How can emission reduction measures for shipping help us meet the threshold and target requirements in the Air Quality directives?

Ships emit gases and particles into the atmosphere, among them are carbon dioxide, nitrogen oxides, sulphur oxides and soot particles. Globally, about 100,000 commercial ships are in service. International shipping is responsible for about 2.2 % of the global CO_2 emissions, but for 15 % of the NOx and 13 % of the SO_2 emissions. In certain regions with heavy ship traffic like the Baltic Sea, they may contribute significantly to the concentrations of air pollutants. To estimate the distribution of contaminations, data – based modelling has been done within the SHEBA and EnviSum projects.

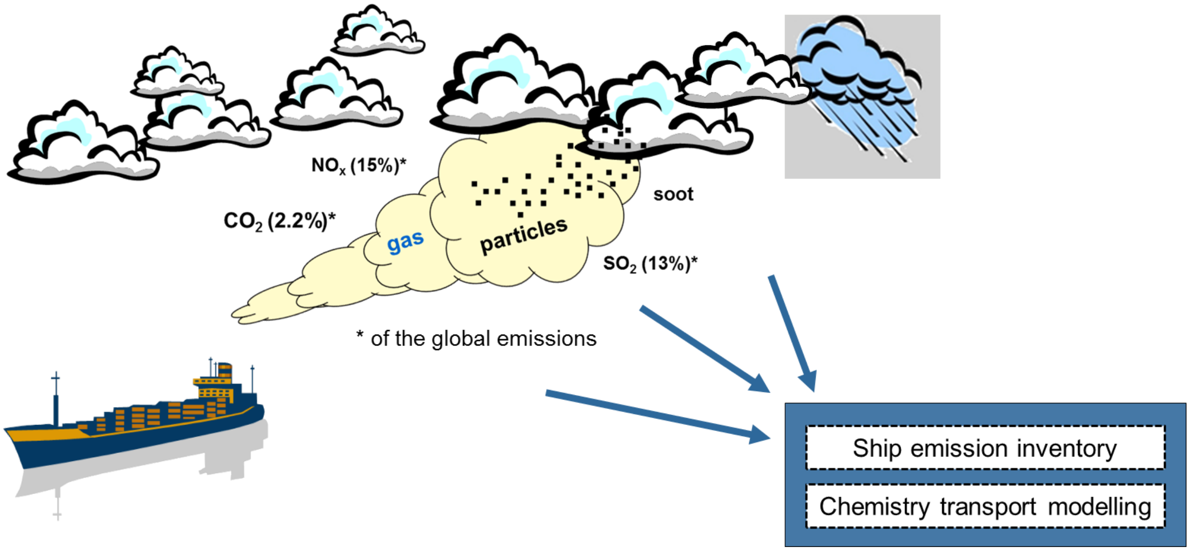

Figure 1 Air pollution modelling within the BONUS SHEBA project

Shipping emissions into air have an influence on climate (CO_2, CH_4, PM) and affect air quality in different ways, e.g. pollution of air with PM, NO_2 and ozone (SOx, NOx, PM), acidification (SO_X, NO_X) . Nitrogen oxides and sulphur from ships contribute to the degradation of air quality regionally, but in particular along the coast where a large portion of the population in the Baltic Sea region lives. These gases are also precursor substances[1] for secondary aerosols. Nitrogen oxides are also involved in the formation of tropospheric ozone. PM, including the secondary aerosol, directly emitted black carbon (BC), sulphate, organic matter, metals and others, has negative health effects. Effect of PM related to shipping on climate is mainly a general a cooling (scattering of solar radiation, and changes in cloud albedo). Nevertheless BC has a warming potential due to its light absorption capabilities, both while air-born and when deposited on bright surfaces, such as ice- and snow-covered parts of the Arctic.

The Air Quality directives set limits for NOx (NO_2), SOx (SO_2), particulate matter and CO. The Baltic Sea (and also the North Sea) are SECA (Sulphur Emissions Control Areas) regions. Here the the regulations have been strengthened in several steps where the latest 2015 IMO regulation led to significant reduction in SO_2 concentrations (see Fig. 2a). Performing the same model calculations with the higher ship emissions from 2014 calculated SO_2 concentrations are greatly overestimated (Figure 3 right). Sulphate levels (emitted directly and formed from SO_2) have also also decreased. As sulphate is

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[1] Precursor is a compound that participates in a chemical reaction that produces another compound

a major contributor to $PM_{2.5}$ (particles suspended in the air with diameters less than 2.5 microns), $PM_{2.5}$ levels are also reduced (see Fig. 2b). The percentage reduction in $PM_{2.5}$ is however much smaller than

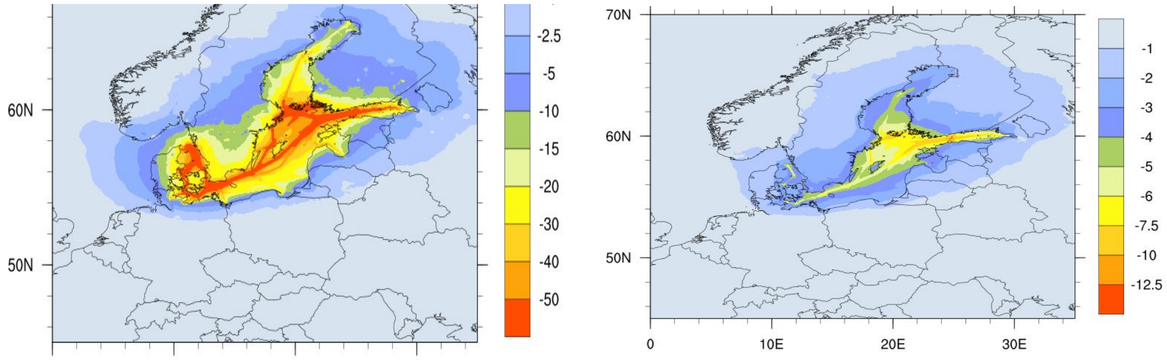

Figure 2: Percentage reductions in annual-mean concentrations of SO_2 (left panel) and $PM_{2.5}$ (right panel) due to the 2015 IMO regulations on sulfur content in fuel for shipping in the Baltic Sea. The maps are based on model calculations on 10 km x 10 km resolution for the Baltic Sea region.

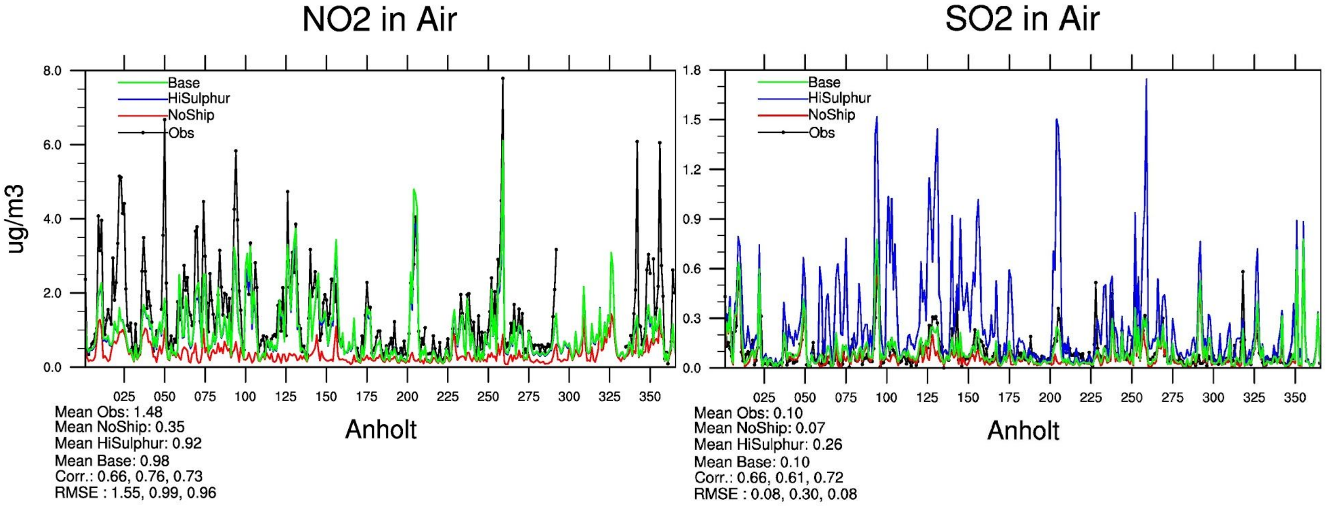

Figure 3: Model calculated versus measured NO_2 (left) and SO_2 (right) at Anholt in Denmark. Obs: observations, Base: with 2016 ship emissions HiSulphur: 2014 ship emissions, NoShips: no ship emissions

for SO_2 since $PM_{2.5}$ has many sources other than ship emissions of sulphur. In the case of SO_2, air quality standards were largely met already before 2014 so that the 2015 SECA rule had no significant effect on the number of exceedances. However, in the case of particulate matter exceedances are more likely to be avoided through reductions of ship emissions. In absolute terms the annual mean $PM_{2.5}$ load has decreased by up to 0.5 $\mu g/m^3$ according to regional and local model simulations On very fine spatial scales (i.e. more locally) the effect can be larger, up to a few $\mu g/m^3$.

Although significantly reduced from 2015, shipping continues to be a source of $PM_{2.5}$ in the Baltic region, mainly resulting from NOx emissions. Ship emissions continue to be a major source of NOx in the region, and for many coastal sites models can not reproduce the measurements without including the ship emissions (see Figure 3, left) From 2021 the Baltic Sea (and also the North Sea) are accepted as NECAs (Nitrogen Emission Control Area). The NECA regulation only apply to new ships, or for major modifications of existing ships. Thus the expected resulting emissions reduction will gradually take effect over several years as the fleet is renewed. The results for nitrogen dioxide in the lowest model layer (Figure 3) demonstrate that shipping is a large contributor to the NO_2 concentrations in the Baltic Sea area. Model run for the current situation, NO_2 concentrations in shipping lanes are comparable or higher than those in big cities along the Baltic Sea coastline. By year 2040 substantial reductions in NO2 levels are expected.

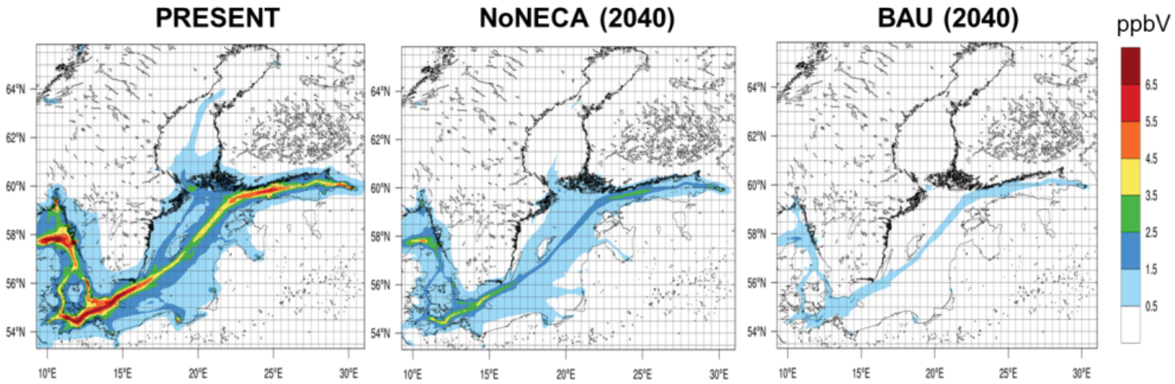

Figure 3: Present NO2 concentrations compared to the situation in 2040 with (BAU) and without NECA implementation.

Sulfur regulations in the Baltic Sea (and the North Sea) are already stricter than the global sulphur cap that will be implemented in 2020, and only minor reductions in long range transport from other sea areas are expected. However, for countries facing the North Atlantic and in in Southern Europe the effects will be significant as shown in Figure 4, likely leading to avoidance of threshold exceedances and thousands of premature deaths related to particulate matter pollution. (a more quantitative statements can probably be made during the lifetime of CSHIPP, based on results from EnviSum and Sheba).

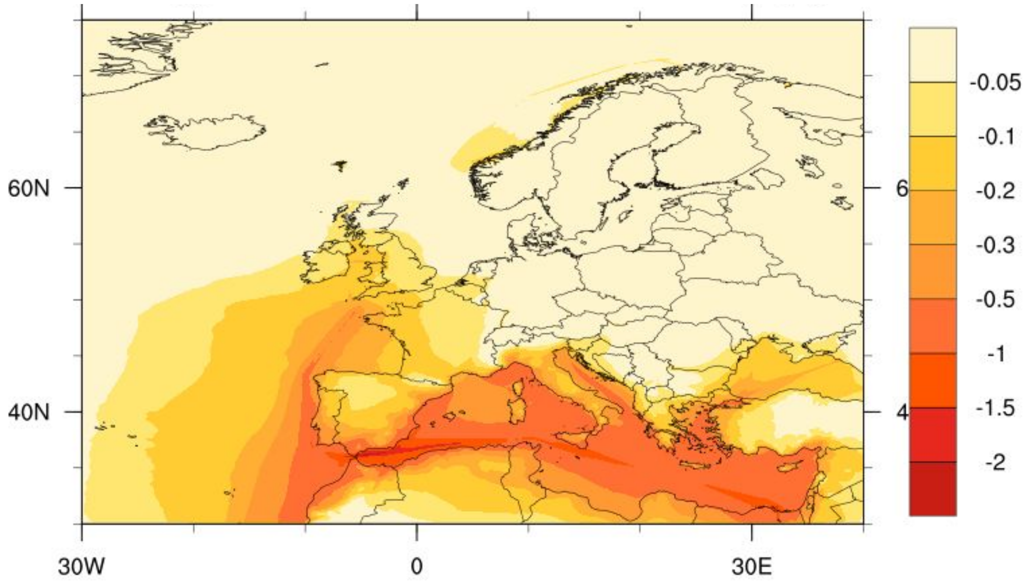

Figure 4: Estimated absolute reductions in annual mean $PM_{2.5}$ due to the introduction of the global sulfur cap in 2020 (unit: μg/m^3). The map is based on model calculations where emissions of SO_2 from shipping were reduced corresponding to the reduction of sulfur content in ship fuel to 0.5%.