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RESEARCH ARTICLE

Detection of possible route of mines broken off during the Russia-Ukraine war with an ocean circulation and a particle model

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Abstract

Russian authorities released a warning on March 18, 2022, stating that about 420 mines were broken off in the ports of Odessa, Ochakov, Chernomorsk, and Pivdenny in the northern coast of the Black Sea due to the stormy conditions. The warning also advised the ships to be careful when navigating in the southwest and western parts of the Black Sea due to the possibility of explosion of the drifting mines. In this study, the probable origin of locations and route of the mines are investigated by using an ocean circulation and a particle model. The results suggest approximate origin of the mines. One of the conclusions is that due to the circulation dynamics along the western coast hydrography of the Black Sea, the mines travelled to the south reaching up to the Istanbul Strait.

Keywords: Black Sea, Russia-Ukraine war, naval mines, Black Sea circulation, drifting model

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Introduction

The Black Sea, a semi-enclosed sea, is currently under the pressure of Russia-Ukraine war. There is an evidence that the war is affecting the marine environment. One of the consequences of the war is the drifting mines in the western part of the Black Sea. The mines released from the northern part of the basin have now reached up to the Istanbul Strait (Figure 1). The mines threaten the ships navigating in this part of the sea. The possible influence of the war on the Sustainable Development Goals (SDGs) has been studied by Pereira *et al.* 2022. However, there is no study analysing the possible origin of these mines. In this study, the possible route of the mines is investigated by using numerical circulation and a drifting model.

Figure 1 shows the average surface currents between 17-30 March 2022. Current velocity is shown in colour. The "Rim Current", which is a known oceanographic feature of the Black Sea (Oguz *et al*. 1993; Özsoy and Ünlüata 1997), enters from the eastern part of the basin and moves toward west, and then turns south, crosses the Istanbul Strait, and then proceeds west, following the Turkish coastline. It is clear that there is a strong southward surface current along the western coast of the Black Sea. The maximum current speed is observed along the Turkish coast. The circulations in the shallow northern part of the basin are under the control of the local winds, and the currents speeds are relatively weak in this region.

Naval mines as weapon of weaker in defence

Naval mines continue to be a weapon of choice in modern warfare. Deployment of naval mines can be done in two categories - where mines are used as stand-alone weapons, and where they are fully integrated with other maritime components. The threat posed by mines is mentioned regularly in academic and military literature, but it seems to be invariably accompanied by a recognition that many navies are inadequately equipped to deal with this threat effectively. For example, in 2009 the US Navy reported that "more than a quarter-million naval mines of more than 300 types are in the inventories of more than 50 navies worldwide". A more recent report noted that Iran has an estimated several thousand naval mines (perhaps as many as 20,000), while North Korea has 50,000, China 100,000 and Russia an estimated quarter-million (Letts 2016). What we see in the ongoing conflict is that Ukraine has laid mines to defend its coastline against possible Russian amphibious operation centered around Odessa and its linked adjacent cities.

Naval mines are also categorized based on their ultimate objective whether to be used against surface, subsurface or other units including those of amphibious assault. They can be called moored, laid into seabed (bottom mines) or be made semimobile which activate when encountering their target. There may be other types as well. Generally, naval mines can be categorized into six types of mines: moored mines, drifting or floating mines, bottom mines, remotely controlled mines, submarine launched mobile mines, and rising or rocket mines. In addition, there are pre-laid mines, which can be armed remotely or manually (Geneva Call 2016). Moored mines have a deep steel line connecting mines to the sea floor with a weight or mooring device attached which can be rarely broken disconnecting mines to drift.

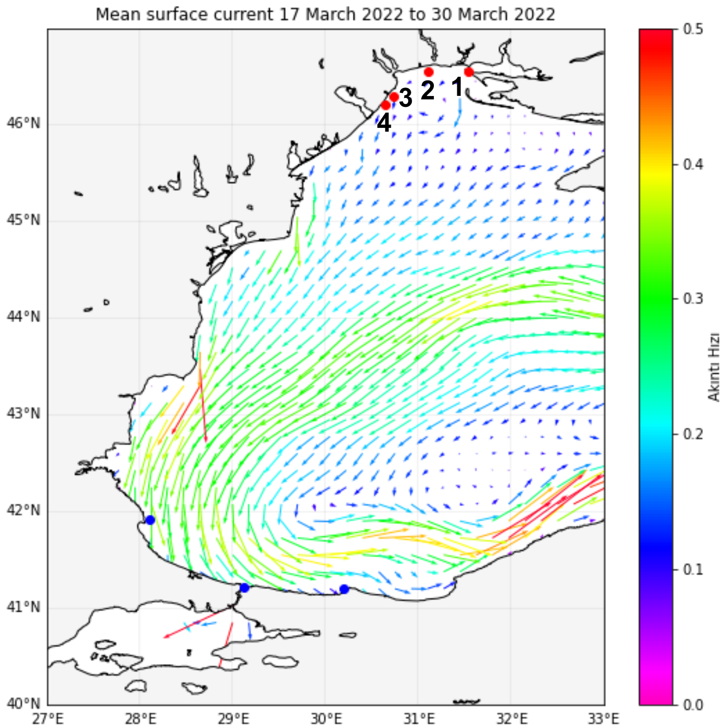

Figure 1. Average surface currents between 17-30 March 2022. Current velocity is shown in color. The "Rim Current", which is a known oceanographic feature of the Black Sea, enters from the eastern part of the basin and moves to the west, and then turns south, crosses the Istanbul Strait, and then proceeds west, following the Turkish coasts. The red dots indicate the ports of Ochakov (1), Chernomorsk (2), Odessa (3), Pivdenn (4), and the blue dots where the mines are seen on the Turkish coast.

Based on the examination of recovered mines after a while, it was understood that the mines laid had very limited charging explosives (1/10 of a normal naval mines) with mooring device attached and anti-invasion type against likely amphibious assault to defend coastlines of Ukraine. The number of mines laid revealed as 420 and no one had initially predicted to what extent they would drift because of sea and/or hydrographic conditions. Though less likely, no one confirmed that they were deliberately released from the location where they had beenlaid. By law, naval mines are legitimately used in defence but the Convention relative to the laying of contact mines (Hague VIII) is required that there must be some measures to take before laying them, e.g., ones released from the bottom of the naval mines, they must activate their self-destruction mechanisms which seemed have not been observed in Russia-Ukraine confrontation. (Minelayers may differ and require operating by qualified sailors.) Türkiye has launched effective mine countermeasures operation to detect as early as possible locations of drifted anti-invasion moored mines towards the Istanbul Strait and to neutralize them as necessary, even though in one incident there was a hit to a fishing boat during the nighttime, causing limited damage. Another incident was also reported from the coast of Romania. Nevertheless, mines from the northern Black Sea drifted together with their detached mooring mechanisms extending to down deep at sea whereby impacting the model studying their movements based on rim currents and winds affecting their drifts.

In this study, five drifting experiments were conducted to understand the possible route of drifting mines in the Black Sea.

Material and Methods

Surface current data were obtained from the CMEMS-Black Sea model (Jansen *et al.* 2022). The circulation model code is known as NEMO (Madec *et al.* 2017, https://www.nemo-ocean.eu/). The numerical model has been used to better understand the dynamics of the regional seas. Gunduz *et al.* (2020) applied successfully the NEMO to the Black Sea with a Marmara Sea box to better understand the dynamics of the Sea. The CMES-Black Sea model has 1/40-degree horizontal grid resolution and 121 unevenly spaced vertical levels. Atmospheric wind data at 10 meters were obtained from the NCEP-global atmosphere model. The atmospheric model has 0.5-degree horizontal resolution. The drifting model used in this study was the model known as OpenDrift (https://github.com/OpenDrift/opendrift). The model has been used successfully in regional and global scale studies (Kotzakoulakis and George 2021; Rodríguez-Villegas *et al.* 2022). Total 5000 drifting objects were released for each of the experiments at the beginning. There were totally five experiments conducted in this study. In each experiment, the initial position of the drifting objects was modified and the final positions of the objects were investigated. All the experiments were started on 17 March 2022 at 12:30. The model was integrated for the following 12 days.

Limitation of the numerical model

There are some limitations of both the circulation and the particle model. The simulated mines in the drifting model are assumed as a surface drifted particle. However, as analyzed above the mines have had some anchor connected. The drifting model needs to be modified to better predict the origin of mines laid location. The weight of the mines are not taking into account. The mine shape at the surface is not given in the drifting model, but as the drifter has a limited surface area it is considered that the shape of the mines is not a critical factor. The above assumptions are convenient for the purposes of the current study. The main motivation behind this study is to evaluate the effects of the circulation dynamics on the drifting mines. The circulation model is not a finite volume model and generally represents the coastal zone better. However, due to the relatively fine horizontal resolution of the model, it is believed that the coast is represented properly. The second limitation of the numerical model could be the time frequency of the model output. But it is known that the strong coastal current is a consistent feature of the western Black Sea. For this reason, it is assumed that hourly frequency is enough to represent the circulation dynamics critical for the drifting model.

Results

The drifting objects (500) were been released in different region of the basin as shown in Figure 2. There were five experiments with different initial conditions. In the first experiment, the objects were released very north of the Black Sea (Figure 2a). In the second experiment, they were released a bit south around Romanian offshore (Figure 2b). In the third experiment, the objects were released in the middle of the sea (Figure 2c). In the next two experiments (Figure 2d and 2e), the objects released more offshore and more southward positions.

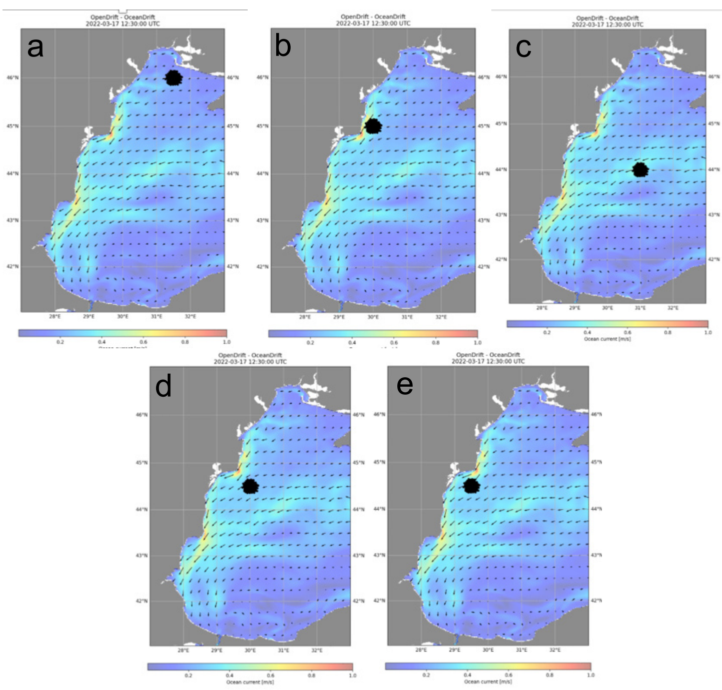

Figure 2. Initial positions of 500 floating objects used in the simulation. (a-e refer to those in Results)

The final positions of the objects after 12 days integration are shown in Figure 3. Depending on the initial positions, the final positions were quite variable. In the first experiment, the objects could not reach the Turkish coast, trapping in the shallow northern part of the basin, off the Romanian coast. In the second experiment, most of the objects landed to the Turkish coast only a few of them reaches up to the Istanbul Strait. In the third experiment, the objects reach to the Black Sea exit of the Istanbul Strait, but not very close to the coast. The fourth experiment showed the positions closer to the observed landing positions of the mines as shown in Figure 1 with blue dots. The objects were lined up along the shore. The fifth experiment was very similar to the fourth experiment except the objects were closer to each other.

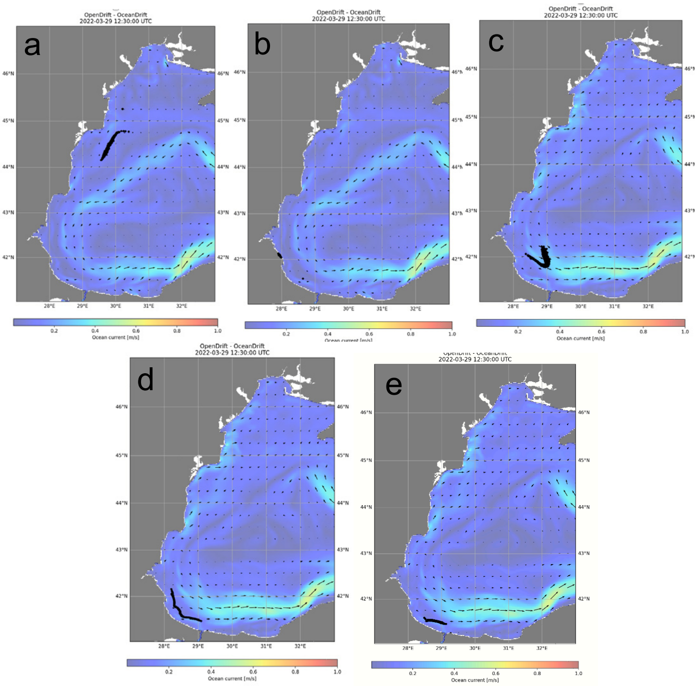

Figure 3. Final positions of the mines after 12 days of integration of the drifting model, shown with black dots. (a-e correspond to those in Figure 2)

Discussion and Conclusion

A drifting model using the currents from an ocean circulation model and winds from a global atmospheric model has been integrated for 12 days to better understand the initial positions of the mines detached from the northern part of the Black Sea. In all the five experiments, the mines travel to the south due to the underlying circulation characteristics. However, the final positions of the mines are quite dependent on the initial positions. The mines released in the shallow northern part are trapped in this shallow region. The objects reaching to the İstanbul Strait needs to be released more south of the shallow part of the sea. In the rest of the four experiments, the mines reach up the Istanbul Strait similar to the observations.

Noyan and Güney (2012) mentioned that cooperation among Black Sea countries is important and the exchange of information is crucial to protect the Black Sea. Finally, the Turkish naval authorities successfully detonated all the mines that they found before reaching the Sea of Marmara and the Aegean Sea, as well as before more catastrophes can occur such as human loss and explosion of ships. This is also contribution to the security at a regional level by the Turkish navy.

Acknowledgments

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Rusya-Ukrayna savaşı sırasında kopan mayınların olası rotasının okyanus sirkülasyonu ve parçacık modeli ile tespiti

Öz

Rus makamları 18 Mart 2022 tarihinde bir uyarı yayınladılar. Uyarıda, fırtına koşulları nedeniyle Odessa, Ochakov, Chernomorsk, Pivdenny limanlarından yaklaşık 420 tane mayının koptuğu belirtildi. Uyarı ayrıca, sürüklenen mayınların patlaması ihtimali nedeniyle gemilerin Karadeniz'in güneybatı ve batı kesimlerinde seyir halindeyken dikkatli olmalarını tavsiye ediyordu. Bu çalışmada, okyanus sirkülasyonu ve parçacık modeli kullanılarak kopan mayınların olası karaya çıkış yerleri ve güzergâhları araştırılmıştır. Sonuçlar, mayınların olası başlangıç konumlarını göstermektedir. Varılan sonuçlardan biri, Karadeniz'in batı kıyısını etkisi altına alan baskın güneyli taşınım nedeniyle, mayınların güneye doğru ilerleyerek İstanbul Boğazı’na kadar ulaştığıdır.

Anahtar kelimeler: Karadeniz, Rus-Ukrayna savaşı, deniz mayınları, Karadeniz sirkülasyonu, parçacık modeli

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