香港科技大學
THE HONG KONG
UNIVERSITY OF SCIENCE
AND TECHNOLOGY

Estimation of Marine Emissions Inventory from all AIS-installed Vessels

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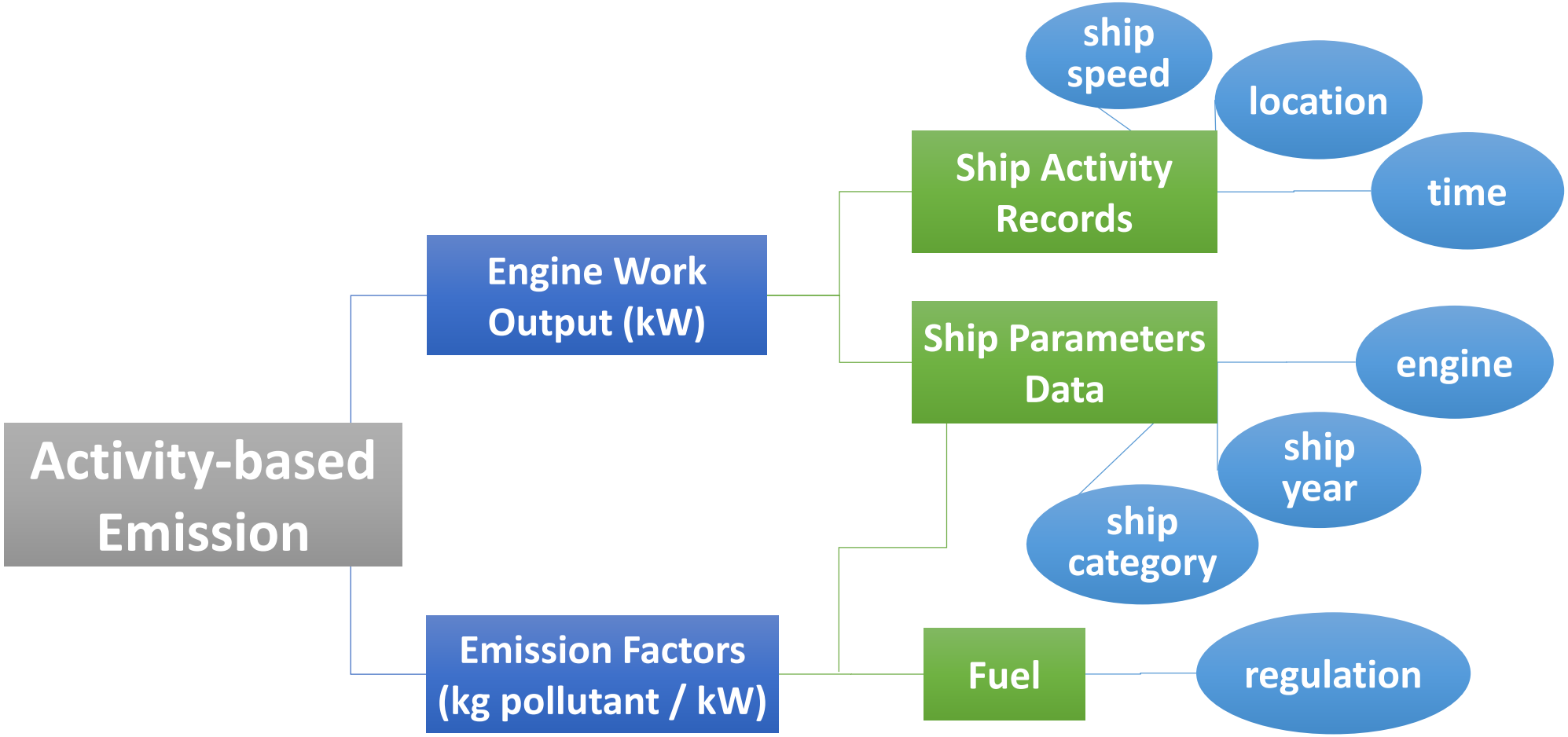
Hong Kong University of Science and Technology

Contents

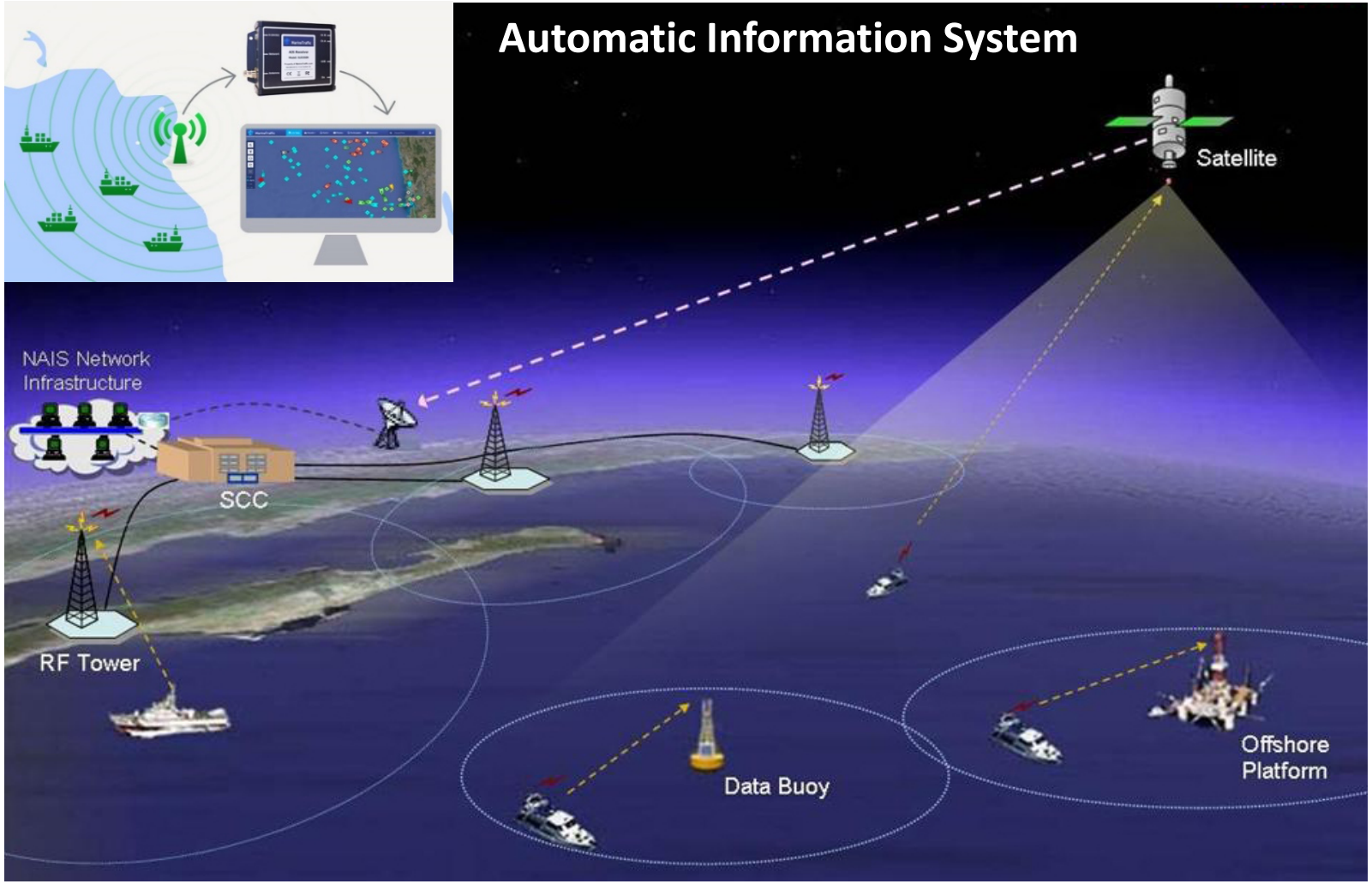
What is Marine Emission?

Introduction

$$Emission = Engine\ Work\ Output \times Emission\ Factor$$



Advancement of Ship Activity Data



Ship Parameter Data

- **World Register of Ships Database**
  - global database, vessels with IMO number
- **Ship Classification Societies**
- **Local Administration Records**
- **Commercial Databases**

Parameter Category	Ship Activity Data (AIS Database)	Ship Parameter Data (World Register of Ships Database)
Vessel Identity	**IMO Number**	**IMO Number**
	MMSI	**MMSI**
	Ship Name	Ship Name
	Call Sign	Call Sign
Vessel Type	--	Statcode5 (industry-standard ship type code)
	Ship Type (AIS-based)	--
Vessel Size	Length, Beam	Length, Beam
	--	GT, DWT, TEU
Engine-related Parameter	--	Engine Power, Engine Speed
	--	Ship Maximum Speed
	Real-time Speed	--
Spatial Info	Longitude, Latitude	--
Temporal Info	Date time	--

Research Questions

Parameter Category	Ship Activity Data (AIS Database)	Ship Parameter Data (World Register of Ships Database)
Vessel Identity	**IMO Number**	**IMO Number**
	MMSI	**MMSI**
	Ship Name	Ship Name
	Call Sign	Call Sign
Vessel Type	--	Statcode5 (industry-standard ship type code)
	Ship Type (AIS-based)	--
Vessel Size	Length, Beam	Length, Beam
	--	GT, DWT, TEU
Engine-related Parameter	--	Engine Power, Engine Speed
	--	Ship Maximum Speed
	Real-time Speed	--
Spatial Info	Longitude, Latitude	--
Temporal Info	Date time	--

AIS-based Estimation

- Ship Activity Data – AIS Records
- Ship Technical Parameters

Identified by IMO number or MMSI

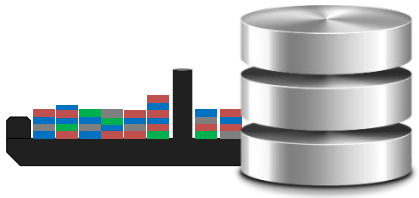
Problem: AIS records **could NOT be identified** in Ship Parameter Database?

- Your available ship parameter database do not cover all the vessels with AIS records, such as some domestic vessels

Could we estimate marine emissions from all vessels with AIS records?

Methodology

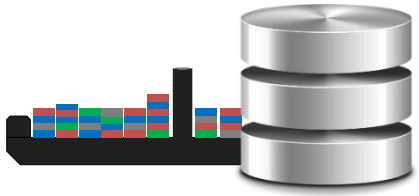
800+ million Activity Records **190,000+** Ships Parameters



AIS Activity Data		Ship Parameters
• IMO • MMSI • Ship Name • Call Sign	Ship Identification	• IMO • MMSI • Ship Name • Call Sign
• AIS Ship Type • Length • Latitude • Longitude • Movement Date Time • Speed	Identified Ship	• Statcode5 • Length • GT, DWT, TEU • Ship Maximum Speed • Engine Power • Engine Speed • Ship Construction Year

Methodology

800+ million Activity Records **190,000+** Ships Parameters



AIS Activity Data		Ship Parameters
• IMO • MMSI • Ship Name • Call Sign	Ship Identification	• IMO • MMSI • Ship Name • Call Sign
• AIS-based Ship Type • Length • Latitude • Longitude • Movement Date Time • Speed	Identified Ship	• Statcode5 • Length • GT, DWT, TEU • Ship Maximum Speed • Engine Power • Engine Speed

Quantile Median

Ship Type – Length Range Ship Parameters

Group Statistics

- AIS-based Ship Type
- Length Range

- Ship Max. Speed
- Engine Power
- Engine Speed

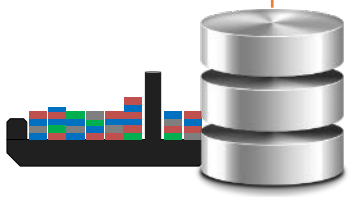
Key Assumptions

- The AIS records of ***Identified Vessels*** could be linked to the available ship parameter database by matching the IMO number or MMSI in both datasets
- The AIS records of ***Unidentified Vessels*** could be assigned the parameters values by matching their AIS Ship Type and Length Range

How to estimate marine emission inventory?

$$Emission = Engine\ Work\ Output \times Emission\ Factor$$

$$Engine\ Load \times Activity\ Time$$



Ship Parameters Database

AIS Activity Records

Literature Review

Rules & Regulations

How to estimate marine emission inventory?

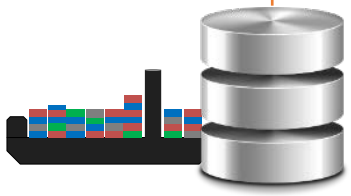
$$Emission = Engine\ Work\ Output \times Emission\ Factor$$

$$Engine\ Load \times Activity\ Time$$

Unidentified Vessels

Ship Type – Length Range Ship Parameters Database

Identified Vessels



Ship Parameters Database

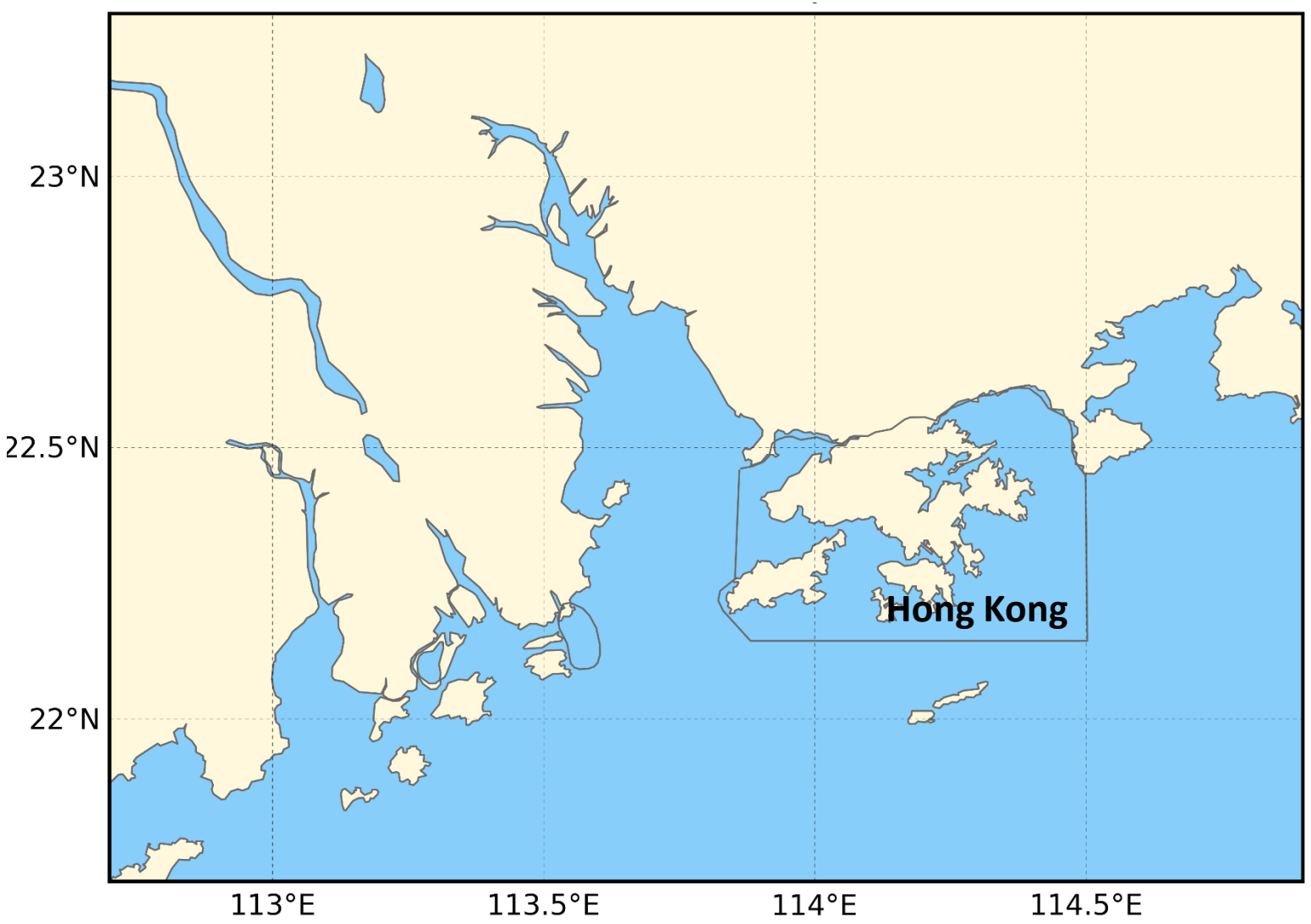
AIS Activity Records

Literature Review

Rules & Regulations

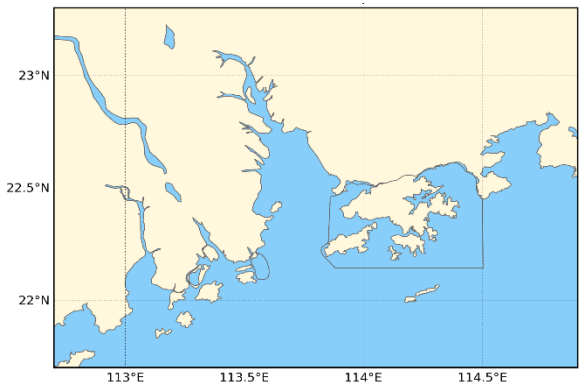
Results

Case Study:
Pearl River Delta, China



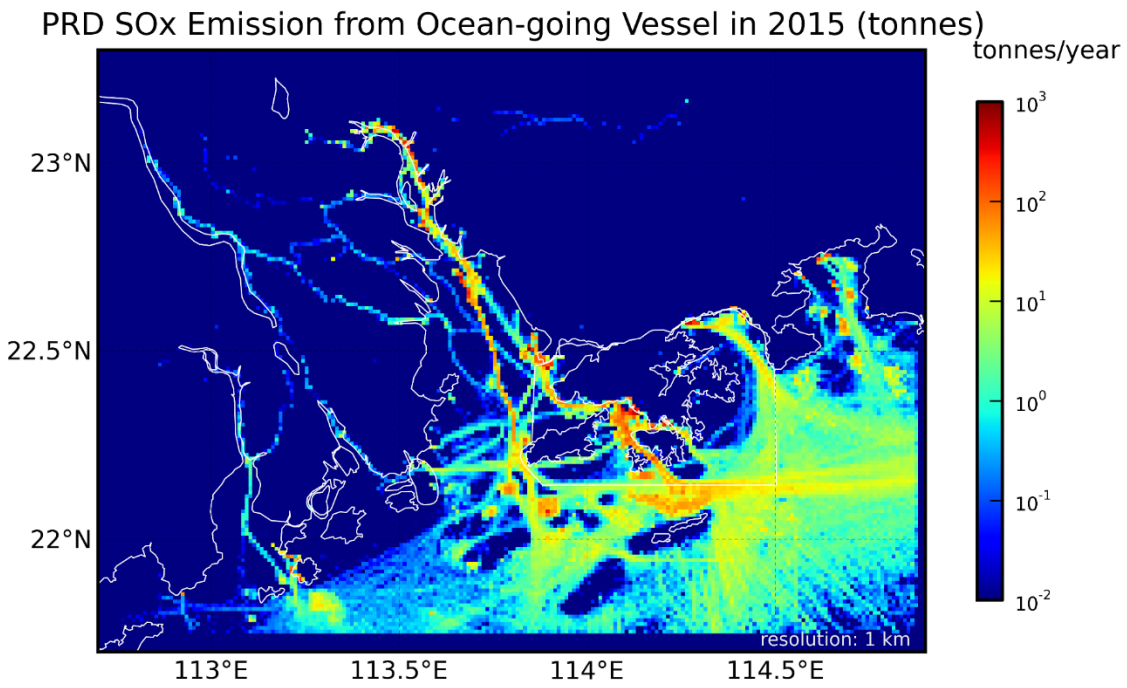
Results

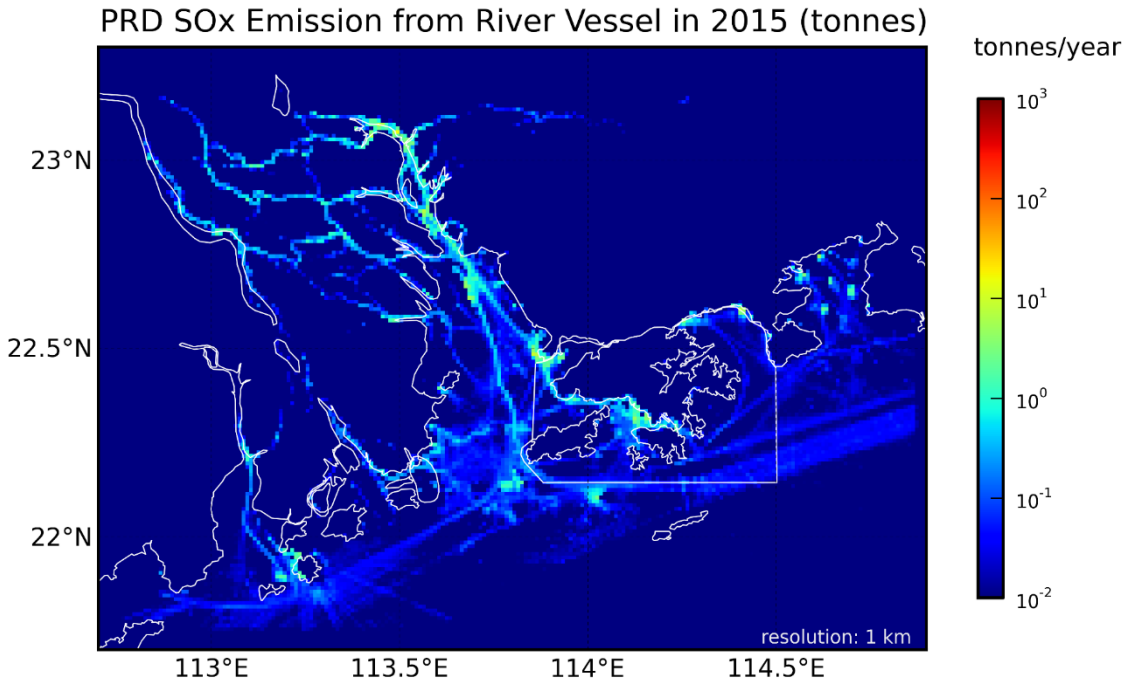
Case Study:
Pearl River Delta, China



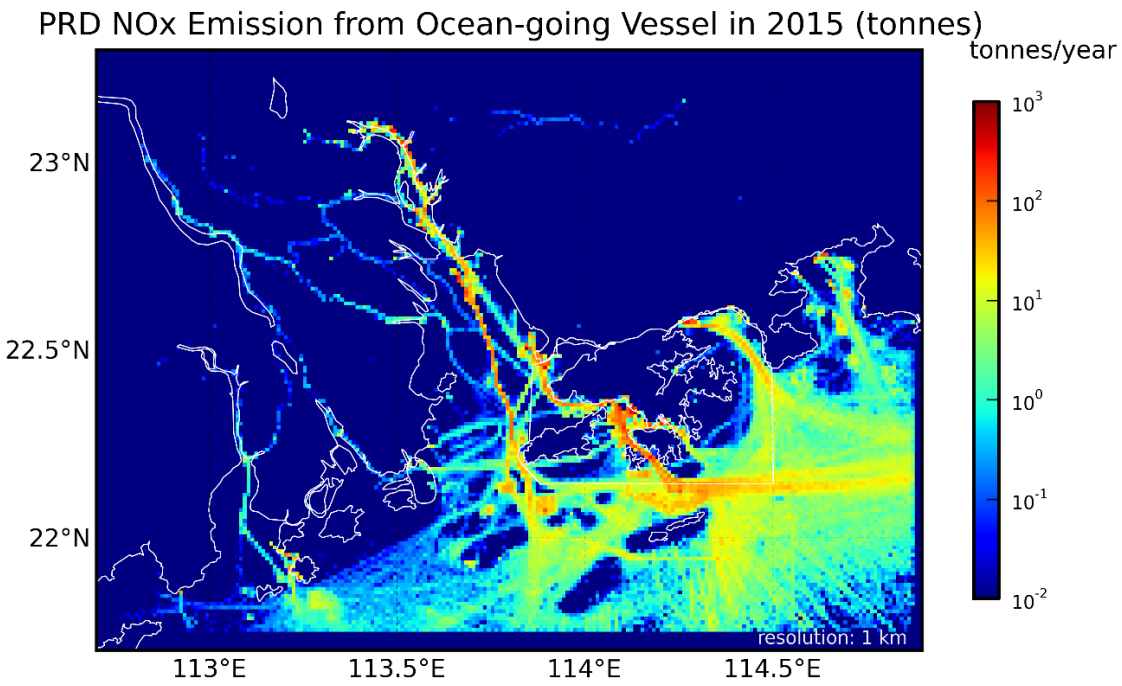
Identified?	Ship Category	Definition	Fuel (S%)
Identified	**Ocean-going Vessels**	Identified vessels that AIS Ship Type is NOT High Speed Craft	2.7%
Identified	**High Speed Craft** (Regional Ferries)	Identified vessels that AIS Ship Type is High Speed Craft	0.04%
Unidentified	**River Vessels**	All unidentified vessels	0.04%

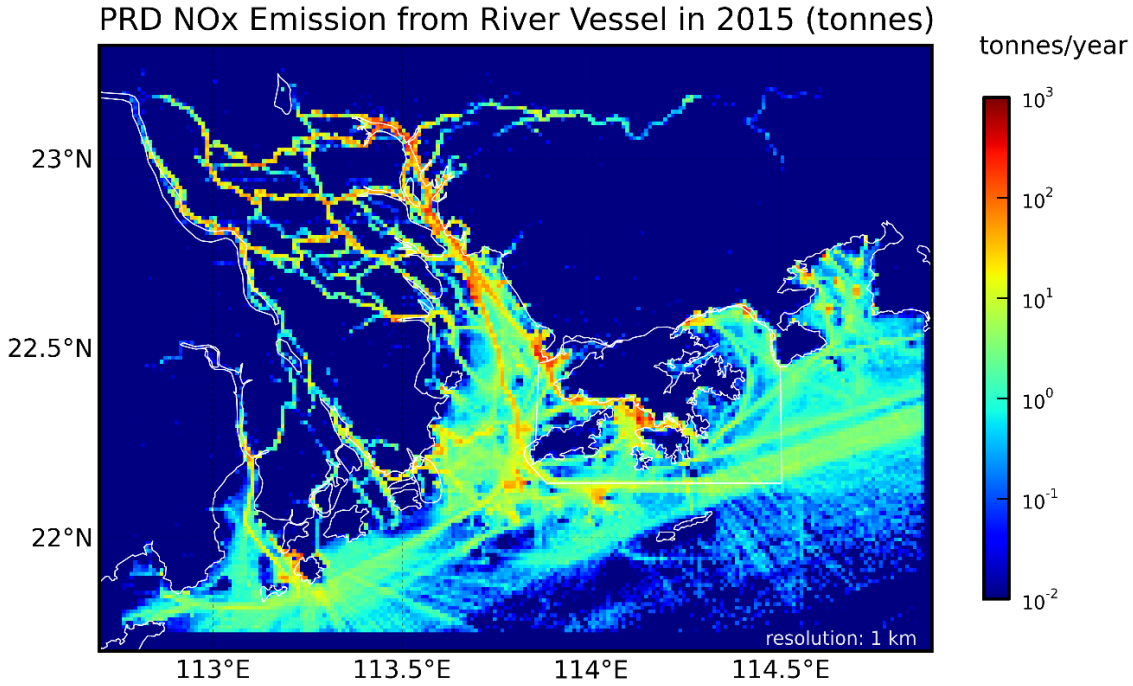
Results


PRD SOx Emission from Ocean-going Vessel in 2015 (tonnes)
tonnes/year
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
23°N
22.5°N
22°N
113°E
113.5°E
114°E
114.5°E
resolution: 1 km


PRD SOx Emission from River Vessel in 2015 (tonnes)
tonnes/year
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
23°N
22.5°N
22°N
113°E
113.5°E
114°E
114.5°E
resolution: 1 km

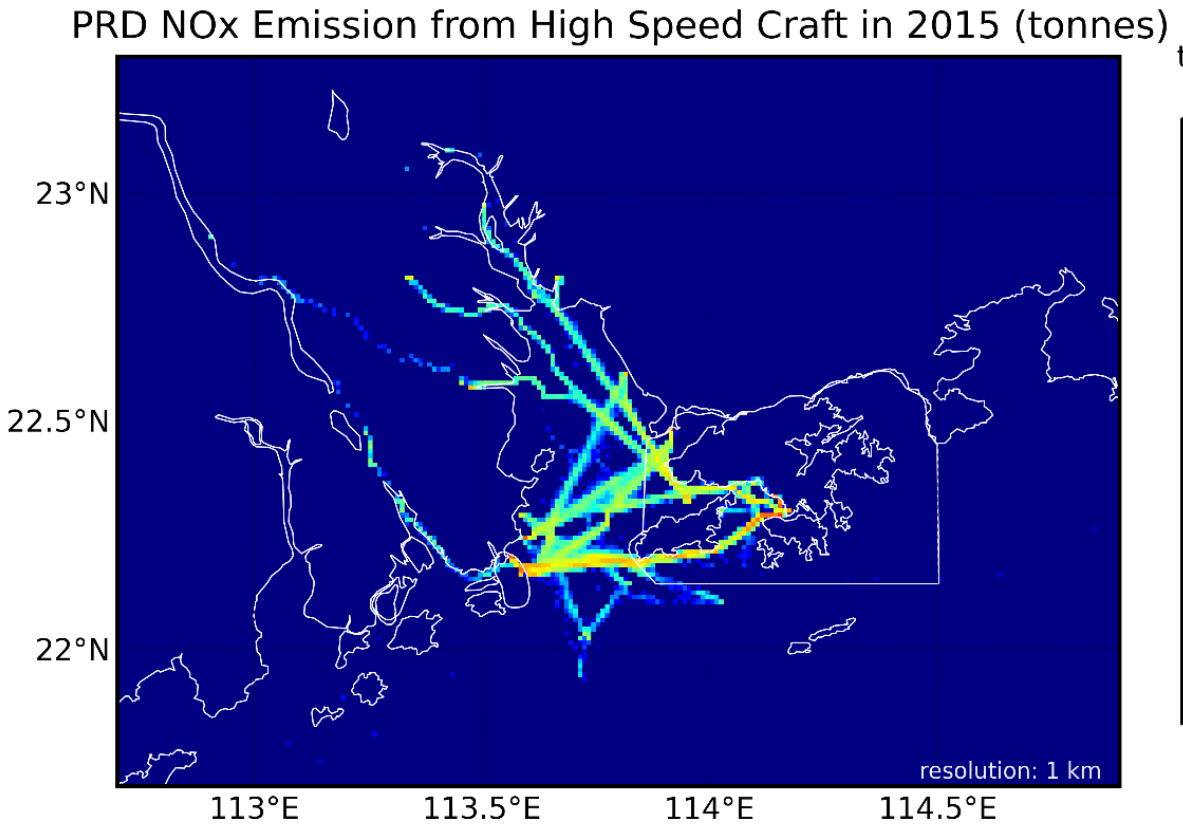
Results

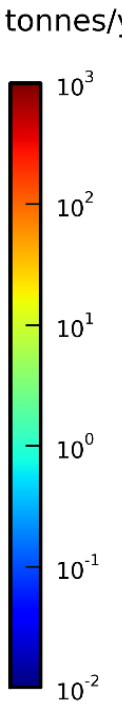




→ **Ship Activity**

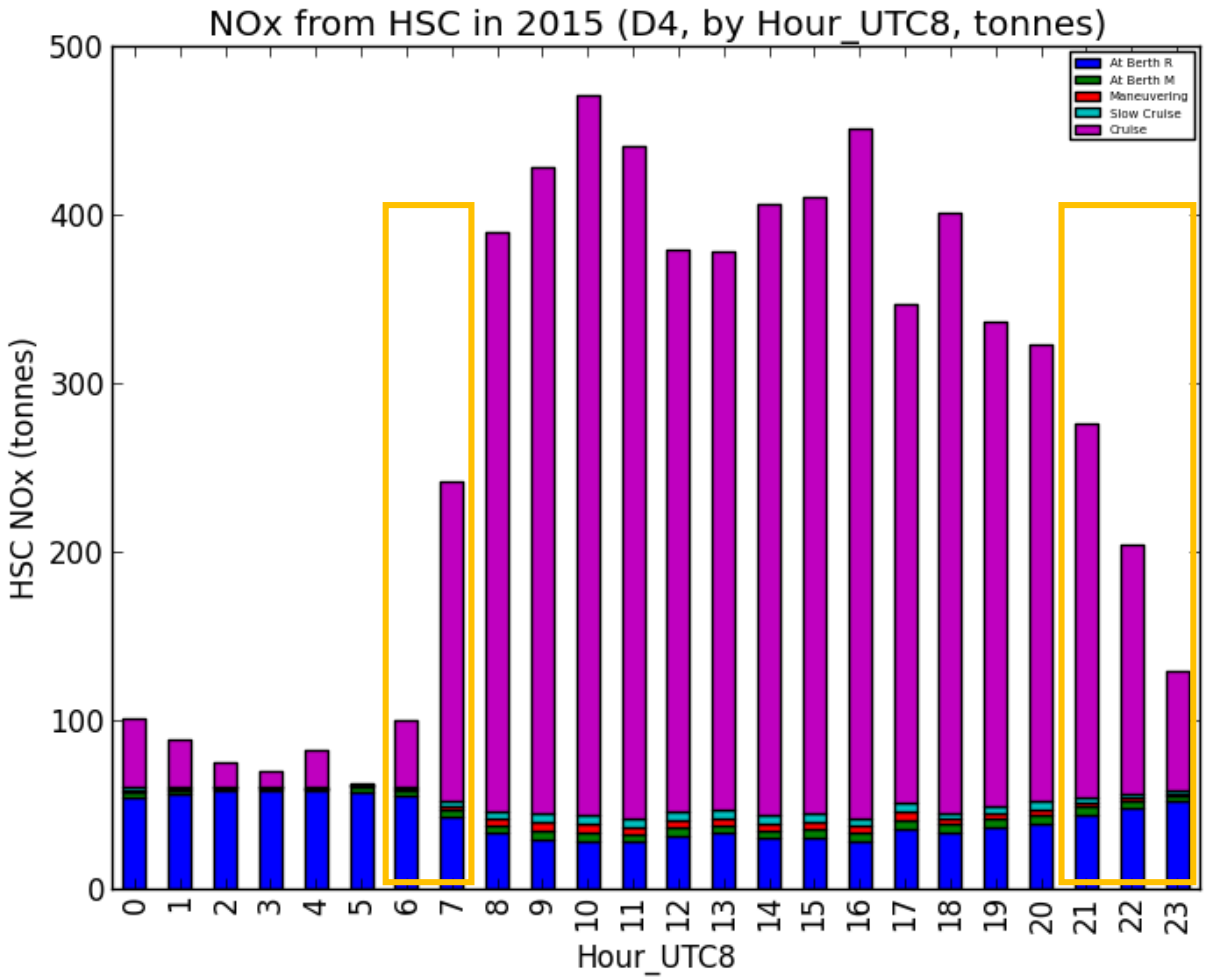
Results





Source: Ship Routes of CKS, TurboJet

Results



Marine Navigation - Summary of Marine Traffic Activites

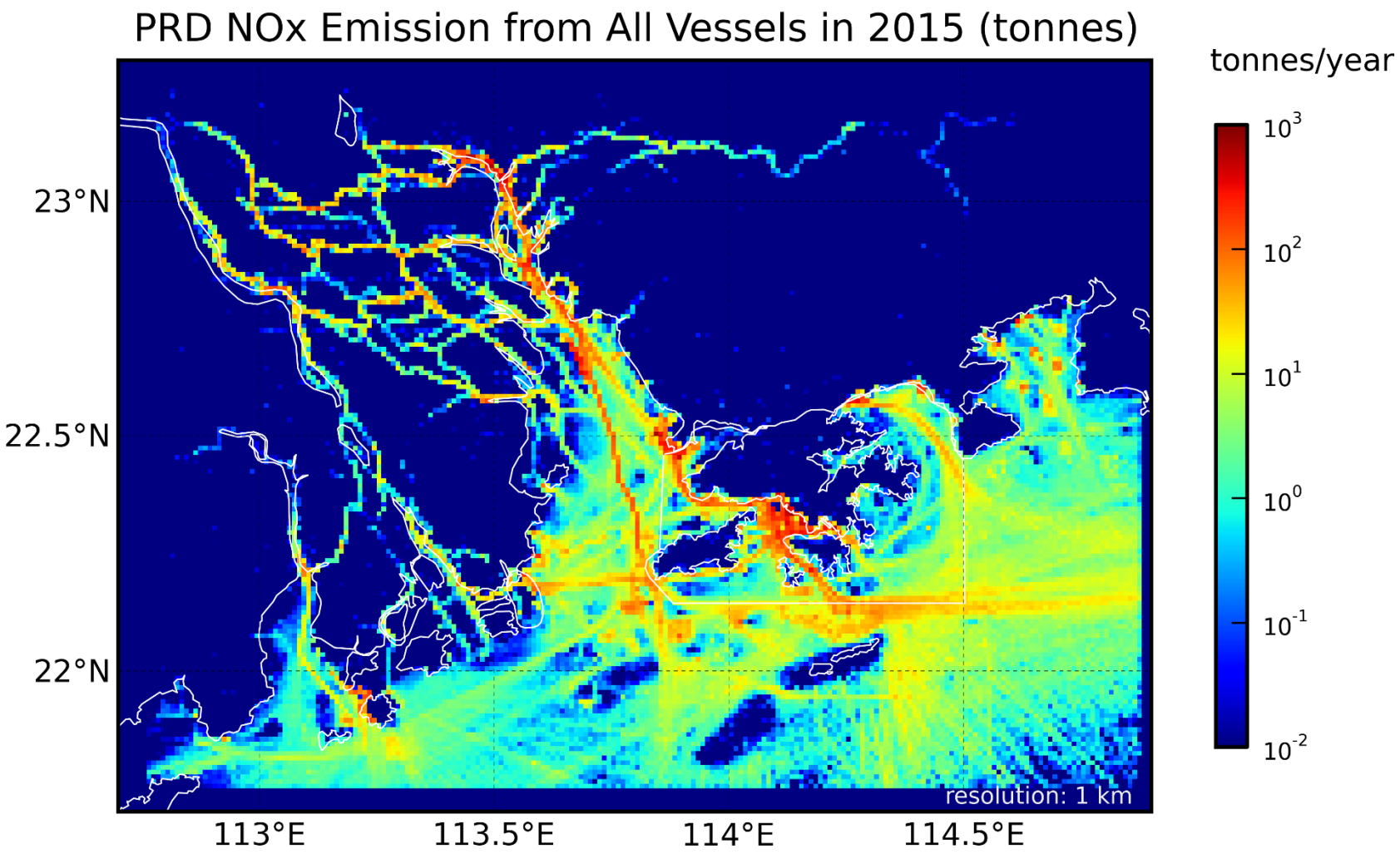
Table 1: Daily Sailing Schedule of Skypier

7 am

Company	From	To	Departure Time
CKS	Shenzhen Shekou	Hong Kong	7:45
Turbojet	Shekou	Hong Kong	7:45
Turbojet	Macau	Hong Kong	7:30
CKS	Hong Kong	Shenzhen Shekou	9:00
CKS	Shenzhen Airport Fuyong Terminal	Hong Kong	8:30
CKS	Macau Outer Harbour Ferry Terminal	Hong Kong	8:20
CKS	Shenzhen Shekou	Hong Kong	8:45
Turbojet	Shekou	Hong Kong	8:45
CKS	Dongguan Humen	Hong Kong	8:15
CKS	Hong Kong	Zhongshan	9:35
CKS	Hong Kong	Shenzhen Shekou	9:50
Turbojet	Hong Kong	Macau	10:00
Turbojet	Macau	Hong Kong	9:15
CKS	Macau Taipa	Hong Kong	9:25
CKS	Hong Kong	Shenzhen Airport Fuyong Terminal	10:15
.....			
CKS	Hong Kong	Shenzhen Shekou	19:30
Turbojet	Hong Kong	Macau	19:50
CKS	Shenzhen Shekou	Hong Kong	19:30
Turbojet	Shekou	Hong Kong	19:30
CKS	Hong Kong	Jiuzhou Port Zhuhai	20:00
CKS	Hong Kong	Shenzhen Airport Fuyong Terminal	20:00
CKS	Hong Kong	Zhongshan	20:10
CKS	Hong Kong	Shenzhen Shekou	20:30
CKS	Shenzhen Shekou	Hong Kong	20:15
Turbojet	Shekou	Hong Kong	20:15
Turbojet	Macau	Hong Kong	20:15
CKS	Shenzhen Shekou	Hong Kong	20:45
CKS	Hong Kong	Shenzhen Shekou	21:20

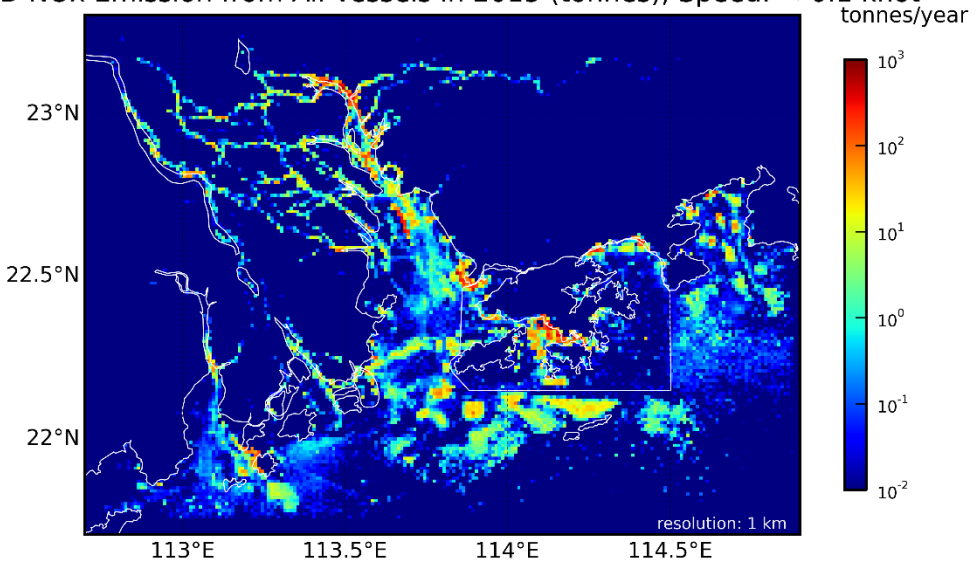
9-10 pm

Results

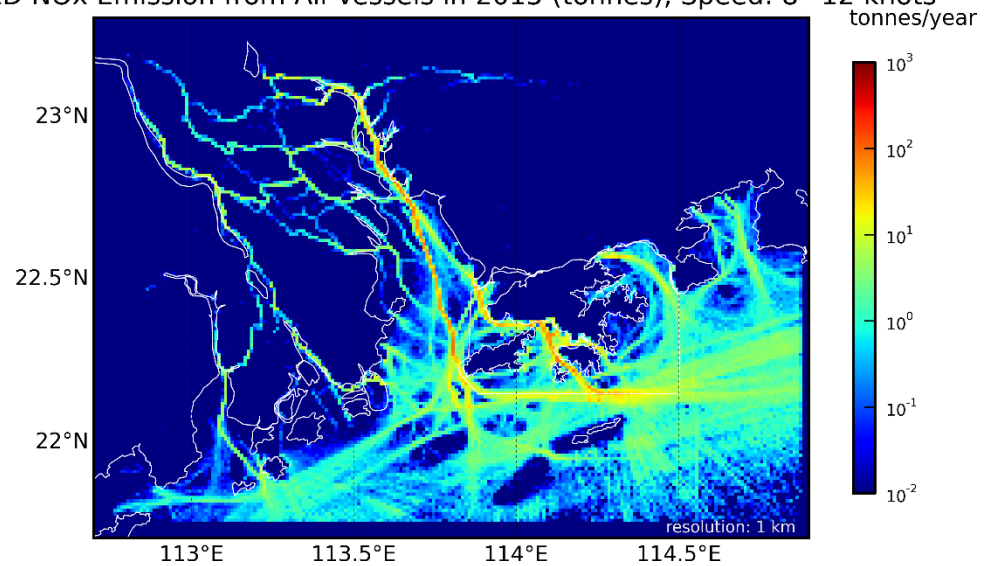

PRD NOx Emission from All Vessels in 2015 (tonnes)
tonnes/year
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
23°N
22.5°N
22°N
113°E
113.5°E
114°E
114.5°E
resolution: 1 km

Results

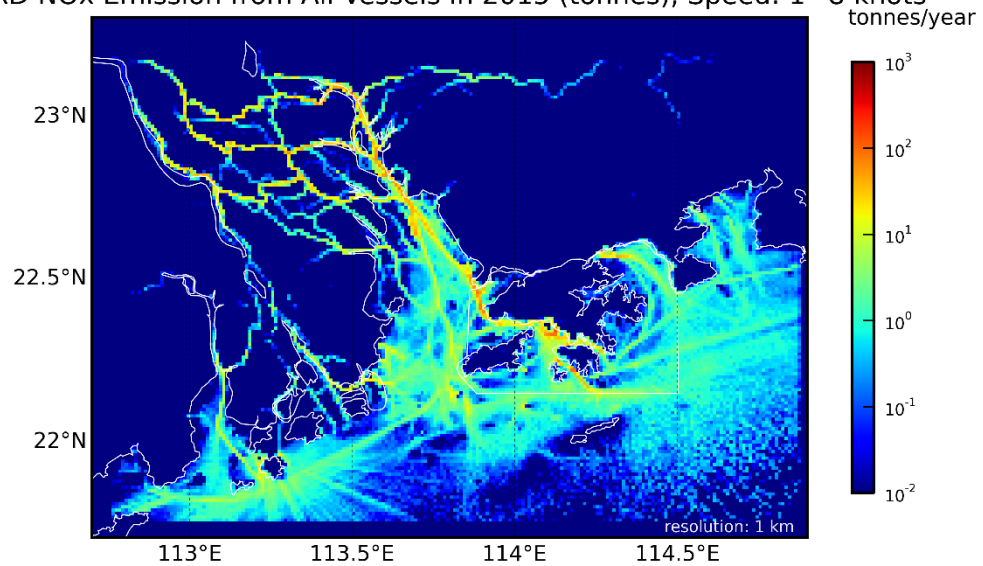
PRD NOx Emission from All Vessels in 2015 (tonnes), Speed: < 0.1 knot



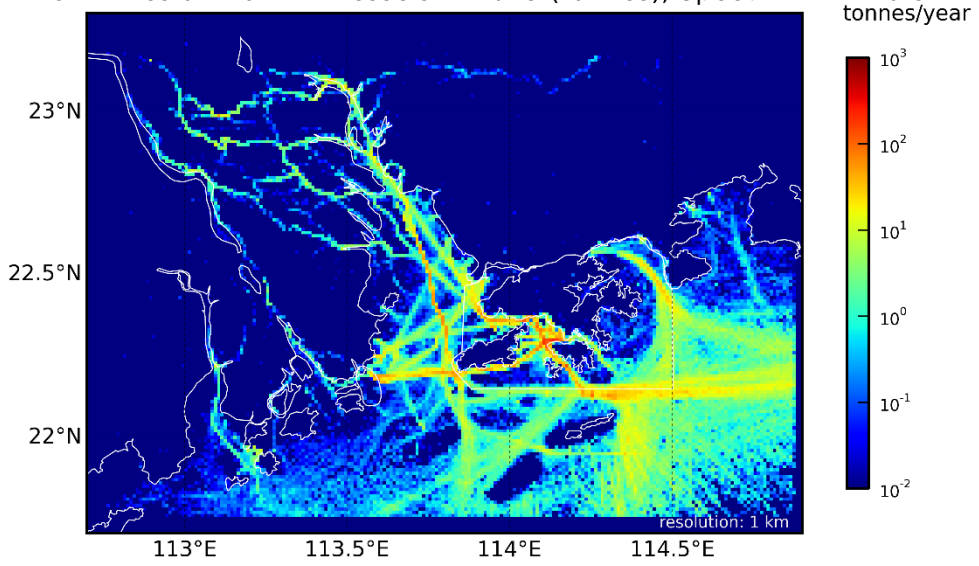
PRD NOx Emission from All Vessels in 2015 (tonnes), Speed: 8~12 knots



PRD NOx Emission from All Vessels in 2015 (tonnes), Speed: 1~8 knots



PRD NOx Emission from All Vessels in 2015 (tonnes), Speed: > 12 knots



Results

Vessel	Fuel (S %)	SO_2 (tonnes, %)		PM_{10} (tonnes, %)		NO_x (tonnes, %)	
OGV	2.7	61,226	98.1%	7,173	83.4%	62,648	45.3%
HSC	0.04	131	0.2%	123	1.4%	6,592	4.8%
RV	0.04	1031	1.7%	1302	15.1%	69,070	49.9%
sum	--	62,388	100%	8,598	100%	138,310	100%

Summary

- An innovative method, based on whole-year global AIS data, is developed to estimate emissions from all vessels with AIS-installed.
- It is necessary to estimate the **emission contributions from unidentified vessels**, especially for the regions with extensive inland river network, e.g. PRD region.

Acknowledgement

- Hong Kong PhD Fellowship Scheme of the Research Grants Council
- Hong Kong Environmental Protection Department (HKEPD)
- Division of Environment and Sustainability, HKUST

Thank you !

Jackie, Yiqi Zhang

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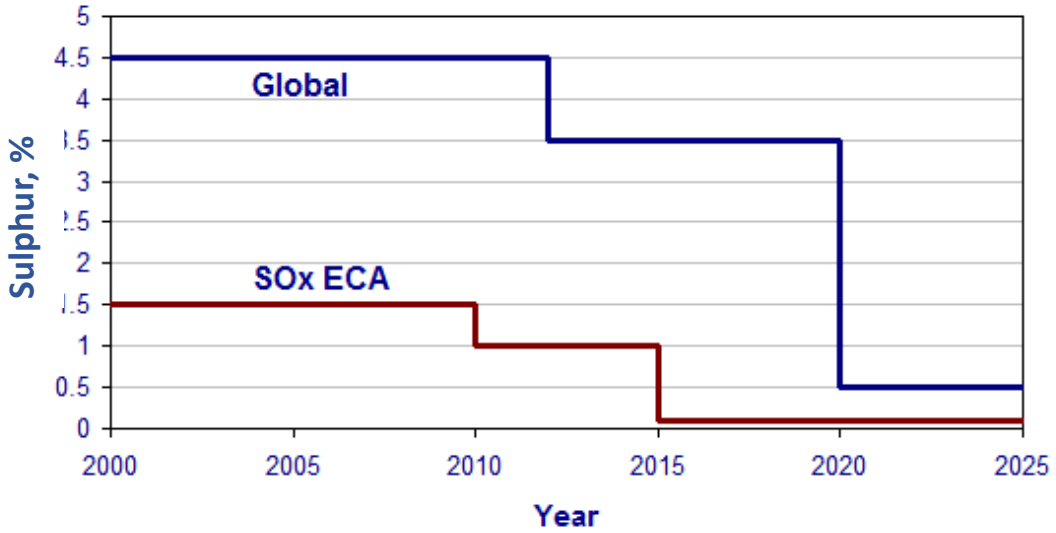
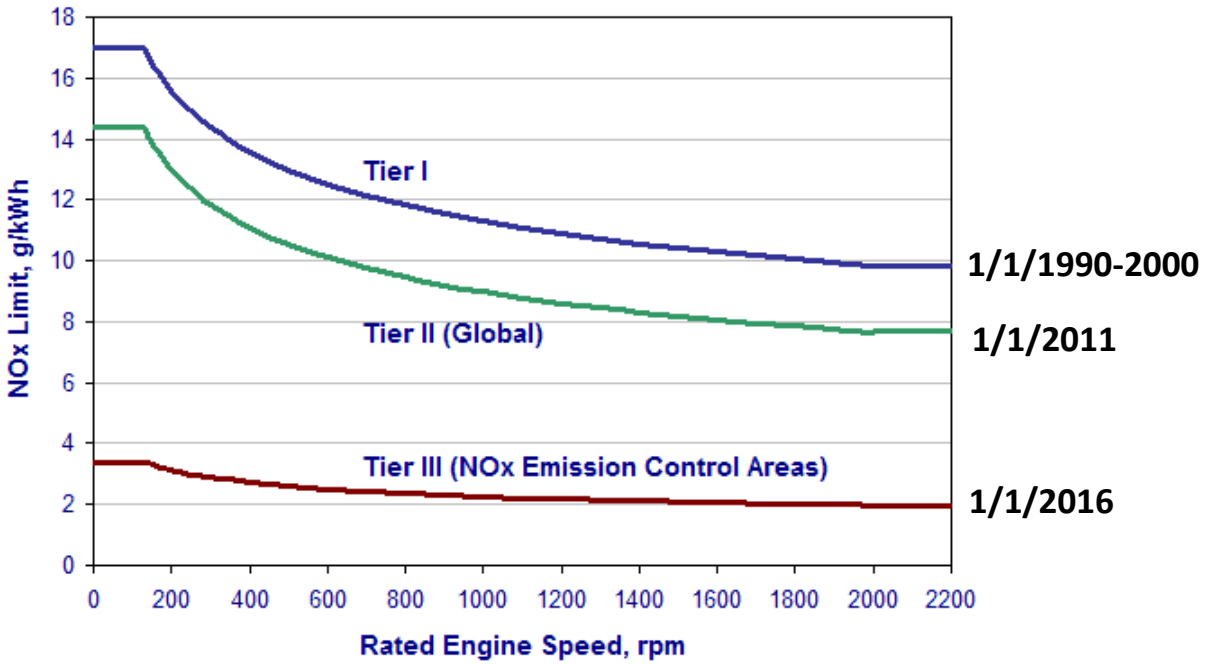
Control Policies

IMO

MARPOL Annex VI



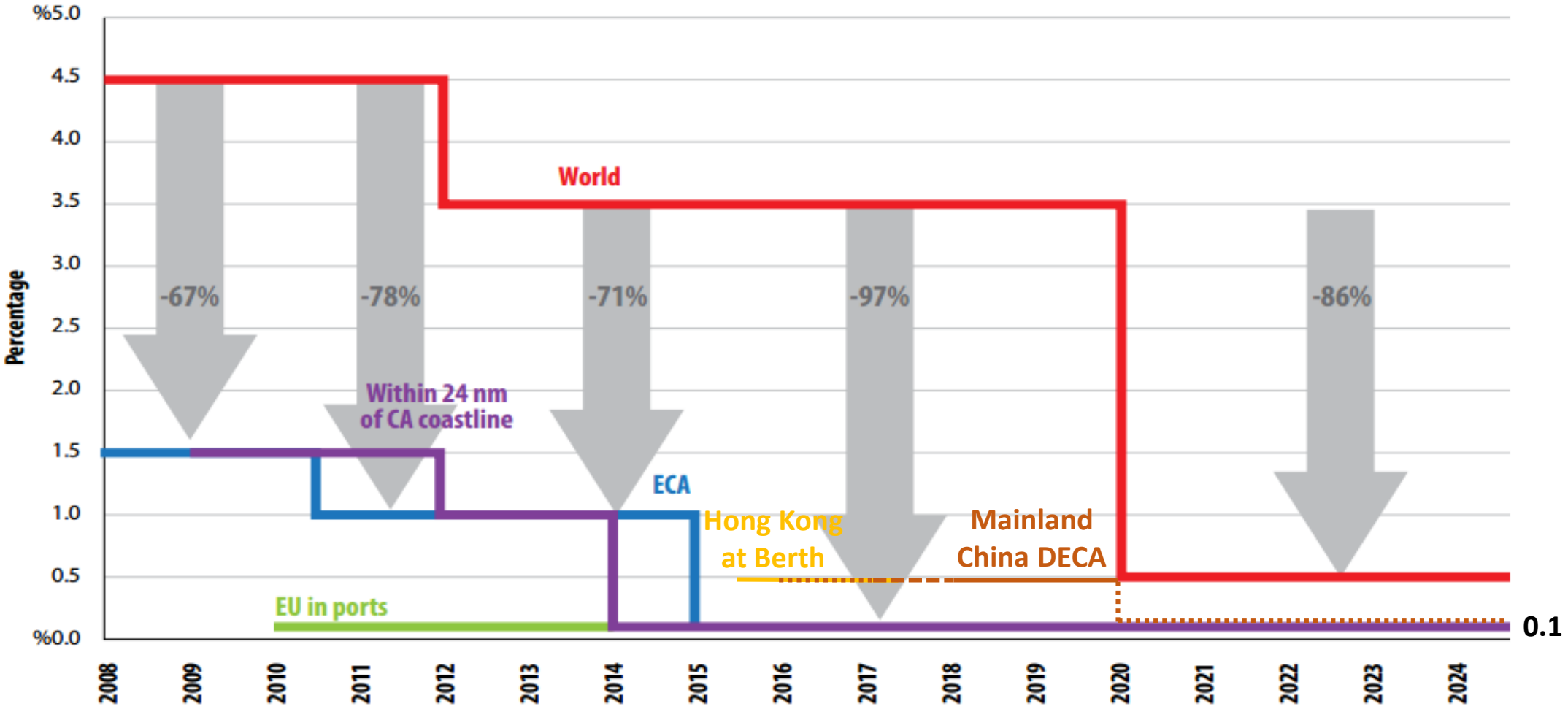
Fuel Sulphur Limits



Engine NO_x Emission Limits

Source: DieselNet; IMO

Control Policies – Fuel Sulphur Content (%)



Source: adapted from Fung, 2014

- **IMO Number:**
  - IMO number is assigned by IHS Fairplay (IHSF) to propelled, sea-going merchant ships of 100 GT and above.
  - The IMO number is an unique seven digit number. It is **never reassigned** to another vessel
  - All OGVs of 100 GT and above **MUST** have IMO number
  - Vessels with IMO number are not necessarily OGVs, as IHSF has extended the IMO Scheme on a voluntary basis.

- **AIS Installment:**
  - OGVs of 300 GT and above **MUST** install AIS.
  - Non-OGVs of 500 GT and above **MUST** install AIS.
  - In China, all coastal vessels and cargo/tanker ships of 500 GT and above are required to install AIS.
  - In China, most OGVs less than 300 GT and Non-OGVs less than 500 GT have installed AIS.

How to estimate marine emission inventory?

$$\boldsymbol{Emission} = \boldsymbol{Engine\ Work\ Output} \times \boldsymbol{Emission\ Factor}$$

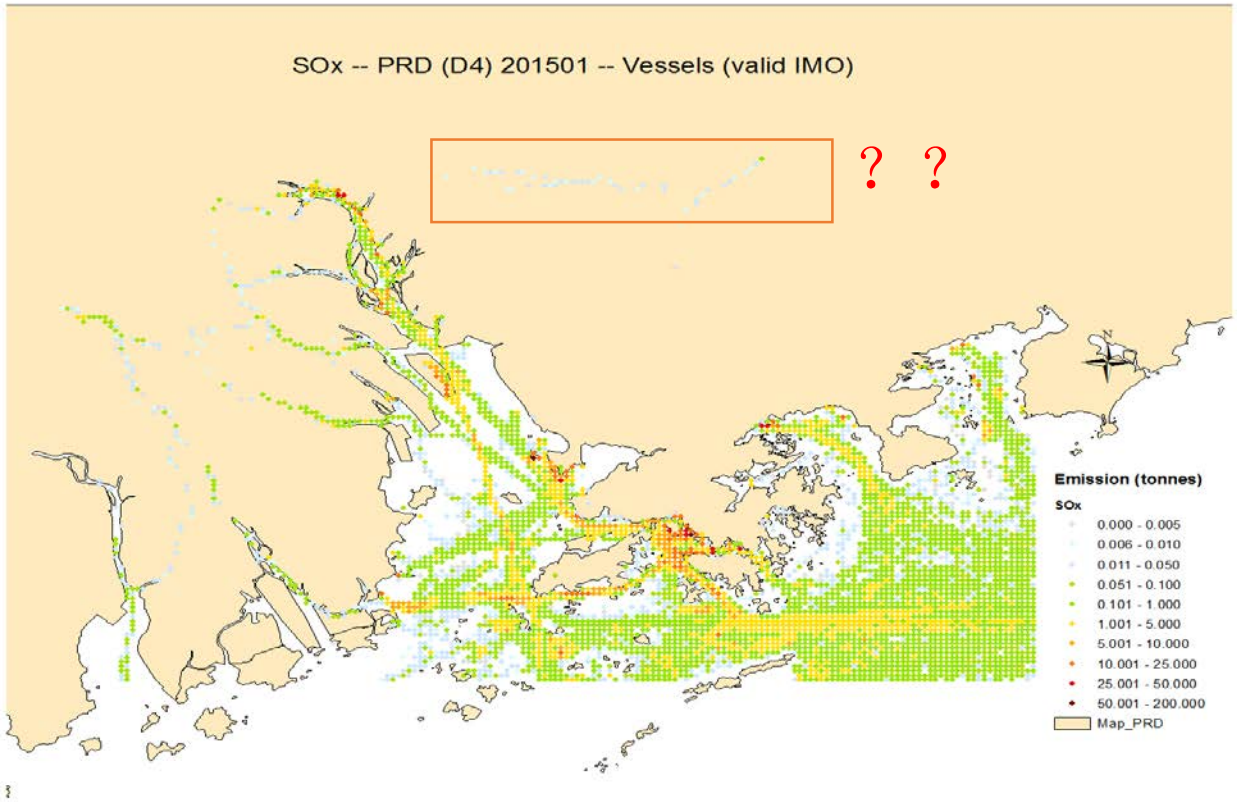
$$Engine\ Load \times Activity\ Time$$

- Main Engine
- Auxiliary Engine
- Auxiliary Boiler

For Main Engine:

$$Engine\ Load = Engine\ Maximum\ Power \times \left(\frac{real-time\ Speed}{Ship\ Maximum\ Speed}\right)^3$$


Deep-water port
Airport
Shallow-water port
Proposed bridge
Huadu (under construction)
C H I N A
Huangpu
Guangzhou
Shati
Dongguan
Huizhou
G U A N G D O N G
Huangtian
Pearl river estuary
Ma Wan & Chi Wan
Yantian
Shenzhen
Shekou
HONG KONG
Chek Lap Kok
Kwai Chung
Zhuhai
Macau
Macau
Hong Kong island
South China Sea
Zhuhai Gaolan
Zhuhai Sanzao
100 km
Source: MVA Hong Kong Ltd



Estimated AIS records

```
:|IMO|MMSI|CallSign|ShipName|ShipType|Length1|Beam1|Draught|Speed|La
|9626223|413475560|AXXS|YUESHAOGUANHUO2929|Cargo|67.0|13.0|0.0|6.5|
|9626223|413475560|BOKL|YUESHAOGUANHUO2929|Cargo|67.0|13.0|0.0|0|23
```

AIS Live

HUA LONG

Anchor Handling Tug Supply

WatchList	
MMSI	413475660
Callsign	BOKL
IMO	9626223
Last seen	1 day ago
Last port	Huizhou Dongma
Destination	Lufenei

YUESHAOGUANHUO 2929

Cargo

WatchList	
MMSI	413475560
Callsign	AXXS
IMO	9626223
Last seen	20 days ago
Destination	N/A

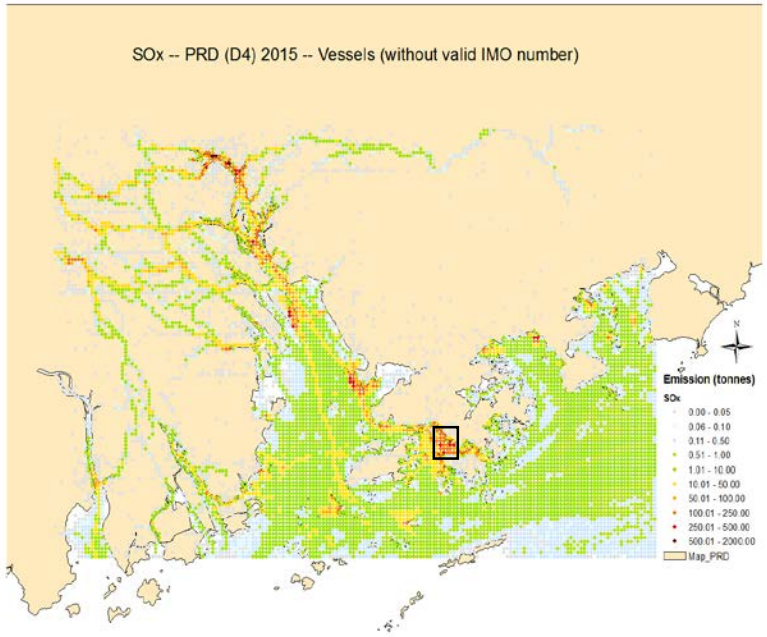
World Registration of Ship

IMO	MMSI	CallSign	ShipNar	Statcod	Status	Length	Beam	Draught	MaxSpeed
9626223	413475660	BOKL	Hua Long	B21B2OA	Delivered	75	16.5	6.1	14.5

Appendix

```
IMO|MMSI|CallSign|ShipName|ShipType|Length1|Beam1|Draught|Speed|Latitude|Longitude
9999999|412469620|BXQQ|JIANGONG188|Unknown|78.0|16.0|3.5|8.5|22.297432|114.149917
9876543|412418880|BLAT3|JIAYUAN99|Cargo|94.0|14.0|5.5|8.4|22.2922|114.13
9678056|477995299|VRLZ|TAIMIN1|Tanker|1.0|1.0|0.0|2.9|22.3279|114.128
9600000|201208170||TEST1|Unknown|50.0|10.0|0.0|0|22.306053|114.122787
9505508|266772656|BBTPT|DGSHI001|Unknown|40.0|8.0|8.8|0|22.3244|114.151
9348182|636014884|A8XE9|ASTERIX|Cargo|1.0|1.0|9.9|0|22.336667|114.127833
9306119|636091487|A8OK4|POEQSINA|Cargo|213.0|32.0|8.2|0|22.329783|114.13215
9306117|565425000|9VKB5|KLEI316|Cargo|213.0|32.0|11.3|0|22.338783|114.12605
9100000|477990007|BADCCBA|FAT|Unknown|30.0|10.0|0.0|0|22.3287|114.129
9041000|413465410|B|IUIJINQIAO181|Unknown|1.0|1.0|0.0|0|22.3119|114.146
9013414|477911000|VRZS8|WINGDART|Cargo|50.0|14.0|8.6|7.6|22.290513|114.130352
8084521|413464990|61035|HUIJINQIAO91|Cargo|49.0|15.0|3.6|0|22.3048|114.15
8061113|413888890|TSTAISB|HAITAI1HAO|Passenger|73.0|14.0|1.4|0|22.301762|114.123152
7869000|412000008|0|WOTAD0|Tender|1.0|1.0|0.0|9.7|22.3004|114.128
7078001|726872647|0000000|000000000000000000000|Law Enforcement|96.0|96.0|4.8|0.1|22.3057|114.123
5536481|412234567|0|SH|Cargo|50.0|6.0|0.0|6.9|22.2933|114.142
5368876|477995084||PILOT5|Pilot Boat|14.0|4.0|0.0|0.2|22.3117|114.159
4973155|412468480|LT6KO|HUIJINQIAO78|Cargo|49.0|15.0|3.5|0.6|22.3118|114.125
4973000|477995124|VRS4487|PILOT83|Pilot Boat|14.0|4.0|0.0|17.6|22.291367|114.137872
4972000|477995123|VRS4486|PILOT82|Pilot Boat|14.0|4.0|0.0|16.2|22.293305|114.13329
4971000|477995122|VRS4485|PILOT81|Pilot Boat|14.0|4.0|0.0|0.7|22.318707|114.149438
4567893|413762739|100200|GUANGBOYUN1000|Cargo|49.0|13.0|0.4|0|22.3056|114.157
4463458|413470140|C3|HUIHAILONG168|Cargo|52.0|17.0|3.8|1.1|22.3257|114.129
4416707|412468480|LNKAW|HUIJINQIAO78|Cargo|49.0|15.0|3.5|0.4|22.3122|114.15
4124732|412473290||NANHANG737|Cargo|75.0|15.0|4.5|0|22.3022|114.15
4124696|412469680||HUIGANGTONG133|Cargo|50.0|14.0|2.0|6.3|22.299|114.128
4047147|413900952|TSTAISB|RONGJING98|Cargo|49.0|13.0|4.2|0.3|22.312137|114.122573
3849388|359593872|PAHPAU1|TDAXXSQDTHTUD|Cargo|625.0|78.0|6.0|0|22.2905|114.139
```

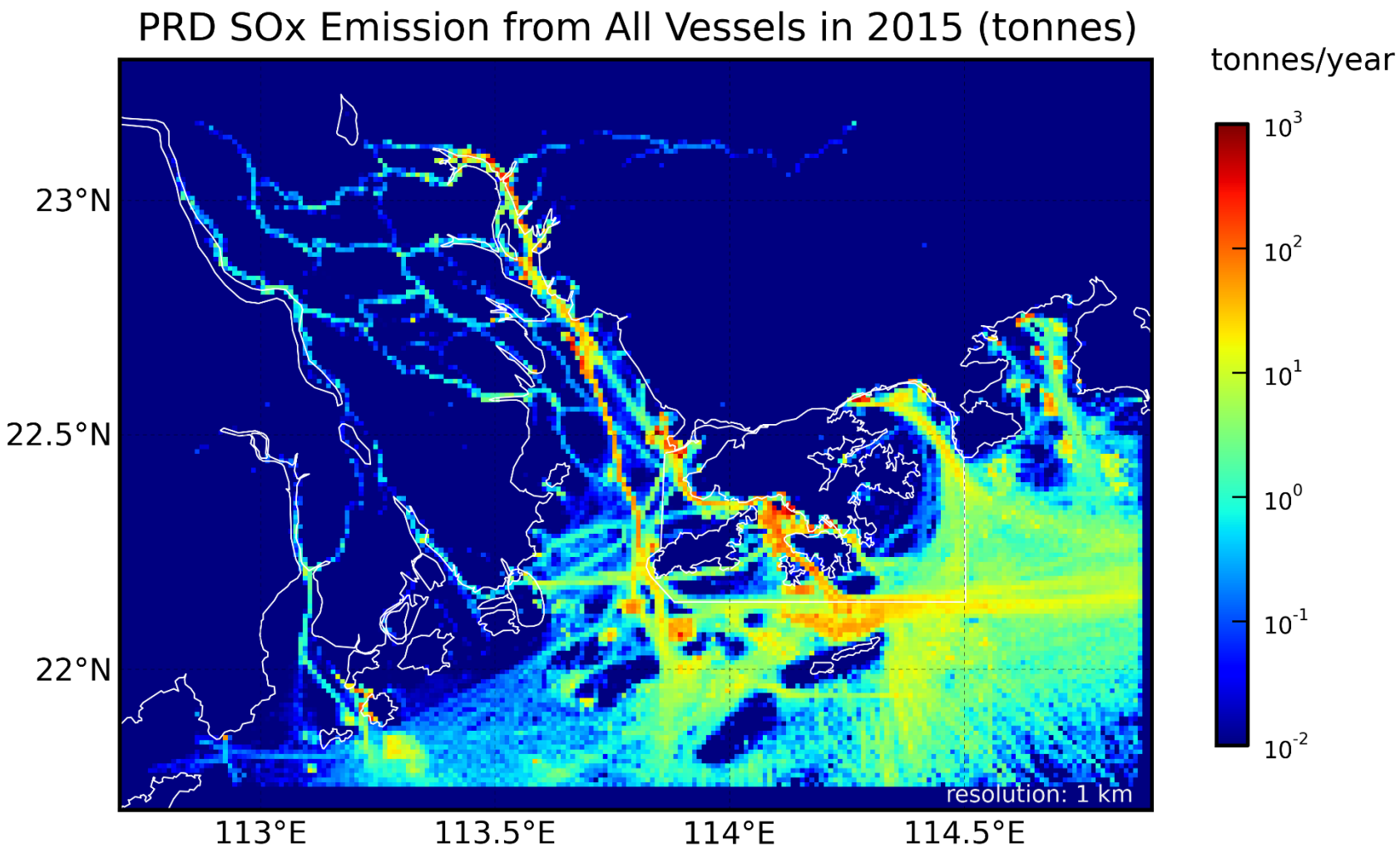
IMO	MMSI	CallSign	ShipNar	Statcod	Status	Length	Beam	Draught	MaxSpeed
9678056		VRLZ2	Taimin 1	A13B2TP	Delivered	48	13.8	5	9
9505508	259073000	LGSY	Havila Sub	B22A2OR	Delivered	98	19.771	8	11.1
9348182			Asterix	A33A2CC	Delivered	182.46	25.2	10	20.2
9013414		3FKW3	Tuo Fu 3	A21A2BC	Scrapped	228.5	32.2	13.29	14.3



Appendix

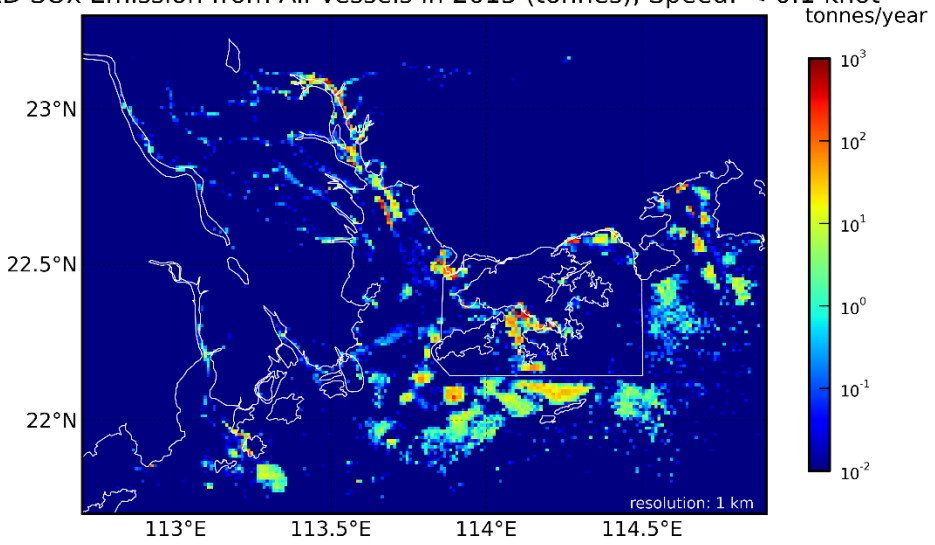
SOx Estimates (tonnes)	Original Data (A)	STL Median (B)	Ratio (B/A)
Unidentified Vessels	1,031	--	--
Identified Vessels	61,357	53,994	0.88

Appendix

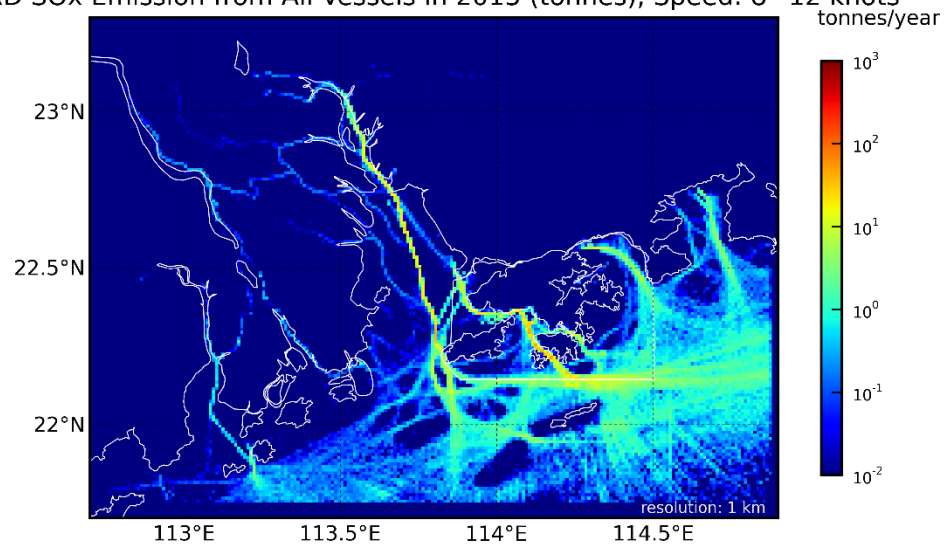

PRD SOx Emission from All Vessels in 2015 (tonnes)
tonnes/year
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
23°N
22.5°N
22°N
113°E
113.5°E
114°E
114.5°E
resolution: 1 km

Appendix

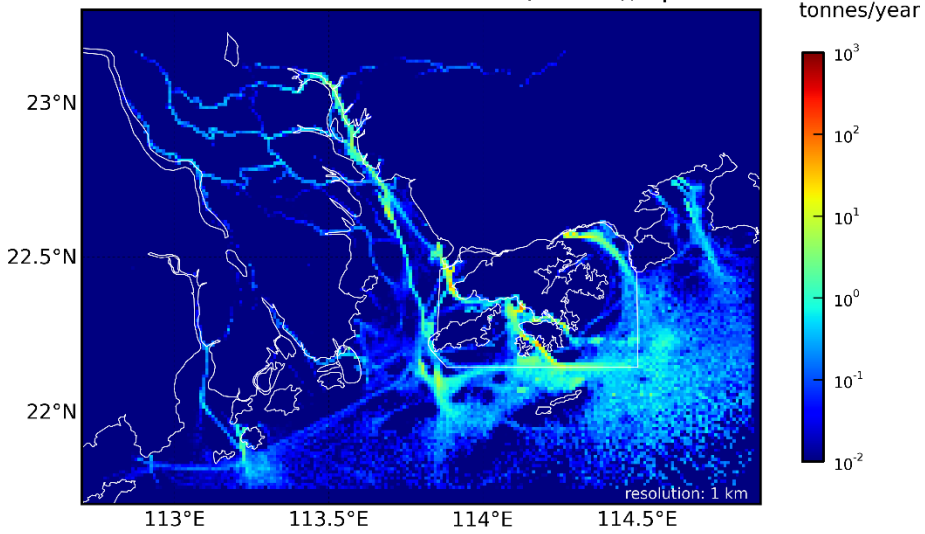
PRD SOx Emission from All Vessels in 2015 (tonnes), Speed: < 0.1 knot



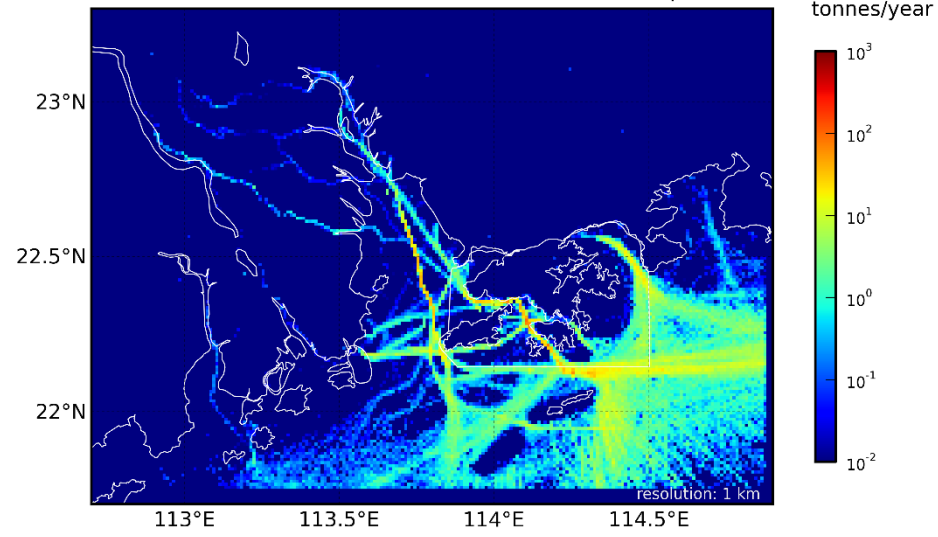
PRD SOx Emission from All Vessels in 2015 (tonnes), Speed: 8~12 knots



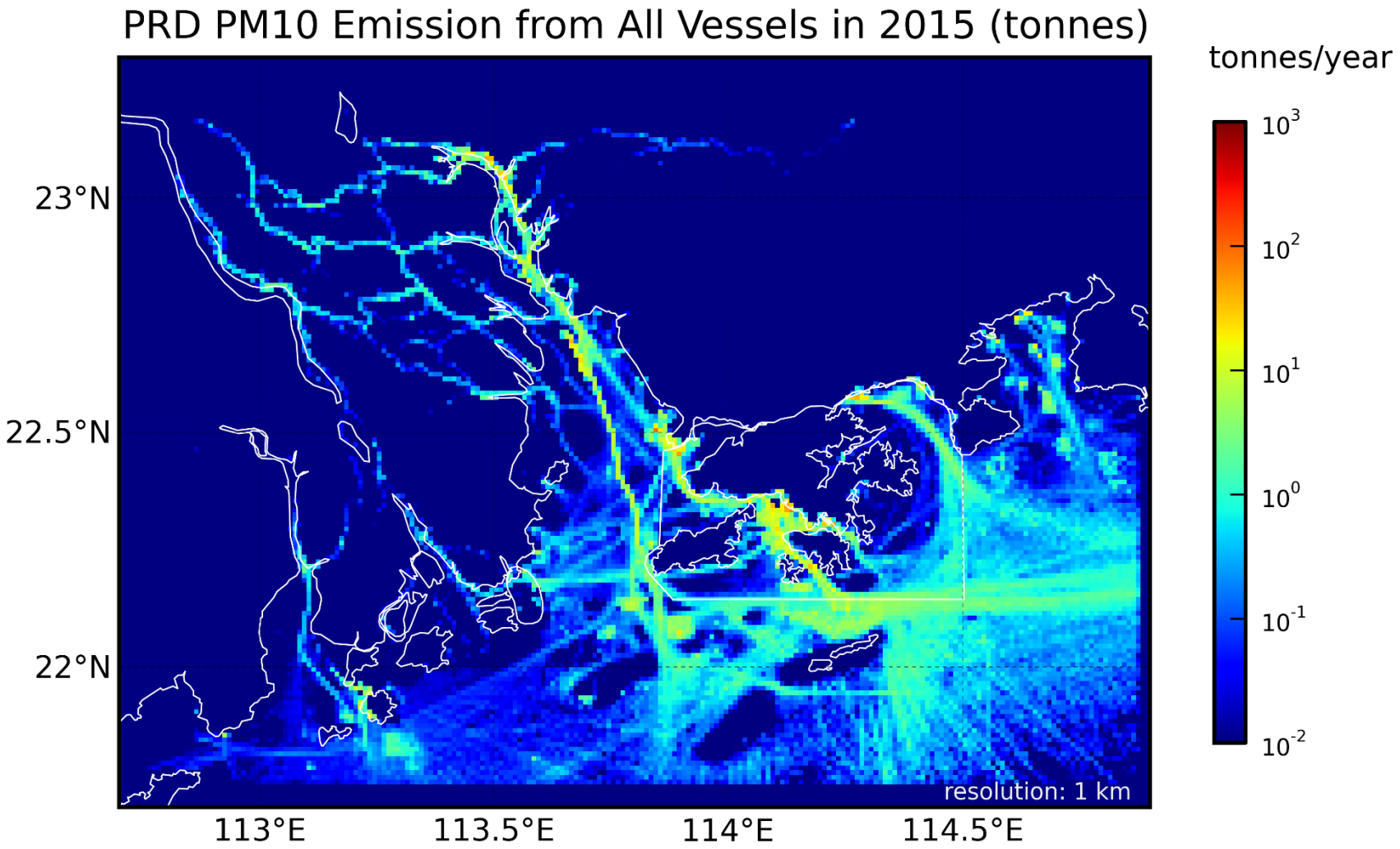
PRD SOx Emission from All Vessels in 2015 (tonnes), Speed: 1~8 knots



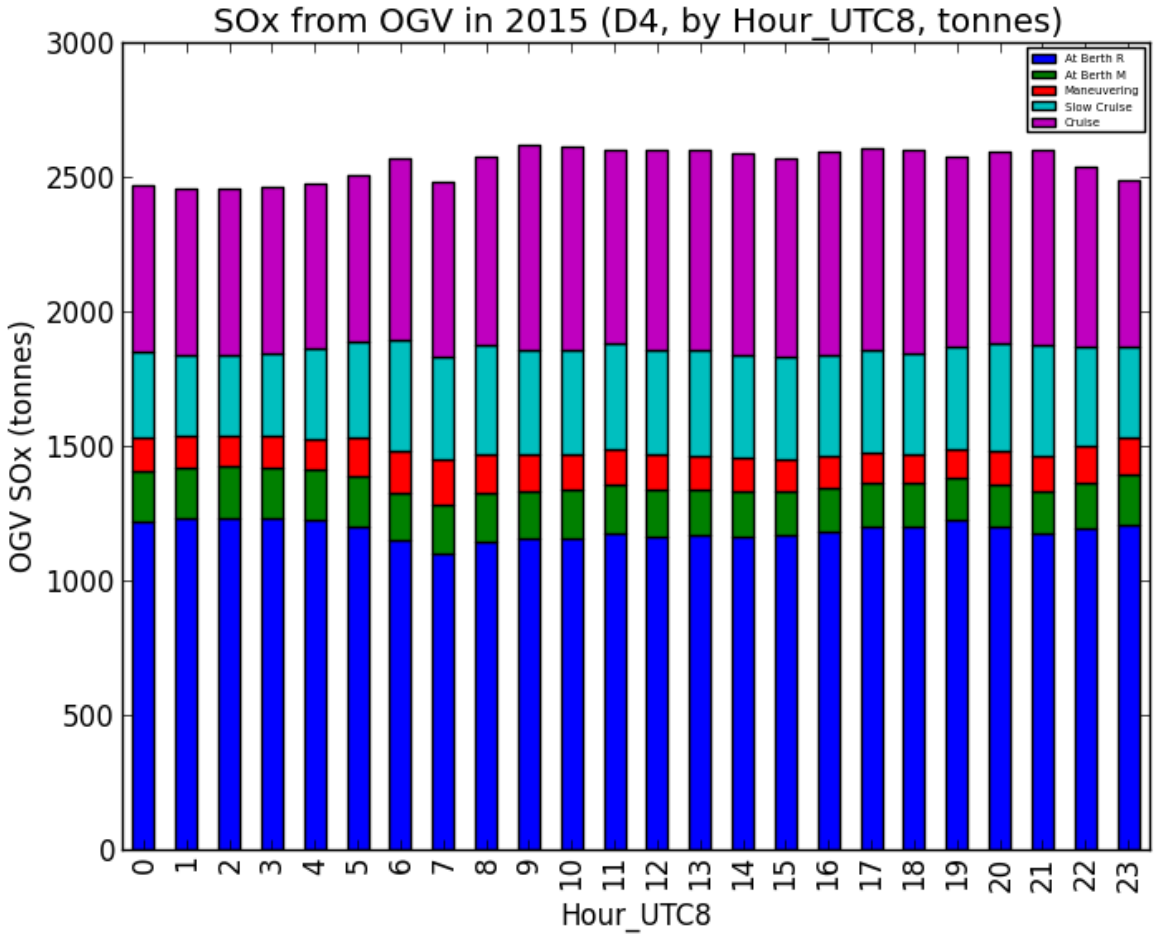
PRD SOx Emission from All Vessels in 2015 (tonnes), Speed: > 12 knots

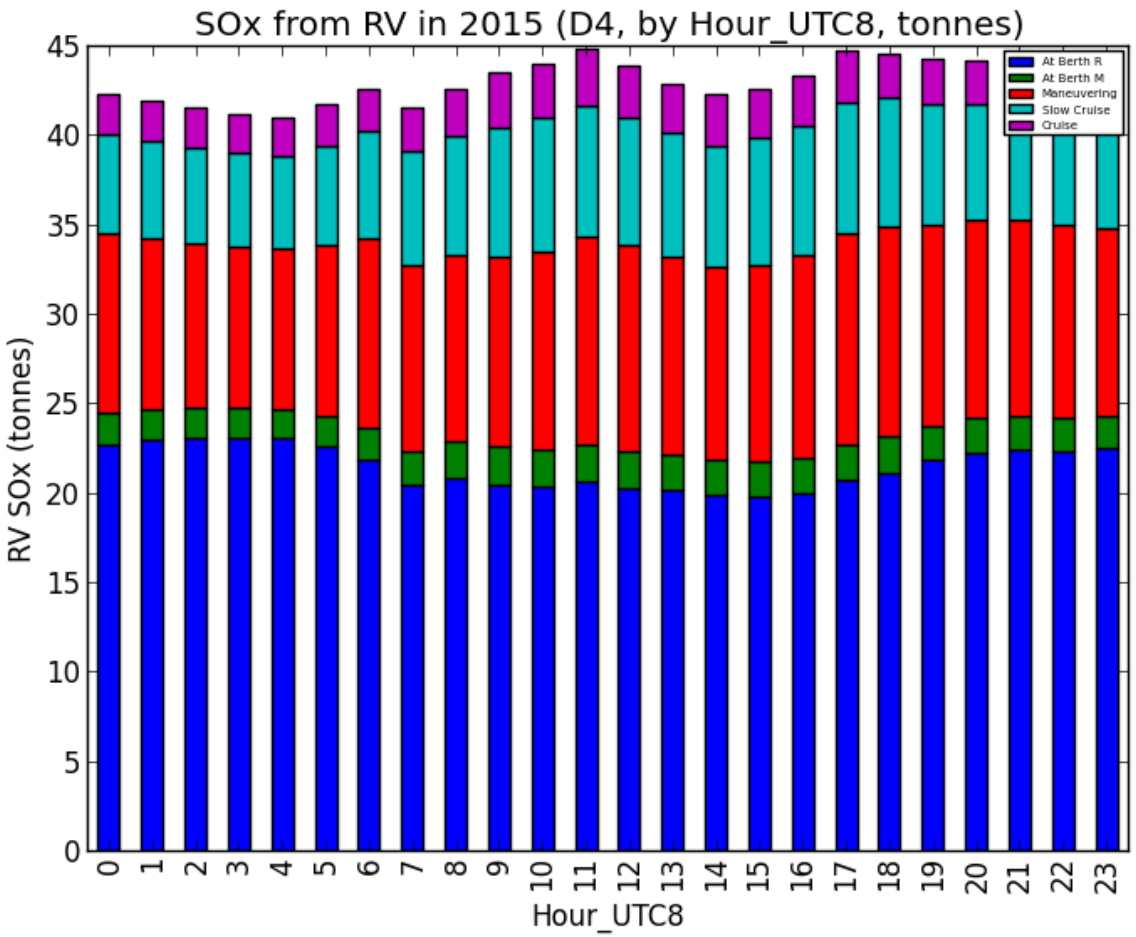


Appendix


PRD PM10 Emission from All Vessels in 2015 (tonnes)
tonnes/year
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
23°N
22.5°N
22°N
113°E
113.5°E
114°E
114.5°E
resolution: 1 km

Appendix


SOx from OGV in 2015 (D4, by Hour_UTC8, tonnes)
OGV SOx (tonnes)
Hour_UTC8
At Berth R
At Berth M
Maneuvering
Slow Cruise
Cruise
0
500
1000
1500
2000
2500
3000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23


SOx from RV in 2015 (D4, by Hour_UTC8, tonnes)
RV SOx (tonnes)
Hour_UTC8
At Berth R
At Berth M
Maneuvering
Slow Cruise
Cruise
0
5
10
15
20
25
30
35
40
45
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

Emission Factors

$$EF(fuel) = EF(baseline) \times Fuel\ Correction\ Factor(fuel)$$

Baseline Emission Factors (HFO with 2.7% sulphur content)

Engine Type	Type	PM10	PM2.5	NOx	SOx	CO	HC
Slow	T0	1.50	1.20	18.10	10.50	1.40	0.60
Slow	T1	1.50	1.20	17.00	10.50	1.40	0.60
Slow	T2	1.50	1.20	14.40	10.50	1.40	0.60
Medium	T0	1.50	1.20	14.00	11.50	1.10	0.50
Medium	T1	1.50	1.20	13.00	11.50	1.10	0.50
Medium	T2	1.50	1.20	11.20	11.50	1.10	0.50
High	T0	1.50	1.20	14.00	11.50	1.10	0.50
High	T1	1.50	1.20	9.80	11.50	1.10	0.50
High	T2	1.50	1.20	7.70	11.50	1.10	0.50

Fuel Correction Factors

Fuel (S%)	PM10	PM25	NOx	SOx	CO	HC
2.7	1	1	1	1	1	1
0.05	0.16	0.16	0.94	0.019	1	1
0.04	0.16	0.16	0.94	0.015	1	1

Emission Factors