

We would like to thank the two anonymous referees for their constructive and insightful comments. We are pleased you found our manuscript to be “interesting and relevant”, “well-written”, and “concise”; and to follow “a clear storyline”. Please find detailed responses to the individual comments below.

Referee #1

Major Comment

[...] Thus, I recommend adding an additional constraint to the analysis: the free-tropospheric humidity.

This is a very valuable comment. We have performed additional analysis of the data stratified by relative humidities above cloud (reanalysis RH700). This shows a strong correlation of LWP adjustments and RH700, with negative adjustments at low and in particular intermediate-low above cloud humidities. We have added the corresponding section to the manuscript.

Added: Section on free tropospheric relative humidity (ll. 108 ff)

Minor Comments

L. 8: To what does “this” refer to? The prior sentence writes about raining clouds, this sentence addresses “rainy and non-rainy conditions”. Please clarify.

This refers to the independence of emissions, which come from balancing, emissions-dependent effects under high and low LWP conditions.

Added: independence of emissions, replaced ‘rainy and non-rainy’ with ‘dry and more humid’

Ll. 41 – 41: Is logging “decreased droplet radii” the only way to identify ship tracks by hand?

Decreased droplet radii show very clearly in the MODIS 3.7 μ m retrievals, which were used in the previous studies cited below. I do not know of any other approaches that people have used in recent years (e.g. just using the visible reflectances/albedo increases). Added: “commonly identified from the IR channels like the 3.7 μ m band of MODIS (Coakley and Walsh, 2002, Segrin et al. 2007, Christensen and Stephens, 2011)”

Ll. 50 – 51: What is the reason for the slow decline in the droplet concentration anomaly? Mixing of the track with its surroundings? Precipitation scavenging? Broadening of the track?

Probably all of these, as well as greater uncertainty at long advection times (time-integrated uncertainty of reanalysis winds). Added: “A number of processes are likely responsible for the decline back to zero: The mixing of surrounding air, the onset of precipitation, and the more uncertain location of the retrieved position with longer advection times.”

Ll. 62 – 63: How much does the water vapor in ship emissions affect LWP adjustments? The amount of water vapor in the emissions should not depend on the IMO regulations.

We cannot rule this out entirely. However (added in l. 154):

“Direct injection of water vapor without aerosol (from nuclear powered ships) showed no cloud responses in the Monterey Area Ship Track (MAST) experiment (Durkee et al., 2000) and therefore seems unlikely to play a role.”

LI. 135 – 137: Kessler (1969) already suggested that autoconversion should depend on a threshold.

Thank you for pointing this out, I was not aware of this!

Added: “The threshold behavior of the initiation of autoconversion on cloud liquid water content has long been known (Kessler, 1969)”

Technical comments

LI. 32, 39: Check citation style.

changed

L. 21: Who is “they”? I guess you refer to ship tracks.

changed word order to clarify

L. 41: I recommend mentioning the sampled regions in the manuscript’s main text.

Done, l. 42

LI. 56 – 58: How do these two sentences relate?

Added: “In some regions, such as off the North American coast and in the North Sea, more stringent limits of 0.1% have been in place since 2015. However, these areas are small compared to our study region, so the 2020 emissions change presents a valuable opportunity to study the effect of low shipping emissions on clouds. Furthermore, compared to other studies on emissions regulation, such as those by...

LI. 66 – 67: While the caption states when the anomalies are determined, I suggest adding this to the main text.

l.69: Added years: 2014 to 2019

Figs. 3 and 4: Put the title of the panels over the figure. Fig. 5, top-left panel: Where is the blue line?

Changed.

We chose not to plot separate lines for the 2021 and other data in the top left panel, as most of the 2021 data is in the very data sparse low-emission bins. The orange line in the top left panel includes all data. Added, l.89: “Note, that in the top panel the orange line includes both 2021 and 2014-2019 data.”

Referee #2

Detailed Comments

Fig. 3, Line 163, the southernmost row of this domain is partly white

Yes, these regions have very little ship traffic and therefore few data points. This makes for insufficient n to calculate means and standard errors, as for low n the assumption of independence is not fulfilled. We decided to exclude this area from the analysis.

Added: “The bottom row has too little ship traffic to collect data.”

How are the out-of-track regions defined?

Added clarification on this (ll. 183 ff): “Out-of-track retrievals are taken by using the shape of the advected emissions track, but 30km to either side of the track. This is done by calculating

the 'direction' of a track, taken as the vector from start to end, then calculating the orthogonal vector, and then displacing the track by 30km in the orthogonal vector's direction."
Replaced all occurrences of 'control' where not referring to the null experiment with 'out-of-track'.

Only one year of post-IMO regulation change data is available (2021). Please discuss in how far this may introduce an uncertainty when pre- and post-IMO conditions are compared.

This is a good question, we have added a discussion section on this.

Added (ll. 132 ff): Having only one year of data for the post-IMO regulation period means that there is not as much data as for the pre-IMO regulation data. However, even a single year of ship track data produces $O(10^5)$ tracks, and results are significant with respect to standard errors. Using a single year can potentially signify different climatological conditions, with different cloud properties in 2021. However, as we are only presenting departures from background states, results would only be different if susceptibility to aerosol changed. This effect is likely small, but hard to rule out or quantify without clear knowledge of the cloud controlling factors, which we are currently investigating. There will also be a change in signal stemming from the cleaner background conditions in 2021, where the aerosol burden in shipping corridors is reduced as a cause of the lower SO_x emissions of the individual ships. We find an average out-of-track N_d of 65.9 cm^{-3} pre-2020 compared to 64.8 cm^{-3} post-2020, a difference that is significant with respect to the standard error of the mean, but likely too small to change the 'average cloud' sensitivity to aerosol perturbations. This may be different in shipping corridors, which will have experienced a larger decrease because of the high concentration of shipping.

Line 175 mentions "best-matched tracks". What does this mean and how is it tested?

We looked at a handful of days when tracks were visible and chose the parameter that gave the best agreement between visible tracks and the advected emissions.

Added (l. 185): "in visual inspection of test days with visible tracks."

Technical comments

Sometimes the position of the parentheses for references is not correct, e.g. in line 39, where it should read: "As in Manshausen et al. (2022), ..."

Fixed

Line 118: add "their" before Fig. 6 to make clear that this is referring to Gryspeerd et al.'s figure.

Added: "their"

Line 171: positons -> positions

Thank you. Fixed.