Geophysical Research Abstracts
Vol. 21, EGU2019-8564, 2019
EGU General Assembly 2019

Disruption of the Earth's foreshock wave field during magnetic clouds

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The Earth's foreshock is a region of intense wave activity, extending upstream of the quasi-parallel sector of the terrestrial bow shock. Quasi-monochromatic fast magnetosonic waves with a period of about 30 s are most commonly observed in the Earth's foreshock. In this study, we investigate how the foreshock wave field is modified when magnetic clouds, a subset of coronal mass ejections which drive the most intense geomagnetic storms, interact with near-Earth space. We use observations from the four-spacecraft Cluster constellation, as multi-spacecraft analysis techniques allow us to determine the wave properties accurately. The enhanced magnetic field inside magnetic clouds results overall in a smaller period of the foreshock fast magnetosonic waves, as expected from previous works. More importantly, we find that the quasi-monochromatic waves are replaced by a superposition of fast magnetosonic waves at different frequencies. The transverse extent of the wave fronts is also significantly reduced during magnetic clouds, suggesting that the foreshock wave field is structured over smaller scales. Numerical simulations performed with the hybrid-Vlasov Vlasiator model further support that an enhanced upstream magnetic field results in smaller wave fronts and less monochromatic wave activity. These modifications of the foreshock wave properties are likely to affect the regions downstream - the bow shock, the magnetosheath and possibly the magnetosphere - as the foreshock waves are advected earthward by the solar wind.