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Diagnosing long-term and short-term changes in ozone production sensitivity to precursor emissions: the view from space

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Ambient exposure to ground-level ozone (O_3) is estimated to cause more than 250,000 global premature deaths per year. $O_3$is produced from photochemical reactions involving its precursors: nitrogen oxides (NO_x) and volatile organic compounds (VOCs). A major challenge in lowering ground-level O_3 in urban areas is to determine whether O_3 production is limited by NO_x (NO_x-limited) or VOCs (VOC-limited) or both (transitional). While satellites cannot retrieve the abundance of ground-level O_3, they have provided continuous global observations of O_3precursors, namely tropospheric columns of NO_2 and formaldehyde (HCHO, a proxy for VOCs), for over two decades. To assess the extent to which satellite retrievals of O_3 precursors can capture the non-linear chemistry of ground-level O_3, we pair daily satellite retrievals of $NO_2$and HCHO from Ozone Monitoring Instrument (OMI) with ground-based observations of surface $O_3$from the U.S. EPA Air Quality System (AQS) network. For urban areas, we find O_3 exceedances ($>$ 70 ppbv) are more likely to occur with NO_x reductions (NO_x-saturated or VOC-limited) when OMI HCHO/NO_2 is lower than 1.8, but less likely to occur with NO_x reduction (NO_x-limited) when OMI HCHO/NO_2 is higher than 2.8. We further contrast how the O_3-NO_x-VOC sensitivity differs on high-ozone versus "average" ozone days. Next, we construct 20-year (1996 to 2016) time series of the O_3sensitivity indicator ratio (HCHO/NO_2) using the state-of-art, harmonized multi-satellite products of tropospheric $NO_2$and HCHO vertical columns from the Quality Assurance for Essential Climate Variables (QA4ECV) project that retrieves products consistently from four satellites, including GOME, SCIAMACHY, GOME-2 and OMI. We analyze the long-term trend in the ratio of HCHO to NO_2 over major cities across the world. Our study aims to demonstrate how satellite HCHO/NO_2 products can complement in-situ O_3networks by providing information on the spatial heterogeneity and long-term evolution of O_3chemical regimes.