SHEBA
Sustainable Shipping and Environment of the Baltic Sea region

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# Different regulations to reduce nitrogen oxide emissions from ships and their effect on future air quality in the Baltic Sea region

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## $NO_X$ emissions in the Baltic Sea area

Shipping emissions of nitrogen oxides ($NO_X$) to air on the Baltic Sea are of similar magnitude as the combined land-based $NO_X$ emissions of Finland and Sweden. For the North Sea and the Baltic Sea a nitrogen emission control area will become effective in 2021 (NECA-2021), permitting only new built ships compliant with Tier III emission limits of the International Maritime Organization (IMO) MARPOL Annex VI. **This study investigates the effect of different regulations to reduce $NO_X$ emissions from ships on the air quality in the year 2040.**

## Scenarios & model set-up

Three scenarios for shipping emission reductions were simulated:

(1) Business as usual (**BAU**) scenario with efficiency increase rates according to Kalli et al. (2013) and implementation of NECA-2021.

(2) No implementation of NECA-2021 (**NoNECA**): new built ships comply with Tier II limits; efficiency increase same as "BAU".

(3) Low efficiency increase (**EEDI**): assumed efficiency increase according to EEDI regulations of IMO but otherwise same as BAU.

Community Multiscale Air Quality (CMAQ) model (Byun and Schere, 2006) v.5.0.1 was used to simulate the current and future air quality situation. Nested simulations with CMAQ were performed on a horizontal resolution of 4 x 4 km² for the entire Baltic Sea. High-resolution meteorological fields were obtained from COSMO-CLM simulations; the meteorology of 2012 was used for the present-day and future simulations. Ship emissions from STEAM (Jalkanen et al., 2012) interpolated to CMAQ resolution were used as hourly input. Future land-base $NO_X$ emissions were reduced by 60 % compared to present-day.

## Regional air quality in 2040

Comparing the three different reduction scenarios in JJA 2040, predicted ambient $NO_2$ in the Baltic Sea area is highest for NoNECA (Fig. 1), while ambient $PM_{2.5}$ is highest for EEDI (Fig. 2).

| | Present (2012) | NoNECA (2040) | BAU (2040) | EEDI (2040) |
|---|---|---|---|---|
| Ship emission of $NO_X$ in Baltic Sea [kt/yr] | 330 | 166 | 68 | 94 |
| Ship emission of $PM_{2.5}$ in Baltic Sea [kt/yr] | 14.9 | 5.2 | 5.2 | 7.3 |
| Avg. JJA ship contribution to ambient $NO_2$ [ppbV] | 0.64 | 0.33 | 0.16 | 0.19 |
| Avg.JJA ship contribution to ambient $PM_{2.5}$ [µg/m³] | 0.29 | 0.06 | 0.05 | 0.13 |

## Conclusions

NECA-2021 suppresses secondary nitrate formation from ship exhaust $NO_X$, thereby reducing $PM_{2.5}$ from shipping as co-benefit. Lower efficiency increase (EEDI) gives a one third higher $NO_2$ ship contribution than BAU scenario in 2040. However, EEDI still results in reduction of $NO_2$ by 70-80 % (JJA) over the Baltic Sea (Fig. 3) in 2040 compared to present-day, reflecting the importance of NECA-2021 for future reduction of atmospheric reactive nitrogen.

## Three reduction scenarios

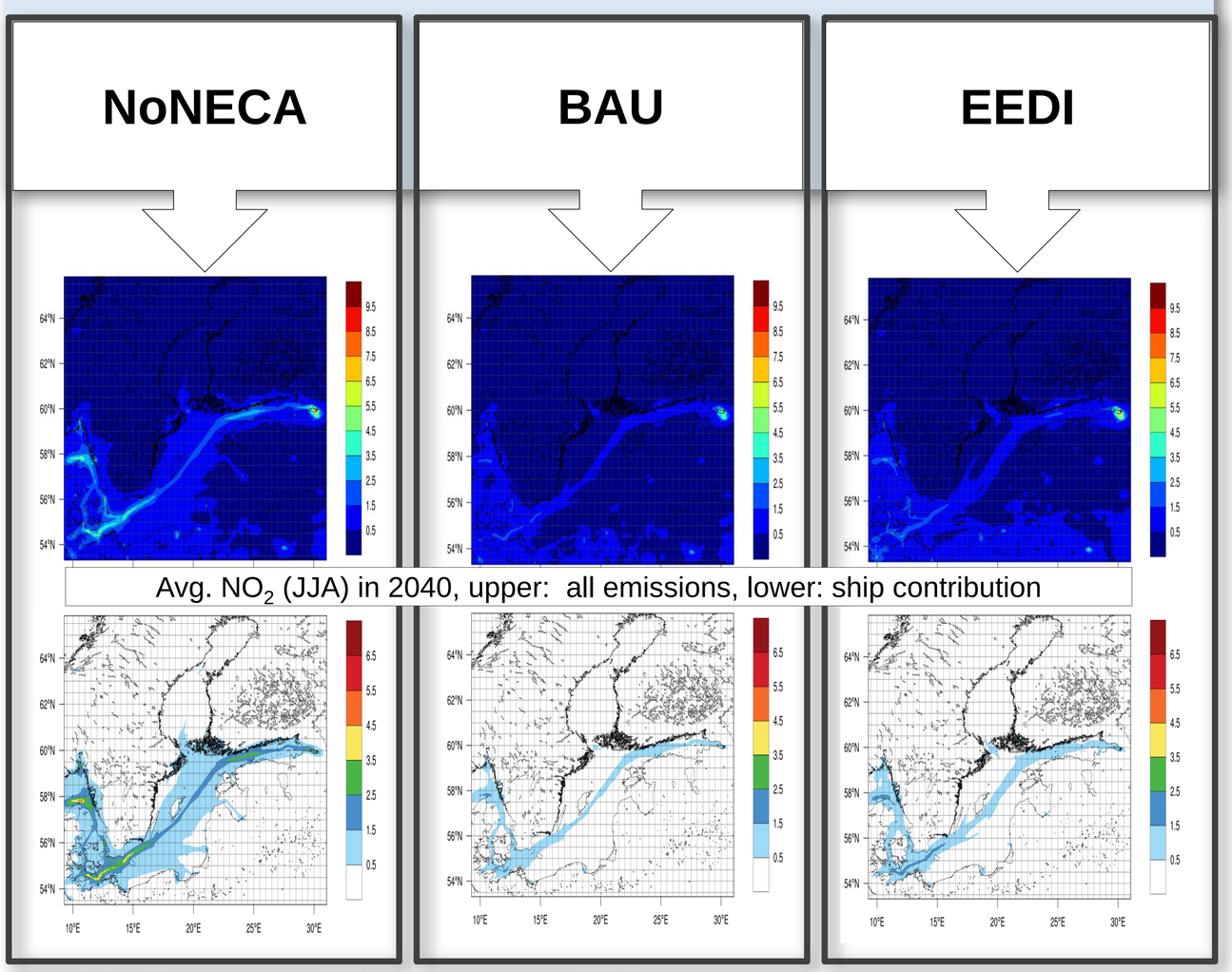


**Figure 1**: Avg. $NO_2$ air concentration (JJA) [ppbV] at ground level in 2040. Upper part: base run with all emissions, lower part: ship contribution.

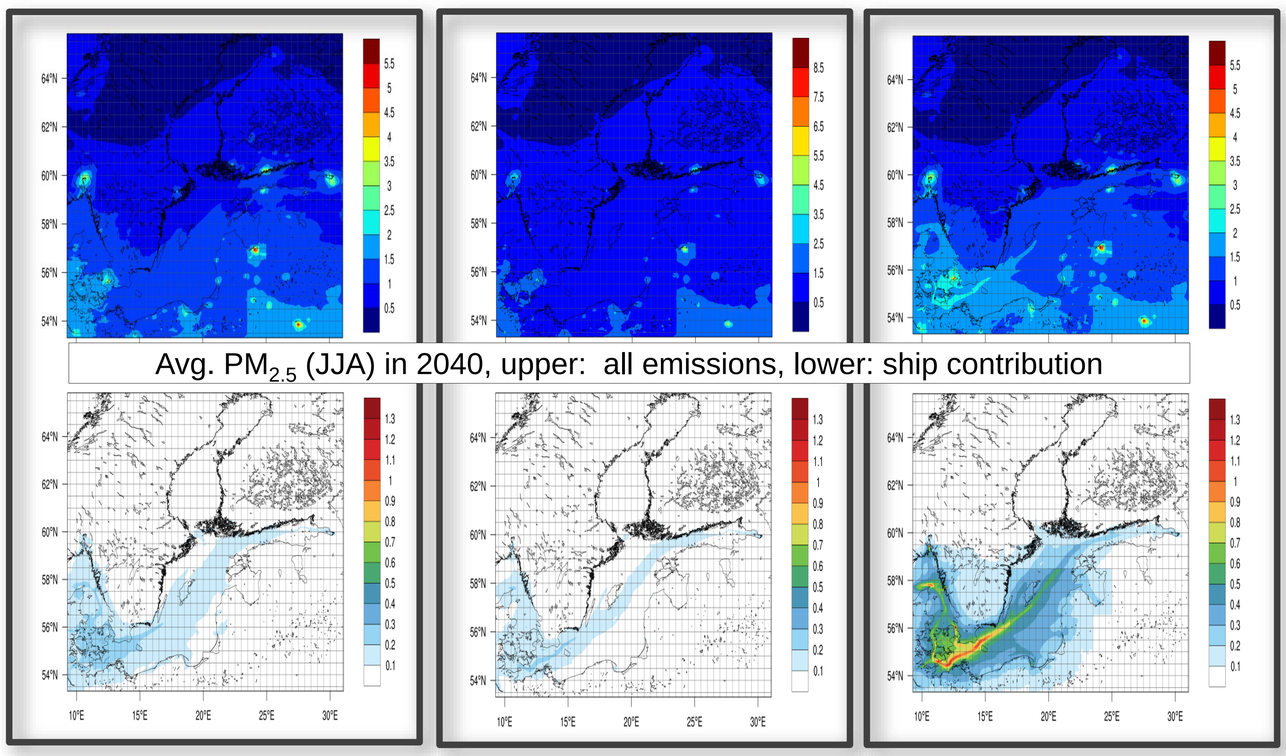


**Figure 2**: Avg. $PM_{2.5}$ air concentration (JJA) [µg m$^{-3}$] at ground level in 2040. Upper part: base run with all emissions, lower part: ship contribution.

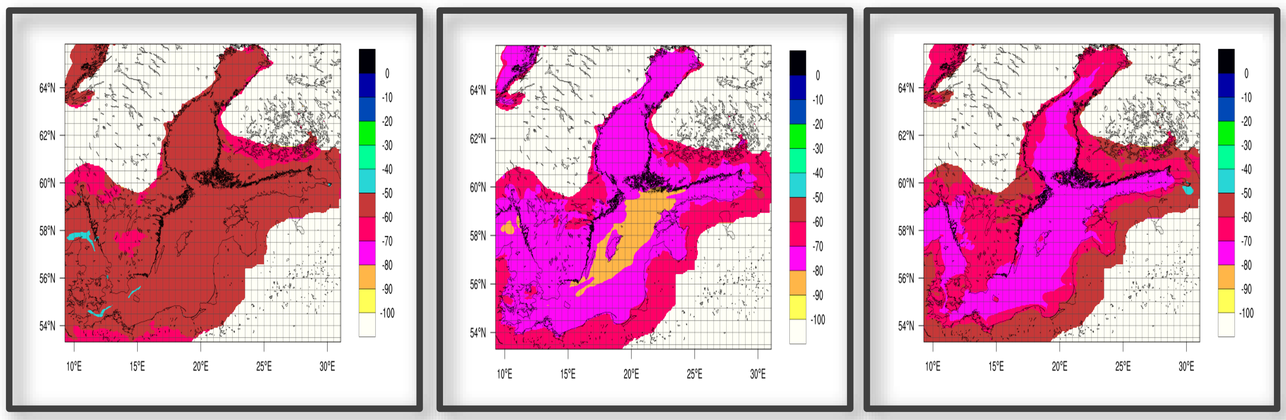

**Figure 3**: Relative change of $NO_2$ air concentration (JJA) in 2040 compared to present-day. White area: ship contribution less than 0.1 ppbV

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Jalkanen, J.-P., Johansson, L., Kukkonen, J., Brink, A., Kalli, J., Stipa, T.(2012). Atmos. Chem. Phys., 12, 2641-59.
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