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Global evaluation of HCHO summertime diurnal variability using Pandonia Global Network (PGN)

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Formaldehyde (HCHO) serves as an important proxy for emissions of volatile organic compounds (VOCs) and their subsequent photochemistry affecting air quality and climate. Understanding HCHO diurnal variability is essential to accurately represent emissions, chemistry, and planetary boundary layer (PBL) mixing in chemical transport models (CTMs). Here we compare HCHO diurnal variations from Pandora Global Network (PGN), GEOS-CF (0.25°x0.25°) and GEOS-Chem (2°x2.5°) CTMs at 55 sites, to characterize the HCHO diurnal patterns in urban and rural sites over North America (NA), Europe (EU) and East Asia (AS) in 2021-2022 summers. We find that HCHO total column (HCHOcol) from GEOS-CF model shows a comparable stronger diurnal variability (quantified by relative amplitude) with that from PGN measurements, which is lower in GEOS-Chem (10-200% bias in late afternoon). While models and PGN show comparable HCHOcol at rural sites (e.g., ChapelHillNC and DearbornMI), PGN shows significantly higher (a factor of 2 - 3) local noon HCHOcol in some urban areas (e.g., Busan and Bangkok), suggesting missing Volatile Organic Compounds (VOCs) emissions in the models. We further examine the relationship between HCHOcol and HCHO near-surface concentration (HCHOsurf). While both model and PGN show a linear relationship ($p<0.05$) between HCHOcol and HCHOsurf in most of EU sites, they show larger discrepancies over a majority of NA and AS sites with a nonlinear relationship, suggesting model issues in PBL mixing. Our systematic evaluation of HCHO diurnal variability, using a global network of ground-based measurements and a global CTM, provides new insights into improving emissions, chemistry and PBL mixing in current models.