International conference
Reducing air pollution from ships in the Mediterranean Sea
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# Impact of maritime transport emissions on coastal air quality in Europe

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# Outline

1. Impact of international shipping on European air quality
   - Tracers and physico-chemical characteristics
   - Impact on ambient PM and on gaseous pollutants

2. Mitigation strategies:
   - Environmental and health benefits from ECAs: case study

3. Conclusions

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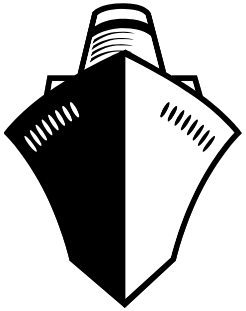
# Rationale

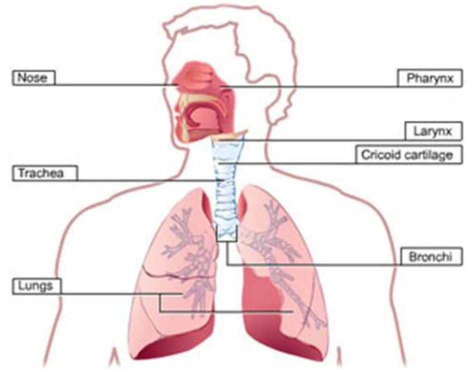
Emissions from the marine transport sector contribute **significantly** to air pollution globally



**Increasing emission source**:

- Globalization of manufacturing processes
- Increase of global-scale trade
- Relatively, large efforts to reduce other sources (industrial, power generation, etc.)
- More future growth expected

**Human health**




**Climate**

**Ecosystems**

# How much of a problem?

- Different approaches used in different countries
- Not yet achieved the goals for protecting human health

Literature Review

# Chemical tracers

Well-known **tracers** of combustion based on crude oil:

- V and Ni (>60 publications)
- Others: La, Th, Pb, Zn and $SO_4^{2-}$ (>18 publications)

| **Where?** | **PMx** | **V/Ni** | **Reference** |
|---|---|---|---|
| Italy | $PM_{10}$ | 3.2±0.8 | Mazzei et al. (2008) |
| | $PM_{2.5}$ | 3.2±0.8 | Mazzei et al. (2008) |
| | $PM_{10}$ | 3.2±0.8 | Mazzei et al. (2008) |
| Ship engine | | 2.3-4.5 | Agrawal et al. (2008) |
| Spain | $PM_{2.5}$ | 4-5 | Viana et al. (2009) |
| | $PM_{10}$ | 4-5 | Viana et al. (2009) |
| Spain | $PM_{10}$ | 3 | Pandolfi et al. (2011) |
| | $PM_{2.5}$ | 3 | Pandolfi et al. (2011) |
| Europe | $PM_{10}$ | 3-4 | Viana et al. (2014) |
| Europe | $PM_{2.5}$ | 3-4 | Viana et al. (2014) |
| Europe | $PM_{10}$ | 2.3-2.5 | Alastuey et al. (2016) |

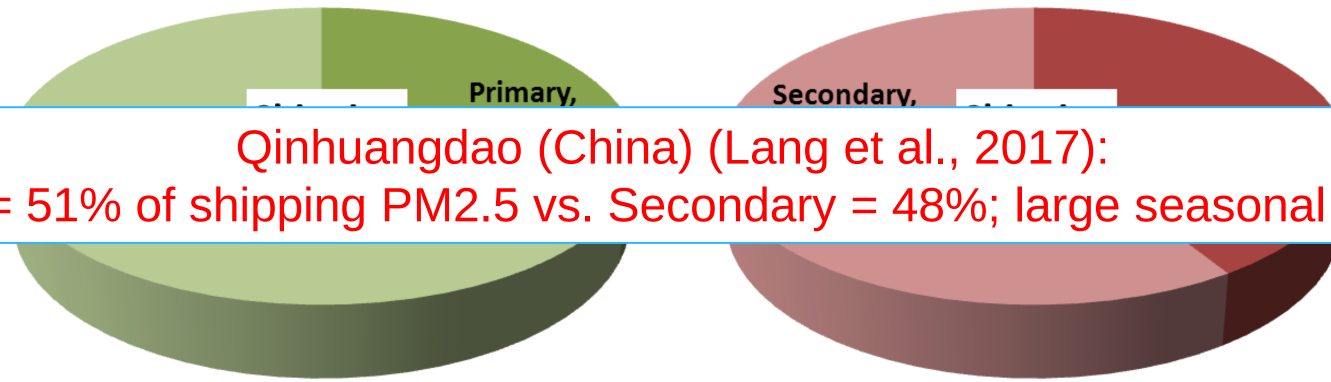
| **Where?** | **PMx** | **Tracer** | **Value** | **Reference** |
|---|---|---|---|---|
| Spain | $PM_{10}$ | V/EC | <2 | Viana et al. (2009) |
| | $PM_{2.5}$ | V/EC | <2 | Viana et al. (2009) |
| Spain | $PM_{10}$ | La/Ce | 0.6-0.8 | Pandolfi et al. (2011) |
| | $PM_{2.5}$ | La/Ce | 0.6-0.8 | Pandolfi et al. (2011) |
| Italy | $PM_{10}$ | soluble V | 80% | Becagli et al. (2012) |
| | $PM_{10}$ | soluble V | >6 ng/$m^3$ | Becagli et al. (2012) |
| | $PM_{10}$ | soluble Ni | 80% | Becagli et al. (2012) |
| | $PM_{10}$ | non-ss $SO_4^{2-}$/V | 200-400 | Becagli et al. (2012) |

Tracers are available, BUT:

**changing fuels result in changing tracers**

# Primary *vs*. Secondary particles

In Southern-Europe:




Qinhuangdao (China) (Lang et al., 2017):
Primary = 51% of shipping PM2.5 vs. Secondary = 48%; large seasonal variability

*Viana et al. (2014)*

Premature deaths/year in Europe:

due to primary particles
(301.000/year)

due to secondary particles
(245.000/year)

**More efficient for health to decrease primary PM emissions?**

*Andersson et al. (2009); Hammingh et al. (2012); Tian et al. (2013); Lang et al. (2017)*

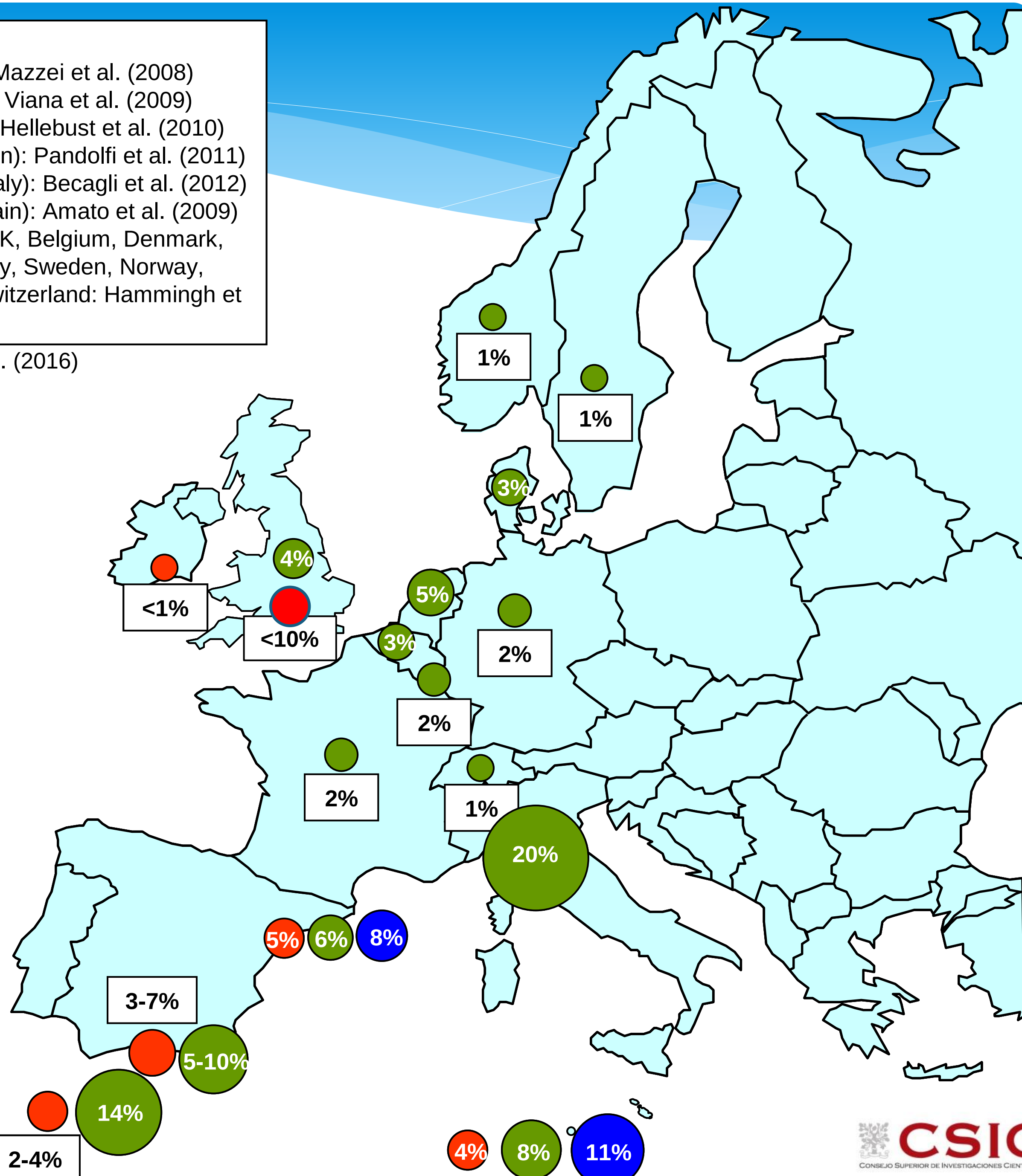
**References**:
- Genoa (Italy): Mazzei et al. (2008)
- Melilla (Spain): Viana et al. (2009)
- Cork (Ireland): Hellebust et al. (2010)
- Algeciras (Spain): Pandolfi et al. (2011)
- Lampedusa (Italy): Becagli et al. (2012)
- Barcelona (Spain): Amato et al. (2009)
- Netherlands, UK, Belgium, Denmark, France, Germany, Sweden, Norway, Luxembourg, Switzerland: Hammingh et al. (2012)

- UK: Hadley et al. (2016)

**1-7% $PM_{10}$**
**1-20% $PM_{2.5}$**
**8-11% $PM_1$**

## Comparability?

$PM_{10}$
$PM_{2.5}$
$PM_1$




13-17% $PM_{2.5}$ in China
Shanghai; Pearl River Delta
*Zhao et al. (2013); Tao et al. (2017)*

10-70% PM2.5 in Western USA, Seattle
*Hadley (2017)*

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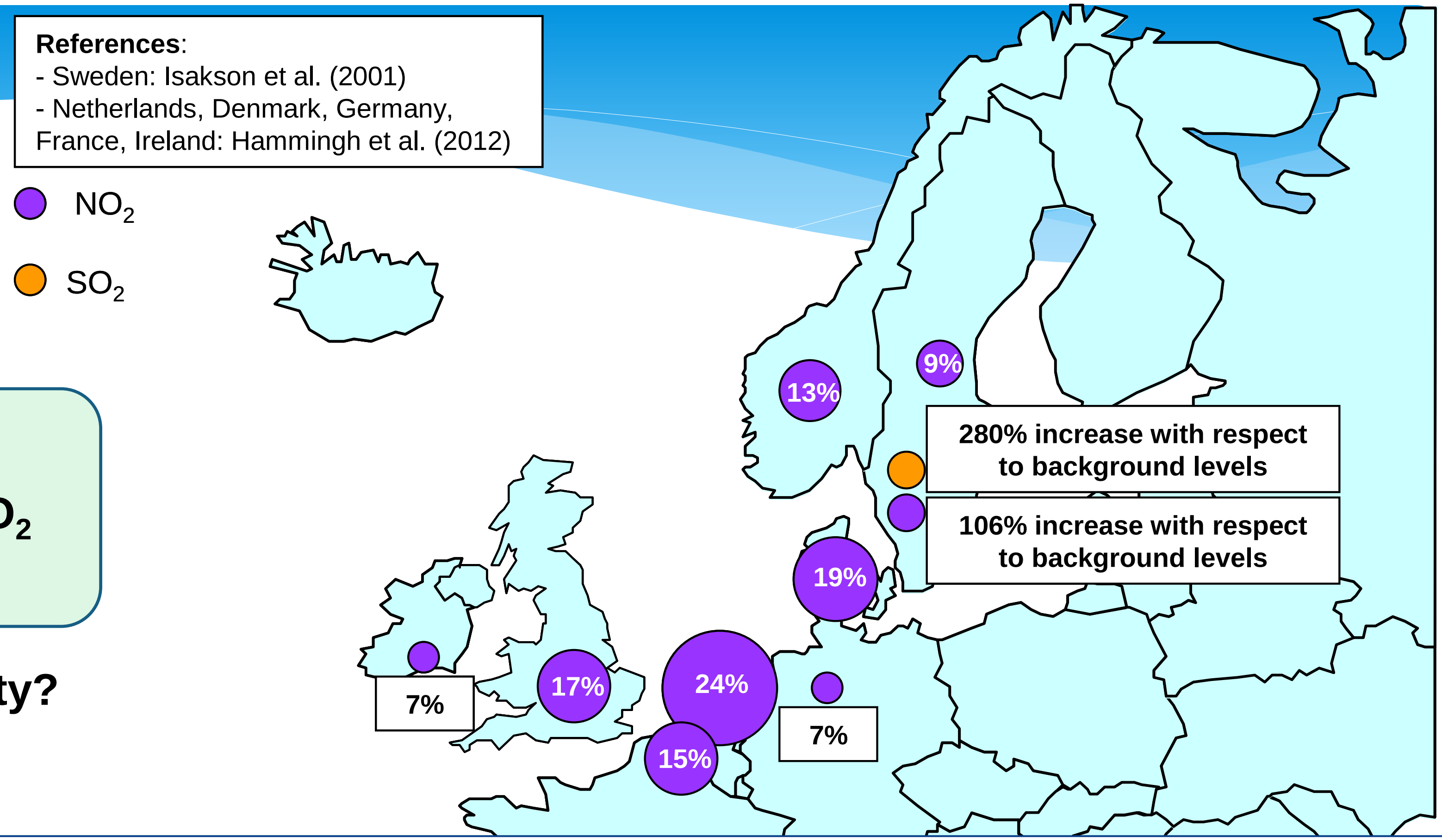



**7-24% $NO_2$**

**Comparability?**

Contributions to gases (NO, $NO_2$, $SO_2$) > PM, N

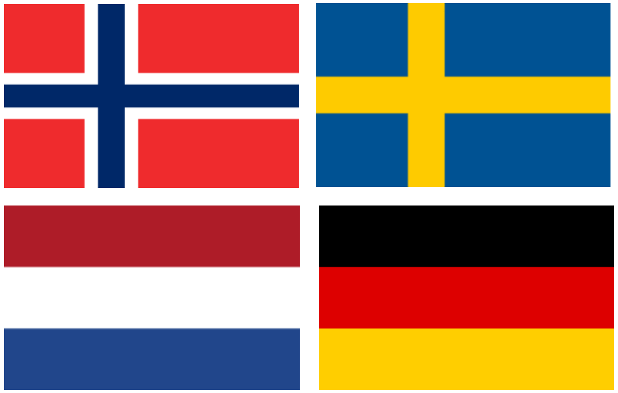
Hotelling: contribution to $SO_2$ < NO & $NO_2$ due to low-S fuels at berth

Contribution to NO >> $NO_2$ and provoked local-scale depletion of $O_3$

*Merico et al. (2016)*

# Mitigation strategies

**IMO (UN), MARPOL, SECAs, NECAs**



**National regulations**

**EU Directive 2005/33/EC on sulphur emissions from ships**

**Technological measures**:

- low sulphur fuels
- sulphur scrubbers
- NOx mitigation measures
- liquid natural gas (LNG)
- slow steaming
- soot particle filters…

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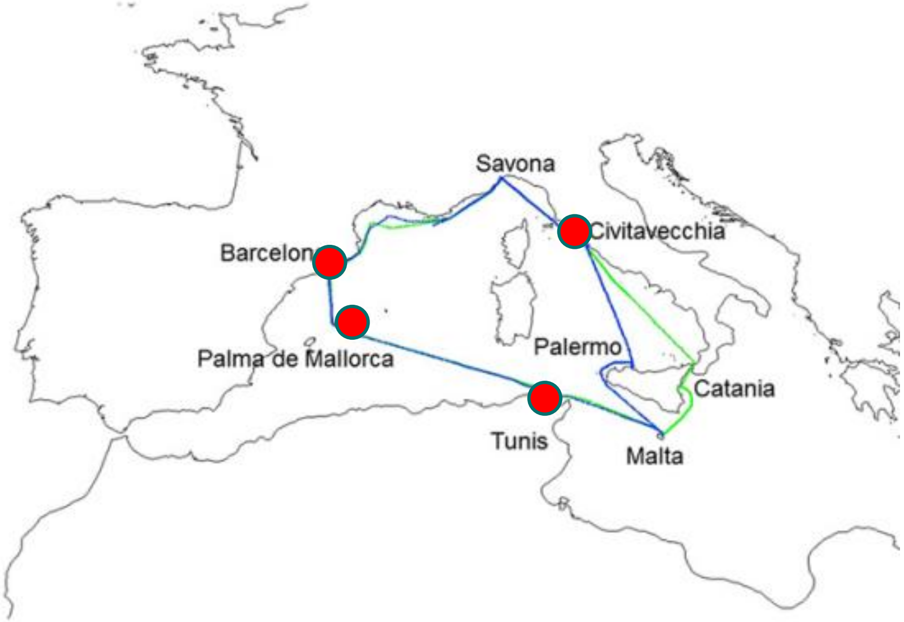
# Mitigation strategies

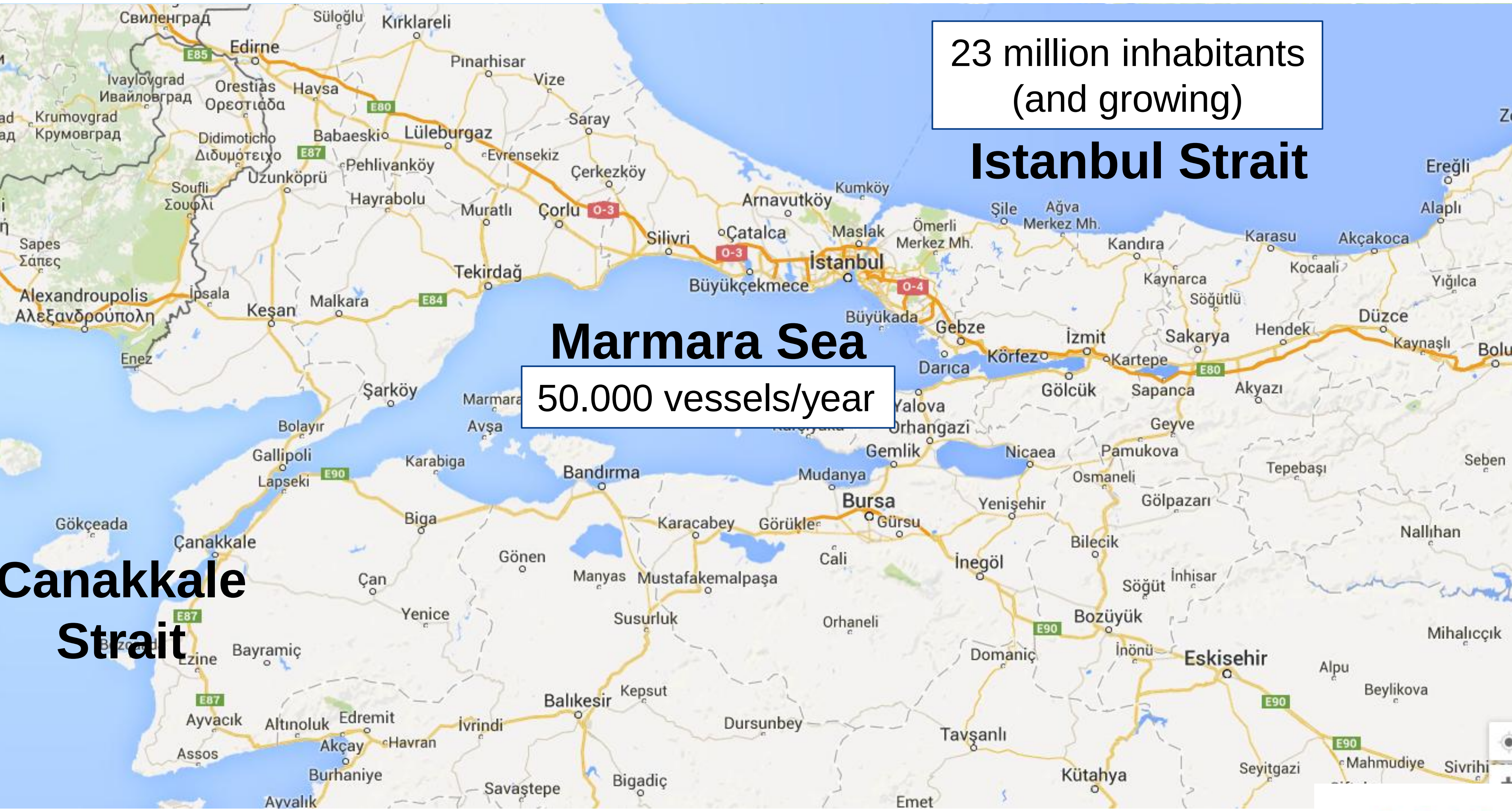
**Directive 2005/33/EC**:

- $SO_2$ concentrations in 3 out of 4 harbours decreased (>2010)
- No decrease was observed in Tunis
- Average decrease $SO_2$ = 66% (daily)
- No significant changes for NOx & BC

*Schembari et al. (2012)*

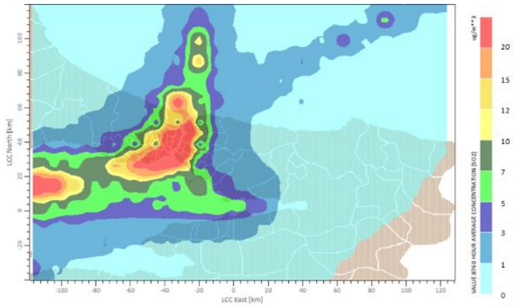


# Case study: ECA in the Marmara Sea

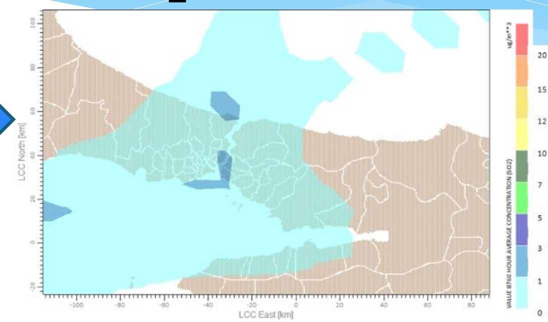


# Environmental benefits

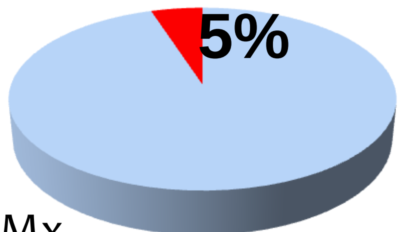
**$SO_2$ before ECA**



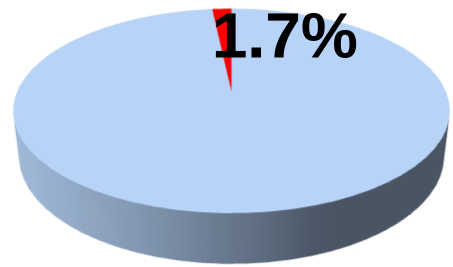
**$SO_2$ after ECA**



**$PM_{2.5}$ before ECA**



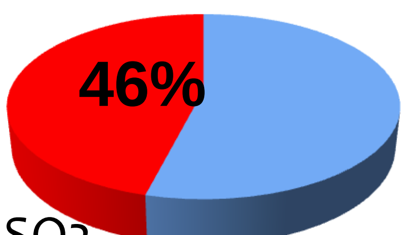

**$PM_{2.5}$ after ECA**



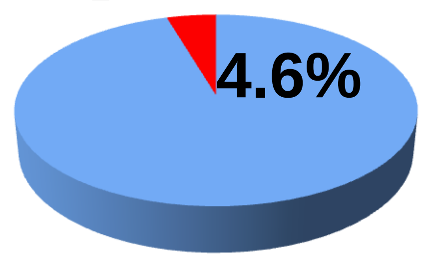

Total PMx

Ship-sourced PMx

**$SO_2$ before ECA**




**$SO_2$ after ECA**




Total SO2

Ship-sourced SO2

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# Health benefits

| | | East domain (90% confidence intervals) | | |
|---|---|---|---|---|
| **Health outcome** | Scenario | **$PM_{10}$** | **$PM_{2.5}$** | **$SO_2$** |
| **Hospital admissions for respiratory diseases (ICD-10 J00-J99)** | Baseline (total burden) | 13,000 (4,900 to 20,000) | 18,000 (6,800 to 20,000) | 1,200 (-830 to 3,200) |
| | Policy scenario (number avoided) | 150 (57 to 230) | 330 (125 to 370) | 180 (-108 to 460) |
| | % Change | -1% | -2% | -14% |
| | | | | |
| **Hospital admissions for circulatory system diseases (ICD-10 I00-I90)** | Baseline (total burden) | 4,300 (770 to 7,800) | 6,000 (1,900 to 9,700) | 1,700 (770 to 2,500) |
| | Policy scenario (number avoided) | 45 (8.1 to 82) | 97 (30 to 160) | 190 (90 to 290) |
| | % Change | -1% | -2% | -12% |
| | | | | |
| **All-cause mortality (ICD-10 A00-R99)** | Baseline (total burden) | 120 (50 to 190) | 670 (140 to 1,000) | 17 (15 to 19) |
| | Policy scenario (number avoided) | 1 (0.4 to 1.6) | 13 (2.7 to 19) | 2 (1.7 to 2.2) |
| | % Change | -1% | -2% | -10% |

*Viana et al. (2015)*

# Health benefits

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**E**

MARINE ENVIRONMENT PROTECTION COMMITTEE
74th session
Agenda item 9

MEPC 74/INF.5
6 February 2019
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**IDENTIFICATION AND PROTEC**

**Technical Feasibility Study for the**
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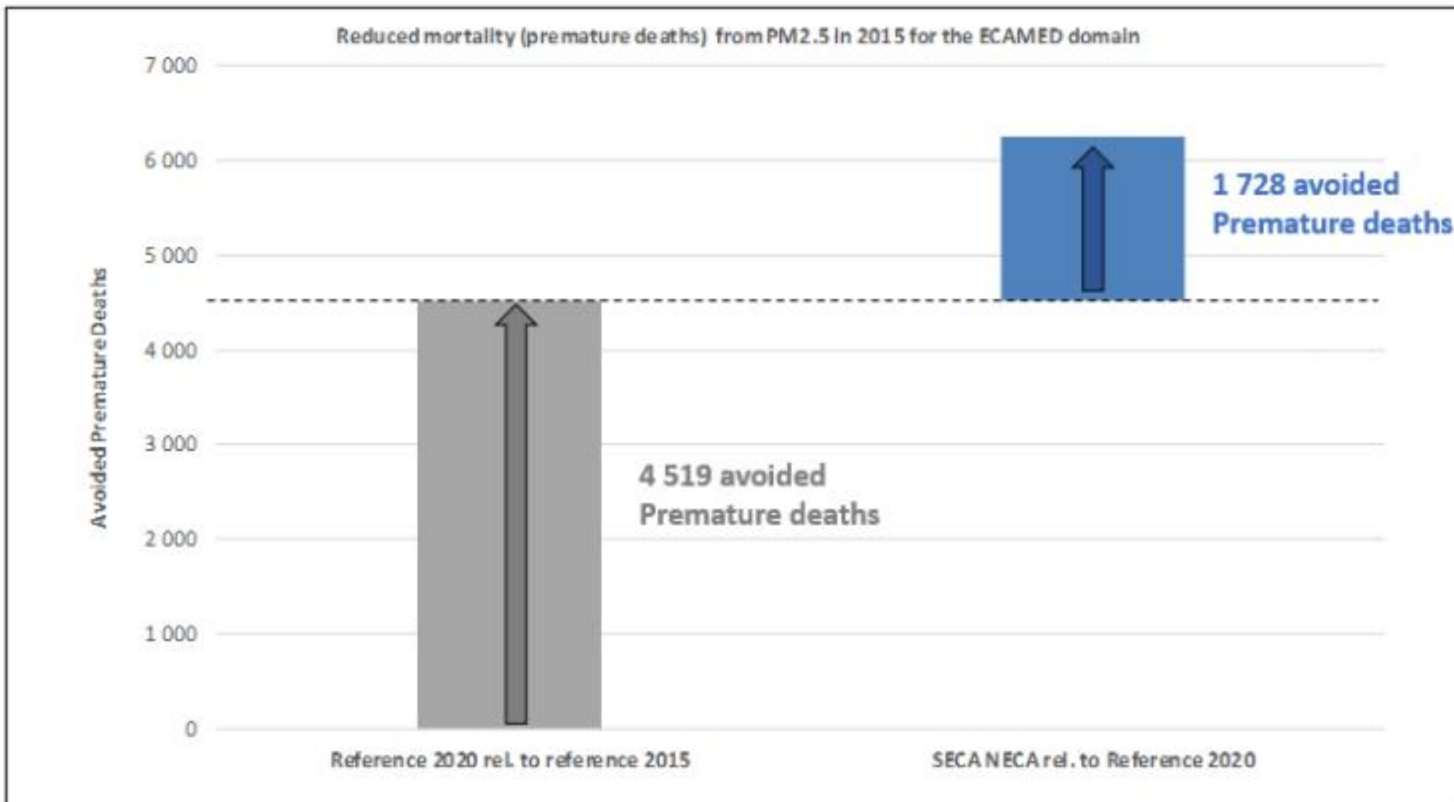


Figure 45 Reduction in $PM_{2.5}$ mortality (premature deaths) - overall ECAMED domain

# Conclusions & knowledge gaps

- What we know:
  - Nr. studies not large, but increasing
  - Contribution to PMx: 1-20% PMx, with large spatial variability

- What we don't know (so well):
  - Is it more efficient to reduce primary or secondary emissions?
  - Impact of harbour operations & how to mitigate them

- Mitigation strategies:
  - Efficient: 50-66% $SO_2$ reduction, and $2^{ary}$ PM

- Environmental and health benefits:
  - Effective reduction of ship-sourced $SO_2$ (46% to 5%, Istanbul)
  - Effective health benefits (12-14% decreased hospital admissions due to $SO_2$ and 10% reduced mortality due to $SO_2$, Istanbul)
  - Similar results for Mediterranean ECA

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# Thank you for your attention

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