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Torsional Alfven waves in the solar wind: Comparison of ACE and WIND observations

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We examined variations of the solar wind magnetic fields which are characterized by smooth field rotations in time scales of 2-7 hours, and identified the existence of two classes of the rotational variations. One class is interpreted as a small-scale magnetic flux rope. In the other class of events, velocity vectors rotate in a manner highly correlated with magnetic field vectors, and magnetic field intensities are maintained almost constant during the events. These features suggest that the observed variations in magnetic fields and velocity fields are due to Alfven waves.
In this study, we concentrate on events in the second class, and attempt to determine the mode of the Alfven wave. It may seem that the elliptically-polarized Alfven wave and/or the torsional Alfven waves can be taken as a possible candidate, at first sight. If we consider the wave propagation in a cylindrical region, the wave fields for the former case are constant in a plane perpendicular to the cylinder axis and rotate as a function of time. In case of the torsional wave, on the other hand, the wave fields are always in the azimuthal direction of the cylinder at any given time, in other words, rotating spatially. The examination of the observed wave fields shows that the rotation angles of the field vectors are generally 180 degrees or slightly less. This fact strongly suggests that the observations are to be consistently interpreted by the torsional Alfven wave.
We performed the least-squares fitting analysis for the observed rotational variations with a simple model of the torsional Alfven wave which is described by rotational wave fields propagating along the background uniform field. The fitted results show satisfactory agreement with observations, and thus confirm that the observations are interpreted by the passage of spacecraft through the cylindrical regions occupied by the torsional Alfven waves. In addition, the examination of ACE and WIND observations reveals several cases in which two spacecrafts encountered the same wave regions at different positions and different times. Comparison of such cases provides further evidence that the observed rotational variations are due to the torsional Alfven waves and not to the polarized wave fields. We also compared the direction of superthermal electron heat flow with the wave propagation direction inferred from the sign of the correlation coefficient between magnetic field and velocity field in each Alfven wave event, and thus confirmed that the Alfven waves are propagating away from the Sun.