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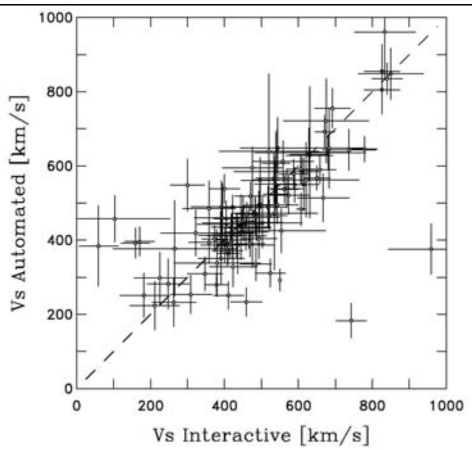
Automated Real-Time Shock Analysis for Space Weather Alerts

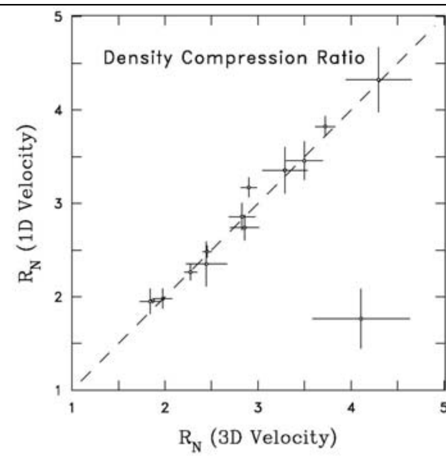
ACE News #100 reported on the development of a technique that can find and analyze interplanetary shocks in spacecraft data sets without the intervention of a trained researcher. We have made significant strides forward in this effort and are now announcing the release of a public web page where real-time solutions to shocks observed by the ACE spacecraft are available to serve the needs of the space weather community.

NASA's Advanced Composition Explorer (ACE) orbits L1 providing solar wind and energetic particle measurements for a broad range of scientific studies including solar, solar wind, and interstellar physics. ACE also provides detailed measurements of the input of solar energetic particles and solar wind energy into the magnetosphere and as part of this effort ACE provides a real-time data stream via the NOAA network of receiving stations. The ACE Real-Time data stream provides 1-minute resolution solar wind, magnetic field, and energetic particle measurements that are processed via automated routines to give early warning capability for space weather applications. Taking into account transmission times from the receiving stations to the central facility at NOAA/SEL, there is no more than 5-min latency in the data. These data continue to provide invaluable information that is monitored continuously by government agencies, private industries, and researchers around the world, including companies that maintain electrical power grids, industries that require accurate GPS information, and airlines.



(left) A comparison of the computed shock speed in the spacecraft frame for interactive and automated solutions using 98 examples of strong shocks from years 1999 to 2002.

(right) A comparison of computed density ratios for 16 strong shocks from year 2000 using automated 3-component and 1-component analyses for solar wind velocity.



The shock analysis codes that we employ solve the Rankine-Hugoniot (R-H) equations and are not based on the simpler but more error-prone minimum variance techniques. Normally, shock analysis codes run in interactive mode and are used only by well-informed scientific investigators. The fully automated shock analysis must perform many of the functions of an experienced shock researcher: (1) Find a shock in the Real-Time data stream; (2) Select upstream and downstream data points to characterize the shock condition; (3) Analyze shocks to obtain their shock compression, shock speed, normal, etc.; and (4) Release the shock solutions to the public. All this must be done within minutes of the shock becoming available in the Real-Time data stream.

Vorotnikov et al. (2008) detail the basic technique used in the automated analysis. (See the left-hand figure for a comparison of automated and interactive solutions.) After the publication of this paper it was realized that the Real-Time data stream contains only the wind speed and not the full 3 components of the solar wind velocity. To overcome this limitation, we assume that all velocities are radial. This is a radical assumption, as the R-H equations are solved in the rest frame of the plasma where there is no average flow. Still, the results of the new automated solutions agree very well with the previous automated results. (See right-hand figure.) A follow-up paper detailing the revised analysis is in preparation.

The technique described here is now fully implemented and running at the ACE Science Center. The automated shock solutions are available at: http://www.srl.caltech.edu/ACE/ASC/DATA/Shocks/shocks.html. While the current solar minimum conditions are unlikely to yield many significant shock events that will drive magnetospheric storm activity, the eventual solar maximum will provide such events and at that time we anticipate that the automated, real-time shock analyzer will prove very useful in space weather applications.

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See http://www.srl.caltech.edu/ACE/ACENews_Archives.html for an archive of earlier ACE News items.