Abstract #2707
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# Validation of PREDICCS Using LRO/CRaTER Observations During Three Major Solar Events in 2012

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## Introduction:

- PREDICCS is an online system designed to provide the community with a near-real-time characterization of the radiation environment of the inner heliosphere, providing a means of forecasting events and improving risk assessment models for future space missions.
- PREDICCS utilizes near-real-time data from various satellites in conjunction with numerical models such as the Earth-Moon-Mars Radiation Environment Module (EMMREM) to produce dose rate, dose equivalent rates and particle flux data at Earth, Moon and Mars (available at http://prediccs.sr.unh.edu/).
- The CRaTER instrument aboard the LRO spacecraft is designed to measure energetic particle radiation, and offers an opportunity to test the capability of PREDICCS to accurately describe the radiation environment of the Moon.
- We provide comparisons between dose rates produced by PREDICCS with those measured by CRaTER during three major solar events occurring in 2012.
- Additionally, we demonstrate a method for computing modulation potential using PREDICCS data products together with our archive of measured CRaTER dose rates, which can be useful in improving the PREDICCS system and in the study of GCRs.

## Computation of Modulation Potential:

- Modulation potential is the amount of energy lost by GCRs during their transit through the heliosphere.
- We compute the modulation potential at the Moon using a table generated by EMMREM, based on the Badhwar and O'Neill GCR model, that contains data for modulation potential as a function of GCR dose rate, atmospheric density, and shielding thickness.
- Using values for atmospheric density and shielding comparable to those for CRaTER, we plot modulation potential against dose rate (Figure 1).
- By fitting this plot, we develop an expression for the modulation potential and by using measured GCR dose rates, we can compute the modulation potential at the Moon.
- Figure 2 shows the evolution of the modulation potential during the LRO mission.
- This computed modulation potential can be scaled out to different points of interest and can be useful in studying GCRs as well as for improving the PREDICCS model which consistently underestimates GCR radiation.

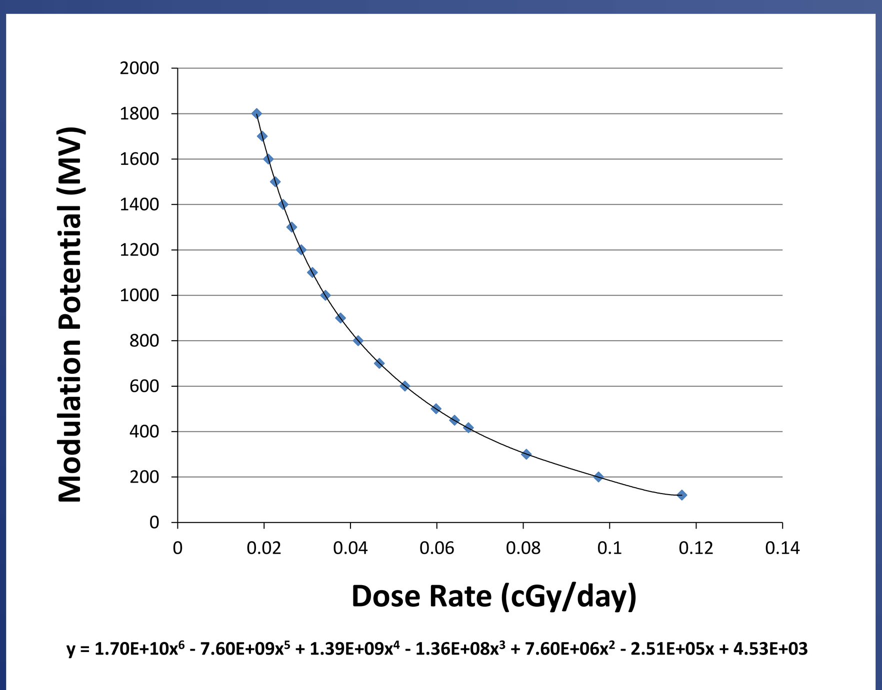


Figure 1: Plot of data taken from an EMMREM-generated table based on the Badhwar and O'Neill GCR model . The data is fit with a 6th order polynomial in order to obtain an expression for the modulation potential as a function of GCR dose rate.

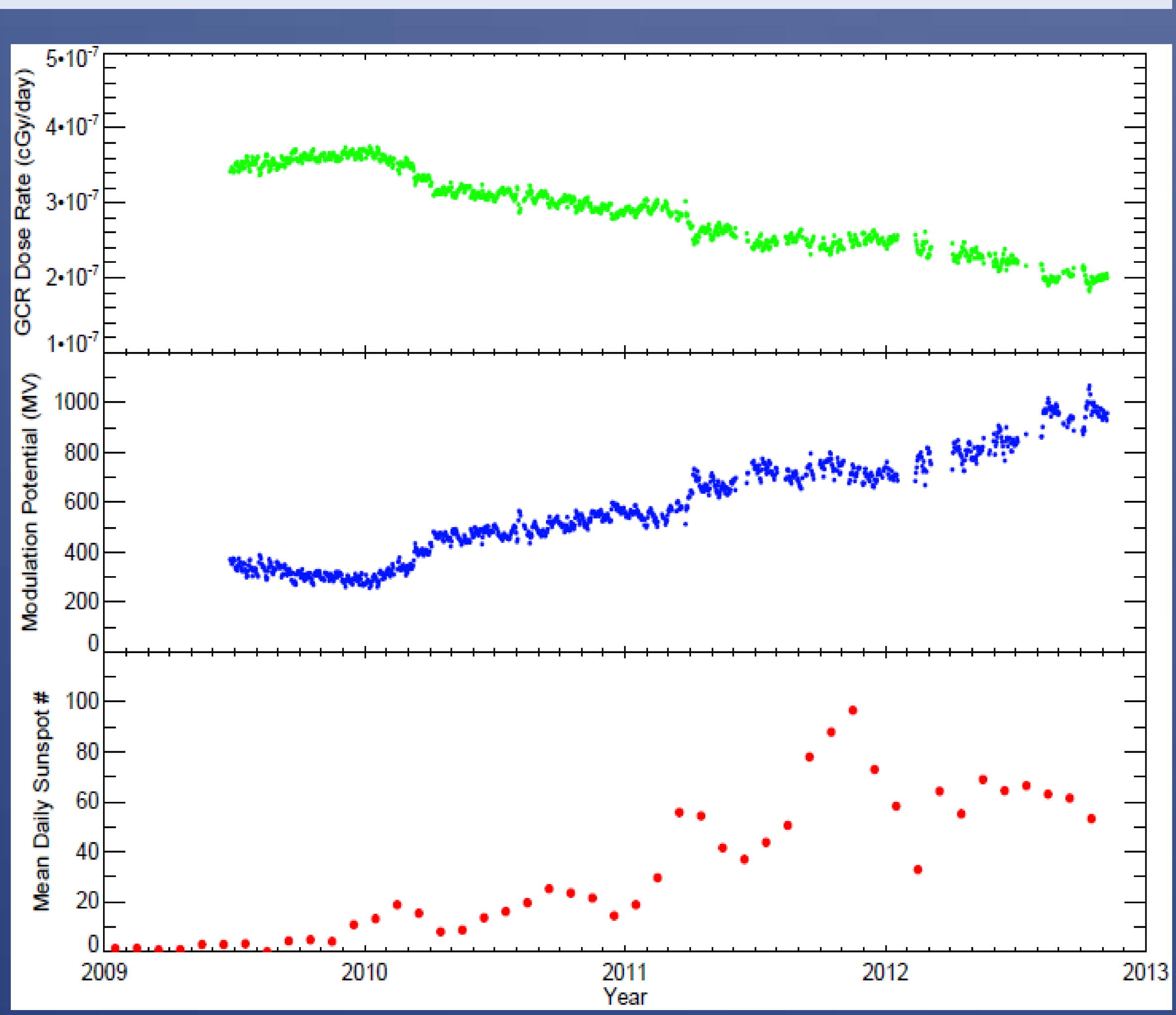


Figure 2: Plot of GCR dose rate and modulation potential for duration of solar cycle. Sunspot number is shown to provide context within the solar cycle.

| Event Comparison | January | March | May |
|---|---|---|---|
| PREDICCS (s=0.3) Dose | 118 cGy | 152 cGy | 2.58 cGy |
| PREDICCS (s=1.0) Dose | 46.0 cGy | 84.7 cGy | 1.73 cGy |
| PREDICCS (s=5.0) Dose | 1.52 cGy | 13.0 cGy | 0.593 cGy |
| PREDICCS (s=10.0) Dose | 0.572 cGy | 6.16 cGy | 0.377 cGy |
| CRaTER (s=0.22) Dose | 185 cGy | 138 cGy | 3.61 cGy |
| PREDICCS/CRaTER % Difference | -36.2 % | +10.1 % | -28.5 % |
| Microdosimeter (s=0.89/2.28) Dose | 3.58 cGy | 11.6 cGy | 0.530 cGy |

Table 1: Comparison of PREDICCS, CRaTER and the microdosimeter for the three solar events. The percent difference between CRaTER and PREDICCS for the nearest level of shielding is shown to quantify the accuracy of the model.

**References**:
O'Neill, P. M., 2006, Adv. Space Res., 37, 1727, doi:10.1016/j.asr.2005.02.001.

## PREDICCS/CRaTER Comparison During Solar Events:

- We compare the dose rates measured by CRaTER to those predicted by PREDICCS for three major solar events in 2012, occurring in January, March, and May.
- For this comparison, we use the combined D1-D2 CRaTER dose rate and the PREDICCS dose rates for 1.0 g/cm$^2$ H2O which is a proxy for skin and eye dose, shielded by 0.3 g/cm$^2$ aluminum which is a proxy for spacesuit and is closest to the level of shielding experienced by CRaTER.
- For comparison, we also show PREDICCS dose rates for three other levels of shielding as well as the dose rate measured by the microdosimeter within CRaTER.
- We also compute the total dose accumulated during each event using both the CRaTER and PREDICCS dose rates, as well as the microdosimeter.
- In the plots, we include the NASA 30 day dose limits for skin (150 cGy) and eye/lens (100 cGy).

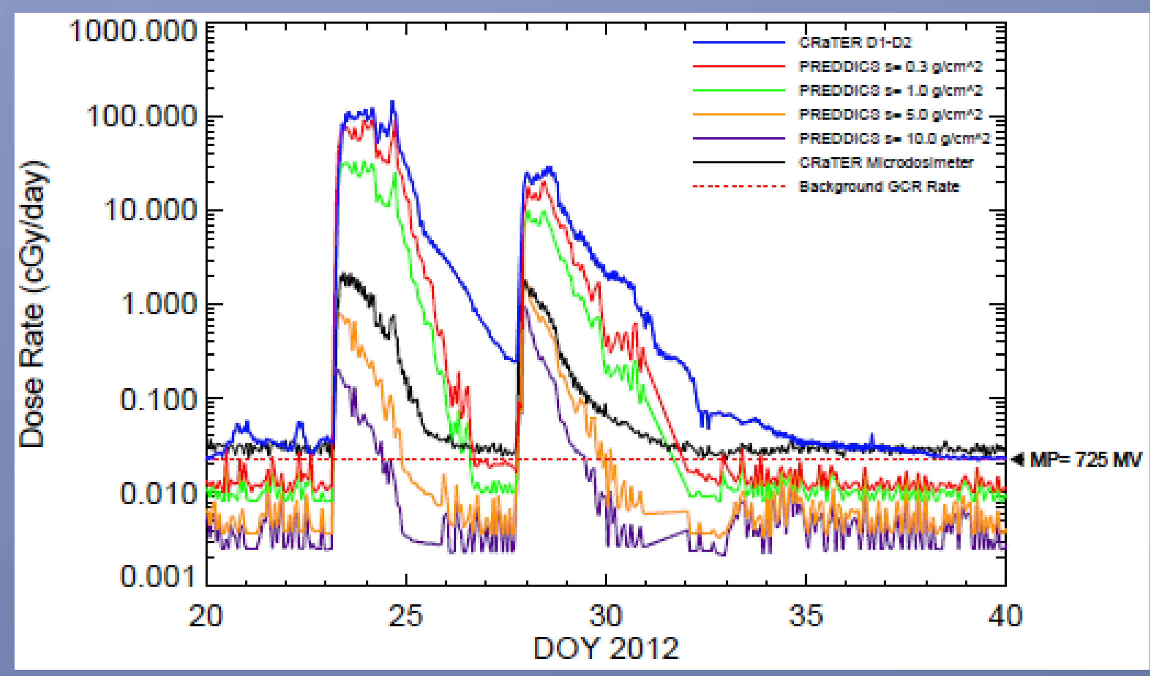


Figure 3: Dose rates during January solar event.

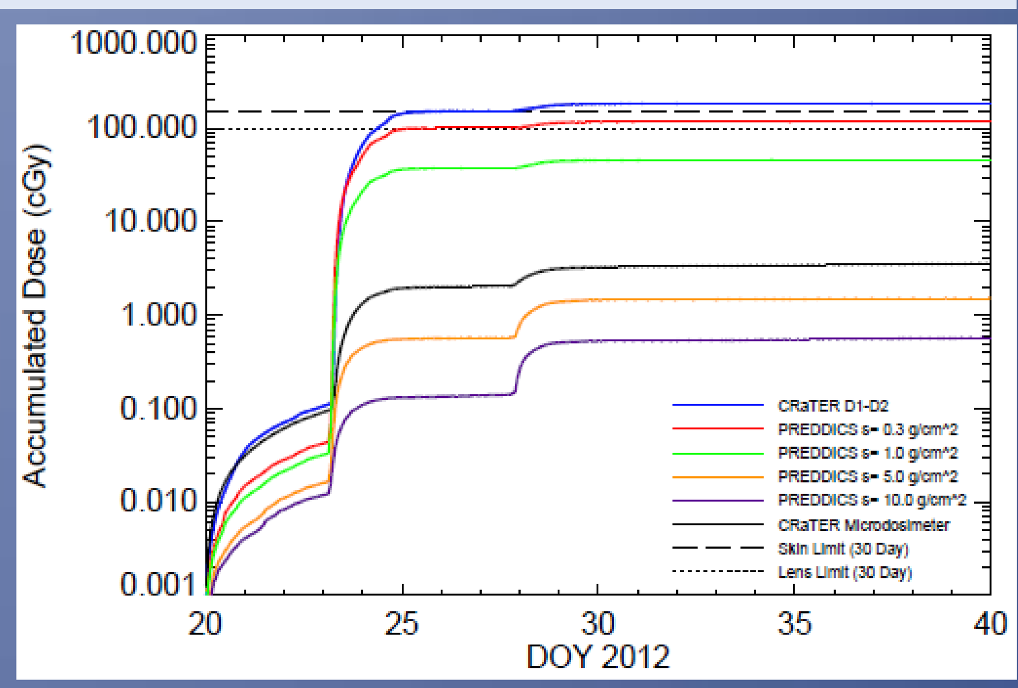


Figure 4: Accumulated dose for January solar event.

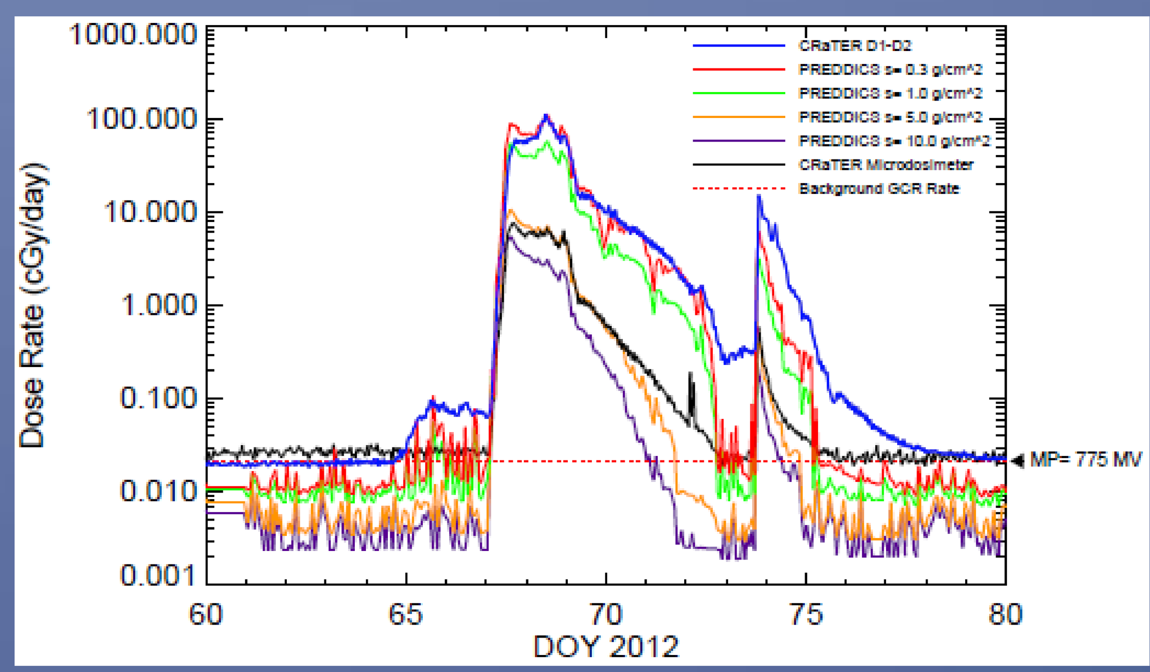


Figure 5: Dose rates during March solar event.

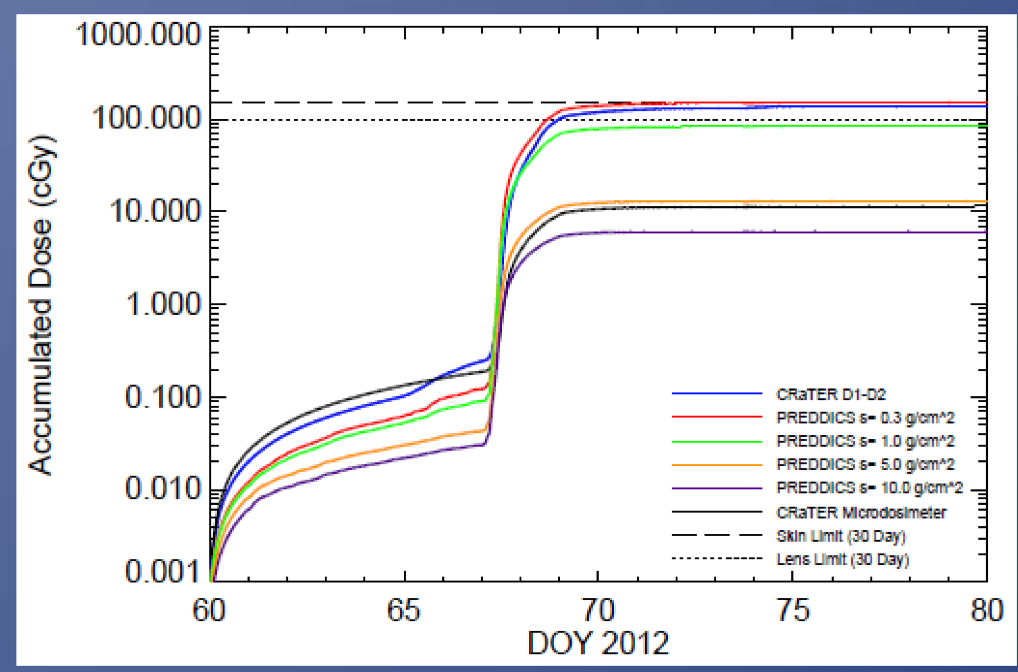


Figure 6: Accumulated dose for March solar event.

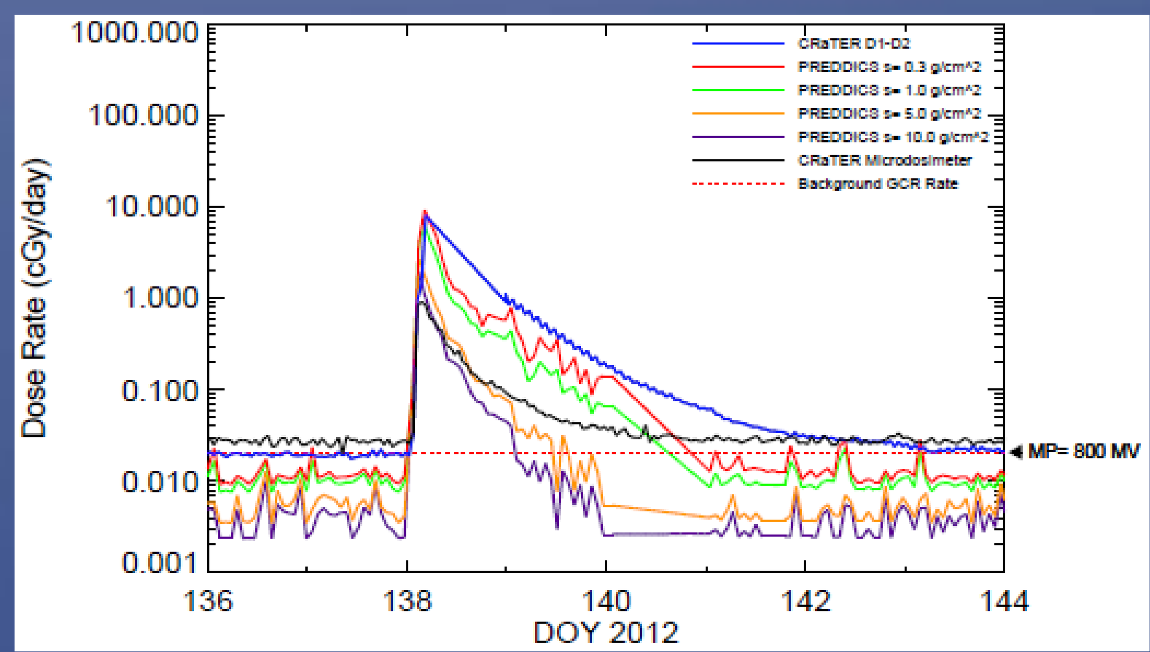


Figure 7: Dose rates during May solar event.

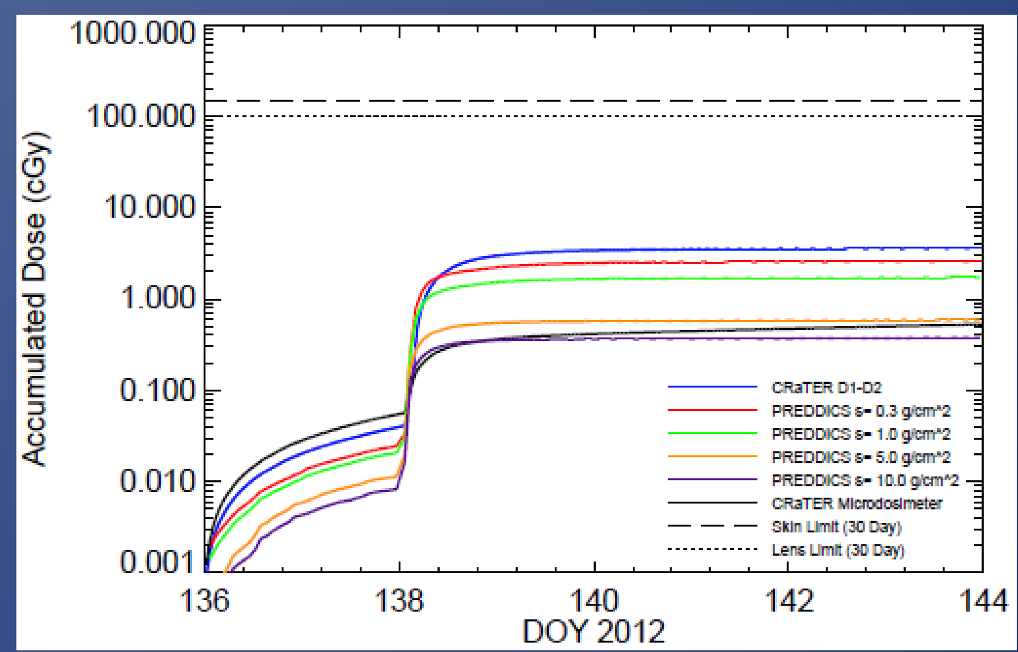


Figure 8: Accumulated dose for May solar event.

## Conclusions:

- PREDICCS accurately predicts the peak dose rates for the event, but that afterward the dose rate drops off much more rapidly than the dose rates measured by CRaTER.
- Based on these three events, the dose accumulated by PREDICCS underestimates the measured dose by as much as 36 percent, and overestimates it by as much as 10 percent.
- The discrepancies are likely due to the inherent limitations of the EMMREM, which is a one dimensional model that only incorporates protons into the calculation of dose.
- We demonstrate a method for computing the modulation potential at the Moon using measured CRaTER dose rates, which may be useful in improving PREDICCS and in the study of GCRs.
- This study represents the first multi-event validation of radiation environment models using observations of solar events from LRO/CRaTER. The model predictions are in good agreement with observations, paving the way for their future use in situational awareness and research.