# Subsurface Flow Divergence related to Solar Activity

R. Komm[1], D. Haber[2], T. Corbard[3], I. Gonzalez Hernandez[1], F. Hill[1], B. Hindman[2], and R. Howe[1]
[1] NSO, Tucson, AZ; [2] JILA, Boulder, CO; [3] Obs. de la Côte d Azur, Nice, France

## Introduction

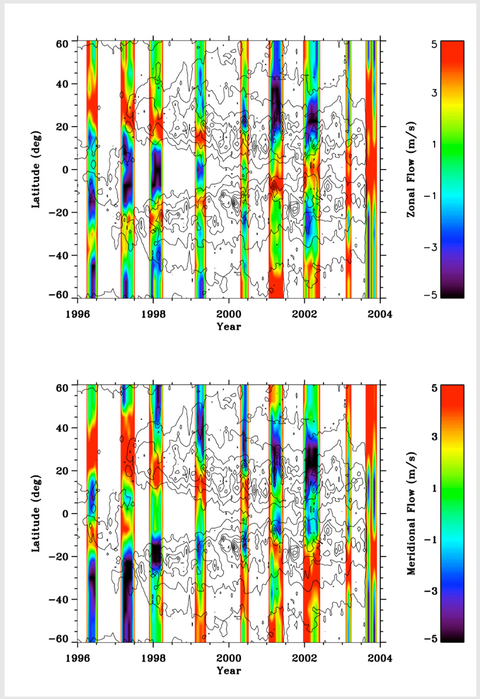
Subsurface horizontal flows converge near locations of surface magnetic activity (Haber et al., 2002, Zhao & Kosovichev, 2003). We begin to quantify this relation between subsurface flows and surface magnetic activity by calculating the divergence of the horizontal flows. Using the continuity equation (representing mass conservation), we derive the vertical velocity component from the measured divergence of the horizontal flow (Komm et al. 2004).

We measure the horizontal components of subsurface flows with the ring-diagram technique and derive the corresponding vertical flow component. We analyze MDI Dynamics Program and GONG data covering 28 and 4 Carrington Rotations.

Here, we focus on:

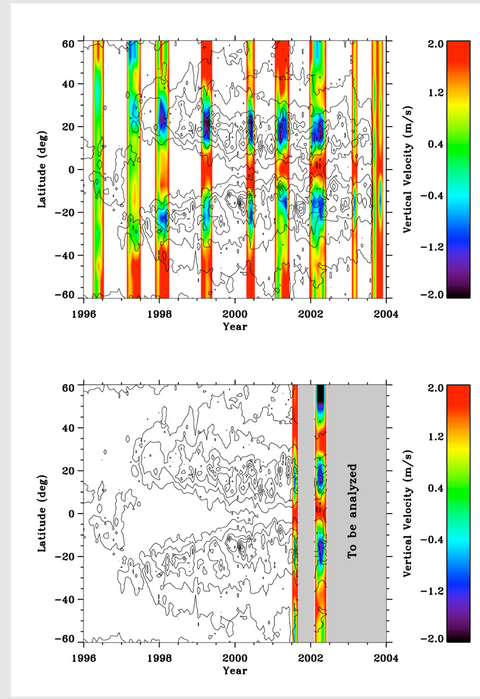
- Solar-cycle variation of the horizontal flows (torsional oscillations and meridional flow);
- Solar-cycle variation of the vertical flows (dominated by the meridional component);
- MDI – GONG comparison of 2002 Dynamics Program data (to establish consistency);
- Zonal and meridional components of the divergence.

## Solar-Cycle Variation of Horizontal Flows



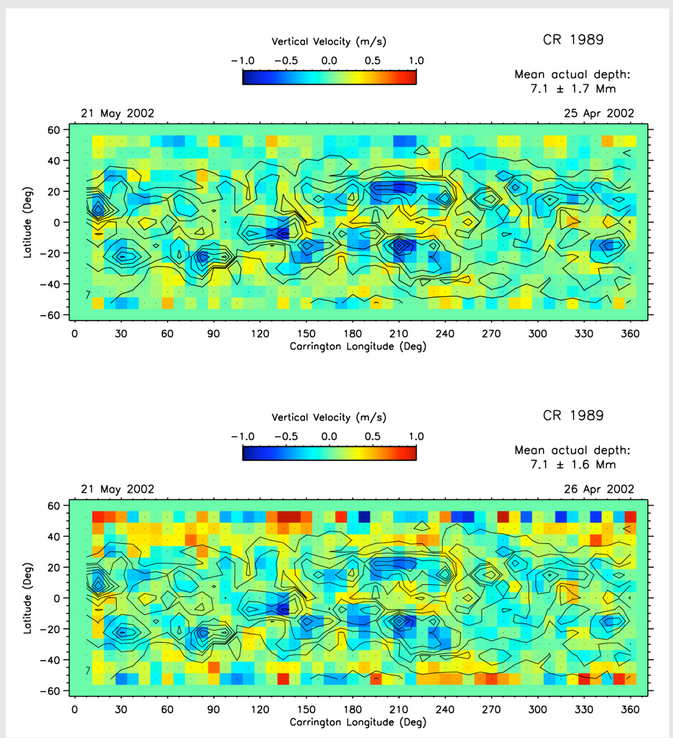

Zonal (top) and meridional flows (bottom) derived from MDI data. The average at each latitude was subtracted to emphasize the solar-cycle variation. For meridional flows, positive/negative values indicate flows to the north/south.

## Solar-Cycle Variation of Vertical Flows



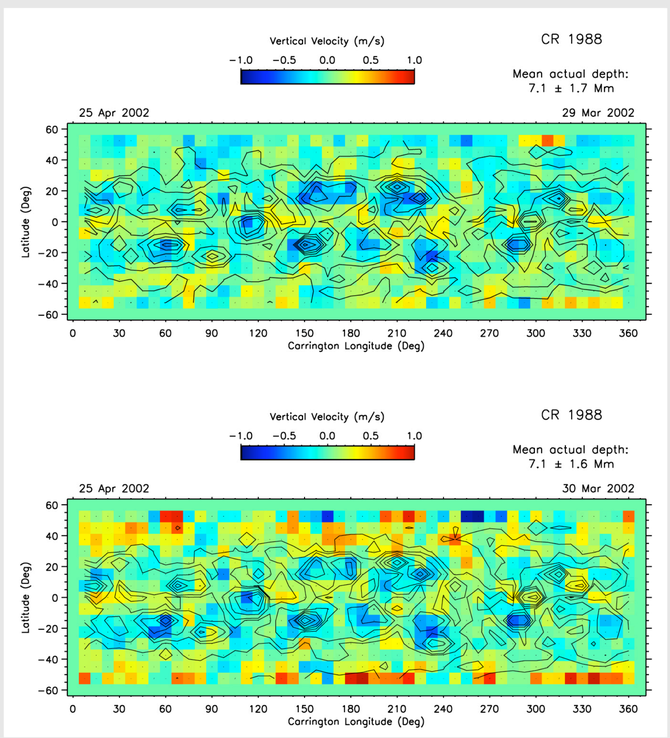

The vertical velocity of near surface layers (0.9 – 4.4 Mm) for each Carrington Rotation derived from MDI data (top) and from GONG data (bottom). The contour lines indicate magnetic flux. Downflows coincide with locations of magnetic activity.

## CR 1989



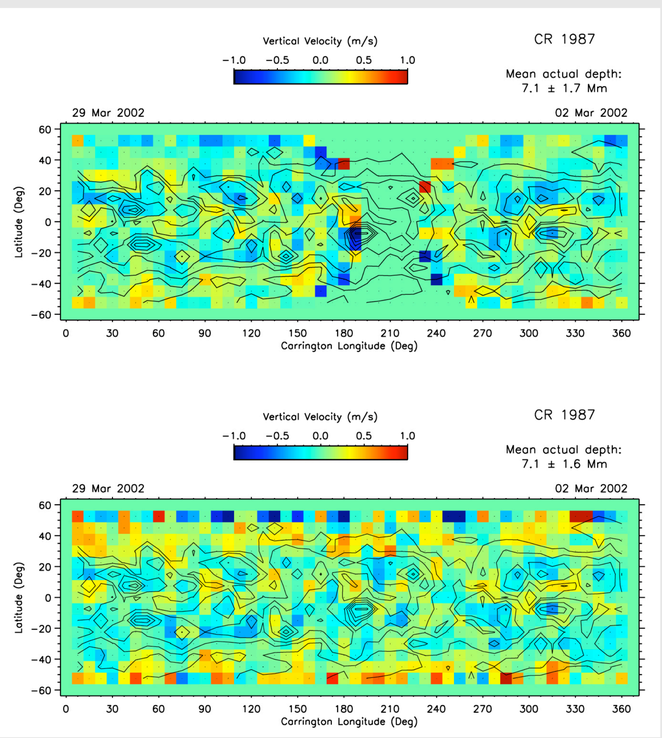

Vertical velocity at a depth of 7.1 Mm (Top: MDI; bottom: GONG). Positive/negative values indicate upflows/downflows.

## CR 1988




The contour lines indicate magnetic flux (5, 10, 20, 40, 60, 80, 120, and 160 Gauss) from NSO Kitt Peak magnetograms.

## CR 1987




MDI and GONG data show very similar results; differences occur mainly at high latitudes.

## Zonal and Meridional Component of Divergence

We separate the divergence into its zonal and meridional component to see how much each flow component contributes. Since active regions move toward the central latitude of activity (Howard, 1991), the measured divergence could simply be due to meridional motions with the zonal flow being uniform in longitude.

The zonal component (top right) shows converging flows near active regions, as does the meridional component (bottom right). The zonal flow does show 'structure in longitude.

The pattern of diverging flows near the equator and converging flows near latitudes of activity is more pronounced in the meridional component.




## Conclusions

- MDI and GONG data show similar results.
- Strong downflows occur at locations of large magnetic flux.
- Zonal and meridional flows contribute to the divergence.
- Meridional flows show a two-cell structure with converging flows near the central latitude of activity.
- As a consequence, downflows track the butterfly diagram during the current solar cycle.
- HMI/SDO will allow us to study the next solar cycle with continuous observations.

## References

Haber D.A., Hindman, B.W., Toomre, J., Bogart, R.S., Larsen, R.M., & Hill, F. 2002, ApJ, 570, 885
Howard R.F. 1991, Solar Phys. 135, 43
Komm, R., Corbard, T., Durney, B.R., González-Hernández, I., Hill, F., Howe, R., & Toner, C. 2004, ApJ, 605, 000
Zhao, J. & Kosovichev, A.G. 2003, ApJ 591, 446

## Acknowledgments

This work was supported by NASA grants S-92698-F and NAG 5-11703 to the National Solar Observatory and NAG 5-7996, NAG 5-11879, NAG 5-11920, NAG 5-12491, NAG 5-103917, and by NSF grant ATM-0219581 to the University of Colorado. SOHO is a project of international cooperation between ESA and NASA. This work utilizes data obtained by the Global Oscillation Network Group (GONG) program, managed by the National Solar Observatory, which is operated by AURA, Inc. under a cooperative agreement with the National Science Foundation. The data were acquired by instruments operated by the Big Bear Solar Observatory, High Altitude Observatory, Learmonth Solar Observatory, Udaipur Solar Observatory, Instituto de Astrofísico de Canarias, and Cerro Tololo Interamerican Observatory. NSO/Kitt Peak data used here are produced cooperatively by NSF/NOAO, NASA/GSFC, and NOAA/SEL.