ATMOSPHERIC AND IONOSPHERIC IMPLICATIONS OF RADIATION BELT REMEDIATION

***C. J. Rodger*[1], *M. A. Clilverd*[2], *Th. Ulich*[3], *P. T. Verronen*[4], *E. Turunen*[3], *N. R. Thomson*[1]**

[1] Department of Physics, University of Otago, P.O. Box 56, Dunedin, New Zealand (crodger@physics.otago.ac.nz; n_thomson@physics.otago.ac.nz)

[2] Physical Sciences Division, British Antarctic Survey, Cambridge, United Kingdom (macl@bas.ac.uk)

[3] Sodankylä Geophysical Observatory, Sodankylä, Finland (esa@sgo.fi, thu@sgo.fi)

[4] Earth Observation, Finnish Meteorological Institute, Helsinki, Finland (pekka.verronen@fmi.fi)

Abstract

In this report we consider the upper atmospheric consequences of an Radiation Belt Remediation (RBR) system operating over either 1 or 10 days. The RBR-forced neutral chemistry changes, leading to NOx enhancements and Ox depletions, are significant during the timescale of the precipitation but are generally not long-lasting. These neutral atmosphere changes are no more significant than those observed during large solar proton events. In contrast, RBR-operation will lead to unusually intense HF blackouts for about the first half of the operation, producing large-scale disruptions to radio communication and navigation systems.

Background Information

It is recognised that high altitude nuclear explosions (HANEs) would shorten the operational lifetime of Low Earth Orbiting satellites, principally due to the population of HANE-injected >1 MeV trapped electrons. Theoretical calculations have concluded that wave-particle interactions caused by manmade very low frequency (VLF) transmissions may dominate non-storm time losses in the inner radiation belts. This finding has sparked considerable interest, suggesting practical human control of the radiation belts to protect Earth-orbiting systems from natural and manmade injections of high energy electrons. This manmade control of the Van Allen belts has been termed "Radiation Belt Remediation" (RBR). In order to be effective, an RBR-system needs to flush the HANE-produced >1 MeV electrons in a short time scale, suggested as (~1-2 days) or perhaps as long as 10 days.

In this paper we consider the upper atmospheric consequences of an RBR system in operation. The dumping of high-energy relativistic electrons into the atmosphere will create intense energetic particle precipitation, leading to large ionisation changes in the ionosphere. Such precipitation is likely to lead to large changes in atmospheric chemistry and communications disruption, particularly for the case of HANE injections. Particle precipitation results in enhancement of odd nitrogen (NO_x) and odd hydrogen (HO_x). NO_x and HO_x play a key role in the ozone balance of the middle atmosphere because they destroy odd oxygen through catalytic reactions. Ionisation changes produced by a 1 MeV electron will tend to peak at ~55 km altitude. Ionisation increases occurring at similar altitudes, caused by solar proton events are known to lead to local perturbations in ozone levels. Changes in NO_x and O_3 consistent with solar proton-driven modifications have been observed. It is well-known that the precipitation of electrons at high latitudes produce addition ionisation leading to increased HF absorption at high-latitudes, in extreme cases producing a complete blackout of HF communications in the polar regions.

In order to estimate the significance of RBR-driven precipitation to the upper atmosphere, we consider two cases of an RBR-system operating to flush the artificial radiation belt injected by a Starfish Prime-type HANE over either 1 or 10 days. In the first case we consider the effect of a space-based system, while in the second case we also consider a ground-based RBR system. This work examines the range of realistic potential environmental and technological effects due to this manmade precipitation, including changes to the ozone-balance in the middle atmosphere, and disruption to HF communication. The results of this study have been previously published as: Rodger, C J, M A Clilverd, Th Ulich, P T Verronen, E Turunen, and N R Thomson, The atmospheric implications of Radiation Belt Remediation, Annales Geophys., 24(7), 2025-2041, SRef-ID: 1432-0576/ag/2006-24-2025, 2006