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GEMSIS-Sun Numerical Model of Sun-Earth System (SUSANOO): Application for Extremely Strong IMF CMEs

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Solar wind including coronal mass ejections (CMEs) is a main driver of various space weather disturbances. MHD modeling of the solar wind is a powerful tool to understand the solar-terrestrial environment and to forecast space weather accurately. Recently, we developed an MHD model of the inner heliosphere on the basis of minimal input, namely, time series of daily synoptic observation of the photospheric magnetic field. The time series of MHD parameters at the Earth position is passed to a radiation belt model [Miyoshi et al. 2004] for forecasting of the radiation belt energetic electron flux. These programs are executed everyday on a server in STEL, Nagoya University and the results are uploaded on the web site (http://st4a.stelab.nagoya-u.ac.jp/susanoo/). This system is named as Space-weather-forecast-Usable System Anchored by Numerical Operations and Observations (SUSANOO).

Carrington event that occurred in September 1859 is the most violent solar storm in the human records. Since the magnetic storm associated with the event influenced globally, aurora was observed in wide area in the world. The magnetic response recorded in Bombay shows a rapid decrease of -1600 nT / h (Tsurutani et al. 2003). The induced electric field to explain the rapid decrease in the ground level is estimated to be 355 mV/m associated with a magnetic cloud influence. The time lag between onsets of solar flare and sudden commencement is 17.5 hours, and therefore shock propagation speed is estimated as 2380 km/s. The magnetic field strength in the associated magnetic cloud is needed to be 150nT. However, it is not clear how such a strong magnetic field can be kept while the strength of ordinary interplanetary magnetic field (IMF) is the order of 10 nT at 1 au.

In order to examine which condition of coronal mass ejections (CMEs) associated with an extreme event such as the Carrington event should be satisfied, we modeled a series of CMEs with the inner heliosphere MHD simulation (used in SUSANOO). In the model, multiple CMEs are injected as a twisted magnetic flux rope accompanying with a velocity pulse through the inner boundary of the simulation and propagate into the solar winds. Because there is almost no information associated with the Carrington event and the solar wind, instead, we used observational data of CMEs associated recent large-scale active regions: NOAA 10486 in October to November 2003 (Halloween event) and NOAA 11520 in July 2012 (far side STEREO event, Russell et al. 2013). Only fast (V >~1000 km/s) and wide (angular width >60 degree) CME data are extracted from LASCO CME catalog (http://cdaw.gsfc.nasa.gov/CME_list/). As a result, the strength of compressed magnetic field becomes as high as about four times of background IMF when a CME interacts with the background solar wind. However, successive CMEs interact with each other to form much stronger magnetic filed due to compression of the magnetic cloud of the preceding CME by shock associated the following CME.

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