Helioseismic Space Weather Predictors from GONG

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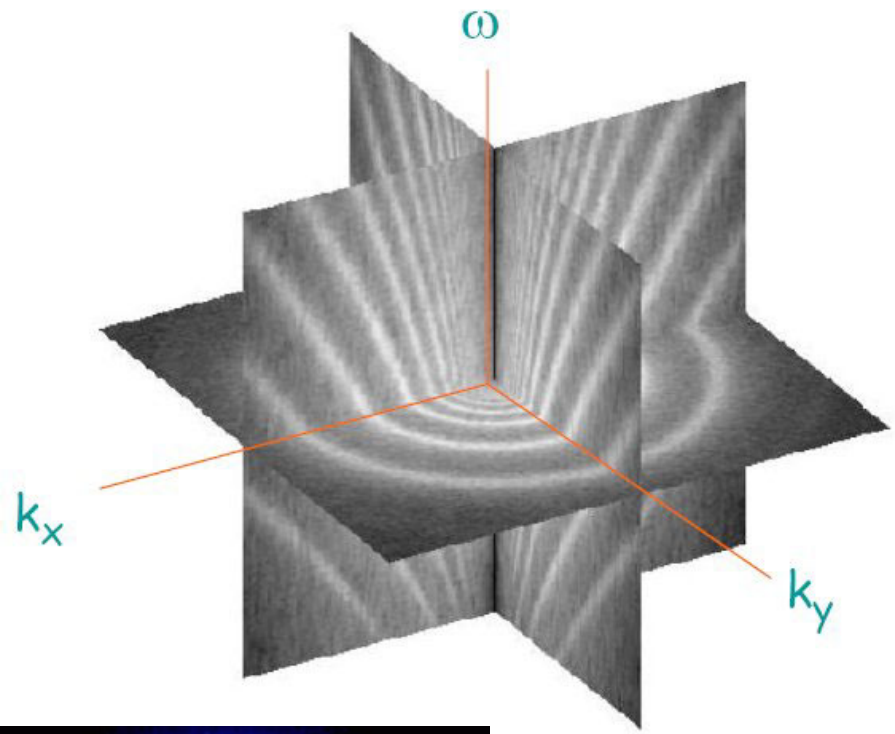
Helioseismology and GONG

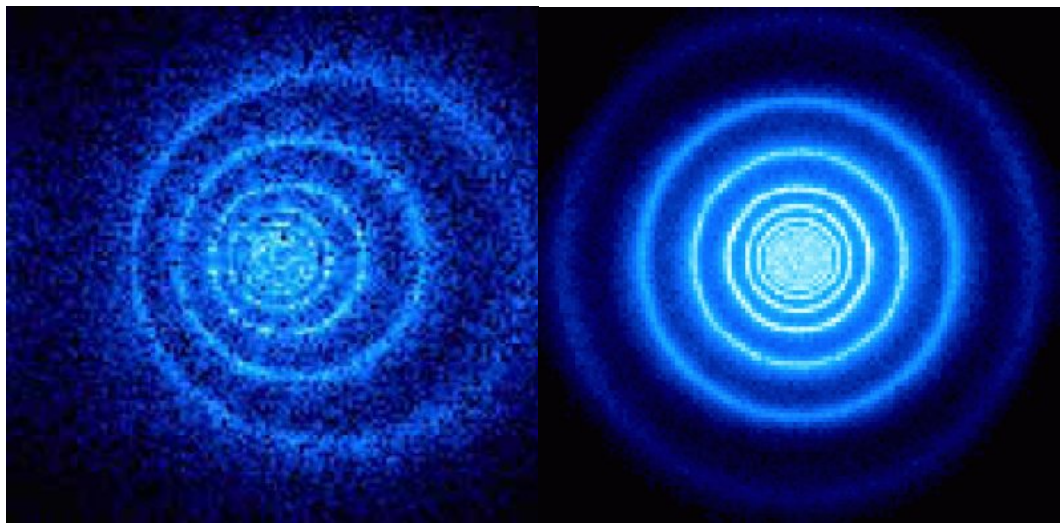
- Solar oscillations sample the sun’s interior
- Ring diagram technique provides picture of active region subsurface structure
- Acoustic holography provides picture of activity on solar farside
- Global Oscillation Network Group (GONG) program of the NSO operates 24-7
- GONG also obtains a full-disk magnetogram every minute, 24-7.

Ring Diagrams - I

- Three-dimensional power spectrum of solar oscillations
- Subsurface flow displaces rings



No tracking for solar rotation

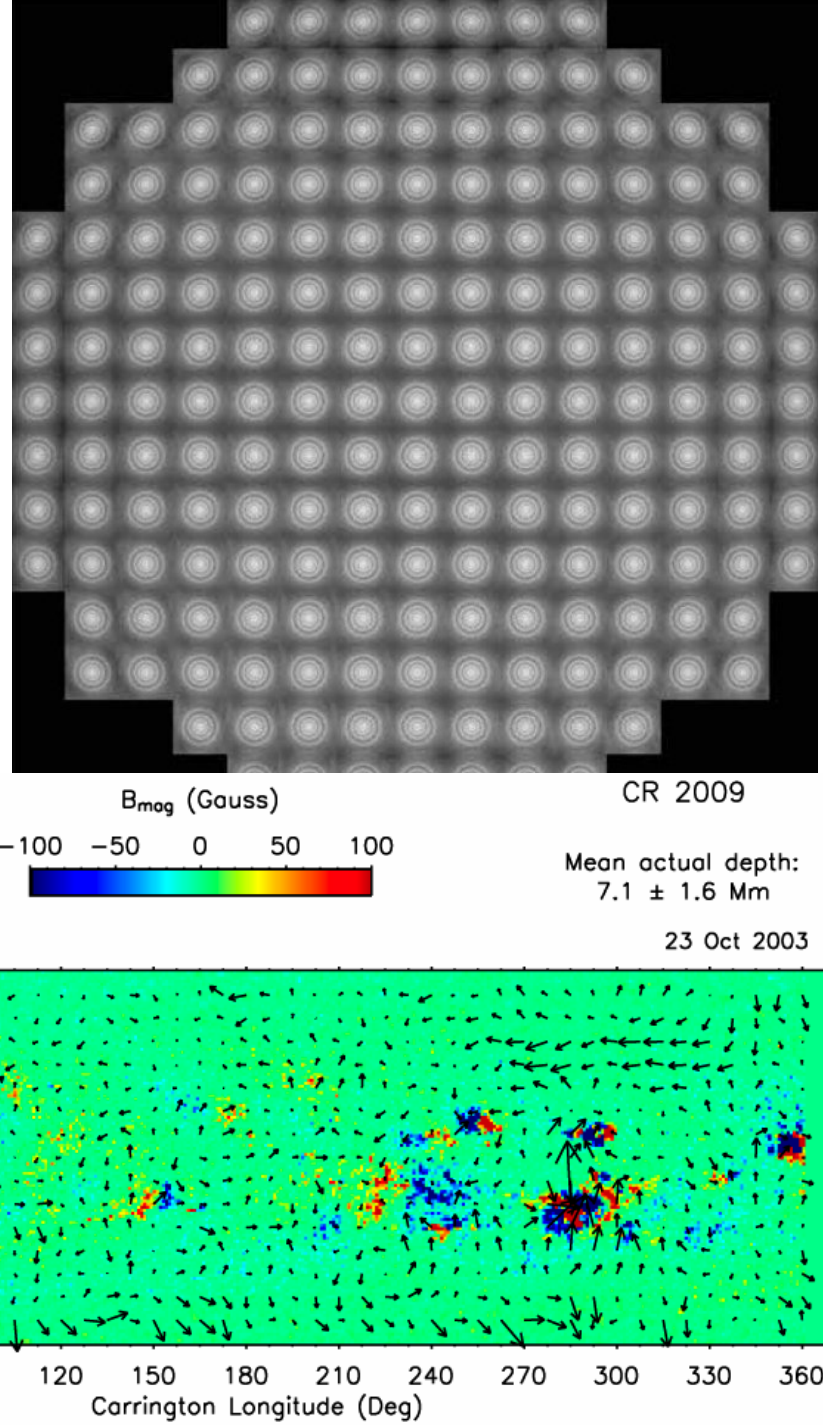


With tracking

Ring Diagrams – II

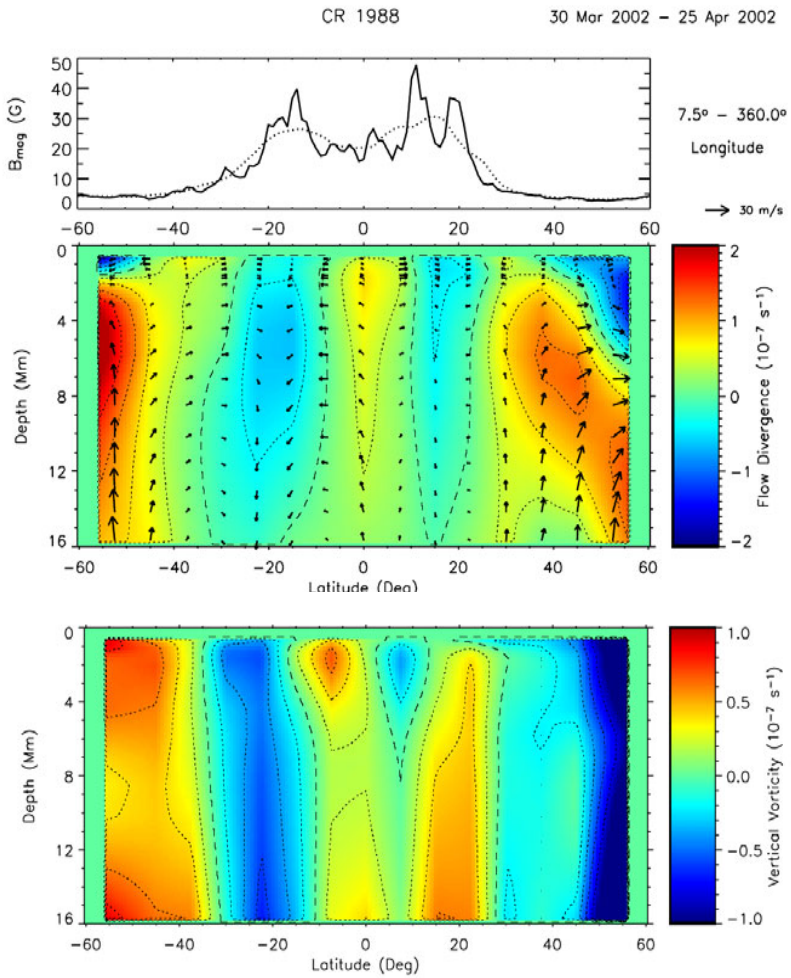
- Perform analysis over solar disk

- Invert for horizontal flows as function of location and depth



Ring Diagrams -III

- Assuming incompressible flow and using solar model density
- Derive vertical velocity and fluid dynamics descriptors: divergence, vorticity, helicity, enstrophy



Flows below strong flare producers

AR 10069

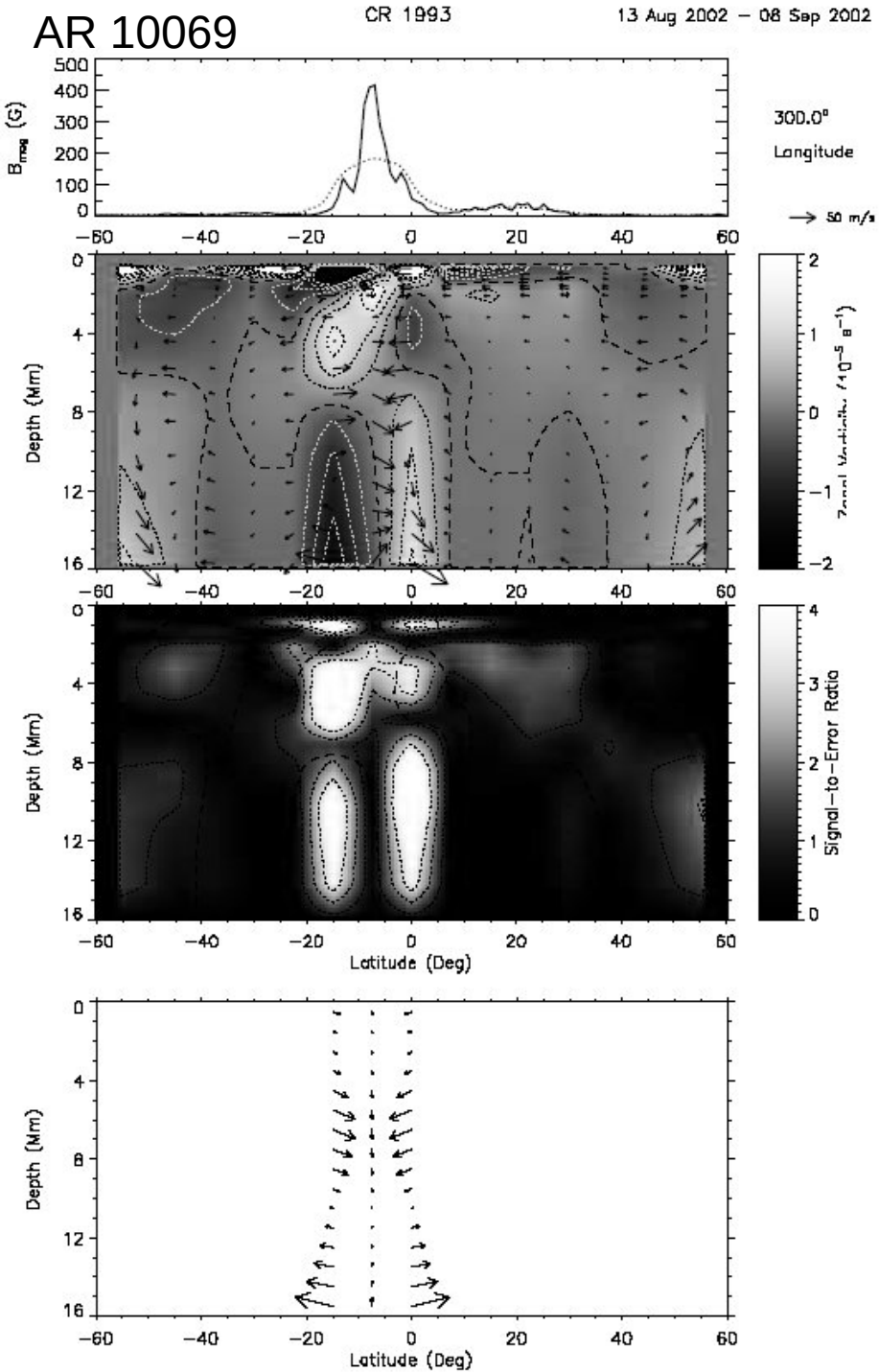
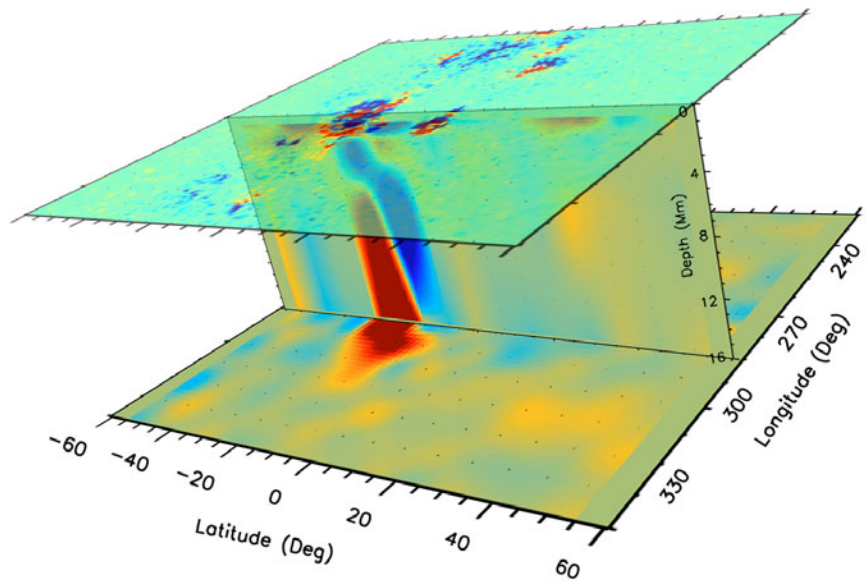


Fig. 4.— Zonal vorticity, ω_x, at 300° longitude in CR 1993 as a function of latitude and depth. *Top:* gross magnetic flux (solid line) and binned over 15° (dotted line); *2nd:* the x-component of vorticity (ω_x); *3rd:* the signal-to-error ratio. The arrows represent the meridional and vertical velocity components with the vertical one increased by a factor of 10 for visibility. *Bottom:* idealized schematic for flows below a strong active region (with arbitrary amplitudes).



AR 10486

Correlation between kinetic helicity and flare activity

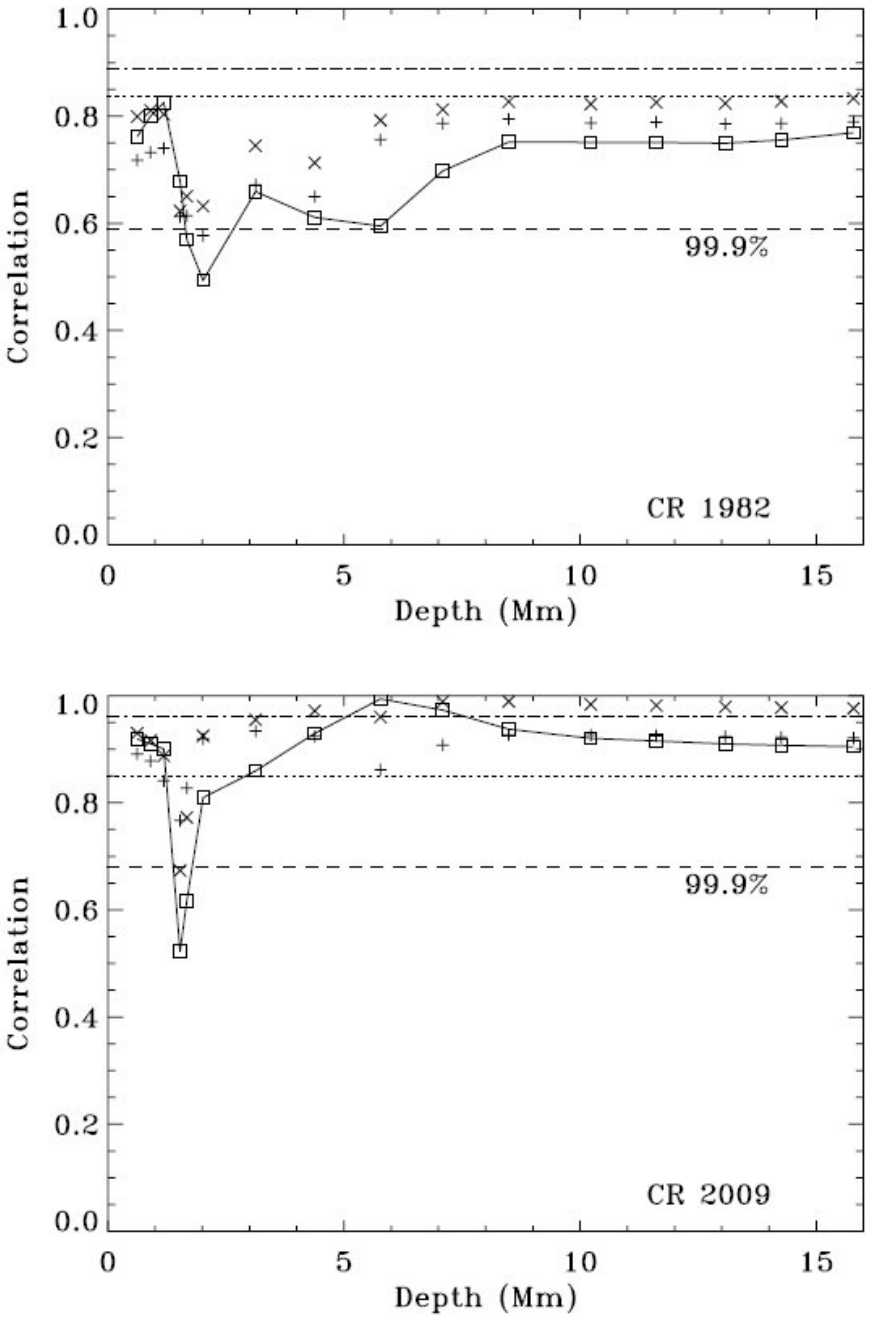
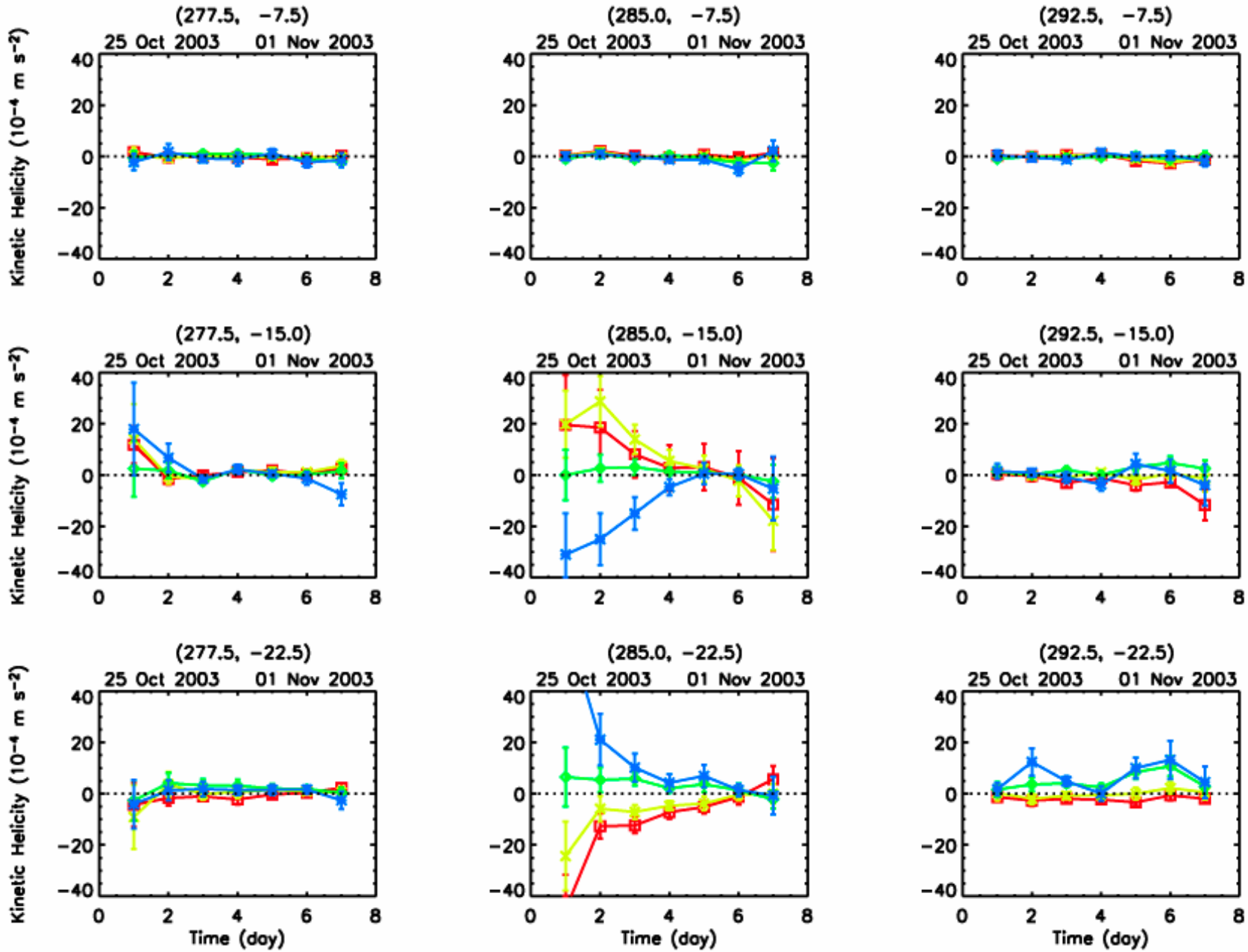


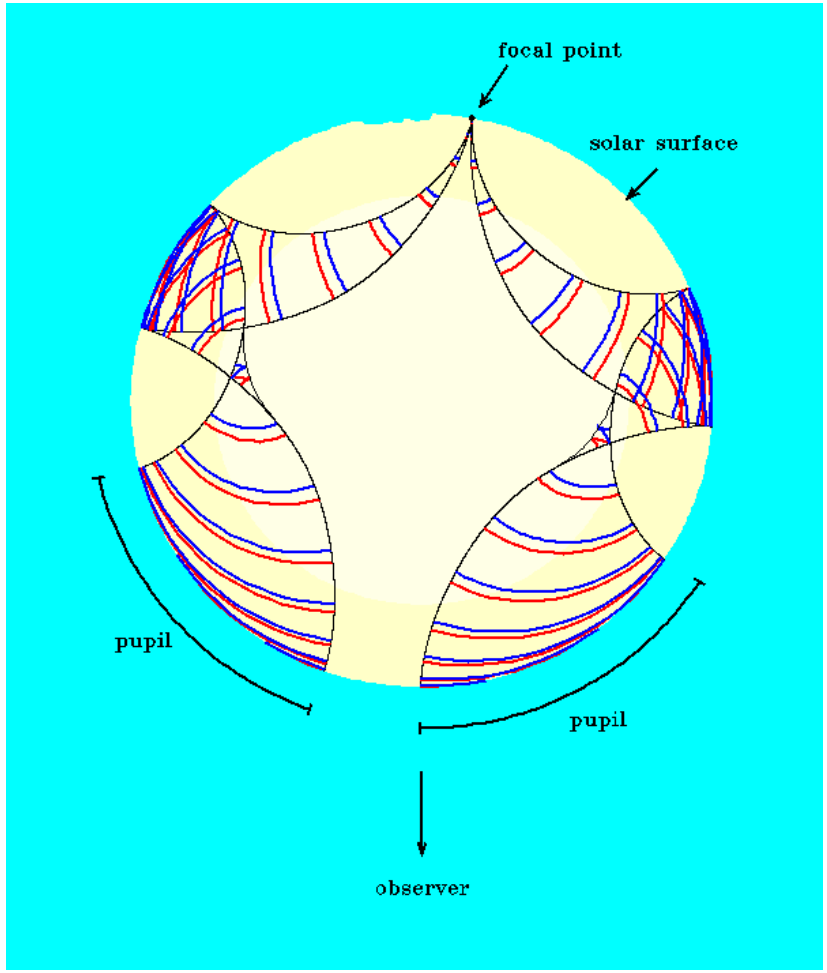
Fig. 5.— Linear correlation between maximum kinetic helicity density and X-ray intensity (square), magnetic flux (+), and square of magnetic flux (×) as a function of depth. The correlation between X-ray intensity and magnetic flux (dotted line) and square magnetic flux (dot-dashed line) is included for comparison. The dashed line indicates the 99.9% confidence level for a given sample size. *Top:* CR 1982, 28 active regions; *Bottom:* CR 2009, 20 active regions.

Temporal behavior of kinetic helicity before a flare

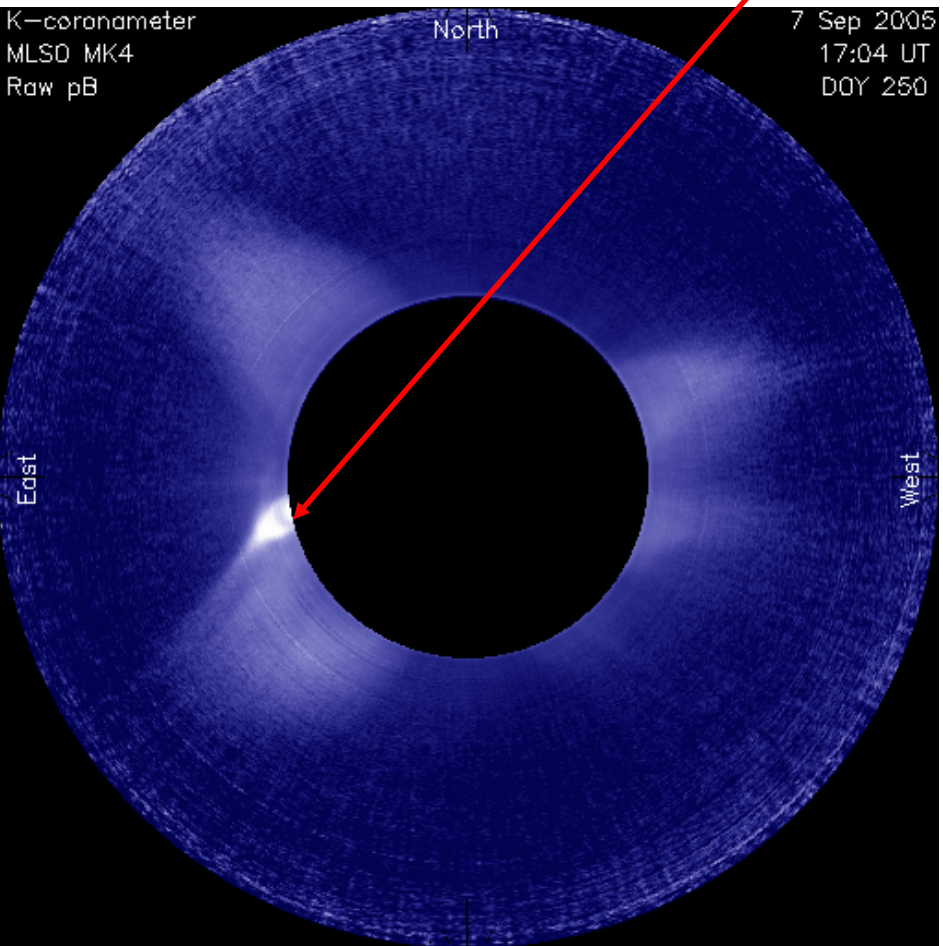


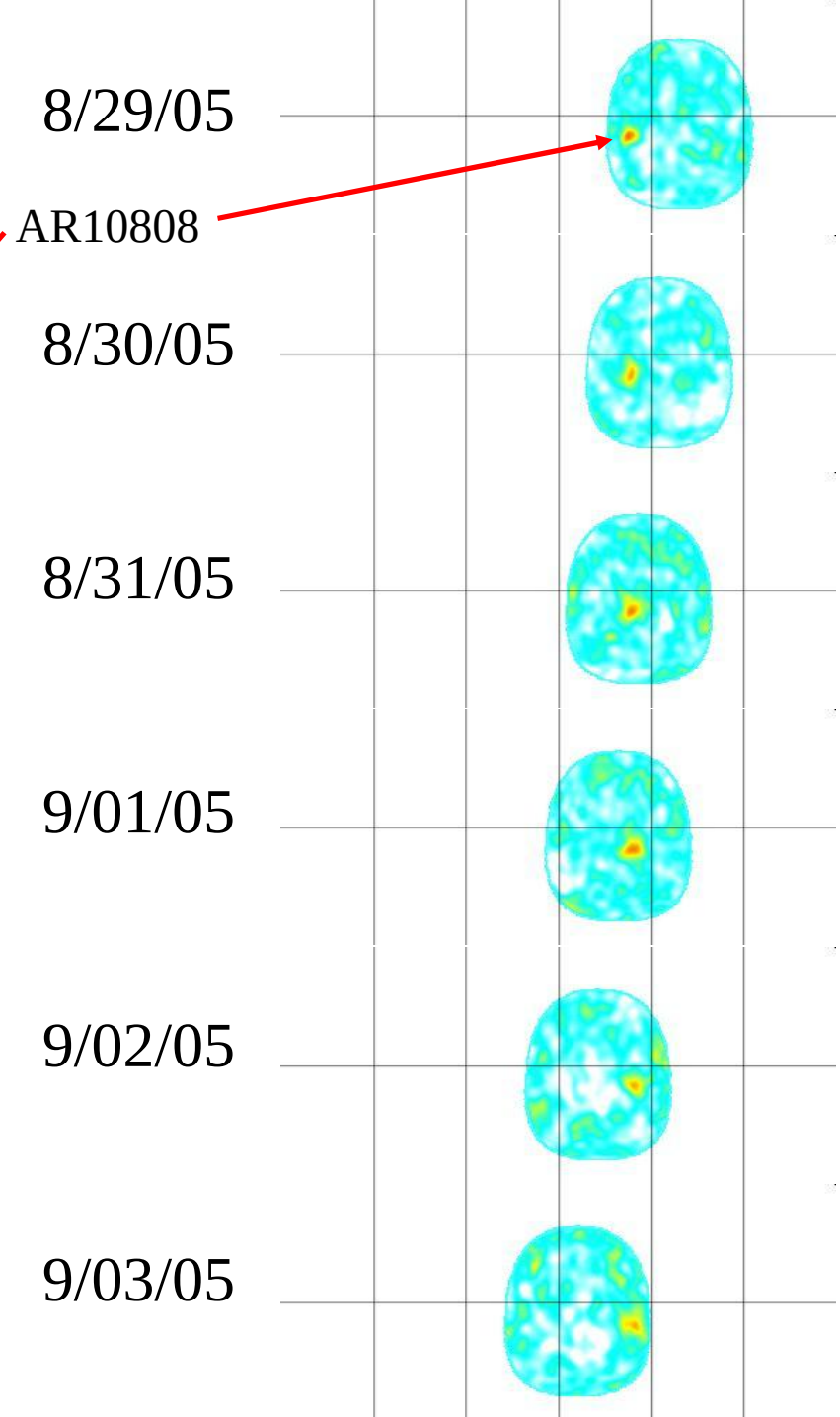
Farside imaging

- Uses acoustic holography
- Time reverse observed wave field to an impulse at a specific depth
- Depth can be located at the farside surface
- Presence of active region causes phase shifts



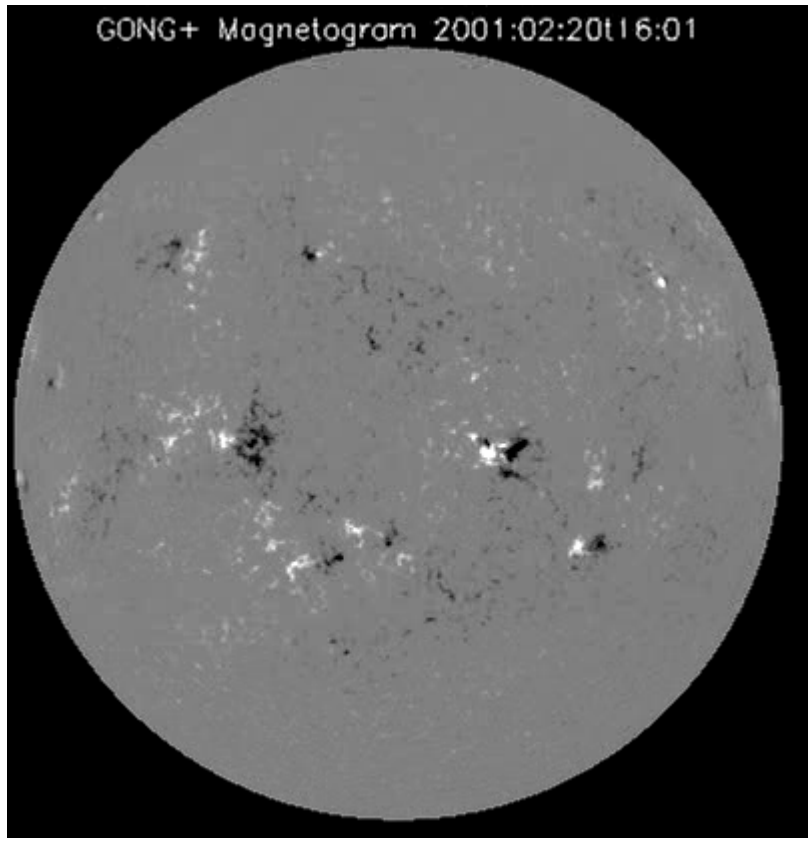
Farside images of AR10808





High-cadence magnetograms

- Full-disk, moderate resolution (800 × 800)
- One per minute per site
- 24 hour coverage, 87% duty cycle
- 1G noise, 10G zero point (improvement underway)
- SSL use for potential field computations



Status of GONG space weather products

Product	Forecast period	Needed development
Subsurface vorticity	1-7 days when region is on front side	1. Measure false alarm & predictive probabilities 2. Speed up data acquisition & processing
Farside imaging	1-14 days before region appears on front side	Calibration of phase signal, magnetic field, and flare probability
High-cadence magnetograms	1-7 days when region is on front side	1. Reduction of zero point (new modulator) 2. Speed up data acquisition & processing