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Navigational and legislative constraints for optimization of ocean routes in the Northern Pacific Ocean

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Abstract

A ship sailing between the coasts of China, Japan, Korea and the Western coast of North America must cross navigational and geographical barriers of the Kuril Islands Archipelago and Aleutian Chain. Passes between the islands are particularly difficult and hazardous in winter. Most of them are covered by drifting ice for 5 months of the year. A number of allowed passes and offshore routes had been established by the maritime authorities of Alaska on the Bering Sea and in Aleutian Chain. However, use of other passes and routes is limited to exceptional cases only. Similar regulations exist in the Okhotsk Sea and other waters under Russian jurisdiction. The ship must then give grounds for a deviation from recommended or allowed passes and tracks and report other required information. Since January 1, 2015, it is mandatory to use the low sulphur fuel oil (sulphur content no higher than 0.01%) in the main propulsion system and auxiliary machinery when navigating inside the Emission Control Area (ECA) zone. Ships face a constant dilemma whether to remain in the ECA zone for the shortest or longer period of time, if the fuel and cost gain in relation to the entire route justify that. Available decision making support systems, like SPOS and Bon Voyage, do not solve that issue satisfactorily.

Introduction

A navigator solving the task of a voyage planning in the Northern Pacific Ocean is restricted in his/her choice of routes by a number of legislative and navigational constraints existing in the area. The article aims to highlight these practical problems that mariners currently face when solving the issues of route programming and optimization in the Northern Pacific Ocean.

Weather conditions in the northern Pacific Ocean

In general, the choice of route in the Northern Pacific is determined by the shape of the coast: they generally follow the Great Circle. The Great Circle route from Luzon Strait to the coast of British Columbia in Canada leads through the Japan Sea and Bering Sea and the Great Circle linking the Luzon Strait with the coast of California leads close to the port of Yokohama and South of Aleutian Chain. This is the shortest track, however, in most cases it leads through areas of inclement weather and unfavorable currents (UK Hydrographic Office NP136, 2014).

Weather in the Northern Pacific is shaped by the high pressure systems over the ocean and low pressure systems travelling eastwards along the Aleutian Chain. In summer, north of latitude 40N, favorable and warm weather prevails over the eastern part of the Northern Pacific, which favors sailing along the Great Circle. Also possible are low-pressure areas, or depression, which bring poor weather conditions over the eastern part of the region and intense fogs over the western part. In winter the Aleutian Low deepens and moves west of Bristol Bay (57° 30' N, 160° 30' W) over the western Aleutian Chain. Violent storms move from the coasts of China and

Japan towards the center of the Aleutian Low and the storms from the central Pacific travel north-west over the Gulf of Alaska. These storms bring rain, snow, and strong violent storms more often than on the Northern Great Circle routes (UK Hydrographic Office NP136, 2014).

Climatic routes in the Northern Pacific Ocean

Routes in the Northern Pacific Ocean do not show seasonal changes. The same routes can be used both in winter and in summer. Much more important is the direction, eastward or westward, in which the ship travels through the ocean. The Eastward route (from Japan to Canada), depends mainly on the actual surface pressure situation and navigational considerations of the voyage. Routes through the Bering Sea should be chosen when the high pressures systems are located there (UK Hydrographic Office NP136, 2014).

Ships proceeding westward should choose either the northern routes, north of Aleutian Chain, or the routes south of 35°N when the northern routes are excluded due to unfavorable weather conditions. Routes north of Aleutian Chain are located north of average storm routes. The Aleutian Chain is a natural breakwater, limiting the height of seas and swell arriving from the Northern Pacific Ocean (UK Hydrographic Office NP136, 2014).

Navigational constraints in route planning and programming in the Northern Pacific Ocean

Ocean routes based on the Great Circle in the Northern Pacific leading both west and east encounter certain geographical barriers which can significantly constrain navigation and affect the choice of route and its programming. A ship sailing between the cost of China and the western coast of North America must cross the following geographical and navigational constraints:

- Passes from the Sea of Japan to the Northern Pacific through the Tsugaru Strait and Soya/La Perouse Strait;

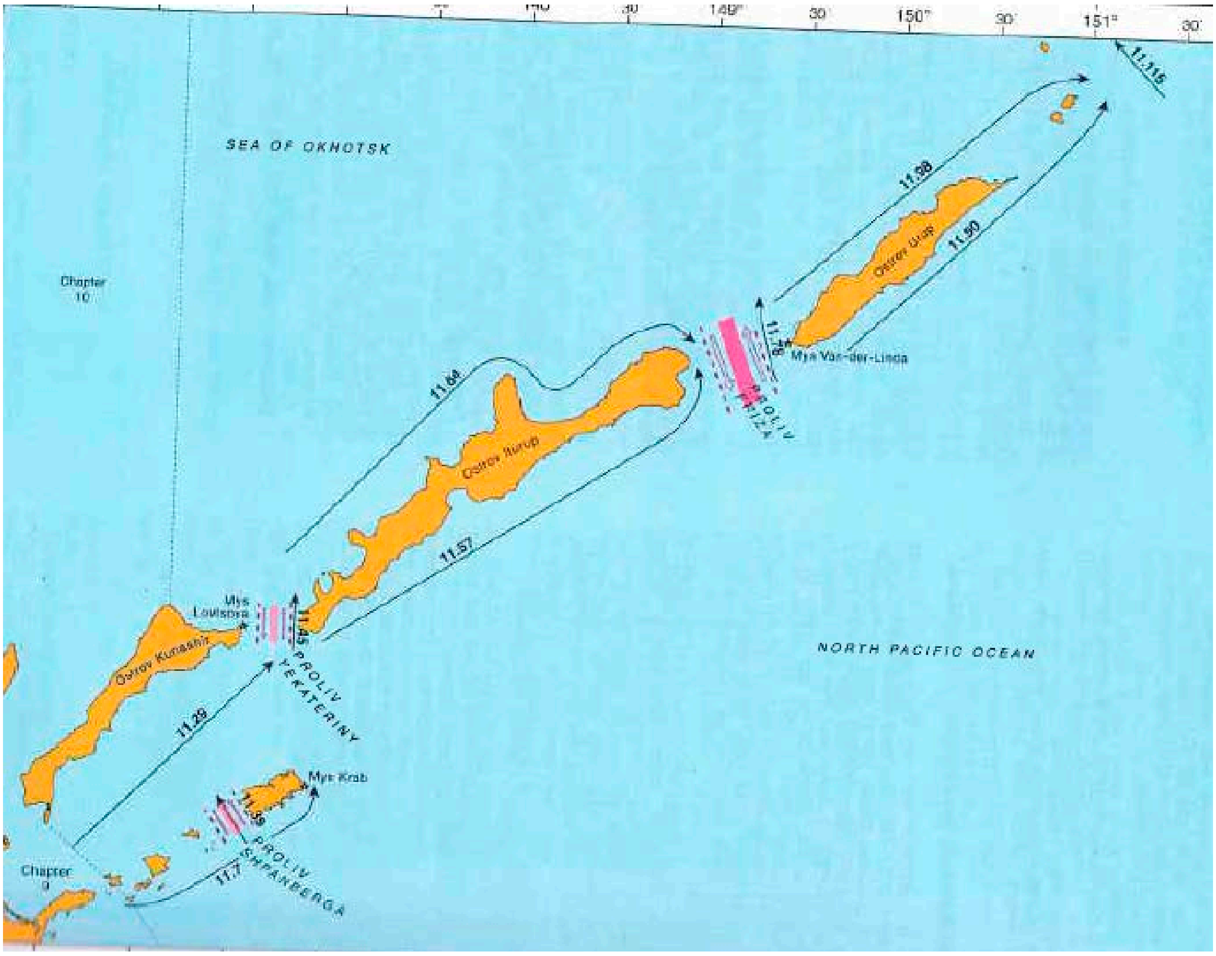

Figure 1. Kuril Islands – southern part (UK Hydrographic Office NP41, 2014)

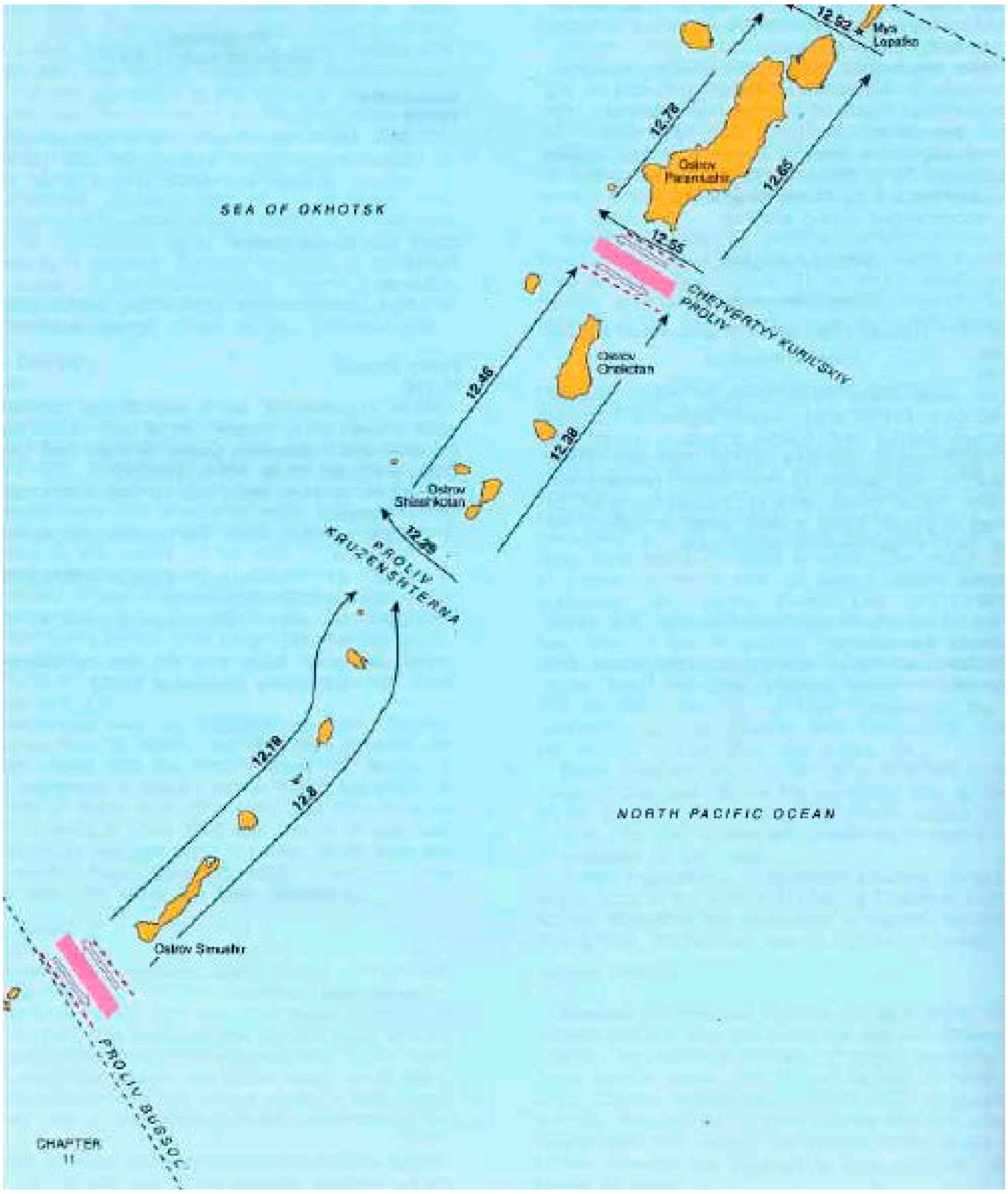

Figure 2. Kuril Islands – northern part (UK Hydrographic Office NP41, 2014)

- Sea of Okhotsk;
- Passes from the Okhotsk Sea to the Northern Pacific Ocean between the islands in Kuril Archipelago;
- Aleutian Chain and passes from the Northern Pacific Ocean to the Bering Sea and Unimak Pass.

Tsugaru Strait is the most convenient pass linking the Sea of Japan and the Pacific Ocean, between the Japanese islands of Honsiu and Hokkaido. It is broad, deep, and ice free all year round. Soya (La Perouse) Strait between the Japanese island of Hokkaido and Russian island of Sakhalin is navigationally less favorable. It is constrained or even blocked by ice for a large part of the year. Fast ice is usually present along the northern shores of Hokkaido and in the southern part of the Soya (La Perouse) Strait from mid-December until the end of March, and sometimes even longer. Drift ice forms along the eastern coast of Sakhalin and travels southward with current and wind reaching the northern shores of Hokkaido in mid-January. The greatest concentration of drift ice in Soya (La Perouse) Strait and along the northern Hokkaido occurs in February and March. Surrounding waters are then one big ice field consisting of dense ice floats 1–2 m thick in which it is impossible for ships to navigate. Ice gets also into the Sea of Japan. Drift ice remains in the Soya (La Perouse) Strait until the end of April and sometimes even until mid-May. As a result, navigation in the Strait for these 5 months of the year is possible only with icebreaker assistance. Moreover, between

February and April even the icebreakers have great difficulty keeping the waterway open for sea traffic.

There are a number of passes to the Pacific Ocean in the Kuril Archipelago (Figures 1 and 2). They are: Nemuro Strait, Proliv Yekateriny, Proliv Friza, Proliv Bussol, Proliv Kruzenshterna, Chetvertyj Kurilskyj Proliv, Pervyj Kurilskyj Proliv. Only three of them: Proliv Bussol, Proliv Kruzenshterna and Chetvertyj Kurilskyj Proliv are ice free all year round. Navigation in the remaining ones between February and mid-May is only possible with great deal of difficulty or not possible at all.

The Southern part of Okhotsk Sea is in principle ice free, however drift ice can be encountered occasionally.

The Southern part of the Bering Sea and all passes from the Bering Sea into the Pacific Ocean in Aleutian Chain are ice free all year round. The following passes are navigationally accessible for large, ocean faring ships: Unimak Pass, Akutan Pass, Umnak Pass, Samalga Pass and Amukta Pass Fox Islands, Seguam Pass, Atka Pass, Adak Strait, Tanaga Pass, Oglala Pass and Amchitka Pass in Andreanof Islands, the pass between the islands Amchitka and Semisopochnoi, the pass between the islands of Buldir and Kiska in Rat Islands, and passes east and west of Near Islands – respectively Buldir/Agattu Pass and north and west of Attu.

The Aleutian Chain and some of the passes in the archipelago are shown on Figures 3 and 4.

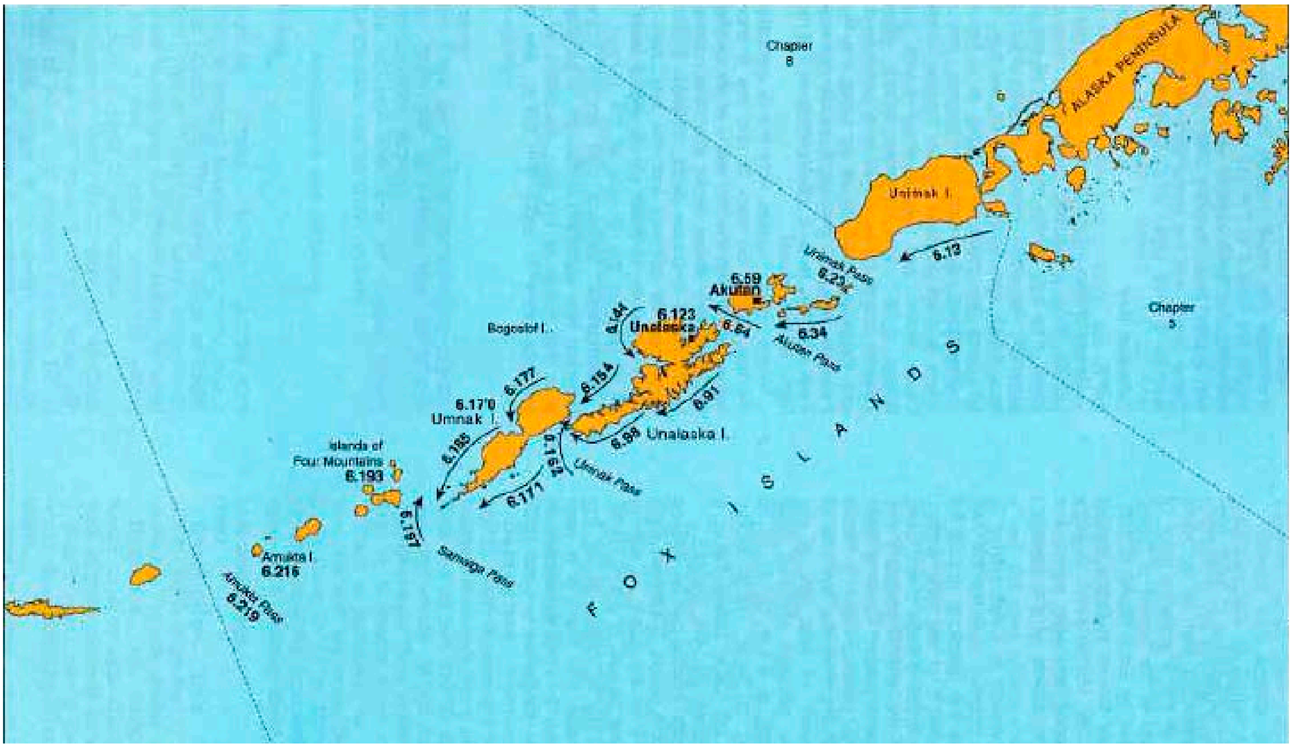

Figure 3. Aleutian Chain – eastern part (UK Hydrographic Office NP23, 2013)

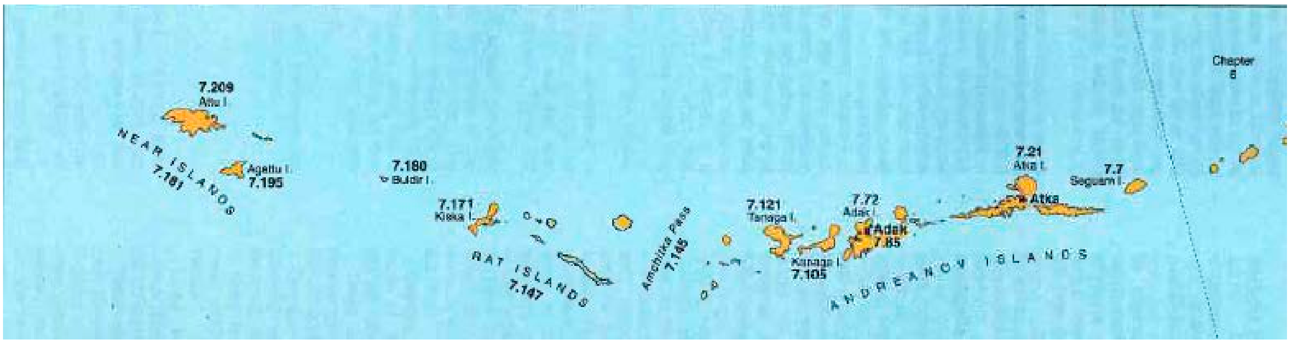

Figure 4. Aleutian Chain – western part (UK Hydrographic Office NP23, 2013)

Legislative constraints in route planning and programming in the Northern Pacific

Aleutian Chain and Bering Sea

The maritime Authorities for the State of Alaska (Alaska Maritime Prevention and Response Network) have established a number of procedures and measures reducing the risk of marine casualties (collision, grounding, oil spill) in order to protect the environment. One of them is the "offshore routing" – a procedure establishing specific routes which should be used by foreign ships transiting the Alaska waters. Foreign flagged ships should keep to those routes, despite the Innocent Passage Status, on the basis of which the voyage takes place. Offshore routing is one means of reducing the risk of marine casualties. The offshore distance provides more time for repairs to be effected by the vessel's crew if a hazardous condition develops, and provides time to respond to navigational errors and time for an assist vessel to arrive on scene before a vessel grounds (Alaska Maritime Prevention & Response Network, 2014).

Ships should keep at least 50 nautical miles offshore unless they proceed to or from the port located on the coast of Alaska, or unless they transit the Aleutian Chain through one of the allowed passes. These passes are: Unimak Pass, Amutka Pass, Amchitka Pass Buldir/Agattu Pass (Figure 5). The minimum distance from shore during transit should be at least 12 nautical miles (Alaska Maritime Prevention & Response Network, 2014).

Use of other passes is acceptable when the ship's Captain determines that, due to weather or other factors, it is safer to make use of an alternative route. In these instances, and before the deviation is made, a Notice of Deviation from Approved Route shall be made addressed to either the *Alaska Maritime Prevention and Response Network* or to the *Captain of the Port Western Alaska* as appropriate, together with the explanation of the reason for the deviation from the risk mitigation measures. The deviation is permissible only when granted by one of the above authorities. A notification to the above authorities is also required when the deviation is no longer necessary (Alaska Maritime Prevention & Response Network, 2014). Ships using the transit routes north or south of the Aleutian Chain should keep the distance of at least 50 nautical miles offshore. Transit routes are shown on Figure 6.

Recommended tracks in the Okhotsk Sea

The Russian Maritime Authorities have introduced the system of recommended routes between

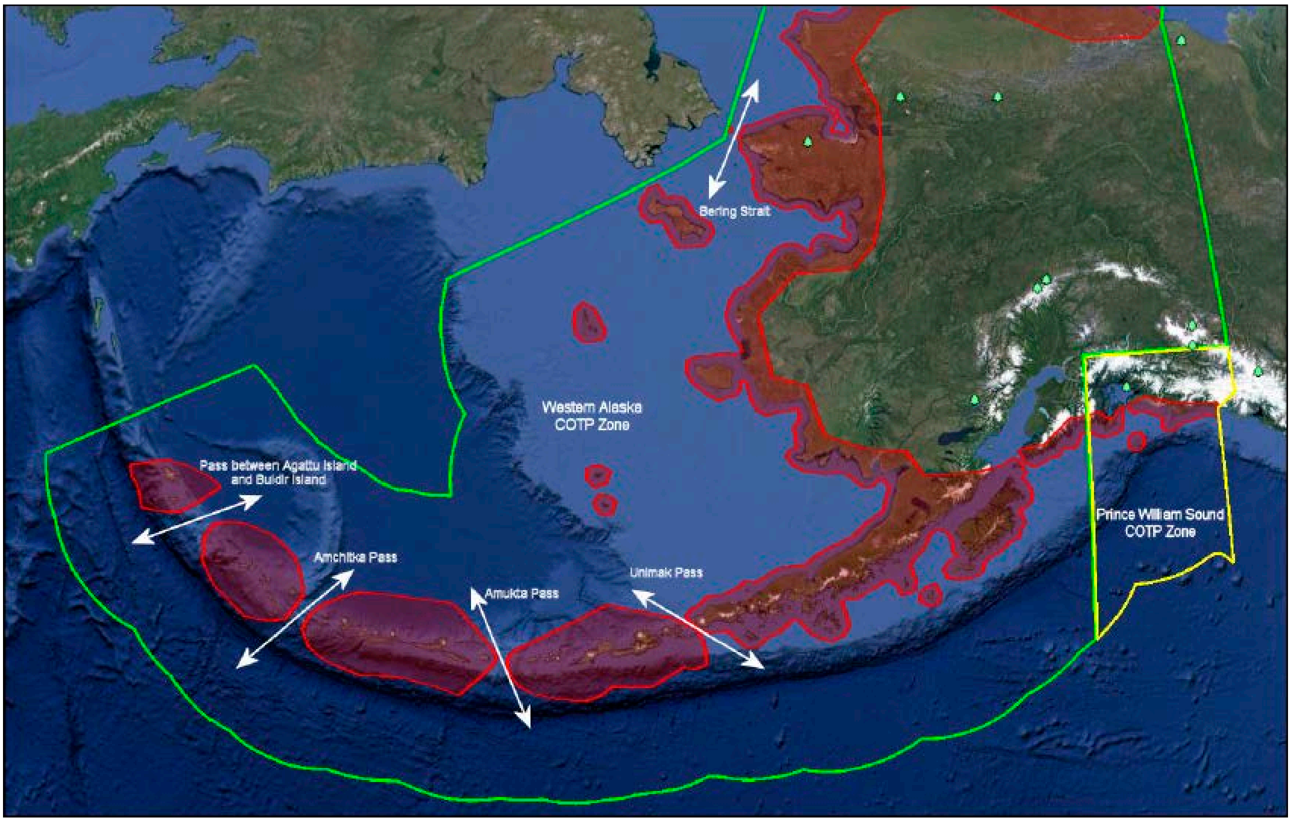

Figure 5. Allowed passes in the Aleutian Chain (Alaska Maritime Prevention & Response Network, 2014)

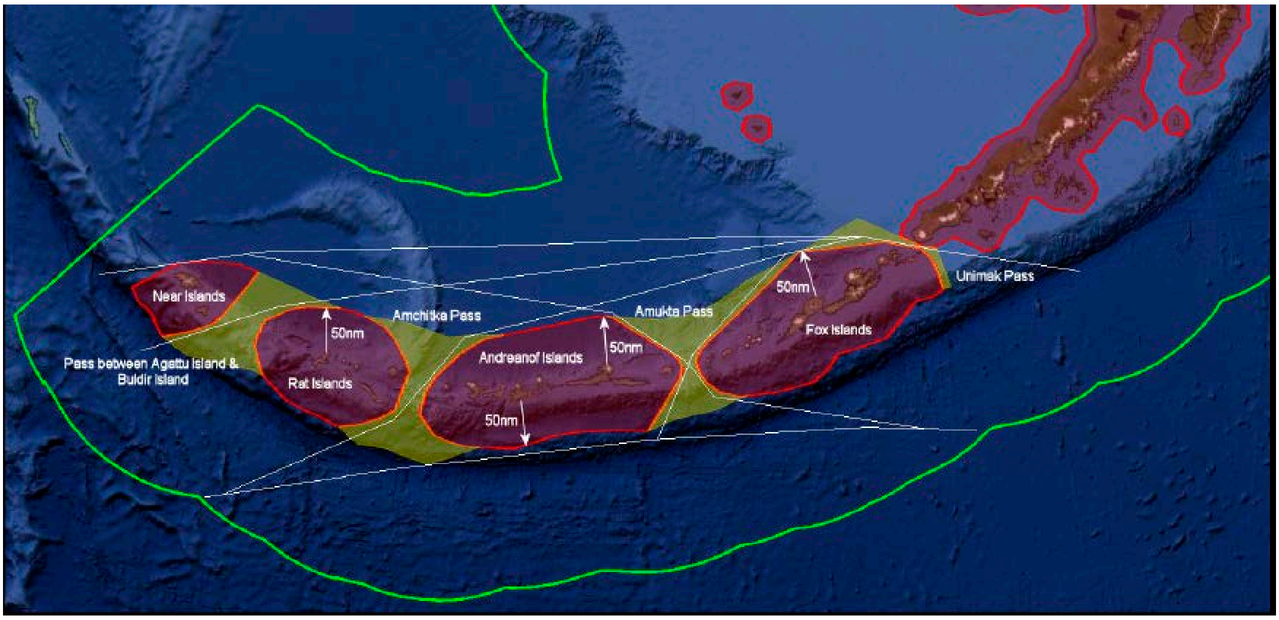

Figure 6. Offshore routes north and south of the Aleutian Chain and allowed passes in the Aleutian Chain (Alaska Maritime Prevention & Response Network, 2014)

passes in the Kuril Islands and ports on the coasts of the Federation in the Okhots Sea and on the parts of the Sea of Japan subjected to Russian maritime jurisdiction. The following routes are of the greatest significance for route optimization and weather navigation:

- Recommended route No. 1: from Nakhodka to La Perouse Strait and recommended route No. 2: from La Perouse Strait to Nakhodka.
- Recommended route No. 3: from La Perouse Strait to Chetvertyj Kurilskyj Proliv and recommended route No. 4: from Chetvertyj Kurilskyj Proliv to La Perouse Strait.

All those recommended routes are shown on Figure 7.

The recommended routes are not obligatory, however it is important to note that the local authorities may try to force the foreign flagged ships (also

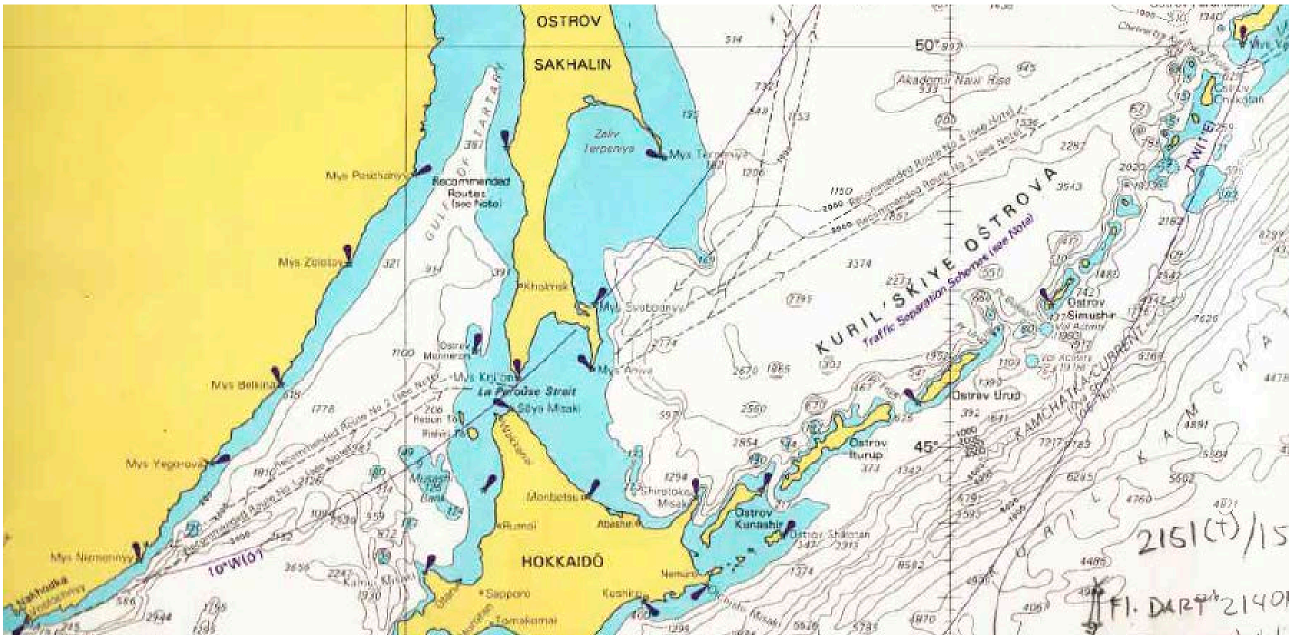

Figure 7. Recommended tracks in the Okhotsk Sea (UK Hydrographic Office BA Chart 4503)

those being in transit under the Innocent Passage rule) to use them.

North American ECA Zone

The North American ECA zone (Emission Control Area) is shown on Figure 8. The ships are obliged to use the fuel oil of sulphur content of less than 0.1% (ULFSO – Ultra Low Sulphur Fuel Oil) inside this zone starting from January 1, 2015. The necessity to switch over from HFO (High Sulphur Fuel Oil) to ULFSO may create, apart from a large scale of technical problems, also significant considerations at planning, programming and optimizing the route of the voyage.

There are technical problems related to the switchover procedure. When a ship is not equipped with two independent fuel systems (a rare and expensive solution) mixing of the fuel must be commenced soon enough in order to have pure ULFSO fuel at the moment of entry into the ECA zone. Sometimes, depending on the type of the engine, fuel mixing can last a couple of days. Such a complicated procedure requires careful planning and strict time management. The latter requirement is particularly difficult to comply with. Each amendment made to previously calculated and planned RPM (revolution per minute) settings of the main propulsion system affects the speed of fuel consumption and thus the time needed to have pure ULFSO in the system. In practice, if a correction in ship's speed is needed, it is increased rather than decreased for fuel purity. The switchover operation itself is also sometimes also long and complicated, with the need to reduce the RPM, usually to maneuvering RPM. After the changeover, RPM build up procedure is usually a complicated process as well.

All these problems result in voyage route optimization difficulties. The time necessary for fuel change over should be included in the overall route planning process. Another ever present issue is the question of how long to remain in the ECA zone: minimize the time to minimize the distance the vessel is running on a more expensive fuel, or to travel

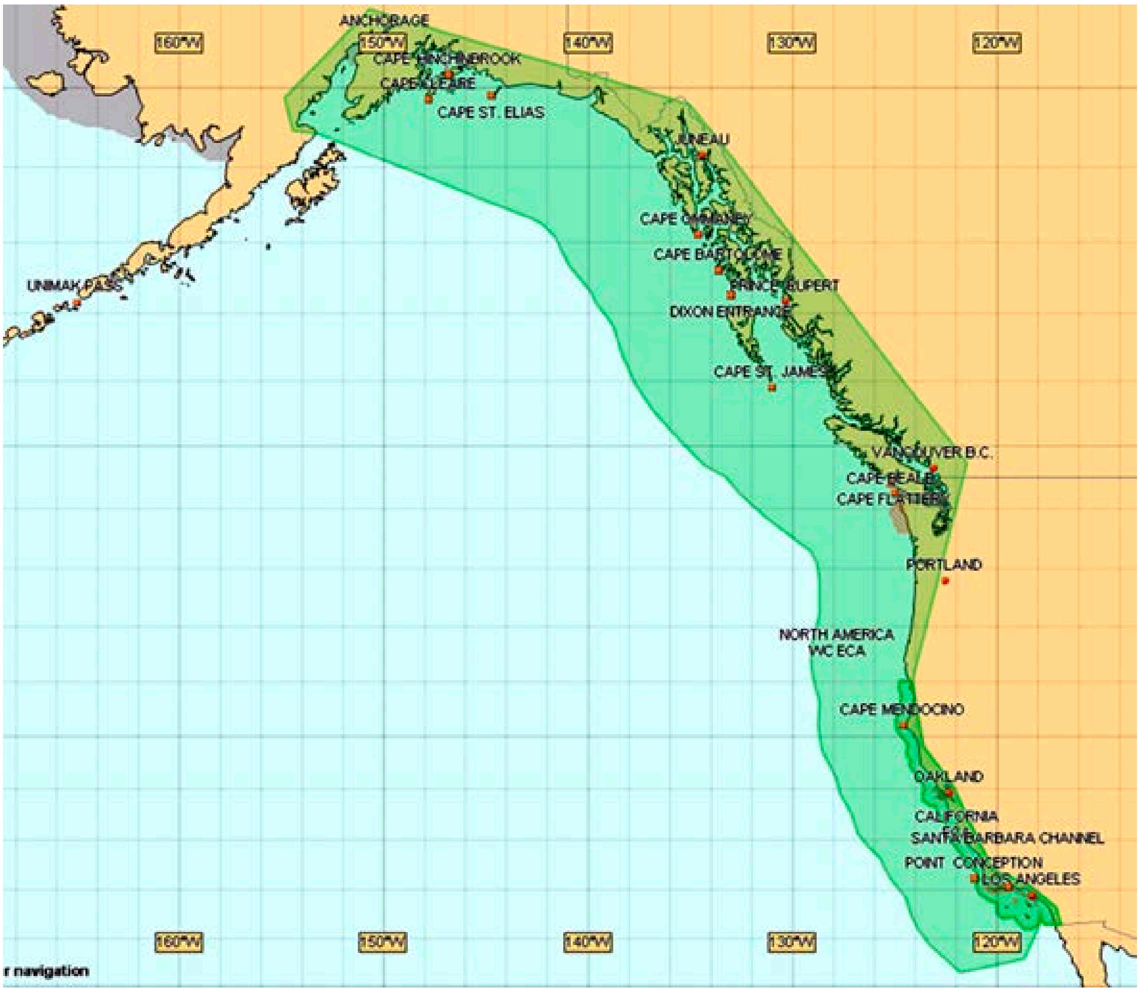

Figure 8. North American ECA Zone – western coast (Applied Weather Technologies, 2014)

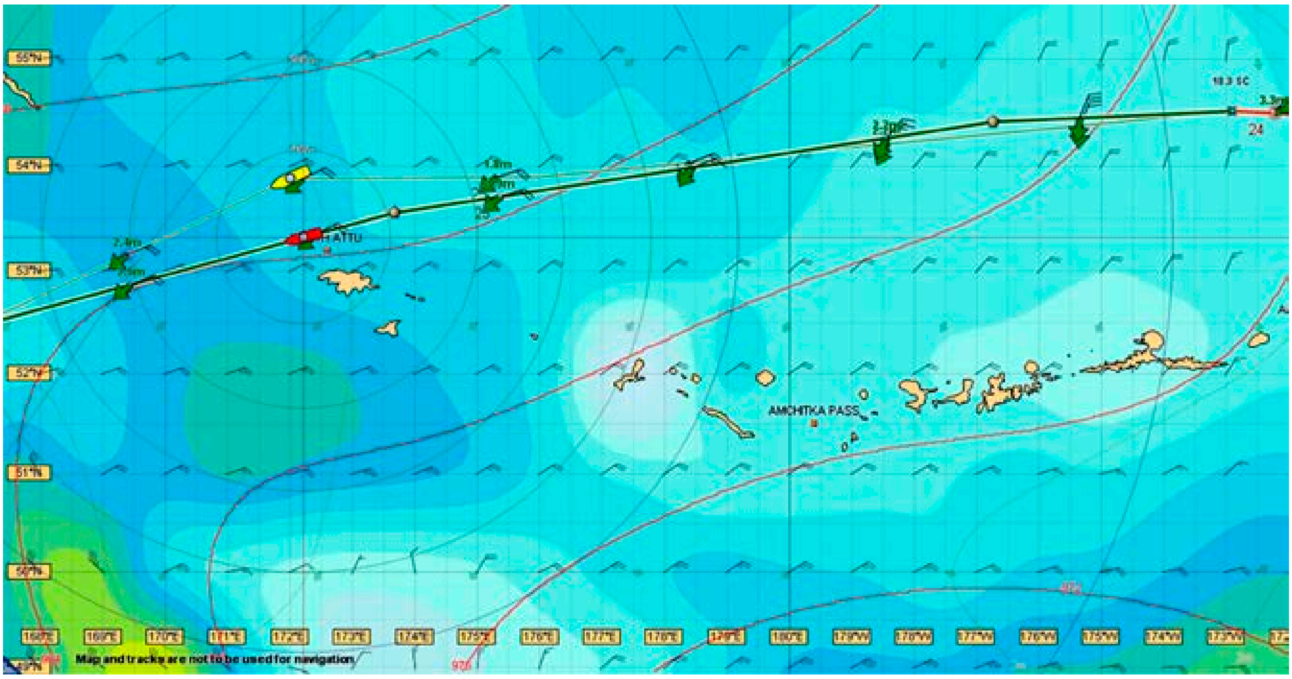

Figure 9. Route optimized in the Bon Voyage system and route programmed manually. The BV route does not meet the requirements of offshore routing (Applied Weather Technologies, 2014)

for longer period time on ULFSO to minimize fuel consumption and exposure to inclement weather conditions en route.

In most of the available route optimization systems (SPOS, Bon Voyage) this task is not solved satisfactorily and optimal solutions must be arrived at manually.

Problems in optimizing and programming of routes in the Northern Pacific Ocean – examples

Figure 9 presents the route, optimized in the *Bon Voyage* system which runs too close to the shore – less than 50 nautical miles off the Attu island (bold route, red vessel symbol). It was necessary to correct it manually (yellow vessel symbol) in order to comply with *offshore routing* requirements.

Figures 10–12 present an example of incorrect optimization of the route leading through the ECA zone with the use of *Bon Voyage* system. The route has been optimized according to the least fuel with fixed ETA (Estimated Time of Arrival) method. The route was optimized in such a way as to have the least possible distance in the ECA zone. However in this instance, the required deviation from the main route was so big that the cost of the burnt fuel had exceeded greatly the gain achieved on minimization of time and distance in the ECA zone.

Figure 10. Route leading through the ECA Zone, optimized in the BV system (bold) and route programmed manually (Applied Weather Technologies, 2014)

Conclusions

A relatively simple and uncomplicated task of planning and programming a route of a ship in the Northern Pacific Ocean becomes a difficult and challenging one due to recently introduced (ECA, Alaska Maritime Prevention & Response Network) and already existing (recommended routes) legal frameworks and circumstances. Achieving an economical passage in terms of a total voyage cost is not always possible. Decision support and optimization tools, currently available and in use onboard the ships, like SPOS and Bon Voyage systems, do not always solve this issue properly and satisfactorily.

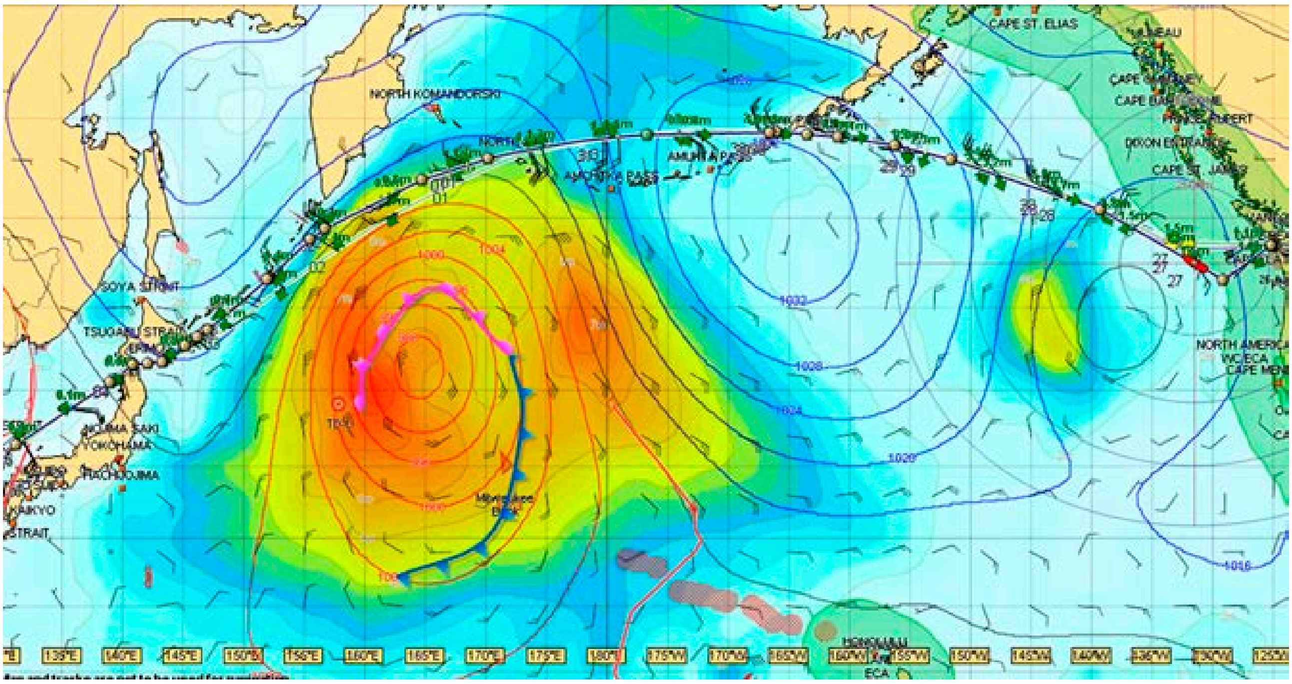

Figure 11. Route from Seattle (USA) to Pusan (South Korea)

Voyage Details | Graph

Actions | Clone | Save | Close | Delete

ETD	Departure	ETA	Arrival	Troll	nm	Hrs	T_FO	HSFO	LSFO	MDO	LSMDO	SC	WxF	CuF	SOG	Fuel(USD)
2015/08/26 16:00	SEATTLE	2015/09/05 21:00	BUSAN	19.4	4576	245.0	1313.3	1204.4	108.8	0.0	0.0	19.0	-0.25	-0.04	18.7	348795
2015/08/26 16:00	SEATTLE	2015/09/05 20:59	BUSAN	19.4	4661	245.0	1369.0	1289.7	79.3	0.0	0.0	19.3	-0.24	-0.02	19.0	352217

Figure 12. Calculation of costs: route optimized in BV (bold) and route programmed manually

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