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# Ice induced ship accidents. How to show data and learn from cases.

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## ABSTRACT

Progress in shipbuilding and navigation is unthinkable without an analysis of previous mistakes. Accidents with sea ice should be investigated for the successful development of the Polar regions. There were many accidents during the long history of navigation in ice infested waters. Some of them became legends and changed attitude and safety regulation. For example, the Titanic tragedy provoked public awareness, which led to SOLAS Convention (1914-1974). Several accidents initiated the development and adaptation IMO Polar Code (2014-2017). But casualties continue to happen even in 2021, and its analyses are not performed in the proper way.
Presented work aims to make accident data accessible and useful; create an online resource, show the events on the map and explain how the situation developed; prepare information for the best perception to ensure the proper social and scientific awareness.
Using created cloud-based Geographical Information System (GIS), one can find and visualize information about accidents and natural conditions, dive into details via hyperlinks. The typical cases such as collision with ice floe/icebergs, ice bounding/drift and icing are shown. GIS layers and presentation tools are discussed in the paper.
Possible inclusion of the GIS into the existing web-mapping services, like “BarentsWatch”, “The Arctic risk map”, or other dedicated portals will make the data even more accessible and requested. It will improve emergency management competence and increase response capacities via innovative training and knowledge dissemination.

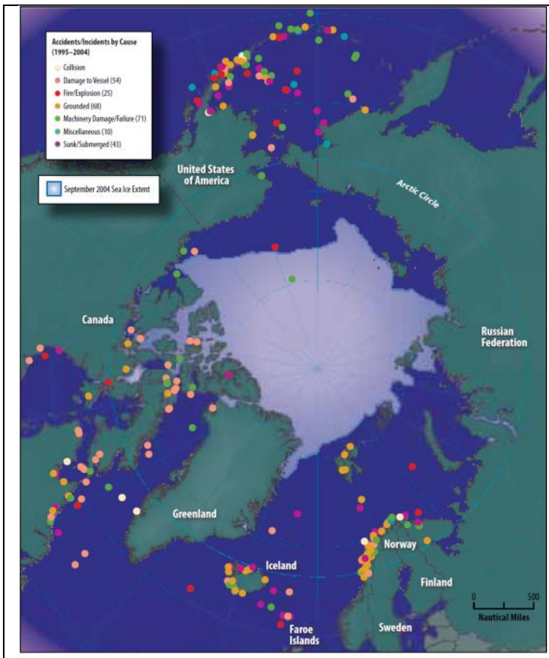
KEY WORDS: Accident; Ice; GIS; Case study; Safety.

## INTRODUCTION

The development of the Arctic as a place with vast and attractive mineral recourses and opportunities for new navigational routes and tourism continues, raising the questions of safety and sustainable technology. The blocking of the Suez Canal for several days by a grounded container ship in March 2021 revived interest in the Northern Sea Route. However, sea ice continues to be the main limiting factor for development, an essential obstacle for navigation and thread for ships and constructions. It will be so. While sea-ice shrinks, navigation routes expand further North and meet ice again. People learn by mistake. Terrible shipwrecks such as Titanic in 1912 and Explorer in 2007 provoked public awareness and initiated safety regulation and legislation. International Convention for the Safety of Life at Sea (SOLAS), with its multiple version (1914-1974) and IMO Polar Code (2014-2017) (IMO

2019), prevent many tragedies and losses. Despite all efforts to avoid casualties in the sea and particularly in the Arctic, where the consequences are much heavier due to harsh weather, accidents happen. Each case must be examined in an attempt not to be repeated. Scientists and engineers still look for good and instructive examples of dealing with ice conditions, successful rescue operations. Discussing the inventions, they refer to previous accidents and not always correctly. There is a demand for resource showing cases, with the possibility of searching particular type, place, outcome, and finding detailed information.

In 2007 the author got the request inspired by Statoil company and implemented the project “Collection of ice pilot experience”, the part of large PetroArctic programme - very relevant for offshore development active that time. In the frame of the project, the information about the Russian Arctic Seas and activities in the area has been gathered and shaped in a bilingual (Russian-English) book (Marchenko 2012). The book contains significant addition to the published in 2009 Arctic Marine Shipping Assessment (Arctic Council 2009). The assessment analyzed the distribution of 275 accidents reported in 1995-2004 by years, months, vessel types, reasons and location (Fig.1). Next, the primary reasons were listed: machinery damage, grounding, damage of vessel, sunk, fire, collision (22 cases; the other numbers are presented on the map – Fig.1), miscellaneous. Only one accident (the bulk cargo Selendang Ayu crash in harsh weather, resulting in a large oil spill) was described, but quite in detail. No information for other accidents and no attention to sea ice were present. The Russian part of the Arctic was not reflected in the Assessment.




Map 5.7 Arctic shipping accidents and incidents causes, 1995-2004. *Source: Lloyd's Marine Intelligence Unit Sea Searcher Database, Canadian Transportation Safety Board (Marine), Canadian Hydraulics Centre- Arctic Ice Regime System Database.*

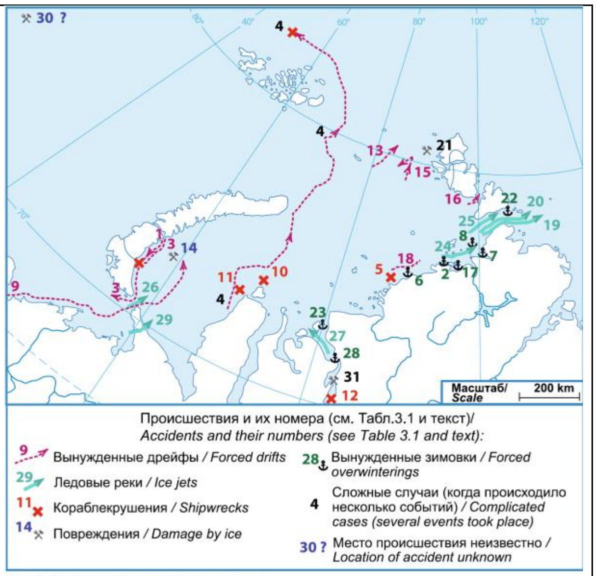



**Рис. 3.11** Происшествия в Карском море

**Fig. 3.11** Accidents in the Kara Sea

| Figure 1. Map of shipping accidents from (Arctic Council 2009) | Figure 2. Example of the map of ice induced accidents from (Marchenko 2012) |
| --- | --- |

In (Marchenko 2012) 94 accidents, induced by heavy ice conditions and occurred in XX century were presented by the maps, devoted to each of four seas of the Northern Sea Route (see example of the map of Kara Sea in Fig. 2), lists of accidents as a legend to the maps and detailed information for many of accidents. The classification of accidents was based on reason and consequences. The main types of accidents are shipwreck due to collision with ice or compression, forced drift (ice jet as a particular case), forced overwintering, damage of ship. There are complicated cases also. For example, the accident with a convoy of the

icebreaker Lenin (1937—1938) began as wintering, but the ice field was torn off, and the ships were taken out and drifted in the high sea, thus one ship sank and many vessels have been damaged.
Since 2014 the author has been involved in various projects on risk assessment, search and rescue and maritime preparedness in the Arctic and continues to collect the cases and aims to present the collection in the best way (MARPART 2021). In the frame of the projects and collaboration with international partners, GIS technologies are used to systematize data and make it available for researchers, practitioners and wide audience.
This paper elaborates on resources showing casualties and describes GIS dedicated to ice induced accidents.

## SHIP ACCIDENTS DATABASES AND COLLECTIONS

There are two basic approaches to collect and present information: database (all possible events with structured description of each) and case study (selected events with all possible info about each). Both ways are important and are used for various but different purposes. In order to find the best way to operate with ice induced accident data, preexisting resources were investigated. The next resources, available in April 2021 were found.

### Official databases and published accident reports

Many countries have accident databases, combined and utilized by the responsible authorities. Local rescue services document events and responses through special forms; government institutions collect information on a national level. Several countries have Transportation Safety Board websites (Canada, Japan, USA, UK) with extensive statistics available. This data is not designed for external use and often has restricted access or limited functionality for outside users. However, it is suitable for statistics-based reports, risk assessments (Marchenko 2020), or special investigations, like (Hill 2010) . Some countries publish online accident investigation reports. Among interesting for sea ice research, the next web-sites should be mentioned. Transportation Safety Board of Canada presents in total 519 reports since 1990 (TSB 2019), National transportation Safety Board of US shows 338 reports since 1996 (NTSB US 2021) Accidents Investigation Board of Norway has 144 reports since 2009 (AIBN 2019) available. Numbers are for in April 2021
Among the devoted to Arctic resources is the Canadian Arctic Shipping Risk Assessment System (CASRAS) made by National Research Council (Kubat, Charlebois et al. 2017). It has a part presenting captain experience. Unfortunately, this information is not available for wide audience and can not be used for research and referencing. However the other open sources should be mentioned (Kubat and Timco 2003) and (Ice Data Canada 2012).

### International projects mapping services and databases

Some of the map services show the distribution of accidents by type within a specific area, but description of events is rather limited. There is intention to show in addition to location, date and vessel name, some details such as ship parameters, crew ability (trained for ice condition, presence of pilot), pollution. But in most cases, the fields with details are blank. For example, The Baltic Marine Environment Protection Commission – also known as the Helsinki Commission (HELCOM) created Map and Data Service for Baltic region (HELCOM 2019). It has “shipping section” with “shipping accidents layer - the classic example of accident database presentation on the map (Fig. 3), where one can see many events and very little information about each one. So for the worse maritime disaster on the 20th century, sinking of cruise ferry MS Estonia in 1994 (only 138 of 989 people on board were rescued), one can find only coordinate, date, ship name and tonnage.

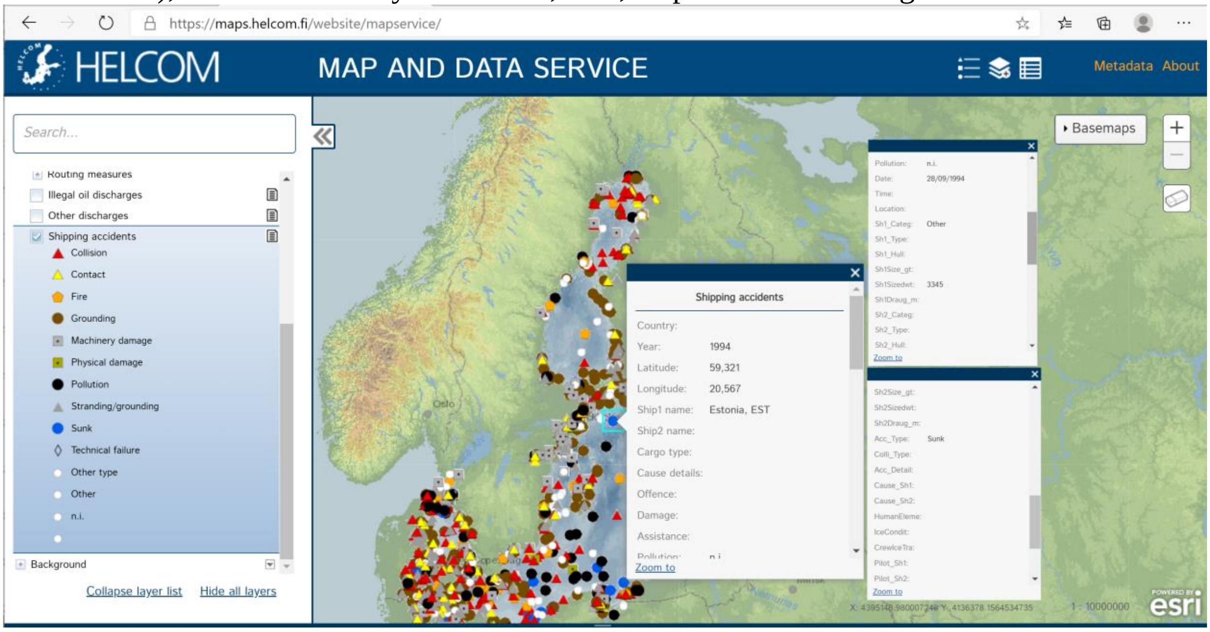



Figure 3. Screenshot of HELCOM with the ship accidents layer activated (HELCOM 2019). Example on the accident description is on the right side

Based on concern about repeated accidents, certain research groups have been formed to investigate accidents at sea and determine their causes. They produce reports and case analyses for educational and training purposes, apart from legal proceedings that may occur. See also examples in "Future development" section of the paper.

## Institutional and Private initiative

Several websites present irregularities at the sea, for example, "Maritime Accident Casebook" (https://maritimeaccident.org/), Safety4sea.com and "Marine Accident Investigators International Forum" (https://maiif.org/). The top seven websites for maritime accident investigation reports and case studies have been analyzed on the "Marine Safety" website (Marine Safety 2016). Unfortunately, all these resources do not address the Arctic region and do not have map interfaces or clear geographical references.

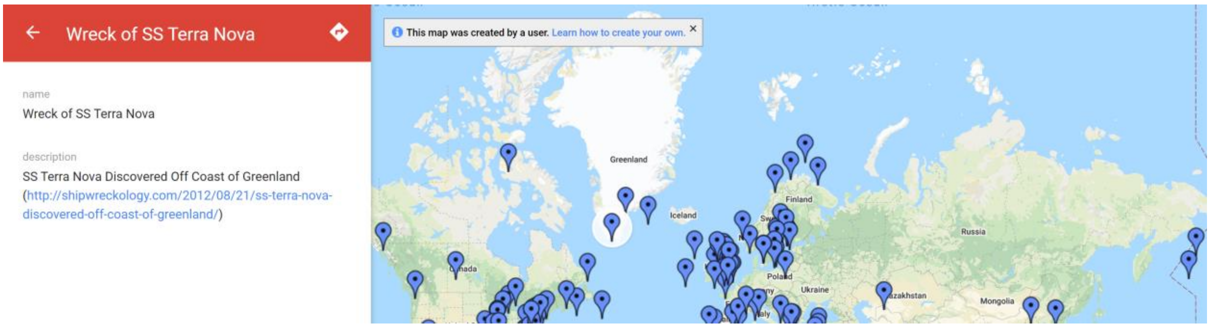



Figure 4. Screenshot of web map on (Shipwrecology 2018)

Only the blog (Shipwrecology 2018) with the reviews of relevant books has the map, where one type symbols located in the places connected to shipwreck remnants and to historical place. Clicking on the symbol will lead you to the page presenting the story with links for further reading and the book review or so on (Fig. 4).

Now days information about the new accident is rapidly distributed via media, including official publishers, information agencies, dedicated websites and social network. However, the information flow is quite chaotic. It is rather challenging to find necessary data, especially for events that happened several years ago, illuminate events for certain area, time, particular type of event. Even powerful tagging/harsh tagging tools will not give results if information had not been properly systematized. Description and analysis of events do not reach responsible representatives, people who are interested in it or should be interested, according to their affiliation. So why the tools (case collection, maps, web-pages) dedicated to particular cases and regions should appear? It is important on the modern faze in society development to make data on marine accidents not only available, but accessible, searchable, operable and useful, put into practice of search and rescue (SAR) services and preparedness affairs.

That's why we created a geographical information based system (GIS) devoted to the accidents in the Arctic Sea, called MarEmAr and described in the next section.

## MarEmAr –'Marine Emergencies in the Arctic' GIS

MarEmAr is a working title for the online GIS solution, which presents case studies and important information about accidents in the Arctic. MarEmAr was created at the University Centre in Svalbard in the frame of MARPART and MAREC projects, as a response to the requests from the project advisory board. The board consisted of representatives of search and rescue and preparedness authorities of Arctic countries. The main features of MarEmAr are described in (Marchenko 2019, Marchenko 2020).

MarEmAr is intended to condense experience gained from accidents; SAR and salvage operations; current available maritime accident investigation reports, provide links to other resources describing the accidents (e.g. web-pages, blogs, photo series, etc.). This online resource can be used for educating maritime professionals about various complications that lead to fatal accidents at sea.

There are several parts and layers in MarEmAr, devoted to particular topics (Mass rescue operations, Oil spills, Large maritime disasters, International exercises, SAR bases and so on). MarEmAr combines database and case approaches. The basemaps provided by mapping services allow obtaining background information. The bathymetry map shows the depth; the sea ice map reveals ice conditions during an accident; a map of protected areas and nature reserves shows the potential environmental impact of an accident. A map with settlements and rescue resources can be useful for planning SAR operations and understanding local preparedness capacities. The benefit of GIS technology is the possibility to update data and edit the map view on demand. The web location/state of MarEmAr allows the use of a hyperlink to data sources and examine the details of the presented cases without copyright problems.

In this article, we concentrate on the sea ice related part of MarEmAr and give corresponding examples.

## MAP ON ICE INDUCED SHIP ACCIDENTS

It should be noted that ice induced accidents can happen not only in the Polar regions and not only in the sea. In wintertime, ice can create a problem for navigation as far from poles as in the Caspian Sea, Azov Sea. Even on 39-40 $^{o}$ North, in the Bohai Sea (China), the risk of ice is very high and loss to the economy is huge (Zhang Zhaohui, Chen Shang et al. 2005). Icebergs from the Antarctic can reach the Australian coast. Thus, there is quite a large area and world map as a scene to show ice induced accidents. For compactness reason, we divide the map into two parts - North (Fig. 5a) and South (Fig. 5b). Ice can create difficulties in lakes and rivers also, but we cover only the sea ice in this article.

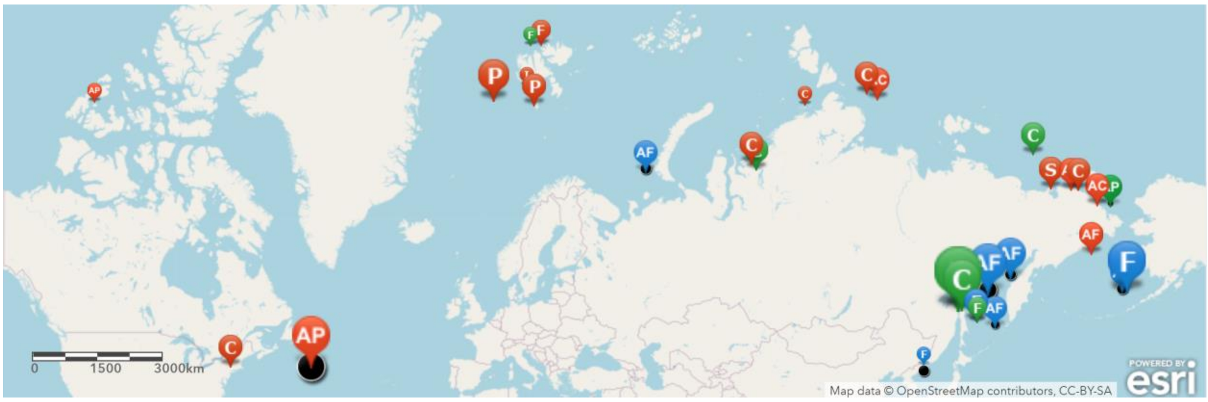
It is important to find adequate way to show events on the map and choose reasonable classification approach, depending on the purpose. In (Marchenko 2012) we concentrated on the consequences of ice action on the ship and distinguished the following four types of the outcomes: forced drift, forced capturing (and possible overwintering further), shipwreck and serious damage to the hull in which the crew could still save the ship. The corresponding symbols were used in the map (Fig. 2). In (Marchenko 2014) we discussed the most possible scenarios of casualties caused by floating ice and presented the recent cases of damage by floe/iceberg hit, capturing and drift with ice field, overwintering.
The ice phenomena dangerous for shipping are icing, early formation of ice cover, ice sticking to ship hull, intensive ice drift ("ice jet"), strong ice compression, inflow of unusually severe ice formations, narrowing of navigable channel, sharp change in ice drift direction. For the best perception of the map we use the risk assessment approach (Marchenko, Andreassen et al. 2018, Marchenko 2020) and define event as a combination of type of accident and type of ship. The types should be generalized and reduced to 3-4, so as not to make the legend to the map too complex and difficult to perceive. We tried to utilize recognizable ship icons as symbols, but this complicates the map and can only be applied for unique events, and no more than 10-15 on one map. Therefore, for a better perception, we use on the map one kind of symbols and show accident type by color, eliminating the main reason of accident (icing, hit and bounding). The letters inside symbol correspond to the type of vessel (Table 1). The letter A in front of vessel type determines shipwreck outcome, when ship sank despite of all efforts. Black circles indicate the fatal accidents. The size of symbol corresponds to accident scale (Fig. 5-6).

Table 1. Types of accidents and symbols

| | Type of vessel and abbreviation on the map in the brackets | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Passenger (PV) | | Cargo (CV) | | Fishing (FV) | | Survey (SV) | |
| Icing |  | P-I |  | C-I |  | F-I |  | S-I |
| Damage by Ice Hit (Floe-Iceberg) |  | P-H |  | C-H |  | F-H |  | S-H |
| Ice-Bounding (capturing by ice, often with drift) |  | P-B |  | C-B |  | F-B |  | S-B |

The click on symbol opens the window with structured accident info. In Fig.6 three cases are open as examples. A title in blue heading gives ship type abbreviation, name, year, essence of case (sank or SAR in case of successful search and rescue operation) and the main reason. The main pop-up window contains short description with links (blue words), redirecting to additional webpages with accident information. The user can choose relevant and reliable sources (sometimes in local language) and continue “further reading”. The reports of an accident investigation by specialized commissions are of particular value for deep learning. They clarify the sequence of events, determine the accident's root causes, identify ways to prevent maritime accidents, and improve safety at sea.

a

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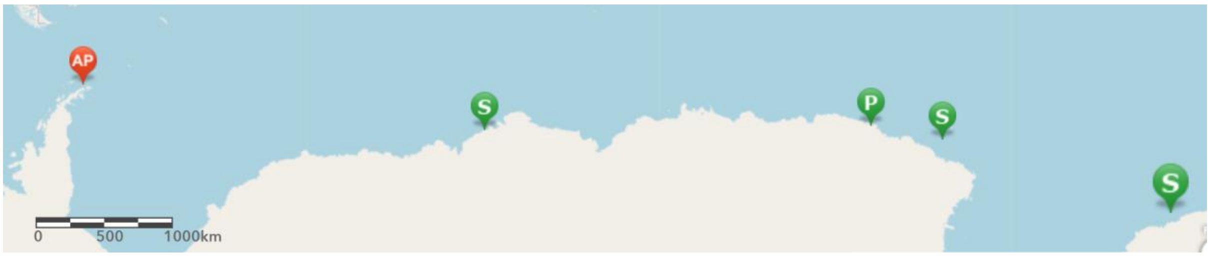


Figure 5. Screenshots of the online map, presenting ice induced accidents. 5a- Northern part, 5b – Southern part (the Antarctic). See the legend in Table 1

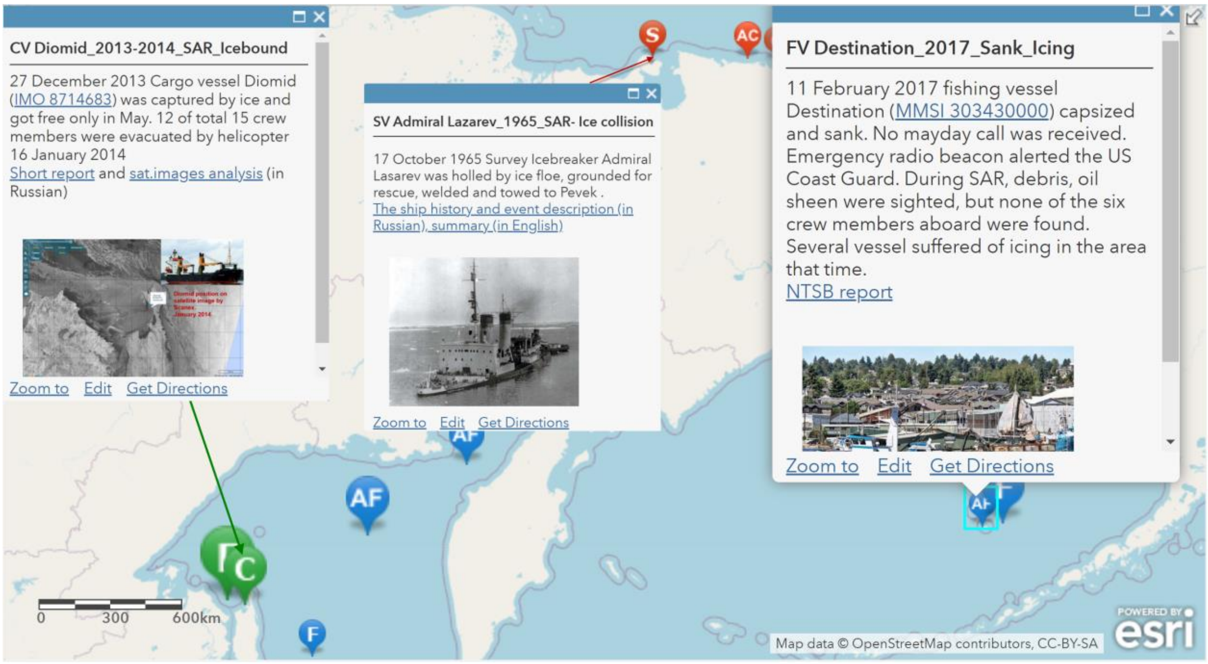


Figure 6. Screenshot of the map with three event windows opened

IMO or MSSI numbers are linked to the corresponding pages on https://www.marinetraffic.com or https://www.vesseltracker.com with detail information about ships involved into the accident. The vesseltracker.com in addition to vessel parameters and location, gives accident description if it is available. For old vessels and famous accidents (such as Titanic, Explorer) we use link to Wikipedia, where one can find vessel description, history and links to resources.
Looking on the map one can find accidents in the particular region, by type of vessel or by reason, ice action. The attributive table gives the list of the accidents, which can be arranged alphabetically, chronologically, searched for specific event. Click on the line in the table highlights the selected event on the map with possibility to find the details.

## FUTURE DEVELOPMENT

Large interest in the Arctic on national and international level inspires various institutions to create Arctic dedicated portals, including interactive maps. Here are some examples

- ArcData – ADMS-Arctic Data Management System https://arcdata.is/cesium-dev/ on the Arctic Portal (Iceland) - https://arcticportal.org/
- The Arctic risk map – by DNV GL (Norway) - https://maps.dnvgl.com/arcticriskmap/
- Armap – Arctic Research Mapping Application https://armap.org/ (US) who, what, where, and when of U.S. Arctic Science.

We do not give analysis of above mentioned maps and do not pretend on completeness. Such maps appear and change constantly with various tasks, design, interactivity, openness. Together with described in the second section official databases, private and project related initiative and social media, they characterize the modern stage of the society development having vast information flows.

Our GIS layers with accident cases can be incorporated into many of mapping resources and be the part of large information portal, making own input to the maritime preparedness. That can be the step to the global goal – combining/unifying the efforts to ensure safe and sustainable development of society, taking into consideration local interest and community.

## CONCLUSIONS

This paper presents a mapping tool with data behind which is one of the ways to ensure the safe development of regions where ice creates the thread for constructions and people. The layers devoted to ice induced accidents (damage, sinking, drift, bounding, icing) and the way to show the information about that are demonstrated and discussed. There is no guarantee and even intention to show all events, but the most instructive ones with description. The online map showing the previous accidents with possibility to follow the links and see the details gives the chance to find appropriate cases, know its reasons and consequences and make decision on own occasion, emergency or planned action.

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