URSI AP-RASC, Sydney, Australia, 17-22 August 2025

Modeling ionospheric variabilities due to chorus waves

Lunjin Chen* (1), Robert Marshall (2), and Grant Berland (3)
(1) The University of Texas at Dallas, Richardson, TX, USA, 75080, e-mail: lunjin.chen@gmail.com;
(2) The University of Colorado Boulder, Boulder, CO, USA, 80309 e-mail: Robert.Marshall@Colorado.EDU;
(3) The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA, 20723; e-mail: grant.berland@jhuapl.edu;

During magnetospheric storms, radiation belt electrons are produced and then removed on varying timescales. An efficient loss process is microbursts, strong, transient precipitation of electrons into the lower atmosphere over a wide energy range, from tens of keV to sub-relativistic and relativistic energies (100s keV and above). Revealing the physical mechanism behind the microbursts advances our understanding of radiation belt dynamics and its impact on the lower atmosphere and space weather. General characteristics of chorus-driven microbursts can be modeled via test particle simulation. The energy-time dispersion of electron microbursts can be explained via time-of-flight analysis with short-living and propagating chorus waves [1]. The effect of individual microbursts on the ionospheric changes is investigated by coupling wave-particle interaction model in the magnetosphere [1], GEANT4 model [2], and ionospheric chemistry (GPI) model [3]. It is found that the response in the ionosphere is highly dependent on altitude, due to various time scales of different processes (chemistry recovery time scale, individual microburst time duration, repetition period of chorus waves) involved. Figure 1 shows an example of simulation results of ionospheric variability induced by a single chorus element. The chorus element in the magnetosphere leads to less-than-1s pulse of ionization rate over 60-150 kms (Fig 1a, 1b). Ionospheric chemistry process leads to a continuous increase of electron density over the duration of the pulse (Fig 1c, 1d), followed by slow recover to the initial state over the typical chemistry time scale, depending on the altitudes, e.g., 10s seconds at 90 km (Fig 1d).

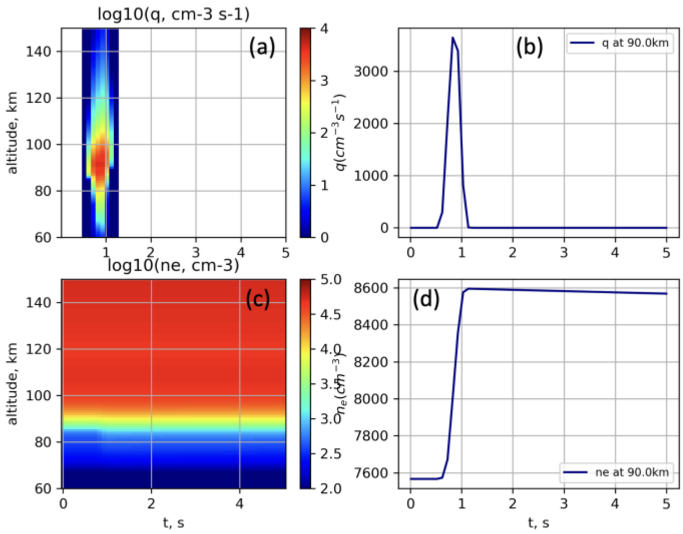

Figure 1. (a) electron-ion pair production rate in unit of cm-3 s-1 as a function of altitude and time due to electron precipitiation due to a single chorus element. (c) electron density variation as a result of the chorus-driven ionization source. (b) and (d) shows line profiles of (a) and (b), respectively, at a fixed altitude of 90 km.

1. Chen, L., Breneman, A. W., Xia, Z., & Zhang, X.-J. (2020). Modeling of bouncing electron microbursts induced by ducted chorus waves. Geophysical Research Letters, 47, e2020GL089400. https://doi.org/10.1029/2020GL089400
2. Berland, G. D., Marshall, R. A., Capannolo, L., McCarthy, M. P., & Zheng, L. (2023). Kinetic modeling of radiation belt electrons with Geant4 to study energetic particle precipitation in Earth's atmosphere. Earth and Space Science, 10, e2023EA002987. https://doi.org/10.1029/2023EA002987
3. Kaeppler SR, Marshall R, Sanchez ER, Juarez Madera DH, Troyer R and Jaynes AN (2022), pyGPI5: A python D- and E-region chemistry and ionization model. Front. Astron. Space Sci. 9:1028042. doi: 10.3389/fspas.2022.1028042