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Relationship of Non–potentiality and Flaring: Intercomparison for an M–class Flare

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Abstract. We have made an attempt to obtain relationship of magnetic shear and vertical currents in NOAA AR7321. Intercomparison of changes observed at several flaring and non-flaring sites associated with an M4/2B flare observed on October 26, 1992 is reported.

Key words. Magnetic shear—electrical current—flare.

1. Introduction

The source of flare energy is believed to be in the form of excess energy stored in non-potential magnetic structures. One may expect to detect measurable flare related changes in magnetic field. Non-potentiality in active regions is generally described by angular or magnetic shear, electric currents, magnetic helicity or force-free parameter (Hagyard 1990; Canfield *et al.* 1993). Basic input for calculating these parameters is accurate, high spatial and temporal resolution, and multi-layer measurement of solar vector magnetic field. So far, this has been difficult to achieve to the desired accuracy. There remain difficulties in interpreting the results due to both solar and non-solar reasons. To redress the problem, quantitative descriptions based on averaging of non-potentiality parameters over an area-of interest have been suggested. A bewildering variety of flare-related changes have been reported, which include increase, decrease, or no change during flares (Ambastha, Hagyard, & West 1993; Wang H. 1992, 1997; Wang J. *et al* 1996; Hagyard, Stark & Venkatakrishnan 1999). There seems to be no direct relation of the strength of shear with the class of flare. Considering the importance of the problem, careful search for flare related changes is needed for large number of active regions in order to establish the results. No significant contribution to the magnetic energy is expected to come from areas of an active region where the longitudinal component B_z = 0, or $B_t \sim 0$ (Forbes 1993). Therefore, an areal averaging over the region between the umbra and the polarity inversion line should hopefully provide measurable changes. Also, H_α flare-ribbons form near the foot points of the magnetic fleldlines along which magnetic energy release takes place. A search for any flare-related change in non-potential index may be promising near flare-ribbons.

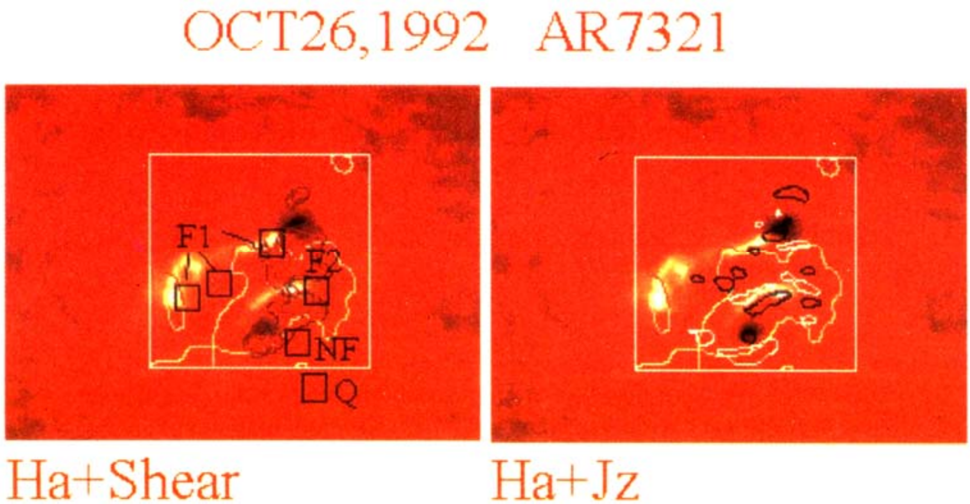

Figure 1. Overlays of shear and vertical currents J_z on H_α filtergrams of NOAA AR7321 on October 26, 1992/14:56 UT

2. Quantitative measure of magnetic non-potentiality and the observational data

We have made magnetic shear $\omega = B_t \times |\theta_{obs} - \theta_{pot}|$, and vertical current density $J_z = \frac{1}{4\pi}(\nabla \times \vec{B})_z$ maps for their comparison. Here θ_{obs} and θ_{pot} are azimuth angles of the observed and potential transverse fields. Overlays of these maps and co-temporal H_α filtergrams show the spatial correlation of flaring locations with shear and currents at 14:56 UT, i.e., before the flare onset (Fig. 1). However, it is usually rather difficult to identify changes in angular shear $|\theta_{obs} - \theta_{pot}|$ occurring at pixel level during the evolution of the flare because – (i) flare related changes in B_t (both in its magnitude and azimuth) are expected to be rather small, (ii) errors in B_t measurements are large, (iii) both solar and non-solar effects introduce ambiguities, and (iv) angular shear depends on the method of the calculated potential field.. Telescope tracking errors and atmospheric changes add further contamination to the data. Due to these difficulties, it is advantageous to use area-averaged shear parameter, which improves the signal-to-noise ratio, and provides a quantitative index. However, the precise location of changes is lost in the process of the spatial averaging. Also, the source of change becomes difficult to identify, i.e., whether the observed change in non-potentiality corresponds to a change in the magnitude of B_t, its azimuth θ_{obs}, or both. Area-averaging may be carried out over the spatial scale of the entire active region, giving the magnitude of non-potentiality for the active region, but any flare related changes occurring at much smaller spatial scales get suppressed. Therefore, it is desirable to select a suitably small area near the flare site. Further, it is important to have simultaneous high quality vector magnetograms and H_α filtergrams over the period of the flare.

We have analysed the vector magnetograms obtained for the active region NOAA7321 on October 26, 1992, obtained from the NASA Marshall Space Flight Center (MSFC). The active region underwent a rapid change in magnetic configuration and produced several flares from its birth on October 24, 1992, till the disappearance behind the western limb on November 2, 1992. A M4/2B flare was

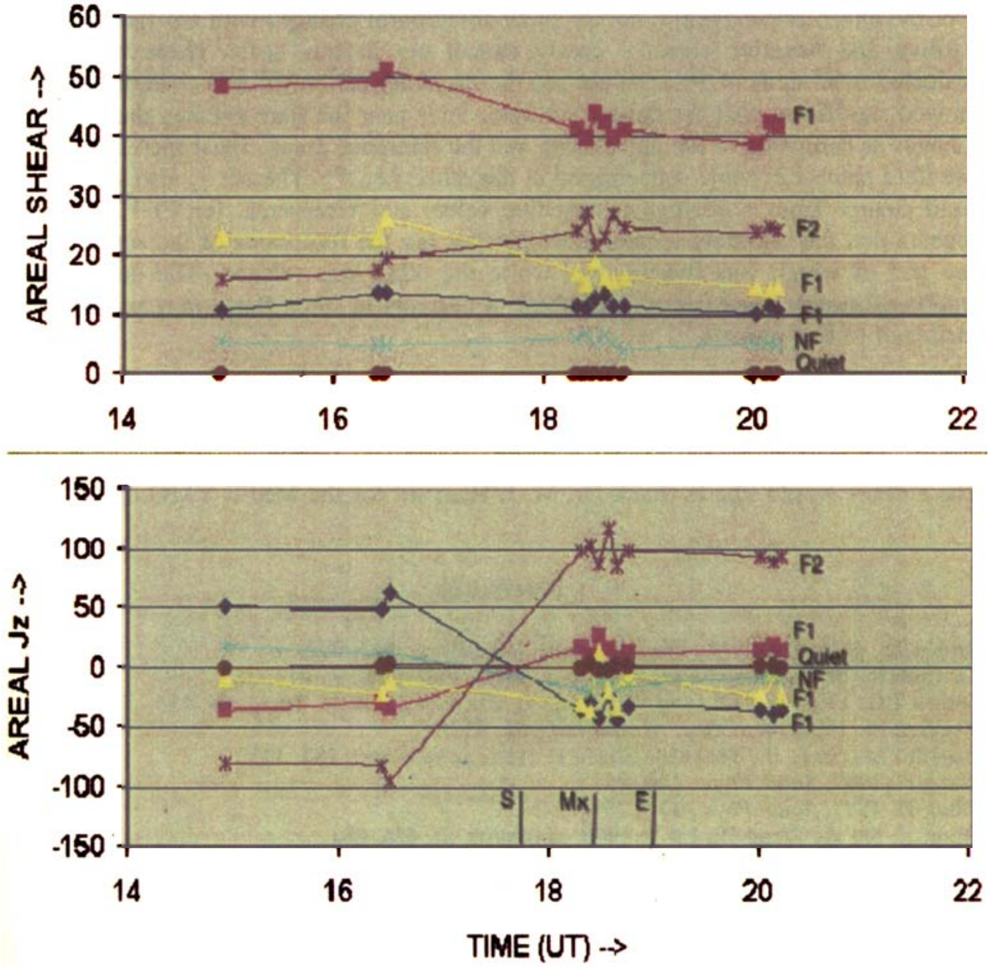

Figure 2. Time evolution of area-averaged shear and current indices.

observed on October 26, 1992/17:4518:34 UT in this active region at the location S21W18. Using the magnetograms available before, during, and after this flare, we have obtained the time profiles of the area-averaged shear and vertical current indices for certain sites near a reference quiet area, flaring (Fl and F2) and non-flaring (NF) locations (Fig. 2). Flare start, maximum phase and end time are marked on the time axis.

3. Results and conclusions

The shear and J_z maps of NOAA7321 show that the sites of large shear and currents generally correspond with locations of H_α flare patches, however, J_z appear to have a closer relationship. Some flare-ribbons are seen in areas having low or no shear, but they appear to be linked to remote sites of strong shear through loop structures, as inferred from the H_α filtergrams. Area-averaged shear and vertical current, obtained over the entire active region, do not show cotemporal changes with the flare, as the positive and negative currents nearly cancel out at this scale. However, when evaluated over areas of 30×30 arc-sec the carefully calibrated and coaligned maps showed significant changes during the flare. Sites near the flare patches show larger changes as compared to the non-flaring and the reference areas. Shear increased near one flare patch F2, while it decreased in the other, i.e., Fl. The net J_z also showed a rapid change from a positive to negative value, and vice-versa, for F1-F2 pair. It appears that the remotely located flare-patches are the footpoints of the same loop; one end of which was twisting up, while the other was relaxed. The conflicting reports of increase and decrease in shear or currents in some flares may perhaps be attributed to this process.

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