Research Article

An investigation on the use of air quality models in ship emission forecasts

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DOI: 10.51513/jitsa.1425614

Abstract: One of the most important sources of air pollution, which has become a global concern today, is transportation. Considering that world trade is largely carried out by sea, ship emissions constitute one of the main components of this pollution. The first and most critical step in combating ship-borne air pollution, which is more intangible than other types of pollution, is the accurate measurement of air pollution. Today, it is possible to calculate ship emissions with individual ship activity data instead of the traditional fuel-based approach. One of the most ideal data sources for this calculation is AIS data. In this study, we investigated how to obtain the highest resolution output with AIS data and the results revealed the critical importance of air quality models. In this direction, air quality models used in ship emission calculation are analysed with PRISMA method and the most commonly used Eulerian and Lagrangian models are discussed. Thus, a profile of alternative air quality models used in ship emission calculation has been obtained and it is aimed to contribute to the literature by creating a reference source for new studies to be conducted with individual activity data.

Keywords: Air quality modelling, Automatic Identification System, ship emissions

Hava kalitesi modellerinin gemi emisyon tahminlerinde kullanılması üzerine bir araştırma

Özet: Günümüzde küresel bir endişe haline gelen hava kirliliğinin en önemli kaynaklarından biri ulaştırmadır. Dünya ticaretinin büyük ölçüde denizyolu üzerinde işlediği düşünüldüğünde, gemi emisyonları bu kirliliğin ana bileşenlerinden birini oluşturmaktadır. Diğer kirlilik türlerine göre daha soyut bir alana işaret eden hava kirliliği ile mücadelede ilk ve en kritik adım hava kirliliğinin doğru ölçülmesidir. Günümüzde gemi emisyonlarını yakıt bazlı geleneksel yaklaşım yerine bireysel gemi faaliyet verileriyle hesaplamak mümkündür. Bu hesaplama için en ideal veri kaynaklarından biri AIS verisidir. Bu çalışmada AIS verileri ile en yüksek çözünürlüklü çıktının nasıl elde edileceği araştırılmış ve elde edilen sonuçlar hava kalitesi modellerinin kritik önemini ortaya çıkarmıştır. Bu doğrultuda gemi emisyon hesaplamasında kullanılan hava kalitesi modelleri PRISMA metodu ile incelenmiş ve en yaygın kullanılan Eulerian ve Lagrangian modeller tartışılmıştır. Böylelikle gemi emisyon hesabında kullanılan alternatif hava kalitesi modellerinin profili elde edilmiş ve bireysel aktivite verisi ile yapılacak yeni çalışmalar için bir referans kaynağı oluşturularak literatüre katkı sağlamak hedeflenmiştir.

Anahtar Kelimeler: Hava kalitesi modelleme, Otomatik Tanımlama Sistemi, gemi emisyonları

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Received 25 January 2024; Received in revised form 12 February 2024; Accepted 16 February 2024
Peer review under responsibility of Bandirma Onyedi Eylul University.

1. Introduction

Today, 90% of world trade is carried out by maritime transportation (ICS, n.d.). Transportation systems that use fossil fuels contribute significantly to global climate change. In this context, the maritime industry is responsible for a significant portion of global climate change (Kodak, 2021). Air pollution from ships plays a decisive role on air quality on a global scale. Studies conducted by the European Environment Agency (EEA) indicate that if effective measures are not taken to reduce emissions, CO2 emissions from international maritime activities may constitute 17% of total CO2 emissions by 2050. Combined with aviation activities, this ratio is estimated to account for 40% of global CO2 emissions by 2050 (Nusa and Kodak, 2023; TERM, 2017). At this point, the fight against air pollution caused by ships has become an international problem and has led the competent authorities to cooperate in making legal arrangements. The International Maritime Organization (IMO) has been operating since the 1960s to combat the harmful environmental effects of shipping. Air pollution from ships falls within the scope of Annex VI of the "The International Convention for the Prevention of Pollution from Ships" (MARPOL 73/78). Annex VI, adopted in 1997, contains the "Regulation for the Prevention of Air Pollution from Ships". The activities and regulations carried out within the scope of MARPOL 73/78 Annex VI generally aim to control the impact of SOx, NOx, ODS and VOC from ship fuels on air quality, human health and environmental problems.

As a result of the studies carried out within the scope of combating ship-borne air pollution in the past ten years, decisions have been taken that will change the dynamics of the world trade fleet. At the Marine Environment Protection Committee (MEPC) 72nd Session held on 9 – 13 April 2018, the first strategy to reduce ship-sourced greenhouse gases was adopted. In this framework, it is aimed to reduce annual greenhouse gas emissions by 50% in 2050 compared to 2008, and to reduce them to zero in the long term. In terms of carbon intensity, the target is to reduce CO2 emissions by 40% by 2030 and by 70% by 2050 compared to 2008 (MEPC 72, n.d.). These aims have emerged as a result of many serious studies carried out in the historical process. In 2011, mandatory energy efficiency regulations were adopted under the "Energy Efficiency Design Index (EEDI)" for new ships and the "Ship Energy Efficiency Management Plan (SEEMP)" for all ships within the framework of MARPOL Annex VI and entered into force in 2013. In 2014, the 3rd IMO GHG Study 2014 was approved. In 2015, EEDI phase 1, which regulates the 10% reduction of carbon intensity on new ships, entered into force (IMO, 2021). With the regulation that entered into force on 1 January 2015 to limit the sulfur content in fuel, it has been decided that the sulfur content in fuel oil should not exceed 0.10% m/m for ships operating in designated emission control areas as of January 1, 2020. It has been decided not to exceed 0.50% m/m for ships carrying out transportation outside these areas (IMO, 2019).

In 2016, the IMO Data Collection System (DCS) was adopted to collect and report fuel consumption data from ships over 5.000 GRT. 2019 was the first year of mandatory reporting of fuel consumption data to the IMO Data Collection System. In 2020, EEDI phase 2 came into effect, regulating up to 20% reduction in carbon intensity on new ships (IMO, 2021). In 2021, the aggregated results of DCS for 2019 have been obtained. In 2022, as of October-November 2021, the evaluation of the effects of the measures on states began.

When the fight against ship-borne air pollution is examined in the historical process, the strategic importance of the data emerges. Adoption of the IMO Data Collection System (DCS) in 2016, making it mandatory to add fuel consumption data to the DCS in 2019, and starting to evaluate the impact of the measures with the DCS results have drawn attention to the critical role of data. Because progressing towards these goals is possible by observing the effect of the regulations made. This depends on the correct calculation of the activity. Today, studies in the field of air quality that give the highest resolution results are air quality models. The use of air quality models in ship emission calculations and forecasts is a fairly new approach. With the introduction of AIS data into the literature, the use of the Tier 3 method in the calculation of ship emissions has increased. The Tier 3 approach, which is based on individual ship emission calculation instead of the traditional method based on fuel data, gives much higher resolution results. AIS data constitutes a unique resource in emission calculation, especially in terms of providing input to model studies. The literature review shows that the use of AIS data in air quality studies is increasing day by day (Kodak 2022).

Considering IMO's targets for 2050 and beyond, air quality models working with AIS data will play a key role in understanding how effective the measures taken are. In other words, the air quality models will serve as a mirror that shows the effectiveness of the regulations made in the field of ship emissions. The key role of AIS data in the calculation of ship emissions has been scientifically discussed before in the literature (Kodak, 2022). In this study, the integration of AIS data into air quality models was examined by PRISMA method and the answers to the following questions were sought.

- Which air quality models use AIS data to calculate ship emissions?
- How has the use of AIS data in air quality model studies been reflected in the literature over time?
- What is the spatial distribution of air quality model studies with AIS data?
- How is the distribution of air quality model studies made with AIS data to scientific journals?

As a result, one of the most critical tools to achieve IMO environmental goals is to measure the effectiveness of regulations. Considering the targets for 2050 and beyond, the use of air quality models in ship emissions studies will be of strategic importance. At this point, it is necessary to recognize air quality models and encourage the use of AIS data as input in these model studies. The aim of this study is to find answers to the above-mentioned research questions and at the same time to raise awareness about new generation data analysis techniques in ship emission studies. Thus, the study will contribute to the literature as a reference source for both the measurements to be made by the IMO and the researchers working in this field.

2. Air quality models

Air quality measurements show the cumulative air quality caused by different pollutant sources together. Air quality measurements alone are not sufficient to determine the individual contributions of polluting sources. Air quality models are used to respond to this need. Air quality models, one of the most critical elements of air quality assessment, are tools that can mathematically simulate the physical and chemical processes that pollutants will be exposed to in the atmosphere (EPA, 2022). Air quality modeling studies are generally carried out to determine the pollutants released into the atmosphere from various sources under effective processes such as diffusion, chemical formation/conversion, dispersion, accumulation, advection/convection in different meteorological conditions. Atmospheric modeling is basically divided into 2 groups according to being Lagrangian and Eulerian based. The difference between Eulerian and Lagrangian models is that the coordinate system is used fixed and dynamic. Eulerian models adopt a fixed coordinate plane, while Lagrangian models are based on a moving coordinate system.

Lagrangian models are constructs with constraining assumptions in their formulation and works with less detail. In contrast, grid-based Euler models that yield high resolution results have much less restrictive assumptions and are potentially the most powerful (Hu, 2015).

Eulerian and Lagrangian approach are shown in Figure.1.

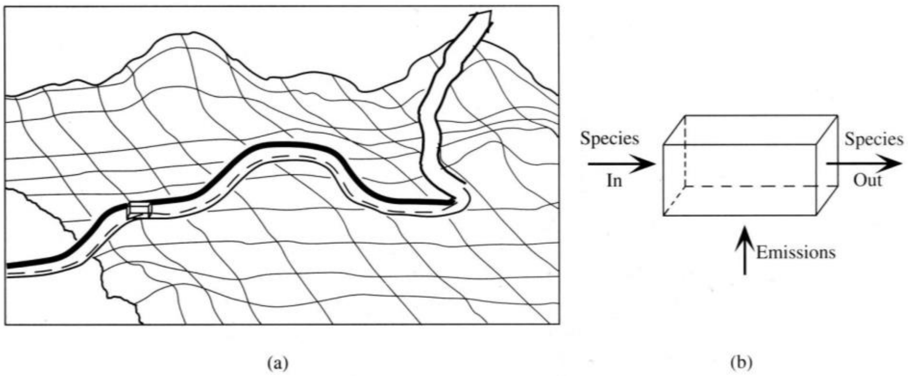

Figure 1. Eulerian and lagrangian approach (Zang, 2019; Seinfeld and Pandis, 2006).

The results obtained within the scope of this study revealed the most frequently used air quality models in the field of ship emission calculation in the last 22 years. In line with the findings, the most frequently used Eulerian models WRF / CMAQ and WRF / CHEM and Lagrangian models CALPUFF and AERMOD were introduced with their general characteristics.

2.1. Eulerian Models

Air quality models are used to determine the concentrations of pollutants in the environment after emissions have occurred. These atmospheric models use emission, meteorology and topography-based information as input data. Then, by operating numerical techniques, they can run physical processes in the atmosphere as well as can be used with chemistry algorithms that process chemical reactions. In the Euler approach, time-dependent physical and chemical changes in the air parcel are followed with a fixed coordinate system. Many of the photochemical air quality models that are widely used today use the three-dimensional Euler grid approach, which has the ability to better characterize the physical processes in the atmosphere (Tayanç, 2013). Euler models are high-resolution models that can analyse many atmospheric processes temporally and spatially. WRF/CMAQ, WRF/CHEM and CAMx are examples of Eulerian models.

2.1.1. WRF/CMAQ

Air quality models are typically operated in two different ways, independent and combined. In standalone models, the previously archived output of a meteorological model is used to run the air quality model. On the other hand, in combined models, air quality and meteorological models are run simultaneously. This provides an advantage for studying interactions between chemical and meteorological processes. One of the most effective examples of coupled models is the WRF / CMAQ model. The model has emerged by integrating the Community Multiscale Air Quality Model (CMAQ) into the Weather Research and Forecasting (WRF) model (EPA, 2023c). In the WRF-CMAQ model, WRF and CMAQ are integrated simultaneously and information from the CMAQ is passed into the WRF to predict how chemical processes will affect the weather. Another advantage of the WRF/CMAQ model is that it provides users options to adjust the estimates of the variables under different possible scenarios (Wong et al., 2012). Typical running cycle of WRF is given in Figure 2.

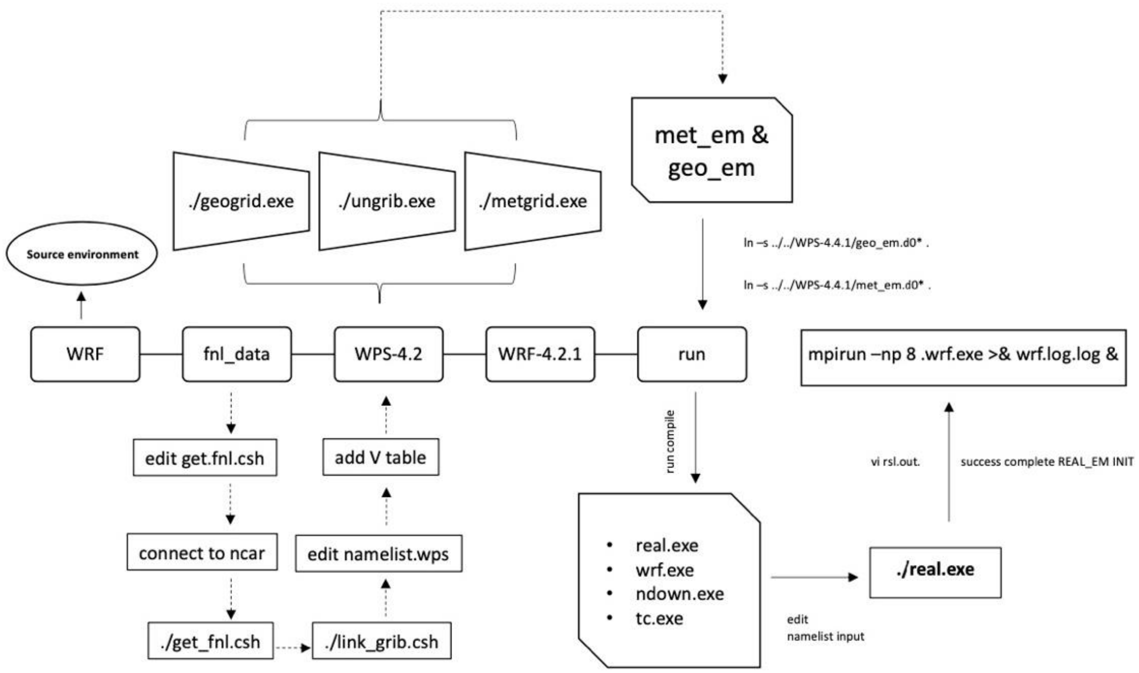

Figure 2. WRF flow chart

The first stage of the WRF running cycle introduced on the Linux operating system within the scope of the study starts with the source environment command. Linux is an operating system that allows us to install different versions of a model. The "source environment" command, which means read and run in the most general sense, makes the version we will use in Linux ready. The second step is to determine the boundaries of the area we will work with for mesoscale models. This requires downloading global model outputs from the NCAR (National Center for Atmospheric Research) database and creating a boundary condition. The fnl_data in WRF contains the meteorology data downloaded for the model. The first thing to do in this context is to organize the date range to be studied on the data. The next stage of the process is to download the topography, land use, etc. data required for WRF in WPS-4.2, organize the parameters to be run under "namelist", and make the model ready for application by introducing the variable table of the global model into V Table. Successfully completing the processes under WPS-4.2 will generate executable geogrid, ungrib and metgrid files. As a result of the successful operation of these three files using namelist.wps as input, met_em and geo_em files will be created. The next step is to link the generated met_em and geo_em files under WRF-4.2.1. When compile the run under WRF-4.2.1, the files we expected to be generated are real.exe, wrf.exe, ndown.exe and tc.exe. After this stage, first real.exe and then wrf.exe are run. Thus, wrf_out files with WRF outputs are obtained.

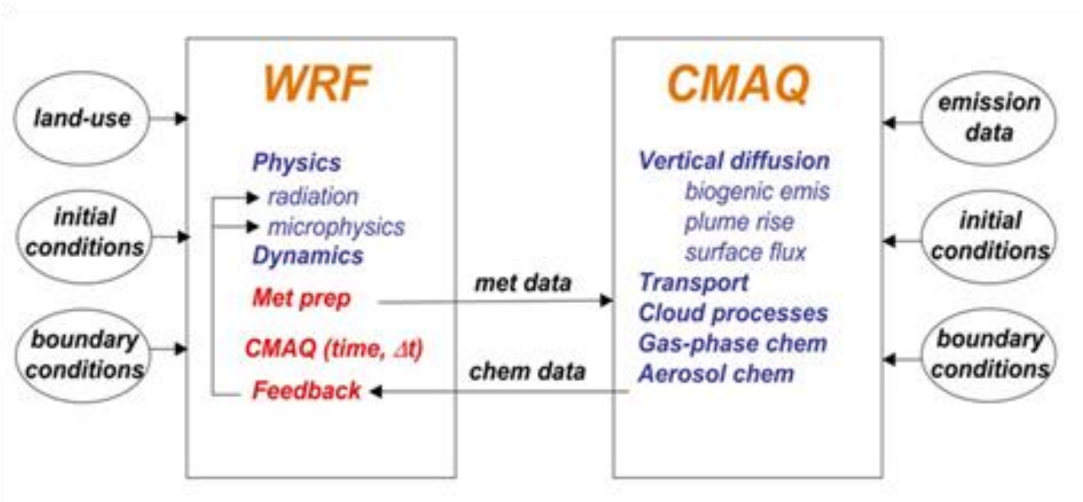

Figure 3. WRF-CMAQ model interaction (Wong et al., 2012).

After the WRF output files are created, the process continues with the pre-processing that must run before installing the CMAQ. The pre-processing process includes boundary conditions, initial conditions and MCIP (Meteorology-Chemistry Interface Processor) stages which preparing the WRF output files for CMAQ.

2.1.2.WRF/CHEM

CMAQ is an offline chemical transport model operating with stored meteorological data from regional to continental scale weather forecast models. The Weather Research and Forecasting with Chemistry model (WRF/Chem) is online coupled chemistry and meteorology. WRF/CHEM is beneficial for analyzing two-way interactions between chemistry, aerosols, meteorology, and radiation. (Herwehe1 and Kang, 2006; Byun and Schere, 2006; Grell et al., 2005). CMAQ is better than WRF/Chem both in terms of chemical mechanism and in correlating observation results and offering a range of values for extremes (Herwehe1 and Kang, 2006).

The WRF/Chem modeling system follows the same structure as the WRF model given in Figure 2. The difference between regular WRF and WRF/CHEM is the chemistry part of the WRF/CHEM model that needs to provide additional gridded input data related to emissions. This additional input data is provided either by the WPS or read in during the real.exe initialization or read in during the execution of the WRF solver. Although some programs are provided to assist the user in generating these external input data files, these programs are not set to work for all possible namelist options for the WRF-Chem model for all emissions. Sometimes, generating emission input data to simulate the state of the atmosphere's chemistry can be incredibly complex. In some cases, the user needs to change the code or model configuration for it to work properly in their project (NOAA, n.d.).

2.2. Lagrangian Models

In the Lagrangian approach, the coordinate system moves with the air parcel. Time-dependent changes in the air parcel are expressed in situ. While the Lagrangian approach provides advantages in pollutant formation and transport calculations, it is disadvantageous because it cannot fully describe the physical and chemical processes (Eliassen, 1984; EPA, 2023). CALPUFF (California Puff Model) and AERMOD (AMS/EPA Regulatory Model) are examples of Lagrangian models. CALPUFF, based on Gaussian dispersion, is a lagrange puff model. The CALMET/ CALPUFF model system is a multilayer dispersion model that can calculate the effects of temporally and spatially varying meteorological conditions during pollutant transport, pollutant removal by wet-dry deposition processes, and transformation by chemical reactions. The CALMET/CALPUFF modelling system consists of CALMET, a 3-D diagnostic meteorological model, and CALPUFF, an air quality dispersion model (Tayanç, 2013). AERMOD modelling system is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts (EPA, 2023b). CALPUFF and AERMOD are widely used air dispersion models around the world to assess the effects of air emissions. There are significant differences that make these two models applicable to different scenario types.

2.2.1. AERMOD

AERMOD is an air dispersion model developed and actively used by the EPA. The model was first released as a full version in 2006. Since 2006, many stakeholders and users, such as government, industry, academia, have collaborated to develop the model on a regular basis. Today, AERMOD, U.S. It is recognized as the preferred model by the EPA. In other words, AERMOD can be used for most modelling applications without special approval. In contrast, use of other models, including CALPUFF, in the USA is subject to specific approval. AERMOD is a steady-state gaussian dispersion model and includes advanced PBL (Planetary Boundary Layer) parameterizations. Gaussian plume models are based on some assumptions as follows.

- Time-averaged spreading of the pollutants generates a normal distribution of pollutant concentrations, both horizontally and vertically through the pollutant plume.
- Continuously released material is transported directly opposite to wind direction.
- Horizontal plume centerline travels downwind in a straight line indefinitely.

Gaussian models assume constant meteorological conditions throughout the model space for each modelled period, regardless of dynamic temporal and spatial conditions. This approach is useful for short distances, as meteorological conditions are similar in the short-term and in close quarters. However, meteorological conditions can vary greatly over longer distances or time scales. Therefore, this approach does not give accurate results over long distances and time periods. For this reason, the US EPA does not recommend the use of AERMOD in areas greater than 50 km (Trinity Consultants, 2020).

2.2.2. CALPUFF

As AERMOD is not recommended in areas over 50 km, CALPUFF has emerged for the analysis of dynamic effects over long distance and time periods. Announced by the US EPA for long-range transport modelling between 2003 and 2017, this model has been reclassified as an alternative model with 2017 revisions. (Guideline on Air Quality Models Appendix W to 40 CFR Part 51) Thus, for a model that requires analysis of effects beyond 50 km, the local regulatory authority must be contacted to request the use of CALPUFF. AERMOD characteristically relies on representative observational meteorological data from a single location. An advantage of the CALPUFF model is that it can use gridded WRF meteorology files. In other words, CALPUFF is capable of using meteorological data from both multiple observation sites and meteorological grid models (Trinity Consultants, 2020).

As can be seen in Figure 2, WRF proceeds by extracting observation and archived meteorological model data from the region around the modelling domain. Thus, WRF datasets provide higher resolution outputs by more realistically representing meteorological changes due to spatial changes and it characterizes more accurately the atmospheric dispersion in complex environments. As a result, when compared to AERMOD, CALPUFF is an option that gives much higher resolution results both at long range and in long periods. With the advantage of using grid data and the ability to use WRF data, CALPUFF can take into account changes in direction due to meteorological or terrain changes and gain the ability to predict concentrations up to 200-300 km (Trinity Consultants, 2020). In addition to these advantages, the CALPUFF model also has some disadvantages. First of all, the processing times of meteorological data are longer than AERMOD because it involves various processing steps and big data files. This situation also requires computer hardware with high capacity in terms of memory. One of the effective solutions that can be developed at this point is to work with a programming language such as Python (Kodak, 2023).

3. Materials and methods

In this study, Scopus electronic database was used and a three-stage literature review was conducted. In the first stage, the literature was searched with the keyword "air quality modelling" and "ship emissions". In the second stage, studies using the AIS data were filtered and then focus on the both automatic and manual screening were performed to select studies and eliminate irrelevant sources. Articles containing “air quality modelling”, “ship emission” and “AIS” in the title, abstract and keywords were determined as inclusion criteria. On the other hand, studies with subject areas of “medicine”, “social sciences”, “health” and studies not written in English have accepted as exclusion criteria. It has been adopted as a separate criterion that the studies included in the literature review have passed at least one peer review. For this reason, studies that are not journal articles, such as conference proceedings, book chapters, editorials, books, notes, and so on, have excluded from the research. Finally, the primary interest of the study is the results of recent academic studies. Therefore, this article focuses on studies conducted in past two decades and covers articles published between 2000 and 2022. The search was carried out by the author on May 24, 2023. Main steps of the investigation are presented in Figure 4.

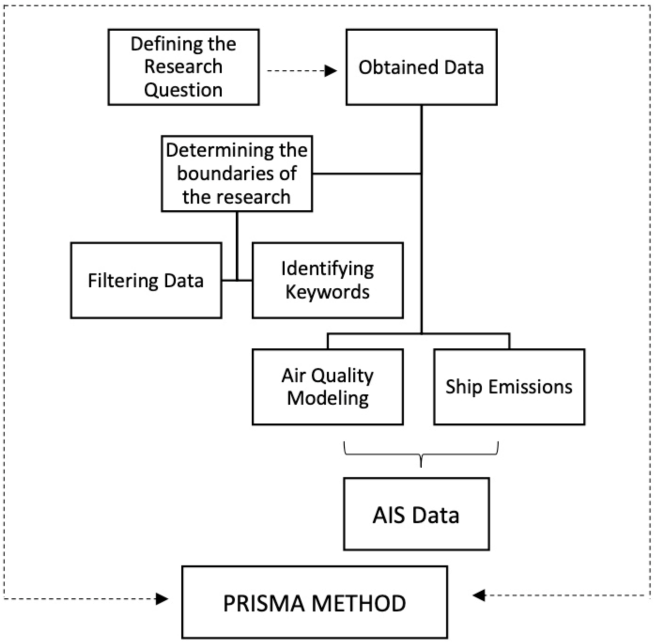

Figure 4. Main steps of the study

Obtained results have been analysed by PRISMA method. In this context, a total of 162 articles were reached. From these studies, review articles, book chapters, conference abstracts, editorials, short communications etc. isolated. In other words, in the first phase of the research, research articles focusing on "air quality modelling" and "ship emissions" have been filtered. Thus, 143 research articles have been reached. In the second stage, among these studies, studies based on AIS data were focused and a total of 38 articles were accessed. 3 review articles and 1 short communication were excluded from the obtained studies. Thus, the past, present and future of air quality model studies using AIS data in ship emission calculation were discussed through 34 articles included in the study. The results obtained with the PRISMA method are given in Figure 5.

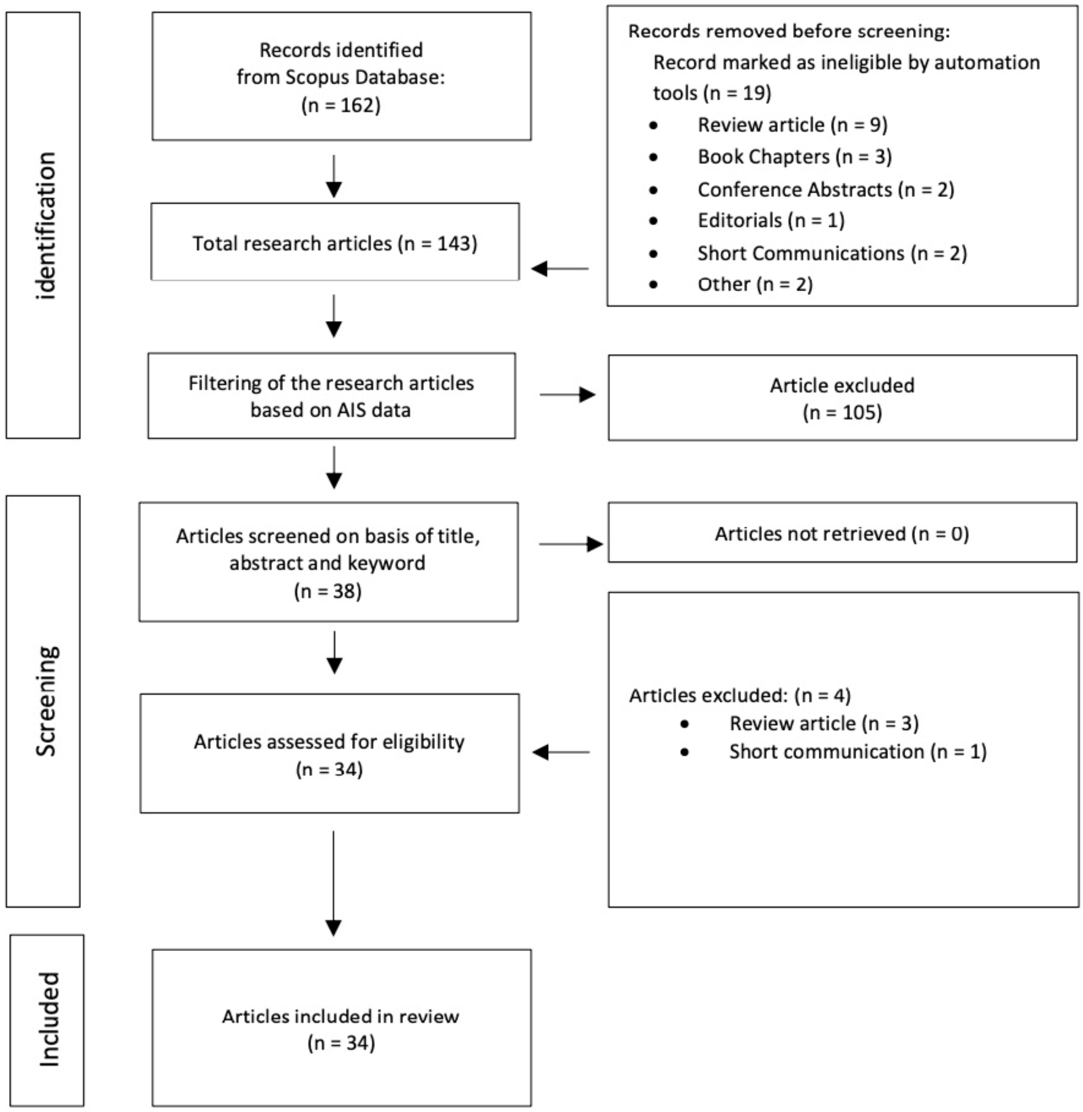

Figure 5. Application of the PRISMA method to the data set

4. Results and Discussion

Today, individual ship emission calculations based on activity data come to the fore instead of the classical method based on fuel data. At this point, AIS data plays a critical role. Kodak (2022) focused on the reflection of the use of AIS data in ship emission calculation in the academic literature. This study aims to go deeper into the problem and encourage the use of emission calculation based on AIS data directly with air quality models. Accordingly, the use of AIS data at the intersection of ship emissions and air quality models is highlighted. In this direction, Eulerian and Lagrangian models used in ship emission calculation were examined and the profile of alternative air quality models used in ship emission calculation was obtained. Thus, it is aimed to contribute to the literature by creating a reference source for new studies to be conducted with individual activity data.

When the 34 articles included in the research were examined in terms of the methods and keywords used, the following results were obtained. First of all, it is seen that studies using AIS data with air quality models in the calculation of ship emissions started after 2012. After 2012, the share of air quality model studies based on AIS data in the total studies generally showed an increasing trend. This rate has been reached its peak with 45% in 2019. Share of studies using AIS data among air quality model studies has been given in Figure 6.

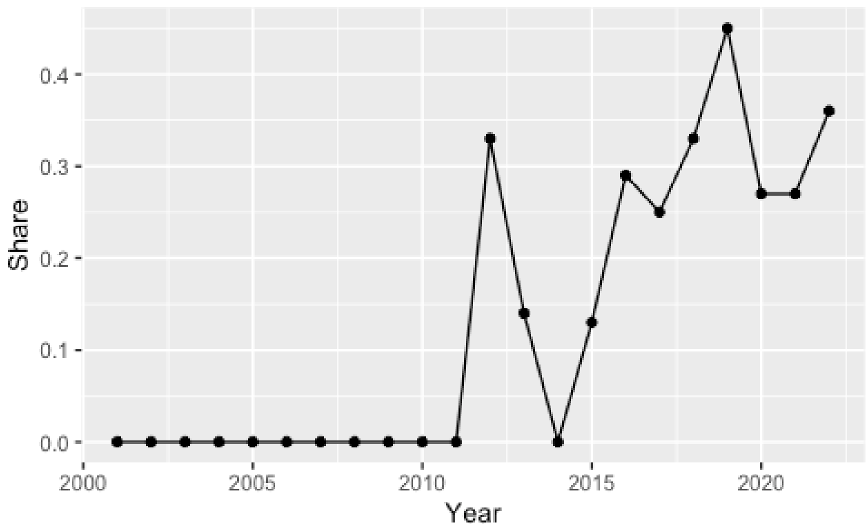

Figure 6. Share of studies using AIS data among air quality model studies

Air quality model studies focusing on ship emissions and time-dependent variation of the studies based on AIS data have given in Figure 7.

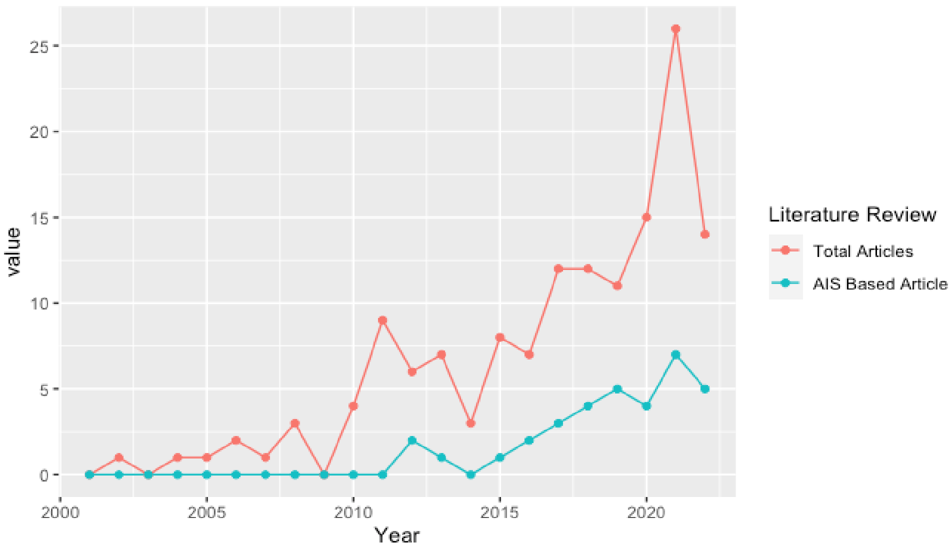

Figure 7. Time-dependent variation of studies using AIS data within air quality model studies

Figure 7 shows that there is a general simultaneous increase trend in both air quality model studies and AIS data-based model studies in terms of ship emission calculations. The year in which the studies reached the peak in both groups was 2019. A steady increase was observed between 2014 and 2019 in studies based on AIS data. The most definite increase in ship emissions & air quality model studies occurred between 2020 and 2021.

Within the literature review, 34 studies focusing on ship emissions, air quality model and AIS data have been reached. 24 of these studies are air quality model studies that directly use AIS data to calculate ship emissions at regional scale. Another critical distinction that comes to mind here is the spatial distribution of studies. The spatial distribution of the studies is given in Figure 8.

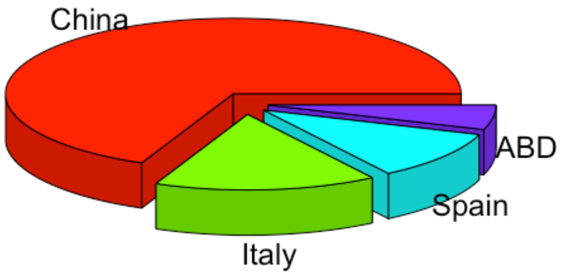

Figure 8. Spatial distribution of studies using AIS data in air quality model studies

Accordingly, it has been observed that the distribution of air quality modeling studies conducted with AIS data by regions is China (13), Italy (3), Spain (2) and the USA (1), respectively. The remaining 5 studies focus on calculating ship emissions on a global scale, not for a specific region. Looking at the geographical distribution of air quality models, it is seen that China is far ahead. Considering the regional distribution of studies conducted in China, it is seen that the main areas examined are Yangtze River Delta (3), Pearl River Delta (2), Bohai Rim Region (1), Tianjin Port (1) and Port. Yanitan (1). There are also 5 studies conducted across China. The distribution of the studies according to the journals is presented in Figure 9.

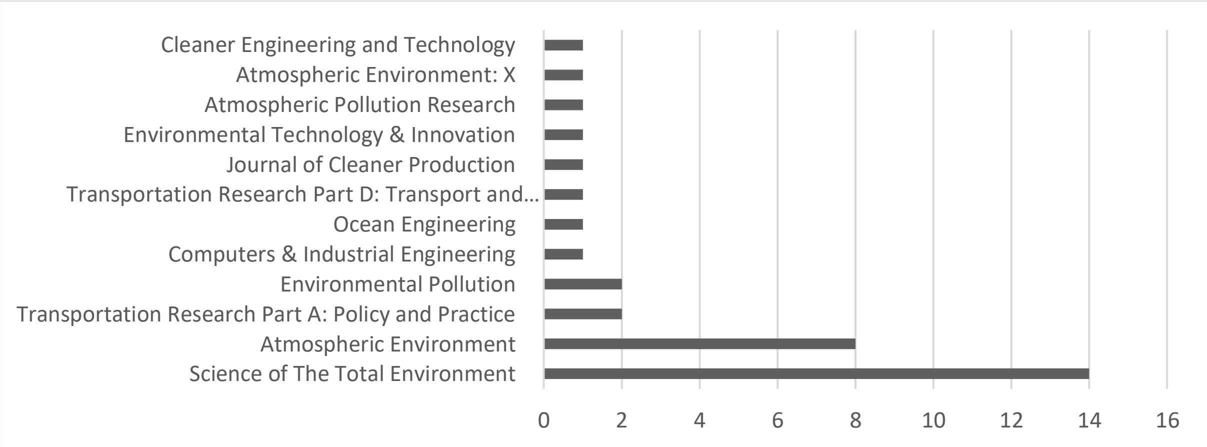

Figure 9. Distribution of the studies according to the journals

The results obtained from the literature review have shown that the studies focusing on AIS data among the air quality model studies are generally concentrated in the "Science of the Total Environment" and "Atmospheric Environment" journals. The 34 studies included in the study have filtered with the help of keywords in terms of the method used and the air quality model. 20 of these studies are air quality model studies that directly use AIS data to calculate ship emissions. Accordingly, Eulerian models WRF / CHEM and WRF / CMAQ, and Lagrangian models CALPUFF and AERMOD are the most widely used air quality models in ship emission calculations performed with AIS data in the 20-year literature. Findings have shown that 30% of these studies were modelled with WRF / CHEM, 15% with WRF / CMAQ and 10% with only CMAQ. Accordingly, 55% of the total studies were carried out with Eulerian models. In contrast, Lagrangian models account for 15% of the total studies. CALPUFF models constitute 10% of these studies, while AERMOD models constitute 5%. The remaining 30% of the total studies consists of studies carried out with the bottom-up approach based on AIS data.

5. Conclusion

Maritime transport is the backbone of international trade. Although it has many advantages in terms of transportation, trade and economy, it causes concern with the environmental pollution it causes. In this context, IMO develops effective strategies to achieve its long-term environmental goals. Especially in the last 10 years, the decisions taken by the Marine Environment Protection Committee within the scope of combating ship-borne air pollution are of a nature to change the dynamics of the world merchant fleet.

The first step in combating ship-borne air pollution is to correctly diagnose the current situation. This is also based on accurate measurement. Accurate estimation of emissions is possible with high quality data and the right method. The implementation of DCS, which was adopted by IMO for the collection and reporting of fuel consumption data in 2016, draws attention to the importance of data. One of the most ideal data sources that can be used as individual ship activity data in emission calculation is AIS data. The literature review shows that the use of AIS data in emission calculations has increased, but most of these studies are based on calculations made with the bottom-up approach. Today, technology enables modelling studies that produce high-resolution outputs in the field of atmospheric sciences. Modelling ship emissions with appropriate air quality models has the potential to yield the highest resolution results for policy makers and scientific researchers. The use of atmospheric modelling, which is essentially a subject of environmental sciences, in the maritime discipline is a fairly new approach. In this study, it is aimed to raise awareness about the interactive approach in question, to encourage studies in this direction and to create an infrastructure for future studies. For this purpose, a systematic literature review was made with the PRISMA method and the use of AIS data with air quality models was investigated. Thus, the past, present and future of the use of air quality models in ship emission calculations and forecasts are discussed. The following results were obtained within the scope of the study.

- In the literature, both eulerian and lagrangian models are used to calculate ship emissions. At this point, the most commonly used eulerian models are WRF/CMAQ and WRF/CHEM, while lagrangian models are CALPUFF and AERMOD.
- When the simultaneous change of use of AIS data in air quality models is examined, it is observed that the first study was done in 2012. In other words, there is no air quality model study based on AIS data in ship emission calculation in the Scopus database before 2012. Although it exhibited a fluctuating behaviour after 2012, it was observed that the share of the use of AIS data in air quality modelling studies generally tended to increase.
- From the perspective of ship emissions, the spatial distribution of studies using AIS data with air quality model studies has shown that China is overwhelmingly ahead. This has followed by Italy, Spain and the USA, respectively.
- When the distribution of the studies using AIS data with air quality models is analysed according to the journals, it is seen that the studies are mainly concentrated in two journals. These are Science of the Total Environment and Atmospheric Environment, respectively.

Researchers' Contribution Rate Statement

All research and writing steps belong to the corresponding author.

Acknowledgment and/or disclaimers, if any

There is no institution or organization to thank.

Conflict of Interest Statement, if any

No conflict of interest was declared by the author.

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