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Atmospheric impact of ship traffic in four Adriatic-Ionian port-cities: Comparison and harmonization of different approaches

E. Merico [a,b], A. Gambaro [b,c], A. Argiriou [d], A. Alebic-Juretic [e], E. Barbaro [b,c], D. Cesari [a], L. Chasapidis [f], S. Dimopoulos [d], A. Dinoi [a], A. Donateo [a], C. Giannaros [i], E. Gregoris [b,c], A. Karagiannidis [d], A.G. Konstandopoulos [f,g], T. Ivošević [h], N. Liora [i,d], D. Melas [i], B. Mifka [e], I. Orlić [j], A. Poupkou [i,d], K. Sarovic [k], A. Tsakis [f], R. Giua [l], T. Pastore [l], A. Nocioni [l], D. Contini [a,*]

[a] Institute of Atmospheric Sciences and Climate, ISAC-CNR, 73100 Lecce, Italy
[b] Department of Environmental Sciences, Informatics and Statistics, Ca' Foscari University of Venice, 30172 Venice Mestre, Italy
[c] Institute for the Dynamics of Environmental Processes, IDPA-CNR, 30172 Venice Mestre, Italy
[d] Laboratory of Atmospheric Physics, University of Patras, 26500 Patras, Greece
[e] Environmental Health Department, School of Medicine/Teaching Institute of Public Health, University of Rijeka, 51000 Rijeka, Croatia
[f] Aerosol & Particle Technology Laboratory, CERTH/CPERI, 57001 Thermi, Thessaloniki, Greece
[g] Department of Chemical Engineering, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
[h] Education and Teacher Training Agency, 51000 Rijeka, Croatia
[i] Department of Physics, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
[j] Department of Physics, University of Rijeka, 51000 Rijeka, Croatia
[k] Ekonerg, 10000 Zagreb, Croatia
[l] Regional Environmental Prevention and Protection Agency, ARPA Puglia, 70126 Bari, Italy

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ABSTRACT

Shipping is a growing transport sector representing a relevant share of atmospheric pollutant emissions at global scale. In the Mediterranean Sea, shipping affects air quality of coastal urban areas with potential hazardous effects on both human health and climate. The high number of different approaches for investigating this aspect limits the comparability of results. Furthermore, limited information regarding the inter-annual trends of shipping impacts is available. In this work, an approach integrating emission inventory, numerical modelling (WRF-CAMx modelling system), and experimental measurements at high and low temporal resolution is used to investigate air quality shipping impact in the Adriatic/Ionian area focusing on four port-cities: Brindisi and Venice (Italy), Patras (Greece), and Rijeka (Croatia). Results showed shipping emissions of particulate matter (PM) and NOx comparable to road traffic emissions at all port-cities, with larger contributions to local SO_2 emissions. Contributions to $PM_{2.5}$ ranged between 0.5% (Rijeka) and 7.4% (Brindisi), those to PM_{10} were between 0.3% (Rijeka) and 5.8% (Brindisi). Contributions to particle number concentration (PNC) showed an impact 2–4 times larger with respect to that on mass concentrations. Shipping impact on gaseous pollutants are larger than those to PM. The contribution to total polycyclic aromatic hydrocarbon (PAHs) concentrations was 82% in Venice and 56% in Brindisi, with a different partition gas-particle because of different meteorological conditions. The inter-annual trends analysis showed the primary contribution to PM concentrations decreasing, due to the implementation of the

* Corresponding author.
E-mail address: d.contini@isac.cnr.it (D. Contini).

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European legislation on the use of low-sulphur content fuels. This effect was not present on other pollutants like PAHs.

1. Introduction

Maritime transport handles over 80% of the volume of global trade (UNCTAD, 2015). Although shipping represents a growing asset within the transport sector, it was difficult, prior to 2008, to quantify its global emissions because these were one of the least regulated anthropogenic sources of atmospheric pollution (IMO, 2008). Due to methodological difficulties in allocating emissions to countries, international shipping was also not regulated by the Kyoto Protocol. Great efforts have been made in Europe to reduce other types of land-based emission sources (industrial, power generation, road traffic), and this resulted, for some pollutants, in an increase of the relative weight of shipping emissions with respect to total anthropogenic emissions (Viana et al., 2014). Recent analysis of global GHG emissions (expressed on a CO_2 basis) of international shipping showed a decrease in relative terms from 2.8% in 2007 to 2.2% in 2012 (Smith et al., 2014). In the Marine Strategy Framework Directive 2008/56/EC of the European Parliament, emissions from ships are mentioned explicitly in the list of pressures and impacts that should be reduced or minimized in order to maintain or to obtain a good ecological status (Blasco et al., 2014). Consequently, several research were dedicated to the analysis of green harbours (Davarzani et al., 2015).

Oceangoing ships were estimated to emit (prior to 2009) annually 1.2–1.6 Tg of particulate matter (PM), 4.7–6.5 Tg of sulphur oxides (SO_X as S), and 5–6.9 Tg of nitrogen oxides (NO_X as N) (Healy et al., 2009). More recent estimates (Smith et al., 2014) are 5.6 Tg of NO_X (as N) and 5.3 Tg of SO_X (as S). In the Mediterranean Sea shipping is responsible for 40 and 49% of the total European shipping emissions of CO_2 and SO_X, respectively (Jalkanen et al., 2016). Given its importance in both health effects and radiative forcing, research efforts have also been devoted to investigate black carbon (BC) emissions from shipping that represent about 2% of global BC emissions (Corbett et al., 2010; Lack and Corbett, 2012). Shipping typically contributes with 1–7% to the annual mean PM_{10} levels, with 1–20% to $PM_{2.5}$, and with 8–11% to PM_1, especially in coastal areas (Viana et al., 2014). Emissions within harbours are a relatively small fraction of global shipping emissions but they can have important effects on human health and climate in coastal areas and nearby towns. The estimate of their impact is also challenging because of the dependence of emissions from engine types and loads, fuels, and the different operating profiles of ships at berth, during manoeuvring and normal cruising. Size distribution of PM emissions is an important parameter, to investigate impacts of shipping, that has been thoroughly studied in several research works showing that shipping emissions in number are dominated by small particles (Kasper et al., 2007; Petzold et al., 2008; Kivekäs et al., 2014; Merico et al., 2016).

The assessment of impacts from shipping is a difficult task because these include environmental effects that occur on very different temporal and spatial scales. The climate effect of ship emissions is complex with opposite contributions: a short-term cooling and a long-term warming (Fuglestvedt et al., 2009). CO_2 and black carbon (BC) emissions from the shipping sector have a warming effect while NO_X increase the levels of greenhouse gases (GHG) and ozone (O_3), reducing methane (CH_4) levels. In summary, nowadays the net radiative forcing (RF) caused by the shipping sector is negative, about $-0.4\ W/m^2$ in 2005 (Eyring et al., 2009). The reduction of SO_2 emissions tends to amplify the warming effect (Fuglestvedt et al., 2009), however, it has to be considered that this reduction could be accompanied with changes of emissions of other pollutants so that the global effect on climate is still unclear.

The environmental regulations expected to have the greatest impact on the future bunker fuel mix are the SO_X and NO_X limits set by the IMO (International Maritime Organization) with the MARPOL Annex VI, which will become more stringent

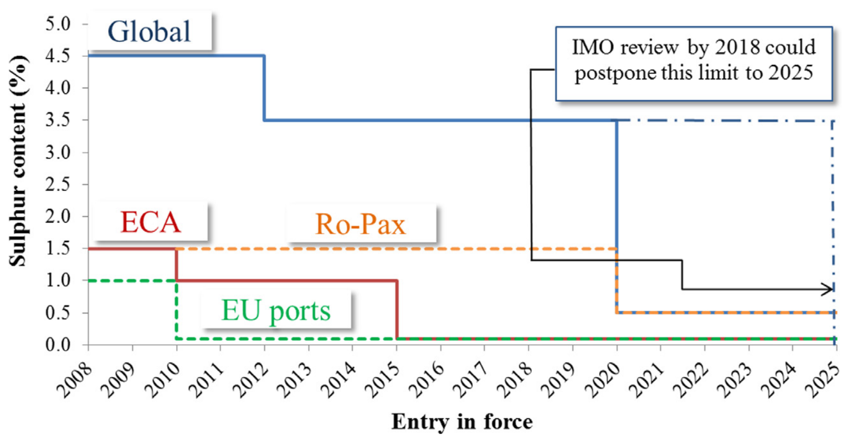

Fig. 1. Maximum sulphur content in fuels according to IMO and EU legislation.