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Estimating Individual Sea Vessel NO2 Emissions using Spatial Autocorrelation on S5P-TROPOMI Satellite Data

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Starting from January 2020, new IMO regulations limiting the Sulphur content of the fuel used by seagoing vessels came into force. As of 2021, new and stricter NOx emission standards are applied for newly built ships entering the North and Baltic Sea. There are various methods that are used to measure the pollution produced by ships in ports or off the coastal areas. Due to practical limitations, however, the conduction of such monitoring above the open sea has not been possible up to now.

The TROPOspheric Monitoring Instrument onboard the Copernicus Sentinel 5 Precursor satellite (TROPOMI/S5P) provides the atmosphere monitoring data with an unprecedented spatial resolution. With this instrument plumes produced by individual ships of substantial size can be detected. In our study we focus on application of the TROPOMI NO2 tropospheric column for tracking back the emission produced by individual ships at open sea.

On a global scale, individual ships are considered to be low-source pollution emitters. As a result, it is difficult to separate an emission plume from the background pollution, especially, in case of comparable background concentration. In order to improve the distinction between the plume and the background, we propose the use of the local spatial autocorrelation measure Moran's I. This measure amplifies regular shaped high-concentration structures and suppresses random co-occurring concentration peaks. By means of the Automated Identification Signal (AIS) data that records historical ship locations, the detected structures can be associated with individual ships. We further propose heuristic algorithms using local weather conditions (wind speed/direction) for an efficient ship-plume matching and NO2 concentration estimation.

We evaluate the quality of a ship-plume assignment by comparing the estimated NO2 concentration with model-based emission estimations determined from speed and length of the ship. Notable linear correlation between our estimations and the model-based values supports the proposed method.

This work contributes to realising global scale verification/estimation of emission plumes with satellites by providing automated and enhanced processing of satellite retrievals for identifying and quantifying of NOx plumes produced by individual seagoing vessels.

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