TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 8 Number 1 March 2014
DOI: 10.12716/1001.08.01.18

The Prevailing Weather and Traffic Conditions in the Evaluation of a Future ECA in the Mediterranean Sea. A view into the Western Mediterranean

M. Castells & F.X. Martínez de Osés
Department of Nautical Sciences and Engineering, Universitat Politècnica de Catalunya (UPC), BarcelonaTech, Spain

ABSTRACT: Appendix III of MARPOL´s Annex VI sets out the criteria and procedures for designating an emission control area (ECA).These criteria includes: a clear delineation of the proposed ECA; types of emissions proposed for control, land and sea areas at risk; emission quantification and impact assessment; prevailing weather conditions; data and quality on marine traffic; land based measures concurrent with the ECA adoption and the relative costs of reducing emissions from ships. This paper analyses the climate parameter together with traffic conditions: prevailing weather conditions as a parameter to be kept in mind for the adoption of a future ECA in the Mediterranean Sea. Preliminary results would show how marine emissions coming from existing traffic will impact the sea and land ecology in the Mediterranean area.

1 INTRODUCTION

There is a growing voice calling for an ECA in the Mediterranean area, claiming significant damages to the environment, crops and health; produced by emissions from shipping both in Mediterranean Sea coastal countries as well as further in shore. The last ship emissions inventory for the Mediterranean developed by Entec UK limited in 2007 appointed that intra-European movements, i.e. Short Sea Shipping (SSS), contributed in 2005 significantly to emissions in the Mediterranean Sea, as 38% of the fuel consumed corresponded to intra-European movements (16% domestic and 22% between EU countries).

Building on the statistics of "Maritime transport statistics – short sea shipping of goods" published by the Eurostat (Eurostat, 2012), short sea shipping traffic volumes in the Mediterranean are already recovering from the downturn suffered due to the current economic crisis. Containerized and RoRo cargo which in 2010 represented 29.4% of the total short sea shipping volumes in the Mediterranean are emerging strong, registering highest traffic shares ever.

The International Maritime Organization has adopted the mandatory installation of Automatic Identification System (AIS) requirements. Based on the AIS data analysis and processing, data of traffic around the world and in the Mediterranean can be analyzed (Xiang, 2012).

Figure 1 clearly depict the high vessel density areas around the world and the main traffic lanes connecting the economic centers in Asia, Africa, Europe and the Americas crossing the Atlantic, Pacific and Indian Oceans. As can be seen, the Mediterranean sees lots of ship traffic.

On the other hand, as can be seen in Figure 2, the Mediterranean ship emissions appear important probably due to the more shipping (and ship emissions) along coastal routes frequented by containerships along coastal shipping, particularly in the Europe and Mediterranean areas.

Table 1. Short sea shipping cargo volumes (in percentage) in the Mediterranean, 2006-2010. Source: Own, based in Eurostat

Cargo (%)	2006	2007	2008	2009	2010
Liquid bulk goods	51.0	50.3	49.8	49.8	48.6
Dry bulk goods	16.6	15.8	15.6	18.0	15.7
Large containers	16.2	16.7	17.4	18.0	18.3
Ro-Ro (self propelled units)	5.3	5.3	6.0	4.8	7.1
Ro-Ro (non –self propelled units)	4.6	5.4	3.9	3.9	4.0
Other	6.4	6.4	7.3	5.5	6.3
Total (million tons)	564	584	589	563	570

2 REGULATION

The International Maritime Organization (IMO, 2009) commenced a debate on the reduction of emissions to air from ships in the 1980's. MARPOL's Annex VI was published in 1998 and came into force May 19, 2005, and was revised in 2008. The main changes were as follows:

Reduce the global cap on sulfur content in fuel oil to 3.50% (effective January 2012), then progressively down to 0.50 % (effective January 2020)

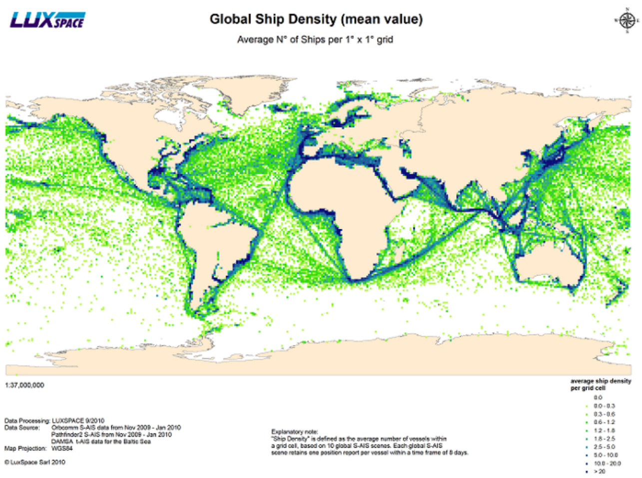

Figure 1. Global ship density map of all class A vessels. Source (Eiden, 2010)

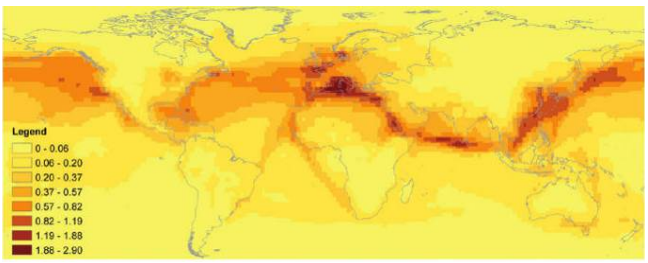

Figure 2. Concentrations of PM2.5 with ICOADS data in micrograms per cubic meter. Source: Winebrake, et al. 2009

Reduce limits applicable in Sulfur Emission Control Areas (SECAs) to 1.00% sulfur content (effective July 2010), being further reduced to 0.10% (effective January 2015)

Reduce limits on nitrogen oxide (NOx) emissions from marine engines, with the most stringent controls on so-called "Tier III" engines (i.e., those installed on ships after January 2016) operating in Emission Control Areas.

Appendix III defines the criteria and procedures for designation of an Emission Control Area (ECA). An ECA should be considered by adoption by the IMO is supported by a demonstrated need to prevent, reduce and control emissions of SOx, NOx and particulate matter (PM) from ships.

The proposal considering criteria for designation of an ECA shall include:

1 A clear delineation of the proposed area of application, along with a reference chart on which the areas is marked;
2 The type or types of emission(s) that is or are being proposed for control;
3 A description of the human populations and environmental areas at risk from the impacts of ship emissions
4 Emission quantification and impact assessment
5 Prevailing meteorological conditions
6 Data on marine traffic
7 Land based measures
8 The relative costs of reducing emissions from ships when compared with land-based controls and the economic impacts on shipping engaged in international trade.

Existing Emission Control Areas include:

– Baltic Sea (SOx, adopted: 1997 / entered into force: 2005)
– North Sea and English Channel (SOx, 2005/2006)
– North American ECA, including most of US and Canadian EEZ (NOx & SOx, 2010/2012).
– US Caribbean ECA, including Puerto Rico and the US Virgin Islands (NOx & SOx, 2011/2014).

Experts expect proposals for other ECAs to be submitted to the Marine Environment Protection Committee (MEPC) in the near future. Most likely candidates are the coastal waters of Mexico and Japan. Norway is also expected to propose an ECA for its coastal waters in the Norwegian Sea, which would be the first ECA in Arctic waters. Proposals for ECAs in the Mediterranean Sea and Straits of Malacca are also expected; however, it will likely be years before it is feasible to meet ECA requirements in these highly trafficked areas.

Figure 3. DNV's map of current and possible ECAs in the future. Source: Det Norske Veritas (DNV)

This paper will analyze relevant information on existing traffic related to weather conditions to demonstrate how marine emissions will impact the sea and land ecology at risk in an area of the Western Mediterranean.

3 METHODOLOGY

To evaluate prevailing meteorological conditions criteria, relevant information pertaining to weather conditions and, particularly, wind patterns in the Mediterranean area is required to demonstrate how marine emissions will impact the sea and land ecology at risk.

Descriptions of climatic conditions which are found in aids to navigation (Pilots, Routing Charts, and Pilot's Charts) make use of average values of meteorological elements. Such an approach follows the methods applied in classical climatology where climate is treated as "a mean state of atmosphere in a many year period" (Ferdynus, 2012). The frequency of occurrence of types of adverse or unfavourable weather conditions is extremely important for determinate marine emissions at land.

Predominately onshore winds result in greater pollution on land. Moreover, topographical, geological, oceanographically, morphological or any other conditions that could lead to increased probability of higher localized air pollution or levels of acidification. Mountainous regions inshore impacted by onshore winds can lead to intensification of air pollution and acid deposition. The situation in the Mediterranean is more complex with varied geography and more complex wind conditions that are more localized and seasonal.

This paper will focus on predominant wind pattern in the Mediterranean to demonstrate areas at risk. Detailed weather conditions are held by a number of organizations, for instance: www.puertos.es, www.idromare.it, www.eurometeo.com and Mediterranean Pilot Volumes of the Admiralty charts and publications and Spanish Hydrographic Office.

3.1 *Mediterranean climate*

The Mediterranean region has morphological, geographical and societal characteristics, which make its climate interesting (Lionello, 2006).

The connotation of "Mediterranean climate" is mentioned in the qualitative classification of the different types of climate on Earth as by Köppen (Sanderson, 1999 & Kottek, 2006).

This climate use to be known due to its mild and wet winters and dry and hot summers. This climate even being very similar to the one of California, central Chile, South Africa or SW of Australia; is due to the topographic close of the sea basin.

We can define two main questions: First of all, in general terms, from October and during the winter season, the high pressure of Azores is reduced in extension and it affords the Atlantic lows to reach southernmost areas. In this season, the Northern Eurasia countries are cooled quickly, whilst the rest of the Mediterranean remains warmer. This means that the Polar and Arctic air masses in its advance to South, will suffer a very intense convection. This situation drives to a Cyclogenesis episode, mainly in the Gulf of Genoa, South of Ionian Sea and around Cyprus Island.

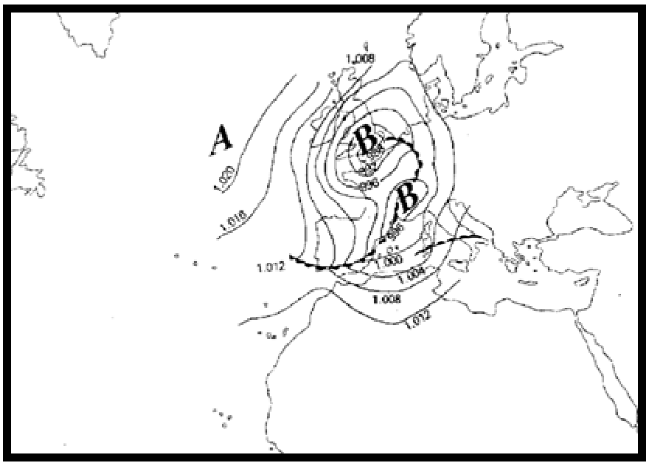

Figure 4. North situation in the Gulf of Genoa. Source: Sailing Directions Nr. 1 Costa Oriental de la Península Ibérica. Instituto Hidrogáfico de la Marina. Ministerio de Defensa. 1990.

On the other hand, to understand the Mediterranean climate, the local winds must be understood. Some of them have a synoptic effect like the Mistral, whilst some others are mainly local. The Mistral (NW), blowing down the Rhone valley, empties into the Gulf of Lion and usually appears with a pattern characterized by the position of a low pressure centred in the Balkans, close to the centre of the high pressure the Azores, together generating a pattern of situation of North winds in French territory. The topographic barriers will later address it as a North West.

During the winter, the wind effect is reinforced by the cooler snow coverage of that area, causing the downward flow of air from the Alps and the Massif Central (France) (see figure 4). The gravitational collapse of cold air and therefore, dense towards the bottom of the valleys, is called katabatic wind. Which is a dry wind, cold, down the valley of the Rhone, and when combined with a strong pattern of synoptic wind, can produce wind speeds of up to 80-85 knots in the vicinity of the Rhone delta? Between December and May, occurs an average of 26 days during which the Mistral can blow at 33 knots or more, with a slight peak of activity between March and April (11 days between the two). These winds are falling rapidly when they penetrate into the sea, but occasionally can be extended to the island of Malta or North Africa. The danger for navigation is actually the rise in a short time: high seas. This phenomenon that occurs mainly in March, when the significant wave height in the southern part of the Gulf of Lion, reaches 2 meters, one of the highest among statisticians in the Mediterranean.

The same effects are associated with the katabatic Bora, which is a NE wind, which blows on the Eastern shore of the Adriatic Northern winter occurs where violent storms and gusts at times up to 100 knots. These conditions are intensified when the Mediterranean Low pressure is well developed and maintained a high pressure lingering over Europe. In particular behind a cold front moving southeast over the Adriatic effect, is reinforced by katabatic descent of cold air from the mountains Dalmatians. All these features well defined throughout the year, we find unexpected effects that do pose a greater hazard to navigation.

Along the Eastern coast of Spain, we find the East wind and gales, which are part of the change as well as the local winds during the winter half of the year. The first characteristic of these storms pattern NE and ENE, passing squalls associated with the Mediterranean between France and Algeria may cause seas really hard when the wind settles and finds considerable NE fetch, showed in figure 5 & 6.

These storms are more frequent and dangerous especially in autumn and spring. The storm characterized by strong winds from the SW, across the Strait of Gibraltar, up the Spanish coast depressions associated with advancing from the late fall to early spring. The main danger is triggered violent storms and electrical appliance involved. The transition from prevailing winds between the two halves of the year completely alters the character of the local winds. In the absence of ciclogenesis, local wind patterns are dominated by the following: where the wind comes from and what happens when it blows.

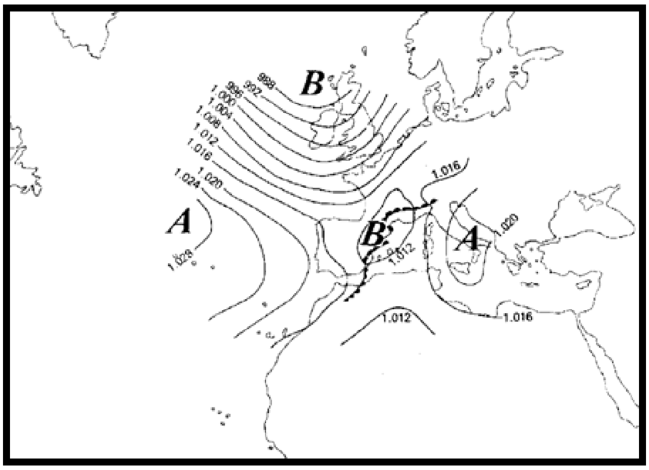

Figure 5. South situation in the Gulf of Genoa. Source: Sailing Directions Nr. 1 Costa Oriental de la Península Ibérica. Instituto Hidrogáfico de la Marina. Ministerio de Defensa. 1990.

For example, the Sirocco is the warm wind SW associated with the advance of a depression moving east direction across the Mediterranean (see figure 7), being most common in the spring because the subtropical high pressure moves north. Since it has warm, dry and full of dust from the Sahara, crossing the Mediterranean when it absorbs large amounts of moisture, makes it an unpleasantly warm and wet air. The most obvious consequence of the Khamsin is its emergence as almost spontaneously without previous evidence, of a narrow channel of wind posing a threat to coastal terminals with open basins, where large ships could be docked (big Bulk carriers, Tankers or Containerships). Due to that channel wind lifts. Another problem for navigation is when the air passes over the colder waters in the Northern Mediterranean in the spring or early fall, quickly forming a dense fog.

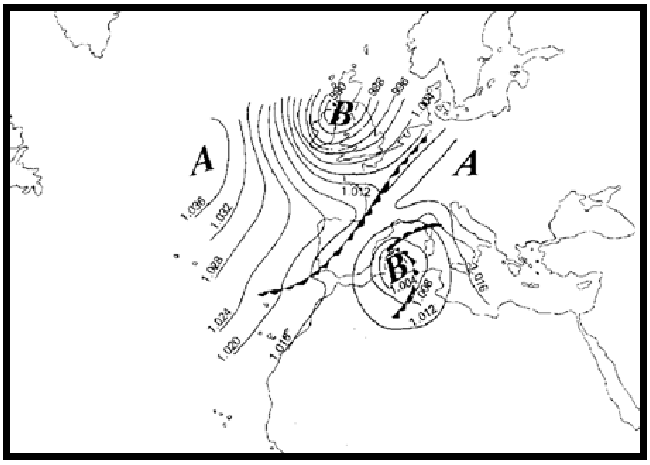

Figure 6. Typical Algeria Low in the Gulf of Genoa. Source: Sailing Directions Nr. 1 Costa Oriental de la Península Ibérica. Instituto Hidrogáfico de la Marina. Ministerio de Defensa. 1990

But perhaps the most famous summer winds are Etesian (the Meltemi Turkish) blowing from the NE and NW Aegean Sea. These are the consequence of a low pressure system extending from NW Anatolia to India, formed by the intense warn down suffered in the region. These winds reach maximum intensity during the month of August when hovering around 15 knots in the southern Aegean, resulting in variable weather conditions, which benefit the coastal regions moderating temperature.

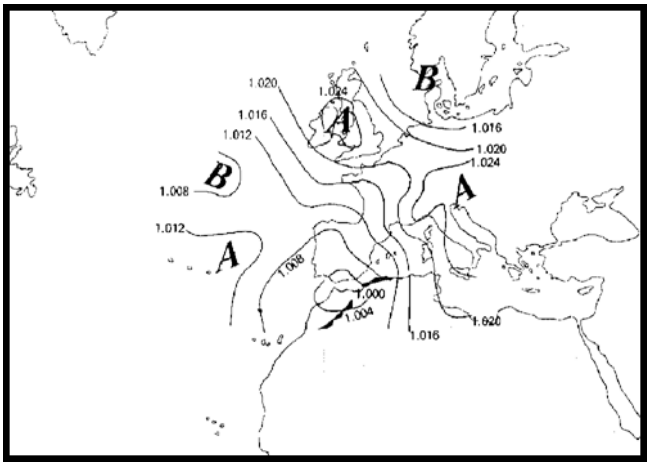

Figure 7. Typical path of a Mediterranean Low in the Strait of Gibraltar. Source: Sailing Directions Nr. 1 Costa Oriental de la Península Ibérica. Instituto Hidrogáfico de la Marina. Ministerio de Defensa. 1990.

Occasionally they can be associated with violent storms, produce winds and sudden squalls (known as Bourini in Greece), causing considerable damage to local navigation.

In the Mediterranean there are other issues such as extremes which can be of relevance in the area. We can observe for example heat waves which are perceived as to be the worst danger. The summer of 2003, was considered the hottest in the Mediterranean area for more than half-a-millennium (Lionello, 2006).

There are consequences of single intense precipitation events like floods and landslides. Because of the morphology of the territory, the periods of persistent precipitation, can be a major problem. Also it is possible to observe specific phenomena like the Medicanes. These are lows generating intense winds but with a very concentric shape that can remember a tropical cyclone. They have been studied and as main mechanisms to create them, are an intense convective activity due to a vertical thermodynamic imbalance (caused by a very cold air mass on top) and the classical Mediterranean baroclinical mechanism.

The parameters influencing in the evolution of the gales are changing and depend on the geographical location but the most important are the latent heat currents and then the specific distribution of the sea and shore areas together with the elevated height of the mountains close to the Mediterranean coast.

Some of the above mentioned topics and their regime changes can pose a real danger to the long Mediterranean coastline, most of it densely populated. There are also small-scale events such as hail, lightning and tornados that can also produce damages.

The Mediterranean Sea plays a role in the global climate system as a source of heat reservoir, source of moisture and salty water exiting into the Atlantic Ocean (Lionello, 2006).

Finally we can remind that Mediterranean climate has been object of study, among others, through the MedCLIVAR project, endorsed by CLIVAR (Climate Variability and Predictability) project or MEDEX project on cyclones that produce high-impact weather in the Mediterranean, both of them from the World Climate Research Programme

4 STUDY OF THE SPECIFIC TRAFFIC AND CLIMATIC CONDITIONS

Maritime traffic developed in the Mediterranean has two main dimensions. Those are the straits of Gibraltar and Bosporus and the Suez Canal.

Within the Mediterranean joints the international traffic just crossing the sea area together with the intra EU and local or regional exchanges. During the year 2006 in the Mediterranean Sea, the registered 252,000 ships 'calls at port (15% at world level), were carried out by 13,000 merchant ships, representing 3.8 million DWT (10% of world fleet) (NESTEAR, 2008)

There were 10.000 transits of ships crossing the Mediterranean Sea bound to ports outside it, what explains us the importance of the Mediterranean as a route of transit.

EU commercial exchanges with Asia, have been strongly growing from 20 years ago. In 2008 they amounted for 1 billion of €, being 613,000 million € as imports and 368,000 million € as exports to Asia.

Those mentioned commercial exchanges are mainly represented by general freight usually carried in containers. It means the 40% of the EU imports and 30% of exports, being the Asian area the first commercial member of the EU ahead of United States.

The countries placed in the southern Mediterranean coast, are selling bulk commodities (including oil) to the entire world and in a minor rate, general cargo shipped into containers. Mainly those last actors are the most populated countries like Turkey and Egypt, exchanging their products to Commonwealth of Independent States, Middle West and United States (COMEXT, 2006).

Within the inner maritime routes, it is possible to distinguish three different types of commercial fluxes: the exchanges among EU countries and Southern Mediterranean countries, the exchanges among south Mediterranean countries and the exchanges among EU Mediterranean countries.

Among the 30% to 70% of the commercial exchanges of South Mediterranean countries has been made with EU countries, mainly from the Maghreb countries. But from the EU point of view those volumes only represent the 5% to 20% of their commercial exchanges. Traffics carried out mainly by France, Greece, Italy or Spain. They are almost totally oil and general bulk traffics, imported by Europe through specialized port terminals.

The trade among South Mediterranean countries is very limited due to the difficulty of customs prices and the enormous economic competence among them. However it is perceived that in the near future when customs barriers would be removed, the trade can grow exponentially among countries with dense populated urban cities like Middle West, Egypt or Turkey.

A general overview in the Suez Canal, shows us that 30% of the registered inbound to Mediterranean traffic is destined to North and West Europe, 20% to North Mediterranean coast Sea and 17.4% to E-SE Mediterranean countries.

The split in countries gives us figures on major exchanges like Italy 10.7%, Holland 10.5% or Spain 10%. The picture derived from the previous figures shows us the main routes the ones connecting Suez canal entrance to Italy and Sicily channel (between Italy and Tunisia) to reach Western Italy, France and Spain or passing through the Gibraltar strait bound to North of Europe.

The trades between Egypt and Ukraine through the Bosporus strait to the Black Sea, are other of the main traffic lanes. During the year 2009, 8% of the global trade passed through the Suez Canal.

For example in Italy the port of Ravenna, is the leader of exchanges with Eastern Mediterranean countries and the Black Sea with almost the 40% of the national share (excluding coal) with such area.

The Port of Trieste placed half way between the Baltic Sea and the Mediterranean is key in the exchanges between the center and East Europe.

4.1 *Marine traffic in the Balearic Islands*

The services between Morocco and the EU covered by SSS traffics are mainly developed by Ro/Pax ships, mainly from Italy, calling at Barcelona port and arriving by Tangier-Med, apart from the services crossing the Gibraltar strait.

Different companies are serving these traffics even several ship owners have disappeared like COMANAV or COMARIT. Grandi Navi Velocci is using 4 ships in this service and Grimaldi Group with one ship; both cover the area from Genoa, Sète and Livorno calling also in Barcelona.

From Sète, Grandi Navi Velocci covers the route with Nador (Morocco) weekly with a ship, being most of them the same modern, big capacity and high speed units.

Grimaldi Group has important routes linking Italian Ports like Salerno and Civitavecchia with the Port of Valencia in Spain. Part of the freight could be discharged in Palma and taken by the lines that link Genoa, Sète and Livorno with Tangier-Med.

Ships used by several companies are giving service between peninsula and Balearic Islands, deploying also different type of ships depending on the frequencies, speed and type of cargo, required. The nowadays offer affords to adjust prices but they are still high because there is no cargo for return to peninsula voyages.

But shipping companies usually has used vessels for carrying rolling cargo with or without passenger capacity and during the last years it has been possible to confirm an increase in the size and speed of the newer ships (Moreno, 2008). As a general trend we can confirm that the vertical cargo has been slowly disappearing and the only freight Ro/Ro ships also are being removed by Ro/Pax units.

Nowadays the average ship used in the studied traffics, is mainly a vessel with a good cargo capacity, with a speed of around 20 knots or more and certain capacity for passengers and their vehicles.

4.2 *Climatology around the Balearic Islands*

With the aim to carry out a sample of the traffic versus climatic conditions in the middle of the Western Mediterranean, the authors have selected the Balearic Islands and specifically the port of Palma of Mallorca.

The port of Palma, is part of the Western Mediterranean scenario in terms of climatic conditions, and it is not an exception. The pressure, temperature and raining, conditions are similar to the ones in this area but the local winds regime is a little bit different.

Pressure has no major variations during the year and this value is relatively high. So we can confirm that there is stability during the year round and in general terms there are very stable conditions due to its situation in the 40º of latitude.

Regarding the wind conditions, we can observe that the most common wind during the year is SW in the Palma bay. The W and NW winds are common in autumn and winter time and even very cold N and NE. Southerlies are typical in summer time which can affect the ships' manoeuvres from midday to the afternoon.

Also in summertime it is possible to register very strong SE winds but those are not so common and can join to coastal breezes.

Temperatures are not so cold in winter but not so hot in summer, this last because of the medium size of the island that does not afford a very high warming of the air during the summer. Because of this mentioned slight warming of the air on the island surface, it elevates leaving pass to the sea breeze and giving a certain degree of humidity in the environment.

Precipitations are most common in autumn, being spring the other season with some rain levels, but in general terms the situation is very similar to the one in the Iberian Peninsula.

5 CONCLUSIONS

This paper has analysed one of the parameters to evaluate the adoption of a future ECA in the Mediterranean Sea: the prevailing weather conditions related with the general traffic.

Obtained analysis demonstrates that the weather pattern in the basin of the Mediterranean is affected by many differing systems and is quietly unpredictable being quick to change and often very different at two places only a short distance apart. Due to the high surrounding land masses and the latitude, the climate can at times be extreme but on the average it is very pleasant especially in the summer months. As big conclusions, we can confirm that excluding the coastal breezes that can carry the smoke among ten to twelve miles inside the shore when it blows from sea, the Mediterranean is characterized by strong Northerly winds in winter time within the Gulf of Lyon, Adriatic Sea and Aegean sea, that carry the smoke to the south coast of the basin. In the other hand, we can face opposite situations when lows travel across the Mediterranean, bringing the air masses from South to the European coasts, as the cases of Sirocco, Ghibli or Khamsin.

The traffic patterns are well represented in the different pictures published in several fora with a main lane between Gibraltar and the entrance to Suez Canal and two main legs in the N-S direction, crossing the Bosporus strait and the western Mediterranean coasts.

Further research is needed to evaluate the rest of criteria to designate a future ECA in the Mediterranean Sea. The emission quantification and impact assessment and land based measures concurrent with the ECA adoption criteria has been evaluated in previous work (Castells et al. 2014, Usabiaga et al, 2012).

In this respect an ECA proposal by a Mediterranean country is all the more essential keeping in mind that since its proposal, around five years is needed until its adoption. On the contrary by 2017 road transport would have swept away maritime transport.

REFERENCES

[1] Admiralty Charts and Publications. Mediterranean Pilot. Volumes I to VI.
[2] Castells, M.; Usabiaga, J.J.; Martinez de Osés, F.X. 2014. Manoeuvring and hotelling external costs: enough for

alternative energy sources?. Maritime Policy & Management, Vol. 41. Nº. 1, 42–60

[3] COMEXT. Statistical Office of the European Communities. 2006. European Commission. Luxembourg.

[4] Eiden G. et al, 2010. Performance of AIS sensors in space - PASTA-MARE project final report executive summary

[5] European Commission, 1998. Directive 1998/70/EC of the European parliament and of the council. Official Journal of the European Union.

[6] European Commission, 2005. Directive 2005/33/EC of the European parliament and of the council. Official Journal of the European Union.

[7] European Commission, 2009. Directive 2009/30/EC of the European parliament and of the council. Official Journal of the European Union.

[8] European Union, 2011. EU transport in figures. Statistical pocketbook 2011. 22 p.

[9] Eurostat, 2012. Maritime transport statistics – short sea shipping of goods. Available from internet: <http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Maritime_transport_statistics_-_short_sea_shipping_of_goods>.

[10] Ferdynus, J, 2012. Polish Seaports – Unfavorable Weather Conditions for Port Operation (Applying Methods of Complex Climatology for Data Formation to be Used by Seafaring). Transnav, the International Journal on Marine Navigation and Safety of Sea Transportation, Volume 6 Number, p 131-139.

[11] International Maritime Organization (IMO), 2009. Revised MARPOL Annex VI – Regulations for the prevention of air pollution from ships and NOx Technical Code. London.

[12] Kottek, M. Grieser, J., Beck, C., Rudolf B. and Rubel, F. 2006. World Map of Köppen-Geiger climate classification updated. Meteorologische Zeitschrift, Vol. 15, Nº 3, 259-263

[13] Lionello, P, Malanotte-Rizzoli, P and Boscolo, R. 2006. Mediterranean Climate variability. Developments on Earth and environmental sciences. ELSEVIER B.V. Amsterdam.

[14] Meech, R., 2008. Designation of the Mediterranean Sea as a SOx Emission Control Area (SECA) under MARPOL Annex VI. SAFEMED project, task 3.7.

[15] Moreno Trobat, C. 2008. Análisis de la evolución del tráfico de transporte rodado en el transporte marítimo de corta distancia en el Mediterráneo Occidental. Thesis Master degree. Facultat de Náutica de Barcelona.

[16] NESTEAR. Nouveaux ESpaces de Transport en Europe Applications de Recherche. 2008. Gentilly. France.

[17] Official Spanish ports portal. Available from internet: www.puertos.es

[18] Sanderson, M., 1999: The classification of climates from

Pythagoras to Koeppen. – Bull. American Meteor. Soc. **80**, 669–673.

[19] Sociedad Estatal de Salvamento Marítimo. Spanish Search and Rescue Agency. 2013. www.sasemar.es.

[20] Suez Canal Authority. 2013. Traffic statistics. http://www.suezcanal.gov.eg/TRstat.aspx?reportId=1. Egypt

[21] Usabiga J.J, Martínez de Osés F.X., Castells M, 2012. Assessment for possible ECA adoption in the Mediterranean Area (Short Sea Shipping vs. Road Transport). International Conference on Traffic and Transport Engineering. Belgrade

[22] Wall C., 2007. Ships Emissions Inventory – Mediterranean Sea. Entec UK limited.

[23] Website of general Mediterranean weather. Available from internet: www.eurometeo

[24] Website of Istitute Superiore per la Protezione e la Ricerca Ambientale. Available from internet: www.idromare.it

[25] Winebrake, J. J.; Corbett, J. J.; Green, E. H.; Lauer, A.; Eyring, V., 2009. Mitigating the Health Impacts of Pollution from International Shipping: An Assessment of Low-Sulfur Fuel Mandates. Environmental Science and Technology, 43(13), p.4776-4782.

[24] Xiang, Z et al, 2012. Applied Research of Route Similarity Analysis Based on Association Rules. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, Volume 6 Number 2, p 181-185.