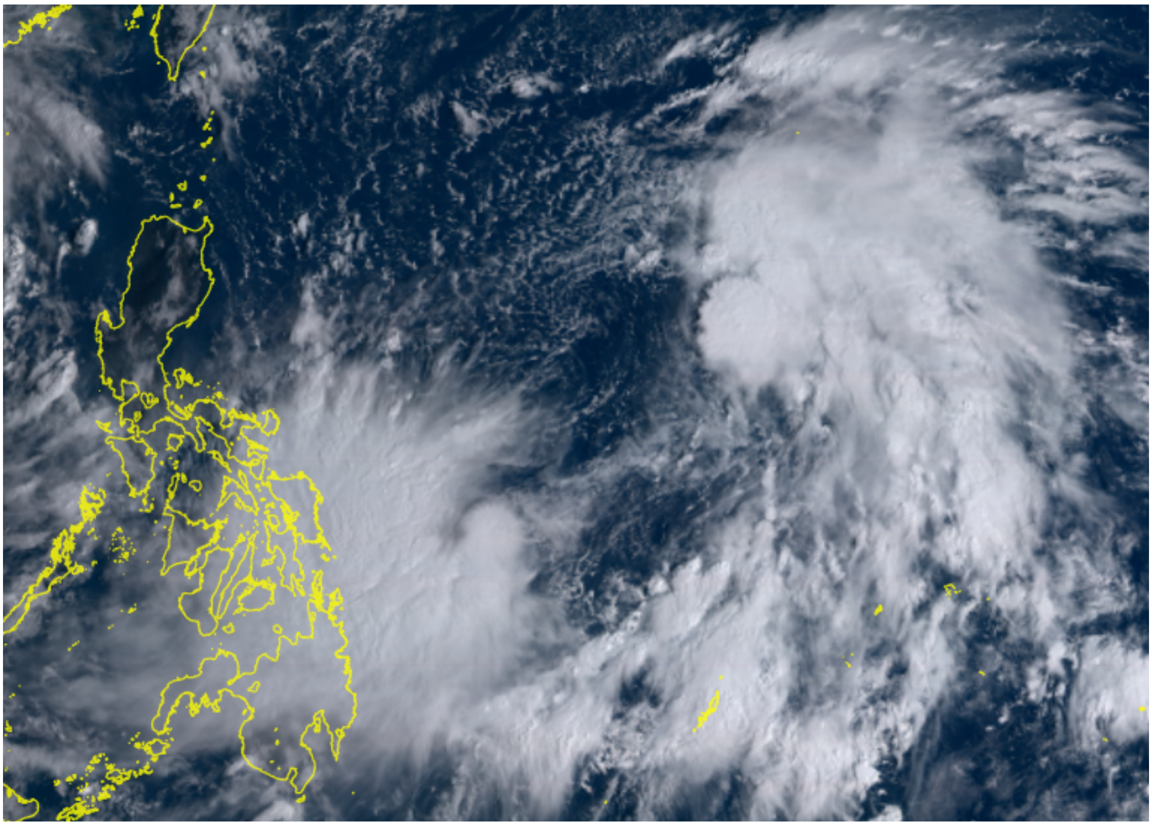
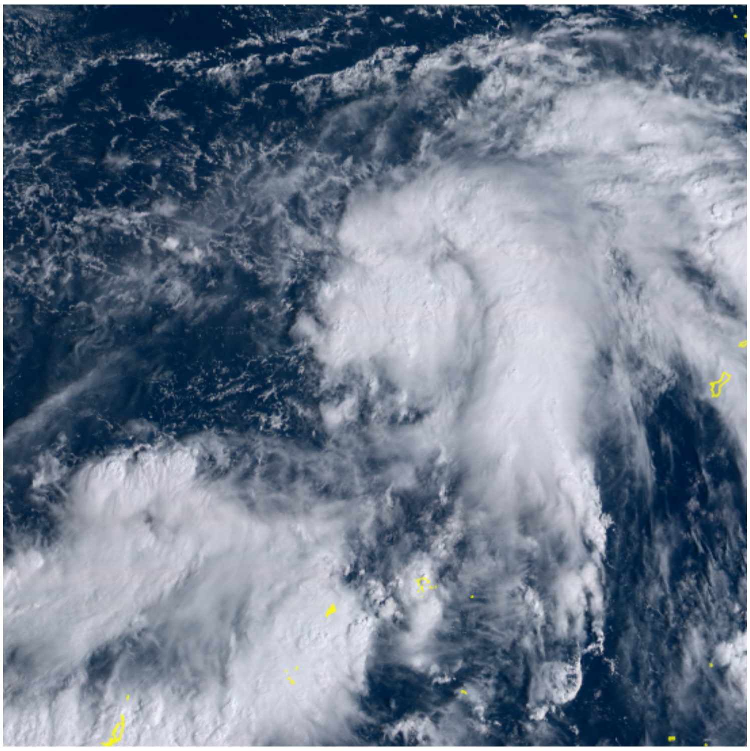


Fig. 4.13.4. Himawari-8 RGB true color enhanced visible image of the large monsoonal circulation that contained both MARING and NANDO. Binary interaction occurred between these two TCs, with MARING eventually assimilating the circulation of NANDO.

Tropical Depression NANDO
UNNAMED

07 to 09 October 2021



Basin-wide peak intensity:
Tropical Depression
30 kt (55 km/h)
996 hPa

Developed:
12 UTC, 07 October 2021

Degenerated:
12 UTC, 09 October 2021

Duration within the PAR:
1 day and 1 hour

Peak category within the PAR:
Tropical Depression

Highest wind signal hoisted:
None

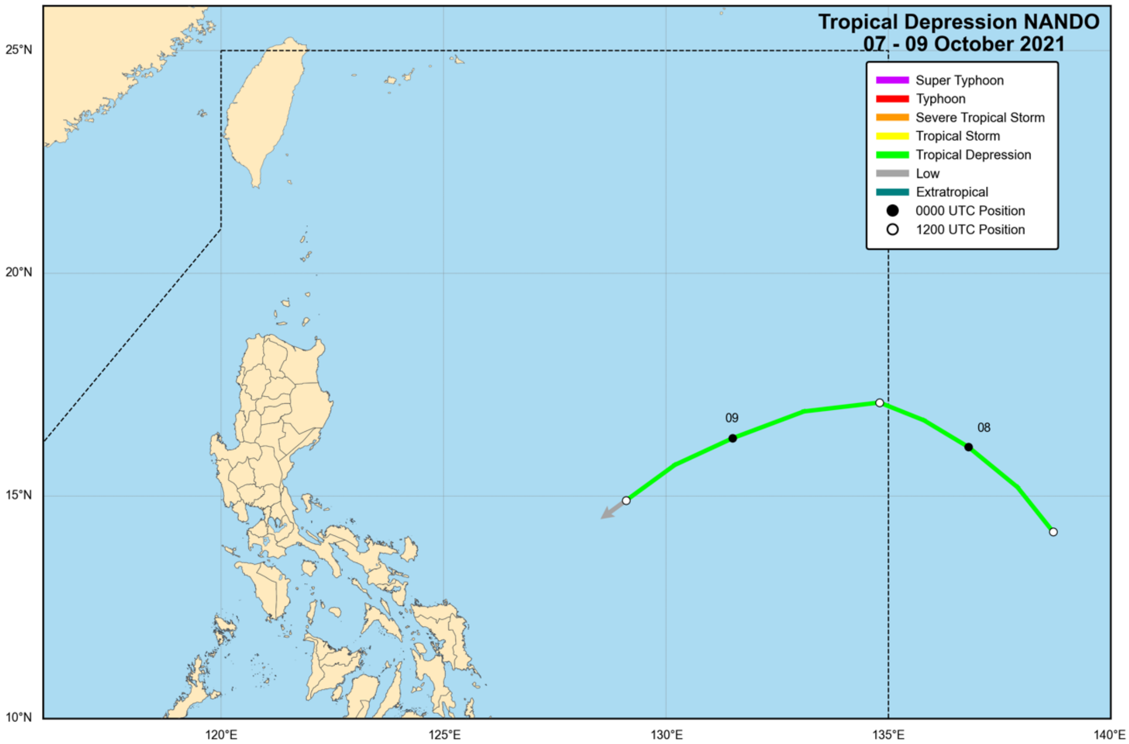


Fig. 4.14.1. Best track position and intensities of Tropical Depression NANDO.

Summary of Meteorological History

Table 4.14.1. Key information about Tropical Depression NANDO.

Parameter	Details
First tracked as a tropical low pressure area	18 UTC, 06 October 2021 Over the sea near Northern Mariana Islands (US)
Developed into a TC	12 UTC, 07 October 2021 Over the Philippine Sea far west of Guam (US)
Weakened into a remnant low	12 UTC, 09 October 2021 Over the Philippine Sea far east of Bicol Region
Period of occurrence (lifetime)	2 days
Entered the PAR region	11 UTC, 08 October 2021
Exited the PAR region	Not applicable
Period of occurrence (within the PAR)	1 day and 1 hour
Peak intensity (lifetime)	Tropical Depression: 30 kt (55 km/h), 996 hPa 06 UTC, 09 October 2021
Peak intensity (within the PAR region)	Tropical Depression: 30 kt (55 km/h), 996 hPa 06 UTC, 09 October 2021
Observed landfalls	**Philippines:** None **Elsewhere:** None

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.14.2. Highest storm duration (08 to 09 October 2021) rainfall over land.

Location of weather station	Rainfall (mm)
San Jose, Occidental Mindoro	140.8
Virac, Catanduanes	121.0
Tacloban City, Leyte	83.0
Catbalogan City, Samar	72.5
Catarman, Northern Samar	62.1

Table 4.14.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
San Jose, Occidental Mindoro	140.8	09 October 2021
Virac, Catanduanes	93.8	09 October 2021
Tacloban City, Leyte	64.8	08 October 2021
Echague, Isabela	48.6	09 October 2021
Dipolog City, Zamboanga del Norte	41.4	09 October 2021

Summary of Warning Information

Number of TC products issued

- Tropical Cyclone Bulletins: **5**
- Tropical Cyclone Advisories: **1**
- Tropical Cyclone Warning for Shipping issued: **5**
- WC SIGMET: **0**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **None**
- No. of provinces with hoisted wind signal: **0**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **No report**
Total cost of damage: **No report**

- Damage to agriculture: **No report**
- Damage to infrastructure: **No report**

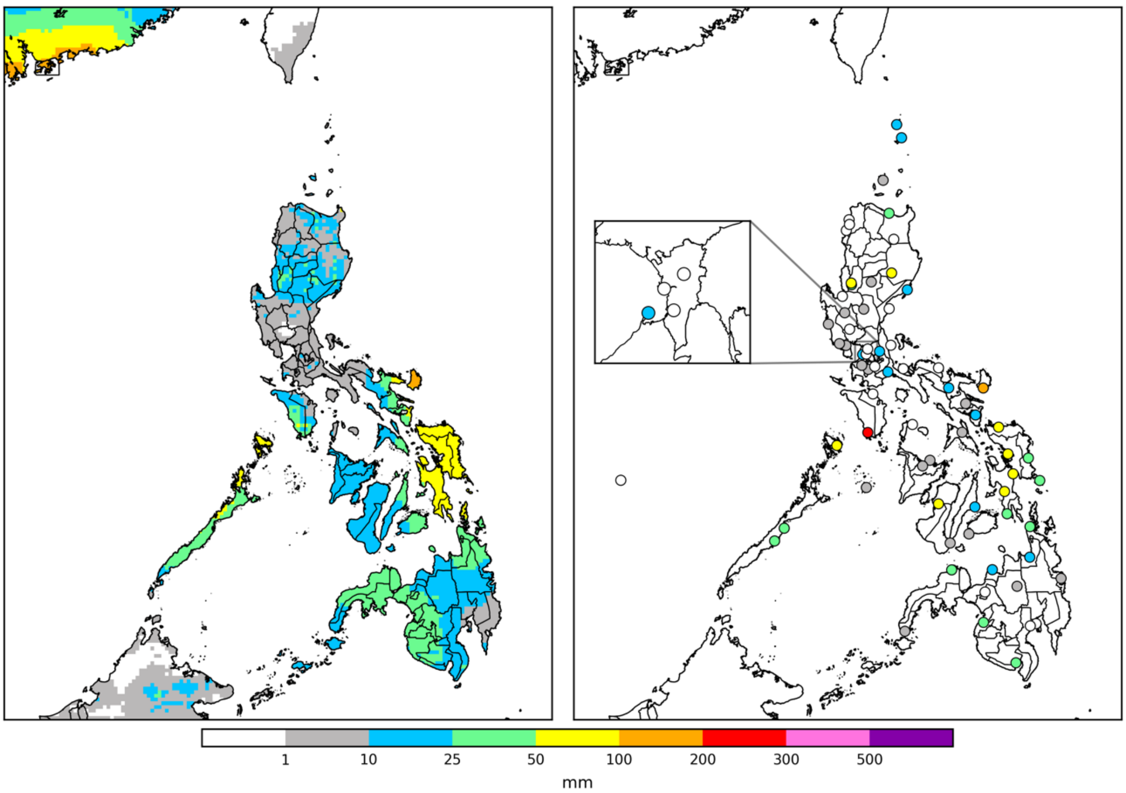
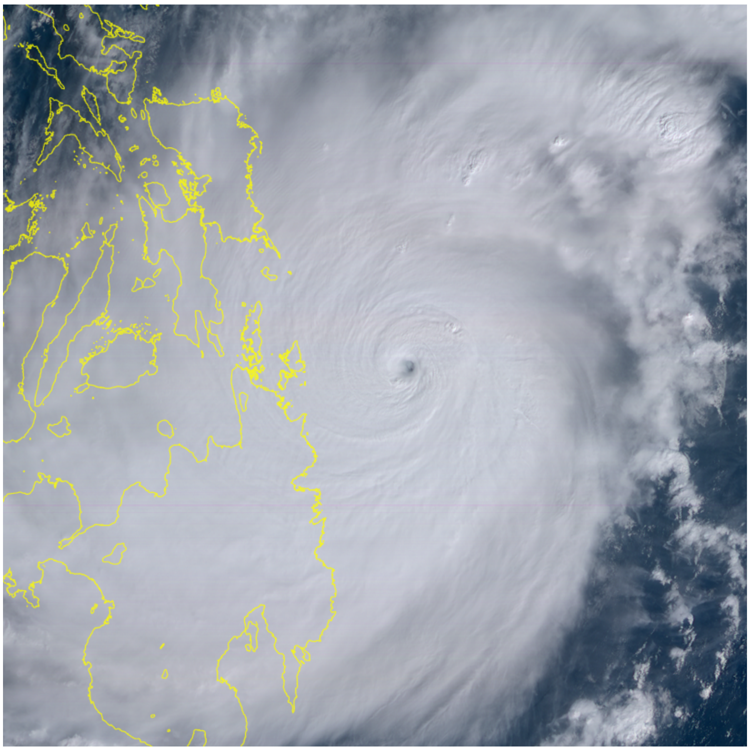


Fig. 4.14.2. Storm duration rainfall over land during the passage of Tropical Depression NANDO within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is outside the domain of the figure.

Super Typhoon ODETTE
RAI (2122)

12 to 21 December 2021



Basin-wide peak intensity:
Super Typhoon
105 kt (195 km/h)
915 hPa

Developed:
00 UTC, 12 December 2021

Degenerated:
06 UTC, 21 December 2021

Duration within the PAR:
3 days and 19 hours

Peak category within the PAR:
Super Typhoon

Highest wind signal hoisted:
Wind Signal No. 4

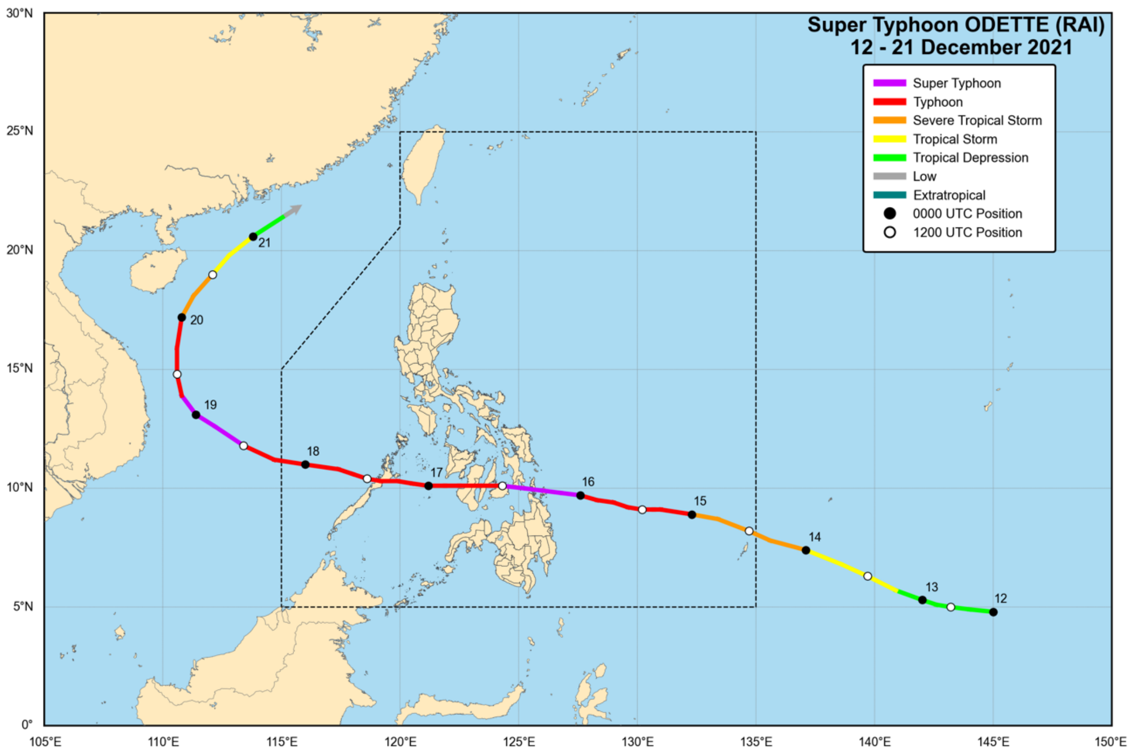


Fig. 4.15.1. Best track position and intensities of Super Typhoon ODETTE.

Summary of Meteorological History

Table 4.15.1. Key information about Super Typhoon ODETTE.

Parameter	Details
First tracked as a tropical low pressure area	06 UTC, 03 December 2021 Over the Philippine Sea north northeast of Palau
Developed into a TC	00 UTC, 12 December 2021 Over the sea south of Yap, Federated States of Micronesia
Weakened into a remnant low	06 UTC, 21 December 2021 Over the West Philippine Sea off the coast of Guangdong, China
Period of occurrence (lifetime)	9 days and 6 hours
Entered the PAR region	10 UTC, 14 December 2021
Exited the PAR region	05 UTC, 18 December 2021
Period of occurrence (within the PAR)	3 days and 19 hours
Peak intensity (lifetime)	Super Typhoon: 105 kt (195 km/h), 915 hPa 00 UTC, 16 December 2021 18 UTC, 18 December 2021
Peak intensity (within the PAR region)	Super Typhoon: 105 kt (195 km/h), 915 hPa 00 UTC, 16 December 2021
Observed landfalls	**Philippines:** 0530 UTC, 16 December 2021 (STY): Pilar, Surigao del Norte 0610 UTC, 16 December 2021 (STY): Del Carmen, Surigao del Norte (Poneas Is.) 0630 UTC, 16 December 2021 (STY): Del Carmen, Surigao del Norte (Kangbangyo Is.) 0710 UTC, 16 December 2021 (STY): Cagdianao, Dinagat Islands 0850 UTC, 16 December 2021 (STY): San Ricardo, Southern Leyte 0940 UTC, 16 December 2021 (STY): Padre Burgos, Southern Leyte 1110 UTC, 16 December 2021 (STY): Pres. Carlos P. Garcia, Bohol (Lapinig Is.) 1140 UTC, 16 December 2021 (STY): Ubay, Bohol 1400 UTC, 16 December 2021 (TY): Carcar City, Cebu 1530 UTC, 16 December 2021 (TY): Guihulngan City, Negros Oriental 0830 UTC, 17 December 2021 (TY): Roxas, Palawan **Elsewhere:** None

Extremes of Surface Weather Observations during TC Days

Based on quality-controlled reports from PAGASA manned surface weather stations

Table 4.15.2. Highest storm duration (14 to 18 December 2021) rainfall over land.

Location of weather station	Rainfall (mm)
Surigao City, Surigao del Norte	432.0
Virac, Catanduanes	270.3
Dauis, Bohol	240.9
Malaybalay City, Bukidnon	218.4
Butuan City, Agusan del Norte	215.7

Note: Maasin City Synoptic Weather Station may have similar or higher storm duration rainfall but the station rain gauge suffered from extensive damage during the passage of the STY.

Table 4.15.3. Highest 24-hour rainfall over land.

Location of weather station	Rainfall (mm)	Date
Surigao City, Surigao del Norte	267.6	16 December 2021
Dauis, Bohol	230.6	16 December 2021
Malaybalay City, Bukidnon	165.6	16 December 2021
Puerto Princesa City, Palawan	156.5	17 December 2021
Virac, Catanduanes	135.7	17 December 2021

Note: Maasin City Synoptic Weather Station may have similar or higher peak 24-hour rainfall but the station rain gauge suffered from extensive damage during the passage of the STY.

Table 4.15.4. Lowest mean sea level pressure over land.

Location of weather station	Minimum MSLP (hPa)	Date (MM/DD) and Time (UTC)
Maasin City, Southern Leyte	944.2	12/16 1100
Surigao City, Surigao del Norte	957.5	12/16 0645
Mactan-Cebu International Airport, Lapu-Lapu City	974.3	12/16 1243
Dauis, Bohol	986.9	12/16 1400
Puerto Princesa City, Palawan	989.2	12/17 1000

Table 4.15.5. Highest peak gust over land.

Location of weather station	Peak gust speed (m/s)	Peak gust direction	Date and Time (UTC)
Surigao City, Surigao del Norte	58	S(190)	12/16 0841
Maasin City, Southern Leyte	55	SE(130)	12/16 1113
Mactan-Cebu International Airport, Lapu-Lapu City	45	NE(040)	12/16 1241
Guiuan, Eastern Samar	38	NE(050)	12/16 0816
Dauis, Bohol	31	WNW(290)	12/16 1335

Note: Maasin City Synoptic Weather Station may have experienced stronger gusts after this peak value but were not recorded as the wind instrument failed during the passage of the STY.

Summary of Warning Information

Number of TC products issued

- Tropical Cyclone Bulletins: **29**
- Tropical Cyclone Advisories: **0**
- Tropical Cyclone Warning for Shipping issued: **23**
- WC SIGMET: **10**

Hoisting of TC Wind Signals

- Highest wind signal level hoisted: **Wind Signal No. 2**
- No. of provinces with hoisted wind signal: **29**

Reported Casualties and Cost of Damage

Based on reports from the Office of Civil Defense

Number of reported casualties: **405 dead, 1,371 injured, and 52 missing**
Total cost of damage: **PHP 51,706,364,278.53**

- Damage to agriculture: **PHP 22,368,178,922.59**
- Damage to infrastructure: **PHP 29,338,185,355.94**

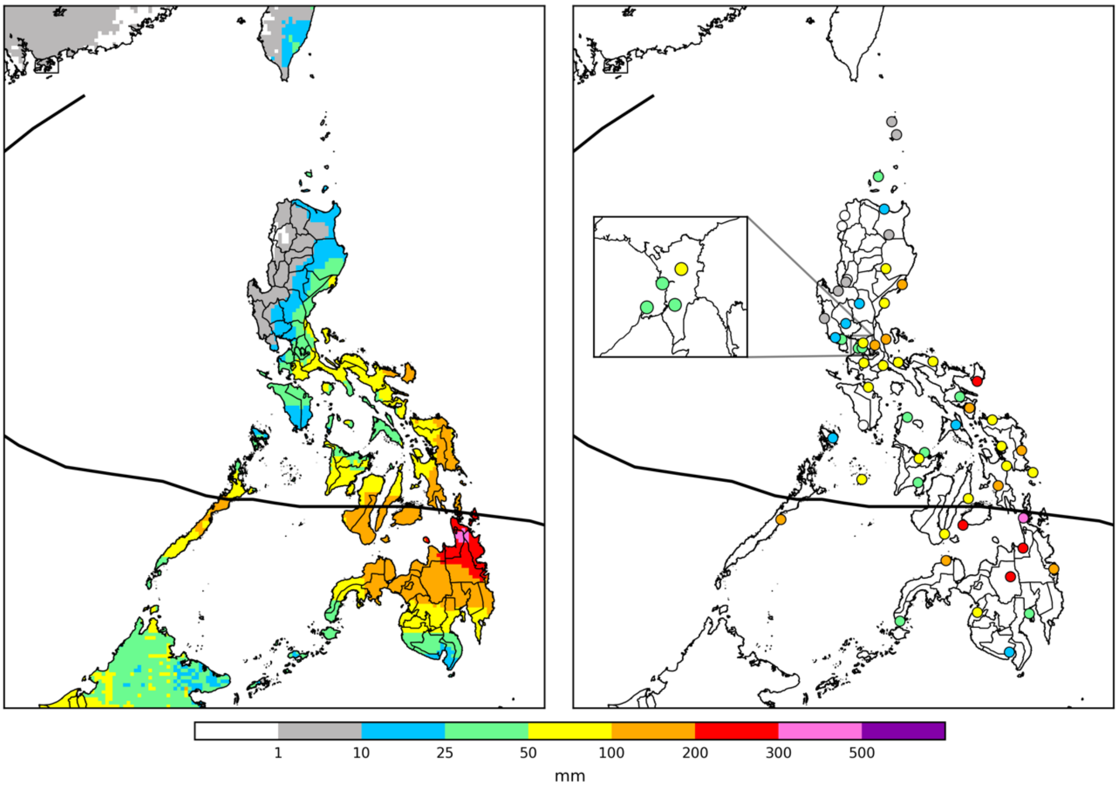


Fig. 4.15.2. Storm duration rainfall over land during the passage of Super Typhoon ODETTE within the PAR based on GSMAP (left) and surface weather station reports (right). The best track is also overlaid as a solid thick black line.

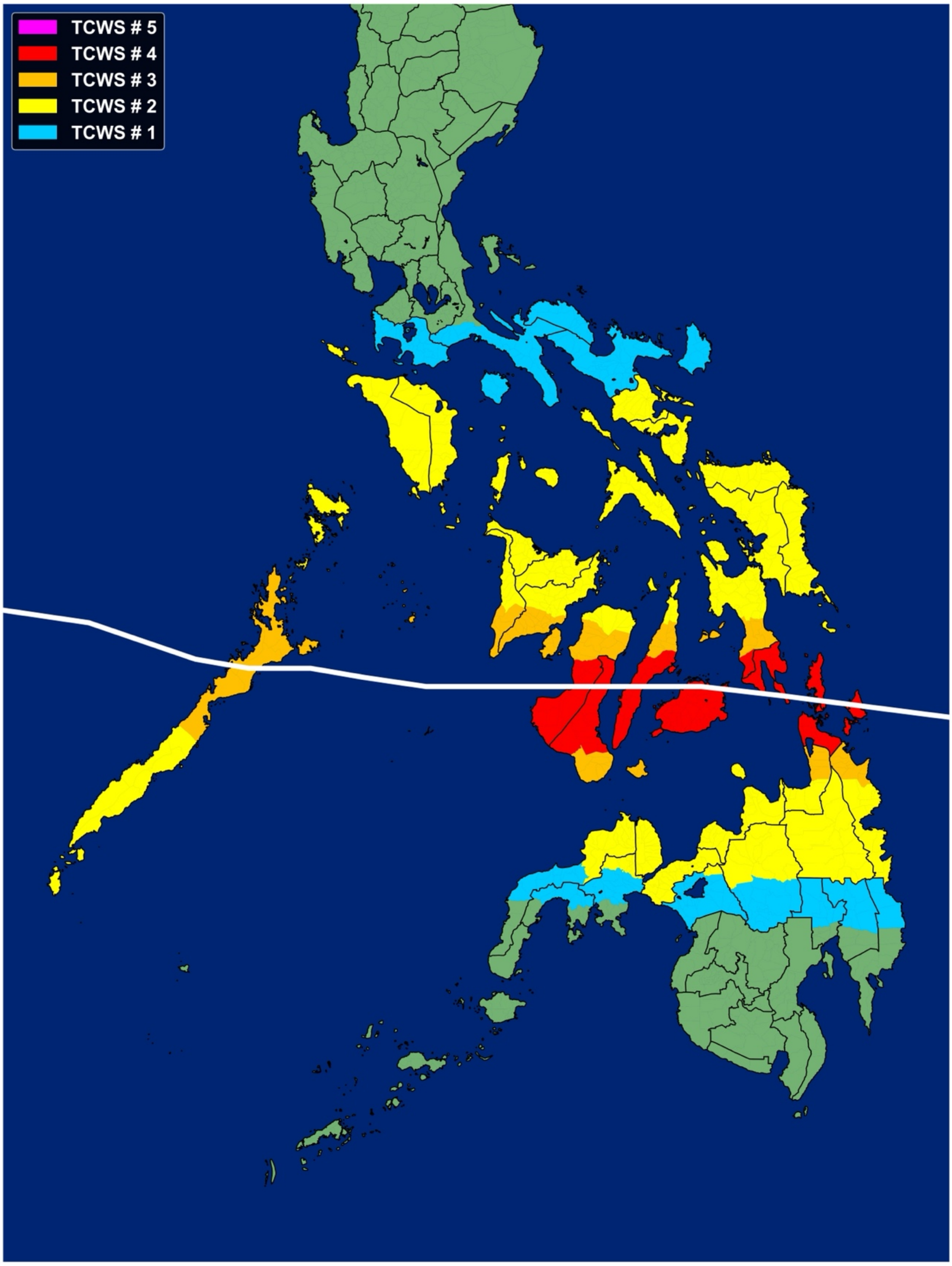


Fig. 4.15.3. Distribution of highest level wind signal hoisted per province or sub-provincial locality during the passage of Super Typhoon ODETTE. The best track is also overlaid as a solid thick white line.

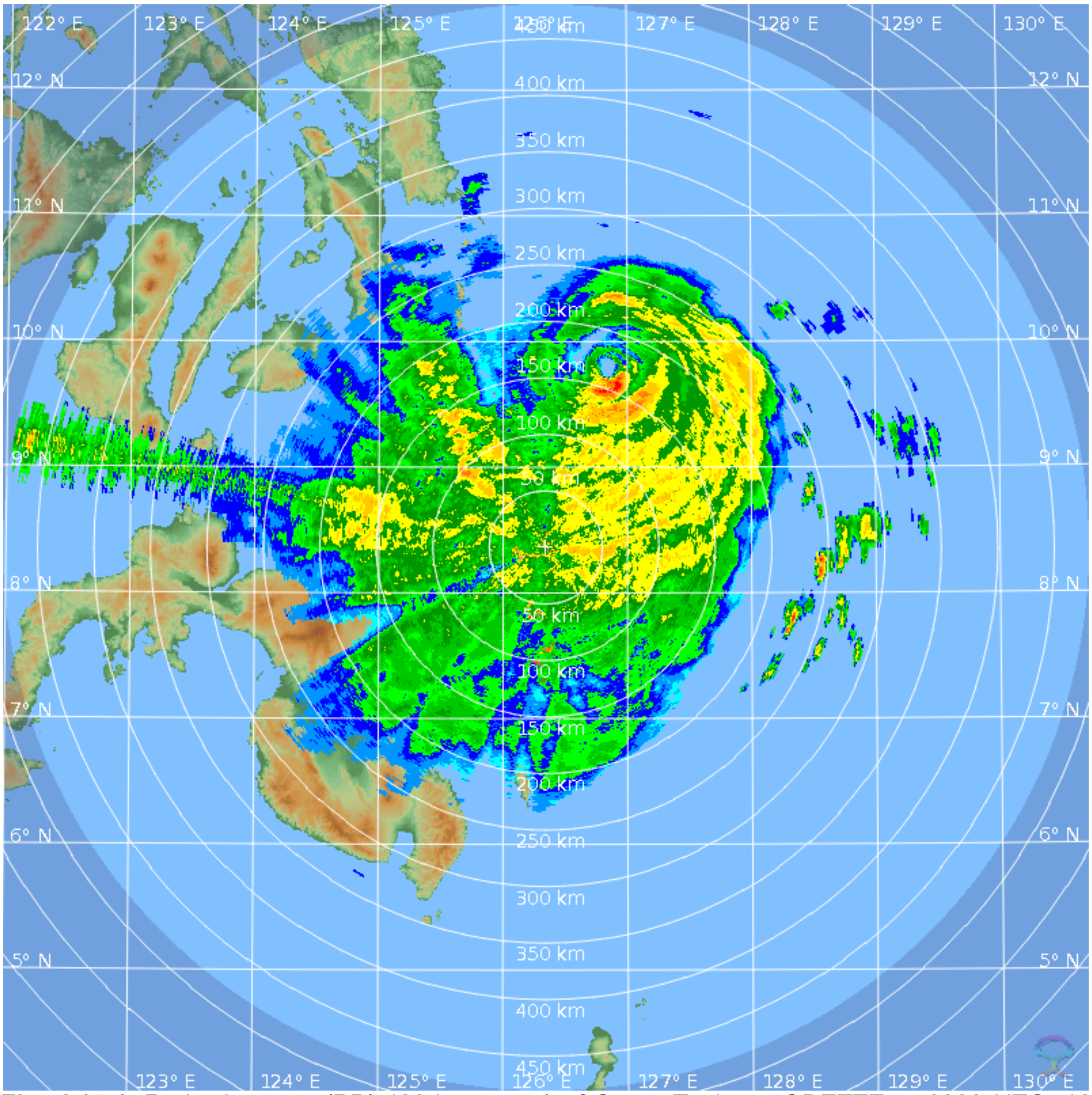


Fig. 4.15.4. Radar imagery (PPI 480-km range) of Super Typhoon ODETTE at 0300 UTC, 16 December 2021 while at peak intensity. Data from the PAGASA Hinatuan Weather Surveillance Radar Station. A concentric eyewall signature is evident from the image.

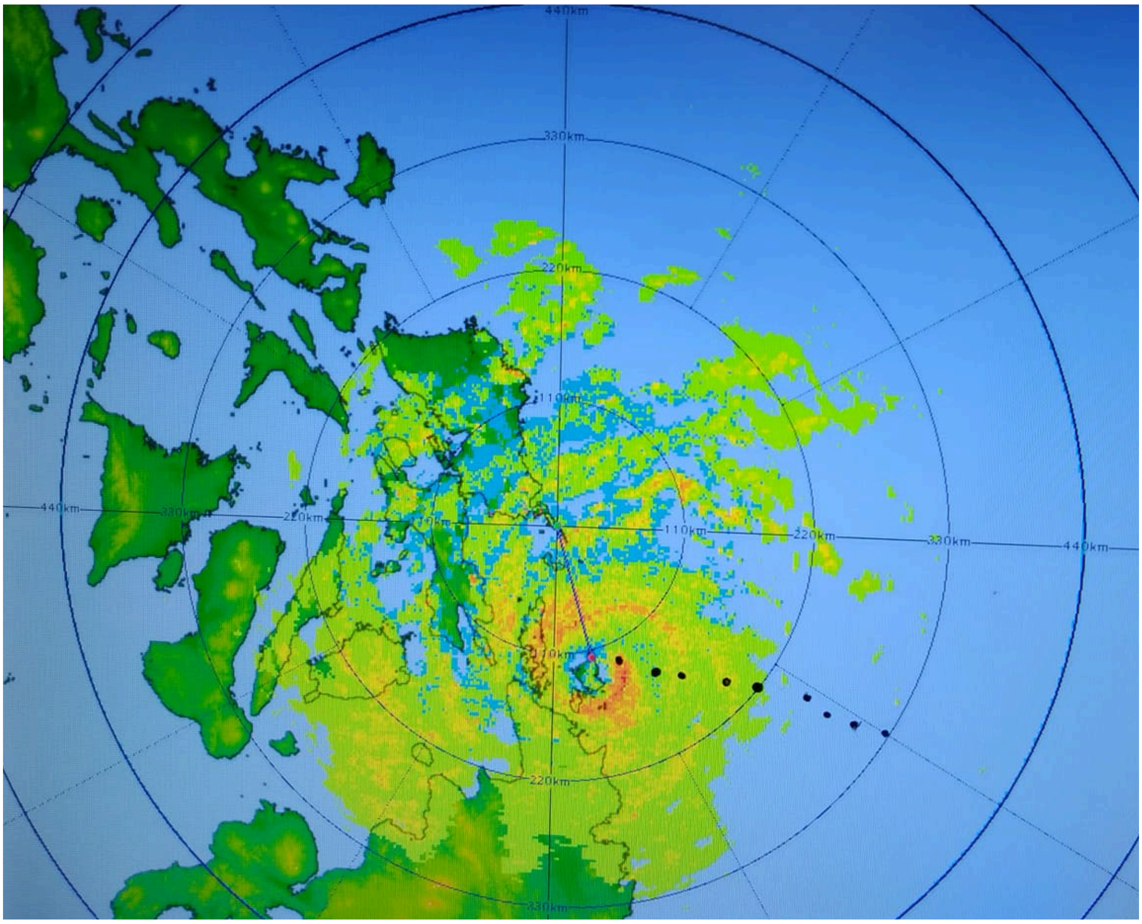


Fig. 4.15.5. Radar imagery (PPI 440-km range) of Super Typhoon ODETTE at 0532 UTC, 16 December 2021 while making landfall over Pilar, Surigao del Norte. Data from the PAGASA Guiuan Weather Surveillance Radar Station. A concentric eyewall signature is evident from the image. Black dots were radar eye fix marks from the station personnel, although best track analysis revealed that the fixes were shifted to the north of the actual path due to station personnel tracking the centroid of the outer eyewall.

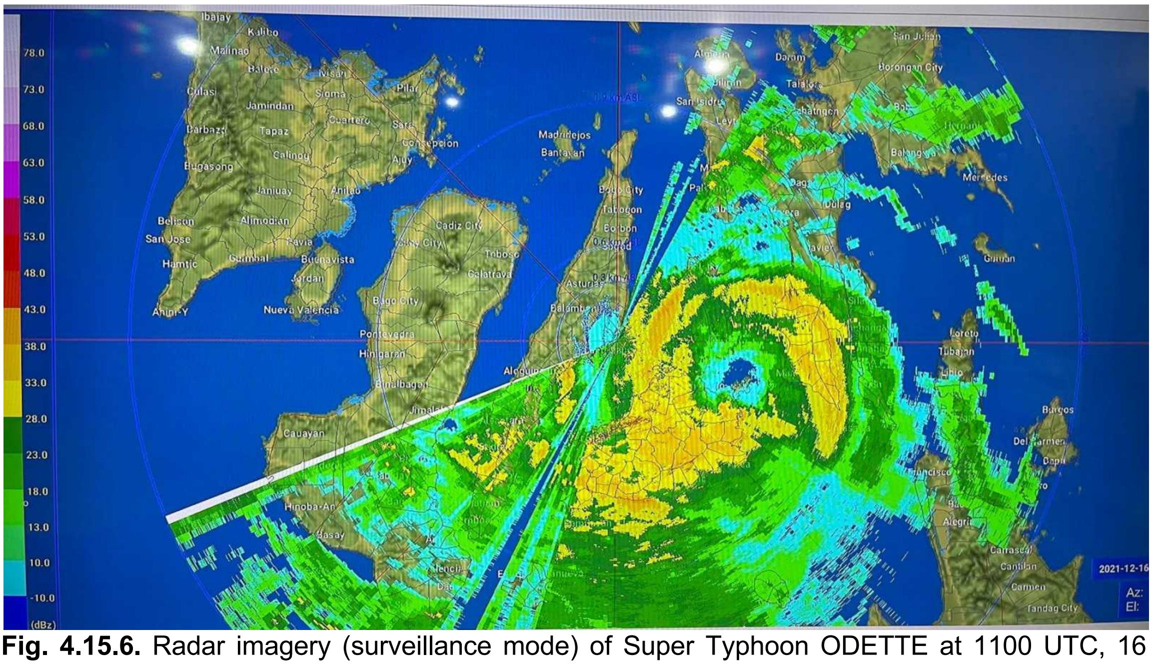


Fig. 4.15.6. Radar imagery (surveillance mode) of Super Typhoon ODETTE at 1100 UTC, 16 December 2021 as it neared Bohol. Data from the PAGASA Mactan Weather Surveillance Radar Station. Deterioration in the northwest and southeast sectors of the eyewall is noted.

VERIFICATION OF OPERATIONAL TROPICAL CYCLONE FORECASTS FOR 2021

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Verification of Operational Tropical Cyclones Forecasts for 2021

This section reports the result of the verification of operational track forecasts for the 15 tropical cyclones (TCs) that occurred within the Philippine Area of Responsibility (PAR). These operational track forecasts (up to five days ahead) were verified against the TC best track data from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA). Track forecasts with initial times at 00, 03, 06, 09, 12, 15, 18, and 21 UTC were evaluated, provided that the corresponding initial intensity is at least 34 kt (i.e., at least tropical storm (TS) category). The non-inclusion of forecasts with initial intensity of less than 34 kt is based on the operational practice of the Regional Specialized Meteorological Center (RSMC) – Tokyo Typhoon Center. As such, 2021 TCs that did not reach TS category on the best track or those TCs whose initial intensities in all operational track forecasts were TD despite reaching TS category at some point in the best track were excluded from the verification. Based on these, no position errors were provided for EMONG, GORIO, LANNIE, and NANDO.

Metrics of Track Forecast Verification

To measure the performance of operational track forecasts, the direct positional error (DPE), along-track error (ATE), and cross-track error of the valid 24-, 48-h, 72-h, 96-, and 120-hour forecast positions were calculated using the verification subsystem of the PAGASA Integrated System for Typhoon Operations (PISTON)[1]. Heming (2016) defines DPE as the great circle distance between the observed position and forecast position at the same forecast validity time. The metric serves as a basic indication of the track forecast performance but does not provide information on the speed or directional bias of a forecast. Such information is provided by the specific forecast bias indicators called ATE and CTE.

To provide a visualized explanation of the ATE and CTE and their relationship with DPE, the metrics are diagrammatically presented in Fig. 5.1. The DPE can be represented as the hypotenuse of a right triangle whose sides comprise the component of the position error along the track (or the ATE) and the component across the track (or the CTE). ATE, the measure of forecast speed bias, is the component of the DPE along the direction[2] of the observed TC track. On the other hand, CTE, the measure of forecast directional bias, is the component of the DPE in the direction perpendicular to the aforementioned direction of the observed track.

Unlike the DPE, which is a non-negative number, ATE and CTE can be both positive and negative in value, with the sign being indicative of the nature of the bias of the track forecast. A positive ATE would indicate that the official track forecast has a fast bias while a negative ATE would indicate a slow bias in the forecast. Similarly, CTE is deemed positive if the forecast position lies to the right of the “extrapolated” observed track looking in the observed direction of motion of the TC in the northern hemisphere. This means that for a non-recurving TC moving east to west, a positive CTE would indicate a poleward bias in the track forecast of the TC.

[1] PISTON is a web-based graphical man-and-machine interactive application tool that integrates various subjective and objective guidance tools and provide other important information to facilitate typhoon forecast operations. This system aims to improve the efficiency of typhoon operations and reduce, but not eliminate, the forecasters’ reliance on paper-based charts for forecast and warning preparation and issuance.

[2] The direction of the observed track at a particular ATE or CTE calculation is represented by the extrapolation of the line formed by connecting the observed position of the TC at forecast validity time and the observed position 6 hours before. The extrapolated line is also referred to in this document as the “extrapolated” observed track for the purpose of CTE calculation.

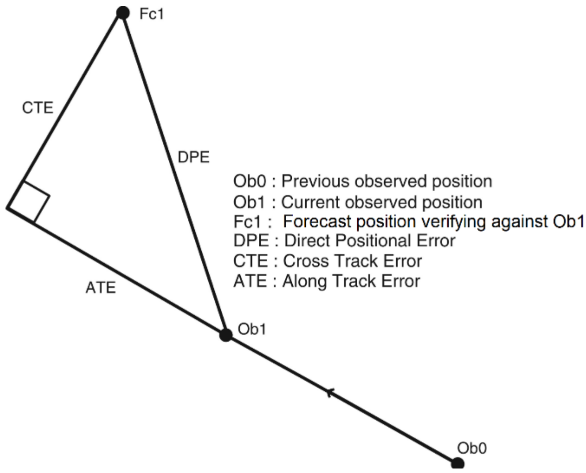

Fig. 5.1. Diagrammatic explanation of the metrics of operational track forecast performance. Figure adapted from Heming (2016).

Summary of 2021 Forecast Position Errors

For the 219 track forecasts issued by PAGASA during 2021 season, the mean DPEs were 77.8, 137.4, 197.7, 260.6, and 317.6 km for the 24-, 48-, 72-, 96-, and 12-hour forecast positions. The annual mean errors in the forecast of TC center position at the 12- to 120-hour forecast times since 2014 are shown in Fig. 5.2. It can be seen that the operational TC track forecasts of PAGASA have steadily improved within the last decade, although year-on-year fluctuations are also observed partly due to differences in the characteristics of TCs occurring within the PAR each year, the overall synoptic environment, and influences of seasonal to interannual climate variability. In particular, it can be seen that DPEs for this season were higher at all forecast times than in 2020. Nevertheless, the mean DPE for the first 72 hours of PAGASA track forecasts during the 2021 season were the 2nd or 3rd lowest since 2014 (and potentially in the history of PAGASA), while forecast positions beyond 72 hours were the 3rd lowest since 2018. The improvements seen in the operational track forecasts are partially attributed to the increased usage of multi-model consensus approach using the guidance information from a combination of global deterministic, regional deterministic, and global ensemble numerical weather prediction (NWP) models.

The details for position errors for each TC that occurred within the PAR region during the 2020 season are presented in Table 5.1. Track forecasts for AURING, CRISING, DANTE, HUANING, and JOLINA were characterized by large position errors. Except for AURING, whose forecasts had a fast and lefthand/equatorward bias, these TCs had a considerable slow and righthand/poleward bias in their track forecasts. The case of TS DANTE was really notable as PAGASA was consistently forecasting an early recurvature based on NWP model guidance at that time, but the TC maintained a generally northwestward track across the archipelago and did not recurve until it was already over the waters west of Ilocos Region (Fig. 5.3). On the other hand, TCs that peaked at typhoon (TY) and super typhoon (STY) categories showed considerably small position errors across different forecast times, with STY BISING and STY ODETTE having position errors less than 100 km within the first 72 hours of the track forecasts, less than 200 km at 96-hour, and less than 300 km at 120-hour forecast.

Fig. 5.4 shows the histogram of position errors of operational 24-, 48-, 72-, 96-, and 120-hour forecasts from PAGASA for the 2020 season. About 76.3% of 24-hour, 80.2% of 48-hour, 80.5% of 72-hour, 85.9% of 96-hour, and 78.9% of 120-hour forecasts had position errors of up to 100 km, 200 km, 300 km, 400 km, and 500 km, respectively.

For the speed and directional biases of the operational track forecast of the 2021 season, the scatter diagram of position errors of operational 24-, 48-, 72-, 96-, and 120-hour forecasts in the along- (ATE) and cross-track directions (CTE) are provided in Fig. 5.5. The mean directional bias across all forecast times and mean speed bias at 24-, 48-, and 72-hour were found to be small (e.g., less than 50 km). However, at all forecast times, a generally slow bias in the track forecasts was observed.

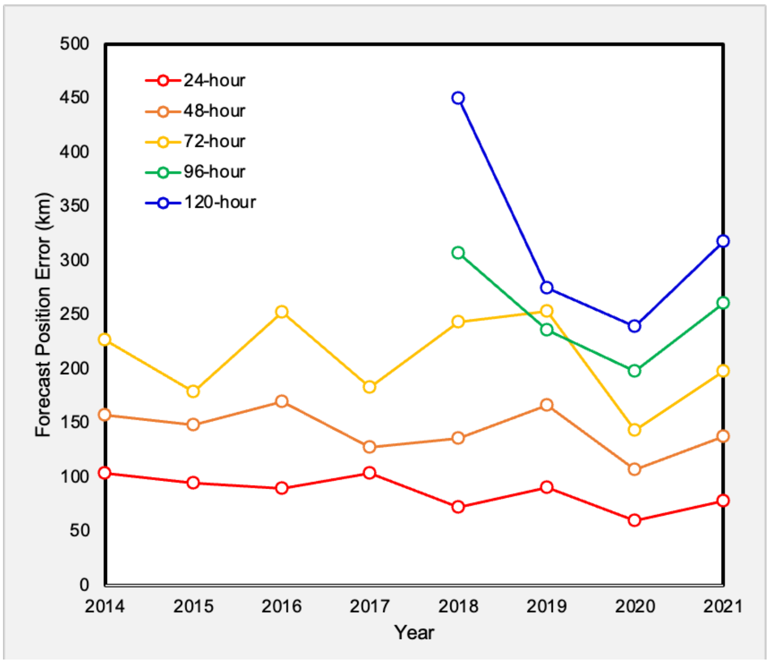

Fig. 5.2. Annual mean DPE of operational 24-, 48-, 72-, 96-, and 120-hour forecast positions from 2014 to 2021. Best track data was used to verify forecasts since 2018, while preliminary or warning tracks were used for the years prior.

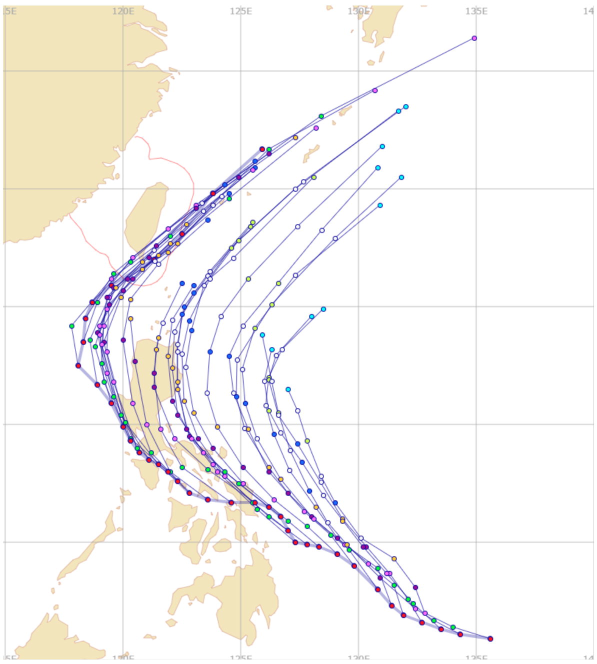

Fig. 5.3. Track forecasts issued by PAGASA for TS DANTE (thin blue lines with multicolored markers) compared with its best track positions (thick, light blue line with red markers).

Table 5.2 shows the hit rate of operational 24-, 48-, 72-, 96-, and 120-hour forecast positions for each TC and for the entire 2021 season. Hit rate is defined as the ratio of the number of forecast confidence circles within which the verifying TC center position fell to the total number of circles. For the 2021 season, the radii of the forecast confidence circles were 97 km, 161 km, 245 km, 293 km, and 434 km for the 24-, 48-, 72-, 96-, and 120-hour forecast positions, respectively. On average, the hit rate of forecast confidence circles during the 2021 season was 75.9% for the 24-hour forecast. The corresponding hit rates for the 48-, 72-, 96-, and 120-hour forecasts were 71.3%, 74.0%, 66.7%, and 71.8%.

Table 5.1. Mean errors of operational 24-, 48-, 72-, 96-, and 120-hour forecasts for each of the TC that occurred within the PAR region. N represents the number of forecast positions that were verified against the PAGASA best track data.

TC Name	24-hour Forecast		48-hour Forecast		72-hour Forecast		96-hour Forecast		120-hour Forecast	
	Mean (km)	N	Mean (km)	N	Mean (km)	N	Mean (km)	N	Mean (km)	N
AURING	160.1	10	315.0	9	365.3	5	462.3	1	-	-
BISING	42.3	36	81.3	32	121.1	28	139.0	24	191.6	20
CRISING	139.6	1	-	-	-	-	-	-	-	-
DANTE	126.6	24	284.6	16	402.9	10	488.9	7	724.8	3
EMONG	-	-	-	-	-	-	-	-	-	-
FABIAN	51.9	25	106.8	25	182.8	25	253.9	25	304.4	22
GORIO	-	-	-	-	-	-	-	-	-	-
HUANING	123.6	2		-	-	-	-	-	-	-
ISANG	75.6	8	113.2	5	243.0	2	-	-	-	-
JOLINA	121.9	22	238.5	14	345.5	11	447.3	8	490.2	3
KIKO	68.6	27	124.7	20	218.8	15	338.4	13	522.0	9
LANNIE	-	-	-	-	-	-	-	-	-	-
MARING	83.6	20	106.8	12	133.6	9	239.9	6	273.5	3
NANDO	-	-	-	-	-	-	-	-	-	-
ODETTE	40.7	28	51.2	24	96.1	18	187.6	15	259.5	11
Mean (N: total)	**77.8**	203	**137.4**	157	**197.7**	123	**260.6**	99	**317.6**	71

Table 5.2. Hit rates of operational 24-, 48-, 72-, 96-, and 120-hour forecast confidence circles for each of the TC that occurred within the PAR region. N represents the number of forecast confidence circles within which the verifying TC center position fell.

TC Name	24-hour Forecast		48-hour Forecast		72-hour Forecast		96-hour Forecast		120-hour Forecast	
	Ratio (%)	N	Ratio (%)	N	Ratio (%)	N	Ratio (%)	N	Ratio (%)	N
AURING	30.0	3	0.0	0	0.0	0	0.0	0	-	-
BISING	100.0	36	93.8	30	96.4	27	100.0	24	100.0	20
CRISING	0.0	0	-	-	-	-	-	-	-	-
DANTE	41.7	10	25.0	4	30.0	3	42.9	3	0.0	0
EMONG	-	-	-	-	-	-	-	-	-	-
FABIAN	96.0	24	96.0	24	88.0	22	56.0	14	63.6	14
GORIO	-	-	-	-	-	-	-	-	-	-
HUANING	50.0	1	-	-	-	-	-	-	-	-
ISANG	87.5	7	100.0	5	50.0	1	-	-	-	-
JOLINA	50.0	11	14.3	2	18.2	2	25.0	2	33.3	1
KIKO	77.8	21	70.0	14	66.7	10	46.2	6	33.3	3
LANNIE	-	-	-	-	-	-	-	-	-	-
MARING	70.0	14	75.0	9	88.9	8	66.7	4	66.7	2
NANDO	-	-	-	-	-	-	-	-	-	-
ODETTE	96.4	27	100.0	24	100.0	18	86.7	13	100.0	11
Mean (N: total)	**75.9**	154	**71.3**	112	**74.0**	91	**66.7**	66	**71.8**	51
Radii of forecast confidence circle	**97 km**		**161 km**		**245 km**		**293 km**		**454 km**	

Current Limits of Verification

Since the 2021 edition, the Annual Report on Philippine Tropical Cyclones (ARTC) has been featuring best track-based track forecast verification statistics. However, users are advised to take note of the following limitations in relation to the presented forecast position error statistics:

1. The DPE, ATE, and CTE values from 2014 to 2017 are considered preliminary because of the absence of best track positions to serve as verifying dataset.
2. Although the provision of five-day TC track forecasts commenced in 2015, Fig. 5.1 only included the verification scores for the 96- and 120-hour forecasts starting in 2018 due to the lack of an extended track data (either best track or warning track) from PAGASA for the years 2015 to 2017 which can be used to evaluate the performance at these forecast times (i.e., forecast positions at 96- and 120-hour usually lie outside the PAR region and observed track data up to the 2017 season are only limited to the PAR region).
3. The provision of official forecast verification statistics ended in 1991 with the publication of the final annual tropical cyclone report of PAGASA. At the time of writing, efforts were underway to retrieve official track forecasts for the 1992 to 2013 seasons that were not yet digitized in order to facilitate its recalculation. Verification statistics using warning track as verifying dataset will be made available for these years in the succeeding editions of the ARTC once these data becomes available. In the absence of verification scores from 1992 to 2013, Fig. 5.2. did not incorporate the verification scores from 1991 and earlier seasons.
4. Other operational centers provide an operational forecast skill score and mean improvement ratios by comparing the official track forecast performance against a generally accepted benchmark, usually a climatological model. For track forecasts, the CLIPER model (Aberson 1998; Neumann 1972; Merrill 1980) serves as the benchmark prediction to assess operation skill. At this time, PAGASA track forecasts are not yet evaluated against these benchmarks, but such comparison is planned for the upcoming ARTCs once the model becomes available for operational use.
5. While PAGASA has commenced the provision of quantitative intensity forecasts in 2021, verification result of the intensity forecasts will be provided beginning in the 2022 edition of the ARTC. However, an updated issue of the ARTC 2021 may also be released at a later date to incorporated intensity forecast verification for the 2021 season.

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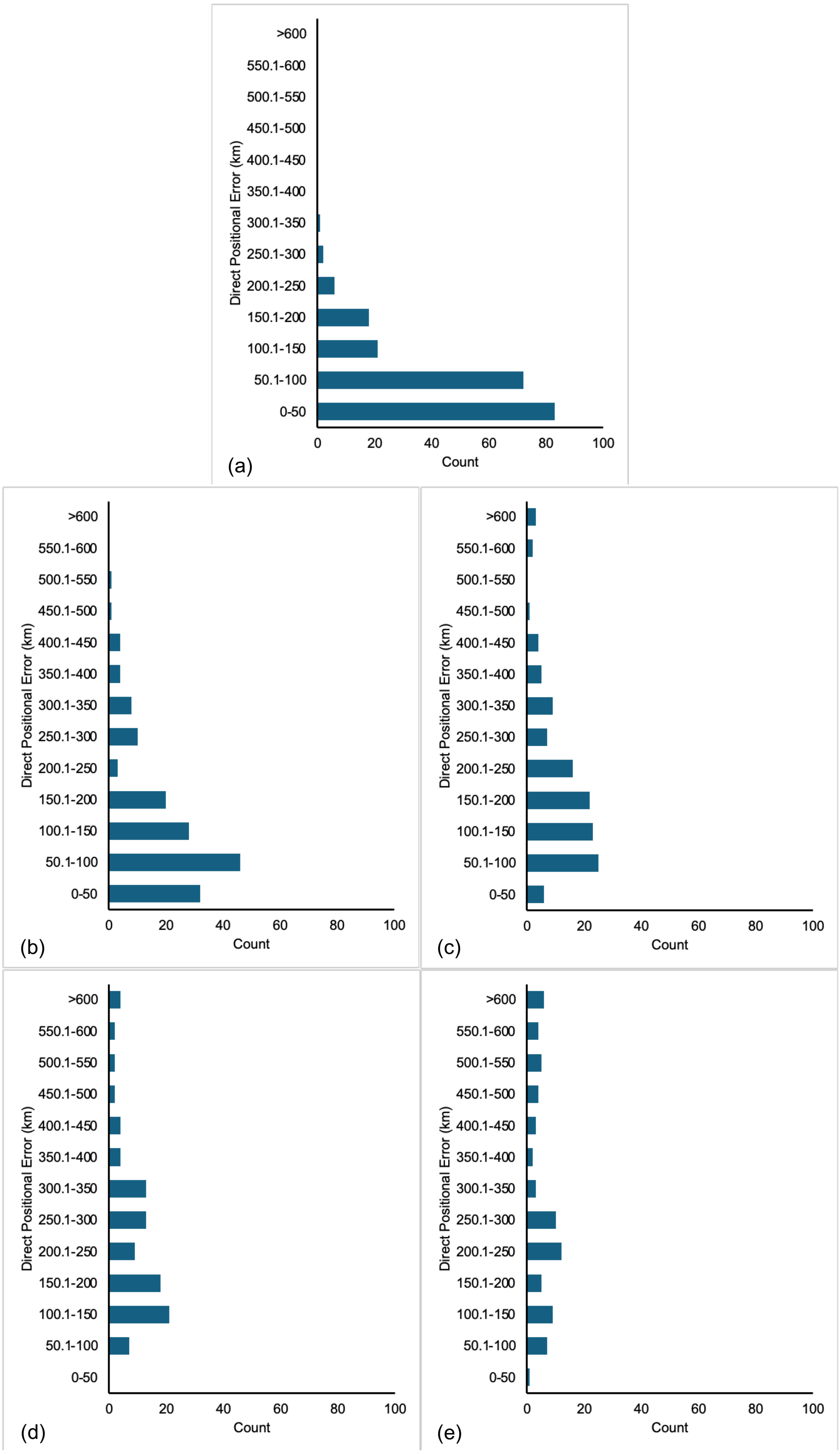

Fig. 5.4. Histogram of position errors of operational (a) 24-, (b) 48-, (c) 72-, (d) 96-, and (e) 120-hour forecasts from PAGASA for the 2021 season.

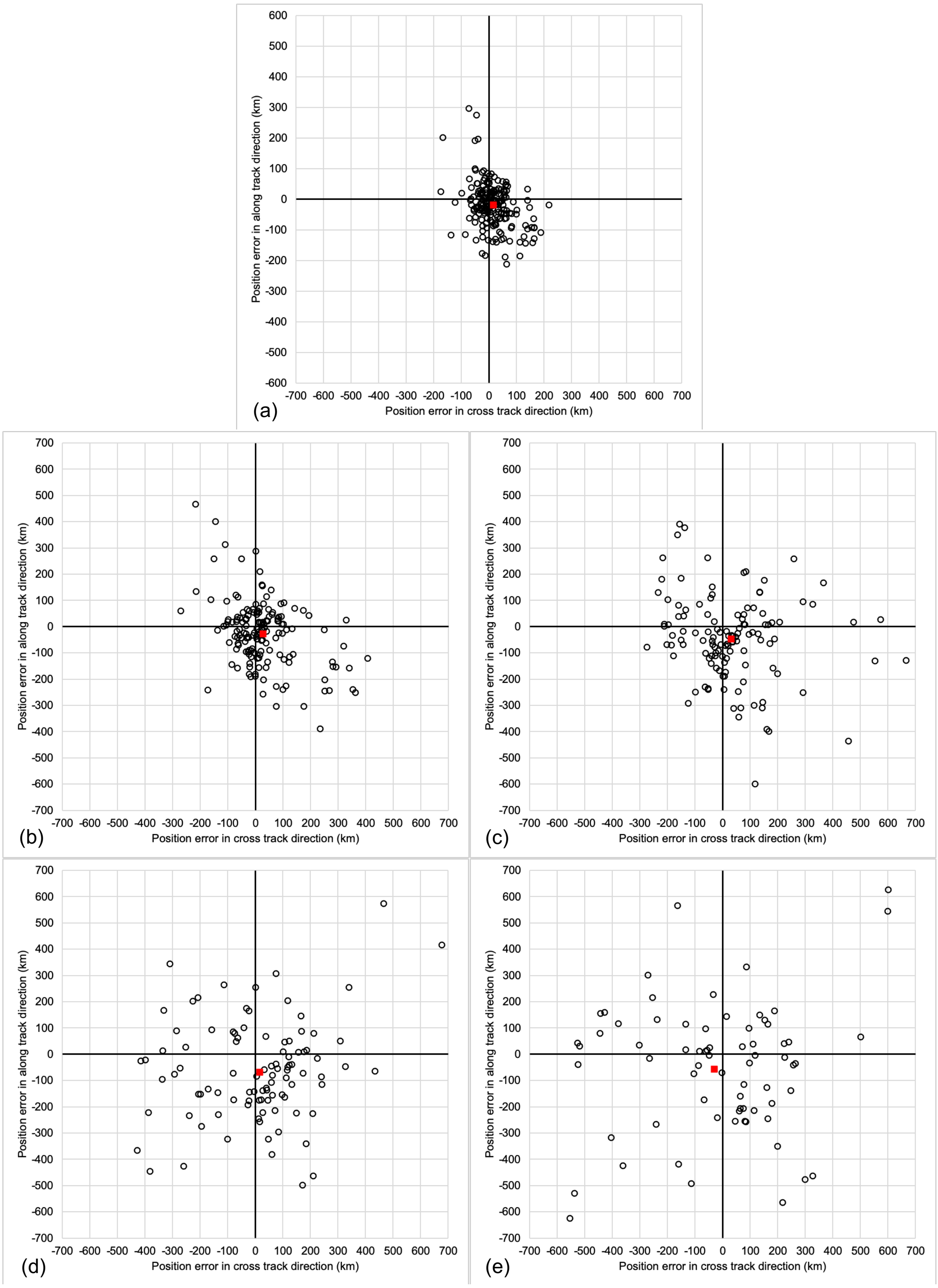

Fig. 5.5. Histogram of position errors of operational (a) 24-, (b) 48-, (c) 72-, (d) 96-, and (e) 120-hour forecasts from PAGASA for the 2021 season. The red triangle denotes the mean ATE and CTE for each forecast time.

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PAGASA BEST TRACK DATA FOR 2021 TROPICAL CYCLONES

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PAGASA Best Track Data for 2021 Tropical Cyclones

The following information are the details of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) best track data for each tropical cyclone (TC) of the 2021 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 a low pressure area or post-tropical low/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 that passed within 30 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 its closest approach[1]. The best track data reverts to using standard synoptic times once the TC is more than 30 nmi from the Philippine coastline. The best track information covers the time the TC was first classified as a tropical depression to either its weakening into a low pressure area or transitioning into a post-tropical low/cyclone.

The best track positions and intensities in this report supersede the warning track[2] and the provisional track[3] that were issued by the Weather Division, PAGASA.

[1] This reference event is used for non-landfalling TCs that passed within 30 nmi of the Philippine coast line.

[2] 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.

[3] 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 Storm AURING (DUJUAN)

DTG	CLAT	CLON	MXWD	PRES
02/16 18	6.8	135.1	25	1004
02/17 00	6.6	134.3	25	1004
02/17 06	6.5	133.7	30	1002
02/17 12	6.5	133.2	30	1000
02/17 18	6.7	132.8	30	1000
02/18 00	7.0	132.5	35	998
02/18 06	7.3	132.1	35	998
02/18 12	7.2	131.9	40	996
02/18 18	7.1	131.6	40	996
02/19 00	7.0	131.2	45	994
02/19 06	6.8	130.4	45	994
02/19 12	6.3	130.5	40	996
02/19 18	6.1	131.0	40	996
02/20 00	6.4	131.3	40	996
02/20 06	6.9	131.1	35	998
02/20 12	7.4	130.4	30	1000
02/20 18	7.8	129.7	30	1000
02/20 21	8.0	129.4	30	1000
02/21 00	8.3	129.1	30	1000
02/21 03	8.6	128.8	30	1000
02/21 06	9.0	128.4	30	1000
02/21 09	9.6	127.6	30	1002
02/21 12	10.1	127.0	25	1004
02/21 15	10.8	126.4	25	1004
02/21 18	11.5	125.9	25	1006
02/21 21	11.9	125.5	25	1006
02/22 00	12.2	125.1	L	1008

Table 6.2. Best track positions and intensities of Super Typhoon BISING (SURIGAE)

DTG	CLAT	CLON	MXWD	PRES
04/12 12	6.5	140.3	25	1006
04/12 18	7.0	139.7	25	1006
04/13 00	7.4	139.2	25	1006
04/13 06	7.7	138.8	30	1004
04/13 12	8.0	138.3	30	1004
04/13 18	8.2	137.9	35	1000
04/14/ 00	8.4	137.6	40	998
04/14 06	8.7	137.3	40	998
04/14 12	8.8	137.0	45	994
04/14 18	8.8	136.8	45	994
04/15 00	8.7	136.6	50	990
04/15 06	8.6	136.1	55	985
04/15 12	8.6	135.8	60	980
04/15 18	8.7	135.3	65	975
04/16 00	8.9	134.6	70	970
04/16 06	9.2	133.8	75	965
04/16 12	9.5	133.1	80	960
04/16 18	10.0	132.1	95	945
04/17 00	10.7	131.1	100	935
04/17 06	11.4	130.1	105	920
04/17 12	12.0	129.2	115	900
04/17 18	12.6	128.4	120	895
04/18 00	13.1	127.7	110	905
04/18 06	13.4	127.1	105	920
04/18 12	13.6	126.8	100	930
04/18 18	13.9	126.5	100	930
04/19 00	14.2	126.4	100	930
04/19 06	14.5	126.3	100	930
04/19 12	14.8	126.3	95	935
04/19 18	15.1	126.2	95	935
04/20 00	15.5	126.1	95	935
04/20 06	15.9	126.0	95	935
04/20 12	16.4	125.9	95	935
04/20 18	17.0	125.5	95	935
04/21 00	17.5	125.2	95	935
04/21 06	18.1	124.9	95	935
04/21 12	18.8	124.8	90	945
04/21 18	19.3	124.8	85	955
04/22 00	19.7	124.9	85	950
04/22 06	20.3	125.4	85	955
04/22 12	20.9	126.1	80	960
04/22 18	21.6	127.0	75	965
04/23 00	22.3	128.0	70	970
04/23 06	23.1	129.0	65	975
04/23 12	23.4	129.9	60	980
04/23 18	23.3	130.5	55	985
04/24 00	23.0	131.2	50	990
04/24 06	22.7	131.8	45	992
04/24 12	22.2	132.8	40	994
04/24 18	21.7	134.1	40	994
04/25 00	21.8	136.0	XT	996

Table 6.3. Best track positions and intensities of Tropical Storm CRISING

DTG	CLAT	CLON	MXWD	PRES
05/12 00	6.5	131.4	25	1006
05/12 06	6.6	131.0	25	1006
05/12 12	6.8	130.4	25	1006
05/12 18	7.0	129.8	30	1004
05/12 21	7.1	129.5	30	1004
05/13 00	7.2	129.1	35	1002
05/13 03	7.3	128.6	35	1002
05/13 06	7.4	128.0	35	1002
05/13 09	7.5	127.2	35	1002
05/13 12	7.5	126.7	30	1004
05/13 15	7.5	126.4	30	1004
05/13 18	7.5	126.1	25	1006
05/13 21	7.5	125.7	25	1006
05/14 00	7.5	125.0	L	1008

Table 6.4. Best track positions and intensities of Tropical Storm DANTE (CHOI-WAN)

DTG	CLAT	CLON	MXWD	PRES
05/29 12	5.9	135.6	25	1004
05/29 18	6.1	134.3	25	1004
05/30 00	6.3	133.5	30	1002
05/30 06	6.6	132.7	30	1000
05/30 12	6.9	131.9	30	1000
05/30 18	7.3	131.4	35	998
05/31 00	8.0	130.8	35	998
05/31 06	9.0	129.8	40	996
05/31 12	9.5	129.1	40	996
05/31 18	9.8	128.3	40	996
05/31 21	9.9	127.8	40	996
06/01 00	10.0	127.3	40	996
06/01 03	10.5	127.0	40	996
06/01 06	11.1	126.7	40	996
06/01 09	11.5	126.2	40	996
06/01 12	11.7	125.6	40	996
06/01 15	11.7	124.6	35	998
06/01 18	11.8	123.6	35	998
06/01 21	12.1	122.8	35	998
06/02 00	12.6	122.3	35	998
06/02 03	13.0	121.9	35	998
06/02 06	13.3	121.5	35	998
06/02 09	13.5	121.1	35	998
06/02 12	13.8	120.7	35	998
06/02 15	14.3	120.3	35	998
06/02 18	14.9	120.0	35	998
06/02 21	15.9	119.5	35	998
06/03 00	16.7	118.9	40	996
06/03 06	17.5	118.1	40	996
06/03 12	18.5	118.3	40	996
06/03 18	19.5	118.4	40	996
06/04 00	20.2	118.7	40	996
06/04 06	20.9	119.5	35	998
06/04 12	22.0	121.3	30	1000
06/04 18	23.1	122.5	30	1000
06/05 00	24.8	123.8	35	998
06/05 06	26.7	125.9	XT	1000

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

DTG	CLAT	CLON	MXWD	PRES
07/03 18	12.7	132.4	25	1004
07/04 00	13.5	131.3	25	1004
07/04 06	14.4	130.1	30	1002
07/04 12	15.6	128.6	30	1002
07/04 18	16.9	127.1	30	1002
07/04 21	17.7	126.1	30	1002
07/05 00	18.4	125.2	30	1002
07/05 03	18.8	124.6	30	1002
07/05 06	19.5	123.5	30	1002
07/05 09	20.1	122.3	30	1002
07/05 12	20.6	121.7	30	1002
07/05 15	21.2	121.4	30	1002
07/05 18	21.7	120.9	30	1002
07/06 00	22.3	120.0	25	1004
07/06 06	23.6	118.4	L	1004

Table 6.6. Best track positions and intensities of Typhoon FABIAN (IN-FA)

DTG	CLAT	CLON	MXWD	PRES
07/15 18	17.4	135.0	25	1006
07/16 00	17.6	134.8	25	1006
07/16 06	18.0	134.6	25	1004
07/16 12	18.8	134.4	25	1004
07/16 18	19.7	134.1	25	1004
07/17 00	20.5	133.6	30	1002
07/17 06	21.1	133.2	30	1000
07/17 12	21.6	132.8	30	1000
07/17 18	22.1	132.6	35	998
07/18 00	22.5	132.5	35	998
07/18 06	22.8	132.4	40	996
07/18 12	23.2	132.3	40	996
07/18 18	23.5	132.2	45	990
07/19 00	23.9	131.9	50	985
07/19 06	24.0	131.7	50	985
07/19 12	24.0	131.5	55	980
07/19 18	24.2	131.2	55	980
07/20 00	24.4	130.8	60	975
07/20 06	24.7	129.8	65	970
07/20 12	24.5	129.0	70	965
07/20 18	24.1	128.2	75	960
07/21 00	24.1	127.9	80	955
07/21 06	24.2	127.2	80	955
07/21 12	24.0	126.6	80	955
07/21 18	23.7	126.2	80	955
07/22 00	23.5	126.0	80	955
07/22 06	23.5	125.9	80	955
07/22 12	23.6	125.8	80	955
07/22 18	23.8	125.5	80	955
07/23 00	24.2	125.4	80	955
07/23 06	24.6	125.1	80	955
07/23 12	24.8	125.0	75	960
07/23 18	25.5	124.9	75	960
07/24 00	26.4	124.7	75	960
07/24 06	27.2	124.3	75	960
07/24 12	28.1	124.0	75	960
07/24 18	28.7	123.7	75	960
07/25 00	29.7	123.0	65	970
07/25 06	30.0	122.5	65	970
07/25 12	30.2	122.0	60	975
07/25 18	30.4	121.6	55	980
07/26 00	30.6	121.2	50	985
07/26 06	30.8	120.9	50	985
07/26 12	31.0	120.5	45	985
07/26 18	31.2	120.0	40	985
07/27 00	31.3	119.5	40	985
07/27 06	31.4	119.0	35	985
07/27 12	31.5	118.9	35	985
07/27 18	32.2	118.2	30	990
07/28 00	32.7	117.6	30	990
07/28 06	33.1	117.0	30	990
07/28 12	33.3	116.9	30	990
07/28 18	33.9	116.8	30	990
07/29 00	34.9	116.7	30	990
07/29 06	35.8	117.1	25	992
07/29 12	37.1	117.4	25	992
07/29 18	38.5	117.6	L	992

Table 6.7. Best track positions and intensities of Severe Tropical Storm GORIO (MIRINAE)

DTG	CLAT	CLON	MXWD	PRES
08/03 18	24.5	125.8	25	998
08/04 00	24.8	126.1	25	998
08/04 06	25.1	126.4	25	998
08/04 12	25.6	126.9	25	998
08/04 18	26.0	127.2	30	996
08/05 00	26.3	127.4	30	996
08/05 06	26.8	128.1	35	994
08/05 12	26.9	128.9	40	992
08/05 18	26.9	130.1	40	992
08/06 00	27.0	131.8	40	990
08/06 06	27.3	133.3	40	990
08/06 12	27.7	134.8	45	985
08/06 18	28.4	136.4	45	985
08/07 00	29.5	137.6	45	985
08/07 06	30.9	138.5	45	985
08/07 12	31.9	138.9	45	985
08/07 18	33.2	139.5	50	980
08/08 00	34.1	140.7	50	980
08/08 06	35.2	142.2	50	980
08/08 12	36.1	143.6	50	980
08/08 18	36.8	145.1	45	985
08/09 00	37.7	147.5	45	985
08/09 06	38.3	149.7	45	985
08/09 12	38.6	152.2	40	990
08/09 18	38.6	154.5	40	992
08/10 00	38.7	158.3	XT	992

Table 6.8. Best track positions and intensities of Tropical Storm HUANING (LUPIT)

DTG	CLAT	CLON	MXWD	PRES
08/02 12	20.9	111.8	25	996
08/02 18	21.0	112.7	25	996
08/03 00	21.3	113.4	30	994
08/03 06	21.5	113.7	30	994
08/03 12	21.2	114.1	30	994
08/03 18	21.0	114.8	30	994
08/04 00	21.2	115.5	35	992
08/04 06	21.5	115.8	35	992
08/04 12	21.7	116.4	40	990
08/04 18	22.5	116.8	45	985
08/05 00	23.1	116.9	45	985
08/05 06	23.5	117.1	40	990
08/05 12	23.9	117.3	40	990
08/05 18	24.2	117.7	35	992
08/06 00	24.4	118.2	35	992
08/06 06	24.7	118.9	35	992
08/06 12	25.0	119.3	35	992
08/06 18	25.1	119.8	35	992
08/07 00	24.8	120.7	35	992
08/07 06	25.6	122.8	35	992
08/07 12	27.2	124.5	35	992
08/07 18	28.3	125.8	40	990
08/08 00	29.3	126.6	40	990
08/08 06	30.1	127.7	40	990
08/08 12	31.5	130.6	40	990
08/08 18	33.7	132.3	45	985
08/09 00	35.3	133.4	XT	980

Table 6.9. Best track positions and intensities of Severe Tropical Storm ISANG (OMAIS)

DTG	CLAT	CLON	MXWD	PRES
08/10 12	12.3	178.8	25	1008
08/10 18	12.4	178.1	30	1006
08/11 00	12.4	177.3	30	1006
08/11 06	12.3	176.6	30	1006
08/11 12	12.2	175.9	30	1006
08/11 18	12.3	175.2	30	1006
08/12 00	12.5	174.5	30	1006
08/12 06	12.6	173.6	30	1004
08/12 12	12.7	172.3	30	1004
08/12 18	12.7	170.8	30	1004
08/13 00	12.7	169.5	30	1004
08/13 06	12.6	168.0	30	1004
08/13 12	12.6	166.3	30	1006
08/13 18	12.5	164.9	25	1008
08/14 00	12.4	163.7	25	1008
08/14 06	12.3	162.2	25	1008
08/14 12	12.3	160.5	25	1010
08/14 18	12.3	158.8	25	1010
08/15 00	12.6	157.0	25	1010
08/15 06	12.9	155.7	25	1010
08/15 12	13.1	154.4	L	1012
08/15 18	13.7	153.1	L	1012
08/16 00	13.8	151.6	L	1012
08/16 06	13.6	149.8	L	1010
08/16 12	13.3	148.2	L	1010
08/16 18	13.2	146.6	L	1008
08/17 00	13.2	145.2	L	1010
08/17 06	13.3	143.5	L	1008
08/17 12	13.5	141.9	L	1010
08/17 18	13.7	140.6	L	1008
08/18 00	14.2	139.1	L	1010
08/18 06	14.6	138.4	L	1008
08/18 12	15.0	137.8	25	1008
08/18 18	15.6	137.0	25	1006
08/19 00	16.7	135.4	25	1008
08/19 06	17.5	134.0	25	1006
08/19 12	17.9	133.1	25	1006
08/19 18	18.4	131.9	30	1004
08/20 00	18.7	131.0	30	1006
08/20 06	18.9	130.1	30	1004
08/20 12	19.3	129.6	35	1002
08/20 18	20.1	129.2	40	1000
08/21 00	21.3	128.4	45	998
08/21 06	22.1	127.7	50	996
08/21 12	22.9	127.0	55	992
08/21 18	23.5	126.5	55	992
08/22 00	24.3	125.9	50	994
08/22 06	25.1	125.3	45	994
08/22 12	25.9	125.0	40	996
08/22 18	27.2	124.8	40	996
08/23 00	29.0	125.3	40	996
08/23 06	31.3	125.7	35	998
08/23 12	33.6	127.0	35	998
08/23 18	36.1	129.5	35	998
08/24 00	37.5	131.4	XT	998

Table 6.10. Best track positions and intensities of Typhoon JOLINA (CONSON)

DTG	CLAT	CLON	MXWD	PRES
09/05 06	10.8	130.4	25	1006
09/05 12	10.4	129.6	30	1004
09/05 15	10.1	129.0	30	1004
09/05 18	10.0	128.6	35	1000
09/05 21	10.1	128.2	40	998
09/06 00	10.3	127.7	45	996
09/06 03	10.5	127.2	50	994
09/06 06	10.8	126.8	55	992
09/06 09	11.0	126.4	60	990
09/06 12	11.2	125.9	65	985
09/06 15	11.4	125.4	60	990
09/06 18	11.6	124.9	60	990
09/06 21	11.8	124.6	55	992
09/07 00	12.0	124.3	55	992
09/07 03	12.2	123.8	55	992
09/07 06	12.4	123.5	50	994
09/07 09	12.7	123.1	50	994
09/07 12	12.9	122.8	55	992
09/07 15	13.1	122.4	55	992
09/07 18	13.3	122.0	60	990
09/07 21	13.5	121.7	65	985
09/08 00	13.7	121.4	55	992
09/08 03	13.9	121.1	50	994
09/08 06	14.1	120.8	50	994
09/08 09	14.4	120.5	45	996
09/08 12	14.8	120.1	40	998
09/08 15	15.4	119.4	40	998
09/08 18	15.6	119.1	40	998
09/09 00	15.7	118.3	40	998
09/09 06	15.8	116.8	40	998
09/09 12	15.8	115.0	45	994
09/09 18	15.9	113.9	50	990
09/10 00	15.7	112.8	50	990
09/10 06	15.7	112.1	50	990
09/10 12	15.6	111.4	50	990
09/10 18	15.6	110.8	50	990
09/11 00	15.6	110.1	45	992
09/11 06	15.5	109.6	45	992
09/11 12	15.3	109.3	40	994
09/11 18	15.2	109.2	35	996
09/12 00	15.2	109.2	30	998
09/12 06	15.3	109.1	30	998
09/12 12	15.3	109.1	25	1000
09/12 18	15.5	109.0	25	1000
09/13 00	15.8	108.8	L	1002

Table 6.11. Best track positions and intensities of Super Typhoon KIKO (CHANTHU)

DTG	CLAT	CLON	MXWD	PRES
09/05 18	13.4	138.9	25	1006
09/06 00	13.5	138.6	25	1004
09/06 06	13.9	138.4	30	1002
09/06 12	14.6	137.9	35	1000
09/06 18	15.2	137.4	45	996
09/07 00	15.6	136.6	50	992
09/07 06	16.1	135.6	65	980
09/07 12	16.3	134.6	75	970
09/07 18	16.3	133.5	80	960
09/08 00	16.0	132.4	90	945
09/08 06	15.7	131.3	95	940
09/08 12	15.5	130.3	95	940
09/08 18	15.4	129.1	100	935
09/09 00	15.5	128.0	105	930
09/09 06	15.8	127.1	105	930
09/09 12	16.1	126.0	100	940
09/09 15	16.3	125.4	100	940
09/09 18	16.6	125.0	100	935
09/09 21	16.9	124.5	105	930
09/10 00	17.1	124.1	105	930
09/10 03	17.5	123.7	110	920
09/10 06	17.8	123.5	115	910
09/10 09	18.3	123.2	115	910
09/10 12	18.7	122.8	115	910
09/10 15	19.1	122.5	115	910
09/10 18	19.5	122.3	115	910
09/10 21	19.9	122.1	115	915
09/11 00	20.3	122.0	110	920
09/11 03	20.7	121.7	110	925
09/11 06	21.0	121.6	105	930
09/11 09	21.3	121.8	105	930
09/11 12	21.8	121.9	100	935
09/11 15	22.2	121.9	100	935
09/11 18	22.8	122.0	95	940
09/12 00	23.8	122.3	90	945
09/12 06	25.2	122.3	90	945
09/12 12	26.2	122.7	85	950
09/12 18	27.6	123.1	85	955
09/13 00	29.1	123.5	80	960
09/13 06	30.7	123.3	75	965
09/13 12	30.9	123.2	70	970
09/13 18	31.4	123.5	65	975
09/14 00	31.3	123.8	60	980
09/14 06	30.9	124.3	55	985
09/14 12	30.5	124.7	50	990
09/14 18	30.2	125.2	45	992
09/15 00	30.3	125.7	45	992
09/15 06	30.4	125.9	45	992
09/15 12	30.2	125.7	45	992
09/15 18	30.2	125.4	50	990
09/16 00	30.4	125.0	50	990
09/16 06	31.1	125.3	50	990
09/16 12	31.7	125.8	50	990
09/16 18	32.3	126.4	50	990
09/17 00	32.9	127.5	50	990
09/17 06	33.5	129.2	50	990
09/17 12	33.8	131.6	45	992
09/17 18	34.0	134.1	40	994
09/18 00	34.5	136.7	30	1000
09/18 06	34.4	137.6	XT	1000

Table 6.12. Best track positions and intensities of Tropical Storm LANNIE (LIONROCK)

DTG	CLAT	CLON	MXWD	PRES
10/03 12	8.7	127.2	25	1004
10/03 15	9.1	126.7	25	1004
10/03 18	9.5	126.2	25	1002
10/03 21	9.9	125.5	25	1002
10/04 00	10.1	125.0	25	1004
10/04 03	10.0	124.4	25	1004
10/04 06	9.8	123.6	25	1002
10/04 09	9.7	122.6	25	1002
10/04 12	10.0	121.7	25	1004
10/04 15	10.4	121.1	25	1004
10/04 18	10.8	120.6	25	1002
10/04 21	11.2	120.0	25	1002
10/05 00	11.8	119.1	25	1002
10/05 03	12.1	118.6	25	1002
10/05 06	12.4	118.1	25	1002
10/05 12	13.0	116.9	25	1002
10/05 18	13.9	115.3	25	1002
10/06 00	14.4	114.3	25	1000
10/06 06	15.0	113.3	25	1000
10/06 12	15.7	112.3	30	998
10/06 18	16.0	112.0	30	998
10/07 00	16.4	111.7	30	998
10/07 06	16.9	111.4	30	996
10/07 12	17.2	111.3	30	996
10/07 18	17.4	111.1	35	994
10/08 00	17.9	110.9	35	992
10/08 06	18.5	110.9	35	992
10/08 12	19.1	110.6	35	992
10/08 18	19.3	110.0	35	992
10/09 00	19.6	110.2	35	994
10/09 06	19.8	110.3	35	994
10/09 12	20.0	109.8	35	994
10/09 18	20.4	109.0	35	996
10/10 00	20.7	108.0	35	996
10/10 06	20.6	106.9	30	1000
10/10 12	20.4	106.2	25	1002
10/10 18	20.3	105.6	L	1004

Table 6.13. Best track positions and intensities of Severe Tropical Storm MARING (KOMPASU)

DTG	CLAT	CLON	MXWD	PRES
10/07 06	13.7	129.7	25	1002
10/07 12	13.5	129.9	25	1002
10/07 18	12.9	130.2	25	1000
10/08 00	12.5	130.2	30	996
10/08 06	12.3	130.1	35	994
10/08 12	12.2	129.9	35	994
10/08 18	11.9	129.8	40	992
10/09 00	11.7	130.3	40	992
10/09 06	12.6	131.1	40	992
10/09 12	14.3	130.4	45	990
10/09 18	15.6	130.1	45	990
10/10 00	17.1	128.8	45	990
10/10 06	17.6	128.0	45	990
10/10 12	18.2	126.7	45	985
10/10 15	18.5	126.0	45	985
10/10 18	18.7	125.3	45	985
10/10 21	18.7	124.9	45	985
10/11 00	18.7	124.4	50	980
10/11 03	18.7	123.7	50	980
10/11 06	18.7	123.0	50	980
10/11 09	18.8	122.3	50	980
10/11 12	18.9	121.7	55	975
10/11 15	18.9	121.0	55	975
10/11 18	18.9	120.3	55	975
10/11 21	18.9	119.7	55	975
10/12 00	18.9	119.1	55	975
10/12 06	18.8	117.3	55	975
10/12 12	18.8	116.2	55	975
10/12 18	19.1	114.6	55	975
10/13 00	19.1	112.8	55	975
10/13 06	19.1	111.0	55	975
10/13 12	18.9	109.3	45	985
10/13 18	18.7	108.5	40	992
10/14 00	18.9	107.5	35	996
10/14 06	19.6	106.7	30	1000
10/14 12	19.4	105.5	25	1004
10/14 18	19.3	103.1	L	1006

Table 6.14. Best track positions and intensities of Tropical Depression NANDO

DTG	CLAT	CLON	MXWD	PRES
10/07 12	14.2	138.7	25	1004
10/07 18	15.2	137.9	25	1004
10/08 00	16.1	136.8	30	1002
10/08 06	16.7	135.8	30	1002
10/08 12	17.1	134.8	30	1002
10/08 18	16.9	133.1	30	1000
10/09 00	16.3	131.5	30	0998
10/09 06	15.7	130.2	30	0996
10/09 12	14.9	129.1	L	0996

Table 6.15. Best track positions and intensities of Super Typhoon ODETTE (RAI)

DTG	CLAT	CLON	MXWD	PRES
12/12 00	4.8	145.0	25	1002
12/12 06	4.9	144.0	25	1002
12/12 12	5.0	143.2	25	1002
12/12 18	5.1	142.6	25	1002
12/13 00	5.3	142.0	30	1000
12/13 06	5.7	140.9	35	0998
12/13 12	6.3	139.7	40	0996
12/13 18	6.8	138.6	45	0992
12/14 00	7.4	137.1	50	0990
12/14 06	7.8	135.6	50	0990
12/14 12	8.2	134.7	55	0985
12/14 18	8.7	133.4	60	0980
12/15 00	8.9	132.3	65	0975
12/15 06	9.1	131.0	70	0970
12/15 09	9.1	130.7	75	0965
12/15 12	9.1	130.2	75	0965
12/15 15	9.2	129.6	80	0960
12/15 18	9.4	129.0	85	0955
12/15 21	9.5	128.3	95	0935
12/16 00	9.7	127.6	105	0915
12/16 03	9.8	126.8	105	0915
12/16 06	9.9	126.0	105	0915
12/16 09	10.0	125.2	100	0925
12/16 12	10.1	124.3	95	0935
12/16 15	10.1	123.4	90	0945
12/16 18	10.1	122.5	85	0950
12/16 21	10.1	121.9	80	0955
12/17 00	10.1	121.2	80	0955
12/17 03	10.2	120.5	80	0955
12/17 06	10.3	119.9	80	0955
12/17 09	10.3	119.2	80	0955
12/17 12	10.4	118.6	80	0955
12/17 15	10.6	118.0	80	0955
12/17 18	10.8	117.4	80	0955
12/18 00	11.0	116.0	85	0945
12/18 06	11.2	114.7	95	0935
12/18 12	11.8	113.4	100	0925
12/18 18	12.6	112.2	105	0915
12/19 00	13.1	111.4	100	0920
12/19 06	13.9	110.8	90	0940
12/19 12	14.8	110.6	80	0960
12/19 18	15.9	110.6	70	0970
12/20 00	17.2	110.8	60	0980
12/20 06	18.1	111.3	50	0990
12/20 12	19.0	112.1	40	1000
12/20 18	19.8	112.8	35	1004
12/21 00	20.6	113.8	30	1006
12/21 06	21.5	115.2	L	1008

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