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Development Of Analytical Method for Finding the High Risk Collision Areas

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ABSTRACT: The traffic condition has been analyzed by models that are based on Gas model and Obstacle Zone by Target (OZT) by using 1 year AIS data for Tsunami measure. By applying Gas model based method, it is possible to analyze the area in terms of ships' relative angle, size, speed and density. The OZT is originally developed to show the collision zone on the target ship's course. By using this method to the marine traffic analysis, high possibility of collision areas are estimated. Moreover, ships that courses are heading to OZT are identified and studied their position and how long they proceed course heading to OZT.

1 INTRODUCTION

Ships were significantly damaged by the Great East Japan Earthquake and the ensuing tsunami on March 11, 2011. Because Nankai Trough Earthquake and Tokai Earthquake occurrence are highly probable in the near future, the importance of evacuation measure for ships has become increasing. While various measures have been discussed, it has not been done to clarify dangerous waters and safe place from actual marine traffic analysis when the tsunami predicted. To let the Tsunami go past safely, the navigators normally navigate ships to the deep-water area that is sometimes said more than 200 meters (Kamaishi Japan Coast Guard 2004). If it is not possible, they instruct abandon the ship and evacuate on the land as one choice. Actually, several ships are evacuated to the safe depth area at the Great East Japan Earthquake (Hidenari M. et al. 2011). Preliminary measures in consideration of the marine traffic situation leads to quickly and safely evacuate ships to safety depth sea area.

The authors introduced marine traffic analytical methods based on the Gas model (Gen F. et al. 2013) and OZT (Gen F. & Ruri S. 2016). In this paper, one year AIS data has been studied with both models. Then results are compared with estimated fishery tracks by hearing observation (Gen F. 2016). Finally, ships that are actually heading to OZT are analyzed.

2 CALCULATION MODELS

2.1 *Gas model based risk analysis*

The Gas model based calculation for the purpose of developing Tsunami measure is introduced and details are shown in Gen F. & Kyoko T. 2015. The risk is become higher when more vessels exist and take different courses in the area during the sampling time. In this study, 1 hour average rate (TR) are calculated as follows:

$$TR = \frac{\sum_{i=1}\sum_{i \neq j} D_{ij} V_{ij} t}{24 \times d \times S} \qquad (1)$$

D_{ij} and V_{ij} are the geometrical collision diameter and relative velocity of ships i and j. The S is a cell area(1/4mile×1/4mile). The t and d are the sampling time and days respectively. Pedersen's model has been used to calculate the geometrical collision diameter (Pedersen P. T. 1995).

2.2 *Estimating collision course areas with OZT*

The OZT model is introduced by Hayama I. et al. 2002. This method is able to show the estimated collision areas called Obstacle Zone by Target. Therefore navigators can sassily understand the collision curse as shown in Figure 1. The calculation model for OZT is used Hayama I. 2014, because of less computation time compared with Hayama I. et al. 2002. Firstly, the zone is decided with a circle of radius r around own-ship. In this study, the radius r is calculated by using the collision diameter (Pedersen P. T. 1995) divided by two. Then it draws tangents to the circle from the target ship. The course Co which is DCPA=r is calculated with angle α in the tangential direction is given by:

$$Co = Az \pm \alpha - \sin^{-1}\left\{\frac{V_T}{V_0}\sin(Az \pm \alpha - C_T)\right\} \qquad (2)$$

The Az, V_T and C_T are target ship's direction from own ship, speed and course respectively. The V_0 is own ship's speed. There are calculated up to 4 TCPAs from the relative speed V_R and course C_R as follows:

$$TCPA = \frac{d\cos(C_R - Az + 180)}{V_R} \qquad (3)$$

The OZT is found by using calculated TCPA times V_T as shown in Figure 1.

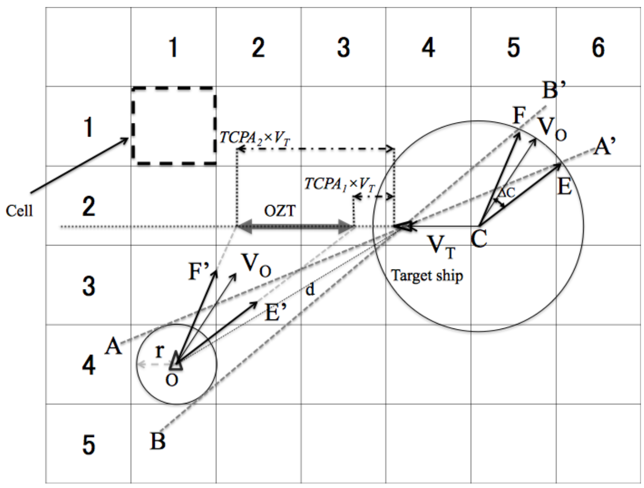

Figure 1. Relationship with OZT and other parameter

Ships are chosen by certain time range. Then, each ship's OZT is calculated with all other ships. If the OZT is passing through the cell (cell number: cn) at time t, the 1 is added to the cell rate TC.

$$TC_t^{cn} = Cell_t^{cn} + 1$$

The d days total cell rate TC_i are summed up and then divided total hours.

$$ATC_n = \frac{\sum_{i=1}^{n} TC_i}{24 * d} \qquad (4)$$

3 RESULT OF 1 YEAR ANALYSIS

3.1 *1 year results with Gas model and OZT model based calculation*

The Shimizu Port area has been found higher risk than other area in Suruga Bay (Gen F. 2015, Gen F. & Kyoko T. 2015, Gen F. & Ruri S. 2016). Therefore, around the Shimizu Port area is studied with Gas model and OZT based analysis by using 1-year AIS data from July 2014 to June 2016.

Cell sizes are decided 1/4 miles square for Gas model based analysis and 1/100 miles square for OZT model based analysis. The sampling time is set 0.5 hours for Gas model based analysis.

The OZT is calculated if it is satisfied following parameters:

- DCPA: less than 0.5 miles,
- distance to other ship: less than 3 miles,
- relative angles to the OZT: less than ±90 degrees from own ship course,
- own ship speed: more than 8 knots,
- other ship's speed: more than 0.5 knots.

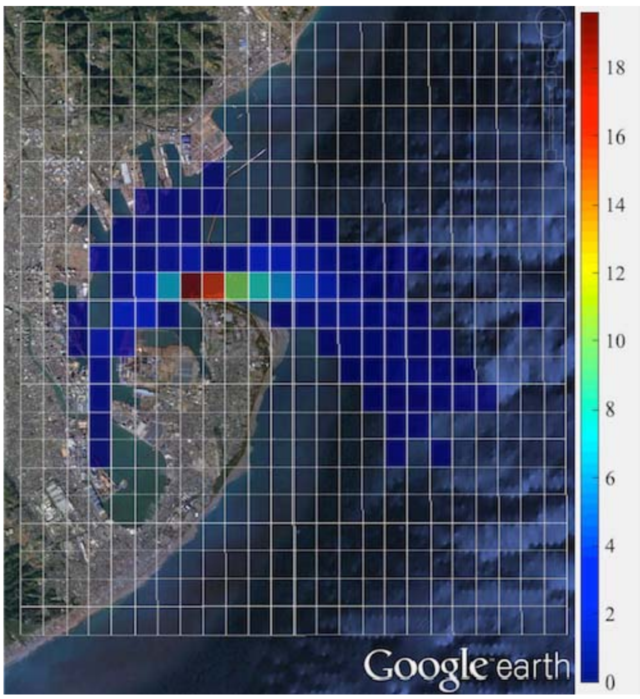

Figure 2. One year analysis data with Gas model based calculation

The 1-year analysis data based on the Gas model calculation is shown in Figure 2. The Shimizu Port entrance is marked as high-risk rate. Since ships are navigated normally same course or passing thorough about 180 degrees relative angles, the north part is found less risk rate compared with south side of port entrance. Since the south side is high-risk rate, extra care is necessary for the safety evacuation.

If there are more OZT found, there are more collision risk is existed. The highest rate that is about 0.05 OZT existences per hour is found near the port entrance No.1 in Figure 3. It should be avoided taking course toward this area. In the port, there is found the line of high rate area that shows 2. This line is along to the container ship course from the container terminal. Because the containership is using similar course when the evacuation is carried out, this area might be dangerous for other ships. High OZT area indicated by 3 is the course, which normally used by outbound vessels. Inbound vessels should avoid this area for evacuation. The high rate areas are also found outside of the port. Even though around 4 areas are more than 200-meter depth and close to the port, it is better not to use for the evacuation. The 5 is normally the course for out bound vessels. The 6 is normally the course for inbound vessels. Since it is difficult to see with other analysis method such as using ships density, this information might be very useful for the navigators for making the evacuation plan.

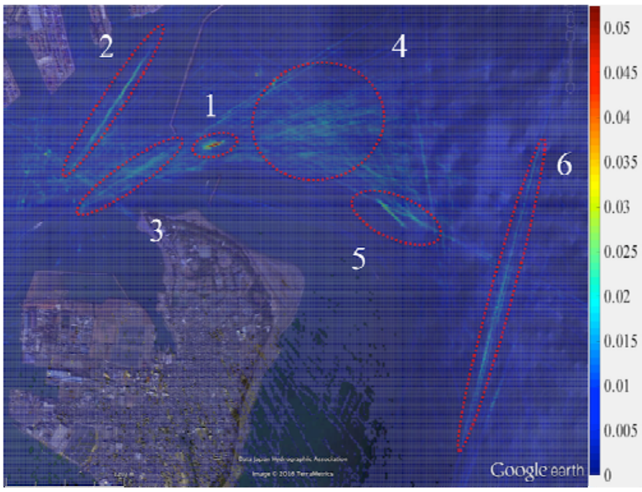

Figure 3. 1-year analysis data with OZT model based calculation

3.2 *Comparing with estimated fishery boat trajectory*

It is known that the white baits fishing boats and Sakura shrimp fishing boat are crossing near the entrance of the Shimizu Port (Gen F. 2016). The white baits fishing starts from 21st of March until 15th January in next year. The starting time is from sunrise until about 9 o'clock in the morning. Sakura shrimp fishing starts from March until 5th June and October until December. They begin fishing from the sun set until around 21 o'clock.

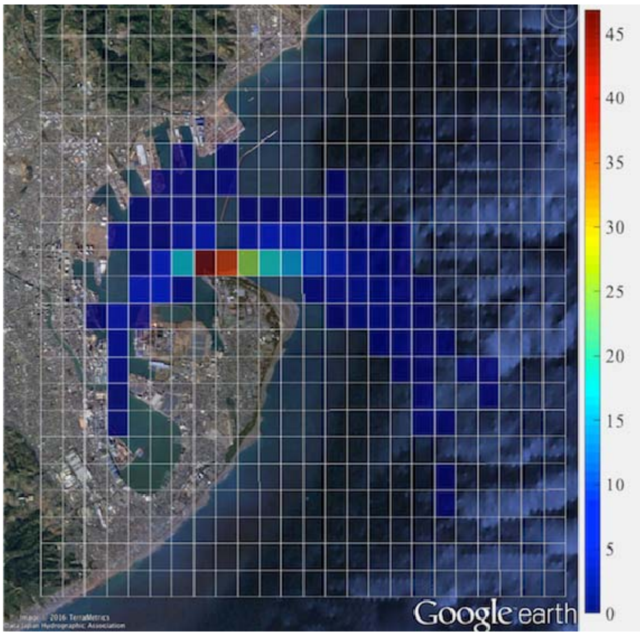

Figure 4. From March to May based on Gas model based calculation

Figure 4 and Figure 5 are shown results from March to May and October to December based on the Gas model calculation. The Gas model based calculation shows very similar risk trend compare with Figure 2.

Figure 6 and Figure7 are the OZT based calculation result from March to May and October to December respectively. The red arrows in the figures are estimated fishing boats tracks by hearing observation (Gen F. 2016). The route, which is indicated as 1 in the both figures, is used mainly Sakura shrimp fishery boats. Therefore, this estimated route is found at the sun set time going to the fishery area and after 21 o'clock going back to the port. The Sakura shrimp route estimated route is crossing and along areas where the OZT existence rate is 0.04 to 0.06 in the Figure 6. When planning the evacuation plan at nighttime in these seasons, it needs to be considered these fishery boats. White baits fishery boats and recreational fishing boat from the Shimizu port mainly use the route, which is indicated as 2. These ships are normally found in the morning. The route is seemed to be not dangerous compared with route indicated as 1. However, these ships are might be drifted by the current caused by the Tsunami. In this case, the entrance of the port could be more dangerous especially around the areas that OZT existence rate is about 0.16 to 0.18.

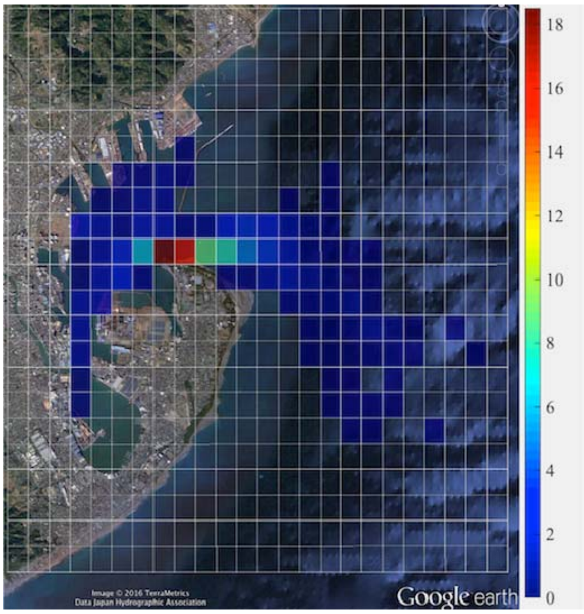

Figure 5. From October to December based on Gas model based calculation

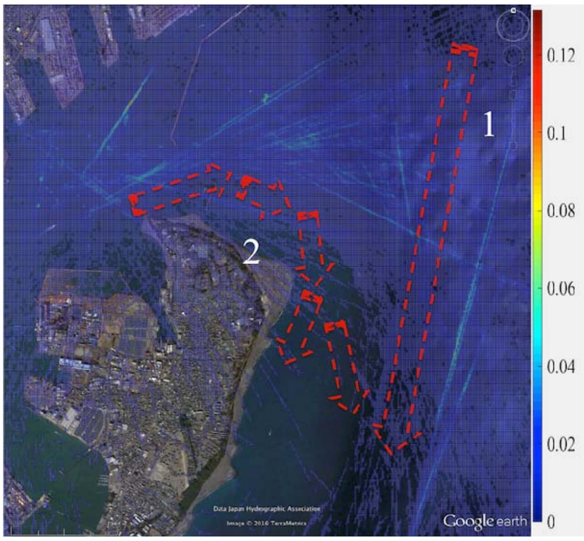

Figure 6. From March to May data with OZT model based calculation and estimated fishery boat track

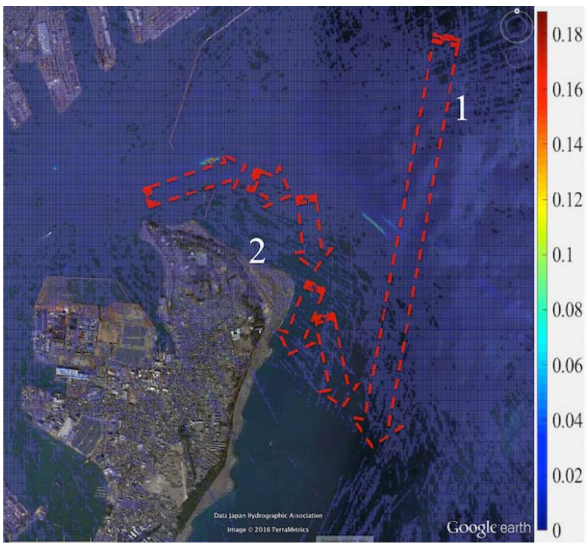

Figure 7. From October to December data with OZT model based calculation and estimated fishery boat track

4 ANALYSING SHIPS THAT ARE HEADING TO OZT

There is one actual collision around the Shimizu Port Entrance shown in Figure 8. By analyzing with OZT, the ship towards the OZT from 5:36:12 for about 160 seconds until the collision. The S1 ship stopped engine ("S1 ship (Stop Engine)" as shown in Figure 8) at about 5:36 A.M. and proceed her course heading to quarantine anchorage. But at this time, the ship has already been heading to OZT as shown in Figure 8. Pilot is on board on S2 ship. They contact by VHF at 5:38 A.M. with S1 ship to tell to pass their stern. Then, the S2 ship starts changing her course to port at 5:41 A.M. The S2 ship continually changing her course to the port and collision occurred. There is no case found heading to OZT such a long time heading to OZT or changing her course rapidly after heading OZT at this time. However, AIS big data can be analyzed with this method for finding the near miss case. For doing this, it needs more collision studies by using OZT.

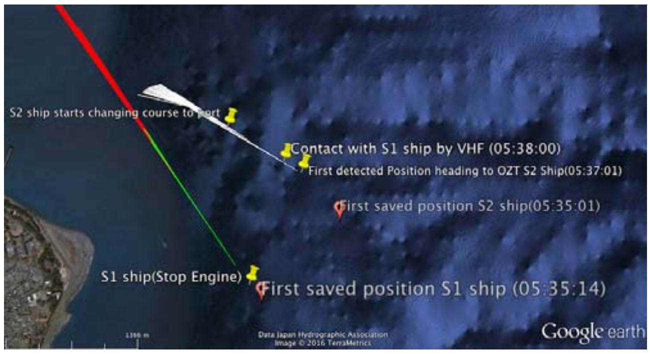

Figure 8. Showing OZT and ships' position by using actual collision data

There are 3 times that is facing OZT continuously OZT for 6 seconds in the previous collision example. Therefore, it has conducted a survey of vessels continuously facing to OZT in the survey area. By using AIS data that is converted to every 1second from July 2014 to December 2014, OZT is calculated and extracted vessels that are proceeding towards to OZT. After extraction of ships, the data that virtually no collision occurred, such as own ship course, target ship course and OZT intersects breakwaters and the lands are deleted. Continuous data at 1-second intervals are counted and shown with ship-ship distance in the Figure 9.

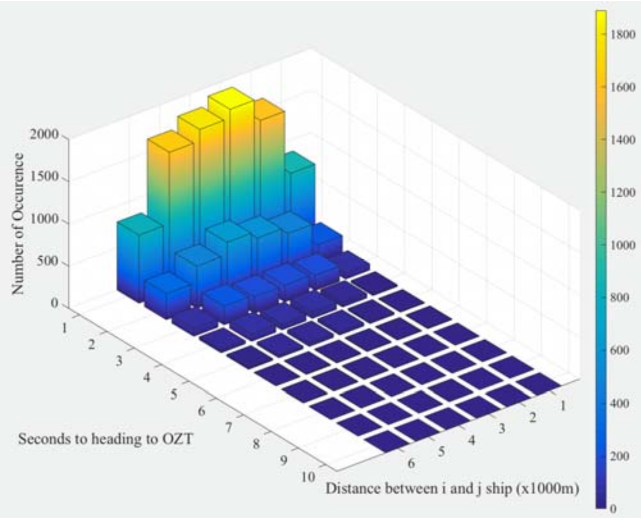

Figure 9. The numbers of ships are heading to OZT

Table 1. Heading to OZT seconds and ship-ship distance

Seconds/Distance (m)	5	6	7	8	9	10
d<1000	6	7	1	1	1	0
d<2000	22	5	1	1	0	0
d<3000	36	10	2	2	2	1
d<4000	40	10	7	2	0	1
d<5000	31	9	7	2	0	0
d<6000	19	4	4	1	0	0
Total	154	45	22	9	3	2

From the data, most of vessels that are facing OZT in succession are within 1 seconds to 4 seconds. During this period, the maximum time towards to OZT is 10 seconds. There are 3, 9, 24, 45 and 154 cases found between 5 to 9 seconds as shown in Table 1.

Analysis is then carried out using the figure. From 8 to 10 seconds and 7 seconds heading to OZT data are shown in Figure 10 and Figure 11 respectively. The white line and green line show own-ship course and target ship course respectively. The red lines represent OZT. In the figure, 9sec_1 means that the ship is heading to OZT for 9 seconds continuously. The total numbers of 235 data that are heading to the OZT time from 5 to 10 seconds are studied. For example, 9sec_1 ship is changing the heading to starboard and entering port after this. 8sec_5 ship is changing her course to starboard. 8sec_6 ship proceeding same course, but target ship changing her course to starboard. Looking at the location of the OZT of a ship navigating towards OZT for 7 seconds to 10 seconds, it is understood tendency for OZT to appear around the Shimizu port. Although there is no near miss data found at this time, this method can be used for finding the near-miss case with AIS big data. For doing this, the more collision case will need to be studied by using this method in the future.

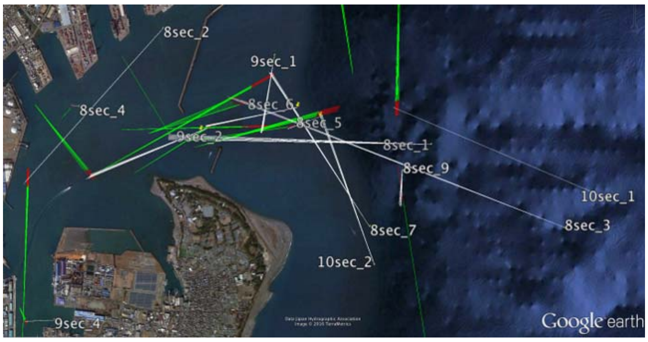

Figure 10. Heading to OZT for 8 to 10 sec with ships' course and OZT Position

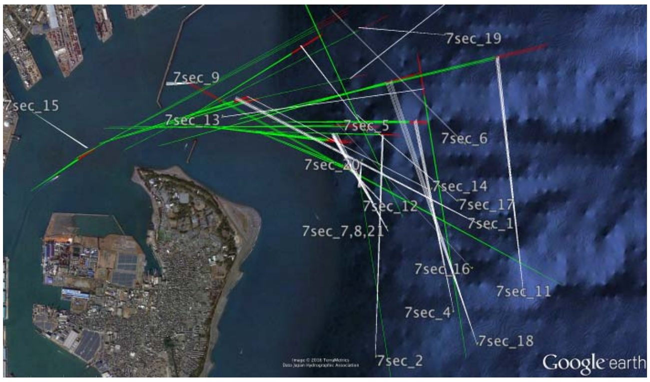

Figure 11. Heading to OZT for 7 sec with ships' course and OZT Position

5 CONCLUSION

The traffic condition has been analyzed by using the Gas model based and OZT model based methods by using a 1-year AIS data for the tsunami measure.

The south side of the Shimizu port entrance has found highest risk place with the Gas model. When ships are evacuating, navigators should have extra caution around this area. The dangerous courses are known with OZT based analysis. The several high OZT existing places are found in the port and also outside of the port. Navigators should be considered seasonal and time zone of fishery boat movement, especially near the port entrance. Ships that courses are heading to OZT are also identified and studied their position and how long she proceeds course heading to OZT. This method can be applied to the AIS big data for analyzing the near miss ship collisions. For this purpose, it needs to analyze actual collisions with the same method and clarify OZT information such as period of heading to OZT, ship-ship distance, speed and encountering situations.

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