Outer radiation belt electron lifetime model based on combined Van Allen Probes and Cluster VLF measurements

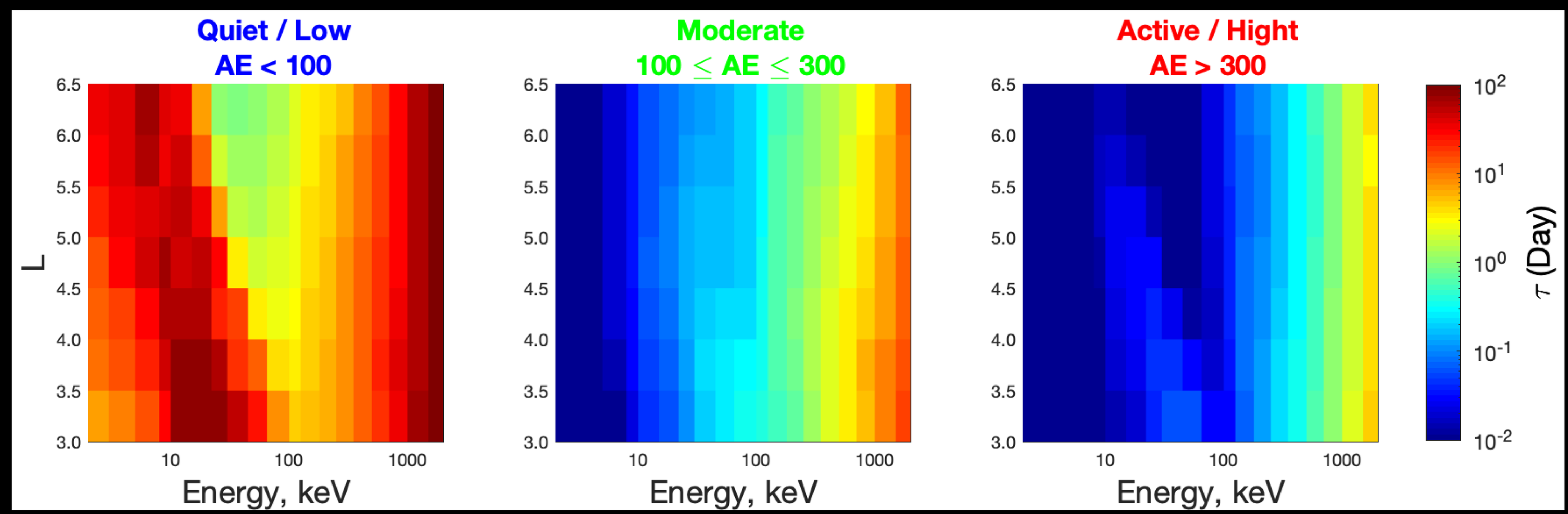
Homayon Aryan[1,2], Oleksiy V. Agapitov[3], Anton Artemyev[4], Didier Mourenas[5], Michael A. Balikhin[2], Richard Boynton[2], and Jacob Bortnik[1],

Abstract:

The flux of energetic electrons in the outer radiation belt shows high variability. Wave-particle interaction of electrons with very low frequency (VLF) chorus waves play a significant role in controlling the flux variation of these particles. Quantification of the effects from these interactions is crucially important for accurately modelling the global dynamics of the outer radiation belt and to provide a comprehensive description of electron flux variations over a wide energy range. We use a synthetic chorus wave model based on a combined database compiled from the Van Allen Probes and Cluster spacecraft VLF measurements (which takes into account recent findings of wave amplitude dependence on geomagnetic latitude, wave normal angle distribution, and variations of wave frequency with latitude) to develop a comprehensive parametric model of electron lifetimes in the outer radiation belt as a function of geomagnetic activity level, L-shell (L), and magnetic local time (MLT). The present model lifetimes are compared to previous studies, analytical results and measured data with good agreement.

Electron Lifetimes:

The lifetime of electrons are calculated using an integral expression. The figure shows the electron lifetimes as a function of L and electron energy for quiet (left), moderate (middle), and active (right) geomagnetic conditions.



Electron lifetimes are relatively long (>10 days above 300 keV) during quiet conditions, but they become shorter during moderate and active geomagnetic conditions. Lifetimes are especially short for low energy electrons (<100 keV) that can be quickly (in less than 1-3 hours) precipitated into the atmosphere by chorus waves.

Generalized Analytical Formula:

The analytical lifetime formula from Mourenas et al. (2014) is used to derive a generalized formula to estimate electron lifetimes as a function of electron energy, L and geomagnetic activity.

$$\tau[days] = \frac{200[days.pT^2](E[keV]/511+1)((E[keV]/511+1)^2-1)^{3/4}}{(Bw[pT](L/6.6)^{3/4})^2}$$

Bw (L, quiet) = -0.5L + 9.1 pT

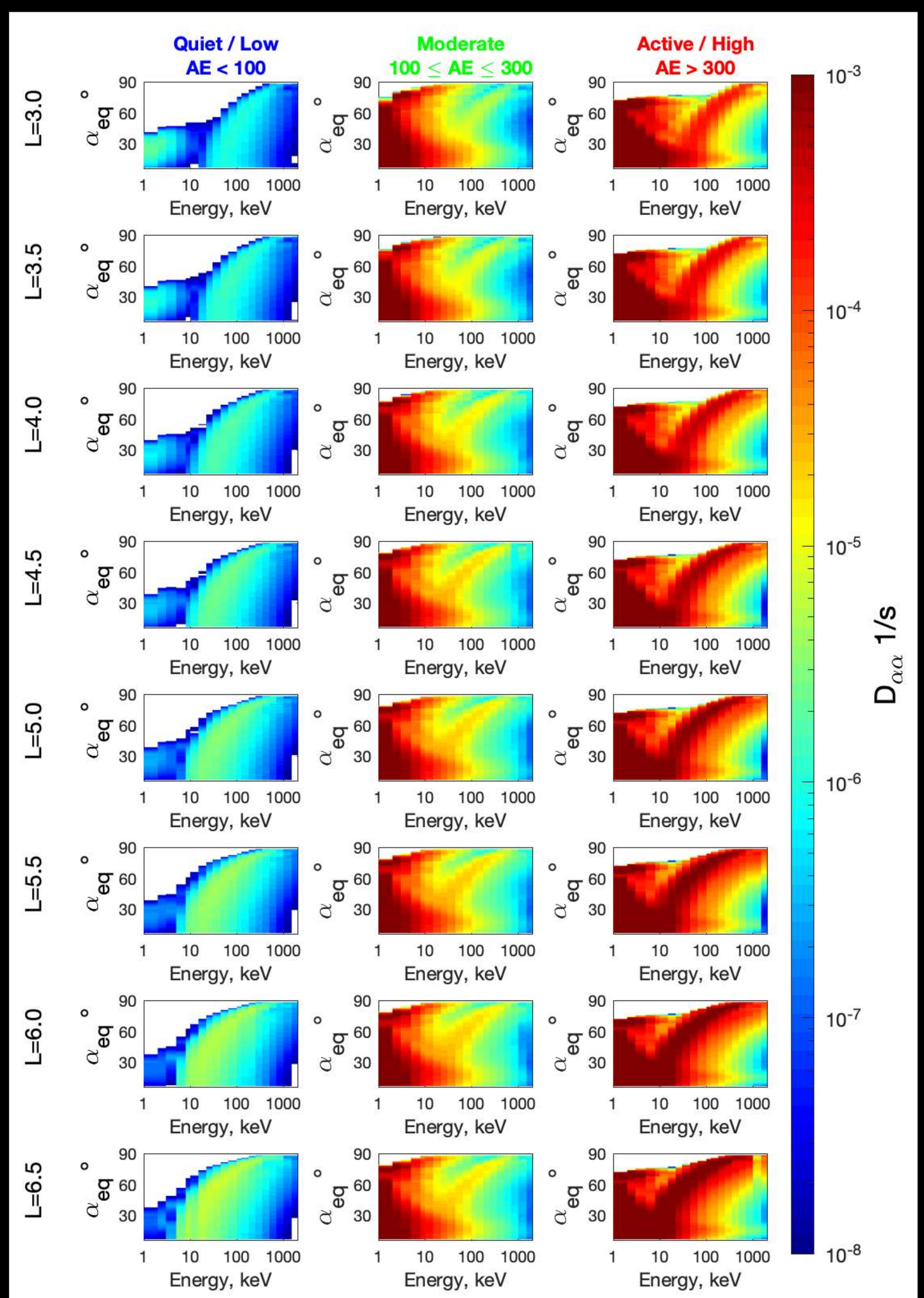
Bw (L, moderate) = -2.2L + 28.9 pT

Bw (L, active) = *Bw*(30 keV) * Exp(-0.1^(74/E[keV])) – 6(L - $\bar{L}$) pT

The above polynomials are derived to estimate the best wave amplitude (Bw) for different geomagnetic conditions as a function of L and electron energy.

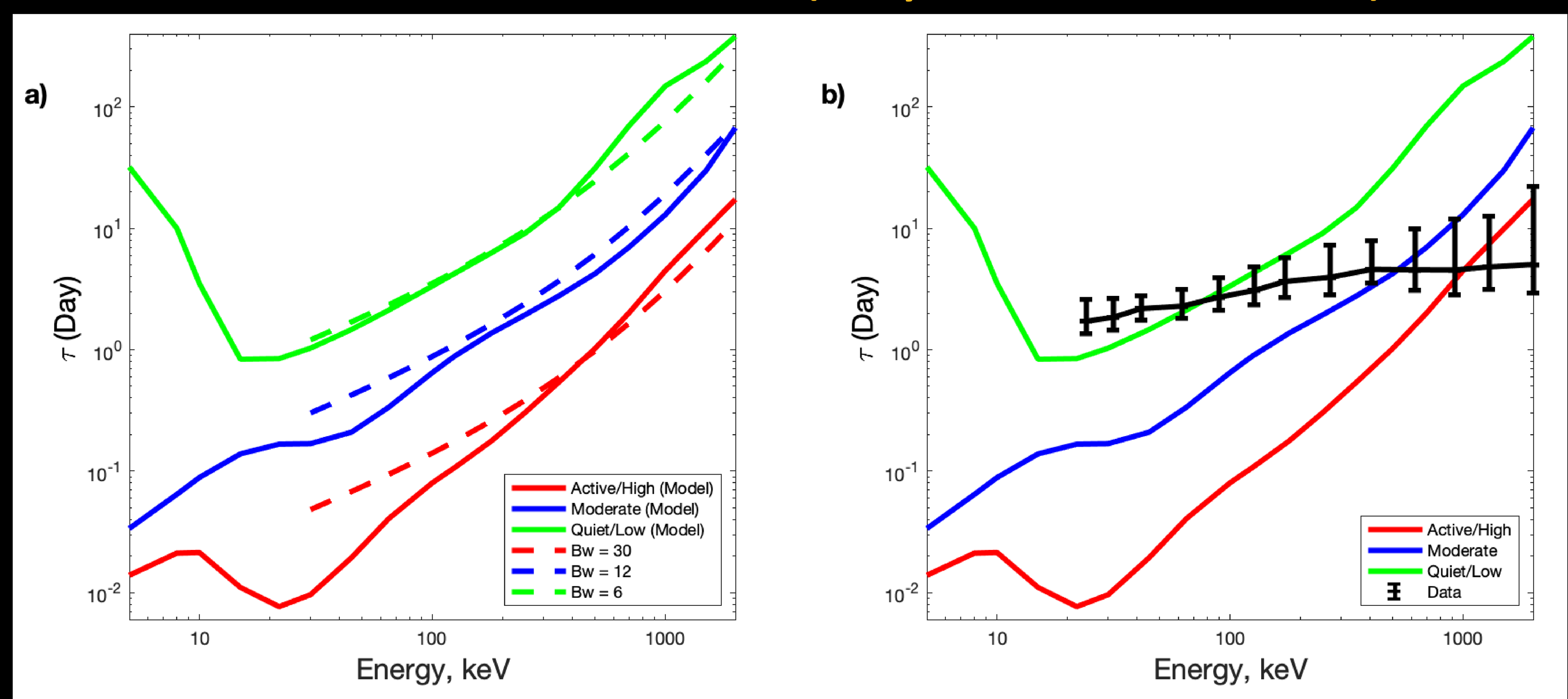
Local Pitch Angle Diffusion Coefficients

The local pitch angle diffusion coefficients are calculated for different MLT sectors as a function of geomagnetic activity, electron energy and equatorial pitch angle α_{eq}. The figure shows the average pitch angle diffusion coefficients $D_{\alpha\alpha}$ at L=3.0-6.5 (top to bottom at L=0.5 intervals) for quiet (left), moderate (middle), and active (right) geomagnetic conditions as a function of electron energy and equatorial pitch angle α_{eq}.



Data and Analytical comparisons:

Electron lifetimes are compared with analytical lifetime estimates (Mourenas et al. 2014) and measured lifetimes at GEO (Boynton et al 2014).



The figure shows the comparison between: a) numerical model (solid curves) and analytical lifetime estimates (dashed curves). b) numerical model and the measured average electron lifetimes at L=6.6, GEO (black curve), with 10 and 90 percentiles.

Conclusions:

A comprehensive synthetic chorus wave model is used to estimate electron lifetimes as a function of L, electron energy and geomagnetic activity. The results appear in relatively good agreement with observations, previous studies and analytical results. We generalize the analytical formula in by deriving numerically the polynomial function Bw(L, E) and estimate lifetimes as a function of L and E in the electron energy range of 30<E<2000 keV and L-shell in the range of 3<L6.5. The electron lifetimes are required to accurately calculate diffusion coefficients needed for radiation belt models. Precise calculations of electron lifetimes are crucial for accurately modelling and forecasting the global dynamics of the outer radiation belt.

Acknowledgment:

H.A. and M.A.B. are grateful to the STFC grant (grant: ST/R000697/1) and H.A. and J.B. are grateful for RBSP-ECT and EMFISIS funding provided by JHU/APL Contract 967399 and 921647 under NASA's Prime Contract NAS5- 01072.

1) *University of California Los Angeles, Atmospheric and Oceanic Sciences, Los Angeles, United States.*
2) *Department of Automatic Control and Systems Engineering, University of Sheffield, Sheffield, UK.*
3) *Space Sciences Laboratory, University of California Berkeley, Berkeley, United States.*
4) *University of California Los Angeles, Earth, Planetary, and Space Sciences, Los Angeles, United States.*
5) *CEA/DAM- ILE DE FRANCE, Arpajon, Chemin du Ru, 91680 Bruyères-le-Châtel, France.}*