Decadal evolution of ship emissions in China from 2004 to 2013 by using an integrated AIS-based approach and projection to 2040

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Abbreviations

AB: Auxiliary Boilers

AE: Auxiliary Engine

AIS: Automatic Identification System

BC: Black Carbon

CCTD: Statistics Communique of China on the Traffic and Transportation Industry Development

CO: Carbon monoxide

CPSY: China Port Statistics Yearbook

CVs: Coastal Vessels

DECAs: Domestic Emission Control Areas

DWT: Dead Weight Tonnage

ECA: Emission Control Area

EGR: Exhaust Gas Recirculation

GDP: Gross Domestic Product

HC: Hydrocarbon

HFO: Heavy Fuel Oil

ICF international: A global Consulting and Technology Services Company

IMO: International Maritime Organization

LNG: Liquefied Natural Gas

LRS: Lloyd's Register of Ships

MD: Marine Department

MDO: Marine Diesel Oil

ME: Main Engine

MEIC: Multi-resolution Emission Inventory for China

NECA: NOx-DECA, Domestic Emission Control Areas for NO_x Control

Nm: Nautical Miles

NMVOC: Non-methane Volatile Organic Compounds

NOx: Nitrogen oxide

OGVs: Ocean-going Vessels

OC: Organic Carbon

PM: Particulate Matter

PoLa: Los Angeles and Long Beach

PRD: Pearl River Delta Region

QAQC: Quality Assurance and Quality Control

RVs: River Vessels

SCR: Selective Catalyst Reduction

SECA: SO_2-DECA, Domestic Emission Control Areas for SO_2 Control

SI: Supporting Information

SO2: Sulfur dioxide

tce/10kt：Ton of Standard Coal Equivalent per 10 Kiloton

U.S.EPA: United States Environment Protection Agency

VAN: Vessel Arrived Number

WHO: world health organization

YRD: Yangtze River Delta Region

1. Domain and ship categorization

According to the "United Nations convention on the law of the sea" approved by United Nations conference on the third law of the sea in 1982, which indicated that 200 nautical miles (Nm) exclusive economic zone (EEZ) belongs to the scope of the jurisdiction of the state, further explain in article 56 of the convention mentioned the right regulation of EEZ including the jurisdiction on the area of artificial islands, installations and science research and Marine environmental protection fields, that is to say the research domain of ship emissions in China expand to 200 Nm zone is acceptable. However, science research does not mean the legislative power, have jurisdiction over 12 Nm of ship emissions control area (ECA) needs to be approved by IMO, e.g., Beihai ECA, Mediterranean ECA. The scope of these international ECAs are 200 Nm, which support the domain in this study, and also enhance the referable of this study. By the way, the domain chosen in this study reflects our focus on densely populated areas and does not represent any national boundaries.

There were 18000 km coastline covered 31760 harbors in this region, which contains 5675 coast harbors and 2001 10kt carrier harbors. More detail for 10kt carrier harbors in table SI-1, SI-2.

Table SI-1 the distribution of 10kt carrier ports in China, 2013

Port size	Coast port	River port	Total
Total	1607	394	2001
[10kt, 30kt]	567	169	736
[30kt, 50kt]	254	102	356
[50kt, 100kt]	532	116	648
≥100kt	254	7	261

Table SI-2 the distribution of the function of 10kt carrier ports in China, 2013

Function	Container	Coal	Metal ore	Crude Oil	Oil product	Chemical	Food	General bulk	General cargo	Total
Number	**321**	**206**	**61**	**68**	**124**	**157**	**6**	**414**	**345**	**2001**

Four sub-categories were classified by cargo types, i.e. container ships carrying containers, cargo ships carrying dry bulk like ore, construction materials, coal and its products, tankers carrying chemicals, gas, oil and its products, and others. More detailed information for sub-categorizes of DWT.

Table SI-3 Classification Basis of Different Operation Modes

Operation Mode	Description	Ship Speed
Cruise (At sea)	Ship operating at service speed, usually in inland waters, offshore open waters or broad fairways	Over 8 knots
Maneuvering	Ship operating at lower speed as it approaches berth/pier/dock or anchorage	1 to below 8 knots
Hotelling (At berth)	Ship at berth or anchored with propulsion engines switched off	Below 1 knot

*knot is a unit of sailing speed measuring, 1 knot=1sea mile/hour; sea mile is a unit of distance measuring, 1 sea mile=1.852km (China Standard), so 1 knot≈1.852 km/h.

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Table SI-4 DWT Classification of Different Ship Types

OGV	CV	RV	OGV	CV	RV
Container	Container	Container	Chemical Tanker	Chemical Tanker	Chemical Tanker
DWT <10000	DWT <3000	DWT＜500	DWT<5000	DWT <3000	DWT＜500
DWT 10000-19999	DWT 3000-4999	DWT 500-1000	DWT5000-9999	DWT 3000-5000	DWT＞500
DWT 20000-29999	DWT 5000-9999	DWT＞1000	DWT 10000-19999	DWT 5000-9999	
DWT 30000-39999	DWT >10000		DWT 20000-39999	DWT >=10000	
DWT 40000-49999			DWT >=40000		
DWT 50000-74999			Conventional Cargo Ship	Conventional Cargo Ship	Conventional Cargo Ship
DWT 75000-99999			DWT <2000	DWT <5000	DWT＜500
DWT >=100000			DWT 2000-4999	DWT 5000-9999	DWT 500-1000
Gas Tanker	Gas Tanker	Gas Tanker	DWT 5000-9999	DWT 10000-29999	DWT＞1000
DWT <5000	DWT <3000	DWT＜500	DWT 10000-29999	DWT >=30000	
DWT 5000-9999	DWT 3000-4999	DWT＞500	DWT >=30000		
DWT 10000-19999	DWT 5000-9999		Dry Bulk Carrier	Dry Bulk Carrier	Dry Bulk Carrier
DWT 20000-39999	DWT >=10000		DWT <10000	DWT <3000	DWT＜500
DWT >=40000			DWT 10000-29999	DWT 3000-4999	DWT 500-1000
Oil Tanker	Oil Tanker	Oil Tanker	DWT 30000-59999	DWT 5000-9999	DWT＞1000
DWT <10000	DWT <3000	DWT＜500	DWT 60000-99999	DWT >=10000	
DWT 10000-29999	DWT 3000-4999	DWT＞500	DWT >=100000		
DWT 30000-59999	DWT 5000-9999		Tug	Tug	Tug
DWT 60000-119999	DWT >=10000		Passenger ship	Passenger ship	Passenger ship
DWT >=120000			Fishing ship	Fishing ship	Fishing ship
			Others	Others	Others

2. Potential influence of transit ships

We did roughly estimate the contribution from passing ships, and concluded that their contribution is relatively low but with potentially high uncertainties. Therefore, we decide to exclude it into this study to avoid negative impact on the results. The research domain is 200Nm to the coast of Mainland China. The main routes in this domain include all routes from/to Chinese ports and the passing routes, mainly from Busan, Korea to Southeast Asia (Busan route) and from Taiwan to destinations other than Mainland China ports (Taiwan route). In order to study the fraction of Busan route and Taiwan route in our research domain, we extracted a real-time AIS map, and highlighted the passing ship routes by red lines (Fig. SI-1).

There were 368 shipping route from/to Korea in 2013, including 85 Southeast Asia routes and 26 Europe routes. As the throughput of Busan port accounted for 75.4% of total throughput (17686kt) in Korea, we estimated that Busan route roughly accounted for 7100kt throughput. With around 800Nm passing distance in our research domain, we estimated the fuel consumption from Busan route was around 70kt HFO. The total throughput in Taiwan was 14 million TEU in 2013, including 2.5 million TEU between Taiwan and Mainland China. Therefore, Taiwan route contributed around 11.5 million TEU. If we assume 1TEU=15t and the average travel distance was 500Nm, the fuel consumption from Taiwan route was around 1070kt HFO. Therefore, the total consumption of Busan route and Taiwan route was around 1140kt HFO, only 7% of total fuel consumption in our research domain. Therefore, we believe excluding the passing route would not significantly impact our analysis results.

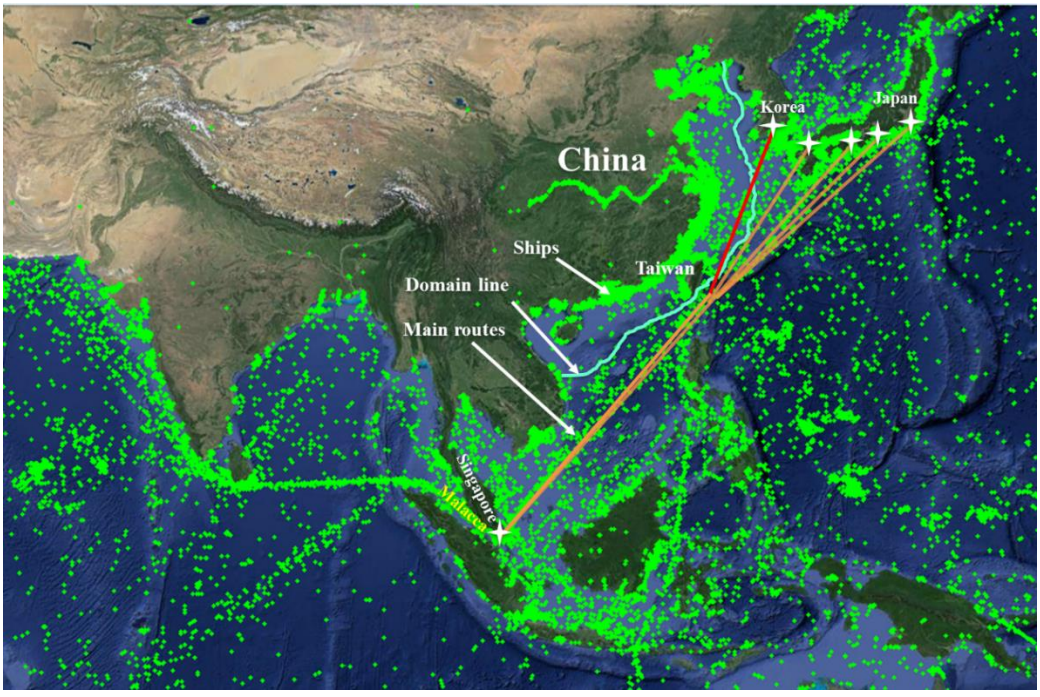


Fig. SI-1 Major shipping routes extracted from a real-time AIS digital map

3. Transport volume information

Transport volume is the real weight of transport cargo for a period time, different statistic approaches used for the Yangtze River ports and other coast ports, the former statistics output cargo weight, and the later statistics input cargo weight. Transport volume statistics from the Chinese National Statistics Bureau and China port statistical yearbook with different classification, but no significant differences of the total amount.

There are 92 Chinese ports with cargo types-based transport volume statistic in this study. Raw data shown below. The regional transport volume statistics including liquid cargo, dry bulk, general cargo, container corresponding to tanker, bulk ship, general cargo ship, container ship, respectively. Among them, liquid cargo cover oil and gas; dry bulk cover ore, coal and building material; general cargo cover food, wood and chemical material; container cover container and roro-car.

Table SI-5 shown in the last.

4. Transport distance information

Transport distance is the weight-based length along common routes of OGVs and CVs in the research domains of 12Nm and 200Nm, respectively. Specifically, transport distances of OGVs were calculated as the average of main international routes from main ports in a particular port cluster, as shown in Fig. SI-2(a), and then multiply by the fraction of regular routes to Korea, Japan, South China Sea and Pacific, respectively (see Table SI-6); transport distances of CVs were derived from transport distances between port clusters measured by AIS data and digital map. Some illustrations are given in Fig. SI-2(c) for readers to understand the AIS-based digital map. We collected information more than 1000 regular routes, including their departure and arrival ports. We classified departure and arrival ports into port clusters, and then used AIS data and digital map to calculate transport distances between port clusters (Fig. SI-2(b)).

Table SI-6 (a) Information of international regular routes from Chinese ports

Destination country/region	Number of regular routes	Fraction
America	115	12%
Japan	110	11%
Korea	78	8%
Southeast Asia	89	9%
Europe	80	8%
Australia	22	2%

Mediterranean	34	3%
Taiwan	38	4%
Black Sea	10	1%
Others	422	42%
Total	998	100%

Table SI-6(b) Port cluster-specific transport distance and its fraction

Port cluster	Main route	Transport distance/Nm	Fraction within the port cluster
PRD	Korea	1250	22%
	Japan	1442	35%
	South China Sea	1082	23%
	Pacific	354	20%
Shandong	Korea	361	34%
	Japan	847	35%
	South China Sea	2130	21%
	Pacific	550	10%
YRD	Korea	436	10%
	Japan	888	15%
	South China Sea	1858	40%
	Pacific	516	35%
Bohai	Korea	450	30%
	Japan	1423	40%
	South China Sea	813	15%
	Pacific	900	15%
Western Taiwan Strait		607	100%
Beibu Gulf		703	100%

(b)

N → S

Departure / Arrival	Yingkou	Dalian	Tianjin	Qingdao	Shanghai	Ningbo-Zhoushan	Xiamen	Shenzhen	Guangzhou
Yingkou	0	4	10	1	6	2	0	0	3
Dalian	4	0	49	49	17	5	0	2	18
Tianjin	9	48	0	22	2	1	0	0	1
Qingdao	0	19	12	0	61	40	3	0	9
Shanghai	7	20	6	31	0	152	25	27	8
Ningbo-Zhoushan	2	2	0	18	166	0	27	33	17
Xiamen	0	0	0	3	22	13	0	31	6
Shenzhen	0	2	0	1	15	11	27	0	12
Guangzhou	0	0	0	0	1	0	3	29	0
Total	22	95	77	125	290	224	85	122	74

N ↓ S

e.g. The share of transport distance between Bohai and PRD region = 36 / 285 = 12.6%

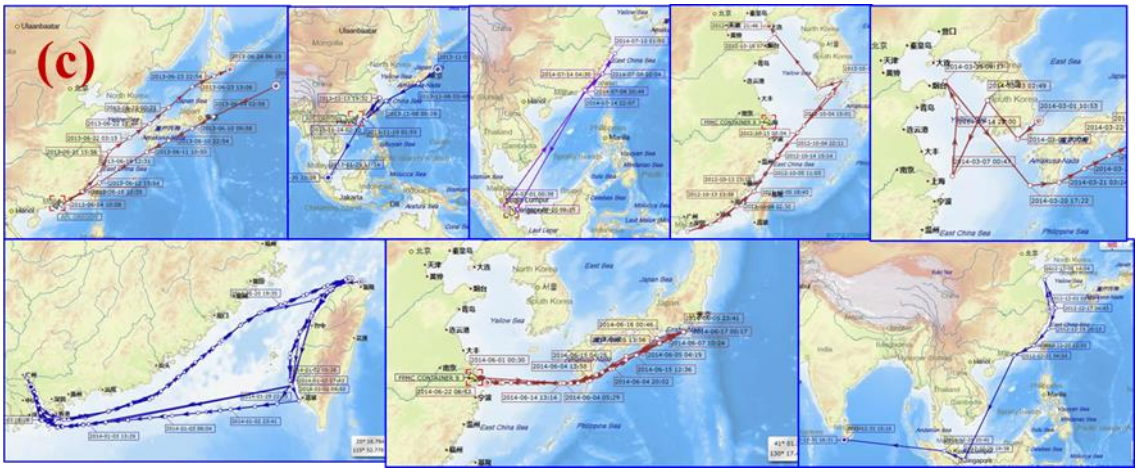


Fig. SI-2 (a) the major international routes in the world (the average transport distance of OGVs can be calculated by using the distance of those ocean-going routes by combining Table SI-6(a))

(b) samples of transport distances calculation process in determining the fraction within the port cluster (area with color were all routes for PRD; area with deep colors were the routes between Bohai and PRD, calculation process shown in this figure, with the same way, then can calculate the share of all routes, and the weight-based transport distance can be calculated by combining each routes' distances)

(c) the sample of calculation process on the share of transport distance among different region (transport distance can be calculated by using the AIS-based digital map with the distance measuring tool)

5. Uncertainties estimation

Uncertainties of emissions factors and activity time for estimation were shown as following.

Table SI-7 Uncertainties of emissions factors for estimation

Pollutants	Categories	Distribution types	Mean	Confidence interval
SO_2	HFO（2.7%）	Weibull	11.3	(-18.2%, 11.3%)
	MDO（0.5%）	Weibull	1.4	(-74.8%, 107.4%)
NOx	SSD	Gamma	16.3	(-19.7%, 21.6%)
	MSD	Gamma	13.8	(-9.6%, 10.4%)
	HSD*	Gamma	11.5	(-26.0%, 29.2%)
CO	OGVs/CVs	Gamma	1.3	(-22.4%, 25.0%)
	RVs	Gamma	1.3	(-22.4%, 25.0%)
PM_{10}	HFO（2.7%）	Gamma	1.5	(-14.7%, 16.4%)
	MDO（0.5%）	Weibull	0.4	(-42.4%, 34.6%)
$PM_{2.5}$	HFO（2.7%）	Weibull	1.3	(-14.7%, 16.4%)
	MDO（0.5%）	Gamma	0.4	(-42.4%, 34.6%)
HC	OGVs/CVs	Gamma	0.5	(-32.7%, 36.5%)
	RVs	Weibull	0.4	(-65.3%, 72.0%)
BC*	All	Weibull	0.3	(-97.7%, 126.5%)
OC*	All	Weibull	0.2	(-68.2%, 111.6%)

*the value of BC and OC were the ratio of $BC/PM_{2.5}$ and $OC/PM_{2.5}$, respectively.

Table SI-8 Uncertainties of time-in-modes for estimation

Ship types		Modes	Distribution types	Mean/hours	Lower bound of uncertainty	Upper bound of uncertainty
OGVs	Tanker	Maneuvering	Weibull	4.3	-28%	31%
		Hoteling	Weibull	25.3	-17%	16%
	Cargo ship	Maneuvering	Gamma	3.4	-15.1%	20.9%
		Hoteling	Weibull	15.8	-9.8%	6.0%
	Container ship	Maneuvering	Weibull	3.7	-11%	10%
		Hoteling	Weibull	22.2	-16%	17%
	Others	Maneuvering	Weibull	1.1	-62.1%	96.5%
		Hoteling	Gamma	17.2	-50.0%	60.1%
CVs	Tanker	Maneuvering	Gamma	2.3	-35.9%	53.8%
		Hoteling	Normal	23.5	-15.3%	19.0%
	Cargo ship	Maneuvering	Gamma	3.2	-84.3%	160.4%
		Hoteling	Gamma	16.8	-17.5%	18.7%
	Container ship	Maneuvering	Normal	3.9	-53.0%	46.7%
		Hoteling	Weibull	19.1	-29.9%	29.4%
	Others	Maneuvering	Gamma	2.7	-84.8%	164.9%
		Hoteling	Gamma	17.7	-84.2%	172.6%

6. AIS data information

According to the most advanced study (Liu et al., 2016), the introduction of automatic vessel position reporting systems has significantly reduced the uncertainty concerning ship activities and their geographical distribution. However, using shipping activity data for research remains a challenging task (Dalsoren et al., 2009; Liu et al., 2016). Different with Liu's study, this study established a model for ship activity data calculation by using a continuously trajectories AIS dataset but not comprehensive in China Sea. Here I given a comparison of AIS data (Dalsoren et al., 2009; Liu et al., 2016) to demonstrate that the representativeness of our ship information dataset in China Sea is acceptable (table SI-9).

Table SI-9 ship information statistics in China and in the other studies

Study area	Year	Area Million km^2	Archived AIS messages	Number of ship with AIS	Number of ship information
China Sea	2013	3.0	3.5E+08	700	12,600
East Asia	2013	4.2	2.0E+09	18,324	18,324
Baltic sea	2009	0.4	2.6E+08	11,606	11,606

The AIS was introduced by the IMO international Convention for the Safety of Life at Sea.

Which include shore-based and satellite-based data. The shore-based data is featured by high temporal resolution (every 30 seconds), but only covers ships less than 50 nautical miles from the shore. For the areas beyond 50 nautical miles, satellite-based data in 2-h interval was used.

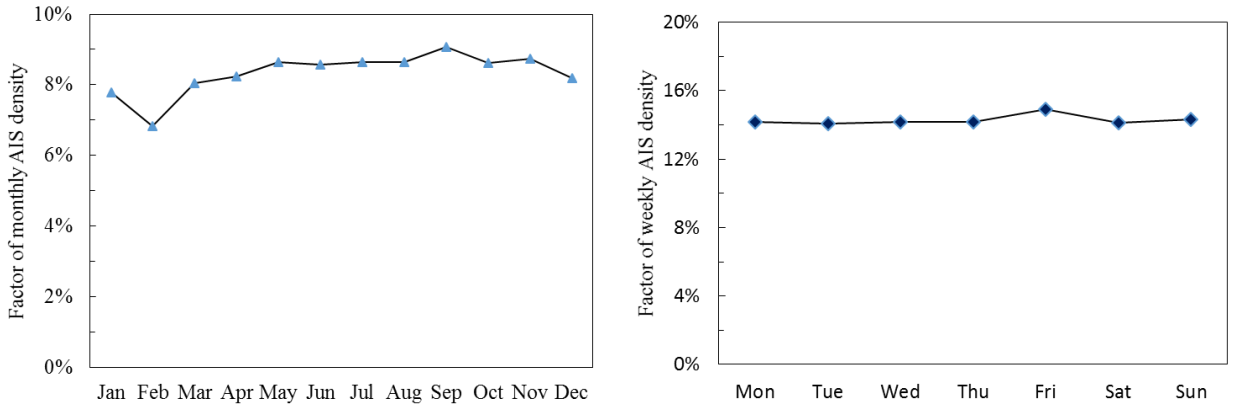


Fig. SI-3 the monthly and weekly variation of ship fuel consumption by using AIS dot-density in 2013

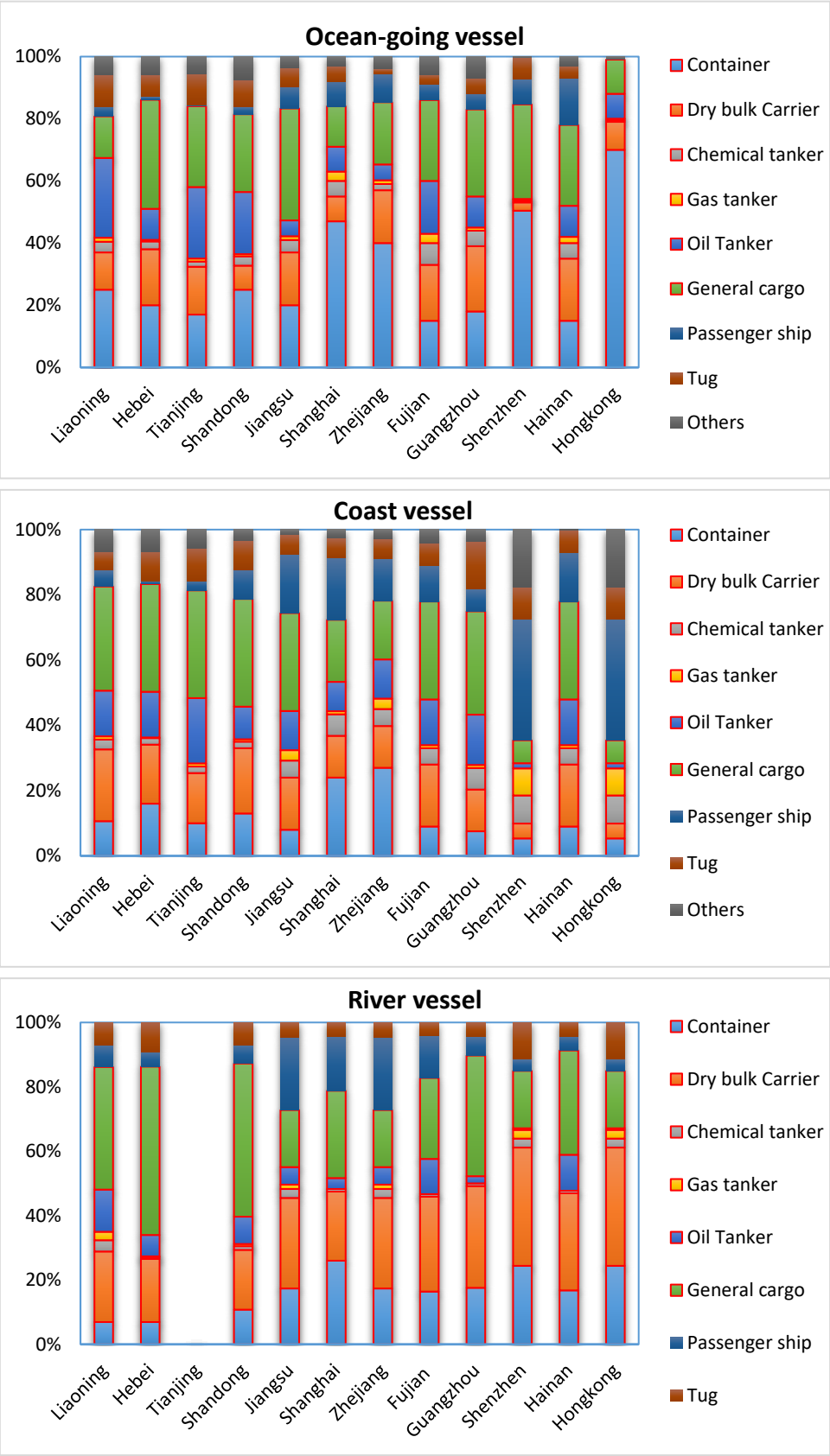


Fig. SI-4 Summary of the stock of ship types navigated in different regions for OGVs, CVs and RVs

7. Fuel consumption information

For fuel consumption rate (Kg tce/KtNm), the value of different ship types can be obtained from CCTD in 2010-2015, but the value of OGVs are not within the typical ranges of corresponding ship type from IMO report (IMO, 2015), as detailed in Fig. SI-6, that maybe caused by the statistics of the international trade in ocean going cargo companies. So the median value of the range provided by IMO were used to estimate in cargo-based approach. For the fuel consumption rate for RVs, which refer to the value from CCTD, 5.2 tce/10kt, that why we do not need the transport distance of RVs.

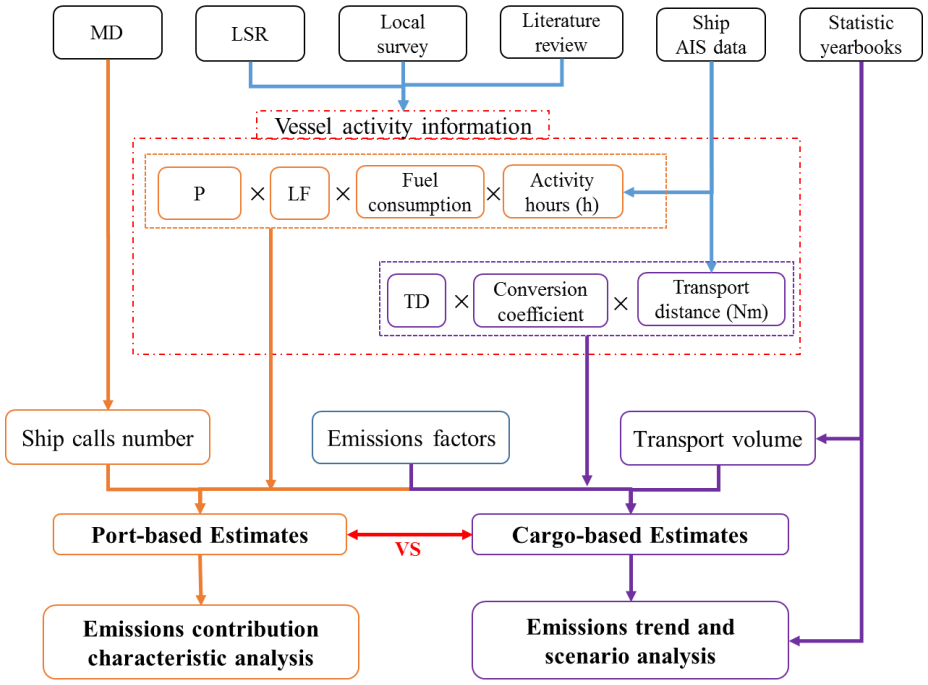


Fig. SI-5 Data sources and flowchart used for emissions estimates in this study

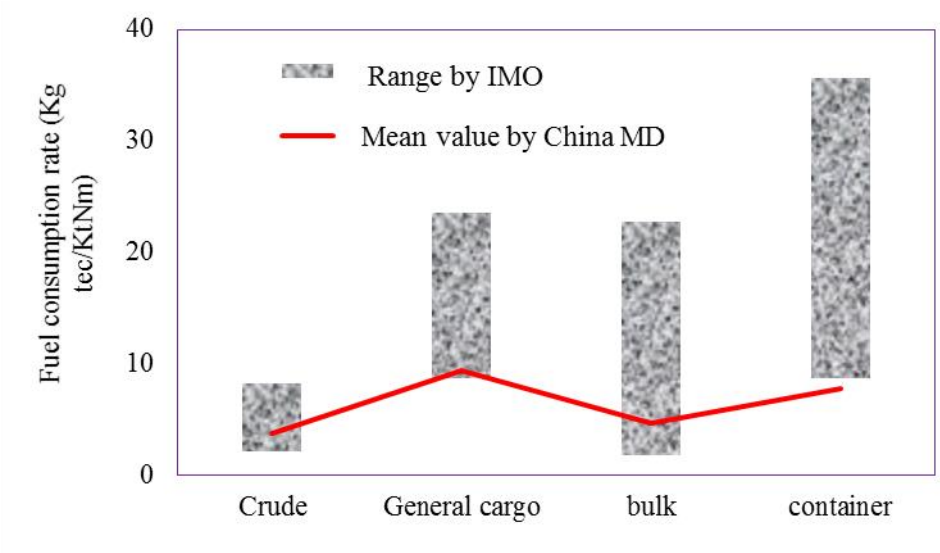


Fig. SI-6 Range of fuel consumption rate used in this study

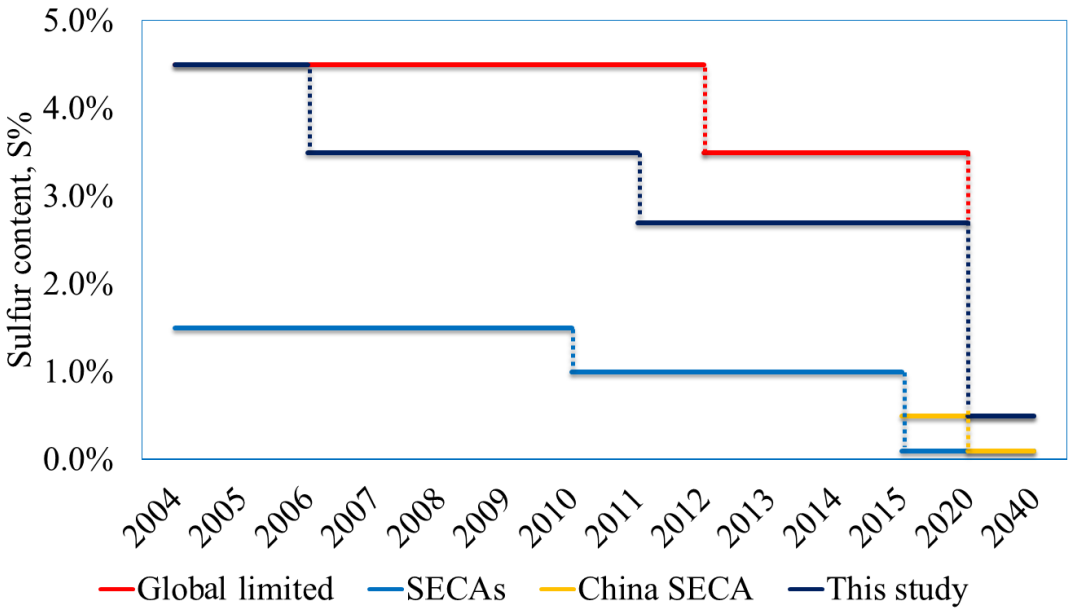


Fig. SI-7 The sulfur content of HFO in this study

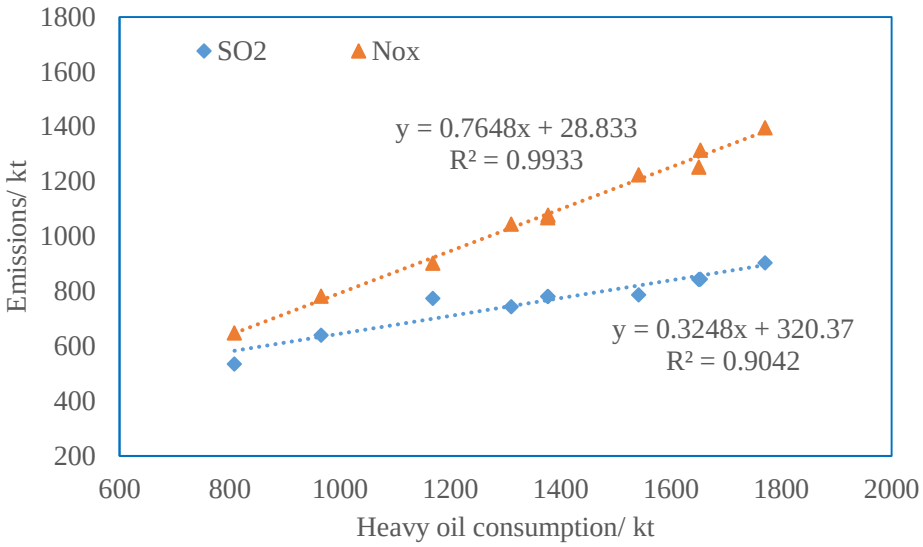


Fig. SI-8 Relationship between fuel consumption and ship emissions from 2004 to 2013

8. Ship engine and emission factor

For ship engine, the slow speed diesel engine were dominated by the international brands, e.g. MAN SE (from Germany, share 78% stock of market), Wärtsilä (from Dutch, share 21% stock of market), this is to say that the emission factor for SSD of ship engine used in China can refer to the international value. However, the medium speed diesel engine (430 kW< P < 14,940 kW) were dominated by the local diesel engine brands, e.g. Zichai, Weichai, Guangchai, Zhongcedongli. Which covered more than 80% of the total population of MSD, mainly used for the main engine and auxiliary engine of river ship and fishing ship, therefore, the emission factor of river vessel refers to the result measured by the local studies (Zhang et al., 2015).

Statistics for main engine speed by vessel type and gross tonnage has been determined from the available database. The RPM value, available for approximately 68% of the main engines, has been used to determine if the engine is high speed diesel (HSD), medium (MSD) or slow (SSD) speed. Consistent with earlier studies (Entec, 2002, 2010; Ng et al., 2012), HSD engines were defined as engines with an RPM>1000, MSD engines were defined as engines with an RPM ≤1000 and RPM >300, and SSD engines were defined as engines with an RPM≤300. The main engine types for three vessel size ranges were determined by identified the number of vessels with HSD, MSD and SSD. For the classification of different operation modes were shown in table SI-3.

The SO_2 emission depend on engine type and sulphur content of fuel oil. Due to the value of sulfur content statistics by China Marine Bunker (Fan et al., 2016) were higher than global averages reported by the IMO

Maritime Environment Protection Committee (MEPC, 67th) , so, sulfur content for HFO and MDO were set as 2.7% and 0.5% in this study, and a sulphur content corresponding to the sulphur limit required in the ECA is assumed in both main engines, auxiliary engines and boilers, meanwhile, the key issue of SO_2 generation rate from the sulphur in fuel oil were solved by literature review, set as 83%, 90% and 94% for HSD, MSD, HSD, respectively (USEPA ship report; Liu et al., 2016; Fan et al., 2016). For NOx emission, as shown in table SI-10, MARPOL Annex VI given a progressive reductions in NOx emissions from marine diesel engine, with more stringent controls being a "Tier II" emission limit required for those marine diesel engines installed on or after 1 January 2011; then with the most stringent controls being "Tier III" emission limit for marine diesel engines installed on or after 1 January 2016. Marine diesel engines installed on or after 1 January 1990 but prior to 1 January 2000 are also required to comply with "Tier I" emission limits, if an approved method for that engine has been certified by an Administration. On the other hand, fuel type and quality sulphur content as a major factor influencing the emissions of PM, HC and CO, and engine type also have effects on PM. As detail shown in table SI-11.

$$SO_2 \text{ Emission} = \text{Fuel consumption} \times 2 \times S\% \times R$$

Table SI-10 NOx emission factors used in this study (unit: g/kg Fuel)

Fuel type	Engine type	Emission Stander	Model year	Emission Factor
HFO (2.7%sulfur content)	SSD	Tier 0[1]	≤1999	79.7
	MSD		≤1999	61.7
	SSD	Tier1	2000-2010	74.9
	MSD		2000-2010	57.3
	SSD	Tier2	2011–2015	67.4
	SSD		2011–2015	49.3
MDO (0.5%sulfur content)	SSD	Tier 0[a]	≤1999	78.3
	MSD		≤1999	60.8
	SSD	Tier1	2000-2010	73.7
	MSD		2000-2010	56.2
	SSD	Tier2	2011–2015	66.4
	SSD		2011–2015	48.4
HFO/MDO	HSD	Before Tier 3[b]	All	46.1
	Boiler[3]	All	All	15.7
LNG or other clean energy	SSD	Tier 3[b]	＞2016	14.8
	MSD		＞2016	11.3
	HSD		＞2016	9.2

[a]IMO Tier 0 refers to all ships constructed prior to January 1, 2000 which did not have an IMO Tier requirement at the time of construction.

[b]Tier 3 means conduct NOx emission control measures, e.g. LNG-fueled engine, Emission gas recycle, Selective catalytic reduction of NOx (SCR), that means the control policies of Emission Control Area (ECA). [3] Which means Boiler engine.

Table SI-11 Emission factors used in ship emission estimates (unit: g/kg Fuel)

Activity Type	Engine Type		Fuel Type	Sulfur content	PM_{10}	$PM_{2.5}$	HC	CO	BC[f]	OC[f]
OGVs/CVs[a]	ME[c]	SSD	HFO	2.7%	6.1	5.7	2.6	6.1	0.36	0.23
OGVs/CVs	ME[c]	SSD	MDO	0.5%	2.2	1.7	2.6	6.1	0.36	0.23
OGVs/CVs	ME[c]	MSD	HFO	2.7%	6.1	5.7	2.2	4.8	0.16	0.18
OGVs/CVs	ME[c]	MSD	MDO	0.5%	2.2	1.7	2.2	4.8	0.16	0.18
OGVs/CVs	AE[d]	HSD	HFO	2.7%	6.1	5.7	1.7	4.8	0.16	0.18
OGVs/CVs	AE[d]	HSD	MDO	0.5%	2.2	2.2	1.7	4.8	0.16	0.18
OGVs/CVs	BE[e]	HSD	MDO	0.5%	1.3	1.0	0.4	0.9	0.58	0.12
RVs[b]	ME[c]	HSD	MDO	0.5%	1.7	1.7	1.7	6.0	0.58	0.12

[a, b]OGVs, CVs and RVs mean Ocean-going vessels, Coast vessels and River vessels, respectively.

[c, d, e]ME, AE and BE mean main engine, auxiliary engine and boiler engine, respectively.

[f]the value of BC and OC were the ratio of $BC/PM_{2.5}$ and $OC/PM_{2.5}$, respectively. Refer to zhang et al., 2015.

Besides, the relationship of ship types to engine types and fuel types were the essential in emission estimation, shown in table SI-12. On the other hand, fuel type and sulfur content are the most important specification in ship fuels. According to the previous research (Ng et al., 2012; Fan et al, 2016; Liu et al., 2016), for three engine types in vessel types with the main fuel types has been identified. On the other hand, no specific ship emission control regulation was assigned in this study domain in 2013 except a two-year industry-led voluntary fuel switch initiative (the Fair Winds Charter, S% ≤0.5%) in Hong Kong in January 2011. Therefore, sulfur content for HFO and MDO were set as 2.7% and 0.5% (set value refer the domestic vessels ranges from 0.2% to 2.0%, provided by China Marine Bunker, CMB) (Fan et al., 2016).

Table SI-12 Relationship of ship types to engine types and fuel types

	Ship types	Engine Types			Fuel Types		
		DWT≤5000GT	5000＜DWT＜25000	≥25000GT	ME	AE	BE
OGVs and CVs	Dry Bulk Carrier	MSD	MSD	SSD	HFO	HFO	MDO
	Container	MSD	MSD	SSD	HFO	HFO	MDO
	General cargo ship	MSD	SSD	SSD	HFO	HFO	MDO
	Tanker	MSD	SSD	SSD	HFO	HFO	MDO
	Others	MSD	MSD	SSD	MDO	MDO	MDO
River ships		HSD				MDO	

*SSD, MSD, HSD mean Slow speed diesel engine, Medium speed diesel engine, High speed diesel engine, respectively. HFO and MDO mean Marine heavy oil and Marine diesel oil.

Table SI-13 Low load adjustment multipliers for emission factors

LF	SO_2	NO_X	CO	PM	HC
0.01	1.00	11.47	19.32	19.17	59.28
0.02	1.00	4.63	9.68	7.29	21.18
0.03	1.00	2.92	6.46	4.33	11.68
0.04	1.00	2.21	4.86	3.09	7.71
0.05	1.00	1.83	3.89	2.44	5.61
0.06	1.00	1.6	3.25	2.04	4.35
0.07	1.00	1.45	2.79	1.79	3.52
0.08	1.00	1.35	2.45	1.61	2.95
0.09	1.00	1.27	2.18	1.48	2.52
0.1	1.00	1.22	1.96	1.38	2.2
0.11	1.00	1.17	1.79	1.3	1.96
0.12	1.00	1.14	1.64	1.24	1.76
0.13	1.00	1.11	1.52	1.19	1.6
0.14	1.00	1.08	1.41	1.15	1.47
0.15	1.00	1.06	1.32	1.11	1.36
0.16	1.00	1.05	1.24	1.08	1.26
0.17	1.00	1.03	1.17	1.06	1.18
0.18	1.00	1.02	1.11	1.04	1.11
0.19	1.00	1.01	1.05	1.02	1.05
0.20	1.00	1.00	1.00	1.00	1.00

9. Emissions intensity calculation

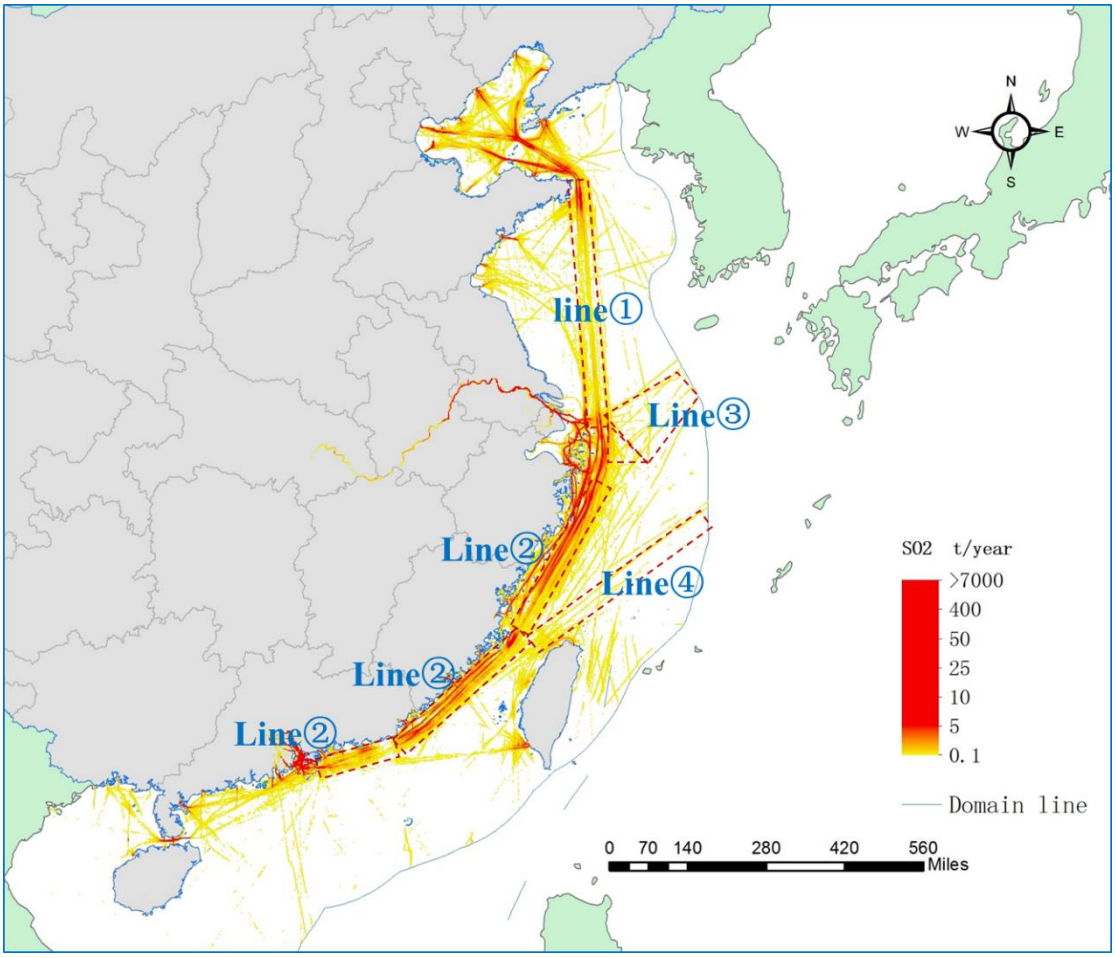
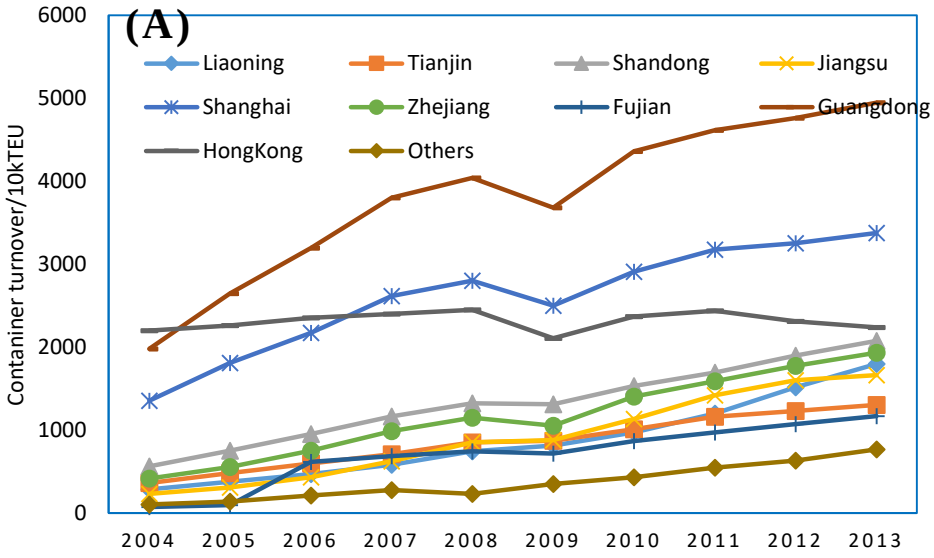


Fig. SI-9 Spatial allocation of typical navigating lines in Emission intensities calculation

10. Emission trends analysis



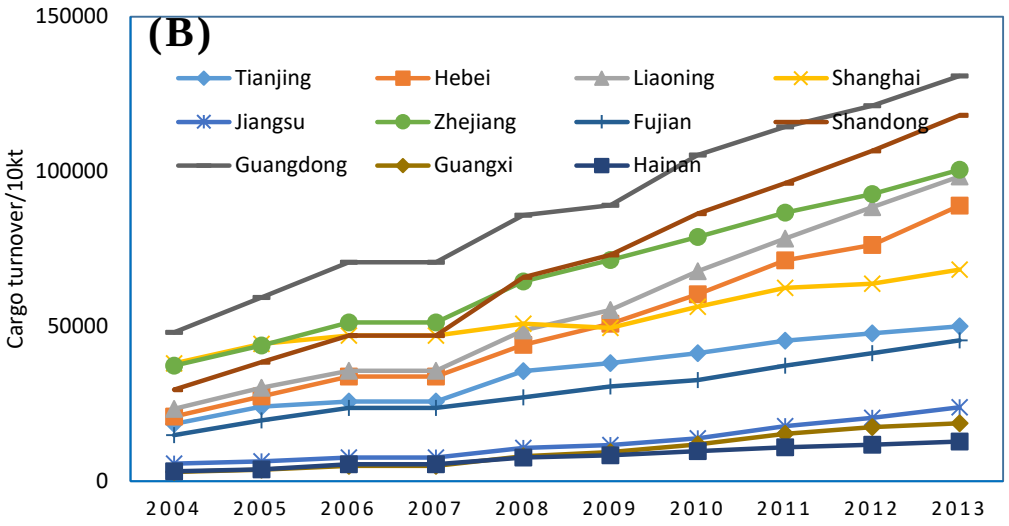


Fig. SI-10 Trends of container turnover (a) and cargo turnover (b) from coast ports in different provinces

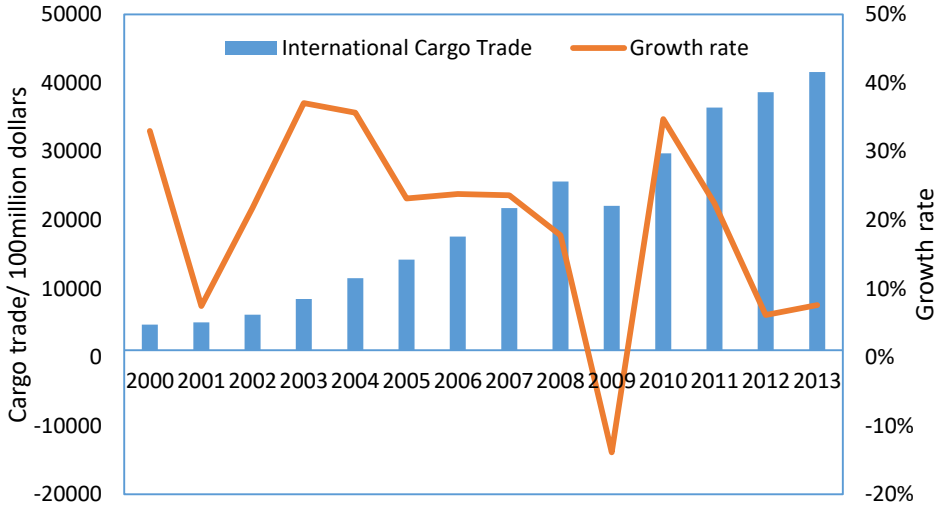


Fig. SI-11 Trends of international cargo trade and growth rate in China

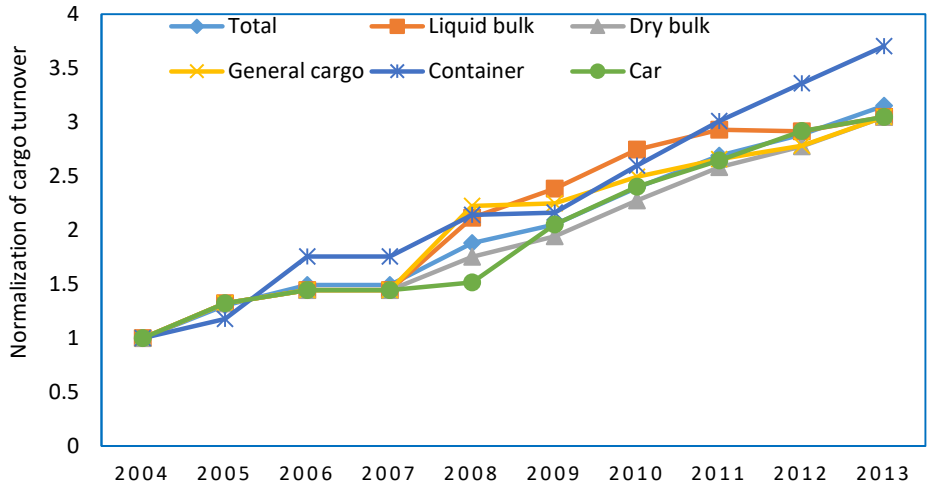


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Fig. SI-13 Trends of cargo turnover with different cargo types in China from 2004 to 2013

Table SI-5(a) Raw data of transport volume for cargo-based approach in 2013

Year: 2013		Ports	Cargo transport (10Kt)						Ocean-going Cargo transport（10Kt）	Container transport (10000TEU)
				Dry bulk			Liquid cargo	General Cargo		
Port clusters	Province		Total	Ore	Building materials	Coal	Oil and Gas	Others (Chemical, food, wood, etc.)		
1.Bohai	Heilongjiang	Heilongjiang	1245	656	22	55	5	508	0	0
	Ji`ning	Ji`ning	13379	0	35	2	1465	11878	0	0
	Hebei	Total	39594	10284	0	28084	1160	0	7008	67
		Huanghua	8310	1360	0	6847	92	0	1471	12
		Qinghuaidao	12681	308	0	11914	440	0	2245	19
		Tangshan	18603	8616	0	9323	628	0	3293	36
	Tianjin	Tianjin	25040	5409	300	4481	2654	11500	13372	651
	Liaoning	Total	49217	11072	7774	3656	12071	13745	9891	899
		Dalian	20381	815	3900	1400	5300	8450	5884	501
		Yingkou	16038	5122	2241	1281	5282	1848	3111	265
		Jingzhou	4266	600	484	975	0	2160	426	48
		Dandong	6025	4100	1150	0	0	700	452	75
		Huludao	1023	435	0	0	0	588	3	0
		Panjin	1498	0	0	0	1489	0	17	10
2.Shandong	Shandong	Total	57337	15555	235	5197	6537	28690	34185	1038
		Qingdao	22894	6822	40	1041	3214	11000	16912	776
		Yantai	14345	1032	130	1393	1108	10500	5323	108
		Rizhao	15904	7163	65	1807	1768	5000	10825	102

		Weihai	2009	17	0	694	55	1200	600	33
		Dongying	715	46	0	64	265	340	200	0
		Binzhou	283	279	0	0	4	0	0	0
		Langfang	1171	197	0	198	124	650	325	3
3.YRD	Shanghai	Shanghai	38794	4715	6712	6534	2427	16725	18853	1681
	Zhejiang	Total	967	0	0	0	0	0	20398	967
		Jiaxing	3023	0	1916	1057	0	0	430	51
		Ningnbo-Zhoushan	43200	19435	0	3963	4400	14535	19208	868
		Taizhou	2815	0	1688	563	0	555	489	8
		Wenzhou	3686	1476	0	1291	0	890	244	29
		Hangzhou	4690	0	610	1126	844	2110	0	0
		Jiaxing-river	5557	0	3100	2150	0	300	0	7
		Huzhou	7660	919	6737	0	0	0	26	4
		Shaoxing	672	0	672	0	0	0	0	0
		Ningbo-river	26	0	0	0	0	26	2	0
		Lanxi	35	0	0	0	0	35	0	0
		Quzhou	0	0	0	0	0	0	0	0
		Lishui	2	0	0	0	0	2	0	0
		Qingtian	9	0	0	0	0	9	0	0
	Hubei	Hubei	24409	6911	0	1320	255	15842	213	54
	Hunan	Hunan	23097	7711	0	888	452	14032	106	15
	Jiangsu	Total	70630	24313	9865	25633	4445	5542	7482	831
		Changzhou	2234	992	0	1235	0	0	237	7
		Jiangyin	4543	1185	2903	395	60	0	481	0
		Lianyungang	6463	4555	1093	67	274	0	685	472
		Nanjing	10553	2116	1723	2747	1713	2255	1118	0

		Nantong	6276	2937	0	2621	688	0	665	30
		Jiangsu	11450	5721	0	5220	243	0	1213	265
		Taizhou	4338	511	0	3589	230	0	460	9
		Wuxi	10315	1084	4146	3570	498	1017	1093	0
		Suqian	925	736	0	138	51	0	98	0
		Xuzhou	1320	147	0	1160	13	0	140	0
		Yancheng	2113	1443	0	651	16	0	224	3
		Yangzhou	5003	216	0	2103	389	2270	530	26
		Zhenjiang	5097	2672	0	2137	269	0	540	19
	Jiangxi	Jiangxi	8676	561	2600	745	91	4665	17	14
	Sichuan	Sichuan	2392	114	45	193	27	2000	0	13
	Anhui	Total	19839	4397	6441	2799	262	5910	0	26
		An`qing	1505	96	323	256	128	700	0	2
		Chizhou	1958	551	451	169	24	762	0	1
		Tongling	2954	509	466	459	11	1506	0	1
		Wuhu	4675	1279	790	874	61	1653	0	14
		Ma`an`shan	3748	1439	1381	384	13	529	0	4
		Hefei	1061	184	330	75	15	453	0	5
		Fuyang	510	1	413	56	1	38	0	0
		Liuan	180	81	90	0	0	9	0	0
		Huainan	808	1	303	394	0	110	0	0
		Bengbu	372	1	266	15	0	89	0	0
		Chuzhou	1308	22	1029	25	0	232	0	0
		Xuancheng	75	18	43	0	0	14	0	0
		Bozhou	521	0	448	37	0	36	0	0
		Xiuzhou	659	0	104	555	0	0	0	0
		Huangshan	6	0	4	0	0	2	0	0

4.Western Taiwan Strait	Fujian	total	23322	2185	0	4183	1389	14980	9282	585
		Fuzhou	6478	1624	0	1569	99	3089	2978	99
		Xiamen	9970	368	0	1195	224	7757	4687	400
		Quanzhou	5487	193	0	690	701	3818	1195	85
		Putian	1412	0	0	730	366	316	422	0
5.PRD	Guangdong	Total	78184	6163	27109	12022	7606	22440	25277	2476
		Guanzhou	23599	3668	4149	3876	913	10117	5731	775
		Shenzhen	11662	421	6587	215	669	2606	9087	1164
		Zhuhai	5011	134	1204	811	691	2128	1018	44
		Foshan	2737	12	654	431	257	1247	1123	138
		Dongguan	5594	8	2626	2152	500	201	1070	99
		Zhongshan	3438	0	2315	118	123	816	338	66
		Jiangmen	3369	0	1941	858	142	381	447	47
		Huizhou	4023	3	1205	350	1941	516	930	8
		Zhaoqing	1477	6	869	173	38	356	136	35
		Shantou	2519	0	692	693	64	1006	714	64
		Chaozhou	525	0	0	438	26	61	317	0
		Jieyang	1255	0	286	317	149	504	0	0
		Shanwei	334	0	0	329	5	0	69	1
		Yangjiang	1028	393	24	321	24	267	582	0
		Zhanjiang	9003	1515	3875	682	1153	1664	2987	23
		Maoming	1185	1	0	88	733	358	637	5
		Shaoguan	40	0	0	39	0	0	0	0
		Heyuan	0	0	0	0	0	0	0	0
		Meizhou	63	0	50	0	0	13	0	0
		Qingyuan	504	0	212	106	0	21	0	1
		Yunfu	818	3	424	26	178	182	91	6

6.Beibu Gulf	Guangxi	Total	5387	1117	1156	2325	31	677	2574	78
		Fangcheng	3485	0	0	0	0	0	0	45
		Qinzhou	722	0	0	0	0	0	0	0
		Beihai	613	0	0	0	0	0	0	0
		Guigang	349	42	17	262	6	18	192	6
		Liuzhou	22	22	0	0	0	0	8	0
		Nanning	27	3	0	23	0	0	9	0
		Wuzhou	123	4	0	55	26	20	43	20
	Guizhou	Guizhou	492	0	0	0	0	492	0	0
	Hainan	Hainan	6420	0	2183	1733	321	1965	1187	71
	Yunnan	Yunnan	247	0	0	0	0	247	0	0

* Data from China port statistical yearbook in 2014.

Table SI-5(b) raw data of transport volume for emission trends estimation in 2013

2013	Port clusters	Ports	Total	Liquid cargo	Bulk cargo	General cargo	Container		Car	
							10k TEU	Weight	Number(10t)	Weight
Unit:10kt		Total	588353	47390	345523	58345	9511	109244	792	27852
Coast ports		Sum	378065	37413	187844	29557	8484	97347	726	25905
	Bohai	Tianjin	25032	3033	11383	1568	651	7608	46	1441
	Bohai	Hebei	44492	1182	40138	2147	68	1026	0	0
	Bohai	Liaoning	49177	5687	17180	6139	899	14191	90	5981
	YRD	Shanghai	34137	1621	11952	2707	1681	17122	70	737
	YRD	Jiangsu	11954	167	8005	1014	277	2768	0	0
	YRD	Zhejiang	50296	7796	28072	2144	955	9830	117	2454
	WTS	Fujian	22738	1359	11071	2610	585	7445	22	253
	Shandong	Shandong	59069	6966	30101	4308	1038	11379	87	6315

	PRD	Guangdong	65416	7581	22192	5052	2210	23974	202	6618
	Beibu Gulf	Guangxi	9337	1079	6415	945	50	852	1	48
	Beibu Gulf	Hainan	6420	945	1336	925	71	1155	93	2060
River ports		Sum	210288	9977	157680	28788	1027	11897	66	1947
	Bohai	Liaoning	23	0	17	7	0	0	0	0
	Bohai	Ji`ning	31	0	31	0	0	0	0	0
	Bohai	Heilongjiang	233	5	179	40	0	0	1	9
	YRD	Shanghai	4651	25	3857	769	0	0	0	0
	YRD	Jiangsu	95040	6371	65348	16895	555	6406	2	20
	YRD	Zhejiang	18730	518	16600	1515	12	98	0	0
	YRD	Anhui	19809	295	16899	2349	27	230	4	37
	WTS	Fujian	218	0	180	39	0	0	0	0
	YRD	Jiangxi	13122	125	12205	619	15	174	0	0
	Shandong	Shandong	3674	0	3604	71	0	0	0	0
	YRD	Henan	101	0	86	15	0	0	0	0
	YRD	Hubei	13110	370	9209	1787	54	787	28	958
	YRD	Hunan	11572	539	9932	912	15	191	0	0
	PRD	Guangdong	12771	1342	7096	1452	266	2881	0	0
	Beibu Gulf	Guangxi	5331	74	3901	886	28	472	0	0
	YRD	Chongqing	6838	225	4420	750	46	521	32	923
	YRD	Sichuan	4098	28	3576	355	13	140	0	0
	Beibu Gulf	Guizhou	492	62	166	265	0	0	0	0
	Beibu Gulf	Yunnan	248	0	196	52	0	0	0	0

* Data from China port statistical yearbook in 2014. WTS is "Western taiwan strait"

Table SI-5(c) raw data of transport volume in 2012

2012	Port clusters	Ports	Total		Bulk cargo		Container	Car

				Liquid cargo		General cargo	10k TEU	Weight	Number(10t)	Weight
Unit:10kt		Total	538802	45313	314550	53218	8874	99074	757	26649
Coast ports		Sum	343988	35913	168320	26802	7899	87993	697	24960
	Bohai	Tianjin	23849	3071	11208	1561	615	6721	42	1288
	Bohai	Hebei	38117	1213	34105	2124	45	676	0	0
	Bohai	Liaoning	44251	5337	15401	#VALUE!	757	12367	76	5217
	YRD	Shanghai	31870	1624	10806	2521	1627	16240	64	680
	YRD	Jiangsu	10252	200	6735	812	252	2506	0	0
	YRD	Zhejiang	46380	7567	25267	1971	880	8906	130	2671
	WTS	Fujian	20680	1340	10113	2235	537	6654	29	338
	Shandong	Shandong	53328	6156	27034	3395	950	9956	86	6788
	PRD	Guangdong	60633	7147	20449	4699	2128	22248	189	6091
	Beibu Gulf	Guangxi	8719	1149	6003	845	41	679	1	45
	Beibu Gulf	Hainan	5910	1111	1202	712	69	1042	82	1844
River ports		Sum	194815	9400	146230	26416	975	11081	60	1689
	Bohai	Liaoning	25	0	15	10	0	0	0	0
	Bohai	Ji`ning	32	0	32	0	0	0	0	0
	Bohai	Heilongjiang	232	#VALUE!	172	40	0	1	1	15
	YRD	Shanghai	4910	37	4077	797	0	0	0	0
	YRD	Jiangsu	87457	6709	60395	14070	548	6278	1	7
	YRD	Zhejiang	19586	325	17031	2170	7	61	0	0
	YRD	Anhui	18049	285	15030	2506	23	194	4	36
	WTS	Fujian	230	0	184	45	0	0	0	0
	YRD	Jiangxi	12636	136	11842	530	12	128	0	0
	Shandong	Shandong	3301	0	3257	45	0	0	0	0
	YRD	Henan	118	0	81	38	0	0	0	0

	YRD	Hubei	11759	350	8444	1516	48	668	25	783
	YRD	Hunan	10934	448	9170	1116	15	201	0	0
	PRD	Guangdong	9755	776	4912	1429	254	2639	0	0
	Beibu Gulf	Guangxi	4749	37	3625	713	23	374	0	0
	YRD	Chongqing	6251	201	3980	775	40	447	30	849
	YRD	Sichuan	3853	41	3468	253	8	92	0	0
	Beibu Gulf	Guizhou	579	54	216	310	0	0	0	0
	Beibu Gulf	Yunnan	195	0	155	41	0	0	0	0

* Data from China port statistical yearbook in 2013.

Table SI-5(d) raw data of transport volume in 2011

2011	Port clusters	Ports	Total	Liquid cargo	Bulk cargo	General cargo	Container		Car	
							10k TEU	Weight	Number(10t)	Weight
Unit:10kt		Total	502057	45539	292744	50875	8184	88727	732	24172
Coast ports		Sum	318012	36314	153776	26500	7316	78985	669	22438
	Bohai	Tianjin	22669	3239	10795	1480	580	5965	38	1192
	Bohai	Hebei	35650	1143	32012	1870	39	626	0	0
	Bohai	Liaoning	39172	5251	14275	5590	600	9558	65	4500
	YRD	Shanghai	31216	1654	10703	2657	1587	15610	56	592
	YRD	Jiangsu	8876	121	5327	1116	244	2313	0	0
	YRD	Zhejiang	43350	8217	22088	2381	792	7874	133	2792
	WTS	Fujian	18640	1278	8554	2416	485	6050	30	343
	Shandong	Shandong	48094	5253	24807	3580	846	8869	74	5587
	PRD	Guangdong	57228	7982	18646	4271	2052	20658	195	5673
	Beibu Gulf	Guangxi	7666	1108	5425	503	37	583	1	49

	Beibu Gulf	Hainan	5453	1072	1148	638	56	882	78	1713
River ports		Sum	184045	9225	138969	24375	868	9743	64	1734
	Bohai	Liaoning	15	0	11	4	0	0	0	0
	Bohai	Ji`ning	35	0	35	0	0	0	0	0
	Bohai	Heilongjiang	229	5	161	48	0	1	1	16
	YRD	Shanghai	5163	67	4404	693	0	0	0	0
	YRD	Jiangsu	81466	6791	55593	13774	465	5304	1	6
	YRD	Zhejiang	17837	311	15634	1871	3	22	0	0
	YRD	Anhui	18710	278	16308	1908	20	172	5	46
	WTS	Fujian	209	0	154	55	0	0	0	0
	YRD	Jiangxi	11779	103	11064	494	10	119	0	0
	Shandong	Shandong	3219	0	3023	196	0	0	0	0
	YRD	Henan	101	0	92	9	0	0	0	0
	YRD	Hubei	10832	287	7825	1340	43	589	27	790
	YRD	Hunan	10532	215	9448	711	12	159	0	0
	PRD	Guangdong	9625	861	4840	1310	256	2614	0	0
	Beibu Gulf	Guangxi	4014	41	3008	660	21	305	0	0
	YRD	Chongqing	5803	177	3571	783	34	395	31	878
	YRD	Sichuan	3538	48	3200	224	6	66	0	0
	Beibu Gulf	Guizhou	546	44	263	240	0	0	0	0
	Beibu Gulf	Yunnan	231	0	191	40	0	0	0	0

* Data from China port statistical yearbook in 2012.

Table SI-5(e) raw data of transport volume in 2010

2010	Port clusters	Ports	Total	Liquid cargo	Bulk cargo	General cargo	Container		Car	
							10k TEU	Weight	Number(10t)	Weight

Unit:10kt		Total	446612	42698	257659	47724	7307	76590	705	21941
Coast ports		Sum	282232	34274	135126	23938	6573	68538	649	20358
	Bohai	Tianjin	20663	3315	9392	1472	505	5458	33	1026
	Bohai	Hebei	30172	842	27382	1451	31	499	0	0
	Bohai	Liaoning	33895	5156	11921	4918	485	7833	66	4067
	YRD	Shanghai	28160	1564	9682	2516	1454	13996	38	403
	YRD	Jiangsu	6924	175	4314	530	196	1905	0	0
	YRD	Zhejiang	39423	7536	19996	1883	702	6138	173	3871
	WTS	Fujian	16344	1336	7196	2147	434	5372	25	293
	Shandong	Shandong	43211	4950	22564	4137	766	7595	61	3966
	PRD	Guangdong	52650	7768	17209	3865	1934	18707	181	5102
	Beibu Gulf	Guangxi	5962	638	4371	450	28	463	2	41
	Beibu Gulf	Hainan	4831	996	1102	571	41	574	71	1590
River ports		Sum	164380	8425	122534	23787	734	8052	57	1583
	Bohai	Liaoning	81	0	81	0	0	0	0	0
	Bohai	Ji`ning	34	0	34	0	0	0	0	0
	Bohai	Heilongjiang	198	6	138	40	0	1	1	2
	YRD	Shanghai	4510	67	3730	713	0	0	0	0
	YRD	Jiangsu	72565	6054	47978	14332	372	4195	1	7
	YRD	Zhejiang	16971	319	15343	1309	0	1	0	0
	YRD	Anhui	16251	304	14014	1806	11	103	3	25
	WTS	Fujian	191	0	127	65	0	0	0	0
	YRD	Jiangxi	10566	111	9880	469	9	107	0	0
	Shandong	Shandong	3273	31	2952	291	0	0	0	0
	YRD	Henan	70	0	66	4	0	0	0	0
	YRD	Hubei	9392	274	6398	1442	39	546	25	733
	YRD	Hunan	9627	260	8605	629	11	134	0	0

	PRD	Guangdong	8479	792	4186	1088	246	2414	0	0
	Beibu Gulf	Guangxi	3354	29	2565	582	15	179	0	0
	YRD	Chongqing	4834	133	2995	571	28	331	28	805
	YRD	Sichuan	3194	42	2929	180	4	44	0	0
	Beibu Gulf	Guizhou	445	7	216	222	0	0	0	0
	Beibu Gulf	Yunnan	210	0	173	37	0	0	0	0

* Data from China port statistical yearbook in 2011.

Table SI-5(f) raw data of transport volume in 2009

2009	Port clusters	Ports	Total	Liquid cargo	Bulk cargo	General cargo	Container		Car	
							10k TEU	Weight	Number(10t)	Weight
Unit:10kt		Total	382854	37063	220221	43025	6120	63764	638	18739
Coast ports		Sum	243686	29477	117441	22866	5510	57208	579	16697
	Bohai	Tianjin	19056	2644	9795	1592	435	4436	20	591
	Bohai	Hebei	25437	513	23530	961	29	435	0	0
	Bohai	Liaoning	27630	4146	9075	6063	406	5859	36	2488
	YRD	Shanghai	24734	1489	8416	2316	1250	12310	20	204
	YRD	Jiangsu	5854	201	3506	712	153	1436	0	0
	YRD	Zhejiang	35731	6972	16850	1772	559	4920	235	5219
	WTS	Fujian	15271	975	7843	1741	358	4501	18	212
	Shandong	Shandong	36536	4265	18699	3415	656	6909	53	3249
	PRD	Guangdong	44562	6954	15266	3245	1618	15716	136	3382
	Beibu Gulf	Guangxi	4704	378	3554	472	18	278	1	23
	Beibu Gulf	Hainan	4173	943	909	579	30	411	61	1332
River ports		Sum	139169	7632	102781	20159	610	6557	60	2042
	Bohai	Shanxi	0	0	0	0	0	0	0	0

	Bohai	Liaoning	127	0	127	0	0	0	0	0
	Bohai	Ji`ning	42	0	42	0	0	0	0	0
	YRD	Heilongjiang	179	4	119	45	0	0	1	11
	YRD	Shanghai	4869	31	4229	609	0	0	0	0
	YRD	Jiangsu	60539	5396	41454	10473	287	3210	1	7
	YRD	Zhejiang	16141	289	14614	1238	0	0	0	0
	WTS	Anhui	13225	233	10531	2354	10	95	2	14
	YRD	Fujian	145	0	130	15	0	0	0	0
	Shandong	Jiangxi	7505	127	6927	365	8	87	0	0
	YRD	Shandong	2407	8	2225	174	0	0	0	0
	YRD	Henan	44	0	43	2	0	0	0	0
	YRD	Hubei	8336	252	5512	1193	34	457	19	923
	PRD	Hunan	8470	242	7569	550	10	110	0	0
	Beibu Gulf	Guangdong	6819	863	2204	1648	222	2105	0	0
	YRD	Guangxi	2748	18	2025	554	12	152	0	0
	YRD	Chongqing	4306	126	2277	538	26	299	37	1067
	Beibu Gulf	Sichuan	2550	43	2292	151	3	44	1	21
	Beibu Gulf	Guizhou	389	1	177	211	0	0	0	0
		Yunnan	170	0	141	30	0	0	0	0
		Shanxi	160	0	145	15	0	0	0	0

* Data from China port statistical yearbook in 2010.

Table SI-5(g) raw data of transport volume in 2008

2008	Port clusters	Ports	Total	Liquid cargo	Bulk cargo	General cargo	Container		Car	
							10k TEU	Weight	Number(10t)	Weight
Unit:10kt		Total	351119	32881	198751	42542	6416	63102	637	13844

Coast ports		Sum	224467	26045	105008	23966	5837	57346	565	12104
	Bohai	Tianjin	17797	2360	8943	1940	425	4296	20	259
	Bohai	Hebei	22033	525	20162	902	33	444	0	0
	Bohai	Liaoning	24342	3579	7606	4905	372	5186	44	3067
	YRD	Shanghai	25404	1510	8282	2499	1401	12996	23	117
	YRD	Jiangsu	5385	195	2849	933	151	1408	0	0
	YRD	Zhejiang	32259	6413	15165	2547	574	4679	243	3457
	WTS	Fujian	13535	699	6686	1795	372	4355	0	0
	Shandong	Shandong	32895	3765	16271	3035	661	7026	108	2799
	PRD	Guangdong	42928	5823	15542	4111	1810	16390	70	1064
	Beibu Gulf	Guangxi	4045	316	2908	539	17	262	1	22
	Beibu Gulf	Hainan	3846	863	597	762	23	307	58	1320
River ports		Sum	126652	6837	93743	18576	579	5756	72	1740
	Bohai	Liaoning	42	0	42	0	0	0	0	0
	Bohai	Ji`ning	42	0	42	1	0	0	0	0
	Bohai	Heilongjiang	280	6	188	66	0	0	2	21
	YRD	Shanghai	3681	40	2886	756	0	0	0	0
	YRD	Jiangsu	52768	4535	35294	10368	275	2563	1	10
	YRD	Zhejiang	15560	236	14342	982	0	0	0	0
	YRD	Anhui	13634	196	11959	1324	12	119	1	36
	WTS	Fujian	176	0	157	20	0	0	0	0
	YRD	Jiangxi	5997	133	5472	331	7	61	0	0
	Shandong	Shandong	2530	0	2469	61	0	0	0	0
	YRD	Henan	53	1	50	3	0	0	0	0
	YRD	Hubei	7985	200	5493	1124	30	352	29	818
	YRD	Hunan	8012	258	6949	720	7	85	0	0
	PRD	Guangdong	6470	1028	1942	1380	210	2121	0	0

	Beibu Gulf	Guangxi	2338	18	1560	649	10	112	0	0
	YRD	Chongqing	3947	148	2234	445	27	300	33	820
	YRD	Sichuan	2459	38	2227	133	4	45	7	18
	Beibu Gulf	Guizhou	379	3	250	126	0	0	0	0
	Beibu Gulf	Yunnan	158	0	73	66	0	0	1	19

* Data from China port statistical yearbook in 2009.

Table SI-5(h) raw data of transport volume in 2007

2007	Port clusters	Ports	Total	Liquid cargo	Bulk cargo	General cargo	Container		Car	
							10k TEU	Weight	Number(10t)	Weight
Unit:10kt		Total	314818	27657	181158	35080	5459	57408	506	13514
Coast ports		Sum	200491	21756	96355	18883	4899	51398	452	12099
	Bohai	Tianjin	15338	1960	7400	1373	380	4105	22	500
	Bohai	Hebei	19468	487	17705	859	29	417	0	0
	Bohai	Liaoning	21086	2820	6917	3565	349	5165	38	2618
	YRD	Shanghai	24462	1313	8258	2182	1279	12396	35	312
	YRD	Jiangsu	4613	124	2710	629	120	1149	0	0
	YRD	Zhejiang	28944	5193	14735	1820	530	4844	151	2354
	WTS	Fujian	12690	703	6226	1577	338	4116	6	66
	Shandong	Shandong	28199	3268	14124	2375	537	5777	71	2656
	PRD	Guangdong	39143	4960	13768	3420	1502	14674	89	2320
	Beibu Gulf	Guangxi	3260	301	2304	394	15	244	1	17
	Beibu Gulf	Hainan	3284	632	581	577	27	398	48	1096
River ports		Sum	114327	5838	85113	16270	538	5763	52	1342
	Bohai	Liaoning	23	0	22	1	0	0	0	0
	Bohai	Ji`ning	69	0	69	0	0	0	0	0

	Bohai	Heilongjiang	324	6	235	64	0	0	1	18
	YRD	Shanghai	3518	29	2834	655	0	0	0	0
	YRD	Jiangsu	46053	3586	31171	8680	252	2607	1	9
	YRD	Zhejiang	15507	332	14019	1116	5	40	0	0
	YRD	Anhui	11816	172	10244	1255	13	118	1	27
	WTS	Fujian	133	0	115	18	0	0	0	0
	YRD	Jiangxi	6546	100	6036	333	7	77	0	0
	Shandong	Shandong	2206	0	2157	49	0	0	0	0
	YRD	Henan	44	0	39	4	0	0	0	0
	YRD	Hubei	7632	202	5303	1058	30	394	22	675
	YRD	Hunan	5973	221	5163	515	6	75	0	0
	PRD	Guangdong	6231	829	2635	1031	167	1736	0	0
	Beibu Gulf	Guangxi	2103	22	1463	480	10	138	0	0
	YRD	Chongqing	3328	119	1993	371	22	253	22	593
	YRD	Sichuan	2216	26	1974	152	5	56	3	9
	Beibu Gulf	Guizhou	320	18	169	133	0	0	0	0
	Beibu Gulf	Yunnan	156	0	97	49	0	0	0	10

* Data from China port statistical yearbook in 2008.

Table SI-5(i) raw data of transport volume in 2006

2006	Port clusters	Ports	Total	Liquid cargo	Bulk cargo	General cargo	Container		Car	
							10k TEU	Weight	Number(10t)	Weight
Unit:10kt		Total	278517	22434	163565	27619	4502	51714	375	13184
Coast ports		Sum	176516	17468	87703	13800	3961	45450	339	12095
	Bohai	Tianjin	12880	1560	5857	807	335	3915	24	741
	Bohai	Hebei	16903	449	15248	815	26	390	0	0

	Bohai	Liaoning	17829	2062	6228	2226	326	5145	32	2168
	YRD	Shanghai	23520	1117	8235	1865	1158	11797	48	507
	YRD	Jiangsu	3842	54	2572	326	89	890	0	0
	YRD	Zhejiang	25629	3973	14305	1093	487	5009	59	1250
	WTS	Fujian	11844	708	5767	1360	304	3878	11	132
	Shandong	Shandong	23503	2772	11977	1714	413	4528	34	2513
	PRD	Guangdong	35359	4098	11995	2730	1195	12958	109	3577
	Beibu Gulf	Guangxi	2475	286	1700	250	13	226	0	13
	Beibu Gulf	Hainan	2722	401	566	392	30	490	39	873
River ports		Sum	102002	4839	76483	13964	498	5771	32	944
	Bohai	Liaoning	4	0	3	1	0	0	0	0
	Bohai	Ji`ning	97	0	97	0	0	0	0	0
	Bohai	Heilongjiang	367	7	283	63	0	0	1	14
	YRD	Shanghai	3355	18	2782	555	0	0	0	0
	YRD	Jiangsu	39338	2637	27048	6993	230	2652	1	8
	YRD	Zhejiang	15454	427	13696	1250	9	80	0	0
	YRD	Anhui	9998	149	8529	1185	13	116	2	19
	WTS	Fujian	89	0	73	16	0	0	0	0
	YRD	Jiangxi	7096	68	6600	334	8	94	0	0
	Shandong	Shandong	1882	0	1846	36	0	0	0	0
	YRD	Henan	34	0	29	5	0	0	0	0
	YRD	Hubei	7279	205	5113	992	30	437	16	532
	YRD	Hunan	3934	183	3376	310	5	65	0	0
	PRD	Guangdong	5991	630	3329	681	125	1352	0	0
	Beibu Gulf	Guangxi	1868	26	1366	310	10	165	0	0
	YRD	Chongqing	2710	89	1752	297	18	206	12	366
	YRD	Sichuan	1973	13	1721	171	6	67	0	0

	Beibu Gulf	Guizhou	261	33	88	140	0	0	0	0
	Beibu Gulf	Yunnan	153	0	121	32	0	0	0	0

* Data from China port statistical yearbook in 2007.

Table SI-5(g) raw data of transport volume in 2005

2005	Port clusters	Ports	Total	Liquid cargo	Bulk cargo	General cargo	Container		Car	
							10k TEU	Weight	Number(10t)	Weight
Unit:10kt		Total	242694	20572	149990	25327	3782	34715	344	12090
Coast ports		Sum	150447	15786	79260	12471	3501	31999	306	10930
	Bohai	Tianjin	12035	1629	6113	842	240	2677	25	774
	Bohai	Hebei	13671	369	12547	671	7	84	0	0
	Bohai	Liaoning	15104	2133	6445	2303	189	1979	34	2244
	YRD	Shanghai	22159	1337	9858	2232	904	8125	58	607
	YRD	Jiangsu	3193	48	2314	293	51	538	0	0
	YRD	Zhejiang	21923	3759	13537	1034	278	2409	56	1183
	WTS	Fujian	9803	653	5325	1255	246	2448	11	122
	Shandong	Shandong	19201	2242	9686	1386	377	3855	28	2032
	PRD	Guangdong	29640	3665	10729	2442	1189	9605	97	3199
	Beibu Gulf	Guangxi	1835	221	1314	194	8	96	0	10
	Beibu Gulf	Hainan	1887	305	432	299	14	186	30	665
River ports		Sum	92248	4503	71159	12992	281	2716	30	879
	Bohai	Liaoning	1	0	0	0	0	0	0	0
	Bohai	Ji`ning	48	0	48	0	0	0	0	0
	Bohai	Heilongjiang	456	9	351	78	0	0	1	18
	YRD	Shanghai	5375	29	4457	889	0	0	0	0
	YRD	Jiangsu	34581	2411	24733	6394	102	1036	1	8

	YRD	Zhejiang	13514	376	12038	1098	0	1	0	0
	YRD	Anhui	8579	128	7352	1022	6	61	2	16
	WTS	Fujian	102	0	84	18	0	0	0	0
	YRD	Jiangxi	6814	65	6394	324	3	30	0	0
	Shandong	Shandong	1143	0	1121	22	0	0	0	0
	YRD	Henan	28	0	23	4	0	0	0	0
	YRD	Hubei	6997	206	5135	996	14	125	16	534
	YRD	Hunan	2645	122	2242	206	8	76	0	0
	PRD	Guangdong	5528	583	3081	631	134	1233	0	0
	Beibu Gulf	Guangxi	1604	24	1266	287	3	27	0	0
	YRD	Chongqing	2626	89	1756	298	11	116	13	366
	YRD	Sichuan	1731	12	1551	154	1	14	0	0
	Beibu Gulf	Guizhou	249	31	84	134	0	0	0	0
	Beibu Gulf	Yunnan	138	0	109	29	0	0	0	0

* Data from China port statistical yearbook in 2006.

Table SI-5(k) raw data of transport volume in 2004

2004	Port clusters	Ports	Total	Liquid cargo	Bulk cargo	General cargo	Container		Car	
							10k TEU	Weight	Number(10t)	Weight
Unit:10kt		Total	168034	13876	101169	17083	2669	27751	232	8155
Coast ports		Sum	111369	11320	56837	8943	2541	26430	220	7838
	Bohai	Tianjin	8314	1064	3994	550	192	2200	16	505
	Bohai	Hebei	9368	251	8522	456	10	139	0	0
	Bohai	Liaoning	10554	1349	4076	1457	164	2252	21	1419
	YRD	Shanghai	17943	947	6982	1581	821	8003	41	430
	YRD	Jiangsu	2688	39	1859	235	55	555	0	0

	YRD	Zhejiang	17545	2840	10226	781	287	2804	42	894
	WTS	Fujian	6636	419	3415	805	169	1919	7	78
	Shandong	Shandong	13271	1557	6730	963	246	2609	19	1412
	PRD	Guangdong	22154	2644	7740	1762	811	7700	70	2308
	Beibu Gulf	Guangxi	1403	165	982	145	7	104	0	7
	Beibu Gulf	Hainan	1495	229	324	224	14	218	22	500
River ports		Sum	56665	2730	43152	7878	220	2372	18	533
	Bohai	Liaoning	3	0	2	1	0	0	0	0
	Bohai	Ji`ning	16	0	16	0	0	0	0	0
	Bohai	Heilongjiang	152	3	117	26	0	0	0	6
	YRD	Shanghai	3230	17	2678	534	0	0	0	0
	YRD	Jiangsu	24439	1669	17122	4427	109	1215	1	5
	YRD	Zhejiang	8317	231	7391	674	2	20	0	0
	YRD	Anhui	4583	68	3921	545	4	40	1	9
	WTS	Fujian	66	0	55	12	0	0	0	0
	YRD	Jiangxi	2526	24	2368	120	1	13	0	0
	Shandong	Shandong	769	0	754	15	0	0	0	0
	YRD	Henan	9	0	8	1	0	0	0	0
	YRD	Hubei	2332	69	1712	332	5	42	5	178
	YRD	Hunan	2375	110	2029	186	5	50	0	0
	PRD	Guangdong	4239	446	2358	483	94	951	0	0
	Beibu Gulf	Guangxi	986	14	753	171	3	49	0	0
	YRD	Chongqing	875	30	585	99	4	39	4	122
	YRD	Sichuan	1385	10	1222	121	3	32	0	0
	Beibu Gulf	Guizhou	232	29	78	125	0	0	0	0
	Beibu Gulf	Yunnan	100	0	79	21	0	0	0	0

* Data from China port statistical yearbook in 2005.