

Regional Service Assessment

Typhoon Sudal

April 9, 2004



U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
Pacific Region Headquarters
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Service Assessment for Typhoon Sudal on Yap

Preface

Preface

On April 9, 2004 Typhoon Sudal struck Yap in the Federated States of Micronesia. Typhoon Sudal was one the most intense typhoons to ever affect the island of Yap. Residents had to go back over 50 years to recant a typhoon with the same or lesser intensity than Sudal.

Due to the magnitude of the event and its impact to Yap, a regional service assessment team was formed to examine the performance of WFO Guam and WSO Yap regarding the forecasts, warnings, communications, and observations leading up to and immediately after the arrival of Typhoon Sudal in Yap. Service assessments provide a valuable contribution to ongoing efforts to improve the quality and timeliness of the National Weather Service products and services. Findings in the assessment will help to improve these products and services.

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Sudal Summary:

Of note: both Guam Local Time and Yap Local Time are the same and 10 hours ahead of Universal Time Coordinated (UTC). All times listed will be in local time.

Disturbed weather was noted east of Chuuk State in the Federated States of Micronesia (FSM) during the first few days of April. The disturbed weather was located at the eastern end of the tropical monsoonal trough in the North Pacific Ocean. Meteorologists at the Joint Typhoon Warning Center (JTWC) began issuing Tropical Cyclone Formation Alerts on Tropical Depression 03W at 1 PM 2 April 2004. National Weather Service Forecast Office Guam began issuing Special Weather Statements on the tropical disturbance at 9 AM 4 April 2004. The tropical disturbance was located at 6.4N 150.4E on the initial alert. The forecast was for the system to intensify into a tropical storm in 24 hours and a typhoon at 48 hours. National Weather Service Forecast Office in Guam began issuing tropical depression advisories to match the JTWC corresponding 2 PM time. Tropical Cyclone Public Advisories began at 5 PM the same date.

The depression took a north-northwest track at 9 knots and intensified to Tropical Storm (TS) 03W at 10 PM 4 April 2004 near 7.2N 149.3E (about 755 miles northeast of Yap). Maximum sustained winds at this time were 35 knots with gusts to 45 knots. Intensification was forecast to make the system a typhoon between 10 PM on 5 April 2004 and 10 AM on 6 April 2004. TS 03W was moving north-northwest at 9 knots. Nearly all the forecast track models moved the TS to between Guam and Yap but closer to Yap (3.5 degrees north of the island ~227 nautical miles (nm) north of Yap at 120 hours).

Tropical Storm 03W intensified to 55 knots and then 60 knots by 4 AM on 6 April and 10 AM on 6 April, respectively, as the translational speed slowed from 9 knots to 6 knots during the time period. TS 03W began a turn toward a westerly heading (260 degrees) during this time. At 10 AM on 6 April 2004, the TS was located 600 nm east northeast of Yap and 330 nm south southeast of Guam. The official forecast track was for the TS to attain typhoon strength in 72 hours and move to 120 nm north of Yap.

By evening on Tuesday 6 April 2004 at 4 PM Guam local time the system was upgraded to a typhoon. Sudal was located at 9.0N146.0E (about 540 nm east of Yap) with maximum sustained winds of 70 knots and gusts to 85 knots and was moving west at 6 knots. The National Weather Service Forecast Office in Guam issued a Typhoon Watch for Yap two hours earlier at 2 PM 6 April 2004. The forecast moved Sudal to 130 nm east-northeast of Yap by 6 AM on 9 April 2004 on the edge of the outermost ring of forecast tropical storm force wind field.

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At 8 PM on 7 April the Yap Emergency Command Post opened for 24/7 operations in conjunction with Typhoon Sudal. By Wednesday 7 April (Guam local time) the schools were closed. Shelters began opening Wednesday 7 April afternoon and evening on Yap.

The WFO Guam posted a tropical storm warning for Yap at 11 PM on 7 April 2004. The Typhoon Watch (winds between 35 and 64 knots are expected within 24 hours and winds in excess of 65 knots are possible) remained in effect. *Tropical storm force sustained winds were recorded on Yap between 9:40 AM on Thursday 8 April for 24 hours until 9:30 pm on Friday 9 April.* At 10 PM on 7 April 2004 Sudal was located near 9.7N142.1E about 239 nm east of Yap with sustained winds of 90 knots moving west-southwest at 10 knots.

Sudal took a west-southwest track and slowed translational speed to approximately 8 knots. At 8 AM on 8 April 2004 the WFO Guam posted a Typhoon Warning for Yap (winds in excess of 65 knots are expected within 24 hours). *Typhoon Force sustained winds began on Yap at 630 AM 9 April 2004 and lasted 6 hours until 1230 PM.* At 7 AM on 8 April, Sudal was located near 9.4N140.E or 165 nm east of Yap. Sudal was forecast to pass 30 nm to the north of Yap by 2 AM on Friday 9 April. Typhoon force sustained winds were forecast to extend out approximately 25 nm from the center

Various Hurricane Local Statements for Yap from the WFO Guam during the overnight and morning hours on Thursday April 8 had rainfall totals forecast to be 5 to 10 inches possible with storm surge of 8 to 14 feet by Friday morning 9 April 2004. *Sudal total rainfall amounts from stations remaining operating were 8.09 at the airport WSO Yap and 6.3 in Maap. Storm surge heights were commonly measured around the island of Yap at 8 to 11 1/2 feet.*

Between 10 AM 8 April to 7 AM on 9 April, Sudal slowed translational speed to 6 knots while moving across the southern tip of Yap. Between 9 and 10 AM 9 April communications between WSO Yap and WFO Guam were lost. Communications were maintained between WSO Yap and PEACESAT in Guam via high frequency (HF) radio. By 4 PM on 9 April Sudal was located at 9.5N137.2E approximately 60 nm west of Colonia, Yap and was moving northwest. Maximum sustained winds were estimated to be 110 knots. See Figures 1 and 6 on the track on Typhoon Sudal.

Summary

- 11 hours lead-time for the Tropical Storm Warning (Conditions possible within 24 hours)
- 23 hours lead-time for the Typhoon Warning (Conditions possible with 24 hours)
- 64 1/2 hours lead-time for the Typhoon Watch (Conditions possible within 36 hours)
- ***No deaths or serious injuries during Sudal.***

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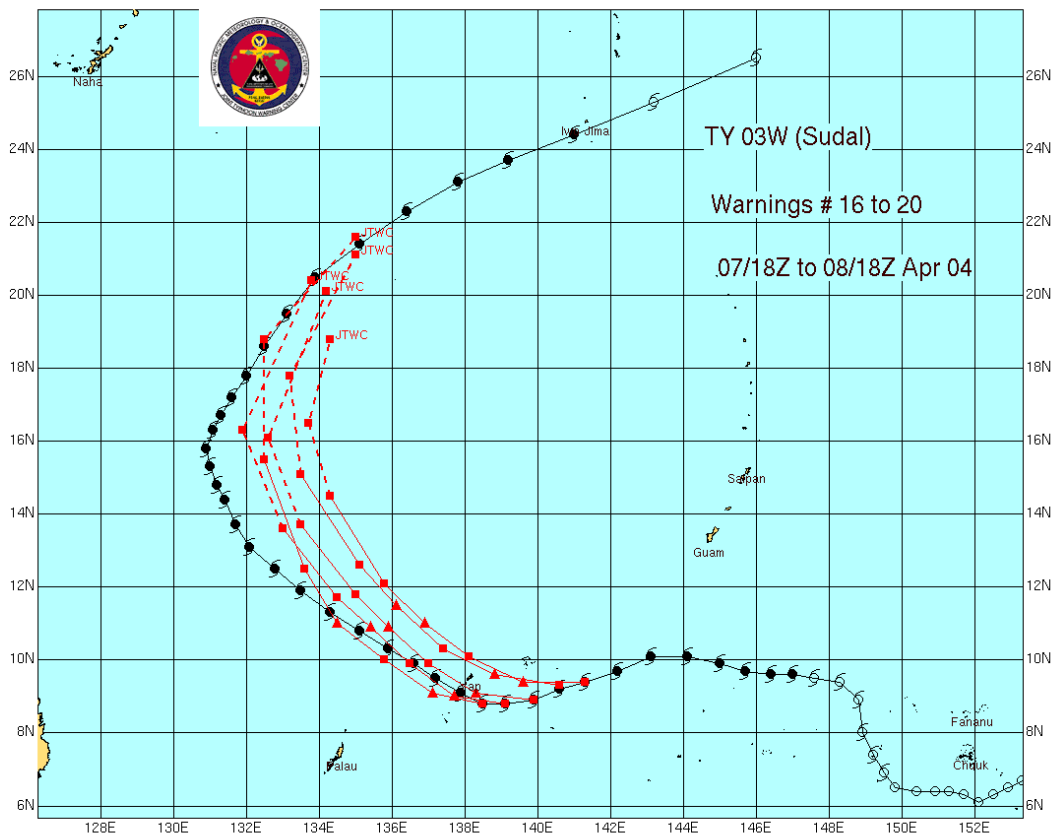


Figure 1. Track of Typhoon Sudal. The red dashed lines represent JTWC forecasts originating from the position along the track of Sudal and are for advisories 16 through 20. The black solid line represents the actual path of Typhoon Sudal.

Offices Responsibility

Joint Typhoon Warning Center

Tropical Cyclone forecasts in the western North Pacific issued by JTWC are the basis for the WFO Guam's tropical cyclone watches and warnings. The JTWC issues 6 hourly advisories, including forecast track, wind speed, and wind radii (distance from the storm center of tropical storm force (34 knots to 49 knots) sustained winds, storm force sustained winds (50 to 99 knots), and 100 knots or greater). A discussion of the meteorological aspects of the tropical cyclone is issued every 12 hours.

JTWC forecasters follow a specific process in preparing typhoon track and intensity forecasts, which like other hurricane forecast centers, place a reliance on the initial position to

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produce a set of guidance models. Track and intensity of tropical cyclones are forecast using computer models as guidance.

Coordination between the WFO Guam and JTWC is performed on a routine basis to aid in overall performance and to attain the best products and services to the users.

PEACESAT, Satellite Telephones and HF Radio – Communications Equipment

The UOG relays weather information from the WFO Guam using a public service satellite telecommunications network called PEACESAT. The university also transmits information via HF radio to the islands throughout the Pacific Ocean. This may be the only means of communication with some of the islands.

Every Pacific Region WSO and WFO has a satellite telephone. The purpose of the phone is for emergency backup communications. However, delays in receiving external antennae prevented this system from being used during Sudal.

There is no operational HF radio transceiver and antenna installed at WFO Guam. An HF radio would provide an additional backup system, allowing WFO Guam to make direct contact with WSOs such as Yap during typhoon events. The NWS is allocated four frequencies for use with this type of radio in the western North Pacific.

Yap Command Post

The Yap Command Post is brought to operations 24 hours a day and 7 days a week during disasters such as Sudal brought to Yap. The command post is located next to the AM radio tower and is in the building where the broadcast for the radio station is held. Any information about Sudal from the Weather Service Office (WSO) Yap was broadcast from the command post to Yap and some of the outer islands on the radio. VHF radio broadcasts cover the remaining islands with information. The Yap command post has multiple phone lines and fax machines. A satellite phone is also located at the command post.

WFO Guam

WFO Guam is tasked with issuing public tropical cyclone advisories, watches, and warnings for its large area of responsibility in the western North Pacific. These products are based on JTWC forecasts of storm intensity and position. The office also issues the normal suite of WFO forecast and warning products, which become more frequent, longer, and more complex during the threat of a tropical cyclone. The suite includes local statements when portions of the WFO area of responsibility are under tropical storm or typhoon watches or warnings. See Figure 2 for WFO Guam's area of responsibility.

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Pacific Region Headquarters

Pacific Region Headquarters in Honolulu, Hawaii provides administrative and technical support to field offices in its region. Currently a Hurricane Watch Office (HWO) is maintained 24/7 when a tropical cyclone is a threat to any of the forecast offices in the region, this excludes the Weather Service Offices in Federated States of Micronesia (FSM), Republic of Palau (ROP), and the Republic of the Marshall Islands (RMI). See Figure 3 for the areal extent of the Pacific Islands in relation to the areal extent of the lower 48 United States.

WSO Yap

WSO Yap provides surface and upper air observing and data collection programs along with local forecast and warnings. The WSO in the Yap state of the Federate States of Micronesia (FSM) is responsible for distributing warnings, watches, advisories, and forecasts to the government's Emergency Command Post. The Emergency Command Post in turn distributes the watches, warning, advisories and forecasts to all the customers, partners, and the greater community in the Yap state through the AM radio station collocated with the Emergency Command Post. The flow of information in Yap is illustrated with Figure 4.

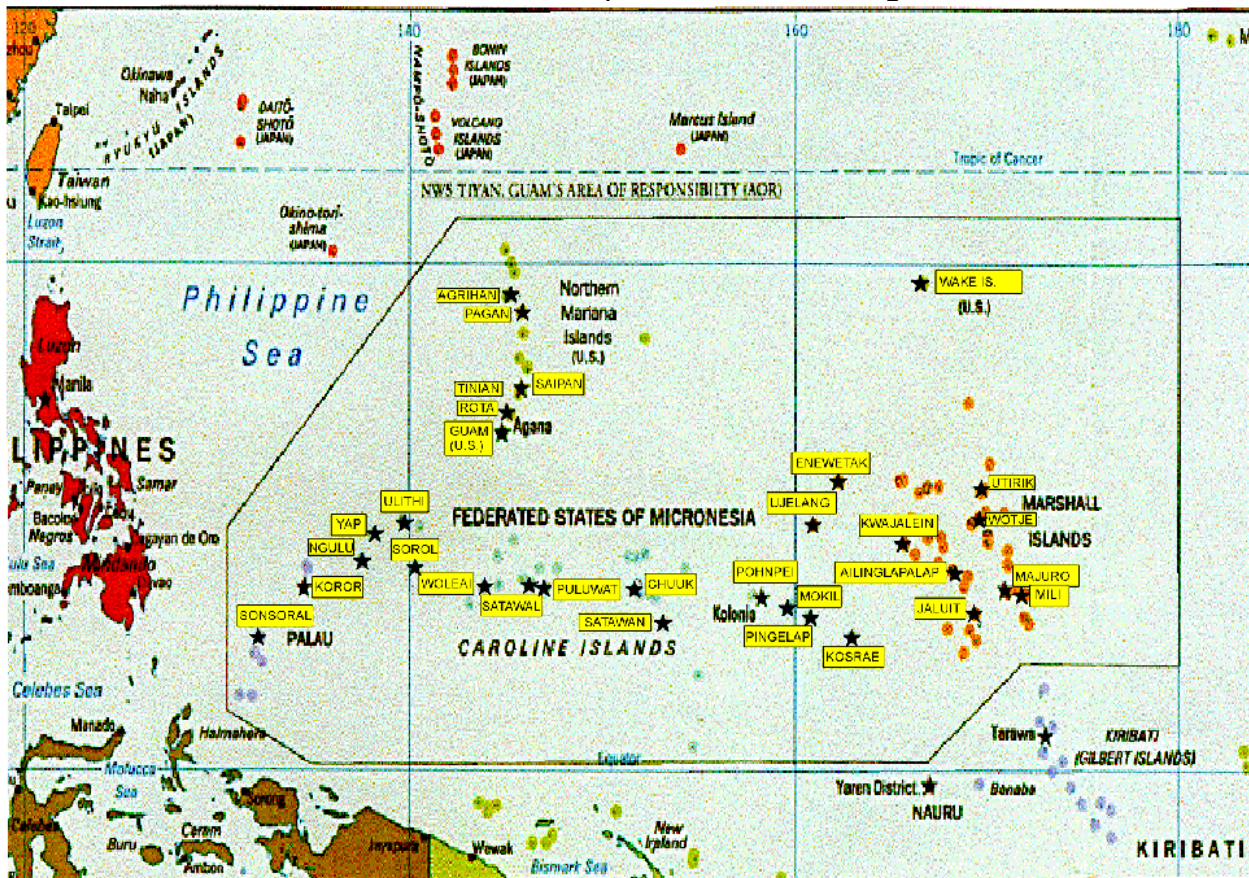


Figure 2. NWS WFO Guam Area of Responsibility

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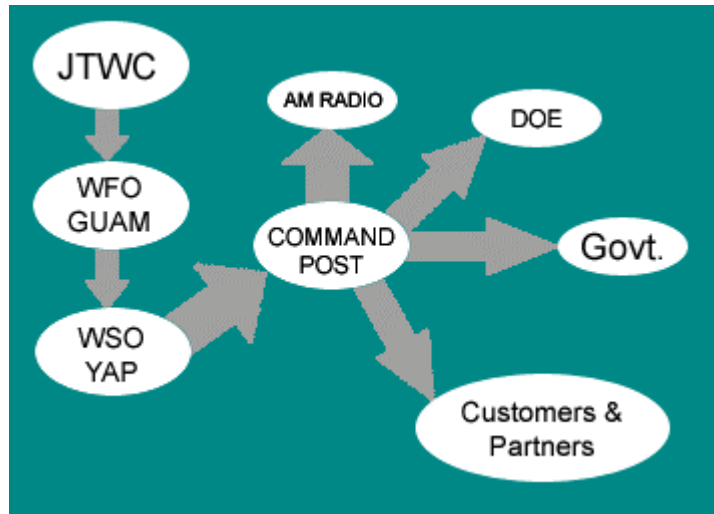


Figure 4. Flow of Typhoon Information in Yap, FSM

Yap Field Damage Report

Typhoon Sudal was a strong category 2 to weak category 3 (Saffir-Simpson scale) typhoon when it reached and moved across the extreme southern end of Yap Island in Yap State of the Federated States of Micronesia (FSM). No other islands were severely impacted from Sudal. The assessment team visited Yap Island.

A map of the island of Yap (Figure 5) has been provided. The Regional Service Assessment Team arrived at the Airport on the south central part of Yap around 1 PM 13 April 2004. A full island tour was conducted to survey the damage.

Wind damage was noted as being weak category 3 on the extreme southern end of the island near Gilman. The eye had been witnessed from residents from about the ten most southern island houses. Eye passage was short lived with residents interviewed indicating anywhere from 3 to 15 minutes. See figure 6 for the track of Sudal across the southern tip of Yap and figure 7 for a satellite image of the system affecting Yap.

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YAP Island



Figure 5. Map of Yap

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Wind damage along the remainder of the east facing side of Yap exhibited category 2 type damage to structures, and foliage. The island of Yap is nearly divided by a canal into distinct southern and northeast halves. The western side of Yap (on the southern half) was opposite the advancing Typhoon Sudal and somewhat protected from the winds by the mountains. Category one type damage was most prevalent on this side of Yap with nearly all trees left standing. Winds in the area of Fanif were estimated at 50 to 65 knots.

The most extensive damage on the island were areas affected by storm surge. The way Typhoon Sudal approached Yap from the southeast at 6 knots allowed the surge to inundate most east facing parts of the islands. All housing in east facing sections of Yap exhibited the worst damage from Bechyal on the northernmost end to Gilman in the south. Estimates of storm surge were easily made throughout the coastline of Yap using debris lines and primitive but accurate methods. Some of the estimates from storm surge on Yap from north to south:

Bechyal	9 ½ feet
Wanyan	9 ½ feet
Tagreng Canal	no runup (the canal separates the two halves of the island of Yap)
East of Weloy	6 feet (west of Pekel island)
Colonia	8-9 feet
Balabaat	8-10 feet
Gilman	11 ½ feet

An extensive coral reef protects the entire island of Yap from having larger waves inside the reef zone. Surf at the reef edge was estimated at 16 to 22 feet.

Areas where nearly all structures were damaged related to storm surge included: Bechyal, Wanyan in Gagil, Balabaat, and much of downtown Colonia. In the capital and main city of Colonia the winds and surge beached a large barge in the port area (figure 12), a scenic antique boat (figure 11) which belonged to the Manta Ray Hotel was pushed against the land, and several boats less than 25 feet had been sunk or moved over land. Yap is famous for its large stone money, which is sometimes greater than 6 feet tall and very heavy. The area of Balabaat is where most of the stone money resides. Much of the money was toppled, scattered and even pushed inland by the force of the water. Nearly 100 percent of the structures in this region were left unlivable. Bechyal was the site of a Cultural Center with an ancient style village built entirely of wood and palm frond roofing for visitors to see. The village underwent extensive damage to all its structures. The two main hotels Manta Ray and Trader's Ridge (figures 8 and 9) experienced damaged. The Pacific Daily News paper from Guam published a photo of a kayak paddler at the Manta Ray Hotel paddling through the hotel lobby just after the height of the typhoon. The airport (figure 10) experienced damage but was fully operational upon the assessment teams arrival.

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Sudal total rainfall amounts from stations remaining operating were 8.09 at the airport WSO Yap and 6.3 in Maap.

Lowest recorded pressure was 958.5 millibars (mb) (figure 13) at 10:50 AM Guam local time 9 April.

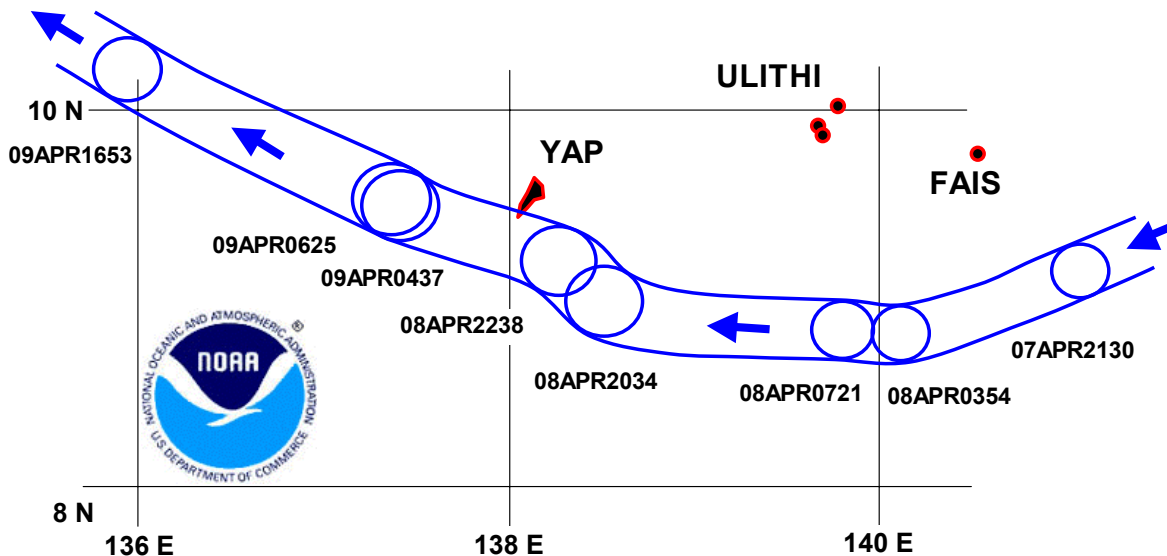


Figure 6. Track of the eye of Typhoon Sudal constructed from microwave imagery. Each circle represents a subjective estimation of the position and diameter of the eye from 37 GHz microwave imagery at the time indicated. This post analysis of microwave imagery was done after imagery was obtained from TRMM, DMSP, and AMSR-E as available on the Naval Research Laboratory, Monterey website: http://www.nrlmry.navy.mil/atcf_web/.

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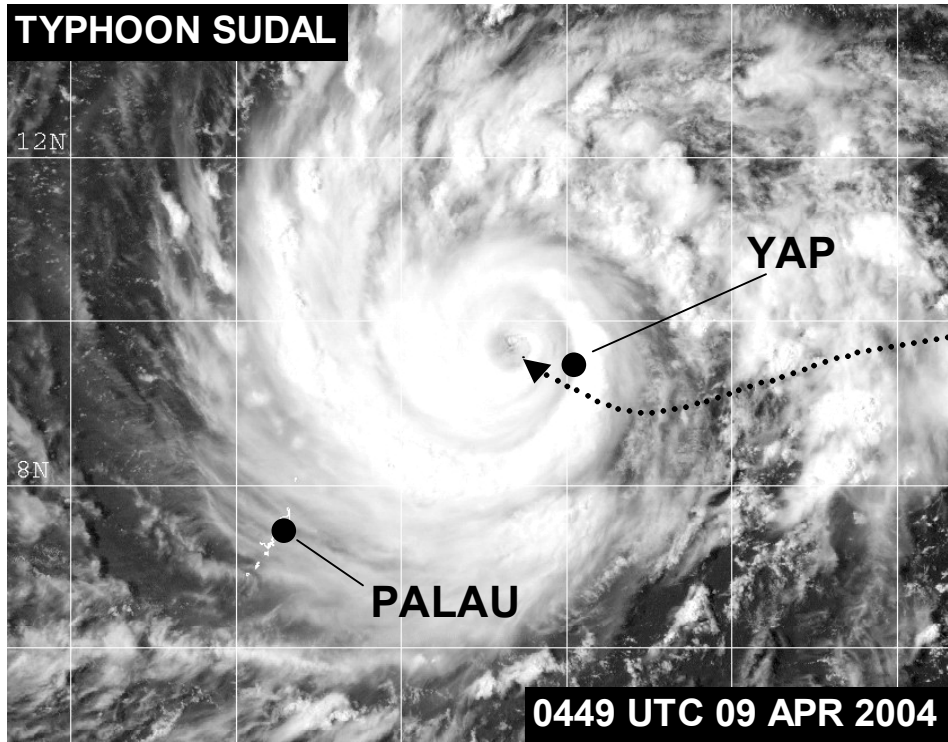


Figure 7. Following a rather unusual track (dotted line), the center of Typhoon Sudal passed just to the south of Yap Island and placed that island in the highest winds, rain, and sea inundation of the northern eye wall. In this picture, the eye has moved to the west of Yap Island, but the island is still being buffeted by wind and rain in the spiral rainbands of the typhoon.

The Federal Emergency Management Agency (FEMA) estimated greater than 90 percent of the homes suffered damage from Typhoon Sudal with about 50 percent unlivable and about 30 percent permanently unlivable. Power, radio communications and phone service was restored within days to most of the island of Yap.

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Figure 8. Trader's Ridge Hotel in Colonia, Yap during Typhoon Sudal.

Considerable damage was done to most wooden structures and wood or tin roofs. Many power and phone lines were downed but concrete power poles were unaffected. The primary radio station was inoperable due to flying debris from tin roofs. The hospital and airport roof (figure 10) were heavily damaged. There was no damage to aircraft navigational aids.

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Figure 9. View toward Trader's Ridge Hotel from the main road in Colonia, Yap after Typhoon Sudal.

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Figure 10. Yap Airport four days and much cleanup after Typhoon Sudal.

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Chronology

All times listed are in local time for Guam and Yap

2 April 2004 - 4 April 2004

System 03W began east of Chuuk and west of Pohnpei

Forecast to go south of Chuuk then northwest to halfway between Guam and Yap

4 April 2004 (Dayshift)

1 PM

Tropical Storm Warning - Puluwat

Tropical Storm Watch - Satawal

5 April 2004 (Midshift)

WSO Chuuk called to correct the Guam initial position

7:40 AM

Tropical Storm Warning - Satawal

6 April 2004 (Midshift)

Coordination between Guam and JTWC allowed the track to be adjusted south

6 April 2004 (Dayshift)

7:55 AM

Typhoon Watch - Guam and Rota

Tropical Storm Warning CANCELED - Satawal and Puluwat

2 PM

Typhoon Watch - Yap and Ulithi

7 April 2004 (Midshift)

Coordination of the fix position from Guam to JTWC allowed JTWC to adjust their initial position and thus the forecast track.

8 AM

Typhoon Watch CANCELED - Guam and Rota

Tropical Storm Warning - Ulithi (Fais mentioned)

7 April 2004 (Evening shift)

9:30 PM

Guam and JTWC satellite fix not the same

9:50 PM

Decision reached through open coordination with Guam NWS WFO and JTWC

11 PM

JTWC adjusted forecast track south of the guidance

Tropical Storm Warning - Yap (Typhoon Watch still in effect)

Typhoon Warning - Ulithi

8 April 2004 (Midshift)

2:30 AM

Eye clearly visible on satellite

9/28/2004

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8 AM

Typhoon Warning - Yap (Ulithi still in Typhoon Warning)

Tropical Storm Warning - Ngulu

The track is now forecast to be between Yap and Ulithi

8 April 2004 (Dayshift)

11AM

JTWC and NWS WFO Guam Coordination allow NWS Guam to bias all track forecast positions 0.4 degree south of the track (TCP #17).

8 April 2004 (Evening shift)

10:40 PM

Yap WSO reports 86 knots at 8000 feet on the sounding

9 April 2004 (Midshift)

2 AM

Typhoon Warning - Ngulu

Typhoon Watch - Koror and Kayangel

4:45 AM

Yap reports houses being downed

5 AM

Yap has 5.5 earthquake

9 April 2004 (Dayshift)

2 PM

Typhoon Warning CANCELED - Ulithi

Typhoon Watch CANCELED - Koror

HF communication only to Yap

10 April 2004 (Midshift)

Sudal slows translational speed

8 AM

Typhoon Warning CANCELED -Yap and Ngulu

Typhoon Watch CANCELED - Kayangel

Pohnpei and PEACESAT still in communications with Yap

9 AM

Yap local phone lines working

Assessment team arrives 1PM 13 April

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Narrative Summary

Communications

Sudal was the worst typhoon in Yap history and the last time any typhoon near this intensity had affected Yap was in the 1950s. Lead times on watches and warnings were documented earlier with good results. In fact, all but one person interviewed on Yap and Guam (out of nearly 100) felt well informed about Typhoon Sudal coming to Yap and the potential threat to life and property. A list of people interviewed is provided in appendix B. The fact that no deaths or serious injuries occurred during the typhoon is a testimonial to the information provided through WFO Guam, JTWC and WSO Yap. Interviewees felt schools and business were closed and the Yap Emergency Command Post opened along with shelters in plenty of time for residents of Yap to move to safety. Nearly all interviewees openly expressed appreciation and gratitude to the weather office for the warnings.

One area of public confusion brought forth from the interviews was the use of terms to communicate danger. Most residents were not familiar with motion terms in regards to the typhoon and Yap. Simpler terms were suggested, such as Typhoon Sudal will begin to affect Yap in the early morning Friday and last until midday on Saturday instead of, Typhoon Sudal is 100 miles southeast of Yap and moving northwest (“up”) at 8 miles an hour with typhoon force winds extending out 30 miles from the center of Sudal.

Wind speeds were forecast to be around 110 knots with 97 knots recorded. Residents had never experienced winds of this magnitude and could not properly assess what the numbers meant for their home. They all expressed the knowledge of danger to their lives and property. Plain language terminology will help the communication between the authorities in Yap and the public in Yap. As a suggestion wording such as wind speeds of 110 knots (125 mph) are expected on Yap with damage expected for all wooden and tin roof structures.

Emergency managers in Guam use terms from the military (conditions of readiness) in conjunction with the National Weather Service watches and warnings. Residents did not fully understand the terms. Confusion was expressed about the length of time to expect strong winds and rains from Typhoon Sudal. The slowing translational speed of Sudal left Yap in tropical storm force or greater sustained winds for a 24-hour period.

The sudden drop in ocean temperatures of 10 to 12 degrees Fahrenheit on the reef surrounding Yap was shocking to residents. Divers measured temperatures in the same dive locations before and after Sudal. The drop in ocean temperatures next to land, lead to extensive fog for two days after Sudal passed Yap. Many residents were scared, having never witnessed fog before. Information on what residents can expect after a typhoon would be useful too.

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The assessment team noted the extensive preparedness efforts from both the Warning Coordination Meteorologist at WFO Guam and the local WSO Staff at Yap. The outreach included the emergency management, schools, radio stations and more. This type of regularly scheduled outreach is recommended to continue. Education on the motion of typhoons, what damage to expect from what wind speed and other meteorological aspects of typhoons needs to continue. Forecasters and staff should try to place emphasis on the simplified wording of these terms when communicating with the public.

Communication between weather offices including WFO Guam and JTWC was extensive. The coordination allowed for greater lead times on watches and warnings. Coordination among WFO Guam and JTWC forecasters proved on several occasions to greatly benefit the public with improved information on Sudal. WFO Guam and WSO Yap communicated often and regularly with the Yap emergency management personnel. All Yapese government officials expressed their appreciation for this type of communication and felt very satisfied with the service provided by the weather offices.

Communications into and out of WSO Yap were interrupted during Typhoon Sudal. Information was processed through the PEACESAT office in Guam direct to the WSO and local government in Yap via HF radio. Other Micronesian weather offices, including WSO Pohnpei, also communicated with Yap via HF band radio. However, PEACESAT was unable to hear WSO Pohnpei, making communications redundant or lacking in some forms of information. Regular phone service at WSO Yap went out during Typhoon Sudal, as did the AFTN/MET circuit. Satellite phones were inoperable unless the phone was outside the building, which was not possible during the typhoon. Internet and fax machines were also inoperable for a time during Typhoon Sudal. Direct communication between the forecasters at WFO Guam and WSO Yap is paramount in the sharing of information and knowledge during typhoon events. Communications are also paramount during typhoon events from WSO Yap to the local command post. Recommendations have been provided in this report to help communications.

The WSO building in Yap suffered little damage and is a new concrete facility. The MIC at WSO Yap had the staff bring their families to the office for safety reasons prior to Sudal. Many of the homes of the WSO Yap staff were severely damaged during the typhoon. Having the families of the staff in the office during the event not only kept the staff safe but allowed them to perform their tasks without concern for their families well being had they not been present. This is a good practice. After the event, tents were purchased via Pacific Region Headquarters for temporary housing of the staffs of each WSO during such events.

Instrumentation

Wind sensor equipment during the typhoon produced varying results. The newly installed ultrasonic wind sensor was not yet operational prior to the typhoon event. The indoor wind speed readout dial for the three-cup anemometer peaks at 100 knots (115 mph). The staff of WSO Yap

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observed the indoor readout dial to have recorded wind gusts to the 100-knot limit on several occasions, however the indoor paper record of the wind speed gusts never went to 100 knots (figure 14), only to 97 knots (110 mph). The instruments had lost calibration between the readout and the paper record of the wind speed making the official wind speed difficult to attain. Recommendations have been set forth on this subject. The WSO Yap barometer trace (figure 13) was unable to record the lowest pressure due to the trace going off the paper recording scale.



Figure 11. Beached dinner boat for the Manta Ray Hotel in downtown Colonia, Yap after Typhoon Sudal.

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WFO Guam, WFO Yap Assessment Facts, Findings and Recommendations

Communications

- **FACT:** The Guam WCM conducted preparedness training for typhoons and weather on Yap on 29-30 September 2003. The training included representatives from government agencies, disaster preparedness groups, MIC WSO Yap, and radio station personnel. The training worked to serve the NWS and users well during Sudal. Preparedness training was performed in the Yap schools during the first days of October 2003 in Yap.
- **FACT:** Communications between the WSO Yap and the emergency management were critical to success during the typhoon. These communications were lost during the height of the typhoon.
- **FACT:** Communications between Pacific Region Headquarters and WSO Yap and between NWS WFO Guam and WSO Yap were lost during the typhoon. AFTN/MET and the Internet were lost during the typhoon. Satellite and cell phones were down during the typhoon.

Recommendation 1a. HF radios and backup radios along with usable satellite phone systems should be in place prior to tropical cyclone activity at the WSOs and WFOs in the region. This communication is essential to ensure continuous information flow between the WSO and the emergency management agencies.

Recommendation 1b. NOAA Weather Radio should be looked into as an option for use in Yap and the outer islands

- **FACT:** No deaths or serious injuries were incurred during Sudal.
- **FACT:** The Yap Emergency Command Post opened for 24-hour operations on Wednesday 7 April at 8:15 pm. The typhoon made landfall on Yap Friday late morning 9 April.
- **FACT:** Sudal slowed while moving over Yap leaving the island in tropical storm force or greater winds for 24 hours (9:40 PM Thursday 8 April through 9:30 PM Friday 9 April) and typhoon force or greater winds for 6 hours (6:30 AM 9 April through 12:30 PM 9 April).

Recommendation 2. Weather offices should try to indicate the length of time tropical storm force or greater winds are expected to affect the area prior to a tropical cyclone arriving.

- **FACT:** Sea surface temperatures and near surface temperatures were attained through dive shop interviews. Temperatures the day after the typhoon were 12 degrees Fahrenheit cooler than the day prior in the same locations. Fog was experienced on Yap for 2 days after Sudal - a rare event, as some of the public had never seen fog before.

Recommendation 3. Any information on rare or unusual weather phenomena to occur after the tropical cyclone should be broadcast prior to the systems arrival.

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- FINDING: The public does not understand terms such as latitude/longitude or up/down, also wind speeds tell them little of the damage to anticipate.

Recommendation 4a. Education through outreach to the public will help understanding.

Recommendation 4b. Using terms of movement in relation to Yap helps the public understand if the typhoon is going to affect them.

Recommendation 4c. Using terms for damage of structures on the island in addition to the wind speeds will help the public better understand the effects of tropical cyclones.

- FINDING: Use of emergency management terms - conditions of readiness versus the watch/warning terms from the NWS was confusing to the public of Yap.
- FINDING: Coordination between NWS Guam Office and JTWC allowed fixes of initial positions and thus the forecast tracks to be adjusted correctly during the event. The forecast track adjustments allowed for greater lead-time on the warnings for Yap.
- FINDING: Public Awareness was high with shelters opened and schools closed well in advance (Thursday afternoon) of strong winds.
- FINDING: Only the PEACESAT radio was maintained between University of Guam and Yap during the height of the typhoon.
- FINDING: The WCM at WFO Guam was talking twice daily to Mr. Francis Intimae, Emergency/Disaster Officer and Chairman of Emergency Task Force and Command Post at Yap FSM from Wednesday until the phones went down. The communication was difficult at first as Mr. Itimai was difficult to reach.

Recommendation 5. An up-to-date telephone list of the civil defense personnel from each WSO area of responsibility should be shared by all the WSOs and WFOs in Pacific Region.

- FINDING: Preparedness training through the WCM at WFO Guam to Yap had provided the users with their own unique tracking maps for Yap and a brochure with photos of damage to buildings and the associated wind speeds to cause such damages.

Recommendation 6. Funding needs to be established and/or maintained to ensure the continuation of this training and printing of the typhoon tracking charts and brochures.

- FINDING: At night WFO Guam is without any Hydro Meteorological Technicians and with two forecasters on staff only. During this time not all forecasters are aware of how to obtain observations in and around the smaller islands in Micronesia.

Recommendation 7. All forecasters and HMT staff at the WSOs and WFOs in Pacific Region must be able to demonstrate proficiency in obtaining and correctly reading the observations from marine and surface based platforms throughout the Pacific Region.

- FINDING: Yap government has set up their Emergency Command Post in the same building as the main communications station for all the islands of Yap State. This allows the emergency managers to directly relay information to the users once it has been sent to them. Co-location of the Emergency Command Post and the main communications station is unique and aided in the quick dissemination of information during Sudal. This is a good practice and is recommended for all Micronesian Islands with weather offices if possible.

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- FINDING: Pacific Region Headquarters of the National Weather Service currently operates a HWO for tropical cyclone events affecting both WFOs and WSO Pago Pago of American Samoa in the region but not the other WSOs.

Recommendation 8. Maintain the HWO when a tropical cyclone is a threat to any office in the region including FSM, ROP or RMI.

Equipment

- FACT: The ultrasonic wind sensor was not working prior to the typhoon.

Recommendation 9. Reliable wind equipment should be installed and maintained at all WSOs.

- FACT: The readout for the cup anemometer peaks at 100 knots.

Recommendation 10. Other wind readouts provide a double scale to record winds greater than 100 knots this should be in all WSOs.

- FINDING: The wind instrument was not calibrated to read the same as the wind trace.

Recommendation 11. Wind equipment should be and remain calibrated to read the same wind speed and direction during the event as set forth in established guidelines.

- FINDING: The WSO Yap barometer trace was unable to record the lowest pressure due to the trace going off the scale.

Recommendation 12. Pressure traces should be properly adjusted to record the lowest pressure and marking accordingly just prior to the onset of typhoon type conditions as set forth in established guidelines.

- FINDING: The new office building for WSO Yap held up very well. Only one lightning rod was lost on the roof of the building and the balloon shelter building roll-up door was stuck in the raised position.
- FINDING: There is no HF radio at the WFO Guam to use during these types of events.

Recommendation 13. Each WFO and WSO in the Pacific Region of the NWS installs and maintains a HF radio and antenna.

Recommendation 14. VHF radio systems and other forms of communication should be taken into consideration.

- FINDING: The use of microwave satellite imagery helped the forecasters at WFO Guam better locate and with high confidence, the center of the initial position of Sudal on several occasions.
- FINDING: Because WFO Guam has no HF radio, information was being sent from WFO Guam through the UOG PEACESAT operations to the government and NWS WSO in Yap. PEACESAT is not regulated by the NWS or the JTWC and is maintained during these events only by the dedication of the PEACESAT staff.

Suggestions

- Six hourly raobs when the system was forming from Micronesia and Guam might have helped the model forecast track. Suggest requesting more raob balloon launches during the life cycle of the typhoon.
- Offices may need water catchment systems to provide healthy drinking water during the post-typhoon time for the staff.

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- Co-locate, when possible the emergency command post with the main communications station on Micronesian Islands with weather offices for the best dissemination of information.

Miscellaneous

- FACT: The path of Sudal moving toward Yap from the southeast would produce the worst storm surge in the capitol and largest city of Colonia.



Figure 12. Large ship barge grounded in Colonia Harbor after Typhoon Sudal. The assessment team member in the photo is 6 feet tall.

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Appendix A:

Acronyms

AFTN/MET	Aeronautical Fixed Telecommunications Network/ Meteorological
FEMA	Federal Emergency Management Agency
FSM	Federated States of Micronesia
HF	High Frequency
HWO	Hurricane Watch Office
JTWC	Joint Typhoon Warning Center
kts	knots
Mb	millibars
MIC	Meteorologist-in-Charge
nm	Nautical Miles
NOAA	National Oceanic and Atmospheric Administration
NWR	NOAA Weather Radio
NWS	National Weather Service
PEACESAT	Pan-Pacific Education and Communication Experiments by Satellite
RMI	Republic of the Marshall Islands
ROP	Republic of Palau
TS	Tropical Storm
UOG	University of Guam
UTC	Universal Time Coordinated
VHF	very high frequency
WCM	Warning Coordination Meteorologist
WFO	Weather Forecast Office
WSO	Weather Service Office
24/7	Operations conducted 24 hours a day and 7 days a week

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Appendix B:

Interviews

The service assessment team would like to thank the following that were interviewed.

NWS Offices

Staff, WFO Tiyan Guam

Staff, WSO Yap

The Honorable Robert Ruecho, Governor of Yap

Chief of Police for Yap State

Mr. Francis Itimai,

Emergency/Disaster Officer and Chairman of the Emergency Task Force and
Command Post

Colonia, Yap Harbor Master

The Honorable Joe Habuchami, Lt. Governor of Yap

Mr. Al Azuma, State Manager of Yap, FSM Telecommunications Corporation

Mr. Faustino Yangmog, General Manager Yap State Public Service Corporation
(Handling of power, water and sewer)

Mr. Freddy Gull, Dive Shop Manager Manta Ray Hotel

Mr. Bill Acker, Owner Manta Ray Hotel

Mr. Robby Wooten, Teacher Seventh Day Adventist School

Mr. Jaime JR. C. Battanga, Principal Seventh Day Adventist School

Dr. A. Mark Durand, Director of Health Services for Yap State Government

Mr. Vincent M. Emopilur, Assistant Manager of Beyond the Reef Dive Shop

Staff, Saint Mary School Catholic Mission

Staff, Federal Emergency Management Agency in Guam

Staff, FEMA detailed to Yap

Numerous residents of Yap

Mr. Bruce Best, Professor University of Guam and PEACESAT communications
specialist

Staff, National Forestry Service detailed to Yap

The Pacific Region Service Assessment Team was comprised of:

Mr. Joel Cline	<i>Team Leader, Regional Operations and Services</i> Meteorologist, NWS Pacific Region Headquarters
Mr. Ceasar Hadley	MIC WSO Pohnpei, FSM
Dr. Mark Lander	Professor of Meteorology, UOG

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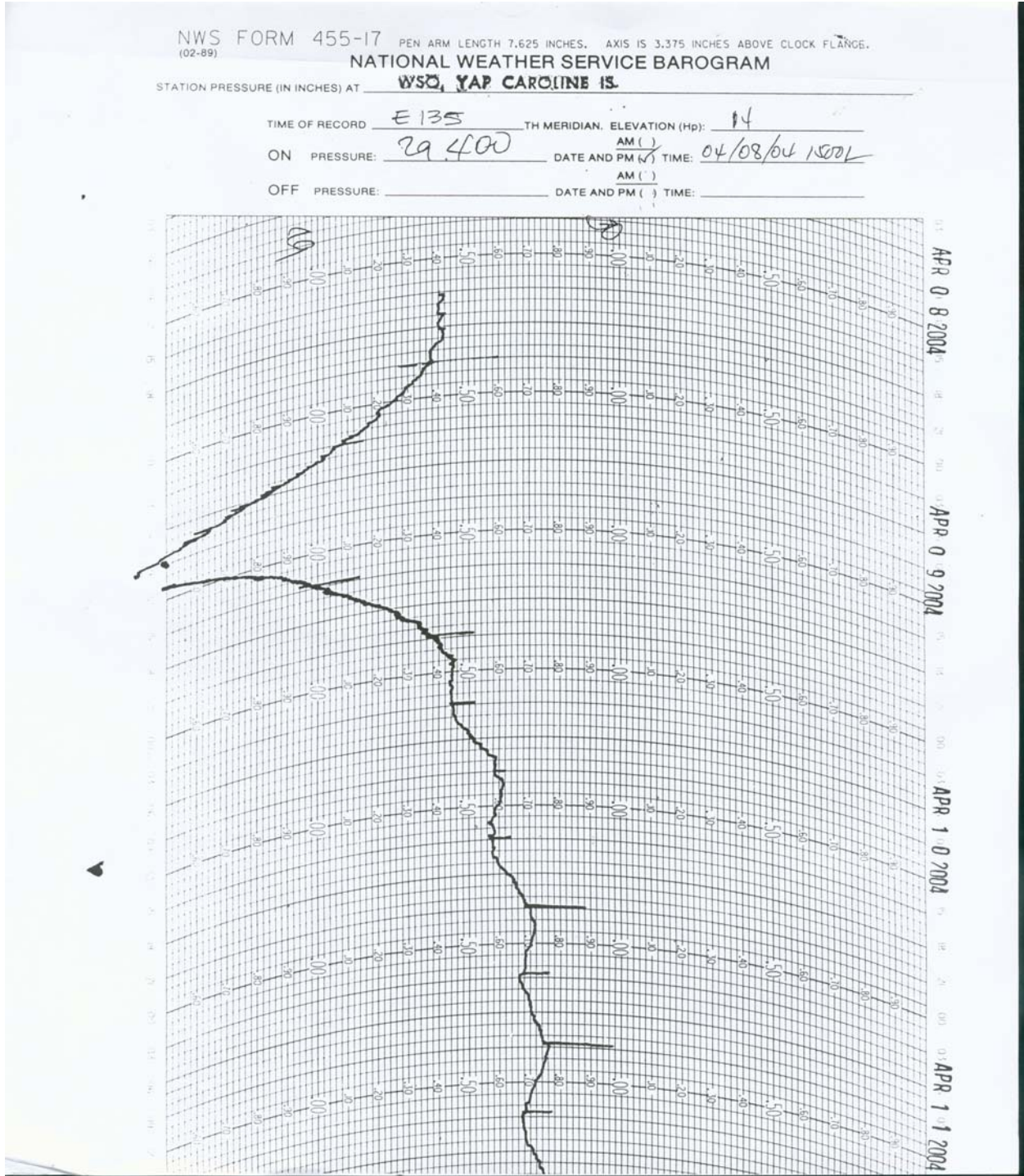


Figure 13. Barometric trace at WSO Yap from Typhoon Sudal. Note the trace goes below the paper.

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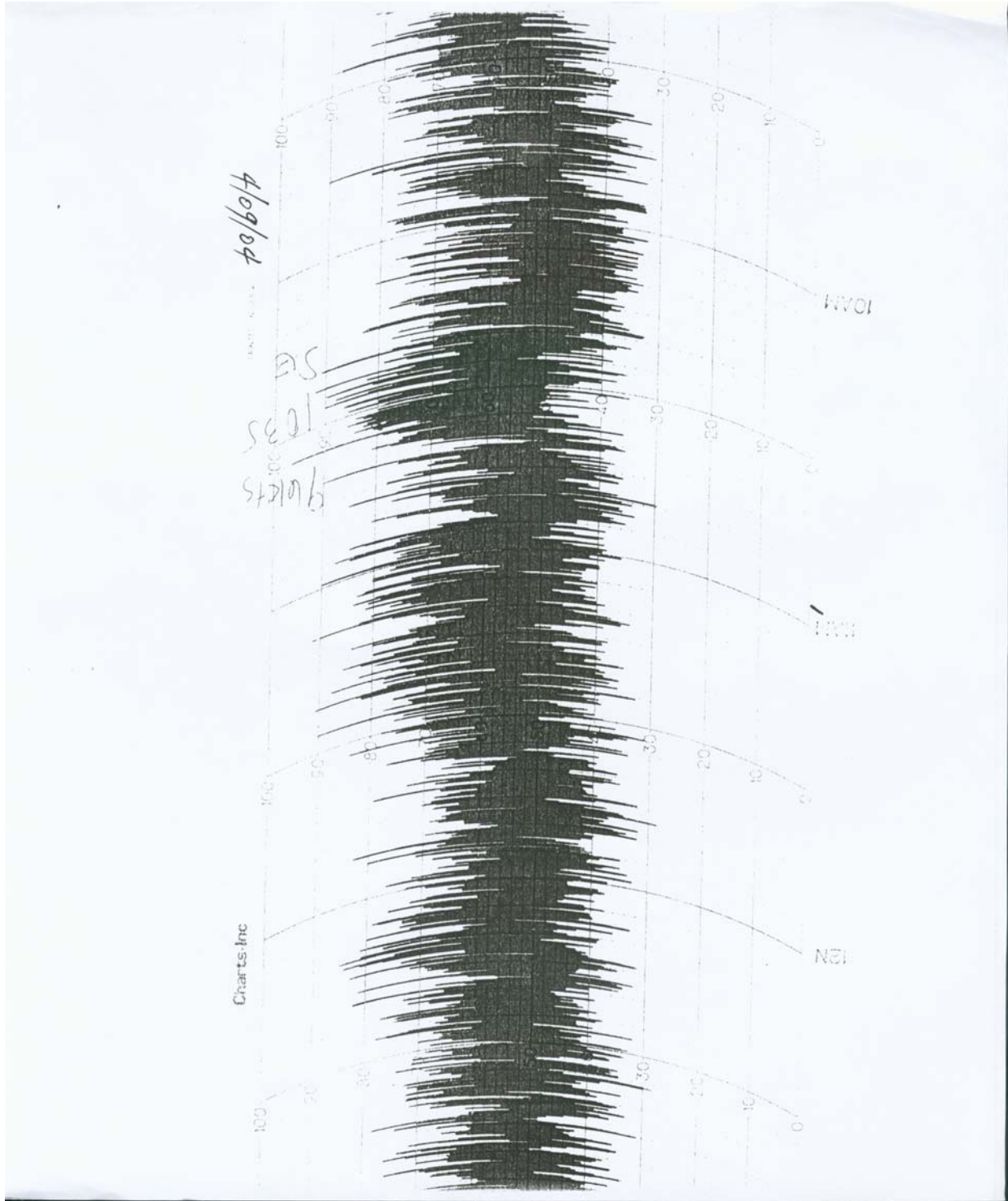


Figure 14. Wind trace from WSO Yap during Typhoon Sudal. Note the trace did not record 100 knots.

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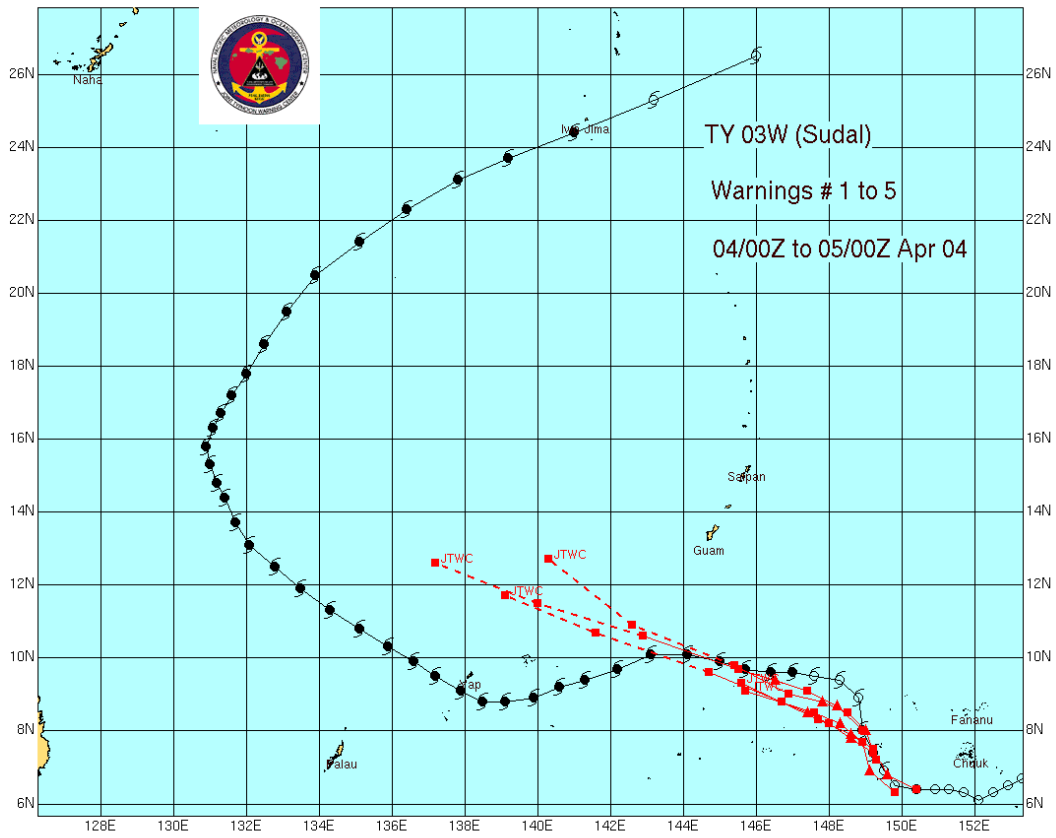


Figure 15. Same as in Figure 1 except for advisories 1 through 5.

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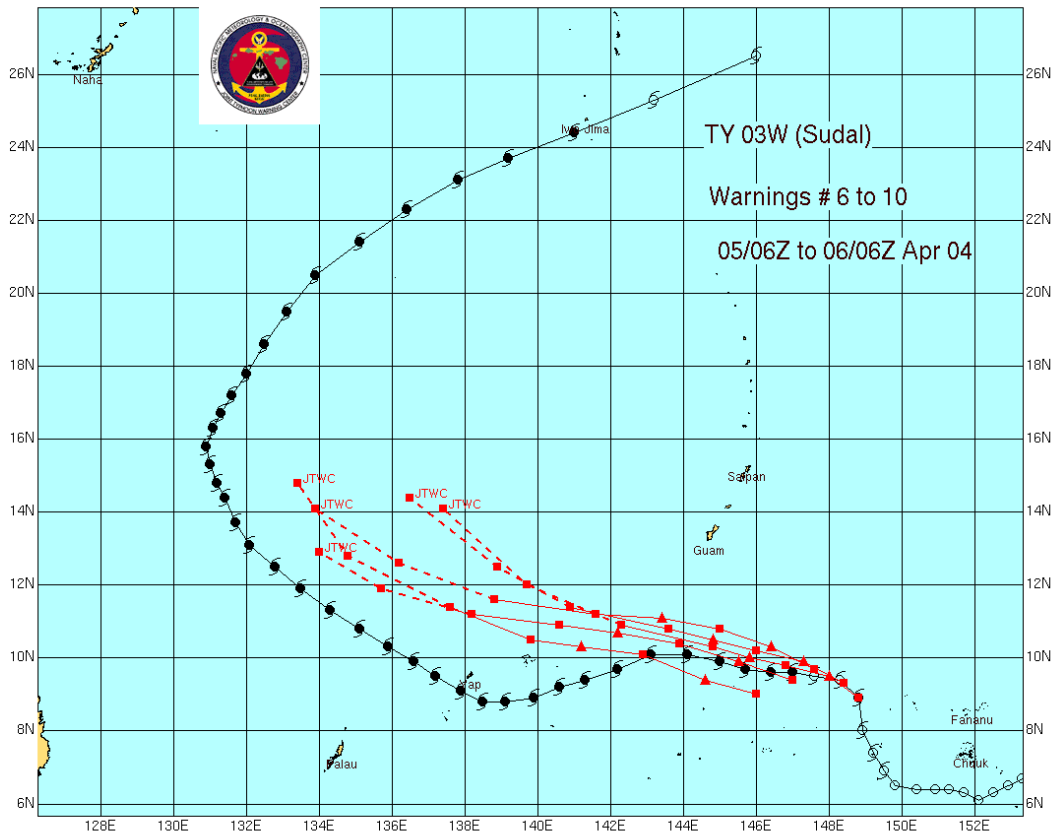


Figure 16. Same as in Figure 1 except for advisories 6 through 10.

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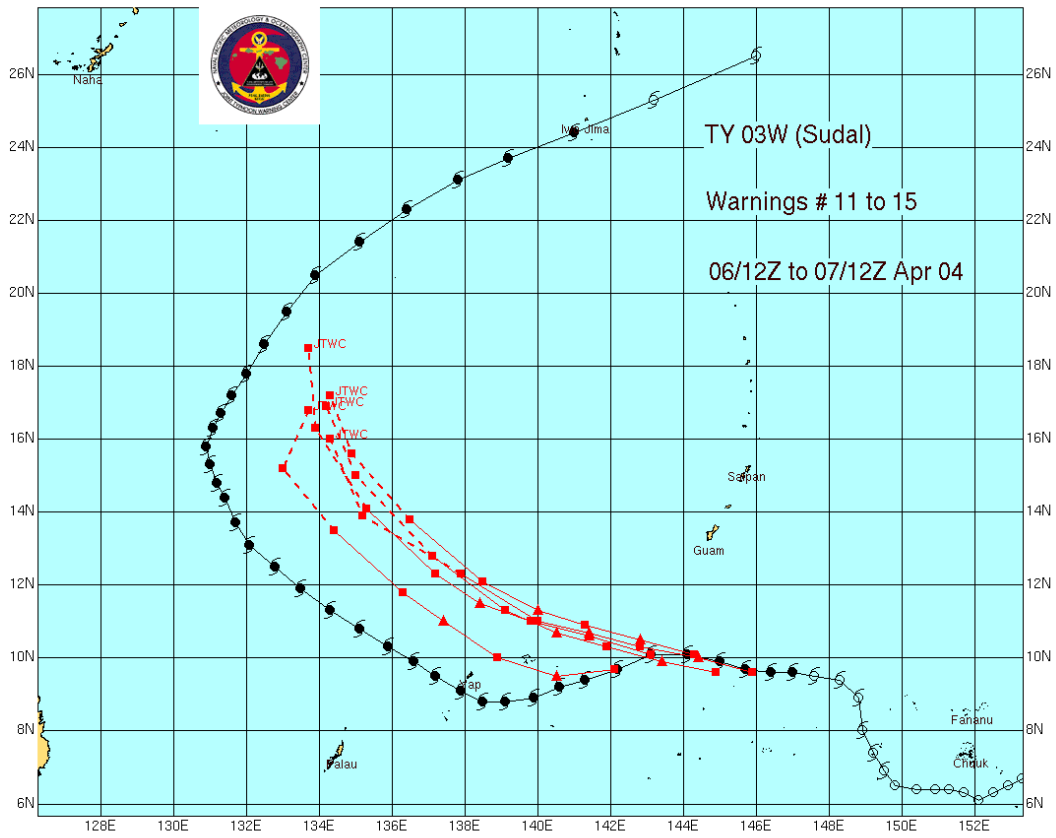


Figure 17. Same as in Figure 1 except for advisories 11 through 15.

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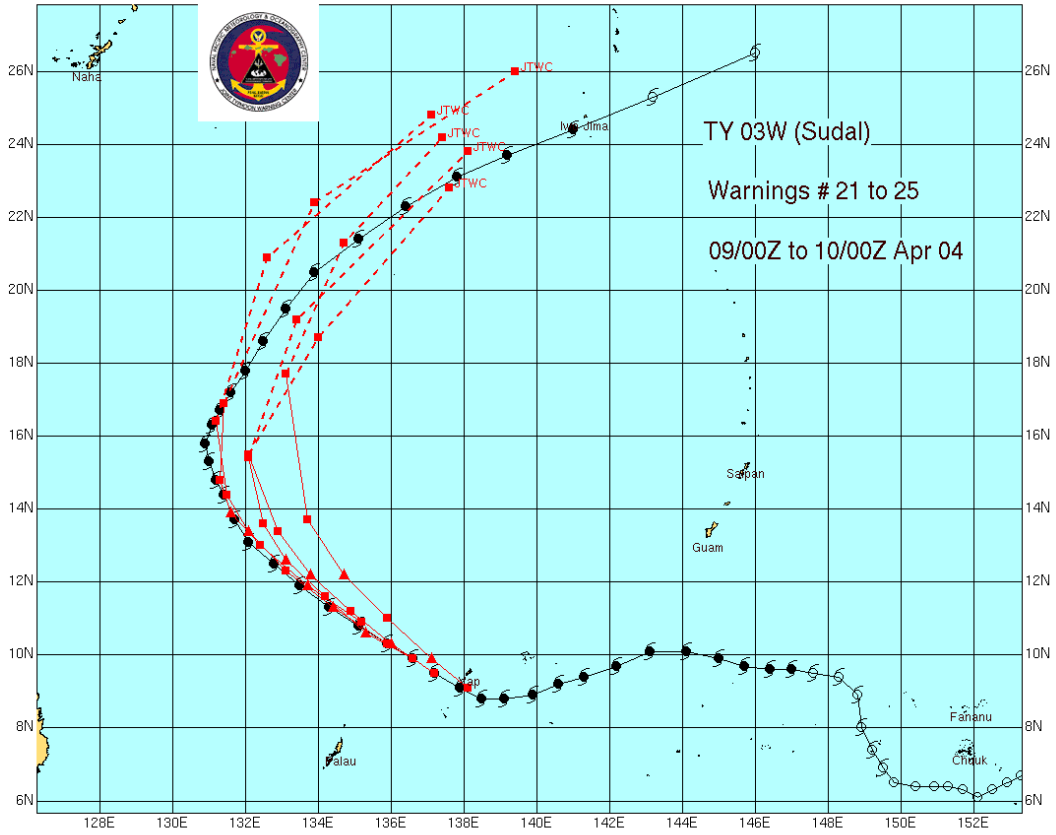


Figure 18. Same as in Figure 1 except for advisories 21 through 25.