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Analyses of solar eclipse effects on mesospheric chemistry and dynamics—a long-term study

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Solar eclipses are short-term, small-scale natural experiments that test photochemical and dynamical responses in near space (from upper stratosphere to lower thermosphere). Using long-term observations by Aura satellite, we analyze the statistics for 33 eclipses events on mesospheric tracer gas and quantify the reduction in solar irradiance by the obscuration (η). The results show that when $\eta > 70\%$, mesospheric ozone around ~ 65 km increases by about 105%. The results of Aura MLS display that, in small solar zenith angles range ($SZA < 45^\circ$), the increases in ozone are accompanied by decreases in HOx, which can be explained by Chapman Cycle and a weakening of HOx-catalyzed loss; in larger SZA range ($SZA \geq 45^\circ$), ozone rises as radiance diminishes as in $SZA < 45^\circ$, but the HOx variability is no longer significant. Given that the satellite operates in a Sun-synchronous orbit—linking SZA to latitude and season, the contrast suggests that at high latitudes or during mid-latitude winter, energetic particle precipitation should become a more important source of HOx, rather than irradiation-dominated photochemistry (Solomon et al., Geophys. Res. Lett., 1983). In the upper-mesosphere region ($\approx 70 - 80$ km), ozone changes under $\eta > 70\%$ exhibit substantial uncertainty, which could be related to event-to-event atomic hydrogen (H) difference in ambient atmosphere (Zhan et al., JGR:SP, 2025). Numerical simulations based on WACCM-X are used to explore the possible mechanisms that are responsible for the features seen in the observations and to identify the common or distinct characteristics of these mechanisms across different eclipse events.