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Ocean-atmosphere exchange of ammonia in the 21st century and the competing effects of temperature and ocean acidification

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Ammonia is the principal alkaline gas in the atmosphere. It therefore plays an important role in atmospheric chemistry, reacting with sulphuric and nitric acids to form ammonium aerosols, which serve as cloud condensation nuclei and negatively impact human health. Anthropogenic ammonia emissions are increasing rapidly in many areas of the world, and are expected to increase dramatically in the future due to the strong effect of temperature on the emission of ammonia. It is therefore of interest to understand the impact of increasing temperatures, atmospheric CO_2, and anthropogenic ammonia emissions on the ocean-atmosphere exchange of ammonia. Global scale estimates of this exchange are difficult to constrain due to the variability of fluxes and the difficulties in measuring them. A modelling approach is therefore required. An interactive scheme for the global exchange of ammonia between the atmosphere and the ocean was developed, and implemented in both an offline physico-chemical model, and the global atmospheric chemistry and aerosol model UKCA-CLASSIC. The scheme takes into account future projections of changes in temperature, terrestrial ammonia emissions, and ocean pH. Results show that ocean acidification has the largest effect, leading to a decrease in global ocean ammonia emissions from a range of 2.8 to 6.6 Tg-N/yr for the present day to a range of -1.1 to 2.3 Tg-N/yr for 2100 (RCP 8.5), suggesting this is one of several routes through which the flux of nitrogen to the oceans will increase in the future.