MHD-test particles simulations of moderate CME and CIR-driven geomagnetic storms at solar minimum

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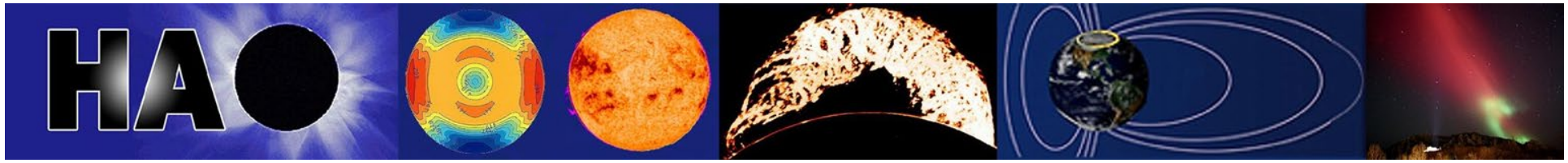
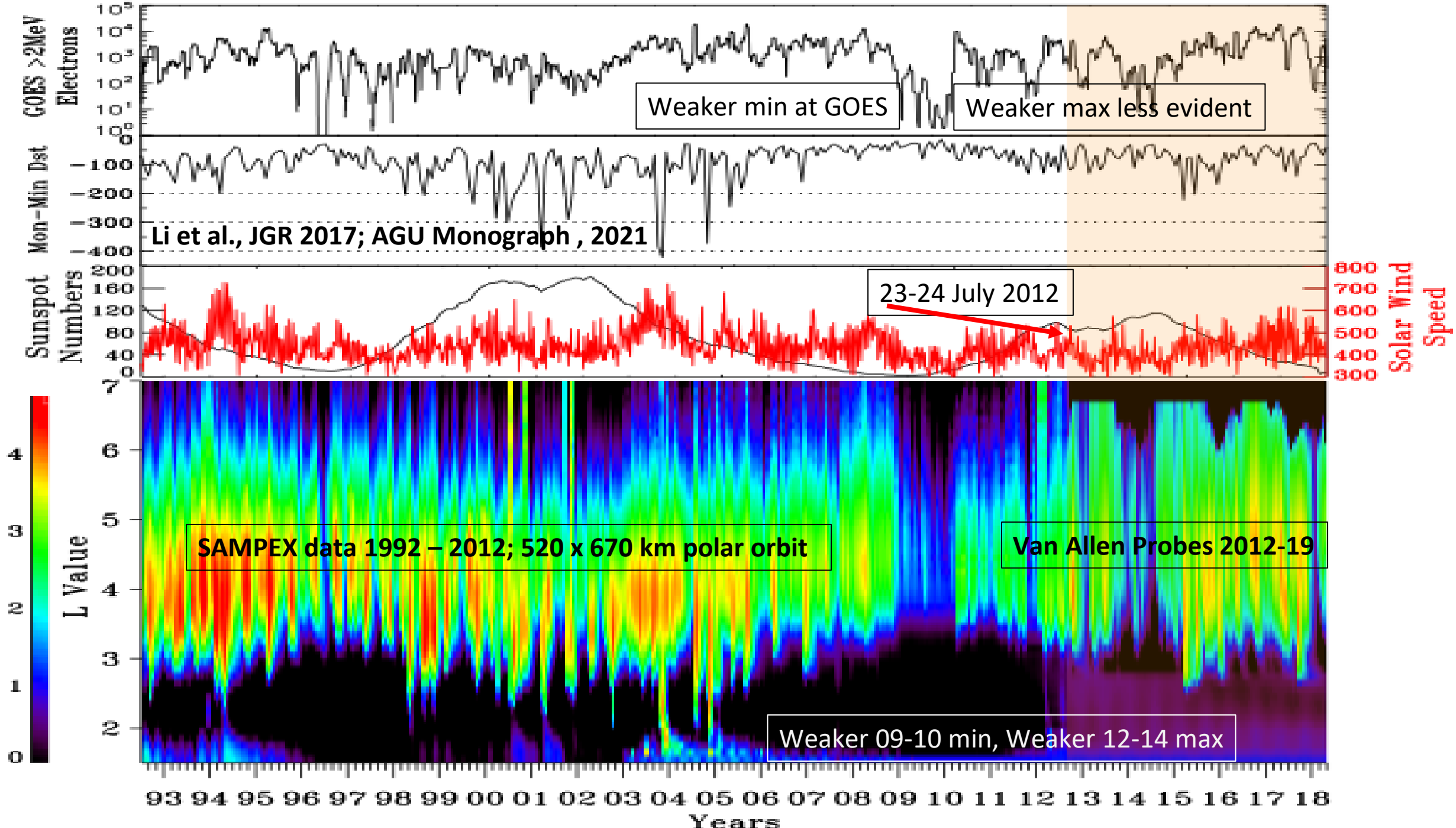
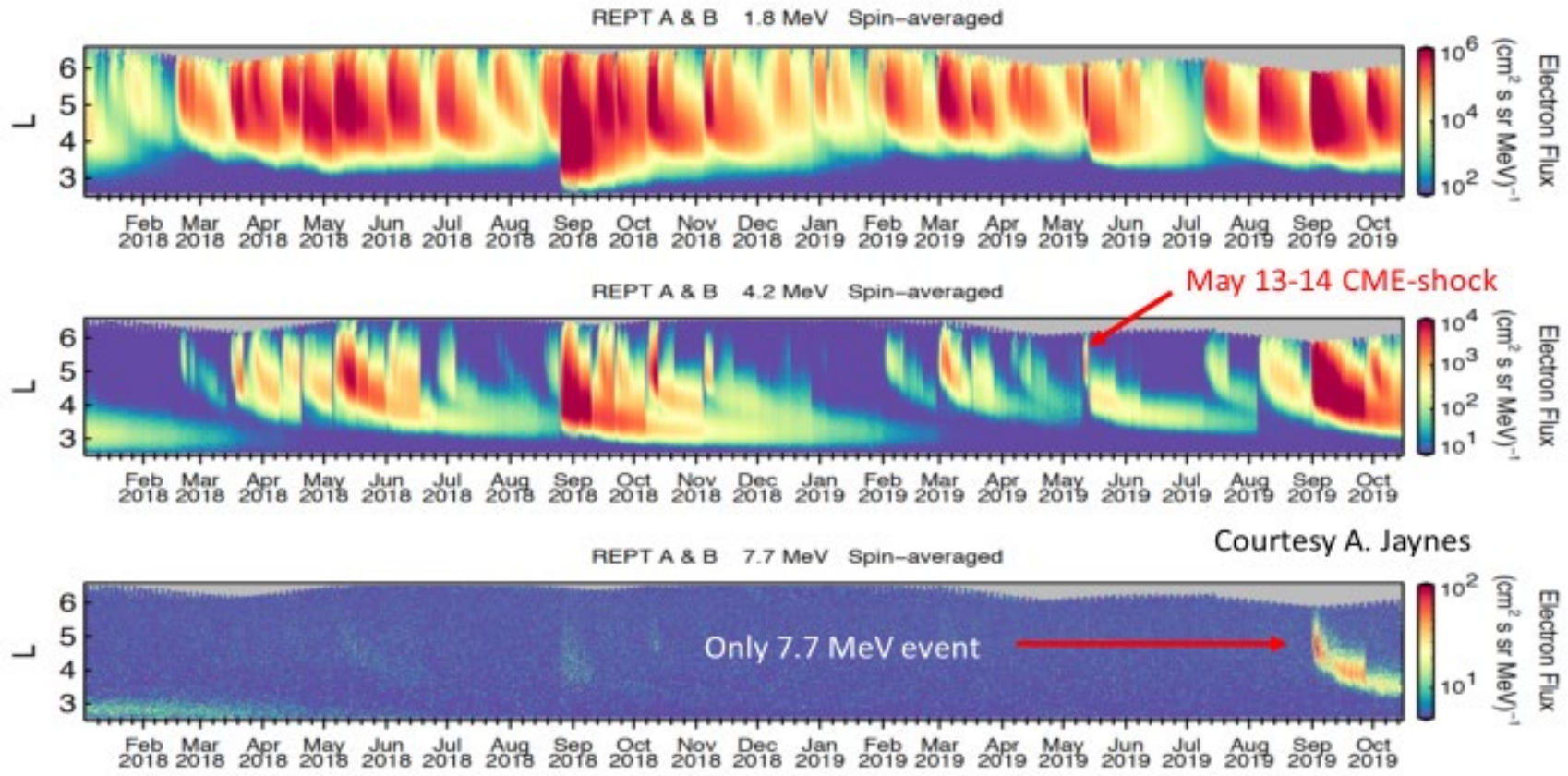


26 Years of Outer Zone Electron Measurements



Van Allen Probes REPT Data 2018-19

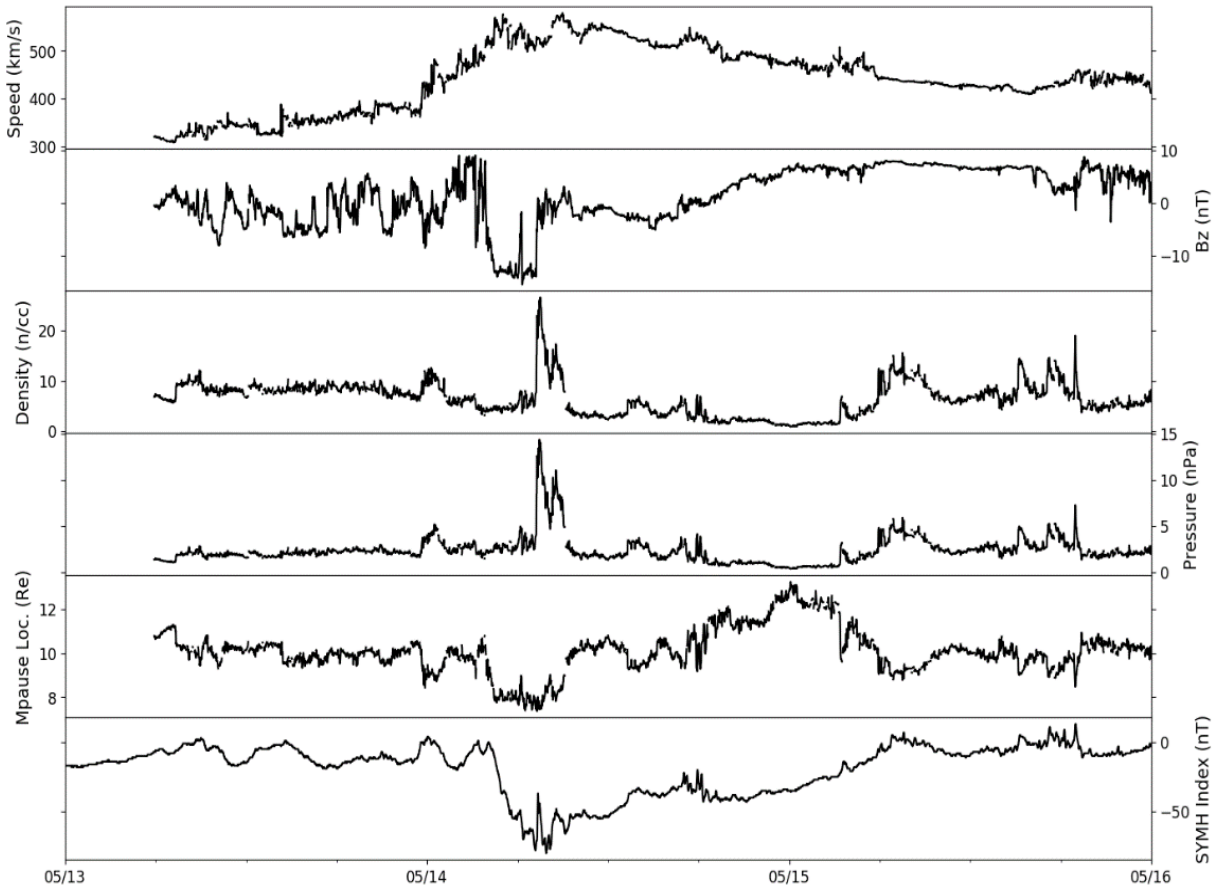


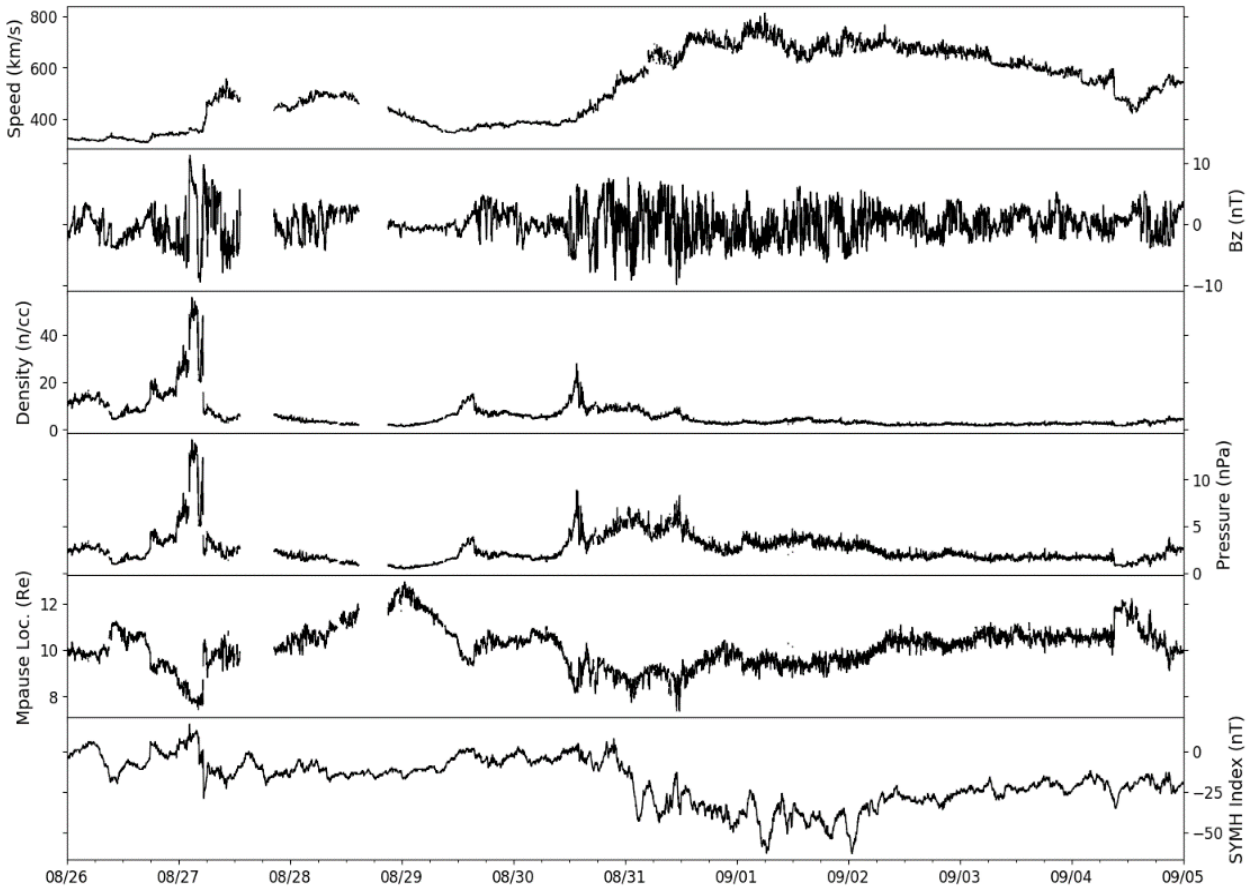
Courtesy A. Jaynes

Differential electron flux vs. *L* value (vertical axis) and time (horizontal axis) from the Relativistic Electron Proton Telescope on Van Allen Probes in three energy ranges from 1 January 2018 until the end of the mission. Arrows indicate the two event periods studied, a CME-shock event 13-14 May 2019 and a CIR event 30 Aug - 4 Sept 2019.

CME shock event 13-14 May 2019

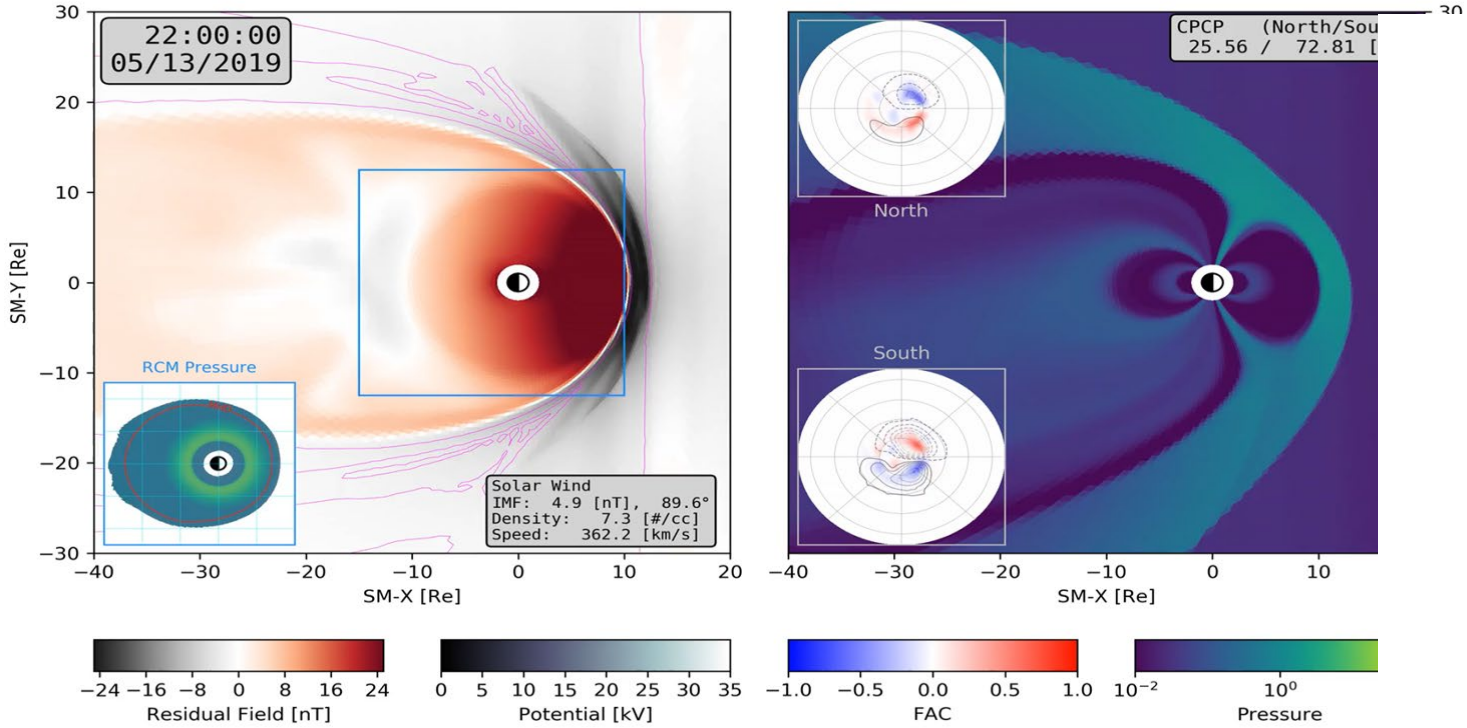
CIR event 26 Aug – 5 Sept

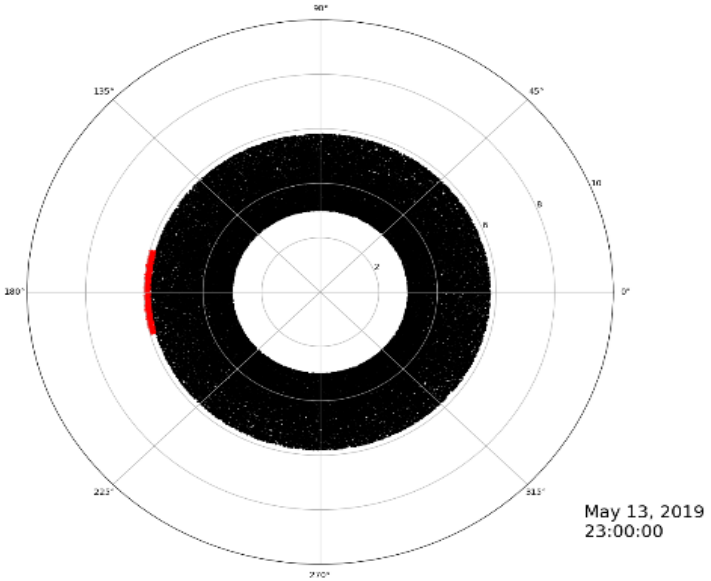




a) OMNIWeb solar wind data for 13 – 14 May 2019 CME-shock driven storm: speed Vsw, IMF Bz, density, pressure; Shue et al. (1998) magnetopause location and SymH in bottom two panels. CME-shock arrives at Earth ~ 00 UT 14 May. b) same for Aug-Sept 2019 CIR event. Vsw exceeds 600 km/s after 09 UT 31 Aug. The magnetopause location remains well outside geosynchronous for both events, however it is compressed inward to L = 8 for the CME-shock event.

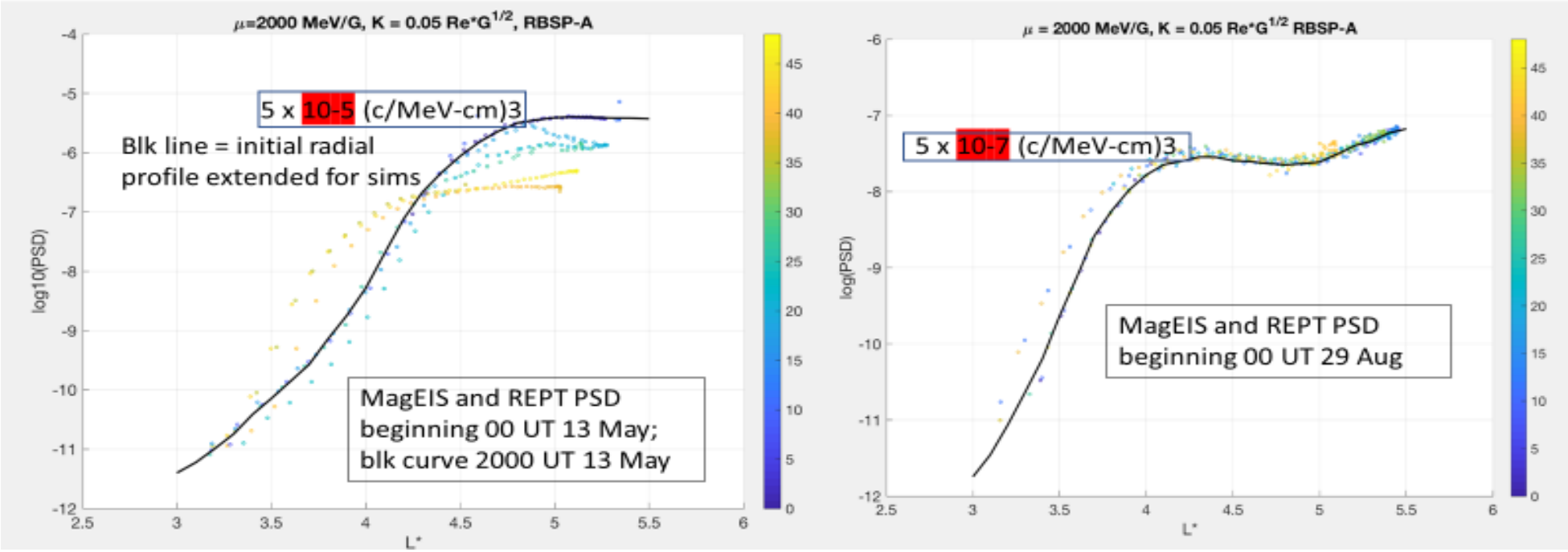
MHD Test Particle Simulations





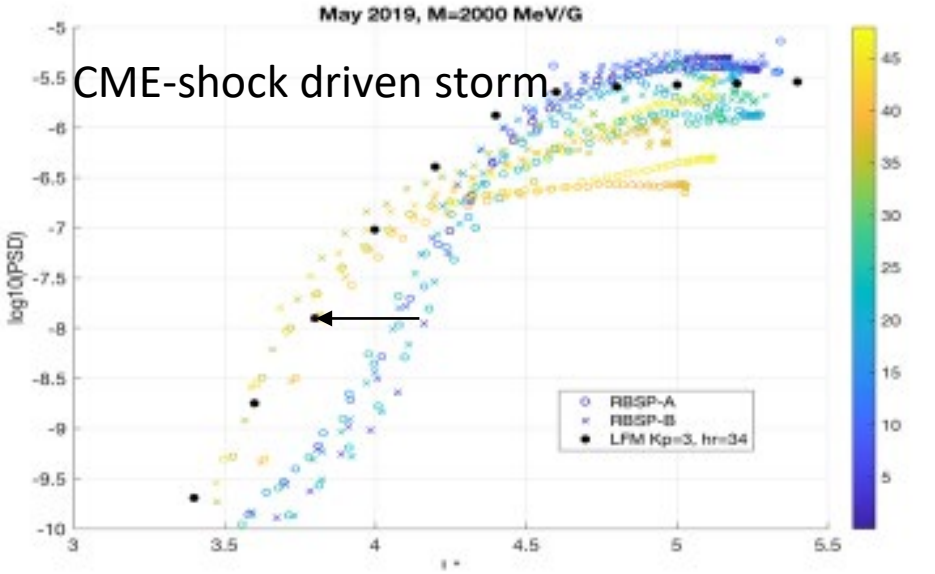
a) CME-shock simulation shown at 2200 UT 13 May 2019, using GAMERA 3D MHD code coupled to the Rice Convection Model and TIEGCM ionospheric model (Pham et al., 2021). Meridional plot of MHD pressure is shown on the right, with northern and southern hemispheric field aligned currents in the polar regions shown as inserts. On the left, residual Bz (dipole subtracted) is plotted along with an insert showing RCM pressure in the inner magnetosphere**.** Upstream solar wind input taken from OMNIWeb
propagated to the 30 Re upstream boundary. b) Initial test particle populations in the GSM equatorial plane. Injected (red) and trapped (black) are the same for both May and Aug – Sept 2019 event studies prior to weighting with PSD measured from

Initial VAP PSD profile May and Sept events

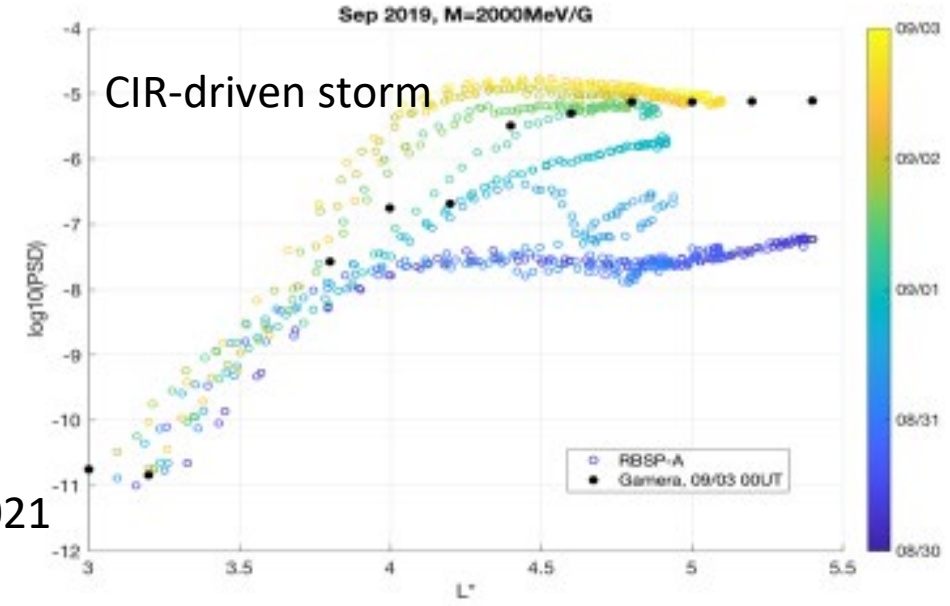


Radial profile of PSD for protons measured by REPT and MagEIS instruments on Van Allen Probe A for first invariant M = 2000 MeV/G (2 MeV at L = 6.6 in a dipole) and second invariant K =0.051 Re $G^{0.5}$ plotted vs. L* (Roederer, 1970) using TS04D magnetic field model. Initial orbit is shown (blue) and subsequent orbits indicated over 48 hours from 0 UT 13 May (left) and 0 UT 29 Aug (right). Black curve is used for simulated initial PSD radial profile of the trapped population for each event.

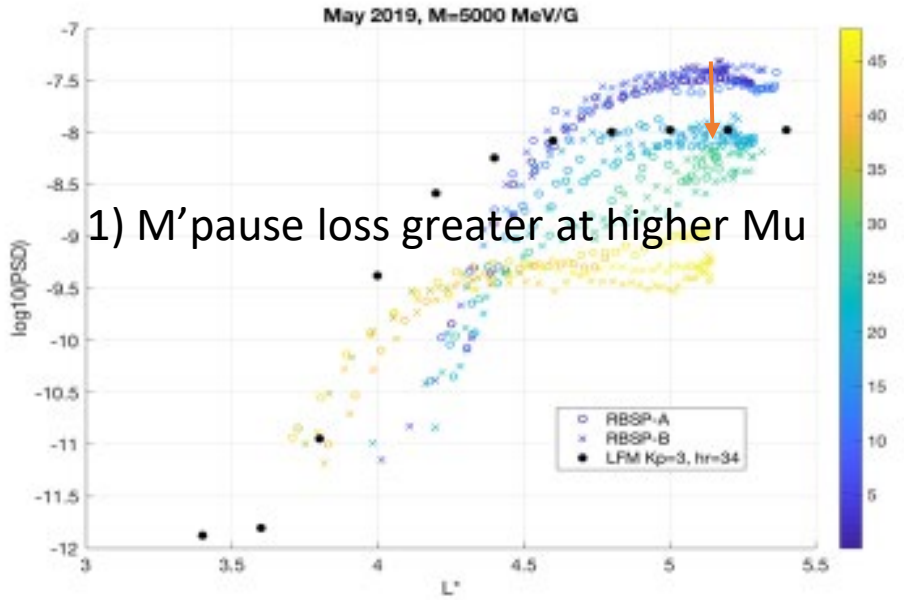
MHD-test particle simulations; following gc electrons in LFM-RCM (top) and GAMERA-RCM fields



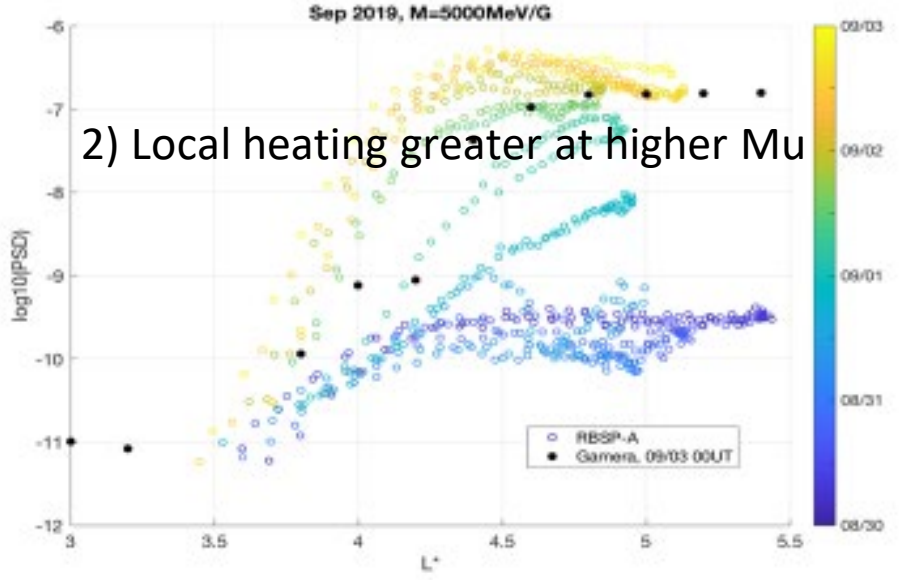
CME-shock driven storm



CIR-driven storm



1) M'pause loss greater at higher Mu

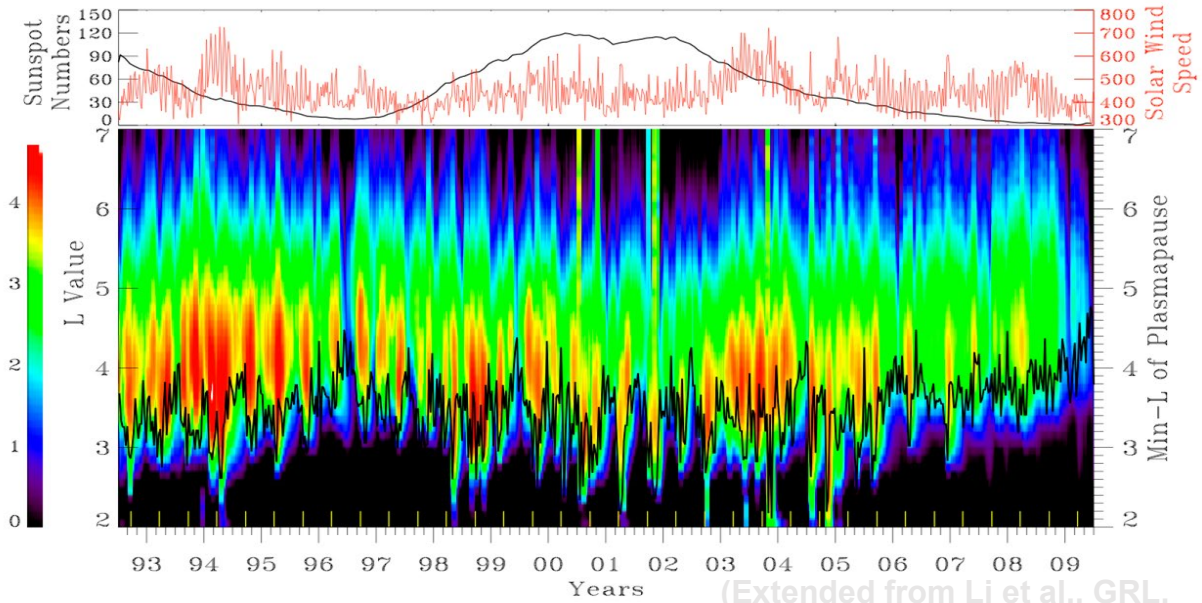


2) Local heating greater at higher Mu

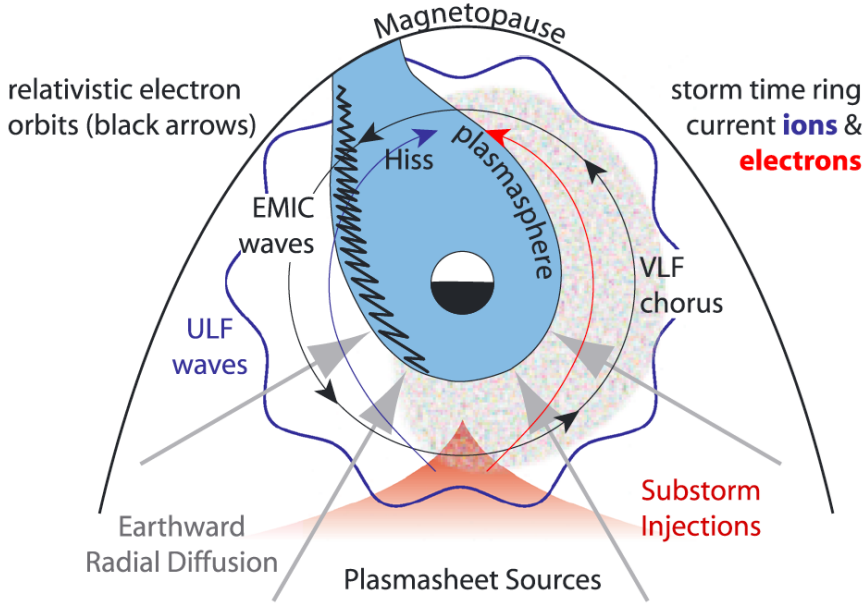
Hudson et al., 2021
WHPI workshop

Conclusions

- Two moderate (Dst = - 65, -52 nT) storms in 2019 with distinct solar wind drivers, CME-shock and CIR, were studied with MHD-test particle simulations and compared with Van Allen Probes measured PSD;
- May 13-14 CME-shock driven storm produced prompt loss at high L and inward radial transport;
- Aug-Sept CIR-driven storm produced enhanced PSD at all L over 4 days & PSD peak at L = 4.5, Mu = 5000 MeV/G
- End by noting importance of plasmasphere in determining inner boundary of outer zone electrons–
- Seen in minimum L of plasmapause: 1) marks transition from hiss loss to chorus acceleration not in MHD simulations;
- 2) obstacle to inward propagation of ULF waves captured by MHD-test particle simulations -> radial diffusion
- Inner magnetosphere is a region of interacting 1 eV to multi-MeV plasma populations – evolve in response to varying solar wind drivers, 2019 solar minimum more active drivers than 2009



(Extended from Li et al., GRL, 2006)



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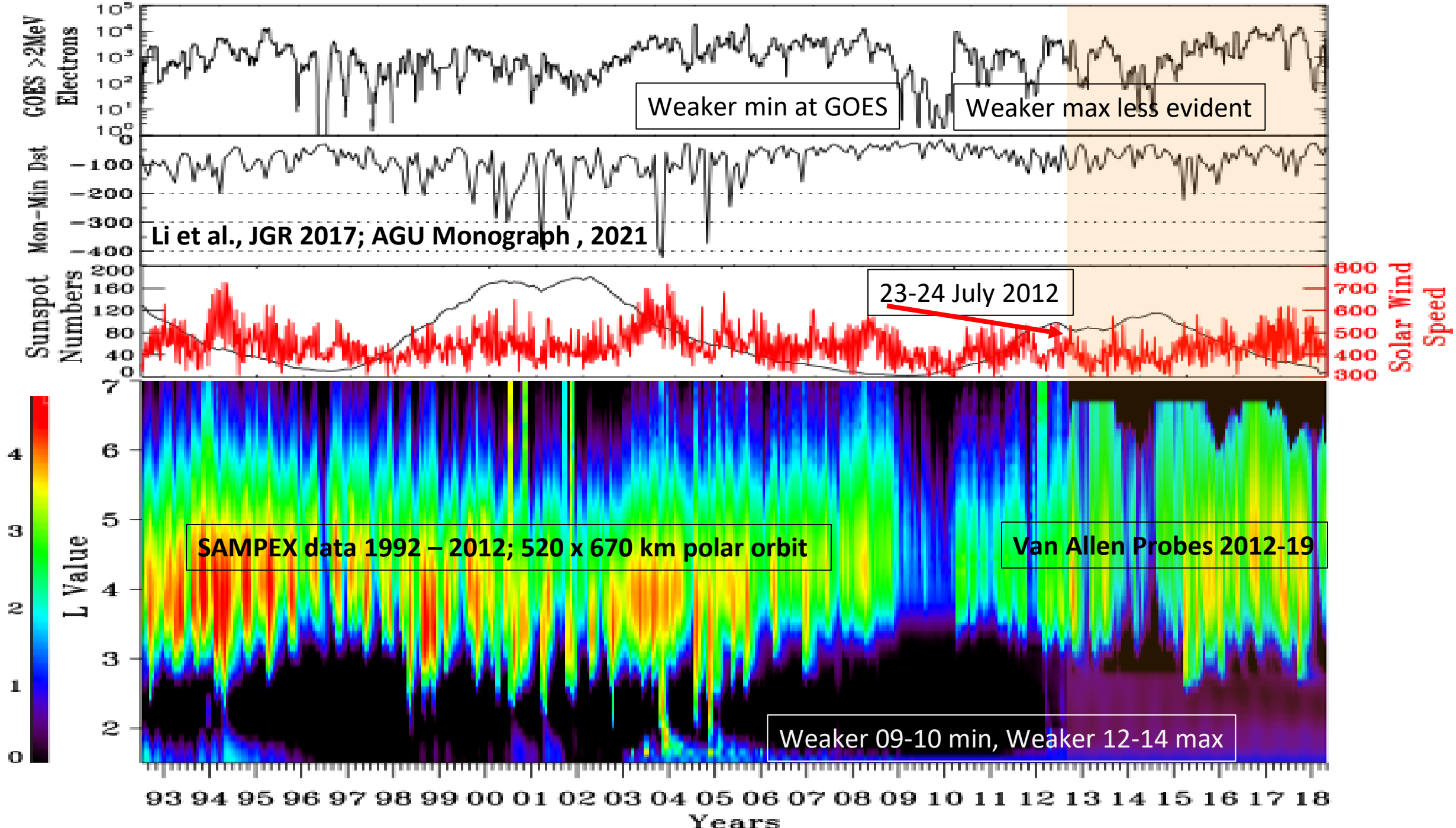
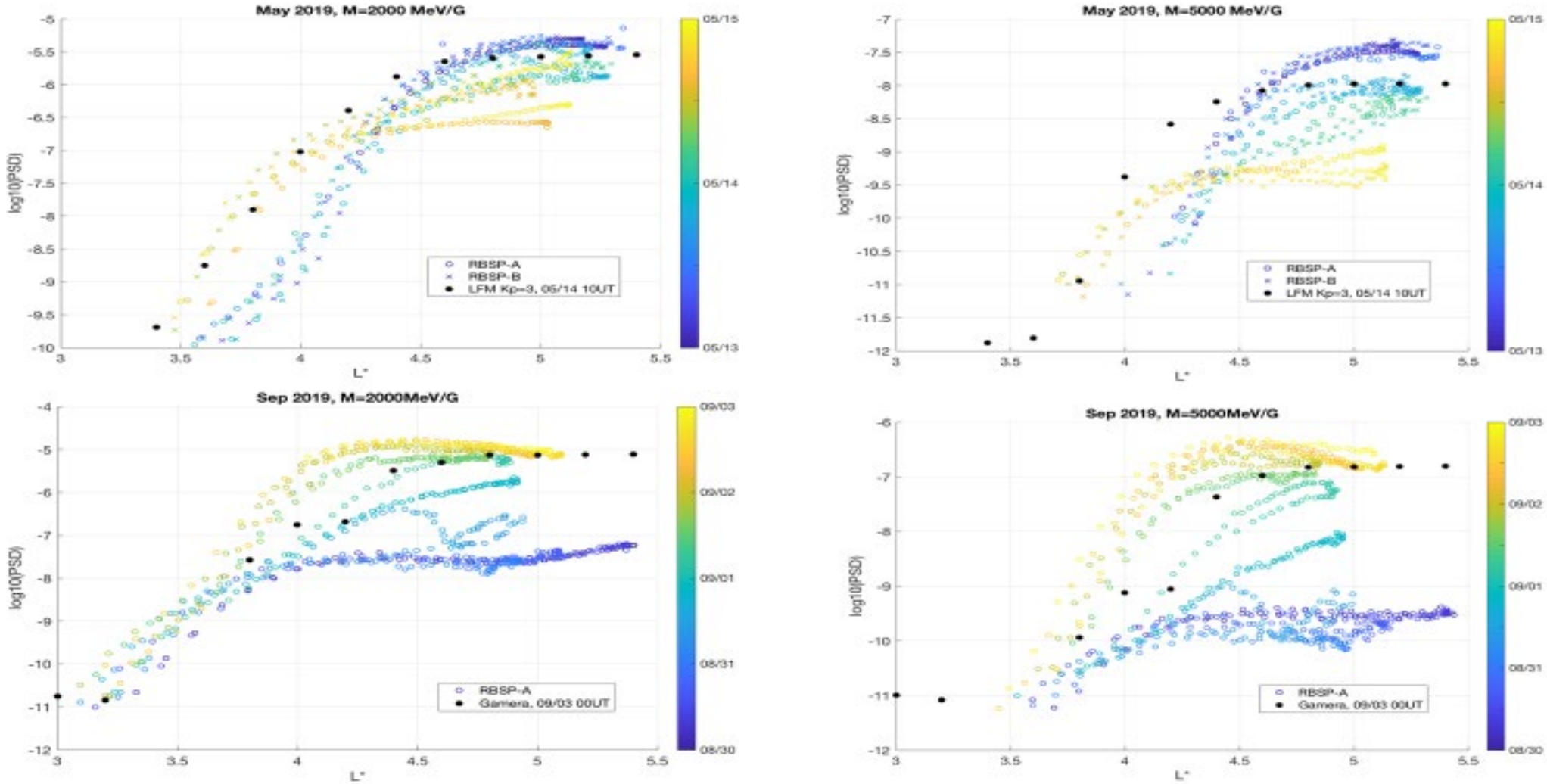


Extra Slides



Comparison of simulated PSD radial profile with measured PSD profiles from Van Allen Probes over sequential orbits. Initial orbit is shown (blue) and subsequent orbits are indicated over 2 days from 0 UT 13 May (top) and 4 days from 0 UT 30 Aug (bottom). Black dots indicate end of the simulation (after 34 hours of data shown for the May event and at 0 UT on 3 Sept for the September event) using PSD updated at apogee every 9 hours for the RBSPA and RBSP B spacecraft with data combined for the May event and only RBSP A measurements available every 9 hours for the September event.