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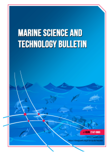

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RESEARCH ARTICLE

Tracking liquefied natural gas fuelled ship's emissions via formaldehyde deposition in marine boundary layer

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ABSTRACT

One of the reasons that anthropogenic greenhouse gas emissions estimation is imprecise is the uncertainty of aerosol impacts on cloud properties. Maritime transportation is slowly changing fuel preferences. With the policy framework changing regulations, the shipping business is going in a direction that emits less sulfur dioxide and black carbon, which are the compounds that cause linear cloud formations known as ship tracks. Aside from their effects on the total radiative forcing of a transportation mean, this phenomenon enables the detection of ships via satellite imagery sensors. The rapidly increasing trend of shifting propulsion of maritime transportation from conventional heavy fuel oil and distillate marine fuels to liquefied natural gas causes enormous hikes in methane emissions. Therefore, oxidation of the volatile organic compound in the marine boundary layer by the hydroxyl radical in the troposphere makes significant deposition of formaldehyde which causes human effects, ecosystem damage, and climate impact. The primary triggering substance among the compounds in the ship plume is methane. This paper discusses methods to assess near real time tracking of anomalies and the deposition of the short lived substance in different seasons in one of the main occurring areas, shipping corridors. The study also employs anomaly map analysis for June and December 2010 and 2020. Several global tracking methods are available with satellites, monitoring experiments, and other satellite tracking tools. Apart from a few areas the results are not indicative since the formaldehyde formations caused by LNG fueled ships are not widespread enough alongside with overall LNG fueled fleet. On the other hand, the analysis and method are promising for the follow-up of the emissions in the future.

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Introduction

There are around 450 compounds in a diesel marine fuel exhaust (Deniz & Durmuşoğlu, 2008). In the recent inventory study of International Maritime Organization (IMO, 2021), in addition to the six initial gases acknowledged under the United Nations Framework Convention on Climate Change process as GHG (carbon dioxide [CO_2], methane [CH_4], nitrous oxide [N_2O], hydrofluorocarbons [HFCs], perfluorocarbons [PFCs] and sulfur hexafluoride [SF_6]), relevant substances to climate change considered as nitrogen oxides (NO_x), nonmethane volatile organic compounds (NMVOCs), carbon monoxide (CO), particulate matter (PM), sulfur oxides (SO_x), and black carbon (BC).

IMO (2018) planned the reduction of shipborne Greenhouse Gas (GHG) emissions with new means. These strategies range from improving the existing energy efficiency framework to employing alternative or renewable fuels. One of the measures in the short term was undertaking additional GHG emission studies. A recent anthropogenic emissions inventory study of IMO (2021) shows that CH_4 emission rates increased more than 2.5 times in 2018 compared to 2012. In the same period, CO_2, NO_x, SO_x, and fine particulate matter ($PM_{2,5}$) also increased by 5.6%, 1.2%, 5.5%, and 3.6%, respectively. To prevent air pollution, IMO has reduced the fuel sulfur limit to 0.1% with the IMO global sulfur cap 2020 regulation within the emission control zones (Bilgili, 2021). Subsequently, Heavy Fuel Oil (HFO) with high sulfur and black carbon concentration is prohibited on the arctic sea routes that the use of which has intensified in the last decade due to melting elements in its cryosphere (in force after 2024) (IMO, 2022a). HFO fuel is the most preferred fuel with 70% in shipping. IMO left these controls to port and flag states and provided three possibilities as solution elements; the use of very low sulfur fuel oil or marine distillate fuels with a lower sulfur content (1), the use of alternative fuels such as Liquefied Natural Gas (LNG), liquefied petroleum gas, biodiesel, biofuel, methanol, ethanol, hydrogen fuel, or hybrid use (2), or the use of a filtration attachment on vessels, closed or open loop (scrubber) (3), (United Nations Conference on Trade and Development [UNCTAD], 2021a).

While most operators chose to equip their ships with scrubber systems, a clear shift to alternative fuels has begun. World LNG fleet by fuel type as of 1st of January 2021 indicates there are 621 LNG ships. More than half of this statistic uses LNG with Very Low Sulfur Intermediate Fuel Oil (VLS IFO). Although the aggregated number of LNG fueled ships do not represent even 1% (0.61%) size wise their deadweight (dwt) represents 1.84% of total dwt of the world merchandise fleet, indicating the cargo volume importance (Authors curation based on UNCTAD, 2021a). According to the statistics obtained from UNCTAD (2021b) data, LNG ships constitute 8.3% of the liner ships arriving at Turkish ports in 2020. Calling ships are 60% younger than the general average, with an average age of 10, and 336% larger than the closest type, container ships, compared to the average size of the ships.

According to previous studies in the literature (Lauer et al., 2007; Fuglestvedt et al., 2009; Eyring et al., 2010), shipping had negative radiative forcing values, but a recent one (Jin et al., 2018a) claims the gap in between climate neutral and cooling effect is closing. The main reasons that these negative values are reaching equilibrium are related to sulfur content, methane and ethanol based fuel choices, and obligations (Lauer et al., 2007; Lindstad et al., 2015; Jensen et al., 2016; Jin et al., 2018a; Sofiev et al., 2018; Kontovas, 2020; Pavlenko et al., 2020; Peng et al., 2020; Bilgili, 2021). Most control policies on substances target non-CO_2 emissions that have tangled linear and nonlinear relationships with fuel usage. In addition, some of the controls on pollutants have uncertain effects on global climate warming (Myhre et al., 2013). One of the examples of this is the Twomey effect which describes how anthropogenic pollution may help to reflect more significant amounts of solar radiation via enhancing the albedo of clouds (Twomey, 1974). Increasing Cloud Condensation Nuclei (CCN) can escalate the cloud droplet number concentration (N_d), thus, increasing reflectivity (Christiensen et al., 2022). In addition, reduced precipitation affected by maritime emissions can cause smaller cloud droplets that enhance moisture in the atmosphere and eventually enhance cloudiness (the so called lifetime effect) (Albrecht, 1989). This phenomenon creates cloud clearing and ship tracks.

The amounts of main polluters released into the atmosphere by the LNG and diesel fuel combustion processes are similar in the tank to propeller cases. From the perspective of life cycle assessment, the quantity doubles for LNG. At the same angle, different emission metrics that calculate emissions in their effective time window show at least a twofold impact against LNG fuel. Average Global Warming Potential 20-year pulse comparison on energy based approach with diesel, LNG fuel scores two times more impactful emissions (Shine et al., 2005; Pavlenko et al., 2020; Peng et al., 2020; Argonne National Laboratory, 2021). LNG fuel's main output is methane emissions which are directly correlated with tropospheric ozone emissions. Most LNG fuelled ships use low pressure dual fuel technology with fossil fuels, which is the least efficient in terms of methane slip. Furthermore, control measures are linear (Pavlenko et al., 2020; IMO, 2021; Christiensen et al., 2022). Another inefficiency is the CO emissions, with almost 25 times more emissions due to the dual fuel technology. In other spark ignited otto cycle versions, this inefficiency is not visible, indicating the low technological readiness level (Pavlenko et al., 2020; IMO, 2021). In Table 1, CO and NO_x emission factors are eye catching. The highest correlations among substances released after LNG combustion are between CH_4 and CO and HCHO (Miller et al., 2020).

Table 1. Emission factors of polluters after the combustion of common marine fuels in the tank to propeller fuel based case (mg emissions/ g fuel), Authors curation based on IMO (2021), missing values of OC is procured from Corbin et al. (2020)

	LSHFO (1% S)	MDO (0.1% S)	LNG
CO_2	3114	3206	2750
N_2O	0.38	0.36	0.41
CH_4	0.11	0.12	2.73
NO_x	29.32	30.83	35.53
SO_x	19.60	1.40	0.03
BC	0.35	0.18	0.03
OC	0.30	0.31	0.0007
CO	6.09	0.55	14.21
VOC	5.94	6.25	5.46
PM	9.65	1.96	0.13

Climatic and Air Quality Interactions: Two opposing indirect effects of NO_x emissions complicate radiative forcing calculations. On the one hand, emissions of NOx inclining O_3 enhancement and, on the other hand, cause CH_4 reductions. Because of the lower altitudes of maritime transportation, CH_4 destruction outweighs the O_3 enhancement compared to land based sources (Myhre et al., 2013). Although the NO_x effect varies in the different time scales and emission metrics, the consensus is on the cooling effect for the emissions (Shine et al., 2005). SO_2 emissions do not have a dispute on them. Most known metrics agree on the cooling effect. The main issues of these two main compounds that differentiate maritime transportation from other transportation are the effects on air quality, regional photochemical oxidants, acidification, and eutrophication (Kontovas, 2020). The imperfect combustion process also causes high CO emissions. Air quality effects of PMs out of ship exhaust include increased human mortality and morbidity, primarily via cardiovascular and respiratory diseases (Brandt et al., 2013).

Aerosol Cloud Interactions: SO_x and NO_x emissions via atmospheric deposition and aerosol nitrate formations are causing a disturbance over terrestrial habitat biodiversity (European Environment Agency [EEA], 2021). These chemical interactions affect precipitation patterns emissions (Shine et al., 2015). The essential aerosols that interact with clouds in order are Sulfate (SO_4) which is the oxidated form of SO_2, BC, Organic Carbon (OC), and nitrate (NO_3). The signal from shipping decays rapidly due to the substance's short lives. Sensitivity studies indicate that three fourth of all direct and indirect aerosol effects can be associated with fuel's sulfur content, whereas BC and PM only contribute 0.4–1.4% and 0.1–1.1%, respectively (Lauer et al., 2007). The direct aerosol effect by scattering and absorbing the solar and thermal radiation from shipping is small (Lauer et al., 2009). The indirect impact is changing cloud properties via aerosol cloud interactions that are most uncertain, but values to refer to aerosol cooling are possibly overestimated (Lauer et al., 2007). Cloud clearing is strongly correlated to SO_x emissions. In order to reach the state of CCN, an aerosol goes through nucleation, condensation, and coagulation, if it is not diluted in the atmosphere. Particles of aerosol act as CCN, enhancing N_d when they enter the cloud. Systematic studies of ship tracks show varying influences on Liquid Water Path (LWP) due to the different atmospheric backgrounds depending on the cloud's pollution level. Significant increases occur under clean conditions and decreases under more polluted conditions (Gryspeerdt et al., 2019). Despite this, inconsistency throughout the studies on the increases in LWP due to aerosol perturbations is argued (Christiensen et al., 2022). When interacting with a cloud, BC emissions, one of the aerosols, can reduce the entrainment when it resides above the cloud and burn off the cloud when it resides in the cloud layer (Johnson et al., 2004). The in-situ measurements indicate that shipping emissions differ vastly within Sulfur Emission Control Areas (SECA) and open seas. Emission factors of SO_4 decrease by 94%. It is also predicted that SECA can decline total CCN by 80%. Seemingly, BC and organic compounds emission factors are not responding to the fuel's sulfur content (Yu et al., 2020).

Shipping emission studies using satellite imagery are mainly formed around ship tracks (Beirle et al., 2004; Peters et al., 2011; Topic et al., 2021). Tied to the given background on the subject, declined CCN indicates fewer cloud formations due to the fuel regulations hence the disappearance of ship tracks (Yuan et al., 2022). This paper discusses the changing use of satellite imagery on maritime transportation emissions. Due to the nature of shipping emissions, previous studies mainly keep the focal point in their studies as sulfur and black carbon originated aerosol effect which causes ship tracks. Although these effects are still visible, the main compound is more restricted (Christiensen et al., 2022). The changing fuel preferences via policies directs shipowners to alternative fuels such as LNG, which causes unexpected atmospheric effects. Few studies concentrated on formaldehyde (HCHO) emissions caused by maritime transportation and their deposition on the Marine Boundary Layer (MBL) in shipping corridors. On top of that, this issue is not associated with rising CH_4 emissions due to the reshaping of bunkering. The paper attempts to investigate means of studying HCHO emissions arising from ship plume via satellite imagery. Various near real time tracking satellites are mentioned, which indicates their availability. An anomaly study has been included via Ozone Monitoring Instrument (OMI) on AURA satellite with the help of Panoply software, comparing June and December of 2010 and 2020. Results are not on a satisfactory level to track emissions of HCHO effectively due to the proliferation of LNG not exceeding the threshold of being one of the main fuel preferences as a bunker.

Materials and Methods

Source Identification

The main causing reason for HCHO in the atmosphere comes primarily from methane oxidation by the hydroxyl radical (OH) in the troposphere. A decade ago, a study observing HCHO emissions on the shipping routes concluded whether or not increased methane degradation due to enhanced OH concentrations derived from emissions of maritime transportation can cause increased levels of atmospheric deposition. This study's results also indicate that the degradation of emitted nonmethane hydrocarbons will not likely explain the increased levels of HCHO values (Marbach et al., 2009). Three possible sources of HCHO are discussed for the source identification of ship plumes in an indirect in situ measurement study: (1) primary HCHO emission from ships, (2) secondary HCHO production in the atmosphere from nonmethane VOCs emitted from ships, and (3) atmospheric process of oxidation of methane. It is found that the atmospheric chemical process of methane oxidation via enhanced levels of OH radicals is the headmost reason for the higher rates of HCHO by 91% (Song et al., 2010). Two studies' explanation of the phenomenon of the OH levels resulting in HCHO along with acidic substances, nitric acid (HNO_3) and sulfuric acid (H_2SO_4), was the oxidation of NO_2 and SO_2 (Kim et al., 2009; Song et al., 2010). Photochemical HCHO production can be done via two atmospheric reactions in Eq (1) and Eq (2).

$$CH_4 + OH + O_2 \rightarrow CH_3O_2 + H_2O \qquad (1)$$

$$CH_4 + O(^1D) + O_2 \rightarrow CH_3O_2 + OH \;\&\; CH_4 + O(^1D) \rightarrow HCHO + H_2 \qquad (2)$$

Due to $O(^1D)$ radicals often reacting with the abundant N_2 and O_2 molecules (quenching reactions) and then H_2O molecules in the MBL, compounds in the second equation can be denoted as an adjunct (Song et al., 2010). Field observations indicate vessels took part in the elevation of O_3 and or OH levels in the MBL (Burkert et al., 2001; Davis et al., 2001; Kim et al., 2009). HCHO emissions are causing air pollution, high GHG effects, radiative forcing, coastal acidification, coral bleaching, and eye, nose, and throat irritations. Also, they are carcinogens. A recent study observed HCHO concentrations in a corridor from Sri Lanka to Indonesia. Satellite data shows that emissions are mainly on the MBL from the observations of clear and cloudy situations. The emissions are in the location of the shipping corridor and vary according to the seasonal shift of the corridor. The data complies with the chemistry transport model (Gopikrishnan & Kuttippurath, 2021).

Tools of Satellite Observation for Formaldehyde

The spectral resolution of the Global Ozone Monitoring Experiment (GOME) is used to enable the tracking of tropspheric ozone precursors; NO_2 and HCHO (Burrows et al., 1999). To obtain better resolutions and near infrared observing capability on CO, CO_2, and CH_4 observations, SCIAMACHY can be utilized (Bovensmann et al., 1999). The inclusion of the record of ultraviolet imagery covering more detailed and high quality came with Ozone Monitoring (Callies et al., 2000; Levelt et al., 2006). According to Tropospheric Emission Monitoring Internet Service (TEMIS, 2022), which was used to be part of the European Space Agency (ESA) H_2CO (chemical formula of formaldehyde) data products from ERS 2 GOME and SCIAMACHY level 1 data (indicating levels further from raw data at full instrument resolution [0 to 4]) can be produced from ESA at the German Aerospace Centre. Level 2 and level 3 H_2CO developments from ERS 2 GOME and SCIAMACHY should be taken from ESA through the TEMIS. GOME 2 H_2CO operational product developed by EUMETSAT can be used for German Aerospace Centre products as well. For Ozone Monitoring Instrument (OMI) data products, level 1 data can be procured from the National Aeronautics and Space Administration (NASA) ozone watch program's tool NASA/KNMI, and level 2 and level 3 OMI H_2CO developments are supported as part of the Sentinel 5 precursor TROPOMI level 2 project. Also following data products gives near real time data recording: OMI on AURA, SCIAMACHY on ENVISAT, GOME 2 on METOP A, and METOP B. Their further specifications are shown in Table 2. Selective visualizations of data products from the database of TEMIS are given in Figure 1.

Table 2. Instruments of satellite to measure tropospheric HCHO column density (Jin et al., 2018b)

Instrument	Platform	Period	Nadir Resolution (km^2)	Overpass time (local time)	Global coverage (days)
GOME	ERS-2	1995– 2003	320 × 40	10:30 AM	3
SCIAMACHY	ENVISAT	2002 to present	60 × 30	10:00 AM	6
OMI	AURA	2004 to present	24 × 13	1:45 PM	1
GOME-2	MetOp	2006 to present	80 × 40	9:30 AM	1
TROPOMI	Sentinel-5	2017 to present	7 × 3.5	1:30 PM	1

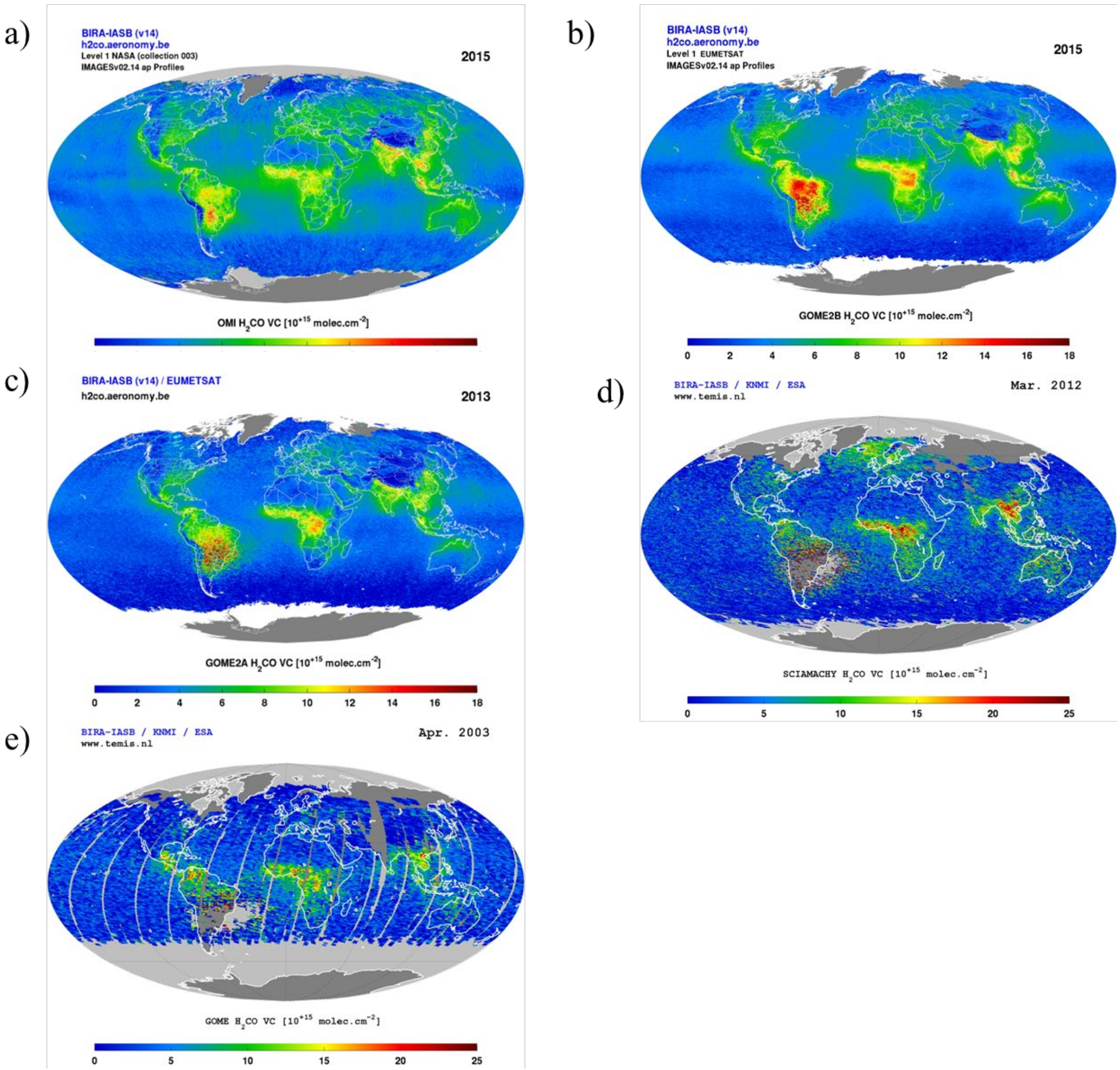

Figure 1. Tropospheric H_2CO columns visualizations from different instruments (TEMIS, 2022) a) yearly mean of 2015 from OMI on AURA. b) yearly mean of 2015 from GOME 2 on METOP B. c) yearly mean of 2013 from GOME 2 on METOP A. d) monthly mean of March 2012 from SCIAMACHY on ENVISAT. e) monthly mean of April 2003 from GOME on ERS-2.

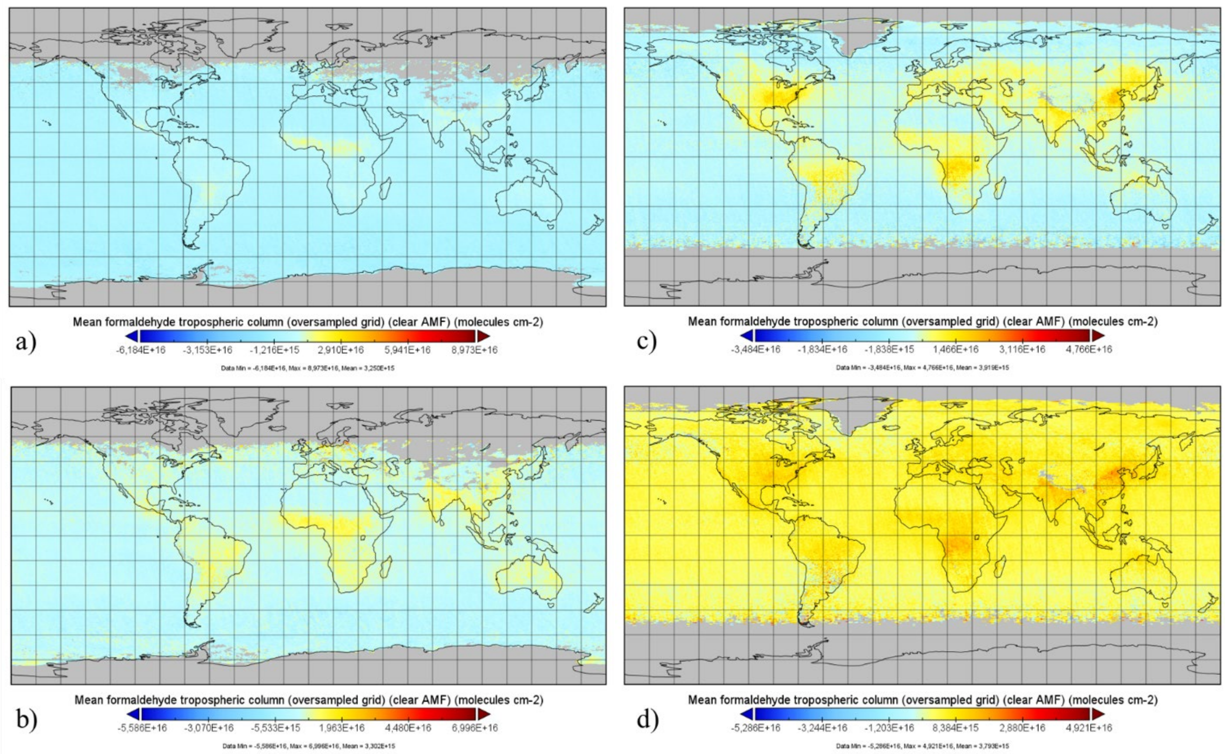

Figure 2. Tropospheric H_2CO columns visualizations of OMI on Panoply; a) 2010 December b) 2020 December c) 2010 June d) 2020 June.

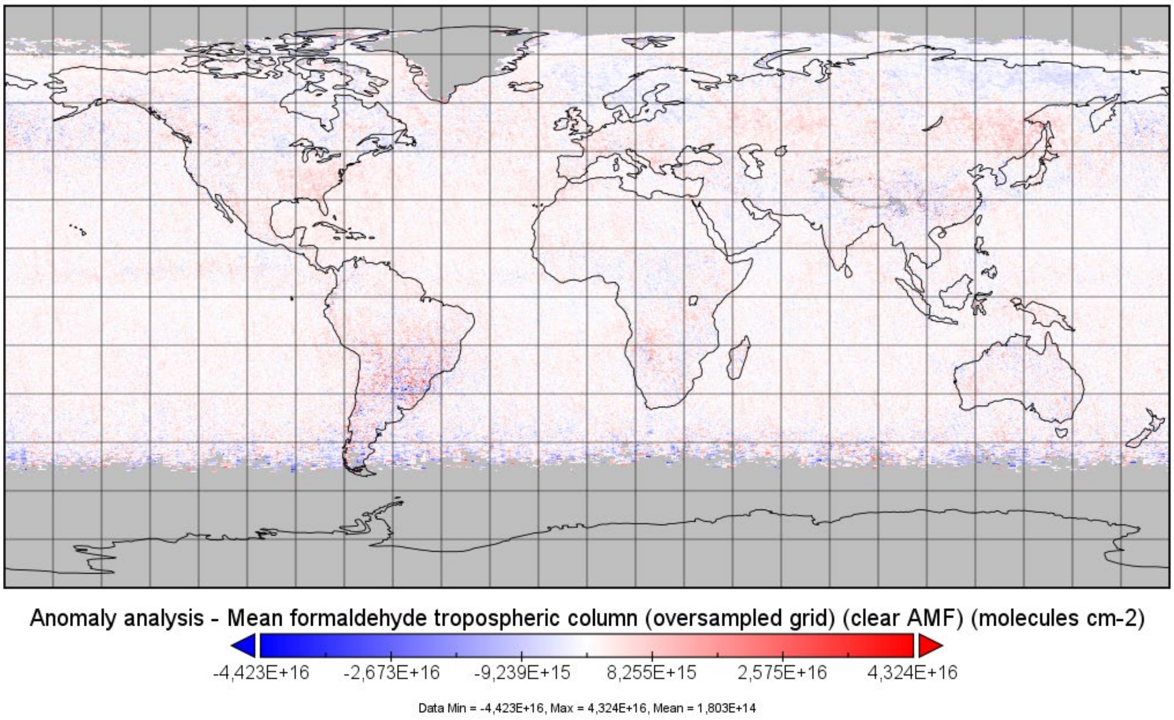

Figure 3. Anomaly map of OMI's global tropospheric H_2CO columns retrievals for June 2010 compared to 2020

Anomaly Analysis

OMI has a cross-track field of view of 115°, a swath of 2600 km, and pixel size between 26 × 135 km^2 at the swath edges. The OMI HCHO gridding algorithm filters out pixels affected by row anomalies (González Abad et al., 2015). Zhu et al. (2016) provided detailed instructions and the validation of the OMI HCHO instrument. Quality Assurance for Essential Climate Variables (QA4ECV) project provides the dataset for HCHO tropospheric column data from OMI (De Smedt et al., 2017). Level 3 clear Air Mass Factor (AMF) interpolated figures of tropospheric HCHO column retrievals from OMI for the periods of 2010 and 2020 December and 2010 and 2020 June have been given in Figure 2. No interpolation or extrapolations are carried out for filling the missing values. Interpolation mentioned here implies one pixel to other transitions, which are used to obtain better visualization.

The periods represent the recent changes in the maritime transportation policy framework (e.g., Initial GHG Strategy, 2018; IMO, 2020). The first action can be denoted as adopting the Energy Efficiency Design Index in 2011. The constant improvements in the framework favored alternative marine fuels, including LNG (IMO, 2022b). The favoritism can be attributed to the Marginal Abatement Cost Curve (MACC) analysis included in feasibility studies for potential regulations (IMO, 2010). The recent one included in the 4th GHG Study envisions 64.08% of total CO_2 reduction to be contributed by using alternative fuels, followed by speed reduction with 7.54% (IMO, 2021). The difference of summer and winter creates a significant effect on tropospheric formaldehyde column retrievals. Therefore, both times are considered.

Results and Discussion

June

As much as the global warming effects are in place, the impact of HCHO attributed only by shipping is not easily distinguishable. Still, an apparent deterioration can be spoken of. Apart from the equatorial, subequatorial, and tropic zones, visible worsening can be seen in the Sea of Okhotsk, East Coast of United States, Sea of Japan, Bay of Biscay, Arctic Sea Routes, Strait of Gibraltar, Suez Canal, and British Columbia. Figure 3 shows the anomaly of HCHO emissions for 2010 and 2020.

The prominent mentioned geographic locations correspondingly hold major trade flows in shipping. In line with the works of Gryspeerdt et al. (2019) and Yu et al. (2020), Canada's busiest shipping flow Port of Vancouver is where the emissions are visible, but the emissions do not lessen in the following SECA. This implies that even though sulfur regulations are in place, shipping originated HCHO emissions did not show extraordinary fluctuations. The analysis is in line with the elaborated work of Gopikrishnan & Kuttippurath (2021), hence implying the same trade routes. In Figure 4, Europe is focused on.

LNG fueled service vessels are mainly used in European countries. In addition, emissions are regulated with emission control areas, implying HCHO emissions will be more distinguishable. Therefore, the Baltic and the North Sea are the areas of importance for further studies in tracking shipping HCHO emissions. In the Black Sea trade flow, the Gallipoli Peninsula and Strait of Kerch have similar significance for being shipping corridors in the area. There is a visible track of emissions near the entrance of the Suez Canal. The most visible emissions of HCHO for shipping occur west of the Bay of Biscay and the Strait of Gibraltar, where the busiest shipping routes are. Another shipping route is in the Adriatic Sea, which ends mostly in Port of Trieste, where emissions of HCHO are depicted in Europe centered tropospheric HCHO anomaly map.

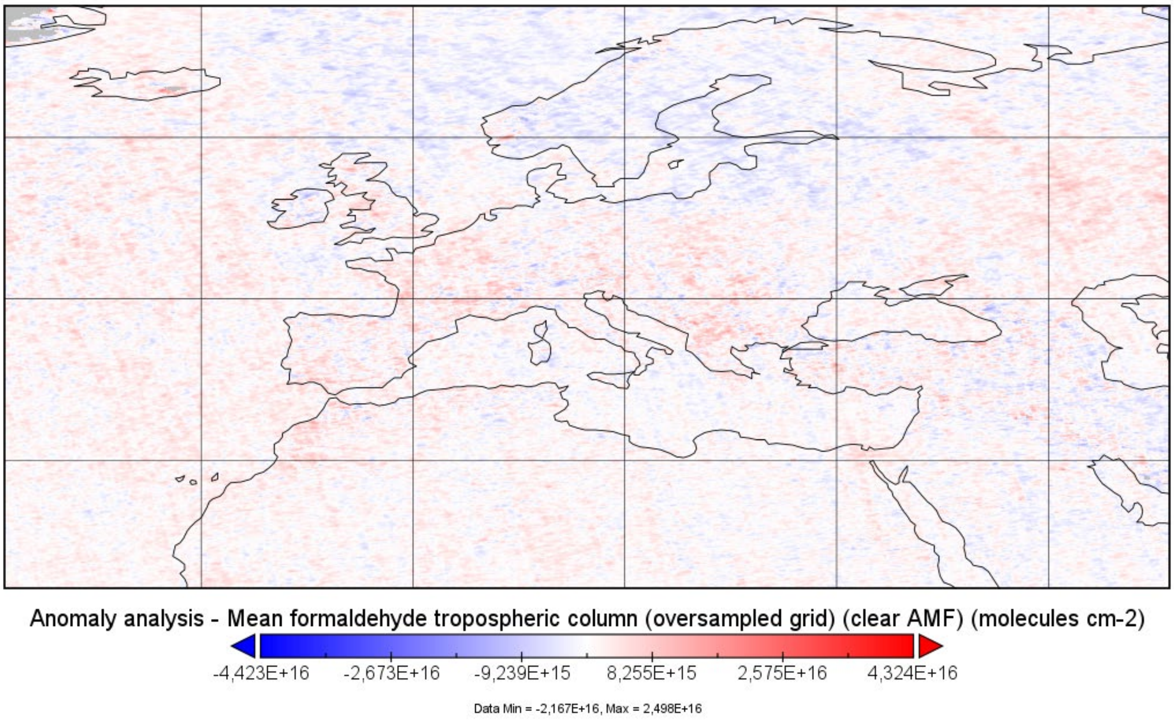

Figure 4. Anomaly map of OMI's tropospheric H_2CO columns retrievals for June 2010 compared to 2020 centered on Europe

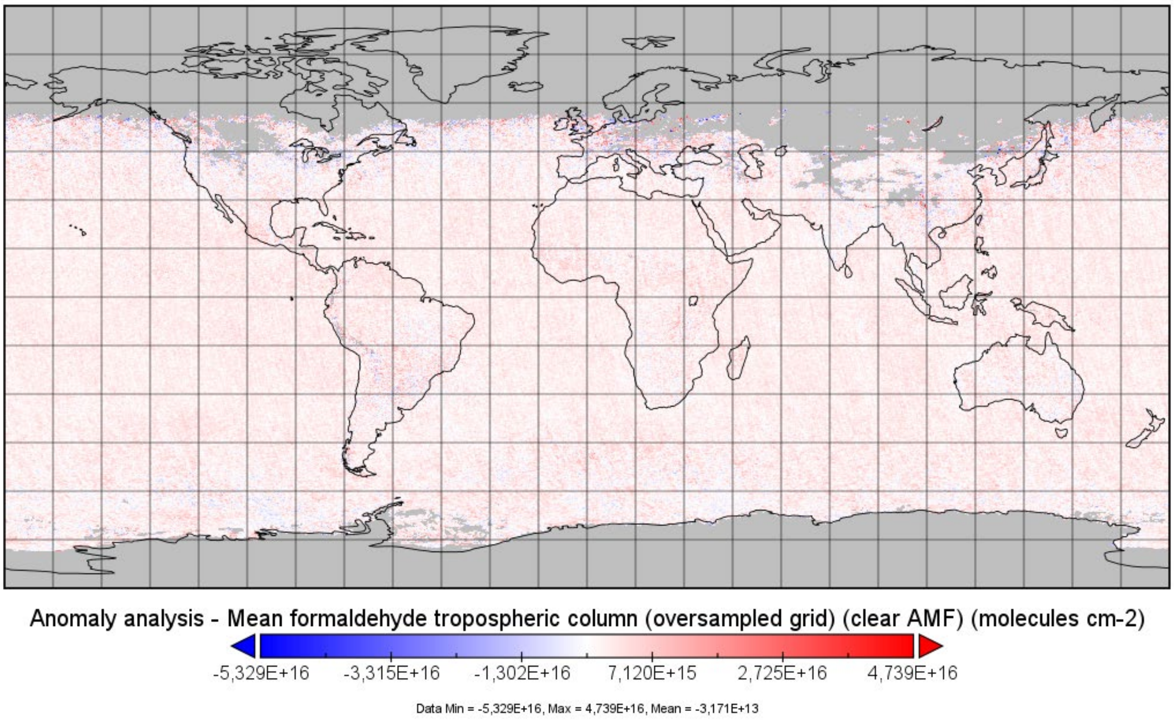

Figure 5. Anomaly map of OMI's tropospheric H_2CO columns retrievals for the months of December 2010 compared to 2020

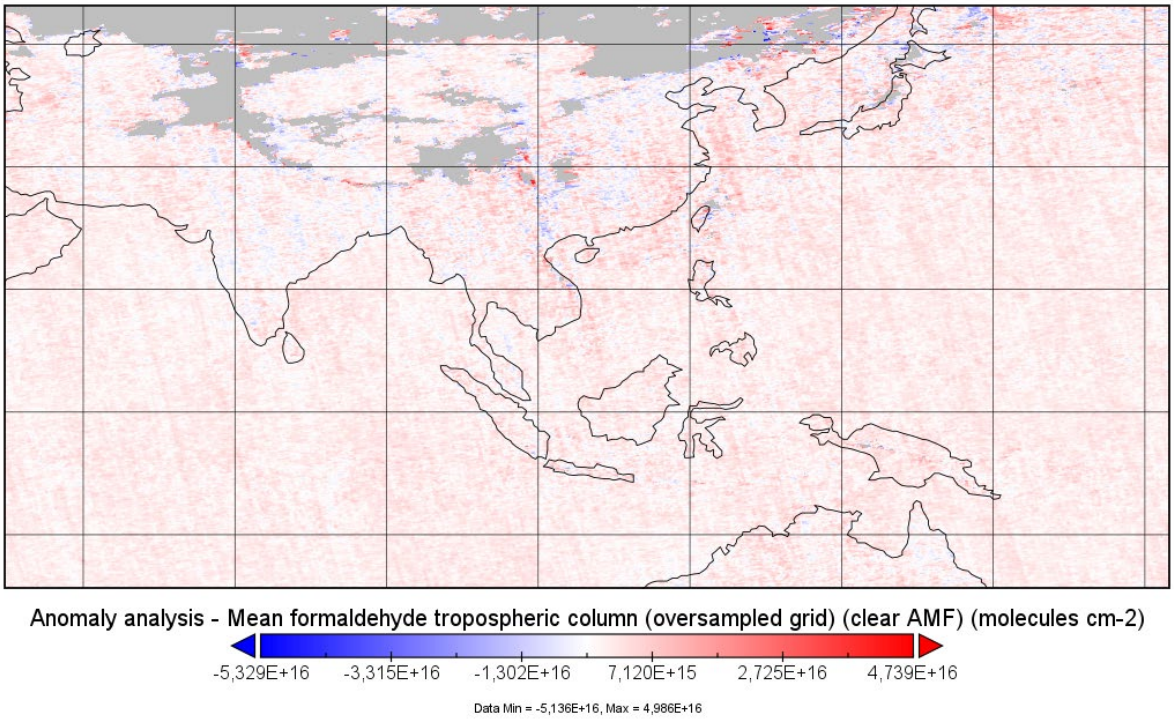

Figure 6. Anomaly map of OMI's tropospheric H_2CO columns retrievals for the months of December 2010 compared to 2020 centered on Asia

December

Exclusion from the heat effect shows that dispersion of HCHO emissions is proportionate to overall global warming. The leading LNG exporters are Qatar, the United States of America, and Australia (Filimonova et al., 2022). According to the International Gas Union (IGU, 2022) report, the most significant global LNG trade flow is in Intra Asia pacific trade. The leading importers are China and Japan, and their biggest exporter is Australia. Australia is followed by Qatar, the United States, and Russia. LNG trade flow includes many re exports. The import of the trade flow consists of small groups that reach out to the whole world. In Figure 5, an equally distributed increase in the overall trend of HCHO emissions can be seen.

Fig. 6 shows the Intra Asia HCHO emissions. The tracks of anomaly can be traced in between above mentioned Australia to Japan and China trade flow. Subsequently Strait of Malacca, sub continent India, and Strait of Hormuz are polluted areas. The Sea of Japan is another central point of anomalies in this period of HCHO emissions.

Overall, tropospheric emissions of HCHO are not strongly visible, which was an expected outcome considering the fuel proliferation is around 1%. In a study by Det Norske Veritas Germanischer Lloyd (DNV GL, 2018), it is said that LNG will be the most dominant fuel type among marine fuels, with a share of between 40% and 80% in 2050 forecasts. Also, Gopikrishnan & Kuttippurath (2021) validated the retrievals of the deposition of HCHO in the shipping corridors with decade long daily emissions. Between anomaly maps, there is a common trend of increased HCHO emissions. Also, main shipping corridors share many similar traceable emissions of HCHO, for instance, the Suez Canal and the Sea of Japan.

Conclusion

This paper discusses the evaluation of changing satellite tracking of maritime transport emissions due to the allocation of emissions. In the older anthropogenic emission trends, satellite tracking was relatively easy to execute due to the formation of cloud clearing and still discussed enhancing LWP. The highly visible Twomey effect enabled scientists to study the impact of sulfur and other aerosols' interactions with the clouds, which scientists even called opportunistic experiments (Christiensen et al., 2022). The transition to the disputable less air polluting fuels allocates emissions, thus, changing the interactions in the tropospheric atmosphere. Formaldehyde, mainly caused by the methane deposition interaction with hydroxyl radical in the MBL, can be attributed to multifold damage on human effects, ecosystem damage, and climate impact compared to dominant sulfur based (2.7% S) fuel emissions. In addition, the increasing volatility of global temperature changes will form more occasional heat waves that will catalyze the deposition of formaldehyde in more significant accumulation in the marine environment and the atmosphere.

This paper suggests that the tracking of formaldehyde via satellite imagery and calculations of anomalies in annual periods will show a clearer picture of the tentative impact of the future with LNG fuel as the transition to alternative marine fuels with greener aspects. OMI on AURA, GOME 2 on METOP A and B, and SCIAMACHY on ENVISAT are identified as near real time possible data sources of formaldehyde to keep track of LNG emissions in shipping corridors. In prior studies, OMI on the AURA satellite has been used to assess the impact created by formaldehyde over the Indian Ocean and the busiest shipping routes. The paper also applied two anomaly analyses for June and December 2010 and 2020. Although the results are not specific since LNG fuel and its emissions are not widespread yet, it shows that the applicability of these prospective analyses and the impact of formaldehyde can be followed like ship tracks.

Further suggestions for studies should include employing different satellite tracking methods with more frequent time windows. Volatile organic compounds and cloud interaction effects can be clarified more. Finally, in situ measurements will be explicitly revealing as well as the satellite tracking on this specific subject.

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Compliance With Ethical Standards

Authors' Contributions

UYÇ wrote the original draft of the manuscript. BZ reviewed, edited, and gave supervision. All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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