# SHIP ROUTE PROGRAMMING IN RESTRICTED AND COASTAL AREAS IN TROPICAL CYCLONE REGIONS

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**Abstract.** The article describes various methods used for tropical cyclone avoidance maneuvers during navigation in restricted and coastal waters. The avoidance maneuvers were carried out with the use of the following methods: the ORS (Onboard Routing System) systems, Bon Voyage 7.0 and SPOS 7.0, the 1-2-3 rule recommended by the US national weather administration NOAA (National Oceanic and Atmospheric Administration), the graphic-manual anti-collision plot, as well as the assistance and recommendations of the shore based AWT (Applied Weather Technologies) Centre. The weather and operational data that were used were from the actual voyage of the 9000TEU container ship POSTPANAMX, from Yantian (China) to Vancouver (Canada), which took place in August 2015. During this voyage the ship encountered the tropical cyclone SOUDELOR.

**Keywords:** tropical cyclone, avoidance maneuvers, Bon Voyage, SPOS, CYKLON, 1-2-3 rule, anti-collision plot, weather routing

## INTRODUCTION

Within the area of a tropical cyclone, the winds are extremely violent and the surface of the sea is very rough. The swells are high and come from different directions, whereas individual systems of waves intersect and overlap with each other. They are therefore dangerous for even large ships and high power machines. The danger becomes greater when a cyclone hits the restricted and shallow waters near land. It is not recommended to approach the eye of the cyclone at a distance of less than 120 Nm, and if possible a ship should stay outside of the winds at all times ≥ 34w (8° B). Early and large deviation from the route is often necessary and the only effective way to meet this condition. (UK Hydrographic Office, NP100, 2015) The key decision is to determine when the manoeuvre should start and to take the right course, which is often difficult in coastal and restricted waters.

This article has discussed the case of the typhoon avoidance manoeuvre in coastal and restricted waters during the voyage of a large container ship with a high engine power and a speed of about 20 knots. The cruise took place from the port of Yantian (China, near Hong Kong) to Vancouver in Canada in August 2015. The planned date of departure from Yantian was 07/08/2015 0100 UTC.

The recommended seasonal route has been presented in Fig. 1. It was based on an orthodrome and took into consideration both navigational and legal restrictions – allowed routes in the Bering Sea and the Aleutian Chain and the ECA zone of the western seaboard of the US and Canada (Szymański & Wiśniewski, 2016, 2017). The weather in the North Pacific is shaped by high pressure over the ocean and low pressure systems moving eastwards, along the Aleutian Chain. In the summer, favourable and warm weather conditions predominate over this part of the ocean allowing for navigation along the orthodromic route.

The weather conditions prior to 7 August 2015 in the North Pacific dictated the choice of the orthodromic route; however access to it was hampered by the typhoon SOUDELOR. In the initial coastal phase of the voyage, it was necessary to handle an unusual navigational and weather-related task: the choice of crossing from the South China Sea to the Pacific, while avoiding the winds of the strong typhoon SOUDELOR in coastal and restricted waters.

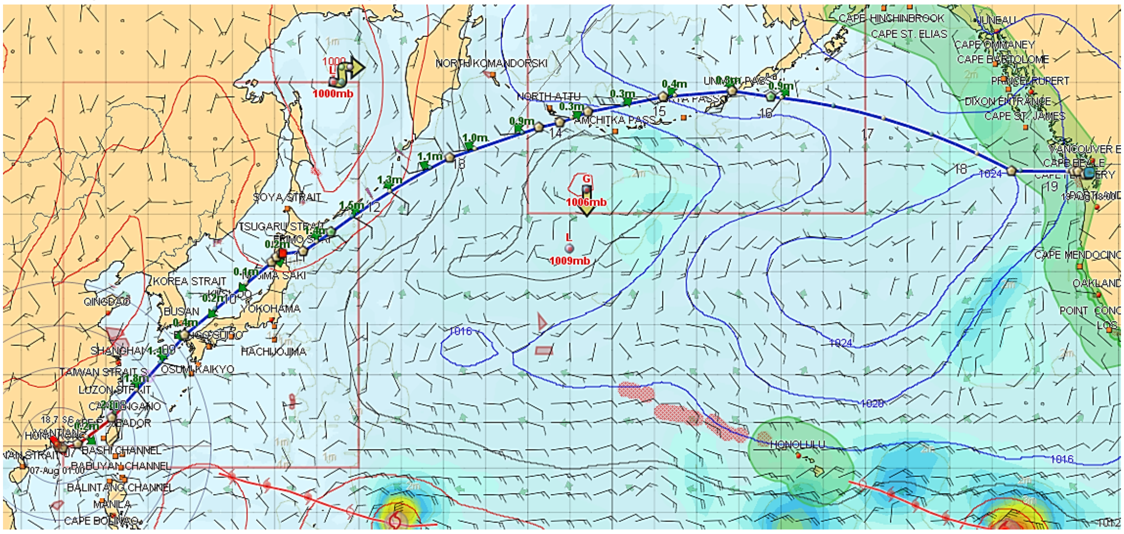

**Fig. 1. Yantian Orthodromic Route – Vancouver.**
Source: authors depiction based on the BVS 7.0 program

Typhoon SOUDELOR was moving WNW from the Philippine Sea over Taiwan to the area of mainland China – Fig. 2. In the forecasts its zone showed the occurrence of winds with velocities of greater than 50 knots. The purple colour indicates a 100% confidence level of occurrence of winds with a force of 50 knots, red colour – a confidence level from 30 to 50%, yellow colour – a confidence level from 5 to 30%.

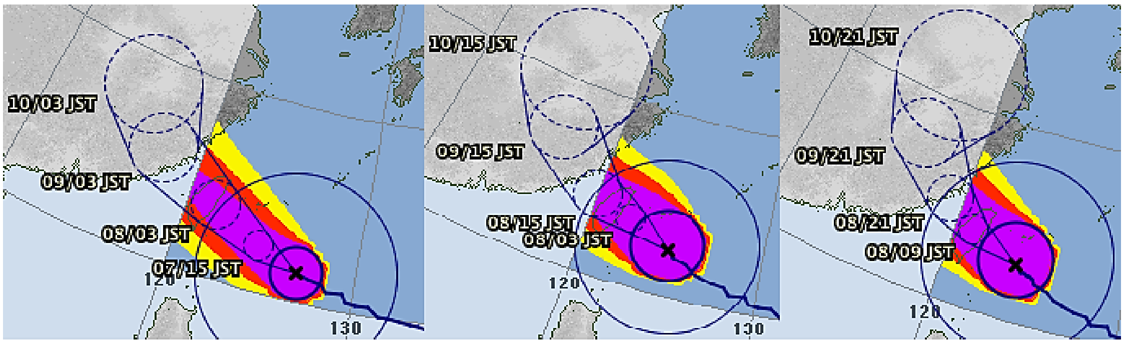


**Fig. 2. Typhoon SOUDELOR track in JMA forecasts from 7 and 8 August 2015.**
Source: JMA

In this situation, three possible options for the avoidance manoeuvre were outlined:
1) Crossing the Taiwan Strait to the north with the intersection of the forecast typhoon course. Waiting until the typhoon passes by moving SW from Taiwan to the South China Sea.
2) Deviating SE towards the Luzon Strait and bypassing the typhoon from S through one of the three deep water crossings: the Bashi Channel, the Balintang Channel or the Babuyan Channel.

## METHODOLOGY

To find the manoeuvre, which was considered the best in terms of safety of the navigation, the onboard routing systems were used: the ORS (ORS – *onboard routing systems*) BVS 7.0 – Bon Voyage System 7.0 (Applied Weather Technologies, 2014), SPOS Fleet Management 7.0.0.1 (Meteo Consult BV, 2009), the 1-2-3 rule (Holweg, 2000), the graphic anti-collision plot (Wiśniewski, 1984, 1994, Bijlsma, 2004), the CYKLON programme (Wiśniewski & Kaczmarek 2012) and the recommendations of the land weather facility (shore based weather routing) AWT – Applied Weather Technologies. The weather data used were the files for the ORS BVS and SPOS system, which contained weather analysis and prognosis up to 9 (SPOS) and 16

(BVS) days ahead, as well as EGC weather reports, forecasts and warnings, bar charts of surface pressure analysis and predictions from the JMA (Japanese Maritime Agency), typhoon prognosis charts from the JMA (up to 120 hrs with 70% confidence level) and typhoon strong winds prognosis charts from the JMA (up to 72 hrs). The obtained results were then compared.

## RESULTS

### Determination of the avoidance manoeuvre through the use of the ORS BVS 7.0 system

Initial testing of the route was carried out prior to 7 August. Automatic programming was adopted according to the fuel criterion with the fixed arrival time – *Least fuel with fixed arrival time.* Weather constraints were defined, so that the zones with wavelengths exceeding 8m and wind velocities higher than 34 knots were avoided. Typhoon SOUDELOR was already visible in the system from 01.08.2015, therefore since that date daily testing was performed – Fig. 3 and 4. The BVS system generated the great orthodromic routes through the Taiwan Strait. Fig. 3 and 4 very clearly show the tendency of the predicted path of the typhoon to move more from WbN to WNW towards northern approaches to the Taiwan Strait.

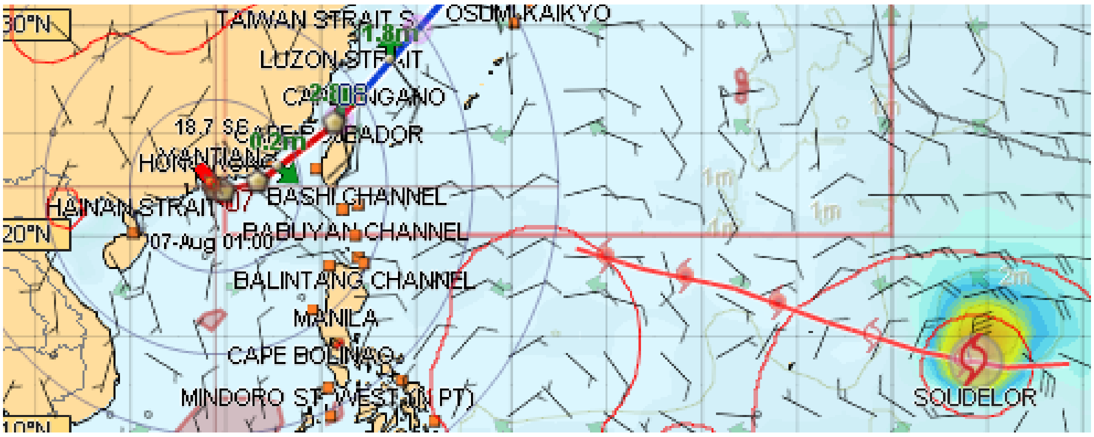


**Fig. 3. Route testing in BVS on 1 August (Developed on the basis of the BVS 7.0 program).**

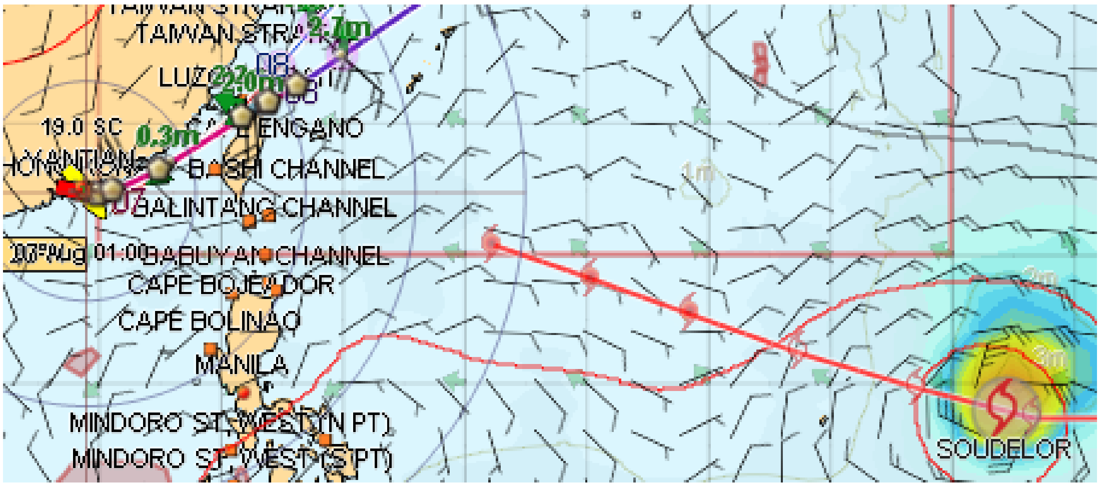


**Fig. 4. Route testing in BVS on 2 August 2015.**

Source: Developed on the basis of the BVS 7.0 program

BVS route testing carried out on 3, 4 and 5 August generated a route through the Taiwan Strait. At that time that route was definitively closed – Fig. 5. Typhoon SOUDELOR was intensifying and moving towards WNW. The choice of the route through the Taiwan Strait would have lead to the crossing of the typhoon route (*crossing the T*) in a restricted manoeuvring area. Therefore these routes were rejected by the captain.

The option of waiting out the typhoon in the south was also rejected, as it would have been too time-consuming.

The correct solution was the route passing through the Balintang Channel in the Luzon Strait, S of Taiwan and the orthodromic route across the ocean. This route would provide a relatively safe distance from the eye of the typhoon (between 150 and 200 Nm) and guide the ship through the safe and deep Balintang Channel. The equally deep Bashi Channel, located further north, was excluded due to the forecast proximity to the eye (about 100 Nm), and further to the south, the Babuyan Channel did not provide sufficient navigational security.

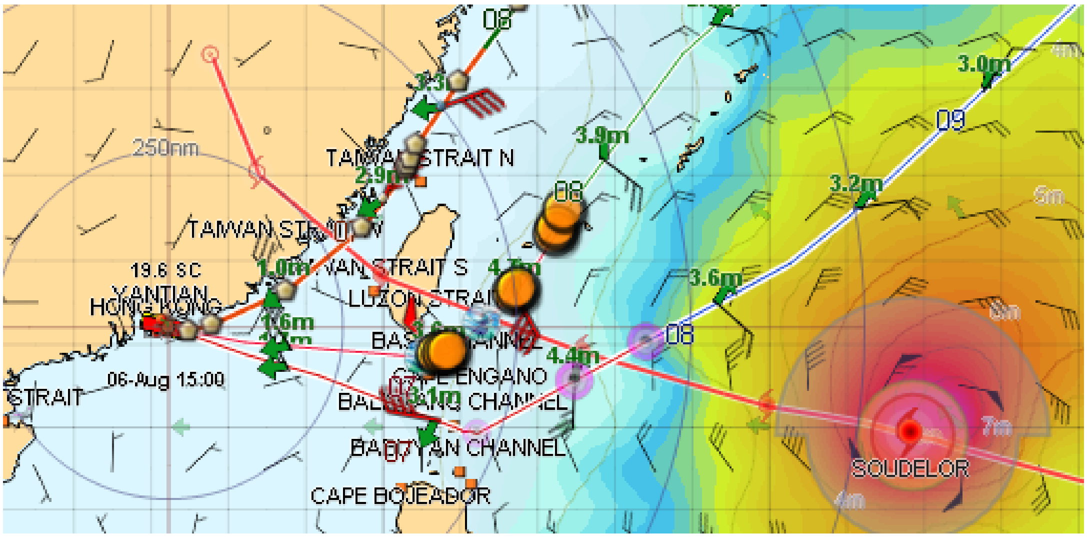

**Fig. 5. Route testing in BVS on 5 August 2015.**
Source: Developed on the basis of the BVS 7.0 program

**DETERMINATION OF THE AVOIDANCE MANOEUVRE WITH THE USE OF ORS SPOS 7.0.0.1**

The route testing in the SPOS system was performed after the voyage. Considering the weather constraints, in the SPOS system it was possible to program the minimum distance from the cyclone (Wiśniewski & Szymański 2016). The maximum wave heights and wind speeds were programmed to be 8m and 34 knots. The minimum distance from the typhoon's eye was set at 250 Nm. The type of route chosen was Optimum High & Wide, with a speed of 19.5 knots, corresponding to the speed of the route programmed in the BVS 7.0 system. By 3 August the SPOS system would have generated the routes through the Taiwan Strait. Later on, the routes generated in the SPOS system ran through the Luzon Strait, initially the Bashi Channel (Fig. 6), and from 6 August (Fig. 7) the Balintang Channel.

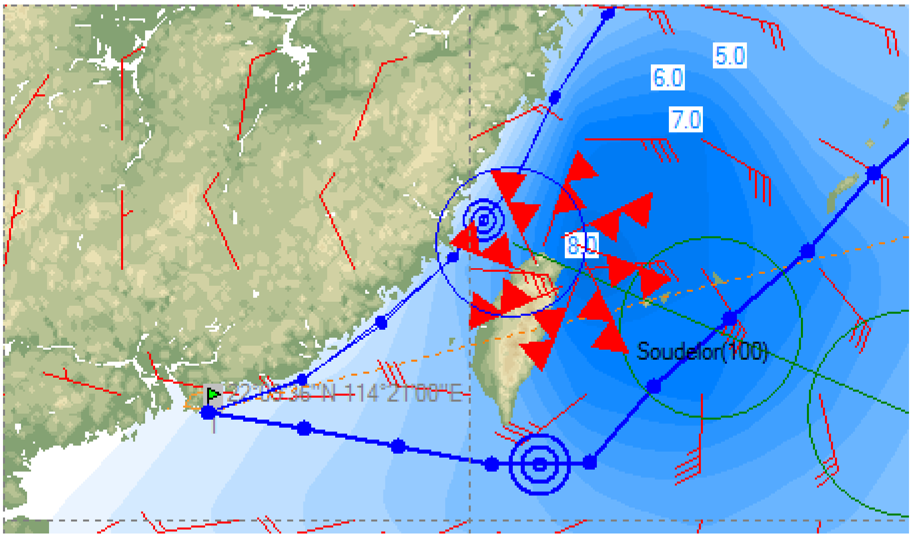

**Fig. 6. Route testing in SPOS on August 3 with cyclone positions and possible ship positions on selected routes on 07.08.2015.**
Source: Prepared on the basis of the SPOS program

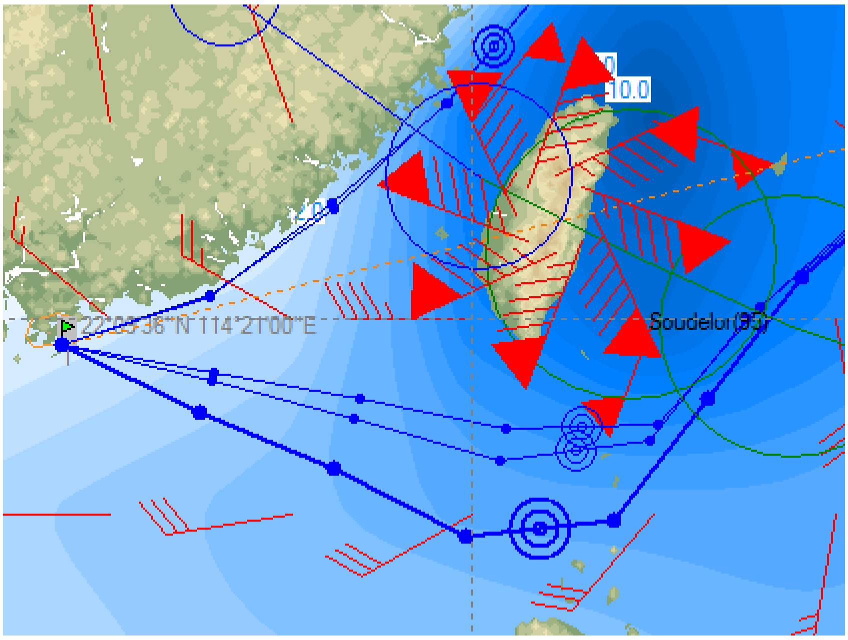


**Fig. 7. Test results in SPOS from 6 August.**

Source: authors findings based on depictions in the SPOS system

## DETERMINATION OF THE AVOIDANCE MANOEUVRE WITH THE USE OF THE 1-2-3 RULE

The current position of the typhoon SOUDELOR, together with the 34 knot strong winds zone, has been marked with the colour blue on 4 August (Fig. 8) and 6 August (Fig. 9) from 1200UTC. Further consecutive positions of the typhoon's eye have been marked green. The 34 knot and higher strong wind zones for the position of the cyclone after 24, 48 and 72 hours were enlarged according to the guidelines of the 1-2-3 rule, by 100, 200 and 300Nm respectively, in relation to the values provided in the guidelines. The only safe outcome of this evasive manoeuvre, obtained using this rule, is a hasty departure from the SW and waiting out the typhoon. In order to visualize the 1-2-3 rule, the images from the CYKLON program were used.

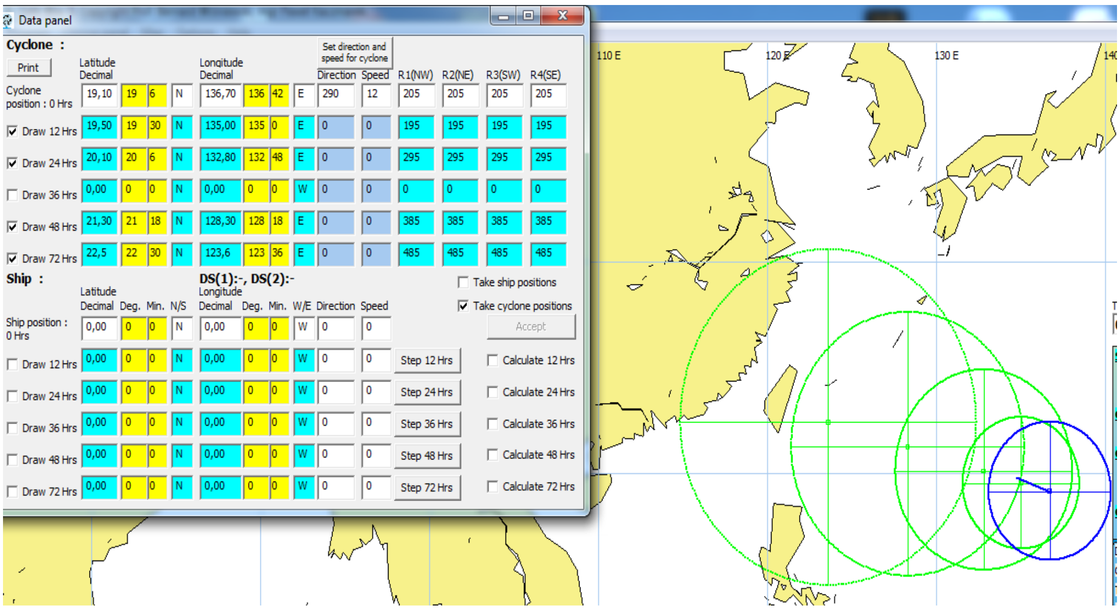


**Fig. 8. 34 knot strong wind zone of the typhoon SOUDELOR calculated by the 1-2-3 rule on 4 August 2015.**

Source: authors findings

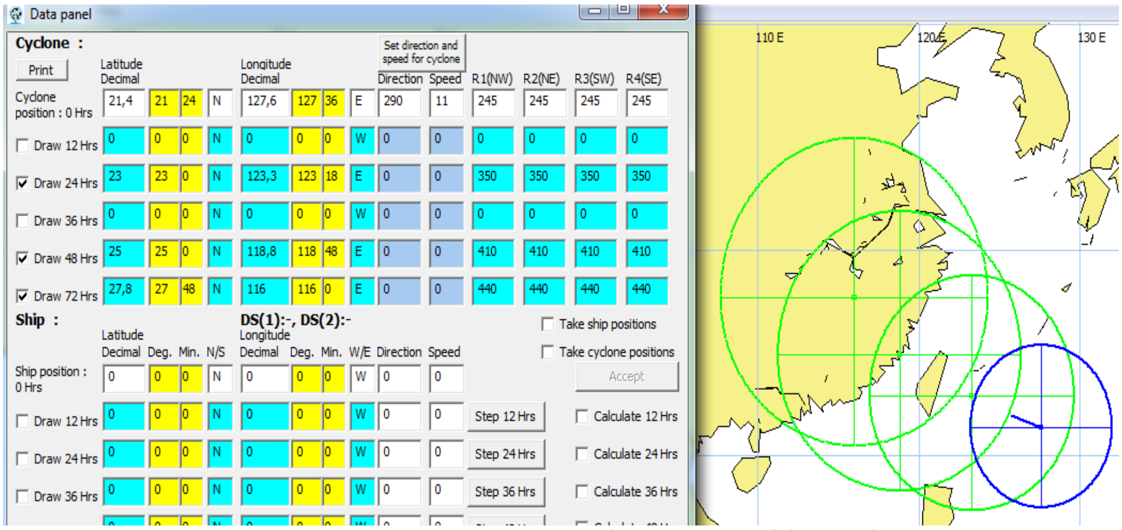


**Fig. 9. 34 knot strong wind zone of the typhoon SOUDELOR calculated by the 1-2-3 rule on 6 August 2015.**

Source: authors findings

## DETERMINATION OF THE AVOIDANCE MANOEUVRE THROUGH THE USE OF THE CYKLON PROGRAMME

The CYKLON programme was populated with the data on the typhoon from 7 August 1200UTC, when the ship began its voyage. The safe course was KDd = 125º. The CYKLON program initially calculated the sector of dangerous routes between 015º and 122º (Fig. 10. After 15 hours of maintaining KDd = 125º, it was safe to take KDd = 095º towards the Balintang Channel – Fig. 11).

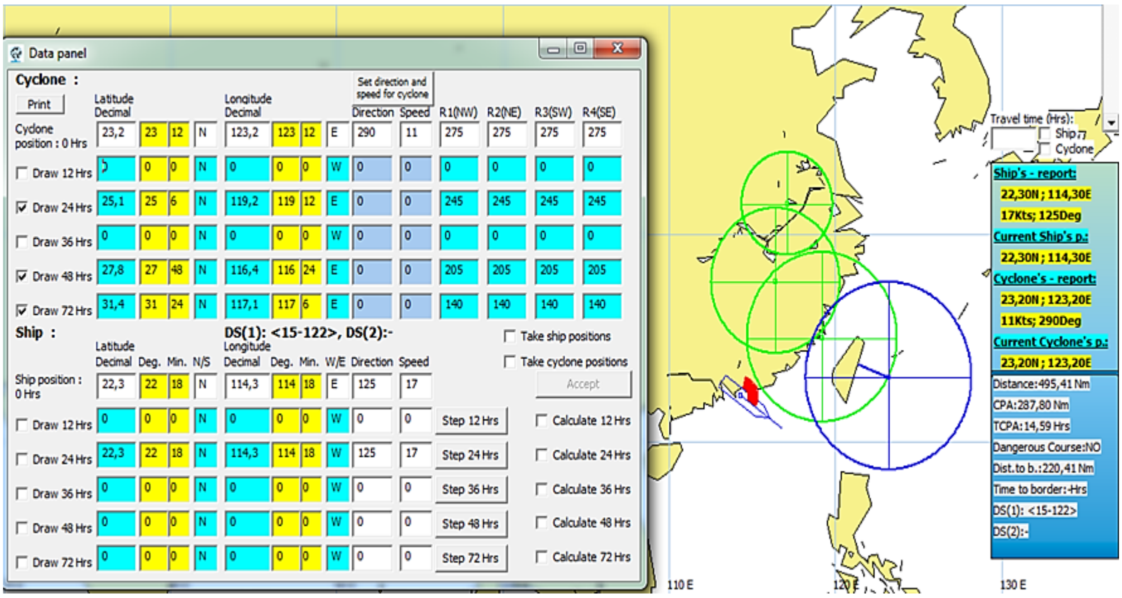


**Fig. 10. Determination of the avoidance manoeuvre through the use of the CYKLON programme on 7 August 2015 1200UTC.**

Source: authors findings

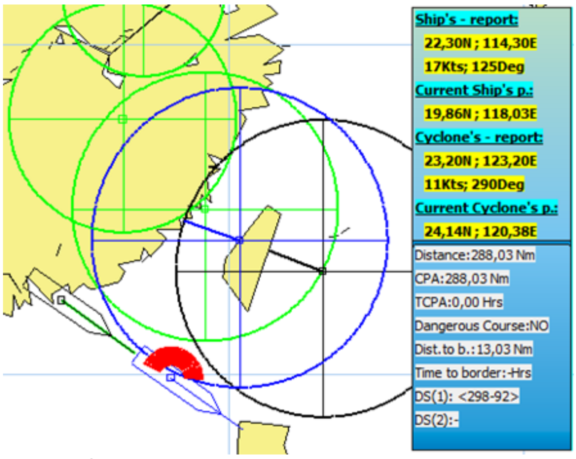


**Fig. 11. Determination of the avoidance manoeuvre through the use of the CYKLON programme on 8 August 0300UTC.**

Source: authors findings based on the CYKLON programme

## DETERMINATION OF THE AVOIDANCE MANOEUVRE WITH THE USE OF THE MANUAL ANTI-COLLISION PLOT

The manual anti-collision plot has been shown in Fig. 12. The data necessary to understand the plot is:

Typhoon's position: 21.4N 127.6E, Δ (34 knot strong wind zone) = 245Nm.

Typhoon movement vector: KDd = 290º, $V_C$ = 11 knots, vessel position on 07/0500GMT: 22.3N 114.3E, speed of the ship above the bottom $V_S$ = 17 knots, the n = 3 coefficient of uncertainty in determining the location of the typhoon was adopted for the final part of the equatorial section of the typhoon track.

The lined area on Fig. 12 shows the sectors of the dangerous courses: 023º = 127º. A recommended action in this case was to take the course to 130º and stay on it for the next 15-20 hrs and then change course towards the Balintang Channel, in order to leave the Pacific Ocean.

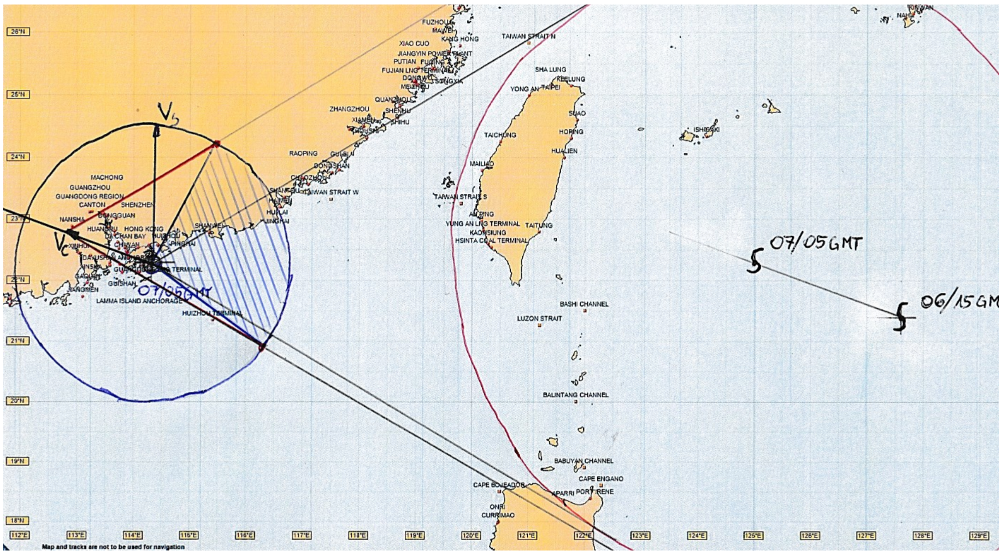


**Fig. 12. Manual anti-collision plot of 7 August 2015, 0500GMT.**

Source: authors findings

## RECOMMENDATION OF THE SHORE BASED CENTRE

During the voyage the recommendations of the AWT shore based centre were used. Their aim was to keep the ship outside the zone of the greater than 35 knot strong typhoon winds. Initially, the centre recommended going to the Pacific through the Balintang Channel. On August 5 and 6, this recommendation was changed to the Babuyan Channel crossing, located further to the south, and on 7 August, after the voyage began, the Balintang Channel was re-recommended in order to enter the Pacific.

## CONCLUSIONS

- A correct solution was not obtained through the use of the Bon Voyage ORS system. It does not meet one of the basic nautical rules of avoiding the cyclone – to circumvent it from the side of the equator. The calculations were based only on the maximum permitted wavelengths and wind speeds declared by the user.
- The 1-2-3 rule was ineffective and over protective. The strong wind zone after 72 hours, calculated by this rule, was almost 900Nm. This meant that the only possible option was to leave heading SW and wait for the typhoon to pass. Finding the optimal solution using this rule is difficult. Its methodological error was also the lack of differentiation of the radius of the strong winds zone, depending on the quadrant of the typhoon.
- The correct solution to the problem was obtained by the means of the CYKLON system and the manual anti-collision plot. The CYKLON programme is recommended more than the manual method. Although the obtained results were almost identical, the accuracy of the calculations obtained in the CYKLON program, due to the methodology (analytical and mathematical in the CYKLON program versus manual-graphics in the anti-collision plot), were more accurate.
- When using the ORS SPOS system a safe solution was obtained only from 7 August 2015, when the distance from the cyclone was less than 250Nm. Therefore, the SPOS system requires further testing.
- The recommendations of the shore based centre were correct. The quality of such a recommendation depends, however, on the knowledge and experience of the operator and the cooperation of the master in the shore based centre. Each centre should be considered individually.

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