Kinetic Helicity in Solar Subsurface Layers

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Introduction

We search for a relation between kinetic helicity of subsurface flows and flare events in high-resolution GONG data. We measure the horizontal components of subsurface flows with the ring-diagram technique (Hill 1988; Haber et al. 2002) and derive the vertical velocity component from the divergence of the horizontal flows (Komm et al. 2004a). Since we derive the complete velocity vector, we can calculate the vorticity and then the kinetic helicity of these flows.

We have previously analyzed AR 10486 (Komm et al. 2004b). Here, we focus on synoptic maps and relate the kinetic helicity of an active region to its flare activity. We show the results for CR 1982 and CR 2009.

Dense-Pack Ring-Diagram Analysis

For each 1664-min day, the full-disk Doppler images are divided into 189 overlapping regions of 16° in size with centers spaced by 7.5° ranging from ±52.5° in latitude and central meridian distance. Each region is tracked using the appropriate surface rotation rate and remapped on great circles. Each image cube is apodized with a circular function of 15° diameter, and fourier-transformed. A 2-dim cut of the power spectrum at a given temporal frequency shows a set of rings shifted by the horizontal flow field. By inverting the derived shifts, 189 pairs of horizontal velocities at depths from 0.6 to 15.8 Mm are derived from each 1664-min day.

Mean Kinetic Helicity Density

The kinetic helicity of a fluid flow is the integrated scalar product of the velocity field, $\vec{v}$, and the vorticity field, $\nabla \times \vec{v}$ (Moffatt & Tsinober, 1992):

$$H = \int \vec{v} \cdot \nabla \times \vec{v} \; dV \qquad (1)$$

where $h = \vec{v} \cdot \nabla \times \vec{v}$ is called the helicity density of the flow. Since the measured flow components represent the average flow in a volume element defined by the horizontal size of each dense pack and the depth extent of the inversion kernels, the resulting scalar product $h = \vec{v} \cdot \nabla \times \vec{v}$ is a mean quantity representing a spatial average. To avoid confusion, we call this scalar product the mean kinetic helicity density. To emphasize the influence of magnetic activity, we subtract the contributions of the mean differential rotation and the mean meridional flow before calculating this quantity.

Summary

We calculate the maximum value of the unsigned kinetic helicity density for each active region and find that it correlates remarkably well with the flare X-ray intensity of active regions. (The correlation is 0.8 for CR 1982 and 0.9 for CR 2009.) Active regions with strong flare activity show also large values of kinetic helicity.

The rms variation of the kinetic helicity decreases rapidly over the outer 2 Mm by about a factor of 5. It then decreases more slowly and remains rather constant at depths below 5 Mm.

MDI and GONG data show similar results. We compared results for CR 1988 (not shown).

Acknowledgments

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References

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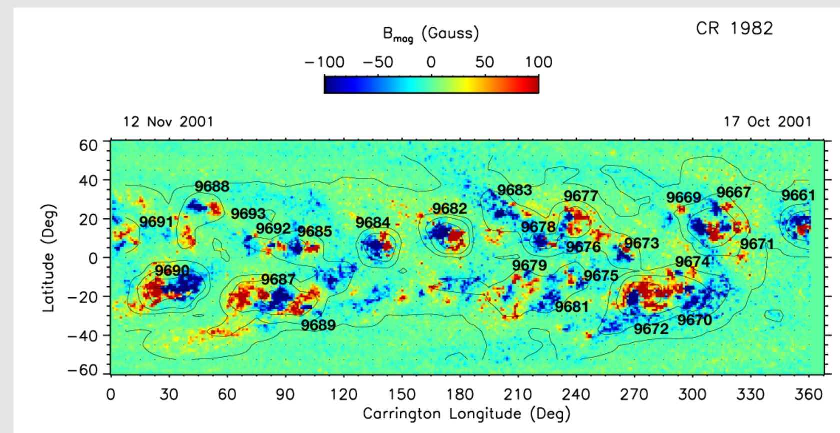
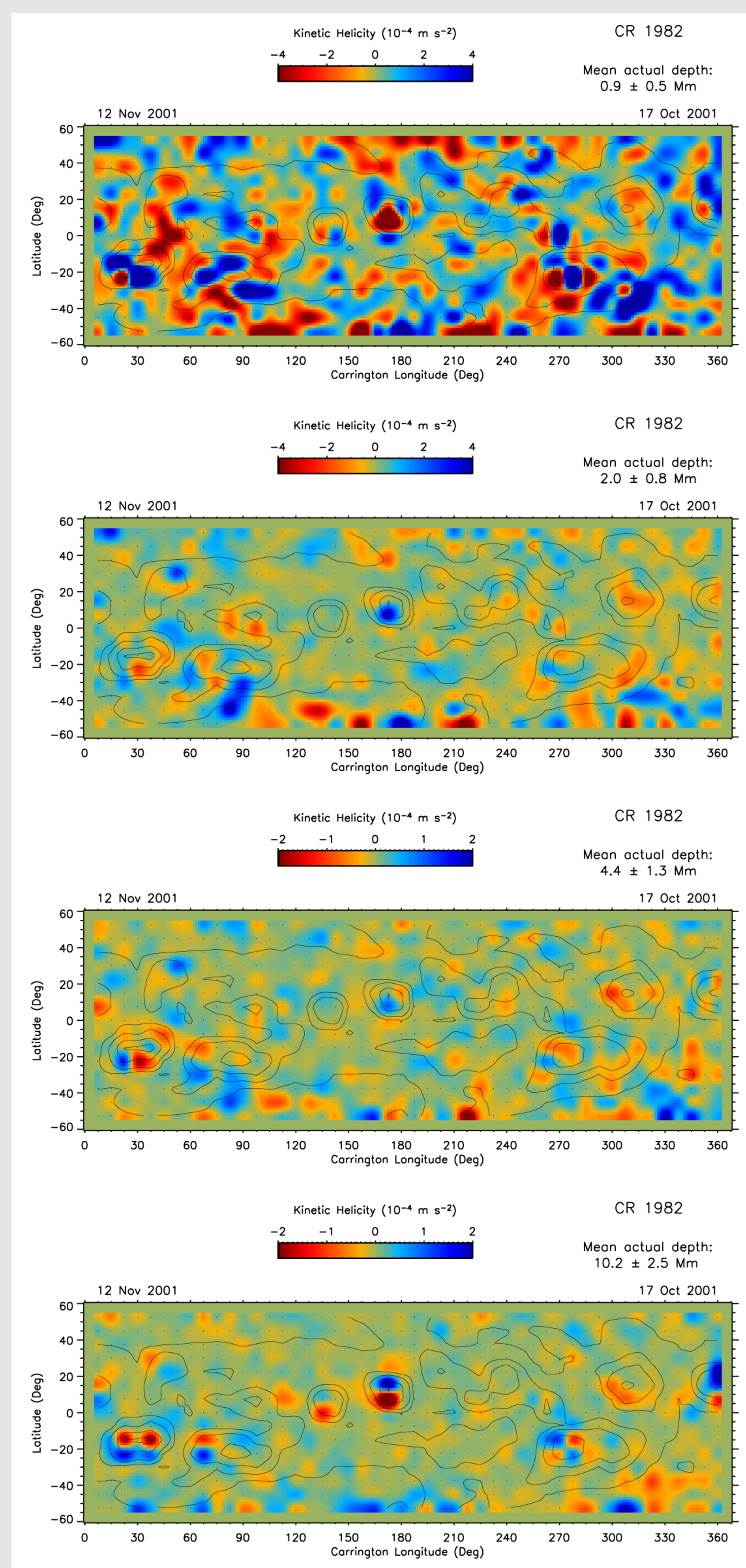
Solar X-ray Flares from the GOES satellite (http://www.ngdc.noaa.gov)

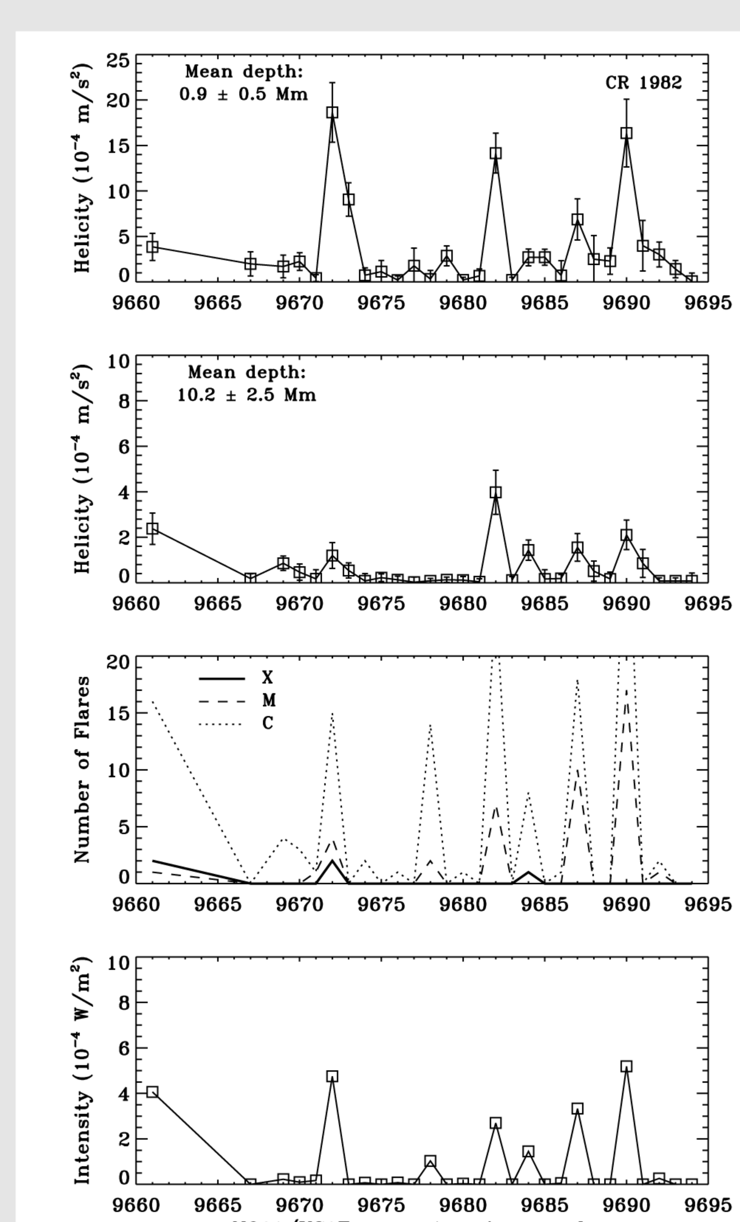
CR 1982



Magnetic synoptic maps from NSO Kitt Peak. The contour lines indicate magnetic flux (5, 20, 40, 80, and 120 Gauss) averaged over the dense-pack areas of the ring-diagram analysis.

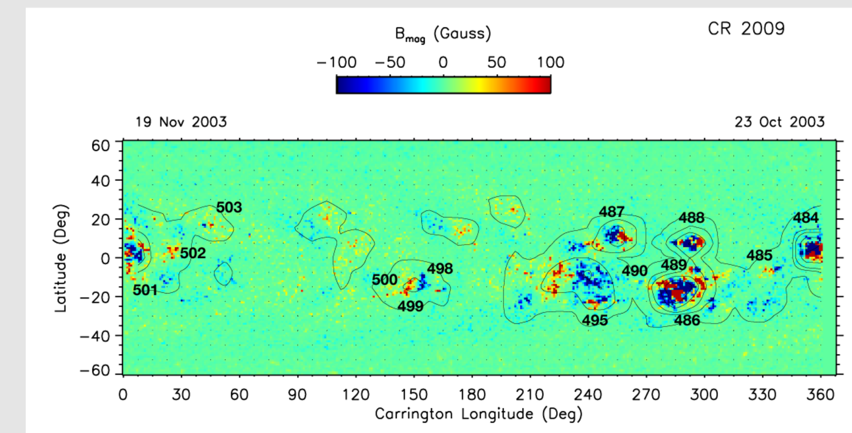


Mean kinetic helicity density at four different depths (0.9, 2.0, 4.4, 10.2 Mm). The contour lines indicate magnetic flux.



Top: Maximum helicity at 0.9 Mm as a function of active region.
2nd: Maximum kinetic helicity at 10.2 Mm.
3rd: Number of flares by X-ray class (C, M, X).
Bottom: Total X-ray intensity as a function of active region.

CR 2009



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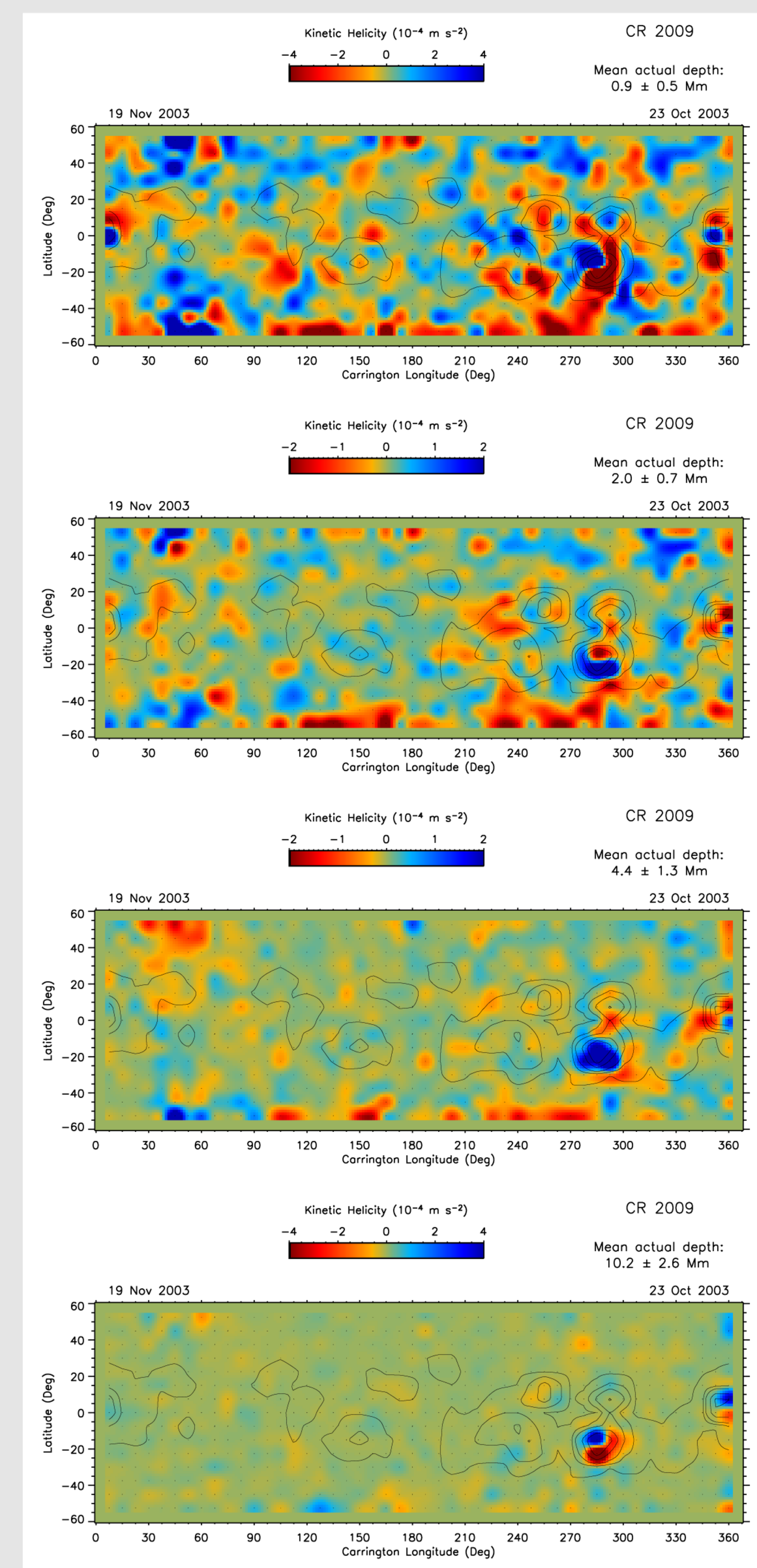

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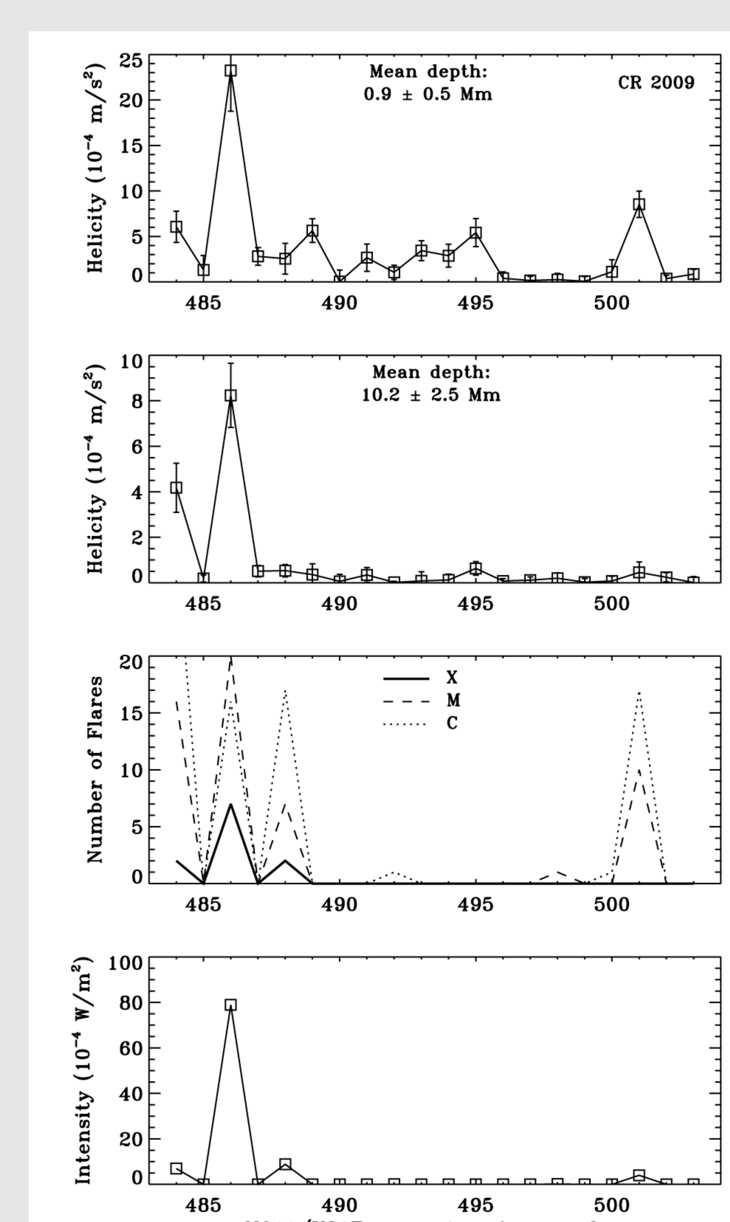

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