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Impact of Typhoon Surigae on Oceanographic Parameters in Sangihe-Talaud Waters

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ABSTRACT

Tropical cyclones influence the vertical mixing process in the ocean, which positively impacts water fertility. This research aimed to analyze the impact of Typhoon Surigae on oceanographic parameters around Sangihe-Talaud Waters. The data used are wind direction and speed, sea surface temperature, salinity, sea wave height, and daily composite data of chlorophyll-a concentration from 02 - 30 April 2021 obtained from Aqua-MODIS satellite, NOAA Physical Sciences Laboratory, Copernicus Marine Service, and Ocean Forecast System (OFS) of the Indonesian Agency of Meteorology Climatology and Geophysics. The result shows that Typhoon Surigae only influenced weak upwelling and vertical nutrient mixing, characterized by sea surface temperature around 26-27 ^{o}C and the value of the chlorophyll-a concentration of 0.1 - 0.7 mg/m3. Furthermore, Typhoon Surigae increased wind speed and significant wave height, creating westward wind patterns and decreased salinity value. This study also found that Typhoon Surigae caused an increase in chlorophyll-a concentration around the Pacific Ocean of Northern Halmahera.

Keywords: Typhoon Surigae, Oceanographic Parameters, Chlorophyll-a

INTRODUCTION

A tropical cyclone is one meteorological disaster that negatively affects human activities. It usually causes increasing rainfall, strong winds, increasing wave height, and potential for lightning activity [1]. On the other hand, tropical cyclone positively impacts the vertical mixing process in the ocean. For instance, when Tropical Cyclone Ernie occurred, it caused downwelling, shown by the high value of sea surface temperature and low chlorophyll-a concentration. After tropical cyclone Ernie occurs, there is an increase in chlorophyll-a concentration, and upwelling occurs in the same area [2].

Several names, such as typhoon, know a tropical cyclone if it forms in the Western Pacific Oceans, Cyclone if it begins around India or Australia, and Hurricane if it starts in the Atlantic Ocean. The Western Pacific Ocean is one of the locations for forming tropical cyclones in Northern Indonesia. Tropical cyclones in the northern part of Indonesia usually occur in April, May, June, July, August, September, October, and November [3]. The Indonesian region is not a good area for the formation process of tropical cyclones. However, the geographical position of Indonesia is adjacent to the formation of cyclone areas [4]. For example, Sangihe-Talaud waters are directly adjacent to the Western Pacific Ocean, which causes Sangihe-Talaud waters to get an indirect impact from

the occurrence of tropical cyclones around the Western Pacific Ocean.

On April 12th, 2021, the Meteorology, Climatology, and Geophysics Agency of Indonesia (BMKG) gave an early warning of tropical depression 94W in the Pacific Ocean from Northeast Papua. It could increase the probability of heavy rain with strong winds and high sea waves from 13 to 19 April 2021. One of the areas with a high potential to be affected is North Sulawesi, especially in Sangihe-Talaud Waters. Tropical depression 94W has become Typhoon Surigae and occurred for 270 hours from 13 to 25 April 2021 [5]. However, there is not much research on the impact of tropical cyclones on oceanographic parameters in the northern part of Indonesia. Therefore, this study aimed to analyze the impact of tropical cyclone Surigae on oceanographic parameters in Sangihe-Talaud waters.

DATA AND METHODOLOGY

Research site

The study area of this research is from Sangihe-Talaud waters to the Pacific Ocean of Eastern Philippines, which is located at 123° – 130° E and 2° – 15° N. This research map also shows the Typhoon Surigae trajectory that passes through the research area, as shown in Figure 1.

Data resources and analysis

The data used in this research consists of typhoon information and oceanographic conditions (sea surface temperature, sea surface wind, salinity, significant wave height, and chlorophyll-a concentration). The typhoon information identifies the typhoon's movement, especially when the typhoon is near the research area. The typhoon information was obtained from the National Institute of Informatics (NII) Japan's website (http://agora.ex.nii.ac.jp/digital-typhoon/summary/wnp/s/202102.html.en).

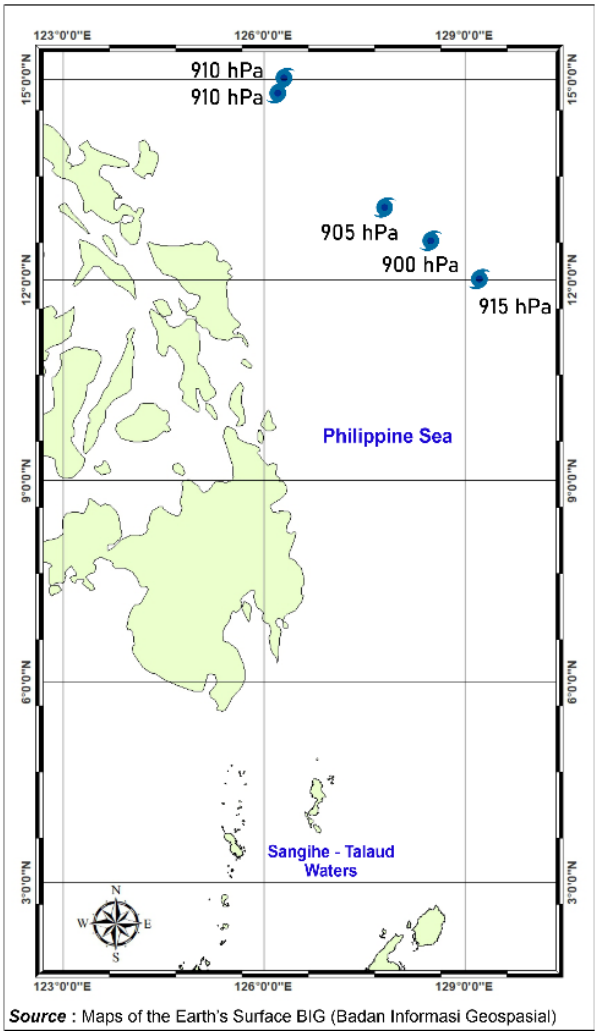

Figure 1. Research Area

The typhoon began as a low-pressure area on April 12, 2021. Then, it began to increase its maximum wind speed on April 14, 2021, and was identified as Tropical Storm Surigae. As the storm entered the Philippines Water, its pressure decreased to 915 hPa, and its maximum wind speed reached 107 knots to be categorized as a typhoon. The typhoon reached its dissipation phase on April 25, 2021. The Typhoon Surigae information when it influenced the research area is shown in Table 1.

Table 1. Typhoon Surigae data when it occurred near the research area

Date	Time (UTC)	Long	Lat	Max Wind Speed (knot)	Type
17 April 2021	06.00	11.4	130.2	97	Typhoon
17 April 2021	12.00	12.0	129.2	107	Typhoon
17 April 2021	18.00	12.6	128.5	115	Typhoon
18 April 2021	00.00	13.1	127.8	115	Typhoon
19 April 2021	15.00	14.8	12.6	120	Typhoon

The oceanographic conditions analyze the upwelling and vertical mixing process around the waters. The monthly average data for the past two years (2019 – 2020) is used to determine the general condition of the water without typhoon disturbances. Sea surface temperature data was obtained from NOAA Physical Sciences Laboratory (https://psl.noaa.gov/data/gridded/data.noaa.oisst.v2.highres.html#detail) with a spatial resolution of 0.25 x 0.25. Copernicus Marine Service brought sea surface wind and salinity data and can be downloaded from https://resources.marine.copernicus.eu/. Sea surface wind data has a spatial resolution of 0.25 x 0.25, and salinity data has a spatial resolution of 0.083 x 0.083.

The monthly significant wave height was obtained from the Ocean Forecast System (OFS) of the Indonesian Agency of Meteorology Climatology and Geophysics. Meanwhile, 3 hours of significant wave height data during Typhoon Surigae was obtained from Copernicus Marine Service (https://resources.marine.copernicus.eu/) with a spatial resolution of 0.083 x 0.083. Chlorophyll-a concentration was obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on the Terra satellite (Aqua-MODIS). Moreover, this study also utilizes 8-day composite data to determine the concentration of chlorophyll-a before, during, and after typhoon Surigae happened. This data has approximately 4 x 4 km resolution and can be found online on the website https://oceancolor.gsfc.nasa.gov/l3/. All oceanographic data are visualized spatially with Grid Analysis and Display System (GrADS). The flowchart of this research can be shown in Figure 2.

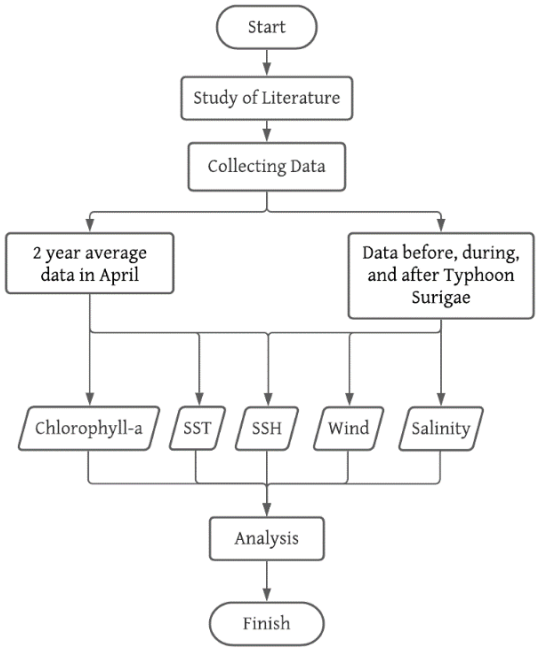

Figure 2. Research flowchart

RESULTS AND DISCUSSION

Wind

Sea surface wind is a parameter that has considerable impact due to the activity of Typhoon Surigae. In April, the wind tends to blow from the northeast to the east, indicating the movement of the Asian monsoon. The monthly average value of wind speed in April has a range value of 8 – 15 knots, as shown in Figure 3.

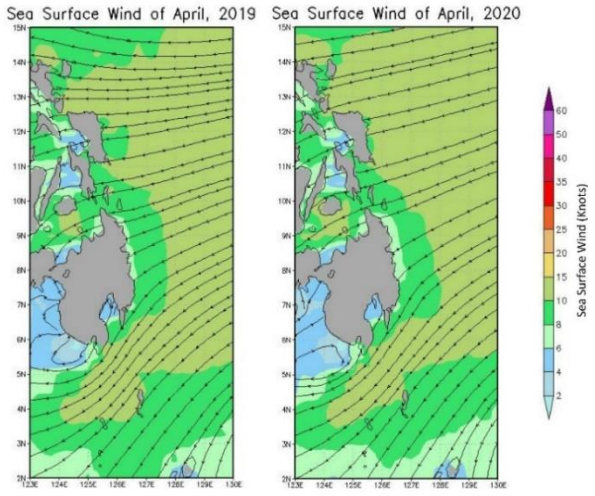

Figure 3. Monthly average sea surface wind condition in April 2019 – 2020

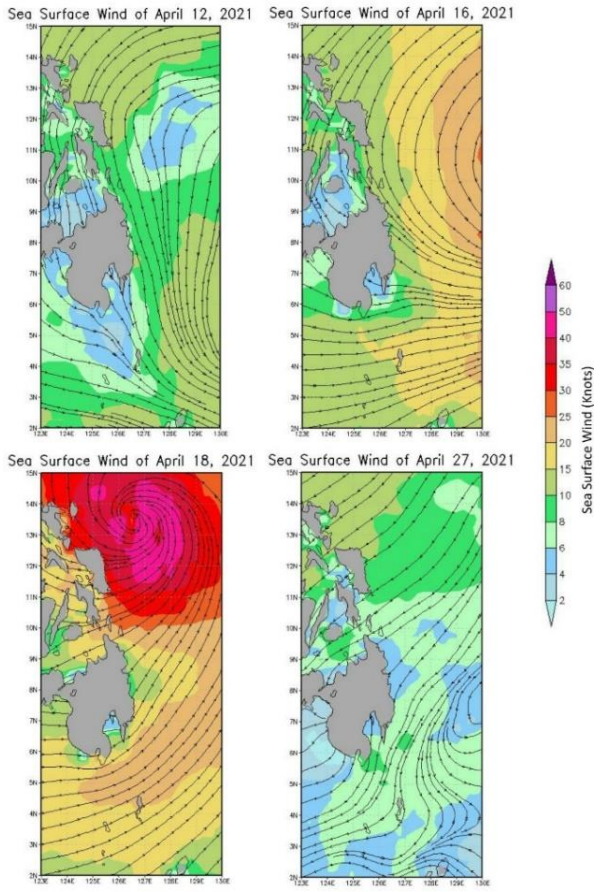

Figure 4. Daily average sea surface wind before (April 12, 2021), during (April 16 and 18, 2021), and after (April 27, 2021) the Typhoon Surigae located near the research area

When Typhoon Surigae happens, the direction of the wind tends to blow from the west on April 12, 2021. It is also coupled with forming a convergence area around the Sangihe-Talaud waters which supports the increase of low-pressure convective activity. When the typhoon approached the study area, the daily average wind speed in Sangihe-Talaud waters generally increased up to 10 – 20 knots on April 16. The daily average wind speed still increased on April 18, 2021, until it reached 15 – 25 knots in Sangihe-Talaud waters and up to 30 – 50 knots along the typhoon trajectory (Figure 4). On the same day, maximum wind speed occurred near typhoon Surigae up to 115 knots at 00.00 UTC, as shown in Table 1. This difference occurred because the wind speed value is the daily average, not the maximum value, as stated in Table 1 (Figure 3). On April 27, the direction of the wind returned to blow from the northeast, with the daily average wind speed decreasing to 6 – 10 knots.

Sea Surface Temperature (SST)

The high sea surface temperatures trigger the formation of low-pressure areas, which cause Typhoon Surigae to form in the waters of Sangihe - Talaud. The monthly average sea surface temperature conditions in Sangihe-Talaud waters in April 2020 tended to be warmer than in April 2019, where the SST value in April 2020 ranged from 29 – 29.5 ℃ (Figure 5). Before Typhoon Surigae on April 12, 2021, the SST value in the waters of Sangihe - Talaud was greater than normal, with values ranging from 29.5 to 30 ^{o}C (Figure 6). During Typhoon Surigae on April 18 - 19, 2021, the value of sea surface temperature showed an increase ranging from 29.5 – to 30 ^{o}C. On April 30, the value of sea surface temperature returns to normal, which runs between 29 – 29.5 ^{o}C.

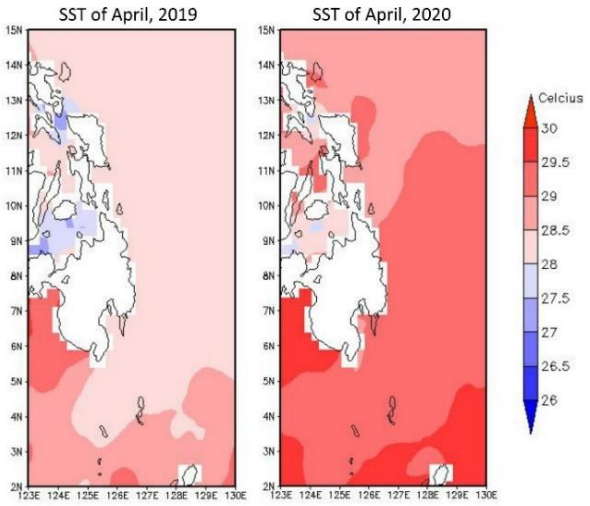

Figure 5. Monthly average sea surface temperature condition in April 2019-2020

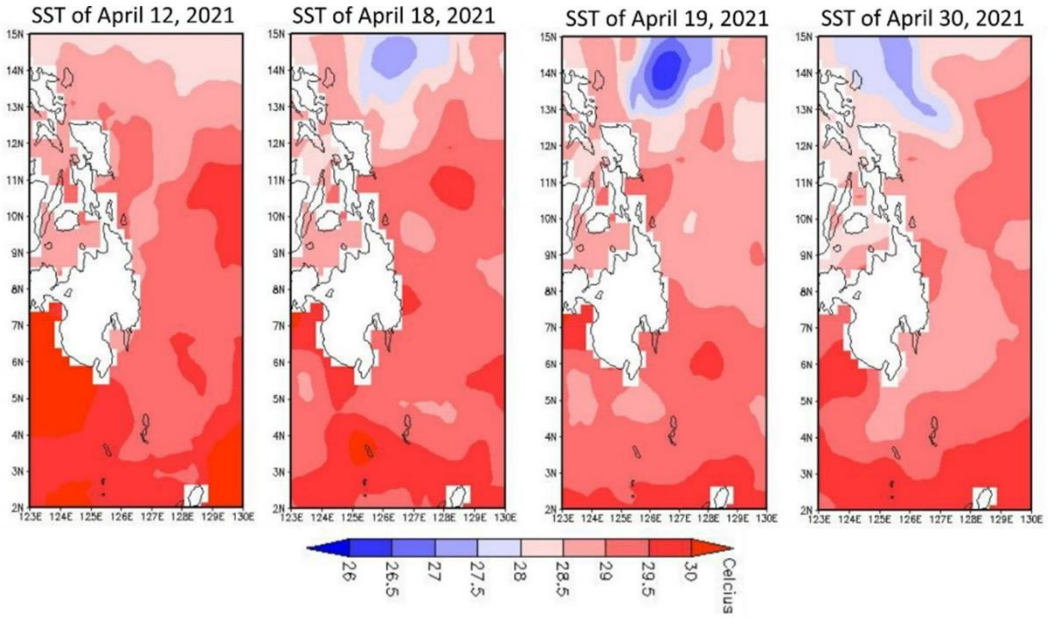

Figure 6. Daily average sea surface temperature before (April 12, 2021), during (April 18 and 19, 2021), and after (April 30, 2021) in Sangihe - Talaud waters

Salinity

In general, salinity values in Sangihe-Talaud waters tend to be homogeneous. It is also in the range of 33 – 35 ppt, considered high, as seen from the monthly salinity values around these waters during 2019 – 2020 (Figure 7). The lowest salinity distribution was in December 2020, in the range of 33 – 34 ppt. Based on the spatial data distribution, it can be seen that the waters of Sangihe-Talaud tend to be salty with a reasonably high salinity value.

Meanwhile, during Typhoon Surigae, the salinity value around the Sangihe-Talaud waters was lower than normal, around 33 – 34 ppt. In addition, there was a mixture of salinity values around these waters when Typhoon Surigae was closest to the waters. On April 15 – 20, 2021, water with low salinity in the south of the Philippines spread to the Sangihe-Talaud waters by 30 – 33 ppt (Figure 8). This low salinity value can be caused by high precipitation in the seas during typhoon events [6].

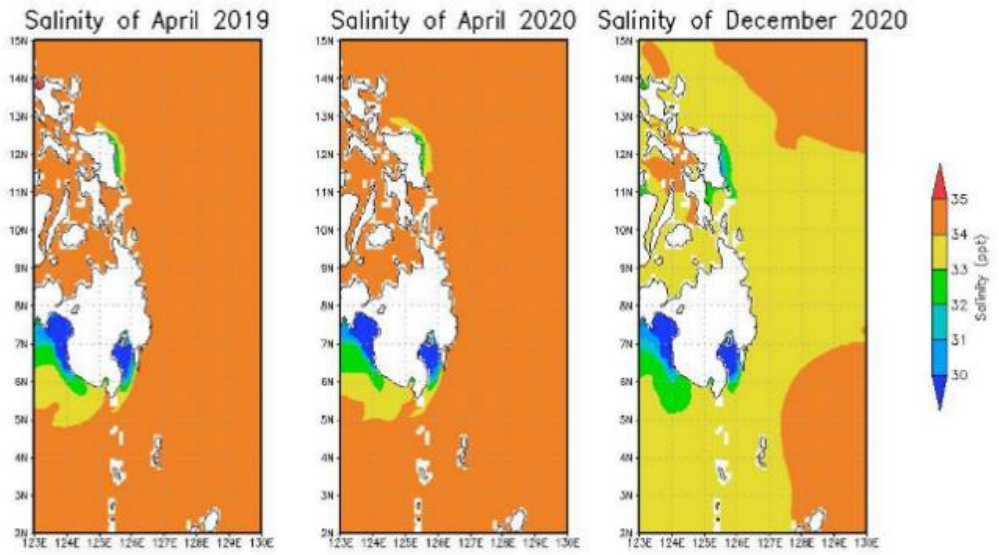

Figure 7. Sample of monthly salinity in the research area.

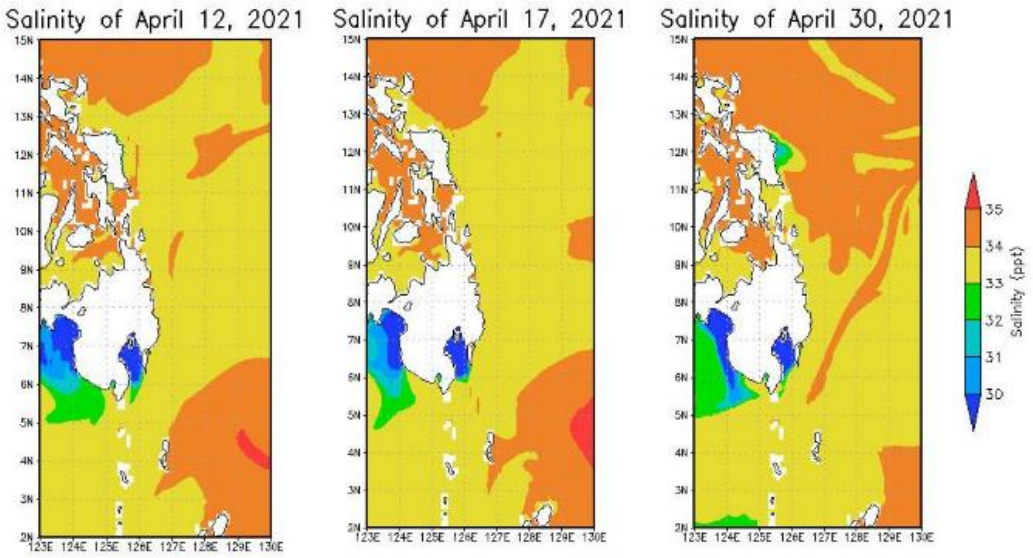

Figure 8. Salinity distribution before (April 12, 2021), during (April 17, 2021), and after (April 30, 2021) Typhoon Surigae located near the research area.

Significant Wave Height

Significant wave height (SWH) in the Sangihe-Talaud Waters based on monthly wave data for 2019 – 2020 tends to be in the medium range, 1.25 – 2.0 m (Figure 9). The highest waves in these waters occur during the rainy season, around December-January-February, with a wave height range of 2.5 – 5.0 m. Meanwhile, the lowest wave height occurred in May 2019, in the range of 0.75 – 1.5 m.

The wave height in the Sangihe-Talaud waters at the time of Typhoon Surigae was in the range of the normal height of the waters, which was 1.25 – 2.5 m. However, the presence of the typhoon did have a very significant effect on the wave height in these waters. As of April 18, 2021, at 06.00 UTC, the wave height value reached 3.0 m (Figure

10). When the typhoon moved away, the wave height was low, which was 0.25 – 1.25 m. The increase in the wave height during Typhoon Surigae was caused by the increase in surface wind speed around Sangihe-Talaud waters which reached 25 knots. Furthermore, the rise of SWH can lead to intensification of vertical mixing, which is essential for a higher increase in biological blooms [7].

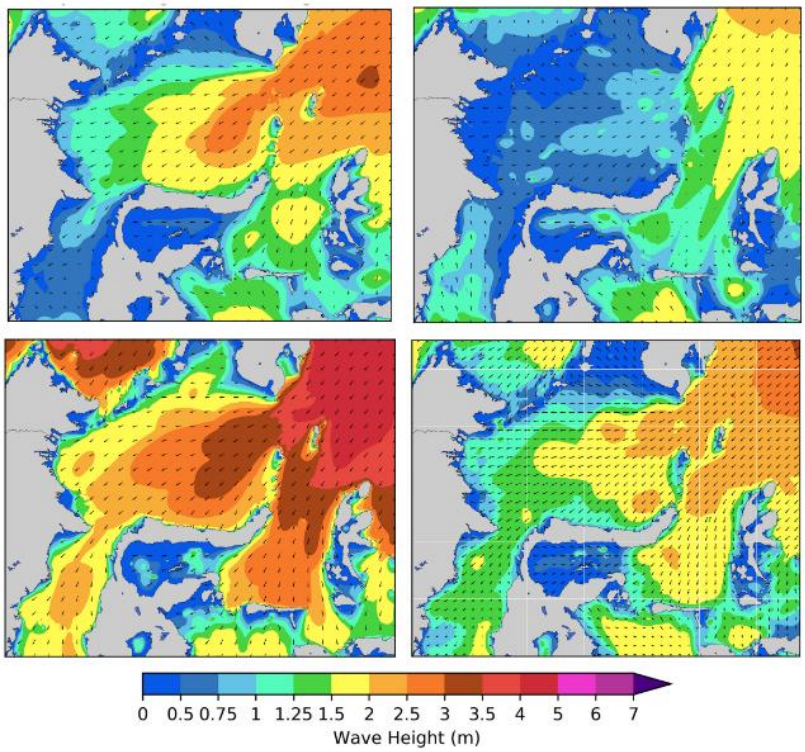

Figure 9. Sample of monthly significant wave height in the research area on April 2019 (a), October 2019 (b), February 2020 (c), and April 2020 (d)

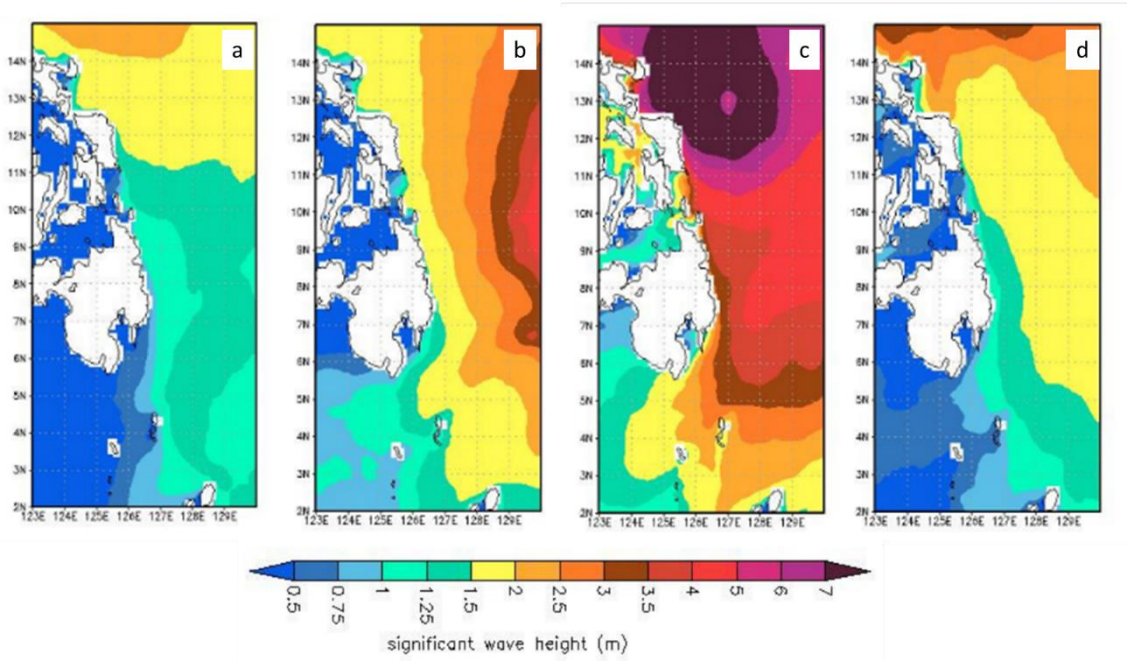

Figure 10. Wave height distribution on April 12, 2021 00.00 UTC (a), April 16, 2021 15.00 UTC (b), April 18, 2021 06.00 UTC (c), and April 22, 2021 00.00 UTC (d).

Chlorophyll-a Concentration

The chlorophyll-a concentration value in Sangihe-Talaud waters has been relatively homogeneous for two years. It was only around 0.05 – 0.2 mg/m3. Monthly average values for April 2019 and 2020 also showed the same value (Figure 11).

This condition continues to occur up to the border of the Philippine waters. Meanwhile, in the southern part of Sangihe-Talaud waters, specifically in the waters around the Sitaro island until the northern part of the Halmahera coast, the monthly average chlorophyll-a concentration is slightly higher with a range value of 0.1 – 0.5 mg/m3.

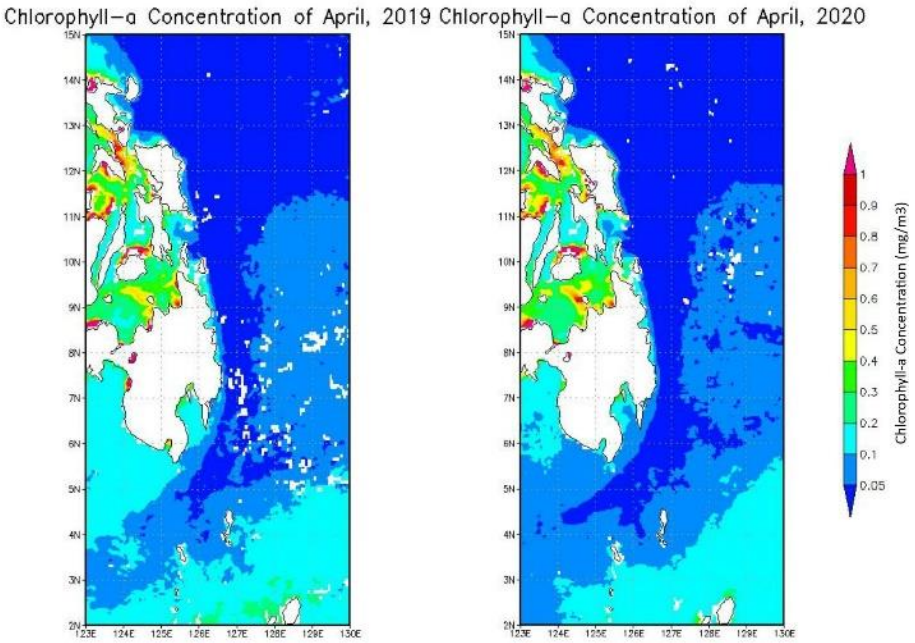

Figure 11. Monthly chlorophyll-a concentration on April 2019 – 2020

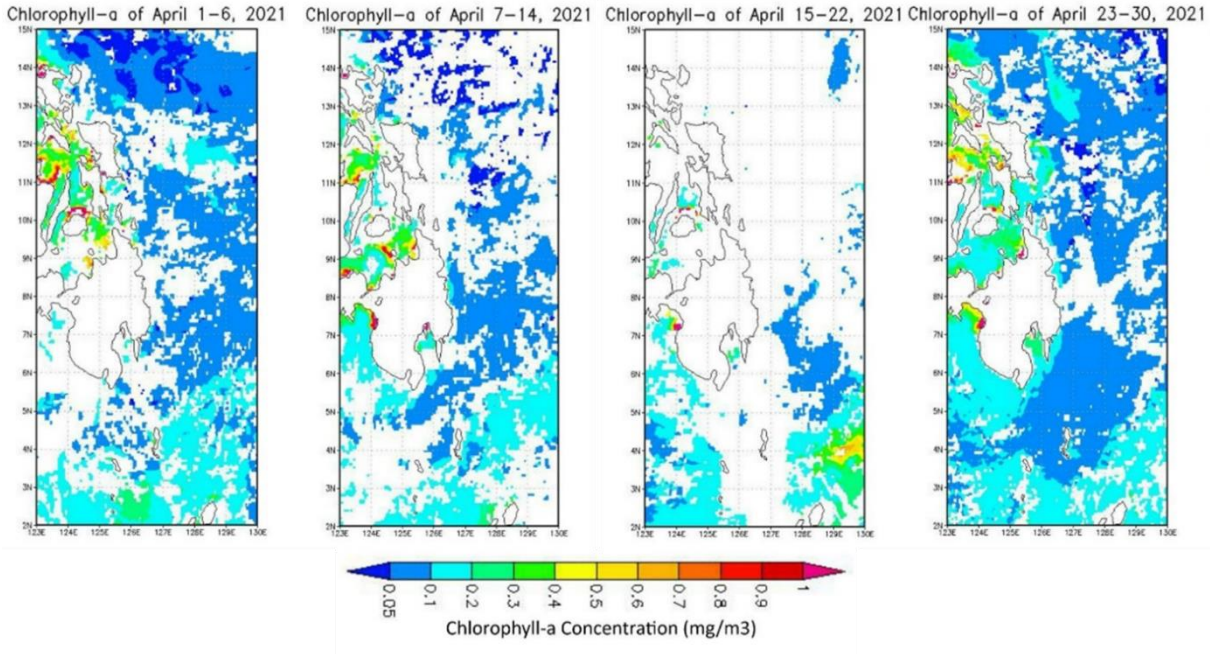

Figure 12. Chlorophyll-a concentration before (a, b), during (c), and after (d) the Typhoon Surigae

This research used 8-day composite data due to the incomplete data of daily chlorophyll-a concentration. At the beginning of typhoon Surigae formed (April 1 – 6, 2021), chlorophyll-a concentration around Sangihe-Talaud waters had a range of values quite similar to the monthly average two years ago with a value of 0.1 – 0.3 mg/m3. When the movement of typhoon Surigae gets closer to the research area (April 7 – 14, 2021), chlorophyll-a concentration decreases to 0.1 – 0.2 mg/m3. During the period when typhoons were in the research area (April 15 – 22, 2021), mostly in the research area, there were blank pixels (no value) due to cloud cover brought by Cyclone Surigae [8]. Meanwhile, there was a significant increase in chlorophyll-a in the Pacific Ocean of North Halmahera with a concentration value of 0.3 – 0.7 mg/m3. This increase is due to the vertical movement of water masses that contain lots of nutrients in the surface water [9]. After typhoon Surigae moved away from the research area, chlorophyll-a concentration around Sangihe-Talaud waters turned into 0.05 – 0.2 mg/m3.

Upwelling

According to Kuttippurath et al., most previous studies have shown that the vertical mixing and upwelling induced by typhoons can uplift the deeper Chlorophyll-a to the surface and bring nutrient-rich deeper water up increasing ocean productivity in the open ocean [10]. This study used the analysis as described in table 2 to determine the characteristics of the upwelling area.

Based on Table 2, it can be assumed that the upwelling which occurs during typhoon Surigae around Sangihe-Talaud waters is an upwelling with weak intensity. This also happens around the trajectory area of Typhoon Surigae. During the occurrence of the typhoon, upwelling around Typhoon Surigae trajectory cannot be analyzed due to the incomplete data of chlorophyll-a. After one week, there was still no significant increase in the amount of chlorophyll around the Typhoon Surigae trajectory.

Table 2. Upwelling intensity criteria [4]

SST (°C)	Chlorophyll-a (mg/m3)	Upwelling Criteria
>27	<1	weak upwelling intensity
26 – 27	1 – 2	moderate upwelling intensity
<26	>2	strong upwelling intensity

CONCLUSION

The oceanographic conditions during Typhoon Surigae in Sangihe-Talaud Waters, such as surface wind, sea surface temperature, salinity, significant wave height, chlorophyll-a concentration, and upwelling, have been examined. The results show that Typhoon Surigae only influenced weak upwelling and vertical nutrient mixing around the research area. It is shown by the result of SST (26 – 29 ℃), the result of chlorophyll-a (0.1 – 0.7 mg/m3), and the increase in wind speed and significant wave height when Typhoon Surigae was located near the research area. Chlorophyll-a concentration did not increase significantly around Sangihe-Talaud waters. A significant increase in chlorophyll-a concentration occurred around the Pacific Ocean of Northern Halmahera, with a value of 0.3 – 0.7 mg/m3 compared to the monthly average for two years.

REFERENCES

1. Sofiati, I.; Putranto, M.F. The Analysis of Tropical Cyclones that occurred in the Southern Sea of Java during the Period 2004-2019 and their Effects on Sea-Atmospheric Conditions. In Proceedings of the IOP Conference Series: Earth and Environmental Science; IOP Publishing Ltd, 2020; Vol. 572.
2. Efendi, U.; Fadlan, A.; Hidayat, A.M. Chlorophyll-a Variability in Southern Coast of Java Island, Indian Ocean: Corresponding to the Tropical Cyclone of Ernie. In Proceedings of the IOP Conference Series: Earth and Environmental Science; Institute of Physics Publishing, 2018; Vol. 162.
3. Haryani, N.S.; Zubaidah, A. Dinamika Siklon Tropis di Asia Tenggara Menggunakan Data Penginderaan Jauh. *J. Ilm. Widya* **2012**, *29*, 54–58.
4. Lumbangaol, A.; Siadari, E.L.; Ryan, M.; Kristianto, A. Dampak Siklon Tropis Frances Terhadap Upwelling Laut Timor dan Sekitarnya. *J. Meteorol. Klimatologi dan Geofis.* **2018**, *5*, 1–9.
5. Wicaksono, A.; Nuzula, N.I. Model SLA Dan ADT di Perairan Indonesia Selama Badai Siklon Surigae. *Zo. Laut J. Inov. Sains dan Teknol. Kelaut.* **2021**, *2*, 40–44, doi:10.20956/ZL.V2I2.13682.
6. Suharyo, G.B.T.; Purba, N.P.; Yuliandi, L.P.S.; Syamsuddin, M.L. Kondisi Suhu dan Salinitas Serta Korelasinya dengan Variabilitas Eddy di Perairan Halmahera dan Mindanao. *Depik J. Ilmu Perairan, Pesisir, dan Perikan.* **2020**, *9*, 421–427, doi:10.13170/depik.9.3.15534.
7. Woo, H.-J.; Park, K.-A.; Woo, H.-J.; Park, K.-A. Long-term Trend of Satellite-Observed Significant Wave Height and Impact on Ecosystem in the East/Japan Sea. *Deep. Res. Part II* **2017**, *143*, 1–14, doi:10.1016/J.DSR2.2016.09.003.
8. Alianto; Hamuna, B. Spatial-Temporal Variability of Chlorophyll-a Concentration in Cenderawasih Bay and Surrounding Waters. *J. Appl. Geospatial Inf.* **2020**, *4*, 343–349, doi:10.30871/JAGI.V4I2.2003.
9. Ye, H.J.; Sui, Y.; Tang, D.L.; Afanasyev, Y.D. A Subsurface Chlorophyll a Bloom Induced by Typhoon in the South China Sea. *J. Mar. Syst.* **2013**, *128*, 138–145, doi:10.1016/J.JMARSYS.2013.04.010.
10. Wang, T.; Zhang, S. Effect of Summer Typhoon Linfa on the Chlorophyll-a Concentration in the Continental Shelf Region of Northern South China Sea. *J. Mar. Sci. Eng. 2021, Vol. 9, Page 794* **2021**, *9*, 794, doi:10.3390/JMSE9080794.