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# Going beyond global mean metrics: Capturing regional climate impacts from the transport sectors

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Metrics for climate change commonly use global averages as input. Such global mean values are very useful for assessment and comparison of many components or scenarios together and provide an understanding of the overall impacts. However, important information about regional variations in the response is hidden. This is especially the case for short-lived components which cause warming and cooling impacts that are highly dependent on the location of emissions, causing a heterogeneous pattern of forcing and response. Emissions of nitrogen oxides (NOx) give a complicated climate impact, leading to production of tropospheric O3 and reduction of CH4 with a warming and cooling impact, respectively. On a global mean level the radiative forcing (RF) from these two opposing effects are of the same order. However, there are several important aspects of regionality acting to complicate the effect of NOx. Hence, even if the positive O3 forcing and negative CH4 forcing were to cancel in the global mean, the local or regional climate impact of NOx would not necessarily be zero.

We investigate the loss of information about regional variability in the response to NOx from the transport sectors in the use of global mean metrics. Surface air temperature and precipitation response due to CO2 doubling, CH4 increase and O3 perturbations for aviation, road traffic, shipping and total transport is obtained from GCM simulations with the ECHAM4. If there is a nonlinear relationship between climate change and its impact the regionality in response can influence a global mean metric. We assume that temperature change causes a damage that varies as the square of the local temperature change ("alternative metric"). The damage is calculated locally and then averaged globally. This metric is compared to global mean temperature change squared ("standard metric"), giving a ratio that expresses the degree of heterogeneity.

For all transport sectors, the relative impact of the net O3 and CH4 perturbation is larger using the alternative metric. Aviation gives the most heterogeneous response of the sectors considered here: The impact is enhanced by 50% with the alternative metric. For shipping and road traffic the values are 33% and 21%, respectively. Due to the feedbacks in the climate system, even a homogeneous RF such as CO2 will cause a temperature response with a specific pattern. The metrics reflect how important the pattern of radiative forcing is for the pattern of the response. For surface air temperature change it is important to consider the regional variations in the case of heterogeneous forcing (O3 and CH4) from the transport sectors. The transport sectors generate emissions of several other short lived components, mainly BC, OC and SO2, and affect climate through formation of cirrus and contrails. These are not included in this analysis, but would likely affect the results.