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# Navigation in emission control area zones

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**Abstract**

The article presents the origin of Emission Control Area (ECA) zones, a timetable for their enforcement, criteria of their implementation and the principles and rules of navigation in these areas. Plans and areas of the next ECA zones envisaged for the future are presented. Least fuel route programming was presented, together with a description of safety rules during the change-over procedure in operations concerning the main engine and other ship systems. An attempt to identify the problems that may be encountered when programming the routes with the use of on-board routing systems, like Bon Voyage of AWT, leading through the ECA zones, has been made. Examples of such problems, taken from a true voyage of a postpanamx container vessel on a transpacific voyage, have been presented. A generalized algorithm for programming the route leading through the ECA zone according to the least fuel criterion has been presented.

## Origin of ECA zones and their description

Navigation in ocean regions has recently been subjected to certain restrictions and constraints by coastal states. This was due to recently introduced means of emission control from ships, with respect to route choice, planning and programming. In Europe, this applies to the Baltic Sea and North Sea and is being implemented in the Mediterranean Sea and Black Sea. In the Pacific and Atlantic areas, it affects the coasts of the USA and Canada. Coastal states aspire to control and restrict emissions from ships.

Introduction of the *Emission Control Areas* (ECA) results from Annex VI of the MARPOL Convention. It regards various aspects of air pollution from ships, its limitation methods and means of control by the administration, surveys and certification of ships greater than 400 GT and having engine power higher than 130 kW. The regulation has been adopted by the IMO in 1997 and, after having been ratified by a sufficient number of member states, came into force on May 19th 2005. Its rules 13 and 14, regarding $SO_x$ and $NO_x$ emissions from ships, are of the greatest significance for shipping.

Annex VI of the MARPOL Convention determines that states, or groups of states, are the only bodies that can apply to IMO for the establishment of an ECA zone. Proposals have to be evaluated according to the following criterions (IMO, 1978):

- Geographical delineations of the ECA zone.
- A description of how the emissions from ships affect the land and sea region on a proposed ECA zone.
- A description of the hydrometeorological conditions in a proposed ECA zone.
- Sea traffic density in a proposed ECA zone.
- Means of control and execution of emission control and restriction.

Until now, 5 such ECA zones have been established. Their list and detailed description is presented in Table 1.

ECA zones in the Baltic Sea, North Sea and English Channel are presented in Figure 1, both North American ECA zones and planned ECA zones are shown on Figure 2.

**Table 1. Currently existing ECA zones and dates of their adoption, introduction and enforcement. $SO_x$ – control of sulphur emission, $NO_x$ – control of nitrogen emission, PM – control of particulate matters emission [authors' findings based on (Raets Marine Insurance BV, 2013; Cullinane & Bergqvist, 2014; Lloys's list, 2015; Maritime Cyprus, 2015; Ministry of Transport of People's Republic of China Website, 2016)]**

| ECA zone | Adoption | Introduction | Coming into force |
|---|---|---|---|
| Baltic Sea ($SO_x$) | 26.09.1997 | 19.05.2005 | 19.05.2006 |
| North Sea and English Channel ($SO_x$) | 22.07.2005 | 22.11.2006 | 22.11.2007 |
| North American ECA zone ($SO_x$, $NO_x$, PM) | 26.03.2010 | 01.08.2011 | 01.08.2012 |
| Caribbean ECA zone ($SO_x$, $NO_x$, PM) | 26.07.2011 | 01.01.2013 | 01.01.2014 |
| Pearl River, Yangtze River, Bohai RIM ECA zones (PRC) ($SO_x$) | 01.01.2016 | 01.01.2016 | 01.01.2016 |


**Figure 1. ECA zones in the Baltic Sea and in the North Sea (Maritime Cyprus, 2015)**

In both European ECA zones, emission control applies for sulphur oxides only ($SO_x$), whereas in American zones emission control also covers nitrogen oxides ($NO_x$) and particulate matters (PM).

Other ECA zones are planned. Figure 2 shows the existing (areas marked green and blue) and planned (areas marked grey) ECA zones. Existing European, North American, Hawaiian and Puerto Rican ECA zones and ECA zones planned for the future are marked.

## Emission regulations in ECA zones

Annex VI of the MARPOL Convention as well as the local acts of law resulting therefrom (e.g. EU Directive 2012/33) regulate the permissible emission limits inside and outside of ECA zones.

Emission control is defined by the maximum allowable sulphur content in marine fuel oil. Annex VI of the MARPOL Convention determines the following limits and their introduction dates (Raets Marine Insurance BV, 2013):

1. Inside ECA zones:
   - Before 01.07.2010 – maximum allowable sulphur content in fuel oil – 1.5%.
   - After 01.07.2010 – maximum allowable sulphur content in fuel oil – 1.0%.
   - After 01.01.2015 – maximum allowable sulphur content in fuel oil – 0.1%.
2. Outside ECA zones:
   - Before 01.01.2012 – maximum allowable sulphur content in fuel oil – 4.5%.
   - After 01.01.2012 – maximum allowable sulphur content in fuel oil – 3.5%.

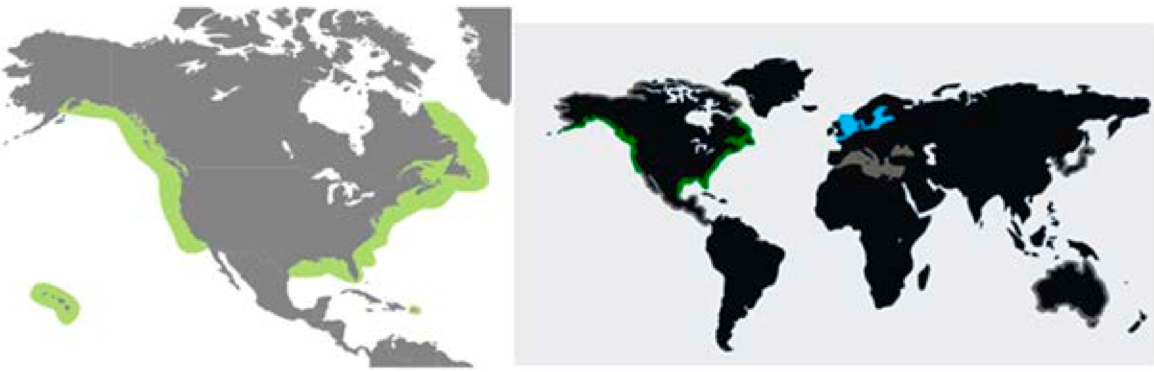

**Figure 2. The North American, Hawaiian, Puerto Rican and other existing ECA zones and planned ECA zones (Maritime Cyprus, 2015; Lloyd, 2015)**

- After 01.01.2020 – maximum allowable sulphur content in fuel oil – 0.5.

Introduction of the 0.5% limit as the maximum allowable sulphur content in fuel oil may be delayed until 01.01.2025, depending on an evaluation of the atmospheric pollution by a panel of independent experts under IMO supervision, planned for 2018. The information has been presented graphically in Figures 3 and 4 (Raets Marine Insurance BV, 2013).

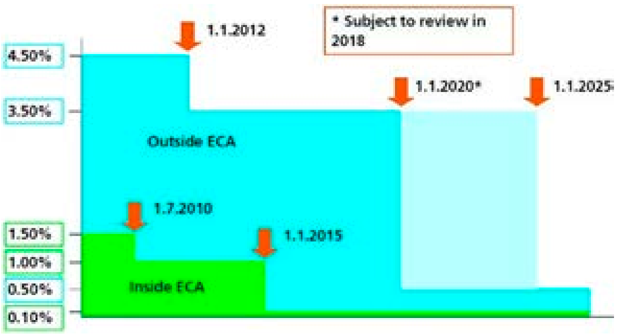


**Figure 3. Maximum limits of sulphur content in marine fuels (vertical axis) and dates of their enforcement (horizontal axis) (Raets Marine Insurance BV, 2013)**

The EU Directive 2012/33 will implement the 0.5% limit for the maximum allowable sulphur content in fuel oil used on ships navigating in waters under the jurisdiction of EU member states outside ECA zones, irrespectively of the IMO evaluations. For ships in transit only, not calling at EU ports, the limit on the maximum allowable sulphur content in fuel oil has been set to 1% o until 01.01.2020. Past that date, it will be decreased to 0.1% (Raets Marine Insurance BV, 2013).

Neither the MARPOL Convention nor the EU Directive 2012/33 impose any obligations to report fuel switchover times or positions on ships; however, the ships are obliged to carry and possess on-board suitable and appropriate documentation, with which it is possible to prove, in case of control, the compliance with rules and regulations. This documentation should include:

- Bunker Delivery Notes that confirm compliance of bunkered oil with existing regulations and limits – provided by the bunker deliverer at bunkering;
- Bunker samples results – performed by a land laboratory;
- Written procedure of fuel switchover approved by a relevant administration;
- Records of fuel switchover in relevant documentation (Deck Log Book, Oil Record Book);
- Voyage plans marked with position of fuel switchover;
- Drawings of installations, valves and fuel pipelines;
- SEEMP (*Ship Energy Efficiency Management Plan*);
- EEDI (*Energy Efficiency Design Index*);
- *Cargo Ship Air Pollution Prevention Certificate* (CSAPPC).

This documentation and records may be subjected to inspection by Port State Control. Coastal states can also monitor compliance with regulations by other means, e.g. monitoring from air or other methods.

## Navigation in ECA zones and least fuel optimization

The above mentioned constraints are the source of certain problems in planning and programming routes passing through the ECA zones, according to the least fuel criterion. A mathematical formula dealing with this set of problems is relatively simple and is shown below:

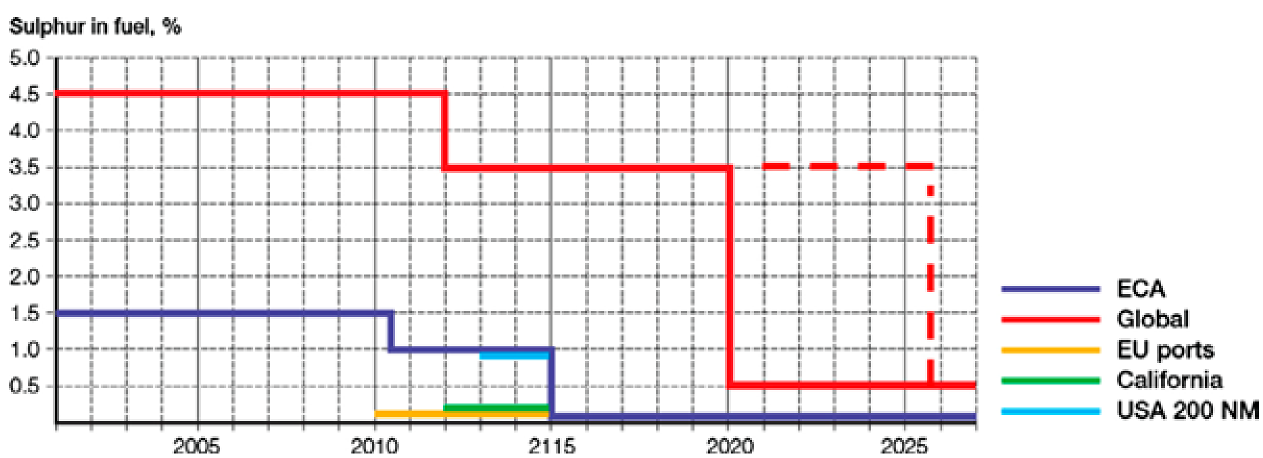


**Figure. 4. Development of the global and local regulations regarding sulphur emissions from ships (Cullinane & Berqvist, 2014)**

$$K_{\text{Fuel}} = F_{\min} \left(K_{\text{Fuel}} (\text{ECA}) + K_{\text{Fuel}} (\text{Non-ECA})\right) \quad (1)$$

where:

$K_{\text{Fuel}}$ – total fuel cost;

$K_{\text{Fuel}}(\text{ECA})$ – function describing the fuel costs inside the ECA zone;

$K_{\text{Fuel}}(\text{Non-ECA})$ – function describing the fuel costs outside the ECA zone.

In practice this set of problems has not been satisfactorily solved in weather optimization systems. It is best illustrated in an example below and in Figures 5 and 6.

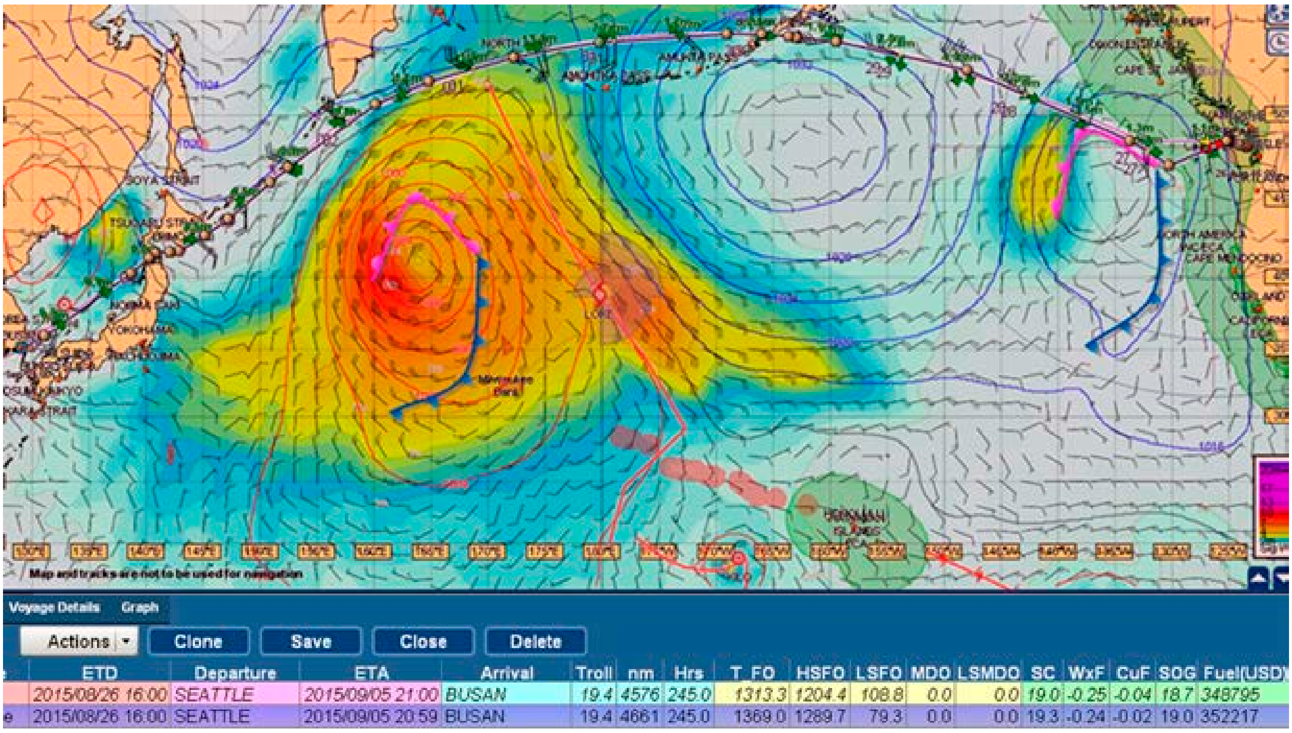


**Figure 5. Voyage Seattle–Busan. Comparison of a least fuel with fixed ETA optimization (bold route on the chart, bottom line in the table) against the route programmed manually (thin route on the chart, upper line in the table)**

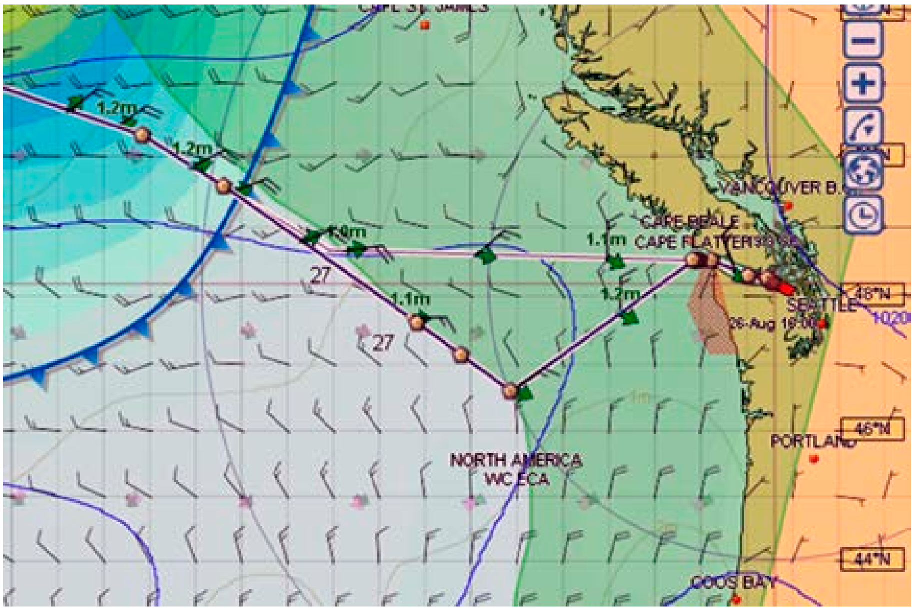


**Figure 6. Voyage Seattle–Busan. Comparison of a least fuel with fixed ETA optimization (bold route on the chart, bottom line in the table) against the route programmed manually (thin route on the chart, upper line in the table) – A close up of the initial stage of both routes**

Explanations for Figure 5:

ETD – Estimated time of departure;

Departure – Port or Point of the completion of the voyage;

ETA – Estimated time of arrival;

Arrival – Port or Point of the beginning of the voyage;

Troll – Roll period;

Nm – Nautical mile;

Hrs – Total steaming time en route in hrs (voyage duration in hrs);

TFO – Total fuel oil consumption en route;

HFSO – High Sulphur Fuel Oil consumption en route;

LSFO – Low Sulphur Fuel Oil consumption en route;

MDO – Marine Diesel Oil consumption en route;

LSMDO – Low Sulphur Marine Diesel Oil consumption en route;

SC – Calm Sea Speed, ship's speed en route for calm seas, calculated according to the following formula:

$$SC = DTG/TTG - WxF - CuF$$

DTG – Distance To Go;

TTG – Time To Go;

WxF – Weather factor showing the influence of weather on speed over ground in knots;

CuF – Current factor showing the influence of surface current on speed over ground in knots;

SOG – Speed Over Ground;

Fuel (USD) – Fuel cost en route;

The route created manually is better than the route created by BVS in terms of fuel consumption and voyage costs, by 56 tons of fuel and 3422 USD, respectively, despite the fact that the amount of low sulphur fuel oil consumed (inside the ECA zone) is greater by 29.8 tons. The above example shows unequivocally that the Bon Voyage System does not solve the fuel optimization problem satisfactorily.

The function describing the consumption of fuel inside the ECA zone is superior to the function describing the consumption of fuel outside the ECA zone. The priority in BVS is the minimal consumption inside the ECA zone, which is a mistaken assumption.

AWT, the maker of the system, is aware of this situation and recommends shore-based weather routing for all ships using the BV system. Voyage optimization of routes leading through ECA zones are given by AWT in the form of text recommendations worked out in the shore-based center by weather experts.

## Conclusions

Coastal states and the IMO constantly aspire to control and restrict emissions from ships in their areas of jurisdiction. New ECA zones and ever-lower limits on sulphur, nitrogen and particulate matters content in marine fuel oil are being constantly implemented. This is a source of significant constraints and restrictions in the choice of routes available to ships and in planning and programming the vessel's route. Another problem is the correct mathematical solution of ocean route optimization according to the least fuel criterion of routes leading through the ECA zones in voyage optimization systems like the Bon Voyage system. Existing tools do not solve that task correctly and satisfactorily.

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