An Overview of Energetic Particle Precipitation Effects on the Earth's Atmosphere and (Potentially) Climate

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Energetic precipitating particles (EPPs) can cause significant constituent changes in the polar mesosphere and stratosphere (middle atmosphere) during certain periods. Both protons and electrons can influence the polar middle atmosphere through ionization and dissociation processes. EPPs can enhance HO_x (H, OH, HO_2) through the formation of positive ions followed by complex ion chemistry and NO_x (N, NO, NO_2) through the dissociation of molecular nitrogen.

The solar EPP-created HO_x increases can lead to ozone destruction in the mesosphere and upper stratosphere via several catalytic loss cycles. Such middle atmospheric HO_x-caused ozone loss is rather short-lived due to the relatively short lifetime (hours) of the HO_x constituents. The HO_x-caused ozone depletion of greater than 30% has been observed during several large solar proton events (SPEs) in the past 50 years. HO_x enhancements due to SPEs were confirmed by observations in solar cycle 23. A number of modeling studies have been undertaken over this time period that show predictions of enhanced HO_x accompanied by decreased ozone due to energetic particles.

The solar EPP-created NO_x family has a longer lifetime than the HO_x family and can also lead to catalytic ozone destruction. EPP-caused enhancements of the NO_x family can affect ozone promptly, if produced in the stratosphere, or subsequently, if produced in the lower thermosphere or mesosphere and transported to the stratosphere. NO_x enhancements due to auroral electrons, medium and high energy electrons, relativistic electron precipitation (REP) events, and SPEs have been measured and/or modeled for decades. Model predictions and measurements show that certain years have significant winter-time meteorological events, which result in the transport of EPP-caused NO_x enhancements in the upper mesosphere and lower thermosphere to lower altitudes.

The NO_x-caused ozone depletion has also been observed during several solar proton events (SPEs) in the past 50 years. Model predictions indicate that the longer-lived SPE-caused polar stratospheric and mesospheric ozone decrease can be >10% for up to five months past the largest events and is statistically significant; however, total ozone measurements do not indicate any long-term SPE impact.

This talk will provide an overview of several of the EPP-related important processes and their impacts on the atmosphere.