A NEW METHOD FOR RESOLVING THE 180° AMBIGUITY IN SOLAR VECTOR MAGNETOGRAMS

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Abstract. We present a new method to resolve the 180° ambiguity for solar vector magnetogram measurements. The basic assumption is that the magnetic shear angle ($\Delta\theta$), which is defined as the difference between the azimuth components of observed and potential fields, approximately follows a normal distribution. The new method is composed of three steps. First, we apply the potential field method to determine the azimuthal components of the observed magnetic fields. Second, we resolve the ambiguity with a new criterion: $-90° + \Delta\theta_{mp} \leq \Delta\theta \leq 90° + \Delta\theta_{mp}$, where $\Delta\theta_{mp}$ is the most probable value of magnetic shear angle from its number distribution. Finally, to remove some localized field discontinuities, we use the criterion $\mathbf{B}_t \cdot \mathbf{B}_{mt} \geq 0$, where $\mathbf{B}_t$ and $\mathbf{B}_{mt}$ are an observed transverse field and its mean value for a small surrounding region, respectively. For an illustration, we have applied the new ambiguity removal method (Uniform Shear Method) to a vector magnetogram which covers a highly sheared region near the polarity inversion line of NOAA AR 0039. As a result, we have found that the new ambiguity solution was successful and removed spatial discontinuities in the transverse vector fields produced in the magnetogram by the potential field method. It is also found that our solution to the ambiguity gives nearly the same results, for highly sheared vector magnetograms and vertical current density distributions, of NOAA AR 5747 and AR 6233 as those of other methods. The validity of the basic assumption for an approximate normal distribution is demonstrated by the number distributions of magnetic shear angle for the three active regions under consideration.

1. Introduction

When one analyzes vector magnetograms from solar magnetograph measurements, one of the most challenging problems is to resolve the 180° ambiguity in the azimuth of the observed transverse fields. This ambiguity is attributed to the fact that the two anti-parallel polarization signals of the transverse fields are identical to each other since the transverse measurements from the magnetograph provides only the plane of linear polarization. For all observed vector magnetograms, the ambiguity should be resolved to obtain the correct direction of the transverse vector fields. A reasonable method to solve this ambiguity is of great importance because knowing the proper orientation of solar magnetic fields is required to gain a meaningful understanding of several physical quantities of flare-producing active regions such as shear angle, vertical current density, magnetic free energy density

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and MAD (the maximum angular difference between two adjacent field vectors, Moon *et al.*, 1999).

Hagyard *et al.* (1984) defined the magnetic shear angle as the angular difference between an observed transverse field and the transverse component of the potential field, which is computed by employing observed longitudinal fields as a boundary condition. That is, the magnetic shear angle $\Delta\theta$ is given by

$$\Delta\theta = \theta_o - \theta_p \,, \tag{1}$$

in which θ_o is the azimuth of the observed transverse field and θ_p is the azimuth of the corresponding potential field component. Noting that flares are associated with large magnetic shear of strong transverse fields, Wang (1992) proposed a transverse weighted mean shear angle given by

$$\Delta\overline{\theta} = \frac{\sum B_t \Delta\theta}{\sum B_t}, \tag{2}$$

where B_t is the transverse field strength and the sum is taken over all of the pixels under consideration. He found that the weighted mean shear angle of a flaring active region jumped about 5° coinciding with an X-class flare. He also showed that five additional X-class flares had the same pattern of shear angle variation (Wang *et al.*, 1994; Wang, 1997). Wang *et al.* (2002) reported on two X-class flares, in addition to the two papers mentioned previously, during which the shear increased.

However, the association of the shear of an active region with solar flares still remains controversial. There were apparently contrary reports that the shear may increase, decrease or remain the same after flares (Ambastha, Hagyard, and West, 1993; Hagyard, West, and Smith, 1993; Hagyard, Stark, and Venkatakrishnan, 1999). Chen *et al.* (1994) found that there were no detectable changes in magnetic shear after 18 M-class flares. Since the determination of the magnetic shear angle strongly depends on resolving the 180° ambiguity, it is very important to solve this problem.

To resolve the ambiguity, some constraints on the field azimuth are to be introduced in terms of theoretical and/or observational aspects (for a review, see Gary and Démoulin, 1995). One of the commonly used techniques is the potential field method based on the fact that an observed transverse magnetic field tends not to deviate much from a tangential component of an associated potential field; that is, the direction of the transverse field is chosen such that the angular difference between the observed and the potential components makes an acute angle. However, this criterion may break down for flaring active regions, which generally have strong shears near a polarity inversion line; that is, the transverse fields are often nearly parallel to the polarity inversion line.

More sophisticated and/or multi-step methods to resolve this ambiguity have been suggested by several authors. Canfield *et al.* (1993) employed a multi-step approach by using several criteria, which was well described in the appendix of their paper. The main step of their methodology is to choose the orientation of