Referee comments on the revised manuscript "Surveillance of SO2 and NO2 from ship emissions by MAX-DOAS measurements and implication to compliance of fuel sulfur content" of Cheng et al., 2019 for submission in ACP

The authors addressed all comments and suggestions in an adequate way. The corrections significantly improve the quality of the revised manuscript. However, the authors reply to some of the reviewer's comments in detail only in the response to comments file, but did not update the manuscript. As the explanations in the reply are of good quality which does improve the understanding of the manuscript, I do recommend considering the manuscript for publication in ACP with the below minor changes:

I do reply to selected authors reply on the first reviewer #1 and #2 comments. The initial reviewer's comments are indicated in black, the authors reply in blue and my comments to the authors reply in green.

Reviewer #1

3. Results presented in section 3.1 do represent only one measurement at one day. If the authors have "more than a dozen cycles" (line 220-221), why they don't show an average of all cycles. The presented cycle is a snapshot and might be not representative to draw conclusions. Well, even an average over one afternoon does represent only a snapshot of the situation. The authors should consider this in their discussion or should skip this section.
R: There may be some misunderstandings due to the unclear description. The purpose of Section 3.1 is to investigate the 2-D distribution of retrieved NO_2 and SO_2 DSCDs using 2-D scanning measurement of MAX-DOAS. The hotspots of NO_2 and SO_2 are related to the azimuth of the berth where the ship is docked and the corresponding ship operation status. It is obviously that the 2-D distribution of NO_2 and SO_2 DSCDs changes with time, so that it seems unreasonable to show the average of all scan cycles, which may weaken the spatial distribution of hotspots. However, the results of the rest of the cycles were also shown in Figure 6. It can be seen that the concentration at a given azimuth and elevation is constantly changing throughout the day.
→ The authors could summarize this description and add it to the manuscript introduction

11. Line 190: What is located opposite the berth? Any industry which might emit NOx or SO2?
R: Opposite the berth is the South Channel of the Yangtze Estuary. The only sources of NOx and SO_2 could be the ships emissions on the channel, and the main channel is more than two kilometers away from the berth. Behind the building of Pudong MSB, there are green land and residential area. The container yard was located between the building and berths.
→ Ok, but the authors should add a short statement to the manuscript that there are no other sources for SO2 and NO2 than emissions from ships.

16. Line 253: ships in navigation or maneuver? Do the authors can exclude emissions from the industry behind the river (visible in Fig 2 (c)) as a source?
R: The ships were in the state of navigation. According to Figure R4, we can see the main green land areas behind the river, including villages and forest parks. In addition, the opposite of the river is a small dock and a station for transporting containers. Due to the lack of relevant research and observations in this region, it is very difficult to estimate the amount of NO_2 and SO_2 emitted from the opposite side, and we have to ignore this part of the source compared with the ship emissions on the channel.
→ Ok, but if the authors cannot exclude this influence the measurements, they have to make a short note in the manuscript. E.g. "A small dock and a station for transport container are

located opposite the river, which might slightly influence the measurements." or something similar.

Figure R6. Relationship between DSCDs of (a) NO_2 and (b) SO_2 and ship density.
Corresponding to Fig. 9 in the revised manuscript
→ In the figure caption the authors have to explain the meaning of the squares, stars and bars or have to refer to Figure 7 for explanation.

21. Line 282-283: To support the conclusion that the ships are the main source for NO2, the authors should roughly estimate the influence of the surrounding emission sources (especially the main roads and highway, because this could be a significant NO2 source).
R: Due to the lack of relevant research in the areas of Wusong site, we are unable to obtain the influence of the surrounding emission sources accurately. We have installed two active LP-DOAS (Long-Path DOAS) in the Wusong MSB and Fudan University Jiangwan Campus in March of 2018, respectively. The locations of Wusong and Fudan have been shown in Figure R7 (a), and the red arrow indicates the light path of the two LP-DOAS. The campus is 4 kilometers away from Wusong and is considered to be free of pollution because the campus is almost covered by green spaces and have no major emission sources.
Considering the synchronization of data, concentration of NO_2 from March 15 to March 30, 2018 have been analyzed. During the observation, the average value of NO_2 in Fudan campus and Wusong site is 12.42 ppb and 30.50 ppb, respectively. In order to make a clearer explanation, we have shown the time series of NO_2 in a short segments of three days as an example in Figure R7 (b). We have calculated the difference of NO_2 between Wusong and Fudan campus, which is considered to represent the sum of NO_2 emissions from ships and surrounding sources at Wusong area. For the red line in Figure R7 (b), the rapidly changing part is discharged by the ships, while the smooth part may come from surrounding emission sources such as roads and highway. After a rough estimation, the proportion of NO_2 emitted by ships is more than 47%. However, this estimation are quite rough and more accurate conclusion need be furthered with multiple measurements and technical method.
→ Ok, but the authors should make a short note in the manuscript that the reader can follow this explanation

23. Line 292: largest container ports related to what? China, Asia, World?
R: Yantian Port in Shenzhen is the largest single port area with the largest container throughput in China. According to the survey, Shenzhen Port is the third port of the world container port in 2017, and Yantian Port is the main port of Shenzhen Port. So the Yantian Port is one of the largest container port in China and even in the world.
→ Ok, but the authors should also mention in the manuscript that Yantian Port is one of the largest container ports in China and even in the world

Reviewer #2

3. In section 2.3, the SO2 and NO2 DSCDs are retrieved at different spectral ranges. How do the authors compensate the effect of wavelength dependency? If it is not considered in the retrieval, an error analysis is required.
R: The configuration of SO_2 and NO_2 spectral analysis was based on many previous studies, e.g. Hendrick et al., 2014; Irie et al., 2011; Seyler et al., 2017; Wang et al., 2014. So the common fitting window of 307.5-320 nm and 338-370 were used for SO_2 and NO_2, respectively. As it can be seen in Fig. R3, the strong absorption band of SO_2 is below 325 nm, where the NO_2 absorption are relatively weak. It means that the wavelength band of SO_2 analysis window should be shorter than that of NO_2.

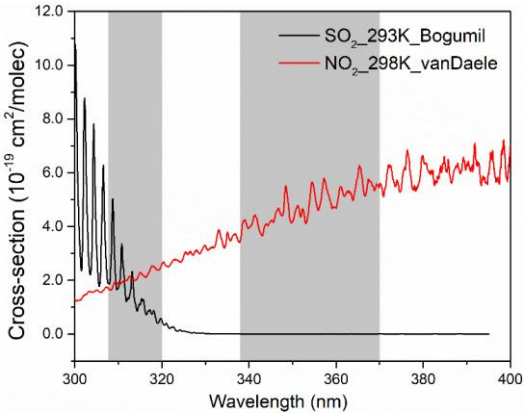

Figure R3. Absorption cross section of NO_2 and SO_2 in the wavelength range of 300~400 nm.

Since it is obvious that the SO_2 analysis cannot be performed well in longer wavelength over 325 nm, we have tried the analysis of NO_2 with the same fitting interval of SO_2 in 307.5~320 nm. As shown in the Fig. R4 (a), we found that the NO_2 DSCD values from fitting window of 307.5~320 nm are larger than that in 338-370 nm and simultaneously shows considerable uncertainties. In addition, Fig. R4 (b) and (c) show that fitting interval of 307.5~320 nm for NO_2 generates even larger RMS and DSCDs error compared to the results from fitting within 338~370 nm. It suggests that the DSCDs from same fitting window will bring large uncertainty and error in the results. Finally, we decided to use the different fitting intervals for SO_2 and NO_2.

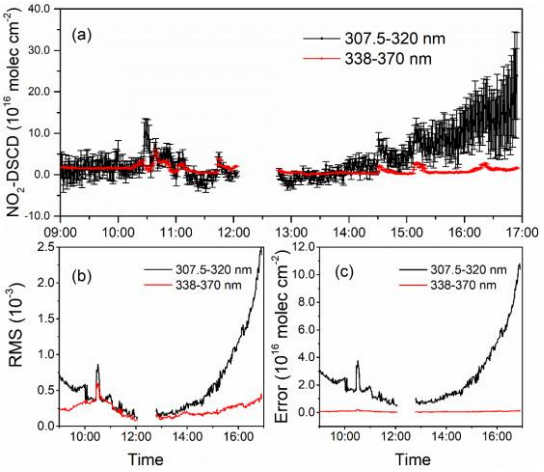

Figure R4. Comparison of NO_2 retrieval with different fitting intervals of 307.5-320 nm and 338-370 nm on 26 June 2018: (a) NO_2 DSCD with error bars, (b) RMS and (c) DSCD error.

Regarding to the compensation of wavelength dependency effect, we think the way to use the ratio of SO_2 to NO_2 DSCDs to identify the ship emission will not be impacted by the effect of wavelength dependency. Because the fixed analysis fitting window was applied for all campaigns and the ratio will not contain the wavelength dependency effect (or in presence as the systematic deviations).

→ Ok, but the authors should add at least some of this response to the manuscript to make it more robust.