

**LORENTZ FORCES AND HELICITY DIAGNOSTICS IN SOLAR ACTIVE REGIONS,
BASED ON A FAST RESOLUTION OF THE AZIMUTHAL AMBIGUITY IN SOLAR
VECTOR MAGNETOGRAMS**

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SUMMARY

We have developed a fast, fully automatic analysis package that expedites substantially the processing of solar vector magnetograms. This tool may be very useful in both existing and imminent ground-based and space-borne solar projects, as well as in demanding Space Weather applications, such as flare and geomagnetic storm prediction from coronal mass ejections. Given an active-region vector magnetogram, the implementation code performs the following tasks: *(i)* It resolves the azimuthal ambiguity of 180° in the magnetogram, *(ii)* it calculates the vertical Lorentz force and a lower limit of the non-field-aligned electric current density on the resolved magnetogram, and *(iii)* it estimates the magnetic helicity budget in the active region. The resolution of the 180° -ambiguity is obtained by a semi-analytical *structure minimization* technique, where we seek to minimize the complexity of the magnetic configuration. The required computation is only a small fraction of the one required by existing methods. For the first time, our technique is disentangled from any explicit use of potential / linear force-free magnetic extrapolations. Moreover, our results are in excellent agreement with the results of sophisticated, but impractically slow, techniques. The ambiguity resolution provides an approximate vertical gradient of the magnetic field strength. We show how this information leads directly to the calculation of the vertical Lorentz force on the plane of the observations. This further leads to a calculation of a lower limit of the non-field-aligned electric current density. Forced areas in an active region are identified quantitatively for the first time. We show that the magnetic configurations on the active-region solar photosphere are strongly forced. The above innovations allow the development of a technique to calculate the relative magnetic helicity budget in an active region. The method only assumes knowledge of the potential photospheric field and of a representative overall value of the force-free parameter for the active region. Based on the linear force-free approximation, the method tracks the coronal magnetic field lines in the active region thus providing an estimate of the relative magnetic helicity. The technique is currently applied to flaring active regions, prolific in coronal mass ejections, in an attempt to detect any signature of the flares or of the magnetic fields ejected in the heliosphere.

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