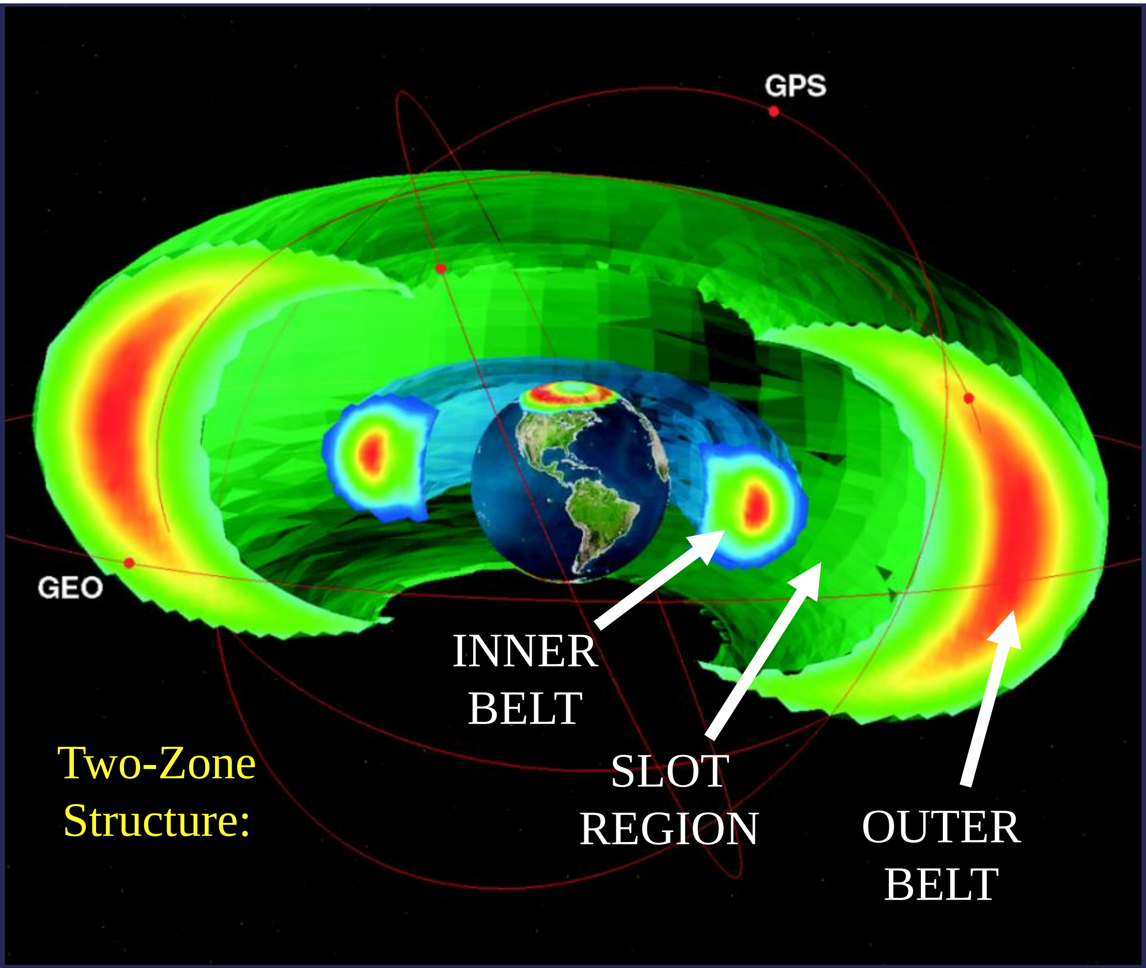
Combining ground and in-situ observations with modeling to understand dynamics of the radiation belts

Yuri Shprits and Adam Kellerman

Collaborators: Roman Makarevich, Emma Spanswick, Eric Donovan

Radiation Belts - Two Zone Structure



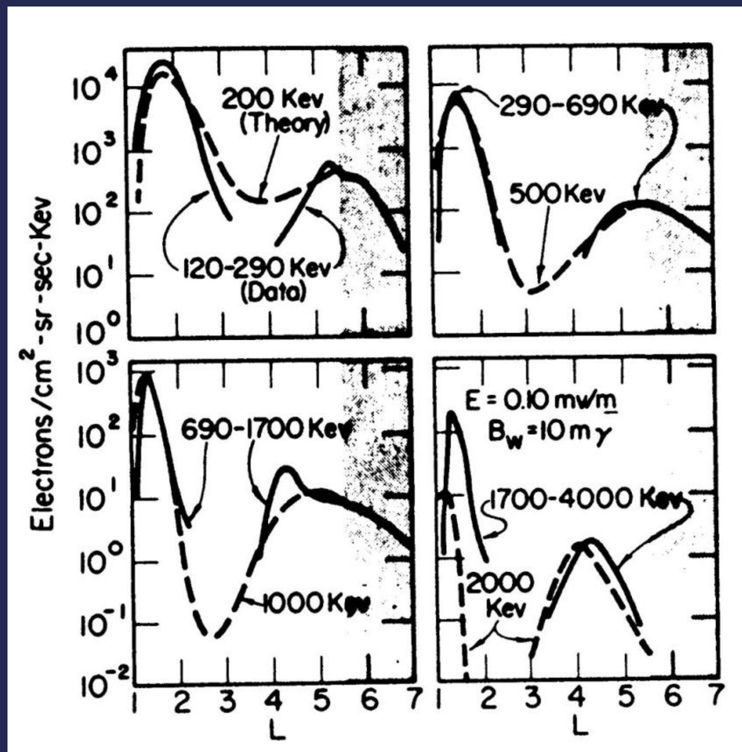
- Radiation belts – two donut shaped regions of high radiation encompassing the Earth
  - energies >100 keV
  - two-zone structure
- Inner belt: fairly stable
- Outer belt: can change on the time scale of an hour.

Theoretical Flux Profiles at Fixed Energy

$$\frac{\partial f}{\partial t} = L^2 \frac{\partial}{\partial L}\left[D_{LL} L^{-2} \frac{\partial f}{\partial L} \right] - \frac{f}{\tau_{effective}}$$

$$J(E,\alpha) = f(\mu, J, L^*) p^2$$

Two-Zone Structure



Underestimated the Inner Zone Fluxes

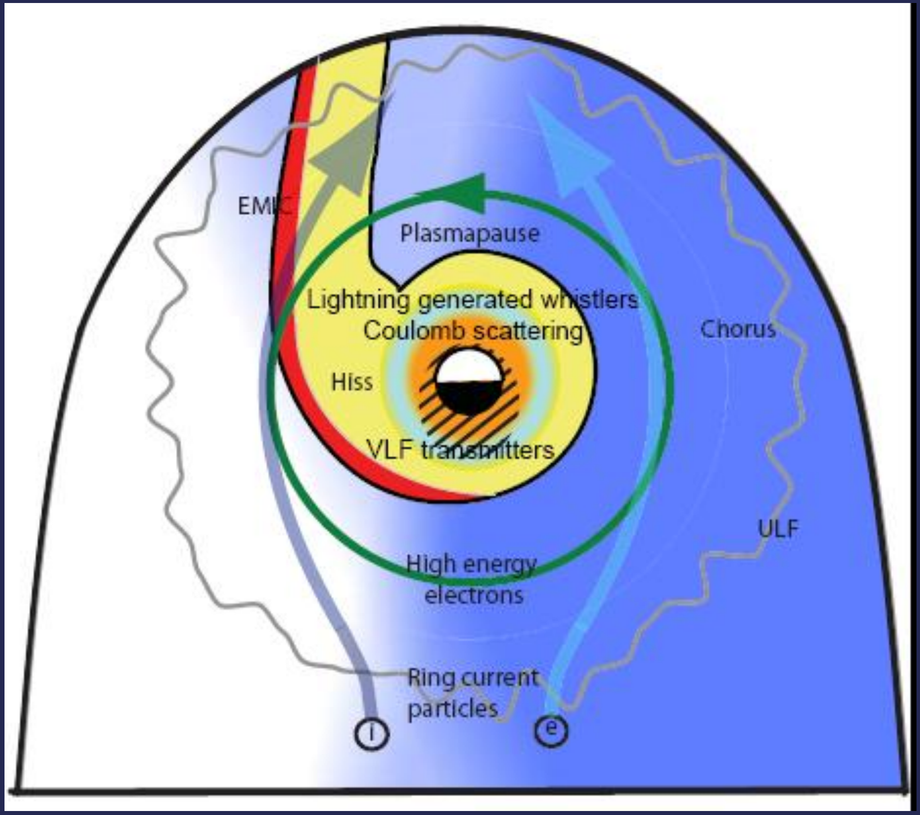
Realistic amplitudes in the outer zone
Successfully reproduced the slot region

Electron profiles obtained from the modeling of the quiet time inward radial diffusion and loss.

Theoretical profiles of fluxes agree with observations

Lyons et a., 1972; Lyons and Thorne, 1973

Competition Between Acceleration and Loss



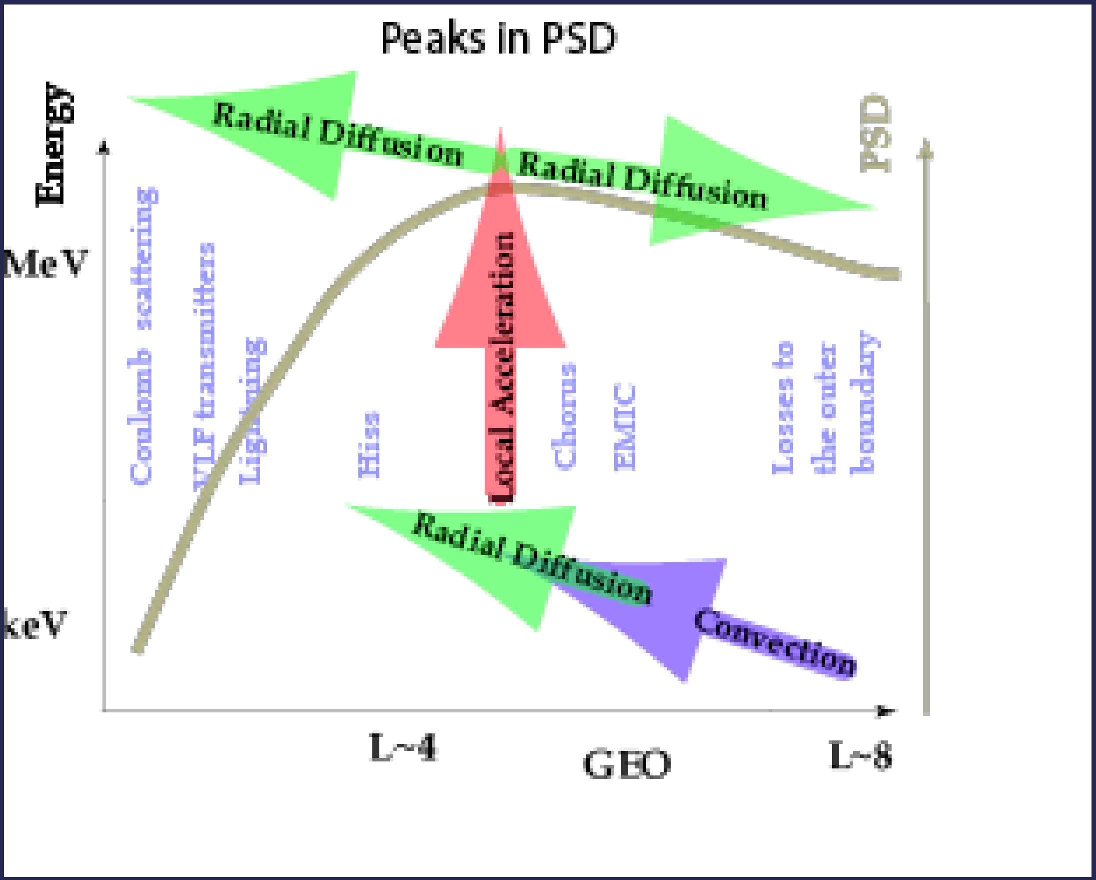
Inward radial diffusion driven by the ULF magnetic fluctuations.

Energy and pitch angle scattering due to resonance interactions with different waves.

Combined effect of losses to magnetopause and outward radial diffusion.

[Shprits et al., 2009 a,b Review JASTP]

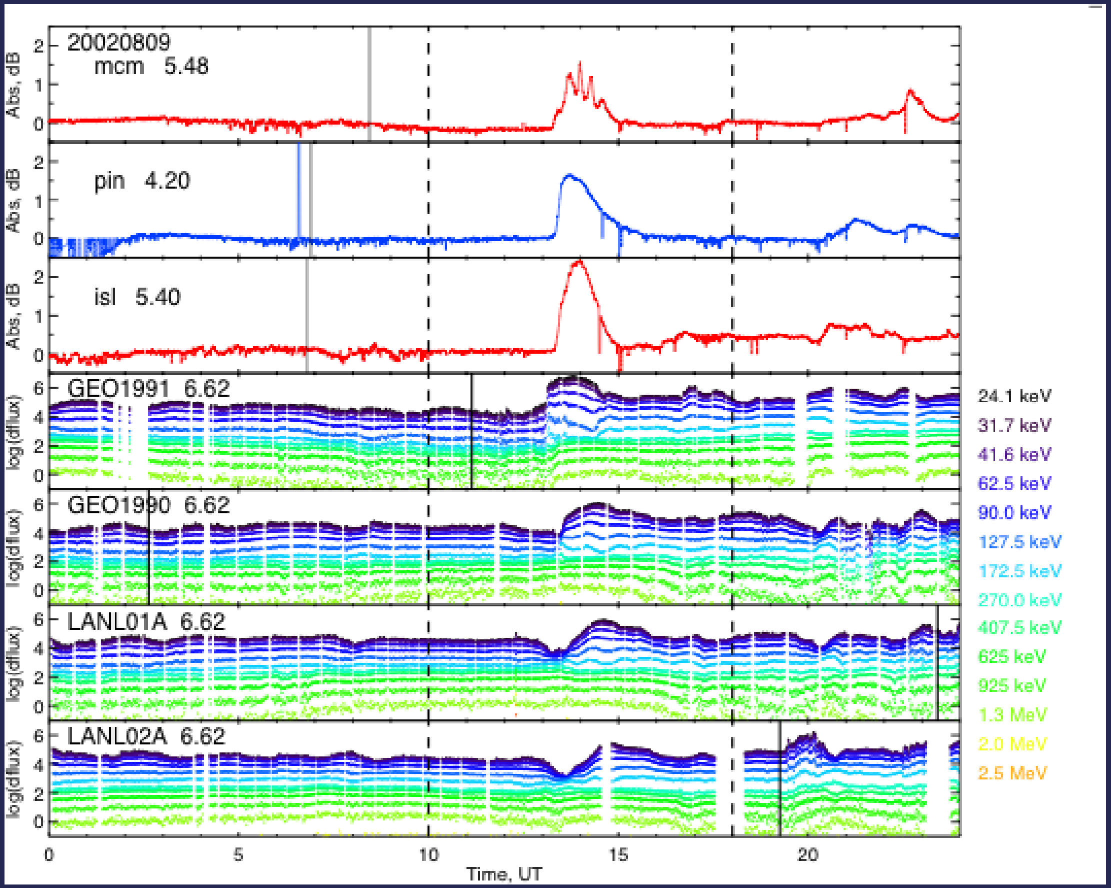
Acceleration Electrons to Relativistic Energies



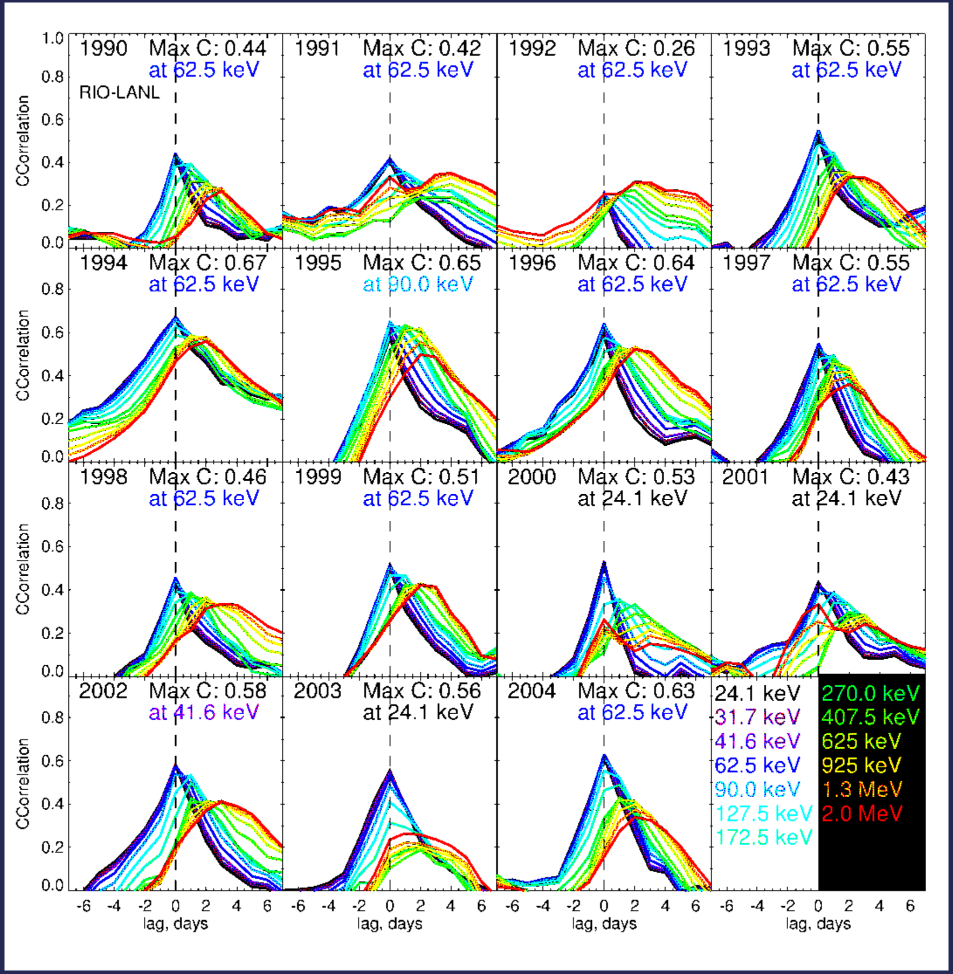
10th of keV electrons are injected into radiation belts. They are further accelerated by the inward diffusion and local acceleration to relativistic energies. This process takes ~2 days. Acceleration is followed by the bi-radial diffusion.

[Shprits et al., 2009, JGR]

Comparison Between Riometer Absorption and in-situ Measurements

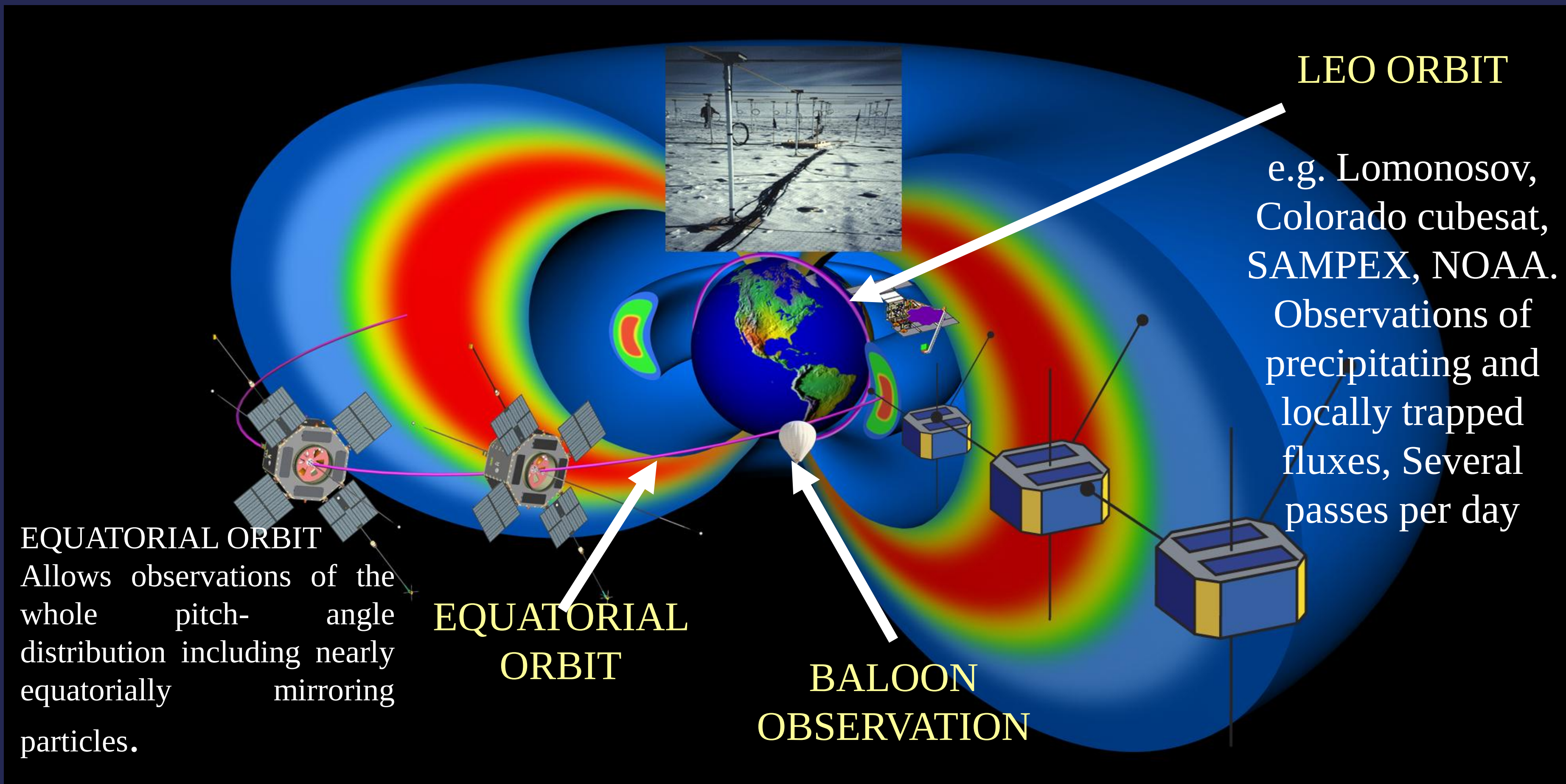


Cross-Correlation between LANL observations and riometers

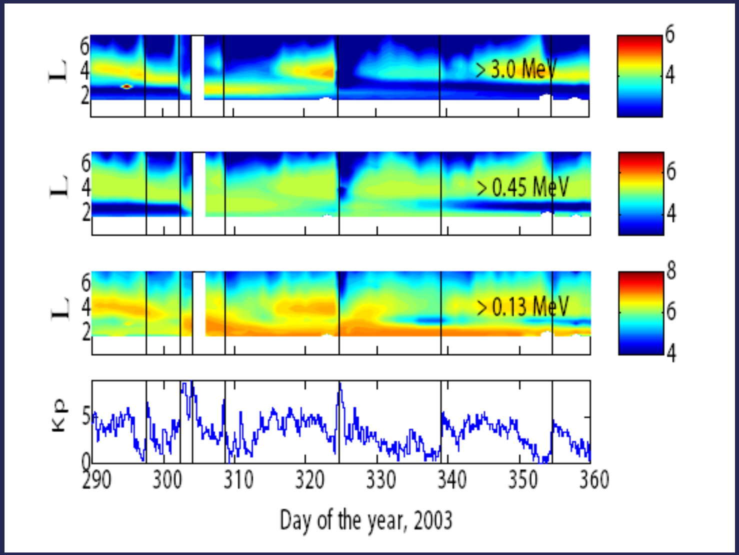


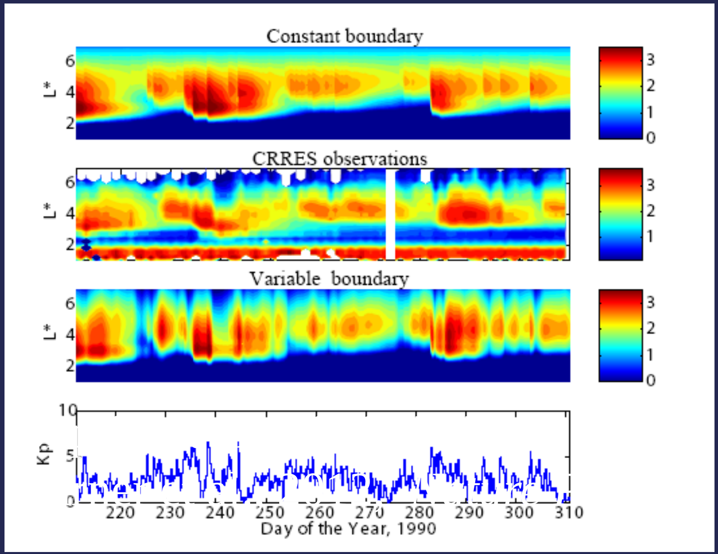
Cross-Correlation between LANL and riometer daily-averaged fluxes and absorption,. The color-coding represents the LANL energy channel (bottom right panel). The max correlation at zero lag and the corresponding energy channel is also shown in each panel.

Multi Point
Ground and In-situ Observations



Loss of Relativistic electrons in the Radiation Belts



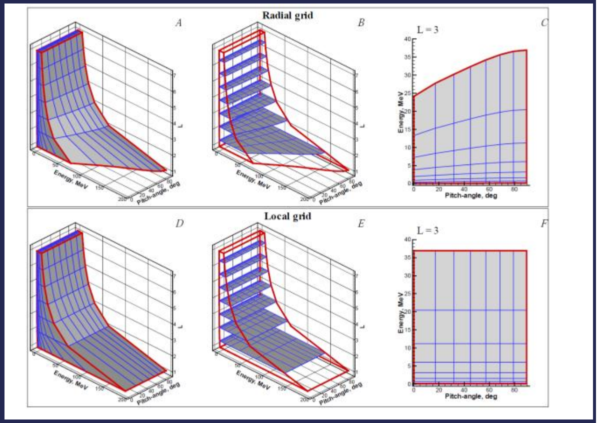


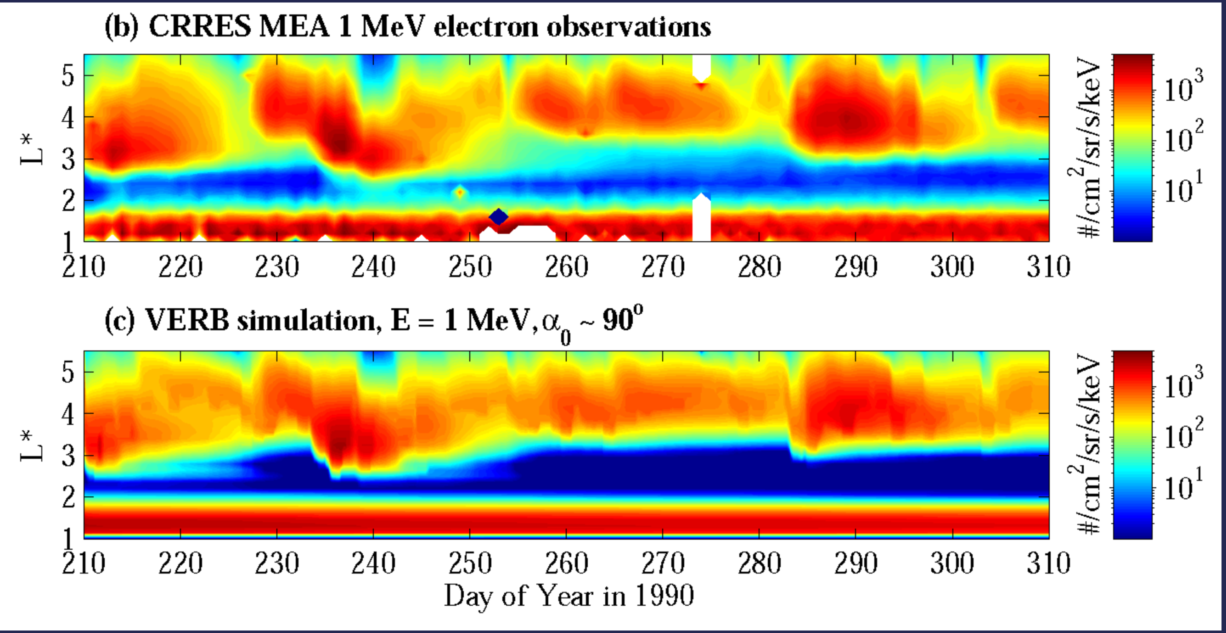
Shprits et al., 2006

Multi energy observations show that dropouts occur when magnetosphere is compresses and occur at low energy. The low energy dropouts cannot be explained by EMIC waves scattering

Radial diffusion simulations show that the outward radial diffusion can propagate losses down to low L-shells. Recent observations of Ohtani et al Morley et al Chen et al and Turner et al showed that loss to magnetopause and the outward radial diffusion may dominate over loss to the atmosphere.

Validation of the VERB Code for Over 100 Days in 1990





- VERB predicts the instantaneous location of the upper boundary of the slot region, the empty slot region, the stable inner belt, the location of the peak of fluxes and the amplitude of fluxes.

Summary

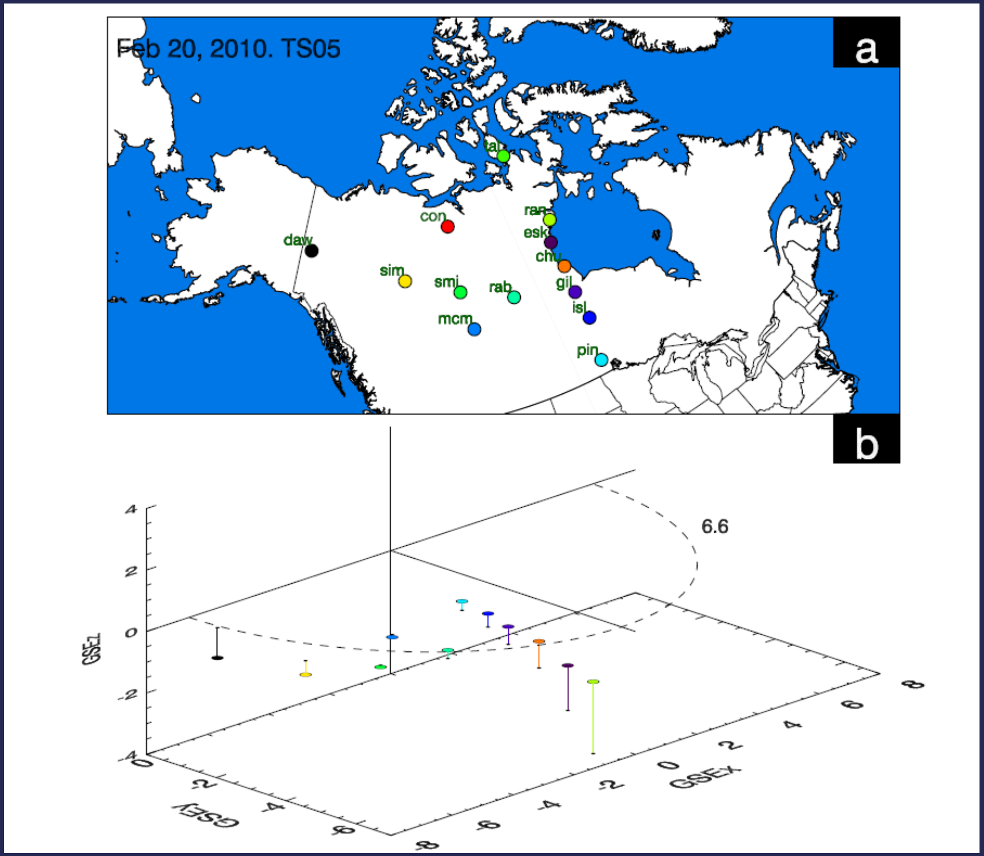
Understanding of the dynamic evolution of waves requires combining ground and in-situ observations.

Time-lagged correlation analysis shows that daily averaged absorption best correlates with 62.5 keV trapped flux, and 100 keV precipitating flux at zero-time lag.

Riometer observations in conjunction with in-situ measurements can be used to evaluate relative contributions of the loss to the atmosphere and loss to the outward radial diffusion.

Riometer observations can be also used as a proxy for the seed population of the radiation belts and as a proxi of wave activity.

Map of the NORSTAR riometer installations (13 stations



(a) on the ground,
and (b) projected to the magnetic equator along field lines, using the TS05 model and
shown in GSE coordinates near 11 UT on Feb 20, 2010. The solid black lines connect the
projection (large colored circles) to the GSEz = 0 plane (small circles). The dashed lined
indicates R = 6:6. The Taloyoak (tal) and Contwoyto (con) riometer stations are located
on eld lines connected to the solar wind (polar cap) and thus are not seen in panel (b).

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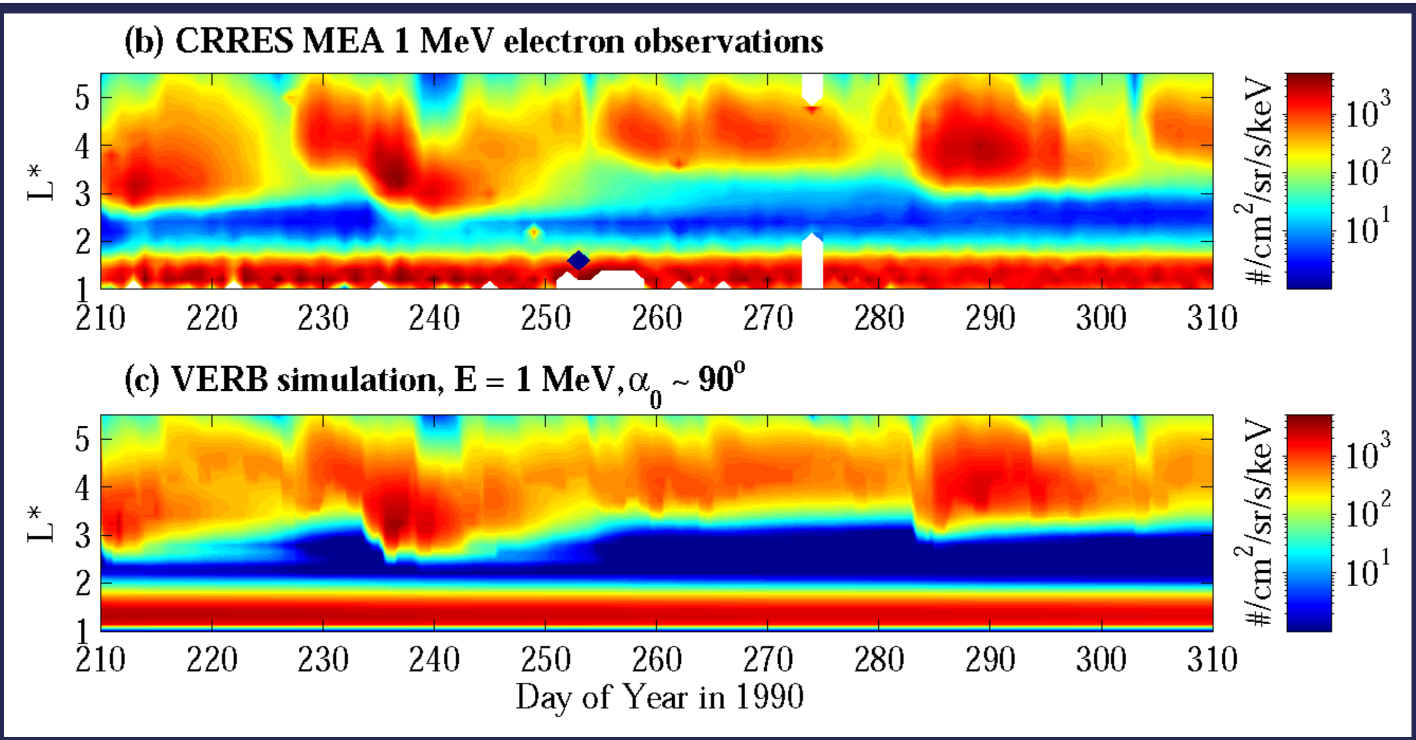

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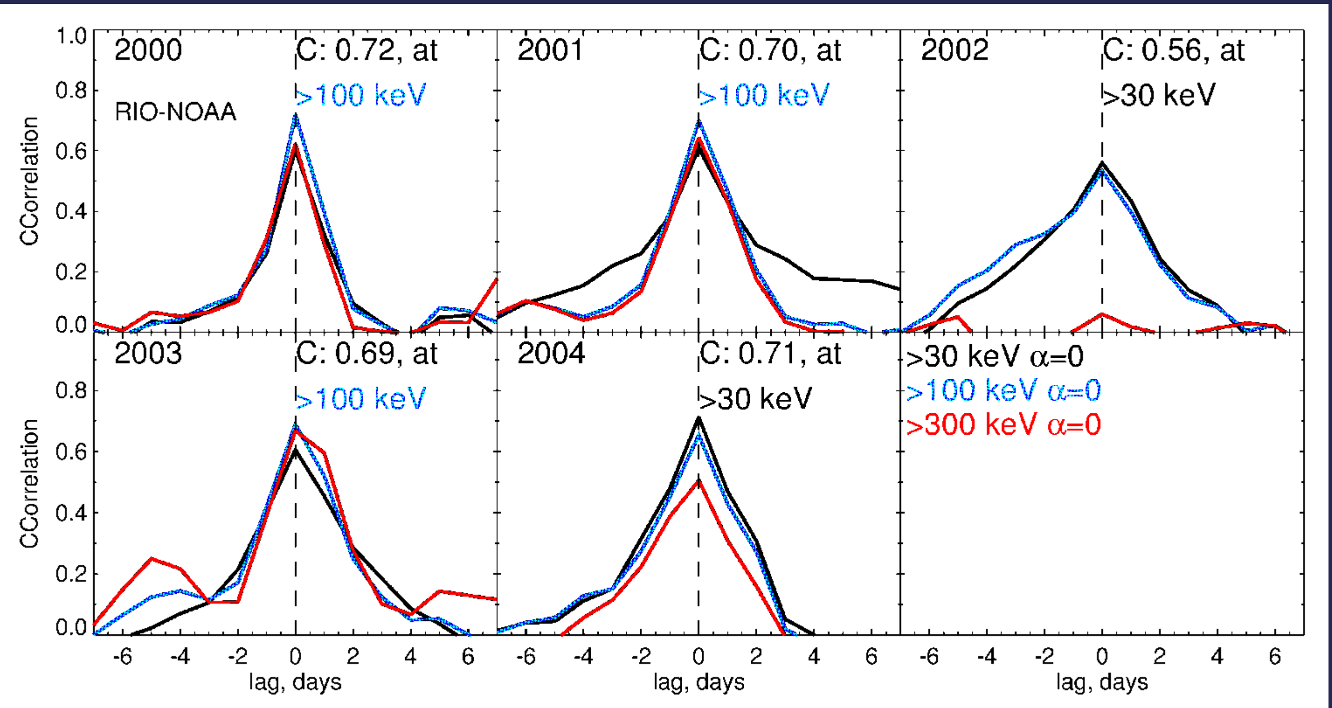


Figure 7. Similar to Fig. 6 except for daily averaged NOAA-POES integrated electron

uxes at a=0 also restricted to 5 < L < 7.

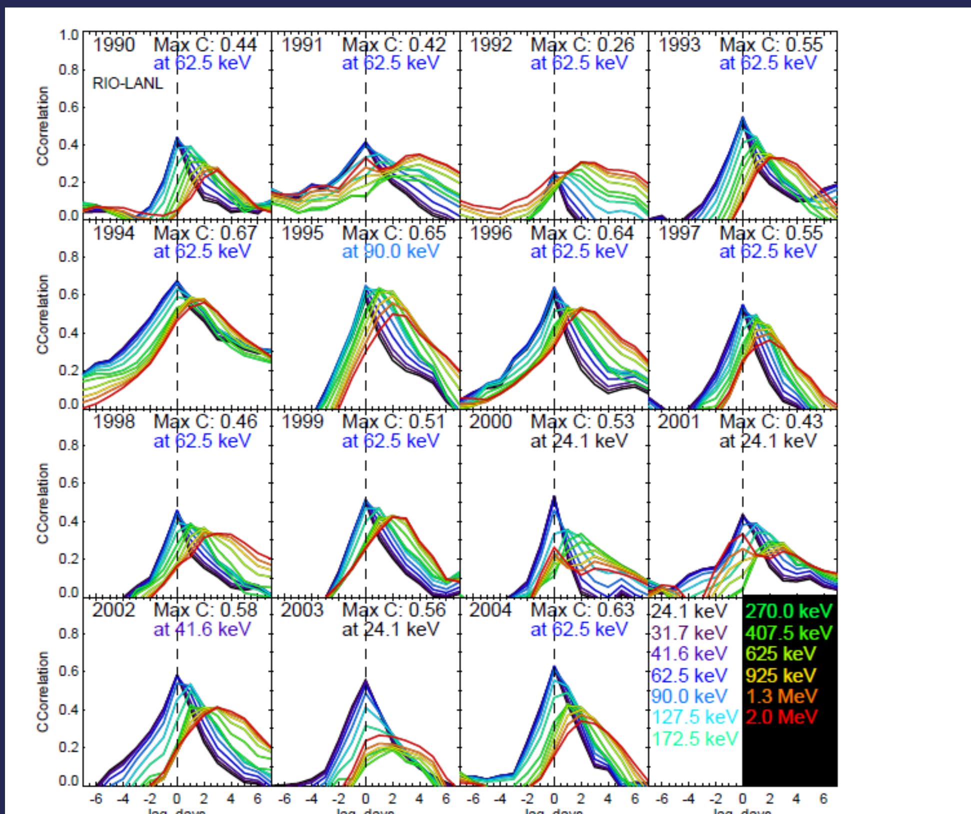
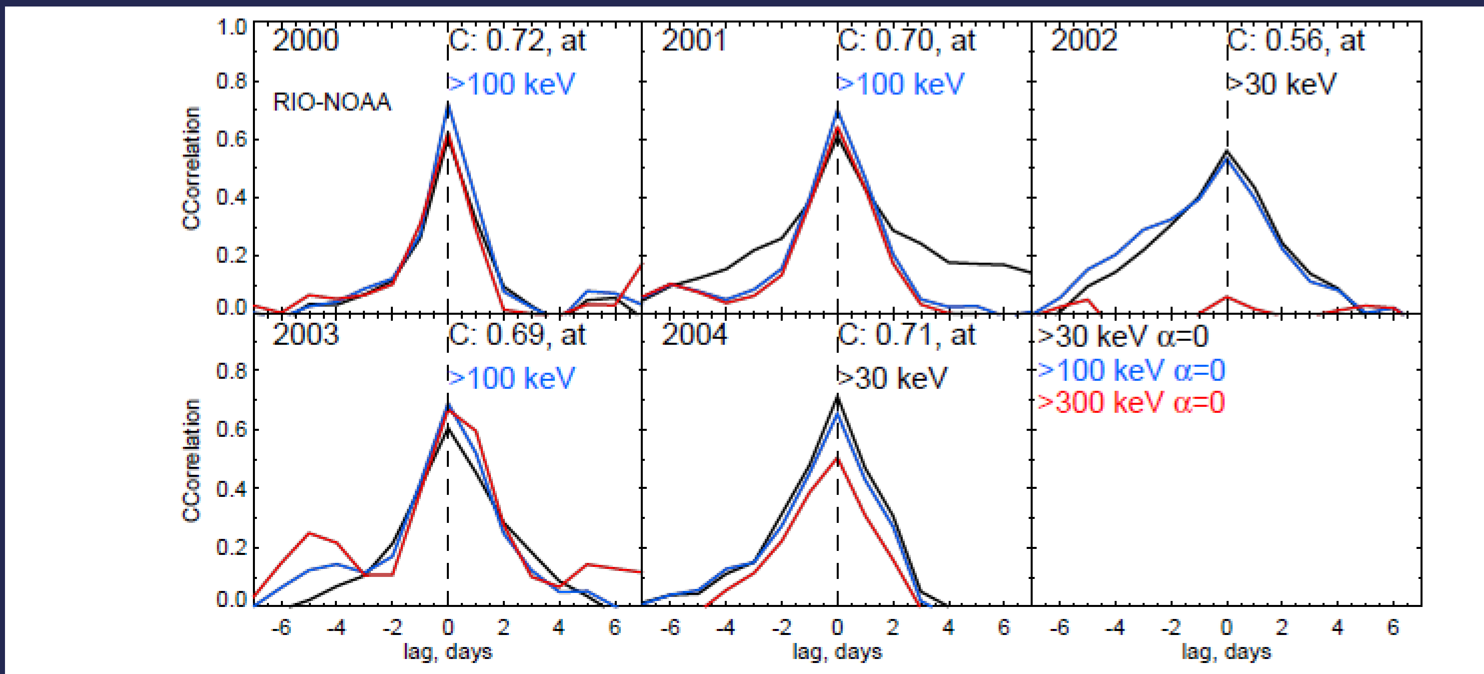


Figure 6. Cross-Correlation between LANL and riometer daily-averaged uxes and absorption, respectively for 1990-2004. Format is similar to Fig. 5.



r to Fig.
y
-POES
on

L < 7.

Riometer measurements

- Extra-terrestrial radiowaves from distant stars and galaxies enter Earth's atmosphere and are absorbed by free electrons.
- The difference between the amount of radiowave power received above the Earth's surface and that on the ground gives an indication of the loss in extra-terrestrial radiowave power occurring in the atmosphere, and is known as cosmic noise absorption (CNA)
- CNA it is most affected by particle precipitation.

[1]Institute of Geophysics and Planetary Physics, UCLA

[2]Department of Atmospheric and Oceanic Sciences, UCLA

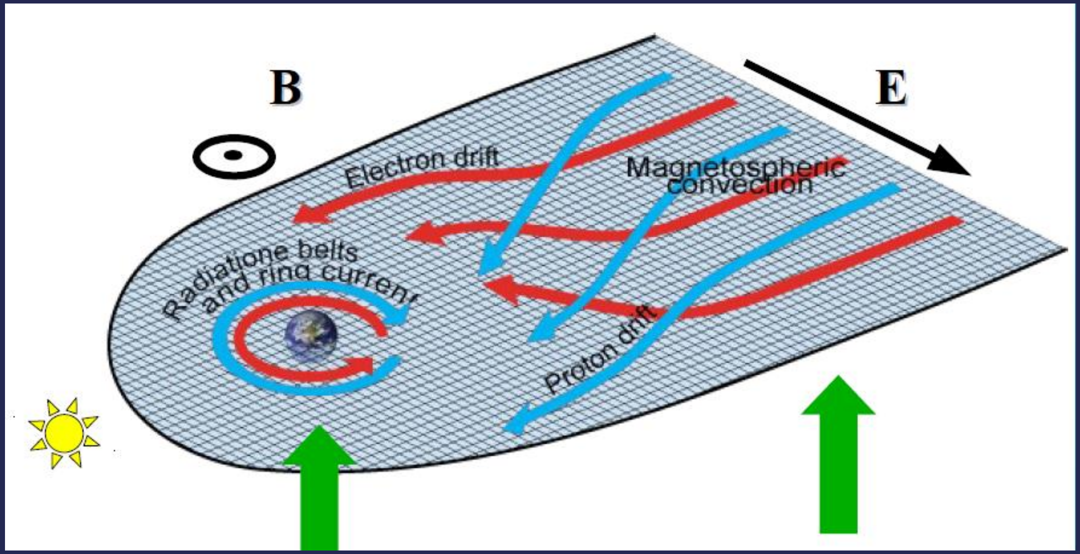
[3] Stanford University, Stanford, CA

[4] École normale supérieure, Paris, France

[5] Los Alamos National Laboratory, Los Alamos, NM

[6] British Antarctic Survey,

Particle Trajectories of Ring Current and Radiation Belt Particles



Stably trapped particles

Convection of the seed population of energetic electrons

Drift of lower energy particles is dominated by ExB drift.

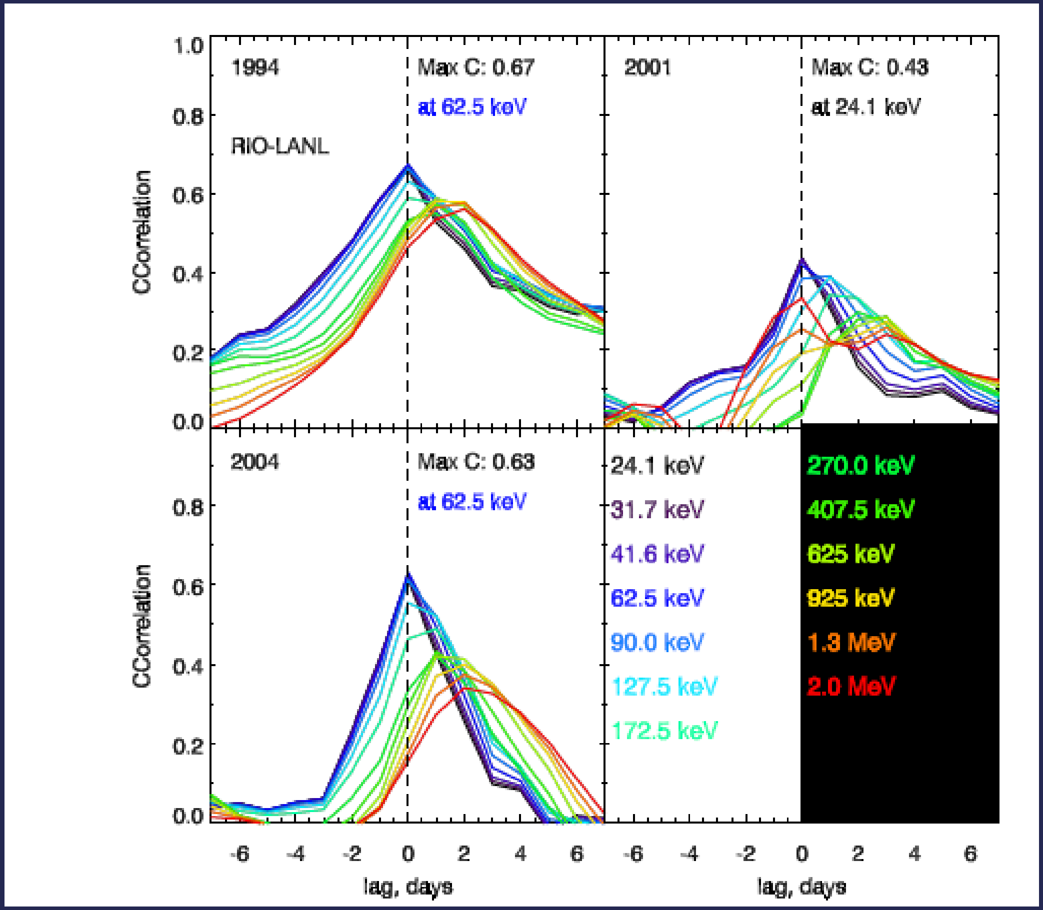
Radiation Belt particles are subject to the gradient and curvature drifts and will drift around the Earth.

Electrons –eastward,

Ions-westward.

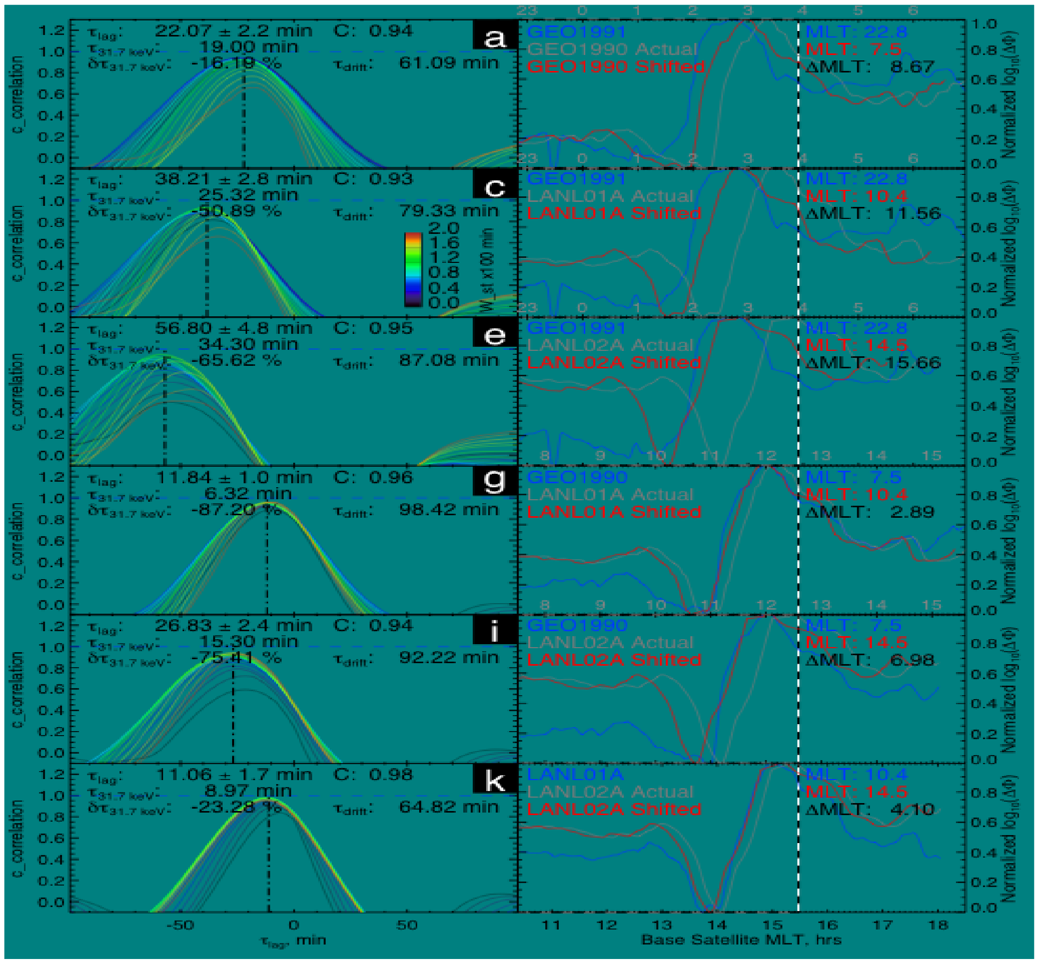
[Subbotin, et al., 2011]

Cross-Correlation between LANL and riometers



Cross-Correlation between LANL and riometer daily-averaged fluxes and absorption, respectively for 1994, 2001 and 2004. Riometers with 5 < L < 7 were considered and daily averaged. The color-coding represents the LANL energy channel (bottom right panel). The max correlation at zero lag and the corresponding energy channel is also shown in each panel.

Kellerman et al., 2013



a
c
e
g
i
k
GEO1991
GEO1990 Actual
GEO1990 Shifted
LANL01A Actual
LANL01A Shifted
LANL02A Actual
LANL02A Shifted
GEO1990
LANL01A
MLT: 22.8
MLT: 7.5
MLT: 10.4
MLT: 14.5
ΔMLT: 8.67
ΔMLT: 11.56
ΔMLT: 15.66
ΔMLT: 2.89
ΔMLT: 6.98
ΔMLT: 4.10
22.07 ± 2.2 min C: 0.94
19.00 min
-16.19 %
61.09 min
38.21 ± 2.8 min C: 0.93
25.32 min
-50.89 %
79.33 min
56.80 ± 4.8 min C: 0.95
34.30 min
-65.62 %
87.08 min
11.84 ± 1.0 min C: 0.96
6.32 min
-87.20 %
98.42 min
26.83 ± 2.4 min C: 0.94
15.30 min
-75.41 %
92.22 min
11.06 ± 1.7 min C: 0.98
8.97 min
-23.28 %
64.82 min
c_correlation
Normalized log10(ΔΦ)
W_st x100 min
min
Base Satellite MLT, hrs