Geophysical Research Abstracts
Vol. 17, EGU2015-7699, 2015
EGU General Assembly 2015

Ensemble Modeling of CME Propagation and Geoeffectiveness

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Ensemble modeling of coronal mass ejections (CMEs) provides a probabilistic forecast of CME arrival time which includes an estimation of arrival time uncertainty from the spread and distribution of predictions and forecast confidence in the likelihood of CME arrival. The real-time ensemble modeling of CME propagation uses the Wang-Sheeley-Arge (WSA)-ENLIL+Cone model installed at the *Community Coordinated Modeling Center* (CCMC) and executed in real-time at the CCMC/*Space Weather Research Center*. The current implementation of this ensemble modeling method evaluates the sensitivity of WSA-ENLIL+Cone model simulations of CME propagation to initial CME parameters. We discuss the results of real-time ensemble simulations for a total of 35 CME events which occurred between January 2013 - July 2014. For the 17 events where the CME was predicted to arrive at Earth, the mean absolute arrival time prediction error was 12.3 hours, which is comparable to the errors reported in other studies. For predictions of CME arrival at Earth the correct rejection rate is 62%, the false-alarm rate is 38%, the correct alarm ratio is 77%, and false alarm ratio is 23%. The arrival time was within the range of the ensemble arrival predictions for 8 out of 17 events. The Brier Score for CME arrival predictions is 0.15 (where a score of 0 on a range of 0 to 1 is a perfect forecast), which indicates that on average, the predicted probability, or likelihood, of CME arrival is fairly accurate. The reliability of ensemble CME arrival predictions is heavily dependent on the initial distribution of CME input parameters (e.g. speed, direction, and width), particularly the median and spread. Preliminary analysis of the probabilistic forecasts suggests undervariability, indicating that these ensembles do not sample a wide enough spread in CME input parameters. Prediction errors can also arise from ambient model parameters, the accuracy of the solar wind background derived from coronal maps, or other model limitations. Finally, predictions of the K_P geomagnetic index differ from observed values by less than one for 11 out of 17 of the ensembles and K_P prediction errors computed from the mean predicted K_P show a mean absolute error of 1.3.

The CCMC, located at NASA Goddard Space Flight Center, is an interagency partnership to facilitate community research and accelerate implementation of progress in research into space weather operations. The CCMC also serves the *Space Weather Scoreboard* website (http://kauai.ccmc.gsfc.nasa.gov/SWScoreBoard) to the research community who may submit CME arrival time predictions in real-time for a variety of forecasting methods. The website facilitates model validation under real-time conditions and enables collaboration. For every CME event table on the site, the average of all submitted forecasts is automatically computed, thus itself providing a community-wide ensemble mean CME arrival time and impact forecast from a variety of models/methods.