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How system identification techniques can help in the study of relativistic electrons and ions at GEO

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The standard scientific approach is to develop mathematical models from first physical principles. However, there are many complex dynamical systems where a mathematical model cannot be deduced from first principles with our present level of knowledge, such as the radiation belts. System science techniques, such as the NARMAX algorithm, are able to automatically determine the dynamical equations that govern the evolution of the complex system from input-output data. From the physically interpretable models of the NARMAX algorithm, it is possible, in some sense, to reverse engineer and obtain understanding of the physical object and the processes involved. Here, the NARMAX system science approach is applied to the evolution of the radiation belts, where ACE measurements are used as the inputs and daily averaged GOES and LANL particle flux data are considered as the outputs. The Error reduction ratio (ERR), a key concept of the NARMAX algorithm, is employed to assess the solar wind control parameters of the particle fluxes. For low energies, the electron fluxes are shown to be influenced by the solar wind velocity with a dependance between the time delay of the velocity and the energy of the electrons. For high energies, it shown that the solar wind density becomes the most significant control parameter. The ion fluxes are mainly effected by the solar wind velocity but also the energetic ions in the solar wind. An online real time forecasting tool has been developed from the results of the NARMAX approach that provide reliable estimates of the >800 keV and >2 MeV electron fluxes.