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Ionization effects in Regener–Pfotzer maximum due to cosmic rays during Ground Level Enhancements GLE 65, 66 and 67 in October–November 2003

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Introduction. One of the main drivers of the possible effect of cosmic ray particles on atmospheric chemistry and physics connected to the high-energy precipitating particles induced ionization. The induced by cosmic rays atmospheric ionization, which can be considerably enhanced during solar proton events, was extensively discussed over the last decade. In most of the recent models, the induced by cosmic rays atmospheric ionization plays a key role on the physics and chemistry of the atmosphere, specifically on minor constituents. It was known that the contribution of galactic cosmic ray particles to ion production in the atmosphere is nearly constant, slightly influenced by the solar activity. On the other hand, the relativistic solar particles could produce a significant excess of ion pair production, particularly over polar caps. This effect is normally strong on a short time scales. The sequence of three ground level enhancement GLE 65, 66 & 67 on October-November 2003 give an unique opportunity to study impact ionization on enhanced manner and extended time scale. Using Monte Carlo simulation and derived solar proton spectra, we computed the ion production during and the corresponding ionization effect in the Earth atmosphere in the region of Regener-Pfotzer maximum during the so-called Halloween events in October-November 2003.

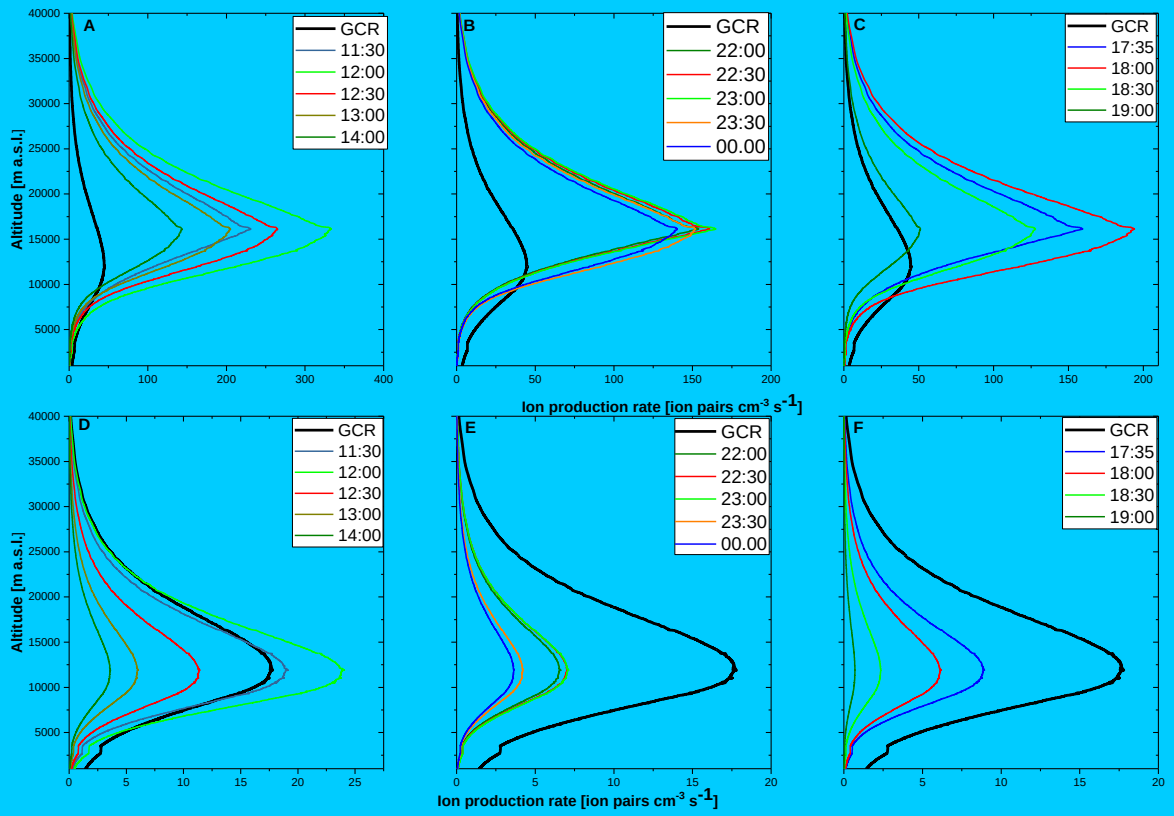

Fig. 1. Ion production rate in the atmosphere during the sequence of three Halloween GLE events in October-November 2003. Panels a,b,c, correspond to region with cut-off rigidity of 1 GV for GLE 65 on 28 October 2003, GLE 66 on 29 October 2003 and GLE 67 on 2 November 2003 respectively, while panels d,e,f, for region with cut-off rigidity 2 GV. The curves are smoothed over the computed data points.

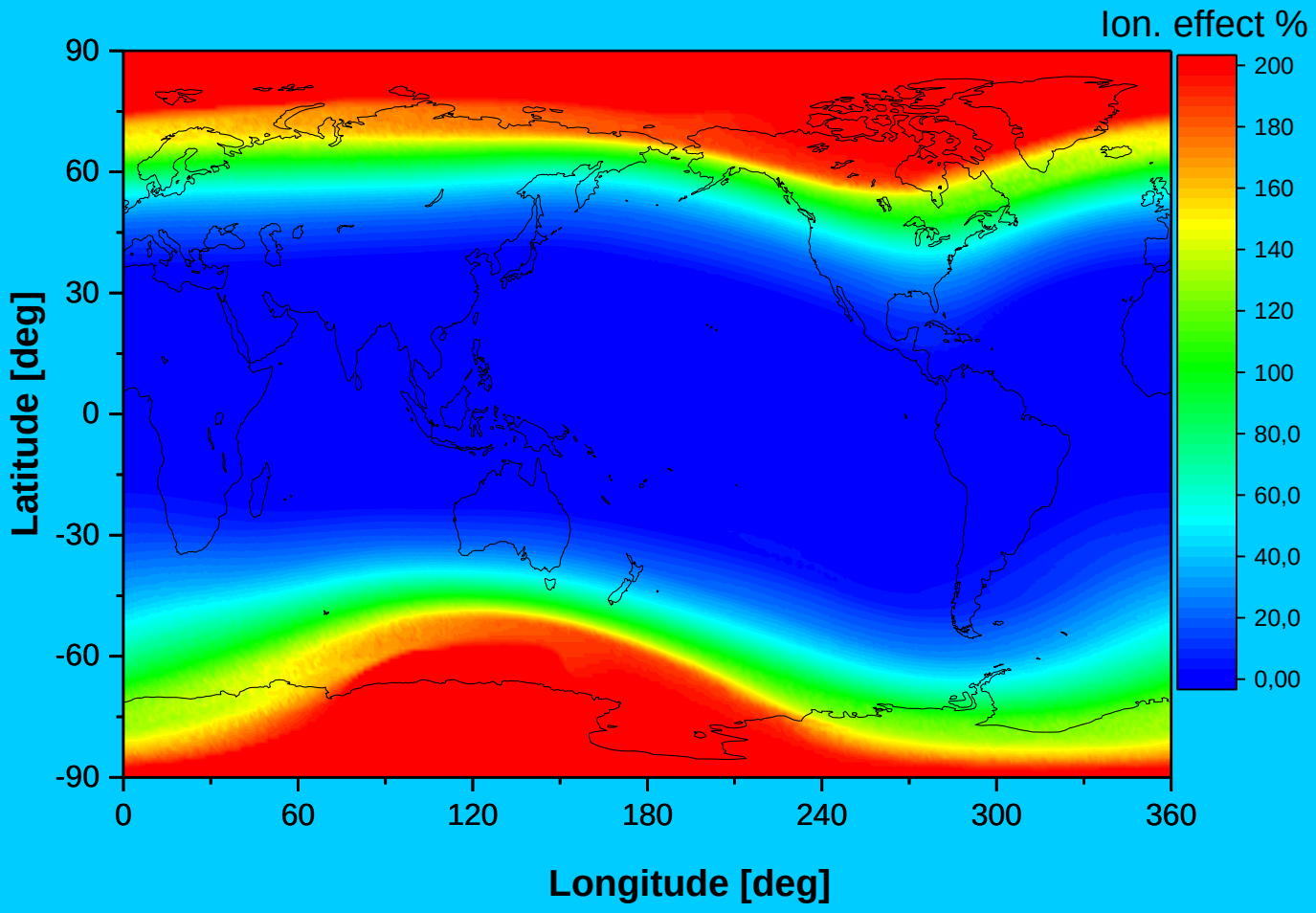

Fig. 2. Global map of Ionization effect in the region of Regener-Photzer maximum due to CRs of galactic and solar origin during the first Halloween event – GLE 65 on 28 October 2003.

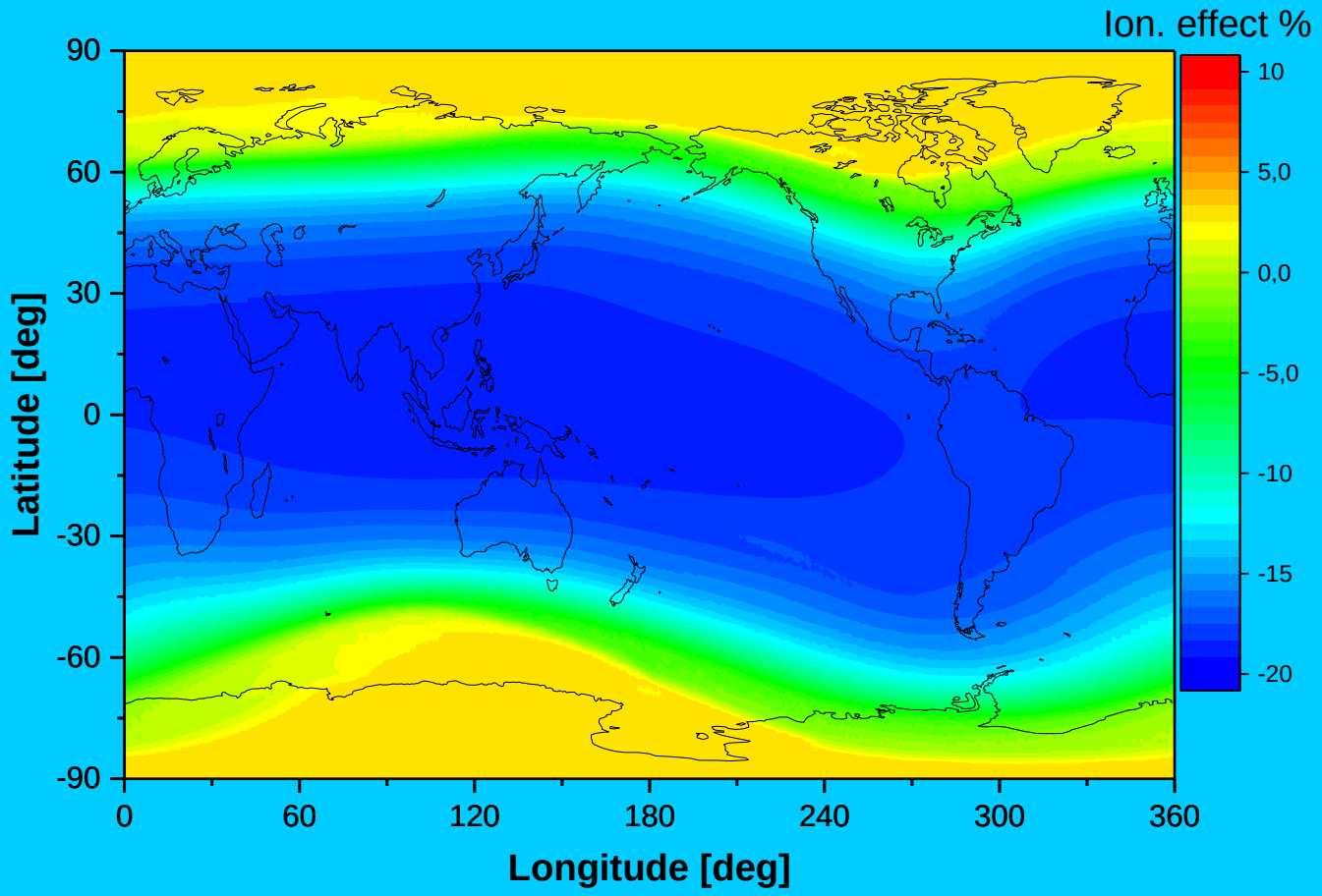

Fig. 3. Global map of Ionization effect in the region of Regener-Photzer maximum due to CRs of galactic and solar origin during the second Halloween event – GLE 66 on 29 October 2003

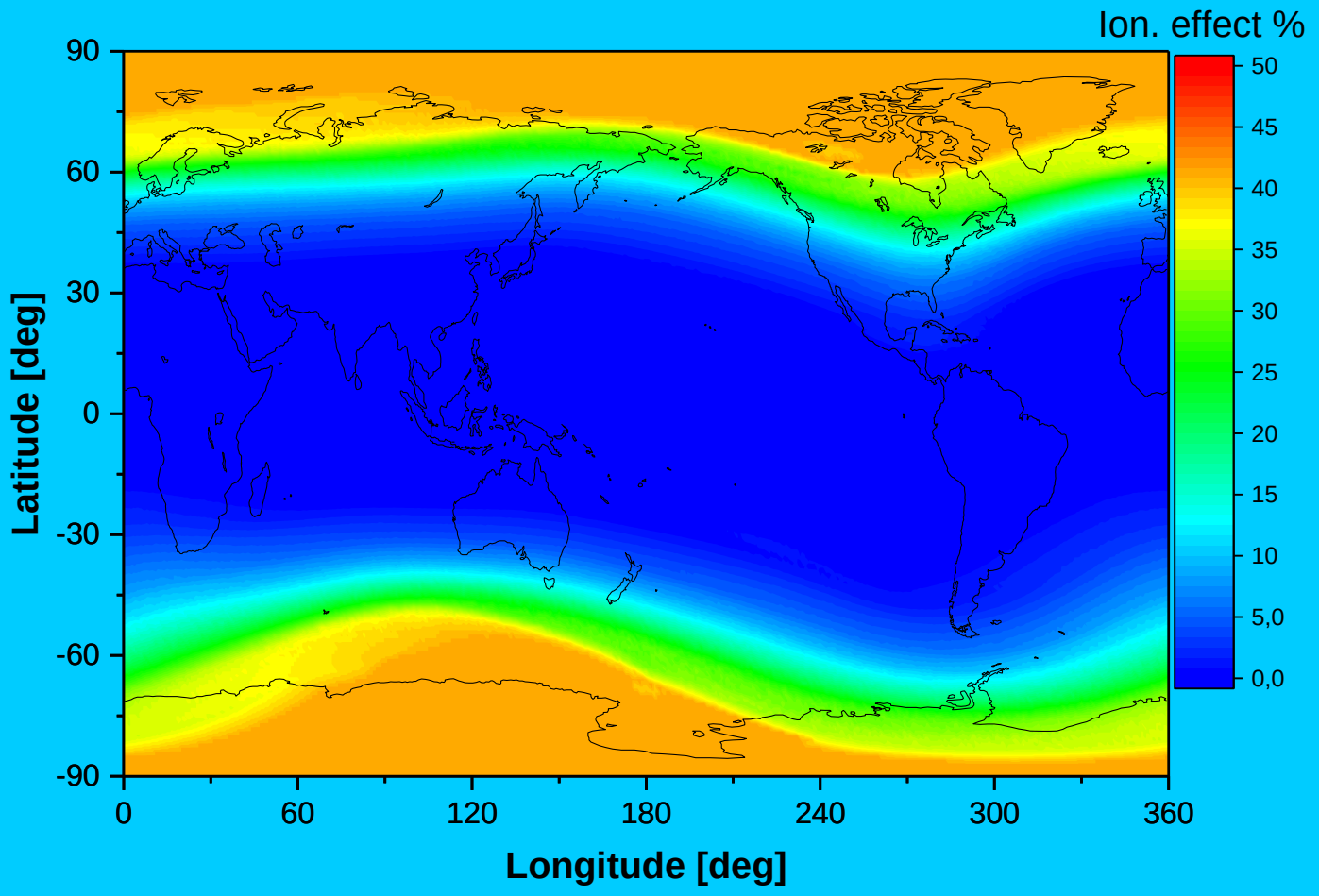

Fig. 4. . Global map of Ionization effect in the region of Regener-Photzer maximum due to CRs of galactic and solar origin during the third Halloween event – GLE 67 on 2 November 2003

Discussion and conclusion. Detailed study ofthe impact ionization due to high-energy particles, specifically during strong solar particle events, allows one to perform a thorough analysis of various mechanisms related to minor components physics.For realistic assessment of the possible effect of precipitating high-energy particles in the atmosphere on atmospheric chemistry and physics, it is necessary to compute the ionization effect at various time scales, possibly over large scales. Therefore, the presented here averaged 24h effect during several GLEs, computed in the region of Regener-Photzer maximum, where the ionization effect reaches its greatest values, is an important contribution in the field of atmospheric physics. In this work, using reconstructed from ground-based and space-borne instruments SEP spectra we derived the ion production rate and the corresponding ionization effect during the sequence of Halloween GLE events in October–November 2003. For the first time the ionization effect due to high-energy SEP was computed during a sequence of several GLEs. The dynamics of GCRs and GLE particles flux was explicitly considered, which allowed us to make a realistic assessment of the ionization effect. The role of the Forbush decrease is significant and considerably reduce the total i.e. the integrated over three events ionization effect, specifically in mid and low latitudes. The computed ionization effect during the Halloween events in October-November 2003 give a good basis for further studies related to the space weather.

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