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Interactive comment on "Emissions factors for gaseous and particulate pollutants from offshore diesel engine vessels in China" *by* F. Zhang et al.

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Thanks very much for your comments. Our replies are given as following according to your comments:

#the purpose of the study #

This study has given the on-board measurement of pollutants from different vessels in China, and also the impact of engine speed on NOx emission. We are focusing on adding the measurement database of shipping emissions in China, because the engine type, fuel and vessel type are very different of Chinese vessels compared with other countries (such as Chinese commercial vessels have an average age of 19.2 yr compared with 8.0 and 8.9 yr for Japan and Germany, more small motor vessels are

used in China, and diesel is the most common fuel used in offshore vessels but with no fuel stands), which makes the ship emissions unknown in China. When ship emissions inventory was calculated or contribution of ship emissions on environment was estimated in China, emission factors always need to adopt to other countries (Song, 2014;Yang et al., 2015;Ng et al., 2013;Zhou et al., 2007). We aim to give detailed emission factors data to establish the system local emission factor database in China, and also provide some data base for the policy making of emission stands of vessels in China. Though the number of test vessels in this study was small, it could reflect the real exhaust condition of offshore vessels in China. And this measurement is just a beginning, more number and more type of vessels' test will be carried out in our next work (two fishing vessels' measurement has been finished up to now).

#relationship of emission factors with engine load#

In this study, a rough discussion of NOx emission factors with engine speed was given, in order to explain why the economic speed should be noticed. The inappropriate speed in a voyage will cause either high NOx emissions or high fuel expense. Actually, most of the previous studies (Khan et al., 2013;Agrawal et al., 2008) were focusing on the impact of engine load on NOx emissions that always had the trend that first descend then increase with the increasing of engine load. And they always had lower NOx emissions at 25% to 50% load. But there was also study (Alfoeldy et al., 2013) showed that when the vessel in a high engine speed, the NOx emissions would have a clearly decreasing trend with increasing crankshaft rpm.

#the test vessels#

As we mentioned in the manuscript, the vessel type, the engine type, the age of the engine and also the fuel in China are different compared with other countries. We assumed they were the main reasons that would cause the different emissions from vessel exhaust. The results in this study also showed that the emissions from the engineering vessel HH had much higher level than previous studies, such as CO, NOx, TVOCs and PM, on the contrary, good maintenance and engine quality vessels such as DFH and XYH had much lower emissions of NOx and PM compared with other studies. The test vessels in this study are not the majority of ships in use in China, but only the common offshore type. Because it is really hard to get the measurement data, not only for the difficulty of the instrument installation, but also for the not easy rent of the ships, several common vessels had been chosen in this study, which was also only a start of our real-world measurement. In the near future, more types and more number of ships including slow speed, medium speed and high speed engines will be tested to give more detailed data of emission factors.

#new references#

New references about the shipping emissions have been added in the context, such as: According to estimates from IMO (http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Greenh Gas-Studies-2014.aspx), for the year 2012, total shipping emissions were approximately 938 million tonnes CO2 and 961 million tonnes CO2e for GHGs combining CO2, CH4 and N2O. International shipping emissions for 2012 are estimated to be 796 million tonnes CO2 and 816 million tonnes CO2e for GHGs combining CO2, CH4 and N2O. International shipping accounts for approximately 2.2% and 2.1% of global CO2 and GHG emissions on a CO2 equivalent (CO2e) basis, respectively. Other studies about characteristic of gaseous species and PM(Anderson et al., 2015;Celo et al., 2015;Mueller et al., 2015;Reda et al., 2015), and also emission factors(Beecken et al., 2015) are added in the manuscript.

#uncertainties#

The detection parameters for the gaseous matters have been added as an accessory in Table R1, including the detection method, range, resolution and accuracy etc. We can see that all the detection uncertainties are within the relative error of 5%. During our sampling, 3 to 5 replicate samples for each operating mode were collected, which

could give the total error shown in Table B1 and Table B2, including the detection error and the artificial error.

#incorrect references#

Thanks for pointing out the incorrect references in the manuscript. We will revise all the mistakes in the revised version.

#OC to EC ratio#

The residence time of soot particle in the pipe could affect the formation of PM, which led to the different composition of PM. The dilution sampling was not used in this study that might be one reason of the lower OC to EC ratio. Besides, TOR was used to measure OC and EC in PM, which always had a lower OC content compared with other methods because of the different definitions of OC and EC. Thanks again.

Reference: Agrawal, H., Welch, W. A., Miller, J. W., and Cocker, D. R.: Emission measurements from a crude oil tanker at sea, Environmental Science & Technology, 42, 7098-7103, 10.1021/es703102y, 2008. Alfoeldy, B., Loeoev, J. B., Lagler, F., Mellqvist, J., Berg, N., Beecken, J., Weststrate, H., Duyzer, J., Bencs, L., Horemans, B., Cavalli, F., Putaud, J. P., Janssens-Maenhout, G., Csordas, A. P., Van Grieken, R., Borowiak, A., and Hjorth, J.: Measurements of air pollution emission factors for marine transportation in SECA, Atmospheric Measurement Techniques, 6, 1777-1791, 10.5194/amt-6-1777-2013, 2013. Anderson, M., Salo, K., Hallquist, A. M., and Fridell, E.: Characterization of particles from a marine engine operating at low loads, Atmos. Environ., 101, 65-71, 10.1016/j.atmosenv.2014.11.009, 2015. Beecken, J., Mellqvist, J., Salo, K., Ekholm, J., Jalkanen, J. P., Johansson, L., Litvinenko, V., Volodin, K., and Frank-Kamenetsky, D. A.: Emission factors of SO2, NOx and particles from ships in Neva Bay from ground-based and helicopter-borne measurements and AIS-based modeling, Atmospheric Chemistry and Physics, 15, 5229-5241, 10.5194/acp-15-5229-2015, 2015. Celo, V., Dabek-Zlotorzynska, E., and McCurdy, M.: Chemical Characterization of Exhaust Emissions from Selected Canadian Marine Vessels: The Case of Trace Metals and Lanthanoids, Environmental Science & Technology, 49, 5220-5226, 10.1021/acs.est.5b00127, 2015. Khan, M. Y., Ranganathan, S., Agrawal, H., Welch, W. A., Laroo, C., Miller, J. W., and Cocker, D. R., III: Measuring in-use ship emissions with international and US federal methods, Journal of the Air & Waste Management Association, 63, 284-291, 10.1080/10962247.2012.744370, 2013. Mueller, L., Jakobi, G., Czech, H., Stengel, B., Orasche, J., Arteaga-Salas, J. M., Karg, E., Elsasser, M., Sippula, O., Streibel, T., Slowik, J. G., Prevot, A. S. H., Jokiniemi, J., Rabe, R., Harndorf, H., Michalke, B., Schnelle-Kreis, J., and Zimmermann, R.: Characteristics and temporal evolution of particulate emissions from a ship diesel engine, ApEn, 155, 204-217, 10.1016/j.apenergy.2015.05.115, 2015. Ng, S. K. W., Loh, C., Lin, C., Booth, V., Chan, J. W. M., Yip, A. C. K., Li, Y., and Lau, A. K. H.: Policy change driven by an AIS-assisted marine emission inventory in Hong Kong and the Pearl River Delta, Atmos. Environ., 76, 102-112, 10.1016/j.atmosenv.2012.07.070, 2013. Reda, A. A., Schnelle-Kreis, J., Orasche, J., Abbaszade, G., Lintelmann, J., Arteaga-Salas, J. M., Stengel, B., Rabe, R., Harndorf, H., Sippula, O., Streibel, T., and Zimmermann, R.: Gas phase carbonyl compounds in ship emissions: Differences between diesel fuel and heavy fuel oil operation (vol 94, pg 467, 2014), Atmos. Environ., 112, 369-380, 10.1016/j.atmosenv.2015.03.058, 2015. Song, S.: Ship emissions inventory, social cost and eco-efficiency in Shanghai Yangshan port, Atmos. Environ., 82, 288-297, 10.1016/j.atmosenv.2013.10.006, 2014. Yang, J., Yin, P.-l., Ye, S.-q., Wang, S.-s., Zheng, J.-y., and Ou, J.-m.: Marine Emission Inventory and Its Temporal and Spatial Characteristics in the City of Shenzhen, Huan jing ke xue= Huanjing kexue / [bian ji, Zhongguo ke xue yuan huan jing ke xue wei yuan hui "Huan jing ke xue" bian ji wei yuan hui.], 36, 1217-1226, 2015. Zhou, F., Guo, H., and Hao, Z.: Spatial distribution of heavy metals in Hong Kong's marine sediments and their human impacts: A GIS-based chemometric approach, Mar. Pollut. Bull., 54, 1372-1384, 10.1016/j.marpolbul.2007.05.017, 2007.

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Table R1 Detection parameters for the gaseous matters

Component	Method	Range	Resolution	Accuracy	Time (T_{90})	Conformity
O_2	Electrochemical sensor	20.95%	0.01%	±5% rel.	45 s	ISO 12039, CTM-030
CO_2	NDIR	5%	0.01%	±3% rel.	45 s	ISO 12039, OTM-13
CH_4	NDIR	5%	0.01%	±3% rel.	45 s	
NO	NDIR	1000ppm	1ppm	±3% rel.	45 s	ISO 10849, Method 7E
NO_2	NDIR	1000ppm	1ppm	±3% rel.	45 s	ISO 10849, Method 7E
SO_2	NDIR	1000ppm	1ppm	±3% rel.	45 s	ISO 7935, Method 6C
N_2O	NDIR	2000ppm	1ppm	±3% rel.	45 s	ISO 21258
VOCs	PID	10000ppm	0.1ppm	±5% rel.	-	

NDIR, Non-dispersive Infra-red

PID, Photo Ionization Detectors

Fig. 1.