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Solar and Magnetospheric Particle Precipitation: Coupling to Earth's Atmosphere

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A complete description of Sun-Earth connections requires a deep understanding of the atmospheric processes that amplify in complex ways the effects of the ever-changing magnetospheric and solar energy inputs. The physical effects of these inputs are not well understood, but must entail nonlinear feedbacks that act to couple all the layers of the Earth's atmosphere. This ultimately shapes the global system in which we live. Central to this problem is determining the atmospheric response to energetic particle precipitation (EPP) both on regional and global scales. This is a last great frontier in solar-terrestrial research that forms the backdrop upon which long-term human-induced atmospheric change is superimposed. Particles deposited into Earth's atmospheric layers lose energy by ionizing constituent molecules. Where and with what strength such ionization occurs is controlled by solar wind forcing and the subsequent levels of geomagnetic activity. Quantifying EPP variations is crucial to understanding the production of key reactive atmospheric chemical constituents, namely reactive odd nitrogen¬ (NO_x) and odd hydrogen (HO_x). NO_x and HO_x participate in ozone (O_3) catalytic cycles, with significant consequences for the temperature structure of the atmosphere. Changes in temperature gradients subsequently affect winds and thus atmospheric wave propagation. After a 6-year run, a Nagoya University team has compiled temporal variation of daily-averaged NO column density and found that the amplitude of seasonal variation is remarkably smaller in 2014, by almost a factor of 2, than those of 2013 and 2015. At the same time, our high-energy electron flux measurements obtained by Van Allen Probes ($E \gtrsim 1$ MeV) for $L \sim 6.0$ which is close to that of Syowa Station ($L \sim 6.1$) also shows significant absence of energetic electrons during the southern summer and winter of 2014. This correlation of NO and electron flux is suggestive evidence that energetic electrons not only cause sporadic enhancement but also influence the long variability of mesospheric and lower thermospheric NO with a timescale of several months. To properly quantify these effects into the future, the incoming precipitating particle spectrum must be known with high accuracy in absolute intensity across the electron range from 10 keV to multiple MeV energies. This accuracy will allow requisite determination of ionization rates at altitudes from 100 km down to below 40 km. There have not yet been, over the foregoing decades of the Space Age, measurements sufficient to characterize the full energy spectrum of EPP over space and time. This presentation discusses a mission concepts that would address with great care the impact and coupling of energetic particles in Earth's atmospheric system.