

Radiation Belt and Ring Current Validation Report: June 2, 2004:

During our testing of the radiation belt and ring current models, we found that there were several unexplained injections occurring in the radiation belt model. We also found that the radiation belt model gave fluxes that were too high. We reported these problems to Mei-Ching Fok.

Mei-Ching gave us three fixes to the code. The first fix involved an equation in the driftp subroutine. The second fix was to eliminate fieldlines that were extremely non-dipolar. These fieldlines were checked using Lutz's fieldline routine and found to be open. The third change was to eliminate the calls to the radial diffusion subroutine. Mei-Ching feels that radial diffusion is already taken calculated with the changing electric and magnetic fields.

We ran five test cases with the new code. The first test case was a five day run starting on May 2, 1998. With the old version, there was an "injection" at the beginning of the run that caused the fluxes to be significantly higher than the data. The newer version eliminated this injection and the fluxes are closer to the data. In addition, there are two other two other time periods where the newer version seems to fit the data better. There is one time period where the old version seems to do a better job.

The second test case was an idealized IMF case for the radiation belt. For this case, we see significant improvement. The first improvement is the elimination of an injection around 14:00 that was not explainable in the old version. In addition, we see decreases in the flux for the highest energies at the beginning of the storm as is expected and we see an increase in the flux for the highest energies when the IMF turns northward. There are still problems in the code. There are occasional localized increases in the flux that are an error in the code.

We also ran the ring current code for 3 idealized cases. The newest version dramatically decreases the overall energy gains especially in the drift terms. This part of the code still needs to be analyzed.

Here are the two fixes:

Replaced

```
if (i.gt.irm(j)) c(j)=p1(irm(j),j)+p2(irm(j),j,k,m)+cor
```

with

```
if (i.gt.irm(j)) c(j)=dt/dphi*(p1(irm(j),j)+p2(irm(j),j,k,m)+cor)
```

To avoid extreme non-dipolar field lines in rb_batsrus and rc_batsrus, in subroutine fieldpara, the following lines were added:

```
.....  
if (i.gt.1.and.ro(i,j).lt.ro(i-1,j)) iout=2  
call indexx(npfl,ra,ind) ! find the longest r ! added on  
if (ra(ind(npfl)).gt.12.) iout=2 ! 25 May 2004  
if (iout.eq.2) then  
.....
```

Radiation Belt Tests:

We studied the effect of different energy diffusion coefficients on radiation belt fluxes at geosynchronous orbit using the May 2-6, 1998 event. During the recovery phase on May 4, the data shows a flux increase. The radiation belt model with no energy diffusion is either level or decreasing in flux during this time period. With the addition of energy diffusion using a wave amplitude of 50 pT, the fluxes increase slightly. In addition, we tried another run with a wave amplitude of 100 pT. In this case we found that the energy diffusion increased the flux too much during the time period of 24 to 48 hours. It also increased the flux during the time period after 48 hours.

A second change in the simulation was to increase the number of grid cells in spatial resolution. We also fixed a problem with the boundary condition. The results of this case are shown in Figure 1.

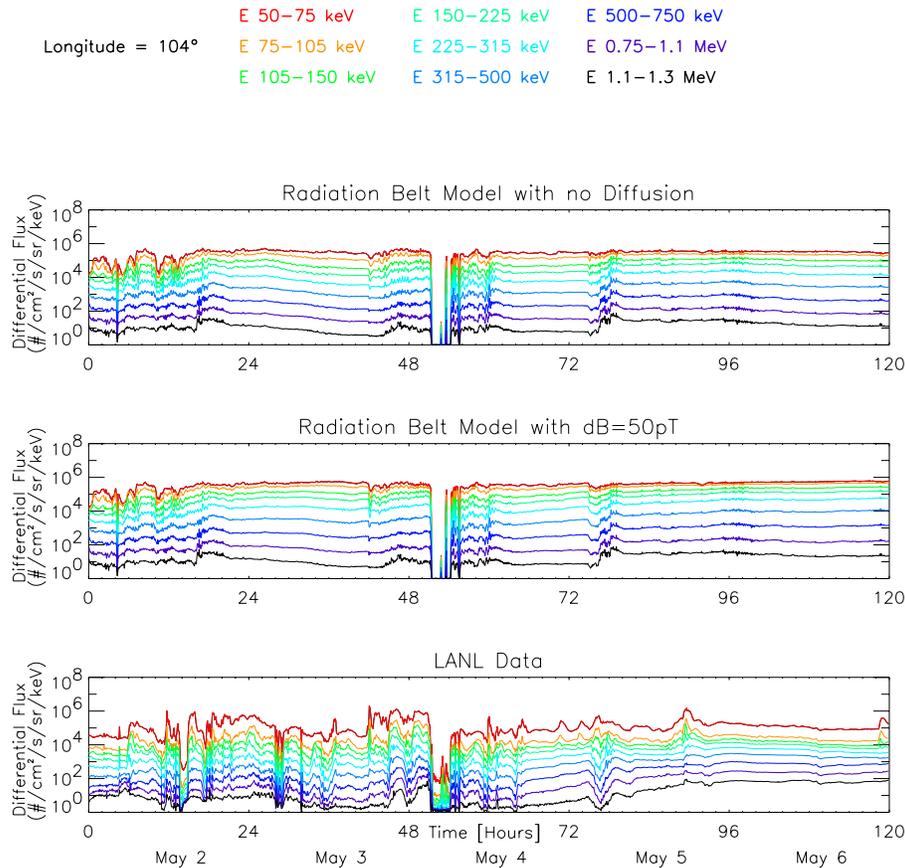


Figure 1.

Without energy diffusion, the flux levels are fairly constant after 48 hours. With the inclusion of energy diffusion with a wave amplitude of 50 pT, only the energies between 50 – 300 keV showed an increase in flux. With the inclusion of energy diffusion with a

wave amplitude of 100 pT, the increase in flux levels after 48 hours are fairly consistent with the data. The levels at the highest energy are higher than the data.

Since the flux levels are too high, we are modifying the boundary conditions. All of the above cases use an empirical formula for density and temperature to define flux levels at the boundary using a kappa function. The kappa value was three. We changed the kappa value to six. This lowers the flux at the higher energies. The results are shown in Figure 2 for a case with a wave amplitude of 50 pT.

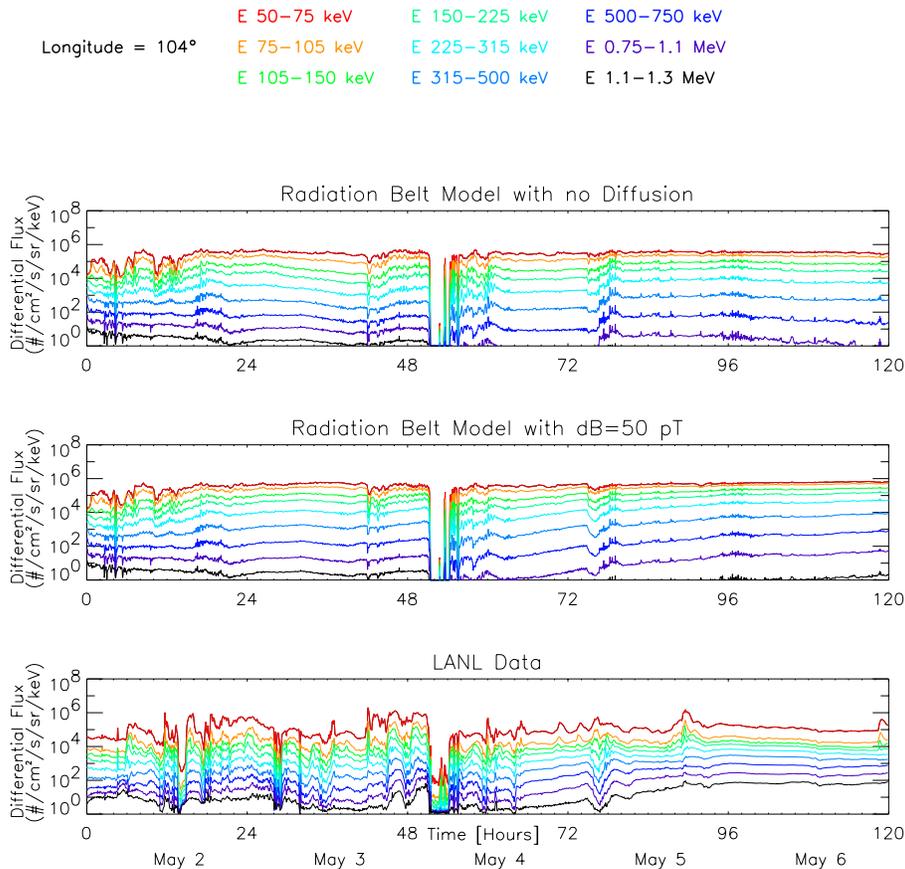


Figure 2.

On May 4, the fluxes with kappa of six are too low compared with the data at the highest energies. For the case without diffusion, the fluxes in the energy ranges from 50-150 keV have a reasonable match to the data in terms of magnitude. For the case with diffusion, the lower energy fluxes tend to be too high. The increase in flux levels is slightly smaller than the increases in flux in the data. Figure 3 shows the case with an wave amplitude of 50 pT.

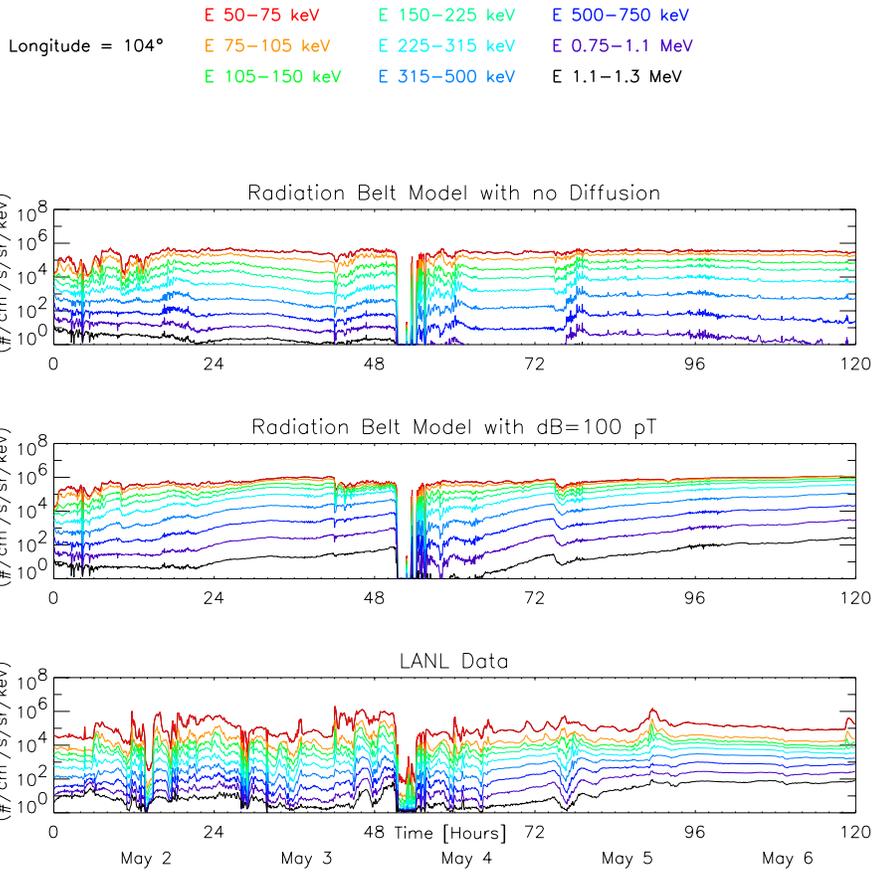


Figure 3.

The increases in flux on May 4 are too high with a wave amplitude of 100 pT. For all the cases, most of the fluctuations in the data are missing from the model results. We looked at using the MHD density and temperature as the cold component for a two-component boundary condition. We found that the MHD density was too high. We also considered using a hot component along with the empirical formula for the cold component. We found that formula made the fluxes too high also. We tried using the empirical formula above with a cold component that was $\frac{1}{4}$ the temperature and four times the density. The results are shown in Figure 4.

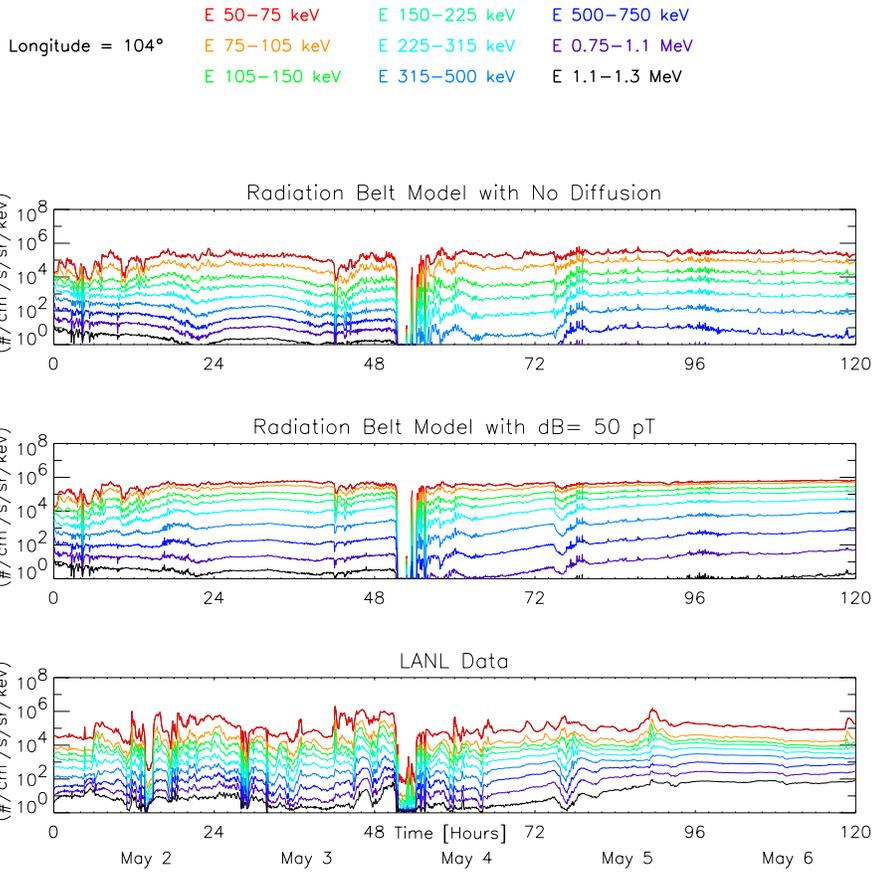


Figure 4.

The results tend to be slightly higher than the one component version with the comparable diffusion except for the higher energies on May 4 and May 5. For these energy ranges (SOPA energy ranges), one component seems to match as well as two components. The one component case with a wave amplitude of 100 pT has the best match at the highest energies during the recovery. We also looked at fluxes in the MPA energy range. In this case the one component version did not fit the data. Figure 5 shows the results with energy diffusion for both one and two component tests. While neither case does particularly well, the two component case does show some spread between different energy levels. The energy diffusion seems to be too much in this energy range. More work needs to be done to test the boundary conditions including using similar formulas on other days.

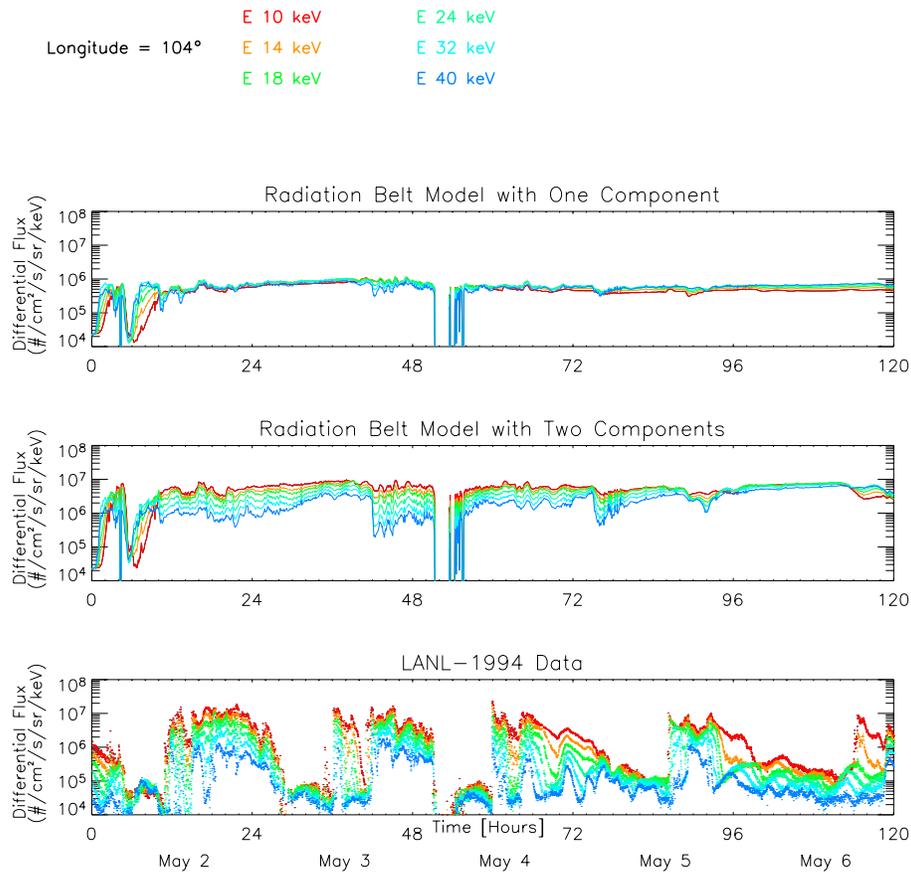


Figure 5.

Ring Current:

A fix was made to the boundary condition formula. In addition, pitch angle diffusion was added to the code. So far only the constant pitch angle diffusion coefficient has run in a stable mode. In this case, pitch angle diffusion was done to see if we could reproduce the rapid recovery seen in the May 1998 storm. Figure 6 shows the energy for the case without pitch angle diffusion compared with Dst. Figure 7 shows the case with pitch angle diffusion. Neither case reproduces the results of the rapid recovery. Without pitch angle diffusion the recovery is too slow. With constant pitch angle diffusion, the recovery is too rapid. We are attempting to add a pitch angle diffusion coefficient that has spatial and temporal dependence.

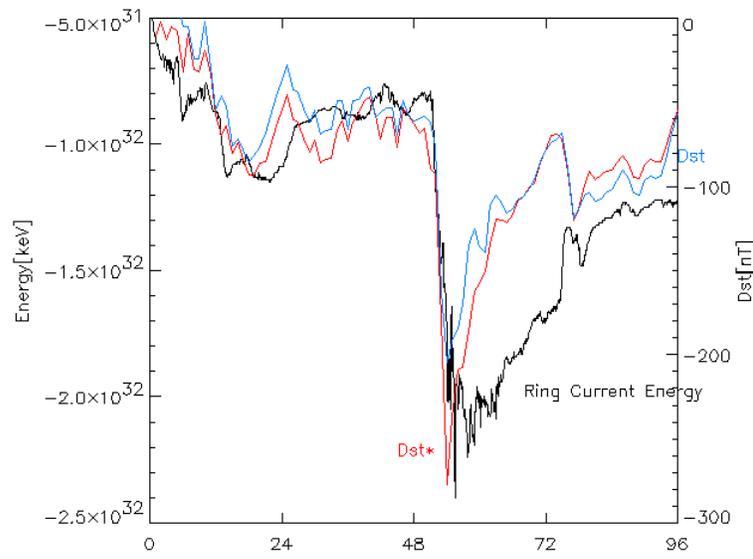


Figure 6. Energy in the ring current without pitch angle diffusion compared to Dst and Dst*.

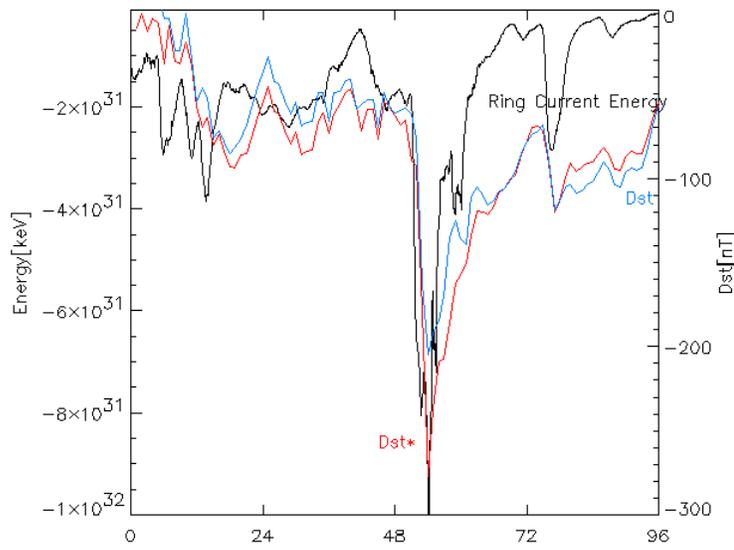


Figure 7. Energy in the ring current with pitch angle diffusion compared to Dst and Dst*.