A04-O06

THE ROLE OF ENERGETIC PARTICLE PRECIPITATION IN COUPLING BETWEEN GEOSPACE ENVIRONMENT, ATMOSPHERE AND CLIMATE

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Solar energetic particles are known to affect upper atmospheric composition by producing neutral minor constituents, such as odd hydrogen and odd nitrogen, which in turn may decrease the concentration of ozone as a result of extreme ionization events and possible transport by atmospheric dynamics. In this review we summarize how ion chemistry couples to neutral chemistry during excess ionization events, the current experimental and model-based evidence on subsequent composition variations, as well as modeling efforts to understand the role of the energetic particle precipitation at high latitudes in causing natural variability of Earth's climate. Special emphasis is given to results by the detailed coupled ion and neutral chemistry modeling by the Sodankyla Ion Chemistry (SIC) model of the lower ionosphere, and verifications by satellite data as well as by various radio propagation and incoherent scatter radar experiments. A series of studies under the general title Chemical Aeronomy of the Mesosphere and Ozone in the Stratosphere (CHAMOS) leads to our current understanding that both large solar proton events and frequently occurring energetic electron precipitation cause significant variations in upper stratospheric and mesospheric ozone concentration, a result which needs further considerations for consequences. The most recent results on energetic electron precipitation show long-term effects, as mapped by the MEPED detector onboard NOAA/POES satellites during 2002-2012. The events caused several long-lasting up to 90% destructions of mesospheric ozone at 60-80 km altitudes, as seen by 3 satellite instruments GOMOS, MLS and SABER. Most studies so far on atmospheric effects of energetic particle precipitation concentrated on the indirect particle precipitation effect caused by the production of odd nitrogen (NOx) in the polar upper atmosphere, its subsequent transport to lower altitudes inside the wintertime polar vortex, depletion of ozone in the stratosphere, and effects on the radiative balance of the middle atmosphere, which may further couple to atmospheric dynamics and propagate downwards by changing polar winds and atmospheric wave propagation through wave–mean flow interaction. We also summarize the near-future plans on developing relevant arctic and antarctic large research infrastructures, which would map continuously the energetic particle precipitation and add to the knowledge base of naturally occurring variability of our atmosphere.