Value-added maps: Fluid-dynamics descriptors from ring diagrams

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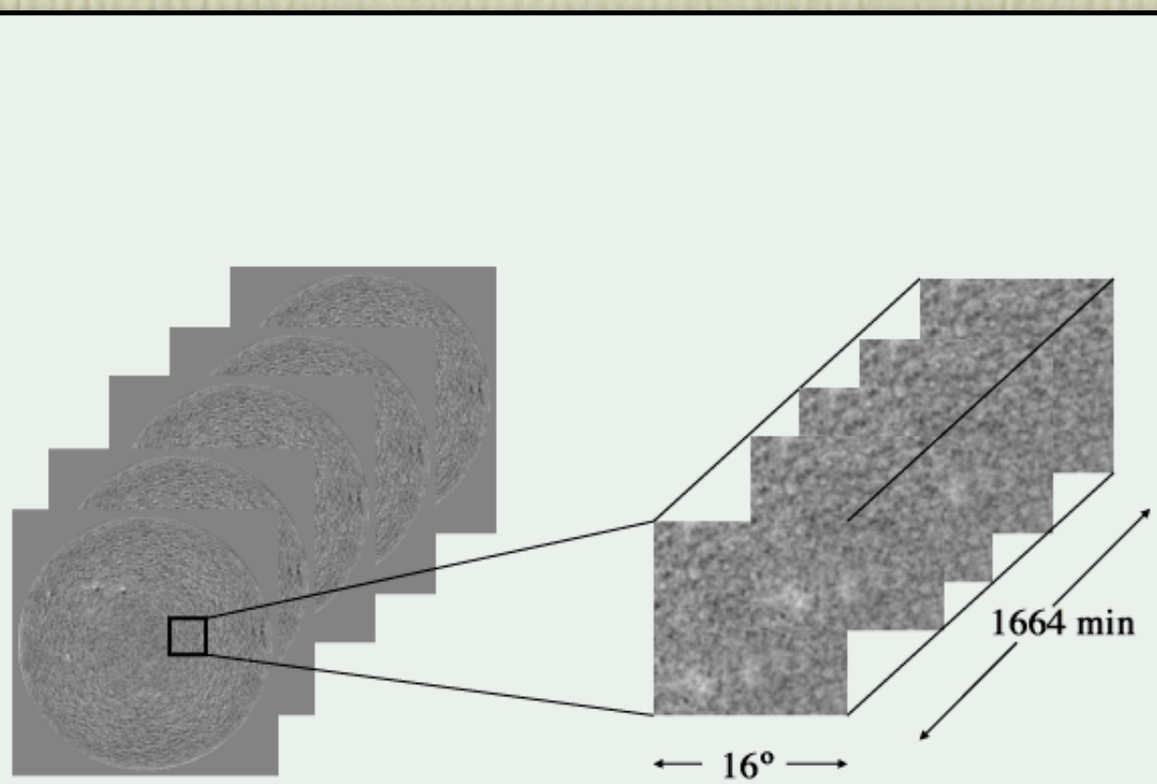
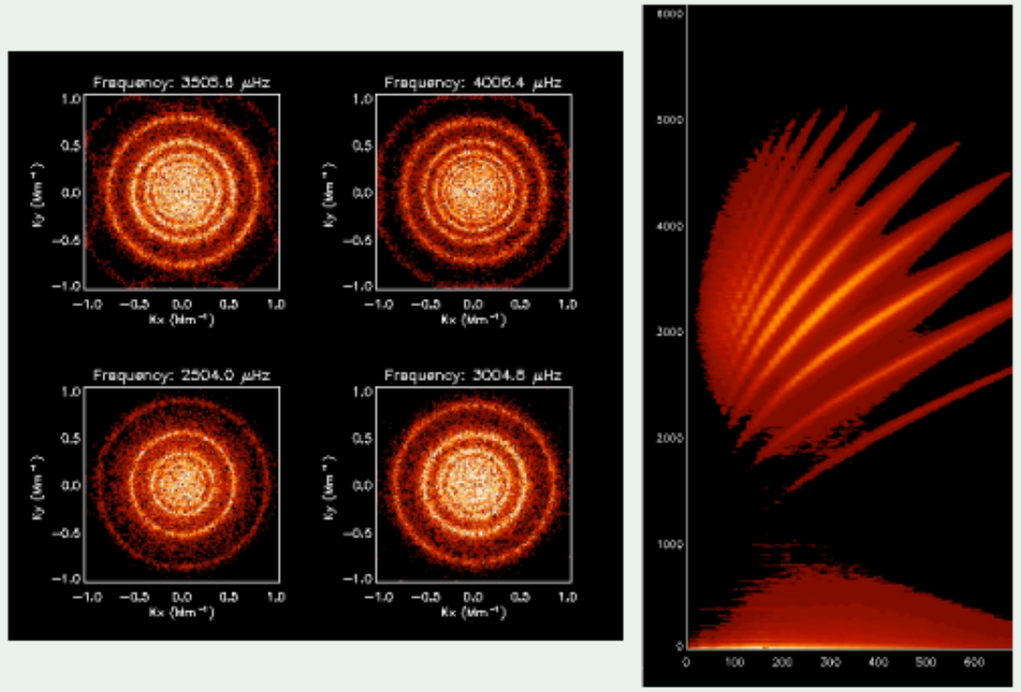
Overview

- FD descriptors from ring-diagram analysis
  - Vertical velocity component
  - Vorticity
  - kinetic helicity density
  - etc. etc.
- What is it good for?

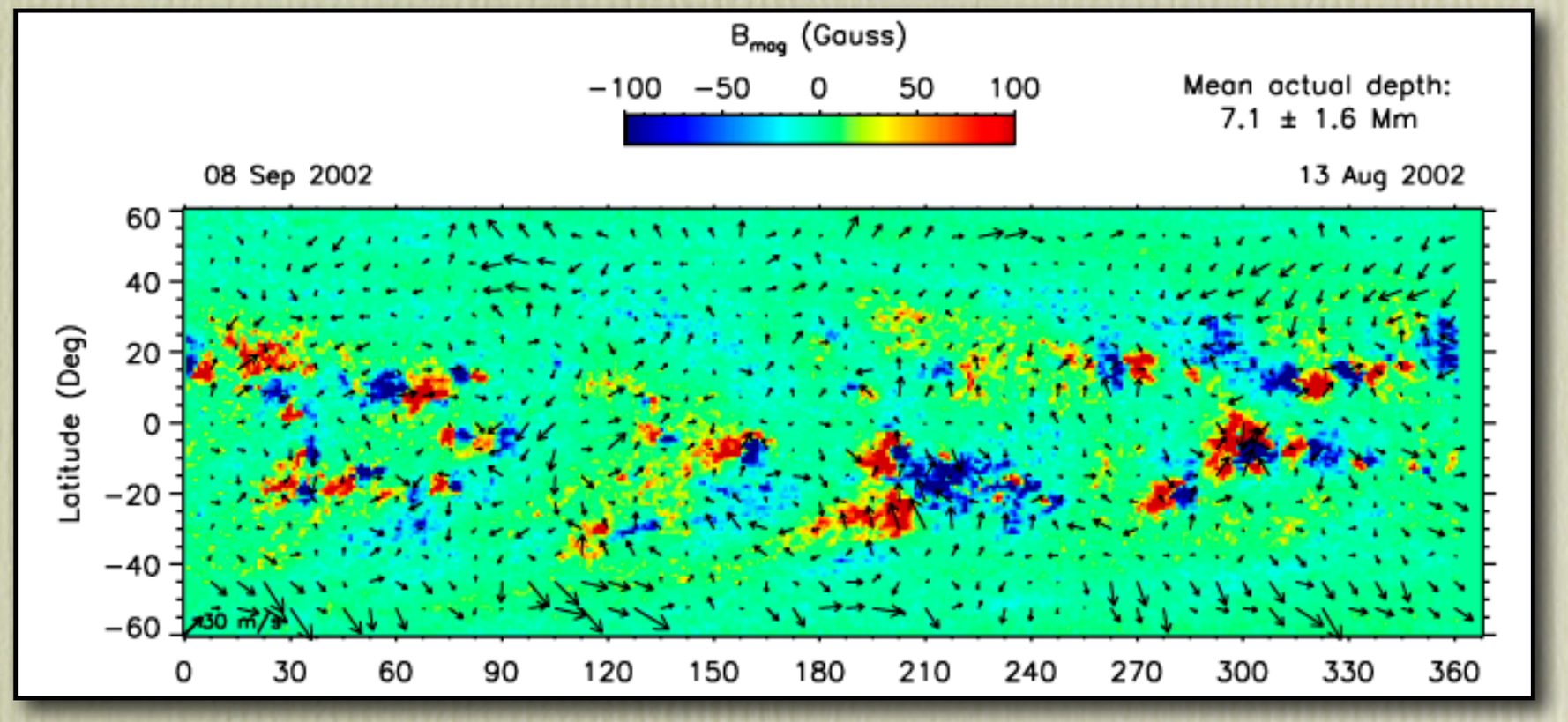
Dense-pack ring diagram analysis





16° patch, circular apodized to 15°
1664 min (1 ring day)
0 - 16 Mm depth

Synoptic map of horizontal flows



AR 10069 at 300° longitude, 7.5° South

(1) How to derive v_z ?

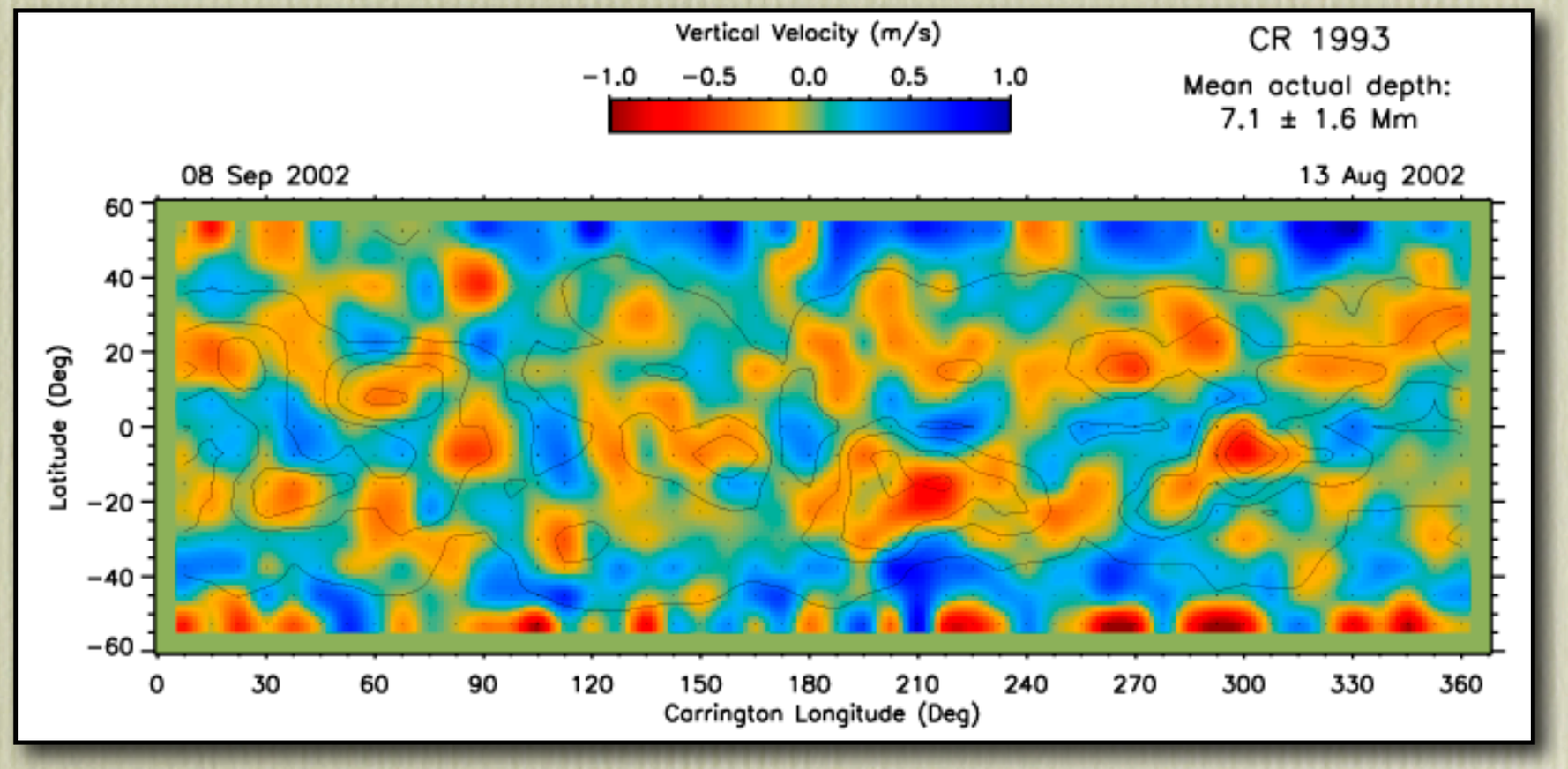
mass conservation

$$(\partial\rho/\partial t) + \nabla\rho\cdot\mathbf{v} + \rho\nabla\cdot\mathbf{v} = 0$$

simplified to:

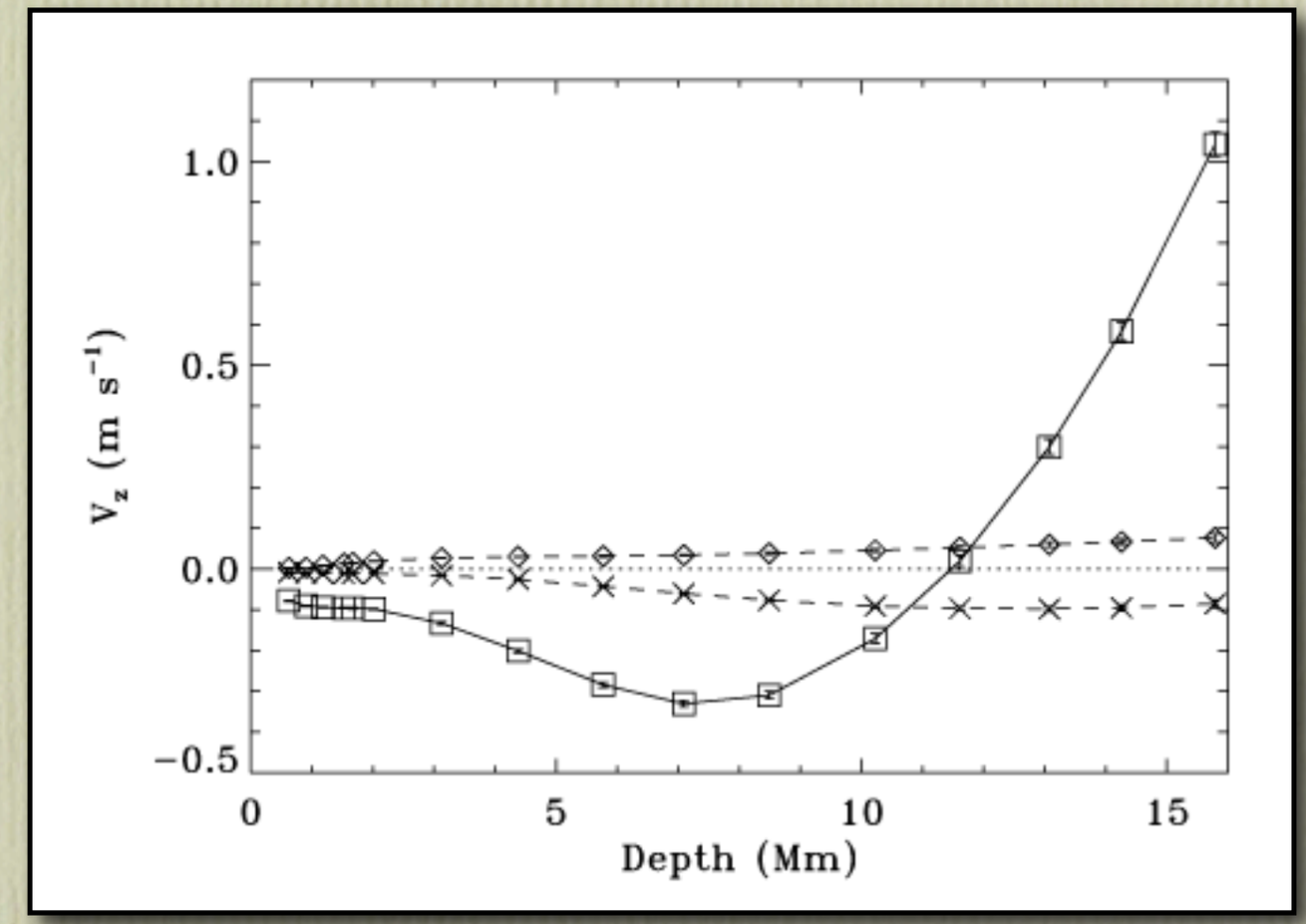
$$(\partial v_z/\partial z) + \rho^{-1}(\partial\rho/\partial z)\, v_z + \mathrm{div}\, v_h = 0$$

Vertical Velocity



AR 10069 at 300° longitude, 7.5° South

Average Vertical Velocity



B > 87 G; 1 year (CR 1979 - 1992)

(2) Vorticity

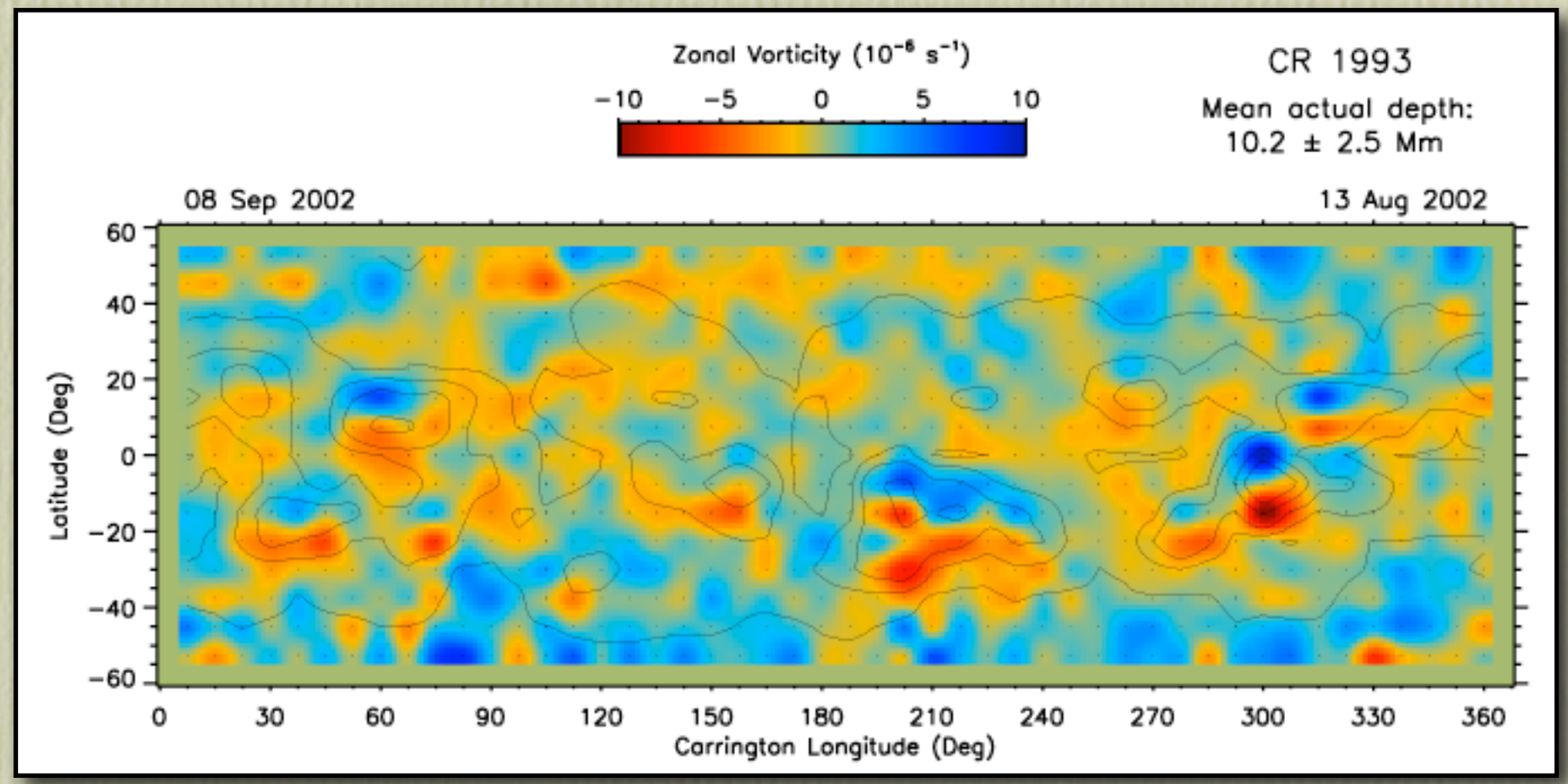
$$\omega = \nabla \times \mathbf{v}$$

$$\omega_x = \partial v_z / \partial y - \partial v_y / \partial z \approx - \partial v_y / \partial z$$

$$\omega_y = \partial v_x / \partial z - \partial v_z / \partial x \approx + \partial v_x / \partial z$$

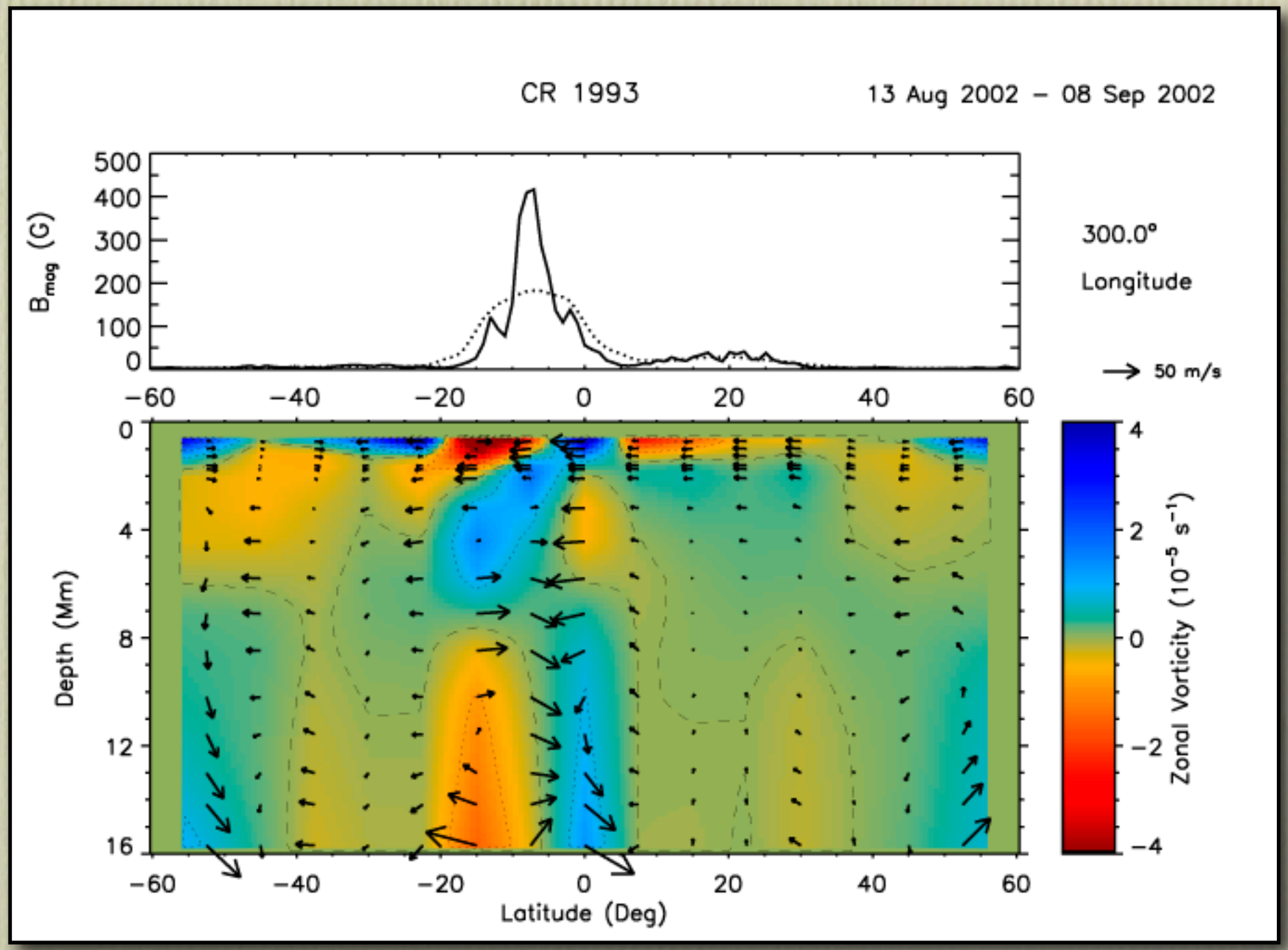
$$\omega_z = \partial v_y / \partial x - \partial v_x / \partial y$$

Zonal Vorticity



AR 10069 at 300° longitude, 7.5° South

Depth-latitude slice of ω_x



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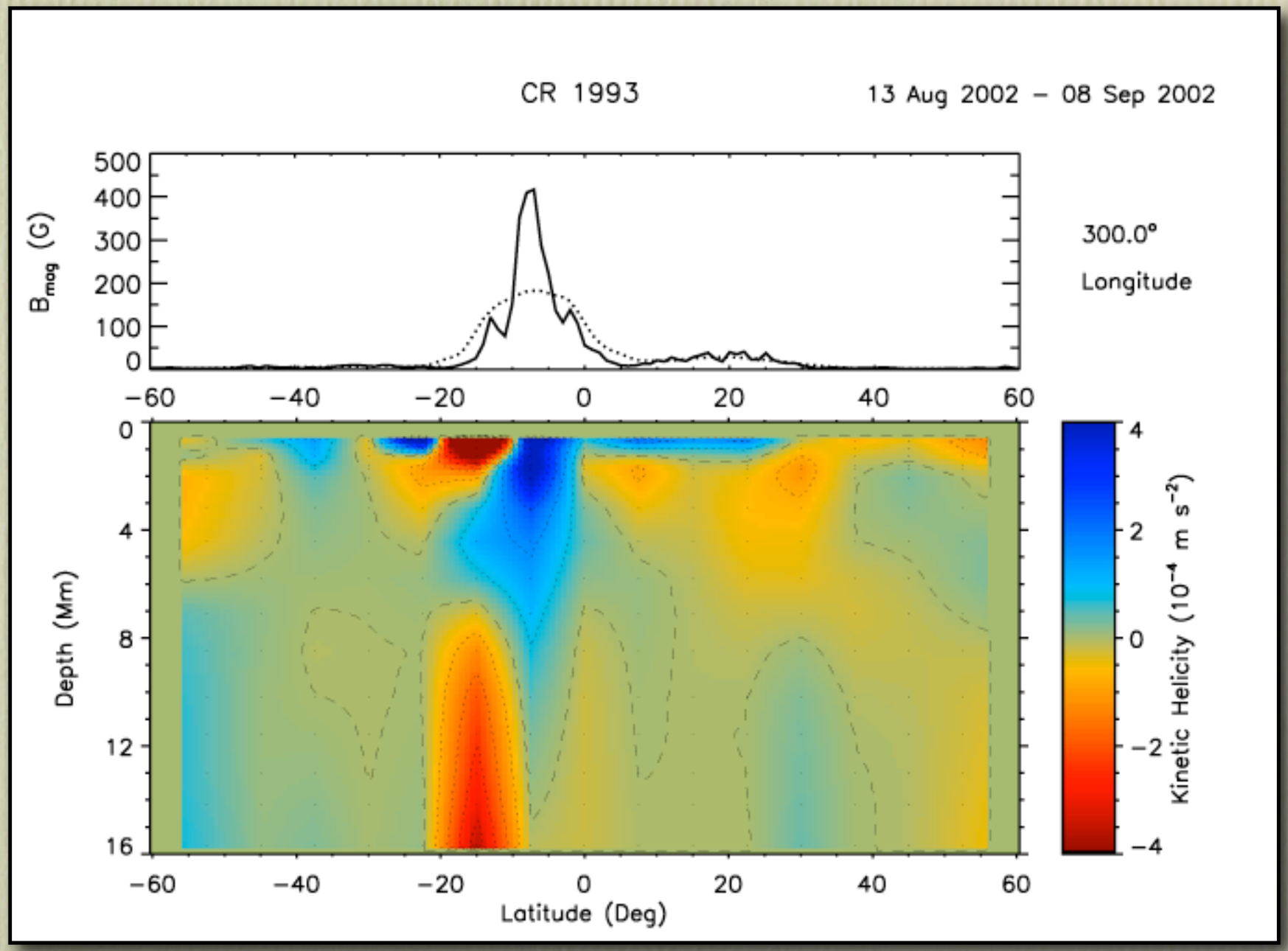
(3) Kinetic Helicity Density

$$h = \omega \cdot \mathbf{v}$$

$$h = \omega_x v_x + \omega_y v_y + \omega_z v_z$$

$$h \approx -(\partial v_y / \partial z)\, v_x + (\partial v_x / \partial z)\, v_y + (\partial v_y / \partial x - \partial v_x / \partial y)\, v_z$$

Kinetic Helicity Density



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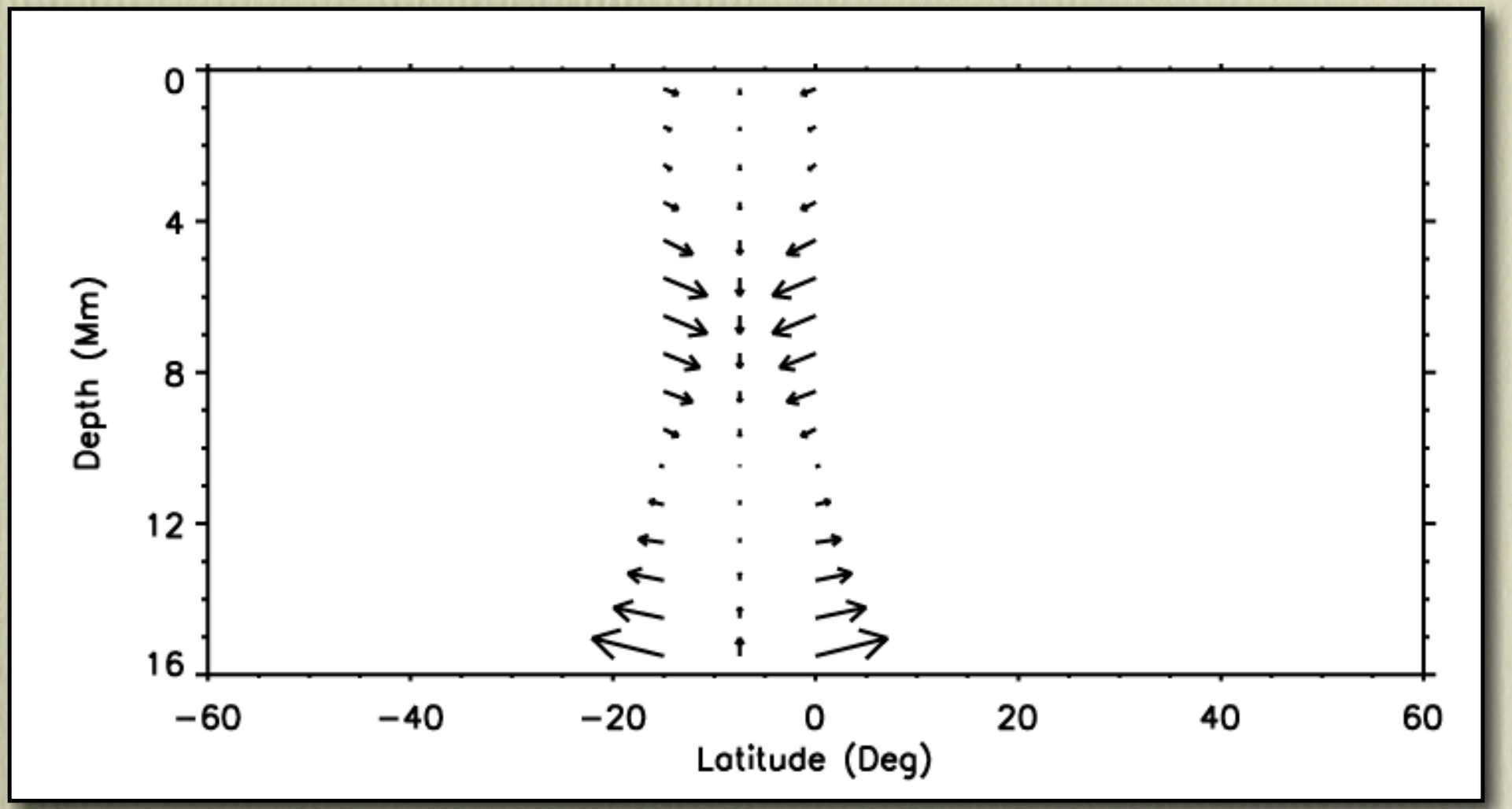
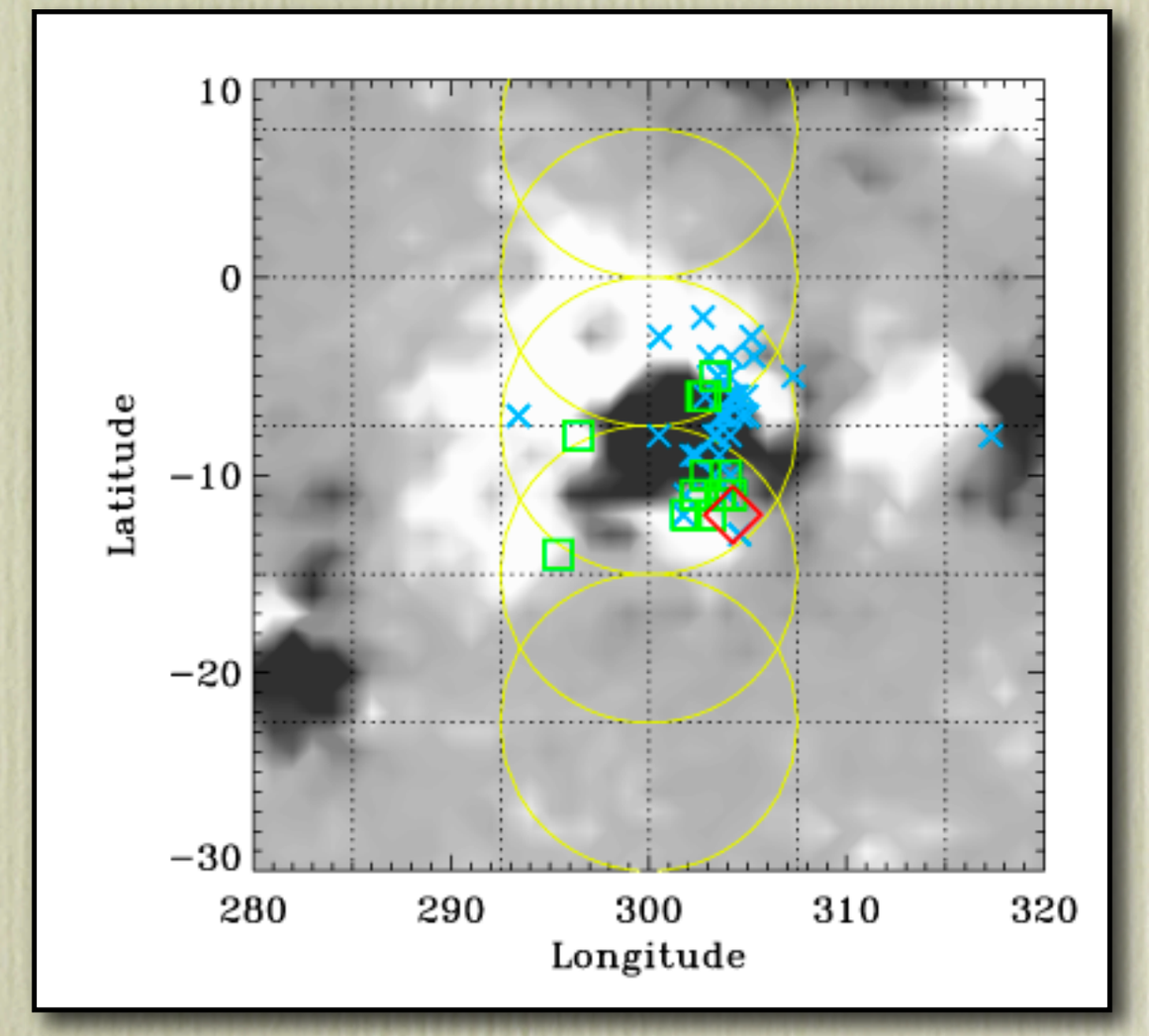
Cartoon view of flows under an active region



(4) Flare activity and vorticity



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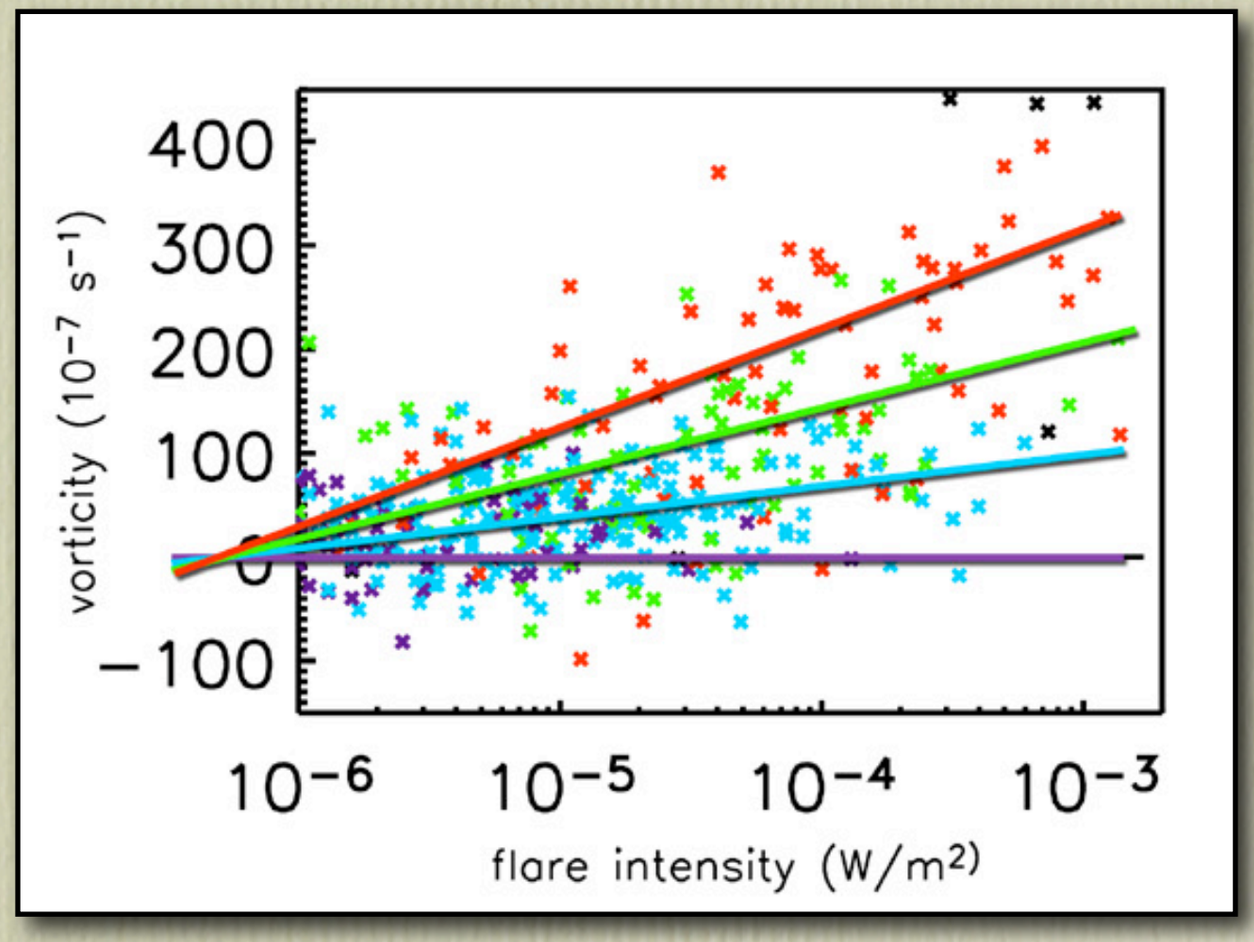
Spatial distribution of X-ray flares (GOES)
by flare class C, M, X

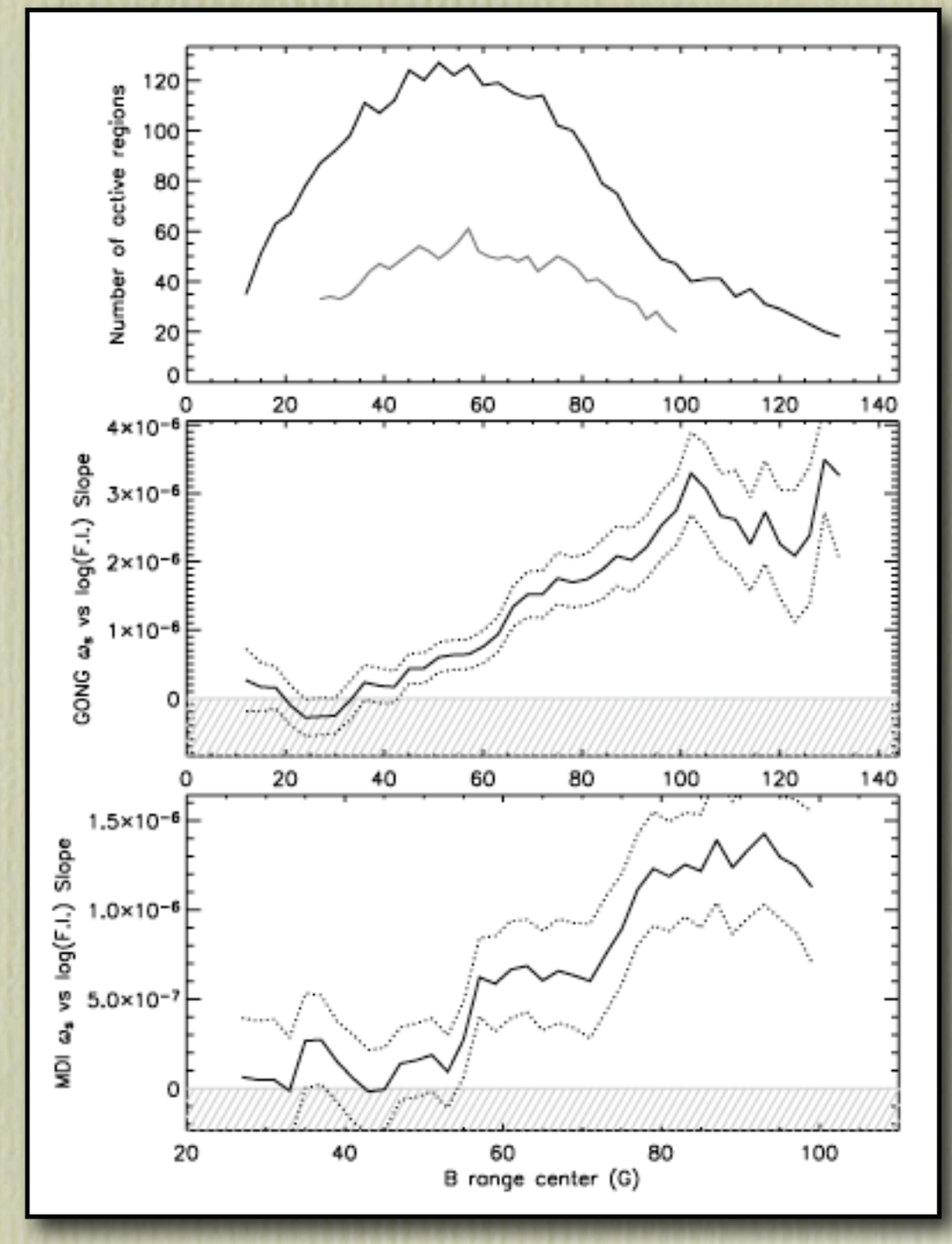
Survey of MDI and GONG data



Mason et al. (2006)

MDI: 159 active regions GONG: 408 regions

Vorticity and flare intensity



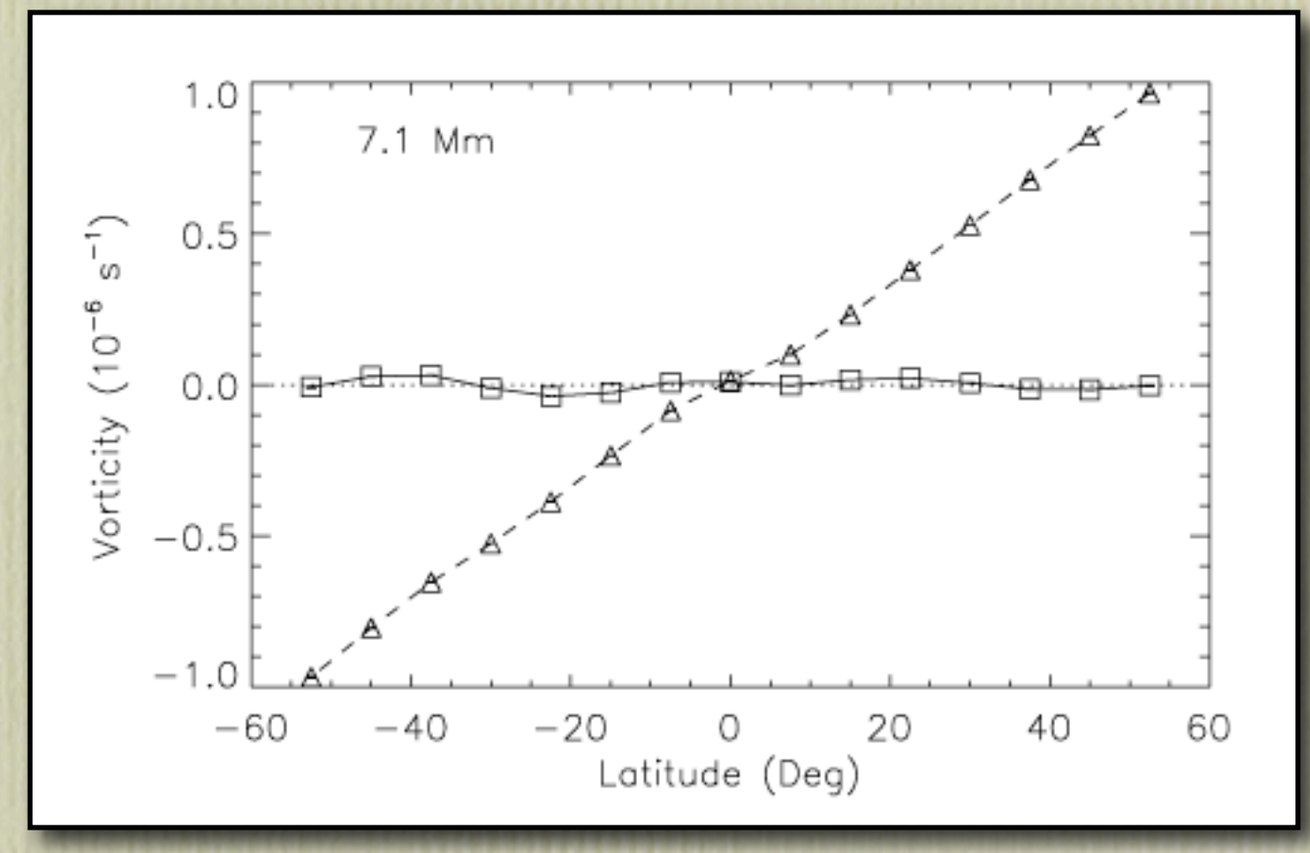
Number of AR

GONG

MDI

Slope as a function of |B|

(5) Vertical Vorticity

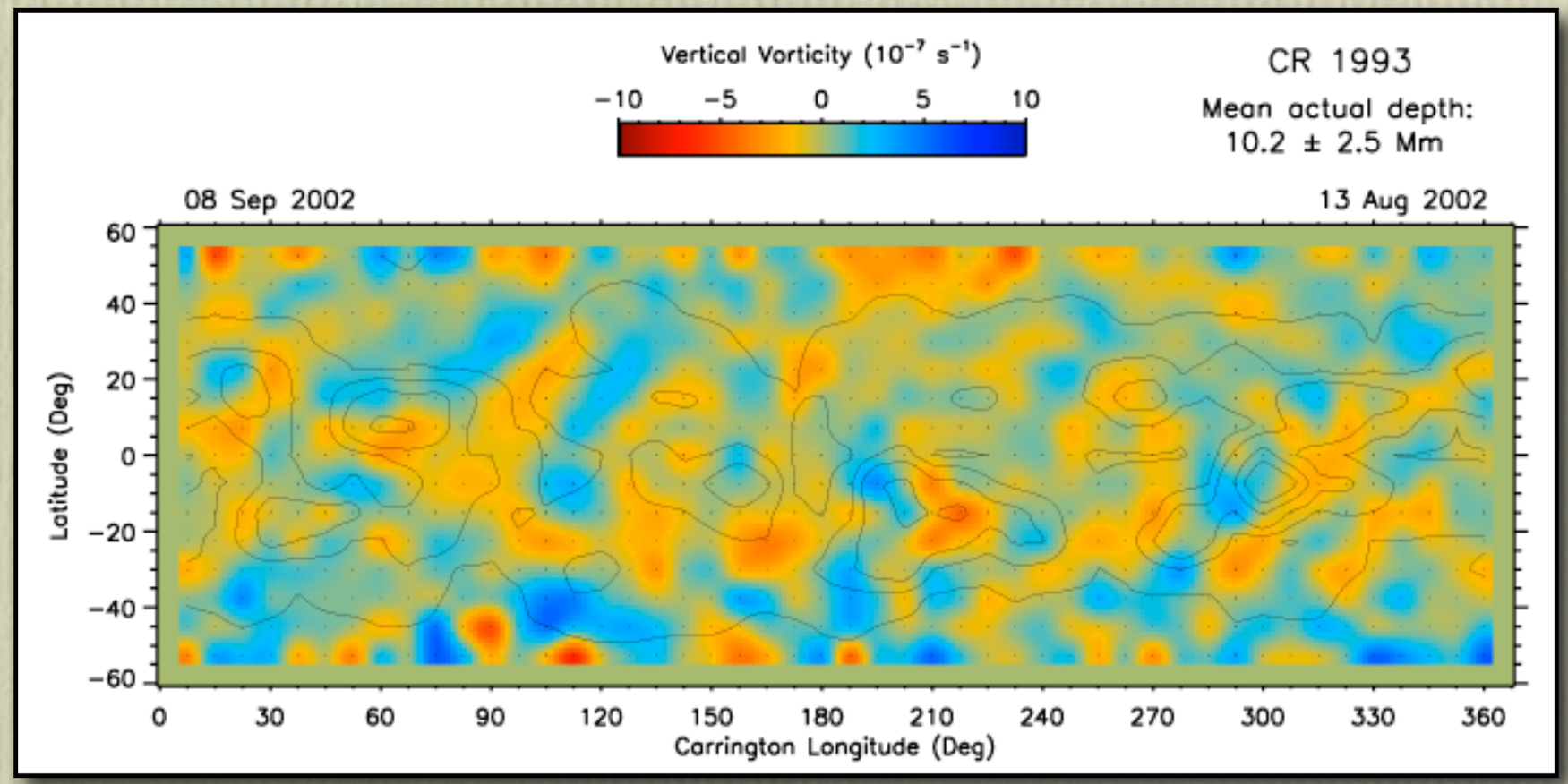


with rotation

without rotation

GONG: July 2001 - August 2005

Vertical Vorticity



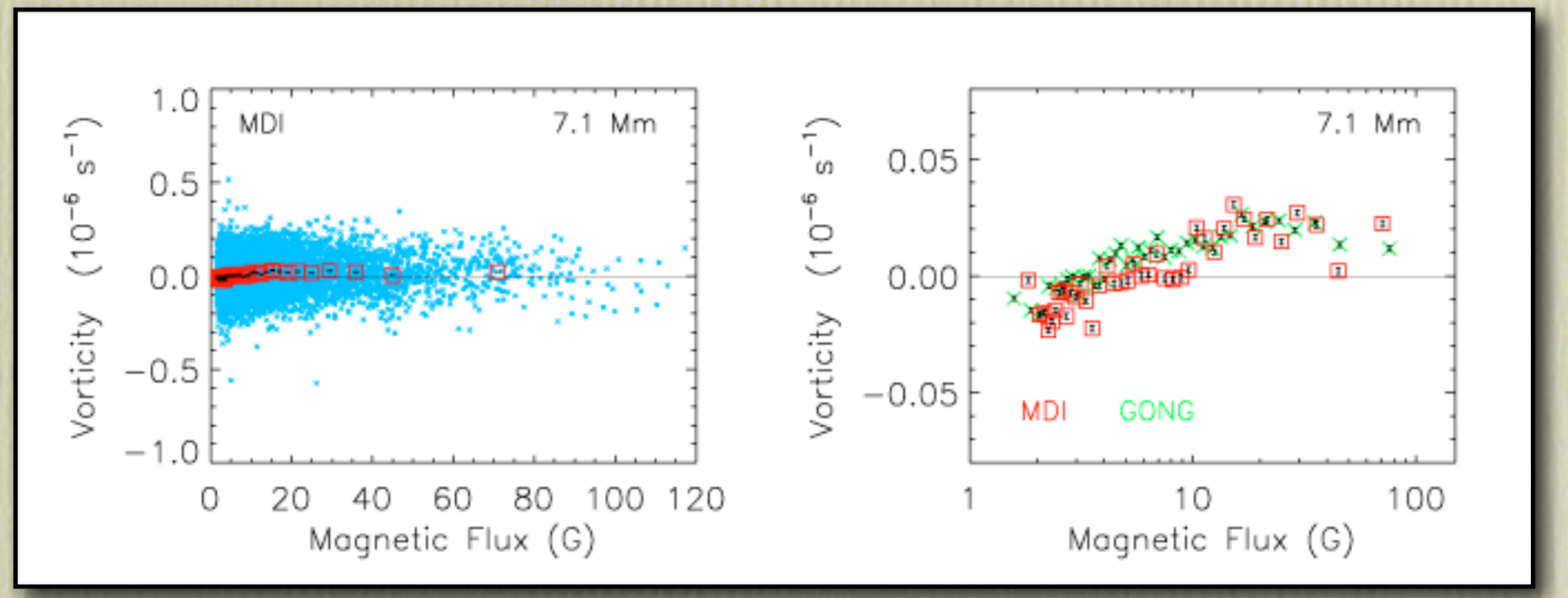
AR 10069 at 300° longitude, 7.5° South

If ω_z is so small, why do I care?

Large-scale simulations of convection zone (Miesch 2005):

A downflow network and intermittent plumes with cyclonic vorticity in a background of weaker anti-cyclonic vorticity associated with diverging upflows.

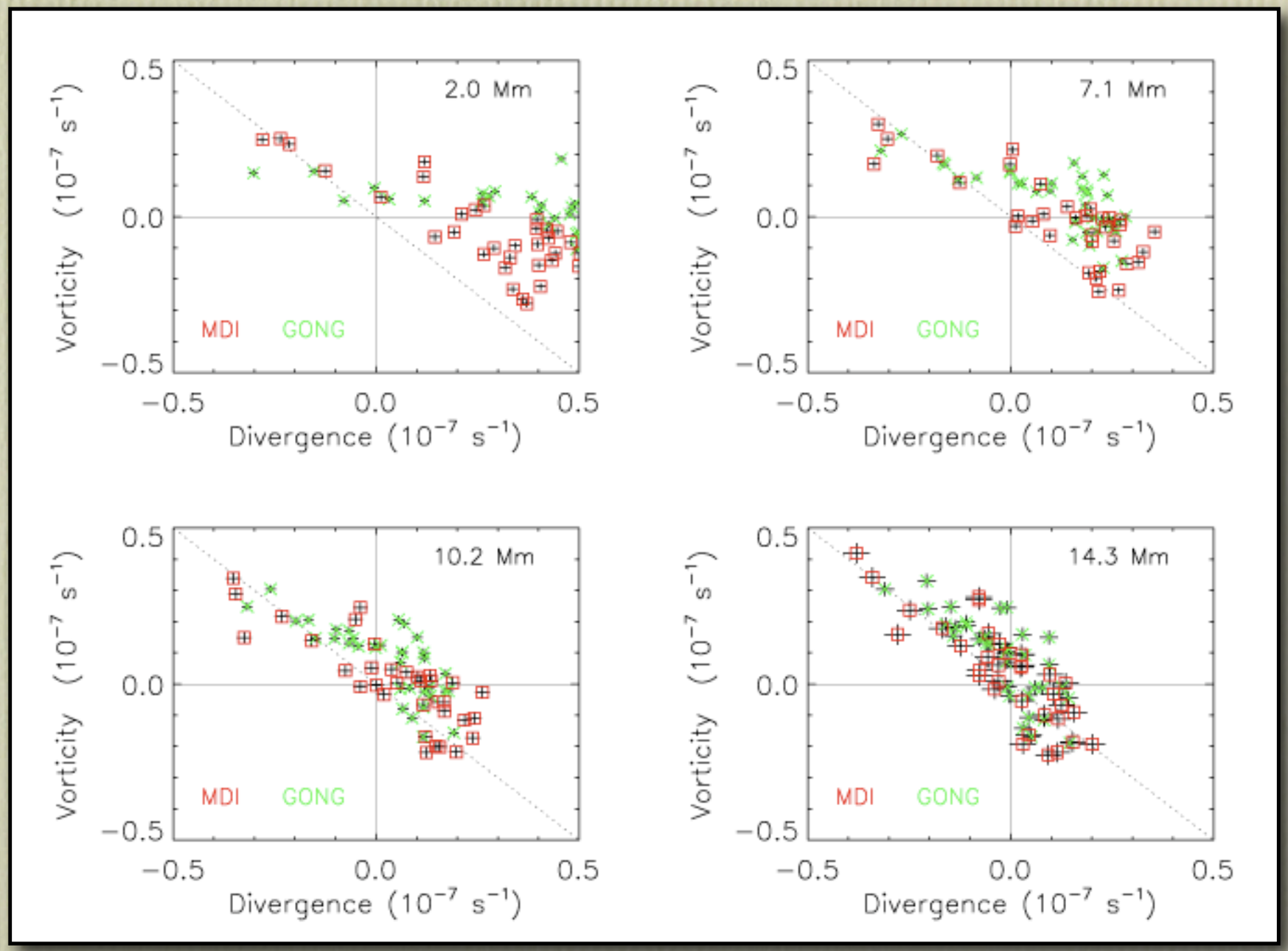
Survey of MDI and GONG data



cyclonic: positive; anti-cyclonic: negative
(sign flip in the South)

MDI: 10,430 data GONG: 25,800 data

Divergence and vorticity



B < 20 G

divergent: positive; convergent: negative

cyclonic: positive; anti-cyclonic: negative

Summary

- Easy-to-calculate descriptors can add value.
- Active regions: upflow - downflow;
  dipolar structure and reversal in vorticity.
- Flares, magnetic flux, and vorticity are related.
- Quiet regions: anti-cyclonic, weak upflows;
  intermediate activity: cyclonic downflows.