The Impact of Energetic Particle Precipitation on the Atmosphere
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Charles Jackman reported on solar energetic precipitating particles (EPPs), which are electrons and protons generated by solar flares, coronal mass ejections, and geomagnetic storms. They precipitate in Earth's polar regions, where they enhance the production of HO_x and NO_x that destroy ozone in the mesosphere and upper stratosphere (Figure 2.9). Because of the relatively short lifetime of HO_x constituents, most of the atmospheric and climate-relevant EPP focus is on NO_x. Solar protons and electrons have episodic seasonal and solar cycle influence on the polar mesosphere. Measurements and models show that in years when significant winter-time meteorological events occur, EPP-enhanced NO_x is transported from the upper mesosphere and lower thermosphere to lower altitudes where their impact may last several months, decreasing ozone by a few percent. There may even be a top-down effect where by EPP-NO_x induced ozone destruction leads to changes in surface air temperature. Jackman noted that there may be a coupling between electron impact and climate,[28,29] but that these findings need further work and affirmation. Jackman stated that GCRs (primarily protons and alpha particles) also create NO_x and HO_x but at lower altitudes due to their higher energy compared to solar particles. Because the incidence of GCRs varies inversely with solar activity, their effects on stratospheric chemistry tend to be out of phase with those of EPPs. Including GCRs in models results in an increase (relative to no GCRs) in NO_y of 10-20 percent in the lower stratosphere, with the greatest effects at high latitudes, and a decrease is stratospheric ozone by around 1 percent. However, a GCR-driven solar-cycle variation in polar NO_y is less than about 5 percent (greater at solar minimum than at solar maximum), resulting in annually averaged variations in polar ozone of less than 0.06 percent.

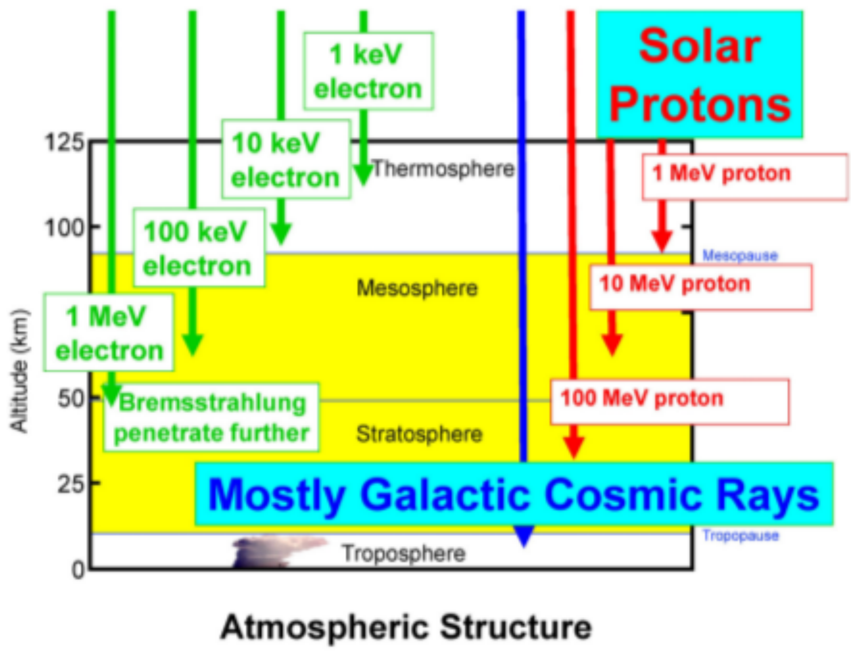

FIGURE 2.9 The atmospheric structure with incoming galactic cosmic rays and solar protons. SOURCE: C. Jackman, NASA Goddard Space Flight Center, "The Impact of Energetic Particle Precipitation on the Atmosphere," presentation to the Workshop on the Effects of Solar Variability on Earth's Climate, September 9, 2011.

[28] E. Rozanov, L. Callis, M. Schlesinger, F. Yang, N. Andronova, and V. Zubov, Atmospheric response to NO_y source due to energetic electron precipitation, *Geophysical Research Letters* 32:L14811, 2005.

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