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SOLAR WIND DYNAMIC PRESSURE JUMPS CHARACTERISTICS AND THEIR MAGNETOSPHERIC EFFECTS

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Abstract. The purpose of our work is to test the OMNI data base(http://omniweb.gsfc.nasa.gov) on interplanetary discontinuities, using ground observations. We study the response time of the ground SYM-index to solar wind dynamic pressure (Pd) jumps, recorded by remote (100-200Re) spacecraft and transferred to Earth bow shock(BS) according to OMNI and by convection time. We also transfer solar wind structures using methods of normal and velocity calculations for given type of discontinuities. Two types of discontinuities corresponding to Pd jumps: tangential (TD), and fast shocks (FS) were considered.We also compare normals from OMNI and those obtained by methods for concrete discontinuities.

62 SYM jumps, corresponding to 35 TDs and 27 FSs, were analyzed. The results are as follows: According to OMNI, TDs come to the bow shock on average 4 min before SIs on the ground. For convection translation the average delays are also 4 min, but the scatter is larger. Thus the OMNI procedure is better than the convection one. For shocks OMNI gives unrealistic results: on average the Pd jumps come to the bow shock 4 min after the ground SIs. As for normals, the average angle between normals from OMNI and our normals is 13 degrees for TDs and 66 degrees for FSs. We conclude, that the OMNI data base is good for TDs and can not be used for FSs.

Introduction

To study the solar wind - magnetosphere interaction it is necessary to determine time, when structures, registered at ~ 200 Re from Earth, come to the Earth BS. Until recently, solar wind parameters were usually transferred by convection time dt = dx / Vsw, implying front of the structures moving with the solar wind and being perpendicular to the Sun-Earth line. However solar wind discontinuities, as well as solar wind phase fronts, are often inclined to the Sun-Earth line, which is taken into account in the recently created OMNI data base. This base contains solar wind/IMF parameters, transferred to the Earth bow shock, and is created for smooth variations of solar wind parameters. It is interesting to test OMNI on solar wind discontinuities.

A good way to test the OMNI data base is to compare it with ground observations. We consider the solar wind dynamic pressure jumps and corresponding ground Sis, comparing the time of the jumps at the bow shock and on the ground.

Time delays between Pd jumps at the BS, taken (1) from OMNI and (2) transferred by convection on the one hand, and jumps of ground SYM- index (SIs) on the other hand, were studied separately for TDs and FSs. These delays were compared with those, based on discontinuity normal and velocity calculation for the given discontinuity. We also compare normal vectors from OMNI and obtained by methods for concrete discontinuities.

Data and methods of normal and velocity determination

In this work events with dynamic pressure jumps, causing SYM-index jumps, were selected. All calculations were performed in the GSE coordinate system. Following data were processed:

- Data from distant spacecrafts ACE (~ 220Re) and WIND (~ 100Re) (~1min plasma and magnetic data), 1995-1998 and 2001.
- SYM index (as the ground characteristics)
- OMNI database (1min) based on Ace and Wind

Each event has been processed and presented as a graph:

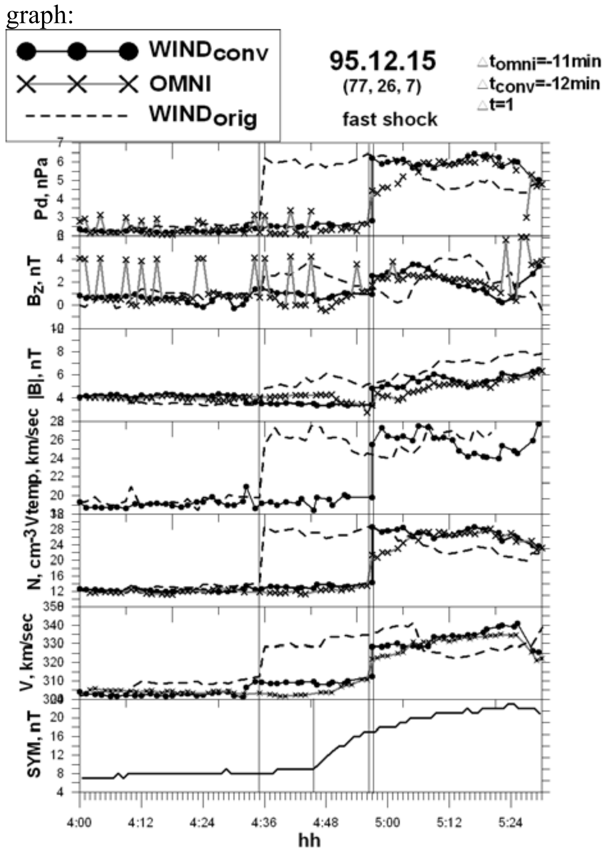


Fig.1 Data from WIND (77,26,7)

<u>Tangential discontinuity (TD):</u>

Normals: $\mathbf{n} = [\mathbf{B}_1 \times \mathbf{B}_2] / \left|[\mathbf{B}_1 \times \mathbf{B}_2]\right|$, where **B1** and **B2** are **the** magnetic field vectors on both sides of discontinuity. This method is used, if the angle between B1 and B2 is smaller than 13^0 (as in the method of OMNI). Otherwise, the MVA method was used for 16-second ACE data and 3-second WIND data.

Velocity: Tangential discontinuity has the same speed as the solar wind

Fast shock (FS):

Normals: Let **B1, B2** and **B3** be the vector magnetic field before fast shock, in the current layer and after the shock. From the coplanarity theorem vectors **B1** and **B3** lie in the same plane as the normal, so the vector **[B1 × B3]** lies in the discontinuity plane. The vector **[B3-B1]** also lies in the discontinuity plane, so the normal vector for fast shock : **nb**= $[\mathbf{B}_1 \times \mathbf{B}_3] \times [\mathbf{B}_3 - \mathbf{B}_1] / \left| [\mathbf{B}_1 \times \mathbf{B}_3] \times [\mathbf{B}_3 - \mathbf{B}_1] \right|$ As the vector **dV** also lies in the plane, containing **B1**, **B3** and **n** , it is possible to determine the normal as **np**= $[\mathbf{B1} \times \mathbf{dV}] \times [\mathbf{B3} - \mathbf{B1}] / \left| [\mathbf{B1} \times \mathbf{dV}] \times [\mathbf{B3} - \mathbf{B1}] \right|$ If the angle between **nb** and **np** was more than 20^0, this case was excluded.

Velocity: From continuity of mass flow: **Vsh=[(V2*ρ2- ρ1*V1)/(ρ2- ρ1)]*n,** and in the solar wind system **Vsh2=[(ρ2/(ρ2- ρ1)]*dV*n** , **Vsh=Vn+Vsh2**. From **E**=0 in the FS reference system[1]: **Vsh1=[dV*B2/(B2- B1)]** (in the solar wind system) . It was required that **Vsh1** and **Vsh2** coincided with an accuracy of 2%.

OMNI database:

*Normals:*Since 2007, most researchers use the OMNI database, which recalculates the interplanetary parameters to the Earth bow shock based on normals to the phase fronts. Normals are calculated as:

n= $[\mathbf{B}_1 \times \mathbf{B}_2] / \left| [\mathbf{B}_1 \times \mathbf{B}_2] \right|$, if the angle between the vectors **B1** and **B2 is** less than 13^0 and Bn <0.035nT. Otherwise the MVA-B0[2] method is used.

Methods of solar wind parameters transport to the BS

One of the earliest and simplest methods of transferring data from spacecraft to the BS is transport by convection. This method is based on a simple calculation of expression (Δx / V), where Δx- is the distance between the observation point and BS along the x axis. This method was tested by comparison with the OMNI database and transfer method, taking into account the discontinuity normal and velocity.

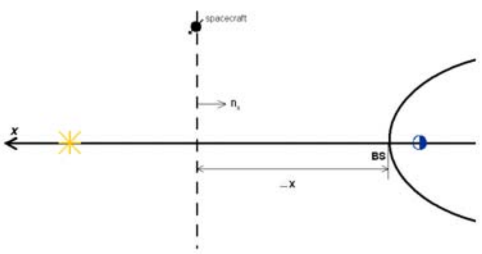


Fig. 2 Scheme of transfer by convection (perpendicular discontinuity).

However real discontinuities are slanted, so the propagation time is (Fig.3)

$$t = \Delta x / V, \quad \Delta x = (x_0 - x_{bs})$$

$$x_0 = (n_y * y_1 + n_x * x_1 + n_z * z_1) / n_x$$

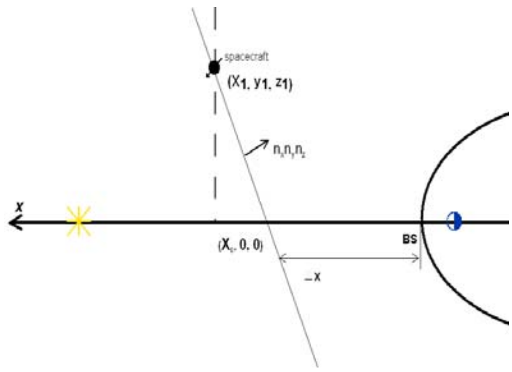


Fig. 3 Transfer scheme for slanted discontinuities.

Results and discussion

Tangential discontinuities:

$$\mathbf{n} = [\mathbf{B}_1 \times \mathbf{B}_2] / \left| [\mathbf{B}_1 \times \mathbf{B}_2] \right|$$

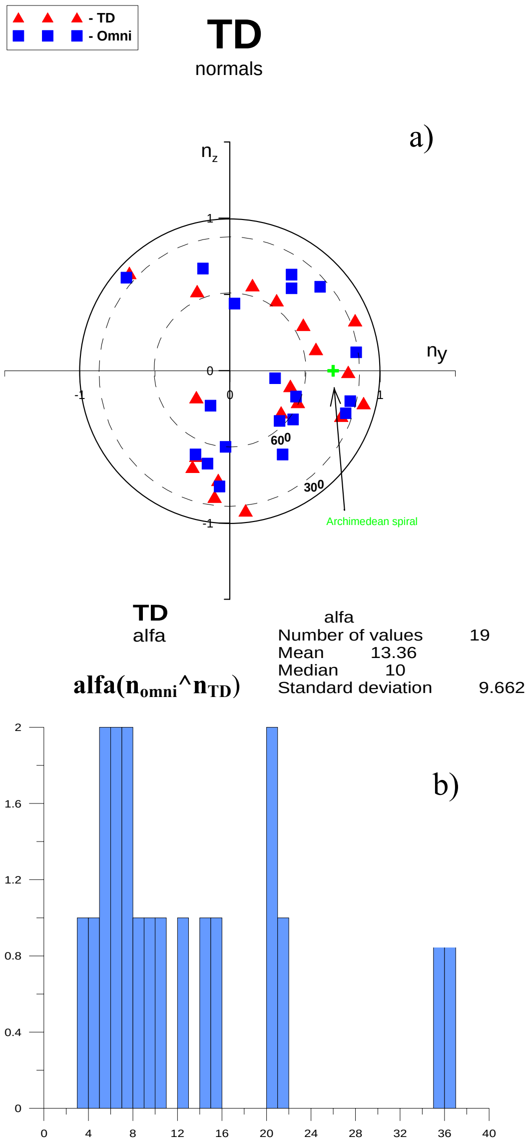


Fig. 4 a) Distribution of normals for TD

b) Histogram of the angles between the normals from OMNI and from our calculations.

The values of OMNI normals agree with the values obtained for tangential discontinuities.

<u>Fast Shoks:</u>

n=(np+nb)/2

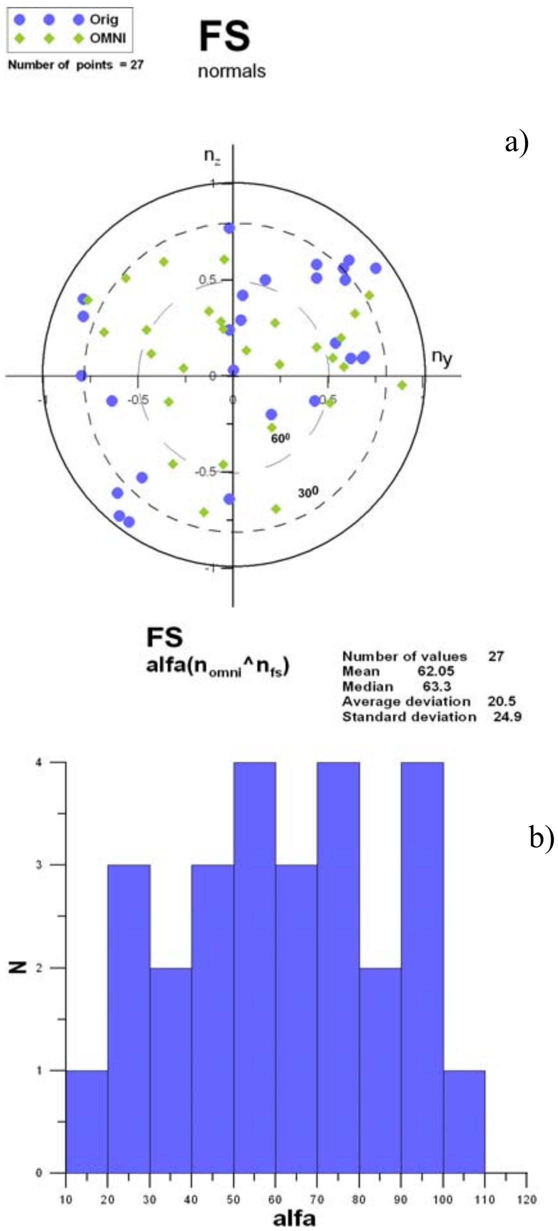


Fig.5 a) Distribution of normals

b)Histogram of the angle between the normals from OMNI and our results for FS

The values of OMNI normals do not agree with the values obtained for FSs

Determination of the time lag: between the SYM-index jump of and contact time:

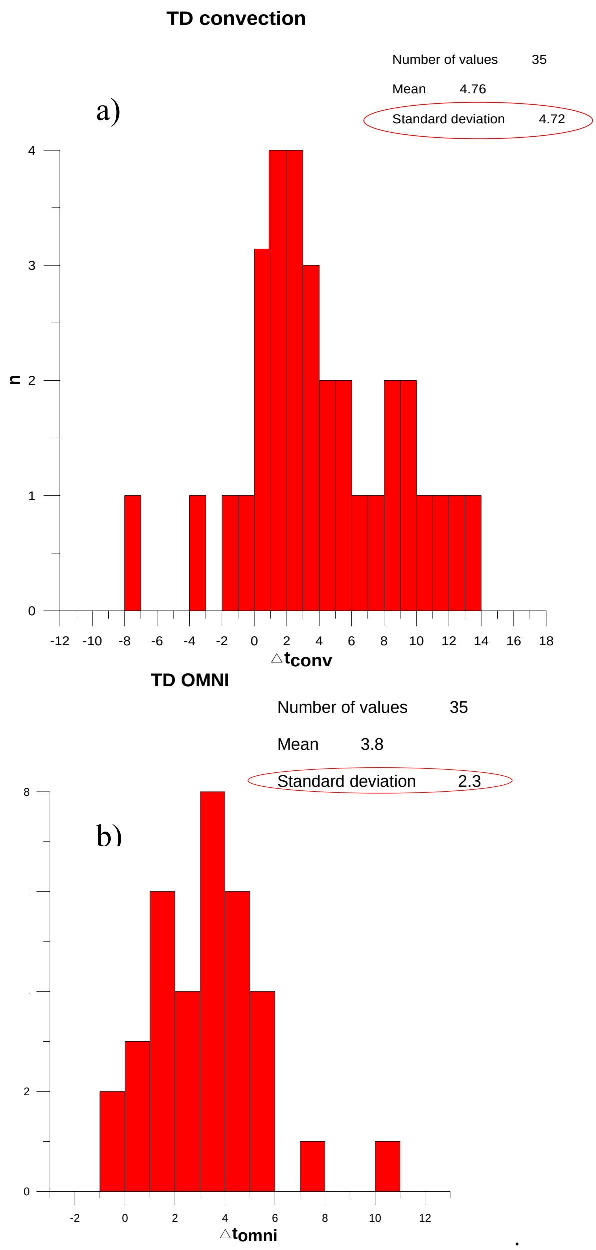
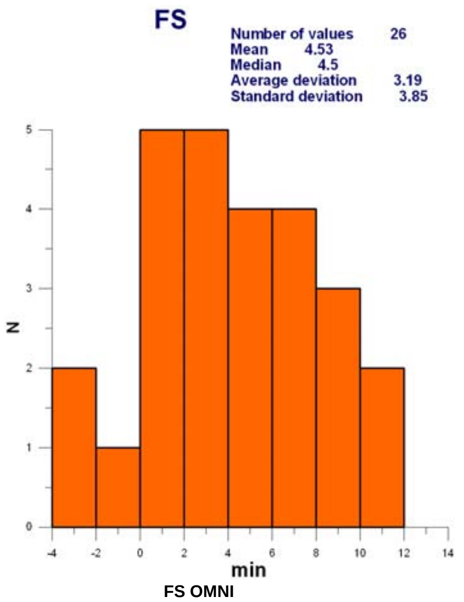


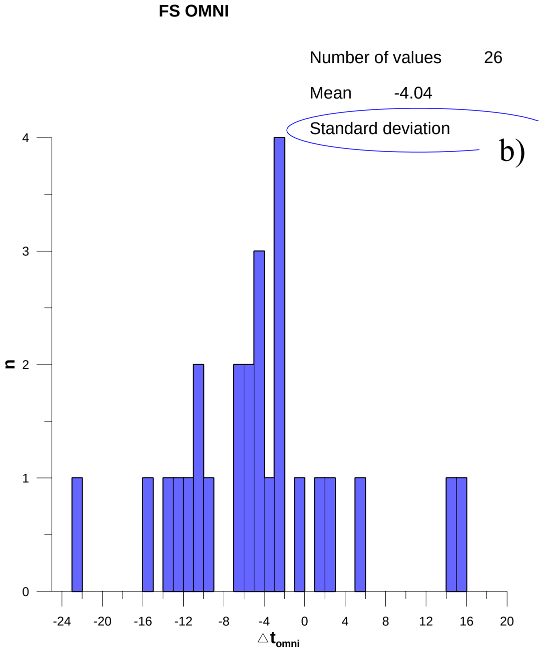
Fig. 6 Histograms:**a)** of the time lag for TD, transferred by convection

b) of the time lag for TD, transferred by OMNI

Transfer by OMNI provides a better (smaller standard deviation) match with the time of SYM registration than transfer by convection.



a)



b)

Fig. 9 Histograms: **a)** of the time lag for FS, using normals and velocity values, calculated for FSs.
b) of the time lag for FS, transferred by OMNI.
FS transfer by OMNI gave incorrect results.

Our analysis shows that tangential discontinuities as well as fast shocks, may have any orientations, the structures being oriented neither perpendicular to the x-axis nor along the Archimedean spiral. Interaction of TDs and FSs with Earth's magnetosphere is extensively studied by MHD modeling and using spacecrafts experiments. For FSs the existing experimental data and the MHD modeling [3, 4] give delay times of about 2-5 min in agreement with our results. For TDs we also obtained propagation times ~4min.

Summary

For the tangential discontinuities the OMNI method gives good results. Omni transfer gives delays between SYM-index jump and the dynamic pressure jump about 4 minutes, standard deviation of about 2 minutes; for convection transfer the difference is about 5 minutes with standard deviation 4 minutes. So the OMNI method gives better results than the convective transport.

The OMNI normals correspond to normals for tangential discontinuities (the average angle between the normals is 13^0). This means that tangential discontinuities have the same orientation as the phase fronts of surrounding SW.

For FSs the OMNI method gives negative SYM delay -4 min., so OMNI transfer is invalid. The calculation of time based on normals and velocities by formulas for FS gives the delay 5 min., consistent with the time of shock propagation through the magnetosheath and magnetosphere to the Earth.

The average angle between the normals, defined by formulas for shock, and given by OMNI, is 63^0, so the shock front has orientation, quite different from the orientation of the solar wind phase front.

The OMNI base is not valid for FSs and is good for TDs.

References

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