# Air quality benefits and their impacts on human health, land ecosystems and eutrophication of the Baltic Sea

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CSHIPP Webinar on International Clean Shipping Policies
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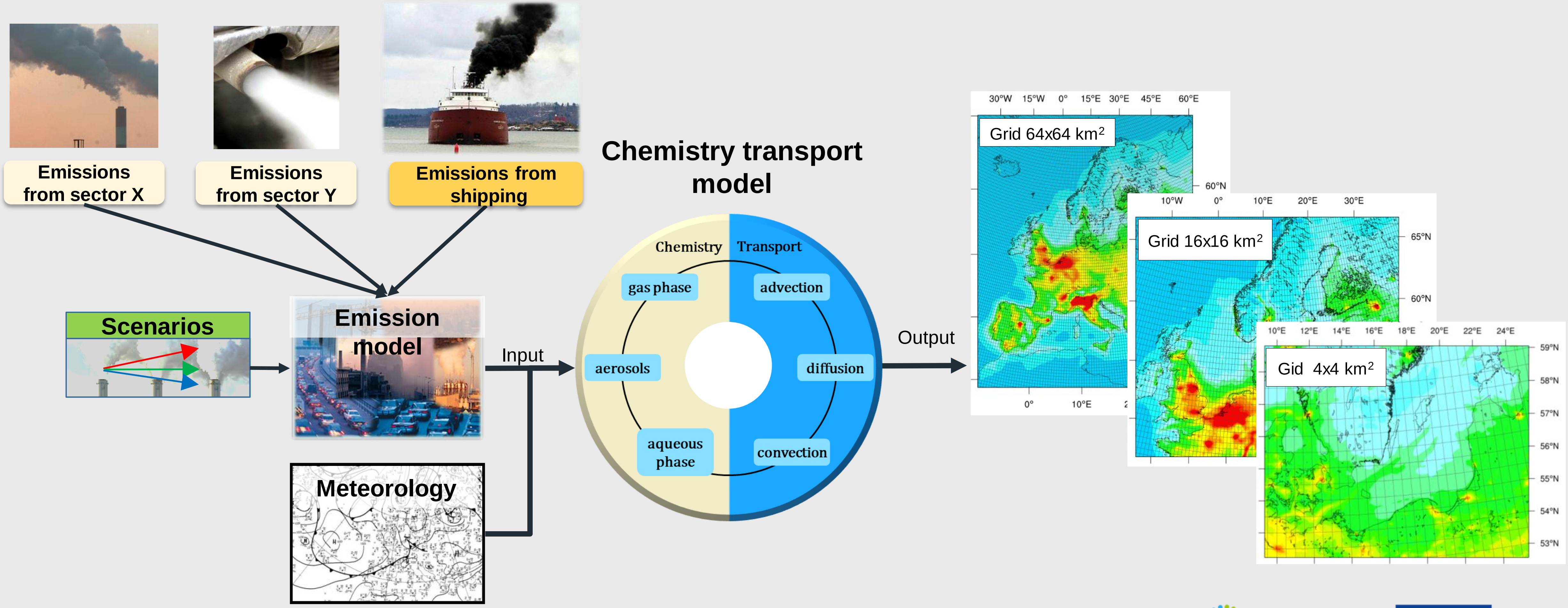
# Chemistry transport modeling

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# Shipping emission scenarios for the Baltic Sea 2040

BAU

- NECA 2021
- Strong efficiency increases

NoNECA

- *No NECA*
- Strong efficiency increases

EEDI

- NECA 2021
- *EEDI efficiency increases*

Emission changes (multiplication factors) compared to the Reference case (2012)

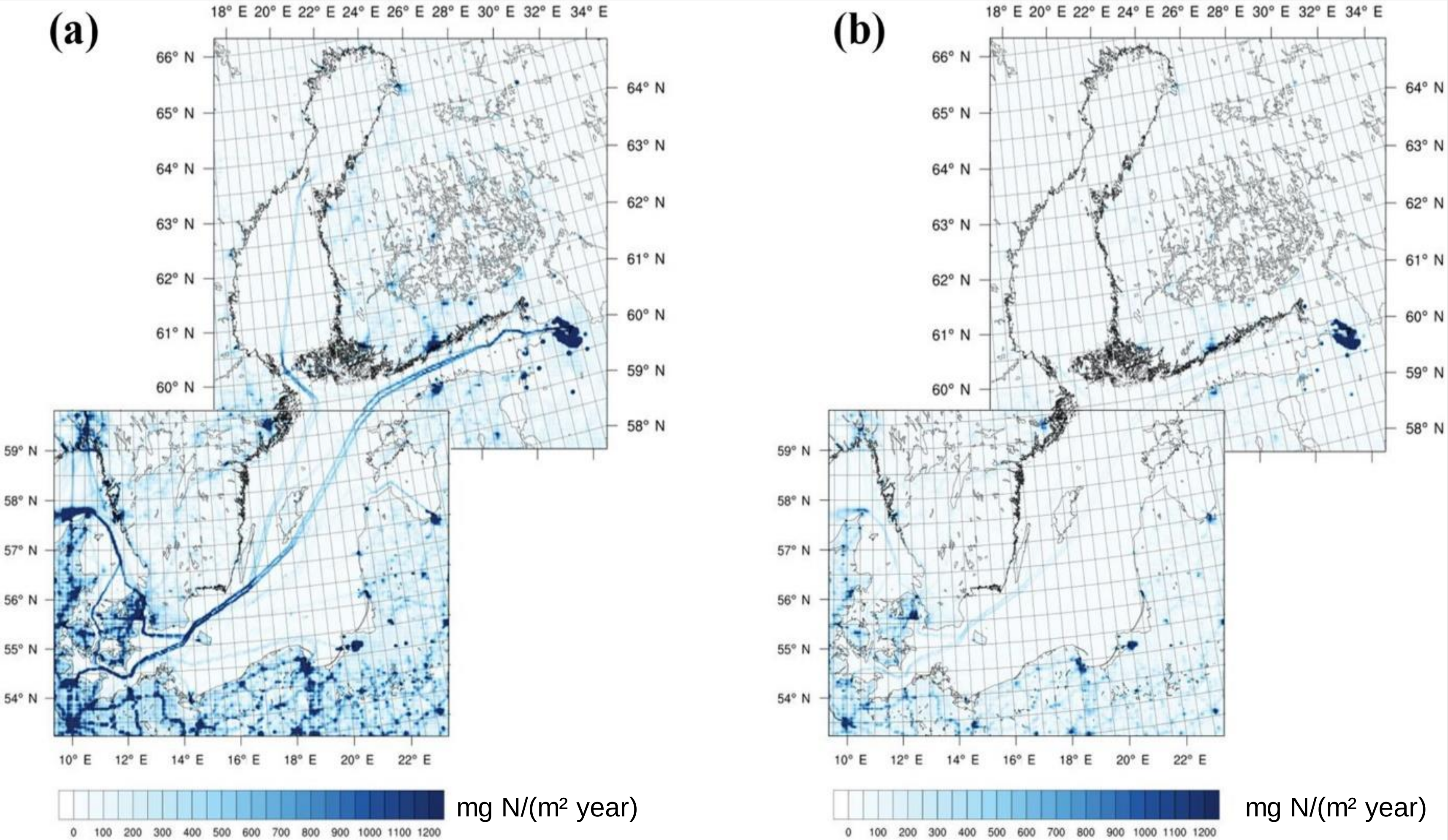
| Scenario | CO | PM-other | $SO_4$ | $SO_x$ | $NO_x$ |
|---|---|---|---|---|---|
| BAU | 0.679 | 0.351 | 0.088 | 0.088 | 0.207 |
| NoNECA | 0.679 | 0.351 | 0.088 | 0.088 | 0.505 |
| EEDI | 0.923 | 0.490 | 0.121 | 0.207 | 0.285 |

Karl et al., Atm. Chem Phys. 19, 1721, 2019

# Emission maps for NOx

2012
Reference case

2040
BAU scenario



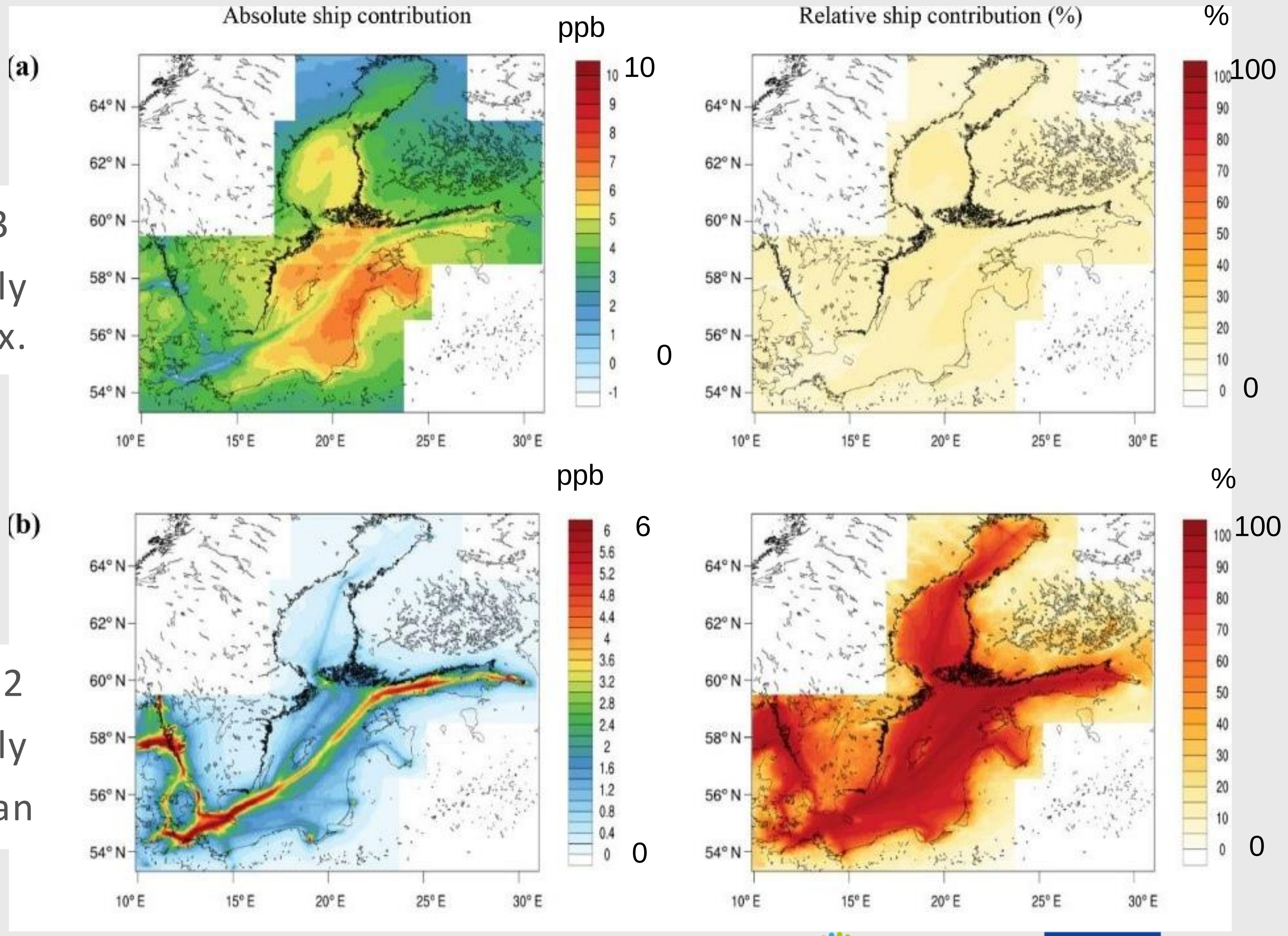

Karl et al., Atm. Chem Phys. 19, 1721, 2019

# Contribution of shipping emissions to $O_3$ and $NO_2$

Summer (JJA) 2012

O3 daily max.

NO2 daily mean




Karl et al., Atm. Chem Phys. 19, 1721, 2019

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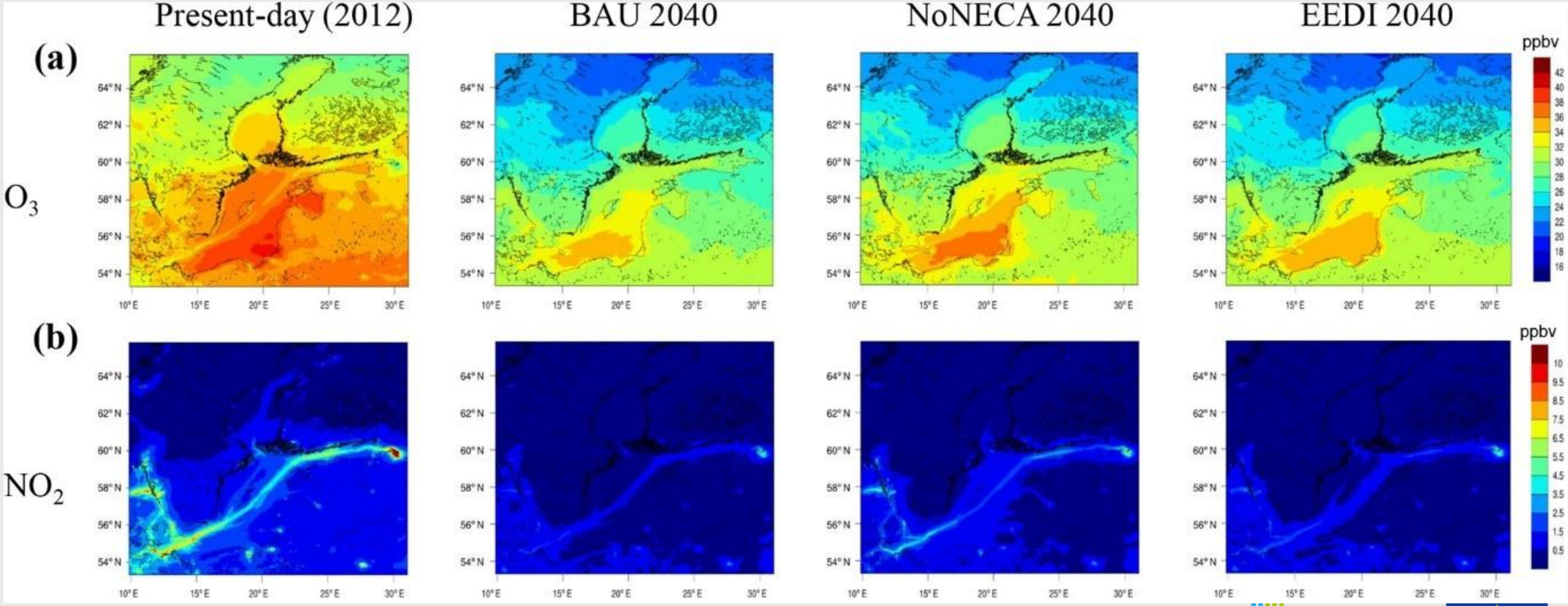
# Contribution of shipping emissions to $O_3$ and $NO_2$

In summer 2012 and for three scenarios




Karl et al., Atm. Chem Phys. 19, 1721, 2019

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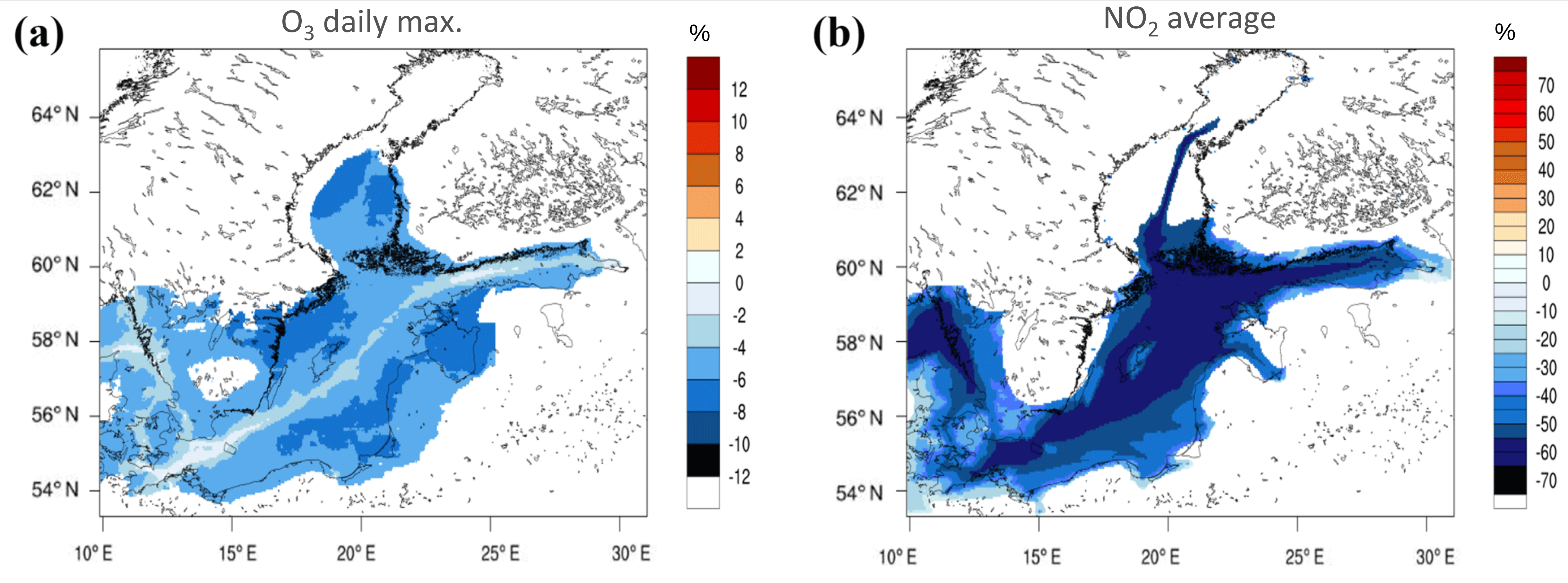
# NECA Effects

Difference between BAU and NoNECA scenario




Karl et al., Atm. Chem Phys. 19, 1721, 2019

# Eutrophication of the Baltic Sea

- Nitrogen is the primary limiting nutrient for phytoplankton in marine ecosystems (Howarth 1998; Howarth and Marino, 2006)
- However, there are thresholds above which additional nitrogen input leads to a degradation of water-quality
  - toxic algal blooms
  - oxygen deficiency
  - loss of habitats and biodiversity
  - decreases in harvestable fish resources
- (see e.g. Rabalais, 2002; Diaz and Rosenberg, 2008; Voss et al., 2011)


*Diaz, R. and R. Rosenberg. 2008. Spreading Dead Zones and Consequences for Marine Ecosystems. Science 321(5891): 926–929.*

*Howarth, R. W. 1998. Nutrient limitation of net primary production in marine ecosystems. Annual Review of Ecology and Systematics, 19:1, 89-110.*

*Howarth, R. W., Marino R., 2006. Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: evolving views over three decades. Limnology and Oceanography, 51:364–376.*

*Rabalais, N.N., 2002. Nitrogen in Aquatic Ecosystems, Ambio, 31(2), 102-112.*

*Voss, M., Baker, A., Bange, H., et al., 2011. Nitrogen processes in coastal and marine ecosystems. In M. Sutton, et al. (Eds.), The European Nitrogen Assessment: Sources, Effects and Policy Perspectives (pp. 147-176). Cambridge: Cambridge University Press.*



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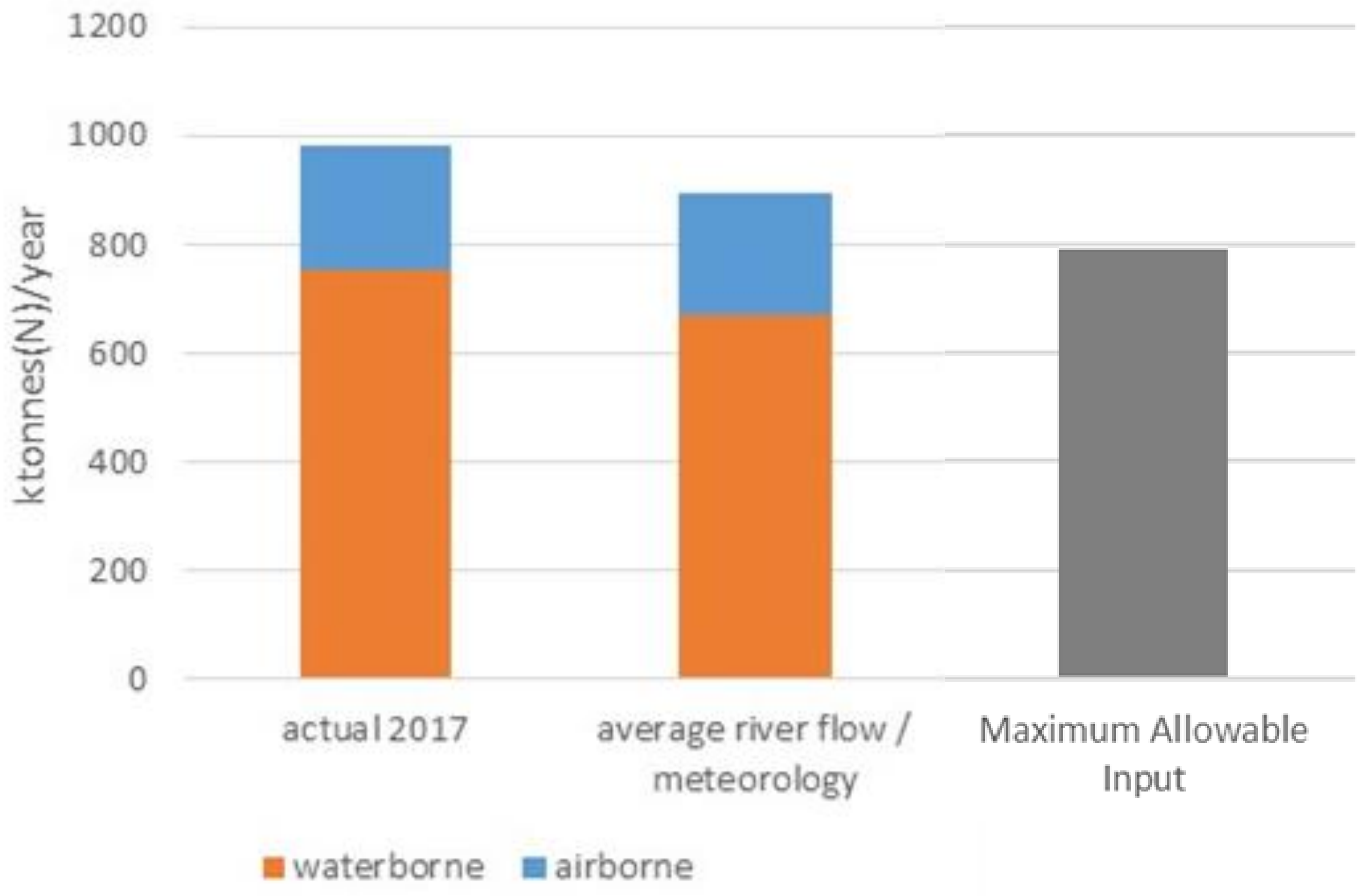
# Total nitrogen input to the Baltic Sea in 2017




Maximum allowable inputs (MAI) for the Baltic Sea have been defined by HELCOM (HELCOM, 2013)

Exceedance of MAI in 2017:

About 101 ktonnes(N)/year

(calculated with average river flow and meteorology)

*Results from : HELCOM (2019) Inputs of nutrients to the sub-basins. HELCOM core indicator report. ISSN 2343-2543*

*HELCOM (2013). Summary report on the development of revised Maximum Allowable Inputs (MAI) and updated Country Allocated Reduction Targets (CART) of the Baltic Sea Action Plan.*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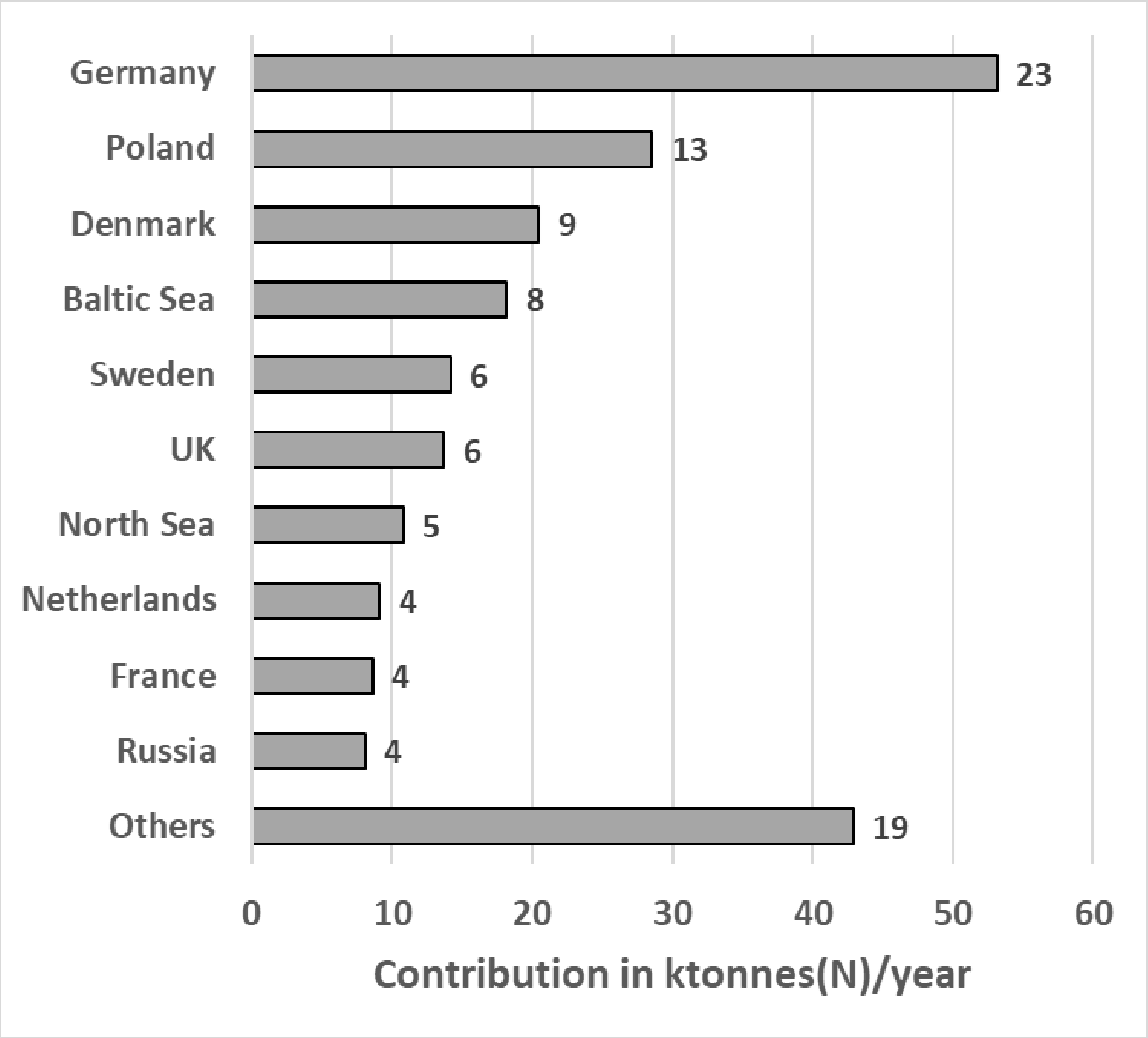
# Contributions to *airborne* N deposition to the Baltic Sea in 2017



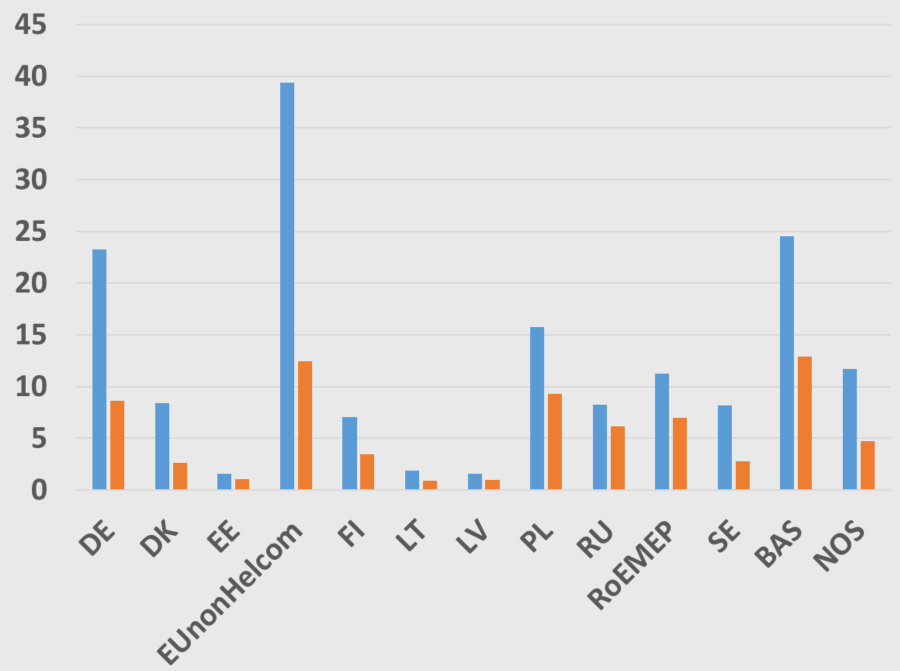

(labels indicate percentage of total)

Baltic Sea and North Sea shipping together contribute about 13% to airborne nitrogen deposition to the Baltic Sea. i.e. as much as the number-two contributing country (Poland)

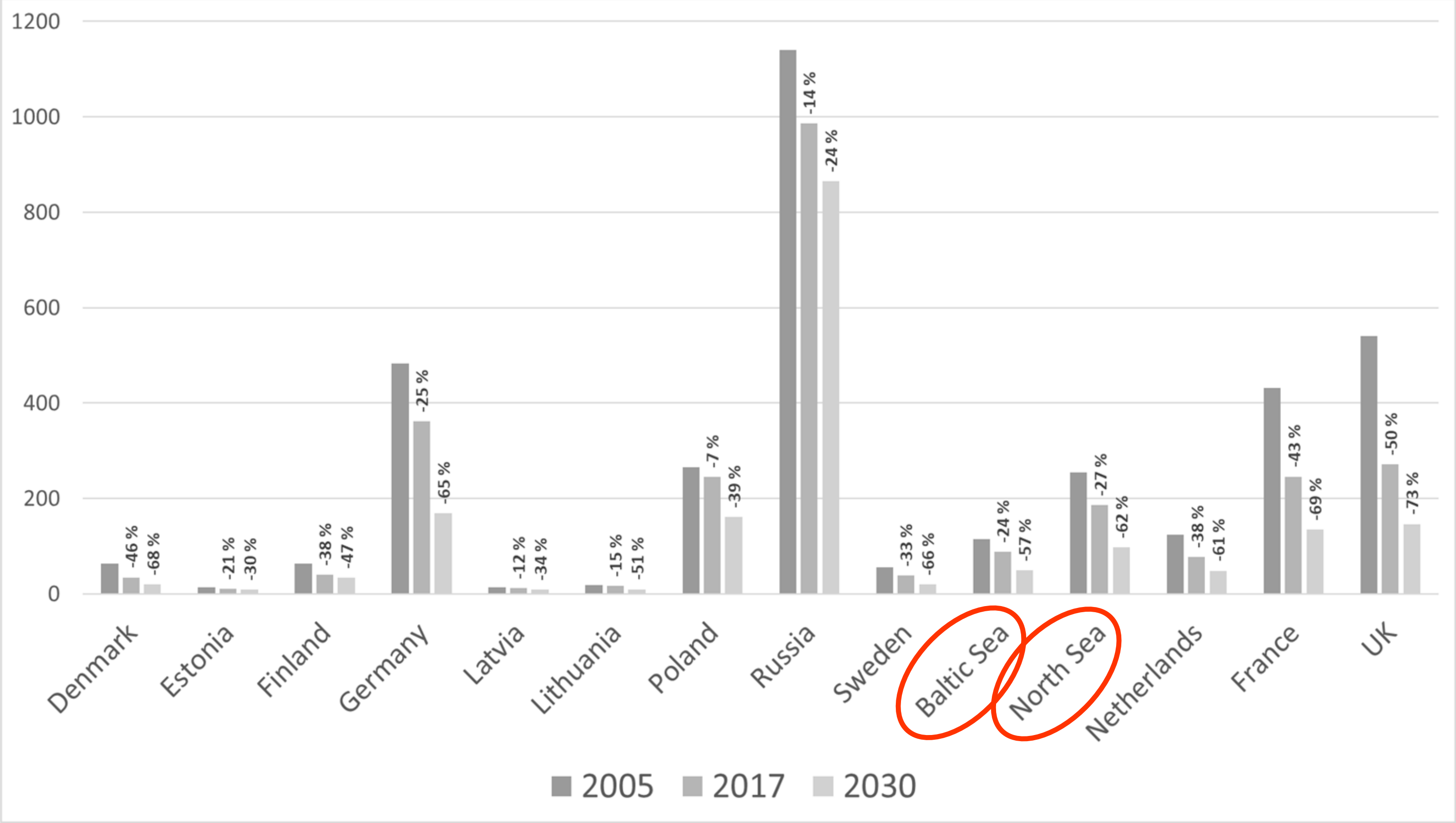
*Model calculations made by EMEP MSC-W for HELCOM*

# Gothenburg Protocol, EU NEC Directive, IMO NECA

## Contributions to deposition of oxidized nitrogen in 2005 (blue) and 2030 (red) (ktonnes(N)/yr)




## NOx emissions and reductions (wrt. 2005) (ktonnes(N)/yr)




The shipping sector, as one of the main contributors, can achieve substantial further reductions in nitrogen deposition by 2030, thanks to NECA.

*Model calculations made by EMEP MSC-W for HELCOM / ship emission scenario provided by FMI (J.P. Jalkanen)*

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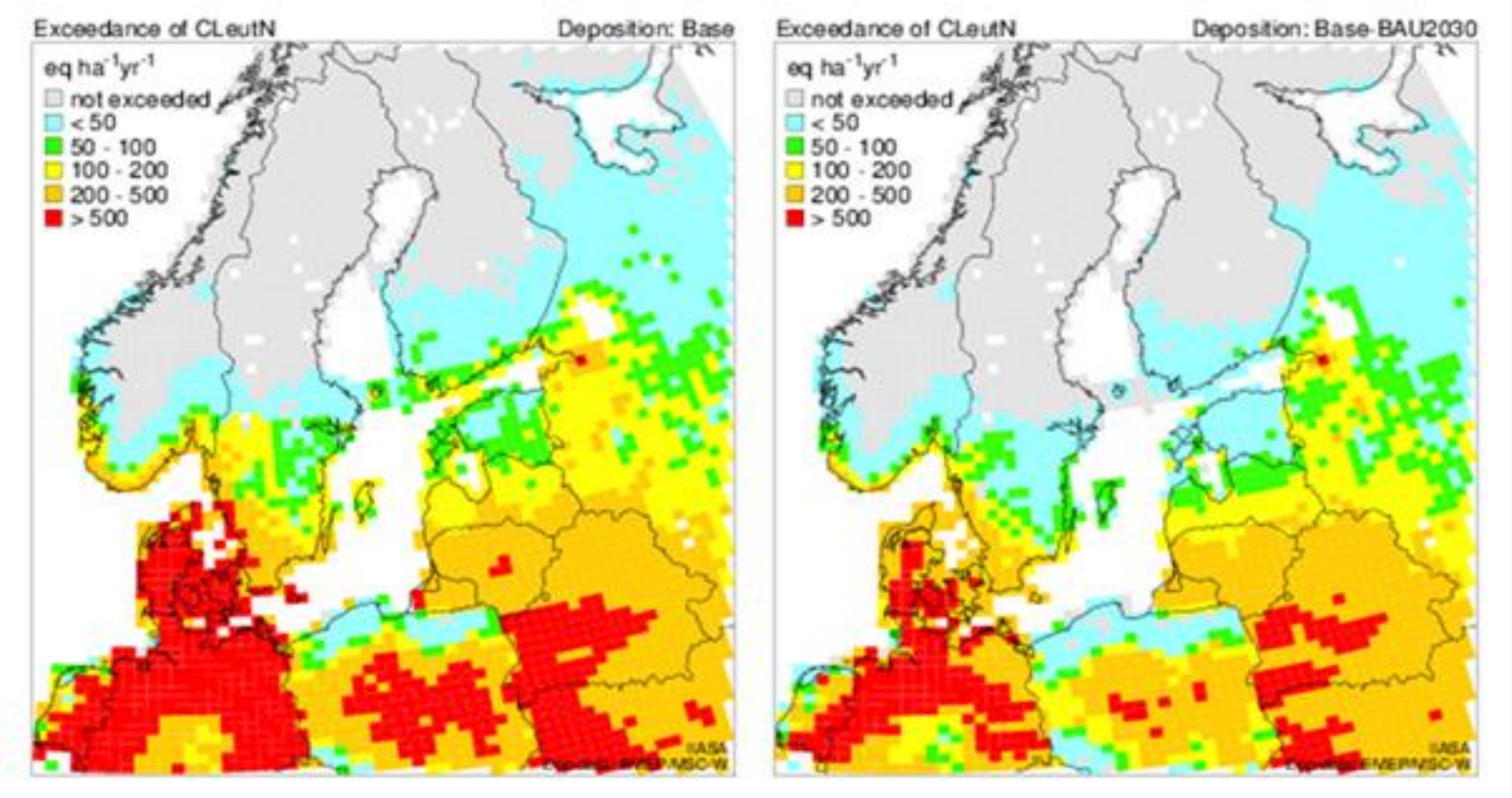
# Critical loads of eutrophication on land

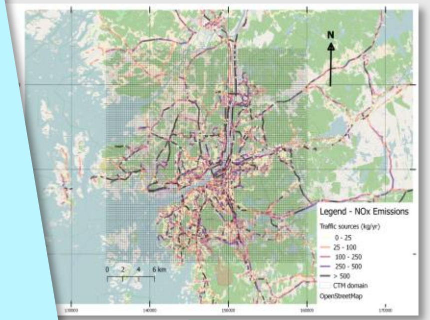



2016 2030

from Repka et al., 2020

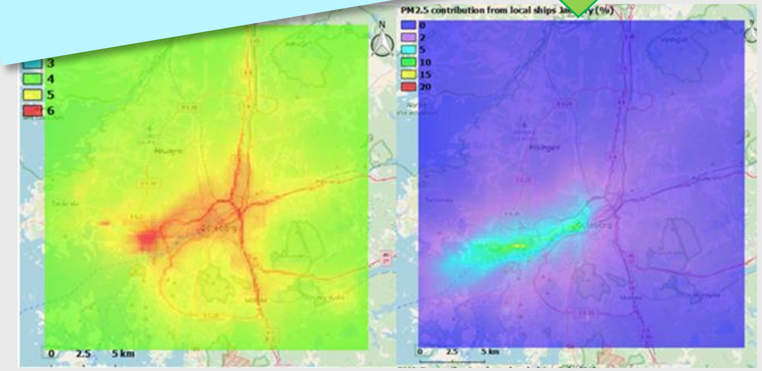
*Repka, S., Erkkilä-Välimäki, A., Jalkanen, J.P., Jonson, J.E., Posch, M., Torronen, J., 2020: IMO regulation of ship-originated SOx and NOx in the Baltic Sea: Assessing the costs and environmental impacts, AMBIO, AMBI-D-20-00082, manuscript under review.*

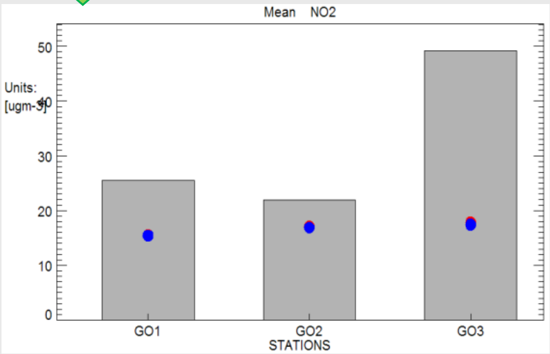
# The impact of shipping on air quality and human health in Gothenburg, Sweden


Scenarios investigated:

- Base year 2012
- BAU 2040
- EEDI 2040
- Shore-electricity in BAU and EEDI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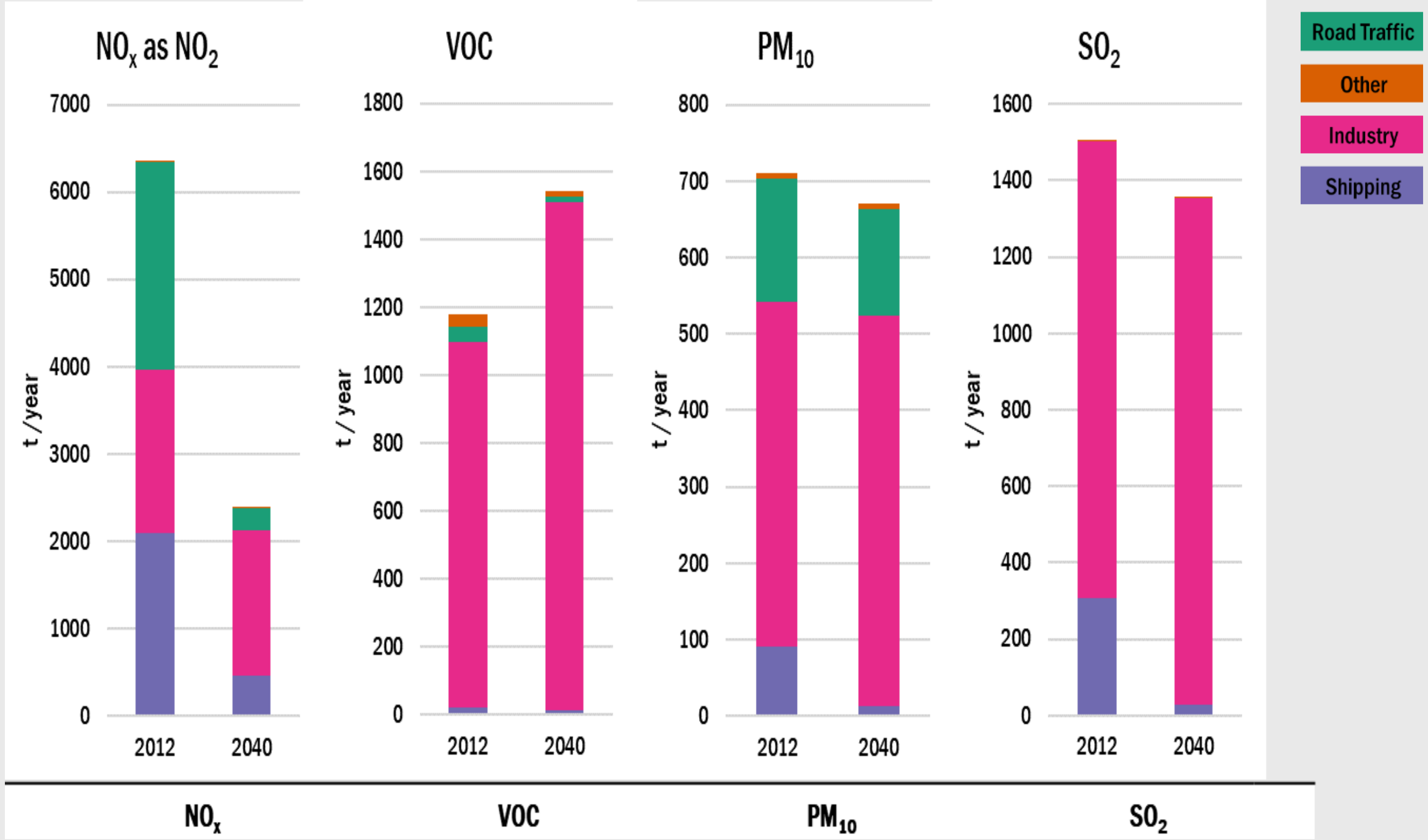
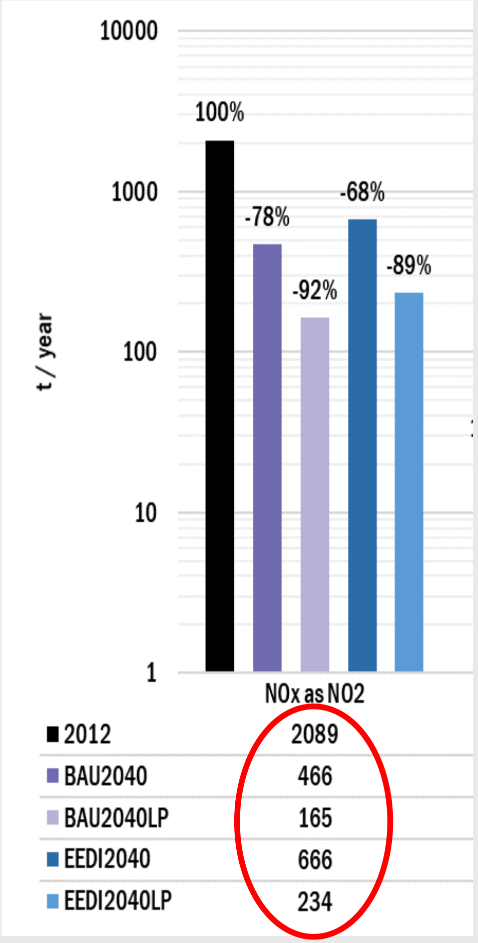
# Emissions in Gothenburg 2012 and 2040 scenarios




2012 and BAU 2040 scenario emissions in Gothenburg,
all emission sources




Tang et al., Atm. Chem Phys. 20, 10667, 2020
Ramacher et al., Atm. Chem Phys. 20, 7509, 2020

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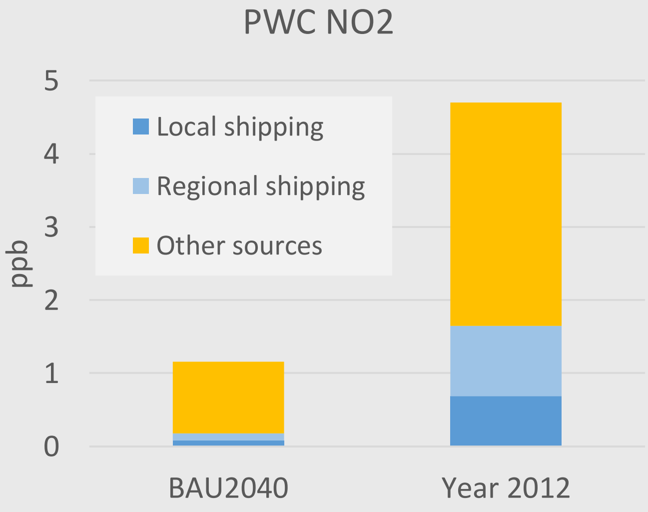
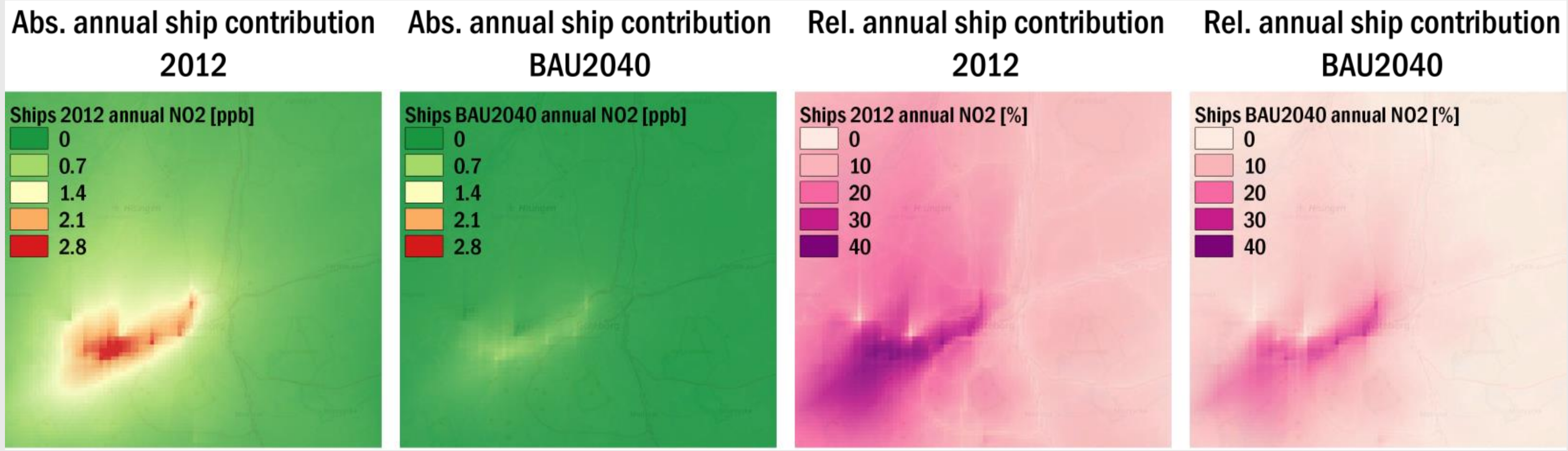
# Impact of shipping emissions on $NO_2$

## $NO_2$ exposure

Population weighted concentration (PWC)




## $NO_2$ concentrations




Tang et al., Atm. Chem Phys. 20, 10667, 2020
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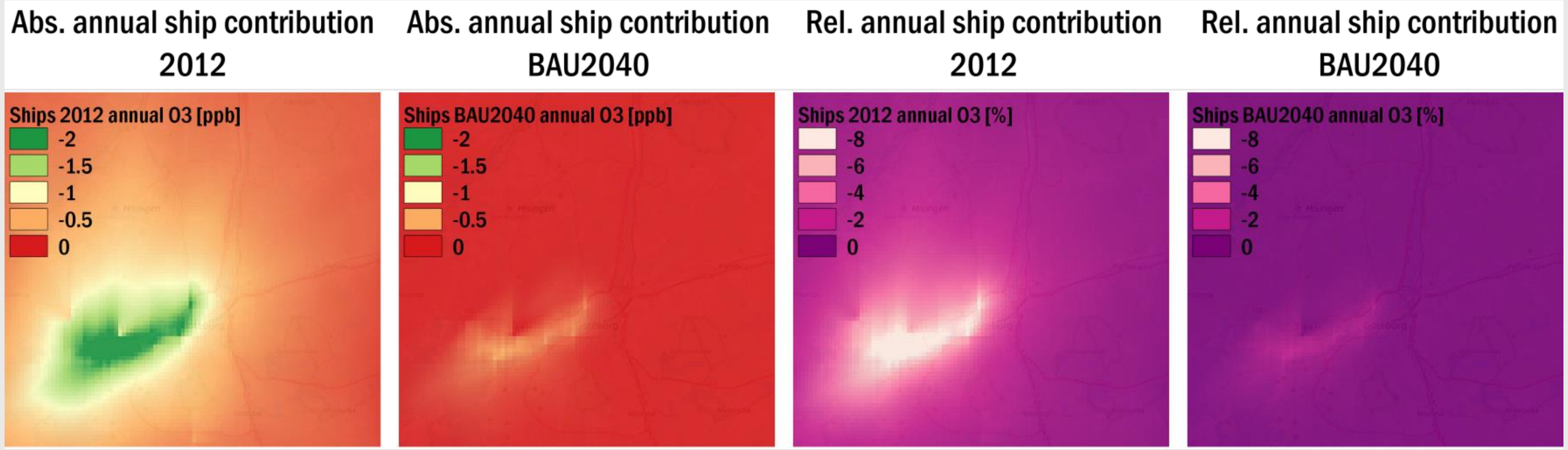
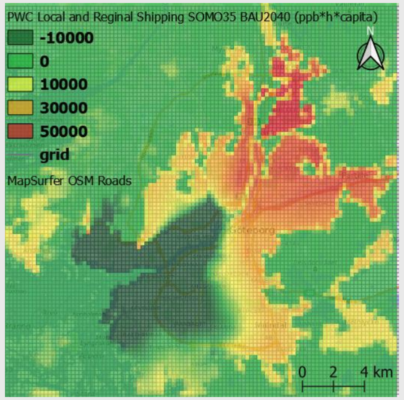
# Impact of shipping emissions on ozone

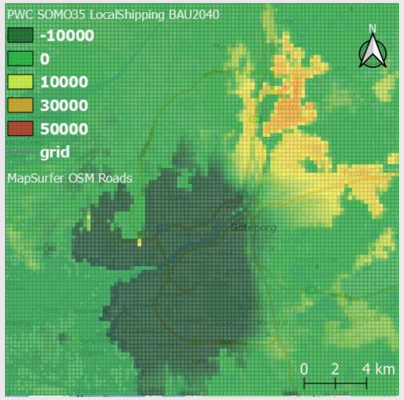
Ozone concentrations




**Annual ship contribution BAU2040**




**Annual local ship contribution BAU2040**




Ozone exposures (PWC SOMO35 = sum of means above 35 ppb)

| SOMO35 | BAU2040 | Year 2012 |
|---|---|---|
| Local shipping | -115 | -1 186 |
| Regional shipping | 150 | 71 |
| Other sources | 18 688 | 20 813 |

Tang et al., Atm. Chem Phys. 20, 10667, 2020, Ramacher et al., Atm. Chem Phys. 20, 7509, 2020

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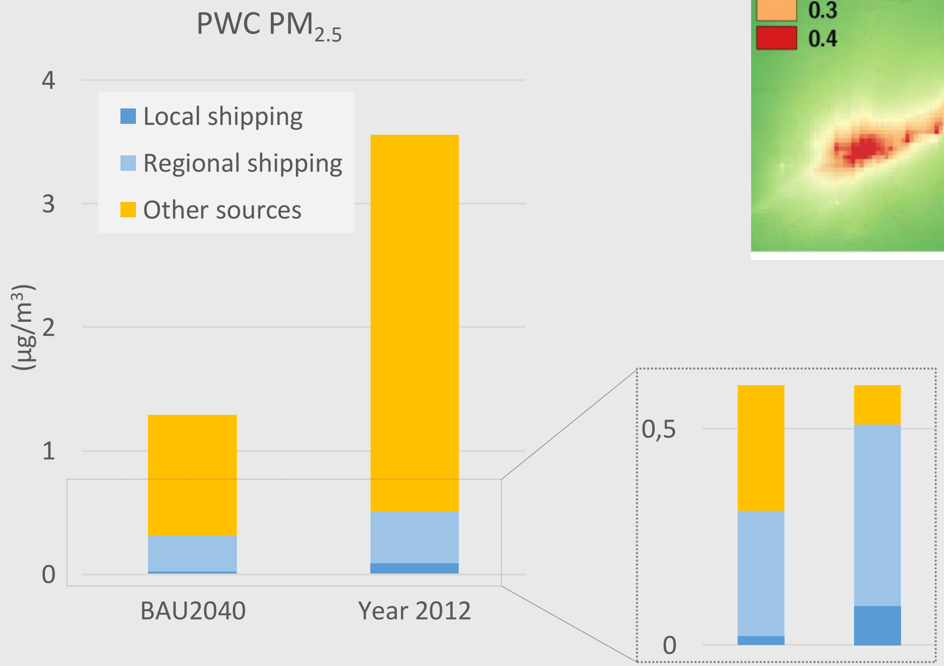
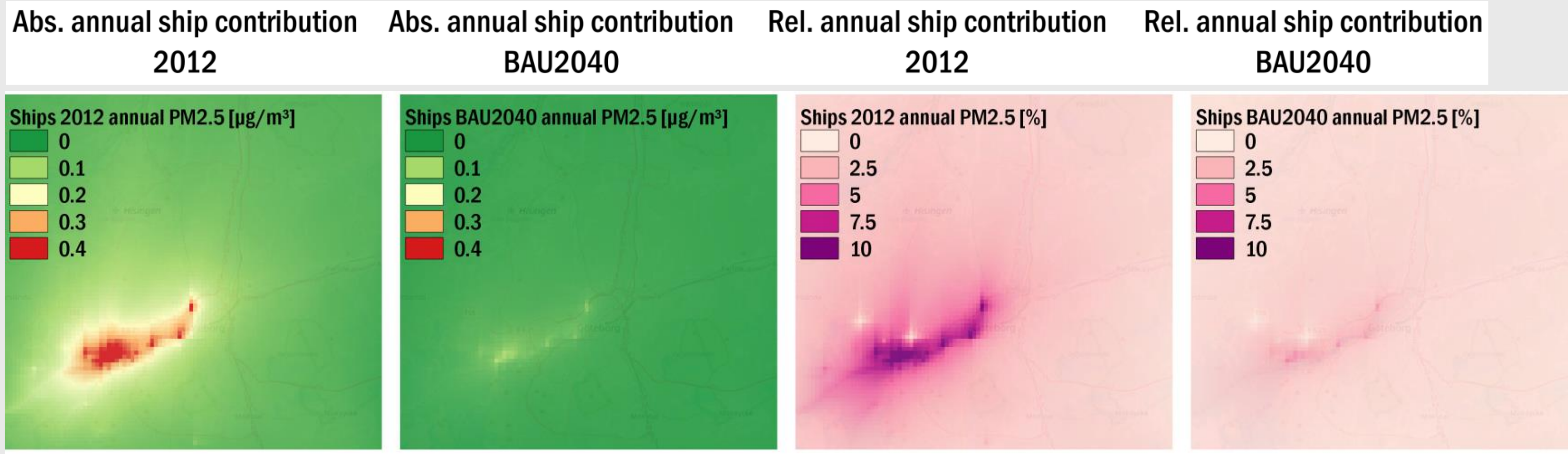
# Impact of shipping emissions on $PM_{2.5}$

## $PM_{2.5}$ exposure



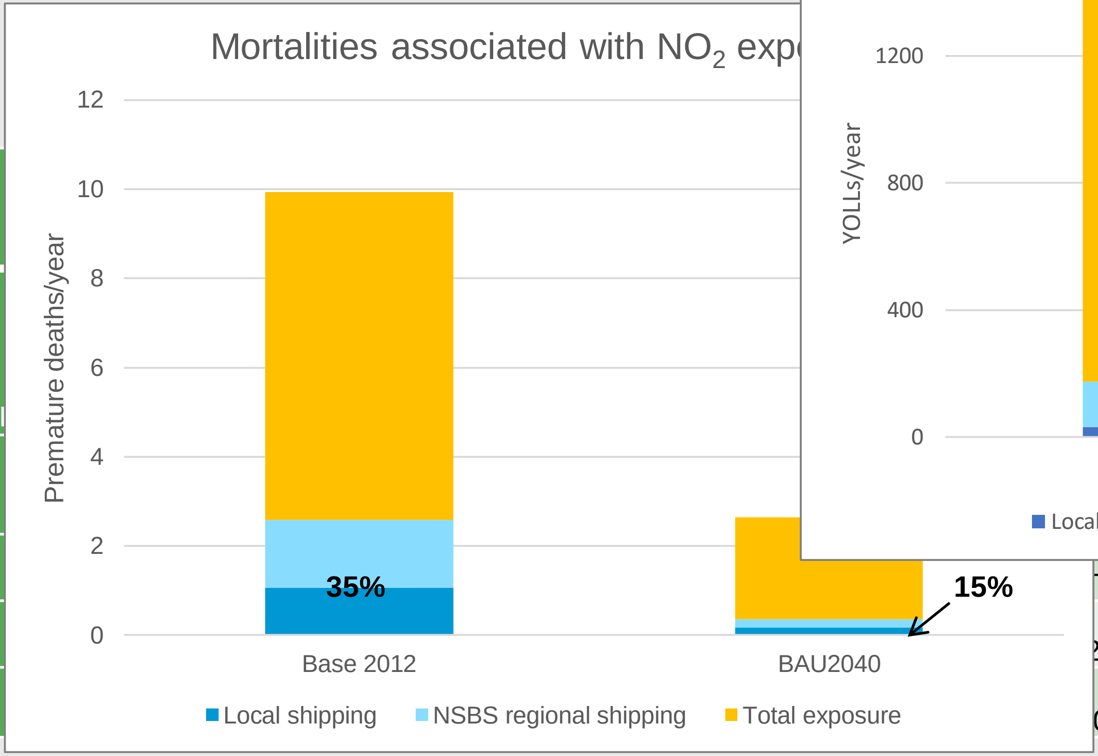

## $PM_{2.5}$ concentrations

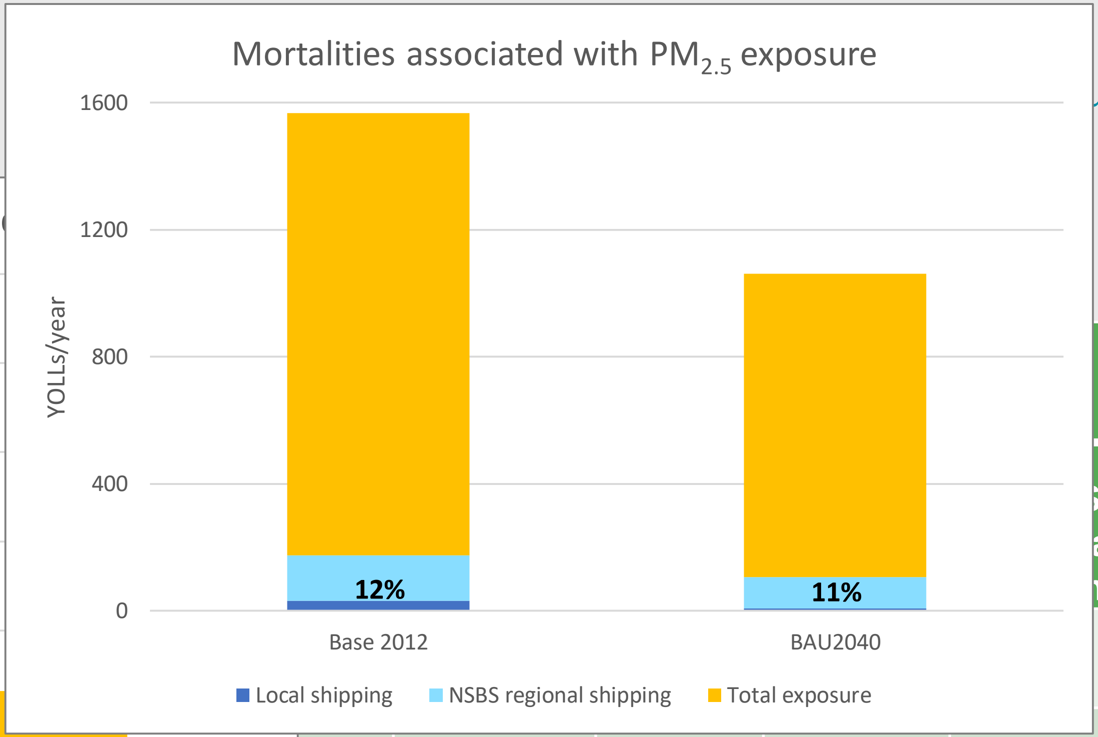



Tang et al., Atm. Chem Phys. 20, 10667, 2020, Ramacher et al., Atm. Chem Phys. 20, 7509, 2020

# Health impact assessment

...ulate air-pollutant




| Pollutant | | | | | | ...al ...ng | Total exposure |
|---|---|---|---|---|---|---|---|
| $PM_{2.5}$ | | | | | | | 955 |
| $PM_{2.5}$ | ...7.5 | 141 | 0.3 | 0.8 | | 12.6 | 120 |
| $NO_2$ | ...2.73 | 7.35 | 0.23 | 0.17 | | 0.19 | 2.28 |
| $O_3$ | ...0.0 | 7.6 | -0.1 | -0.1 | | 0.1 | 9.0 |

*Emissions at berth avoided by being replaced by land-power in the LP scenarios
** Includes emissions at berth

# Conclusions

- NOx from shipping emissions affect air quality, health and ecosystems
- The effects can be quantified with sophisticated model chains
- Emission scenarios demonstrate large reductions in atmospheric $NO_2$ concentrations and nitrogen depositions until 2040 in nitrogen ECAs

However:

- Critical loads for eutrophication will still be exceeded
- Additional measures like on-shore power supply will give significant benefits in harbour cities