Drift Track Simulation for Past Marine Incidents Using SARMAP

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***Abstract*-Once marine accident occurs, it is important to find the people or marine crafts adrift in the ocean in a timely fashion. For this, one has to be able to calculate or predict the tracks of the drifting objects or persons. This study used SARMAP, a search and rescue program developed by ASA (Applied Science Associates), to simulate drift tracks of accidents occurred previously in the Taiwan Seas and compared the results with the final rescue positions reported by the coast guard.**

For the wind and current, we used three types of data. These include: (1) Wind and current data from COASTMAP (a data base kept by the ASA), (2) Seasonal average currents in the Taiwan Seas form National Center for Ocean Research (based on shipboard ADCP data), and (3)Wind and current data from the Central Weather Bureau (CWB). Results showed that SARMAP would predict satisfactory drift tracks when we have good current data.

I. INTRODUCTION

On average there are close to one hundred marine accidents in the Taiwan Seas. It is imperative to locate the people or marine crafts adrift in the ocean so that successful rescue missions can be achieved. For this, one needs to calculate or predict the tracks of the drifting objects or persons. The most commonly used method is the Automated Manual Solution (AMS) prescribed in the International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual [1], as corrected by the 2000 errata [2] and as supplemented by the U.S. National Search and Rescue Plan [2]. This method calculates the drift track based on the input current speed, current direction, wind speed, and wind direction, incorporating the leeway characteristics of the object. The second method is the Monte Carlo method, which determines a probability grid based on the trajectory of a large number of particles, each moving with some randomness [2]. SARMAP is a search and rescue program developed by the Applied Science Associates (ASA). The program has a simple GIS framework for integrating different data such as digital sea chart, environmental information, search and rescue patterns, etc. It can be used to predict object drift track by either AMS or Monte Carlo method by inputting the last know position of an object, object configurations and environmental data. The program contains a database of drift behavior for a variety of objects, based on the U.S. Coast Guard data. The effect of surface wind is accounted for by the wind drift and the leeway estimation. Leeway is "the movement of a search object through water caused by winds blowing against exposed surface [3]." The SARMAP includes the standard search objects listed in the IAMSAR manual supplemented by fifty other objects with their associated leeway factor [4].

The objective of this study is to compare the drift track calculated by the SARMAP to the final rescue position reported by the coast guard. It is well known that the drift track is highly dependent on the input sea current and wind data. In this paper, we used wind and tidal current data supplied by the ASA, called COASTMAP, which is an on-line data server that provides hindcase, nowcast, and forecast winds and tidal current. We also used current and wind data from the Central Weather Bureau. At locations where currents are dominated by ocean current with negligible tidal current, we used the seasonal mean current reported by the National Center for Ocean Research. Drift tracks calculated using these different data sources are compared.

II. METHODS

To calculate a drift track by the SARMAP, one first builds a scenario. A scenario in SARMAP is a collection of information that defines a model simulation [2]. This information includes a definition of the search and rescue scenario such as: date, Last Known Position (LKP), type of missing object, etc.; the environmental data files (land-water boundary, winds and currents) used in the simulation and the search and rescue units deployed. (Fig. 1)

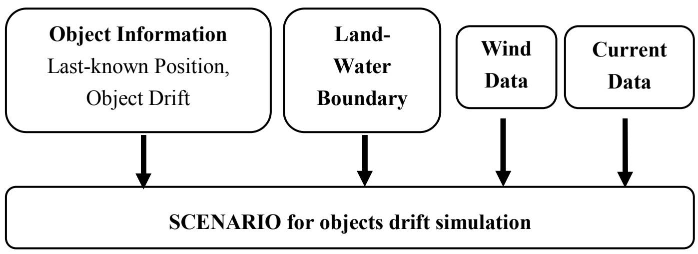

Fig. 1 Data that a scenario needs (ASA, 2008)

With the necessary input data, the drift track of an object can be computed by either the AMS or Monte Carlo method. From the last known position, the AMS solution calculates successively the location of the drifting objects or persons according to the total current, including input sea current, wind driven current and leeway, in each time step. Due to the crosswind component of the leeway the direction of the object can be to the left or right of the down wind direction rather than directly down wind. Hence, the possible drift track of the

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object will separate by the leeway. Thus, the search area of the drift object increases with time. The AMS solution does not provide information on the probabilities of locating the object within the search area, and the search can become quite large.

One can also use Monte Carlo or Particle Method to predict the drift track. This solution uses a large number of individual particles to represent the missing objects, each particle moving in response to currents, wind, leeway, and random variability [2]. Since the leeway is dependent on the type of search object, each particle initially is assigned a preferred direction of motion – either to the left or to the right of the wind direction. At regular intervals during the simulation, a small percentage of randomly chosen particles switch their preferred direction.

The final result of the Monte Carlo solution is a gridded area encompassing the position of all the individual particles. The grid divides the area into sectors based on the probability of containment (POC), which is the probability of the sector containing the object. The more densely populated sectors have higher probabilities of the search object being located there. The Monte Carlo solution in general provides a smaller and more accurate search area than that of the AMS solution. In this study, we used Monte Carlo solution to calculate the drift tracks.

For the wind and tidal current, we used three types of data. These include: (1) Wind and current data from COASTMAP (A database kept by the ASA), (2) Wind and current data from the Central Weather Bureau (CWB), and (3) Seasonal average currents in the Taiwan Seas form National Center for Ocean Research (based on shipboard ADCP data). Table I shows the spatial and time resolution of each data source.

TABLE I
CURRENT AND WIND DATA

Data Type	Data Source	Spatial Resolution	Time Resolution
Tidal current from COASTMAP	ASA COASTMAP	Western and Northern Taiwan (1/20)° x (1/20)° Northeastern and Southern Taiwan (1/10)° x (1/10)° Southern and Eastern Taiwan (1/5)° x (1/5)°	1hr
Wind from COASTMAP	NCEP (National Centers for Environmental Prediction)	(1/2)° x (1/2)°	6hrs
Sea current from CWB	CWB	(1/8)° x (1/8)°	1hr
Wind from CWB	CWB	(1/2)° x (1/2)°	6hrs
Seasonal average currents	NCOR (National Center for Ocean Research)	15’ x 15’	3 months mean

In this study we tested three reported incidents: (1) Nanching vessel divers, (2) Lungdung bay fisherman, (3) Baumashan cargo ship. In the incident 1, there were seven recreational divers diving off the Nan-Ching vessel at southern Taiwan. Due to rough seas, they were not picked up by the diving vessel when they came up. They were in the ocean in about 40 hours, drifted about 100km, and were found in eastern Taiwan. In the incident 2, two fishermen fell into the sea from the shore in rough seas at northeastern Taiwan. They were found near the LKP. In incident 3, the Baumashan cargo ship adrift in western Taiwan due to engine failure. After about 30 hours, it went aground at the Penghu Island in the Taiwan Strait. The geographic location, time and object type of these incidents are listed in Table II.

TABLE II
DETAILS OF INCIDENTS INVESTIGATED

Incidents	1:Nanching vessel divers	2:Lungdung bay fishermen	3:Baumashan cargo ship
LKP	21° 45’ N 121° 49’ E	25° 06’ N 121° 55’ E	23° 49’ N 119° 33’ E
Position found	22° 33’ N 121° 07’ E	25° 06’ N 121° 57’ E	23° 40’ N 119° 31’ E
Incident initial time	2008/04/26 12:10	2007/11/25 18:00	2007/11/20 20:05
Incident rescue time	2008/04/28 05:27	2007/11/29 11:35	2007/11/22 07:10
Object selected	7 Persons in water	2 Persons in water	Coastal freighter

III. RESULTS AND DISCUSSION

Figure 2 shows the Monte Carlo simulation for the incident 1 divers, using COASTMAP tidal current and wind. Since COASTMAP current is simulated tidal current only, which is only a minor component of the sea current in that area, at the end of the drift simulation the drift objects only move a little distance to the west by the wind with some back and forth movements by the tide. As can be seen, the final distribution of the particles was quite a distance from the location of the divers been rescued; the particles did not even reach the eastern coast. This is apparently due to the lack of correct current input for the simulation. The result of drift track simulation using CWB current and wind is similar to what is shown in Fig. 2. Apparently, the divers were carried by the tidal and ocean currents toward the east and past the southeastern tip of Taiwan. It is known that the dominant current in the sea to the east of Taiwan is the Kuroshio. When they were in the eastern coast, they were mainly carried northward by the Kuroshio. For this, we used the seasonal mean current obtained by NCOR

(National Center of Ocean Research). These were long term seasonal average of the shipboard acoustic Doppler current profiler data. With the seasonal mean current, which is constant in time in the whole simulation period, the Monte Carlo simulation showed a better result. Figure 3, which includes a probability grid, shows the input mean current vectors and the final particle distribution. As can be seen, some of the particles landed on the southern coast and most of the particles move around the southeastern tip and then northward. The locations of the majority of the particles at the final time step were much closer to the final rescue location than that of Fig. 2. There is still some distance from the particle to the final rescue location. This is due to the difference between the seasonal mean current from the current actually experienced by the divers. Moreover, portion of the difference can also be attributed to the actions of the divers.

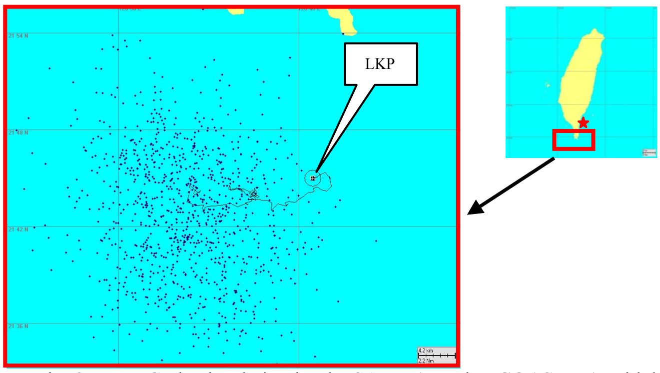

Fig. 2 Mote Carlo simulation by the SARMAP using COASTMAP tidal current and wind for the environmental data. Left figure is the distribution of the particles at the final time step of the simulation. The Curvy line is the trace of the center of the grid containing the particles and the star the rescue location.

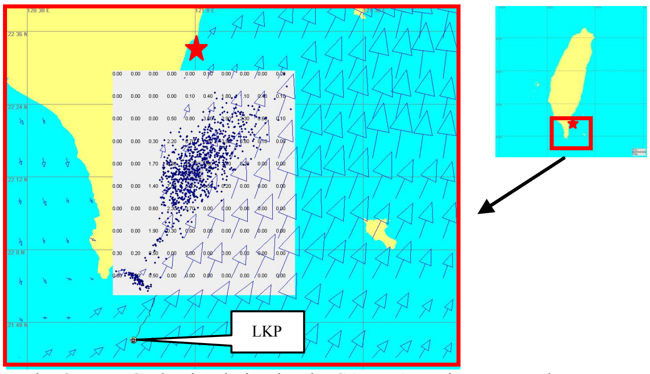

Fig. 3 Mote Carlo simulation by the SARMAP using seasonal mean current and COASTMAP wind. Star is the final rescue location, the dotted rectangle the probability grid encompassing the particles, and arrows current vectors.

As mentioned earlier, the second incident is an incident of fishermen falling off shore cliff after being struck by dangerous waves. Once fell into the ocean, they often collide with the shore rocks by the actions of incoming waves, resulting in the loss of consciousness and often their lives. Tsai et al. [5] investigated the wave conditions related to this type of drowning incidents. Using CWB's wind and current data, the drift track simulated by the Monte Carlo method is shown in Fig. 4. The figure shows that most of the particles came ashore and stopped at the shore close to the last known position. The two grids closest to the LKP contain 98% of the probability of containment. These two grids are very close to where the victims were found. Using COASTMAP tidal current and wind, the SARMAP simulation showed similar result to that using CWB data. The grid with highest probability is also very close to the location where victims were found (Fig. 5), although the particles spread in a longer section of the coast. The three darkened grids contain about 76% of probability.

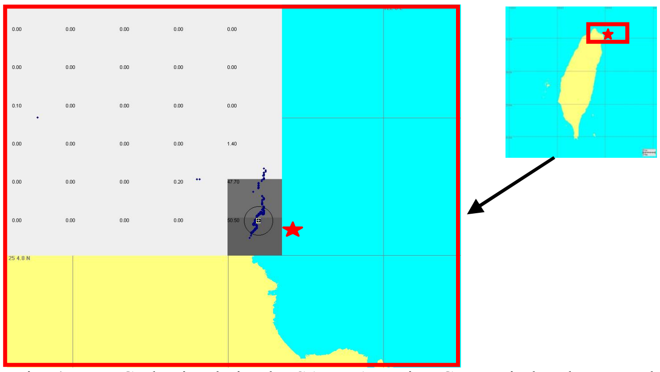

Fig. 4 Mote Carlo simulation by SARMAP using CWB wind and current data for the incident 2. Star represents the location where the victims were found. The darkened two grids contain 98% probability.

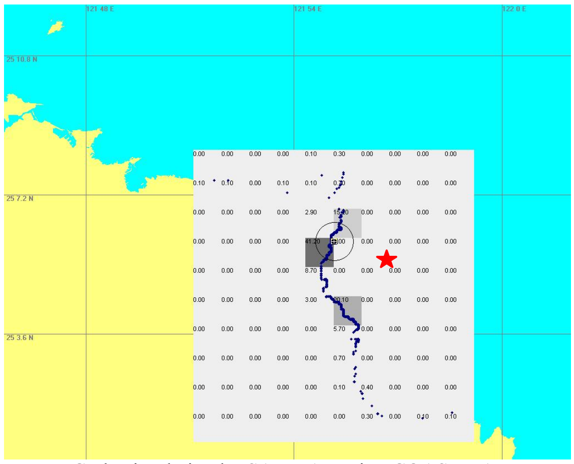

Fig. 5 Mote Carlo simulation by SARMAP using COASTMAP current and wind for the incident 2. Star represents the location where the victims were found. The three darkened grids contain 76% of probability.

The simulation for the drifting coastal freighter in the Taiwan Strait in the incident 3, using COASTMAP tidal current and wind, predicted a location very close to final location of the freighter (Fig. 6). Highest probability grids are near the location where the freighter was found. Figure 7 shows the results of the simulation but based on CWB current and wind. Again, near the location where the freighter was found have high probability of containment, about 38%. This illustrates that for this scenario, COASTMAP and CWB data are similarly effective for drift track simulation. Overall, in the three scenarios, the distance between the highest probability grid in the simulations varied from 20 nautical miles to 0.1

nautical miles (Table III). The larger distance is the result of the lacking of correct Kuroshio data.

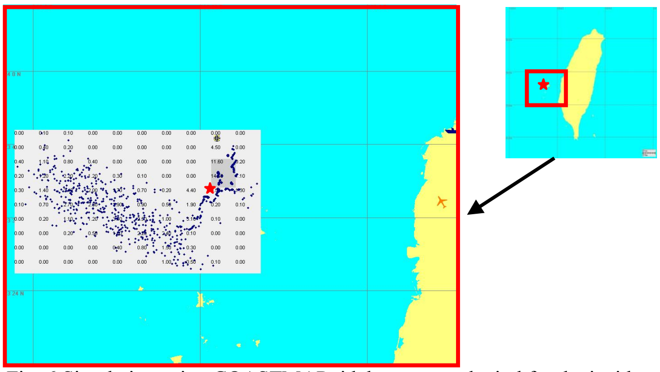

Fig. 6 Simulation using COASTMAP tidal current and wind for the incident 3. The Curvy line is the trace of the center of the grid containing the particles and the star where the freighter was found.

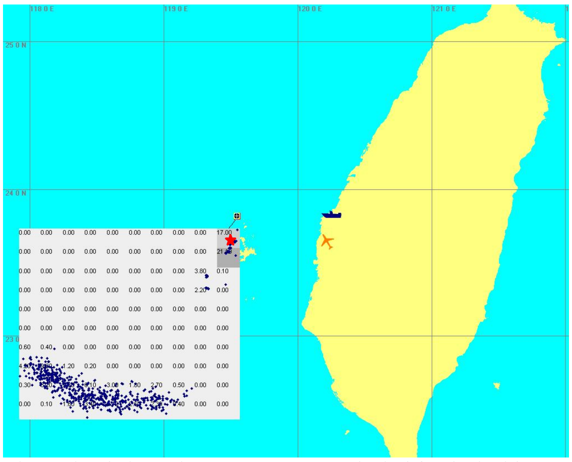

Fig. 7 Simulation using CWB current and wind for the incident 3.

TABLE III
THE DISTANCE FROM THE RESCUE LOCATION TO HIGHEST POC GRID

Incident	Data type	Distance
Nanching divers	NCOR current COASTMAP wind	18.5 NM
Lungdung bay anglers	CWB data	0.86 NM
Baumashan cargo ship	COASTMAP tidal current and wind	1.25 NM

IV. CONCLUSION

This study uses SARMAP to simulate drift tracks for three marine accidents around Taiwan and compare the predicted object locations with those reported by the coast guard. Input current and wind data came from COASTMAP data server, CWB and NCOR. It was found that at different sectors of the Taiwan Sea, one needs different types of current source. This is because at some sectors sea current is dominated by tides such as in the Taiwan Strait and northern coast. At the southern coast, tidal and mean currents are important. And in the eastern seaboard, Kuroshio is the most significant force for drifting objects. For the eastern coast, we have to use the seasonal mean current. This partly reflects that we still do not have comprehensive current database for search and rescue operations. This study also found that in the three scenarios different sources of the wind data do not affect the result of track simulation. Further conclusions can be stated as follows:

(1) In the Taiwan Strait and the northern coast of Taiwan current data obtained from COASTMAP and CWB provide good simulation results.
(2) In the southern sea of Taiwan, NCOR seasonal mean current should be used.

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