Halo CMEs in October - November 2003: predictions and reality

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We have found recently that the intensity of Bz in the IMF is correlated with the plane of sky speed of coronal mass ejections (CMEs)¹,². In turn, the Bz in the IMF is correlated with the Dst index of geomagnetic activity ²,³,⁴,⁵ (see figures below).

Here we present results of prediction of the Bz and the Dst index made for 3 halo CMEs erupted in October-November 2003 (Oct 28, Oct 29 and Nov 18; events I, II and III respectively).

The comparison between the predicted values of the Bz and the Dst index and the observed data shows that we were able to successfully predict the magnitude of the Bz and Dst index for the October events I and II, while we have underestimated the magnitude of the Dst for the November event III.
Prediction Scheme: I. relationship between the expansion speed of halo CMEs and the magnitude of Bz in IMF:

Solid line is an exponential fit

\[ Bz[nT] = 12.3 + 0.7 \exp(V/404). \] (r.m.s=7nT)

Yurchyshyn et al. 2003, Adv. Space Res. 32, #10
Yurchyshyn et al. 2004, Space Weather, 2, S02001

Plane of sky speed of halo CMEs, km/s
Prediction Scheme: II. relationship between the Bz in IMF and the Dst index of geomagnetic activity:

Solid line is a 3rd degree polynomial fit.

(r.m.s=33nT)

Cane et al. 2000, GRL, 27
Wu & Lepping, 2002, JGR, 107, #A11
Yurchyshyn et al. 2003, Adv. Space Res. 32, #10
Yurchyshyn et al. 2004, Space Weather, 2, S02001
Results of the prediction of the magnitude of the Bz in the IMF from the plane of sky speed of 3 halo CMEs in October-November 2003
**Event I:**
The X17.2/4B flare started at 0951UT on Oct 28 2003 and it produced a halo CME. The solar data suggested that the axial field of the CME may have a southward component and the erupted field has negative helicity. The clock angle (measured clockwise from the east) of the post flare loops system, associated with this CME, was about \( 215 \) deg. The plane of sky speed of the CME was about 1500km/ s. Based on this speed we predicted

i) \( B_z \) in IMF to be -30 ... -44 nT and ii) changes in the Dst index: -250 ... -320 nT.

The shock arrived at 1 AU on Oct 29 at about 06:00UT, while the magnetic cloud arrived at about 1200UT. The magnetic cloud was southwardly oriented with the clock angle of about \( 266 \) degree and it had negative helicity (see the event reconstruction figure).

The \( B_z \) measured by the ACE satellite reached -26 nT, while the Dst index dropped by -320 nT and reached -360 nT.

**Event II:**
The X11 flare at 2037UT on Oct 29 2003 produced a second halo CME. The lack of the data did not allow us to reliably determine the possible orientation of the axial field and/or magnetic helicity. The plane of sky speed of the CME was, too, about 1500km/ s. Based on this speed we predicted

i) \( B_z \) in IMF : -30 ... -44 nT and ii) Changes in the Dst index: -250 ... -320 nT

The shock arrived at 1 AU on Oct 30 at about 1530UT, while the corresponding magnetic cloud could not be confidently distinguished in the ACE data.

Nevertheless this, quite possibly, complex ejecta presented a strong southward \( B_z \) component of -29 nT and the Dst index dropped by about -300 nT from -100 to -400 nT.
Event III:

The M3.9/2N flare started at 0812UT on Nov 18 2003 and it produced another halo CME. The solar data suggested that the axial field of the CME may have a southward component and the erupted field had positive helicity. The clock angle (measured clockwise from the east) of the post flare loops system, associated with this CME, was about 10 deg. The plane of sky speed of the CME was about 1400km/s. Based on this speed we predicted

i) Bz in IMF to be -21 ... -35 nT and ii) changes in the Dst index: -190 ... -250 nT.

The shock arrived at 1 AU on Nov 21 at about 0700UT, while the magnetic cloud arrived at about 1100UT. The magnetic cloud was south-eastwardly oriented with the clock angle of about 311 deg and positive helicity (see the event reconstruction figure).

However, the magnitude of the Bz, measured by the ACE satellite, was about -52 nT (!), while the Dst index dropped by 450 nT from +20 nT to -430 nT.

References:

3. Cane, H.V., Richardson, I.G., and St. Cyr, O.C., 2000, GRL, 27

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The two CMEs on Oct 28 and 29 had similar plane of sky speeds (≈1500 km/s) and the predicted ranges of changes in the Dst index in both cases were the same -250...-320 nT (blue boxes).

In reality, the Dst index decreased by 320 nT due to the first CME (event I) and by 300 nT due to the second CME (event II).
Oct 29 ACE Event I Reconstruction

Ejecta Time: 10/29 1117 UT
- 10/30 0349 UT

Cone angle: 113 deg
Clock angle: 266 deg
(clockwise from positive Y)

Axial Field: $B_z = 45$ nT

Magnetic Helicity: Negative

Orientation of the Ejecta was 266 deg
Event I: Oct 28 2003 X17.2/4B Flare

The long (short) arrows indicate the direction of the axial (azimuthal) field in the post flare arcade. This arcade was associated with a halo CME and its magnetic field had negative helicity. The clock angle of this arcade was about 215 degrees.

Oct 28 Halo CME was earth directed and, as suggested by the ACE data, it was approximately oriented along the NS line.
The CME on November 18 had the plane of sky speed of about 1400 km/s and the predicted range of changes in the Dst index was about -190 ... -250 nT (blue box).

In reality, we have underestimated this event: the ejecta had an extremely large and prolonged southward Bz, which caused a 450 nT decrease of the Dst index.
Nov 21 ACE Event III Reconstruction

Ejecta Time: 10/29 1117 UT - 10/30 0349 UT

Cone angle: 105 deg

Clock angle: 311 deg (clockwise from positive Y)

Axial Field: B_0^z = 57 nT

Magnetic Helicity: Positive

Orientation of the Ejecta was 311 deg
Event III: Nov 18 2003 M3.9/2N Fla

The long (short) arrows indicate the direction of the axial (azimuthal) field in the post flare arcade.

This arcade was associated with a halo CME and its magnetic field had positive helicity.

The clock angle of this arcade was about 10 degree.