



Organizan:

Environmental Impact of Ship Emissions Based on AIS Big Data for the Port of Rio de Janeiro

By: Maricruz A. Fun Sang Cepeda - Gabriel P. Monteiro - João V. M. d. O. Moita - LUIZ FELIPE ASSIS and J.- D. Caprace



Instituto Alberto Luiz Coimbra de
Pós-Graduação e Pesquisa de Engenharia

COPPE
UFRJ



Agenda



- Introduction
- Objective
- Case Study
- Model
- Results
- Conclusions





BIG DATA

Is about managing and analyzing large volumes of various types of data with great velocity

Introduction

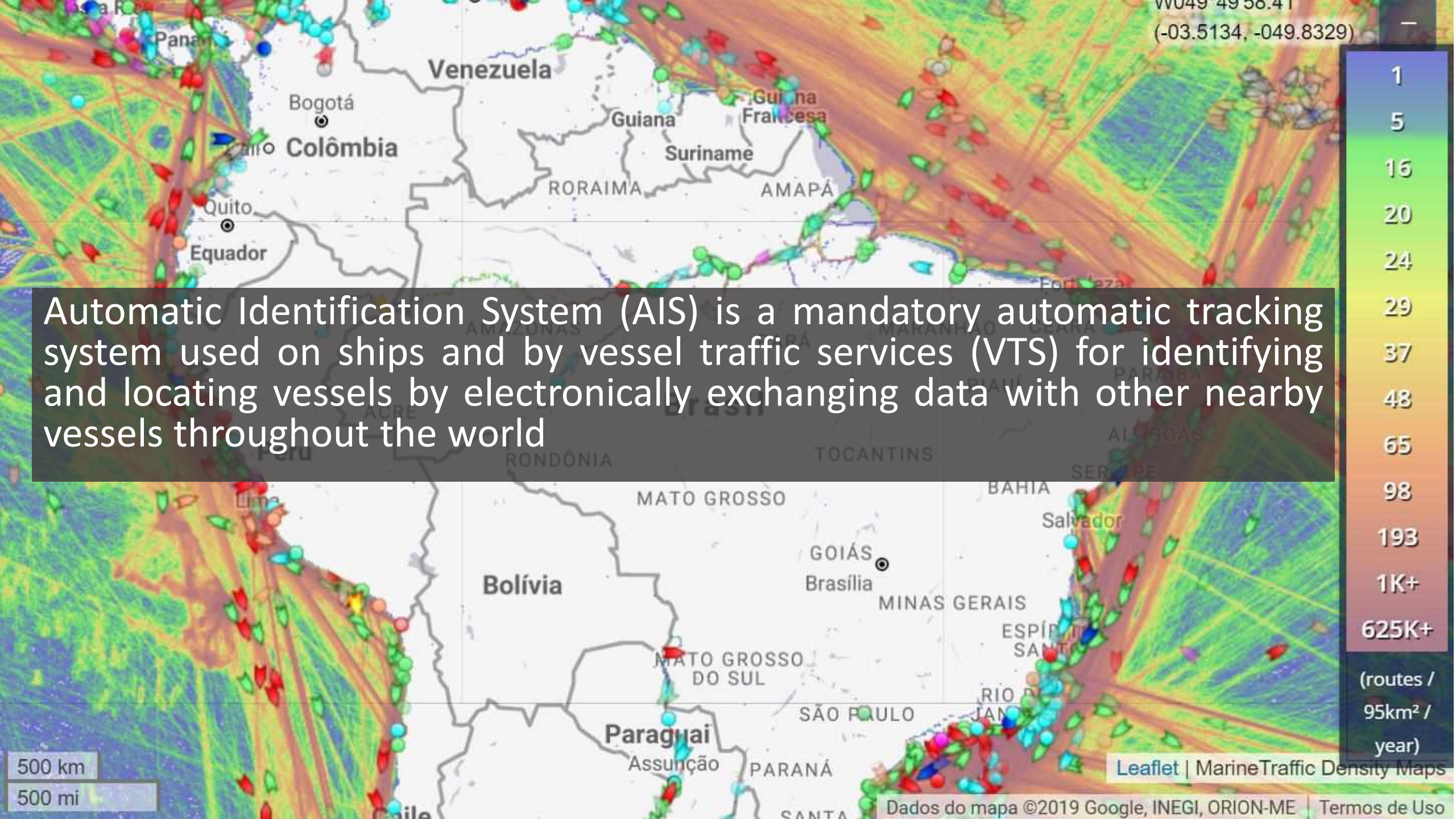


In the marine industry

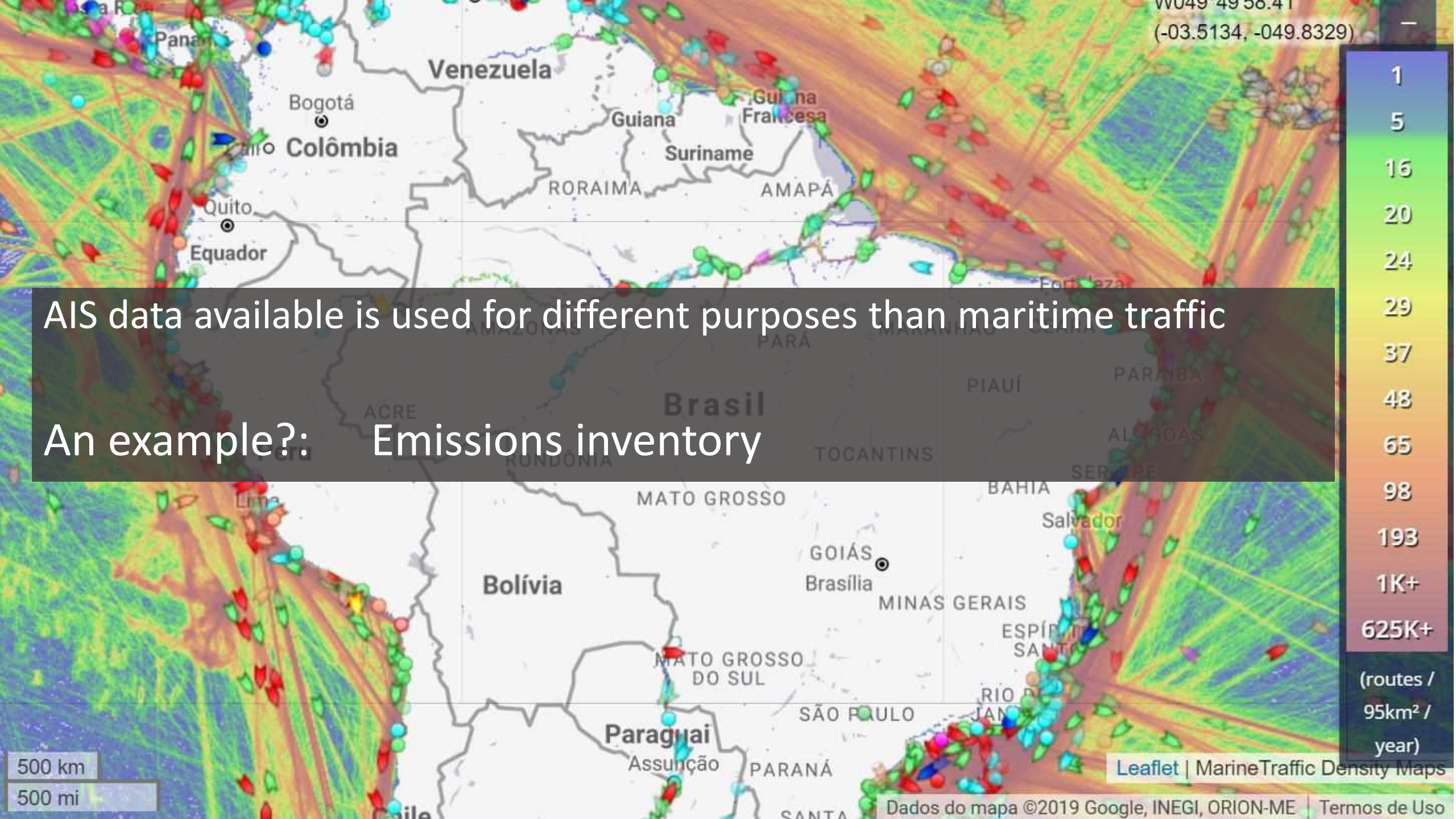


An example of BIG DATA?
AIS





Automatic Identification System (AIS) is a mandatory automatic tracking system used on ships and by vessel traffic services (VTS) for identifying and locating vessels by electronically exchanging data with other nearby vessels throughout the world

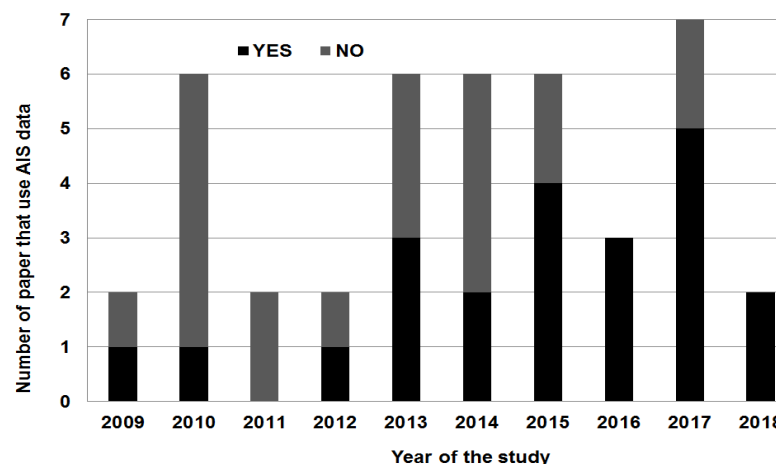


AIS data available is used for different purposes than maritime traffic

An example?: Emissions inventory

Last study

- Reviewed 41 papers about emissions calculations since 2009
- Most of the cases focuses on ports in Europe and Asia
- The use of AIS data is more common in the last 5 years



Introduction

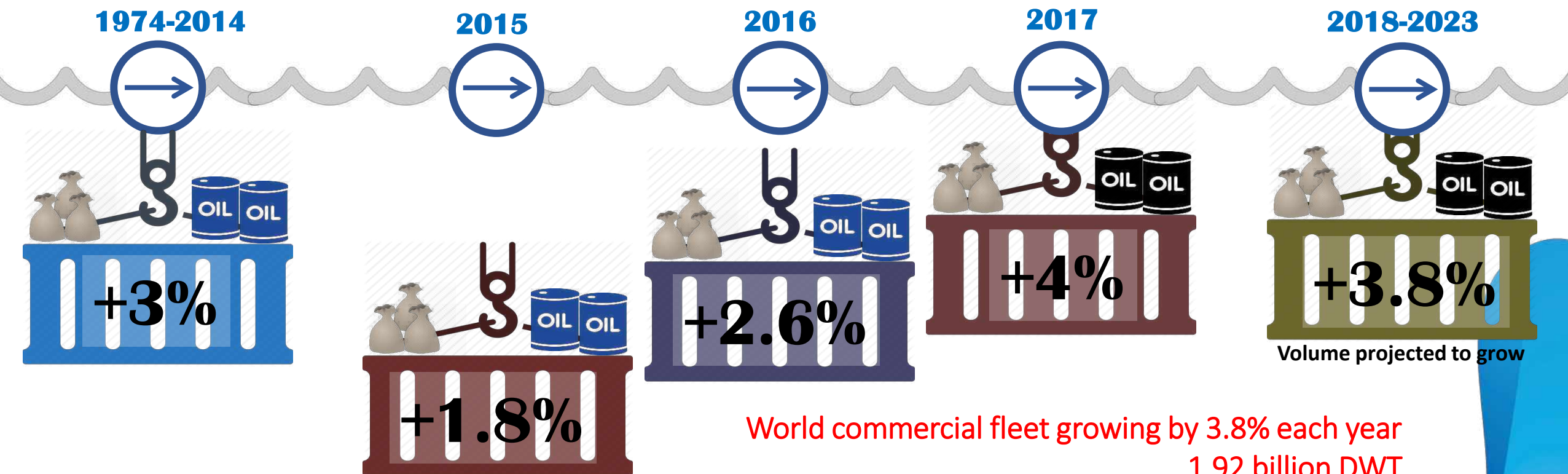


Life Cycle Assessment (LCA)

- LCA is an environmental management tool that helps to evaluate the effects of a product on the environment over the entire period of its life
- The use of LCA is not common in emission studies and that it has been studied in the maritime area in isolation
- The use of bigdata in conjunction with LCA has not been done



Introduction



World commercial fleet growing by 3.8% each year
1.92 billion DWT
94171 vessels





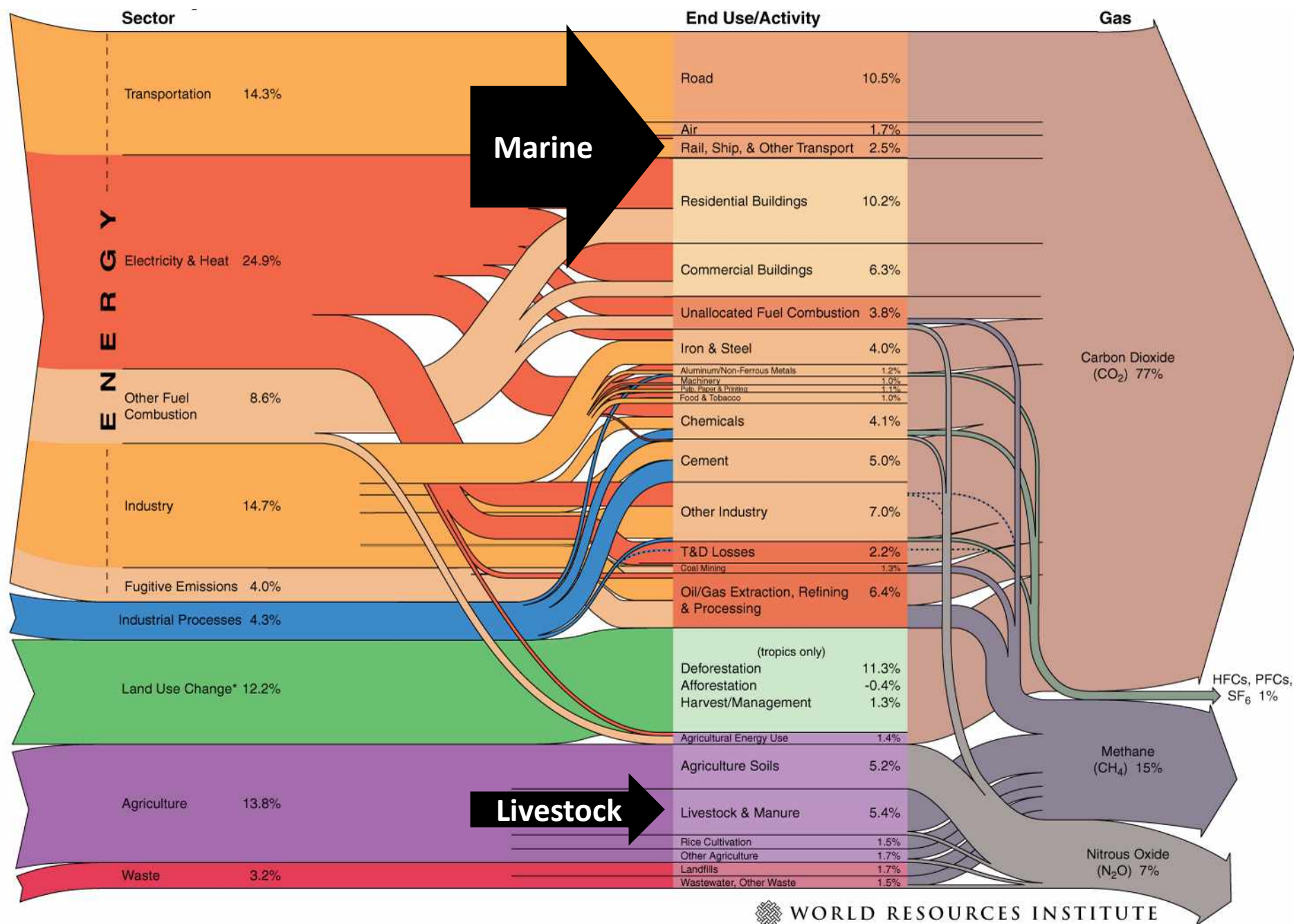
Shipping work (distance*payload) almost doubled in 10 years

Emissions in Maritime Industry • Doubled in 10 years

- Carbon dioxides
- Sulfur dioxides
- Nitrogen dioxides
- Particulate Matter



GHG emissions 2005



WORLD RESOURCES INSTITUTE

Transportation 14% • Marine ~ 2.5% • Some forecast → increase ~50%-250% by 2050 (IMO)

Introduction



Marine Environment Protection Committee

- 72nd session, 9-13 April 2018
- **0.50% limit on sulfur** in fuel oil on board ships will come into effect on **1 January 2020**
- 0.10% in emission control areas (ECAs)
- includes a specific reference to “**a pathway of CO2 emissions reduction consistent with the Paris Agreement temperature goals**”



Introduction



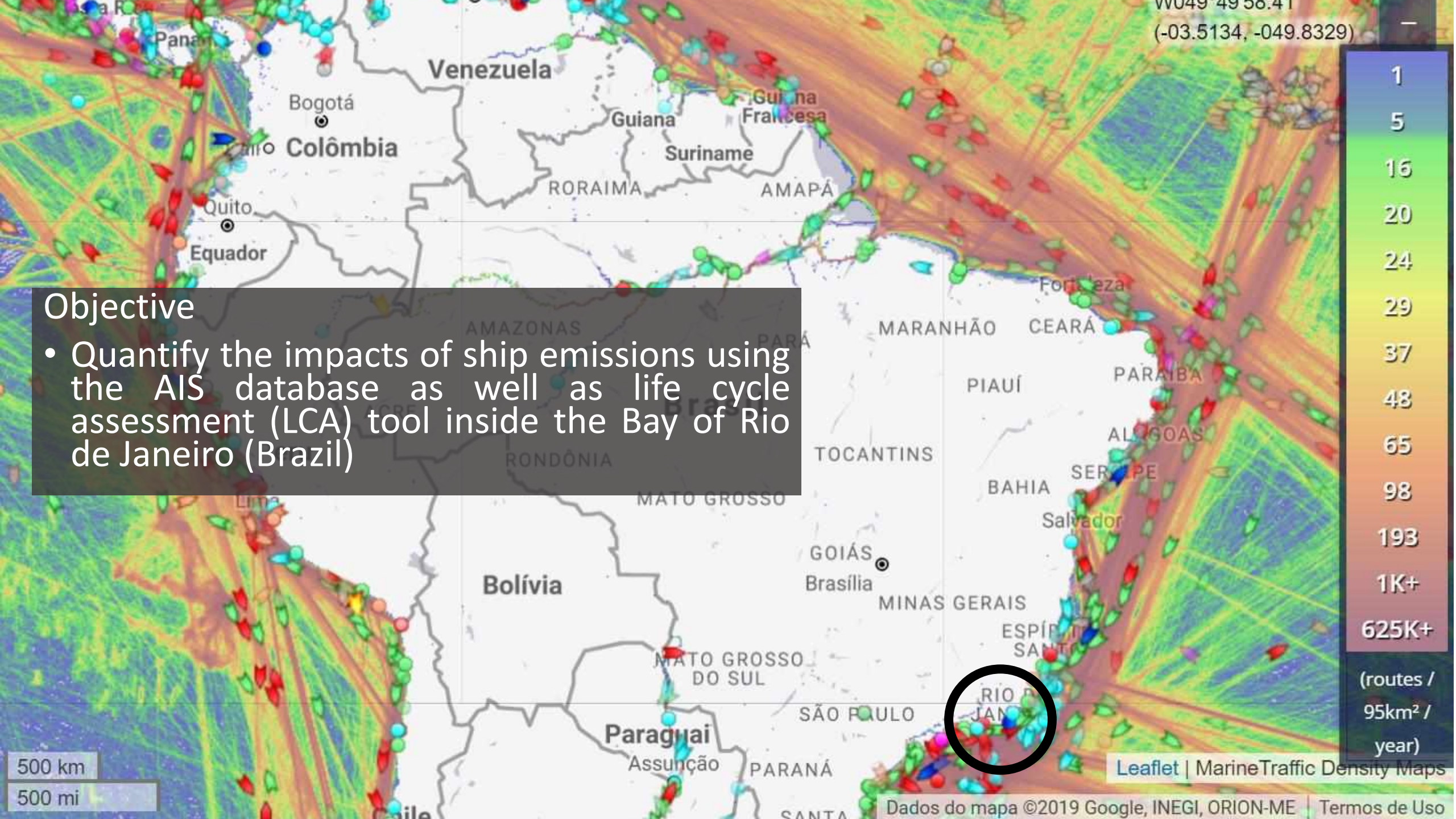
Marine Environment Protection Committee

- MARPOL amendments entered into force on 1 March 2018
- Make mandatory the data collection system for fuel oil consumption of ships
- Require data collection to start from 1 January 2019 for ship above 5000 GT



Objective

- Quantify the impacts of ship emissions using the AIS database as well as life cycle assessment (LCA) tool inside the Bay of Rio de Janeiro (Brazil)





These data are consumed instantaneously by the ship and are generally not stored excepted for VTS

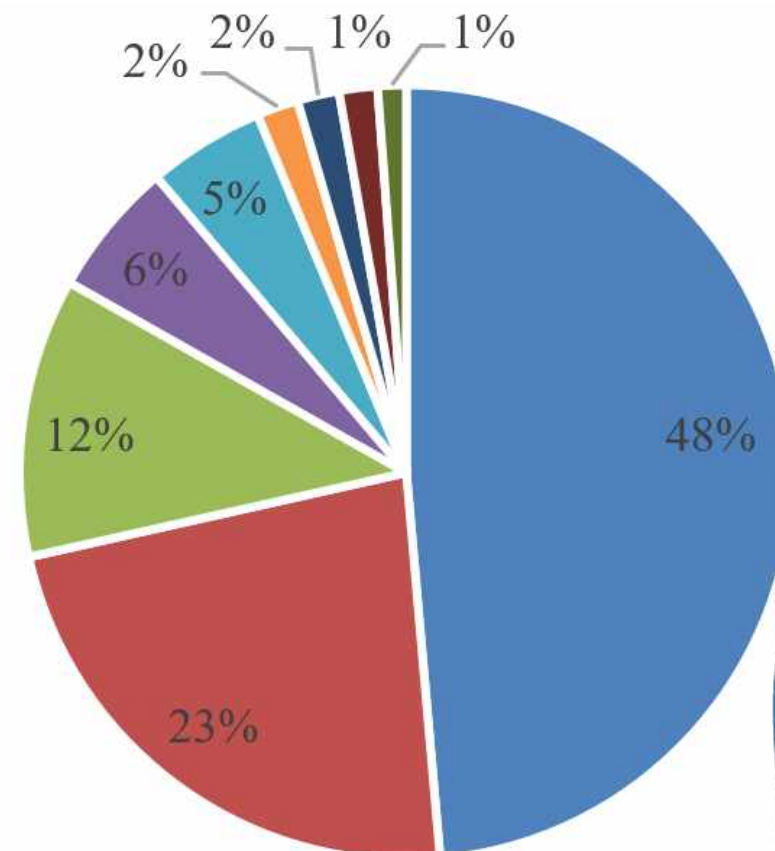
Case Study



- **Transponder in each ship over 300GT**
 - 2002 IMO SOLAS Agreement
- **VHF frequency**
 - Channel A 161.975 MHz – Big ships (**Actual Study**)
 - ~~Channel B 162.025 MHz – Small ships~~

- 1432 vessels studied

■ Cargo ■ Others ■ Tanker
■ Cargo, Hazardous category A
■ Tug ■ Passenger ■ Military
■ Fishing ■ Sailing



Case Study



Big Data collection - Hardware of our base station

1. VHF antenna - 162Mhz
2. VHF Filter and VHF Amplifier
3. VHF Reducer
4. Receiver
5. Raspberry Pi 3
6. Ethernet → AIS messages

UFRJ-COPPE

Range

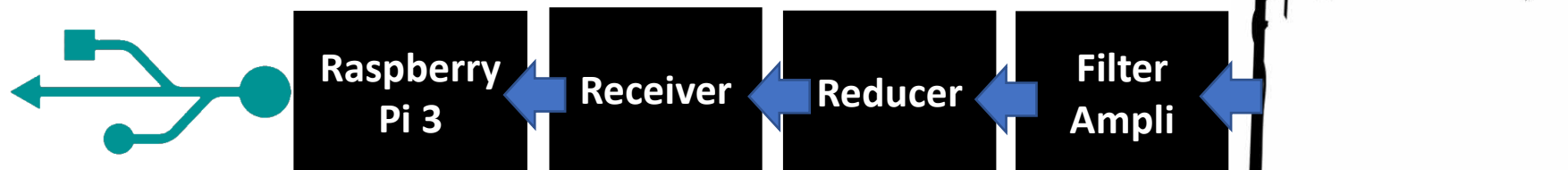
Average: 11 NM = 20 km

Max: 74.5 NM = 137 km

Messages

Average: 395/minute

~ 60 million messages
records in 4 months



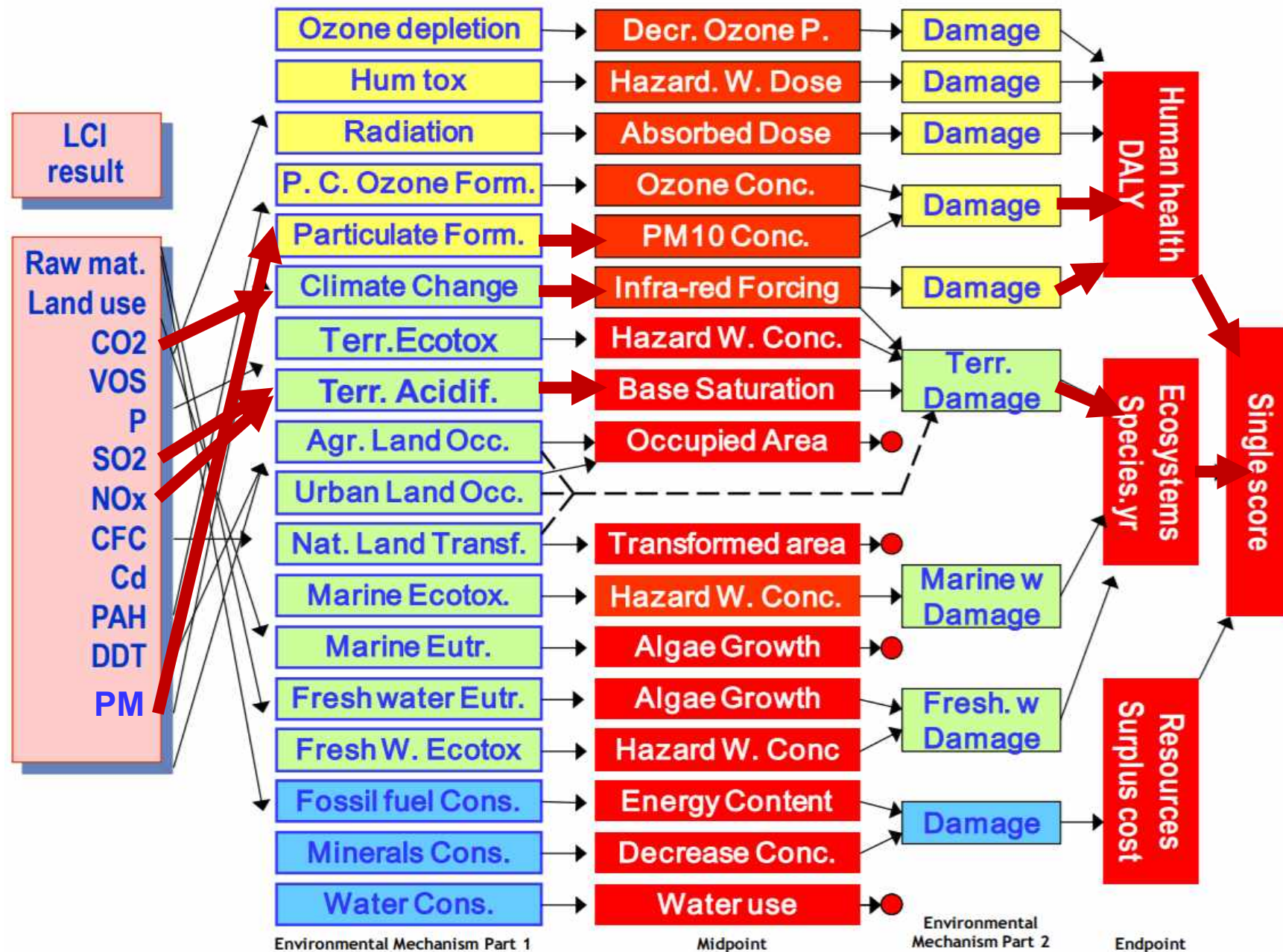
Case Study



- The environmental impacts and related aspects were evaluated through life cycle assessment (LCA): a quantitative method to assess the environmental performance throughout the entire life cycle of a product. In practical terms, the life cycle of a ship is composed of ship production, ship operation, and ship end of life
- In this study, the evaluation of environmental impact is in the operational phase of the cycle
- The **ReCiPe method** has been used including hierarchic, egalitarian and individualist perspectives, with the aim of identifying potential distortions in the LCA results that may ultimately affect the evaluation of the environmental impact



Life Cycle Impact



Quantifying the impact of the emissions is much more complex ...

- CO₂, SO₂, NO_x, PM₁₀, and PM_{2.5} emissions has been calculated between two report positions of each vessel

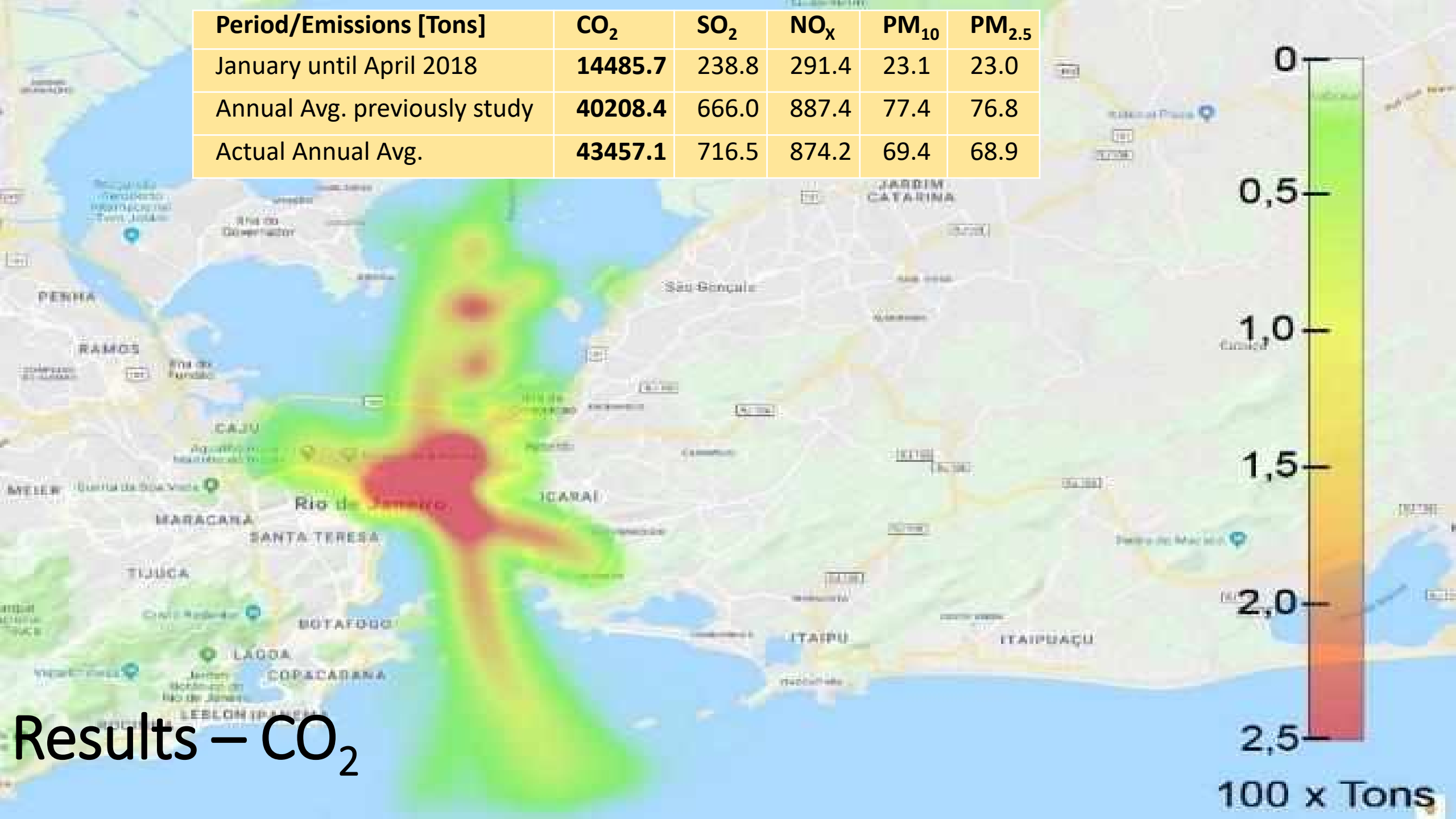
$$E_{i,j,k,l} = P_j \times LF_{j,l} \times T_{j,k,l} \times EF_{i,j,k} / 10^6$$

$$LF_{j,l} = (AS / MS)^3$$

$E_{i,j,k,l}$	Total emission of pollute i from engine j using fuel type k during operation mode l (tons)
P_j	Installed power for engines j (kW)
$LF_{j,l}$	Load factor for engine j during operation mode l (%)
$T_{j,k,l}$	Operating time for engine type j , using fuel type k during operation mode l (h)
$EF_{i,j,k}$	Emission factor for pollute i from engine j using fuel type k (g/kWh)
AS	Actual Speed (knots)
MS	Maximum Speed (knots)

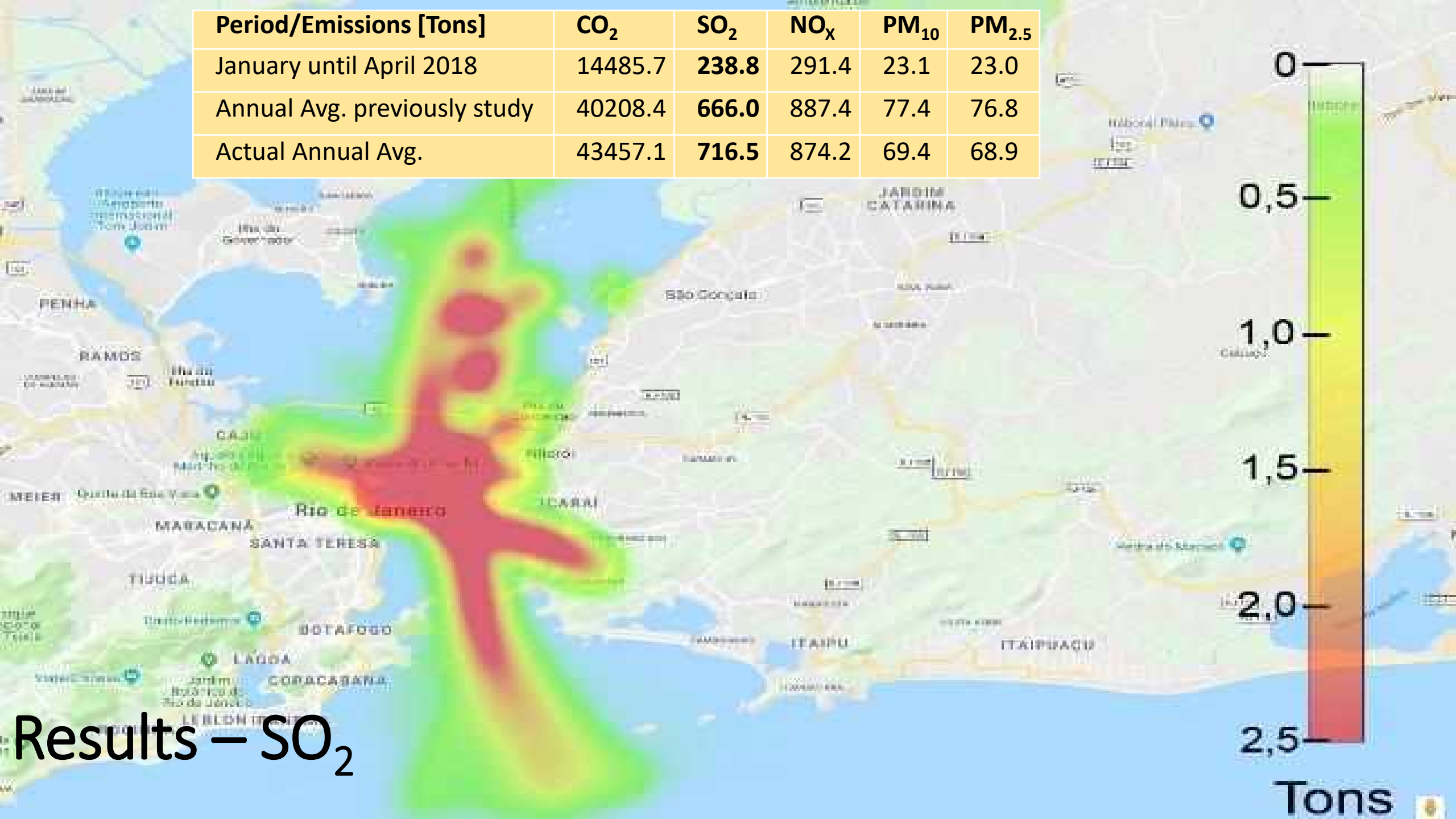
Emission factors might be encountered in the references

Period/Emissions [Tons]	CO ₂	SO ₂	NO _x	PM ₁₀	PM _{2.5}
January until April 2018	14485.7	238.8	291.4	23.1	23.0
Annual Avg. previously study	40208.4	666.0	887.4	77.4	76.8
Actual Annual Avg.	43457.1	716.5	874.2	69.4	68.9



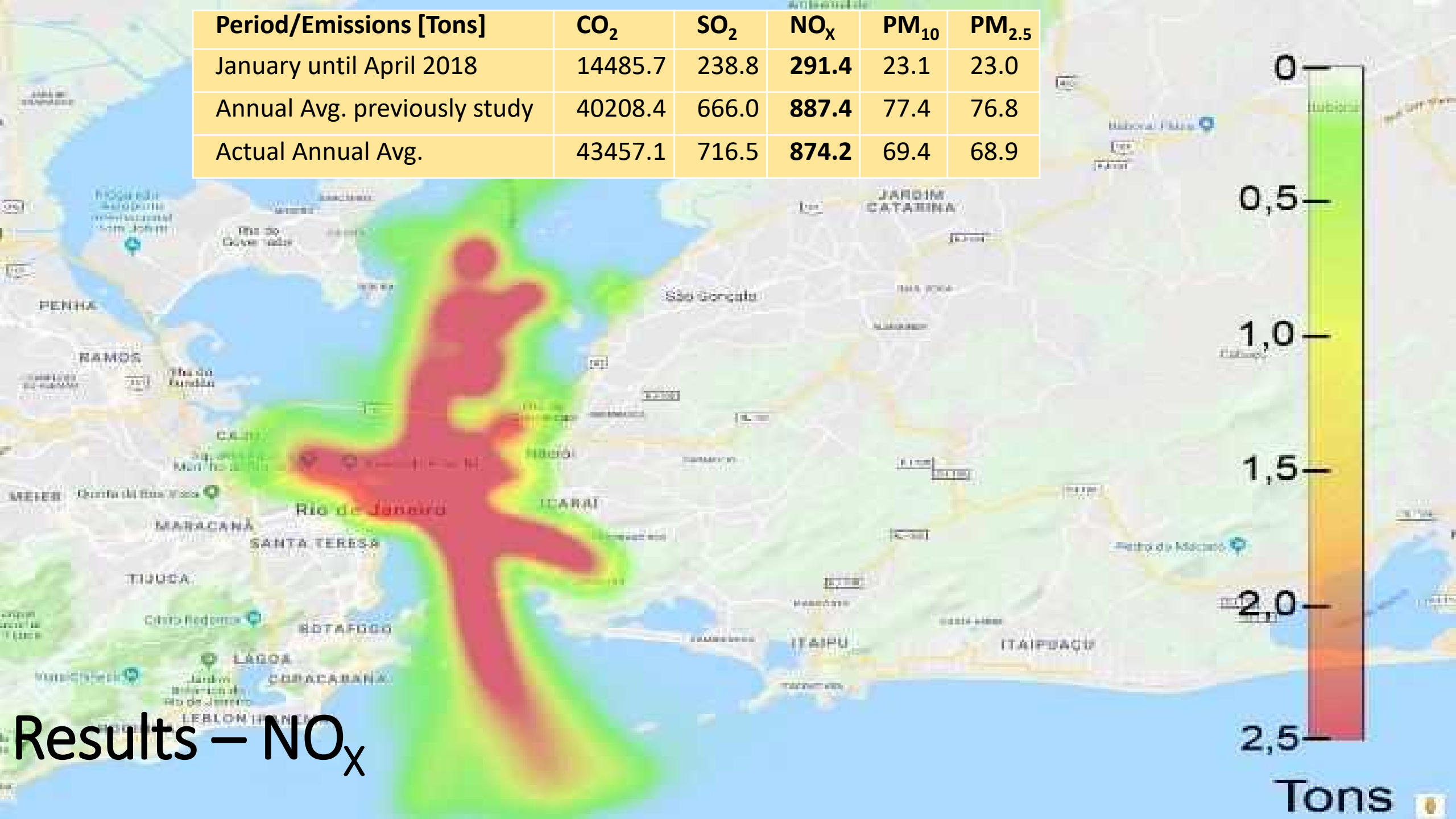
Results – CO₂

Period/Emissions [Tons]	CO ₂	SO ₂	NO _x	PM ₁₀	PM _{2.5}
January until April 2018	14485.7	238.8	291.4	23.1	23.0
Annual Avg. previously study	40208.4	666.0	887.4	77.4	76.8
Actual Annual Avg.	43457.1	716.5	874.2	69.4	68.9



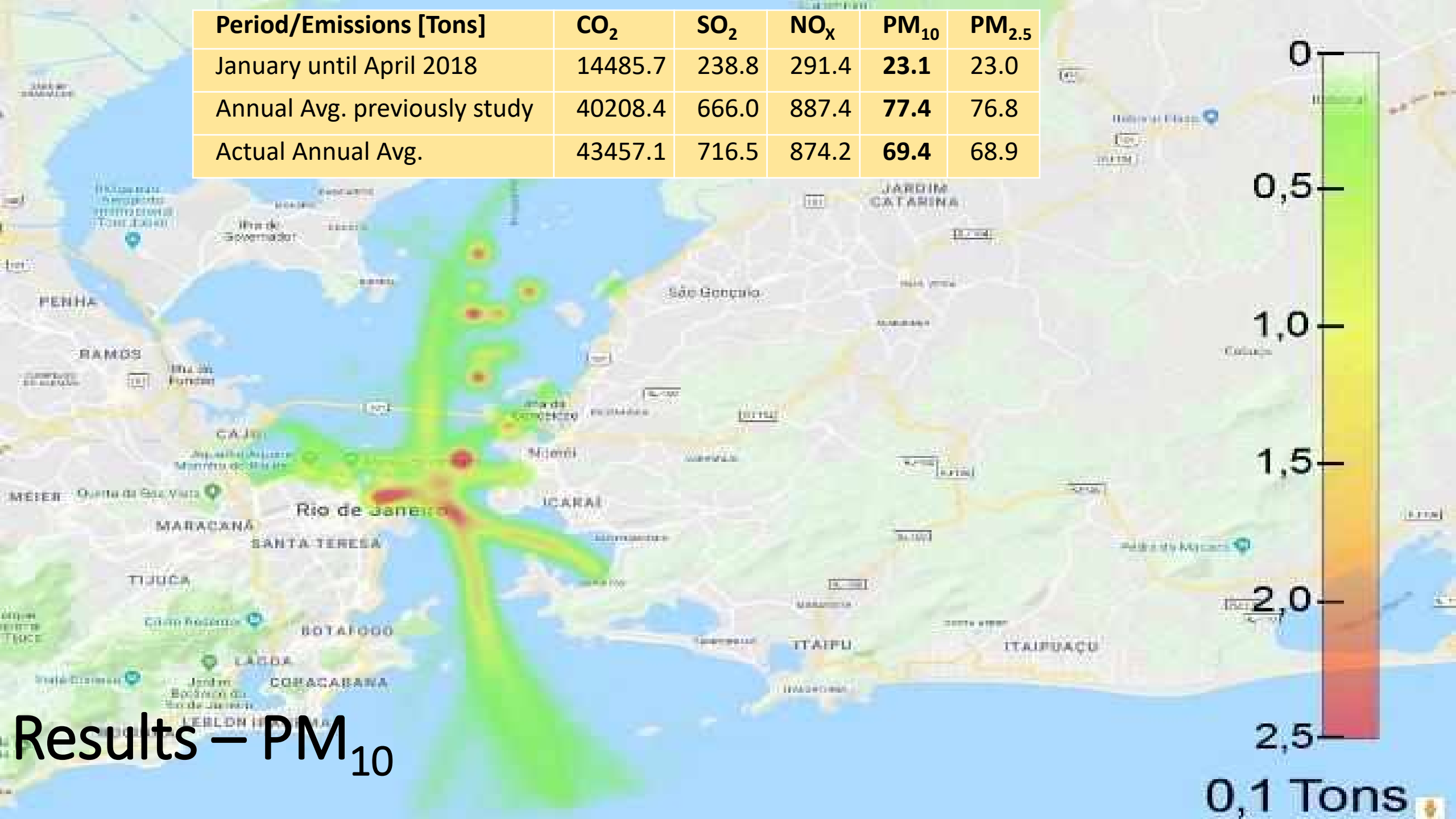
Results – SO₂

Period/Emissions [Tons]	CO ₂	SO ₂	NO _x	PM ₁₀	PM _{2.5}
January until April 2018	14485.7	238.8	291.4	23.1	23.0
Annual Avg. previously study	40208.4	666.0	887.4	77.4	76.8
Actual Annual Avg.	43457.1	716.5	874.2	69.4	68.9



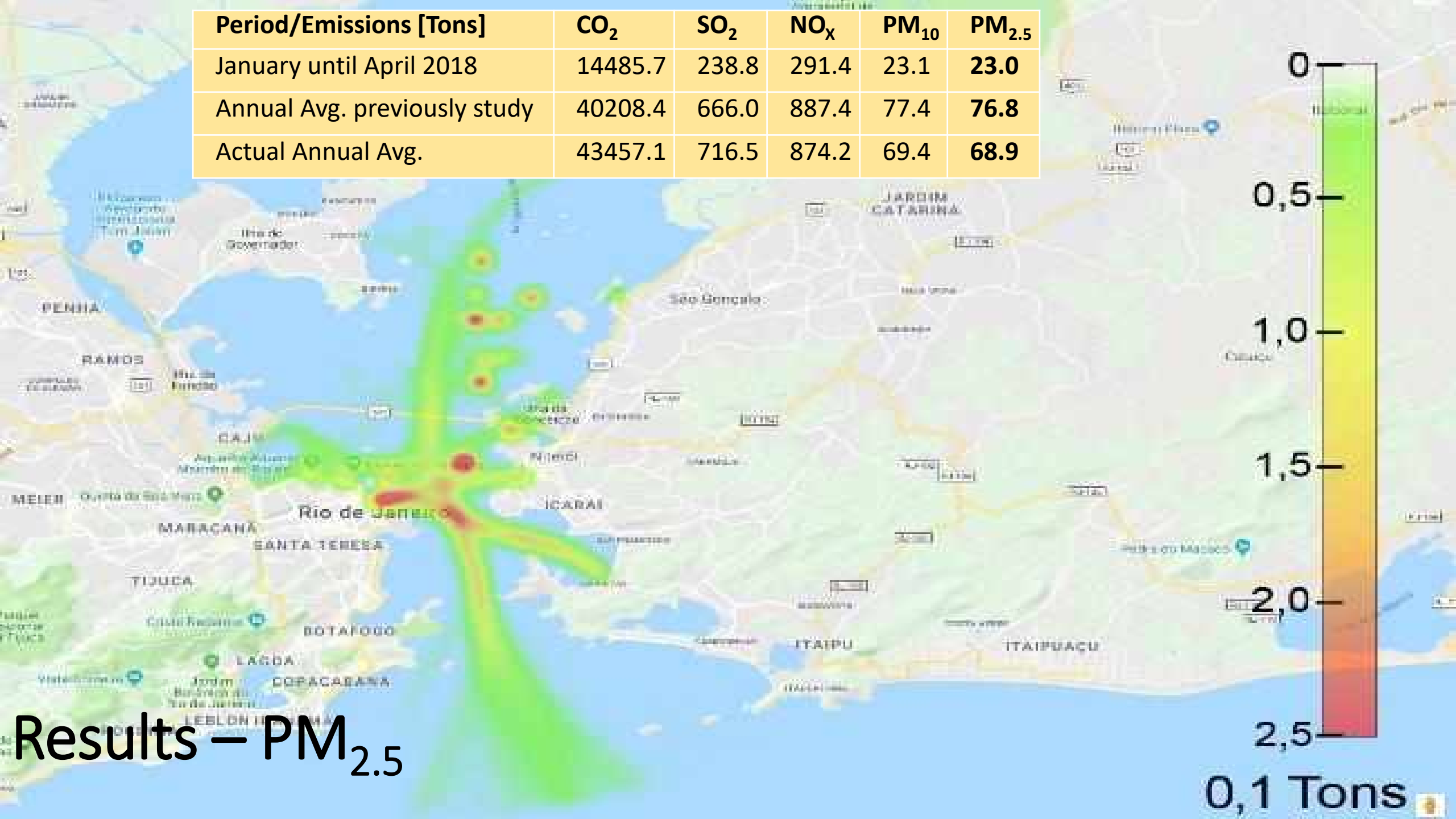
Results – NO_x

Period/Emissions [Tons]	CO ₂	SO ₂	NO _x	PM ₁₀	PM _{2.5}
January until April 2018	14485.7	238.8	291.4	23.1	23.0
Annual Avg. previously study	40208.4	666.0	887.4	77.4	76.8
Actual Annual Avg.	43457.1	716.5	874.2	69.4	68.9



Results – PM₁₀

Period/Emissions [Tons]	CO ₂	SO ₂	NO _x	PM ₁₀	PM _{2.5}
January until April 2018	14485.7	238.8	291.4	23.1	23.0
Annual Avg. previously study	40208.4	666.0	887.4	77.4	76.8
Actual Annual Avg.	43457.1	716.5	874.2	69.4	68.9



Results – PM_{2.5}

Results



- Total estimated emissions from ships for January until April 2018 as well as an estimation of the annual average are calculated
- The life cycle impact assessment (LCIA) was calculated using the factors of characterization and normalization available in the LCA-ReCiPe website (rivm.nl/en/life-cycle-assessment-lca/recipe), based on the total emissions estimated
- Of all the 18 mid-points, only 6 were directly affect by the considered pollutants, and only 2 of the 3 end-points. Each pollute contribute in at least one of these mid-points and were converted to the equivalent unit when necessary, following the ReCiPe's factors



Results



- The resultant impact in Human health is measured in DALY (Disability-Adjusted Life Year), which is a measure of overall disease burden, expressed as the cumulative number of years lost due to ill-health, disability or early death. In short, the DALY sum up the years lived with disability and the years of life lost. Moreover, the DALY is an established term in medical world
- The resultant impact in ecosystem diversity, it's on the other hand measured in species loss per year



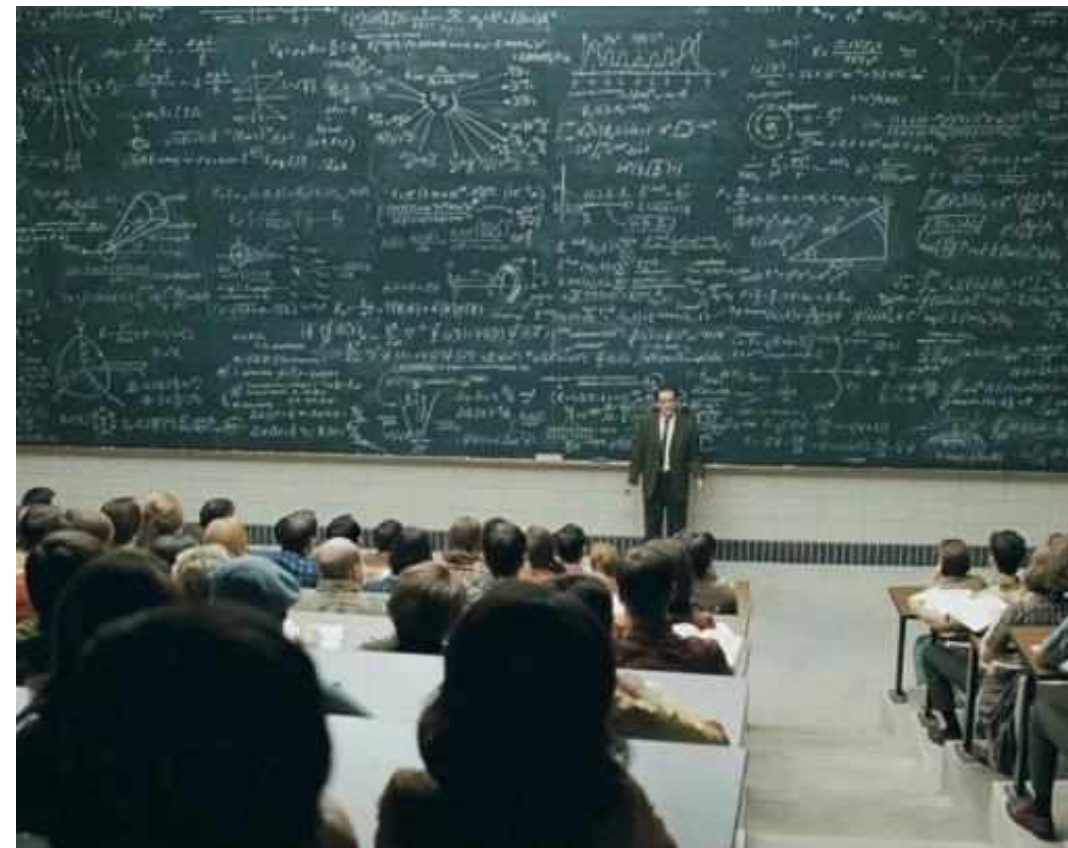
Life cycle impact assessment (LCIA) of actual annual average emission due to marine traffic in Rio de Janeiro

Endpoint	Midpoint	Individualist	Hierarchist	Egalitarian	Unit
Human health	Global Warming	1,2	13,4	181,1	DALY
	Fine particulate matter formation	14,4	78,2	78,2	
	Photochemical ozone formation	0,3	0,3	0,3	
Ecosystem diversity	Global Warming	7,7E-03	4,1E-02	3,6E-01	Species lost per year
	Photochemical ozone formation	3,77E-02	3,77E-02	3,77E-02	
	Acidification	7,29E-02	7,29E-02	7,29E-02	

Conclusions



- Controlling the ship emission is becoming a huge challenge and constraint for the marine sector
- AIS data might be used for other purpose that the originally purpose designed for (marine safety)
- Big Data might fasten considerably the querying of the recorded AIS data
- We succeeded to assess the ship emission starting from a 4 months AIS DB - more effective than the previous study



Conclusions



- The implementation of estimation of life cycle impact assessment is an accomplished achievement quantifying the environmental impact and damages to human health (HH) as well as damages to ecosystem diversity (ED)
- The biggest impact is in HH endpoint in Global Warming and Fine particulate matter formation, the first one is due to the CO_2 emissions, and the last one is due to the $\text{PM}_{2.5}$ emissions. Therefore, these two emissions should be prioritized in the future
- Next step is to scale up to the entire world fleet



Thank you!

Prof. Luiz Felipe Assis

felipe@oceanica.ufrj.br

Maricruz A. Fun Sang Cepeda - maricruzcepeda@oceanica.ufrj.br

Jean-David Caprace - jdcaprace@oceanica.ufrj.br

<http://www.oceanica.ufrj.br/labsen/>



COPPE
UFRJ

Instituto Alberto Luiz Coimbra de
Pós-Graduação e Pesquisa de Engenharia





Colombia
mar 2019