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Multi-satellite sensor study on precipitation-induced emission pulses of NO_x from soils in semi-arid ecosystems

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Soil emissions of NO_x ($\equiv$ NO + NO_2), stemming from biotic emissions of NO, represent a considerable fraction of total NO_x emissions, and may even dominate in agricultural and remote areas. Rain-induced spikes in NO_x have been observed by in-situ measurements and also satellite observations. However, the estimation of soil emissions over broad geographic regions and on short time scales remains uncertain.

This study presents a top-down approach to estimate pulsed soil emissions of trace gases on a global scale using tropospheric NO_2 column densities (as a proxy for NO_x) as observed by OMI, GOME-2 and SCIAMACHY. We introduce an optimized algorithm that synchronizes and averages multiple time series of atmospheric variables either from one location only, or also from different grid pixels, by aligning them on a relative scale to each other. This method allows investigating changes in the evolution of NO_2 VCDs around the first day of rainfall after a prolonged dry period with a temporal resolution of one day and a spatial resolution of 0.25°.

We find enhancements in NO_2 VCDs on the day of first rainfall in many semi-arid regions in the world which are highly dependent on the season and land cover type. Strongest and most clustered enhancements are found in the distinct band of the Sahel region during the onset of the wet season in April-May-June. Absolute enhancements averaged over the Sahel region for four seasons from 2007 to 2010 range from $0.3*10^{15}$molec cm^{-2} for OMI to $0.4*10^{15}$molec cm^{-2} for GOME-2 and SCIAMACHY on the first day of rainfall. A thorough analysis of other influences on the retrieved signal as well as sensitivity studies are conducted which help to better characterize these short term enhancements.

Translating the observed enhancements in NO_2 VCDs to emission rates, leads to estimates between 5 and 65 ng N m^{-2} s^{-1} for the first day of rainfall which is in line with previous literature. We find that the enhancement in NO_2 VCDs already starts to develop several days before the actual first rainfall. After the initial large pulse, soil emissions diminish rapidly the subsequent day, but stay still enhanced over the following two weeks with 1.6 ng N m^{-2}s^{-1} averaged over the Sahel region.

We also present a case study in the surroundings of Lake Chad which is based on daily orbits of OMI and does not rely on averaging over multiple time series. A characteristic enhancement in NO_2 VCDs, in response to the first rain of the wet season, is found which agrees well with our general findings for the Sahel region.