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Gridded 1 km × 1 km emission inventory for paddy stubble burning emissions over north-west India constrained by measured emission factors of 77 VOCs and district-wise crop yield data

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Paddy stubble burning is a major environmental issue that plagues the ambient air quality of the Indo-Gangetic Plain. Every year, during the post-monsoon season (October and November), approximately 17 million tons of paddy stubble are burnt openly in the fields of Punjab and Haryana. Over two months, this large-scale biomass burning results in persistent smog and severely perturbs the regional air quality. The emission of reactive gaseous pollutants like volatile organic compounds (VOCs) from this source drive the surface ozone and aerosol formation. However, there is a considerable knowledge gap regarding their identification, amounts and spatial distribution over North India. Widely used top-down global fire emission inventories like GFED, GFAS and FINN rely on the high-resolution MODIS and VIIRS satellite fire products. However, they are severely constrained by the missed fires, limited VOC speciation and uncertain biomass burnt calculations due to non-region-specific emission and land use parametrization factors. The current bottom-up emission estimates also have high uncertainties because of non-region-specific emission factors and burning practices. This work presents a new "hybrid" gridded emission inventory for paddy stubble burning over Punjab and Haryana in 2017 at 1 km × 1 km spatial resolution. First, the emission factors (EFs) of 77 VOCs were measured in smoke samples collected from the on-field paddy fires of Punjab. These were then combined with 1 km × 1 km stubble burning activity, constrained by annual crop production yields, regional rice cultivars, burning practices and satellite-detected fire radiative power. The results revealed that paddy stubble burning is a significant source of oxygenated VOCs like acetaldehyde (37.5±9.6 Ggy^{-1}), 2-furaldehyde (37.1±12.5 Ggy^{-1}), acetone (34.7±13.6 Ggy^{-1}), and toxic VOCs like benzene (9.9±2.8 Ggy^{-1}) and isocyanic acid (0.4±0.2 Ggy^{-1}). These compounds are also significantly underestimated and unaccounted for by existing top-down and bottom-up emission inventories. Additionally, it was found that the emissions of NMVOC (346±65 Ggy^{-1}), NOx (38±8 Ggy^{-1}), NH_3 (16±4 Ggy^{-1}), PM2.5 (129±9 Ggy^{-1}), GHG CO_2 equivalents (22.1±3.7 Tgy^{-1}) from paddy stubble were up to 20 times higher than the corresponding emissions from traffic and municipal waste burning over north-west India during October and November 2017. Mitigation of this source alone can yield massive air-quality climate co-benefits for more than 500 million people.