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A scalable hybrid model to predict riverine nitrous oxide emissions from the reach to the global scale

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Nitrous oxide, N_2O, is the leading cause for stratospheric ozone depletion and one of the most potent greenhouse gases. Its emissions from riverine systems have been poorly constrained. Thus, we present a novel conceptual framework that leverages the strength of a data driven machine learning technique and physically based model to predict global nitrous oxide emissions (N_2O) from streams and rivers worldwide at the reach-scale resolution (about 1-km length). The model accounts for reactant loads, mainly dissolved inorganic nitrogen, biochemical transformation rates, and riverine hydro-morphology. Its high resolution and ability to account for hyporheic, benthic and water column N_2O contributions identify small streams (those with widths less than 10 m) as a primary source of riverine N_2O emissions to the atmosphere. These streams contribute nearly 36 GgN_2O-N/yr, almost 50% of the entire N_2O emissions from riverine systems, although they account for only 13% of the total riverine surface area worldwide. Large rivers (widths wider than 100 m), such as the main stems of the Mississippi (2 GgN_2O-N/yr) and Amazon River (7 GgN_2O-N/yr), only contribute 30% of global N_2O emissions, which primarily originate from their water column. Our approach introduces a dimensionless Emission Factor that varies spatially and temporally and can be quantified from standard hydromorphological and water quality data routinely measured in streams and rivers or can be predicted with good accuracy from interpolation methods such as machine learning. This approach can improve the accuracy of climate change models which can account for a better prediction of N_2O spatial and temporal distribution.