

SOLIS Vector Spectromagnetograph: Status and Science

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Abstract. The Vector Spectromagnetograph (VSM) instrument has recorded photospheric and chromospheric magnetograms daily since August 2003. Full-disk photospheric vector magnetograms are observed at least weekly and, since November 2006, area-scans of active regions daily. Quick-look vector magnetic images, plus X3D and FITS formatted files, are now publicly available daily. In the near future, Milne-Eddington inversion parameter data will also be available and a typical observing day will include three full-disk photospheric vector magnetograms. Besides full-disk observations, the VSM is capable of high temporal cadence area-scans of both the photosphere and chromosphere. Carrington rotation and daily synoptic maps are also available from the photospheric magnetograms and coronal hole estimate images.

1. Introduction

The VSM currently operates at Kitt Peak, Arizona and is part of the Synoptic Optical Long-term Investigations of the Sun (SOLIS) project (Keller, Harvey, & Giampapa 2003). The VSM provides a unique record of solar full-disk vector magnetograms along with high-sensitivity photospheric and chromospheric longitudinal magnetograms (Henney, Keller, & Harvey 2006). The VSM began recording full-disk vector magnetograms in August 2003 at a temporary site in Tucson, Arizona. In April 2004, the VSM was relocated to Kitt Peak and resumed operations in May 2004. The VSM records the full Stokes profiles of the Fe I 630.15 and 630.25 nm lines with a current spatial and spectral sampling of 1.125 arcsec and 2.71 pm respectively. The 50-cm aperture VSM utilizes a Ritchey-Chrétien optical design, where full-disk images are constructed from 2048 individual steps in declination of the projected solar image on the entrance slit (hereafter referred to as scan-lines). Observations with fewer scan-lines are referred to as area-scans and are typically recorded for active region areas. For example, 88 area-scans were recorded in the month of October 2003 during an exceptionally active flare period.

The VSM is available for user-requested programs and currently supports ongoing solar missions (e.g. MDI, STEREO, Hinode/SOT) and will support forthcoming missions (e.g. SDO/HMI). For example, VSM observations provide temporal and spatial context for the SOT observations. Though SOT/SP has exceptional spatial resolution, the VSM observes any solar region eight times

faster than SOT/SP and ten times larger in one spatial direction. The VSM also provides full-disk coverage not available with SOT. In addition, the future SDO/HMI instrument will have high temporal cadence and spatial resolution, but will have very limited spectral resolution (with six filter images) that the VSM will complement with fully resolved Stokes profiles.

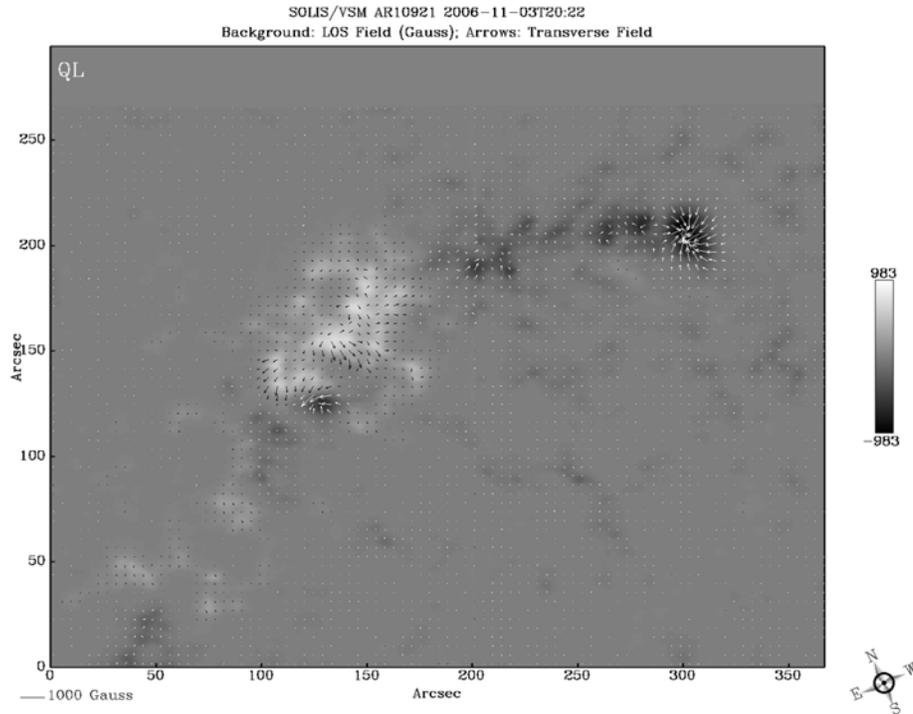


Figure 1. An example VSM vector quick-look image of NOAA active region 10921, observed on November 3, 2006. The gray-scale illustrates the line-of-sight magnetic flux and the arrows indicate the transverse field strength (the length scale is shown in the lower left-hand corner) and direction.

1.1. VSM Upgrades

Starting in 2004, the VSM suffered from a slow degradation of the vector polarization modulator needed to measure full Stokes profiles. This complicated VSM vector calibrations and slowed efforts to release the vector magnetic data. In February of 2006, the vector polarization modulator was replaced along with two modulators for the line-of-sight component of the magnetic field in the solar photosphere (630.2 nm) and the chromosphere (854.2 nm). During this maintenance period, a broken part was also replaced to reduce grating flexure. Though the new modulators are performing well, e.g. the strength of the 854.2 nm signal has significantly increased, the vector modulator has a polarization fringe pattern that is temperature dependent. The fringe pattern has recently been well parameterized to minimize the number of terms required for a good fit. The fringe fitting algorithm is expected to be incorporated in the SOLIS pro-

cessing pipeline in 2008. Since 2003, the VSM has incorporated two interim CMOS hybrid cameras made by Rockwell Scientific (now Teledyne Scientific & Imaging, LLC). During the first year of operation, several unexpected camera signals were revealed. Two of the pronounced artifacts, a variable dark level and signal cross-talk at the 0.5% level, required significant modification to the data reduction pipeline. The cameras were also found to have a 25% residual signal from previous frames. These interim cameras are scheduled to be replaced in 2008 with cameras produced by Sarnoff that better match the spatial scale, sensitivity, low readout noise and desired frame rate for the VSM.

2. VSM Data Products

The raw VSM spectral data is processed using a pool of distributed data reduction processes that are managed by the Data Handling System (DHS) on 10 dual-CPU Linux computers (see Wampler 2002; Jones et al. 2002). The VSM vector data processing pipeline is designed to provide products in two stages: first, as a quick-look (QL) product within 10 minutes of data acquisition, and then as a Milne-Eddington (ME) inversion product within 3 to 24 hours of each observation. The QL parameter data, following Auer, Heasley & House (1977), include estimates of the magnetic field strength, inclination, and azimuth (see Henney et al. 2006). The ME vector parameters are determined with the inversion technique of Skumanich & Lites (1987). Currently, the VSM QL data is made publicly available using azimuth disambiguation code that automatically selects the active regions following Georgoulis, Raouafi, & Henney (2008). Once the polarization fringe fitting algorithm, discussed in Section 1.1, is part of the DHS, the ME vector parameter products will be publically available.

All of the VSM QL data are corrected for the 180-degree ambiguity using the Non-Potential Field Calculation method (Georgoulis 2005). VSM quick-look vector magnetic FITS-formatted data and JPEG image files are available for recent observations. An example disambiguated active region using VSM QL data is shown in Figure 1. The VSM quick-look vector data is also available in X3D format such that the data can be explored as a 3-D virtual model. An example 3-D snapshot of the magnetic field for an active region, using VSM data, is shown in Figure 2. In addition, Carrington rotation and daily synoptic maps derived from VSM photospheric magnetograms are available. Estimated coronal hole synoptic images and maps, derived from He I 1083.0 nm data (see Henney & Harvey 2005), are also available.

3. Early Science Results

Raouafi, Harvey, & Henney (2007) utilized VSM chromospheric (Ca II 854.2 nm) line-of-sight magnetograms to study the latitude distribution of the magnetic flux in the polar regions. For the northern polar cap observed during Sep-Dec 2006, a strong latitudinal dependence was found: increasing towards 75 deg-lat, then flattening to the pole. In addition, using GONG and VSM magnetogram data, Harvey et al. (2007) found that the solar photosphere has a weak ubiquitous and dynamic horizontal magnetic field. The field variance is found strongest near the limb suggesting low-lying field line connections between convectively driven

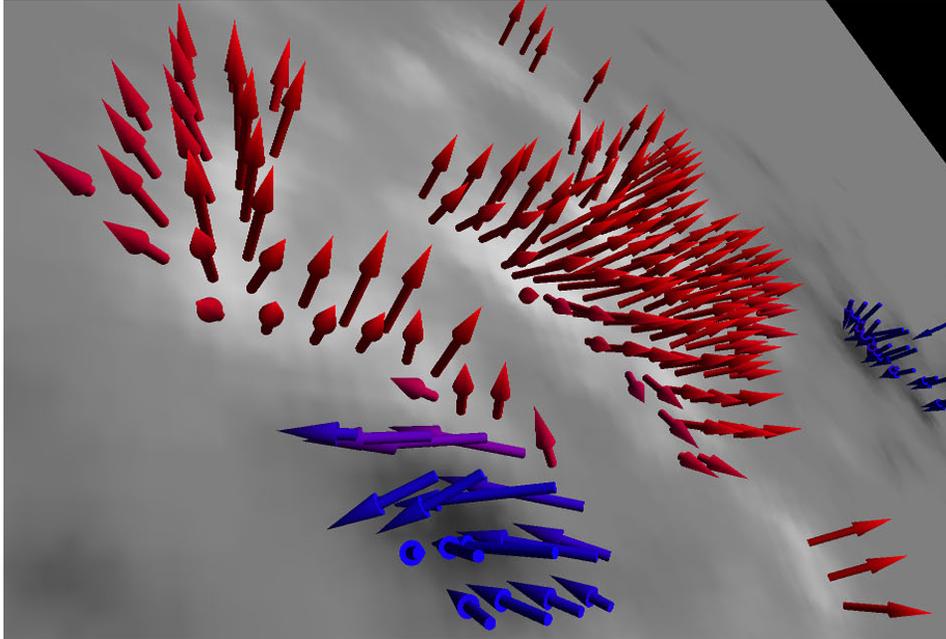


Figure 2. An example snapshot of VSM quick-look X3D formatted data (using Flux Player by Media Machines, Inc), where the arrows indicate the orientation of the magnetic field. The X3D formatted data allows the VSM vector data to be explored as a 3-D virtual model. This snapshot exhibits the magnetic field orientation of active region AR 10921 using VSM data observed November 3, 2006.

erupting and evolving network and intra-network fields. This work prompts a cautionary note on the common assumption that the observed photospheric weak magnetic fields are radial when extrapolating into the corona.

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