Subsurface Helicity of Active Regions 12192 & 10486

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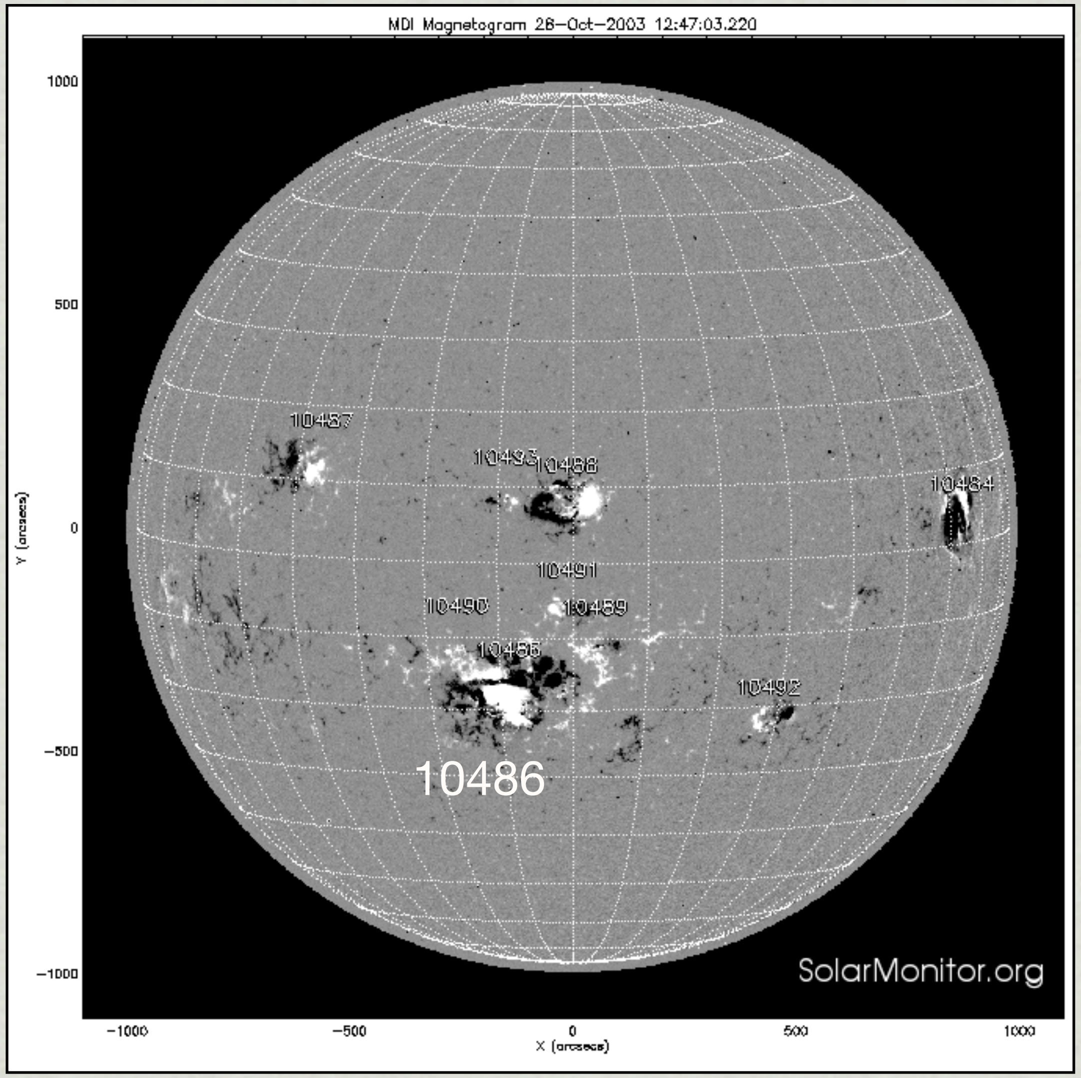
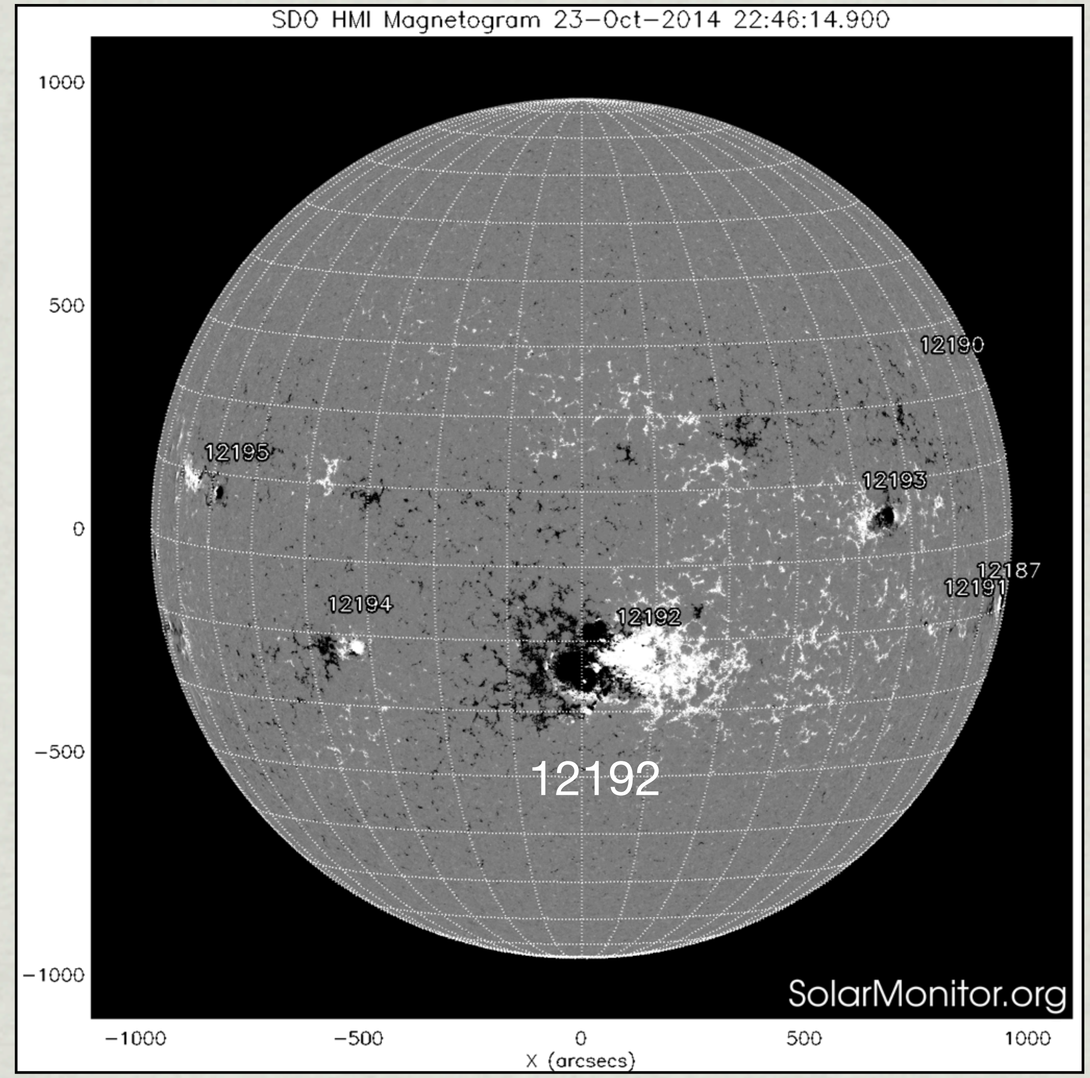
Introduction





Two active regions separated by 11 years.
AR 10486 (left): large and complex, many flares;
AR 12192 (right): larger but simpler, not as many flares.

Introduction

- How different / similar are their subsurface flows? Especially their kinetic helicity?
- Is it obvious from the subsurface flows which region produced more eruptive events?
- Subsurface flows from ring-diagram analysis (0-16 Mm)
    - SOHO/MDI (AR 10486)
    - GONG (AR 10486, 12192)
    - SDO/HMI (AR 12192).

Kinetic helicity (density)

Kinetic helicity density is the scalar product of the vorticity and velocity vector.

$$h_k = \boldsymbol{\omega} \cdot \boldsymbol{v}$$

Helicity: volume integral of helicity density

$$\boldsymbol{\omega} = \boldsymbol{\nabla} \times \boldsymbol{v}$$

ω : vorticity;
v : velocity vector

Kinetic helicity density (vertical contribution)

Div Curl of horizontal velocities is a proxy of the vertical contribution.

$$\langle h_z \rangle = \langle \omega_z \cdot v_z \rangle = \left\langle \left(\frac{\partial v_y}{\partial x} - \frac{\partial v_x}{\partial y} \right) \cdot v_z \right\rangle$$

Current helicity (density)

Current helicity density (vertical component)

$$\langle h_c \rangle = \langle J_z \cdot B_z \rangle = \left\langle \left(\frac{\partial B_y}{\partial x} - \frac{\partial B_x}{\partial y} \right) \cdot B_z \right\rangle$$

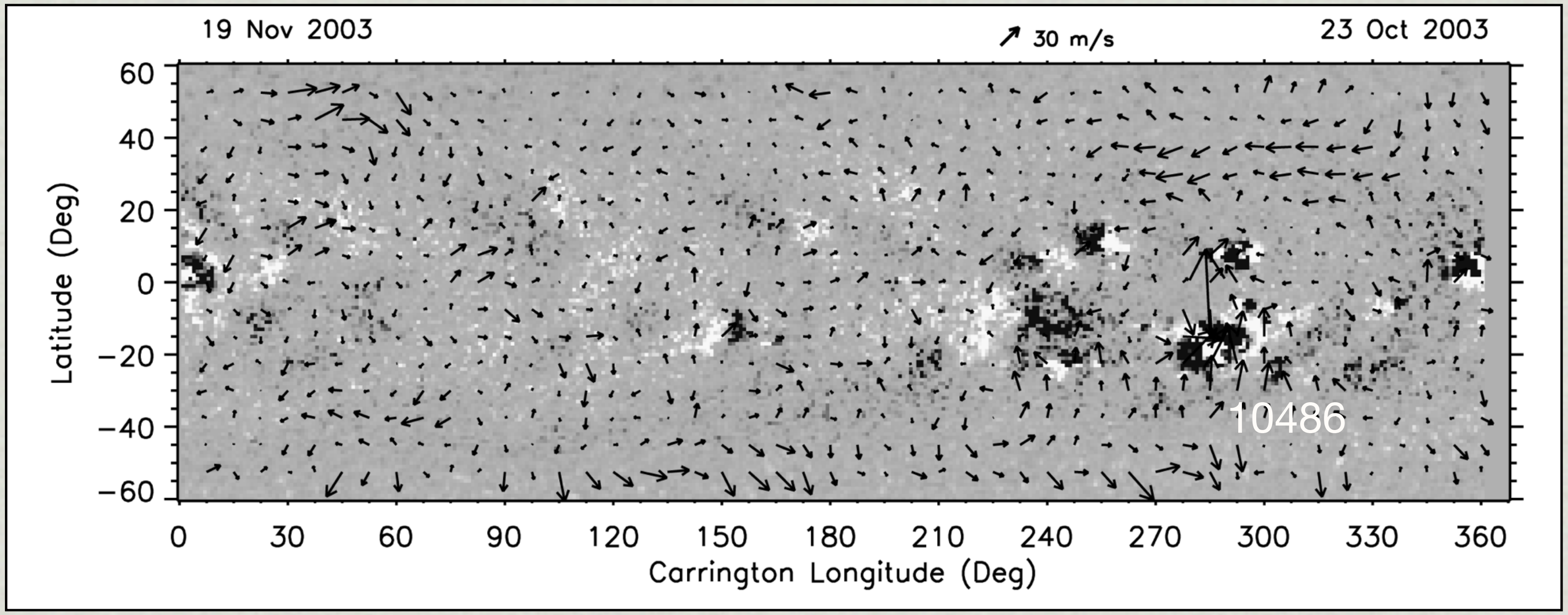
J_z : vertical current density

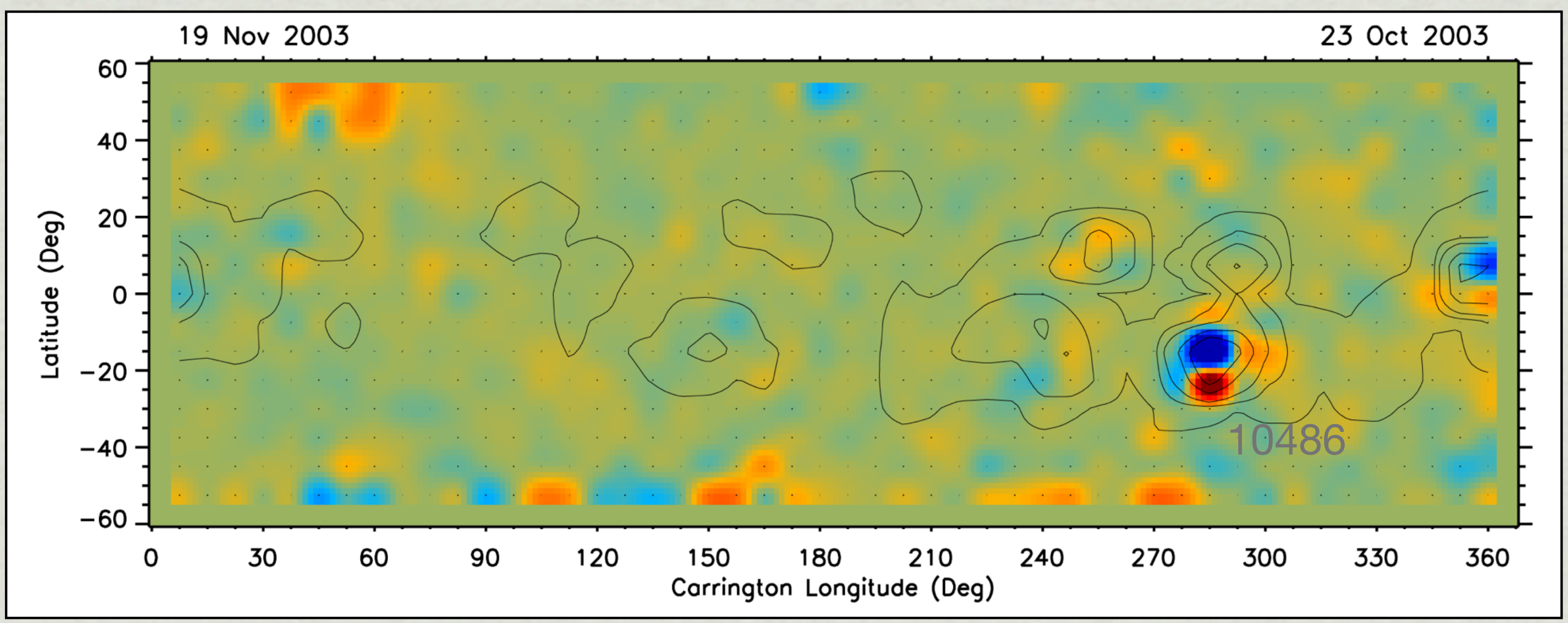
(B_x, B_y, B_z) : magnetic field components

$$\langle \alpha_z \rangle = \langle J_z / B_z \rangle$$

Mean twist parameter

Flow and helicity of AR 10486



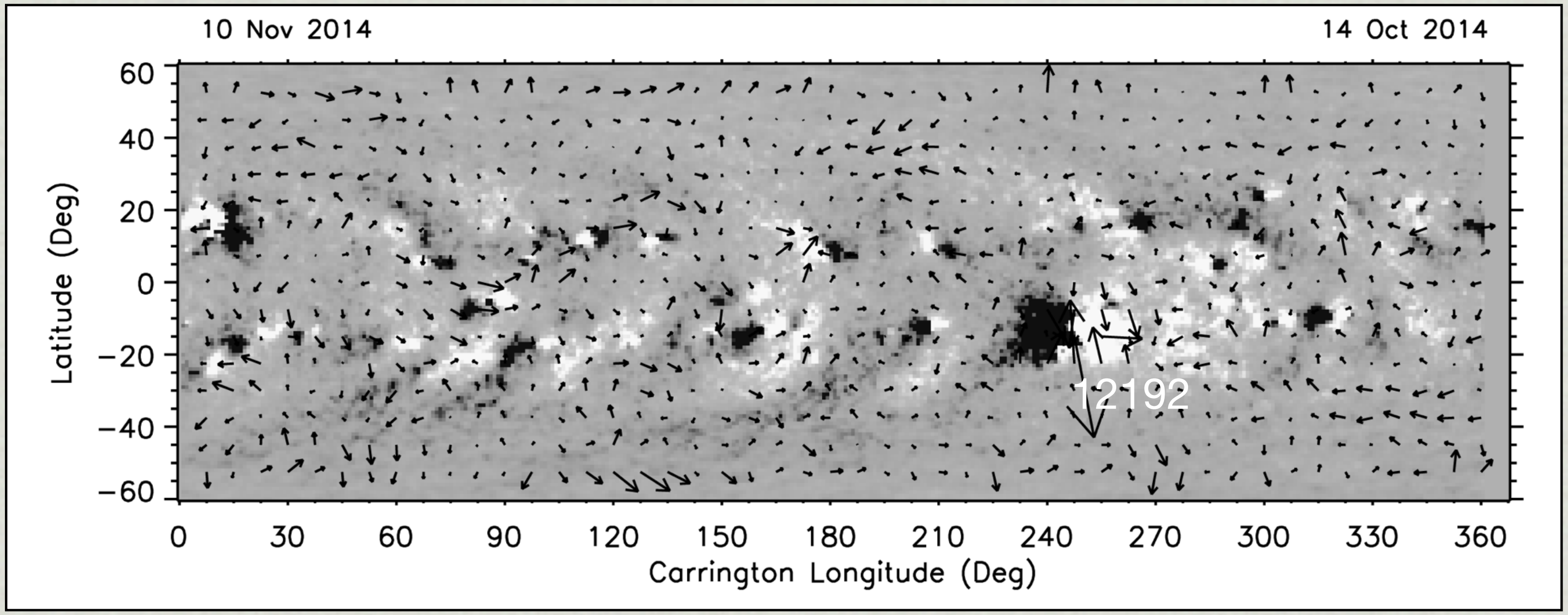


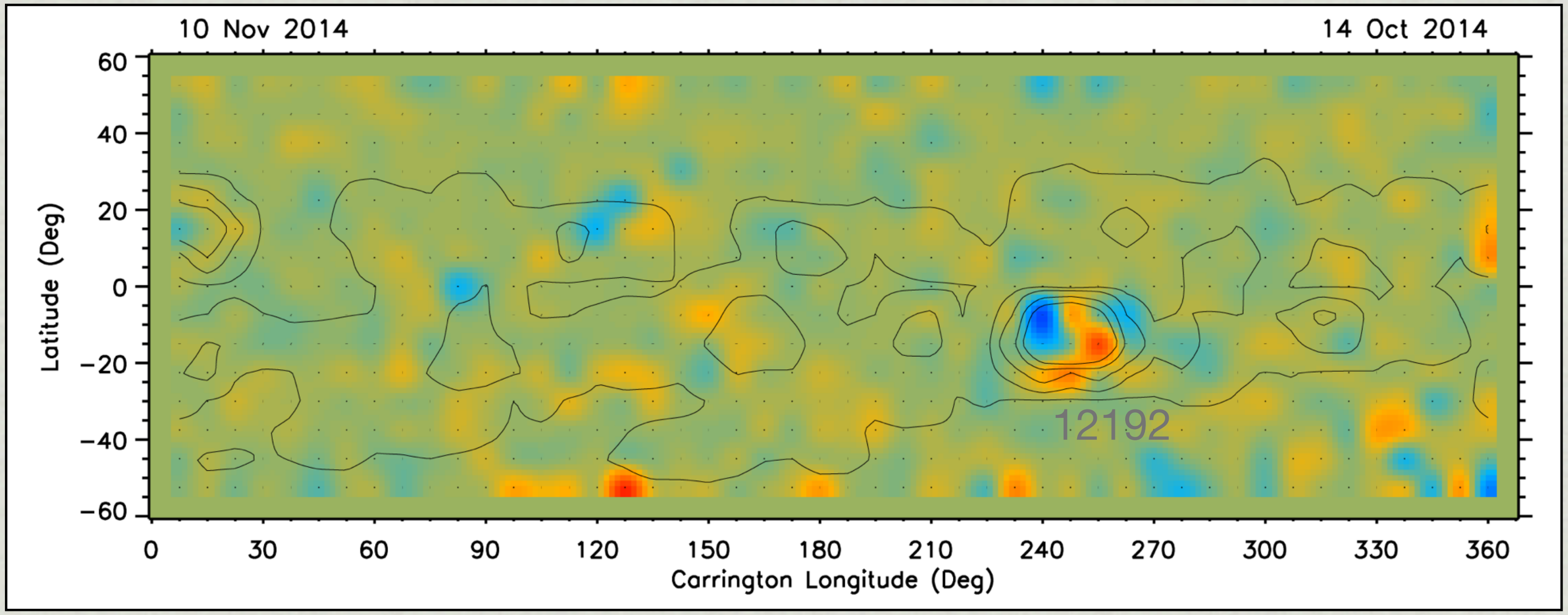
CR 2009 7.1 Mm GONG

Complex flows near active regions in synoptic maps.

Flare-productive regions show “dipolar” pattern in kinetic helicity density.

Flow and helicity of AR 12192



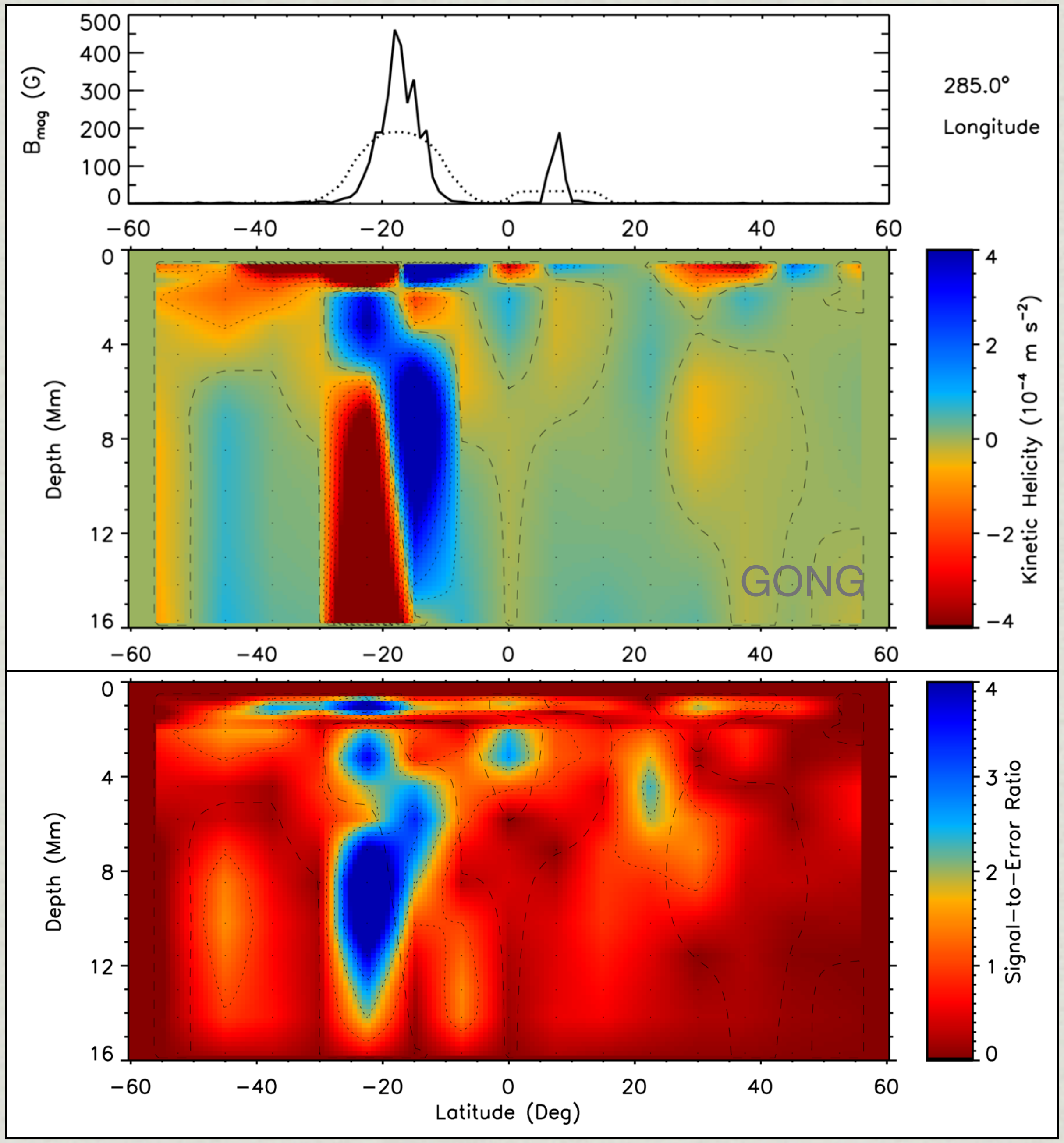


CR 2156 7.1 Mm GONG

Residual flows: average rotation and meridional flow has been subtracted.

Magnetic polarity separates kinetic helicity pattern.

Helicity slice of 10486



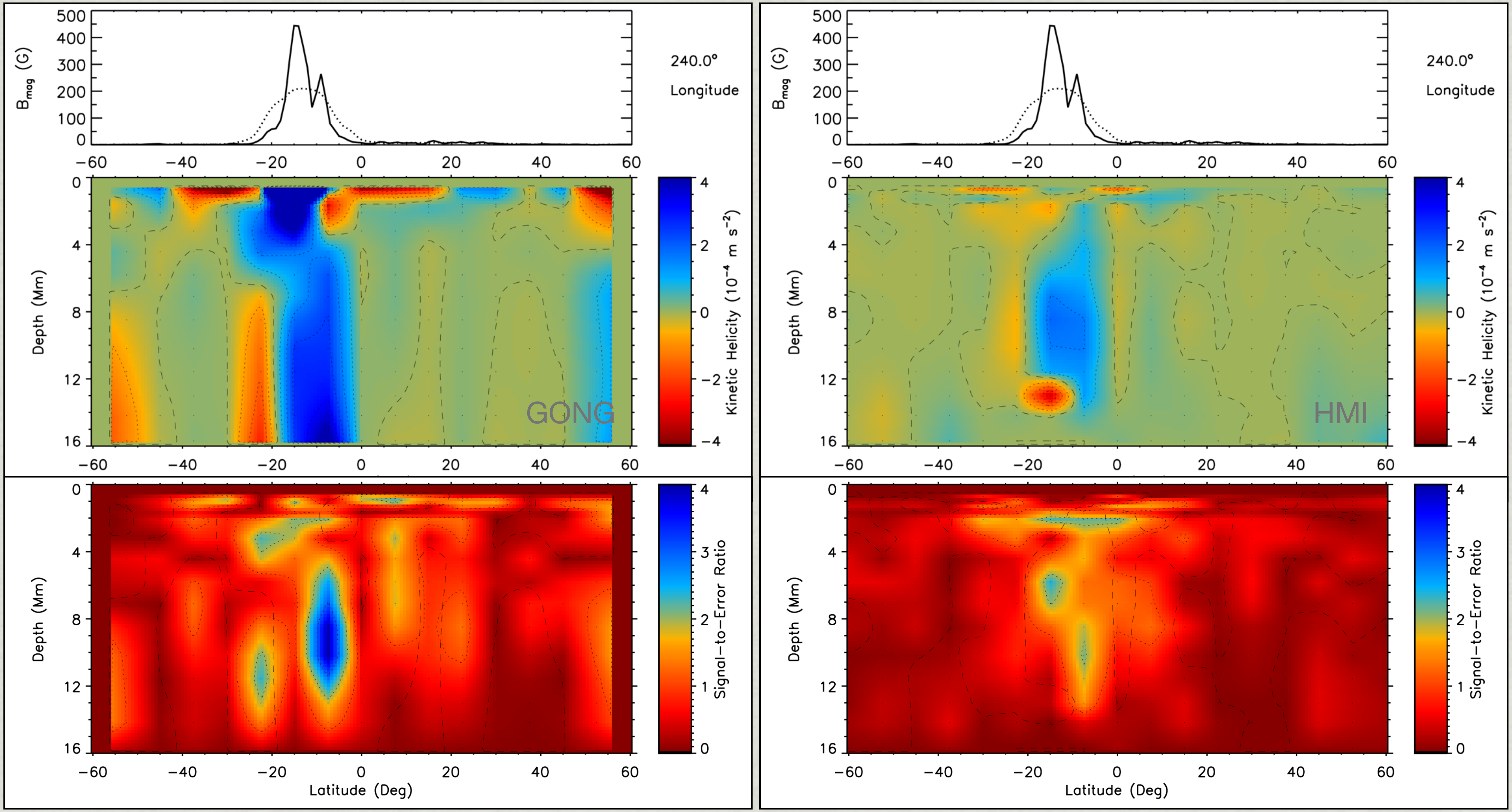
Top: magnetic flux
Middle: kinetic helicity density
Bottom: signal-to-noise ratio.

Strong “dipolar” pattern in kinetic helicity density with a sign change near 2 and 6 Mm.

This is a characteristic of flare-productive active regions.

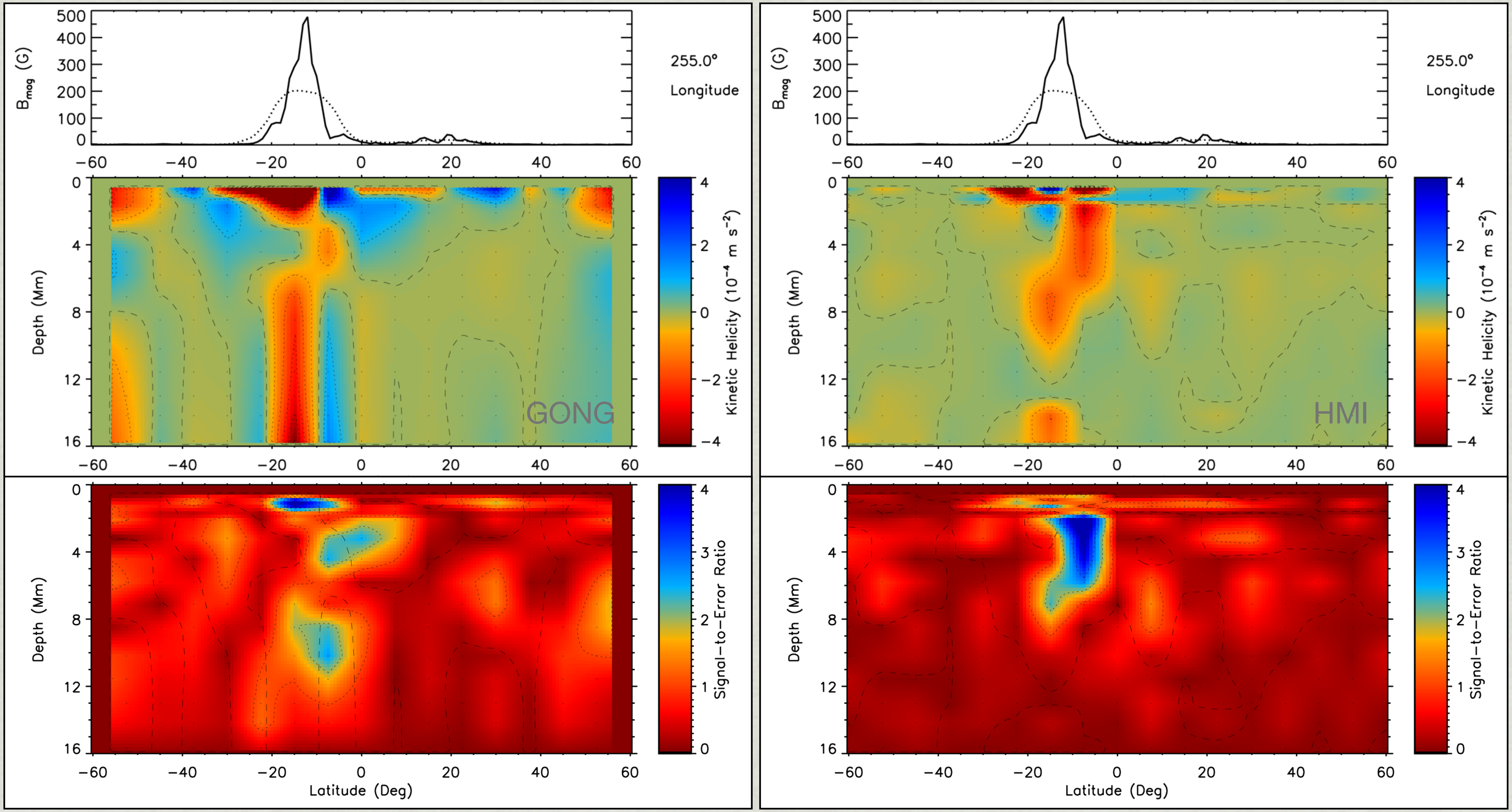
Interpreted as stacked vortex rings.

Helicity slice of 12192 (N)



Dipolar pattern is rather weak. S/N ratio is smaller. GONG and HMI are reasonably similar for large S/N.

Helicity slice of 12192 (P)

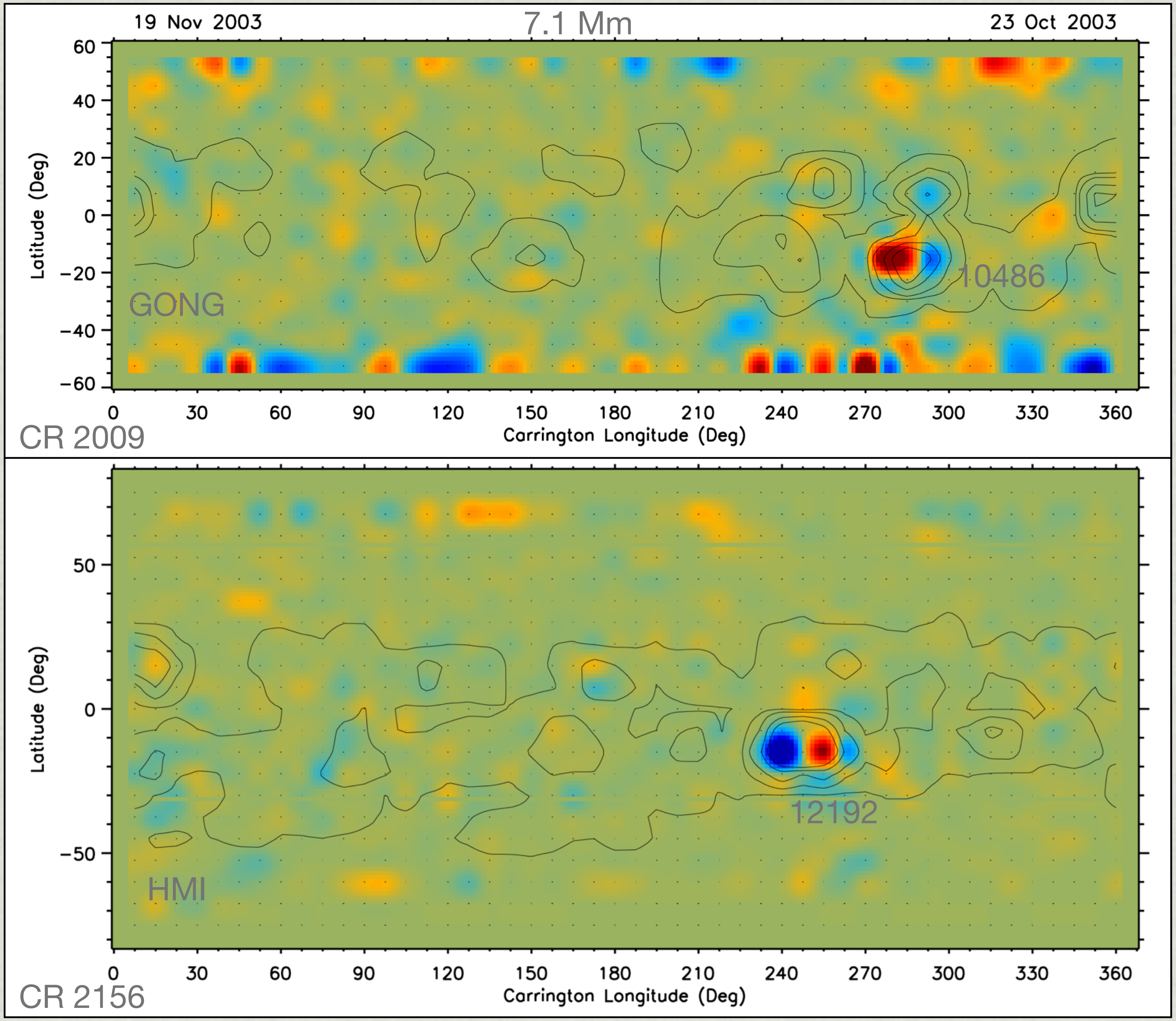


Dipolar pattern is rather weak. S/N ratio is smaller.
GONG and HMI are reasonably similar for large S/N.

Summary (1)

- The subsurface flows of AR 10486 show large values of kinetic helicity density and a strong dipolar pattern.
- The kinetic helicity values of AR 12192 are much smaller and the dipolar pattern is weaker.
- Conclusion: AR 10486 had greater potential of producing eruptive events.

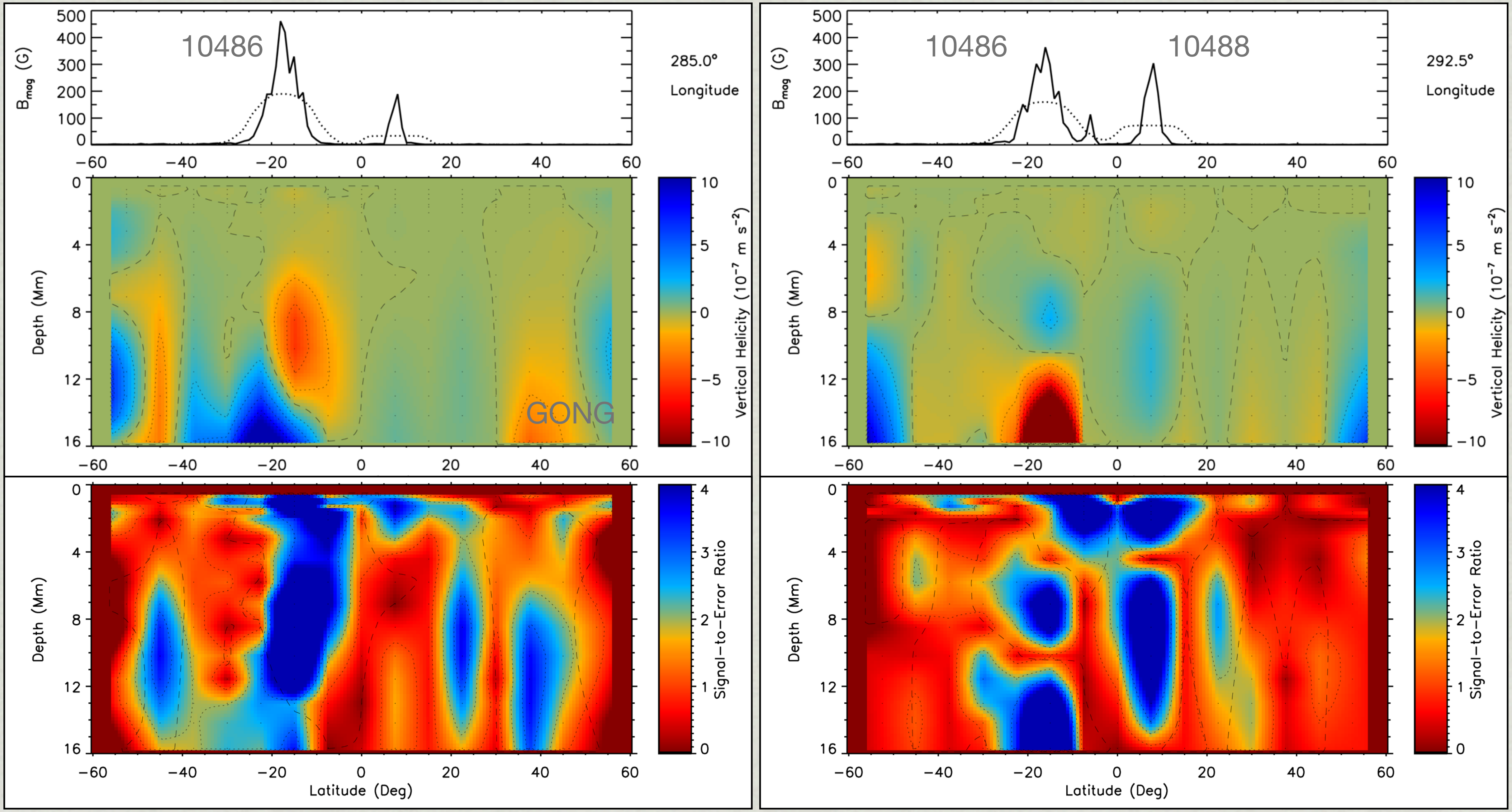
Vertical helicity of 10486 & 12192



What about the vertical component of kinetic helicity density?

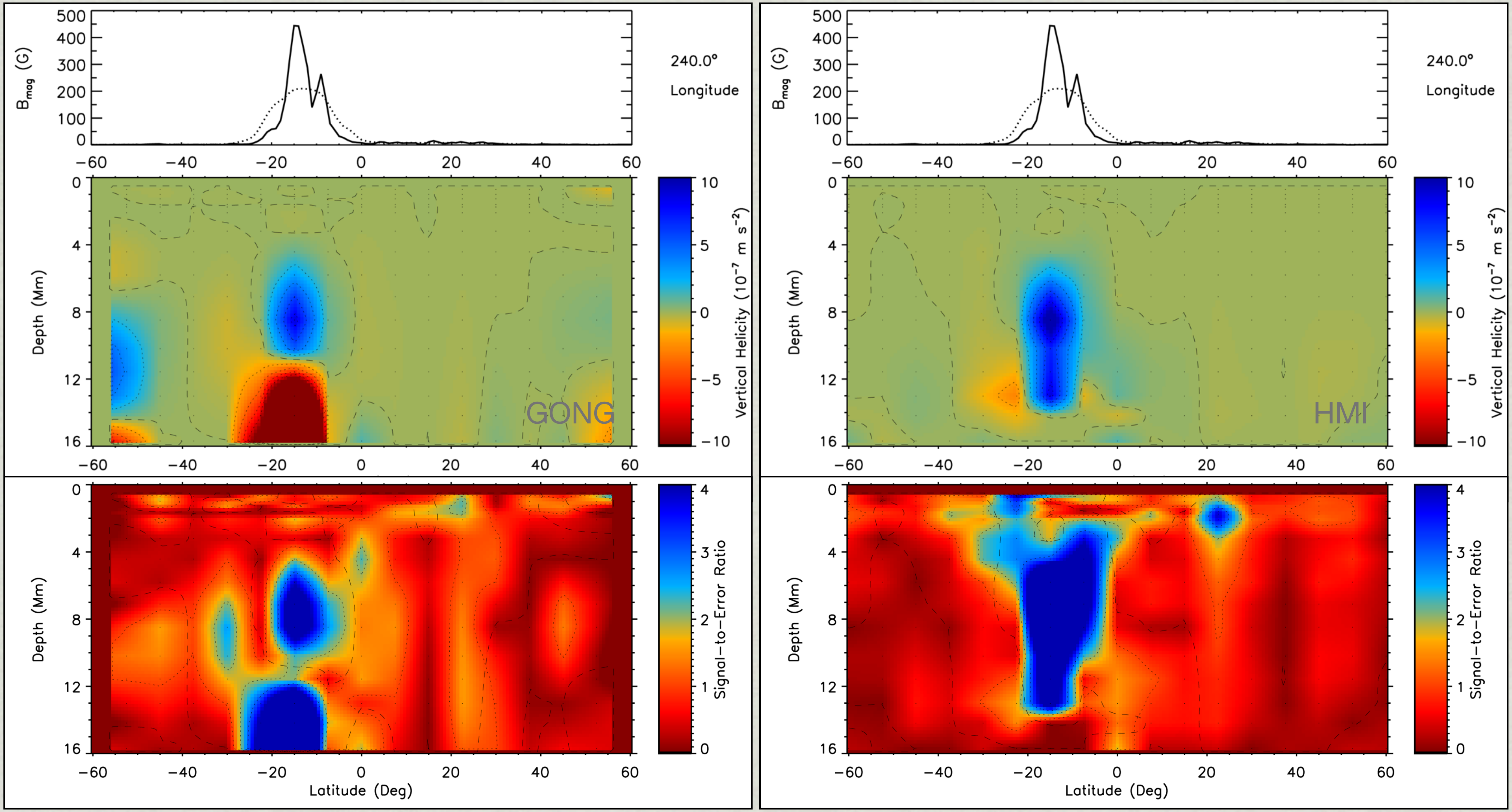
The equivalent of current helicity density.

Vertical helicity of 10486



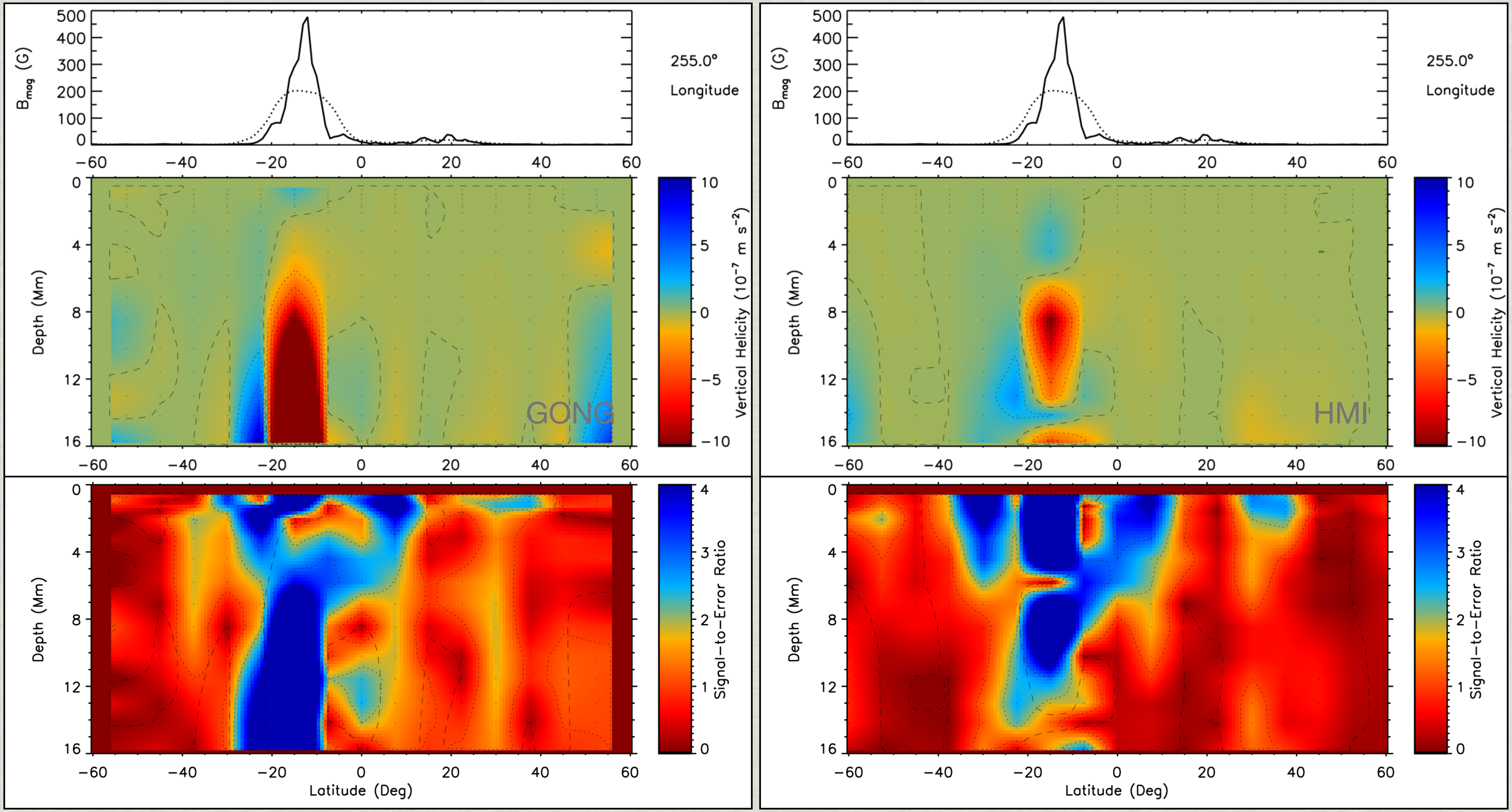
Large negative values of vertical helicity near 10486.
Are AR 10486 and AR 10488 connected?

Vertical helicity of 12192 (N)



Large positive values of vertical helicity near 6 -11 Mm.
GONG and HMI are reasonably similar for large S/N.

Vertical helicity of 12192 (P)



Large negative values of vertical helicity near 6 -11 Mm.
GONG and HMI are reasonably similar for large S/N.

Summary (2)

- The vertical kinetic helicity density of AR 10486 is negative (opposite of hemispheric helicity rule).
- The vertical kinetic helicity density of AR 12192 is large and its sign is different for different magnetic polarities.
- HMI and GONG helicity values are reasonably similar when the S/N ratio is high.