



Real-world emission factors of gaseous and particulate pollutants for marine fishing boats and estimate of their total emissions in China

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- ◆ Why does **on-board measurement** necessary for fishing boats?
- ◆ Emission factors of **gaseous pollutants and PM** of fishing boats
- ◆ Estimated total emissions from **motor-powered marine fishing boats**
in China



✓ Why does on-board measurement necessary for fishing boats?

➤ Ship emissions have significant negative impact on **climate change, ambient air quality and human health**, especially in coastal areas.

➤ Almost all of the studies are focusing on **large engines**, such as ocean-going vessels and coastal transport ships

➤ Fishing boats typically have **large number and active in nearshore areas** in fisheries developed countries, such as China.

Pollutants from shipping boats have been neglected almost all over the world, **measured emission data** and **emission characteristics** of fishing boats are in acute shortage

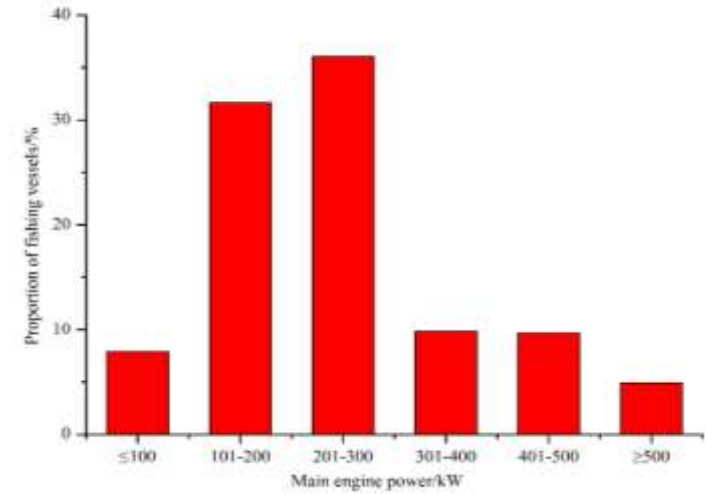
Fishing boats in China:

- China has the largest number of fishing boats in the world, about **1.04 million** by the end of 2015 (**0.17 million transport ships**), account for $\frac{1}{4}$ of total number in the world;
- China had the biggest fisheries in the world, about **73.66 million tons** that accounted for **42.13%** of the worldwide total amount of fisheries in 2015;
- **Fuel consumption** of fishing boats in China is very large, which could account for **41.7%** of the total fuel consumption of ships in China;
- Only very few studies have involved in fishing boat emissions ([Lin, 2006](#); [Song, 2015](#)).

Methods: test fishing boats

Technical parameters of test boats

Vessel ID	Engine power (kW)	Vessel type	Ship length ×width (m)	Material	Vessel age (year)
GB1	91	Gillnet	20*4.3	Wooden	10
GB2	178	Gillnet	27*5.6	Wooden	7
AB1	129	Angling boat	21*4.3	Wooden	6
AB2	176	Angling boat	22.7*4.8	Wooden	5
TB1	88	Trawler	13*3.5	Wooden	8
TB2	132	Trawler	13*3.5	Wooden	5
TB3	235	Trawler	22.5*4.2	Wooden	6
TB4	235	Trawler	24*5.2	Wooden	7
TB5	265	Trawler	29*5.4	Metal	10
TB6	265	Trawler	29*5.4	Metal	10
TB7	397	Trawler	34*5.6	Metal	1
TB8	397	Trawler	34*5.6	Metal	1

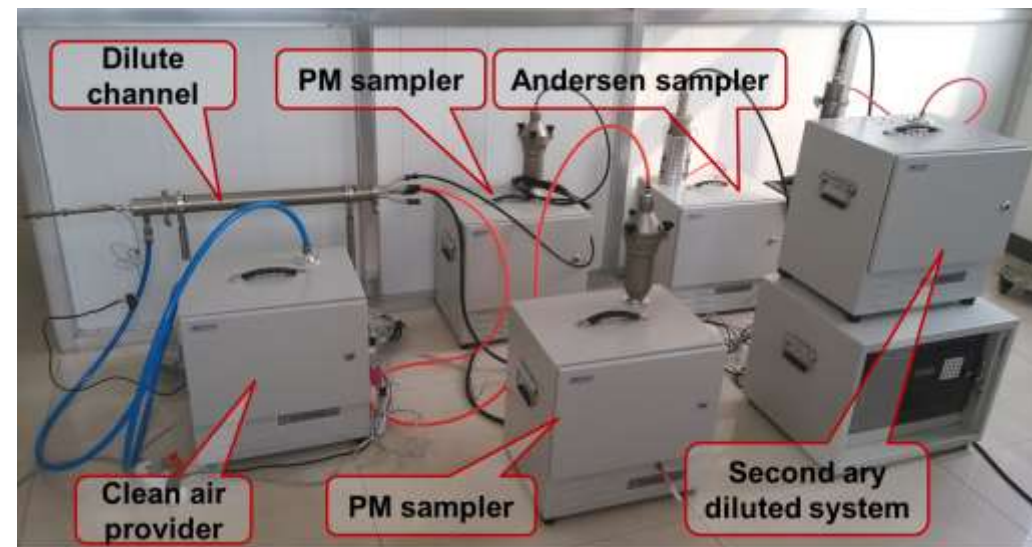
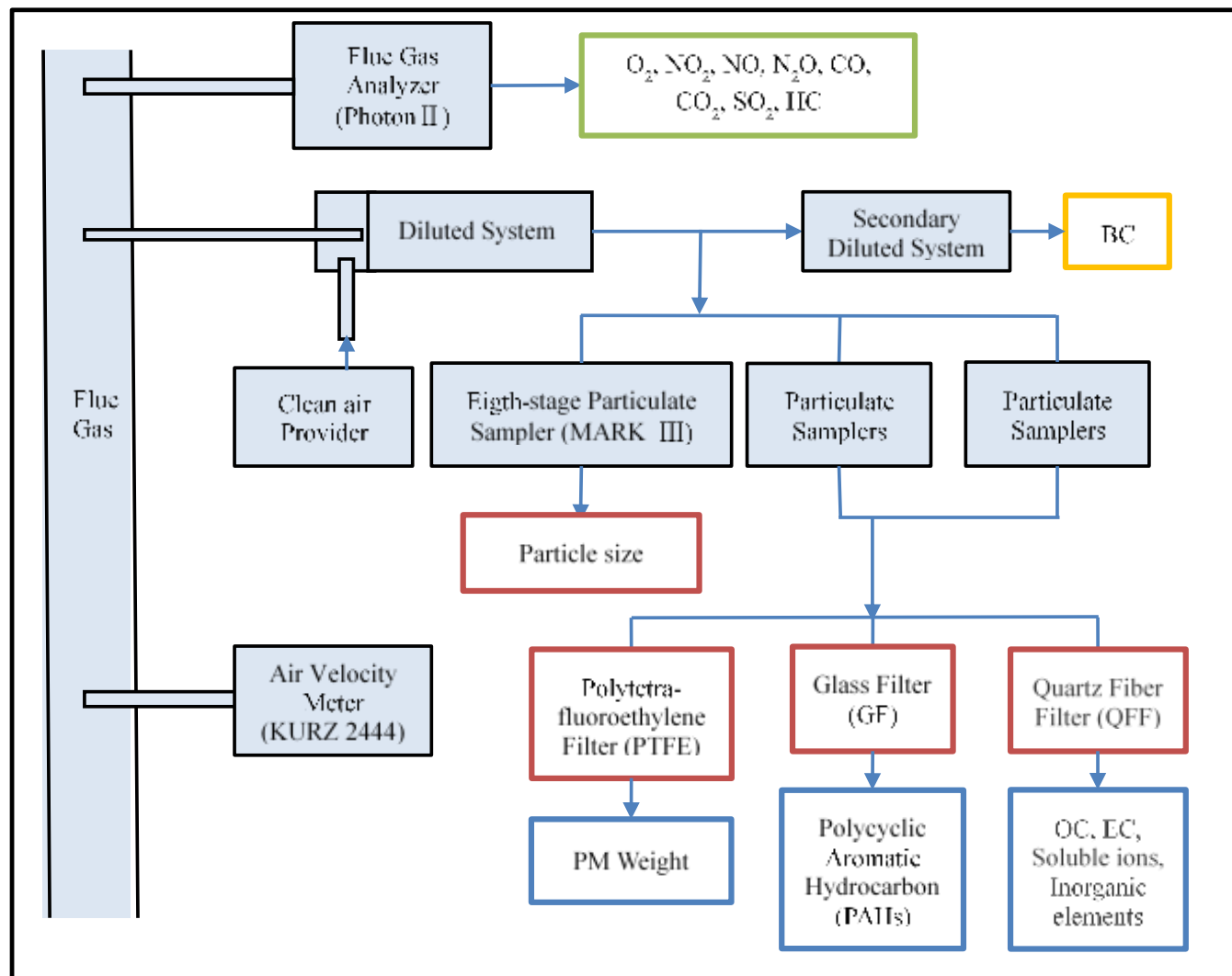


Proportion of fishing boats based on main engine power in China

An overview of fishing boat fleet in China in 2015

	Trawler	Seiner	Gillnet	Stow boat	Angling boat	Others
Quantity	35,820	7,448	100,070	18,958	10,439	14,476
Total power (million kW)	6.80	1.10	3.94	0.83	1.04	0.71
Fuel consumption (million ton)	3.81	0.32	1.97	0.19	0.68	0.32
Percentage in quantity (%)	19	4.0	54	10	5.6	7.7
Percentage in power (%)	47	7.6	27	5.8	7.2	4.9
Percentage in fuel consumption (%)	52	4.4	27	2.6	9.4	4.4

Methods: **sampling system**

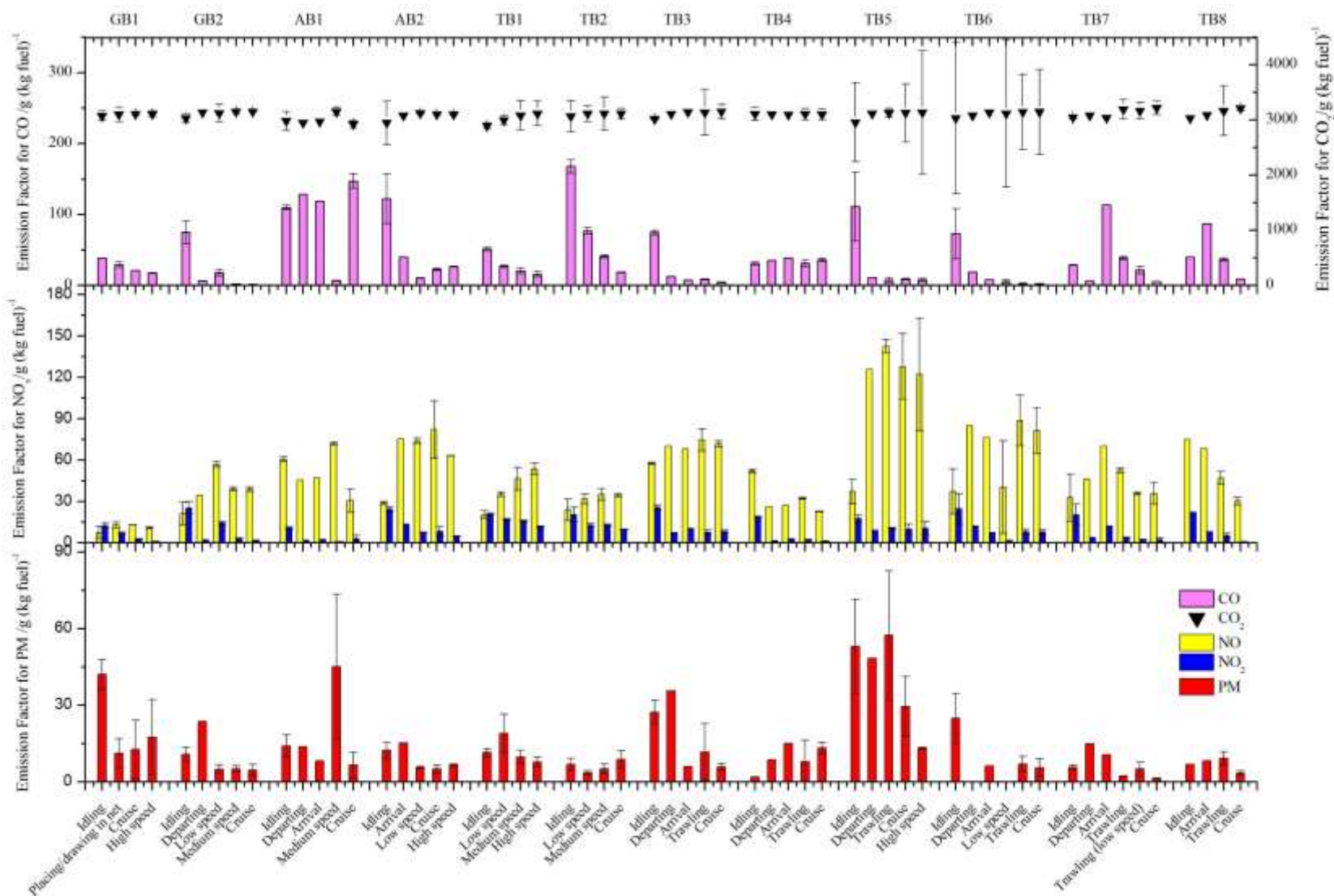


Activity modes of the test fishing boats and operating time for each circle (h)

Activity modes/Vessel ID	GB1	GB2	AB1	AB2	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8
Idling	0.5	10	12.0	10.0	1.0	1.0	1.0	1.0	1.5	1.5	2.0	2.0
Starting	0.3											
Departing		0.3	0.3				0.3	0.3	0.5	0.3	0.3	
Arrival			0.3	0.5			0.3	0.3		0.3	0.3	0.5
Placing/drawing in net	5.0											
Trawling (low load)											√	
Trawling							4.0	4.0	5.0	5.0	9.0	9.0
Low speed		√		√	1.0	1.0				√		
Medium speed		√	√		2.0	2.0						
Cruise	12.0	12.0	10.0	12.0	6.0	6.0	5.0	5.0	6.0	6.0	4.0	4.0
High speed	√			√					√			

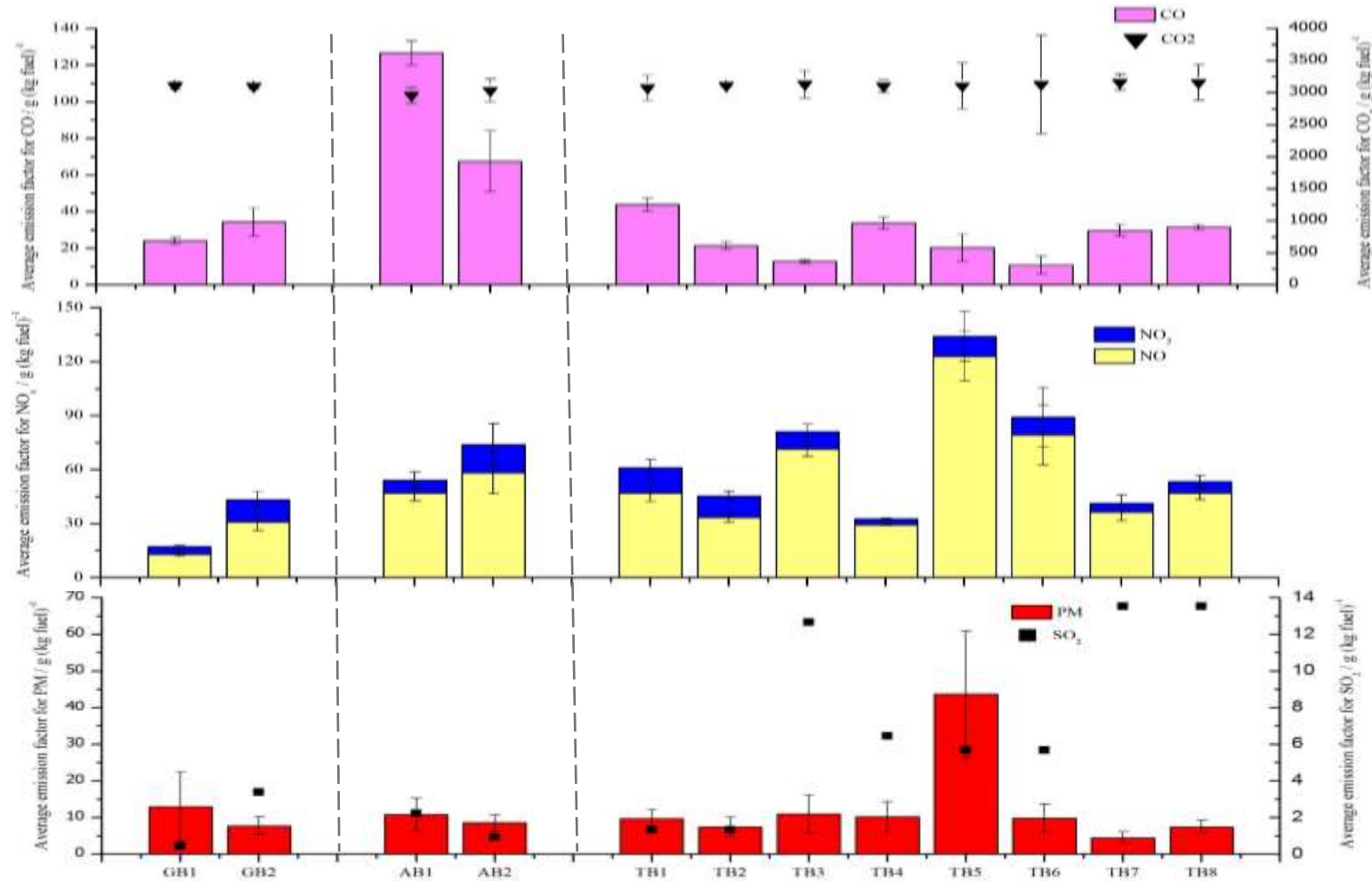
√, activity mode tested in this study but rarely operating in actual situation.

✓ Emission factors of gaseous pollutants and PM of fishing boats



EFs for pollutants in different activity modes

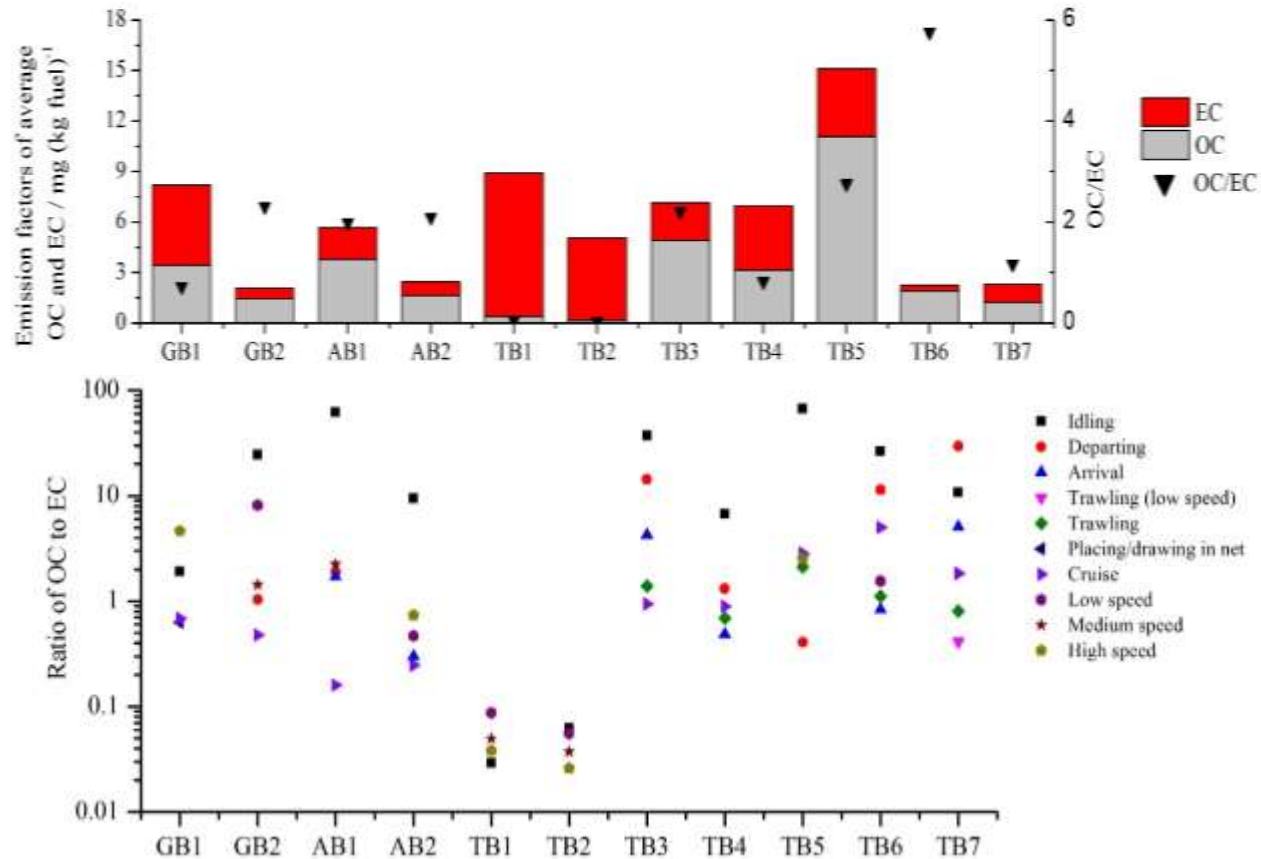
✓ Emission factors of gaseous pollutants and PM of fishing boats



- Angling boats had relatively higher CO emission factors compared with the other two types of boats.
- NO_x EFs of gillnet boat had relatively lower values. The size of engine power of the fishing boats had no significant impact on NO_x EFs in this study.
- For the same type of boats, EFs for PM had no significant variation, engine power and engine age were considered to be the main reasons for the PM EFs differences.

Average EFs for pollutants of fishing boats

✓ Emission factors of gaseous pollutants and PM of fishing boats



Ratios of OC to EC for all test fishing boats

- OC: 2.1% to 44.9% of PM weight in total;
- EC: 3.4% to 87.5% of PM weight in total.
- Ratios of OC to EC in this study ranged between 0.72 to 5.76 except for boat TB1 (0.05) and boat TB2 (0.03), **lower than that of large diesel ships** reported previously.
- Almost all the fishing boats showed higher OC to EC ratios under lower engine power loads, and decreased with the increasing of engine load.

✓ Emission factors of gaseous pollutants and PM of fishing boats

	CO ₂	CO	NO	NO _x	NO ₂	HC	PM	SO ₂	
Average EFs for gillnet (this study)	1.91±2.08								HSD
Average EFs for angling boat (this study)	1.57±0.92								HSD
Average EFs for trawler (this study)	4.35±5.12								HSD
Average EFs for fishing boats (this study)	5.94±6.38								HSD
Swedish cod fishery{Ziegler, 2003 #728}	3170	1.07-3.22			22.9-37.6	0.92-2.36		0.70	trawling
Fishing boats *{Hsieh, 2009 #728}								0.70	gillnet fishing 74-404 kW
Fishing boats*{Lin, 2006 #728}									HSD
Engineering vessel{Zhang, 2016 #1175}								1.60	HSD
Research vessel{Zhang, 2016 #1175}	3153	6.93	30.2	5.09	35.7	1.24	0.72	0.92	MSD
Research vessel{Zhang, 2016 #1175}	3151							2.60	MSD
Cargo vessel{Moldanova, 2009 #816}								39.32	SSD
Diesel engine{Haglund, 2008 #816}								54	SSD
Ocean-going ships{Sinha, 2005 #816}								2.9	SSD
Cargo and passenger ships{Endresen, 2003 #816}	3170	7.4	-	-	57	2.4	1.2	10	HSD
	3170	7.4	-	-	87	2.4	7.6	10	SSD

Emission factors for pollutants of fishing boats in this study had **higher values of CO, NO_x and PM than previous studies about fishing boat emissions.**

All the test high-speed diesel vessels in offshore area of China had **higher EFs of CO and PM compared with other vessels.**

High-speed diesel vessels such as fishing boats had **relatively higher CO EFs and lower NO_x EFs** compared with medium-speed diesel and slow-speed diesel vessels.

✓ Estimated total emissions from motor-powered marine fishing boats in China

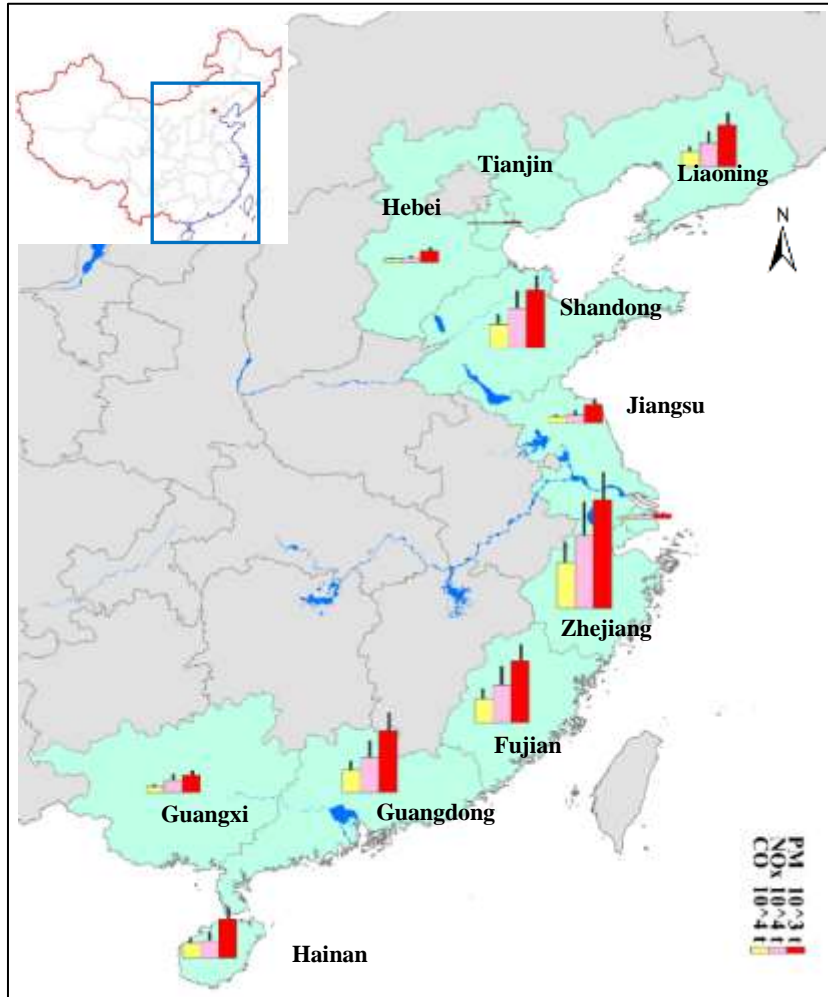
Estimate of pollutants emitted from motor-powered marine fishing boats in China from 2006 to 2015 (10^4 ton)

	CO ₂	CO	NO	NO ₂	NO _x	PM	SO ₂
2006	2150±20.7	24.7±11.1	33.0±17.6	6.30±3.02	39.6±19.4	6.39±1.74	3.62±2.87
2007	2224±20.8	25.1±11.1	33.9±18.1	6.49±3.13	40.8±20.0	6.61±1.82	3.75±2.95
2008	2019±18.1	21.9±9.47	31.0±16.6	5.86±2.82	37.2±18.3	5.97±1.66	3.49±2.70
2009	2036±18.0	22.0±9.43	31.0±16.6	5.90±2.86	37.2±18.3	6.03±1.68	3.50±2.70
2010	2033±18.0	22.4±9.57	30.8±16.4	5.91±2.88	37.1±18.2	6.04±1.68	3.44±2.66
2011	2068±18.4	23.1±9.86	31.2±16.5	6.02±2.94	37.6±18.3	6.15±1.71	3.46±2.68
2012	2079±18.4	23.2±9.84	31.5±16.6	6.05±2.96	37.9±18.4	6.18±1.72	3.50±2.70
2013	2135±19.0	24.4±10.4	32.2±16.8	6.24±3.07	38.8±18.7	6.36±1.76	3.52±2.72
2014	2210±19.9	26.0±11.0	33.2±17.1	6.49±3.21	40.0±19.2	6.61±1.82	3.57±2.77
TE_X = ∑(EF_{X,j} × C_{f,j}) 2015	2261±20.2	26.4±11.2	33.8±17.5	6.62±3.28	40.8±19.7	6.76±1.87	3.65±2.84

Non-road mobile sources:
231.8×10⁴ t CO, 360.4×10⁴ t NO_x and 32.0×10⁴ t PM_{2.5}
 Fishing boats account for :
10.7%, 10.9% and 19.3%

where TE_X represents the total emission of species X (million ton), $EF_{X,j}$ represents the emission factor for species X of type j boat, $C_{f,j}$ is the total consumption of fuel (million ton) for j type boat.

✓ Estimated total emissions from motor-powered marine fishing boats in China



- Most of the emissions from the motor-powered marine fishing boats, accounting for **more than half** of the total emissions, are concentrated on **southern China** in provinces such as Zhejiang, Guangdong, and Fujian.
- Zhejiang Province: 11.3×10^4 tons of NO_x, 16.7×10^3 tons of PM, account for **18.5% of the total NO_x** emission (60.7×10^4 tons) and **5.1% of the total PM** emissions (33.0×10^4 tons).



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Thanks!

