Geophysical Research Abstracts
Vol. 16, EGU2014-2522-1, 2014
EGU General Assembly 2014

Empirical Determination of Solar Proton Access to the Polar Atmosphere

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Violent expulsions on the Sun's surface release high energy solar protons that ultimately affect ionization levels and the local chemical composition in the upper atmosphere as well as High Frequency (HF) communication used by aircraft. The geomagnetic field screens the low altitude equatorial region, but these protons can access the atmosphere over the poles. The latitudes over which the solar protons can reach vary with geomagnetic indices such as Kp and Dst. In this study we use observations from Low Earth Orbit to determine the atmospheric access of solar protons and hence the flights paths most likely to be affected. Observations taken by up to six polar orbiting satellites during 15 solar proton events are analyzed. From this we determine 16,850 proton rigidity cutoff estimates across 3 energy channels. Empirical fits are undertaken to estimate the most likely behavior of the cutoff dependence with geomagnetic activity.

We provide simple equations by which the geomagnetic latitude (spatial extent) at which the protons impact the atmosphere can be determined from a given Kp or Dst value. The variation found in the cutoff with Kp is similar to that used in existing operational models, although the changing Kp value is found to lead the variation in the cutoffs by $\sim$3 hours .We also suggest a $\sim$1-2° equatorward shift in latitude would provide greater accuracy. This solar proton access can be used as an input into coupled chemistry climate models and give the likely polar regions to be effected by Polar Cap Absorption (PCA) which causes HF radio "blackout zones". We find that a Kp predictive model can provide additional warning to the variation in proton cutoffs. Hence a prediction of the cutoff latitudes can be made $\sim$3 hours to as much as 7 hours into the future, meeting suggested minimum planning times required by the aviation industry.