

# **Analytical Approach to Cosmic Ray Ionization by Nuclei with Charge $Z$ in the Middle Atmosphere - Distribution of Galactic / Solar CR and SEP Effects**

**P. I. Y. Velinov** (1), H. Ruder (2), and L. Mateev (1)

(1) Central Solar-Terrestrial Influences Laboratory, Bulgarian Academy of Sciences, Sofia 1113, Bulgaria, pvelinov@bas.bg; (2) Institut für Astronomie und Astrophysik, Eberhard-Karls-Universität Tübingen, D-72076, Deutschland

The effects of galactic and solar cosmic rays (CR) in the middle atmosphere are considered in this work. The solar energetic particles (SEP) effects are important in the upper stratosphere, mesosphere and lower thermosphere. In fact CR determine the electric conductivity in the middle atmosphere and influence on this way on the electric processes in it. CR introduce the solar variability in the middle atmosphere - because they are modulated by solar wind. A new analytical approach for CR ionization by protons and nuclei with charge  $Z$  in the lower ionosphere and middle atmosphere is developed in this paper. For this purpose the ionization losses ( $dE/dh$ ) according to the Bohr-Bethe-Bloch formula for the energetic charged particles are approximated in five different energy intervals similarly to Dorman (Cosmic Rays in the Earth's Atmosphere and Underground, Kluwer Academic Publishers, Dordrecht, 2004), but a few precision corrections are involved. More accurate expressions for energy decrease  $E(h)$  and electron production rate profiles  $q(h)$  are derived. The obtained formulas allow comparatively easy computer programming. The integrand in  $q(h)$  gives the possibility for application of adequate numerical methods - such as Romberg method, or Gauss quadrature, for the solution of the mathematical problem. On this way the process of interaction of cosmic ray particles with the upper, middle and lower atmosphere will be described much more realistically. Computations for cosmic ray ionization in the middle atmosphere are made. The full CR composition is taken into account: protons, helium, light L, medium M, heavy H and very heavy VH group of nuclei. The influence of solar CR from proton flare on 20 January 2005 is considered quantitatively.