Cross-Correlating Radiation Belt Electron Flux and Substorm Activity

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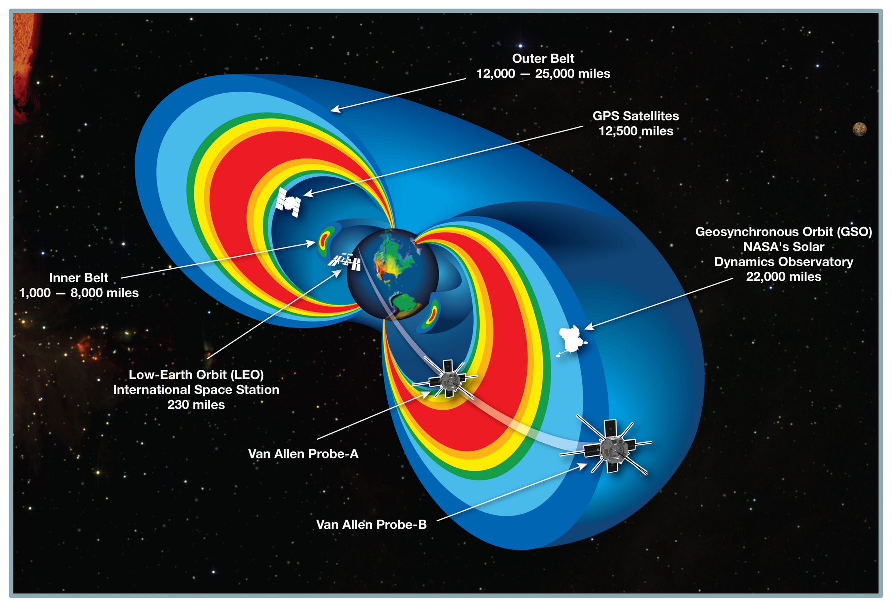
Introduction

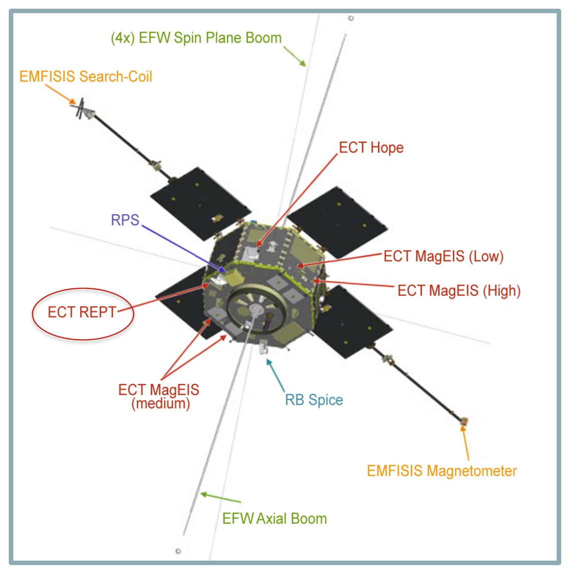
Magnetic reconnection in the tail of the Earth's magnetosphere causes geomagnetic 'substorms,' which are known to enhance particle content in the radiation belts. The enhancement is a result of magnetospheric waves accelerating particles to relativistic energies. Therefore, electron flux in Van Allen belts and substorm activity are physically related. To measure the electron flux, we use data from the Van Allen Probes. Lower Auroral Electrojet (AL) index characterizes substorm activity but does not correlate well with electron flux data. The goal of this project is to cross-correlate electron flux data and a modified version of AL index to gain insight into the physical relation between magnetic reconnection and radiation belt content.



A diagram showing the structure of the radiation belts and the orbit of the Van Allen Probes.

Van Allen Probes Data

In order to study electron flux in the outer radiation belt, we used data from the Relativistic Electron Proton Telescope (REPT) on board the Van Allen Probes, which are identical spacecraft in eccentric orbits that take them through the radiation belts about every nine hours. Electron flux was averaged over a small range in L-shell (ΔL of 0.2), giving two points for each orbit.



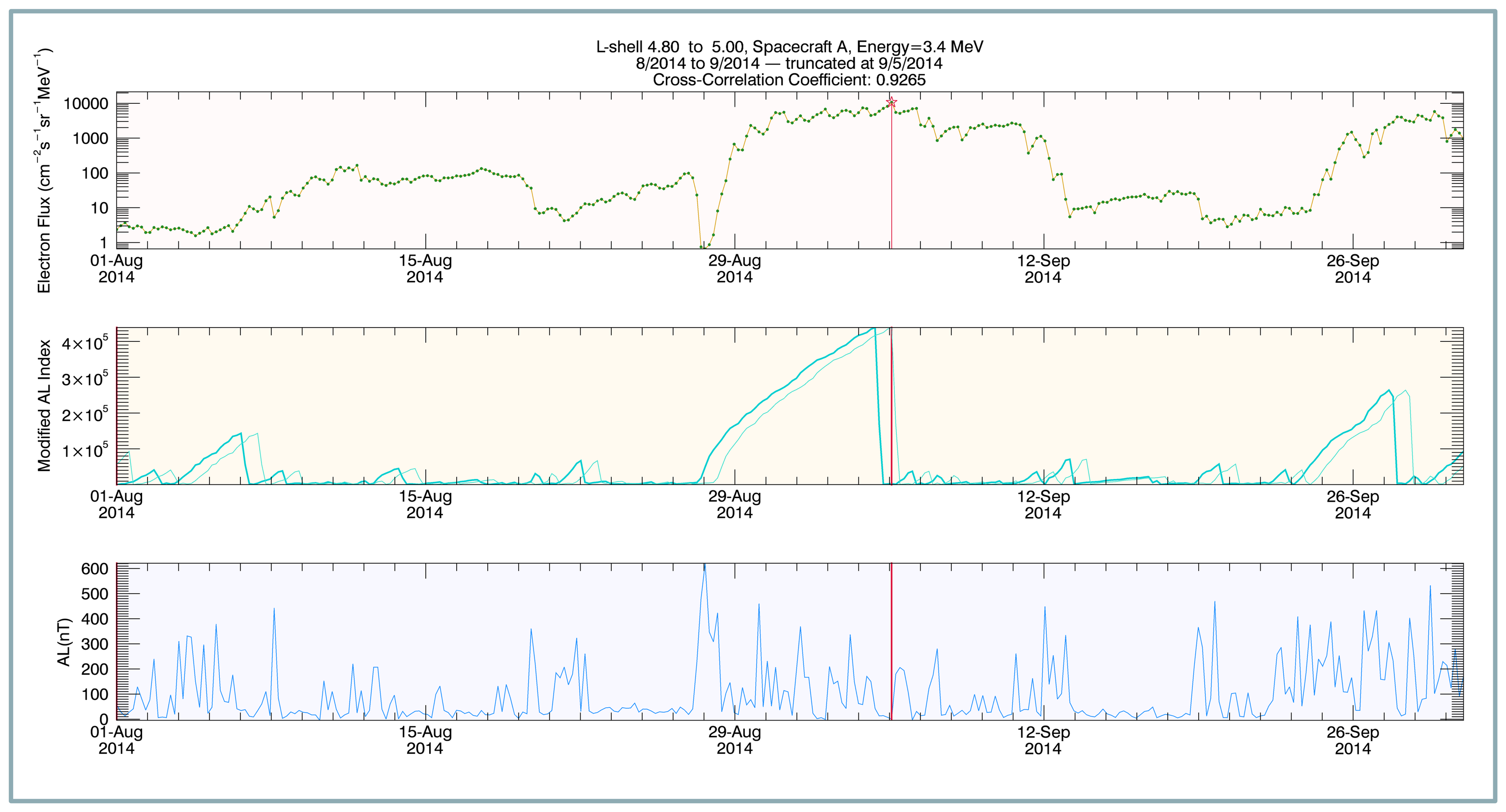
A diagram of one of the Van Allen probes, including the REPT instrument.

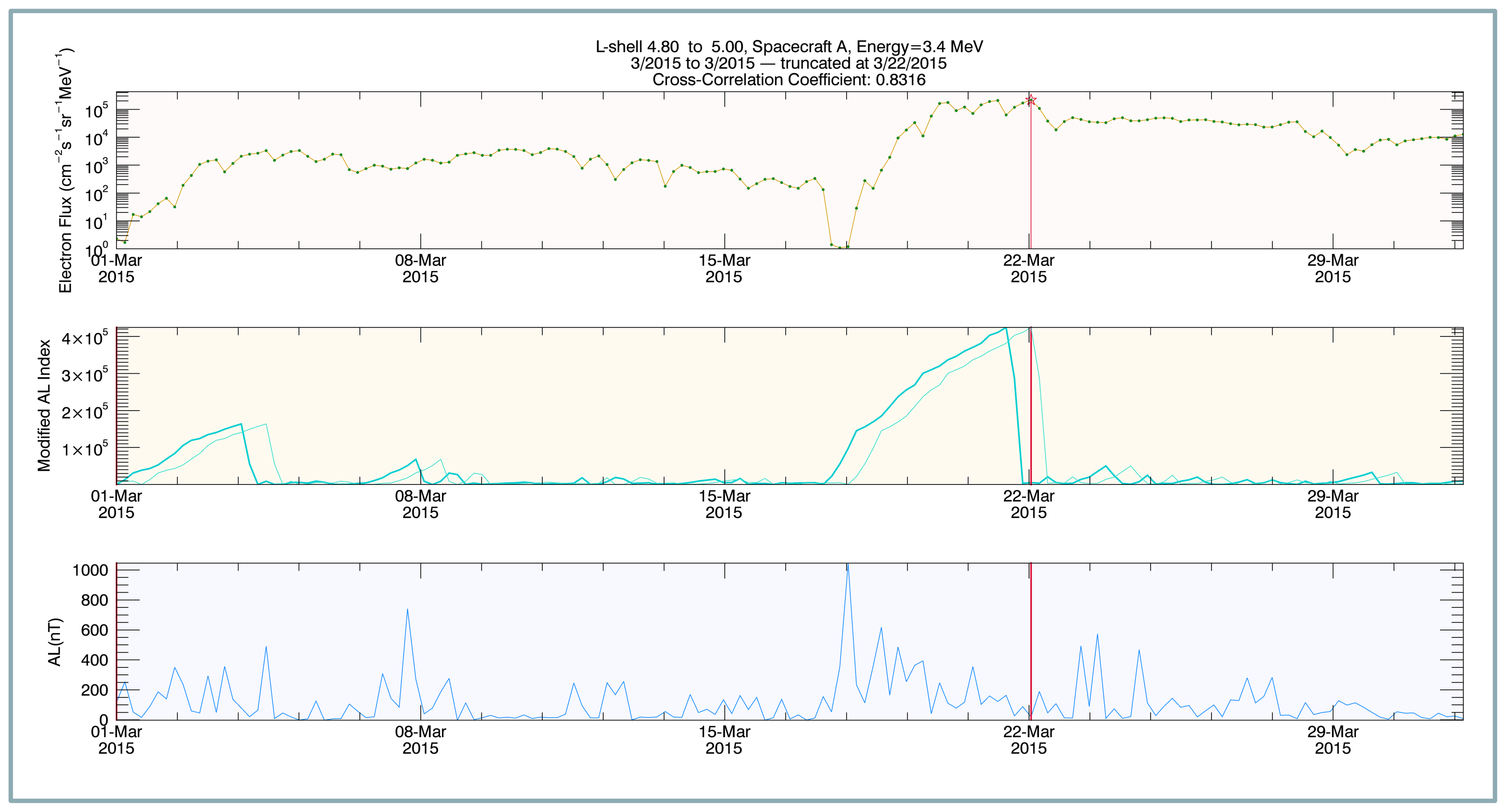
AL index

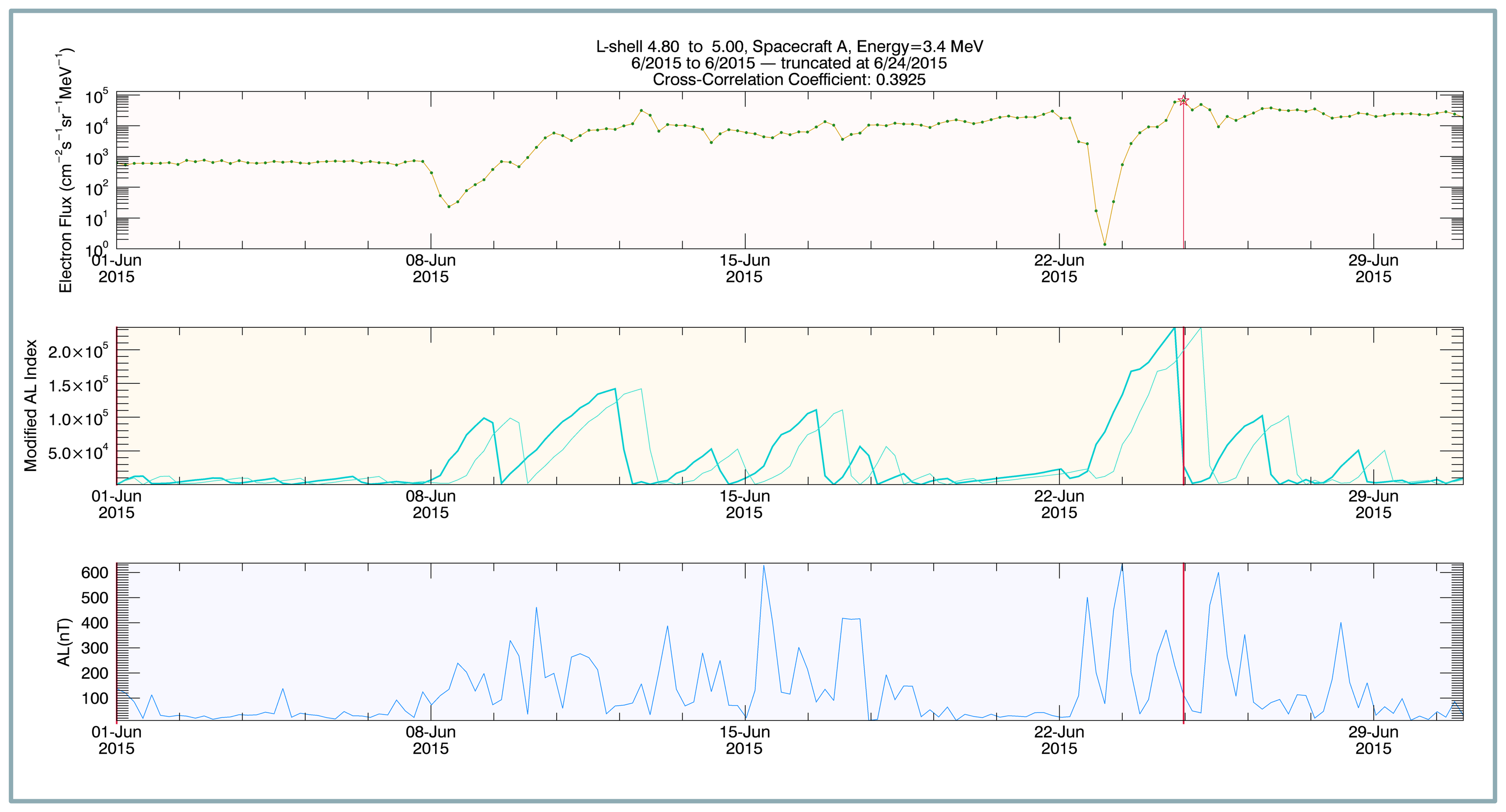
AL index quantifies deviation of magnetic field at high-latitude ground magnetometer stations and is a measure of substorm activity.

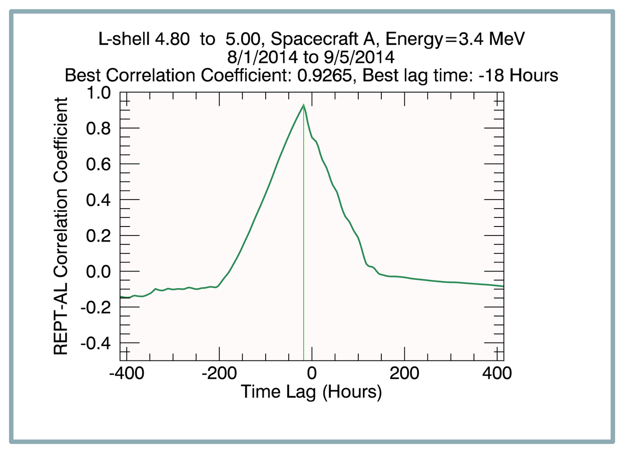
Modified AL index

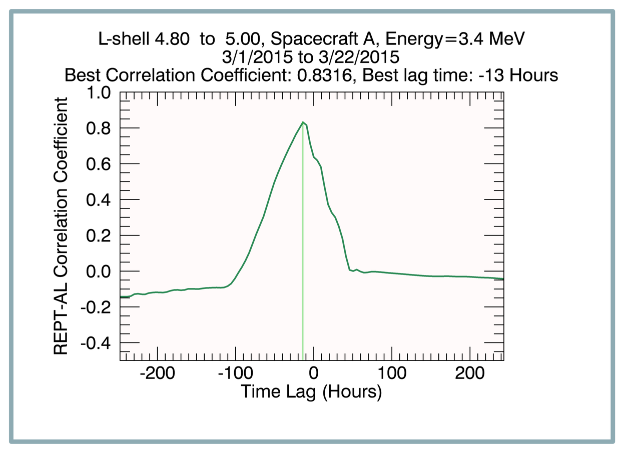
In order to cross-correlate a rise in substorm activity with a following rise in electron flux, we cumulatively integrated AL index over time steps varying in size according to predefined conditions to reset integration. For each time interval, the median AL index is determined. AL index over each ~4.5 hour time period within that interval is determined to be high or low depending on the ratio of AL above the median to AL below the median. If a low interval switches to a high one (or vice versa), integration resets. This method captures periods of high AL that may correlate with a later rise in electron flux.

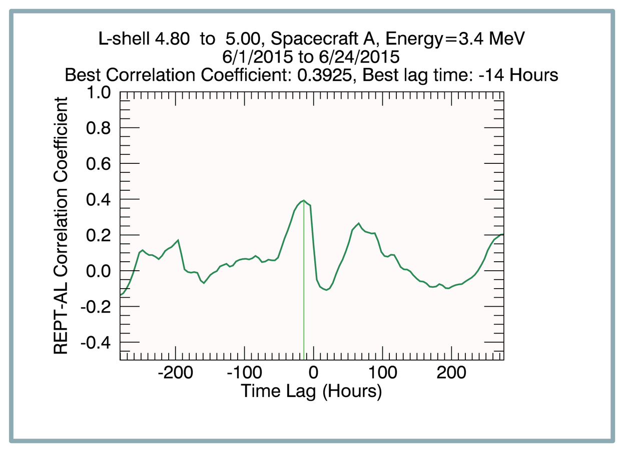












Above: Plots of cross-correlation coefficient versus lag time. They correspond to the plots to the right. The lag time has uncertainties due to time resolution, interpolation, and the integration reset parameters. Note that the bottom plot has poor correlation due to a flux dropout from the Dst effect.

Left: In each figure, from top to bottom, electron flux, Modified AL index, and AL index are plotted for the given time interval. The Modified AL index is shifted by the lag corresponding to best correlation (lighter line). The red line is defined by the maximum flux value for the time interval, and is where correlation stops. A flux dropout can be seen in the top plot of the bottom figure.

Results

- A strong cross-correlation can be found between electron flux and Modified AL index
- Lower energy bins (below 4.2 MeV) correlate better, implying the substorm does not have as much effect on the higher-energy population
- Lower L-shell ranges correlate poorly, implying that populations of electrons near the Earth are not as variable
- Other processes can reduce the cross-correlation coefficient, such as the Dst (disturbance storm time) effect – an artificial flux dropout relating to Earth's ring current
- It is possible to quantify the lag time, but more work must be done to reduce uncertainty

Future Study

- Look at a statistically significant number of substorm intervals
- Adjust Modified AL index to achieve better correlation and more accurate lag time
- Find the average lag time between rise in substorm activity and rise in electron flux to better understand the physical processes at work

References

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This work was supported by the NSF REU grant 1157020 to the University of Colorado