Chapter VII
Discussion and Summary

The simulation of dense pulses of particles released from the Sun, using the wind program simulation (Figure 5.2), and results from Earl's theory (Figure 5.3) are not completely identical. The results from the wind program are more accurate than the results from Earl's theory because we define the distance traveled (vt) in this simulation to be 2 AU, so the particles are not to exceed this distance. However, in the results of Earl's theory, the particle flux does not go to 0 until a distance of about 2.5 AU, while the flux from the wind program goes to zero before $z = 2$ AU as it should. The error in the plot based on Earl's theory comes from the approximations of Earl (1976a) in solving the transport equation.

The technique for fitting data as developed in this thesis work will be useful for future work. It derives an estimate of the duration of emission of any flare. When we have data of the interplanetary transport (intensity and anisotropy data) and we know the response function, we can determine the true injection function. This technique determine the set of coefficients of each function and the uncertainly of each coefficient, so we will have a quantitative corrected injection function. We hope that in the future this technique will be developed to automatically search for the appropriate of the set of time intervals for calculating the response function. Now this technique is easy for fitting data, has less human error, and is useful for a full survey of solar flares in the ISEE-3/ICE data set.

The durations of injection for impulsive and gradual flares seem to be different, which is important information for the study of the acceleration of solar cosmic rays. In the long term, this new technique for studying the injection of particles will allow the precise examination of data from most solar flares. In an upcoming project, it is hoped that by determining the injection profiles at different solar longitudes from multispacecraft observations of selected flares, one will be able to determine whether coronal transport or shock acceleration is responsible for the injection of particles on magnetic field lines that start out far from the flare site.

In summary, we used the numerical simulation program of Ruffolo (1995), "wind," to analyze the characteristics of particles released from the Sun and to derive the duration of their emission from impulsive and gradual flares. We adapted the wind program in various versions that are suited to our objectives. Finally, we obtained interesting results from these simulations as follows:

1. We can simulate the characteristics of dense pulses of particles released from the Sun. The density of particles from Earl's theory and from the simulation are consistent, when we set the focusing length to be constant in the program. With a more realistic focusing length, propagation as a pulse will occur in the weak focusing region, and the pulse slowly decays in the diffusion region as the propagation speed steadily decreases with increasing z. By simulating the propagation of coherent pulses for various mean free paths λ and indices q, we found that the pulse occurs very rapidly, and for a constant $\lambda = 1$, a dominant coherent pulse appears and the highest peak is for the lowest q. The time profile of a pulse for $\lambda = 1$ is narrow and high, but for the lower values of λ the height of the peak is small. The late-time characteristics for various λ are simular, showing the decay of the coherent pulse into the diffusive region. The propagation of these particles will follow the magnetic field fastest for the longest mean free path, i.e., the weakest scattering.

2. An estimation of the effects of gradient and curvature drifts for protons of 33 MeV, an interplanetary magnetic field strength of 5×10^{-5} G, and a radius

of ≈ 1 AU shows that the maximum distance drifted is less than $3°$, which is a small effect for the transport of particles released from the Sun. The effects of perpendicular diffusion on the transport, based on values from previous work, are small when compared with parallel diffusion. Therefore, the effects of drifts and diffusion perpendicular to the magnetic field on propagation of the particles released from the Sun can be neglected, and we do not need to consider the effects of perpendicular motion on the transport in this simulation.

3. We developed a fitting technique for studying the injection profile of cosmic ray particles from the Sun, and derived the injection near the Sun for impulsive and gradual flares. The durations of particle emission for the two flares are different. The duration of particle (proton) emission for the impulsive flare has a short duration, but the gradual flare has a long duration. These trends are consistent with a possible correlation with the X-ray duration.